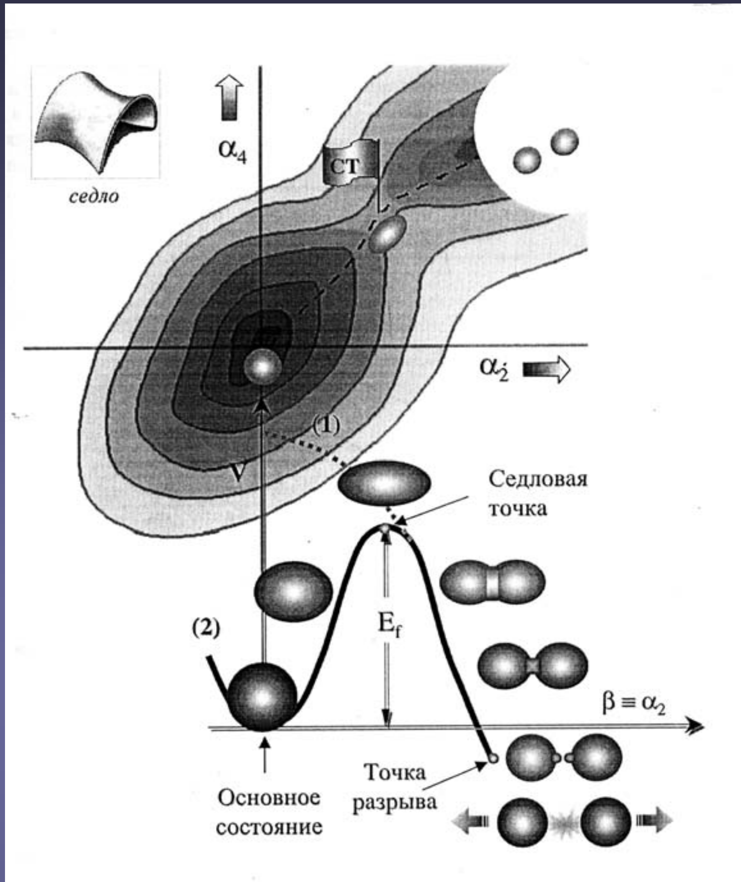
СТОХАСТИЧЕСКИЕ МЕТОДЫ В ФИЗИКЕ ДЕЛЕНИЯ АТОМНЫХ ЯДЕР

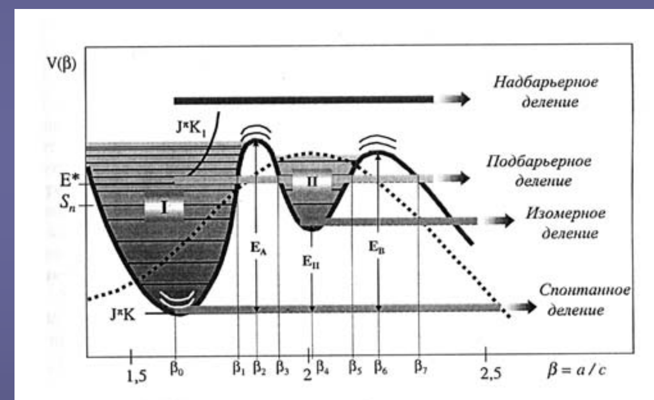


Статистическая модель

$$\Gamma_f^{BW} = \frac{1}{2\pi\rho\ (E^*,J)} \int_0^{E^*-B_f} d\varepsilon \frac{\rho_{sad}(E^*-B_f-\varepsilon,J)}{1+e^{-2\pi\varepsilon/(\hbar\omega_{sad})}}$$

$$\tau_f = \frac{\hbar}{\Gamma_f^{BW}+\sum_i \Gamma_i} \qquad P_f = \frac{\Gamma_f^{BW}}{\Gamma_f^{BW}+\sum_i \Gamma_i}$$

Bohr N., Wheeler J.A. The mechanism of nuclear fission Physical Review. 1939. V.56. P.426-450.



Динамическая модель (стохастические уравнения)

Уравнение Фоккера-Планка

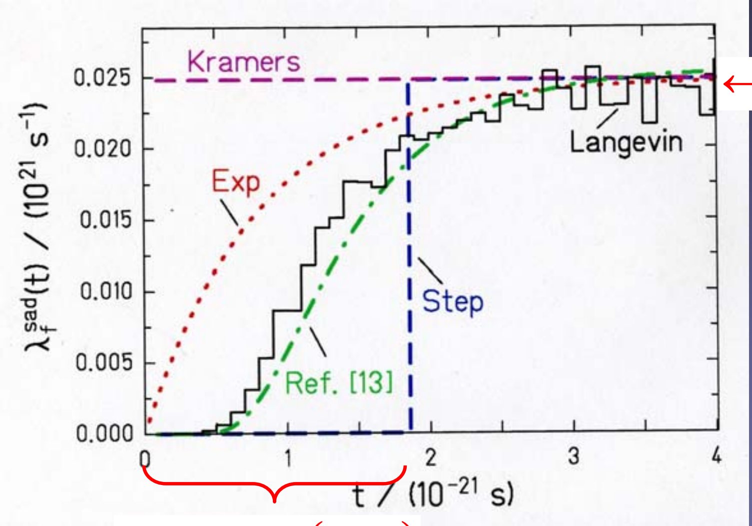
$$\frac{\partial f(x,p,t)}{\partial t} = -\frac{p}{m}\frac{\partial f}{\partial x} + \frac{\partial U(x)}{\partial x}\frac{\partial f}{\partial p} + \beta\frac{\partial}{\partial p}(fp) + \beta m T^* \frac{\partial^2 f}{\partial p^2}$$

Kramers H.A. Brownian motion in a field of force and the diffusion model of chemical reactions. Physica. 1940. V.7. P.284-304.

Уравнение Ланжевена

$$\begin{cases} \dfrac{dp}{dt} = -\dfrac{1}{2}\left(\dfrac{p}{m(r)}\right)^2 \dfrac{dm(r)}{dr} - \dfrac{dV}{dr} - \beta(r)p + f(t) \\[2ex] \dfrac{dr}{dt} = \dfrac{p}{m(r)} \end{cases}$$

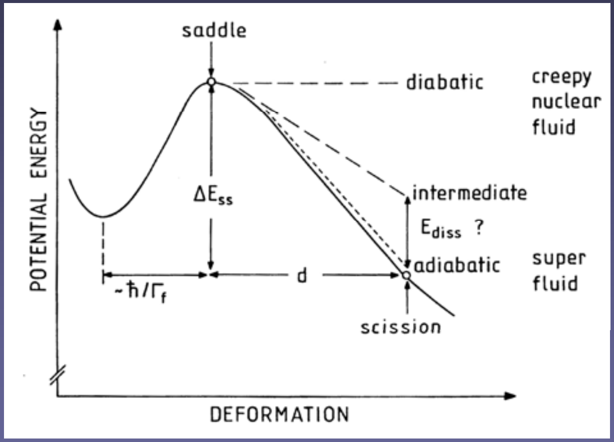
Ядерная диссипация - необратимая передача энергии коллективного ядерного движения одночастичным степеням свободы



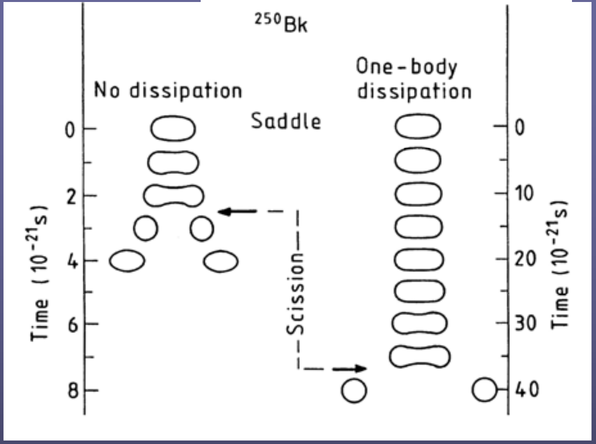
$$\leftarrow \Gamma_f = C_{Kram}(\beta)\Gamma_f^{BW}$$

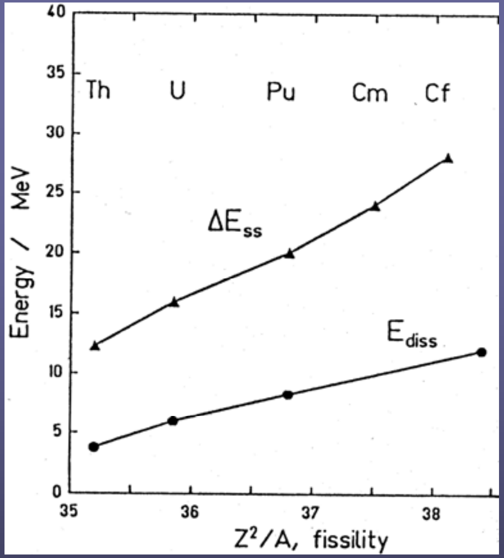
$$C_{Kram} = \left[\sqrt{1+\frac{\beta^2}{4\omega_{sad}^2}} - \frac{\beta}{2\omega_{sad}}\right] < 1$$

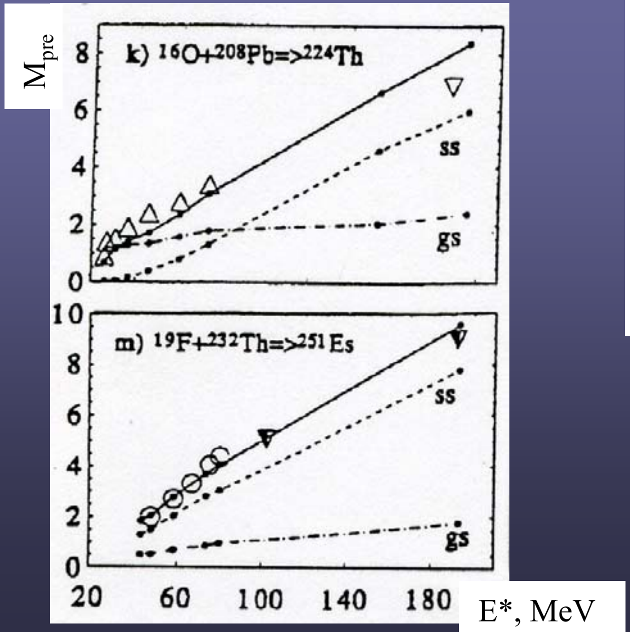
$$\tau_{trans} = \frac{\beta}{2\omega_{eq}^2}\ln\left(\frac{10B_f}{T}\right)$$



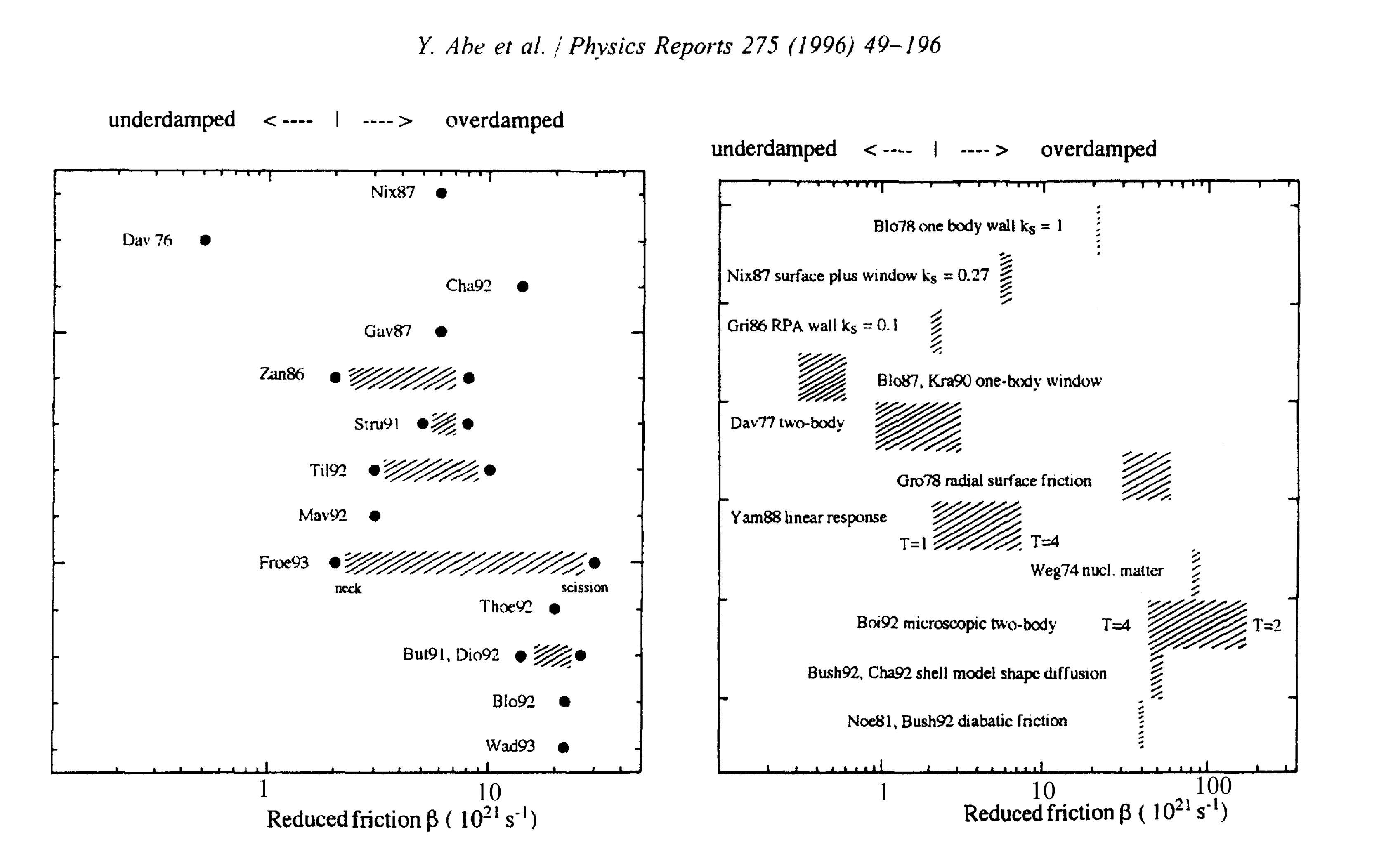
$$\tau_{ss} = \tau_{ss}^0\left(\sqrt{1+\left(\frac{\beta}{2\omega}\right)^2} + \frac{\beta}{2\omega}\right)$$





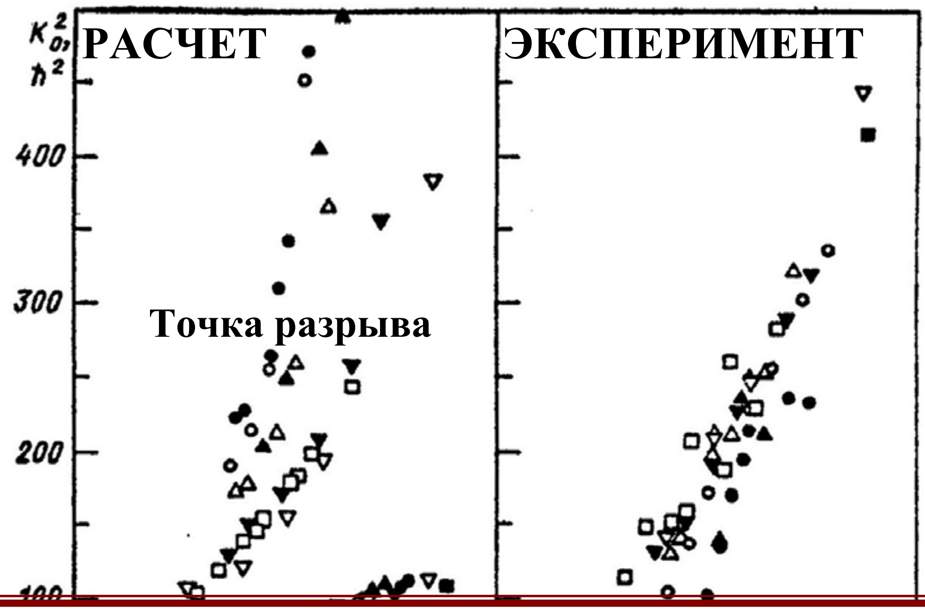


- ♦ Множественности легких частиц и γ-квантов;
- ♦ Сечения образования остатков испарения;
- ♦ массово-энергетические и зарядовые распределения осколков деления

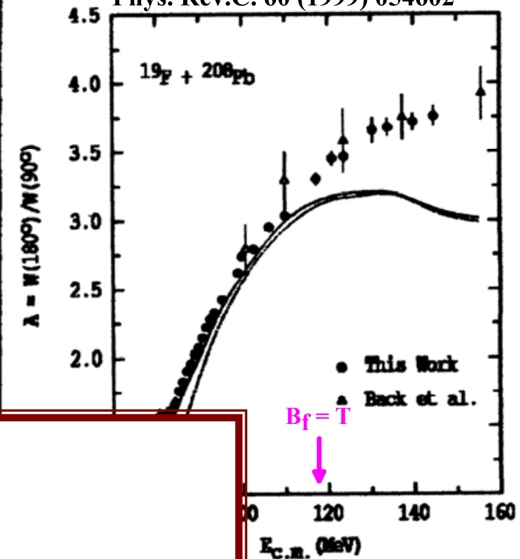


Механизм ядерной диссипации ?
Амплитуда диссипативных сил ?

СТАТИСТИЧЕСКИЕ МОДЕЛИ



D.J.Hinde et al., Limiting angular momentum for statistical model description of fission.
Phys. Rev.C. 60 (1999) 054602



Зависимость … еских моделей.

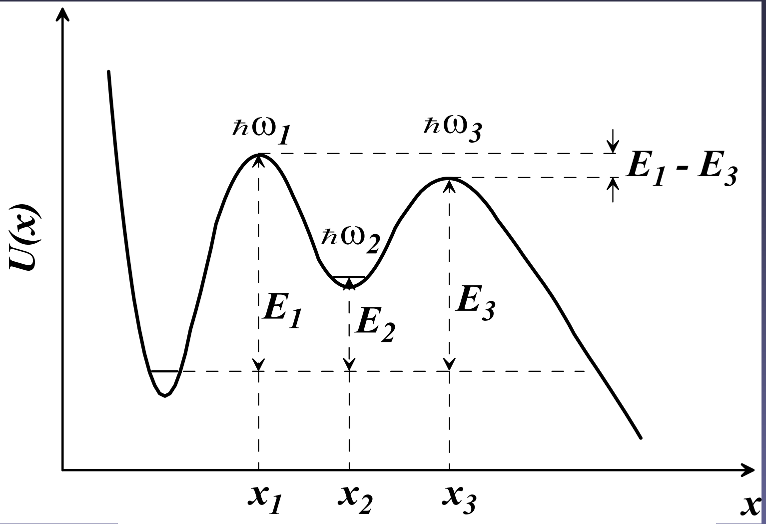
ПРОБЛЕМА:

Динамический механизм процесса формирования угловых распределений осколков деления.

Freifelder R., … d experiment
for fission- … of stability.
Physics Reports. 1986. V.133. P.315-335.)

ДИНАМИКА КОЛЛЕКТИВНОГО ЯДЕРНОГО ДВИЖЕНИЯ ВО ВТОРОЙ ПОТЕНЦИАЛЬНОЙ ЯМЕ

Ядерная диссипации приводит к тому, что только часть ядер, преодолевших внутренний барьер деления, может достичь второй седловой точки с “первой попытки”– прямое деление.



$$U(x) = E_i \pm \frac{1}{2} m\omega_i^2 (x - x_i)^2$$

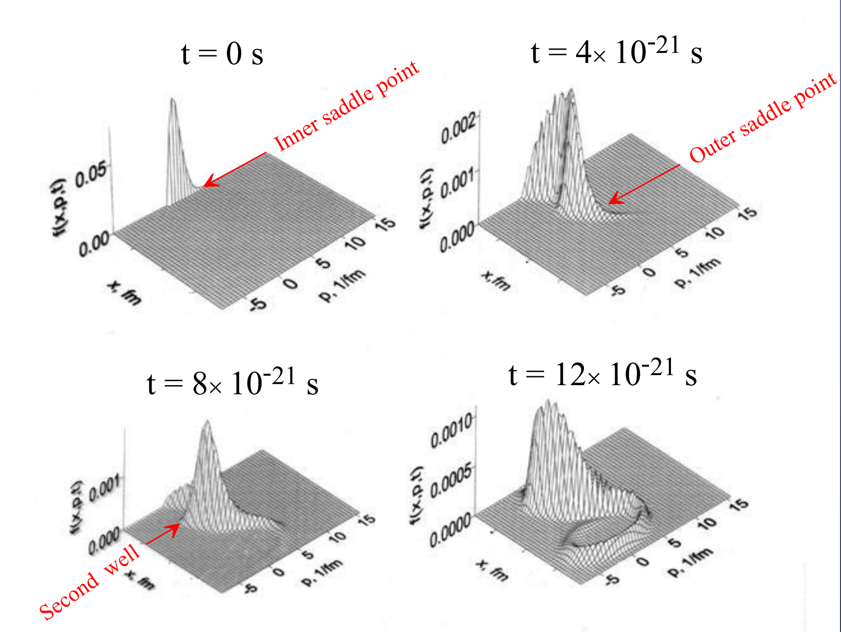
Уравнение Фоккера-Планка

$$\frac{\partial f}{\partial t} = -\frac{p}{m}\frac{\partial f}{\partial x} + \frac{\partial U(x)}{\partial x}\frac{\partial f}{\partial p} + \beta\frac{\partial}{\partial p}(fp) + \beta m T^* \frac{\partial^2 f}{\partial p^2}$$

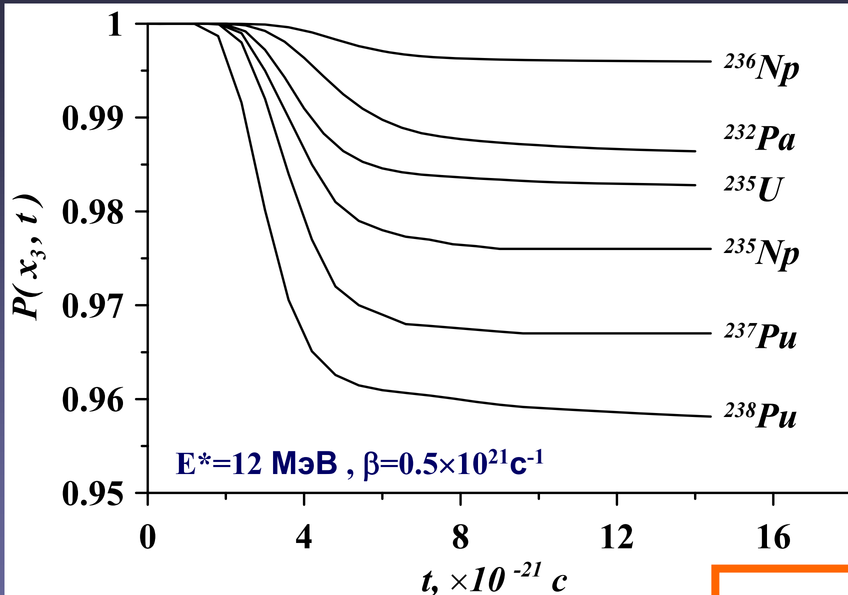
$$f(x,p,t=0) = f(p)\delta(x - x_1)$$

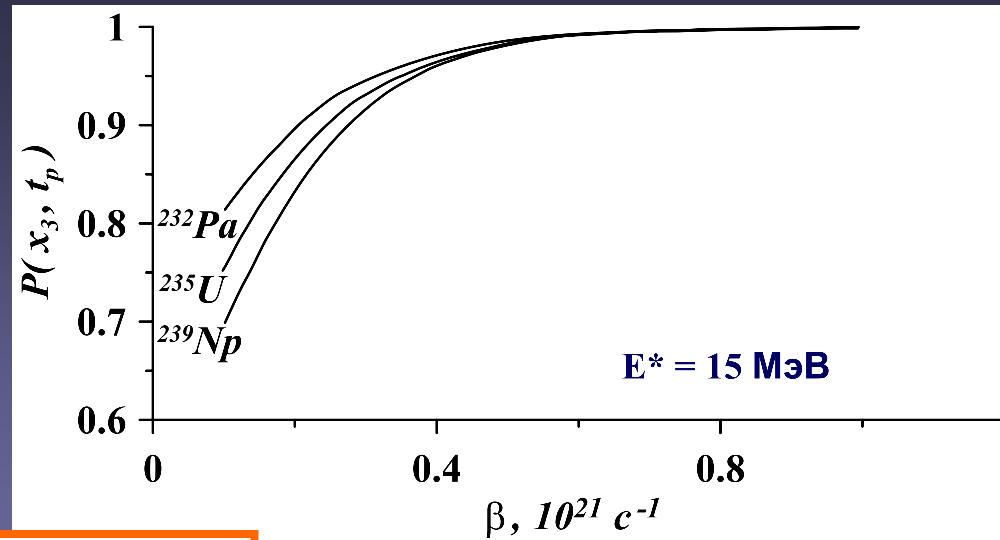
$$\Phi(\varepsilon) = C\,\frac{\rho(E^* - U(x_1) - \varepsilon)}{1 + \exp\left(\dfrac{2\pi\varepsilon}{\hbar\omega_1}\right)}$$

$$P(x_3,t) = \frac{\int_{-\infty}^{+\infty} dp \int_{x1}^{x_3} dx\, f(x,p,t)}{\int_{-\infty}^{+\infty} dp \int_{x1}^{+\infty} dx\, f(x,p,t)}$$

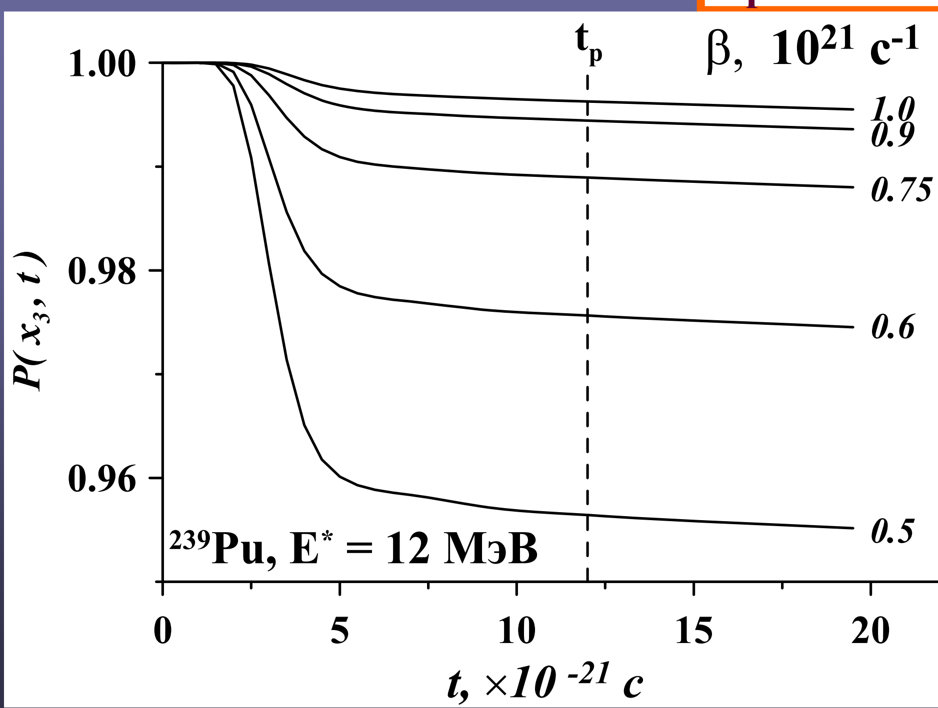


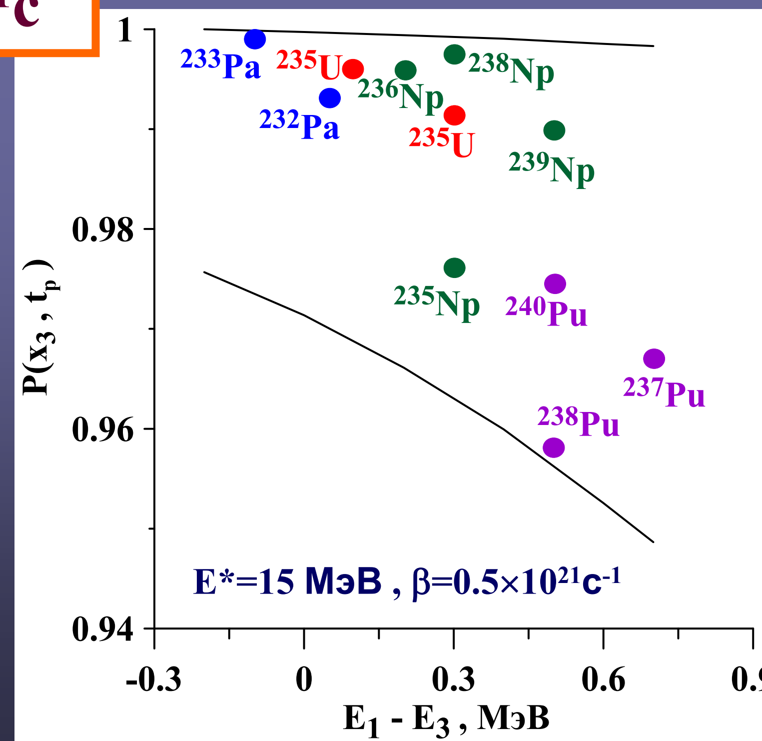
^{240}Pu, E* = 12 MeV, β = 0.5 × 10^{21} s^{-1}





$t_p = 12\times10^{-21}$c





УГЛОВЫЕ РАСПРЕДЕЛЕНИЯ ОСКОЛКОВ ДЕЛЕНИЯ ЯДЕР С ДВУГОРБЫМ БАРЬЕРОМ ДЕЛЕНИЯ

$$W(\theta)=\sum_i b_i\left\{(1-P_i)W_{i,1s}(\theta)+P_iW_{i,2s}(\theta)\right\}$$

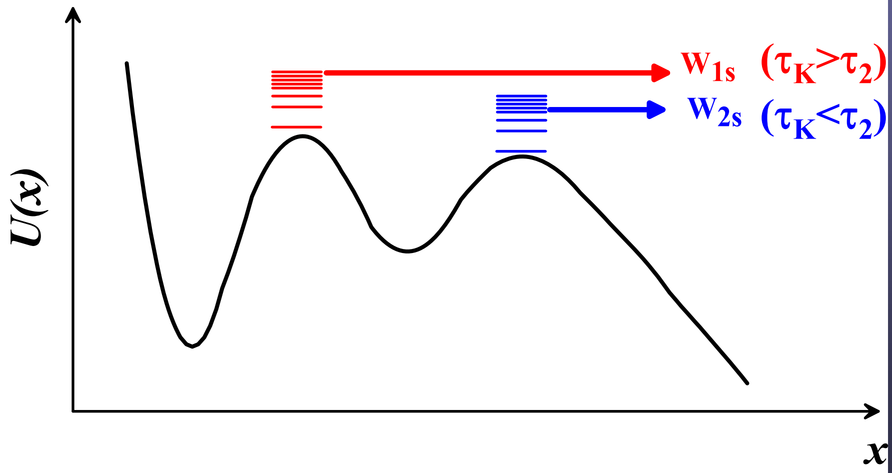
$$W_{i,1s(2s)}(\theta)=\sum_{J=0}^{\infty}\sum_E B_i(J,E)\frac{\sum\limits_{M=-J}^{J}\exp\left(-\frac{M^2}{2M_0^2}\right)\sum\limits_{K=-J}^{J}\frac{1}{2}(2J+1)\left|d^J_{M,K}(\theta)\right|^2\exp\left(-\frac{K^2}{2K_{0,i}^2}\right)}{\sum\limits_{J=0}^{\infty}\sum\limits_E B_i(J,E)\sum\limits_{M=-J}^{J}\exp\left(-\frac{M^2}{2M_0^2}\right)\sum\limits_{K=-J}^{J}\exp\left(-\frac{K^2}{2K_{0,i}^2}\right)}$$

$$B_i(J,E)=\frac{\sigma_{if}(J,E)}{\sum_J\sum_E\sigma_{if}(J,E)}$$

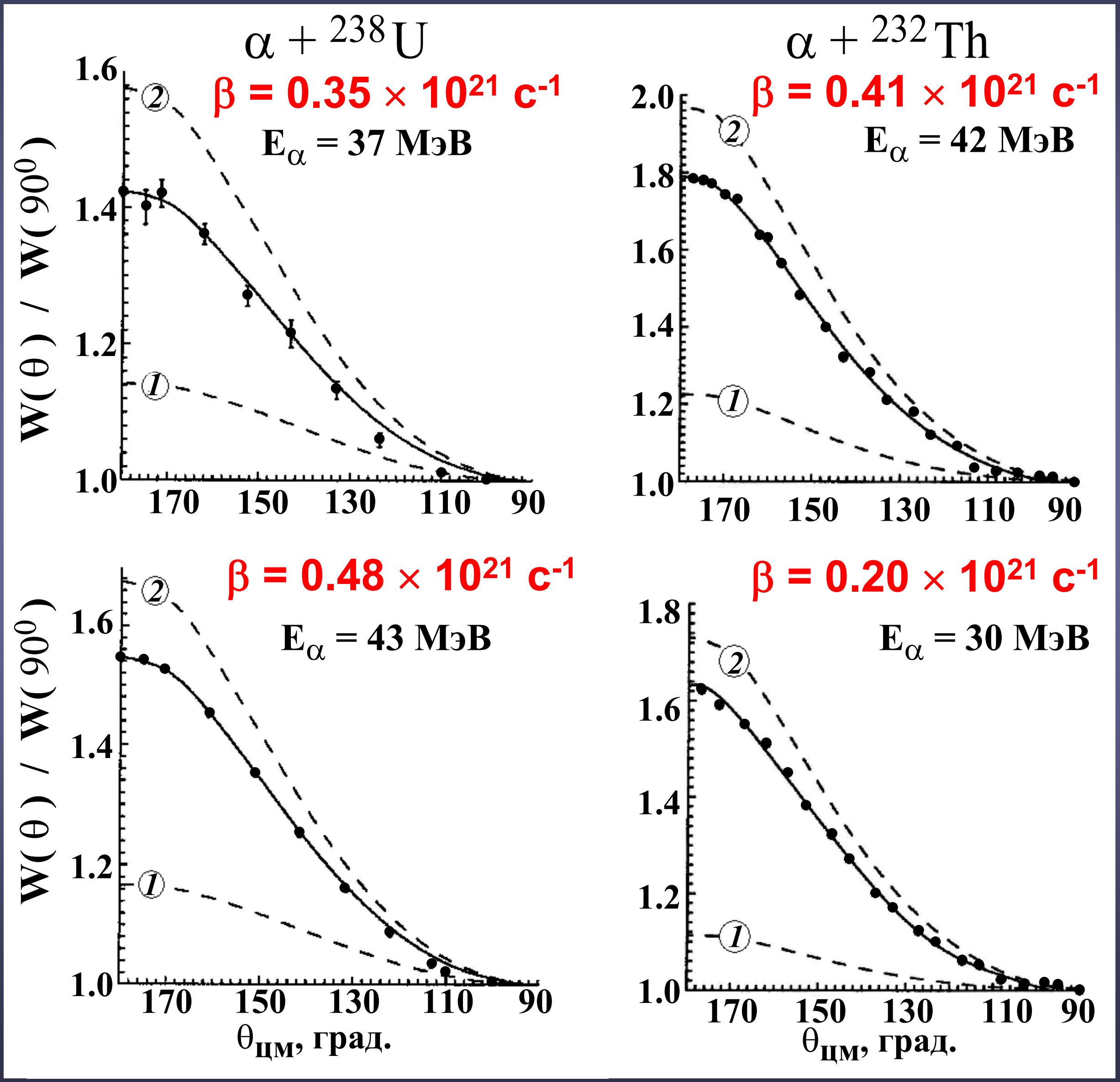
- вероятность деления i-го ядра эмиссионного каскада с угловым моментом J и энергией возбуждения E

$$b_i=\frac{\sum_J\sum_E\sigma_{if}(J,E)}{\sum_i\sum_J\sum_E\sigma_{if}(J,E)}$$

-вес осколков деления i-го ядра эмиссионного каскада в полном выходе осколков



Сечения деления i-го ядра с энергией возбуждения E и угловым моментом J $\sigma_{if}(J,E)$ рассчитывались в рамках программного комплекса GFOT, в котором реализован формализм Хаузера-Фешбаха.



E* = (10 ÷ 40) MeV

Second well

$\beta=(0.2 \div 0.5)\times10^{21}$ c^{-1}

СХЕМА РАСЧЕТОВ

$$\begin{cases} \dfrac{dp}{dt} = -\dfrac{1}{2}\left(\dfrac{p}{m(r)}\right)^2 \dfrac{dm(r)}{dr} - \dfrac{dV}{dr} - \beta(r)p + f(t) \\ \dfrac{dr}{dt} = \dfrac{p}{m(r)} \end{cases}$$

$f(t) = \eta(T\, m\, \beta)^{1/2}$ – **случайная сила,**

$<\eta>=0\,, <\eta(t_1),\eta(t_2)> = 2\,\delta(t_1 - t_2)$

$\beta(r) = \gamma(r)/m(r) \qquad T = \sqrt{E_{int}/a(r)}$

$E_{int} = E^* - p^2/(2m) - V(r,J)$

$a(r) = a_1 A + a_2 A^{2/3} B_s(r)$ - *A.V.Ignatuyk et al., Sov.J.Nucl.Phys. 21 (1975) 1185*

$V(r,J,T) = V_{ldm}(r,J) + V_{shell}(r,T=0)F(T)$

V_{ldm} (r,J) - W. D. Myers and W. J. Swiatecki, Nucl.Phys. 1966 V.81, P.1.
V_{shell} (r, T= 0 MeV) = $V_{d.h.}$(r) – V_{ldm}(r, J=0ħ) at T = 0 MeV

Эмиссия n,p,α и γ

$F(p,r,J) \propto \exp\left(-\dfrac{p^2/(2m)+V}{T}\right)\dfrac{d\sigma(J)}{dJ}\delta(r - r_{eq})$

Second saddle
Second well
First saddle
B_f
DEFORMATION

without populating the second well
with populating the second well
...rn to the first well

Dynamical calculation for $t<t_{stat}$ and $T>T_{stat}$ → *Statistical calculation* → *Dynamical calculation (sadlle-scission)* → *FISSION*

Evaporation residues

ВРЕМЯ ДЕЛЕНИЯ

$$\langle \tau_i \rangle = \frac{1}{N_f} \sum_{i=1}^{N_f} \tau_{fi}$$

- $^{238}U + ^{28}Si$; - $^{28}Si + ^{nat}Pt$;
-$^{232}Th(p,xnf)$; -$^{232}Th(\alpha,xnf)$
$^{232}Th(^{3}He,xnf)$

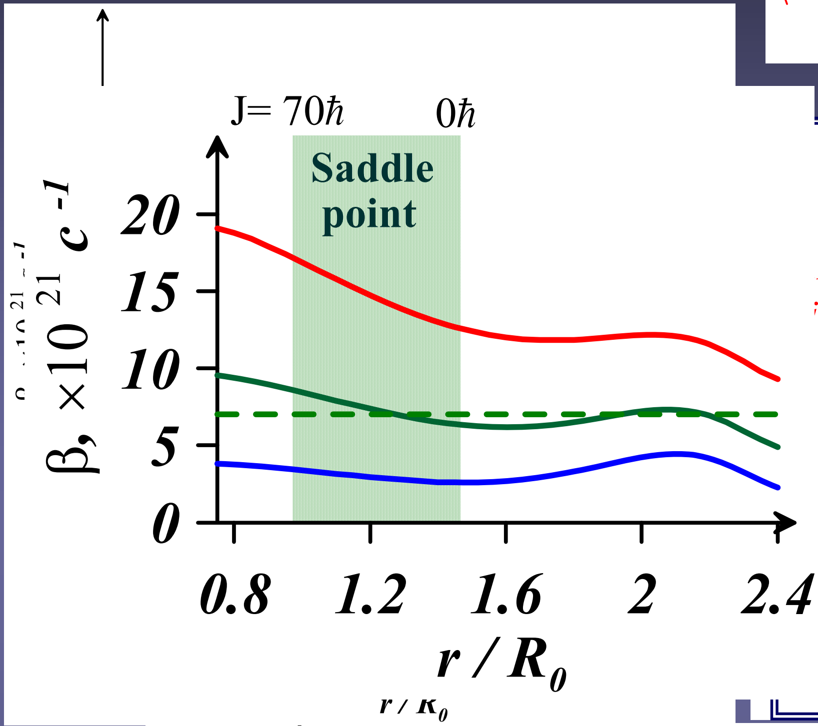
$$\rho(E,r) = \rho_{int}(E,r) K_{vibr}(E,r) K_{rot}(E),$$

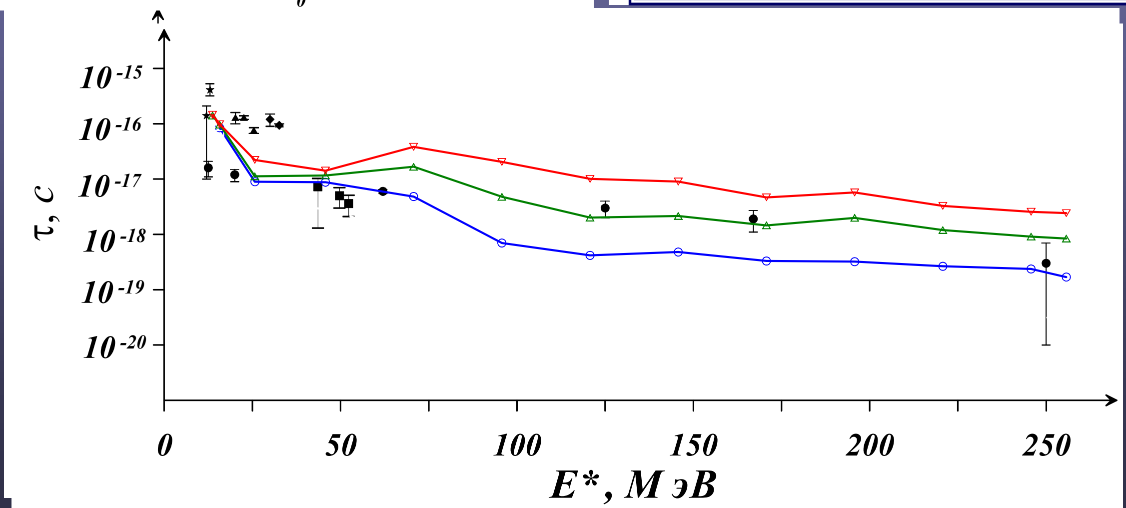
One-body dissipation

$$\gamma_{ij}^{w} = \frac{1}{2}\rho_m \bar{v}\left\{\frac{\partial R}{\partial q_i}\frac{\partial R}{\partial q_j}\Delta\sigma + k_s \pi \int_{Z_{min}}^{Z_{max}} \frac{\partial \rho_s^2}{\partial q_i}\frac{\partial \rho_s^2}{\partial q_j}\left(\rho_s^2 + \left(\frac{1}{2}\frac{\partial \rho_s^2}{\partial Z}\right)^2\right)^{-\frac{1}{2}} dZ\right\}$$

$$\gamma_{ij} = \begin{cases} k_s \gamma_{ij}^{w} & - \text{ with neck} \\ f k_s \gamma_{ij}^{w} + (1-f)\gamma_{ij}^{sw} & - \text{ without neck} \end{cases}$$

$$f = \sin^2\left[\frac{\pi r_{neck}}{2R_{frag}}\right]$$

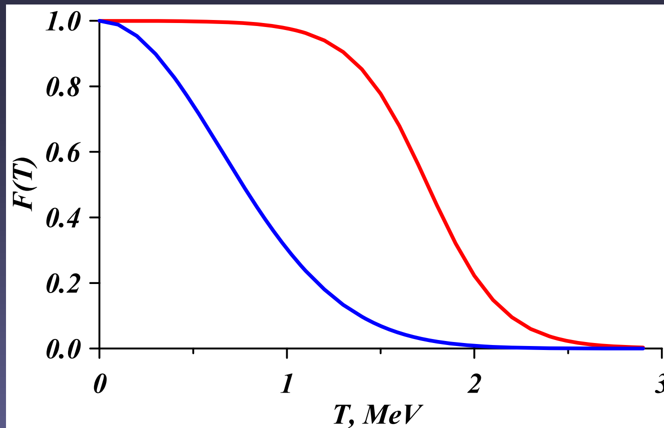




- - - - - - $\beta = 7.0\times10^{21}$ s $^{-1}$

— $k_s = 1.0$
— $k_s = 0.5$
— $k_s = 0.2$,

^{238}U (J = 0 ħ)



$$V_{shell}(r,T) = V_{shell}(r,T=0)\,F(T)$$

$$F(E^*) = exp\left(-\frac{E^*}{E_d}\right)$$

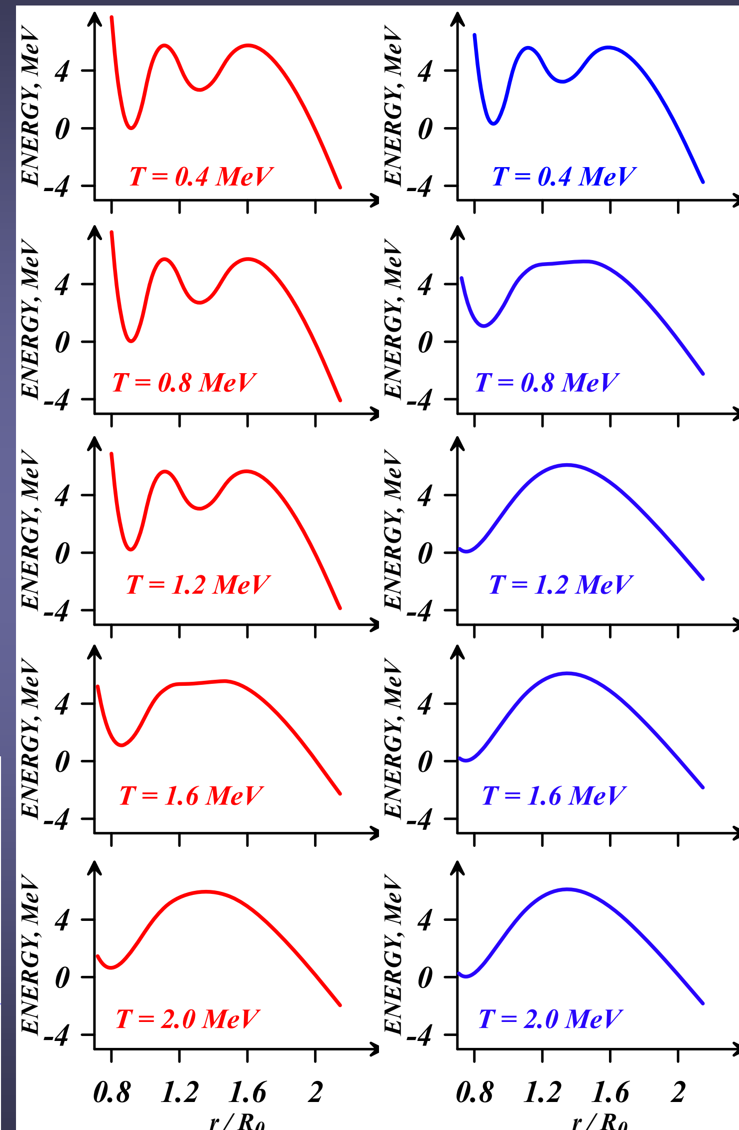
E_d = 20MeV

$$F(T) = \left[1 + exp\left(\frac{T-T_0}{d}\right)\right]^{-1}$$

T_0 = 1.80MeV, d = 0.2MeV

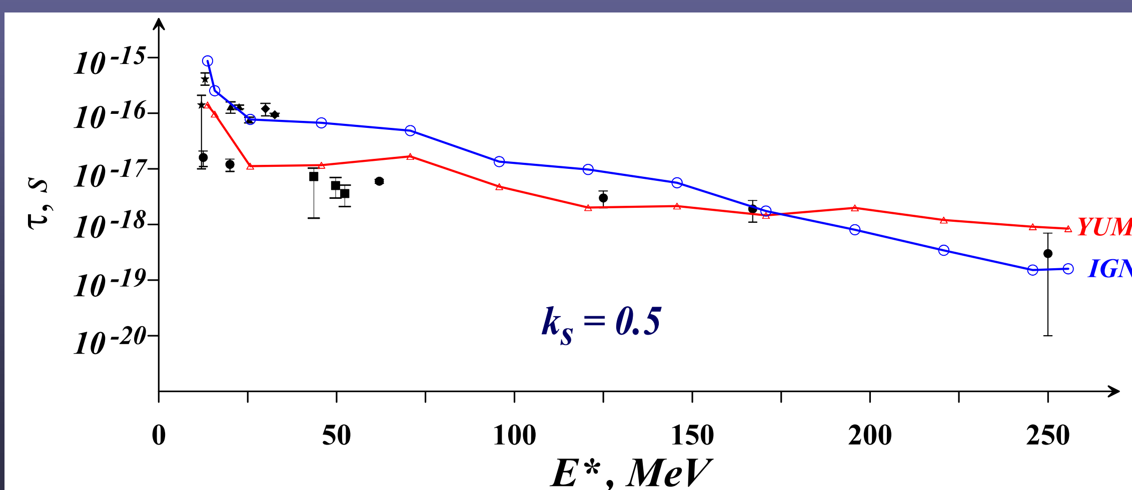
A.V.Ignatyuk et al., Phys. At. Nucl. 21 (1975) 485.

O.A.Yuminov et al., Phys. At. Nucl. 65 (2002) 18.



М.Г.Иткис и др., Письма в ЭЧАЯ *5 (2008) 40.*

44Ca+206Pb →250No (fragment mass distribution) E=(30-40)MeV*



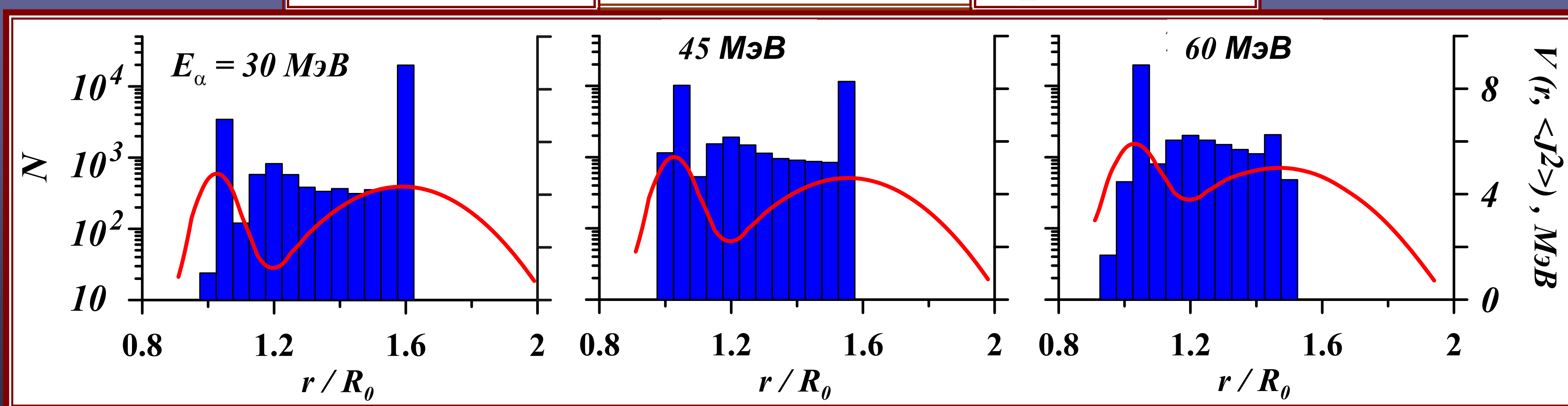
УГЛОВЫЕ РАСПРЕДЕЛЕНИЯ ОСКОЛКОВ ДЕЛЕНИЯ: МЕТОД РАСЧЕТОВ, ОСНОВАННЫЙ НА ИСПОЛЬЗОВАНИИ ПРЕДСТАВЛЕНИЙ О СУЩЕСТВОВАНИИ ЭФФЕКТИВНЫХ ПЕРЕХОДНЫХ СОСТОЯНИЙ

$$r_{tr} = \langle r(t) \rangle_{\tau_K} \longrightarrow K_{0i}^2 = \frac{T_i(r_{tr})}{\hbar^2} \Im_{eff,i}(r_{tr})$$

$$W_i(\theta) = \sum_{K=-J_i}^{J_i} \frac{\frac{1}{2}(2J_i+1)\left|d_{0,K}^{J_i}(\theta)\right|^2 \exp(-K^2/2K_{0i}^2)}{\sum_{K=-J_i}^{J_i} \exp(-K^2/2K_{0i}^2)}$$

$$W(\theta) = \frac{1}{N_f} \sum_{i=1}^{N_f} W_i(\theta)$$

$\beta = 1.5\times10^{21}\ s^{-1}$ | $\alpha + {}^{238}U \rightarrow {}^{242}Pu$ | $\tau_K = 8.\times10^{-21}\ s$



ЗАТУХАНИЕ ОБОЛОЧЕЧНЫХ ЭФФЕКТОВ

$$V(r,J) = V_{l.d.}(r,J) + V_{shell}(r)\,F(T)$$

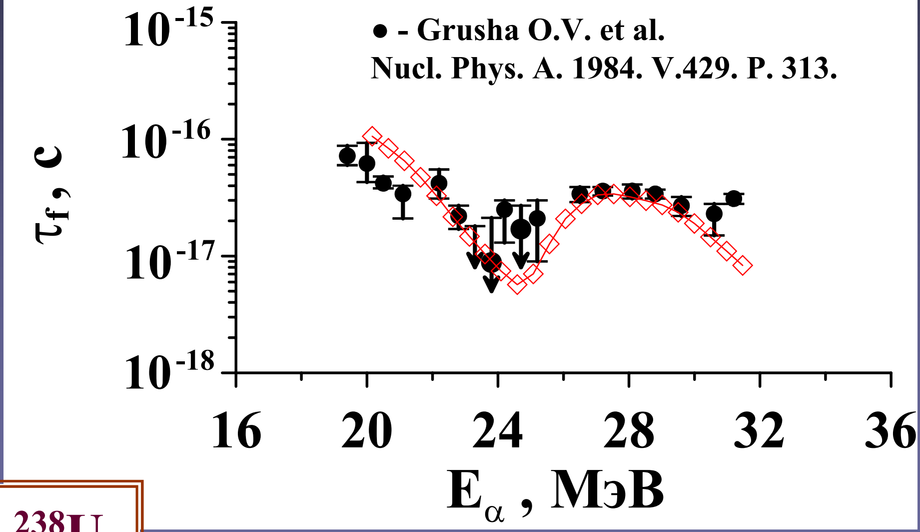
$$F(T) = \frac{1}{1+\exp\left(\frac{T-T_0}{d}\right)}$$

$$T_0 = 1.75\ MeV$$

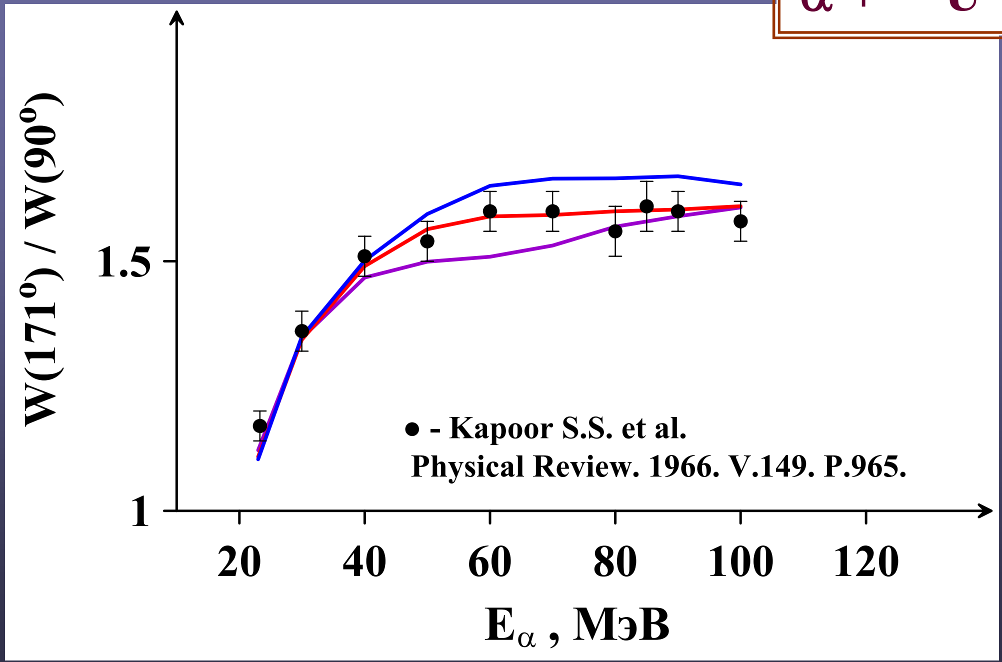
$$d = 0.2\ MeV$$

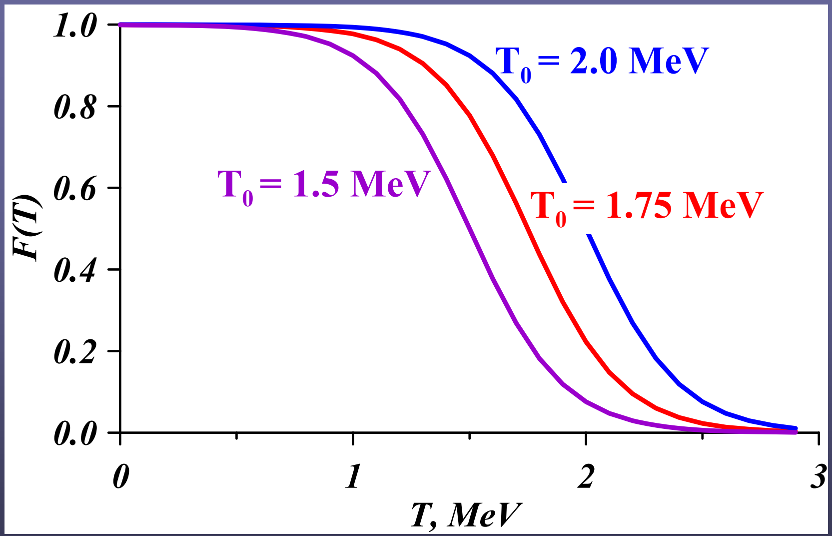
$$\beta = 1.5\times10^{21}\ s^{-1}$$

$$\tau_K = 8.\times10^{-21}\ s$$



$\alpha + {}^{238}U$



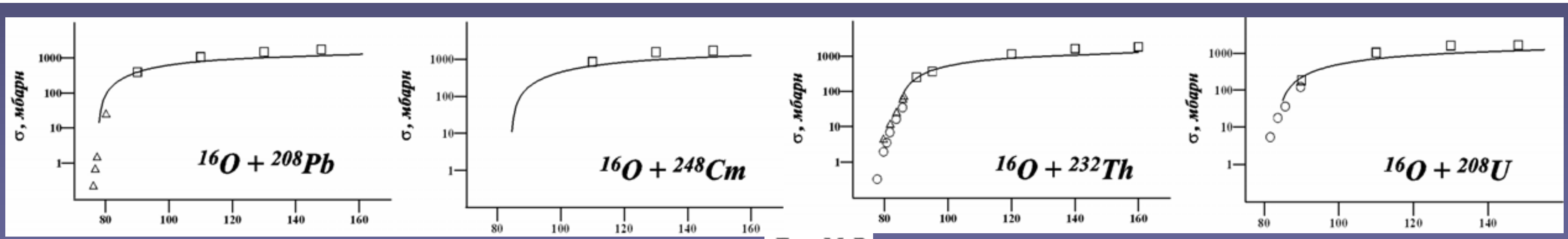


$$B_f \leq T$$

$$V_{shell} = 0$$

$$F(p,r,J) \sim \exp\left(- \frac{p^2/(2m) + V(r,J)}{T} \right) \frac{d\sigma(J)}{dJ} \delta(r - r_{eq})$$

$$\frac{d\sigma(J)}{dJ} = \frac{2\pi}{k^2} \frac{2J+1}{1 + \exp\left(\frac{J - J_c}{\delta J}\right)}$$; J_c *and* δJ *from Frobrich P., Gontchar I.I. // Phys.Rep. 1998. V.292. P.131.*



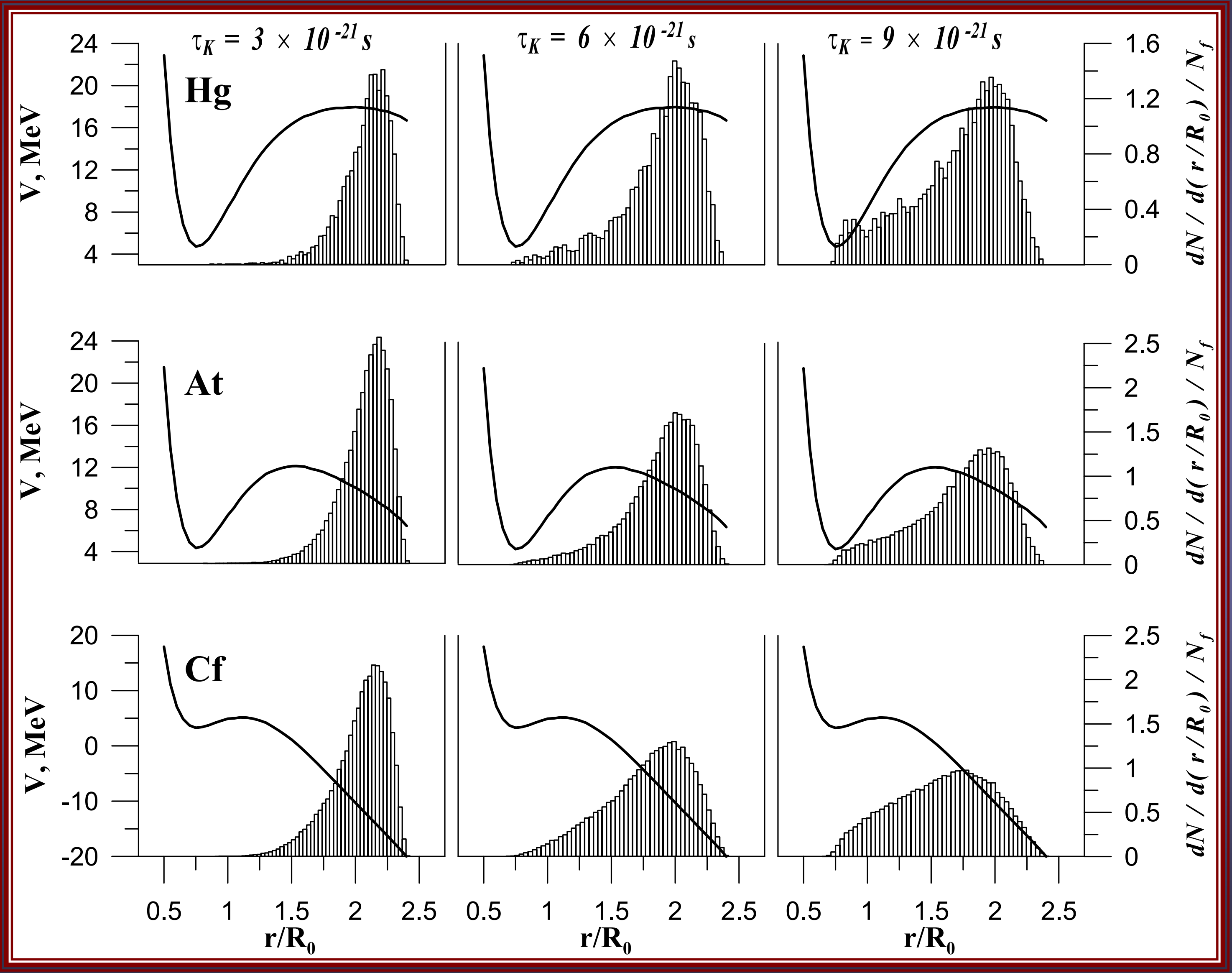
$$r_{tr} = \langle r(t) \rangle_{\tau_K} \rightarrow K_{0i}^2 = \frac{T_i(r_{tr})}{\hbar^2} \Im_{eff,i}(r_{tr})$$

$$W(\theta) = \frac{1}{N_f} \sum_{i=1}^{N_f} W_i(\theta)$$

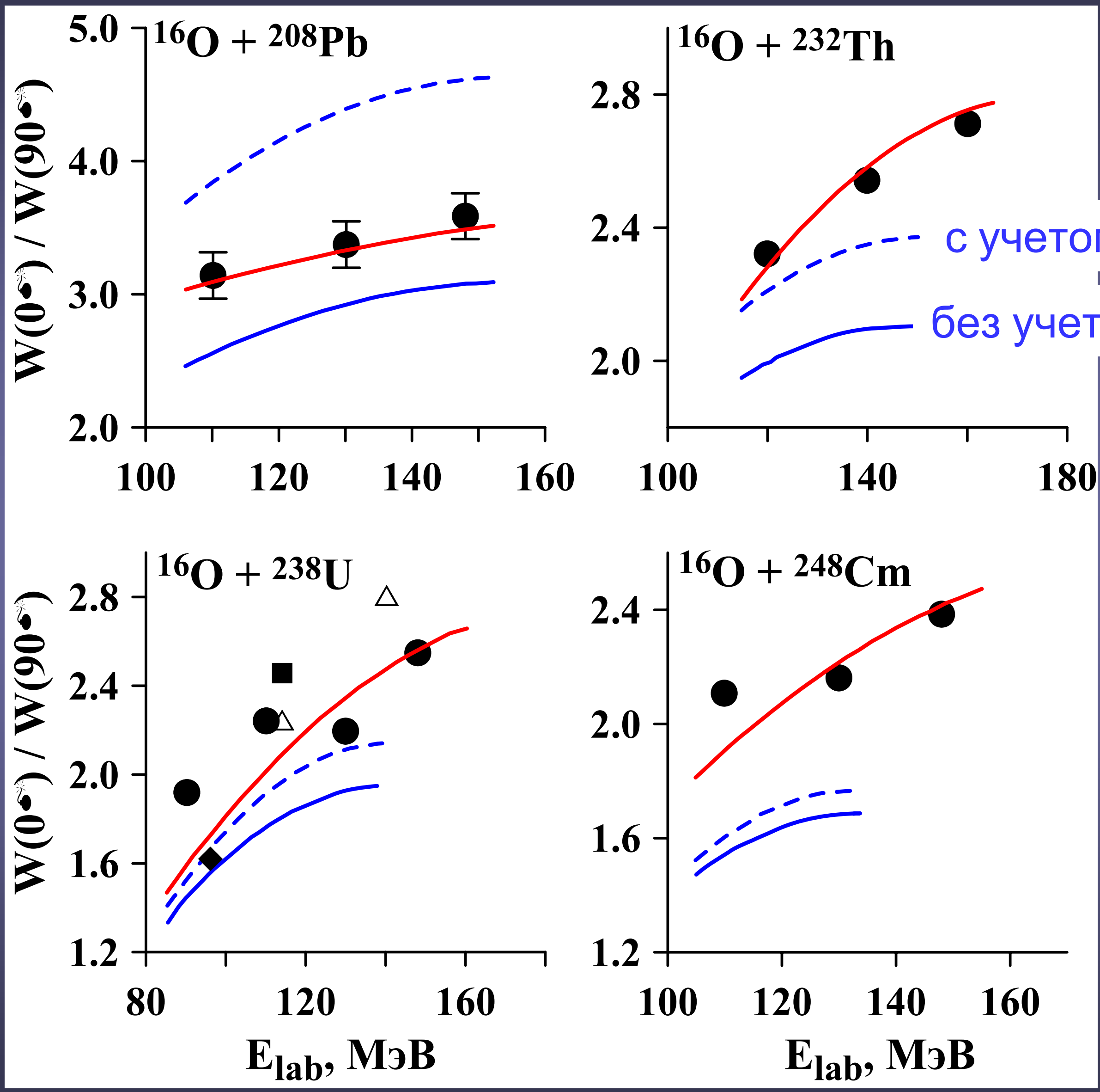
$$W_i(\theta) = \sum_{M=-J_i}^{J_i} \sum_{K=-J_i}^{J_i} \frac{\frac{1}{2} \exp(-M^2/2M_{0i}^2)(2J_i+1) \left| d^{J_i}_{M,K}(\theta) \right|^2 \exp(-K^2/2K_{0i}^2)}{\sum_{M=-J_i}^{J_i} \exp(-M^2/2M_{0i}^2) \sum_{K=-J_i}^{J_i} \exp(-K^2/2K_{0i}^2)}$$

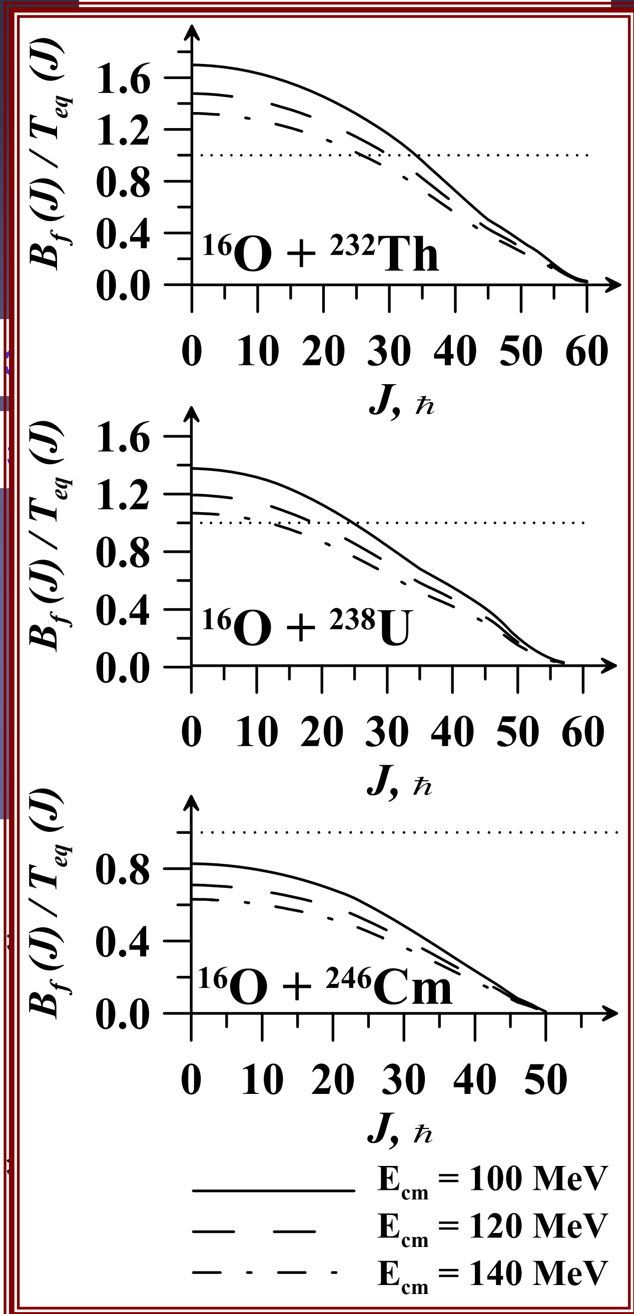
Эмиссия в $\mathbf{r}_{em}$ $\longrightarrow$ $$M_{0i}^2 = \frac{T_i(r_{em})}{\hbar^2} \Im_{\|,i}(r_{em})$$

$E^{*}=100$ МэВ, $\beta=4\times10^{21}$ с$^{-1}$, $J=30\ \hbar$

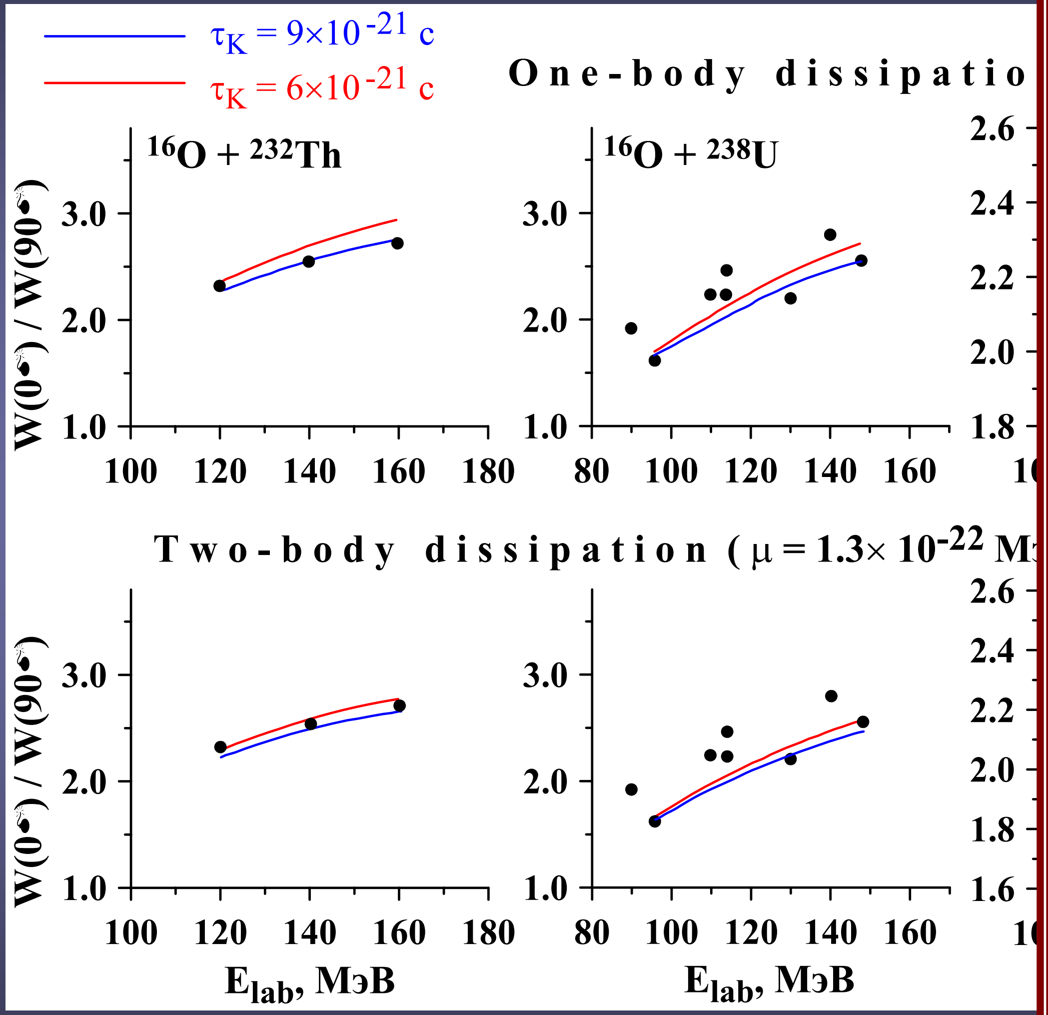


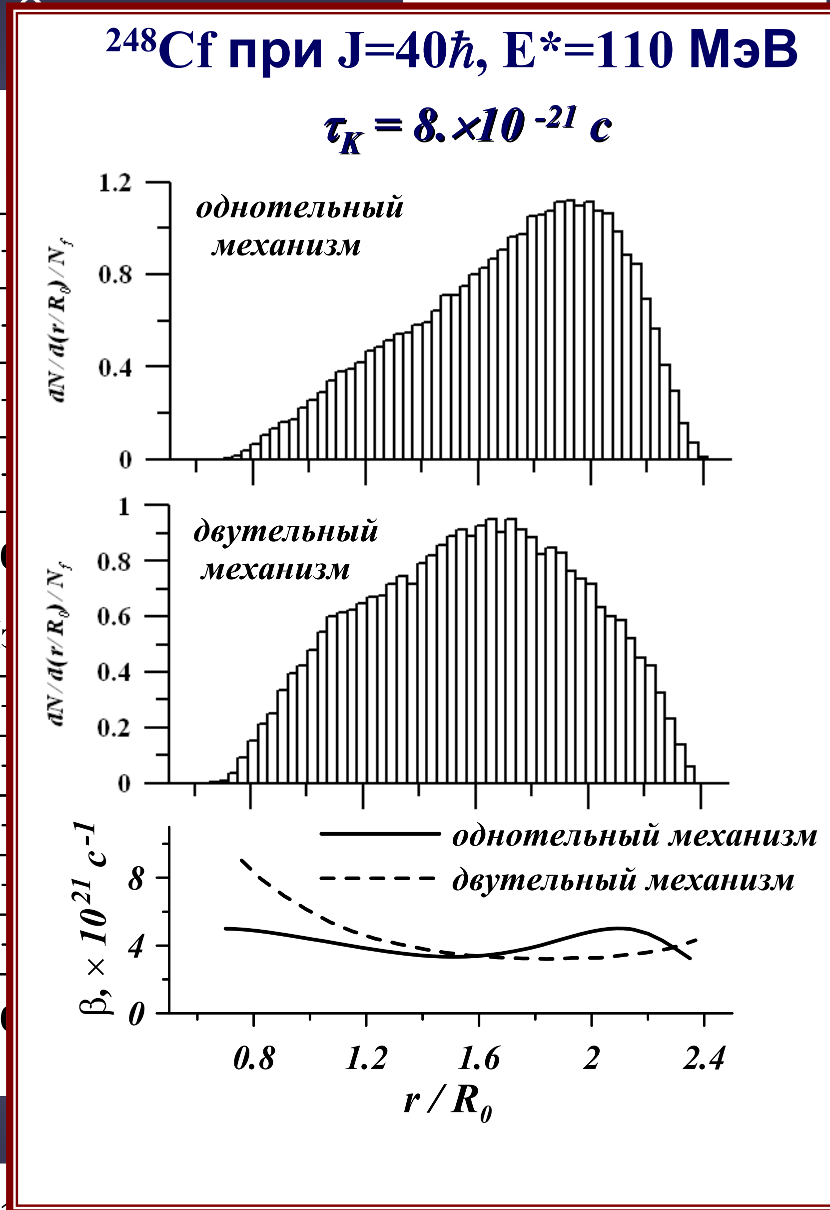
$\tau_K = 6 \times 10^{-21}\ c$





Деформационная зависимость ?





Mass-energy distribution

Адеев Г.Д. и др., ЭЧАЯ, 26 (2005) 732.

$\Longrightarrow$

μ = (0.9 ÷ 1.9)

k_s = (0.1÷ 0.5)

ДИНАМИКО-СТОХАСТИЧЕСКАЯ МОДЕЛЬ

$$V(r,J,K) = B_s(r)E_s^o(Z,A) + B_c(r)E_c^o(Z,A) + \frac{[J(J+1)-K^2]\hbar^2}{2\Im_\perp} + \frac{K^2\hbar^2}{2\Im_\parallel}$$

W. D. Myers and W. J. Swiatecki, Nucl. Phys. 1966 V.81, P.1.

$$\begin{cases} \dfrac{dp}{dt} = -\dfrac{1}{2}\left(\dfrac{p}{m(r)}\right)^2 \dfrac{dm(r)}{dr} - \dfrac{dF}{dr} - \beta(r)p + f(t) \\ \dfrac{dr}{dt} = \dfrac{p}{m(r)} \end{cases}$$

$f(t) = \eta(T\,m\,\beta)^{1/2}$ – случайная сила

$<\eta(t)>=0\,,\ <\eta(t_1),\eta(t_2)>=2\delta(t_1-t_2)$

$$F(r,T,J,K)=V(r,J,K)-a(r)T^2$$

$T = (U/a(r))^{1/2}$

$U = E^* - p^2/(2m) - V(r,J,K)$

$a(r)=a_1A+a_2A^{2/3}B_s(r)$

A.V.Ignatuyk et al., Sov.J.Nucl.Phys. 21 (1975) 1185

$$\rho(U,K) = \frac{a^{1/4}}{8\sqrt{6\pi}\,U^{5/4}}\left(\frac{\hbar^2}{\Im_\parallel}\right)^{1/2} \exp(2\sqrt{aU})$$

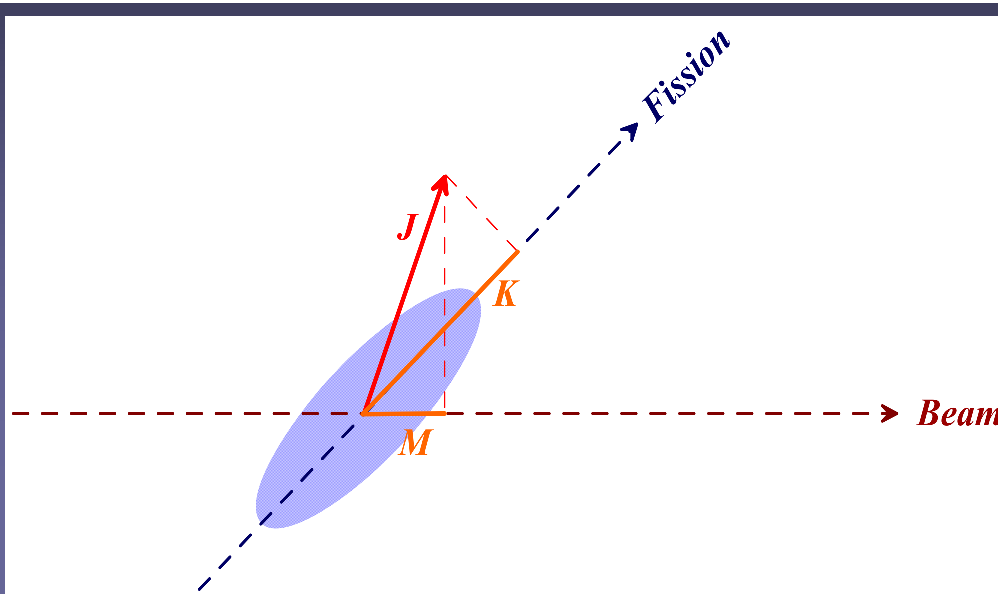
O.Bohr and S. Bjornholm

УГЛОВЫЕ РАСПРЕДЕЛЕНИЯ ОСКОЛКОВ ДЕЛЕНИЯ

$$P(K',t\,|\,K,t_0) = e^{-(t-t_0)/\tau_K}\,\delta(K-K_0) + \left(1-e^{-(t-t_0)/\tau_K}\right)\Phi(K)$$

$$\Phi(K) \sim \exp\left[\frac{-\Delta F(\mathbf{r},T,J,K)}{T}\right]$$

$$-J \le K \le J$$



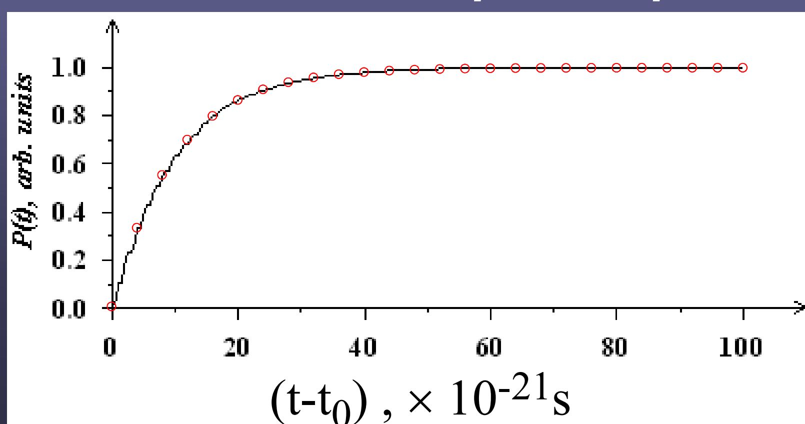
1. $\xi \in [0,1]$

2. $\xi < h/\tau_K$

3. $\Phi(K) \rightarrow K$

4. $W(\theta) = \frac{1}{N_f}\sum_{i=1}^{N_f}\frac{1}{2}(2J_i+1)\left|d^{J_i}_{M_i,K_i}(\theta)\right|^2$

τ_K – время релаксации для K-моды; h – временной шаг численного интегрирования уравнений Ланжевена; N_f - количество Ланжевеновских траекторий, достигших точки разрыва

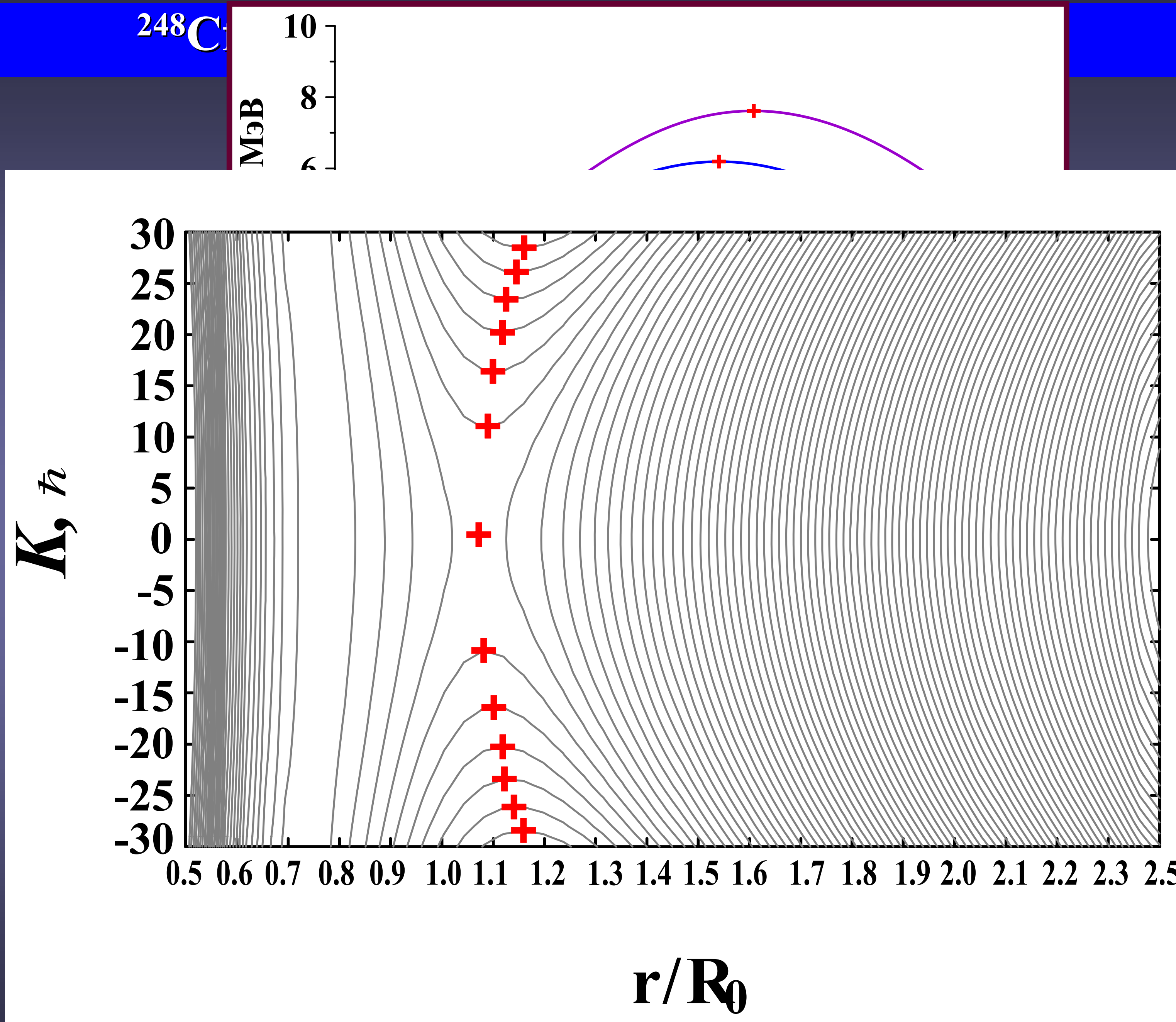


$\tau_K = 10\times10^{-21}$ s

○ - $P(K',t\,|\,K,t_0)$

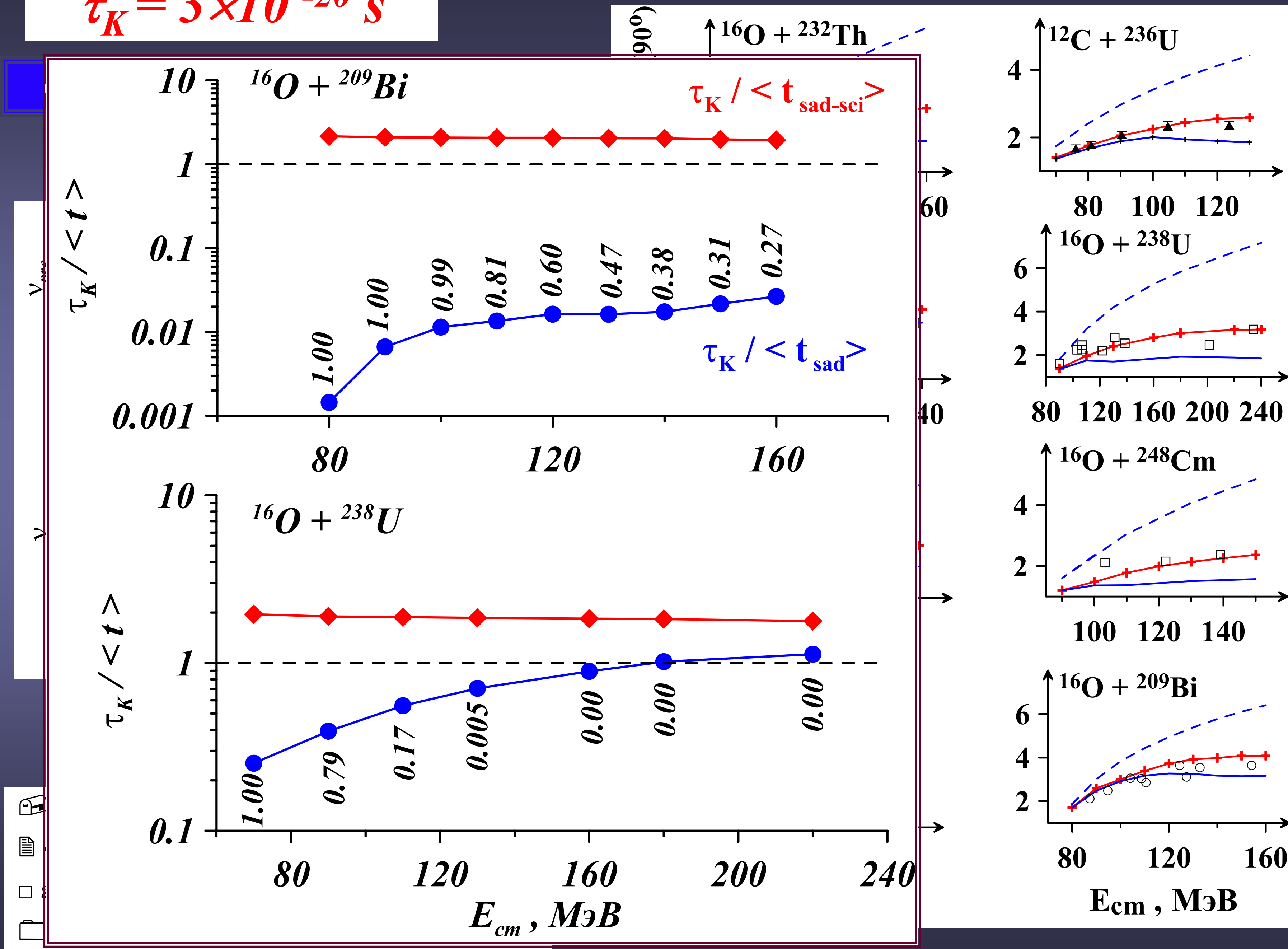
——— - simulation

^{248}C

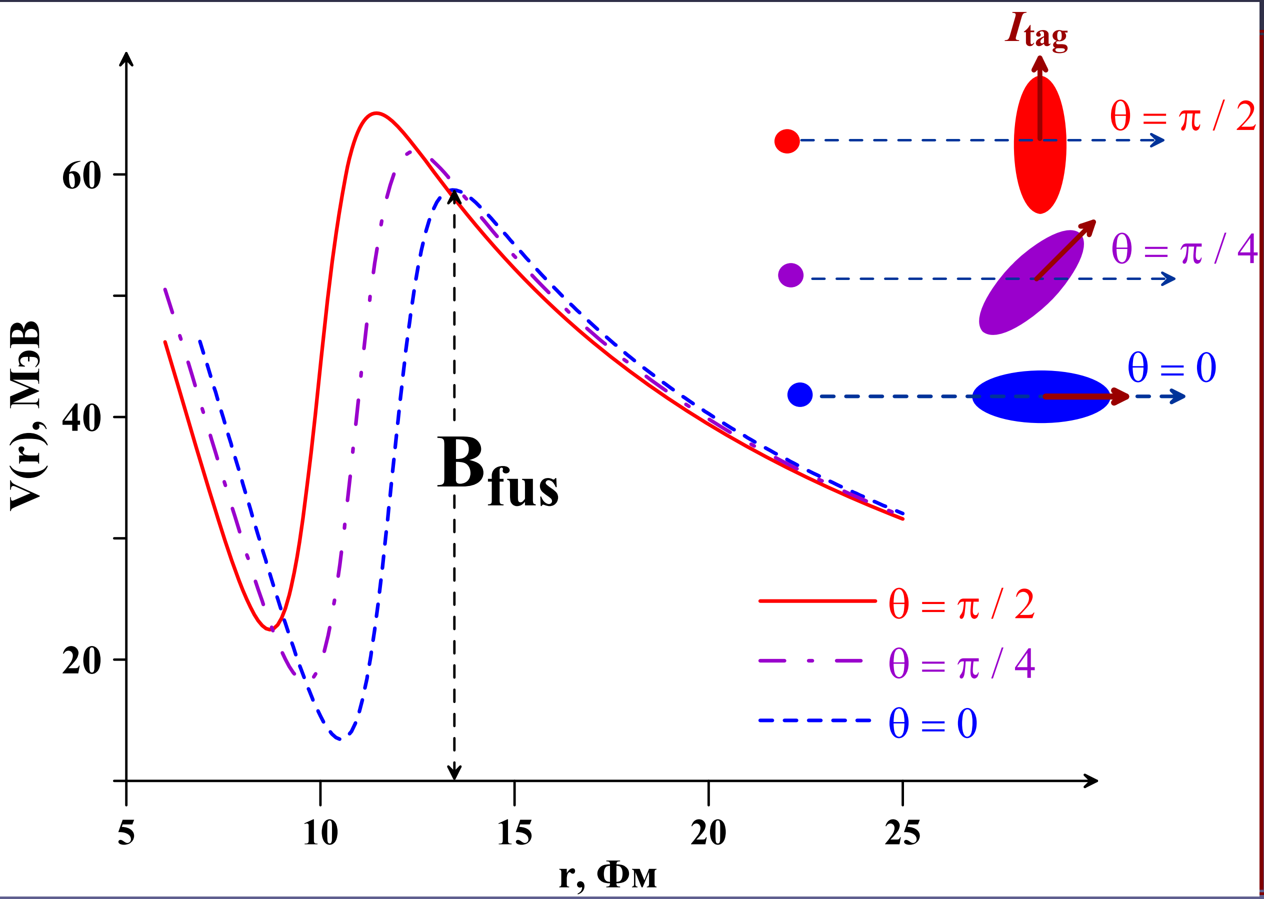


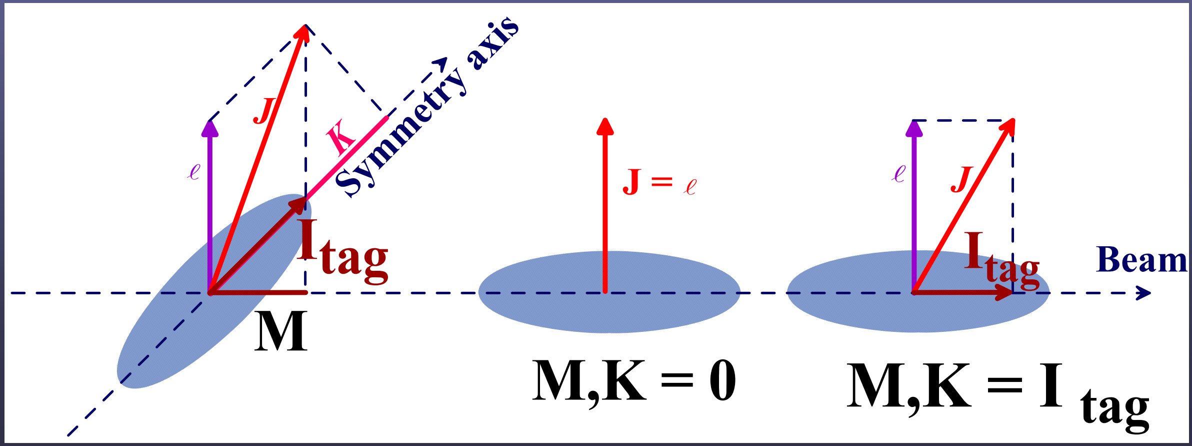
10
8
6
МэВ
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
K, ħ
0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.3 2.5
r/R0

$\tau_K = 3\times10^{-20}$ s

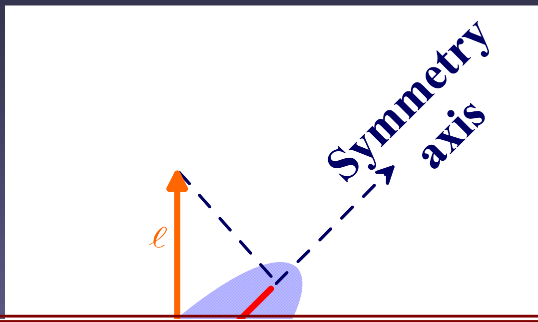


Угловые распределения осколков деления в реакциях полного слияния деформированных ядер





$$w(J,K) = \frac{\sum\limits_{\ell=0}^{\infty} \sum\limits_{K_\ell=-\ell}^{\ell} \partial\sigma(\ell,K_\ell) \left| C^{I_{tag},\ \ell,\ J}_{I_{tag},\ K_\ell,\ K} \right|^2}{\sum\limits_{\ell=0}^{\infty} \sum\limits_{K_\ell=-\ell}^{\ell} \partial\sigma(\ell,K_\ell)}$$



$$\mathbf{w}(\mathbf{J},\mathbf{K}) = \sum_{\ell=0}^{\infty} \sum_{S=|I_{tag}-I_p|}^{I_{tag}+I_p} \sum_{K_\ell=-\ell}^{\ell} \frac{\partial\sigma(\ell,K_\ell,K_p) \left| C^{S,\ \ell,\ J}_{K-K_\ell,\ K_\ell,\ K} \right|^2 \left| C^{I_{tag},\ I_p,\ S}_{I_{tag},\ K-I_{tag}-K_\ell,\ K-K_\ell} \right|^2}{\sum\limits_{\ell=0}^{\infty} \sum\limits_{K_\ell=-\ell}^{\ell} \sum\limits_{K_p=-I_p}^{I_p} \partial\sigma(\ell,K_\ell,K_p)}$$

$$\partial\sigma(\ell,K_\ell,K_p) = \iint \left| d^{\ell}_{K_\ell,0}(\theta_{tag}) \right|^2 \left| d^{I_p}_{I_p,K_p}(\theta_p) \right|^2 \partial\sigma(\ell,\theta_{tag},\theta_p)\ \sin(\theta_{tag})\ \sin(\theta_p)\ d\theta_{tag}\ d\theta_p$$

$$\partial\sigma(\ell,\mu_{tag}) = \int \left| d^{I_{tag}}_{I_{tag},\mu_{tag}}(\theta_{tag}) \right| \partial\sigma(\ell,\theta_{tag}) \sin(\theta_{tag})\ d\theta_{tag}$$

R.D.Butt et al., Phys. Rev. C, V. 66 (2002) 044601

$$V = V_{Nucl} + V_{Coul} + V_{Rot}$$

$$V_{Nucl}(R,\theta) = \frac{-V_0}{1 + exp\left\{\frac{R - R_p - R_{tag}(\theta)}{a}\right\}}$$

$$R_{tag} = r_0 A_{tag}^{1/3} \left\{ 1 + \beta_2 Y_{20}(\theta) \right\}$$

$$R_p = r_0 A_p^{1/3}$$

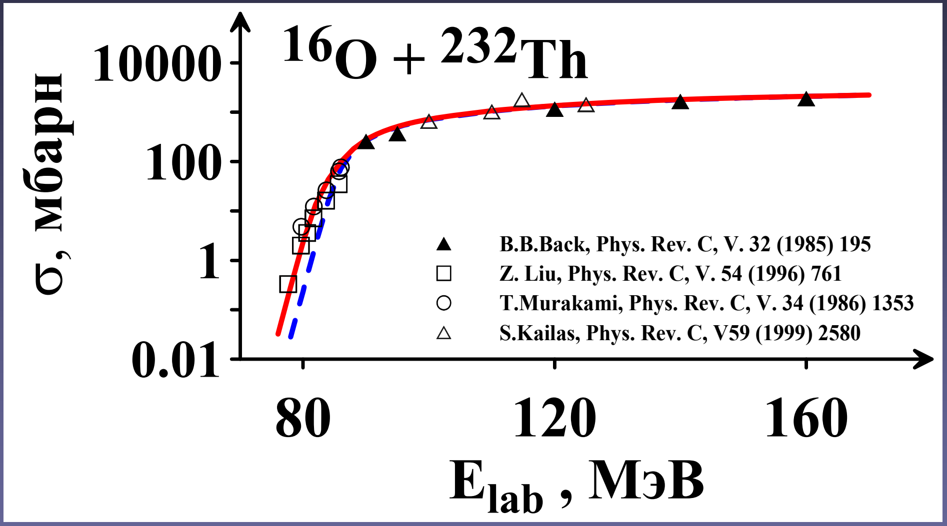
$$V_{Rot}(R,\ell) = \frac{\hbar^2 \ell(\ell + 1)}{2\mu R^2}$$

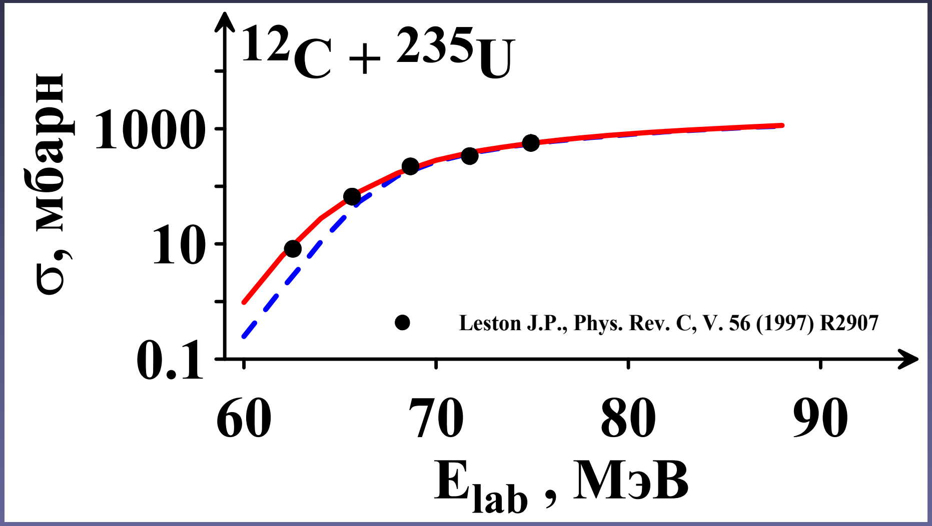
$$V_{Coul}(R,\theta_{tag},\theta_p,\beta_{tag},\beta_p) = \frac{Z_p Z_{tag} e^2}{R} + \left(\frac{9}{20\pi}\right)^{1/2} \left(\frac{Z_p Z_{tag} e^2}{R^3}\right) \sum_{i=p,tag} R_i^2 \beta_i P_2(\cos\theta_i) + \left(\frac{3}{7\pi}\right)\left(\frac{Z_p Z_{tag} e^2}{R^3}\right) \sum_{i=p,tag} R_i^2 (\beta_i P_2(\cos\theta_i))^2$$

$$\hbar\omega(\ell,\theta) = \hbar\left\{\left[\frac{d^2 V(\ell,\theta)}{dR^2}\right]\frac{1}{\mu}\right\}^{1/2}$$

$$\sigma(\ell,\theta) = \left(\frac{\pi\hbar^2}{2\mu E}\right) \frac{2\ell + 1}{1 + exp(2\pi(B(\ell,\theta) - E)/\hbar\omega(\ell,\theta))}$$

$$\sigma_{tot} = \sum_{l=0}^{\infty} \int_0^{\frac{\pi}{2}} \sigma(l,\theta) sin(\theta) d\theta$$



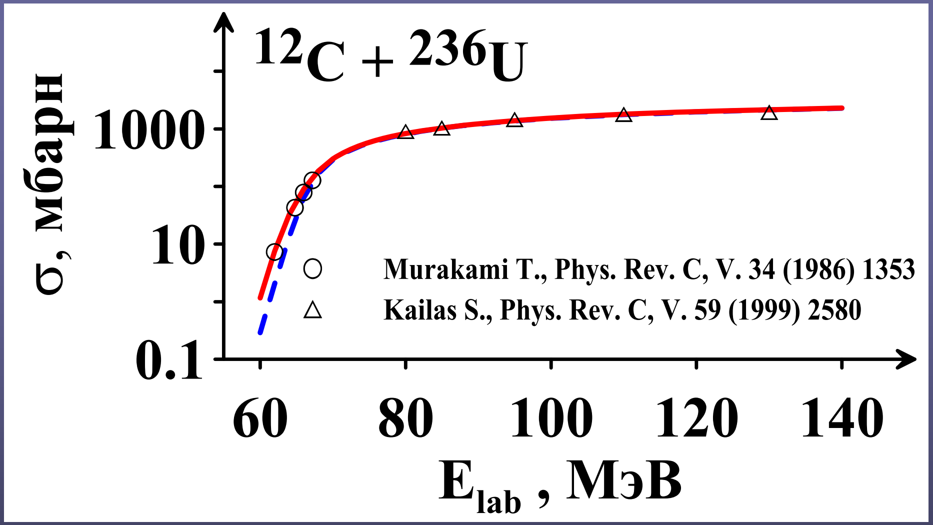


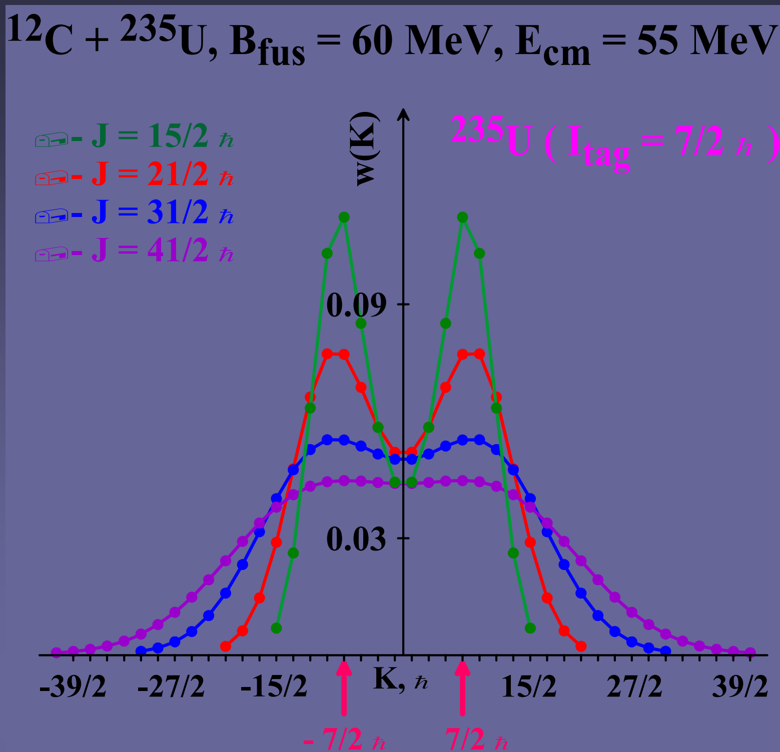
$V_0 = 70\ MeV$ $\quad r_0 = 1.26\ fm$

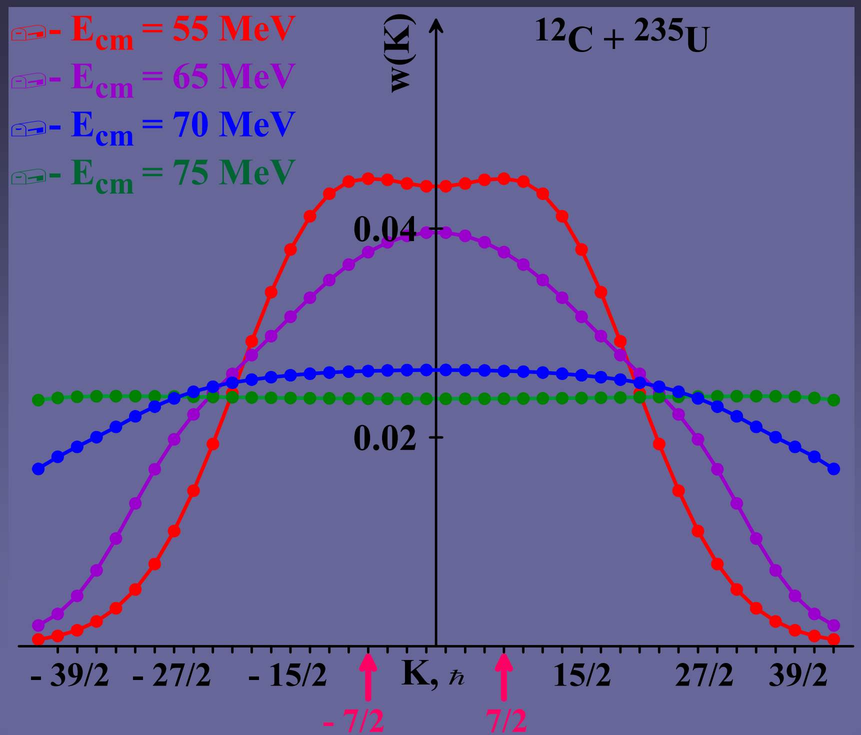
А.С.Ильинов и др., ЯФ Т.36 (1982) 118

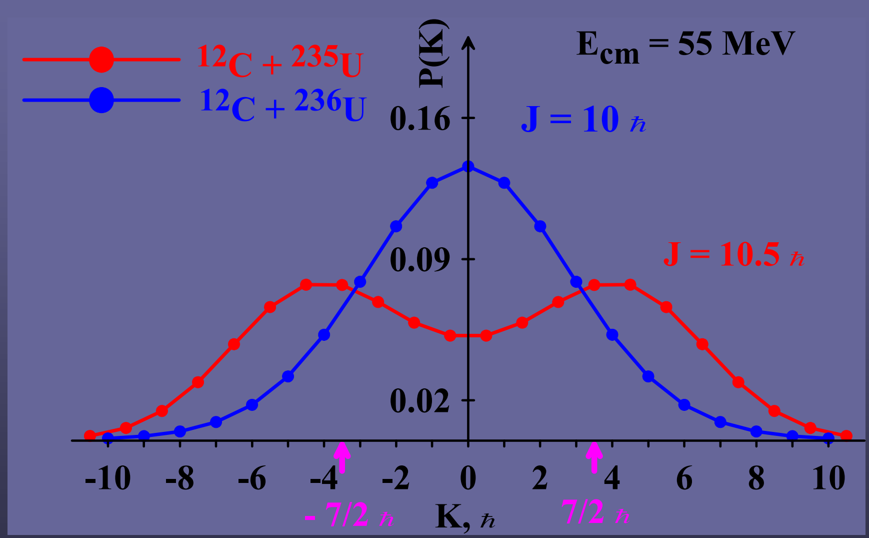
a = 0.53 fm (O+Th)

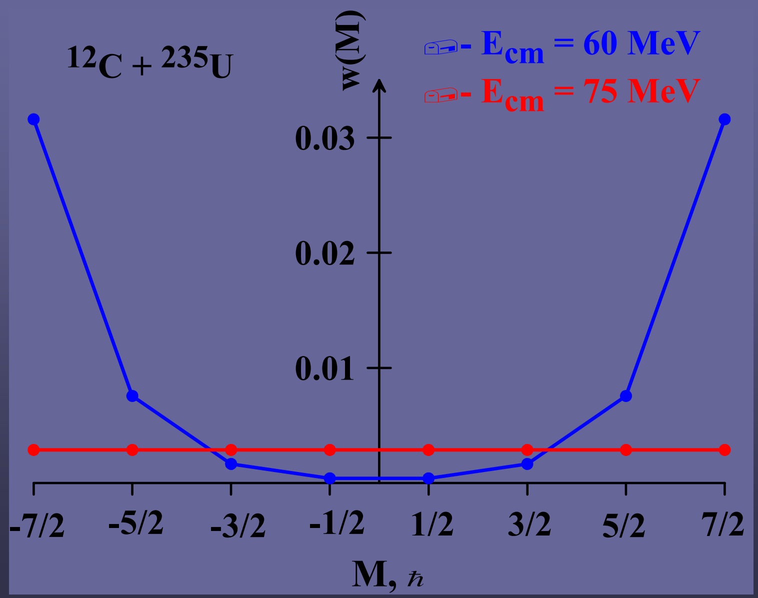
a = 0.47 fm (C+U)

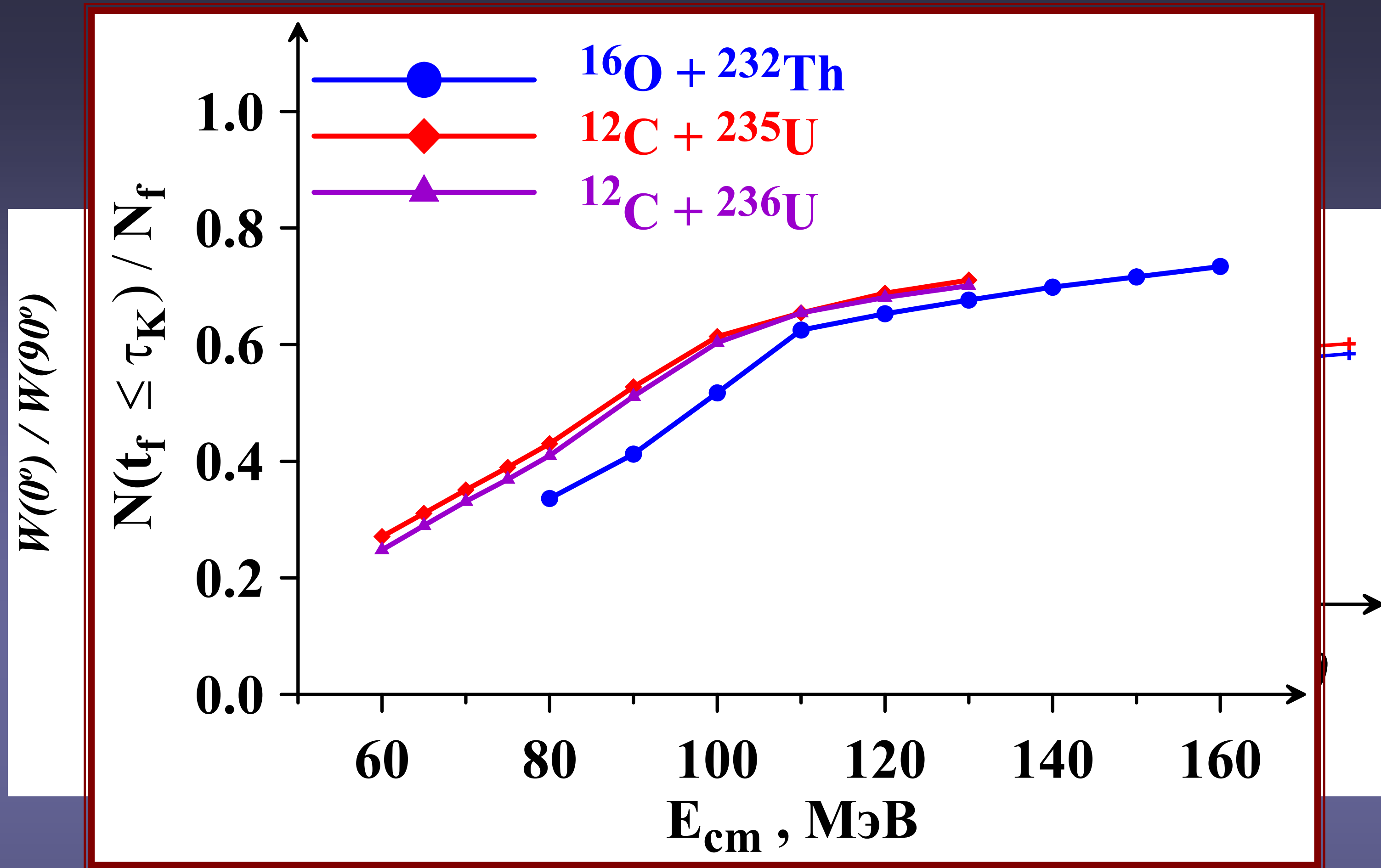



12C + 235U, Bfus = 60 MeV, Ecm = 55 MeV
J = 15/2 ℏ
J = 21/2 ℏ
J = 31/2 ℏ
J = 41/2 ℏ
w(K)
235U (Itag = 7/2 ℏ)
0.09
0.03
-39/2
-27/2
-15/2
K, ℏ
15/2
27/2
39/2
- 7/2 ℏ
7/2 ℏ


Ecm = 55 MeV
Ecm = 65 MeV
Ecm = 70 MeV
Ecm = 75 MeV
w(K)
12C + 235U
0.04
0.02
- 39/2
- 27/2
- 15/2
K, ℏ
15/2
27/2
39/2
- 7/2
7/2


12C + 235U
12C + 236U
P(K)
Ecm = 55 MeV
0.16
J = 10 ℏ
0.09
J = 10.5 ℏ
0.02
-10
-8
-6
-4
-2
0
2
4
6
8
10
- 7/2 ℏ
K, ℏ
7/2 ℏ


12C + 235U
w(M)
Ecm = 60 MeV
Ecm = 75 MeV
0.03
0.02
0.01
-7/2
-5/2
-3/2
-1/2
1/2
3/2
5/2
7/2
M, ℏ



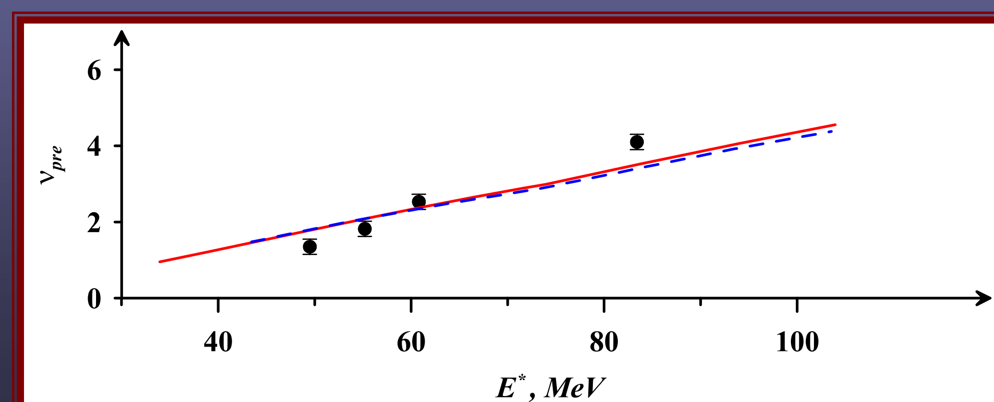
$\tau_K = 5 \times 10^{-20}$ *c*

- Experiment ($^{16}O + {}^{232}Th \rightarrow {}^{248}Cf$),

A.Saxena, Phys. Rev. C 49 (1994) 932

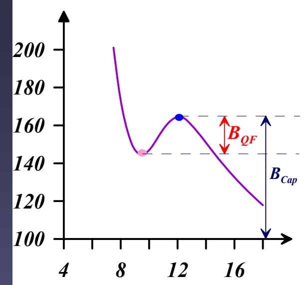
Calculation ($^{16}O + {}^{232}Th \rightarrow {}^{248}Cf$) with $k_s = 0.2$

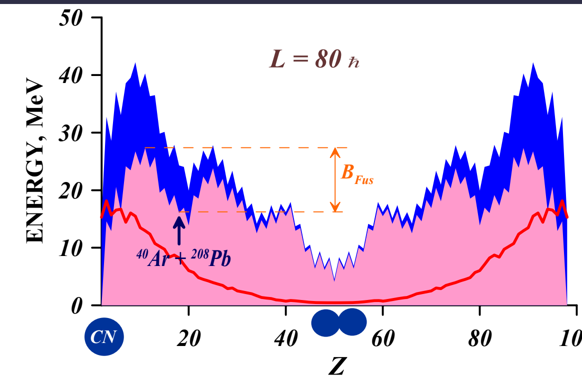
Calculation ($^{12}C + {}^{236}U \rightarrow {}^{248}Cf$) with $k_s = 0.2$

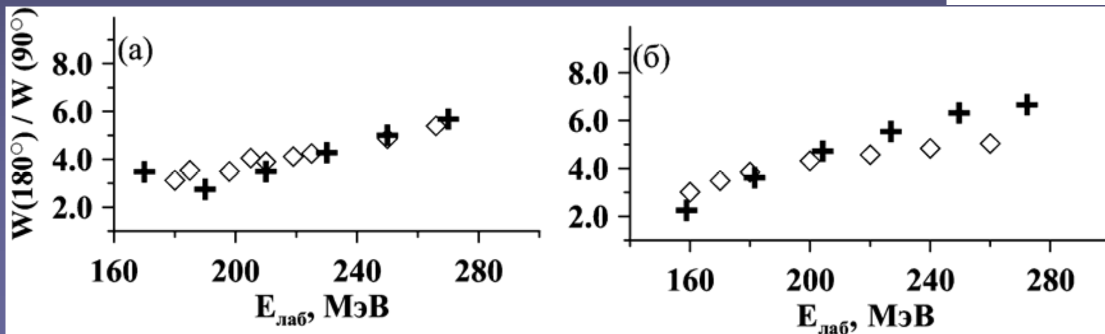


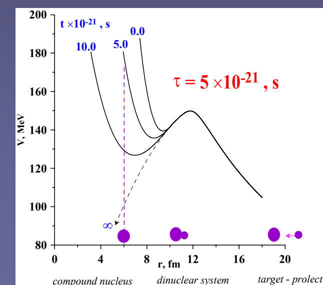
QUASIFISSION

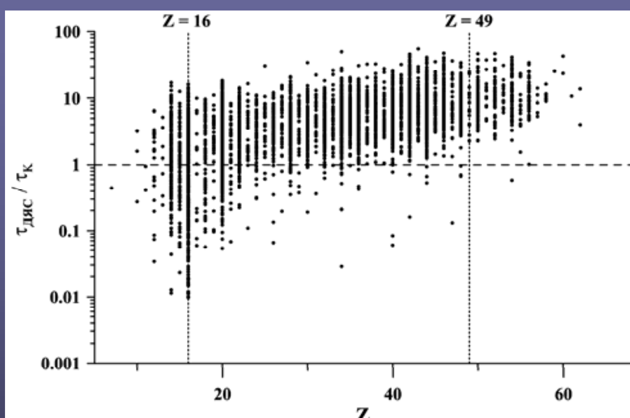
(а) -$^{32}S + ^{208}Pb$ и (б) - $^{28}Si + ^{208}Pb$

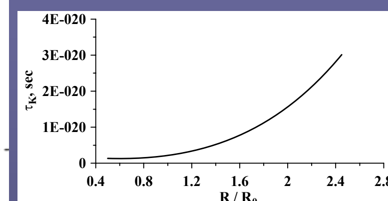


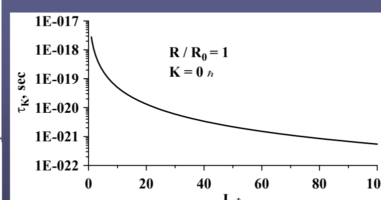






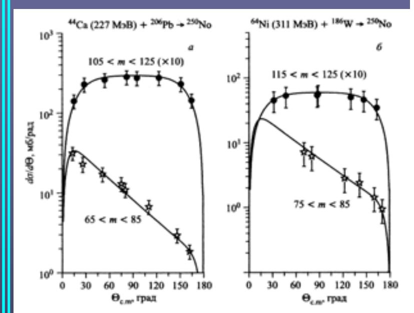






$$\tau_K \propto \frac{1}{\omega^2_{DNS}}$$

Mass-angle correlations



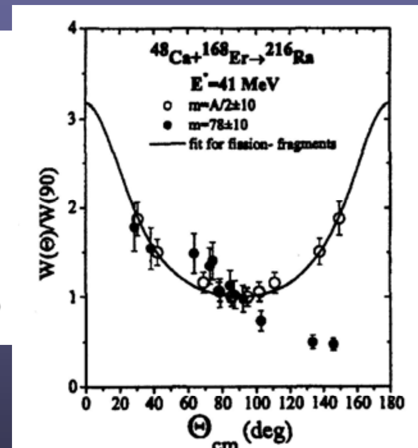
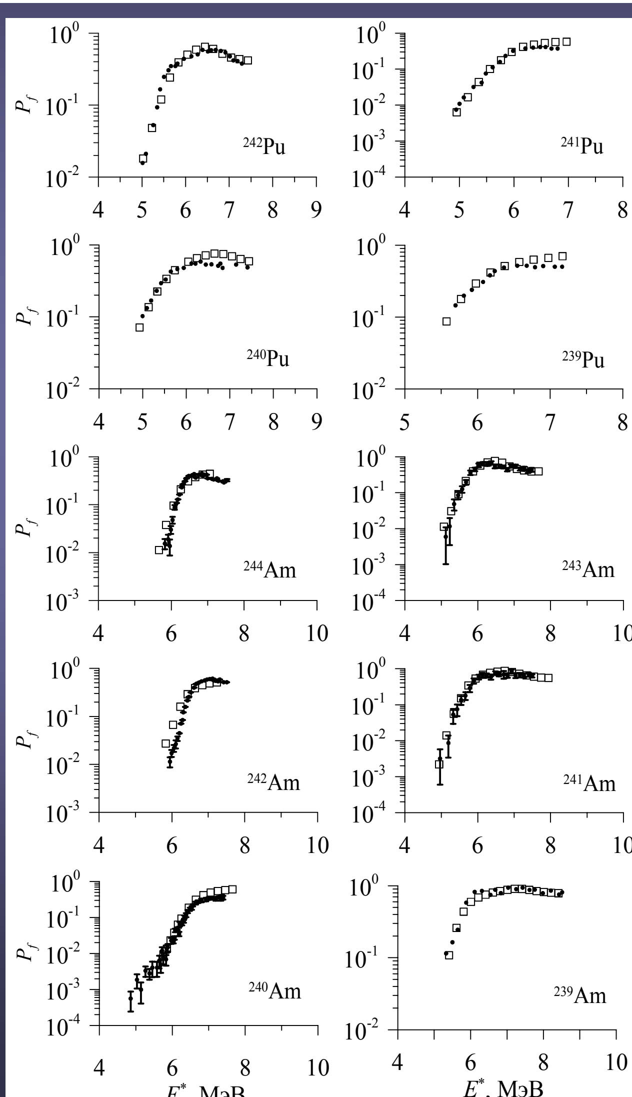
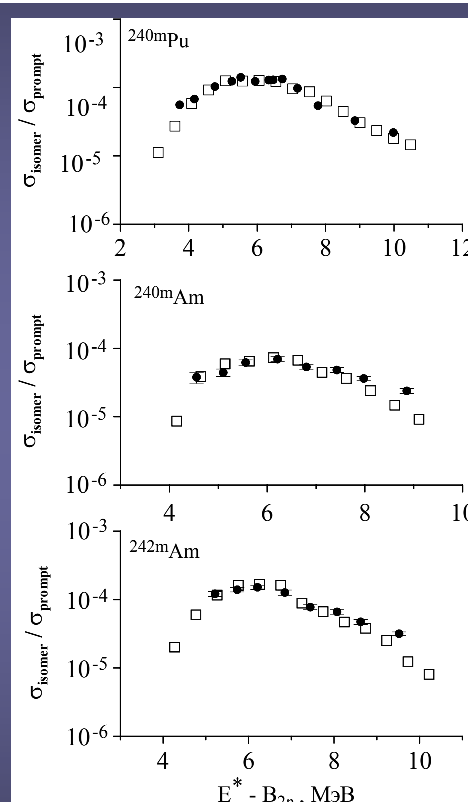


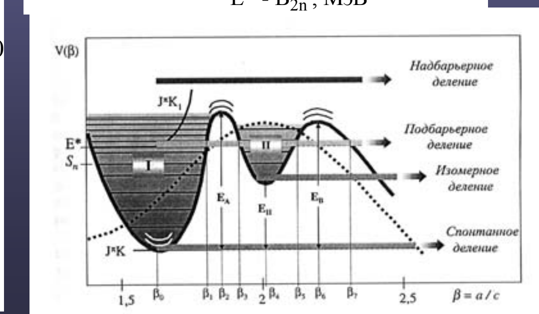
Figure 2: Experimental angular distributions of fission fragments from the reaction $^{48}Ca+^{168}Er$ at E_{lab} = 195 MeV.

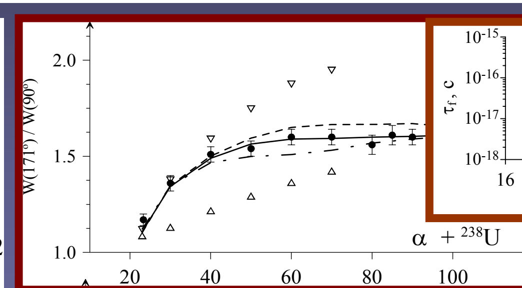
$$\tau_{DNS} = ?$$

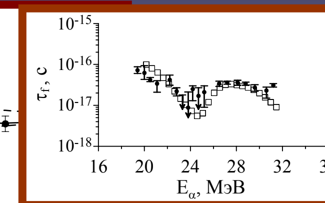
Согласованное описание экспериментальных данных по
-вероятностям деления ядер изотопов Pu и Am;
- выходам изомеров формы для реакций α + 238U при Eα = (20÷32) МэВ
и d + 242,240Pu при Ed = (20÷30) МэВ;
-длительностям деления для реакции α + 238U при Eα = (20÷32) МэВ;
-угловым распределениям осколков деления для реакций α + 238U, 237Np при Eα = (20÷100) МэВ

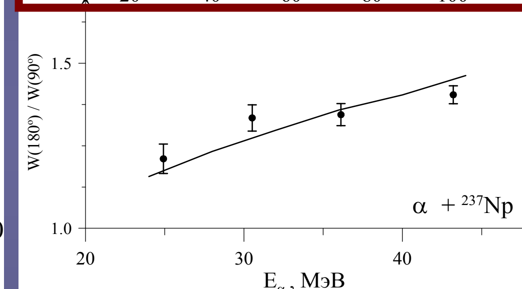


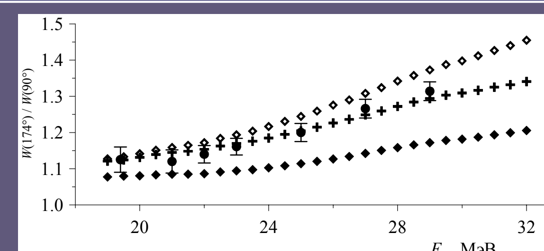






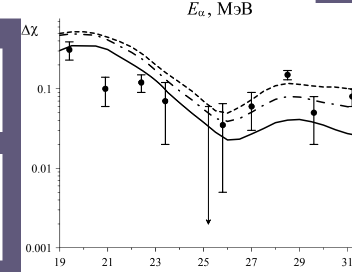






α + ^{235}U

Blocking technique

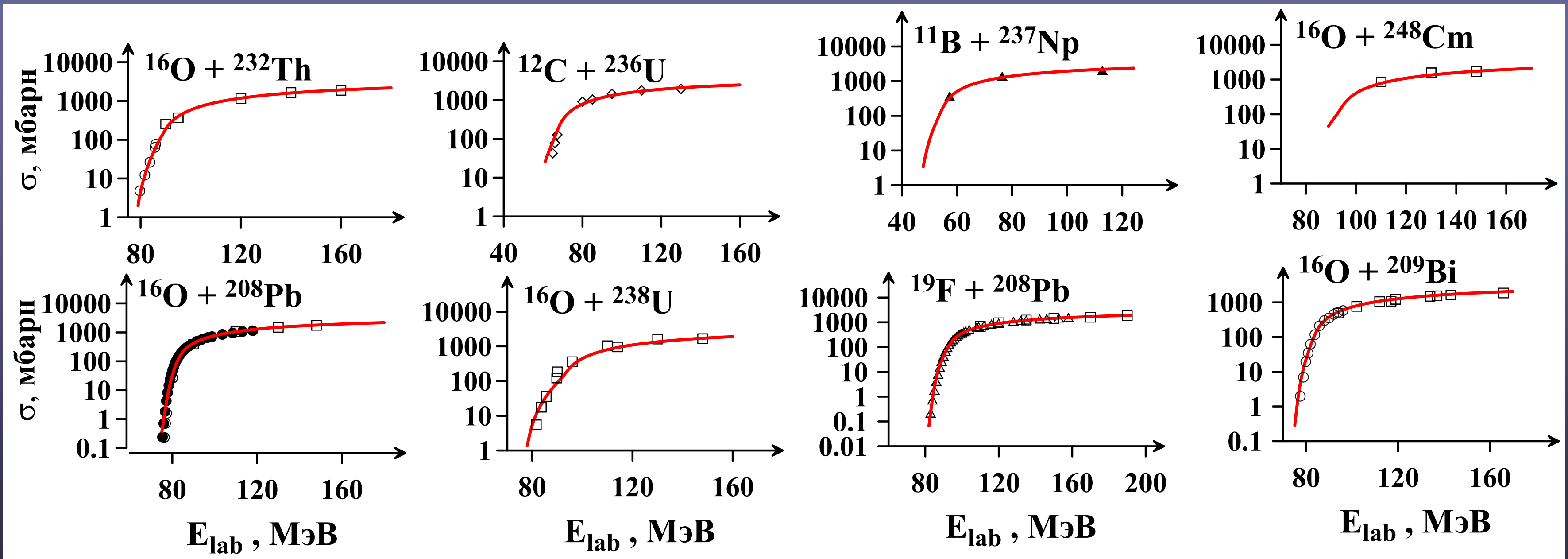


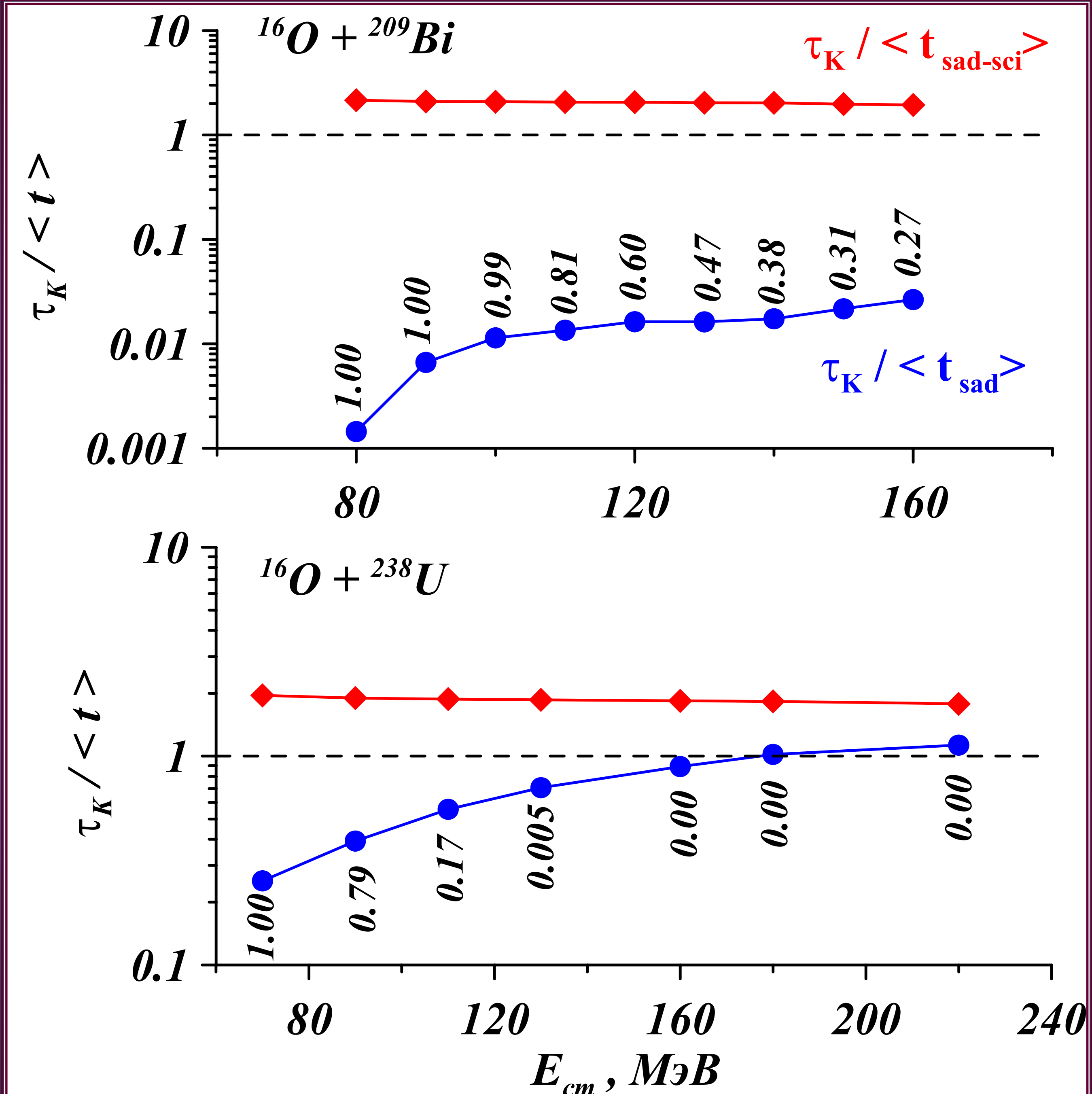
INITIAL CONDITIONS

$$\Phi(r,p,J,K,M) = \frac{1}{\sqrt{2\pi mT}} \; exp\left(-\frac{p^2}{2mT}\right) \; \delta(r-r_o) \;\; w(J,K,M)$$

$$w(J,K,M) = \frac{d\sigma}{dJ} w_J(K,M)$$

Wong model for $\frac{d\sigma}{dJ}$





$^{16}O + ^{209}Bi$
$\tau_K / < t_{sad\text{-}sci} >$
$\tau_K / < t_{sad} >$
$\tau_K / < t >$
10
1
0.1
0.01
0.001
1.00
1.00
0.99
0.81
0.60
0.47
0.38
0.31
0.27
80
120
160
$^{16}O + ^{238}U$
$\tau_K / < t >$
10
1
0.1
1.00
0.79
0.17
0.005
0.00
0.00
0.00
80
120
160
200
240
E_{cm} , МэВ