A new approach to fission dynamics

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More details in Bertsch, arXiv:1407.1899.pdf

Why a new approach?

--Incorporate diffusive dynamics in the computational framework.
J. Randrup and P. Moller, Phys. Rev. Lett. 106 12305

--Computations are easier in discrete bases and implementation of continuum approaches rely on discrete configurations.
R. Bernard, H. Goutte, D. Gogny, and W. Younes, Phys, Rev. C 84 044308

--There is data that is incompatible with the present computational approach.

U-235+n ---> fission;   E_B = 5.67 MeV,   S_n = 6.55 MeV

Moore, et al., Phys. Rev. C18 1328 (1978)
Moore, et al., Phys. Rev. C30, 214 (1980)

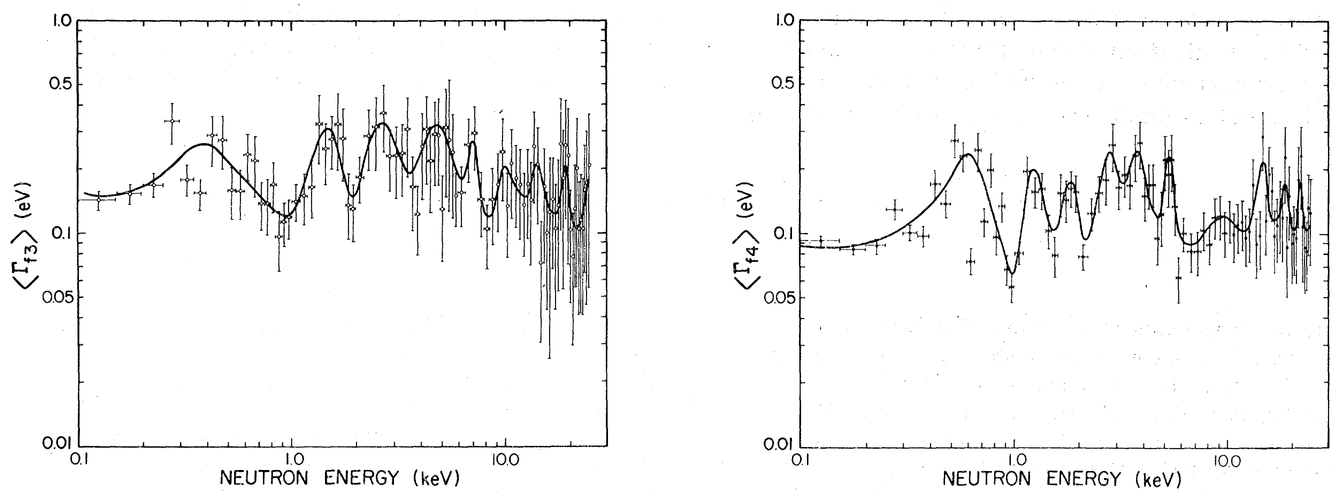

FIG. 16. Average spin-3 fission width for ($^{235}U+n$) from 0.1 to 25 keV obtained from the unresolved resonance analysis described in the text. The curve has no theoretical significance; it is simply the authors' eyeguide.

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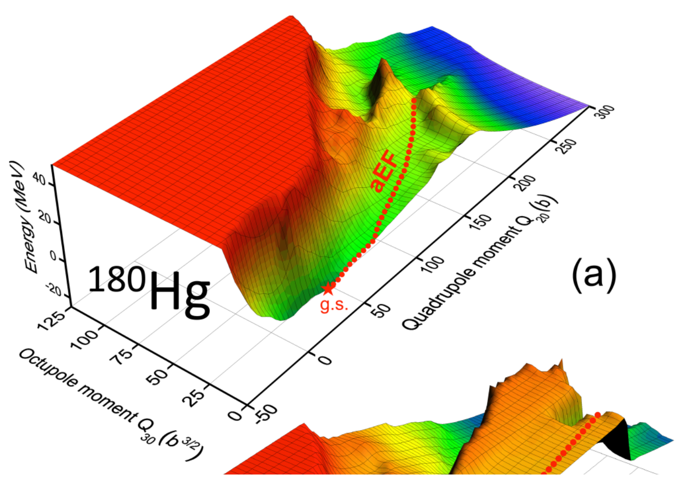
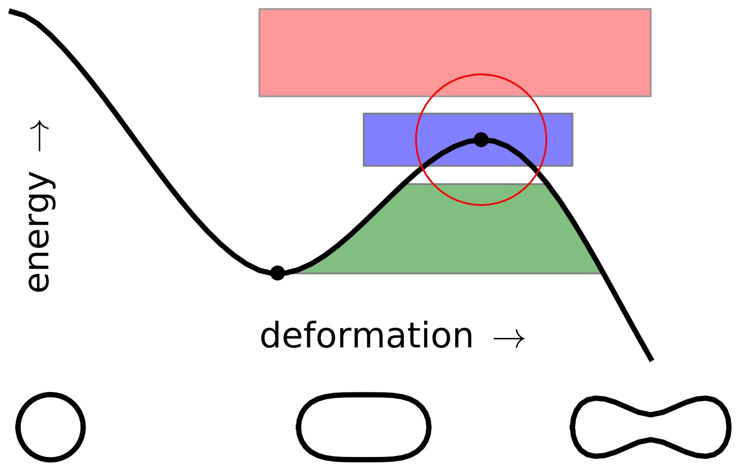
The landscape

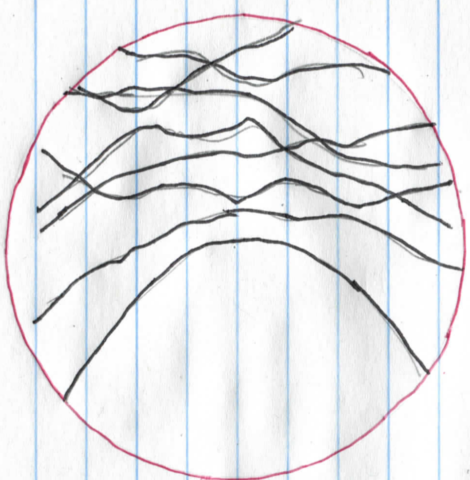
PHYSICAL REVIEW C **90**, 021302(R) (2014)



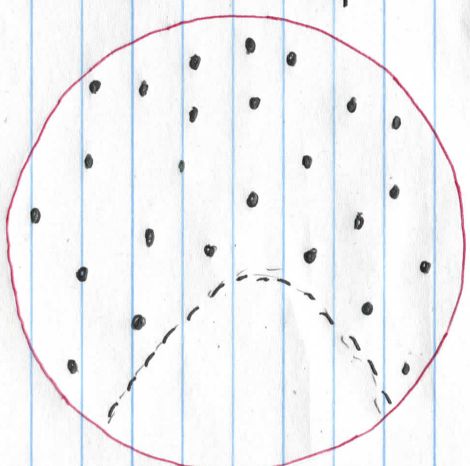


Choice of representation

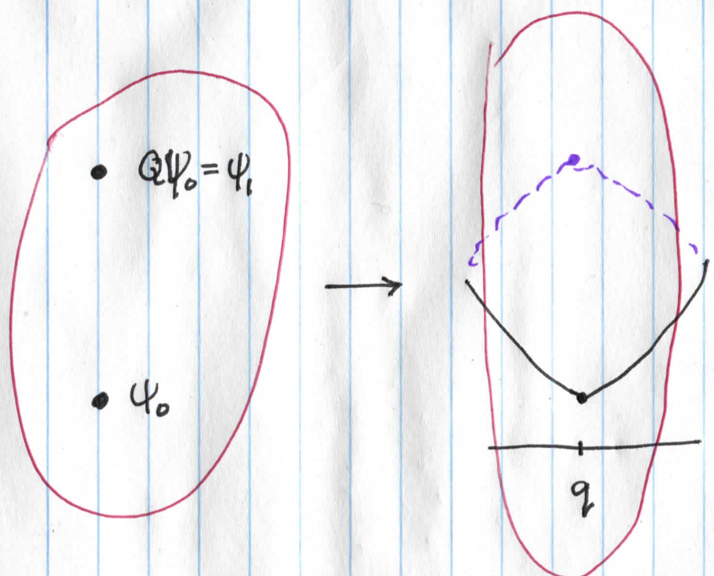
GCM representation



Discrete-basis representation



The two representations are equivalent, in principle



$$\psi(q) \sim \sqrt{1-q^2}\,\psi_0 + q\,\psi_1$$

The Hamiltonian

Level density:

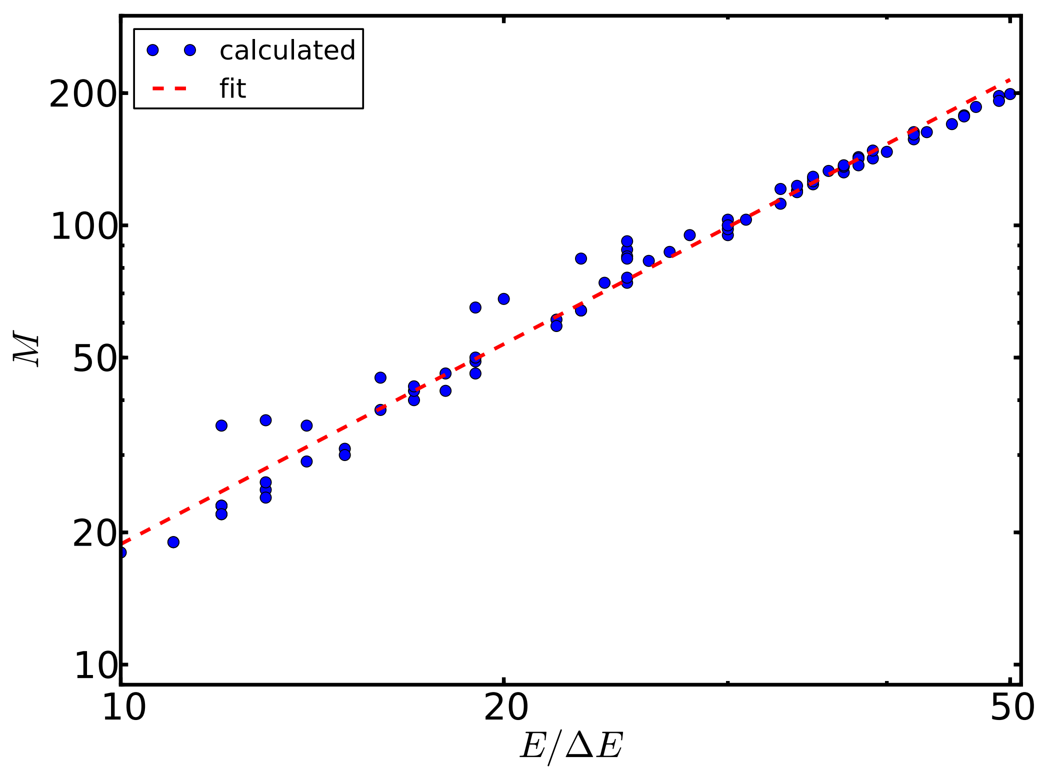
Definition $$\rho(q,E) = \sum_i \delta(q-q_i)\delta(E-E_i).$$

Parameterization $$\rho(q,E) = \rho_0 \exp(\beta(E - V_0(q))).$$

Off-diagonal interaction:

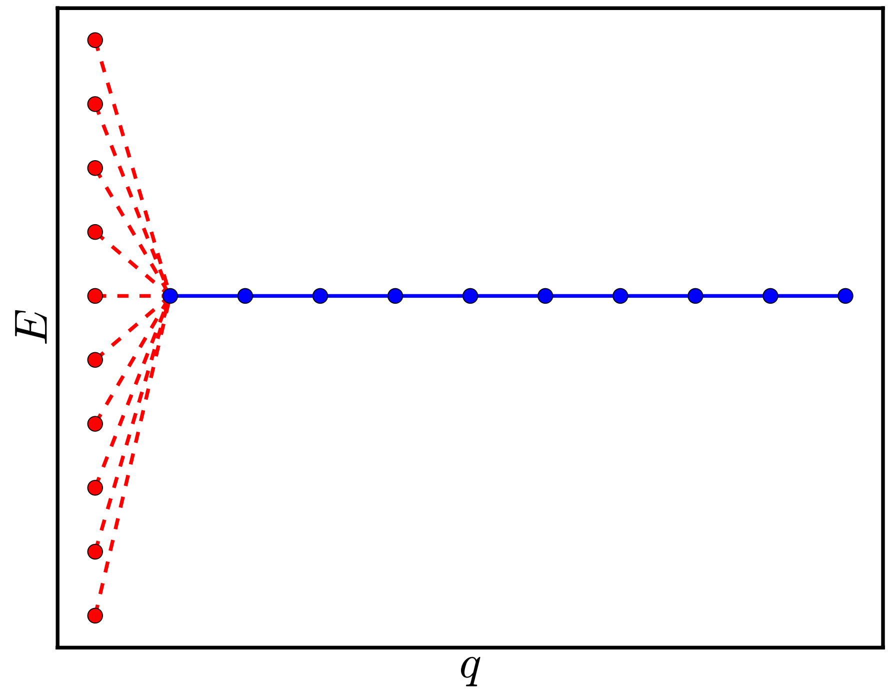
$$\overline{\langle i|v|j\rangle^2} = v_0^2 e^{-(q_i-q_j)^2/2q_0^2} \frac{(E_i+E_j)^{3/2}}{(\rho(E_i)\rho(E_j))^{1/2}}$$

Fit to a power law



M ~ E**1.51

Channel physics in the discrete basis

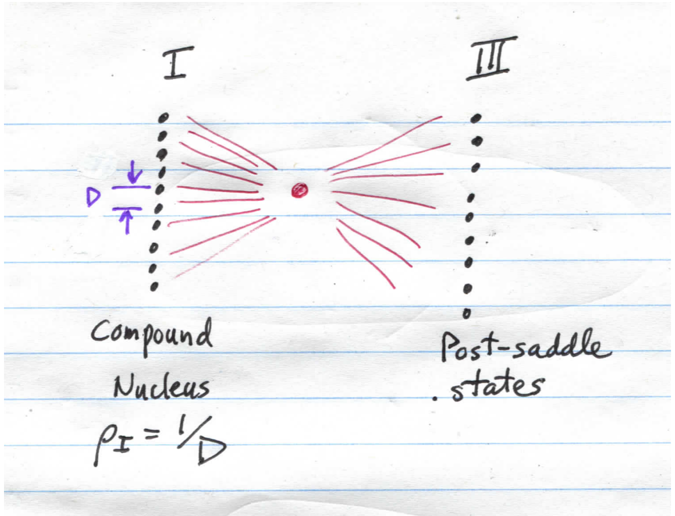


Red dots: compound nucleus states
Blue dots: channel states

Where is the point of no return?

R-matrix answer: at the top of the outer barrier

My answer: when the local level density exceeds rho_I



Verified by numerical experiments.

When does the dynamics become diffusive?

$$\frac{\partial P}{\partial t} = D \frac{\partial^2 P}{\partial q^2}. \tag{1}$$

The diffusion coefficent D is given by

$$D(q_i, E_i) = 2\pi\hbar \sum_j (q_i - q_j)^2 \langle i|v|j\rangle^2 \delta(E_i - E_j) \tag{2}$$

The control parameter determining the proximity to the diffusive limit is

$$\alpha = q_0 \rho_0 v_0 \tag{3}$$

See B.W. Bush, G.F. Bertsch, and B.A. Brown, Phys. Rev. C 45 1709 (1992)

Connection to mesoscopic physics

The Landauer formula for conductance

$$C = R^{-1} = \frac{e^2}{2\pi\hbar}\sum_c T_c$$

Derived from the Bohr-Wheeler formula:
J. Phys. Cond. Mat. **3** 373 (1991)

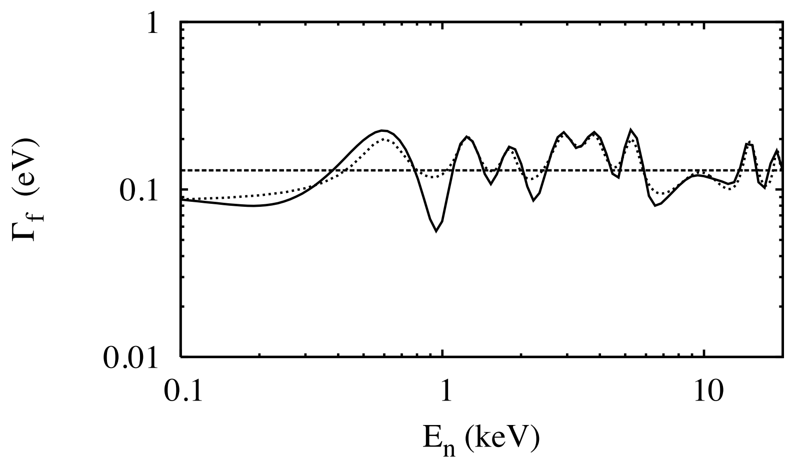
$$W = \frac{1}{2\pi\hbar\rho_I}\sum_c T_c.$$

Quantum-dot-mediated conductance

$$\sum_c T_c \to \sum_b \frac{\Gamma_{bR}\Gamma_{bL}}{E_b^2 + (\Gamma_{bR}+\Gamma_{bL})^2/4}$$

A challenge to R-matrix theory

U-235+n ---> fission; E_B = 5.67 MeV, S_n = 6.55 MeV



Solid line: experiment from Moore, et al., PRC 30 214 (1984).

How can one get fluctuations on the scale of 1 keV at 1 MeV above the barrier?
Dashed line: a fit with 13 non-interfering resonances.

$$W = \frac{1}{2\pi\hbar\rho_I}\sum_c T_c. \qquad \sum_c T_c \to \sum_b \frac{\Gamma_{bR}\Gamma_{bL}}{E_b^2 + (\Gamma_{bR}+\Gamma_{bL})^2/4}$$

R-matrix theory requires a parameterization

$$\sum_c T_c = \sum_c \frac{1}{1+\exp\left(2\pi(E_c - E)/\hbar\omega\right)}$$

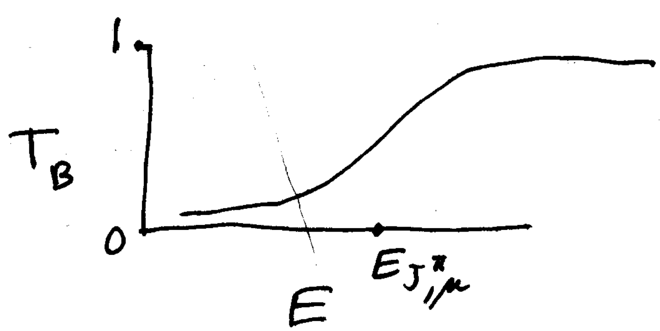
Details (Bouland, Lynn, Talou, Phys. Rev. C88 054612

$$\sigma_{nf}(E, J^\pi) = \sigma_n(E, J^\pi)\, P_f(E, J^\pi)$$

$$P_f = \frac{\Sigma T_f}{\Sigma T_f + T_{I,\gamma} + T_{I,n}} \qquad \Gamma_f = \frac{1}{2\pi\rho_I} P_f$$

$$T_f = \frac{T_A T_B}{T_A + T_B + T_{II,\gamma} + T_{II,n}}$$

$$T_B(E, J^\pi, \mu) = \frac{1}{1 + \exp\left(2\pi\,(E_{J^\pi,\mu} - E)/\hbar\omega\right)}$$



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