Optical Model Studies for Nuclear Data Evaluation

S. Kunieda, S. Chiba and E. Soukhovitskii*

Japan Atomic Energy Agency
*Joint Institute for Energy & Nuclear Research (Belarus)

The JENDL-4 Project

Neutron cross sections (<20 MeV)

- Major and minor actinoid nuclei
- Bulk of fission product nuclei
- Some light and structural material nuclei

Will be released on Mar.?, 2010

Issues & Purpose

OMP is depends on nucleus, particle and energy

- Lack of exp. data (FP, MA, …)
- “K-D global” for spherical nuclei

Nucleus has it’s own collective (rot.-vib.) character

→ Coupled-channel (CC) calculation

$$-\frac{\hbar^2}{2\mu}\nabla^2\psi_i + \sum_c \left\langle \phi_i \left| U \right| \phi_c \right\rangle \psi_c = E_i \psi_i$$

Issues & Purpose

Objective : Getting CC global OMP

- Particle : neutrons & protons, (& alpha)
- Energy range : < 200 (MeV)
- Target nuclei : medium-to-heavy nuclei (Z=26 ~ 92)

Adopted Framework

- Potential Depth, e.g.,

$$V_R(E^\dagger) = \left(\sum_n V_R^{(n)} E^{\dagger n} + V_R^{DISP} e^{-\lambda_R E^\dagger} \right) \times \left[1 + \frac{C_{symm.}}{V_R^0 + V_R^{DISP}} \cdot \frac{\mp (N-Z)}{A} \right] + C_{coul} \frac{ZZ'}{A^{1/3}} \varphi_{coul}(E^\dagger)$$

Symm. *Coul.*

- Rigid-rotor CC (RRM-CC) as a first step !

$$R(\theta,\phi) = R_0 \left\{ 1 + \sum_\lambda \beta_{\lambda 0} Y_{\lambda 0}(\theta,\phi) \right\}$$

where, R_0=1.21A$^{1/3}$

Deformation parameters

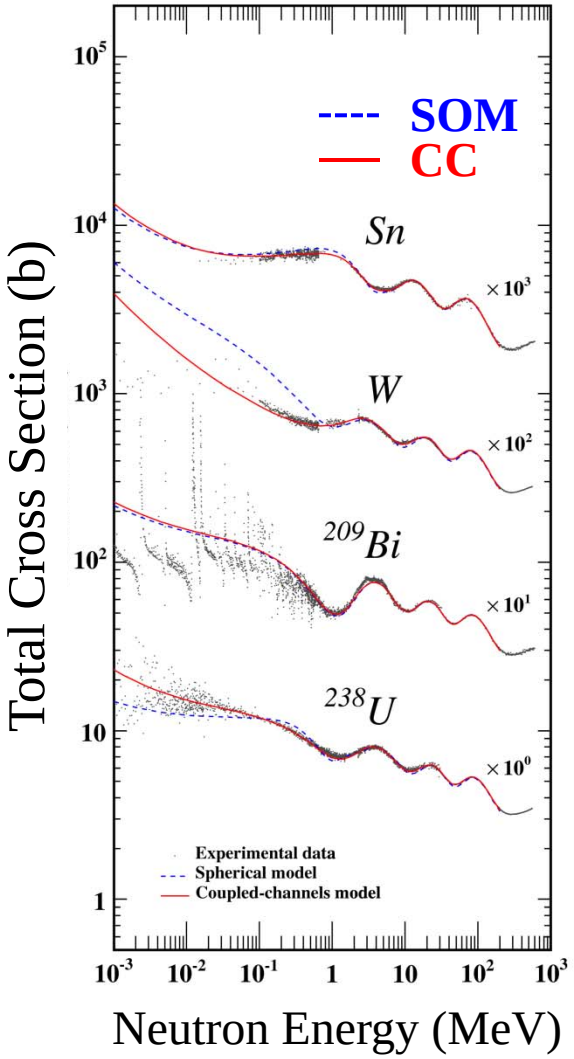
Useful Experimental Data

- Total cross sections
  OHO-LANL (Finlay+, …)

  - WNR@LANSCE measurements
  - Wide energy range (<600 MeV)
  - Systematic measurements

⇩

- Energy & Mass dependence
- Geometry parameters



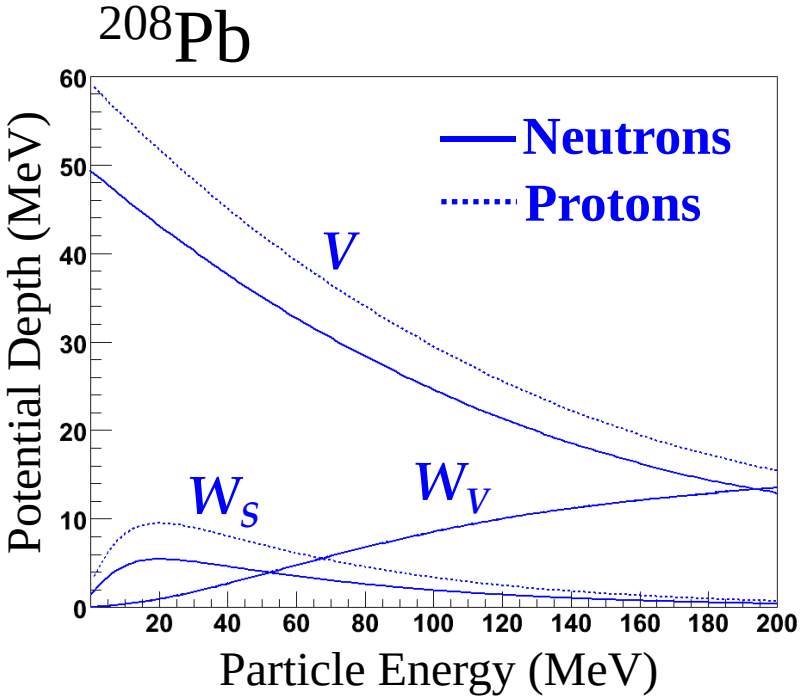
Useful Experimental Data

- Elastic scattering DA

- Neutrons : ANL (A.B.Smith+)
  : Tohoku (Ibaraki+)
- Protons : many data

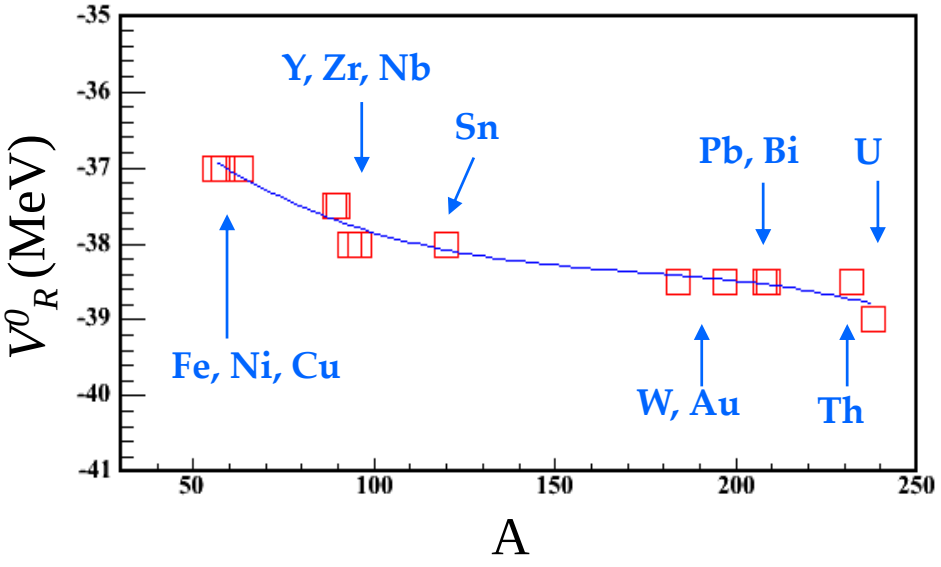
n & p simultaneous analysis

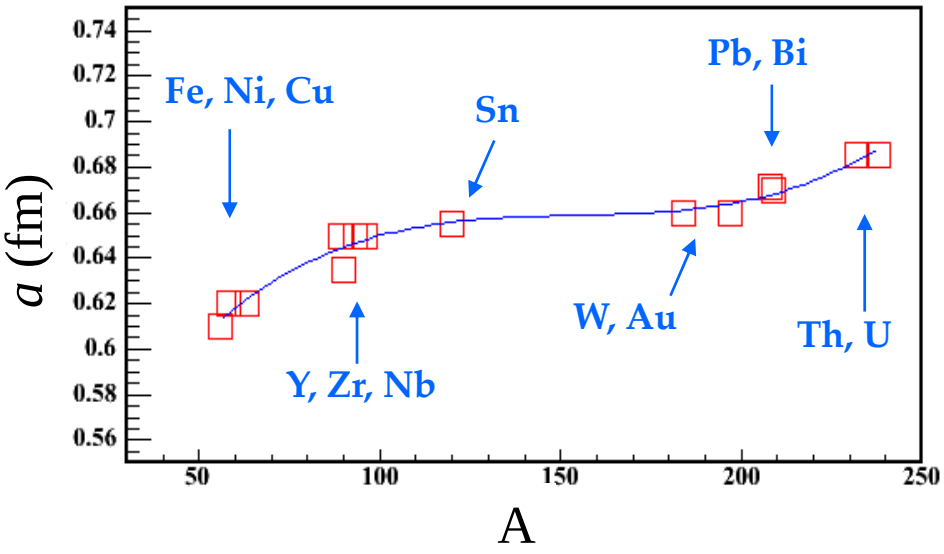
→ OMP Isospin terms :
$C_{symm.}$ & $C_{Coul.}$



Mass Dependence

Fe, Ni, Cu, Y, Zr, Nb, Mo, Sn,
W, Au, Pb, Bi, Th and U





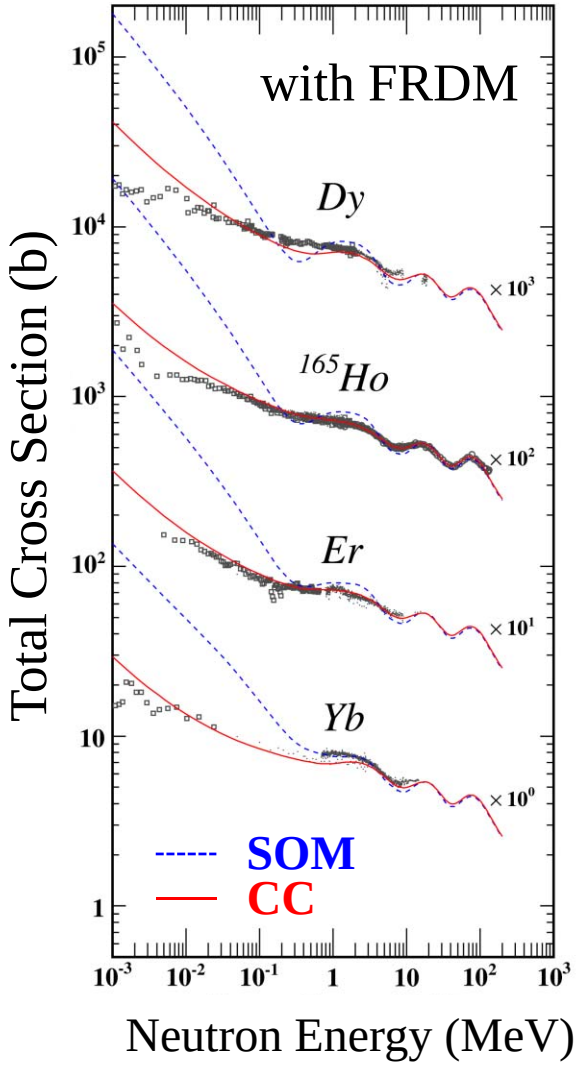
⟶ Systematics (50 < A < 240)

Global Calculation

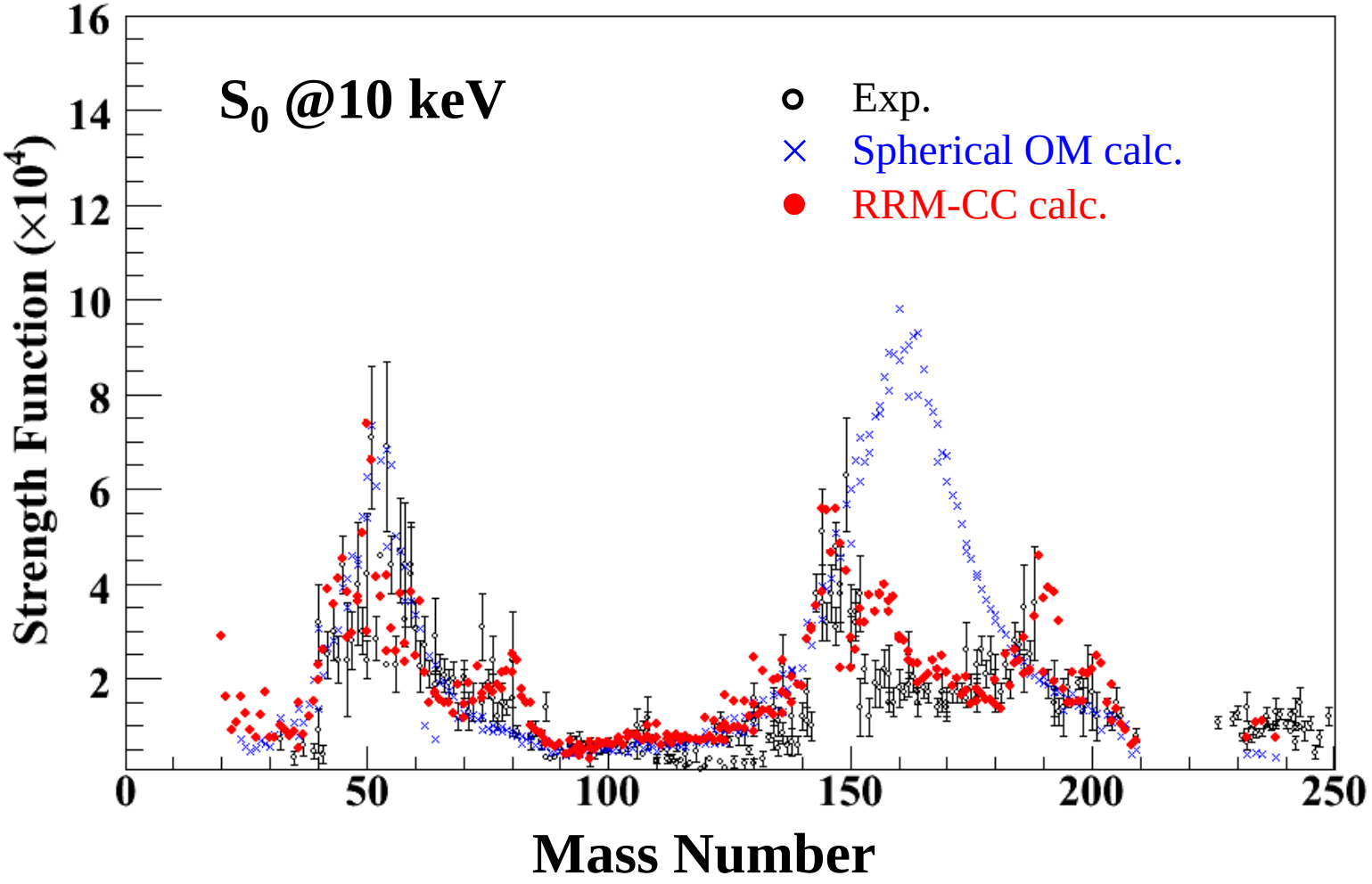
Our systematic OMP

+

β_λ - Exp. B(E2)
- FRDM
- HFB
- KTUY

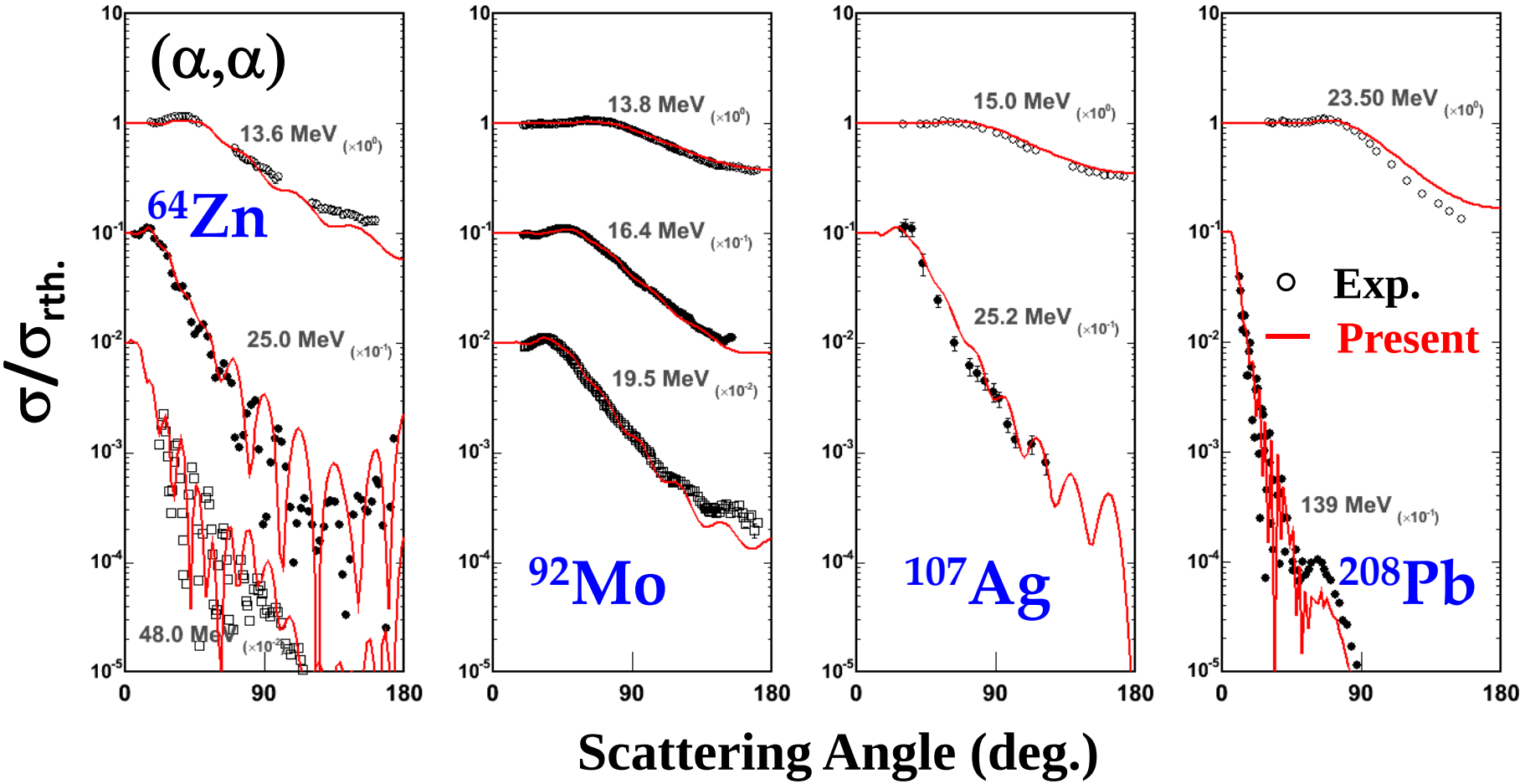


Global Calculation



(α,α) by n- & p-OMP

Estimated by the simplified folding model : $U_\alpha(E) = 2U_n(E/4) + 2U_p(E/4)$



Soft-rotor Model (SRM)

- Hamiltonian

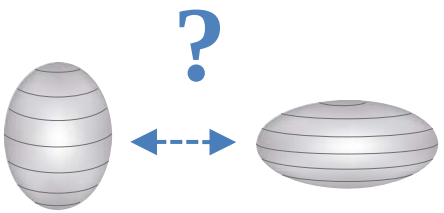
$$\hat{H} = \frac{\hbar^2}{2}\hat{T}_r + \frac{\hbar^2}{2B_2}\left\{\hat{T}_{\beta_2} + \frac{1}{\beta_2^2}\hat{T}_\gamma\right\} + \frac{\hbar^2}{2B_3}\hat{T}_{\beta_3} + V(\beta_2) + \cdots$$

Rotation — Vibration

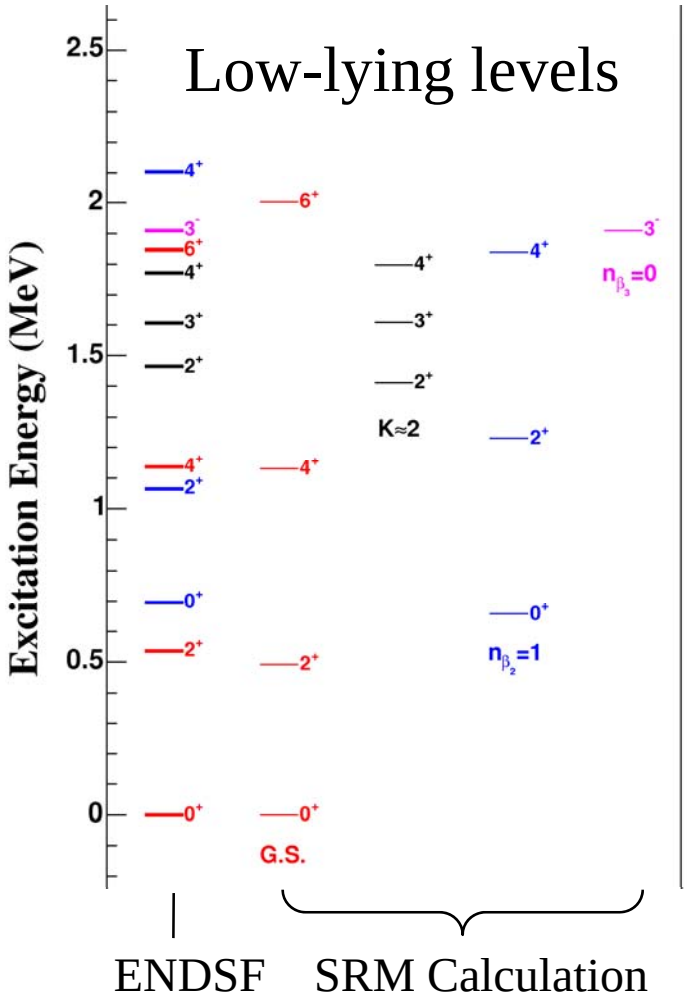
- Moment of inertia

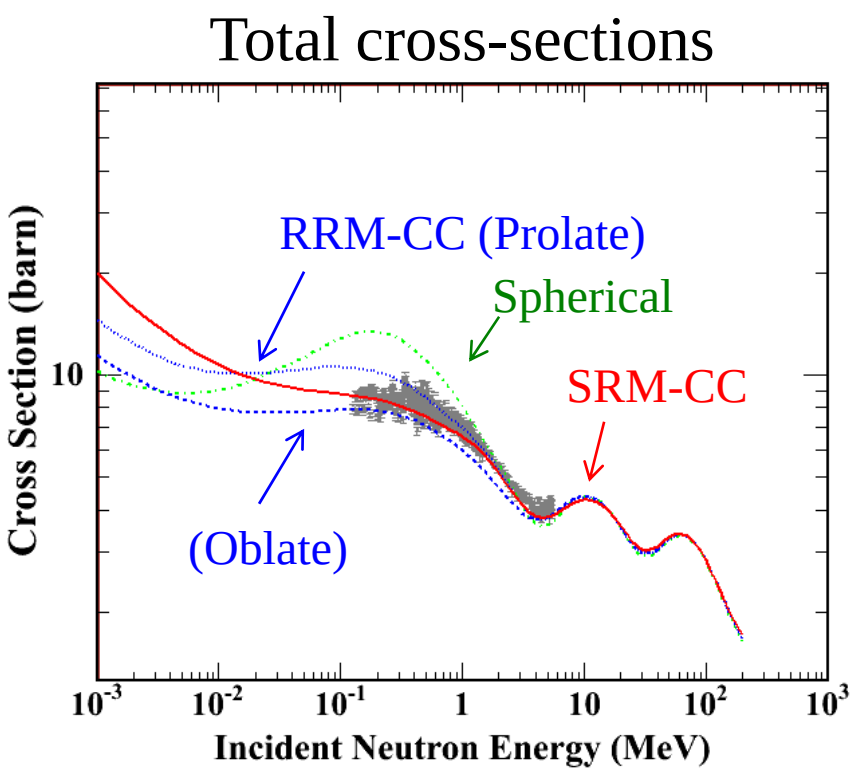
$$J_i^{(2)} = 4B_2\beta_2^2 \sin^2\left(\gamma - \frac{2}{3}\pi i\right), \qquad (i = 1,2,3)$$

γ : non-axial deformation



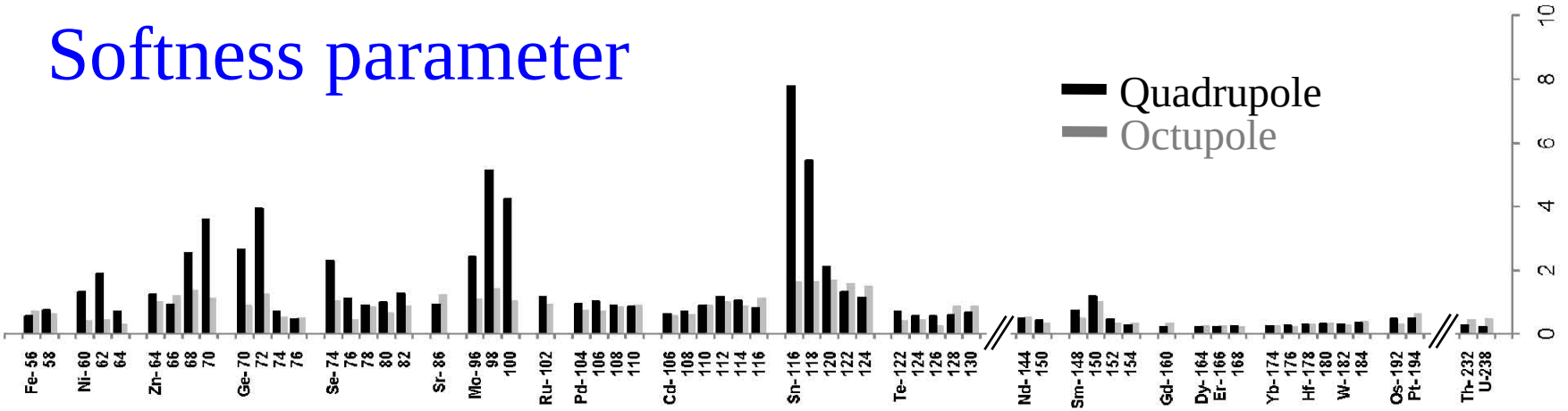
SRM-CC for ^{100}Mo



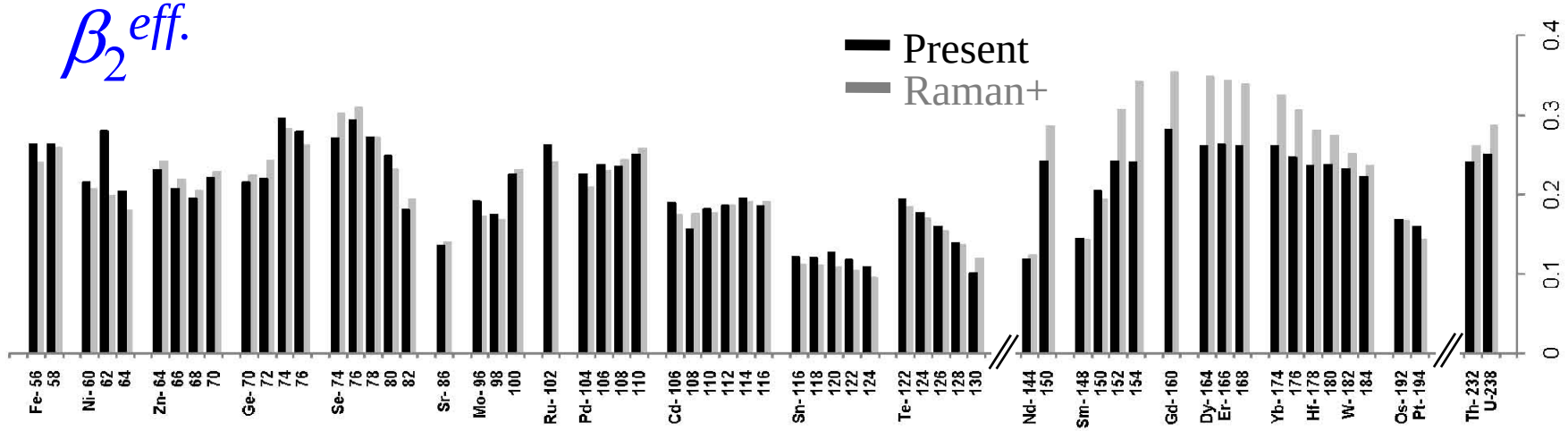


SRM for 63 Even-Nuclei

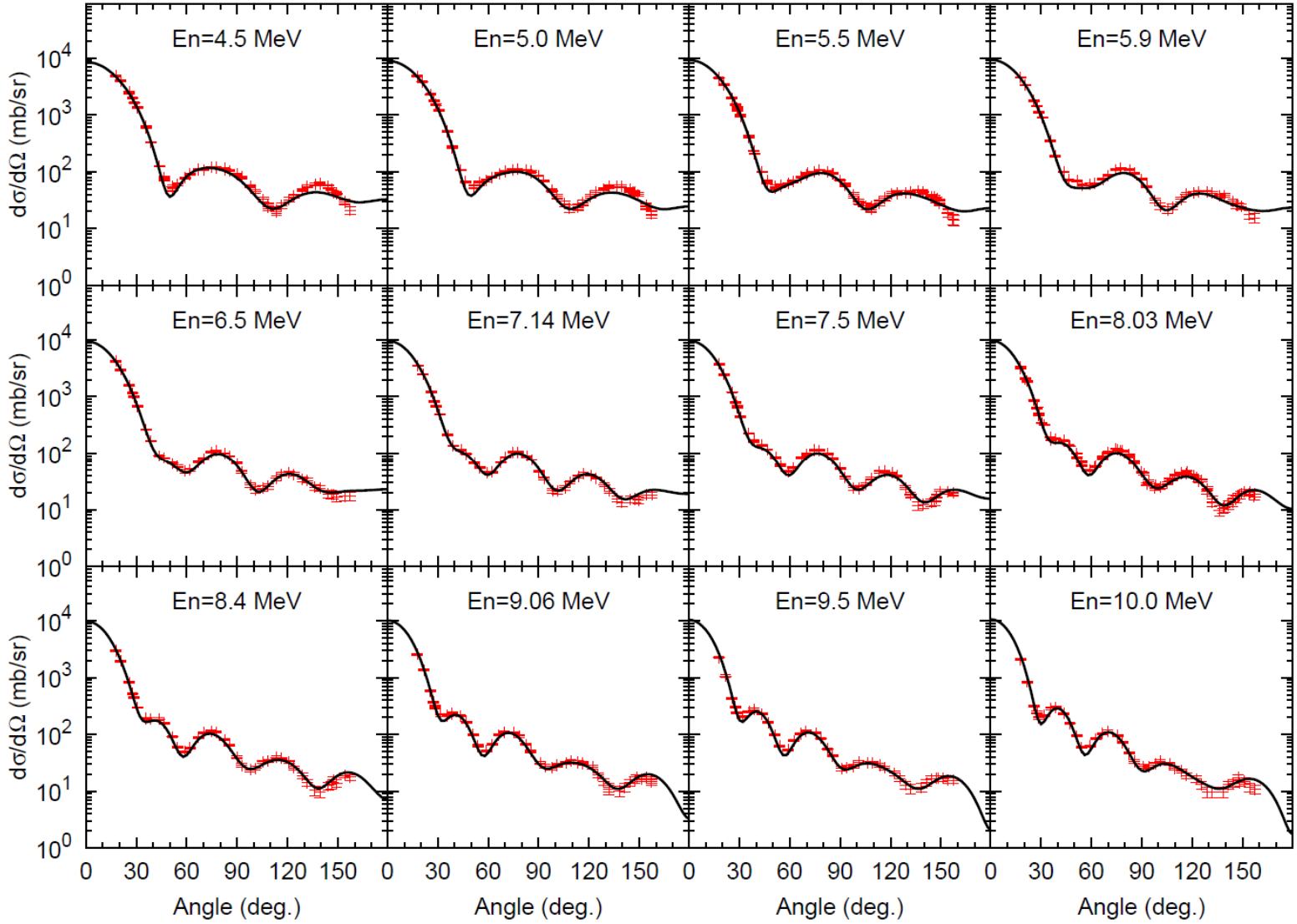
Softness parameter



$\beta_2^{eff.}$



^{238}U(*n*,*n*+*n*') for JENDL-4



Summary

- CC-OMP was obtained for nucleons < 200 MeV for medium-to heavy nuclei.
- Global calculation reproduced exp. data fairly well.
- We can easily get reasonable OMP for α-particle.
- SRM Hamiltonian was estimated for 63 nuclei.