Search for the 0^+_2 state in ^{80}Ge from the beta decay of isomerically purified ^{80}Ga states

CERN-INTC-2021-058
INTC-P-619

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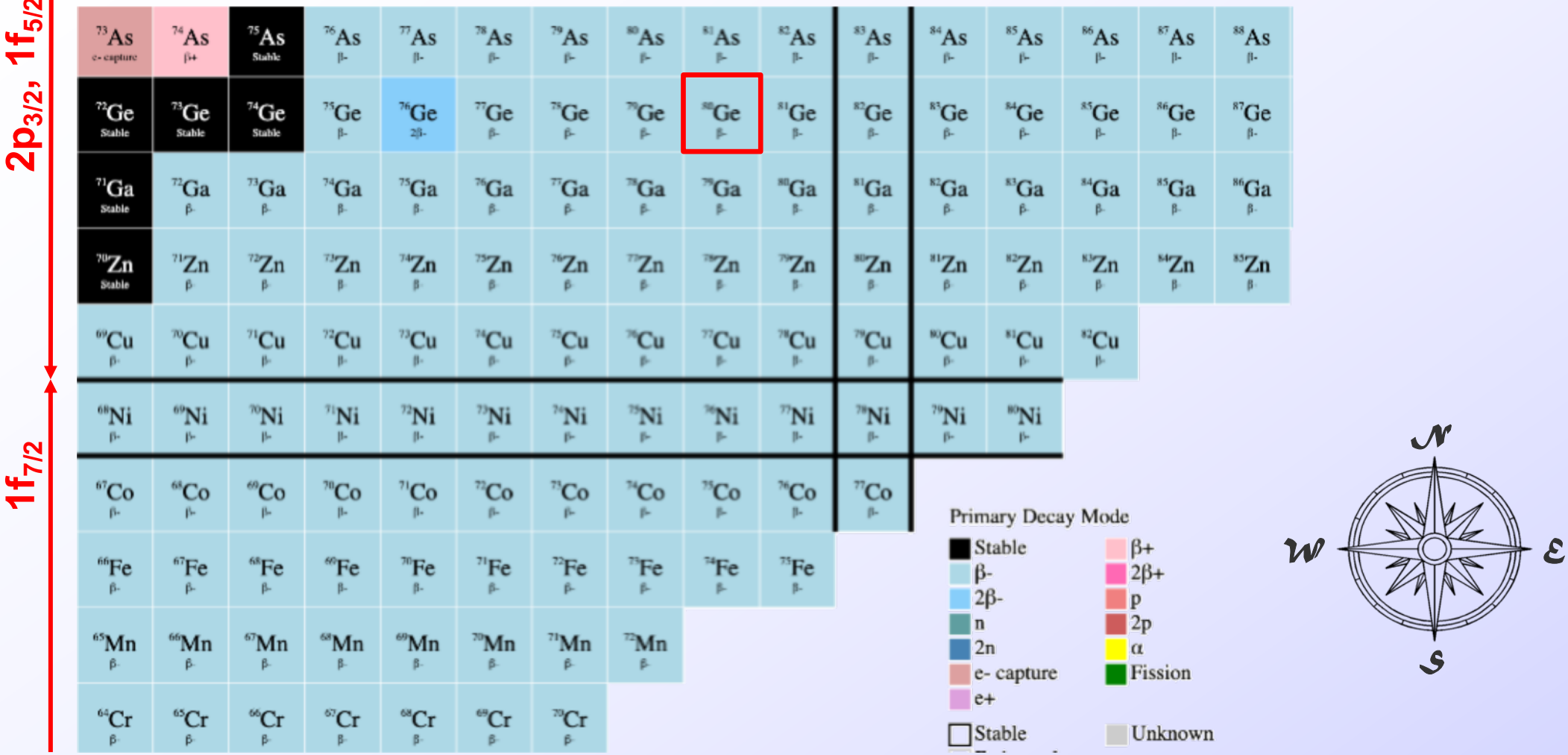
^{80}Ge


2p3/2, 1f5/2, 2p1/2
1f7/2
1g9/2
2d5/2, 1g7/2, 2d3/2
Primary Decay Mode
Stable
β-
2β-
n
2n
e- capture
e+
β+
2β+
p
2p
α
Fission
Stable
Unknown
N
W
E
S

Experimental observation of states in ^{78}Ni

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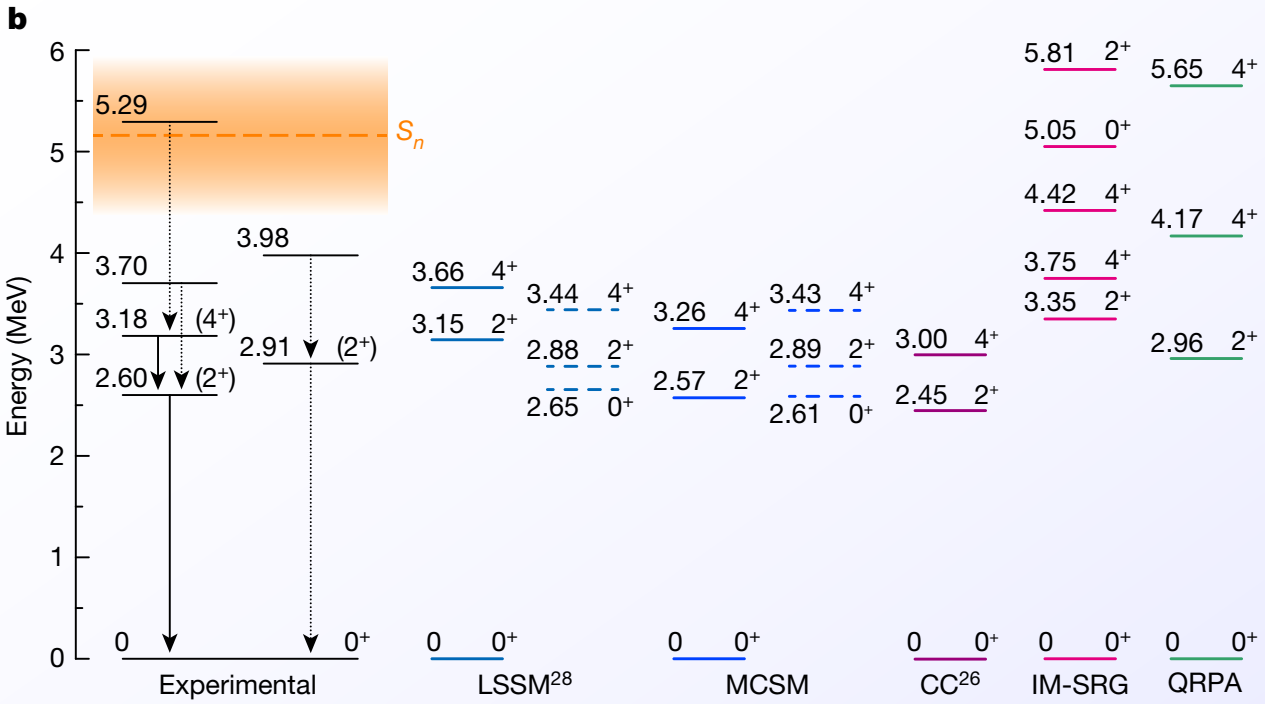

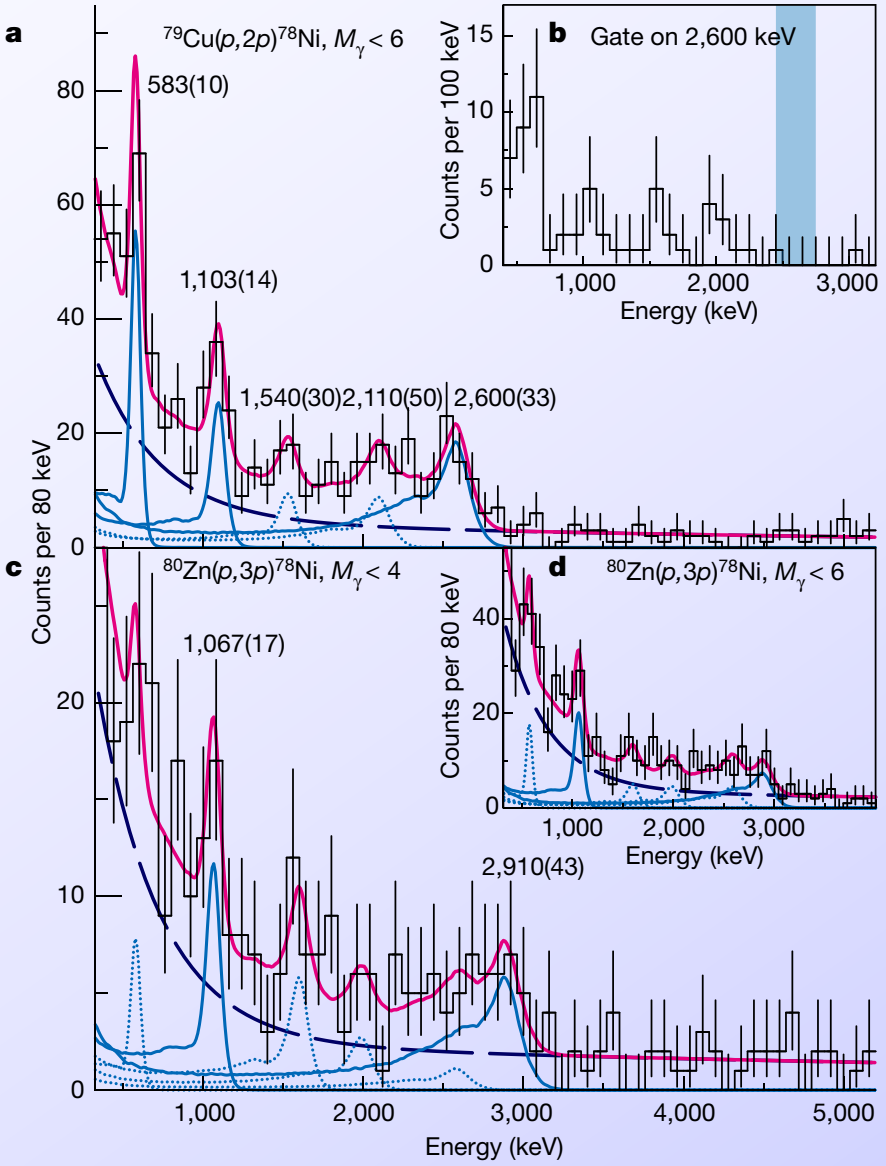

- Evidence for the doubly-magic nature of ^{78}Ni
- Role of collective effects: appearance of deformed states at low excitation energy

Taniuchi et al., Nature 569 (2019) 53

^{80}Ge (N=48, Z=32)

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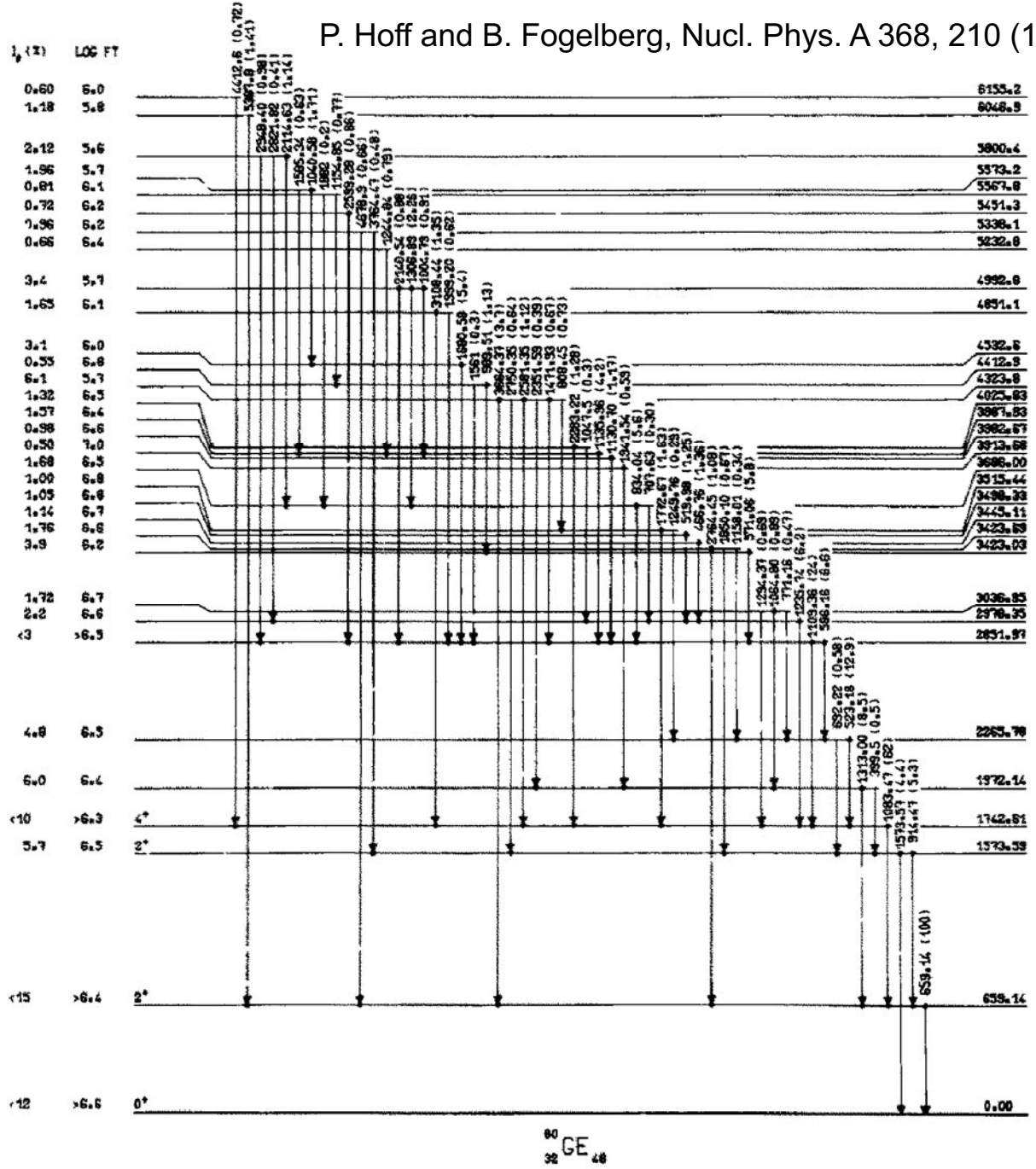
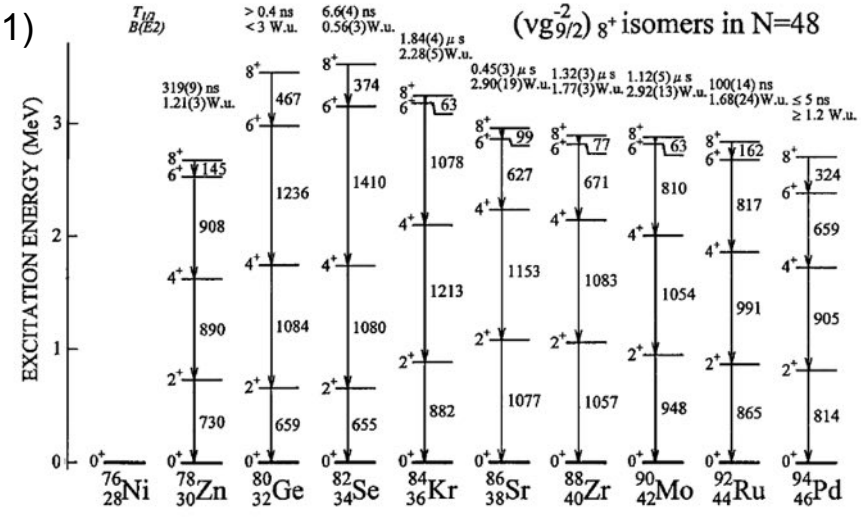
P. Hoff and B. Fogelberg, Nucl. Phys. A 368, 210 (1981)





A coherent picture of the excited structure of ^{80}Ge is believed to exist:

- **β-decay of ^{80}Ga**, 2 β-decaying states
- CoulEx in inverse kinematics
- DIS reactions
- 8^+ lifetime in beta-decay

Surprise, surprise…

PRL 116, 182501 (2016) PHYSICAL REVIEW LETTERS 6 MAY 2016

First Evidence of Shape Coexistence in the ^{78}Ni Region: Intruder 0_2^+ State in ^{80}Ge

A. Gottardo,[1,*] D. Verney,[1] C. Delafosse,[1] F. Ibrahim,[1] B. Roussière,[1] C. Sotty,[2] S. Roccia,[3] C. Andreoiu,[4] C. Costache,[2] M.-C. Delattre,[1] I. Deloncle,[3] A. Etilé,[5] S. Franchoo,[1] C. Gaulard,[3] J. Guillot,[1] M. Lebois,[1] M. MacCormick,[1] N. Marginean,[2] R. Marginean,[2] I. Matea,[1] C. Mihai,[2] I. Mitu,[2] L. Olivier,[1] C. Portail,[1] L. Qi,[1] L. Stan,[2] D. Testov,[6,7] J. Wilson,[1] and D. T. Yordanov[1]

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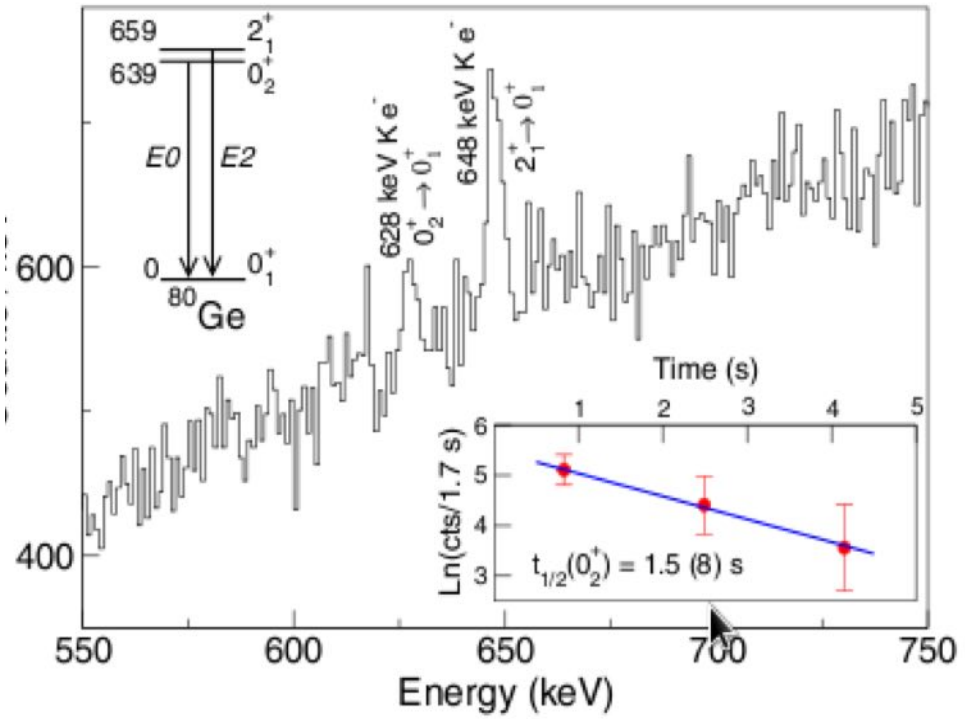
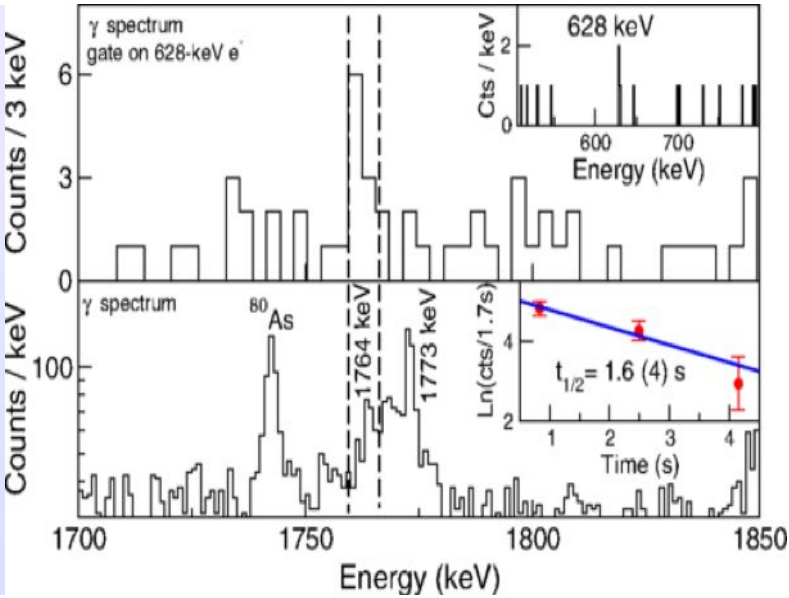
(Received 26 January 2016; published 5 May 2016)

The $N = 48$ ^{80}Ge nucleus is studied by means of β-delayed electron-conversion spectroscopy at ALTO. The radioactive ^{80}Ga beam is produced through the isotope separation on line 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 a 639(1) keV intruder 0_2^+ state, is observed for the first time. This new state is lower than the 2_1^+ level in ^{80}Ge, and provides evidence of shape coexistence close to one of the most neutron-rich doubly magic nuclei discovered so far, ^{78}Ni. This result is compared with theoretical estimates, helping to explain the role of monopole and quadrupole forces in the weakening of the $N = 50$ gap at $Z = 32$. The evolution of intruder 0_2^+ states towards ^{78}Ni is discussed.

DOI: 10.1103/PhysRevLett.116.182501



- A new intruder state 0^+_2 is observed, proposed at 639 keV
- E0 e^- in coincidence with a new gamma of 1764 keV
- New level @ 639 + 1764 = 2403 keV



See also F. Nowacki, A. Poves, E. Caurier, PRL 117, 272501 (2016)

Is there shape-coexistence in ^{80}Ge?

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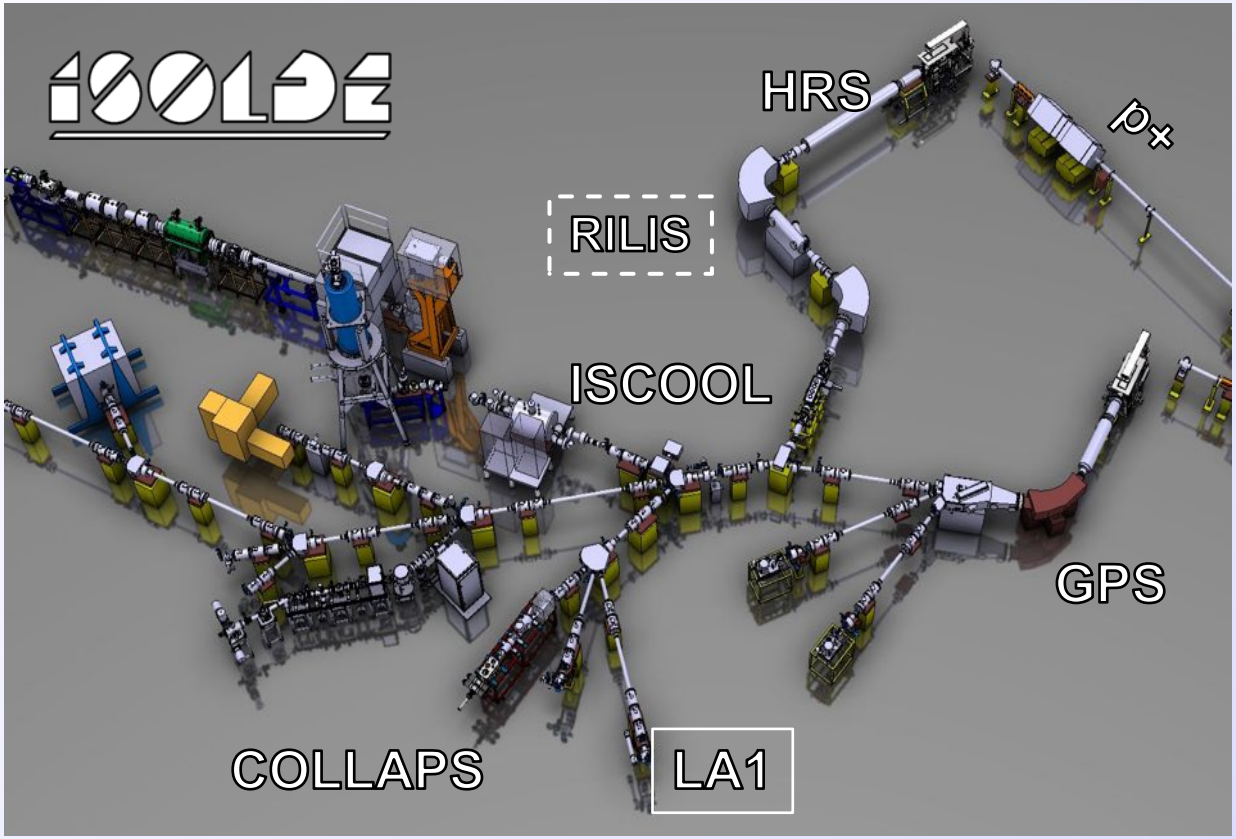
Experiment at ISOLDE

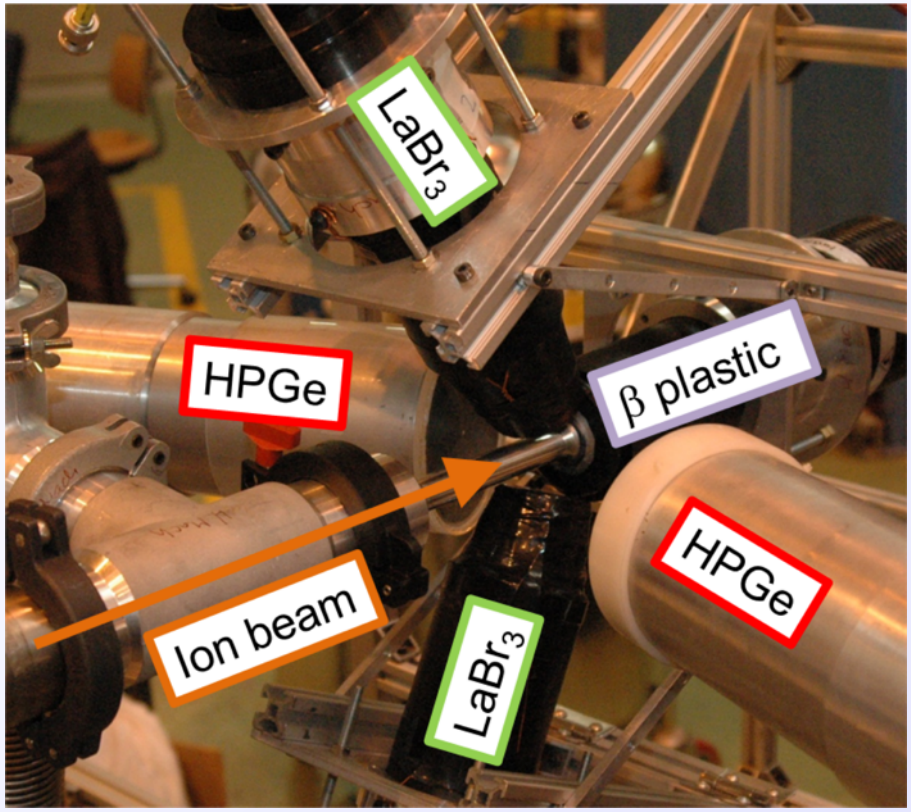
→ Beta-decay, starting from ^{81}Zn

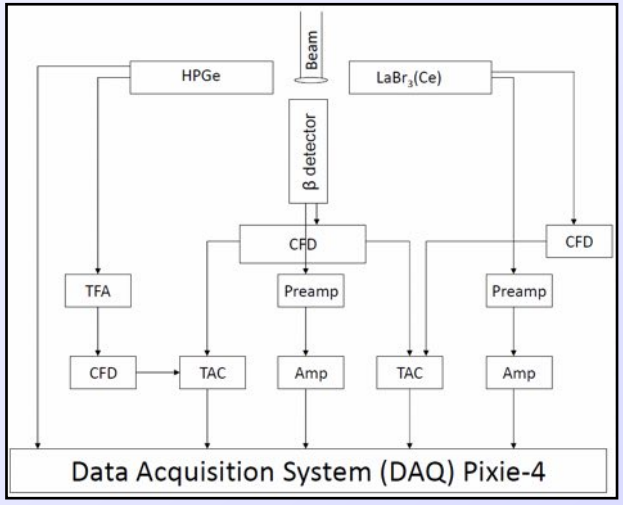
→ Pure beam, ^{80}Ga parent mostly in **3**$^{-}$

→ $\gamma\gamma$ and fast timing, no e^{-}

Analysis by Smain Sekal







Search for 2nd 0+ state in ^{80}Ge

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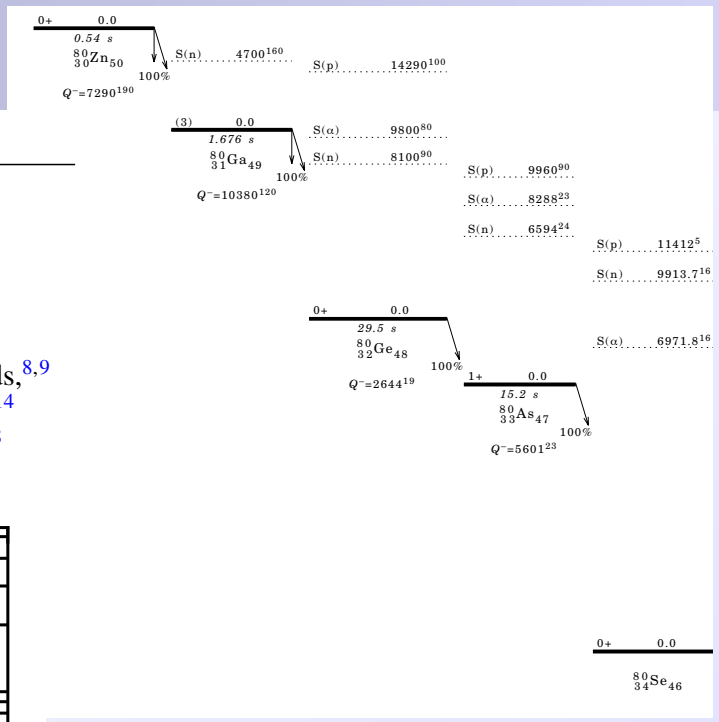
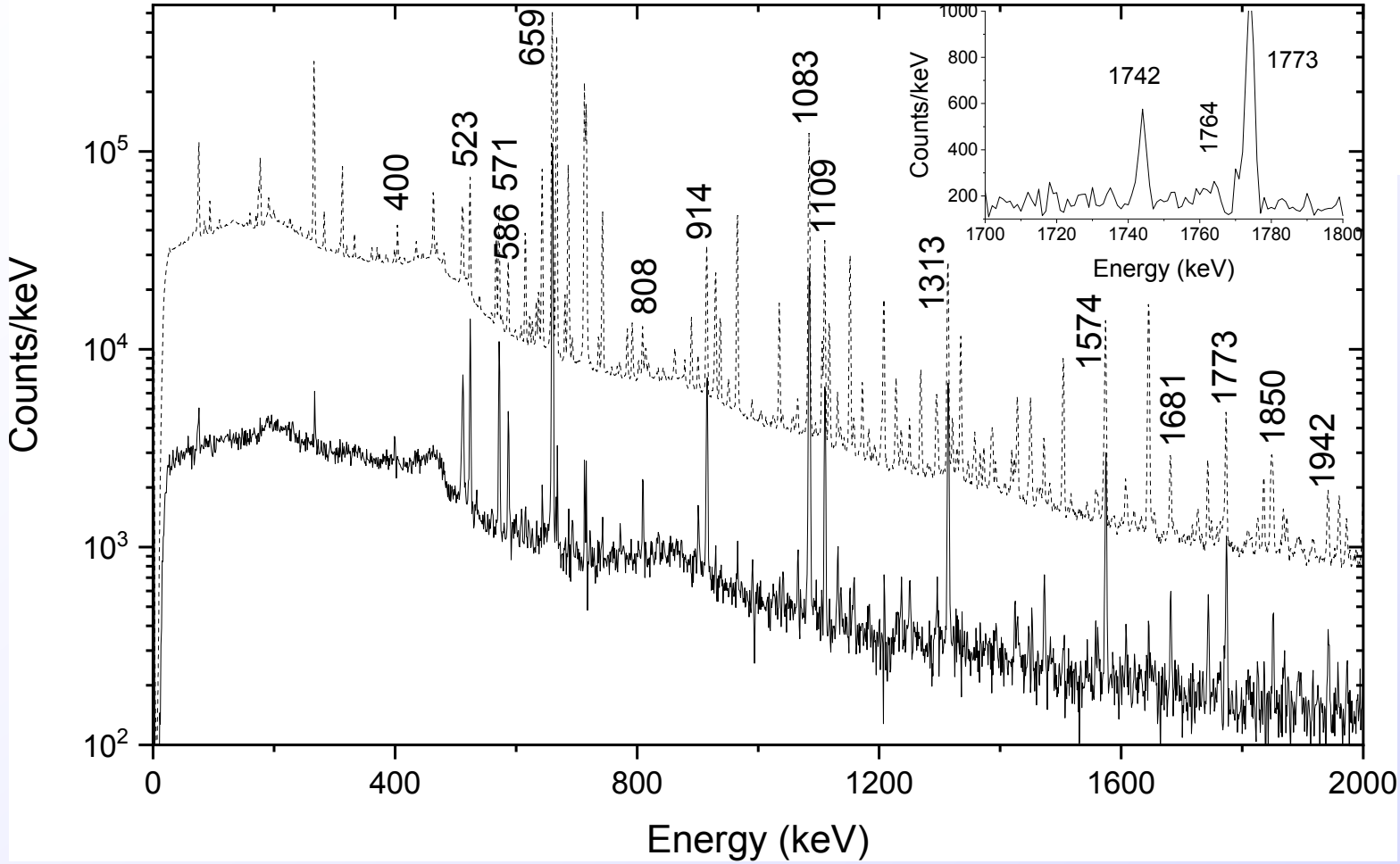
PHYSICAL REVIEW C **104**, 024317 (2021)

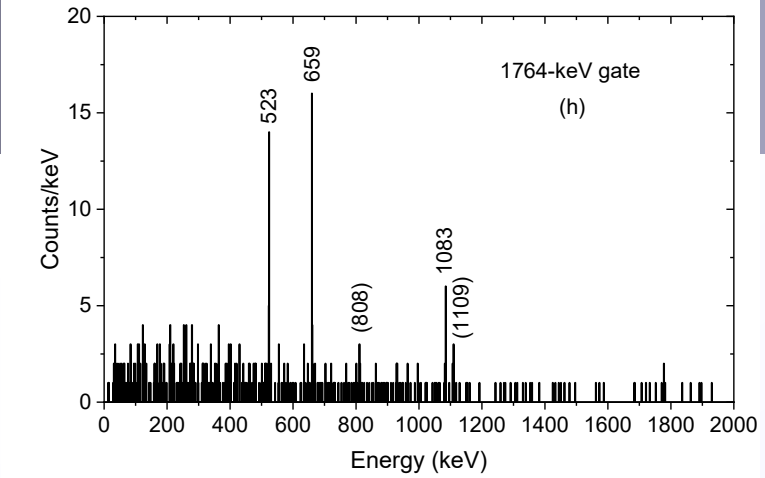


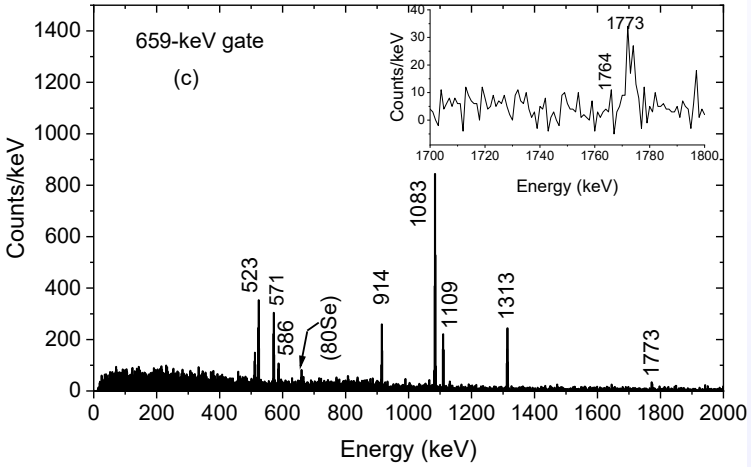
Low-spin states in ^{80}Ge populated in the β decay of the ^{80}Ga 3$^-$ isomer

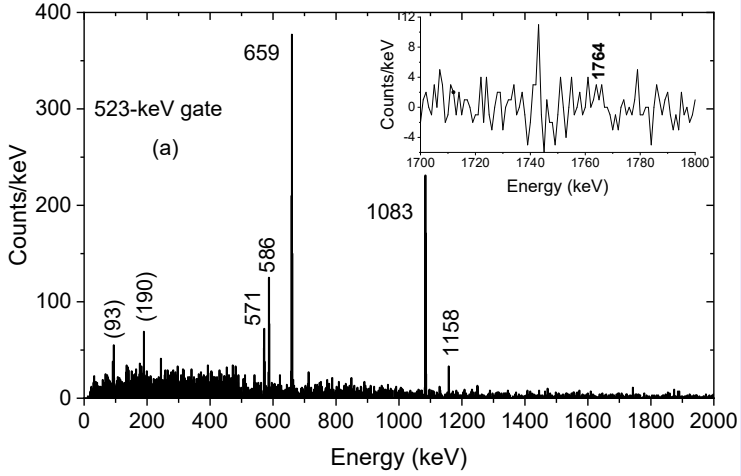
S. Sekal,[1,2,*] L. M. Fraile,[3,†] R. Lică,[2,4] M. J. G. Borge,[5] W. B. Walters,[6] A. Aprahamian,[7] C. Benchouk,[1] C. Bernards,[8,9] J. A. Briz,[5] B. Bucher,[10] C. J. Chiara,[6,11,‡] Z. Dlouhý,[12,§] I. Gheorghe,[4] D. G. Ghiţă,[4] P. Hoff,[13] J. Jolie,[8] U. Köster,[14] W. Kurcewicz,[15] H. Mach,[3,16,§] N. Mărginean,[4] R. Mărginean,[4] Z. Meliani,[1] B. Olaizola,[2,3] V. Paziv,[3] J. M. Régis,[8] M. Rudigier,[8] T. Sava,[4] G. S. Simpson,[17,18] M. Stănoiu,[4] and L. Stroe[4]

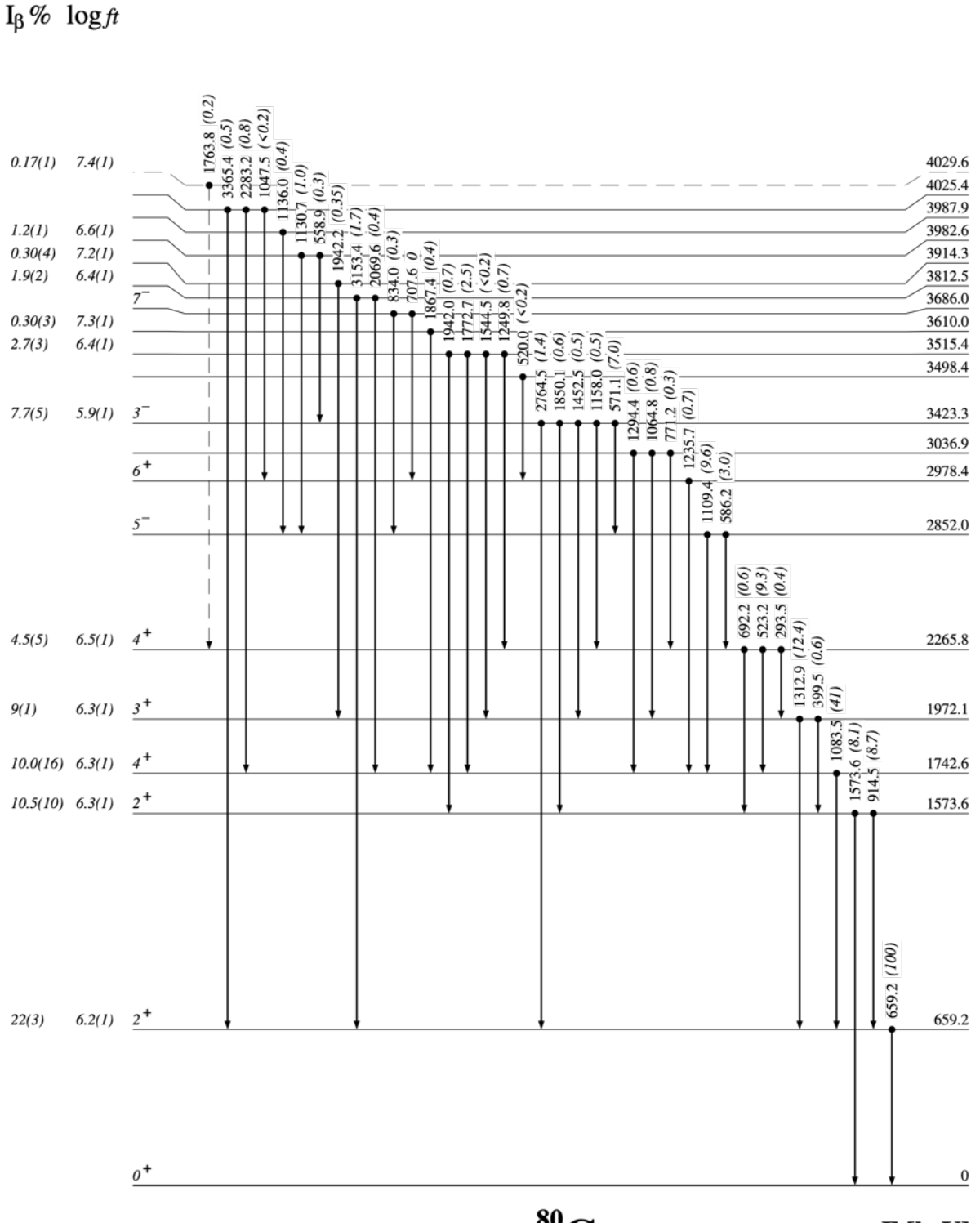


1764 keV from our analysis





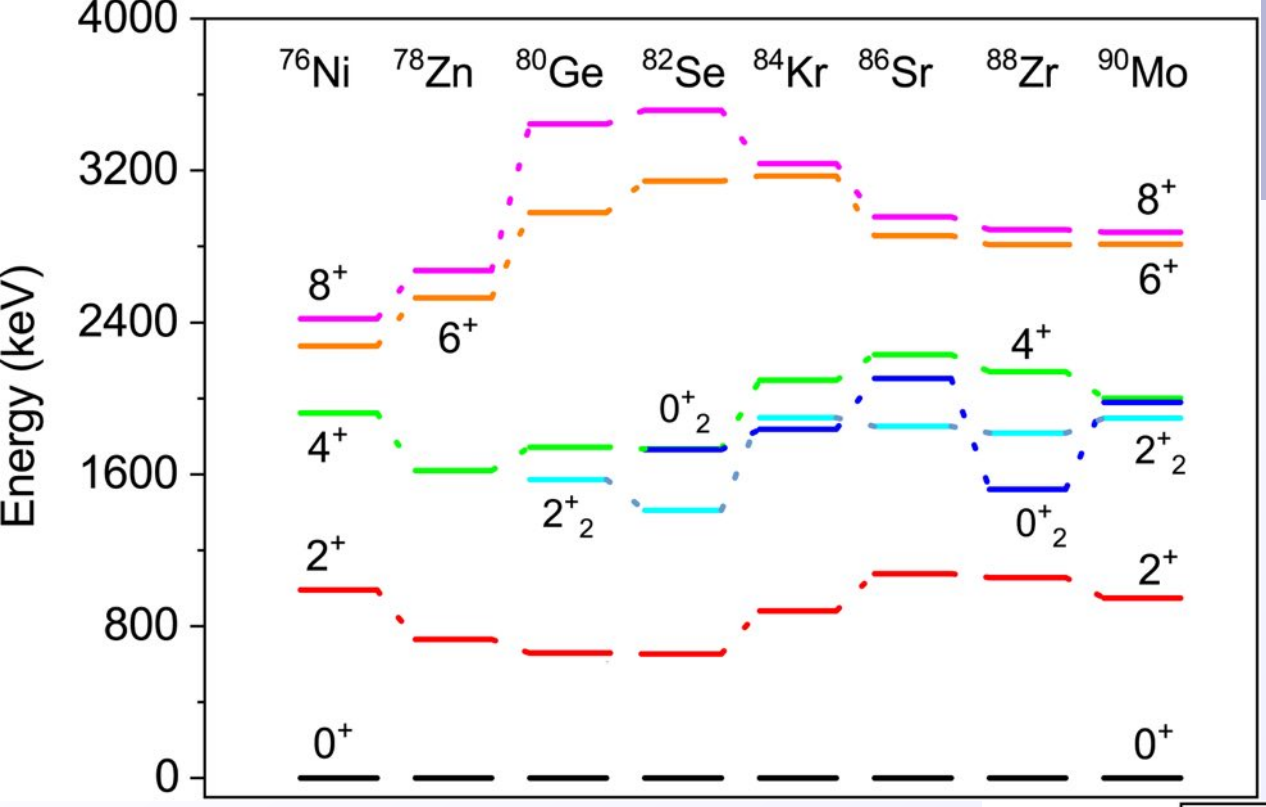




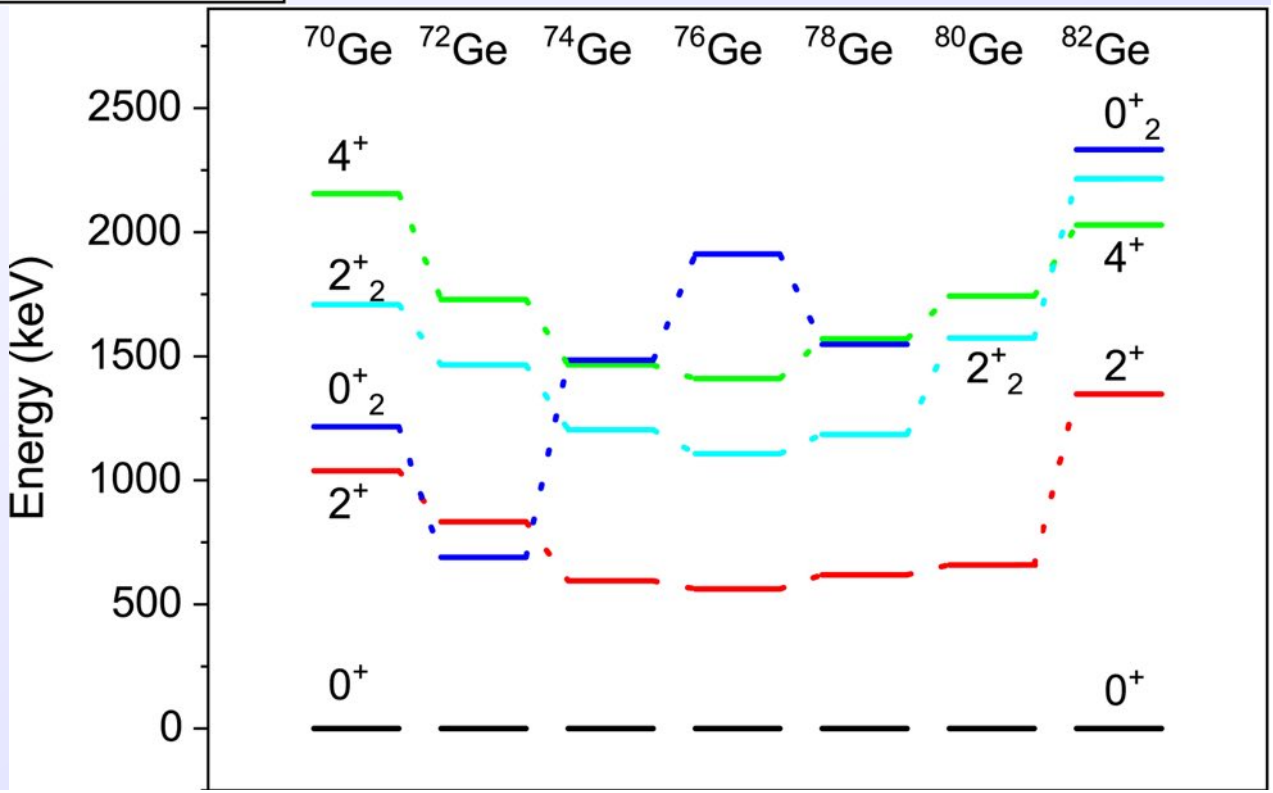
I. Sekal et al., PRC104 024317 (2021) $^{80}_{32}Ge_{48}$

Systematics

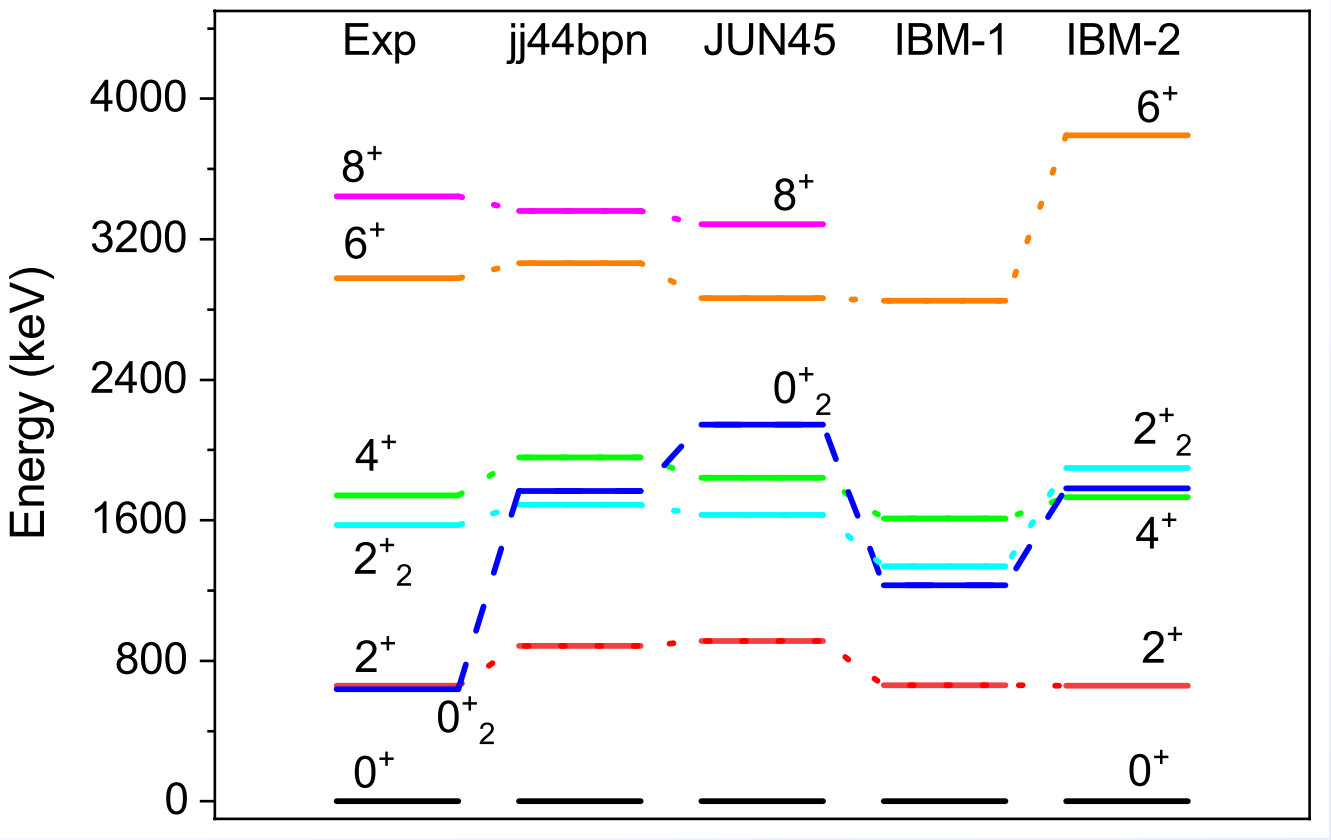
I. Sekal et al., PRC104 024317 (2021)



Both the Ge isotopic chain and the N = 48 isotones suggest the location of the 0^+_2 state at around 1.5 MeV



Experiment and calculations



SM calculations succeed to explain most of the experimental levels, but fail to reproduce the presence of a 0^+_2 state below ~1200 keV in ^{80}Ge.

IBM calculations as well, with exception of Zhang et al., 2018.

We observe a 1764-keV γ ray in coincidence with the 659-keV $2^+_1 \rightarrow 0^+$ g.s., and with other transitions in ^{80}Ge.

No connecting transitions from previously-known levels to the proposed 639-keV 0^+_2 and 2403 2^+_3 states [Gottardo et al.] could be established.

The experimental evidence and the shell model calculations cannot be reconciled with the presence of such state at low excitation.

High-statistics experiment with and electron spectroscopy

Absence of Low-Energy Shape Coexistence in ^{80}Ge: The Nonobservation of a Proposed Excited 0_2^+ Level at 639 keV

F. H. Garcia,[1,*] C. Andreoiu,[1] G. C. Ball,[2] A. Bell,[1] A. B. Garnsworthy,[2] F. Nowacki,[3,4] C. M. Petrache,[5] A. Poves,[6] K. Whitmore,[1] F. A. Ali,[7,8] N. Bernier,[2,9,†] S. S. Bhattacharjee,[2,‡] M. Bowry,[2] R. J. Coleman,[10] I. Dillmann,[2,11] I. Djanto,[1] A. M. Forney,[12] M. Gascoine,[1] G. Hackman,[2] K. G. Leach,[13] A. N. Murphy,[2] C. R. Natzke,[14,13] B. Olaizola,[14] K. Ortner,[1] E. E. Peters,[15] M. M. Rajabali,[16] K. Raymond,[1] C. E. Svensson,[10] R. Umashankar,[14] J. Williams,[1,§] and D. Yates[14,9]

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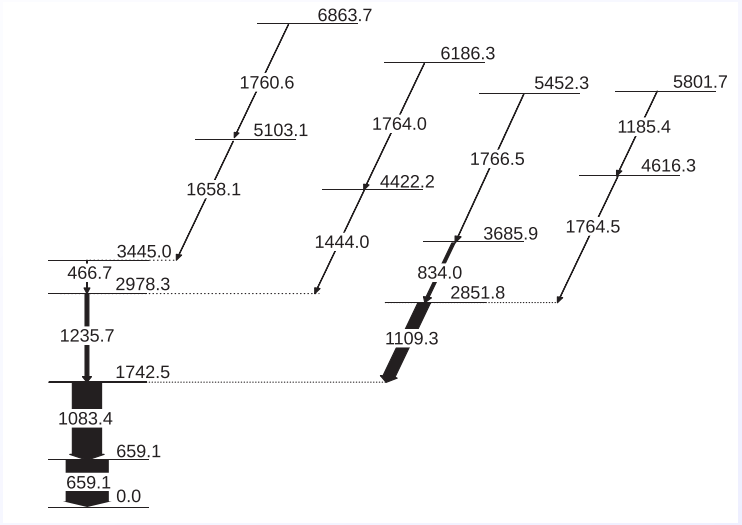
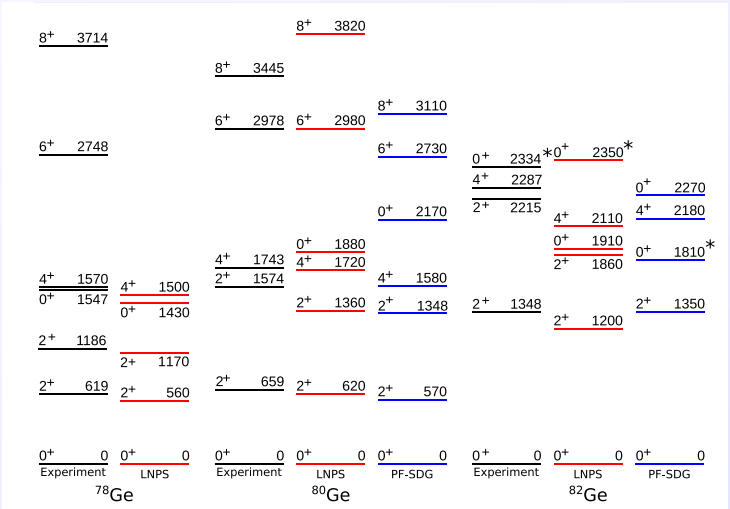
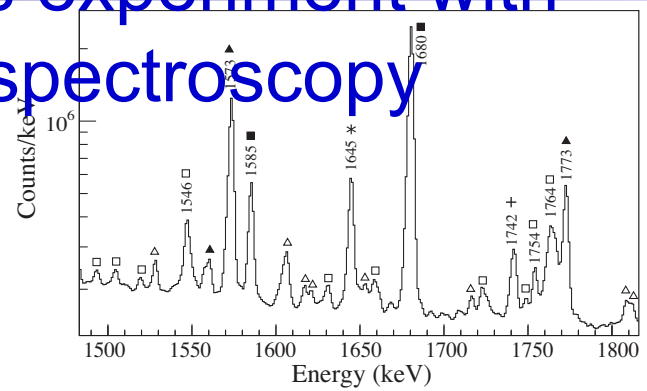
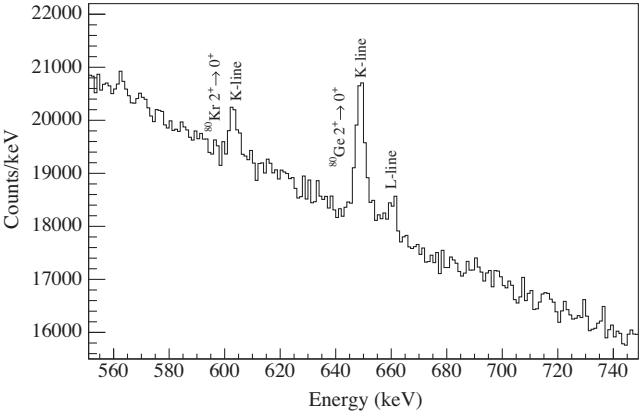
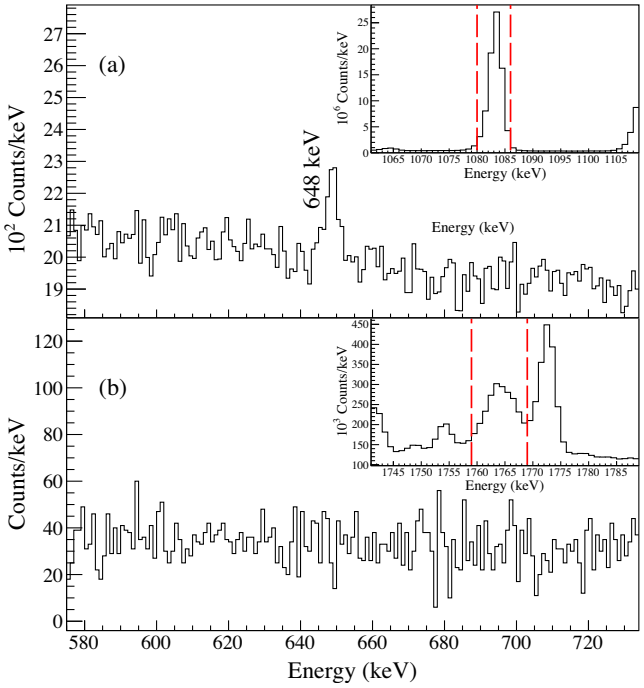
(Received 19 June 2020; revised 19 August 2020; accepted 18 September 2020; published 23 October 2020)











No evidence for an excited 0+ state located below the 2+ state at 659 keV is found in this experiment, despite detailed investigations using multiple **β**-electron, **γ**-electron, and **γ-γ** coincidences. Additionally, driven by these experimental results, large-scale shell-model calculations that reproduced well the excited 0+ states in 78,82Ge and other low-lying levels in 78-82Ge, cannot replicate the 0+ state suggested at 639 keV in 80Ge; the calculations instead predict the first excited 0+ state at 2 MeV.

Aim of the proposal

Investigate the structure of ^{80}Ge populated separately in the β decay of the isomerically purified ^{80}Ga 6^- ground state and the ^{80}Ga 3^- using the PI-LIST ion source.

Search for the 0^+_2 state in ^{80}Ge

Independent study of both isomers

Measure β-decay half-lives

γ spectroscopy and γγ coincidences to search for feeding and de-exciting transitions from the 0^+_2 and conversion-electron spectroscopy to look for the internal conversion from the E0 transition to g.s.

Expected improvement

Competitive wrt. F.H. Garcia et al., PRL 125 (2020) GRIFIN due to

- **Isomer separation**
- Duty cycle
- Beta detector efficiency (~90% vs. 40%)

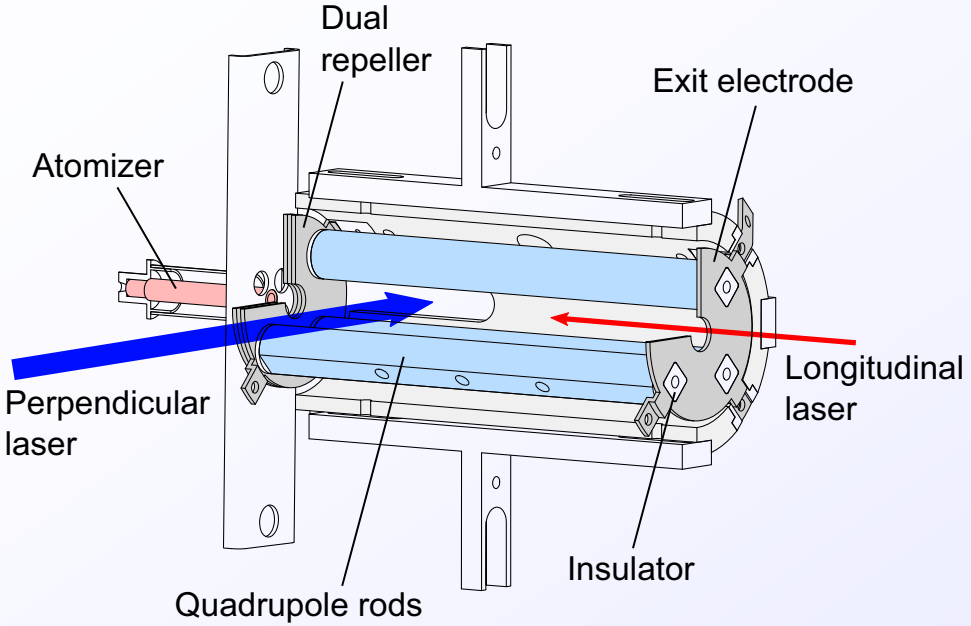
Improvement wrt. S. Sekal et al., PRC104 024317 (2021)

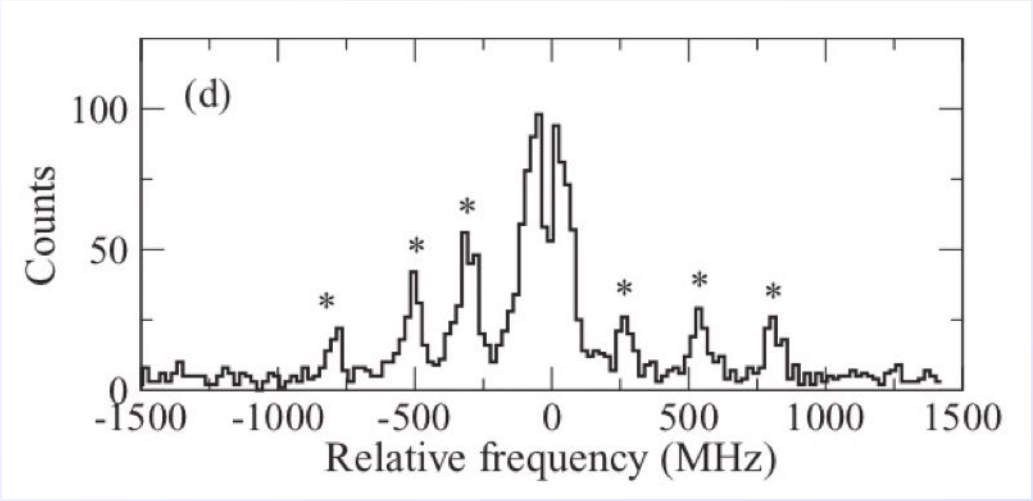
- **Electron spectroscopy**
- Gamma (and coincidence) efficiency

Allows for independent measurement of decay lifetimes

Beam time request

- UC_2/graphite target
- PI-LIST





B. Cheal et al., Phys. Rev. C 82, 051302(R) (2010)

TISD will be required to verify the performance of the PI-LIST

Most likely 100 MHz resolution not required

- IDS setup with 4 Clovers and internal conversion spectroscopy setup

Beam time request

L.M. Fraile

^{80}Ga state	$T_{1/2}$ (s)	Yield (ions/μC)	p current (μA)	trans. (%)	PI-LIST eff. (%)	ions /s	duty cycle (%)	ions /hour	ions /shift
3^-	1.3	4.5E6	1.7	90	0.1	6.9E3	74	1.8E7	1.5E8
6^-	1.9	4.5E6					65	1.6E7	1.3E8

40% of PSB pulses

Implantation for 2 out of 5 **p**$^+$ cycles
1 s tape movement

Assumed equal yield for each
Assumed factor 30 enhancement due to RILIS

1000 loss factor

Optimization of PI-LIST: 1 shift

^{80}Ga 3^- isomer: 7 shifts

^{80}Ga 6^- g.s.: 3 shifts

1 shift for cycle adjusted to beta lifetimes measurements

Collaboration

L.M. Fraile[1], J. Benito[1], J.A. Briz[1], M. Llanos[1], J.R. Murias[1], V. Sánchez-Tembleque[1], J.M. Udías[1], K. Chrysalidis[2], V. Fedosseev[2], R. Heinke[2], R. Lică[2], B. Marsh[2], B. Olaizola[2], S. Pascu[2], B. Reich[2], S. Rothe[2], K. Wendt[3], F. Weber[3], S. Sekal[4], J. Jolie[5], U. Köster[6], K.Y. Hee[6], M.J.G. Borge[7], O. Tengblad[7], W.B. Walters[8], A. Briscoe[9,10], A. Illana-Sison[9,10], A. Montes Plaza[9,10], J. Ojala[9,10], J. Pakarinen[9,10], A. Algora[11], E. Nácher[11], J. Carroll[12], C.J. Chiara[12] (for the IDS Collaboration)

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