

Fiesta2017

Fission ExperimentS and Theoretical Advances

Neutron Cross Section Evaluation of U-238

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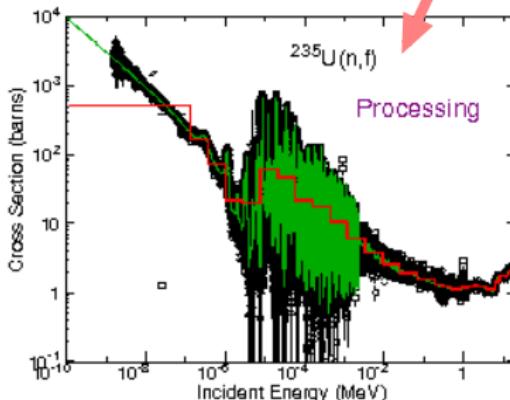
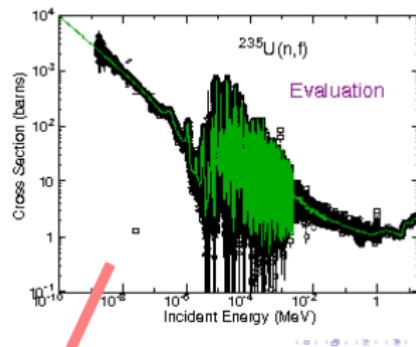
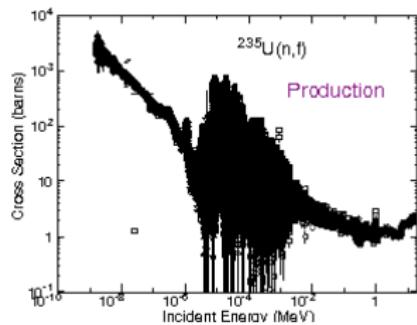
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Introduction

- Nuclear Data Evaluation
 - Analyzing the measured physical quantities
 - + Combing them with theoretical predictions
 - => Extract the true values of such quantities
- DataBase
 - ENDF Library (Compact format)
 - Processed to Pointwised or Groupwised Libraries
- Application
 - Inputs for various simulation codes
(MCNP, Geant4, PHITS, DRAGON, DANTSYS, DORT . . .)

Nuclear data activities

An example of nuclear data eval. for ^{235}U



Uranium

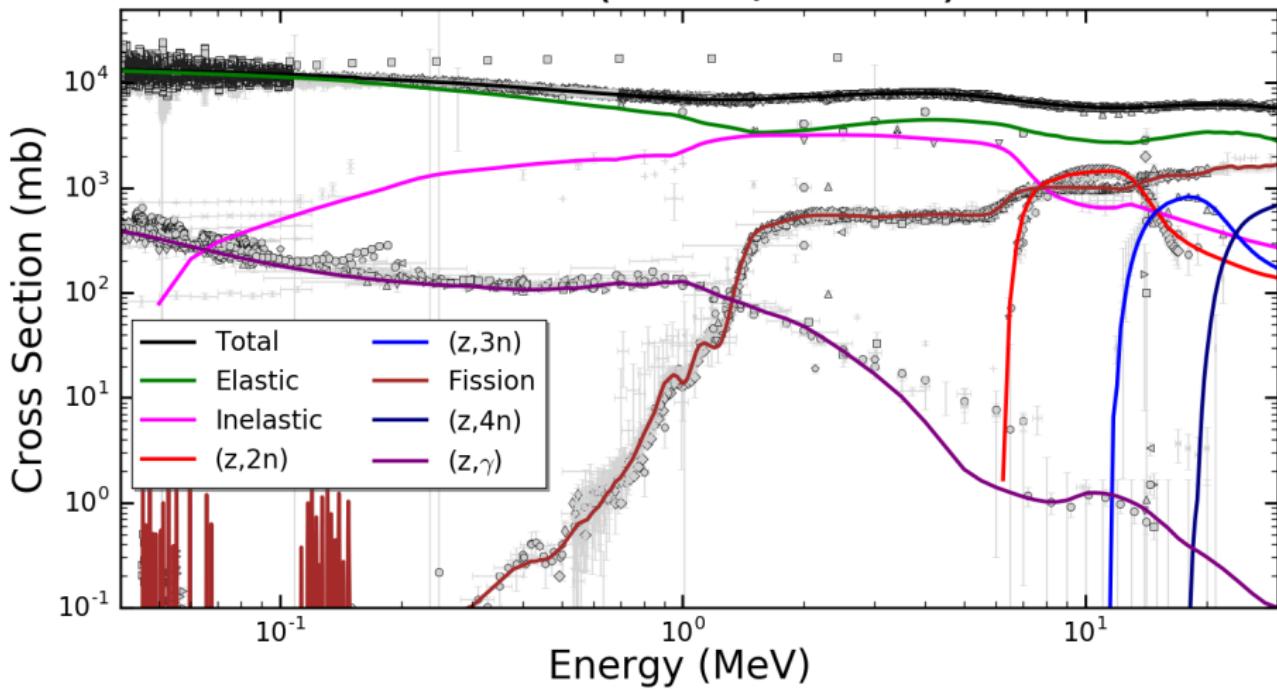
- Abundances of natural uranium

- ^{234}U : 0.0054 %
- ^{235}U : 0.7204 %
- ^{238}U : 99.2742 %

- U-238

- Fuel of nuclear reactor
 - LWR: 95 ~ 97 %, HWR: 98 ~ 99 %
- Well evaluated but Continuously updated
- Current version:
 - ENDF/B-VII.1, JENDL-4.0, JEFF-3.2, CENDL-3.1, RUSFOND-2010, ...
- Preliminary:
 - ENDF/B-VIII-b4, JEFF33T4

Cross sections for U-238

 $n + {}^{238}\text{U}$ (ENDF/B-VII.1)

Cross Sections

- Cross Sections

- Cross Section: function of the kinetic energy of the particle a

$$\sigma(E_a) = \int \int \frac{d^2\sigma(E_a, E_b, \Omega)}{dE_b d\Omega} dE_b d\Omega$$

- Differential Cross Section: Distributions of an emitted particle for angle **or** energy

$$\frac{d\sigma(E_a, E_b)}{dE_b} \quad \frac{d\sigma(E_a, \Omega)}{d\Omega}$$

- Double-Differential Cross Section (DDX): Distributions of an emitted particle for angle **and** energy

$$\frac{d^2\sigma(E_a, E_b, \Omega)}{dE_b d\Omega}$$

Interactions between particle and nucleus

- Schrödinger equation

$$\left(-\frac{\hbar^2}{2\mu} \nabla^2 + U(r) \right) \Psi = E\Psi,$$

where $\Psi(r, \theta, \phi) = R(r) Y_l^m(\theta, \phi)$.

- Scattering matrix



$$\begin{array}{c} I_l(kr) \\ \longleftarrow \\ S_l O_l(kr) \\ \longrightarrow \\ r \end{array}$$

$$\Psi(r) = \frac{i}{2} \left(I_l(kr) - S_l O_l(kr) \right)$$

Scattering Matrix

Phenomenological Optical Model Potential (OMP)

$$U(r, E) = V_c(r, E) \quad \text{Coulomb}$$
$$-(V_V(E) + iW_V(E))f_V(r) \quad \text{Volume}$$
$$+(V_D(E) - iW_D(E))g_D(r) \quad \text{Surface}$$
$$-2l \cdot \vec{s}(V_{SO}(E) + iW_{SO}(E))h_{SO}(r), \quad \text{Spin-Orbit}$$

where $V_{V,SO}$ and $W_{V,D,SO}$ are the real and imaginary components of the volume central (V), surface-central (D) and spin-orbit (SO) potentials, respectively.

$$f_i(r) = \frac{1}{(1 - \exp[(r - R_i)/a_i])}, g_i(r) = -4a_D \frac{d}{dr} f_i(r), h_i(r) = \frac{1}{r} \frac{d}{dr} f_i(r),$$

where the geometry parameters are the radius $R_i = r_i A^{1/3}$, whith A begins atomic mass number, and the diffuseness parameters a_i .

K-D form

$$V_V(E) = v_1[1 - v_2(E - E_f) + v_3(E - E_f)^2 - v_4(E - E_f)^3],$$

$$W_V(E) = w_1 \frac{(E - E_f)^2}{(E - E_f)^2 + w_2^2},$$

$$W_D(E) = d_1 \frac{(E - E_f)^2}{(E - E_f)^2 + d_3^2} \exp[-d_2(E - E_f)],$$

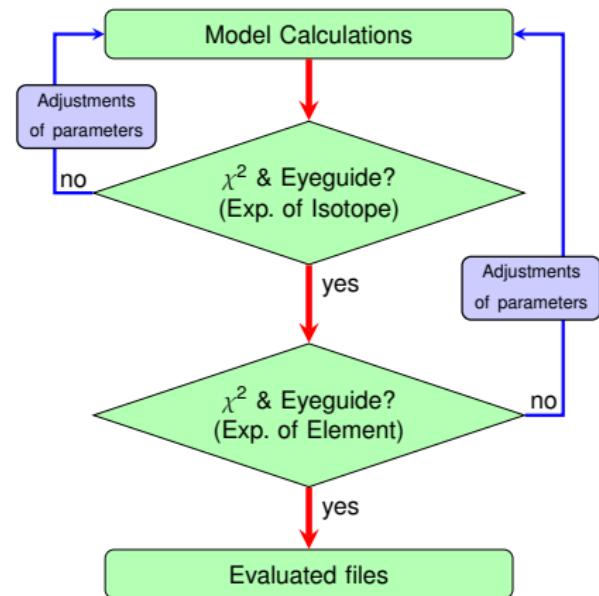
$$V_{SO}(E) = v_{so1} \exp[-v_{so2}(E - E_f)],$$

$$W_D(E) = w_{so1} \frac{(E - E_f)^2}{(E - E_f)^2 + (w_{so2})^2},$$

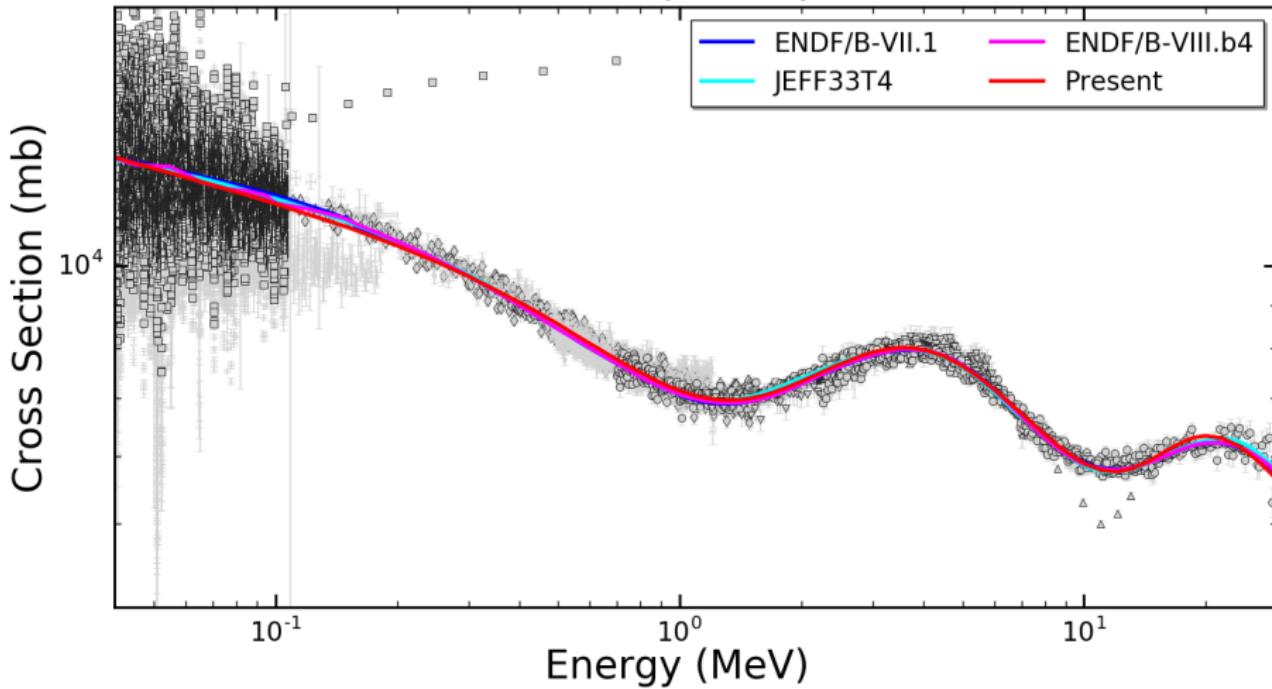
where E_f, N, Z and A are the Fermi energy, number of neutrons, number of protons, and mass number, respectively. In all cases, the geometry (r_i, a_i) of the potential is assumed to be independent of the energy.

Model calculation

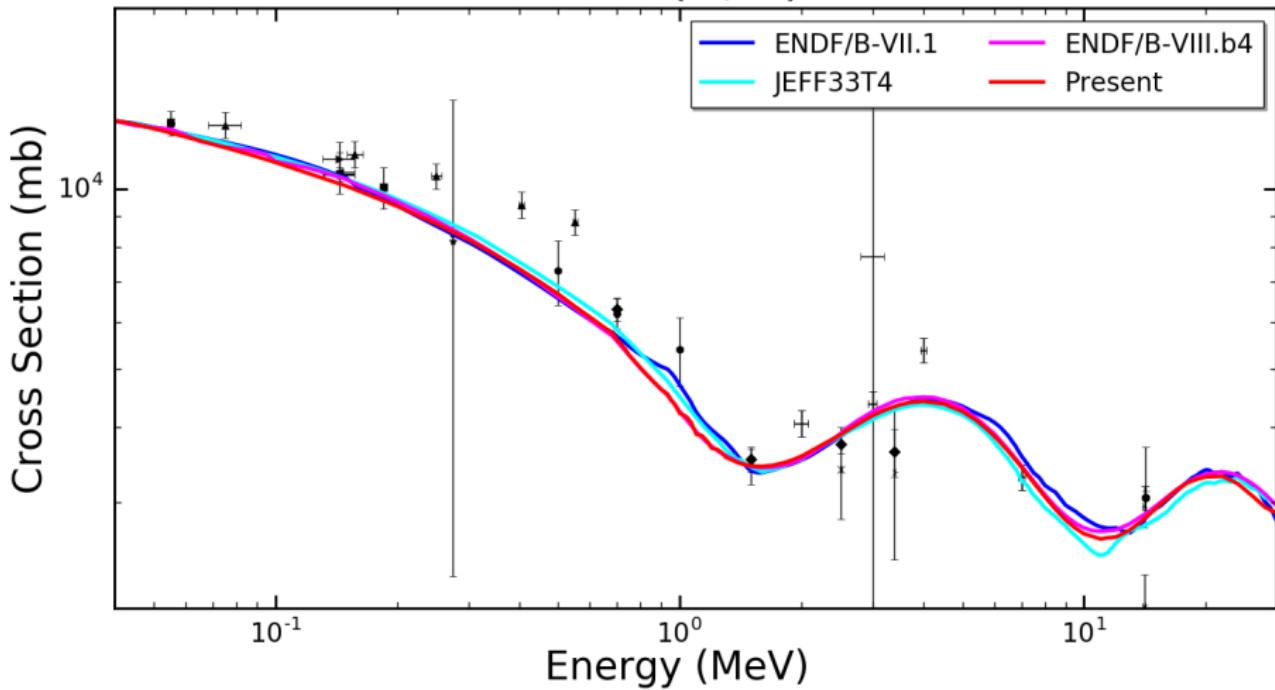
- Model
 - OMP, Level density, preequilibrium, fission model, γ -ray strength function, ...
- Parameterization
 - Default parameters:
Taken from the recommended data in RIPL-3 (Reference Input Parameter Library)
 - Parameterizing to reproduce the measured data
- Code: Empire-3.2



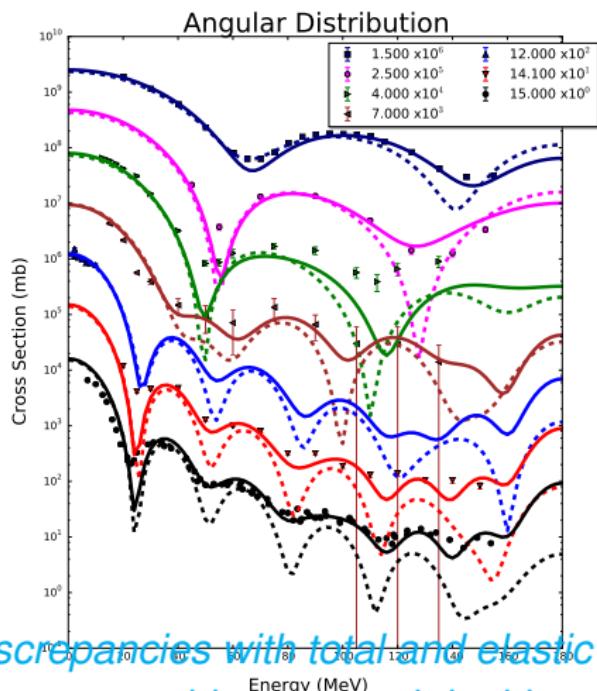
Total cross section

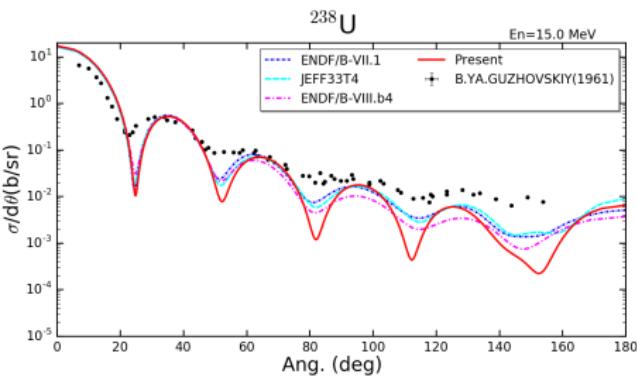
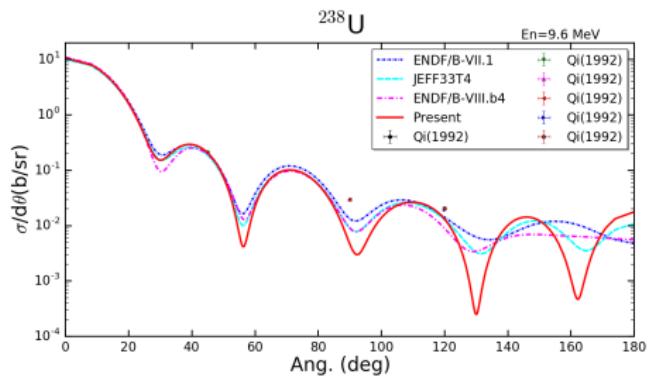
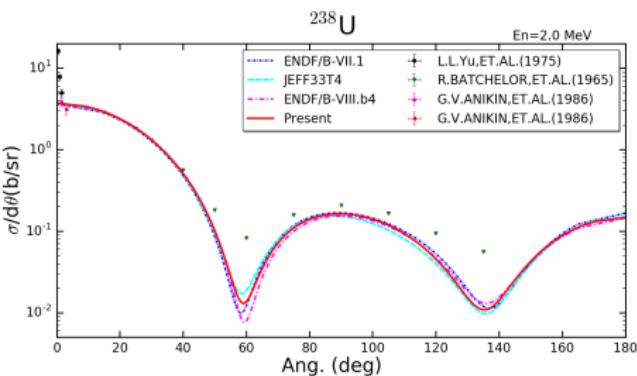
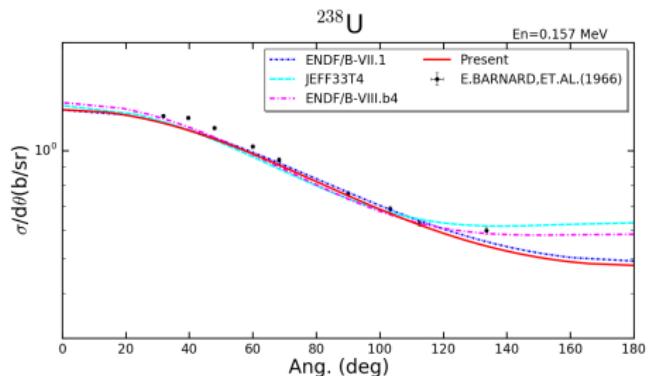
 ^{238}U (n,tot)

Elastic cross section

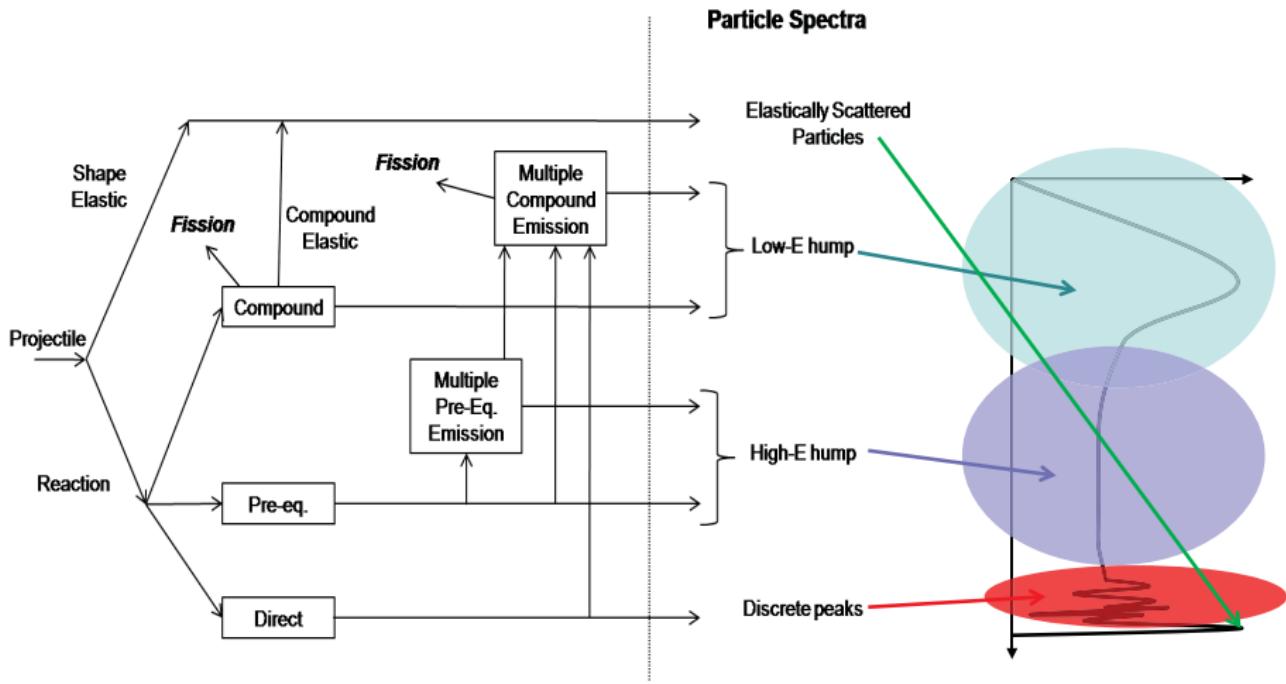
 ^{238}U (n,el)

Elastic Angular Distribution

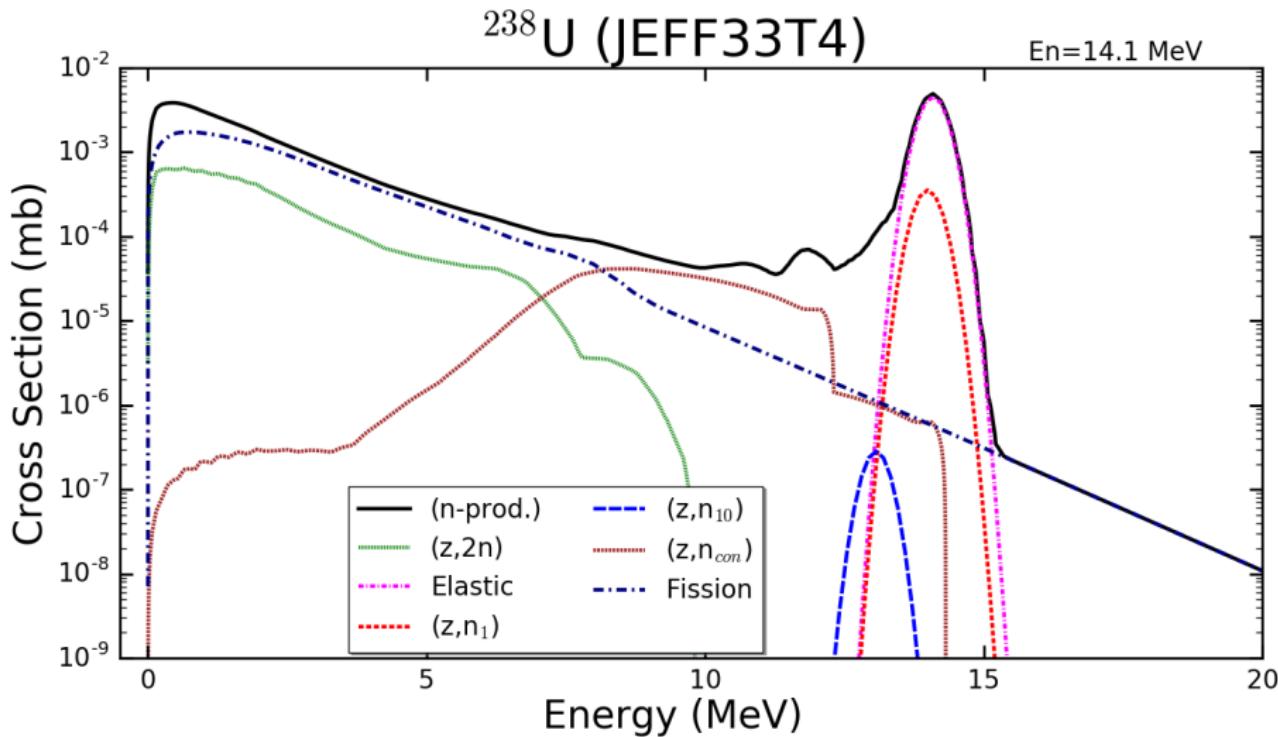




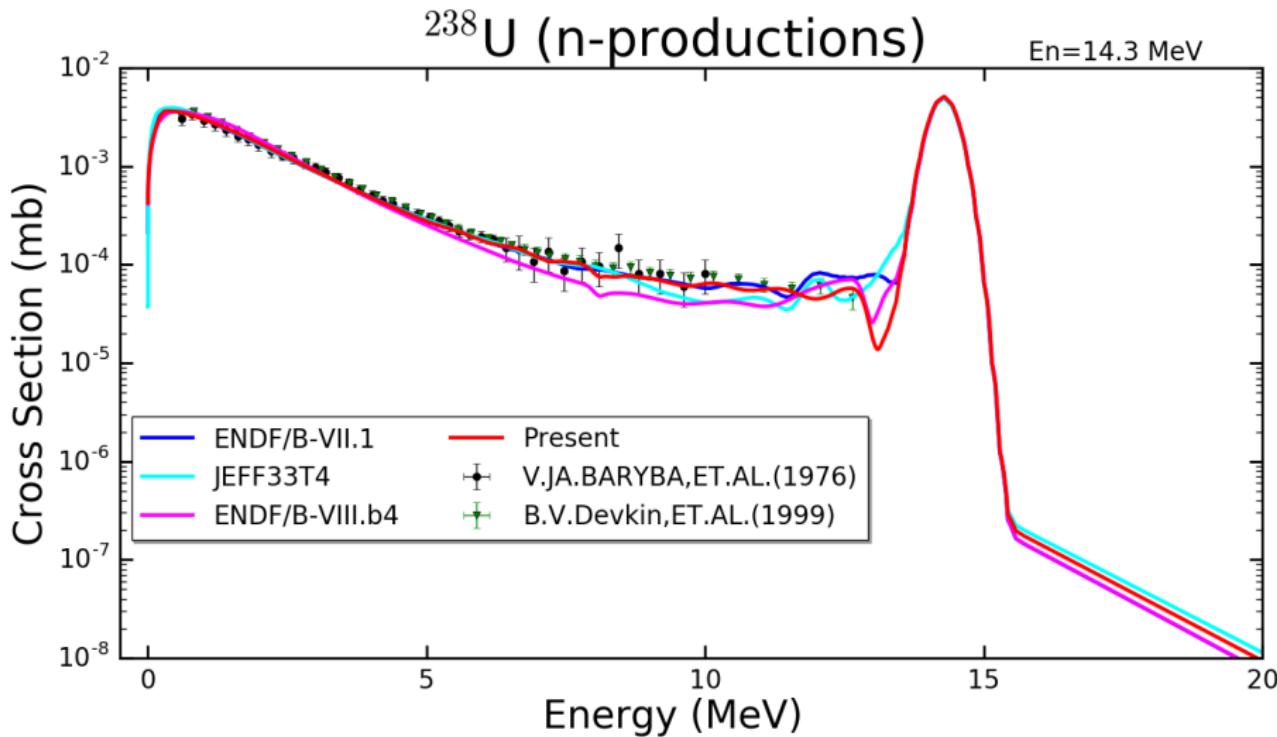
Particle Spectra



Neutron productions induced by neutron with 14.1 MeV energy

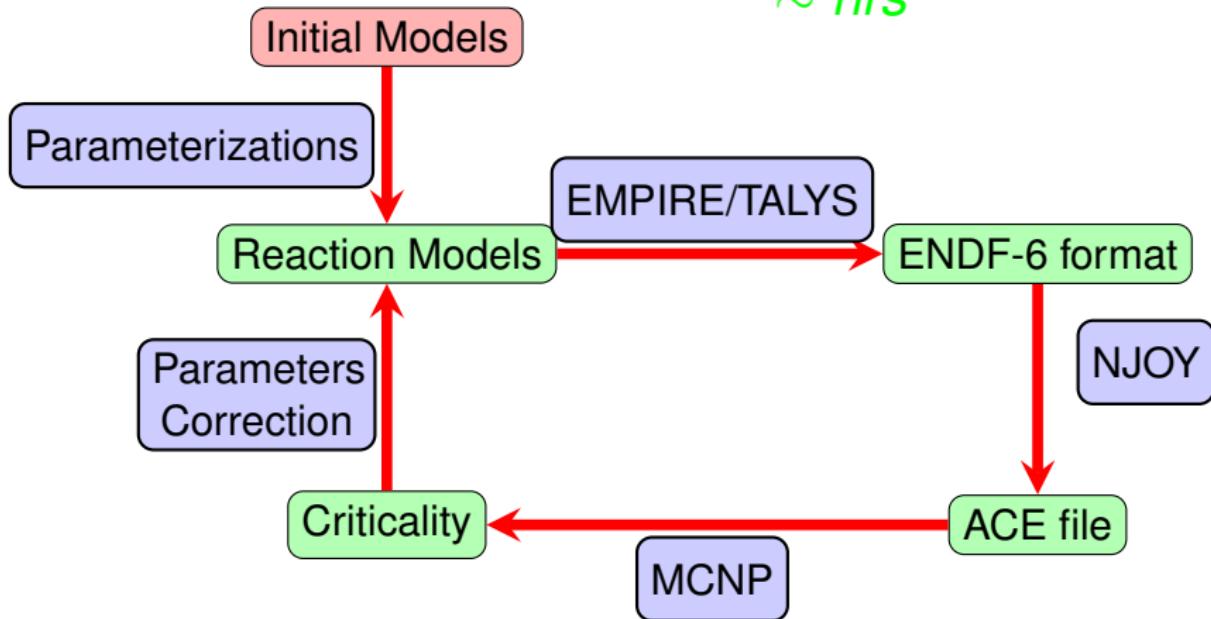


Neutron productions induced by neutron around 14 MeV

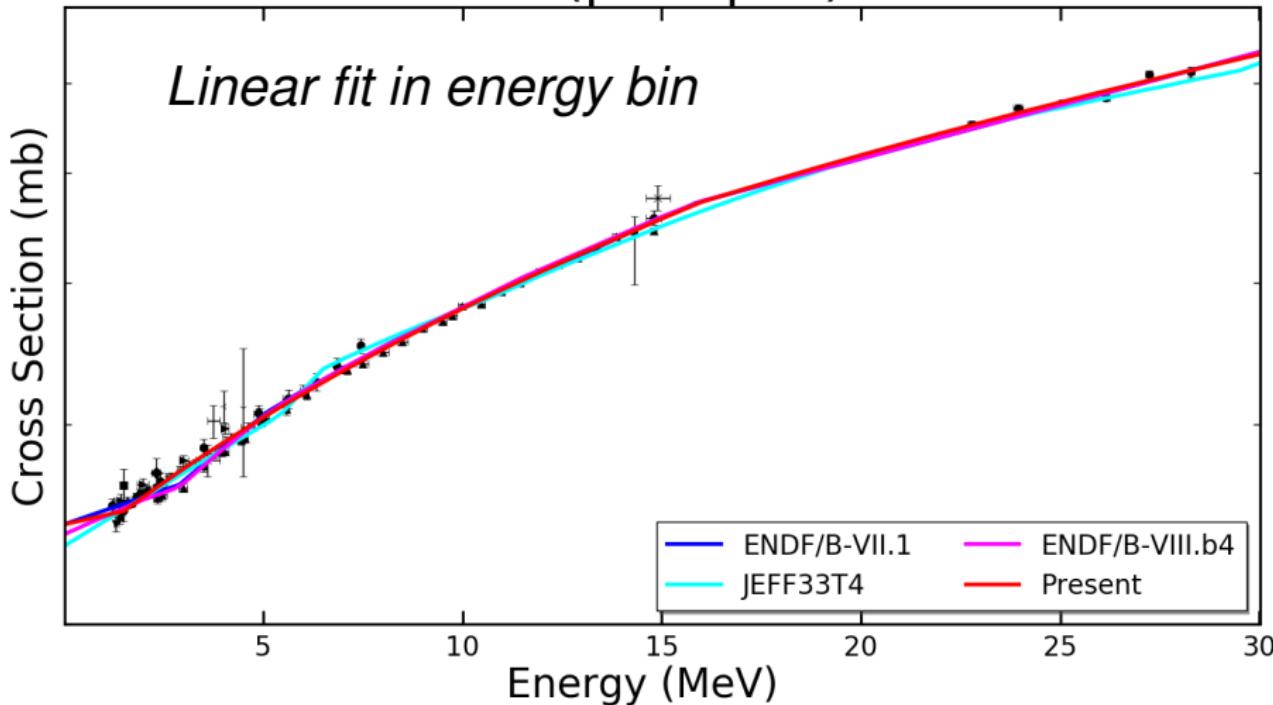


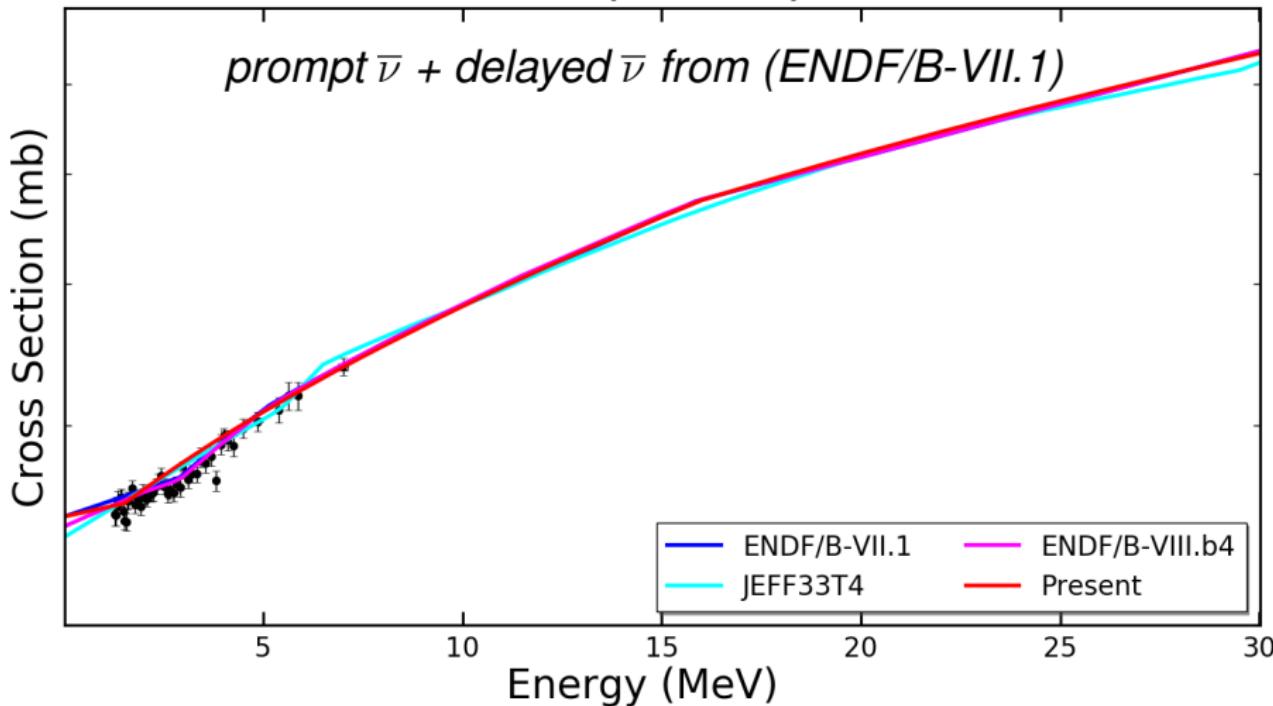
KAERI/NDC evaluation

Modern Computing Power
 \sim hrs

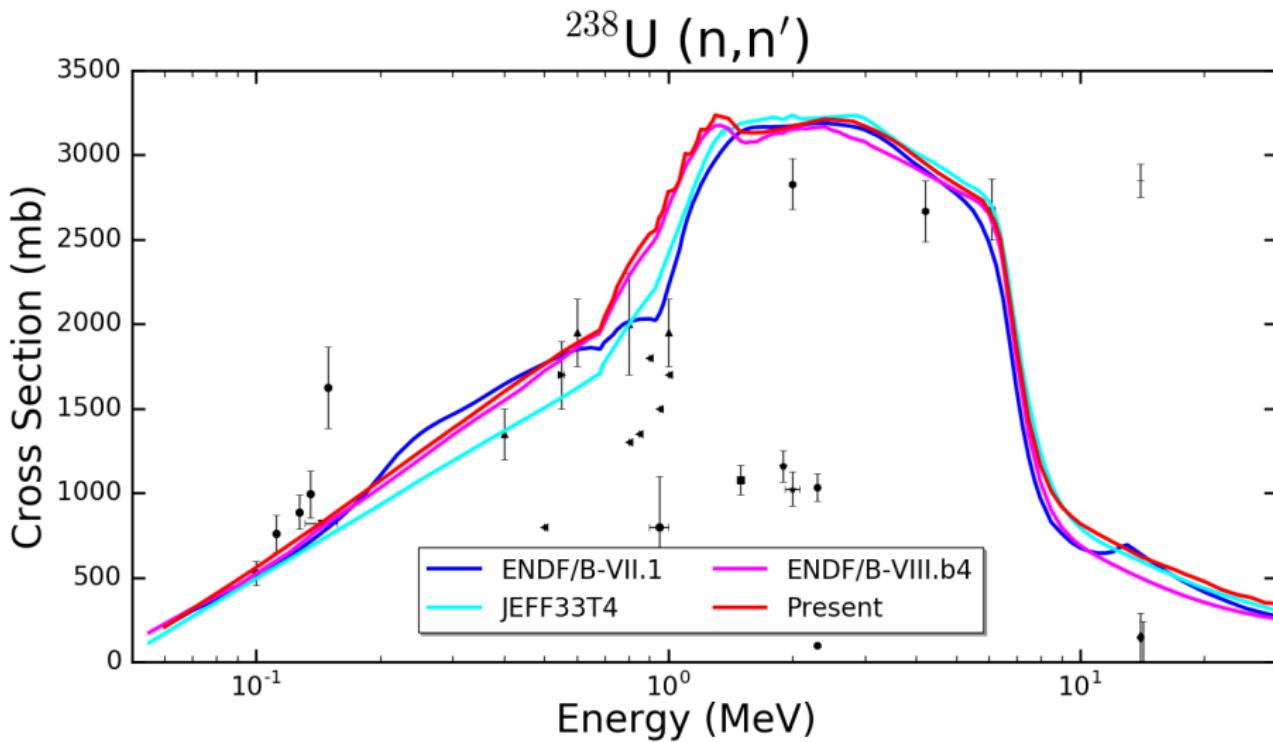


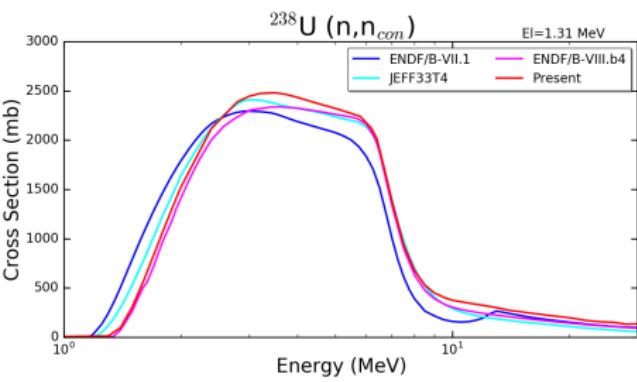
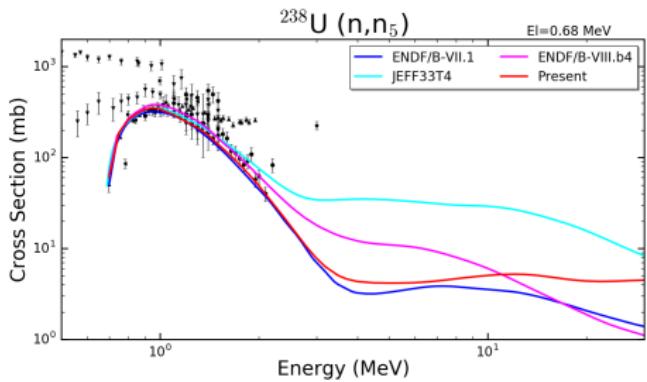
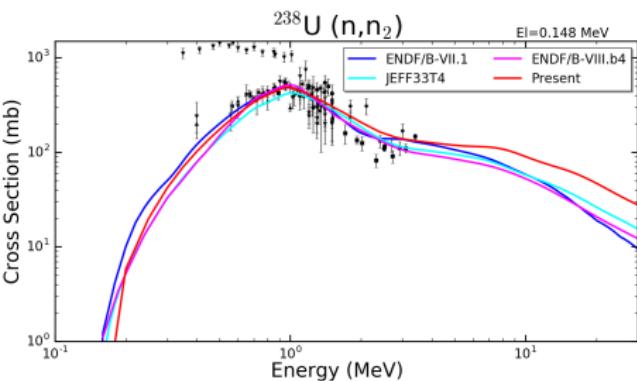
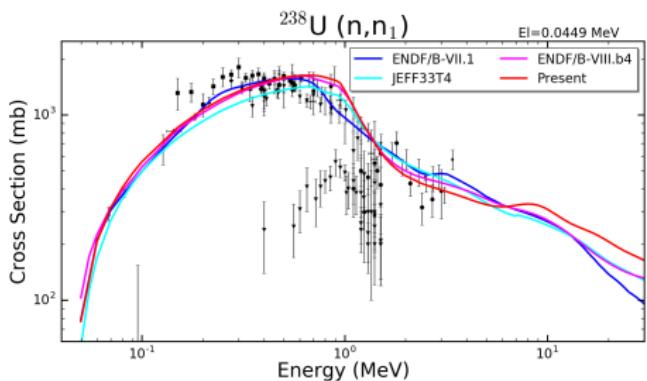
Results

Prompt $\bar{\nu}$ ^{238}U (prompt $\bar{\nu}$)

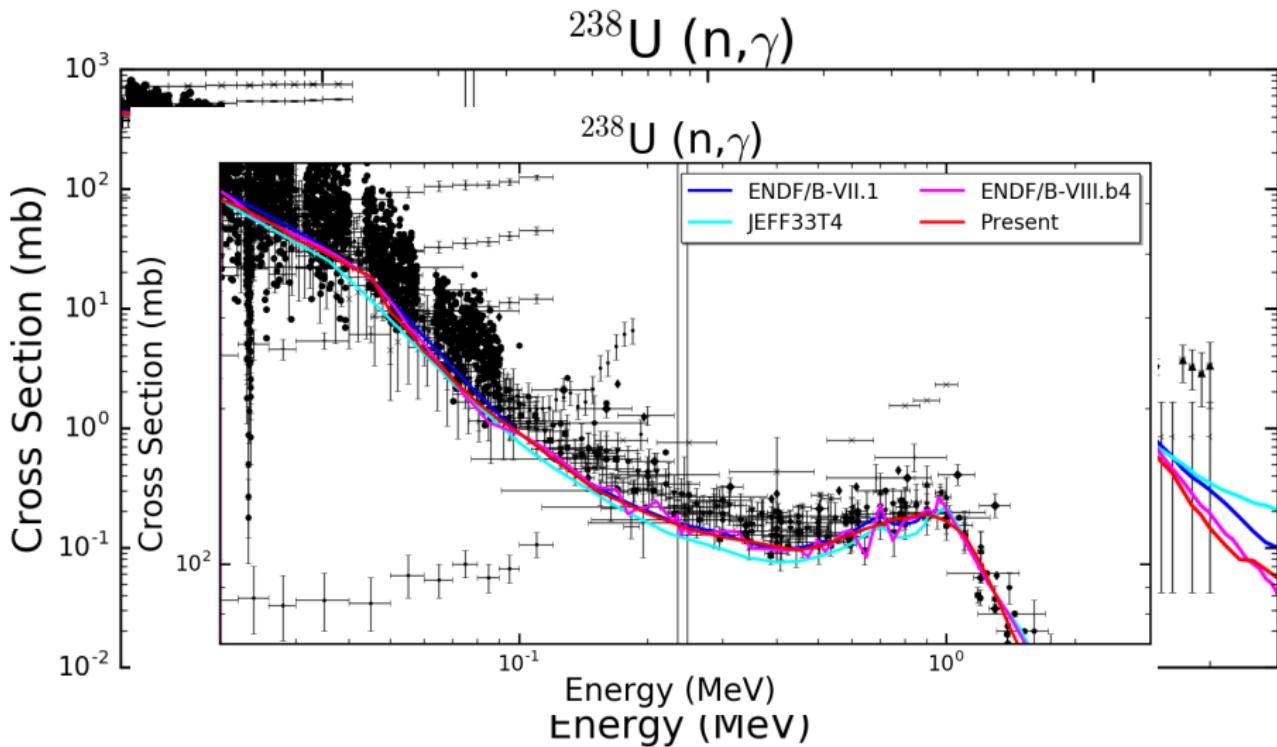
Total $\bar{\nu}$ ^{238}U (total $\bar{\nu}$)

Inelastic cross section

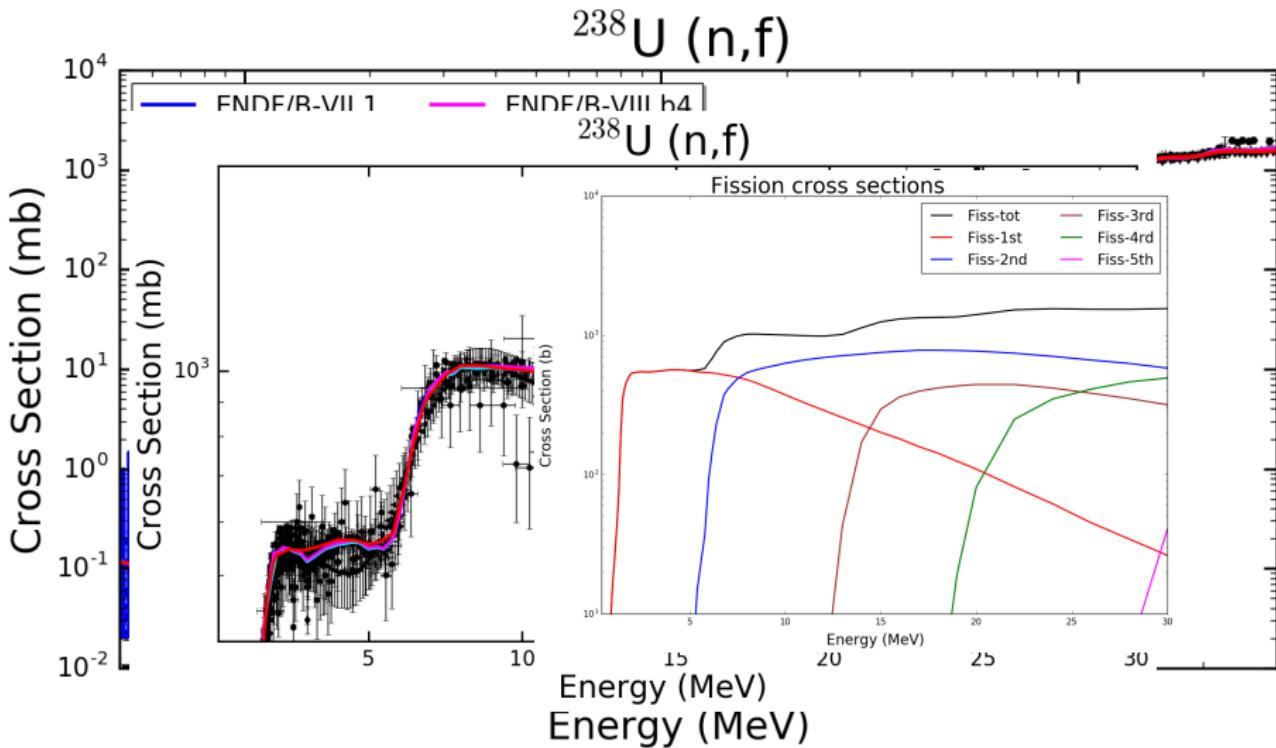




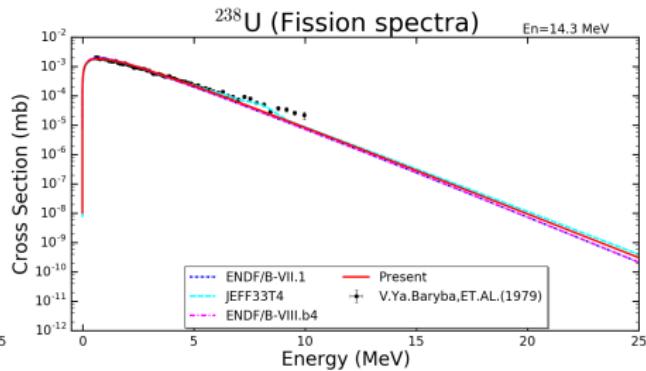
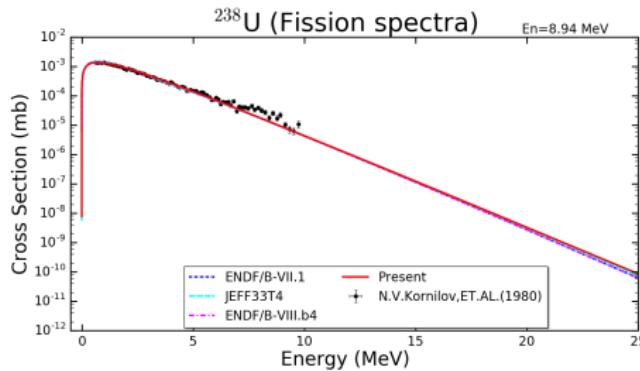
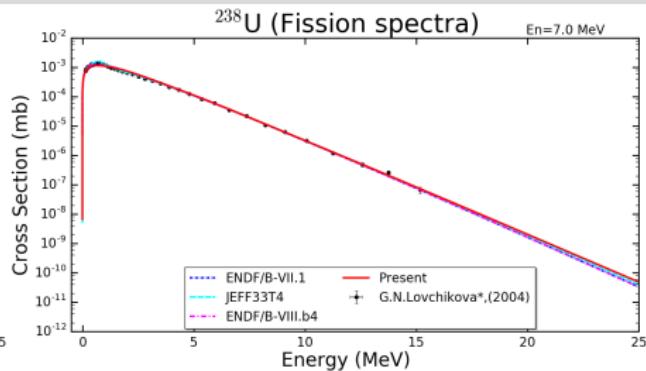
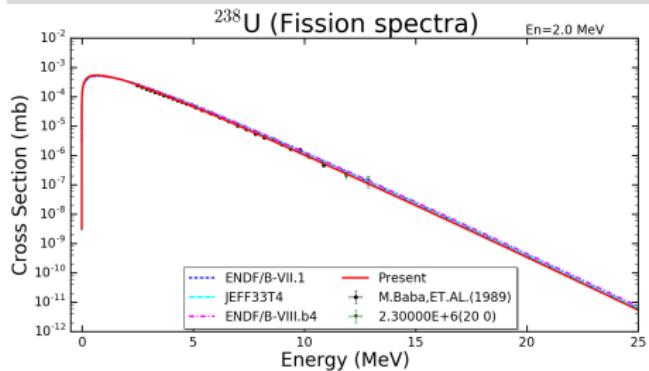
Capture cross section



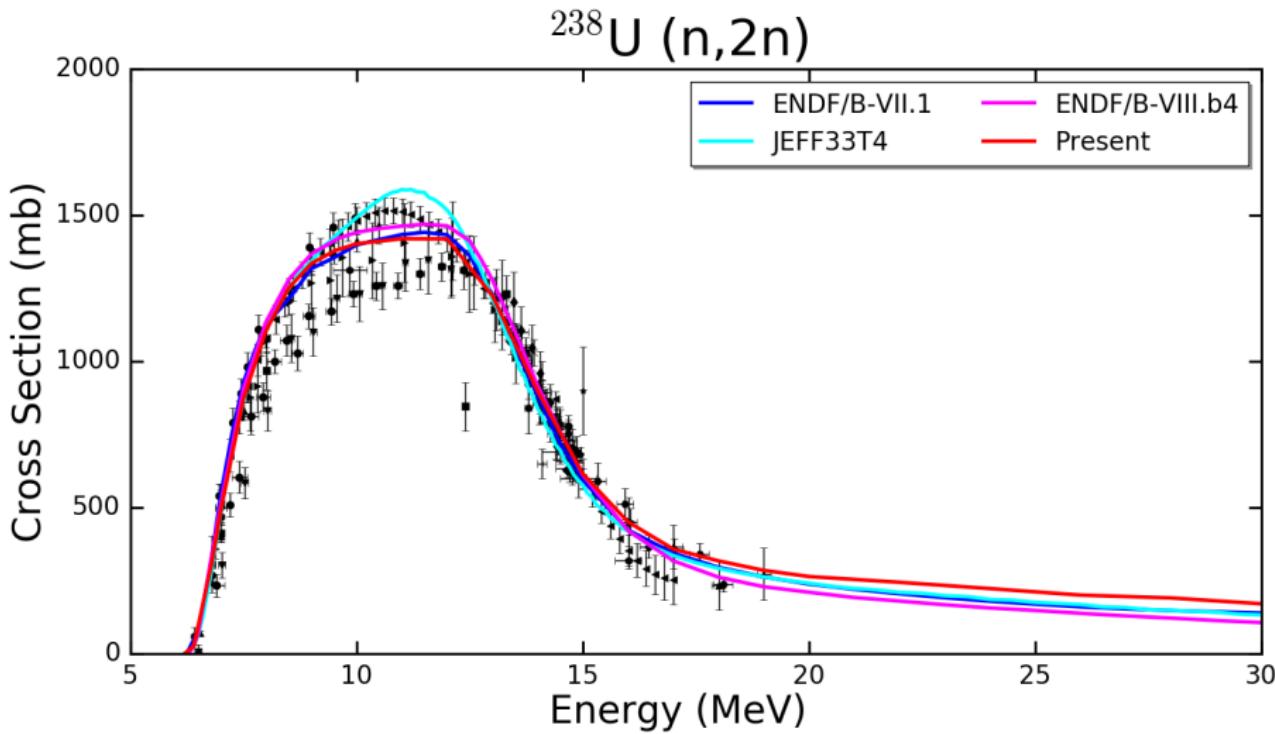
Fission cross section



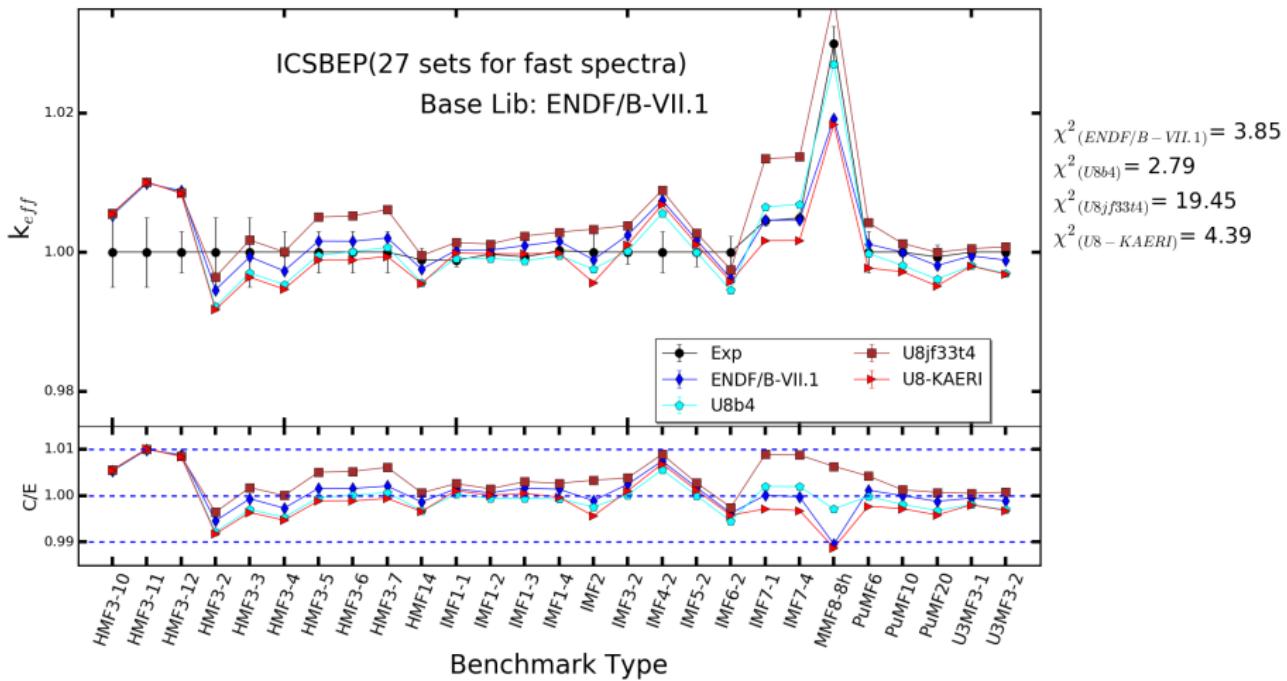
Fission spectra



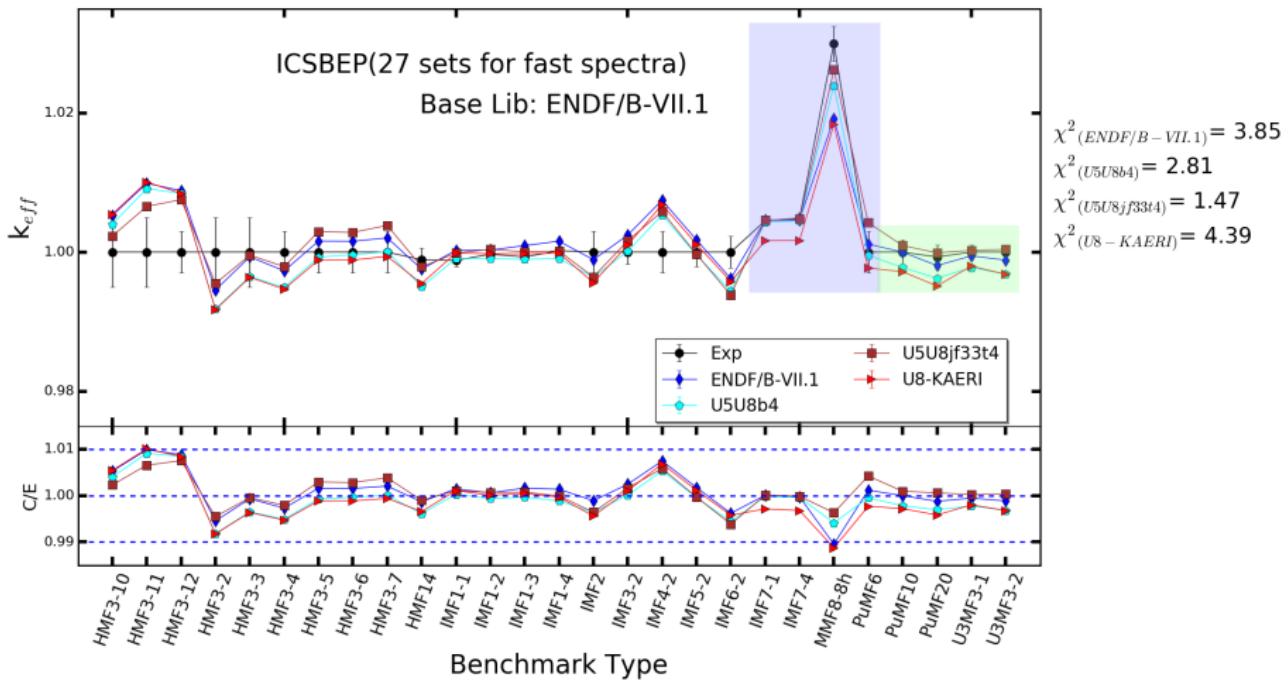
(n,2n) cross section



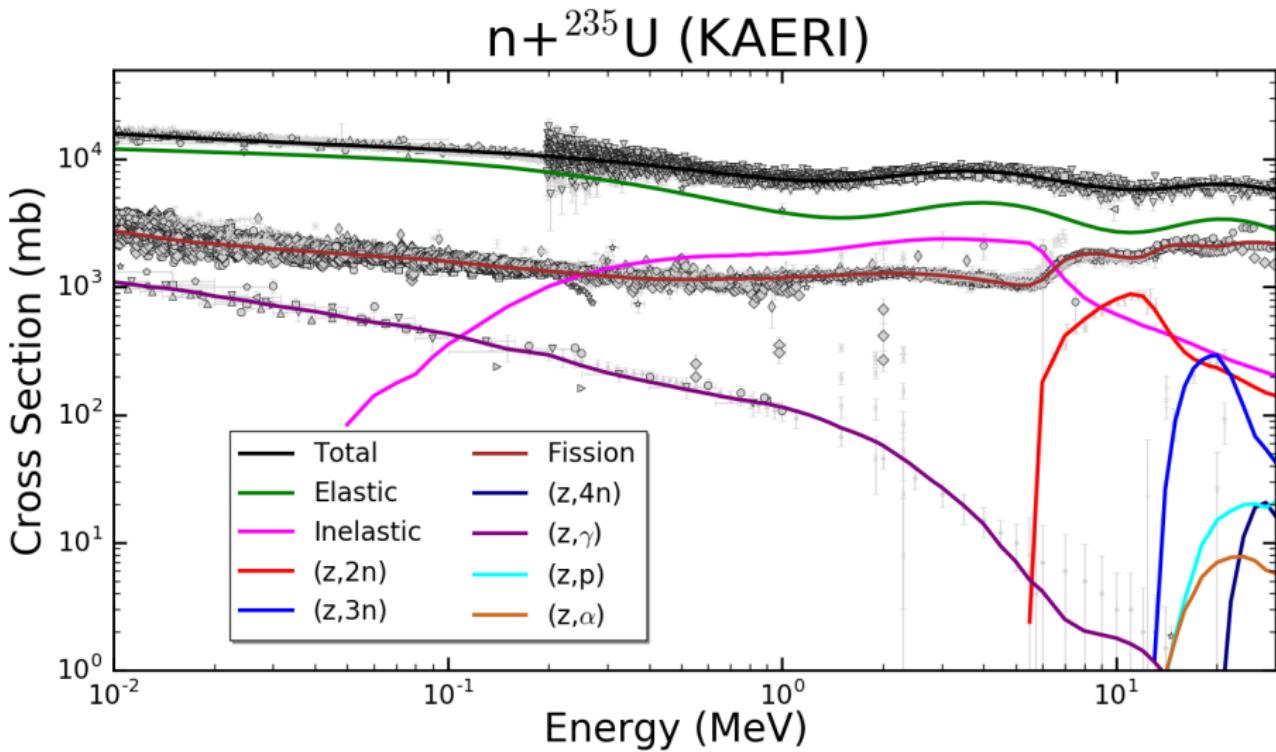
Criticality (Fast Spectra)



Criticality (Fast Spectra)



Cross Sections of U-235



Summary

- The U238 evaluation in fast neutron region was introduced.
- The fast check from evaluation to validation is possible by the up-to-date nuclear reaction model code and modern computing power.
- Our U-238 evaluation will be finalized soon together with the U-235 one.



Thank you for your attention!