Fission Cross Section Theory

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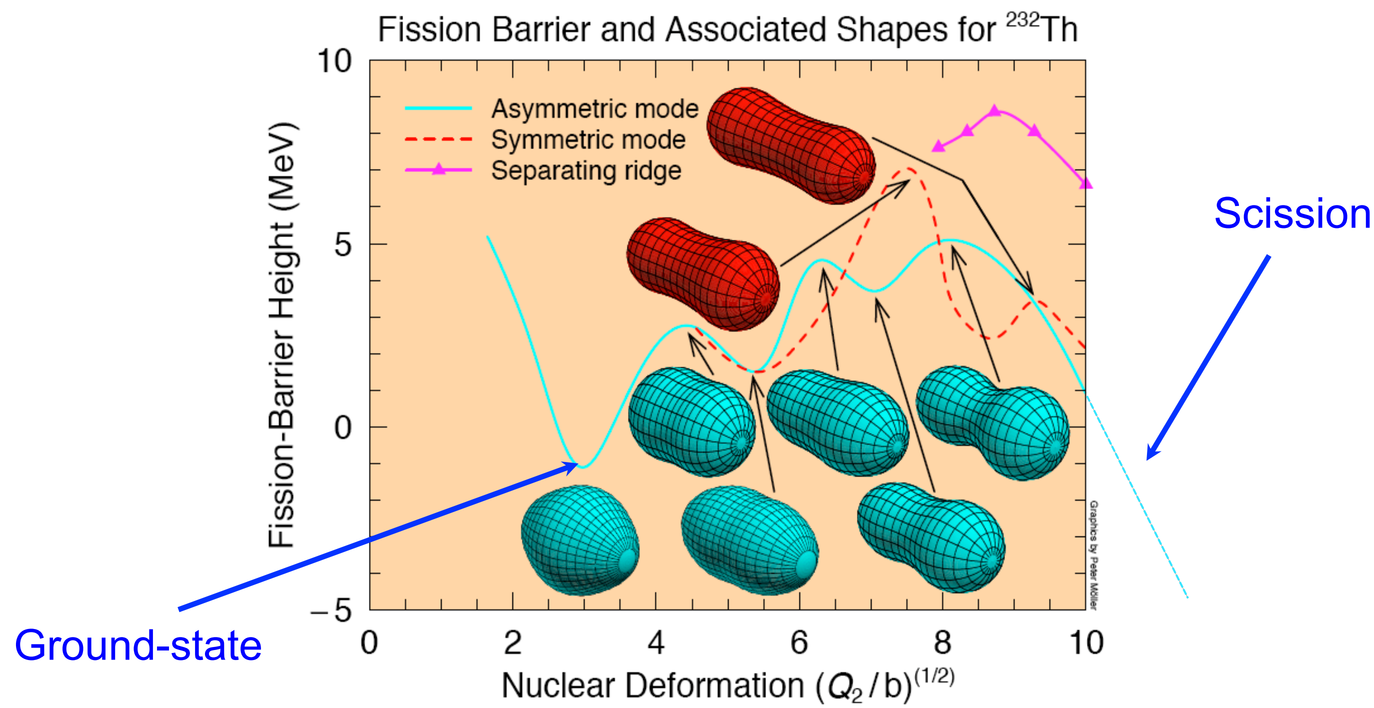
Fission Paths and R-Matrix Approach

- **R-matrix approach to fission channel (J.E.Lynn et al.)**
  - Fission occurring through fission transition states at saddle point
  - Well-known complications due to double-hump nature of fission barriers



Source: P.Möller, T-2, LANL

Starting Point: Hauser-Feshbach

- **Cross section for (c,c') channel**

$$\sigma_{c,c'} = \sigma_{c,CN} \times \sum_{s'=|I'-i'|}^{|I'+i'|} \sum_{l'=|J-s'|}^{|J+s'|} \frac{T_{c'}^{J^\pi (l's')}}{\sum_{c''} T_{c''}^{J^\pi (l''s'')}}$$

- **Transmission channels T_c (neutron, capture) – strength function formalism**
- **Width fluctuation corrections: Moldauer**
- **Double-hump barriers**
  - Class-I and II states
    - Class-I: large density of compound states at $E^* \sim B_n$
    - Class-II: smaller number of states, deviations from statistical distribution
  - Residual interaction between class-I and class-II states

$$H = H_\eta + H_{int}(\zeta, \eta_0) + H_c(\eta, \zeta; \eta_0)$$

Class-I and Class-II States

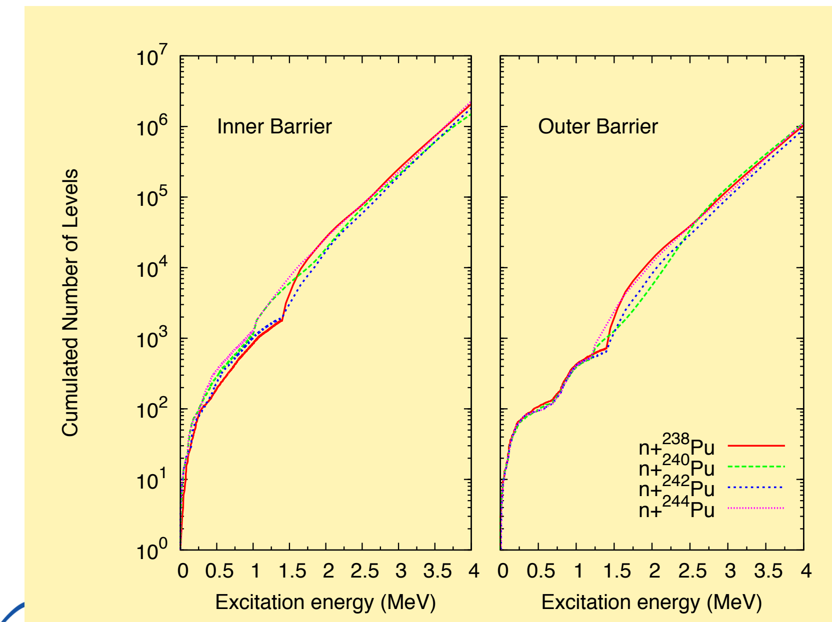
- **Eigenstates of total hamiltonian decomposed over intrinsic and collective states**

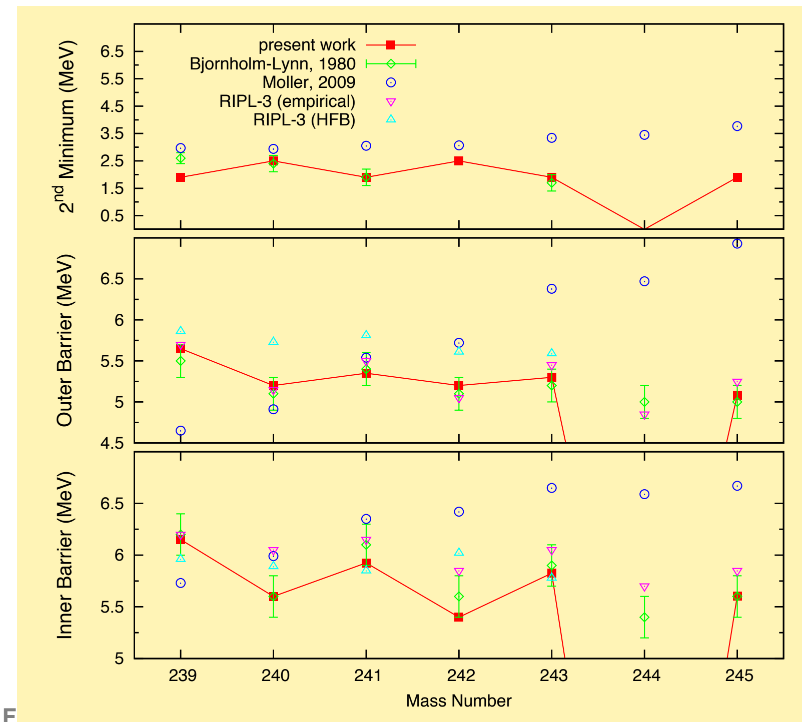
$$X^{\lambda} = \sum_{\nu\mu} C_{\lambda(\nu\mu)} \Phi_{\nu}^{(\mu)} \chi_{\mu}$$

- **Below inner barrier, X^{λ} → either class-I or class-II states**
- **Interaction term H_c leads to coupling**
  - Between vibrational and intrinsic states
  - Between class-I and class-II states
- **Different approximations depending on degree of coupling**
  - Undamped vibrations
  - Partially damped vibrations
  - Completely damped vibrations

Important Model Input Parameters

- **Important parameters in calculation**
  - Fission barrier heights and widths
  - Individual transition states and continuum level densities at saddle points
  - Coupling terms between class-I and class-II states (coupling strengths, class-II coupling and fission widths, density of class-II states, etc.)



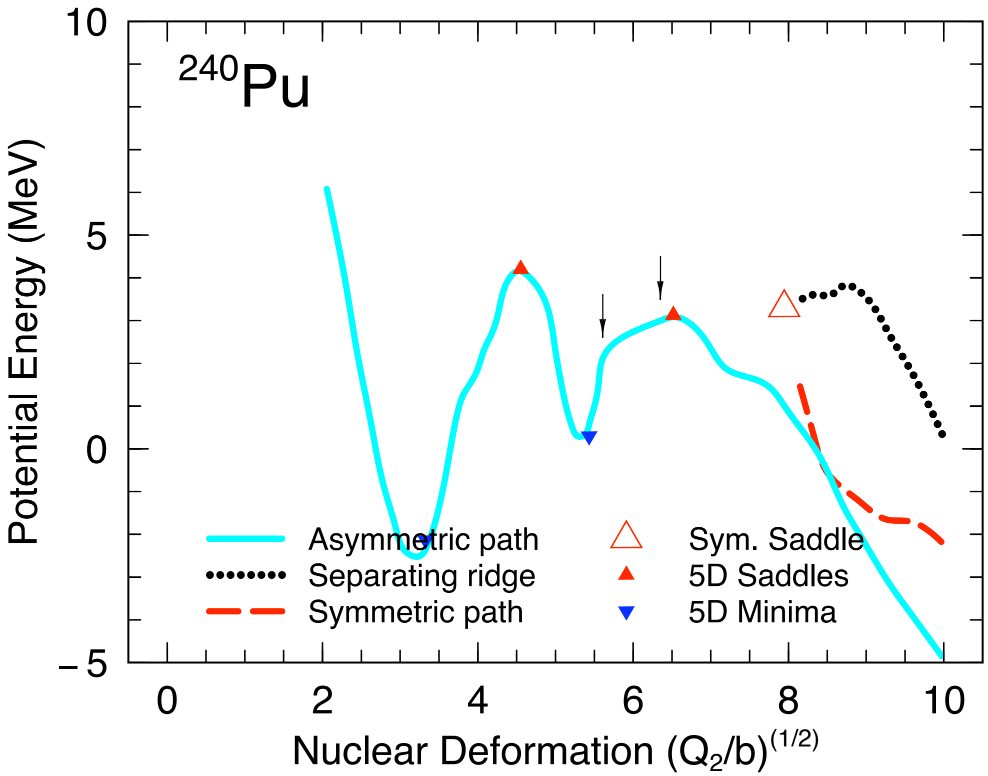


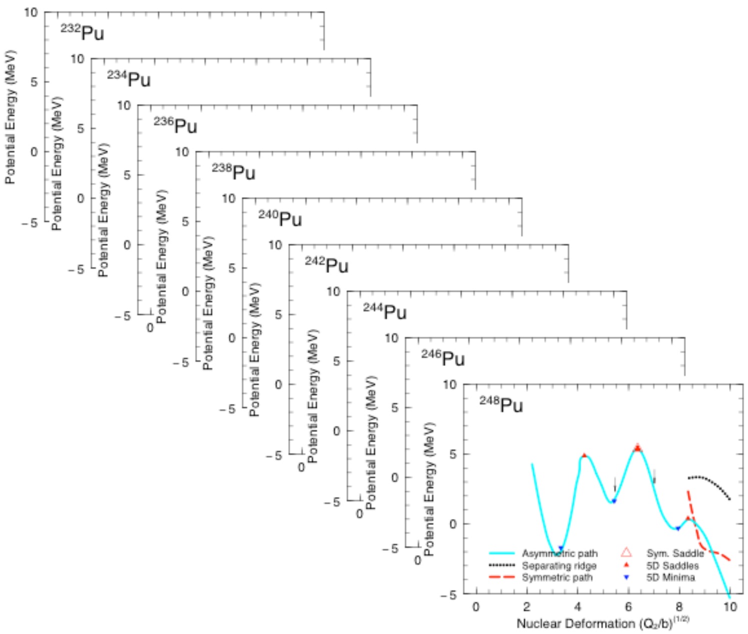
Practical Developments

- **Develop new version of AVXSF code from J.E.Lynn**
  - O.Bouland, CEA, France in visit at LANL for past 2 years
  - Fortran 95 version w/ XCode IDE
- **First application to suite of plutonium isotopes**
  - Robust database of consistent model input parameters
  - Level densities obtained by either fits to cross section or by combinatorial of single-particle states from FRLDM calculations
- **Publication in preparation**
  "Low-Energy Neutron-Induced Fission Cross Sections of Plutonium Isotopes", O.Bouland, J.E.Lynn, and P.Talou, to be submitted to Phys. Rev. C.

FRLDM potential energy surfaces for Pu isotopes

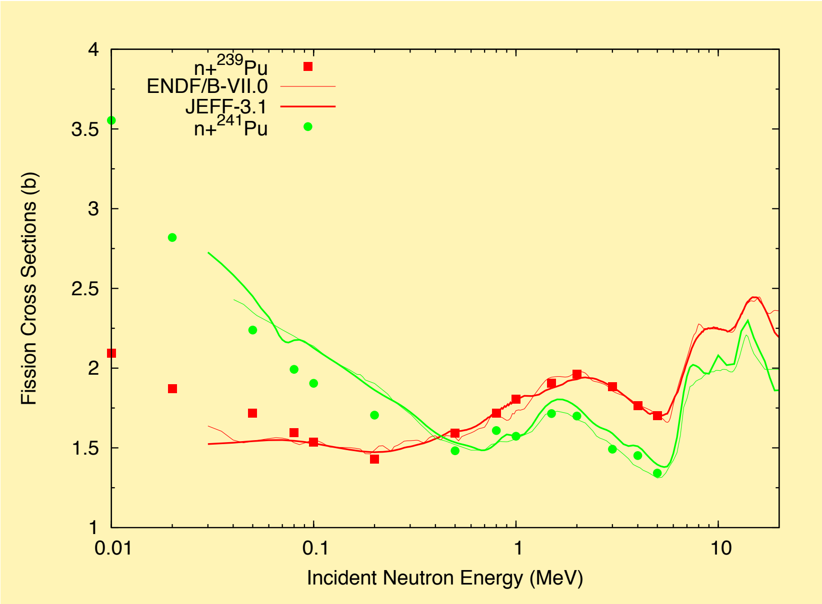
P.Möller *et al.* calculations, 2010



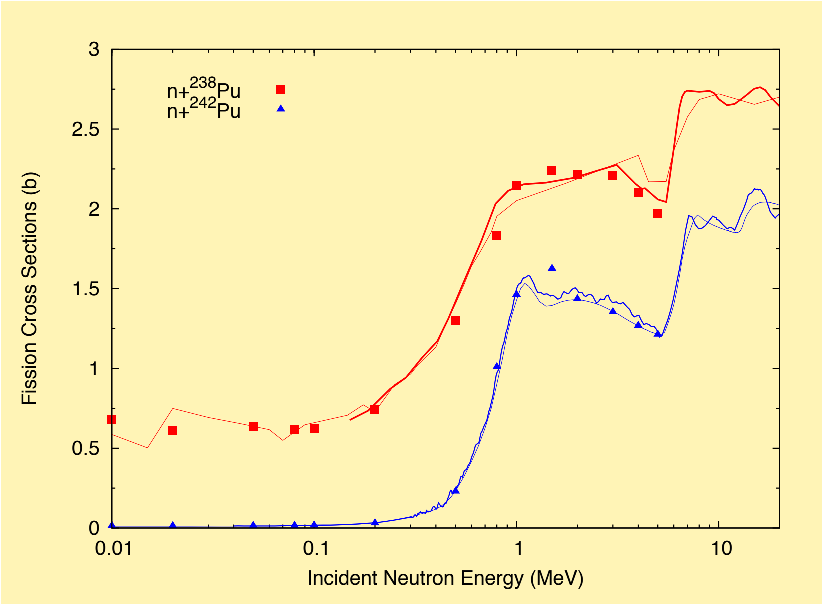


Preliminary Results for n+^{239,241}Pu and n+^{238,240}Pu

Odd target



Even target



Future Work

- **Finalize cross-section calculations for suite of plutonium isotopes and publish results**
- **Release (internally) Version 1.0 of new code**
  - based on AVXSF code by Lynn
- **Integrate new code with other T-2 reaction codes (Kawano, Talou) for improved treatment of competing reaction channels (neutron, capture)**
- **Study comprehensive fission cross section data: (n,f), (γ,f), (t,pf), …**