Multiple Coulomb Excitation of ^{72}Zn with MINIBALL at ISOLDE using a new Coulex silicon geometry

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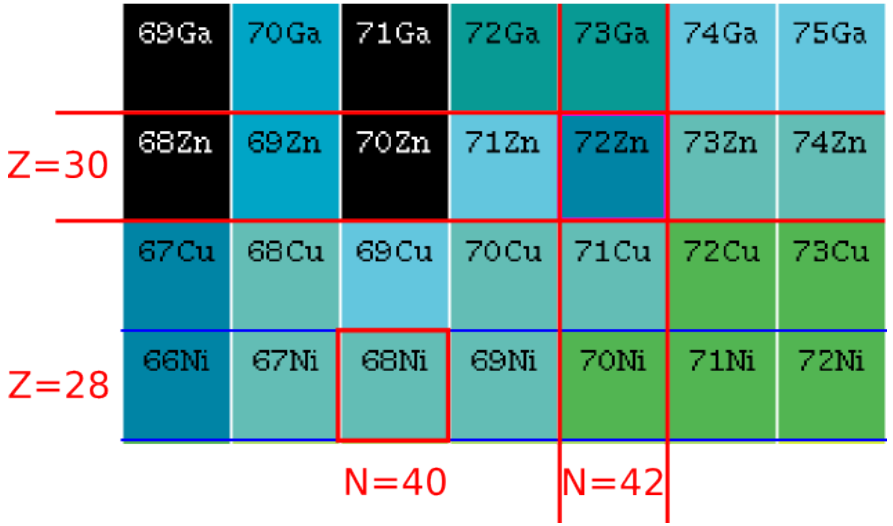
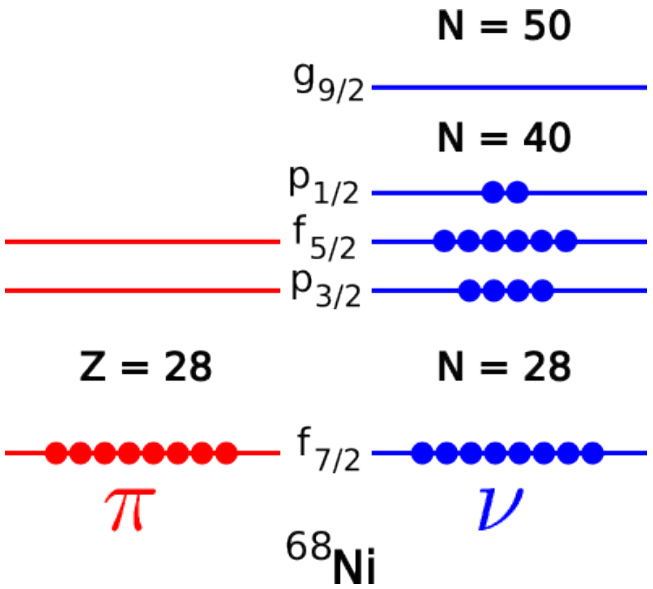
Motivation

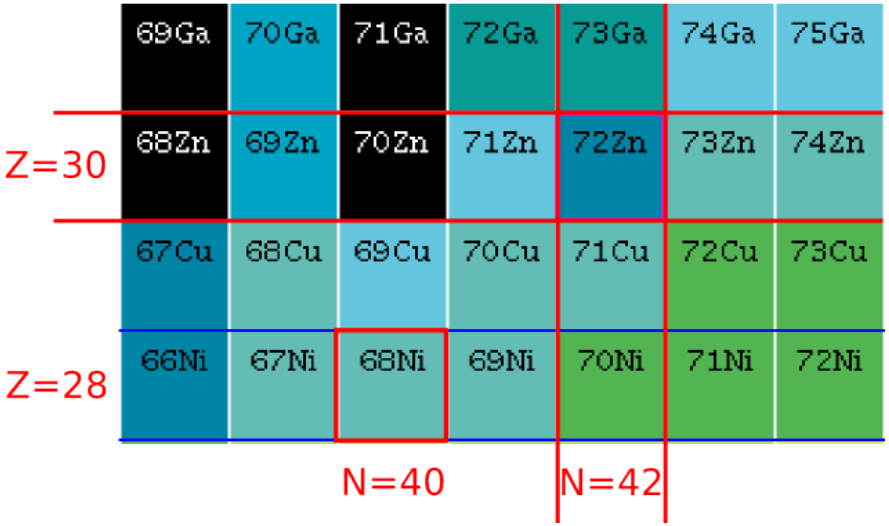


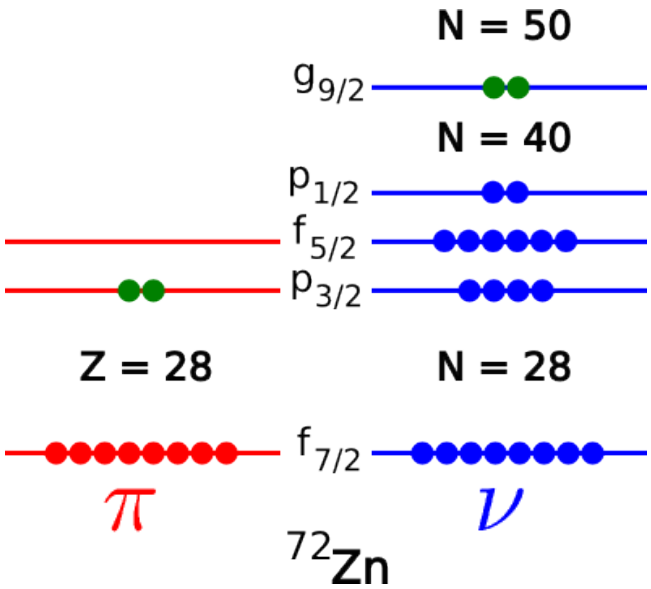


- Today it is not clear if ^{68}Ni is doubly magic or not.

$\Rightarrow$ Study of the proton-neutron interaction near N = 40 with a ^{72}Zn beam

Motivation



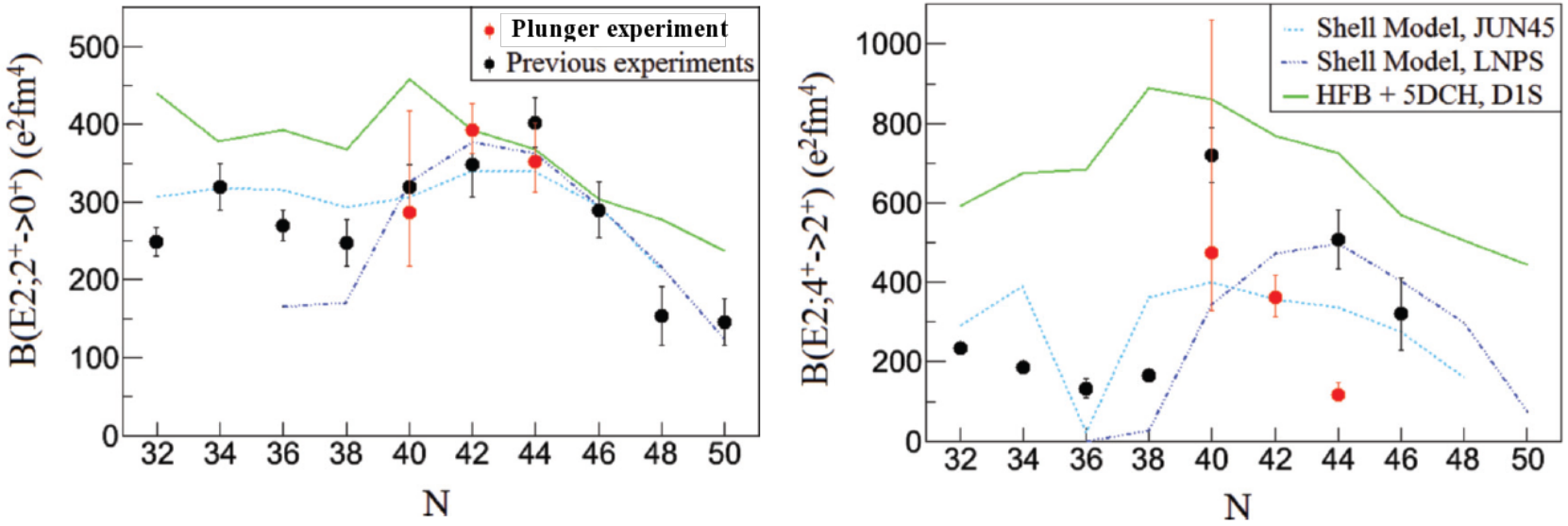


- Today it is not clear if ^{68}Ni is doubly magic or not.

$\Rightarrow$ Study of the proton-neutron interaction near N = 40 with a ^{72}Zn beam

Motivation: B(E2) values of the Zn isotopes

C. Louchart et al.: Phys. Rev. C 87, 054302 (2013)

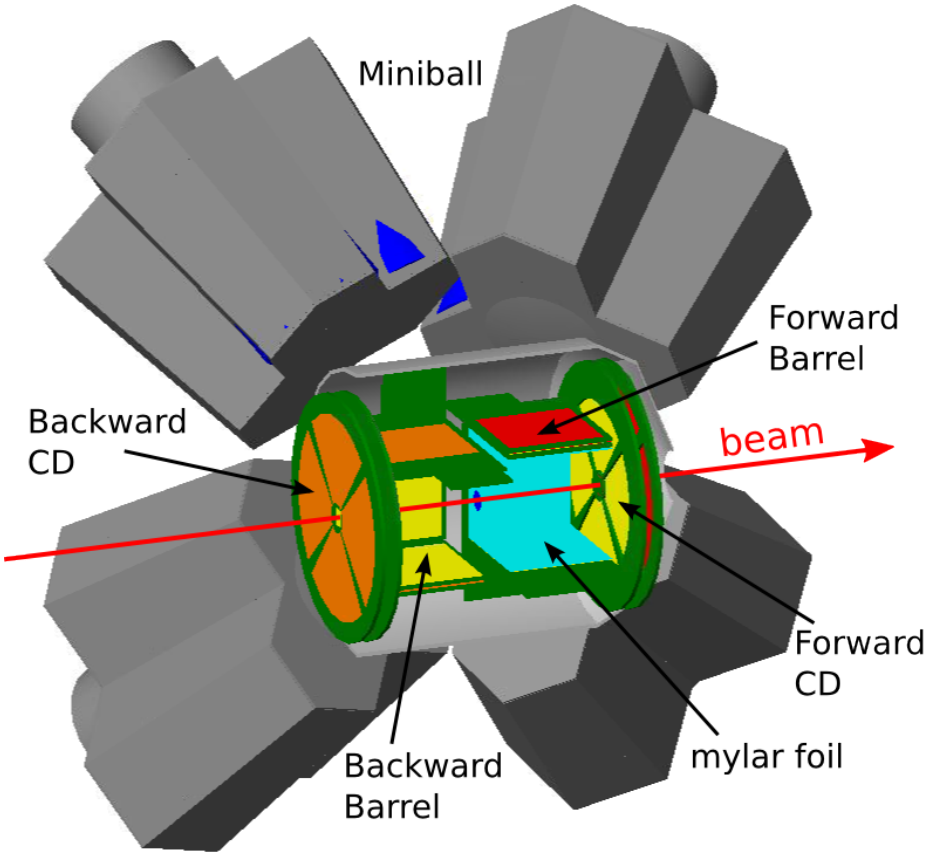


- Good agreement for B(E2; $2_1^+ \rightarrow 0_1^+$)
- But: Discrepancies for B(E2; $4_1^+ \rightarrow 2_1^+$), especially in the experimental data (see also talk of Magdalena Zielinska)

$\Rightarrow$ Additional measurements needed $\rightarrow$ Is510

Experimental setup: T-REX + MINIBALL

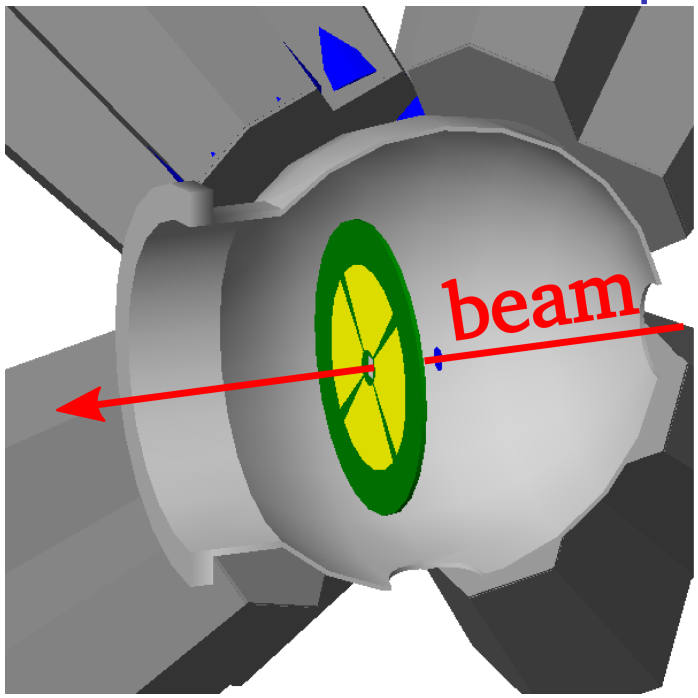
- Experimental setup is based on the T-REX setup at REX-ISOLDE (CERN)
- T-REX: Good tool for studying transfer reactions



- Segmented $\Delta E - E$ Si-telescopes for particle identification (p, d, ...)
- 12 μm mylar protection foils can be installed
- MINIBALL for γ-rays
- Possible targets: ^{2}D or ^{3}H

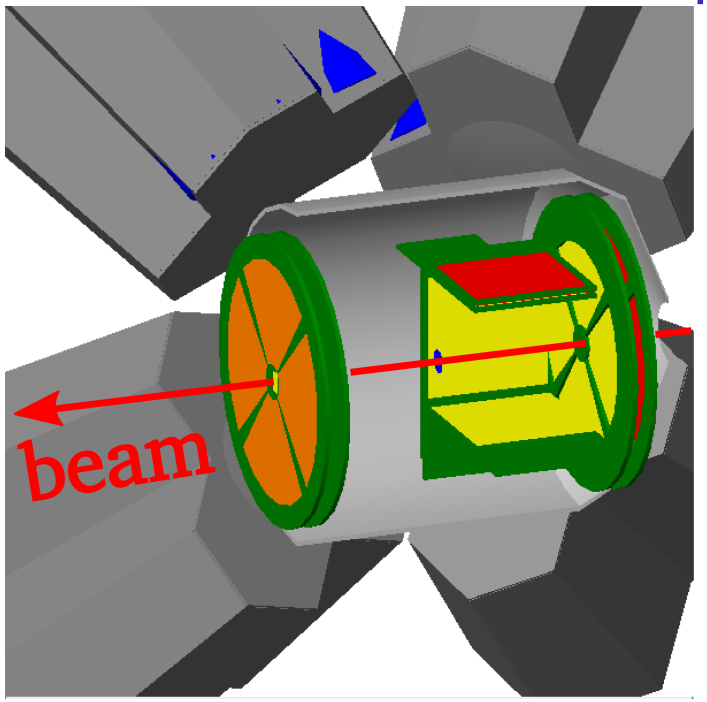
Modifications of T-REX for Coulex experiments

Standard Coulex setup



Fixed CD target distance ($\theta_{lab} = 16° - 54°$)

Coulex with T-REX setup



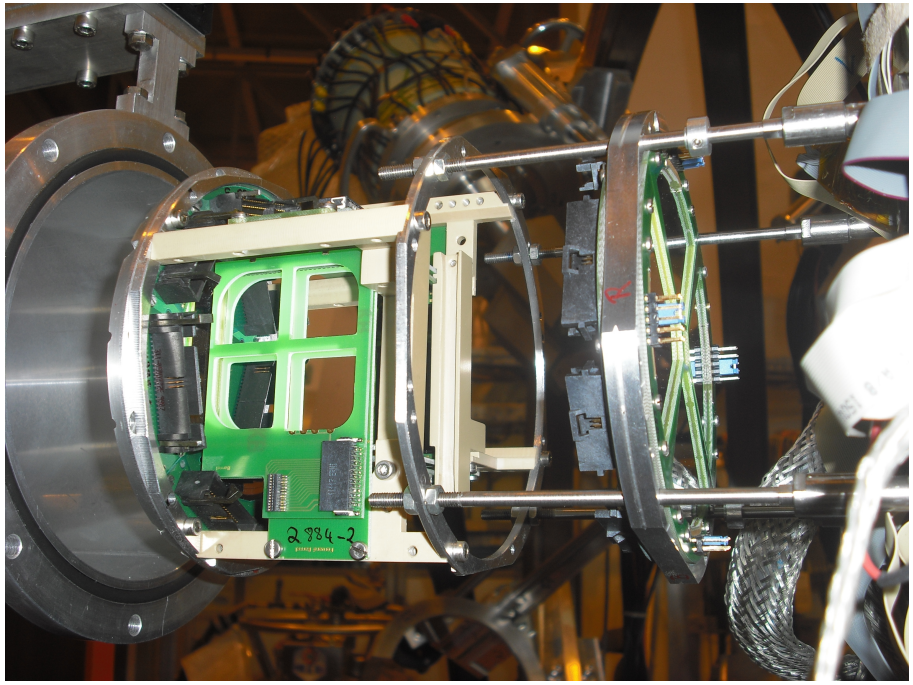
FCD with variable target distance

Optimize Coulex setup

- Largest possible angular coverage
- Tolerable count rates of elastically scattered particles

Photographs of the new Coulex setup

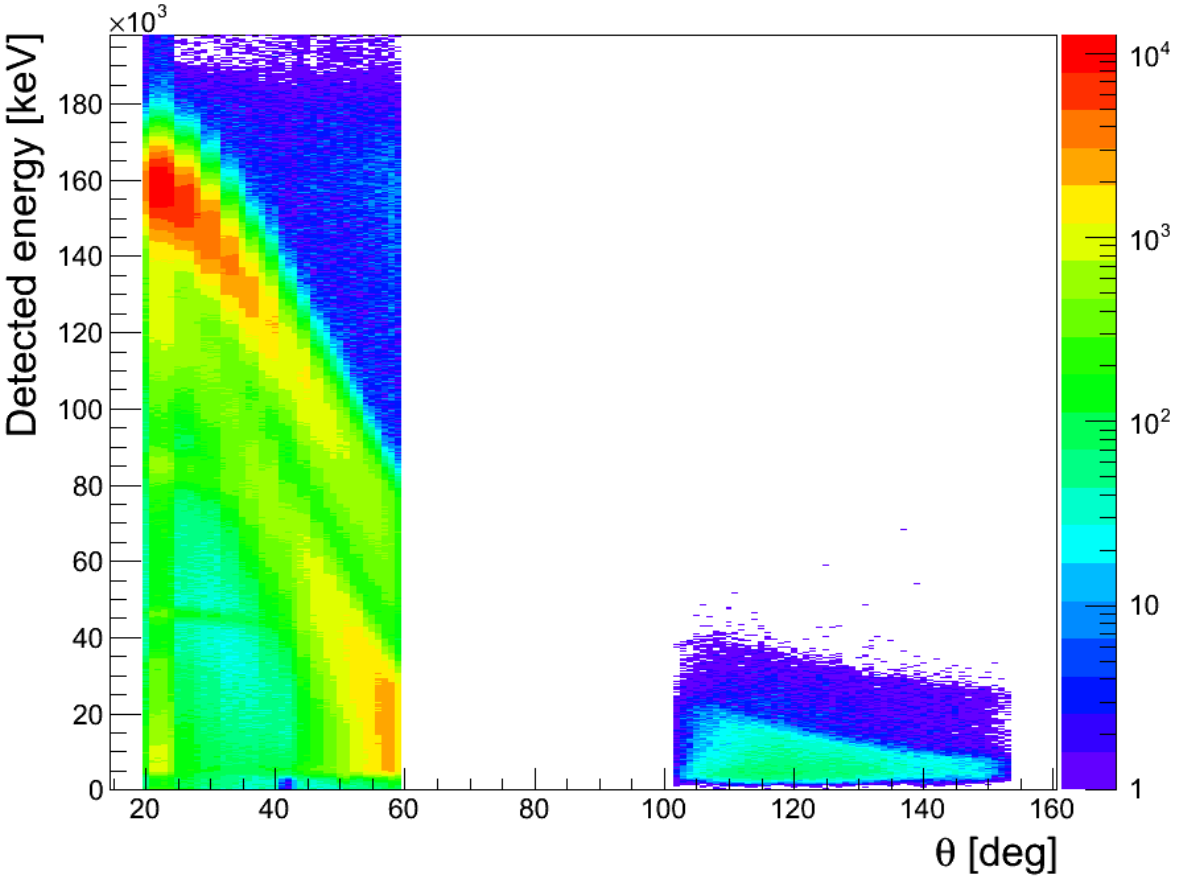
New Coulex setup in T-REX vacuum chamber



Closest distance between target and FCD: 2.45 cm

Coulomb excitation of ^{72}Zn

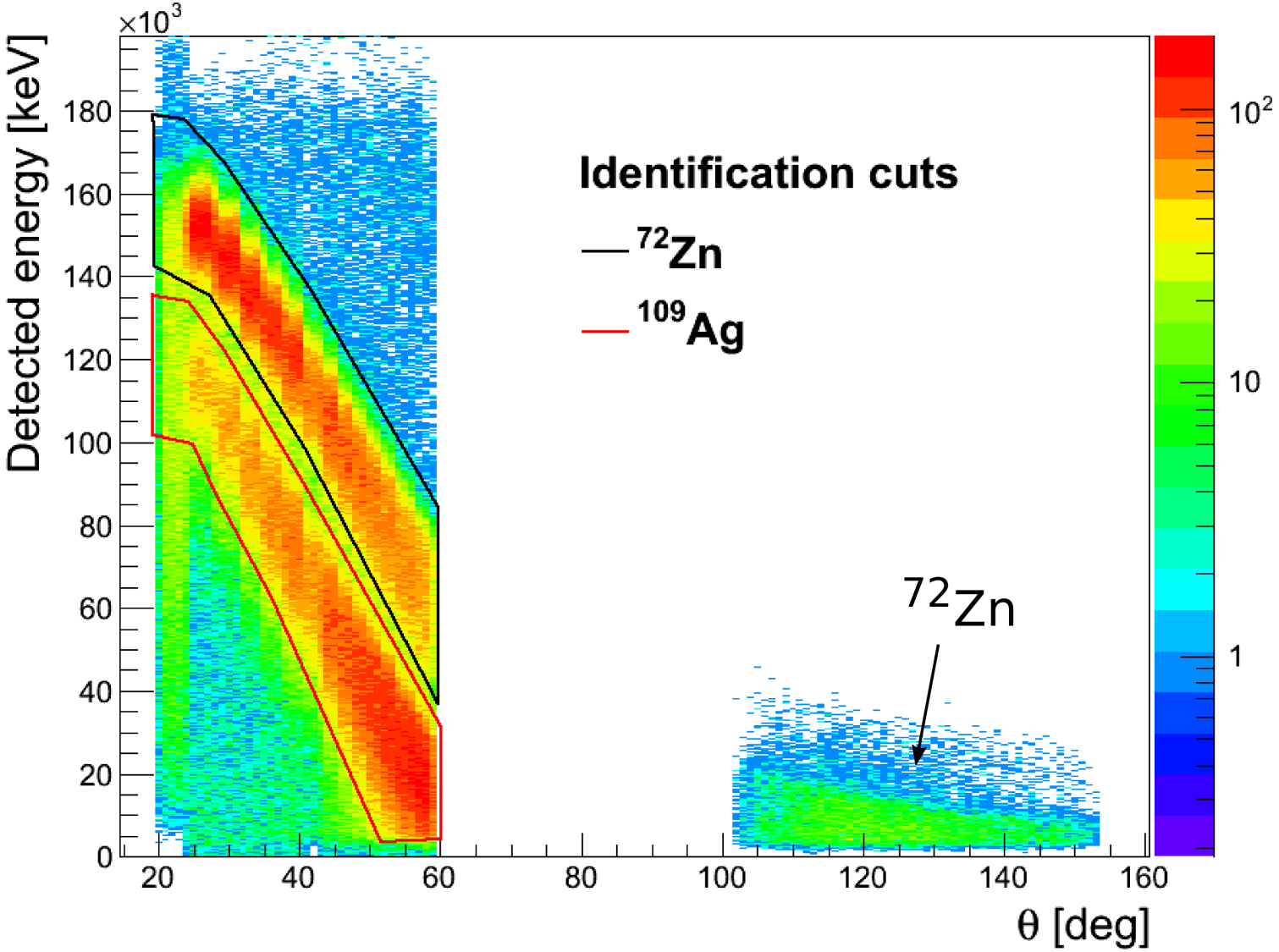
- Coulomb excitation of the ^{72}Zn beam with a 1.17 $\frac{\text{mg}}{\text{cm}^2}$ ^{109}Ag target (E_b = 2.85 MeV/u, 66 h good data, $I_{MB} \approx 2 \cdot 10^7$ pps)



- All particles in the Silicon detectors

⇒ No clear separation between ^{72}Zn and ^{109}Ag

Identification of the ejectile and the recoil

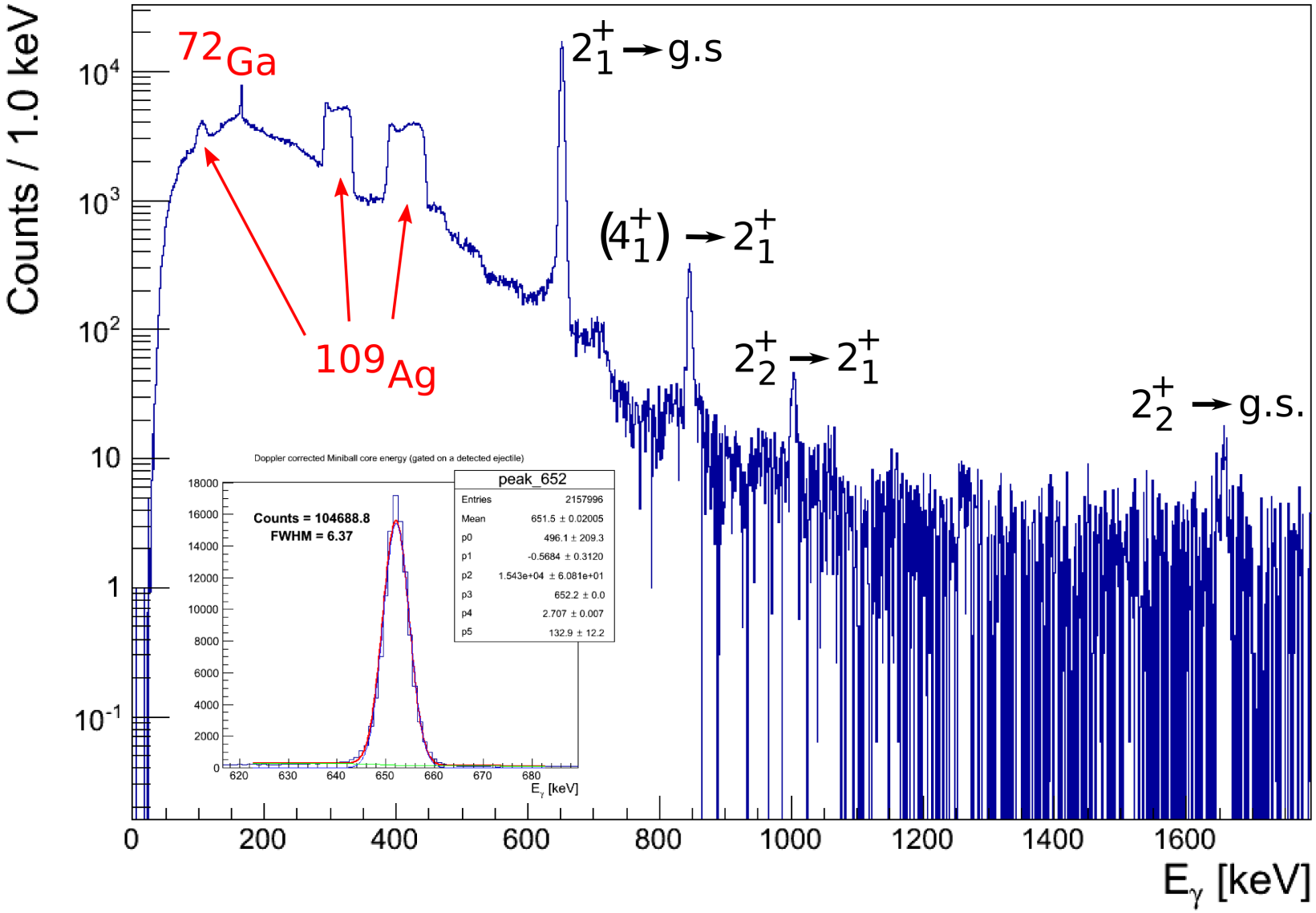


- Look only at particles with a coincident γ-ray in MINIBALL

$\Rightarrow$ Clear separation between ^{72}Zn and ^{109}Ag

Doppler corrected γ-ray-spectra

- ^{72}Zn detected in the FCD
- Doppler correction with respect to ^{72}Zn



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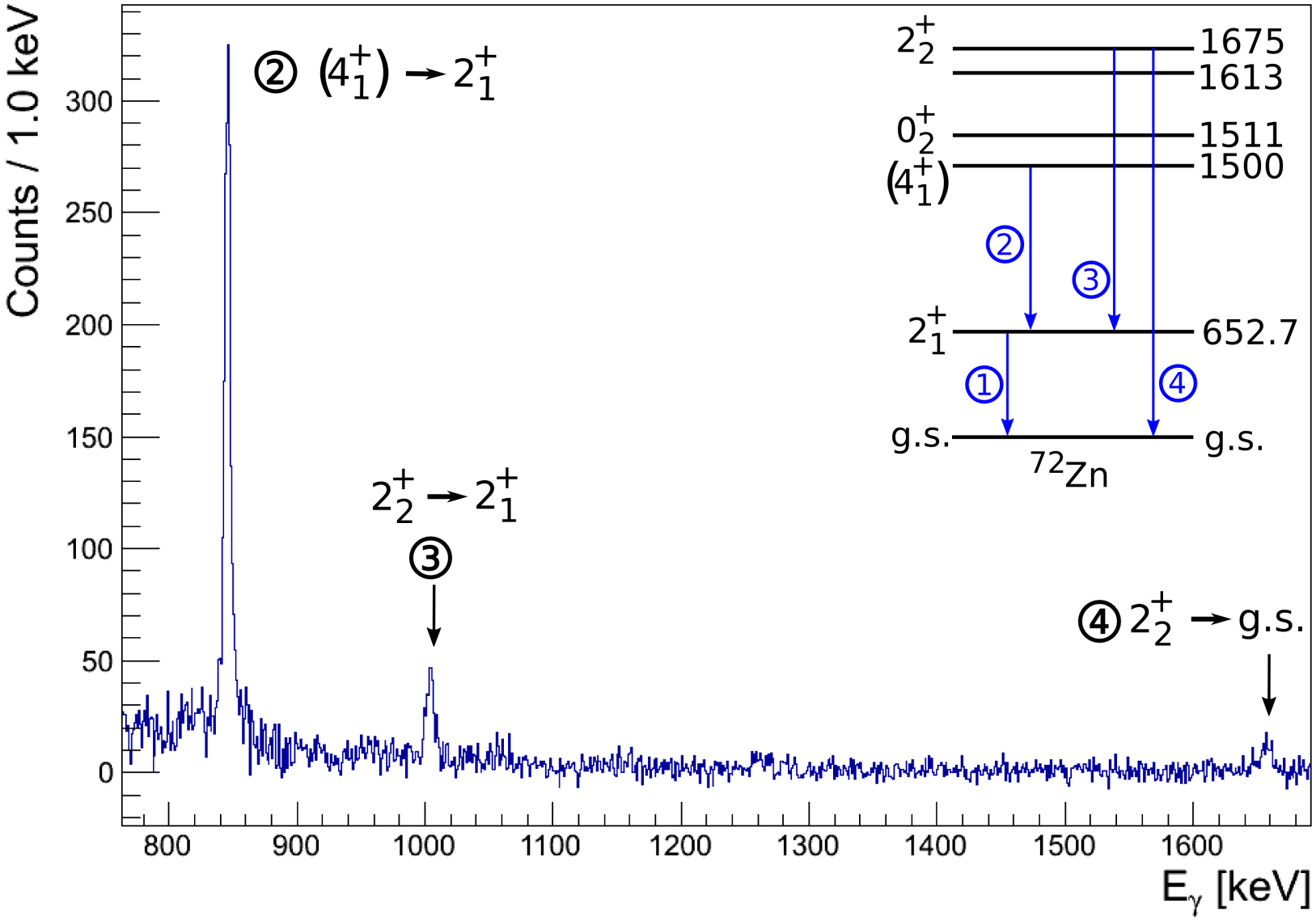
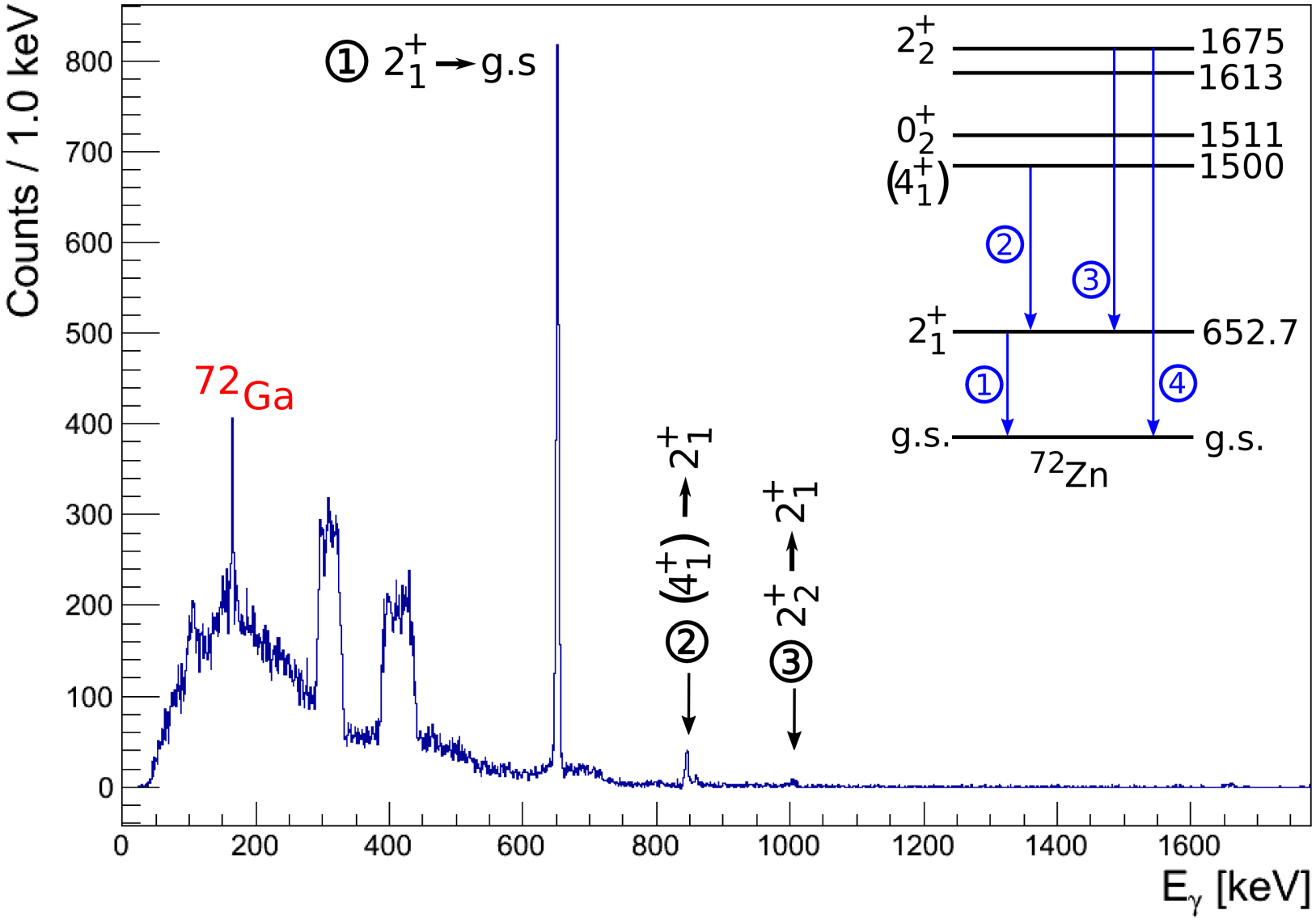


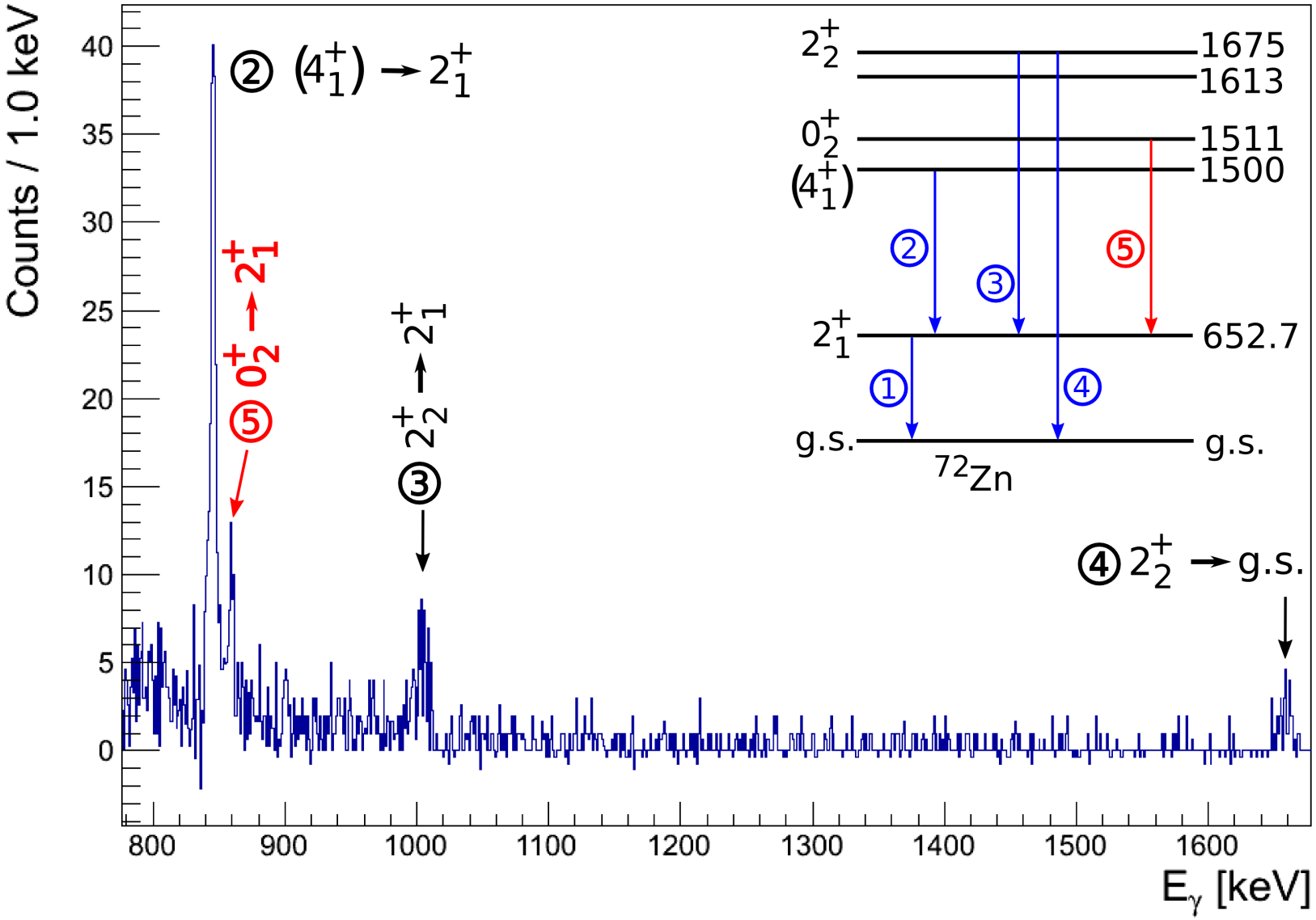
Doppler corrected γ-ray-spectra

- ^{72}Zn detected in the Backward Barrel
- Doppler correction with respect to ^{72}Zn



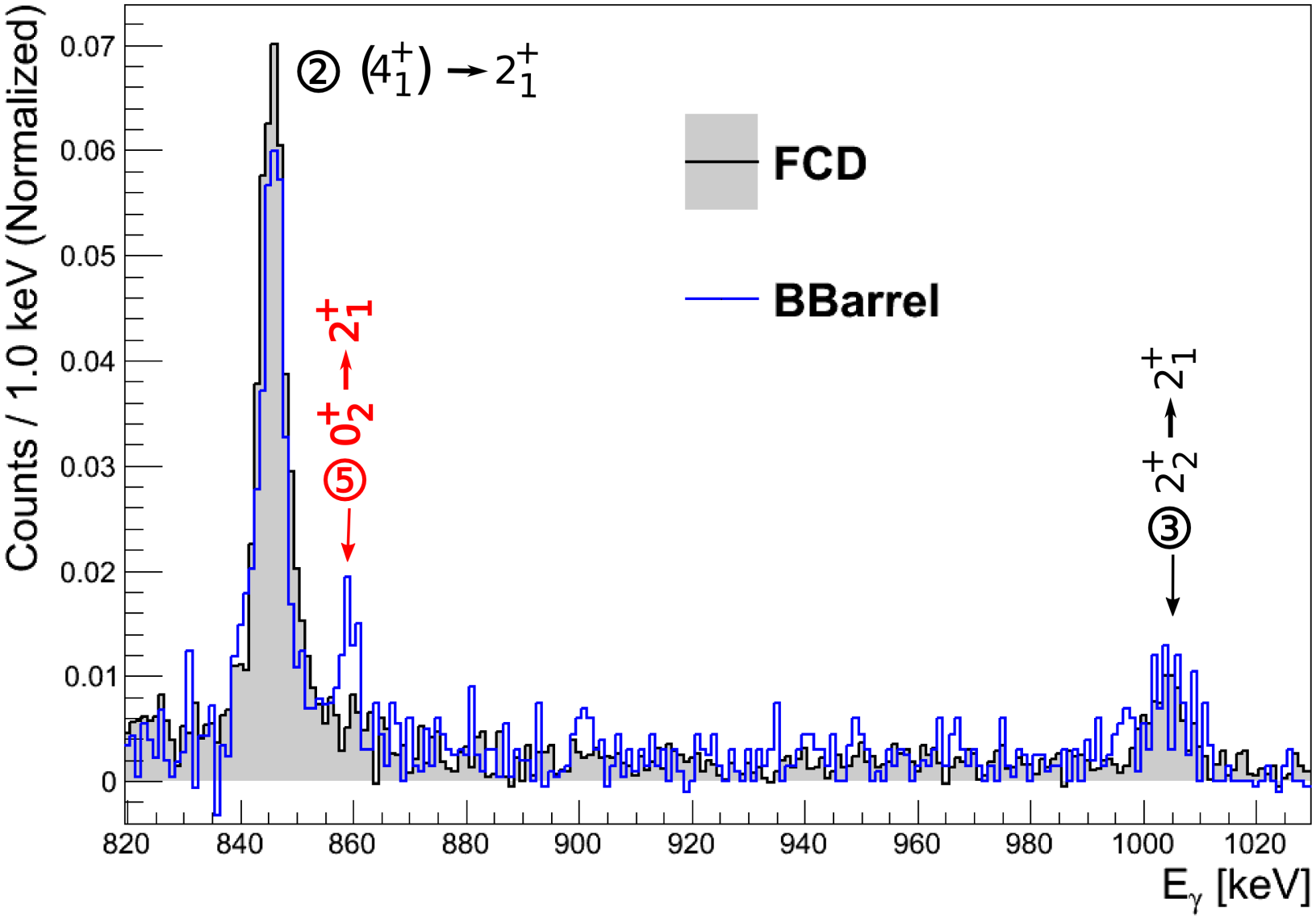
Doppler corrected γ-ray-spectra

- ^{72}Zn detected in the Backward Barrel
- Doppler correction with respect to ^{72}Zn



Doppler corrected γ-ray-spectra

- ^{72}Zn detected in the FCD or Backward Barrel
- Doppler correction with respect to ^{72}Zn

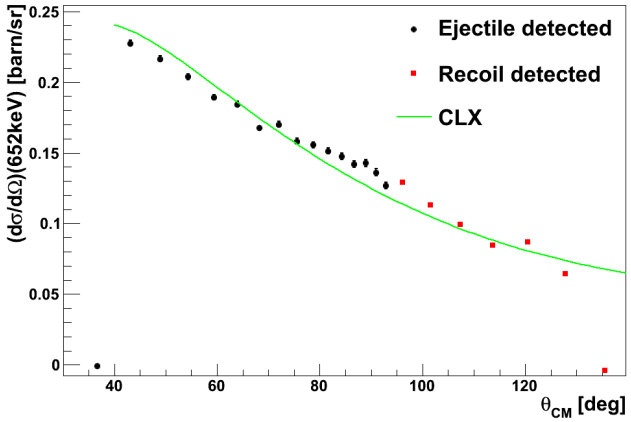


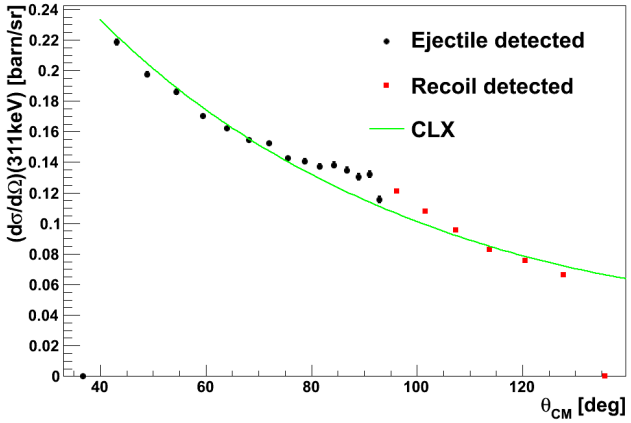
PRELIMINARY differential cross sections

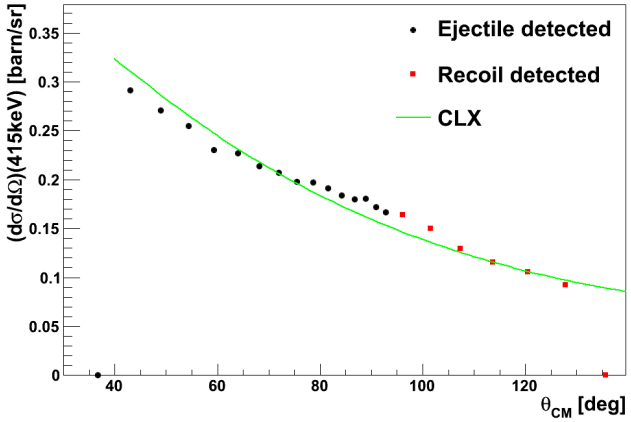
- Number of ^{72}Zn in 2_1^+−state and emitted in $\Delta\Omega_{CM}^{ring}$:
  $N_\uparrow(Zn) = L \cdot (\frac{d\sigma}{d\Omega})_{CM}^{Zn} \cdot \Delta\Omega_{CM}^{ring}$
  $\Rightarrow \quad (\frac{d\sigma}{d\Omega})_{CM}^{Zn}$
  analogue:
  $N_\uparrow(Ag) = L \cdot (\frac{d\sigma}{d\Omega})_{CM}^{Ag} \cdot \Delta\Omega_{CM}^{ring}$

$\Rightarrow$ Relative measurement:
$$\frac{(d\sigma/d\Omega)_{CM}^{Zn}}{(d\sigma/d\Omega)_{CM}^{Ag}} = \frac{N_\uparrow(Zn)}{N_\uparrow(Ag)}$$

- Feeding and MINIBALL efficiency included





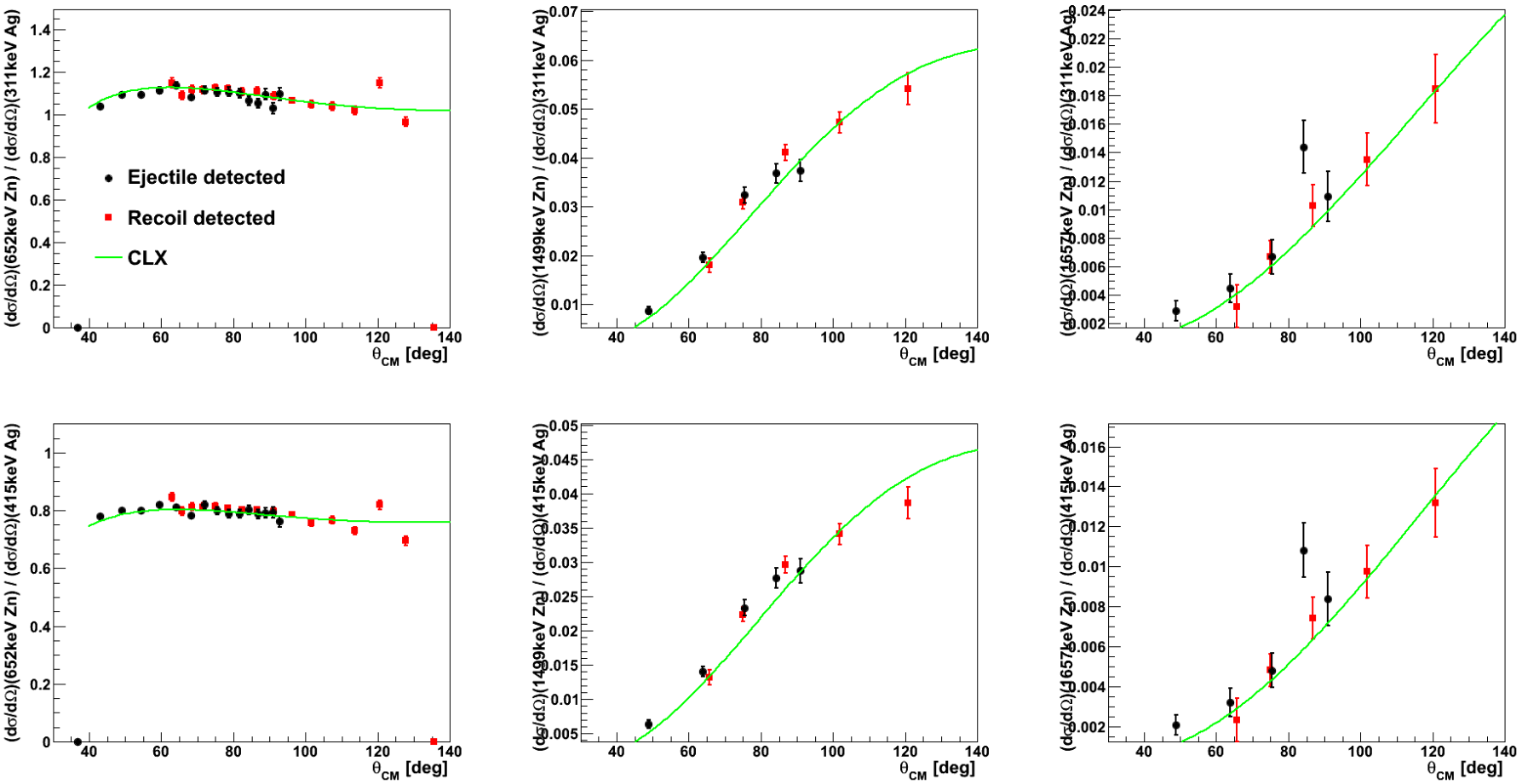


PRELIMINARY relative measurement

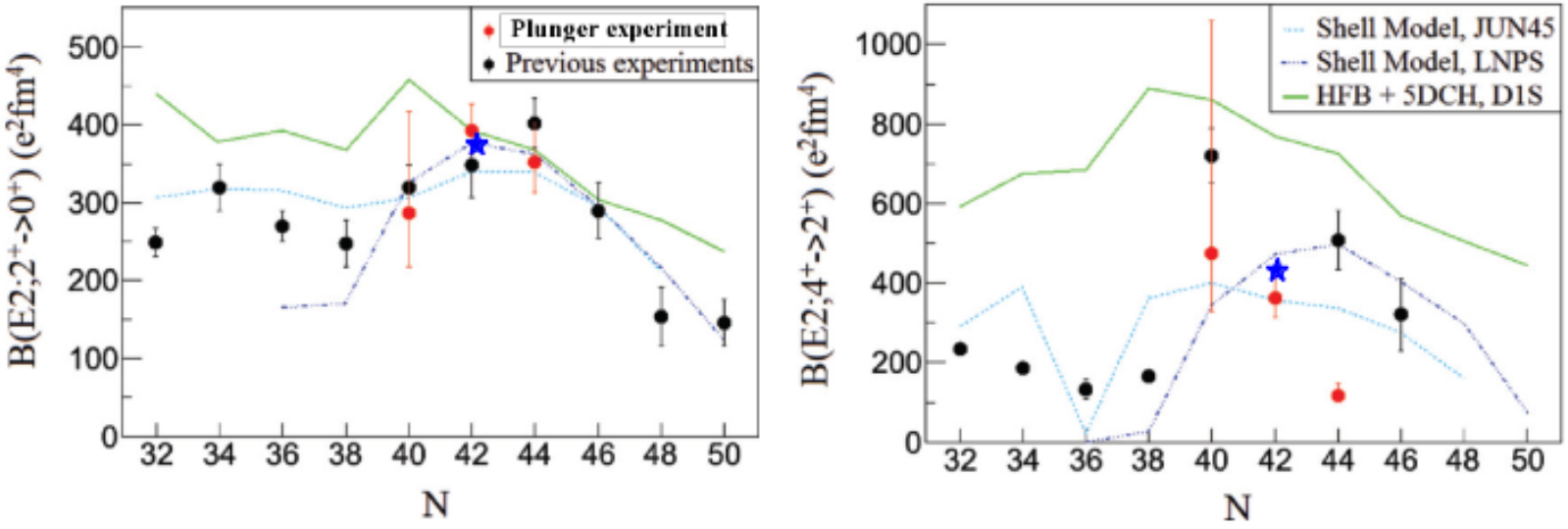
2_1^+-state of ^{72}Zn

4_1^+-state of ^{72}Zn

2_2^+-state of ^{72}Zn



VERY PRELIMINARY B(E2) values of ^{72}Zn

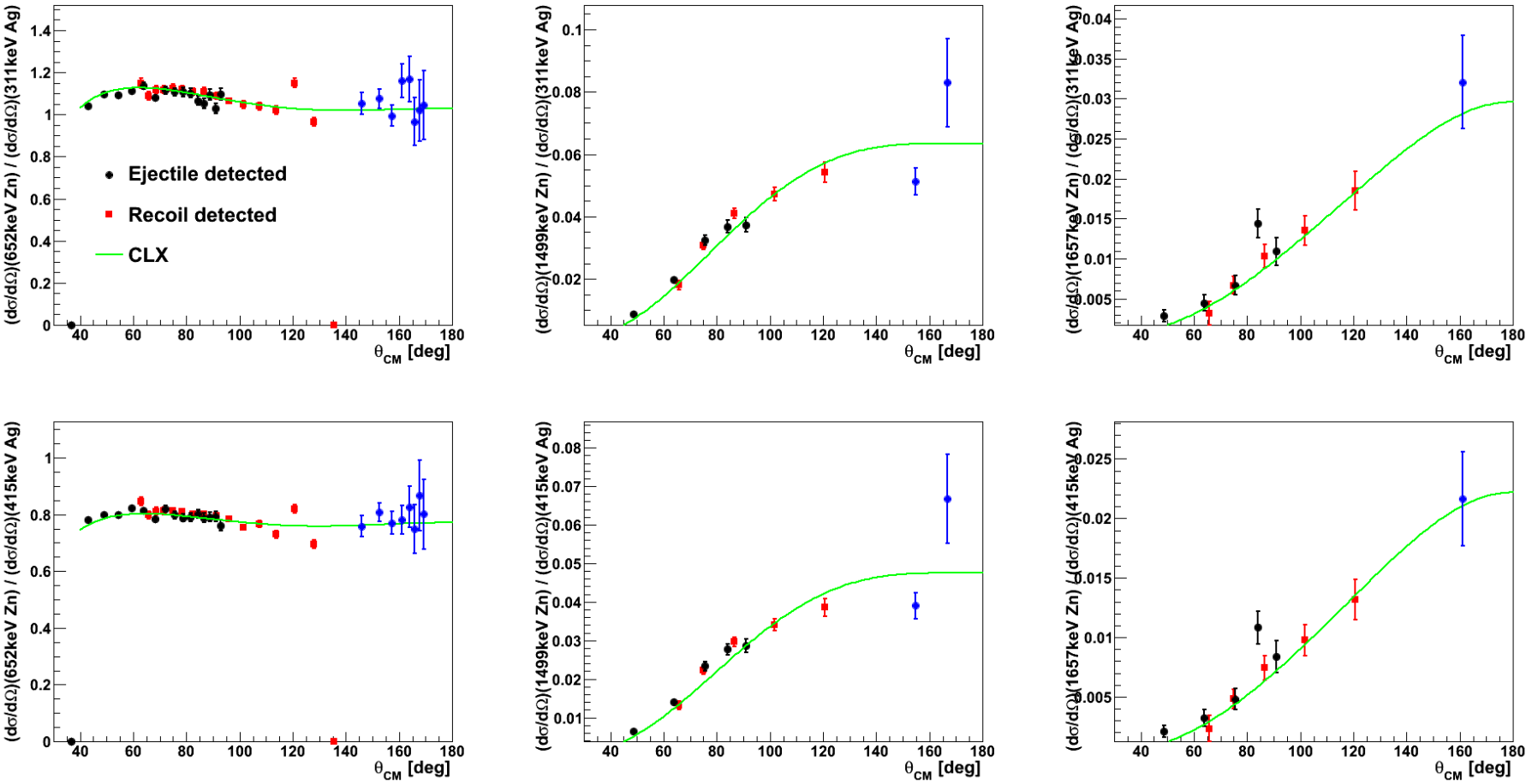


- CLX: B(E2: $2_1^+ \rightarrow$ g.s.) = 21 W.u. (blue star) which is in good agreement with the previous measurements
- CLX: B(E2: $4_1^+ \rightarrow 2_1^+$) = 24 W.u. (blue star)

Including the Backward Barrel data

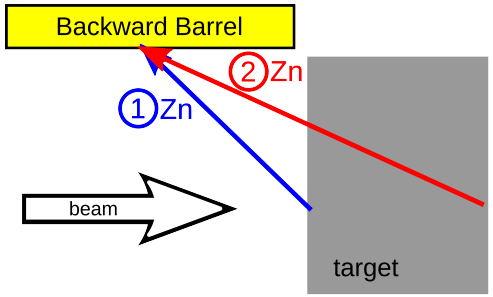
- Backward Barrel and Backward CD contain more important information at high θ_{CM} angles

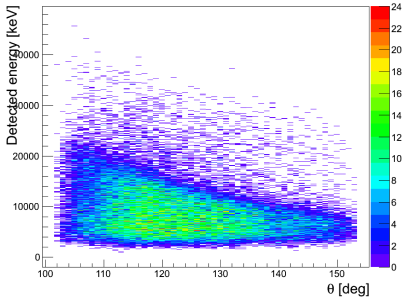
2_1^+-state of ^{72}Zn $\quad$ 4_1^+-state of ^{72}Zn $\quad$ 2_2^+-state of ^{72}Zn



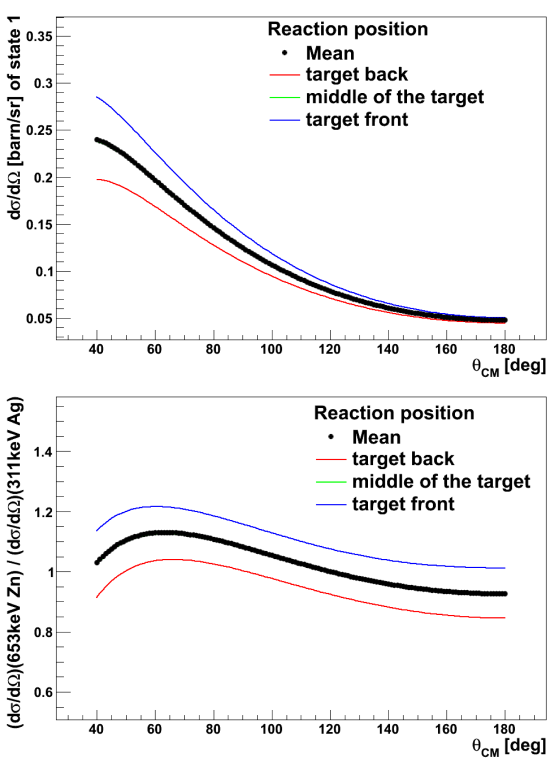
Influence of the energy threshold in the BBarrel

- Coulex cross sections are strongly energy dependent

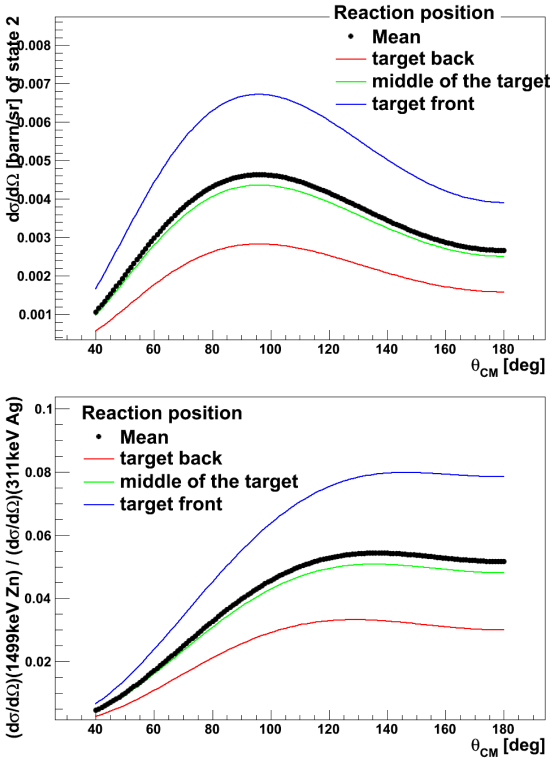




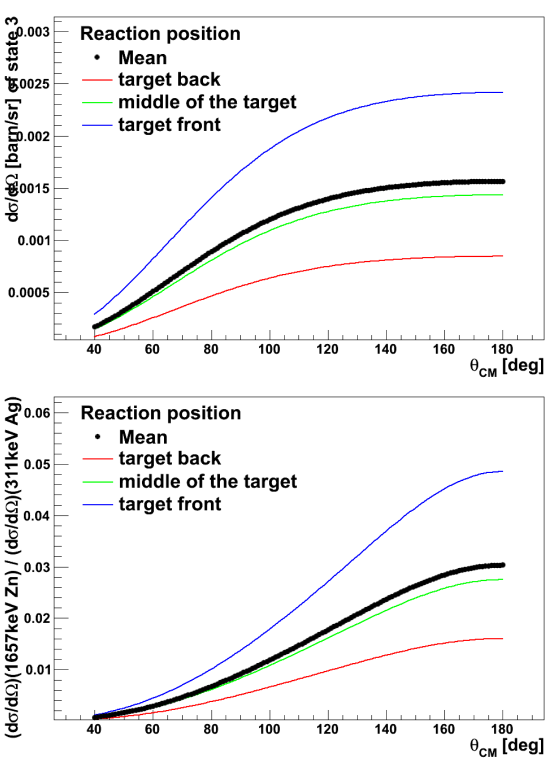
2_1^+-state of ^{72}Zn



4_1^+-state of ^{72}Zn



2_2^+-state of ^{72}Zn



Conclusion and outlook

Study of the p-n interaction in the neutron rich Zn isotopes with a ^{72}Zn beam at REX-ISOLDE.

- Good statistics to extract the most important B(E2) values of ^{72}Zn
- Good Doppler correction of 6.37 keV FWHM at 653 keV achieved
  $\Rightarrow$ Clear separation of the 4_1^+ and the 0_2^+ state in ^{72}Zn
- Up to now only preliminary CLX results are presented
  $\Rightarrow$ GOSIA calculations and error determination is strongly needed
- Have a closer look at the detectors in backward direction

Thank you!

Dennis Mücher[1], Roman Gernhäuser[1], Stefanie Hellgartner (Klupp)[1], Reiner Krücken[1,2], Katharina Nowak[1], Vinzenz Bildstein[3], Kathrin Wimmer[4], Simone Bottoni[5], Jytte Elseviers[5], Freddy Flavigny[5], Jedrzej Iwanicki[13], Andrea Jungclaus[6], Malin Klintefjord[12], Thorsten Kröll[7], Rudi Lutter[8], Riccardo Orlandi[5], Janne Pakarinen[9], Norbert Pietralla[7], Riccardo Raabe[5], Elisa Rapisarda[5], Sebastian Reichert[1], Peter Reiter[10], Markus Scheck[7], Mirko von Schmid[7], Michael Seidlitz[10], Burkhard Siebeck[10], Andrés Illana Sisón[6], Tim Steinbach[10], Nigel Warr[10], Kasia Wrzosek-Lipska[5] and Magdalena Zielinska[11]

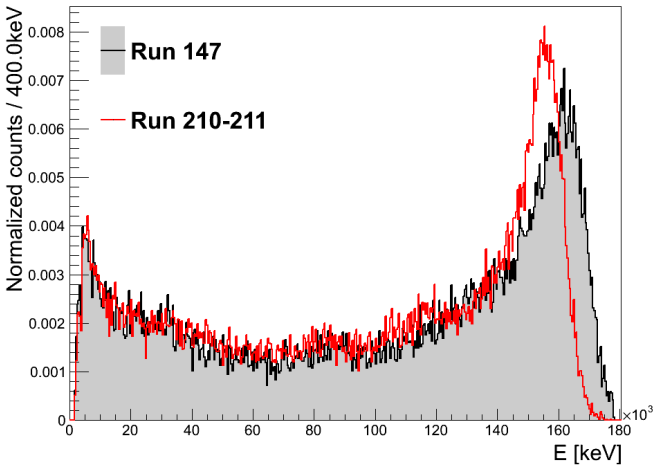
1 Technische Universität München - 2 TRIUMF, Vancouver - 3 University of Guelph - 4 NSCL, Michigan State University - 5 KU Leuven - 6 CSIC, Madrid - 7 IKP, Technische Universität Darmstadt - 8 Fakultät für Physik, LMU München - 9 CERN, Genf - 10 IKP, Universität zu Köln - 11 CEA, Saclay - 12 University of Oslo - 13 Heavy Ion Laboratory, Warsaw University

Appendix

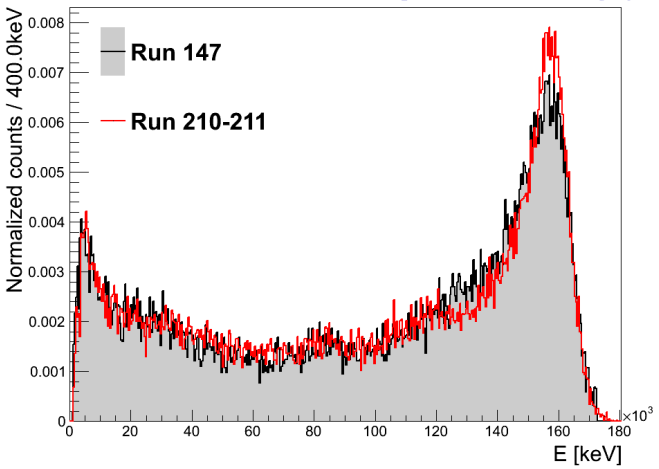
Analysis strategy

- Coulomb excitation of the ^{72}Zn beam with a 1.17 $\frac{\text{mg}}{\text{cm}^2}$ ^{109}Ag target (E_b = 2.85 MeV/u, 66 h good data, $I_{MB} \approx 2 \cdot 10^7$ pps)
- target thickness = 1.17 $\frac{\text{mg}}{\text{cm}^2}$
- Doppler correction formula: $E_{rest} = E_{lab} \cdot \gamma \cdot [1 - \beta \cdot \cos(\alpha)]$
  - MINIBALL angles: ^{22}Ne(d,n)^{23}Na, ^{22}Ne(d,p)^{23}Ne and $2_1^+ \rightarrow$ g.s. transition of ^{72}Zn
  - $\beta = \sqrt{\frac{2E_{kin}}{m_0 c^2}}$: Time dependent energy calibration of the Silicon detectors with a $A/Q = 4$ EBIS beam + ^{72}Zn
  - Energy loss in the dead layers of the Silicon detectors is taken into account

Uncorrected strip energy



Corrected strip energy



Coulex: Save Coulex criterion

- Save bombarding energy:
  $E_b(\theta_{CM}) = 0.72 \cdot \frac{Z_p Z_t}{D_{min}} \cdot \frac{A_p + A_t}{A_t} \left[1 + \frac{1}{\sin(\theta_{CM}/2)}\right]$ [MeV]
  with $D_{min} = 1.25 \cdot (\sqrt[3]{A_p} + \sqrt[3]{A_t}) + 5$
- Beam energy of ^{72}Zn: 205 MeV