Collectivity of the 4_1^+ states in heavy Zn isotopes and the first HIE-ISOLDE experiment

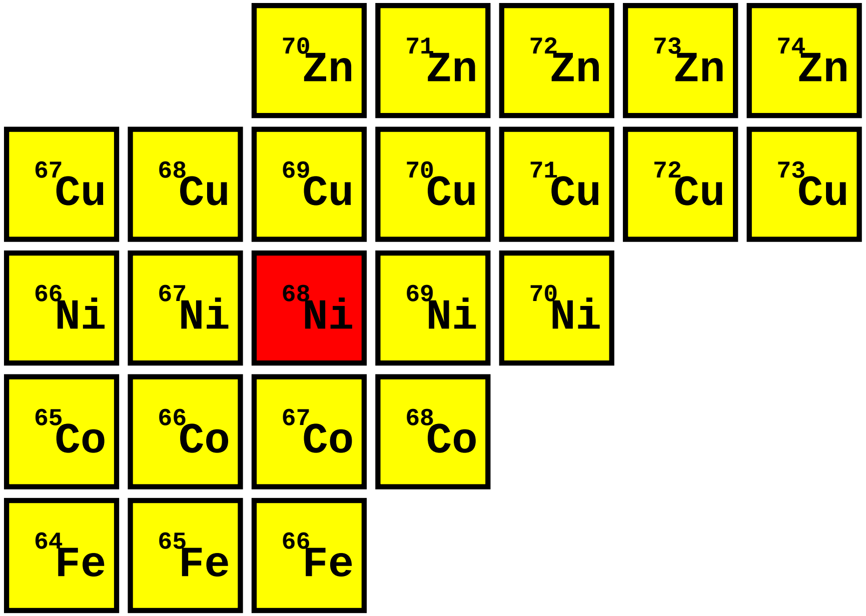
Magda Zielińska[1], Andres Illana Sison[2],
Elisa Rapisarda[3], Piet Van Duppen[2]

[1] IRFU/SPhN, CEA Saclay, France; [2] KU Leuven, Belgium; [3] PSI Villigen, Switzerland

and the IS557 – MINIBALL collaboration

- Motivation
- Lifetime measurements in heavy Zn isotopes
- Coulomb excitation measurements
    - First HIE-ISOLDE experiment
- What have we learnt so far?

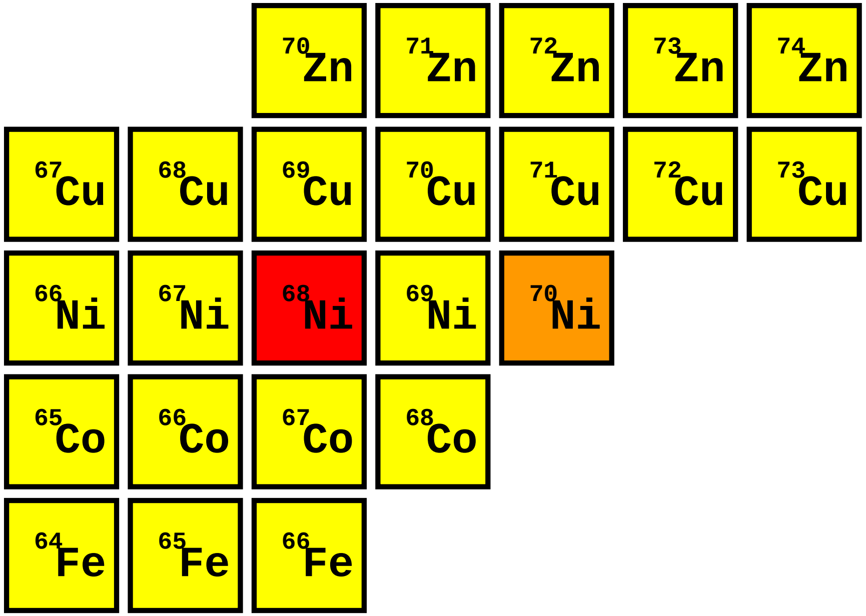
Vicinity of ^{68}Ni



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

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

Vicinity of ^{68}Ni



- polarisation of the Z=28 proton core in ^{70}Ni
  O. Perru et al., PRL 96 (2006)

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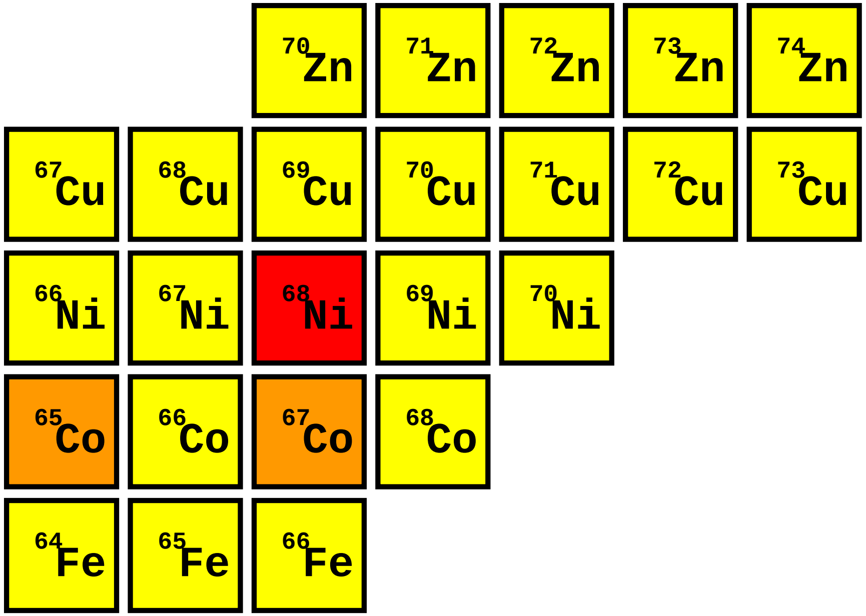

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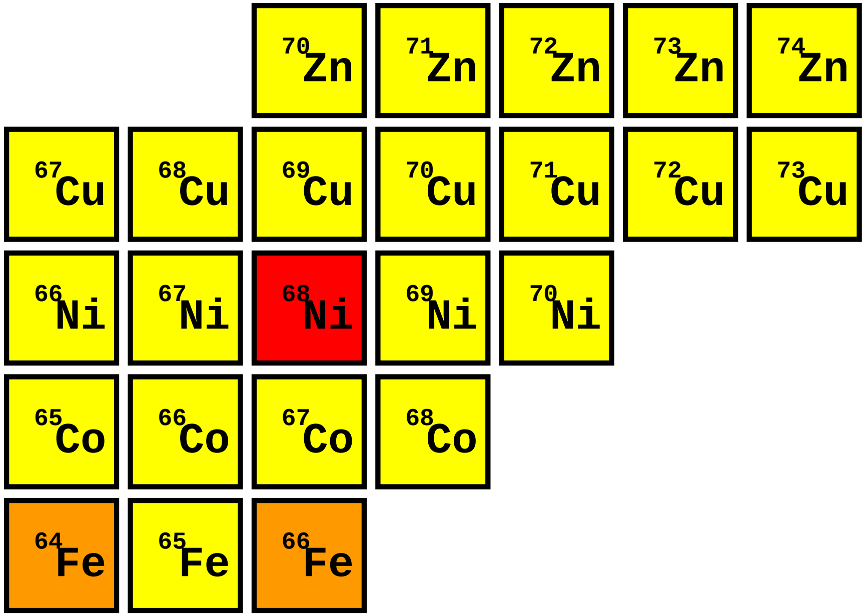

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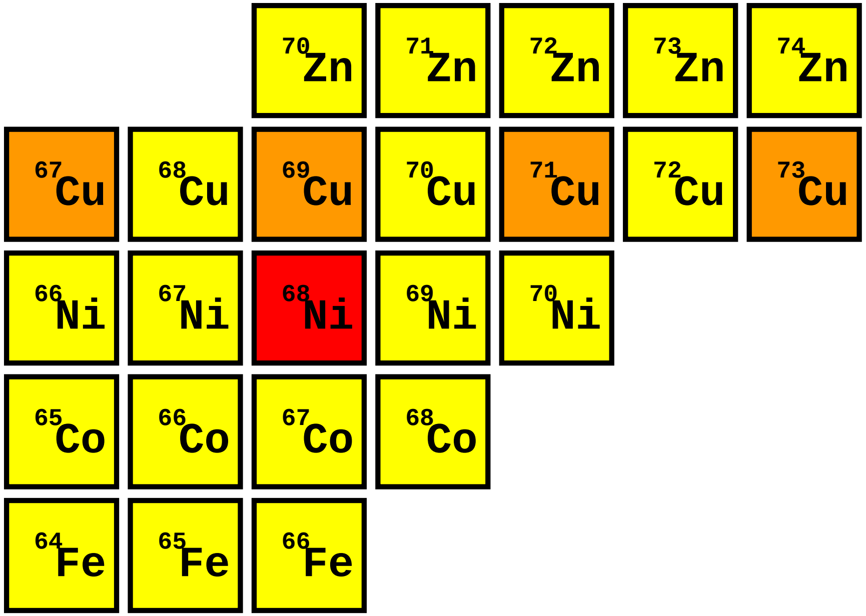

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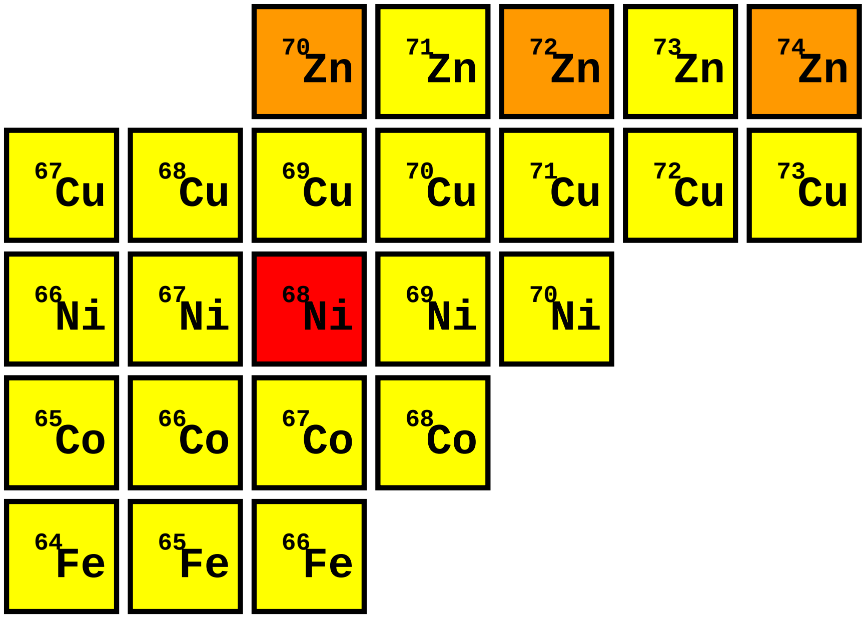

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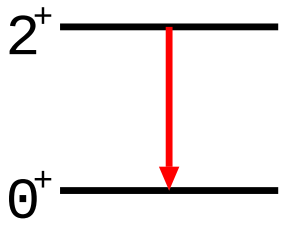
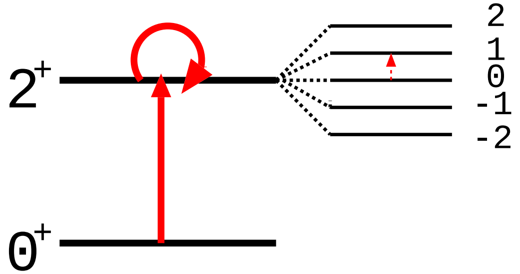
Experimental methods to measure transition probabilities around ^{68}Ni

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



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

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

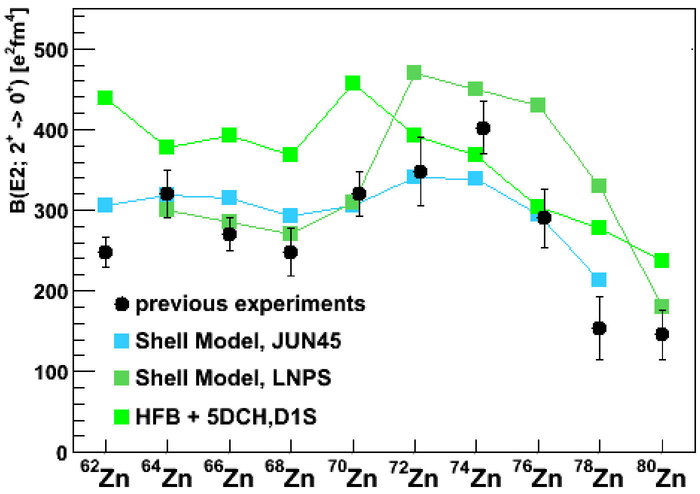


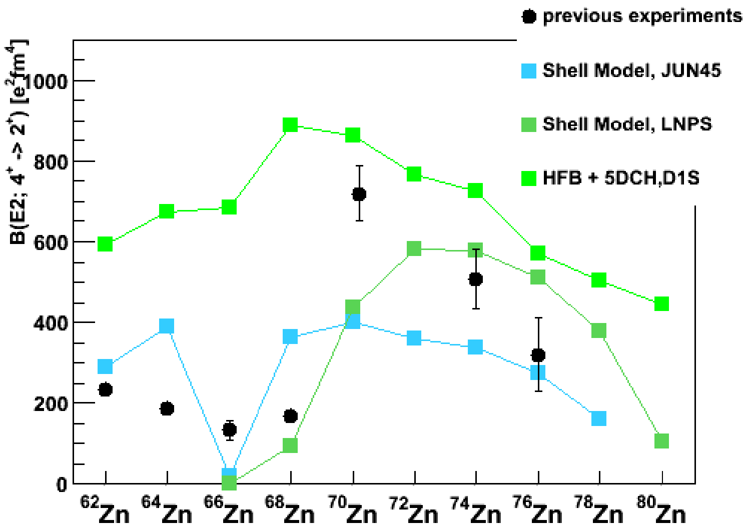
$\langle 2^+ \| E2 \| 2^+ \rangle \sim Q_0$

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

Transition probabilities in Zn isotopes: status five years ago

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

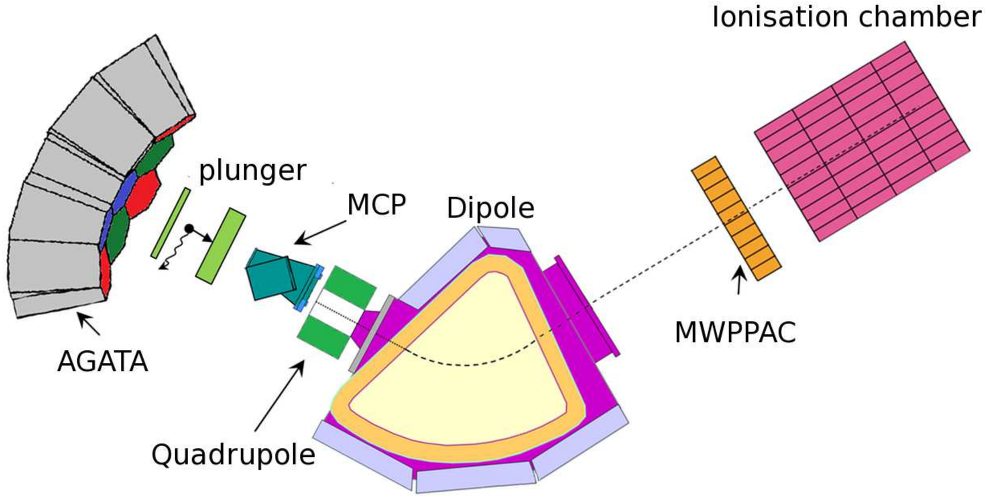


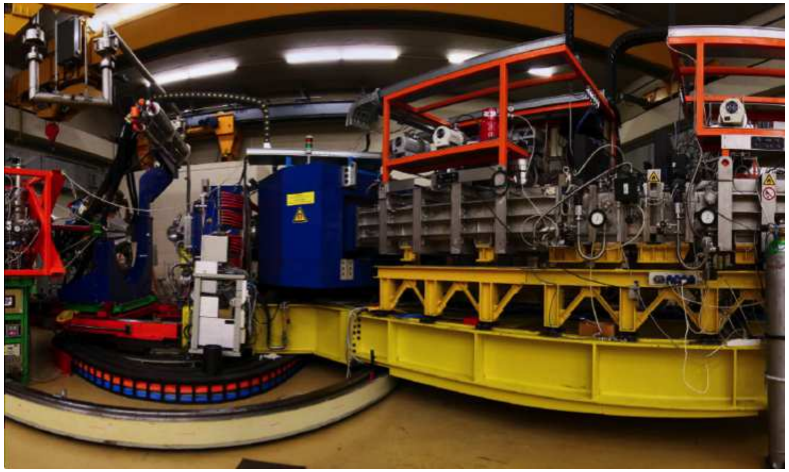


- B(E2; $4^+ \rightarrow 2^+$) better test for theories than B(E2; $2^+ \rightarrow 0^+$)
- collectivity overestimated by beyond-mean-field calculations

Lifetime measurements in $^{70-74}$Zn

C. Louchart, PRC 87 (2013) 054302

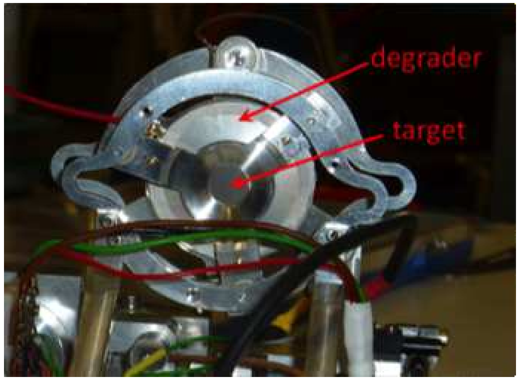




4 AGATA clusters

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

Cologne plunger

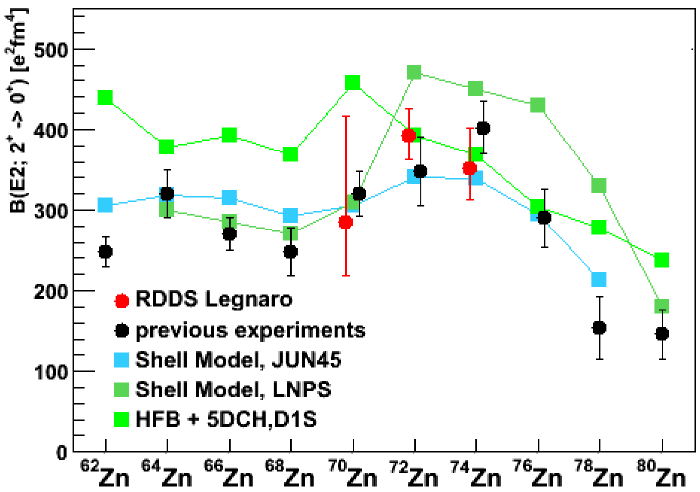


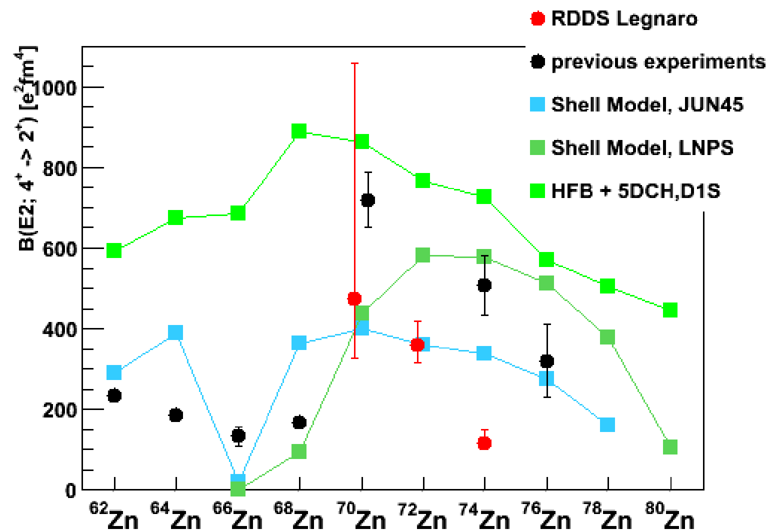
Target: 1.4 mg/cm^2
Degrader: Nb – 4.2 mg/cm^2
5 plunger distances:
100, 200, 500, 1000, 1900 μm
(20 hours each)

Lifetime measurements in $^{70-74}$Zn

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^+

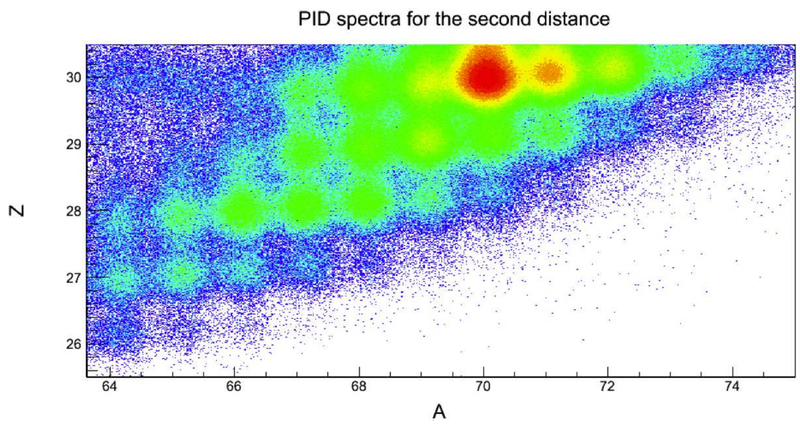




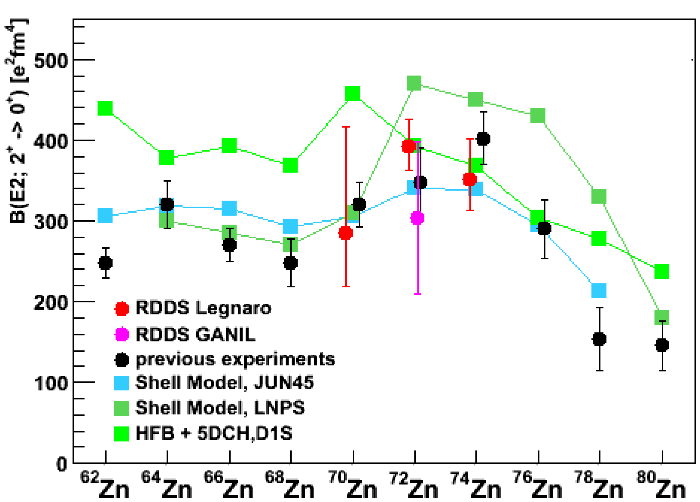
- discrepancy of the new lifetimes for 4^+ states with low-energy Coulex results (especially for ^{74}Zn)

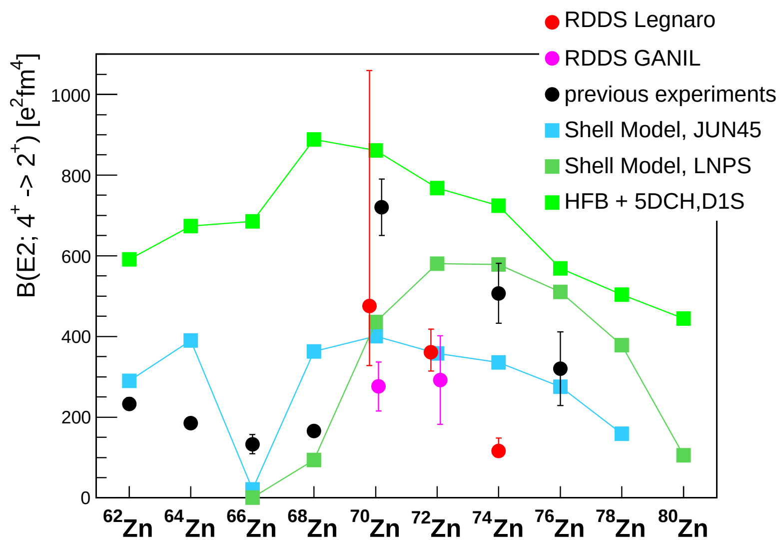
Lifetime measurements in ^{70,72}Zn

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



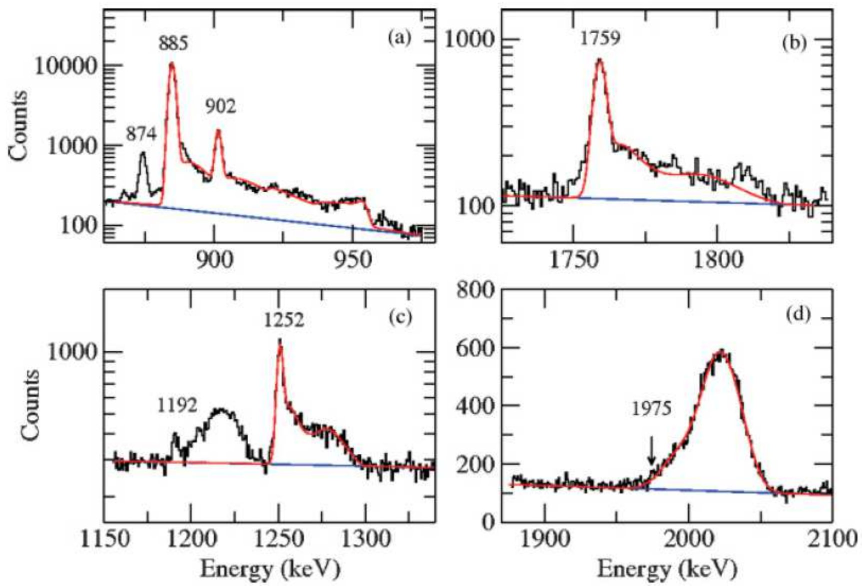
- plunger measurement at GANIL: EXOGAM+VAMOS
- ^{238}U beam (6.8 MeV/u) on ^{70}Zn
- confirmation of the RDDS results from Legnaro

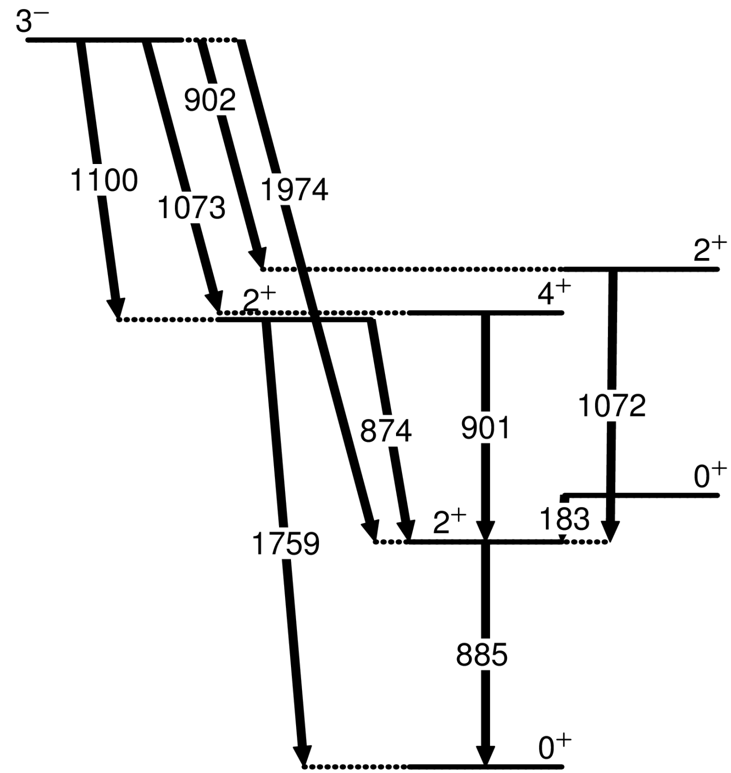




Transition probabilities in ^{70}Zn

D. Mücher et al PRC 79 (2009)



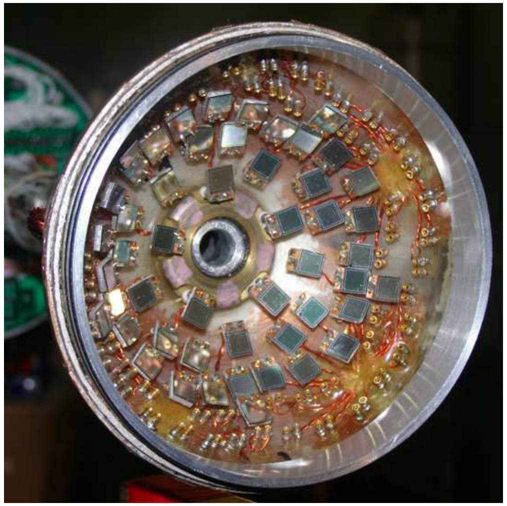
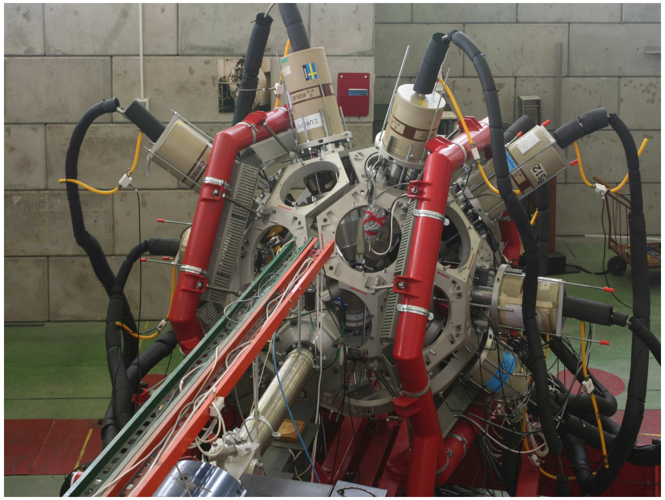


- DSAM measurement, excited states in ^{70}Zn populated by non-safe Coulex on ^{12}C

- $4^+ \rightarrow 2^+$ (901 keV) and $2^+ \rightarrow 0^+$ (885 keV) close in energy
- Coulomb excitation seems a more appropriate method to measure B(E2)'s in ^{70}Zn (no double peaks/tails)

Coulomb excitation of ^{70}Zn

M. Zielińska et al, HIL Warsaw

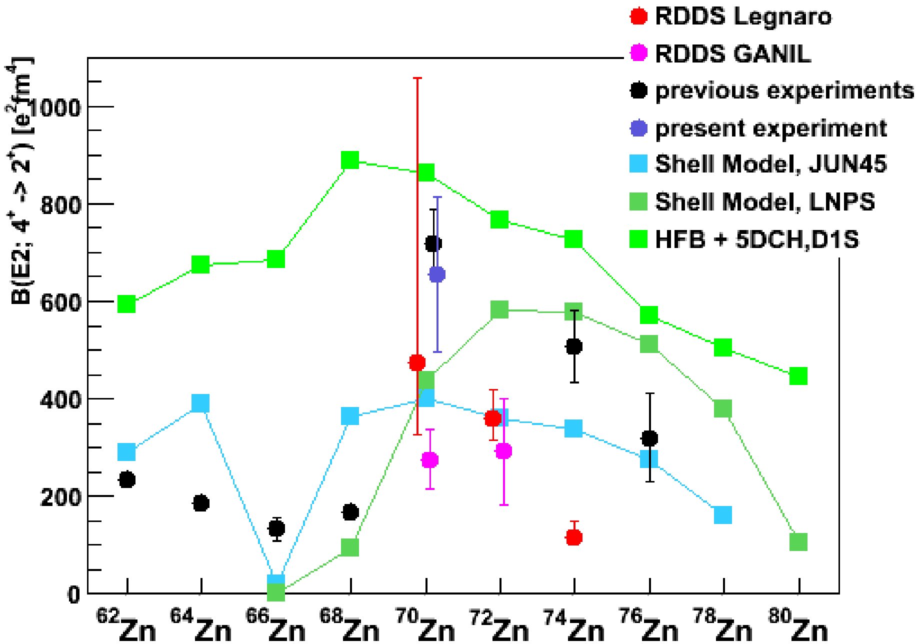




48 PIN diodes (120° – 155°)

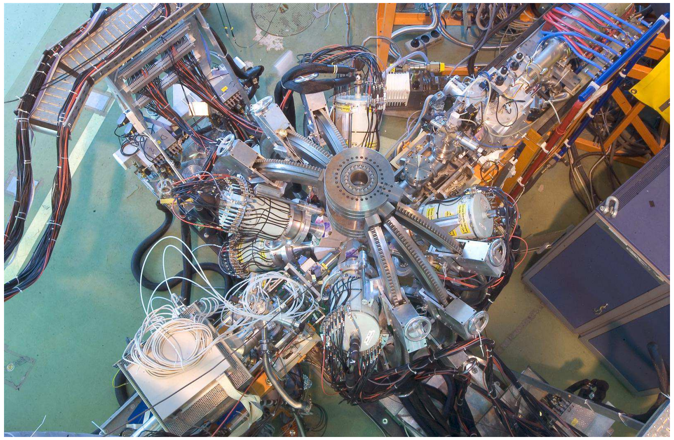
EAGLE: 15 ACS Ge detectors

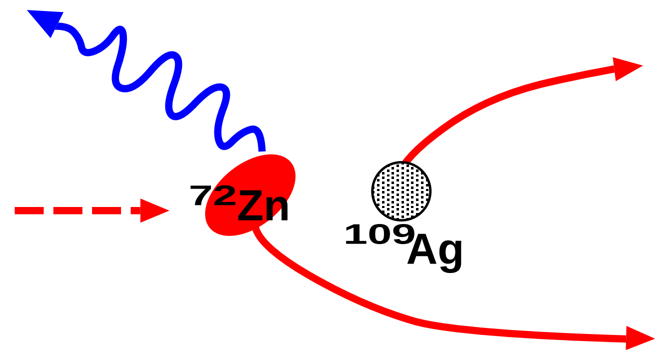
^{32}S beam (68 MeV),
^{70}Zn target (0.7 mg/cm^2)
5 days of data-taking

Preliminary – not full statistics



Coulomb excitation of exotic Zn nuclei at ISOLDE





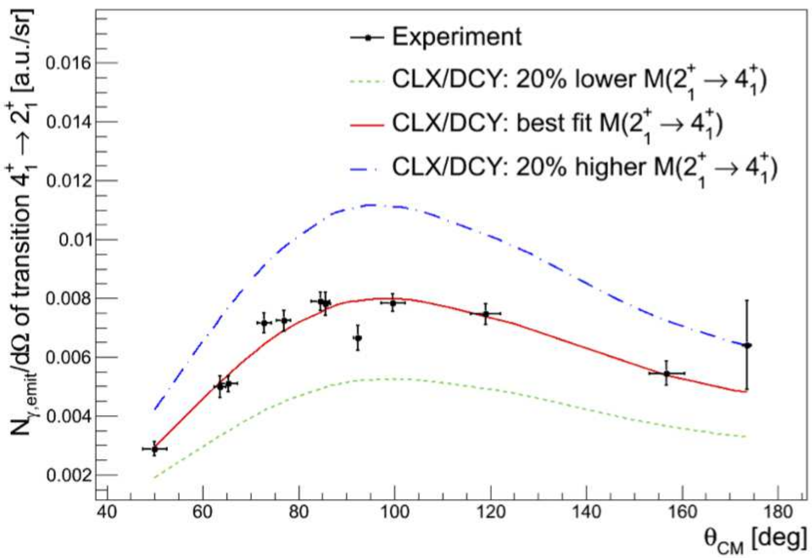
gamma-ray detection array:
MINIBALL
8 triple clusters, 8% efficiency

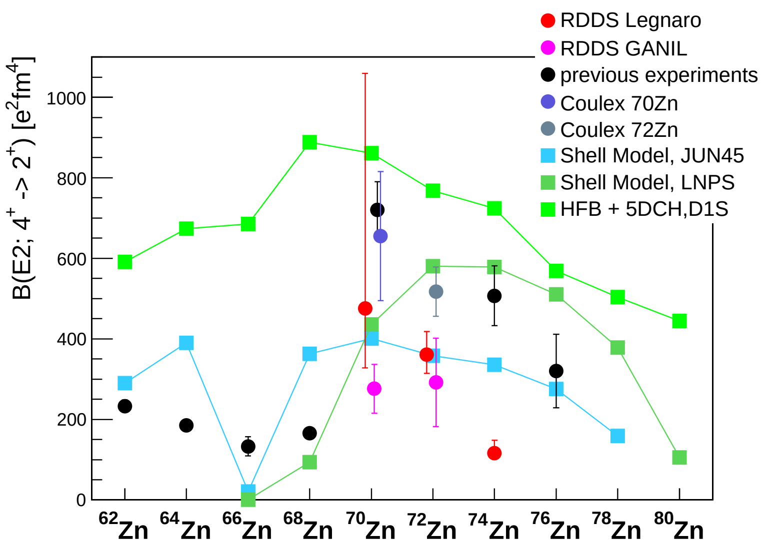
particle detection setup:
annular DSSD detector at forward angles
detection of scattered Zn
and recoiling target nuclei

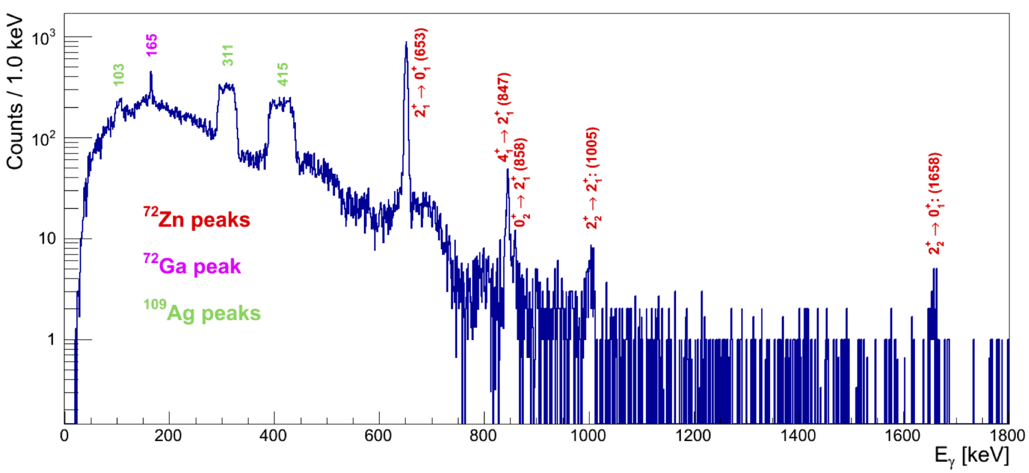
- deexcitation γ rays mesured in coincidence with particles (Zn and target recoils)
- laser ionisation to suppress strong Ga contamination

Coulomb excitation of ^{72}Zn

PhD S. Hellgartner, TU Munich (2015)



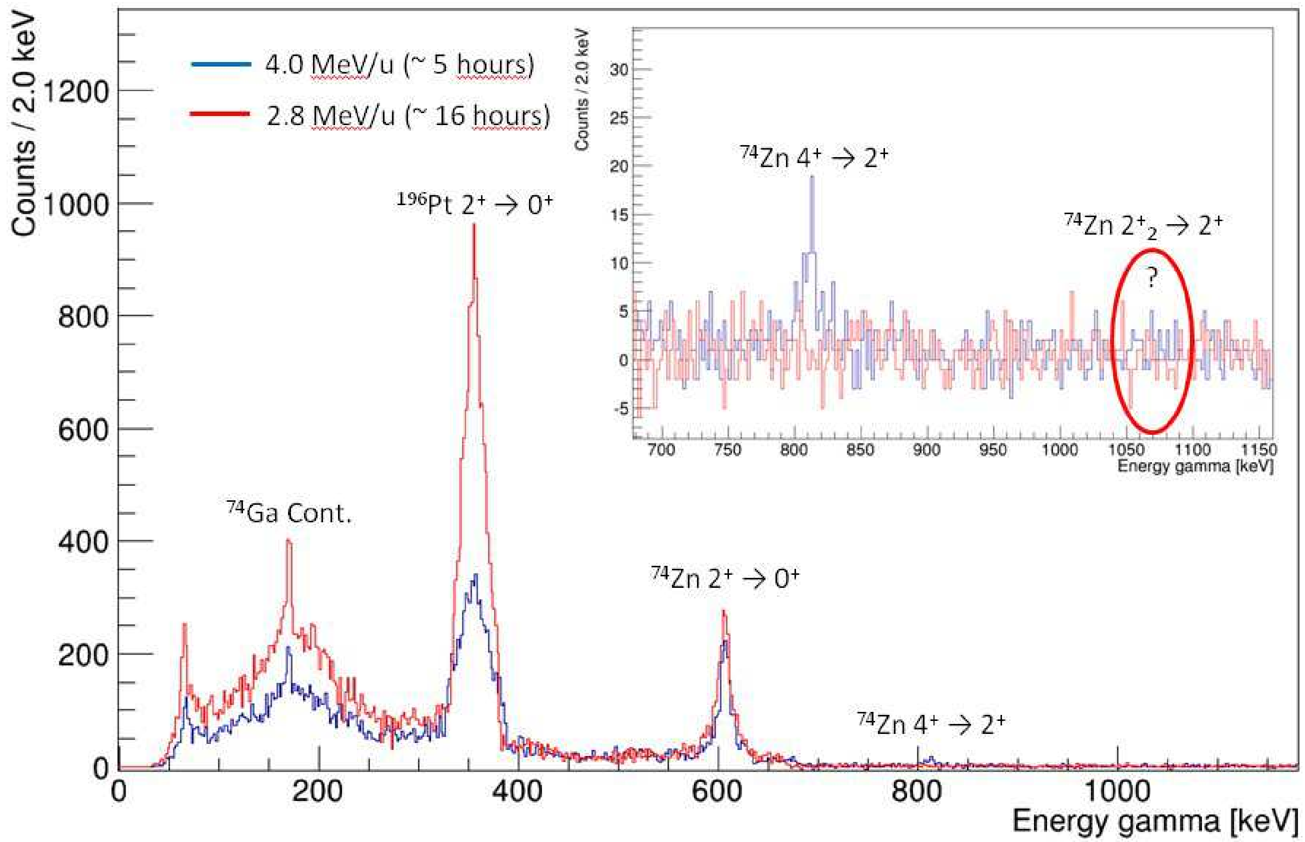




- low-energy Coulex at ISOLDE
- C-REX setup
  - broad range of CM angles
- large statistics
  - differential cross sections
  - high-precision measurement
  - consistency check

Coulomb excitation of ^{74,76}Zn: the first HIE-ISOLDE experiment

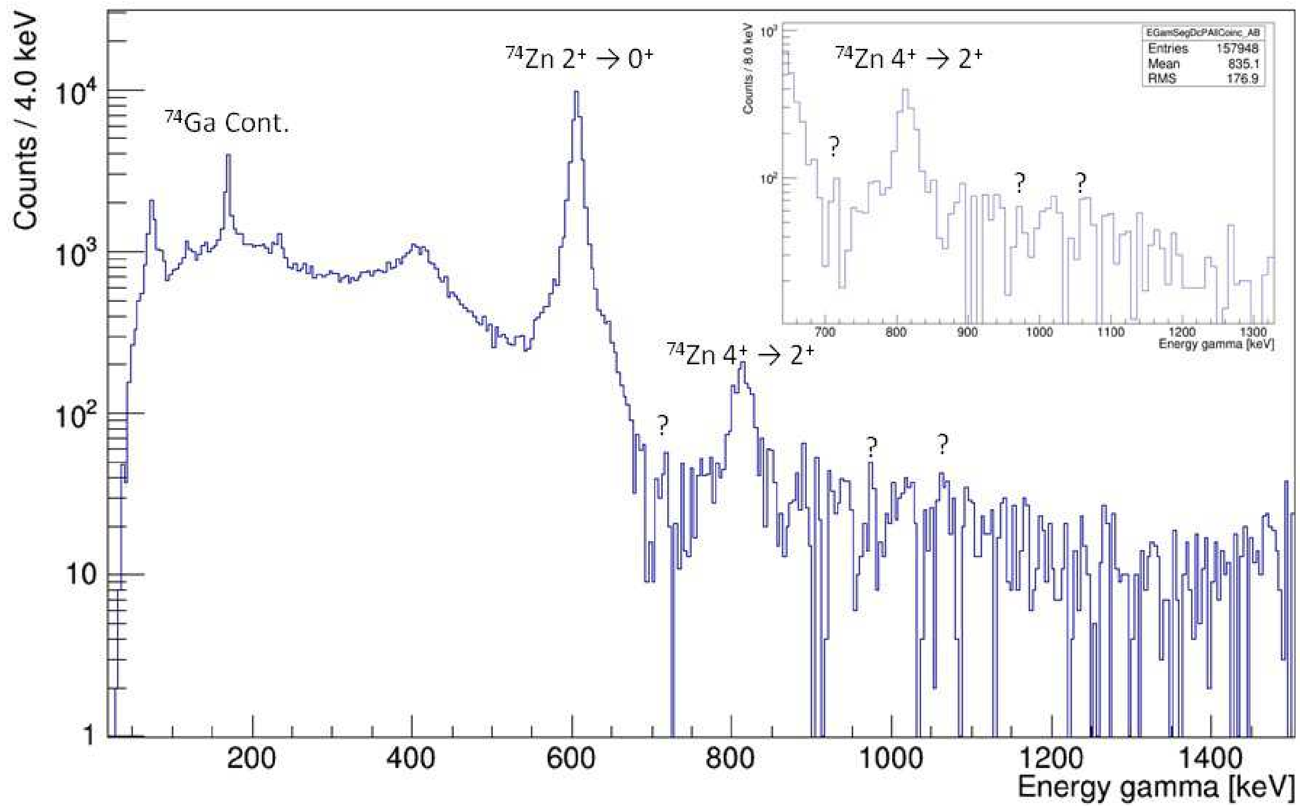
^{74}Zn on ^{194}Pt: analysis by A. Illana, KU Leuven



- 🙂 increased probability of multi-step excitation
- 🙂 higher sensitivity to quadrupole moments
- 🙁 max 6 hours of 4MeV/A beam per day, only on weekdays
- 🙁 bad beam time structure (150 μs bursts) – high particle multiplicity

Coulomb excitation of ^{74,76}Zn at HIE-ISOLDE

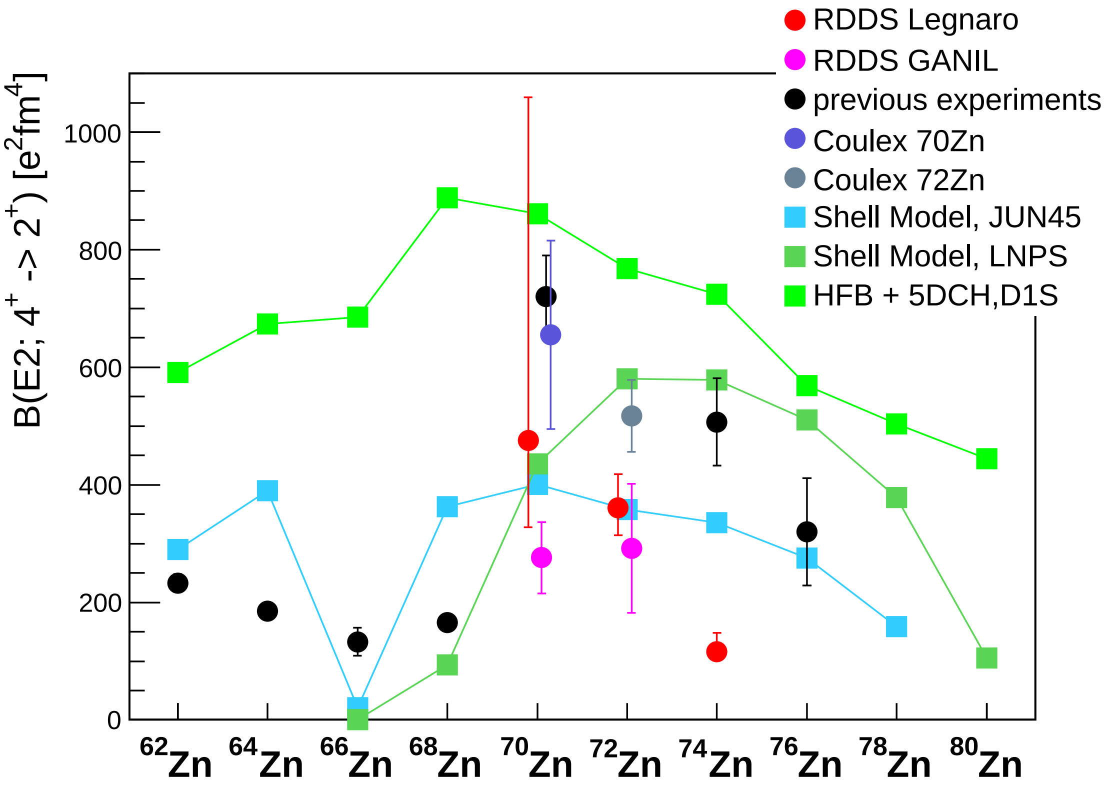
^{74}Zn on ^{208}Pb: analysis by A. Illana, KU Leuven



Analysis under way, we expect to obtain:

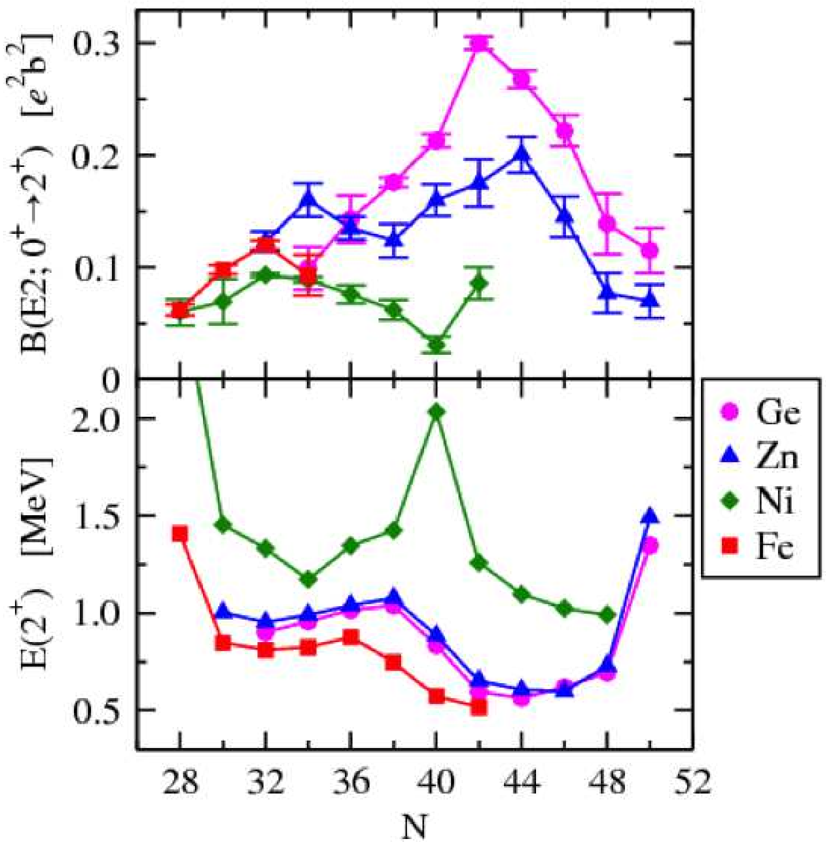
- B(E2; $4^+ \to 2^+$) in ^{74,76}Zn
- quadrupole moments of 2^+_1 in ^{74,76}Zn
- B(E2; $2^+_2 \to 2^+_1$) in ^{74}Zn (?)

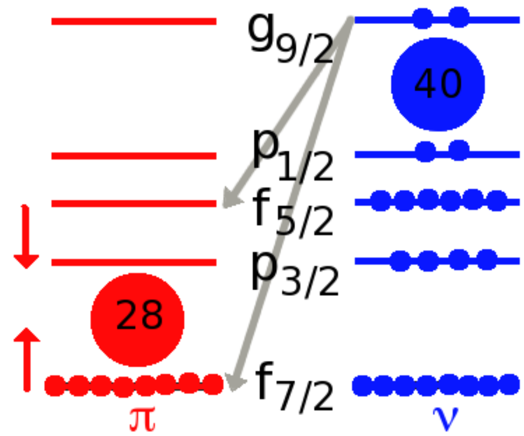
What have we learnt so far?



- systematic disagreement between RDDS and Coulex results for 4^+ states
- DSAM result (states populated in non-safe Coulex) seems consistent with Coulex
- ...but the RDDS result from GANIL, also with states populated in non safe Coulex, is not!
- better control of possible sources of systematic errors needed
  - feeding in lifetime measurements
  - second-order effects in Coulex $\rightarrow$ higher statistics necessary
- too early to make comparisons with theory

Description of the region south of ^{68}Ni

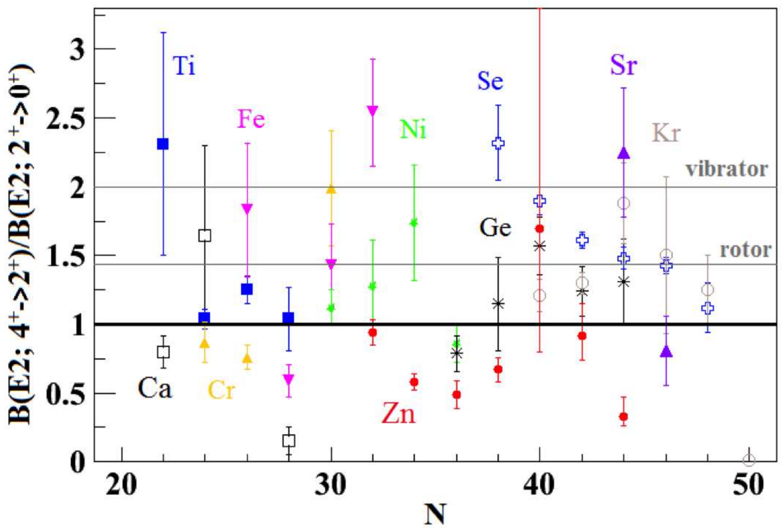




- Interaction between neutron $g_{9/2}$ and proton fp shell causes lowering of the $f_{5/2}$ and raising of the $f_{7/2}$
- collectivity increases with filling of the $g_{9/2}$
- transition probabilitities important to test validity of model descriptions

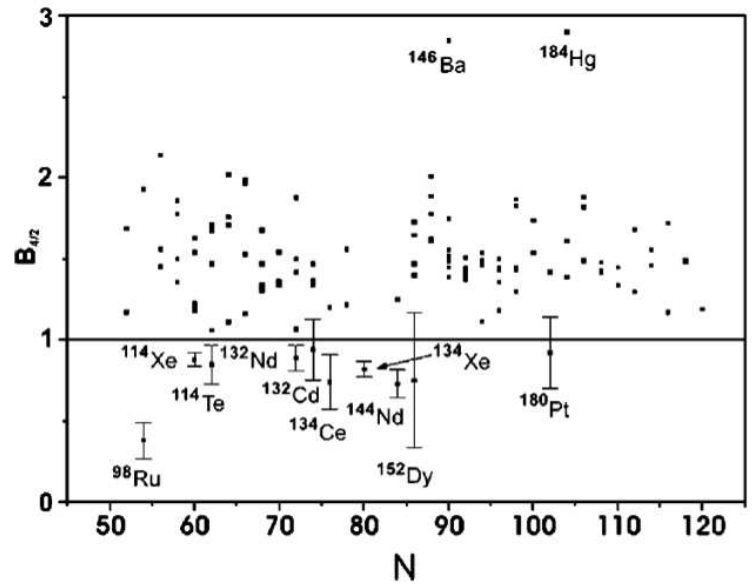
Collectivity of 4^+ states

Z<40 nuclei



40<Z<80 nuclei

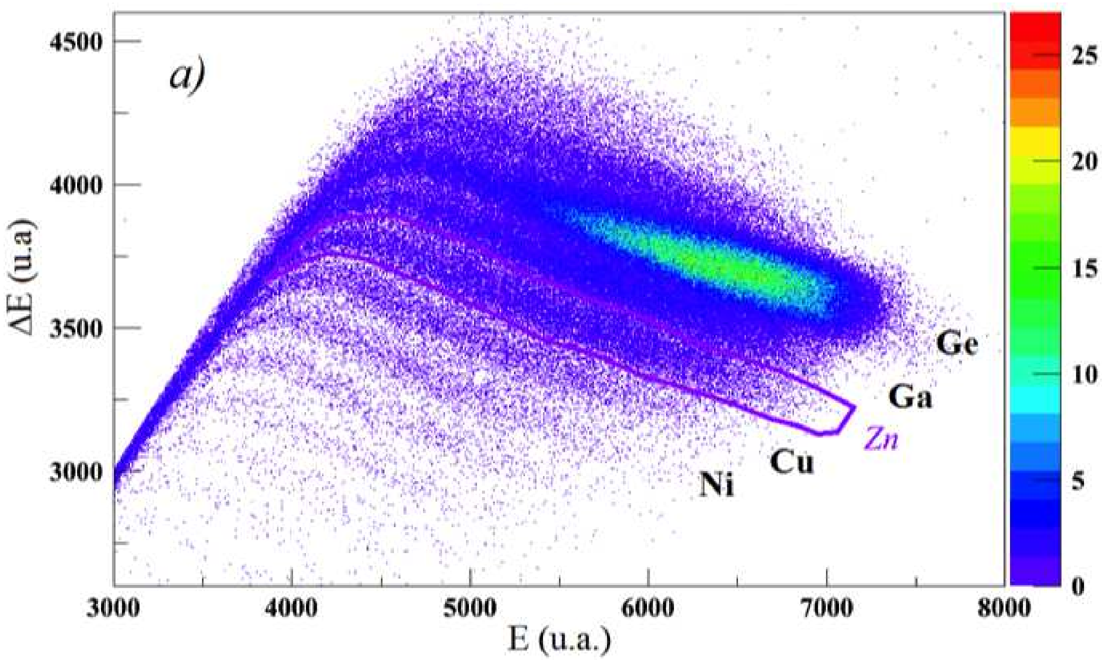
R.B. Cakirli et al. PRC 70, 047302 (2004)

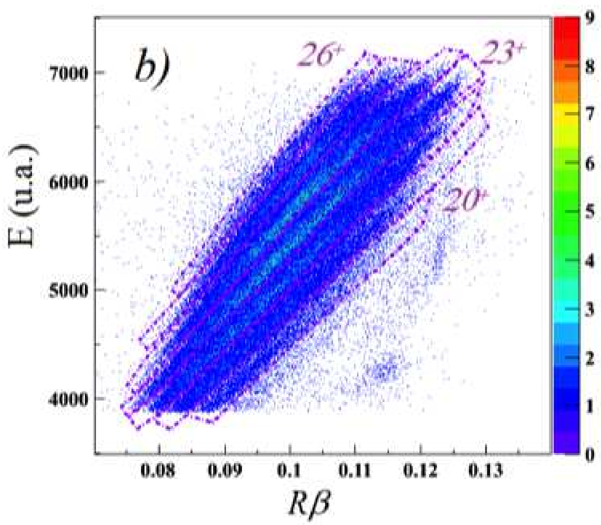


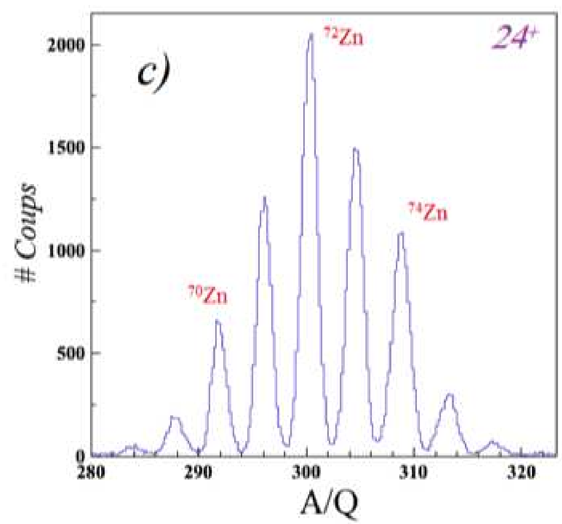
- Small B(E2;$4^+ \rightarrow 2^+$)/B(E2;$2^+ \rightarrow 0^+$) ratio for all Zn isotopes $\rightarrow$ indication of a non-collective character of the 4^+ states

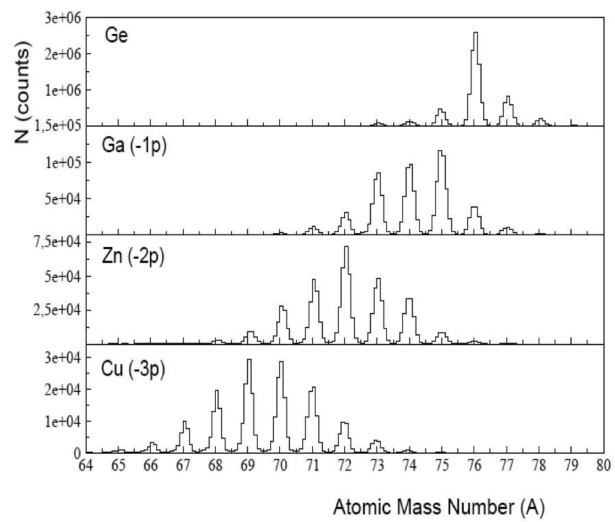
Identifications of recoils

C. Louchart, PRC 87 (2013) 054302









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