Investigating the intra-nuclear cascade process using the reaction ^{136}Xe on deuterium at 500 AMeV

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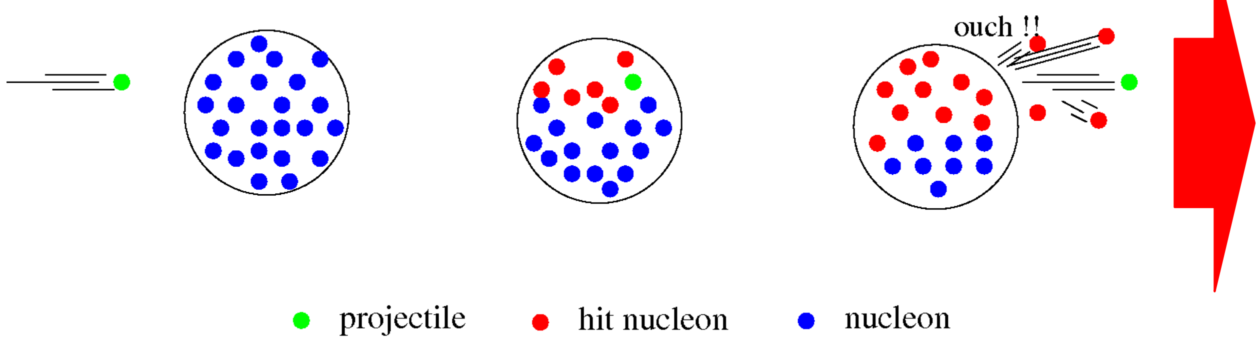
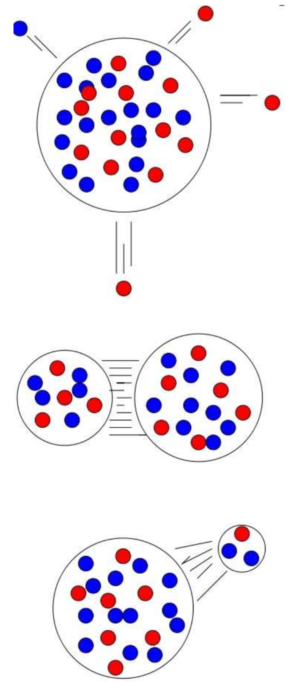
Spallation Reactions:

Interactions between relativistic light projectiles and heavy target nuclei
Collision -> nucleon-nucleon

Intra-nuclear cascade
10^{-23} s.



de-excitation
10^{-16} - 10^{-19} s.



In general, Spallation reactions are:

✓ optimum neutron sources with many application fields,
✓ source for the radioactive ion beam productions.

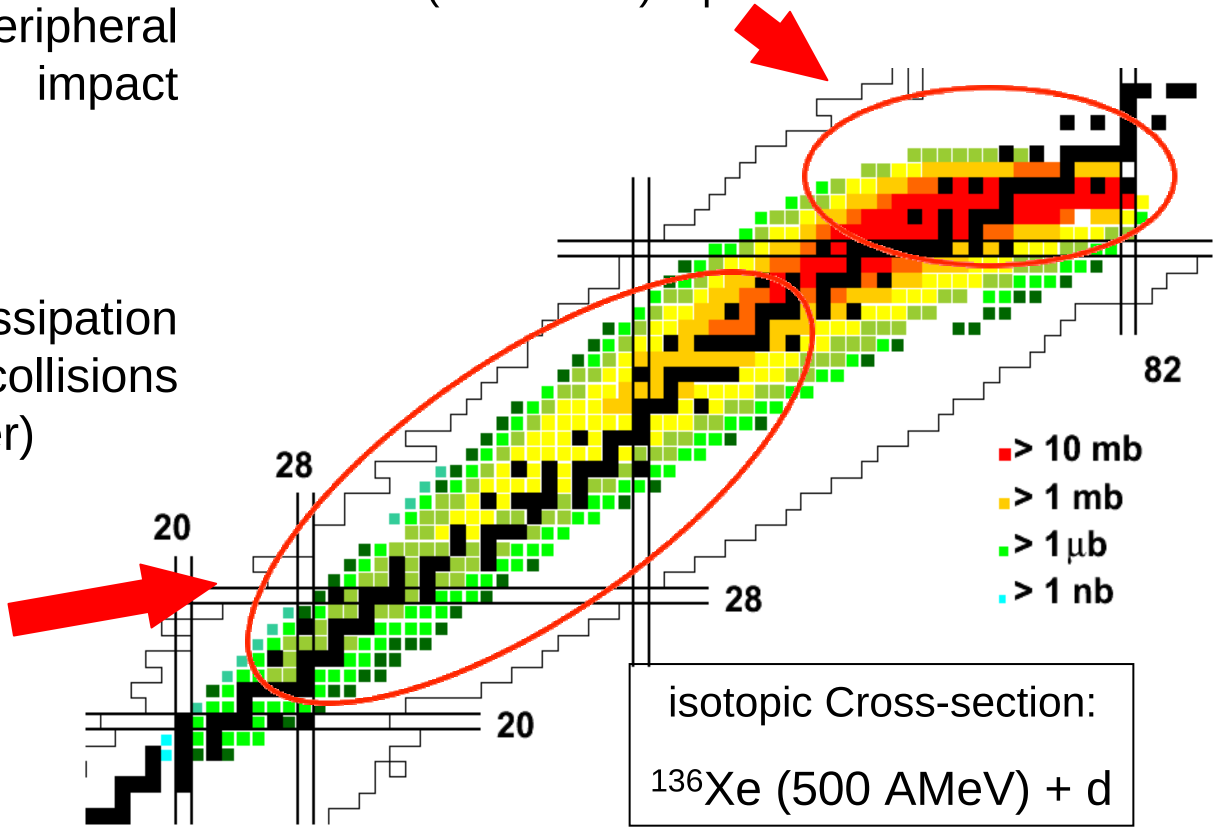
^{136}Xe + deuterium reaction

Motivations:

✓ Study of the intra-nuclear cascade process (NN collisions) measuring the isotopic production cross-section of the spallation residues in the reaction ^{136}Xe + d at 500 AMeV using inverse kinematics.

- understand the role that neutrons play in the peripheral collisions (large impact parameter)
- the energy dissipation mechanism in frontal collisions (small impact parameter)

peripheral collisions
^{136}Xe (500 *A*MeV) + p

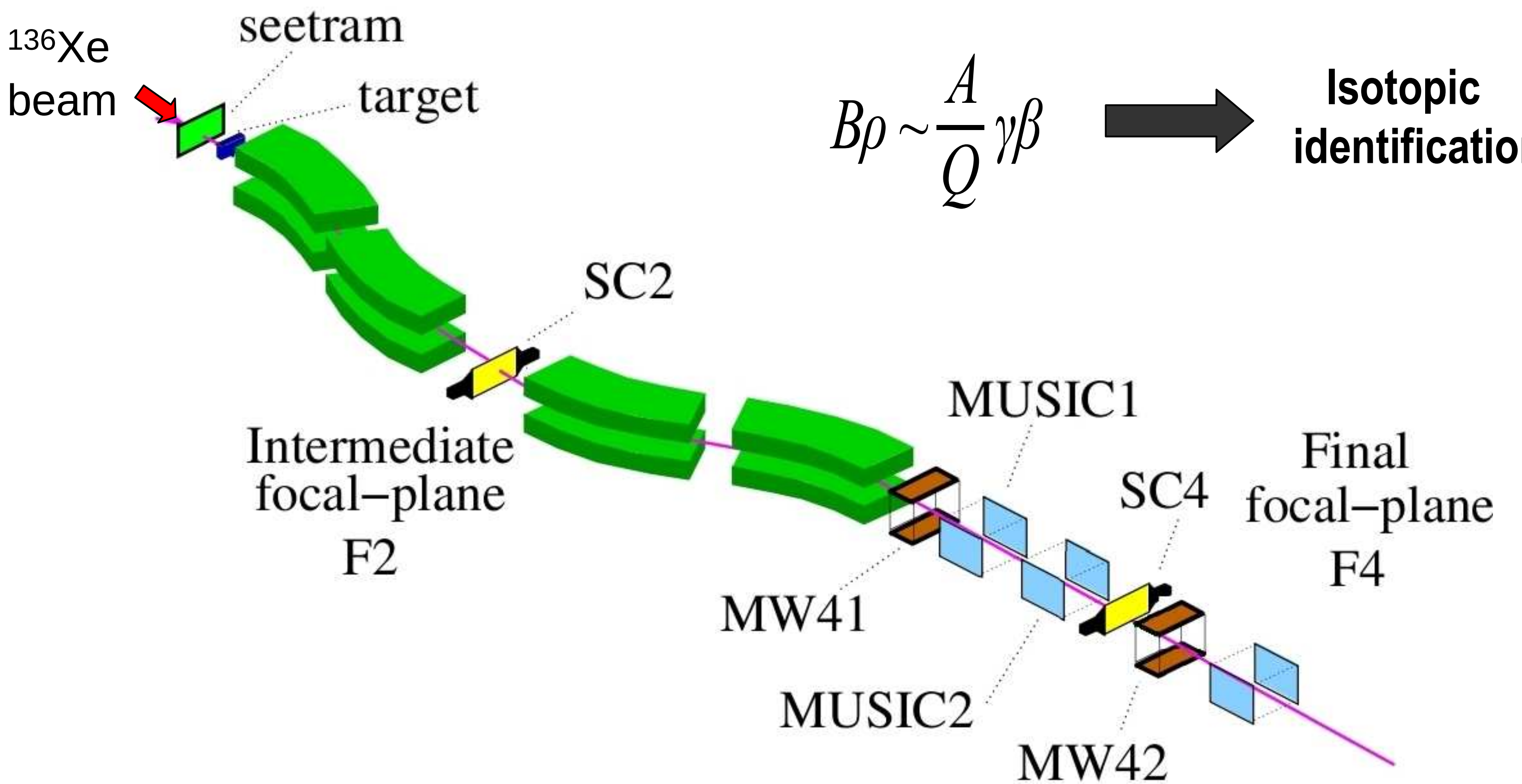


frontal collisions
^{136}Xe (1000 *A*MeV) + p

Experimental Procedure

Setup: FRagment Separator (FRS) at GSI Inverse Kinematics

^{136}Xe(500 *A*MeV) + d →	**residual fragments in the forward direction**

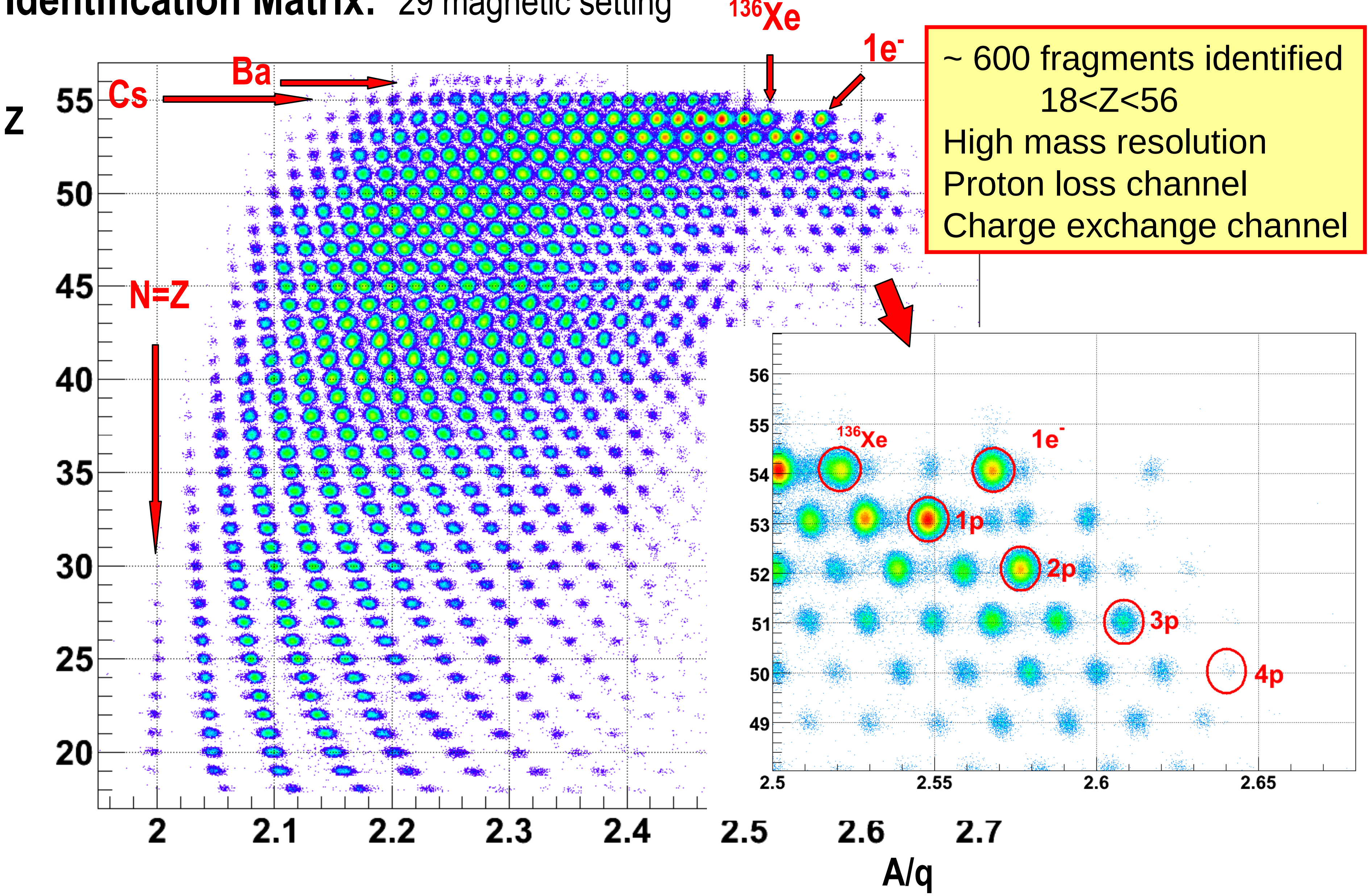


$$B\rho \sim \frac{A}{Q}\gamma\beta$$ → **Isotopic identification**

Separation of fragments

Identification Matrix: 29 magnetic setting

~ 600 fragments identified
18<Z<56
High mass resolution
Proton loss channel
Charge exchange channel

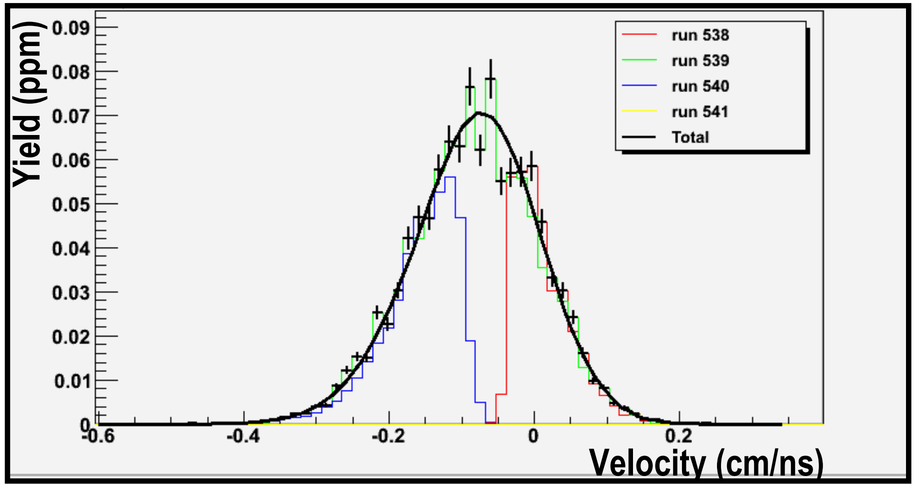


Velocity Distribution

Momentum Distribution:

$B\rho \rightarrow p_{\|} \leftarrow$ Several magnetic setting

^{122}**Te**



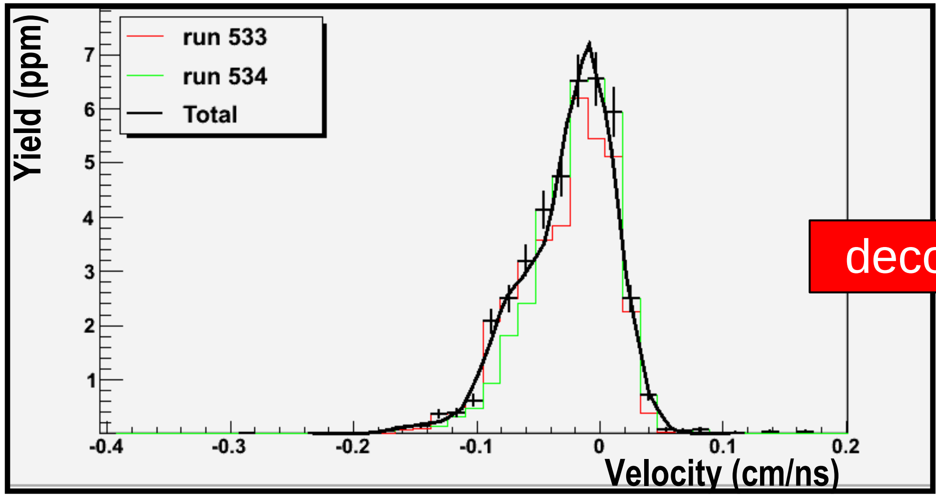
Integration area of distribution → yield for each nucleus

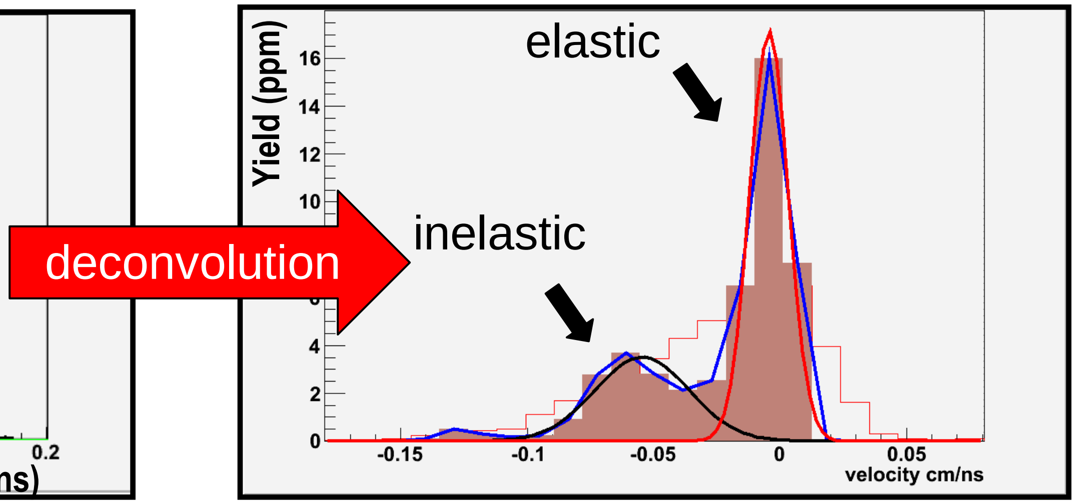
Response function from spectrometer

⬇

Deconvolution → good resolution

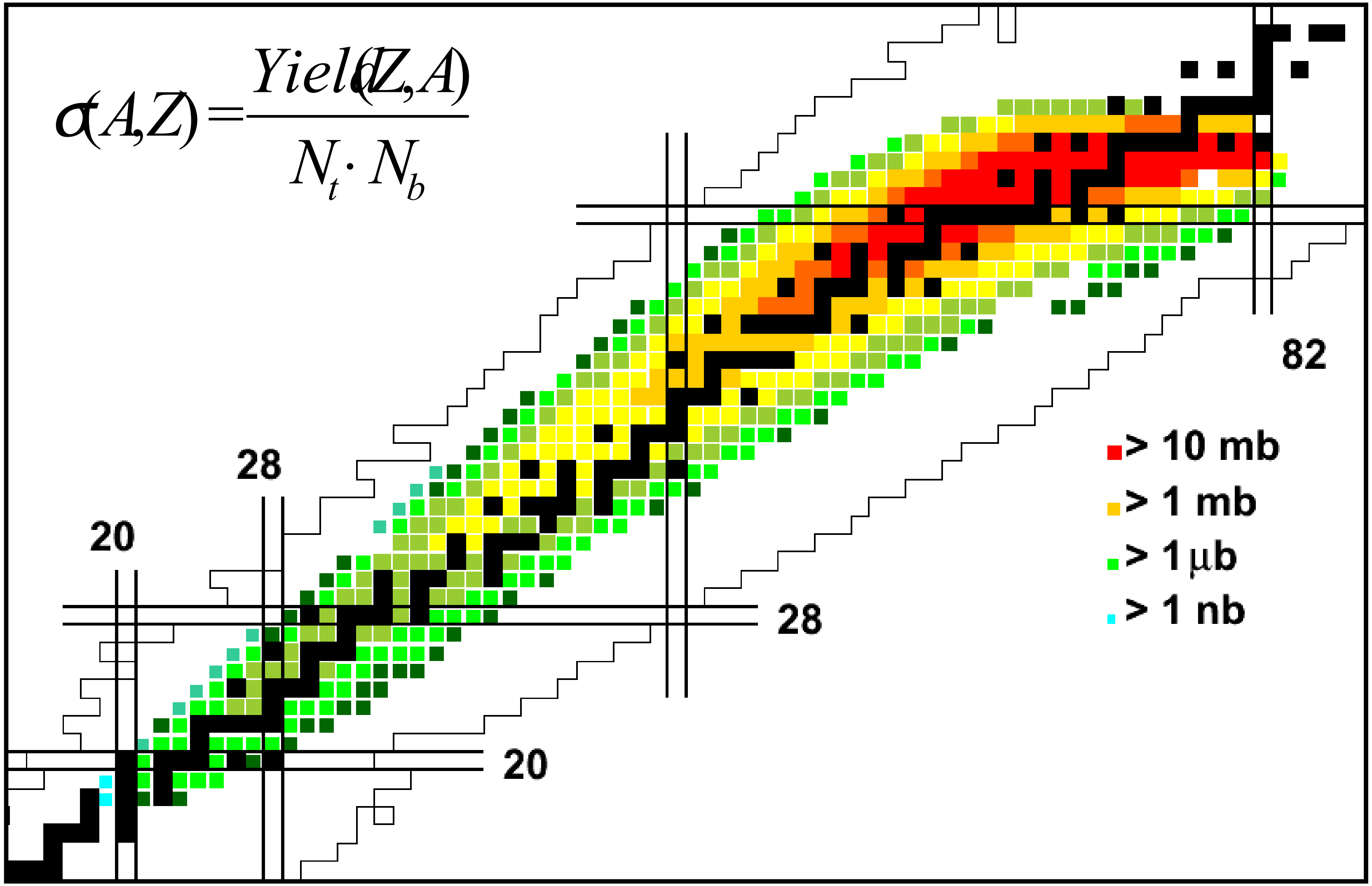
^{136}**Cs**





Isotopic production Cross-section

$$\mathbf{Yield}_{\mathbf{real}} \rightarrow \quad \text{yield}_{mea} * f_{dead} * f_{trans} * f_{ch\,st} * f_{mult} * f_{sec}$$

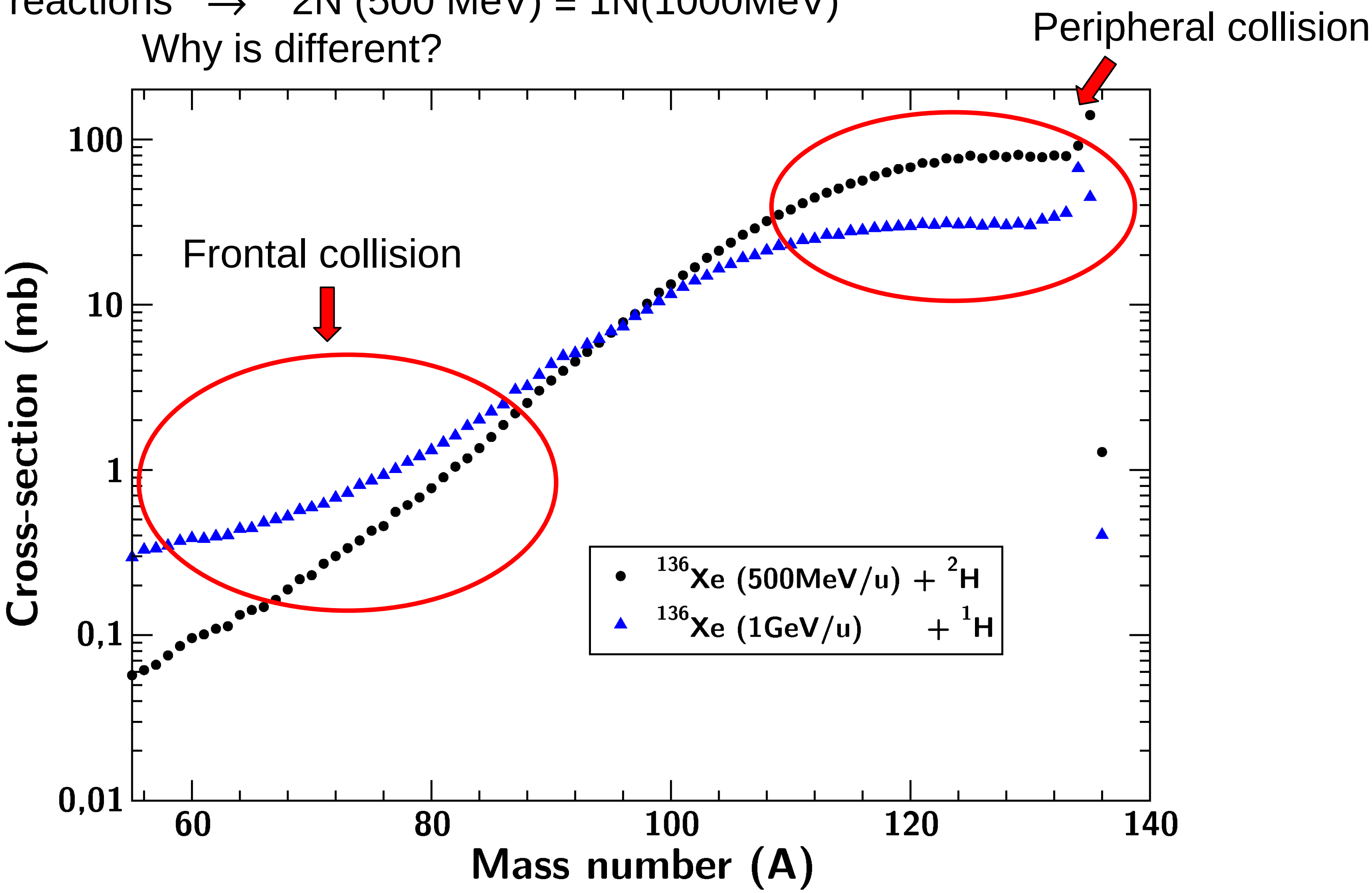


Energy deposition in spallation reaction

Peripheral reactions → differents

Frontal reactions → 2N (500 MeV) ≡ 1N(1000MeV)

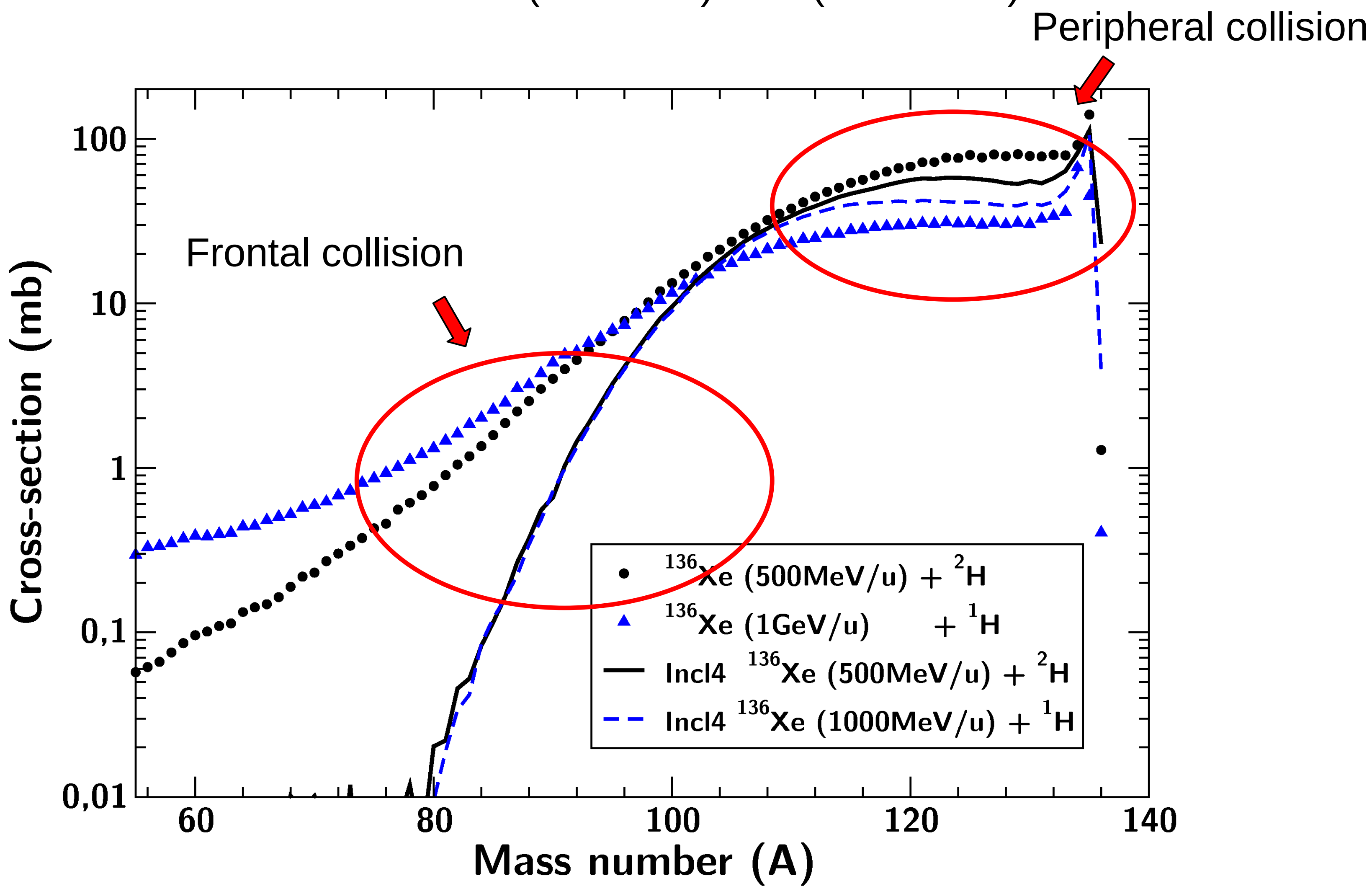
Why is different?



Energy deposition in spallation reaction

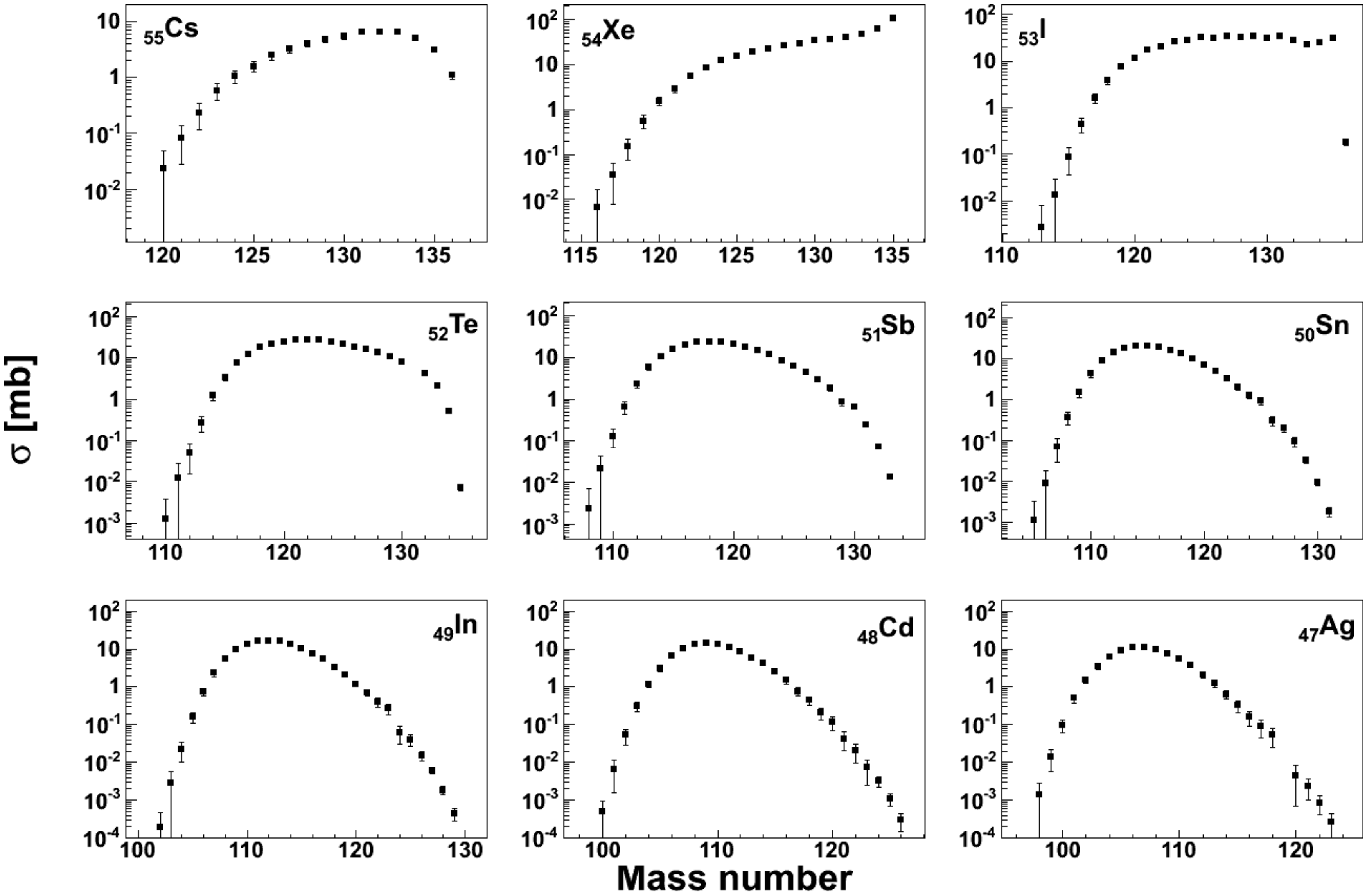
INCL4 → Peripheral collision → different

Frontal collision → 2N (500 MeV) ≡ 1N(1000 MeV)



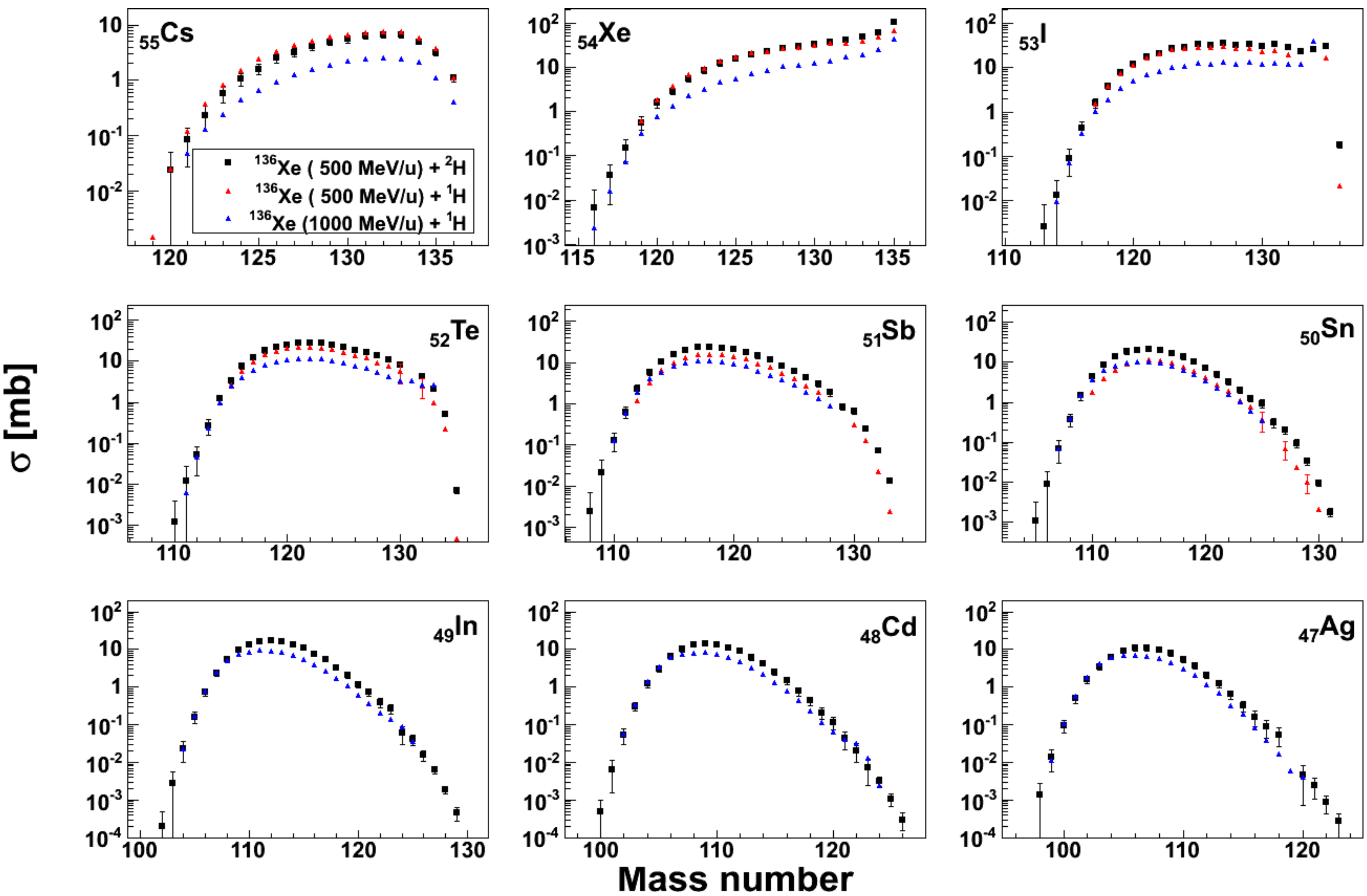
Role that the neutron plays in the reaction

^{136}Xe(500 *A*MeV) + d $\rightarrow$ residual fragments



Role that the neutron plays in the reaction

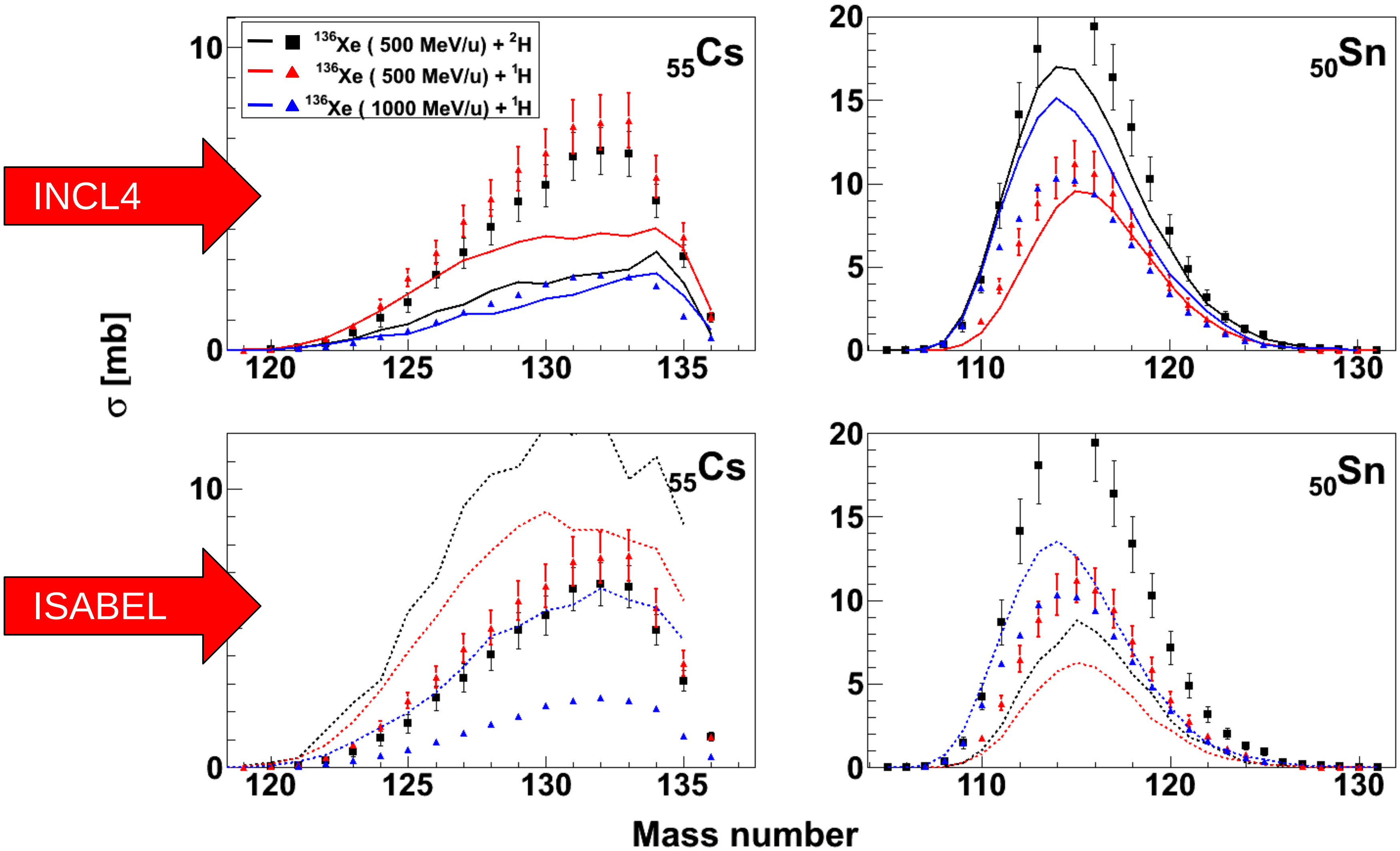
Comparison with other system: ^{136}Xe(500 *A*MeV) + p , ^{136}Xe(1000 *A*MeV) + p



Role that the neutron plays in the reaction

INCL4 → good description (1GeV) / agree in tendency (500MeV)

ISABEL → bad description (1GeV) / tendency is inverted (500MeV)



Summary

- More than 600 residual nuclei produced in reactions induced by ^{136}Xe projectiles on deuterium were unambiguously identified and their production cross sections were determined with high accuracy.

- The magnetic analysis used in this work even made possible to separate the elastic and inelastic components for the charge pickup channels

- These data, together with other reactions previously measured, were used to investigate the energy deposition and the nature of in-medium N-N collisions in spallation reactions.

- The comparison of the isobaric distributions of residual nuclei obtained in this reaction and in the reaction ^{136}Xe+p at 1000 AMeV show that contrary to expectations and intra-nuclear casacade simulation codes, two nucleons at 500 AMeV deposit less energy in the target nucleus than a single proton at 1000 AMeV.

- The comparison of the isotopic distributions of residual nuclei close to the projectile shows a larger production for reactions induced by ^{136}Xe projectiles on protons at 500 AMeV than on deuterium at the same energy. This observation is explained by the fact that the neutron inside the deuterium does not contribute to any elastic charge-exchange process. This behaviour is not described by all intra-nuclear cascade codes.

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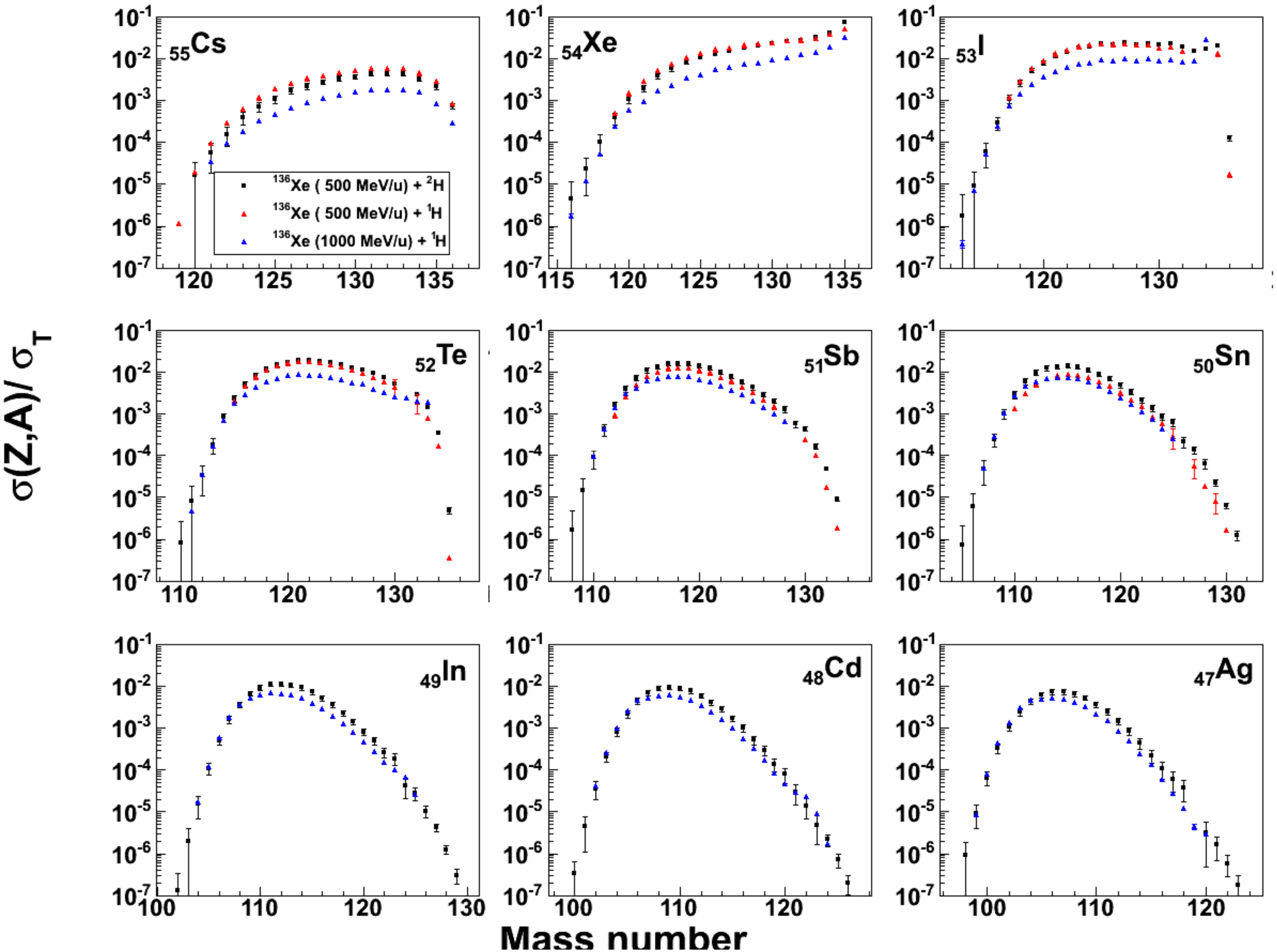
Cross-section

Comparison with other system: ^{136}Xe(500 *A*MeV) + p , ^{136}Xe(1000 *A*MeV) + p



Feynman diagrams

proton-Nucleus and neutron-Nucleus inelastic reactions: