Evolution of the N=50 shell gap :
New insights from spectroscopic data on ^{82}Ge

Damien Thisse – CEA Saclay
for the ν-Ball collaboration

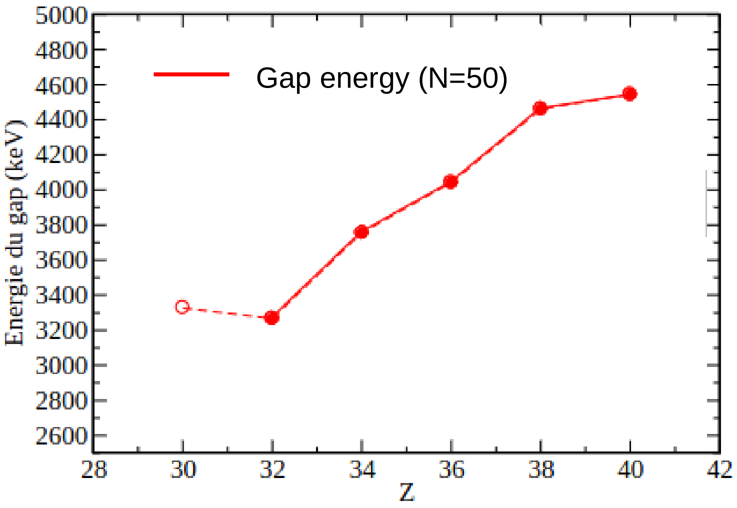
Colloque GANIL 2023
28 septembre 2023 - Soustons

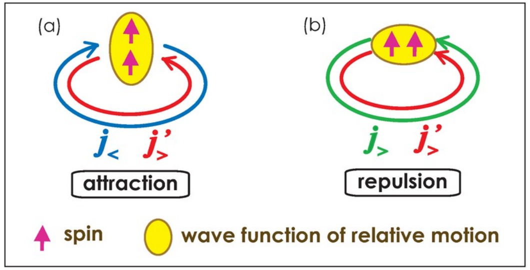
Shell structure evolution along N = 50

N=50 gap: $\Delta\varepsilon^{[N=50]} = \varepsilon(2d_{5/2}) - \varepsilon(1g_{9/2})$
Known to **reduce when approaching ^{78}Ni**

Central force + spin-orbit : not sufficient to describe nuclei far from stability
Tensor force mechanism added to explain the single particle orbits energy evolution
→ but limitations especially near ^{78}Ni

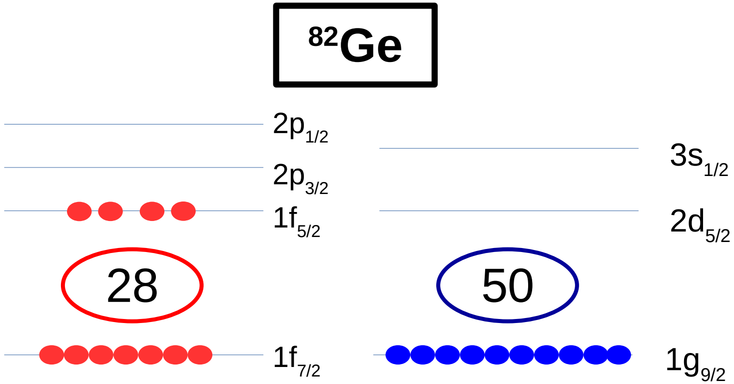
To access the gap size using spectroscopy :
Observation of states whose wave functions are **dominated by the 1p-1h configuration**



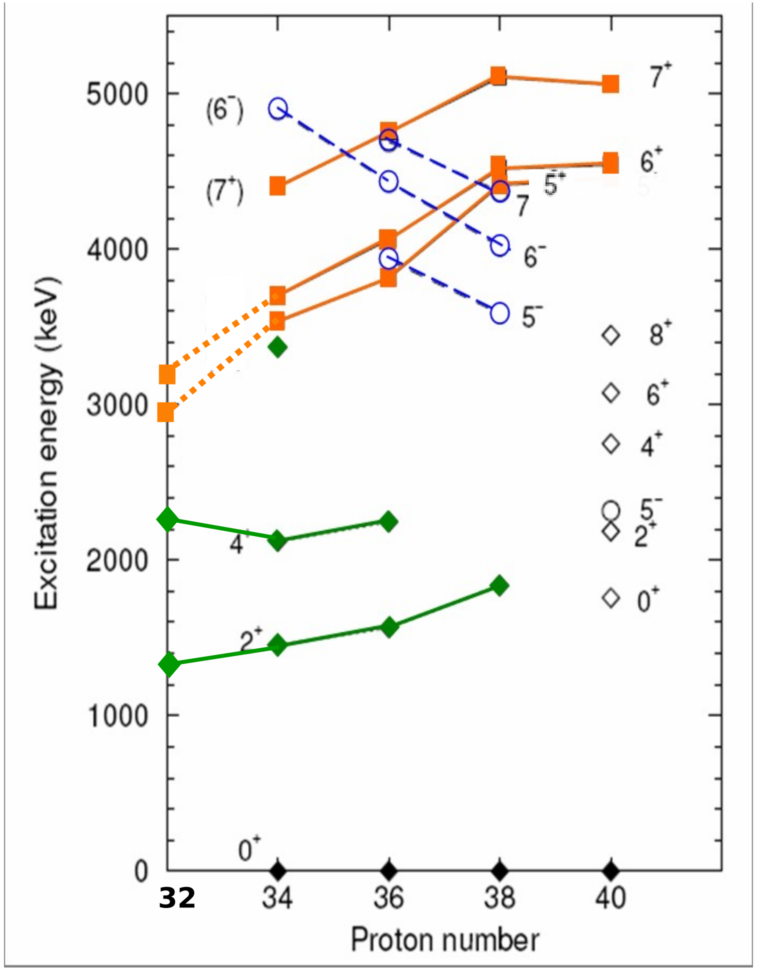


The tensor force to drive these evolutions

Spectroscopy of ^{82}Ge



Rather low spin states (≤ 6)



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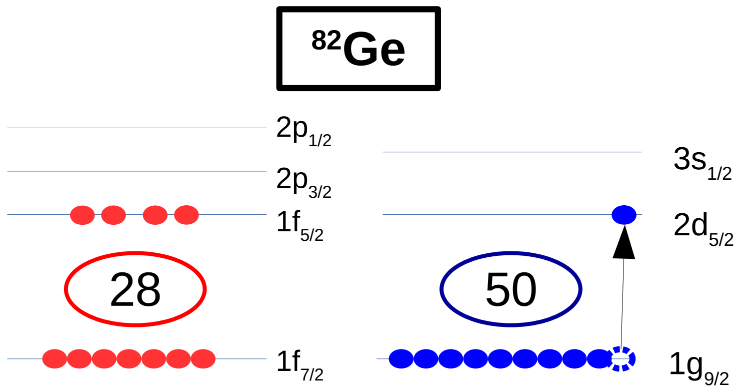

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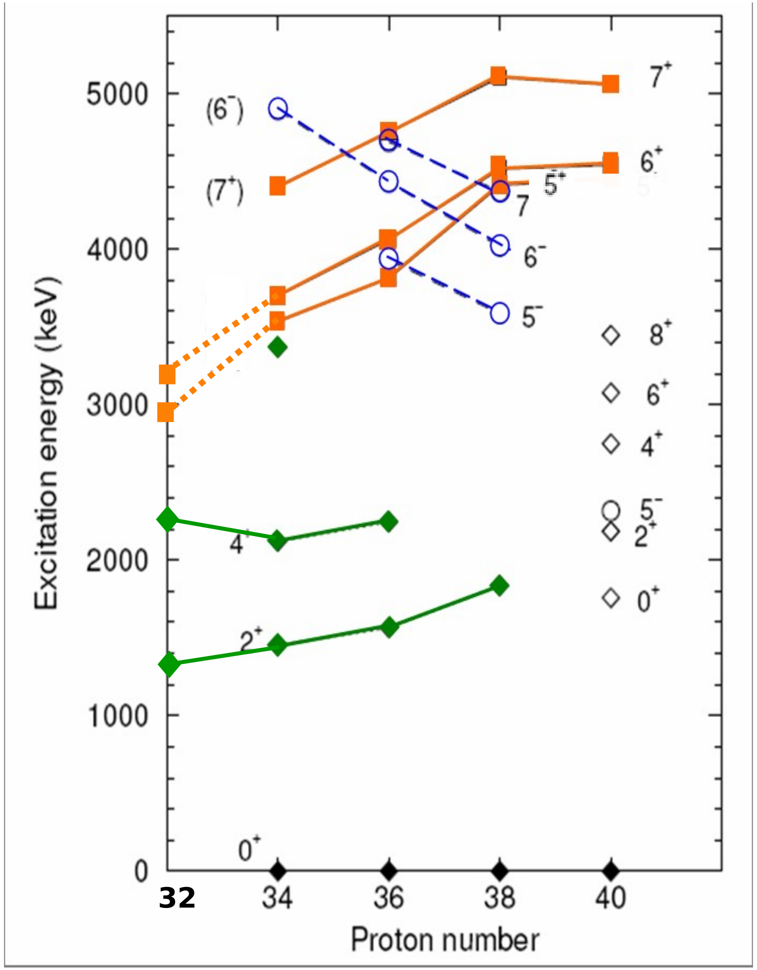
Multiplet from 2^+ to **7^+**

$(\nu 2d_{5/2})^1(\nu 1g_{9/2})^{-1}$ core-breaking configuration can be related to the N=50 gap properties



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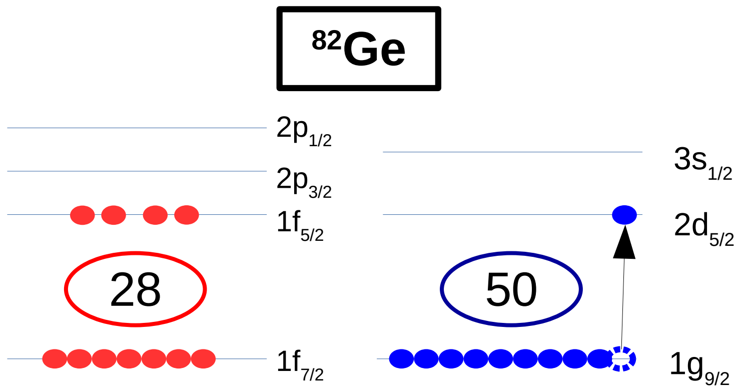

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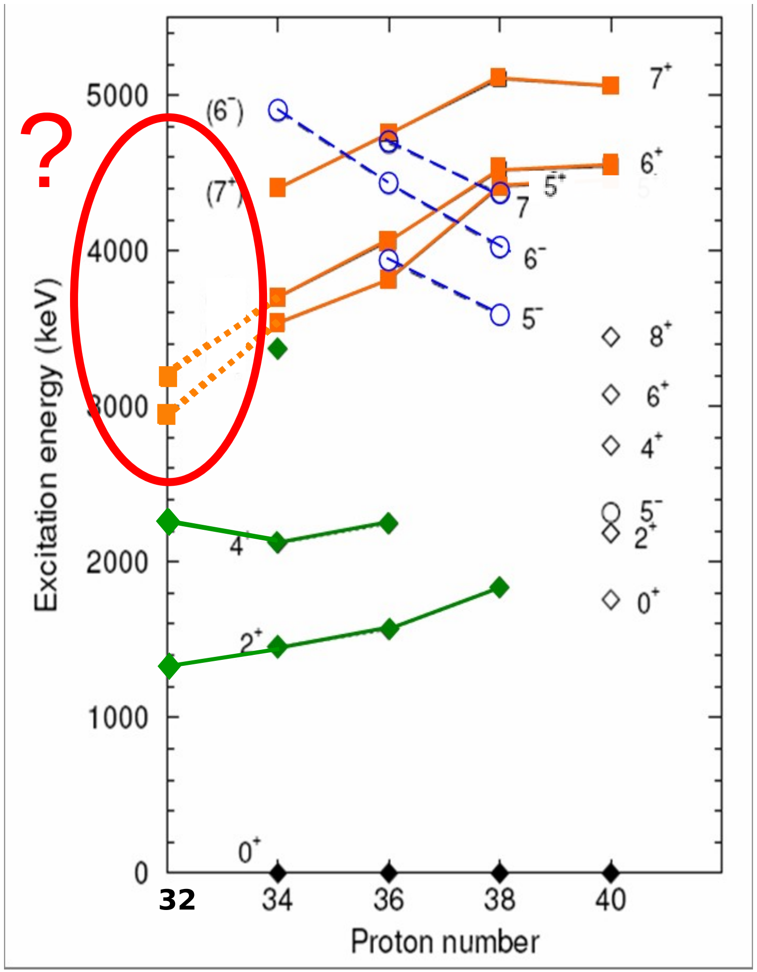
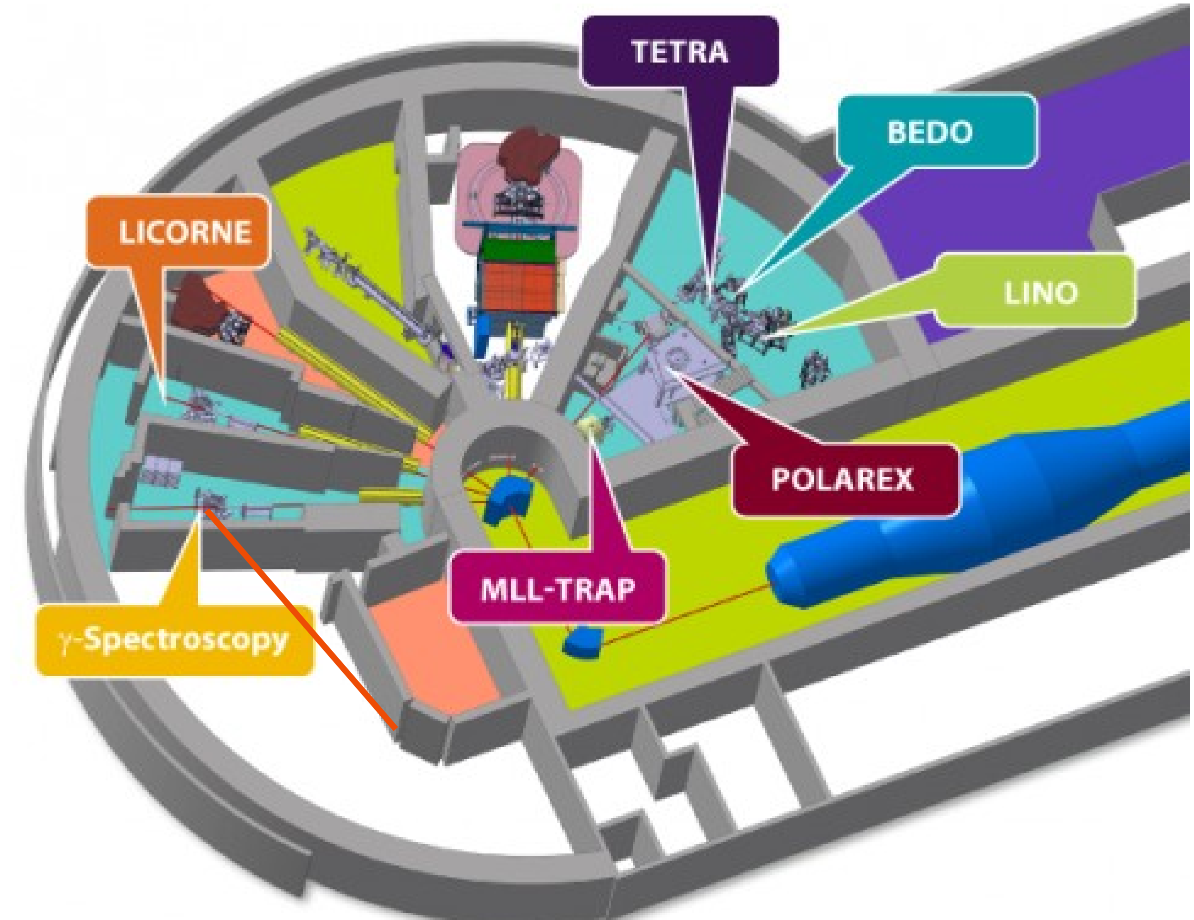
→ **Search for 7^+ <u>yrast*</u> state in ^{82}Ge**

→ Production of neutron-rich nuclei using fission reaction to populate **medium/high spin yrast states.**



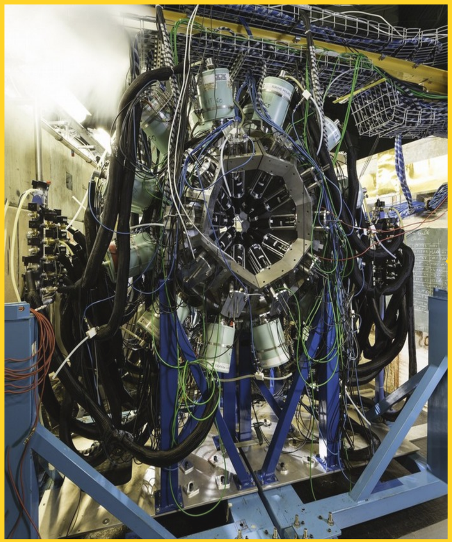
*Other 7+ states (related to core coupling) are expected at higher energy (+1.5 MeV)

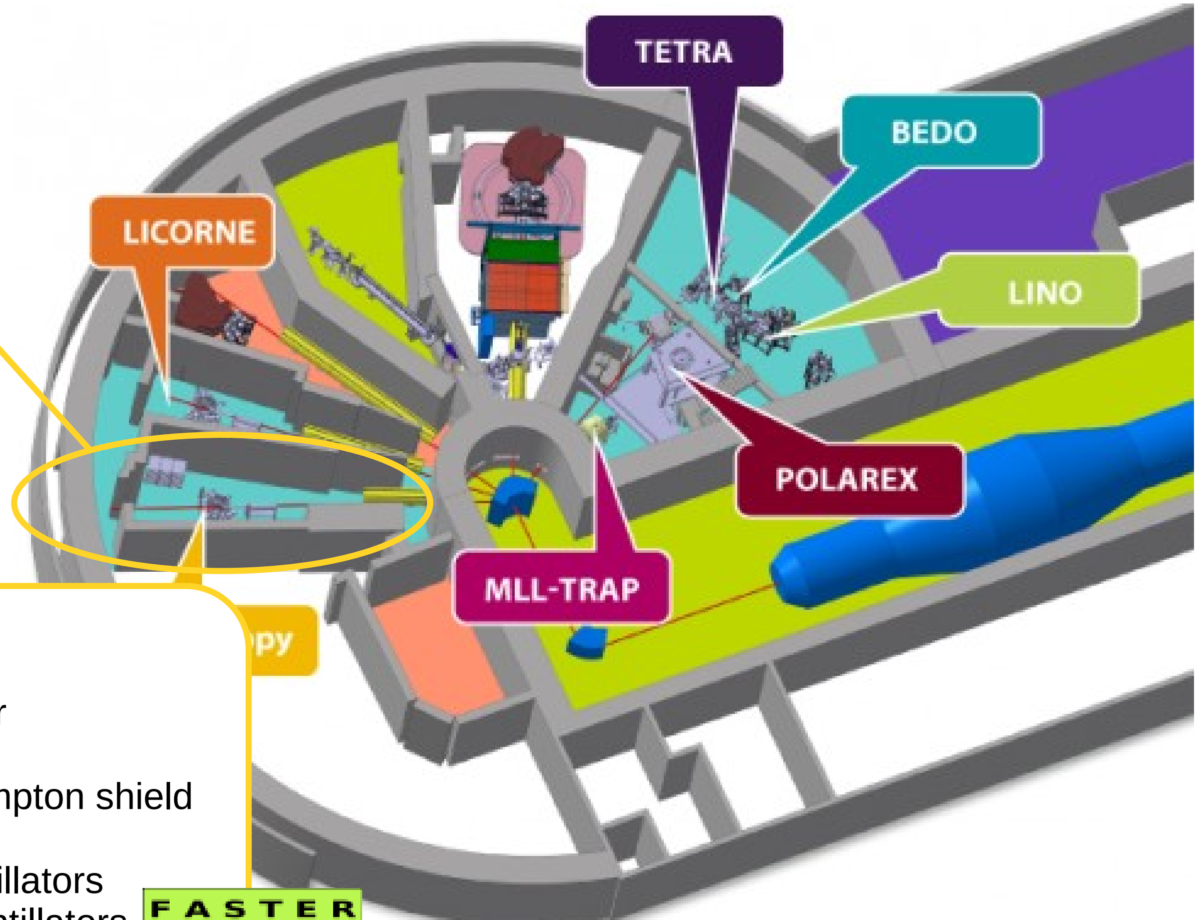
The ν-Ball spectrometer @ ALTO



The ν-Ball spectrometer @ ALTO

M. Lebois *et al,* NIM A. **960** (2020)





Setup

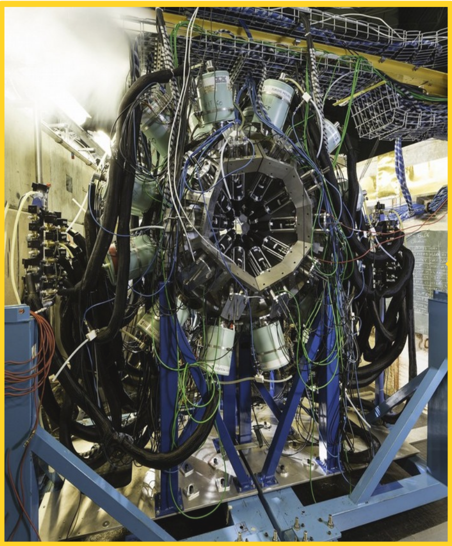
24 HPGe Clover
9 coaxial HPGe
All equipped with BGO Compton shield

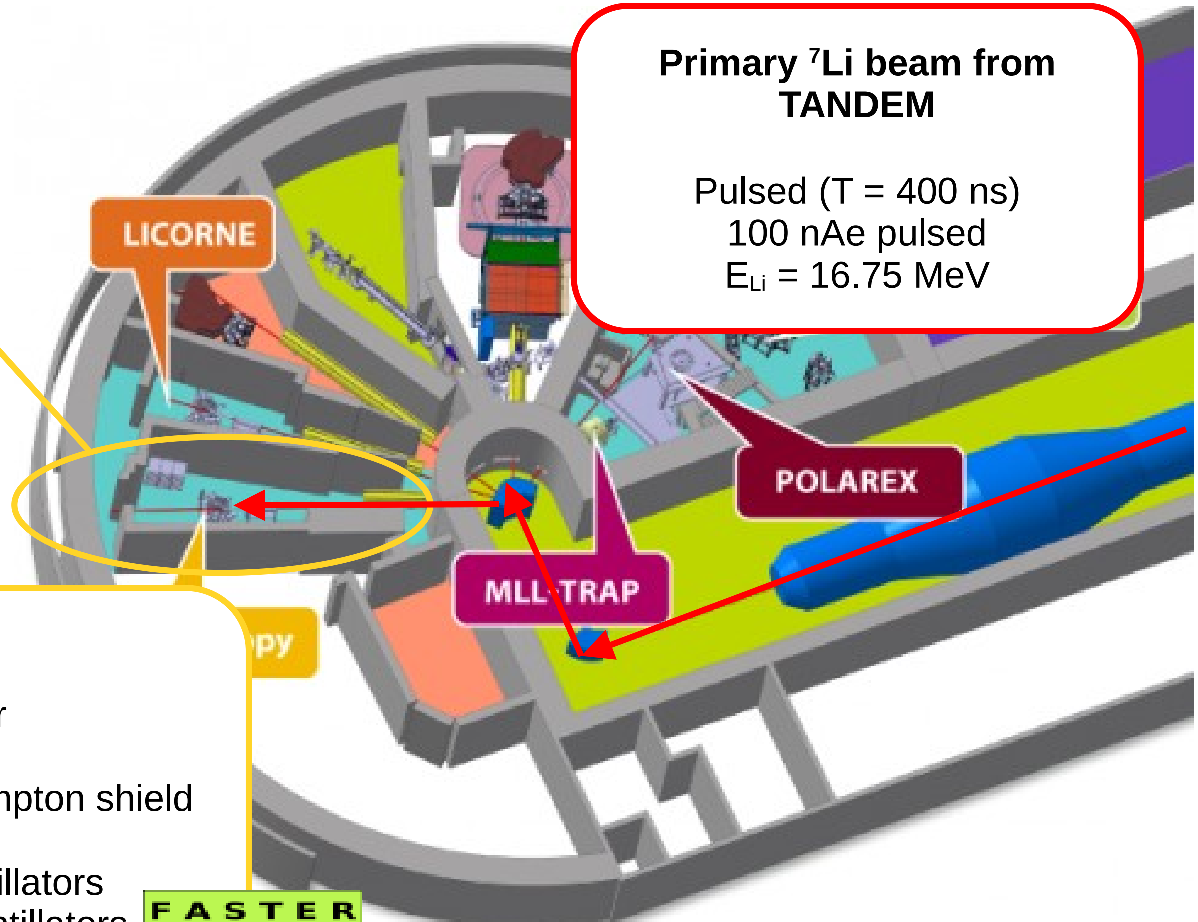
10 conical $LaBr_3$ scintillators
10 cylindrical $LaBr_3$ scintillators

FASTER

The ν-Ball spectrometer @ ALTO

M. Lebois *et al*, NIM A. **960** (2020)





Primary ^{7}Li beam from TANDEM

Pulsed (T = 400 ns)
100 nAe pulsed
E_{Li} = 16.75 MeV

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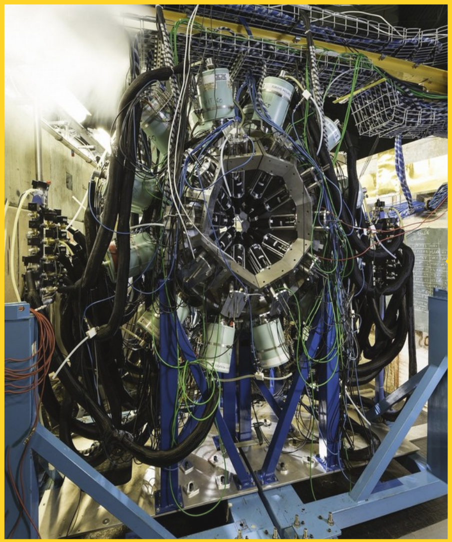

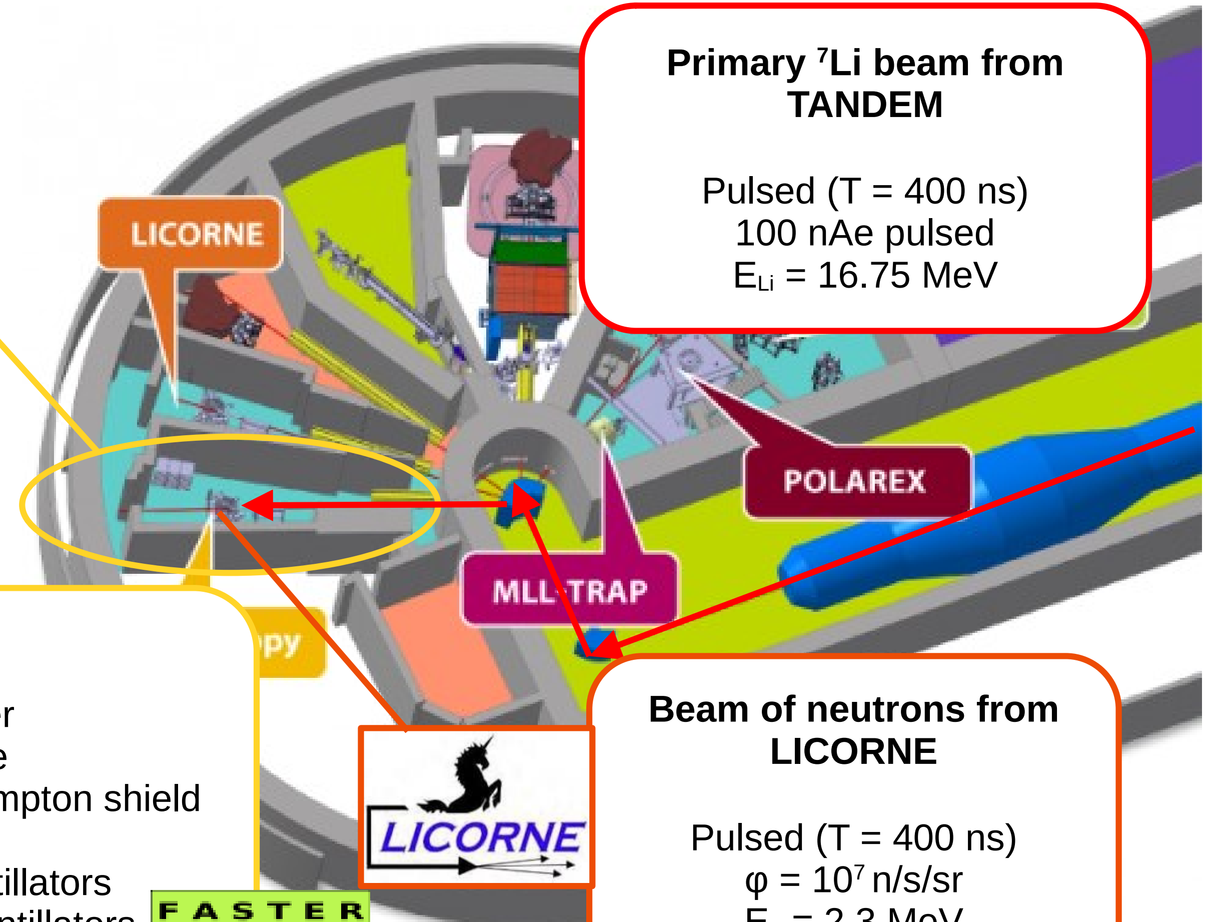

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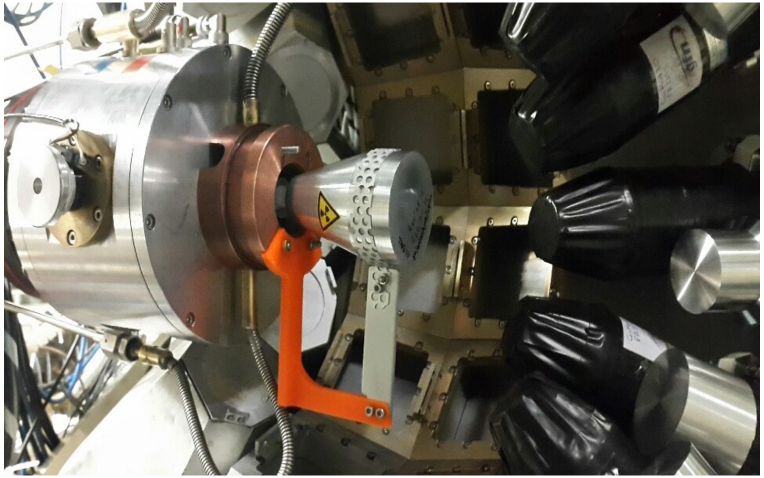
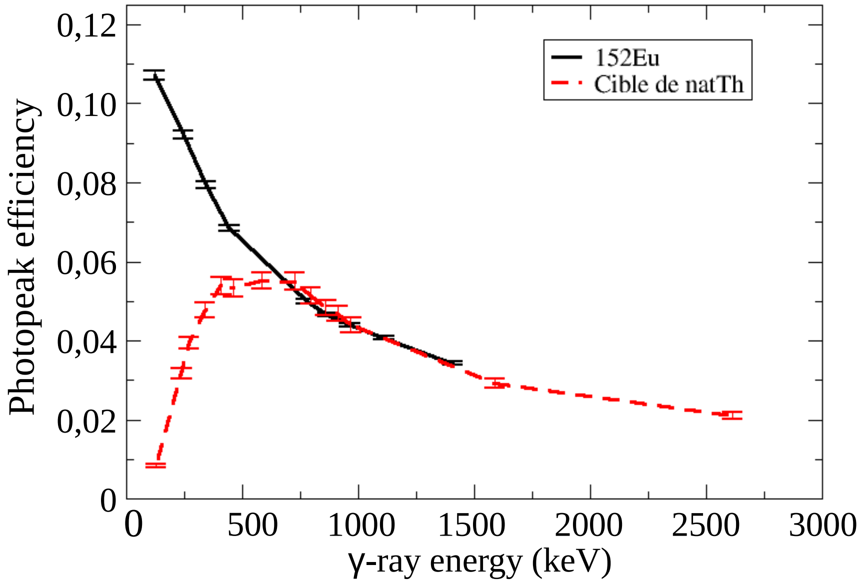
Beam of neutrons from LICORNE

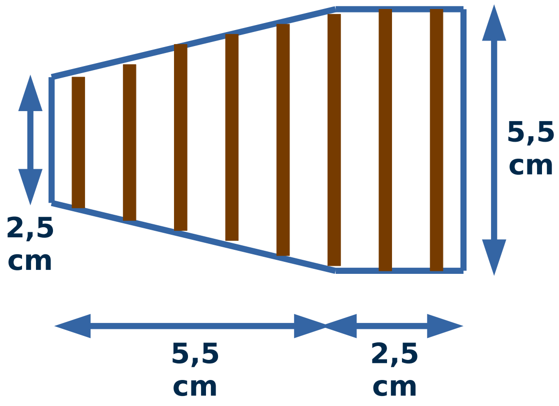
Pulsed (T = 400 ns)
φ = 10^{7} n/s/sr
E_n = 2.3 MeV

M. Lebois, J. N. Wilson, *et al.,* NIM A **735** (2014)

The ν-Ball spectrometer @ ALTO



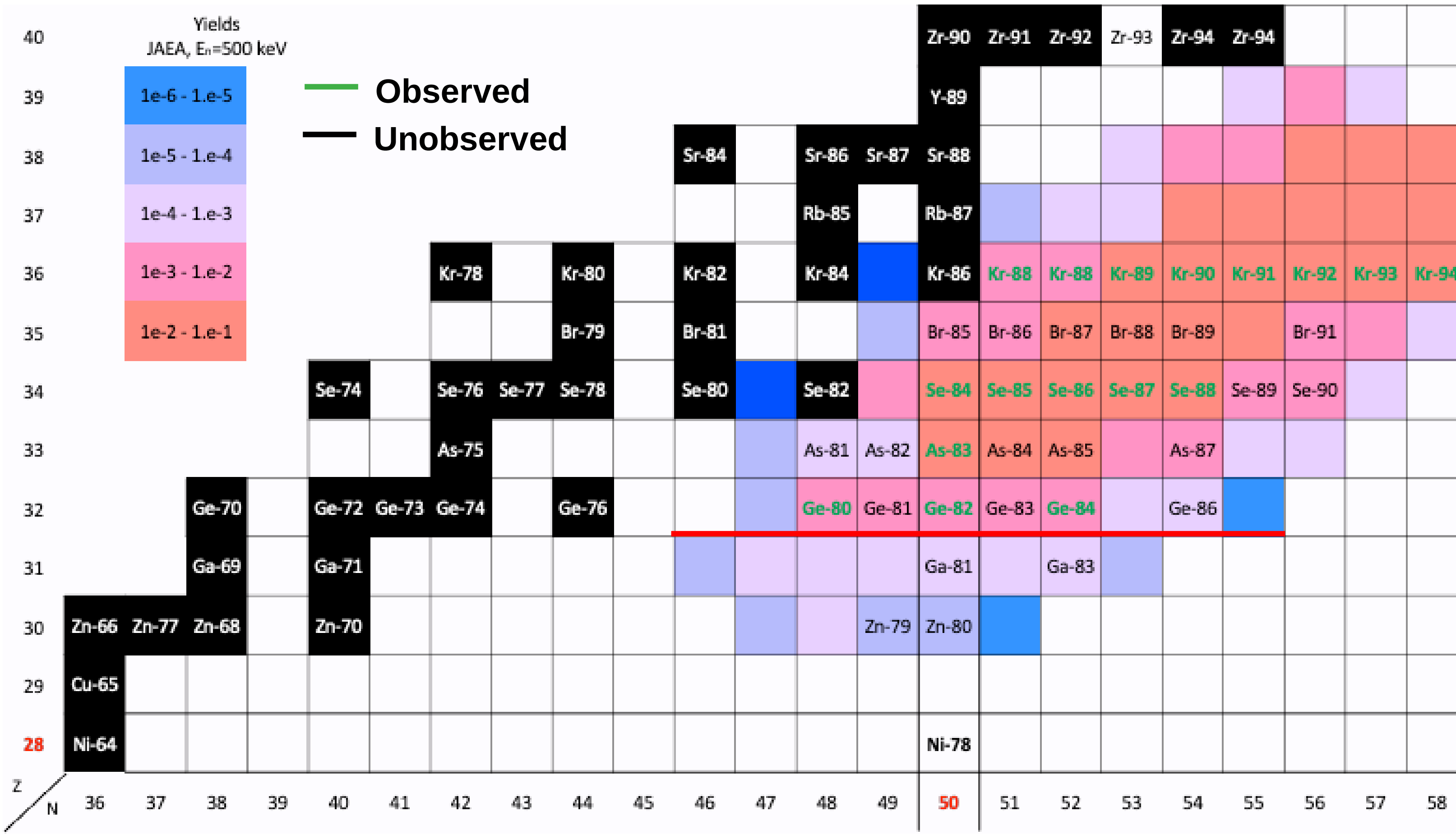




Analysis

- Event reconstruction (based on beam pulsation)
- Fission selection (multiplicity and timing)
- γ-γ matrices and γ-γ-γ cubes

Observation limit (lower mass area)



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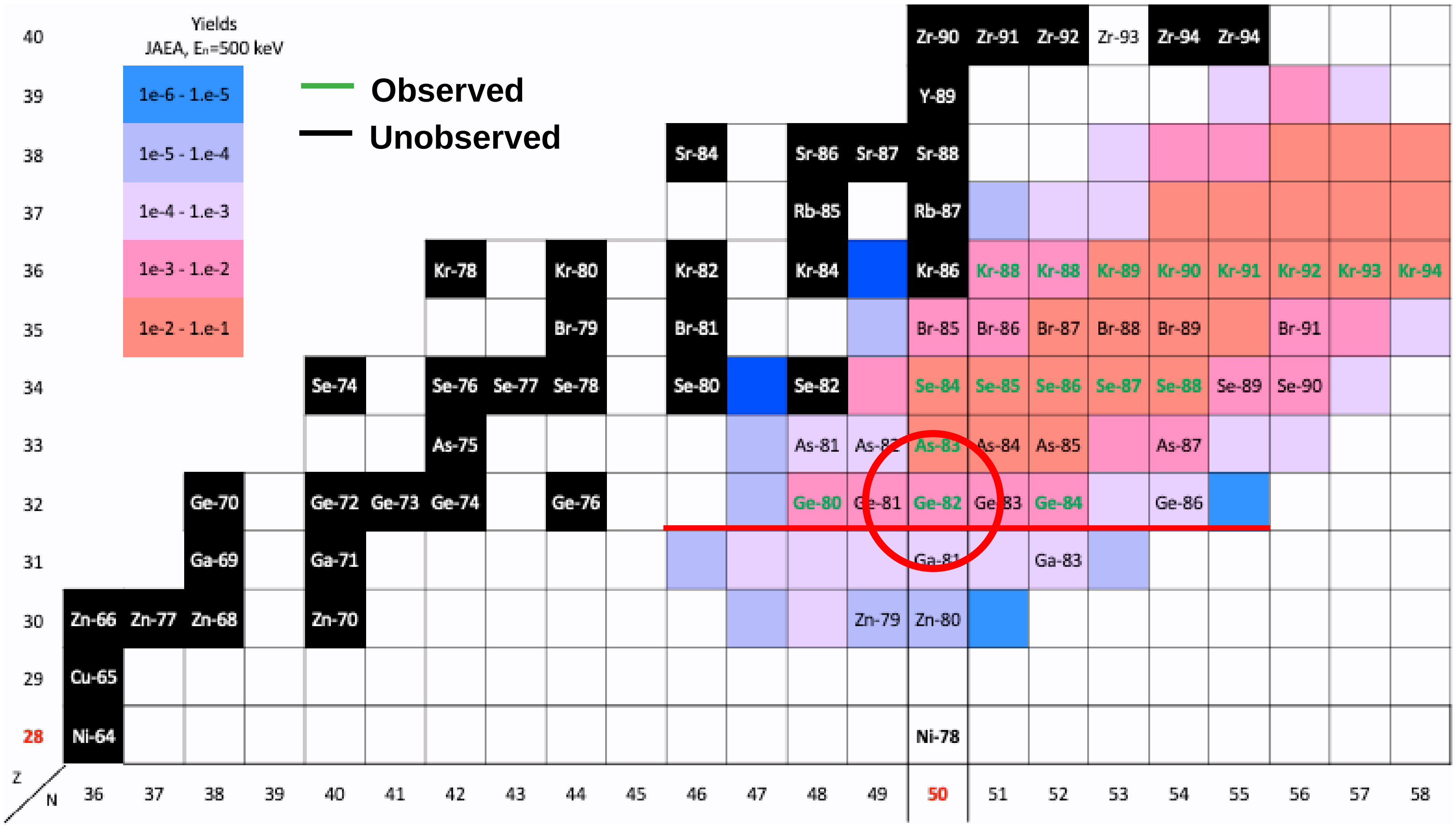
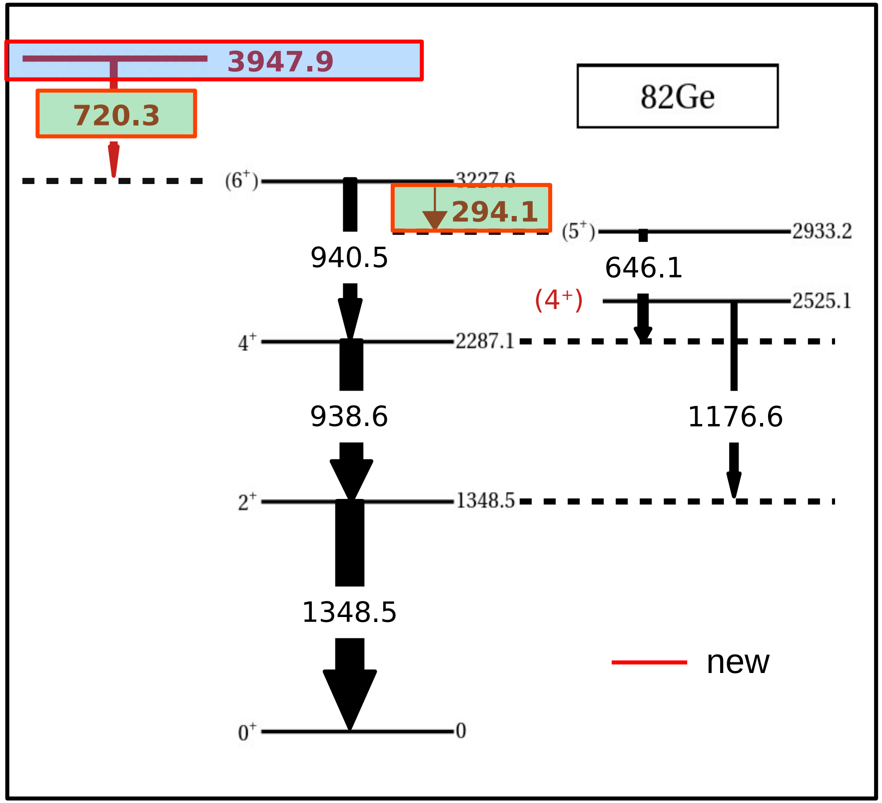


Level scheme of ^{82}Ge from ^{232}Th(n,f)



Two new transitions attributed to ^{82}Ge

One new state added into the level scheme

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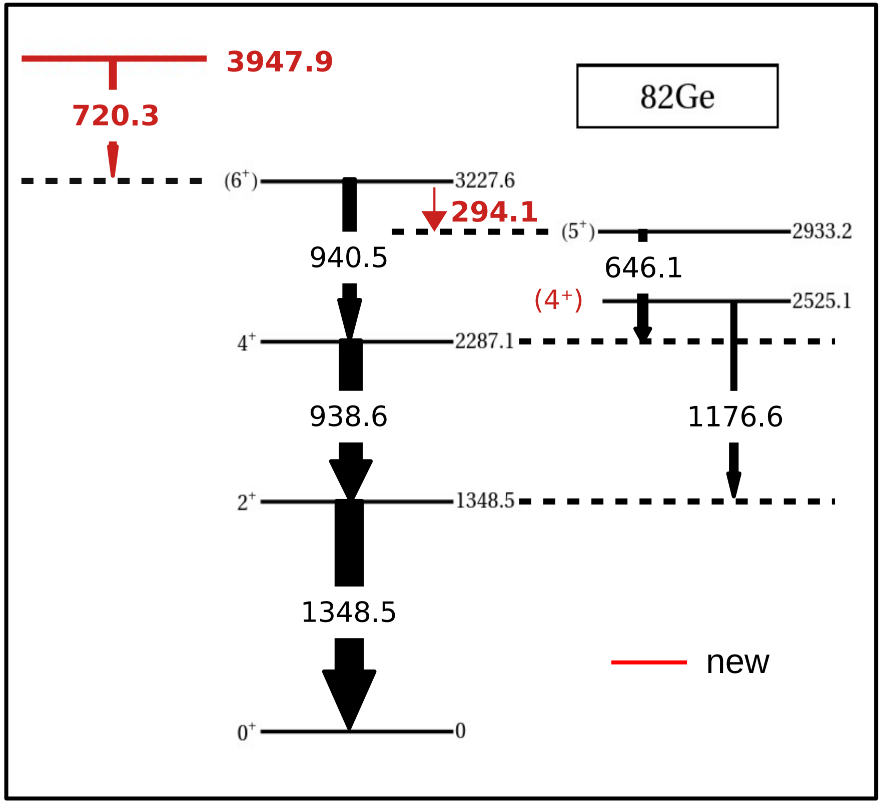
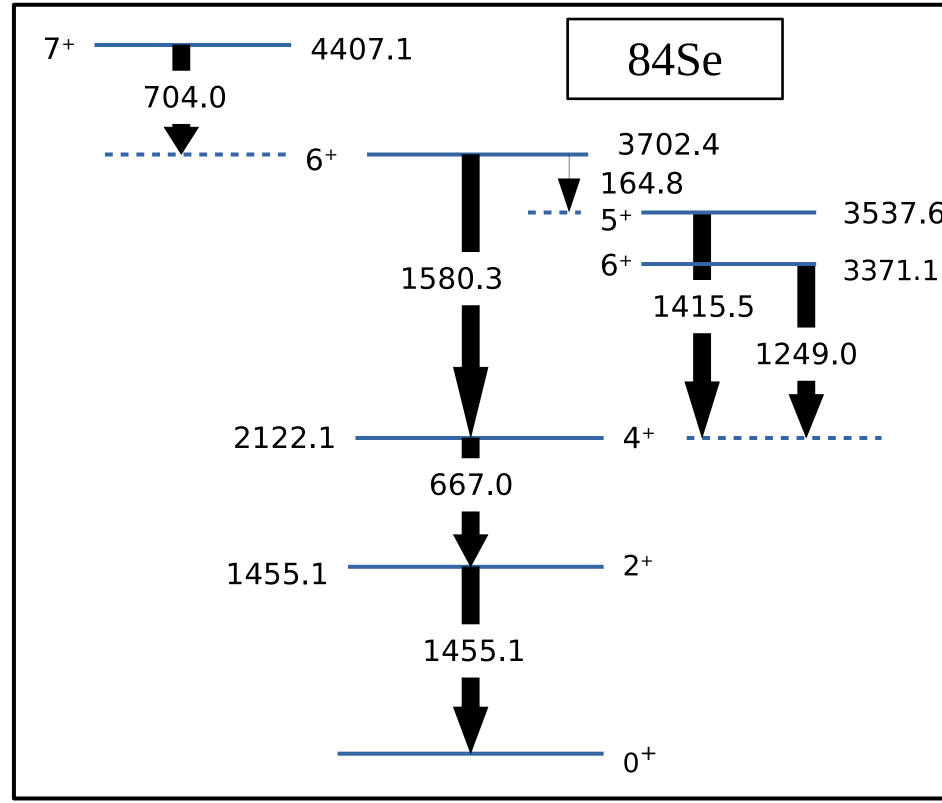
Comparison with neighboring even-even nucleus ^{84}Se





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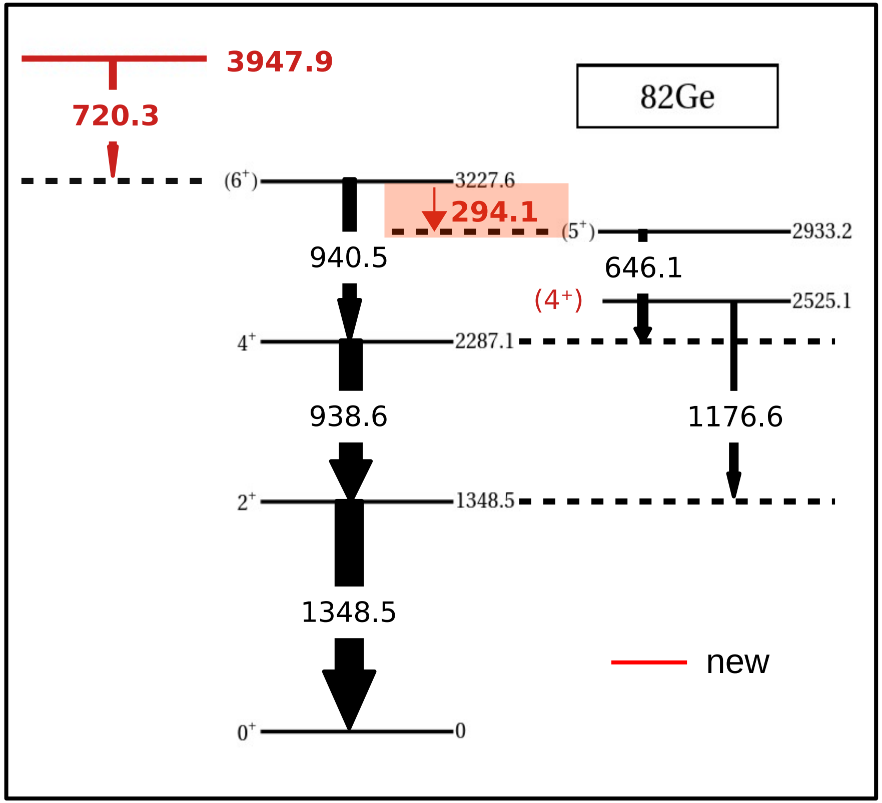

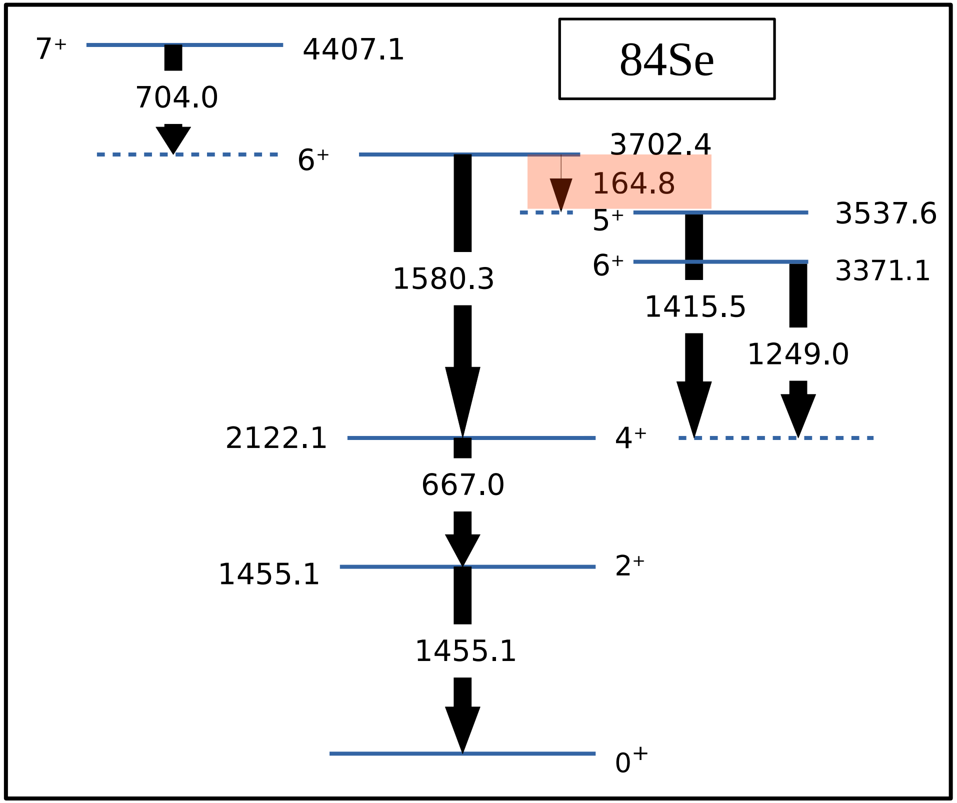

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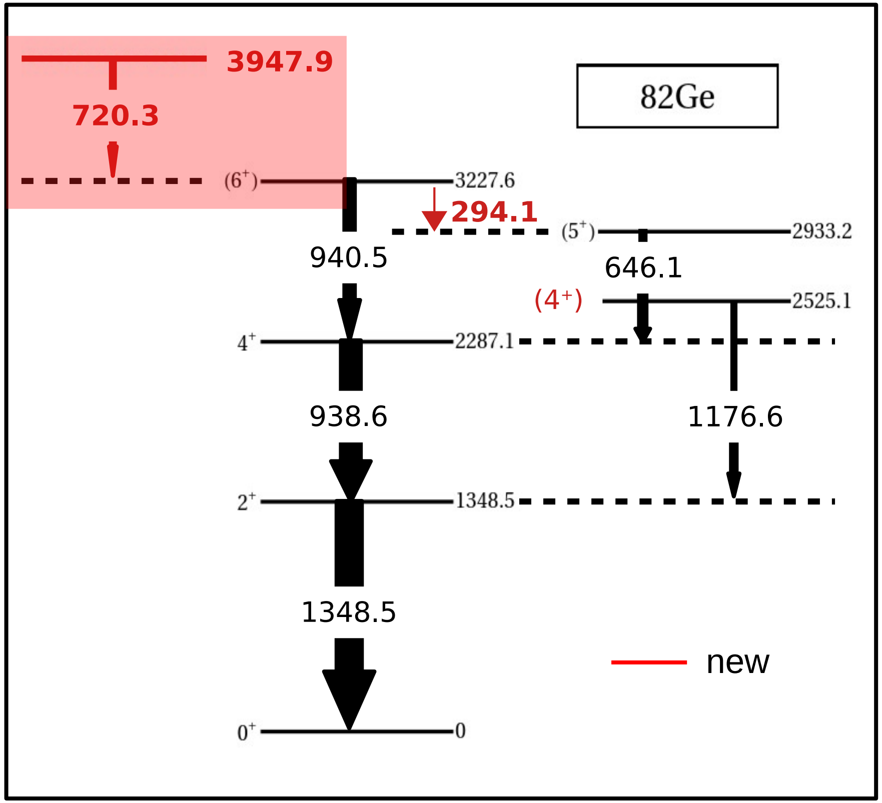

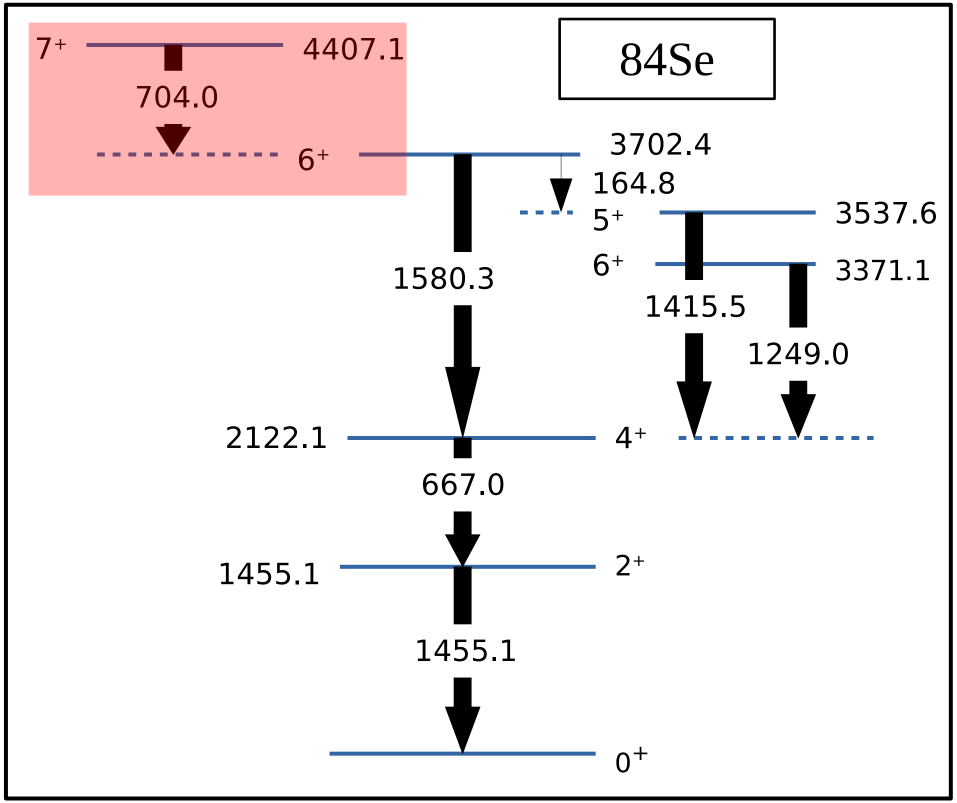

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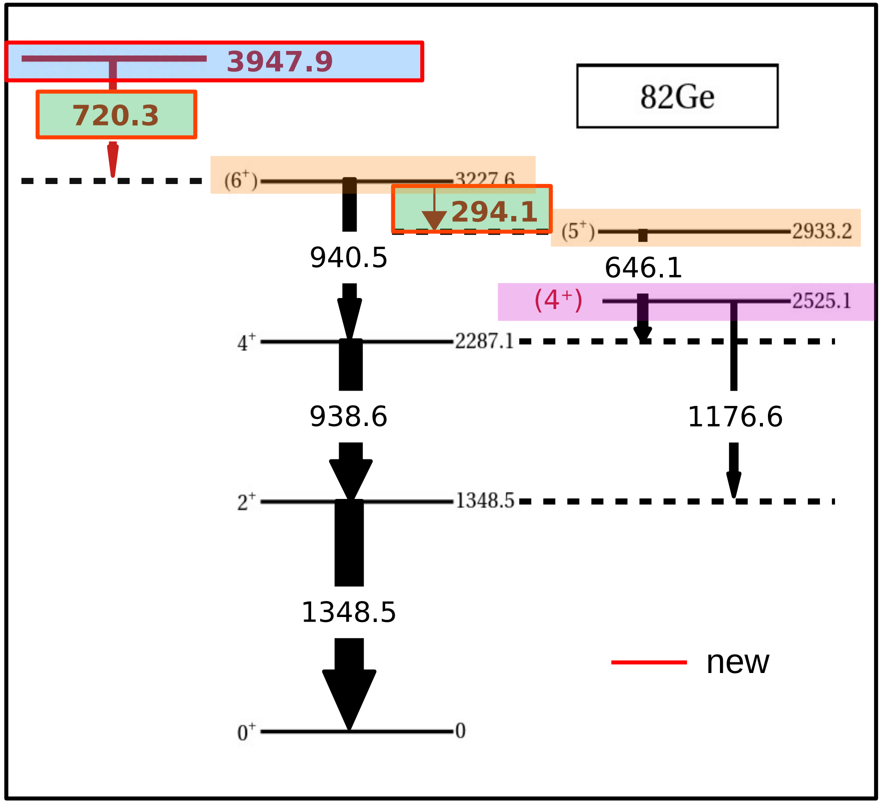


D. Thisse *et al. EPJ A 59* (2023)

Main results

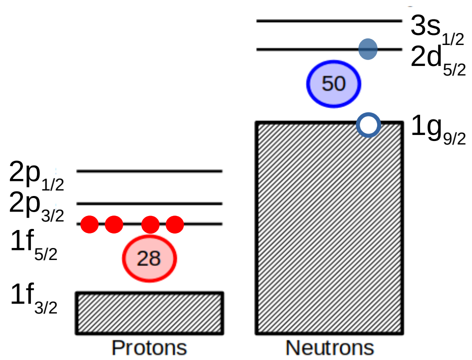
Two new transitions attributed to ^{82}Ge

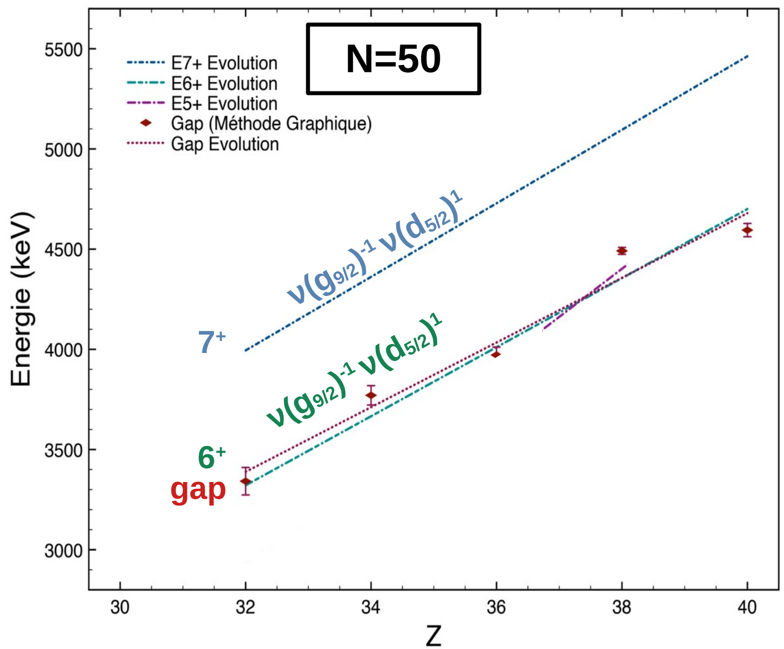
One new state added into the level scheme → supposed 7^+

New evidences for the attribution of spin-parities 5^+ and 6^+

Change the spin assignment from 2^+ to 4^+ for the state at 2525.1 keV

Evolution of structure along N=50





Interpretation

Theoretical calculation with a contact interaction:

$$E(7^+, g_{9/2}^{-1} d_{5/2}^{1}) = \Delta\epsilon^{[N=50]} + \frac{cst}{A^{1/3}}$$

6+ and 7+ states : dominated by the $\nu(g_{9/2})^{-1}\,\nu(d_{5/2})^{1}$ configuration

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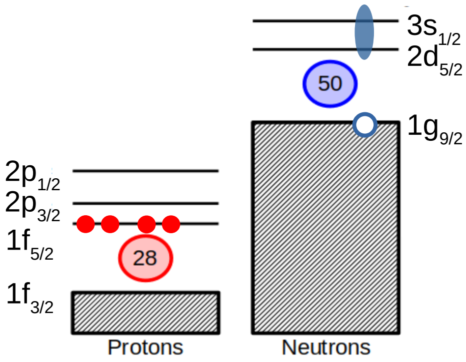

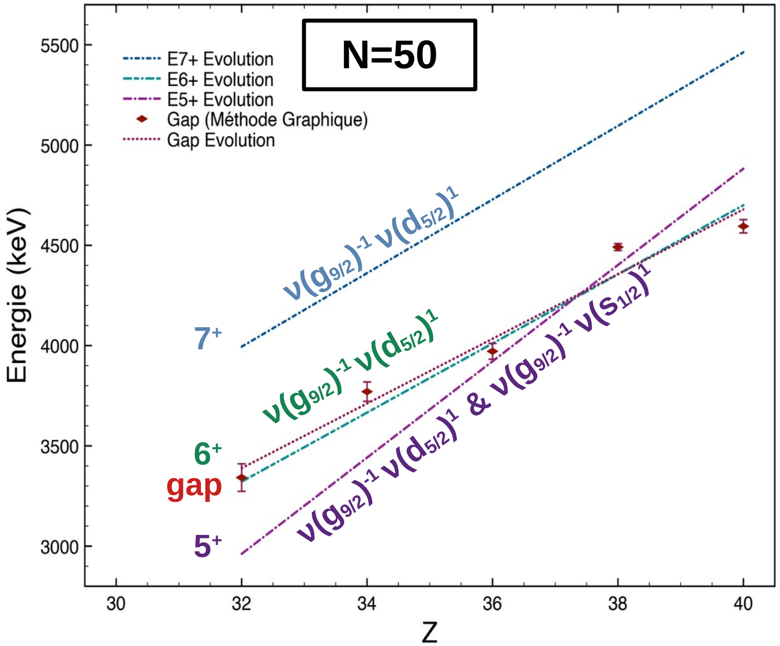

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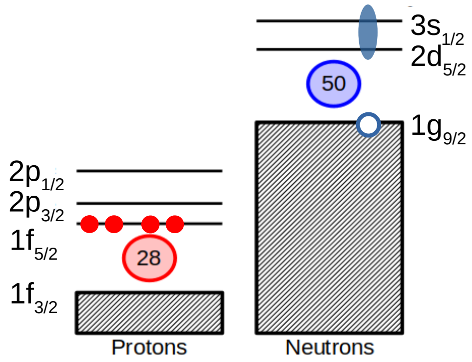

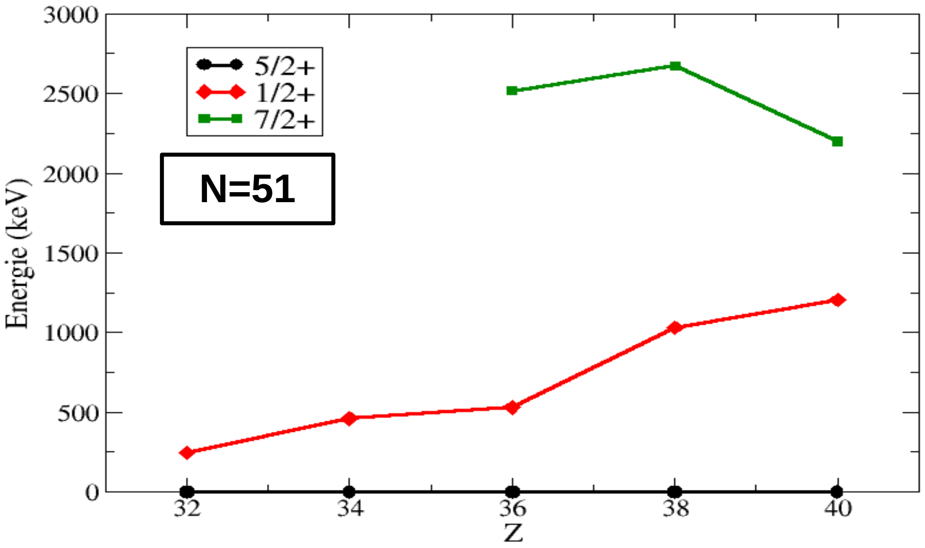

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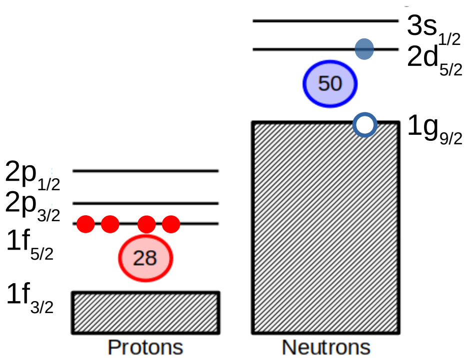
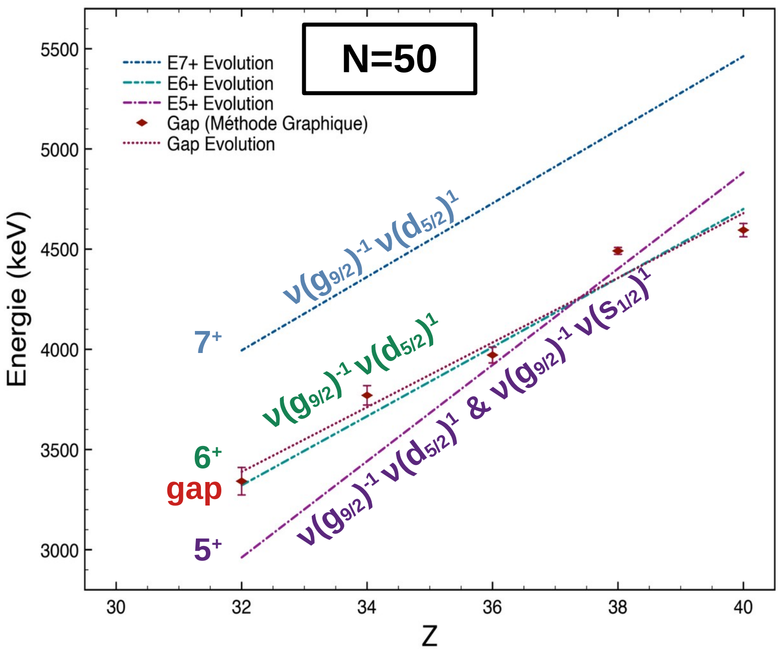
Single particle orbitals evolution in N=51 isotones

Evolution of structure along N=50





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$2d_{5/2}$ approaching $1g_{9/2}$
$3s_{1/2}$ approaching $2d_{5/2}$

Non fully interpretable with the tensor force mechanism

Change the framework :

looking for a more straightforward way to explain these evolutions

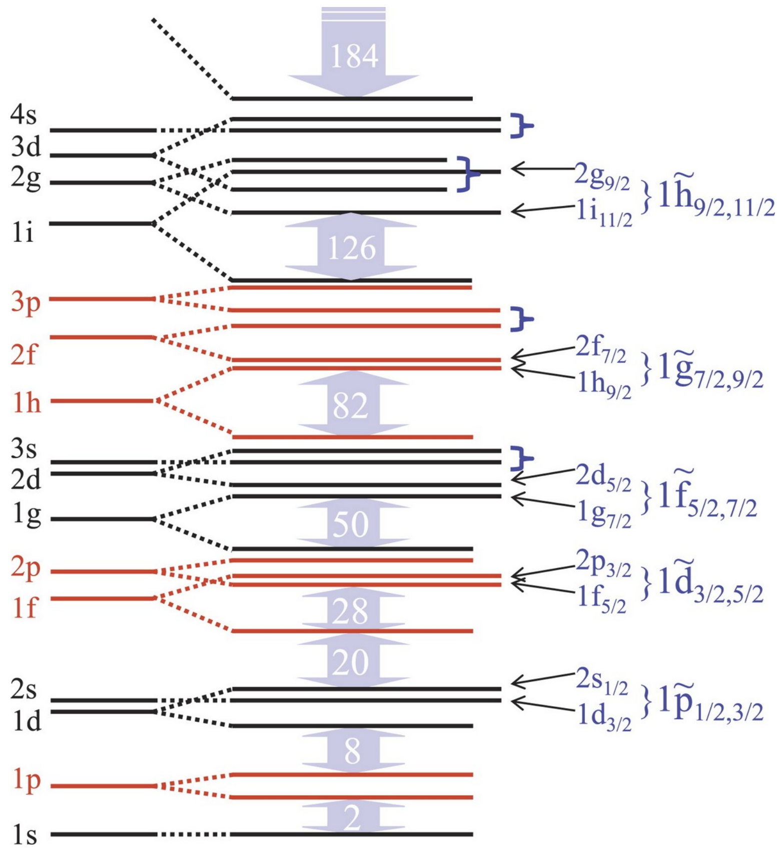
The pseudospin symmetry (PSS)

States with quantum numbers :
$\tilde{\ell}_{\downarrow}$(n, ℓ, j= ℓ +1/2) & $\tilde{\ell}_{\uparrow}$(n-1, ℓ+2, j= ℓ +3/2)
are **quasi-degenerated.**

Naturally emerging from **relativistic mean field theories**.

Pseudostates are labeled with $\left(\tilde{n}=n, \tilde{\ell}=\ell+1, j_1, j_2\right)$

But this symmetry is **always broken for bound nuclei**



H. Liang *et al.* Physics Reports 570 (2015)

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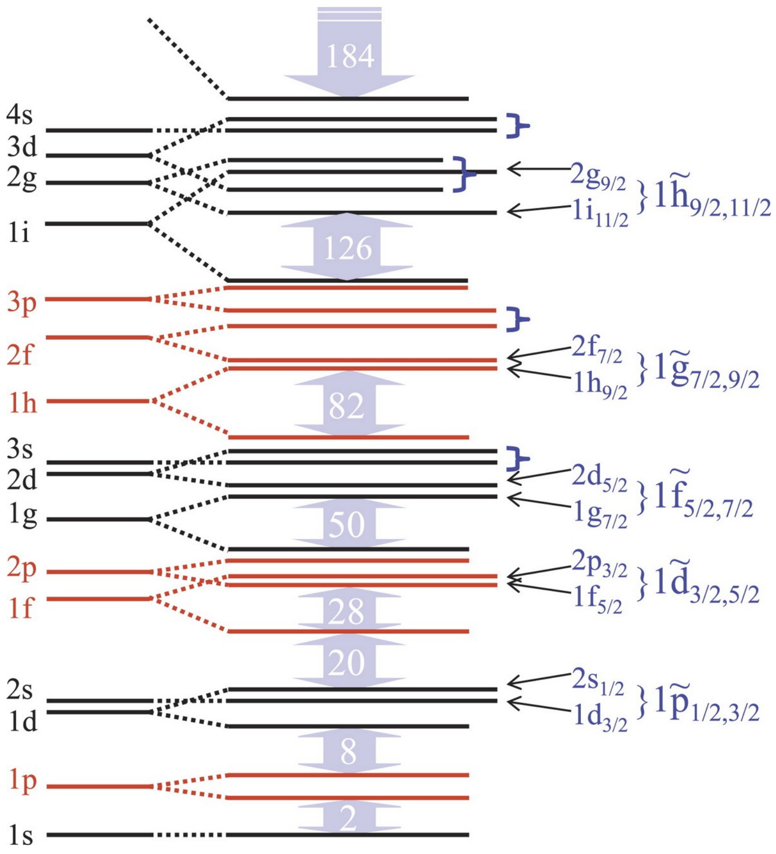
=> How does PSS breaking offer a phenomenological explanation for the evolution of magicity ?



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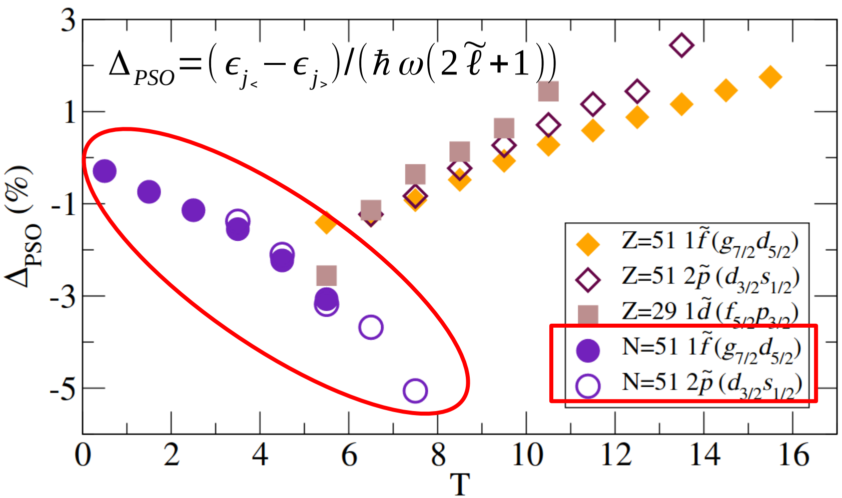
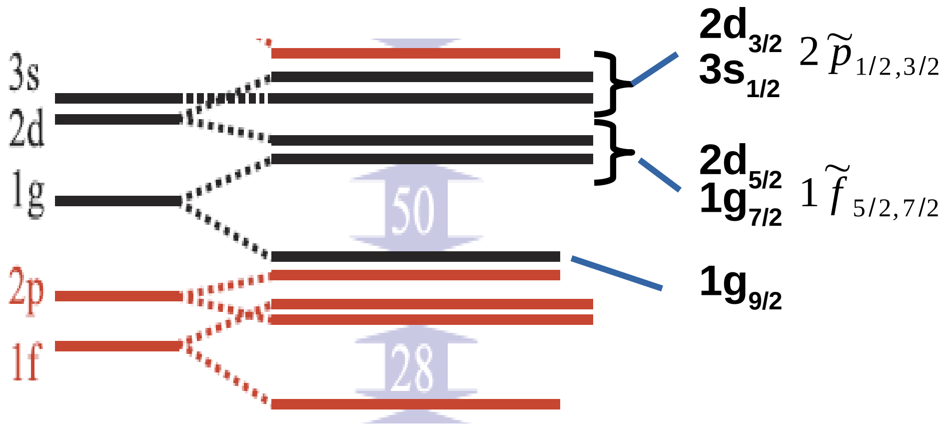


C. Delafosse *et al.* PRL 121, 192502 (2018)



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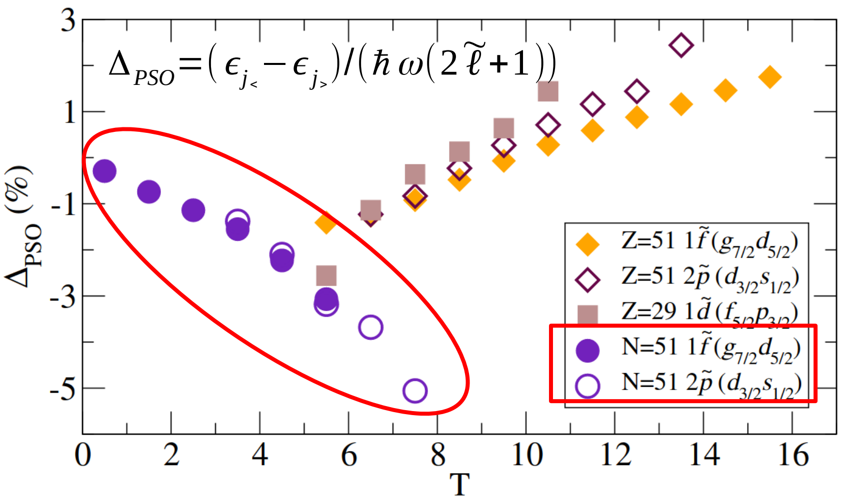

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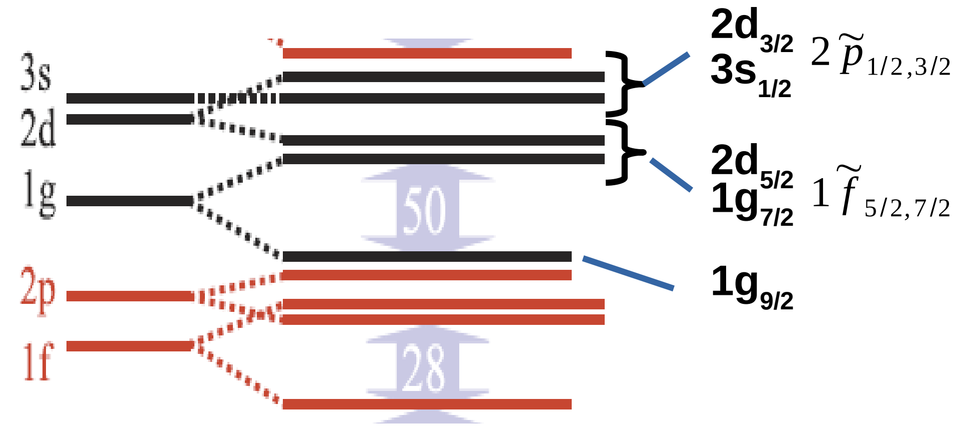

Splitting between the pseudospin partners evolve with the isospin T

Along an isotonic chain, with T increasing

$\tilde{\ell}_{\uparrow}$ ↗

$\tilde{\ell}_{\downarrow}$ ↘

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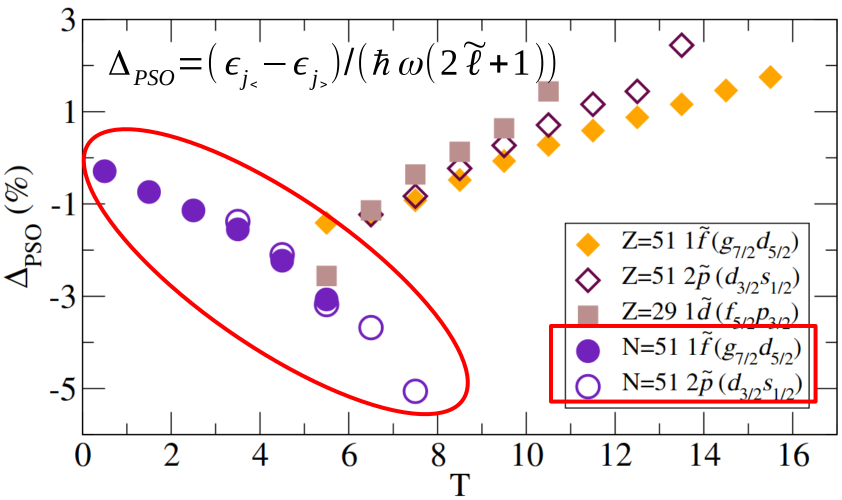

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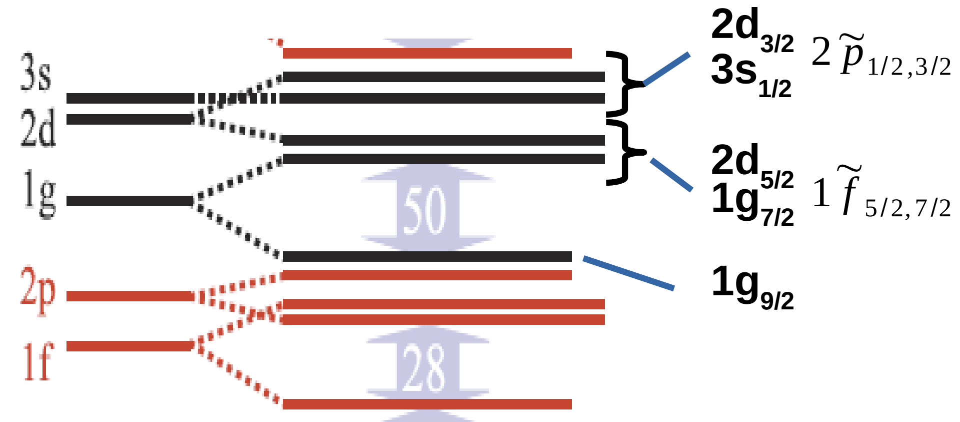

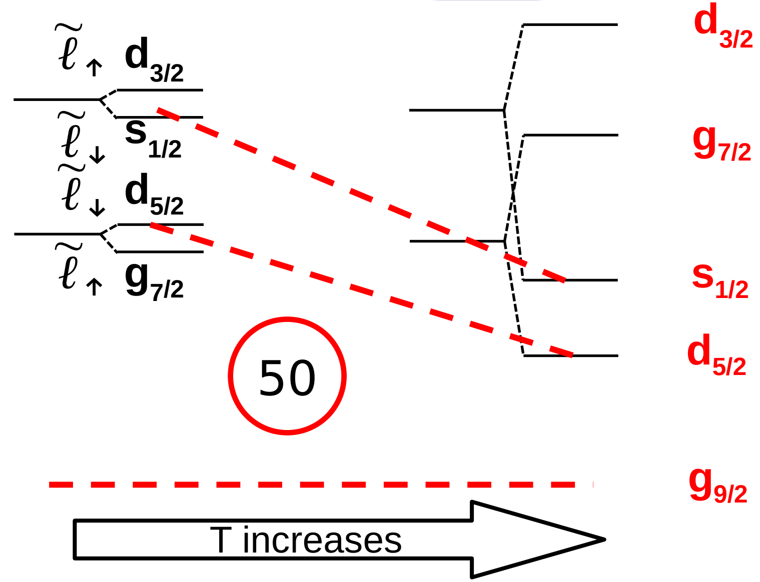

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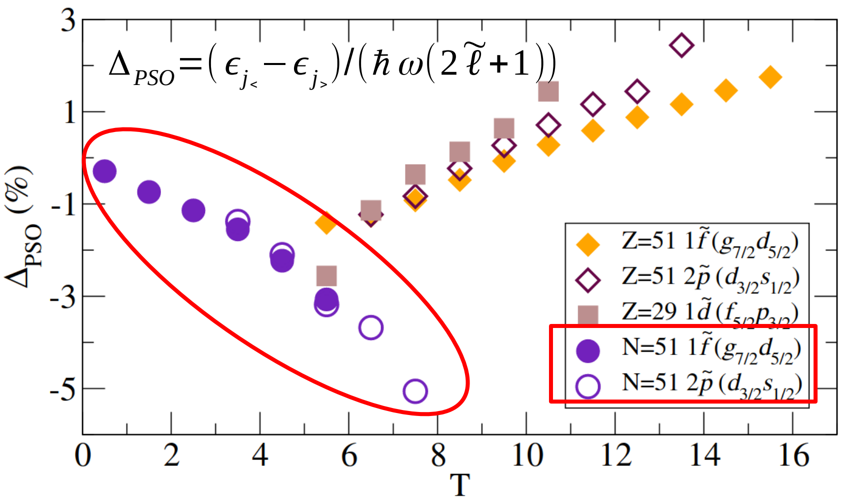

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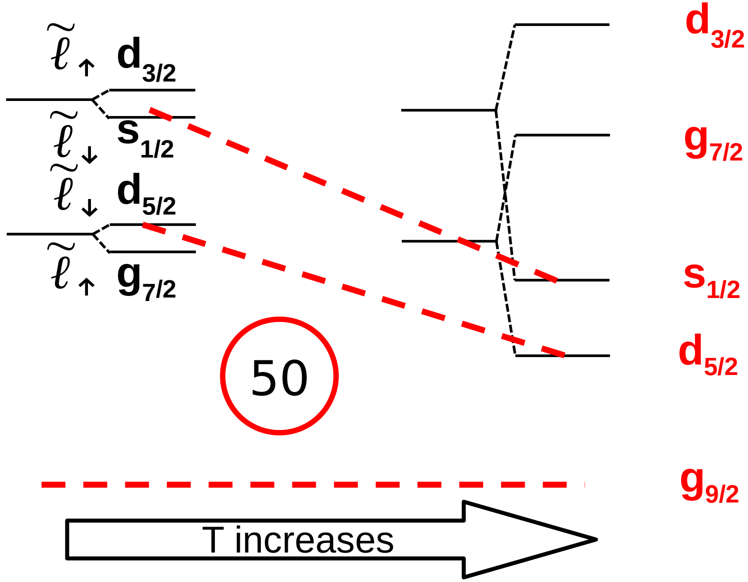
PSS explains :

- The progressive closure of N=50 shell gap (down to ^{82}Ge)
- The lowering of $s_{1/2}$ orbital energy (related to the faster decrease of 5^+ state energy)
- The fact that $g_{7/2}$ orbital energy is not decreasing



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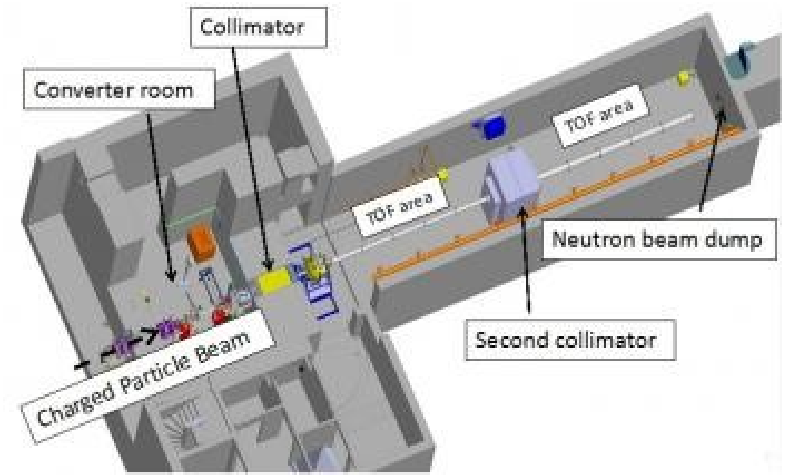
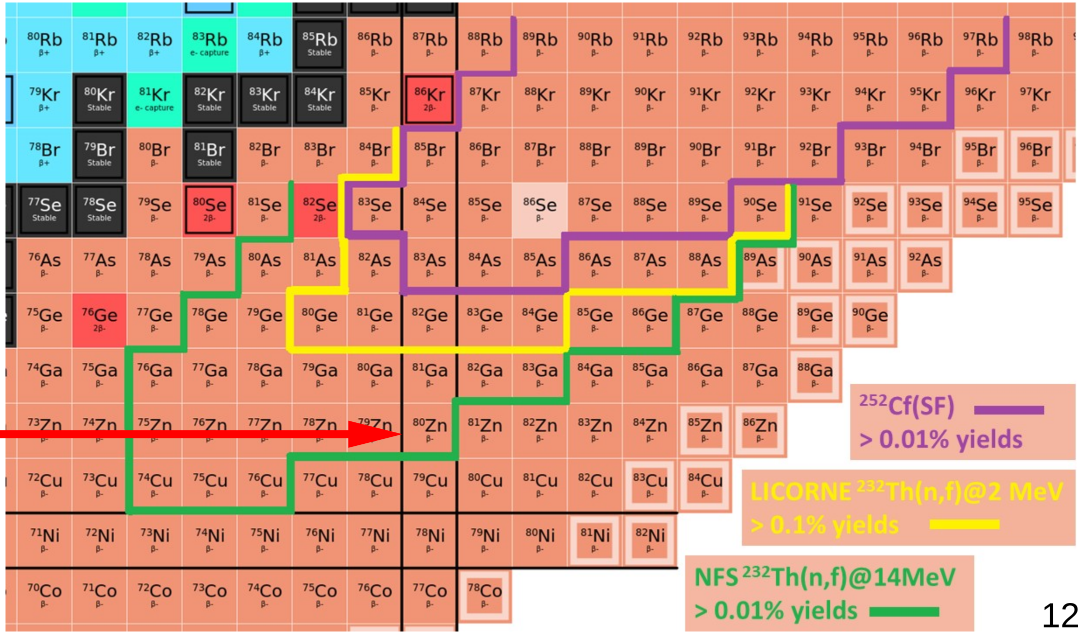
In the future ?



Fission of ^{232}Th at NFS (See talk of J. Wilson)

- EXOGAM array
- ~8 g of pure ^{232}Th target
- « white » neutron spectrum from NFS



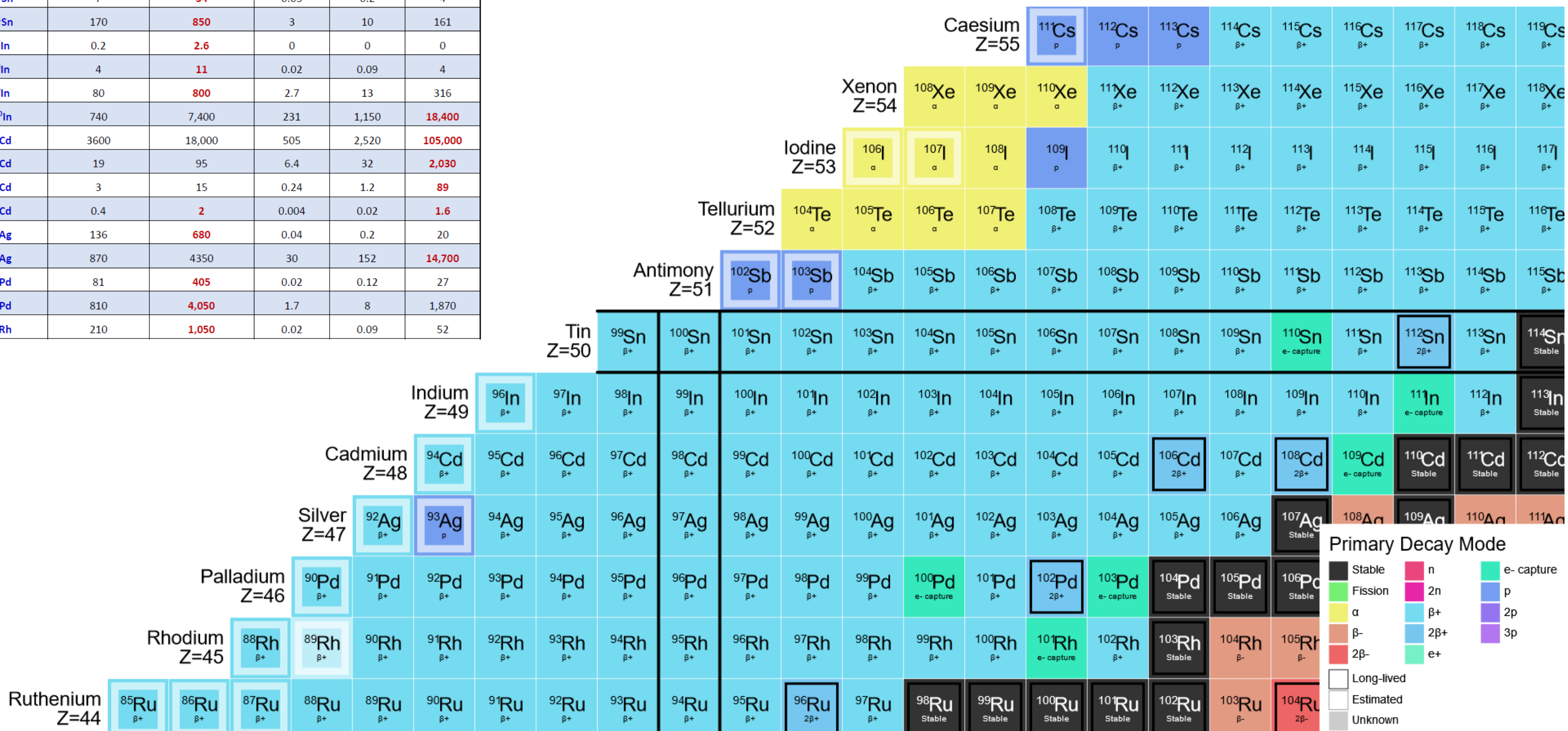
Spectroscopy of ^{80}Zn

- Measure of 5,6,7^{+} states energy
- Prediction of the energy of 7^{+} state from simple model and ν-Ball data : 4008(169) keV

In the future ?

Study the evolution of the single particle orbits along N=50 on **the other side of the valley of stability**

Intensities [pps]	S^3 LEB (A/q=3)	S^3 LEB (A/q=7)	FRIB1	FRIB2	FRIB Final
^{100}Sn	7	34	0.05	0.2	4
^{101}Sn	170	850	3	10	161
^{97}In	0.2	2.6	0	0	0
^{98}In	4	11	0.02	0.09	4
^{99}In	80	800	2.7	13	316
^{100}In	740	7,400	231	1,150	18,400
^{98}Cd	3600	18,000	505	2,520	105,000
^{97}Cd	19	95	6.4	32	2,030
^{96}Cd	3	15	0.24	1.2	89
^{95}Cd	0.4	2	0.004	0.02	1.6
^{94}Ag	136	680	0.04	0.2	20
^{95}Ag	870	4350	30	152	14,700
^{91}Pd	81	405	0.02	0.12	27
^{92}Pd	810	4,050	1.7	8	1,870
^{90}Rh	210	1,050	0.02	0.09	52



In the future ?

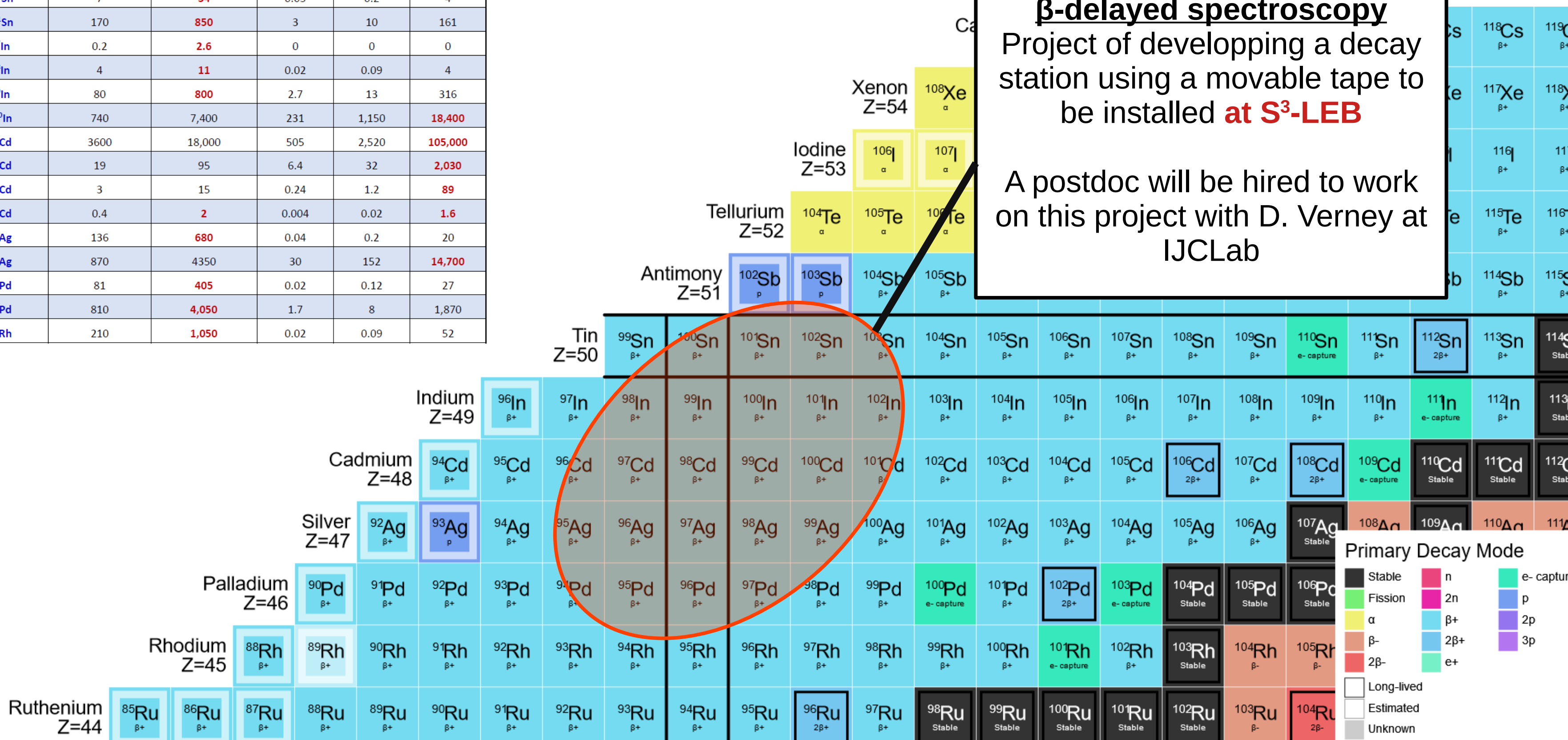
Study the evolution of the single particle orbits along N=50 on **the other side of the valley of stability**

Intensities [pps]	S^3 LEB (A/q=3)	S^3 LEB (A/q=7)	FRIB1	FRIB2	FRIB Final
^{100}Sn	7	34	0.05	0.2	4
^{101}Sn	170	850	3	10	161
^{97}In	0.2	2.6	0	0	0
^{98}In	4	11	0.02	0.09	4
^{99}In	80	800	2.7	13	316
^{100}In	740	7,400	231	1,150	18,400
^{98}Cd	3600	18,000	505	2,520	105,000
^{97}Cd	19	95	6.4	32	2,030
^{96}Cd	3	15	0.24	1.2	89
^{95}Cd	0.4	2	0.004	0.02	1.6
^{94}Ag	136	680	0.04	0.2	20
^{95}Ag	870	4350	30	152	14,700
^{91}Pd	81	405	0.02	0.12	27
^{92}Pd	810	4,050	1.7	8	1,870
^{90}Rh	210	1,050	0.02	0.09	52

<u>β-delayed spectroscopy</u>

Project of developping a decay station using a movable tape to be installed **at S^3-LEB**

A postdoc will be hired to work on this project with D. Verney at IJCLab



The ν-Ball (N-SI-109) collaboration

D. Thisse[1,a], M. Lebois[1,2], D. Verney[1], J. N. Wilson[1], N. Jovančević[3], M. Rudigier[4,5], R. Canavan[4,6], D. Etasse[7], P. Adsley[1], A. Algora[9], M. Babo[1], K. Belvedere[4], J. Benito[10], G. Benzoni[11], A. Blazhev[12], A. Boso[6], S. Bottoni[11,13], M. Bunce[6], R. Chakma[1], N. Cieplicka-Oryńczak[14], S. Courtin[15,16], M. L. Cortés[17], P. Davies[18], C. Delafosse[1], M. Fallot[19], B. Fornal[14], L. Fraile[10], D. Gjestvang[20], A. Gottardo[21], V. Guadilla[9], R.-B. Gerst[12], G. Häfner[1,12], K. Hauschild[1], M. Heine[15], C. Henrich[5], I. Homm[5], J. Hommet[7], F. Ibrahim[1], Ł. W. Iskra[11,14], P. Ivanov[6], S. Jazrawi[4,6], A. Korgul[8], P. Koseoglou[5,22], T. Kröll[5], T. Kurtukian-Nieto[23], L. Le Meur[19], S. Leoni[11,13], J. Ljungvall[1], A. Lopez-Martens[1], R. Lozeva[1], I. Matea[1], K. Miernik[8], J. Nemer[1], S. Oberstedt[24], W. Paulsen[20], M. Piersa-Silkowska[8], W. Poklepa[8], Y. Popovitch[1], C. Porzio[11,13,25], L. Qi[1], D. Ralet[26], P. H. Regan[4,6], D. Reygadas-Tello[27], K. Rezynkina[28], V. Sánchez-Tembleque[10], S. Siem[20], C. Schmitt[15], P.-A. Söderström[5,29], K. Solak[8], C. Sürder[5], G. Tocabens[1], V. Vedia[10], N. Warr[12], B. Wasilewska[14], J. Wiederhold[5], M. Yavahchova[30], F. Zeiser[20], S. Ziliani[11,13]

Thank you for your attention !