Eurorib'15, 9 June Hohenroda, Germany

Identification of deformed intruder states in semi-magic ^{70,72}Ni

W. B. Walters,[1] **C. J. Chiara**,[1,2,*] **R. V. F. Janssens**,[2] **C. Prokop**,[3] D. Weisshaar,[3] T. Otsuka,[3,4,5] Y. Tsunoda,[4] F. Recchia,[3,6] J. L. Harker,[1,2] A. Gade,[3,7] M. Albers,[2,†] M. Alcorta,[2,‡] V. M. Bader,[3,7,§] T. Baugher,[3,7,¶] D. Bazin,[3,7] J. S. Berryman,[3] P. F. Bertone,[2,**] C. M. Campbell,[8] M. P. Carpenter,[2] J. Chen,[9] H. L. Crawford,[8] H. M. David,[2,10] D. T. Doherty,[2,10,††] C. R. Hoffman,[2] M. Honma,[11] F. G. Kondev,[9] A. Korichi,[2,12] C. Langer,[3,13] N. Larson,[3,14] T. Lauritsen,[2] S. N. Liddick,[3,14] E. Lunderberg,[3,7] A. O. Macchiavelli,[8] S. Noji,[3] A. M. Rogers,[2,‡‡] D. Seweryniak,[2] N. Shimizu, R. Stroberg,[3,7 ‡] S. Suchyta,[3,14 §§] Y. Utsuno,[15] S. J. Williams,[3] K. Wimmer,[3,16] and S. Zhu[2]

[1] Department of Chemistry and Biochemistry, University of Maryland, College Park, Maryland 20742, USA
[2] Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA
[3] National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, Michigan 48824, USA
[4] Department of Physics, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[5] Center for Nuclear Study, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[6] Dipartimento di Fisica e Astronomia, Universit`a degli Studi di Padova, I-35131 Padova, Italy
[7] Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan 48824, USA
[8] Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA
[9] Nuclear Engineering Division, Argonne National Laboratory, Argonne, Illinois 60439, USA
[10] School of Physics and Astronomy, University of Edinburgh, Edinburgh, EH9 3JZ, UK
[11] Center for Mathematical Sciences, University of Aizu, Aizu-Wakamatsu, Fukushima 965-8580, Japan
[12] CSNSM-IN2P3/CNRS, F-91405 Orsay Campus, France
[13] Joint Institute for Nuclear Astrophysics, Michigan State University, East Lansing, Michigan 48824, USA
[14] Department of Chemistry, Michigan State University, East Lansing, Michigan 48824, USA
[15] Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Ibaraki 319-1195, Japan
[16] Department of Physics, Central Michigan University, Mt. Pleasant, Michigan 48859, USA

*Present address: U.S. Army Research Laboratory, Adelphi, Maryland 20783, USA
†Present address: Ernst & Young GmbH, Mergenthalerallee 3-5, 65760 Eschborn/Frankfurt (Main), Germany
‡Present address: TRIUMF, Vancouver, British Columbia V6T 2A3, Canada
§Present address: Patentanwälte Maikowski & Ninnemann, Kurfürstendamm 54-55, 10707 Berlin, Germany
¶Present address: Department of Physics and Astronomy, Rutgers University, Piscataway, New Jersey 08854-8019, USA
**Present address: Marshall Space Flight Center, Huntsville, Alabama 35812, USA
††Present address: CEA Saclay, Gif-sur-Yvette 91191, France
‡‡Present address: Department of Physics, University of Massachusetts Lowell, Lowell, Massachusetts 01854, USA
§§Present address: Department of Nuclear Engineering, University of California Berkeley, Berkeley, California 94720, USA

Based on work supported in part by the USDOE (DE-FG02-94ER40834, DE-AC02-06CH11357, DE- AC02-05CH11231), NSF (PHY-1102511), and NNSA (DE-NA0000979).

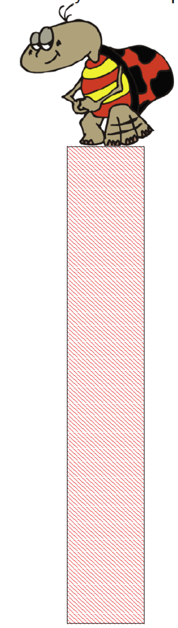
Shape coexistence in $^{66,68,70,72}Ni_{38,40,42,44}$

The identification of a deep deformed prolate minimum in $^{70}Ni_{42}$

The hero of this story is the 2_2^+ level at 1868 in $^{70}Ni_{42}$.

This material is based upon work supported by the National Science Foundation under contract NSF-06067007 (NSCL), the U.S. Department of Energy, National Nuclear Security Administration under Award Nos. DE-FC03-03NA00143, DE-NA0000979, the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Grant Numbers. DE-FG02-94ER40834 (Maryland), DE-FG02-96ER40983 (UT), DE-AC05-060R23100 (ORAU), and, under Contract Number DE-AC02-06CH11357 (ANL) and DE-AC05-00OR22725 (ORNL). This research used resources of ANL's ATLAS facility, which is a DOE Office of Science User Facility.

An old Maryland Terrapin saying:



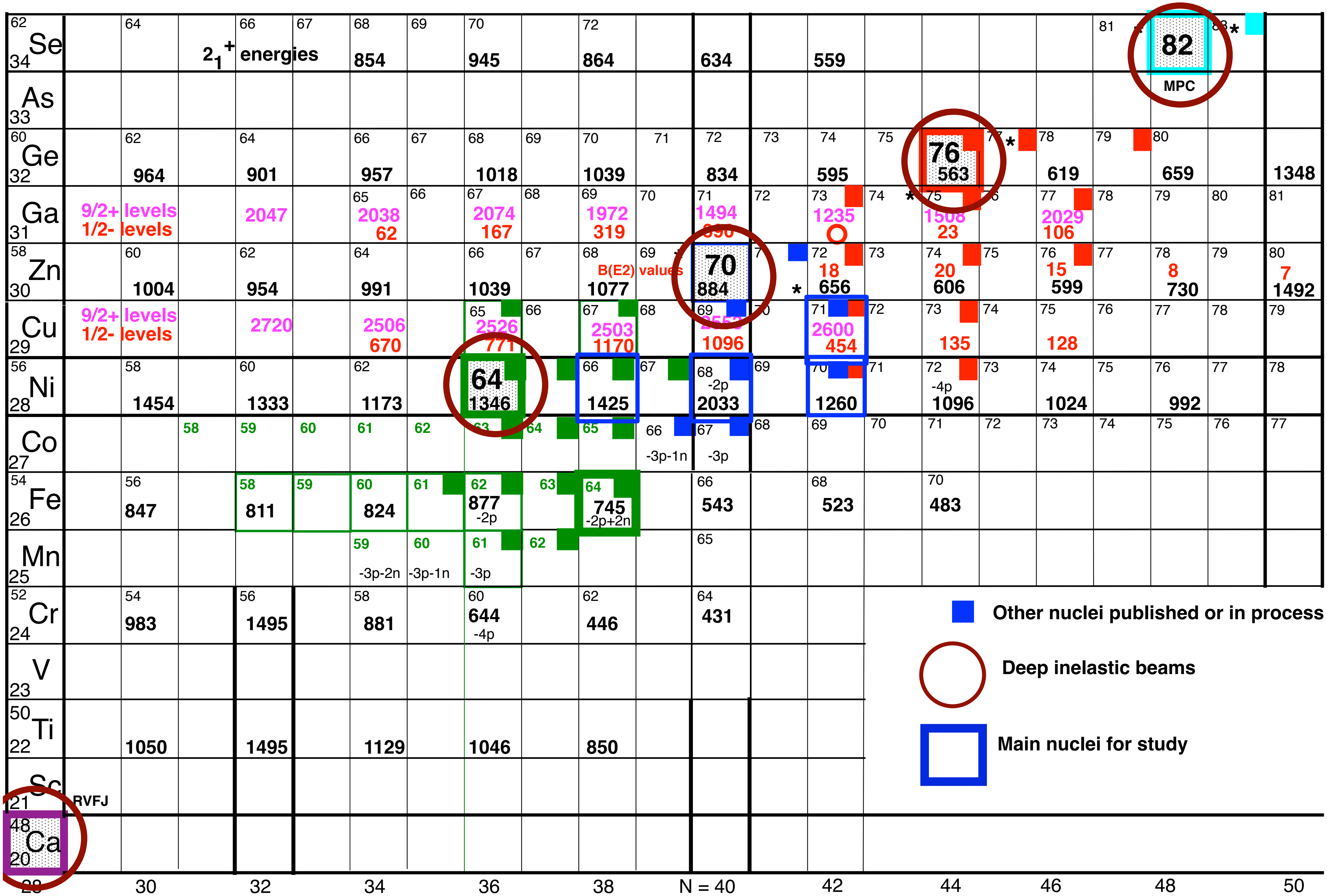
When you see a turtle up on a pole, you can conclude that he had a lot of HELP GETTING THERE!!!!

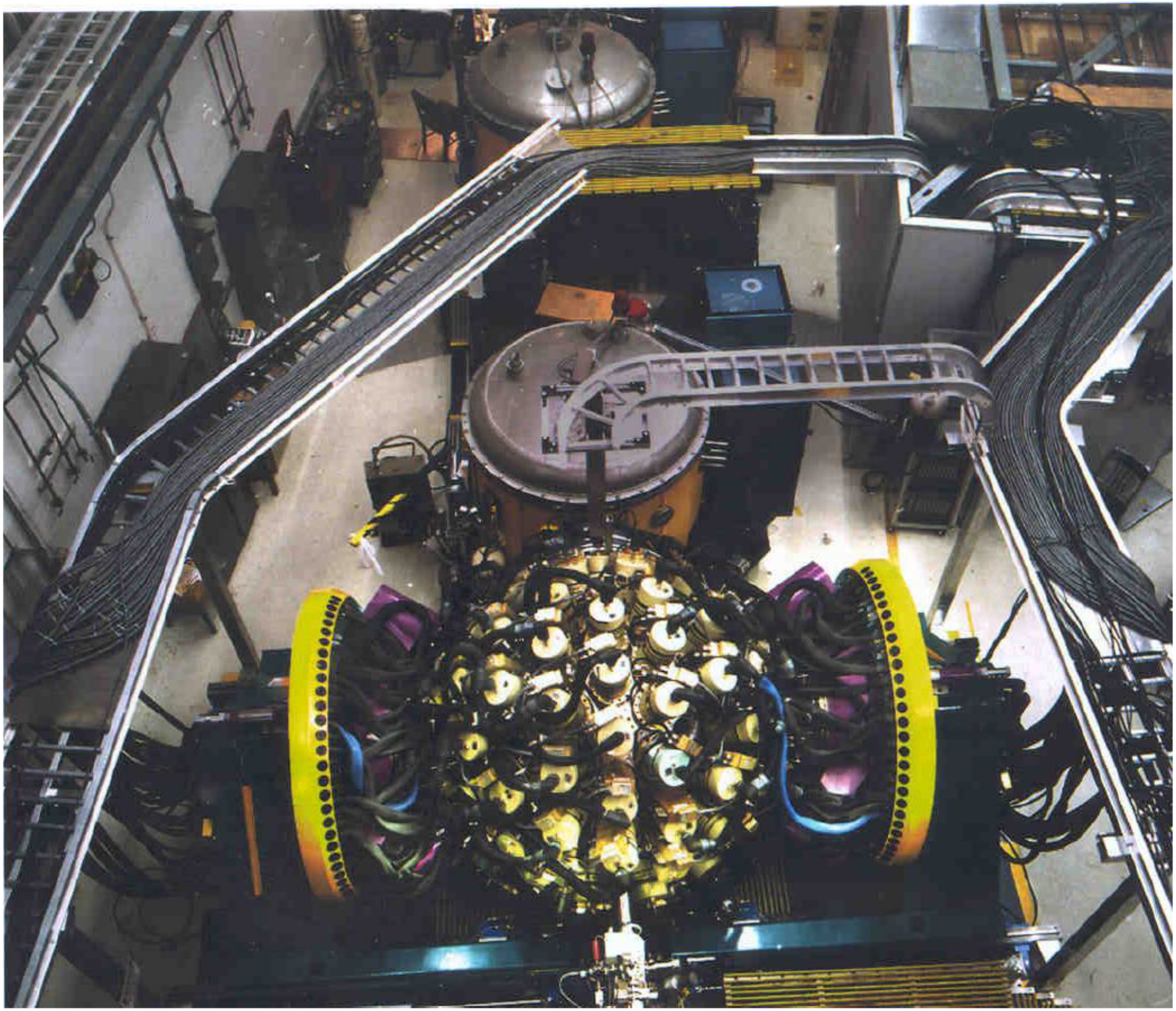
This work was supported in part by the US Department of Energy, Office of Nuclear Physics, under Grant No. DE-FG02-94-ER40834 and Contract No. DE-AC02-06CH11357, by FWO-Vlaanderen (Belgium), GOA/2004/03 (BOF-K. U. Leuven), the 'Interuniversity Attraction Poles Programme-Belgian 044309-14 State-Belgian Science Policy' (BriX network P6/23), the European Commission within the Sixth Framework Programme through I3-EURONS (contract no. RII3-CT-2004- 506065), and by the Polish Ministry of Science under Contracts No. 1P03B05929 and No. NN202103333.

The University of Maryland is located inside the Capital Beltway around Washington, DC.

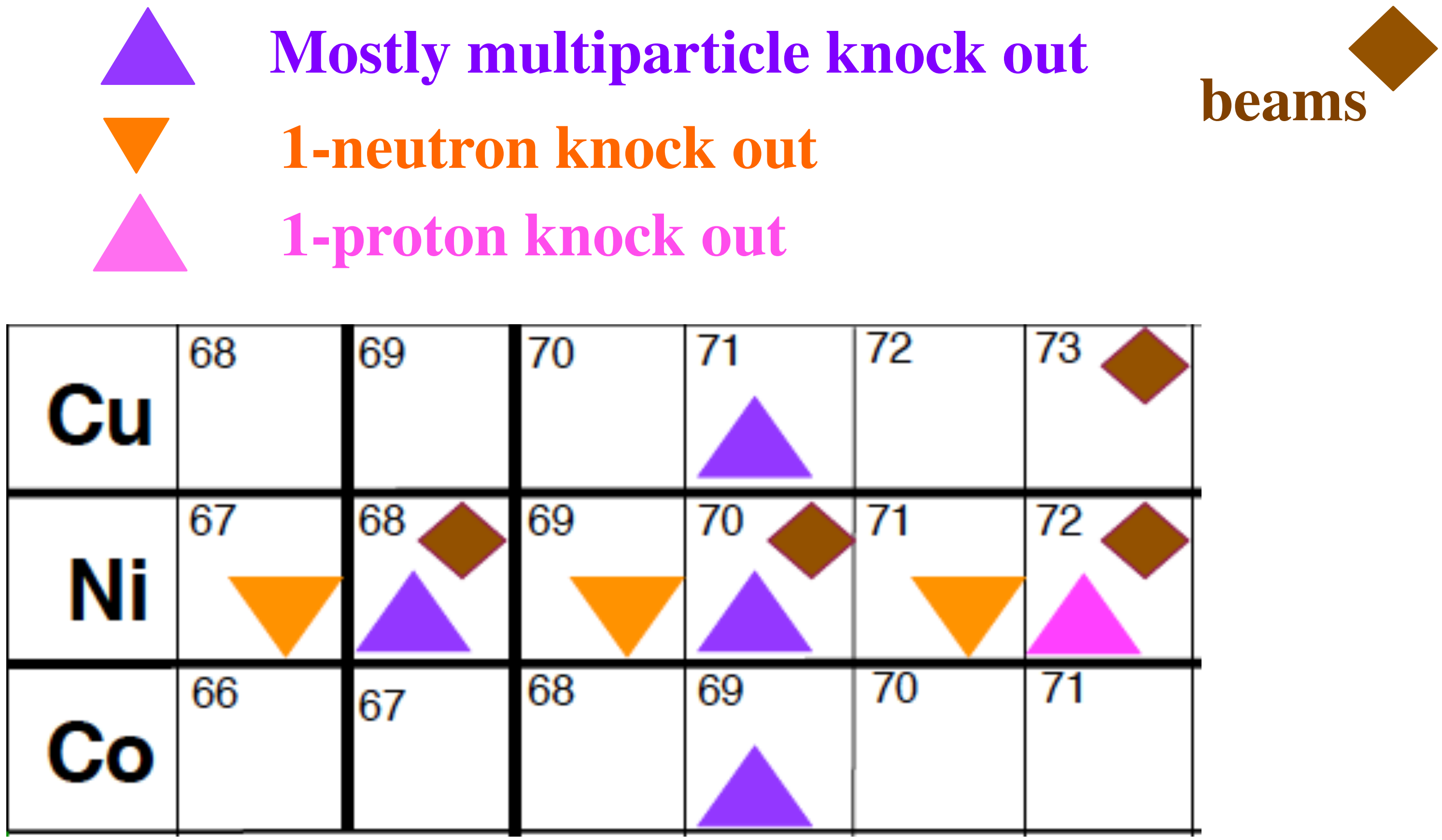
The ANL-Gammasphere deep inelastic reaction data sets

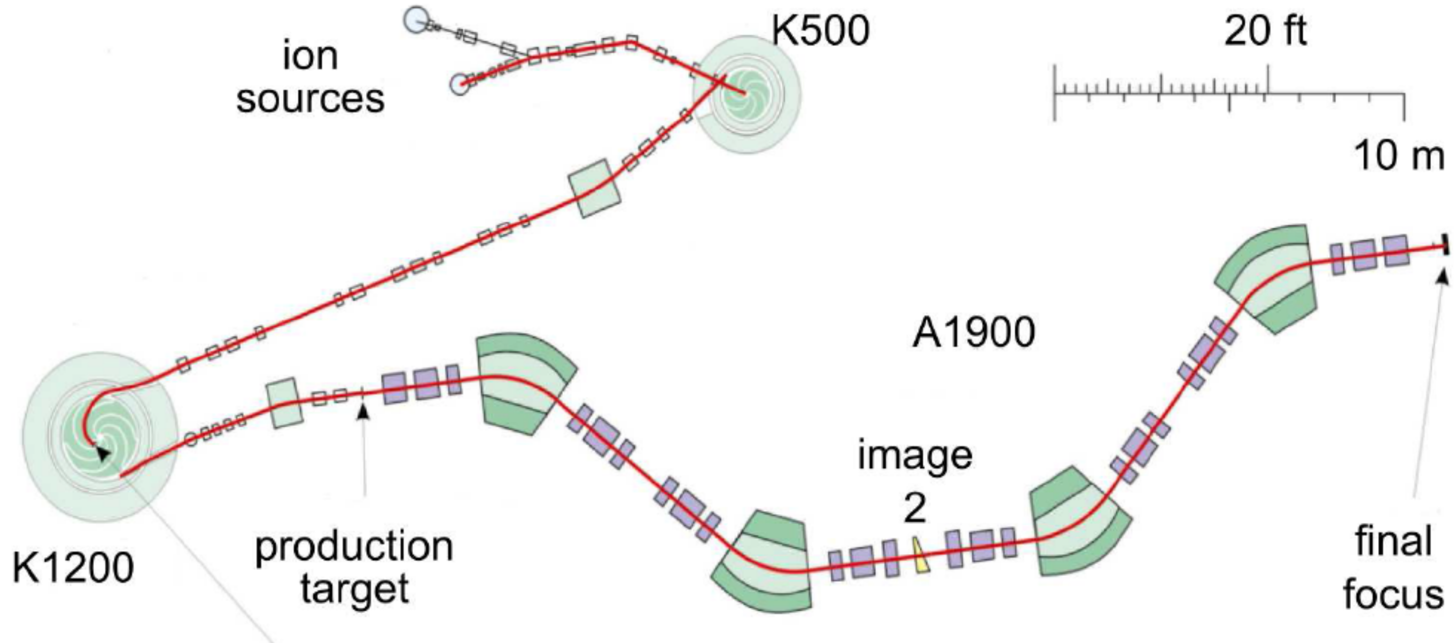
$^{198}Pt, ^{197}Au, ^{208}Pb, ^{238}U$ targets



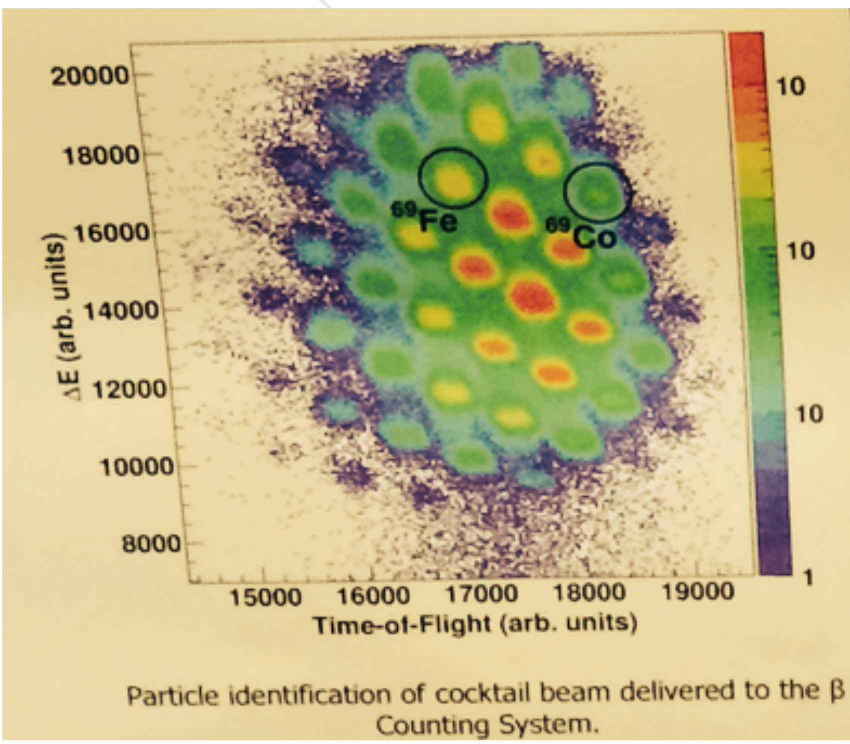


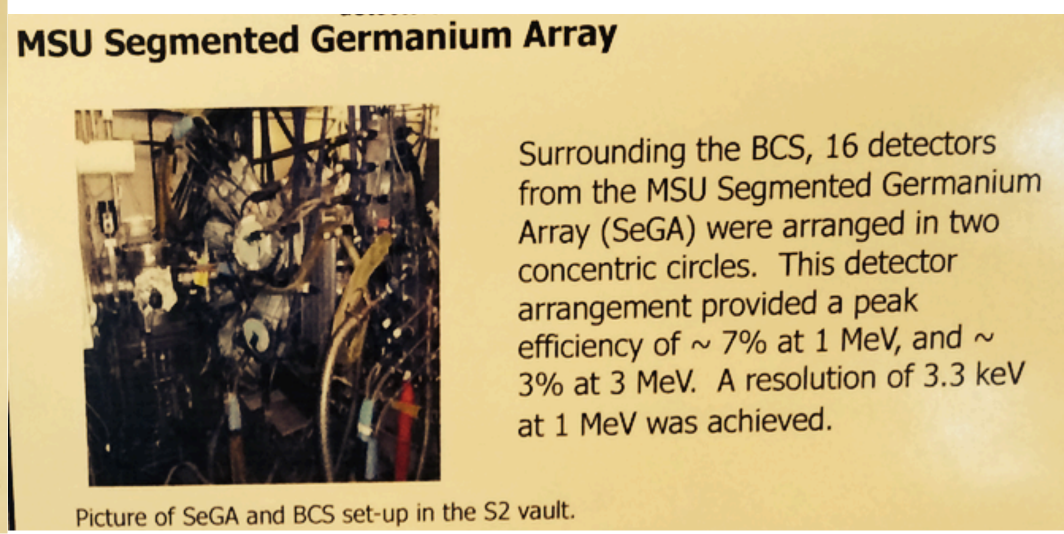
Data from knock-out reactions at NSCL with GRETINA.

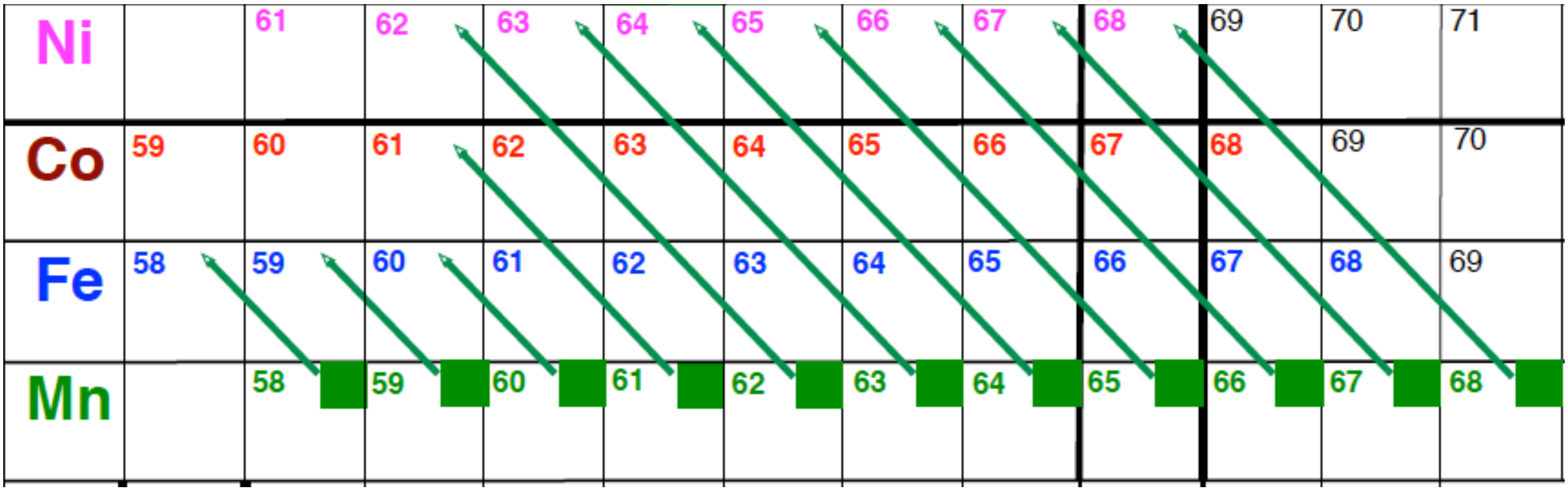




MSU beta-counting system







PHYSICAL REVIEW C **91**, 034310 (2015)

Characterization of the low-lying 0^+ and 2^+ states in ^{68}Ni via β decay of the low-spin ^{68}Co isomer

F. Flavigny,[1,*] D. Pauwels,[1] D. Radulov,[1] I. J. Darby,[1] H. De Witte,[1] J. Diriken,[1,2] D. V. Fedorov,[3] V. N. Fedosseev,[4] L. M. Fraile,[5] M. Huyse,[1] V. S. Ivanov,[3] U. Köster,[6] B. A. Marsh,[4] T. Otsuka,[7,8] L. Popescu,[2] R. Raabe,[1] M. D. Seliverstov,[1,3,9] N. Shimizu,[7] A. M. Sjödin,[4] Y. Tsunoda,[8] P. Van den Bergh,[1] P. Van Duppen,[1] J. Van de Walle,[10] M. Venhart,[1,11] W. B. Walters,[12] and K. Wimmer[8,13]

Beta-decay data for $^{58\text{-}68}$Mn nuclei, followed with a digital system from each Mn isobar to the stable or long-lived Ni nuclei. The data were taken at CERN/ISOLDE using the Resonance Ionization Laser Ion Source and the ISOLDE Decay Station with Leuven digital electronics. These data are from the Ph. D. theses of Dieter Pauwels and Deyan Radulov, as well as Madrid collaborators.

PHYSICAL REVIEW C, VOLUME 61, 054308

β decay of ^{66}Co, ^{68}Co, and ^{70}Co

W. F. Mueller,* B. Bruyneel, S. Franchoo,† M. Huyse, J. Kurpeta, K. Kruglov, Y. Kudryavtsev, N. V. S. V. Prasad, R. Raabe, I. Reusen, P. Van Duppen, J. Van Roosbroeck, L. Vermeeren, and L. Weissman†
Instituut voor Kern- en Stralingsfysica, University of Leuven, B-3001 Leuven, Belgium

Z. Janas, M. Karny, T. Kszczot, and A. Płochocki
Insitute of Experimental Physics, Hoza 69, 00-681 Warsaw, Poland

K.-L. Kratz and B. Pfeiffer
Institut für Kernchemie, Universität Mainz, D-55099 Mainz, Germany

H. Grawe
Gesellschaft für Schwerionenforschung, D-64291, Darmstadt, Germany

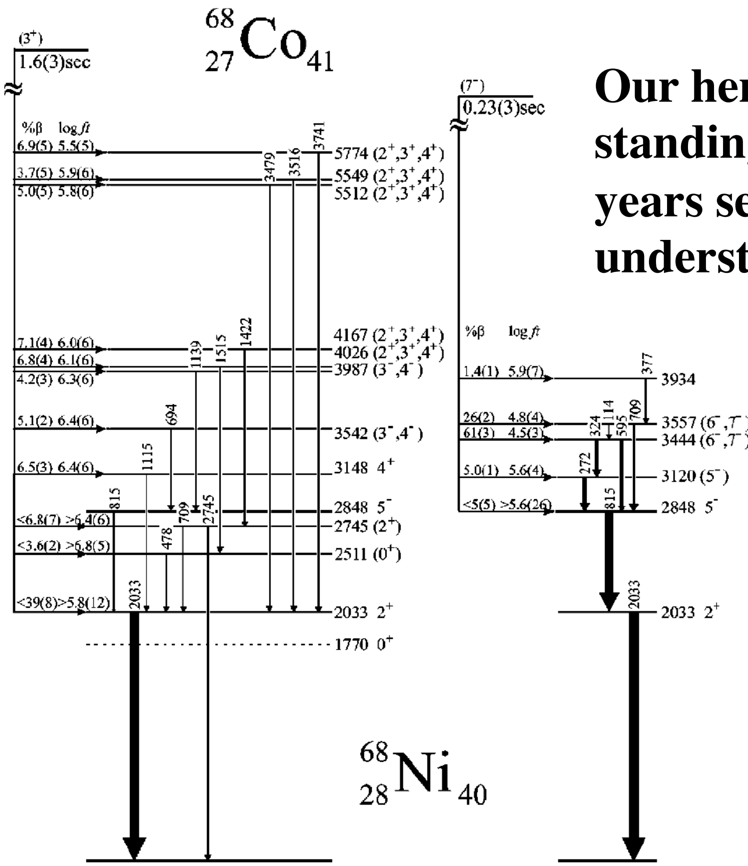
U. Köster
Physik-Department, Technische Universität München, D-85748 Garching, Germany

P. Thirolf
Sektion Physik, Universität München, D-85748 Garching, Germany

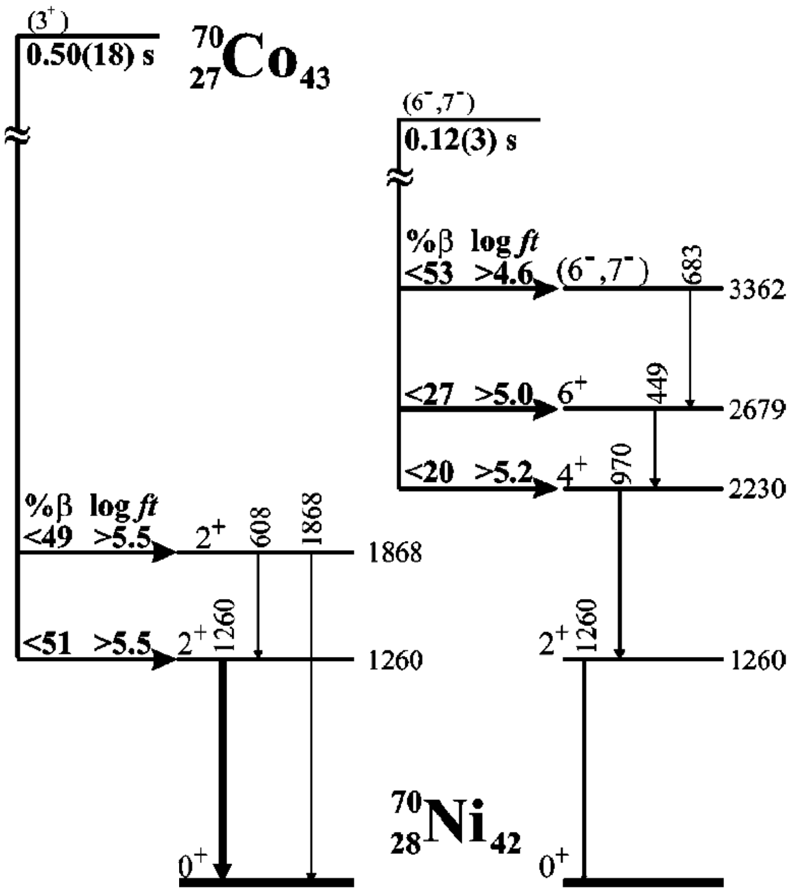
W. B. Walters
Department of Chemistry, University of Maryland, College Park, Maryland 20742

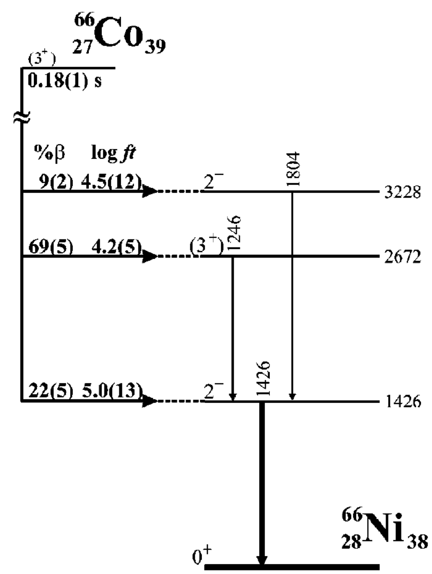
(Received 29 November 1999; published 21 April 2000)

Nov 1999

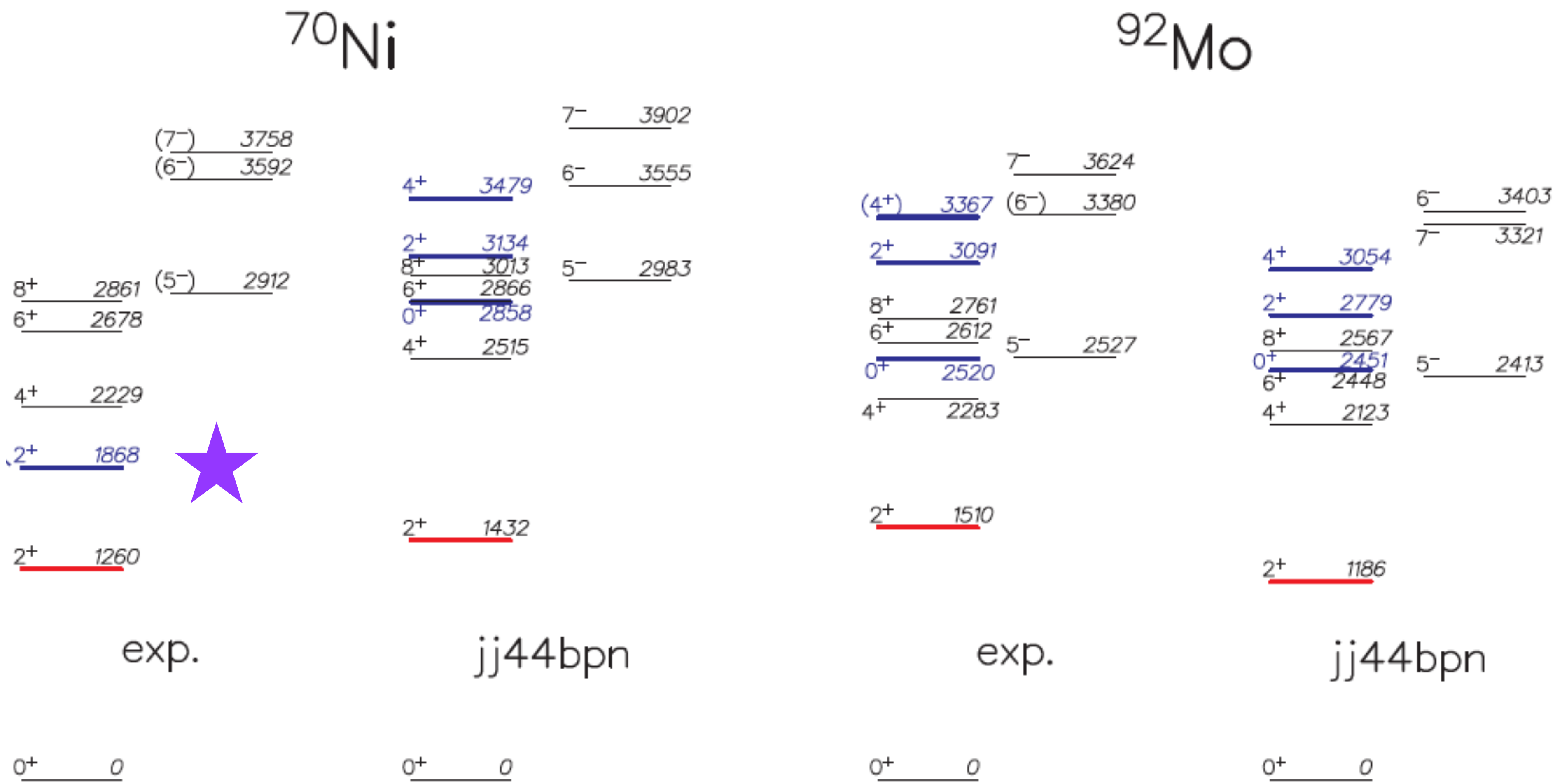


Our hero has been standing here for 16 years seeking an understanding.





Few models with neutron valence spaces showed a 2_2^+ level below 2 or even 3 MeV, nor was such a state observed in Z = 42 ^{92}Mo. In other words, neither systematics nor neutron-valence-space models could account for this state at 1868 keV.



VOLUME 84, NUMBER 1 PHYSICAL REVIEW LETTERS 3 JANUARY 2000

Core-Excited States in the Doubly Magic ^{68}Ni and its Neighbor ^{69}Cu

T. Ishii,[1] M. Asai,[1] A. Makishima,[2] I. Hossain,[3] M. Ogawa,[3] J. Hasegawa,[3] M. Matsuda,[1] and S. Ichikawa[1]
[1]*Advanced Science Research Center, Japan Atomic Energy Research Institute, Tokai, Ibaraki 319-1195, Japan*
[2]*Department of Liberal Arts and Sciences, National Defense Medical College, Tokorozawa, Saitama 359-8513, Japan*
[3]*Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology, Meguro, Tokyo 152-8550, Japan*
(Received 7 June 1999)

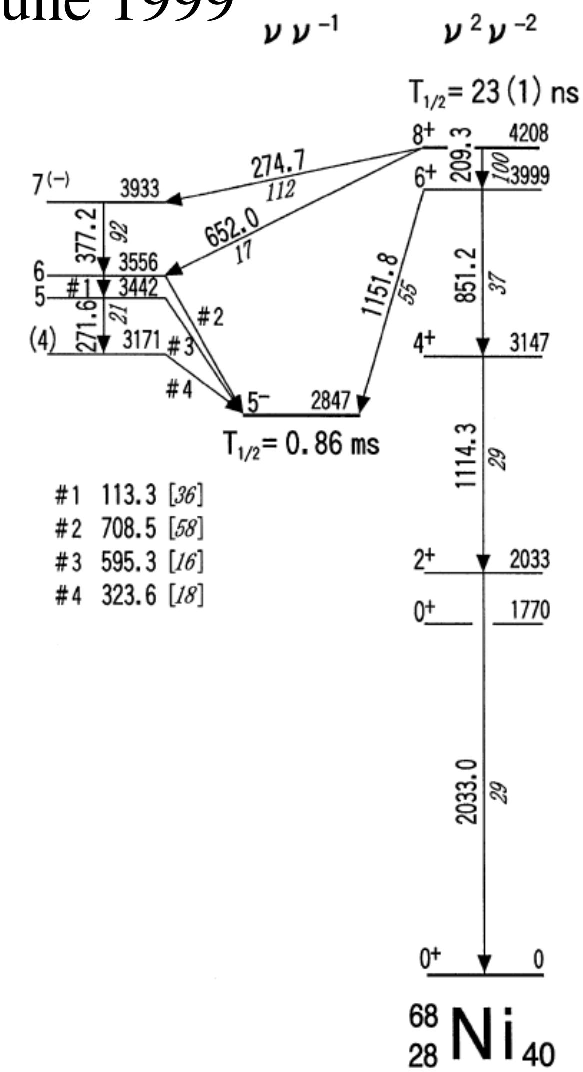
In deep-inelastic collisions of 8 MeV/nucleon ^{70}Zn projectiles with ^{198}Pt, we have found an 8^+ isomer

PHYSICAL REVIEW C **86**, 064312 (2012)

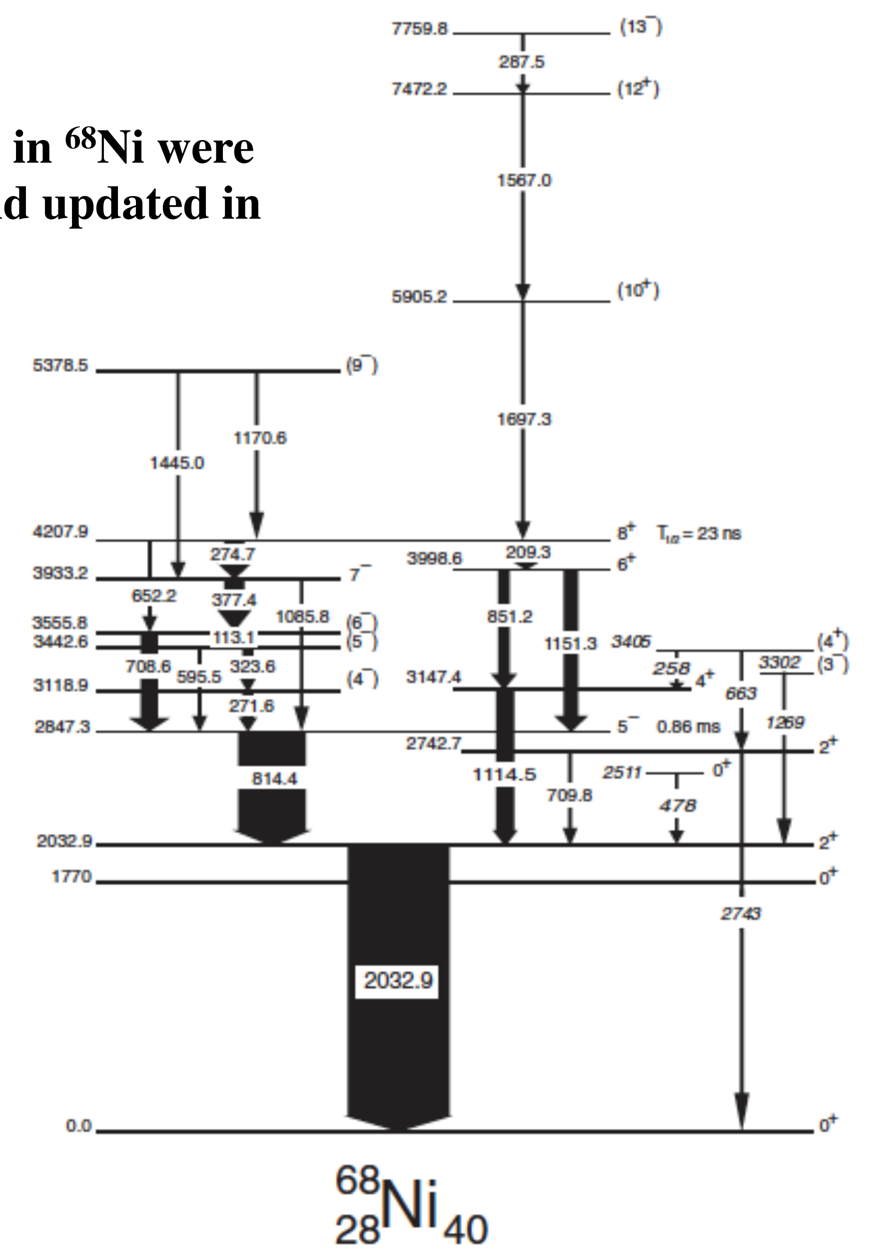
Spectroscopic study of the ^{64,66,68}Ni isotopes populated in ^{64}Ni + ^{238}U collisions

R. Broda,[1] T. Pawłat,[1] W. Królas,[1] R. V. F. Janssens,[2] S. Zhu,[2] W. B. Walters,[3] B. Fornal,[1] C. J. Chiara,[2,3] M. P. Carpenter,[2] N. Hoteling,[3] Ł. W. Iskra,[1] F. G. Kondev,[4] T. Lauritsen,[2] D. Seweryniak,[2] I. Stefanescu,[2,3] X. Wang,[2] and J. Wrzesiński[1]

June 1999



Higher spin state in ^{68}Ni were studied then…and updated in 2012.

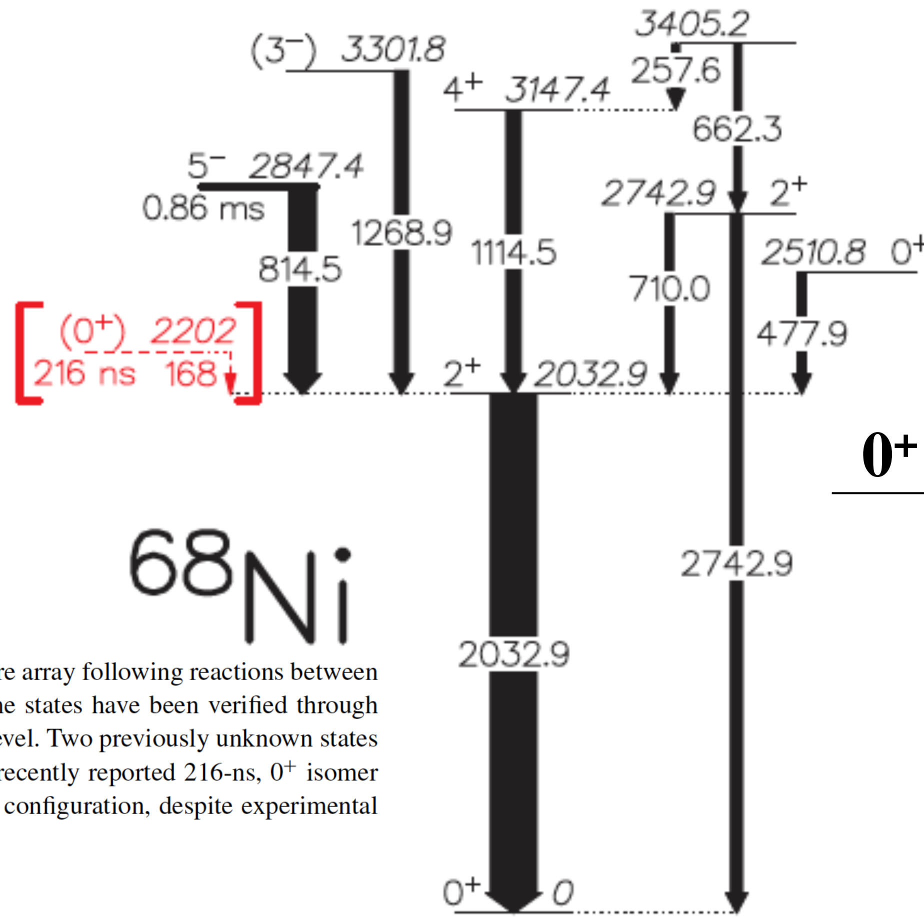


PHYSICAL REVIEW C **86**, 041304(R) (2012)

Low-spin states and the non-observation of a proposed 2202-keV, 0^+ isomer in ^{68}Ni

C. J. Chiara,[1,2] R. Broda,[3] W. B. Walters,[1] R. V. F. Janssens,[2] M. Albers,[2] M. Alcorta,[2] P. F. Bertone,[2] M. P. Carpenter,[2] C. R. Hoffman,[2] T. Lauritsen,[2] A. M. Rogers,[2,*] D. Seweryniak,[2] S. Zhu,[2] F. G. Kondev,[4] B. Fornal,[3] W. Królas,[3] J. Wrzesiński,[3] N. Larson,[5] S. N. Liddick,[5] C. Prokop,[5] S. Suchyta,[5] H. M. David,[2,6] and D. T. Doherty[2,6]
[1]*Department of Chemistry and Biochemistry, University of Maryland, College Park, Maryland 20742, USA*
[2]*Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA*
[3]*Niewodniczański Institute of Nuclear Physics PAN, PL-31342 Kraków, Poland*

Then, more detailed studies were performed on 68Ni that led to the rather firm identification of THREE 0^+ levels our of the first four states, 0^+ 0^+ 2^+ 0^+.



0^+ 1604

The low-spin level scheme of ^{68}Ni was investigated with the Gammasphere array following reactions between a ^{70}Zn beam and ^{238}U, ^{208}Pb, and ^{197}Au targets. Spin assignments for some states have been verified through γ-ray angular correlations, including the 0^+ assignment for the 2511-keV level. Two previously unknown states at 3302 and 3405 keV have been identified. No evidence was found for a recently reported 216-ns, 0^+ isomer at 2202 keV that was attributed to a proton two-particle, two-hole intruder configuration, despite experimental conditions similar to those used in the measurement reporting its discovery.

FIG. 3. (Color online) Partial, low-spin level scheme of ^{68}Ni from the present study. The 168-keV isomeric transition proposed in Ref. [21] was *not* observed in this work but is indicated for reference.

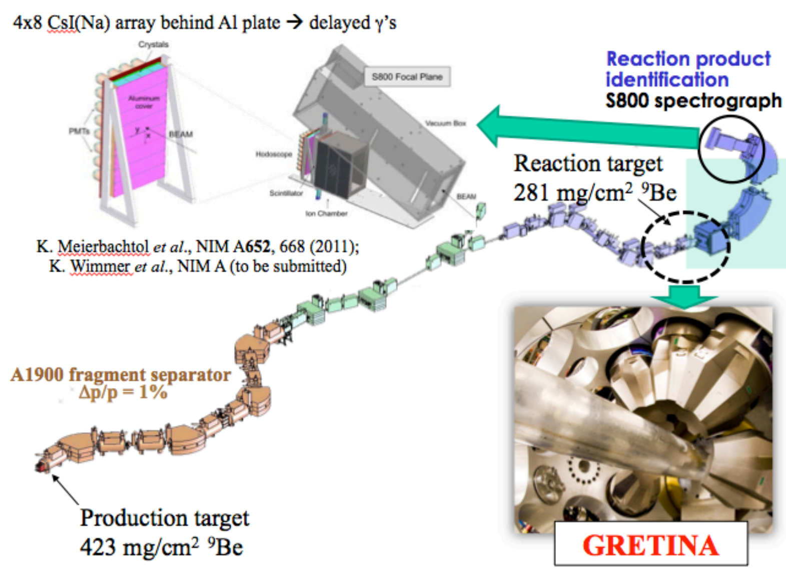
^{68}Ni was also produced in two-neutron knockout (2nKO) reactions at the Coupled Cyclotron Facility of the National Superconducting Cyclotron Laboratory (NSCL). A secondary cocktail beam containing ^{70}Ni, ^{69}Co, and ^{71}Cu ions was produced in the projectile fragmentation of a 140-MeV/u ^{82}Se beam on a 423-mg/cm^2 ^{9}Be production target located at the entrance of the A1900 fragment separator [18]. The momentum acceptance of the separator was set to 1%. Secondary beams with typical intensities of 10^5 ions/s were delivered to the experimental area and impinged upon a 281-mg/cm^2 ^{9}Be reaction target located at the pivot point of the S800 spectrograph [19] to induce knockout reactions at a midtarget energy of 75 MeV/u. Reaction products were identified on an event-by-event basis at the S800 focal plane [19]. The high-resolution γ-ray detection system GRETINA [20,21], an array of 36-fold segmented HPGe detectors, surrounded the S800 target position and was used to detect prompt γ rays emitted by the projectile-like reaction residues. The GRETINA quadruple-crystal detector modules were arranged in two rings, with four detectors located at 58° and three at 90° with respect to the beam axis. Signal decomposition [21] provided sub-segment spatial resolution used for the event-by-event Doppler reconstruction of the γ rays emitted in flight by the projectile-like reaction products. The photopeak efficiency of the detector array was calibrated with standard sources and corrected for the Lorentz boost of the γ-ray distribution emitted by the recoils moving at velocity 0.38c. Finally, delayed γ rays could also be identified within a 0.4- to 25-μs time window following implantation of the ions in an Al plate in front of a 4 × 8 array of CsI(Na) detectors located behind the focal plane of the S800 spectrograph [22,23].

RAPID COMMUNICATIONS

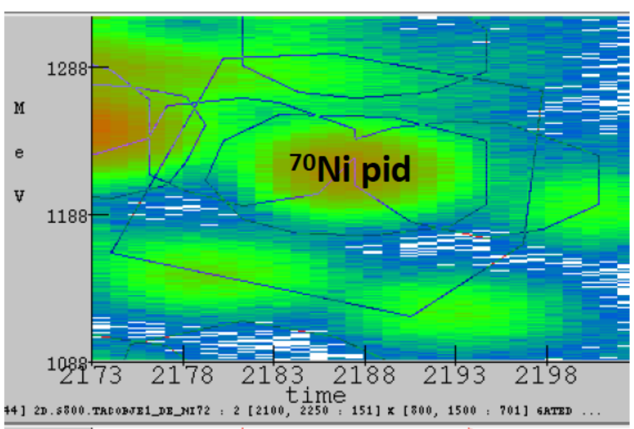
PHYSICAL REVIEW C **88**, 041302(R) (2013)

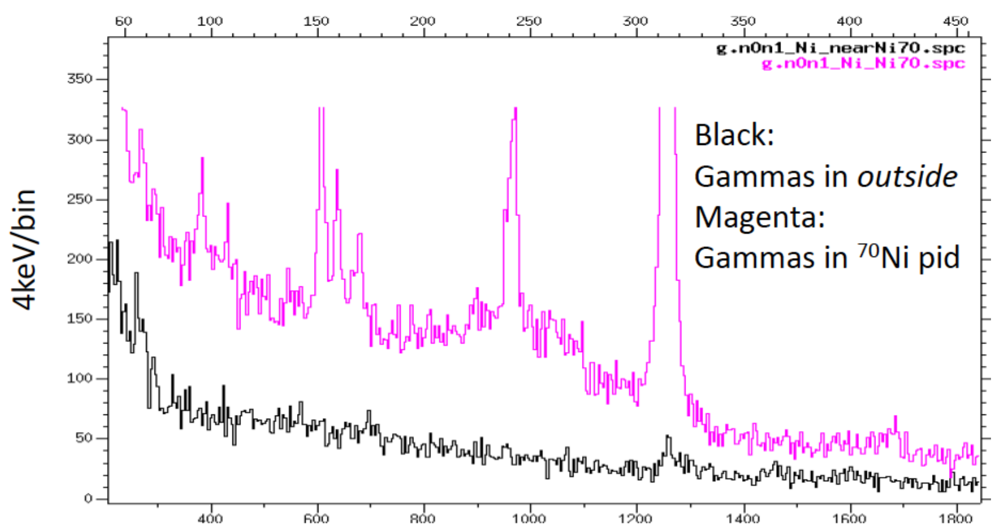
Configuration mixing and relative transition rates between low-spin states in ^{68}Ni

F. Recchia,[1,*] C. J. Chiara,[2,3] R. V. F. Janssens,[3] D. Weisshaar,[1] A. Gade,[1,4] W. B. Walters,[2] M. Albers,[3] M. Alcorta,[3] V. M. Bader,[1,4] T. Baugher,[1,4] D. Bazin,[1] J. S. Berryman,[1] P. F. Bertone,[3,†] B. A. Brown,[1,4] C. M. Campbell,[5] M. P. Carpenter,[3] J. Chen,[6] H. L. Crawford,[5] H. M. David,[3,7] D. T. Doherty,[3,7] C. R. Hoffman,[3] F. G. Kondev,[6] A. Korichi,[3,8] C. Langer,[1] N. Larson,[1,9] T. Lauritsen,[3] S. N. Liddick,[1,9] E. Lunderberg,[1,4] A. O. Macchiavelli,[5] S. Noji,[1] C. Prokop,[1,9] A. M. Rogers,[3,‡] D. Seweryniak,[3] S. R. Stroberg,[1,4] S. Suchyta,[1,9] S. Williams,[1] K. Wimmer,[1,10] and S. Zhu[3]



GRETINA:
- 7 detector modules
- 4 HPGe crystals per module
- 6x6 segmentation of each crystal
- Signal decomposition provides sub-segment position resolution
- Detected prompt γ's





PHYSICAL REVIEW C **89**, 021301(R) (2014)

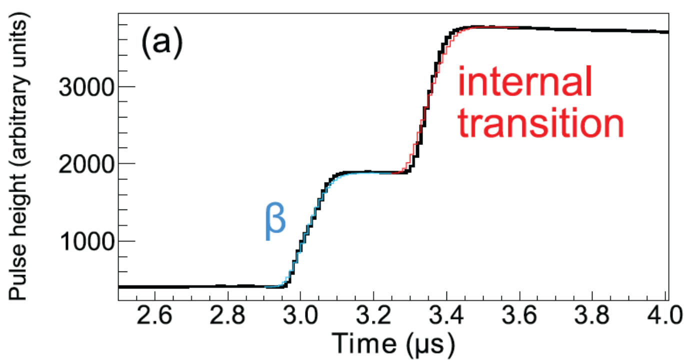
Shape coexistence in ^{68}Ni

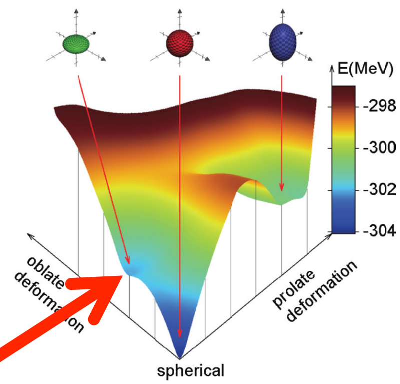
S. Suchyta,[1,2] S. N. Liddick,[1,2] Y. Tsunoda,[3] T. Otsuka,[1,3,4,5] M. B. Bennett,[1,4] A. Chemey,[1] M. Honma,[6] N. Larson,[1,2] C. J. Prokop,[1,2] S. J. Quinn,[1,4] N. Shimizu,[5] A. Simon,[1] A. Spyrou,[1,4] V. Tripathi,[7] Y. Utsuno,[8] and J. M. VonMoss[7]

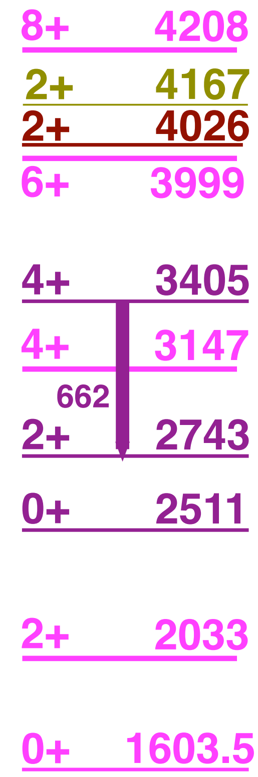
PHYSICAL REVIEW C **89**, 031301(R) (2014)

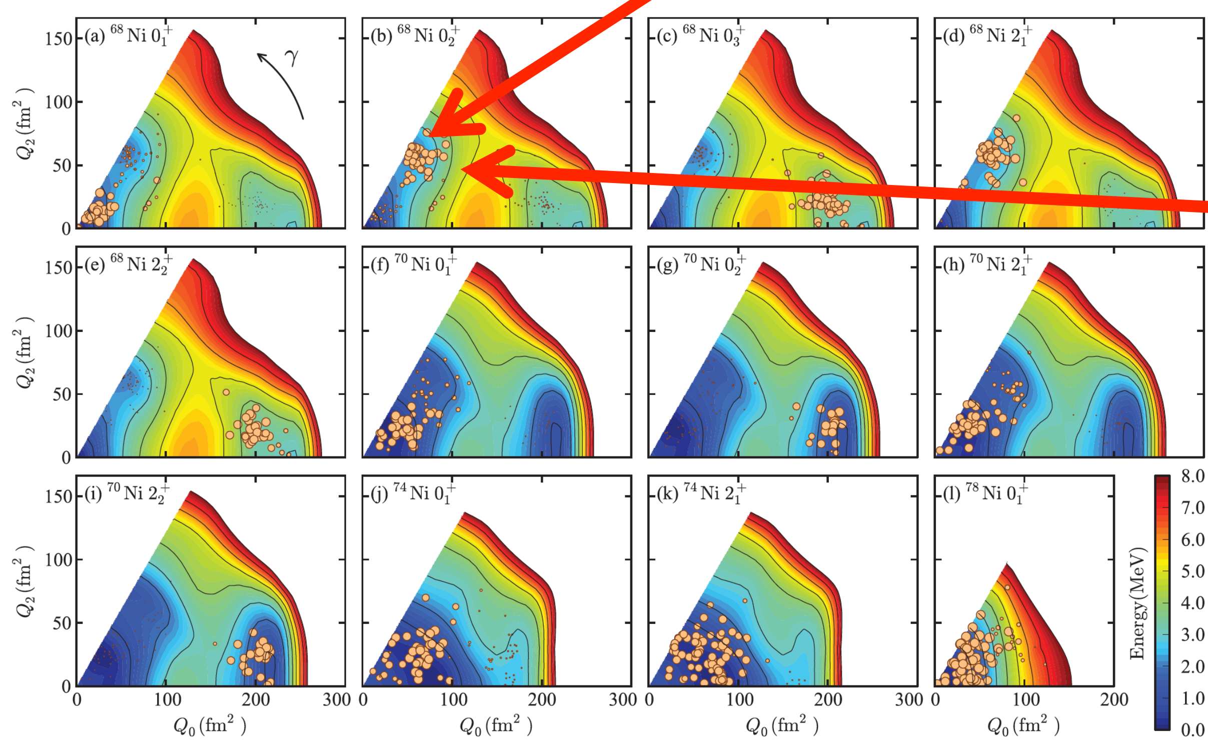
Novel shape evolution in exotic Ni isotopes and configuration-dependent shell structure

Yusuke Tsunoda,[1] Takaharu Otsuka,[1,2,3] Noritaka Shimizu,[2] Michio Honma,[4] and Yutaka Utsuno[5]

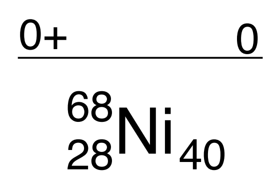








In all of this renewed work, the exact position of the 0_2^+ level was identified at 1603.5 keV.



PHYSICAL REVIEW C **89**, 021301(R) (2014)

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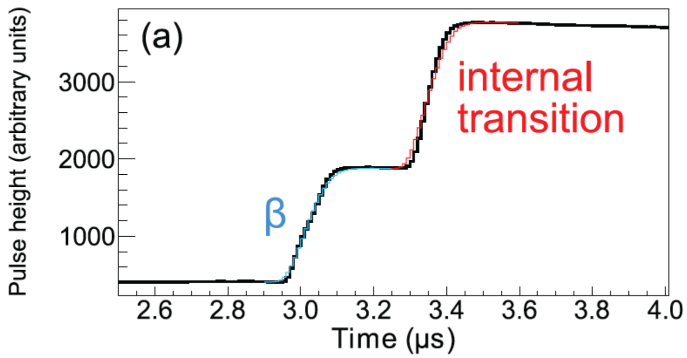

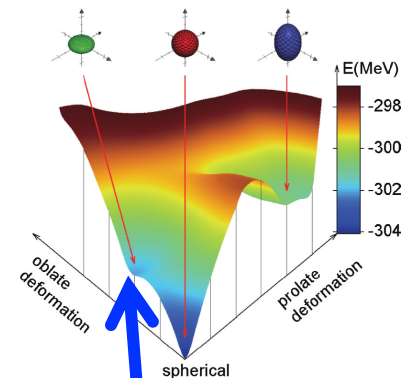

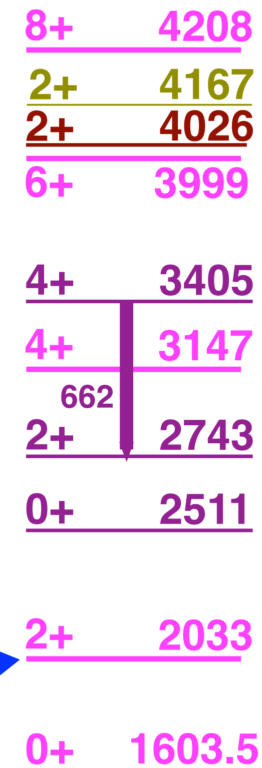

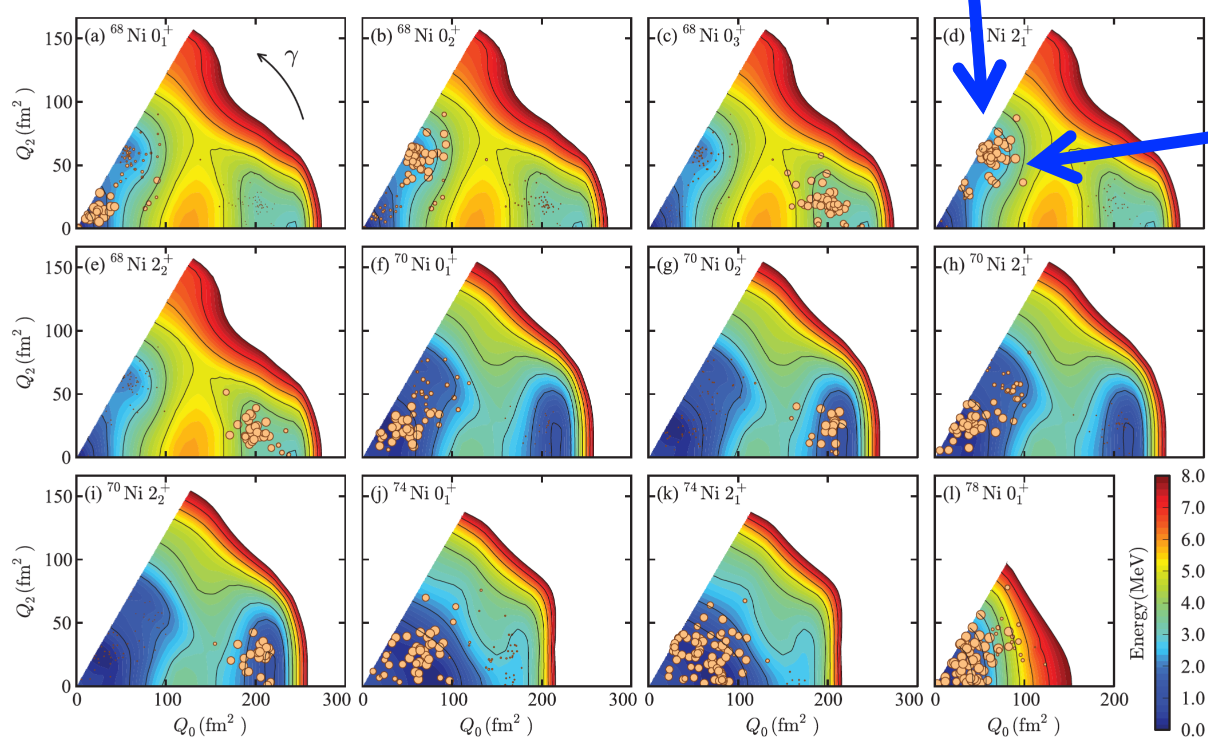

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0+ 0

$^{68}_{28}\mathrm{Ni}_{40}$

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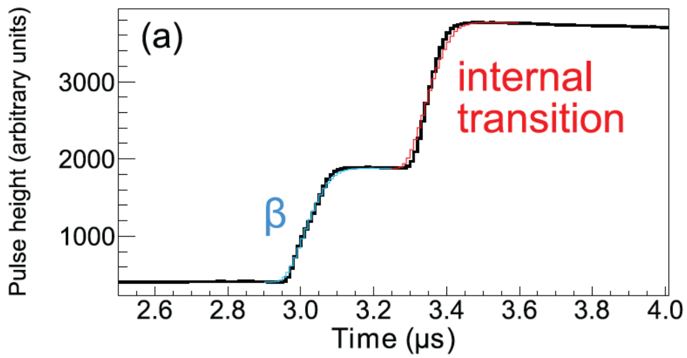
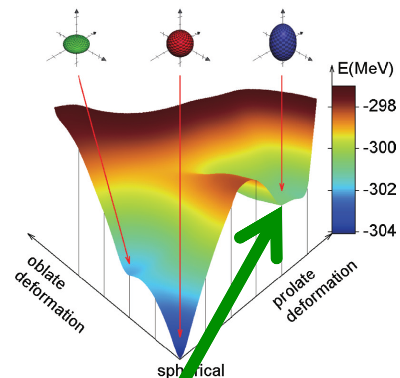
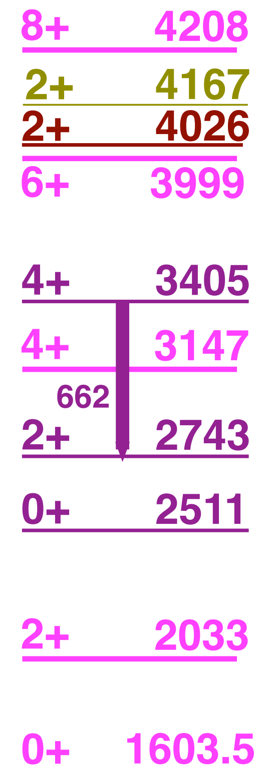
Novel shape evolution in exotic Ni isotopes and configuration-dependent shell structure

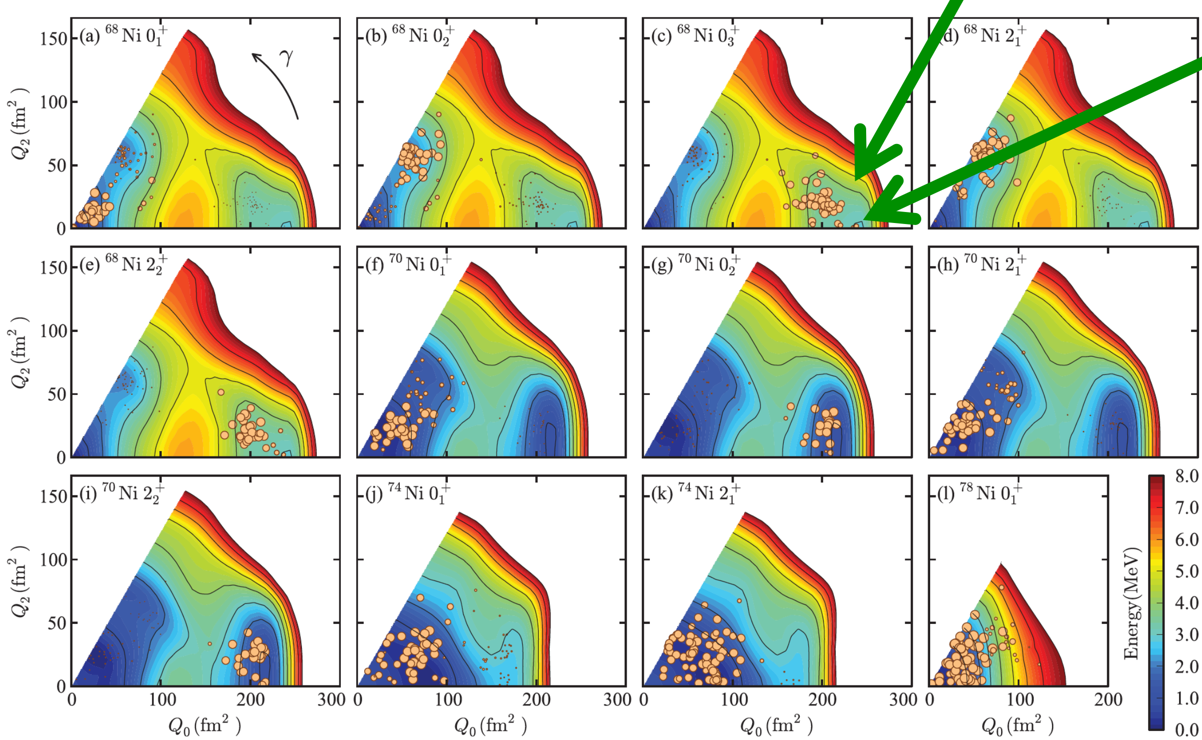
Yusuke Tsunoda,[1] Takaharu Otsuka,[1,2,3] Noritaka Shimizu,[2] Michio Honma,[4] and Yutaka Utsuno[5]



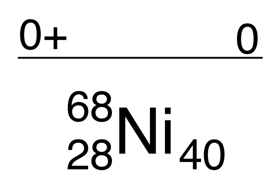




PHYSICAL REVIEW C **89**, 031301(R) (2014)



In all of this renewed work, the exact position of the 0_2^+ level was identified at 1603.5 keV.



PHYSICAL REVIEW C **89**, 021301(R) (2014)

Shape coexistence in ^{68}Ni

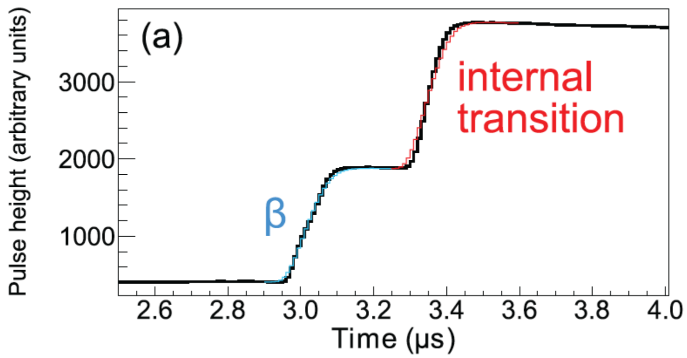
S. Suchyta,[1,2] S. N. Liddick,[1,2] Y. Tsunoda,[3] T. Otsuka,[1,3,4,5] M. B. Bennett,[1,4] A. Chemey,[1] M. Honma,[6] N. Larson,[1,2] C. J. Prokop,[1,2] S. J. Quinn,[1,4] N. Shimizu,[5] A. Simon,[1] A. Spyrou,[1,4] V. Tripathi,[7] Y. Utsuno,[8] and J. M. VonMoss[7]

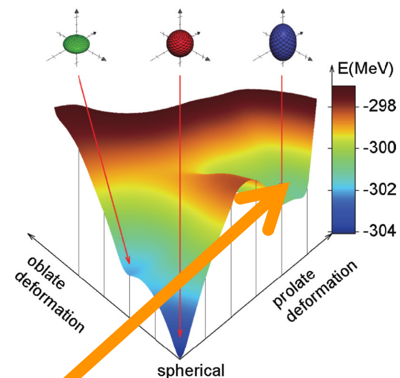
PHYSICAL REVIEW C **89**, 031301(R) (2014)

Novel shape evolution in exotic Ni isotopes and configuration-dependent shell structure

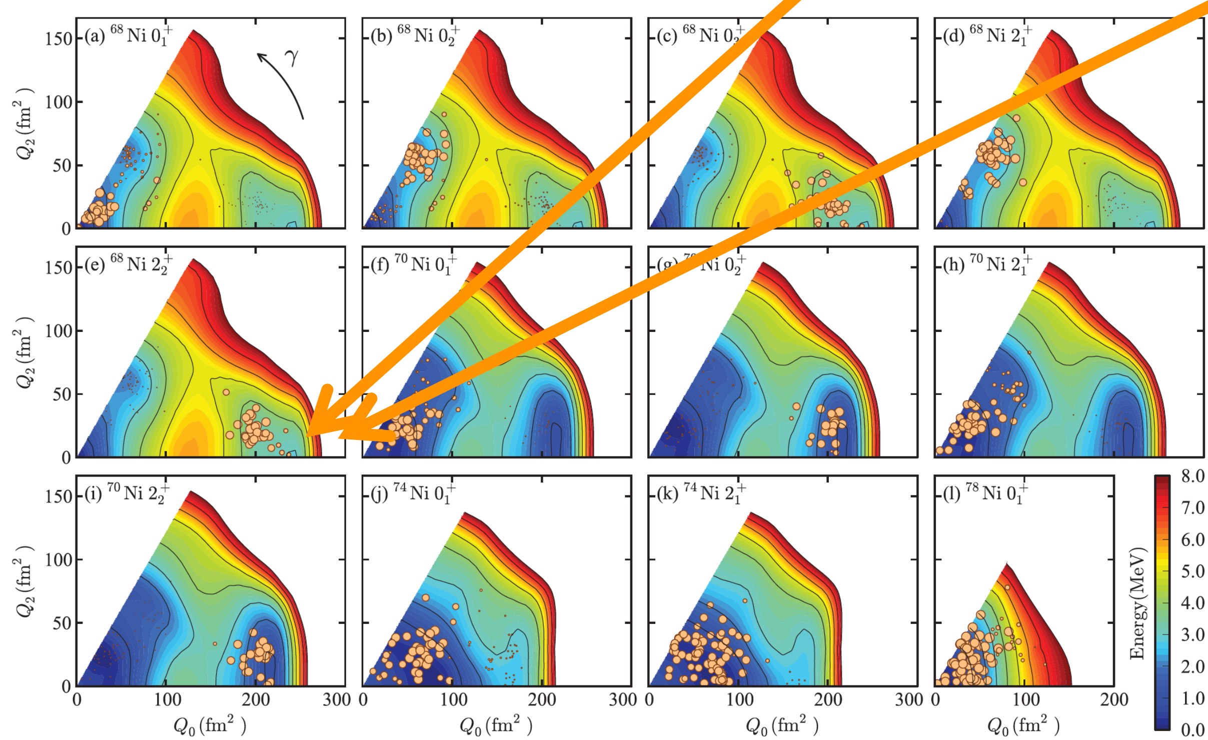
Yusuke Tsunoda,[1] Takaharu Otsuka,[1,2,3] Noritaka Shimizu,[2] Michio Honma,[4] and Yutaka Utsuno[5]

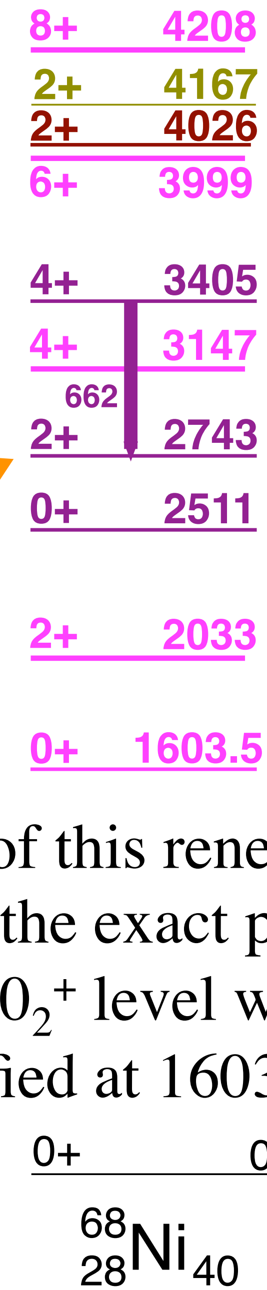
S. SUCHYTA *et al.*





NOVEL SHAPE EVOLUTION IN EXOTIC Ni ISOTOPES . . . PHYSICAL REVIEW C **89**, 031301(R) (2014)





In all of this renewed work, the exact position of the 0_2^+ level was identified at 1603.5 keV.

PHYSICAL REVIEW C **91**, 044309 (2015)

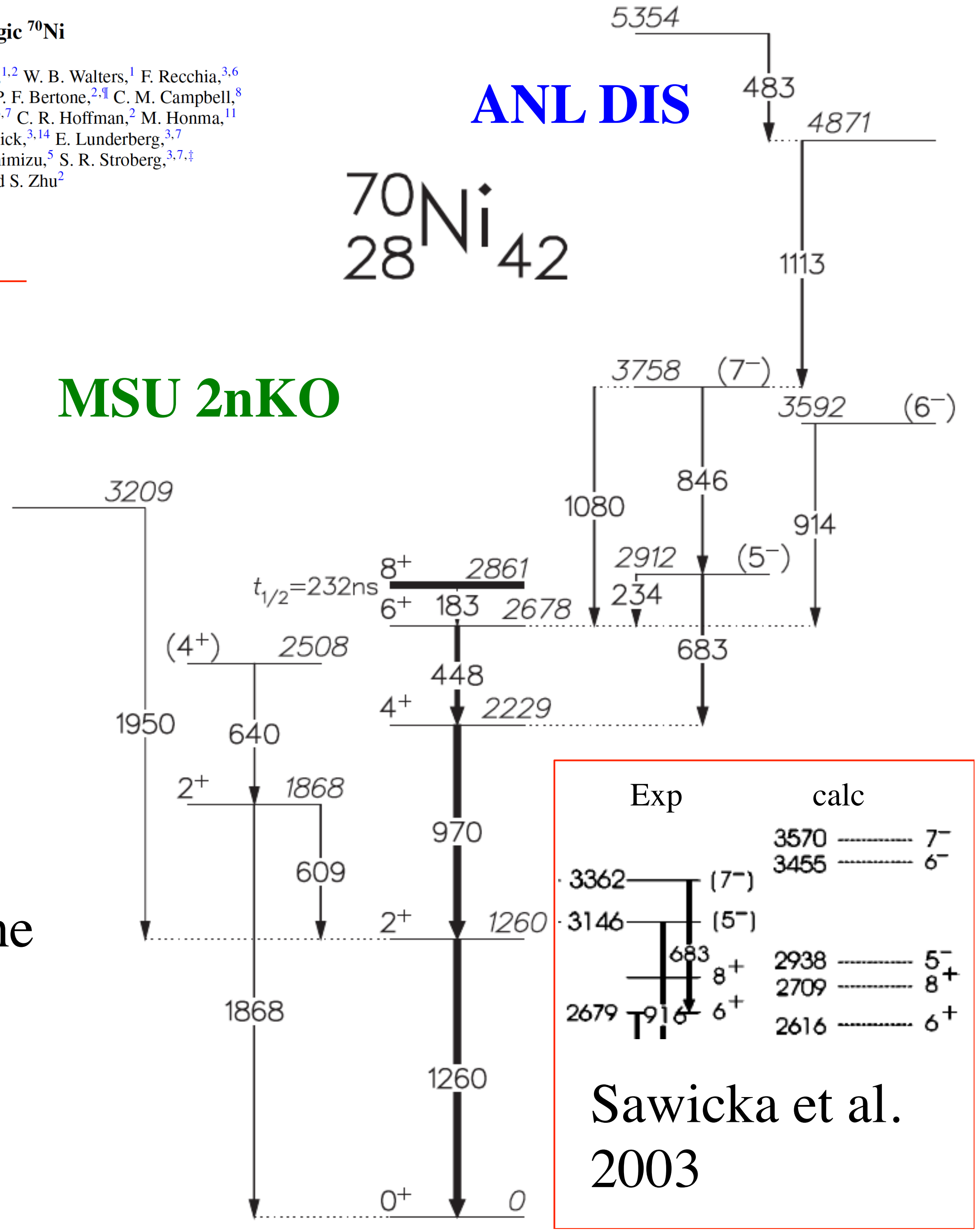
Identification of deformed intruder states in semi-magic ^{70}Ni

C. J. Chiara,[1,2,*] D. Weisshaar,[3] R. V. F. Janssens,[2] Y. Tsunoda,[4] T. Otsuka,[3,4,5] J. L. Harker,[1,2] W. B. Walters,[1] F. Recchia,[3,6] M. Albers,[2,†] M. Alcorta,[2,‡] V. M. Bader,[3,7,§] T. Baugher,[3,7,∥] D. Bazin,[3,7] J. S. Berryman,[3] P. F. Bertone,[2,¶] C. M. Campbell,[8] M. P. Carpenter,[2] J. Chen,[9] H. L. Crawford,[8] H. M. David,[2,10] D. T. Doherty,[2,10,#] A. Gade,[3,7] C. R. Hoffman,[2] M. Honma,[11] F. G. Kondev,[9] A. Korichi,[2,12] C. Langer,[3,13] N. Larson,[3,14] T. Lauritsen,[2] S. N. Liddick,[3,14] E. Lunderberg,[3,7] A. O. Macchiavelli,[8] S. Noji,[3] C. Prokop,[3,14] A. M. Rogers,[2,**] D. Seweryniak,[2] N. Shimizu,[5] S. R. Stroberg,[3,7,‡] S. Suchyta,[3,14,††] Y. Utsuno,[15] S. J. Williams,[3] K. Wimmer,[3,16,‡‡] and S. Zhu[2]

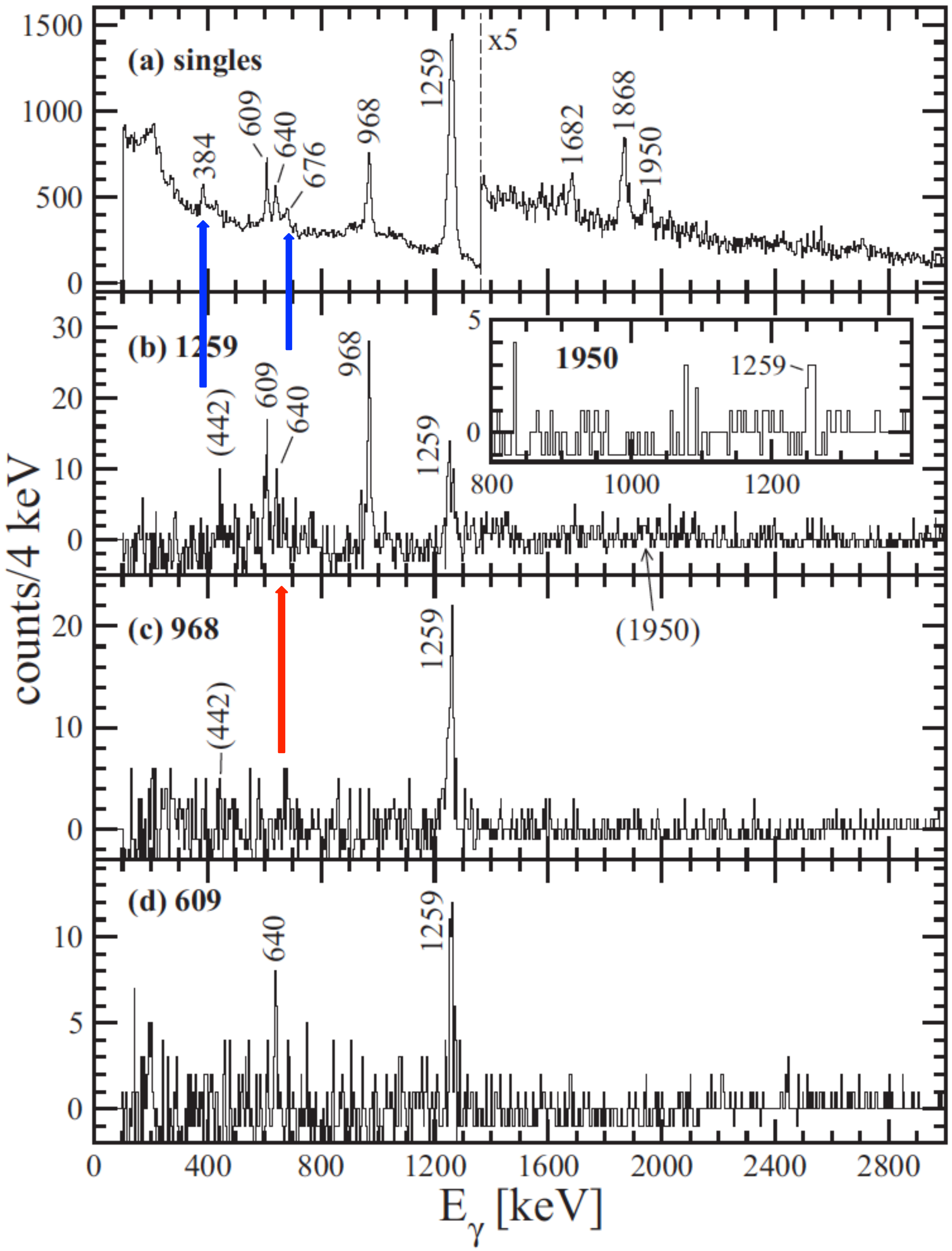
Excited states in ^{70}Ni were populated in multinucleon-transfer reactions between a 440-MeV ^{70}Zn beam and a ~50-mg/cm^2 ^{208}Pb target. The beam was provided by the ATLAS facility at Argonne National Laboratory in ~0.3-ns-wide beam pulses delivered to target every 412 ns. The target, located at the center of the Gammasphere array of 100 Compton-suppressed high-purity Ge (HPGe) detectors [37], was sufficiently thick to stop all reaction products. Additional

A complementary experiment employing secondary fragmentation reactions from a cocktail beam including predominantly ^{73}Cu and ^{72}Ni ions at the Coupled Cyclotron Facility of the National Superconducting Cyclotron Laboratory was also used to study excited states in ^{70}Ni. Details of this experiment are provided in Ref. [31]. The ^{70}Ni reaction products were identified on an event-by-event basis with the focal-plane detection system of the S800 spectrograph [39].

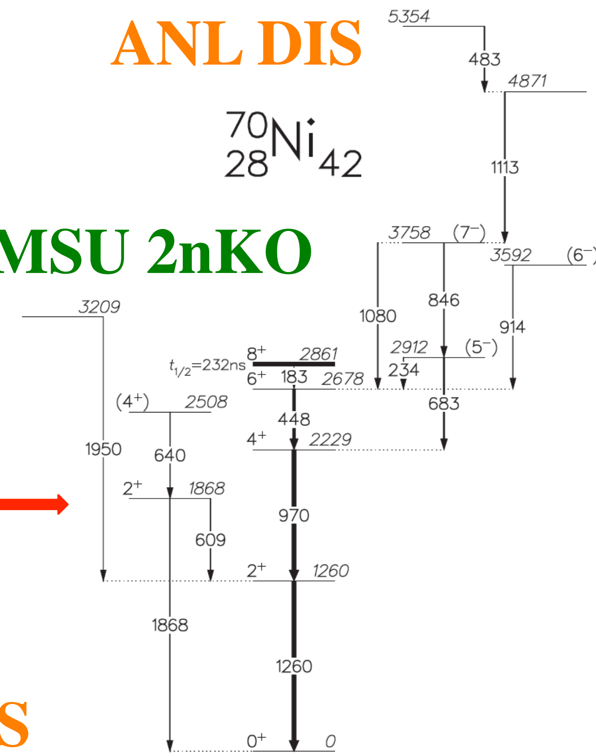
The question was asked, " are there new data for ^{70}Ni from the 2nKO study?"



MSU 2nKO

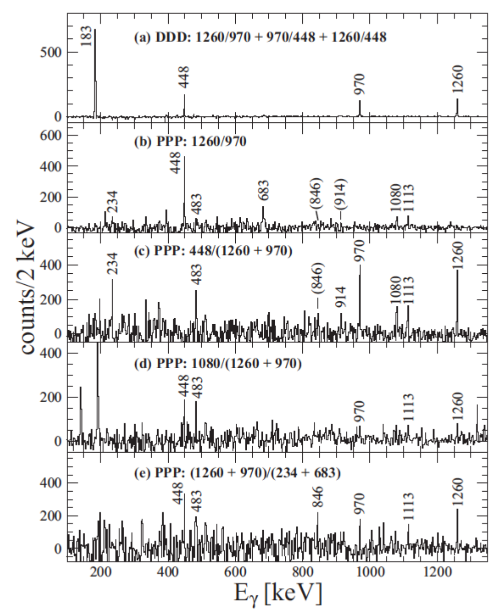


ANL DIS

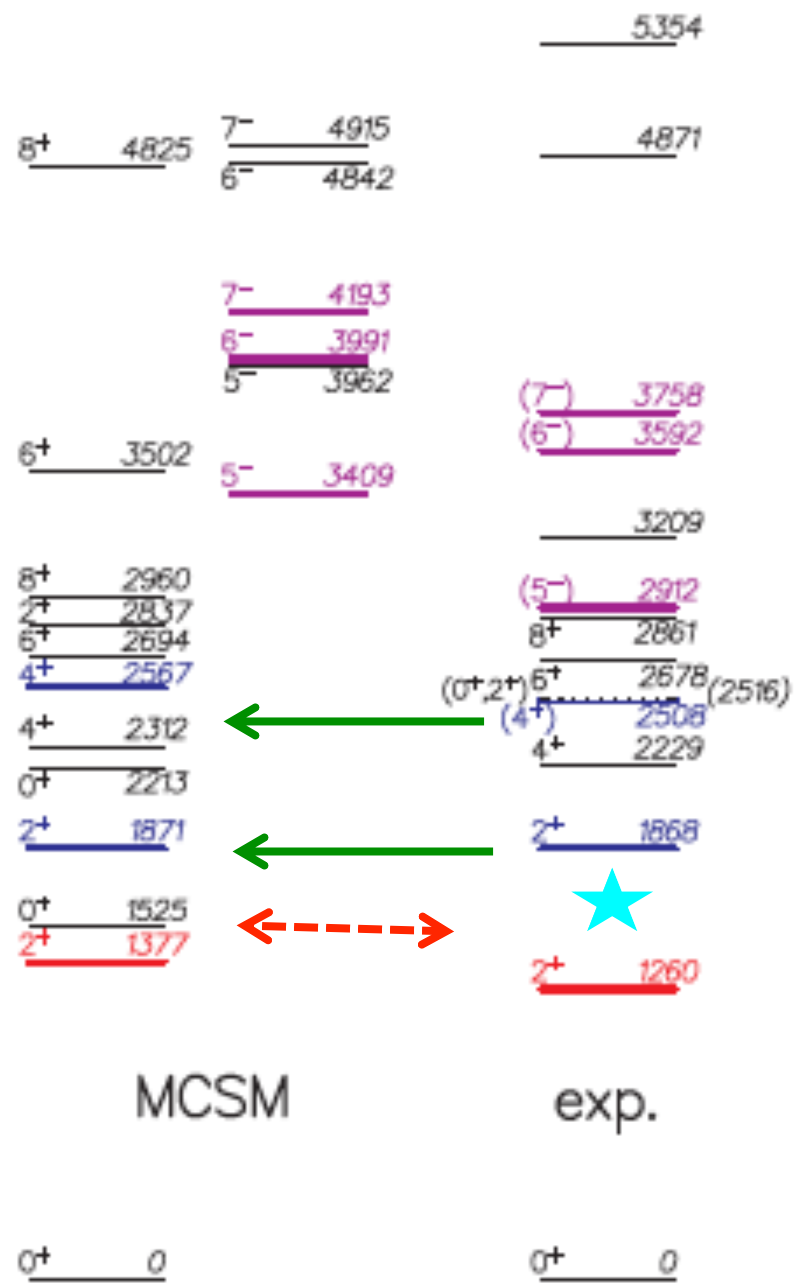


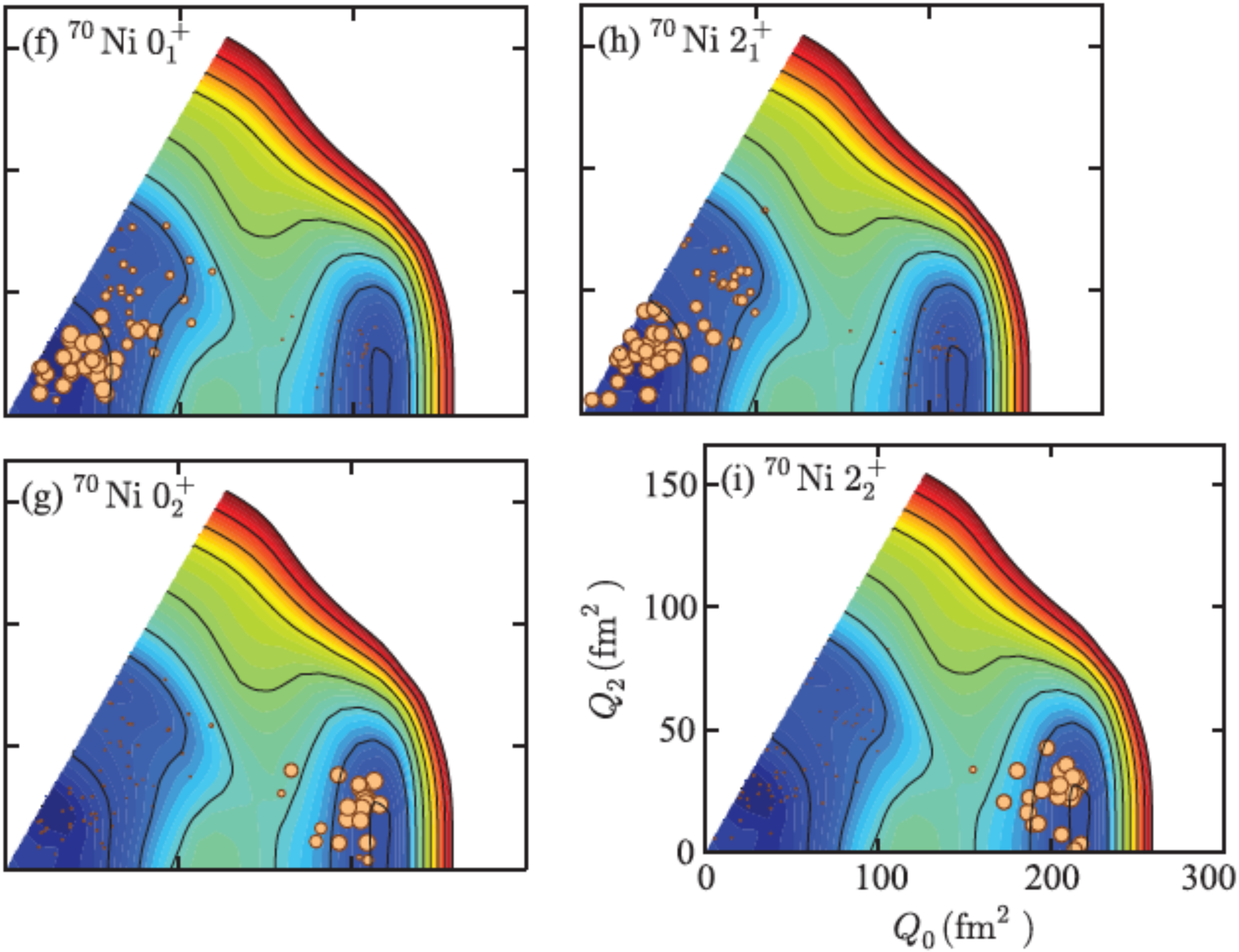
MSU 2nKO

ANL DIS

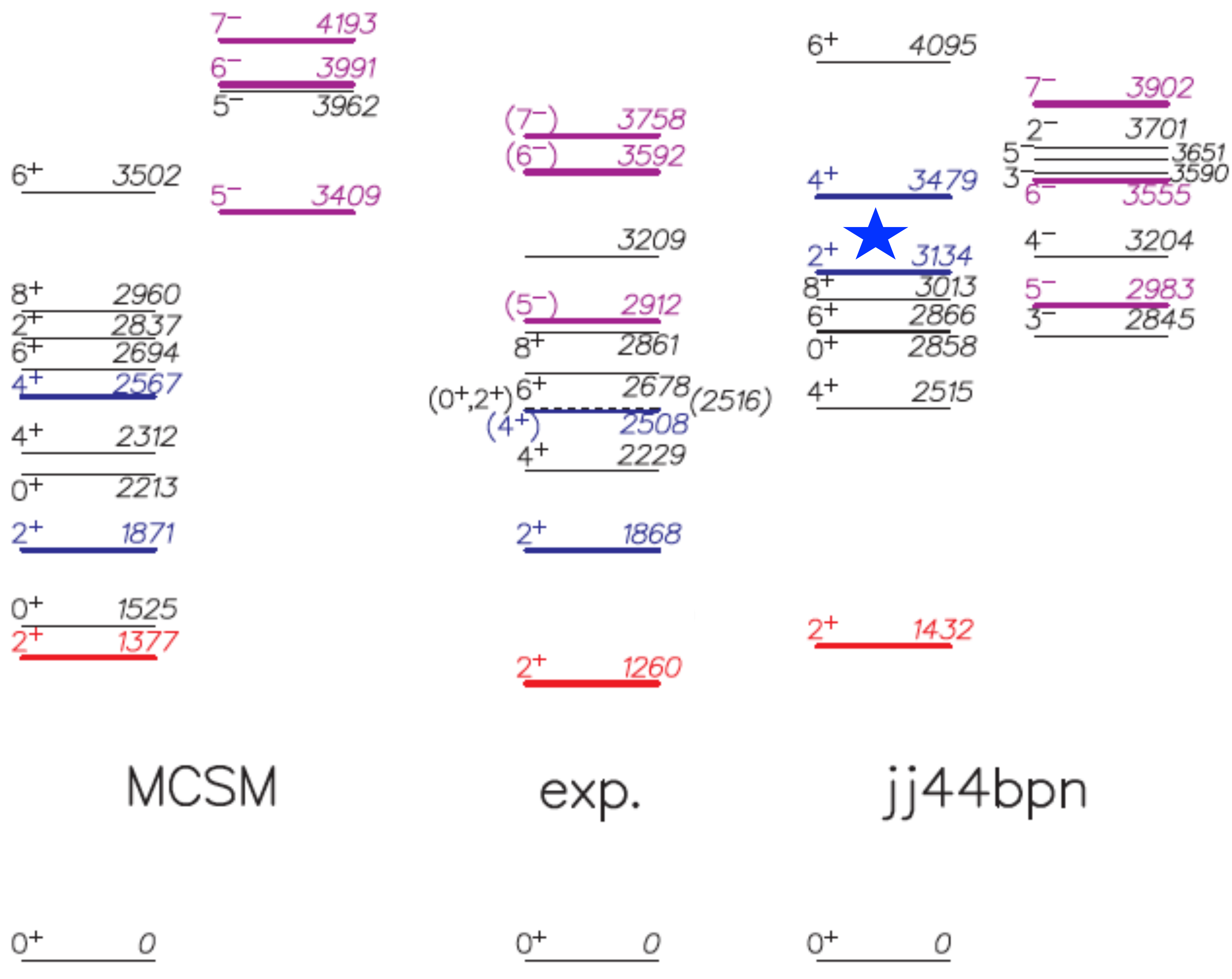


These new calculations from the Otsuka group in the form of Yusuke Tsunoda's thesis exhibited a good fit for the existing 2^+ and 4^+ levels AND a prediction of a low-energy 0^+ level for which we have a possible candidate. They are using a Monte-Carlo Shell Model code that includes both pfg neutrons **and, much more important, pfg protons.** The key is the inclusion of the full pfg proton valence space, not possible in the previous shell-model calculations with only pfg neutrons. **The "ugly duckling" level at 1868 keV turns out to be the key to a whole new interpretation of the structure of ^{70}Ni….even if it took 15 years to get to this point.**

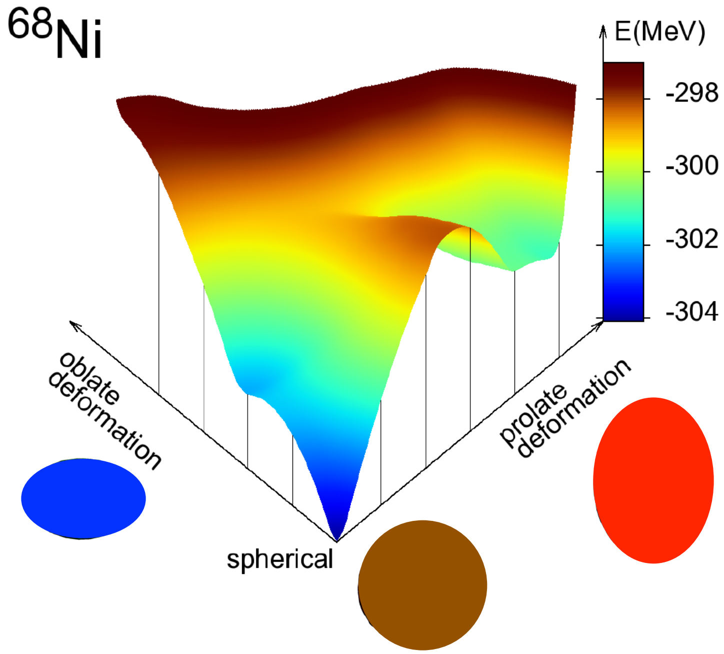


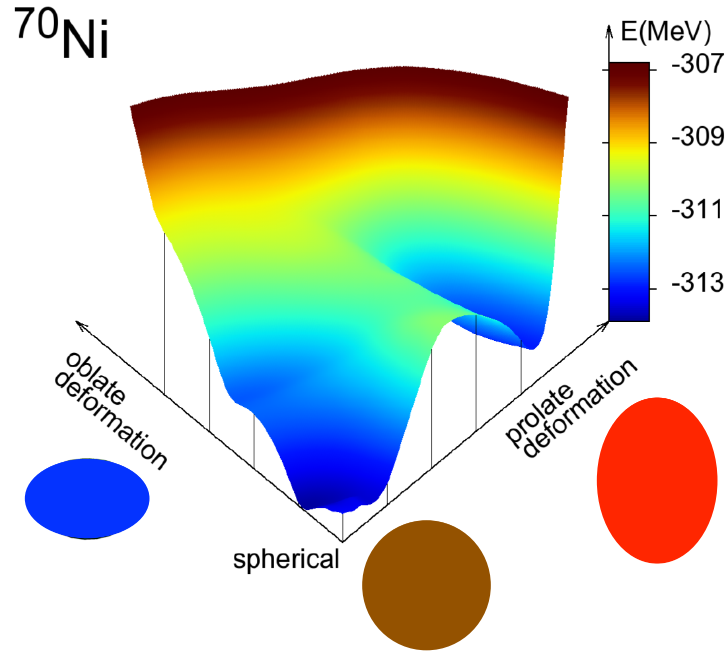


(f) ^{70}Ni 0_1^+
(h) ^{70}Ni 2_1^+
(g) ^{70}Ni 0_2^+
(i) ^{70}Ni 2_2^+
150
100
50
0
Q_2 (fm^2)
0
100
200
300
Q_0 (fm^2)

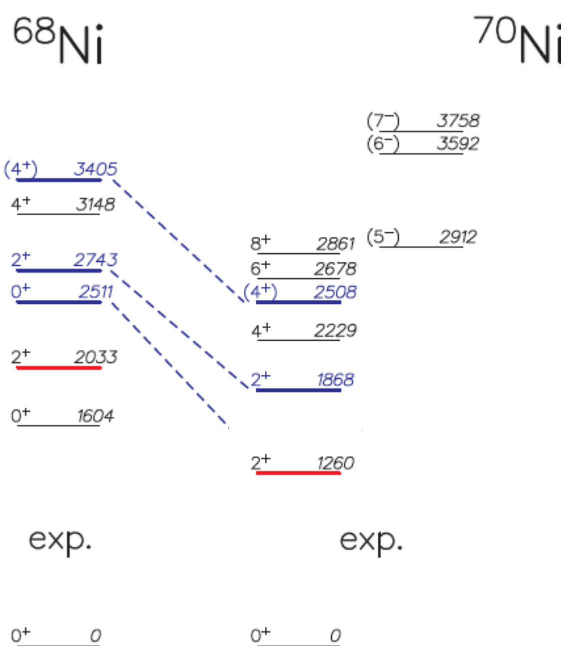


7− 4193
6− 3991
5− 3962
6+ 3502
5− 3409
8+ 2960
2+ 2837
6+ 2694
4+ 2567
4+ 2312
0+ 2213
2+ 1871
0+ 1525
2+ 1377
0+ 0
MCSM
(7−) 3758
(6−) 3592
3209
(5−) 2912
8+ 2861
(0+,2+) 6+ 2678 (2516)
(4+) 2508
4+ 2229
2+ 1868
2+ 1260
0+ 0
exp.
6+ 4095
4+ 3479
2+ 3134
8+ 3013
6+ 2866
0+ 2858
4+ 2515
2+ 1432
0+ 0
7− 3902
2− 3701
5− 3651
3− 3590
6− 3555
4− 3204
5− 2983
3− 2845
jj44bpn





Oblate **Spherical** **Pr**



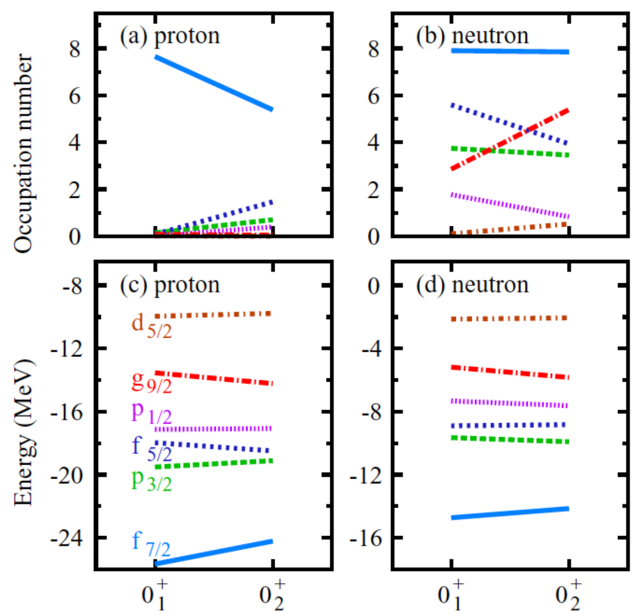


FIG. 9. (Color online) Occupancies and energies of proton and neutron orbitals near the Fermi surface for the $0^+_{1,2}$ levels in ^{70}Ni. The same line styles are used in all panels, as labeled in (c).

It is now plausible that the prolate minimum has dropped by ~ 1 MeV in ^{70}Ni.

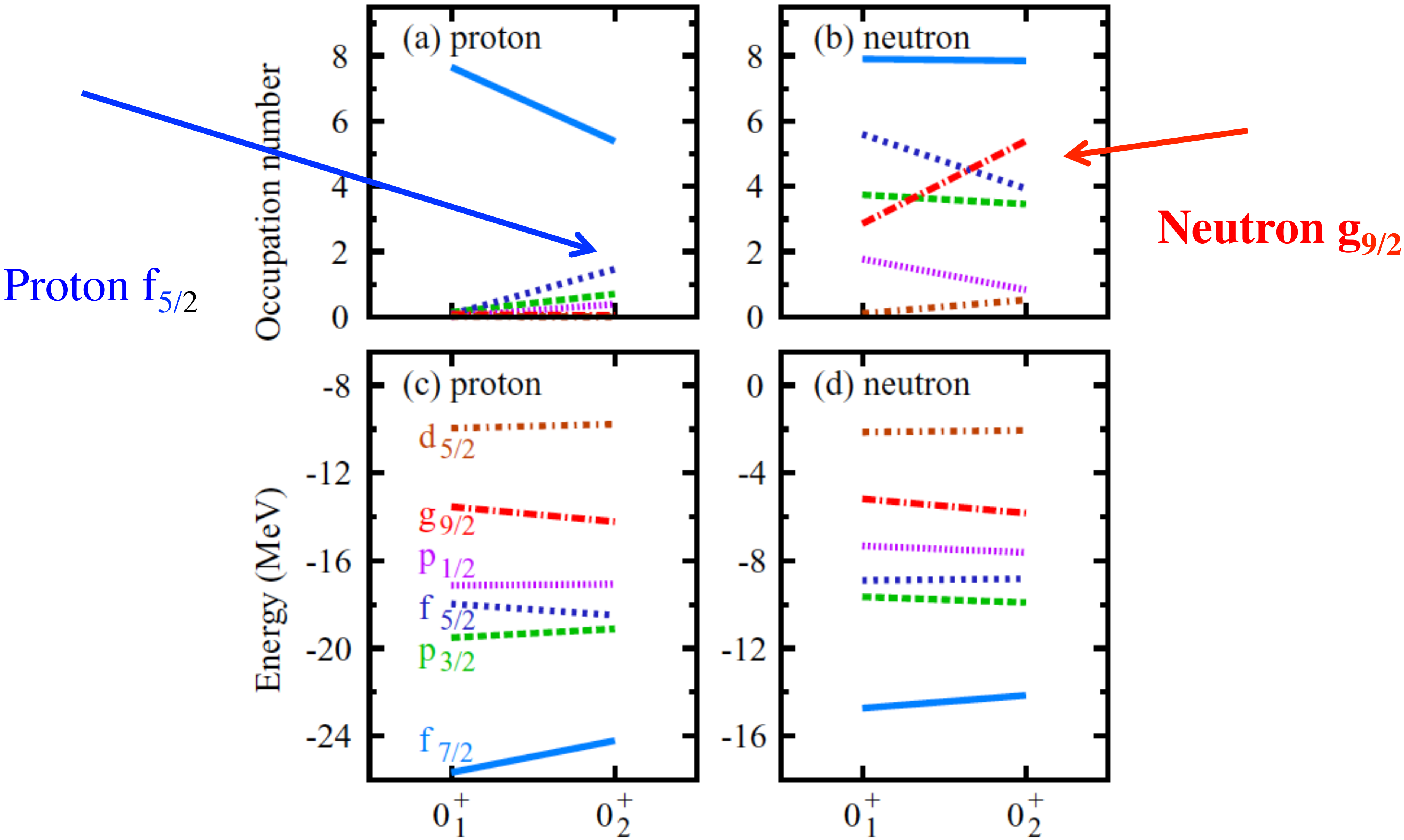


FIG. 9. (Color online) Occupancies and energies of proton and neutron orbitals near the Fermi surface for the $0^+_{1,2}$ levels in ^{70}Ni. The same line styles are used in all panels, as labeled in (c).

PRL **103,** 212501 (2009) PHYSICAL REVIEW LETTERS week ending 20 NOVEMBER 2009

Global Calculation of Nuclear Shape Isomers

Peter Möller,[1,*] Arnold J. Sierk,[1] Ragnar Bengtsson,[2] Hiroyuki Sagawa,[3] and Takatoshi Ichikawa[4,†]
[1]*Theoretical Division, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA*
[2]*Department of Mathematical Physics, Lund Institute of Technology, P. O. Box 118, SE-22100 Lund, Sweden*
[3]*Center for Mathematical Sciences, University of Aizu Aizu-Wakamatsu, Fukushima 965-80, Japan*
[4]*RIKEN Nishina Center, RIKEN, Wako, Saitama 351-0198, Japan*
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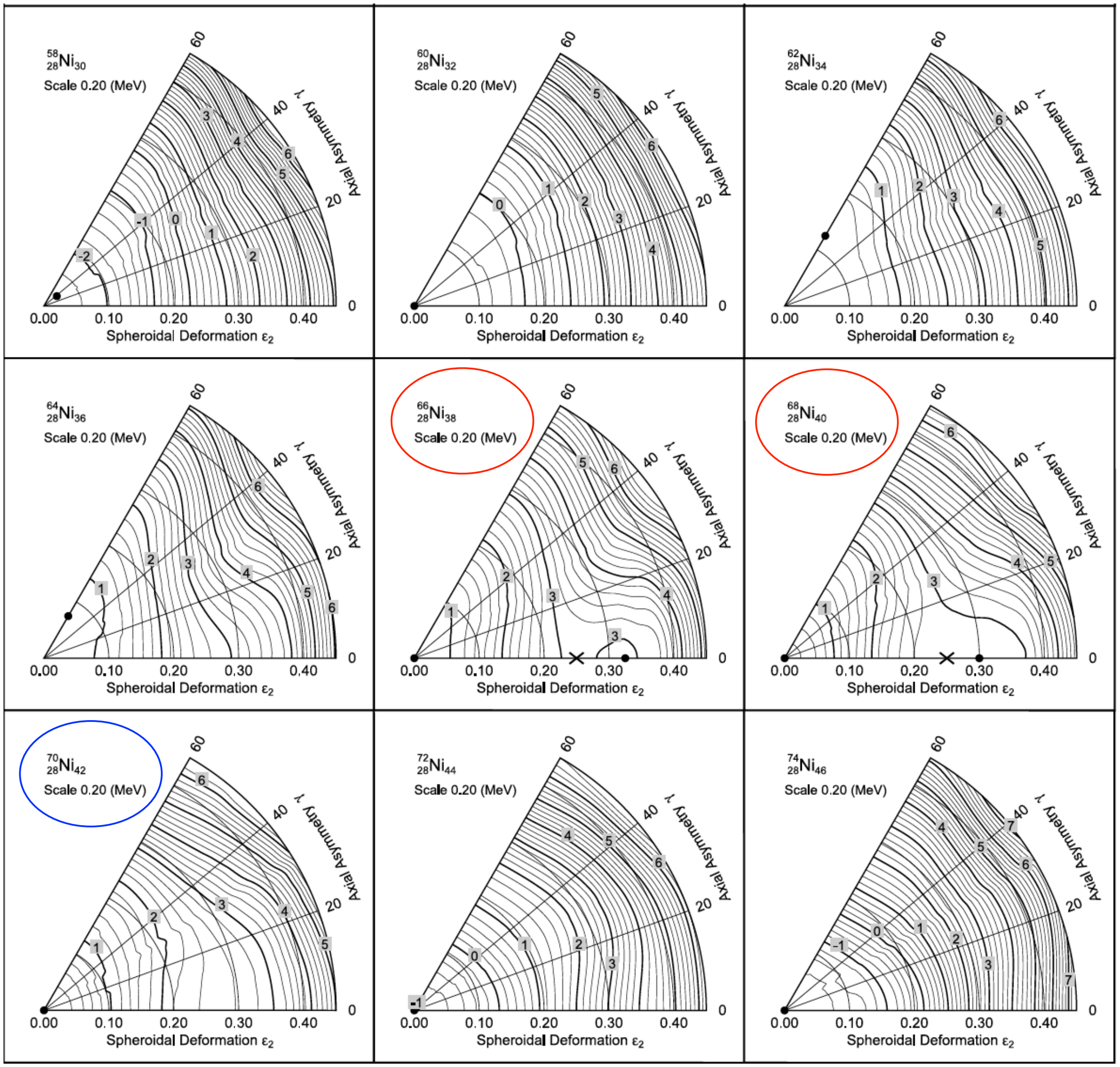

Graph 20

Atomic Data and Nuclear Data Tables 98 (2012) 149–300
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Nuclear shape isomers

P. Möller[a,*], A.J. Sierk[a], R. Bengtsson[b], H. Sagawa[c], T. Ichikawa[d]
[a] *Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545, United States*
[b] *Department of Mathematical Physics, Lund Institute of Technology, P.O. Box 118, SE-22100 Lund, Sweden*
[c] *Center for Mathematical Sciences, University of Aizu, Aizu-Wakamatsu, Fukushima 965-80, Japan*
[d] *Yukawa Institute for Theoretical Physics, Kyoto University, Kyoto 606-8502, Japan*

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ABSTRACT

We calculate potential-energy surfaces as functions of spheroidal (ϵ_2), hexadecapole (ϵ_4), and axial-asymmetry (γ) shape coordinates for 7206 nuclei from $A = 31$ to $A = 290$. We tabulate the deformations and energies of all minima deeper than 0.2 MeV *and* of the saddles between all pairs of minima. The tabulation is terminated at $N = 160$. Our study is based on the FRLDM macroscopic–microscopic model defined in Atomic Data and Nuclear Data Tables [P. Möller, J.R. Nix, W.D. Myers, W.J. Swiatecki, At. Data Nucl. Data Tables 59 (1995) 185]. We also present potential-energy contour plots versus ϵ_2 and γ for 1224 even–even nuclei in the region studied. We can identify nuclei for which a necessary condition for shape isomers occurs, namely multiple minima in the calculated potential-energy surface. We find that the vast majority of nuclear shape isomers occur in the $A = 80$ region, the $A = 100$ region, and in a more extended region centered around ^{208}Pb. A calculated region of shape isomers that has so far not been extensively explored is the region of neutron-deficient actinides "north-east" of ^{208}Pb.

Peter Möller's model finds shape coexistence for $^{66,68}Ni$, but not for ^{70}Ni.

PHYSICAL REVIEW C VOLUME 37, NUMBER 6 JUNE 1988

Spectroscopy of neutron-rich nickel isotopes: Experimental results and microscopic interpretation

M. Girod
Service de Physique et Techniques Nucléaires, C.E. Bruyeres-le Châtel, Boîte Postale 12, 91680 Bruyeres-Le-Chatel, France

Ph. Dessagne,* M. Bernas, M. Langevin,† F. Pougheon, and P. Roussel
Institut de Physique Nucléaire, Boîte Postale 1, 91406 Orsay Cedex, France

(Received 18 May 1987)

Earlier, I had carefully noted that “few models showed a low-energy 2_2^+ level, but not NO models.

The energies are 10% high.

TABLE IV. Observed states in ^{68}Ni and ^{67}Ni with their assumed spin and parities. The normalizing factor N is the ratio $d\sigma/d\Omega_{\mathrm{exp}}/d\sigma/d\Omega_{\mathrm{DWBA}}$.

^{68}Ni Excitation energy (MeV)	Spin	N	^{67}Ni Excitation energy (MeV)	Spin	N
g.s.	0^+	0.4	g.s.	$(\frac{1}{2}^-)$	0.37
1.77±0.3	0^+	0.13	0.77±0.2	$\frac{9}{2}^+$	2.93
				$\frac{5}{2}^+$	2.35
2.20±0.4	2^+	0.21	1.14±0.03	$\frac{3}{2}^-$	0.20
2.70±0.04	0^+ 2^+	0.1 0.5	1.97±0.04	$\frac{3}{2}^-$	1
3.28±0.05	2^+ 4^+	0.2 1.43	3.68±0.05	$\frac{3}{2}^-$	1.1
3.45±0.05					
4.12±0.05					

The energies are 10% high.

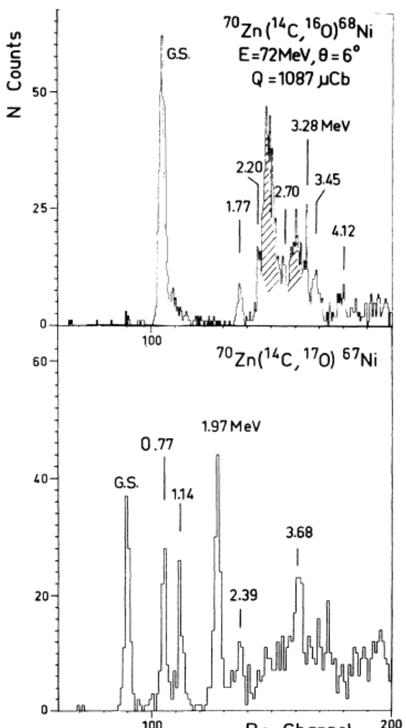


FIG. 1. Spectra of ^{16}O and ^{17}O showing the excited states of ^{68}Ni and ^{67}Ni. The dashed area is due to oxygen target contaminant.

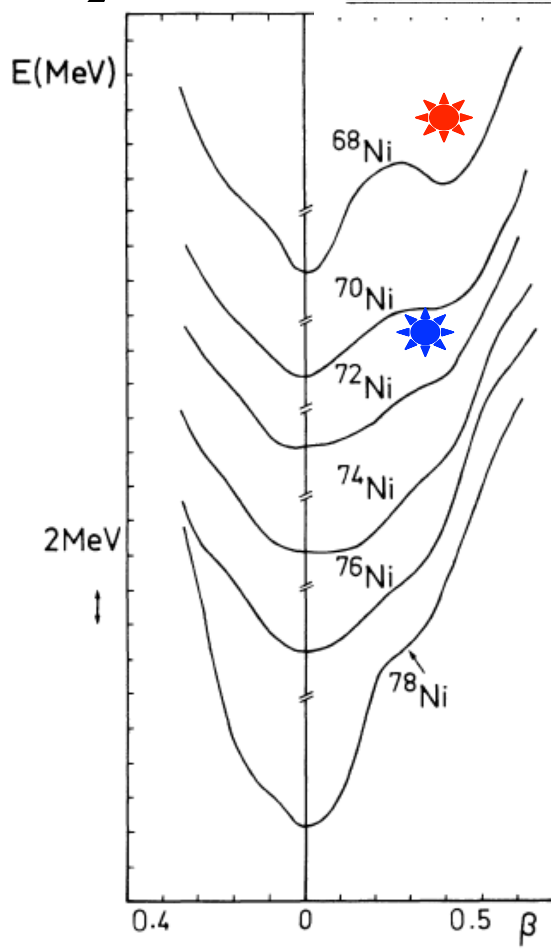


FIG. 4. Axial deformation energy curve calculated for the series of even Ni isotopes with $A=68$ to $A=78$.

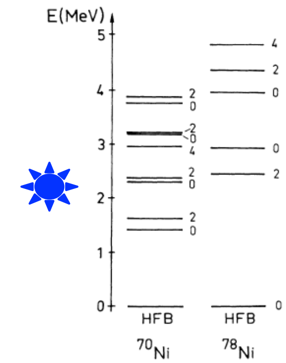
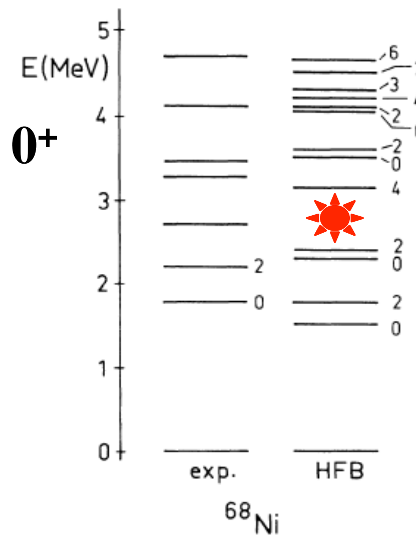


FIG. 9. Predicted collective levels of the unknown isotopes of ^{70}Ni and ^{78}Ni.

0^+ 0^+ 2^+ 0^+



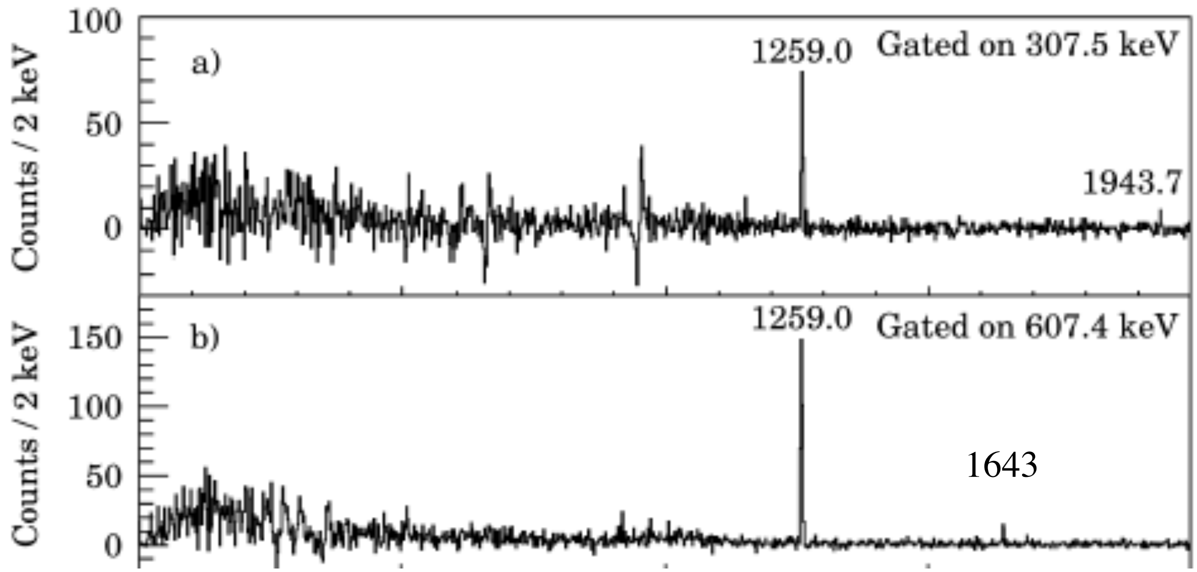
New low-energy 0^+ state and shape coexistence in ^{70}Ni

C. J. Prokop,[1,2,*] B. P. Crider,[1] S. N. Liddick,[1,2] A. Ayangeakaa,[3] J. Carol,[4] J. Chen,[1] C. J. Chiara,[3,4] H. M. David,[3] A. Dombos,[1,5] S. Go,[6] R. Grzywacz,[6] J. Harker,[3,7] R. V. F. Janssens,[3] N. Larson,[1,2] T. Lauritsen,[3] R. Lewis,[1,2] S. Quinn,[1,5] F. Recchia,[8] D. Seweryniak,[3] A. Spyrou,[1,5] S. Suchyta,[9] and W. B. Walters[7]

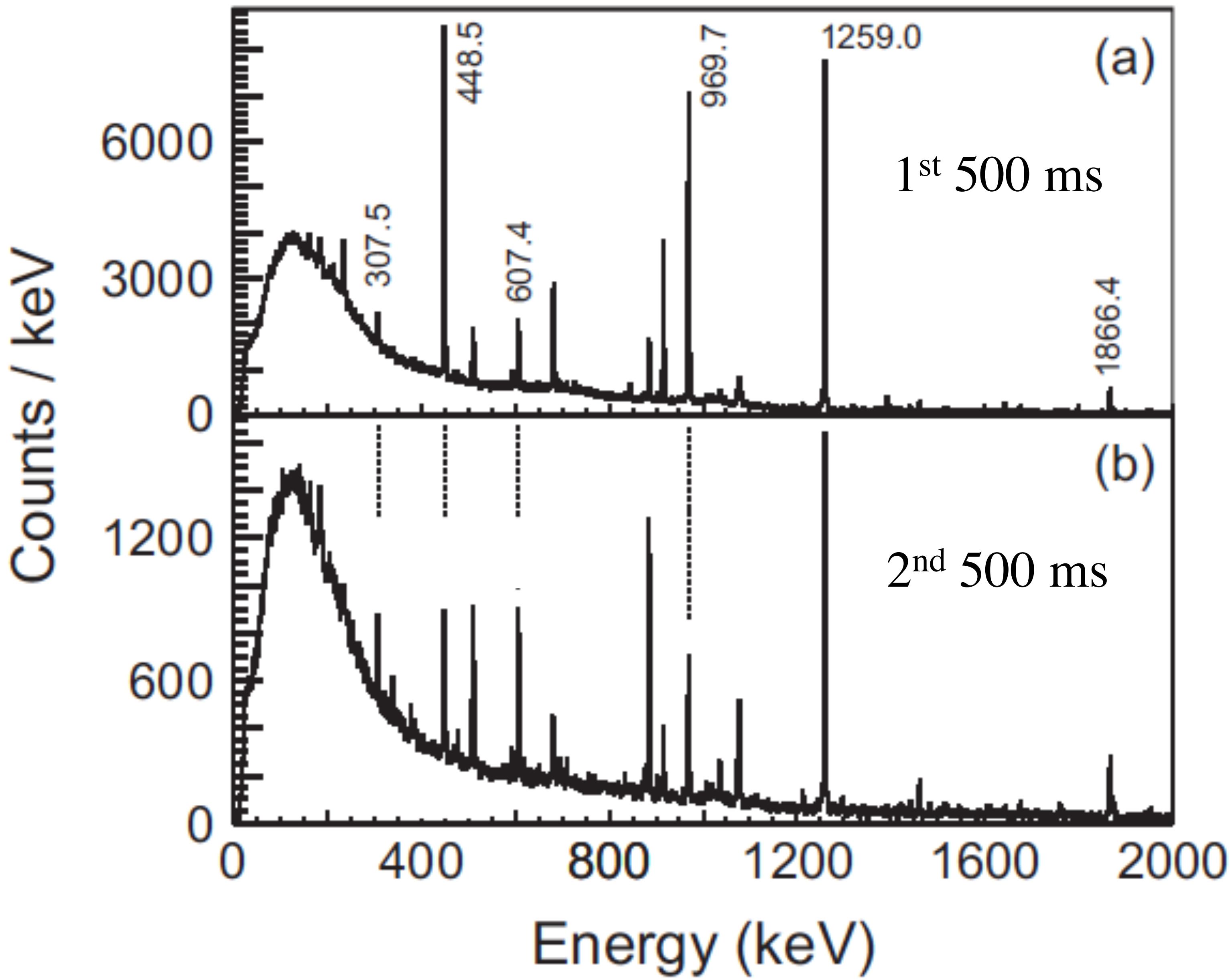
[1] *National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, MI 48824, USA*
[2] *Department of Chemistry, Michigan State University, East Lansing, MI 48824, USA*
[3] *Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA*
[4] *Army Research Laboratory, Adelphi, Maryland 20783, USA*
[5] *Department of Physics, Michigan State University, East Lansing, MI 48824, USA*
[6] *Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee 37996, USA*
[7] *Department of Chemistry and Biochemistry, University of Maryland, College Park, Maryland 20742, USA*
[8] *Dipartimento di Fisica e Astronomia, Universit'a degli Studi di Padova, I-35131 Padova, Italy*
[9] *Department of Nuclear Engineering, University of California Berkeley, Berkeley, CA 94720, USA*

(Dated: June 1, 2015)

This paper comes from **beta-decay experiments at NSCL** in which a candidate for the **"plausible"** low-energy prolate 0_2^+ level in ^{70}Ni **has been identified at 1566 keV.**



Decay of ^{70}Co isomers [short (high spin) and long (low spin)] to levels in ^{70}Ni



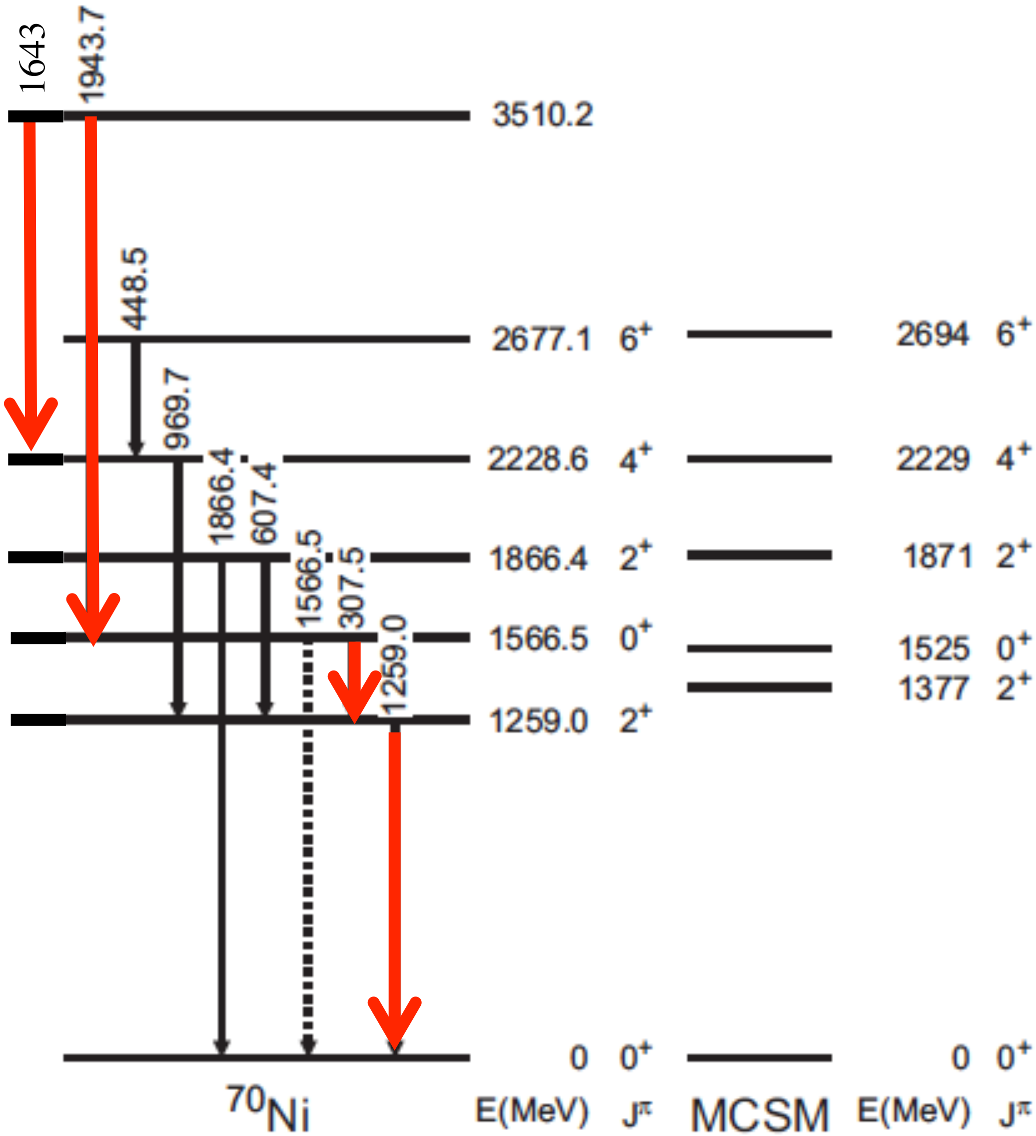
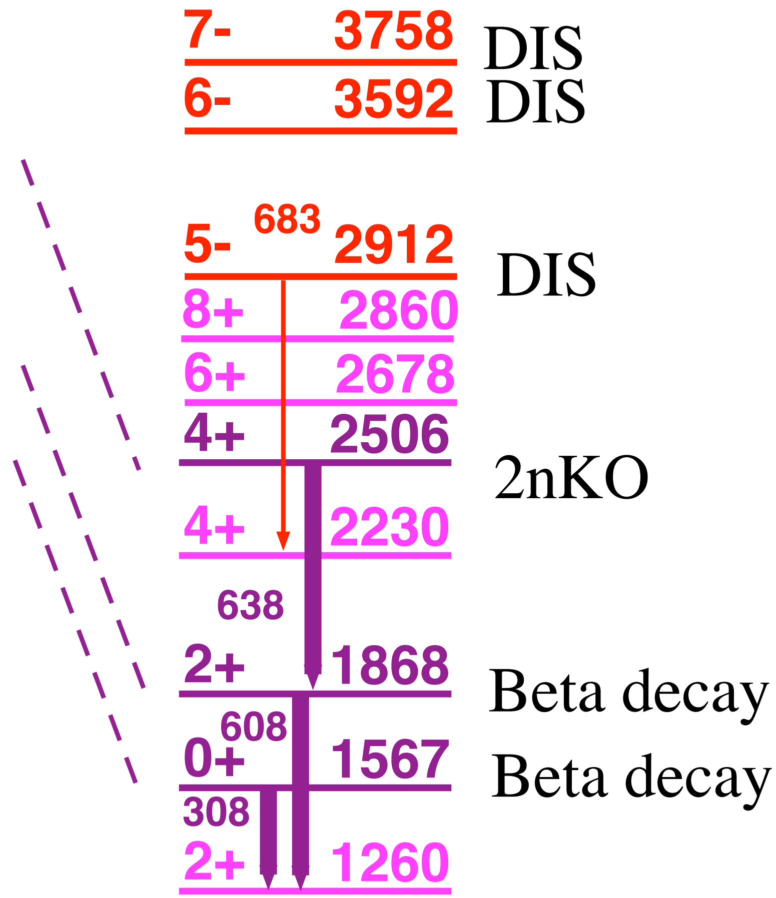
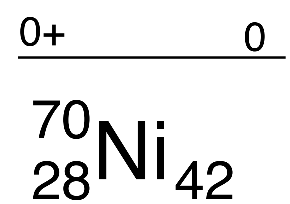
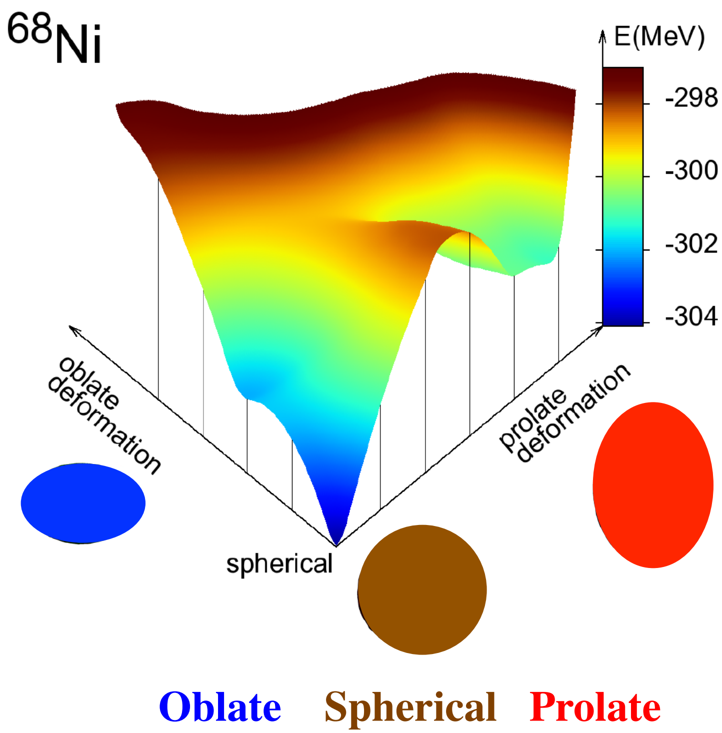


FIG. 3. Simplified low-energy level scheme of ^{70}Ni populated in the decay of ^{70}Co. Experimentally observed transitions and tentative spins and parities are shown on the left compared to the predictions of the MCSM on the right [28]. The 1566-keV E0 transition is inferred from coincidence spectra (see text for details) and is indicated by a dashed line.

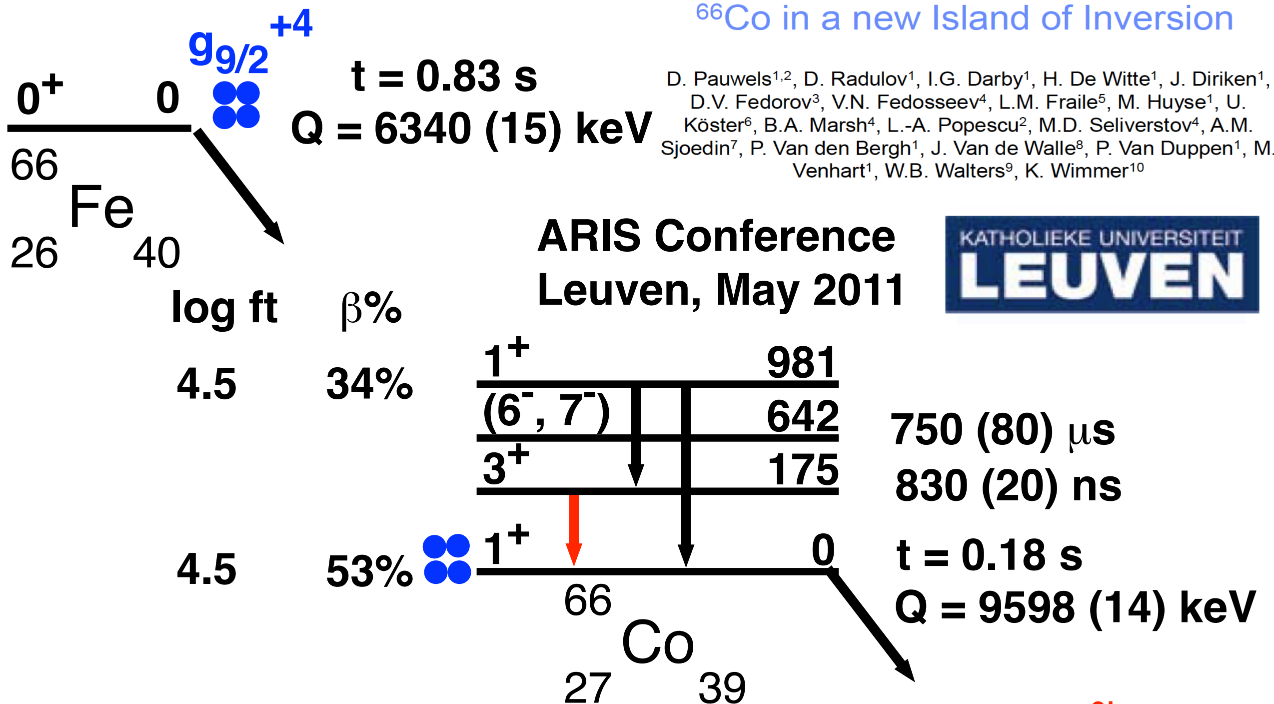


Now the set is complete for ^{70}Ni, a 0^+ 2^+ 4^+ sequence in the second well.

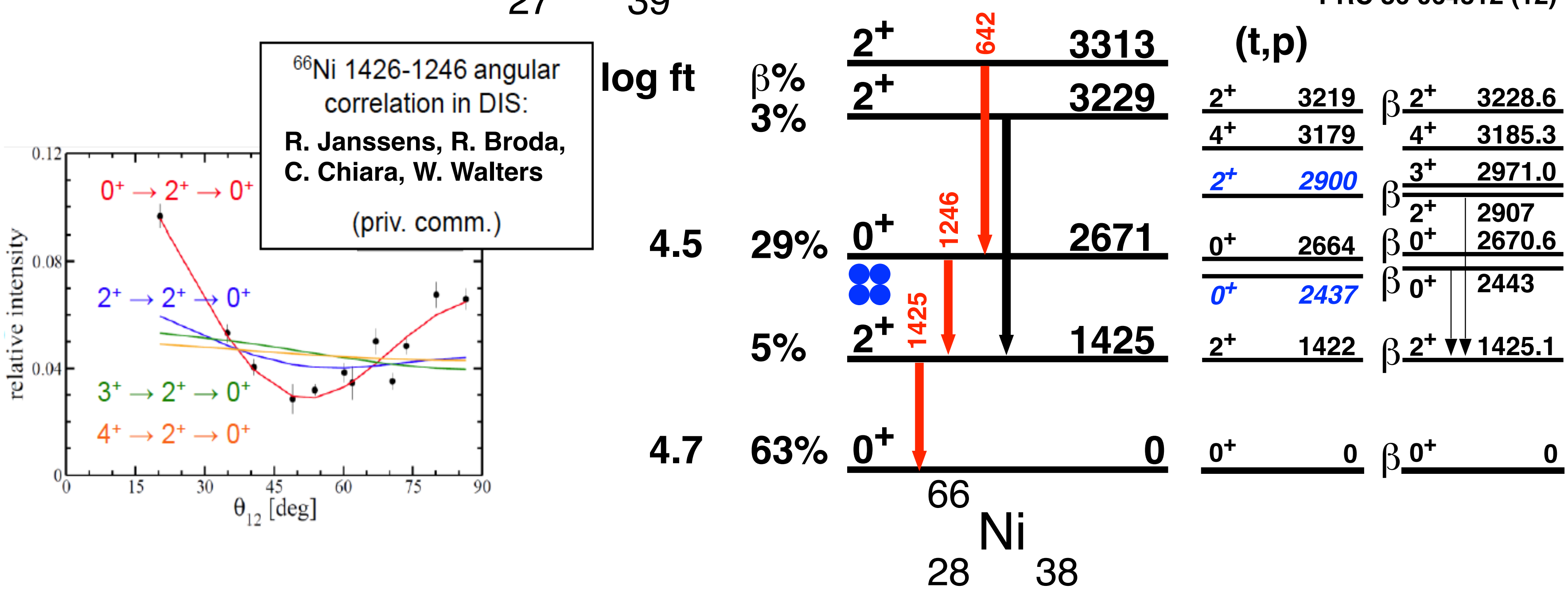




68Ni
E(MeV)
-298
-300
-302
-304
oblate deformation
prolate deformation
spherical
70Ni
E(MeV)
-307
-309
-311
-313
oblate deformation
prolate deformation
spherical
Oblate
Spherical
Prolate



This is my favorite drawing for A = 66, that shows deformation being maintained from ^{66}Fe to ^{66}Ni. The primary decay involves the GT allowed decay of 2 sequential $f_{5/2}$ neutron decays that fill the last two $f_{7/2}$ proton holes, leaving the other parts of the neutron configuration unchanged. **The line at 642 keV and level at 3313 keV come from the DIS experiments at ATLAS using Gammasphere in a triple coincidence mode following 2-neutron transfer.**



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Seniority, collectivity, and $B(E2)$ enhancement in ^{72}Ni

C. J. Chiara,[1,2] W. B. Walters,[1] I. Stefanescu,[1,2] M. Alcorta,[2] M. P. Carpenter,[2] B. Fornal,[3] G. Gürdal,[4] C. R. Hoffman,[2] R. V. F. Janssens,[2] B. P. Kay,[2,*] F. G. Kondev,[4] W. Królas,[3,5] T. Lauritsen,[2] C. J. Lister,[2] E. A. McCutchan,[2,†] T. Pawłat,[3] A. M. Rogers,[2] D. Seweryniak,[2] N. Sharp,[1] J. Wrzesiński,[3] and S. Zhu[2]

[1]*Department of Chemistry and Biochemistry, University of Maryland, College Park, Maryland 20742, USA*

[2]*Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA*

[3]*Niewodniczański Institute of Nuclear Physics PAN, Radzikowskiego 152, PL-31-342 Kraków, Poland*

[4]*Nuclear Engineering Division, Argonne National Laboratory, Argonne, Illinois 60439, USA*

[5]*Joint Institute for Heavy Ion Research, Oak Ridge, Tennessee 37831, USA*

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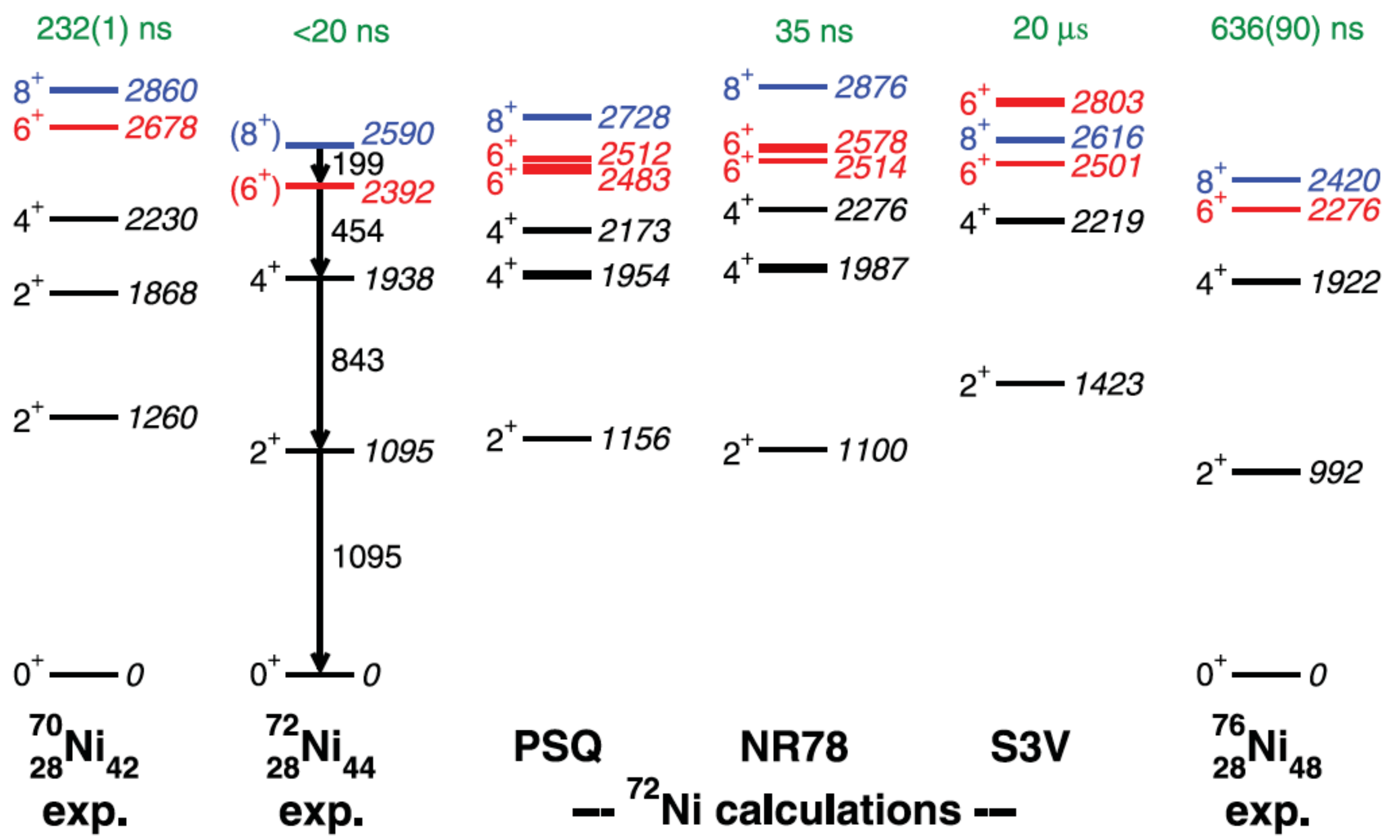
Gamma rays assigned to $^{72}_{28}$Ni$_{44}$ have been identified with Gammasphere in deep-inelastic reactions involving a 450-MeV ^{76}Ge beam and a ^{198}Pt target. Using a combination of spectra produced by double gates on the known 454-, 843-, and 1095-keV members of the ground-state cascade, a coincident line at 199 keV has been identified and is tentatively assigned as the $8^+ \rightarrow 6^+$ transition. These γ-ray coincidences have been observed only in prompt events, indicating an 8^+ half-life below 20 ns and requiring a large $B(E2)$ enhancement compared to that expected from a seniority scheme. This value is consistent with models showing decay to a seniority $\nu = 4$, 6^+ level that is depressed by the same two-body interaction responsible for the rather low 1095-keV 2^+_1 energy, as compared to the valence-symmetry counterpart $^{94}_{44}$Ru$_{50}$.

The absence of the predicted 8^+ isomer in ^{72}Ni was "solved" by measuring the energy and showing it had a short lifetime. **The theoretical solution involved postulating seniority-four 6^+ and 4^+ states with fast transitions.**



This reaction involved the transfer of four protons from ^{76}Ge to ^{198}Pt.

This has just been published and includes THREE new gamma rays, the peak at **1069 keV** and the others at **579 and 699 keV**. As the (3^+) spin and parity for the 181-ms isomer is uncertain, the proposed (4^+) assignment for the new level at 2164 keV might not be correct, it could also be 2^+ or 0^+.

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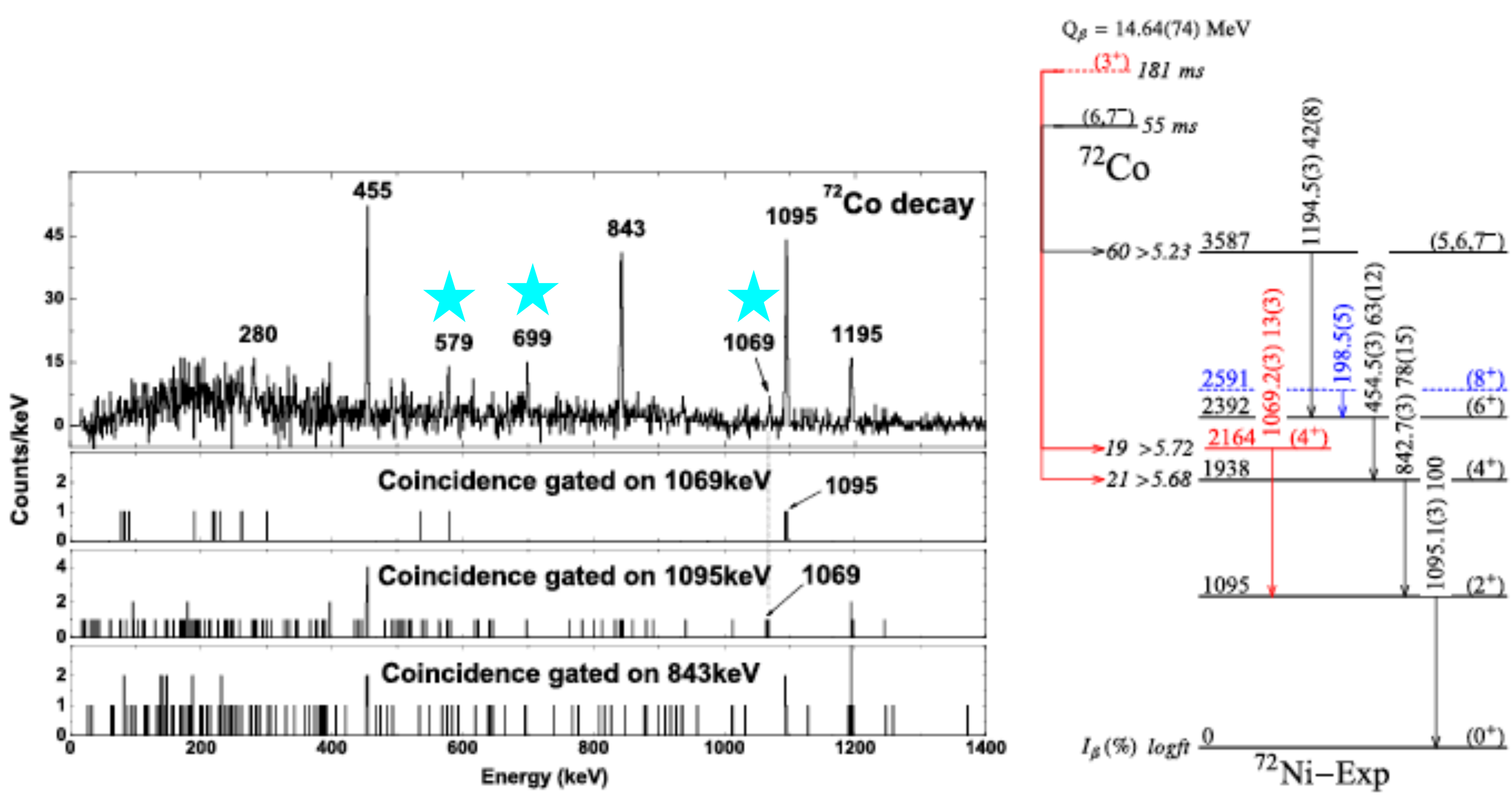
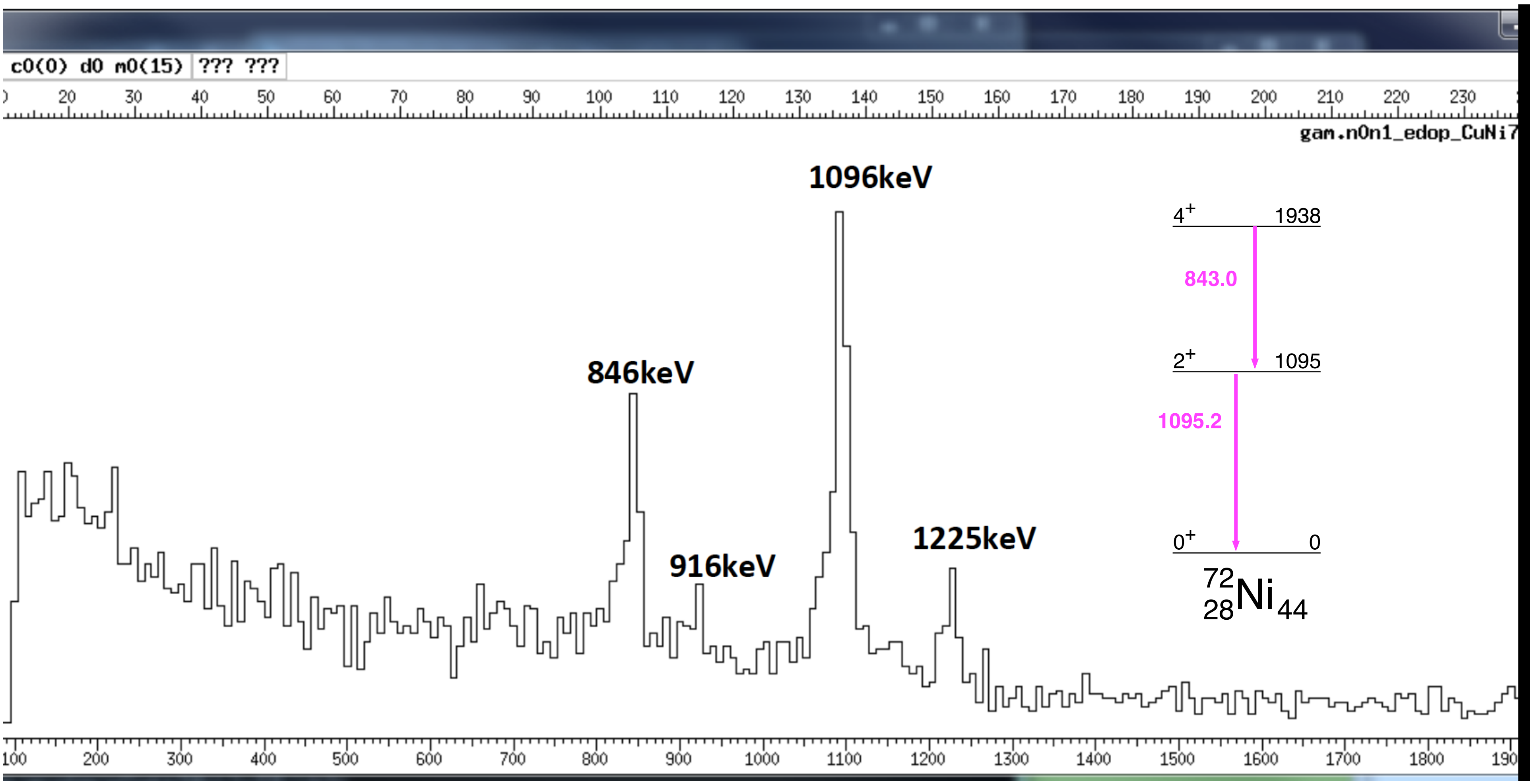
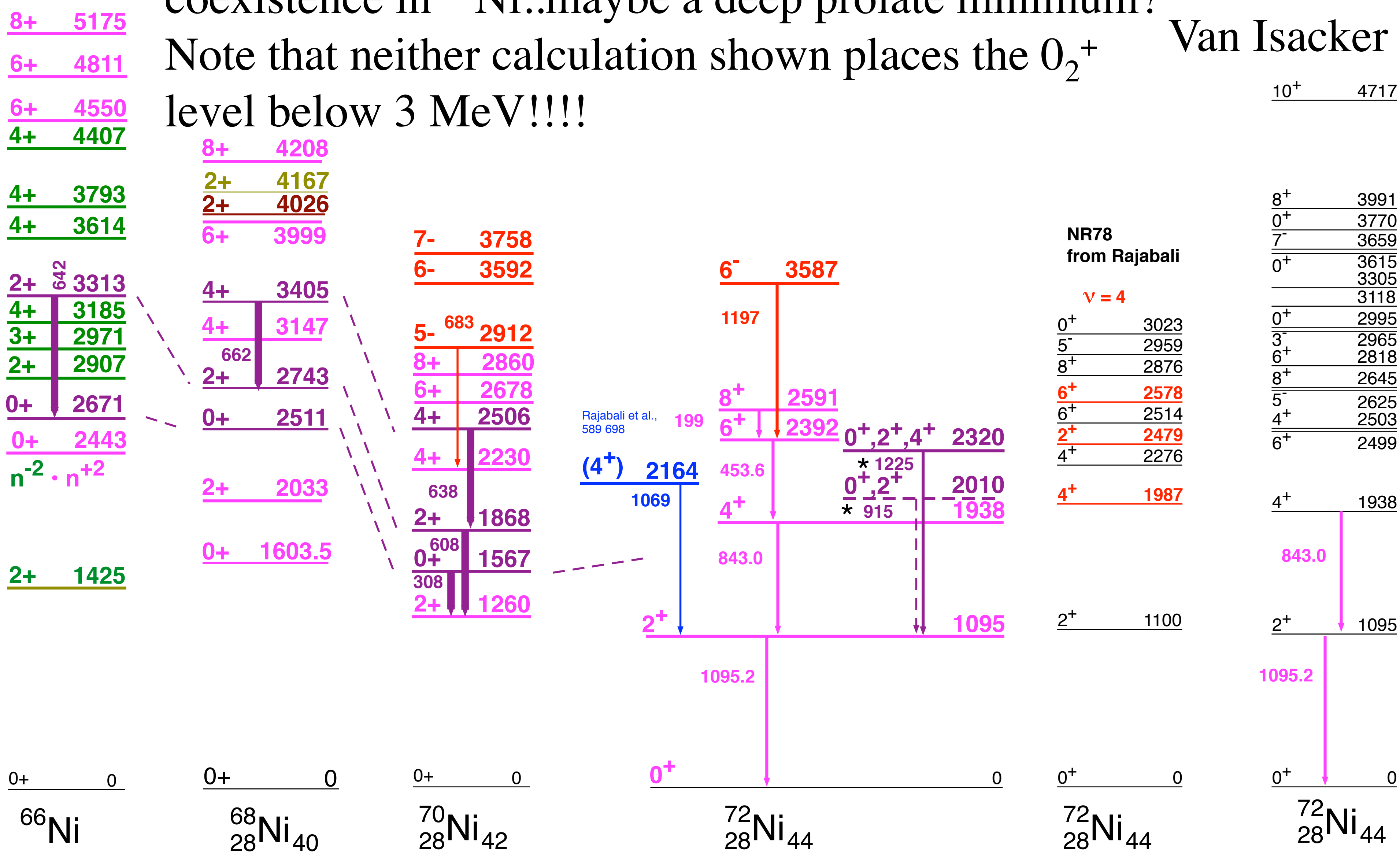


Here is a singles spectrum provided by Dirk Weisshaar with four prominent gamma rays, only two of which were previous assigned to levels in ^{72}Ni. These came from the same MSU GRETINA experiment that yielded the ^{70}Ni data, and, in this case, **via a 1-proton knock-out reaction from ^{73}Cu**..........**two more new gamma rays!!!!!**



It is now “plausible” that there is modest shape coexistence in ^{72}Ni..maybe a deep prolate minimum? Note that neither calculation shown places the 0_2^+ level below 3 MeV!!!!



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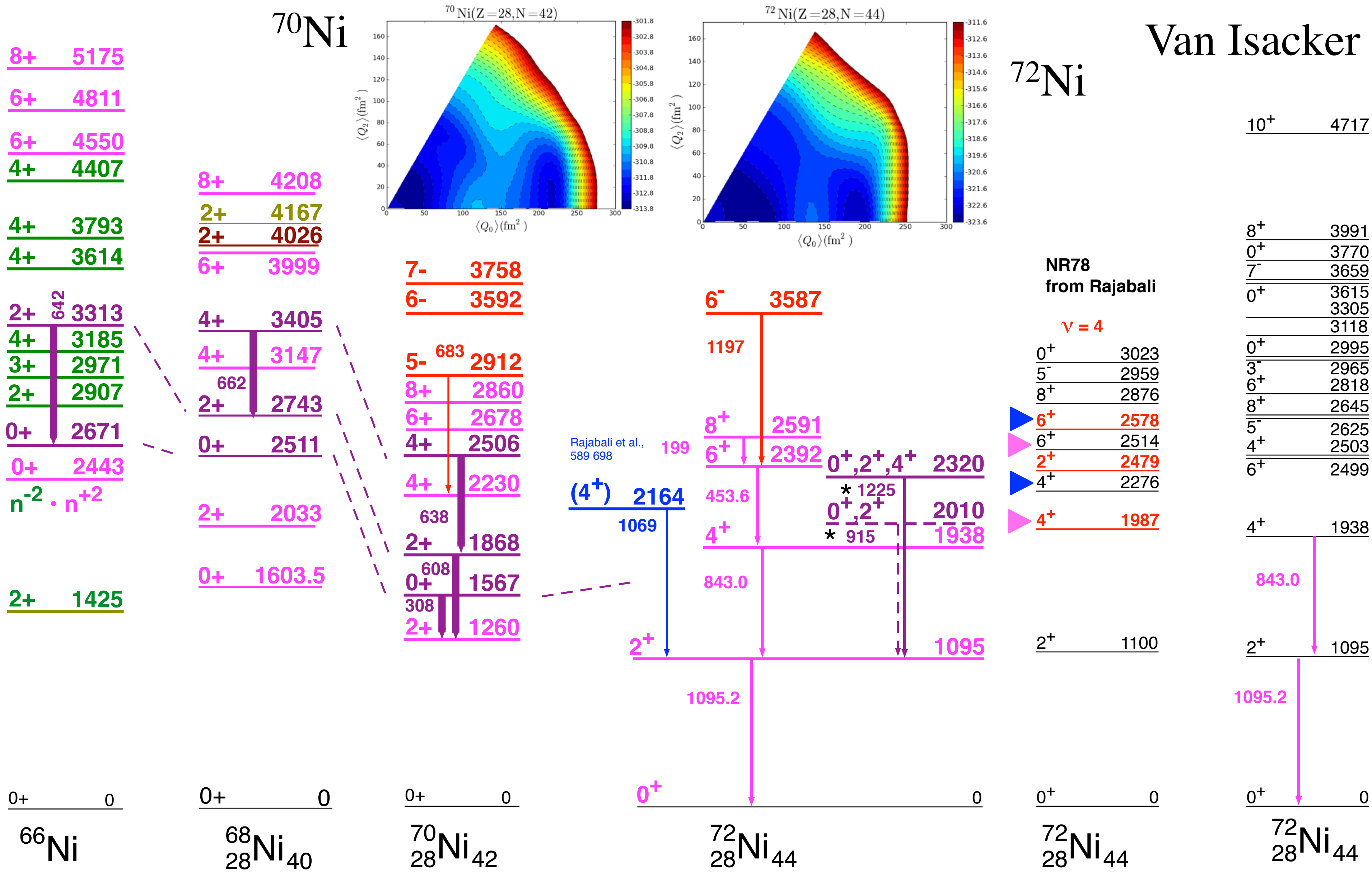

Conclusions:

New levels in ^{70}Ni, are identified that are consistent with a **deep prolate minimum at N = 42. These include a 4_2^+ to 2_2^+ sequence and a 0_2^+ level that is placed in the prolate well.**

One conclusion would seem to be that "something is missing" in that several models show a rather shallow minimum at N = 40 whereas, the data seem to suggest a deep prolate minimum either N = 42 or co-minima at N = 42 and N = 44. Perhaps the "missing something" is the full incorporation of the tensor interaction, that, in turn, better describes the proton components of these structures, largely isolated in a separate minimum.

This is a 3-part effect, the presence of the $g_{9/2}$ neutrons lowers the position of the $f_{5/2}$ protons, that, in turn, lowers the energy of the downsloping K = 1/2$^{\pm}$ and K = 3/2$^{\pm}$ Nilsson states for both protons and neutrons. Stated another way, the monopole shift that lowers the $f_{5/2}$ proton orbital is key to the prolate minimum in ^{70}Ni.