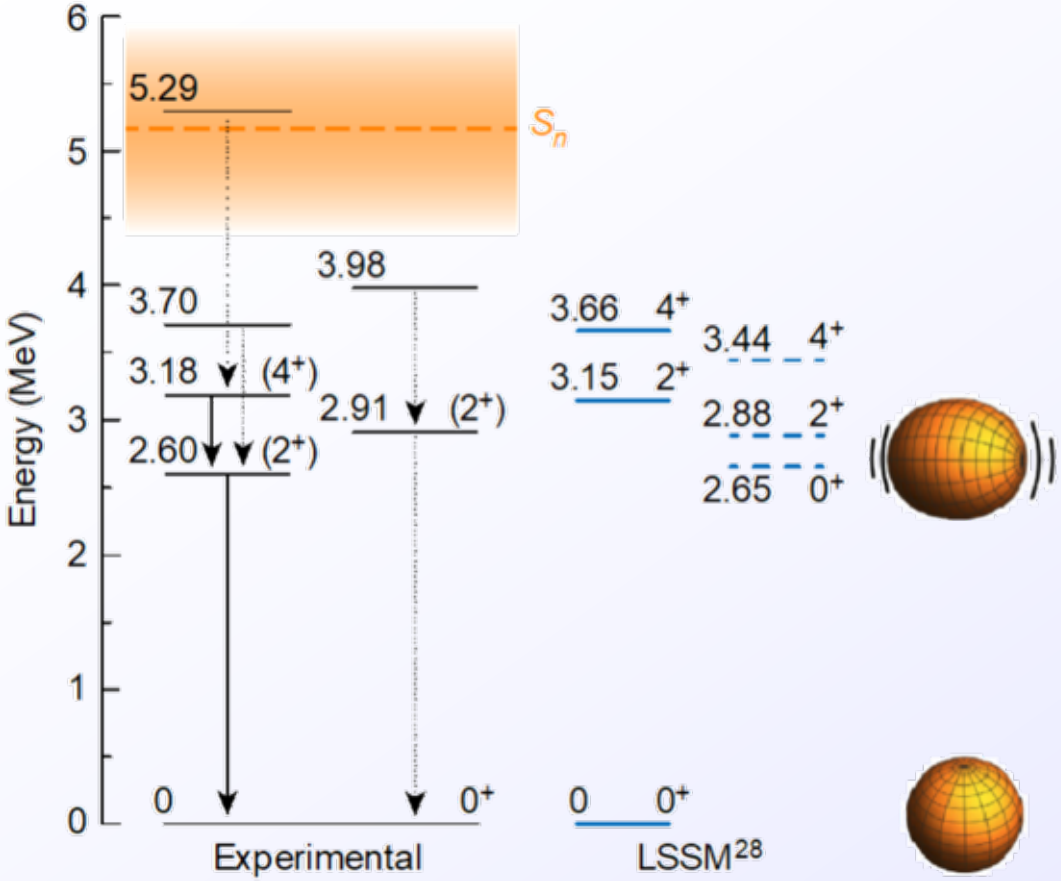
Shell evolution in Ge isotopes with N≥50 investigated via fast-timing methods

CERN-INTC-2024-071
INTC-P-723

L.M. Fraile, J. Benito, A. Illana
Grupo de Física Nuclear & IPARCOS
Universidad Complutense, Madrid, Spain

The region around ^{78}Ni



Reorganization of orbitals:
π $0f_{5/2}$ & $1p_{3/2}$ inverted when the
ν $0g_{9/2}$ orbital is filled

Onset of deformation
Shape co-existence

Role on nucleosynthesis processes

R. Taniuchi *et al.*, Nature 569 (2019) 53

N>50 region north from ^{78}Ni

Neutron-rich Ge (Z=32) isotopes populated in beta-decay of Ga

Evolution of structure as a function of neutron number

Excitations of the N=50 core may play a role

Calculated co-existence of shapes

$2p_{3/2}$, $1f_{5/2}$, $2p_{1/2}$

$1f_{7/2}$

$1g_{9/2}$

$2d_{5/2}$, $1g_{7/2}$, $2d_{3/2}$

Beta decay

- ß-delated neutron branches
- GT vs. ff
- Impact on r-process

Aims

- ✓ Profit from enhanced production and purity of Ga beams at ISOLDE to investigate Ge structures populated in beta-decay
  - → proton configurations for fp shell: SM calculations limited occupation of the $1p_{3/2}$ orbit
  - → main role by neutron contributions, specifically the $1d_{5/2}$

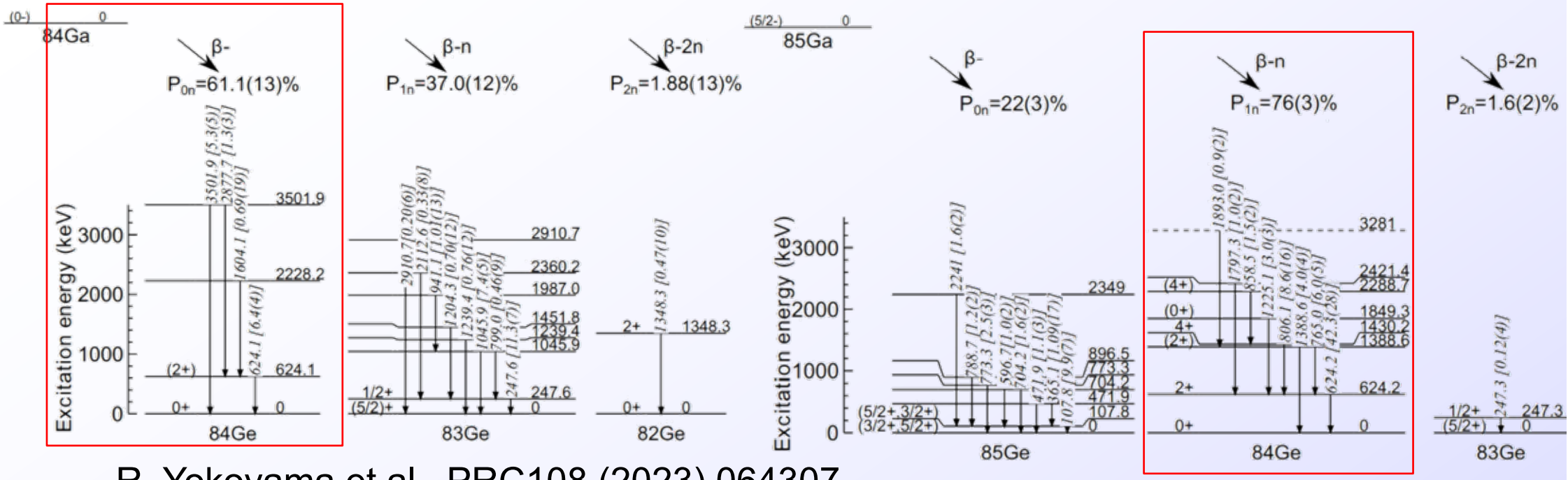
  Does it change for more neutron rich nuclei? Deformed structures?
- ✓ Beta-decay from Ga is of strong interest
  - → GT transitions involves cross-shell transformations that populate states at high excitation energies.
  - → It favours beta-delayed neutron emission branches
  - → Competition with 1^{st} forbidden transition

Take advantage of full IDS spectroscopy capabilities to expand level schemes

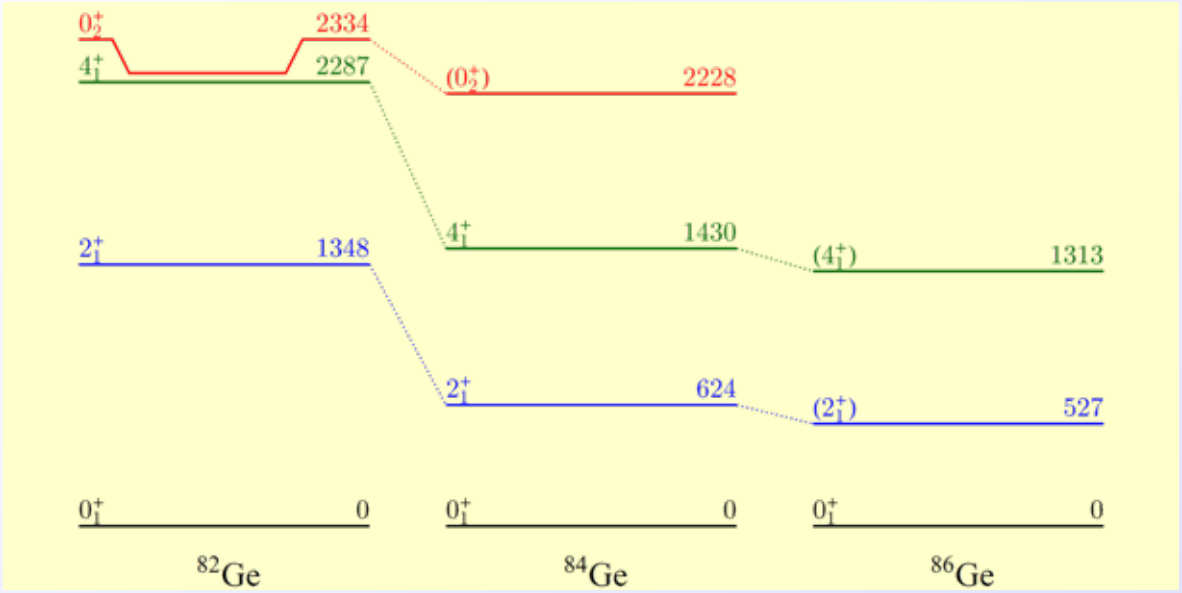
Complementary measurements of state lifetimes by fast-timing

Provide robust theoretical interpretation

Even-even Ge isotopes



R. Yokoyama et al., PRC108 (2023) 064307



Expand level schemes

^{84}Ge: Q_β = 14 MeV $Q_{\beta n}$ = 10 MeV

^{86}Ge: very little known

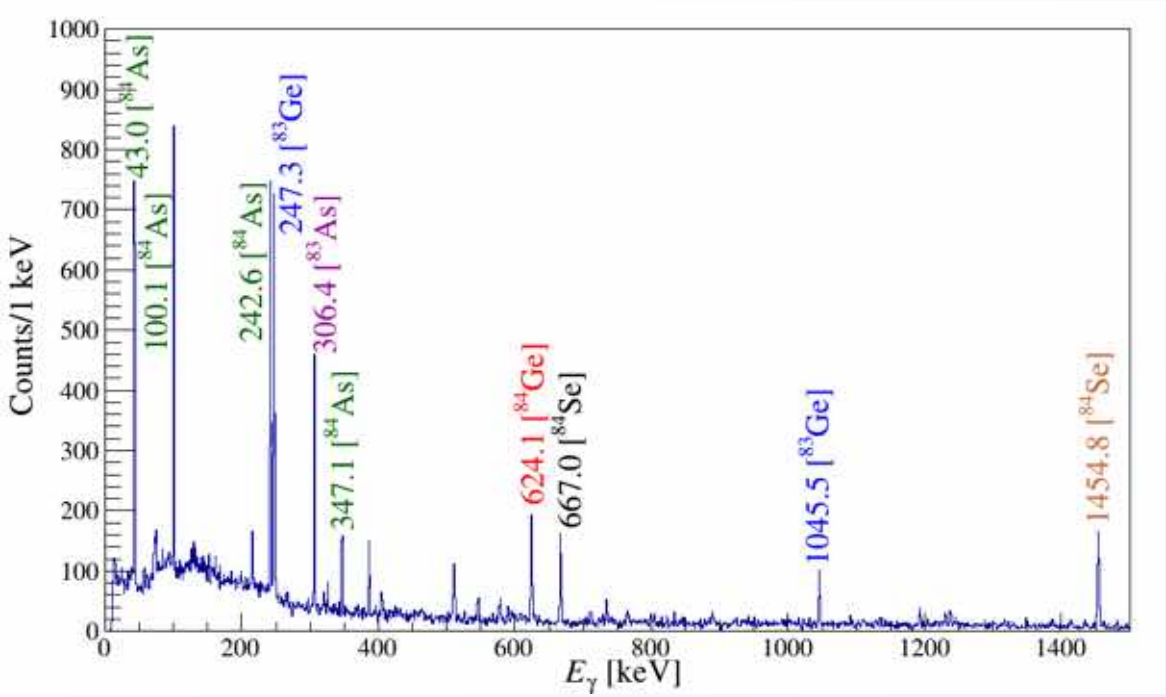
Identify 0_2^+

Neutron/gamma

Lifetime investigation

2_1^+ states: 15 to 35 ps / branches from **0_2^+** states / high-lying states?

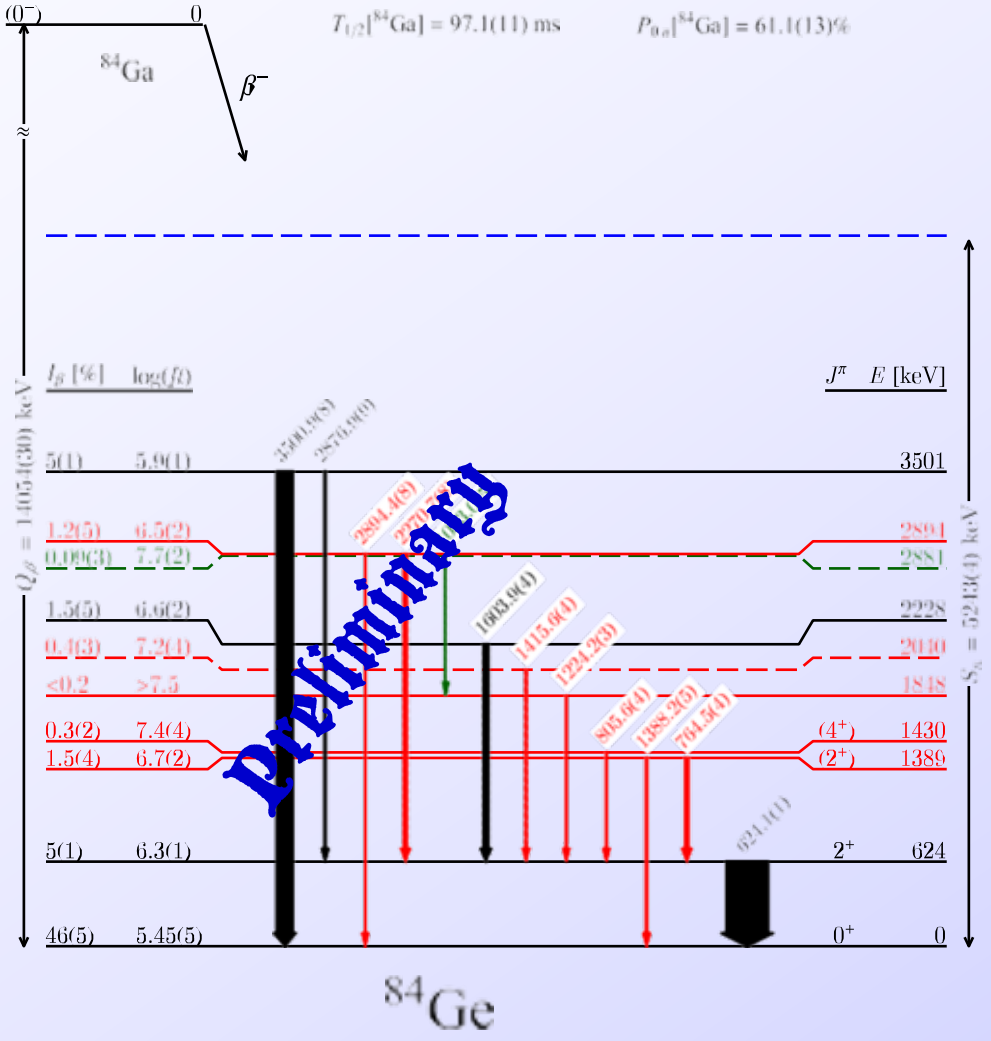
Even-even isotopes: test beam ^{84}Ge



Singles, direct ß-feeding

Also ß-delayed neutron branches

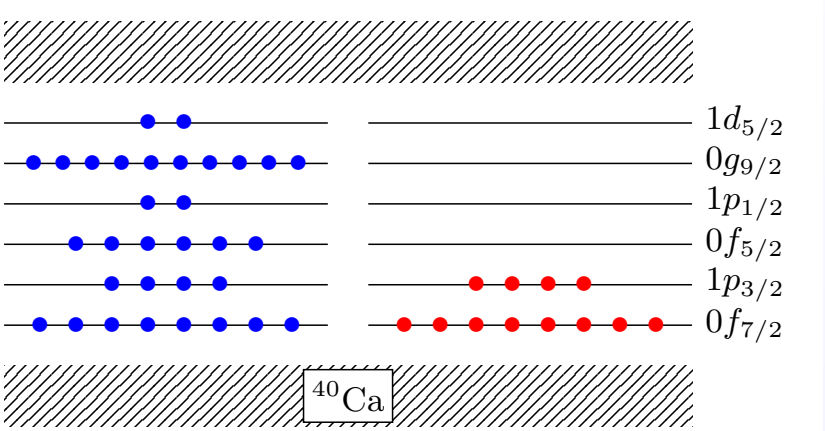
Access to feeding pattern and emission above S_n



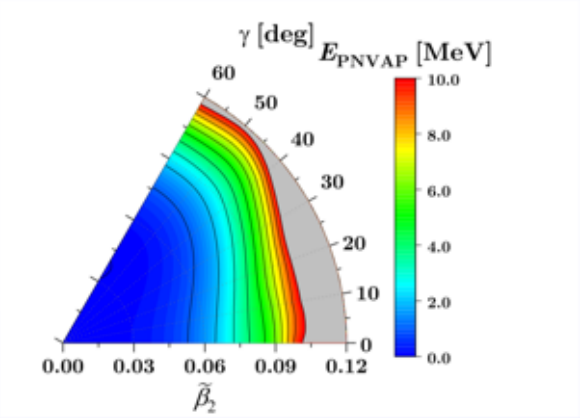
P. González-Tarrío et al., Master Thesis, UCM

Theoretical interpretations (^{84}Ge)

Int SM: LNPS



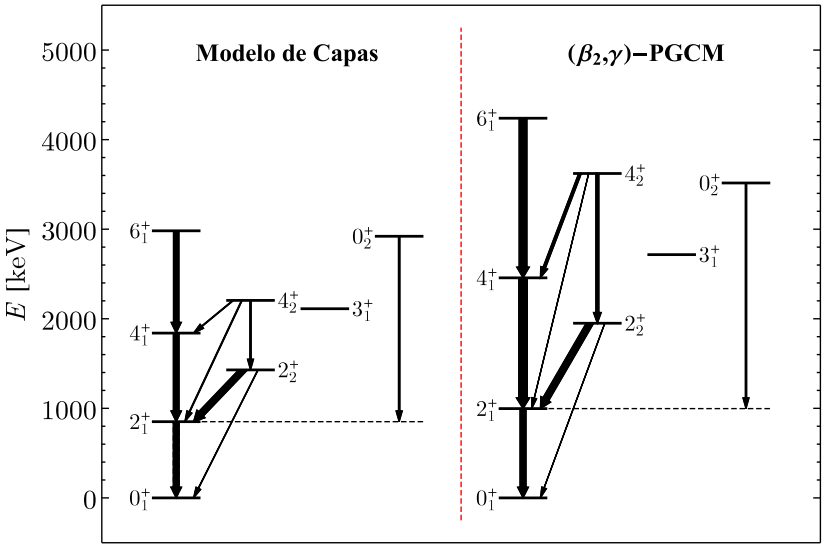
HFB, projected to N,Z, J

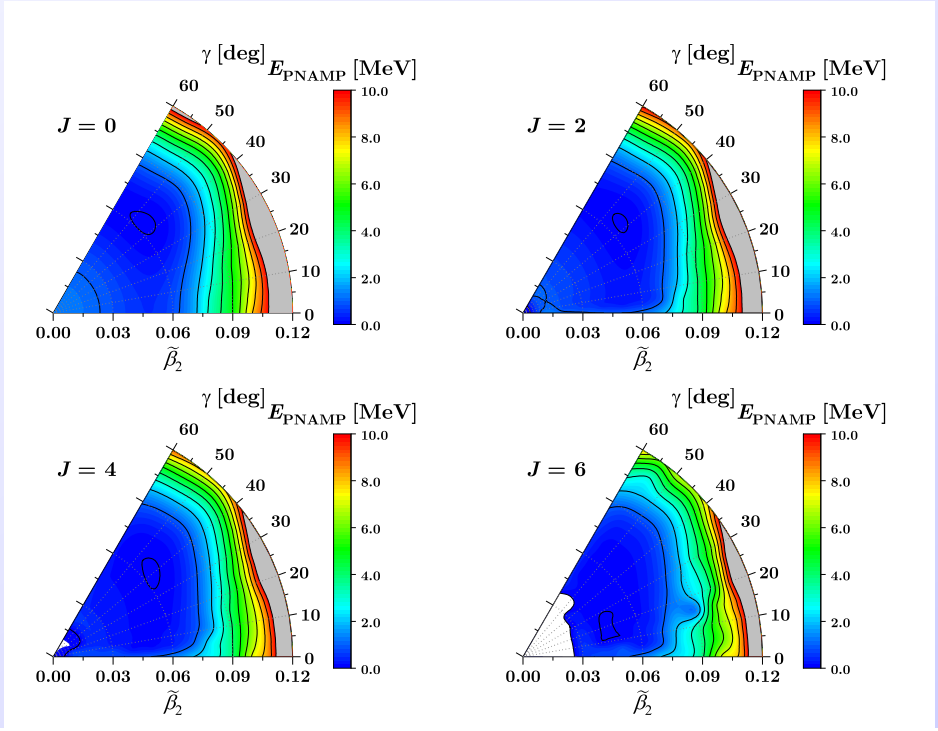


$J^{\pi}_{\sigma,i}$	$J^{\pi}_{\sigma,f}$	$B(E2)$ [W.u.]	Q_s [e fm^2]
2^+_1	0^+_1	37.9	23.65
2^+_2	2^+_1	41.2	−25.67
	0^+_1	0.6	
4^+_1	2^+_2	0.2	9.37
	2^+_1	53.6	
4^+_2	4^+_1	16.3	42.76
	2^+_2	18.8	
	2^+_1	0.9	
0^+_2	2^+_1	7.8	0
6^+_1	4^+_1	49.4	−0.25

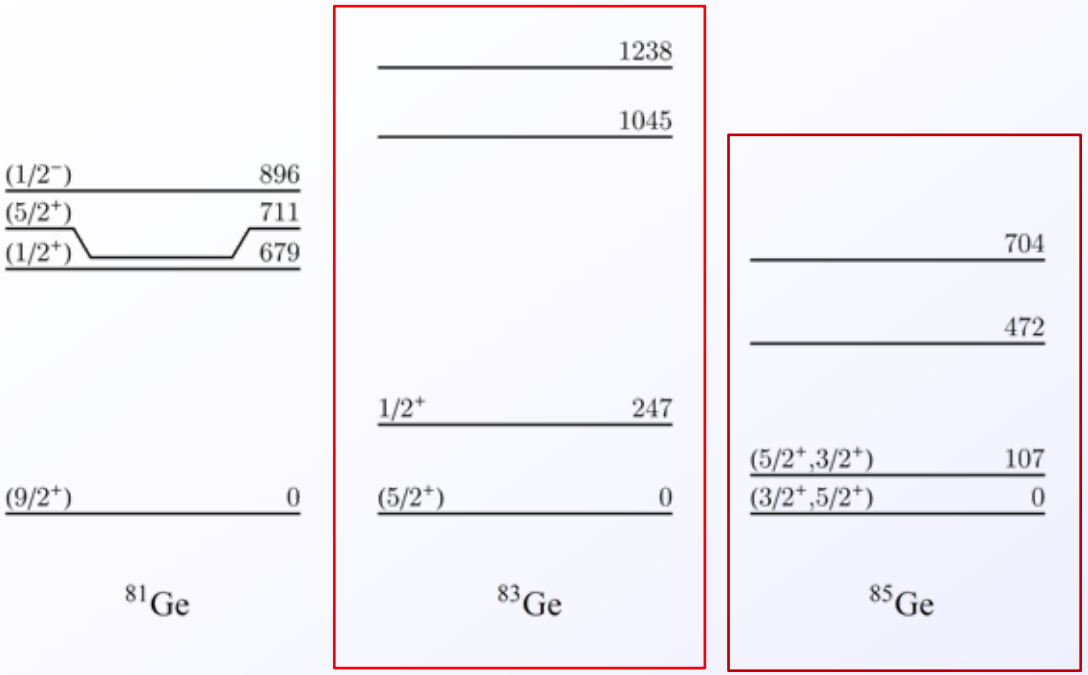
T.R. Rodríguez, P. González-Tarrío et al.,

Spectra + transition rates + deformation





Odd-A Ge isotopes



Single-neutron *qp*, neutron configurations, ordering

Direct ß-feeding and ß-delayed neutron branches

Access to feeding pattern (emission above S_n?)

Expand level schemes

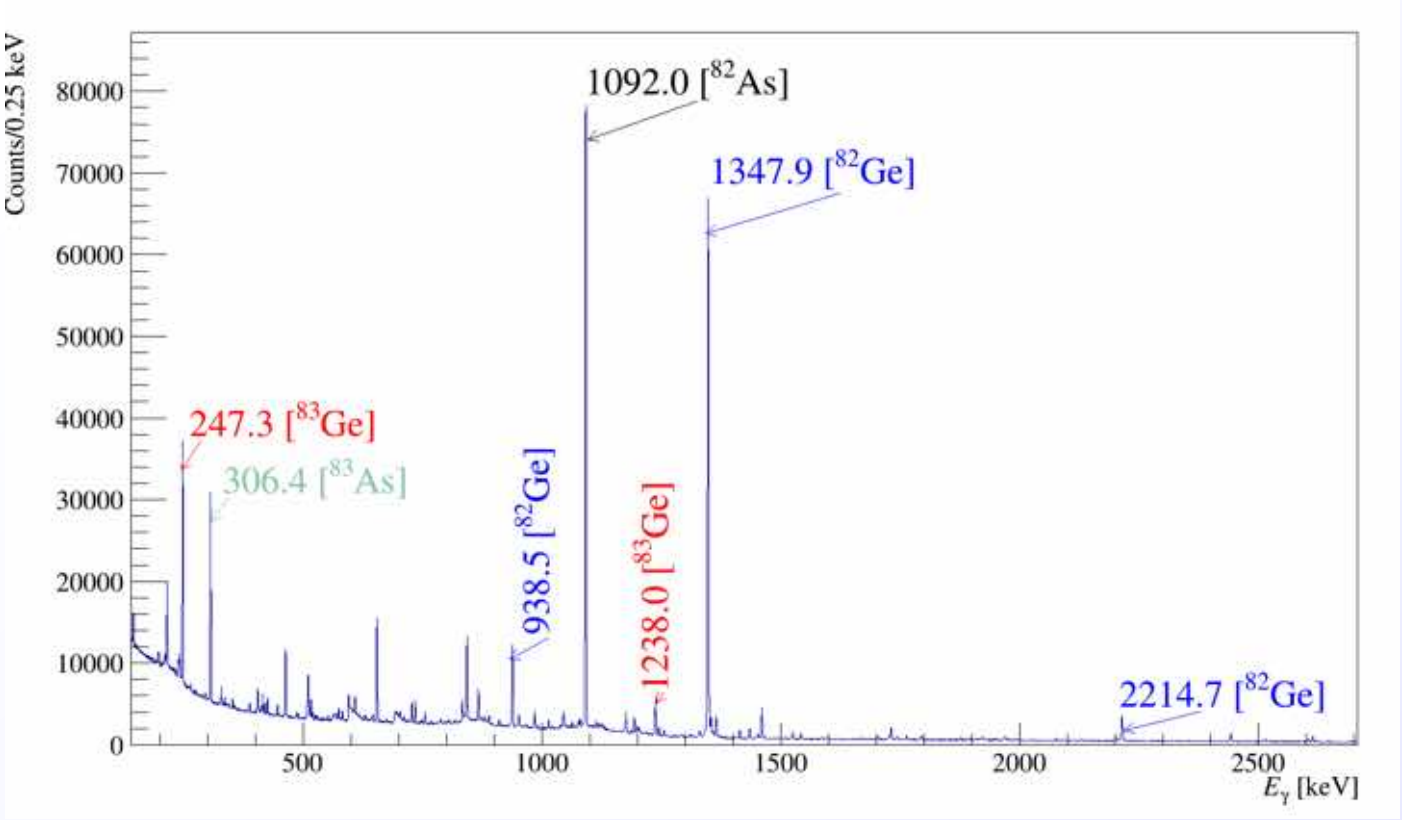
Nature of the low-lying states

Lifetime investigation

1st excited states and other low-lying: core coupling yields long lifetimes

high-lying states should be accessible

Preliminary data: ^{83}Ga decay



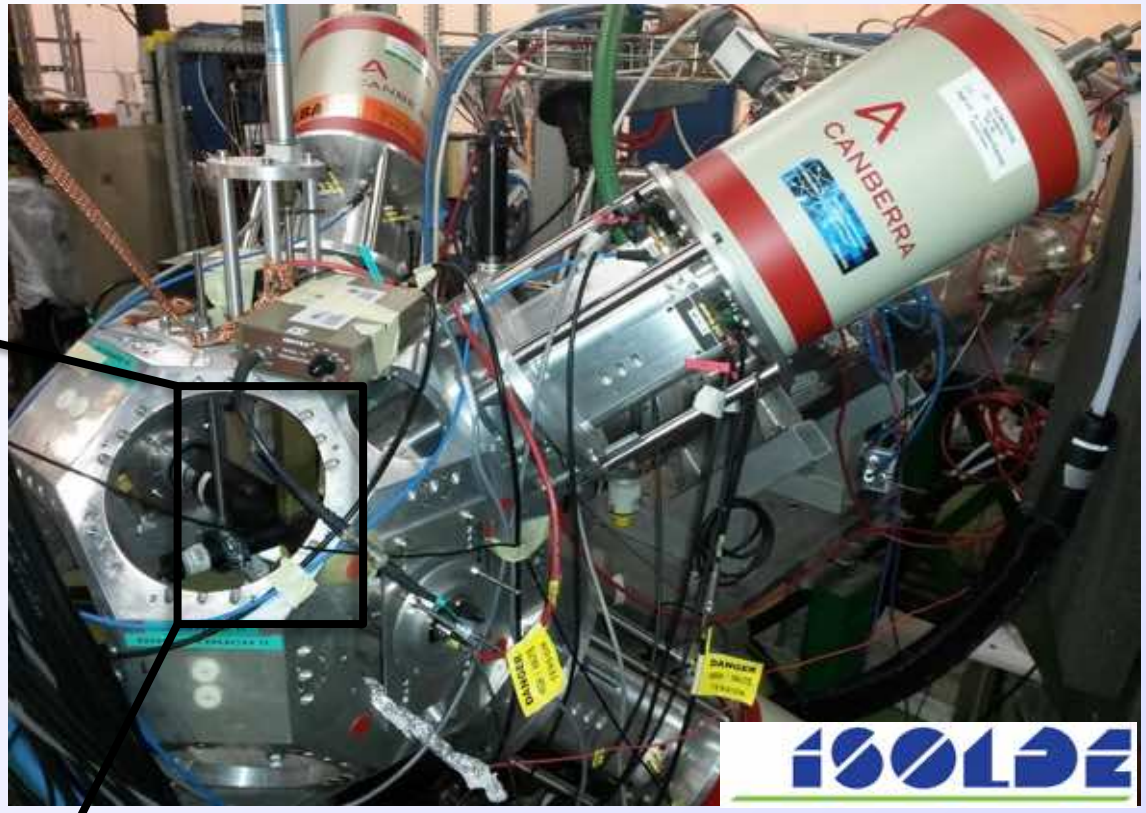
Limited coincidence study

Assessment of contaminants

Note interesting nuclei are populated down the decay chains towards N=50

IDS setup

ISOLDE Decay Station



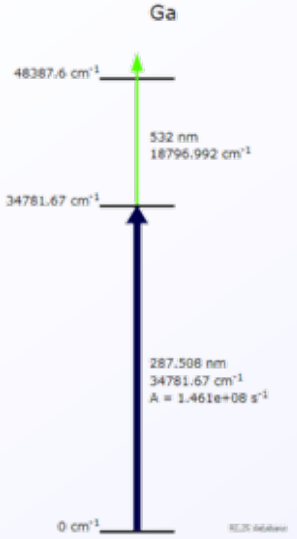
New IDS configuration

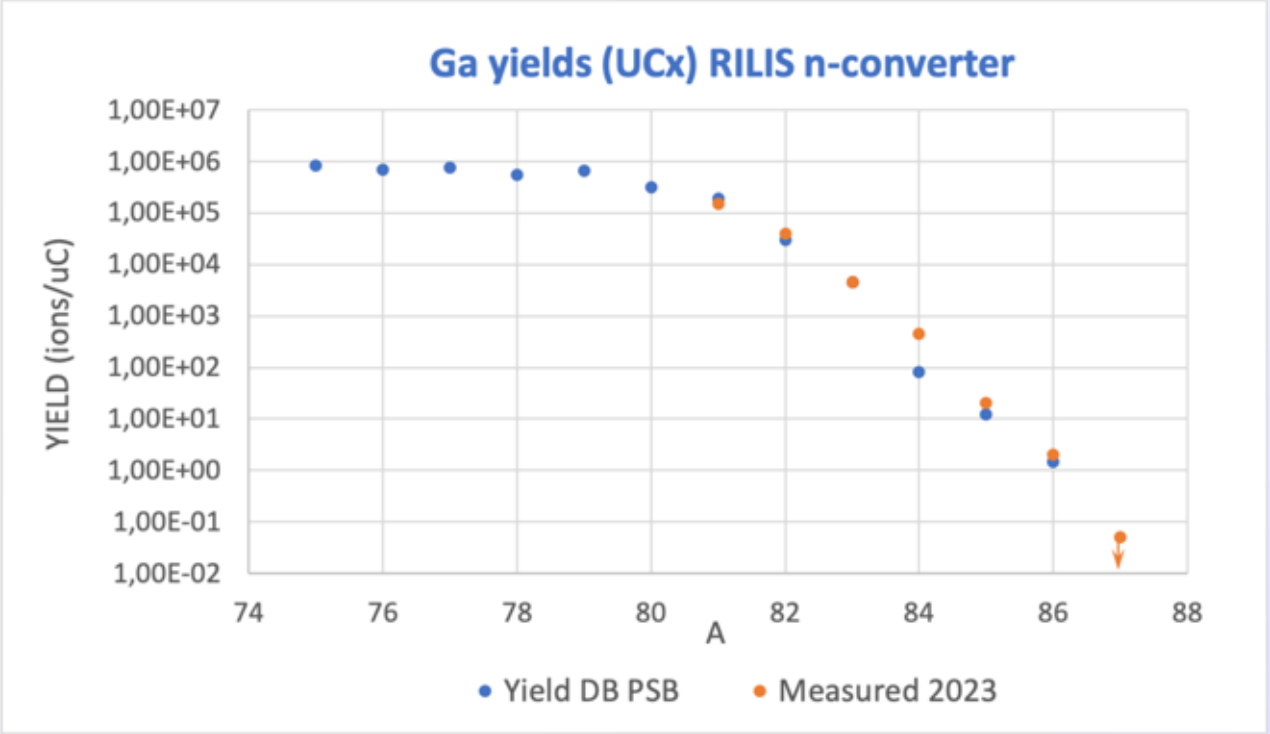
Increased number of Clovers

Increased beta-efficiency

Beam time request

- UC_2/graphite target
- neutron converter
- RILIS





Online calibrations: 2 shift

$^{83\text{-}86,87}$Ga: 19 + 1 shifts (including RILIS off)

Isotope (J^π)	$T_{1/2}$ [ms]	Yield [ions/μC]	Ions/s	Decay mode	br(%)	β_{Gated}-γ_{Ge} [Counts/shift]	β-γ_{LaBr}-γ_{Ge} [Counts/shift]	Shifts
^{83}Ga ($5/2^-$)	308(1)	4500	7700	β	37(3)	$6.3\cdot10^5$	525	1.5
				β-n	63(3)	-	-	
^{84}Ga (0^-)	95(2)	450	770	β	61(2)	$6.3\cdot10^4$	155	3.5
				β-n	37(2)	-	340	
^{85}Ga ($5/2^-$)	92(4)	20	34	β	22(3)	$2.8\cdot10^3$	65	6
				β-n	76(3)	-	70	
^{86}Ga (?)	43(2)	2	3.4	β	26(3)	$2.8\cdot10^2$	-	8
				β-n	60(3)	-	-	
^{87}Ga ($5/2^-$?)	29(4)	$\leq$0.05	$\leq$0.1	β-n	?	-	-	1

Collaboration

L.M. Fraile[1], J. Benito[1], A. Illana[1], O. Alonso-Sañudo[1], A.N. Andreyev[2], A. Algora[3], O. Alonso-Sañudo[1], M.J.G. Borge[4], J.A. Briz[1], M. Caballero[1], S. Casci[5], T.E. Cocolios[5], J.G. Cubiss[3,6], G. García de Lorenzo[1], P. González-Tarrío[1], R. Grzywacz[7], J.L. Herraiz[1], J. Jolie[8], A. Korgul[9], U. Köster[10], R. Lica[11], M. Llanos-Expósito[1], M. Madurga[7], N. Marginean[11], R. Marginean[11], A. McFarlane[2], C. Mihai[11], E. Nácher[3], A. Negret[11], C.R. Nita[11], V.M. Nouvilas[1], J. Ojala[12,13], B. Olaizola[4], C.A.A. Page[3], R.D. Page[14], J. Pakarinen[12,13], P. Papadakis[15], S. Pascu[11], A. Perea[4], T.R. Rodríguez[1], F. Rotaru[11], B. Rubio[3], J. Sanchéz-Prieto[4], C. Sotty[11], M.M. Satrazani[5], M. Stryjczyk[12,13], O. Tengblad[4], J.M. Udías[1], M. Vogiatzi[5], N. Warr[8], J. Wilson[2], H. de Witte[5], Z. Yue[2], and the IDS Collaboration

[1] *Grupo de Física Nuclear & IPARCOS, Universidad Complutense de Madrid, Madrid, Spain.*
[2] *School of Physics, Engineering and Technology, University of York, York, YO10 5DD, UK.*
[3] *Instituto de Física Corpuscular, CSIC and Universidad de Valencia, Paterna, Spain.*
[4] *Instituto de Estructura de la Materia, CSIC, Madrid, Spain.*
[5] *KU Leuven, Instituut voor Kern- en Stralingsfysica, 3001 Leuven, Belgium.*
[6] *School of Physics and Astronomy, University of Edinburgh, Edinburgh, EH9 3FD, UK.*
[7] *Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee, USA.*
[8] *Institut für Kernphysik, Universität zu Köln, Köln, Germany.*
[9] *Faculty of Physics, University of Warsaw, Warsaw, Poland.*
[10] *Institut Laue Langevin, F-38042 Grenoble Cedex 9, France.*
[11] *"Horia Hulubei" National Institute of Physics and Nuclear Engineering, Bucharest, Romania.*
[12] *Accelerator Laboratory, Department of Physics, University of Jyväskylä, Jyväskylä, Finland.*
[13] *Helsinki Institute of Physics, Helsinki, Finland.*
[14] *Oliver Lodge Laboratory, University of Liverpool, Liverpool, L69 7ZE, UK.*
[15] *STFC Daresbury Laboratory, Daresbury, Warrington, WA4 4AD, UK.*