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

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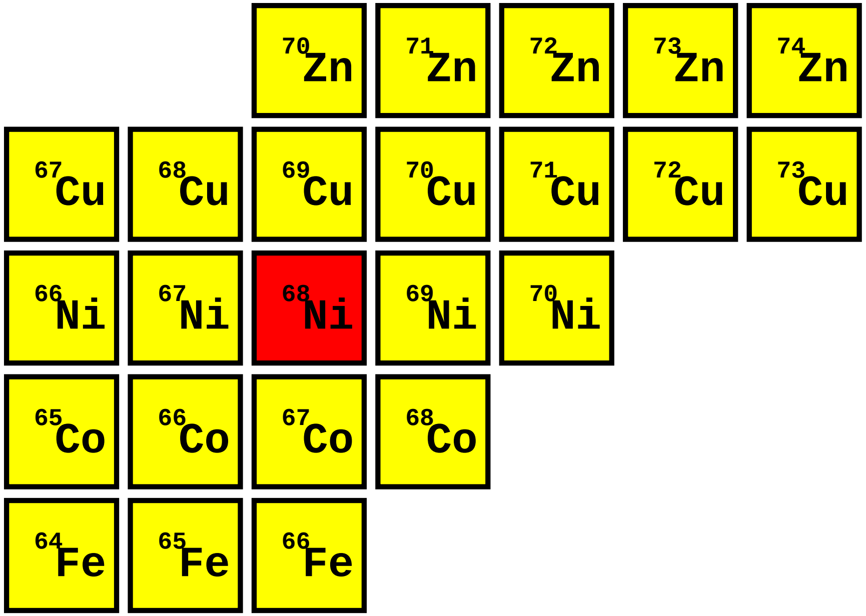
and the IS557 – MINIBALL collaboration
(KU Leuven, CEA Saclay, CERN, PSI Villigen, HIL Warsaw, IKP Köln, TU Darmstadt, U. Jyväskylä, INFN Firenze, INFN Legnaro, U. West of Scotland, TU Munich, U. Lund, U. Surrey, U. Sofia, CSNSM, IPN Orsay, IEM-CSIC)

- 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

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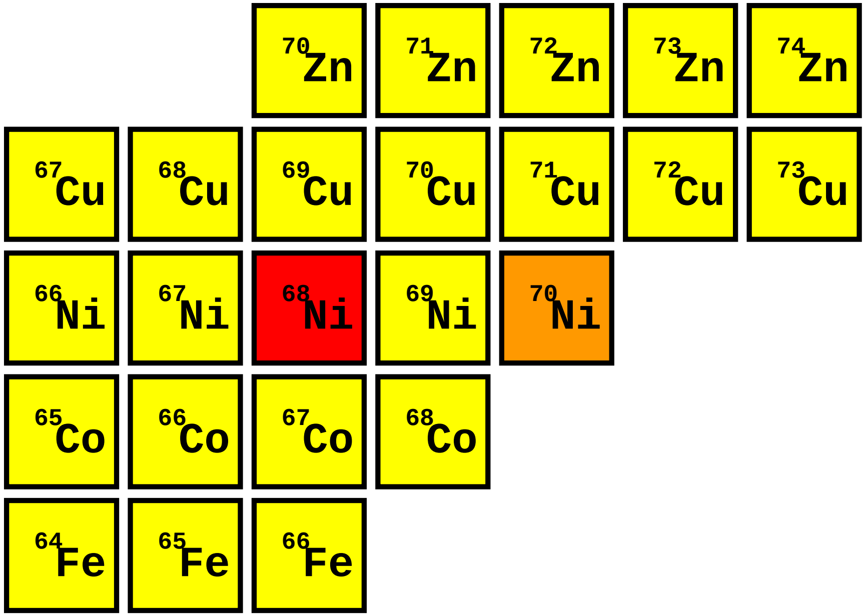

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  O. Perru et al., PRL 96 (2006)

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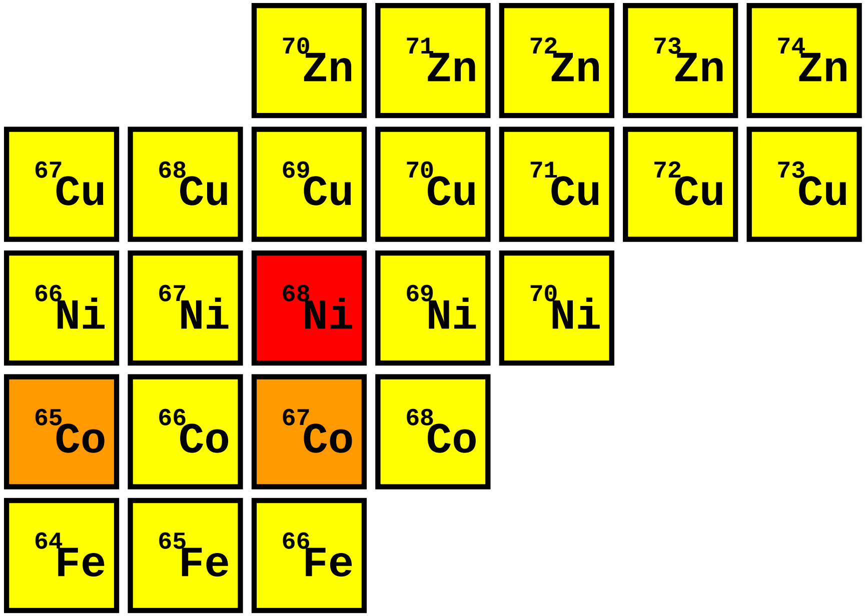

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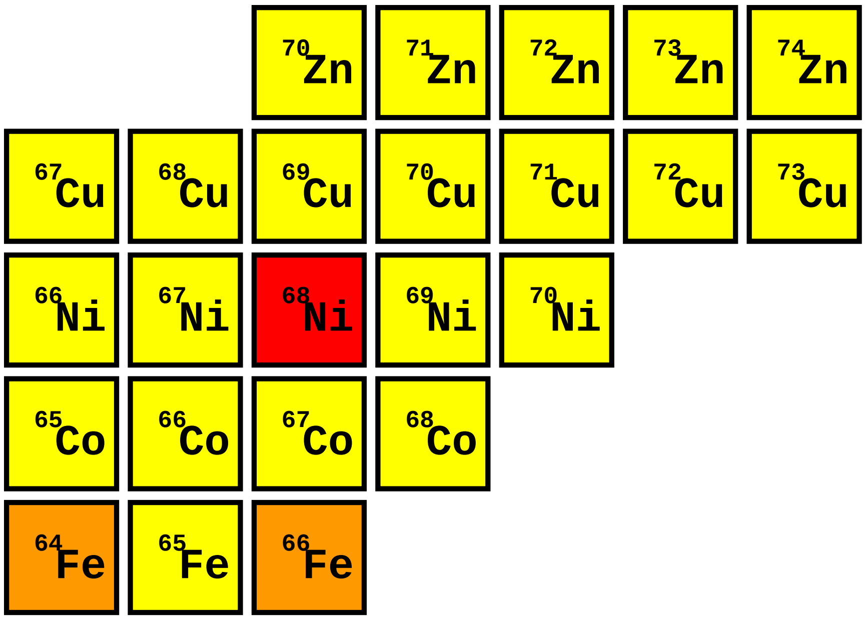

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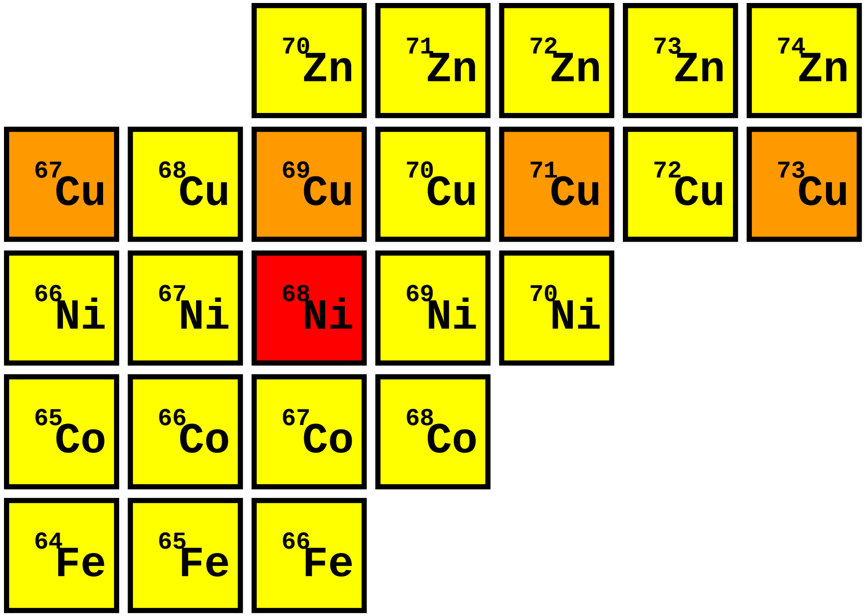

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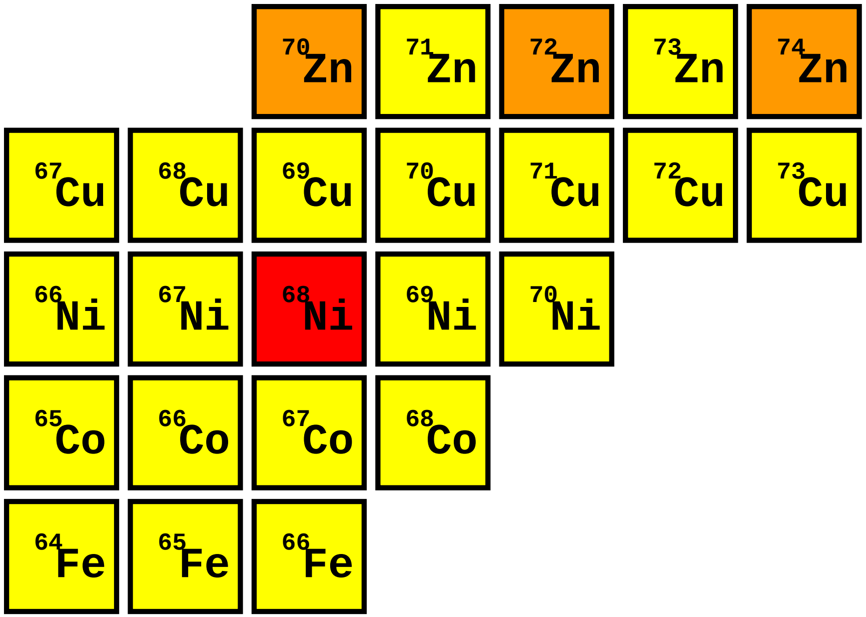

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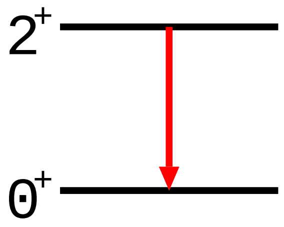
Experimental methods to measure transition probabilities around ^{68}Ni

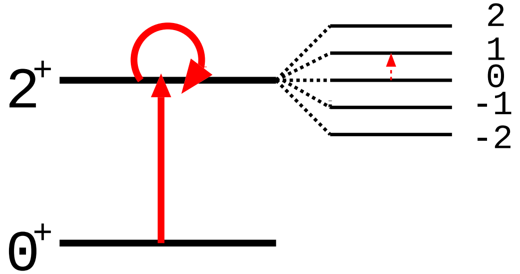
- Lifetime measurements after deep-inelastic reactions
  - yrast states
  - problem of unknown feeding



$\langle 2^+ \| E2 \| 0^+ \rangle^2$

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

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

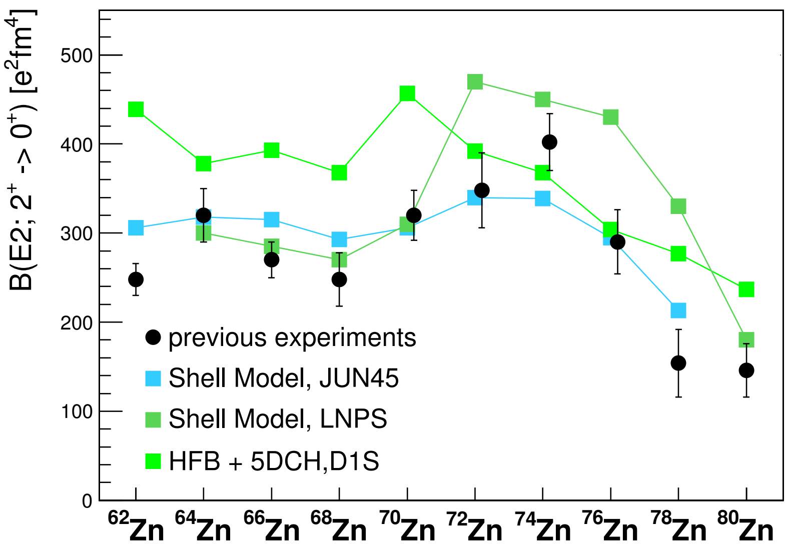


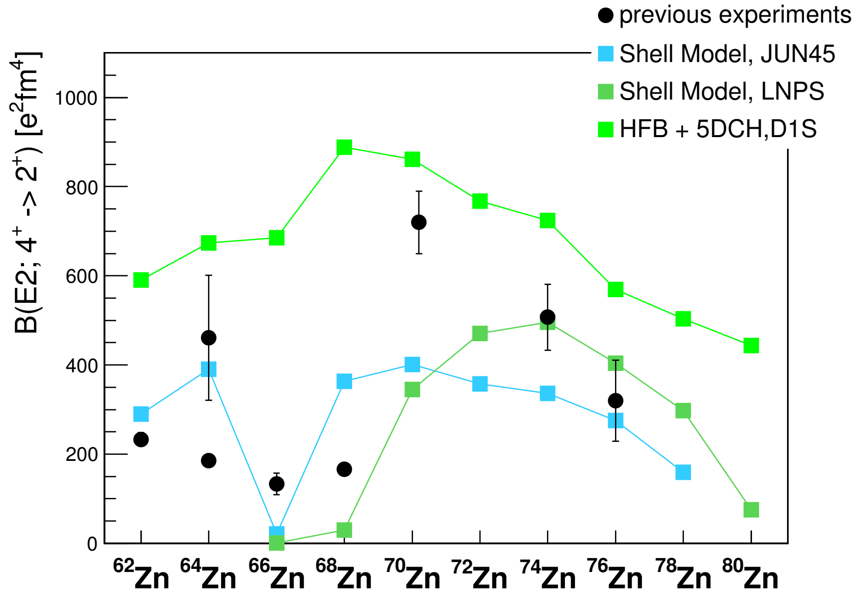
$\langle 2^+ \| E2 \| 2^+ \rangle \sim Q_0$

Combination of both methods should in principle give information on quadrupole moments, provided that the measurements are precise and accurate

Transition probabilities in Zn isotopes: status five years ago

- B(E2)'s for stable Zn isotopes: Coulex, RDDS, DSAM: some important discrepancies (^{64,66}Zn)
- neutron-rich Zn isotopes: low-energy Coulex, relativistic Coulex for 2^+



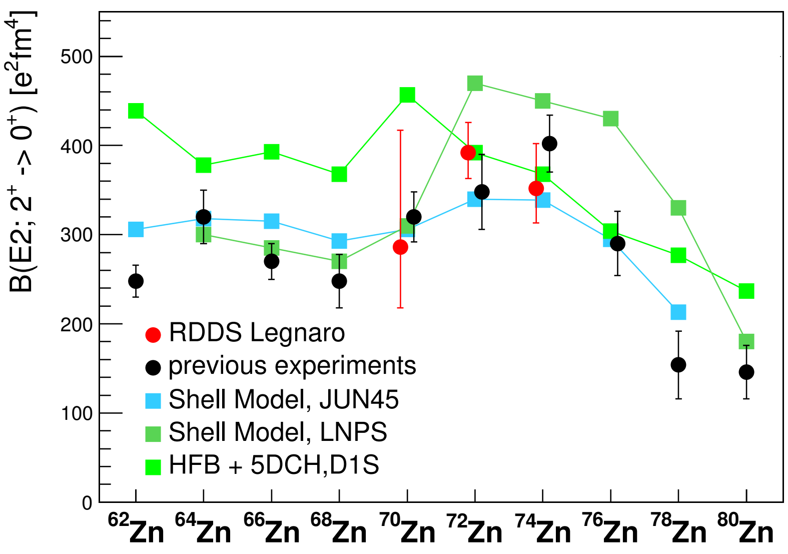


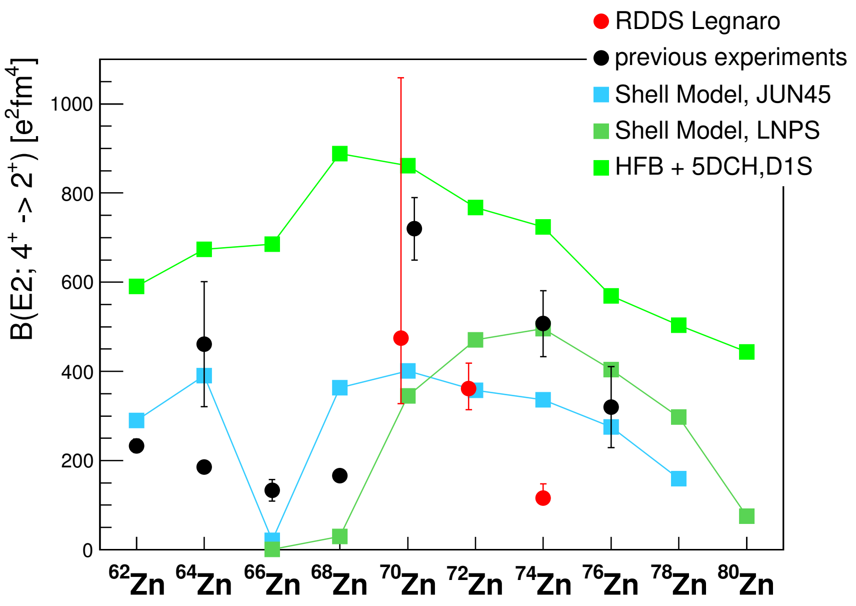
- B(E2; $4^+ \rightarrow 2^+$) better test for theories than B(E2; $2^+ \rightarrow 0^+$)
- collectivity overestimated by beyond-mean-field calculations

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

C. Louchart, PRC 87 (2013) 054302

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

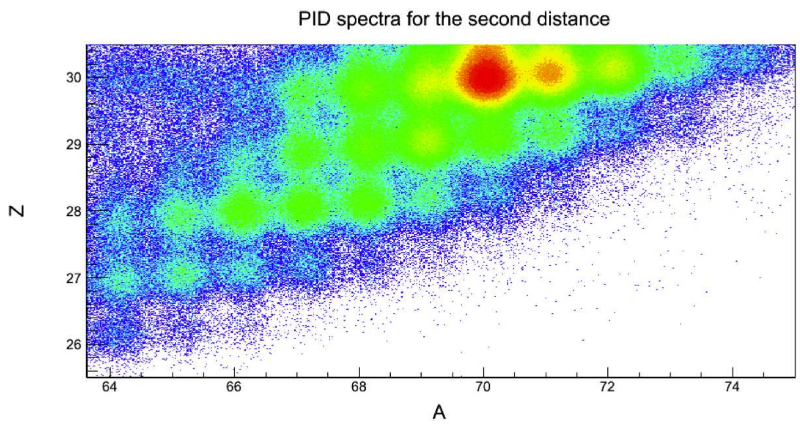




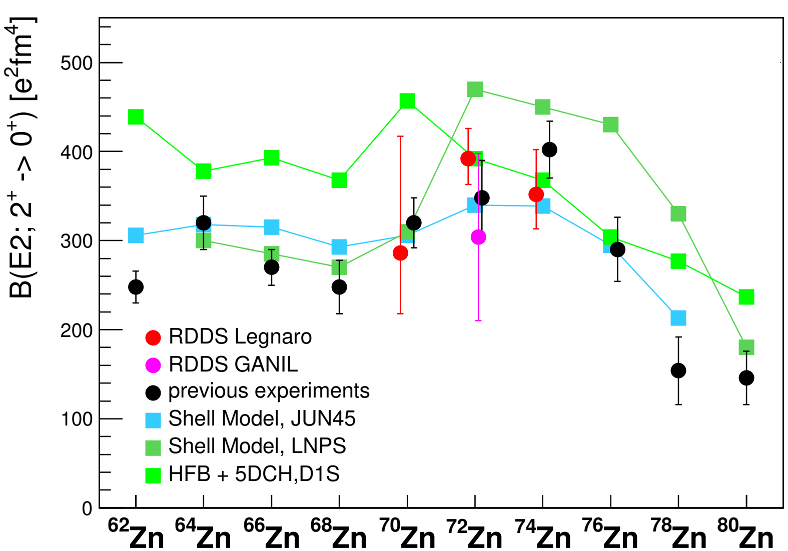
- discrepancy of the new lifetimes for 4^+ states with low-energy Coulex results (especially for ^{74}Zn)

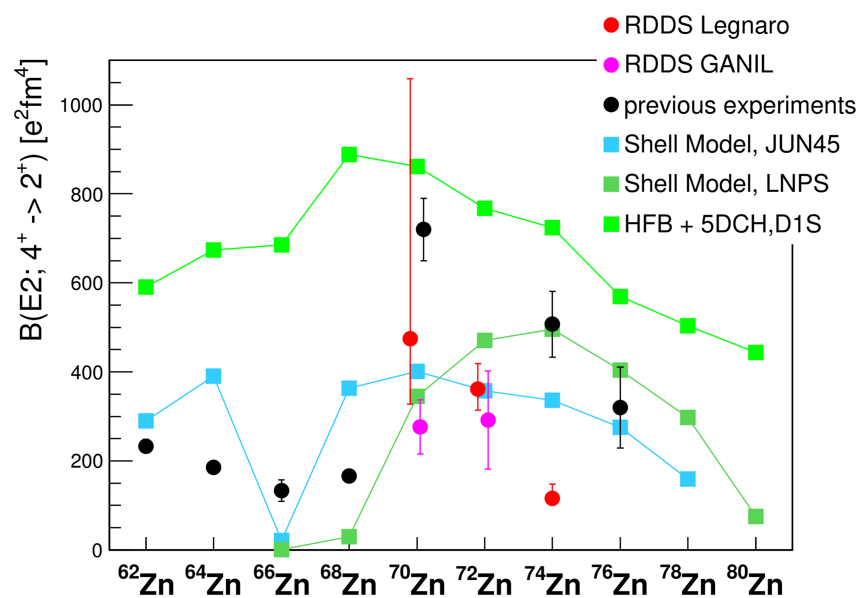
Lifetime measurements in ^{70,72}Zn

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

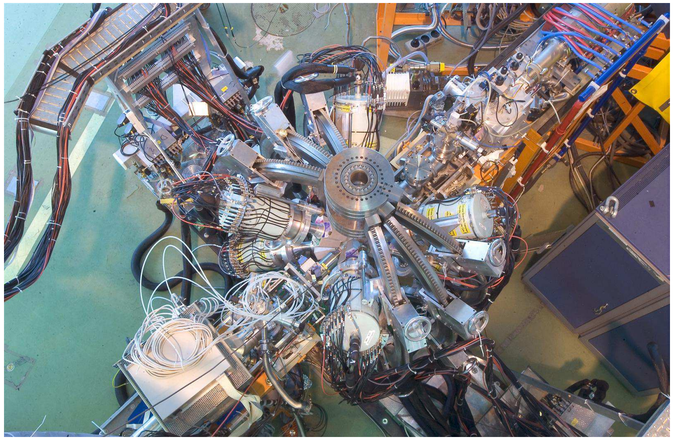


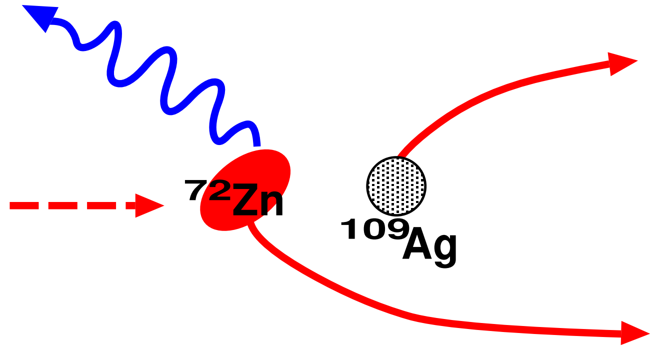
- plunger measurement at GANIL: EXOGAM+VAMOS
- ^{238}U beam (6.8 MeV/u) on ^{70}Zn
- confirmation of the RDDS results from Legnaro





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
(+ sometimes C-REX Barrel Si)
detection of scattered Zn
and recoiling target nuclei

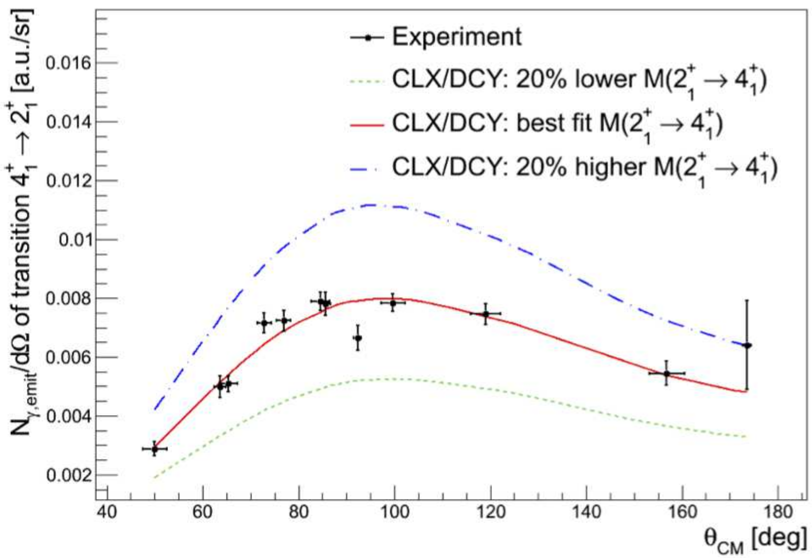
deexcitation γ rays mesured in coincidence with particles (Zn and target recoils)

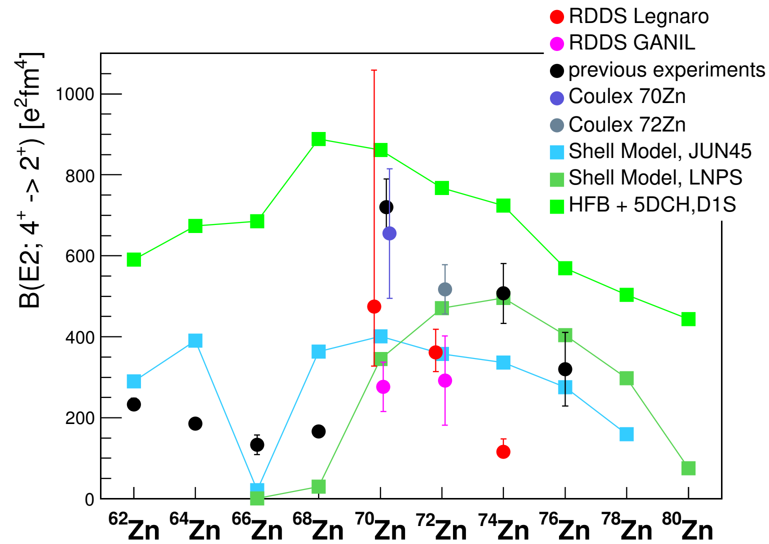
laser ionisation to suppress strong Ga contamination

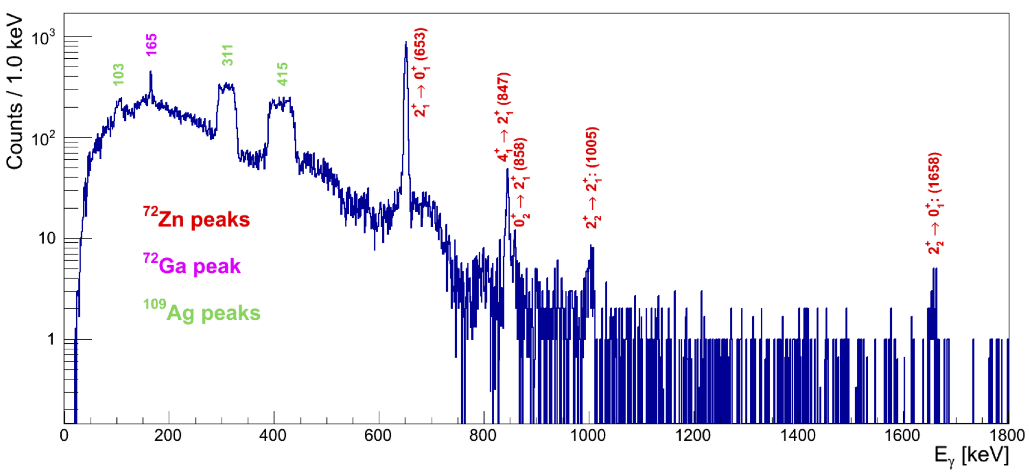
beam intensities: 3 10^7 pps (^{72}Zn), 1 10^6 pps (^{74}Zn), 5 10^5 pps (^{76}Zn), 3 10^4 pps (^{78}Zn)

Coulomb excitation of ^{72}Zn

PhD S. Hellgartner, TU Munich (2015)



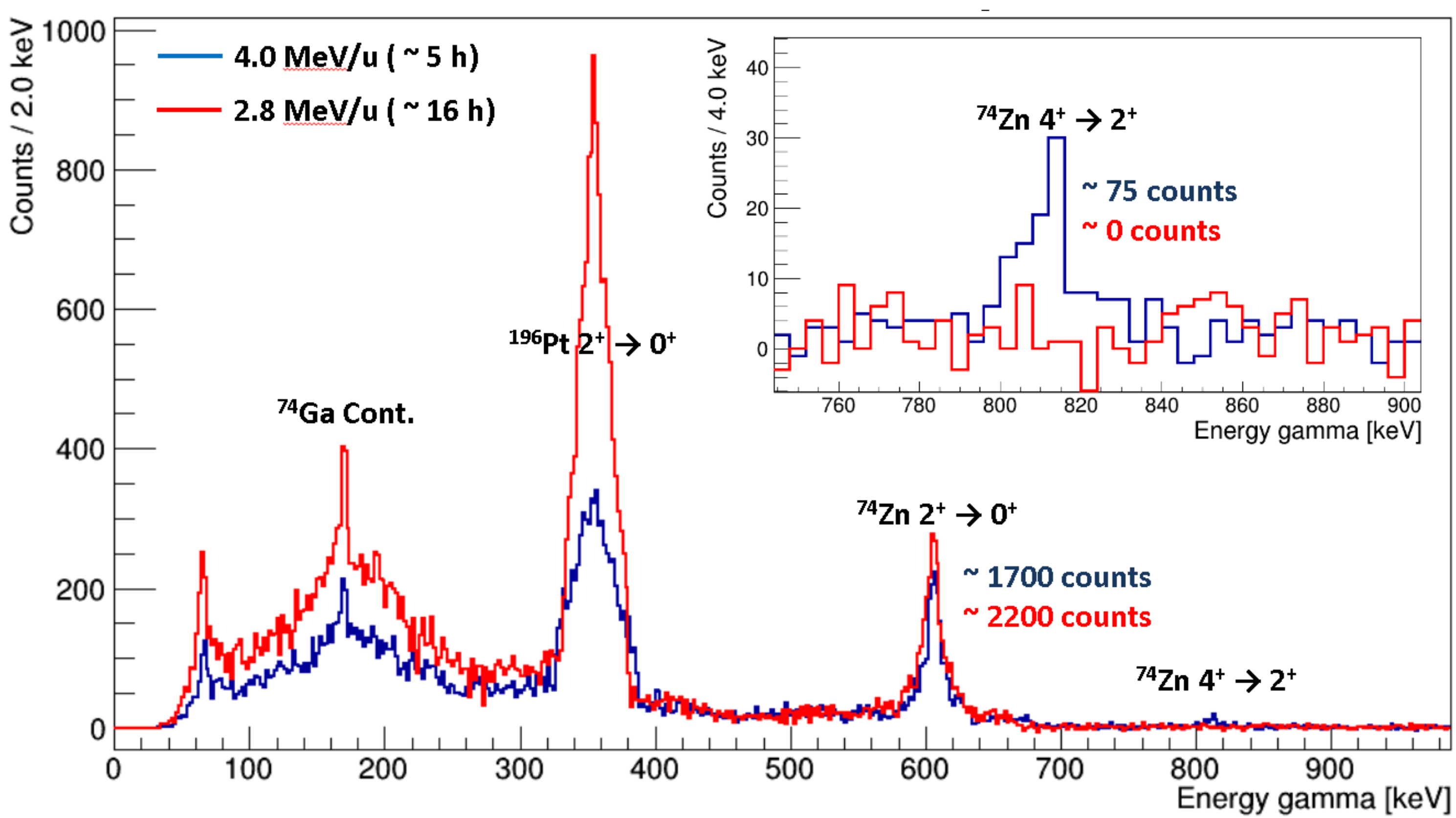




- low-energy Coulex at ISOLDE
- C-REX setup
  - broad range of CM angles
- large statistics
  - differential cross sections
  - high-precision measurement
  - consistency check

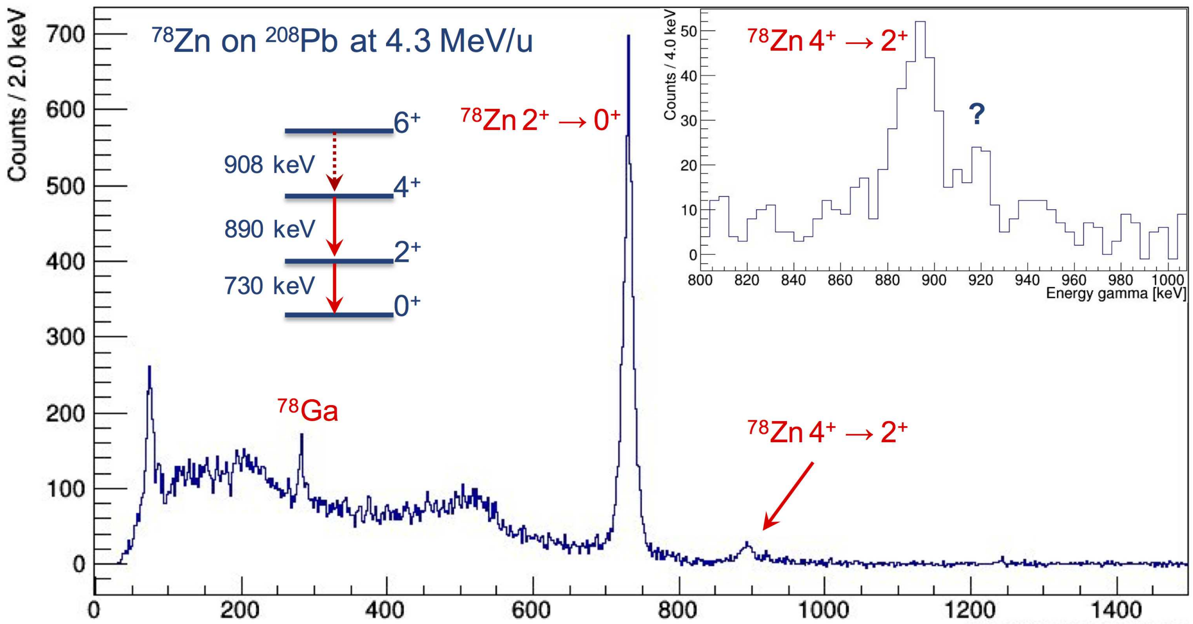
Coulomb excitation of ^{74,76}Zn: the first HIE-ISOLDE experiment

October 2015, ^{74}Zn on ^{196}Pt: analysis by A. Illana Sison

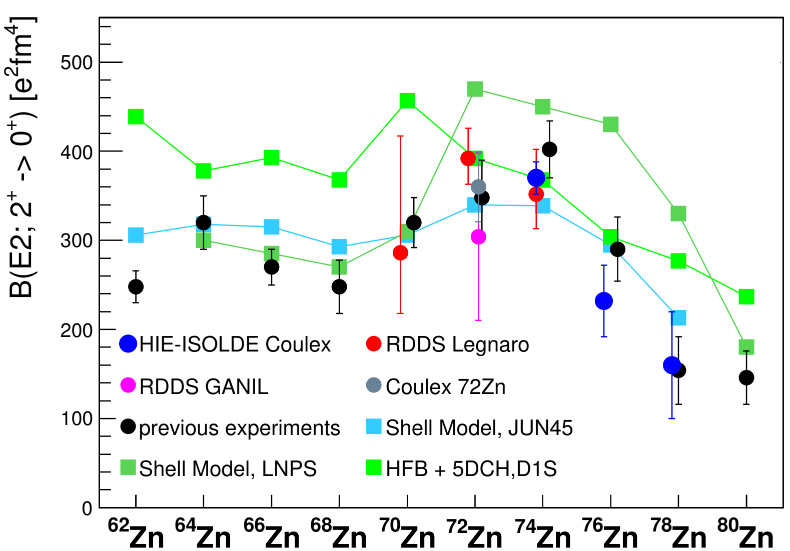


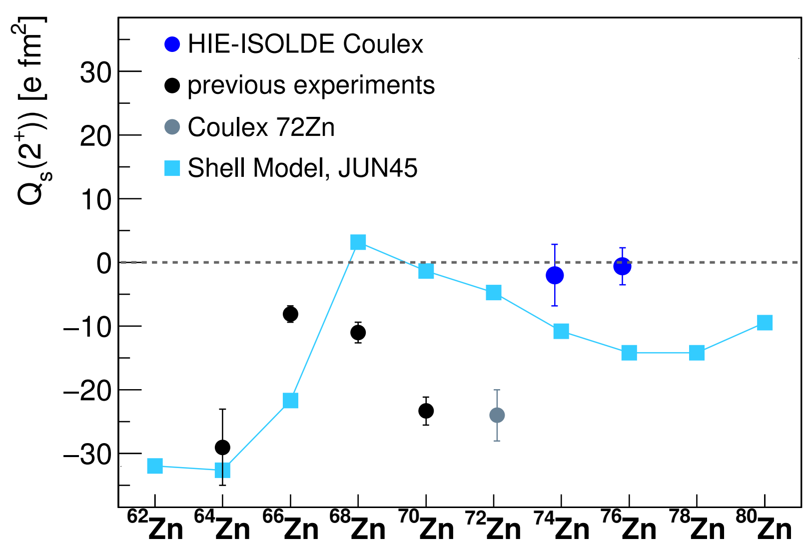
- increased probability of multi-step excitation
- higher sensitivity to quadrupole moments
- max 6 hours of 4MeV/A beam per day, only on weekdays
- bad beam time structure (150 μs bursts) – high particle multiplicity

Coulomb excitation of ^{74,76,78}Zn: preliminary results

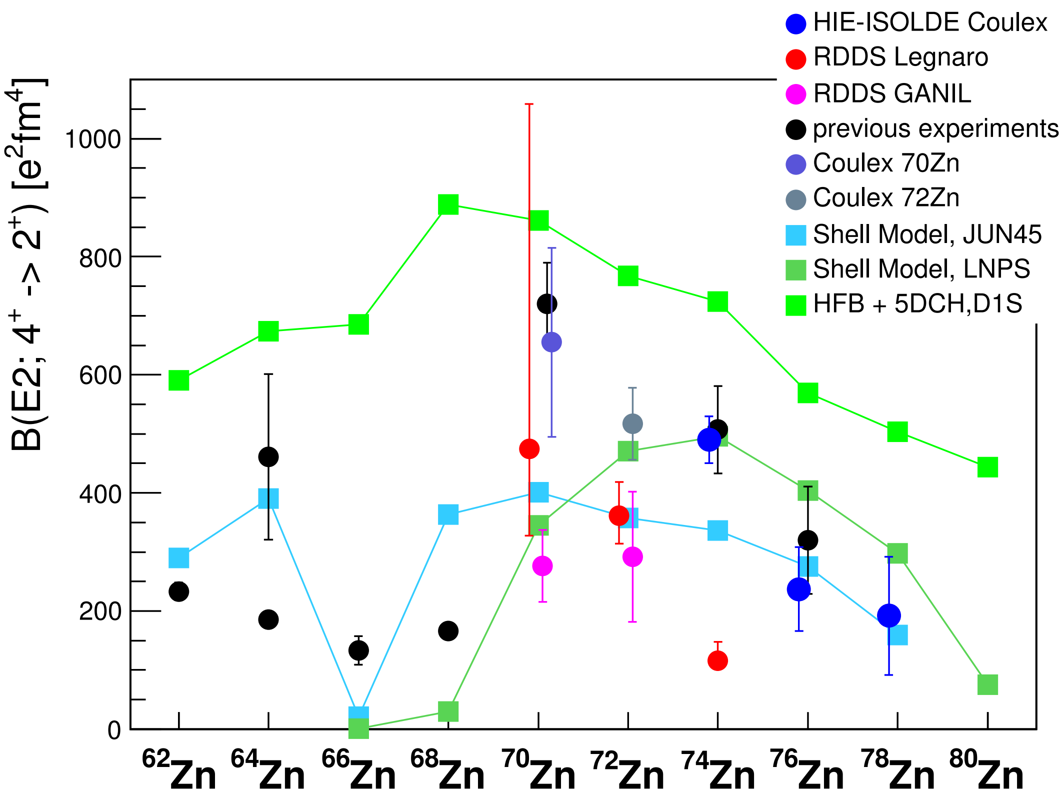


- October 2016:
  5 days of ^{78}Zn
  (4.3 MeV/u)
  on ^{196}Pt/^{208}Pb
- analysis in the final stage
  (A. Illana Sison)





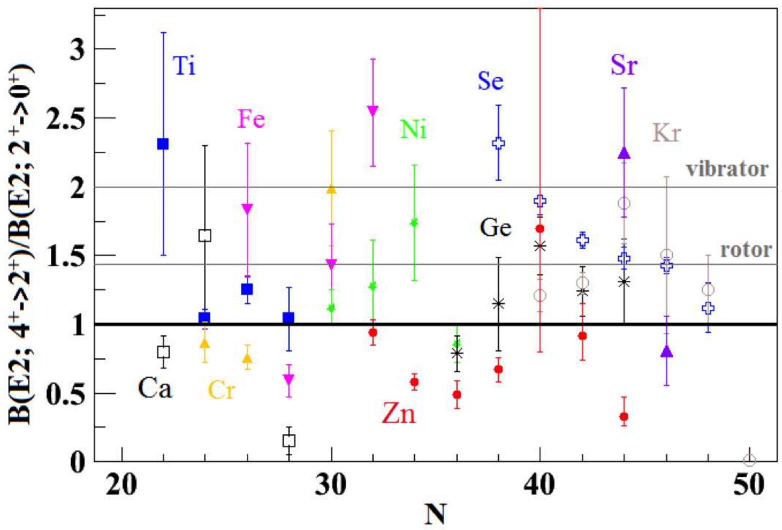
What have we learnt so far?



- 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

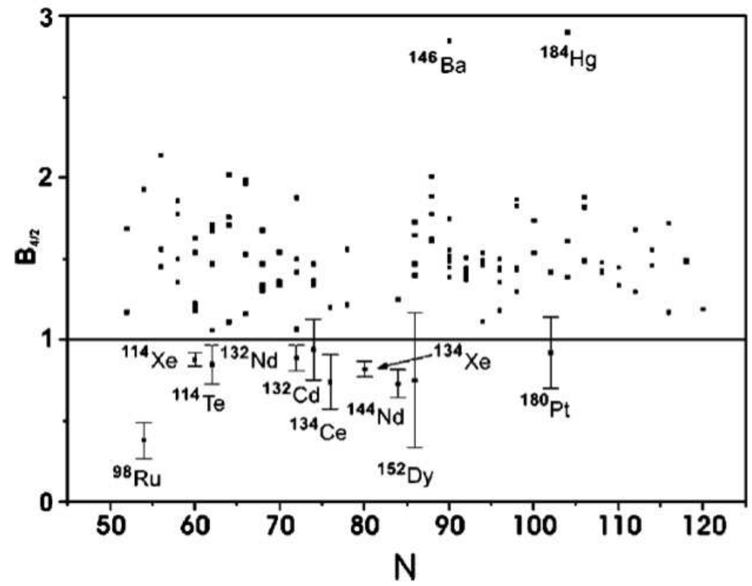
Collectivity of 4^+ states

Z<40 nuclei



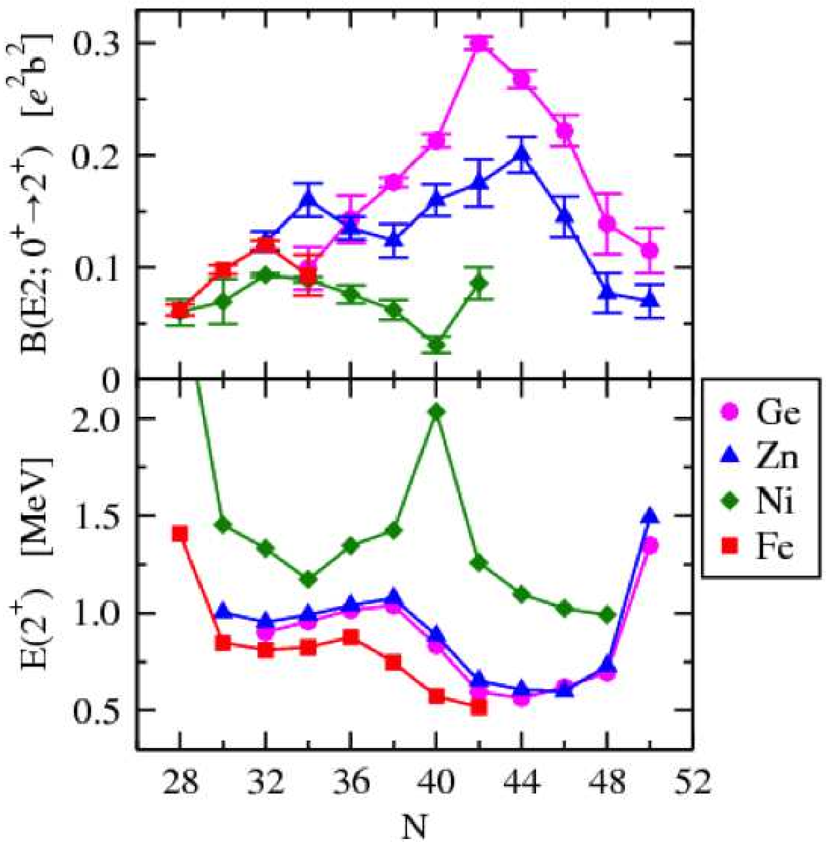
40<Z<80 nuclei

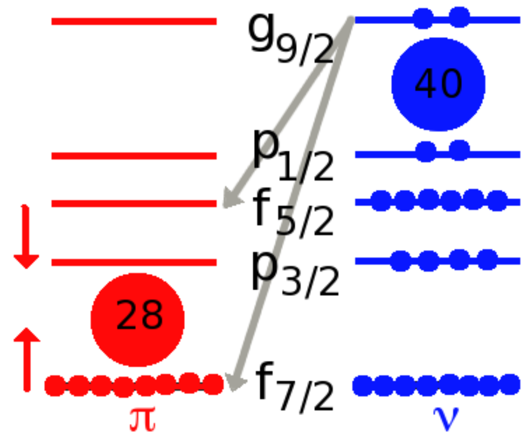
R.B. Cakirli et al. PRC 70, 047302 (2004)



- 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

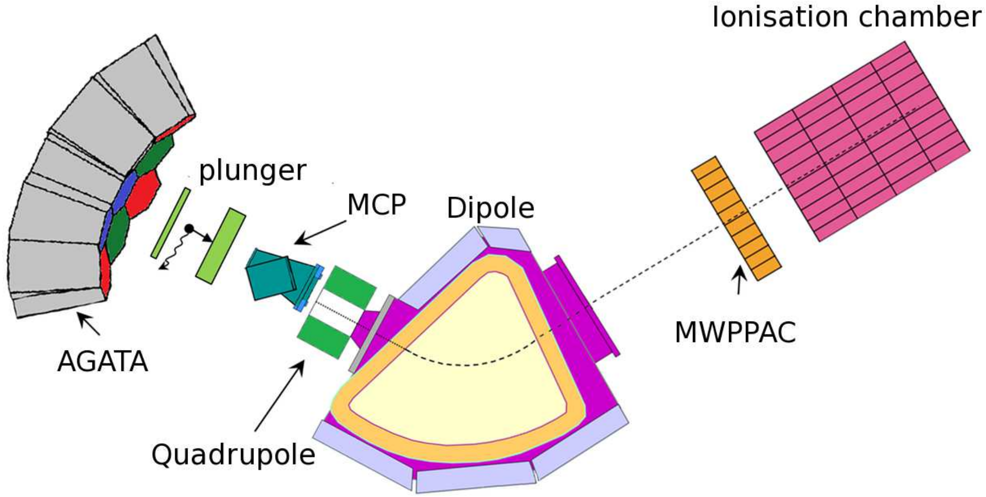
Description of the region south of ^{68}Ni



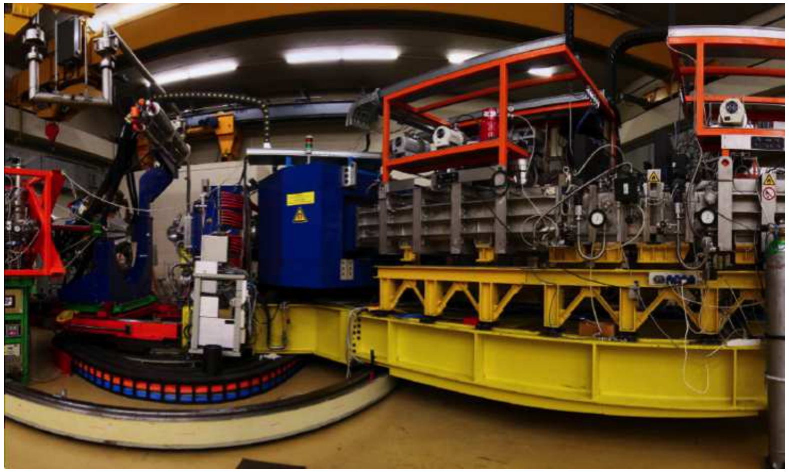


- Interaction between neutron $g_{9/2}$ and proton fp shell causes lowering of the $f_{5/2}$ and raising of the $f_{7/2}$
- collectivity increases with filling of the $g_{9/2}$
- transition probabilitities important to test validity of model descriptions

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



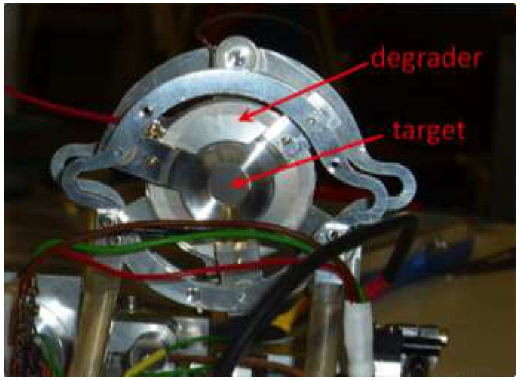
C. Louchart, PRC 87 (2013) 054302



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

4 AGATA clusters

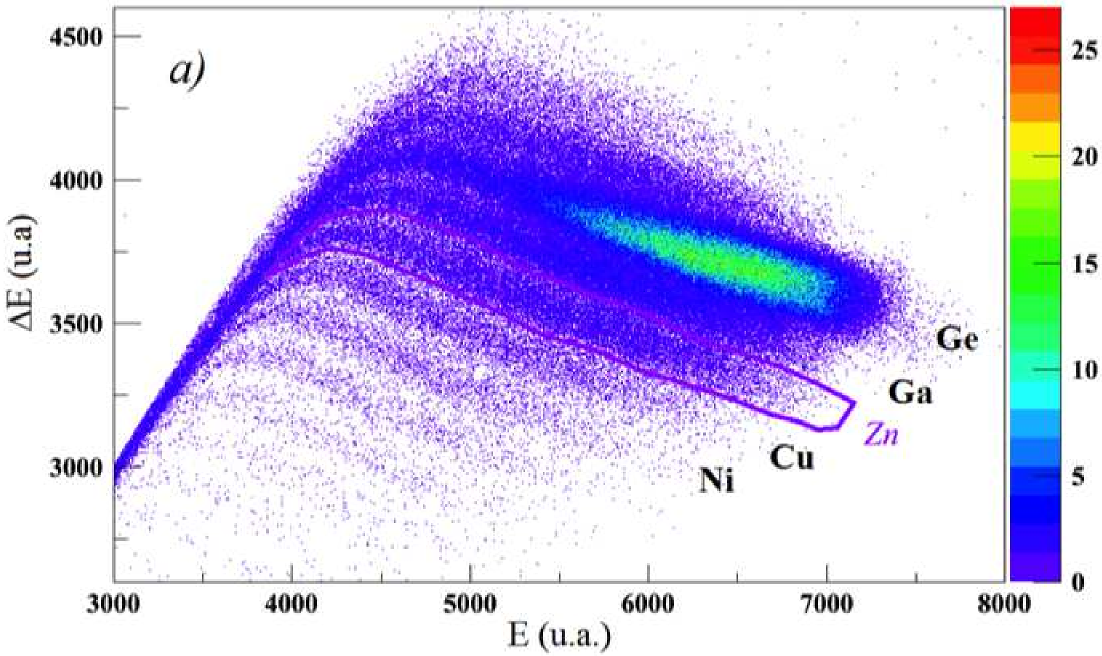
Cologne plunger

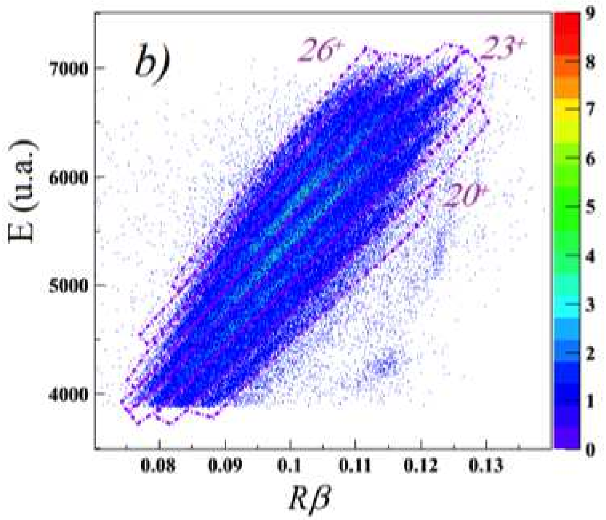


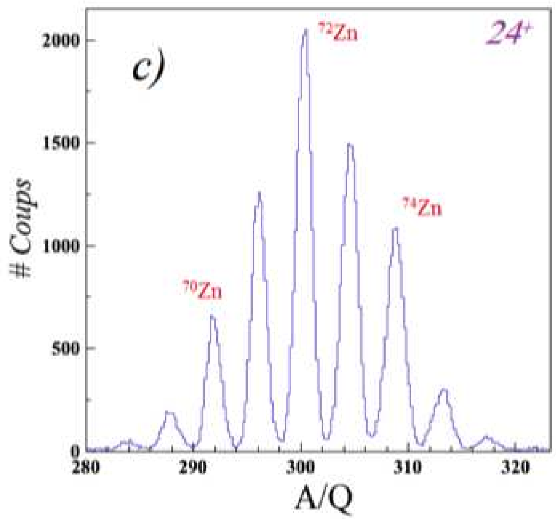
Target: 1.4 mg/cm^2
Degrader: Nb – 4.2 mg/cm^2
5 plunger distances:
100, 200, 500, 1000, 1900 μm
(20 hours each)

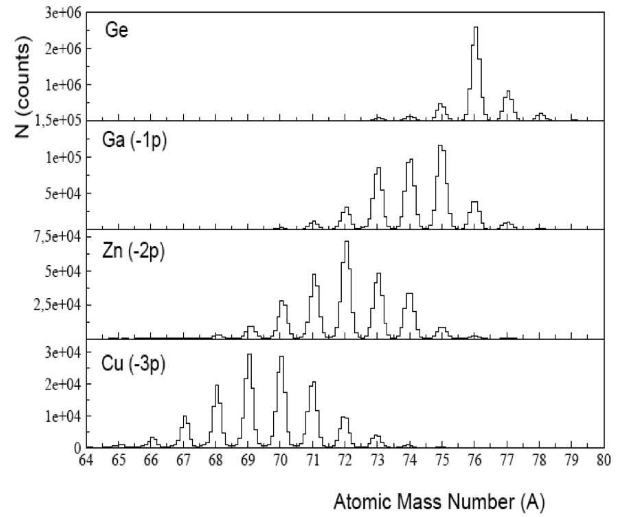
Identifications of recoils

C. Louchart, PRC 87 (2013) 054302



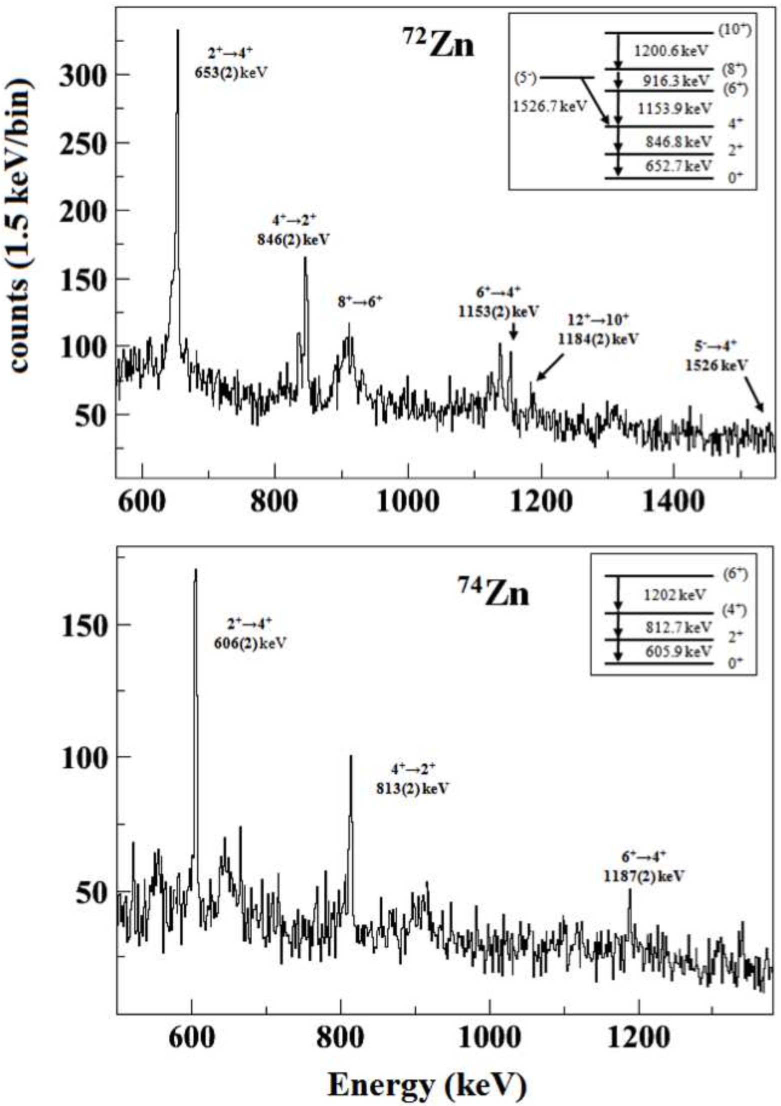


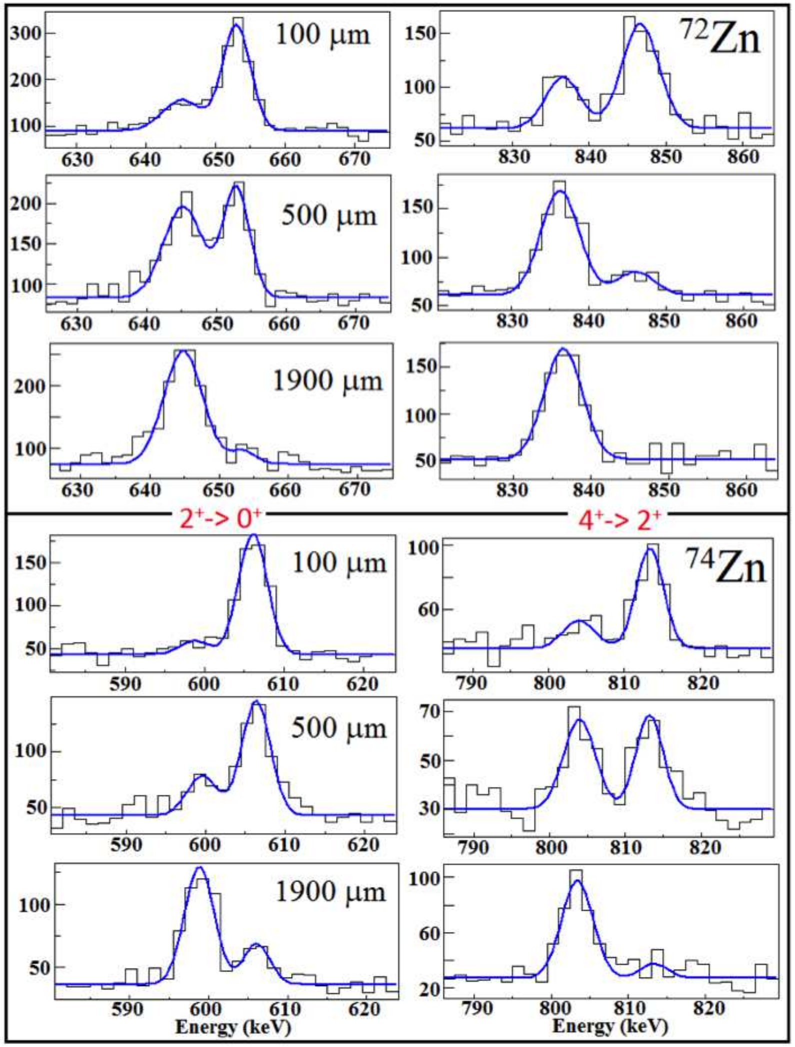




Lifetime measurements in $^{70-74}$Zn

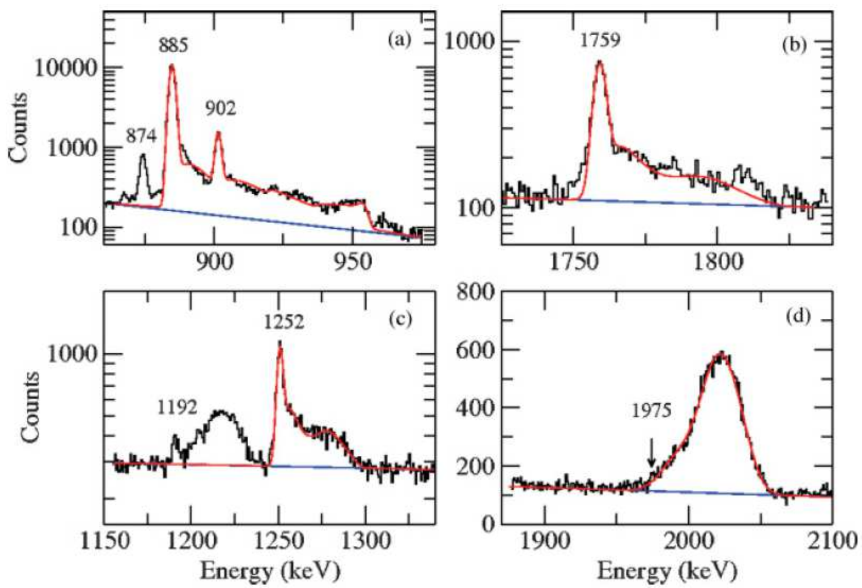
C. Louchart, PRC 87 (2013) 054302

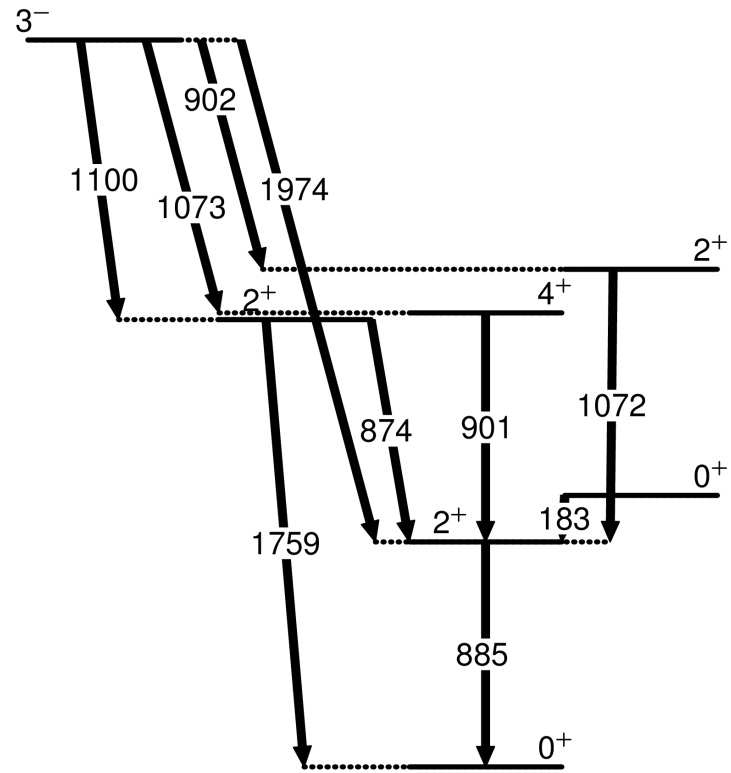




Transition probabilities in ^{70}Zn

D. Mücher et al PRC 79 (2009)



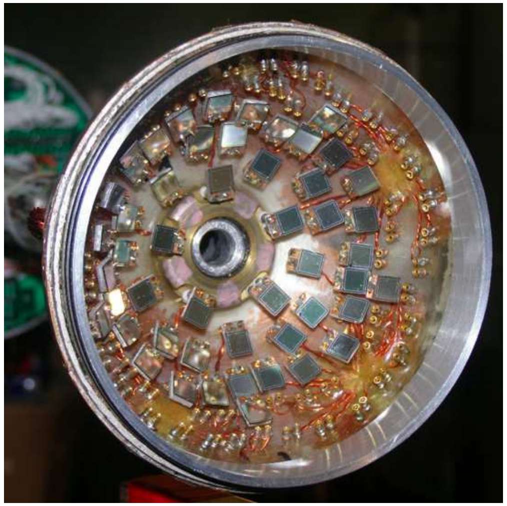


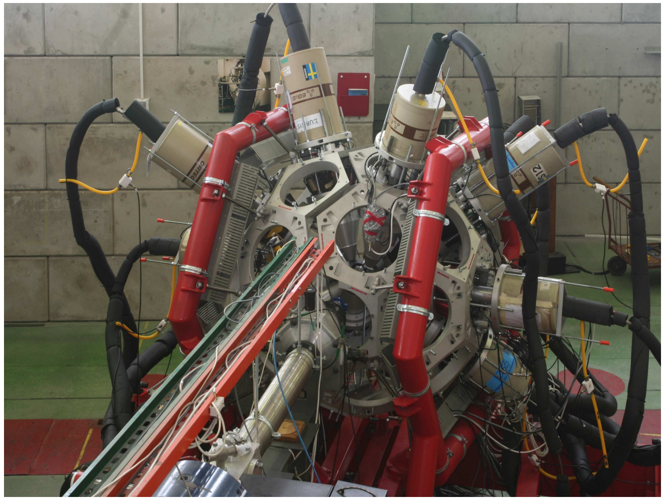
- DSAM measurement, excited states in ^{70}Zn populated by non-safe Coulex on ^{12}C

- $4^{+} \rightarrow 2^{+}$ (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