Study of Neutron-Rich Nuclei Near N = 50

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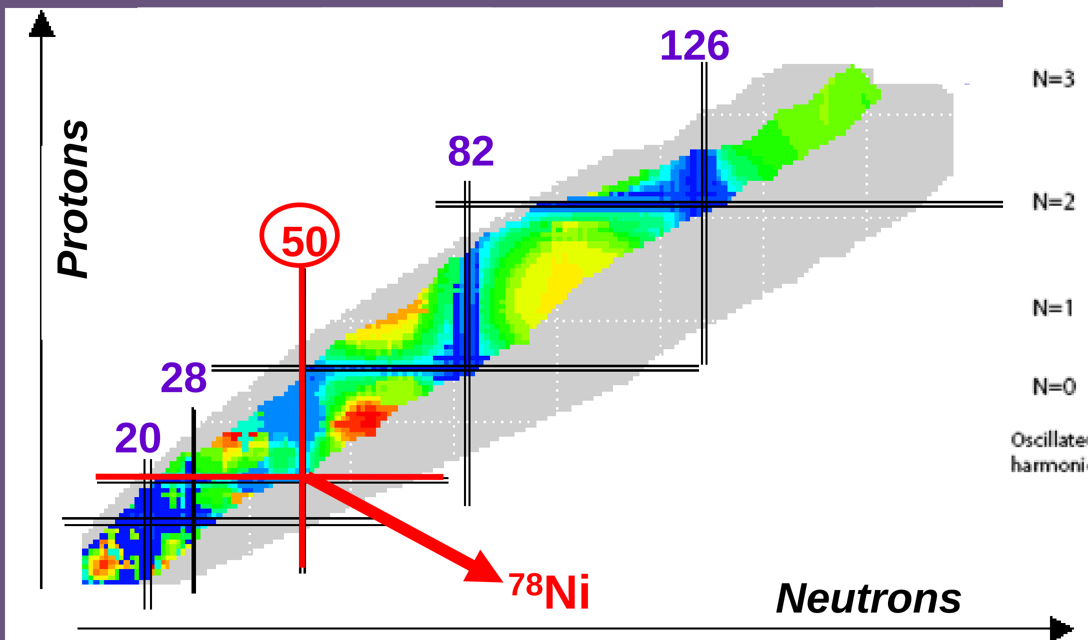
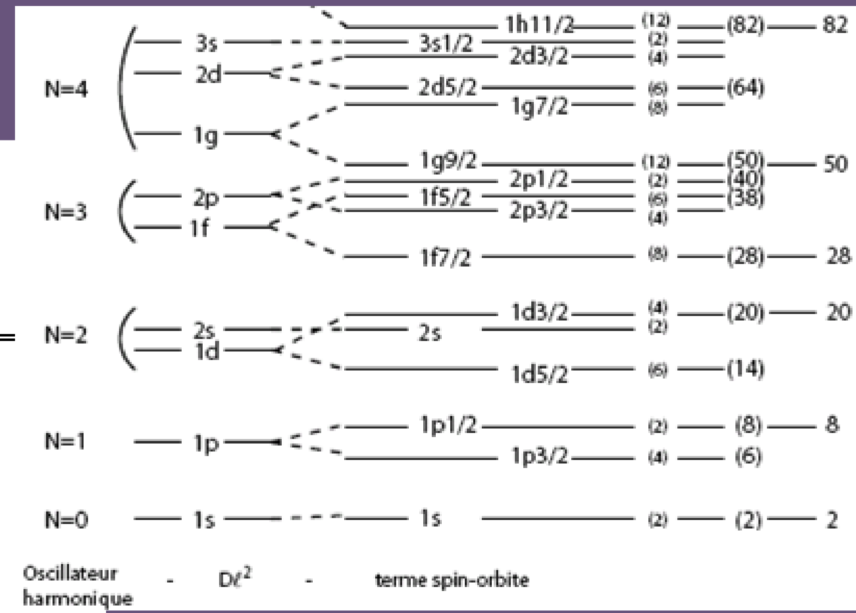
Physics case :





Magic numbers : 2, 8, 20, 28, **50**, 82 …

- More stability
- Sphericity

❖ **What happens when we go far from stability valley ?**

❖ **Magic numbers change?**

❖ Disappearance of N=20 : $^{31}Na_{20}$ et $^{32}Mg_{20}$ ➔ **inversion island**

D. Guillemaud-Muller et al. Nucl. Phys. A 426 (1984)

❖ N=28 : ^{42}**Si** ➔ **weakening of the gap**

B. Bastin Phys. Rev. Lett. 99, 022503 (2007)

❖ Appearance of N=40 : ^{68}**Ni**

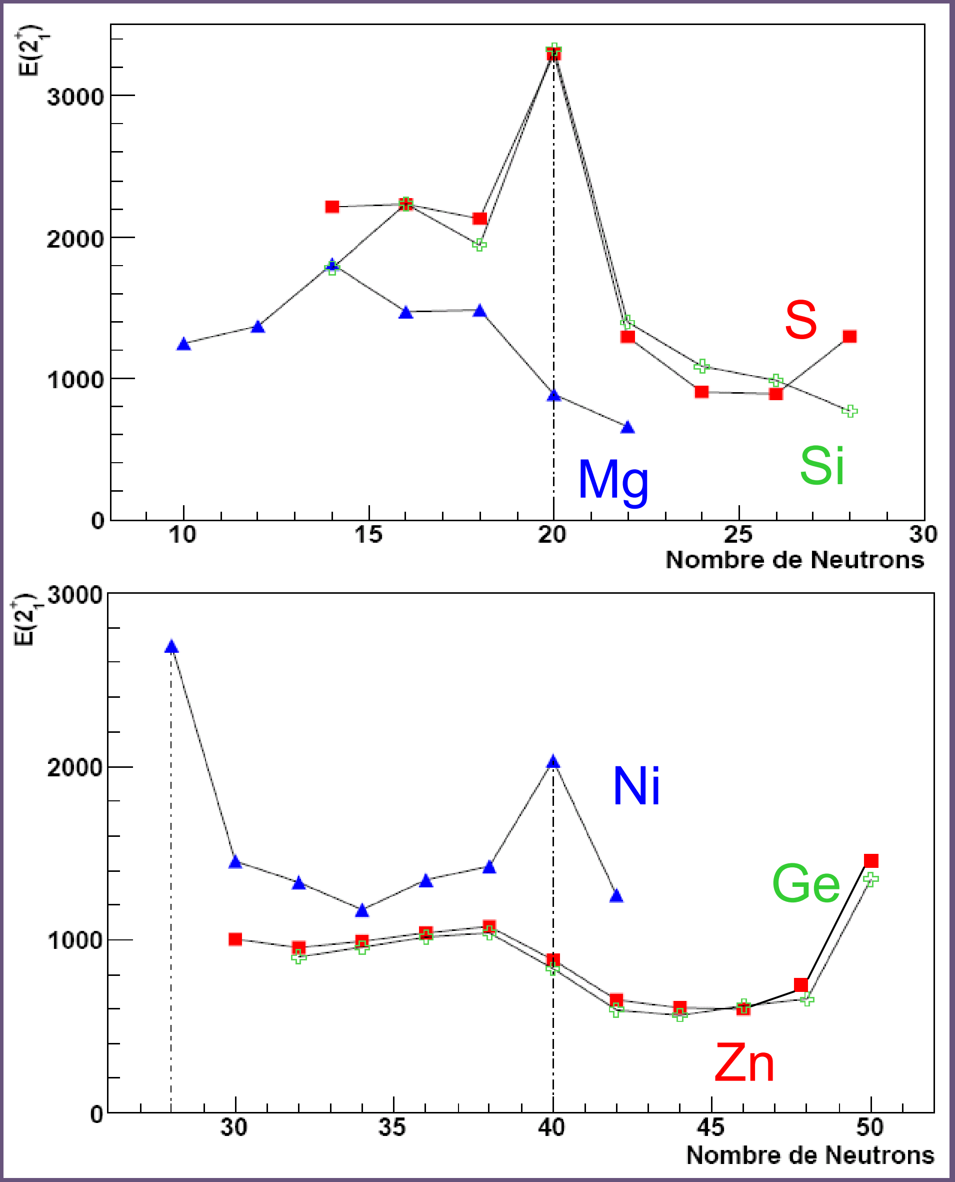
M. Bernas et al. Phys. Lett. 113B (1982) 279

❖ New domain of interest ➔ N=50

$^{20}C_{14}$, ^{32}Mg ,^{42}Si ➔ Loss magicity

^{78}Ni ➔ ?

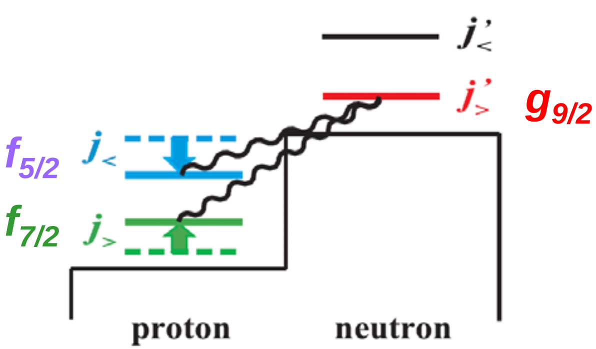
^{132}Sn, ^{208}Pb ➔ magic



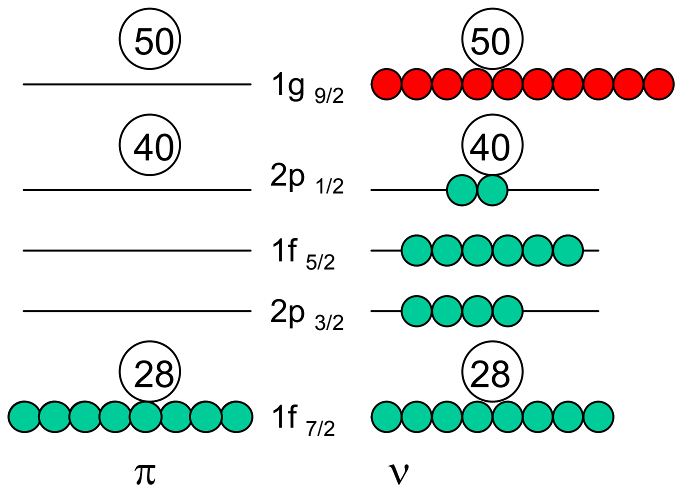
Tensor force and shell evolution :

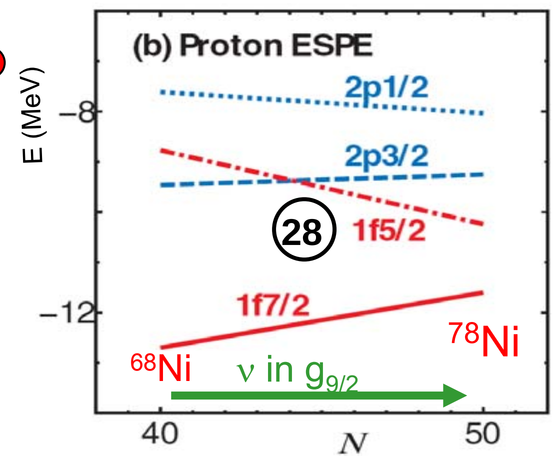
- Proton-neutron interaction + tensor interaction

  T. Otsuka et al. Phys Rev. Lett. 87 (2001), 082502



$j_< = \ell - 1/2$
$j_> = \ell + 1/2$





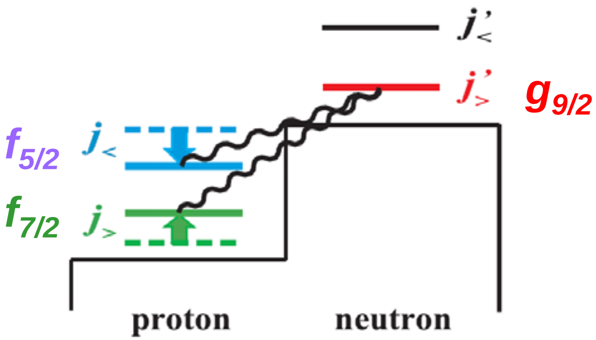
- Between j< et j'> ➔ attractive tensor force
- Between j> et j'> ➔ repulsive tensor force

fp orbitals evolution : Z = 28

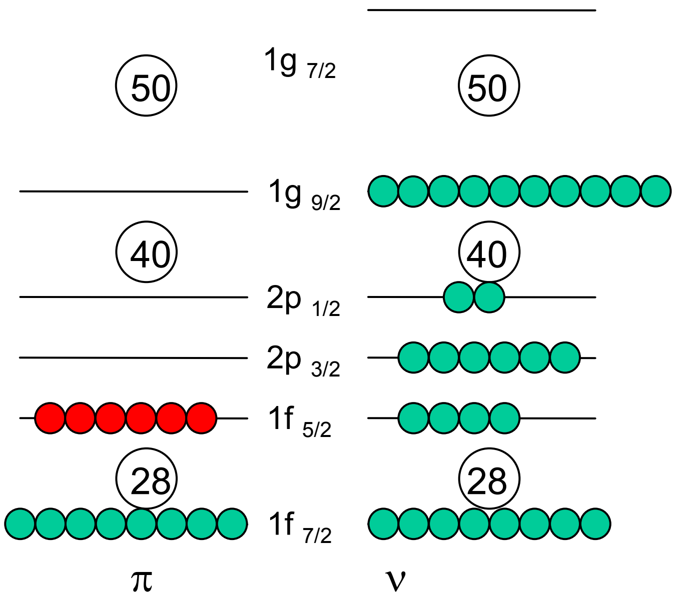
Tensor force and shell evolution :

- ❖ Proton-neutron interaction + tensor interaction

  T. Otsuka et al. Phys Rev. Lett. 87 (2001), 082502



j< = ℓ -1/2
j>= ℓ +1/2



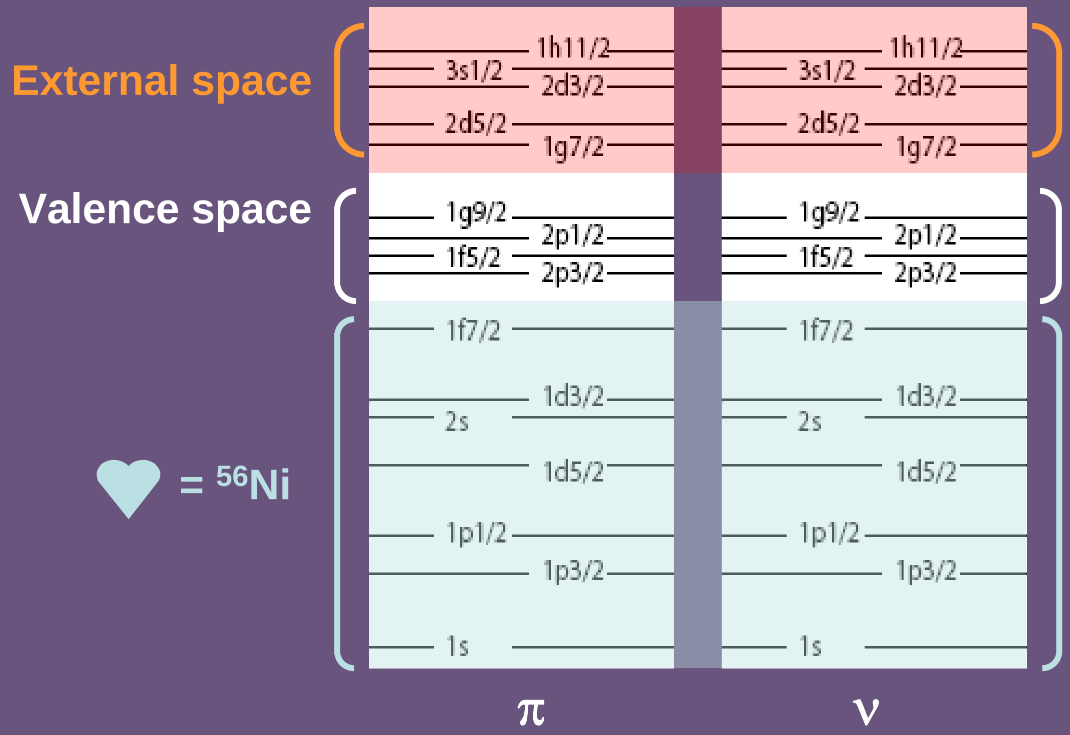
- ❖ Between j< et j'> ➔ attractive tensor force
- ❖ Between j> et j'> ➔ repulsive tensor force

➡ ***fg orbitals interaction* : N = 50**

Shell-Model calculations :

Antoine code *E. Caurier, G. Martinez-Pinedo, F. Nowacki, A. Poves, A.P. Zuker, Rev. Mod. Phys. 77, 427 (2005)*

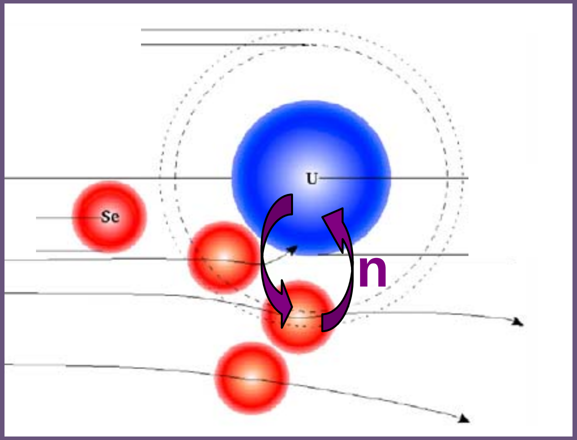
- Calculation space :



- Interaction rg5.45
- Interaction rg5.45mod

Experiments at Legnaro:

- ➔ DI reactions + Multi-nucleon transfers
- ❖ N/Z(^{238}U)=1.59 & N/Z(^{82}Se)=1.41 & N/Z(^{192}Os)=1.53
- ❖ 10% above the Coulomb barrier
- ➔ **^{82}Se @ 515 MeV + ^{238}U and θ_{graz}= 64°**



$$\frac{A}{q} = \frac{TOF \times B\rho}{Dist}$$

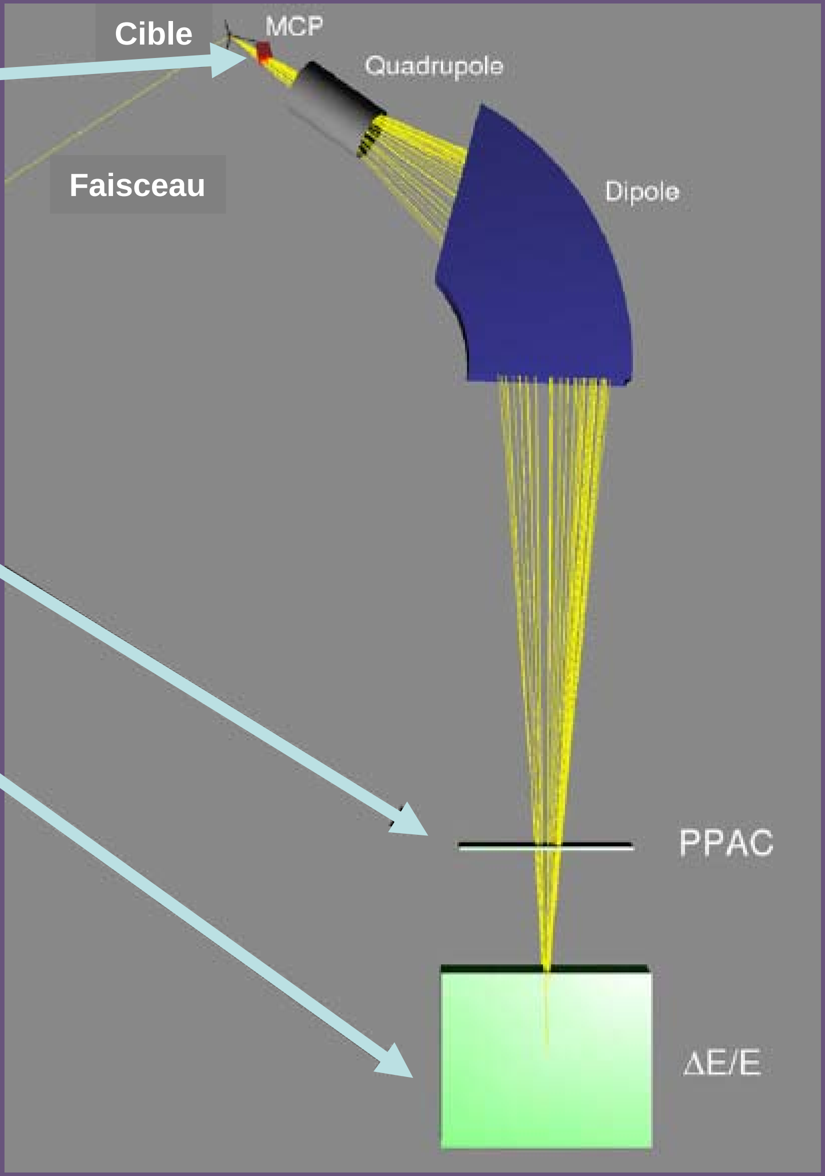
❖ Entry position :
$x_i - y_i$, t_i

❖ Focal plane position:
$x_f - y_f$, t_f

$$\frac{\Delta E}{E} \propto \frac{AZ^2}{E}$$

❖ Ionisation chamber:
Energy loss
Total energy

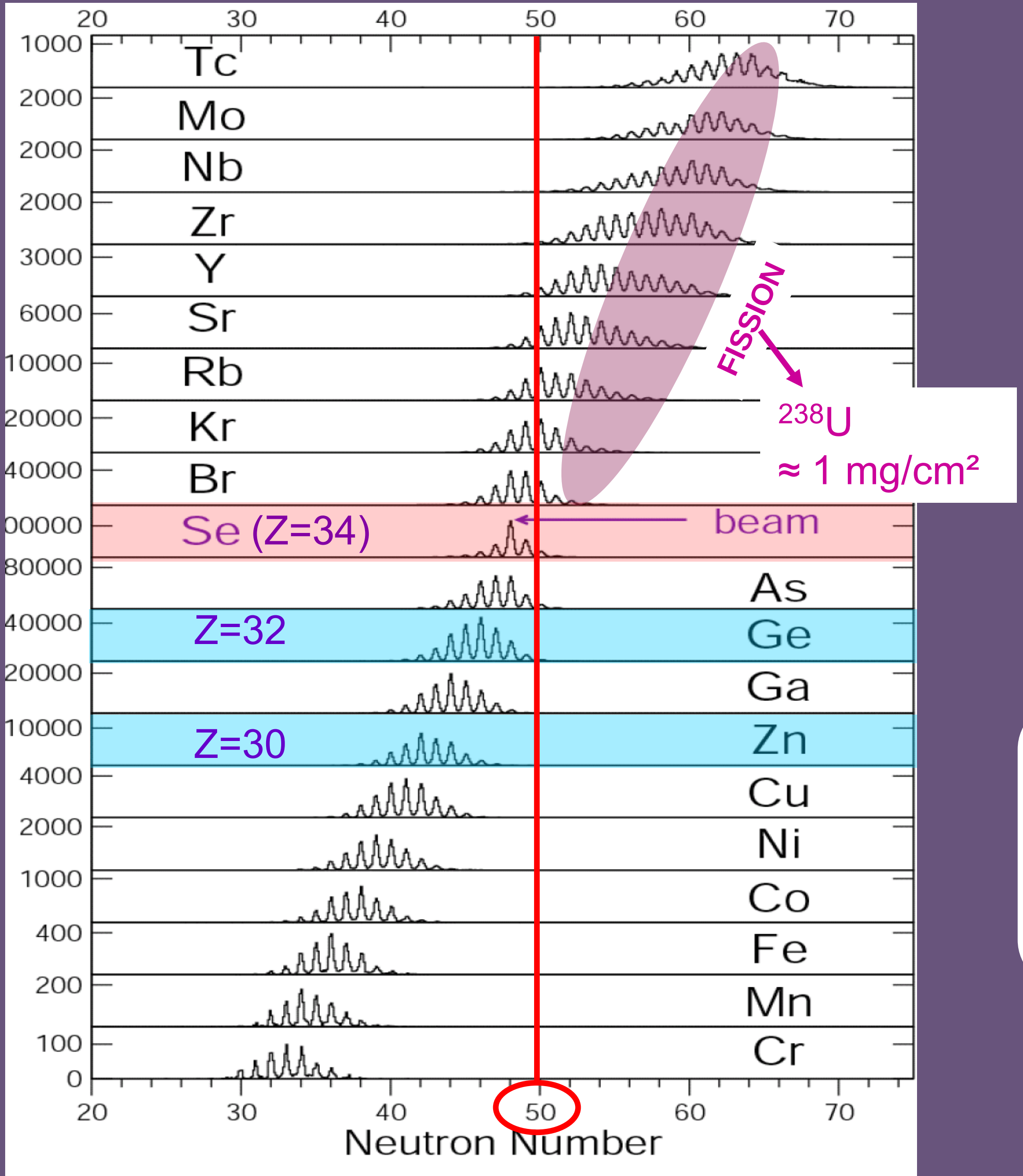
Parameters → IDENTIFICATION
x_i , y_i , TOF, ΔE, E_{tot}

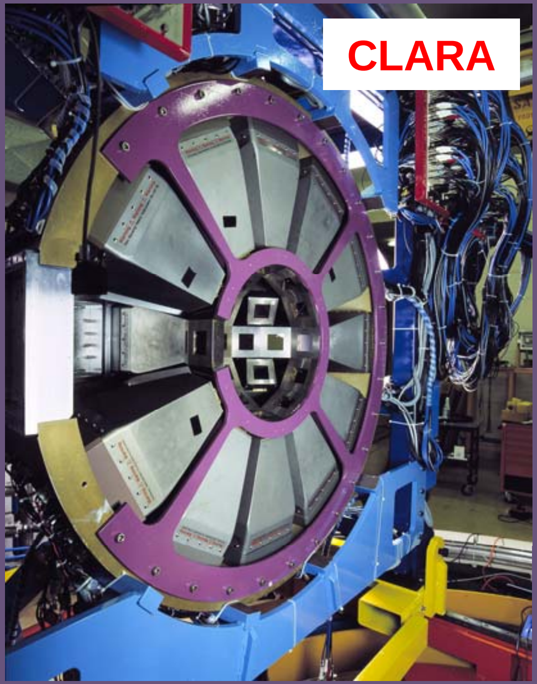


A. Gadea et al. Eur. Phys. J. A 20, 193-197 (2004)

Mass distributions :

Precise identification of quasi-projectiles

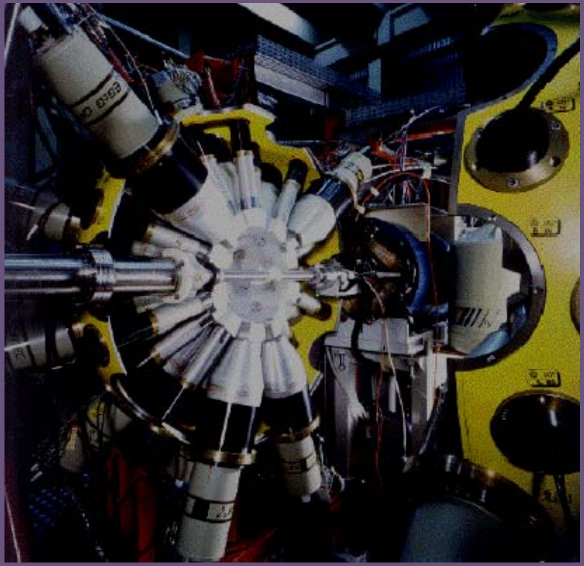




- **25 Ge Clover detectors**
- **Efficiency ≈ 3%**
- **Peak/Total ratio ≈ 50%**
- **FWHM 10 keV @ 1.3 MeV with v/c ≈ 10%**

Identified γ spectra

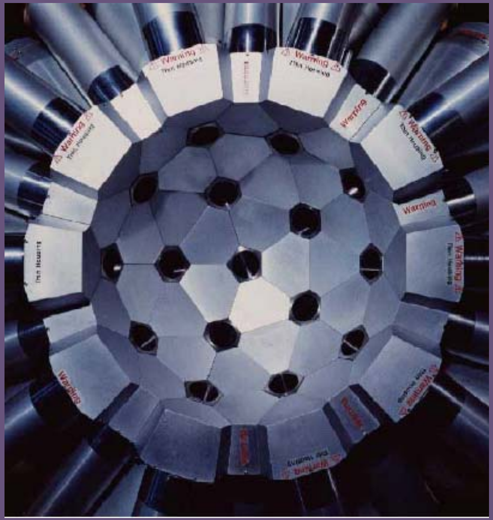
GASP ➔ Construction of level schemes



CLARA-PRISMA
➔ Double coincidences ➔ statistics too low

➔ GASP: 4π ball
➔ 40 HP- Ge Phase I detectors
➔ BGO calorimeter = multiplicity filter + total energy spectrometer.
➔ Absolute photopeak efficiency = 3%
➔ BGO efficiency = 70%

^{82}Se @ 460MeV + ^{192}Os



Complementary

CLARA-PRISMA
➔ Identified γ rays (A;Z)
➔ NO γ–γ–Prisma

GASP
➔ NO identification
➔ γ–γ–γ !

Analysis technics :

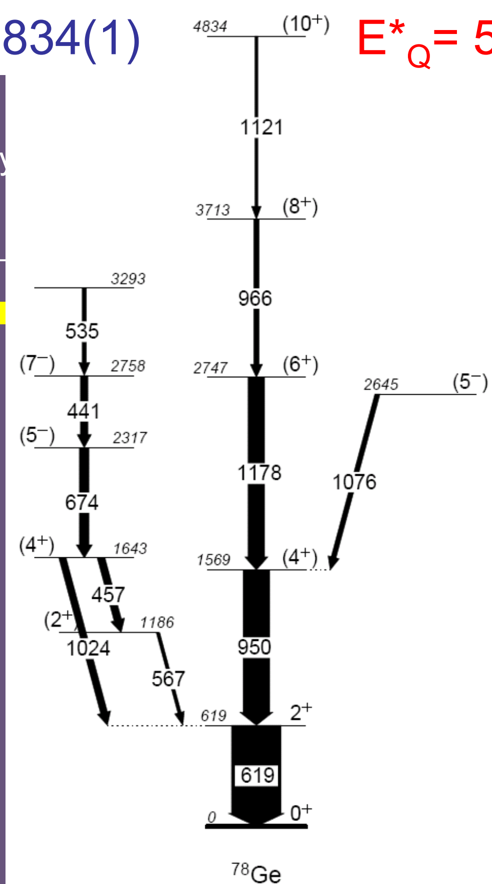
1) Asymmetry ratio :

$$R_{Asym} = \frac{\text{Peak area at } 180° + 154°}{\text{Peak area at } 102°}$$

2) Q-value spectra :

E*= 4834(1)

E^*_Q= 5045(560)

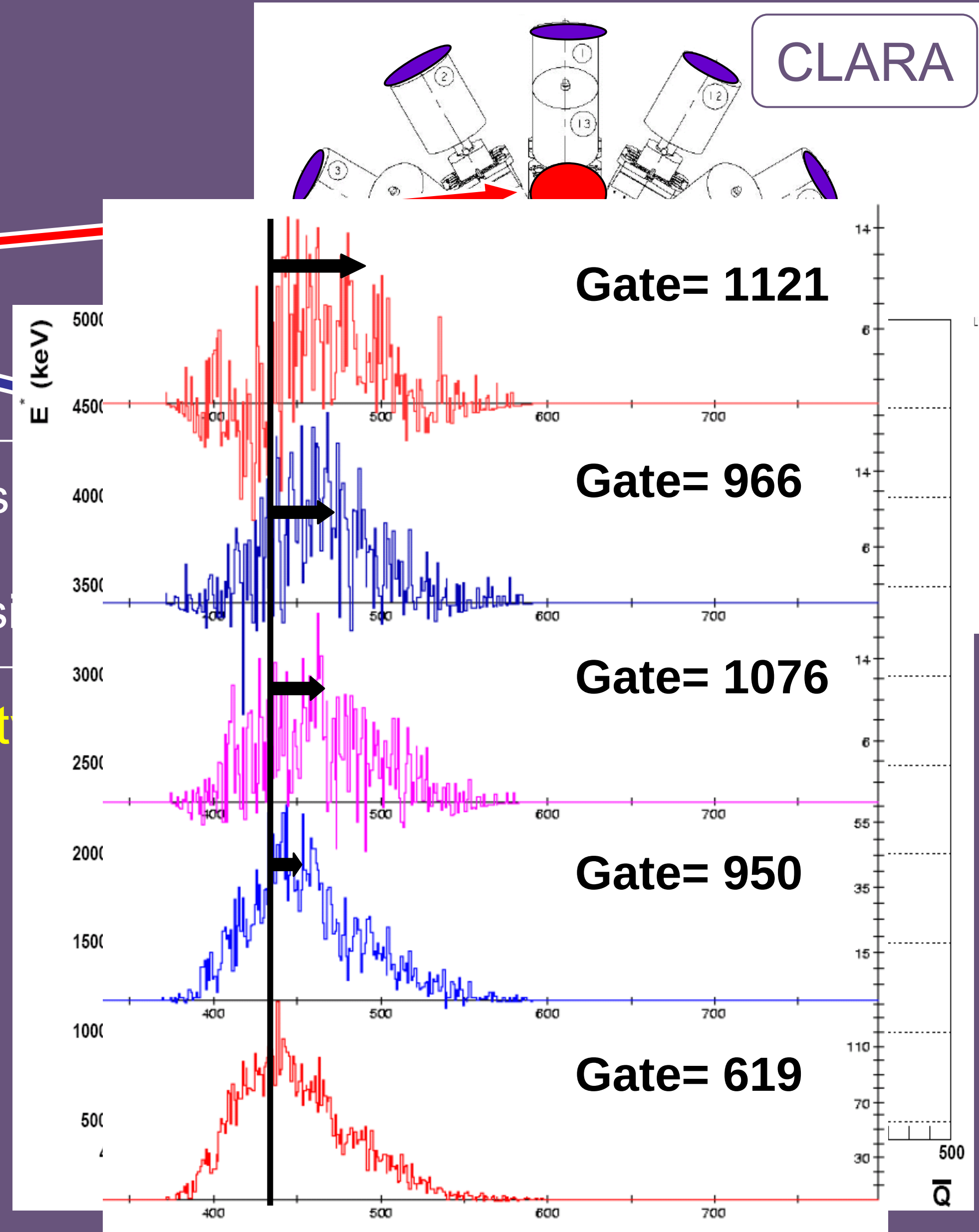


R_{asy} ...

...ole transitions

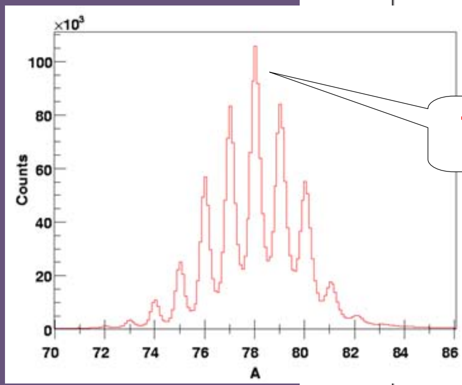
...drupole transi...

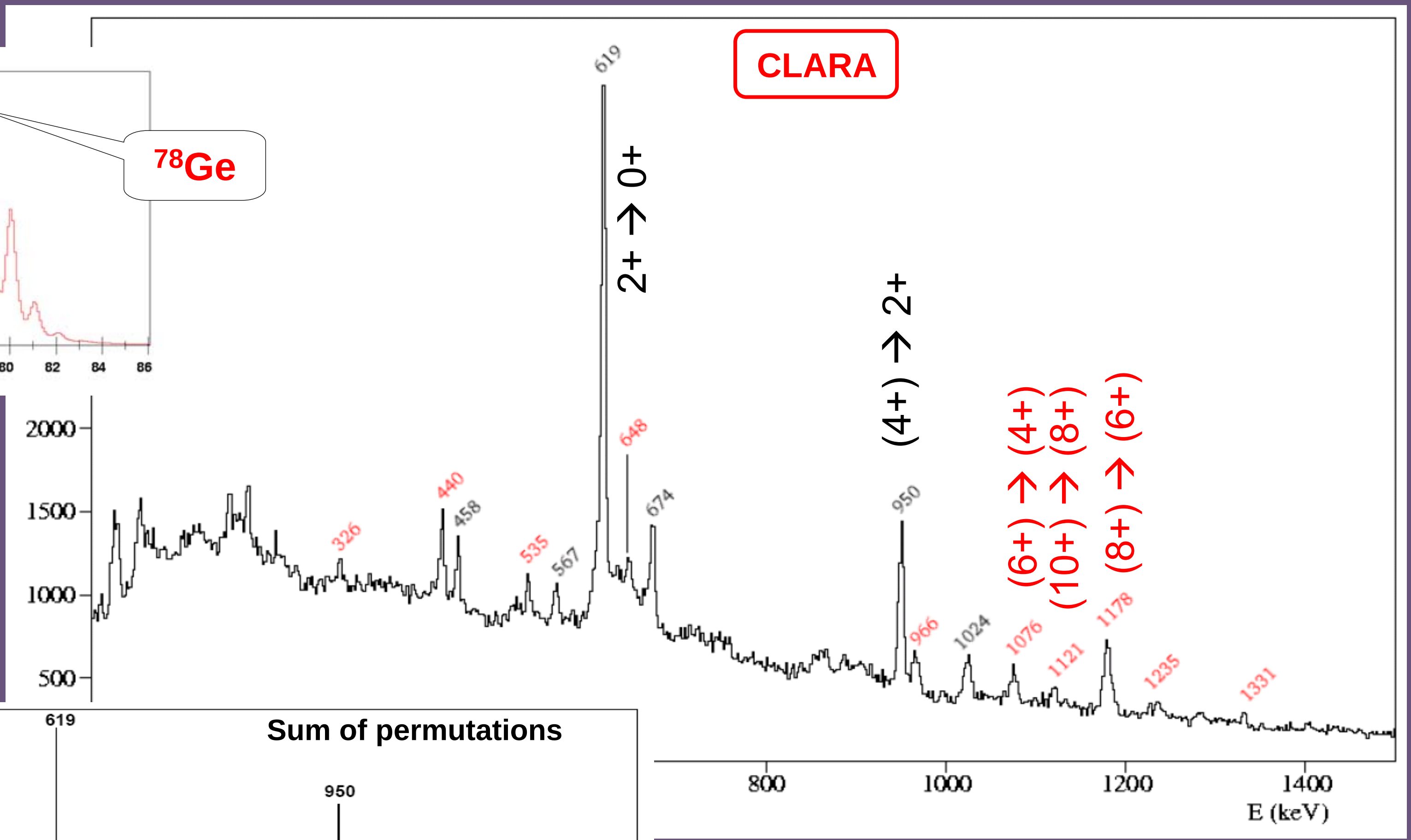
... multipolarit...

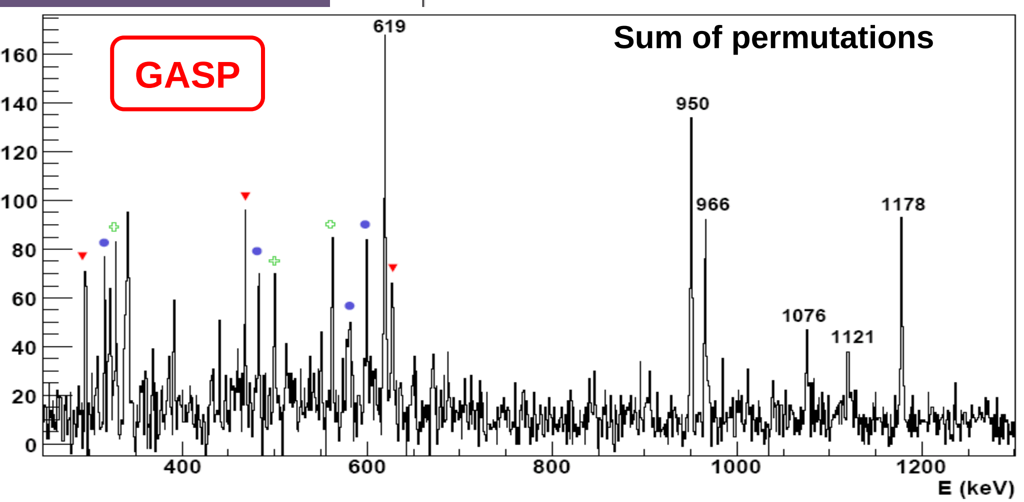


Indication on ≈ E* of the emitting state

Ge isotopic chain → ^{78}Ge



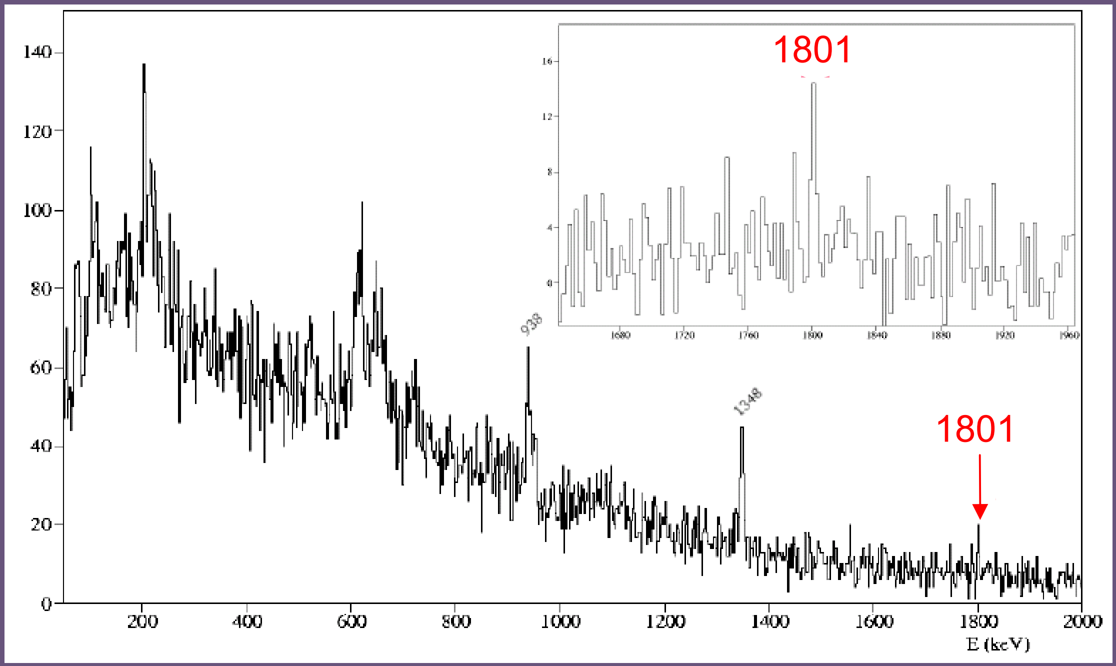




R_{asym} (966 keV) = 1.37(22)
R_{asym} (1179 keV) = 1.14(11)
R_{asym} (1121 keV) > 1

→ Construction of Yrast line

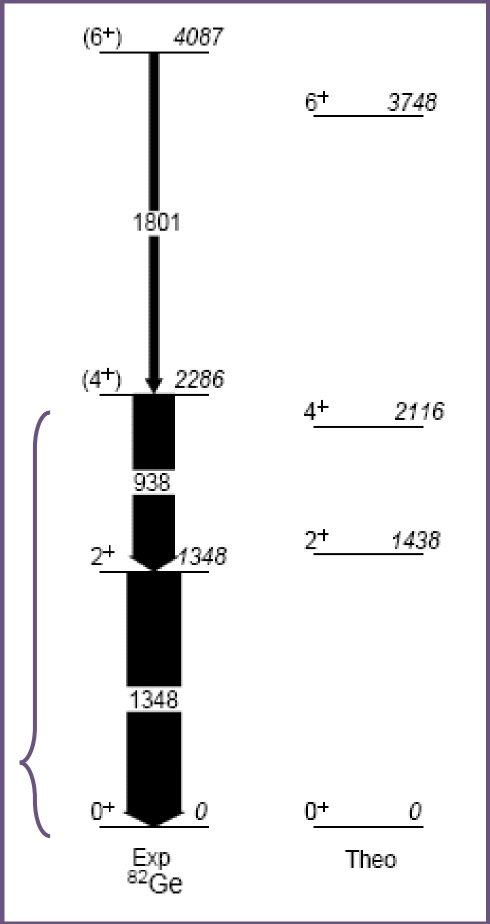
^{82}Ge
→ N=50



E_γ (keV)	Aires	$I_{relatives}$	R_{asym}
203.5(2)	112(12)	37(6)	
608.5(14)	155(76)	78(40)	
644.7(13)	91(31)	47(17)	
938.7(1)	117(15)	77(14)	2.10(77)
949.5(8)	53(16)	38(12)	
1348.1(9)	120(15)	100(12)	1.53(45)
1800.6(10)	18(6)	18(13)	2(1)

T. Rzaca-Urban et al.
Phys. Rev. C, 76 (2007)

Agreement



Antoine code
♥ ^{56}Ni

Even Zn systematics :

Ground state of $^{74}Cu \rightarrow (2,3)$

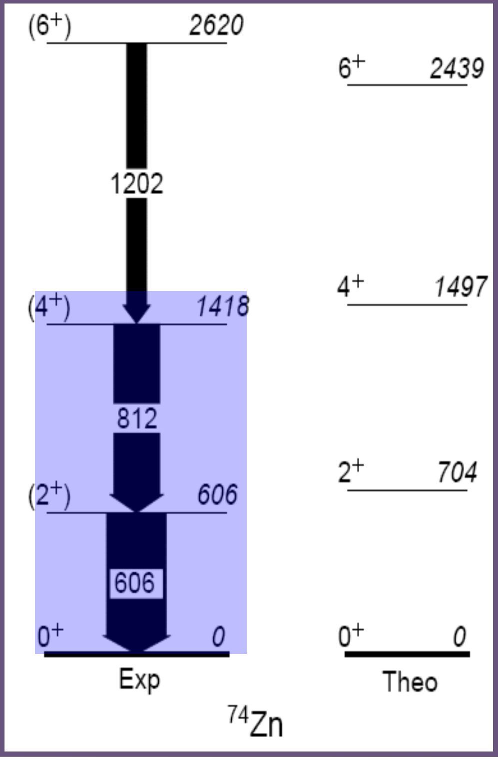
$\Delta J = 3,4$

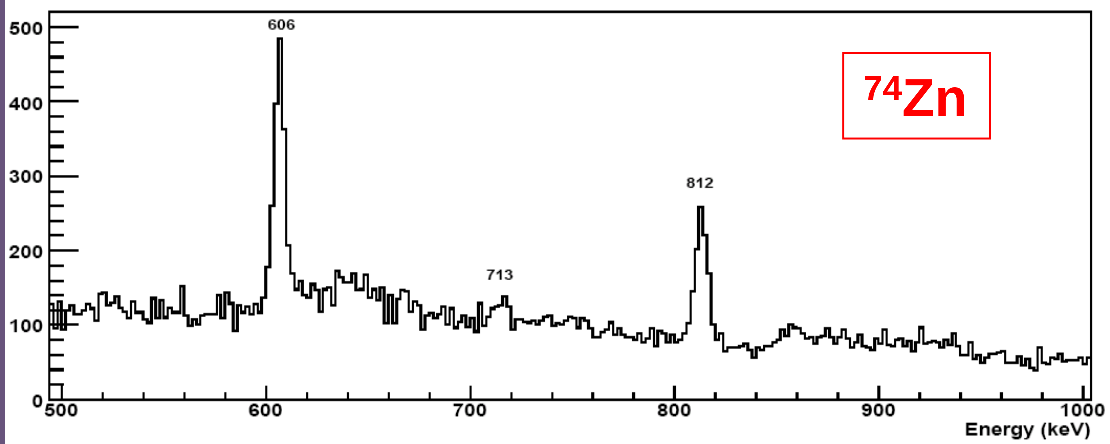
Agreement

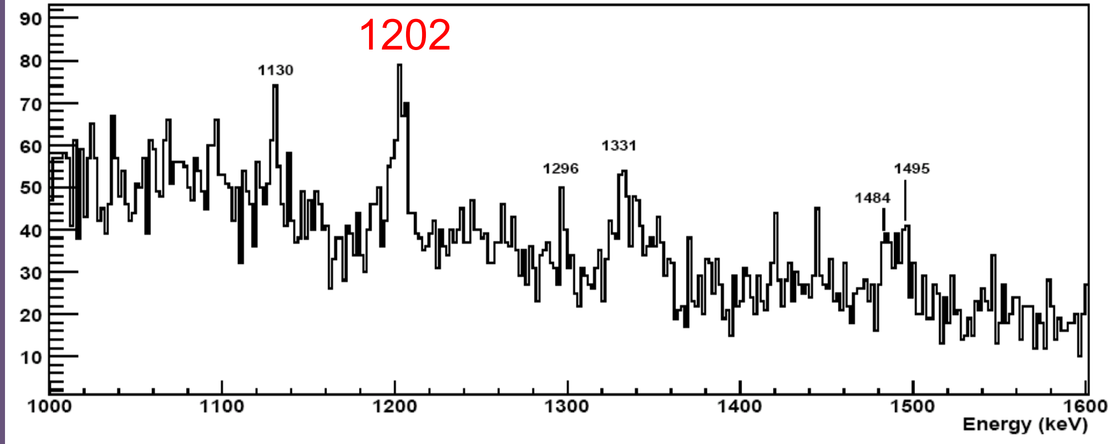
R_{asym}= 1.82(58)

R_{asym} = 1.37(19)

R_{asym}= 1.14(11)







J.Van Roosbroeck et al.
Phys. Rev. C 71 (2005)

^{76}Zn

^{76}Cu ground state → 3,4

log ft = 8(+4)

log ft > 8

R_{asym} = 2.89(97)

log ft = 5.84(15)

log ft > 6

R_{asym} = 2.40(86)

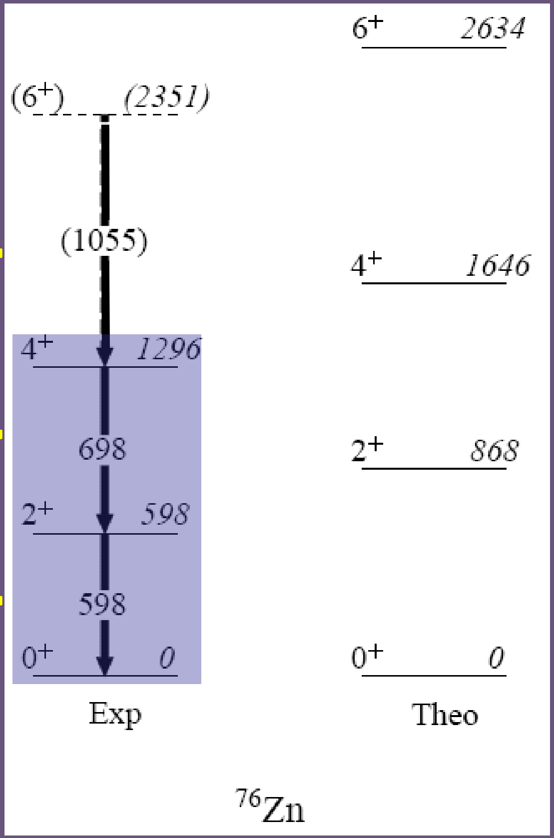
log ft = 5.83(14)

log ft > 8

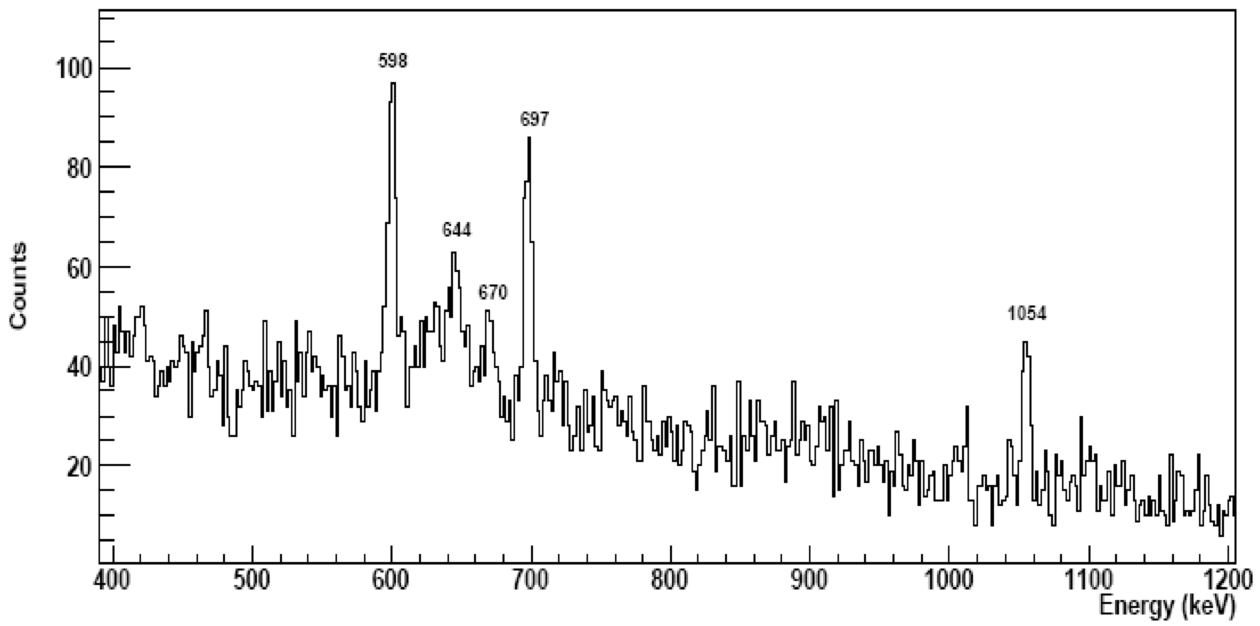
R_{asym} = 3.44(96)

J. Winger et al.
Phys.Rev. C42, 956 (1990)

- → Isomeric state J = 3
- → By ANTOINE code
  - → 3^- at ~ 100 keV



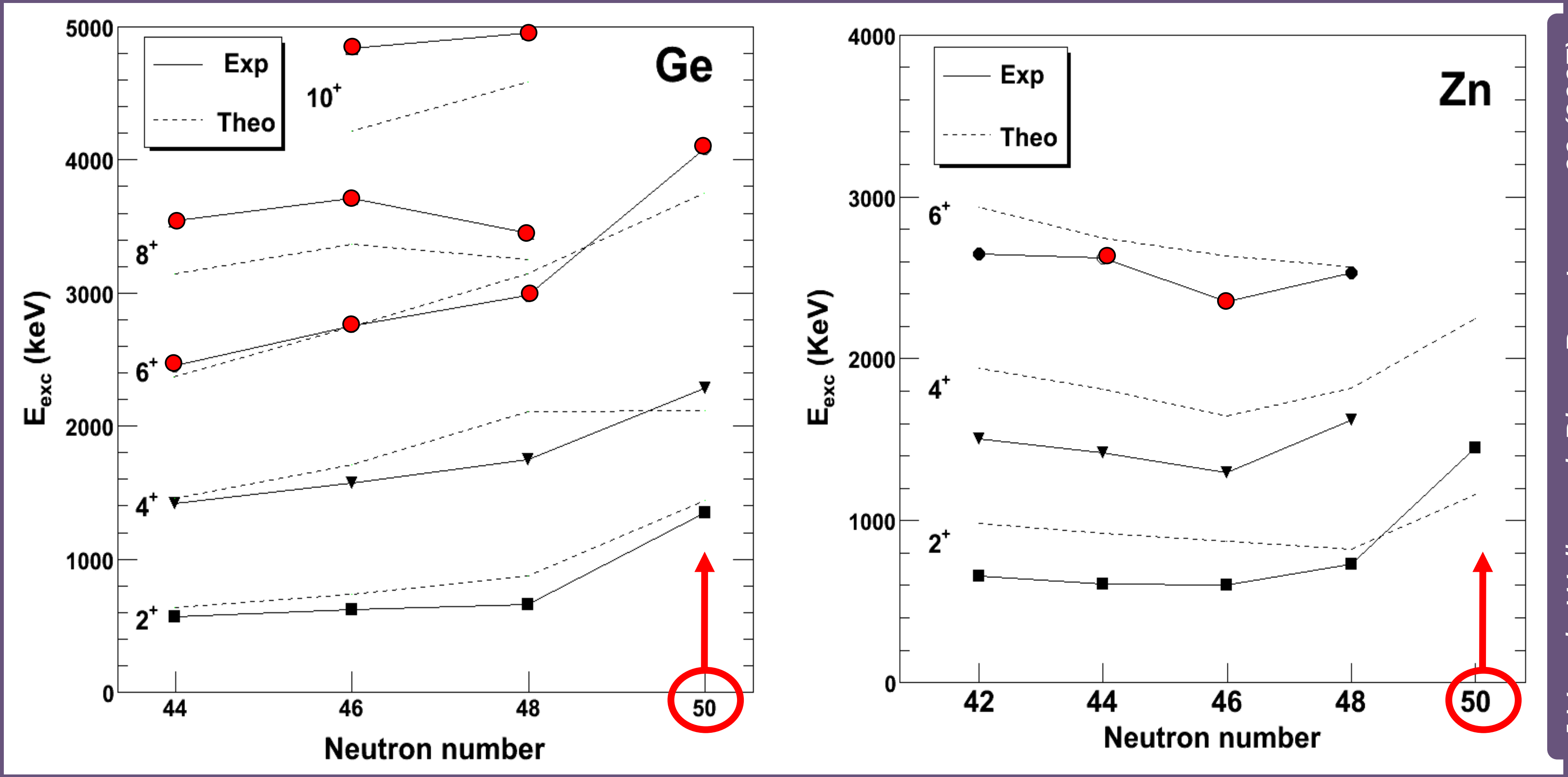
Agreement



J.Van Roosbroeck et al.
Phys. Rev. C 71 (2005)

Ge & Zn isotopic chains:

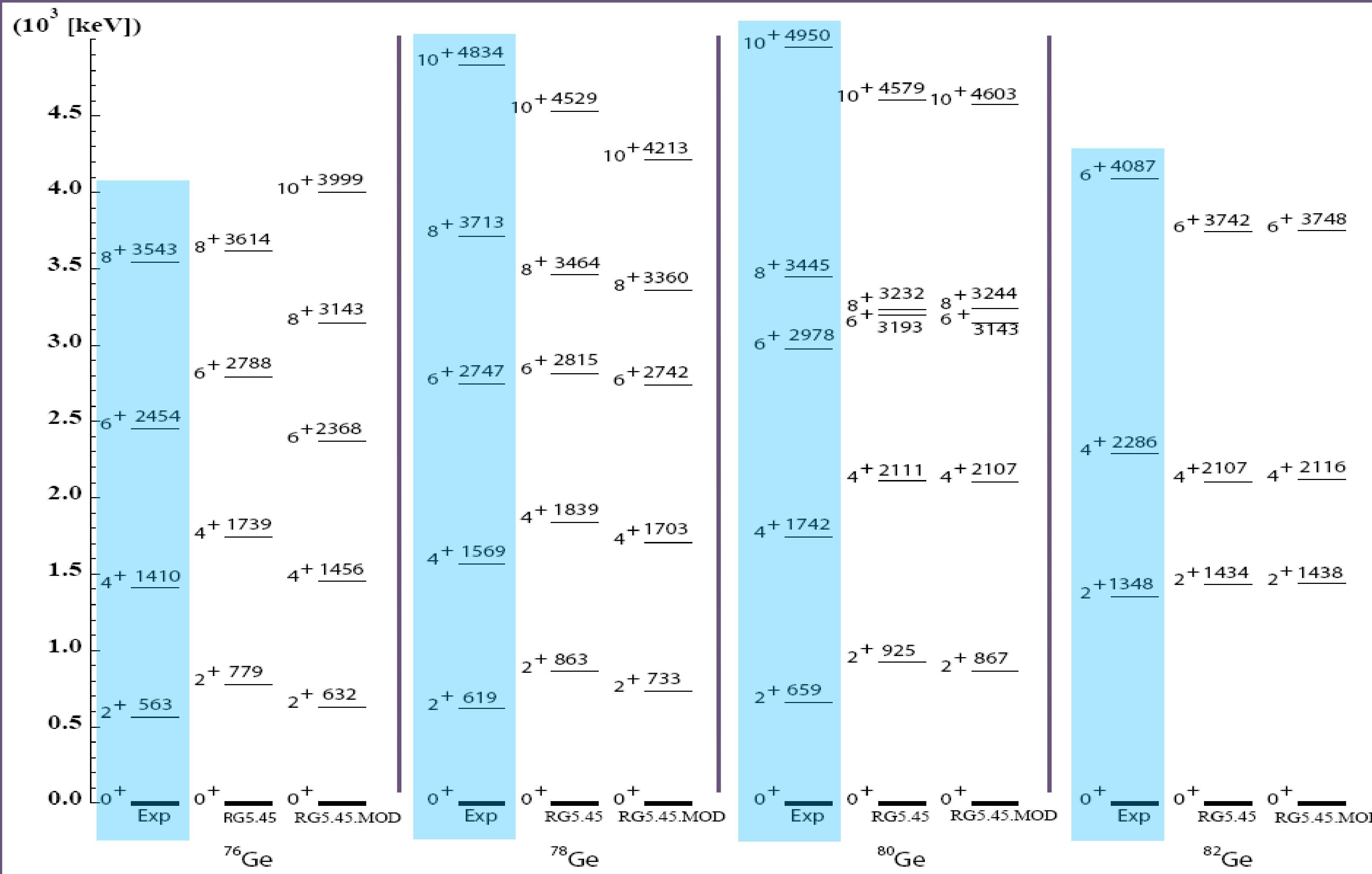
T.Faul, G.Duchêne et al. to be published in Phys. Rev. C



J.Van de Walle et al. Phys. Rev .Letters 99 (2007)

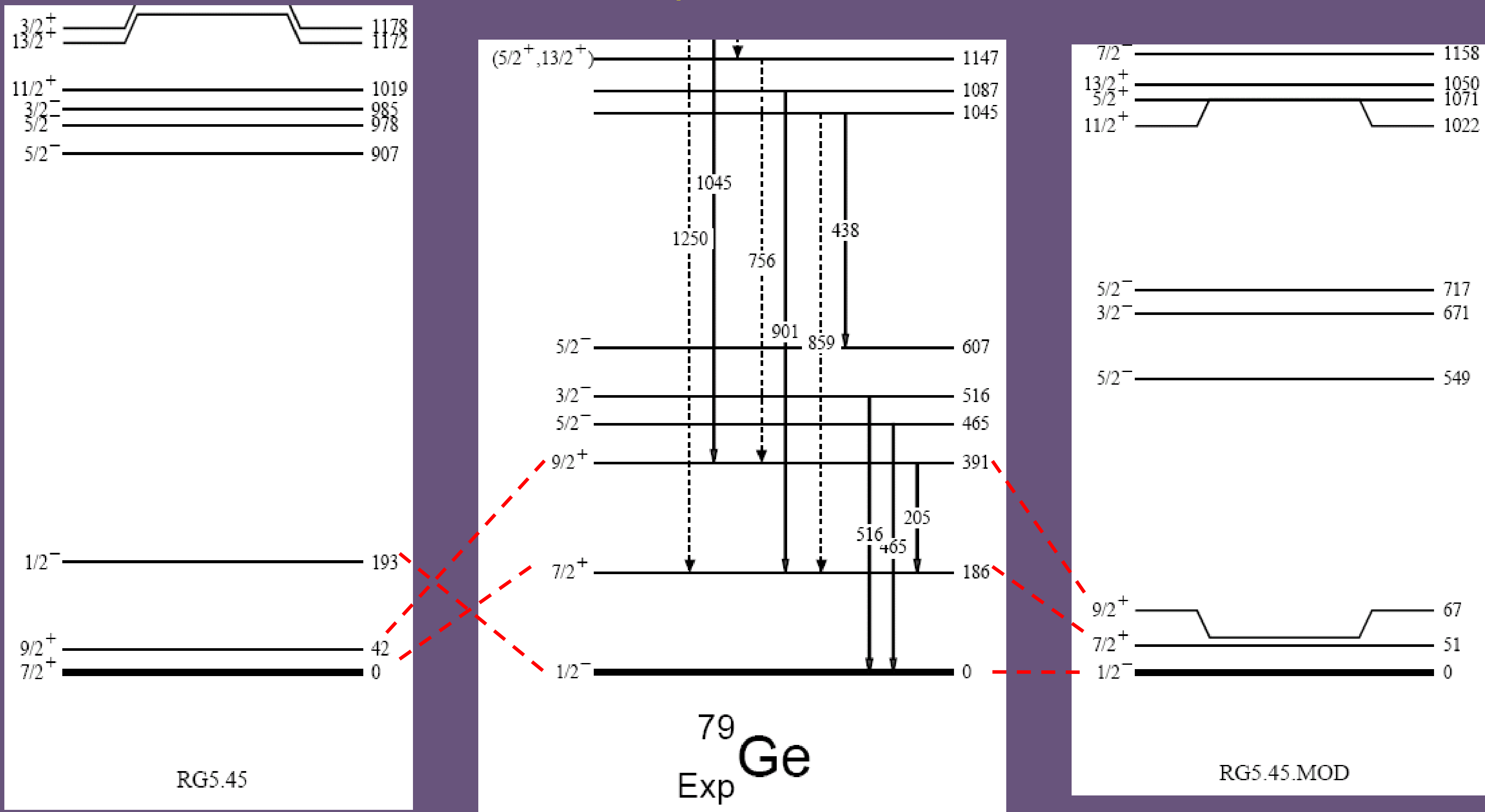
➔ Up to Z = 30, the N = 50 gap shows a resistant character

Even Ge systematics :



❖ <u>For even nuclei</u>

→ *Agreement improved when ν $g_{9/2}$ pairing + monopoles modified*



❖ <u>For odd nuclei</u>

→ *Better… but*

→ *Improvements still awaited*

CONCLUSIONS

- Study of the Ge & Zn isotopic chains → clear exp improvements
- Resistance of the N=50 shell-gap for Ge & Zn.
- Systematic comparison of experimental data with Shell-Model calculations.
- Validation of our results + interaction improvements.

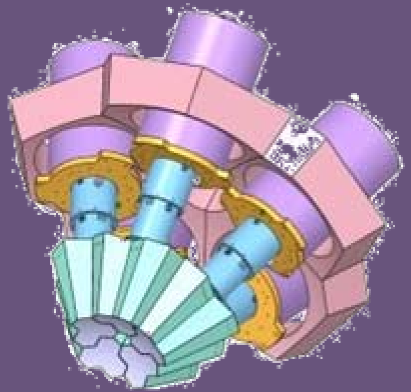
- γ Outlooks : → Necessity of more statistics

  → Setups more efficient → AGATA

  LNL: AGATA Demonstrator + PRISMA

  Eff : 6 % @ $M_\gamma = 1$

  → N=50 nuclei



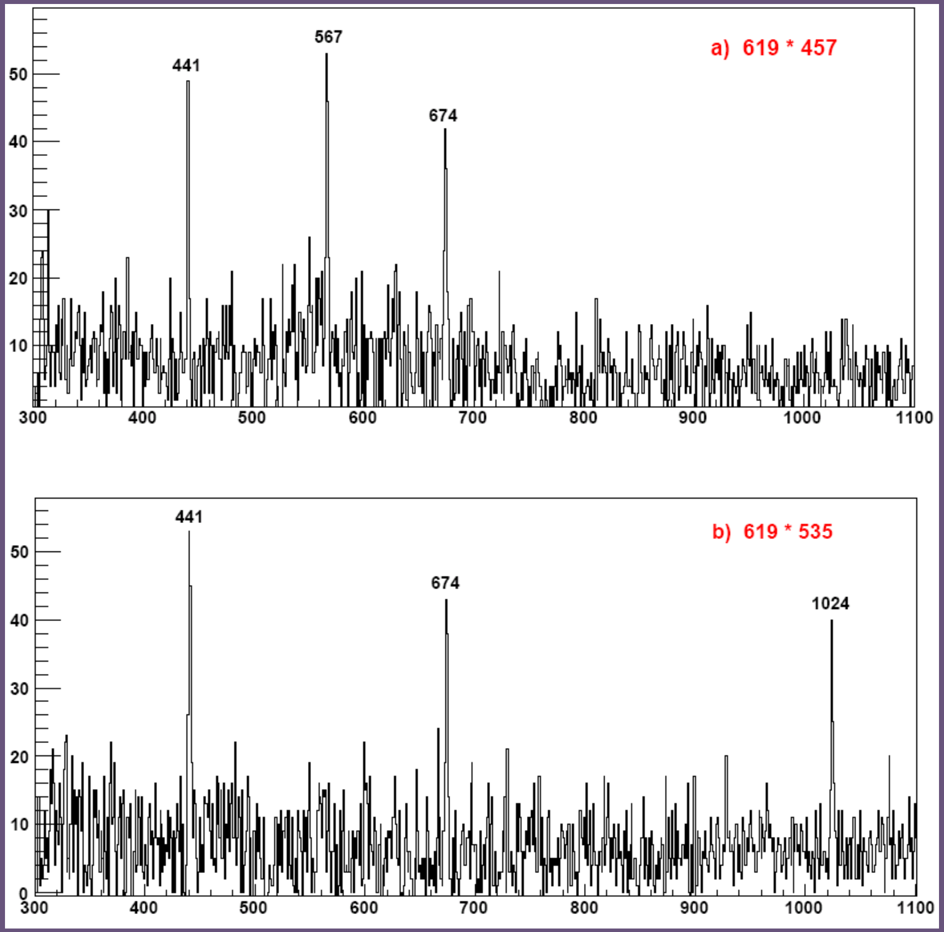
- SM Calculations : → Improvements are necessary….

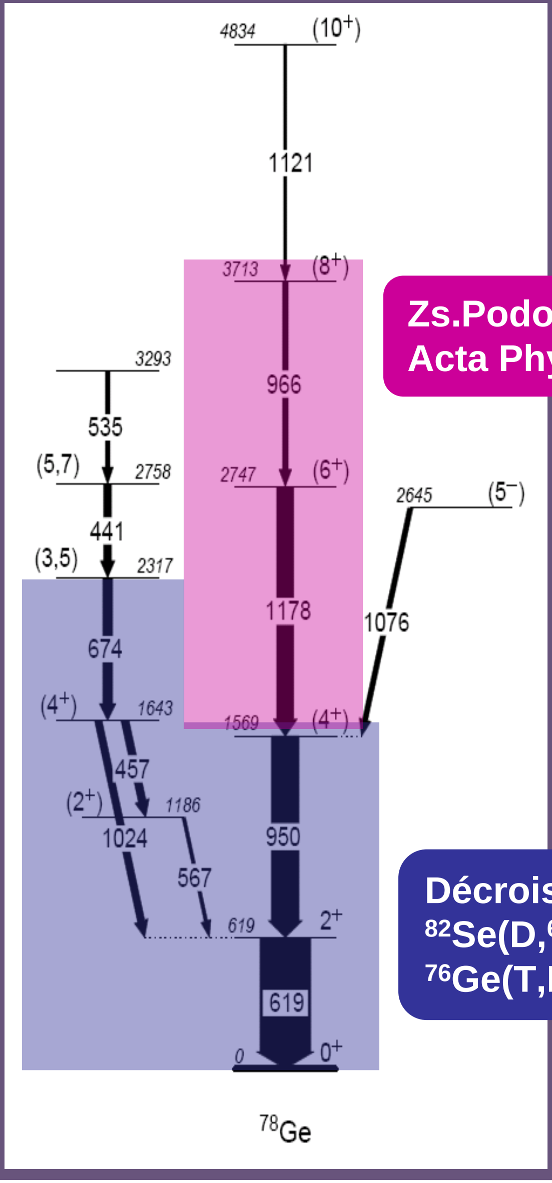
  → Interaction $1\hbar\omega$:

  - Excitation from $f_{7/2}$ to $fp+g_{9/2}$
  - Excitation from $fp+g_{9/2}$ to gd

Transitions non Yrast également

Schéma de niveaux du ^{78}Ge





Zs.Podolyak et al.
Acta Phys.Pol. B, 35, 2004

Décroissance β+
^{82}Se(D,^{6}Li)^{78}Ge+
^{76}Ge(T,P)^{78}Ge