Argonne NATIONAL LABORATORY

"pls see me"

(and some adventures with single-nucleon transfer)

Ben Kay, Argonne National Laboratory

(Slides prepared using Comic Sans ... John's preferred font for his slides)

Thank you

The organizing committee who gently pressured me into speaking at this event and for their support and wisdom in putting the event together.

(In no particular order) A very special thank you to Peter Littlewood and the University of Chicago for their support of this event, to Kawtar Hafidi and the Physical Sciences and Engineering Directorate, and to Paul Kearns and the Office of the Director.

Finally, Robin Harris, Barb Weller, Paula Dahlberg, Colleen Tobolic, who have helped me a lot with logistics and likely have no desire to see or hear from me again for quite some time.

"pls see me"

I first met John at the tandem lab in Yale in November of 2005. I was terrified at the time of our first encounter. We worked closely together ever since.

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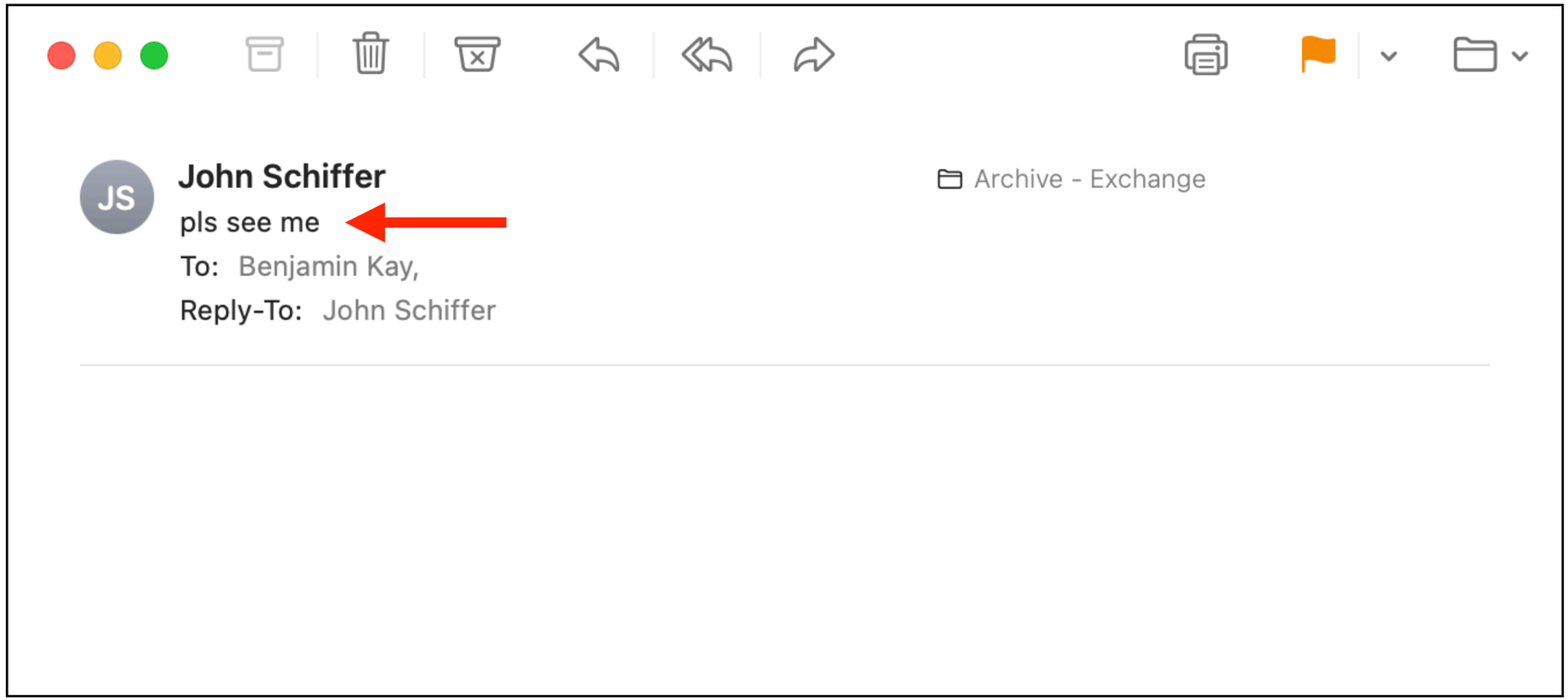

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John Schiffer Archiv...
pls see me

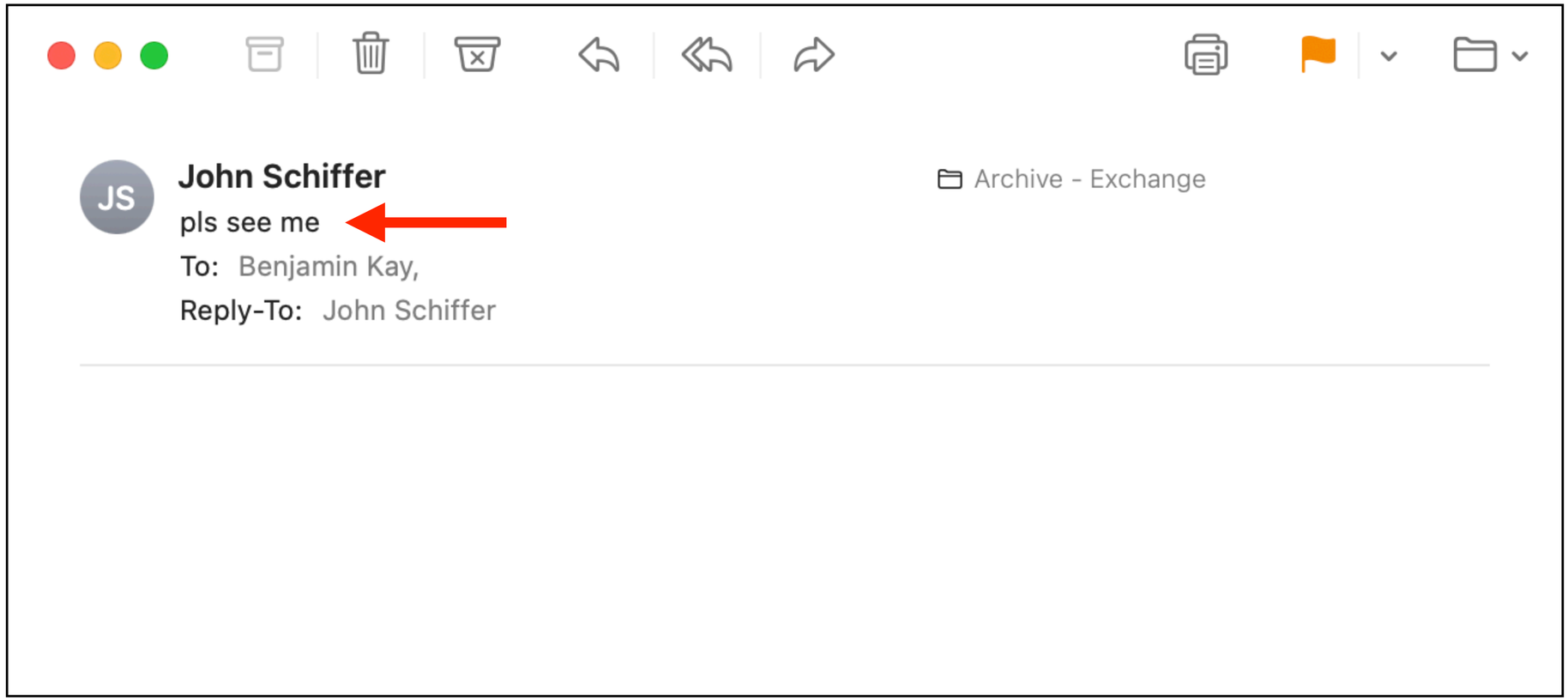
John Schiffer Archive...
pls see me

John Schiffer Archive...
pls see me

John Schiffer Archi...
pls see me when you are in

John Schiffer Archive...
pls see me when you get in

John Schiffer Archive...
pls see me



John Schiffer Archiv...
pls see me

John Schiffer Archive...
pls call/see me

John Schiffer Archiv...
pls see me

John Schiffer Archive...
pls see me

John Schiffer Archiv...
pls see me

John Schiffer Archiv...
pls see me

"pls see me"

"The interesting thing about Ben is that he worked with John as a postdoc ... and in spite of this, he still accepted a position here ..."

-- (Paraphrasing) Kim Lister introducing me at a PHY Seminar I gave in 2013, shortly after rejoining the Division as a member of staff

Outline

"The fascinations of physics"

I want to use two examples that show John's approach to science*

- The impact of "weak binding" (s-states, bubbles, ISOLDE, FRIB, ...)
- Deep thinking ... (quenching) and the tin paper, single-particle energies
- John in his own words

*From ~2000 to 2022 ... the impact of his work, and its relevance at the forefront of research today, is quite remarkable ... as I hope to show.

A process

- Idea/result/plot (postdoc)
- Not always a positive response, but … (John)
- Deep thinking and suggestions (a lot of work for postdoc, rich experience)
- Enthusiasm (both)
- Deeper thinking, systematics, insight, impact

PHYSICAL REVIEW C **88**, 044317 (2013)

Single-neutron excitations in ^{18}N

C. R. Hoffman,[1,*] M. Albers,[1] M. Alcorta,[1] S. Almaraz-Calderon,[1] B. B. Back,[1] S. I. Baker,[1] S. Bedoor,[2] P. F. Bertone,[1,†] B. P. Kay,[1,3] J. C. Lighthall,[1,2,‡] T. Palchan,[1] R. C. Pardo,[1] G. Perdikakis,[4,5] K. E. Rehm,[1] A. M. Rogers,[1,§] D. Santiago-Gonzalez,[6] Cenxi Yuan,[7] and J. P. Schiffer[1]

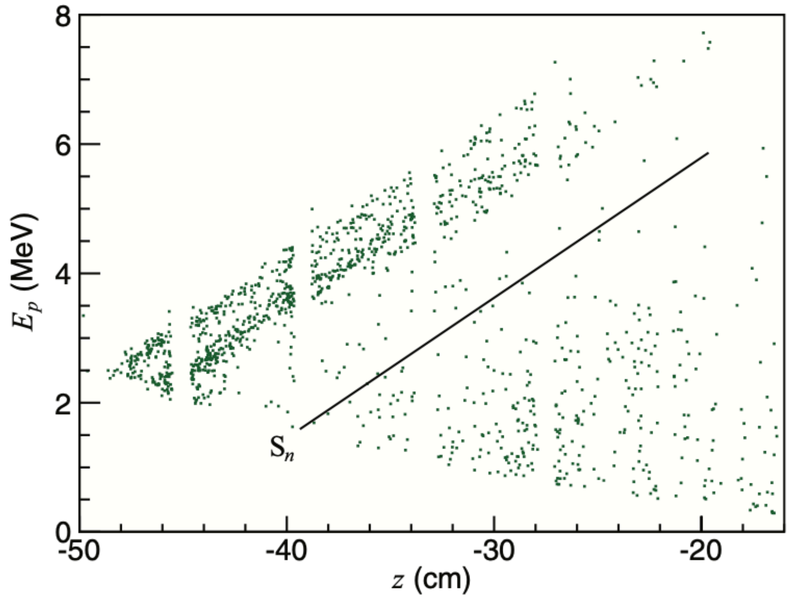


FIG. 1. (Color online) Proton energies (E_p) as a function of the longitudinal distance from the target (z) for the ^{17}N$(d,p)^{18}$N reaction in inverse kinematics. The events shown required a coincidence in the recoil detector telescope with either ^{18}N ions for bound states, or ^{17}N for unbound ones.

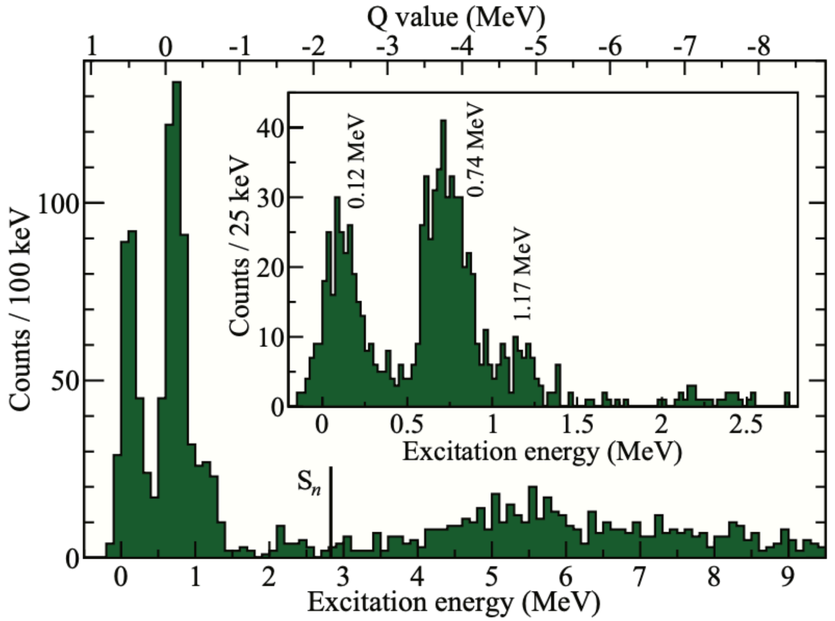
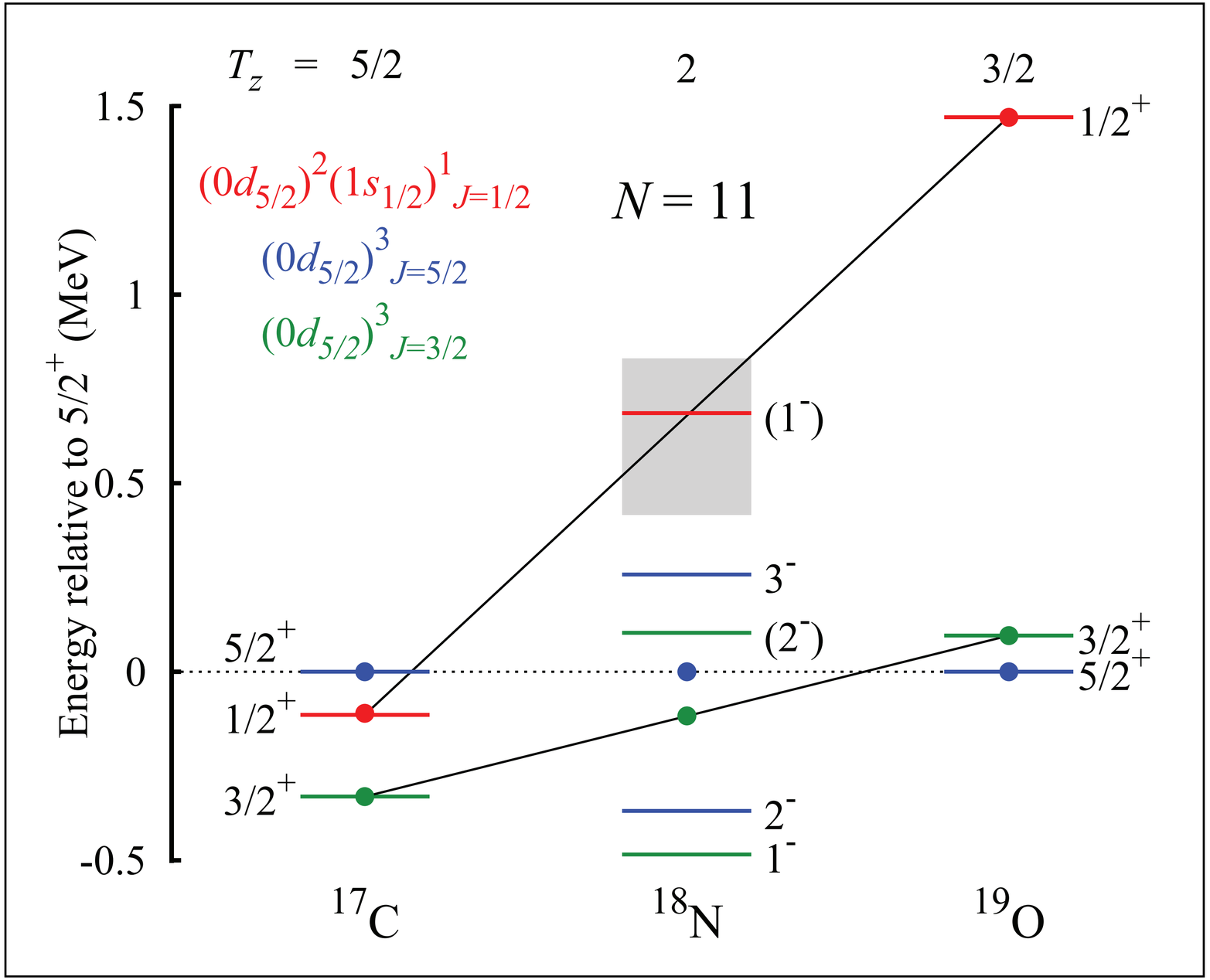


FIG. 2. (Color online) The measured excitation-energy (Q-value) spectrum for the ^{17}N(d,p) reaction with the same data set as is in Fig. 1. An expanded region of the excitation energy below the neutron separation energy (S_n) is shown in the inset.

Some of Calem's early work with HELIOS



Something interesting to show John

ORDER OF LEVELS IN THE SHELL MODEL AND SPIN OF Be^{11}*

I. Talmi and I. Unna
Department of Physics, The Weizmann Institute of Science, Rehovoth, Israel
(Received April 4, 1960)

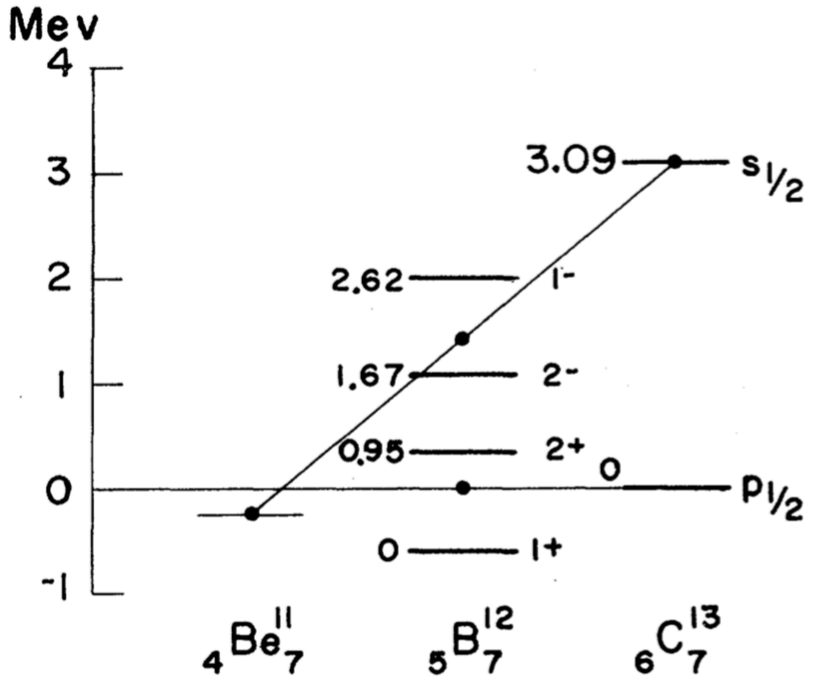


FIG. 1. Competition between $s_{1/2}$ and $p_{1/2}$ levels.

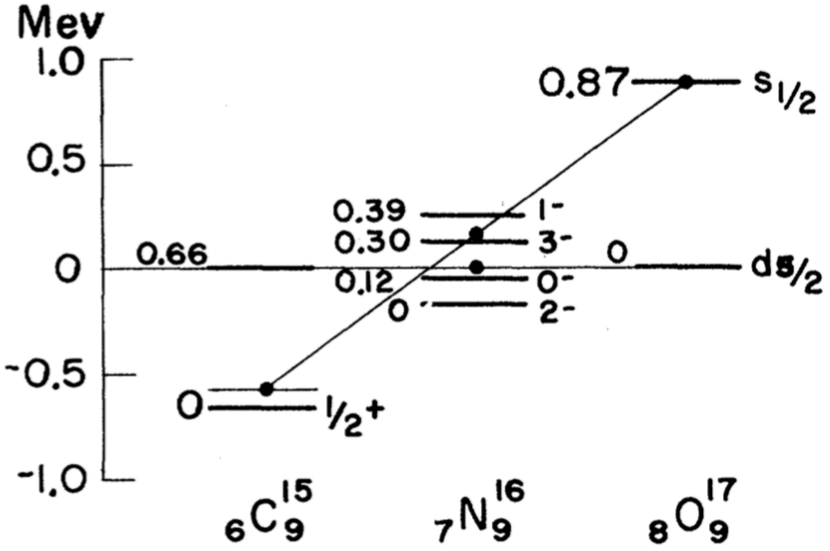
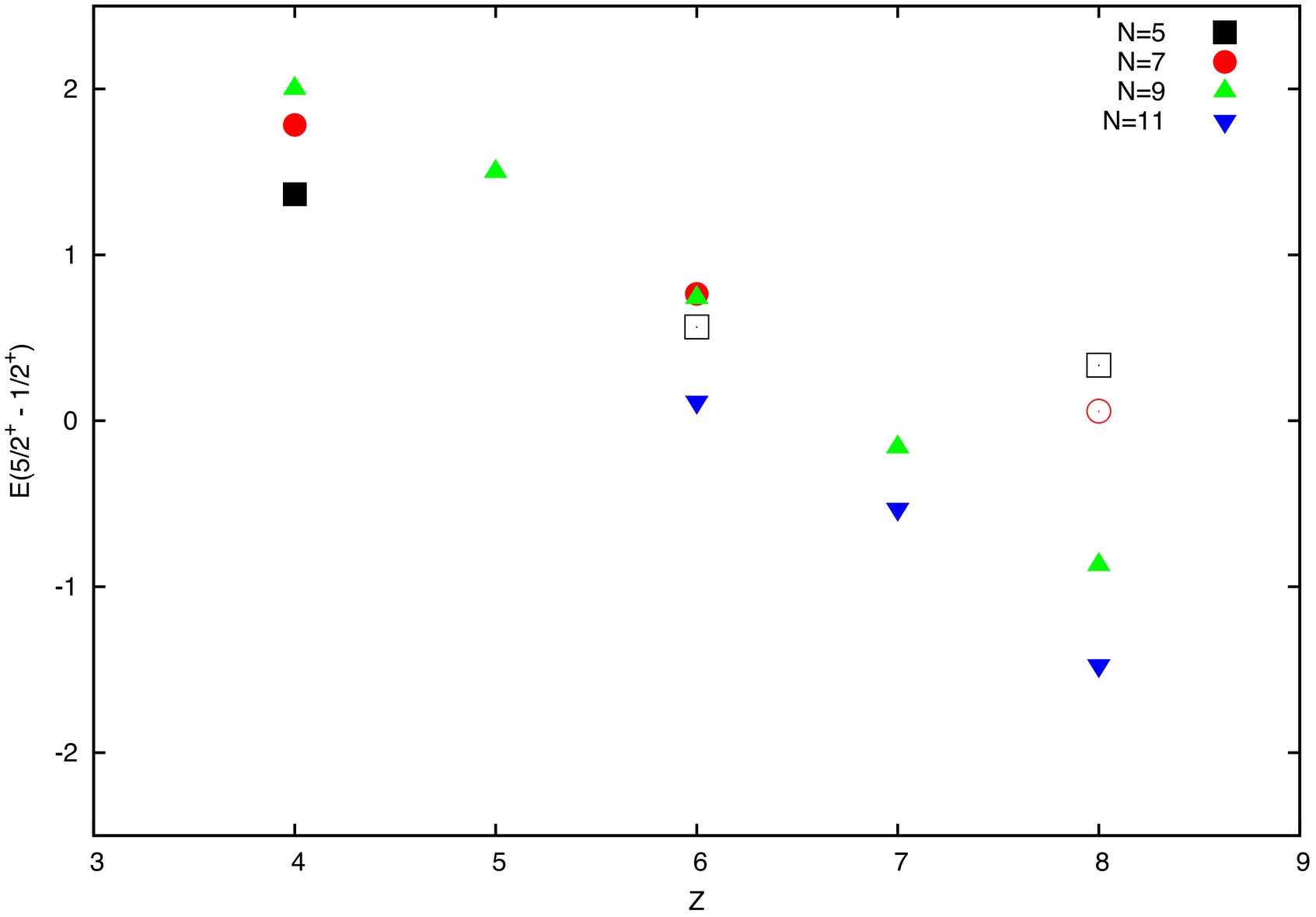
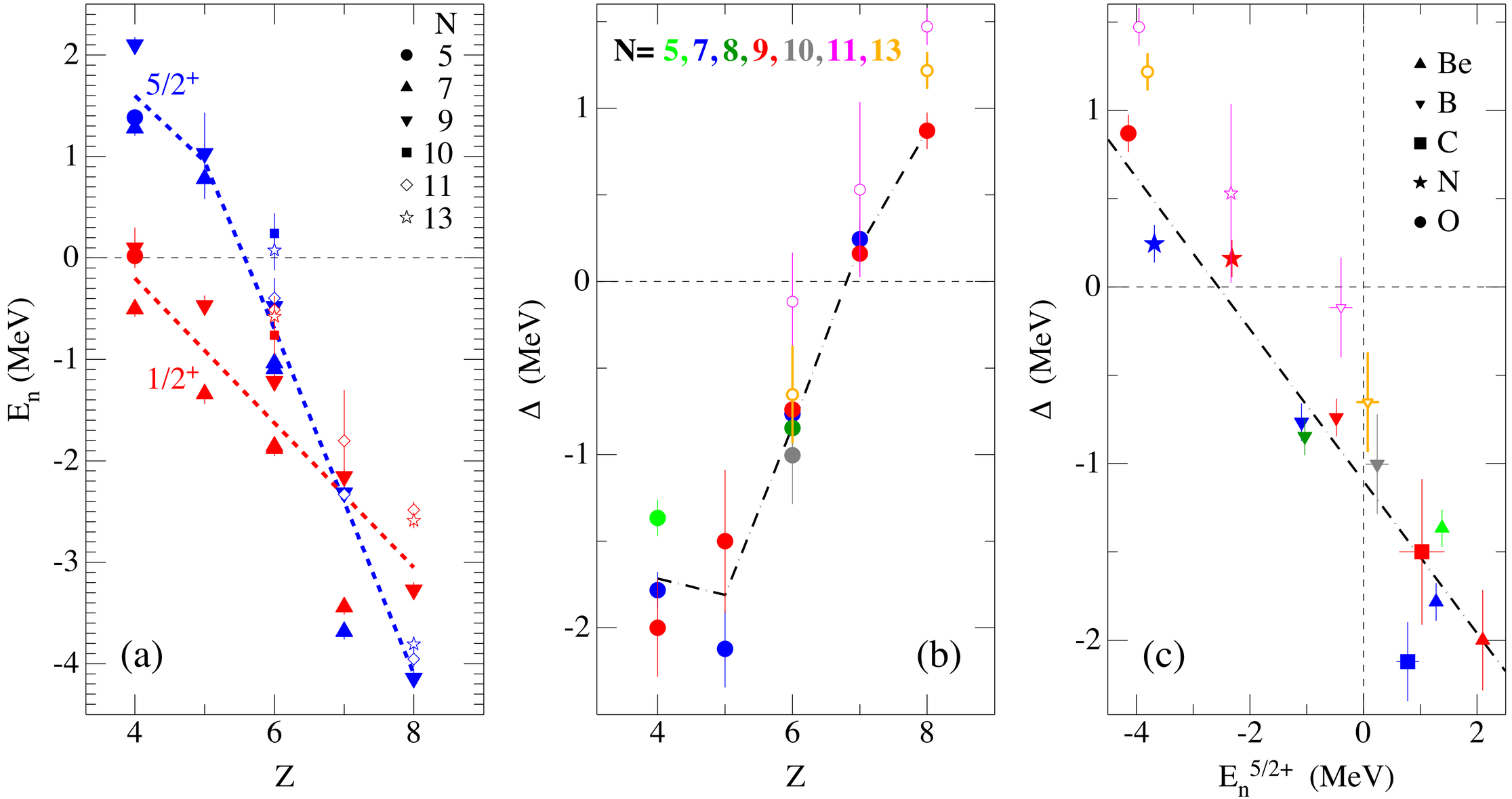


FIG. 2. Competition between $d_{5/2}$ and $s_{1/2}$ levels.

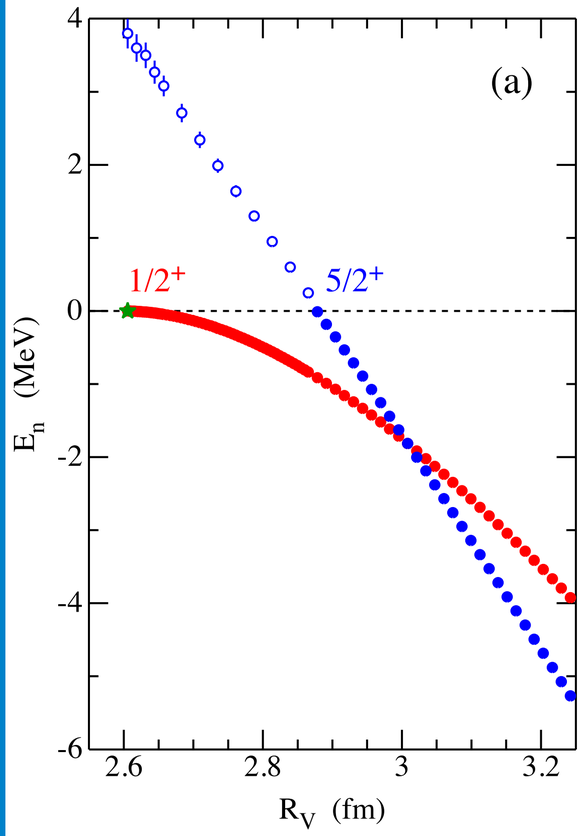
"That's just Talmi and Unna, but for N = 11" ...

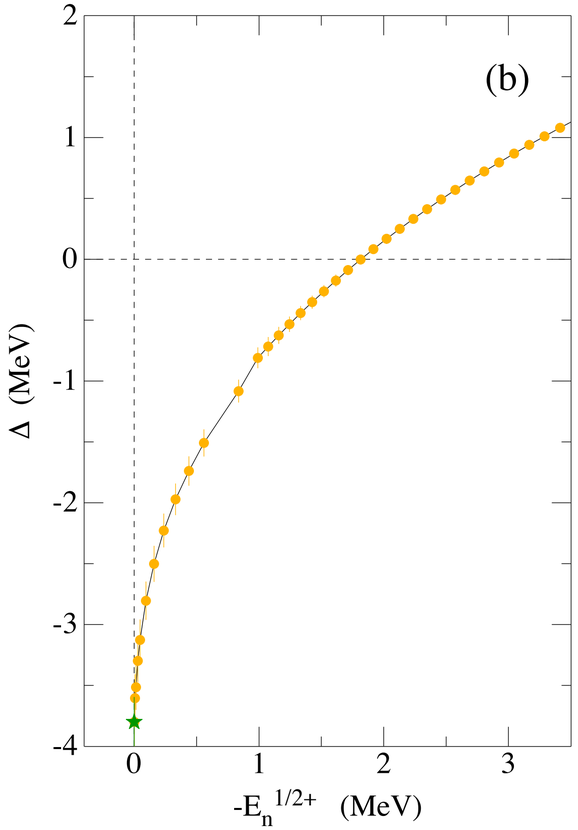


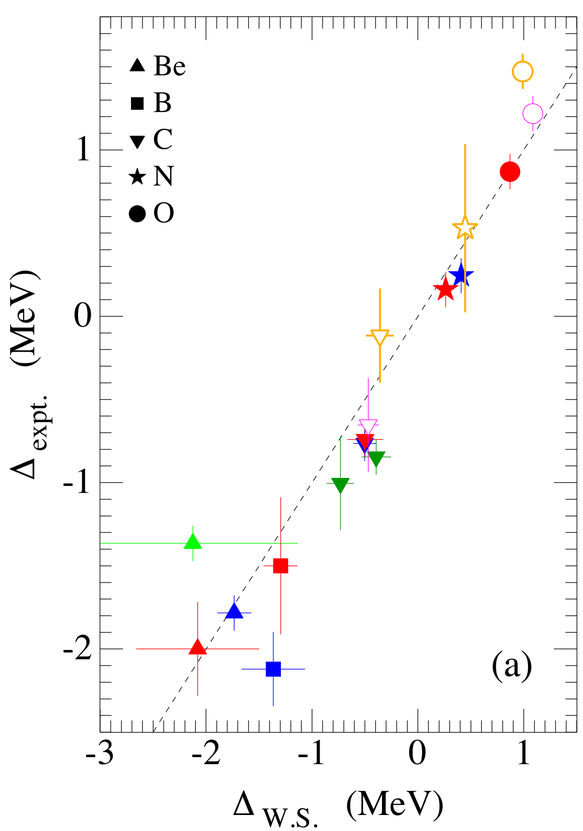
(After some time ...) but ... let's look a little closer though, systematics!

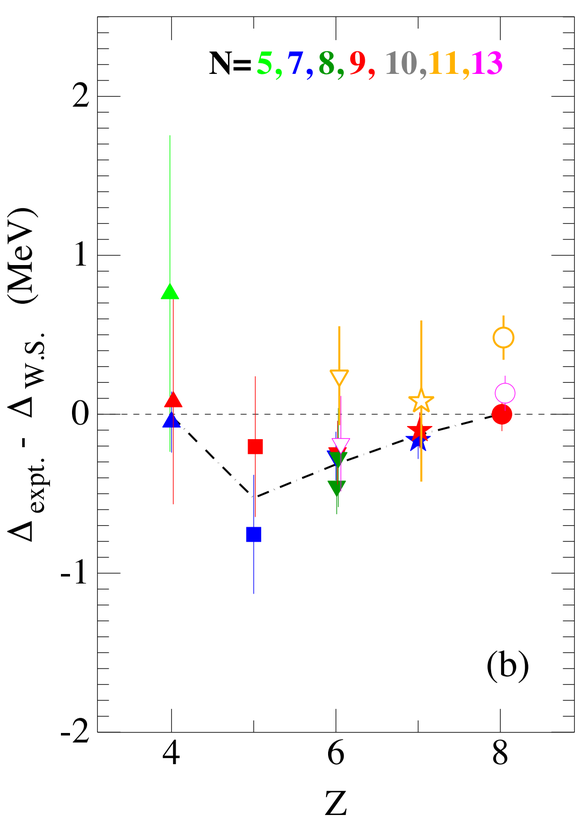


The full Schiffer treatment







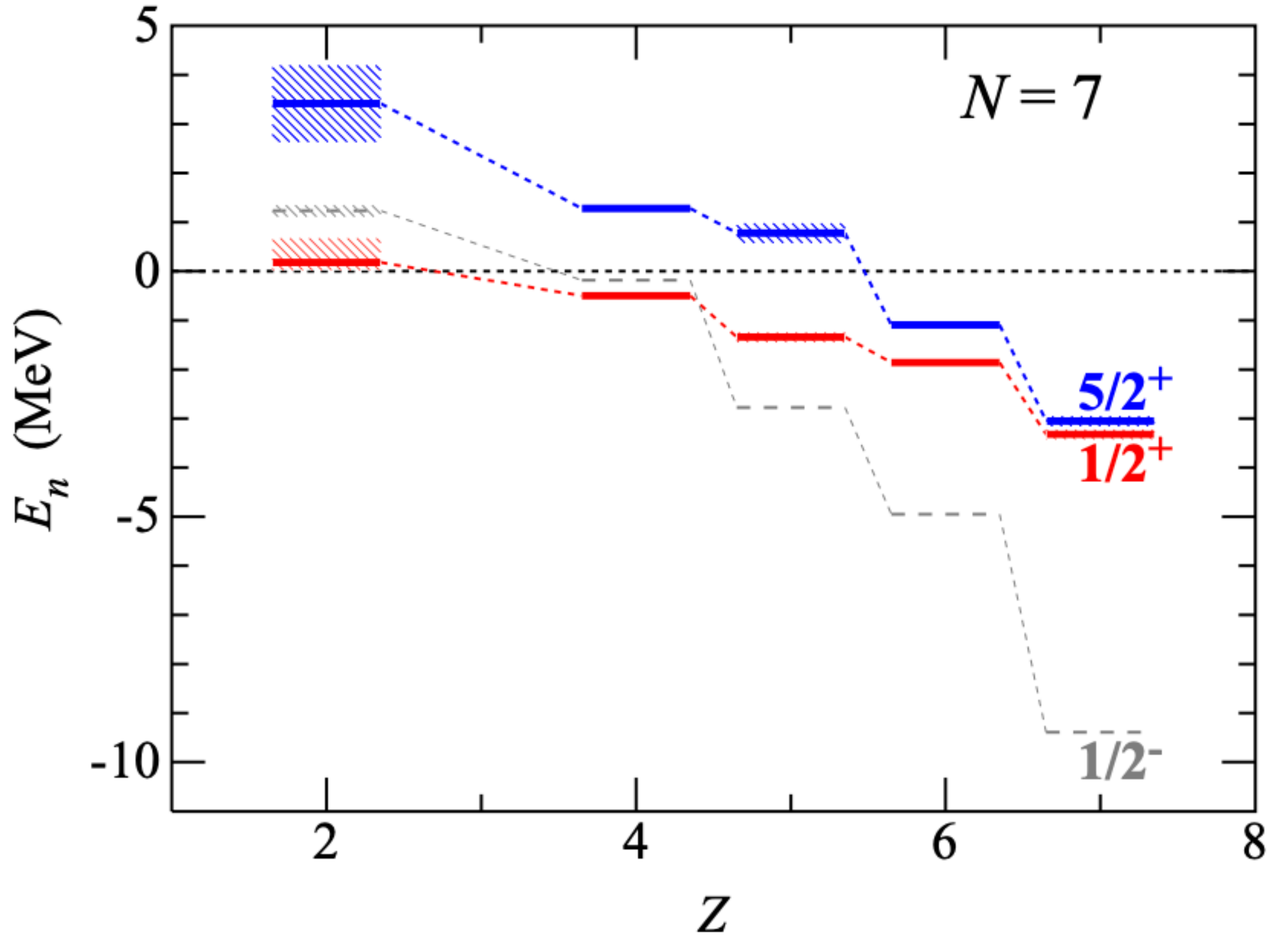


(Obviously) A consequence of a finite potential, weak binding

PHYSICAL REVIEW C **89**, 061305(R) (2014)

Neutron *s* states in loosely bound nuclei

C. R. Hoffman, B. P. Kay, and J. P. Schiffer
Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA
(Received 6 November 2013; revised manuscript received 13 May 2014; published 13 June 2014)



- An idea/result/plot
- Not always a positive response, but …
- Deep thinking and suggestions,
- Enthusiasm,
- Deeper thinking and systematics, insight, influence

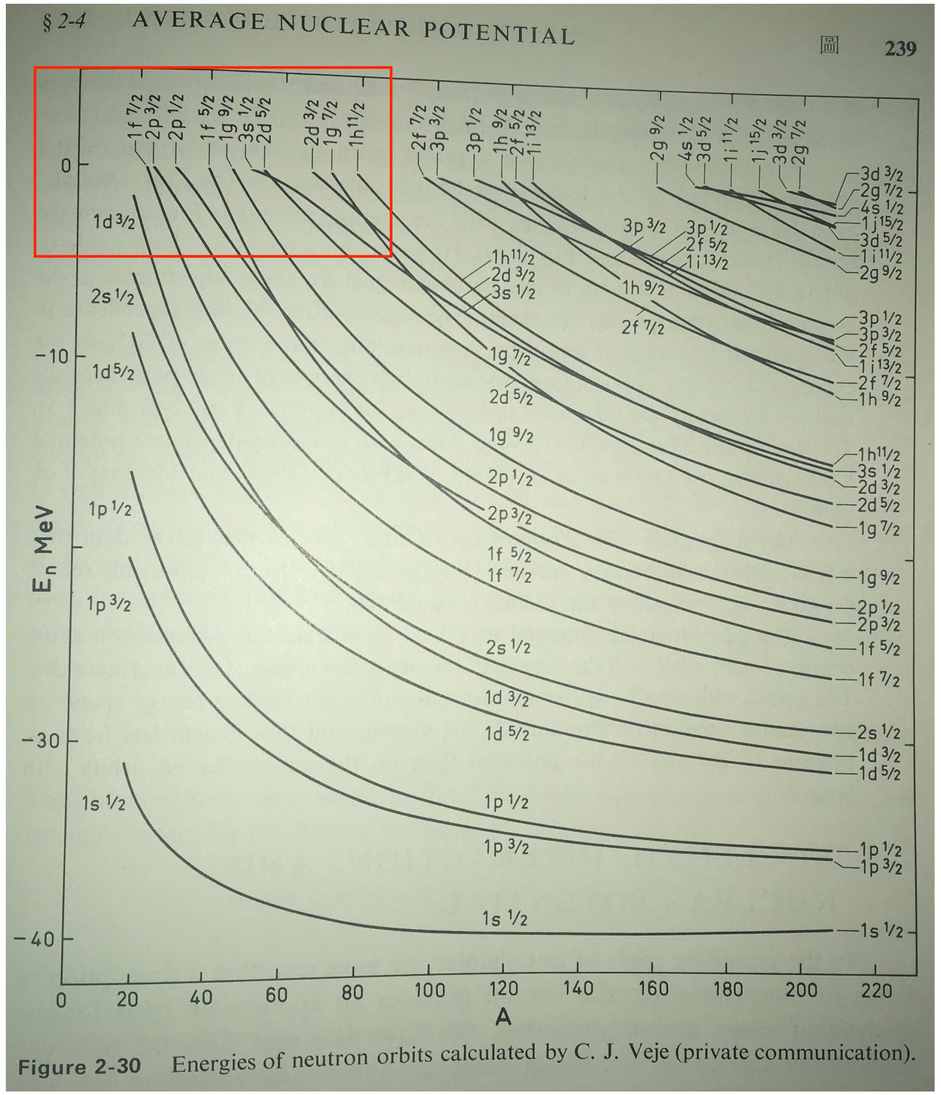
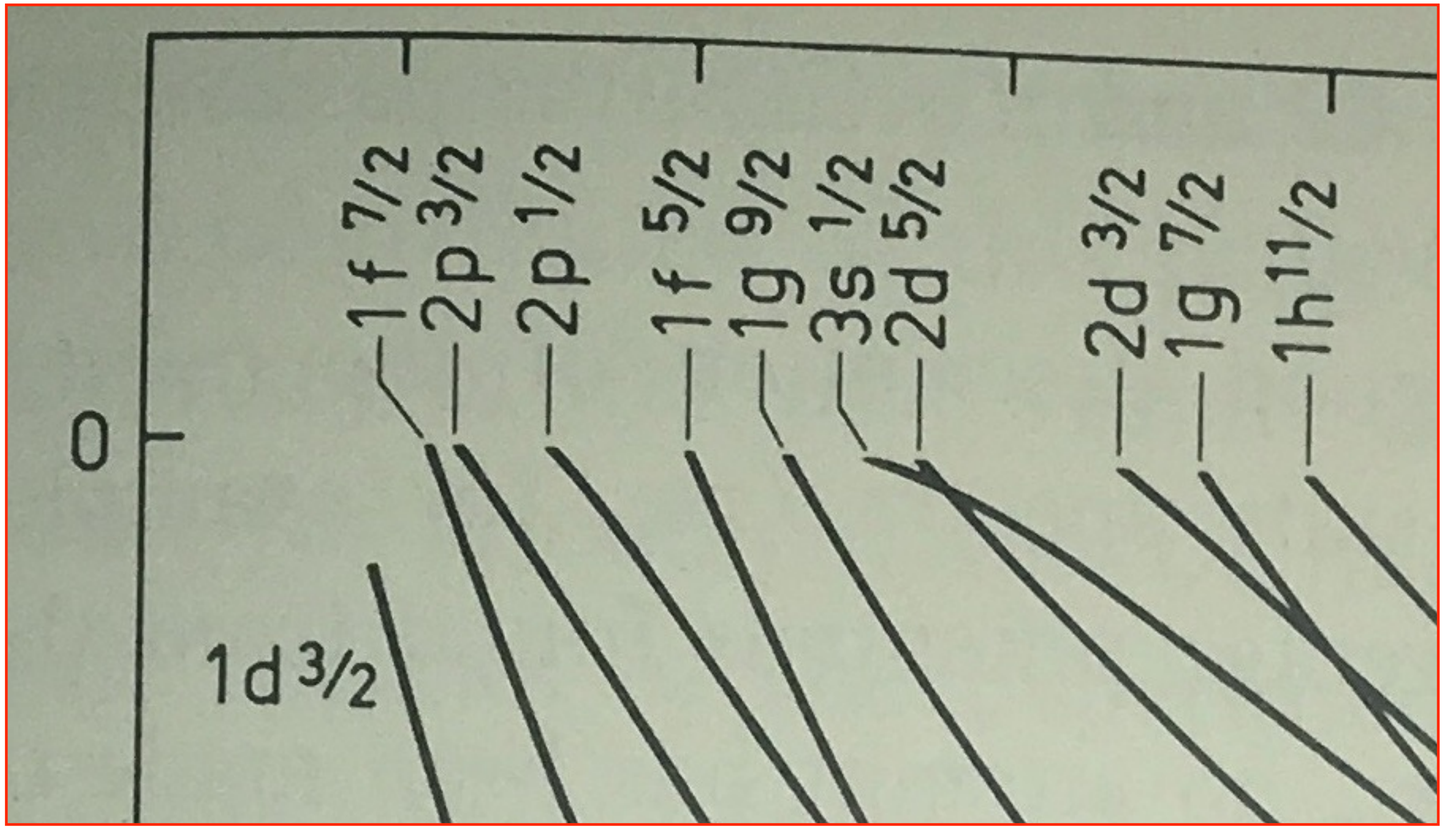


Figure 2-30 Energies of neutron orbits calculated by C. J. Veje (private communication).

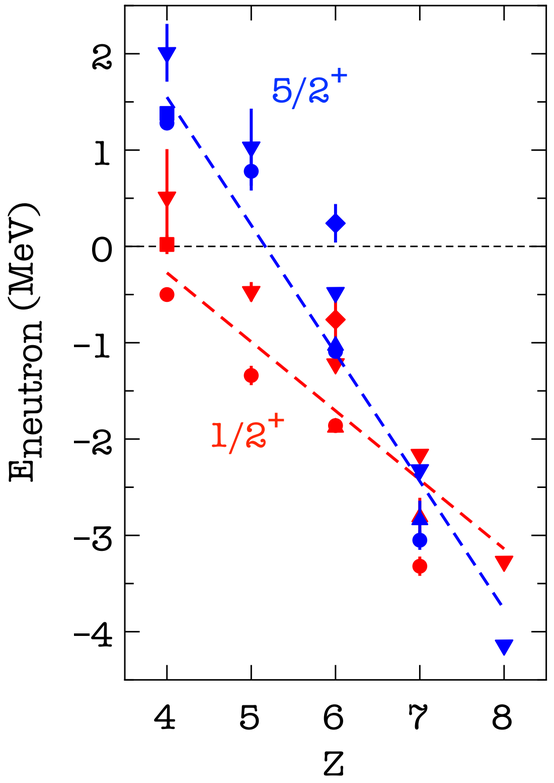
Not new



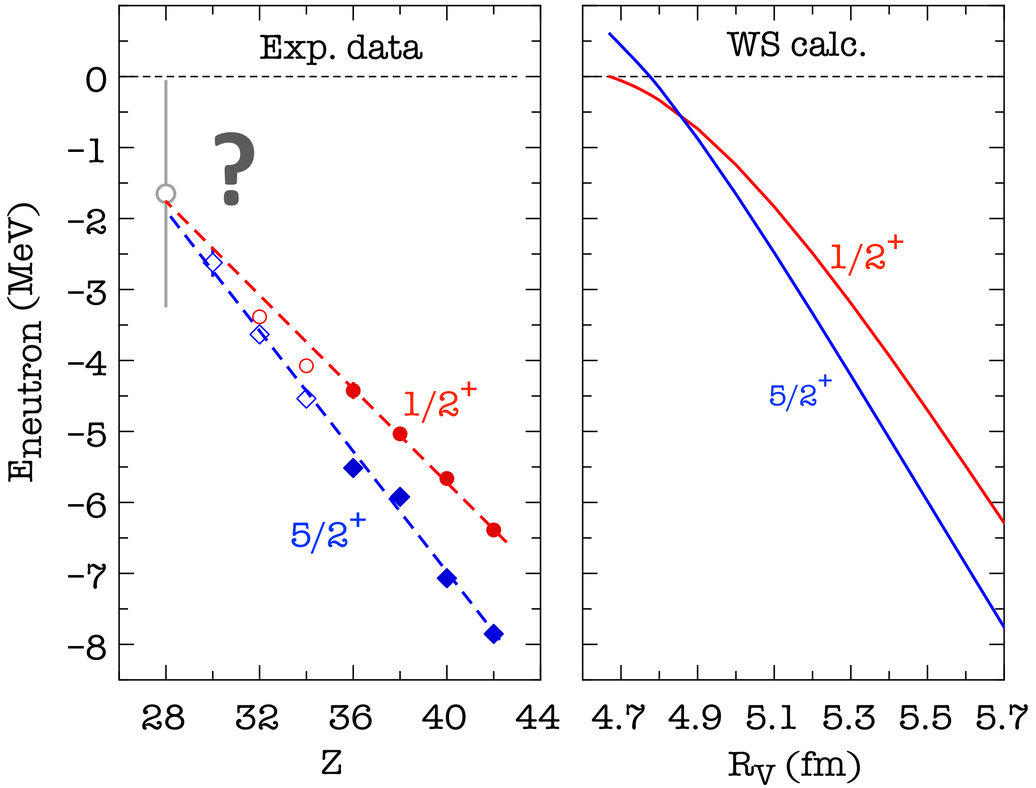
Of course, Bohr and Mottelson noted this in Volume I of the Bible. We put together the data and considered the NN interaction part … systematics, deeper insight, putting the pieces together.

More enthusiasm

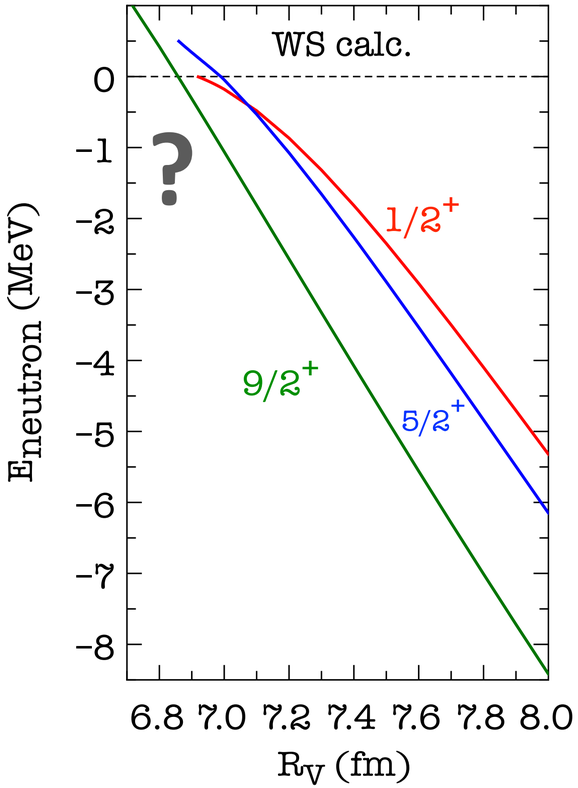
$1s_{1/2}$ w.r.t $0d_{5/2}$



$2s_{1/2}$ w.r.t $1d_{5/2}$



$3s_{1/2}$ w.r.t $2d_{5/2}$ / $1g9/2$



More on this after an interlude

Interlude 1: Homework from Berkeley

On May 3-5, 2017, I was in Berkeley to give a seminar. Augusto gave me several bits of "homework" ... I failed to do any of it, but his talking about the bubble nucleus ^{34}Si got me curious. The dramatic movement of the p-states (the $p_{1/2}$ in particular) along N = 21 just didn't seem quite right to me ... and could it be weak binding? (we sort of ignored p states originally)

PRL **119,** 182502 (2017) PHYSICAL REVIEW LETTERS week ending 3 NOVEMBER 2017

Effect of Weak Binding on the Apparent Spin-Orbit Splitting in Nuclei

B. P. Kay,[1,*] C. R. Hoffman,[1] and A. O. Macchiavelli[2]
[1]*Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA*
[2]*Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA*
(Received 25 May 2017; revised manuscript received 20 July 2017; published 31 October 2017)

"We thank John Schiffer ... for insightful comments"

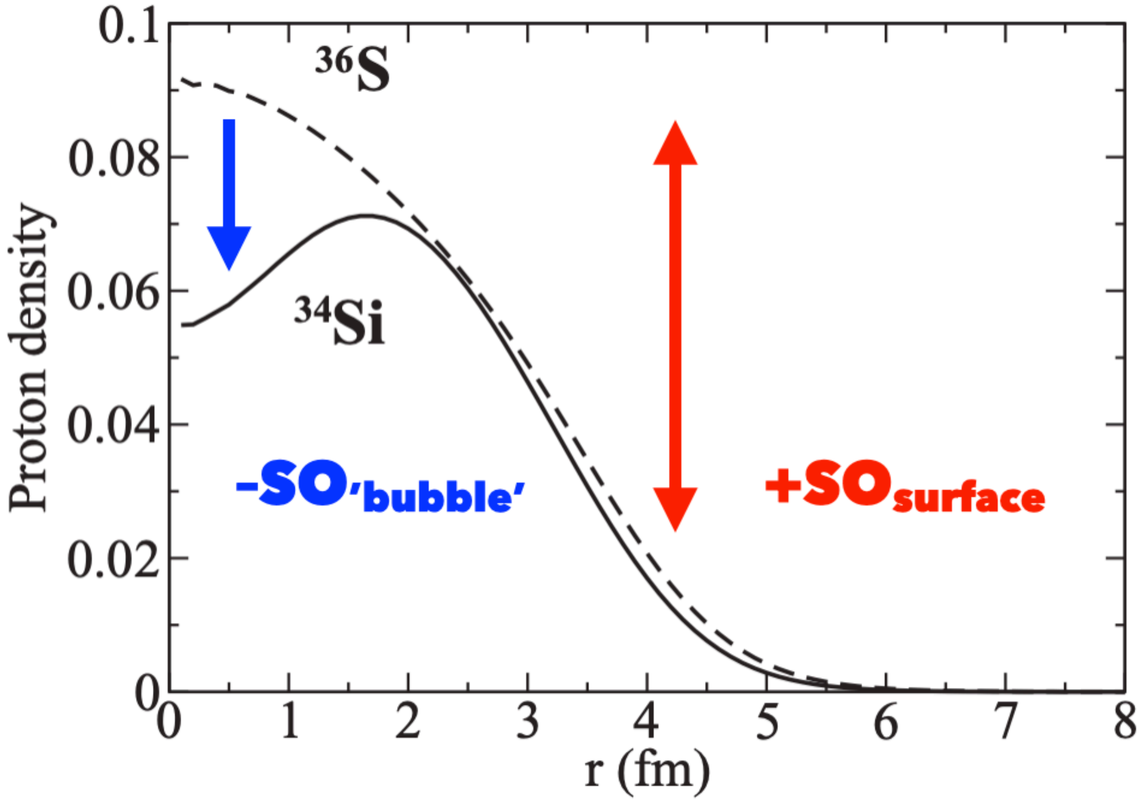
Bubble or binding?

	36Sc	37Sc	38Sc	39Sc	40Sc	41Sc	42Sc	43Sc	44Sc	45Sc	46Sc	47Sc	48Sc	49Sc	50Sc
34Ca	35Ca	36Ca	37Ca	38Ca	39Ca	40Ca	41Ca	42Ca	43Ca	44Ca	45Ca	46Ca	47Ca	48Ca	49Ca
32K	33K	34K	35K	36K	37K	38K	39K	40K	41K	42K	43K	44K	45K	46K	47K	48K
31Ar	32Ar	33Ar	34Ar	35Ar	36Ar	37Ar	38Ar	39Ar	40Ar	41Ar	42Ar	43Ar	44Ar	45Ar	46Ar	47Ar
30Cl	31Cl	32Cl	33Cl	34Cl	35Cl	36Cl	37Cl	38Cl	39Cl	40Cl	41Cl	42Cl	43Cl	44Cl	45Cl	46Cl
29S	30S	31S	32S	33S	34S	35S	36S	37S	38S	39S	40S	41S	42S	43S	44S	45S
28P	29P	30P	31P	32P	33P	34P	35P	36P	37P	38P	39P	40P	41P	42P	43P	44P
27Si	28Si	29Si	30Si	31Si	32Si	33Si	34Si	35Si	36Si	37Si	38Si	39Si	40Si	41Si	42Si	43Si
26Al	27Al	28Al	29Al	30Al	31Al	32Al	33Al	34Al	35Al	36Al	37Al	38Al	39Al	40Al	41Al	42Al

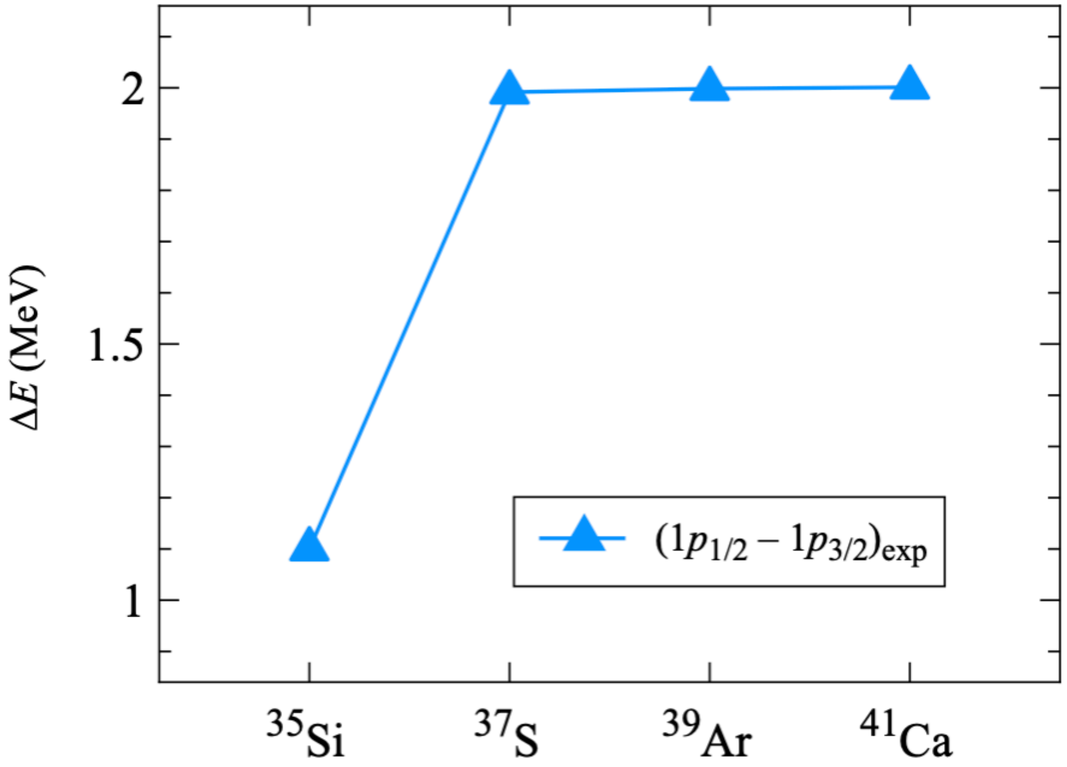
$0d_{3/2}$

$1s_{1/2}$

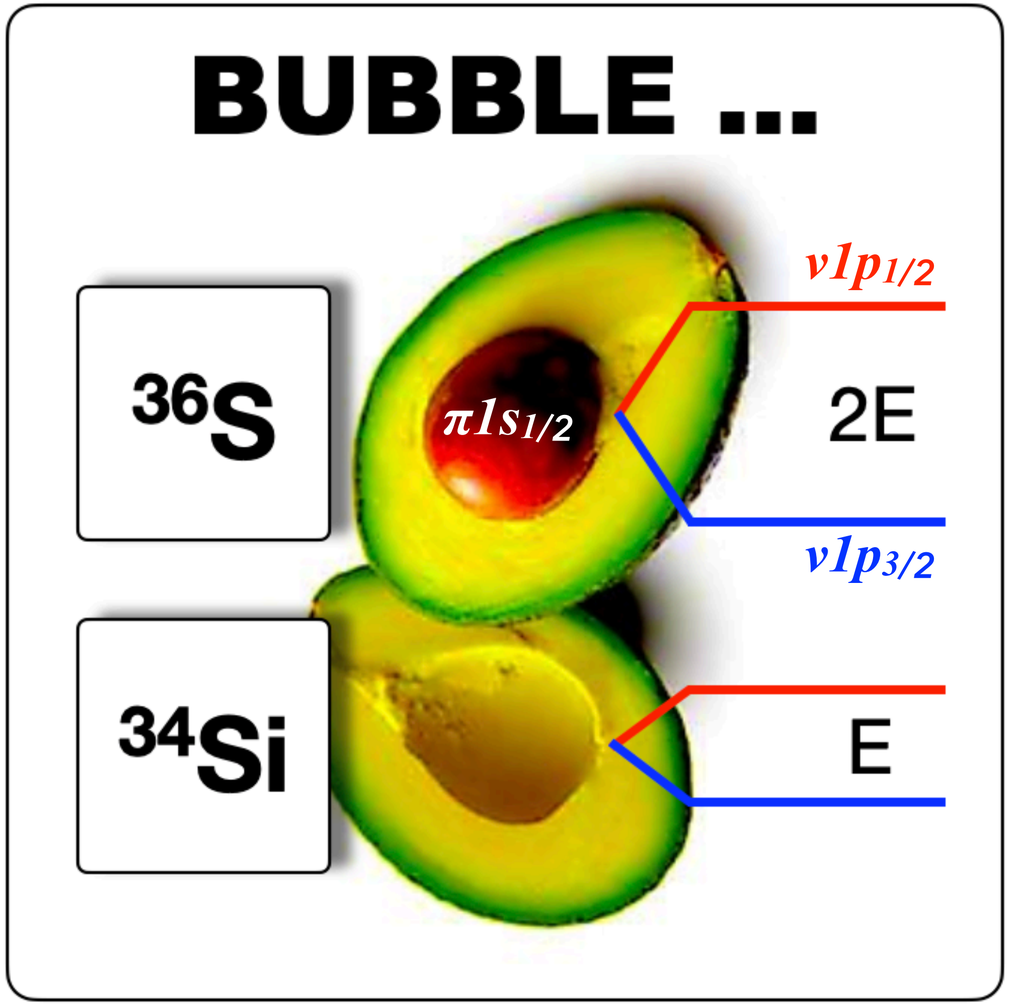
Proton density

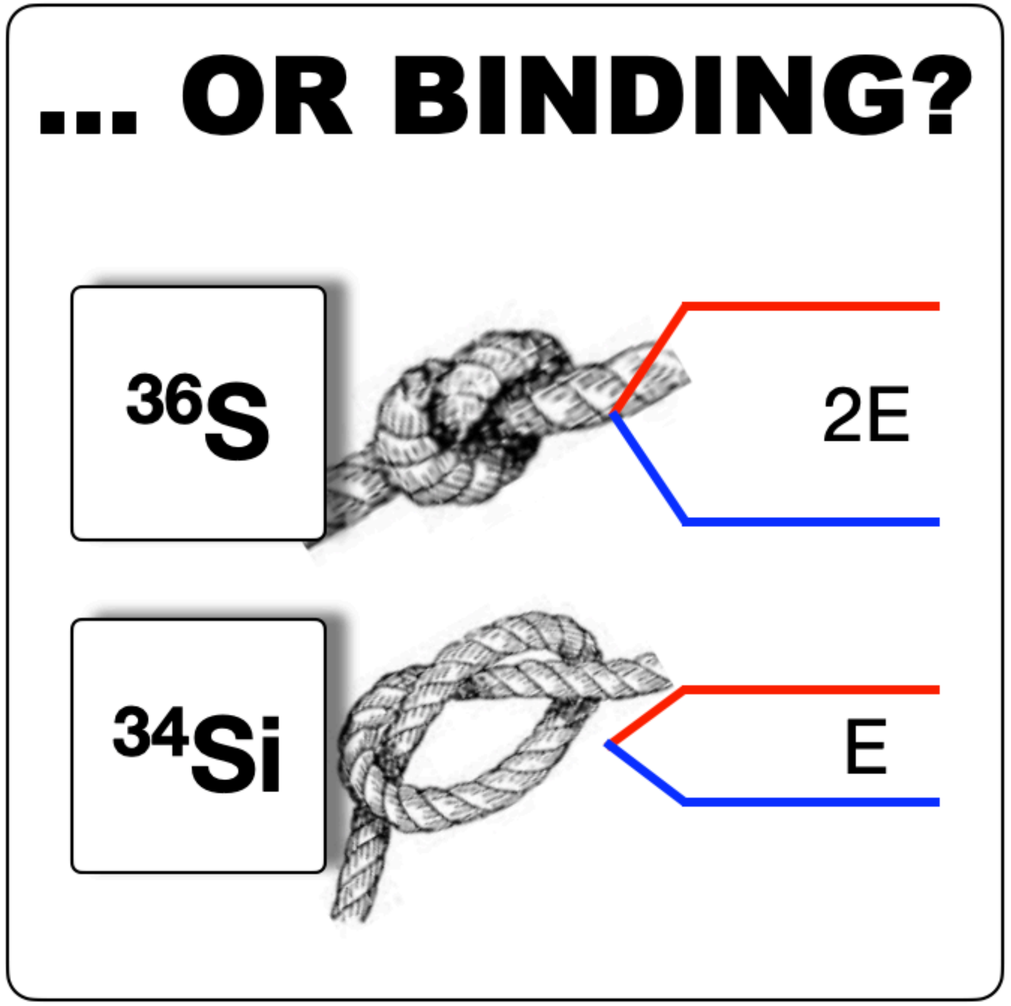


Neutron SPEs

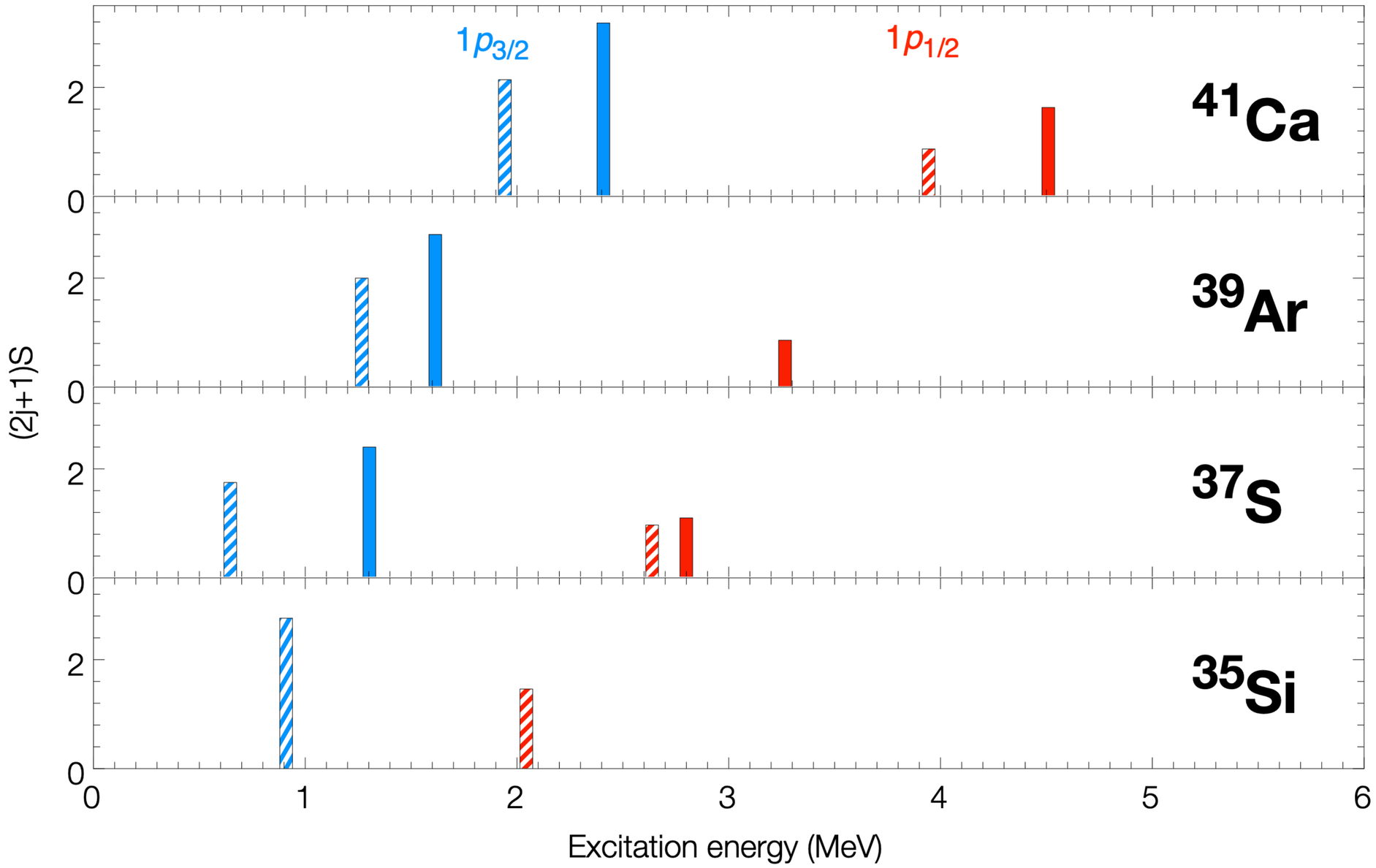


Postulated to be the consequence of a "proton bubble"





(John was quite amused by this image [to my surprise])



States versus single-particle energies

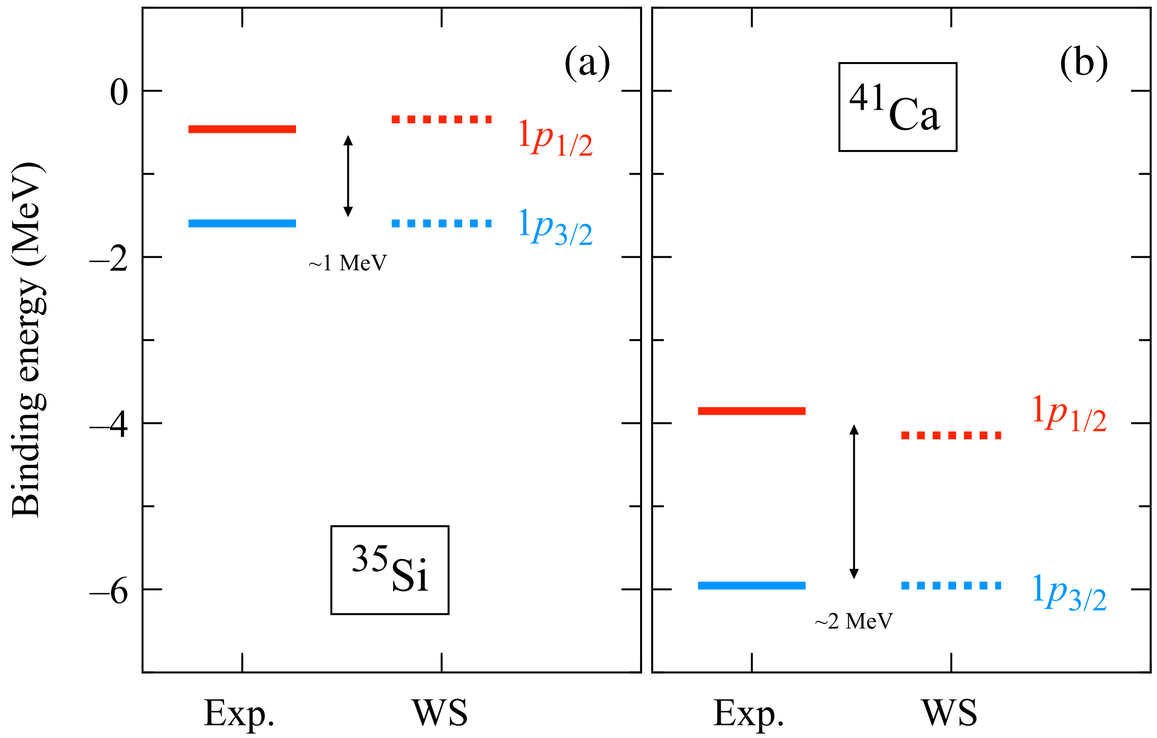


FIG. 2. For (a) ^{35}Si and (b) ^{41}Ca, a comparison of the experimentally determined binding energies (Exp.) [6] of the $1p$ orbitals with those obtained from Woods-Saxon calculations (WS) with a fixed spin-orbit potential, potential depths of 47.0 MeV (^{35}Si) and 51.8 MeV (^{41}Ca), and parameters given in the text.

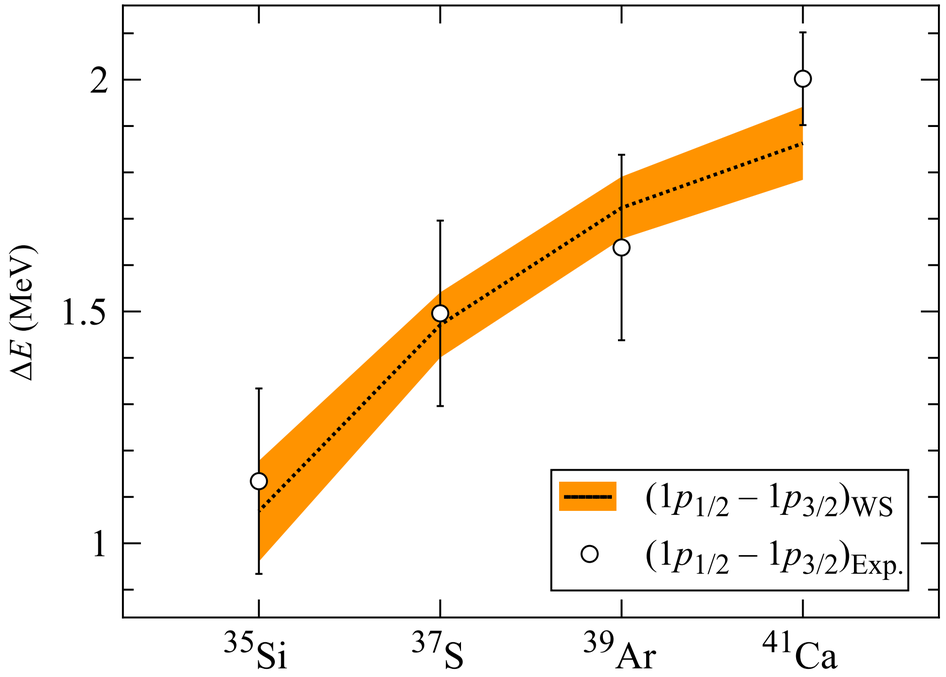


FIG. 3. A comparison between experimental spin-orbit splitting of the $1p$ states at $N = 21$ for $14 \leq Z \leq 20$ compared with calculations of the same splittings in a Woods-Saxon potential with a fixed spin-orbit strength. The width of the shaded region is to give a measure of the uncertainties associated with the calculations. The uncertainties on the experimental data points are discussed in Ref. [6].

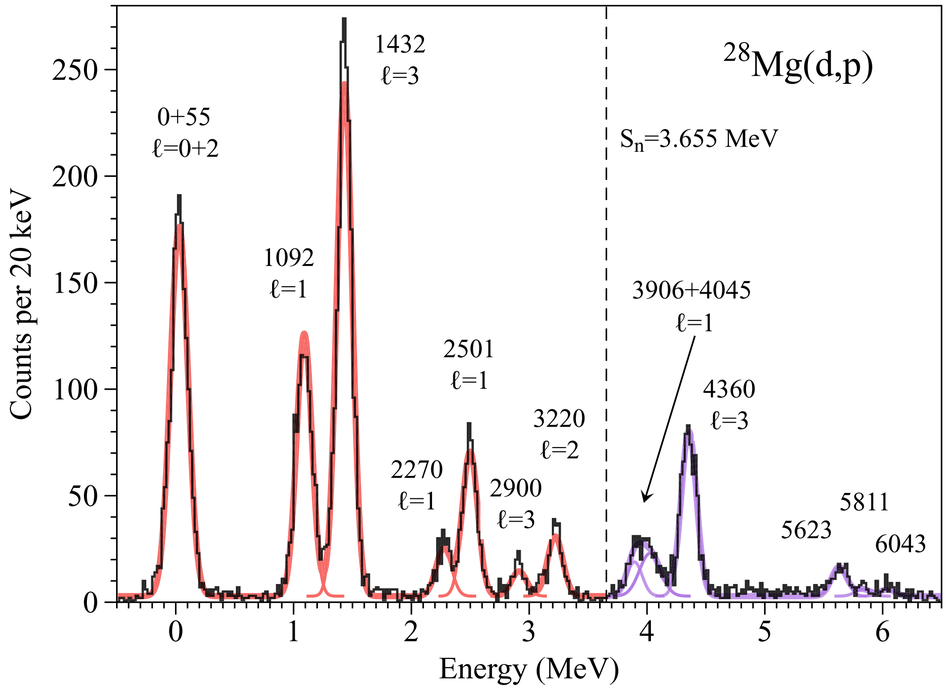
Discussions persist, data grows

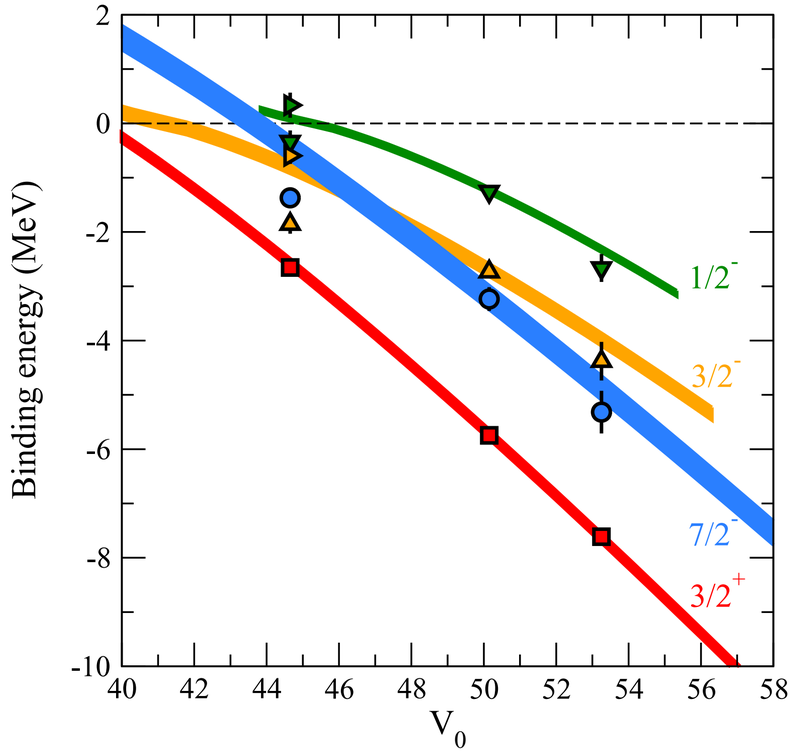
PHYSICAL REVIEW C **104**, L051301 (2021)

Letter

Evolution of single-particle structure near the $N = 20$ island of inversion

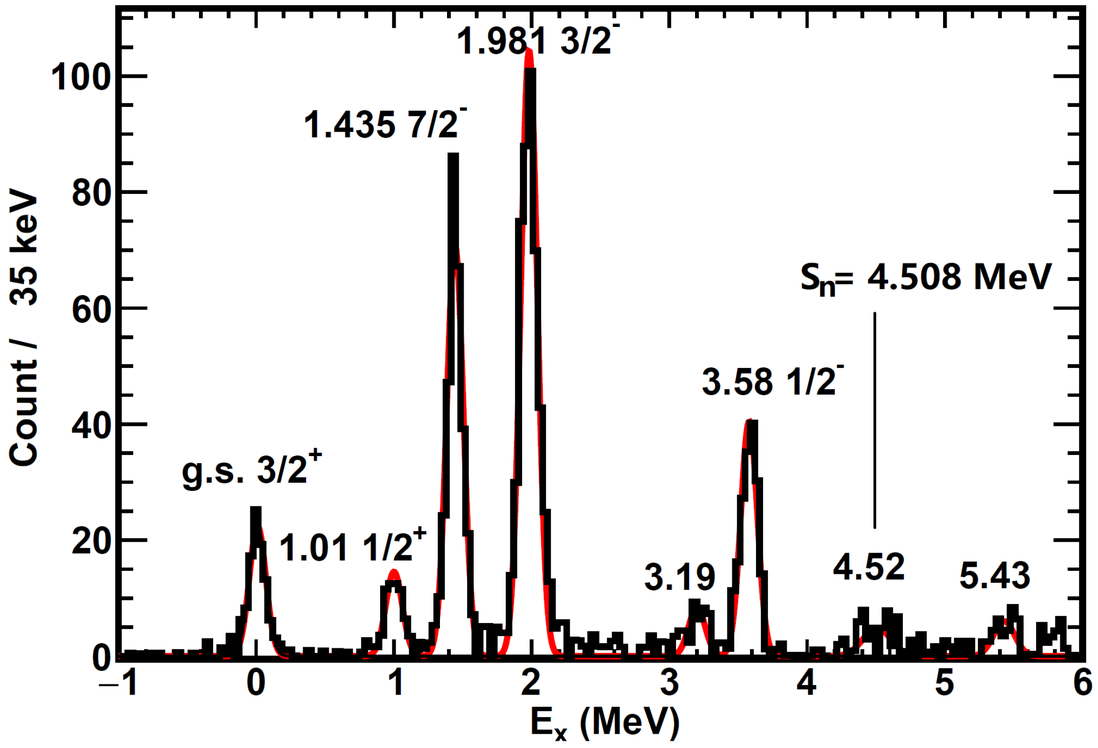
P. T. MacGregor,[1] D. K. Sharp,[1,*] S. J. Freeman,[1] C. R. Hoffman,[2] B. P. Kay,[2] T. L. Tang,[2] L. P. Gaffney,[3,4] E. F. Baader,[4] M. J. G. Borge,[5] P. A. Butler,[3] W. N. Catford,[6] B. D. Cropper,[1] G. de Angelis,[7] J. Konki,[4] Th. Kröll,[8] M. Labiche,[9] I. H. Lazarus,[9] R. S. Lubna,[10,11] I. Martel,[3,12] D. G. McNeel,[13] R. D. Page,[3] O. Poleshchuk,[14] R. Raabe,[14] F. Recchia,[15,16] and J. Yang[14]

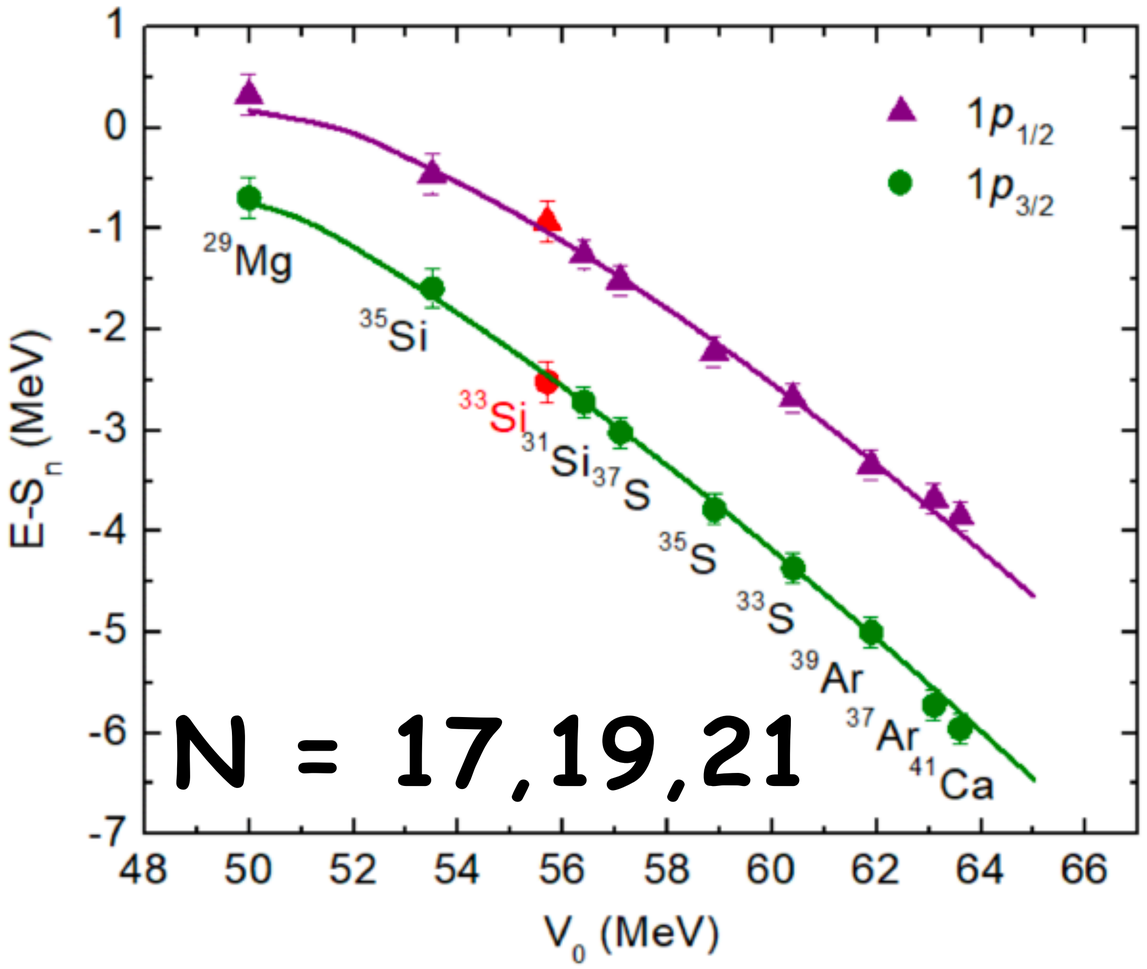




N = 19

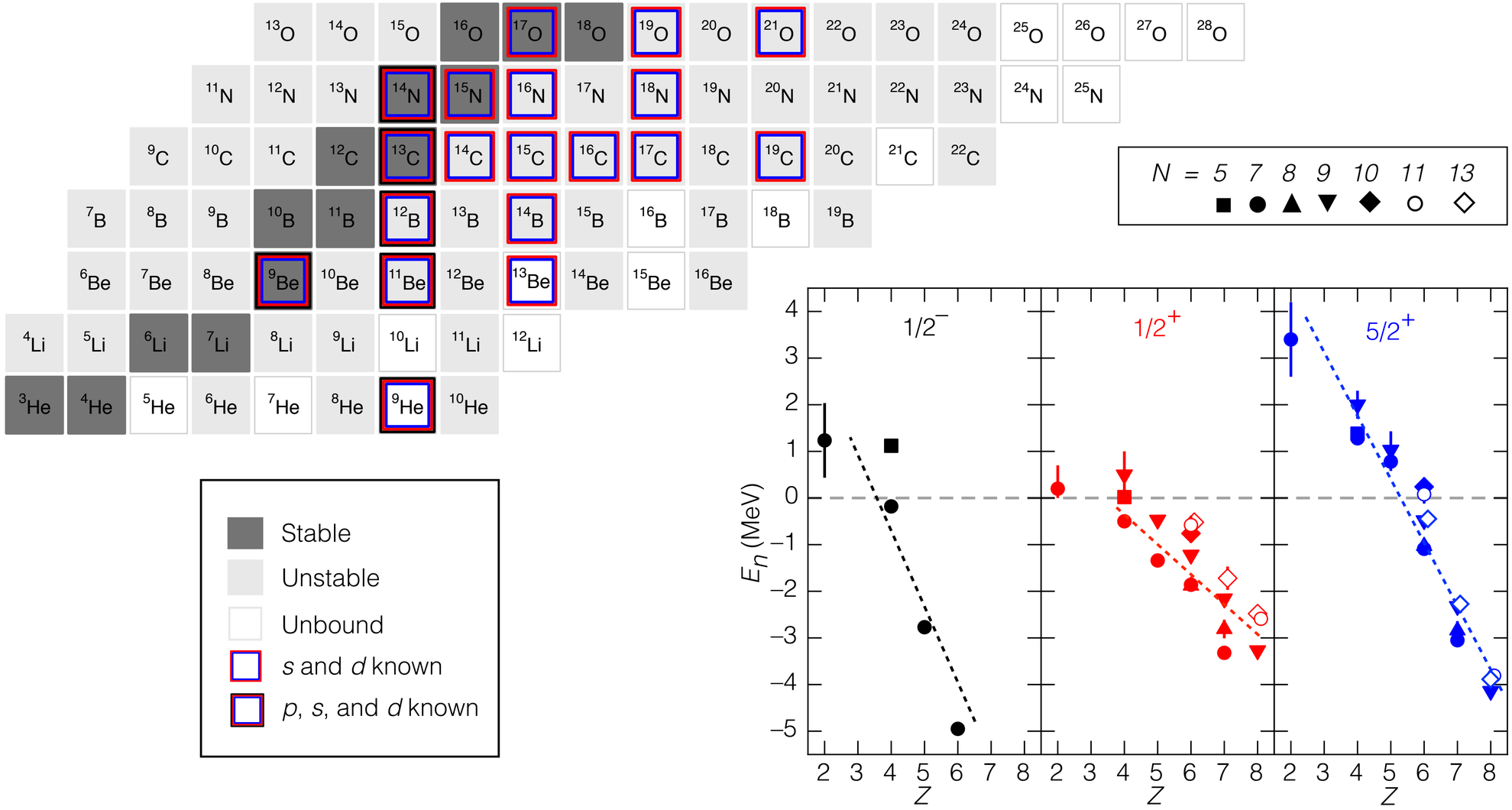
2020s and Beyond (SOLARIS)





To be published (Chen et al.), intriguing to see how this evolves

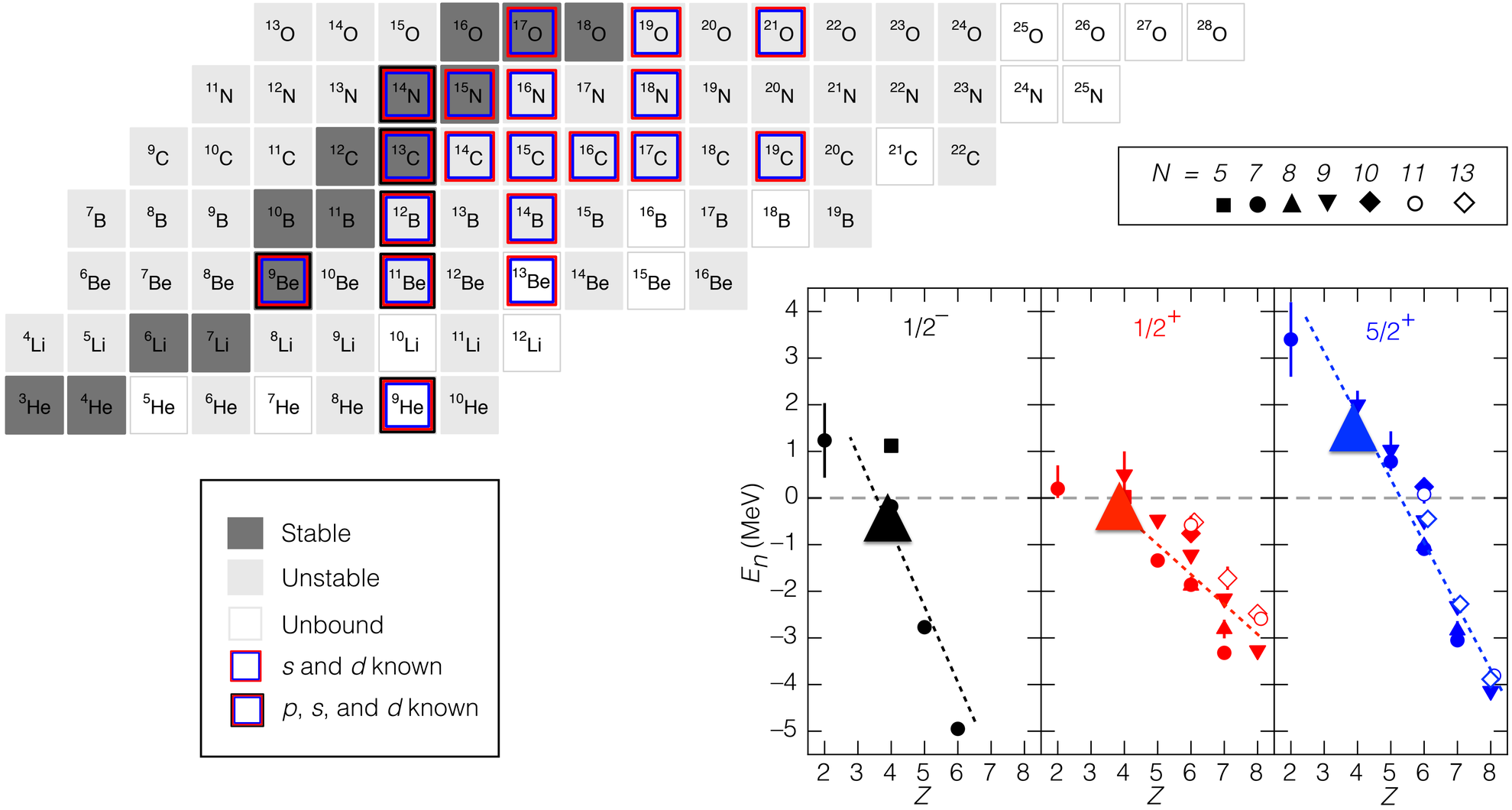
2020s and Beyond (ISS/SOLARIS)



To be published (Chen et al./Muñoz-Ramos et al.),

... intriguing to see how this evolves

2020s and Beyond (ISS/SOLARIS)



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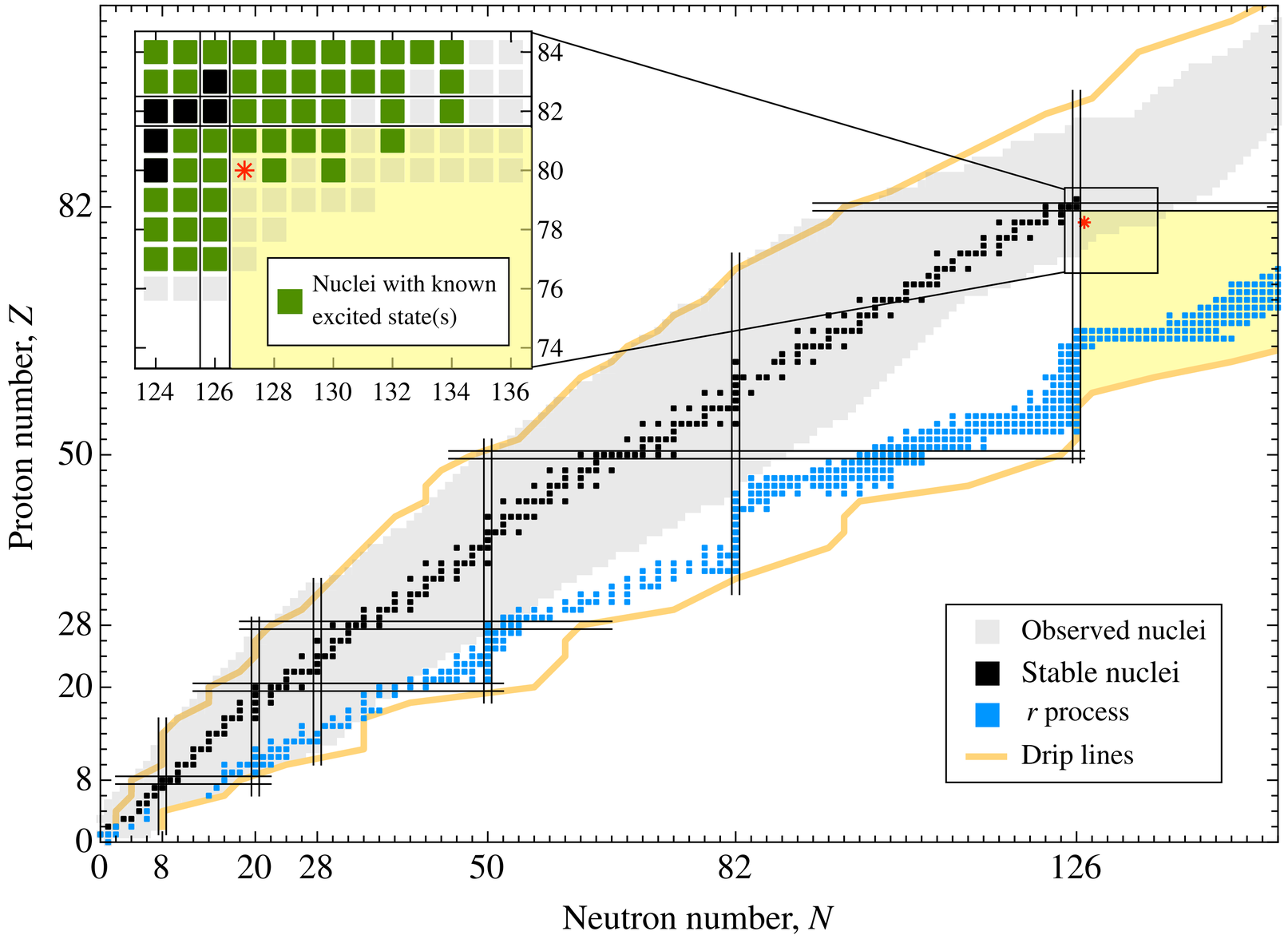
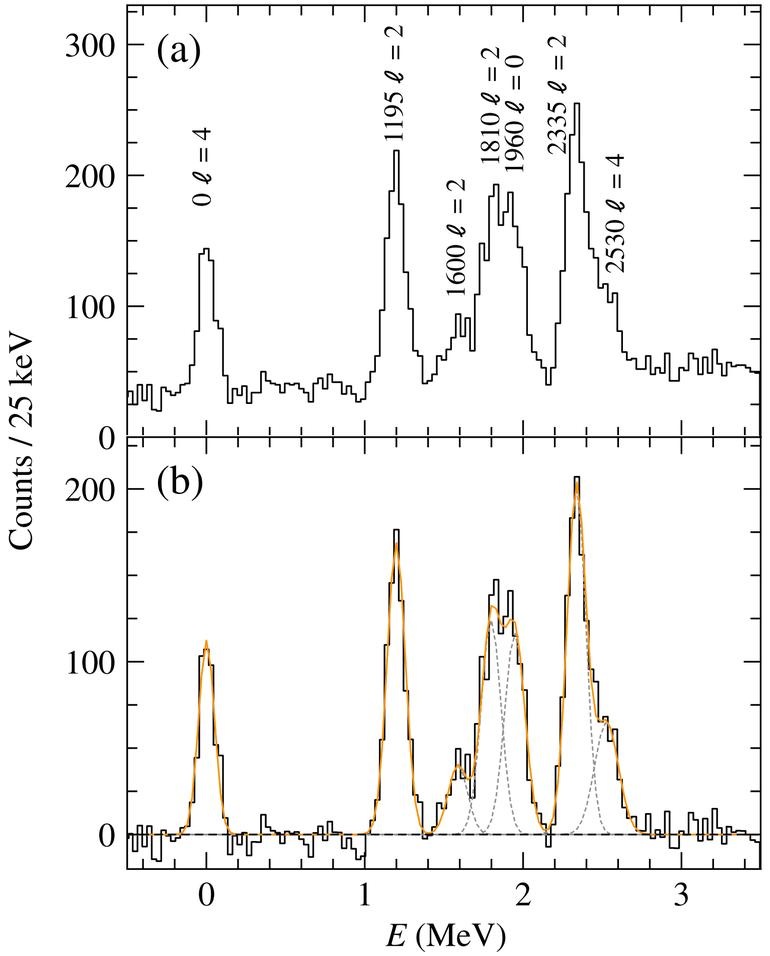
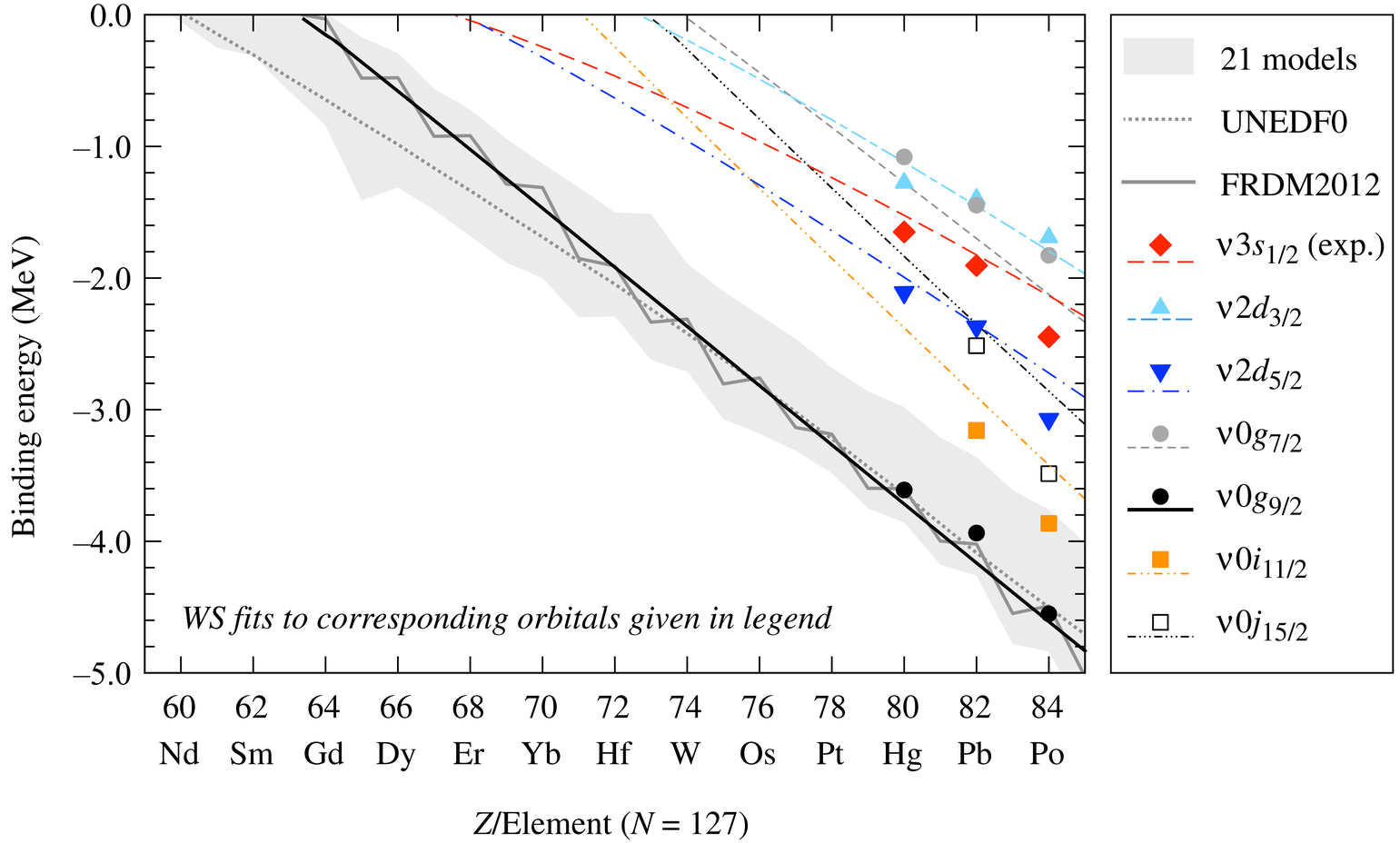
Weak binding: Into the unknown



First Exploration of Neutron Shell Structure below Lead and beyond $N = 126$

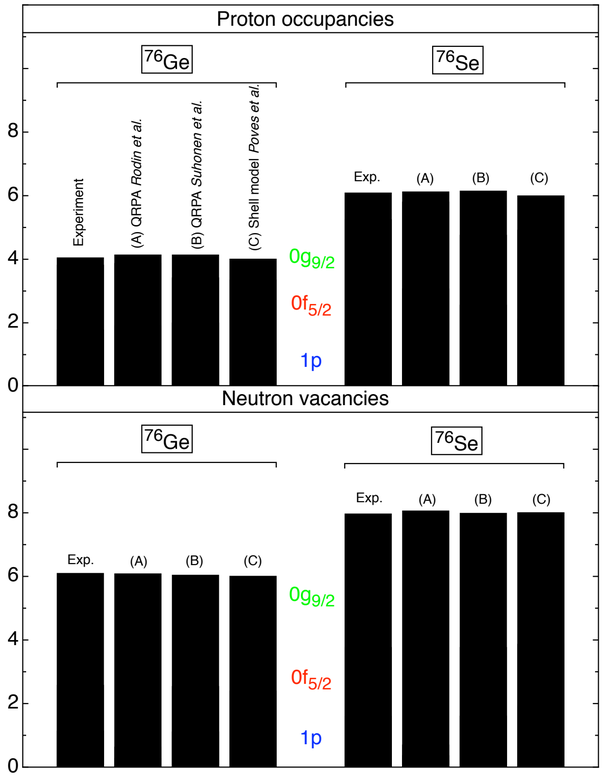
T. L. Tang,[1] B. P. Kay,[1,*] C. R. Hoffman,[1] J. P. Schiffer,[1] D. K. Sharp,[2] L. P. Gaffney,[3] S. J. Freeman,[2] M. R. Mumpower,[4,5] A. Arokiaraj,[6] E. F. Baader,[3] P. A. Butler,[7] W. N. Catford,[8] G. de Angelis,[9] F. Flavigny,[10,11] M. D. Gott,[1] E. T. Gregor,[9] J. Konki,[3] M. Labiche,[12] I. H. Lazarus,[12] P. T. MacGregor,[2] I. Martel,[7] R. D. Page,[7] Zs. Podolyák,[8] O. Poleshchuk,[6] R. Raabe,[6] F. Recchia,[13,14] J. F. Smith,[15] S. V. Szwec,[16,17] and J. Yang[6]





Interlude 2: Figures

John had a very specific approach to aesthetics ... patience is key, many versions (and John's favorite file name was "temp")



Interlude 2: Figures

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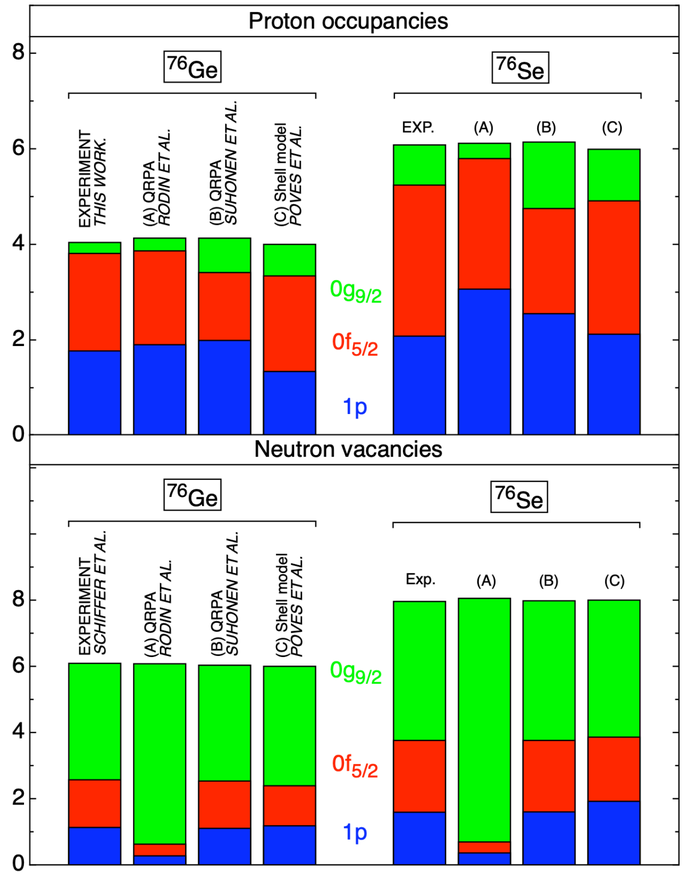
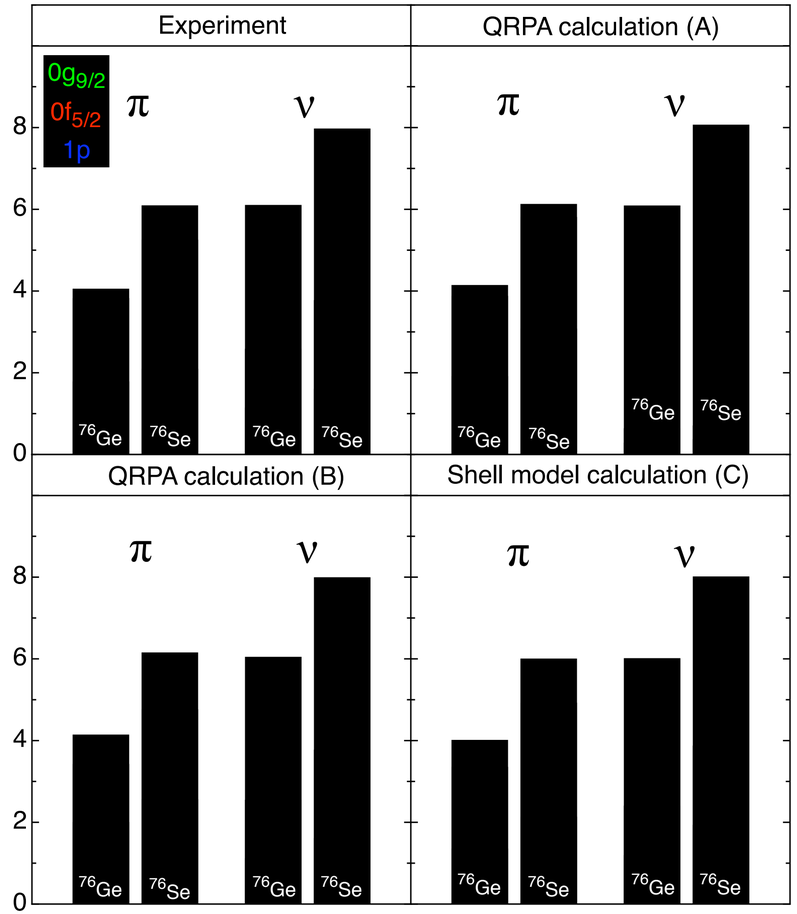


Interlude 2: Figures

John had a very specific approach to aesthetics ... patience is key, many versions (and John's favorite file name was "temp")



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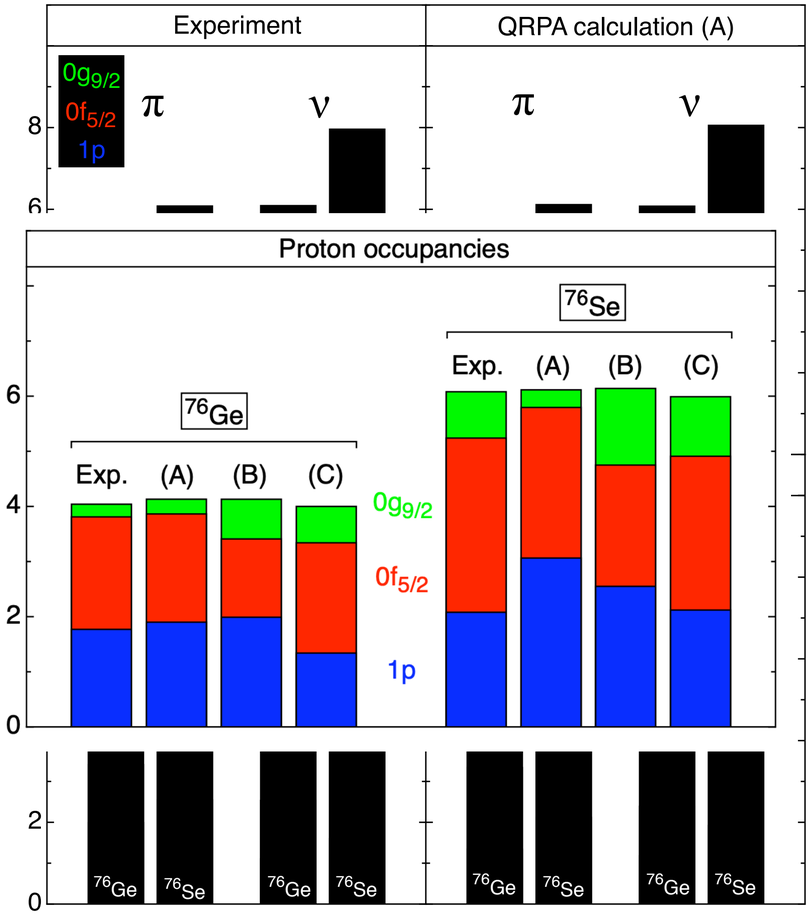

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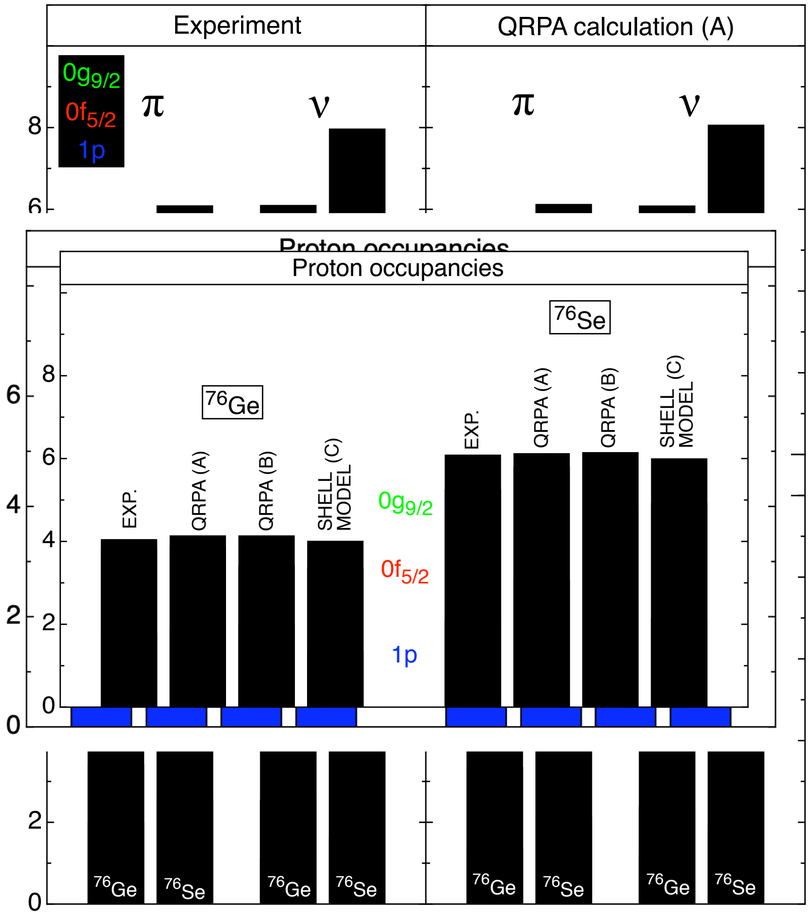

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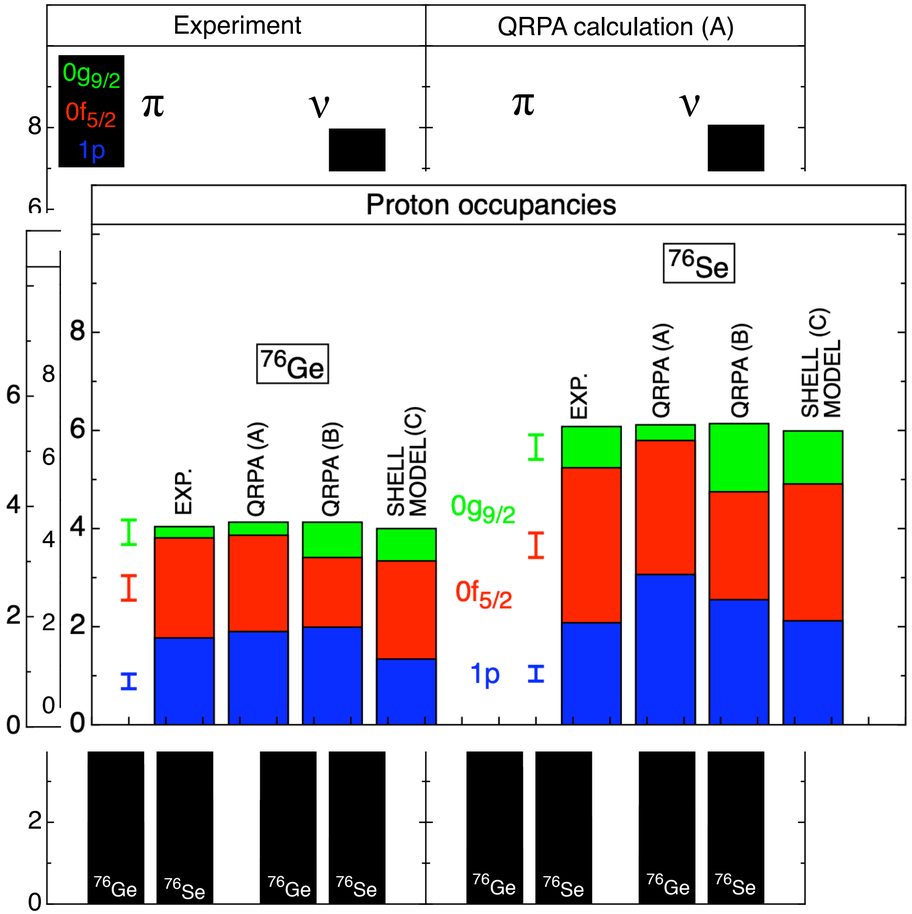

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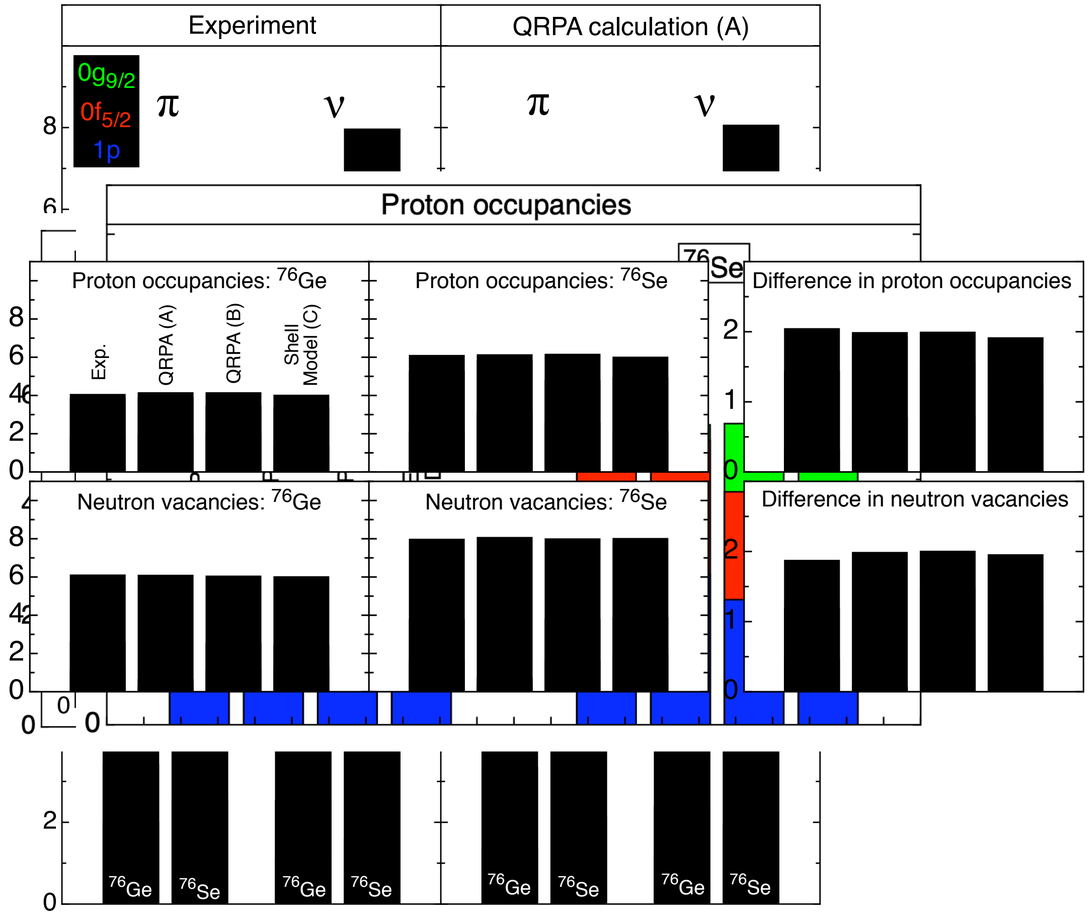

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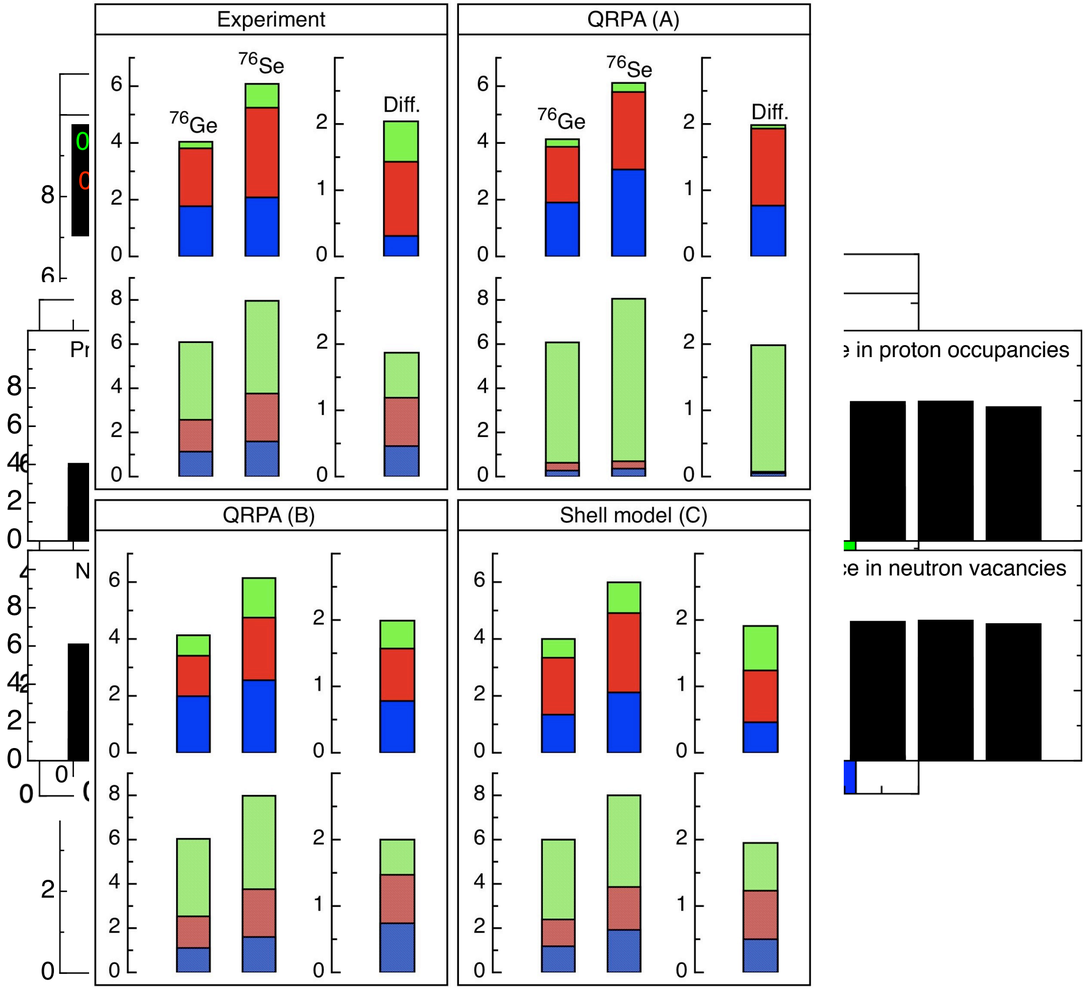

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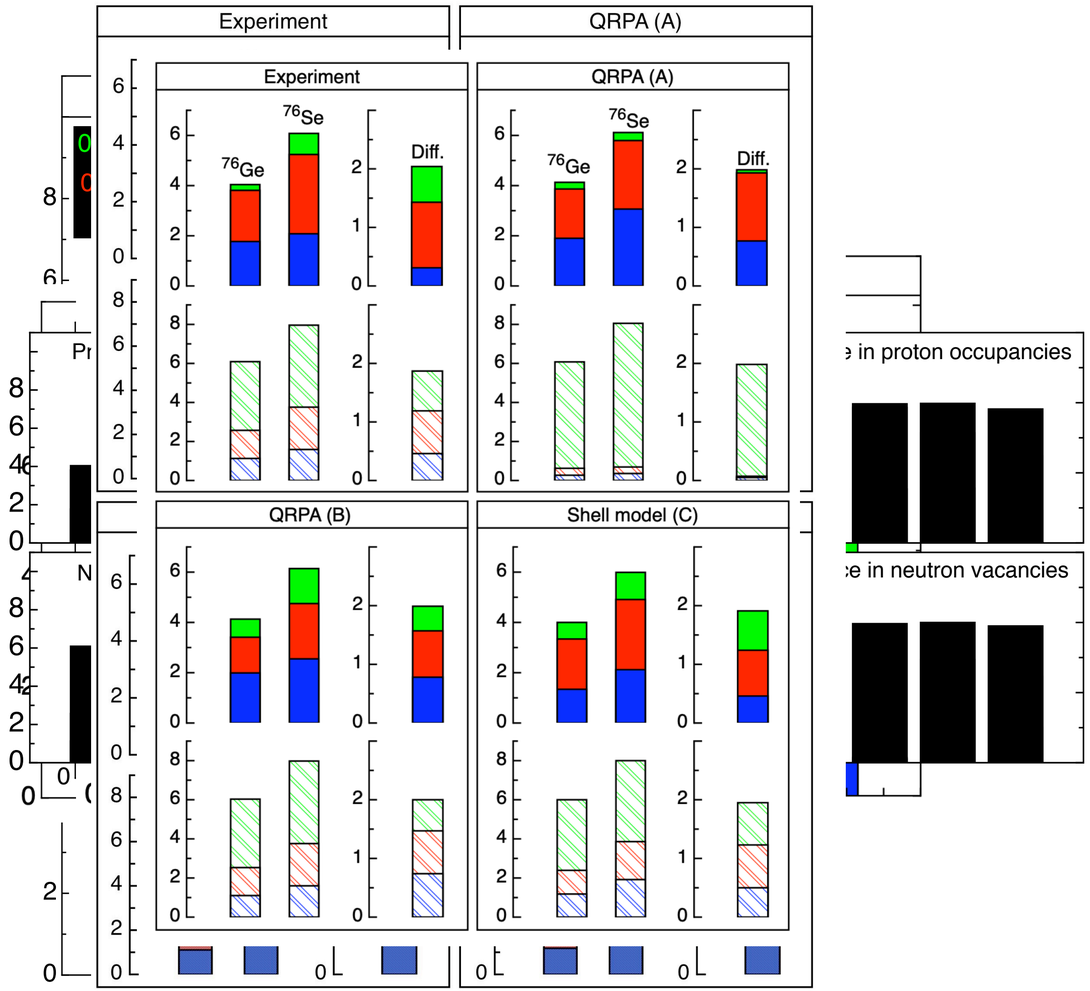

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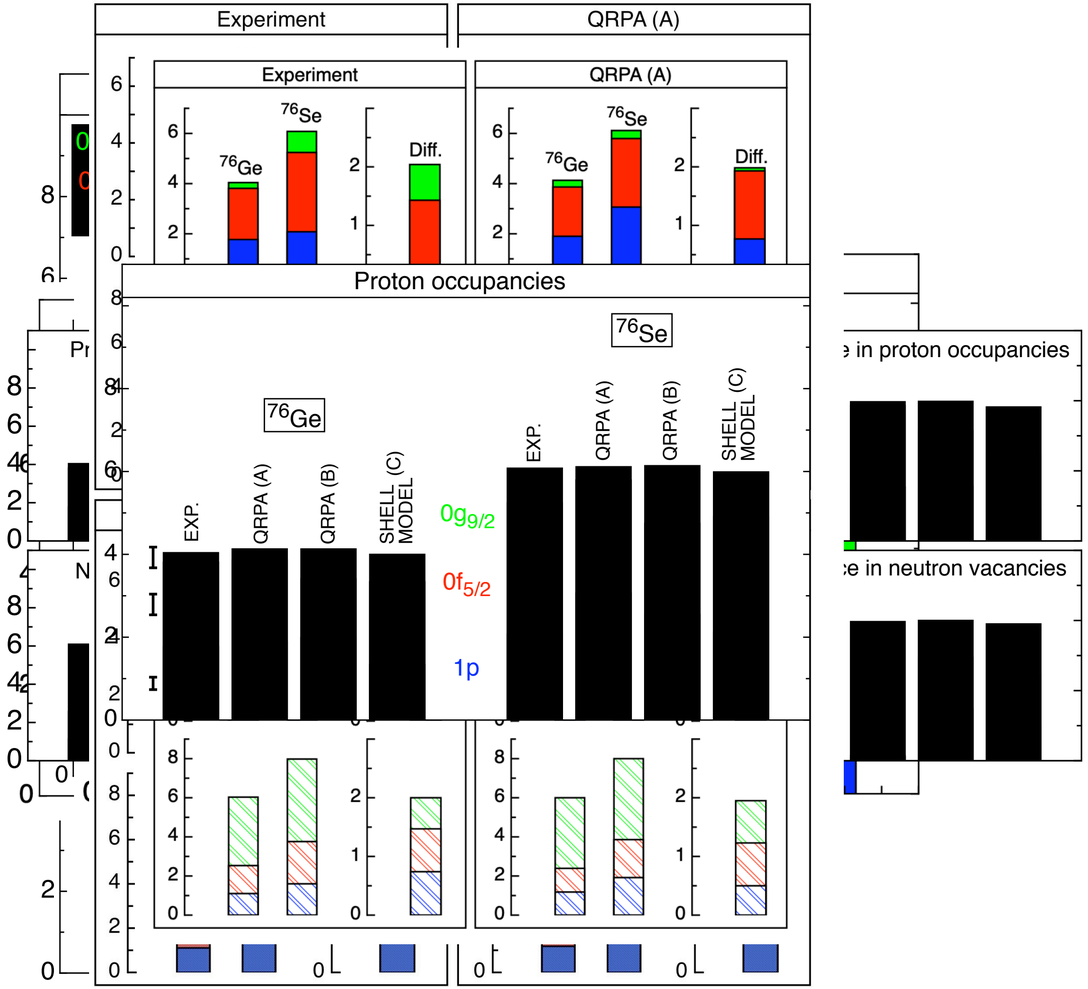

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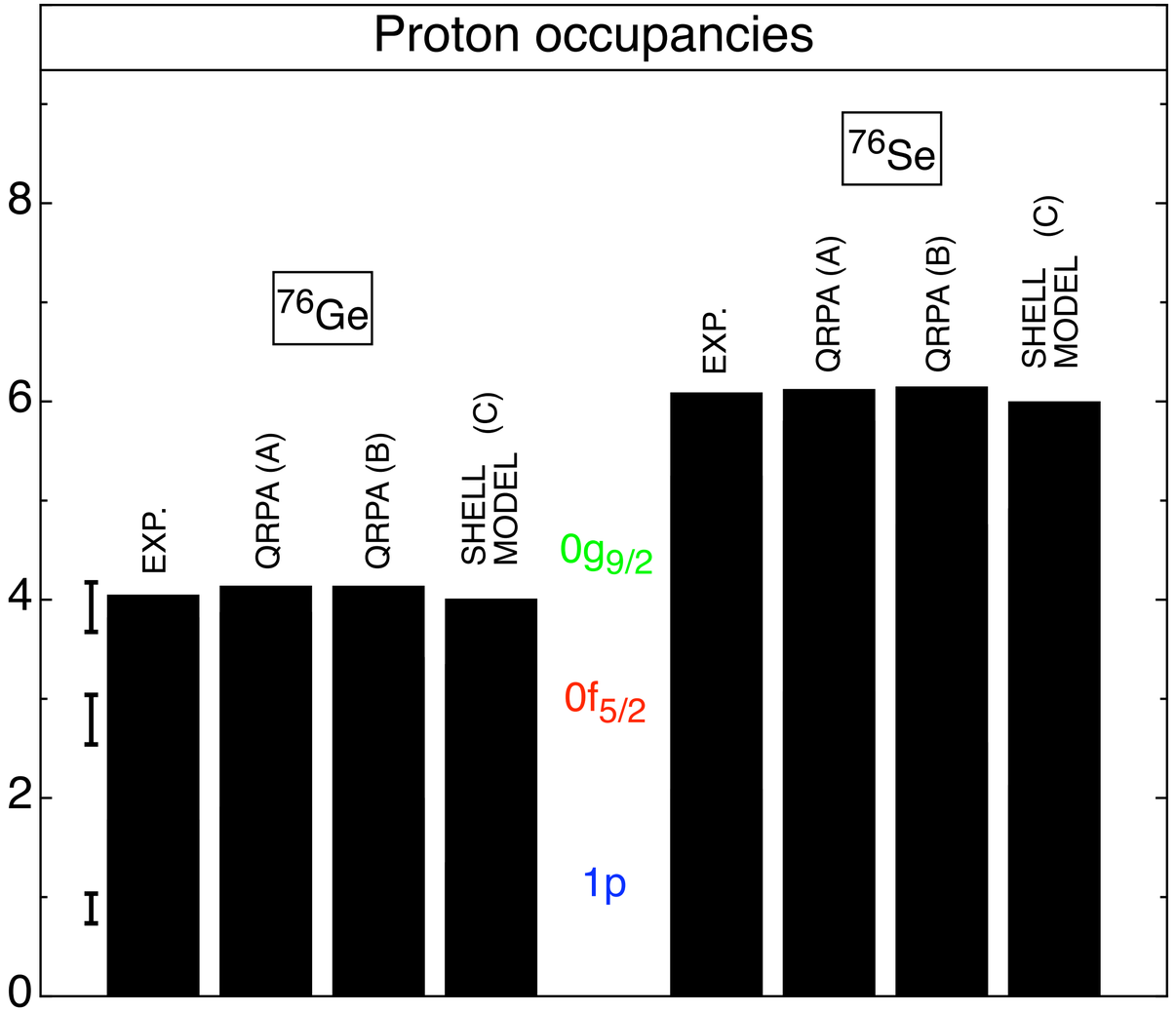


Around 2016

John and I started to write an article for Review of Modern Physics ... but we became eternally distracted (frustrating the editor in the process). We did so much data analysis, and original work, that the project remains unfinished---a rare thing when working with John

Single-particle overlaps and one-nucleon transfer

B. P. Kay and J. P. Schiffer

Physics Division,
Argonne National Laboratory,
Argonne, Illinois 60439,
USA

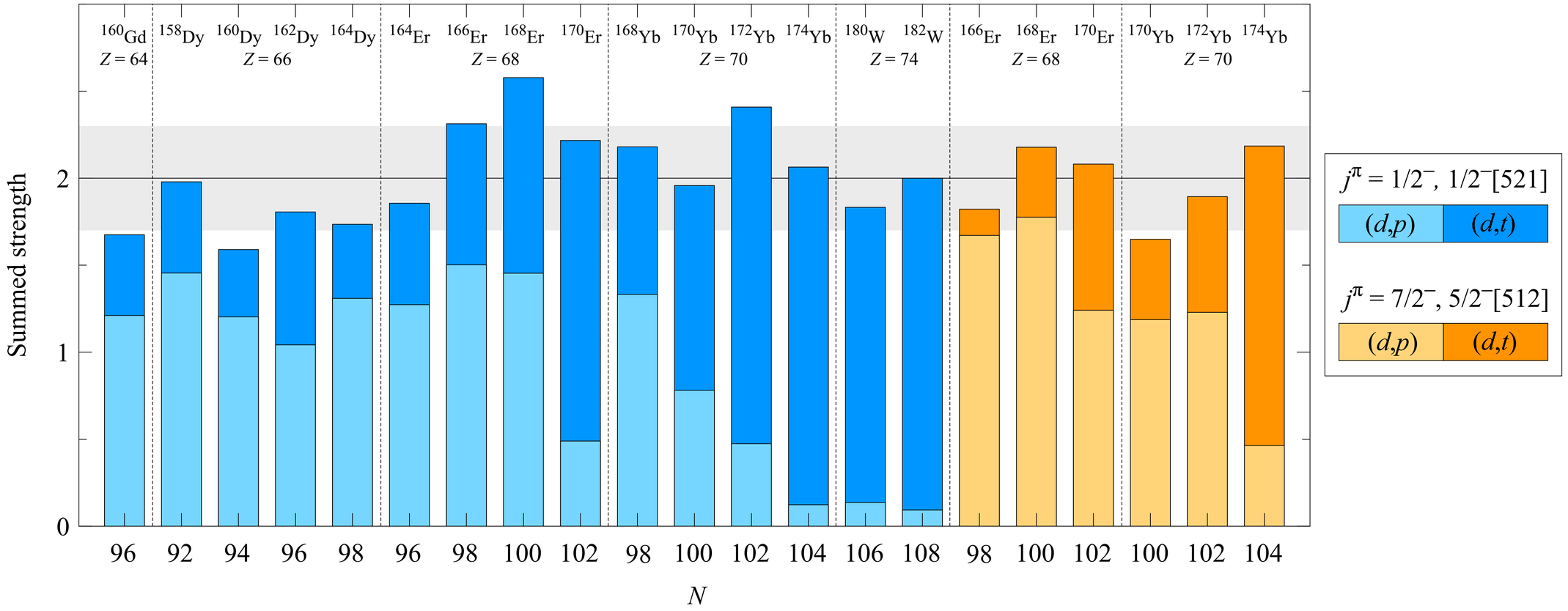
(Dated: January 23, 2017)

Single-particle overlaps extracted from one-nucleon-transfer yields are reviewed. Emphasis is placed on the experimental aspects of nucleon transfer and the reliability of the extracted spectroscopic factors using the framework of the distorted-wave Born Approximation. While spectroscopic factors are not observable properties of nuclear structure, these quantities, closely related to the cross sections measured in nucleon transfer reactions, have and continue to provide essential insights into the structure of the atomic nucleus. Using historic and recent examples, we assess the degree to which these quantities are reliable and how best these could be exploited with the advent of precise radioactive ion beam facilities at the appropriate energies.

CONTENTS

I. INTRODUCTION

(Useful) distractions 1

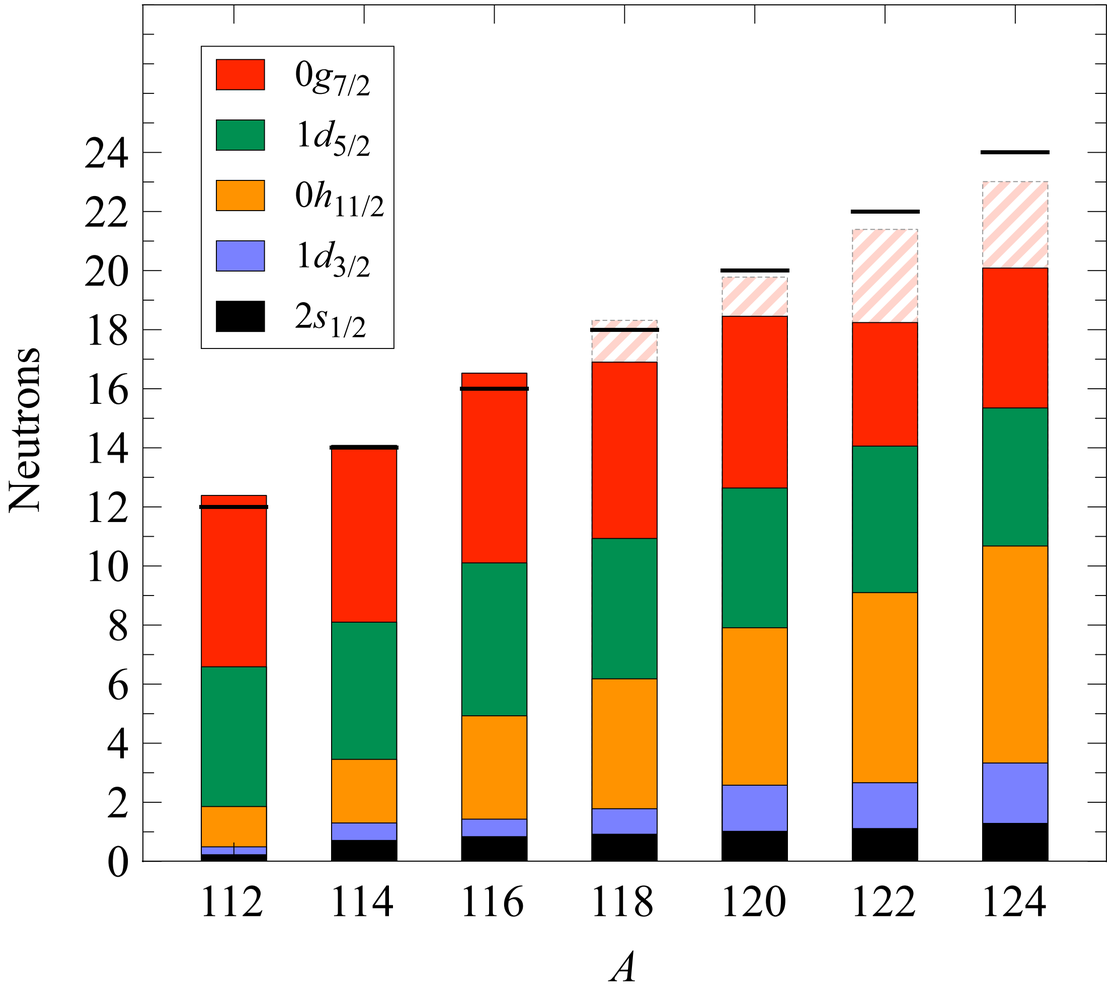


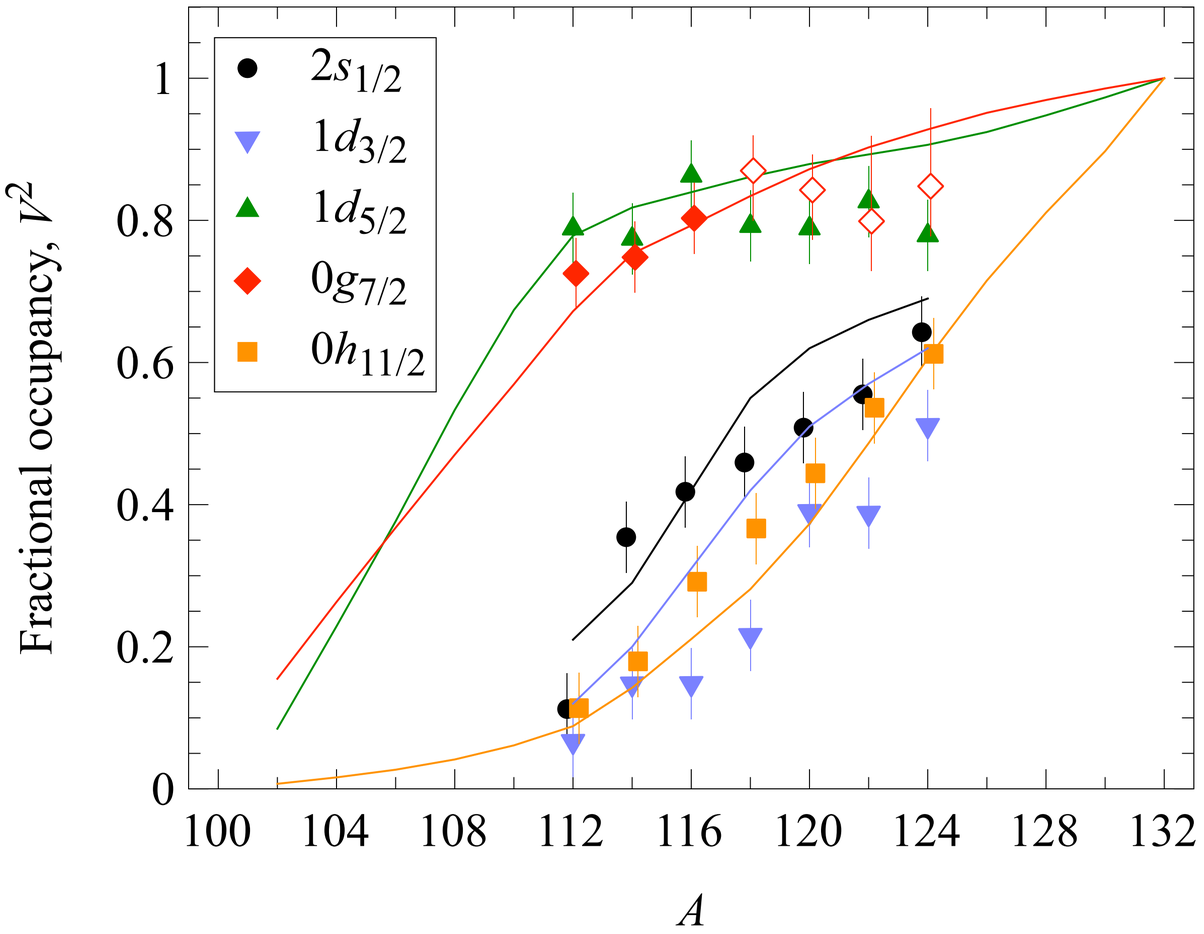
PHYSICAL REVIEW C **103**, 024319 (2021)

Consistency of nucleon-transfer sum rules in well-deformed nuclei

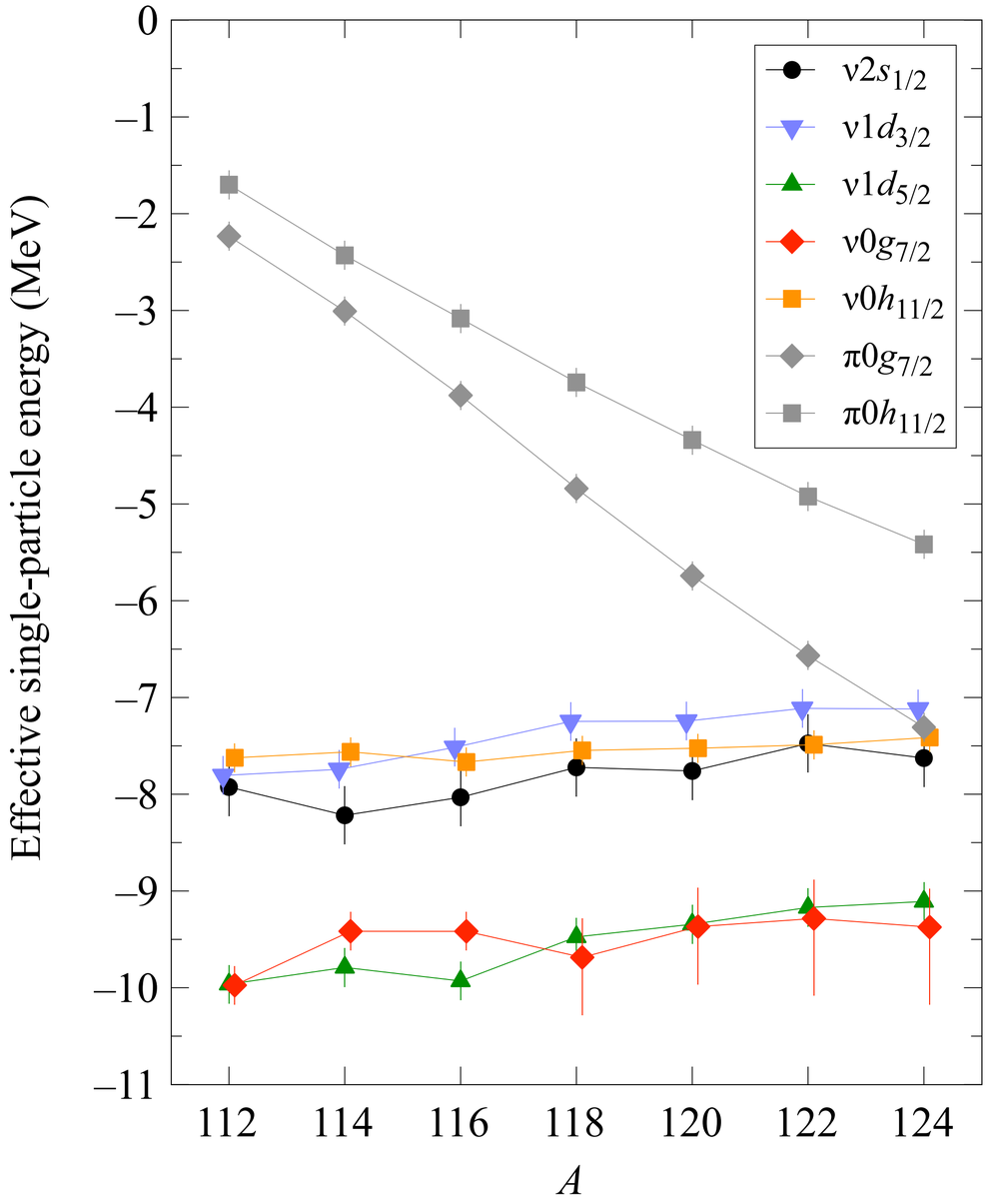
B. P. Kay,[1,*] J. P. Schiffer,[1] S. J. Freeman,[2] T. L. Tang,[1] B. D. Cropper,[2] T. Faestermann,[3,4] R. Hertenberger,[5] J. M. Keatings,[6] P. T. MacGregor,[2] J. F. Smith,[6] and H.-F. Wirth[5]

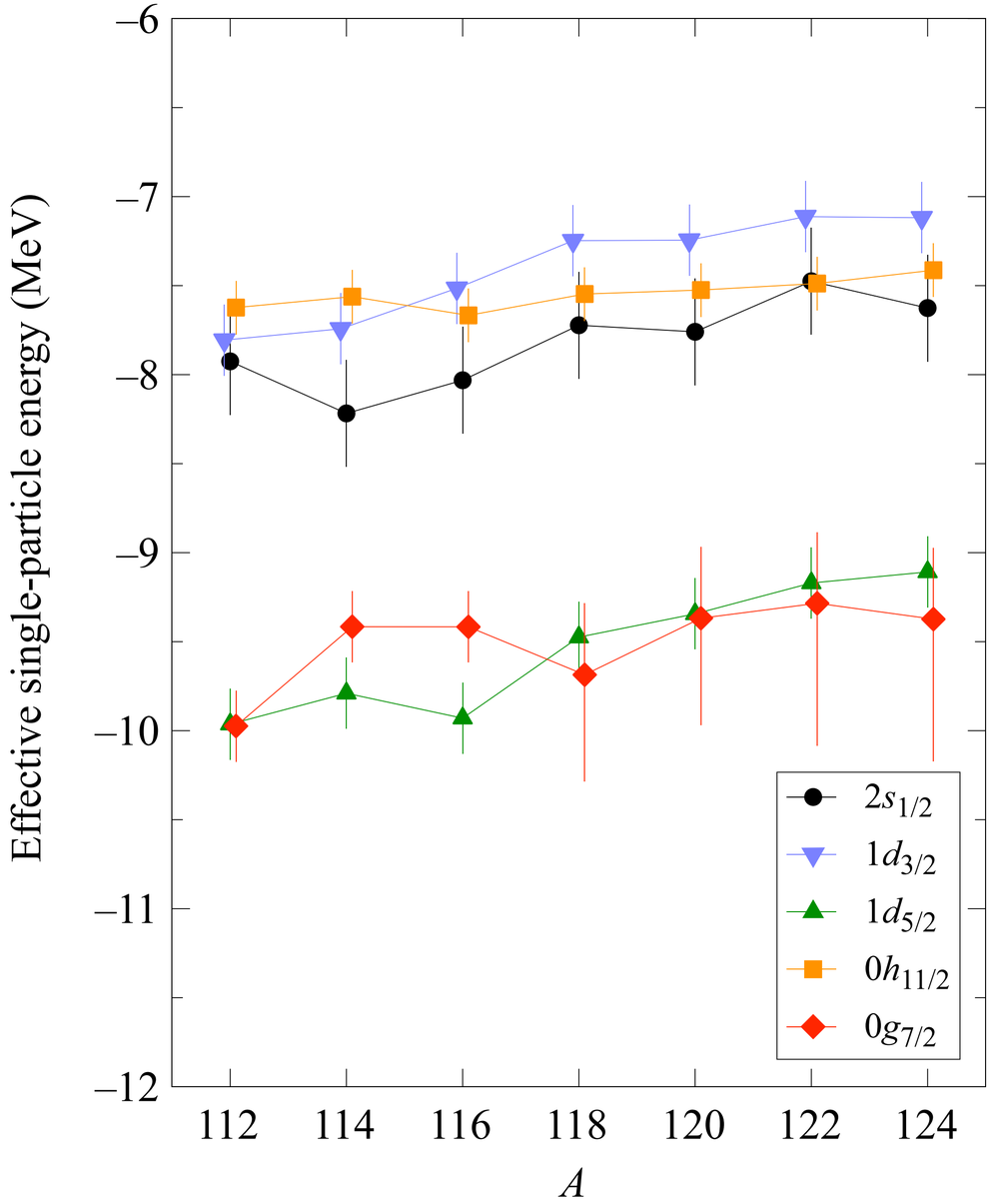
(Useful) distractions 2





New data from the Manchester group, tin ... one of John favorite playground





(The process) ... "why plot this, Ben? It's distracting"

Not the end ...

PHYSICAL REVIEW C **104**, 054308 (2021)

Neutron occupancies and single-particle energies across the stable tin isotopes

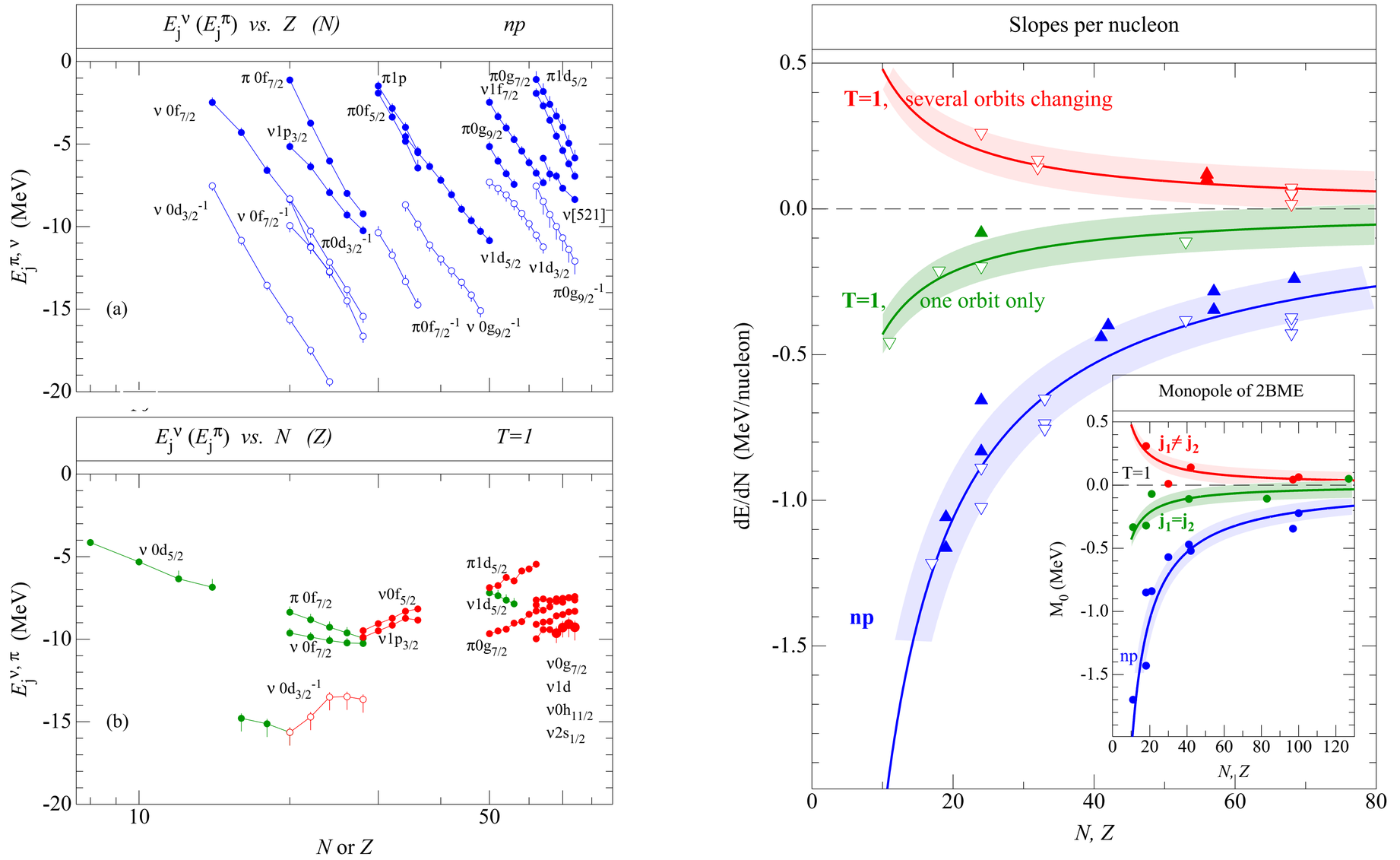
S. V. Szwec,[1,*] D. K. Sharp,[1,†] B. P. Kay,[2,‡] S. J. Freeman,[1] J. P. Schiffer,[2] P. Adsley,[3,§] C. Binnersley,[1] N. de Séréville,[3] T. Faestermann,[4,5] R. F. Garcia Ruiz,[1,‖] F. Hammache,[3] R. Hertenberger,[5,6] A. Meyer,[3] C. Portail,[3] I. Stefan,[3] A. Vernon,[1,‖] S. Wilkins,[1,‖] and H.-F. Wirth[5,6]

PHYSICAL REVIEW C **105**, L041302 (2022)

Letter

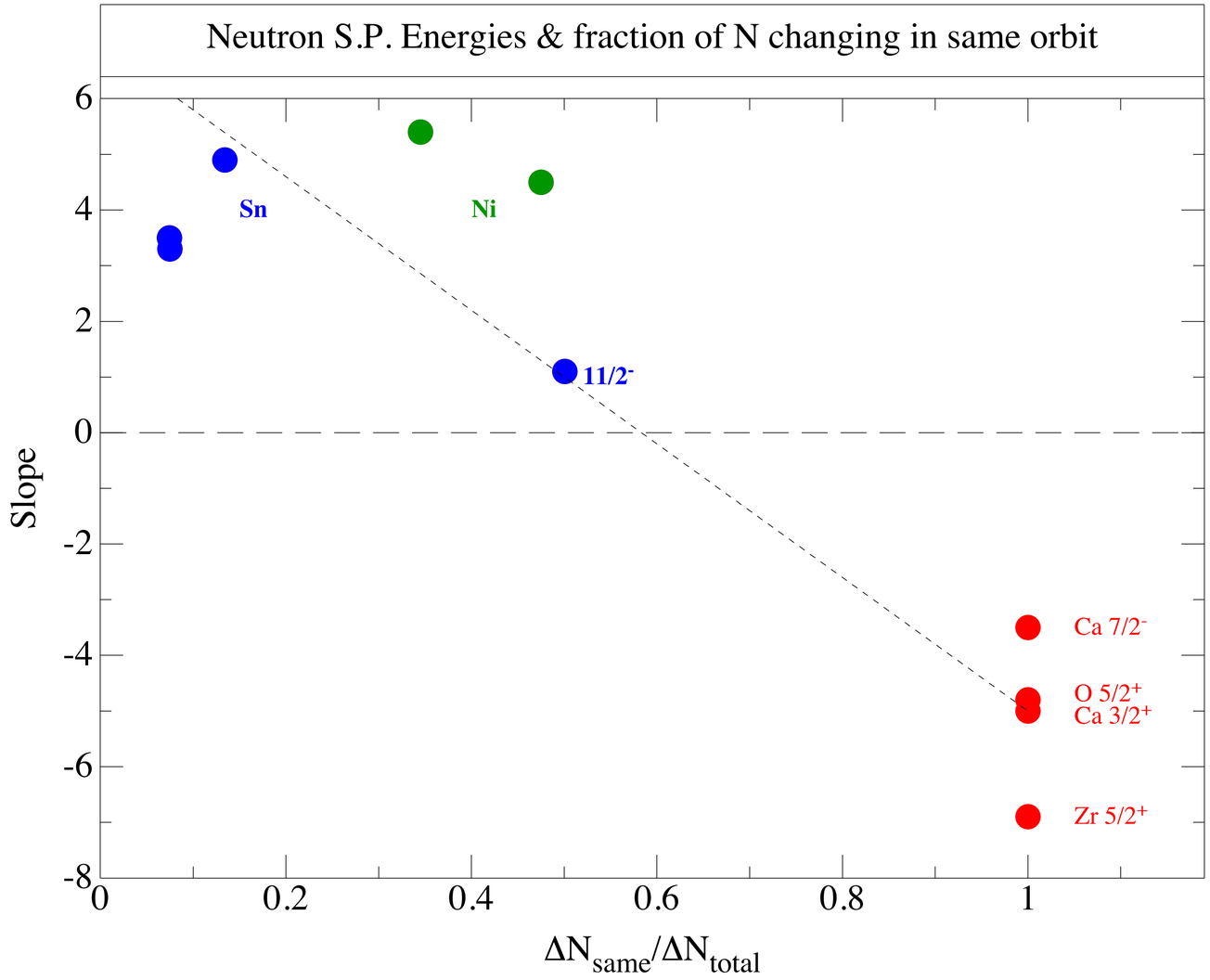
Single-nucleon energies changing with nucleon number

J. P. Schiffer,[*] B. P. Kay, and J. Chen

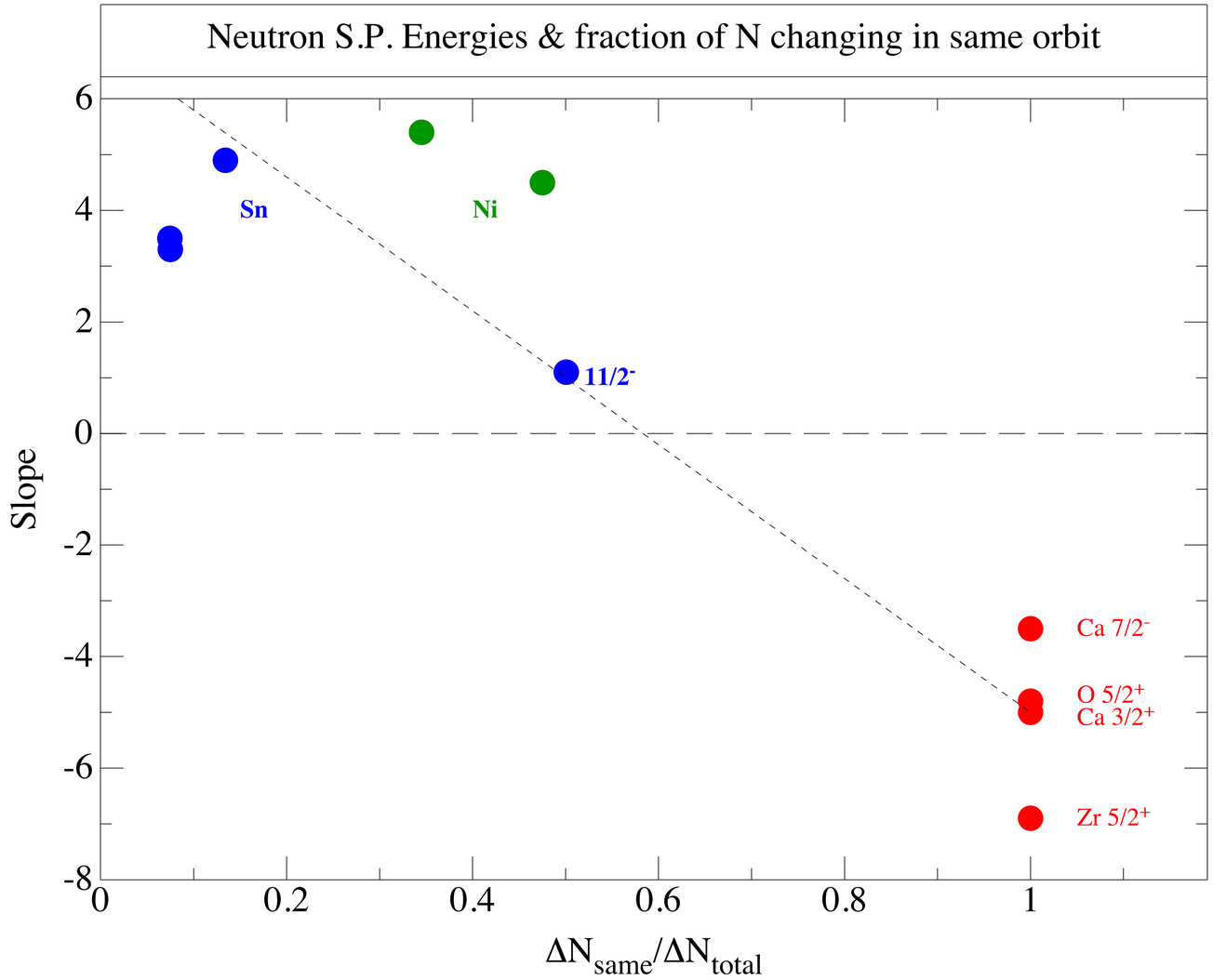


These trends fascinated John, where data and systematics connect his 1975 work with his later exploration of single-particle energies. He was adamant that there is much more to this yet to be explored …

Not the end ...


Neutron S.P. Energies & fraction of N changing in same orbit
Slope
6
4
2
0
-2
-4
-6
-8
0
0.2
0.4
0.6
0.8
1
ΔN_same/ΔN_total
Sn
Ni
11/2-
Ca 7/2-
O 5/2+
Ca 3/2+
Zr 5/2+

Not the end ...



(No idea what this means ...)

John in his own words (John on John)

Of his Bonner Prize work ...

"This is what I would probably consider the most significant contribution – but it is not the way theorists think about effective interaction. Our systematic collection of information still has the potential to lead to a major insight, in my view, ..."

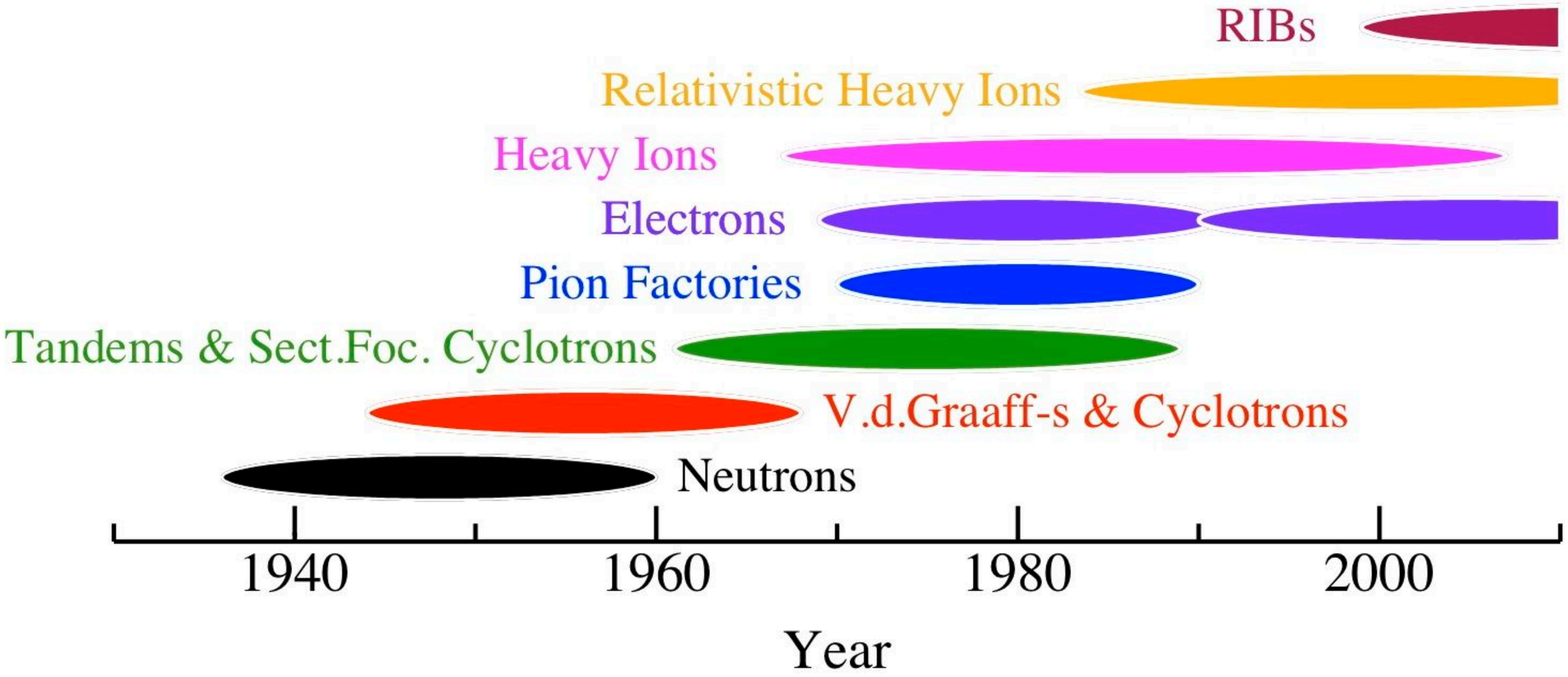
Of his 2000s work ...

"Recent precise work on transfer reactions to extract systematics in single particle energies and especially the evidence for a tensor term in the Hamiltonian that become evident in high-j orbits. Mapping out the Fermi surface in nuclei to try and constrain calculations of matrix elements for neutrinoless double beta decay, again by transfer reactions. Both of these latter two try to demonstrate how such transfer reactions should be done."

John in his own words (John on Irrationalities)

In the past decade colleagues from more than 20 institutions world-wide have collaborated with us on nuclear physics experiments at the Q3D alone. When our lab was closed in 2015 for half a year because of fire protection issues, a distinguished colleague from the Argonne National Laboratory, who has a really profound understanding of nuclear physics and who initiated the programme to determine single-particle occupancies in double-beta decay partners, commented [Sch15]: "I guess it seemed irrational some 40-50 years ago that there were suddenly so many tandems and cyclotrons built for nuclear structure around the world. But it is even more irrational now to see the world heading for literally NO capability in this field."

John in his own words (John on Fashion)



"I guess science is subject to the same human fashion sense as clothing."

Summary ... boundless curiosity and fascination

Glimpses into 1-2 examples of the major research programs John motivated

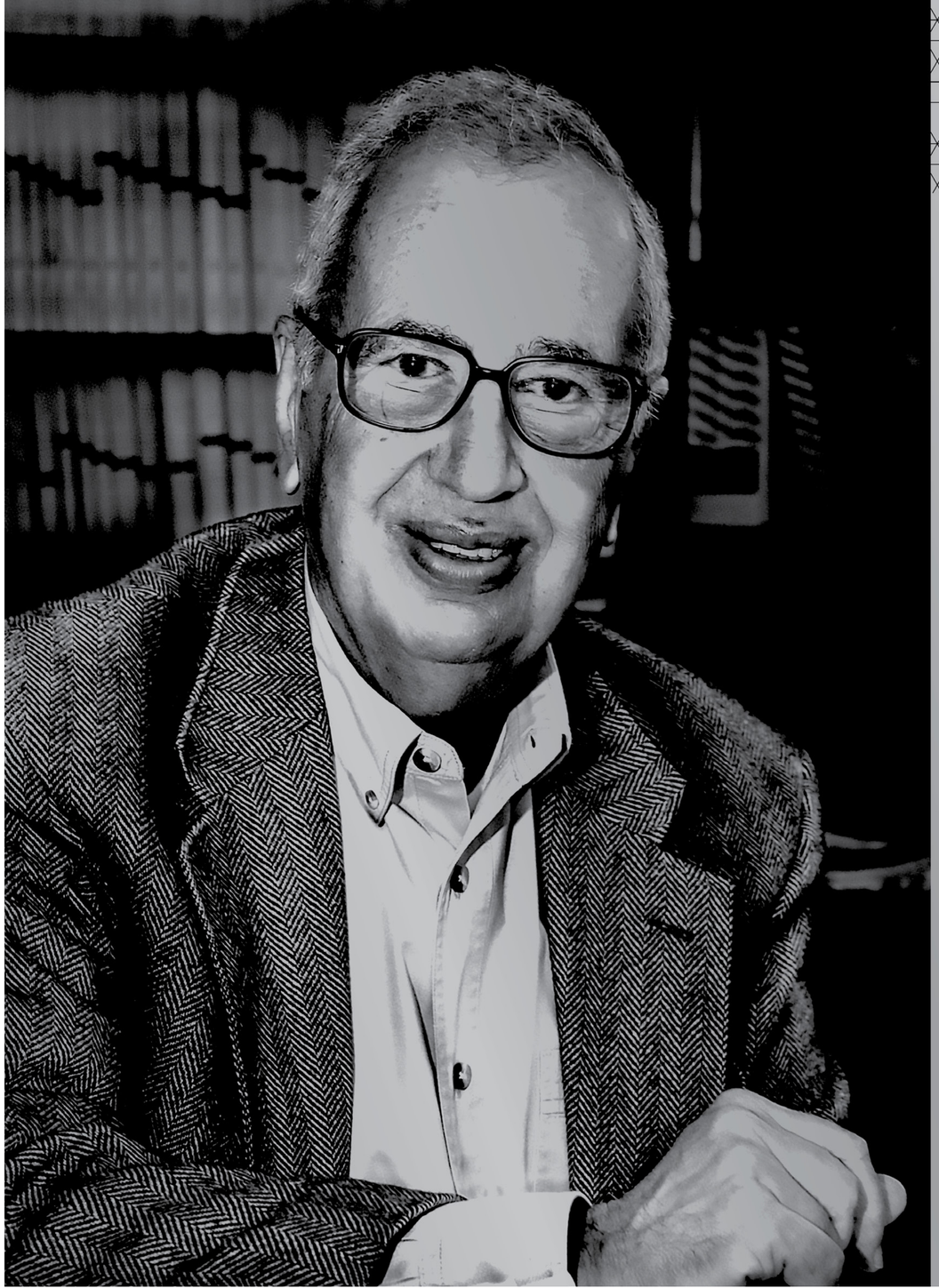
The impact of these works are front and central in the field today and will be for years to come (solenoidal spectrometers, quenching, weak binding, evolution of effective single-particle energies ... transfer reactions central to all)

His insight, deep thought, tinkering with data and trends, curiosity and fascination, lead to such rich outcomes -- extremely rare in the field

Thank you ...

... and thank you,
John P. Schiffer

(if you were a speaker, and he started to chew his glasses, you knew he was engaged [in a good or bad way] and likely a very challenging question was coming your way)



IN MEMORY OF

JOHN P. SCHIFFER

1930–2022

John was a member of the Physics Division from 1956 to 2022. He was the heart and soul of the division over this period, guiding not only its path but that of nuclear physics in the United States. His high scientific and ethical standards greatly influenced generations of physicists who passed through this room and these corridors.

Argonne NATIONAL LABORATORY