

Basic Research for the Transmutation of Nuclear Waste

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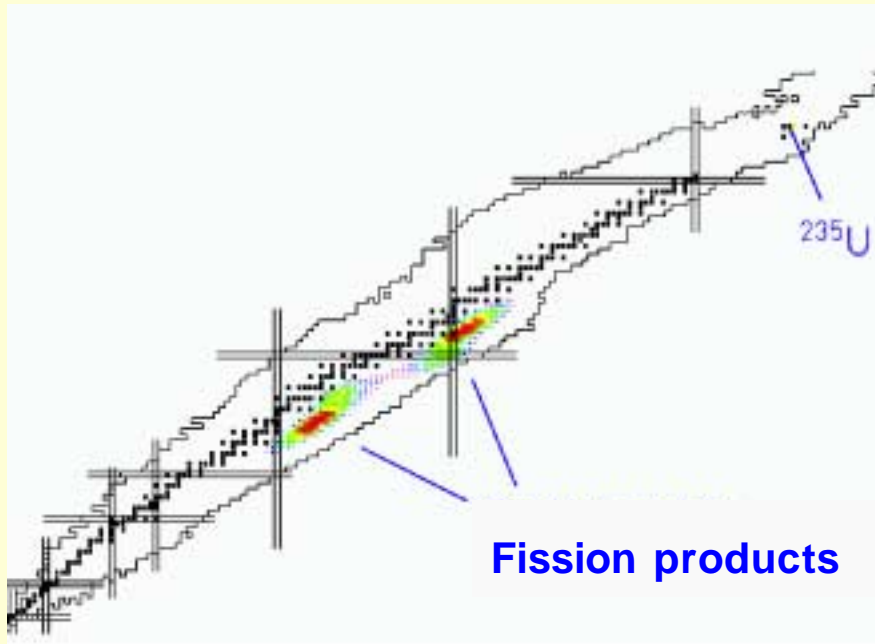
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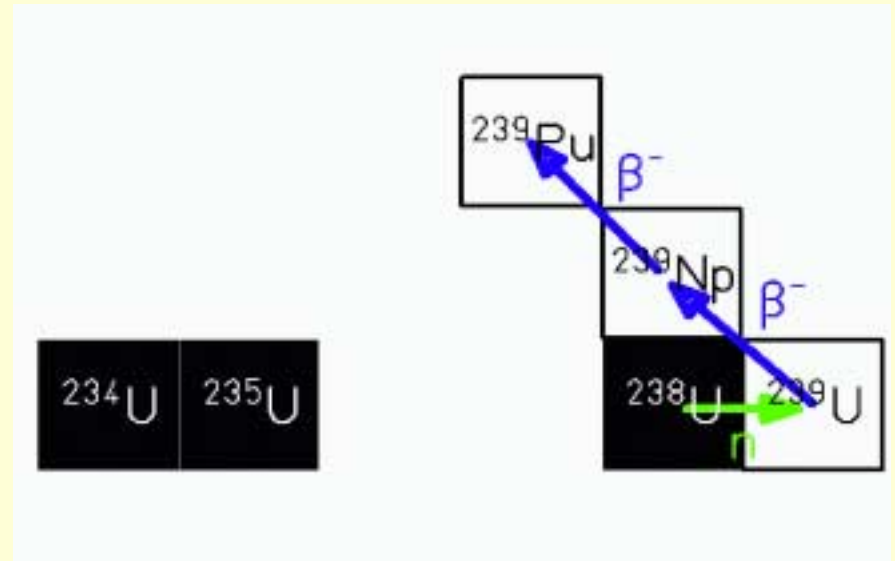
Motivation - Radioactive waste

Fission:



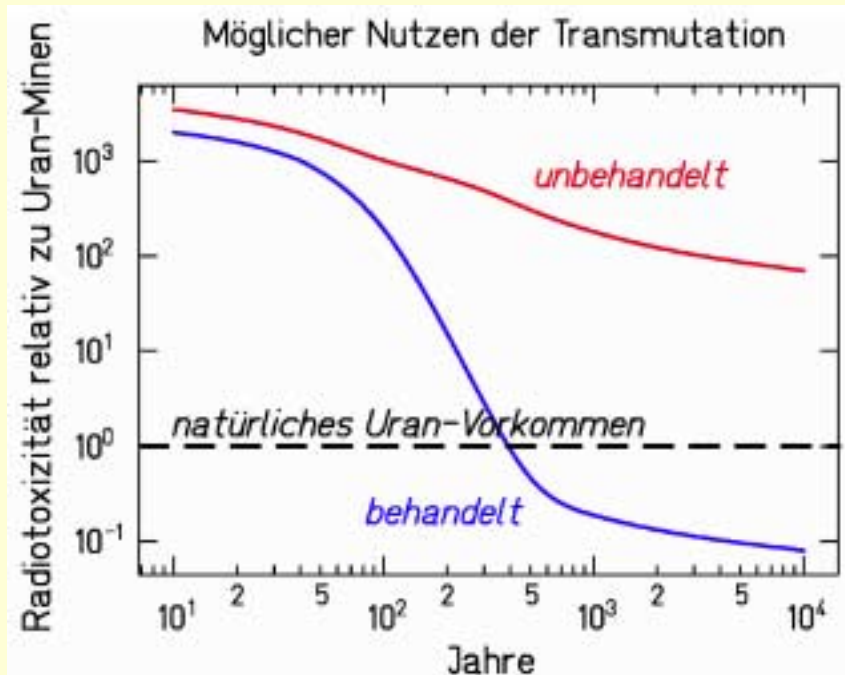
^{129}I ($15.7 \cdot 10^6$ y),
 ^{107}Pd ($6.5 \cdot 10^6$ y),
 ^{135}Cs ($2 \cdot 10^6$ y),
 ^{93}Zr ($1.5 \cdot 10^6$ y) ...

n-Breeding:

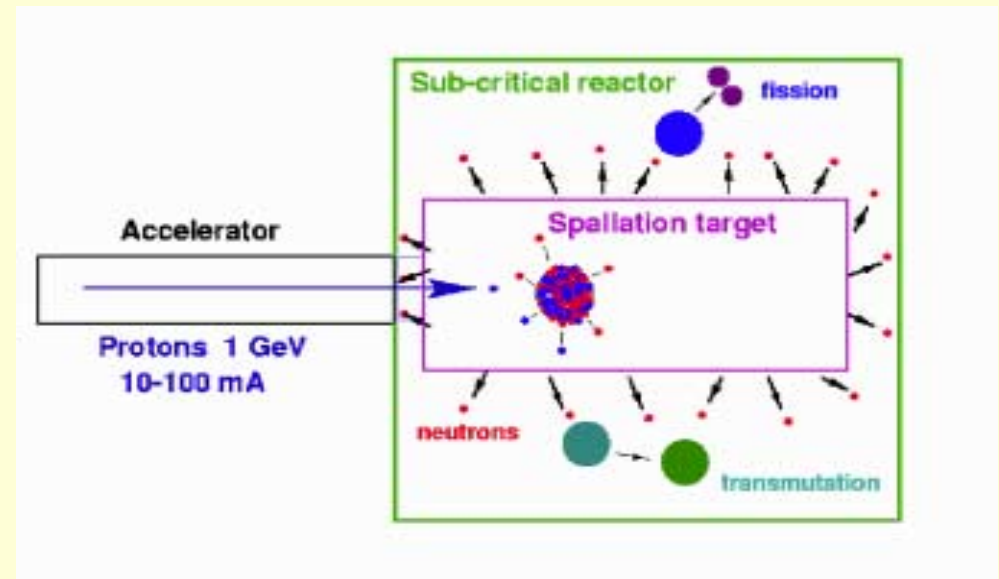


Pu, Am, Cm, Np isotopes.

Motivation - Hybrid System (ADS)



HINDAS, nTOF, MUSE...



Problems:

- Nuclear reactions up to 1 GeV must be known!!

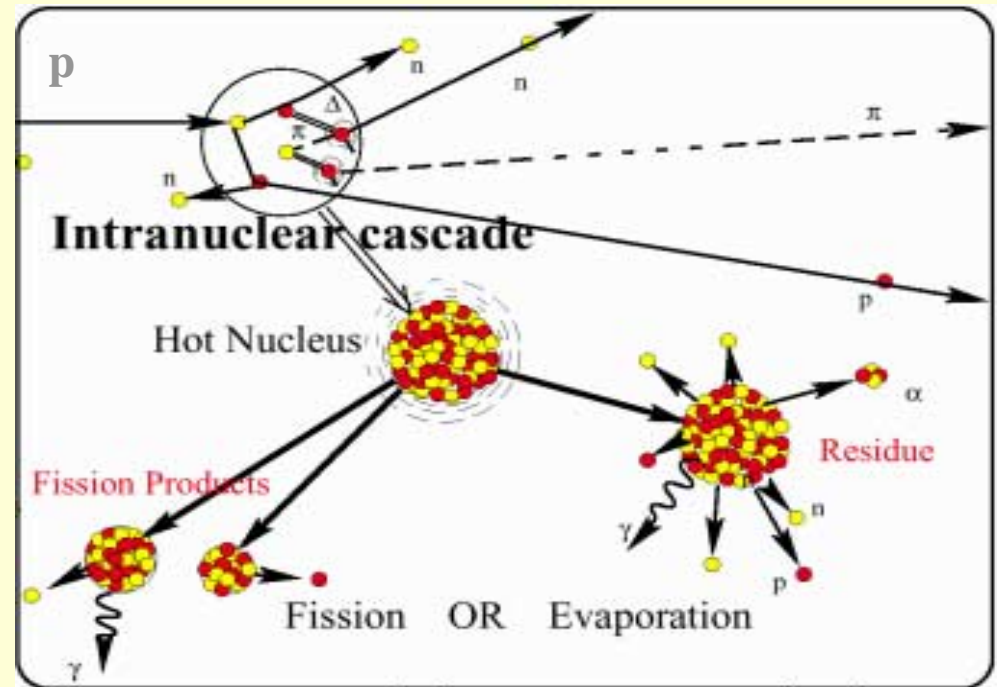
- Yield of spallation neutrons.
- Production of radioactive nuclei by spallation.
- Material damages due to irradiation.

Nuclear physics at GSI for ADS design

Aim:

- Complete understanding and modelling of spallation reactions at 0.2 - 2 A GeV:

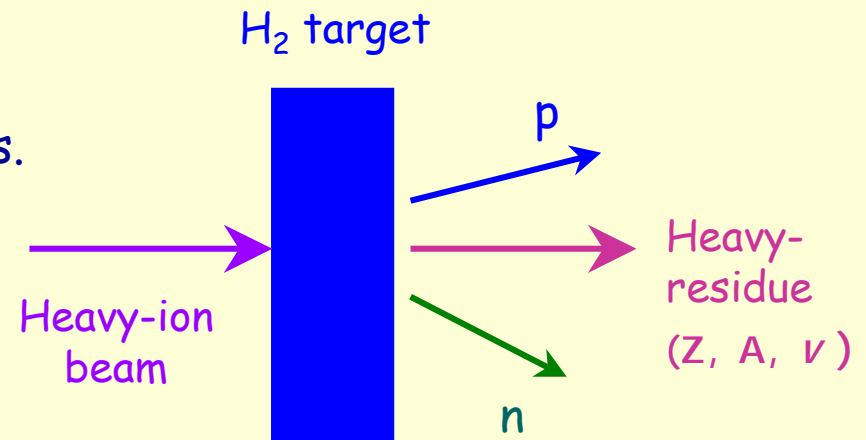
- energy deposition in spallation
- decay of hot nucleus
- kinematics of final products ...



Nuclear physics at GSI for ADS design

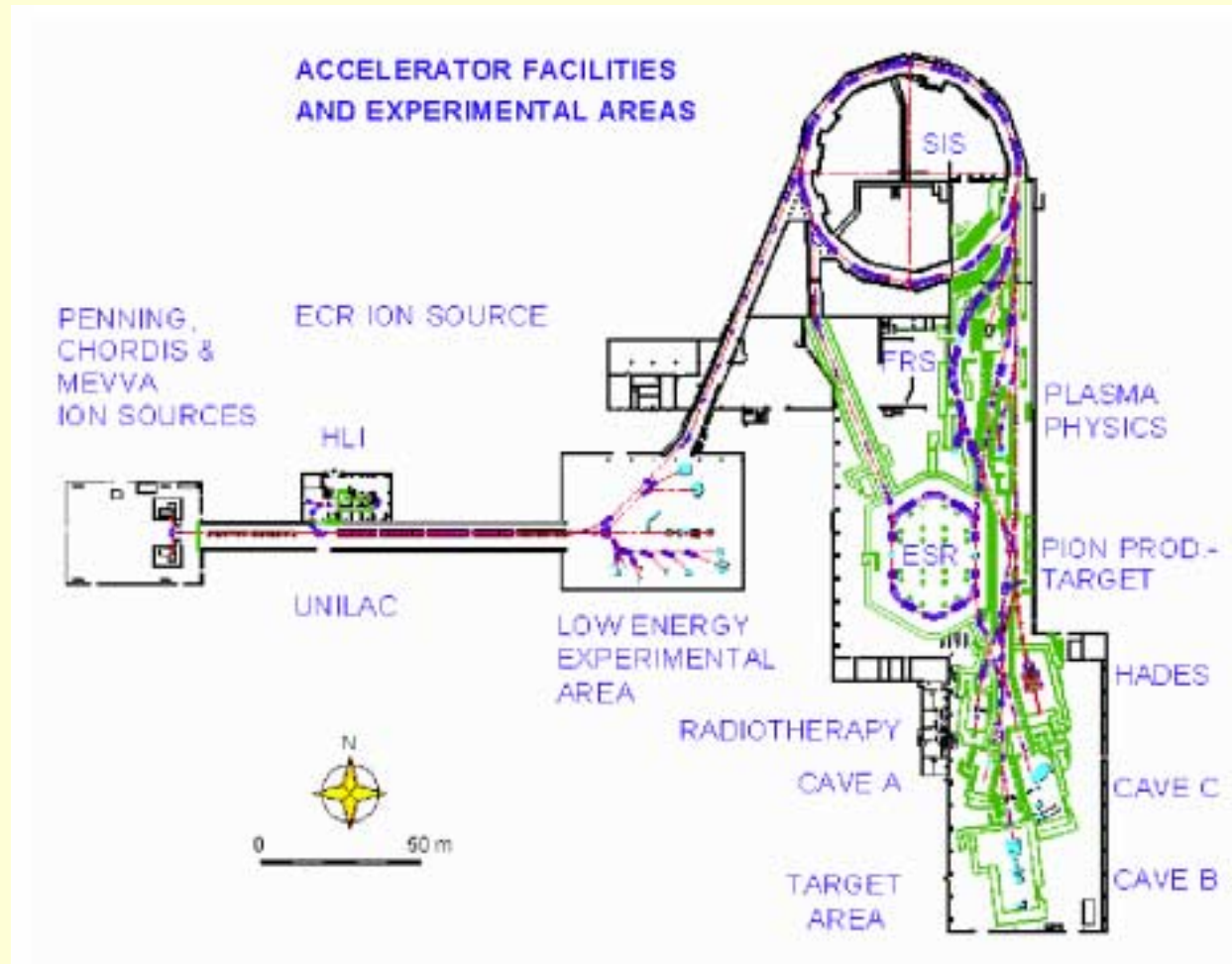
How-to:

- The data on systematic investigation of a few representative systems (Fe, Xe, Au, Pb, U) put important constraints on the models to be improved or developed.
- Measurements in inverse kinematics: in-flight identifications of heavy reaction products and their kinematical properties.

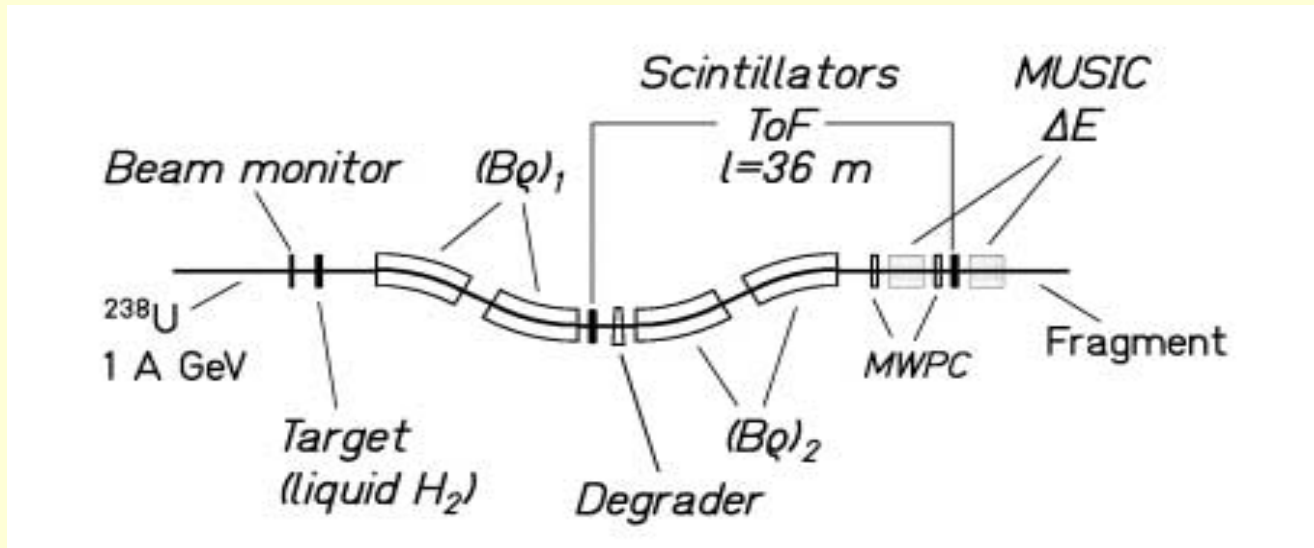


Experimental facility at GSI

Offers excellent conditions for identification of heavy residues of nuclear reactions.



The GSI Fragment Separator



Projectile-like fragments:

- Transmitted with $\Delta(B\rho)/(B\rho) = 3\%$ and $\Theta_{\max} = 15$ mrad.
- Identification in Z and A by magnetic deflection in FRS, tracking,

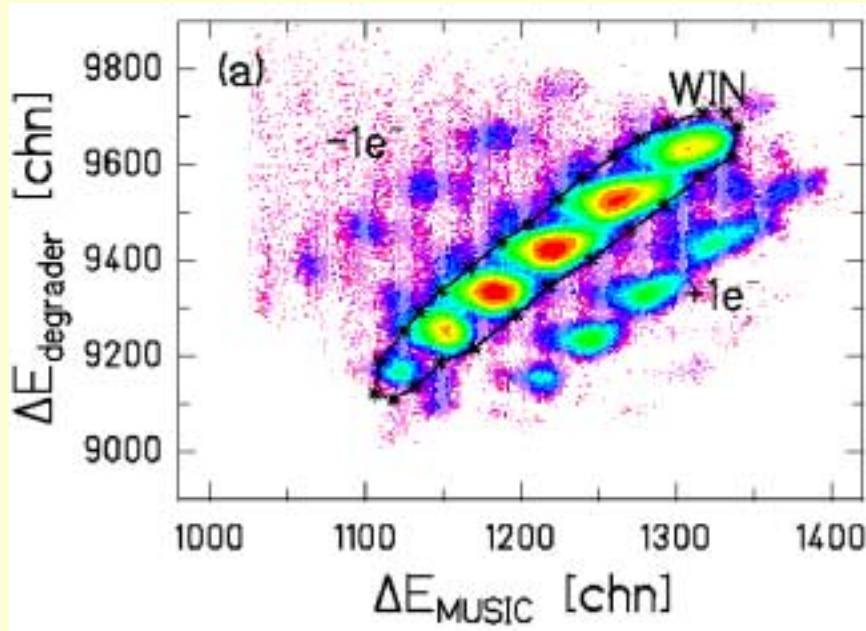
ToF and ΔE :

$$A/Z \propto B\rho / \beta\gamma$$

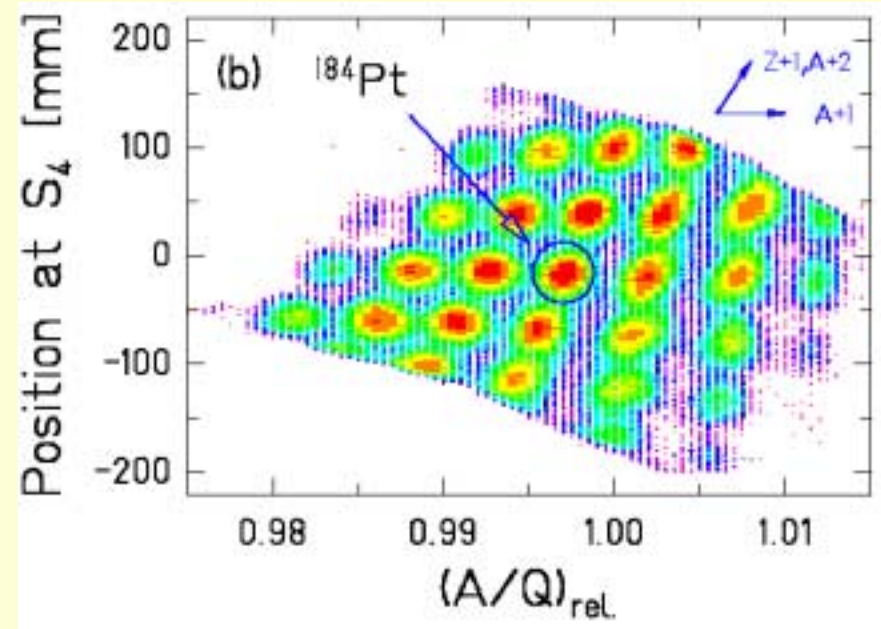
$$\Delta E \propto Z^2 / v^2$$

Identification pattern

$^{208}\text{Pb} + ^1\text{H}, 1 \text{ A GeV.}$

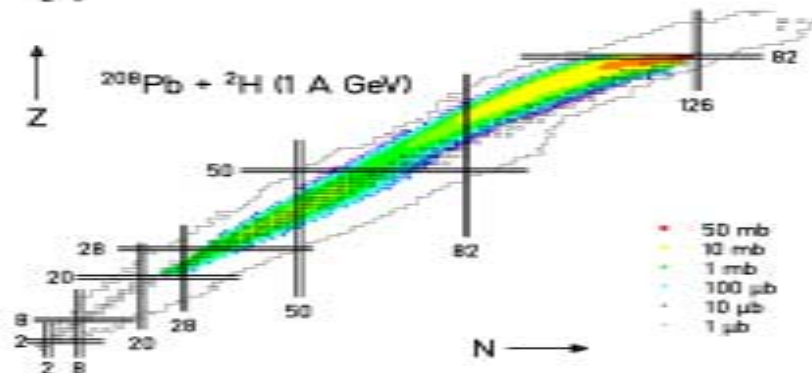
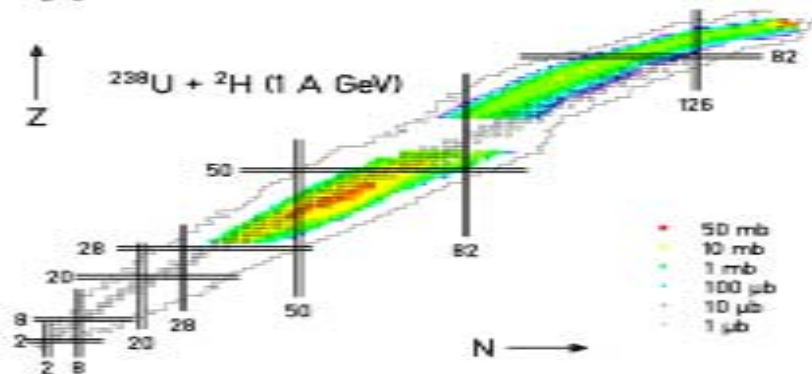
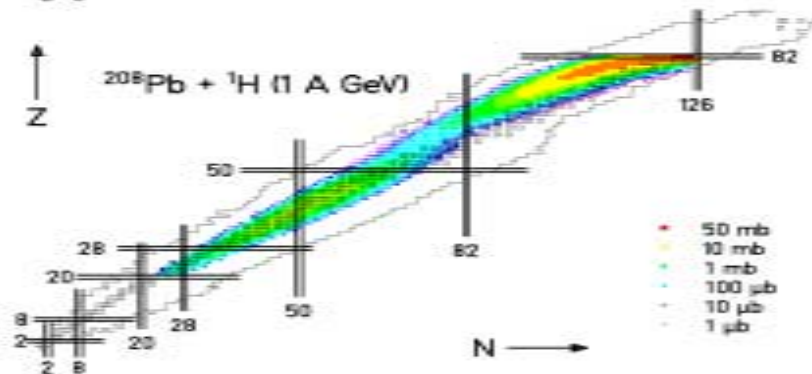
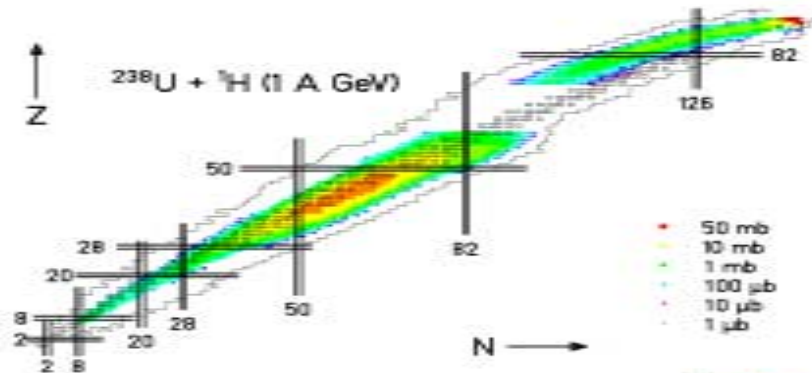
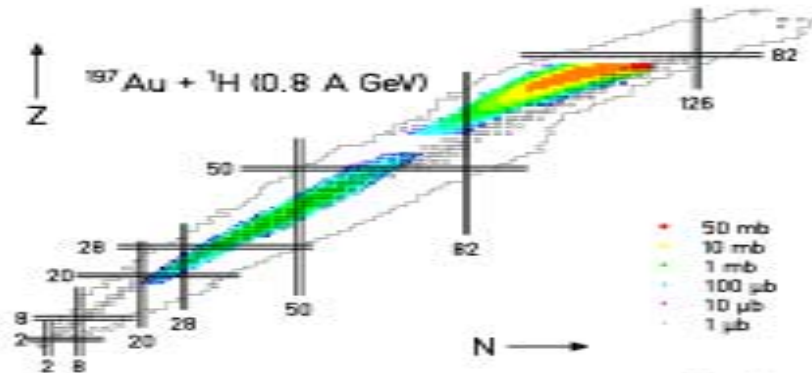


Identification of ionic charge states



Separation in A and Z.

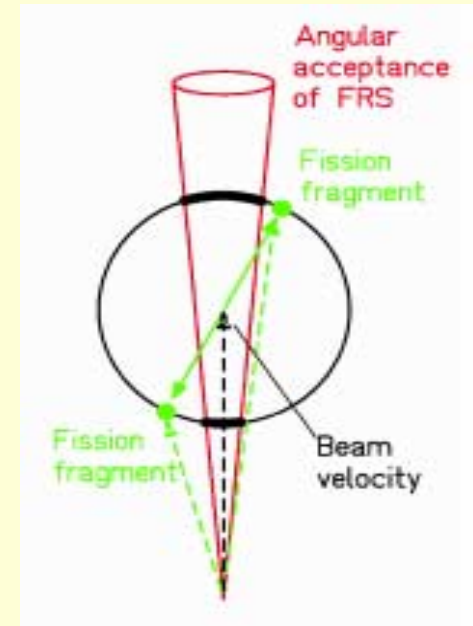
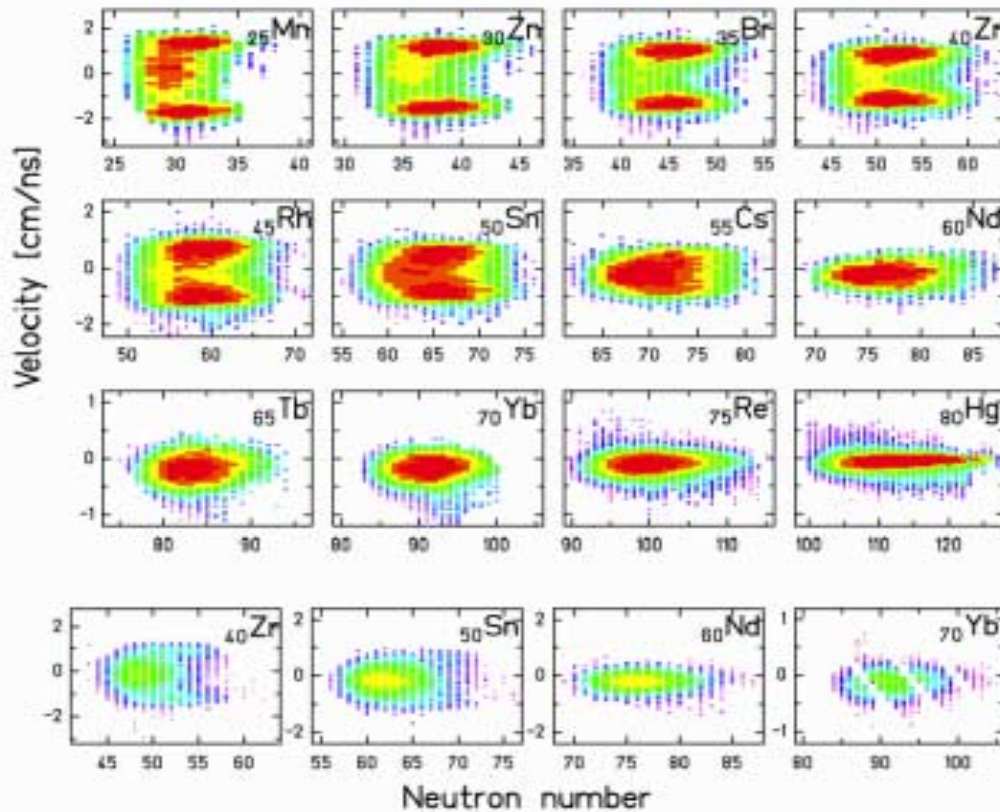
Production cross sections



F. Rejmund et al., NPA 683 (2001) 540.
J. Benlliure et al., NPA 683 (2001) 513.
T. Enqvist et al., NPA686 (2001) 481.
T. Enqvist et al., NPA703 (2002) 435.
M. Bernas et al., to be published.
PhD: B. Mustapha, E. Casarejos, J. Taieb,
M.V. Ricciardi, J. Pereira

Kinematics

$^{208}\text{Pb} + ^1\text{H}$, 1 A GeV

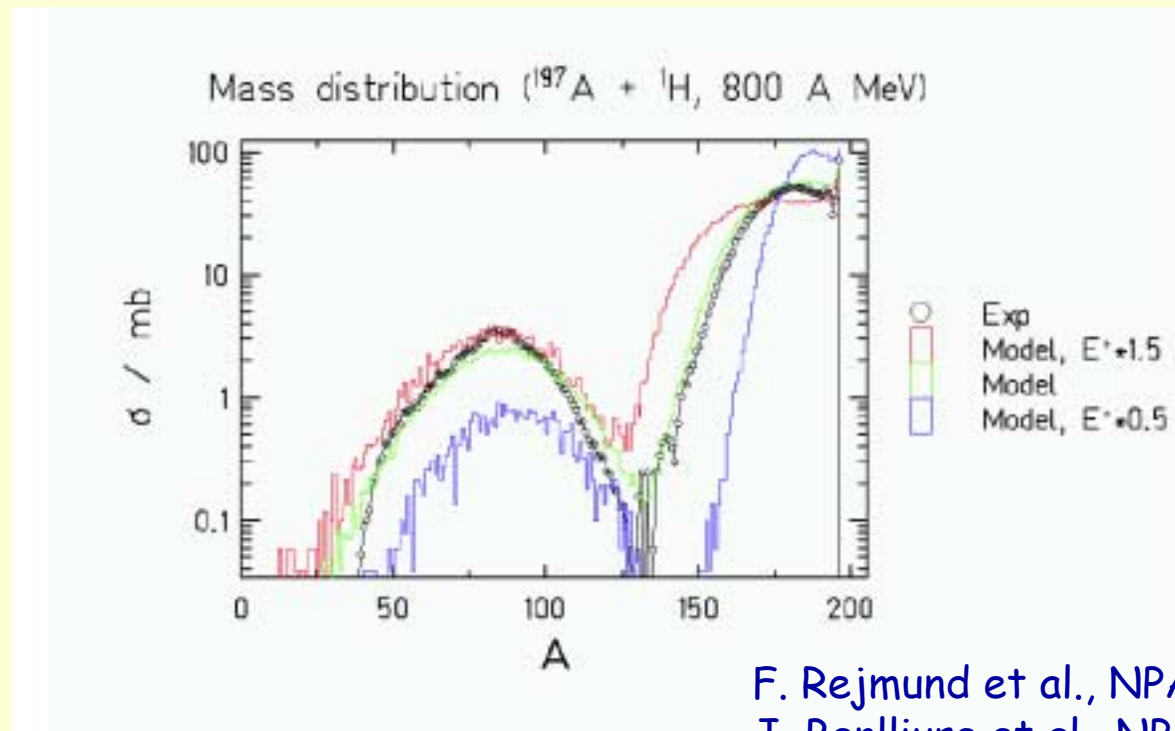


Velocity distribution of every nuclide:

- Recoil energy.
- Production mechanism.

T. Enqvist et al, NPA686 (2001), 481.

Energy deposition in spallation

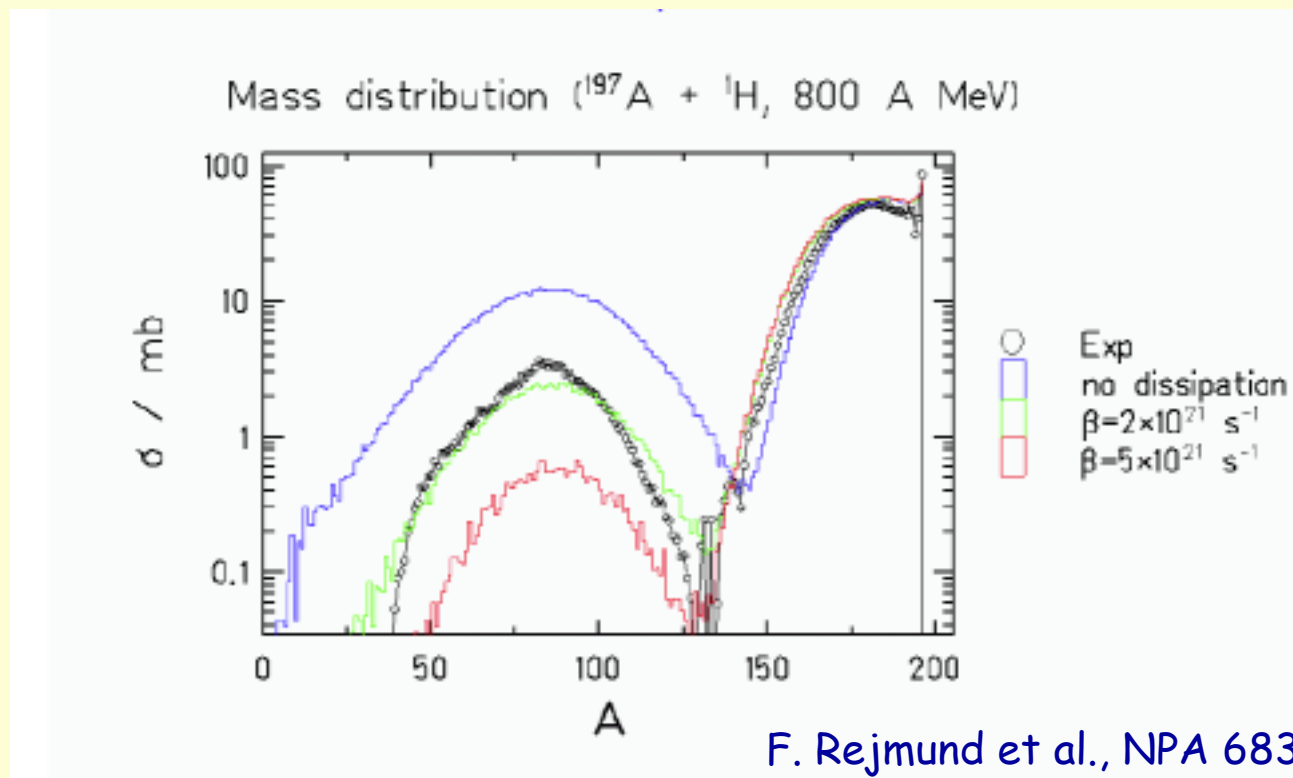


F. Rejmund et al., NPA 683 (2001) 540.
J. Benlliure et al., NPA 683 (2001) 513.

Sensitivity of measured mass distribution on the excitation energy introduced in the first stage of reaction.

Thermal instability of nuclei - maximum temperature above which compound system can not survive as an entity.

Role of dissipation in fission



F. Rejmund et al., NPA 683 (2001) 540.

J. Benlliure et al., NPA 683 (2001) 513.

Sensitivity of fission cross section on the strength of dissipation.

Outlook

1. Energy dependence of proton-induced spallation of ^{136}Xe (0.2 ... 1 A GeV) at FRS. (Analysis of data in progress).
Modelling spallation in a thick target.
2. Coincidence measurement of heavy residues, light charged particles and neutrons with ^{56}Fe and heavier systems at ALADIN. (Experiment in preparation).
Investigation of the decay of highly excited heavy nuclei.
3. Full identification of both fission fragments, simultaneous measurement of neutrons, light charged particles and gammas with new R3B magnetic spectrometer. (Preparative studies).
Aiming for a kinematically complete fission experiment.

Summary

Experimental goal:

Full coverage of yields and velocities of:

- Heavy residues.
- Neutrons.
- Light charged particles.

Status:

- Most complete set of relevant data measured (~ 1000 isotopes /system, previous: ~ 20).
- 2nd generation experiment in preparation.

New information on critical topics:

- Energy deposition in INC phase.
- Thermal instability of nuclei (D. Henzlova dedicated talk).
- Dissipative hindrance of fission.