Nuclear Structure 2016

Knoxville, Tennessee, USA July 24-29

Conference Program & Book of Abstracts

Oak Ridge National Laboratory

Book of Abstracts
Nuclear Structure Conference 2016
Knoxville
Editors: **Elisa Romero-Romero**, **Alfredo Galindo-Uribarri**, **James T. Matta**
OAK RIDGE NATIONAL LABORATORY

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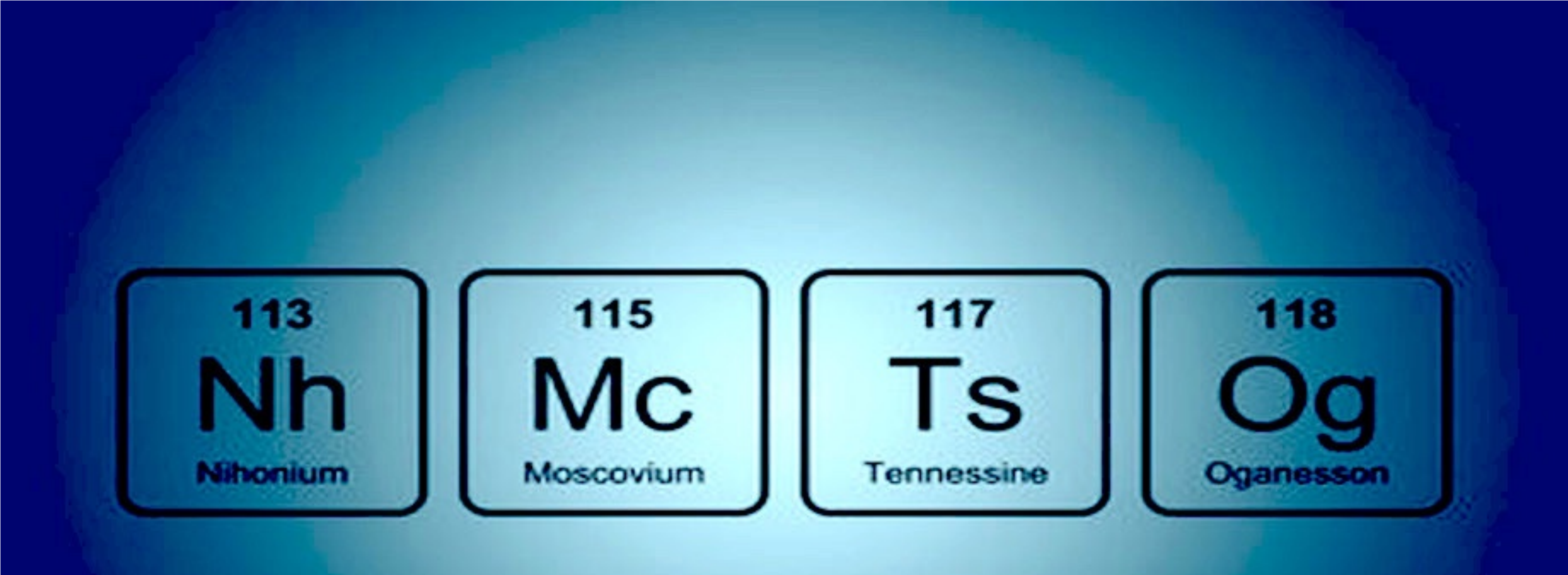
I General Information

General Information



1. Welcome

1.1 Introduction

The Nuclear Structure 2016 conference is hosted by the Physics Division of Oak Ridge National Laboratory (ORNL), on July 24-29, 2016, at the Hilton Hotel downtown Knoxville. This will be the 16^{th} in this series of biennial conferences organized by North American national laboratories. Previous meetings have been held in East Lansing (2008), Berkeley (2010), Argonne (2012), Vancouver (2014).

The scientific program will be devoted to the latest research and development in experimental and theoretical nuclear structure physics, with emphasis on the properties of nuclei at the extremes of isospin, excitation energy, mass, and angular momentum.

1.2 Book Description

We are proud to present the Conference Program & Book of Abstracts for the Nuclear Structure 2016 Conference (NS2016).

Oak Ridge National Laboratory is very happy to welcome all of you in Knoxville for the 16^{th} Nuclear Structure conference. We would like to acknowledge the work of the International Organizing Committee (IOC) suggesting speakers and helping select the oral talks from the contributed abstracts. With special thanks to all of you, our Local Organizing Committee (LOC) has put together an exciting conference program with 16 invited and 51 contributed talks in 15 plenary sessions and two mini-talk sessions with a total of 28 talks and 2 poster sessions.

The next 5 days will be dedicated to the Nuclear Structure hottest topics.

The main topics include:

- Nuclear physics with radioactive beams
- Nuclear spectroscopy far from stability
- Collective phenomena
- Reaction dynamics of light and heavy ions
- Single particle structure in transfer reactions
- Production and properties of the heaviest nuclei
- Ab-initio calculations, cluster models, and shell-model
- Nuclear energy density functionals
- Applications
- Results of gamma-ray tracking devices
- Mass measurements and traps
- Charge exchange reactions
- Decay spectroscopy
- Astrophysical aspects of nuclear studies
- Fundamental symmetries and interactions

To guide you during your NS2016 Conference experience, we have created this digital booklet, which provides you with information on the program and activities planned. The first part includes details on the program and sessions (i.e. the quick glance timetable, the agenda), practical information related to the conference venue, and the city of Knoxville. Parts II-**??** contain the abstracts of the presentations at the NS2016. With this booklet we hope to cover all your basic conference needs. This digital booklet has numerous internal links to aid navigation.

In the first session M1 the elected president of the American Physical Society (APS), Laura H. Greene, accompanied by members of the Historic Sites Committee will present a plaque to Thomas Zacharia, Scientific Director of ORNL, to commemorate the scientific achievements of the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL), designated as an historical site by the APS.

I-Yang Lee (2016 Tom W. Bonner Prize in Nuclear Physics) from Lawrence Berkeley National Laboratory, will give a presentation to highlight the many scientific accomplishments of the array to mark the twentieth anniversary of the dedication of Gammasphere.

A session at NS2016 will be dedicated to superheavy elements. IUPAC has very recently named the four new elements nihonium, moscovium, tennessine, and oganesson. Yuri Oganessian, from Russia's Joint Institute for Nuclear Research (JINR) in Dubna, who has helped to discover numerous superheavy elements will give a presentation. It will mark only the second time that an element has been named after a living scientist.

Tennessine is in recognition of the contribution of the Tennessee region, including Oak Ridge National Laboratory, Vanderbilt University, and the University of Tennessee at Knoxville, to superheavy element research, including the production and chemical separation of unique actinide target materials for superheavy element synthesis at ORNL's High Flux Isotope Reactor (HFIR) and Radiochemical Engineering Development Center (REDC).

It is a pleasure for us to host the NS2016. We hope you enjoy your stay in Tennessee. You can contact us for any help you might need. Please see section 1.4 for the list of contacts.

1.3 Timetable

SUNDAY, JULY 24 — HIWASSEE 1ST FLOOR

3:00 PM	7:00 PM	**REGISTRATION**
6:00 PM	9:00 PM	**RECEPTION**

MONDAY, JULY 25 — CHEROKEE BALLROOM

7:30 AM	8:30 AM	**Breakfast (Exhibitors/Open Research Discussions)**
M1		**Chair: David Dean**
8:30 AM	9:00 AM	**Laura Greene** *Opening Ceremony*
9:00 AM	9:30 AM	**Thomas Zacharia** **Mark Riley** *HRIBF Dedication*
9:30 AM	10:00 AM	**Krzysztof Rykaczewski** *Reactor Anti-neutrino Spectra and Decay Heat in Fission Fragments from Total Absorption Spectroscopy*
10:00 AM	10:30 AM	**Coffee Break**
M2		**Chair: Robert K. Grzywacz**
10:30 AM	11:00 AM	**Anna Hayes** *The Neutrino Anomalies*
11:00 AM	11:25 AM	**Andrei Andreyev** *Shape Coexistence and Charge Radii in Mercury Isotopes Studied by In-source Laser Spectroscopy at VADLIS/RILIS-ISOLDE*
11:25 AM	11:45 AM	**Akaa Daniel Ayangeakaa** *Shape Coexistence and the Role of Axial Asymmetry in Neutron-rich Ge isotopes*
11:45 AM	12:05 PM	**Andrea Gottardo** Shape Coexistence in the ^{78}Ni Region: Intruder 0^+_2 State in ^{80}Ge
12:05 PM	12:25 PM	**Peter Bender** *Exploring the Onset of Shape Coexistence using (d,p) with Exotic Sr Isotopes.*
12:25 PM	12:45 PM	**Augusto Macchiavelli** *The ^{30}Mg(t,p)^{32}Mg Puzzle Revisited*
12:45 PM	2:00 PM	**LUNCH (on your own)**
M3		**Chair: Carl Svensson**
2:00 PM	2:30 PM	**Alexander Obertelli** *In-beam Gamma Spectroscopy at the RIBF: Recent Results from Proton-induced Direct Reactions*
2:30 PM	2:50 PM	**Heather Crawford** *Characterizing Deformation in the Mg Isotopes: N=20 to N=28*
2:50 PM	3:10 PM	**Ingo Wiedenhoever** *Isomeric Character of the Lowest 4^+ State in ^{44}S*
3:10 PM	3:30 PM	**John Sharpey-Schafer** *On Low-lying $K_\pi=0^+$ and 2^+ Rotational Bands in Deformed Nuclei*
3:30 PM	4:00 PM	**Coffee Break**
4:00 PM	6:00 PM	**CHAIR Mini-Talks I - SAM TABOR** Crider, Benjamin Walters, William B Allmond, Mitch Stolze, Sanna Sethi, Jasmine Bucher, Brian Baker, Robert Nevo Dinur, Nir Cizewski, Jolie de Groote, Ruben Grzywacz, Robert Goetz, Callie Hartley, Daryl Ahn, Tan
		End of Talks
6:00 PM	8:00 PM	**Poster Session (Reception in Lieu of Dinner) SEQUOYAH CONFERENCE CENTERS**

TUESDAY, JULY 26 — CHEROKEE BALLROOM

7:30 AM	8:30 AM	**Breakfast (Exhibitors/Open Research Discussions)**
T1		**Chair: Jolie Cizewski**
8:30 AM	8:50 AM	**Thomas Papenbrock** *Effective Field Theory for Nuclear Vibrations with Quantified Uncertainties*
8:50 AM	9:10 AM	**Arianna Carbone** *Nuclear Matter from a Green's Function Approach*
9:10 AM	9:30 AM	**Daniel Lubos** *Spectroscopy around Sn-100*
9:30 AM	9:50 AM	**Robert Wadsworth** *Isomer Decays in the N = Z Nucleus ^{96}Cd Populated via Fragmentation*
9:50 AM	10:10 AM	**Steven Pain** *The First Campaign of Direct Reaction Measurements using GODDESS*
10:10 AM	10:30 AM	**Coffee Break**
T2		**Chair: Anatoli Afanasjev**
10:30 AM	11:00 AM	**Heiko Hergert** *Novel Ab Initio Methods for Nuclei*
11:00 AM	11:20 AM	**Carlo Barbieri** *Advances in Self-Consistent Green's Function Calculations of Medium Mass Isotopes*
11:20 AM	11:40 AM	**Bruce Barrett** *Ab Initio Nuclear Shell Model for sd-shell Nuclei*
11:40 AM	12:00 PM	**Sven Binder** *Effective field theory in the harmonic oscillator basis*
12:00 PM	12:20 PM	**Elena Litvinova** *Pion-nucleon Correlations and their Impact on Nuclear Structure Observables*
12:20 PM	2:00 PM	**LUNCH (on your own)**
2:00 PM	3:45 PM	**CHAIR Mini-Talks II - INGO WIEDENHOVER** Ong, Hooi Jin Tabor, Samuel Pickstone, Simon Glynn Brewer, Nathan Chowdhury, Partha Demand, Greg MacLean, Andrew Mazzocchi, Chiara Smallcombe, James Febbraro, Michael Tsoneva Larionova, Nadia Miller, Andrew Morris, Titus Mukhi, Kumar Raju
		End of Talks
3:45 PM	4:00 PM	**PHOTO**
4:00 PM	6:00 PM	**Poster Session (Refreshments Served) SEQUOYAH CONFERENCE CENTERS**

WEDNESDAY, JULY 27 — CHEROKEE BALLROOM

7:30 AM	8:30 AM	**Breakfast (Exhibitors/Open Research Discussions)**
W1		**Chair: Gordon C. Ball**
8:30 AM	9:00 AM	**Jon Engel** *Beta Decay with Energy Density Functionals and the r Process*
9:00 AM	9:20 AM	**Maciej Konieczka** *DFT-rooted Calculations of Gamow-Teller Matrix Elements*
9:20 AM	9:40 AM	**Nobu Hinohara** *Binding Energy Differences of Even-even Nuclei as Pairing Indicators*
9:40 AM	10:00 AM	**Luis Robledo** *Octupole Correlations in a Full-symmetry Restoring Framework*
10:00 AM	10:20 AM	**Kenichi Yoshida** *Enhanced Collectivity of Gamma Vibration in Neutron-rich Dy Isotopes with N=108-110*
10:20 AM	10:50 AM	**Coffee Break**
W2		**Chair: David C. Radford**
10:50 AM	11:20 AM	**I-Yang Lee** *Gamma sphere and its Recent Science Highlights*
11:20 AM	11:40 AM	**Amel Korichi** *Characterization of Gamma--ray Tracking Arrays: Performance of the First Phase of AGATA and GRETA using a ^{60}Co Source*
11:40 AM	12:00 PM	**Francesco Recchia** *Neutron Single-particle Strengths in N = 40, 42 Nickel Isotopes*
12:00 PM	12:20 PM	**Walter Reviol** *Detailed Spectroscopy of ^{137}Xe and ^{139}Ba – role of the $\nu i_{13/2}$ Intruder in the Heavy Tin Region*
12:20 PM	12:40 PM	**Andrew Stuchbery** *g Factors and Nuclear Collectivity*
12:40 PM	2:00 PM	**LUNCH (on your own)**
W3		**Chair: Partha Chowdhury**
2:00 PM	2:20 PM	**Krzysztof Starosta** *Chiral Basis for Particle-rotor Model for Odd-odd Triaxial Nuclei*
2:20 PM	2:40 PM	**Alain Gillibert** *Spectroscopy of Neutron Rich Iron Isotopes Obtained from Proton Induced Direct Reactions*
2:40 PM	3:00 PM	**Christina Burbadge** *Investigating the Nature of Excited 0^+ States Populated via the ^{162}Er(p,t) Reaction*
3:00 PM	3:20 PM	**Lee Evitts** *Electric Monopole Transition Strengths in Stable Nickel Isotopes*
3:20 PM	3:40 PM	**Andrej Herzan** *Detailed Spectroscopy of the Neutron-Deficient Bismuth Isotopes Bi-193,195*
3:40 PM	4:10 PM	**Coffee Break**
W4		**Chair: John Simpson**
4:10 PM	4:40 PM	**Guy Savard** *Mass Measurements on very Neutron-rich isotopes with a new Penning Trap Phase detection Technique*
4:40 PM	5:00 PM	**Kei Minamisono** *Charge Radii of ^{36,37}K and Disappearance of Shell-closure Signature at N = 20*
5:00 PM	5:20 PM	**Gaute Hagen** *Coupled-cluster Computations of Atomic Nuclei*
5:20 PM	5:50 PM	**Ronald Garcia-Ruiz** *Laser Spectroscopy Studies on Neutron-rich Calcium Isotopes*
		End of Talks

THURSDAY, JULY 28 — CHEROKEE BALLROOM

7:30 AM	8:30 AM	**Breakfast (Exhibitors/Open Research Discussions)**
J1		**Chair: Adam Garnsworthy**
8:30 AM	9:00 AM	**Miguel Madurga** *Nuclear Structure of Ca and In isotopes from β-delayed neutron spectroscopy*
9:00 AM	9:20 AM	**Giovanna Benzoni** *Investigation of ^{70,72,74}Ni from Beta Decay of ^{70,72,74}Co*
9:20 AM	9:40 AM	**Michael Carpenter** *Gauging Octupole Collectivity in Neutron Rich Ce Nuclei*
9:40 AM	10:00 AM	**Michelle Dunlop** *High-Precision Half-Life Measurements for the Superallowed β^+ Emitter ^{10}C: Implications for Weak Scalar Currents*
10:00 AM	10:20 AM	**David Perez Loureiro** *β-delayed γ-decay of ^{26}P: Evidence for a Proton Halo?*
10:20 AM	10:45 AM	**Coffee Break**
J2		**Chair: Thomas Papenbrock**
10:45 AM	11:10 AM	**Manuela Cavallaro** *Signatures of the Giant Pairing Vibration in the ^{14}C and ^{15}C nuclei*
11:10 AM	11:30 AM	**Paul Stevenson** *Effective Interaction Effects in Nuclear Dynamics*
11:30 AM	11:50 AM	**Isao Tanihata** *Effect of Tensor Interaction and High-momentum Nucleons near the Ground States of Nuclei*
11:50 AM	12:10 PM	**Umesh Garg** *Are there Nuclear Structure Effects on the Isoscalar Giant Monopole Resonance and the Nuclear Incompressibility*
12:10 PM	12:30 PM	**Katsuhisa Nishio** *Study of Fission using Multi-nucleon Transfer Reactions*
12:30 PM	2:00 PM	**LUNCH (on your own)**
J3		**Chair: Lee Riedinger**
2:00 PM	2:30 PM	**Takaharu Otsuka** *Shape Coexistence, Shape Transition and Nuclear Forces*
2:30 PM	2:50 PM	**Alexandre Lepailleur** *Spectroscopy of ^{26}F and ^{28}Na to Probe Proton-neutron Forces Close to the Drip Line*
2:50 PM	3:10 PM	**Sunji Kim** *Unbound Excited States in ^{17}C*
3:10 PM	3:30 PM	**Anna Corsi** *Search for Dineutron Correlation in Borromean Halo Nuclei*
3:30 PM	4:00 PM	**Coffee Break**
J4		**Chair: Robert Wadsworth**
4:00 PM	4:30 PM	**Yuri Oganessian** *Superheavy Nuclei*
4:30 PM	4:50 PM	**Anatoli Afanasjev** *Structure of Superheavy Elements Reexamined*
4:50 PM	5:10 PM	**Michael Block** *Laser Spectroscopy on Nobelium Isotopes at GSI*
5:10 PM	5:30 PM	**Piet Van Duppen** *In-gas-jet Laser Spectroscopy of Neutron-deficient ^{214,215}Ac Isotopes and Prospects for Studies of the Actinide Region*
5:30 PM	5:50 PM	**Filip Kondev** *Nuclear Archaeology: Properties of K isomers in ^{244,246}Cm Populated in β^- decays of ^{244,246}Am*
		End of Talks
6:00 PM	9:30 PM	**Banquet (Jackson Terminal)**
7:15 PM	8:15 PM	**Dinner**
8:00 PM	8:45 PM	**Dinner speaker: Ray Smith Historian, Y-12**

FRIDAY, JULY 29 — CHEROKEE BALLROOM

7:30 AM	8:30 AM	**Breakfast (Exhibitors/Open Research Discussions)**
F1		**Chair: Kate Jones**
8:30 AM	8:55 AM	**Tibor Kibedi** *The Radiative Width of the Hoyle State from Pair Conversion and Proton-gamma-gamma Measurements*
8:55 AM	9:15 AM	**Moshe Gai** *The Triangular D_{3h} Symmetry of ^{12}C*
9:15 AM	9:35 AM	**Kelly Chipps** *The Curious Case of the Second 0^+: Resonances in ^{25}Al(p,γ)^{26}Si*
9:35 AM	9:55 AM	**Alexandrina Petrovici** *From Isospin-related Phenomena to Stellar Weak Processes within Beyond-mean-field Approach*
9:55 AM	10:15 AM	**Toshio Suzuki** *Electron-capture Rates at Stellar Environments and Nucleosynthesis*
10:15 AM	10:30 AM	**Coffee Break**
F2		**Chair: Alfredo Galindo-Uribarri**
10:30 AM	11:00 AM	**Rituparna Kanungo** *Exploring the Exotic Landscape with Direct Reactions*
11:00 AM	11:30 AM	**Mark Huyse** *The HIE-ISOLDE Facility: Post-accelerated Beams at ISOLDE*
11:30 AM	12:00 PM	**Remco Zegers** *Spin-isospin Excitations with rare Isotope Beams*
12:00 PM	12:15 PM	**Closing Remarks**
		End of NS2016
12:30 PM	2:00 PM	**LUNCH (on your own)**
3:00 PM	8:00 PM	**Neutrino in Nuclear Physics Workshop**

1.4 Contact List

Conference Chair		
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Audiovisual Support		
James T. Matta	mattajt@ornl.gov	-

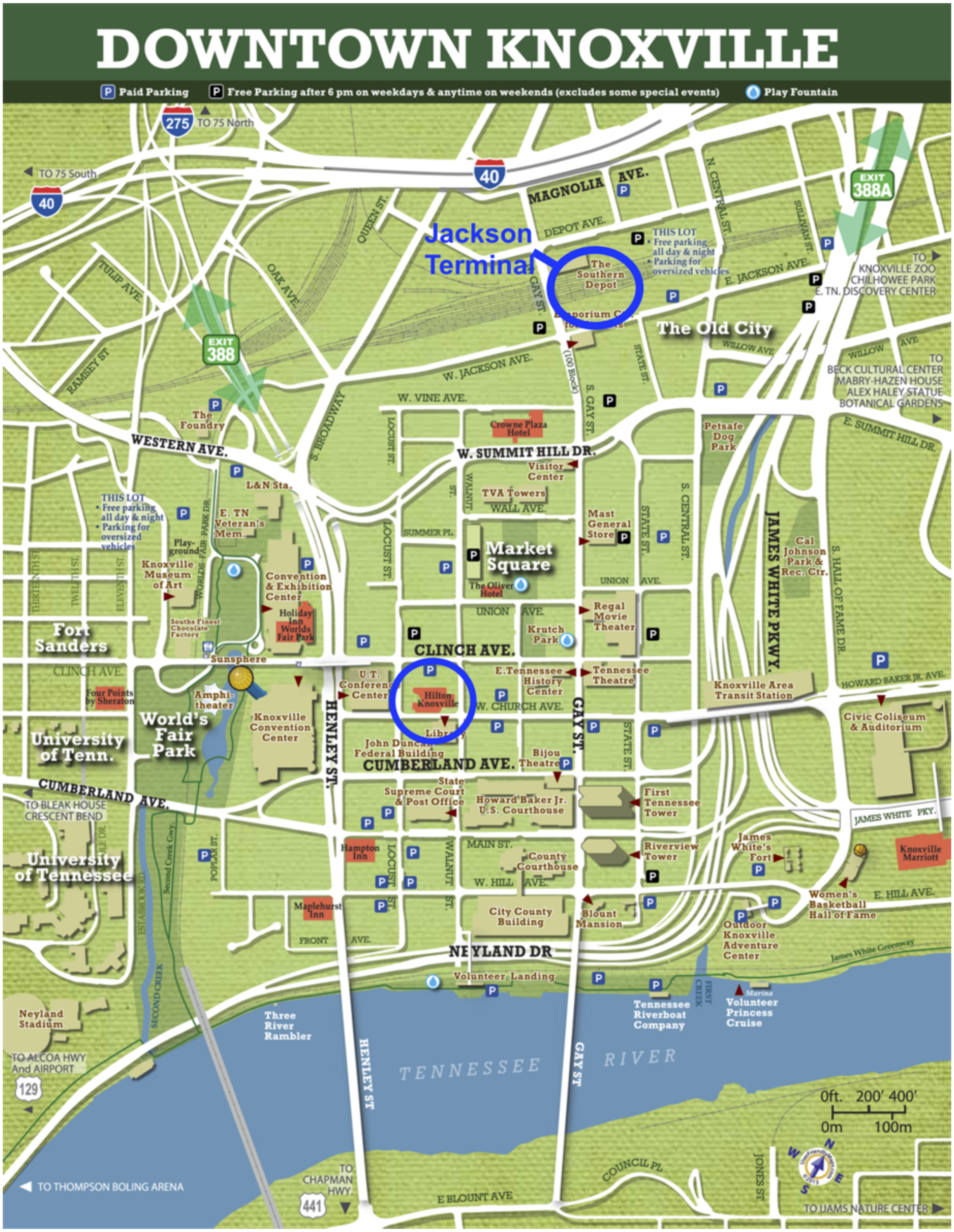
2. Knoxville

Knoxville, Tennessee is often described as a hidden gem. First time visitors are typically amazed by all this city has to offer. The fact that some of its most appealing attractions are within walking distance of a very vibrant downtown is a plus.

2.1 Maps

In this section you will find maps that can help you to get around downtown Knoxville and to localize important events related to the NS2016 conference like the hotel layout and the recommended route to the Banquet location (Jackson Terminal). We also present the map layout for the posters location.

2.1.1 Downtown Knoxville



2.1.2 Jackson Terminal (Banquet)

Address:213 West Jackson Avenue, Knoxville, TN 37902

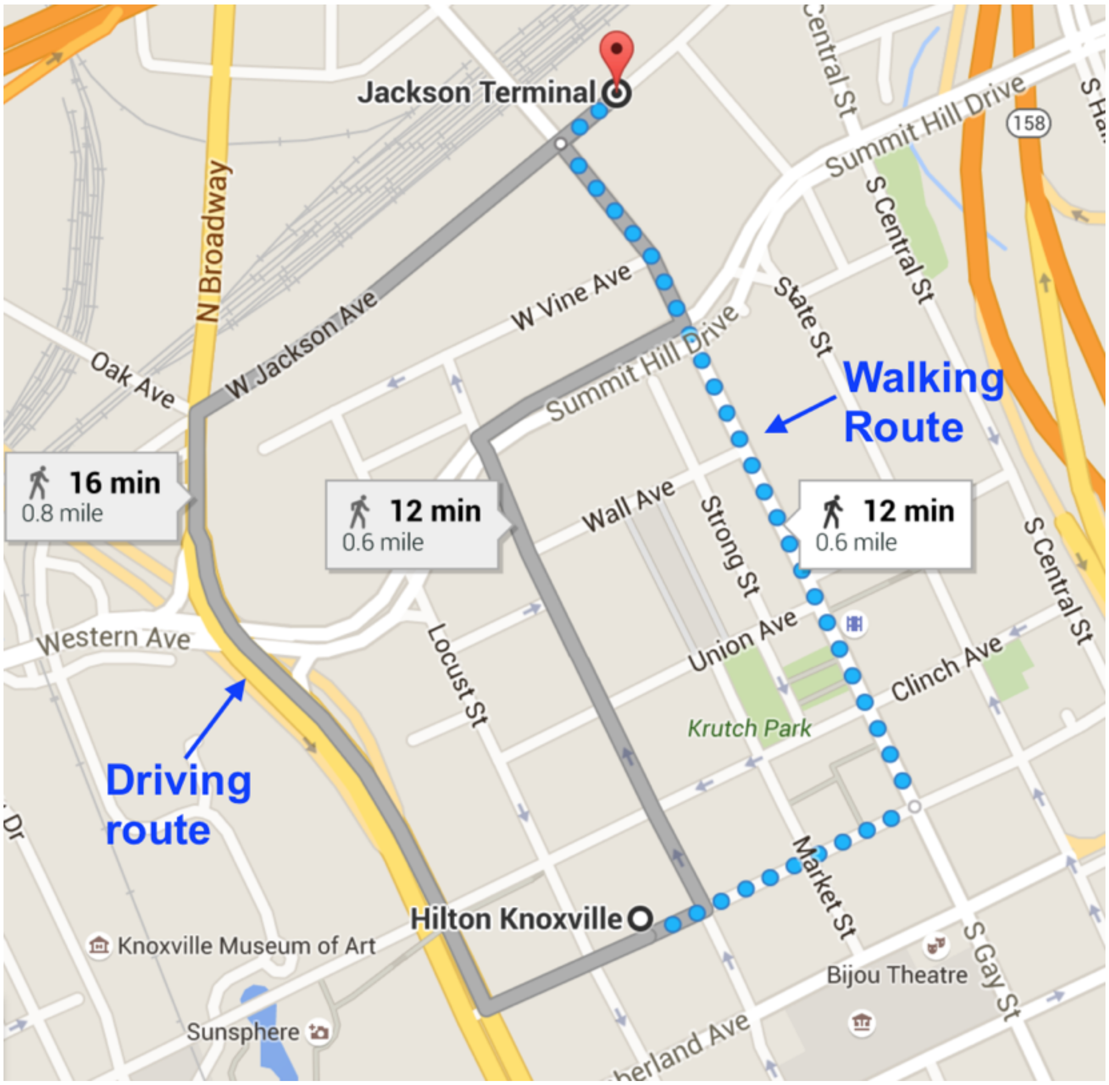


Figure 2.1: Route from Hilton Hotel to the Jackson Terminal

2.1.3 Hilton Hotel Layout

Address: 501 West Church Ave., Knoxville, TN 37902

The orals and mini-talks are going to be held at the Cherokee Ballroom. Poster sessions will be located in the Sequoyah Conference Centers (see Section 2.1.4). Registration and Reception on Sunday will be at the HIWASSEE 1st Floor. On Monday registration desk will be located in the Mezzanine.

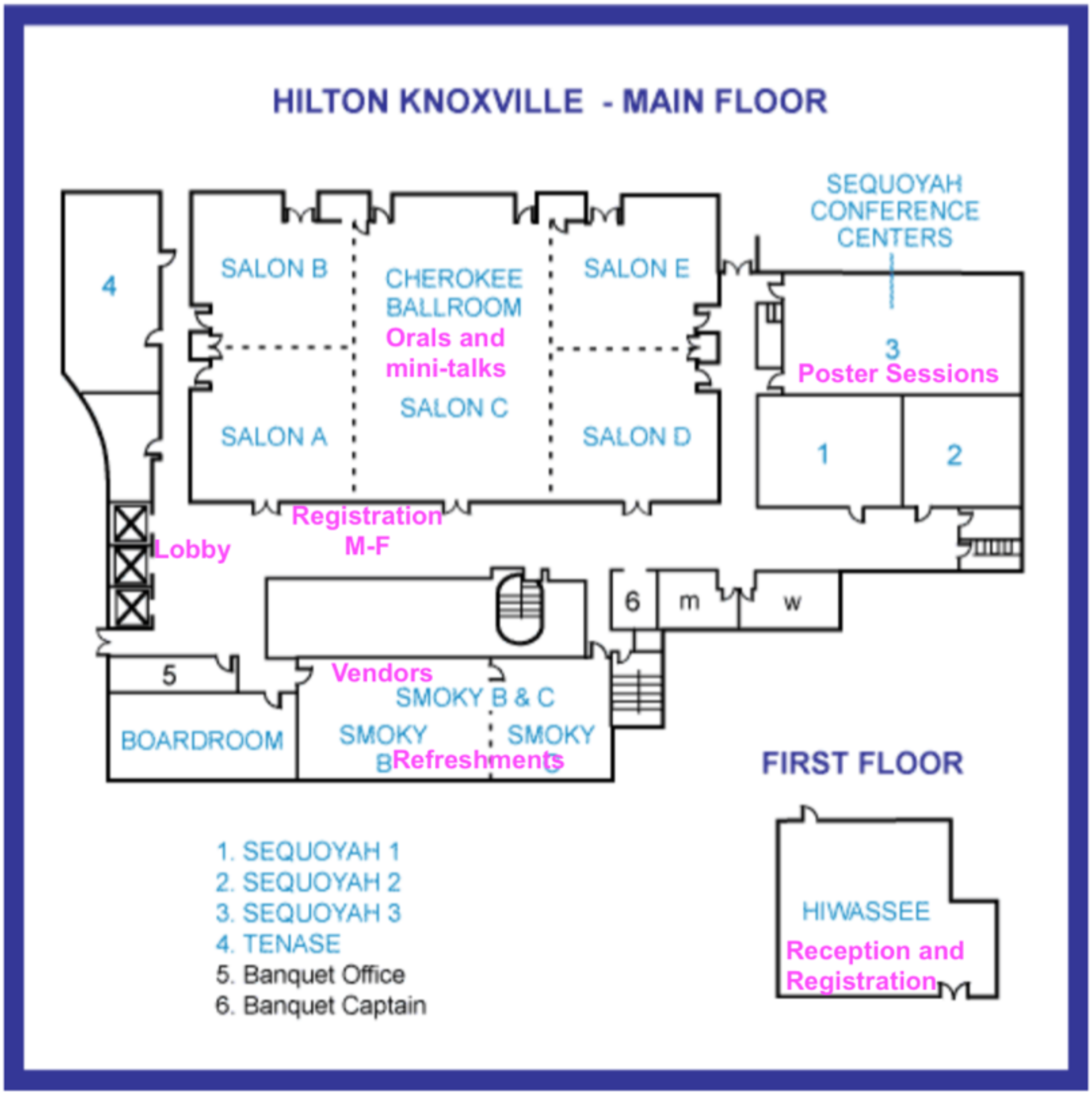


Figure 2.2: Hilton Hotel Knoxville

2.1.4 Sequoyah Conference Centers (Poster Layout)

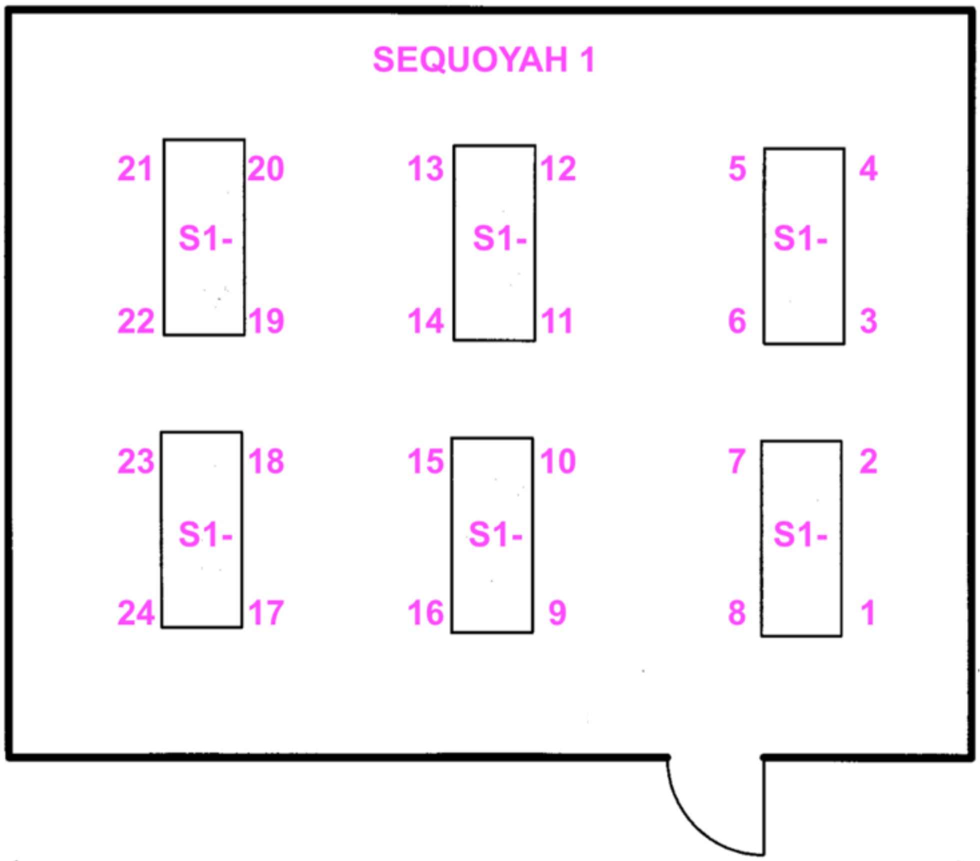


Figure 2.3: Sequoyah 1

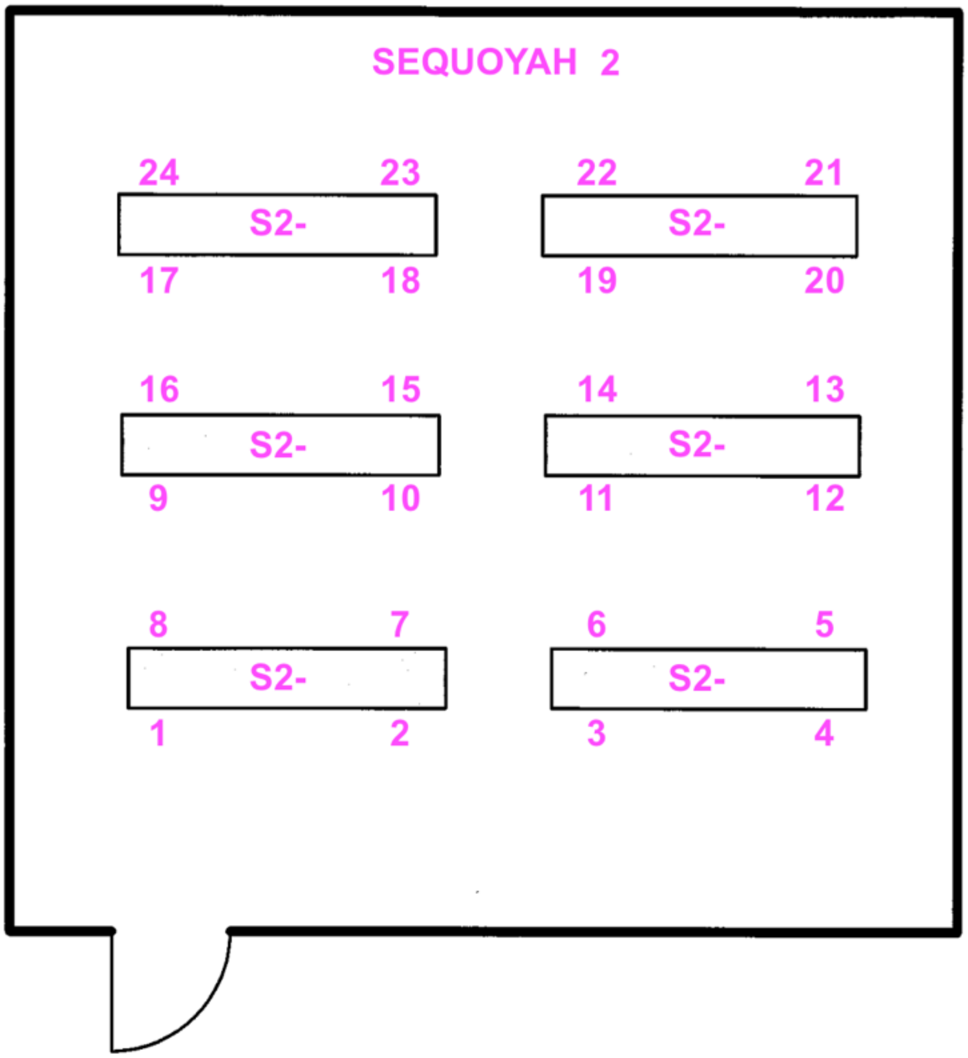


Figure 2.4: Sequoyah 2

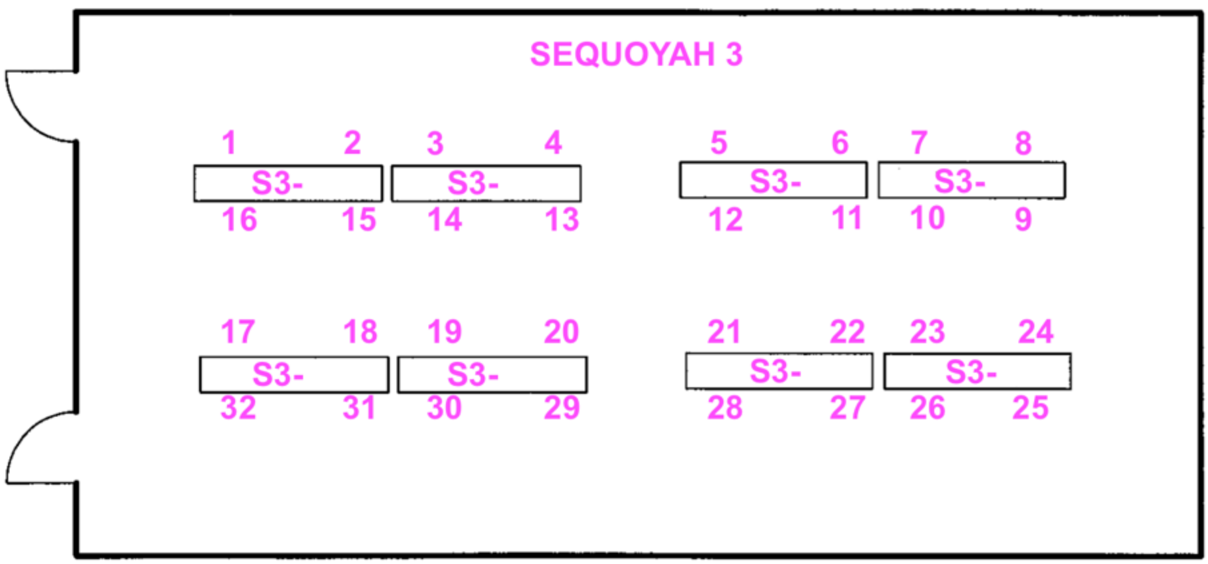


Figure 2.5: Sequoyah 3

2.2 Restaurants

CONVENTION CENTER AREA

Chesapeake's Seafood House (673-3433)	600 Union Ave.	Seafood/American $$$$
Flow Brew Parlor (603-9929)	603 W. Main St.	Coffee/Bar $
Firefly - Hilton Hotel (523-2300)	501 Church Ave.	Seasonal Beer Garden $
Primo's Restaurante Italiano (249-7321)	810 Clinch Ave.	Italian/Cocktails $$$
K Brew (210-8267)	800 Market St.	Coffee/American $
Marble City Kitchen - Hilton Hotel (523-2300)	501 Church Ave.	American/Buffet $$
McEwan's Kitchen - Four Points by Sheraton (971-4663)	1109 White Ave.	American/Bar $$
Starbucks - Hilton Hotel (523-2300)	501 Church Ave.	Coffee/Market $
Windows on the Park - Holiday Inn (522-2800)	525 Henley St.	American/International $$$
Yassin's Falafel House (387-8275)	706 Walnut St.	Mediterranean/Falafel $

GAY STREET AREA

Archer's BBQ (985-4554)	408 S. Gay St.	BBQ/Ribs $$
Babalu Tacos & Tapas (329-1002)	412 S. Gay St.	Tapas/Bar $$
Best Bagels & Deli (691-3154)	800 S. Gay St.	Deli/American $$
Bistro at the Bijou (544-0537)	807 S. Gay St.	Southern/American $$$
Brown Bag (474-0587)	800 S. Gay St.	American/Catering $$
Casual Pint (951-2160)	421 Union Ave.	Craft Beer Market $
Clancy's Tavern & Whiskey House (219-1266)	602 S. Gay St.	American/Irish Pub $$
Club LeConte (523-0405)	800 S. Gay St.	American/Continental $$$$
Coffee & Chocolate (688-9244)	327 Union Ave.	Coffee/Dessert $$
Coolato Gelato (971-5449)	524 S. Gay St.	Café/Italian $$
Crú Bistro and Wine Bar (544-1491)	141 S. Gay St.	American/Wine Bar $$$
Dazzo's Pizzeria (525-2105)	710 S. Gay St.	Pizza/Italian $$
Downtown Grill & Brewery (633-8111)	424 S. Gay St.	American/Brewery $$
Downtown Grind (454-8263)	418 S. Gay St.	Coffee/Smoothies $
Empire Deli (219-1753)	625 S. Gay St.	American/Italian $
FIVE (219-1676)	430 S. Gay St.	Seafood/American $$$
The French Market Crêperie (540-4372)	530 S. Gay St.	Crepes/Coffee $
Frussie's Deli & Bakery (333-5359)	722 S. Gay St.	Deli/Sandwiches $
Garrett's Downtown Deli (540-4141)	800 S. Gay St.	Deli/American $$
Just Ripe (851-9327)	513 Union Ave.	Vegetarian/Grocery $
Knox Mason (544-2004)	131 S. Gay St.	Southern/Contemporary $$$
Lenny's Sub Shop (521-8380)	522 S. Gay St.	American/Sandwiches $
The Library - Crowne Plaza (522-2600)	401 Summit Hill	Cocktails/American $
Mahogany's - Crowne Plaza (522-2600)	401 Summit Hill	American/Casual $$$
Mirage Knoxville (200-8910)	415 S. Gay St.	Mediterranean/Bar $$
The Market (541-5150)	504 S. Gay St.	Grocery/Deli $
Nama Sushi Bar (633-8539)	506 S. Gay St.	Asian/Sushi $$$
Pete's Coffee Shop & Restaurant (523-2860)	540 Union Ave.	American/Diner $$
Peter Kern Library at Oliver Hotel (521-0050)	407 Union Ave.	Cocktails/Southern $$
Primetime Hotdog (405-1739)	800 S. Gay St.	Hot Dog/American $
Sapphire Modern Bar and Restaurant (637-8181)	428 S. Gay St.	American/Cocktails $$
Skybox Sports Bar and Grill (200-8910)	415 S. Gay St.	American/Sports Bar $$
Sugar Mama's Knox (851-5429) (Spring 2016)	135 S. Gay St.	American/Craft Beer $$
Suttree's High Gravity Tavern (934-3814)	409 S. Gay St.	Craft Beer/American $$

MARKET SQUARE AREA

Blue Coast Grill & Bar (243-2300)	37 Market Square	American/Bar $$
Café 4 (544-4144)	4 Market Square	Southern/American $$$
Cocoa Moon (521-3888)	19 Market Square	International/Fusion $$$
Juice Bar (Summer 2016)	2 Market Square	Smoothie/Vegetarian $$
Uncorked (521-0600)	20 Market Square	Small Plates/ Wine Bar $$$
KOI Fusion (521-3888)	19 Market Square	Asian/French $$$

The Lunchbox (409-4211)	607 Market Street	American/Catering $$
Market House Café (444-5949)	36 Market Square	Sandwiches/American $
Not Watson's Kitchen + Bar (766-4848)	15 Market Square	American/Bar $$$
Oliver Royale (622-6434)	5 Market Square	American/Bar $$$
Preservation Pub (524-2224)	28 Market Square	Bar/Pizza $
Rita's Italian Ice (673-4888)	26 Market Square	Italian Ice/Desserts $
Scruffy City Hall (524-2224)	32 Market Square	Brewery/Tapas $$
Soccer Taco (544-4471)	9 Market Square	Mexican/Sports Bar $
Stock & Barrel (766-2075)	35 Market Square	Burgers/American $$
Subway (524-9446)	25 Market Square	Deli/Sandwiches $
The Tomato Head (637-4067)	12 Market Square	Pizza/Vegetarian $$
Trio Café & Sunset Bar (246-2270)	13 Market Square	American/Bar $$
Tupelo Honey Café (522-0004)	1 Market Square	Southern/Bar $$$

UNIVERSITY OF TENNESSEE AREA

Chaiyos Thai and Sushi (249-8081)	601 James Agee St.	Thai/Sushi $$
Cool Beans (522-6417)	1817 Lake Ave.	American/Sports Bar $
Copper Cellar (673-3411)	1807 Cumberland Ave.	Steakhouse/Burgers $$
Field House Social (525-4481)	2525 University Commons Way	Sports Bar/ American $$
Goal Post Tavern (523-4597)	1824 Cumberland Ave.	American/Sports Bar $
Golden Roast (544-1004)	825 Melrose Place	Coffee/Bakery $
Gus's Good Times Deli (525-9485)	815 Melrose Place	Deli/Burgers $
Hanna's Café (522-9933)	1836 Cumberland Ave.	Bar/American $
Half Barrel (595-4848)	1829 Cumberland Ave.	Sports Bar/American $
Hilton Garden Inn Grille	1706 Cumberland Ave.	American/Bar $$
House of Dragon (546-2565)	1907 Cumberland Ave.	Chinese/Asian $
Niro's Gyros (546-5868)	1823 Cumberland Ave.	Gyros/Deli $
Oscar's (524-3663)	1840 Cumberland Ave.	Italian/Pizza $$
Oscar's Taco Shop (633-0330)	2121 Cumberland Ave.	Mexican/Tacos $
Sunspot (637-4663)	2200 Cumberland Ave.	Vegetarian/American $$
Uptown Bar and Grill (525-4442)	1912 Cumberland Ave.	American/ Bar $$

THE OLD CITY AREA

Awaken Coffee (951-0427)	125 W. Jackson Ave.	Coffee/Pastries $
Barley's Taproom & Pizzeria (521-0092)	200 E. Jackson Ave.	Pizza/Bar $$
Balter Beerworks (999-5015)	100 S. Broadway	Brewery/American $$
Boyd's Jig & Reel (247-7066)	101 S. Central St.	Scottish/Pub $$
Curious Dog (544-9997)	200 W. Jackson Ave.	Deli/Bar $$
The Crown & Goose (524-2100)	123 S. Central St.	English/Gastropub $$$
DaVinci's Pizzeria and Calzones (637-5040)	113 S. Central St.	Pizza/Italian $
Hanna's Old City (637-8908)	102 S. Central St.	Bar/American $
Knox Public House (247-4344)	212 W. Magnolia Ave.	Pub/Southern $
The Melting Pot (971-5400)	111 N. Central St.	Fondue/Dessert $$$$
Old City Java (523-9817)	109 S. Central St.	Coffee/Pastries $
Old City Wine Bar (851-7676)	102 W. Jackson Ave.	Wine/Small Plates $$
Oli Bea (200-5450)	119 S. Central St.	Breakfast/Coffee $
Sweet P's BBQ & Downtown Dive (281-1738)	410 W. Jackson Ave.	Barbeque/Bar $$
Urban Bar and Corner Café (546-2800)	109 N. Central St.	Bar/American $

VOLUNTEER LANDING AREA

Calhoun's On the River (673-3355)	400 Neyland Dr.	American/Barbeque $$$
Hill Street Café at the Marriott (637-1234)	500 E. Hill Ave.	American/Breakfast $$$
Ruth's Chris Steakhouse (546-4696)	950 Volunteer Landing	Steakhouse/Seafood $$$$

2.3 Transportation

- Information of taxis licensed to do business at the airport can be found here: Airport Taxis
- **Discount Taxi** (865-755-5143) charges $35 per van from the airport to downtown Hilton. Reservations at: Reservations
- **UBER service:** UBER. Estimate fare from Airport to the Hilton: $13-$18
- Transportation from the Hilton Hotel to the Jackson Terminal (banquet) will be provided.
- **Knoxville Area Transit (KAT)** is the City of Knoxville's transit system, operating buses, trolleys (see Figure 2.6) and paratransit service across the city. For routes and schedules visit the webpage: KAT

Figure 2.6: Trolley Map

2.4 Calendar of Events in Knoxville (7/24-8/1)

visit knoxville TENNESSEE

Sunday, July 24, 2016

Summer Movie Magic: Breakfast at Tiffany's	Tennessee Theatre	8:00 P.M.
Sunday Assembly Knoxville	The Concourse at The International	10:30 A.M.
Layover Sunday Brunch	The Concourse at The International	12:00 P.M.
Shakespeare: The Merry Wives of Windsor	Scruffy City Hall	2:00 P.M.
Angela Perley & The Howlin Moons	Preservation Pub	10:00 P.M.
DIY Recycled Accent Walls	Ijams Nature Center	2:00-3:00 P.M.
Tennessee Smokies vs. Mississippi	TN Smokies Ballpark	5:05 P.M.
Shakespeare on the Square	Market Square	7:00-10:00 P.M.
Legally Blonde, JR. Musical	Knoxville Children's Theatre	3:00 P.M.

Monday, July 25, 2016

Geeks Who Drink: Trivia Contest The Speakeasy

8:00-9:00 P.M.

The Mallet Brothers Preservation Pub

10:00 P.M.

Barre Belle Outdoor Yoga Ijams Nature Center

9:00-10:00 A.M.

Norris Paddling Kayaking Discovery Class Norris Dam Marina

9:00 A.M.

Tuesday, July 26, 2016

Summer Slaughter Tour 2016 The International

2:00 P.M.

Open Mic Night The Speakeasy

7:00-10:00 P.M.

Einstein Simplified- Comedy Improv Scruffy City Hall

8:00 P.M.

Marble City 5 Market Square Stage

8:00-10:00 P.M.

The Joy of Pasta Making for Beginners Ijams Nature Center

6:00-7:30 P.M.

Tuesday Morning Bike Ride Cycology Bicycles

10:30 A.M.

Jazz on the Square Market Square Stage

8:00-10:00 P.M.

The Viking Age and Norse Genealogy East TN History Center

12:00-1:00 P.M.

Wednesday, July 27, 2016

Master Gardener Workday Knoxville Botanical Gardens

9:00 A.M.

Best of Ijams Guided Hike Ijams Nature Center

10:00 A.M.

Hike To Ramsey Cascades Alcoa Food City

8:00 A.M.

Positive Hits Tour Knoxville Civic Coliseum

7:00 P.M.

Thursday, July 28, 2016

Tarocco: A Soldier's Tale Bijou Theatre

7:30 P.M.

BoomBox The Concourse at The International

9:00 P.M.

Parlor Jazz The Emporium

7:00-9:00 P.M.

Barre Belle SUP Yoga Ijams Nature Center

6:00 P.M.

Barre Belle Outdoor Yoga Ijams Nature Center

6:30-7:30 P.M.

Legally Blonde, JR. Musical Knoxville Children's Theatre

7:00 P.M.

Friday, July 29, 2016

Greg Tardy Quintet Red Piano Lounge

9:00-11:55 P.M.

Legally Blonde, JR. Musical Knoxville Children's Theatre

7:00 P.M.

Saturday, July 30, 2016

ACO World Championships of Cornhole Knoxville Convention Center

7:30 A.M.

Barre Belle SUP Yoga Ijams Nature Center

9:00 A.M.

Making a Gourd Birdhouse Ijams Nature Center

1:00-3:00 P.M.

Legally Blonde, JR. Musical Knoxville Children's Theatre

1:00 & 5:00 P.M.

Ancestry in Detail East TN History Center

1:00-3:00 P.M.

World Wrestling Entertainment Live Thompson Bowling Arena

7:30 P.M.

Slide the City Mary Costa Plaza

9:00 A.M. & 2:00 P.M.

Sunday, July 31, 2016

Summer Movie Magic: Breakfast at Tiffany's Tennessee Theatre

2:00 P.M.

DigiTour Summer The Concourse at The International

3:00 P.M.

Shakespeare: King Lear Scruffy City Hall

2:00 P.M.

Party in the Park World's Fair Park

11:00 A.M.-2:00 P.M.

Legally Blonde, JR. Musical Knoxville Children's Theatre

3:00 P.M.

Monday, August 1, 2016

Mighty Musical Monday Tennessee Theatre

12:00 P.M.

Barre Belle Outdoor Yoga Ijams Nature Center

9:00-10:00 A.M.

2.5 Poster Reproduction Location

FedEx Office Print & Shop Center
1715 Cumberland Avenue
Knoxville, TN 37916
(865)-523-8213
Hours:

- **M-F 7:30 AM-9:00 PM**
- **Sat 8:00 AM-6:00 PM**
- **Sun 12:00 PM-6:00 PM**

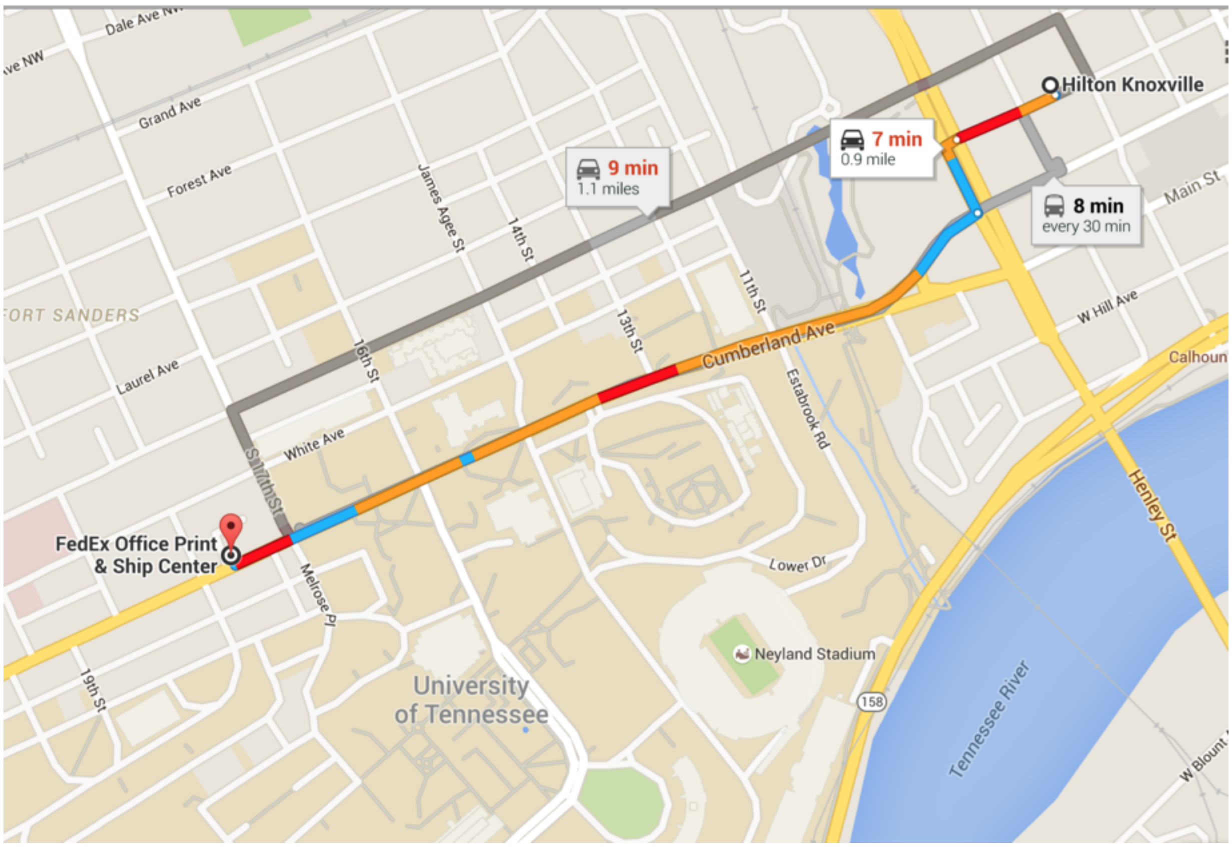


Figure 2.7: Route to the closest FedEx Office Print & Shop Center to the Hilton Hotel

3. Agenda

3.1 Sunday July 24th

		SUNDAY JULY 24
		HIWASSEE 1ST FLOOR
3:00 PM	7:00 PM	**REGISTRATION**
6:00 PM	9:00 PM	**RECEPTION**

3.2 Monday July 25th

		MONDAY, JULY 25
		CHEROKEE BALLROOM
7:30 AM	8:30 AM	**Breakfast (Exhibitors/Open Research Discussions)**
M1		**Chair: David Dean**
8:30 AM	9:00 AM	**Laura Greene** *Opening Ceremony*
9:00 AM	9:30 AM	**Thomas Zacharia** **Mark Riley** *HRIBF Dedication*
9:30 AM	10:00 AM	**Krzysztof Rykaczewski** *Reactor Anti-neutrino Spectra and Decay Heat in Fission Fragments from Total Absorption Spectroscopy*
10:00 AM	10:30 AM	**Coffee Break**
M2		**Chair: Robert K. Grzywacz**
10:30 AM	11:00 AM	**Anna Hayes** *The Neutrino Anomalies*
11:00 AM	11:25 AM	**Andrei Andreyev** *Shape Coexistence and Charge Radii in Mercury Isotopes Studied by In-source Laser Spectroscopy at VADLIS/RILIS-ISOLDE*
11:25 AM	11:45 AM	**Akaa Daniel Ayangeakaa** *Shape Coexistence and the Role of Axial Asymmetry in Neutron-rich Ge isotopes*
11:45 AM	12:05 PM	**Andrea Gottardo** *Shape Coexistence in the ^{78}Ni Region: Intruder 0_2^+ State in ^{80}Ge*
12:05 PM	12:25 PM	**Peter Bender** *Exploring the Onset of Shape Coexistence using (d,p) with Exotic Sr Isotopes.*
12:25 PM	12:45 PM	**Augusto Macchiavelli** *The ^{30}Mg(t,p)^{32}Mg Puzzle Revisited*
12:45 PM	2:00 PM	**LUNCH (on your own)**
M3		**Chair: Carl Svensson**
2:00 PM	2:30 PM	**Alexander Obertelli** *In-beam Gamma Spectroscopy at the RIBF: Recent Results from Proton-induced Direct Reactions*
2:30 PM	2:50 PM	**Heather Crawford** *Characterizing Deformation in the Mg Isotopes: N=20 to N=28*
2:50 PM	3:10 PM	**Ingo Wiedenhoever** *Isomeric Character of the Lowest 4^+ State in ^{44}S*

		Monday, July 25
		CHEROKEE BALLROOM
3:10 PM	3:30 PM	**John Sharpey-Schafer** *On Low-lying $K^{\pi} = 0^{+}$ and 2^{+} Rotational Bands in Deformed Nuclei*
3:30 PM	4:00 PM	**Coffee Break**
4:00 PM	6:00 PM	**Mini-Talks** Benjamin Crider William B. Walters Mitch Allmond Sanna Stolze Jasmine Sethi Brian Bucher Robert Baker Nir Nevo Dinur Jolie Cizewski Ruben de Groote Robert Grzywacz Callie Goetz Daryl Hartley Tan Ahn
		End of Talks
		SEQUOYAH CONFERENCE CENTERS
6:00 PM	8:00 PM	**Posters** **(Reception in Lieu of Dinner)**

3.3 Tuesday July 26th

		Tuesday July 26
		CHEROKEE BALLROOM
7:30 AM	8:30 AM	**Breakfast (Exhibitors/Open Research Discussions)**
T1		**Chair: Jolie Cizewski**
8:30 AM	8:50 AM	**Thomas Papenbrock** *Effective Field Theory for Nuclear Vibrations with Quantified Uncertainties*
8:50 AM	9:10 AM	**Arianna Carbone** *Nuclear Matter from a Green's Function Approach*
9:10 AM	9:30 AM	**Daniel Lubos** *Spectroscopy around Sn-100*
9:30 AM	9:50 AM	**Robert Wadsworth** *Isomer Decays in the $N = Z$ Nucleus ^{96}Cd Populated via Fragmentation*
9:50 AM	10:10 AM	**Steven Pain** *The First Campaign of Direct Reaction Measurements using GODDESS*
10:10 AM	10:30 AM	**Coffee Break**
T2		**Chair: Anatoli Afanasjev**
10:30 AM	11:00 AM	**Heiko Hergert** *Novel Ab Initio Methods for Nuclei*
11:00 AM	11:20 AM	**Carlo Barbieri** *Advances in Self-Consistent Green's Function Calculations of Medium Mass Isotopes*
11:20 AM	11:40 AM	**Bruce Barrett** *Ab Initio Nuclear Shell Model for sd-shell Nuclei*
11:40 AM	12:00 PM	**Sven Binder** *Effective field theory in the harmonic oscillator basis*
12:00 PM	12:20 PM	**Elena Litvinova** *Pion-nucleon Correlations and their Impact on Nuclear Structure Observables*
12:20 PM	2:00 PM	**LUNCH (on your own)**
Mini II		**Chair: Ingo Wiedenhover**
2:00 PM	3:45 PM	**Mini-Talks** Hooi Jin Ong Samuel Tabor Simon Glynn Pickstone Nathan Brewer Partha Chowdhury Greg Demand Andrew MacLean

		TUESDAY JULY 26
		CHEROKEE BALLROOM
		Chiara Mazzocchi James Smallcombe Michael Febbraro Nadia Tsoneva Larionova Andrew Miller Titus Morris Kumar Raju Mukhi
		End of Talks
3:45 PM	4:00 PM	**PHOTO**
		SEQUOYAH CONFERENCE CENTERS
4:00 PM	6:00 PM	**Posters** **(Refreshments Served)**

3.4 Wednesday July 27th

		WEDNESDAY JULY 27
		CHEROKEE BALLROOM
7:30 AM	8:30 AM	**Breakfast (Exhibitors/Open Research Discussions)**
W1		**Chair: Gordon C. Ball**
8:30 AM	9:00 AM	**Jon Engel** *Beta Decay with Energy Density Functionals and the r Process*
9:00 AM	9:20 AM	**Maciej Konieczka** *DFT-rooted Calculations of Gamow-Teller Matrix Elements*
9:20 AM	9:40 AM	**Nobuo Hinohara** *Binding Energy Differences of Even-even Nuclei as Pairing Indicators*
9:40 AM	10:00 AM	**Luis Robledo** *Octupole Correlations in a Full-symmetry Restoring Framework*
10:00 AM	10:20 AM	**Kenichi Yoshida** *Enhanced Collectivity of Gamma Vibration in Neutron-rich Dy Isotopes with N=108 - 110*
10:20 AM	10:50 AM	**Coffee Break**
W2		**Chair: David C. Radford**
10:50 AM	11:20 AM	**I-Yang Lee** *Gamma sphere and its Recent Science Highlights*
11:20 AM	11:40 AM	**Amel Korichi** *Characterization of Gamma-ray Tracking Arrays: Performance of the First Phase of AGATA and GRETA using a ^{60}Co Source*
11:40 AM	12:00 PM	**Francesco Recchia** *Neutron Single-particle Strengths in N = 40, 42 Nickel Isotopes*
12:00 PM	12:20 PM	**Walter Reviol** *Detailed Spectroscopy of ^{137}Xe and ^{139}Ba - role of the $\nu i_{13/2}$ Intruder in the Heavy Tin Region*
12:20 PM	12:40 PM	**Andrew Stuchbery** *g Factors and Nuclear Collectivity*
12:40 PM	2:00 PM	**LUNCH (on your own)**
W3		**Chair: Partha Chowdhury**
2:00 PM	2:20 PM	**Krzysztof Starosta** *Chiral Basis for Particle-rotor Model for Odd-odd Triaxial Nuclei*
2:20 PM	2:40 PM	**Alain Gillibert** *Spectroscopy of Neutron Rich Iron Isotopes Obtained from Proton Induced Direct Reactions*

		Wednesday July 27
		CHEROKEE BALLROOM
2:40 PM	3:00 PM	**Christina Burbadge** *Investigating the Nature of Excited 0^+ States Populated via the ^{162}Er(p,t) Reaction*
3:00 PM	3:20 PM	**Lee Evitts** *Electric Monopole Transition Strengths in Stable Nickel Isotopes*
3:20 PM	3:40 PM	**Andrej Herzan** *Detailed Spectroscopy of the Neutron-Deficient Bismuth Isotopes Bi-193,195*
3:40 PM	4:10 PM	**Coffee Break**
W4		**Chair: John Simpson**
4:10 PM	4:40 PM	**Guy Savard** *Mass Measurements on very Neutron-rich Isotopes with a New Penning Trap Phase detection Technique*
4:40 PM	5:00 PM	**Kei Minamisono** *Charge Radii of ^{36,37}K and Disappearance of Shell-closure Signature at N=20*
5:00 PM	5:20 PM	**Gaute Hagen** *Coupled-cluster Computations of Atomic Nuclei*
5:20 PM	5:50 PM	**Ronald Garcia-Ruiz** *Laser Spectroscopy Studies on Neutron-rich Calcium Isotopes*
		End of Talks

3.5 Thursday July 28th

		THURSDAY JULY 28
		CHEROKEE BALLROOM
7:30 AM	8:30 AM	**Breakfast (Exhibitors/Open Research Discussions)**
J1		**Adam Garnsworthy**
8:30 AM	9:00 AM	**Miguel Madurga** *Nuclear Structure of Ca and In isotopes from β-delayed neutron spectroscopy*
9:00 AM	9:20 AM	**Giovanna Benzoni** *Investigation of ^{70,72,74}Ni from Beta Decay of ^{70,72,74}Co*
9:20 AM	9:40 AM	**Michael Carpenter** *Gauging Octupole Collectivity in Neutron Rich Ce Nuclei*
9:40 AM	10:00 AM	**Michelle Dunlop** *High-Precision Half-Life Measurements for the Superallowed β^+ Emitter ^{10}C: Implications for Weak Scalar Currents*
10:00 AM	10:20 AM	**David Perez Loureiro** *β-delayed γ-decay of ^{26}P: Evidence for a Proton Halo?*
10:20 AM	10:45 AM	**Coffee Break**
J2		**Chair: Thomas Papenbrock**
10:45 AM	11:10 AM	**Manuela Cavallaro** *Signatures of the Giant Pairing Vibration in the ^{14}C and ^{15}C nuclei*
11:10 AM	11:30 AM	**Paul Stevenson** *Effective Interaction Effects in Nuclear Dynamics*
11:30 AM	11:50 AM	**Isao Tanihata** *Effect of Tensor Interaction and High-momentum Nucleons near the Ground States of Nuclei*
11:50 AM	12:10 PM	**Umesh Garg** *Are there Nuclear Structure Effects on the Isoscalar Giant Monopole Resonance and the Nuclear Incompressibility?*
12:10 PM	12:30 PM	**Katsuhisa Nishio** *Study of Fission using Multi-nucleon Transfer Reactions*
12:30 PM	2:00 PM	**LUNCH (on your own)**
J3		**Chair: Lee Riedinger**
2:00 PM	2:30 PM	**Takaharu Otsuka** *Shape Coexistence, Shape Transition and Nuclear Forces*
2:30 PM	2:50 PM	**Alexandre Lepailleur** *Spectroscopy of ^{26}F and ^{28}Na to Probe Proton-neutron Forces Close to the Drip Line*
2:50 PM	3:10 PM	**Sunji Kim** *Unbound Excited States in ^{17}C*

		THURSDAY JULY 28
		CHEROKEE BALLROOM
3:10 PM	3:30 PM	**Anna Corsi** *Search for Dineutron Correlation in Borromean Halo Nuclei*
3:30 PM	4:00 PM	**Coffee Break**
J4		**Chair: Robert Wadsworth**
4:00 PM	4:30 PM	**Yuri Oganessian** *Superheavy Nuclei*
4:30 PM	4:50 PM	**Anatoli Afanasjev** *Structure of Superheavy Elements Reexamined*
4:50 PM	5:10 PM	**Michael Block** *Laser Spectroscopy on Nobelium Isotopes at GSI*
5:10 PM	5:30 PM	**Piet Van Duppen** In-*gas-jet Laser Spectroscopy of Neutron-deficient* $^{214,215}Ac$ *Isotopes and Prospects for Studies of the Actinide Region*
5:30 PM	5:50 PM	**Filip Kondev** *Nuclear Archaeology: Properties of K isomers in* $^{244,246}Cm$ *Populated in* β^- *decays of* $^{244,246}Am$
		End of Talks
		THURSDAY JULY 28
		Jackson Terminal
6:00 PM	9:30 PM	**Banquet**
7:15 PM	8:15 PM	**Dinner**
8:00 PM	8:45 PM	**Dinner speaker:** **Ray Smith** **Historian, Y-12**

3.6 Friday July 29th

		FRIDAY JULY 29
		CHEROKEE BALLROOM
7:30 AM	8:30 AM	**Breakfast (Exhibitors/Open Research Discussions)**
F1		**Chair: Kate Jones**
8:30 AM	8:55 AM	**Tibor Kibedi** *The Radiative Width of the Hoyle State from Pair Conversion and Proton-gamma-gamma Measurements*
8:55 AM	9:15 AM	**Moshe Gai** *The Triangular D_{3h} Symmetry of ^{12}C*
9:15 AM	9:35 AM	**Kelly A. Chipps** *The Curious Case of the Second 0^{+}: Resonances in $^{25}Al(p,\gamma)^{26}Si$*
9:35 AM	9:55 AM	**Alexandrina Petrovici** *From Isospin-related Phenomena to Stellar Weak Processes within Beyond-mean-field Approach*
9:55 AM	10:15 AM	**Toshio Suzuki** *Electron-capture Rates at Stellar Environments and Nucleosynthesis*
10:15 AM	10:30 AM	**Coffee Break**
F2		**Chair: Alfredo Galindo-Uribarri**
10:30 AM	11:00 AM	**Rituparna Kanungo** *Exploring the Exotic Landscape with Direct Reactions*
11:00 AM	11:30 AM	**Mark Huyse** *The HIE-ISOLDE Facility: Post-accelerated Beams at ISOLDE*
11:30 AM	12:00 PM	**Remco Zegers** *Spin-isospin Excitations with Rare Isotope Beams*
12:00 PM	12:15 PM	**Closing Remarks**
		End of NS2016
12:30 PM	2:00 PM	**LUNCH (on your own)**
3:00 PM	8:00 PM	**NEUTRINOS IN NUCLEAR PHYSICS WORKSHOP**

4. Posters and Mini-Talks

4.1 Poster List

NAME	ABSTRACT TITLE	AFFILIATION	LOC
Auranen Kalle	Systematic studies of non-Yrast isomeric intruder $1/2^+$ states in odd-mass nuclei $^{197-203}$At	Argonne National Laboratory/University of Jyväskylä	S3-1
Anne Marie Forney	Structure and shape coexistence of ^{73}Zn	University of Maryland	S3-2
Jessica Harker	The level structure of ^{72}Zn: triaxiality and shape coexistence	University of Maryland	S3-3
Bruno Olaizola	Deformed Structures and Shape Coexistence in ^{98}Zr	University of Guelph	S3-4
Erin Peters	Revealing the structure of ^{106}Pd	University of Kentucky	S3-5
Harris Bidaman	A Study on Low Spin States in ^{154}Gd Using (p,p') Reaction	University of Guelph	S3-6
Alison Dreyfuss	Probing alpha-clustering in intermediate-mass nuclei	Louisiana State University	S3-7

Badamsambuu Jigmeddorj	High-statistics β^+/EC decay study of ^{122}Xe	University of Guelph	S3-8
Shelly Lesher	Collectivity in Gadolinium	University of Wisconsin	S3-9
James Matta	Observation of Transverse Wobbling in ^{135}Pr	Oak Ridge National Laboratory	S3-10
Sharmistha Mukhopad-hyay	Nuclear structure of ^{76}Ge from inelastic neutron scattering measurements and shell model calculations	University of Kentucky	S3-11
Mansi Saxena	Study of static quadrupole moments in ^{120}Te isotope	University of Delhi	S3-12
Jonathan Baron	Ultra-High Spin and Band-Terminating Structures in ^{157}Ho	Florida State University	S3-13
Aaron Chester	Doppler shift lifetime measurements in ^{94}Sr using the TIGRESS Integrated Plunger	Simon Fraser University	S3-14
Rebeka Sultana Lubna	Structure of $T_{z=+3/2}$, ^{33}P Nucleus	Florida State University	S3-15
Kalisa Villafana	Rotational Behavior in ^{179,180}W	Florida State University	S3-16
Enhong Wang	Reinvestigation of octupole correlations in ^{146,147}La	Vanderbilt University	S3-17
Jonathan Williams	Study of ^{22}Ne and ^{28}Mg excited states using fusion-evaporation and Doppler shift measurements	Simon Fraser University	S3-18
Marija Vostinar	Spectroscopy of ^{257,258}Db in the vicinity of the N=152 deformed shell gap	University of Tennessee	S3-19
Brittany Abromeit	Study of Nuclear Structure of ^{39}P Using Beta-Delayed Gamma Spectroscopy	Florida State University	S3-20
Ryan Dunlop	First Results from GRIFFIN: Half-Lives of Neutron Rich $^{128-130}$Cd	University of Guelph	S3-21

Nicole Larson	Reinvestigation of low-lying isomeric states in ^{115}Ru	National Superconducting Cyclotron Laboratory/Michigan State University	S3-22
Jennifer Pore	A High-Statistics Measurement of the Beta Decay of ^{46}K with the GRIFFIN Spectrometer	Simon Fraser University	S3-23
Mustafa Rajabali	The β decay of ^{34,35}Mg and the structure of ^{34}Al	Tennessee Technological University	S3-24
Umesh Silwal	Correcting the database: the case for ^{74}Ga β-decay	Mississippi State University	S3-25
Steven Taylor	Beta-Delayed Neutron Spectroscopy of Statistical and Shell-Model Nuclei Using VANDLE	University of Tennessee	S3-26
Gemma Wilson	Beta-delayed neutron emission studies with a C^7LYC array at CARIBU	University of Massachusetts Lowell	S3-27
Marzena Wolinska-Cichocka	β-decay Studies of Decay Chain $^{142}Cs->^{142}Ba->^{142}La$ with Modular Total Absorption Spectrometer	Heavy Ion Laboratory University of Warsaw	S3-28
Tammy Zidar	Investigation of the nuclear structure of ^{33}Al through β-decay of ^{33}Mg to probe the island of inversion	University of Guelph	S3-29
Daniel Negrea	Proton–neutron pairing in N=Z nuclei: Quartetting versus pair condensation	National Institute of Physics and Nuclear Engineering	S3-30
Yongchi Xiao	Search for the heaviest N$\sim$Z alpha emitters	University of Tennessee, Knoxville	S3-31
Igor Izosimov	Gamma-decay in Light Nuclei. Isospin, Borromean Halo, Tango Halo, and Halo- Isomers.	Joint Institute for Nuclear Research	S1-1
Igor Izosimov	Fine structure of the β-decay strength functions S_β(E) in spherical, deformed, and transition nuclei	Joint Institute for Nuclear Research	S1-2
Michael Jones	Two-neutron sequential decay of ^{24}O	Lawrence Berkeley National Laboratory	S1-3

Sean Kuvin	Precise Tests of Ab-initio Calculations of Light Nuclei and Charge Symmetry Breaking in A=10 ^{10}B	University of Connecticut	S1-4
Craig Mehl	Determining the shape of the clustering nucleus ^{20}Ne	The University of the Western Cape	S1-5
Christopher Morse	New measurement of the first 2_1^+ state lifetime of ^{12}Be	University of Massachusetts Lowell	S1-6
Andrea Richard	Spectroscopy of Neutron-rich Mg Isotopes in and around the Island of Inversion	Ohio University	S1-7
Vandana Tripathi	Shell evolution in neutron rich Phosphorus isotopes	Florida State University	S1-8
David Garand	Proposed optical pumping schemes for the determination of charge radii of radioactive nuclides of transition metals	National Superconducting Cyclotron Laboratory/Michigan State University	S1-9
Shintaro Go	Segmented scintillator based implantation detectors for decay studies	University of Tennessee	S1-10
Kyle Schmitt	Neutron dEtector with Tracking (NEXT)	University of Tennessee	S1-11
Karl Smith	First Data with the Hybrid Array of Gamma Ray Detectors (HAGRiD)	University of Tennessee	S1-12
Paul Thompson	Next Generation Nuclear Structure Studies Using JENSA	University of Tennessee	S1-13
Joseph Turko	Simulating the DESCANT Neutron Detection Array with the Geant4 Toolkit	University of Guelph	S1-14
Jonathan Wright	The Effects of Pulse Shape Analysis on Single Element Compton Imaging using a Double Sided Germanium Strip Detector	University of Liverpool	S1-15
Elisa Romero-Romero	Search for Doubly Charge Negative Atomic Ions using Accelerator Mass Spectrometry	Oak Ridge National Laboratory	S1-16

Rebecca Toomey	A neutron spectroscopic approach to measuring low cross section (α,n) reactions.	Rutgers University	S1-17
David Walter	Spectroscopic Factors near the r-process path using Combined Measurements	Rutgers University	S1-18
Sylvester Agbemava	A global analysis of octupole deformation in the ground states of even-even nuclei within the covariant density functional theory.	Mississippi State University	S1-19
Daniel Odell	Infrared Extrapolations of Quadrupole Moments and Transitions	University of Tennessee	S1-20
JamesTracy Jr	A Binding Energy Study of the Atomic Mass Evaluation 2012	Mississippi State University	S1-21

4.2 Mini-Talk and Optional Poster List

NAME	ABSTRACT TITLE	AFFILIATION	LOC
Benjamin Crider	Shape coexistence from lifetime and branching-ratio measurements in ^{68,70}Ni	National Superconducting Cyclotron Laboratory / Michigan State University	S1-23
William B. Walters	New structures for ^{68}Zn: subshell effects at N = 38 and superdeformation	University of Maryland	-
Mitch Allmond	Moments of Inertia of Axially Asymmetric Nuclei	Oak Ridge National Laboratory	S1-24
Sanna Stolze	Collectivity and single-particle structures in ^{166,168}Os	University of Jyväskylä	S2-1
Jasmine Sethi	Structure and shape evolution in ^{75}Ge	University of Maryland	S2-2
Brian Bucher	First direct observation of enhanced octupole collectivity in ^{144,146}Ba	Lawrence Livermore National Laboratory	S2-3
Robert Baker	Ab initio symmetry-adapted no-core shell model results for light to medium-mass nuclei	Louisiana State University	S2-4
Nir Nevo Dinur	Nuclear structure and the proton radius puzzle	TRIUMF	S2-5
Jolie Cizewski	Fragmentation of Single-Neutron States in Neutron-Rich Tin Isotopes	Los Alamos National Laboratory	-
Ruben de Groote	High-resolution laser spectroscopy of neutron-rich copper isotopes ^{76,77,78}Cu with CRIS	Katholieke Universiteit Leuven	S2-6
Robert Grzywacz	Gamow-Teller decays of ^{74}Co ground state and isomer	University of Tennessee	S2-7
Callie Goetz	Total absorption spectroscopy of ^{84,85,86}Br	University of Tennessee/Center for Interdisciplinary Research and Graduate Education	S2-8
Daryl Hartley	New Beta Decay Studies of Deformed, Neutron-Rich Nuclei in the A$\sim$160 Region	United States Naval Academy	-
Tan Ahn	Search for cluster structure in ^{14}O using resonant α scattering	University of Notre Dame	S2-9

Hooi Jin Ong	Understanding effect of tensor interactions in light nuclei via high-momentum one-neutron-transfer reaction	RCNP/ Osaka University	S2-10
Samuel Tabor	Using GRETINA as a Compton Polarimeter	Florida State University	S2-11
Simon Glynn Pickstone	The γ-decay behaviour of the Pygmy Dipole Resonance in ^{92,94}Mo	Institute for Nuclear Physics	S2-12
Nathan Brewer	Characterization of detectors and activities found at the Dubna Gas Filled Separator.	ORNL/UTK/JINPA	S2-13
Partha Chowdhury	Fast Neutron Spectroscopy with a Novel C7LYC Scintillator Array	University of Massachusetts Lowell	S2-14
Greg Demand	A transition centric approach to level scheme determination	University of Guelph	S2-15
Andrew MacLean	Gamma-Gamma Angular Correlation Measurements With GRIFFIN	University of Guelph	S2-16
Chiara Mazzocchi	Exotic decay modes studied by means of the Warsaw Optical Time Projection Chamber	University of Warsaw	S2-17
James Smallcombe	The Spectrometer for Internal Conversion Electrons at TRIUMF-ISAC	TRIUMF	S2-18
Michael Febbraro	Study of the d(7Be,n)^{8}B reaction through neutron spectroscopy and d(^{7}Be,^{7}Be) elastic scattering measurement	Oak Ridge National Laboratory	S2-19
Nadia Tsoneva Larionova	Energy-density functional plus multi-phonon theory as a powerful tool for nuclear structure and astrophysics	Frankfurt Institute for Advanced Studies	-
Andrew Miller	Charge radii and nuclear moments of ^{52,53}Fe, and the shell-closure signature at N = 28	National Superconducting Cyclotron Laboratory	S2-20
Titus Morris	Recent Improvements in the In-Medium Similarity Renormalization Group	Oak Ridge National Laboratory	S2-21

Kumar Raju Mukhi	Reorientation-effect measurement of the first 2^+ state in ^{12}C: Testing ab initio and cluster calculations	University of the Western Cape	S2-22

II

Abstracts

5. Invited Talks

5.1 Otsuka, Takaharu

Shape coexistence, shape transition and nuclear forces

T. Otsuka[1], Y. Tsunoda[2], T. Togashi[2] and N. Shimizu[2]

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Key words: shape coexistence, shape transition, shell evolution, Ni, Zr, nuclear forces

Abstract

We first show how Ni and Zr isotopes, including exotic ones, can be described by state-of-the-art large-scale Monte-Carlo shell-model calculations. For each chain of the isotopes, a single Hamiltonian is used. A unified description has been obtained for each chain, including effects of (sub-)shell closures and strong deformations. For instance, very low-lying excited 0^+ levels in ^{68,70}Ni are shown to be states of strong prolate deformation. The double magicity of ^{78}Ni can be discussed quantitatively in comparison to ^{56,68}Ni. The Zr isotopes can be described as well. For example, the sharp lowering of the 2^+ level at ^{100}Zr is reproduced precisely as well as other properties of exotic Zr isotopes, as a clear evidence of the first-order quantum phase transition in the nuclear shape described by the shell model. The crucial role of Type II shell evolution is presented in both cases of Ni and Zr. Actually there is an underlying common mechanism arising from Type II shell evolution driven by the tensor and central forces. The central force provides with strong quadrupole-quadrupole interactions, while the tensor force controls the resistance power against the deformation. It is thus illustrated that the nuclear forces, including the tensor force, are crucial ingredients to the nuclear shapes, represented by features such as shape coexistence and shape transition, somewhat beyond our conventional expectations.

We shall discuss some other related properties. In particular, if time allows, we can mention possible relevance of superdeformation and fission along the same line.

Some details of this possible new feature can be found in Ref. [1].

[1] T. Otsuka and Y. Tsunoda, J. Phys. G: Nucl. Part. Phys. **43** (2016) 024009.

5.2 Cavallaro, Manuela

Signatures of the Giant Pairing Vibration in the ^{14}C and ^{15}C nuclei

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Giant resonances are collective excitation modes for many-body systems of fermions governed by a mean field, such as the atomic nuclei. The microscopic origin of such modes is the coherence among elementary particle-hole excitations, where a particle is promoted from an occupied state below the Fermi level (hole) to an empty one above the Fermi level (particle). The same coherence is also predicted for the particleparticle and the holehole excitations, because of the basic quantum symmetry between particles and holes. In nuclear physics, the giant modes have been widely reported for the particlehole sector but, despite several attempts, there is no precedent in the particleparticle and holehole ones, thus making questionable the aforementioned symmetry assumption.

The Giant Pairing Vibration (GPV) is the leading particleparticle giant mode. Recently we have provided the first experimental signature of the GPV in light nuclei ^{14}C and ^{15}C excited by the two-neutron transfer reaction (18O,16O) at 84 MeV and 270 MeV incident energy. These results, published in Nature Commun. [1], will be presented and discussed.

[1] F. Cappuzzello,*et al.*, Nat. Commun. 6:6743 doi: 10.1038/ncomms7743 (2015).

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5.3 Engel, Jon

Beta Decay with Energy Density Functionals and the r Process

Jon Engel[1]*
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I report on work to use Skyrme energy-density functional theory to calculate beta decay rates in all heavy nuclei, particularly those important for r process nucleosynthesis. The calculations entail a fit to determine the time-odd part of the Skyrme functional, a part that is unconstrained by ground-state properties in even-even nuclei or nuclear matter. I discuss both the consequences of the new calculations for our understanding of the astrophysical conditions in which the r process takes place and ways in which the calculations can be improved further.

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5.4 Garcia-Ruiz, Ronald

Laser spectroscopy studies on neutron-rich calcium isotopes

Isotopes in the vicinity of doubly magic nuclei are of particular importance for our understanding of the nuclear many-body problem. Their simple structure provide an ideal test for our knowledge of the nuclear force and the development of many-body methods.
With a magic number of protons (Z=20) and two naturally occurring doubly-magic isotopes, ^{40}Ca (N=20) and ^{48}Ca (N=28), the calcium isotopic chain constitutes a unique nuclear system. Additionally, evidence of doubly-magic features have been suggested for two short-lived isotopes ^{52}Ca (N=32) [1] and ^{54}Ca (N=34) [2].

Here, we will discuss recent experimental results obtained with the collinear laser spectroscopy setup (COLLAPS) at ISOLDE, CERN [3]. The ground state electromagnetic moments, spins and root-mean-square charge radii were determined from measurements of the hyperfine structure spectra and isotope shifts of $^{40-52}$Ca [4].

The isotope ^{52}Ca (estimated yield of ~ 250 ions/s) is at the limit of optical detection techniques. To extend our knowledge to isotopes further from stability, a highly sensitive experimental setup has been developed at the COLLAPS beam line [5, 6]. The first results will be presented in addition to ongoing developments for the next experimental campaigns.

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[2] D. Steppenbeck *et al., Nature* 502, 207 (2013).
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[4] R.F. Garcia Ruiz *et al., Nature Physics* 12, 594 (2016).
[5] L. Vermeeren, *et al., Phys. Rev. Lett.* 68, 1679 (1992).
[6] R.F. Garcia Ruiz *et al. In preparation* (2016).

5.5 Hagen, Gaute

Coupled-cluster Computations of Atomic Nuclei

Gaute Hagen[1*]
[1]*Oak Ridge National Laboratory*

This talk reviews recent progress in first-principles computations of atomic nuclei. An optimization of an interaction from chiral effective field theory to few-nucleon systems and oxygen isotopes yielded much improved binding energies and charge radii in light and medium-mass nuclei. The computation of the nucleus ^{48}Ca showed that its neutron skin (difference between the radii of the neutron and proton distributions) is smaller than previously thought, and we made prediction for its dipole polarizability. We predicted the 2^+ state in ^{78}Ni from a correlation with the 2^+ state in ^{48}Ca using chiral nucleon-nucleon and three-nucleon interactions. Our results confirm that ^{78}Ni is doubly magic. We found that continuum effects play an important role in the level ordering of ^{79}Ni, and we also found a low-lying 2^+ state in ^{80}Ni.

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5.6 Hayes, Anna

The Neutrino Anomalies

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The neutrino anomalies generally refer to the hints from appearance and disappearance experiments for eV-scale neutrinos. In the 1990s, the LSND experiment reported a neutrino appearance oscillation signal that, when viewed together with the solar and atmospheric neutrino oscillation experiments, is in conflict with the Standard Model expectation of three neutrino flavors. The follow-on experiment to LSND, MiniBooNE, reported inexplicable excess events at low energies, but not at high energies. More recently, two additional low-energy neutrino disappearance anomalies have been reported. These are the Reactor anomaly, in which the number of observed reactor antineutrinos is fewer than expected in all short-baseline experiments, and the Gallium anomaly, in which the number of neutrinos from radioactive sources detected in gallium detectors is fewer than expected. If these anomalies are neutrino oscillation phenomena, they require the existence of 1eV sterile neutrinos that do not interact via the normal Standard Model electroweak interaction. In this talk I review the current neutrino anomalies. I discuss the uncertainties involved and possible standard model explanations, with an emphasis on the Reactor anomaly. Finally, I will briefly summarize the needs for and the planned new very short-baseline experiments designed to confirm or refute the existence of sterile neutrinos.

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5.7 Hergert, Heiko

Novel *Ab Initio* Methods for Nuclei

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In recent years, there has been tremendous progress in the field of *ab initio* nuclear many-body theory. Computationally efficient methods like Coupled Cluster (CC) [1,2], Self-Consistent Greens Function (SCGF) theory [3], and the In-Medium Similarity Renormalization Group (IM-SRG) [4] are nowadays routinely applied for nuclei as heavy as the tin isotopes, greatly increasing the opportunities for confronting modern nuclear two- and three-nucleon interactions from Chiral Effective Field Theory (EFT) with a wealth of experimental data.

New variants extend these many-body methods to open-shell nuclei [3-8], e.g., through symmetry breaking and restoration, concepts that are customarily associated with nuclear density functional theory. Using the Multi-Reference IM-SRG as a representative example, I will discuss the perspectives of such an approach for including correlations that are hard to capture in more traditional expansion schemes, and survey current capabilities for describing ground and excited state properties with controlled theoretical uncertainties.

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[2] S. Binder *et al.*, Phys. Lett. B**736**, 119 (2014)
[3] V. Somá *et al.*, Phys. Rev. C**89**, 061301 (2014)
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[6] T. Duguet, J. Phys. G**42**, 025107 (2015)
[7] A. Signoracci *et al.*, Phys. Rev. C**91**, 064320 (2015)

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5.8 Kanungo, Rituparna

Exploring the exotic landscape with direct reactions

Rituparna Kanungo

Saint Mary's University, Halifax, Canada

Nuclei far from stability offer us the scope of exploring new features that surface prominently at large isospin and weak binding. Direct reactions have laid the foundations of unraveling unexpected phenomena through the discovery of the nuclear halo. This has triggered a new era in nuclear science breaking the boundaries of conventional concepts. The halo properties elucidate new features that till date remain a challenge to decipher from fundamental principles. Defining the nuclear force from the foundations built on quantum chromodynamics remains one of the major tasks in nuclear physics. Nuclear reactions hold promise to be sensitive probes for constraining the nuclear interaction.

This presentation will introduce the reaction spectroscopy facility, IRIS, stationed at TRIUMF, Canada that uses a novel thin windowless solid hydrogen target. Recent experiments from the facility will be discussed exploring the neutron halo nucleus, ^{11}Li at the neutron drip-line. Observations at the proton-drip line exploring the nuclear force with experiments coupled to *ab initio* theory will also be discussed.

5.9 Kibedi, Tibor

The radiative width of the Hoyle state from pair conversion and proton-gamma-gamma measurements*

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Stellar formation of carbon occurs when three alpha particles fuse and form the excited 7654 keV 0^+ Hoyle state in ^{12}C. Stable carbon is only formed if the excited nucleus decays to the ground state. The Hoyle state is located above the 3α threshold, which makes the triple alpha process very unlikely as the excited carbon nucleus decays back to three alpha particles 99.96% of the time. The process is therefore a bottleneck in nuclear astrophysics, and good knowledge about the production rate is imperative for proper modelling of carbon formation in the universe. Since the formation of stable carbon depends on the electromagnetic decays from the Hoyle state, the 3α rate is directly related to its radiative transition probabilities. The internal decay of the Hoyle state occurs either by a 7654 keV $E0$ transition to the 0^+ ground state, or by a 3215 keV $E2$ transition to the first excited 2^+ state. The current value of the radiative width, Γ_{rad}, has been determined in an indirect way, resulting in a $\approx$12.5% uncertainty on the 3α rate.

Here we report on two new experiments to improve our knowledge on Γ_{rad}. In both experiments the Hoyle state was excited with proton bombardment of natural carbon. In the first experiment, carried out at the Oslo Cyclotron Laboratory, using the CACTUS and SiRi arrays the cascading gamma-rays of E2 multipolarity and 3.215 MeV and 4.439 MeV energy were observed. The Γ_{rad}/Γ ratio was determined from the ratio of singles proton events to number of proton-gamma-gamma triple coincidences. The angular correlation of the $\gamma - \gamma$ events corresponding to the $0_2^+ - 2_1^+ - 0_1^+$ transition was also measured, which uniquely confirms a spin parity of 0^+ of the Hoyle state.

In the second experiment, carried out at the Australian National University, using the Super-e spectrometer, the pair conversion of the 3.215 MeV E2 and 7.654 MeV E0 transitions, de-exciting the Hoyle state, was observed in a single experiment for the first time since the state was observed in the laboratory more than sixty years ago. The experimental ratio of the E0 and E2 pair conversion events will allow the determination of Γ_{rad} in more direct way.

* Australian Research Council DP140102986

5.10 Lee, I-Yang

Gammasphere and its Recent Science Highlights

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Gammasphere being operated at ATLAS is continued to be a forefront instrument. Its high scientific productivity, evident by the steady stream of high impact publications, is due to a number factors. These include new research ideas, a dedicated management staff, sufficient beam time, performance enhancing upgrades, and the addition of more powerful auxiliary detectors. This talk will review some of these factors, as well as a give a few examples of science highlight in the study of highest spin states, the detection the weakest decay branch, and the results from the use of auxiliary detectors. Possible detector development pathways beyond the current generation of tracking detectors will be discussed briefly.

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5.11 Madurga, Miguel

Nuclear Structure of Ca and In isotopes from β-delayed neutron spectroscopy*

M. Madurga[1], A. Gottardo[2], R. Grzywacz[3,4], and the VANDLE and IDS collaborations
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[2] *Centre de Spectromtrie Nuclaire et de spectromtrie de Masse (CSNSM), CNRS/IN2P3 and Universit Paris-Sud, F-91405 Orsay Campus, France.*
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[4] *Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830, USA.*

The investigation of nuclei far away from stability is one of the most promising avenues to learn about the nuclear properties in extreme conditions. Large proton-neutron imbalances are possible for neutron-rich nuclei resulting in interesting new phenomena. Classical magic numbers can disappear [1] and deformation can quickly dominate for nuclei thought to be described by good spherical shell properties [2]. The β-decay provides a selective and sensitive tool to study both the properties of the daughter states populated in the decay as well as the ground state configuration of the mother using the decay strength distribution [3].

Naturally, as we study neutron-rich nuclei further away from stability, increasing β-decay windows and decreasing neutron separation energies result in large portions of the decay strength populating neutron-unbound states. The Versatile Array of Neutron Detectors at Low Energies (VANDLE) is a scintillator array designed at University of Tennessee/ORNL to study β-delayed and reactions' neutron spectroscopy using the time-of-flight (ToF) technique [4]. The array consists of 100 individual scintillator detector modules that can be arranged in experiment-tailored configurations for high-efficiency and flexibility. The use of state-of-the-art digital electronics [4] and photo-multiplier tubes allows for unprecedentedly large detection efficiency, 45% at 1 MeV, and low energy detection thresholds.

Here we report the first results of two experimental campaigns with VANDLE at the ISOLDE facility, CERN. The first experiment studied the neutron-unbound single particle states in odd calcium isotopes populated in β-decay of potassium. The energies of single particle states in ^{53}Ca are necessary to validate shell-model calculations using competing three-body-force frameworks [5]. The β-delayed two-neutron emission channel and decay strength distribution of $^{51-53}$Ca were also studied.

The second experiment investigated the beta decay of the r-process waiting point ^{132}Cd. The decay properties of even-even Cd isotopes are heavily determined by the position of the first 1^+ state in their In daughters [6]. Here we report the observation of very large and concentrated neutron intensity at 1.6 MeV, indicating a lightly fragmented $\nu[(f_{7/2})^{+2}(g_{7/2})^{-1}]\pi(g_{9/2})^{-1}$ 1^+ state at 4.0 MeV in ^{132}In.

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[4] S.V. Paulauskas *et al*., Nucl. Instr. and Methods **737**, 22 2014.
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* List here your supporting agencies.

5.12 Obertelli, Alexander

In-beam Gamma Spectroscopy at the RIBF: Recent Results from Proton-induced Direct Reactions

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In-beam γ-ray spectroscopy is a powerful tool to investigate new excited states and the properties of very exotic nuclei. At the Radioactive Isotope Beam Factory (RIBF), it combines the in-flight BigRIPS fragment separator with an efficient γ-ray spectrometer. Details of the method are described alongside the performance of the γ-ray spectrometers, first results, and prospects for future experiments and setups.

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5.13 Oganessian, Yuri

Superheavy nuclei*

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The first experimental evidence of the existence of superheavy nuclei (SHN) was obtained in 2000 in complete fusion reactions of the ^{244}Pu and ^{248}Cm target nuclei with ^{48}Ca projectiles. These results have opened up new possibilities of synthesis of the heaviest nuclei and study of nuclear and atomic properties of the superheavy elements. As a result of the experiments performed with use of a beam of ^{48}Ca ions and neutron-rich isotopes of actinides, the heaviest elements with atomic numbers from 113 to 118 were synthesized. In these investigations 53 new nuclides, isotopes of elements 104 to 118 having the largest number of neutrons, were produced for the first time, and their decay properties have been determined. A significant increase in the stability of the SHN with the number of neutrons, their relatively high cross sections caused by high fission barriers; scenario and decay characteristics of new nuclides form a direct indication of the existence of an island of stability among very heavy (superheavy) elements predicted by the microscopic theory over 45 years ago. In the talk the experimental approaches to the synthesis of SHN as well as brief compares experimental data with the predictions of the macro-microscopic theory will be given. Some prospects associated with the new accelerator and experimental facilities will be discussed also.

* for a collaboration JINR Dubna-LLNL Livermore-ORNL Oak Ridge-Vanderbilt Nashville-UTK Knoxville

5.14 Rykaczewski, Krzysztof

Reactor anti-neutrino spectra and decay heat in fission fragments from total absorption spectroscopy.*

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Decay studies of over seventy nuclei abundantly produced in nuclear reactors were performed at ORNL using Tandem, on-line mass separator and Modular Total Absorption Spectrometer MTAS [1,2,3]. The results are showing increased decay heat values, typically by about 10% to 40%, which is of interest for nuclear fuel cycle analysis. Respectively, the energy spectra of emitted beta particles and anti-neutrinos got shifted towards lower energies [4]. It results in a reduced number of anti-neutrinos interacting with matter, often by tens of percent per studied fission product [5], affecting the reported value of reactor anti-neutrino anomaly [6,7]. However, the discrepancy between predicted and directly measured high energy part of the reactor anti-neutrino spectrum (see, e.g., [8,9,10] gets increased, when MTAS results are accounted in the reference anti-neutrino flux [11]. MTAS results for several nuclei will be presented and their impact on reactor anti-neutrino properties and decay heat pattern in power reactors will be discussed.

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[4] A. Fijałkowska *et al*., Nuclear Data Sheets 120, 26, 2014.
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* work supported by the U.S. DOE Office of Nuclear Physics under DOE Contract No. DE-AC05-00OR22725 with UT-Battelle.

5.15 Savard, Guy

Mass measurements on very neutron-rich isotopes with a new Penning trap phase detection technique*

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[2]*University of Chicago, Chicago, IL 60637, USA*

Mass measurements provide key insight into changes in nuclear structure as one moves away towards the neutron dripline. They also are a critical input to the modeling of nucleosynthesis events such as the r-process. A series of mass measurements on very neutron-rich isotopes has recently been completed with the CPT mass spectrometer at CARIBU. It utilizes a new mass measurement technique based on the determination of the phase of the cyclotron motion of radioactive ions stored in a Penning trap. Determining the phase of the cyclotron motion instead of the frequency itself allows one to overcome the Fourier limit and obtain much higher resolution for short-lived isotopes. Recent results using this novel approach will be presented and their implication for nuclear structure around doubly-magic ^{132}Sn and in the octupole deformation region in neutron-rich Barium isotopes will be discussed. Recent results on isotopes with enhanced influence on the astrophysical r-process scenarios will also be mentioned.

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5.16 Zegers, Remco

Spin-isospin excitations with rare isotope beams*

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Charge-exchange reactions at intermediate energies ($\gtrsim$100 MeV/u) provide a unique way to test the isovector sector of theories that aim to describe nuclei and their interactions. One of the key methods is to extract Gamow-Teller strength distributions model-independently from measured differential cross sections at forward scattering angles, based on the proportionality between these cross sections and the associated strengths. The proportionality can relatively easily be calibrated by using transitions for which the strength is known from β-decay experiments. This methods has been used successfully for about 35 years. With the advent of rare-isotope beam facilities, charge-exchange reactions are now used to inspect the spin-isospin response of rare isotopes, and to develop novel reaction tools that provide selectiveness for specific types of transitions (e.g. with and without spin-transfer).

At NSCL, a variety of charge-exchange reactions are studied for different purposes. The (t,^{3}He) reaction, performed with a secondary triton beam, is used to study isovector transitions from stable targets. In recent years, the (t,^{3}He) reaction has been also measured in coincidence with γ rays, and most recently with neutrons. The primary goal of these experiments is to benchmark and test theoretical models used for estimating weak reaction rates that are employed in astrophysical simulations, but they also provide information about other, more exotic, excitations, such at the isovector giant monopole resonances. The latter have also been successfully studied with the newly developed (^{10}Be,^{10}B+γ) reaction.

The (^{7}Li, ^{7}Be) and (p,n) reactions in inverse kinematics have been developed to study isovector excitations from unstable nuclei. The (p,n) reaction in inverse kinematics is particularly interesting to study the spin-isospin response of rare isotopes up to high (20 MeV and beyond) excitation energies. The further development of these techniques is especially important in preparation for experiments far from stability at FRIB.

An overview of the program with charge-exchange reactions at NSCL will be given, with a focus on the impact of the experiments on constraining modern nuclear structure models. An outlook for future opportunities at FRIB will also be provided.

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6. Contributed Talks

6.1 Afanasjev, Anatoli

Structure of superheavy elements reexamined*

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The questions of the existence limits and the properties of shell-stabilized superheavy elements (SHEs) have been a driving force behind experimental and theoretical efforts to study such nuclei. Unfortunately, theoretical predictions for SHEs differ considerably. In such a situation an assessment of the accuracy of the description of existing experimental data and theoretical uncertainties for the prediction of the properties of unknown nuclei becomes imperative.

To address the issue a systematic investigation of even-even SHEs in the region of proton numbers $100 \leq Z \leq 130$ and in the region of neutron numbers from the proton-drip line up to neutron number $N = 196$ is performed in the framework of covariant density functional theory (CDFT) [1]. For this study we use the five state-of-the-art functionals representing different classes of covariant energy density functionals. Their global performance in the description of the ground state properties has recently been established [2,3,4]. Pairing correlations are treated within relativistic Hartree-Bogoliubov theory based on an effective separable particle-particle interaction of finite range and deformation effects are taken into account. This allows us to evaluate the accuracy of the theoretical description of binding energies, deformations, shell structure and α-decay half-lives and to estimate theoretical uncertainties in the predictions of these observables in unknown superheavy nuclei. The most important results are as follows:

- Contrary to the previous studies in CDFT, it was found that the impact of the $N = 172$ spherical shell gap on the structure of superheavy elements is very limited. Similar to non-relativistic functionals, some covariant functionals predict an important role played by the spherical $N = 184$ gap. For these functionals (NL3*, DD-ME2, and PC-PK1) there is a band of spherical nuclei along and near the $Z = 120$ and $N = 184$ lines.

- Some functionals such as DD-PC1 and DD-MEδ predict only very few spherical SHEs above $Z = 110$ and $N = 172$; the oblate ground states dominate the nuclear landscape here. Such a possibility has never been discussed before and it is a consequence of the competition of the shell effects at spherical and oblate shapes.

- Available experimental data on heavy and superheavy elements are, in general, described with comparable accuracy and do not make it possible to discriminate between these predictions.

In addition, the inner fission barriers, which define the stability of SHEs, and theoretical uncertainties in their description are systematically studied in the $Z = 106 - 130$ nuclei [5].

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6.2 Andreyev, Andrei

Shape coexistence and charge radii in mercury isotopes studied by in-source laser spectroscopy at VADLIS/RILIS-ISOLDE

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Since more than four decades, the long chain of mercury (Z=80) isotopes represents a text-book example of shape coexistence in the lead region [1], being the first in which an abrupt change of charge radii was observed by approaching the neutron mid-shell at N=104 [2,3], see Figure. In particular, the so-called shape staggering was observed, whereby the charge radii of the low-spin ground states in ^{181,183,185}Hg manifested their strongly-deformed shape, while the high-spin $13/2^+$ isomer in ^{185}Hg and the 0^+ ground states of the neighboring even-even $^{182\text{-}186}$Hg continued a smooth trend of weakly-oblate heavier mercury isotopes.

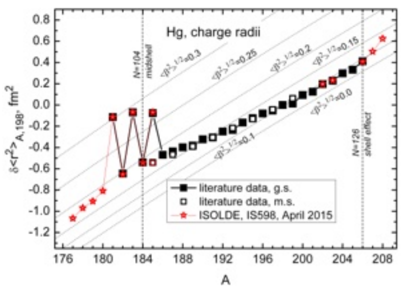

Figure. The charge radii for the chain of mercury isotopes. The previously-known data are shown by the black solid and open squares, the new data from the IS598 experiment – by the red stars.

This presentation will discuss the data from the 2015's IS598 experiment at ISOLDE, in which our collaboration was able to extend the measurements down to ^{177}Hg. The data for ^{207,208}Hg, situated just above the N=126 shell closure were also collected for the first time. This experiment became possible due to the use of a molten lead target coupled to the recently-developed laser ionization technique in the VADLIS [4] ion source at ISOLDE. By combining the high sensitivity of the in-source laser spectroscopy technique, ISOLDE mass separation and Windmill α-decay spectroscopy setup [5], it has been possible to perform the measurements with the yields as low as ~0.1 ions/μC for ^{177}Hg. Along with the Faraday cup and Windmill measurements, also the Multi-Reflection Time-of-Flight (MR-ToF) mass separation technique [6] involving the ISOLTRAP collaboration was used, which proved to be indispensable for the measurements of especially ^{207,208}Hg.

Our new data show that ^{181}Hg is the lightest isotope which possesses a large deformation, with all lighter nuclei showing the charge radii values consistent with the weakly-deformed shapes. The comparison with several modern theoretical approaches will also be discussed.

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6.3 Ayangeakaa, Akaa Daniel

Shape coexistence and the role of axial asymmetry in neutron-rich Ge isotopes*

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The low-lying states in even-even Ge isotopes have been a subject of intense scrutiny for many years due to the inherent challenge of interpreting their intrinsic structure. While several explanations such as vibrational-rotational coupling, 2p-2h intruder mixing and shape coexistence have been proposed, none have been able to satisfactorily reproduce the properties of these low-lying excitations. Recent theoretical calculations have, however, emphasized the importance of the triaxial degree of freedom and, indeed, ^{76}Ge is proposed to exhibit rigid triaxiality. In this study, the electromagnetic properties of low-lying states in ^{72,76}Ge were investigated via projectile multiple Coulomb excitation with GRETINA [1] and CHICO-2 [2]. In the case of ^{72}Ge, substantial evidence for triaxiality and shape coexistence, based on the model-independent shape invariants deduced from the Kumar-Cline sum rule, have been observed [3]. These, and results of multi-configuration mixing calculations carried out within the framework of the triaxial rotor model will be presented. The role of triaxiality and preliminary results for ^{76}Ge will also be highlighted.

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6.4 Barbieri, Carlo

Advances in Self-Consistent Green's Function Calculations of Medium Mass Isotopes*

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The computational effort required by Self-consistent Green's function theory (SCGF) scales smoothly with increasing particle number. At the same time, the theory naturally yields information on the spectral distribution of correlated particle and hole states inside the medium. As such, SCGF is the method of choice for ab-initio investigations of medium mass nuclei and to learn how their structure evolves toward the driplines. This talks will review recent results from nuclear interactions based on chiral perturbation theory and on lattice QCD simulations.

Ab-initio SCGF results for standard chiral interactions have confirmed the role of three-nucleon forces (3NF) in determining the dripline behaviour of isotopes from N to F [1] and from Ar to Ti [2]. At the same time, the lack of saturation led to a refit of chiral interaction to correctly predict nuclear radii (NNLOsat). I will discuss new SCGF results for Oxygen isotopes and for the pf shell up to the Ni chain. The NNLOsat predicts correct radii near the valley of stability but with a tendency to deviate for neutron rich isotopes. Correspondingly, the spectral function distribution is improved with respect to traditional chiral interacitons.

The method exploited by the Hadron to Atomic nuclei form Lattice QCD (HALQCD) collaboration consists in extracting the nucleon-nucleon interaction from lattice simulations and then using it for ab-initio calculations of large nuclei. The numerical accuracy of SCGF theory with these (hard) potentials is sufficient to draw conclusions on binding for nuclei up to ^{40}Ca. The HALQCD approach predicts a curious evolutions of the nuclear chart with respect to the variation of quark masses, with isolated islands of binding being generated first when the physical quark-mass limit is approached from above.

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6.5 Barrett, Bruce

Ab initio nuclear shell model for sd-shell nuclei*

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One of the long term goals of nuclear-structure theory has been to derive the input for standard inert-core shell-model calculations from the fundamental nucleon-nucleon (NN) and three-nucleon interactions. Using a formalism based on the No Core Shell Model (NCSM) [1,2,3], we have determined microscopically the core and single-particle energies and the effective two-body interactions that are the input to standard shell model (SSM) calculations [4,5]. The basic idea is to perform a succession of an Okubo-Lee-Suzuki (OLS) transformation, a NCSM calculation, and a second OLS transformation to a further reduced space, such as the sd-shell, which allows the separation of the many-body matrix elements into an "inert" core part plus a few valence-nucleons calculation. We have used this technique to calculate the properties of the nuclides in the Fluorine chain, using a chiral Effective Field Theory N3LO NN interaction [6]. The obtained SSM input, along with the results of the SSM calculations for the Fluorine isotopes, will be presented and compared with similar results obtained using the In-Medium Similarity Renormalization Group method [7]. We focus on the sensitivity to the derived single-particle energies in order to explore the inferred role of three-nucleon interactions.

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6.6 Bender, Peter

Exploring the Onset of Shape Coexistence using (d,p) with exotic Sr isotopes.*

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The structure of nuclei in the $Z \sim 40$, $N \sim 60$ mass region is perhaps best characterized by the deformation seen in the transition from $N = 58 - 60$ [1]. The competition of both spherical and deformed shell gaps near the Fermi surface in this region leads to an unusually sudden onset of deformation with the addition of only a few nucleons. Work to better understand the competition and stabilization of different shapes in these nuclei is of substantial interest both experimentally and theoretically. To help drive the ongoing theoretical discussion of both mean field [2] and shell model [3] calculations, measurements of the occupations of shape-driving orbitals in this mass region are critical.

The present work explores this shape transition region, using one-neutron transfer reactions on exotic Sr isotopes in inverse kinematics at the TRIUMF ISAC-II facility, the first such high-mass ($A > 30$) experiments performed there. Beams of ^{94,95,96}Sr were produced by impinging a 500 MeV proton beam on an ISAC UC$_x$ target. The extracted beams were charge bred using an ECR before being accelerated to approximately 5.5 MeV/u. The experimental station where the d(^{94,95,96}Sr,p)^{95,96,97}Sr reactions were performed consisted of the TIGRESS gamma-ray spectrometer [4] which surrounded the SHARC charged particle detector [5].

The combination of detected gamma-rays as well as light charged particles is being used to extract energy levels, cross-sections, and proton angular distributions of observed low-lying states. This information gives insight into the underliying wavefuctions of these states. A presentation of the analysis will be made with results compared to current large scale shell model calculations in the mass region.

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6.7 Benzoni, Giovanna

Investigation of ^{70,72,74}Ni from β decay of ^{70,72,74}Co

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One of the main unanswered questions of modern nuclear physics is whether the traditional magic numbers of protons and neutrons, such as they are known near stability, are maintained at extreme values of isospin, or whether new magic numbers emerge as a result of the unbalanced neutron-to-proton ratios. The nuclear region around ^{78}Ni, with 28 protons and 50 neutrons, has attracted great attraction for this purpose. This work aims at studying the even-even ^{70,72,74}Ni nuclei from β-delayed γ spectroscopy of the ^{70,72,74}Co progenitors to test the strength of state-of-the-art shell-model calculations in the vicinity of the doubly-magic ^{78}Ni core.

The data were collected in an experiment performed at RIKEN at the Radioactive-Isotope Beam Factory (RIBF) facility, as part of the EURICA campaign [1,2]. Nuclei in the isotopic chains of Cu, Ni, Co and Fe were produced in in-flight fission of a 345 AMeV ^{238}U stable beam impinging on a 3 mm Be target. The reaction residues were identified using the large-acceptance magnetic spectrometer BigRIPS [3], and were sent through the Zero-Degree spectrometer to a β-decay station, consisting of the WAS3ABi active stopper [1] and the EURICA γ spectrometer [2]. An array of 18 $LaBr_3$ scintillation detectors were also mounted to allow for fast-timing measurements.

The unprecedented high intensities of the primary beam, 10 pnA, enabled the collection of high statistics for the nuclei of interest. The β-delayed γ spectroscopic study is providing a large amount of new information in the populated isotopic chains, resulting in the establishment of new decay schemes in the Fe chain and great extension of existing level schemes for the Ni isotopes.

In this contribution an insight on the shape coexistence and seniority conservation in exotic nuclei of the Ni isotopic chain will be given.

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6.8 Binder, Sven

Effective field theory in the harmonic oscillator basis

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We develop interactions from chiral effective field theory (EFT) that are tailored to the harmonic oscillator basis. As a consequence, ultraviolet convergence with respect to the model space is implemented by construction and infrared convergence can be achieved by enlarging the model space for the kinetic energy. In oscillator EFT, matrix elements of EFTs formulated for continuous momenta are evaluated at the discrete momenta that stem from the diagonalization of the kinetic energy in the finite oscillator space. By fitting to realistic phase shifts and deuteron data we construct an effective interaction from chiral EFT at next-to-leading order. Many-body coupled-cluster calculations of nuclei up to ^{132}Sn converge fast for the ground-state energies and radii in feasible model spaces.

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6.9 Block, Michael

Laser spectroscopy on nobelium isotopes at GSI

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Precision measurements of atomic properties by laser spectroscopy allow probing an element's electronic structure. This is of particular importance for the heaviest elements whose electronic structure is strongly affected by relativistic effects, quantum electrodynamics, and electron correlations.

Despite significant progress in laser spectroscopy of radionuclides in recent years no experimental data on atomic levels of any element beyond fermium are available to date. Isotopes of these elements can be produced in complete fusion-evaporation reactions at accelerator facilities on-line, however, only at rates of at most a few particles per second.

A very sensitive method based on a two-step laser-ionization scheme has been applied for optical spectroscopy of nobelium. In 2015 for the first time atomic transitions including several high-lying Rydberg-states in ^{254}No were identified. In addition, the isotope shift of the $^1S_0$-$^1P_1$ transition in the isotopes ^{252,253}No was studied.

In this contribution, the experimental results will be presented and compared to predictions by state-of-the-art theories. Perspectives for future measurements in heavier elements will be addressed.

6.10 Burbadge, Christina

Investigating the nature of excited 0^+ states populated via the ^{162}Er(p,t) reaction

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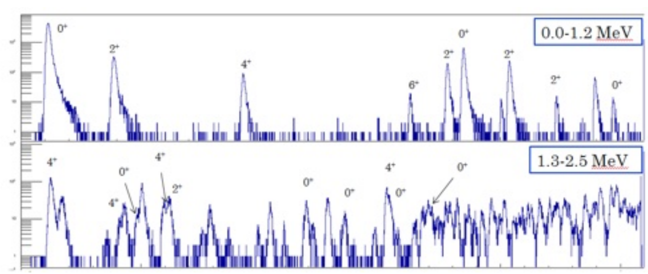
Interpreting the nature of excited states in well-deformed nuclei has been an ongoing challenge in our understanding of nuclear structure. Some of the approaches that have been implemented to interpret the occurence of low-lying excited 0^+ states include vibrational excitations in β-phonons and γ-phonons, as well as pairing excitations. A further complication is the presence of shape coexistence which can increase the number of low-lying states, and if the shapes undergo mixing that spectroscopic signatures can become ambiguous. The $N = 90$ region is just such a case with a well known rapid change in the ground state shape from $N = 88$ to $N = 92$. However, one of the difficulties in resolving the nature of these states is that there is an absence of data, particularly for excited 0^+ states, in the rare earth region.

Two-neutron transfer reactions are ideal for probing $0^+ \to 0^+$ transitions in deformed nuclei. Excited 0^+ states in ^{160}Er have been studied via the (p, t) reaction with a highly-enriched ^{162}Er target at the Maier-Leibnitz Laboratory in Garching, Germany. Reaction products were momentum-analyzed with a Quadrupole-3-Dipole magnetic spectrograph. A sample spectrum from the reaction taken at 30 degrees up to an excitation energy of 2.5 MeV is shown below; a large number of previously unobserved excited states are observed, including six 0^+ states below 2.5 MeV.



The variance in the cross section of these low-lying excited 0^+ states suggests a special character for the 0_2^+ state that may be consistent with shape co-existence. Preliminary results of the relative population of the excited 0^+ states in ^{160}Er will be presented, and placed into context with similar experiments in the $N = 90$ region.

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6.11 Carbone, Arianna

Nuclear matter from a Green's function approach*

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In the past few decades, the study of low-density nuclear matter has found in chiral effective field theory a direct root to the underlying quantum theory, QCD. The combination of ab initio many-body approaches and chiral interactions has then provided a promising framework to obtain a realistic description of infinite nuclear matter.

To achieve this goal, the self-consistent Green's function theory (SCGF) is particularly suited. Via iterative solution of Dyson equation, the fully correlated propagator is obtained, which provides an accurate description of both microscopic and bulk properties [1].

In this talk I will address several aspects of nuclear matter, ranging from zero to finite temperatures: from the prediction of the saturation of nuclear matter to the stiffening of pure neutron matter energy due to three-body forces [2]; from the study of the liquid-gas phase transition in nuclear matter to the analysis of thermal effects important for equations of state for simulations in core-collapse supernovae. Theoretical uncertainties as well as errors due to the many-body approximation will be discussed. The goal is to analzye behaviors that can impact aspects connected to a variety of astrophysical processes.

[1] C. Carbone *et al*., PRC **88** , 054326 (2013)
[2] C. Carbone *et al*, PRC **90** , 054322 (2014)

* This work was supported by the Alexander von Humboldt Foundation through a Humboldt Research Fellowship for Postdoctoral Researchers
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6.12 Carpenter, Michael

Gauging Octupole Collectivity in Neutron Rich Ce Nuclei*

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The CARIBU facility at ATLAS offers new opportunities to study the nuclear structure of neutron-rich nuclei populated following the spontaneous fission of the ^{252}Cf source. The Ba-Ce nuclei around $N = 88$ are of particular interest from a nuclear structure standpoint in that they exhibit properties associated with strong octupole collectivity. Previously, much of the experimental information concerning octupole collectivity in these nuclei came from prompt γ-ray coincidence studies using ^{252}Cf sources placed inside large gamma-ray arrays such as Gammasphere. The CARIBU facility allows us to probe these nuclei with different techniques. For example, Coulomb excitation of ^{144,146}Ba [1] has been performed at ATLAS by accelerating beams of these isotopes onto heavy targets and measuring the scattered projectiles with the CHICO2 detector [2] in coincidence with de-excitation gamma-rays measured with GRETINA [3]. These studies show $B(E3)$ matrix elements which are larger than theorectically predicted and consistent with a static octuople shape.

The other technique which CARIBU affords is to probe these nuclei by measuring properties of excited states fed from the β decay of the parent nucleus. In contrast to the prompt fission and Coulomb excitation work, non-yrast states can be readily identified in these types of studies. A decay station, SATURN, which consists of a tape station, beta counter and five large volume HPGe Clover detectors in a box configuration has been constructed in order to perform these types of β-decay measurements [4]. We have recently performed experiments at CARIBU using SATURN to study excited states in ^{148,150}Ce following the β decay of ^{148,150}La. High-spin studies of these two nuclei indicate that these isotopes show evidence for enhanced octupole collectivity [5,6]. Our new measurment on ^{148}La has expanded on the previous decay work [7] and identifies states which decay exclusively to the lowest-lying negative-parity band making them candidates for multiphonon states involving at least one octupole phonon. For ^{150}Ce, we have identified the excitation energy of the lowest-lying negative-parity levels for the first time, and thus have established the excitation energy of the lowest lying one-phonon octupole state. These results and their impact on our understanding of octupole collectivity in this region will be discussed.

[1] B. Bucher *et al*., Phys. Rev. Lett. **116**, 112503 (2016) and to be published.
[2] M. Simon *et al*., Nucl. Instr. Meth. A **452**, 205 (2000).
[3] S. Paschalis *et al*., Nucl. Instr. Meth. A **709**, 44 (2013).
[4] A.J. Mitchell *et al*., Nucl. Instr. Meth. A **763**, 232 (2014).
[5] Y.J. Chen *et al*., Phys. Rev. C **73**, 054316 (2006).
[6] S.J. Zhu *et al*, Phys, Rev. C **85**, 014330 (2012).
[7] R.L. Gill *et al*., Phys. Rev. C **27**, 1732 (1983).

* This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under Contract No. DE-AC02-06CH11357 and Grant No. DE-FG02-94ER40848. This research used resources of ANLs ATLAS facility, which is a DOE Office of Science User Facility
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6.13 Chipps, Kelly A.

The Curious Case of the Second 0^+: Resonances in ^{25}Al(p,γ)^{26}Si*

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Thanks to a characteristic decay, ^{26}Al remains an intriguing and important target for observational gamma-ray astronomy. The ^{25}Al(p,γ)^{26}Si reaction is a crucial link in a reaction sequence that bypasses the production of the observable ^{26}Al^g in favor of the short-lived isomeric state, which produces no gamma ray. Due to its importance, determining this astrophysical reaction rate across a range of stellar environments has been the focus of many studies, and a wealth of data have been amassed regarding the relevant structure of the resonances above the proton threshold in ^{26}Si.

A significant discrepancy arises when comparing prediction and measurement, however. Based on mirror arguments and shell model calculations, only one 0^+ level is expected in the energy region about half an MeV above the proton threshold in ^{26}Si, yet two levels consistent with a 0^+ assignment have been found experimentally. Furthermore, existing data suggest that neither of these 0^+-assigned levels are consistent with a missing 4^+ level predicted in this energy range. Is this missing 4^+ yet to be identified, while one of the two 0^+ levels is instead an unanticipated intruder state from another shell? Aside from its value in benchmarking and refining nuclear structure models, the question potentially affects the astrophysical ^{25}Al(p,γ)^{26}Si reaction rate as well, with the location of the single 0^+ (if it is indeed the only one) altering the total reaction rate at nova temperatures by as much as 14%.

A reanalysis [1] of previous work, utilizing recent improvements in excitation energies and ground state masses, will be presented, to help reduce the ambiguities in the literature and provide focus for future measurements and theoretical studies, to determine the nature of the second 0^+.

[1] K. A. Chipps, Phys. Rev. C 93, 035801 (2016).

* This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics

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6.14 Corsi, Anna

Search for dineutron correlation in borromean halo nuclei

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Neutron drip-line nuclei are characterized by a dilute neutron density around the nuclear surface and offer a unique testing ground to investigate correlations at different densities. As an example, a strong dineutron correlation was predicted [1] and later found experimentally in ^{11}Li via a measurement of the low-lying dipole strength distribution [2].
In order to directly determine the momentum distribution of the two valence neutrons, which allows access to the dineutron correlation, the first kinematically complete measurement was performed at RIKEN RIBF for the quasi-free *(p,pn)* reaction on Borromean nuclei ^{11}Li, ^{14}Be, and ^{17,19}B. The novelties of the experiment are the capability to select the kinematical region corresponding to high momentum transfer, where the reaction mechanism is simpler, and to pin down the excited states of the core nucleus by γ-ray detection. The experiment was carried out with the SAMURAI spectrometer [3] and the MINOS system which combines a 15-cm liquid hydrogen target with a vertex tracker to increase luminosity without degrading energy resolution [4]. The momentum distribution of the valence neutrons was reconstructed from the measured momentum vectors of all the particles involved in the reaction. In this talk, we will discuss the dineutron correlation in ^{11}Li from the asymmetry in the opening angle distribution of the emitted neutrons within a newly developed formalism [5]. The invariant-mass spectra of ^{10}Li, ^{13}Be, ^{16}B, where new resonances have been observed, and the core-excitation contribution deduced from γ-ray measurement will also be discussed.

[1] G. F. Bertsch and H. Esbensen, Ann. Phys. 209, 327 (1991); [2] T. Nakamura *et al*., Phys. Rev. Lett. 96, 252502 (2006); [3] T. Kobayashi *et al*., Nucl. Instr. Meth. B317, 294 (2013); [4] A. Obertelli *et al*., Eur. Phys. Jour. A50, 8 (2014) ; [5] Y.Kikuchi *et al*., arXiv:1603.03858

6.15 Crawford, Heather

Characterizing Deformation in the Mg Isotopes: N=20 to N=28*

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The elementary modes of excitation in atomic nuclei are a central theme of study in nuclear structure physics. One of the most interesting findings of these studies is the competition of single-particle and collective degrees of freedom, in particular the emergence of deformation and associated rotations. With the development of exotic beams, we have started to chart the character and evolution of these excitation mechanisms with isospin as one moves toward the neutron dripline. Due largely to the monopole part of the spin-isospin components of the nuclear force, effective single-particle levels for a given isotope change dramatically as protons or neutrons are added to the system. The competition between monopole shifts of single particle energies and pairing plus quadrupole correlations leads to competition between spherical and deformed configurations. In the region around ^{32}Mg the change in the effective single particle spacing reduces the N=20 shell gap and the deformed intruder configuration, with neutron pairs promoted from the sd to the fp shell, is energetically favoured. Near N=28 and ^{40}Mg, there is a similar development of deformation along the isotonic chain below ^{48}Ca, with the removal of protons driving rapid shape oscillations between the N=28 nuclei.

I will discuss new experimental results along the Mg chain from N=20 to N=28. The region near ^{32}Mg has been a subject of intense work in recent years, both experimental and theoretical. In spite of the fact that there is clear evidence for the existence of deformed ground states, band structures, which are considered the fingerprints of rotational motion, have not been observed and a basic question on what exactly are the excitation spectra and collective modes remains largely unanswered. I will present results from a measurement with GRETINA [1] at the S800, studying the yrast structures in ^{32,33}Mg populated via a fragmentation reaction [2], and discuss the results, consistent with a rotational description, but requiring a strong reduction in pairing already at the 6^+ state in ^{32}Mg. I will also present results for proton knockout into ^{40}Mg [3], for which the inclusive reaction cross-section provides a mechanism to constrain the nature of the deformation in this most exotic Z=12 nucleus.

[1] S. Paschalis, *et al.*, NIM A, **709**, 44 (2013).
[2] H. L. Crawford, *et al.*, Phys. Rev. C, **93**, 031303(R) (2016).
[3] H. L. Crawford, *et al.*, Phys. Rev. C, **89**, 041303(R) (2014).

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6.16 Dunlop, Michelle

High-Precision Half-Life Measurements for the Superallowed β^+ Emitter ^{10}C: Implications for Weak Scalar Currents*

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High precision measurements of the $\mathcal{F}t$ values for superallowed Fermi beta transitions between $J^\pi = 0^+$ isobaric analogue states allow for stringent tests of the electroweak interaction described by the Standard Model. These transitions provide an experimental probe of the Conserved-Vector-Current hypothesis, the most precise determination of the up-down (V_{ud}) element of the Cabibbo-Kobayashi-Maskawa quark-mixing matrix, and set stringent limits on the existence of scalar currents in the weak interaction. Precise measurements for the lightest of the superallowed emitters, particularly ^{10}C and ^{14}O, are of interest as the low-Z superallowed decays are most sensitive to a possible scalar current contribution.

A discrepancy between recent measurements of the ^{10}C half-life is addressed in this work through two independent high-precision half-life measurements performed at TRIUMF's Isotope Separator and Accelerator (ISAC) facility: the first, via γ-ray photopeak counting using the 8π spectrometer, yielding $T_{1/2}(^{10}C)_\gamma = 19.2969 \pm 0.0074$ s, and the second, via direct β counting using a 4π continuous-flow gas proportional counter, yielding $T_{1/2}(^{10}C)_\beta = 19.3009 \pm 0.0017$ s. These consistent measurements resolve the discrepancy between previous measurements of the ^{10}C half-life, with the β counting result being the single most precise superallowed half-life measurement reported to date and the first to achieve a relative precision below 10^{-4}. A fit to the world superallowed β-decay data including the ^{10}C half-life measurements reported here, as well as recent measurements for ^{14}O [1, 2], yields an updated value of $b_F = -0.0018 \pm 0.0021$ (68% C.L.) for the Fierz interference term and $C_S/C_V = +0.0009 \pm 0.0011$ for the ratio of the weak scalar to vector couplings assuming left-handed neutrinos. The ^{10}C half-life measurements will be presented and updated limits set on scalar currents will be discussed.

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6.17 Evitts, Lee

Electric Monopole Transition Strengths in Stable Nickel Isotopes*

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Electric monopole ($E0$) transition strengths are a useful probe for detailed investigations of nuclear structure and shape coexistence. There are surprisingly few experimentally known $E0$ transition strengths, especially for non-zero $J^\pi \to J^\pi$ transitions. The majority of the known $J^\pi \to J^\pi$ cases, where $J > 0$, are in the rare-earth and actinide regions where nuclei have well-deformed ground-state structures. There is a need for $E0$ transition strengths in closed shell nuclei in order to develop our understanding of the mechanisms responsible for the generation of electric monopole strength. In order to determine an $E0$ transition strength, a measurement of the parent lifetime, branching ratio, internal conversion coefficient and mixing ratio is required. The measurement of the conversion coefficient requires simultaneous detection of γ rays and internal conversion electrons emitted from excited states.

A series of measurements in the stable nickel isotopes were performed at the Australian National University. Excited states in ^{58,60,62}Ni were populated via inelastic scattering of proton beams delivered by the 14UD Pelletron accelerator. The CAESAR array of Compton-suppressed HPGe detectors was used to measure the $(E2/M1)$ mixing ratio of multiple transitions from angular distributions of γ rays. The Super-e spectrometer was used to measure conversion coefficients for a number of $J^\pi \to J^\pi$ transitions. New data from both devices is combined with previously measured parent lifetimes to determine $E0$ transition strengths.

An overview of the experiments will be presented, along with preliminary results for $E0$ transition strengths between $J^\pi \neq 0$ states in the semi-magic nuclei, ^{58,60,62}Ni.

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6.18 Gai, Moshe

The Triangular $\mathcal{D}_{3h}$ Symmetry of ^{12}C*

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Recent measurements of the structure of ^{12}C [1] using an optical readout TPC (O-TPC) [2] and gamma beams allowed the first study of the rotation vibration spectrum of ^{12}C which appears strikingly similar to the spectrum predicted by a new algebraic cluster model [3] employing a geometrical triangular shape with $\mathcal{D}_{3h}$ symmetry with predicted recurring rotational bands including the states of $J^\pi = 0^+,\ 2^+,\ 3^-,\ 4^\pm,\ 5^-$ etc [4], as shown in the figure including the $4^\pm$ parity doublet. Such structures and symmetries are common in molecular physics, but have been observed in nuclear physics for the first time. This model also allows us to elucidate the structure of the Hoyle state and as such it is in conflict with ab-initio effective field theory calculations on the lattice [5] that predict an obtuse triangular geometry of the Hoyle state. The calculations on the lattice on the other hand use the Hoyle state to conclude the masses of light quarks and the strength of the electromagnetic interaction (within the anthropic view of the universe). Extension of this study to the newly constructed ELI-NP gamma ray facility in Bucharest with a Warsaw-UConn-ELI electronic readout TPC (eTPC) will be discussed [6].

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[2] M. Gai *et al.*; JINST **5**, 12004 (2010).
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[6] D. Filipescu *et al.*; Eur. Phys. J. A **51**, 185 (2015).

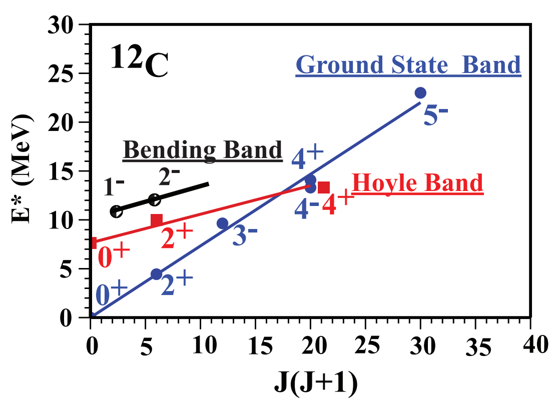

FIG. 1. Rotational band structure of the ground-state band, the Hoyle band and the bending vibration in ^{12}C.

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6.19 Garg, Umesh

Are there nuclear structure effects on the isoscalar giant monopole resonance and the nuclear incompressibility?*

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The excitation energy of the isoscalar giant monopole resonance (ISGMR) exhibits, in general, a very smooth behavior ($E_x \sim \mathrm{A}^{-1/3}$) over the periodic table [1]. In recent work [2], it was reported, however, that the ISGMR energies for ^{92}Zr and ^{92}Mo are appreciably higher than that for ^{90}Zr, suggesting significant nuclear structure effects on ISGMR and, hence, on the nuclear compressibility. Such nuclear structure effects have not been observed in any of the investigations of ISGMR going back to its first identification in the late 1970's [3, 4] and, indeed, are contrary to the standard hydrodynamical picture associated with this mode of collective oscillation.

To examine these surprising and highly intriguing results, inelastic scattering of 385-MeV α particles has been measured on the aforementioned three nuclei using the Grand Raiden Spectrometer at RCNP, Japan [5]. "Background-free" inelastic α-scattering spectra covering excitation energies of up to 35 MeV have been obtained at extremely forward angles, including 0^o, where the ISGMR cross section is maximal. Extensive analyses of the observed α-inelastic spectra indicate that the ISGMR strength distributions, as shown in Fig. 1, are nearly identical in the three nuclei, establishing clearly that nuclear incompressibility is not influenced by nuclear shell structure. Results of detailed multipole decomposition analyses to extract the ISGMR strength distributions in the three nuclei will be presented.

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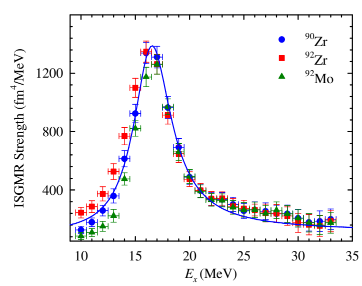

FIG. 1. ISGMR strength distributions for all the three nuclei. The solid line represents the Lorentzian fit for ^{90}Zr.

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6.20 Gillibert, Alain

Spectroscopy of neutron rich iron isotopes obtained from proton induced direct reactions

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The SEASTAR program at RIBF has been developed for the study of low lying excited states of very neutron rich nuclei [1]. It takes benefit of the most neutron-rich radioactive beams available worldwide and a powerful and compact experimental set-up, combining the ZeroDegree spectrometer, the DALI2 γ-spectrometer and the new MINOS device [2]. The cryogenic liquid hydrogen target of the MINOS device gives mainly access to (p,2p), (p,pn) and (p,p') reactions.

The first campaign of the SEASTAR program was done with a ^{238}U primary beam at 345 MeV/nucleon and different settings for the secondary beams around ^{78}Ni. First results were obtained on ^{70,72}Fe for nuclei addressing shell effects for N=40 [3]. One of the settings was dedicated to the study of ^{67,68}Fe and N=40 far from stability. γ-γ coincidences and level schemes will be discussed as well as cross sections.

[1] P. Doornenbal et al., RIKEN Accel. Prog. Rep. 48 (2015)

[2] A. Obertelli et al., Eur. Phys. J. A 50, 8 (2014).

[3] C. Santamaria et al., Phys. Rev. Lett. 115, 192501 (2015)

6.21 Gottardo, Andrea

Shape coexistence in the ^{78}Ni region: intruder 0_2^+ state in ^{80}Ge

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The coexistence of normal and intruder nuclear states close in energy is a characteristic feature of nuclear structure [1]. The lowering in energy of states originating from excitations across the shell closures is a delicate balance between the energy cost to break the shell gap, and the gain in pairing and quadrupole energy. A region of great interest for these studies in the $N = 50$ isotonic chain, down to ^{78}Ni. On the one hand, the size and reduction of the $N = 50$ gap in exotic nuclei are a much debated issue, impossible to reproduce with two-body forces from first principles. On the other hand, the presence of the $g_{9/2}, d_{1/2}, s_{1/2}$ neutron shells across the gap determines a large quadrupole interaction. Therefore, the search for excited 0^+ states from two-particle two-hole $(2p - 2h)$ excitations in the region can help to set benchmarks for nuclear models in the region.
The $N = 48$ ^{80}Ge nucleus was studied by means of β-delayed electron-conversion spectroscopy at ALTO [2]. The radioactive ^{80}Ga beam was produced through the ISOL photofission technique and collected on a movable tape for the measurement of γ and e^- emission following β decay. An electric monopole $E0$ transition which points to an intruder 0_2^+ state was observed for the first time. This new 639 keV state is lower than the 2_1^+ level in ^{80}Ge (659 keV), and provides evidence of shape coexistence close to ^{78}Ni. This result will be compared with theoretical estimates, helping to explain the role of monopole and quadrupole forces in the weakening of the $N = 50$ gap at $Z = 32$,as shown in Fig. 1. The evolution of intruder 0^+ states towards ^{78}Ni will be discussed.

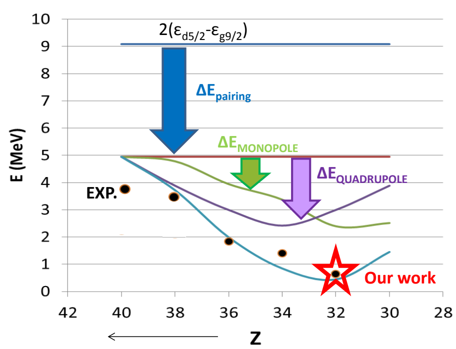

FIG. 1. Evolution as a function of Z of the different energy gains for the $N = 48$ isotones $\nu(2p - 2h)$ 0_2^+ states. The light blue line is the sum of all the contributions. The black dots are the known excited 0^+ states best fitting the $\nu(2p - 2h)$ configuration.

[1] K. Heyde and J. L. Wood, Rev. Mod. Phys. 83, 1467 (2011)
[2] A. Gottardo *et al.*, accepted in Phys. Rev. Lett. (2106)

6.22 Herzan, Andrej

Detailed spectroscopy of the neutron-deficient bismuth isotopes ^{193,195}Bi*

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Two experiments aiming to study the shape coexistence and competing structures in ^{193}Bi and ^{195}Bi isotopes have been performed at the Accelerator laboratory of the University of Jyväskylä, Finland (JYFL). Many new states have been found, hugely extending the previously known level schemes [1, 2, 3] for both isotopes. The $\pi i_{13/2}$ bands were extended up to I^π = 45/2$^+$ in both the ^{193,195}Bi isotopes.

In case of ^{193}Bi, the I^π = 31/2$^+$ member of the $\pi i_{13/2}$ band was found to de-excite also to a long-lived isomeric state. This link determines the energy of the isomeric state to be 2350(1) keV and suggests a spin and parity of 29/2$^+$. The half-life of the isomeric state was measured to be 85(3) μs. A level structure on top of this isomeric state was constructed. The newly observed 49 keV $E2$ transition provides a link between the (29/2$^-$) isomeric state and lower-lying structures in ^{193}Bi. A superdeformed band almost identical to that present in the neighboring isotope ^{191}Bi [4] has been identified.

Both the 29/2$^+$ and (29/2$^-$) isomeric states, together with the full decay-paths have also been identified in ^{195}Bi. In both isotopes, the decay cascades from 31/2$^+$ states to the 29/2$^+$ isomeric states are surprisingly similar. Compared to ^{193}Bi, measured half-lives of these isomeric states are considerably shorter in ^{195}Bi. Experimental evidence is given proving the smaller quadrupole deformations in ^{195}Bi when compared to ^{193}Bi nucleus. Moreover, several new rotational collective structures have been identified in ^{195}Bi, even though their variety is not as rich as in ^{193}Bi. This is the first time the collective structures have been observed up to a high spins and excitation energies in ^{195}Bi. Strong manifestation of shape coexistence is thus proved to be present also in ^{195}Bi.

[1] T. Lönnroth *et al.*, Phys. Rev. C **33**, 1641 (1986)
[2] P. Nieminen *et al.*, Phys. Rev. C **69**, 064326 (2004)
[3] T. Roy *et al.*, Eur. Phys. J. A **51**, 153 (2015)
[4] M. Nyman *et al.*, Eur. Phys. J. A **51**, 31 (2015)

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6.23 Hinohara, Nobuo

Binding energy differences of even-even nuclei as pairing indicators

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Nucleonic pairing is a common phenomenon in atomic nuclei associated with spontaneous gauge symmetry breaking. Pairing correlations are usually described within superfluid nuclear density functional theory (DFT). Because of the lack of the experimental observables, considerably less is known about the pairing component of the energy density functional (EDF). The experimental odd-even mass differences and theoretical pairing gaps are usually used to adjust the coupling constants of the pairing EDF, although pairing gaps are not experimental observables in the strict sense. As the DFT description of odd-A nuclei is difficult because of the broken time-reversal symmetry, it is desirable to constrain the pairing EDF using experimental data involving even-even systems only.

We have assessed the performance of nuclear DFT for pairing rotational bands in even-even nuclei by employing the linear response formalism of the nuclear DFT for the Nambu-Goldstone modes [1]. We show that the pairing rotational moments of inertia are excellent pairing indicators, which are free from ambiguities associated with the choice of an odd-mass system [2]. We offer a new, unified interpretation of the binding-energy differences of even-even nuclei (the shell gaps $\delta_{2\mathrm{n}}$ and $\delta_{2\mathrm{p}}$, and the proton-neutron interaction energy δV_{pn}) in terms of the neutron and proton gauge symmetry breaking. We present the first systematic analysis of the off-diagonal pairing rotational moments of inertia, which is present in the case of the simultaneous neutron and proton gauge symmetry breaking in doubly-open shell nuclei, and demonstrate the mixing of the neutron and proton pairing rotational modes in the ground states of even-even nuclei. Finally, we discuss the importance of the mass measurements in very neutron-rich semi-magic nuclei for constraining the pairing EDF through the pairing rotational moment of inertia.

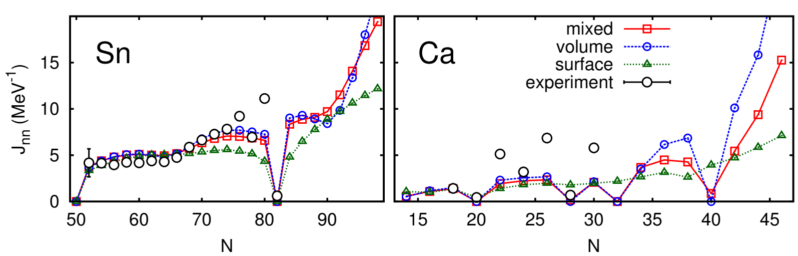

FIG. 1. Neutron pairing rotational moments of inertia for Sn and Ca isotopes computed with three EDFs assuming different density dependence in the pairing channel.

[1] N. Hinohara, Phys. Rev. C **92**, 034321 (2015).
[2] N. Hinohara and W. Nazarewicz, Phys. Rev. Lett. in press, arXiv:1601.00677.

6.24 Huyse, Mark

"The HIE-ISOLDE facility: post-accelerated beams at ISOLDE"

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The HIE-ISOLDE project represents a major upgrade of the ISOLDE nuclear facility with a mandate to significantly improve the quality and increase the intensity and energy of radioactive nuclear beams produced at CERN. The project expands the experimental nuclear physics programme at ISOLDE by focusing on an upgrade of the existing **R**adioactive ion beam **EX**periment (REX) linac with a 40 MV superconducting linac. The new linac will raise the energy of post-accelerated beams from 3 MeV/u to over 10 MeV/u. The upgrade is staged: in the fall of 2015 beams with energies of 4.5 MeV/u using one high-cryomodule placed downstream of REX has been delivered for first experiments; in 2016 beam energies of 5.5 MeV/u will be reached by adding a second cryomodule. In 2017, two additional high-cryomodules will be installed to attain energies up to 10 MeV/u. The third stage of the project to obtain full energy variability above 0.45 MeV/u/ is in a preparatory phase with the development of two low-β cryomodules.

An overview of the project will be given, including an outline of the physics goals, a presentation of the status and schedule of the post accelerator and the status of the dedicated experimental equipment.

6.25 Kim, Sunji

Unbound excited states in ^{17}C*

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Neutron-rich carbon isotopes have attracted attention in recent years due to their anomalous level structures. From the migration of the 2^+_1 states, the collapse of the $N = 14$ shell gap was found while the shell gap clearly emerges in oxygen isotopes [1]. It indicates the near degeneracy of the $\nu 1d_{5/2}$ and $\nu 2s_{1/2}$ orbits and different strength of the proton-neutron interaction in carbon isotopes from that in oxygen isotopes. Another striking property of neutron-rich carbon isotopes is compression of 2^+_1 energies in ^{18,20}C compared with the shell model calculations in the conventional WBT and WBP interactions. In order to describe the measured 2^+_1 energies, the reduction of the neutron-neutron interaction strength has been proposed in the calculations empirically [1, 2]. However, detailed mechanisms and interplay of nucleons remain to be answered.

For the purpose of furnishing information on energy levels and understanding the behavior of p-sd orbits in the neutron-rich carbon isotopes, we conducted a spectroscopic study of unbound excited states in ^{17}C. The experiment was performed by using SAMURAI spectrometer [3] at RIBF of RIKEN, and unbound states of ^{17}C were produced via the one-neutron knockout reaction of ^{18}C. The excitation energies of the unbound states were obtained by the momentum vectors of the ^{16}C fragments and neutrons in invariant mass method with γ-ray energies emitted from the ^{16}C. As a result, four unbound states of ^{17}C were observed. To determine orbital anglar momenta of the observed states, momentum distributions in the measurement were compared with the ones calculated within the sudden approximation. Also spin-parities of the states were assigned by the shell model calculation in a new effective interaction based on a monopole based universal interaction. The presentation will describe the detailed analysis and results with the interpretations.

[1] M. Stanoiu *et al.*, Phys. Rev. C **78**, 034315 (2008).
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[3] T. Kobayashi *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. B **317**, 294 (2013).

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NRF-2014M2B2B1071110
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6.26 Kondev, Filip

Nuclear Archaeology: Properties of K isomers in ^{244,246}Cm populated in β^- decays of ^{244,246}Am*

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Deformed nuclei in the transfermium region are known to exhibit K isomerism, owing to the presence of high-K orbitals near the proton and neutron Fermi surfaces. The properties of such states provide complementary information on the single-particle structures in the region, as well as on pairing and residual nucleon-nucleon interactions, which play an important role in the quest to understand the structure of the heaviest elements. There has been a significant effort recently aimed at discovering and elucidating properties of K isomers in this region using heavy-ion fusion evaporation reactions in conjunction with recoil mass separators. However, in most studies, spin and parity assignments are tentative and the decay schemes are partially completed, which contributed to different interpretations of the structure of the isomers. The existing discrepancies can be attributed to the paucity of good-quality spectroscopy data that are needed to fully characterize the decay of the isomers, whereas only a few counts might be sufficient to claim a discovery.

Very heavy nuclei were studied in the past using light beams and long-lived actinide targets. For example, the ^{244}Am and ^{246}Am nuclides were produced in early 1970s by irradiating ^{244}Pu targets with α-particle beams from the Argonne 152-cm cyclotron. The reaction products were chemically extracted from the target and run through a mass separator, thus producing isotopically pure sources of those isotopes. High-statistics γ-ray singles and $\gamma-\gamma$-coincidence data with Ge(Li) detectors, as well as conversion electron data with a cooled Si(Li) detector, were collected using these sources. However, they were never published - only partial results on ^{246}Am decay were presented in Ref. [1]. We have digitized and reanalyzed these data using modern spectroscopy tools. Because of their high spin, the ground state of ^{244}Am (K$^\pi$=6$^-$) and ^{246}Am (K$^\pi$=7$^-$) preferentially β^- decays to the two-quasiparticle, K$^\pi$=6$^+$ and 8$^-$ isomers in ^{244}Cm and ^{246}Cm, respectively. The γ-ray information allowed for the full characterization of the decay schemes of the isomers in both ^{244}Cm and ^{246}Cm, while the conversion electron data enabled unambiguous spin and parity assignments to be made. In addition, a 254.6 keV M1 γ ray has been identified in the decay of ^{246}Am and assigned to depopulate the newly observed, two-quasiparticle K$^\pi$=7$^-$, ν(5/2$^+$[622],9/2$^-$[734]) state. The data analysis allowed high-precision information to be obtained on the strength of transitions depopulating the isomers. A notable observation is the low hindrance of the 128-keV, ΔK=4 forbidden E2 transition, depopulating the K$^\pi$=8$^-$ isomer in ^{246}Cm to the 6$^-$ member of the K$^\pi$=2$^-$ octupole band, compared to an equivalent E2 decay from the K$^\pi$=6$^+$ isomer in ^{244}Cm.

Data from these experiments will be presented and the results will be compared with predictions from multi-quasiparticle blocking calculations. The effect of the octupole degrees of freedom on the K-forbidden transition strengths will also be discussed.

[1] A.P. Robinson *et al.*, Phys. Rev. **C78**, 034308 (2008).

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6.27 Konieczka, Maciej

DFT-rooted calculations of Gamow-Teller matrix elements*

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Multi-reference Density Functional Theory (MRDFT) is capable to treat rigorously both fundamental and approximate symmetries and, in turn, allows to calculate transition rates for various nuclear reactions [1]. The scheme can be further extended to include correlations from relevant (multi)particle-(multi)hole excitations by performing configuration-interaction (CI) calculations.

The aim of this presentation is to introduce the MRDFT model involving angular momentum and isospin projections and its extension to the no-core CI (NCCI) scheme developed by our group [2]. We shall present applications of the MRDFT and NCCI models to the structure of selected nuclei focusing on their capability to describe Gamow-Teller (GT) beta decay matrix elements in $N \approx Z$ nuclei ranging from $A = 6$ up to $A = 100$. In particular, we shall demonstrate that our MRDFT scheme is, in general, sufficient to describe ground state to ground state (GS) GT transitions, with the accuracy comparable to state-of-the-art shell model calculations [4,5], see Fig. 1. Those two models treat correlations in different manners and have different model spaces; therefore we shall also discuss the quenching effect of axial-vector coupling constant g_A. At variance, the GT matrix elements describing decays to excited states are often very sensitive to CI and require the NCCI approach to be used. This will be discussed in detail for a representative example of the ^{20}Na $\rightarrow$ ^{20}Ne decay where the effect is due to large density of 2^+ excited states which mix significantly in the daughter nucleus.

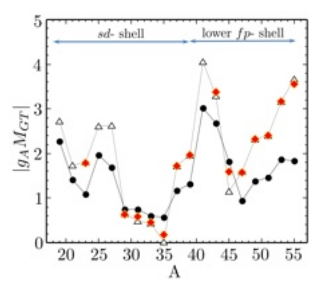

FIG. 1. Gamow-Teller matrix elements for the GS to GS decays of $T = 1/2$ mirror nuclei calculated using MRDFT (triangles) and NCCI (diamonds) approaches in comparison with experimental data (dots) taken from [4] (sd-shell) and [5] (pf-shell)

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[2] W. Satuła, P. Bączyk, J. Dobaczewski and M. Konieczka, arXiv:1601.03593
[3] M. Konieczka, P. Bączyk and W. Satuła, Phys. Rev. C **93**, 042501(R) (2016)
[4] B. Brown and B. Wildenthal, Atomic Data and Nuclear Data Tables **33**, 347 (1985)
[5] G. Martinez-Pinedo *et al*. Phys. Rev. C **53**, R2602 (1996).

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6.28 Korichi, Amel

Characterization of gamma–ray tracking arrays: a comparison of the first phase of AGATA and GRETA using a ^{60}Co source*

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The AGATA (Advanced GAmma Tracking Array) and GRETINA (Gamma Energy Tracking In beam Array) tracking detector arrays are designed to far surpass the performance of the previous generation, Compton suppressed, arrays. In this presentation, we provide a formalism for the characterization of these new arrays with emphasis on the proper corrections required to extract their photopeak efficiencies and peak–to–total ratios. The methods are first applied to Gammasphere, a well characterized 4π array based on the principle of Compton suppression, and subsequently to AGATA and GRETINA. The tracking efficiencies are then discussed and some guidelines as to what clustering angle to use in the tracking algorithm are presented. We have processed AGATA and GRETINA data through the same tracking and sorting software. Thus, it was possible to provide a detailed characterization and comparison of the two tracking arrays. It was possible, using GEANT4 simulations, to scale the measured efficiencies up to the expected values for the full implementations of AGATA and GRETA. It was found that the two tracking arrays have very similar performances.

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6.29 Lepailleur, Alexandre

Spectroscopy of ^{26}F and ^{28}Na to probe proton-neutron forces close to the drip line

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Nuclear forces play a decisive role to account for the creation and modifications of shell gaps, to explain deformed nuclei, to permit the development of halo structures and to fix the limits of particle stability. To probe the evolution of the proton-neutron interaction when going from the stability toward the neutron drip-line, we studied the odd-odd N=17 isotones on the neutron rich side. These nuclei exhibit a $\pi d_{5/2} \times \nu d_{3/2}$ coupling which leads to a quadruplet of states J=1-4 of positive parity. The determination of all of these states in the nuclei of ^{30}Al, ^{28}Na and ^{26}F was required to achieve our goal.
The weakly bound neutron-rich ^{26}F is a benchmarking nucleus for studying this interaction close to the drip line. As lying close to the ^{24}O doubly magic nucleus, its nuclear structure at low excitation energy can be viewed as the interaction between a single deeply bound proton $d_{5/2}$ (~ -15.1 (3) MeV) and a single unbound neutron $d_{3/2}$ (~ +0.77 (20) MeV) on top of a closed ^{24}O core. Its structure has been investigated at GANIL and GSI using three experimental techniques: in-beam gamma-ray spectroscopy using the fragmentation method for the $J = 2^+$ state [1], study of the isomeric decay for $J = 4^+$ [2], and in-beam neutron spectroscopy using the one proton knock-out reaction for the unbound $J = 3^+$. Comparing the experimental results to shell model calculations, we found a reduction of the residual interaction for this nucleus.
We studied the ^{28}Na through the β-decay of ^{28}Ne at GANIL and the in-beam γ-ray spectroscopy technique at the NSCL facility. Combining these two experiments we have established two new levels of $J = 3^+_1$ and 4^+_1 [3], completing the quadruplet $J = 1^+$ - 4^+ ($J = 1^+$ and 2^+ previously known [4]). Combined with the previously studied ^{30}Al experimental results [5], we find a systematic deviation between experimental and theoretical binding energies along the N=17 isotones: while the states are calculated too bound in ^{26}F, they are not enough bound in ^{30}Al (which lies close to stability). This suggests that the effective proton-neutron interaction used in the shell model should better take into account the proton-to-neutron binding energy to model nuclei from the valley of stability to the drip line.

This work was supported in part by the National Science Foundation.

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6.30 Litvinova, Elena

Pion-nucleon correlations and their impact on nuclear structure observables*

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Self-consistent nuclear structure models based on quantum hadrodynamics (QHD) will be addressed. Recent applications and developments have shown that they represent a successful strategy toward a universal and precise description of low-energy nuclear dynamics for arbitrarily heavy nuclei including those at neutron and proton drip lines.

The approach is based on QHD Lagrangian and applies quantum field theory methods considering nuclei as systems of nucleons and mesons. While the QHD provides a fundamental and consistent description of nuclear processes of short and medium range, there are long-range correlations with the range of the order of nuclear size, which cannot be described directly by the exchange of heavy and intermediate-mass mesons. In medium-mass and heavy nuclei, the collective effects, such as low-lying vibrational modes, emerge as new degrees of freedom and introduce an order parameter, which is in the immediate relevance to the energy scale of the low-energy nuclear structure. These vibration modes are treated as effective quasi-bosonic fields exchanged by nucleons, while their characteristics are computed consistently from the effective meson-exchange interaction using the response formalism or alternative techniques. Thereby, a link between the short-range, medium-range, and long-range correlations is established, and all of them are taken into account in calculations of various nuclear structure observables.

Single-particle properties and excitations of even-even nuclear systems, such as giant resonances and soft modes are described with a very good precision [1,2], in some cases achieving spectroscopic accuracy [3]. Lately, nuclear response formalism was extended to higher-order correlations, aiming at a unified description of high-frequency oscillations and low-energy spectroscopy [4]. Possible interference of quasiparticle-vibration coupling with tensor interaction was addressed in a quantitative study for Z=50 isotopic and N=82 isotonic chains [5]. Recent progress on the response theory in the isovector channel [6] has allowed a very good description of spin-isospin-flip excitations which are formed predominantly by pions coupled to proton-neutron configurations in nuclear medium. Such excitations as, for instance, Gamow-Teller and spin-dipole resonances in medium-mass nuclei are of a high astrophysical importance as they are in the direct relation to beta-decay and electron capture rates, which are now at systematic study. Based on these developments, a clear separation of the pion degrees of freedom has become possible and their effects on the nuclear shell structure of ^{100,132}Sn were studied [7]. Thereby, dynamical contributions of pion exchange are included in the theory beyond Hartree-Fock approximation and, in particular, an underlying mechanism for proton-neutron pairing is proposed.

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Spectroscopy around ^{100}Sn*

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^{100}Sn is the heaviest doubly magic N=Z nucleus. Calculations in the extreme single particle model predict a pure Gamow-Teller transition [1] and more recent realistic large scale shell model (LSSM) calculations also show that this transition is fragmentated by less than 5% [2]. Thus, the transition $^{100}\mathrm{Sn} \rightarrow {}^{100}\mathrm{In}$ is the ideal playground in order to derive the full transition strength and probing the shell model. The results for half-lives in this region serve as input for astrophysical rp-process calculations. We have performed an experiment concerning the Gamow-Teller transition strength $\mathcal{B}_{\mathrm{GT}}$ of the β-decay of ^{100}Sn using the BigRIPS separator of the Radioactive Isotope Beam Factory (RIBF) of the RIKEN Nishina Center, Japan. Focusing on the production of ^{100}Sn and new isotopes, we used a ^{124}Xe beam at 345 MeV/u fragmentating on a 4-mm ^{9}Be target. For decay spectroscopy, the detector arrays EURICA and WAS3ABi were used which consist of High Purity Ge- and LaBr-detectors for γ-spectroscopy as well as Si-detectors for calorimetry of positrons. The N=Z-2 nuclei ^{90}Pd, ^{92}Ag, ^{94}Cd and ^{96}In were discovered [3]. The number of nuclei with N$\leq$Z in this region has been significantly increased compared to previous experiments [4]. We present results of the half-lives of these nuclei where half-lives of the most exotic species could be determined for the first time. Furthermore, the systematic study on the Q_β-value of ^{100}Sn revealing an improved value for the GT-strength and results from the analysis of γ-spectra along the N=Z line will be discussed.

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6.32 Macchiavelli, Augusto

The ^{30}Mg(t,p)^{32}Mg Puzzle Revisited*

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The N=20 *Island of Inversion* has been the subject of intense work, both experimentally and theoretically [1]. As protons are removed from $^{40}_{20}$Ca, changes in the balance between the monopole shifts of the single-particle levels and the pairing plus quadrupole correlations erode the N=20 shell gap, leading to deformed $(2p2h, 4p4h)$ ground states in these nuclei, expected *a-priori* to be semi-magic and spherical. The nucleus ^{32}Mg takes center stage in this region where neutron pairs promoted from the sd to the fp levels across the narrowed N=20 gap are energetically favored. The enhanced occupation of these deformation-driving fp orbitals causes the nucleus to deform [2,3].

Wimmer *et al.* [4] studied the reaction ^{30}Mg(t,p)^{32}Mg at CERN/ISOLDE and discovered the first excited 0^+_2 (at 1.058 MeV), which was attributed to be (largely) the spherical state. Following on these results, Fortune [5] carried out a two-level model analysis of the reaction data and put forward the puzzling conclusion that in ^{32}Mg the 0^+_1 is dominated by the sd-shell components ($\approx$ 80%) and the excited 0^+_2 by the fp-shell two-particles-two-holes intruder, contrary to the accepted interpretation which places this nucleus inside the *Island of Inversion*.

Large-scale shell model calculations [6] predict the coexistence of $0p0h$, $2p2h$ and $4p4h$ states in the low-lying excitation spectra and question the validity of a two-level only approach. Inspired by these results we have revisited the analysis of Fortune extending it to a 3x3 level mixing. Assuming wave-functions of the form:

$$|0^+_j\rangle = \alpha_j|0p0h\rangle + \beta_j|2p2h\rangle + \gamma_j|4p4h\rangle \tag{1}$$

we adjusted the amplitudes to reproduce the available experimental data. A typical solution of our approach gives for the relevant lower states:

$|0^+_1\rangle \approx 0.707|2p2h\rangle + 0.707|4p4h\rangle$ and $|0^+_2\rangle \approx 0.5|0p0h\rangle + 0.5|2p2h\rangle - 0.707|4p4h\rangle$

with the third state dominated by the spherical components;

$|0^+_3\rangle \approx 0.9|0p0h\rangle - 0.4|2p2h\rangle + 0.15|4p4h\rangle$

The results of our phenomenological 3x3 analysis agree well with those of the shell model, and provide a simple framework that captures the main structure ingredients and solves Fortune's puzzle.

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6.33 Minamisono, Kei

Charge radii of ^{36,37}K and disappearance of shell-closure signature at N = 20*

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Neutron and proton shell closures can be identified as discontinuities in the chain of charge radii [1], indicating a spherical shape at the shell closure and a gradual development of a deformation away from the shell closure. The shell-closure signature can be seen, for example at the N = 28 neutron-shell closure for the isotopic chains of K [2], Ca [3] up to Mn [4]. The shell-closure signature at N = 20, however, is absent in the Ca region, which was first found in charge radii of Ar isotopes [5]. The charge radii of neutron-deficient ^{36,37}K isotopes were determined in the present study [6] to see whether or not this absence persists in K charge radii and to aid in understanding this abnormal behavior. The experiment was performed at the BEam COoling and LAser spectroscopy (BECOLA) facility [7] at NSCL/MSU. The charge radii were obtained from isotope shifts determined from the hyperfine structure measurements by the optical pumping and subsequent β-decay asymmetry detection. The absence of an unambiguous signature of the shell-closure effect at N = 20 is attributed to a balance of monopole and quadrupole proton-core polarizations above and below N = 20, respectively. The global behavior of the isotopic chain of K charge radii will be discussed.

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Study of fission using multi-nucleon transfer reactions

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We are promoting a study of fission using multi-nucleon transfer reactions, where excited states in neutron-rich actinide nuclei, which cannot be accessed by particle capture and/or fusion reactions, are populated. This allows us to study fission mechanism in the new region of chart of nuclei. Also, the excited states in the fissioning nucleus are widely populated by the multi-nucleon transfer reactions, from which effects of excitation energy on fission properties can be investigated. Experiments were carried out at the JAEA tandem facility in Tokai, Japan. We studied reactions using the ^{18}O beam (~ 9MeV/u) and several actinide target nuclei such as ^{232}Th, ^{238}U, ^{237}Np, ^{248}Cm. Ejectile nuclei were identified by a newly developed silicon ΔE-E detectors (ΔE=75μm, E=300μm). Clear separation of oxygen isotopes ($^{16,17,18,19}O$) was obtained as well as lighter element isotopes (Be, B, C, N). Number of produced nuclei reached to more than fifteen in a single measurement. Both fission fragments were detected by multi-wire proportional counters, and fission fragment mass distributions (FFMDs) were measured for each isotopes. The data allows us to obtain the systematic trends of FFMDs in detail. Measured FFMDs are reproduced by a calculation based on the fluctuation-dissipation model, from which the shell damping energy was determined. Fission fragment angular distribution relative to the recoil direction suggested the increase of the spin of the fissioning nucleus with the number of transferred nucleons. We also started to measure the prompt neutrons accompanied by fission. The correlation between both fragments and neutrons gives direct information on the deformation of nascent fission fragment at the scission point. Discussion will be given also neutron evaporation process in connection with the structure of neutron-rich fragments.

6.35 Pain, Steven

The first campaign of direct reaction measurements using GODDESS*

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Direct reactions, such as nucleon transfer, inelastic scattering, and charge-exchange reactions, are well-established probes providing cornerstones of nuclear structure models. Though such reactions have been measured for decades in normal kinematics on stable targets, often using high-resolution spectrometers for light-ion detection, more recent developments have focussed on highly-segmented large-area silicon detectors and inverse-kinematic measurements applicable to both stable and radioactive beams. The detection of gamma rays is critical to some of these measurements, and highly advantageous in others, but typically there are trade-offs between optimizing for charged-particle or gamma-ray detection - most notably between gamma-ray efficiency and charged-particle angular resolution.

GODDESS [1,2] (Gammasphere ORRUBA: Dual Detectors for Experimental Structure Studies) is a coupling of a $\sim$ 700-channel highly-segmented silicon detector array (based on ORRUBA [3]) with the Gammasphere array of Compton-suppressed HPGe detectors [4]. Gammasphere, which is arguably the most powerful and well-characterized high-resolution gamma-ray detector in current use, has an unusually large internal geometry (14" cavity), allowing a full implementation of a large charged particle array that is well optimized for high-resolution measurement of light ions. GODDESS provides charged-particle detection with $\sim 1^\circ$ resolution in polar angle, between 15° and 165° with $\sim 80\%$ coverage in azimuthal angle. In addition, a compact fast ionization chamber is incorporated for measurement of beam-like species at zero degrees, capable of particle identification at rates over 1×10^5 pps.

The first campaign of measurements with GODDESS was conducted July-September 2015, comprised of three experiments. The commissioning experiment was the first measurement of the ^{134}Xe(d,p γ)^{135}Xe reaction, to track the fragmentation of single-particle strengths in Xe isotopes close to the N=82 shell closure. The ^{95}Mo(d,p γ)^{96}Mo reaction was measured in order to verify the (d,pγ) reaction as a surrogate for statistical neutron capture when performed in inverse kinematics. Finally, the charge exchange measurement ^{19}F(^{3}He,$t\gamma$)^{19}Ne was performed to constrain J^π assignments of states in ^{19}Ne that are important for nova nucleosynthesis. An overview of the GODDESS equipment, and preliminary data from the first campaign of measurements, will be presented.

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6.36 Papenbrock, Thomas

Effective field theory for nuclear vibrations with quantified uncertainties*

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We develop an effective field theory (EFT) for nuclear vibrations. The key ingredients – quadrupole degrees of freedom, rotational invariance, and a breakdown scale around the three-phonon level – are taken from data. The EFT is developed for spectra and electromagnetic moments and transitions. We employ tools from Bayesian statistics for the quantification of theoretical uncertainties. The EFT consistently describes spectra and electromagnetic transitions for ^{62}Ni, ^{98,100}Ru, ^{106,108}Pd, ^{110,112,114}Cd, and ^{118,120,122}Te within the theoretical uncertainties. This suggests that these nuclei can be viewed as anharmonic vibrators [1]. Preliminary calculations suggest that certain odd-mass isotopes of rhodium and silver can be understood within an EFT that couples a fermion to vibrational nuclei of ruthenium and palladium, respectively.

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6.37 Perez Loureiro, David

β–delayed γ–decay of ^{26}P : evidence for a proton halo?*

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The β-decay of proton-rich nuclei is a powerful tool in nuclear science; it can be used to probe isospin asymmetries, and nuclear astrophysics. ^{26}P β-delayed γ-decay has been recently measured at the National Superconducting Cyclotron Laboratory at MSU with much higher sensitivity than the previous experiment [1]. A fast ^{26}P beam produced using nuclear fragmentation was implanted into a planar germaninum detector. This detector was surrounded by the SeGA germanium array in order to detect the γ rays emitted in coincidence with β-decays with high resolution. Absolute γ-ray intensities were measured and a complete decay scheme was built for the allowed transitions to bound excited states of ^{26}Si. $\log ft$ values and Gamow-Teller strengths were determined for each transition and compared to shell-model calculations and the β-decay of its mirror nucleus ^{26}Na [2]. Results of this study, including a substantial mirror asymmetry observed for the transitions to the first excited state and the potential relationship between this asymmetry and the existence of a proton halo in ^{26}P will be presented.

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6.38 Petrovici, Alexandrina

From isospin-related phenomena to stellar weak processes within beyond-mean-field approach*

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Proton-rich nuclei in the A∼70 region are proper candidates to get insights into fundamental symmetries and interactions having relevance for the astrophysical scenarios on the rp-process path. Recent results concerning the interplay between isospin-symmetry-breaking and shape-coexistence effects on isospin-related phenomena in A∼70 isovector triplets obtained within the beyond-mean-field *complex* Excited Vampir variational model are presented [1]. Using the same approach and effective interaction obtained from a G matrix based on the charge-dependent Bonn CD potential in a relatively large model space, weak interaction rates for A∼70 nuclei dominated by shape coexistence have been self-consistently investigated [2,3]. Results on β-decay properties under terrestrial conditions as well as the contribution of the termally populated low-lying excited states in the X-ray burst astrophysical environment on the effective half-lives are illustrated. The influence of the shape mixing in the structure of the low-lying parent states as well as in the independently calculated daughter states on the stellar weak interaction rates is discussed.

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6.39 Recchia, Francesco

Neutron single-particle strengths in *N = 40, 42* Nickel isotopes*

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Neutron-rich isotopes are an important source of new information on nuclear structure. Specifically, since the spin-isospin components in the nucleon-nucleon (NN) interaction, e.g. the proton-neutron tensor force (in particular the strongly attractive monopole parts), are expected to modify shell structure in exotic nuclei. These potential changes in the intrinsic shell structure are of fundamental interest. The study of the single-particle character of the first excited states of odd-A neutron-rich Ni isotopes probes the evolution of the neutron orbitals around the Fermi surface as a function of the neutron number *N*, and allows a step forward in the understanding of the region and the nature of the NN interaction at large *N/Z* ratios.

In an experiment carried out at the National Superconducting Cyclotron Laboratory, the distribution of single-particle strengths in ^{67,69}Ni was characterized by means of single-neutron knockout from ^{68,70}Ni secondary beams. The spectroscopic strengths, deduced from the measured partial cross sections to the individual states tagged by their de-exciting gamma rays, is used to identify and quantify configurations that involve neutron excitations across the *N = 40* harmonic oscillator shell closure. The de-excitation γ rays were measured with the GRETINA gamma-ray tracking array.

The results challenge the validity of the most current shell-model Hamiltonians and effective interactions, highlighting shortcomings that cannot be yet explained. These results suggest that our understanding of the low-energy states in such nuclei is not complete and requires further investigation.

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6.40 Reviol, Walter

Detailed spectroscopy of ^{137}Xe and ^{139}Ba – role of the $\nu i_{13/2}$ intruder in the heavy tin region*

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Recent developments in instrumentation and techniques for precision spectroscopy have enabled progress in the identification and characterization of single-neutron states in the ^{132}Sn region (e.g. Ref. [1-3]). While the systematics of the negative-parity single-neutron states in the N=82-128 shell appears to be fairly complete, issues remain with the $\nu i_{13/2}$ intruder orbital and the corresponding single-particle energy (SPE). For example, in $^{137}Xe_{83}$ the agreement between the measured and calculated energies of the $13/2^+_1$ level is comparatively poor [4]. The factors responsible for this are: a $13/2^+_1$–$13/2^+_2$ admixture and the uncertainty of the SPE used in the shell-model calculations.

To aid in the solution of this problem, two experiments have been performed studying excited states in ^{137}Xe and ^{139}Ba by using the single-neutron transfer reactions ^{13}C(^{136}Xe,^{12}C) [^{9}Be(^{136}Xe,^{8}Be→2α)] and ^{13}C(^{138}Ba,^{12}C), respectively. Particle-γ and -γγ coincidence events have been measured with the technique described in Refs. [1,3]. The setup comprised the Phoswich Wall [5] and Gammasphere (^{137}Xe experiment) or GRETINA (^{139}Ba run); in the latter case a $LaBr_3$(Ce) detector array was added as well. The heavy-ion beams were provided by the ATLAS accelerator.

In ^{137}Xe, the yet unobserved $13/2^+_2$ level and additional $3/2^-$ and $5/2^-$ levels are found. A systematic shell-model study of $13/2^+_1$ and $13/2^+_2$ levels in a series of odd-mass N=83 nuclei has been performed, indicating the need for a lower $\nu i_{13/2}$ SPE value, as compared to that in the literature (e.g. Ref. [6]). While the ^{137}Xe study has been completed, the analysis of the ^{139}Ba experiment is ongoing. The half-life obtained from the $13/2^+ \rightarrow (11/2^-)$ 231-keV transition [7], for which the $LaBr_3$(Ce) fast-timing measurement has already provided a preliminary value, will be available by the time of the conference. The half-life information will help to put further constraints on the wavefunction of the $13/2^+_1$ level.

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6.41 Robledo, Luis

Octupole correlations in a full-symmetry restoring framework*

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Understanding and modeling the competition between static and dynamic octupole correlations in atomic nuclei is a delicate issue as it requires the restoration of the broken reflection symmetry and, at the same time, the consideration of fluctuations in the octupole (and often quadrupole) degree of freedom [1,2]. In addition, the failure of the rotational formula connecting intrinsic multipole moments with transition strengths near sphericity is more evident in the case of the E3 transition characteristic of octupole deformed nuclei [3]. Finally, the development of octupole correlations with its subsequent lowering of level densities around the Fermi level is often associated to a loss of pairing correlations that lead the nucleus into the realm of dynamical pairing correlation regime. Therefore, the ideal framework to consider octupole correlations would be the one including octupole, quadrupole and pairing fluctuations of angular momentum, parity and particle number projected Hartree- Fock- Bogoliubov wave functions. In this talk, we will report on the status of the implementation of the above program by describing the physics of the octupole deformed nucleus ^{144}Ba (focus of recent experimental interest [4]) using a full-symmetry restoring framework (angular momentum, parity and particle number symmetries) with fluctuations in the octupole and quadrupole degrees of freedom treated with the Generator Coordinate Method (GCM) using axially symmetric wave functions obtained using the Gogny D1S force [5]. Excitation energies and transition strengths of both negative and positive parity states are obtained in the calculation. The comparison with available experimental data shows a good agreement between theory and experiment and the slight deviations observed are discussed.

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6.42 Sharpey-Schafer, John

On low-lying $K^{\pi}=0^{+}$ and 2^{+} rotational bands in deformed nuclei

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Classical considerations of the time-dependent vibrations of a nuclear liquid drop suggest that the excitation energies of these modes must lie well above the pairing gap in even-even nuclei. This casts doubt on the textbook identification of the lowest lying excited 0^{+} and 2^{+} rotational bands in deformed nuclei as β and γ vibrations of the nuclear shape. We show that the properties of the $K^{\pi}=0_{2}^{+}$ levels, at excitation energies below 1.0 MeV in N=88 and 90 nuclei, indicate that they are neutron 2p-2h states lowered into the pairing gap by configuration pairing [1]. The $K^{\pi}=2^{+}$ bands are truly collective and arise from the γ degree of freedom which breaks the axial symmetry. Representations of these $K^{\pi}=2^{+}$ excitations as phonons or bosons is discussed and the lack of convincing experimental data for two phonon excitations is addressed.

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6.43 Starosta, Krzysztof

Chiral basis for particle-rotor model for odd-odd triaxial nuclei *

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In the last decade nuclear chirality resulting from an orthogonal coupling of angular momentum vectors in triaxial nuclei has been a subject of numerous experimental and theoretical studies. Three perpendicular angular momenta can form two systems of the opposite handedness, the right-handed and the left-handed system; the time-reversal operator, which reverses orientation of each of the components, relates these two systems. The underlying mechanism for generating chiral geometry of angular momentum coupling emphasizes the interplay between single-particle and collective degrees of freedom in nuclear structure physics. In the simplest case of odd-odd nuclei, two out of three mutually orthogonal angular momenta are provided by the high-j valence proton and neutron quasiparticles, which are of particle and hole character as defined by the respective position of the Fermi level within a unique-parity sub-shell. The single-particle contribution to the total energy is minimised when the angular momenta of the particles and holes align along the short and the long axis of the core, respectively. The third angular momentum component is provided by the collective core rotation and aligns along the axis of the largest moment of inertia; this is the intermediate axis for irrotational flow-like moments of inertia for a triaxial body. This simple picture leads to prediction of distinct observables manifesting chirality in rotational structures, most notably to the doubling of states. In recent years all these effects have been demonstrated using variety of nuclear structure models for triaxial nuclei.

It needs to be noted, though, that one of the common feature of current model calculations is that the chiral geometry of angular momentum coupling is extracted from expectation values of orientation operators, rather than being a starting point in construction of a model. In that sense, chirality has been perceived as an approximate symmetry attained only in a limited range of angular momentum. However, using the particle-hole-coupling model for triaxial odd-odd nuclei it is possible to construct a basis which contains right-handed, left-handed and planar states of angular momentum coupling. If this basis is used, the chirality is explicit rather than extracted feature as in any other models with non-chiral basis. The time-reversal symmetry which relates the basis states of opposite handedness can be used to reduce the dimension of matrices for diagonalization of the model Hamiltonian, proving usefulness of this approach. Moreover, the final model eigenstate wave functions show a concentration of amplitudes among relatively small number ($\sim$1%) of components as comparing to the full model space. In that sense, the "chiral" basis provides a useful tool to examine model predictions providing direct insight into the structure of doublet states.

In this work similarities and differences between the rotational behaviour of an axial and triaxial body will provide a starting point for derivation of the basis optimal for valence nucleon coupling to an axial and a triaxial core. The derived "chiral" basis is optimal for coupling of a valence particle and hole to the triaxial core. Model predictions will be presented and discussed along with a comparison to the data. The summary will focus on an outlook towards three-nucleon and quasiparticle coupling models addressing doublet bands in odd-mass nuclei.

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6.44 Stevenson, Paul

Effective Interaction Effects in Nuclear Dynamics

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The use of effective interactions, such as those of the Skyrme type, within mean-field theories, has allowed a thorough exploration of many nuclear properties and processes. The effective interactions contain unconstrained parameters which are fitted to properties of nuclear matter and ground states of finite nuclei, and sometimes also to other observables, though typically not large-amplitude dynamic processes like heavy-ion collisions, which are computationally too costly to be included in fitting procedures.

Through selection of different observables, many different effective interactions have been developed. We present results exploring the variation in outcome of dynamical processes using the time-dependent Hatree-Fock approximation, as different effective interactions are used, all of which give largely identical ground state data. We show that e.g. sizeable variations in fusion thresholds can be found [1], that heavy-ion reactions at low energies (around Coulomb barrier) show systematic dependence upon nuclear matter properties [2] and that non-adiabatic effects in fission reactions allow a study of the structure properties of fission fragments as well as a microscopic understanding of the fission process [3,4]

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6.45 Stuchbery, Andrew

g factors and nuclear collectivity*

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The emergence and evolution of collective excitations in complex nuclei remains a central problem in the quest to understand the nuclear many-body problem. Nuclear quadrupole collectivity is usually investigated via electric quadrupole observables. Here, however, the focus is on $M1$ observables, especially g factors, in relation to the emergence of nuclear collectivity.

As a first example, the g factors of low-excitation states in ^{111}Cd and ^{113}Cd will be shown to be sensitive to the nature of the collectivity in these nuclei in ways that the electric quadrupole observables are not [1]. The particle-vibration model, which assumes spherical core-excitations, cannot explain the g factors whereas a particle-rotor model with a small, non-zero core deformation does. The contrast of the two models is made stark by the fact that they begin from the same limiting g-factor values, as indicated in Fig. 1. It will be shown that when an odd nucleon occupies a spherical orbit with angular momentum $j = 1/2$, or a deformed orbit with $j = 1/2$ parentage, the particle-vibration model and the particle-rotor model both reduce to the same g-factor value in their respective limits of zero particle-vibration coupling or zero deformation.

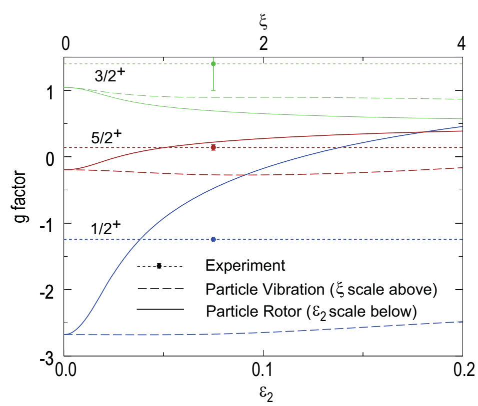

FIG. 1. Comparison of g-factor variations with deformation or particle-vibration coupling strength.

Following on from this example, a short survey will be given of other cases where g-factor measurements and calculations can play a key role in delineating the emergence and nature of nuclear collectivity.

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6.46 Suzuki, Toshio

Electron-capture rates at stellar environments and nucleosynthesis*

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Electron-capture rates in nuclei at stellar environments are evaluated by using new shell-model Hamiltonians. A new Hamiltonian for pf-shell, GXPF1J [1], can describe Gamow-Teller (GT) strengths in Ni isotopes very well [2]. In particular, large spreading in the GT strength in ^{56}Ni and ^{55}Co obtained for GXPF1J has been confirmed by a recent experiment [3]. The updated e-capture rates as well as beta-decay rates obtained in a large region of pf-shell nuclei including both proton-rich and neutron-rich isotopes are applied to study nucleosynthesis in type-Ia supernova explosions [4] and core-collapse supernova explosions as well as cooling of stars by nuclear URCA processes. The e-capture rates with GXPF1J are generally smaller than those with conventional shell-model Hamiltonians such as KB3G [5] for proton-rich nclei and lead to less production of neutron-rich nuclei such as ^{58}Ni and ^{54}Cr [4]. We can thus solve the problem of over-production of neutron-rich isotopes in the Fe region compared to the solar abundance [6].

For more neutron-rich isotopes such as ^{78}Ni, extension of the configuration space outside the pf-shell is essential. Here, GT strength and spin-dipole strengths in ^{78}Ni are evaluated within pf+$g_{9/2}$+$d_{5/2}$ shells [7]. Core-collapse supernova explosiuons are sensitive to the e-capture rates for nuclei around this region [8]. We will discuss e-capture rates of nuclei around ^{78}Ni.

Electron-capture and beta-decay rates for nuclear pairs in sd-shell are evaluated with USDB at high densities and high temperatures relevant to the final evolution of electron-degenerate O-Ne-Mg cores of stars with the initial masses of 8-10 solar mass ($M_\odot$) [9]. The rates for pairs with A=23 and 25 are found to be important for nuclear URCA processes [10,11] that determine the cooling rate of O-Ne-Mg core as well as the fate of the stars with 8-10 $M_\odot$.

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6.47 Tanihata, Isao

Effects of tensor interactions and high-momentum nucleons near the ground states of nuclei

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Recent *ab initio* type nuclear model present the importance of tensor forces for binding nuclei. For example, a deuteron is not bound without D-wave mixing caused by the tensor interactions. Also it is important to include high-momentum nucleon introduced by the short-range nature of the tensor interactions [1].

We presented (p, d) scattering data at high-momentum transfer from ^{16}O and showed the ratio of the cross sections to different final states are consistent with the component of high-momentum neutrons produced by the tensor interactions [2]. Two different experimental studies have been made since then; one is the 0 degree measurement of (p,d) reaction for estimating the effect of reaction mechanism to the (d, p) reaction, and the other is (p, pd) reaction to see the isospin dependence of the high-momentum component.

This abstract present the second experiment at RCNP in Osaka university. Using 400 MeV proton incident beam $^{16}O(p,pd)^{14}N$ and $^{12}C(p,pd)^{10}B$ reactions were measured at quasi-free scattering kinematics but at scattering angle relevant to neutron pick up mechanism with high momentum (~400 MeV/c). The high-resolution spectrometer Grand-RAIDEN was used to detect forward going deuterons and the plastic scintillator array was used to detect backward going protons. Excitation energy resolution of ~200 keV was attend for the excitation energy spectra of the final state nuclei. A few low-lying states were observed in both ^{14}N and ^{10}B. Among the low-lying states, no transition to T=1 states was observed. This observation shows a strong contrast to the observation of such states in (e, e'd) and (p, pd) reactions at deuteron knock out kinematics. The missing transition to T=1 states suggests that high-momentum-correlated pn pairs in nuclei are T=0 but are not T=1. It is very much in accordance with the interaction with the correlated pn pair produced by tensor interactions.

We are going to present such new data and discuss the relation to the tensor interactions.

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6.48 Van Duppen, Piet

In-gas-jet laser spectroscopy of neutron-deficient ^{214,215}Ac isotopes and prospects for studies of the actinide region

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Laser spectroscopy studies provided charge radii, spins and nuclear moments, key ingredients to test and validate nuclear models. To perform laser spectroscopy on exotic nuclides, the highest efficiencies in combination with a high spectral resolution are required. The In-Gas Laser Ionization and Spectroscopy (IGLIS) technique whereby radioactive atoms stopped in a buffer gas cell and subsequently positioned in a supersonic gas jet produced by a de Laval nozzle are resonantly ionized using resonant, multistep laser ionization fulfills these requirements.
In the last years IGLIS was employed within the gas cell at the LISOL facility (Leuven Isotope Separator On-Line) to measure magnetic moments of $^{57\text{-}59}$Cu [1] and $^{97\text{-}101}$Ag [2]. A typical spectral resolution of 5 to 10 GHz was obtained. The measurements were recently extended to the heavy mass region by resolving the hyperfine structure of neutron deficient actinium isotopes $^{212\text{-}215}$Ac [3]. Carrying out laser ionization in the low-temperature and low-density supersonic gas jet formed at the exit nozzle allows eliminating the pressure broadening thus improving significantly the spectral resolution [4].
The in-gas jet laser ionization spectroscopy was recently proven in an on-line experiment measuring the short-lived ^{214,215}Ac isotopes produced in the ^{22}Ne(^{197}Au,xn) reaction. A narrow bandwidth, high repetition rate laser system brought together from GANIL, Mainz University and JYFL has been used to investigate the hyperfine structure of the 438 nm atomic transition in actinium. The data obtained reveal a total spectral resolution of ~400 MHz. Thus, the isotope shifts as well as the hyperfine A- and B- parameters could be extracted and a firm spin assignment for the N=126 ^{215}Ac ($T_{1/2}$=0.17 s) and 214Ac was obtained. The results are compared to shell-model calculations. A ~0.5 %total ionization efficiency that can be improved up to one order of magnitude by increasing the duty cycle was obtained. Further characterization and optimization of the technique is investigated at the off-line IGLIS laboratory, recently commissioned at KU Leuven. Here, the physical and technical limits of the IGLIS technique will be explored. This will ensure the best performance in spectral resolution and ionization efficiency for the future IGLIS setup [5] linked to the Superconducting Separator Spectrometer (S3) at the new radioactive ion beam facility SPIRAL2 (GANIL).

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6.49 Wadsworth, Robert

Isomer decays in the N = Z nucleus ^{96}Cd populated via Fragmentation

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The presentation will discuss results obtained from experiments designed to investigate the decay properties of isomeric states in N ~ Z nuclei in the ^{100}Sn region. Specifically, this talk will focus on new decay properties of the known 16^+ spin-gap isomer in ^{96}Cd [1], along with data which reveal for the presence of isomeric gamma decaying state in this nucleus. The data were taken at the Radioactive Isotope Beam Factory (RIBF) at RIKEN during the EURICA campaigns [2]. ^{96}Cd was produced by the fragmentation of a 345 MeV/nucleon ^{124}Xe primary beam (~30-35 pnA) colliding with a ^{9}Be target and the ions were identified using the BigRIPS spectrometer. In the RIBF83, RIBF9 experiments approximately 13,500, 20,000 ^{96}Cd ions were implanted into a Si active stopper (Simba) [3], respectively.

Evidence for β-delayed proton decay from the 16^+ isomer in ^{96}Cd will be presented. The β-delayed proton branching ratio has been measured, along with upper and lower limits for the B(GT) strength of the decay from the 16^+ isomer to the known 15^+ isomer in ^{96}Ag [4] and to the predicted [1] 15^+,16^+ and 17^+ 'resonance-like' states which lie above the proton separation energy, respectively. The results will be compared with large scale shell model calculations using the *sdg* model space and WKB estimates for the proton to gamma decay widths for the 'resonance-like' states.

Evidence for a gamma decaying isomer in ^{96}Cd will also be presented and the results compared with shell model calculations. These allow a tentative decay scheme to be deduced for the transitions and also provide a possible interpretation for the nature of the isomer. The resulting energy level sequence will be discussed in terms of the systematics for the low-lying states in the N = Z nuclei approaching ^{100}Sn.

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6.50 Wiedenhoever, Ingo

Isomeric Character of the Lowest 4^+ State in ^{44}S*

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(Dated: March 31, 2016)

Previous experimental results established the lowest 4^+ state in the N=28 nucleus ^{44}S and suggested that this state may exhibit a hindered E2-decay rate inconsistent with being a member of the collective ground state band. Recent theoretical investigations by Utsuno *et al.* [2] and Egido *et al.* [3] supported this suggestion and propose a characterization with a dominant K=4 component, despite substantial triaxiality. We populate this lowest 4^+ state via two-proton knockout from a beam of ^{46}Ar projectiles and measure its lifetime using the recoil distance method with the GRETINA γ-ray spectrometer. Our experiment establishes an isomeric level lifetime and allows to deduce a hindered B(E2) value for the $4^+_1 \rightarrow 2^+_1$ transition. This value confirms that the lowest 4^+ state in ^{44}S is not a collective rotational excitation and suggests a K=4 isomer. The unusual properties of this state are discussed in the context of recent theoretical calculations.

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* Supported in part by the National Science Foundation, The Department of Energy (DOE) National Nuclear Security Administration, award number DE-NA0000979 and the DOE Office of Science.
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6.51 Yoshida, Kenichi

Enhanced collectivity of γ vibration in neutron-rich Dy isotopes with $N = 108 - 110$

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The γ vibrational mode of excitation is the acknowledged collective mode in deformed nuclei. The collectivity depends on the details of the shell structure around the Fermi levels, in particular the presence of the orbitals that have the enhanced transition matrix elements of the non-axial quadrupole excitation. Quite recently, a sudden decrease in the excitation energy of the γ vibration was measured at RIKEN RIBF in the neutron-rich Dy isotopes at $N = 106$.

By studying systematically the microscopic structure of the γ vibration in the neutron-rich Dy isotopes with $N = 98 - 114$, we discuss the mechanism for the observed softening. The low-frequency modes of excitation in the neutron-rich rare-earth nuclei are described based on nuclear density-functional theory. We employ the Skyrme energy-density functionals (EDF) in the Hartree-Fock-Bogoliubov calculation for the ground states and in the Quasiparticle Random-Phase Approximation (QRPA) for the excitations.

The lowering of the excitation energy around $N = 106$ is reproduced well by employing the SkM* and SLy4 functionals. It is found that the coherent contribution of the $\nu[512]3/2 \otimes \nu[510]1/2$, $\nu[510]1/2 \otimes \nu[512]5/2$, and $\nu[512]3/2 \otimes \nu[514]7/2$ excitations satisfying the selection rule of the non-axial quadrupole matrix element plays a major role in generating the collectivity. As shown in the Figure below, we find the similar isotopic dependence of the excitation energy in the neighboring nuclei.

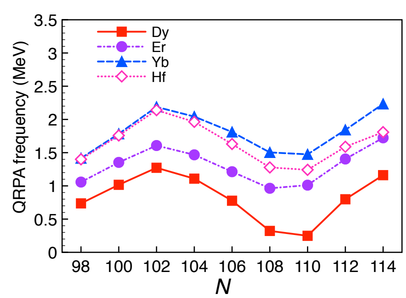

FIG. 1. QRPA frequencies of the γ vibrational mode in the Dy, Er, Yb, and Hf isotopes with $N = 98 - 114$ obtained by using the SkM* functional.

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7. Mini-Talks

Due to the large number of high-quality abstracts (over 200) being submitted, a new session is being introduced this year that allows for short highlights to be given. These mini-highlight talks are limited to 6 minutes.

7.1 Ahn, Tan

Search for cluster structure in ^{14}O using resonant α scattering*

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The conditions governing the appearance of cluster structure in nuclei is still an open question. Do extra nucleons contribute to stabilizing cluster structure and what role does isospin play? We recently found evidence for an elongated α-cluster structure in ^{14}C [1], which has been predicted from Anti-Symmetrized Molecular Dynamics calculations [2]. The existence of a similar structure in ^{14}O would give additional evidence that such cluster structures exist in these nuclei and that clusterization can be stabilized by both extra protons and neutrons. We have performed an experiment using resonant α-scattering reaction to look for α-cluster structure in ^{14}O. We used a radioactive ^{10}C beam produced at the University of Notre Dame using the TwinSol superconducting solenoids and the Prototype Active-Target Time-Projection Chamber (PAT-TPC). The PAT-TPC provided a He gas target while simultaneously imaging charged-particle tracks to measure differential cross sections. Preliminary results of the data will be presented.

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* Supported by the National Science Foundation.
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7.2 Allmond, Mitch

Moments of Inertia of Axially Asymmetric Nuclei*

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Empirical moments of inertia, $\mathcal{J}_1, \mathcal{J}_2, \mathcal{J}_3$, of 28 atomic nuclei are extracted from experimental $2^+_{g,\gamma}$ energies and electric quadrupole matrix elements, determined from multi-step Coulomb excitation data, and the results are compared to expectations based on rigid and irrotational inertial flow. Only by having the signs of the $E2$ matrix elements, i.e., $\langle 2^+_g||\hat{M}(E2)||2^+_g\rangle$ and $\langle 0^+_g||\hat{M}(E2)||2^+_g\rangle\langle 2^+_g||\hat{M}(E2)||2^+_\gamma\rangle\langle 2^+_\gamma||\hat{M}(E2)||0^+_g\rangle$, can a unique solution to all three components of the inertia tensor be obtained. While the absolute moments of inertia fall between the rigid and irrotational values as expected, the relative moments of inertia appear to be qualitatively consistent with irrotational flow for nuclei with prolate electric quadrupole moments. However, there appears to be a breakdown for nuclei with oblate electric quadrupole moments. Interestingly, the $\mathcal{J}_1/\mathcal{J}_{rigid,1}$ values appear correlated with the β deformation and the $\mathcal{J}_2/\mathcal{J}_{rigid,2}$ values appear inversely correlated with the γ (axial asymmetry) deformation. The results suggest that a better description of collective dynamics and inertial flow for atomic nuclei is needed. This is the first report of empirical moments of inertia for all three axes and the results should challenge both collective and microscopic descriptions of inertial flow.

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7.3 Baker, Robert

Ab initio symmetry-adapted no-core shell model results for light to medium-mass nuclei*

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Since its initial development, the *ab initio* no-core shell model (NCSM) [1] has made significant progress in describing nuclear structure from first principles, particularly for light nuclei. We report on results from the recently developed *ab initio* symmetry-adapted no-core shell model (SA-NCSM) [2], which has proven to be a powerful approach for studying intermediate to medium-mass nuclei. This stems from the model's ability to manage the growth of model space dimensions, which occurs with the addition of harmonic oscillator shells and number of nucleons, and especially to reveal emergent symmetry patterns [3]. Specifically, the symplectic symmetry, which provides a microscopic picture of nuclear collective motion [4], has been shown to naturally emerge in light nuclei, as illustrated in Fig. 1, where over 80% of the *ab initio* wavefunction for the 1^+ ground state of ^{6}Li projects on to just one symplectic irrep [5].

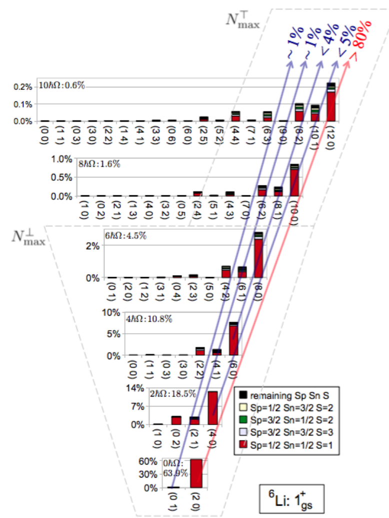

FIG. 1. Probability distribution for the allowed SU(3) $(\lambda\ \mu)$ states in the 1^+ ground state of ^{6}Li. The arrows represent projections on to individual symplectic irreps. Figure adapted from Ref. [5].

To better utilize this symmetry and expand the *ab initio* SA-NCSM's capabilities further, we have developed a novel feature, which allows us to use realistic interactions in the symplectic basis and incorporate multiple symplectic irreps [6]. Here, we present SA-NCSM results for ^{16}O, ^{20}Ne, and ^{42}Ti using realistic interactions, with a view toward studying nuclei of astrophysical importance.

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7.4 Brewer, Nathan

Characterization of detectors and activities found at the Dubna Gas Filled Separator.*

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The 'Hot Fusion Island' is formed by over 50 super-heavy nuclei identified in fusion-evaporation reactions between ^{48}Ca beams and actinide targets [1-3]. Most of these nuclei have been discovered in experiments at the Dubna Gas Filled Recoil Separator (DGFRS). These studies have been recently augmented by using a new highly segmented Si detector and digital detection system [4,5] commissioned by the ORNL-UTK team and implemented at the DGFRS. The system has robust analysis capabilities, especially for very short lived activities and detection efficiency at high beam rate.

The utility of this new system will be detailed by discussing the observation of heavy and super-heavy recoils and the subsequent alpha and/or spontaneous fission radiations. The measurement of several Th activities from the ^{48}Ca + ^{nat}Yb calibration reaction will be shown including activities on the order of 1μs. Also, spontaneous fission isomers and alpha decay of heavy implants observed during irradiations of Pu and Ca targets will be shown. The discovery of a new Flerovium isotope will be displayed [5] as well as details of the experiment running through June 2016 which attempts to go beyond the edge of the nuclear chart to create the heaviest isotopes of element 118 yet synthesized.

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[4] R. Grzywacz et al., Nucl. Instr. Methods in Phys. Res. B 261(1103) 2007.
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* Supported by the U.S. DOE Office of Nuclear Physics under contracts DE-AC05-00R22725 (ORNL), DE-FG02-96ER40983 (UTK), and Russian Foundation for Basic Research Grants, grant No. 13-02-12052.
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7.5 Bucher, Brian

First direct observation of enhanced octupole collectivity in ^{144,146}Ba*

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The neutron-rich Ba isotopes near N=90 have long been predicted to exhibit enhanced octupole correlations. Until now, only indirect experimental evidence was available in the form of low-lying interleaved positive- and negative-parity levels with enhanced E1 linking transitions. However, recent Coulomb excitation measurements performed at ATLAS using post-accelerated ^{144,146}Ba beams from ^{252}Cf fission (CARIBU source) provide the first direct confirmation of enhanced octupole collectivity in this mass region. Compared to a number of theoretical calculations using mean-field, beyond-mean-field, algebraic, and cluster model approaches, the new experimental octupole strengths are larger than any of those predicted with a measured $B(E3; 3^- \to 0^+)$ transition probability in ^{144}Ba of 48 W.u. [1]. Moreover, the new measurements do not indicate a reduction in octupole strength from ^{144}Ba to ^{146}Ba, despite a drop in E1 strength by nearly 2 orders of magnitude between the two isotopes, which is in agreement with the interpretation that the dipole moments in this region can be mainly attributed to shell-induced displacements of the center-of-charges and center-of-masses between protons and neutrons [2]. The experiment, which utilized the advanced capabilities of the new GRETINA γ-ray tracking array and CHICO2 heavy-ion counter, will be presented in detail along with a discussion of the new results.

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7.6 Chowdhury, Partha

Fast Neutron Spectroscopy with a Novel C^{7}LYC Scintillator Array*

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Emerging scintillators are of great current interest to the nuclear structure community, as preparations for instrumenting the Facility for Rare Isotope Beams (FRIB) gain momentum. While consensus has been achieved on the choice of segmented germanium tracking detectors for high-resolution gamma-ray spectroscopy, the decision on scintillator arrays have been purposely delayed, in order to take advantage of any technological advances in the extended FRIB construction and commissioning period. $LaBr_2$ detectors (for their superior energy resolution and fast timing) and Cs_2LiYCl_6 (CLYC) detectors for their dual neutron-gamma capabilities and promise for fast neutron spectroscopy are currently front-runners in this discussion.

At UMass Lowell, a scintillator array of sixteen 1" x 1" CLYC detectors has been commissioned for low energy nuclear science. Standard CLYC crystals detect both gamma rays and neutrons rays with excellent pulse shape discrimination, with thermal neutrons detected via the ^{6}Li(n,α)t reaction. The discovery of spectroscopy-grade response of CLYC for fast neutrons via the ^{35}Cl(n,p) reaction, with a pulse height resolution of under 10% in the $<$ 8 MeV range, led to our present array of ^{7}Li enriched C^{7}LYC detectors, where the large thermal neutron response is essentially eliminated [1,2]. While the intrinsic efficiency of C^{7}LYC for fast neutron detection is low ($\sim$1%), the array can be placed very close to the target, since a long time-of-flight (TOF) arm is no longer needed for neutron energy resolution, thus recovering efficiency through increased solid angle coverage.

The array was tested at the LANSCE WNR facility at Los Alamos for its capability in measuring elastic and inelastic differential scattering cross sections as a function of energy for ^{56}Fe and ^{238}U. One test experiment has been completed and a second experiment approved to run later this year. The incident energy from the pulsed white neutron source is measured via TOF, and the scattered neutron energy measured via the pulse height in the C^{7}LYC array. In addition, the array has also been incorporated in a recent test experiment at the CARIBU radioactive beam facility at Argonne, to evaluate its applicability in measuring beta-delayed neutrons from ^{252}Cf fission fragments. Measurements with a recently acquired larger 3" x 3" C^{7}LYC crystal are planned in the near future.

Techniques, analysis and first results from these experiments will be presented.

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* Supported by the Department of Energy NNSA Stewardship Science Academic Alliance under Grant DE-NA00013008.
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7.7 Cizewski, Jolie

Fragmentation of Single-Neutron States in Neutron-Rich Tin Isotopes

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The (d, p) reaction was measured with radioactive ion beams of ^{128}Sn and ^{126}Sn and a stable beam of ^{124}Sn in inverse kinematics at the Holifield Radioactive Ion Beam Facility at Oak Ridge National Laboratory, utilizing the SuperORRUBA silicon detector array. Spectroscopic information extracted from transfer reactions such as these is critical for constraining shell model parameters in the $A \sim 130$ region. A complete set of (d, p) reaction data on tin isotopes from doubly magic ^{132}Sn to stable ^{124}Sn will be presented. The data were analyzed using the same reaction formalism with consistent optical model and bound-state parameters. The consistent analysis procedure enables a direct comparison of spectroscopic factors that maps out the onset of fragmentation of single-neutron states with $N < 82$ along the tin isotopic chain.

This work is supported in part by the U.S. Department of Energy's National Nuclear Security Administration and Office of Nuclear Physics and the National Science Foundation.

7.8 Crider, Benjamin

Shape coexistence from lifetime and branching-ratio measurements in ^{68,70}Ni*

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Areas of rapid change in the structure of atomic nuclei with the addition or removal of a few protons or neutrons provide important tests for our understanding of nuclear systems. In many regions of the nuclear chart, the shell evolution that occurs under changing nucleon number, coupled with excitations across shells, can give rise to collective structures at relatively low excitation energy. In ^{68,70}Ni, low-energy, excited 0^+ states have been observed and recent, advanced shell-model calculations associate these states with shapes that differ from those of the ground states. More stringent tests of these predictions require going beyond energy and spin-parity assignments to the determination of transition strengths, which act as fingerprints of different nuclear configurations. New lifetimes have been determined for the 0_3^+ in ^{68}Ni and the (0_2^+) in ^{70}Ni, as well as the branching ratio of the 2_1^+ to 0_2^+ transition in ^{68}Ni, using β-delayed, γ-ray spectroscopy at the National Superconducting Cyclotron Laboratory. This information has allowed for the determination of $B(E2)$ values from the 2_1^+ state in ^{68}Ni which were used in a two-level mixing model to extract the mixing between the 0_2^+ and 0_1^+ states. Additionally, limits on the ^{70}Ni $B(E2 : 2_1^+ \to 0_2^+)$ and $E0$ transition strengths between 0^+ states in both ^{68,70}Ni have been determined. The transition rates are compared to large-scale shell-model calculations, firmly identifying shape coexistence between deformed and spherical shapes in ^{68}Ni and providing evidence for its extension along the isotopic chain to ^{70}Ni.

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7.9 de Groote, Ruben

High-resolution laser spectroscopy of neutron-rich copper isotopes ^{76,77,78}Cu with CRIS

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The Collinear Resonance Ionization Spectroscopy experiment (CRIS) at ISOLDE combines the high sensitivity and the universal applicability of resonance ionization spectroscopy with the high resolving power offered by collinear laser spectroscopy. The first experiments at CRIS demonstrated the ability to reach exotic isotopes, normally out of reach for collinear laser spectroscopy methods based on photon detection, but did so with an intermediate resolving power [1].

Considerable experimental developments have allowed the CRIS experiment to now reach a resolution that matches the resolution of collinear laser spectroscopy experiments, and in some cases even surpass it [2]. This contribution will explain how this was achieved, focusing in particular on the developments required for the study of neutron-rich copper isotopes in the vicinity of N=50. The latest experimental results obtained on ^{76,77,78}Cu, which extend our previous collinear work [3,4,5,6] up to N=49, will be presented. A brief discussion on the future plans will also be presented, focusing on the required technical developments for future exotic cases.

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7.10 Demand, Greg

A transition centric approach to level scheme determination

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Powerful γ-ray spectrometers are capable of rapidly collecting large data sets that incorporate hundreds of transitions. The determination of nuclear level schemes from the resulting experimental data is time consuming and is a substantial obstacle to the rapid development and formulation of new ideas, particularly when examining trends amongst large numbers of nuclei.

This presentation will introduce a new transition-centric framework for level scheme determination. Using a transition-centric level scheme representation that closely matches the form of the experimental data allows for the derivation of an analytical formula that directly relates experimental data to level scheme structure. This approach transforms level scheme determination into a moderately complicated optimization problem. These developments, in combination with an evolutionary algorithm will be used to demonstrate the automatic construction of a complicated level scheme from realistic simulated data.

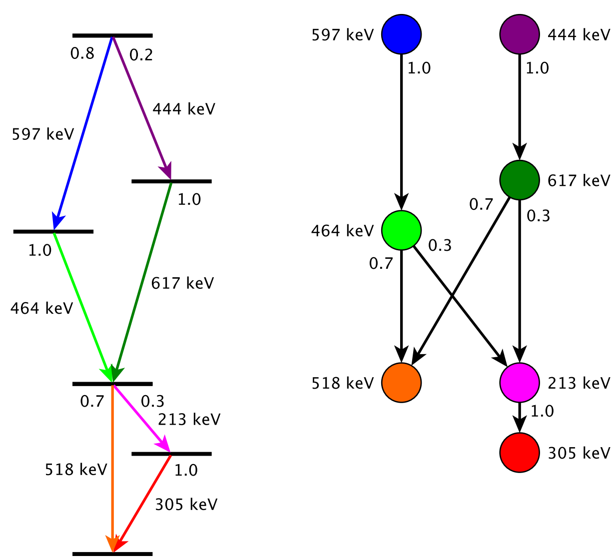

FIG. 1: An example level-centric scheme (left) and the corresponding transition-centric level scheme (right).

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7.11 Febbraro, Michael

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Study of the d(^{7}Be,n)^{8}B reaction through neutron spectroscopy and d(^{7}Be,^{7}Be) elastic scattering measurement

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The (d,n) reaction serves as an ideal spectroscopic tool to probe proton single-particle states, and can be used to constrain astrophysical (p,γ) rates. To date, relatively few (d,n) reaction studies using radioactive ion beams (RIBs) has been performed due to low beam intensities associated with RIBs and inherent difficulties with neutron detection. The highly inverse kinematic nature of this reaction with high mass radioactive ion beams causes kinematic focusing of the residual recoil ion to small angles making it often not possible to extract angular distributions from the residual recoil ion directly. Thus extraction of angular distributions and subsequent spectroscopic factors require detection of the outgoing neutron. The high beam intensities ($2x10^6$ pps) of ^{7}Be produced using the in-flight production technique in combination with the well-studied ^{7}Be(p,γ) reaction makes the d(^{7}Be,n)^{8}B reaction ideal test case for (d,n) neutron spectroscopy with rare isotope beams.

We present results from a neutron spectroscopic study of the d(^{7}Be,n)^{8}B reaction and an elastic scattering measurement of d(^{7}Be, ^{7}Be)d at E(^{7}Be) = 31 MeV. In addition to its use as test case of (d,n) reaction with RIBs, the d(^{7}Be,n)^{8}B reaction is of particular interest as a spectroscopic tool for the study of proton single-particle states in the proton halo nucleus, ^{8}B. This reaction also serves as a surrogate reaction to astrophysically important ^{7}Be(p,γ)^{8}B reaction. The experiments were performed at the *Twin-Sol* radioactive ion beam facility at the University of Notre Dame. Neutron energy spectrum were extracted using neutron time-of-flight with n/γ discriminating organic liquid scintillator detectors. d(^{7}Be,n)^{8}B and d(^{7}Be, ^{7}Be)d cross section results as well as extracted optical model parameters will be shown. The importance neutron detectors with n/γ discrimination in (d,n) reactions with in-flight RIBs beams and complete kinematic measurements for deuteron elastic scattering cross section measurements will be discussed. In addition, a new array of position sensitive liquid scintillator detectors for transfer reactions with RIBs will be introduced.

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7.12 Goetz, Callie

Total absorption spectroscopy of 84,85,86Br*

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The study of beta decay species near doubly magic ^{78}Ni is a vital probe to test the robustness of shell structure in neutron rich nuclei. The decay of less exotic nuclei in this region contribute heavily to decay heat production in nuclear reactors and the more exotic species are important participants in stellar nucleosynthesis. The Modular Total Absorption Spectrometer (MTAS) [1,2] collected data with mass-separated beams on 70 fission products of ^{238}U [3] during runs in 2012, 2015 and 2016 at the On-line Test Facility of Tandem Laboratory at ORNL. This work focuses on three isotopes of bromine at and around the N=50 neutron magic number for which a test of the shell model calculation of beta decay strength can be performed in a consistent manner. New analysis of the ^{84,85,86}Br data from the March 2015 MTAS run performed using chemically selective LaB^6 ion source [3] indicate a significant modification of the beta strength function when compared with previous measurements for all three nuclei, including the introduction of new high energy states not previously detected, compare to [4,5]. Preliminary analysis of ^{86}Br decay measured during the 2012 MTAS run performed with plasma ion source [3] was presented earlier [6]. Through the study of bromine isotopes with N=49,50,51 the decay properties around a neutron shell closure governed by the interplay between core and valence nucleons and Gamow-Teller decay in a ^{78}Ni core can be understood and provide a pinpoint for the study of more exotic nuclei.

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7.13 Grzywacz, Robert

Gamow-Teller decays of ^{74}Co ground state and isomer

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Excited states in ^{74}Ni were populated in the decay of ^{74}Co beyond those previously observed in a prior decay study [1]. The experimental data shows the existence of low- and high-spin isomers in ^{74}Co deduced from the observation of two gamma–ray cascades populating low and high spin states in ^{74}Ni. Low-spin isomeric states were systematically identified in neutron rich ^{68,70,72,76}Co isotopes [1-6]. Both states decay via strong Gamow-Teller transformation of the $\nu f_{5/2}$ to $\pi f_{7/2}$. The decays of the cobalt isotopes probe the- influence of the increasing number of neutrons in the $g_{9/2}$ neutron orbital on the Gamow-Teller strength distribution, which should be sensitive to the occupancy of the proton and neutron fp orbitals. Experimental systematics of the B(GT)s will be compared with shell model predictions. Ions of ^{74}Co were produced by projectile fragmentation of ^{82}Se ions at an energy of 140 MeV/nucleon on a ^{9}Be target at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU). These isotopes were implanted in a germanium double-sided strip detector (GeDSSD) [7], which was surrounded by eight clover germanium detectors to detect gamma rays in coincidence with beta particles.

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7.14 Hartley, Daryl

New β^- Decay Studies of Deformed, Neutron-Rich Nuclei in the $A \approx 160$ Region*

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Properties of deformed, neutron-rich nuclei in the rare-earth region near $A \approx 160$ are not very well known, which is partially due to difficulties in their production at the present RIB facilities. There is considerable interest in achieving a better understanding of the nuclear structure in this region. For example, the observed minimum of the energy of the lowest 2^+ states at $N = 98$ is surprising, and this may be an indicator of deformation-driven shell changes. This behavior is still not well understood and additional nuclear structure information is needed to characterize the conditions associated with the creation of this unexpected minimum. In addition, the observation and interpretation of the rare-earth peak at $A \approx 160$ in the r-process abundance distribution has also been attributed to the effect of nuclear deformation [1,2]. Reproducing this "pygmy" peak is an important ingredient in the quest for understanding the r process, and various theoretical models depend sensitively on the nuclear structure input.

We have initiated a new experimental program at Argonne National Laboratory in our pursuit of understanding the structure of deformed nuclei in the $A \approx 160$ region. The first experiment recently took place where a combination of the CARIBU radioactive beam facility with the new SATURN β-decay station [3] and the X-array of clover detectors was performed. High-purity beams of ^{156}Pm, ^{160}Eu, and ^{162}Eu were implanted onto a moving tape system that was operated with different time-cycle conditions. For the first time, we have obtained detailed decay schemes of ^{160,162}Eu and elucidated decay paths associated with both low- and high-spin β^--decaying states. Two-quasiparticle structures populated by these decays in the daughter ^{160,162}Gd nuclei were also characterized. The decay scheme of the previously known ^{156}Pm nucleus was extended and ambiguities from previous studies were resolved. Multi-quasiparticle blocking calculations were carried out to predict the structure of the observed parent and daughter states, which will be discussed together with the experimental results.

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7.15 MacLean, Andrew

Gamma-Gamma Angular Correlation Measurements With GRIFFIN*

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In a $\gamma - \gamma$ cascade from an excited nuclear state an anisotropy is generally found in the spatial distribution of the second γ-ray with respect to the direction of emission of the first γ-ray even when there is no alignment of the decaying ensemble of nuclei. These $\gamma - \gamma$ angular correlations depend on the sequence of spin values for the nuclear states involved, the transition multipolarities, and mixing ratios of the emitted γ-rays and can thus be used for the assignment of spins and parities to the nuclear states.

The goal of the current work was to explore the sensitivity of the new Gamma-Ray Infrastructure For Fundamental Investigations of Nuclei (GRIFFIN) 16 clover-detector γ-ray spectrometer at TRIUMF-ISAC to such $\gamma - \gamma$ angular correlations. The methodology was established using the well-known $4^+ \rightarrow 2^+ \rightarrow 0^+$ $\gamma - \gamma$ cascade from ^{60}Co decay, and optimized through both experimental measurements and Geant4 simulations that were used to create angular correlation templates for the exact GRIFFIN geometry. Direct comparisons were then made between experimental data sets and the simulated angular correlation templates.

A first in-beam test of the $\gamma - \gamma$ angular correlation measurements with GRIFFIN was performed with a radioactive beam of ^{66}Ga ($T_{1/2}$ = 9.49 hours) from the ISAC facility at TRIUMF. Mixing ratios of $\delta = -2.1(2)$ and $\delta = -0.08(3)$ were measured for the $2^+ \rightarrow 2^+ \rightarrow 0^+$ 833-1039 keV and $1^+ \rightarrow 2^+ \rightarrow 0^+$ 2752-1039 keV cascades in the daughter nucleus ^{66}Zn. These results are in good agreement with pervious literature values and the mixing ratio for the 833-1039 keV cascade has a higher precision. Also, the sensitivity to the 1333-1039 keV cascade, with its pronounced $0^+ \rightarrow 2^+ \rightarrow 0^+$ angular correlation, was measured. A test experiment was preformed with a radioactive beam of the short-lived ($T_{1/2}$ = 116.121 ms) superallowed Fermi β emitter ^{62}Ga to clarify the spin assignment of the 2.34 MeV excited state in the daughter nucleus ^{62}Zn, for which conflicting measurements with important implications for the isospin symmetry breaking corrections in ^{62}Ga superallowed decay have been reported [1,2]. Results from the decay of ^{60}Co, ^{66}Ga and ^{62}Ga will be presented and the outlook for future $\gamma - \gamma$ angular correlation measurements with GRIFFIN discussed.

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7.16 Mazzocchi, Chiara

Exotic decay modes studied by means of the Warsaw Optical Time Projection Chamber

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The development of an Optical Time Projection Chamber (OTPC) at the University of Warsaw about a decade ago opened the possibility to investigate a broad range of rare decay modes with very high efficiency. The detection of one decay event is sufficient to unambiguously identify the decay mode and establish its branching ratio.

The detector is a TPC with amplification stage formed by a stack of GEM foils and optical readout consisting of a CCD camera and a photomultiplier tube (PMT). The images recorded by the CCD together with the time distribution of light collected in the PMT allow to reconstruct the trajectory of the decay products [1]. Such an approach is ideally suited to study the decay by (multi-) particle emission of very exotic isotopes. It was originally designed to obtain the first unambiguous proof of two-proton (2p) decay of ^{45}Fe and to study angular correlations between the protons [2].

The same methodology and detection set-up was successfully applied also to measure the 2p decay of ^{48}Ni [3], to discover the β-delayed 3 proton (β3p) emission decay branch in ^{45}Fe [4] and ^{43}Cr [5] at the NSCL, and in ^{31}Ar at GSI Darmstadt [6] (see Figure 1 for an example). Moreover, it was applied to measure the energy distribution of β-delayed ^{2}H from the decay of ^{6}He at ISOLDE [7] and the B_{GT} distribution in the β-delayed ^{3}H emission from ^{8}He at the JINR in Dubna [8]. Recently it was used to study the most neutron-deficient Ge isotopes (discovery of ^{59}Ge [9] and first measurement of ^{60}Ge decay [10]) at the NSCL and ^{27}S at the JINR in Dubna [11]. A review of the results and an outlook on future studies will be presented.

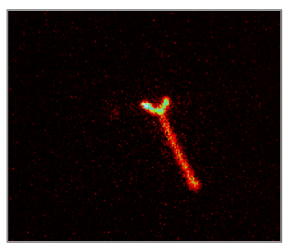

FIG. 1. CCD image of three protons emitted following the β decay of ^{31}Ar [6]. The ^{31}Ar ion was implanted about 32 ms before its decay and was recorded in a separate image, hence it is not visible.

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7.17 Miller, Andrew

Charge radii and nuclear moments of ^{52,53}Fe, and the shell-closure signature at $N = 28$*

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Nucleon shell closures can be identified as "kinks" in the isotopic chain of charge radii, $\langle r^2 \rangle$, indicating a spherical shape at and a gradual deformation away from the shell closure [1]. These sharp local minima can be seen, for example, at the $N = 28$ neutron shell closure for K [2], Ca [3], and Mn [4] isotopes, giving evidence of the shell closure. However, from the isotopes of Mn (proton number $Z = 25$) to Co ($Z = 27$), the two-neutron separation energies show no discontinuities at $N = 28$ [5], suggesting a weakened neutron shell gap. Given the soft nature of the ^{56}Ni ($Z = 28$) nucleus [6], it is essential to extend $\langle r^2 \rangle$ measurements across $N = 28$ in elements around the $N = Z = 28$ region for a global and microscopic understanding of this contradictory behavior.

This work represents the first measurement of $\langle r^2 \rangle$ in neutron deficient Fe ($Z = 26$) isotopes across $N = 28$. Using the collinear laser spectroscopy technique at the BEam COoling and LAser spectroscopy (BECOLA) facility [7] at NSCL/MSU, the hyperfine structure of ^{52,53}Fe ($N = 26,\ 27$) were measured. The isotope shifts of the ^{52,53}Fe hyperfine spectra relative to stable ^{56}Fe were used to extract the charge radii, while the hyperfine spectrum of ^{53}Fe allowed the electromagnetic moments to be deduced as well. Preliminary analysis shows an increase in charge radius moving from $N = 28$ to $N = 26$, confirming the presence of the $N = 28$ shell-closure signature in the $\langle r^2 \rangle$ of the Fe isotopic chain. Details of the full results, including the nuclear moments of ^{53}Fe, will be discussed.

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7.18 Morris, Titus

Recent Improvements in the In-Medium Similarity Renormalization Group

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The In-Medium Similarity Renormalization Group (IM-SRG) has been applied successfully to the ground state of both closed and open shell finite nuclei. Recent work has extended its ability to target excited states of closed shell systems via equation of motion methods, and also complete spectra of the whole SD shell via effective shell model interactions. An alternative method for solving of the IM-SRG equations, based on the Magnus expansion, not only provides a computationally feasible route to producing observables, but also allows for approximate handling of induced three-body forces.

7.19 Mukhi, Kumar Raju

Reorientation-effect measurement of the first 2^+ state in ^{12}C: Testing *ab initio* and cluster calculations

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The ^{12}C nucleus provides a benchmark for *ab initio* and α cluster calculations of nuclear properties [1,2,3]. We have determined the sign and magnitude of the $\langle 2_1^+ \parallel \hat{E}2 \parallel 2_1^+ \rangle$ diagonal matrix element in ^{12}C through the reorientation effect in particle-γ coincidence measurements. The 2_1^+ state at 4.439 MeV in ^{12}C was populated through the Coulomb excitation of ^{12}C beams onto a 3 mg/cm^2 thick ^{194}Pt target at a safe energy of 59.7 MeV. The de-exciting γ rays have been detected using eight highly-efficient and segmented TIGRESS clover detectors, whereas scattering particles were detected at forward angles, [30.7°, 61.0°], using a CD-type annular double-sided silicon detector. Data have been collected employing particle-γ coincidence conditions within a prompt time window and including energy sharing and inelastic tagging. This is the first measurement of diagonal matrix elements for such a high-lying 2_1^+ state from γ-ray data. The results show evidence for the 4.439 MeV γ ray with a reasonable yield of $\approx$ 1300(50). The only previous measurement of $Q_S(2_1^+)$ was done from singles measurements of particle data yielding $Q_S(2_1^+) = +6(3)$ eb[5]. The GOSIA semi-classical coupled channel Coulomb-excitation code has been used to estimate the theoretical γ-ray integrated yields inputting the well known matrix elements, lifetimes and transition probabilities of states in ^{12}C and ^{194}Pt, and the polarizability parameter, κ, for the 2_1^+ state in ^{12}C calculated using the no-core shell-model (NCSM). The Coulomb excitation curve has been generated by normalising the experimental and calculated γ-ray integrated yields [6]. The results will be presented and discussed during the conference.

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7.20 Nevo Dinur, Nir

Nuclear structure and the proton radius puzzle

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The charge radius of the proton was recently extracted from precision spectroscopy of muonic hydrogen. The result disagrees by 7σ with the CODATA value, leading to the ”proton radius puzzle”. To further investigate this, similar measurements were performed in other light muonic atoms, where the uncertainty in nuclear structure corrections determine the attainable precision of the extracted charge radii. We have performed first ab-initio calculations of the nuclear structure corrections relevant for these on-going experiments, reducing their uncertainties from ∼20% to a few percent.

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7.21 Ong, Hooi Jin

Understanding effect of tensor interactions in light nuclei via high-momentum one-neutron-transfer reaction

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We report supporting evidence for the effect of tensor interactions in ^{16}O via measurements of high-momentum one-neutron transfer reactions centered at 0 degree at the FRS, GSI. The experiment was performed using proton beams at energies from 403 MeV to 1209 MeV. Previously, we have measured the reaction at lower energies and at finite angles up to 25 degrees [1]. However, the observed "enhanced high-momentum components" at these finite angles could have been falsely caused by reaction mechanisms, which may become important at these angles.

The tensor interactions which originate from the pion exchange are essential interactions that provide the most significant two-body attraction in nuclear interactions. Theoretically, ab-initio calculations [2] have pointed out the essential importance of the tensor interactions for binding nuclei up to mass number *A*=12. However, while it is generally accepted that the tensor interactions play a dominant role in nuclei, experimental evidence has been scarce and was limited to the lightest nuclei up to ^{4}He.

In this work, we bombarded a POM (^{16}O) target with proton beams. The scattered deuterons were momentum analyzed by the FRS, operated in a momentum-dispersive mode, and detected at the focal plane using two multi-wire drift chambers and a plastic scintillator. Missing-mass spectra for the residual ^{15}O nucleus were reconstructed using the momentum and angular information of the scattered deuterons. Measurements with a ^{nat}C target were also performed to subtract the contributions from the ^{12}C contaminant in the POM target. The results at 403 MeV are consistent with the previous measurement at finite angles [1], indicating that the effect of reaction mechanisms is negligible. Although detailed data analyses for other energies are still in progress, we expect the results to be consistent with the measurements at finite angles. The present work, together with the earlier works, suggests possible observations of enhanced high-momentum neutrons due to the tensor interactions.

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7.22 Pickstone, Simon Glynn

The γ-decay behaviour of the Pygmy Dipole Resonance in ^{92,94}Mo*

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Low-lying E1 strength, commonly denoted by Pygmy Dipole Resonance (PDR), is subject of many studies both in experimental and in theoretical nuclear physics [1-3]. One key observable crucial to understand its nature is the γ-decay branching to excited levels, since it is a direct measure of the overlap of the respective wave functions. Experimentally, the observation of these decays is challenging and requires a selective excitation of the PDR states. This can be done, *e.g.* by using (quasi-)monoenergetic photons for Nuclear Resonance Fluorescence [4].

However, this contribution will focus on (p,p'γ) coincidence experiments, in which the excitation of certain levels can be selected in the offline analysis by gating on the ejectile energy. Therefore, two semiconductor-detector arrays at the 10 MV tandem accelerator in Cologne are combined: the particle-detector array SONIC consisting of up to 12 single silicon detectors or 10 silicon ΔE-E-telescopes for particle identification and the γ-ray detector array HORUS consisting of up to 14 HPGe detectors. The high solid angle coverage for particle detection and the high resolution of the γ-ray spectra allows for a clean selection even of weak reaction and decay channels.

Experiments on ^{92}Mo and ^{94}Mo have already been performed and their results for individual branching ratios of PDR states to excited states will be presented. Since ^{94}Mo has already been investigated earlier [5,6], the agreement of the deduced branching ratios serves as a verification of the different methods. In both cases, theoretical calculations will be shown, which might help to understand the underlying structure of low-lying E1 strength.

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7.23 Sethi, Jasmine

Structure and shape evolution in ^{75}Ge*

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Shell evolution and the emergence of collectivity in the *fpg* model space have been subjects of considerable theoretical and experimental research in recent years. Experimental investigation of the level structure of neutron-rich nuclei in the A $\sim$ 76 region provides data which can be compared with the results of large-scale shell-model calculations, leading to the determination of single-particle energies and the optimization of effective interactions [1, 2]. In particular, the single-particle states observed in ^{75}Ge and ^{77}Ge are, respectively, important in estimating neutron occupancies and vacancies in ^{76}Ge, a candidate for neutrinoless double β decay [3]. Also, ^{75}Ge is observed to have close structural resemblance with its isotone ^{77}Se, known to exhibit shape changes [4]. With these motivations, the excited states of ^{75}Ge have been studied in a deep inelastic reaction of a ^{76}Ge beam with various thick targets, $\sim$ 25% above the Coulomb barrier, using Gammasphere at the ATLAS accelerator facility at Argonne National Laboratory. A number of low-lying transitions in ^{75}Ge, known from β decay, (d,pγ), or (n,γ) reactions, were confirmed. New high-spin transitions in the negative-parity bands have been identified. A new positive-parity band has also been observed which is expected to be built on the $g_{9/2}$ proton configuration. Preliminary results and comparison of the experimental observations with the theoretical calculations will be presented.

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7.24 Smallcombe, James

The Spectrometer for Internal Conversion Electrons at TRIUMF-ISAC*

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SPICE (SPectrometer for Internal Conversion Electrons) is a powerful tool to measure conversion coefficients and $E0$ transitions in atomic nuclei. $E0$ transition strengths, which are not accessible from gamma-ray spectroscopy, are a sparsely measured observable on the nuclear chart. Such transition strengths are particularly sensitive to nuclear shape and state mixing effects and as such are a key item of data in studying the evolution of shape coexistence behaviour.

SPICE is an ancillary detector that has been commissioned for use with Radioactive Ion Beams (RIBs) at the ISAC-II facility of TRIUMF. The main feature of SPICE is high efficiency over a wide range of electron energies from 100 to 3500 keV, crucial for work with RIBs, and an effective reduction of beam-induced backgrounds. This is achieved with a magnetic lens upstream of the target, a high-Z photon shield and a large-area annular lithium-drifted silicon detector. SPICE is designed to be operated in conjunction with the TIGRESS HPGe spectrometer to perform combined in-beam gamma-ray and conversion-electron spectroscopy.

A major theme of the physics program will be the investigation of shape coexistence and state mixing in exotic nuclei. An overview of the main features of SPICE will be presented alongside details of the commissioning and preliminary data from the first experiment studying excited 0^+ structures in ^{78}Kr.

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7.25 Stolze, Sanna

Collectivity and single-particle structures in ^{166,168}Os

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Neutron-deficient osmium isotopes exhibit a variety of different phenomena with changing neutron number. Near neutron the mid-shell the nuclei are prolate with $E(4^+)/E(2^+)$ ratio close to the rotational limit 3.3. The collectivity decreases with decreasing neutron number enabling shape coexistence in ^{172}Os [1]. When approaching the neutron shell closure the shape of the nuclei become spherical. In ^{164}Os [2] the energy ratio $E(4^+)/E(2^+)$ has reached the vibrational limit 2.0.

The transitional nuclei ^{166,168}Os have been studied in detail in the Accelerator laboratory at the University of Jyväskylä. Their level schemes have been considerably extended and lifetimes of the excited states have been measured with the Recoil distance Doppler-shift method. The transition probabilities between low-spin states exhibit an unusual phenomenon, in which the experimental $B(E2)$ values differ considerably from any theoretical model. The combined results will be presented and discussed.

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7.26 Tabor, Samuel

Using GRETINA as a Compton Polarimeter*

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Knowledge of the parity of states is an important key to understanding their structure and to compare with models since the parity of major shells generally alternates. But parity can be hard to determine for states not populated strongly in simple direct reactions and for which internal conversion decay is very weak or non-existent. The parity change can be determined by measuring the linear polarization of the decay photon between the states using the sensitivity of Compton scattering to the direction of polarization. This technique has been used in the past, but its sensitivity and reliability have been limited by available equipment. "Clover" detectors have provided the best instruments, but statistics and sensitivity are limited by the need to observe Compton scattering between crystals and the relatively wide angle range for such crystal to crystal scattering. The best Compton polarimeters available today are tracking detectors such as GRETINA[1] and AGATA. In these the Compton scattering angle can be measured much more accurately both between crystals and within individual crystals. Characterization of GRETINA as a polarimeter has been done by the LBNL group [1] using the ^{24}Mg(p.p') reaction. Here we will present results for the ^{18}O reaction on ^{18}O at 28.7 MeV with 7 modules of GRETINA and the PhoswichWall charged particle detector array for channel separation. An example below shows the Compton scattering azimuthal angle φ dependence for the 2235 keV $2^+ \rightarrow 0^+$ decay in ^{30}Si, along with the expected behavior of E2 and M2 transitions.

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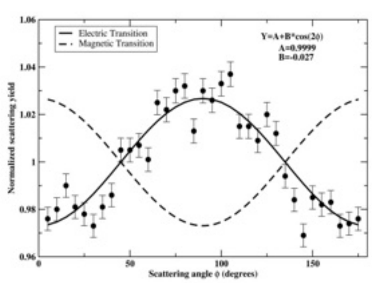

7.27 Tsoneva Larionova, Nadia

Energy-density functional plus multi-phonon theory as a powerful tool for nuclear structure and astrophysics*

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Energy-density functional (EDF) plus extended with multi-phonons, quasiparticle-random-phase approximation (QRPA) approach [1,2] is applied in exploratory investigations of new modes of nuclear excitations, of different multipolarities and parities, in stable and exotic nuclei. From systematic studies of the nuclear low-energy response, it has been proven that the method is very successful in prediction of pygmy resonances. The latter are found closely related to neutron or proton skin oscillation induced by the action of the electromagnetic and hadronic external fields [1-6].

Recently, within this theoretical approach a new excitation mode, called pygmy quadrupole resonance (PQR), was predicted for the first time in Sn isotopic chain [6]. It is found to be closely connected with higher order multipole vibrations of nuclear skin. These theoretical predictions initiated new experiments using (^{17}O,^{17}O$'\gamma$) [7], $(\alpha, \alpha'\gamma)$ and (γ, γ') [8] reactions which were carried out in ^{124}Sn nucleus. The aim of these experiments was to search for a PQR mode. The detailed analysis of the obtained experimental results in comparison with the EDF plus quasiparticle-phonon model theory [1,2] in ^{124}Sn nucleus, indicates clearly the presence of a multitude of discrete low-energy 2^+ excitations of neutron type which can be addressed to PQR mode [6-8]. The independent measurements of E2 transitions with different probes and the theoretical predictions allow to identify the dominant isoscalar character of the PQR states. Newly determined γ-decay branching ratios clearly distinguish between PQR neutron skin excitations and multiphonon states, and exclude a statistical origin of the PQR strength.

Furthermore, our microscopically obtained, within the EDF+QPM approach, strength functions are implemented in a statistical reaction model widely used for astrophysical applications [9,10]. The impact of low-energy multi-phonon excitations and pygmy resonances on radiative neutron and proton capture reaction cross sections in nuclei of key importance for nucleosynthesis is systematically investigated [9,10]. The obtained results are found in very good agreement with the experiment. For nuclei which are hardly accessible experimentally, theoretical predictions are made.

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7.28 Walters, William B.

New structures for ^{68}Zn: subshell effects at N = 38 and superdeformation

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$^{68}Zn_{38}$ sits at a major crossroads in nuclear structure. The Ni nuclei, $^{66,68,70,72}Ni_{38,40,42,44}$ with 2 fewer protons, exhibit coexisting spherical, prolate, and oblate structures [1,2]. Ge nuclei, with 2 additional $p_{3/2}$ protons show complex low-energy triaxial structures [3]. Particularly interesting is the behavior of the B(E2) strength, one indicator of collectivity, which reaches a minimum at N = 38 in contrast to N = 40 for the Ni nuclei [4,5]. In this presentation, new Gammasphere data for ^{68}Zn will be exhibited from multi-nucleon transfer reactions with a ^{70}Ni beam on several heavy neutron-rich targets. It will be postulated that, owing to the tensor interaction, adding two $p_{3/2}$ protons to closed shell Ni nuclei leads to a sufficient rearrangement of the neutron orbitals at low energies in ^{68}Zn to create the “vacuum nucleus” in this region in which collective features found in adjacent Zn nuclides are inhibited by the position of the now isolated low-*j* $1p_{1/2}$ orbital [6]. At higher spin, superdeformed structures have been identified in ^{68}Zn and ^{68}Ge that appear to form a separate region of superdeformation [7,8]. Possible linking transitions to the superdeformed levels in ^{68}Zn will be discussed.

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8. Posters

8.1 Abromeit, Brittany

Study of the Nuclear Structure of ^{39}P Using Beta-Delayed Gamma Spectroscopy*

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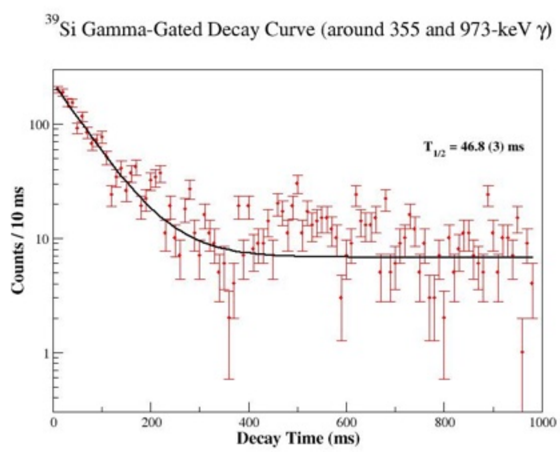
Investigation of nuclei with neutron and proton imbalance is at the forefront of nuclear physics research today. This is driven by the fact that the structure in these regimes may vary with that seen near the valley of stability. With eight neutrons more than the stable isotope of phosphorous, ^{39}P is a neutron-rich exotic nucleus that has very limited information on it: previous studies of ^{39}P produce only three known energy levels and gamma rays. The fragmentation of a ^{48}Ca primary beam on a 564mg/cm^2 thick Be target at the National Superconducting Cyclotron Laboratory (NSCL) was used to produce exotic ^{39}Si. Using the NSCL Beta Counting System (BCS), consisting of a thick planner germanium double-sided strip detector (GeDSSD) and 16 High-purity germanium detectors in an array, SeGA, the beta-gamma coincidences from the decay of ^{39}Si to ^{39}P were analyzed. The resulting level scheme of ^{39}P, including over 12 new gamma rays and energy states, confirmation of the previously measured half-life, and first-time log*ft* values will be presented.



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8.2 Agbemava, Sylvester

A global analysis of octupole deformation in the ground states of even-even nuclei within the covariant density functional theory*

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A global search for octupole deformation has been performed within covariant density functional theory (CDFT) for even-even nuclei with $Z \leq 106$ located between the two-proton and two-neutron drip lines [1]. This is a continuation of our previous efforts to study global performance and theoretical uncertainties in the description of different physical observables within CDFT [2,3,4]. For this study of octupole deformed nuclei, five most up-to-date covariant energy density functionals of different types were used. These are functionals with non-linear meson coupling (NL3*), with density-dependent meson coupling (DD-ME2 and DD-MEδ) and with non-linear and density-dependent zero-range interactions (PC-PK1 and DD-PC1). Pairing correlations are treated within relativistic Hartree-Bogoliubov (RHB) theory based on an effective separable particle-particle interaction of finite range. This allows us to assess theoretical uncertainties within the present covariant models for the prediction of physical observables relevant for octupole deformed nuclei. In addition, a detailed comparison with the predictions of non-relativistic models is performed. A new region of octupole deformation, centered around $Z \sim 98, N \sim 196$ is predicted for the first time [1]. In terms of its size in the (Z, N) plane and the impact of octupole deformation on binding energies this region is similar to the best known region of octupole deformed nuclei centered at $Z \sim 90, N \sim 136$. For the latter island of octupole deformed nuclei, the calculations suggest substantial increase of its size as compared with available experimental data.

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8.3 Auranen, Kalle

Systematic studies of non-Yrast isomeric intruder $1/2^+$ states in odd-mass nuclei $^{197-203}$At.

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In nuclei heavier than lead the $\frac{1}{2}[400]$ Nilsson orbital approaches the Fermi surface rapidly if the nucleus is considered to be slightly oblate deformed. This makes proton hole excitations from the $s_{1/2}$ orbital across the $Z = 82$ shell gap energetically possible. An excited state formed through this mechanism is often isomeric in neutron deficient nuclei beyond lead. However, in some cases this state becomes the ground state. This $1/2^+$ intruder state is well known in bismuth isotopes ([1], and references therein), the level energy of the state decreases as the neutron number decreases, and it becomes the ground state in ^{185}Bi. This systematic behavior is typical for intruder states in this part of the nuclide chart.

In astatine nuclei the $1/2^+$ state was first observed in ^{197}At, where it lies at the excitation energy of 52 keV, and it is depopulated through α decay [2]. In isotopes ^{191,193,195}At the $1/2^+$ state is observed to be the ground state [3,4]. In heavier isotopes ^{199,201,203}At the $1/2^+$ state is observed as an isomeric state which is depopulated through internal $E3$ type transition to low-lying $7/2^-$ state [5,6]. The corresponding state is also observed in a few odd-mass francium isotopes, namely $^{201-205}$Fr [7-9]. In addition, it may become the ground state in ^{199}Fr [7,10,11].

Understanding of the level pattern above the $1/2^+$ is now under interest. Our recent publication [5] reported the level structure above this isomeric state in ^{199,201}At, and the continuation [6] of this systematic study will do the same for isotopes ^{197,203}At. It is suggested that the two lowest states above the $1/2^+$ isomer, having a spin and parity of $3/2^+$ and $5/2^+$, originate from the $\pi(d_{3/2})^{-1}$ and $\pi(d_{5/2})^{-1}$ hole configurations, respectively.

In this presentation we will briefly introduce the used experimental methods, and show how the level scheme below and above the $1/2^+$ state was extracted from the experimental data for $^{197-203}$At. A systematic comparison to neighboring nuclei and respective core states will be also presented.

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8.4 Baron, Jonathan

Ultra-High Spin and Band-Terminating Structures in ^{157}Ho*

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Studies of ^{158}Er and neighboring nuclei [1, 2] have revealed the presence of a number of structures which reveal a return to collectivity at ultra-high ($\sim 60\,\hbar$) spin, beyond the well-known band-terminating states. It was proposed to study ^{157}Ho at high excitation, as it is an isotone of ^{158}Er, to search for similar ultra-high spin Triaxially Strongly Deformed (TSD) structures. In addition, recent theoretical studies [3,4,5] have drawn extra special attention to these structures, which may represent "the highest spin states ever observed"[6].

An experiment was performed using ATLAS at Argonne National Lab, using the reaction ^{124}Sn (^{37}Cl, 4n) ^{157}Ho, at 210 MeV. Gammasphere was used to collect the de-exciting gamma rays. Three TSD structures have been found, with similar moments of inertia to the TSD bands of ^{158}Er. Several previously known [7] bands have been extended, some into band terminating regions. These new additions to ^{157}Ho will be discussed.

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8.5 Bidaman, Harris

A Study on Low Spin States in ^{154}Gd Using (p,p') Reaction*

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Located at the stability line, the low lying spin states of the ^{154}Gd nucleus were investigated at the University of Jyväskylä accelerator laboratory in Finland using the ^{154}Gd(p,p'γ) reaction. A proton beam of 12 MeV was used to excite the ^{154}Gd target, with the gamma-rays from the reaction detected with the JUROGAM II array, while the LISA charged-particle spectrometer was used for detection of the inelastically scattered protons. This experiment marked one of the first uses of the LISA spectrometer at Jyväskylä, which enabled the efficient tagging of the proton-emitting reactions, thus helping to distinguish between the (p,p') and the much more copious (p, xn) channels. By analysing the peaks obtained from the gamma-gamma, and gamma-gamma-proton coincidence matrices, a decay scheme has been built using the RadWare software Escl8r. Experimental methods, new transitions, and future steps will be discussed.

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8.6 Chester, Aaron

Doppler-shift lifetime measurements in ^{94}Sr using the TIGRESS Integrated Plunger

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Neutron-rich Sr isotopes are characterized by a sudden onset of quadrupole deformation at neutron number $N = 60$ demonstrated by the dramatic drop in excitation energy of the first 2_1^+ state. While theoretical calculations reproduce this onset of deformation qualitatively, they differ in the details of the deformation parameters and excitation energies. Though the emphasis is usually put on the sudden onset of collectivity at $N = 60$, it is equally surprising that there is no onset of collectivity when adding up to 8 neutrons beyond the $N = 50$ shell closure, which points to an amazing robustness of both the $Z = 38$ and $Z = 40$ proton (sub)-shell closures. This retardation of the onset of collectivity was first observed by Mach et al. [1] measuring extremely low $B(E2)$ values of ≈ 10 W.u. in even-even Sr isotopes from ^{90}Sr to ^{96}Sr using the fast timing technique. These measurements have an uncertainty of $\approx 40\%$ and are at the limit of the fast timing technique with lifetimes of ≈ 10 ps. A high precision lifetime measurement in ^{94}Sr will elucidate whether the onset of collectivity is as sudden as generally assumed.

Intense re-accelerated beams delivered by the ISAC-II facility at TRIUMF, Canada's national laboratory for particle and nuclear physics, permit access to nuclear structure information for a wide range of radionuclides via in-beam gamma-ray spectroscopy with TIGRESS, a high-efficiency and Compton-suppressed segmented HPGe array. To take advantage of this opportunity, the TIGRESS Integrated Plunger (TIP) has been constructed at Simon Fraser University [2]. The TIP infrastructure supports Doppler-shift lifetime measurements via the Recoil Distance Method (RDM) using a 24-element TIP CsI(Tl) wall for charged-particle identification. An experiment aimed towards a high-precision ($< 10\%$) measurement of the $B(E2, 2_1^+ \rightarrow 0_1^+)$ reduced transition probability in ^{94}Sr was performed in December 2015 using inelastic scattering near the Coulomb barrier coupled with an RDM lifetime measurement of a radioactive ^{94}Sr beam. A Geant4-based code for TIP is being developed as a tool to aid the analysis and for the optimization of future experiments. The device, experimental approach, analysis, and preliminary results will be presented and discussed. This work is presented on behalf of the TIP and TIGRESS collaborations.

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8.7 Dreyfuss, Alison

Probing α-clustering in intermediate-mass nuclei*

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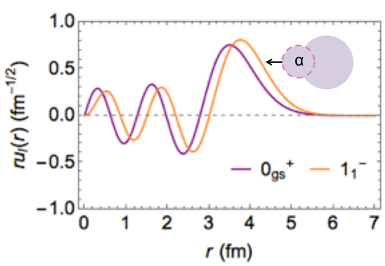
We present no-core shell model results for spectroscopic amplitudes (SA) and factors computed (SF) from overlaps between cluster-like and shell-model states in intermediate-mass nuclei, in order to probe surface α-clustering. Overlaps for ^{20}Ne are calculated for the ^{16}O + α cluster configuration, using a simple recursion formula [1], where wavefunctions of ^{20}Ne are expressed in a symplectic symmetry-adapted shell-model basis. These wavefunctions are computed with the no-core symplectic shell model (NCSpM) [2,3] and the *ab initio* symmetry-adapted no-core shell model (SA-NCSM) [4] in 13 shells, for comparison. The overlaps are used to find SA and SF (shown below for ^{20}Ne). Results reveal evidence for surface α-clustering for the 1^- state. This allows one to determine the α-decay width for $^{16}\mathrm{O}(\alpha,\gamma)^{20}$Ne through the low-lying 1^- state of ^{20}Ne.

There has been remarkable progress in *ab initio* approaches to scattering and nuclear reactions [5,6,7]. Of particular note is the work that has been done with the no-core shell model with the resonating group method (NCSM/RGM) [8] and its successor, the no-core shell model with continuum (NCSMC) [9], which describe both bound and scattering states in light nuclei. The work presented here is a first step toward a similar coupling of RGM with the *ab initio* SA-NCSM, which takes advantage of the SU(3) and symplectic symmetries in order to reduce computational effort with a view toward heavier nuclei.



Spectroscopic amplitudes for the ground state (gs) and first 1^- state of ^{20}Ne (shown in purple and orange, respectively), computed using NCSpM wavefunctions.

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8.8 Dunlop, Ryan

First Results from GRIFFIN: Half-Lives of Neutron-Rich $^{128-130}$Cd

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The β-decay half-lives of $N = 82$ nuclei below doubly-magic $^{132}_{50}Sn_{82}$ are key input parameters for any astrophysical r-process scenario and play an important role in the formation and shape of the second r-process abundance peak. Shell-model calculations for neutron-rich nuclei near the $N = 82$ neutron shell closure that are not yet experimentally accessible have been performed by adjusting the quenching of the Gamow-Teller (GT) operator to reproduce the ^{130}Cd half-life reported in Ref. [1]. The calculated half-lives of other nuclei in the region are known to be systematically too long. Recently, a shorter half-life for ^{130}Cd was measured by the EURICA collaboration [2] that would resolve this discrepancy by scaling the GT quenching by a constant factor for all of the nuclei in the region. Distinguishing between these discrepant half-life measurements for ^{130}Cd is thus of critical importance since the as yet unknown half-lives of other $N = 82$ waiting-point nuclei with $40 \leq Z \leq 44$ play a key role in the production of the second r-process abundance peak.

These half-lives are challenging to measure as this neutron-rich region contains many complicated decay chains due to the presence of significant β-delayed neutron decay branches and the population of isomeric states with half-lives comparable to the nuclear ground-states. Much of this complicated background can be removed by measuring the time distribution of characteristic γ-rays emitted following the β-decay of interest. We have measured the half-lives of $^{128-130}$Cd using the newly-commissioned, high-efficiency GRIFFIN γ-ray spectrometer at TRIUMF to be 246.2(21) ms for ^{128}Cd, 157(8) ms and 147(3) ms for the $3/2^+$ and $11/2^-$ states of ^{129}Cd and 126(4) ms for ^{130}Cd. This improves the precision of the ^{128,129}Cd half-lives, and confirms the shorter half-life of ^{130}Cd recently reported in Ref. [2]. Details of the GRIFFIN experiments will be presented and the implications of the resulting half-lives discussed.

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8.9 Forney, Anne Marie

Structure and shape coexistence of ^{73}Zn*

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Although studied for decades, a coherent decay and level scheme of ^{73}Zn has not converged in the refereed literature. Bernas *et al*. [1] identified low-energy excited states in multi-nucleon transfer (MNT) reactions and suggested the possibility of a coexisting low-energy prolate structure. Huhta *et al*. [2] observed a 13 ms isomer at 195 keV, for which they proposed a spin-parity assignment of 5/2$^+$, now confirmed by laser measurements [3]. Several γ rays were identified in a mass-gated MNT reaction conducted at CLARA-PRISMA, only some of which were identified in a subsequent β-decay investigation [4]. MNT reactions at the ATLAS facility at Argonne National Laboratory with the Gammasphere Ge-detector array were used to detect prompt and delayed γ rays. In conjunction with the reported transitions, two new high spin sequences have been discovered. One sequence is identified as being of negative parity as it feeds the proposed negative parity level at 450 keV. We propose the second sequence as positive parity feeding the 9/2$^+$ level. These high-spin structures will be compared with those in adjacent nuclei.

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8.10 Romero-Romero, Elisa

Search for Doubly Charge Negative Atomic Ions using Accelerator Mass Spectrometry

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Abstract

Strong correlations between component particles are the common thread linking a number of fascinating physical systems, including (clockwise from top left) high-temperature superconductors, quark–gluon plasmas, organic superconductors and – under some conditions – clouds of ultracold atoms. An important goal of negative ion physics is to better understand the role played by electron correlation in the structure and dynamics of many-electron systems. Single negative ions have been a key in understanding a number of areas of physics and chemistry. Doubly charge atomic ions in gas phase are still unseen. This work present a technique to assess and identify doubly charged negative ions. We want to demonstrate that the conventional mass spectroscopy is not enough for the search of the doubly charged negative ions. Accelerator Mass Spectroscopy plays a crucial role in proving their existence.

8.11 Garand, David

Proposed optical pumping schemes for the determination of charge radii of radioactive nuclides of transition metals*

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The charge radii and electromagnetic moments of short-lived nuclides of selected elements have been extensively studied using the collinear laser spectroscopy (CLS) technique [1,2]. However, data are still sparse for many elements, including the 1st and 2nd row transition metals, Ti-Zn and Zr-Cd respectively. These rows span the N = 28-50 neutron magic numbers and encompass the debated subshell closure at N = 40 [3], as well as the region of rapid development in collectivity beyond N = 40 [4]. The deficiency in charge radii data is due in part to difficulties in the production of radioactive isotopes of these elements. Other reasons include unreachable wavelengths from a laser system, weak atomic transition strengths, non-favorable atomic configurations to extract nuclear properties and/or a scatter of initial atomic populations over the dense atomic energy levels. One of the promising methods to overcome these difficulties is the manipulation of atomic populations by way of the optical pumping technique to redistribute the populations in favor of laser spectroscopy. This was first realized in the laser spectroscopy of Nb ions [5] and later in other systems [6,7]. Similar measurements are being planned for the transition metals at the BEam COoling and LAser spectroscopy (BECOLA) facility [8] at NSCL/MSU. In this approach, the trapping region of the radiofrequency ion trap is illuminated with laser light, where efficient optical pumping is made possible due to the extended laser-ion interaction time in the trap. An excited state will be selected so that the excited state decays to populate metastable states, from which high-resolution CLS can be performed. A pulsed laser system will be added to the existing BECOLA laser system to enable optical pumping for the manipulation of atomic populations. Possible optical pumping schemes for the 1st and 2nd row transition metals, as well as the expected impact on the CLS measurements will be discussed.

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8.12 Go, Shintaro

Segmented scintillator based implantation detectors for decay studies*

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A new implantation detector system for alpha and proton emission measurements was developed and used with fusion evaporation residues at the electromagnetic recoil separator at Japan Atomic Energy Agency (JAEA). The detector combines the capability for spatial recoil-decay correlations typically implemented with a Double-sided Silicon Strip Detector, but is able to provide a rapid response time by using a fast scintillator. The YAP scintillator and segmented light readout method [1,2] enables measurements of correlated particle decays in 10 ns time-scale, that are not possible for conventional semiconductor based detectors. Proof of principle measurement was performed at the Recoil Mass Separator [3] at JAEA Tandem. Particle decays of isotopes in the vicinity of ^{100}Sn were studied to demonstrate the performance of the new detection system in typical experimental conditions. The results of these measurement will be presented. Another key application for fast timing, and neutron time of flight measurements and the possibility of the pulse shape discrimination will be discussed.

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8.13 Harker, Jessica

The level structure of ^{72}Zn: triaxiality and shape coexistence*

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The structure of ^{72}Zn provides a critical link in the description of the evolution of nuclear structure in nuclei around the N=40 region. It has two $p_{3/2}$ protons beyond ^{70}Ni, which shows strong evidence of shape coexistence [1,2], and two protons less than ^{74}Ge, which shows strong evidence towards being triaxial [3]. Does ^{72}Zn favor one of these characteristics or neither? Current data for the ^{72}Zn have come from β-decay, transfer, and Coulomb excitation studies [4,5,6,7]. These studies have mostly documented the low-energy, low-spin collective structure up to $\sim$2.5 MeV with a few higher-spin levels that were previously identified by Wilson *et al*. as well as by de Angelis [8,9]. New data from recent γ-ray coincidence measurements using Gammasphere to study the deep-inelastic scattering of 430- and 440- MeV ^{70}Zn beams with thick ^{208}Pb, ^{197}Au, and ^{238}U targets will be presented and, these include new results for the higher spin states of ^{72}Zn. The data will also be used to identify possible evidence for both shape coexistence and triaxiality in this nucleus.

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8.14 Izosimov, Igor

Gamma-decay in Light Nuclei. Isospin, Borromean Halo, Tango Halo, and Halo-Isomers.

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It has been shown that isobar-analog (IAS), double isobar-analog (DIAS), configuration (CS), and double configuration states (DCS) can simultaneously have *n-n, n-p,* and *p-p* halo components in their wave functions [1,2]. Both the Borromean and tango halo types can be observed for *n-p* configurations of atomic nuclei [3-6]. In atomic nucleus whose ground state does not exhibit halo structure, but the excited state may have one, the γ-transition from the excited state to the ground state can be essentially hindered, i.e. the formation of a specific type of isomers (halo-isomers) becomes possible [3-5]. The radial factor r^{λ} for the electric and $r^{\lambda-1}$ for the magnetic multipole γ-transition operator of order λ may compensate the differences in the large-distance parts of halo and no halo wave functions. The most sensitive for detection of the γ-transition hindrance between halo $\rightarrow$ no halo states will be M1 (or may be E1 and M2) γ-transitions.

B(Mλ) and B(Eλ) for γ-transitions in $^{6-8}$Li, $^{8-10}$Be, ^{8,10,11}B, $^{10-14}$C, $^{13-17}$N, $^{15-17,19}$O, and ^{17}F are analyzed and systematics are presented. For A=6-17 nuclei the hindrance factor of M1 γ-transitions is up to 10^4, of E1 γ-transitions is up to 5×10^4, of E2 γ-transitions is up to 10^2 for halo$\rightarrow$ no halo in comparison with halo $\rightarrow$ halo γ-transitions. On the contrary, observed halo $\rightarrow$ halo γ-transitions are enhanced. The IAS (3.56 MeV) in ^{6}Li has the Borromian *n-p* halo structure [3-8]. A large value of the reduced probability of M1 γ-transition from IAS to the ground state is the evidence for the existence of tango *n-p* halo structure [3-5] in the ^{6}Li ground state.

The structure of the ground and excited states with different isospin quantum number in halo-like nuclei is discussed.

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8.15 Izosimov, Igor

Fine structure of the β-decay strength functions $S_\beta(E)$ in spherical, deformed, and transition nuclei

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The β-decay probability is proportional to the product of the lepton part described by the Fermi function $f(Q_\beta - E)$ and the nucleon part described by $S_\beta(E)$ [1]. At the nuclear excitation energies E up to Q_β (total energy of β-decay) $S_\beta(E)$ determines the character of the β-decay and the half-lives ($T_{1/2}$) of the β-decay, spectra of β-particles and neutrinos emitted in β-decay, spectra of γ-rays and internal conversion electrons resulting from de-excitation of daughter nucleus states excited in the β-decay, and probabilities of delayed processes accompanying the β-decay [1-4]. Development of experimental technique allows application of methods of nuclear spectroscopy with high energy resolution for $S_\beta(E)$ fine structure measurement [2-4]. The combination of the total absorption spectroscopy (TAS) with high resolution γ-spectroscopy may be applied for detailed decay schemes construction [2].

High-resolution nuclear spectroscopy methods [2-4] made it possible to demonstrate experimentally the resonance nature of $S_\beta(E)$ for first-forbidden (*FF*) β-transitions and reveal splitting of the peak in the $S_\beta(E)$ for the *GT* β^+/*EC* decay of the deformed nuclei into two components. This splitting indicates anisotropy of oscillation of the isovector nuclear density component.

It is shown that the high-resolution nuclear spectroscopy methods give conclusive evidence of the resonance structure of $S_\beta(E)$ for *GT* and *FF* β-transitions in spherical, deformed, and transition nuclei. The influence of the $S_\beta(E)$ fine structure on the delayed particles spectra is analyzed.

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8.16 Jigmeddorj, Badamsambuu

High-Statistics β^+/EC-Decay Study of ^{122}Xe*

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The Xe isotopes are centrally located in the $Z > 50$, $N < 82$ region that displays an extraordinarily smooth evolution of simple collective signatures. However, the collectivity of excited states in this region is very poorly characterized because of a general lack of spectroscopic data for low-spin states that provide a measure of collective properties such as relative and absolute $B(E2)$ decay strengths and the occurrence of $E0$ decays. There are spectroscopic hints to unusual structures in this region. The 0_3^+ states in $^{124-132}$Xe are very strongly populated in $(^3He, n)$ reactions [1, 2], suggesting a pairing vibrational structure influenced by proton subshell gaps, perhaps leading to shape-coexistence that could give rise to strong $E0$ transitions. Recent work on ^{124}Xe [3] has established nearly identical quadrupole collectivity for the pairing vibrational 0_3^+ band and the ground state band. However, in ^{122}Xe, the 0_3^+ state has not been firmly identified. A high-statistics ^{122}Cs β^+/EC decay experiment to obtain detailed spectroscopic data for low-spin states was performed at the TRIUMF-ISAC facility using the 8π γ-ray spectrometer and its auxiliary detectors including PACES, an array of five Si(Li) detectors, for conversion electron spectroscopy. Excited 0^+ states have been confirmed and several new 0^+ states identified via γ-γ angular correlation analysis. The status of the data analysis and preliminary results will be presented.

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8.17 Jones, Michael

Two-neutron sequential decay of ^{24}O*

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Neutron-decay spectroscopy is a powerful method for exploring neutron-unbound states in nuclei near the dripline. In the case of two-neutron emission, the three-body correlations of two-neutron unbound nuclei provide a valuable tool for discriminating between the possible decay mechanisms in addition to giving insight into their structure.

A recent experiment performed at the NSCL populated a two-neutron unbound excited state in ^{24}O through a (d,d') reaction at 83.4 MeV/u. Using the MoNA-LISA Sweeper setup, invariant mass spectroscopy was employed to measure the two neutrons in coincidence with the recoiling fragment. A state at an energy of $E = 715 \pm 110$ (sys) $\pm$ 45 (stat) keV with a width of $\Gamma < 2$ MeV was observed above the two-neutron separation energy placing it at 7.65 $\pm$ 0.2 MeV with respect to the ground state. The three-body correlations for the decay of $^{24}\text{O} \rightarrow {}^{22}\text{O}$ + 2n show clear evidence of a sequential decay through an intermediate state in ^{23}O, constituting the first confirmation of a two-neutron sequential decay with full energy and angular correlations. This decay mechanism is supported within the shell model giving a tentative spin-parity assignment of 2^+ or 4^+.

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8.18 Kuvin, Sean

Precise Tests of Ab-initio Calculations of Light Nuclei and Charge Symmetry Breaking in A=10 ^{10}B*

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Electromagnetic transition matrix elements have provided stringent tests of modern *ab-initio* calculations using realistic nuclear forces. Precise measurements of the B(E2:2→0) transition rates in ^{10}Be and ^{10}C have been compared to recent Variational and Greens Function Monte Carlo calculations and the formulation of the 3-body forces [1,2]. They revealed that these electric transitions are almost purely isoscalar in character, corresponding to tumbling of the di-alpha core. Precise measurements of the analogous transition in ^{10}B provide additional constraints for a possible isotensor contribution. However, ^{10}B is an odd-odd nucleus and the relevant 5.163 MeV state (J^{π}=2^{+}, T=1) is particle unbound, so precise measurements of both the particle decay branch and the gamma branch are needed to extract the electric transition rate. In an experiment conducted at Yale [3], the gamma-decay branching ratios for this state were measured, resolving an ambiguity that had existed between previous experimental results. Meanwhile, since the total width of the state is reasonably well-known, the largest uncertainty is in the alpha decay width. Alpha decay is technically isospin forbidden, but in practice is sufficiently suppressed that alpha and gamma-ray decays compete. In order to precisely measure the alpha decay branch, the ^{10}B(p,p′)^{10}B(5.163 MeV) reaction has been studied in inverse kinematics using the HELical Orbital Spectrometer (HELIOS) at Argonne National Laboratory [4]. HELIOS provides a unique method for determining the alpha- and gamma-decay branches as the reaction products are all constrained by the kinematics and the magnetic field and so can be efficiently counted. Thus, by counting the scattered protons in "singles", and in coincidence with either ^{10}B or ^{6}Li, the alpha decay branch can be measured with relatively high precision.

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8.19 Larson, Nicole

Reinvestigation of low-lying isomeric states in ^{115}Ru*

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The region of the nuclear chart of neutron-rich nuclei with A~110 has long been thought to exhibit signs of changing nuclear shapes. Theoretical calculations predict a transition between prolate to oblate shapes in this region [1-3] with increasing neutron number, though calculations differ as to where this transition is expected along particular isotopic chains.

In the Ru isotopic chain, this transition is predicted at A=108 [3] or A=110 [1-2]. However, current high-spin data suggest this transition may occur at ^{111}Ru [4-5]. In several of the odd-A Ru nuclei, isomeric (7/2-) or (9/2-) states have been found [5-7], likely originating from the νh11/2 orbital.

In ^{115}Ru, previous experimental results [7] found two excited states, a (7/2-) isomeric state at an unknown energy above a 61.7 keV state. A more recent experimental beta-decay study of ^{115}Ru indicates a ground state spin and parity of (3/2+), suggesting an oblate configuration and a (9/2-) isomeric state [8]. The present work firmly places the isomeric state in ^{115}Ru at an energy of 123.8 keV through conversion electron and gamma-ray spectroscopy with a half-life of 85(13) ms, consistent with the previous determinations.

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*This work was supported by NSF Grant-PHY1102511 and DOE NNSA award DE-NA0000979. Work at ANL is supported by the US Department of Energy, Office of Science, Office of Nuclear Physics under Contract No. DE-AC02-06CH11357.

8.20 Lesher, Shelly

Collectivity in Gadolinium*

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The nature of low-lying excitations, $K^{\pi} = 0^+$ bands in deformed nuclei remain enigmatic in the field, especially in relationship to quadrupole vibrations. One method of characterizing these states is by reduced transition probabilities, B(E2) values, a measure of the collectivity. These values can be measured directly by Coulomb excitation or calculated from measured lifetime values. Within the deformed region, there are five stable Gd isotopes, three of which have been studied to obtain B(E2) values, a fourth, ^{160}Gd is the focus of this work. We have examined ^{160}Gd with the $(n, n'\gamma)$ reaction and neutron energies up to 3.0 MeV to confirm known 0^+ states. Angular distributions at three different neutron energies were performed to determine their lifetimes through DSAM measurements. Gamma-ray excitation functions, angular distribution, and lifetime measurements will be presented and compared with the other Gd isotopes.

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8.21 Lubna, Rebeka Sultana

Structure of $\mathbf{T_z = +3/2}$, ^{33}P Nucleus*

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The excited states of the nucleus ^{33}P were populated by the ^{18}O(^{18}O, p-2nγ)^{33}P fusion evaporation reaction at $E_{lab} = 25$ MeV.Gammasphere was used along with the particle detector Microball to detect the γ emissions in coincidence with the emitted charged particles from the compound nucleus ^{36}S. The auxiliary detector Microball was used to select the charged particle channel and to determine the exact position and the energy of the emitted proton. The purpose of finding the position and energy of proton was to determine a more precise angle between the recoil nucleus and the emitted γ which was later employed to get a better Doppler correction (figure 1). Along with the selection of the proton channel, the γ-γ coincidence technique helped to isolate ^{33}P from the other phosphorus isotopes and also reduced the contaminations from the dominant pure neutron channels. A number of transitions and states was identified that were not observed before. The 4π arrangement of Gammasphere offered an excellent opportunity to measure the angular distribution of the electromagnetic emissions leading to the assignment of the spins for most of the new states. The experimental observations were compared to the shell model calculation using WBP-a interaction.

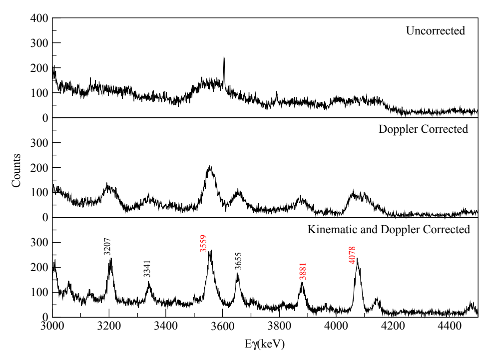

FIG. 1. Picture showing that the Doppler correction after kinematic reconstruction makes the spectrum cleaner.

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8.22 Matta, James

Observation of Transverse Wobbling in ^{135}Pr*

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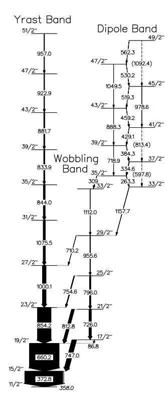

A "wobbler partner" band has been identified in the nucleus ^{135}Pr, the first observation of wobbling in a mass region other than near A$\sim$160. The nature of wobbler bands is confirmed by verifying the ΔI=1, E2 character of the inter-band transitions via angular distribution and polarization measurements. The transverse nature of wobbling is evidenced by the characteristic decrease in the wobbling energy, E_{wobb}[1]. A transition from transverse wobbling to longitudinal wobbling is also observed. The wobbling structure evolves into a three-quasiparticle band of the magnetic rotation type. TAC calculations indicate that this three-quasiparticle band has a chiral character, suggesting that both characteristic signatures of triaxiality–wobbling and chirality–are manifest in this nucleus.

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* Supported in part by NSF Grants No. PHY07-58100 (UND) and PHY-1068192 (UND), by DOE Contracts No. DE-AC02-06CH11357 (ANL) and DE-FG02-95ER40934 (UND), by the APS India Visitation Program, and by DAE and DST, Government of India.

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8.23 Mehl, Craig

Determining the shape of the clustering nucleus, ^{20}Ne

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Determining the shape of the clustering nucleus, ^{20}Ne The shape of ^{20}Ne is relevant to understand the mixing between mean field and cluster states [1]. This work aims at determining the spectroscopic quadrupole moment of the first excited 2^+_1 state, $Q_s(2^+_1)$ in ^{20}Ne at safe energies. At present the current nuclear collective and mean field models overestimate the $Q_s(2^+_1)$ value in ^{20}Ne [2] by about 30%. Two of the previous RE measurements [4,5,6] regards the separation between nuclear surfaces of about 4 fm [2]. The third RE measurement was done by Schwalm et al. [5] and has a rather large uncertainty associated with the gas ^{20}Ne target that was utilized to make the measurement. In fact, the RE is enhanced for light beams onto heavy targets.

The measurement of the $\langle 2^+_1||E2||2^+_1\rangle$ diagonal matrix element in ^{20}Ne was carried out at iThemba LABS over the course of three days. The safe Coulomb excitation of ^{20}Ne^{3+} beams at 73 MeV was undertaken with a ^{194}Pt target having a thickness of 1.2 mg$\cdot cm^{-2}$. The detection of γ rays was done using the AFRODITE HPGe detector array, which consisted of 8 clover detectors, of which 4 were positioned at 90° and 4 at 135° in coincidence with the ^{20}Ne particles detected with an annular S3 silicon detector at backward angles. The $Q_s(2^+_1)$ value in ^{20}Ne, has been determined using the Gosia Coulomb excitation code [7] and will be presented during the conference.

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8.24 Morse, Christopher

New measurement of the 2_1^+ state lifetime of ^{12}Be*

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The structure of light nuclei presents an important opportunity for developing our understanding of nuclear forces, especially learning more about 3-body and higher order correlations. These systems are simultaneously accessible to experimental studies which can elucidate their properties, and are or will soon be within the range of feasible *ab initio* calculations which are providing an increasingly detailed microscopic picture of the nucleus. As these calculations become more advanced, it becomes increasingly important to provide precise data in order to benchmark their results.

Electromagnetic transition rates between bound nuclear states have provided important constraints for the evaluation of *ab initio* calculations [1]. These transition rates are expected to be sensitive to 3-body correlations, which lead to small cancellations between the different components of the nuclear wave functions. Especially in nuclei that exhibit α-clustering, such as the beryllium and carbon isotopes, the transition rates can provide a strong test of the results of *ab initio* calculations and guide the formulation of 3-body forces. ^{12}Be is an especially interesting system in this light, as it embodies a tension between the tendency of the beryllium isotopes to form α-clustering structures [2] and the canonically magic neutron number $N = 8$. The sharp decrease in the 2_1^+ state energy of ^{12}Be relative to ^{10}Be suggests that clustering dominates over the $N = 8$ magic number. Thus, it might be expected that the $B(E2; 2_1^+ \to 0_1^+)$ transition rate would increase compared to ^{10}Be, consistent with a departure from the spherical shell model picture. However, the measured 2_1^+ state lifetime $\tau = 2.5 \pm 0.7$(stat) ± 0.3(sys) ps [3] has a ~30% uncertainty, which is too large to determine whether the $B(E2)$ increases or decreases relative to ^{10}Be. A more precise measurement is necessary to clarify this picture and to provide a meaningful constraint for *ab initio* calculations.

In this study, we remeasured the lifetime of the first 2^+ state of ^{12}Be. The lifetime was measured using the Doppler Shift Attenuation Method, with γ rays from ^{12}Be detected by GRETINA (Gamma Ray Energy Tracking In-beam Nuclear Array) [4] in coincidence with inelastically scattered ^{12}Be ions detected in the S800 spectrograph at the National Superconducting Cyclotron Laboratory at Michigan State University. To check for systematic consistency, several targets of varying thicknesses and materials were used to excite the ^{12}Be. The results indicate that the lifetime is considerably shorter than previously reported; about a factor of two shorter. This has important implications for the structure of ^{12}Be, which will be discussed in this presentation.

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8.25 Mukhopadhyay, Sharmistha

Nuclear structure of ^{76}Ge from inelastic neutron scattering measurements and shell model calculations*

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The low-lying, low-spin levels of ^{76}Ge were studied with the (n,n′γ) reaction at the University of Kentucky Accelerator Laboratory. Gamma-ray excitation function measurements performed at incident neutron energies from 1.6 to 3.7 MeV helped determine the threshold for the γ rays and hence their placement in the level scheme. Gamma-ray angular distributions were measured at neutron energies of 3.0 and 3.5 MeV. From these measurements, level spins, level lifetimes, γ-ray transition intensities, and multipole mixing ratios were determined. No evidence for a number of previously placed levels was found. Below 3.3 MeV, many new levels were identified, and the level scheme was re-evaluated. A comparison of the level characteristics with large-scale shell model calculations yielded excellent agreement. Fig. 1 shows the observed low-lying band structure.

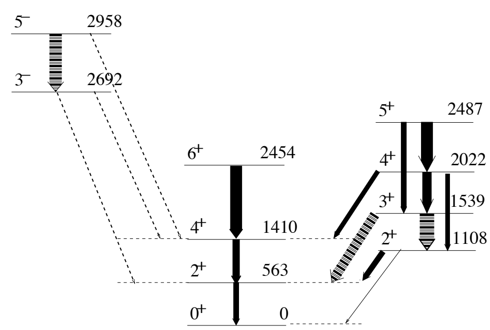

FIG. 1. Partial level scheme of ^{76}Ge. The thickness of the solid arrows is proportional to the B(E2)s. For the 2958- and 1539-keV levels, approximate (broad dashed lines) transition rates are shown. The out-of-band E1 transitions are shown as dashed lines.

The E2 transition rates measured here reinforce the band structure identified in recent above-barrier Coulomb excitation measurements by Toh *et.al* [1]. For example, the lowest 5^+ state, assigned as a member of the γ-band, decays with large B(E2)s to the 4^+ and 3^+ states, which are interpreted as the lower-lying members of the band. A decay to the lower-lying 4^+ state, an out-of-band transition, is not observed.

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8.26 Negrea, Daniel

Proton–neutron pairing in N=Z nuclei: Quartetting versus pair condensation

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The isovector pairing, including both proton–neutron and like-particle pairing, and isoscalar proton–neutron pairing are treated in a formalism which conserves exactly the particle number and the isospin. The formalism is designed for self-conjugate (N=Z) systems of nucleons moving in axially deformed mean fields and interacting through the most general isovector and isoscalar pairing interactions. The ground state of these systems is described by a superposition of two types of condensates, i.e., condensates of isovector quartets, built by two isovector pairs coupled to the total isospin T=0, and condensates of isoscalar proton–neutron pairs. The comparison with the exact solutions of realistic isovector–isoscalar pairing Hamiltonians shows that this ansatz for the ground state is able to describe with high precision the pairing correlation energies. It is also shown that, at variance with the majority of Hartree–Fock–Bogoliubov calculations, in the present formalism the isovector and isoscalar pairing correlations coexist for any pairing interactions. The competition between the isovector and isoscalar proton–neutron pairing correlations is studied for N=Z nuclei with the valence nucleons moving in the *sd* and *pf* shells and in the major shell above ^{100}Sn. We find that in these nuclei the isovector pairing prevail over the isoscalar pairing, especially for heavier nuclei.

8.27 Odell, Daniel

Infrared Extrapolations of Quadrupole Moments and Transitions

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Recent studies of the infrared convergence of finite basis calculations have led to accurate descriptions of numerical data. I will discuss how similar concepts can be applied to the study of bound-state quadrupole moments and transitions governed by the quadrupole operator. I will show that good agreement between analytically derived and numerically computed convergence behavior in finite harmonic oscillator spaces is obtained and will show results for realistic and simple systems.

8.28 Olaizola, Bruno

Deformed Structures and Shape Coexistence in ^{98}Zr

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Nuclei exhibit a wide variety of collective phenomena associated with their discrete many-body character. This collectivity is dominated by quadrupole deformations, either static or dynamic. Traditionally, nuclear collectivity has been classified as weak at or near closed shells and strong far away from them. A few exceptions have been found in the form of shape coexistence, that is, nuclear states with different quadrupole deformations at similar energies. In general, evidence for such structures is indirect, e.g., excited rotational bands in nuclei with spherical ground states, which lack evidence of quadrupole deformation, most notably via enhanced electric quadrupole transitions.

The zirconium isotopes sit in one of the most interesting regions of the chart of nuclides. With a closed proton shell ($Z = 40$) the nuclear structure evolves from a mid-open neutron shell deformed region (^{80}Zr, $\nu 1p_{1/2}$), through a closed spherical shell (^{90}Zr, $\nu 0g_{9/2}$) and subshell (^{96}Zr, $\nu 1d_{5/2}$), and then to a sudden reappearance of deformation (^{100}Zr, $\nu 0g_{7/2}$). The rapid onset of deformation across the Zr isotopes is unprecedented, and the issue of how collectivity appears and disappears in these isotopes is of special interest. Until recently, only for ^{98}Zr [1] (and maybe ^{100}Zr) has indirect and weak (while not contradictory [2]) evidence for shape coexistence been reported, with only speculative interpretation of the experiments. Recent results from high-precision B(E2) measurements provided for the first time direct evidence of shape coexistence in ^{94}Zr and suggested that it may occur in several other nuclei in this region [3].

In order to provide direct evidence of shape coexistence in ^{98}Zr a high-statistics $\gamma\gamma$ experiment was performed. This experiment was aimed at precisely measuring very weak low-energy branching ratios in the β-decay of ^{98}Y, which, due to the energy dependence of the quadrupole transitions (E_γ^5 for E2 transitions), is dominated by high-energy γ-transitions. This effect may obscure low-energy lines, even those with a large reduced transition rate, resulting in a failure to identify band structures.

The experiment was carried using the 8π spectrometer at TRIUMF-ISAC, which consists of an array of 20 Compton-suppressed hyper-pure germanium detectors in conjunction with β particle and conversion electron detectors. Excited states up to ~ 5 MeV in ^{98}Zr were populated in the β^- decay of ^{98}Y $J^\pi = (0^-)$, greatly expanding the known level scheme. Preliminary results on key branching ratios that affect the band structure will be presented.

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8.29 Peters, Erin

Revealing the structure of ^{106}Pd*

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Inelastic neutron scattering (INS) coupled with gamma-ray spectroscopy at the University of Kentucky Accelerator Laboratory has been used to examine the low-spin structure of ^{106}Pd. The Doppler-shift attenuation method was used to determine level lifetimes in the femtosecond region. Angular distributions were measured and multipole mixing ratios were also obtained. With this information, B(E2) values were determined. E0 strengths were also extracted by combining the INS data with internal conversion electron measurements by Colvin et al. [1].

New B(E2) values for many transitions in ^{106}Pd reveal important information about the structure of this nucleus, once thought to be a good candidate for a nucleus of vibrational character, a description which was based on level energies and spins. When comparing the reduced transition probabilities obtained in the present measurements with various models describing vibrational nuclei, a lack of experimentally observed E2 strength is evident for the purported higher phonon states. The E2 strengths for states up to ∼3 MeV were summed in an attempt to account for possible fragmentation, but the E2 strength is still lacking. It does not appear that ^{106}Pd can be depicted as vibrational.

The new rho-squared values lend further insight into the structure of this nucleus. Large E0 strengths were found not only for levels with $J_i = J_f = 0$, but also for $J_i = J_f = 2$. Such large E0 strengths have been established as a model-independent means of identifying shape coexistence and configuration mixing in nuclei. Thus we interpret the large rho-squared values in ^{106}Pd as evidence for shape coexistence, extending its observation among the N=60 isotones.

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8.30 Pore, Jennifer

A High-Statistics Measurement of the Beta Decay of ^{46}K with the GRIFFIN Spectrometer

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The neutron-rich calcium isotopes are currently a frontier for modern ab-initio calculations based on NN and 3N forces [1,2]. Detailed experimental data from the calcium nuclei are necessary for a comprehensive understanding of the region. Due to its very low natural abundance of 0.004%, the structure of the ^{46}Ca nucleus has not been studied in great detail compared to its even-even calcium neighbours. Many excited states in ^{46}Ca have been identified by various reaction mechanisms, most notably from *(p,p′)* and *(p,t)* reactions [3], but many spins are only tentatively assigned or not measured. The low-lying structure has been investigated by two previous beta-decay experiments, both with minimal detection capabilities, but large discrepancies are present between the two reported decay schemes [4,5].

A high-statistics data set of the ^{46}K decay into low-lying levels of ^{46}Ca was taken with the new GRIFFIN spectrometer located at TRIUMF-ISAC. A $4x10^5$ pps beam of ^{46}K was delivered and implanted at the center of the spectrometer, which operated with 15 HPGe clover detectors used for the detection of gamma rays. The addback capabilities of the clovers allowed for the reconstruction of Compton-scattered events. The level scheme of ^{46}Ca has been greatly expanded to include 160 new gamma-ray transitions and 12 new excited-states. Also, angular correlations between cascading gamma rays have been investigated to obtain information about the spins of the excited states. An overview of the experiment and a discussion of the preliminary results will be presented.

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8.31 Rajabali, Mustafa

The β decay of ^{34,35}Mg and the structure of ^{34}Al*

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Nuclei in the island of inversion, near the $N = 20$ shell closure, exhibit a fascinating behaviour where the nuclear ground states show deformed configurations dominated by particle-hole excitations across the neutron shell gap. The $^{31-35}$Mg nuclei are in or at the border of this island displaying intruder ground-state configurations, while the $^{31-35}$Al isotopes are suggested to have mixed ground- state configurations of normal and intruder type and thus serve as a transition from intruder dominated Mg isotopes to the normal ground-state configuration in Si isotopes.

An experiment was performed at the TRIUMF-ISAC-I facility with the goal of populating states in $^{33-35}$Al via the beta decay of $^{33-35}$Mg. A UC$_x$ target with laser-ionization from TRILIS was bombarded with 500 MeV protons to produce beams of Mg ions. The ions were transported and implanted onto a moving Mylar tape at the center of the GRIFFIN spectrometer [1]. A set of 20 plastic scintillators (SCEPTAR) was used for beta tagging. This was surrounded by 12 HPGe GRIFFIN-clover detectors for γ-spectroscopy.

Results obtained from the analysis of the ^{34,35}Mg decay data from this experiment will be presented. This includes the half-lives of ^{34,35}Mg and ^{34,35}Al which clarify current conflicting information in the literature [2].

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8.32 Richard, Andrea

Spectroscopy of Neutron-rich Mg Isotopes in and around the Island of Inversion*

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One of the fundamental questions in nuclear physics is whether or not the magic numbers and the shell model description of nuclei are valid far from stability, or more broadly, how to build a comprehensive picture of the nuclear landscape. The "Island of Inversion" located at Z$\sim$12 and N$\sim$20 [1] is a region where a narrowing of the N=20 shell gap and collective *np-nh* excitations result in nuclei with deformed ground states. However, despite years of theoretical and experimental efforts [1-6], a complete picture of the detailed nature of deformation has not been achieved and level schemes remain largely incomplete for many of these neutron-rich nuclei. A β-decay experiment has been performed at the National Superconducting Cyclotron Laboratory (NSCL) to investigate level schemes for neutron-rich Mg, Al, and Si isotopes between N=20 and N=28. In going from N=20 and toward N=28, the evolution of single particle states and their changing separation with the addition of neutrons can be indirectly probed. The details of the experiment will be presented and level schemes, along with preliminary implications for the evolving structure, will be discussed.

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8.33 Saxena, Mansi

Study of static quadrupole moments in ^{120}Te isotope

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In recent years the region in the vicinity of tin isotopes has been intensively investigated both from experimental and theoretical perspectives. In particular, the excitation energies and the reduced transition probabilities across the Z=50 chain has been examined in detail. In tellurium nuclei with two protons outside the major shell, the partial level schemes are dominated by the $1g_{7/2}$ orbit leading to 6^+ isomers in the vicinity of N=82 shell closure. The Te nuclei with 52 protons lies in the transitional region between the spherical nuclei at $Z = 50$ and deformed Xe and Ba nuclei. At low spin, the Te nuclei are considered to be one of the best examples of quadrupole vibrators. For the mid-shell ^{120,122,124}Te nuclei the partial level show the expected vibrational-like structure with equal energy spacing between the phonon states [1]. This observation is quite in contrast to the measured quadrupole moments Q_2^+ for the doubly even Te isotopes [2, 3]. These quadrupole moments can reach 60% of the one predicted by the symmetric rigid rotor.

In our recent Coulomb excitation experiment [4] at IUAC, New Delhi we used ^{58}Ni beam @ 175MeV to excite ^{120,122,124}Te isotopes. In these measurements the scattered particles were detected at forward angles. The B(E2; $0^+ \rightarrow 2^+$) value in ^{120}Te was re-measured with a much higher precision to allow a comparison with the predictions of the large scale shell model calculations (LSSM). Based on all experimental findings, level schemes and reduced transition probabilities, for ^{120,122,124}Te one obtained the best agreement with an asymmetric rotor behaviour.

To further investigate the second order effects (diagonal matrix elements) in ^{120}Te, an experiment was performed at Heavy Ion Laboratory, Warsaw, where particle detectors are in the backward direction enabling a more precise and sensitive measurement of the quadrupole moments. The measurement was carried out using a highly enriched ^{120}Te target and a ^{32}S 100 MeV beam from the U-200P cyclotron at HIL. A multi-step Coulomb excitation of ^{120}Te was observed up to 4^+ state in the g.s. band and the preliminary results will be presented at the conference.

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8.34 Schmitt, Kyle

Neutron dEtector with Tracking (NEXT)*

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Neutron detection plays an important role for several spectroscopic techniques. Current arrays have been used to characterize neutron emission decays, detect ejectiles from proton transfer, and identify neutron-unbound states for a variety of nuclei. Future studies to take place at the next generation of radioactive ion beam facilities will require improved energy resolution and neutron/gamma discrimination to make the best use of valuable beam time and eliminate crippling background.

The NEXT array proposes to accomplish 1% energy resolution between 100 keV and 2 MeV using neutron time of flight. The array will employ thin plastic scintillators (Eljen EJ-299) to improve position resolution. Neutron/gamma discrimination will be performed using pulse shape discrimination. The scintillators will be layered to maintain detection efficiency and enable neutron tracking. Silicon photomultipliers will be used for light collection in a compact design.

A prototype module is currently being developed. Results of simulations and advances in detector design will be presented.

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8.35 Silwal, Umesh

"Correcting the database: the case for ^{74}Ga β-decay"

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Detailed study of β decay far from stability relies heavily on a good understanding of the daughter and grand-daughter decays in order to correctly assign weaker transitions to the decays. This was the case in our study of the A=74 β-decay chain. Since ^{74}Ga decays to stable ^{74}Ge, we believed the decay would have been well studied and would provide a good internal check for the data analysis. What we discovered was that the two previous β-decay measurements of ^{74}Ga were fraught with inconsistencies.[1,2] Although the two experiments agreed on the observed γ rays, the placement of these transitions into a decay scheme disagreed significantly. This lead to numerous double placements and erroneous levels being assigned within the ENSDF database.[3] The problem arose due to the lack of γγ coincidence information being obtained in the two experiments. In our measurement, data on γ-ray emission following β-decay, including βγ and γγ coincidences, in the A=74 decay chain starting from ^{74}Cu were obtained. Gated γγ spectra were analyzed to identify the statistically significant coincidences and decay schemes have been developed for all three nuclei within the decay chain. Presented here are results for ^{74}Ga. In our purposed decay scheme, states below 2.6 MeV are in good agreement with the two previous measurements. However, above 2.6 MeV significant changes are made based on the γγ coincidence relationships. We have modified the placement of 21 γ rays, removed 10 incorrectly identified levels, and established 20 new energy levels. We have also determined the splitting of intensity in cases where unresolved doublets have been identified. It is unclear if any of these modifications have repercussions on other experiments, but do point out the need to recheck some of the older data included in the ENSDF database. This work is supported by the Office of Science of the Department of Energy and Grant No. DE-FG02-96ER41006, No. DE-SC0014448, No. DE-AC05-00OR22725, No. DE-FG02-96ER40983, No. DE-AC05-06OR23100 and No. DE-FG02-96ER40978 and National Nuclear Security Administration Grant No. DEFC03-03NA00143.

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8.36 Smith, Karl

First Data with the Hybrid Array of Gamma Ray Detectors (HAGRiD)*

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Transfer reaction and beta-decay studies are powerful tools for studying the structure of nuclei, including those far from stability. These studies can also provide insight into astrophysical reactions that are difficult to measure directly. Particle-gamma coincidence developed techniques provide invaluable additional information beyond that from particle detection alone.

The Hybrid Array of Gamma Ray Detectors (HAGRiD) is an array of $LaBr_3$(Ce) scintillators to detect gamma rays. HAGRiD has been designed to be coupled with particle detector systems such as the Oak Ridge Rutgers University Barrel Array (ORRUBA) of silicon detectors, the Versatile Array of Neutron Detectors at Low Energy (VANDLE), and beta detection scintillators. As well as the Jet Experiments in Nuclear Structure and Astrophysics (JENSA) advanced target system. HAGRiD maximizes gamma-ray detection efficiency without compromising the charged-particle resolution when coupled with ORRUBA. $LaBr_3$(Ce) crystals provide superior resolution and intrinsic efficiency over NaI, 2.6% and 40% respectively for ^{137}Cs, and increased portability and flexibility over germanium detectors. First experiments with HAGRiD coupled to VANDLE and JENSA were performed in Spring 2016. The current status of the project, some preliminary results, and future plans will be discussed.

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8.37 Taylor, Steven

Beta-Delayed Neutron Spectroscopy of Statistical and Shell-Model Nuclei Using VANDLE*

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In recent years there has been a revival of interest in spectroscopic measurements of beta-delayed neutron emitters in medium mass nuclei for the purpose of understanding nuclear structure. The Pandemonium effect[1] suggests that structures in neutron energy spectra can be attributed to the effects of statistical fluctuations. However, the ramifications of statistical fluctuations for nuclei near closed shells diminishes due to the lower density of states above the neutron separation energy. This allows for features of the neutron energy spectra to reflect underlying nuclear shell structure. It is not yet clear where the boundary of statistical effects and structure effects on the neutron spectra occurs. A research program using the Versatile Array of Neutron Detectors at Low Energy(VANDLE)[2,3], a time of flight detector array, addresses this challenge using systematic studies of nuclei in mid and closed shell regions. Gamma-ray detection systems paired with VANDLE enable the measurement of gamma-rays emitted in coincidence with neutrons, and provides more complete information about the decay path compared to previous results. Measurement of β-n-γ coincidences are critical for accurate data interpretation. Results will be presented on the decays of beta-delayed neutron precursors near doubly magic ^{132}Sn, and in nearby regions thought to be dominated by the statistical effects. These measurements were performed at Oak Ridge National Laboratory using ^{238}U fission fragments and at Argonne National Laboratory using ^{252}Cf fission fragments.

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8.38 Thompson, Paul

Next Generation Nuclear Structure Studies Using JENSA

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Measurements of light-ion-induced reactions, particularly those using hydrogen and helium, are a cornerstone of nuclear structure models. A major focus of the new Facility for Rare Isotope Beams (FRIB) will be measurement of these reactions on unstable nuclei, to help extend the benchmarking of structure models into more exotic regions of the nuclear chart. As these reactions must be undertaken in inverse kinematics, targets of hydrogen and helium are required. However, because hydrogen and helium are gaseous in their elemental form, traditionally-employed targets for such studies utilize either gas cells or chemical compounds (such as CH_2); both approaches introduce unwanted background reactions. The Jet Experiments in Nuclear Structure and Astrophysics (JENSA) gas jet target system[1] is a highly versatile next-generation target for use in multiple areas of reaction study, currently installed on a dedicated beamline in the ReA3 hall at the NSCL. JENSA produces a target of dense, localized, and pure gas, by creating a supersonic jet of the desired gas species, overcoming many of the difficulties inherent in foils and gas cells. The JENSA system is able to utilize rare and expensive gases as target material, such as ^{3}He, by recirculating the gas of interest, and can incorporate high-segmentation, high-solid-angle charged particle detector arrays for light-ion-induced reaction studies. This enables a multitude of next-generation measurements, including nuclear structure via particle transfer [2,3]. The versatility of the JENSA gas jet target system with regard to nuclear structure studies will be presented, including an example case of recent experimental results from a ^{20}Ne(p,t)^{18}Ne experiment performed with JENSA at Oak Ridge National Laboratory. Excitation energies and spin and parity assignments for the populated levels in ^{18}Ne will be presented.

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8.39 Toomey, Rebecca

A neutron spectroscopic approach to measuring low cross section (α,n) reactions.

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To be able to fully understand what is happening in the cosmos, we need to be able to understand the fundamental processes that give rise to the primary building blocks of our universe; the elements. One such nucleosynthesis process is slow neutron capture (s process), which occurs mainly in asymptotic giant branch stars. The neutron sources are predominantly (α,n) reactions, with the dominant source being the ^{13}C(α,n) reaction. Therefore, it is important to fully characterise this reaction rate in order to constrain the neutron flux at stellar temperatures. Neutrons from (α,n) reactions are also important background signals for other areas of active research, such as underground neutrino experiments, dark matter measurements and other important astrophysics experiments.

Direct measurement of the ^{13}C(α,n) reaction at astrophysical energies is made difficult by the extremely low cross sections, which drop precipitously with decreasing energy, and the inherent difficulties in neutron detection. The current generation of high-current accelerators, whilst able to produce pure beams at relevant energies, produce DC beams that do not allow time-of-flight neutron measurements to be performed. Measurements typically rely on high-efficiency neutron counters, such as ^{3}He detectors [1] and Cadmium capture detectors [2], which measure integrated neutron fluxes, but provide no information on the energies of incident neutrons. To measure the cross section at lower energies, measurements may need to be performed in underground laboratories in order to reduce the background neutron flux and increase experimental sensitivity.

An alternative approach presented here uses deuterated scintillator detectors, from which the energy spectrum of the incident neutrons can be determined, without requiring time-of-flight measurement, via spectrum unfolding. This approach significantly enhances the sensitivity to the mono-energetic neutrons from ^{13}C(α,n) reactions by supressing background neutrons based upon their energies, rather than total flux alone. This approach was tested at the University of Notre Dame where an alpha beam impinged on a Boron target to determine the cross section of the ^{10}B(α,n) reaction. Preliminary results from this experiment demonstrate that this technique works. This presentation would summarise the status of the ^{10}B(α, n) measurements and plans to measure the ^{13}C(α, n) reaction.

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8.40 Tracy Jr, James

A Binding Energy Study of the Atomic Mass Evaluation 2012

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Abstract

In contrast to the current collection of mass prediction models which are exploratory in nature, a new simplified study of ground state binding energy values listed in the Atomic Mass Evaluation 2012 (AME2012) takes an interpretive approach. A postulate requiring all protons to pair with available neutrons to form bound α clusters as the ground state for an $N = Z$ core leads to a study of the binding energy as a function of excess neutrons built upon this core for 1142 qualifying nuclei. A quadratic functional form is selected as a first-guess fit to these isotope chains, and a weighted least-squares fit is performed for each core. This reveals a smooth decaying exponential behavior as a function of core size for the a_2 fit parameters. A novel mass-excess calculation for the a_0 fit parameter values reveals a near-symmetry around $Z = 50$ for $N = Z$ nuclei and is compared to Hartree-Fock-Bogoliubov (HFB) series and the Finite Range Droplet Model (FRDM). The a_1 fit parameters are linear functions of core size and are compared to the Coulomb force, suggesting that the nuclear interaction between a nucleon and the core is a conservative, inverse-radius-law force. The vertices of these fits correspond to the the neutron drip-line boundary and are compared against current predictions for the drip line, extending this boundary significantly. By considering the possibility of a core of α clusters, a new level scheme is presented; n-n pairing is shown to have a greater role in level filling.. This model, tentatively referred to as the Alpha-Deuteron-Neutron (ADN) Model, yields promising first results with root-mean-square variances from the AME2012 values, which are generally treated more as initial estimates rather than exact values. These RMS variances range between 431.4 keV for a raw three-parameter fit of the data to 1046.3 keV for a one-free parameter fit, with 76% of the qualifying 1142 nuclides agreeing within 1 MeV and 51% showing agreement within 500 keV for the one-free parameter fit.

8.41 Tripathi, Vandana

Shell evolution in neutron rich Phosphorus isotopes *

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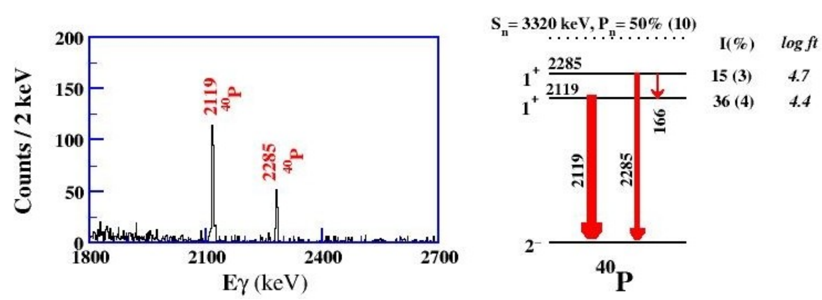
The evolution of shell structure *i.e.* the migration of orbitals as a function of the N/Z ratio remains one of the focal points of investigation at the present and future radioactive facilities. The force behind the migration of orbitals is the neutron-proton interaction namely the monopole part of the tensor interaction. Refinement of this monopole term to increase the predictive power of the shell model calculations is the driving force of our experimental and theoretical endeavors. Odd Z and odd-odd nuclei provide one of the most stringent tests of theoretical predictions because of the many more degrees of freedom available; paradoxically they are the least investigated. Recently the β-decay of Si isotopes was investigated at the National Superconducting Cyclotron Laboratory to populate intruder states in exotic P (Z=15) isotopes. First γ transitions in the $T_z = 5$ ^{40}P have been observed (figure below) de-exciting the strongly populated 1^+ states in the β-decay. Shell model calculations using the SDPF-MU interaction show these states to have a complex structure involving many orbitals, suggesting deformation. The collectivity in these exotic nuclei is related to the near degeneracy of the proton sd orbitals along with the narrowing of the N=28 shell gap. Results for $^{37,38,39,40}P$ will be discussed highlighting the effects of adding neutrons on the shell structure.



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8.42 Turko, Joseph

Simulating the DESCANT Neutron Detection Array with the Geant4 Toolkit*

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The DEuterated SCintillator Array for Neutron Tagging (DESCANT) is a newly developed high-efficiency neutron detection array composed of 70 hexagonal deuterated scintillators. Due to the anisotropic nature of elastic (n,d) scattering, the pulse-height spectra of a deuterated scintillator contains a forward-peaked structure that can be used to determine the energy of the incident neutron without using traditional time-of-flight methods. Simulations of the array are crucial in order to interpret the DESCANT pulse heights, determine the efficiencies of the array, and examine its capabilities for conducting various nuclear decay experiments. To acheive this, we plan: (*i*) a verification of the low-energy hadronic physics packages in Geant4, (*ii*) a comparison of simulated spectra with data from a simple cylindrical "test can" detector geometry, (*iii*) expanding the simulated light response to a prototype DESCANT detector, and (*iv*) simulating the entire DESCANT array.

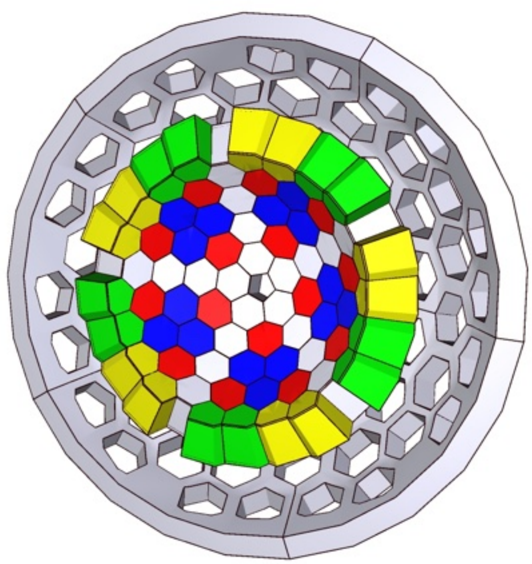

FIG. 1. The Geant4 simulation of the DESCANT neutron array.

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8.43 Villafana, Kalisa

Rotational Behavior in ^{179,180}W*

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High spin states of ^{179,180} W were produced via the 4n and 5n channels respectively in the ^{14}C + ^{170}Er reaction at beam energies of 68 MeV and 75 MeV. This experiment was performed at Florida State's John D. Fox Laboratory with three escape-suppressed germanium clovers and seven escape-suppressed single crystal germanium detectors in order to deteect gamma rays.

The experiment produced 852 million γ-γ coincidences and 82 million γ-γ-γ coincidences at 75 MeV beam energy. Additionally, at 68 MeV, there were 119 million γ-γ coincidences and 9.6 million γ-γ-γ coincidences. Analysis of this data is in progress using the Radware analysis package [1] using both double (matrix) and triple (cube) formats. Preliminary analysis is already revealing extensions to previously known structures [2,3] as well as new bands being observed. These results will be presented and discussed.

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8.44 Vostinar, Marija

Spectroscopy of ^{257,258}Db in the vicinity of the N = 152 deformed shell gap

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Valuable information on the existence of superheavy nuclei can be obtained by studying the nuclear structure of elements in the region of the N = 152 deformed shell gap. Recent experimental studies have led to the determination of the size [1] and the strength [2] of this gap. Its influence was studied for nuclei like ^{255}Lr [3] and ^{256}Rf [4]. Despite the low production cross-sections numerous detailed spectroscopic investigations in that region have been performed in recent years in many laboratories [5]. In continuation of this successful program, we have performed two measurements in which we have synthetized and studied ^{257}Db (N = 152) and ^{258}Db (N = 153).

The Db isotopes were produced in fusion-evaporation reactions of ^{50}Ti beams with ^{209}Bi rotating targets. The ^{257}Db experiment was performed at GANIL where the two previously observed [6] long lived states were confirmed, as well as the two isomeric states of the daughter nuclei ^{253}Lr.

The ^{258}Db experiment was performed at GSI where a strong indication of two different states with different half-lives was observed. A new γ-ray transition of ^{250}Md was identified and its placement in the partial level scheme is proposed. The α decay of ^{258}Rf was also observed, suggesting a smaller branching ratio than previously [7] reported.

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8.45 Walter, David

Spectroscopic Factors near the r-process path using Combined Measurements

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The structure of low-lying states above nuclear shell closures is dependent on the shape of the bound-state potential, which when poorly constrained, can greatly affect the uncertainty in the extracted spectroscopic factor. One way to mitigate this uncertainty is to use a combined, two-measurement method [1], in which the external contribution of the wave function is fixed using a peripheral reaction, and that result is combined with a higher energy measurement with a larger contribution from the interior. These two measurements should constrain the single-particle asymptotic normalization coefficient, ANC, and enable spectroscopic factors to be deduced with uncertainties dominated by cross-section measurements rather than the limited knowledge of the bound-state potential. Published measurements of ^{86}Kr(*d,p*) at 5.5MeV/u [2] were used to determine the external contribution of this reaction. ^{86}Kr(*d,p*) at 35MeV/u has been measured in inverse kinematics at the NSCL using the ORRUBA and SIDAR arrays of silicon strip detectors. Results of the ANC analysis from the archival data and from the ^{86}Kr(*d,p*) measurement at 35MeV/u will be presented, as well as prospects for measurements with radioactive ion beams.

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8.46 Wang, Enhong

Reinvestigation of octupole correlations in ^{146,147}La*

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High spin states of neutron rich ^{146,147}La have been reinvestigated by γ-γ-γ and γ-γ-γ-γ coincidence data from a ^{252}Cf spontaneous fission experiment by using Gammasphere. Thirty-two new transitions in ^{146}La are observed. Two new bands in ^{146}La have been established. One of them is proposed to be the octupole parity partner of the previously known band. Twenty new transitions in ^{147}La are observed. The ground state band of ^{147}La has been established with a proposed 5/2$^+$ band-head. Angular correlation of cascades has been used to study the spins and parities of the states. The $B(E1)/B(E2)$ ratios between the proposed octupole bands in ^{146,147}La have been measured showing a decreasing octupole deformation from ^{144}La to ^{146}La, and from ^{145}La to ^{147}La. The backbending phenomenon of the four bands in ^{147}La has been studied.

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8.47 Williams, Jonathan

Study of ^{22}Ne and ^{28}Mg excited states using fusion-evaporation and Doppler shift measurements*

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Electromagnetic transition rate measurements serve as a fundamental probe of nuclear structure and provide a stringent test for theoretical models. Doppler shift lifetime measurements offer an opportunity to directly access information about electromagnetic transition rates and discriminate between model calculations. The TIGRESS Integrated Plunger device (TIP) [1], constructed at SFU, supports Doppler shift lifetime measurements via gamma-ray spectroscopy with the TIGRESS segmented Ge array as part of the experimental program at the ISAC-II facility of TRIUMF.

A recent study using TIP employs the fusion-evaporation reaction of ^{18}O + ^{12}C at beam energies of 56 and 48 MeV, with reaction channel selection provided via coincident charged particle detection using ancillary CsI(Tl) detectors [2]. Transitions were identified belonging to the 2 alpha particle and 2 proton evaporation channels from the compound system ^{30}Si, corresponding to ^{22}Ne and ^{28}Mg respectively. Lineshapes, from which lifetimes can be determined by comparison to simulated data, have been observed for these transitions. The experimental approach, analysis procedure, and preliminary comparison of lineshapes to simulations developed using the GEANT4 toolkit will be discussed. This work is presented on behalf of the TIP and TIGRESS collaborations.

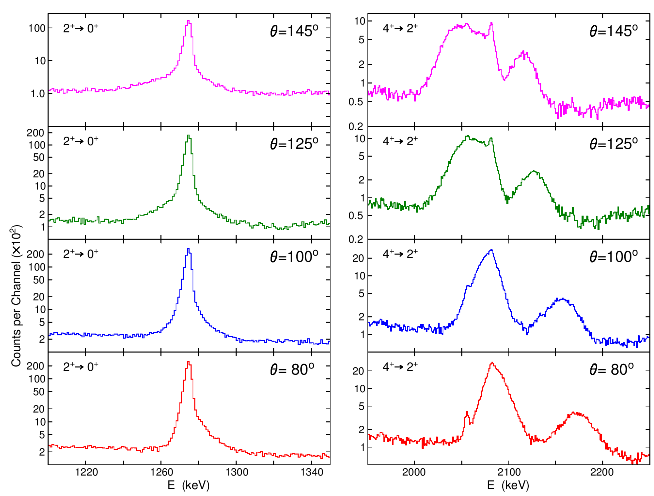

FIG. 1. Lineshapes observed for select ^{22}Ne transitions at various TIGRESS detector angles.

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* supported by Natural Sciences and Engineering Research council of Canada.
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8.48 Wilson, Gemma

Beta-delayed neutron emission studies with a C^7LYC array at CARIBU*

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If the Q-value of β decay is large enough, excited states in the daughter nucleus are populated above the neutron-separation energy, and then the daughter nucleus is expected to decay by neutron emission. Beta-delayed neutron emission studies are particularly relevant to astrophysics in understanding the r-process and determining r-process lifetimes, and to nuclear structure. These studies are also important for the design and safety of nuclear reactors, as beta-delayed neutron emission is used to control the power level.

This work is a study of β-delayed neutron emission from ^{94}Rb. Approximately 150 γ rays are known in the daughter ^{94}Sr, most of which are misplaced. An estimated 26% of γ rays are thought to be missing. The probability of neutron emission from ^{94}Sr is $10.2(2)\%$. Recently [1] there have been reports of substantial γ-decay from above the neutron separation energy in ^{94}Rb. This research is aimed at understanding this high-lying γ-strength.

A pulsed beam of isotopically-pure ^{94}Rb was produced by CARIBU (CAlifornium Rare Isotope Breeder Unit). The X-Array, comprising three HPGe clovers and one larger 'superclover', and SCANS (Small CLYC Array for Neutron Scattering) were arranged in a cube geometry around the beam implantation site, for the detection of γ rays and neutrons, respectively. A plastic scintillator, for β-particle detection, makes the sixth side of the cube, on the beam axis. This scintillator is part of the SATURN decay station (Scintillator And Tape Using Radioactive Nuclei)[2], which also includes a tape-moving mechanism to prevent the build-up of radioactivity. SCANS comprises sixteen $1'' \times 1''$ $Cs_2{}^7LiYCl_6$ (C^7LYC) detectors arranged in a 4×4 configuration, and can detect both γ rays and neutrons with excellent pulse-shape discrimination [3,4]. As time of flght is not needed for the measurement of the neutron energy, SCANS was mounted $8\frac{1}{4}''$ from the implantation site, increasing the efficiency for fast-neutron detection.

Data were collected in a triggerless digital data acquisition system, with β, γ and n correlated offline. A large amount of background from CARIBU has been eliminated through the use of β-γ time correlations, making it possible to identify γ rays from ^{93}Sr and therefore confirm β-delayed neutron emission from ^{94}Rb. A level scheme for ^{93}Sr and ^{94}Sr is being developed using γ-γ matrices. Pulse-shape discrimination in C^7LYC is being developed in order to produce a more definitive neutron gate. The analysis of these data will be presented, including n-γ-γ gating to determine levels in ^{94}Sr that are populated above the 6.83-MeV neutron separation energy.

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8.49 Wolinska-Cichocka, Marzena

Beta-decay studies of decay chain ^{142}Cs→^{142}Ba→^{142}La with Modular Total Absorption Spectrometer*

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Understanding beta-decay features and following decay heat release in nuclear fuel contributes to the optimization of energy production and to the analysis of safety during the nuclear fuel cycle, including the transportation and storage of radioactive waste [1-4]. It is also important for the analysis of processes involving reactor anti-neutrinos [5-7]. In particular, based on earlier existing data in the Evaluated Nuclear Structure Data Files (ENSDF), the decay of ^{142}Cs was expected to provide an important contribution to the high energy part of reactor anti-neutrino spectra [8,9].

The mass A=142 decay chain have been investigated by means of the 6-ton, Modular Total Absorption Spectrometer (MTAS) [10] at the ORNL's Tandem-ISOL facility. MTAS efficiency for full gamma energy absorption is around 80% at few hundred keV and is still at the level of 70% for few MeV gamma-transition. MTAS results obtained for the decay of ^{142}Cs, ^{142}Ba and ^{142}La will be presented and discussed with respect to the beta-strength and antineutrino energy spectra. In particular, the observed shift of ^{142}Cs-emitted anti-neutrinos towards lower energies will be addressed during my presentation.

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8.50 Wright, Jonathan

The Effects of Pulse Shape Analysis on Single Element Compton Imaging using a Double Sided Germanium Strip Detector*

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The potential for single element Compton imaging using a Double Sided Germanium Strip Detector (DSGSD) has been investigated for seven γ-ray energies ranging from 121 keV to 1408 keV. The effects of applying Pulse Shape Analysis (PSA) [1] techniques have been examined using a simulated pulse shape database generated within the Agata Detector Library (ADL) [2] software package. Charge pulses from experimental data were compared with pulses from a Monte Carlo simulation using a χ^2 minimisation grid search algorithm. Using the raw positional information provided by the detector segmentation, Compton reconstructions failed to locate the source position. However with the improved position sensitivity afforded by PSA, Compton images were reconstructed to within $\sim$ 10 mm of the known source location with a source position resolution of $\sim$100 mm, illustrated in FIG.1. The results of this experiment provide a solid grounding for future work on this project, with the prospects of single element Compton imaging using a DSGSD looking promising. The concept has been proved viable, with further work required to improve the efficiency of the process. The results of this experiment and the implications for future work will be presented.

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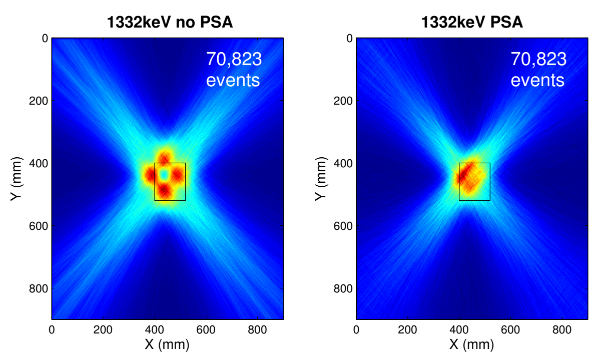

FIG. 1: Compton image reconstruction for experimental ^{60}Co data showing the effects of PSA on two different energies. The number of events is displayed in the top right of each image, in addition to a box highlighting the position of the detector face

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8.51 Xiao, Yongchi

Search for the heaviest N∼Z alpha emitters*

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Enhancement of α-decay probability for nuclei above ^{100}Sn is expected because valence protons and neutrons above Z=N=50 occupy the same single-particle orbitals [1]. The program to search for the new α-particle emitters in this region was initiated at JAEA Tandem Accelerator at Tokai, Japan. The proof of principle experiments were performed with the Double-sided Silicon Strip Detector at Recoil Mass Separator (RMS) [2] using digital electronics and resulted in observation of ^{109}Xe α-decay chain. The first discovery-aimed experiment, which searched for ^{113}Ba α-decay took place in December 2014 with possible candidates for decay of this isotope observed. The current status of analysis will be presented.

[1] R. D. Macfarlane, and A. Siivola. "New region of alpha radioactivity." Physical Review Letters 14.4 (1965): 114.
[2] H. Ikezoe, *et al*., "JAERI recoil mass separator." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 376.3 (1996): 420-427.

* This work was supported in part by the Reimei Research Program (Japan Atomic Energy Agency) and Grant No.DE-FG02-96ER40983, by the U. S. Department of Energy, and in part by the JSPS KAKENHI Grant Number 26887048.

8.52 Zidar, Tammy

Investigation of the nuclear structure of ^{33}Al through β-decay of ^{33}Mg to probe the island of inversion*

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Some nuclei, away from the valley of stability, have been found to have ground state properties that are different than those naively expected from the nuclear shell model. The term "island of inversion" is used to refer to a region of the chart of the nuclides around the N = 20 closed shell nucleus ^{32}Mg where large ground state deformations occur in association with intruder configurations from the $f_{7/2}$ shell. The nuclear structure of transitional nuclei, in which the normal and intruder configurations compete, can be used to corroborate (or not) theoretical models used to explain the inversion mechanism. One such transition occurs along the N = 20 isotones, where neutron rich ^{32}Mg is known to have a deformed ground-state configuration, while ^{34}Si displays a normal one. Previous studies [1, 2] of the intermediate N = 20 isotone ^{33}Al gave conflicting results regarding its structure. In the present work we studied ^{33}Al through the β-decay of ^{33}Mg to clarify this discrepancy.

A low-energy radioactive beam of ^{33}Mg was delivered at a rate of 10^4 ions/s by the Isotope Separator and Accelerator (ISAC-I) facility at TRIUMF. Data were collected with the GRIFFIN [3] high-purity germanium γ-ray spectrometer coupled with the SCEPTAR plastic scintillator β particle detector. The majority of the data were collected in a cycled mode (with a period of $\sim$10 s beam on, 1.5 s beam off) to provide sensitivity to all of the ^{33}Mg, ^{33}Al and ^{33}Si half-lives. The high efficiency of the GRIFFIN detector provide new γ-γ coincidences to elucidate the excited state structure of ^{33}Al, and the capability of GRIFFIN to detect weak transitions has provided more complete β-decay branching ratios for the ^{33}Mg$\rightarrow$ ^{33}Al$\rightarrow$ ^{33}Si decay chain. Preliminary results from the data analysis will be presented and their significance discussed.

[1] V. Tripathi et al., Phys. Rev. Lett. 101, 142504 (2008)
[2] J. C. Angelique et al., AIP Conf. Proc. 831, 134 (2006)
[3] C. E. Svensson and A. B. Garnsworthy, Hyperfine Int. 225, 127 (2014)

* Research supported by the Canadian Foundation for Innovation, The National Research Council of Canada, the Natural Sciences and Engineering Research Council of Canada and the Canada Research Chair Program

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Neutrinos in Nuclear Physics Workshop

9. Neutrinos Workshop (Agenda)

(Please note that the registration of the neutrino workshop is separate from NS2016)
https://public.ornl.gov/conferences/ns2016/nw.shtml

The neutrino workshop will start on the afternoon of Friday July 29th and end by noon on Sunday July 31st. The workshop will host a mixture of invited and contributed talks as well as a poster session. We anticipate that in the long term, this workshop may develop into a periodic meeting. The primary goal of this workshop is to identify areas of opportunity and common interest between various scientific communities (NP-HEP-Astro-Data). We will highlight some of the current ORNL activities and will provide a forum to bring together experts from diverse backgrounds in order to identify areas of common interest, and present possible pathways for future collaborations.

The scientific program will include topics such as: low-energy neutrino physics, including solar and supernova neutrinos; nuclear astrophysics, small- and mid-scale projects, neutrinoless double beta decay studies, absolute neutrino mass measurements, mixing, sterile neutrinos, interactions of neutrinos with matter at low and high energy, coherent elastic scattering of neutrinos from nuclei, experimental investigations of the weak interaction in neutrino processes, neutrinos and nucleosynthesis in hot and dense matter, theoretical needs and new detection technologies, isotopic enrichment, determination of matrix elements using nuclear reactions, studies of beta decay of fission fragments using total absorption spectrometers, decay heat in nuclear reactors and nuclear data and in general a discussion on the role of nuclear physicists in enabling and interpreting experiments that utilize reactors and radioactive sources.

International Advisory Committee

- John F. Beacom (Ohio)
- Raph Hix (ORNL)
- Chuck Horowitz (Indiana)
- Jorge Piekarewicz (FSU)
- Hamish Robertson (Seattle)
- Kate Schoelberg (Duke)

Local Organizing Committee

- Chair Alfredo Galindo-Uribarri
- Félix Charry Pastrana
- Noel Cruz Venegas
- Angela Fincher
- Brennan Hackett
- Blaine Heffron
- Sherry Lamb
- James T. Matta
- Paul Mueller
- Elisa Romero-Romero

9.1 Friday July 29th

		FRIDAY JULY 29
		SALON D&E
F3		**Chair: Alexandrina Petrovici**
3:00 PM	3:30 PM	**John P. Schiffer** *Nuclei and Neutrinos: an Experimenter's Perspective*
3:30 pM	4:00 PM	**Jonathan Engel** *The future of double-beta decay calculations*
4:00 PM	4:30 PM	**Francesco Cappuzzello** *The nuclear matrix elements of neutrino-less double beta decay decay and the NUMEN project at INFN-LNS*
4:30 PM	5:00 PM	**Pinghan Chu** *The Status and Initial Results of the MAJORANA DEMONSTRATOR Neutrinoless Double-Beta Decay Experiment*
5:00 PM	5:30 PM	**Coffee Break**
F4		**Chair: Jirina Stone**
5:30 PM	6:30 PM	**Manfred Lindner** *Lepton number violating decays: Theoretical and experimental challenges*
6:00 PM	6:30 PM	**Gaute Hagen** *Theory for Double-Beta Decay and fundamental Symmetries*
6:30 PM	7:00 PM	**Alejandro Garcia** *Using Cyclotron Radiation Spectroscopy in Searches for Chirality Flipping Interactions*
		End of Talks
		SEQUOYAH CONFERENCE CENTER 1
7:00 PM	8:00 PM	**Posters** **(Reception in Lieu of Dinner)**

9.2 Saturday July 30th

		SATURDAY JULY 30
		SALON D&E
ST1		**Chair: Cheuk-Yin Wong**
9:00 AM	9:30 AM	**Bryce Littlejohn** *Recent absolute reactor spectrum measurements*
9:30 AM	10:00 AM	**Aleksandra Fijalkowska** *New results from MTAS and the impact on the reactor anomaly*
10:00 AM	10:30 AM	**Charlie Rasco** *The decays of three top contributors to the reactor anti-νe high-energy spectrum studied with total absorption spectroscopy*
10:30 AM	10:45 AM	**Coffee Break**
ST2		**Chair: Krzysztof Rykaczewski**
10:45 AM	11:15 AM	**Michael Febbraro** *The 13C(α,n)16O reaction: A background source for underground astrophysics measurements and geo-neutrino measurements*
11:15 AM	11:45 AM	**Alejandro Sonzogni** *Improvements in the Summation Method to Calculate Nuclear Reactors Antineutrino Spectra*
11:45 AM	12:15 PM	**Tom Langford** *PROSPECT: A reactor oscillation and spectrum experiment at HFIR*
12:15 PM	1:30 PM	**LUNCH (included)**
ST3		**Chair: Yang Sun**
1:30 PM	2:00 PM	**Robert Mills** *Preliminary modelling of the anti-neutrino production from a Magnox reactor*
2:00 PM	2:30 PM	**Andrew Stuchbery** *Overview of our progress toward the Stawell Underground Physics Laboratory in Australia*

		SATURDAY JULY 30
		SALON D&E
2:30 PM	3:00 PM	**Sowjanya Gollapinni** *Neutrino-nucleus interactions with LArTPCs*
3:00 PM	3:30 PM	**Coffee Break**
ST4		**Chair: Nathaniel Bowden**
3:30 PM	4:00 PM	**Tom Kieck** *Neutrino Mass Determination by Electron Capture in Holmium-163 – ECHo*
4:00 PM	4:30 PM	**Christopher Mauger** *The CAPTAIN Program: Measuring electron neutrino cross-sections on argon*
4:30 PM	5:00 PM	**Osvaldo Civitarese** *Extracting information from* $0\nu\beta\beta$ *decay and LHC pp-cross sections: Limits on the left-right mixing angle and right-handed boson mass*
		End of Talks

9.3 Sunday July 31st

		SUNDAY JULY 31
		SALON D&E
SN1		**Chair: Yuri Kamyshkov**
9:00 AM	9:30 AM	**Jorge Morfin** *Neutrino-nucleus interactions*
9:30 AM	10:00 AM	**Kate Scholberg** *Coherent neutrino scattering*
10:00 AM	10:30 AM	**Juan Collar** *Development of detectors sensitive to coherent neutrino-nucleus scattering*
10:30 AM	10:45 AM	**Coffee Break**
SN2		**Chair: Alfredo Galindo-Uribarri**
10:45 AM	11:15 AM	**Toshio Suzuki** *Neutrino-nucleus reaction cross sections for neutrino detection and nucleosynthesis in supernova explosions*
11:15 AM	12:00 PM	**Baha Balantekin** *Neutrinos in Physics and Astrophysics*
12:00 PM	1:00 PM	**Closing Remarks** **LUNCH (included)** **(Open Research Discussions)**
		End of Neutrinos in Nuclear Physics Workshop

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