Light nuclides observed in the fission and fragmentation of ^{238}U

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OUTLOOK

1) Experiment: $^{238}U \rightarrow p + Ti$ at 1 A·GeV

2) The tool: the FRS at GSI

3) Four new (preliminary) results:

Fission of ^{238}U in $^{238}U \rightarrow$ **p**

- extremes of fission

Fragmentation of ^{238}U in $^{238}U \rightarrow$ **Ti**

- velocity of the light residues
- N/Z of the light residues
- even-odd structure in N=Z nuclei

THE EXPERIMENT: 1 A·GeV $^{238}U \rightarrow H_2$

AIM: to measure the formation cross sections of residues in the reaction **p + ^{238}U** at **1 GeV**.

Advantages of the inverse kinematics:

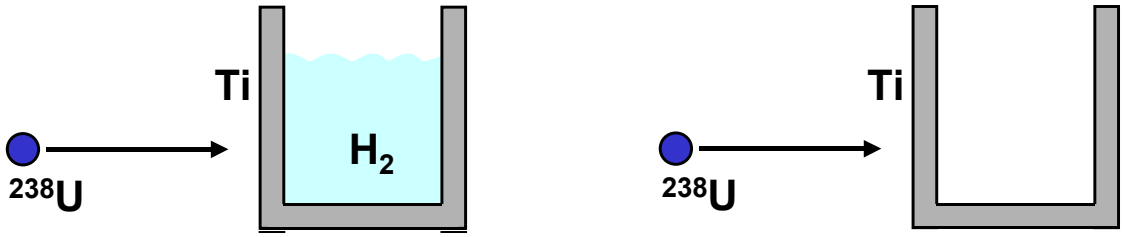
complete identification

knowledge of the kinematics

Disadvantage:

I need a H_2 target

So, actually I have to perform two experiments:



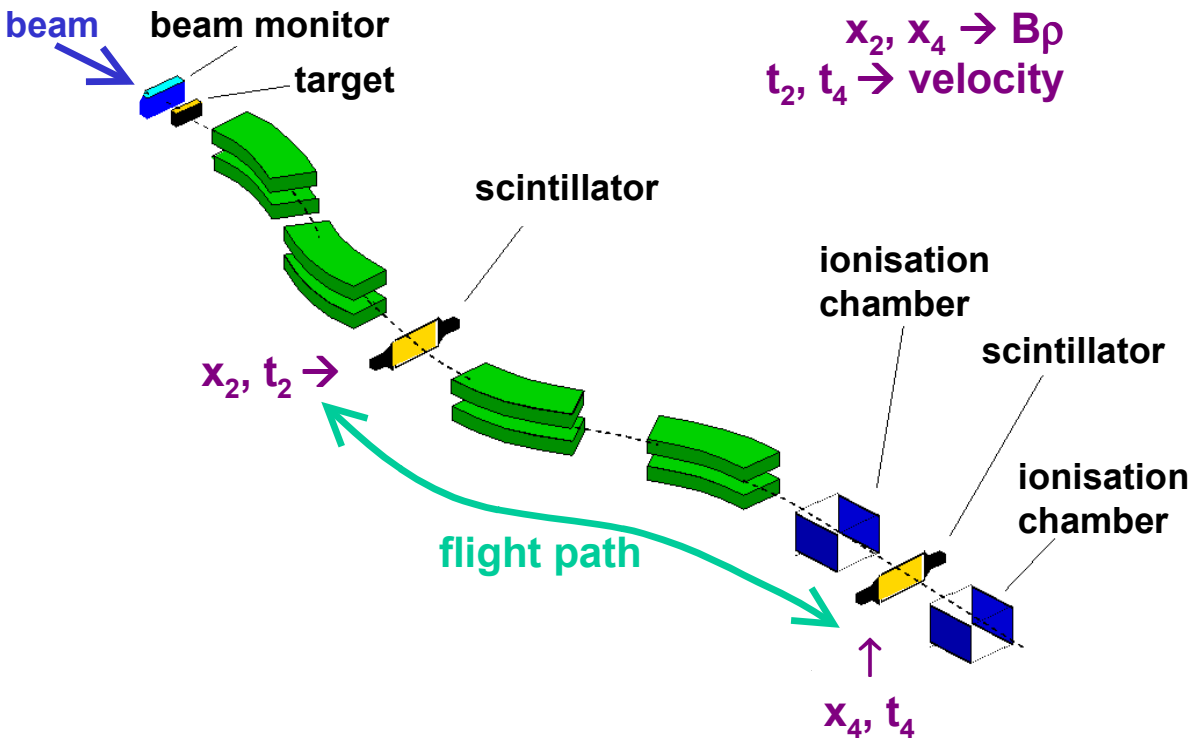
results from the two experiments

Where can I perform such experiments?

I need 1 A·GeV ^{238}U beam

a recoil separator

THE FRAGMENT SEPARATOR AT GSI



- identification of Z from IC: $\Delta E \propto Z^2$

- identification of A/Z from time and position:

$$\frac{A}{Z} = \frac{m_0}{e}\frac{B\rho}{c\beta\gamma} \qquad \beta = \frac{v}{c} \quad with \quad v = \frac{s}{ToF}$$

- once nuclides are identified (i.e. A and Z are integer numbers), velocity is calculated from Bρ:

$$\gamma v = B\rho \frac{Z \cdot e}{A \cdot m_0}$$

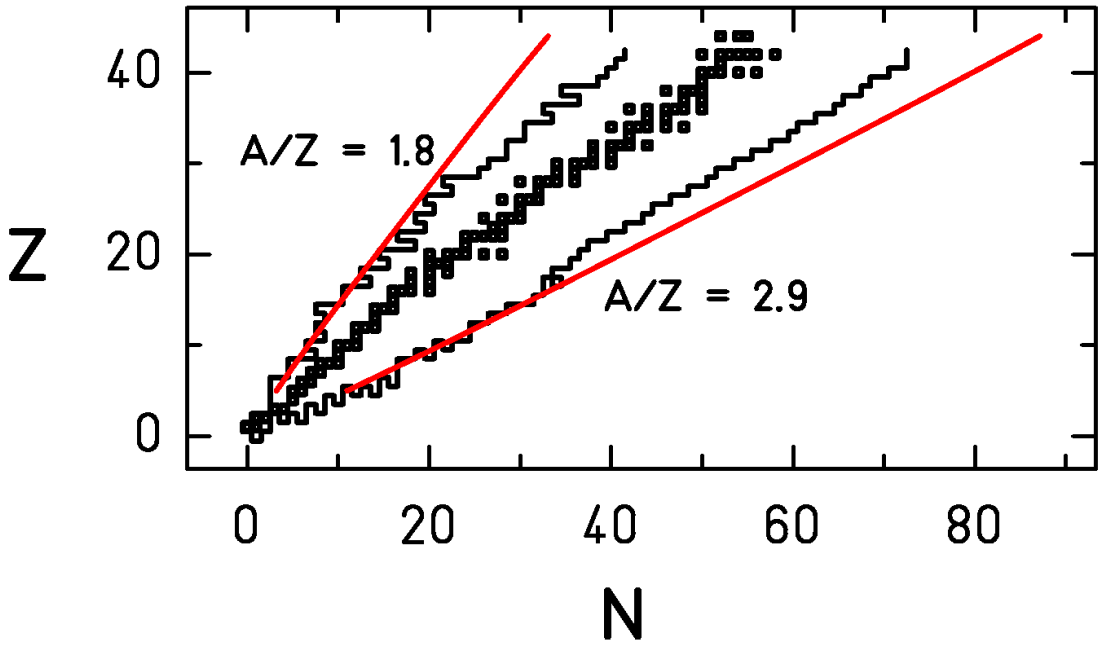
very precise evaluation!

FEATURES OF THE FRS

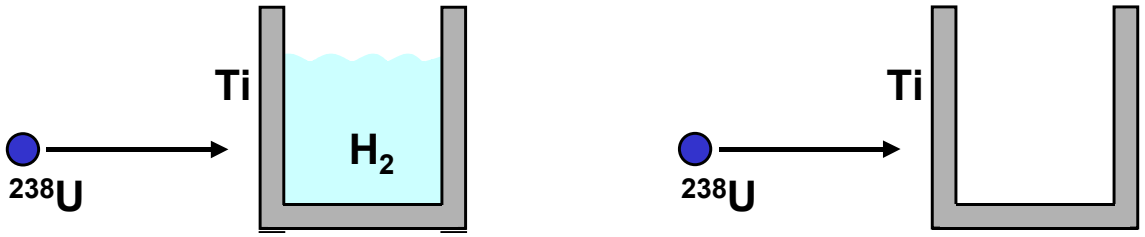
- full identification (**A**, **Z**)
- **absolute velocity** - extremely precise (from Bρ; Bρ resolution ~ $3 \cdot 10^{-4}$)

NO SUCH AN ACCURATE INFORMATION BEFORE!

- limited acceptance in magnetic rigidity: needs to combine several Bρ settings to cover all A/Z and velocities,
- limited angular acceptance: only a part of the real production is measured.

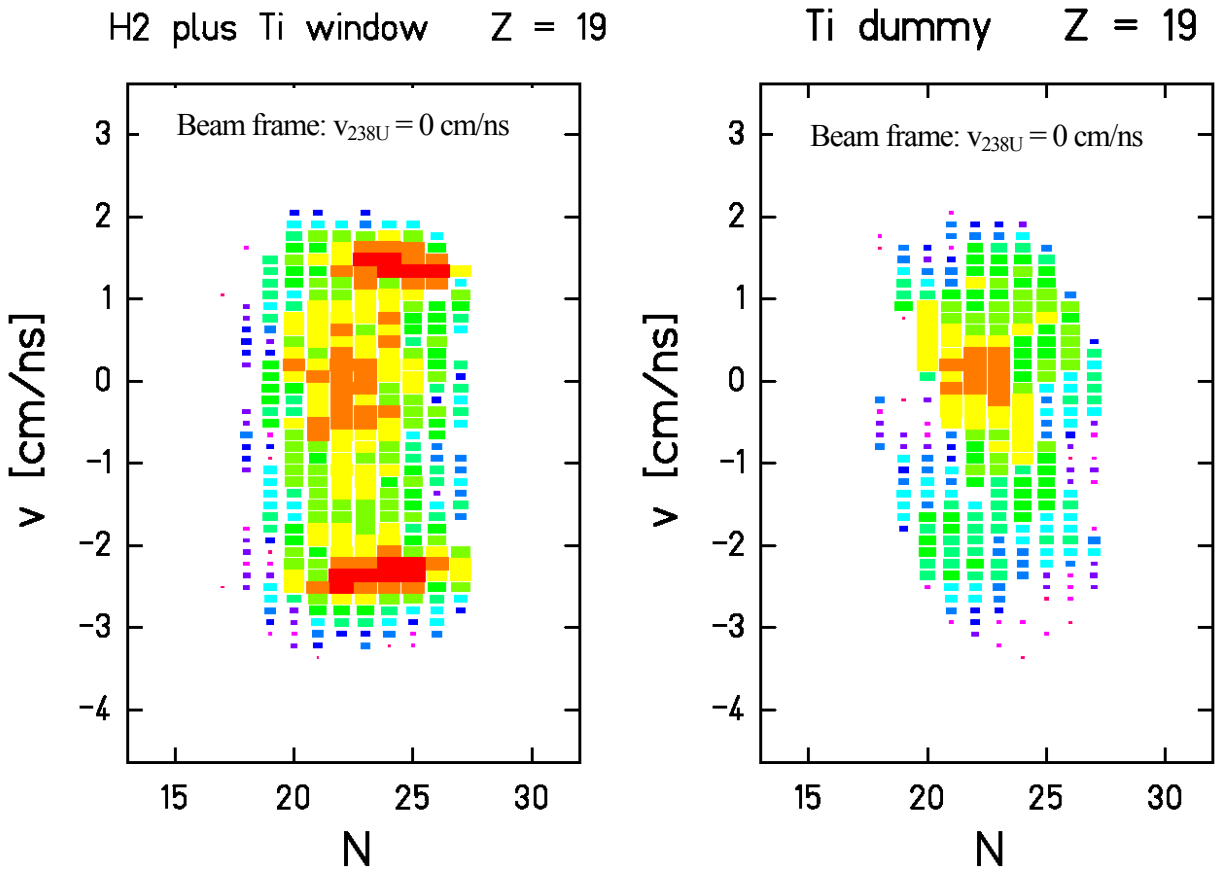


OUR DATA: 1 A·GeV $^{238}U \rightarrow H_2$ (+ Ti)



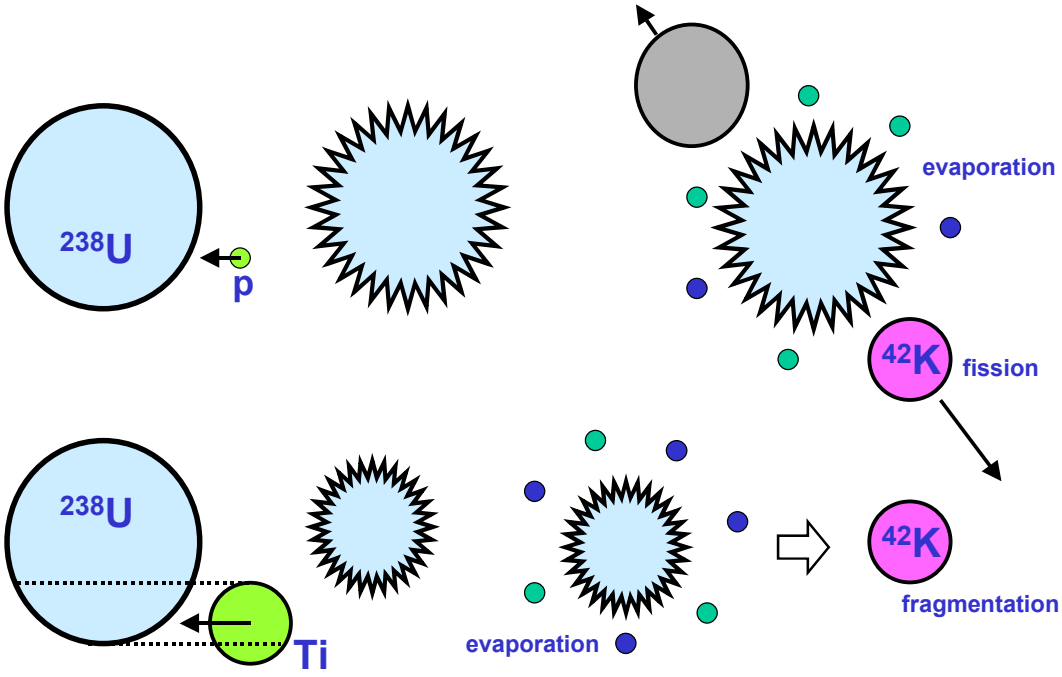
A, Z, v → VELOCITY SPECTRUM FOR EVERY ISOTOPE

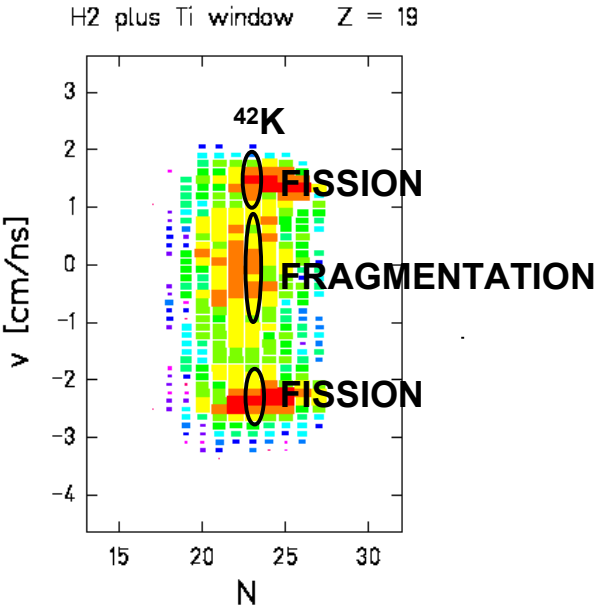
All isotopes of one element: potassium

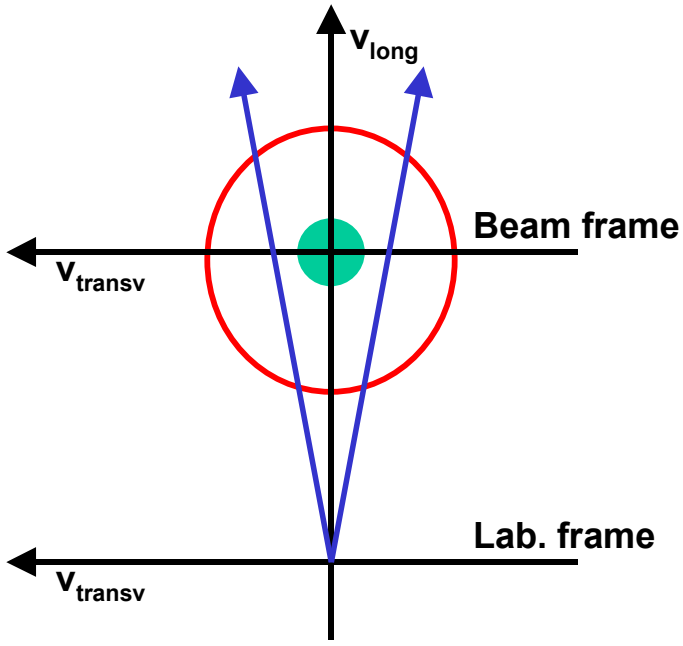


What do we learn from these pictures?

REACTION MECHANISM





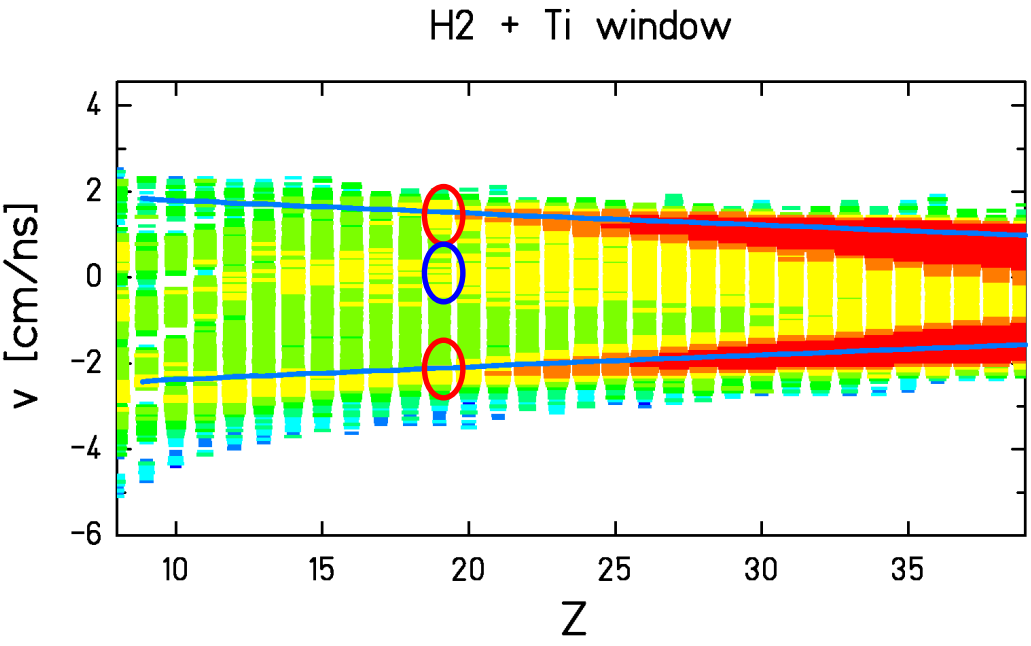


fission due to the interaction with H

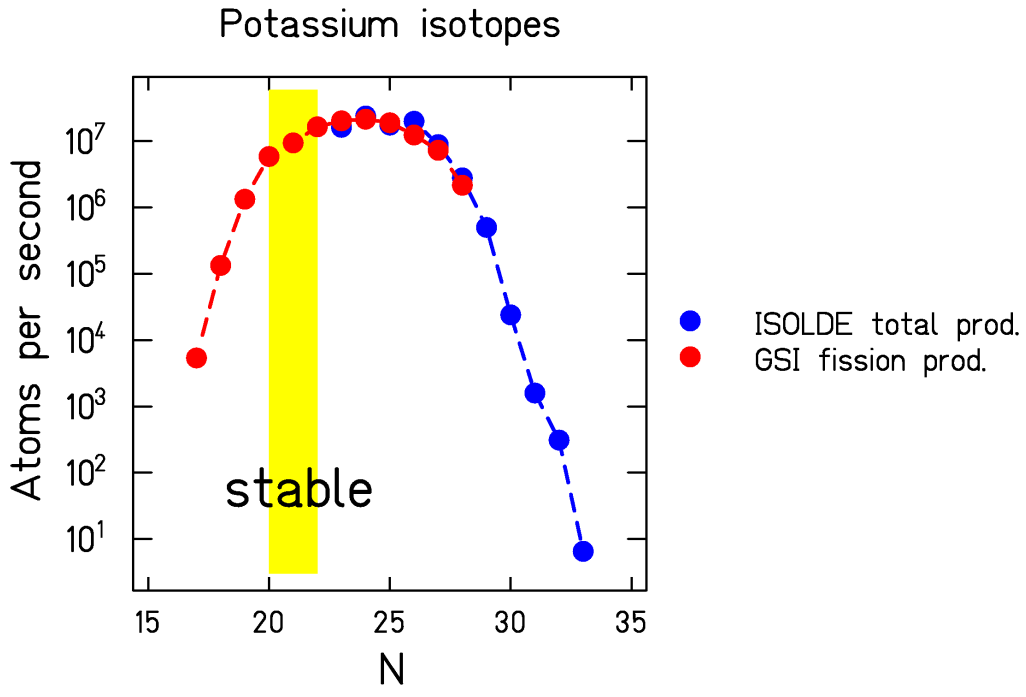
fragmentation due to the interaction with Ti

1st RESULT: ^{238}U + p (fission)

Extremely asymmetric fission

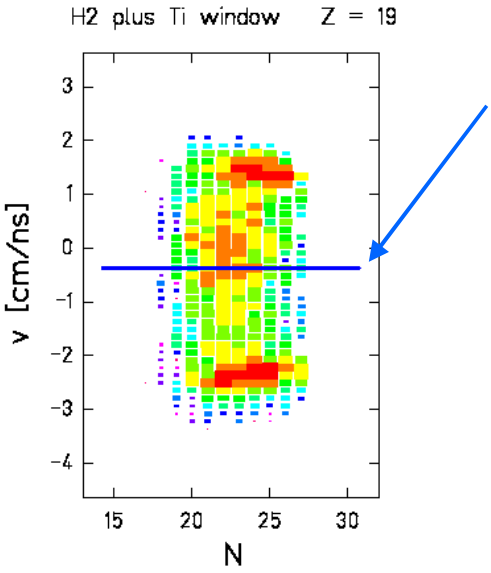


Lines: calculated velocities of fission fragments from the compound nucleus Z = 84, A = 214

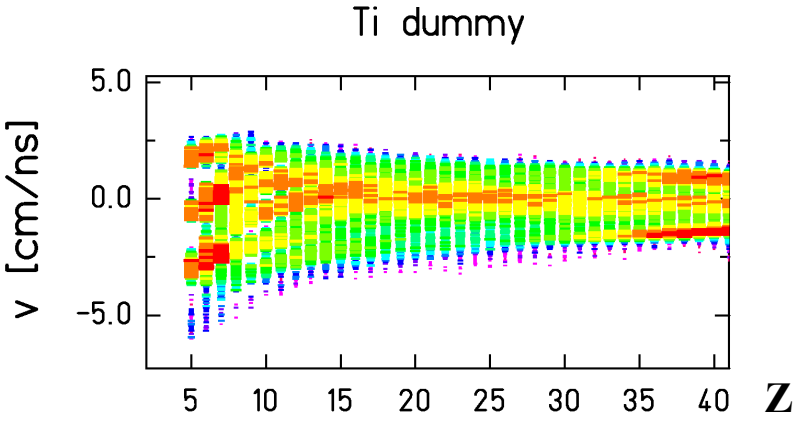


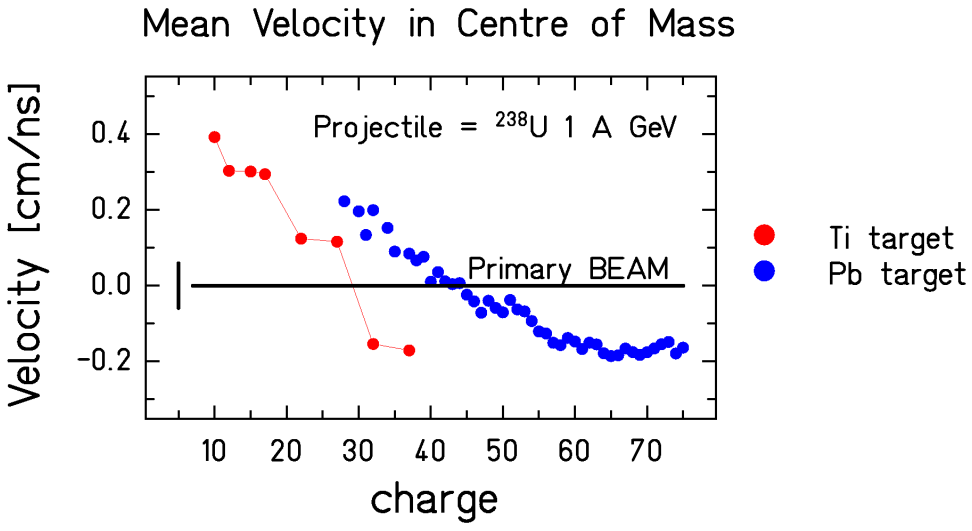
(*) H.-J. Kluge, ISOLDE user's guide, CERN 86-05 (1986)

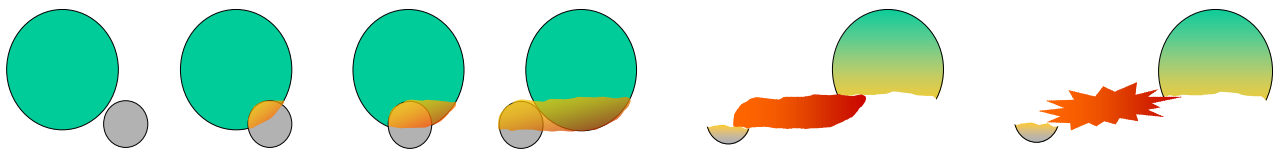
2nd RESULT: ^{238}U + Ti (fragmentation)
Velocity of light residues



symmetry line for fission products, i.e. average velocity of the compound nucleus

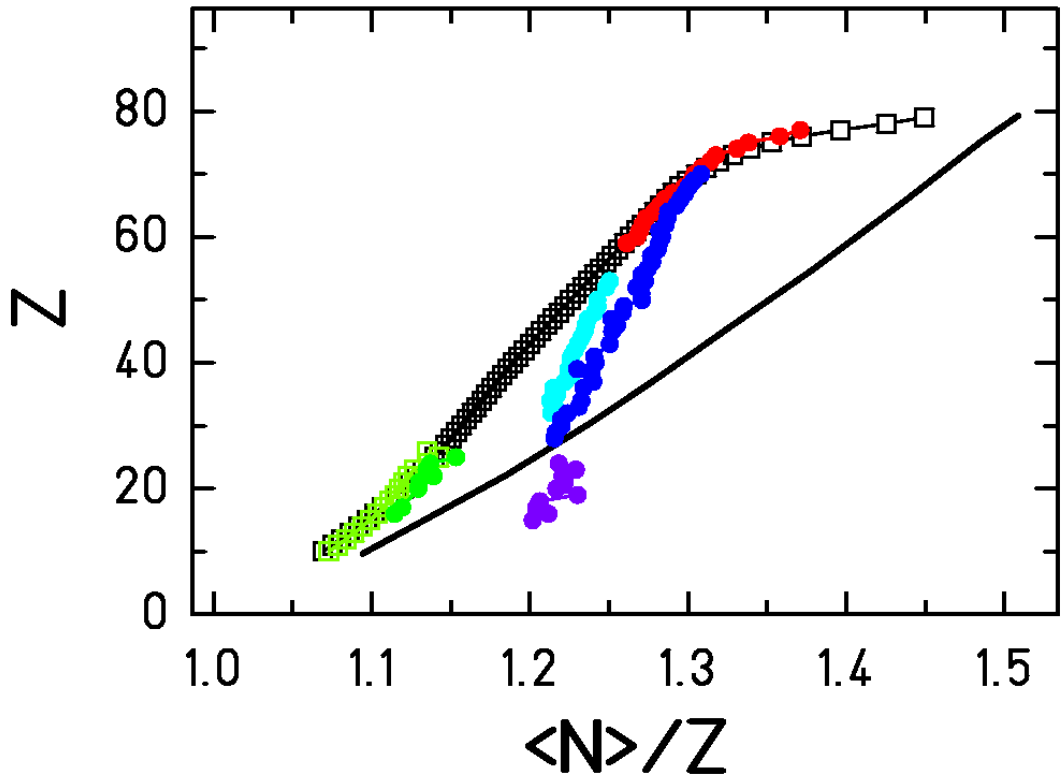






3rd RESULT: ^{238}U + Ti (fragmentation)

Mean N/Z of fragments



— stability line

EPAX, projectile = Au

EPAX, projectile = Fe

● 800 A·MeV Au + p

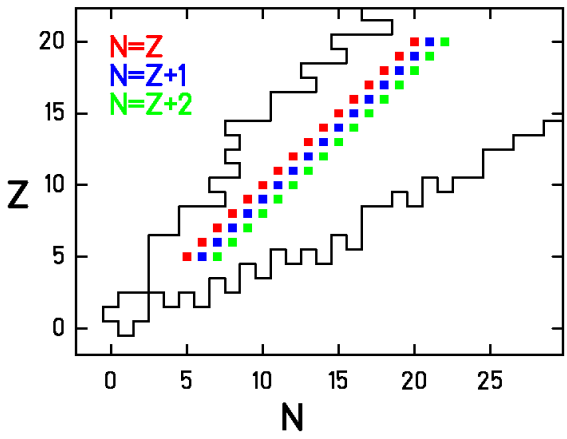
● 414 A·MeV Fe + p

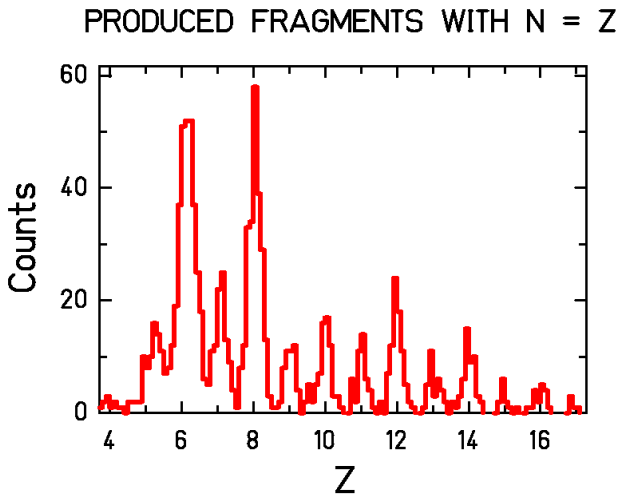
● 750 A·MeV U + Pb

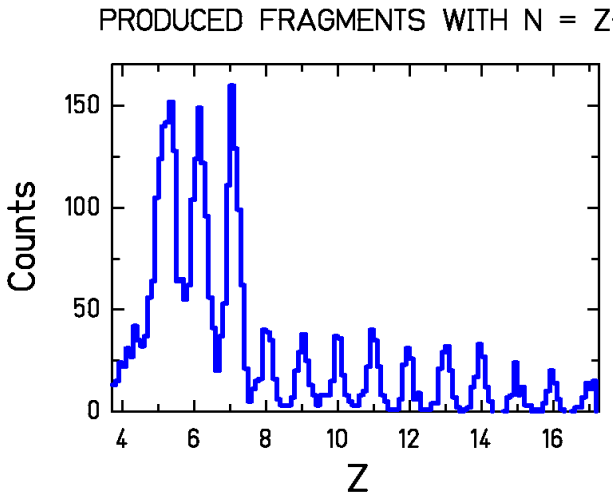
● 1000 A·MeV U + Pb

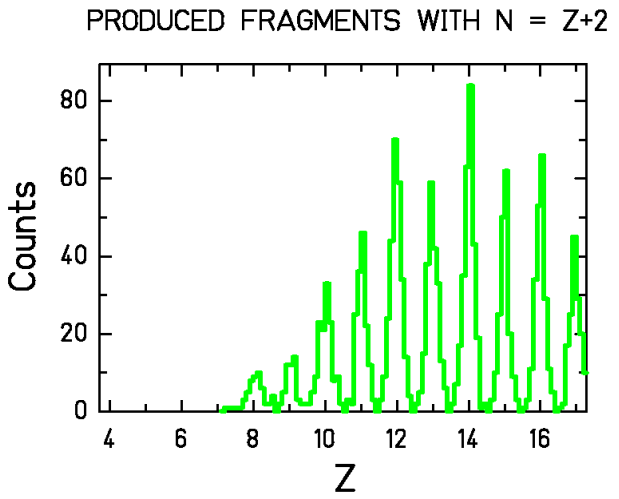
● 1000 A·MeV U + Ti

4th RESULT: ^{238}U + Ti (fragmentation)
Even-odd structure in N=Z nuclei









➨ **In contradiction to theoretical expectations:**

"The combined pairing effects in binding energies and level densities cancel in such a way that evaporation cross sections become approximately independent of pairing effects"

(T. Ericson, Advances in Physics 9 (1960) page 471)

Conclusions

LIGHT NUCLIDES FROM 1 A·GeV ^{238}U + p and Ti

The apparatus:

FRS allows full (A, Z) identification and very precise determination of the velocity of produced residues

→ formation cross section for every isotope, with its velocity distribution

Four new aspects of the physics of the two reactions:

^{238}U + p

- extremely asymmetric fission (down to Z_{frag}=10)

^{238}U + Ti

- acceleration of light residues

- deviation of the N/Z of fragments from the asymptotic value

- unexplained even-odd structure in N=Z nuclei