New (and old) results from GRIFFIN

C. Andreoiu et al. - SFU-TRIUMF, Canada
C.M. Petrache et al. - IJClab, Orsay, France

TOPICS

- shape coexistence in $^{114\text{-}120}$Sn (Pore, Cross, Ortner, Wu)
in ^{80}Ge (Garcia), in ^{134,136}Nd (Petrache)

- nuclei around ^{132}Sn (Dunlop, Garcia, Withmore)

- PDR in ^{80}Ge (Garcia), in ^{82}Sr (Spagnoletti)

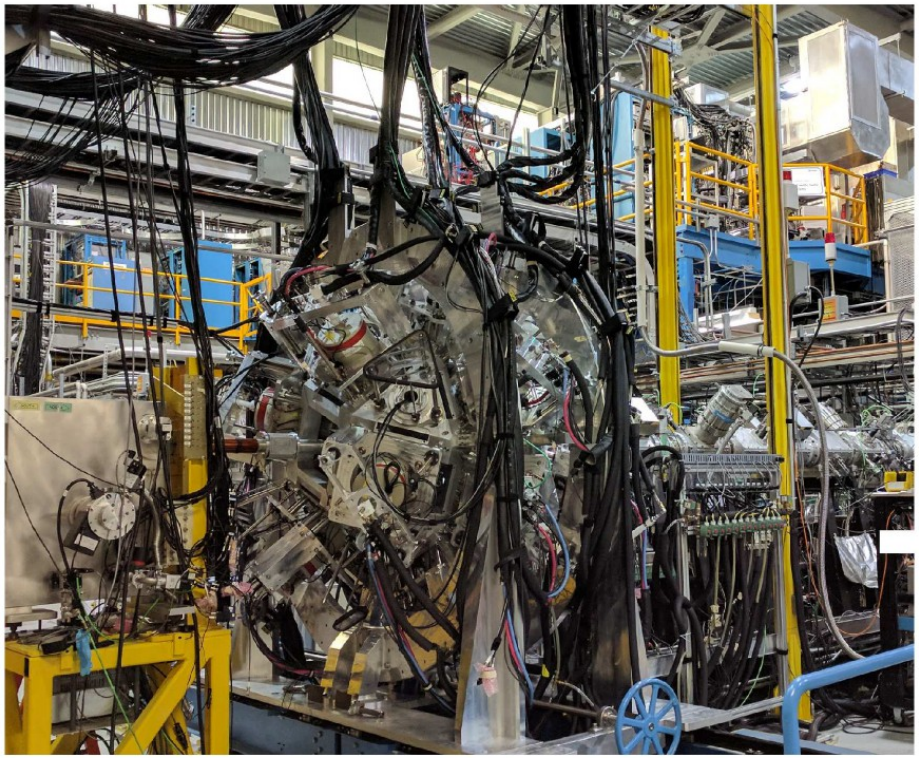
- neutron-rich nuclei: ^{160}Gd (Yates)

GRIFFIN

A powerful array with a number of ancillaries:

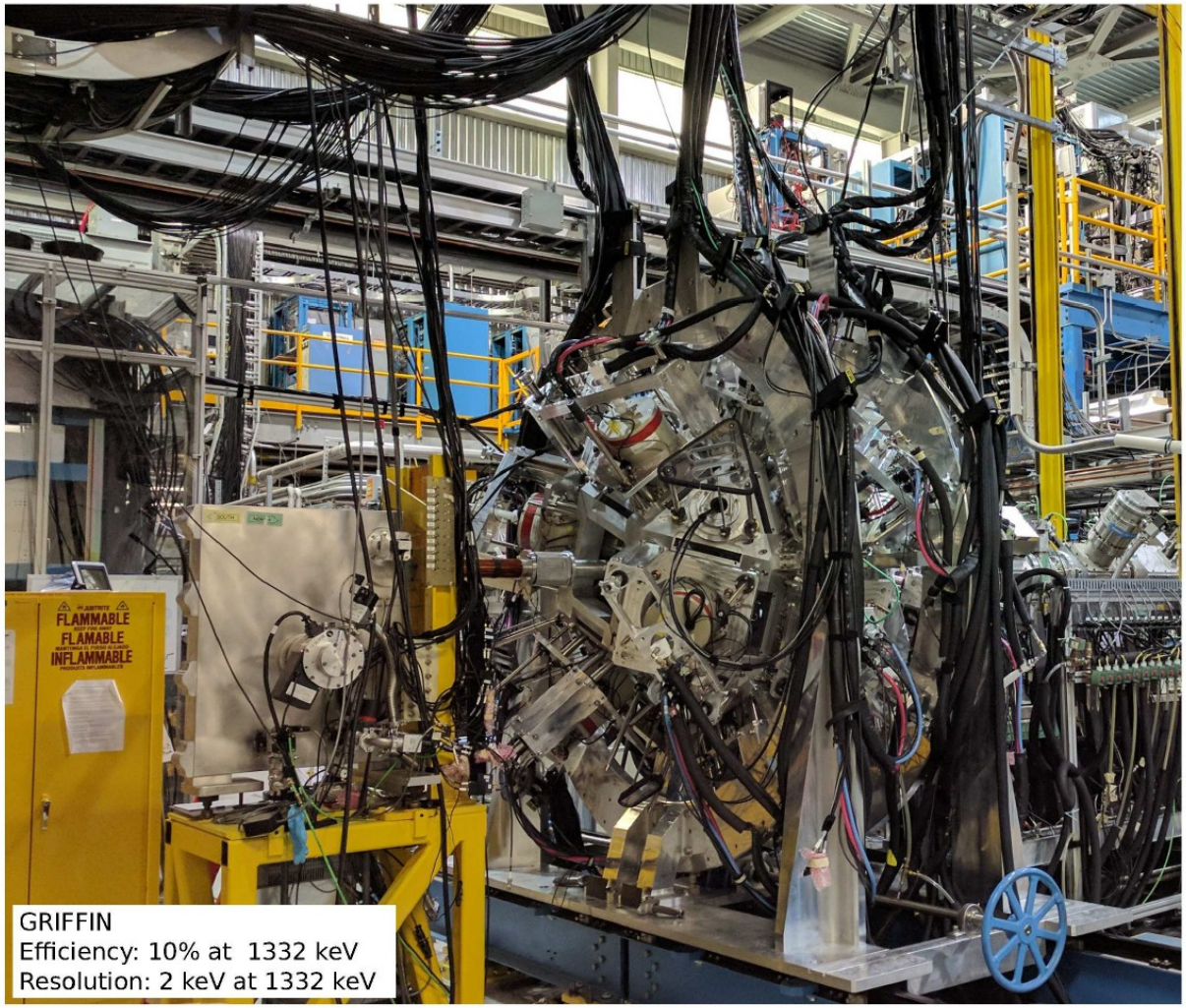
- 16 HPGe detectors: $\gamma - \gamma$
- GRIFFIN+ZDS: $\gamma - \beta$
- GRIFFIN+SCEPTAR: $\gamma - \beta$
- GRIFFIN+PACES: $\gamma - e$
- GRIFFIN+DESCANT: γ−n
- GRIFFIN+$LaBr_3$: level lifetimes

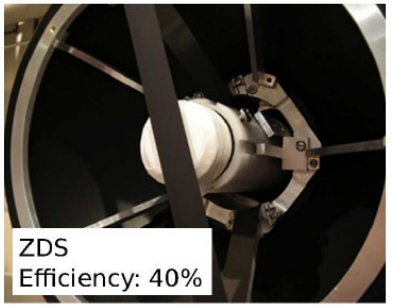
making for a versatile and modular decay station

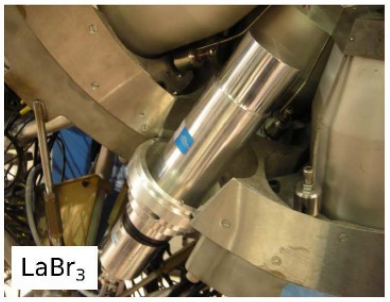


Garnsworthy, A. B. *et al.*, *NIM A* 918,9 (2019)

GRIFFIN for β-decay spectroscopy

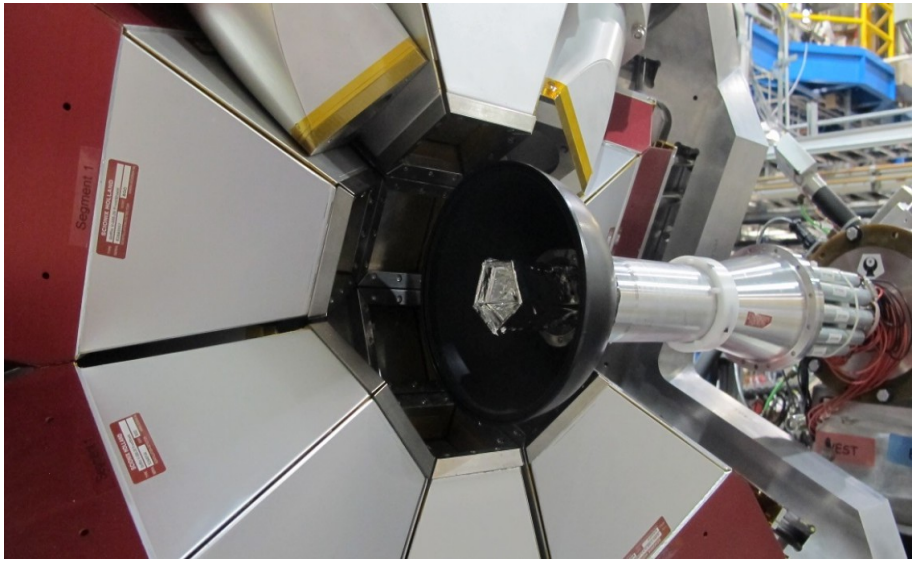




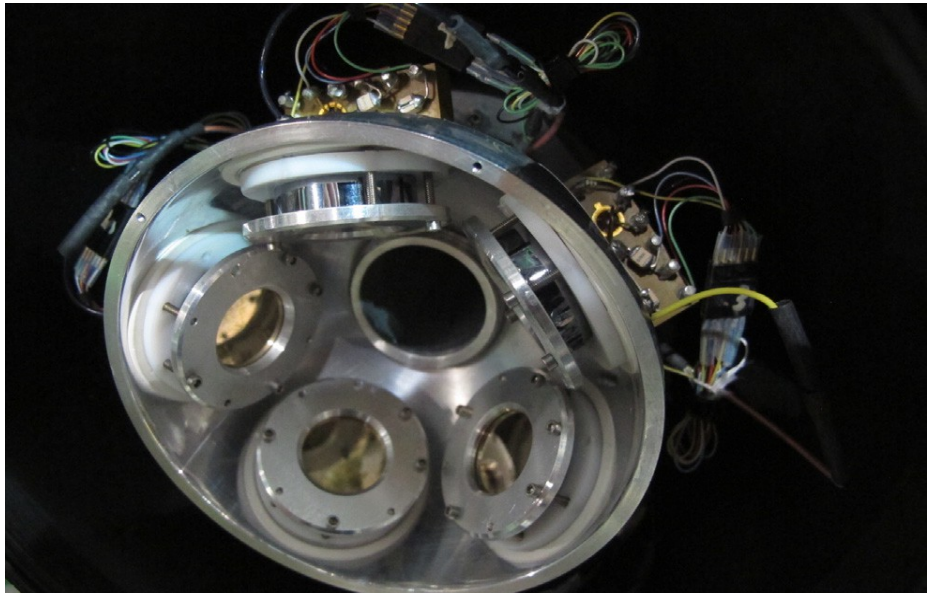


Garnsworthy, A. B. *et al.*, *NIM A* 918,9 (2019)

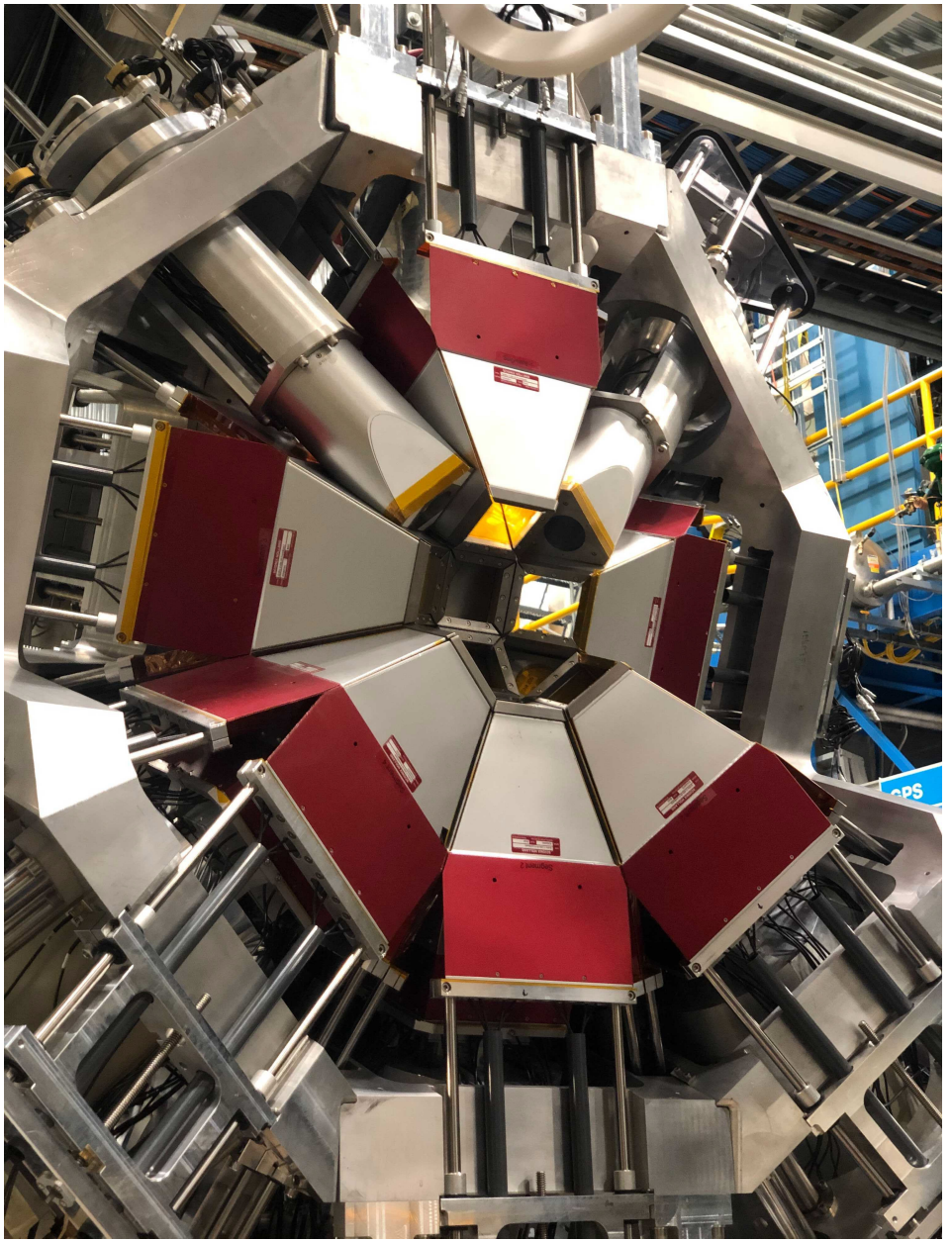
SCEPTAR



PACES



GRIFFIN



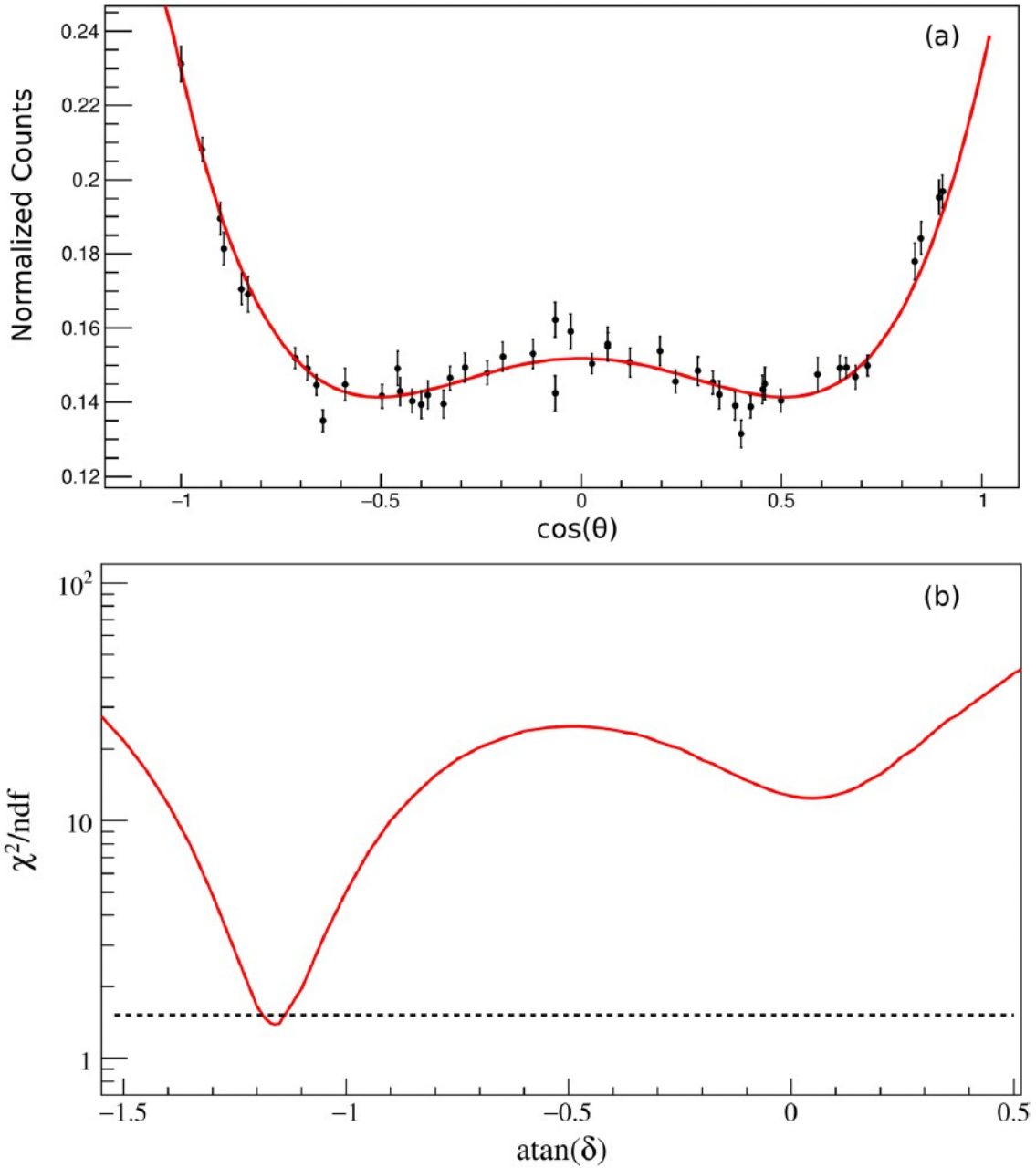


FIG. 3. Angular correlation (a) of the $2_2^+ \rightarrow 2_1^+ \rightarrow 0_1^+$ (813 keV–1230 keV coincidence) and its corresponding χ^2 minimization plot (b) to determine the mixing ratio. In (b), the dashed line represents the 3σ limit to identify the mixing ratio for a given spin assignment. In this case, the $2_2^+ \rightarrow 2_1^+$ has a $\delta = -2.28(7)$ which agrees with the literature value of $-2.34(16)$.

Exploring the predicted shape coexistence in ^{134,136}Nd using the β-decay in ^{134,136}Pm and the GRIFFIN+PACES setup

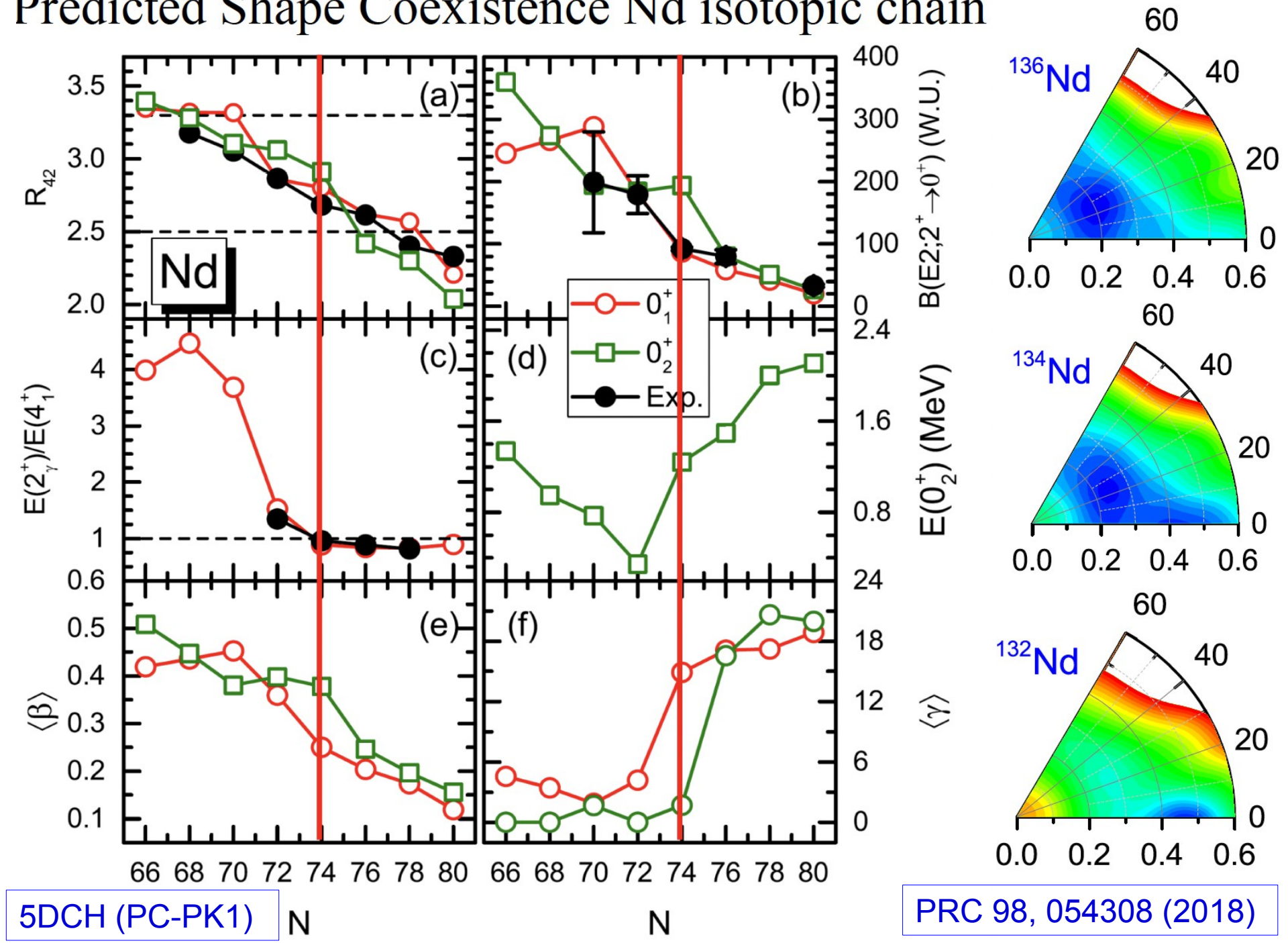
Beam approved, not yet scheduled: 15 shifts

- 12 shifts of ^{134}Pm, intensity 1.36×10^{2} pps
- 3 shifts of ^{136}Pm, intensity 1.44×10^{4} pps

Target/source : Ta/Re surface ionization + IG-LIS

Conservative estimates with proton beam of only 20 μA!

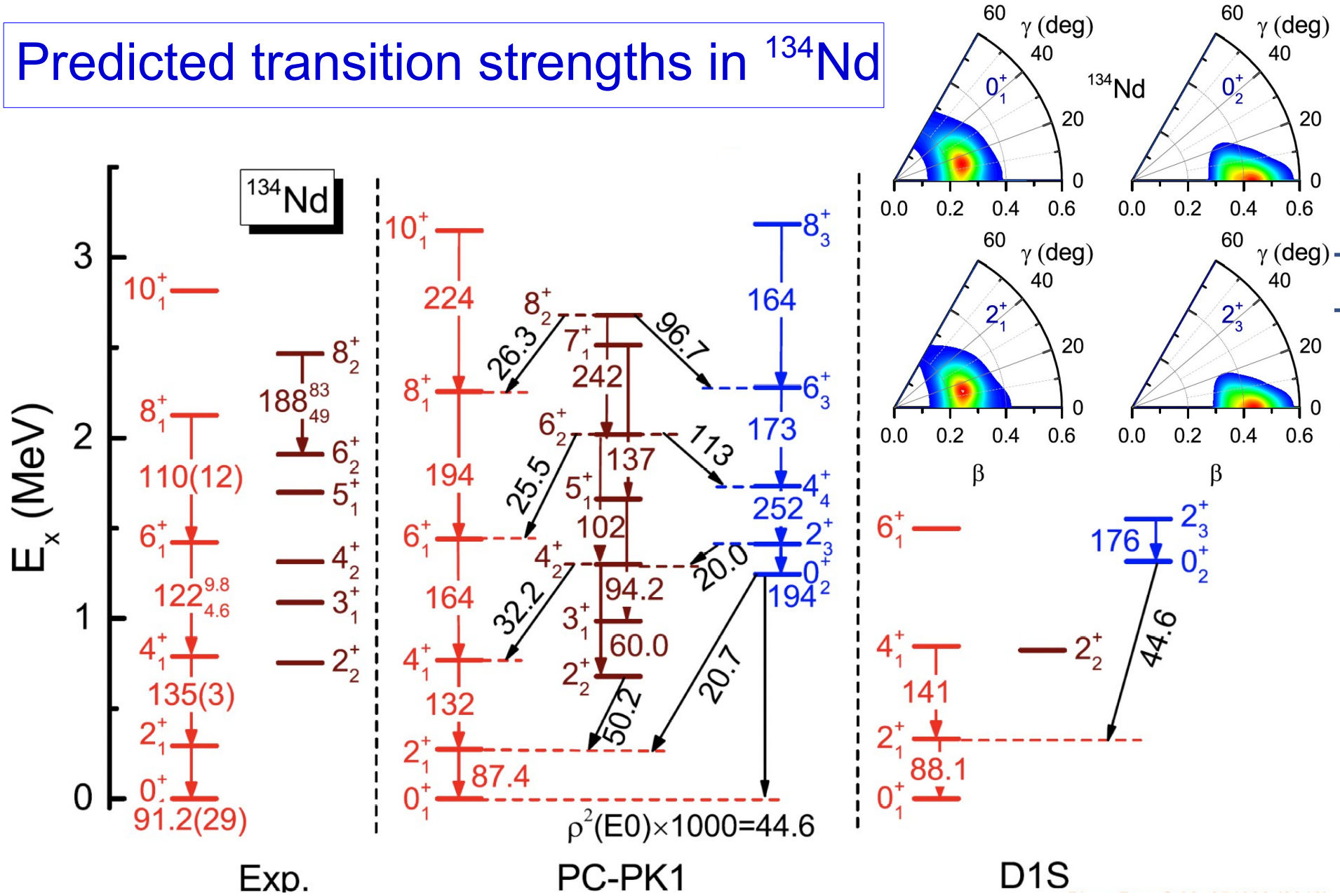
Predicted Shape Coexistence Nd isotopic chain



5DCH (PC-PK1)

PRC 98, 054308 (2018)

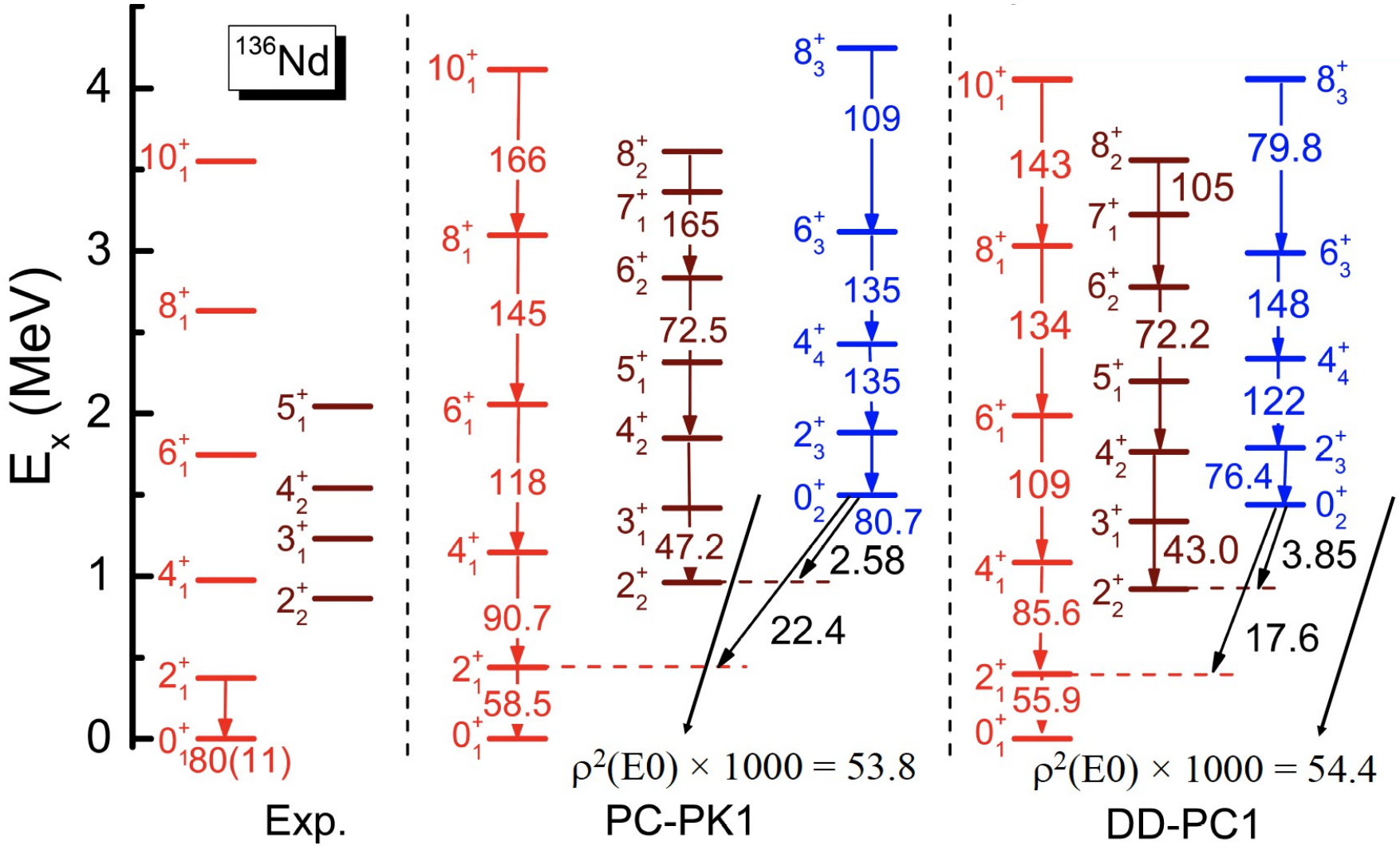
Predicted transition strengths in ^{134}Nd



^{98}Sr : ρ^2(E0)x1000=51(5)

PRC 98, 054308 (2018)

Predicted transition strength in ^{136}Nd

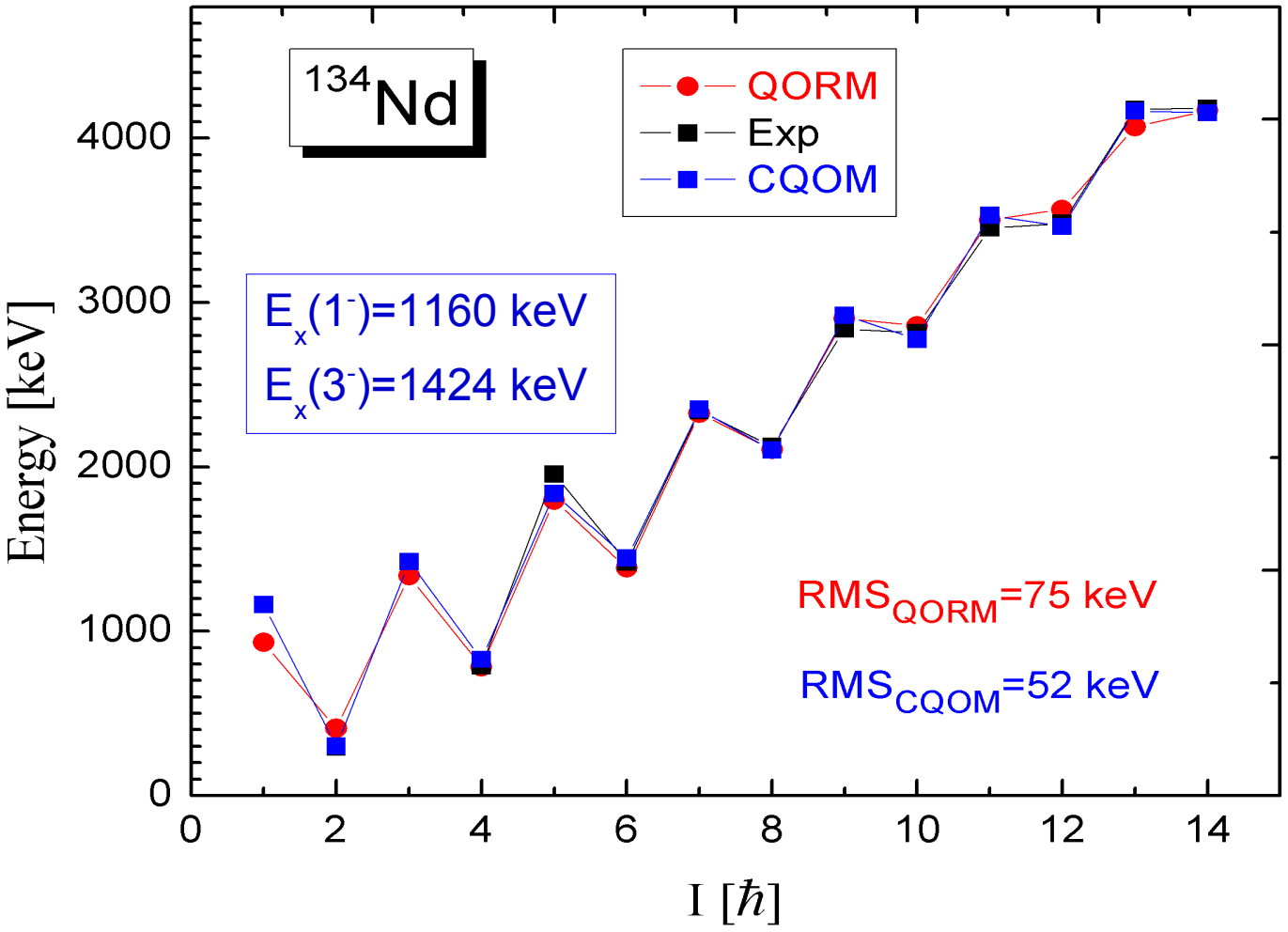


^{98}Sr : ρ^2(E0)x1000=51(5)

PRC 98, 054308 (2018)

Predicted 1^-, 3^- levels in ^{134}Nd

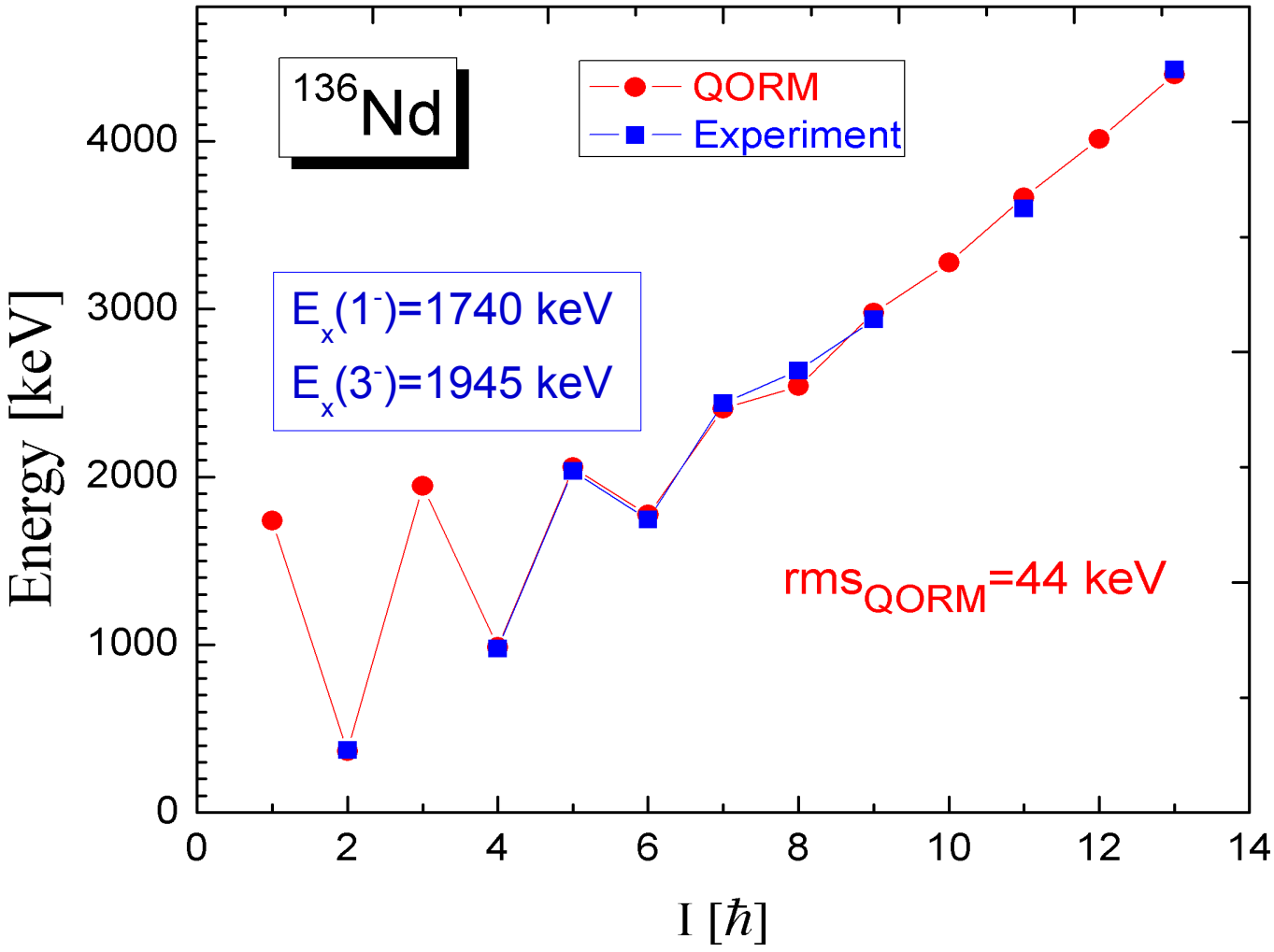
Occupation of $\pi h_{11/2}$ and $\pi d_{5/2}$ with $\Delta I=3$



N. Minkov, BJP 46, 386 (2019)

Predicted 1^-, 3^- levels in ^{136}Nd

Occupation of $\pi h_{11/2}$ and $\pi d_{5/2}$ with $\Delta I=3$



C. Petrache, PRC 102, 014311 (2020)

Goals of the proposed experiment

- Search for predicted excited 0^+ states.

- Precise measurement of the branching ratios of the predicted $0^+_2 \longrightarrow 0^+_1$ transitions and the $\rho^2(E0)$ strengths.

- Perform the γ-γ, γ-e^- angular correlations for spin assignment.

- Measure the level lifetimes by using fast timing with $LaBr_3$ detectors.

- Search for predicted 1^- or 3^- levels to establish the octupole collectivity and measure the branching ratios.

Collectivity of the 2p-2h proton intruder band of ^{116}Sn

C. M. Petrache,[1,*] J.-M. Régis,[2] C. Andreoiu,[3] M. Spieker,[4] C. Michelagnoli,[5] P. E. Garrett,[6] A. Astier,[1] E. Dupont,[1] F. Garcia,[3] S. Guo,[7] G. Häfner,[2] J. Jolie,[2] F. Kandzia,[5] V. Karayonchev,[2] Y.-H. Kim,[5] L. Knafla,[2] U. Köster,[5] B. F. Lv,[1,7] N. Marginean,[8] C. Mihai,[8] P. Mutti,[5] K. Ortner,[3] C. Porzio,[5,9] S. Prill,[2] N. Saed-Samii,[2] W. Urban,[10] J. R. Vanhoy,[11] K. Whitmore,[3] J. Wisniewski,[10] and S. W. Yates[12]

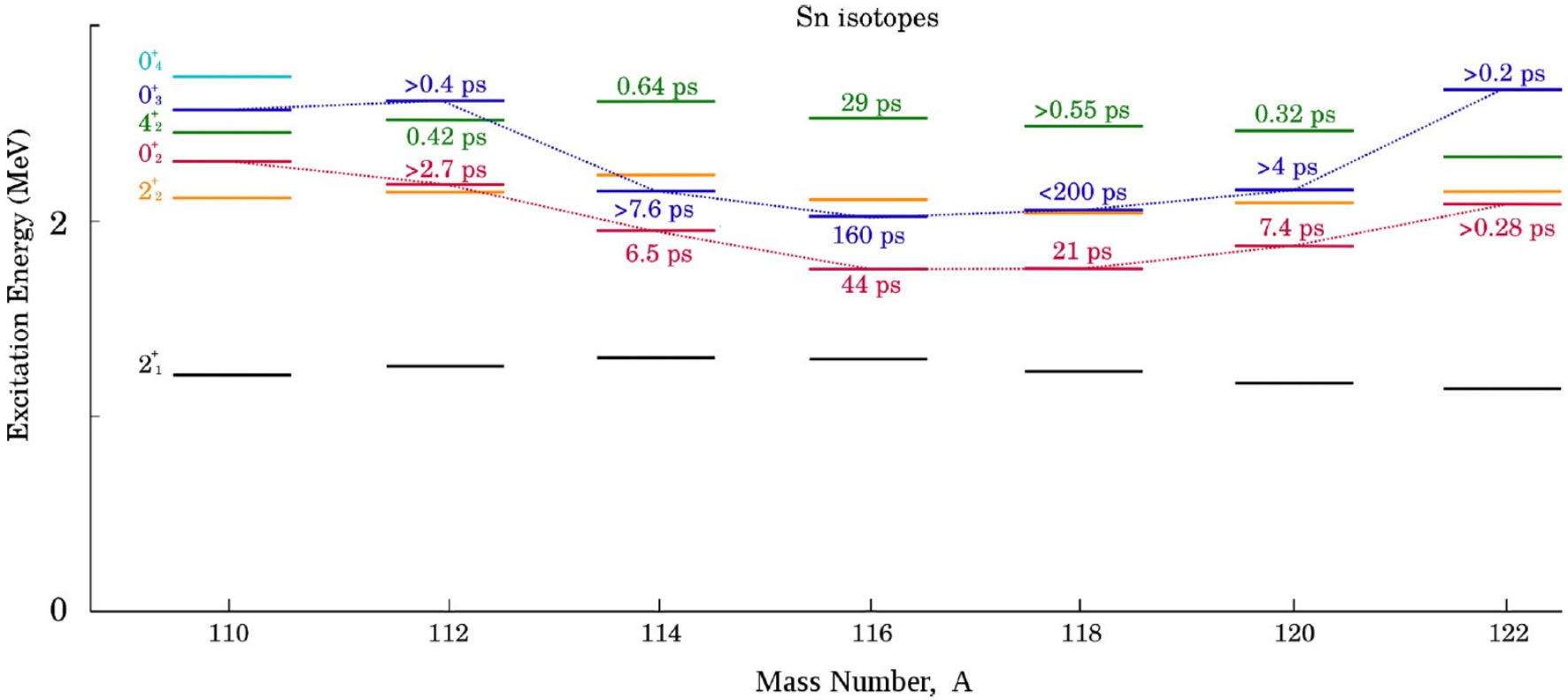
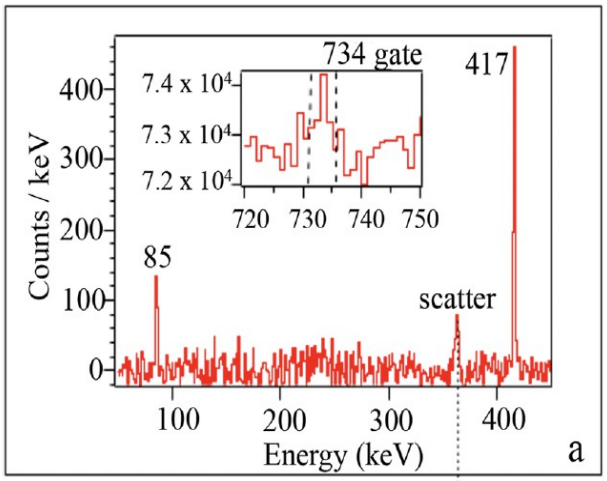
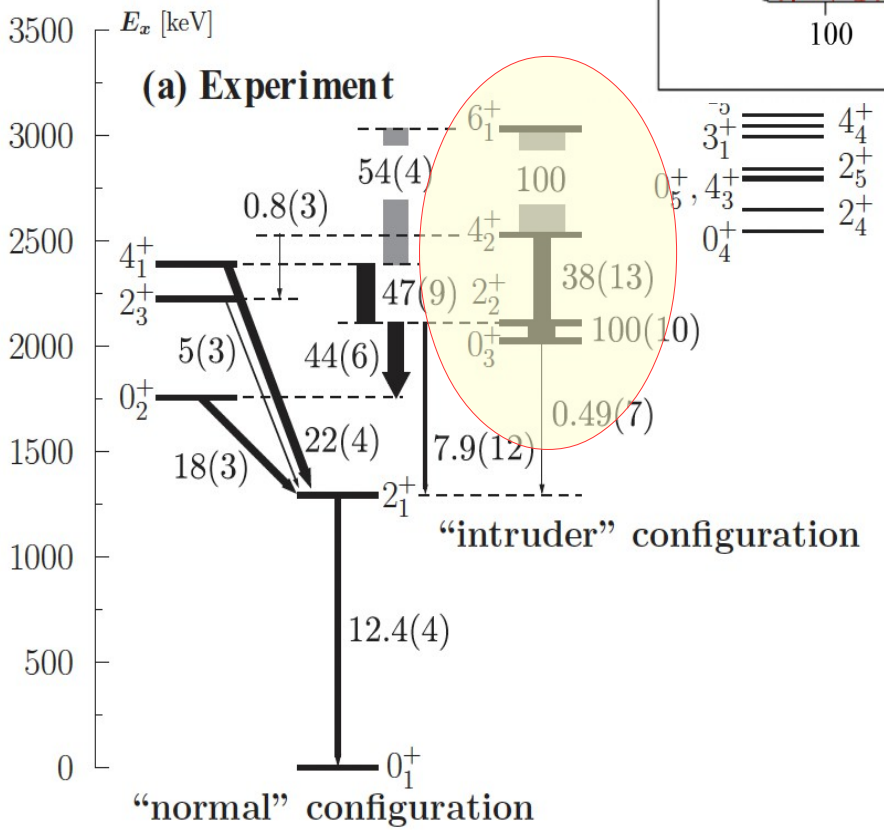
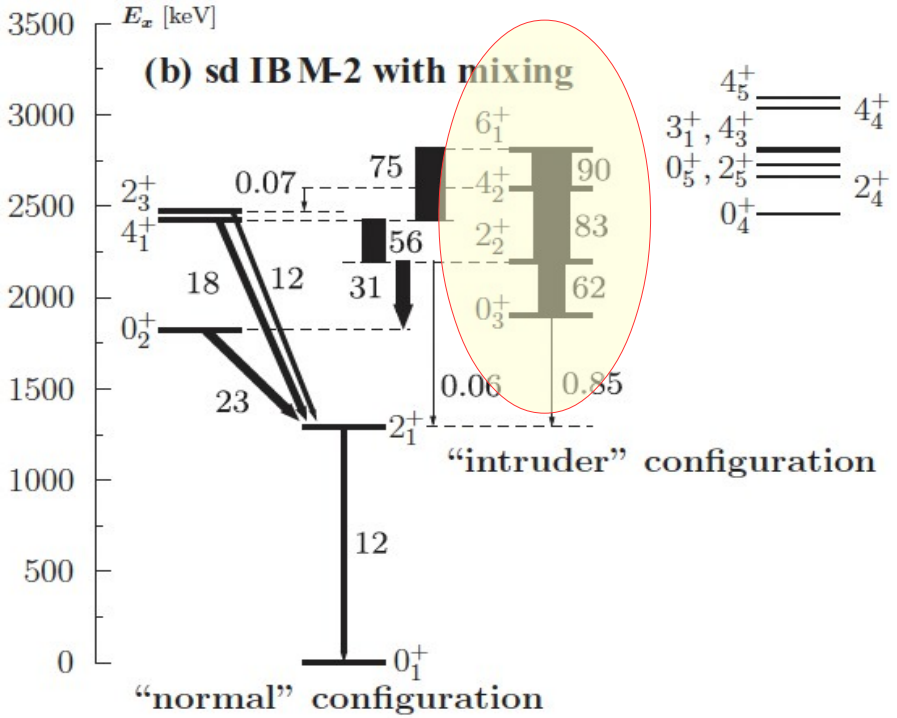


FIG. 1. Systematics of the Sn isotopes showing the half-lives or the limits of half-lives of the 0^+_2 (red), 0^+_3 (blue), and 4^+_2 (green) states. The half-lives are taken from Refs. [36,37] and from this work.


734 gate
417
7.4 x 10⁴
7.3 x 10⁴
7.2 x 10⁴
720 730 740 750
85
scatter
Counts / keV
400
300
200
100
0
100 200 300 400
Energy (keV)
a


E_x [keV]
(a) Experiment
3500
3000
2500
2000
1500
1000
500
0
6_1^+
54(4)
100
0.8(3)
4_2^+
4_1^+
2_3^+
47(9)
2_2^+
38(13)
0_3^+
100(10)
5(3)
44(6)
0_2^+
0.49(7)
22(4)
18(3)
7.9(12)
2_1^+
"intruder" configuration
12.4(4)
0_1^+
"normal" configuration
3_1^+
4_4^+
$0_5^+, 4_3^+$
2_5^+
2_4^+
0_4^+


E_x [keV]
(b) sd IBM-2 with mixing
3500
3000
2500
2000
1500
1000
500
0
6_1^+
75
4_2^+
90
2_3^+
0.07
2_2^+
83
4_1^+
56
18
12
31
0_3^+
62
0_2^+
0.06
0.85
23
2_1^+
"intruder" configuration
12
0_1^+
"normal" configuration
4_5^+
4_4^+
$3_1^+, 4_3^+$
$0_5^+, 2_5^+$
2_4^+
0_4^+

Investigation of the Excited States of ^{114}Sn Using the GRIFFIN Spectrometer at TRIUMF

N. K. Syeda[a], C. Andreoiu[b], P. Spagnoletti[b], C.M. Petrache[c], D. Annen[b], R.S. Lubna[d], V. Vedia[d], A. Algora[i], A. Babu[k], G.B. Ball[d], S. Bhattacharjee[d], R. Caballero-Folch[d], R. Coleman[h], I. Dillmann[d,1], E.G. Fuakye[g], L.P. Gaffney[j], F. H. Garcia[b], A.B. Garnsworthy[d], P.E. Garrett[h], C. Griffin[d], G.F. Grinyer[g], G. Hackman[d], R. Kanungo[l], K. Kapoor[g], A. Laffoley[h], G. Leckenby[d], K. Mashtakov[h], C. Natzke[d,1], B. Olaizola[d], K. Ortner[b], C. Porzio[d], M. Rocchini[h], N. Saei[g], Y. Saito[d], M. Satrazani[j], D. Shah[g], M. Siciliano[m], J. Smallcombe[j], C.E. Svensson[h], A. Talebitaher[g], R. Umashankar[d], S. Valbuena Burbano[h], J. Williams[d], F. Wu (吴桐安)[b], D. Yates[d], T. Zidar[h]

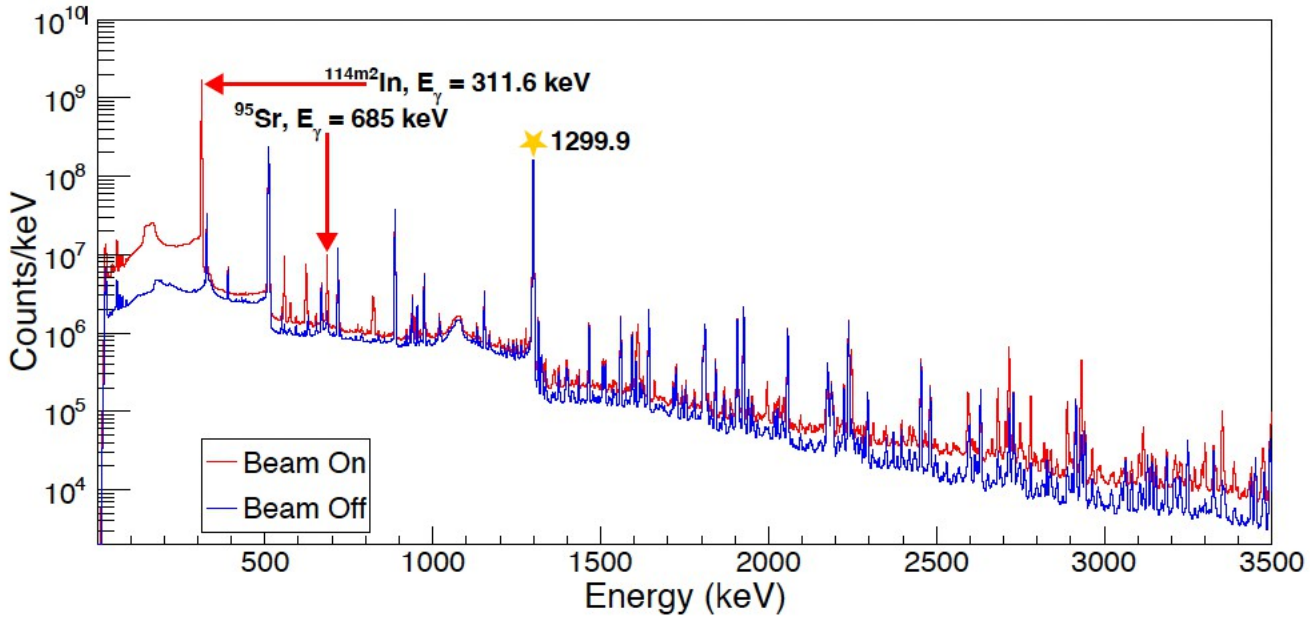


Figure 2: Gamma-ray singles spectra with add-back for beam-on (red) and beam-off (blue). The yellow star indicates the $2_1^+ \rightarrow 0_1^+$ 1299.9-keV transition in ^{114}Sn. The 311.6-keV γ-ray seen in the beam-on spectrum is associated with the $8^- \rightarrow 5^+$ isomeric transition in ^{114}In and disappears in the beam-off spectrum. The transition at 685-keV is associated with the β^--decay of ^{95}Sr to ^{95}Y.

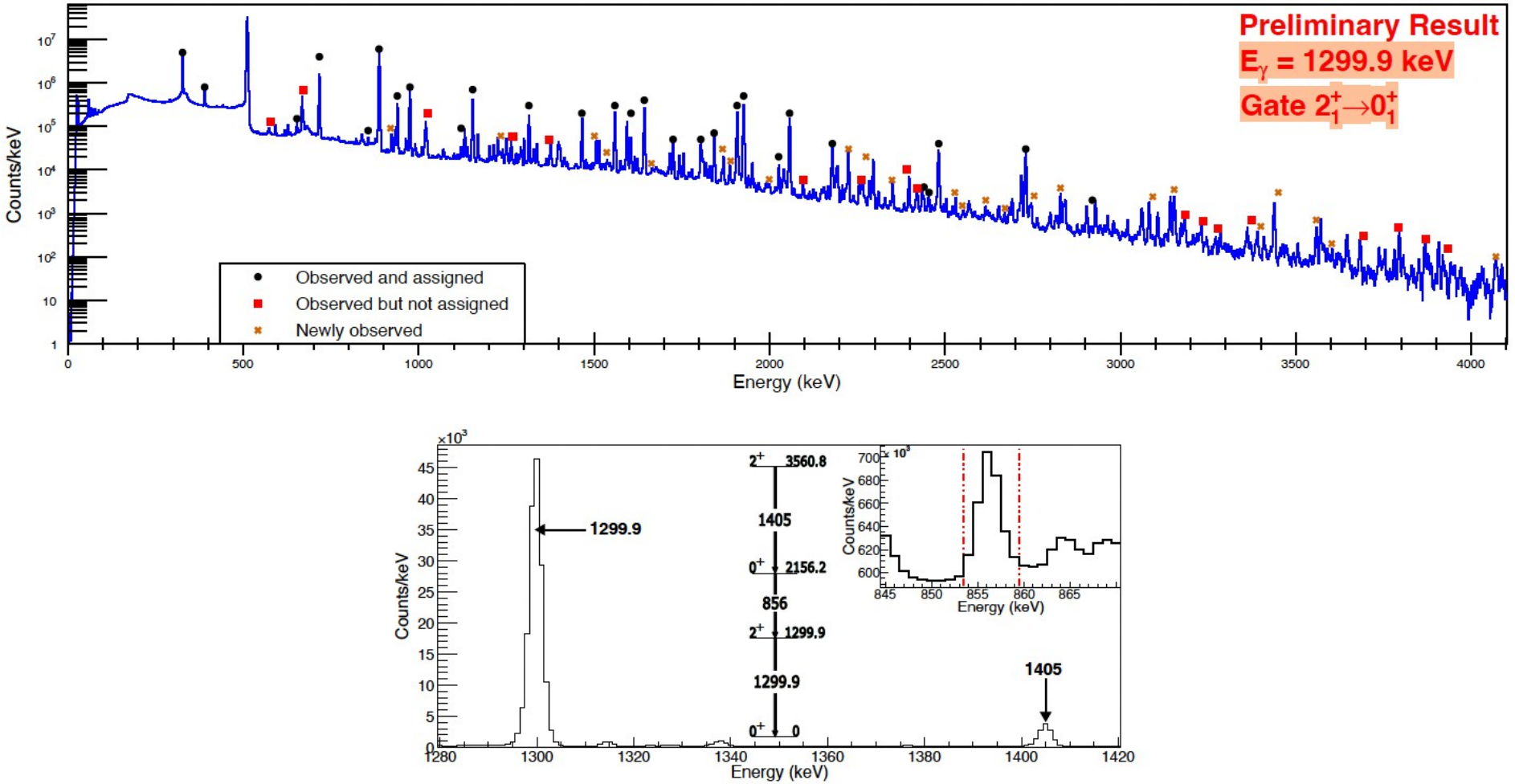
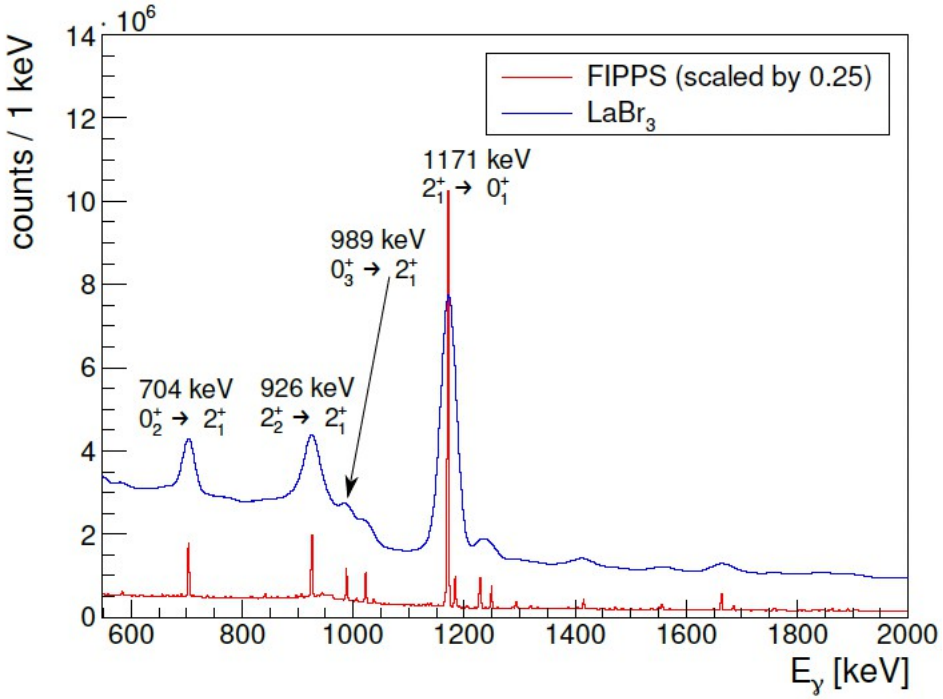


Figure 4: The γ-ray spectrum in coincidence with the 856-keV transition in ^{114}Sn. The inset shows the gating transition in the addback γ-ray spectrum. The presence of the 1299.9-keV and 1405-keV transitions allow for the building of the partial level scheme shown. This cascade shows the placement of the 1405-keV and 856-keV transitions, which had been observed in a previous β^+ decay experiment but had not been placed.

Evidence for shape coexistence in ^{120}Sn from the first 0_3^+ lifetime measurement

F. Wu (吴桐安),[1,*] C. Andreoiu,[1] V. Karayonchev,[2] C.M. Petrache,[3] J.-M. Régis,[4] A. Gargano,[5] G. De Gregorio,[6,5] A. Esmaylzadeh,[4] C. Michelagnoli,[7] M. Beuschlein,[8] P. Spagnoletti,[1] G. Colombi,[7] J.M. Daugas,[7] L. Domenichetti,[7] P.E. Garrett,[9] J. Jolie,[4] M. Ley,[4] S. Pannu,[9] and E. Taddei[1]



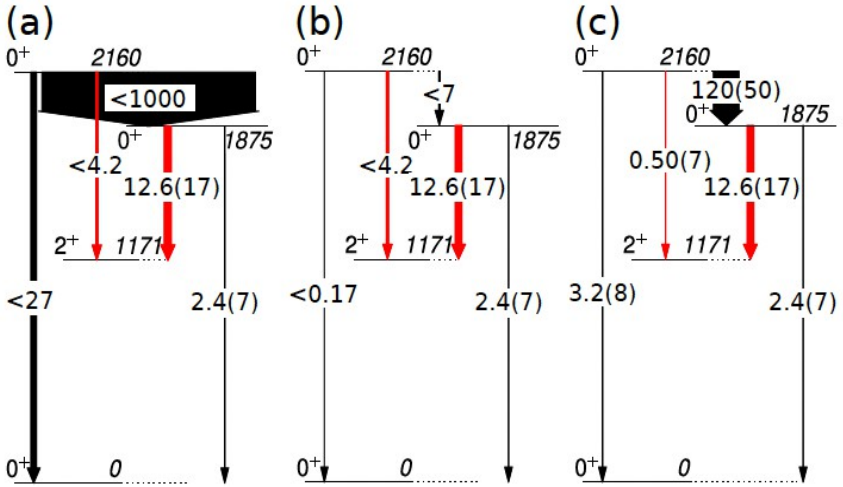


FIG. 6. The electromagnetic transition rates from the low-lying excited 0^+ states in ^{120}Sn from (a) 2005 [17], (b) 2022 [18], and (c) this work. The $B(E2)$ values (in red) are in W.u., and the $10^3\rho^2(E0)$ values are in black. The widths of the arrows are proportional to the transition strengths.

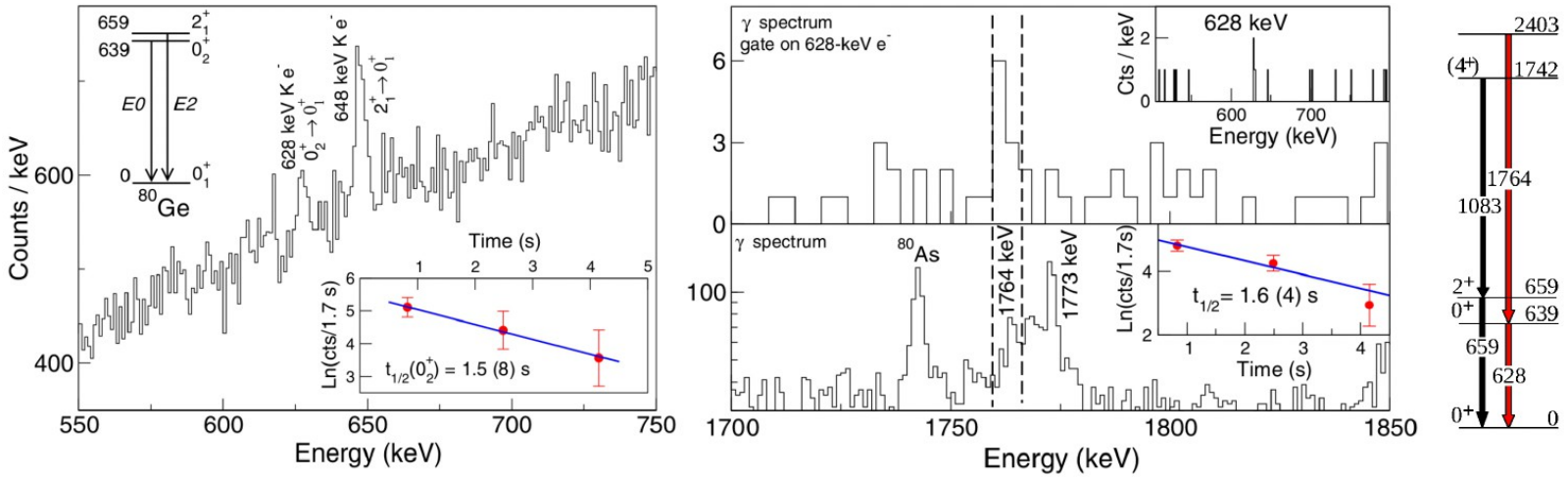
E_{level} (keV)	J^π	$\tau_{\text{this work}}$ (ps)	τ_{NNDC} (ps)
1171	2_1^+	< 11	0.92(17)
1875	0_2^+	< 18	10.7(14)
2097	2_2^+	< 13	1.9(6)
2160	0_3^+	50(7)	> 6

$J_i^\pi \to J_f^\pi$	$B(E2)_{\text{exp}}$ (W.u.)	$10^3\rho^2(E0)_{\text{exp}}$	$10^3\rho^2(E0)_{\text{lit.}}$
$0_3^+ \to 0_1^+$	-	$3.2^{+0.9}_{-0.7}$	< 0.17 [18]
			< 27 [17]
$0_3^+ \to 0_2^+$	-	120(50)	< 7 [18]
			< 1000 [17]
$0_3^+ \to 2_1^+$	0.50(7)	-	

Absence of low-lying shape coexistence in ^{80}Ge

An ALTO experiment observed a proposed 0_2^+ state in ^{80}Ge at 639 keV, through a conversion electron peak at 628 keV.

A coincidence was also observed between the 628-keV conversion electron peak and a 1764-keV γ-ray, from a proposed 2403 keV state.



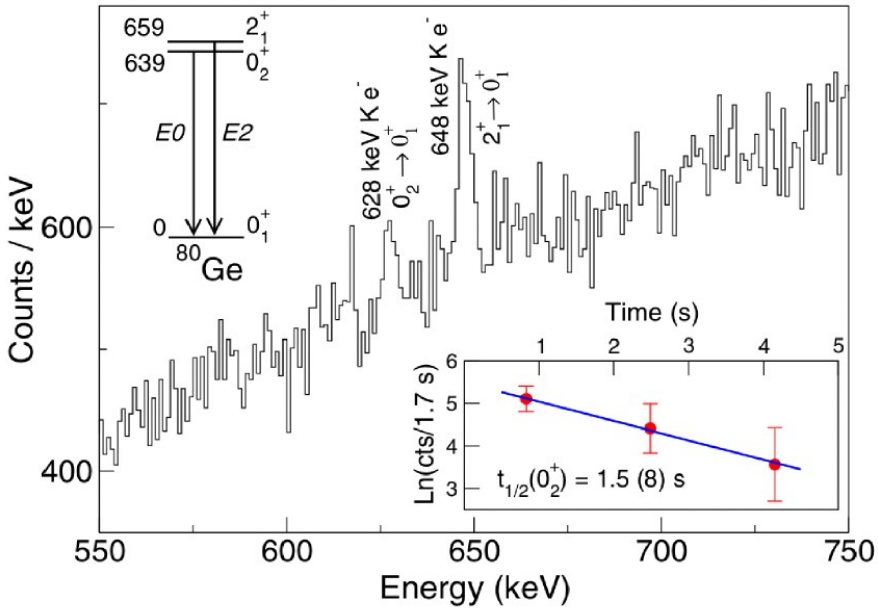
The binding energy of the K-shell electron in ^{80}Ge is 11 keV

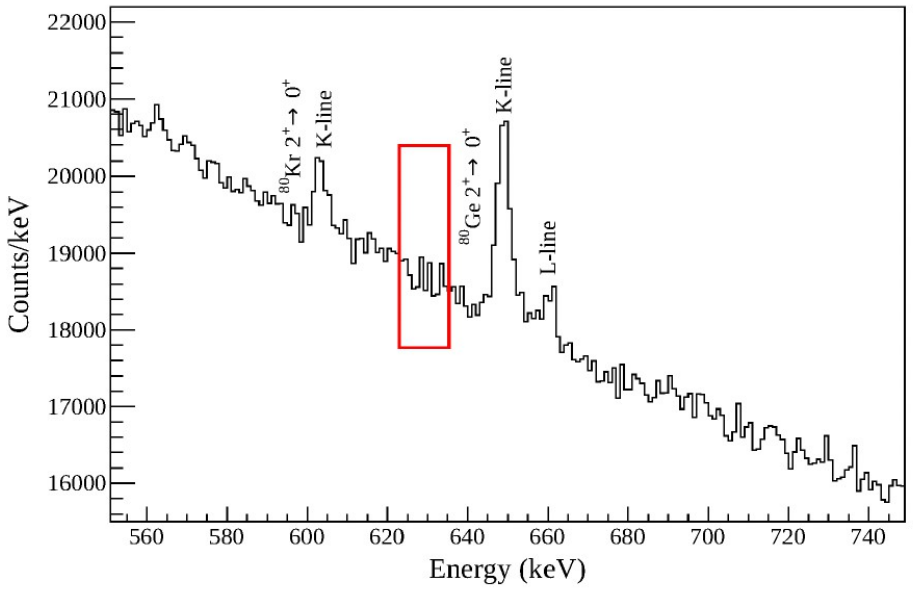
Gottardo, A. *et al.*, *PRL* 116, 182501 (2016)

Contradictory results

(conclusion confirmed by two recent Coulex and Isolde experiments)

The GRIFFIN experiment used PACES for conversion electron detection.





ALTO I^{628}: $\sim$0.08%

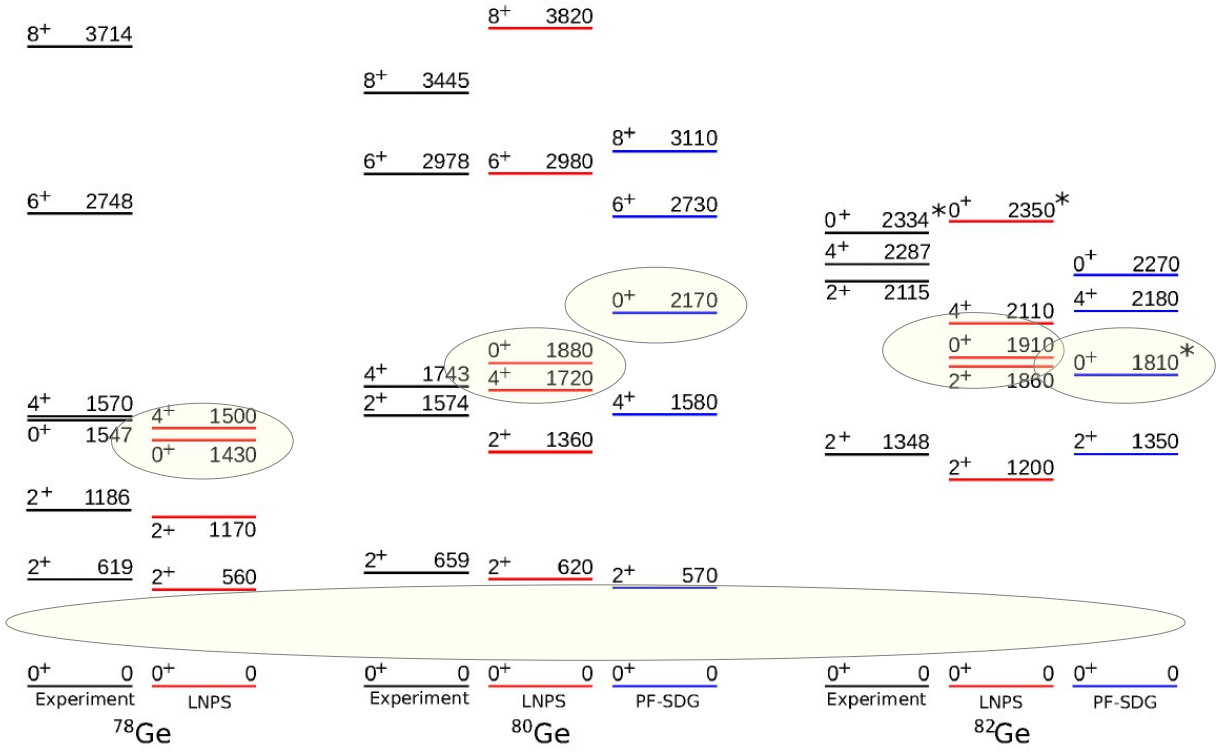
GRIFFIN 2σ limit: $<$0.02%

Gottardo, A. *et al.*, *PRL* 116, 182501 (2016)

Garcia, F. H. *et al.*, *PRL* 125, 172501 (2020)

Theoretical considerations

Large-scale shell model calculations were performed, and were able to reasonably predict intruder configurations in neighbouring isotopes.



Garcia, F. H. *et al.*, *PRL* 125, 172501 (2020)

Lenzi, S., Nowacki, F. Poves, A. and Sieja, K. *PRC* 82, 054301 (2010)

Nowacki, F., Poves, A., Caurier, E. and Bounthong, B., *PRL* 117, 272501 (2016)

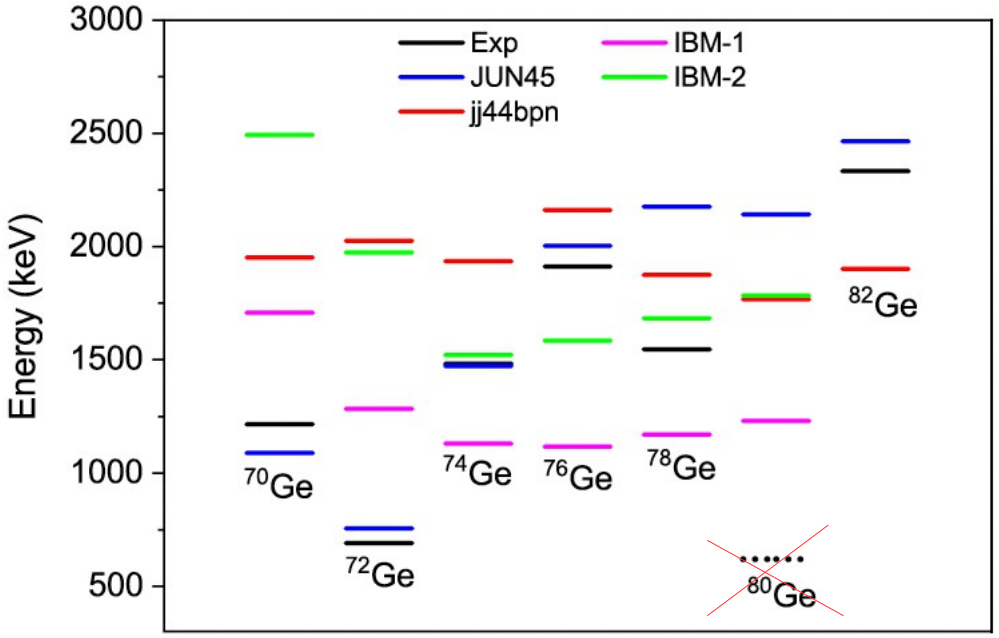
Low-spin states in ^{80}Ge populated in the β decay of the ^{80}Ga 3$^-$ isomer

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. Paziy,[3] J. M. Régis,[8] M. Rudigier,[8] T. Sava,[4] G. S. Simpson,[17,18] M. Stănoiu,[4] and L. Stroe[4]

PHYSICAL REVIEW C **105**, 024325 (2022)

Evolution of shape and collectivity along the Ge isotopic chain: The case of ^{80}Ge

D. Rhodes,[1,2,*] B. A. Brown,[1,2] A. Gade,[1,2] S. Biswas,[1,†] A. Chester,[1] P. Farris,[1,2] J. Henderson,[3] A. Hill,[1,2] J. Li,[1] F. Nowacki,[4,5] E. Rubino,[1] D. Weisshaar,[1] and C. Y. Wu[6]



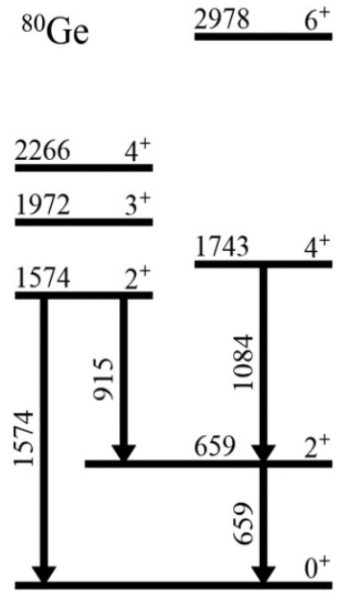
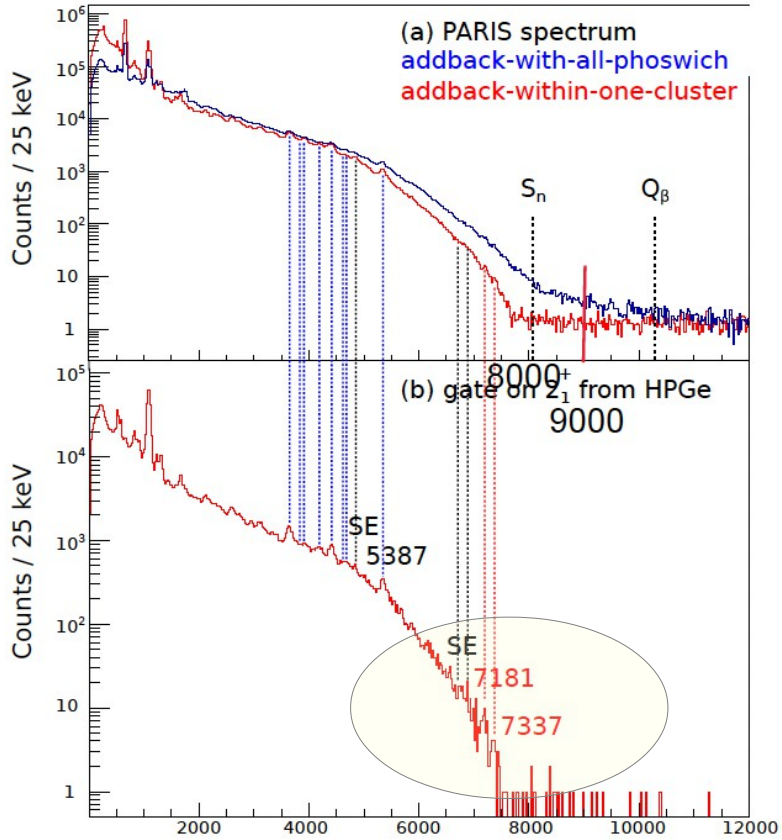
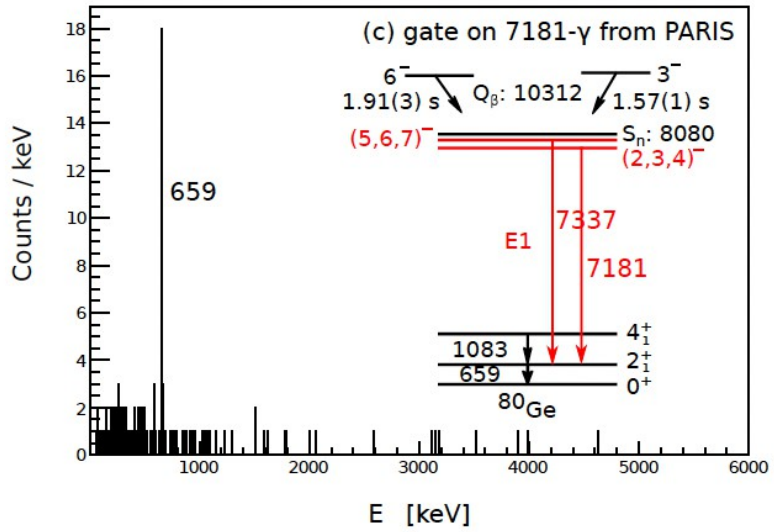
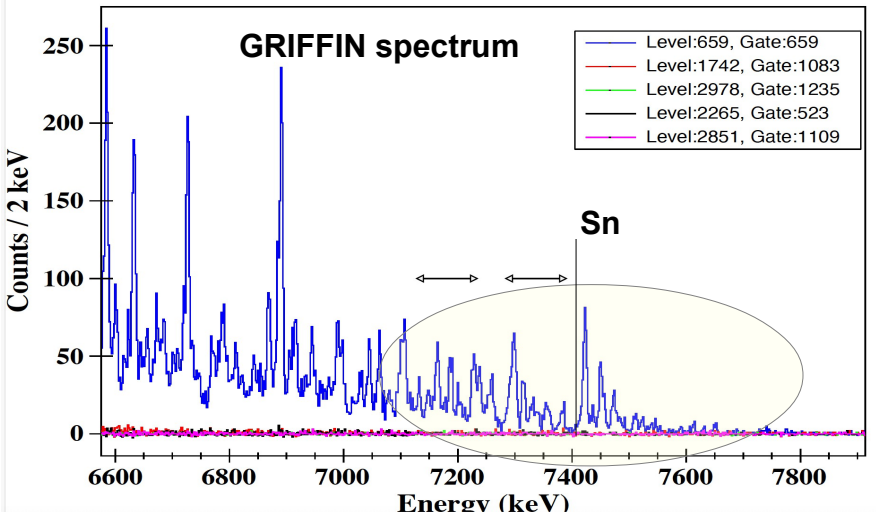
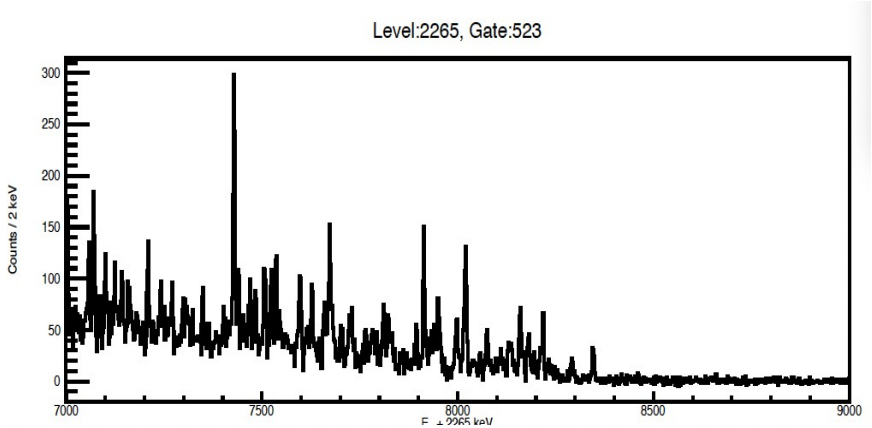


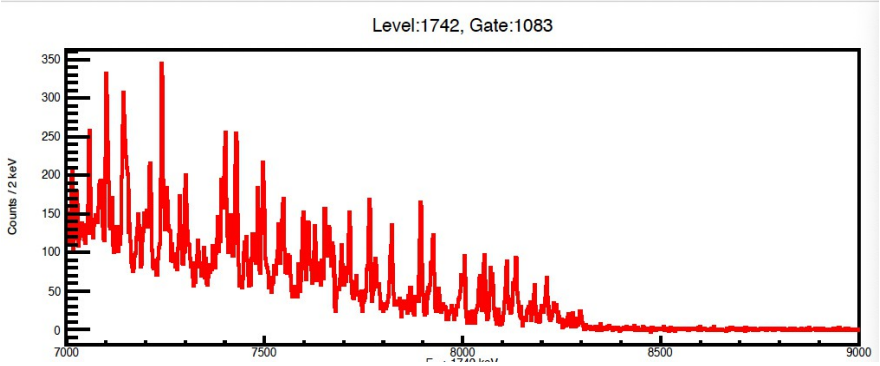
FIG. 3. The level scheme of ^{80}Ge used in the GOSIA and GOSIA2 analyses. Only transitions observed during the experiment are indicated. Energies are in keV.


(a) PARIS spectrum
addback-with-all-phoswich
addback-within-one-cluster
Counts / 25 keV
S_n
Q_β
(b) gate on 2_1^+ from HPGe
8000+
9000
SE
5387
SE
7181
7337
Counts / 25 keV

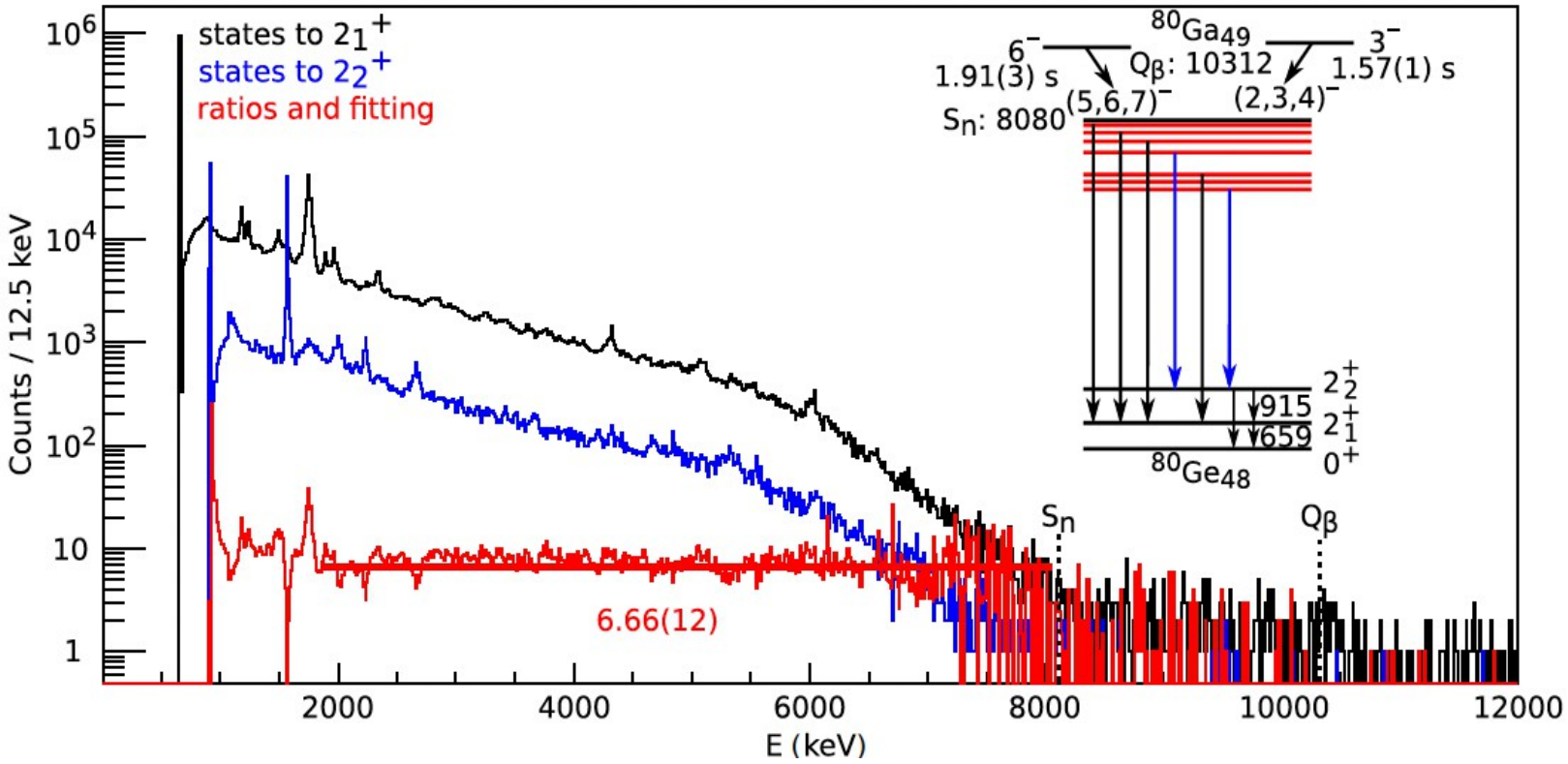

(c) gate on 7181-γ from PARIS
6^-
1.91(3) s
Q_β: 10312
3^-
1.57(1) s
$(5,6,7)^-$
S_n: 8080
$(2,3,4)^-$
659
7337
E1
7181
1083
659
4_1^+
2_1^+
0^+
^{80}Ge
Counts / keV
E [keV]


GRIFFIN spectrum
Level:659, Gate:659
Level:1742, Gate:1083
Level:2978, Gate:1235
Level:2265, Gate:523
Level:2851, Gate:1109
Sn
Counts / 2 keV
Energy (keV)


Level:2265, Gate:523
Counts / 2 keV


Level:1742, Gate:1083
Counts / 2 keV

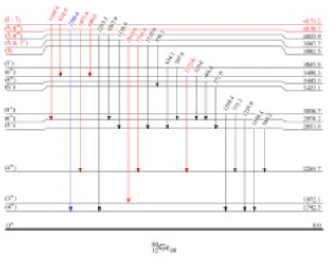
New spectra from ALTO



Spectroscopy of ^{80}Ge

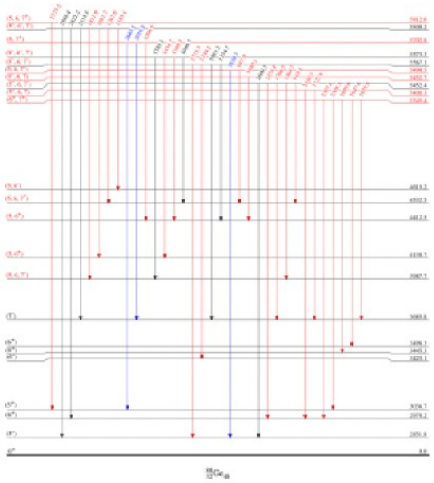
Work in progress

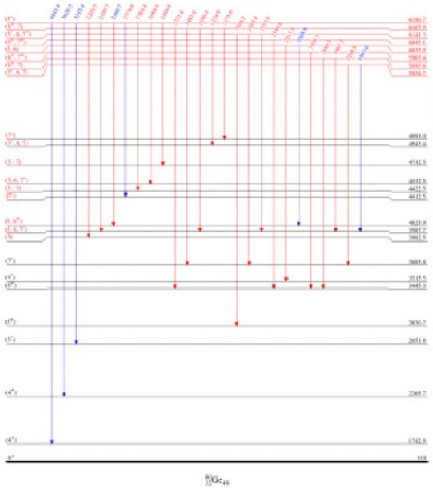
The γ-ray data obtained from this experiment is comprehensive and rich.

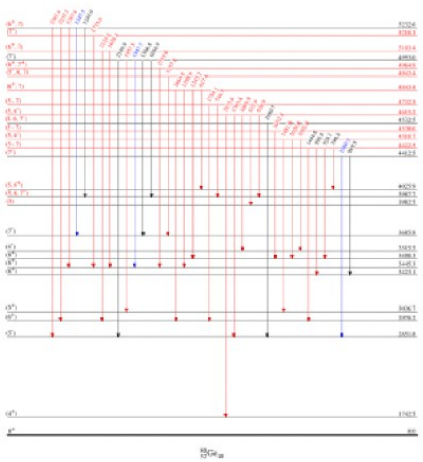


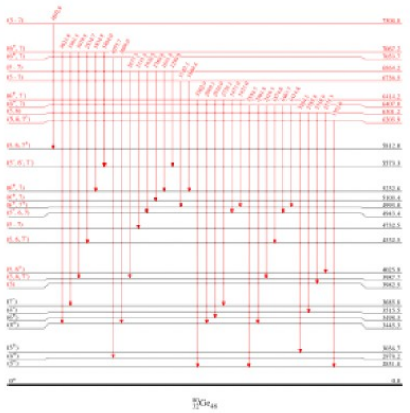
^{80}Ga ground state decay:

- 35 newly observe excited states
- 111 newly observed transitions
- 12 placed from previous observartion









logft values have been calculated and spins and parities suggested based on these values and decay systematics.

Thank you !