Results on Dissipation in Fission from Peripheral Heavy-Ion Collisions at Relativistic Energies

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How much time does a nucleus need to populate its deformation space?

↓

Fission

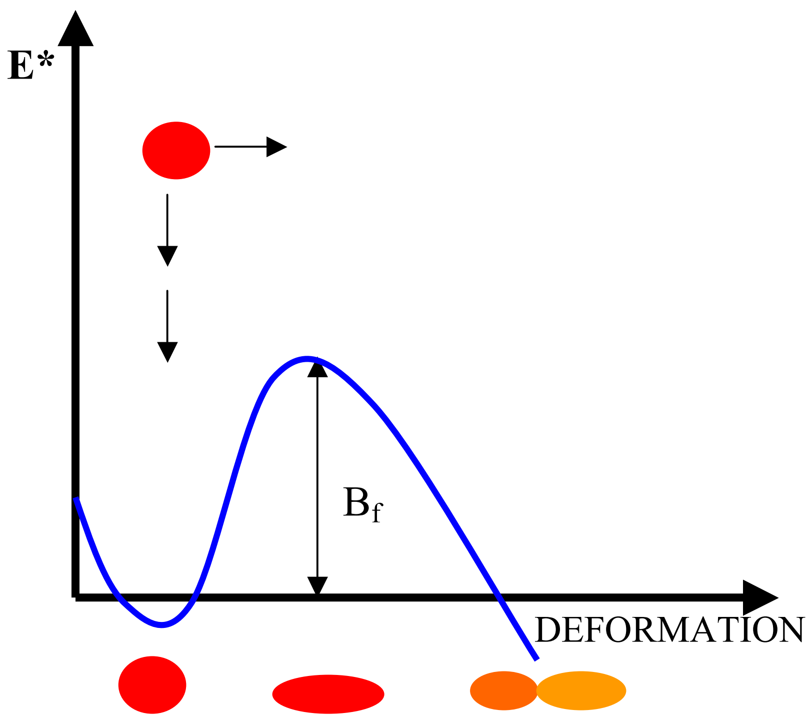
↓

How much time does a nucleus need to populate the deformation space between ground state and saddle, τ_f?

At which excitation energy do we start to be sensitive to τ_f?

Ideal scenario

- No deformation, no angular momentum. Only intrinsic degrees of freedom are excited
- High Excitation energies



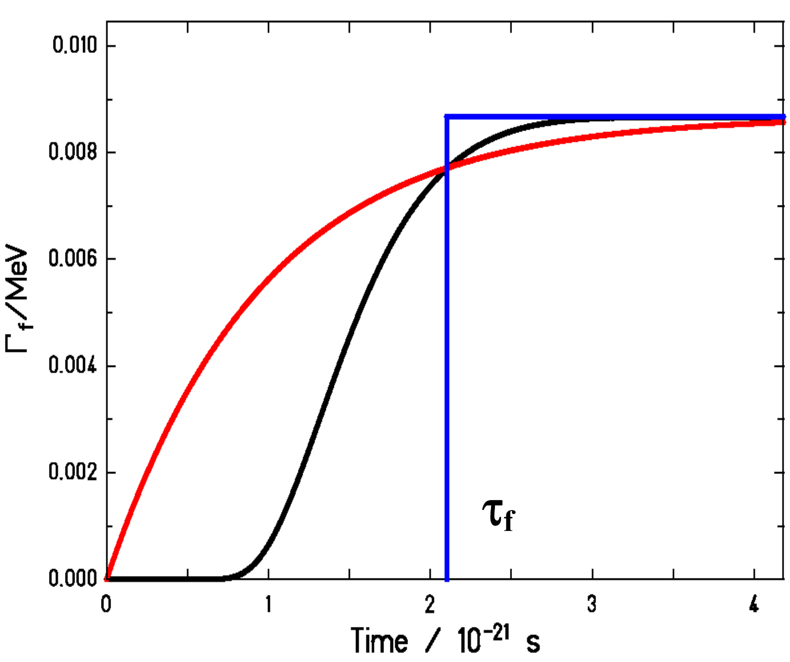
If there is a transient time τ_f, at high excitation energies the number of systems that fission should be less than what the transition-state model predicts

Model of Grangé & Weidenmüller (1980)
(Kramers 1940)

Fission process is considered as the evolution of the fission collective degree of freedom (e.g. elongation) in the heat bath formed by the individual nucleons

This process is described by the Fokker-Planck equation (FPE)

Solution of the FPE under the initial conditions of the ideal scenario, $\Gamma_f(t)$



$\Gamma_f(t)$ =Solution of FPE

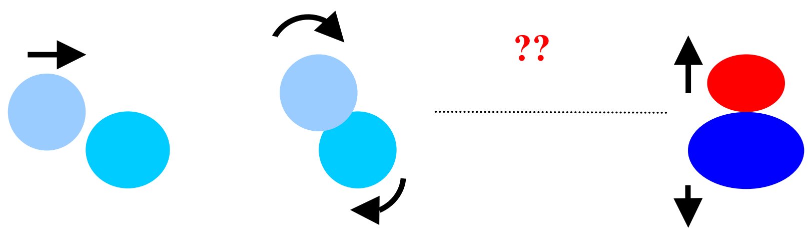
$\Gamma_f(t) = \Gamma^{BW} \cdot K(1-\exp(-2.3 \cdot t/\tau))$

$\Gamma_f(t)$ = Step Function

Experimental approach that reproduces the ideal scenario

…common experiments…

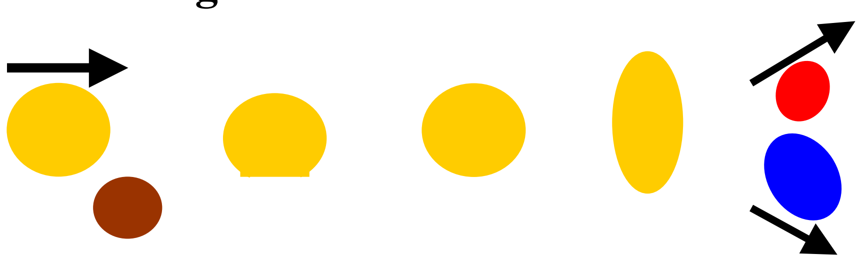
Fusion-Fission reactions



- **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)**

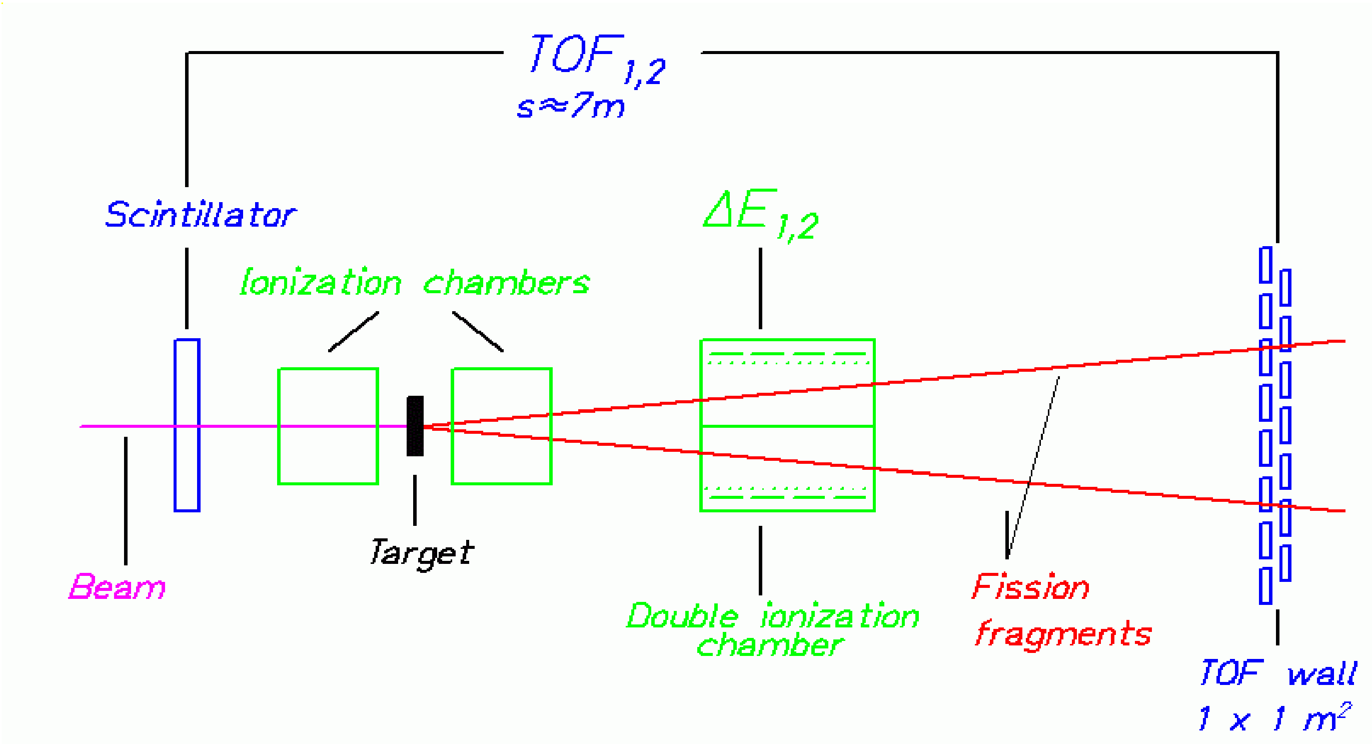
…our approach…

Fission induced by peripheral heavy-ion collisions at relativistic energies



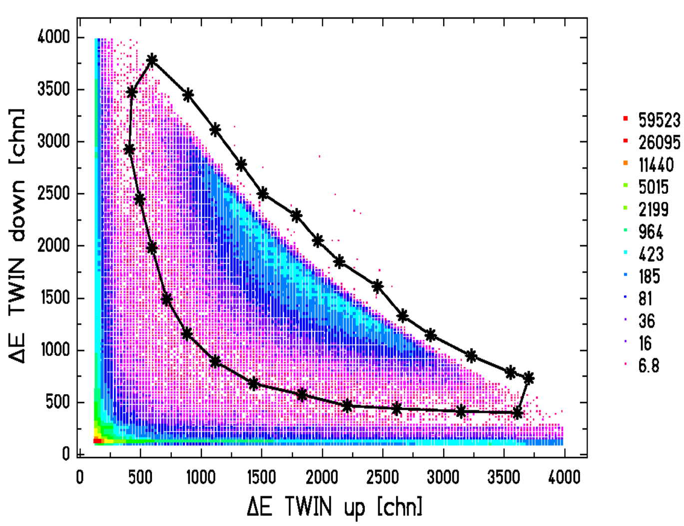
- **Small shape distortion**
- **Low angular momentum**
- **High intrinsic excitation energies E* ~ ΔA**
- **Inverse kinematics**

Experimental set-up

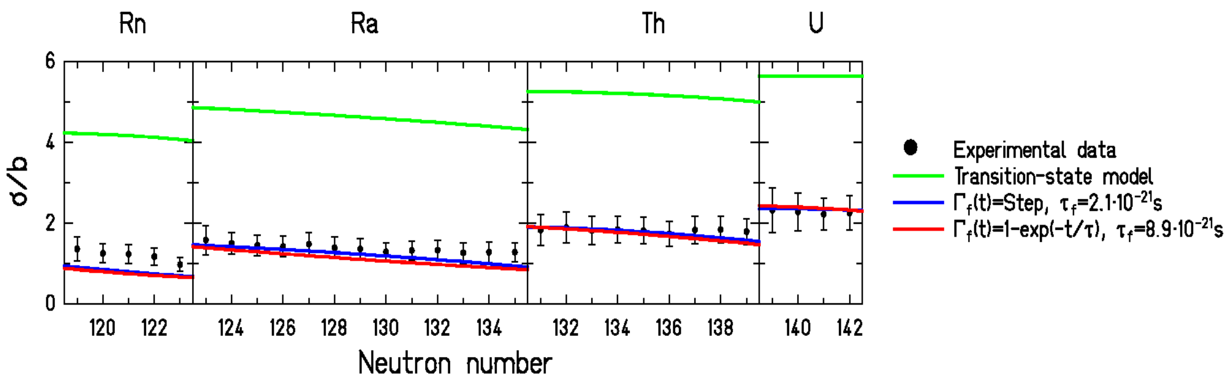


Identification of fission events

$^{238}U(1\ A\cdot GeV) + CH_2$



Total nuclear fission cross sections of unstable nuclei in Pb



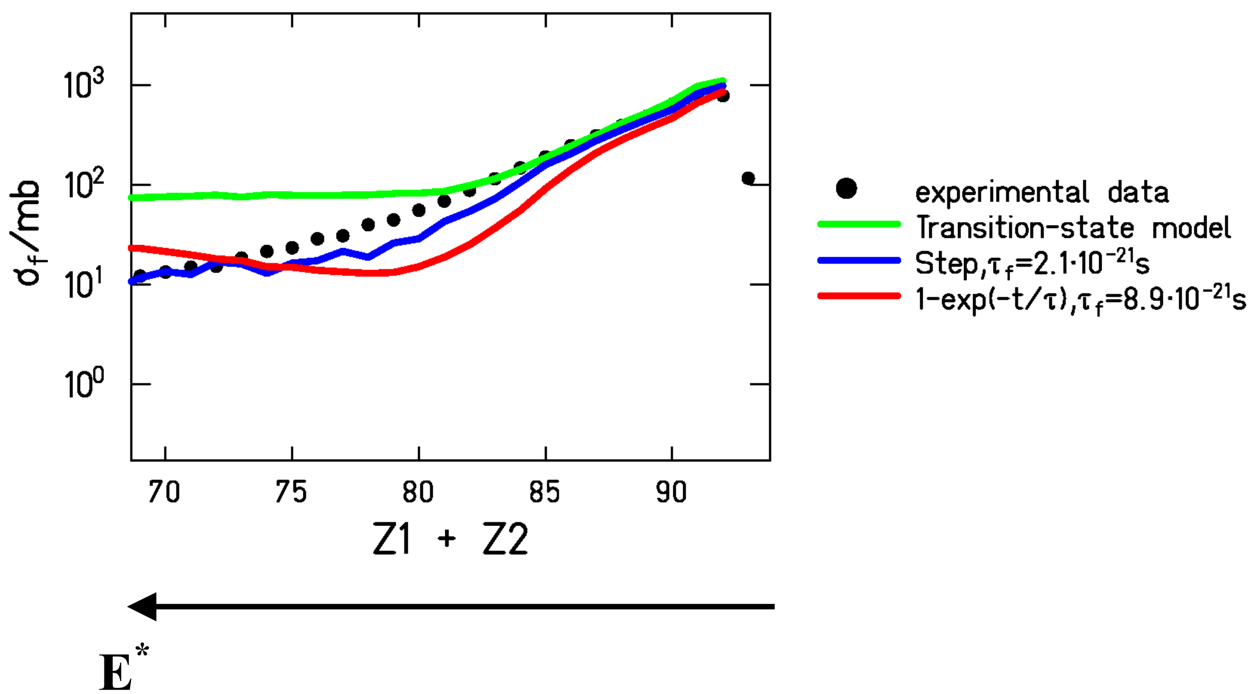
σ_f^{tot} **are reproduced by**

$\Gamma_f(t)$ = Step function, $\tau_f = 2.1\cdot10^{-21}$s

$\Gamma_f(t) \propto 1-\exp(-2.3t/\tau_f)$, $\tau_f = 8.9\cdot10^{-21}$s

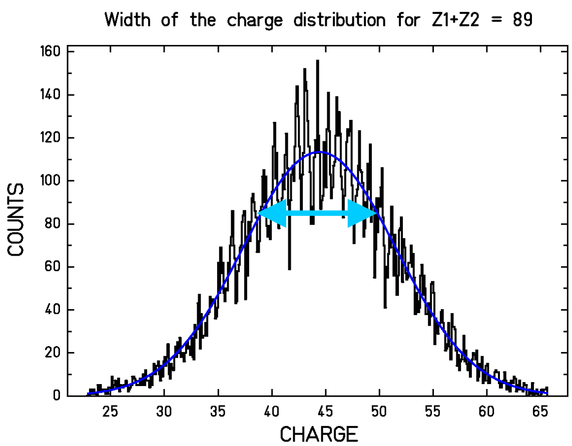
Partial fission cross sections

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



σ_f (Z1+Z2) are not reproduced by $\Gamma_f(t) \propto 1- \exp(-t/\tau)$, τ_f=8.9·10^{-21}s!!!

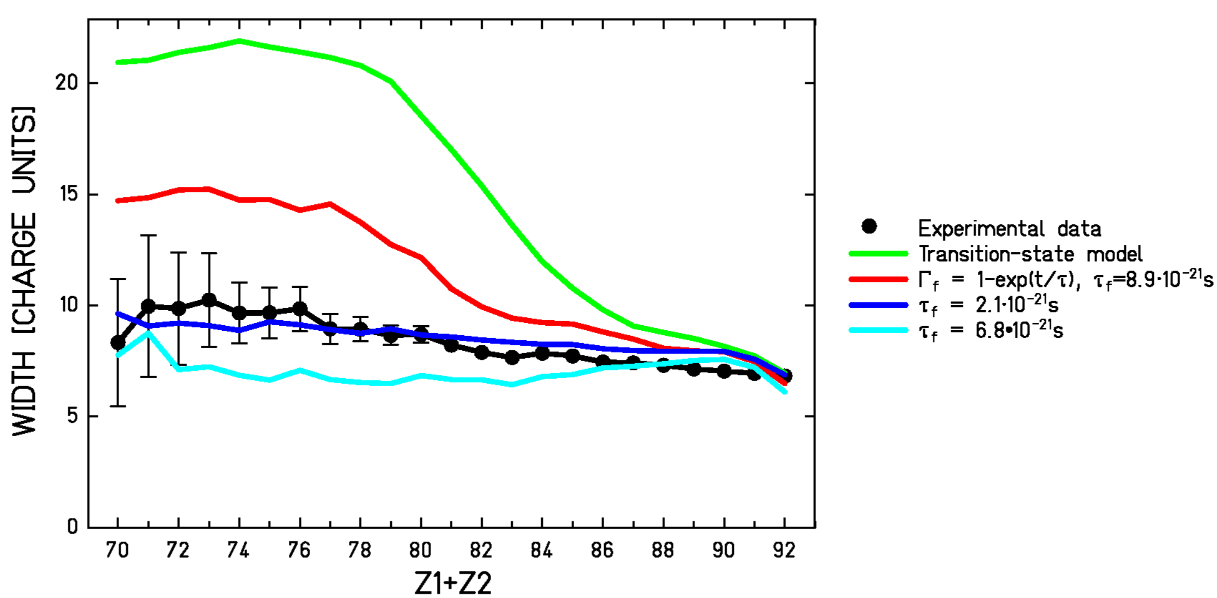
Widths of charge distributions



$$2\sigma_z^2 = \frac{T}{C}$$

C(Z,A) → **S. I. Mulgin et al. Nucl. Phys. A 640 375-388 (1998)**

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

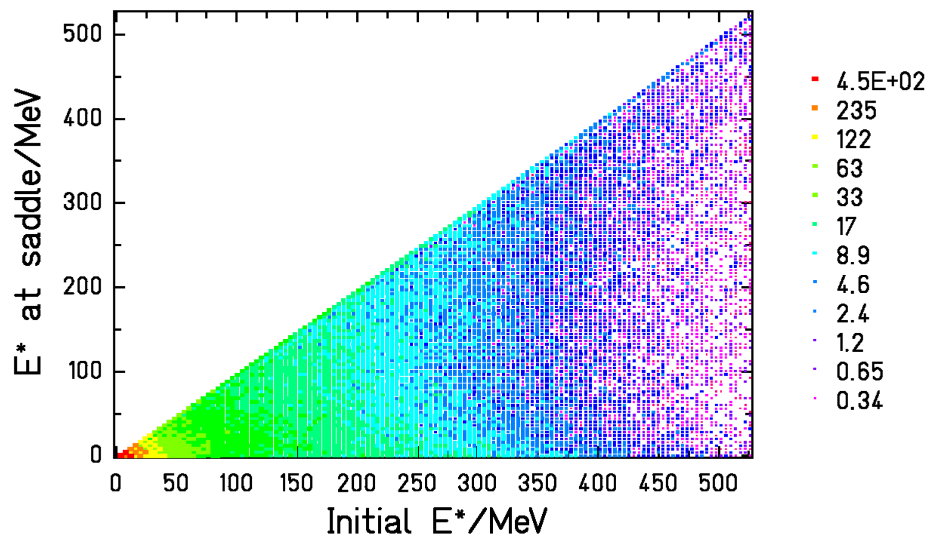


E^*

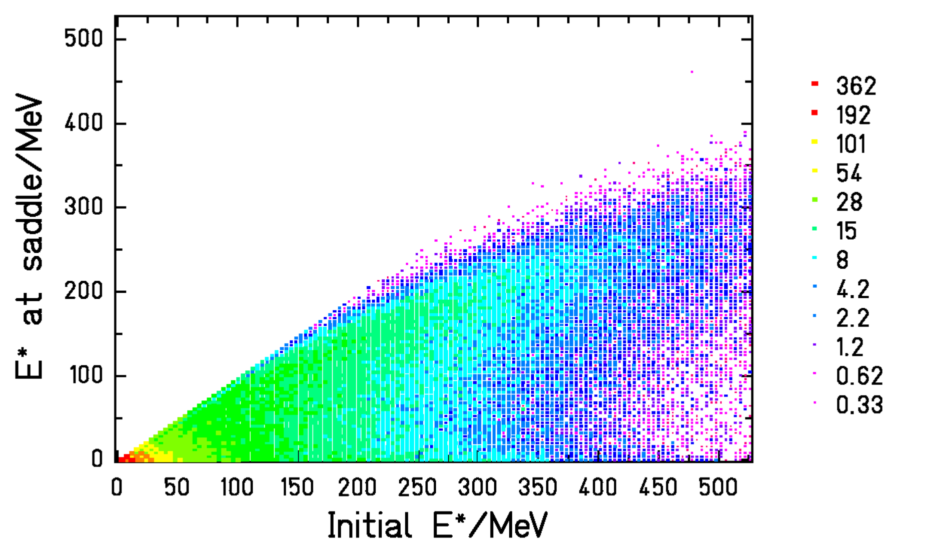
Best description: step function, $\tau_f = 2.1 \cdot 10^{-21}$s

Excitation energy

Transition-state model



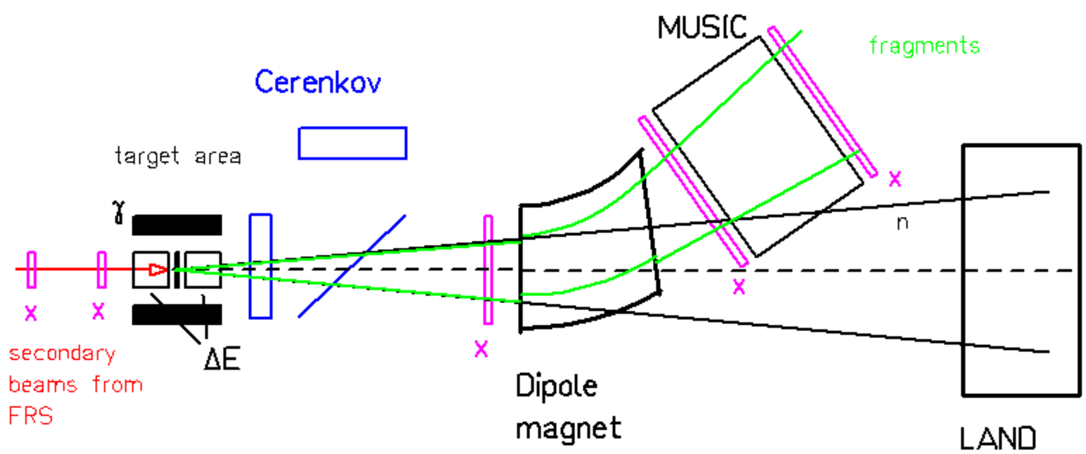
$\tau_f \approx 2.1 \cdot 10^{-21}$s



We start to be sensitive to τ_f at E*≈ 100 MeV

Outlook

Better knowledge of the reaction dynamics at high excitation energies → **R3B-Project**



- **Full identification of fission fragments and light particles**
- **Full kinematics**

ABRABLA

- **Abrasion model**
  (Eisenberg Y., *Phys. Rev. C* 96 1378 (1954))

- **Evaporation and fission**

-Transition-State model
(Bohr N. and Wheeler J. A., *Phys. Rev.* 56, 426 (1939))

$-\Gamma_f(t) = \Gamma^{BW} \cdot K \cdot f(t)$

Γ^{BW}
B_f **(Sierk, A. J. *Phys. Rev. C* 33, 2039 (1986))**
a_f/a_n **(Ignatyuk A. V. et al., *Nucl. Phys. A* 593, 519-534 (1995))**

f(t)
Step function
$1-\exp(-2.3 \cdot t/\tau_f)$