SOME SHORT NOTES ON THE FISSION PROCESS
SOME EXAMPLES OF RESULTS
OF RELATED MICROSCOPIC CALCULATIONS

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DESCRIBE THE SHAPE OF THE DEFORMED DROP (AXIAL) WITH A SURFACE EQUATION

axial sym.

$$|\vec{r}| = R(\theta)$$

$$R(\theta) = R_0(\{\beta_i\})\left[1+\sum_{i=2}^{\infty}\beta_i P_i(\cos\theta)\right]$$

$$\rho(\vec{r}) = \rho_0 H[R(\theta)-r]$$

MOST IMPORTANT $i=2$

$$E_s(\beta) = E_s(0)\left[1+\frac{2}{5}\beta^2\right]$$

$$E_c(\beta) = E_c(0)\left[1-\frac{1}{5}\beta^2\right]$$

LORD RAYLEIGH (1882)

$$E_{def}(\beta) = E(0) + \frac{2}{5}\beta^2 E_s(0)\left[1-\frac{E_c(0)}{2E_s(0)}\right]$$

$$\left(E(0) = E_s(0) + E_c(0)\right)$$

$E_c(0) = a_c Z^2 A^{-1/3}$ $\quad a_c \sim 0.7$ MeV

$E_s(0) = a_s A^{2/3}$ $\quad a_s \sim 18$ MeV

$$\Rightarrow x \text{ fissility} = \frac{E_c(0)}{2E_s(0)}$$

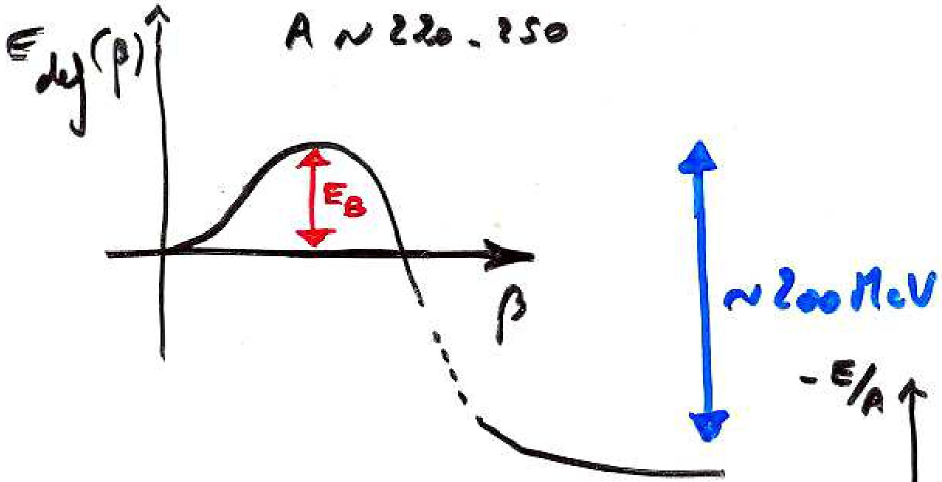
$$= \frac{Z^2}{A} \Big/ \left(\frac{Z^2}{A}\right)_{crit} \qquad \left(\frac{Z^2}{A}\right)_{crit} = \frac{2a_s}{a_c}$$

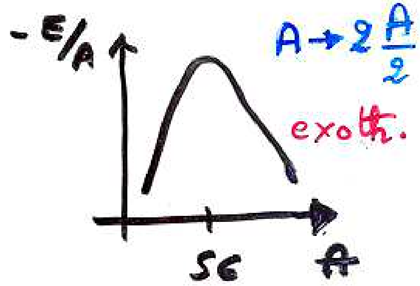
$\underline{x > 1}$ sphere ($\beta = 0$) unstable

$\underline{x < 1}$ sphere ($\beta = 0$) stable

$$\left(E_{def}(\beta) = E(0) + \frac{2\beta^2}{5}(1-x) \right)$$

$x < 1$





Cohen–Swiatecki:

$0.75 < x < 1$

$$E_B \approx 0.83\,(1-x)^3 \quad \text{MeV}$$

BUT

NUCLEI ARE "MESOSCOPIC"

$\exists$ QUANTAL EFFECTS

s.p. level density highly singular

$$g(e) = \sum_i \delta(e - e_i)$$

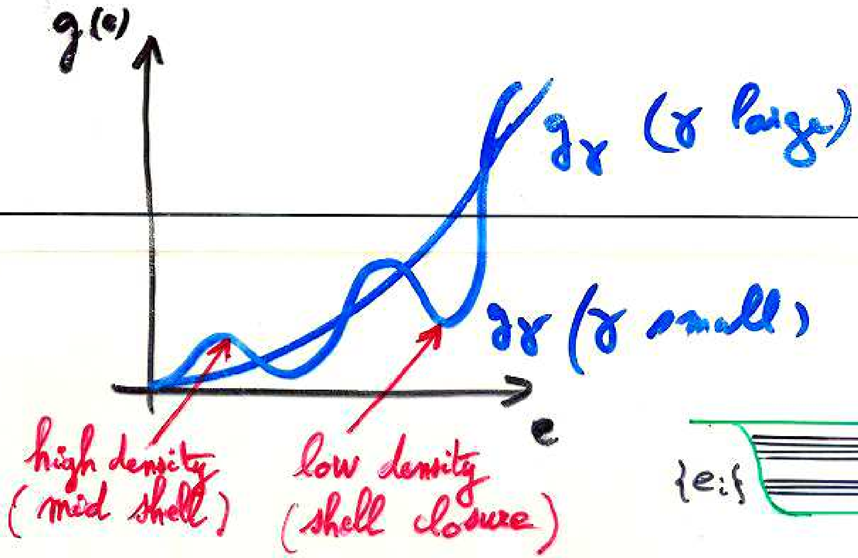
convolution with a smoothing function of range γ

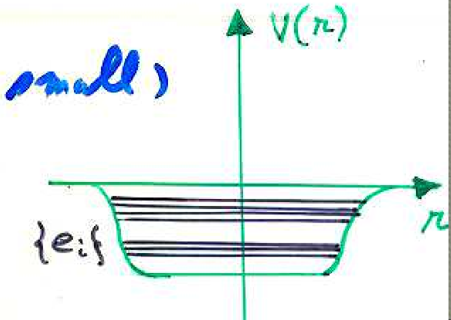
$\gamma \sim$ inter-level distances

$g_\gamma(e)$ reflects the shell structure

$\gamma \sim$ inter-shell distances

$g_\gamma(e)$ exhibits the underlying continuous structure





quantal total energy

- $E = \sum_i e_i$ if $H_{\text{one body}}$

  $\sim \frac{3}{4} \sum_i e_i$ if $H_{\text{two body attractive}}$ generating a HO-like attractive mean-field

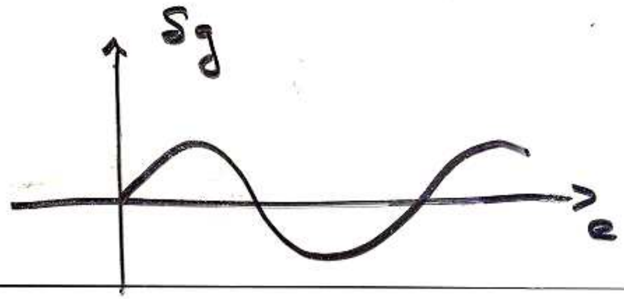
  Virial theorem

- $E \propto \int e \, g(e) \, de$

$\bar{g}(e) = g_\gamma(e)$ $\quad \gamma$ large

$\tilde{g}(e) = g_\gamma(e)$ $\quad \gamma$ small

$\delta g = \bar{g} - \tilde{g}$



$\Rightarrow \delta E \propto \int e \, \delta g(e) \, de$

Near shell closu

E < average

At mid shell

E > average

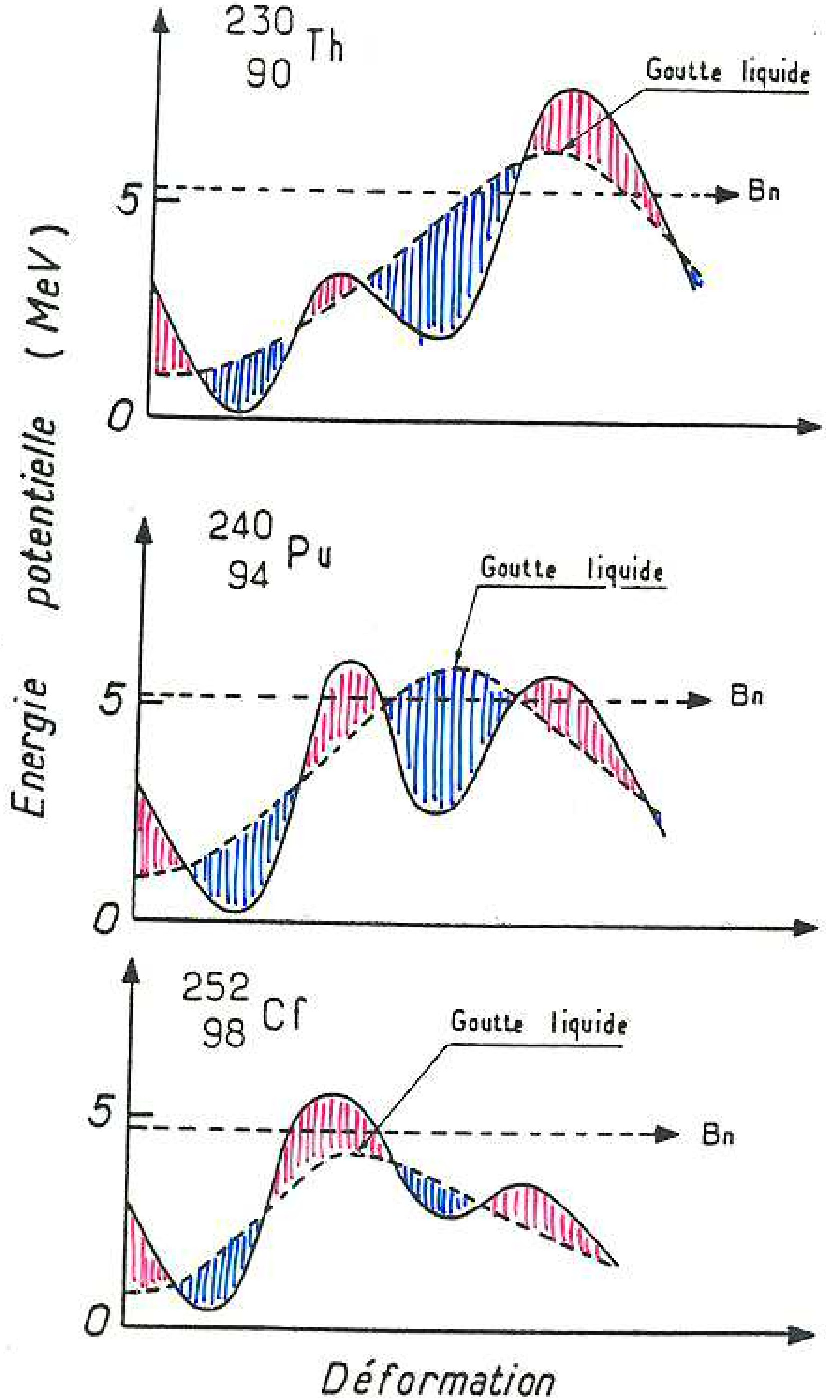
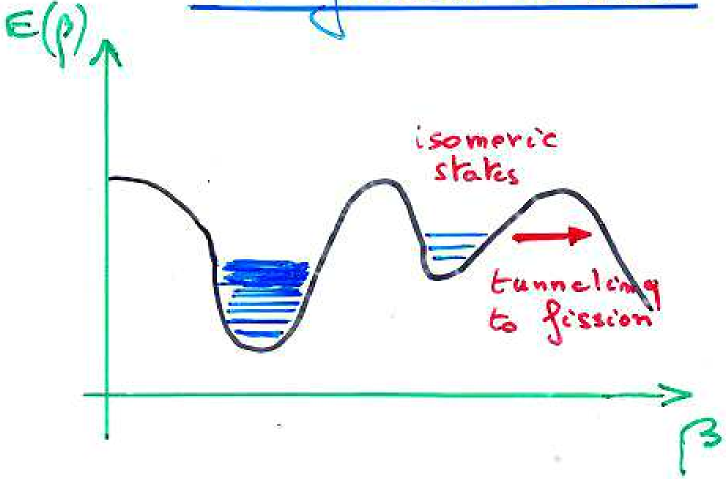


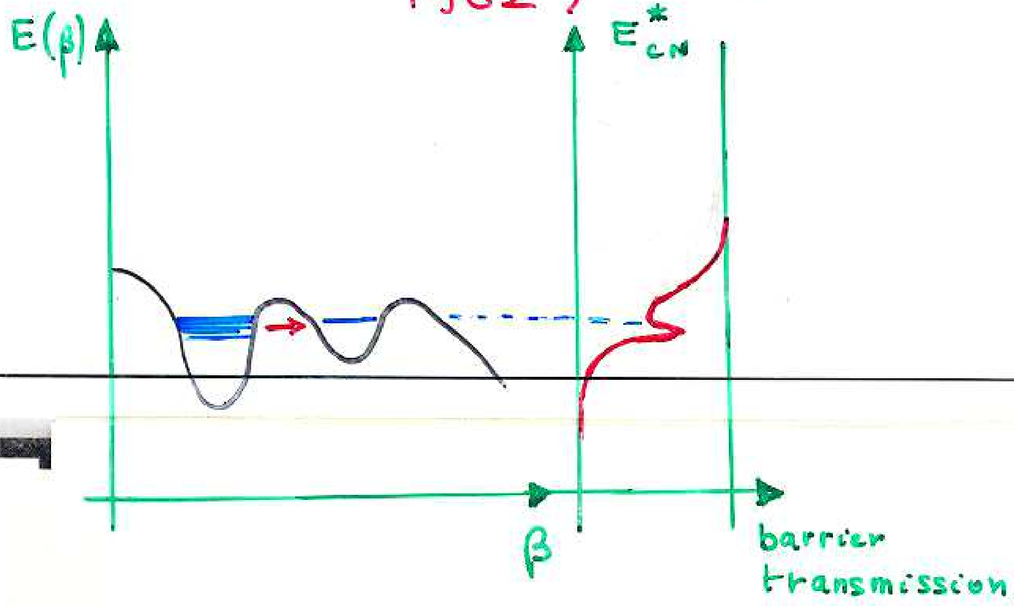
Fig.B3-2: Allure des barrières de fission calculées par la méthode de Strutinski et comparées aux barrières type goutte liquide (B_n est l'énergie de liaison d'un neutron pour le noyau considéré).

These shell effects explain

The fission isomers (Polikanov, Dubna 1962)

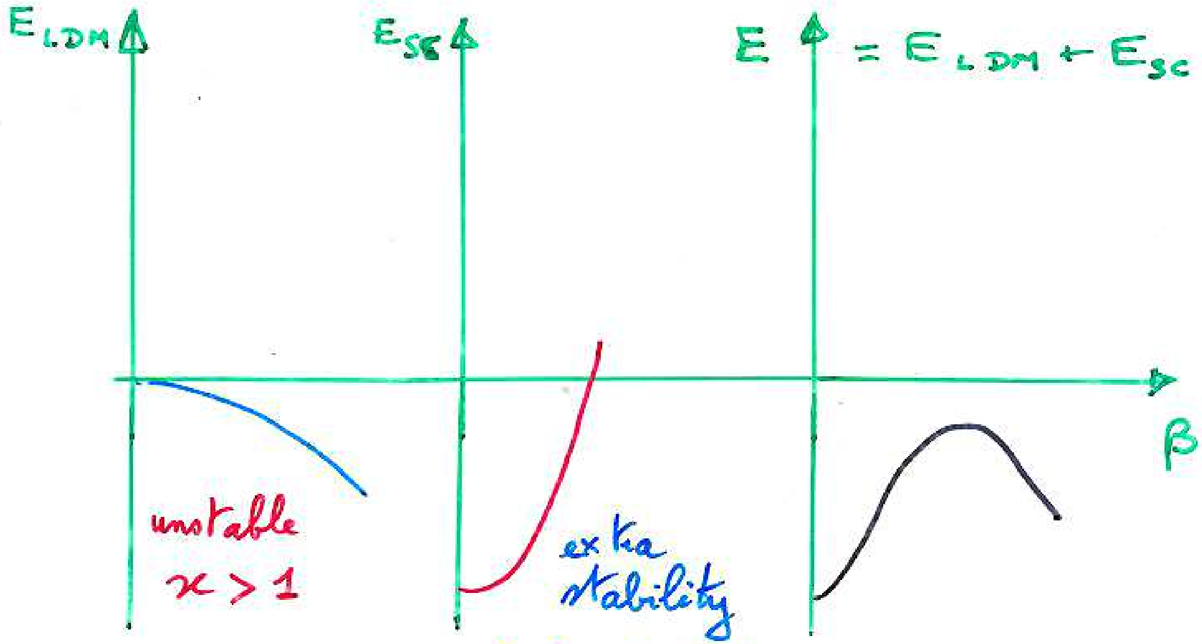


The sub-barrier resonances (e.g. in n-f reactions) (Michaudon, Saclay 1962)

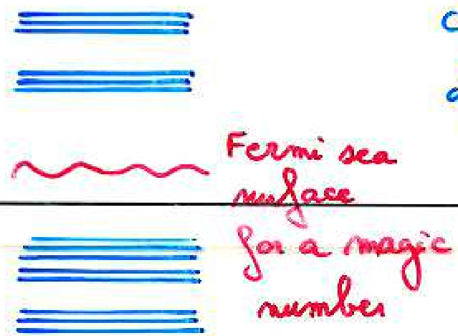


It also explains the "existence" of "super-heavy" nuclei (up to $Z = 117$ $A = 294$)

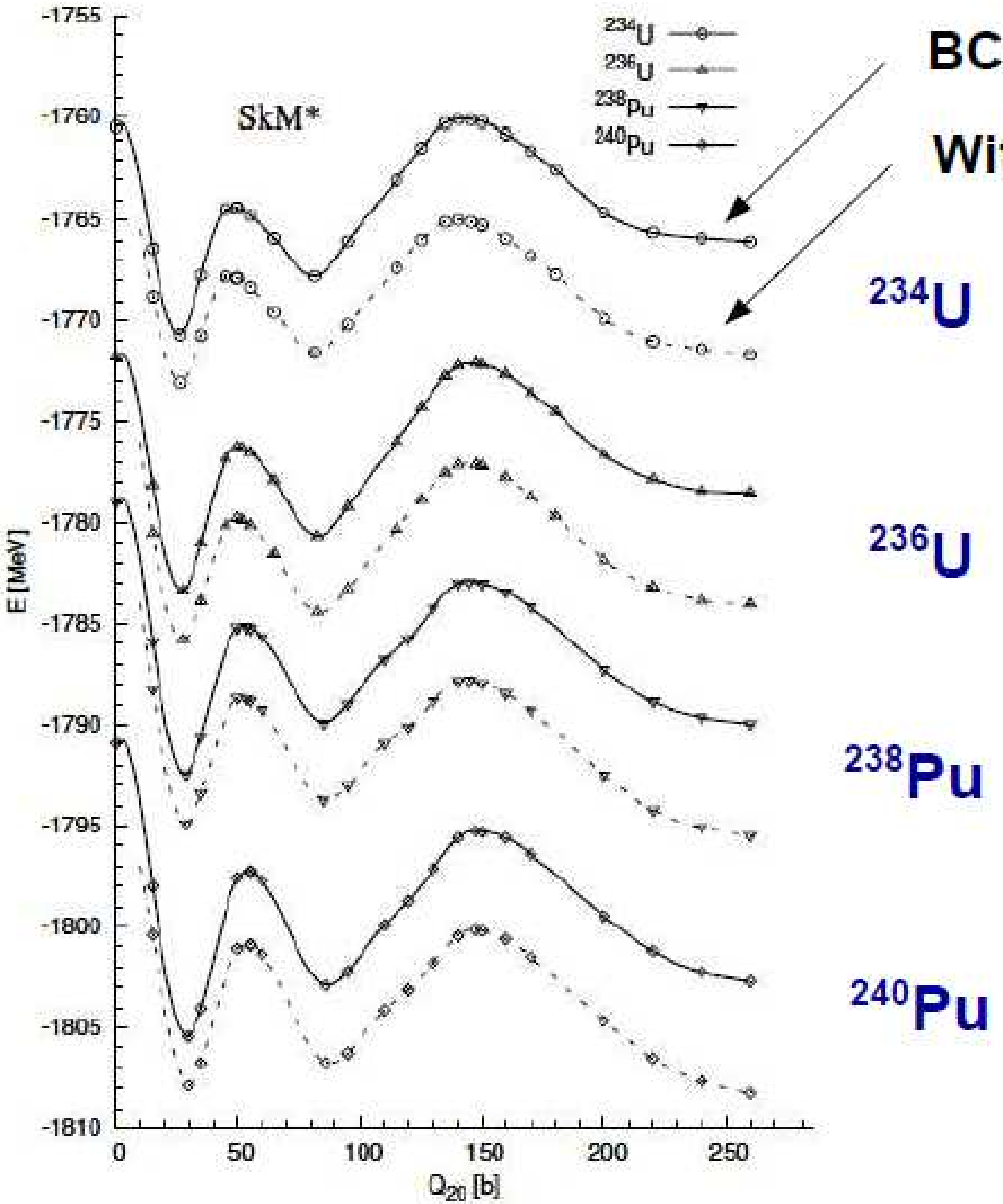
evidenced in Dubna



extra stability (closed shell with high $j \Rightarrow$ high concentration of levels

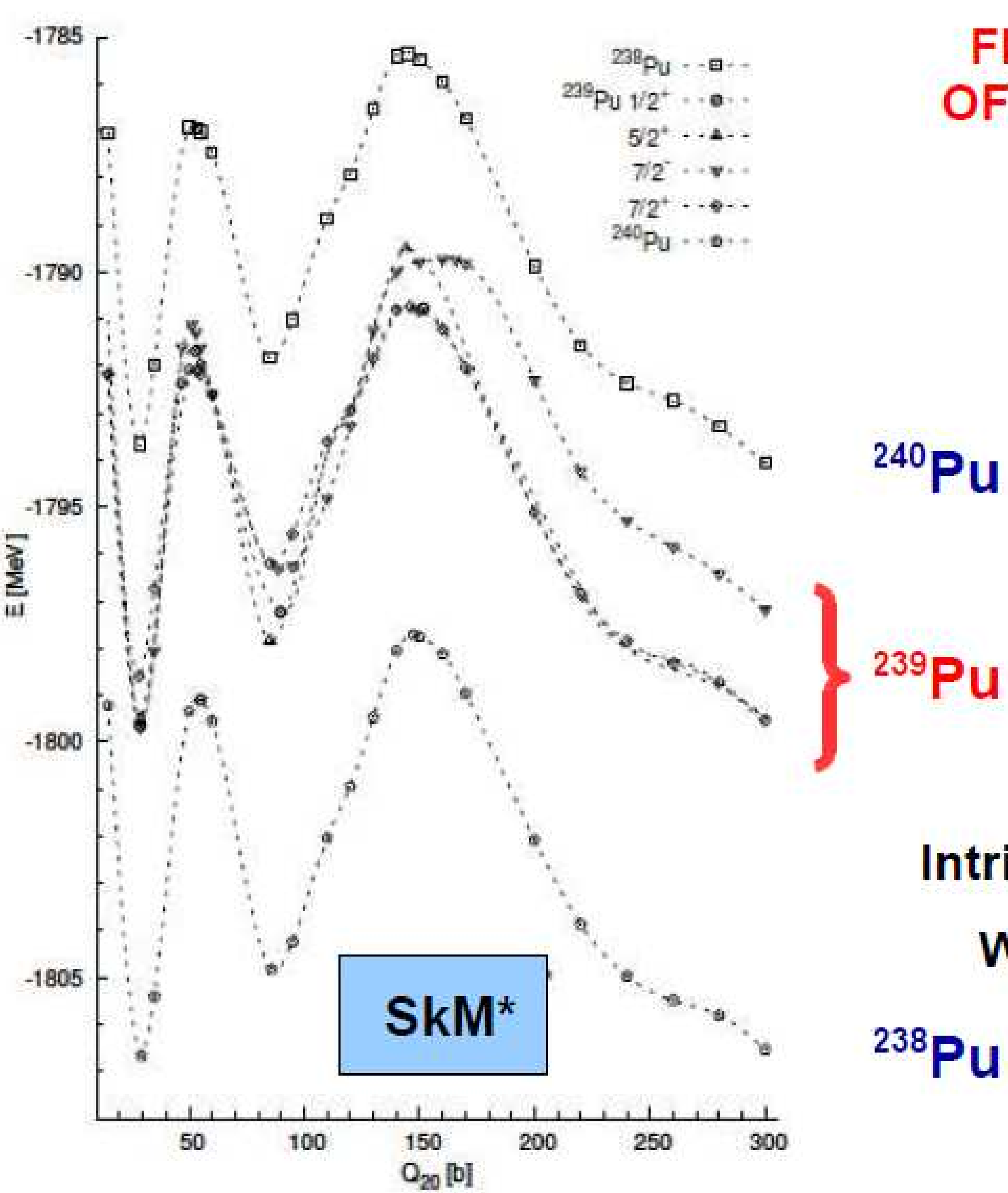


A SELECTION OF SOME FISSION BARRIER RESULTS



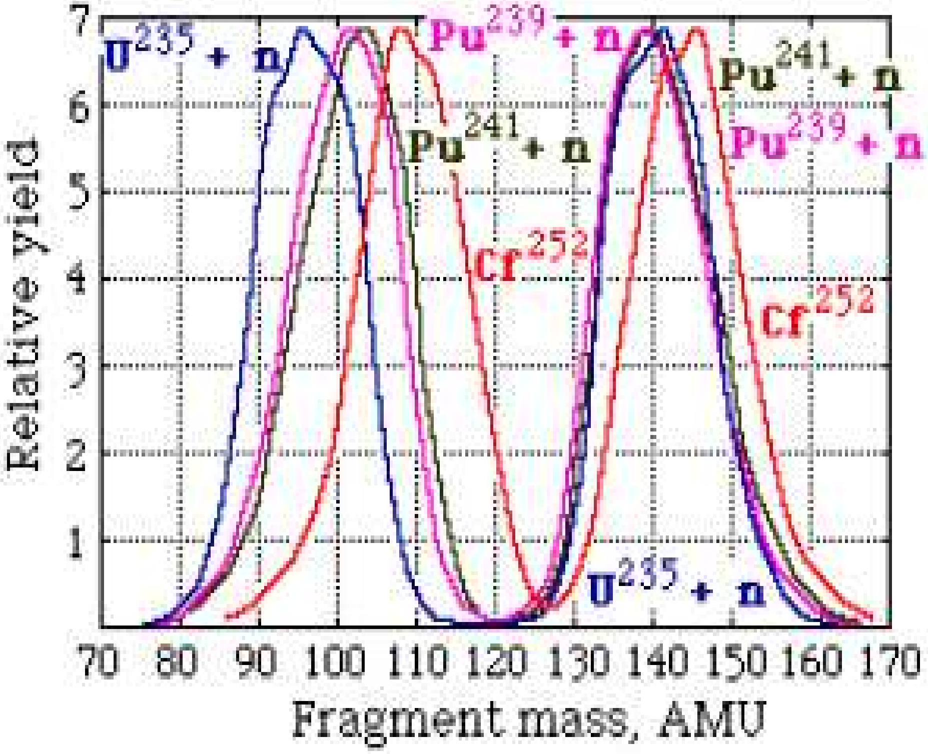
SkM*
Even-Even Nuclei
Intrinsic Parity Conserved

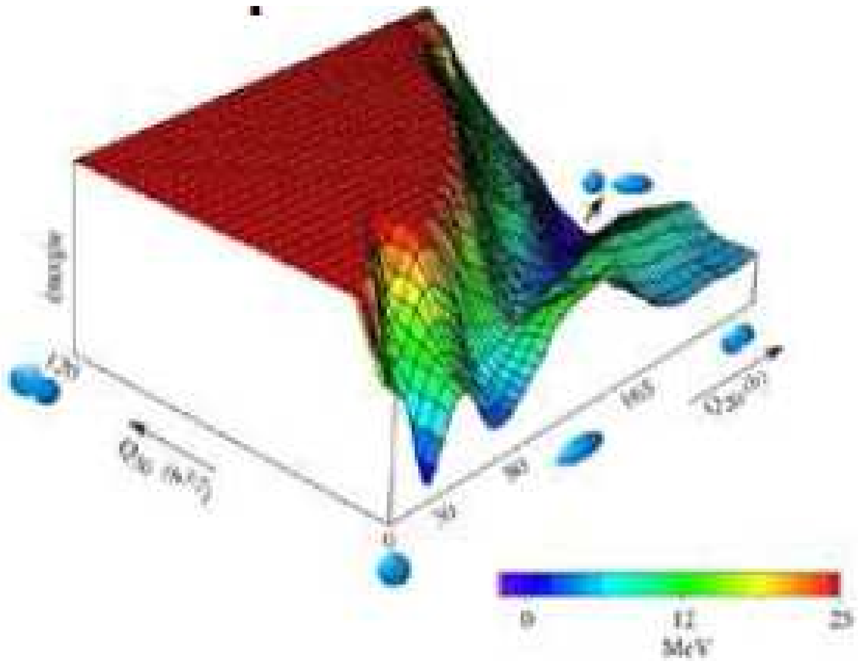
FISSION BARRIERS OFTHREE PLUTONIUM ISOTOPES



Intrinsic Parity Conserved

With Rot. Correction


U235 + n
Pu239 + n
Pu241 + n
Pu241 + n
Pu239 + n
Cf252
Cf252
U235 + n
Relative yield
1
2
3
4
5
6
7
70
80
90
100
110
120
130
140
150
160
170
Fragment mass, AMU


0
12
25
MeV

EFFECT OF INTRINSIC PARITY BREAKING ON THE FISSION BARRIERS

With Rotational Correction