NEW RESULTS ON DISSIPATION IN NUCLEAR FISSION

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INTRODUCTION

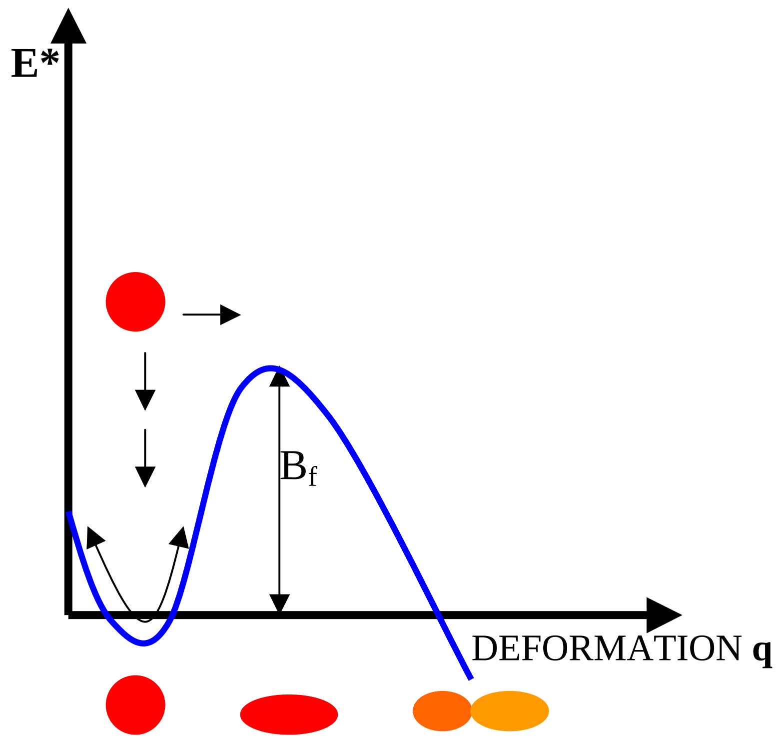
- ❑ The influence of dissipation on fission in a simple scenario
  - ⇒ Diffusion model of Grangé and Weidenmüller

- ❑ Difficulties for the study of dissipation
  - ⇒ Most experiments present side effects that make difficult the extraction of relevant information

- ❑ Our approach for studying dissipation
  - ⇒ Fission induced by peripheral heavy ion collisions at relativistic energies

An appropriate scenario to investigate dissipation in fission

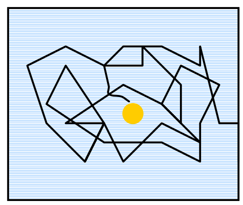
Fission is a diffusion process of the fission degree of freedom "q" over the fission barrier.



- **Time is needed to build up fission**
- **This time is determined by the dissipation**
- **We want to investigate this delay**

MODEL FOR DESCRIBING FISSION AS A DIFUSSION PROCESS (Kramers 1940 Grangé & Weidenmüller 1980)

The process is considered as the evolution of the fission collective degree of freedom "q" in the heat bath formed by the individual states of the nucleons.
This is described by the Fokker-Planck equation (FPE)



Important parameter of FPE, dissipation coefficient

$$\beta = \frac{1}{E^0_{colec}} \left(\frac{\partial E}{\partial t} \right)$$

Dissipation coefficient β quantifies how fast the energy is transferred between "q" and the heat bath

How to calculate $\Gamma_f(t)$?

$$\beta \xrightarrow{\textbf{FPE}} \mathbf{W(q,t)} \xrightarrow{\int} \mathbf{\Gamma_f(t)}$$

Grangé-Weidenmüller calculated $\Gamma_f(t)$ under very specific <u>initial conditions</u>:

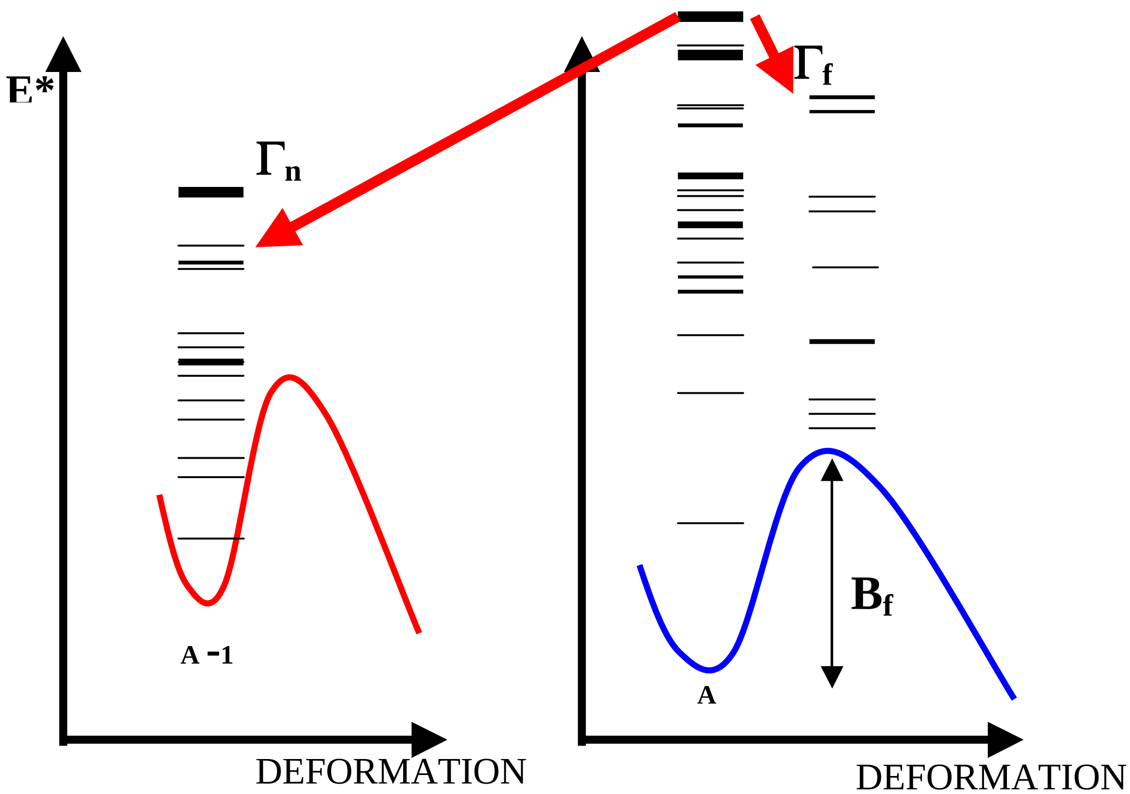
- no energy in fission degree of freedom q
- spherical shape

Time-dependent fission width $\Gamma_f(t)$:

$$\Gamma_f(t) = \Gamma^{BW} \cdot \underbrace{\left(\sqrt{1+\left(\frac{\beta}{2\omega_0}\right)^2} - \frac{\beta}{2\omega_0}\right)}_{K} \cdot f_\beta(t)$$

Γ^{BW}?

TRANSITION STATE MODEL (BOHR-WHEELER 1939)



level density parameter A

$$a = \alpha_v A + \alpha_s B_s A^{2/3} \rightarrow \frac{a_f}{a_n} > 1!$$

Ignatyuk et al. Nucl. Phys. 21 (1975) 612

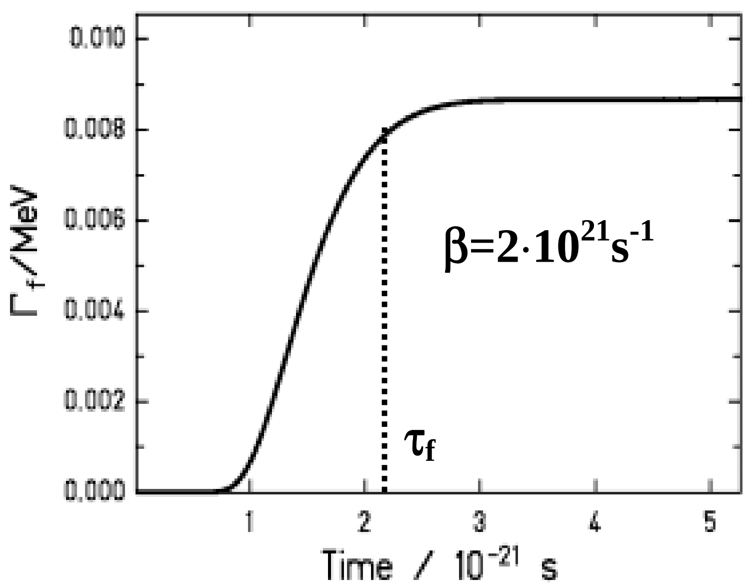
FISSION BARRIER B_f

ROTATING FINITE-RANGE LIQUID-DROP MODEL

A.J. Sierk, Phys. Rev. C 33 (1986) 2039

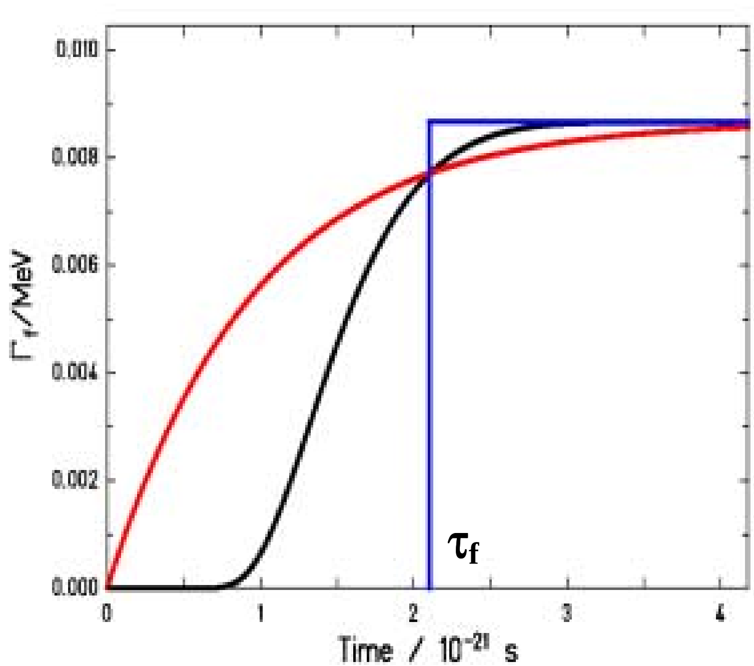
$K\cdot f_\beta(t)$??

Solution Fokker Planck eq. for parabolic potential



The fission width Γ_f is 0 at the beginning of the process!!!

Two approximations for $\Gamma_f(t)$



$\Gamma_f(t)$ =Solution of FPE

$\Gamma_f(t) = \Gamma^{BW}\cdot K(1-\exp(-t/\tau))$

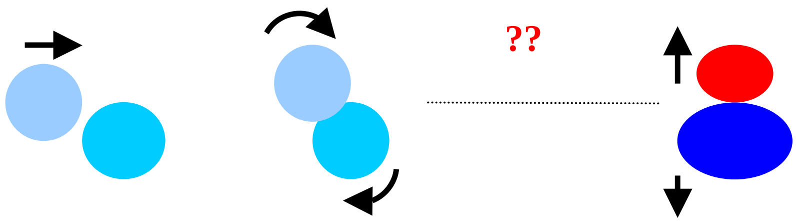
$\Gamma_f(t)$ = Step Function

The 1-exp(-t/τ) description presents a too steep slope at the beginning of the process!!

Experimental approaches for the investigation of dissipation

…done up to now…

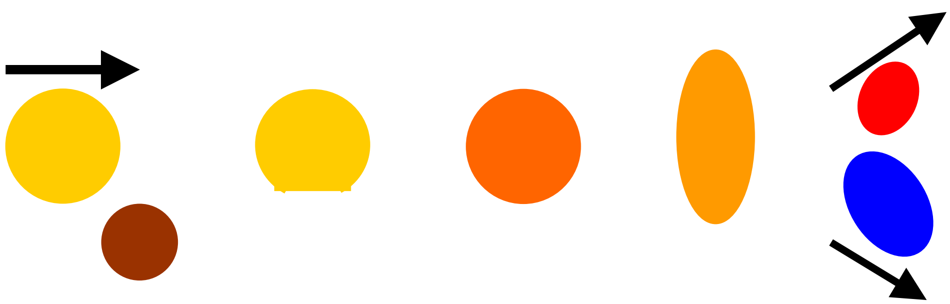
Fusion-fission, fast-fission



- **Large deformation and large angular momentum**
- **Grangé-Weidenmüller model cannot be applied**
- **Very complicated models needed to describe process,**
  e.g. HICOL (H. Feldmeier, Rep. Prog. Phys. 50 (1987) 915)

…our approach…

Peripheral heavy ion collisions at relativistic energies:

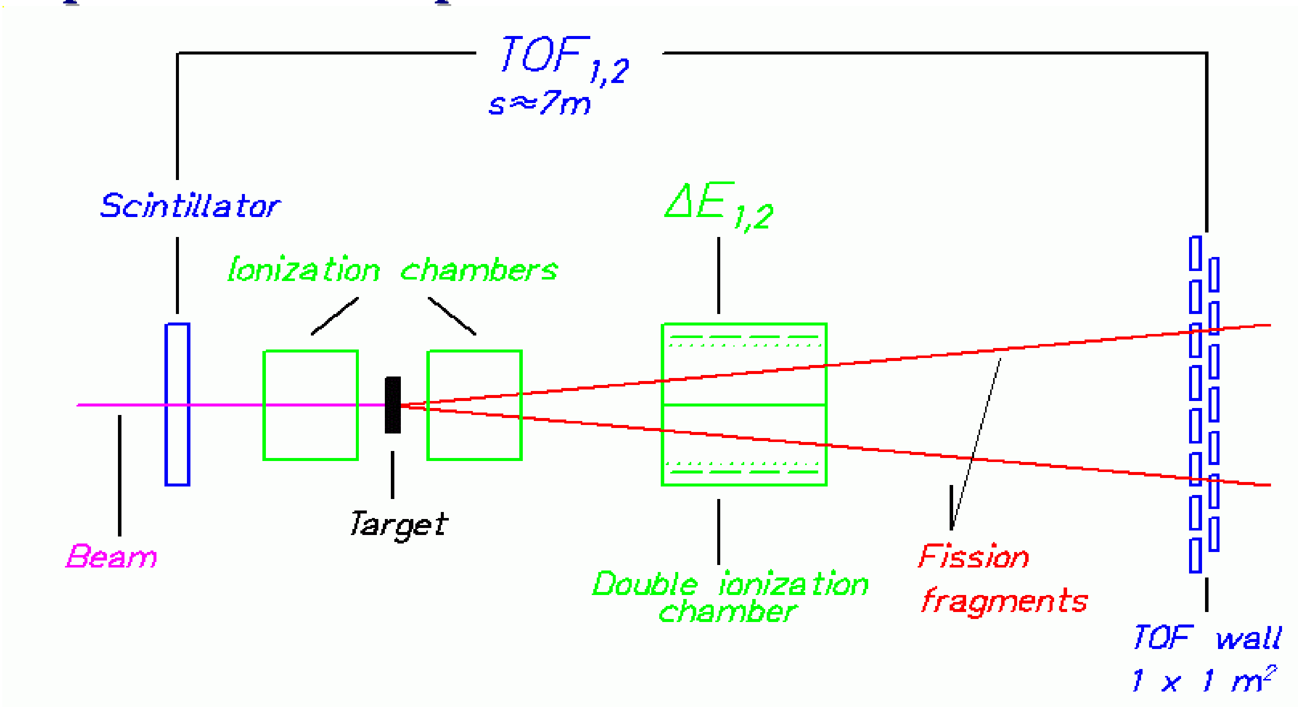


- **Grangé-Weidenmüller model can be applied:**

  -small shape distortion
  -high intrinsic excitation energies
  -low angular momentum

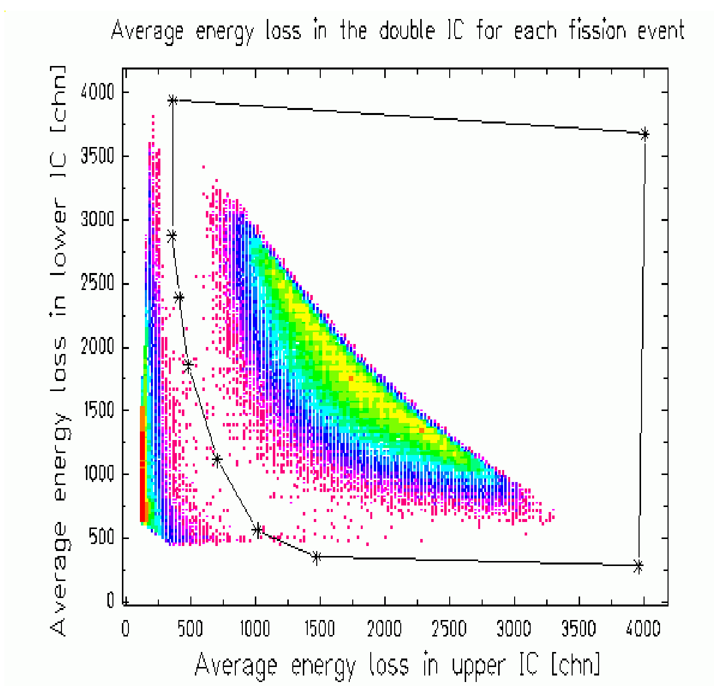
- **Inverse kinematics**

Experimental set-up for fission studies

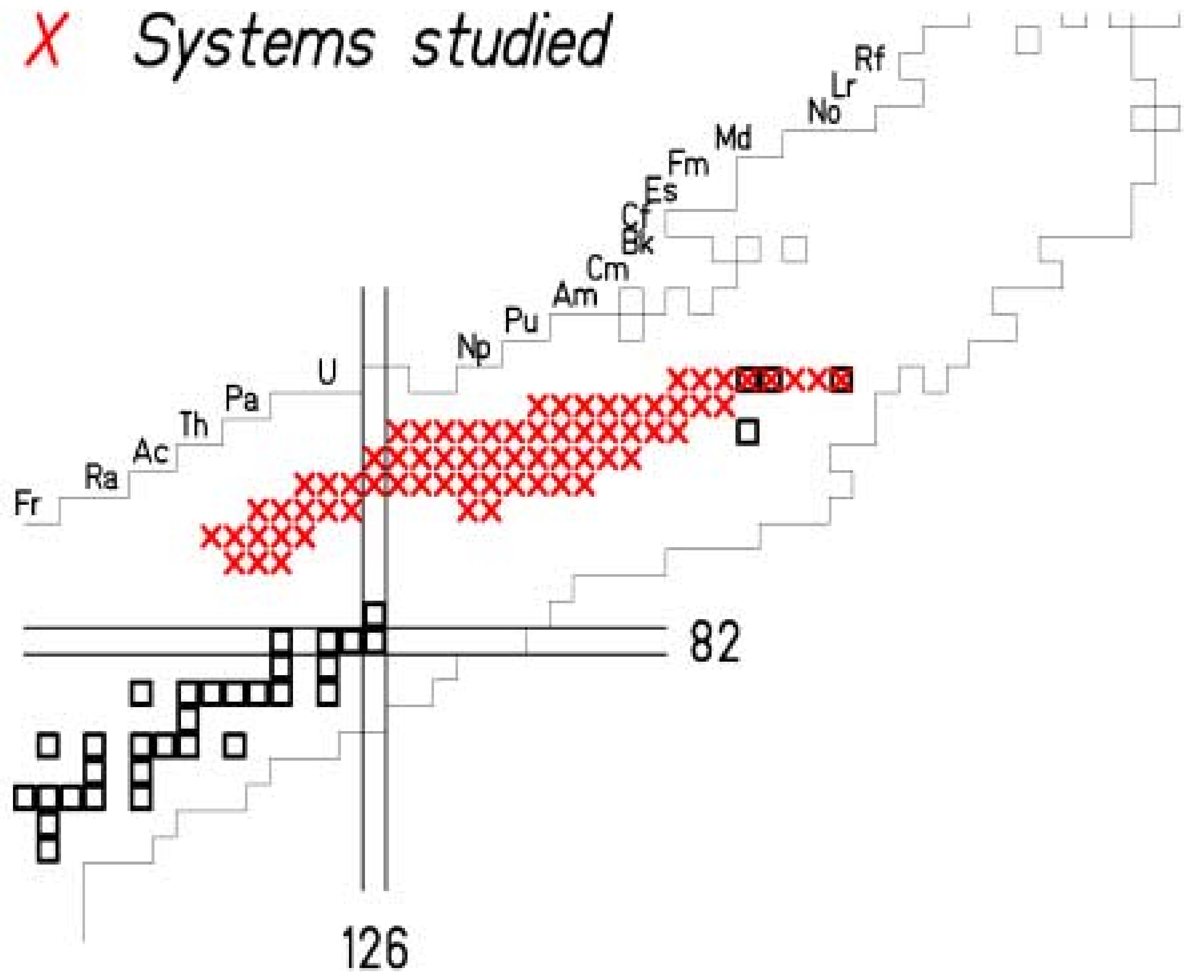


Identification of fission events:

^{238}U(1000 A MeV) + CH_2

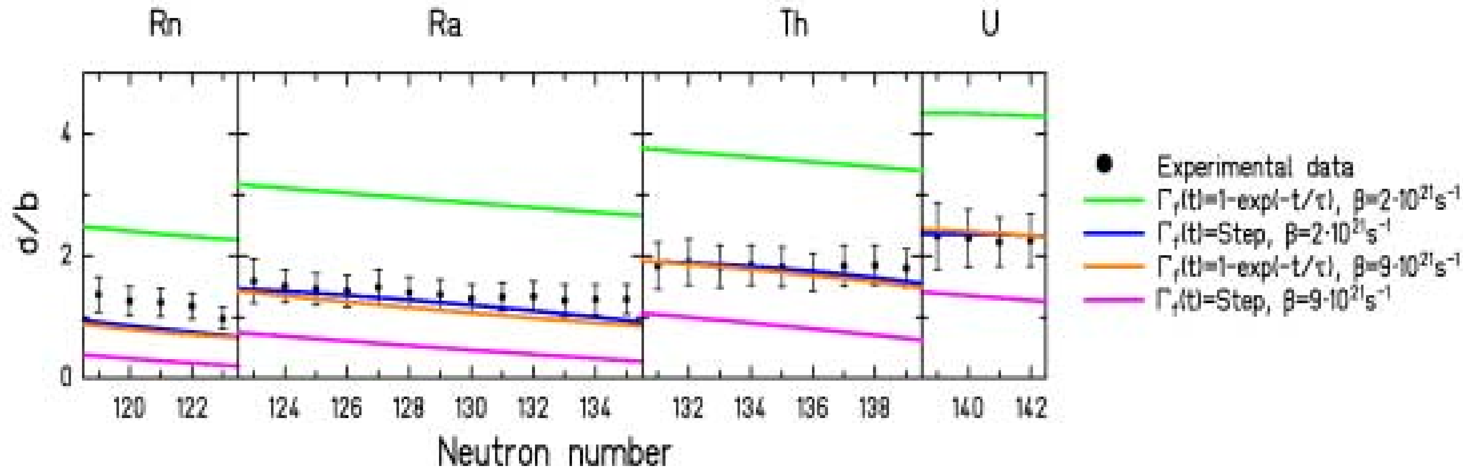


PROJECTILES



INFLUENCE OF $\Gamma_F(T)$

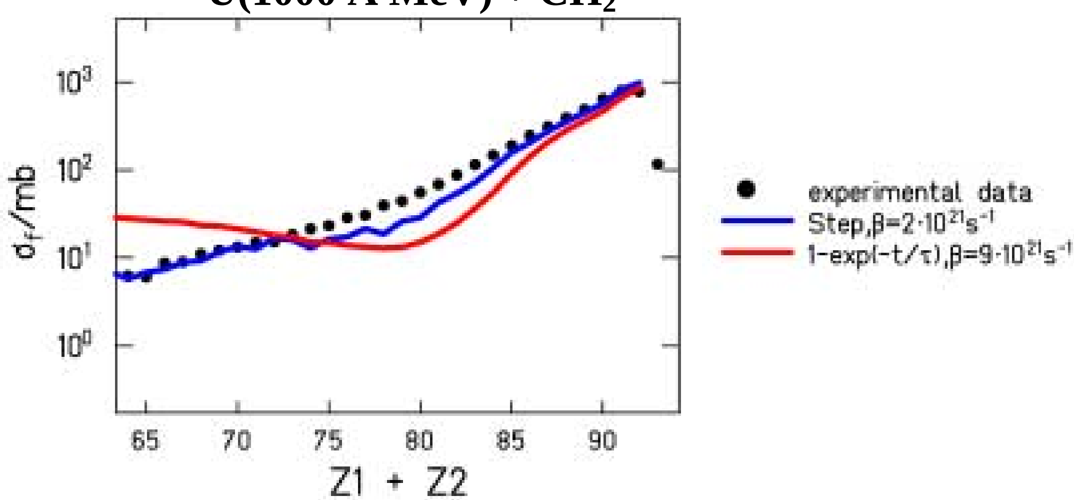
Total nuclear fission cross sections in Pb



Data are very sensitive to $\Gamma_f(t)$
σ_f^{tot} are reproduced by
$\Gamma_f(t)$ =Step function, $\beta = 2 \cdot 10^{21} s^{-1}$
$\Gamma_f(t) \propto$ 1- exp(-t/τ), $\beta=9 \cdot 10^{21} s^{-1}$

Partial fission cross sections

^{238}U(1000 A MeV) + CH_2

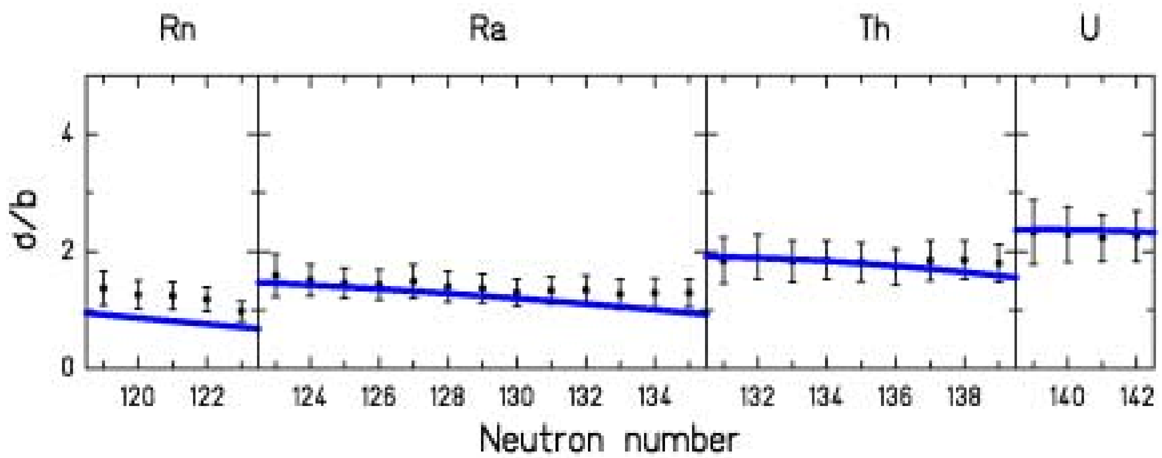


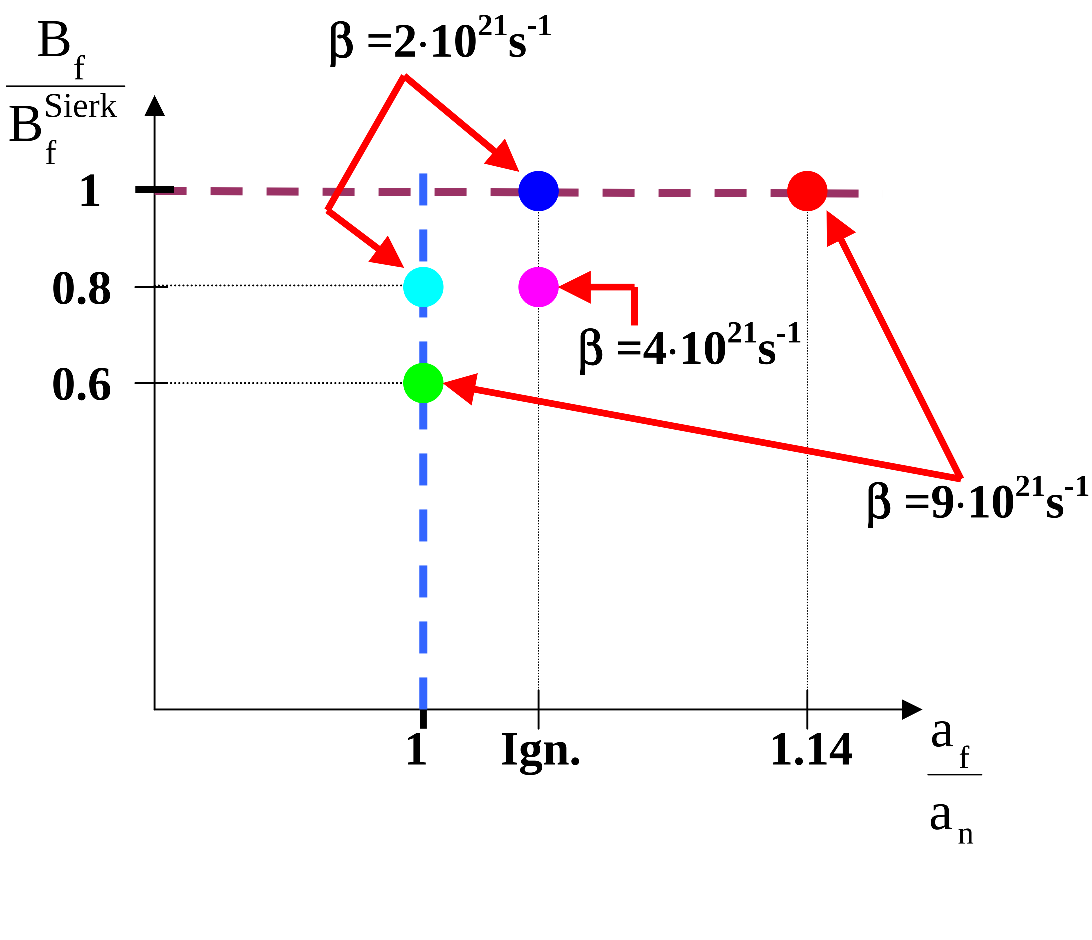
σ_f (Z1+Z2) are not reproduced by $\Gamma_f(t) \propto$ 1- exp(-t/τ), $\beta=9 \cdot 10^{21} s^{-1}$!!!

Attempt to determine the relevant parameters

$\frac{a_f}{a_n}$, B_f, β

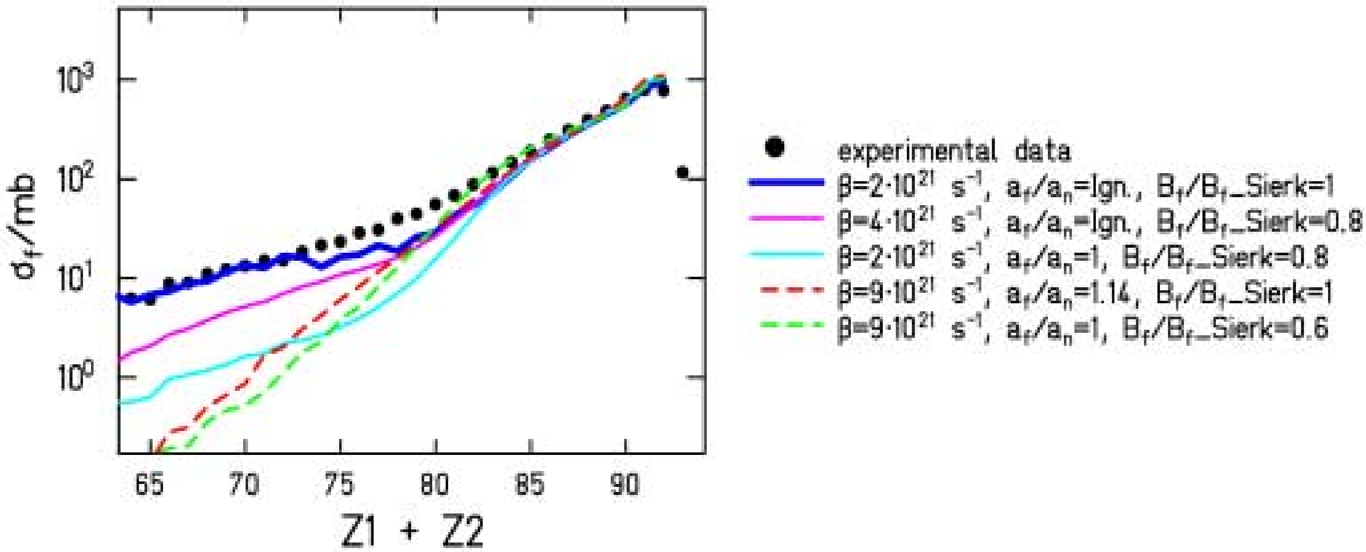
For a combination $\frac{a_f}{a_n}, \frac{B_f}{B_f^{Sierk}}$ → **β determined from** σ_f^{total}

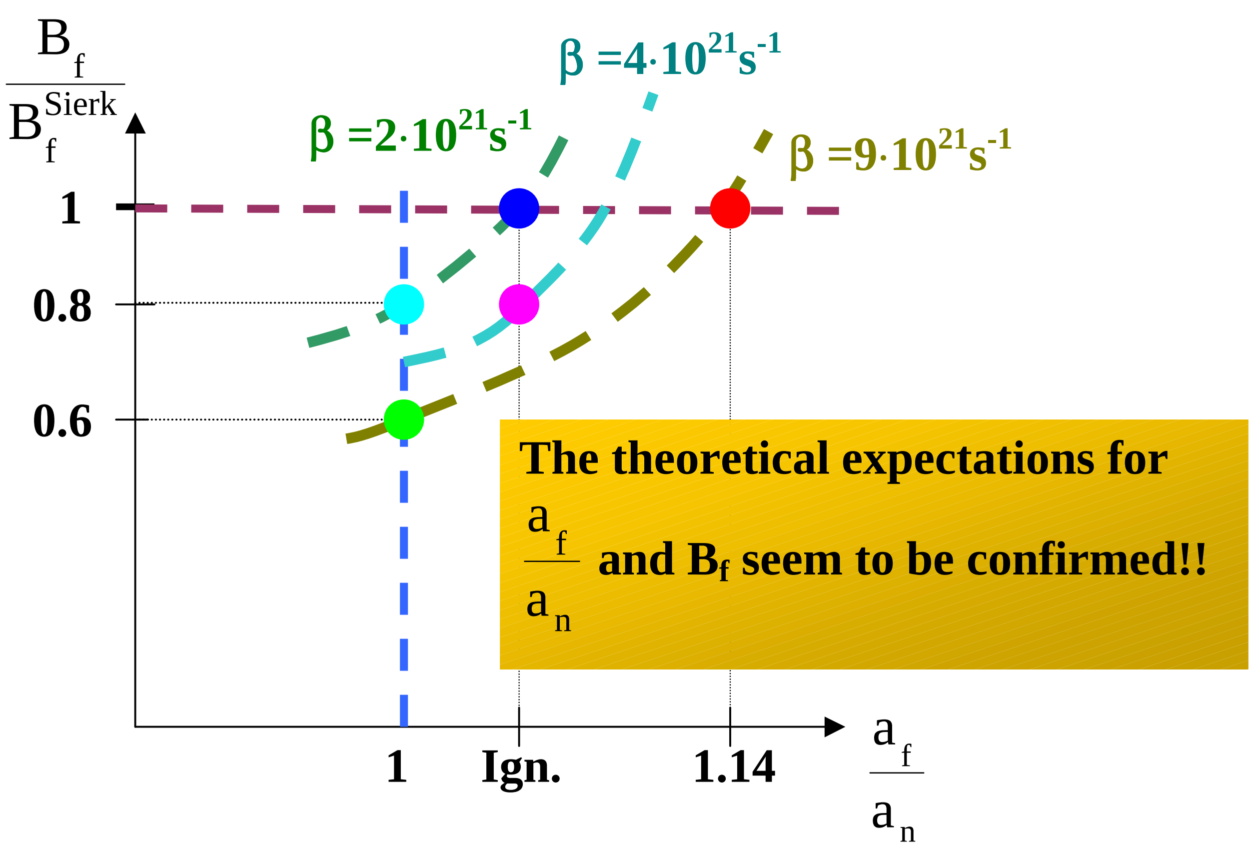




PARTIAL FISSION CROSS SECTIONS

$^{238}U(1000\ A\ MeV) + CH_2$





Conclusion

- Experiment corresponds to model of Grangé-Weidenmüller

- The deduced dissipation coefficient β depends strongly on the shape of $\Gamma_f(t)$

- $\Gamma_f = \Gamma^{BW} \cdot K(1-\exp(-t/\tau))$ does not reproduce our data

- Preliminary parameter values defined by our experiment

$$\frac{a_f}{a_n} = \text{Ign.}, \quad \frac{B_f}{B_{f\_Sierk}} = 1, \beta = 2 \cdot 10^{21} s^{-1}$$

$$\downarrow$$

$$\tau = 3.6 \cdot 10^{-21} s$$