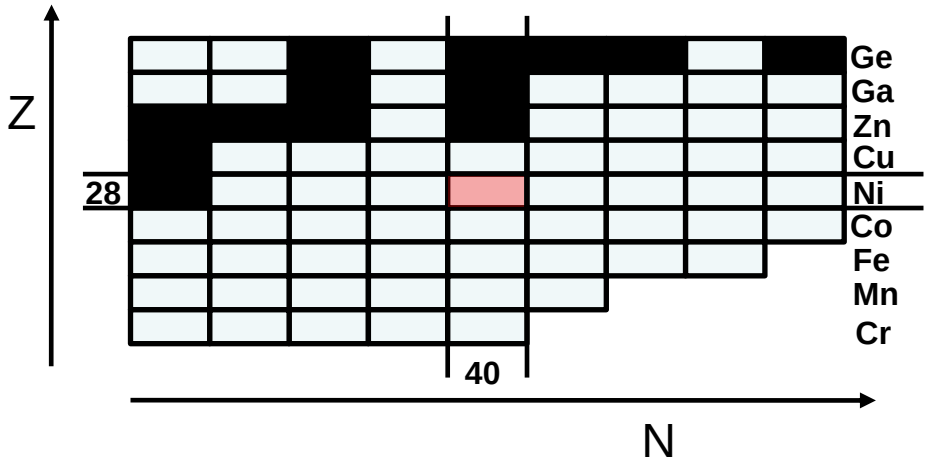
# A Recoil-Distance Doppler-Shift lifetime experiment on neutron-rich Zn isotopes with the AGATA demonstrator


Corinne Louchart, CEA Saclay

LEA-COLLIGA Meeting, 2011

# Onset of collectivity near N=40



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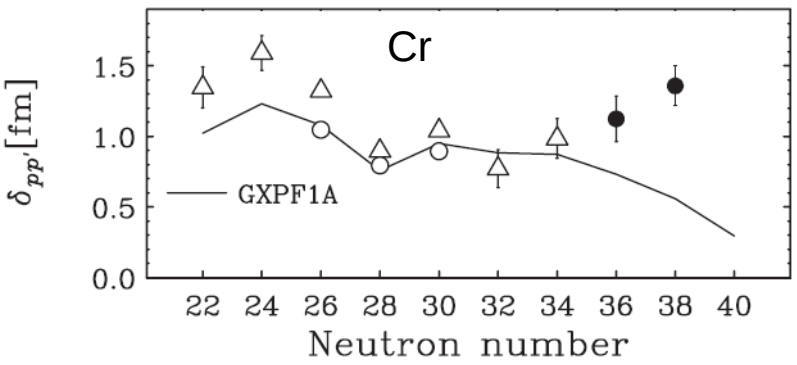
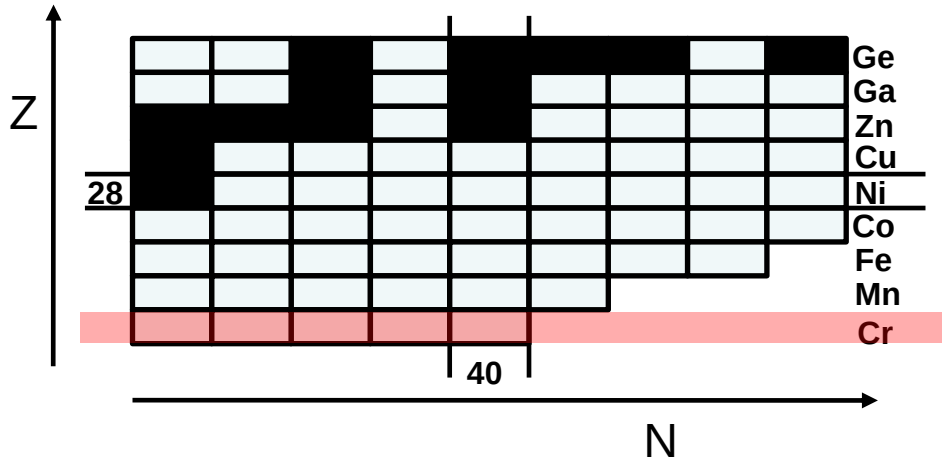
N. Aoi *et al*. PRL 102, 012502 (2009)




➢Enhancement of collectivity from $^{56}$Cr to $^{62}$Cr

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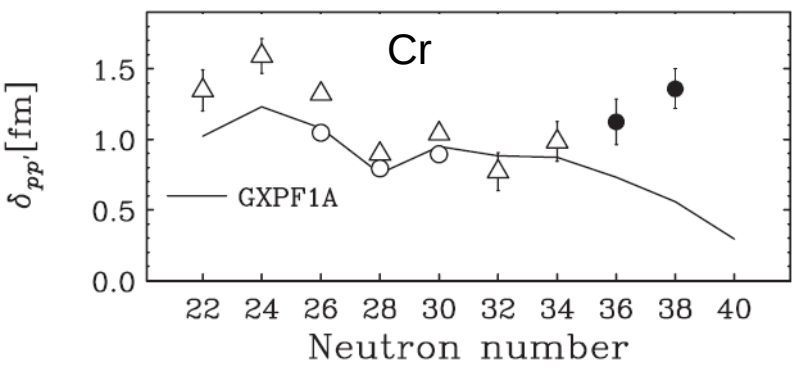


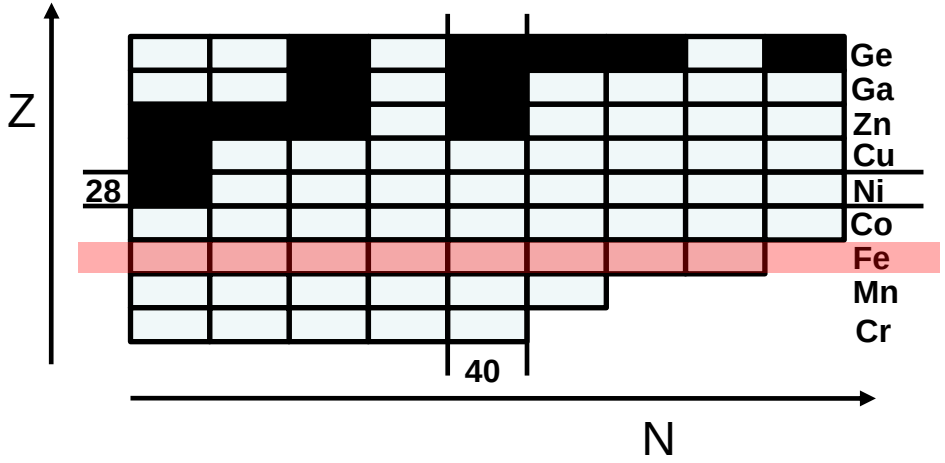


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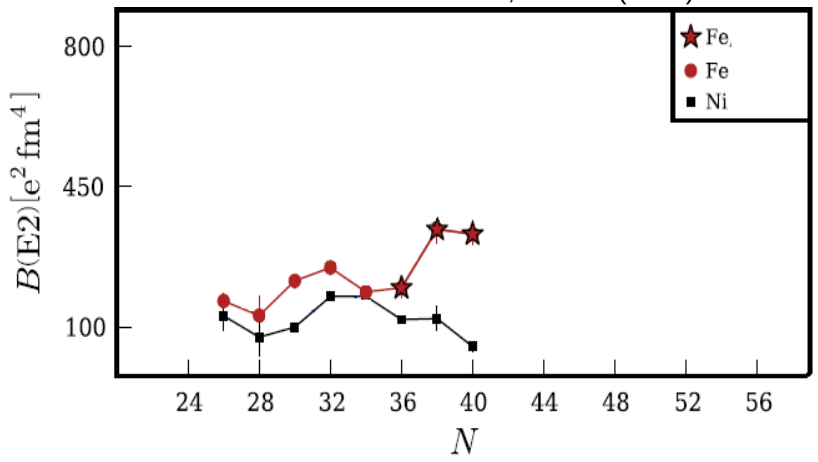


➢Rapid increase of collectivity

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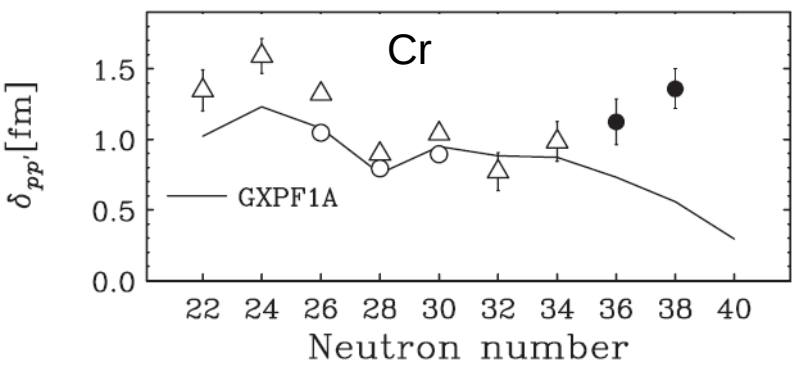


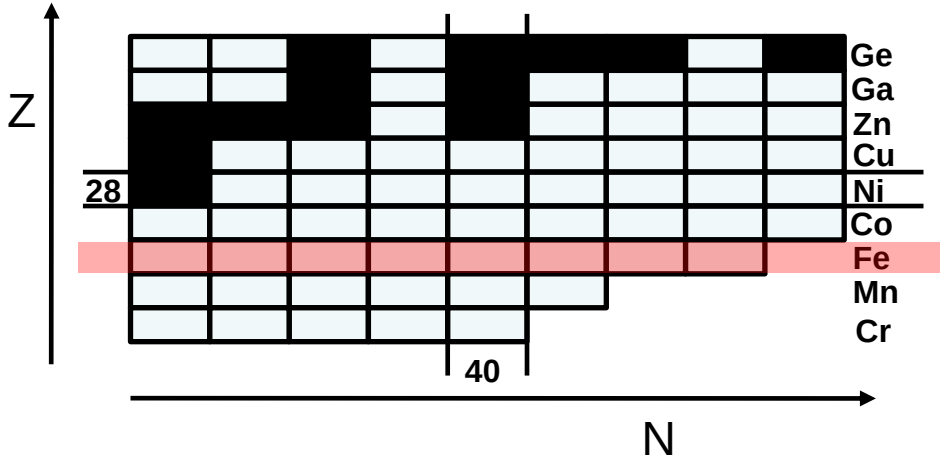


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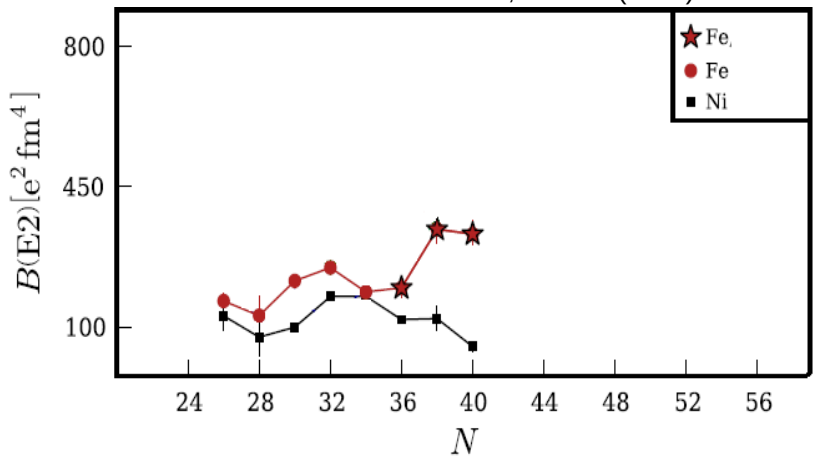


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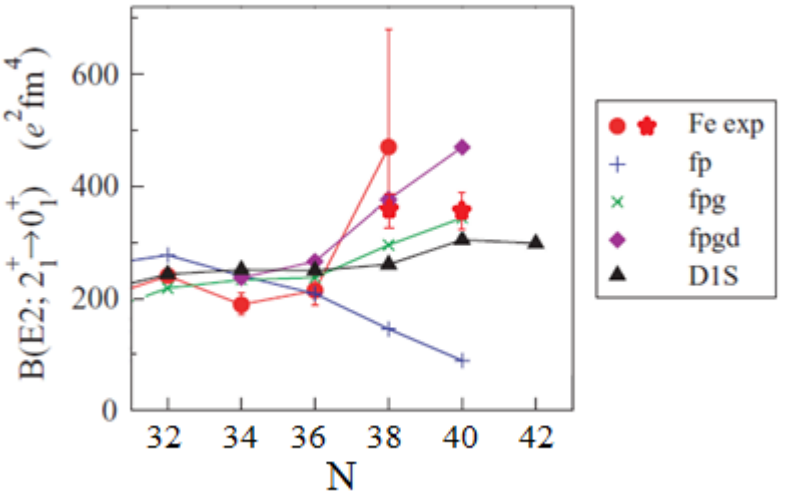


→ Important role of the neutron $g_{9/2}$ and $d_{5/2}$ intruder orbitals

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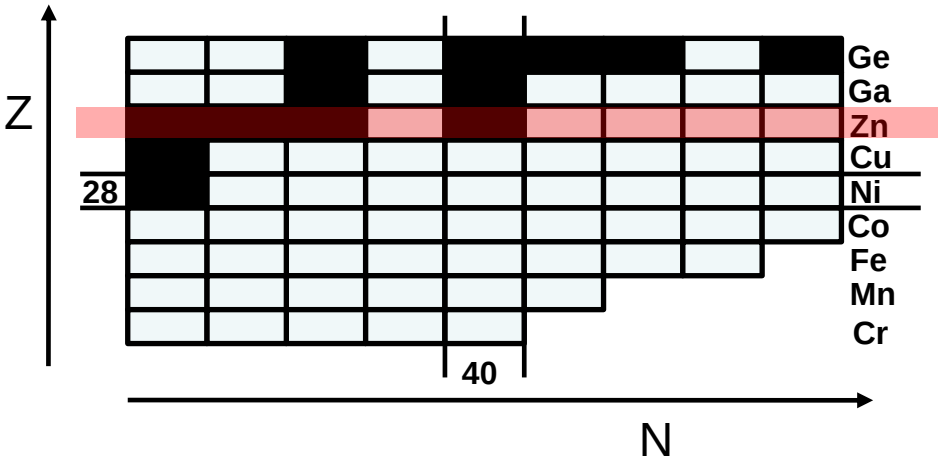


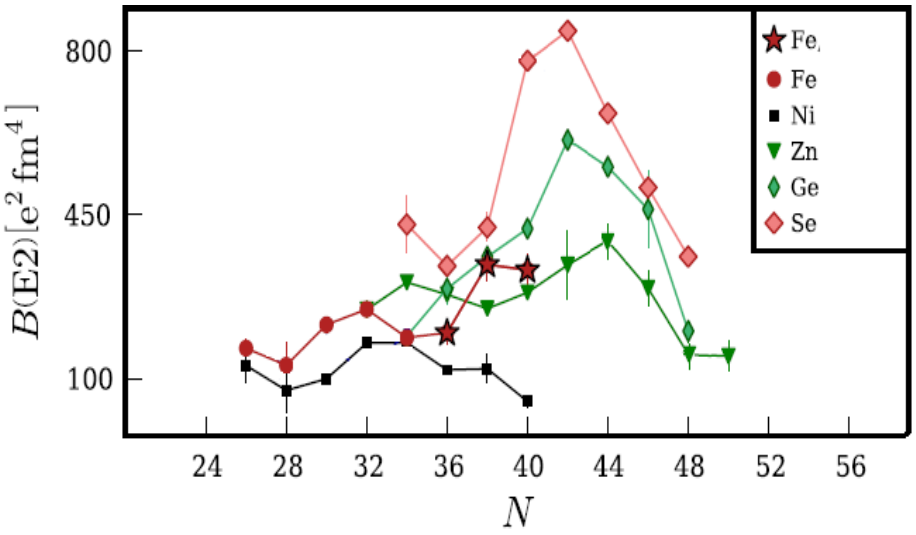

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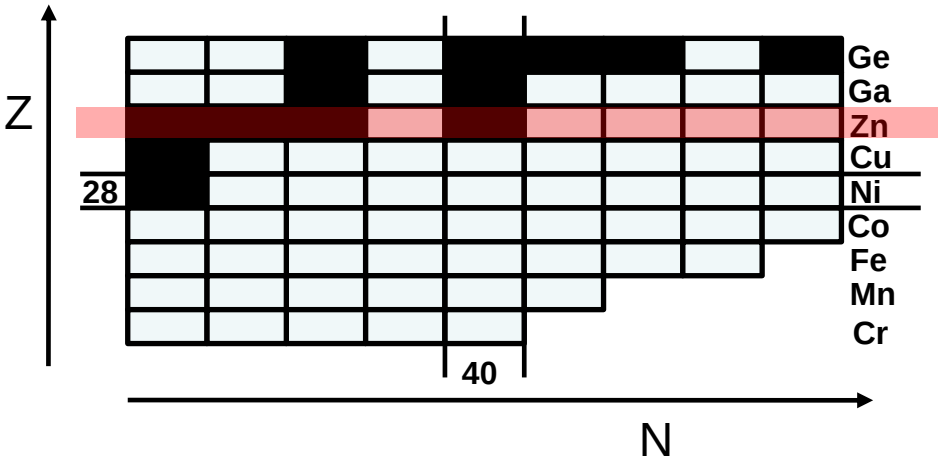


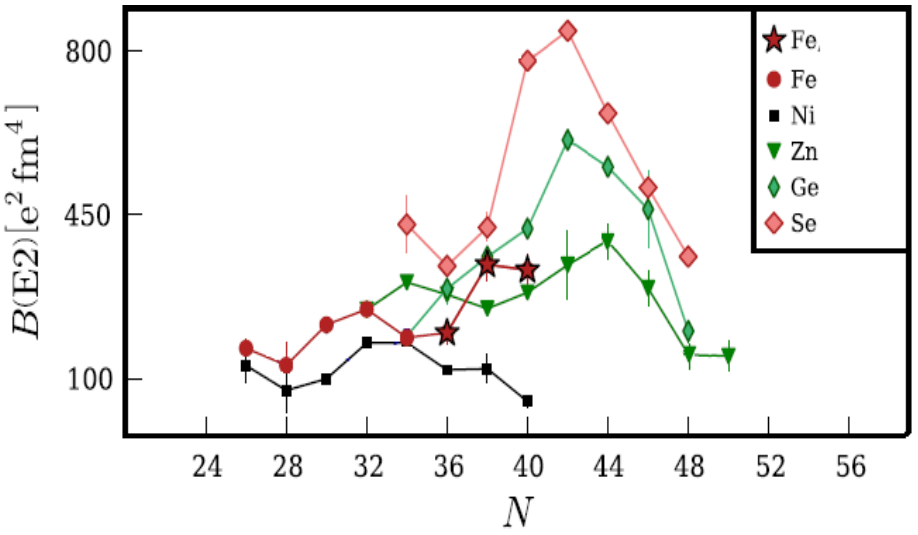


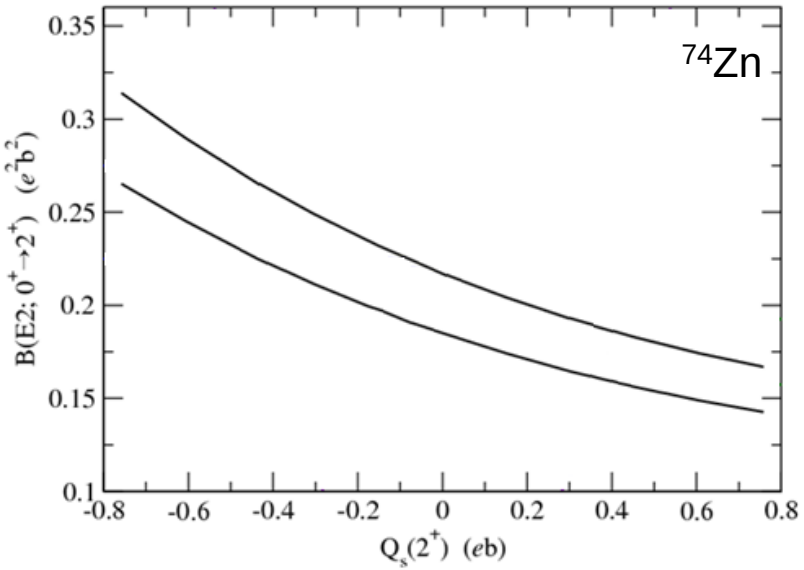


Ref: J. Van de Walle thesis

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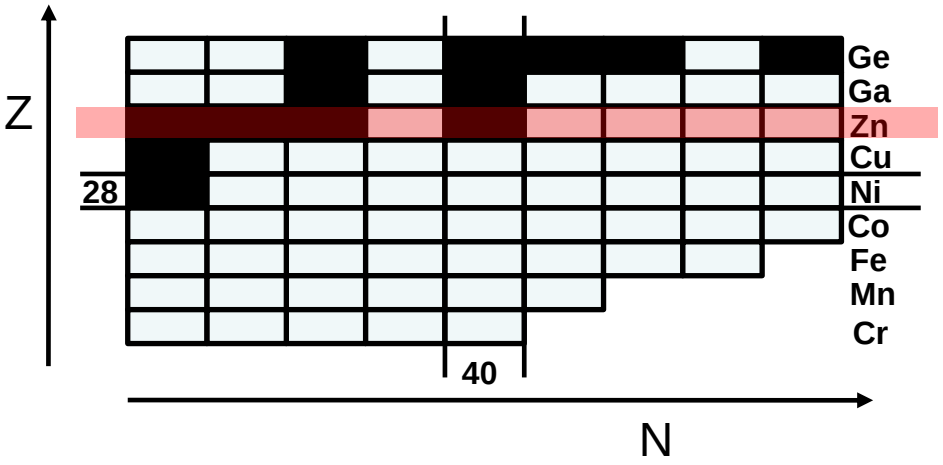


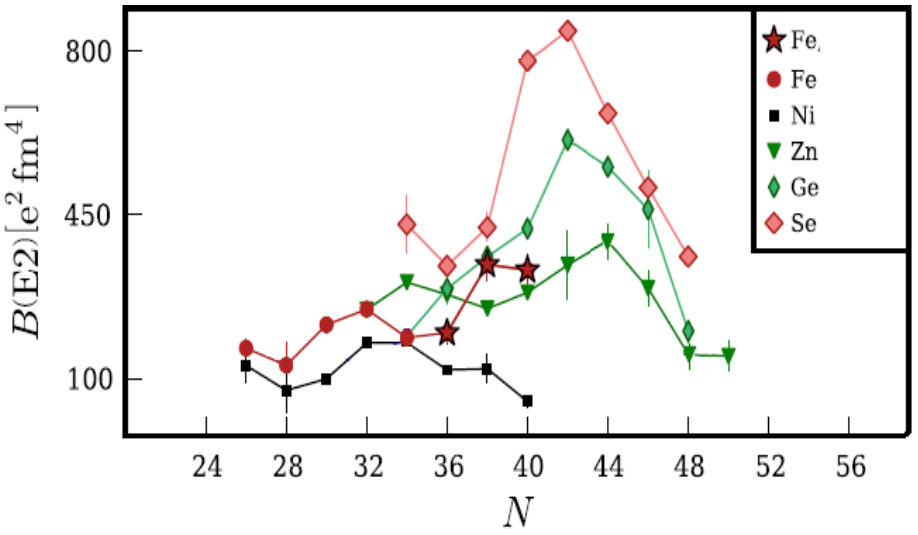


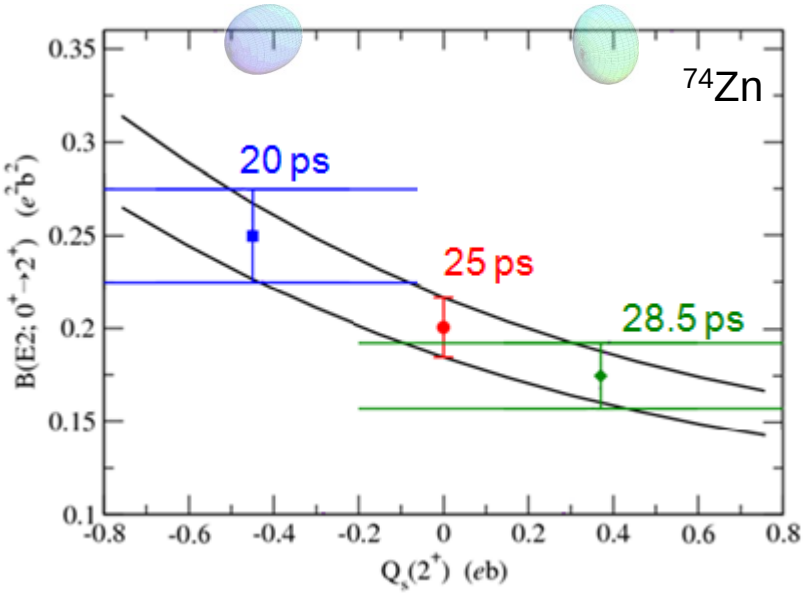


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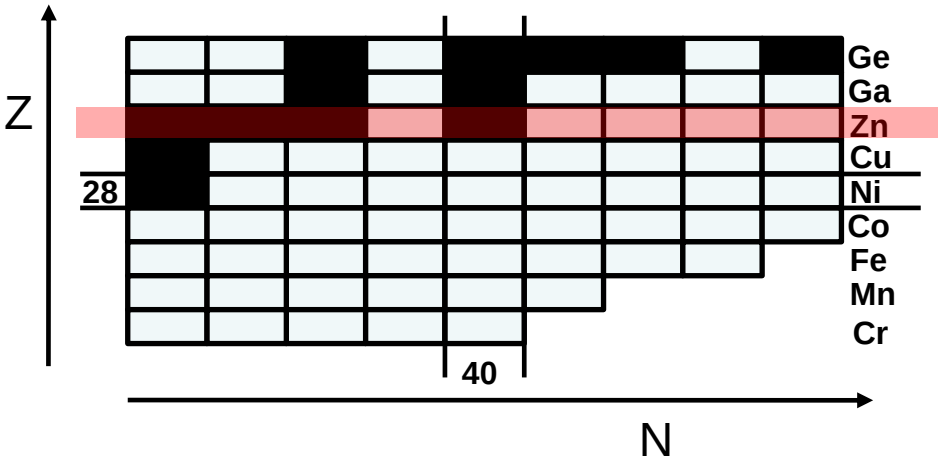


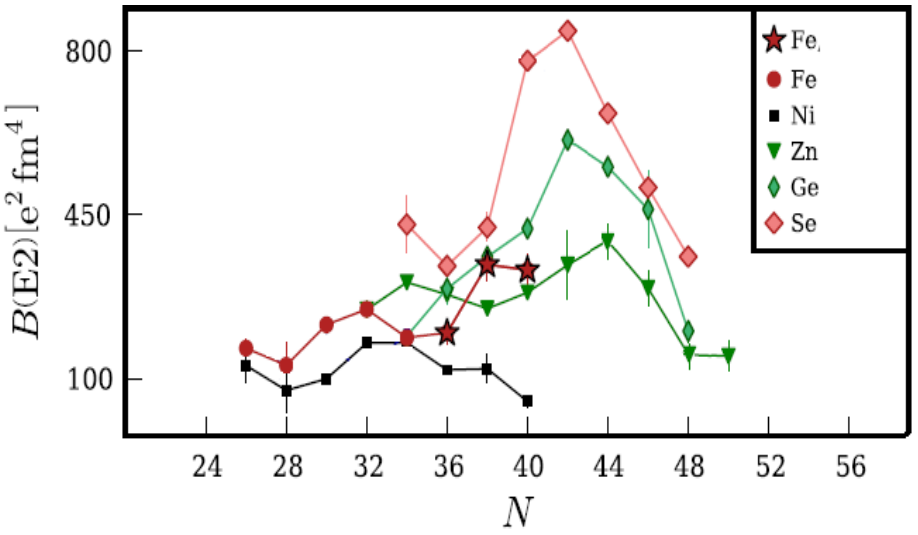


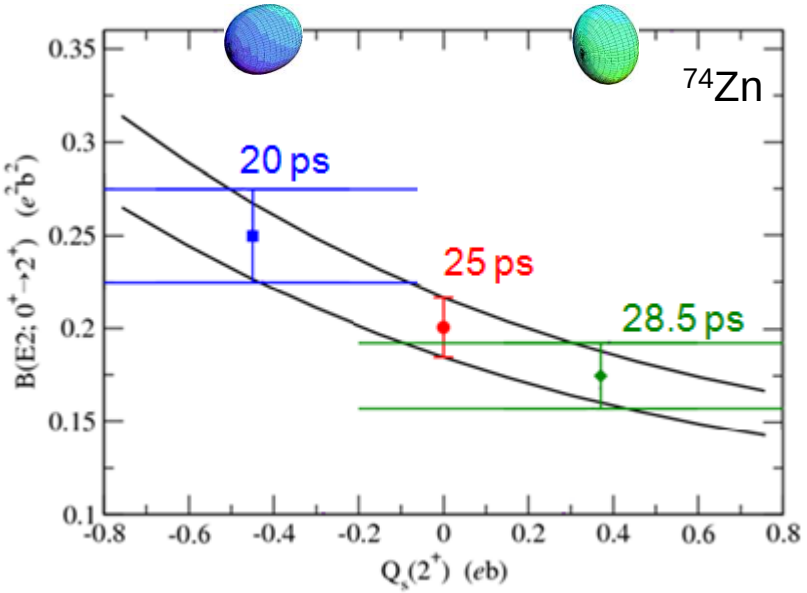


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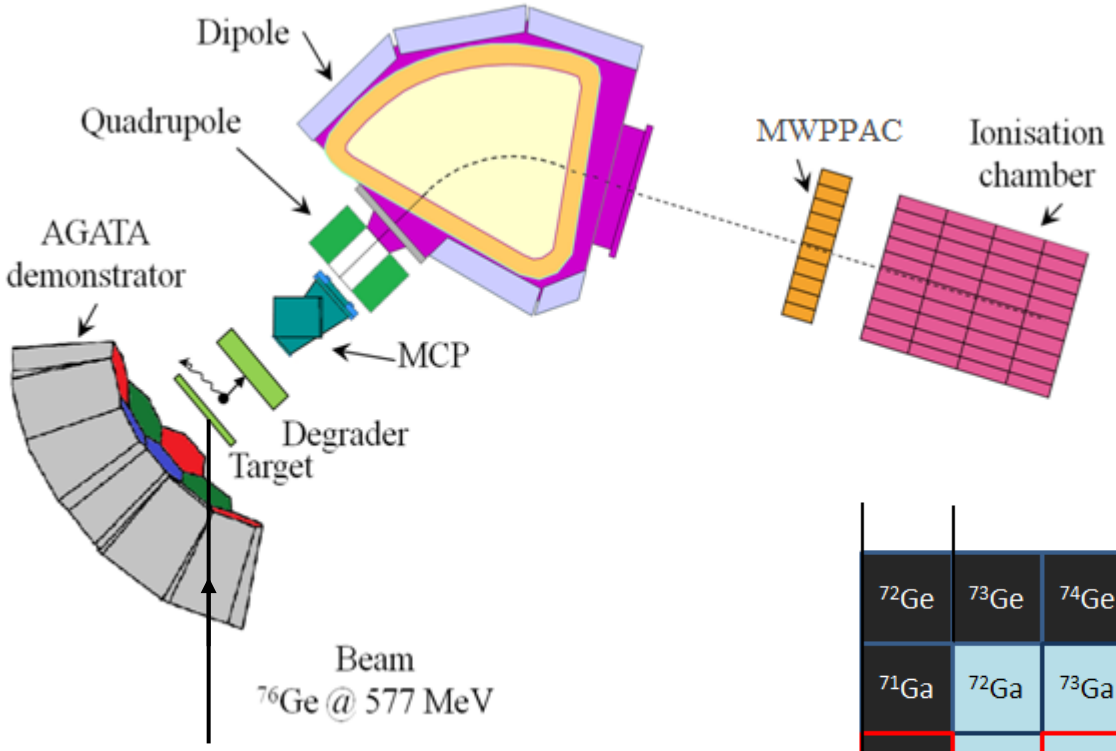
- Lifetime measurement to determine accurate :
  - B(E2) value for $2^+/4^+$ states
  - shape
- Comparison with theory

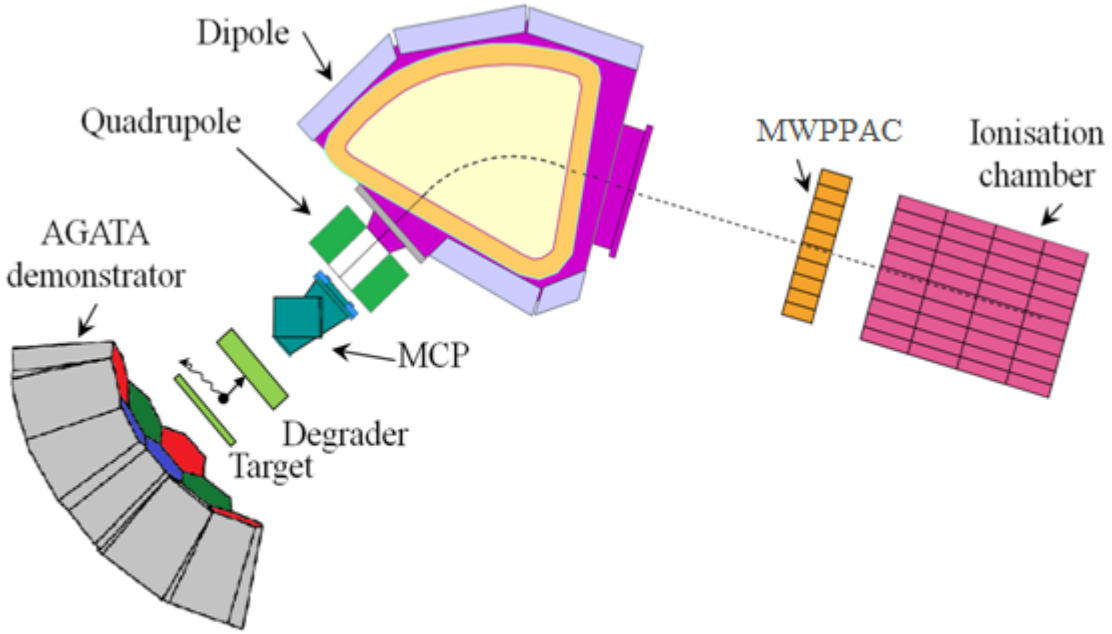
# Experiment



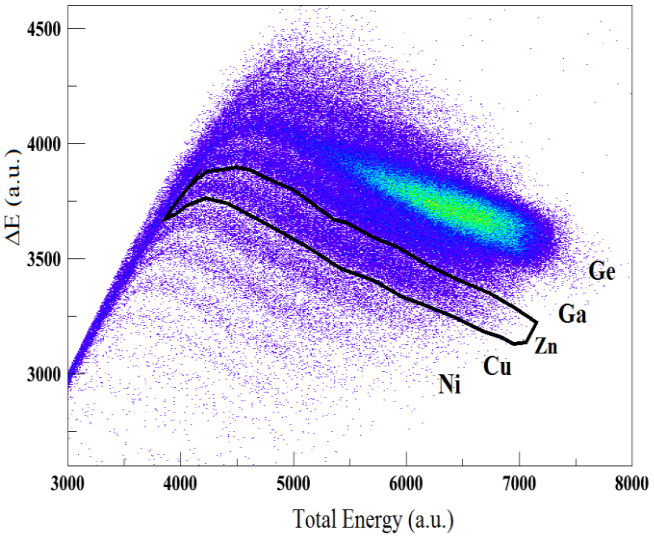

❖ multi-nucleon transfer reaction :
$^{76}$Ge on $^{238}$U @ 577MeV, 0.3 pnA

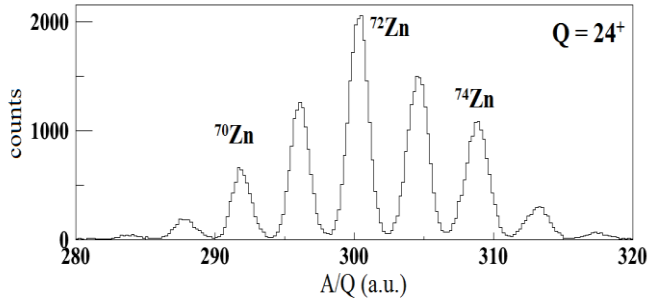
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $^{72}$Ge | $^{73}$Ge | $^{74}$Ge | $^{75}$Ge | $^{76}$Ge | $^{77}$Ge | $^{78}$Ge | $^{79}$Ge | $^{80}$Ge | $^{81}$Ge | $^{82}$Ge |
| $^{71}$Ga | $^{72}$Ga | $^{73}$Ga | $^{74}$Ga | $^{75}$Ga | $^{76}$Ga | $^{77}$Ga | $^{78}$Ga | $^{79}$Ga | $^{80}$Ga | $^{81}$Ga |
| $^{70}$Zn | $^{71}$Zn | $^{72}$Zn | $^{73}$Zn | $^{74}$Zn | $^{75}$Zn | $^{76}$Zn | $^{77}$Zn | $^{78}$Zn | $^{79}$Zn | $^{80}$Zn |
| $^{69}$Cu | $^{70}$Cu | $^{71}$Cu | $^{72}$Cu | $^{73}$Cu | $^{74}$Cu | $^{75}$Cu | $^{76}$Cu | $^{77}$Cu | $^{78}$Cu | $^{79}$Cu |
| $^{68}$Ni | $^{69}$Ni | $^{70}$Ni | $^{71}$Ni | $^{72}$Ni | $^{73}$Ni | $^{74}$Ni | $^{75}$Ni | $^{76}$Ni | $^{77}$Ni | $^{78}$Ni |
| N=40 | | | | | $\nu g_{9/2}$ | | | | | N=50 |

# Experiment



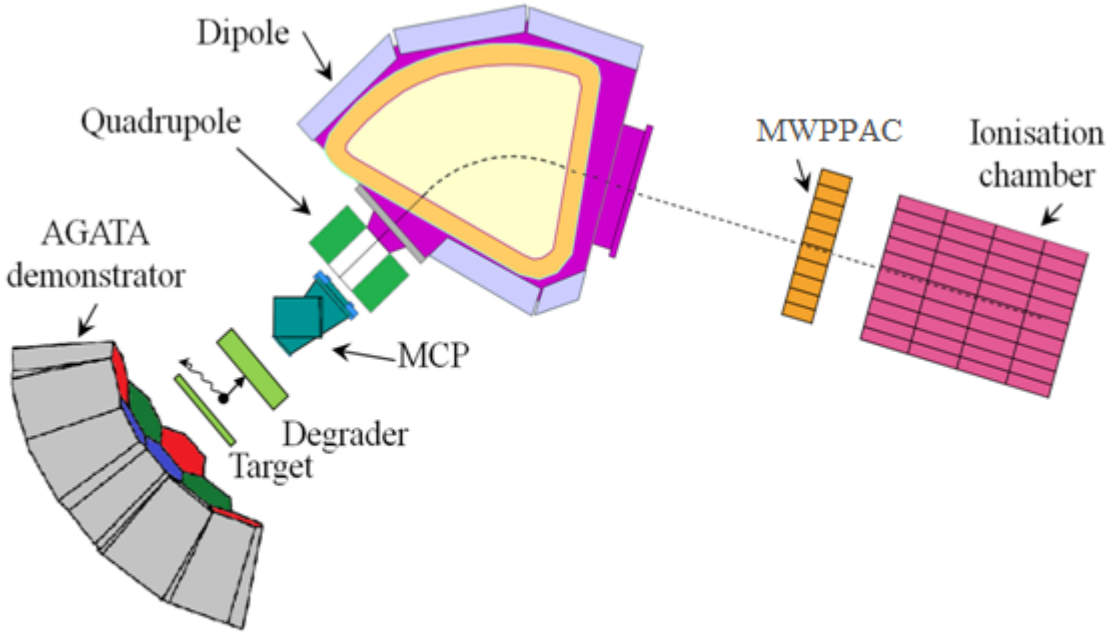

PRISMA




- PRISMA rotated at 55°
- Z, Q, A well separated

# Experiment

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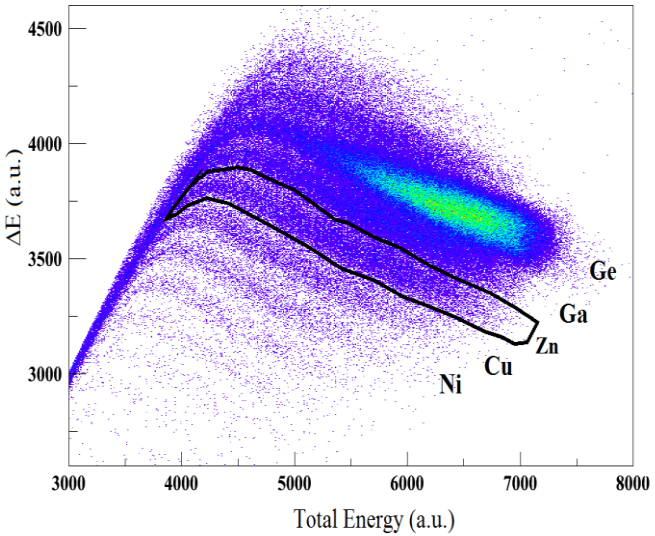


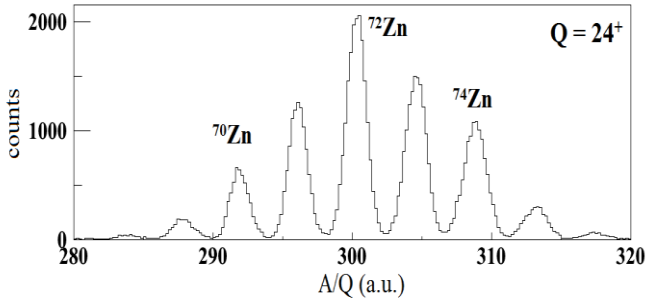


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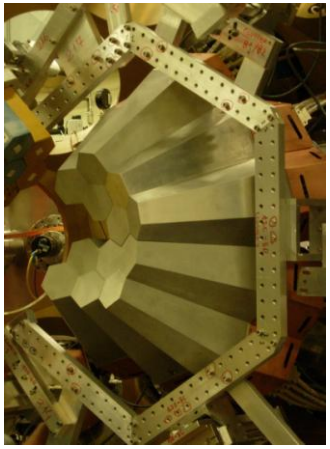
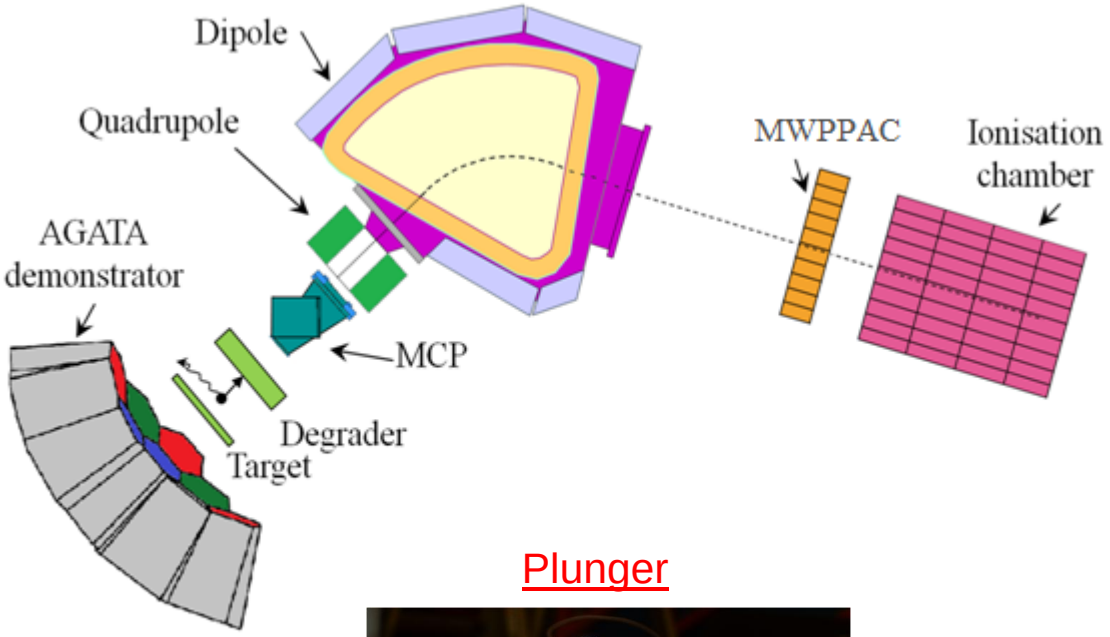
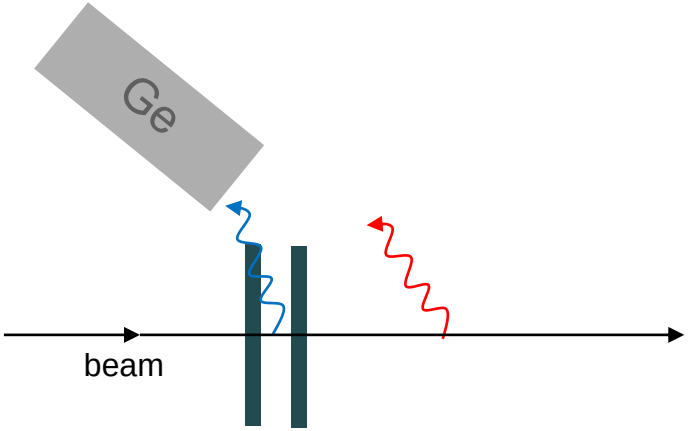


AGATA

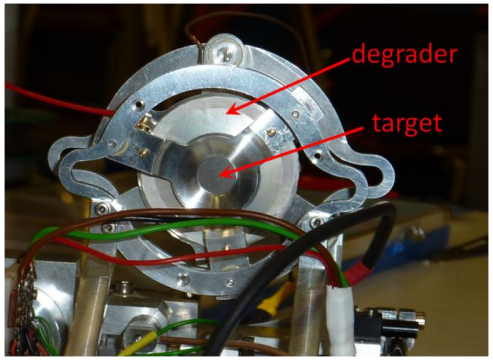
❖ 4 triple clusters
❖ γ rate : 50 kHz per crystal
❖18 cm from target and [135°/175°] range

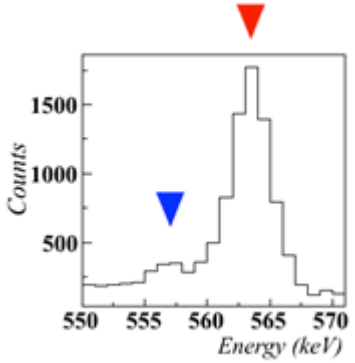
# Experiment



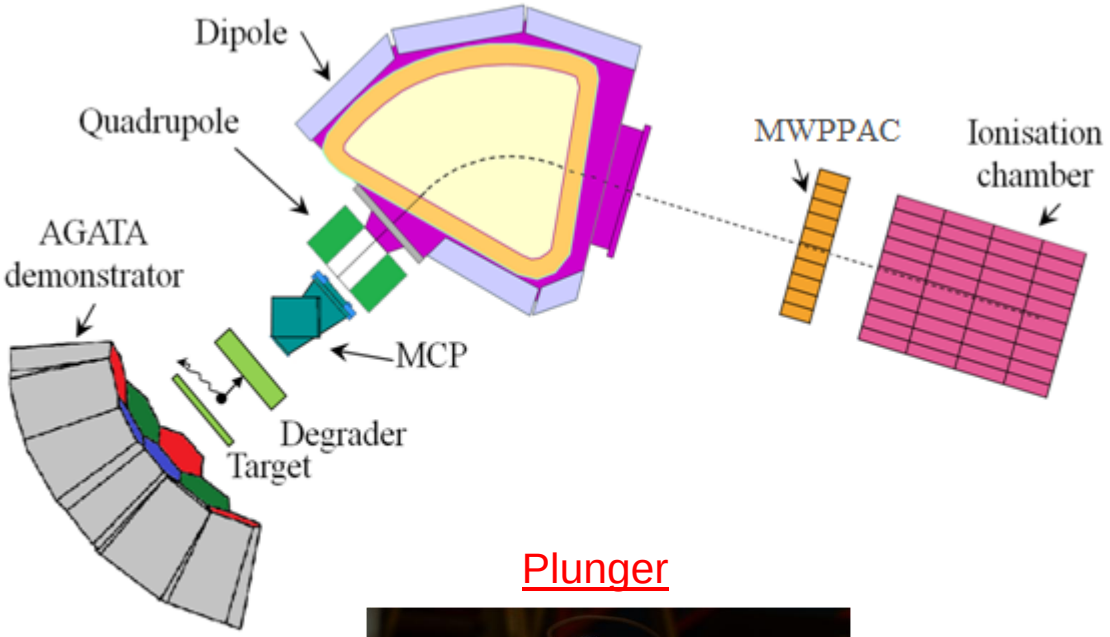

Plunger

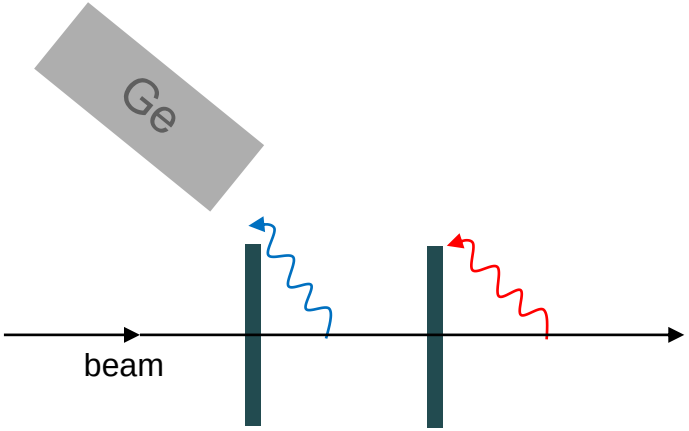



- 1.4 mg/cm$^2$-thick $^{238}$U target
- 4.2 mg/cm$^2$-thick Nb degrader
- 5 distances : 100, 200, 500, 1000, 1900 µm

# Experiment

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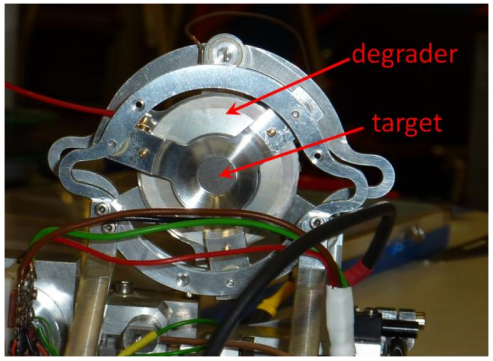


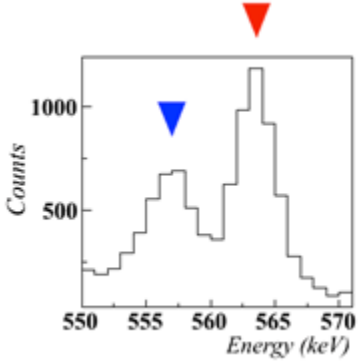


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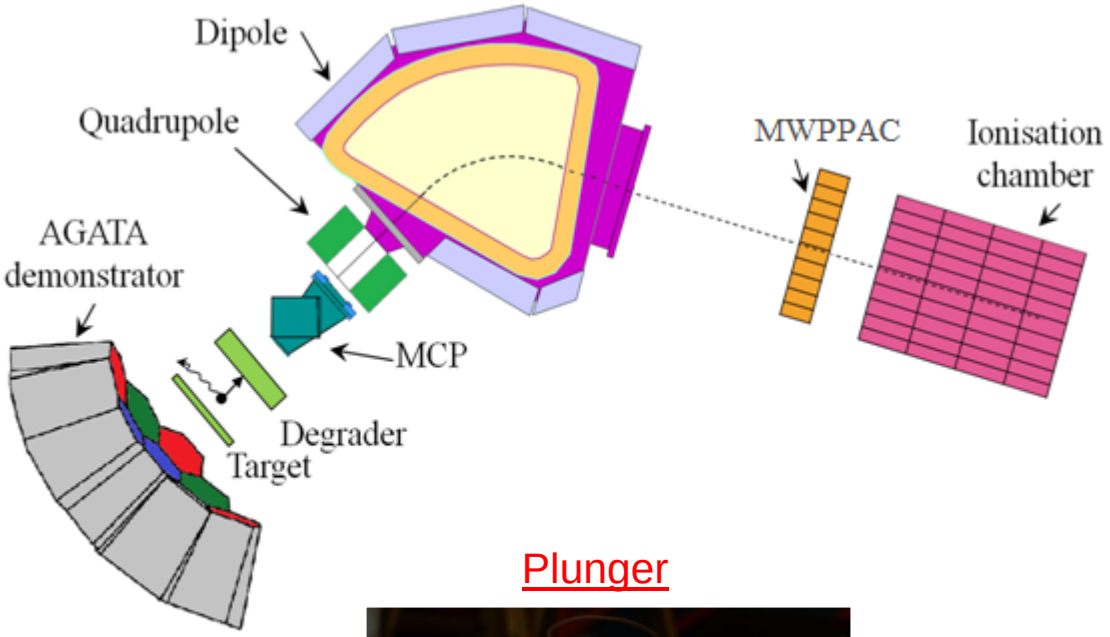
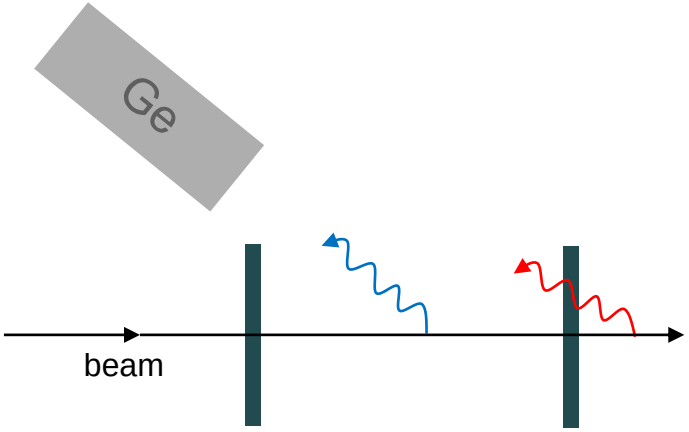
# Plunger device

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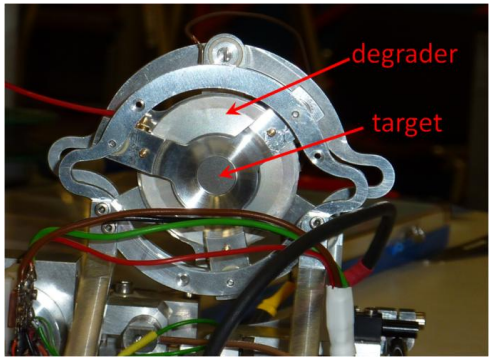


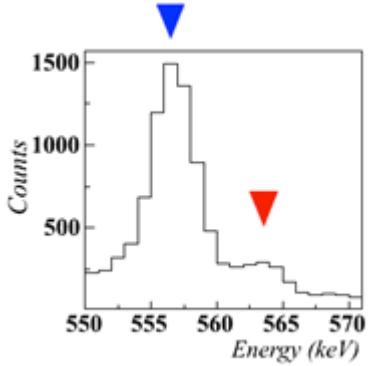


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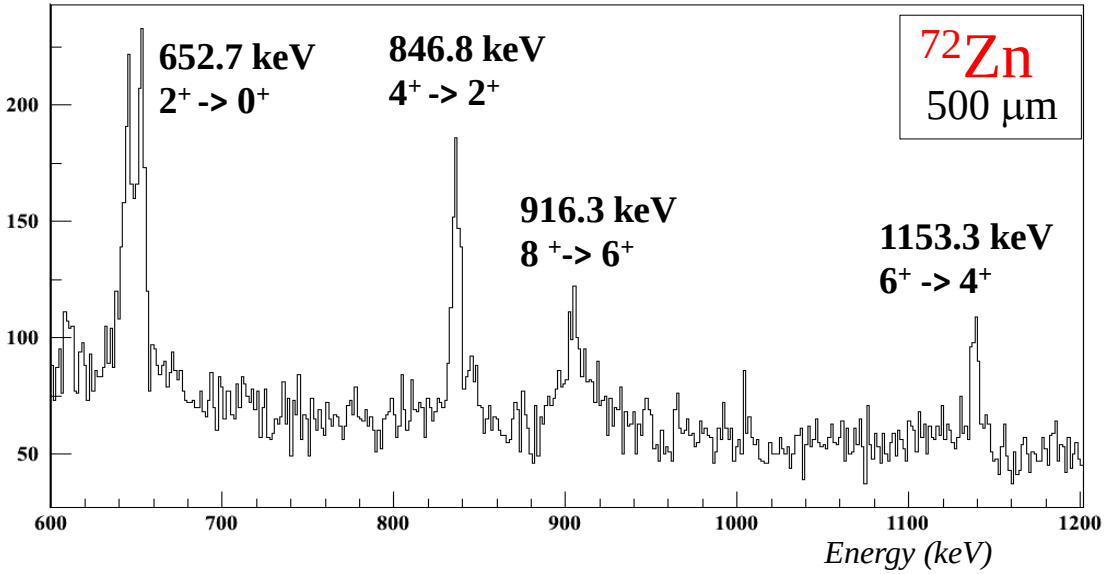
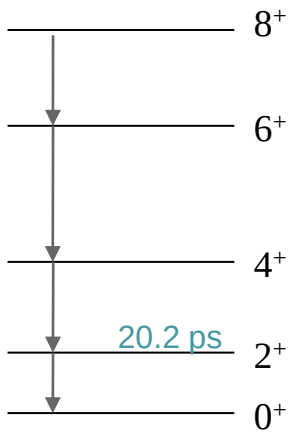
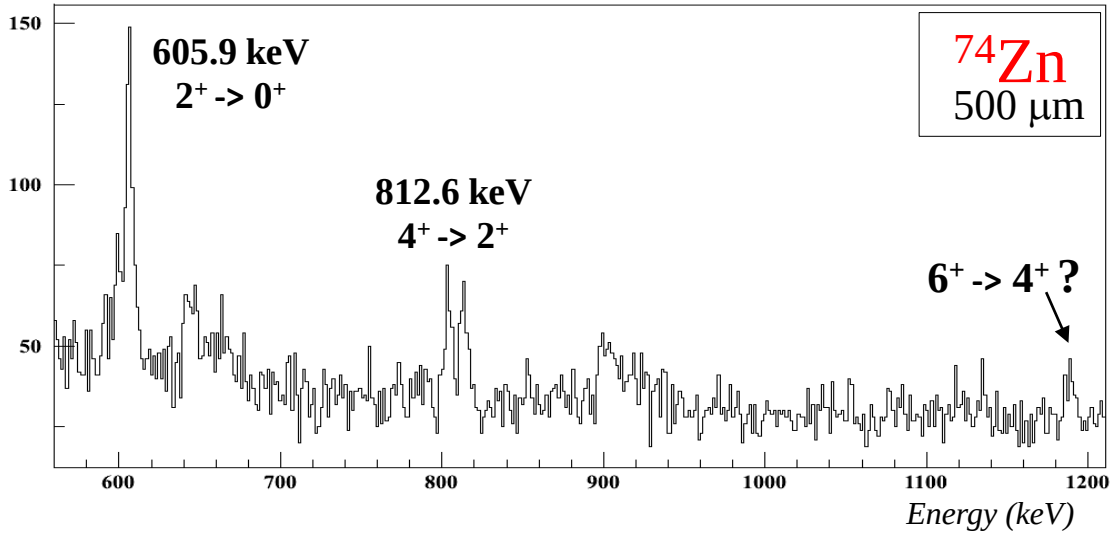
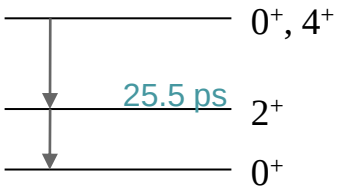
# $^{72,74}$Zn spectra



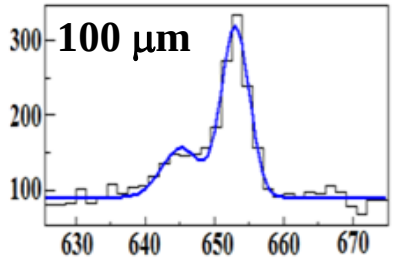



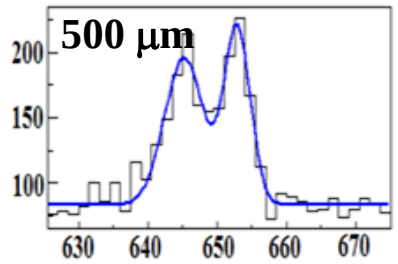

Data taken from NNDC

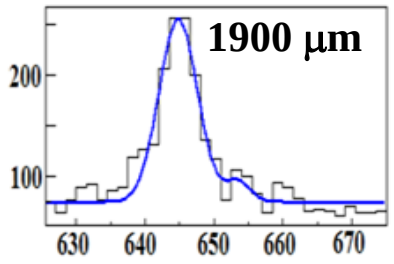
# $^{72,74}$Zn spectra

$^{72}$Zn

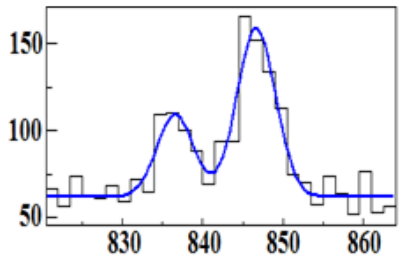
$2^+ \rightarrow 0^+$

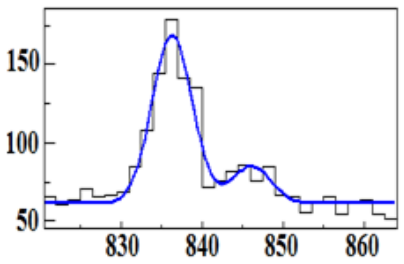


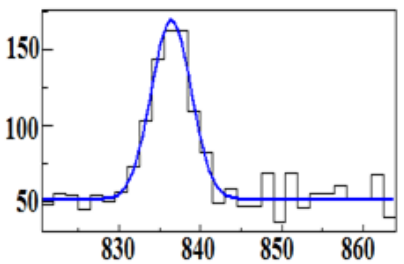




$4^+ \rightarrow 2^+$

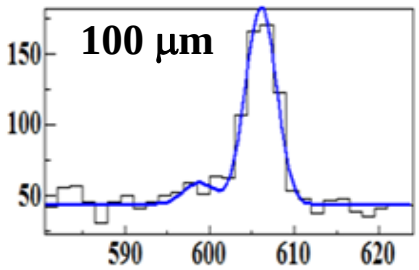


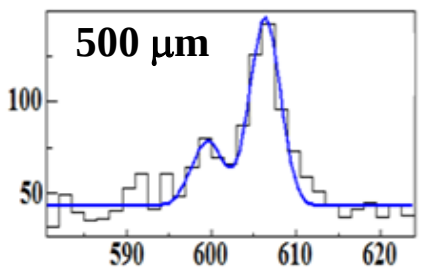


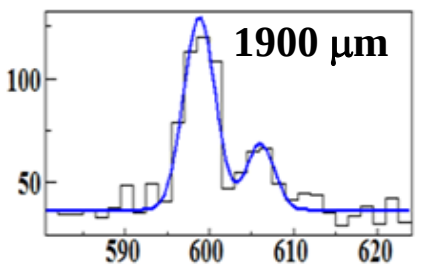


$^{74}$Zn

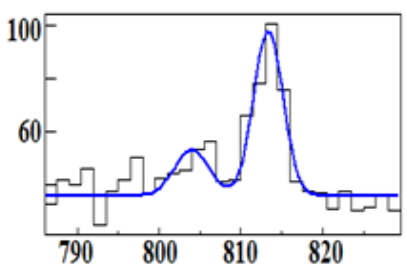
$2^+ \rightarrow 0^+$

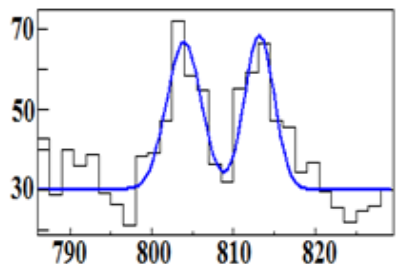


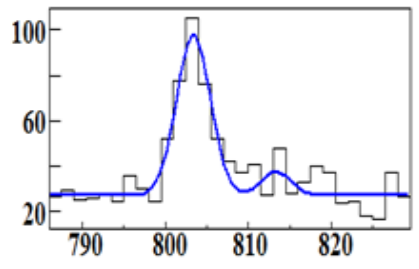




$4^+ \rightarrow 2^+$

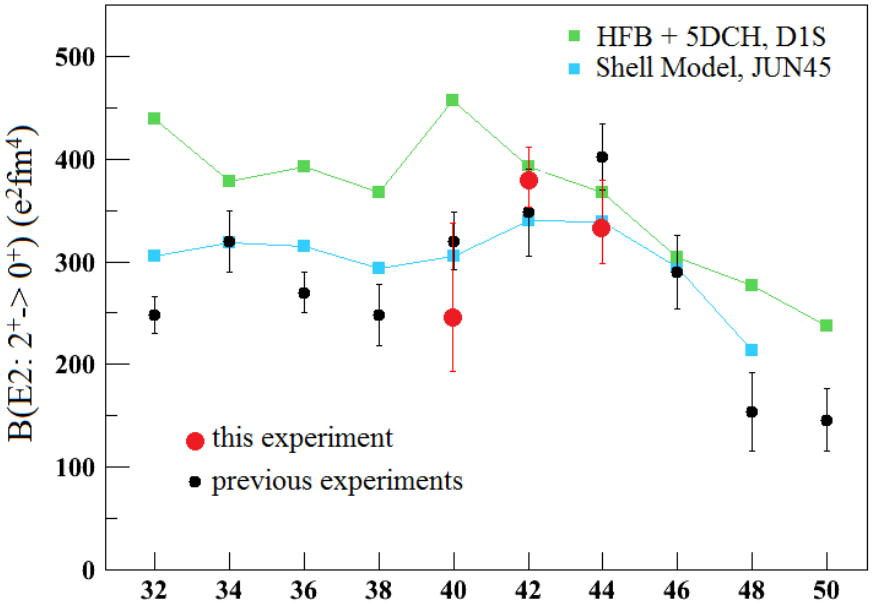






# B(E2; $2^+ \rightarrow 0^+$)

- Maximum of collectivity at N=42

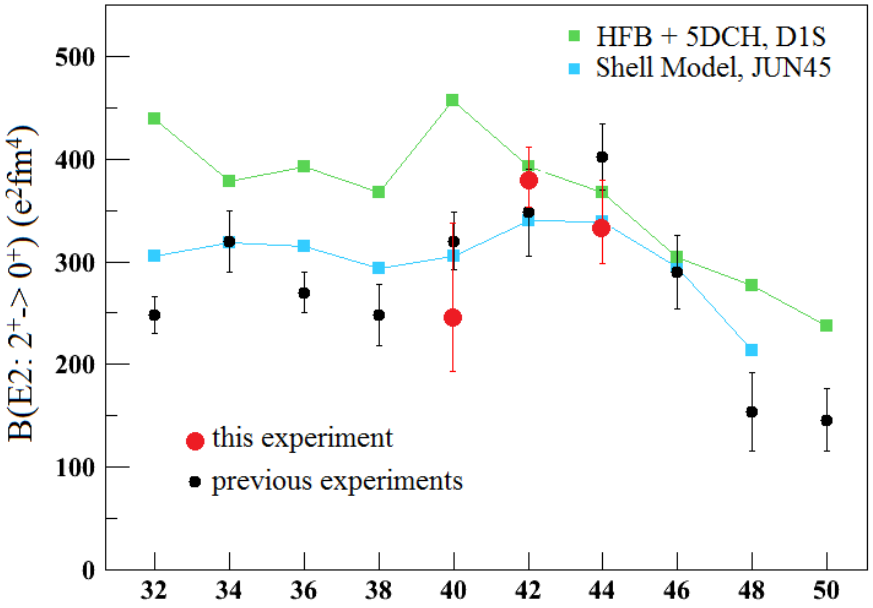



Ref : B. Pritychenko *et al.* arXiv : 1102.3365v1 (2011)

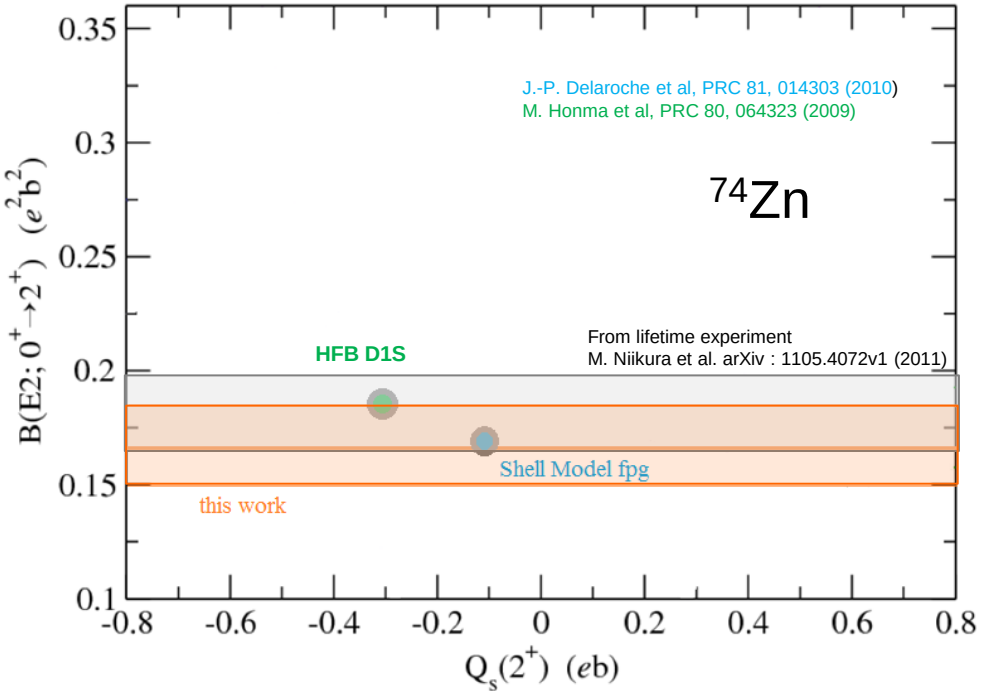
| | $\tau$ (ps) | B(E2) down ($e^2fm^4$) |
|---|---|---|
| $^{70}$Zn | $6.2 \pm 1.7$ | $244^{+92}_{-52}$ |
| $^{72}$Zn | $18.2 \pm 1.4$ | $380^{+32}_{-27}$ |
| $^{74}$Zn | $30.1 \pm 3.6$ | $333^{+46}_{-35}$ |

# B(E2; $2^+ \rightarrow 0^+$)

- Maximum of collectivity at N=42
- In agreement with other lifetime measurement and theory

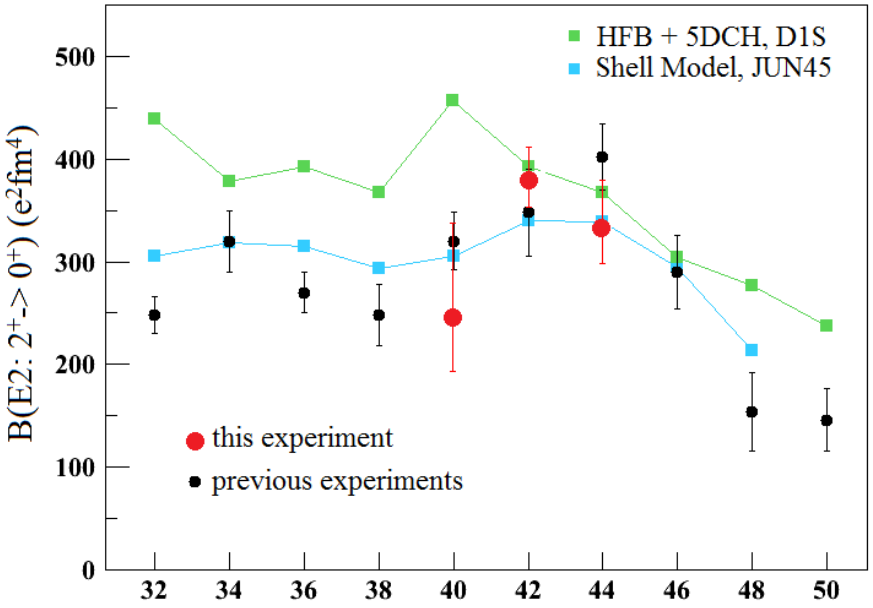



Ref : B. Pritychenko *et al.* arXiv : 1102.3365v1 (2011)

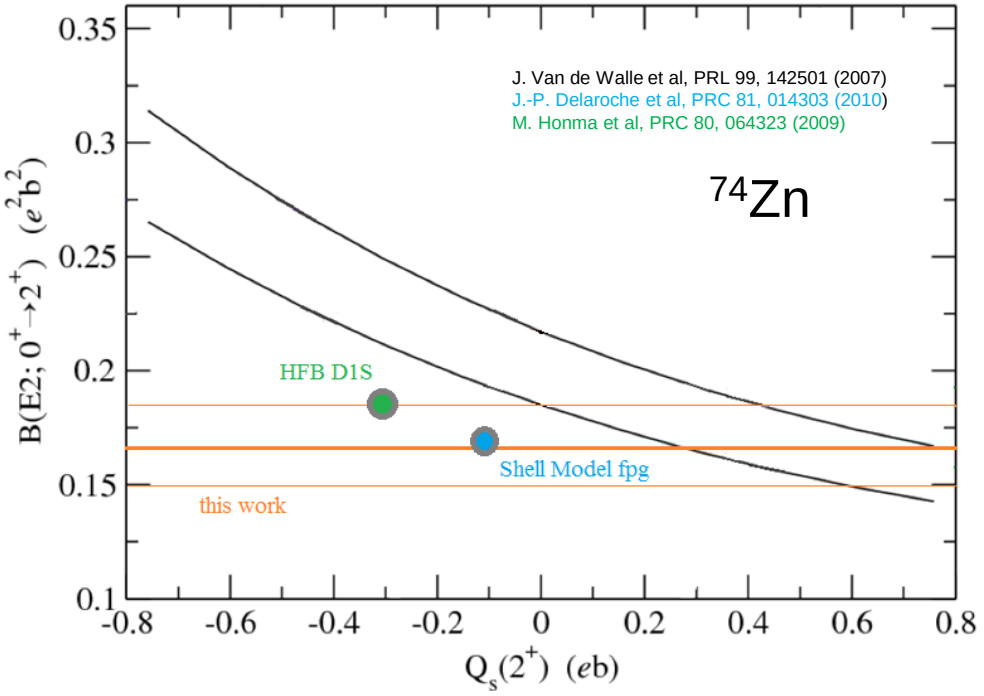


# $B(E2; 2^+ \rightarrow 0^+)$

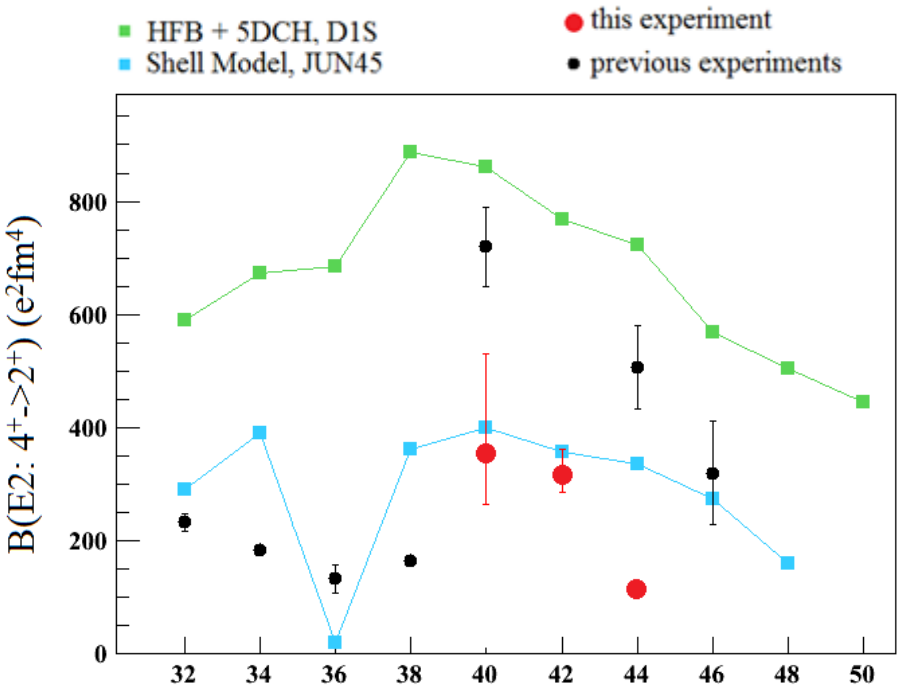
- Maximum of collectivity at N=42
- In agreement with other lifetime measurement and theory
- From coulex data, an oblate shape is favored




Ref : B. Pritychenko *et al.* arXiv : 1102.3365v1 (2011)



# B(E2; $4^+ \rightarrow 2^+$)



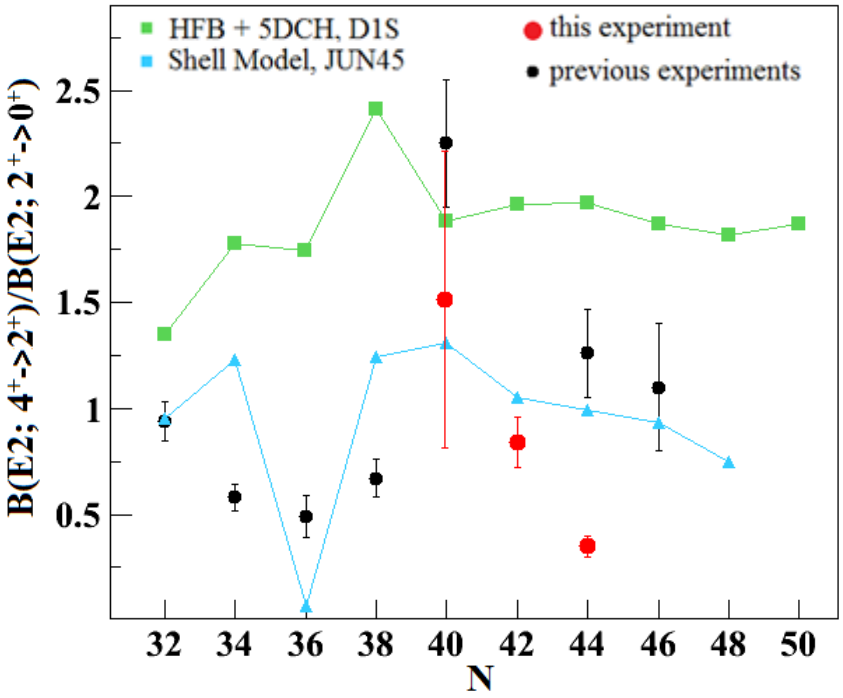

| | $\tau$ (ps) | B(E2) down ($e^2fm^4$) |
|---|---|---|
| $^{70}$Zn | $3.9 \pm 1.3$ | $353^{+176}_{-89}$ |
| $^{72}$Zn | $5.9 \pm 0.7$ | $319^{+43}_{-34}$ |
| $^{74}$Zn | $20.0 \pm 1.8$ | $116^{+11}_{-10}$ |

- Similar than in stable Zn isotopes
- Discrepancy for $^{70,74}$Zn with previous values

- Rapid decrease toward N=44

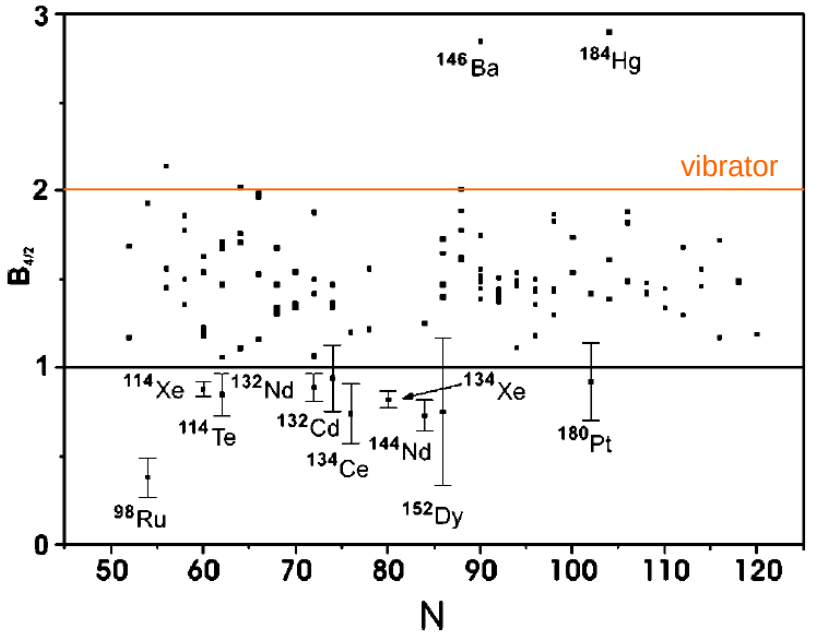
# B(E2) ratio

Zn isotopes




Other low values in this mass region:
$^{60}$Ni: 0.57, $^{64}$Ni: 0.86
$^{68}$Ge: 0.79, $^{70}$Ge: 0.55

Nonmagic nuclei 40<Z<80




From R.B. Ckirli et al. PRC 70, 047302 (2004)

# Conclusion

- Lifetime measurements of $2^+$,$4^+$ states in $^{70,72,74}$Zn
- Deduced B(E2) and comparison with previous data and theory

- Agreement for B(E2; $2^+ \rightarrow 0^+$) with previous measurement
- Maximum of collectivity at N=42

- Low B(E2; $4^+ \rightarrow 2^+$)/B(E2; $2^+ \rightarrow 0^+$) for $^{70,72,74}$Zn:
  Inconsistent with previous B(E2; $4^+ \rightarrow 2^+$) extraction
  Decrease toward $^{74}$Zn, sign for non collective $4^+$ states?

<u>Prospective</u>: extend lifetime to $^{76}$Zn
dedicated coulomb excitation for $^{70/72}$Zn

**M. Doncel** [a], **A. Görgen** [b], **E. Sahin** [c], M. Albers [d], S. Aydin [e], M. Bostan [f], E. Clément [g], L. Corradi [c], G. de Angelis [c], G. de France [g], A. Dewald [d], G. Duchene [h], M.N. Erduran [f], E. Farnea [e], E. Fioretto [c], C. Fransen [d], G. Friessner [d], A. Gadea [i], A. Gottardo [c], M. Hackstein [d], T. Huyuk [i], H. Iwasaki [d], A. Jungclaus [j], W. Korten [b], R. Krücken [k], A. Kusoglu [f], S. Lenzi [e], J. Ljungvall [ℓ], S. Lunardi [e], R. Menegazzo [e], D. Mengoni [e], C. Michelagnoli [e], G. Montagnoli [e], D.R. Napoli [c], A. Obertelli [b], R. Orlandi [m], Th. Pissulla [d], G. Pollarolo [n], B. Quintana [a], F. Recchia [e], W. Rother [d], M.-D. Salsac [b], F. Scarlassara [e], R.P. Singh [o], A. Stefanini [c], B. Sulignano [b], S. Szilner [p], Ch. Theisen [b], C. Ur [e], J.J. Valiente-Dobón [c], J. van de Walle [q]

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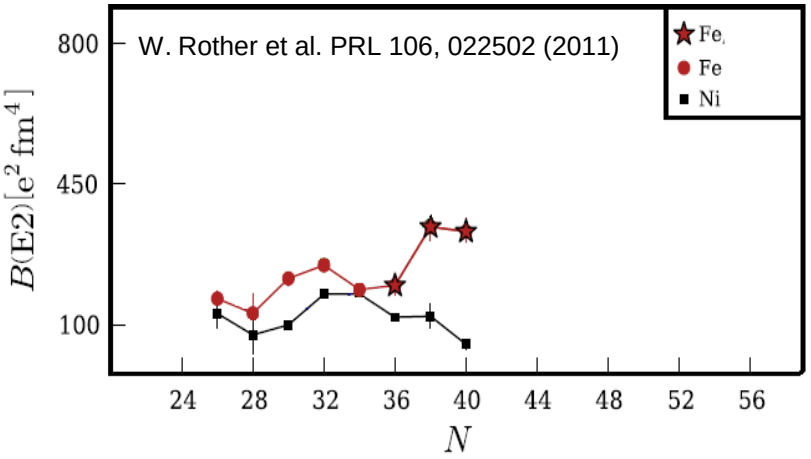
[k] *Technische Universität München, Germany*
[ℓ] *CSNSM Orsay, IN2P3/CNRS, France*
[m] *University of the West of Scotland, Scotland*
[n] *Dipartimento di Fisica Teoria, Universitá di Torino, Italy*
[o] *Inter-University Accelerator Centre, New Delhi, India*
[p] *Ruder Boskovic Institute, Zagreb, Croatia*
[q] *ISOLDE, CERN, Geneva, Switzerland*

# Thank you for your attention

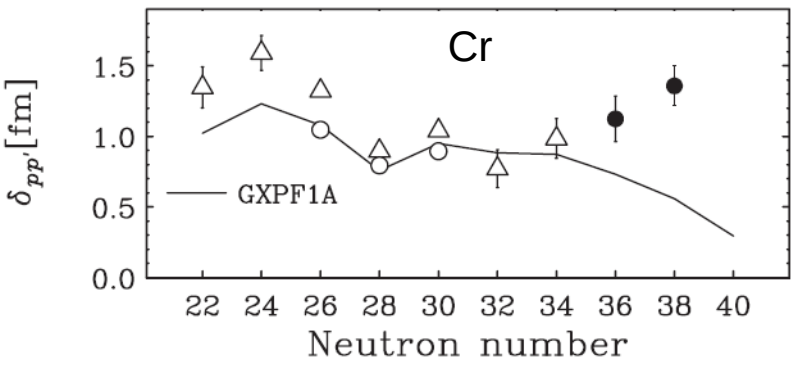
# Onset of collectivity near N=40



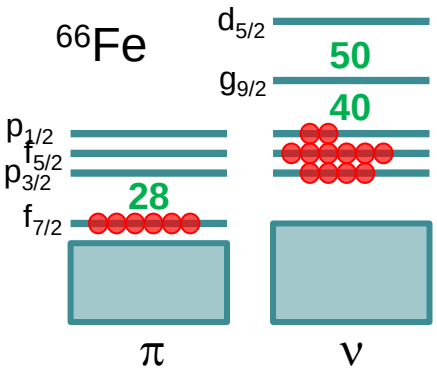

➢ Rapide increase of collectivity. Only reproduced by Shell Model with $^{48}$Ca core + LNPS interaction

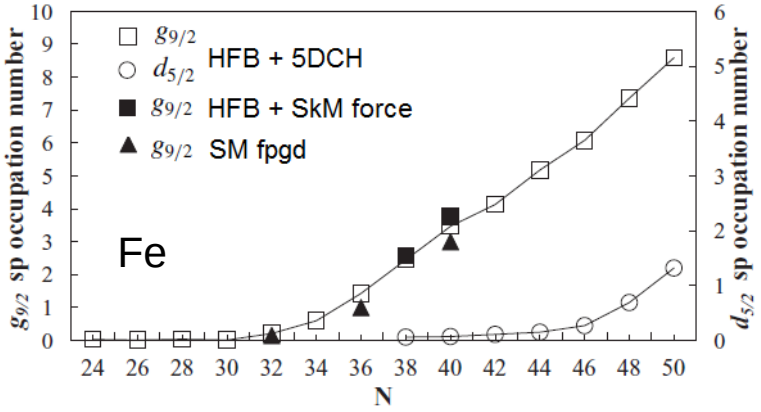
Ref: S.M. Lenzi et al. PRC 82, 054301 (2010)

N. Aoi *et al.* PRL 102, 012502 (2009)




➢Enhancement of collectivity from $^{56}$Cr to $^{62}$Cr

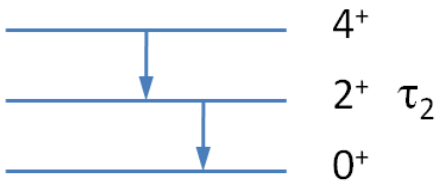



→ Important role of the neutron $g_{9/2}$ and $d_{5/2}$ intruder orbitals

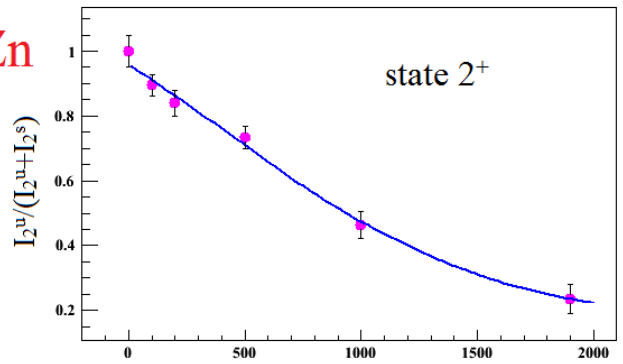
# Differential Decay Curve method

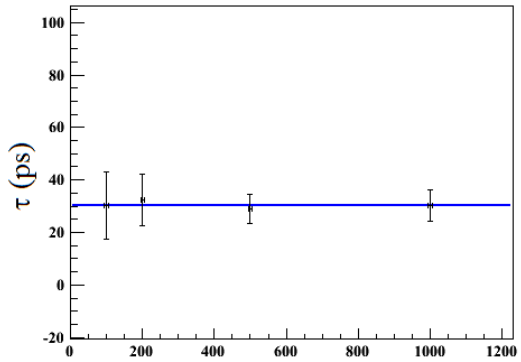
$$\tau_2(x) = \frac{-\left(I_{u,2}(x) - I_{u,4}(x)\right)}{v * \frac{d}{dx}\left(I_{u,2}\right)}$$



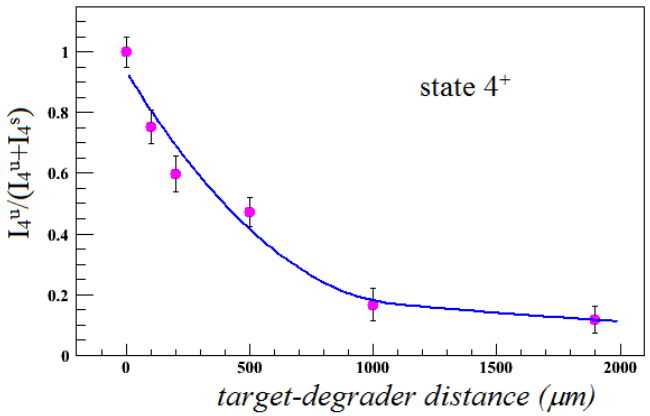

Ref: A. Dewald *et al.*, Z. Phys. A – Atomic Nuclei 334, 163-175 (1989)

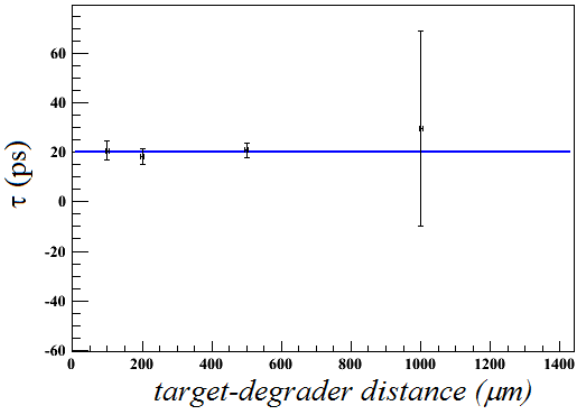
$^{74}$Zn




$\tau_{2+}$ = 30.1 ± 3.6 ps

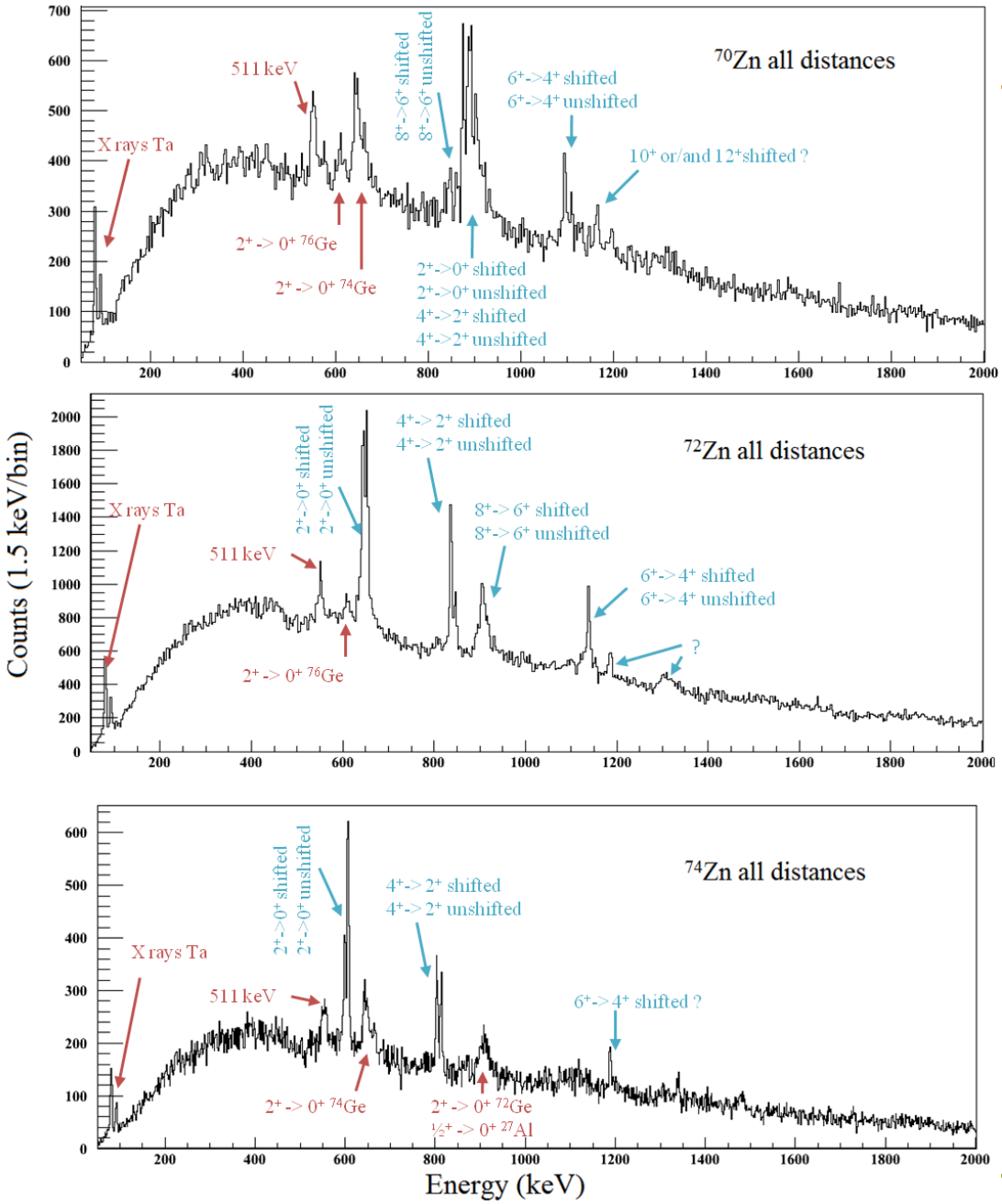


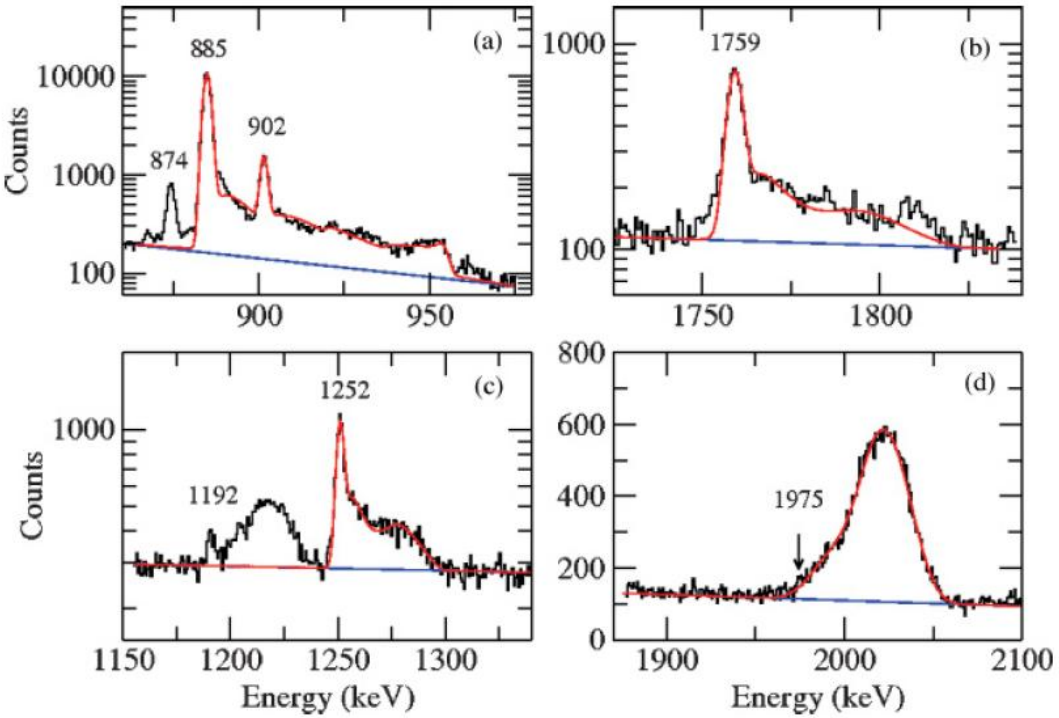




$\tau_{4+}$ = 20.0 ± 1.8 ps

| $^{76}$Ge | | $\tau$ (ps) | B(E2) down ($e^2fm^4$) |
|---|---|---|---|
| $2^+ \rightarrow 0^+$ : 563 keV | this experiment | $26.6 \pm 0.6$ | $545^{+12}_{-11}$ |
| | R. Lecomte *et al.* (coulomb excitation) | | $556 \pm 6$ |
| $4^+ \rightarrow 2^+$ : 847 keV | this experiment | $2.5 \pm 0.4$ | $750^{+140}_{-100}$ |
| | R. Lecomte *et al.* (coulomb excitation) | | $730 \pm 13$ |

| $^{74}$Zn | | $\tau$ (ps) | B(E2) ($e^2fm^4$) |
|---|---|---|---|
| $2^+ \rightarrow 0^+$ : 606 keV | this experiment | $30.1 \pm 3.6$ | $333^{+46}_{-35}$ |
| | O. Perru *et al.* (coulomb excitation) | | $408 \pm 30$ |
| | J. Van de Walle *et al.* (coulomb excitation) | | $401 \pm 32$ |
| | M. Niikura *et al.* (plunger experiment) | $27.2 \pm 1.9$ | $367 \pm 26$ |
| $4^+ \rightarrow 2^+$ : 813 keV | this experiment | $20.0 \pm 1.8$ | $116^{+11}_{-10}$ |
| | J. Van de Walle *et al.* (coulomb excitation) | | $507 \pm 74$ |


70Zn all distances
511 keV
X rays Ta
8+->6+ shifted
8+->6+ unshifted
6+->4+ shifted
6+->4+ unshifted
10+ or/and 12+shifted ?
2+ -> 0+ 76Ge
2+ -> 0+ 74Ge
2+->0+ shifted
2+->0+ unshifted
4+->2+ shifted
4+->2+ unshifted
72Zn all distances
Counts (1.5 keV/bin)
2+->0+ shifted
2+->0+ unshifted
4+-> 2+ shifted
4+-> 2+ unshifted
8+-> 6+ shifted
8+-> 6+ unshifted
6+-> 4+ shifted
6+-> 4+ unshifted
?
74Zn all distances
6+-> 4+ shifted ?
2+ -> 0+ 72Ge
½+ -> 0+ 27Al
Energy (keV)




| $E_x$ (MeV) | $I^\pi$ | $\tau$(ps) [Ref.] | $\tau$(ps) (this work) |
|---|---|---|---|
| 0.885 | $2_1^+$ | 5.3(3) [1] | –[a] |
| 1.068 | $0_2^+$ | 5628(289) [15] | |
| 1.759 | $2_2^+$ | 0.35(+35, −17) [15] | 1.9(3) |
| 1.786 | $4_1^+$ | | 1.9(2) |
| 2.859 | $3_1^-$ | | 0.29(2) |
| 3.038 | $5_1^-$ | | 1.5(1) |

[a]A unique fit to the mean lifetime of the $2_1^+$ state was not obtained from the data in this experiment because of the partially overlapping $4_1^+$ state, the feeding into the $2_1^+$, and the correlations between the various parameters in the multiline fit.