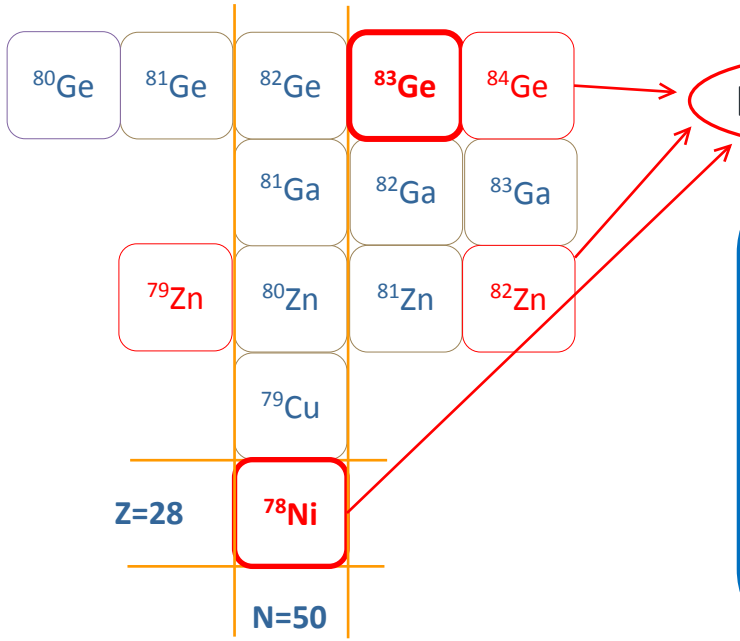
Intruder states in ^{83}Ge studied by neutron knockout @ RIBF-RIKEN

LÉO PLAGNOL

POST-DOC, IJCLAB

Magicity of ^{78}Ni : aiming for ^{83}Ge



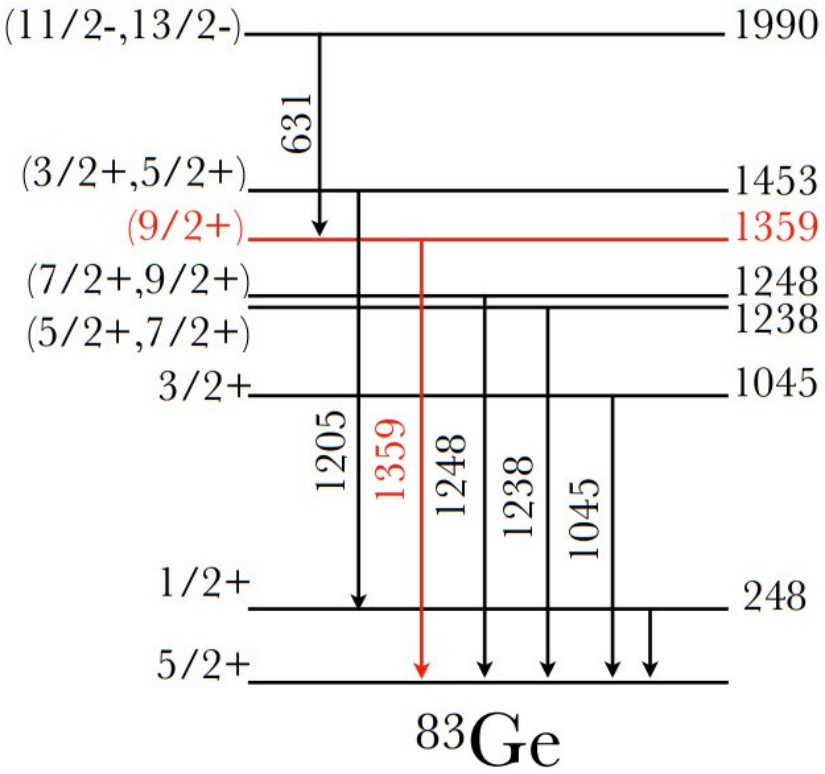
Deformed ?

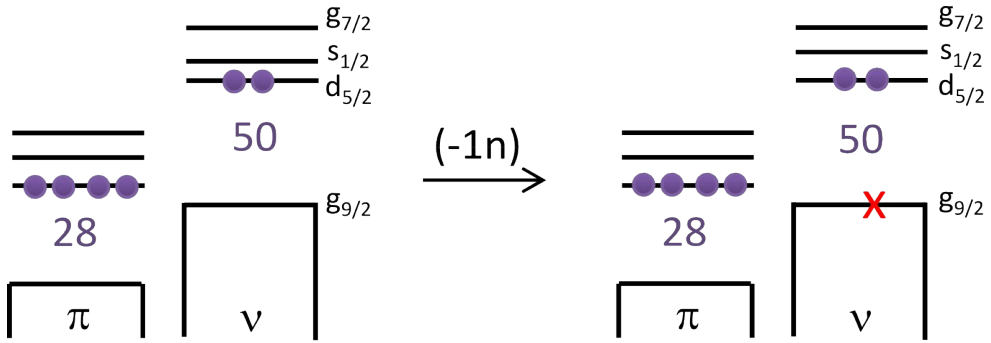
Goals of the experiment on ^{83}Ge

- From β-spectroscopy & plunger (C. Delafosse, 2018)
  → Intruder candidate 2p-1h @1359 keV
  (**log(ft)**, $T_{1/2}=74^{+73}_{-67}$ ps)

Our reaction : neutron knockout from N=52

- Selective population of $9/2^+$ intruder state
- Measure $T_{1/2}$ & $P_{//}$ → orbital **L**





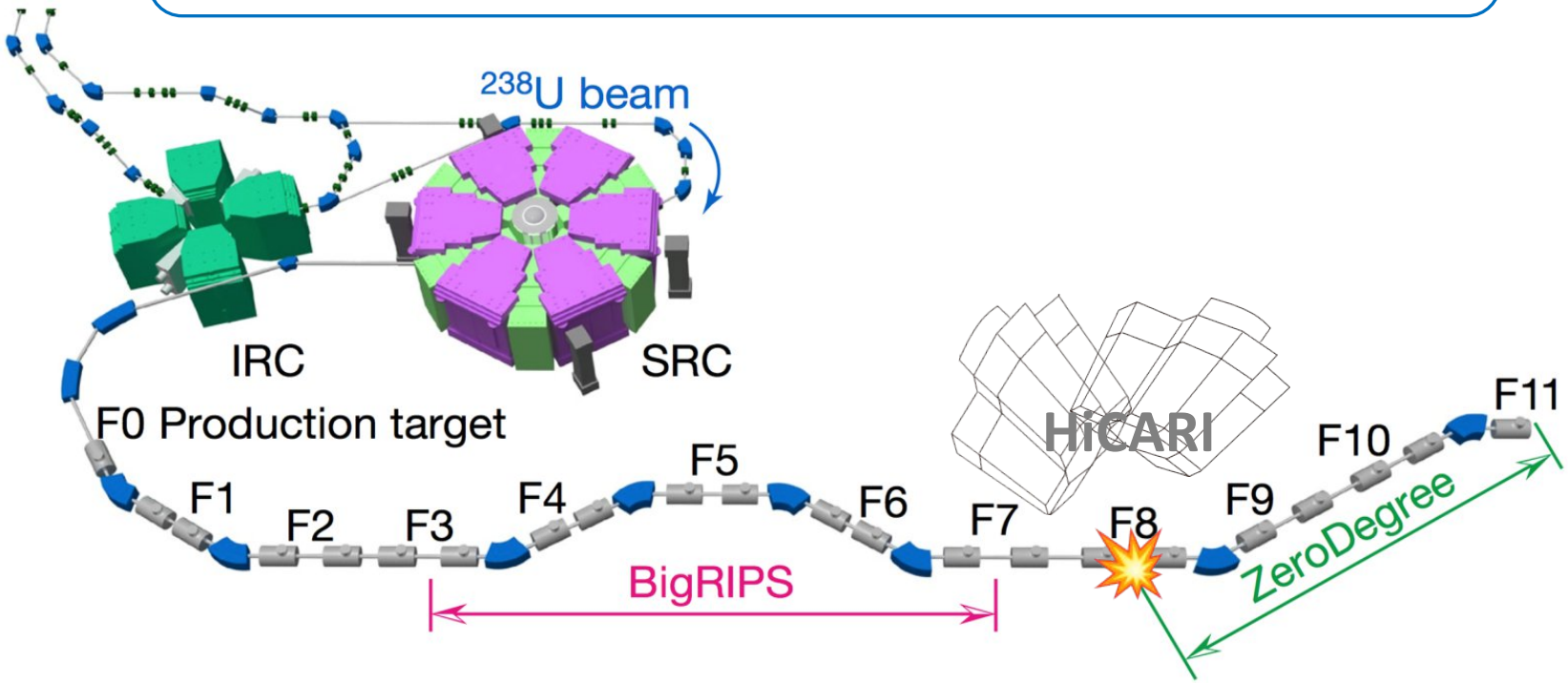
^{84}Ge (gs)

^{83}Ge : $9/2^+$ (2p-1h) intruder

Setup : HiCARI @ RIBF-RIKEN

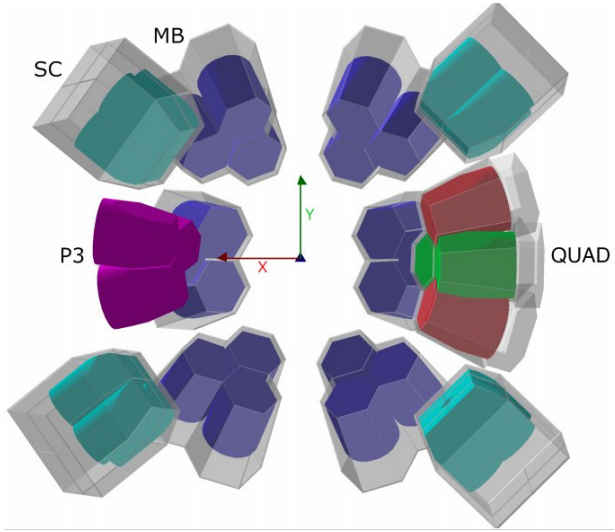
In-flight method @ RIBF

- In-flight fission of ^{238}U
- Cocktail beam spectrometer : **BigRIPS**
- Secondary target : 6mm Beryllium
- Reaction products spectrometer : **ZeroDegree**



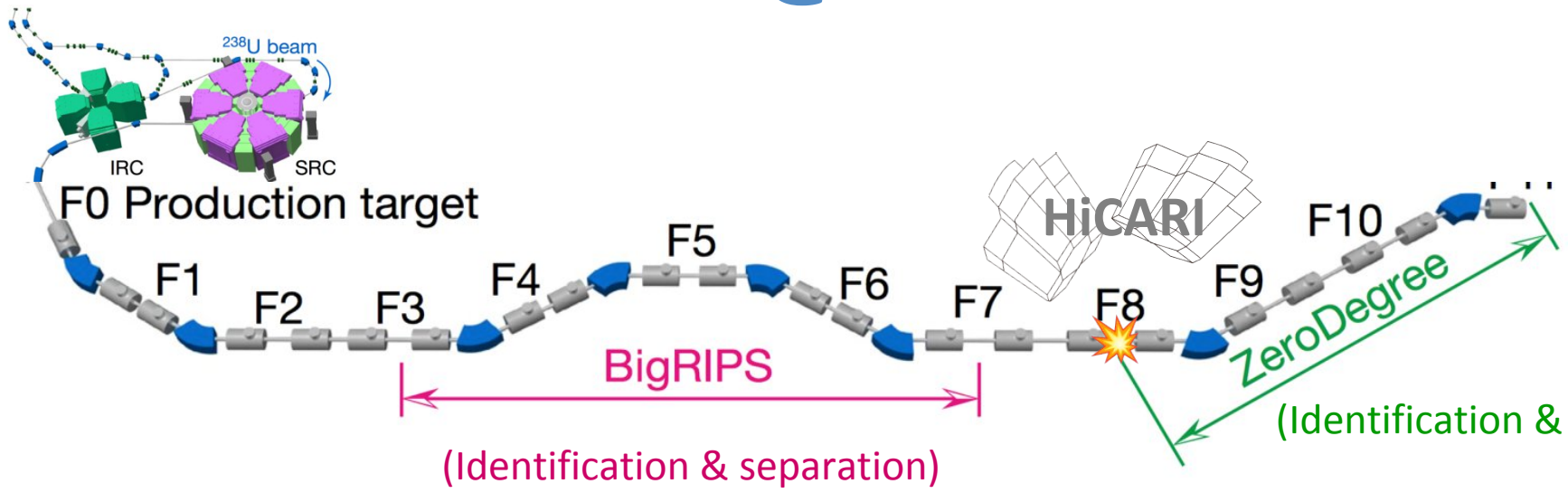
HiCARI

γ-rays emitted in flight



- 12 HPGe
- of which 2 highly segmented (36 segments)

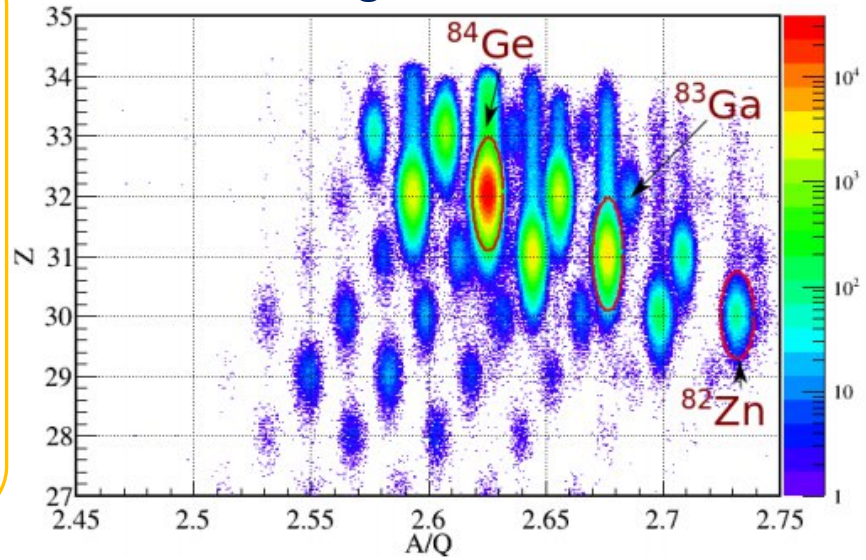
Beam identification @ RIBF



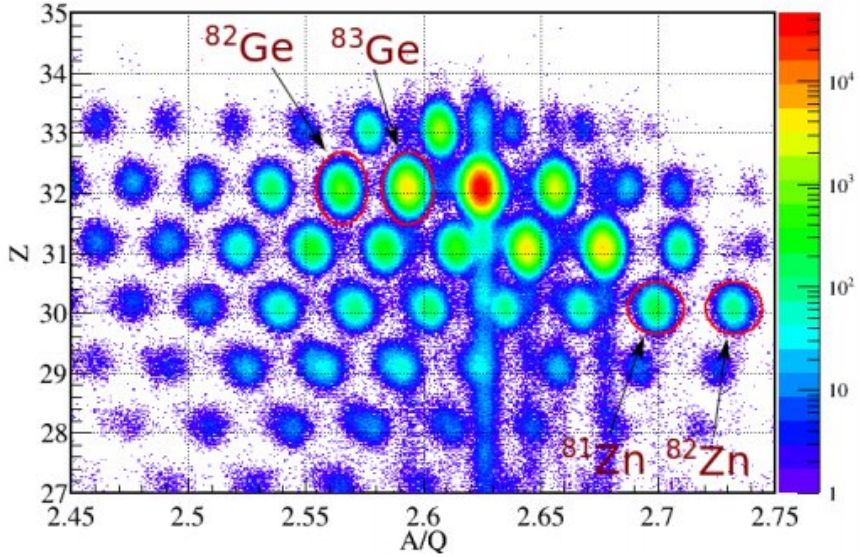
- 26 PPAC → trajectory
- 4 plastic scintillators
  → TOF (β)
- 2 ionisation chambers
  → ΔE

→ **Bρ, β** → **Z, A/Q**

BigRIPS PID

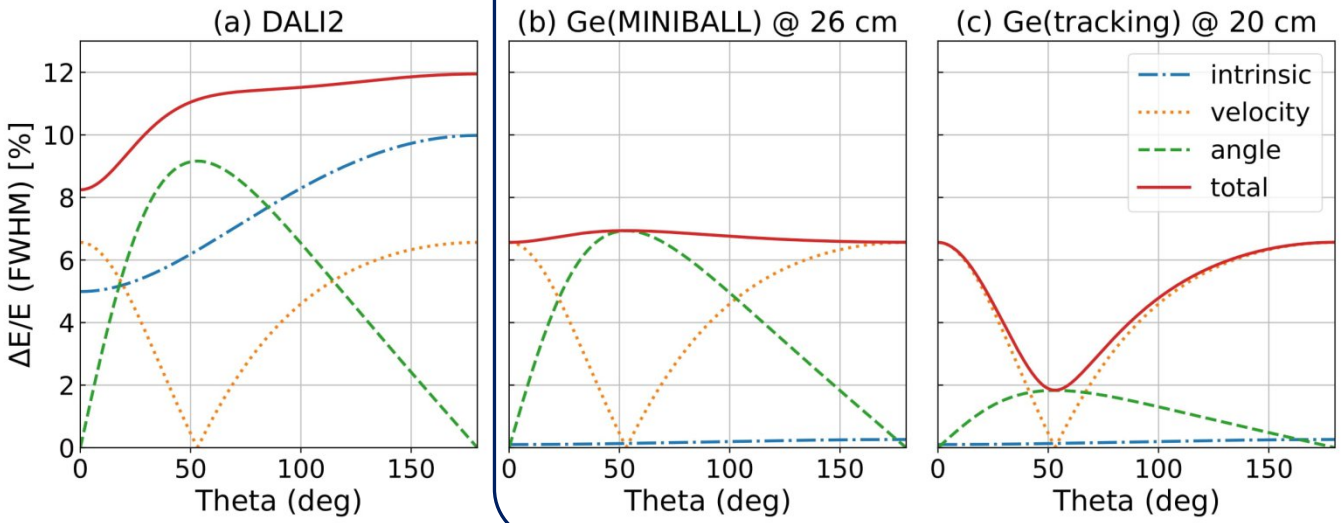


ZeroDegree PID



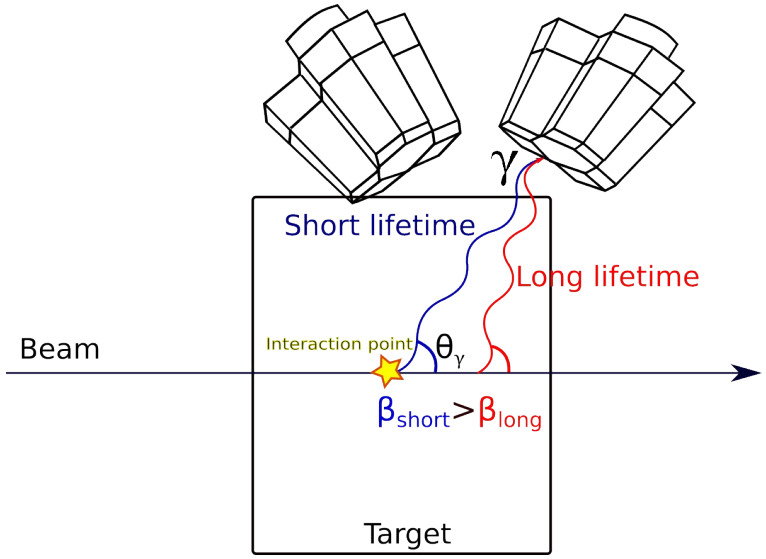
Gamma spectroscopy with HiCARI

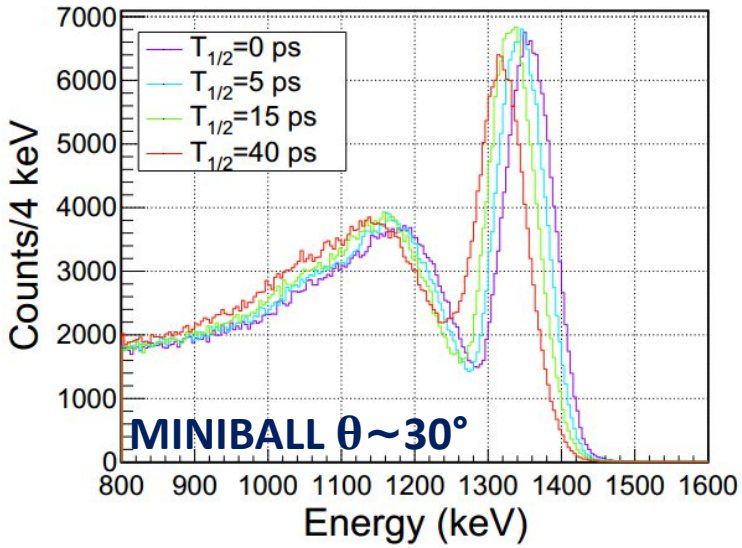
In flight resolution

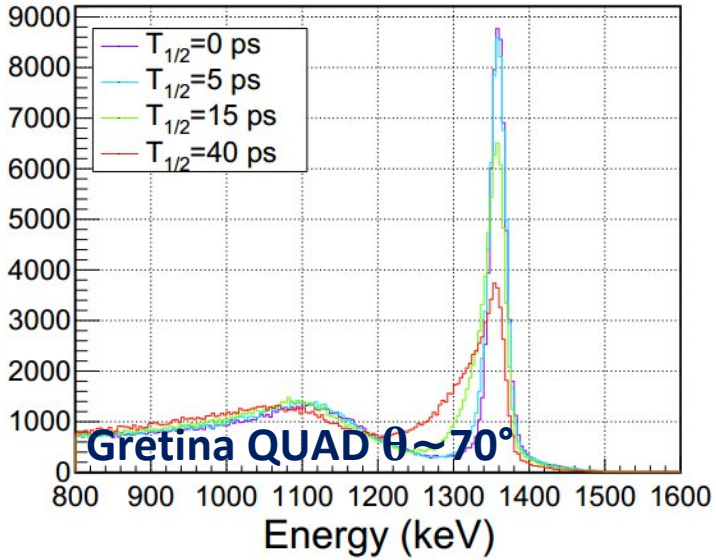


Gammas in flight (β=0.6)

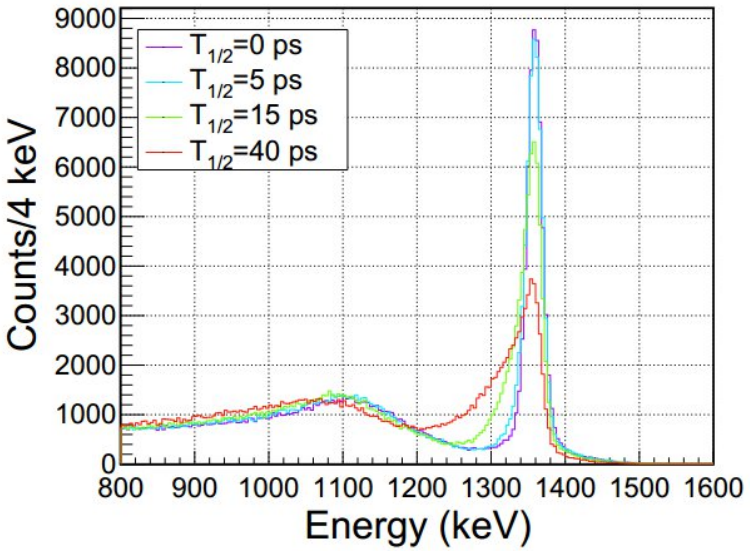
$$E_0 = E_{lab}\frac{1-\beta\cos\theta_\gamma}{\sqrt{1-\beta^2}}$$







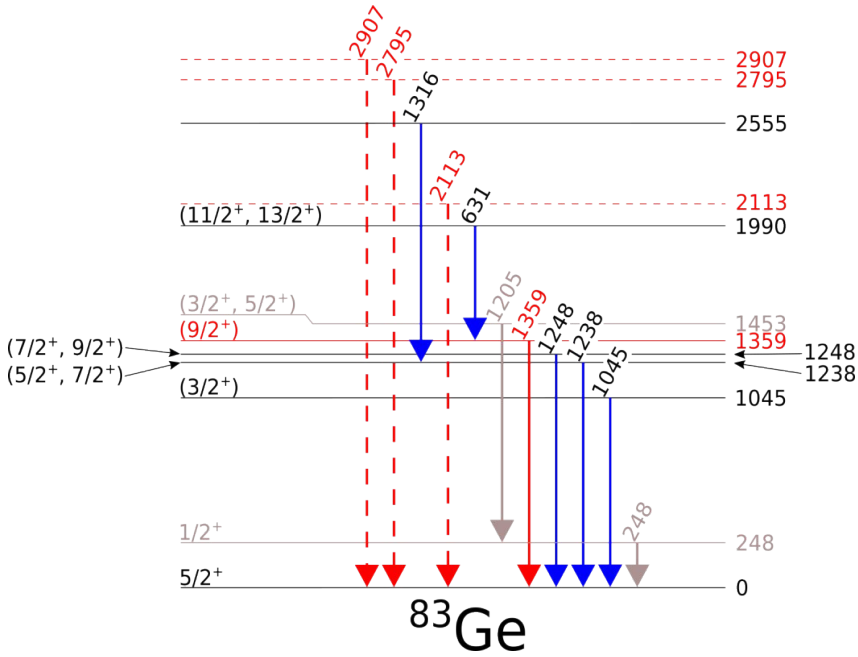
Results : spectrum fitting

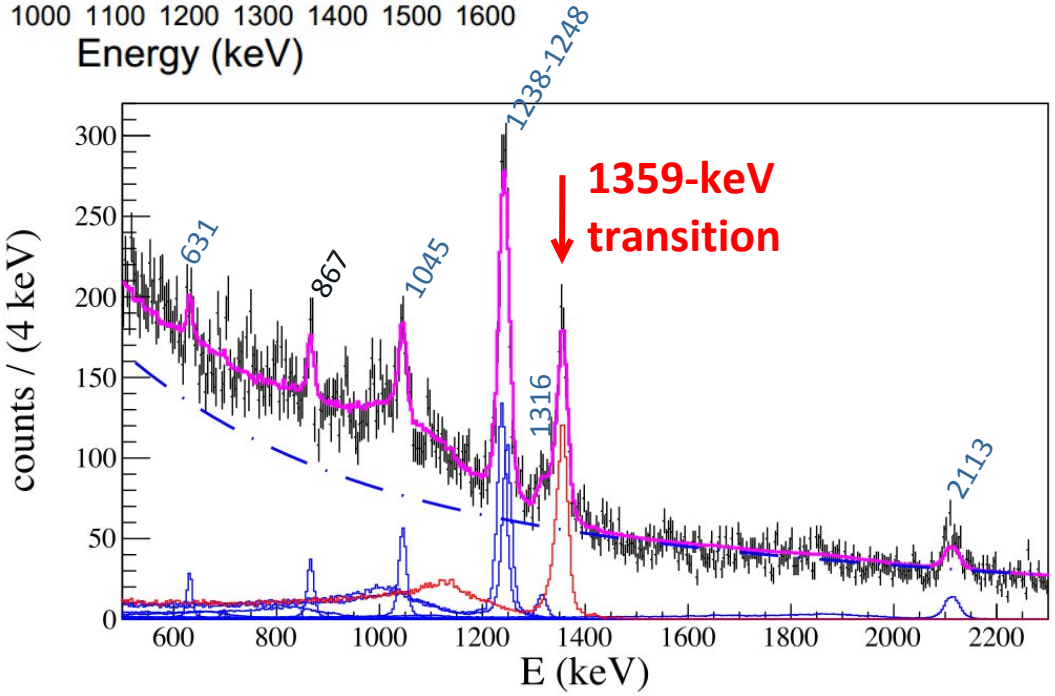


Simulation tuning

Unknowns :

- Target position :
  - ➢ tuned to match β-decay energies
- Average tracking resolution :
  - ➢ tuned to minimise χ^2

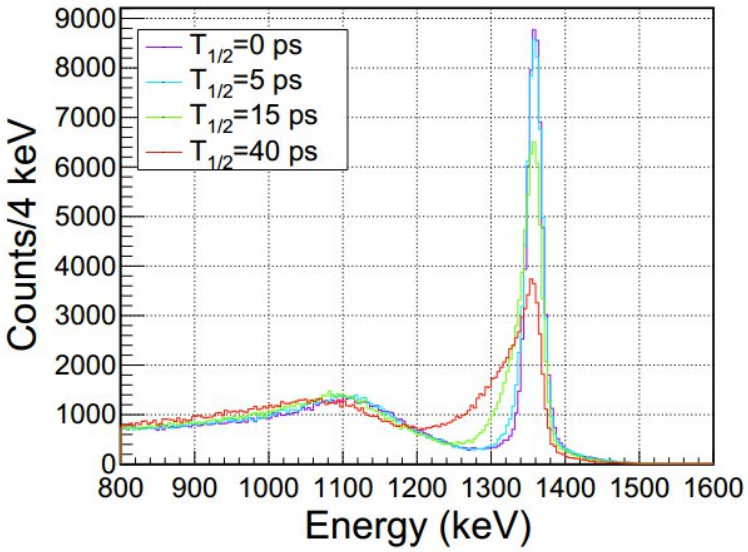


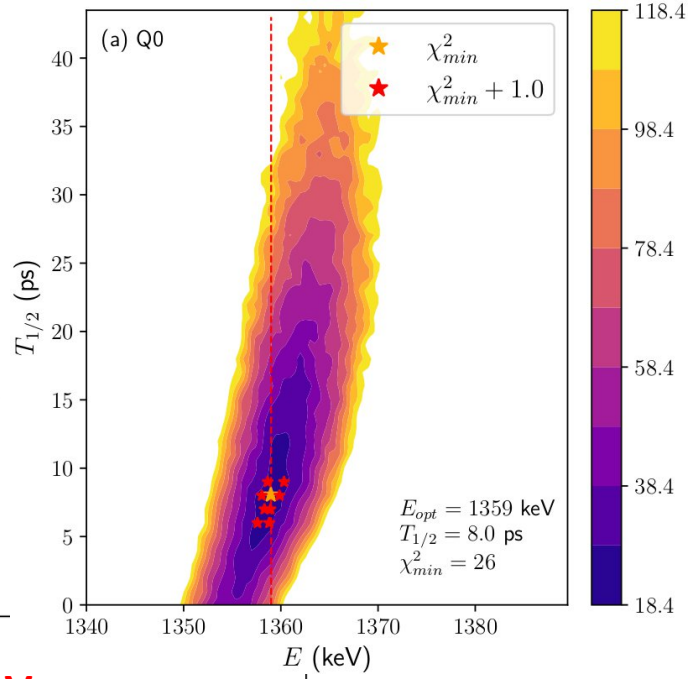


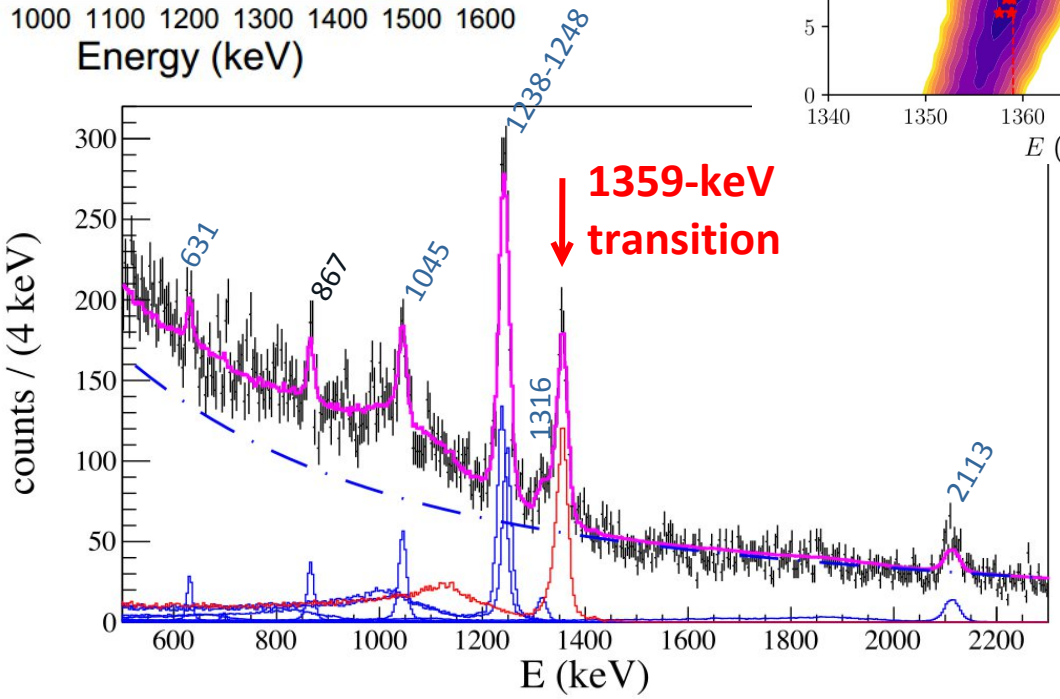
Spectrum analysis

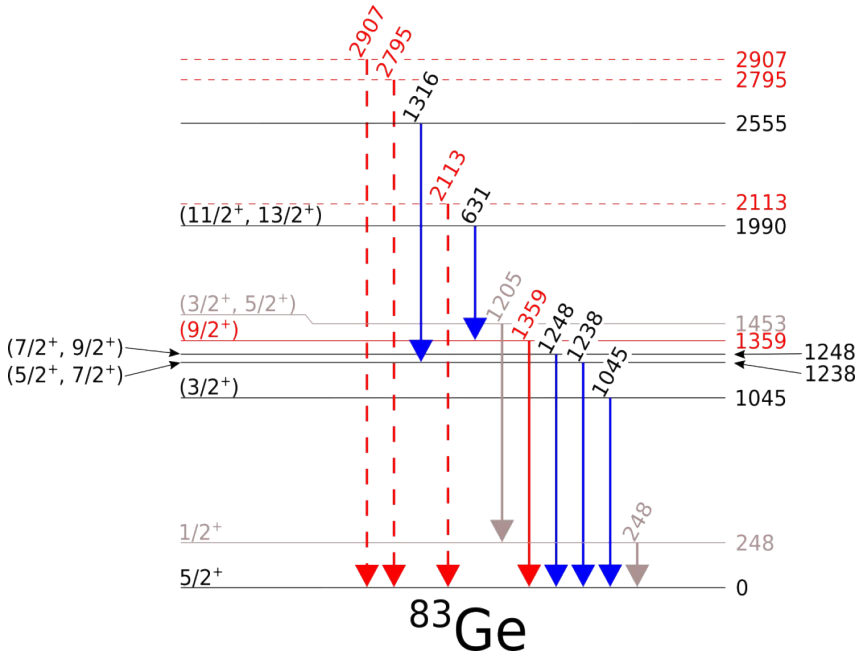
- Spectra fit with simulations
- $T_{1/2}$ & transition energy varied
- Energy : measured *via* β-decay

Results : half-life measurement









Spectrum analysis

- Spectra fit with simulations
- $T_{1/2}$ transition energy varied
  → χ^2 matrix with an optimum
- Energy : measured *via* β-decay

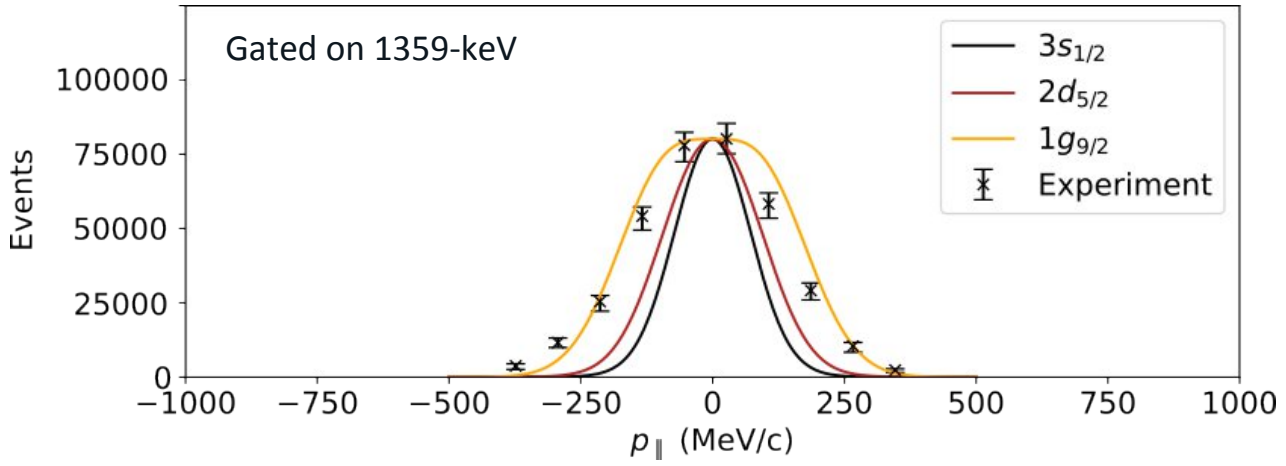
→ $T_{1/2}$ ~ 8(2) ps

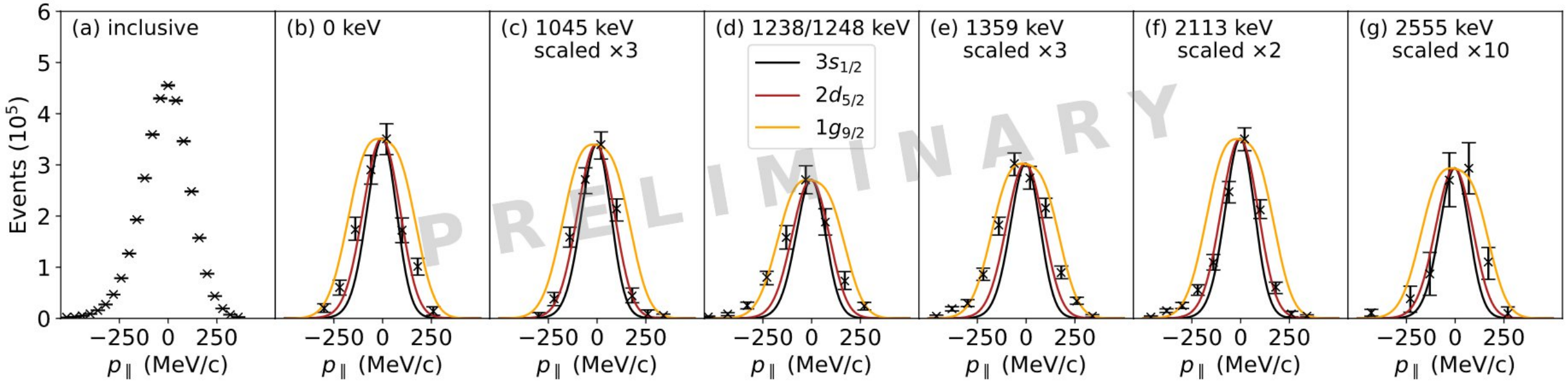
Results : identification of $g_{9/2}$ intruder state

Momentum distribution analysis

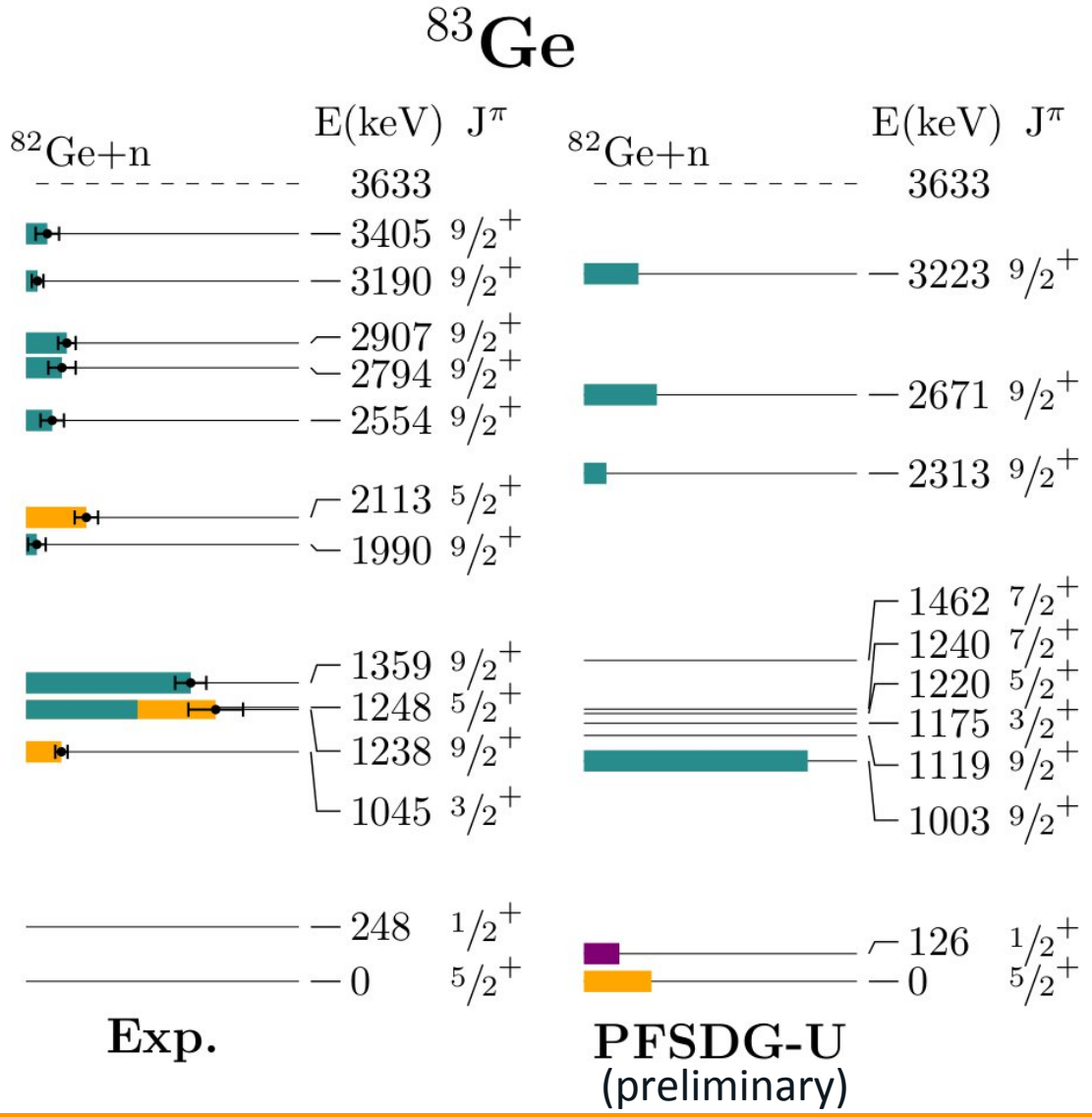
- Parallel momentum measured in ZDS
- Calculated distribution ⊗ experimental uncertainties
- Fits for different knocked out neutron's **L**

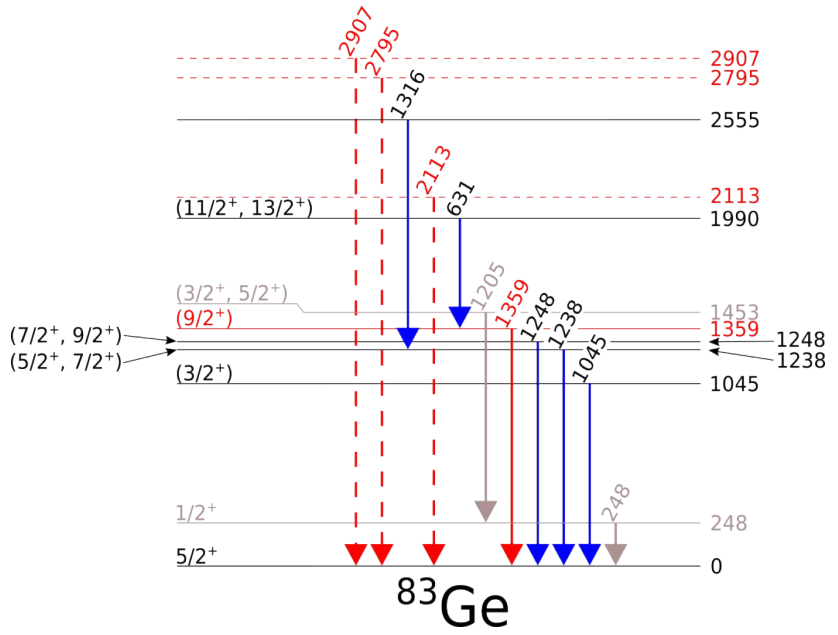
→ Agreement with a L=4 neutron





Comparison with shell model





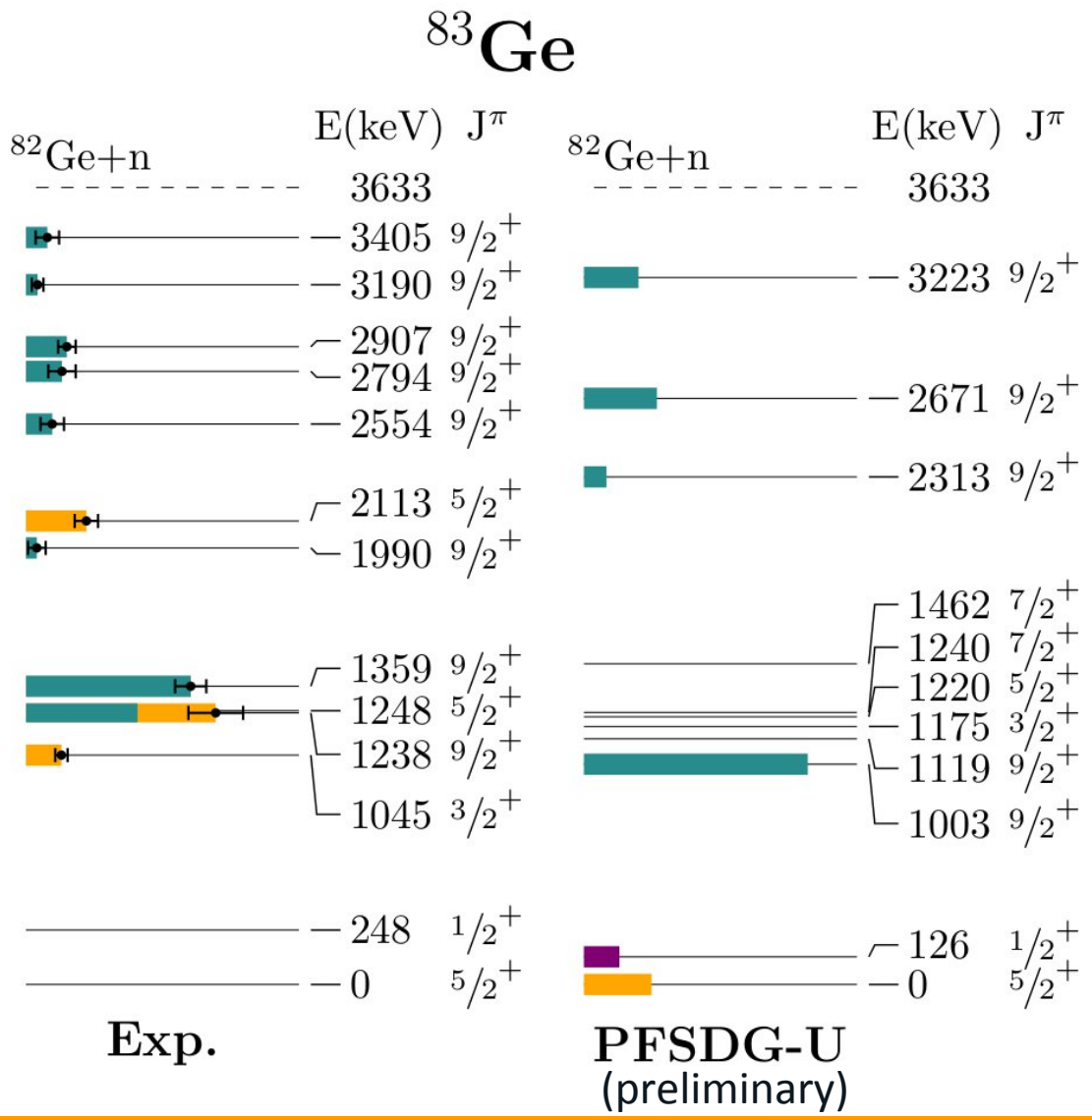
LSSM calculations

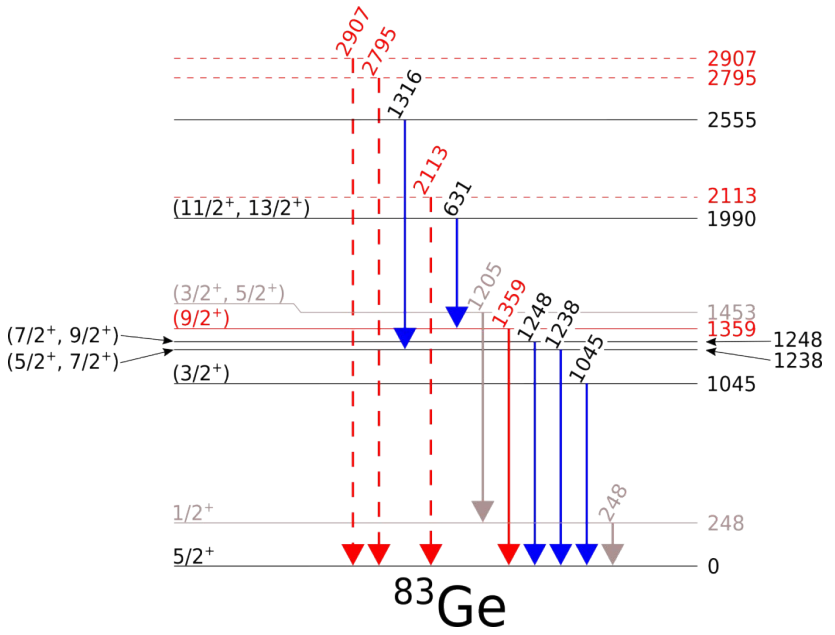
(credit to F. Nowacki)

- ^{60}Ca Core with extended valence space
- 9/2$^+$ state with 20 ps half life @ 1 MeV
  - ➢ 2p-1h intruder

			Neutrons				
Nucleus	E(keV)	J$^\pi$	$1g_{9/2}$	$2d_{5/2}$	$3s_{1/2}$	$1g_{7/2}$	$2d_{3/2}$
^{84}Ge	0	0$^+$	9.41	1.55	0.62	0.28	0.14
^{83}Ge	1004	9/2$^+$	**8.44**	1.45	0.67	0.26	0.18

Comparison with shell model





LSSM calculations

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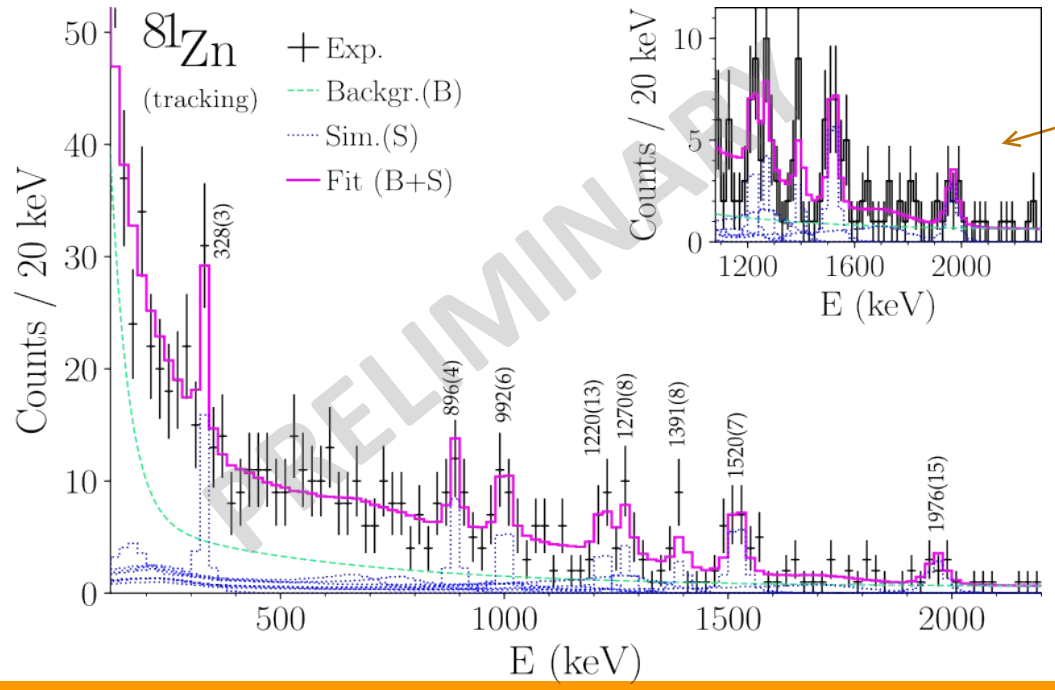
- ^{60}Ca Core with extended valence space
- 9/2$^+$ state with 20 ps half life @ 1 MeV
  - ➢ 2p-1h intruder
- **Questions remain** :
  - $g_{9/2}$ strength more fragmented in data
  - $d_{5/2}$ strength between 1 MeV & 2 MeV

Conclusions and perspectives

Conclusion : shape coexistence in ^{83}Ge

- Half-life 1359-keV ≫ others
  → déformation (⟨ | EM | ⟩)
- L = 4 → $9/2^+$ 2p-1h state

Competition between fondamental and deformed state @ 1359-keV



Perspective on ^{83}Ge

- Strong transition @ 1238-1248 keV
  → Why populated by knockout
- Higher energy (~ 3 MeV) states

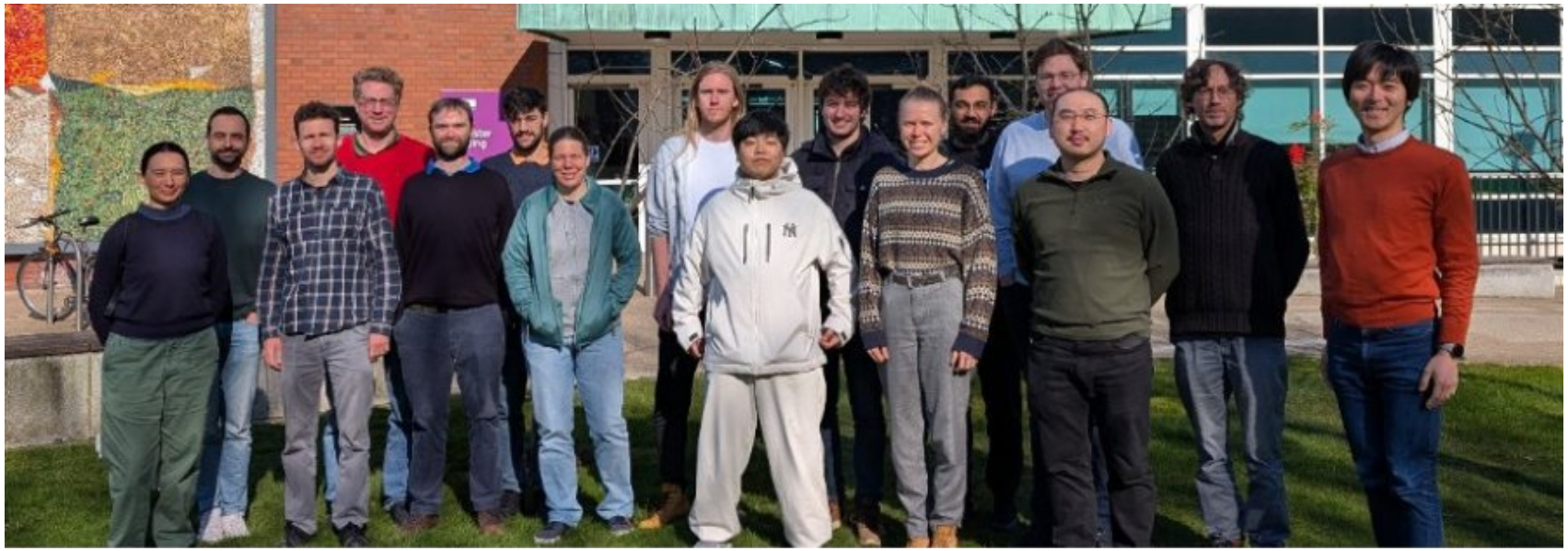
Other channels :

- ^{81}Zn :
  - Next N=51 nucleus leading to ^{79}Ni
  - Bunch of transitions but low statistics

  7 unknown transitions in the fit + 1 already known
  - Largest transition @ 1520 keV
    → $9/2^+$ state decay ?
- ^{84}Ge inelastic : possible lifetime measurements as a complement to dedicated experiments

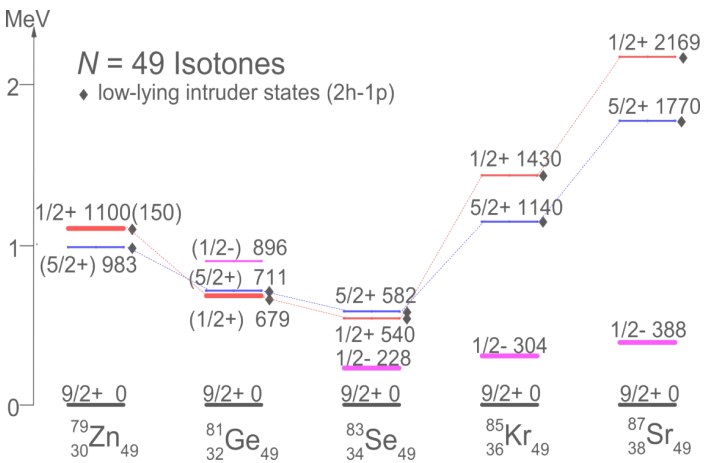
Acknowledgement

Thanks to all our collaborators :
F. Flavigny, T. Beck, F. Nowacki, D. Verney, J. A. Tostevin, P. Doornenbal , K. Wimmer , J. Acosta , A. Jungclaus, M. Górska , Zs. Podolyák, N. Aoi , M. Armstrong ,, H. Baba , F. Browne , C. Campbell , H. Crawford , H. de Witte , C. Fransen , H. Hess, E. Ideguchi , S. Iwazaki , J. Kim, A. Kohda, T. Koiwai, B. Mauss , R. Mizuno , B. Moon , M. Niikura , R. Orlandi , T. Parry , P. Reiter , H. Sakurai , D. Suzuki , R. Taniuchi , S. Thiel, and Y. Yamamoto

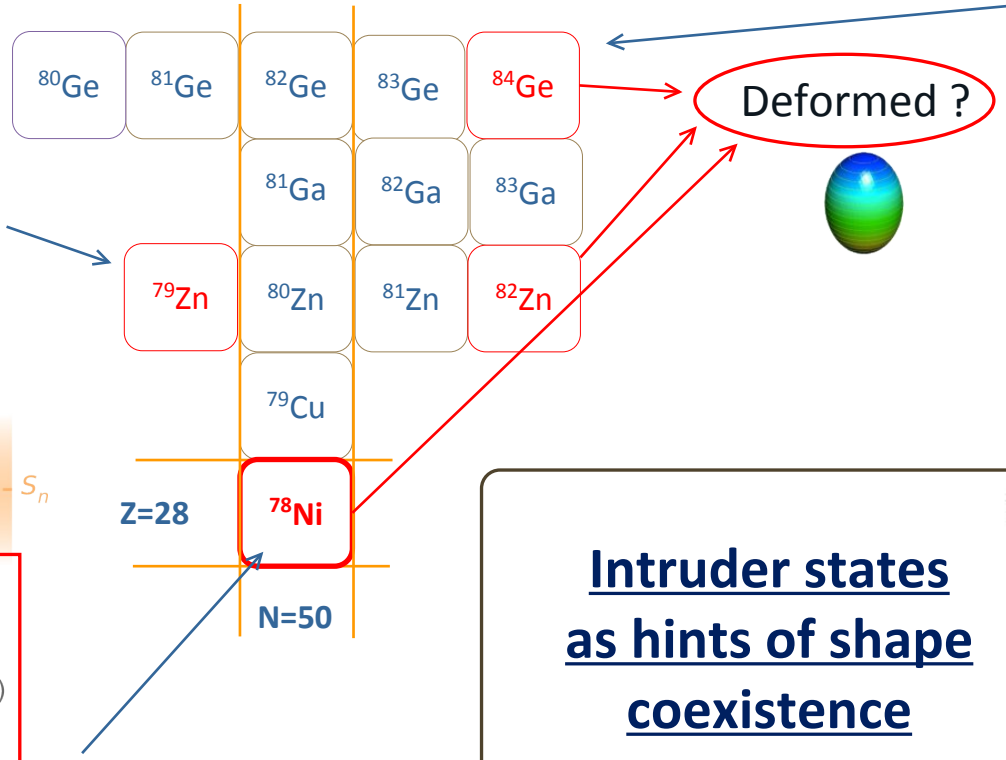


Backup

Shape coexistence in the region of ^{78}Ni



[Yang et al., PRL 116 182502 (2016)]



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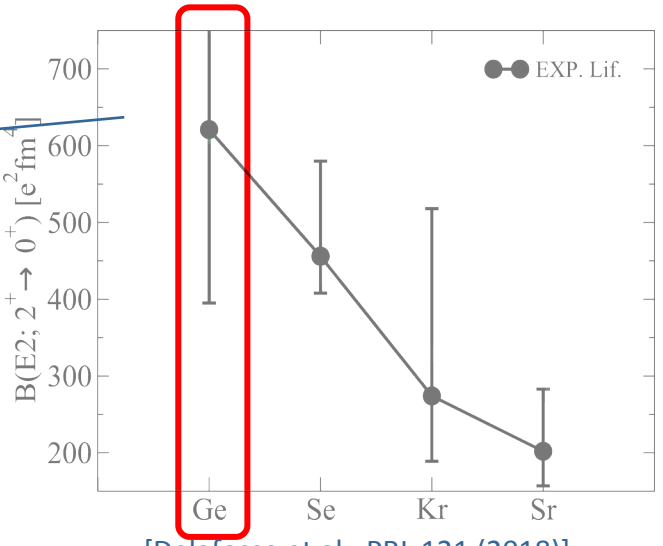
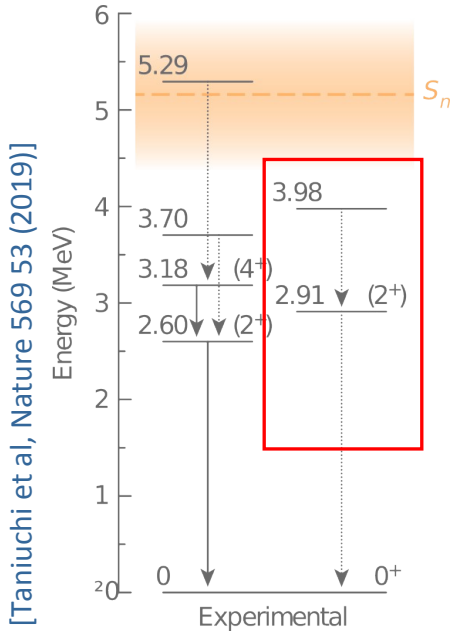
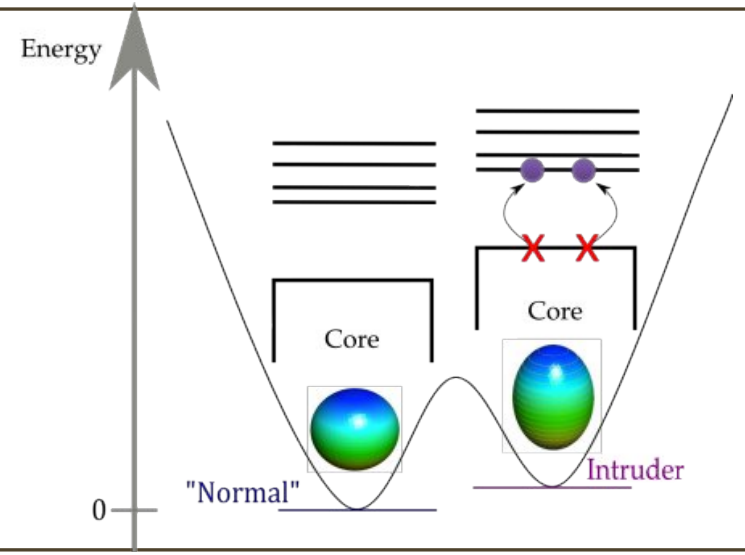


[Delafosse et al., PRL 121 (2018)]

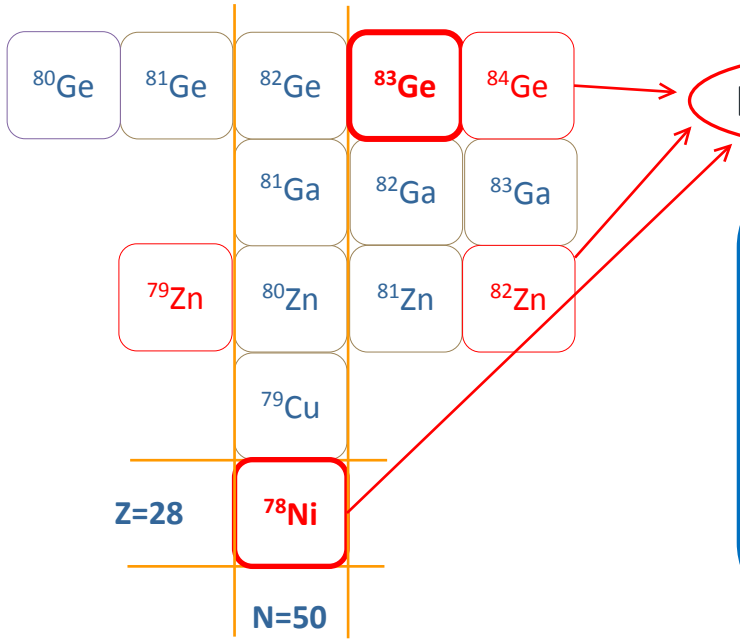


Intruder states as hints of shape coexistence

Particle-hole excitations (p-h) @ low energy



Magicity of ^{78}Ni : intruders in the region



Deformed ?

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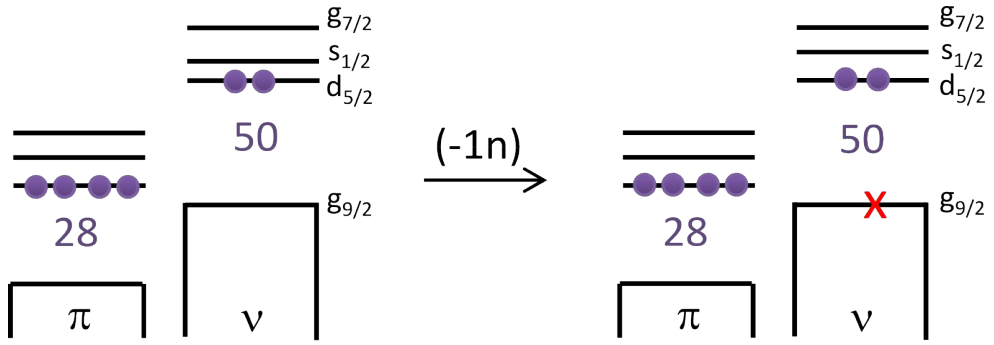
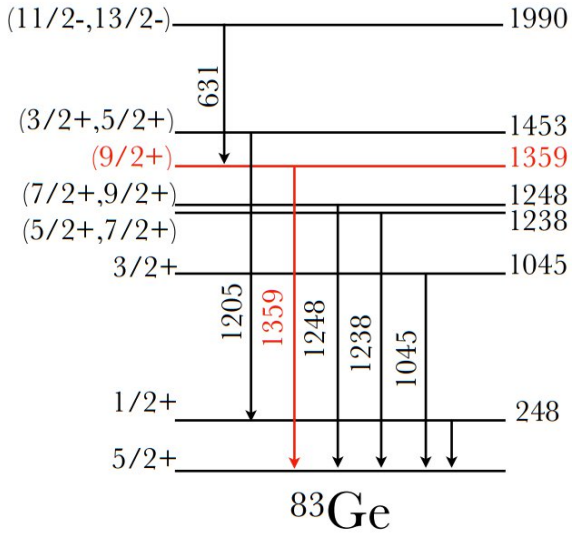


^{84}Ge (gs)

^{83}Ge : $9/2^+$ (2p-1h) intruder



Abundant literature on the subject

N=50 & below :

- ^{78}Ni : 2nd bande deformed
  [Taniuchi et al, Nature 569 53 (2019)]
- ^{79}Zn : Laser + reactions + masses :
  - ➢ Deformed isomer
    [Yang et al., PRL 116 182502 (2016)]
    [Anh et al. PRC 100 044613 (2019)]
    [Nies et al., PRL 131 222503 (2023)]

Beyond N=50 :

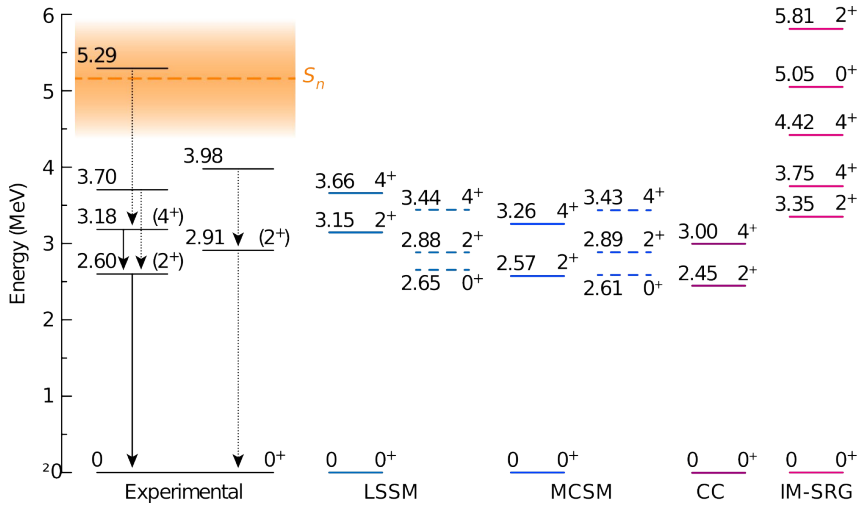
- ^{84}Ge : Collectivity
  [Delafosse et al., PRL 121 (2018)]
- ^{82}Zn : 2nd 0^+ deformed
  [Shand et al., Phys. Let. B (2017)]

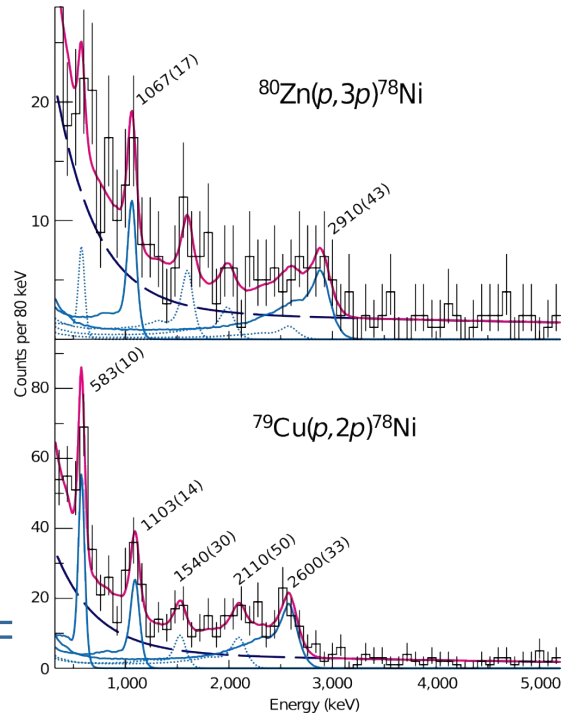
Others :

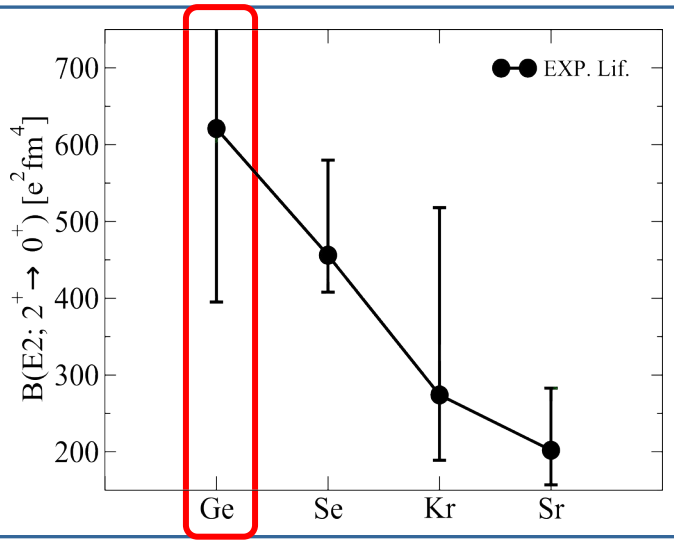
- ^{85,87}As : Deformation
  [Rezynkina et al., PRC 106 (2022)]
- ^{81}Ga : intruder 1p-1h
  [Dudouet et al., PRC 100 (2019)]

Close to ^{78}Ni

Dans le ^{78}Ni

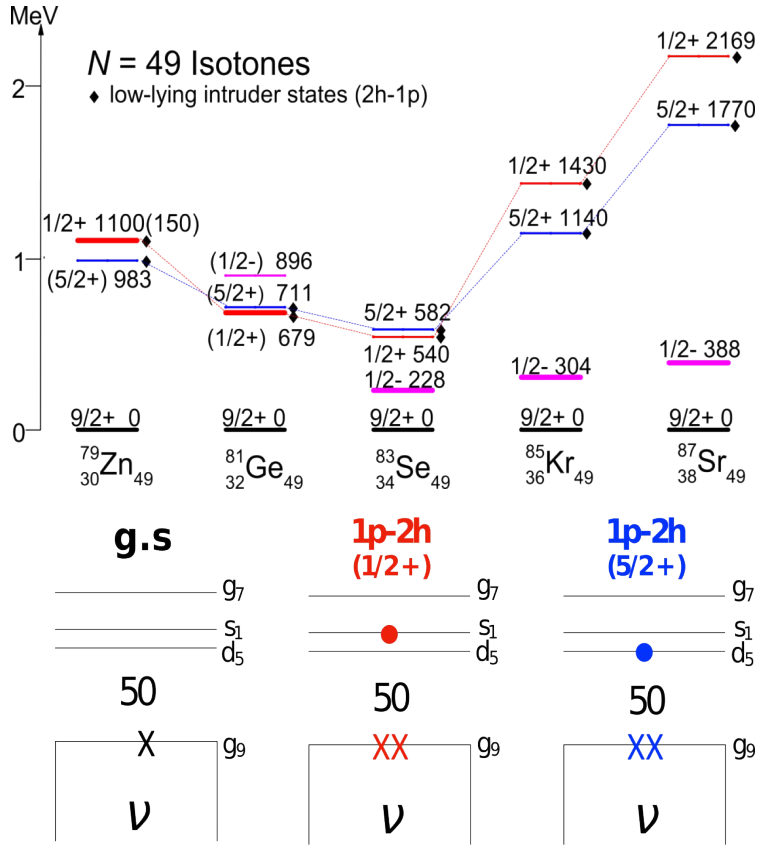






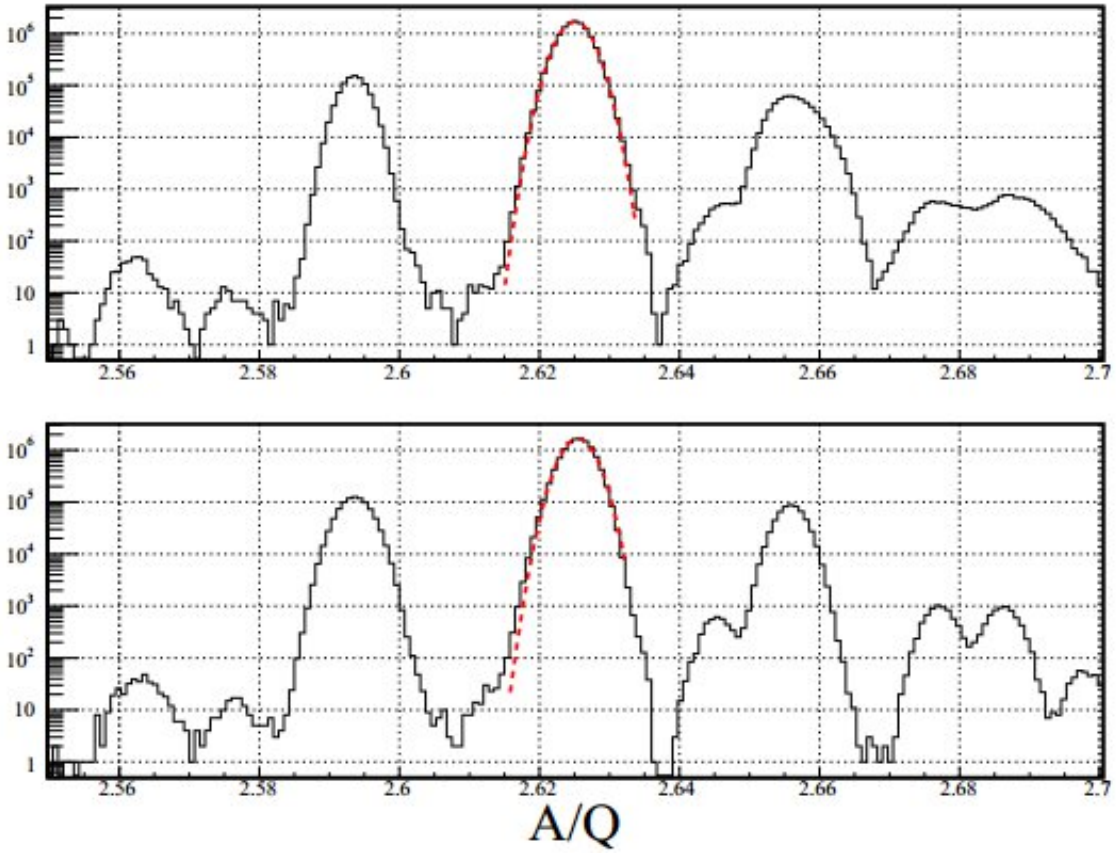
N=52 systematics
$T_{1/2}(2^+) \rightarrow {}^{84}$Ge
collective ?

^{79}Zn



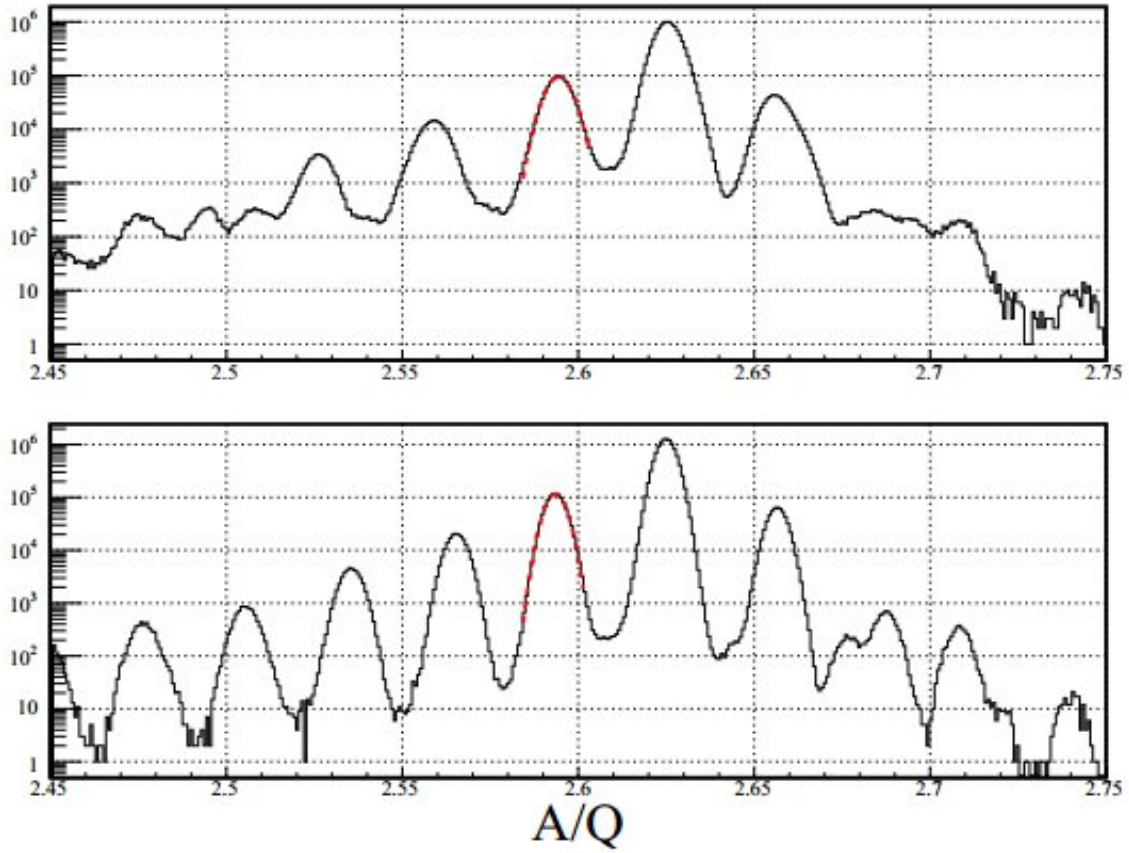
A/Q resolution

BigRIPS



FWHM : 4.83 x 10^{-3} → 4.78 x 10^{-3}
(on 84Ge)

ZeroDegree

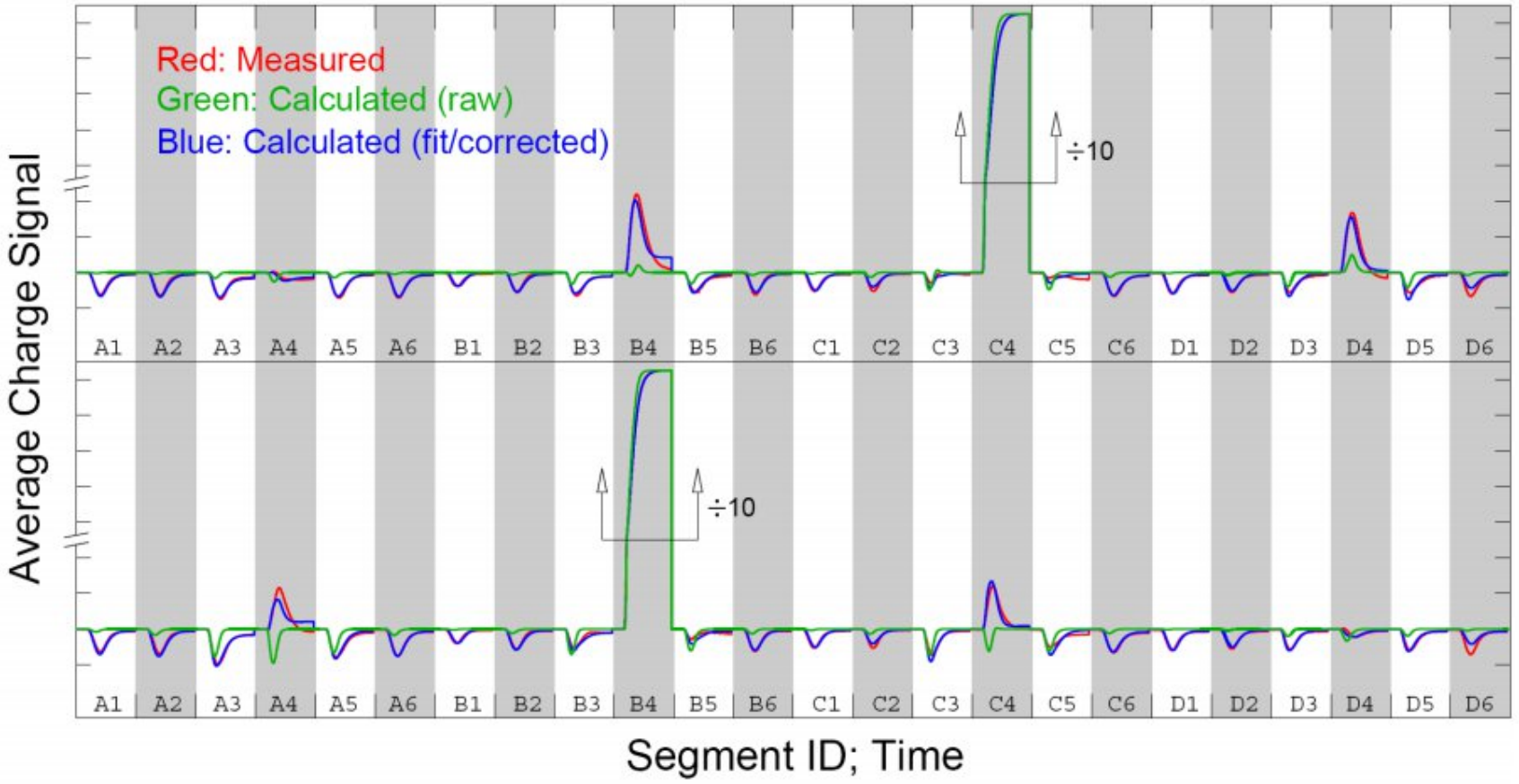


FWHM : 8.12 x 10^{-3} → 6,48 x 10^{-3}
(on ^{83}Ge)

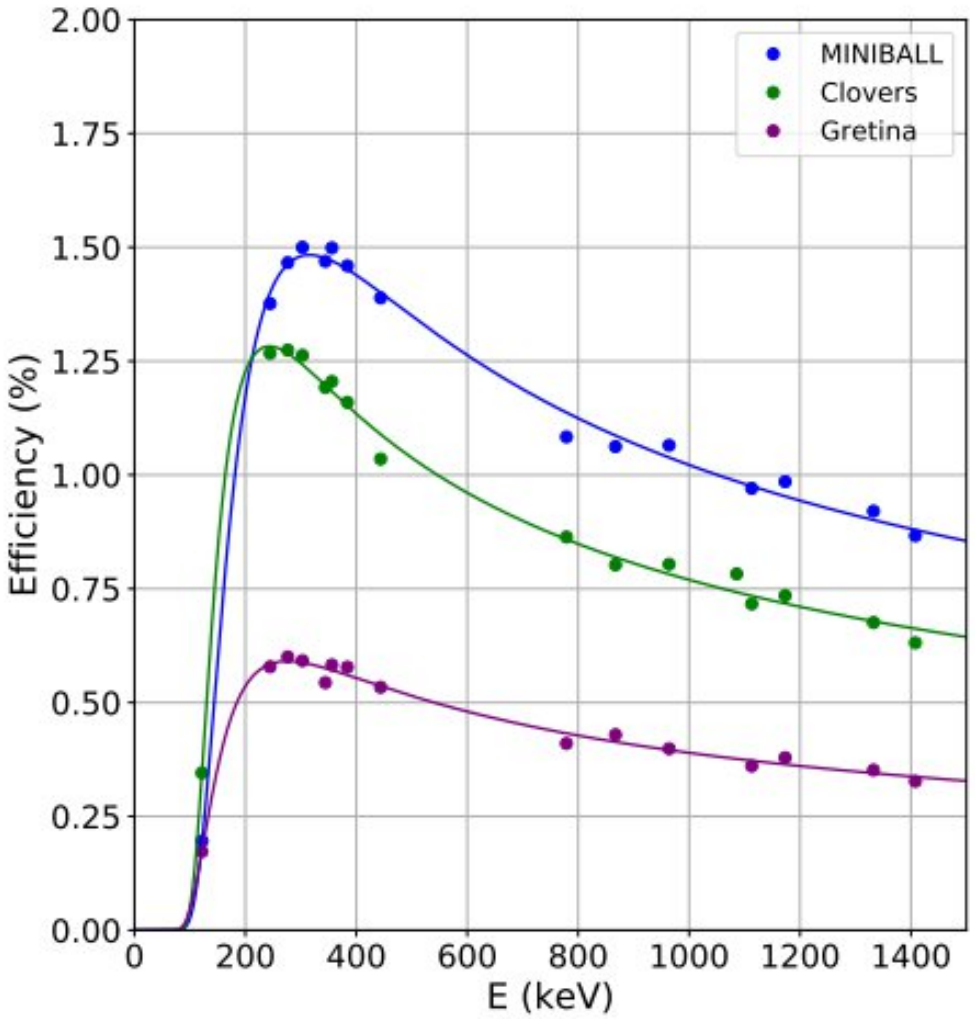
Decomposition

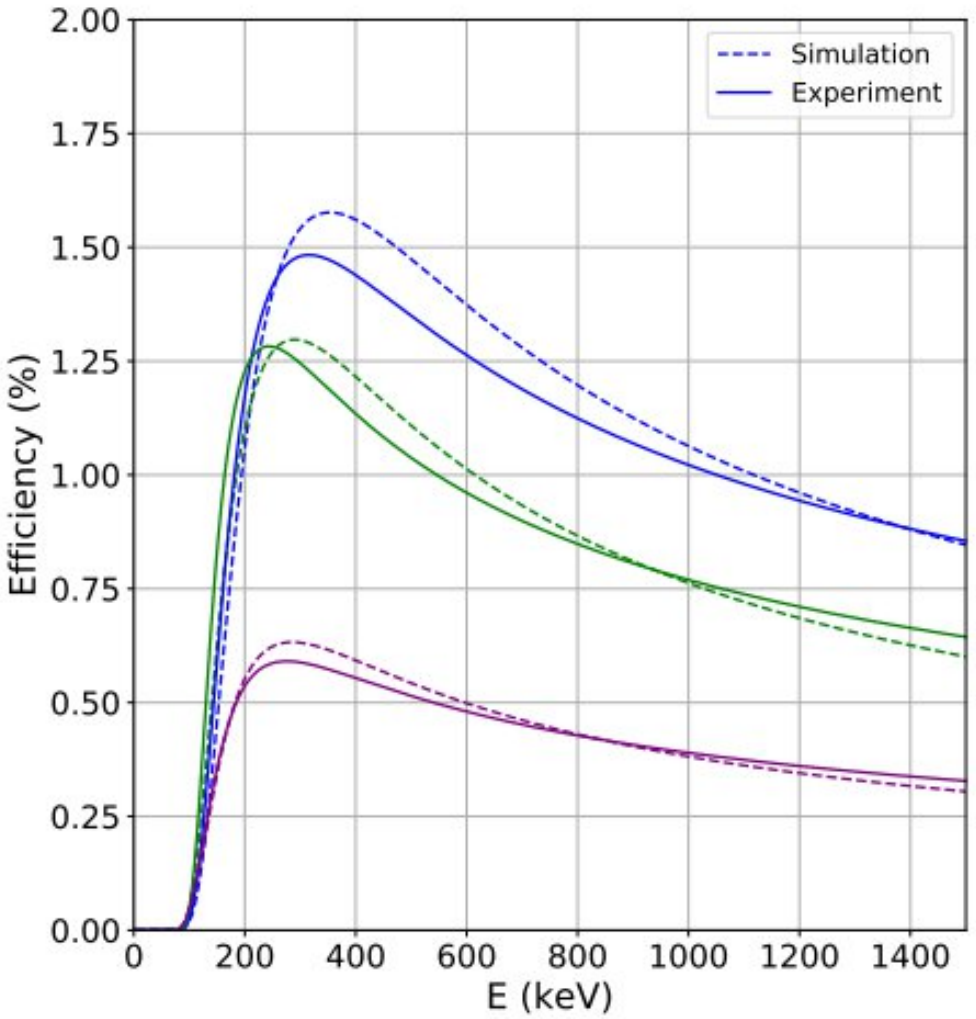
Basis generation

- Mesurement : « super-pulse »
- Fit of simulations (~1000 params)
- Signal simulations (grid)
  - ➢ « Basis »
- Decomposition



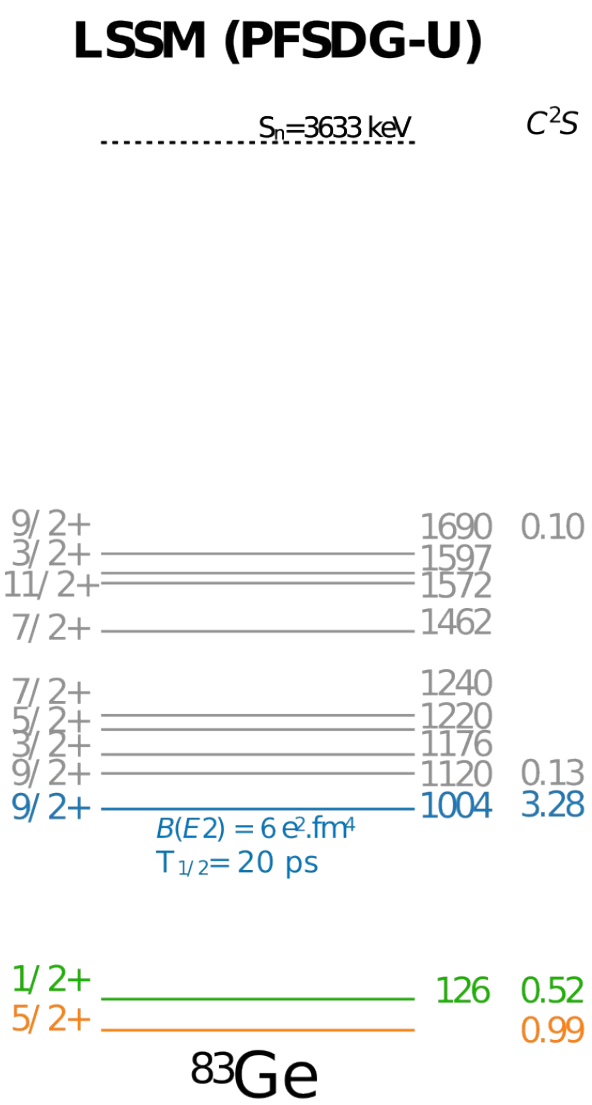
Source efficiency

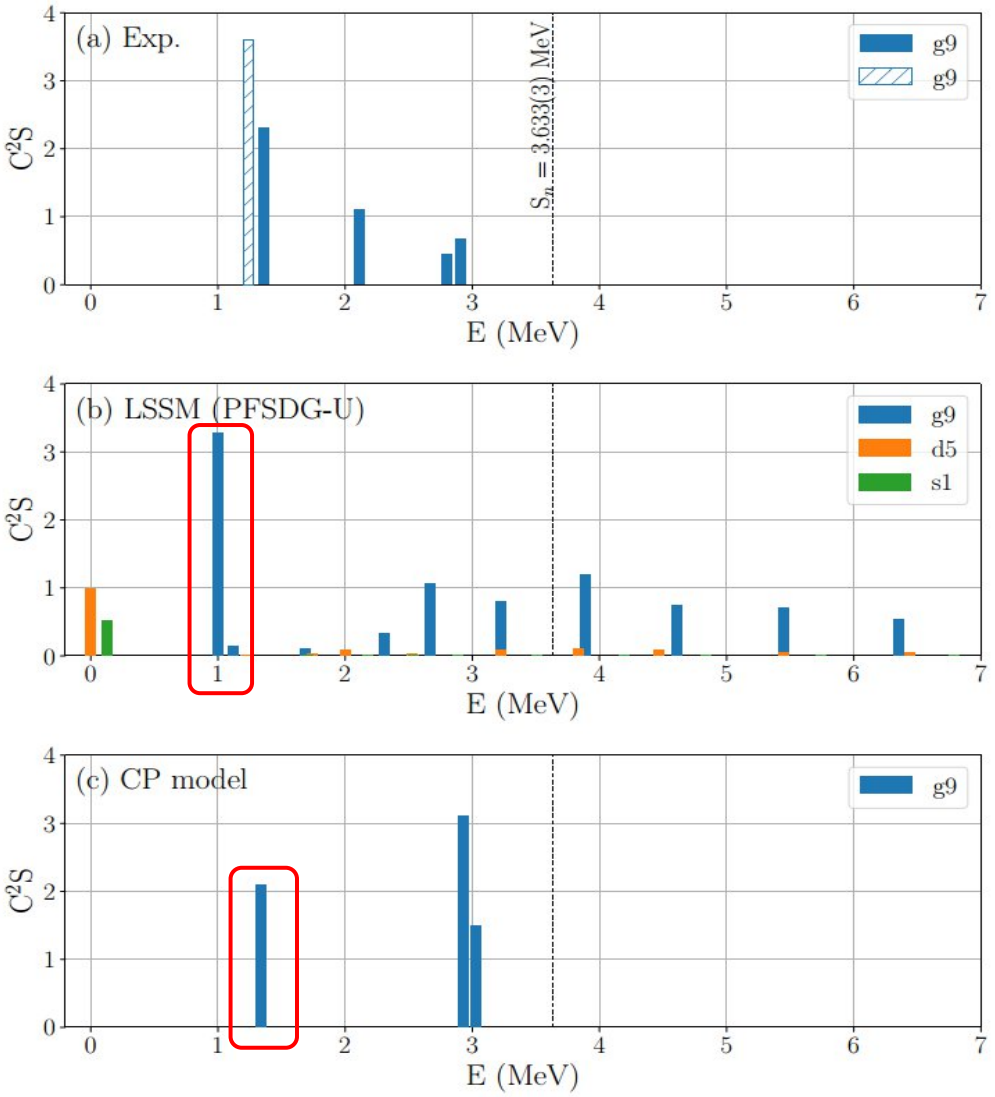




Shell model in ^{83}Ge

LSSM (PFSDG-U)





Summary per detector (2D-χ^2)