核分裂の微視的理解に向けて

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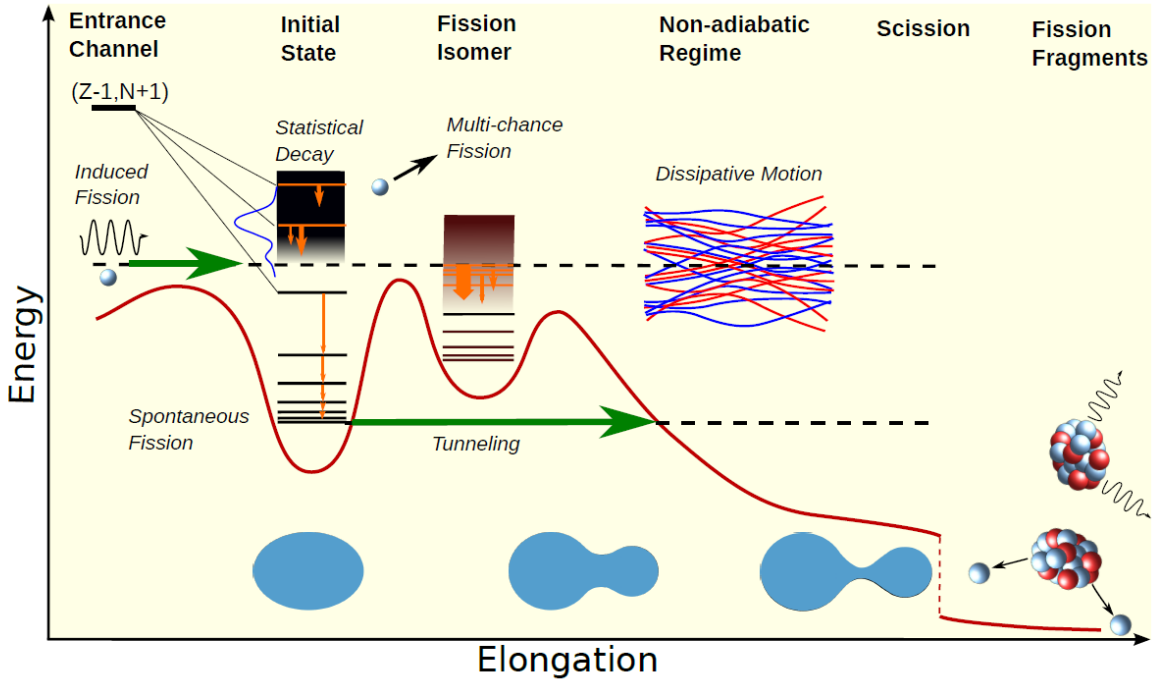
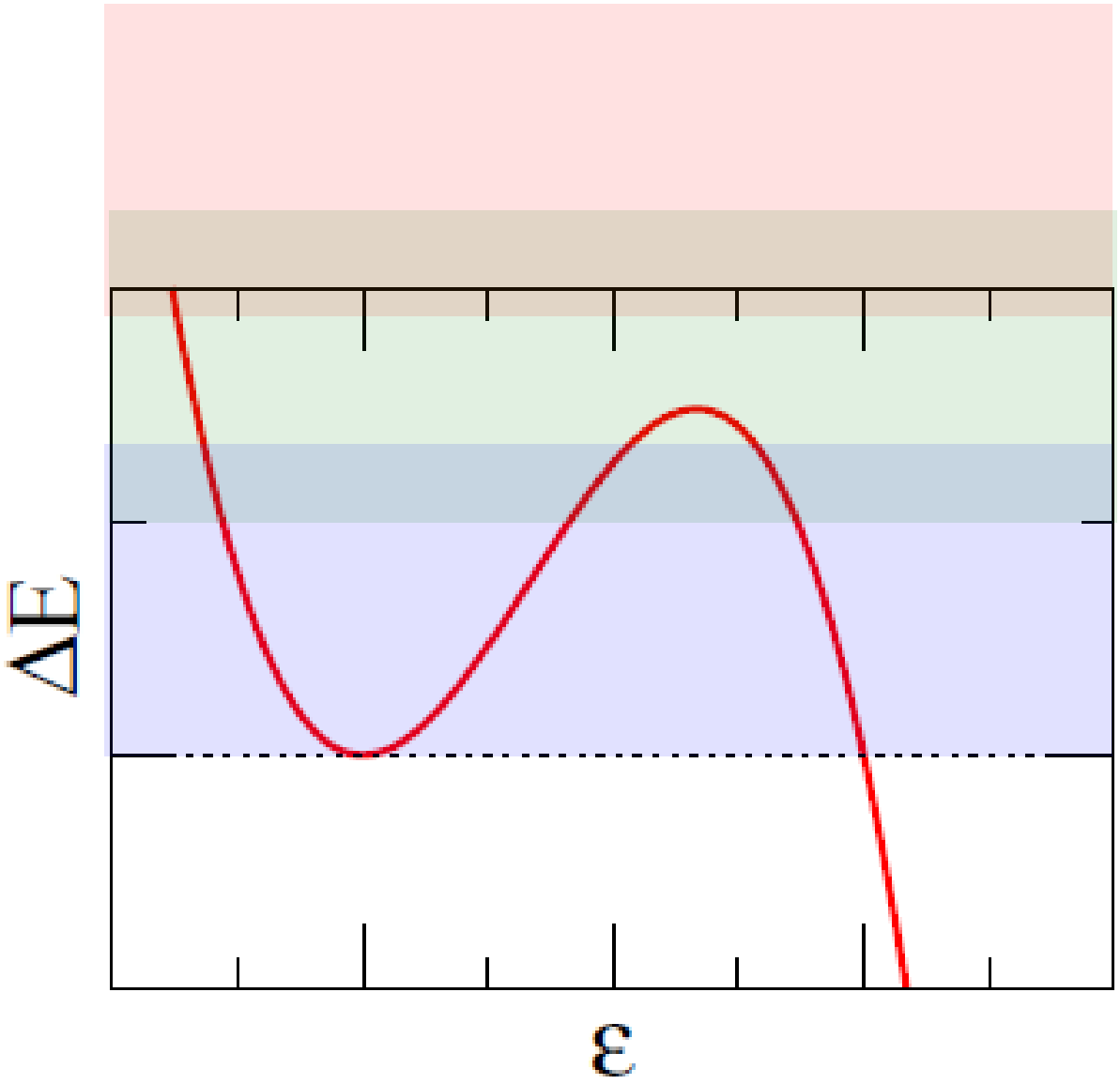


- ✓ 微視的に
- ✓ 量子力学的に

核分裂を記述したい

量子的多体ハミルトニアンに基づいて

核分裂のエネルギー領域



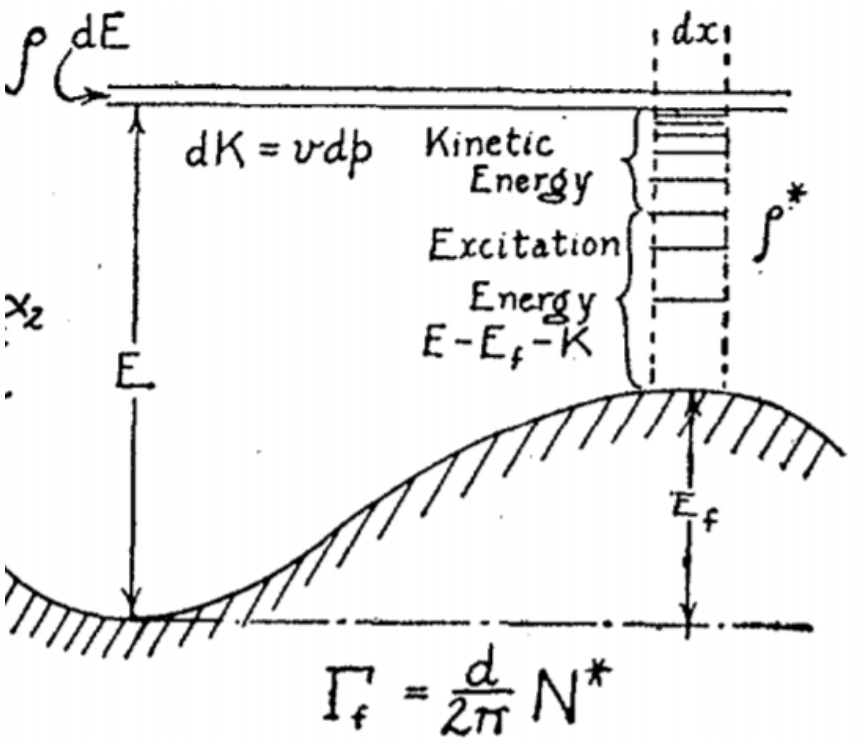
statistical/
dissipative (Langevin)

barrier-top

cf. r-プロセスでの
核分裂

tunneling (WKB)

Bohr-Wheeler formula (transition state theory)



fission の確率:
- ✓ 障壁でのみ決まる
- ✓ 障壁の外でのダイナミックスには依存しない

微視的に理解できるのか？

N. Bohr and J.A. Wheeler,
Phys. Rev. 56, 426 (1939)

$$\Gamma_f = \frac{1}{2\pi\rho_{\rm gs}(E^*)}\int_0^{E^*-B_f}\rho_{\rm sd}(E^*-B_f-K)dK$$

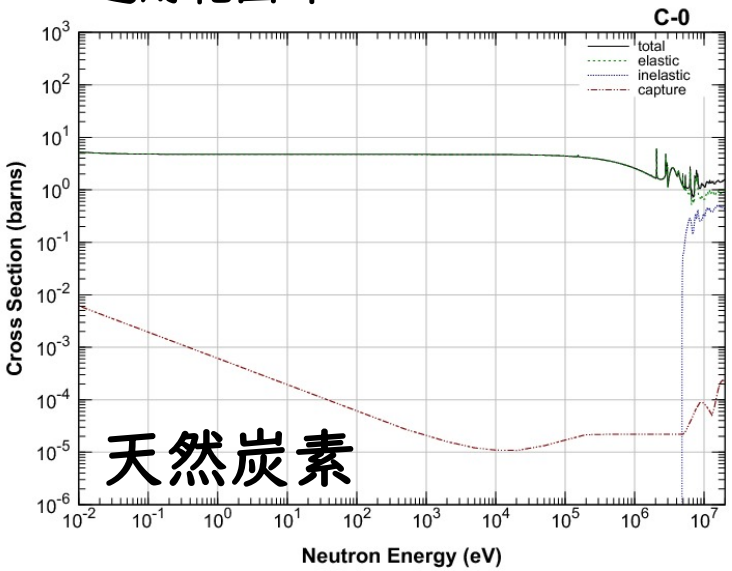
CNに何個の状態があるか

saddle に何個の状態があるか

湊太志氏(JAEA)のスライドを一部改変

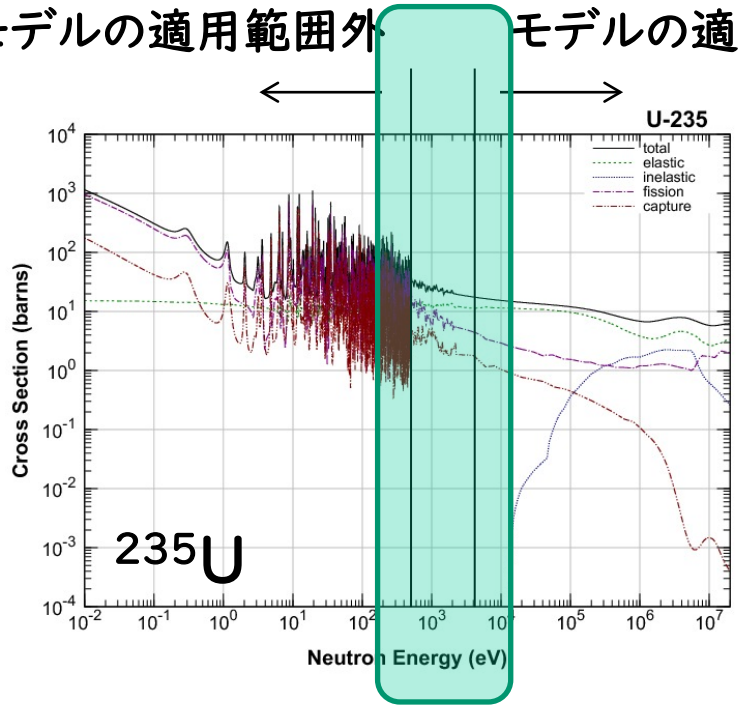
Hauser-Feshbach 統計モデルは共鳴が十分に多いエネルギー領域でなければ正しい記述ができない

このエネルギー範囲では、
Hauser-Feshbachモデルは
適用範囲外



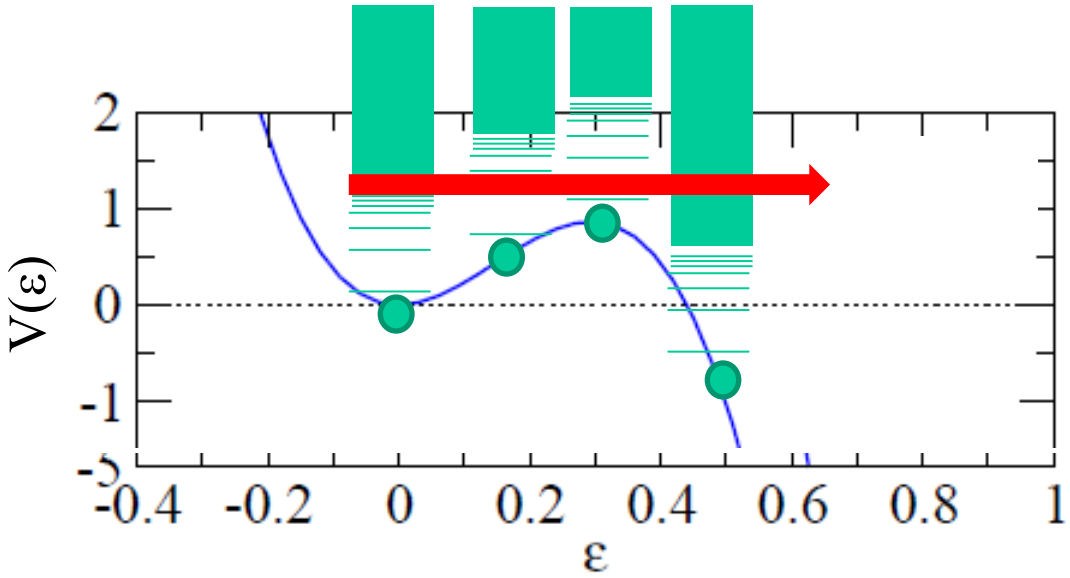
Hauser-Feshbach
モデルの適用範囲外

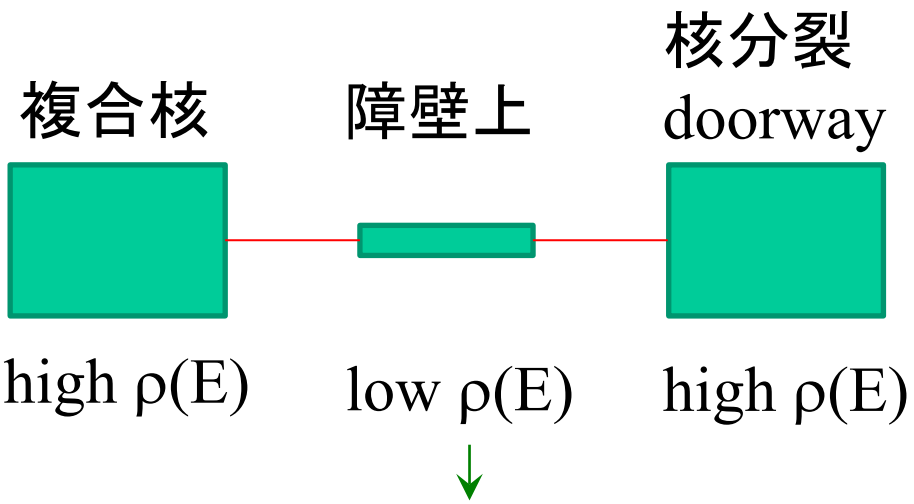
Hauser-Feshbach
モデルの適用範囲



この領域を理解したい
→多体ハミルトニアンに基づく記述が必要

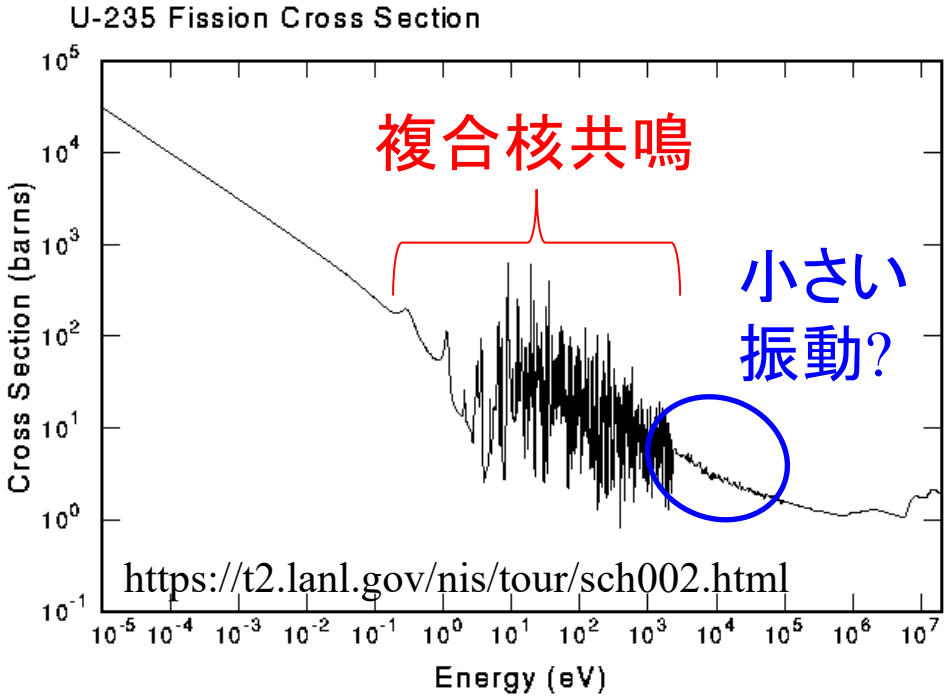
barrier-top fission

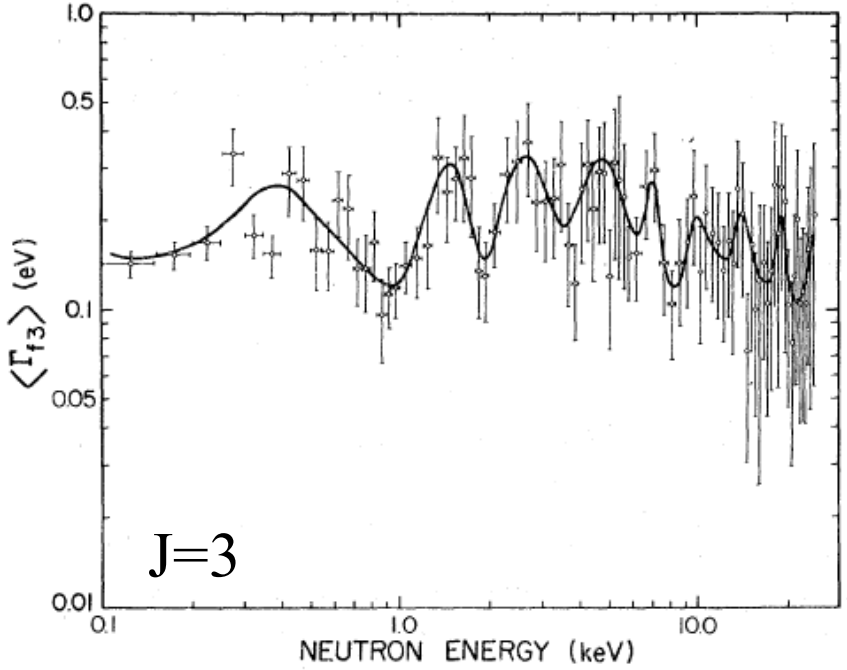




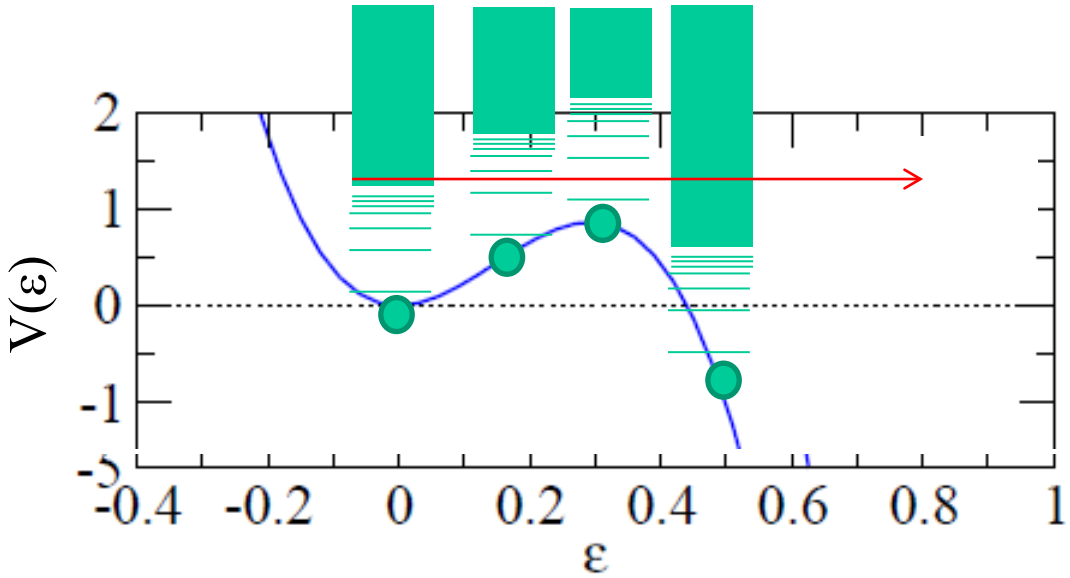
離散準位を取り扱う必要がある

$n + {}^{235}U \rightarrow {}^{236}U^* \rightarrow$ fission

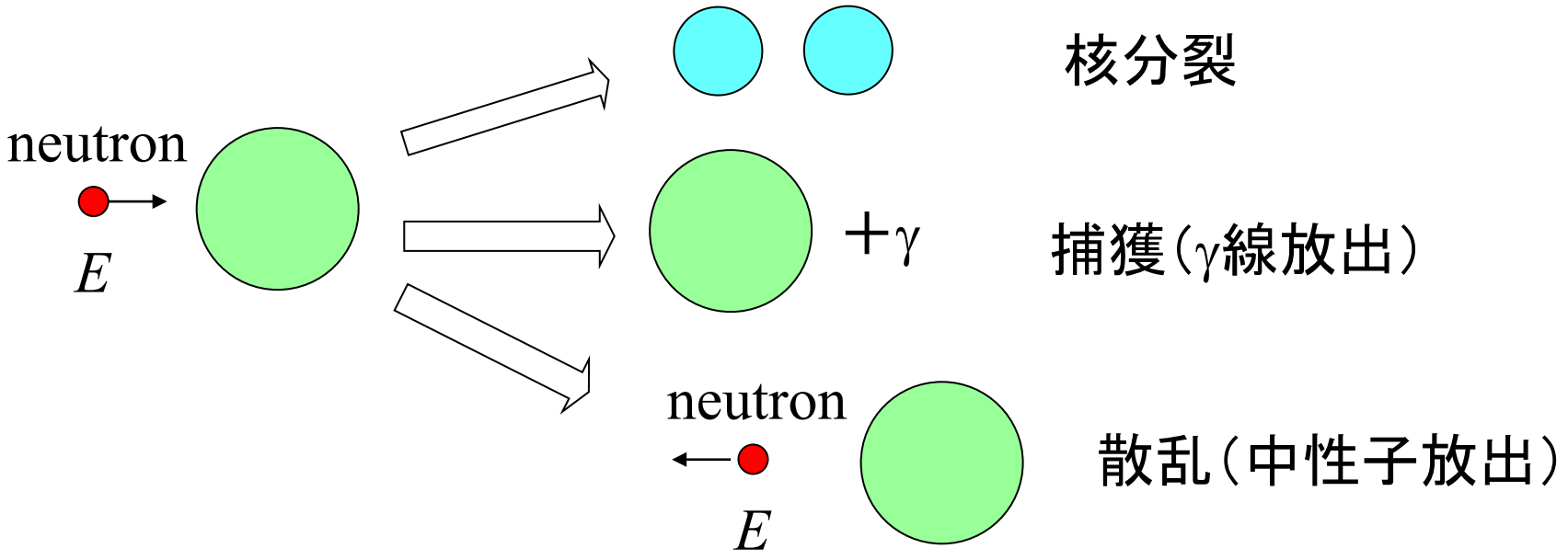


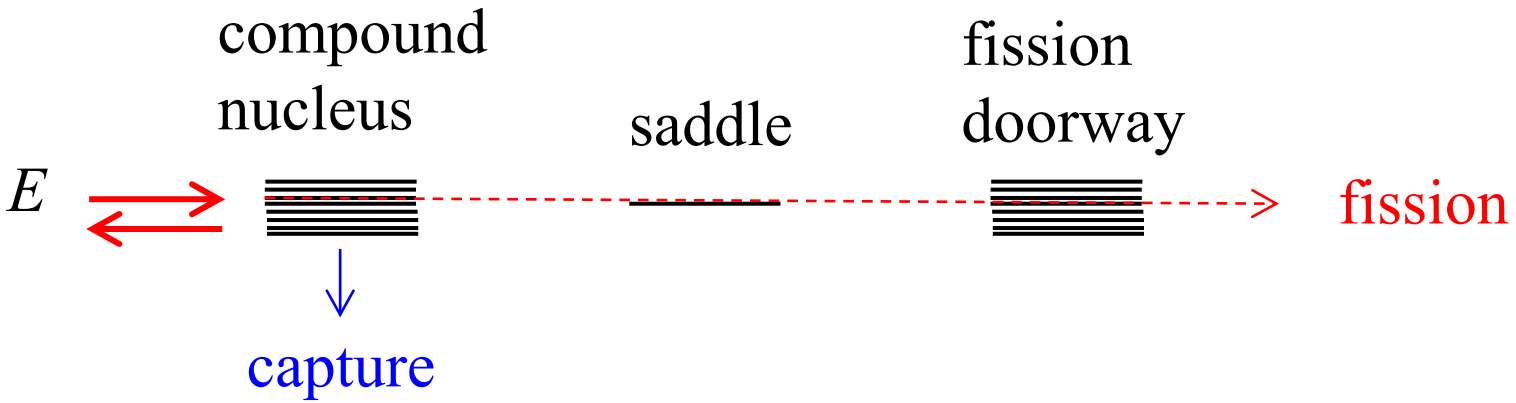


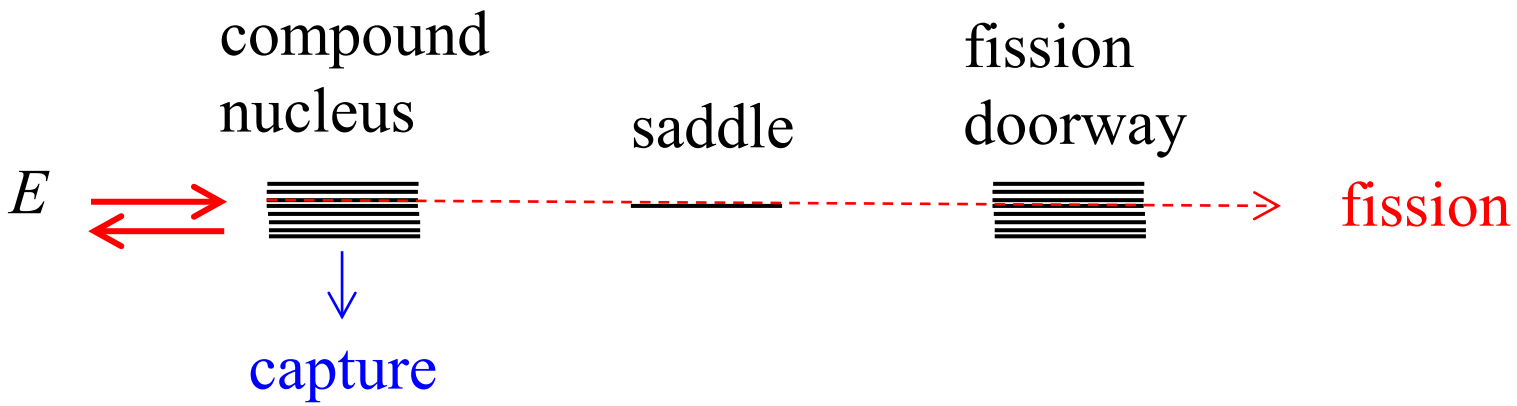
M.S. Moore et al.,
PRC18 ('78) 1328



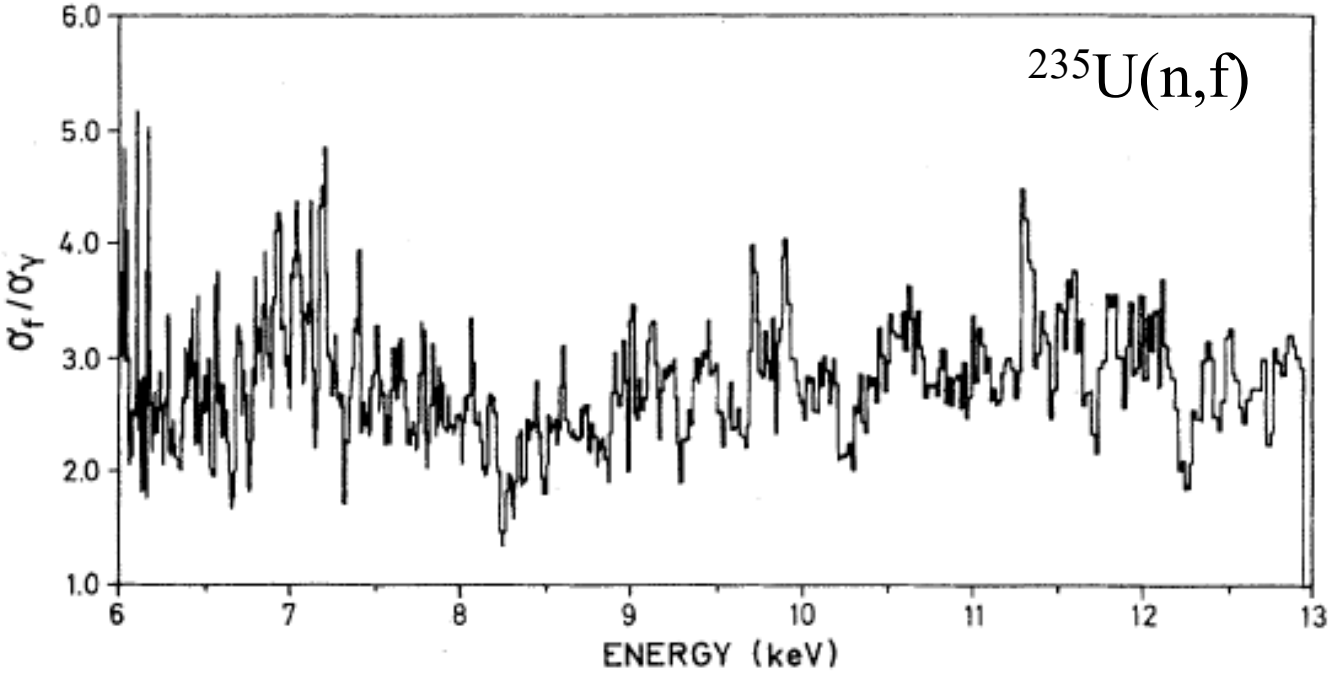
どういう問題を考えるか







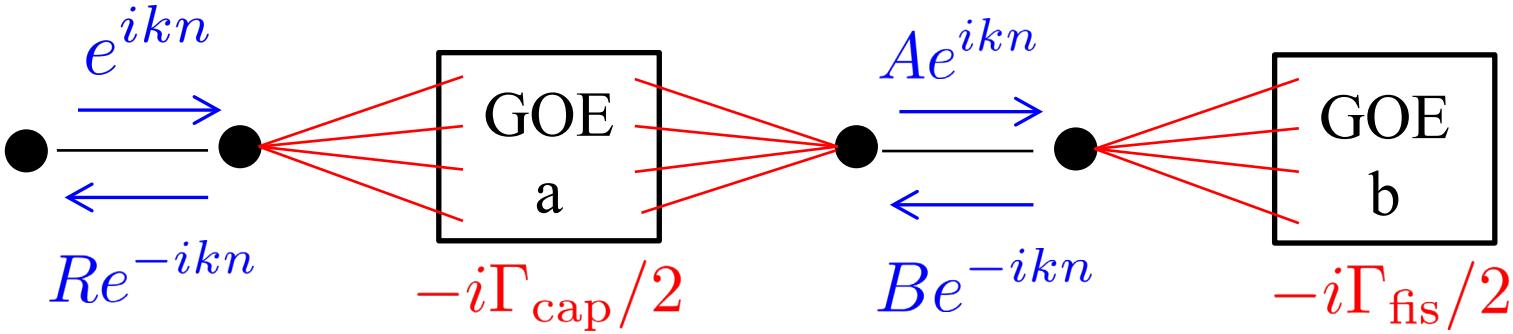
the fission-to-capture branching ratio $\alpha^{-1} = \frac{\sigma_f}{\sigma_\gamma}$



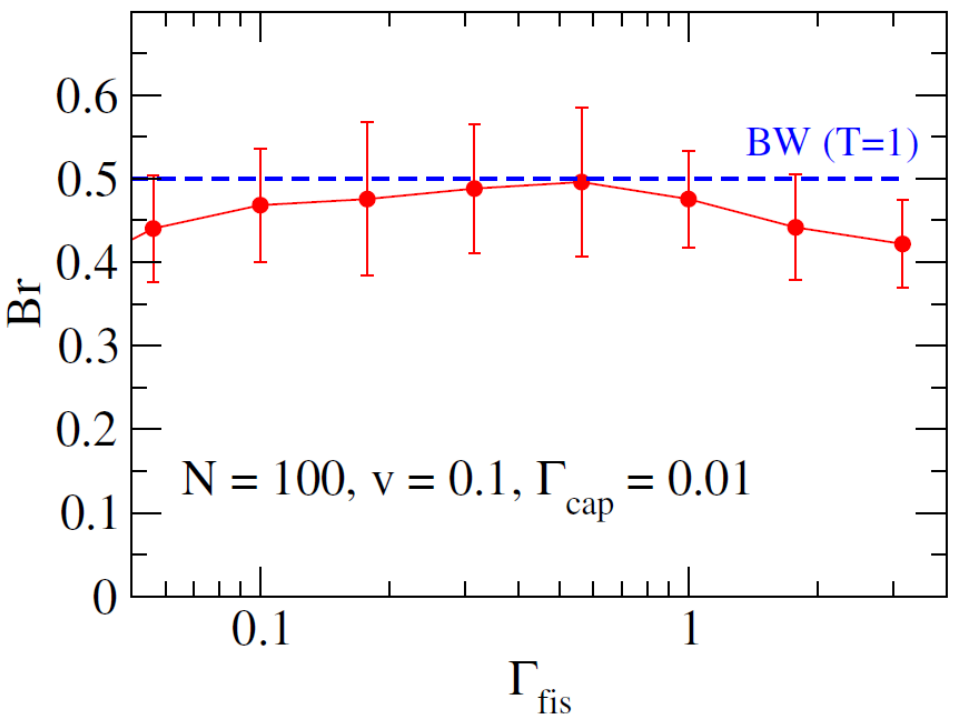
中間的な構造
に敏感な観測量

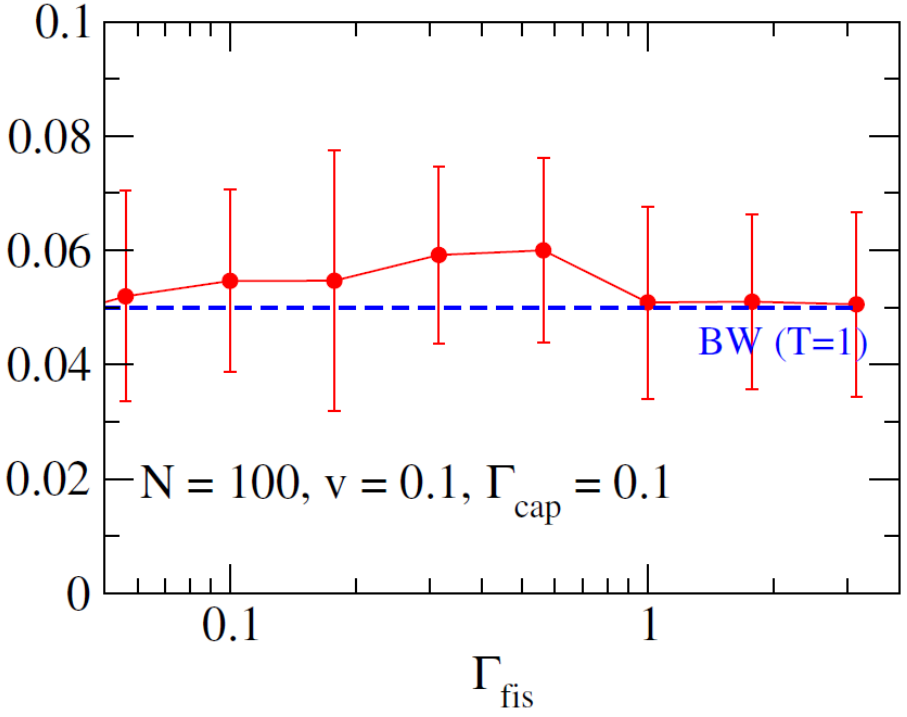
M.S. Moore et al., PRC30 (‘84) 214

殻模型的な計算 G.F. Bertsch and K.H., arXiv:2102.0784, 2105.12073



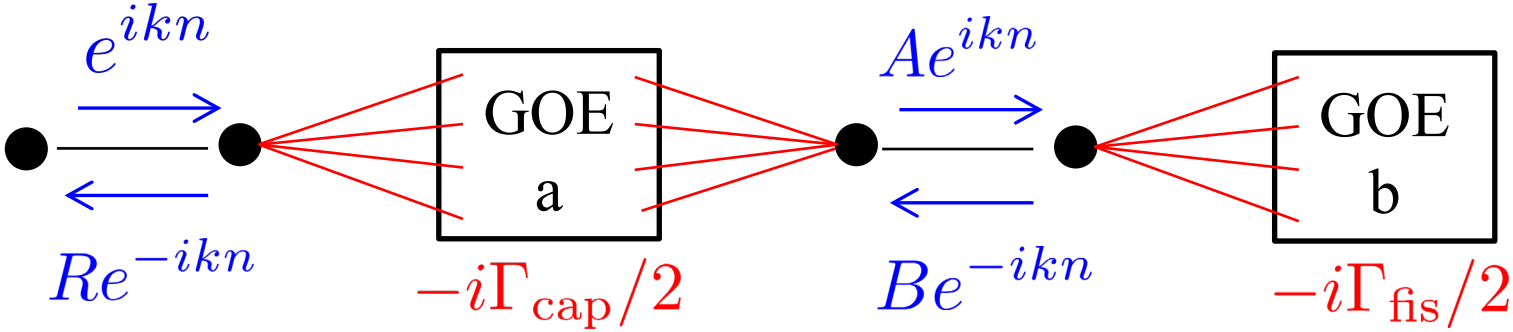
20アンサンブルの平均と分散





分岐比はΓ_{cap} に大きく依存するが Γ_{fis} にはあまり依存しない

殻模型的な計算 G.F. Bertsch and K.H., arXiv:2102.0784, 2105.12073



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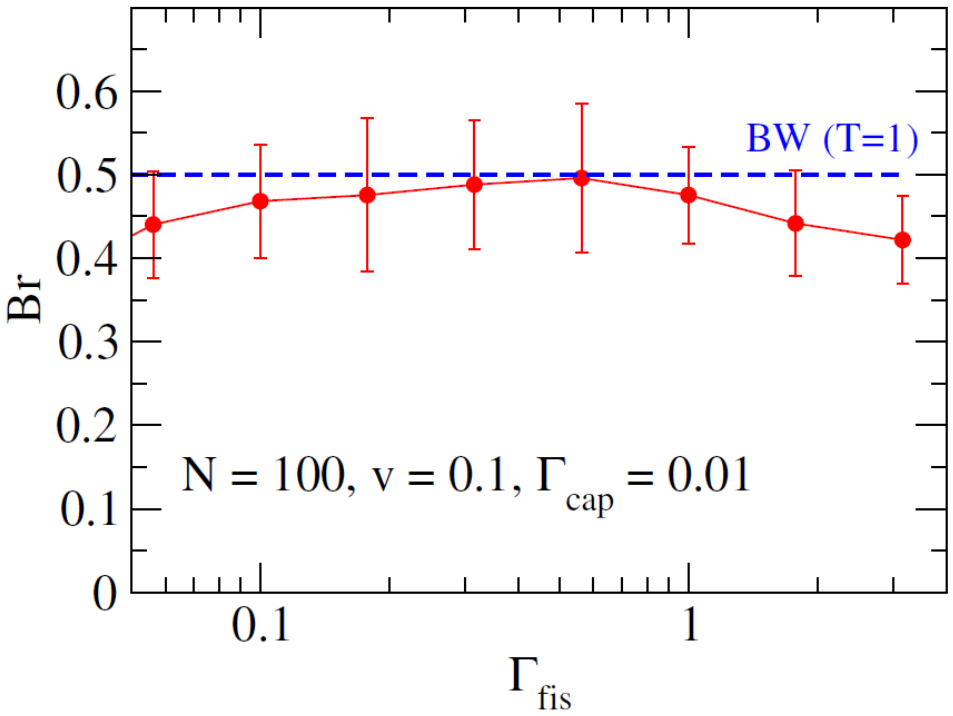


$$Br_{\rm BW} = \frac{1}{2\pi\rho_0}\cdot\frac{1}{\Gamma_{\rm cap}}$$

$$\rho(E) = \rho_0\sqrt{1-\left(\frac{E}{\sqrt{4N}v}\right)^2}$$

$$\rho_0 = \frac{\sqrt{N}}{\pi v}$$

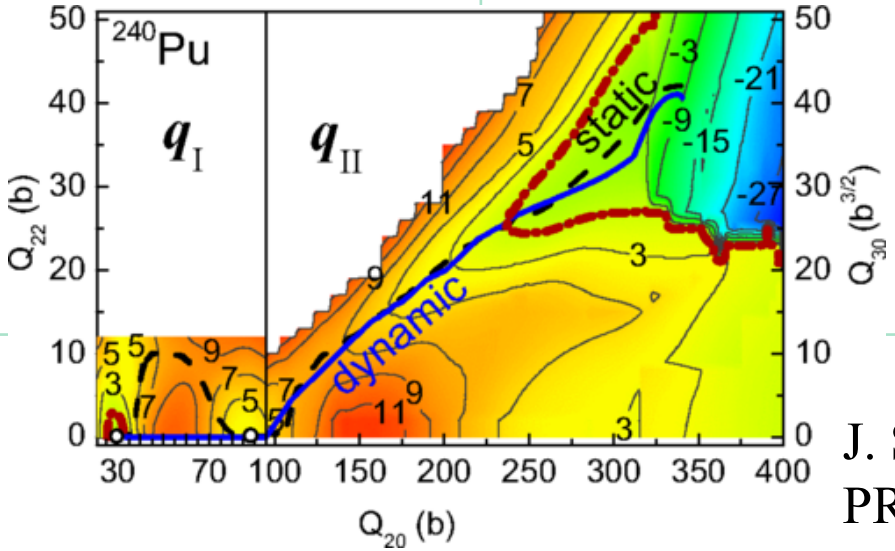
Bohr-Wheeler の仮定を初めて微視的に実現

まとめ

r-プロセス：中性子過剰核の核分裂

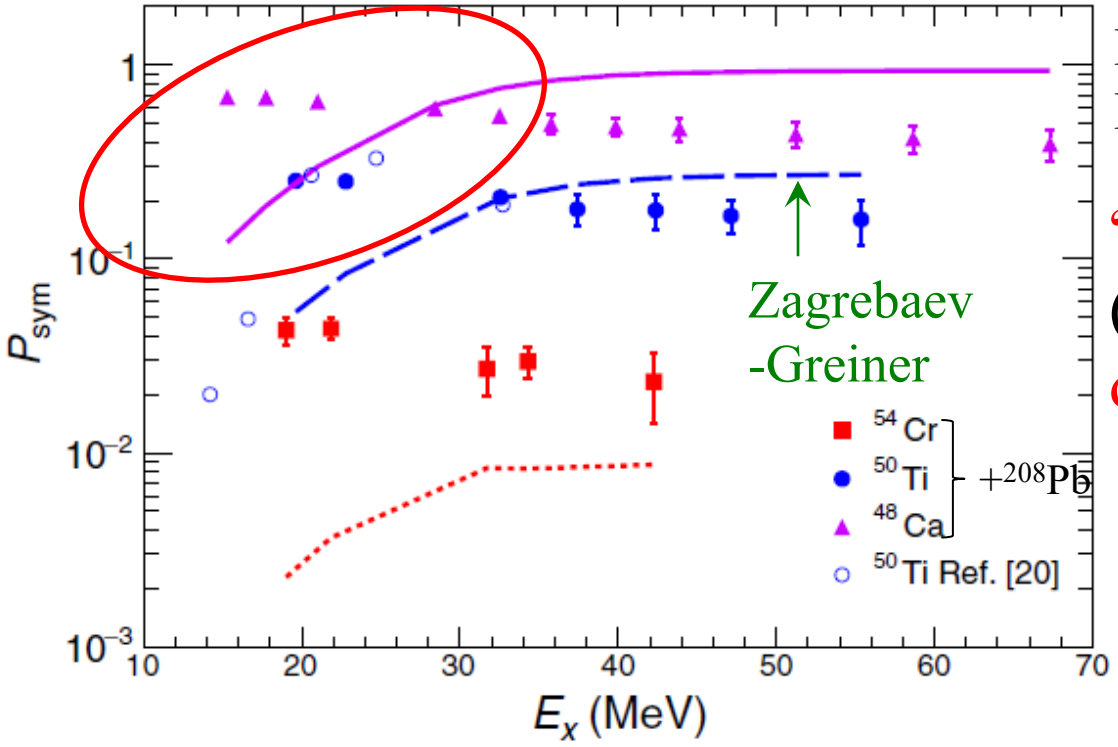
low E^*, low $\rho(E^*)$に対応できる（微視的）アプローチが必要

	Time-indep. approach	Time-dep. approach
Induced fission	✓Bohr-Wheeler (statistical model) **✓CI approach**	✓Langevin-type Wada, Abe, Aritomo, Chiba….. Moller, Randrup
Spontaneous fission	✓PES+Mass+WKB	✓Im.-time TDHF (Negele) ✓Time-dep. Hill-Wheeler (Goutte et al.) ✓TDHF(B) (Bulgac…..)



J. Sadhukhan, W. Nazarewicz, N. Schunck, PRC93(‘16)011304(R)

Recent publication by Banerjee et al. (ANU)



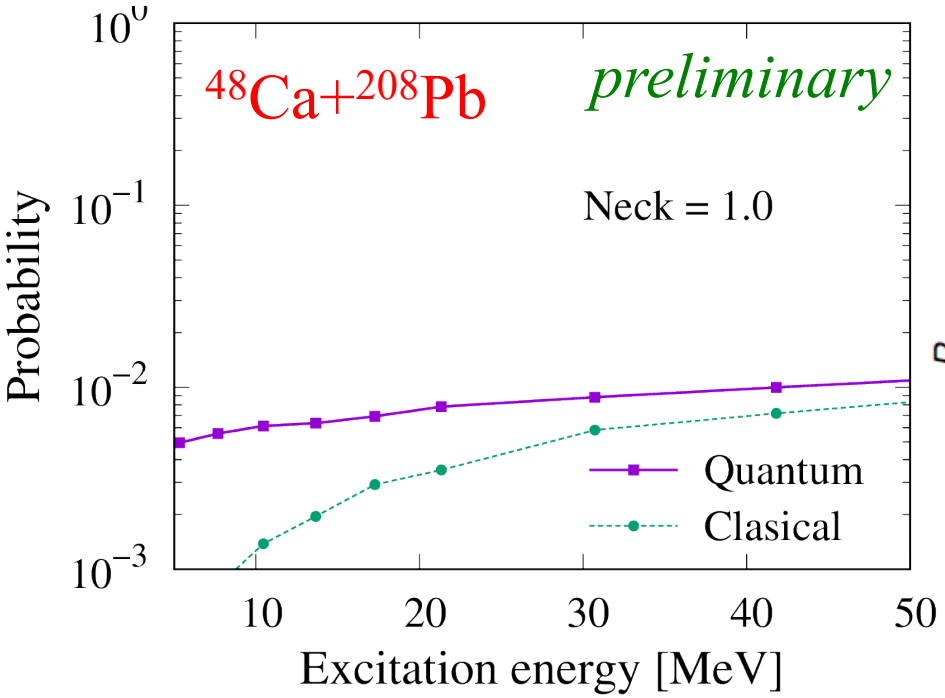
K. Banerjee, D.J. Hinde, et al.,
PRL122, 232503 (2019)

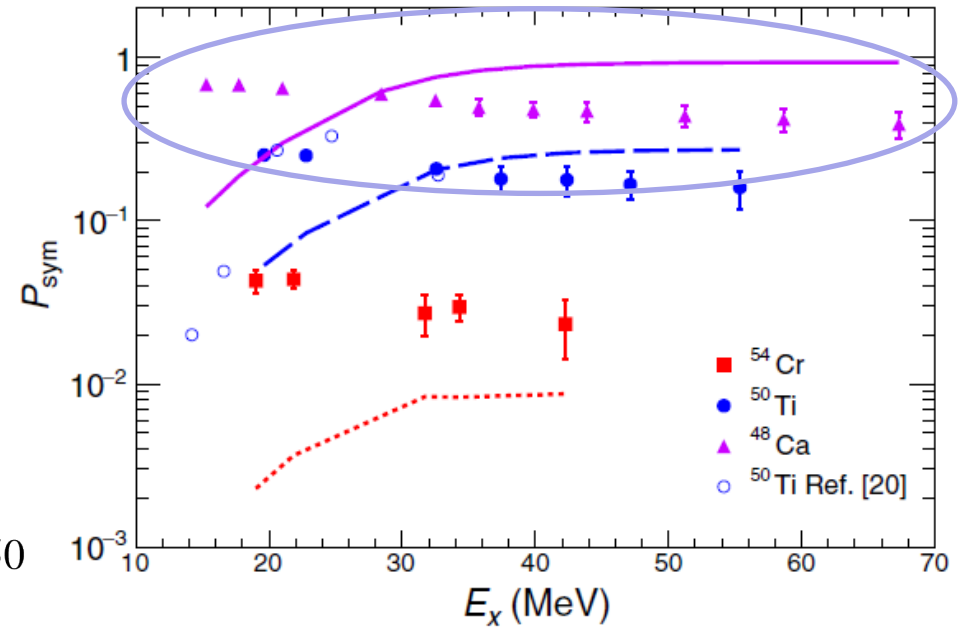
"cold fusion reactions (involving ^{208}Pb) are not driven by a diffusion process"

comparisons: to a classical Langevin calculation

→ quantum effect should be crucial at low E_x

2D Langevin calculations with the rel. coordinate and the mass asym.





K. Banerjee, D.J. Hinde, et al.,
PRL122, 232503 (2019)

qualitatively good,
but quantitatively bad

→ neck d.o.f?

K. Washiyama and K.H., in preparation