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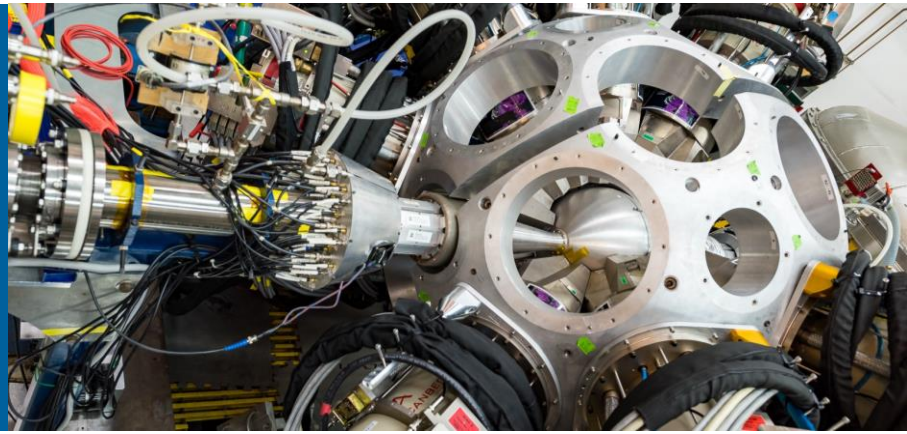
ATLAS PLANS FOR ACCELERATOR AND EQUIPMENT



GUY SAVARD
Director of ATLAS

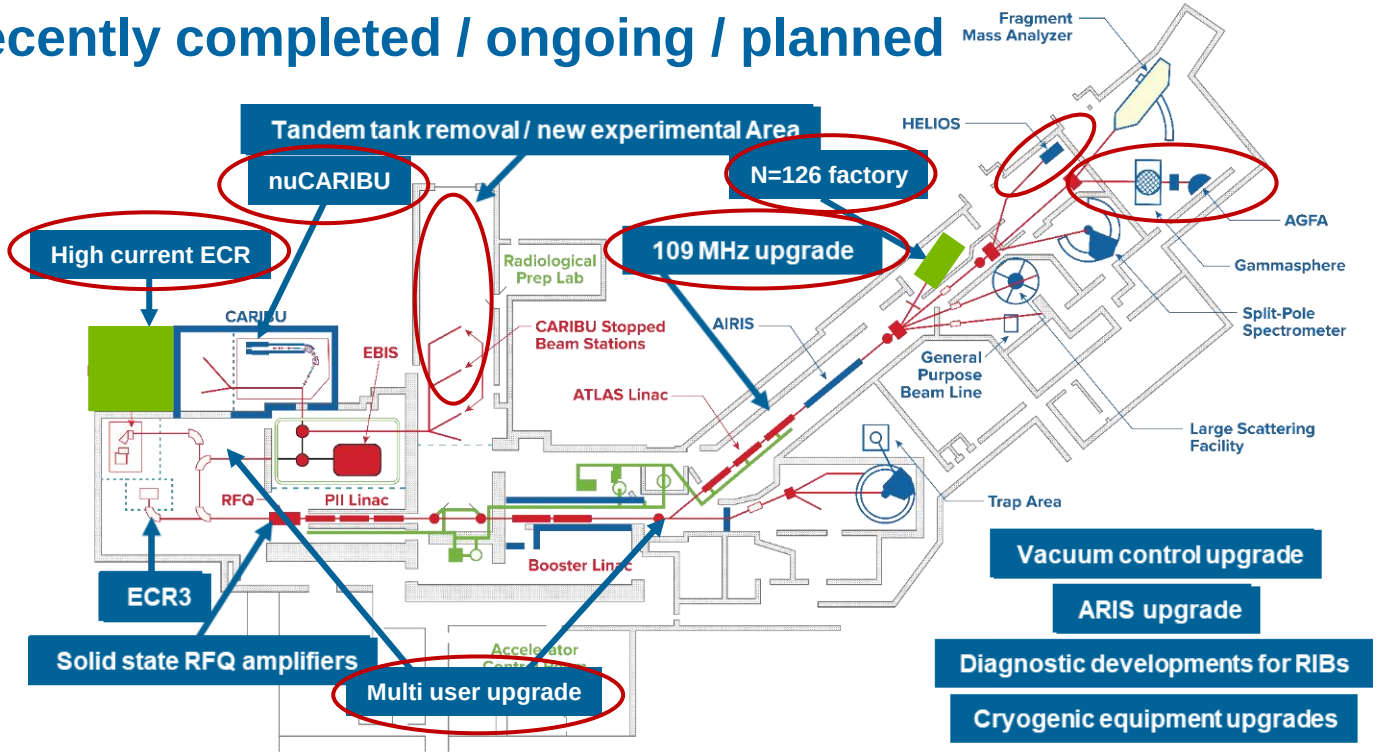
11/15/2022
Argonne National Laboratory

MAIN INITIATIVES BEING FOLLOWED TO ADDRESS THESE SCIENTIFIC OPPORTUNITIES

- Take advantage of the significant new capabilities in last few years: AGFA, RAISOR, EBIS and the low-background experimental area for CARIBU
- Move forward with the development and implementation of the ATLAS multi-user upgrade to allow ATLAS to address the large oversubscription of the facility by providing more research hours to its user community
- Expand the range and intensity of unstable neutron-rich beams available from ATLAS with the CARIBU upgrade by implementing the nuCARIBU upgrade
- Provide first access to the north-east region of the chart of nuclei near ^{208}Pb through the completion of the N=126 factory
- Extend the energy range of ATLAS for high-intensity stable beams, primarily for in-flight production of exotic beams with RAISOR and the N=126 factory
- Maintain an infrastructure capable of sustaining and improving the ATLAS experimental equipment and developing or adapting other detectors designed by the community for use at ATLAS.

ATLAS UPGRADE OVERVIEW

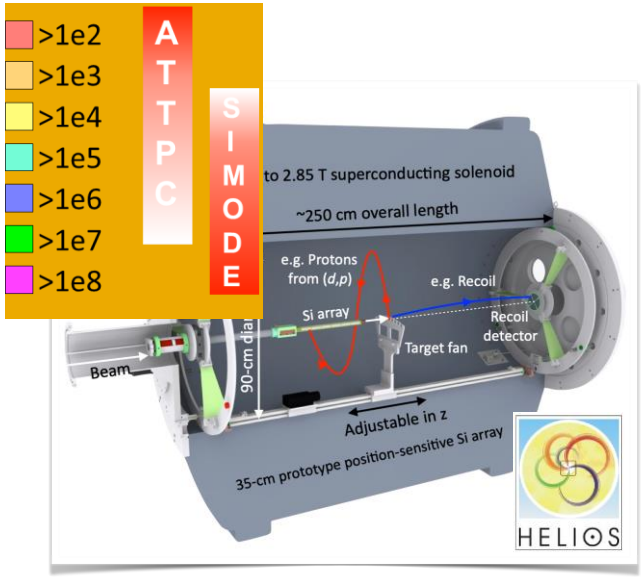
Recently completed / ongoing / planned

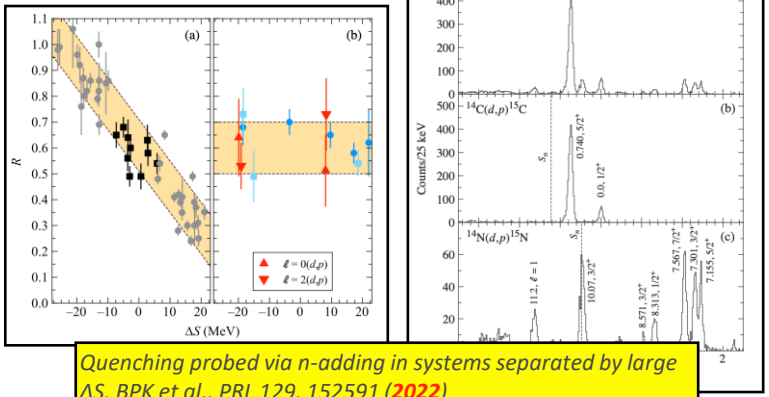


The HELIOS program

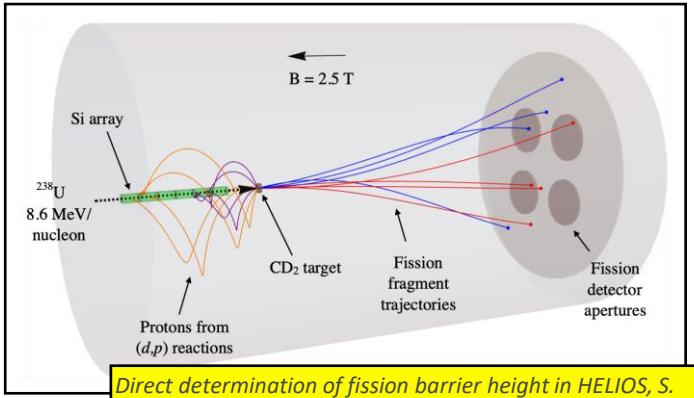
The first of kind, continuous evolution of capabilities

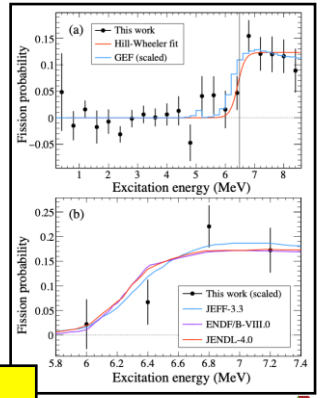
- *The "(d,p) machine" (mass 8-238), a broad class of reactions [(d,p), (d,t), (d,^{3}He), (d,α), (d,d'), (p,p'), (^{6}Li,d), (a,p), (t,p), etc.), isomeric beams (^{26}Al, ^{18}F, ^{16}N,...)*
- ***Expanding** suite of auxiliary detectors, Apollo, LSU fast-counting ionization chamber, gas-cell targets, AT-TPC, SOLSTISE, fission-fragment detectors, etc.*
- *Future: RAISOR beams (inc. isomer beams), nuCARIBU beams, large demand for stable beams, actinides, AT-TPC campaigns*





*Quenching probed via n-adding in systems separated by large ΔS, BPK et al., PRL 129, 152591 (**2022**)*





*Direct determination of fission barrier height in HELIOS, S. Bennett et al., submitted (**2022**)*

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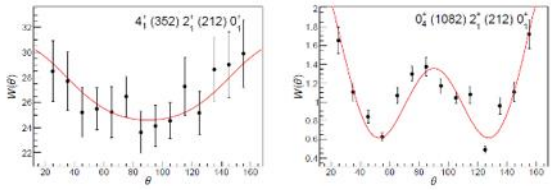
BETA DECAY FACTORY IN AREA 1

Gammasphere Decay Station

- β–γ coincidences for proper feeding intensities
- γ–γ, γ–γ–γ for level structure determination and spin assignments from angular correlations
- Reduced summing and crystal to crystal scattering (in contrast to X-Array)
- Calorimetry provides information on excitation energy on event-by-event basis (Ge + BGO)
- Gammasphere electr… provides 3 co… @ 4, 8 a…

γ ray an… …ations following ^{100}Y beta …ay with Gammasphere

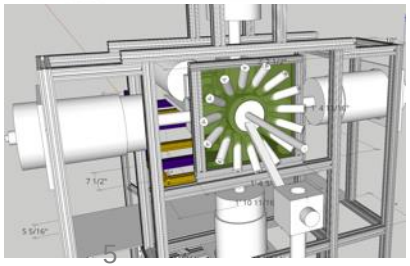


Saturn/X-Array Upgrades

- $LaBr_3$ to measure lifetimes – 2 rings, 15 1”x1” crystals each ring.
- Conversion electron measurements utilizing Laces (LSU)
- 1-2 BEGe detectors f… gamma-ray an…

Si(Li)… …n

1 LaBr3 Ring @ X-Array



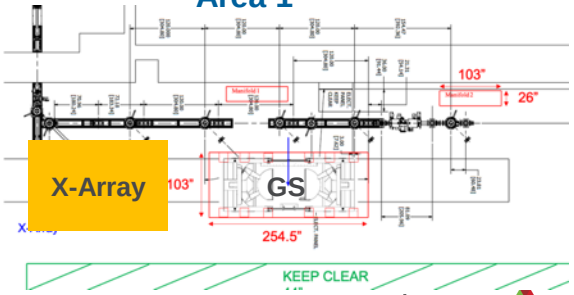
Beta Decay Factory

- Gammasphere upgrade project allows for relocation of… to Area 1.
- Using n… stimate 2 …ease in …

…here gives multi-fold …incidences, total gamma-ray energy, angular correlations, for spin, parity, mixing rations.

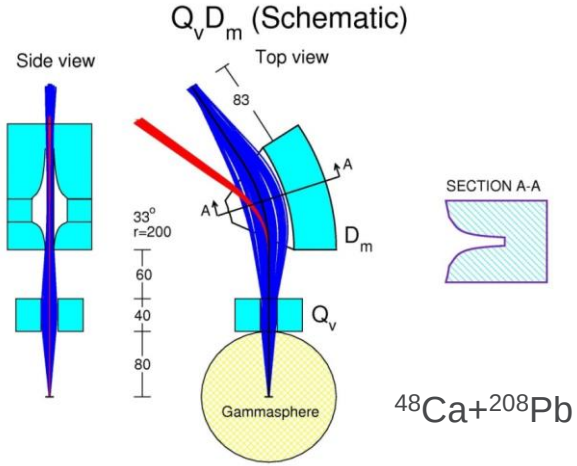
- X-Array – lifetimes ($LaBr_3$), low-energy gamma detections (BEGe), conversion electron measurement (LACES).
- Campaign of six months to measure 30-50 parent decays – FY23-24

Area 1



4 instrument stations now, including 1 fed by an RF buncher, will add 2 more stations, with 1 with all services needed for Gammasphere

AGFA PUSH FOR WEAKER CROSS-SECTION EVENTS



FEATURES:

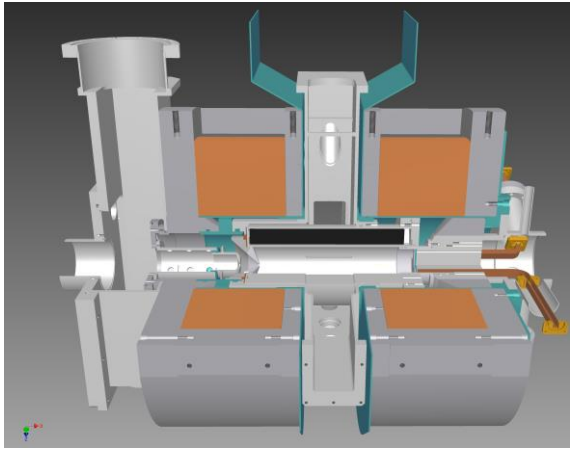
- Gas-filled – differential pumping - no entrance foil
- Compact design – two magnets, length 3.7- 4.3 m
- Quad: vertical focusing
- Dipole: 38º bend and horizontal focusing
- Gammasphere at target position – solid angle 22.5 msr
- Small focal plane – one DSSD implantation detector
- Bρ-max: 2.5 Tm

- Operating for over 5 years
- Very successful program but for the next step in very heavy systems need improvements:
  - Higher beam intensity
  - Electric beam scanner
  - Actinide targets
  - Full refurbishing of Gammasphere

HIGH INTENSITY ECR

ECR4 to ECR2+

- Higher currents needed to support N=126 and super heavy element programs
- We were collaborating with University of Jyvaskyla to adapt their 18 GHz ECR technology (HIISI), but details could not be worked out
- Now ATLAS Ion Source Group will look at upgrading the current ECR2
  - Increased hexapole fields
  - Higher frequency operation
  - Improved iron shaping
  - Upgraded material introduction mechanisms

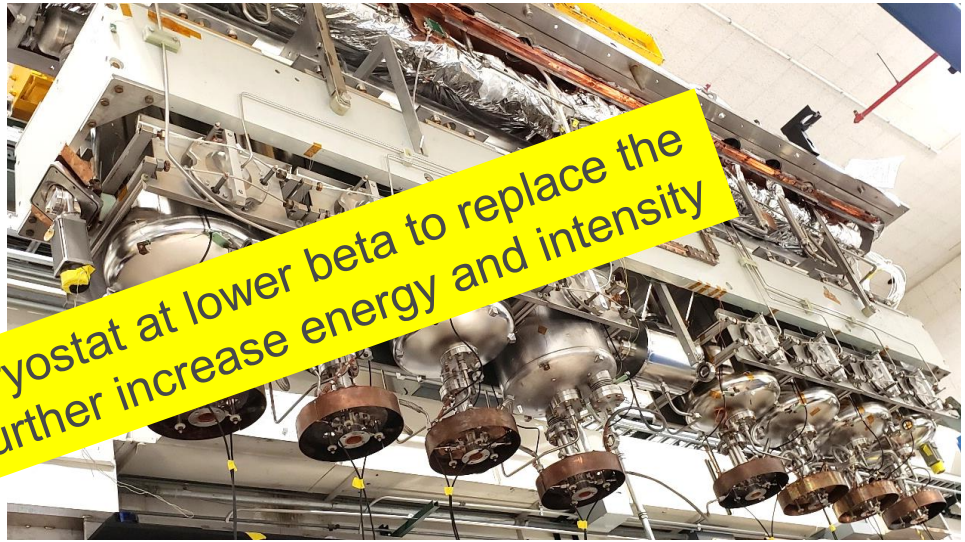


Species	14 GHz 0.94 T	14 GHz 1.11 T	18 GHz 1.11 T
$^{16}O^{6+}$	563 eμA	703	1163
$^{16}O^{7+}$	265	331	548
$^{40}Ca^{11+}$	70	87	145
$^{40}Ca^{12+}$	40	50	83
$^{50}Ti^{11+}$	9	11	19
$^{50}Ti^{12+}$	18	22	37
$^{136}Xe^{25+}$	35	44	72
$^{136}Xe^{26+}$	30	37	62
	Current ECR2		

ATLAS 109 MHZ AIP

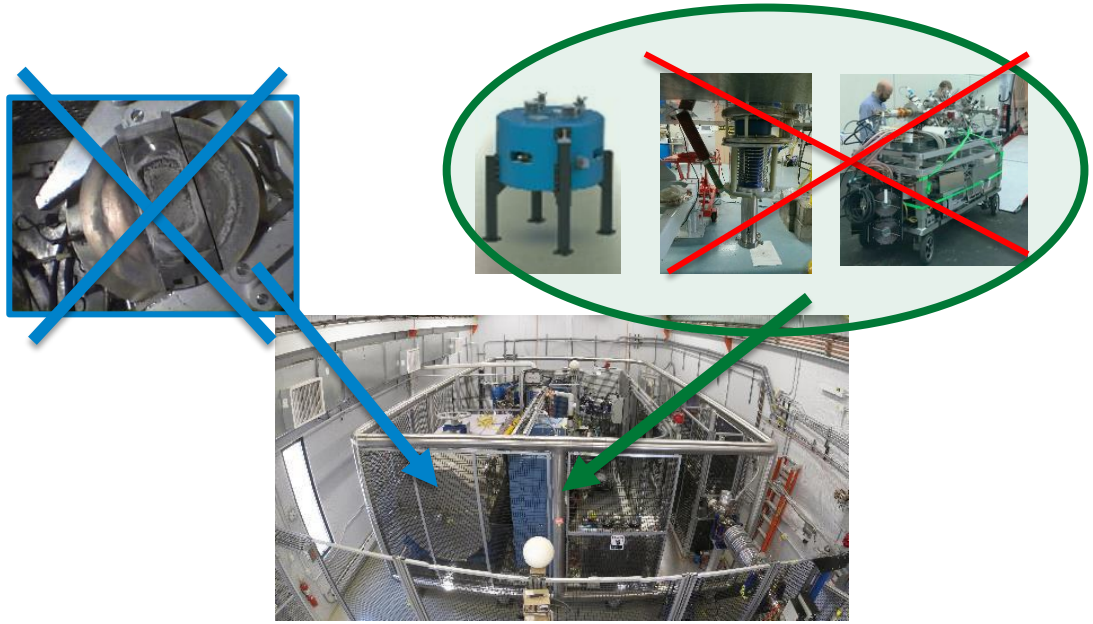
Upgrades to position ATLAS for delivery of beams for N=126 factory

- Energy gain and good transmission → high intensity beams for N=126
  - Pre-refurbishment 10 MV → post-refurbishment 20 MV
- **Complete:** Baking, cleaning, and chemistry performed on all 8 cavities
- **Complete** hardware:
  - New 109 MHz cavity
  - Large bore SC sole
  - Digital low l
  - Eight new) RF couplers (remove VCX tuners)
  - Smaller u (dual RF pickups)
  - Lessons le rned from 10 years of Ops
- Cryomodule installed in tunnel and cooled to operating temperature
  - Full power testing of cavities ongoing … right now



NEUTRON GENERATOR UPGRADE TO CARIBU

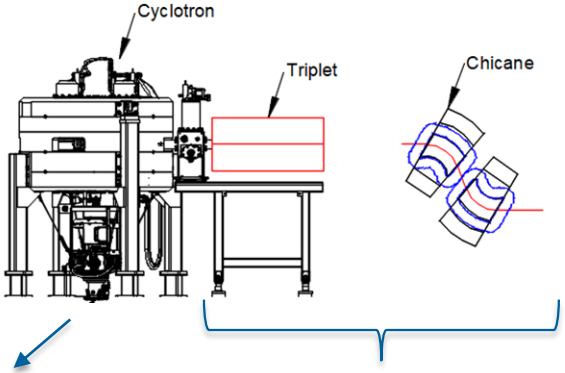
- Replace ^{252}Cf source by neutron-induced fission on actinide foils
  - More reliable source of fission products
  - Operationally easier to maintain and operate
  - Gain an order of magnitude in overall fission rate … i.e. ~ 10^9 fission/sec vs current few 10^7 fission/sec
  - Higher fission yield feeding in the ^{132}Sn region or above ^{78}Ni region



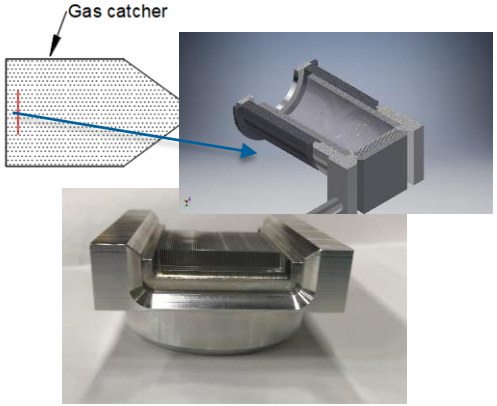
NUCARIBU PROGRESS

Neutron generator

- *Cyclotron passed factory acceptance test*
- *Has been delivered to Argonne on Jan 31 2022*



- *Beam transport system design completed*
- *Solicitation period for triplet and magnetic chicane closed on Feb 14 2022*
- *Scheduled Nov 2022 delivery*

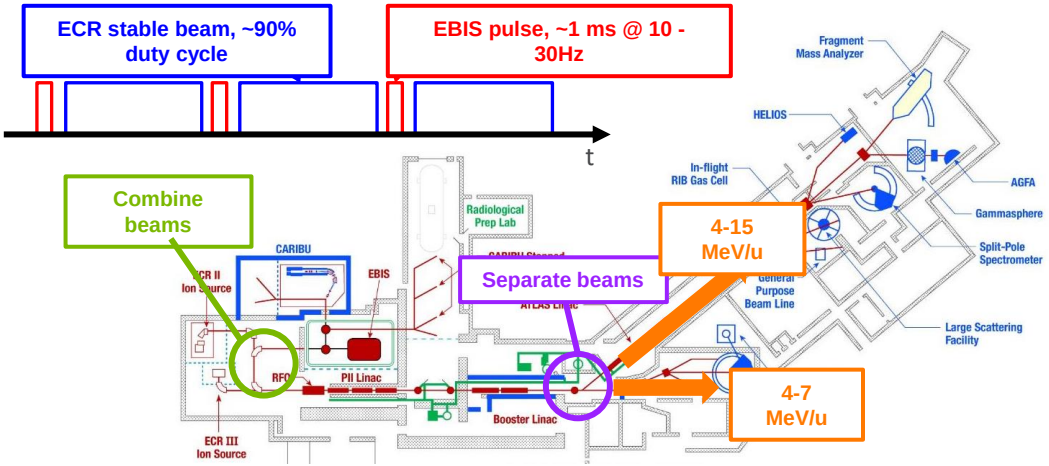


- *Concept developed for high power heat removal*
- *Prototype built and being tested*

NEXT BIG STEP AT ATLAS: MULTI-USER UPGRADE

AMUU goal: overcome the ~7000 hrs/yr limit by providing reliable simultaneous multi-user capability

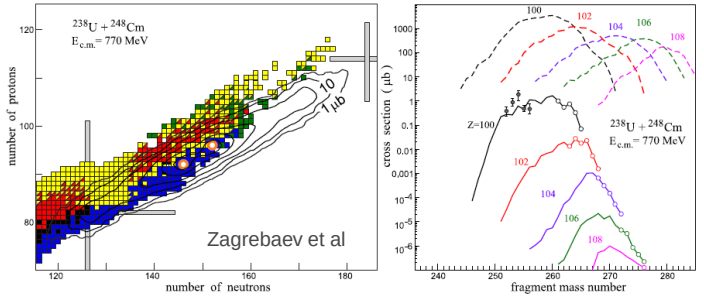
- EBIS beams represents 1-3% duty factor
- Combine pulsed EBIS beam with stable ECR beam
  - Address high demand on facility
  - Enable long duration experiments
  - Maximize efficient accelerator usage



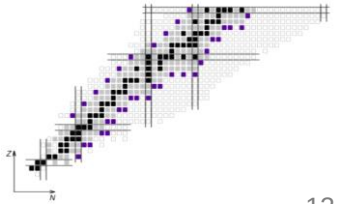
NEED FOR AMUU: NEW OR CONTINUING STABLE BEAM PROGRAMS WITH VERY HIGH BEAMTIME REQUIREMENTS

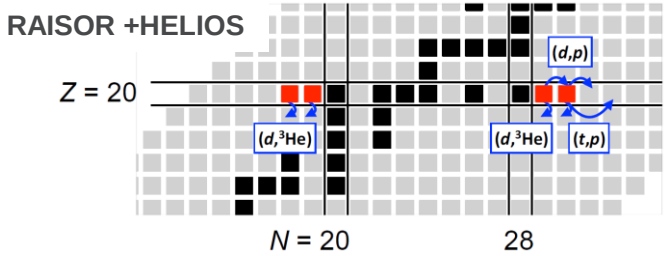
- **Spectroscopy of the heaviest isotopes**
  - Recoil and gamma efficiencies are now optimized, beam intensity limited by rate in germanium detectors … the main knob left is running longer

- **Production of new neutron-rich isotopes of the heaviest elements**
  - Small cross-sections and large running time



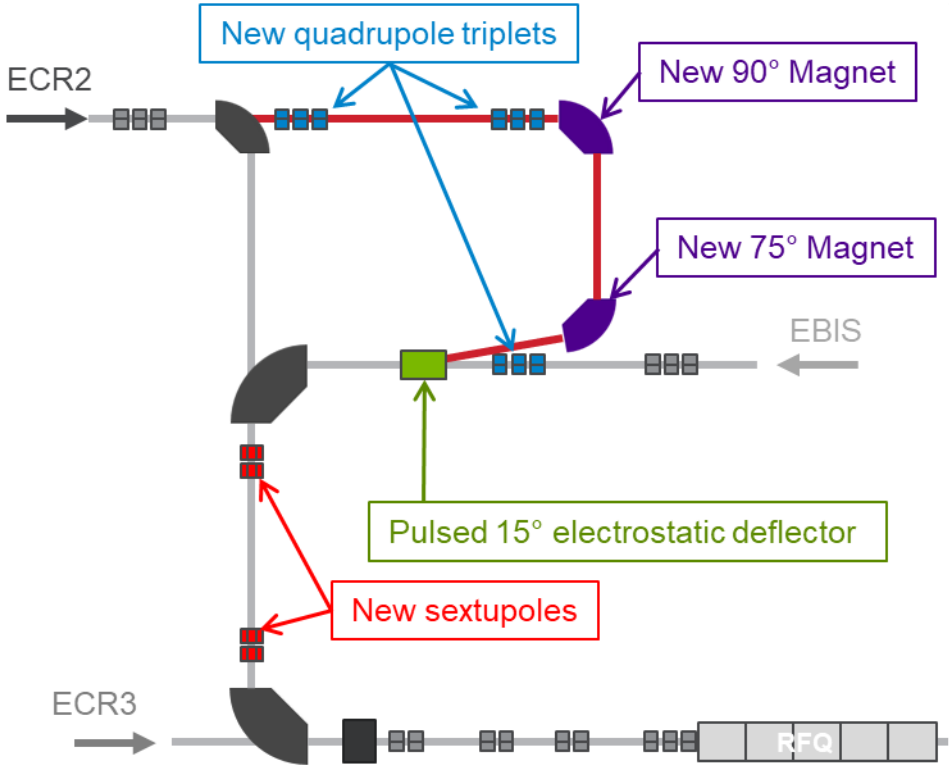
- **Detailed single-particle spectroscopy in the medium mass region**
  - Limited intensities





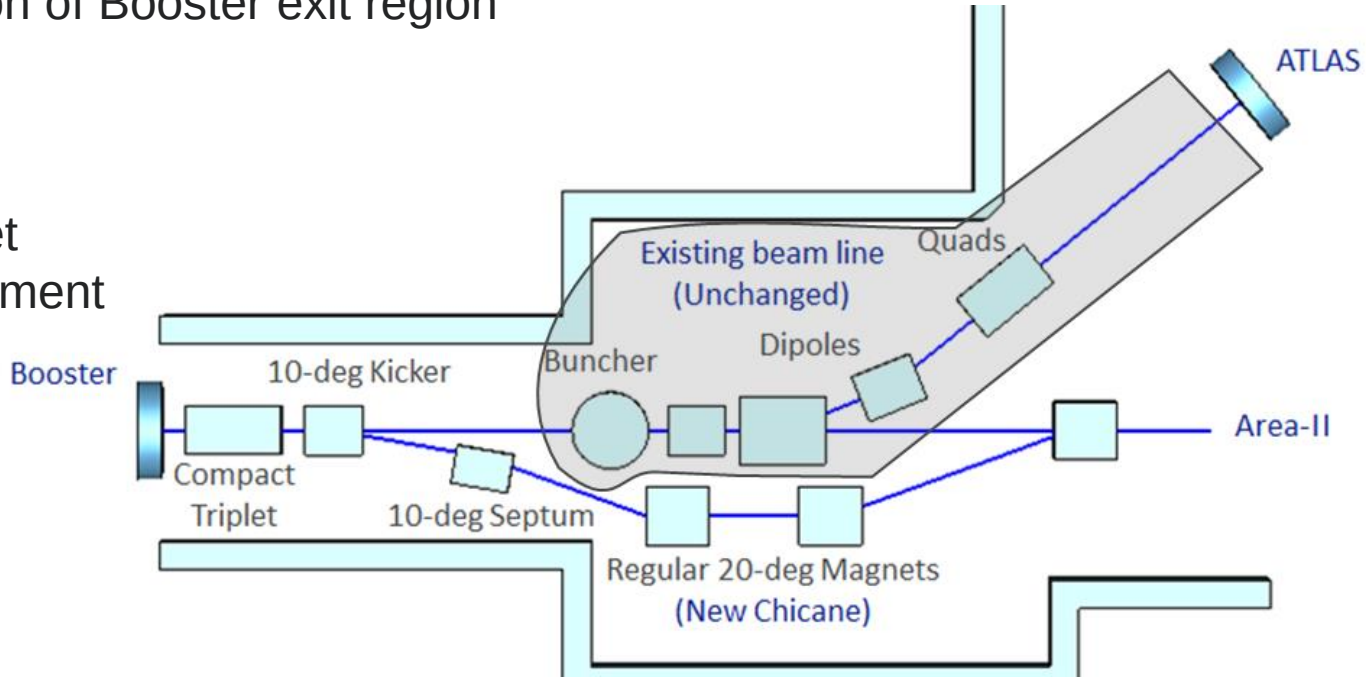
PROJECT SCOPE

- Mixing modification of PII LEBT
  - Dipole magnets
  - Pulsed Electrostatic deflector
  - Sextapoles
  - Triplets
  - Vacuum equipment
  - Chambers
  - Diagnostics
  - Controls
  - Utilities

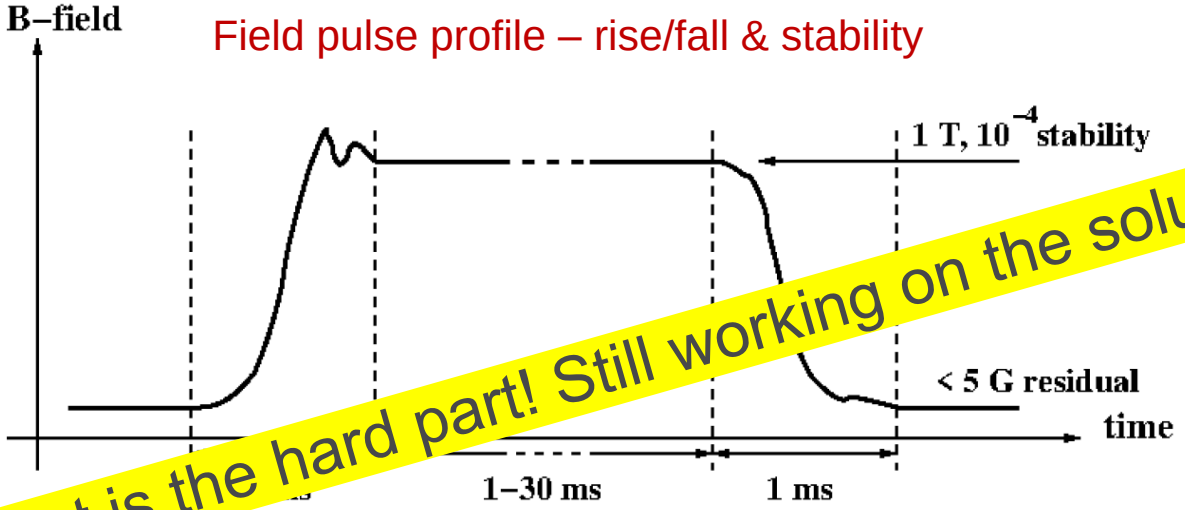


PROJECT SCOPE

- Separation
  - Reconfiguration of Booster exit region
  - Kicker
  - Septum
  - Chicane
  - Compact triplet
  - Vacuum equipment
  - Chambers
  - Controls
  - Utilities



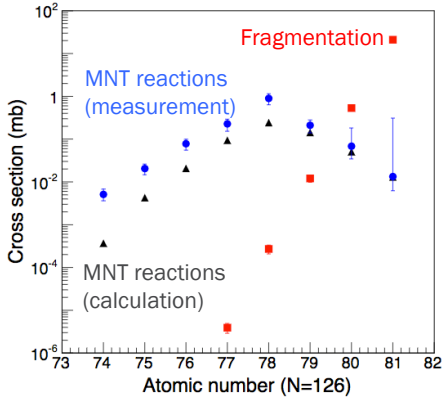
KICKER FIELD STABILITY & REPRODUCIBILITY



That is the hard part! Still working on the solution.

- Field stability and repeatability are important in the flat-top and between pulses
- The 10^{-4} stability level comes from ~ 1 mm beam jitter on target in Area II
- The < 5 G residual field is required to have minimal effect on un-deflected beam

KEY COMPONENT: N=126 FACTORY … MULTI-NUCLEON TRANSFER VERSUS FRAGMENTATION FOR NEUTRON-RICH HEAVY ISOTOPES

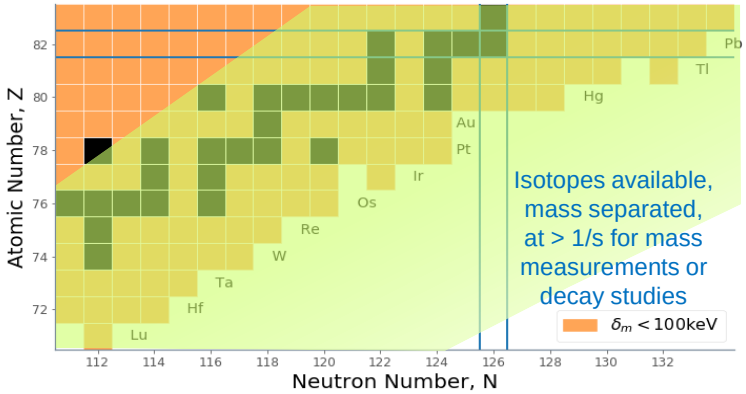


Hirayama *et al*., EPJ Web Conferences **109,** 08001 (2016)

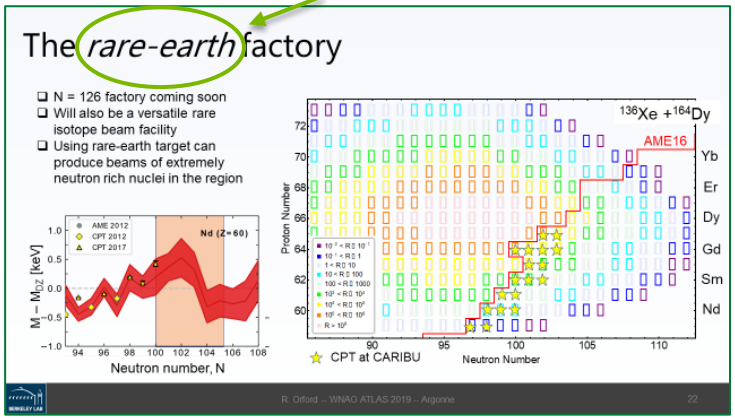
^{208}Pb + ^{9}Be at 1 GeV/u (best fragmentation reaction cross-sections for N = 126)

versus

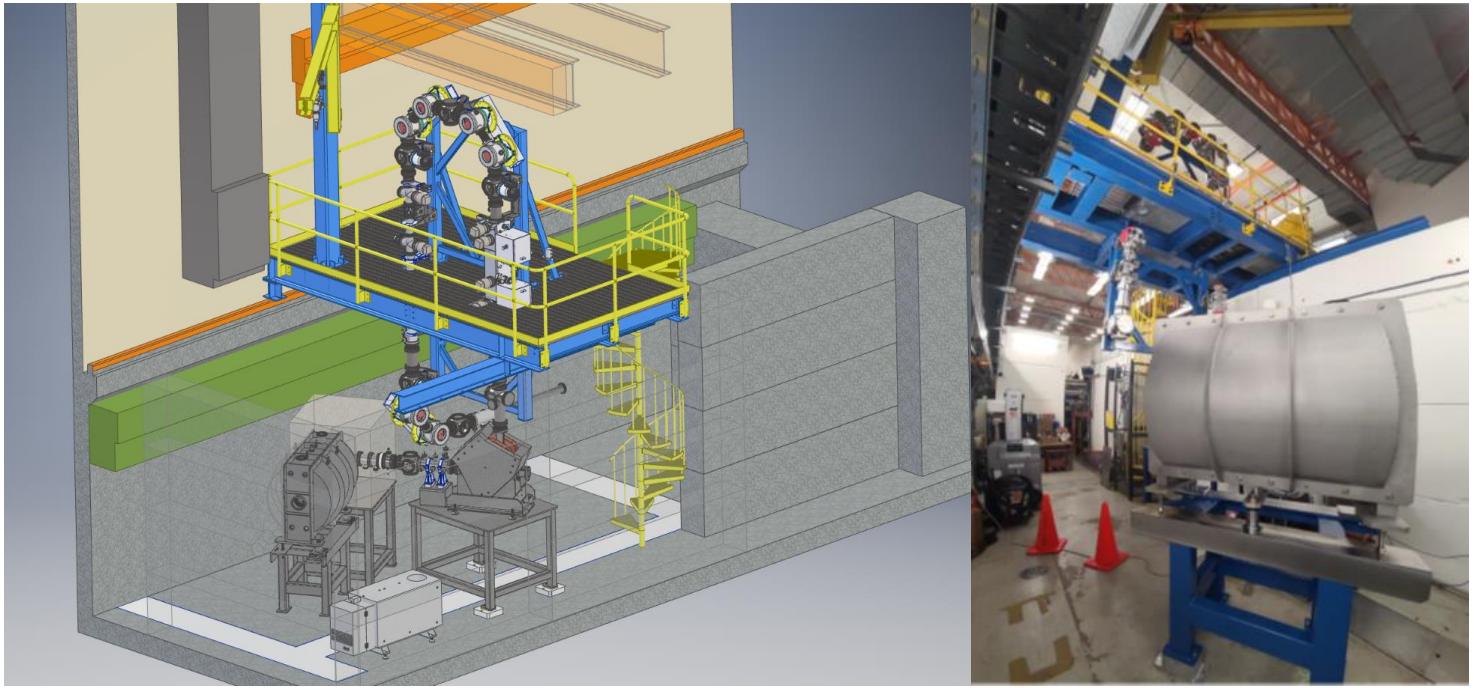
^{136}Xe + ^{198}Pt at 10 MeV/u (best multi-nucleon transfer (MNT) reaction)



N=126 and much more … slide from our users

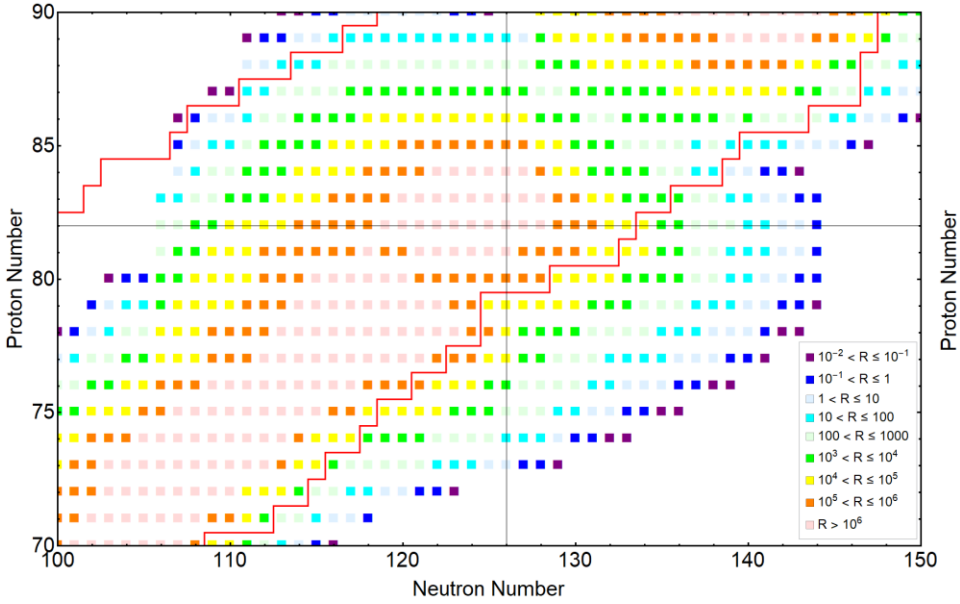


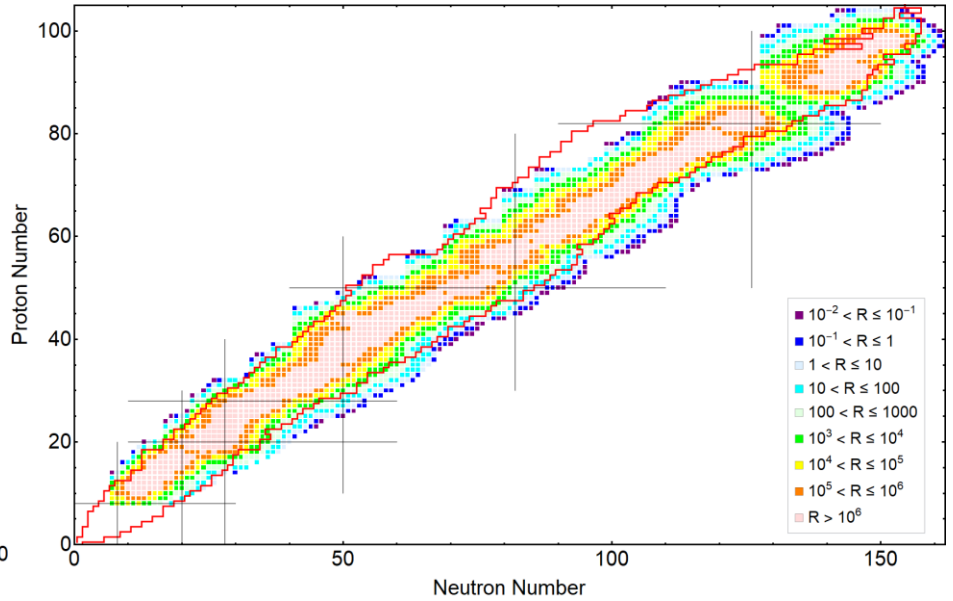
The N=126 factory



- Compact design: using all three dimensions to make it fit into the room
- 1 or 2 experiments can fit in the room … CPT will take beam first
- Background will be high … not a problem for CPT but will be for decay spectroscopy … a connected low-background area would help for many applications

REACH OF THE N=126 FACTORY … FOR N-RICH NUCLEI





Courtesy of Biying Liu

- Red line is limit of known masses
- Reaction ^{136}Xe + target … with 10 mg/cm^2 target and > 1% abundance isotopes
- For very heavy, limit target thickness to 50 mCi activity

STATUS

- ATLAS is constantly evolving to better fulfill the needs of its users.

- Needs are:
  - More intense stable, CARIBU and RAISOR beams
  - More beamtime
  - Higher sensitivity and rate capability for the instruments
  - Access to new regions

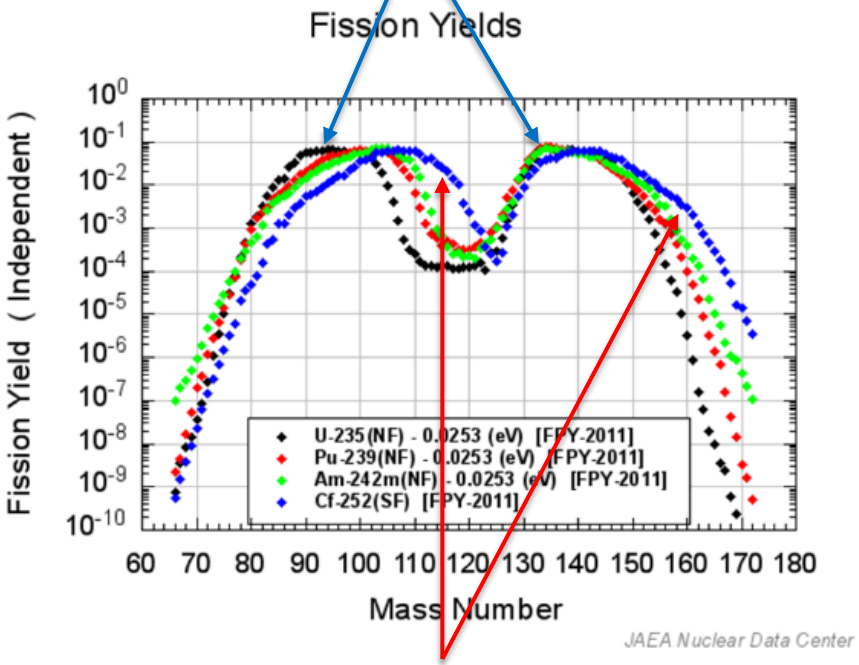
- Currently being addressed by:
  - New ECR source, 109 MHz cryostat upgrade, nuCARIBU, and better targets
  - ATLAS Multi-User Upgrade
  - Gammasphere upgrade, AT-TPC at HELIOS, MUSIC2, PI-ICR at CPT, …
  - N=126 facility

- Need sustained R&D to keep ATLAS, and facilities in our field in general, at the forefront

SUPPLEMENTARY MATERIAL

CHANGES IN FISSION DISTRIBUTION

Significant gain



Significant loss