Neutron Rich Nuclei via MNT Reactions

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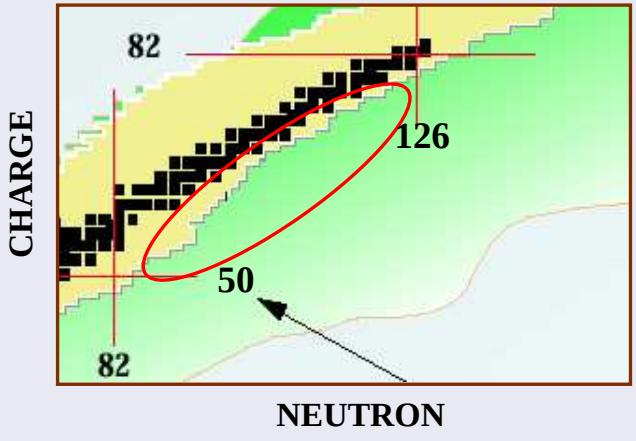
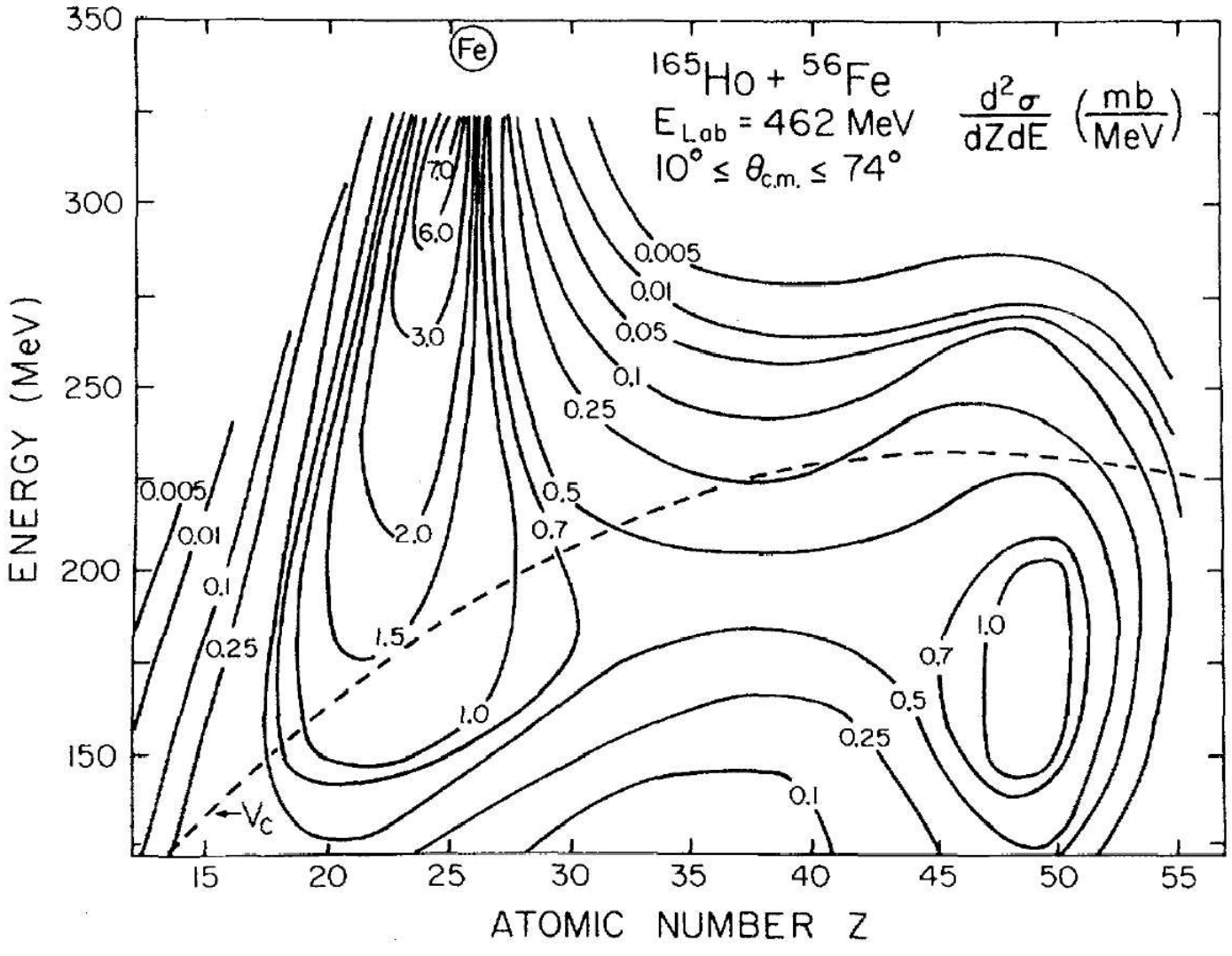


IRIS 10 1st Workshop on
Inelastic Reaction Isotope Separator for Heavy Elements
March 01, 2010, GSI, Darmstadt, Germany

HI reactions, a short overview



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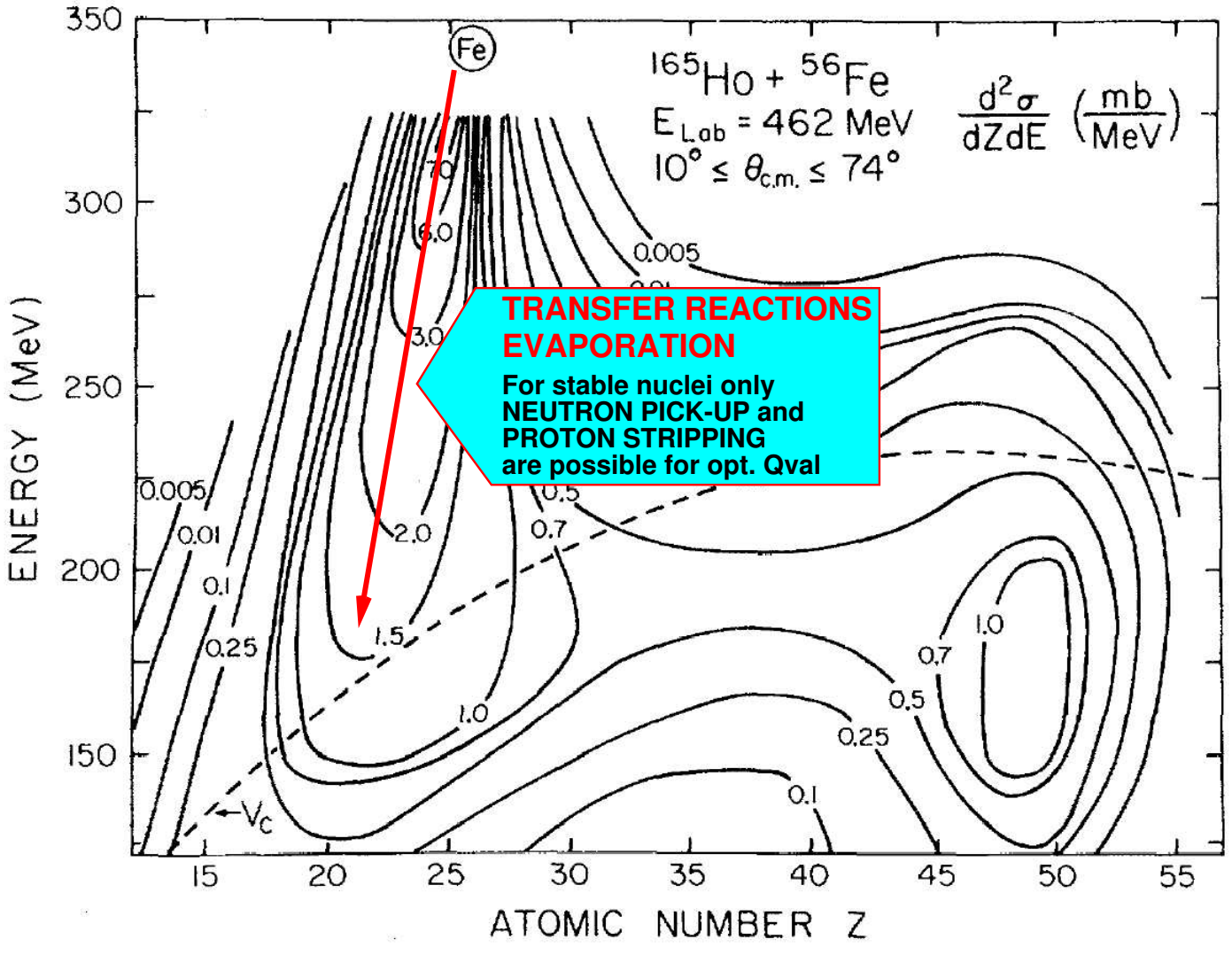

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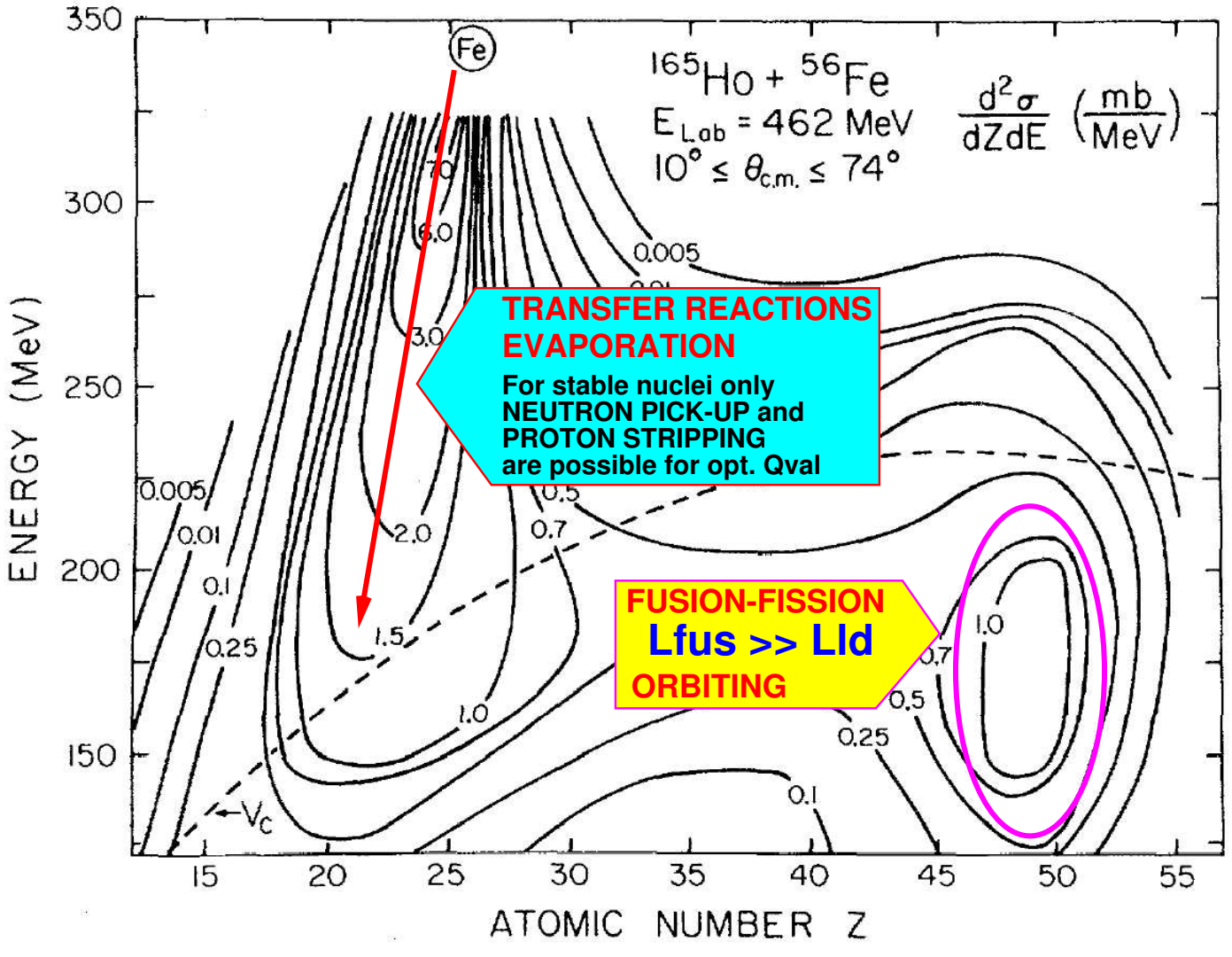
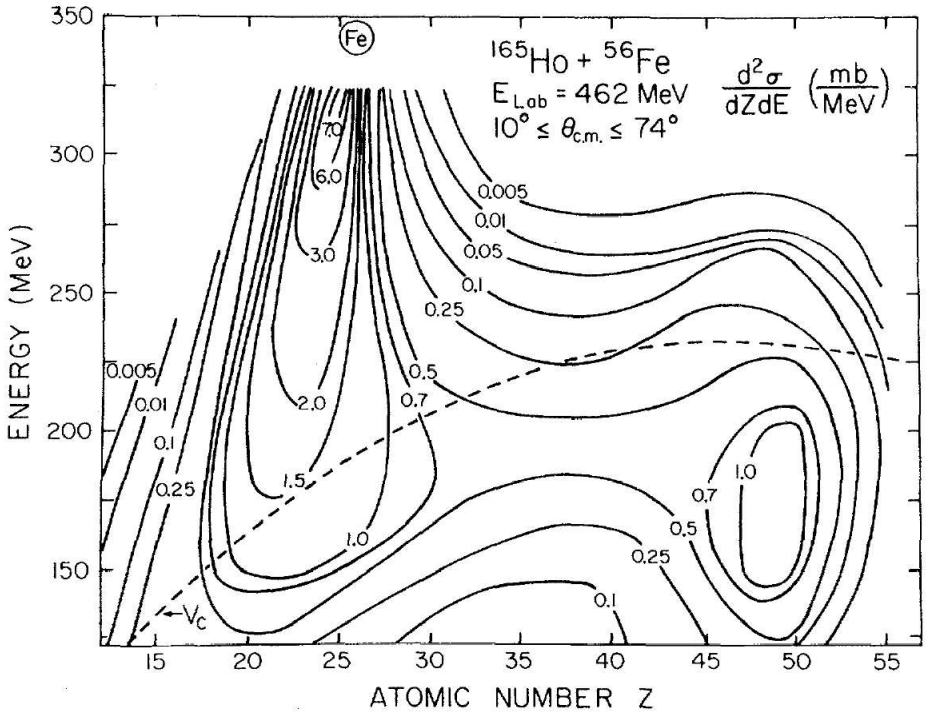


Macroscopic approach



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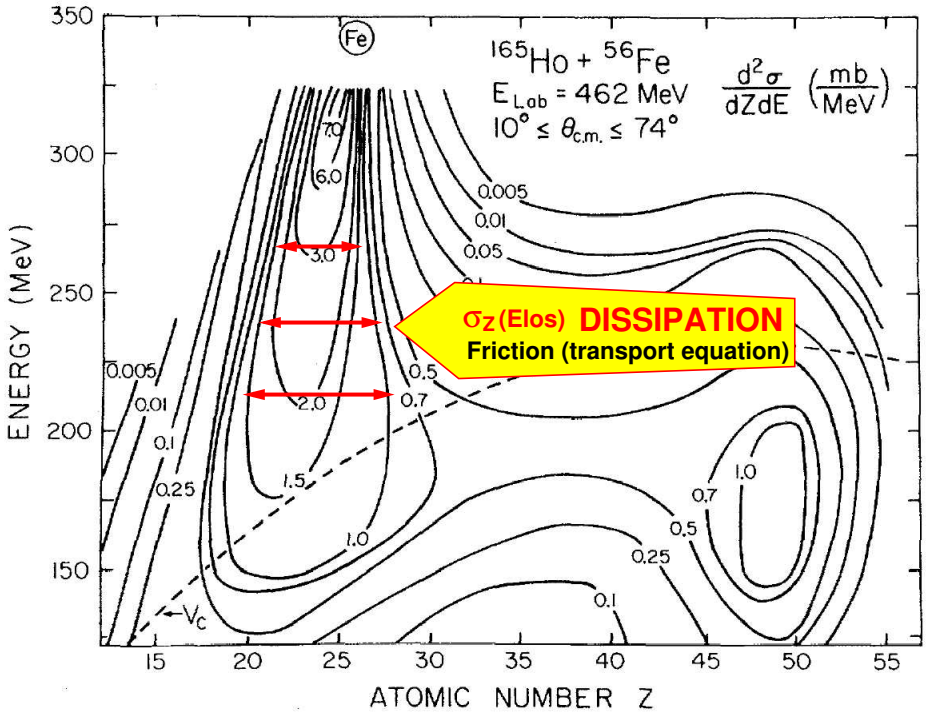

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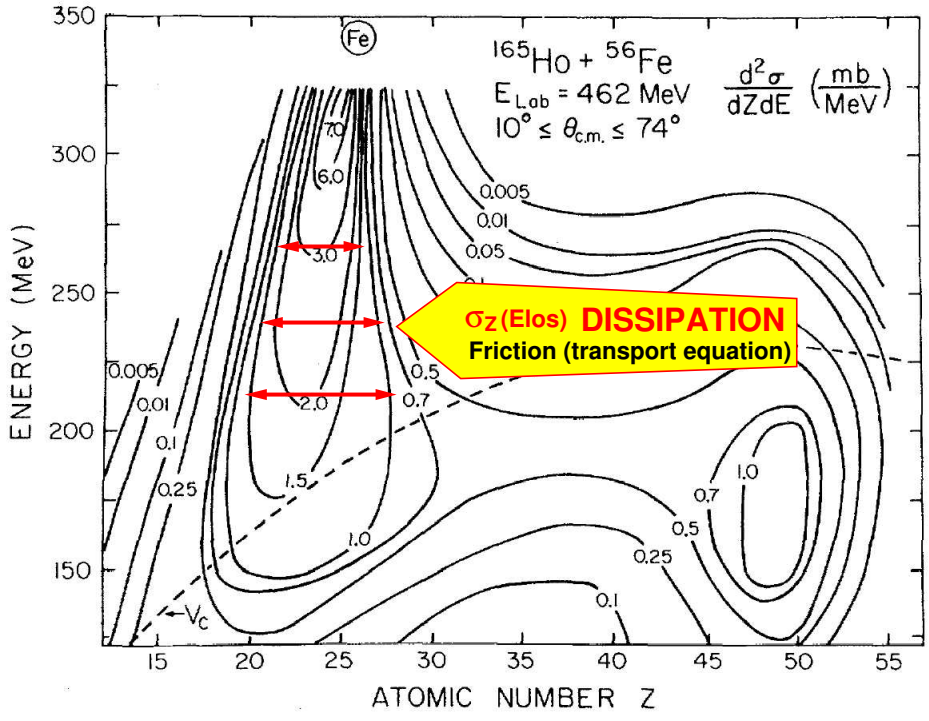

- **Transport equations**
  for the exchange of mass and charge.
- **friction forces**
  for energy and angular momentum dissipation

Microscopic approach (elementary modes)

Nuclear degrees of freedom (*collision time* $\tau = \sqrt{a/\ddot{r}_o}$)

- **INELASTIC** $f_{in}(r) \sim e^{-r/a_{in}}$ $a_{in} = 0.65\ fm$
  (few channels but strong)
  - low lying: mass (D) large — NON adiabatic
    force (C) small — coupled-channels
  - high lying: mass (D) small — adiabatic
    force (C) large

- **TRANSFER** $f_{tr}(r) \sim e^{-\kappa_{a'} r}$ $\frac{1}{\kappa_{a'}} = a^1_{tr} = 1.2\ fm$
  (many channels but weak)

play an important role in: energy dissipation (friction),
Imaginary (iW) and polarization (ΔV) potentials
$< n >= Np$ $E_{loss} = \Delta E < n >$

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About transfer reactions

Transfer reactions are driven by **Optimum Q-value** condition. In the time-dependent picture the ampliture for a transfer is:

$$c_{\beta\alpha} = \frac{1}{i\hbar}\int_{-\infty}^{+\infty} dt < \psi_\beta | H_{int} | \psi_\alpha >_t$$

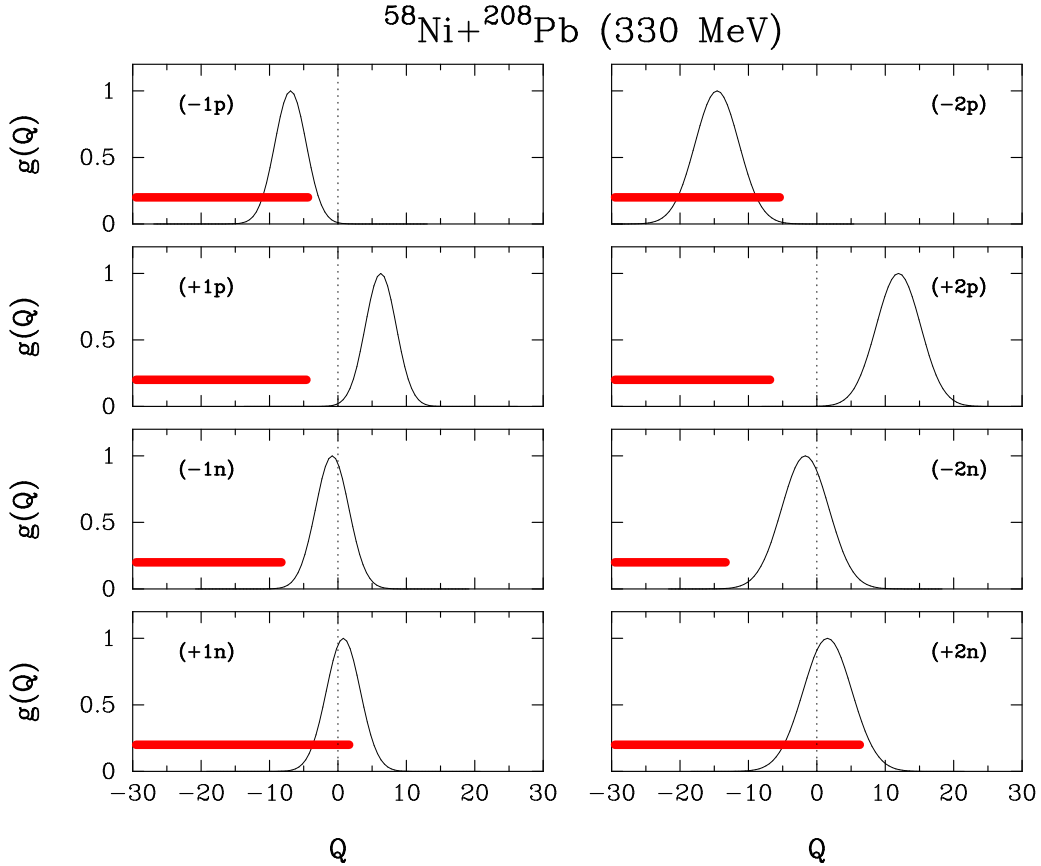
and the probability becomes:

$$P_{\beta\alpha} = (...)|f_{\beta\alpha}(0, r_0)|^2 \exp\left(- \frac{(Q - Q_{opt})^2}{\hbar^2 \ddot{r}_0 \kappa_{a'_1}} \right)$$

- $\psi_\alpha = \psi_a(\xi_a)\psi_A(\xi_A)e^{i\delta_{aA}}$ is the channels wave function
- δ_{aA} the semi-classical phase
- $f_{\beta\alpha}(\vec{R}(t))$ the transfer form-factors
- Q_{opt} the Q-optimun of the reactions

About transfer reactions

The **optimum-Q value** amount to require that the entrance and exit trajectories must match smoothly.



GRAZING (A. Winther)

GRAZING solves in the semiclassical approximation the system of coupled equations derived from the Hamiltonian:

$$\hat{H}_0 = \sum_i^{(a)} \epsilon_i a_i^\dagger a_i + \sum_{\lambda\mu}^{(a)} \hbar\omega_\lambda a_{\lambda\mu}^\dagger a_{\lambda\mu} + (A)$$

$$\hat{V}_{int}(t) = \hat{V}_{tr}(t) + \hat{V}_{in}(t) + \Delta U_{aA}(t)$$

V_{int} contains the well known **form-factors** for **inelastic excitation** and for **one-particle transfer** (both protons and neutrons).

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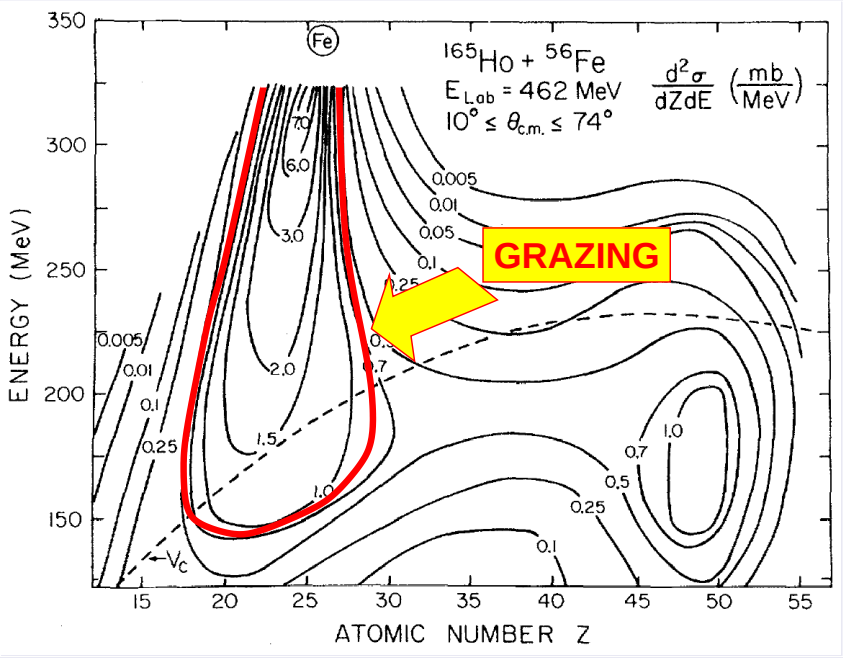
The **time dependence** of the matrix elements is obtained by solving the Newtonian equations for the relative motion in the nuclear plus Coulomb field. For the nuclear potential we use the **Akyüz-Winther parametrization** that describes quite well elastic scattering data for several projectile and target combinations.

What can be calculated (by GRAZING)

GRAZING calculates how the reaction cross section is shared among the different final mass partitions up to the ORBITING:



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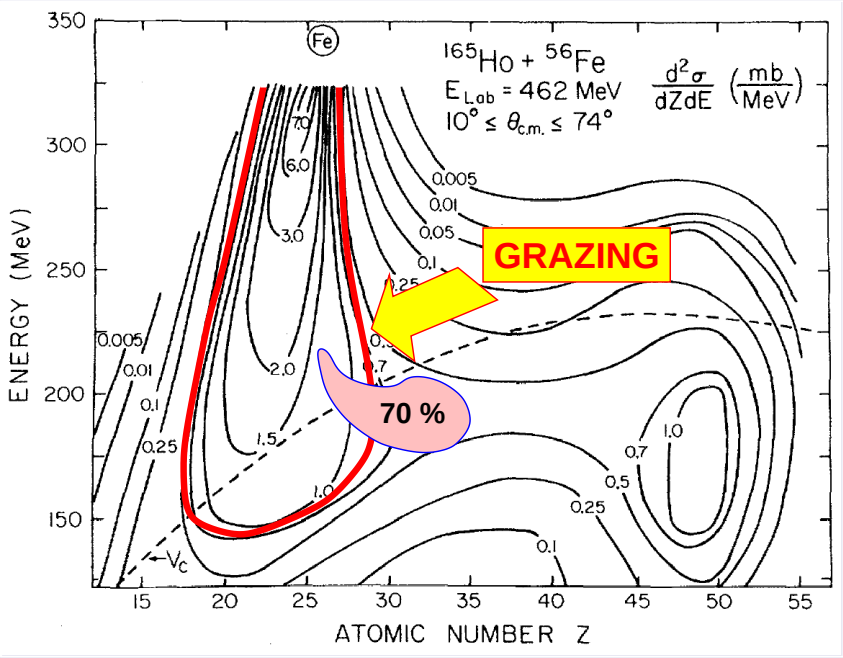

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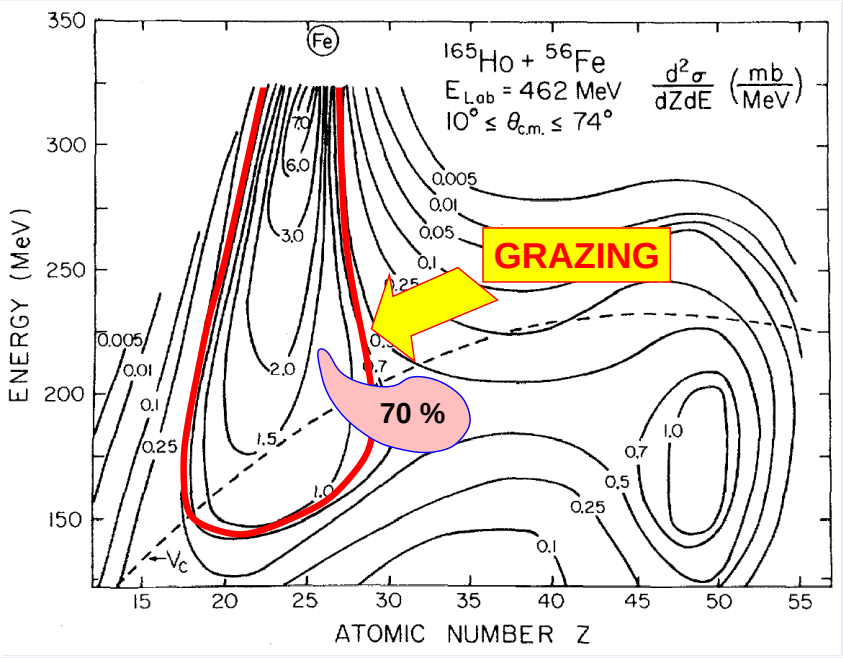

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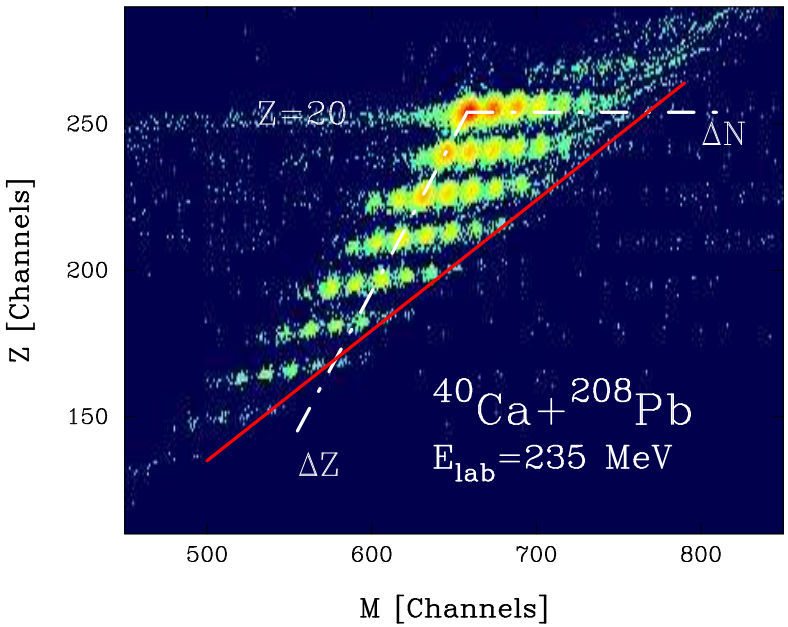
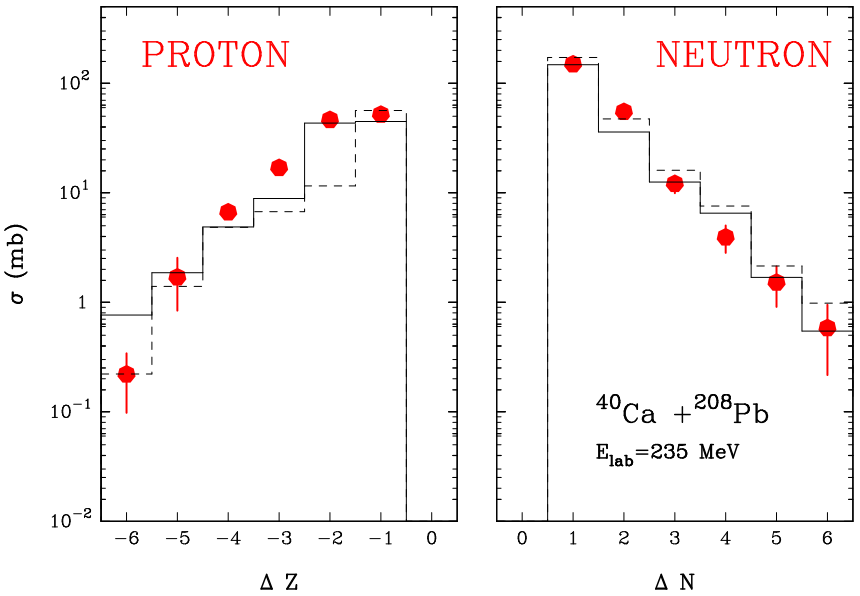
Some Phenomenology of MNT





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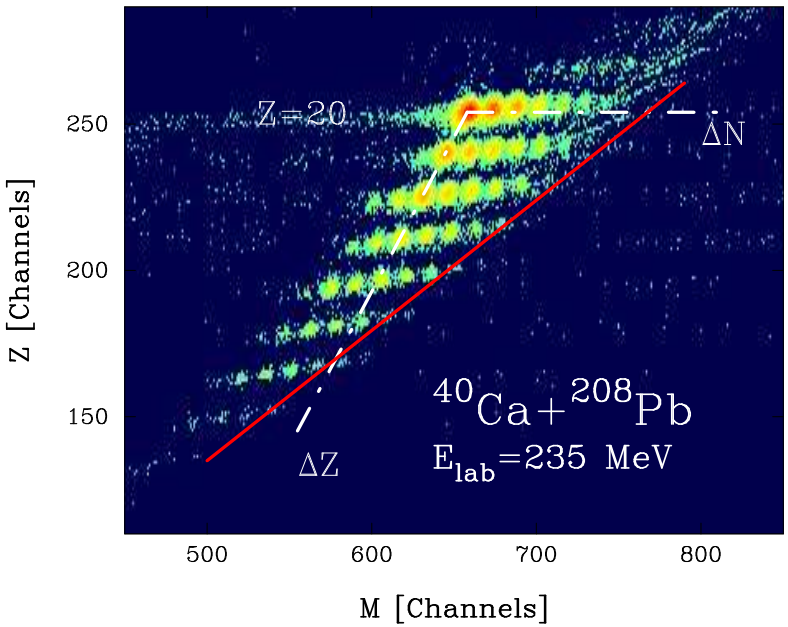
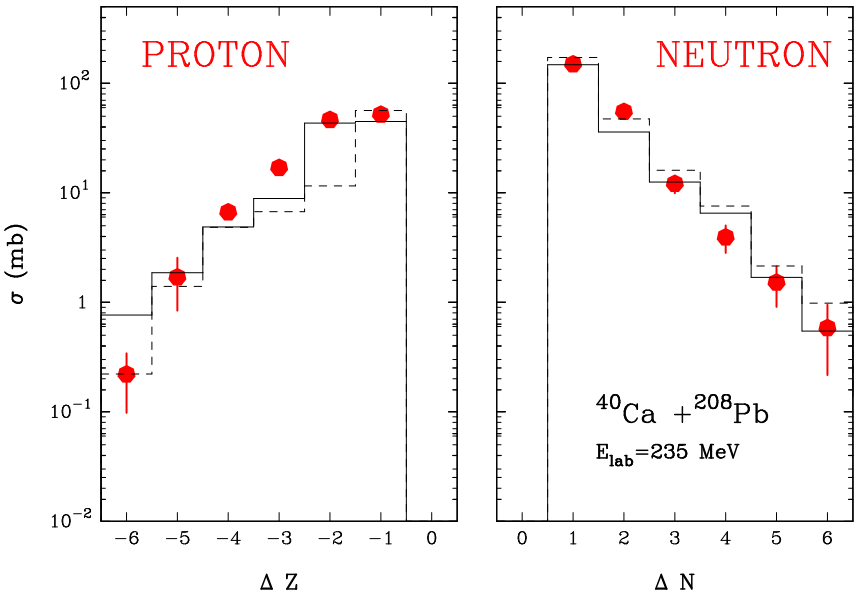
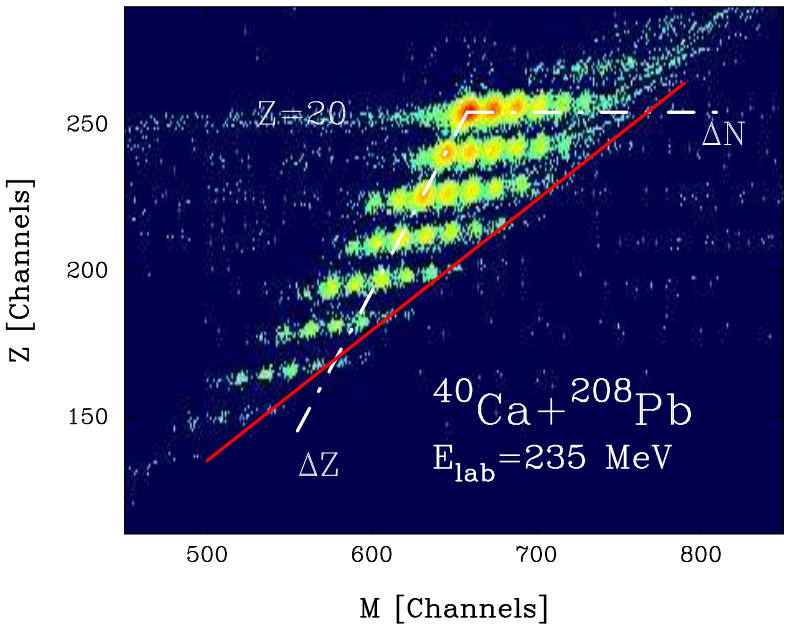
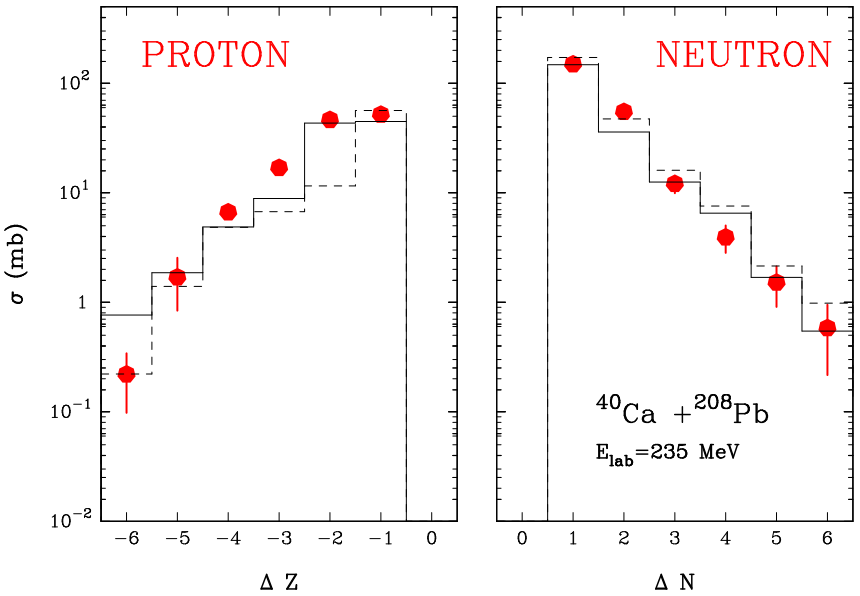




- The system does not reach charge equilibration. The population in the (N,Z) plane is dictated by the Q_{opt}
- For each transferred neutron the cross section drops by a constant factor (∼3.5) **(sequential transfer)**

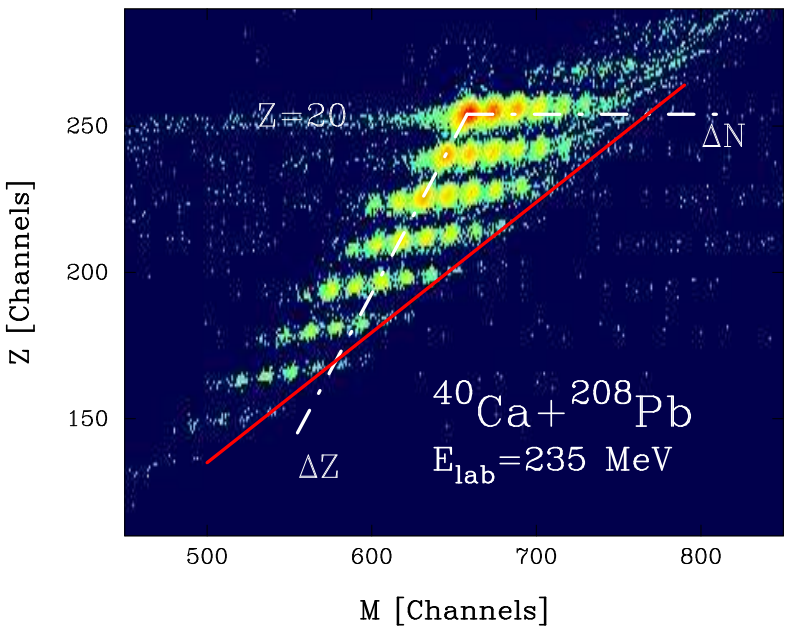
Some Phenomenology of MNT

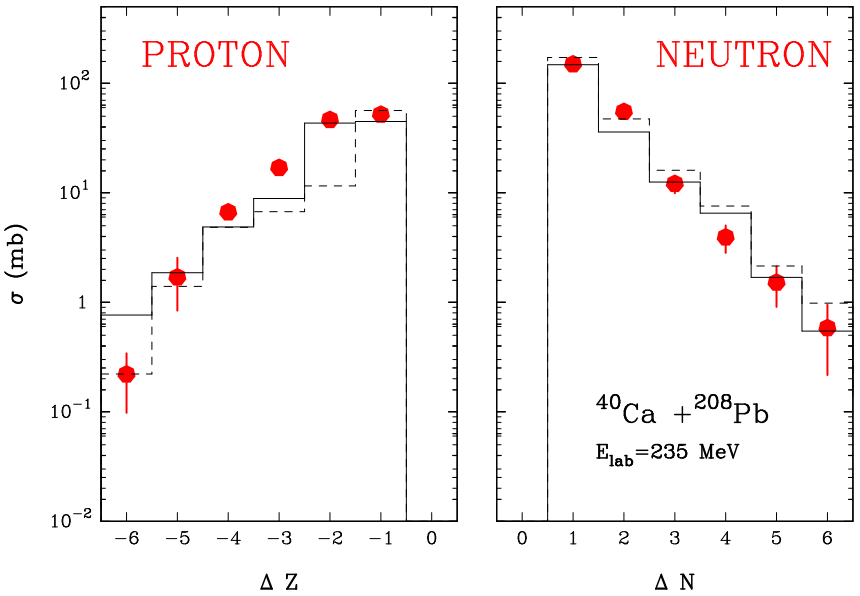




- The ONE-neutron transfer channel is much larger than the ONE-proton transfer channel
- The pure TWO-proton transfer is as large as the ONE-proton transfer **(pair-transfer mode ?)**

Some Phenomenology of MNT





- EVAPORATION may strongly influence the isotopic distribution of the final fragments, these are indeed produced quite HOT (at high excitation energies)

The ^{58}Ni+^{208}Pb reactions

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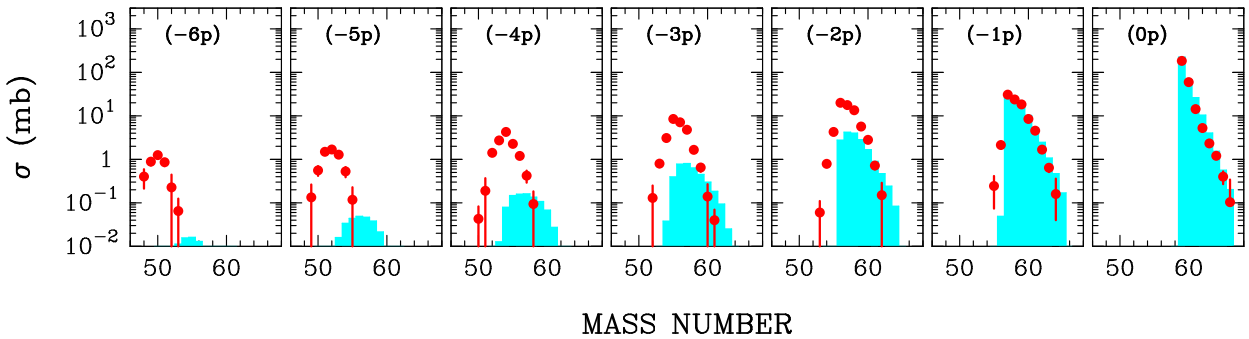

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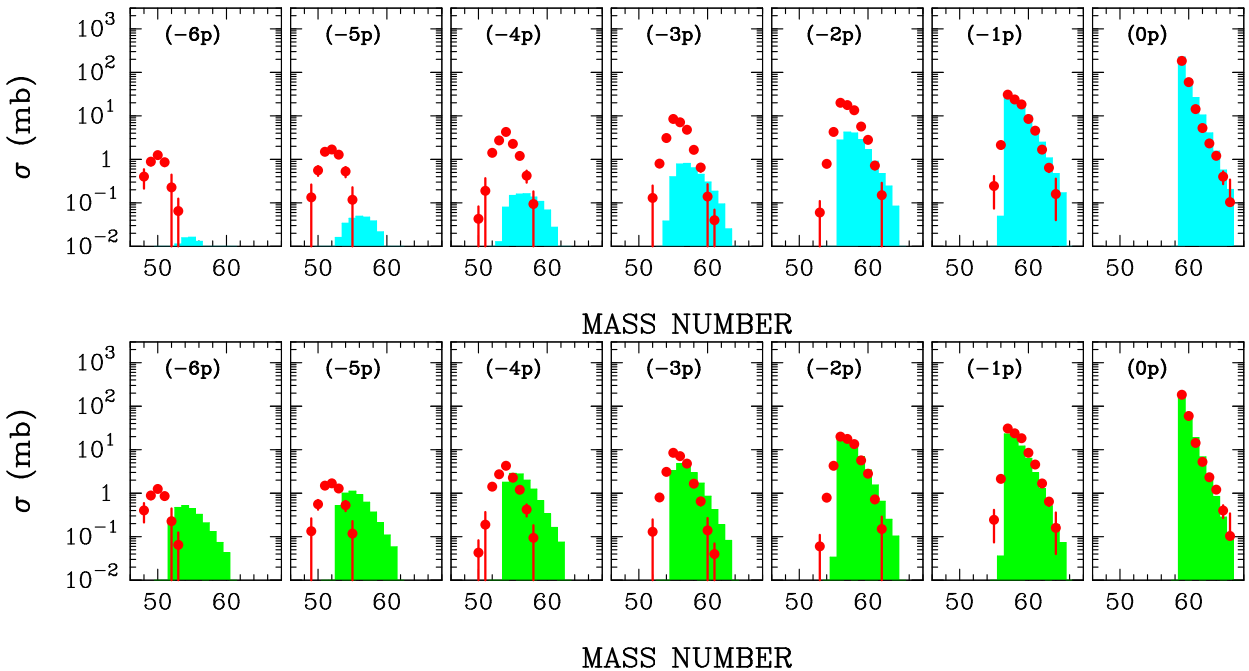

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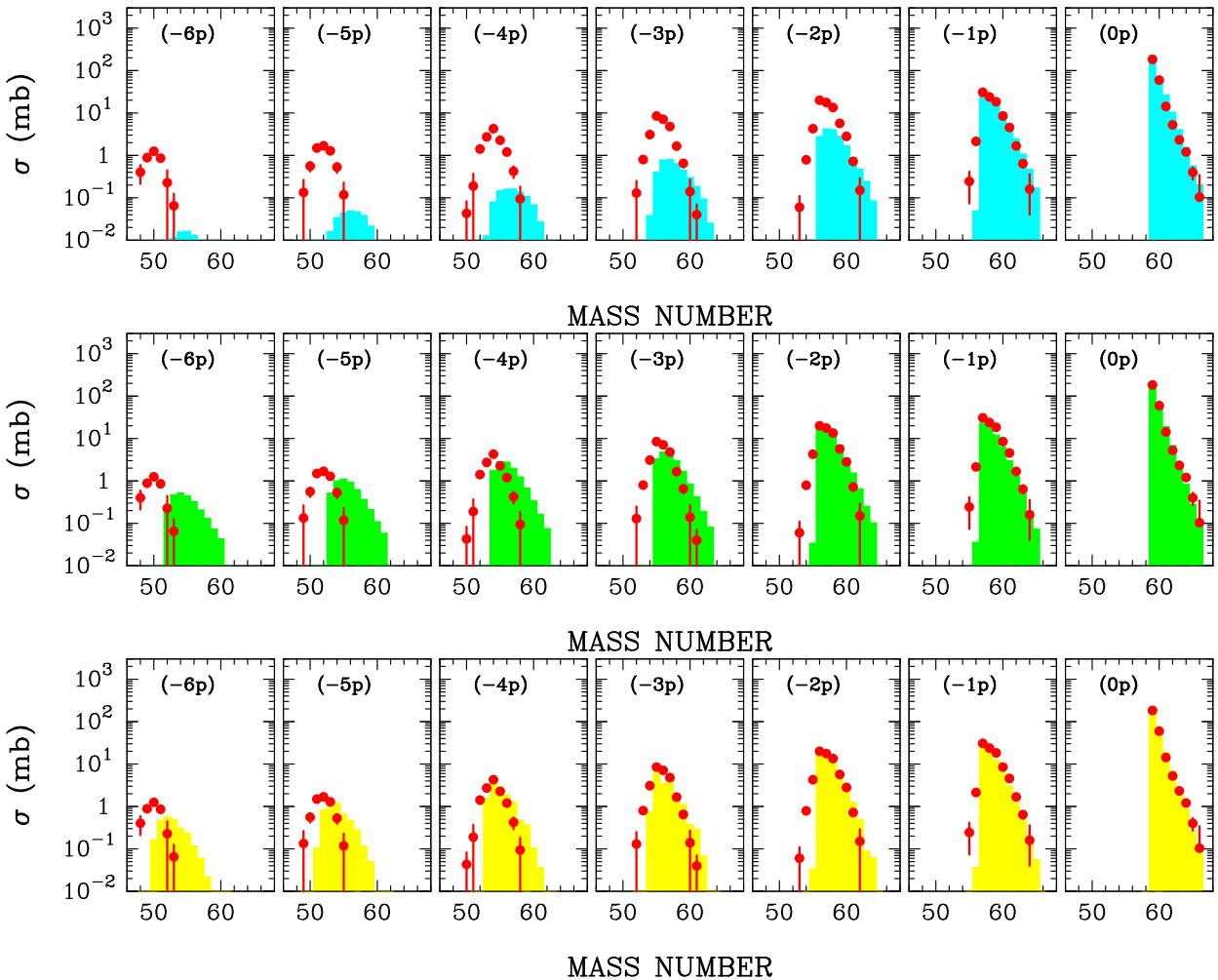

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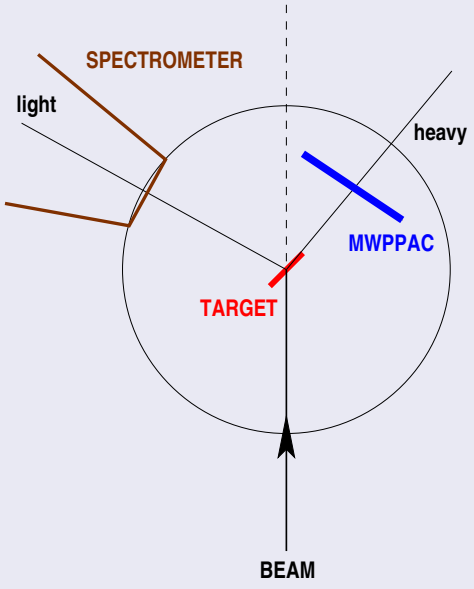
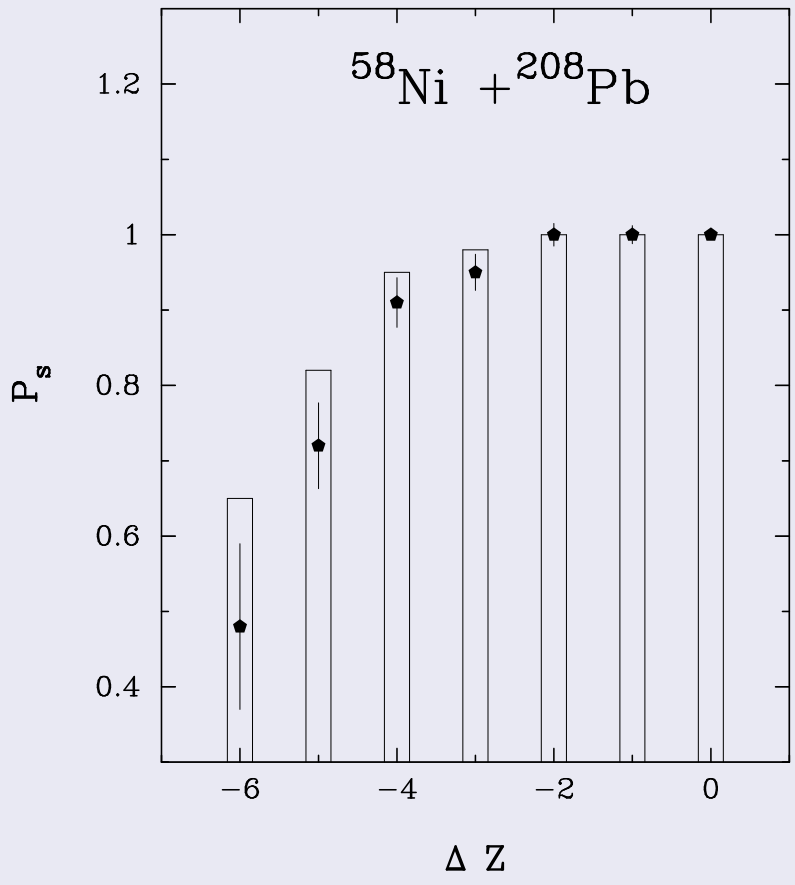
+Evap.

The ^{58}Ni+^{208}Pb reactions

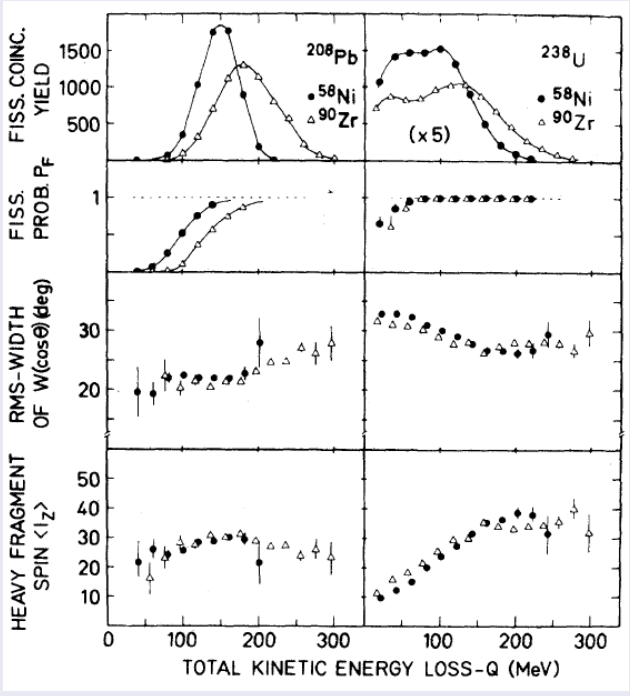
For the population of the heavy fragments is important to consider FISSION.





Fission and Angular momentum loss in DIC

FISSION has been used to study angular momentum loss in DIC.



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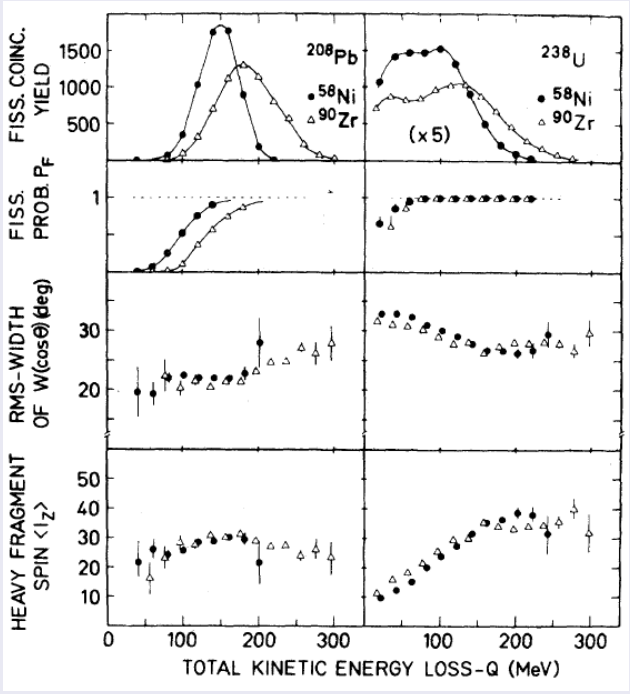
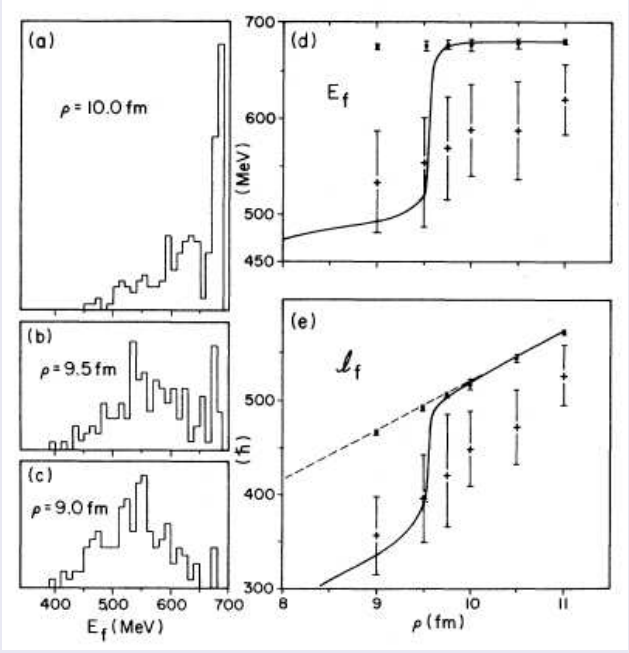


The precursor (1978) of GRAZING. Importance of surface modes. (ZPM and large fluctuations)



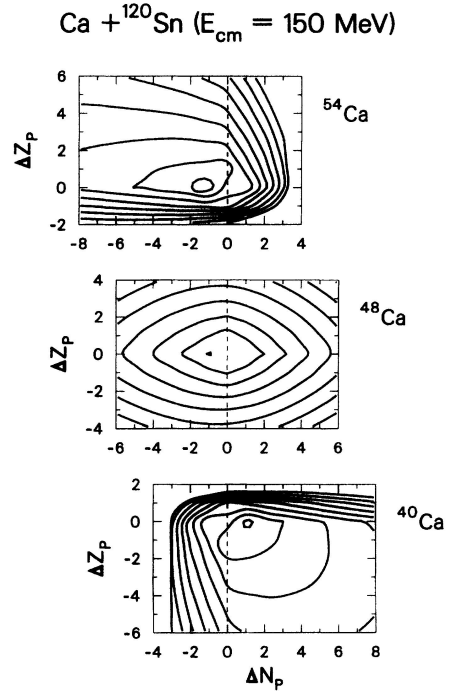
Neutron Rich

What we have seen up to now concern stable nuclei. To populate **N-rich nuclei** besides:

- proton stripping (-1p)
- neutron pick-up (+1n)

we have to **OPEN** also the channels:

- proton pick-up (+1p)
- neutron stripping (-1n)



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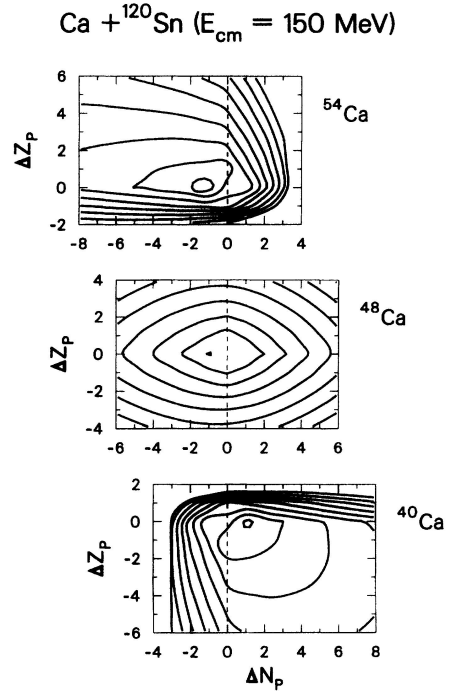


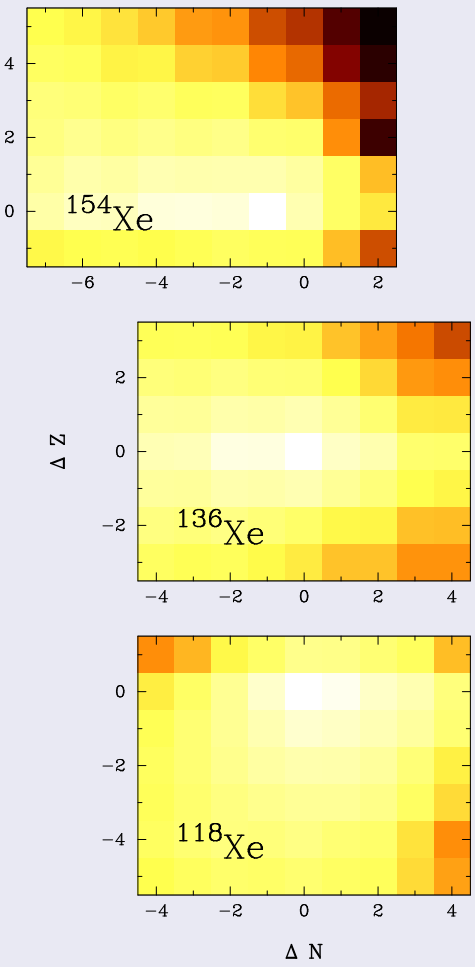
N-rich projectiles

The Xe + ^{208}Pb reaction at $E_{c.m.}$=700 MeV

The population of projectile-like fragments (corrected by evaporation of the light)

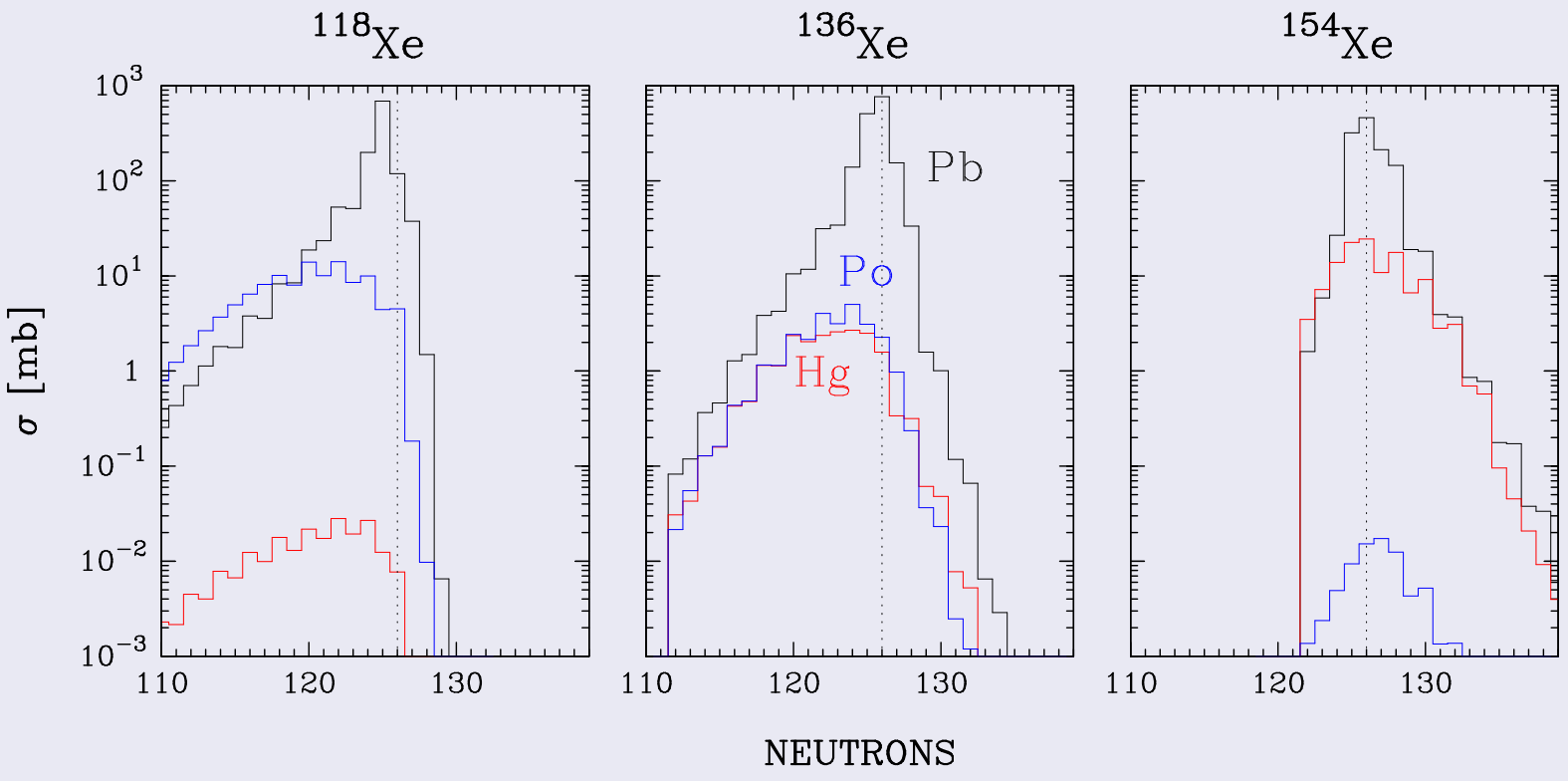
For stable nuclei the $Q_{opt}(N, Z)$ is such that only:
- proton stripping (-1p)
- neutron pick-up (+1n)

are possible.

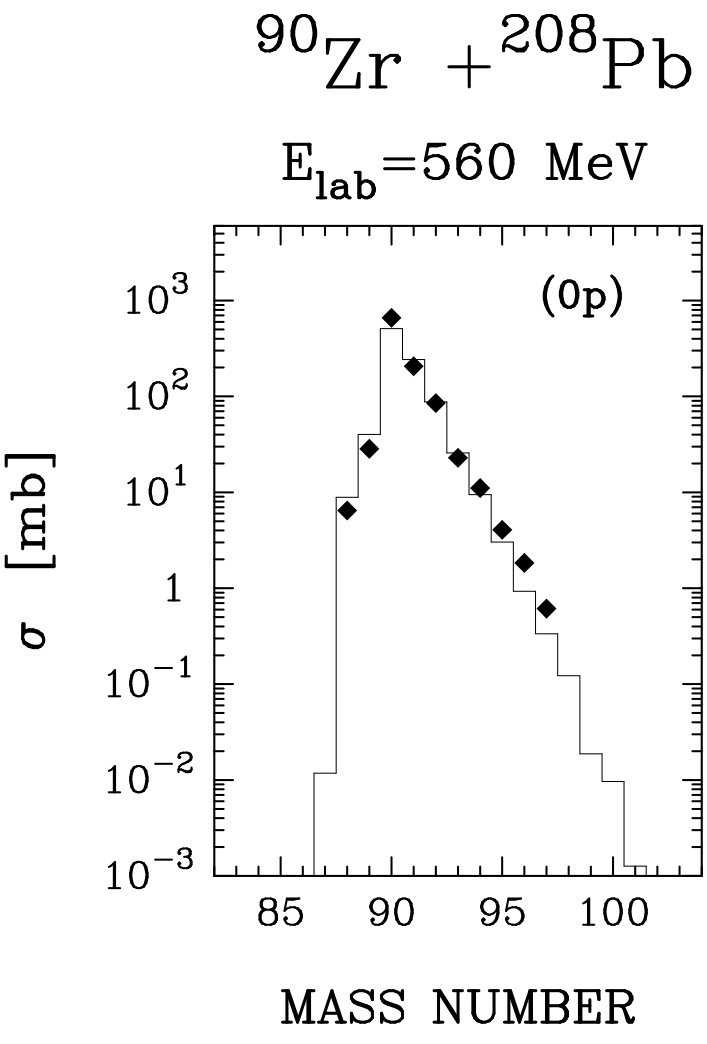


The Xe + ^{208}Pb reaction at $E_{c.m.}$=700 MeV

The population of the target-like fragments:



The ^{90}Zr+^{208}Pb system



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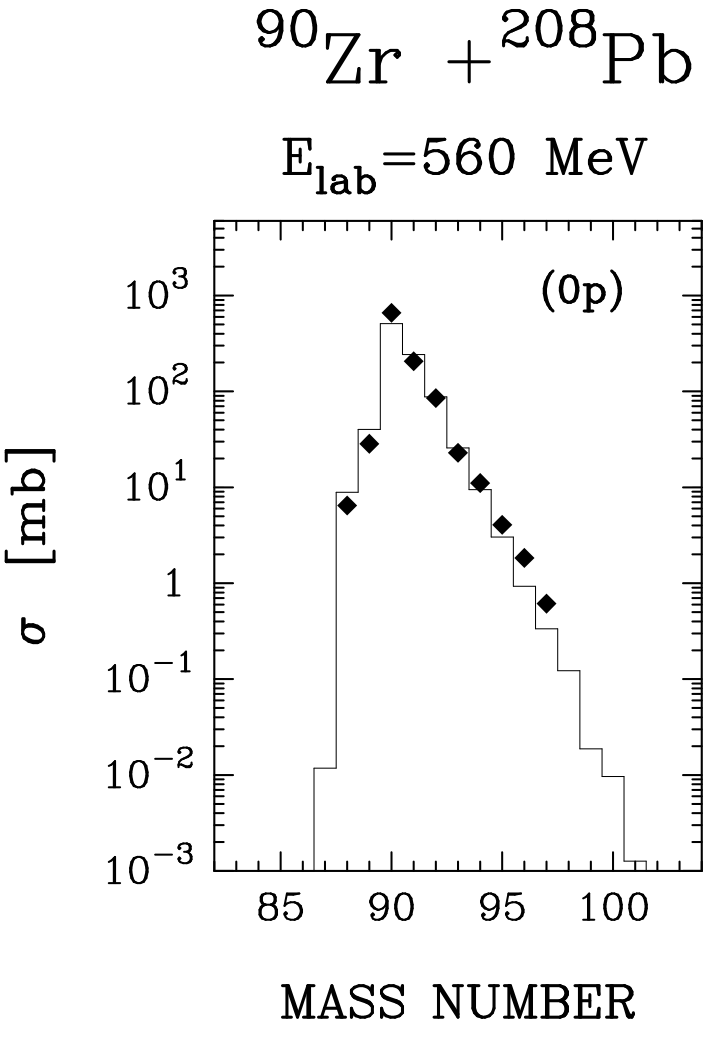

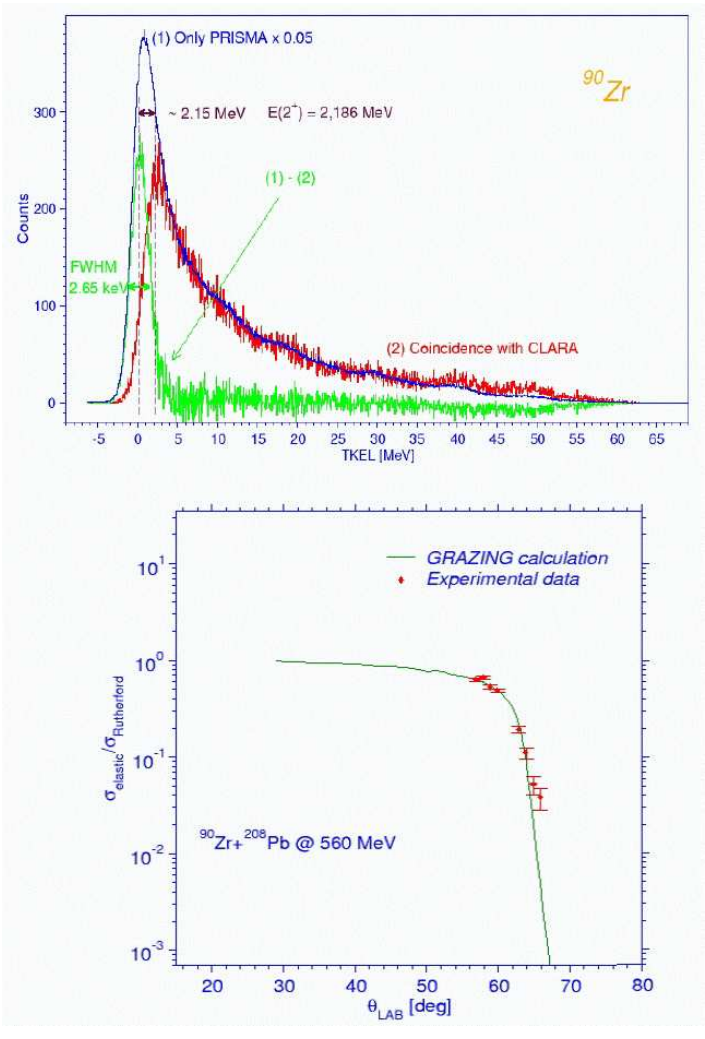

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The ^{40}Ca $+^{208}$Pb: Isotopic distribution

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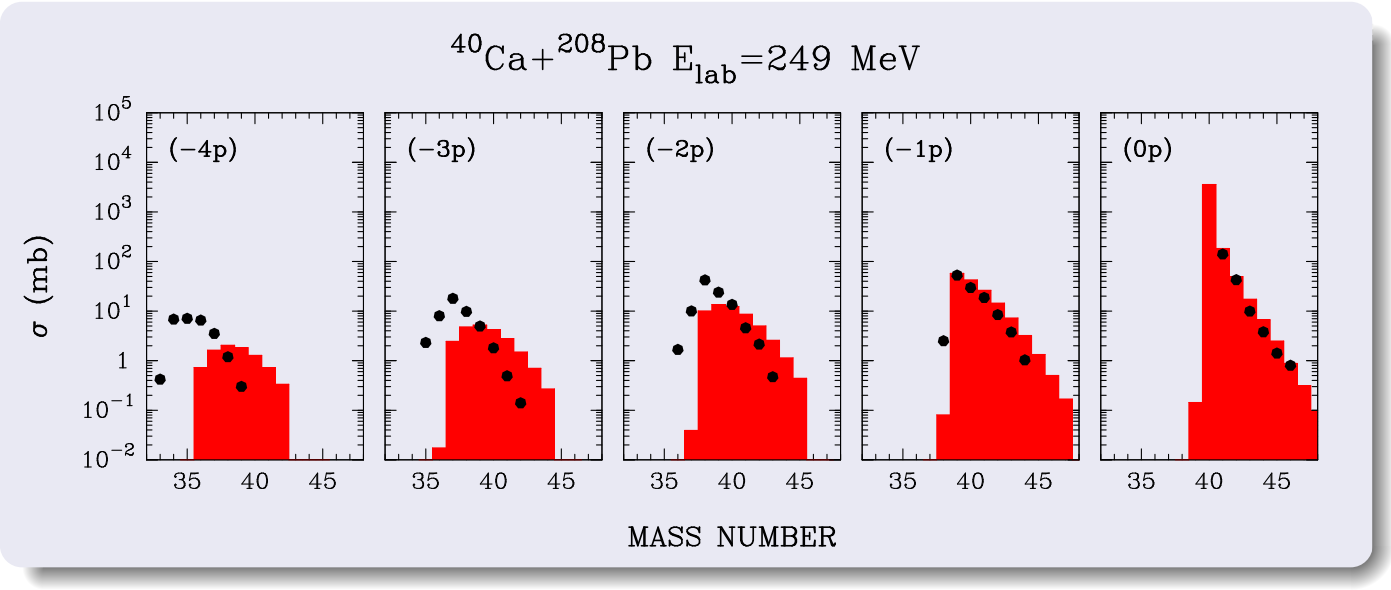

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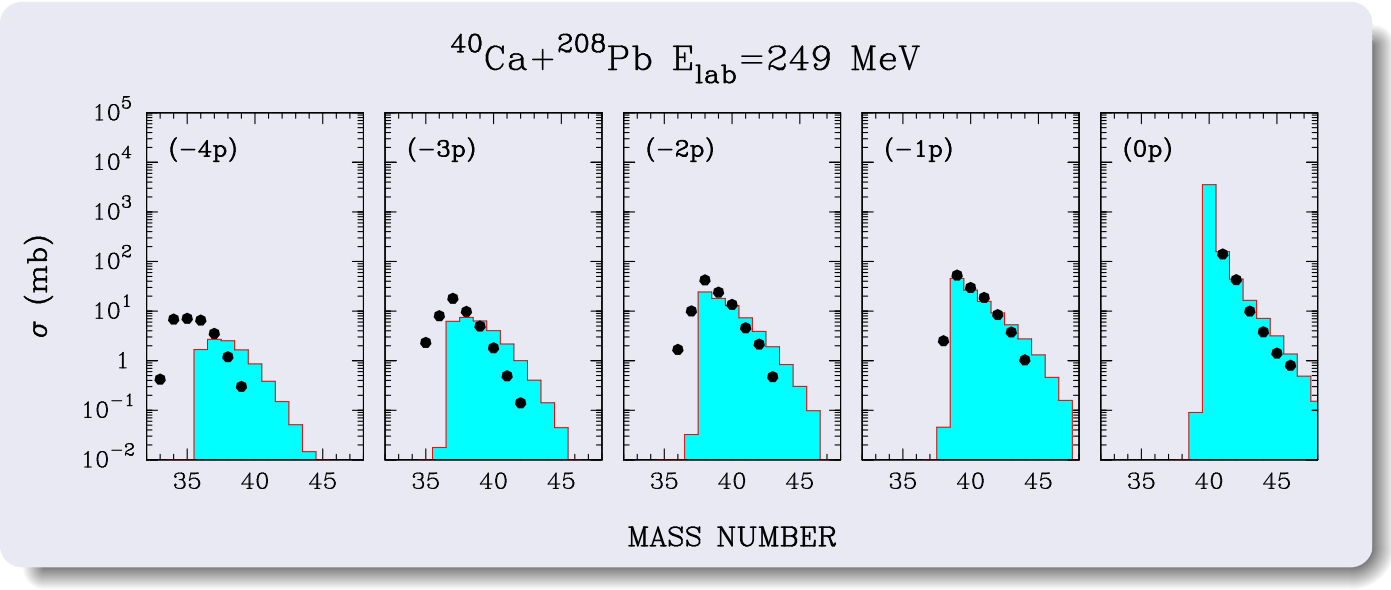

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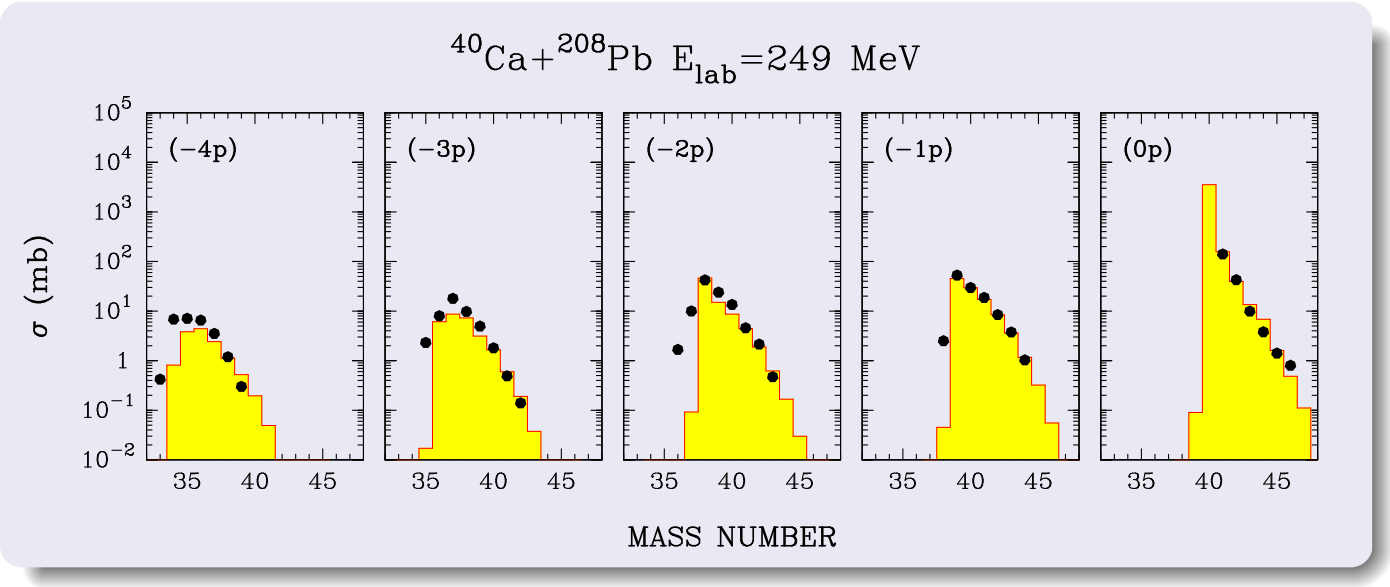

+Evap.

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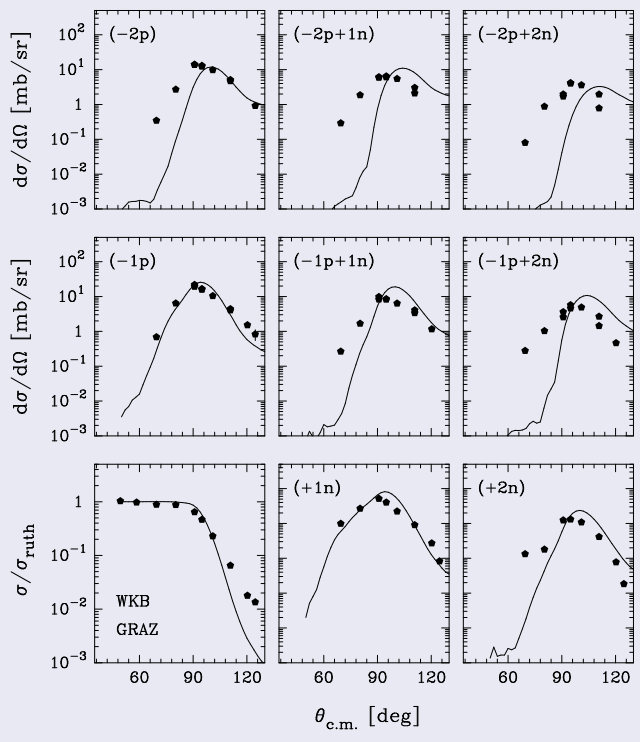

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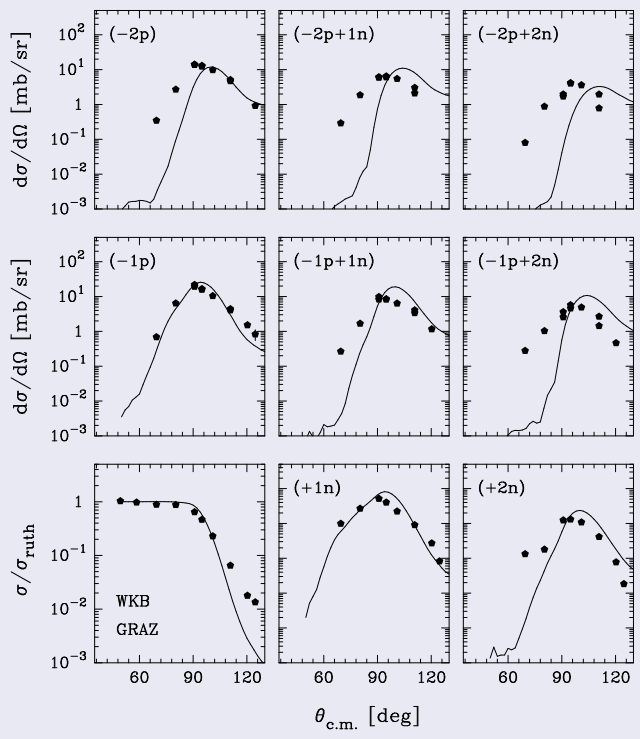

Nuclear Potential

From Grazing we extract the imaginary potential $iW_{tr}(r)$ to calculate with a quantal coupled-channels calculation elastic and inelastic scattering.