

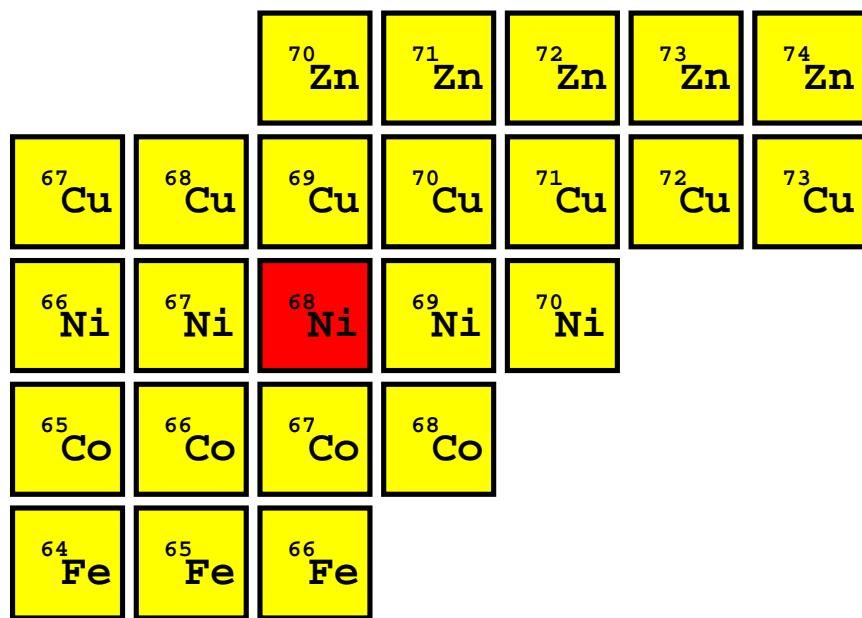
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# Collectivity of the $4_1^+$ states in heavy Zn isotopes

Magda Zielińska  
IRFU/SPhN, CEA Saclay, France

- Motivation (talk of Elisa Rapisarda)
- Lifetime measurements in  $^{70-74}\text{Zn}$
- Coulomb excitation of  $^{70}\text{Zn}$
- Perspectives
- $^{72}\text{Zn}$  – talk of Stefanie Hellgartner

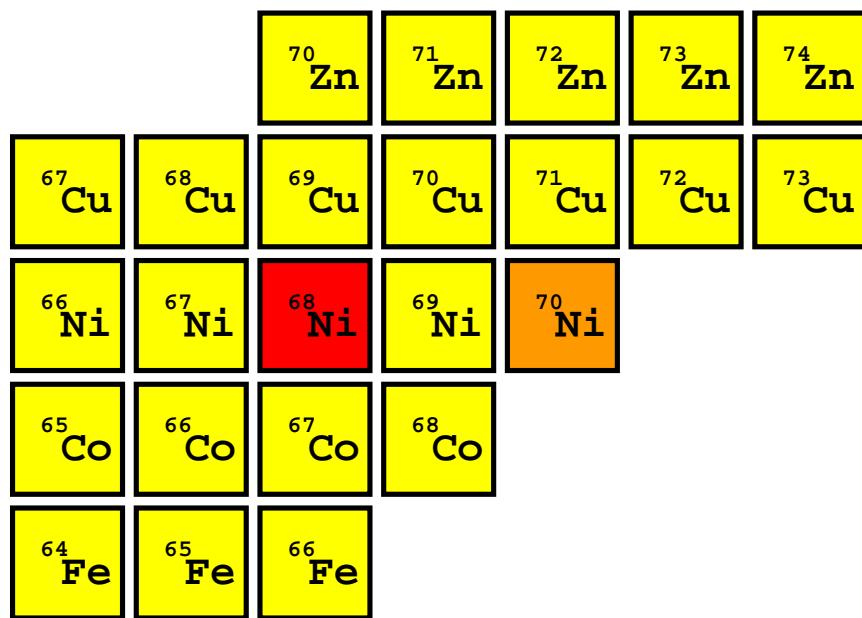
## Vicinity of $^{68}\text{Ni}$



high excitation energy of the  $2^+$  state  
and low  $B(E2)$  in  $^{68}\text{Ni}$

weakness of the N=40 shell gap:  
rapid onset of collectivity  
when moving away from  $^{68}\text{Ni}$

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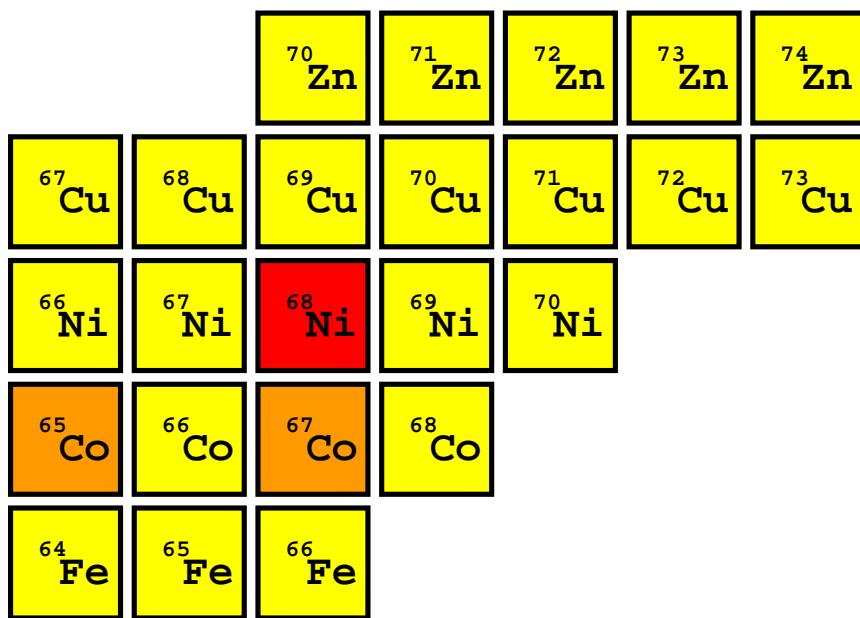
- polarisation of the  $Z=28$  proton core in  $^{70}\text{Ni}$

O. Perru et al., PRL 96 (2006)

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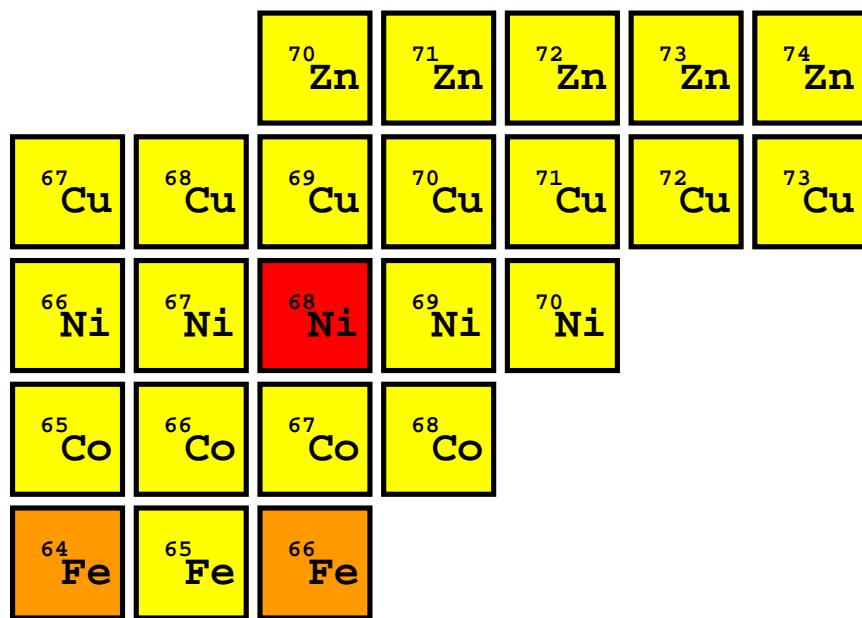


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O. Perru et al., PRL 96 (2006)
- Core-coupled states (Fe-like and Ni-like) in Co isotopes  
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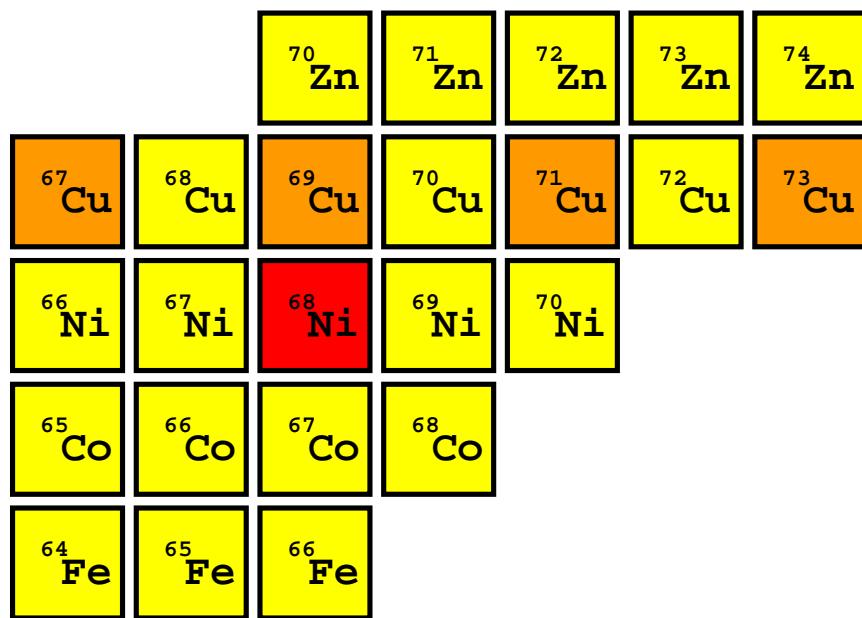


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J.Ljungvall et al., PRC 81 (2010)  
W.Rother et al., PRL 106 (2011)

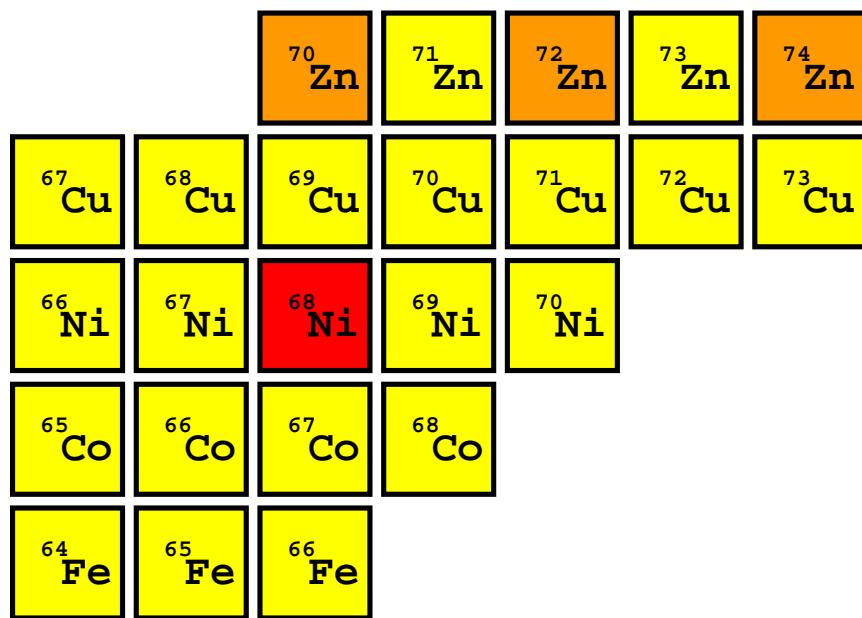
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I.Stefanescu et al., PRL 100 (2008)

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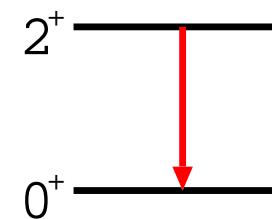
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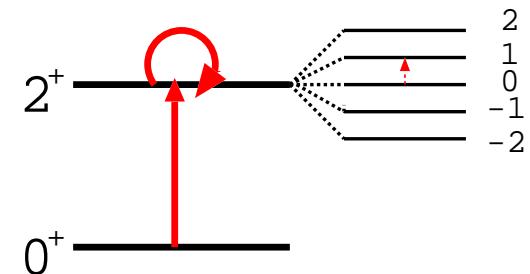
# Experimental methods to measure transition probabilities around $^{68}\text{Ni}$

- Lifetime measurements after deep-inelastic reactions
  - yrast states
  - problem of unknown feeding



$$\langle 2^+ || \text{E2} || 0^+ \rangle^2 \\ \sim B(\text{E2}; 2^+ \rightarrow 0^+)$$

- Coulomb excitation
  - collective states
  - Coulex cross-sections depend on quadrupole moments

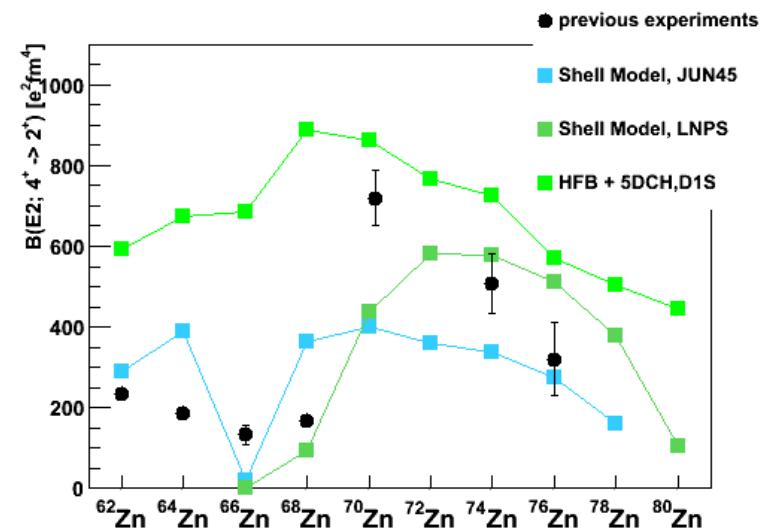
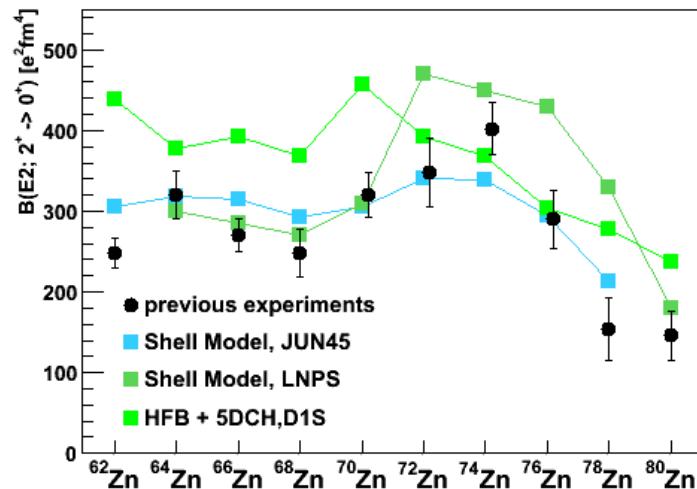


$$\langle 2^+ || \text{E2} || 2^+ \rangle \sim Q_0$$

Combination of both methods should in principle give information on quadrupole moments, but it depends strongly on accuracy and quality of the results...

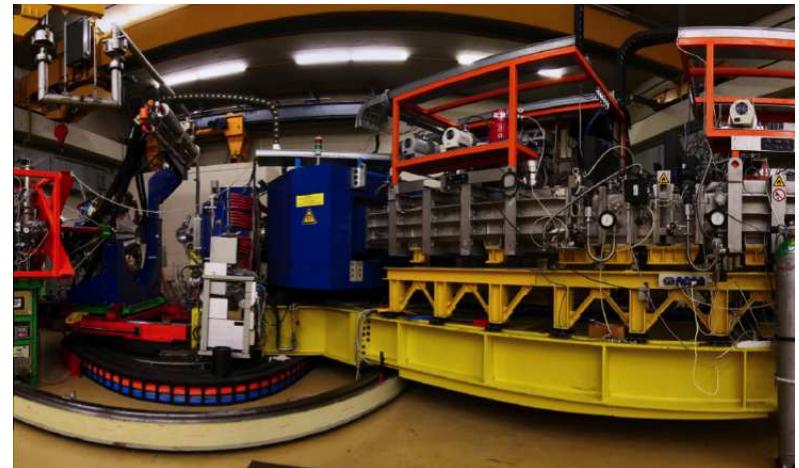
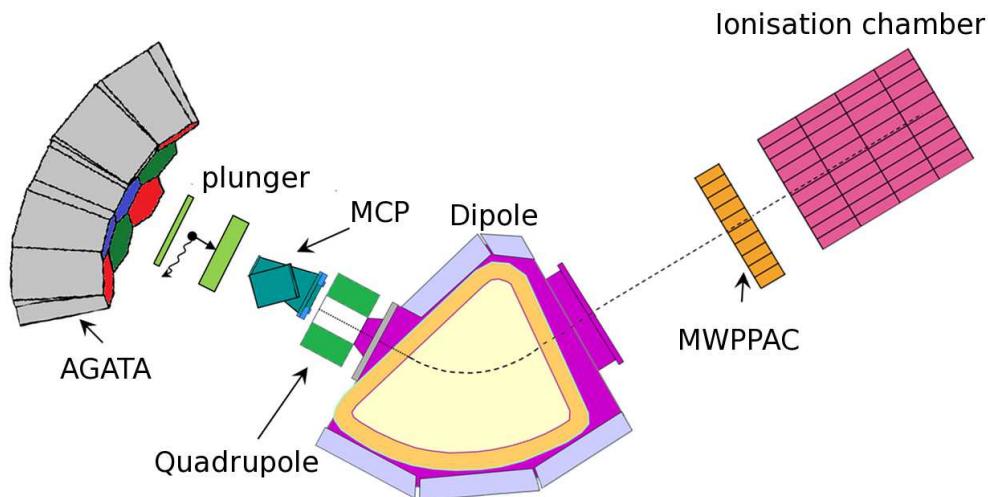
# Transition probabilities in Zn isotopes

- $B(E2)$ 's for stable Zn isotopes: Coulex, RDDS, DSAM: some important discrepancies ( $^{66}\text{Zn}$ )
- heavy Zn isotopes: Coulex, high-energy Coulex for  $2^+$



- $B(E2; 4^+ \rightarrow 2^+)$  better test for theories than  $B(E2; 2^+ \rightarrow 0^+)$
- collectivity overestimated by beyond mean field calculation

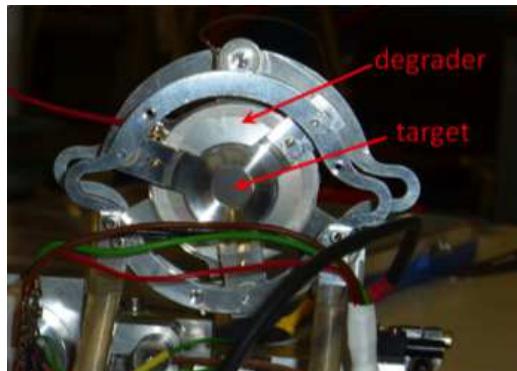
# Lifetime measurements in $^{70-74}\text{Zn}$



4 AGATA clusters

Deep inelastic reaction :  $^{76}\text{Ge}$  (7.6 MeV/u) +  $^{238}\text{U}$   
PRISMA spectrometer at grazing angle ( $55^\circ$ )

Cologne plunger

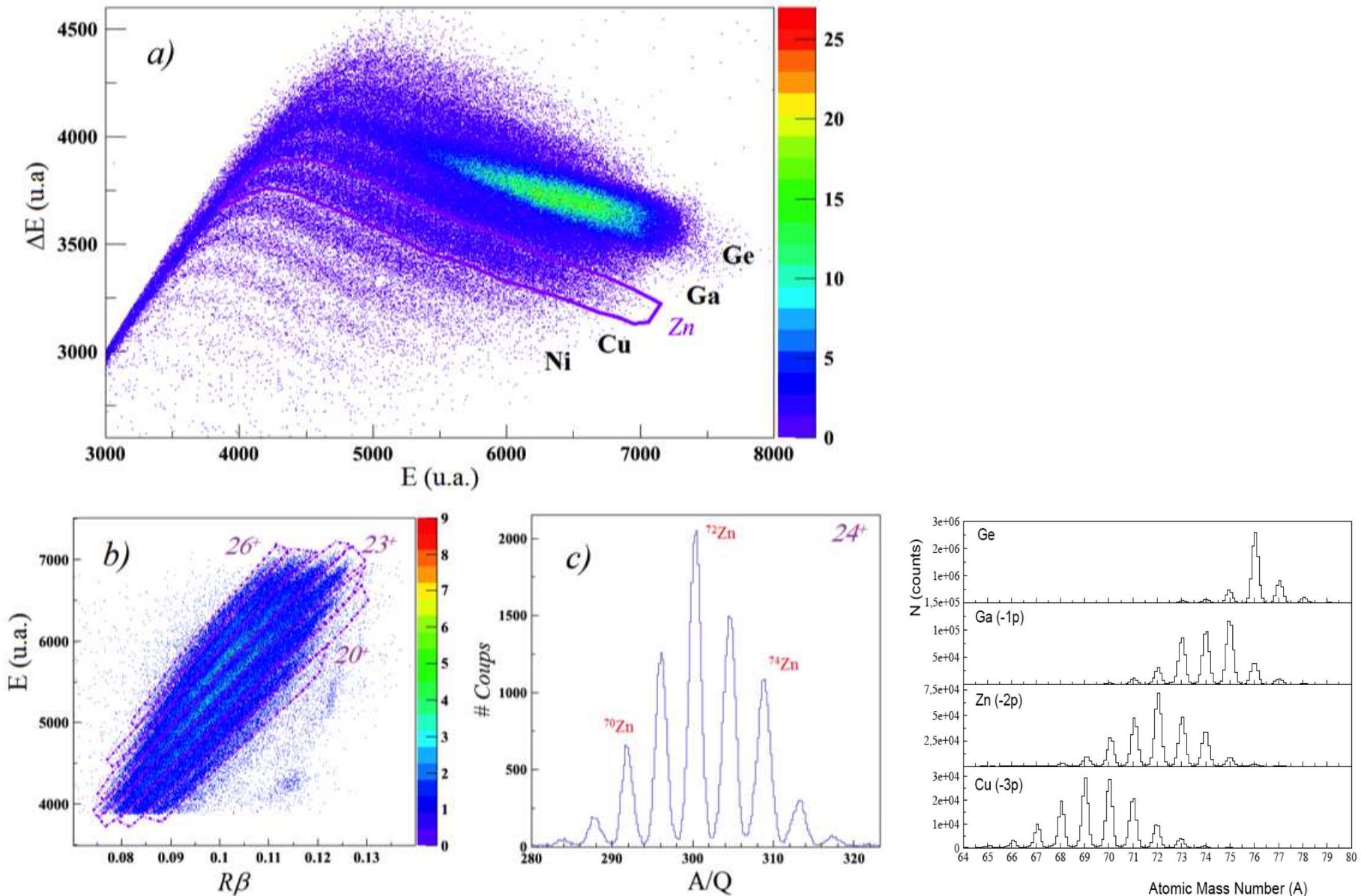


Target: 1.4 mg/cm<sup>2</sup>  
Degrader: Nb – 4.2 mg/cm<sup>2</sup>  
5 plunger distances:  
100, 200, 500, 1000, 1900  $\mu\text{m}$   
(20 hours each)



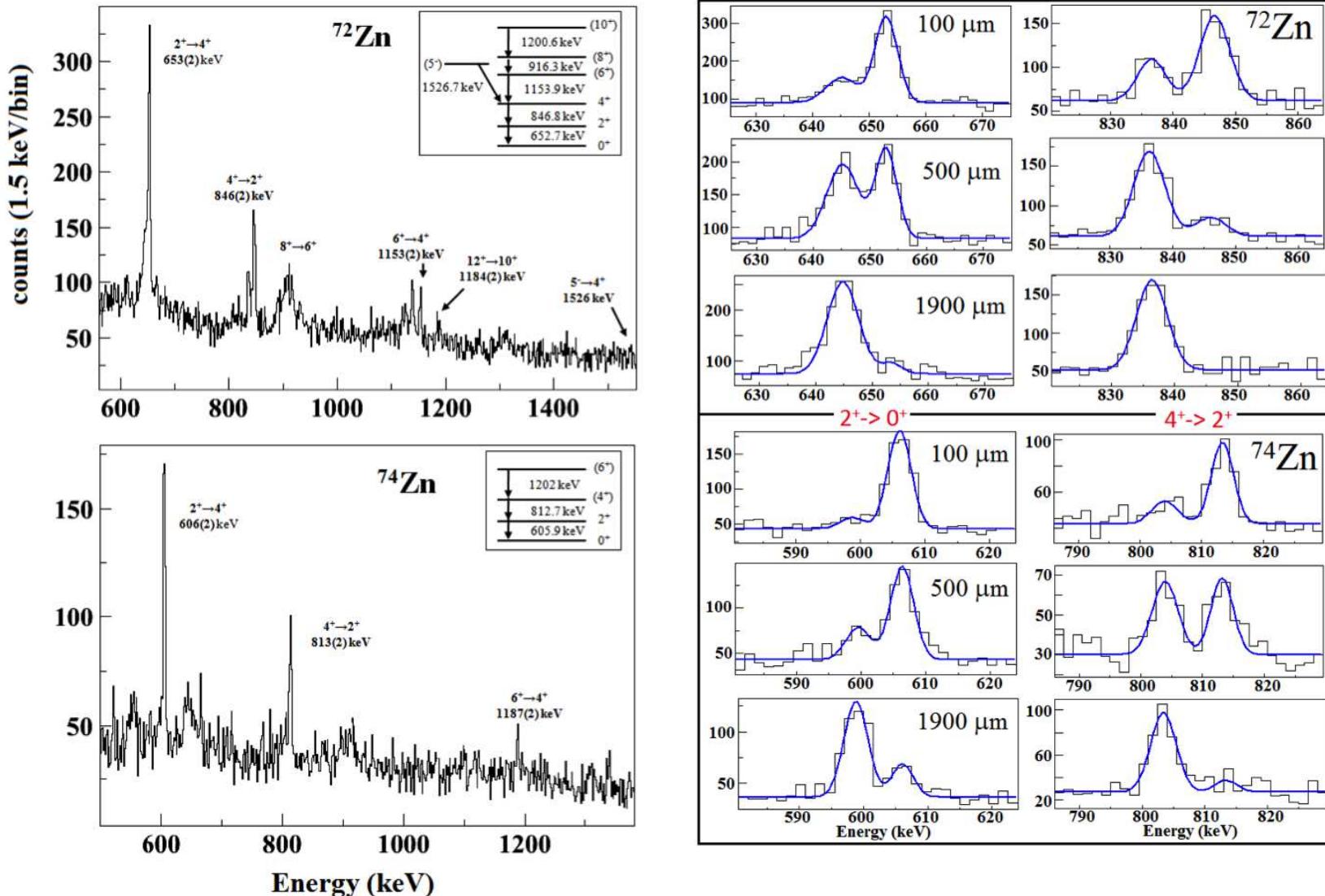
# Identifications of recoils

C. Louchart, PRC 87 (2013) 054302



# Lifetime measurements in $^{70-74}\text{Zn}$

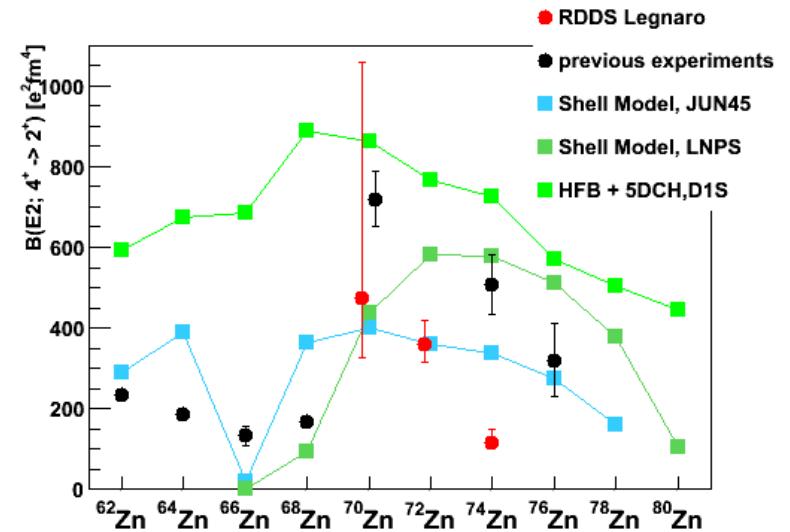
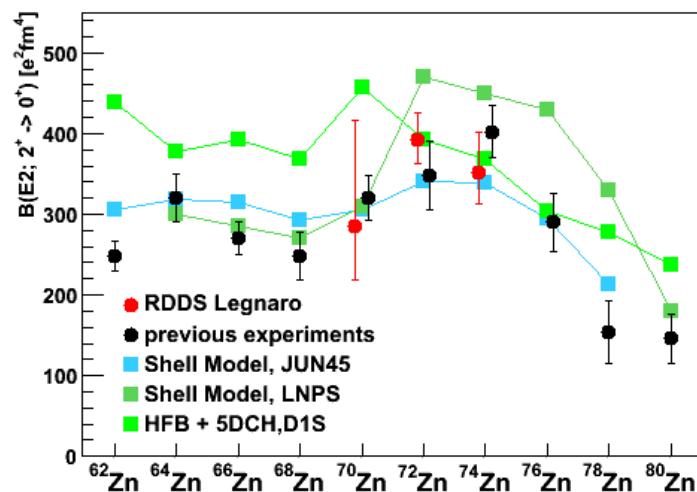
C. Louchart, PRC 87 (2013) 054302



# Transition probabilities in Zn isotopes

C. Louchart, PRC 87 (2013) 054302

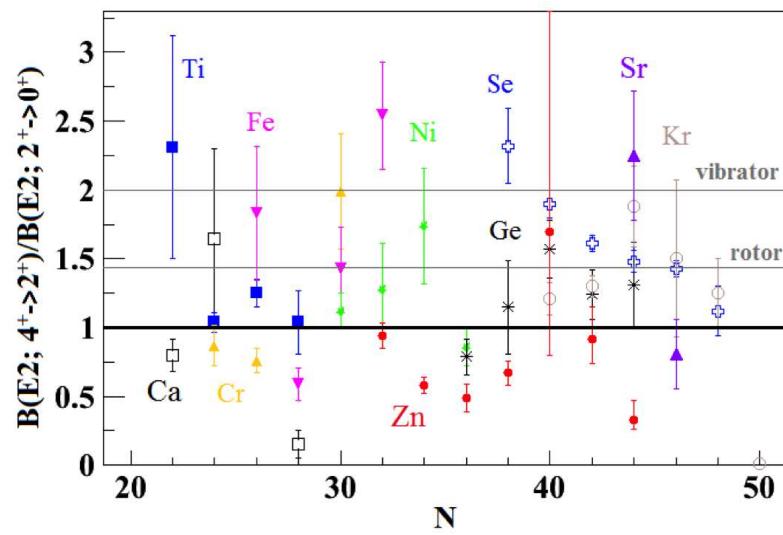
- RDDS measurement with AGATA (Legnaro)
- new lifetimes for the  $2^+$  states in agreement with previous  $B(E2; 2^+ \rightarrow 0^+)$  values
- good agreement with model calculations for the  $2^+$



- discrepancy of the new lifetimes for  $4^+$  states with low-energy Coulex results (especially for  $^{74}\text{Zn}$ )
- shell model calculations do not reproduce the observed trend for the  $4^+$

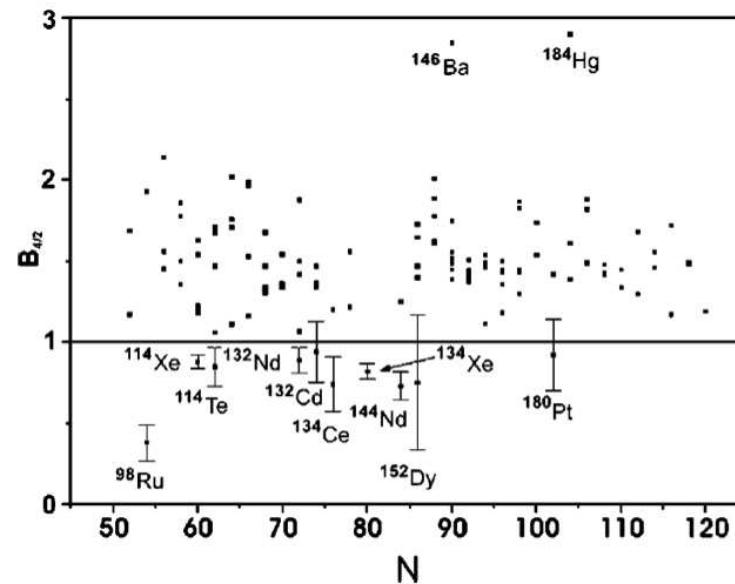
# Collectivity of $4^+$ states

$Z < 40$  nuclei



$40 < Z < 80$  nuclei

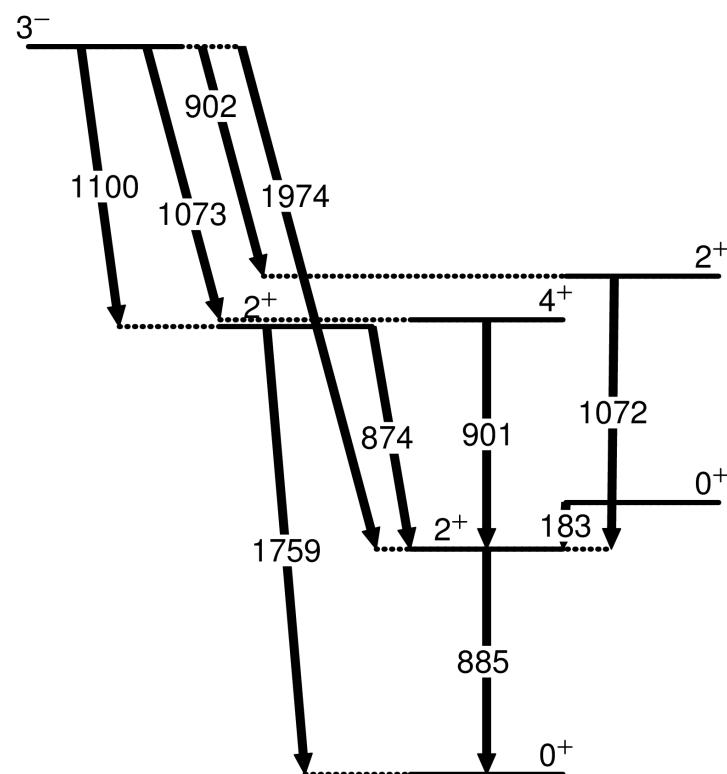
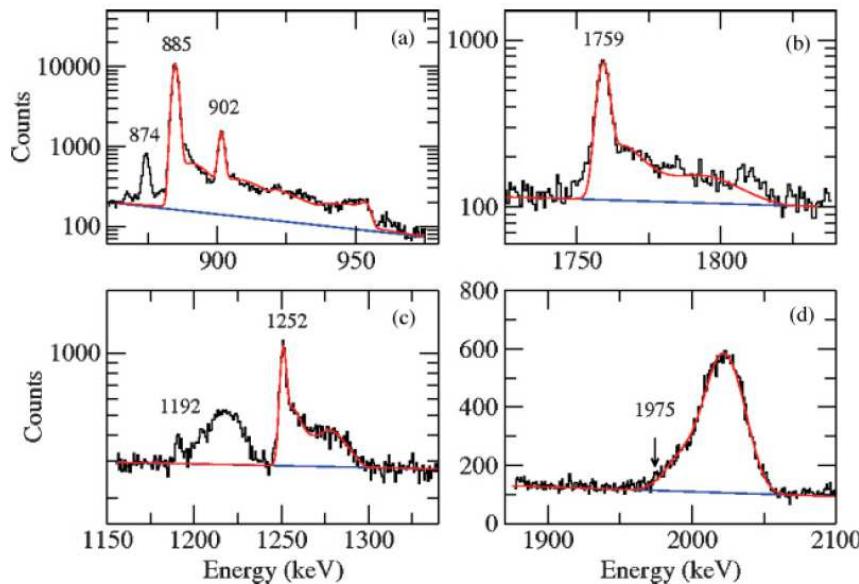
R.B. Cakirli et al. PRC 70, 047302 (2004)



- Small  $B(E2; 4^+ \rightarrow 2^+)/B(E2; 2^+ \rightarrow 0^+)$  ratio for all Zn isotopes → indication of a non-collective character of the  $4^+$  states

# Transition probabilities in $^{70}\text{Zn}$

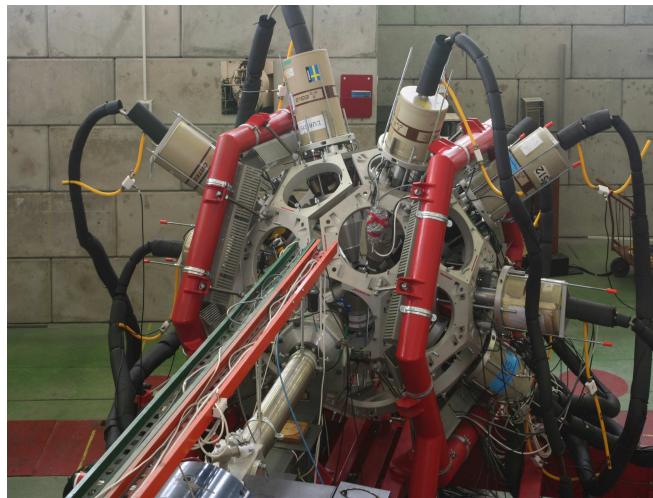
D. Mücher et al PRC 79 (2009)



- $4^+ \rightarrow 2^+$  (901 keV) and  $2^+ \rightarrow 0^+$  (885 keV) close in energy
- Coulomb excitation seems a more appropriate method to measure  $B(\text{E}2)$ 's in  $^{70}\text{Zn}$  (no double peaks/tails)
- dedicated Coulomb excitation experiment to measure  $B(\text{E}2; 4^+ \rightarrow 2^+)$  in  $^{70}\text{Zn}$ : November 2012, HIL Warsaw, Poland
- low-Z beam ( $^{32}\text{S}$ ) to minimize the contribution of the  $3^-$  decay to the 902 keV line

# Coulomb excitation of $^{70}\text{Zn}$

HIL Warsaw, November 2012



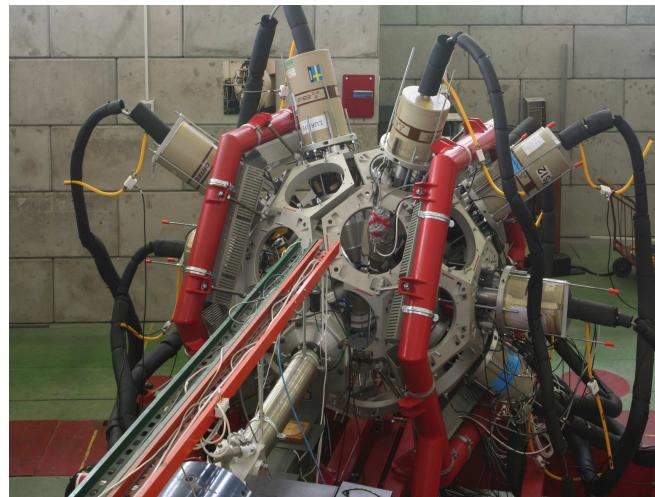
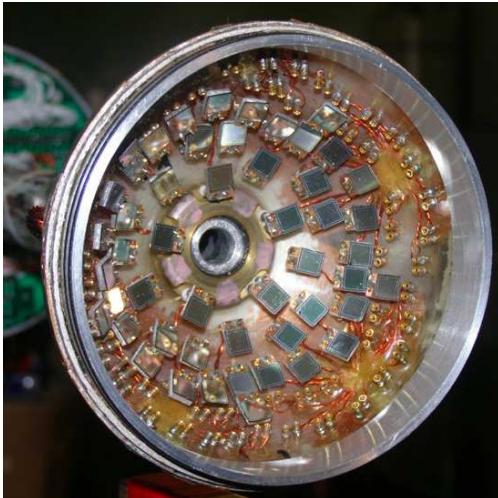
48 PIN diodes ( $120^\circ - 155^\circ$ )

EAGLE: 15 ACS Ge detectors

$^{32}\text{S}$  beam (68 MeV),  
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5 days of data-taking

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HIL Warsaw, November 2012

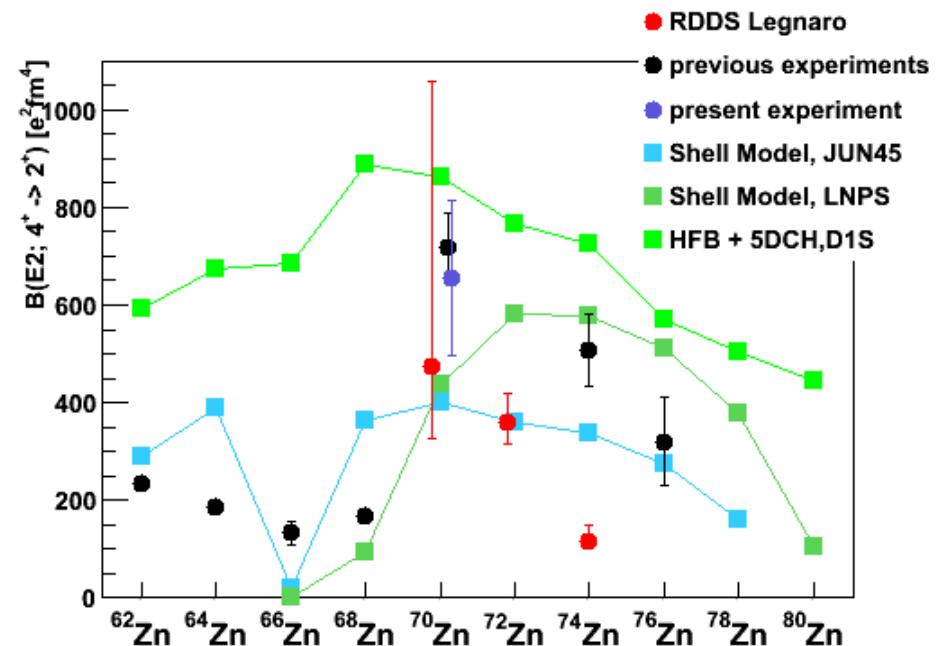


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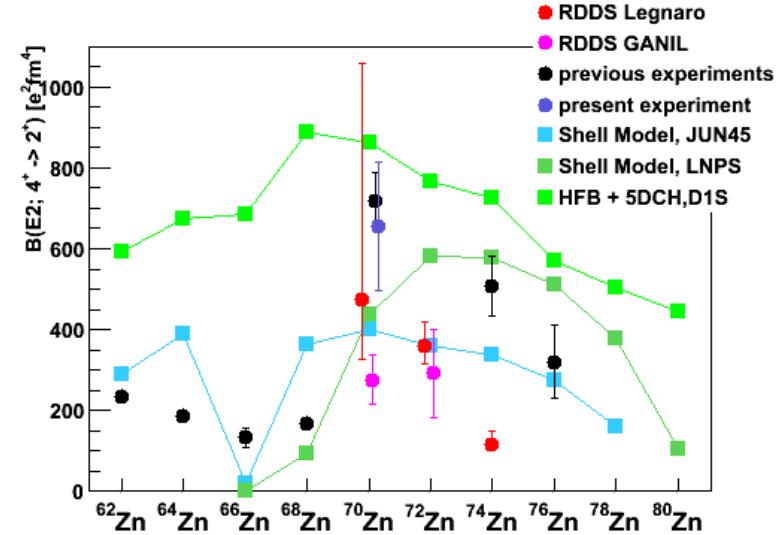
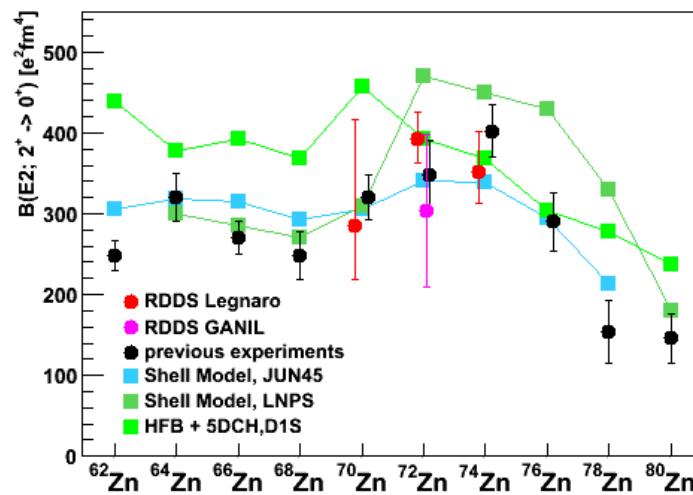
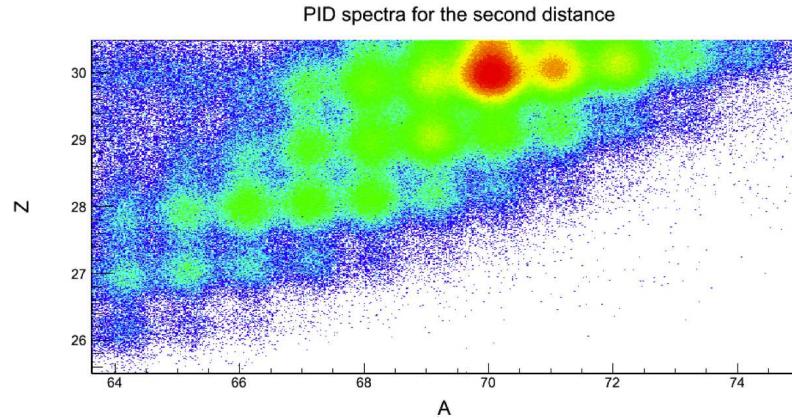
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5 days of data-taking

Preliminary – data only from  
particle detectors at  $155^\circ$



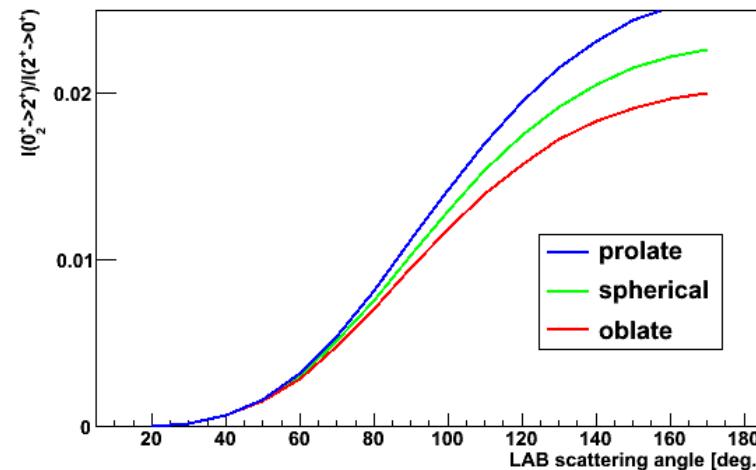
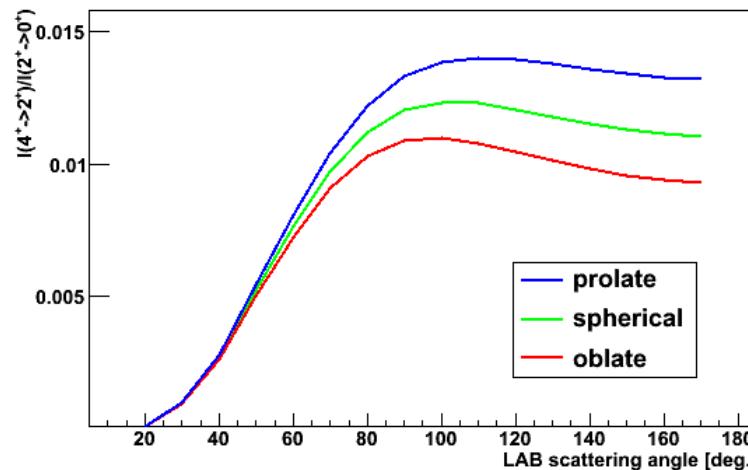
# Lifetime measurements in $^{70,72}\text{Zn}$

I. Celikovic, Acta Phys. Pol. B44 (2013)



## Perspectives

- finalisation of the Coulex analysis for  $^{70}\text{Zn}$  - data from particle detectors at lower scattering angles
  - better accuracy ( $\approx 10\%$ )
  - quadrupole moment of the  $2^+$  state?



- Coulomb excitation of  $^{74-80}\text{Zn}$  at HIE-ISOLDE: proposal accepted by INTC
  - collectivity of higher-lying states
  - quadrupole moments in exotic Zn isotopes?
- Coulomb excitation of  $^{72}\text{Zn}$  at ISOLDE (spokesperson D. Mücher, 2012)
  - talk of Stefanie Hellgartner

## Collaboration:

### Lifetimes in $^{70-74}\text{Zn}$ :

C. Louchart,<sup>1,\*</sup> A. Obertelli,<sup>1</sup> A. Görgen,<sup>1,†</sup> W. Korten,<sup>1</sup> D. Bazzacco,<sup>2</sup> B. Birkenbach,<sup>3</sup> B. Bruyneel,<sup>1</sup> E. Clément,<sup>4</sup> P. J. Coleman-Smith,<sup>5</sup> L. Corradi,<sup>6</sup> D. Curien,<sup>7</sup> G. de Angelis,<sup>6</sup> G. de France,<sup>4</sup> J.-P. Delaroche,<sup>8</sup> A. Dewald,<sup>3</sup> F. Didierjean,<sup>7</sup> M. Doncel,<sup>9</sup> G. Duchêne,<sup>7</sup> J. Eberth,<sup>3</sup> M. N. Erduran,<sup>10</sup> E. Farnea,<sup>2</sup> C. Finck,<sup>7</sup> E. Fioretto,<sup>6</sup> C. Fransen,<sup>3</sup> A. Gadea,<sup>11</sup> M. Girod,<sup>8</sup> A. Gottardo,<sup>6</sup> J. Grebosz,<sup>12</sup> T. Habermann,<sup>13</sup> M. Hackstein,<sup>3</sup> T. Huyuk,<sup>11</sup> J. Jolie,<sup>3</sup> D. Judson,<sup>14</sup> A. Jungclaus,<sup>15</sup> N. Karkour,<sup>16</sup> S. Klupp,<sup>17</sup> R. Krücken,<sup>17</sup> A. Kusoglu,<sup>18</sup> S. M. Lenzi,<sup>2</sup> J. Libert,<sup>8</sup> J. Ljungvall,<sup>16,1</sup> S. Lunardi,<sup>2</sup> G. Maron,<sup>6</sup> R. Menegazzo,<sup>2</sup> D. Mengoni,<sup>19,2</sup> C. Michelagnoli,<sup>2</sup> B. Million,<sup>20</sup> P. Molini,<sup>2</sup> O. Möller,<sup>21</sup> G. Montagnoli,<sup>2</sup> D. Montanari,<sup>2</sup> D. R. Napoli,<sup>6</sup> R. Orlandi,<sup>19</sup> G. Pollarolo,<sup>22</sup> A. Prieto,<sup>9</sup> A. Pullia,<sup>20</sup> B. Quintana,<sup>9</sup> F. Recchia,<sup>2</sup> P. Reiter,<sup>3</sup> D. Rosso,<sup>6</sup> W. Rother,<sup>3</sup> E. Sahin,<sup>6</sup> M.-D. Salsac,<sup>1</sup> F. Scarlassara,<sup>2</sup> M. Schlarb,<sup>17</sup> S. Siem,<sup>23</sup> P. P. Singh,<sup>6</sup> P.-A. Söderström,<sup>24</sup> A. M. Stefanini,<sup>6</sup> O. Stézowski,<sup>25</sup> B. Sulignano,<sup>1</sup> S. Szilner,<sup>26</sup> Ch. Theisen,<sup>1</sup> C. A. Ur,<sup>2</sup> J. J. Valiente-Dobón,<sup>6</sup> and M. Zielinska<sup>1</sup>

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### Coulex of $^{70}\text{Zn}$ :

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