Multiple Coulomb Excitation with High Intense ^{72}Zn Beam at ISOLDE

Stefanie Hellgartner

Technische Universität München
Physik Department, E12

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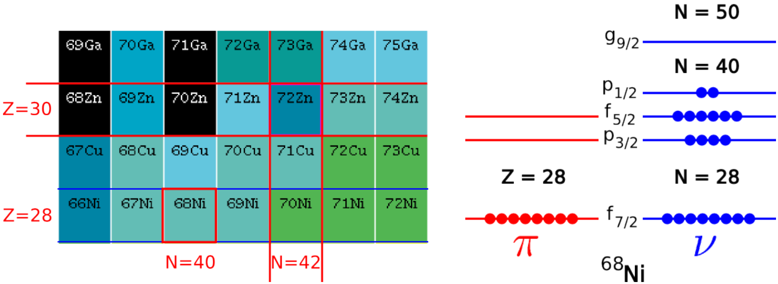
Motivation



- ^{68}Ni shows some doubly magic features, e.g. high $E(2_1^+)$ and low $B(E2; 2_1^+ \rightarrow g.s.)$

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

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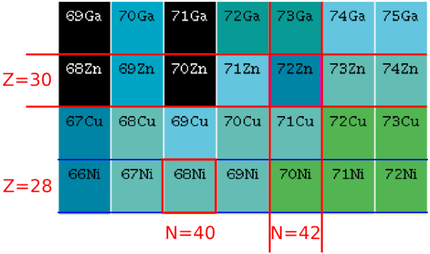
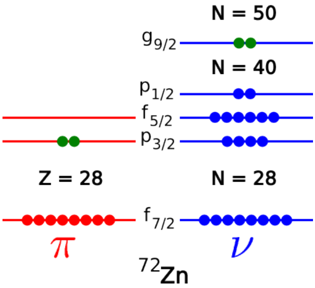


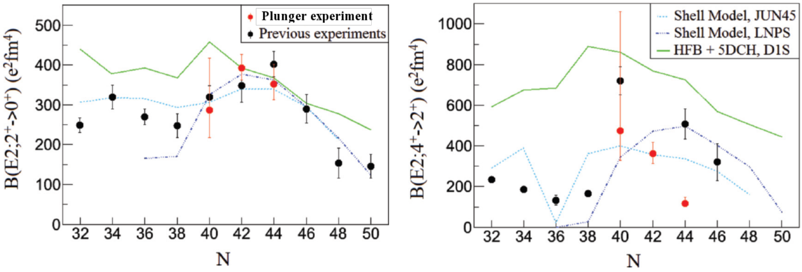


- ^{68}Ni shows some doubly magic features, e.g. high $E(2_1^+)$ and low $B(E2; 2_1^+ \rightarrow g.s.)$

$\Rightarrow$ 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)

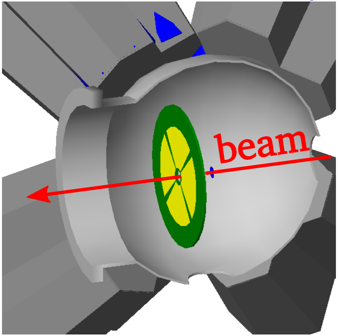


- Good agreement for B(E2; $2_1^+ \rightarrow 0_1^+$)
- But: Discrepancies for B(E2; $4_1^+ \rightarrow 2_1^+$), especially in the experimental data

$\Rightarrow$ Additional measurements needed $\rightarrow$ Coulomb excitation experiment with a ^{72}Zn beam

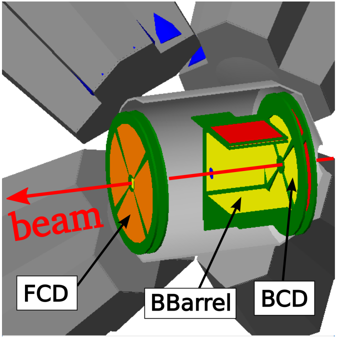
New experimental setup

Standard Coulex setup



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

Coulex with T-REX setup



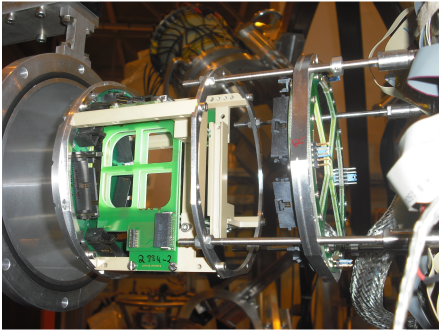
FCD with variable target distance

Optimize Coulex setup

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

Photographs of the new Coulex setup

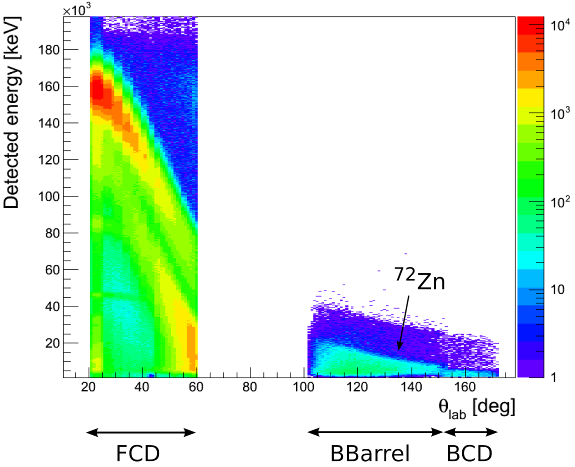
New Coulex setup in T-REX vacuum chamber



Closest distance between target and FCD: 2.35 cm

Coulomb excitation of ^{72}Zn

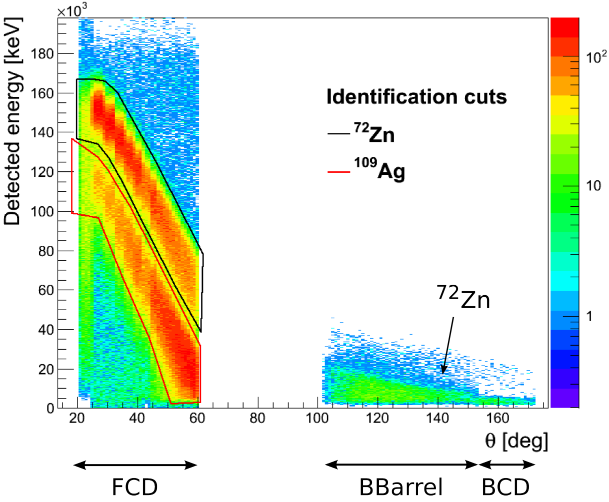
- Coulomb excitation of the ^{72}Zn beam with a 1.17 $\frac{mg}{cm^2}$ ^{109}Ag target (E_b = 2.85 MeV/u, 66 h good data, $I_{MB} \approx 2 \cdot 10^7$ pps)



- All particles in the Silicon detectors

$\Rightarrow$ No clear separation between ^{72}Zn and ^{109}Ag

Identification of the ejectile and the recoil

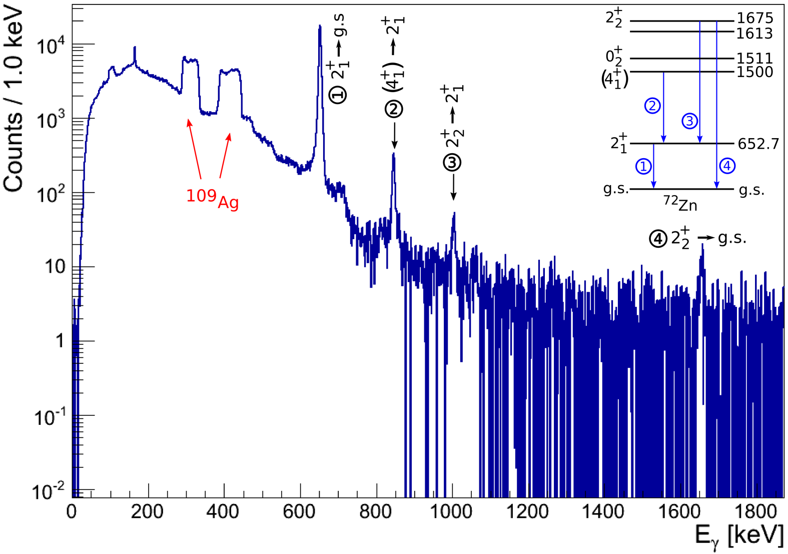


- Particles in the Silicon detectors in coincident with a γ-ray in MINIBALL

$\Rightarrow$ 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



Doppler corrected γ-ray-spectra

- ^{72}Zn detected in the FCD
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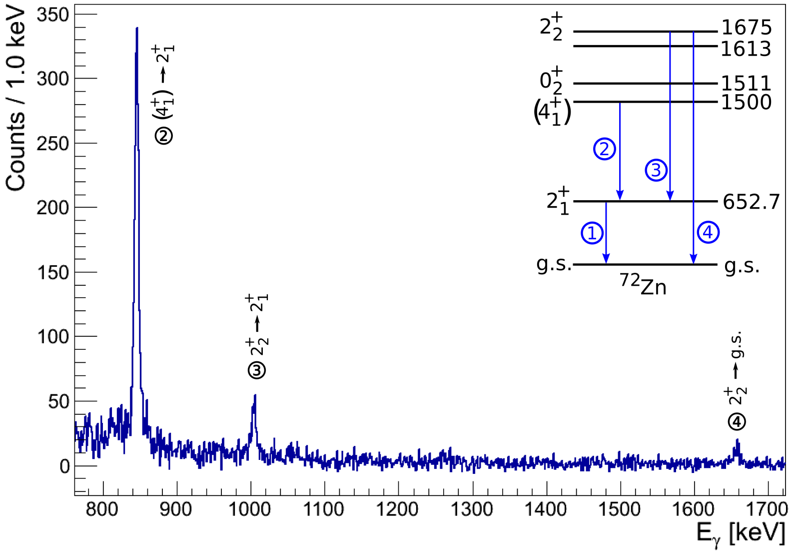
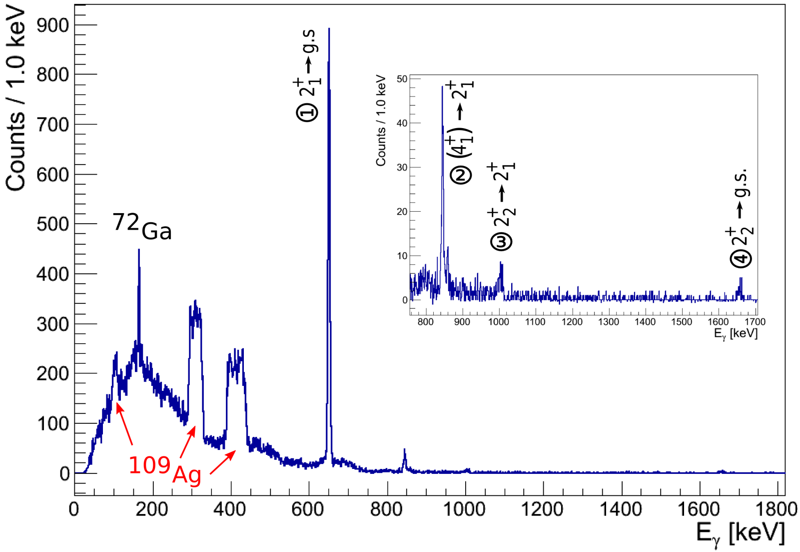


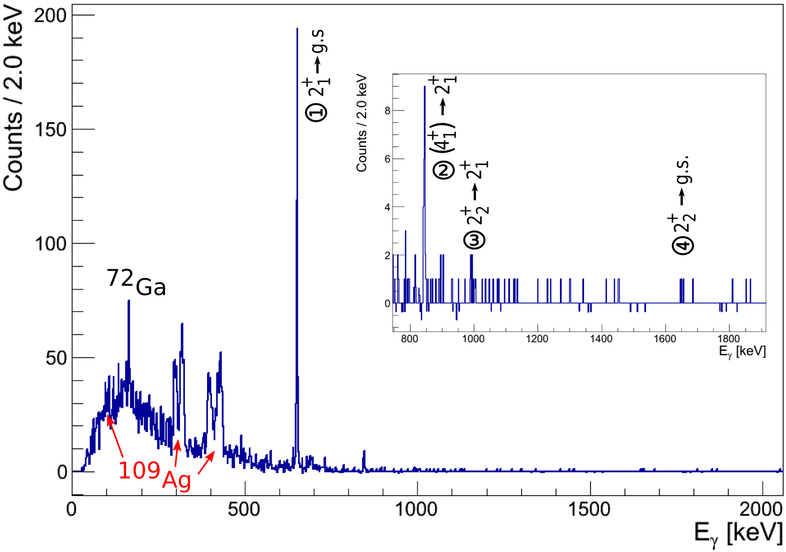
Doppler corrected γ-ray-spectra

- ^{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 CD
- Doppler correction with respect to ^{72}Zn



Extracting nuclear structure from γ-ray peaks

- σ is directly connected to the reduced transition probability $B(\pi\lambda; J_i \rightarrow J_f) = \frac{1}{2J_i+1}|\langle J_i||\mathcal{M}(\pi\lambda)||J_f\rangle|^2$
- σ can be calculated from the number of counts in the γ-ray peaks:
  - Number of detected $2_1^+ \rightarrow g.s.$ ^{72}Zn γ-rays in MINIBALL:

$$N_{det}(Zn) = L \cdot \sigma(Zn) \cdot \epsilon_{MB}(Zn) \cdot \epsilon_{Si}$$

  - Analogue for ^{109}Ag:

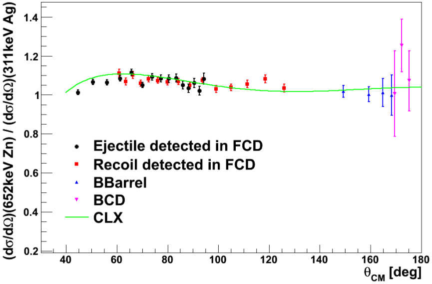
$$N_{det}(Ag) = L \cdot \sigma(Ag) \cdot \epsilon_{MB}(Ag) \cdot \epsilon_{Si}$$

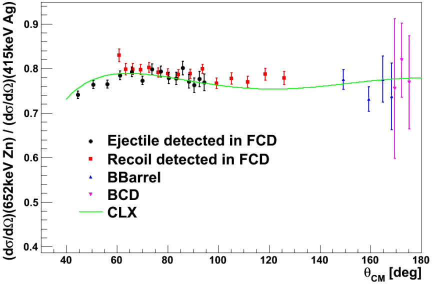
  - Luminosity L and efficiency ϵ_{Si} cannot be determined precisely $\Rightarrow$ Relative measurement:

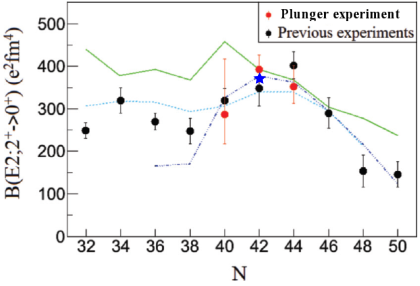
$$\frac{\sigma(Zn)}{\sigma(Ag)} = \frac{N_{det}(Zn)}{N_{det}(Ag)} \cdot \frac{\epsilon_{MB}(Ag)}{\epsilon_{MB}(Zn)}$$

  - Consider feeding contributions

PRELIMINARY $B(E2; 2_1^+ \rightarrow 0_1^+)$ of ^{72}Zn





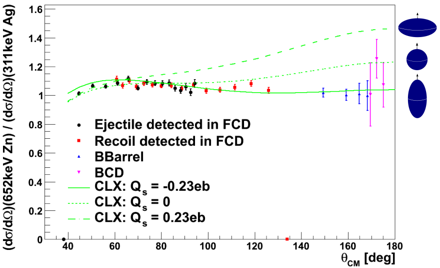


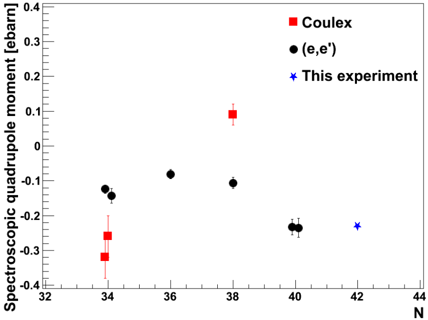
- Good agreement between the **Coulex experiments**, the lifetime measurements and our experiment.

PRELIMINARY quadrupole moment of ^{72}Zn

Spectroscopic quadrupole moment:

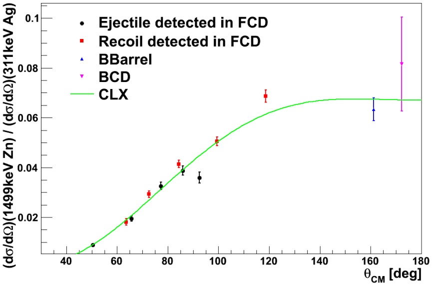
$$Q_s(J) = \sqrt{\frac{16\pi}{5}}\frac{\langle JJ20|JJ\rangle}{\sqrt{2J+1}}\langle J||E2||J\rangle \quad \Rightarrow \quad Q_s(2_1^+) = 0.7579\langle J||E2||J\rangle$$

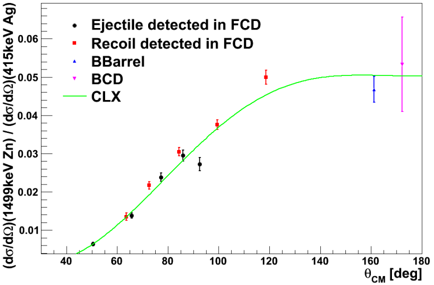


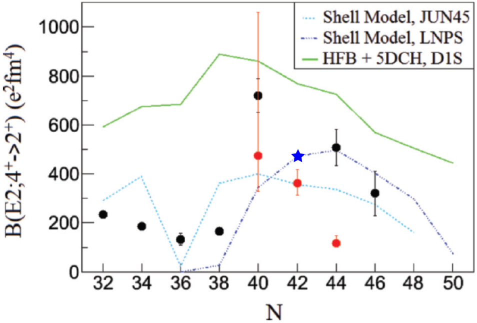


- Detectors in backward direction have the highest sensitivity for Q_s.
- Prolate shapes are preferred in the neutron-rich Zn isotopes.

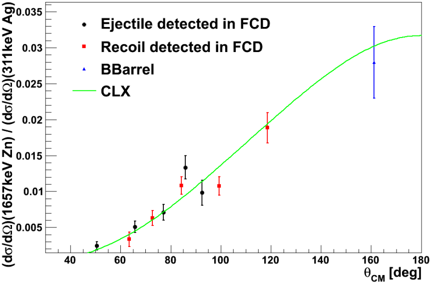
PRELIMINARY $B(E2; 4_1^+ \rightarrow 2_1^+)$ of ^{72}Zn

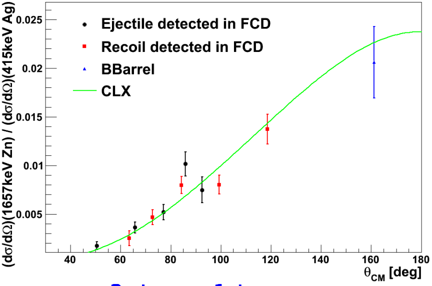


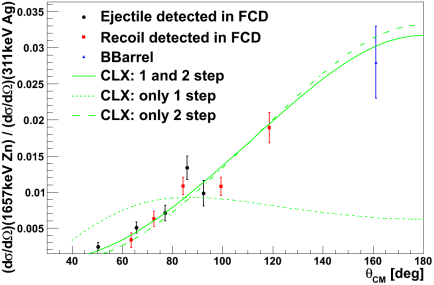


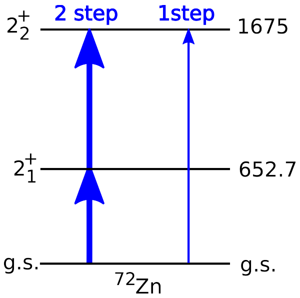


PRELIMINARY $B(E2; 2_2^+ \to 2_1^+, 0_1^+)$ of ^{72}Zn

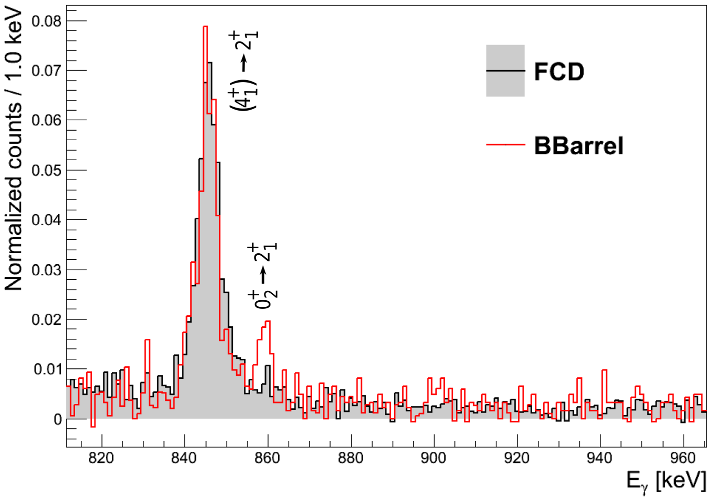






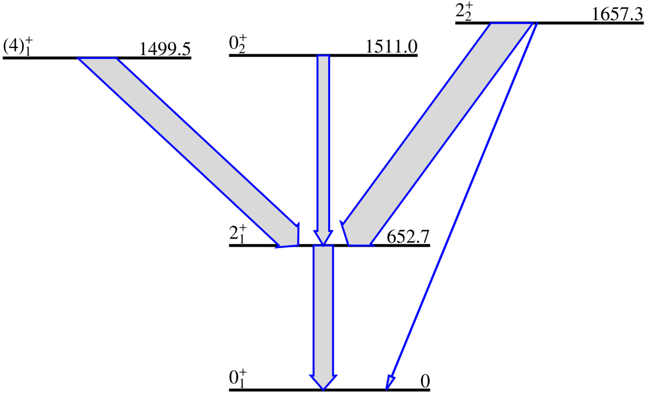


PRELIMINARY $B(E2; 0_2^+ \rightarrow 2_1^+)$ of ^{72}Zn



- 0_2^+-state only clearly visible in backward direction

Summary



- Good statistics to extract the most important B(E2) values of ^{72}Zn (arrow widths are proportional to B(E2)-values)
- Determination of the quadrupole moment $Q_s(2^+_1)$ $\rightarrow$ prolate shape is preferred

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

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