New evaluation of general purpose neutron data for stable W-isotopes up to 200 MeV

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Objective

Provision of new general purpose neutron cross-section data for tungsten isotopes A=180, 182, 183, 184, and 186 up to 200 MeV neutron energy

To replace obsolete JEFF data files with up-to-date data evaluations based on modern nuclear data evaluation methodologies and recent experimental data

Data evaluation methodology

1. Analysis of experimental data

2. Choice/optimization/construction of optical potential

   total, elastic cross-sections, inelastic scattering cross-sections, angular distributions, general systematics information

3. Calculations: TALYS-GDH

   preequilibrium emission: GDH, phenomenological models for cluster emission: pick-up, knock-out, direct emission. GDH parameters for targets from C to Bi

4. Preliminary ENDF file: TEFAL

5. Processing data for evaluation: FOX, BEKED (KIT)

   data in two column format, graphics etc

6. Correction of data

   elimination of small inconsistencies (if necessary)

7. Evaluation: GLS method, BEKED

   using experimental data, reference data for gas production components

8. Recording the file: FOX

   proper and consistent change of the data, integration of evaluated cross-sections in final file

9. Check and final correction: ENDF-6 checking codes, A.Trkov code

TALYS – GDH (modified TALYS-1.74)

Geometry dependent hybrid model (M.Blann) + models for cluster emission

(preeqmode 5), Fermi gas CT-model *(ldmodel 1)*

Particle emission spectra

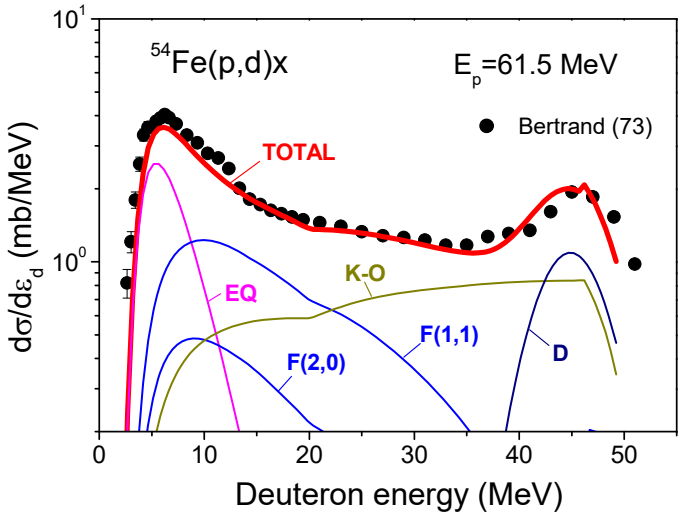
$$\frac{d\sigma}{d\varepsilon_x} = \pi\lambda^2 \sum_{l=0}^{\infty} (2l+1) T_l \sum_{n=n_0} {}_n X_x \frac{\phi(p-1,h,U)}{\phi(p,h,E)} \frac{\lambda_x^e}{\lambda_x^e + \lambda_x^+} g D_n$$

Emission and transition rate

$$\lambda_x^e = \frac{(2S_x+1)\mu_x \varepsilon_x \sigma_x^{inv}(\varepsilon_x)}{\pi^2 \hbar^3 g_x},$$

Cluster emission

$$\frac{d\sigma}{d\varepsilon_t} = \frac{d\sigma^{P-U,C}}{d\varepsilon_t} + \frac{d\sigma^{K-O}}{d\varepsilon_t} + \frac{d\sigma^{D}}{d\varepsilon_t}$$



Description

EFFDOC-1102 (2009) (http://www.oecd-nea.org/dbdata/nds_effdoc/effdoc-1102.pdf)

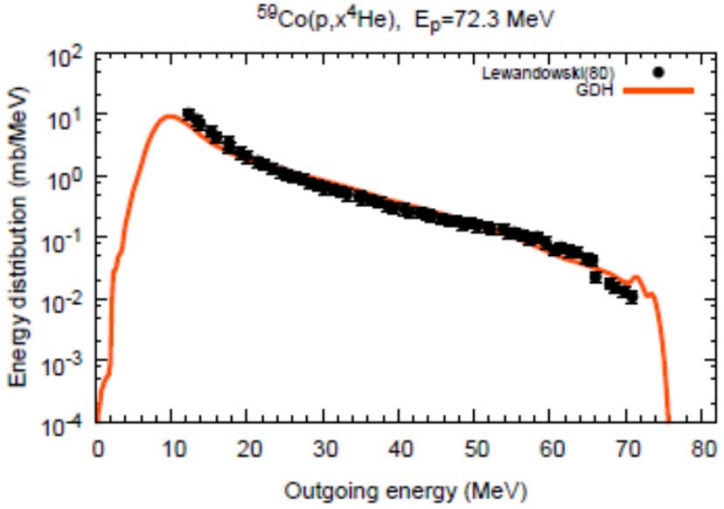
ND-2010 (https://doi.org/10.3938/jkps.59.935)

EFFDOC-1269 (2015) (http://www.oecd-nea.org/dbdata/nds_effdoc/effdoc-1269.pdf)

KIT SWP Report, N45 (2016) (https://publikationen.bibliothek.kit.edu/1000052543)

Advantages

Charged particle emission spectra,
gas production, recoil production



ENDF data file structure

MF

1 MT= 451 : description

2 MT= 151 : resonance parameters

^{180}W: S.Mughabghab, $^{182, 183,184,186}$W: JEFF-3.3

3 : reaction cross-sections

4 : angular distributions

6 : product energy-angle distributions

8 : decay and fission product yields (references on MF=6, 9,10 only)

9 : multiplicities of radioactive products

10 : production cross-sections for radionuclides

12 : photon production yields

14 : photon angular distributions

33 : covariances of cross-sections

calculated using MC and GLS method

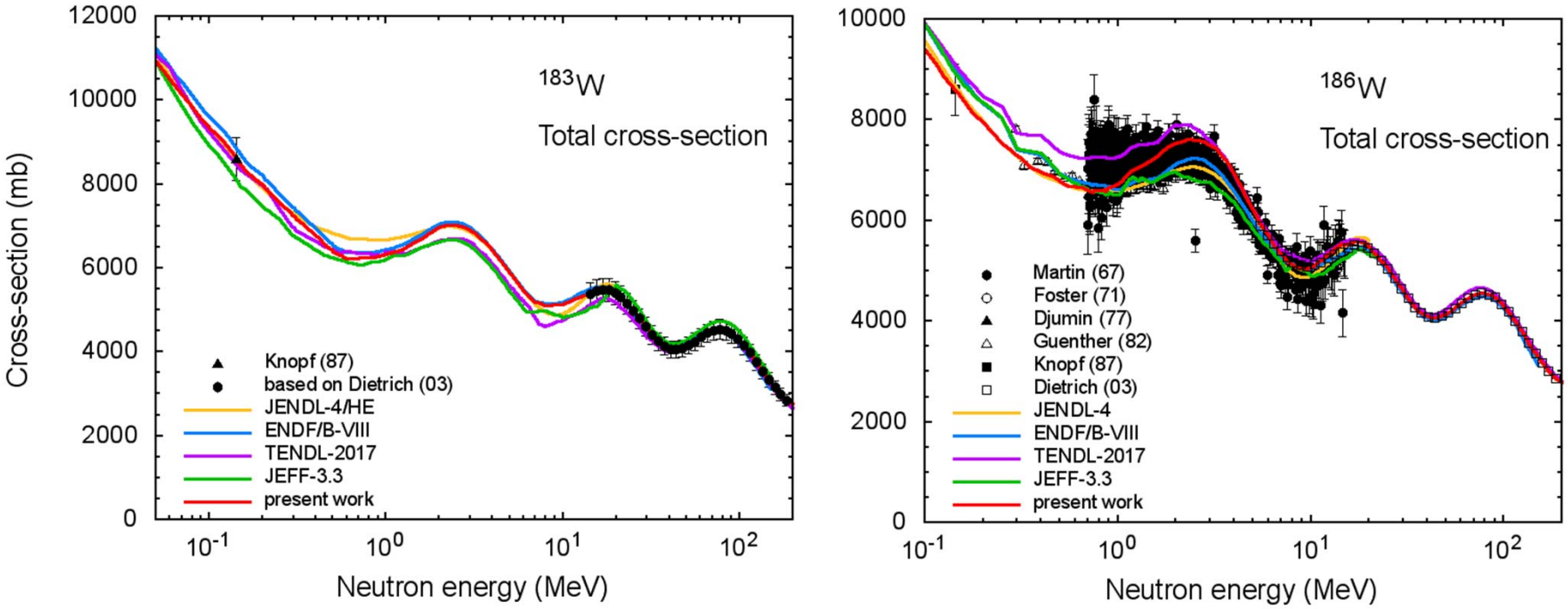
Following examples show typical features of evaluated data

A comprehensive comparison with experimental data:

^{182,186}W: KIT SWP Report, N108 (2019), https://publikationen.bibliothek.kit.edu/1000090132

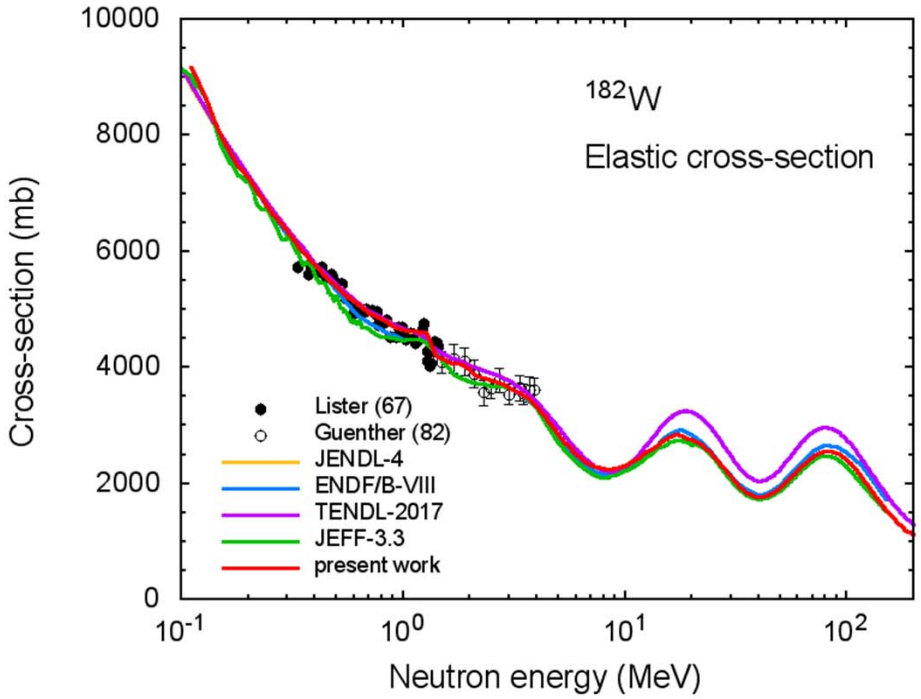
^{180,183}W: KIT SWP Report (2019), to be published

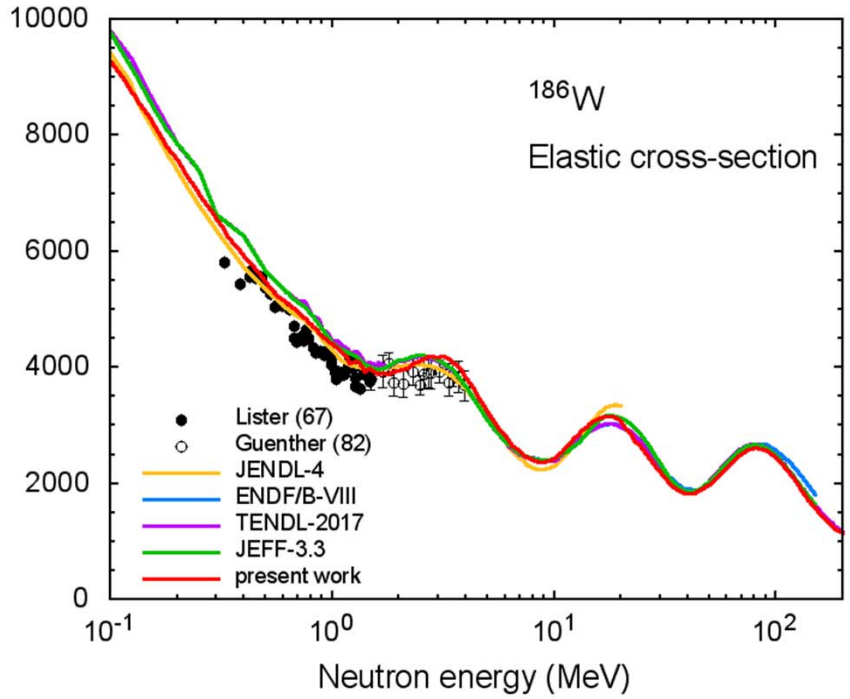
Total cross-section



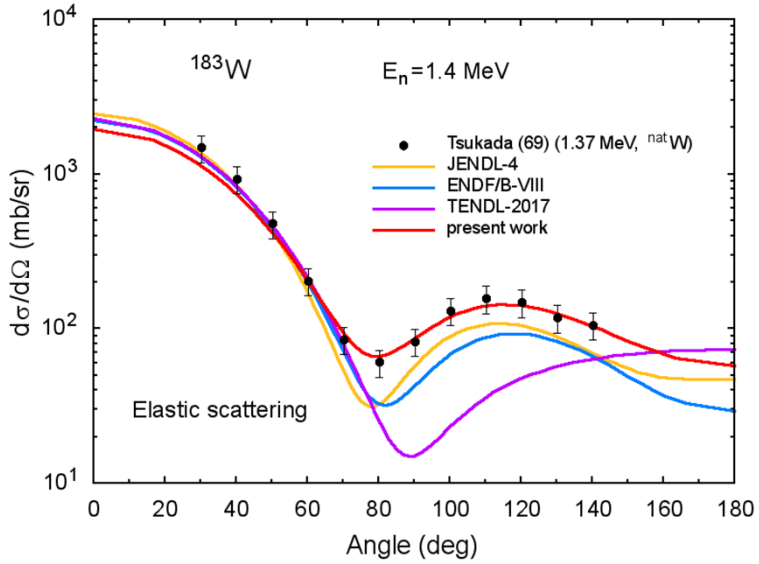
"Based on Dietrich (03)": obtained using measured data for ^{182}W, ^{184}W, and ^{186}W and systematic approach

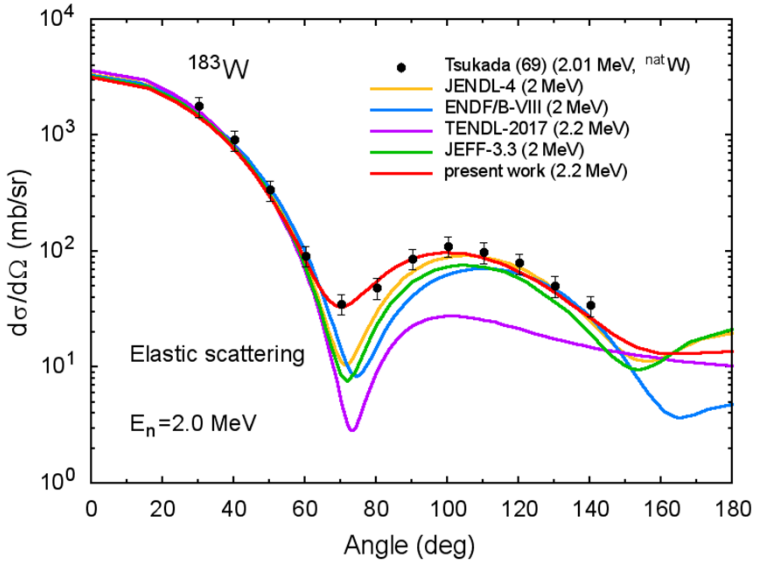
Elastic cross-section

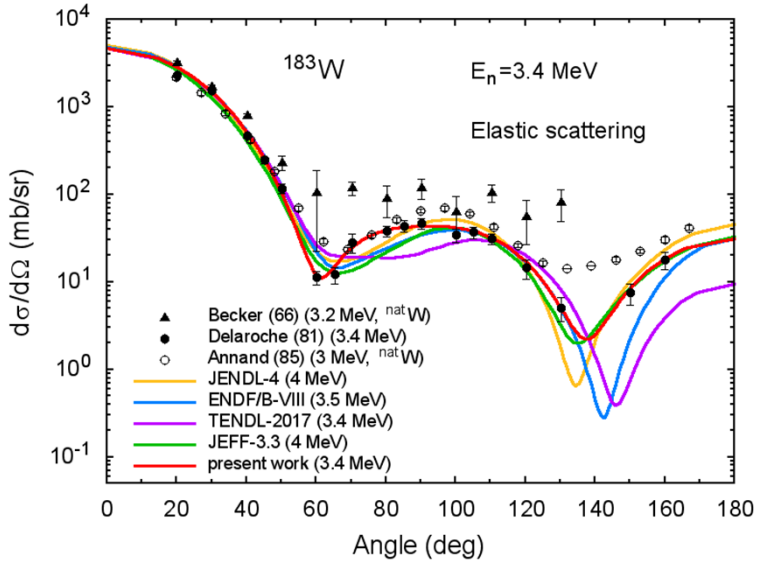


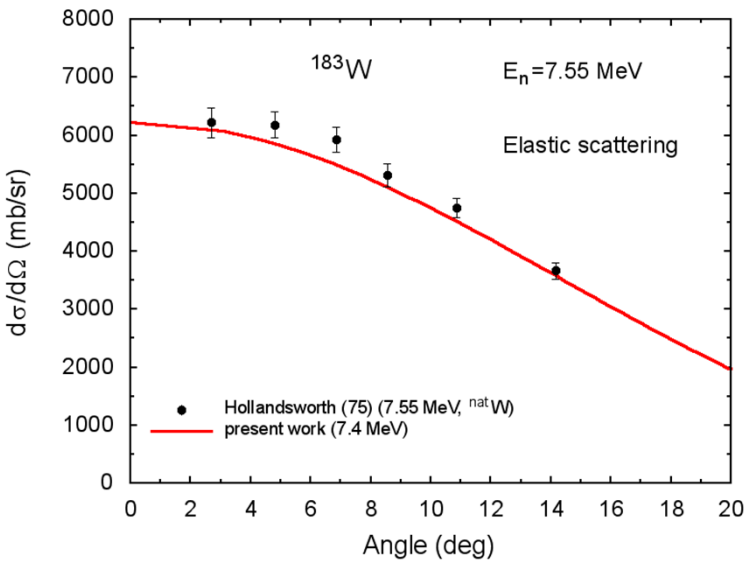


Angular distribution for neutron elastic scattering

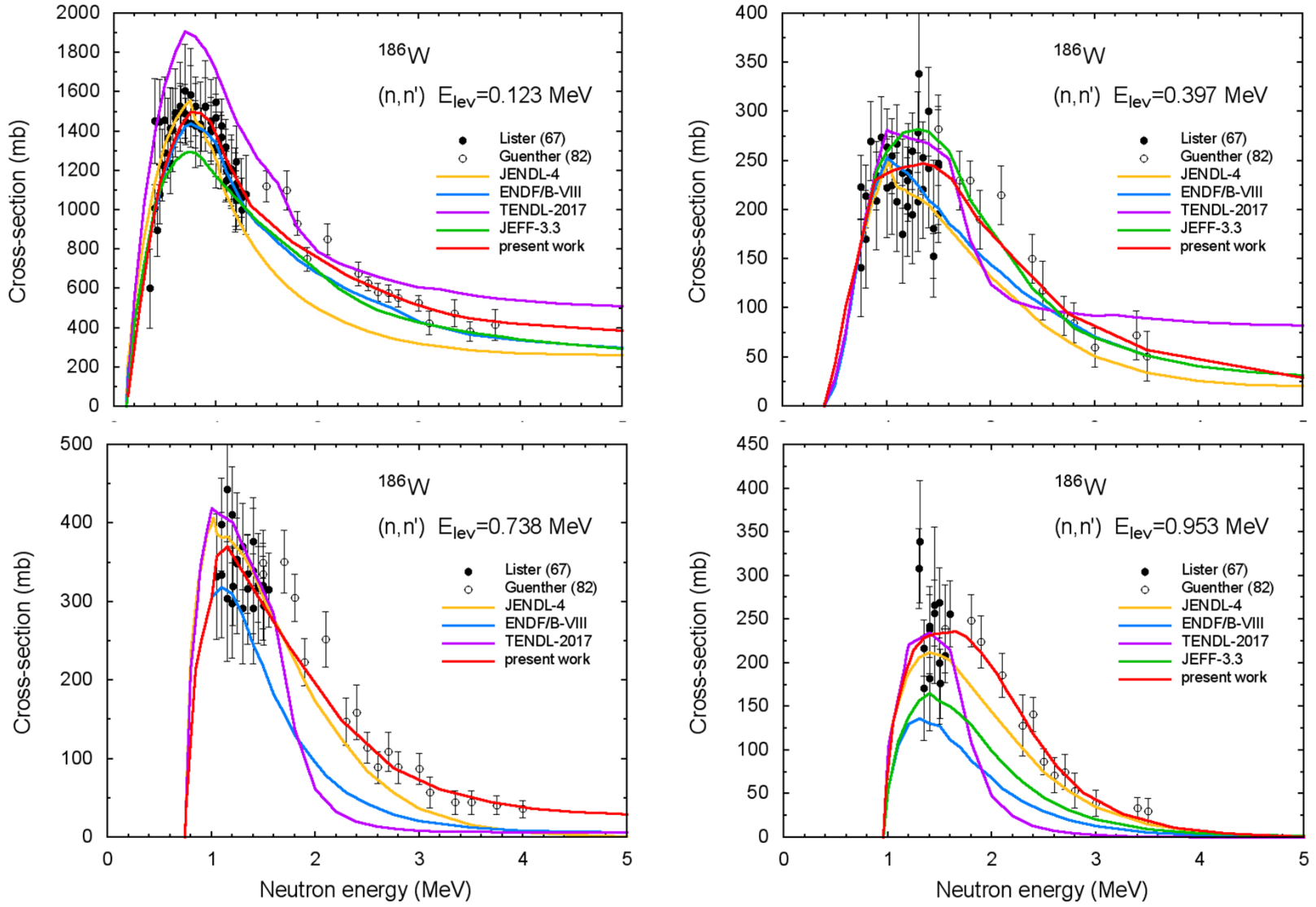




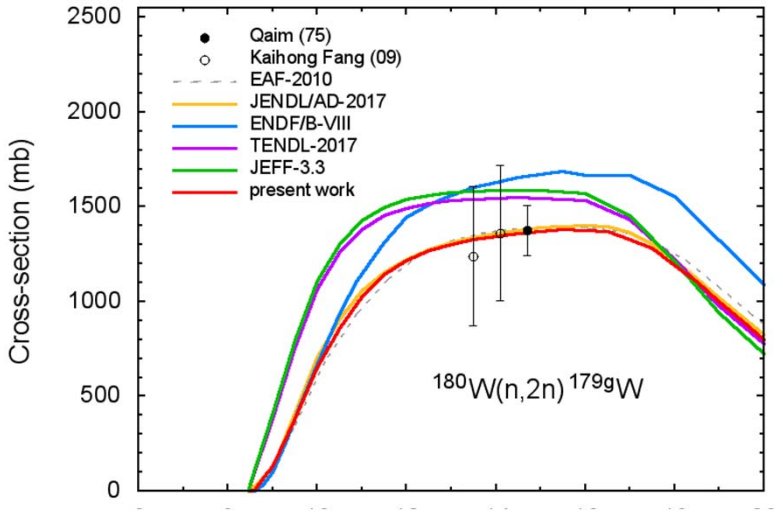


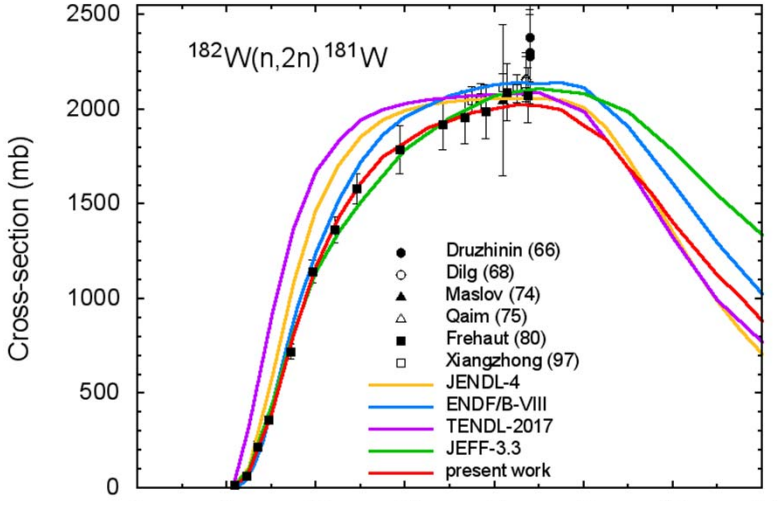


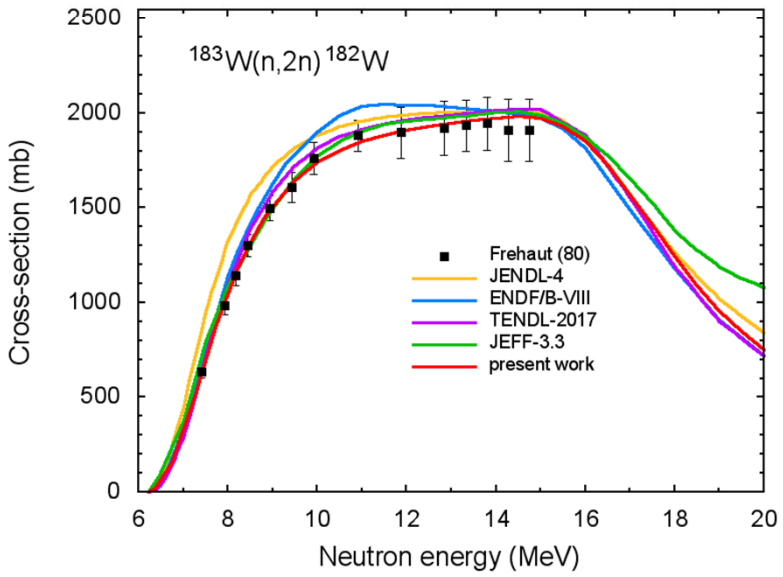
Inelastic scattering cross-section

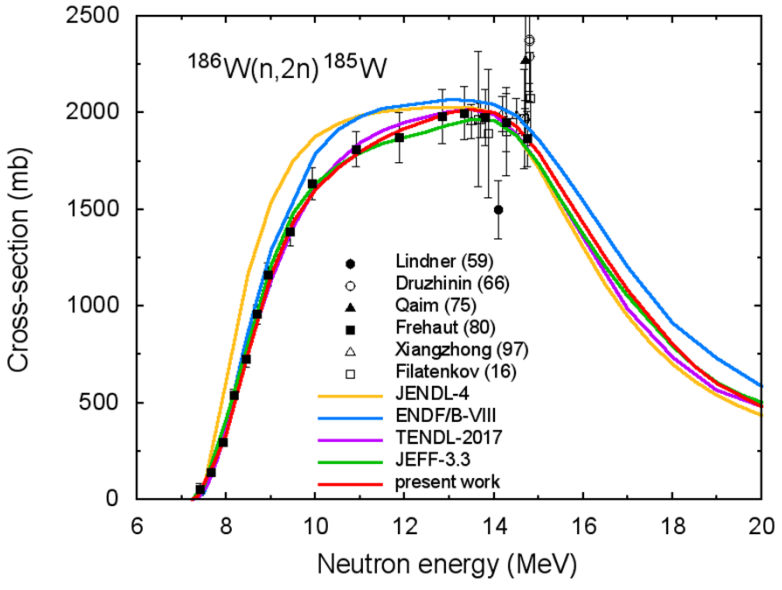


(n,2n) reaction cross-section

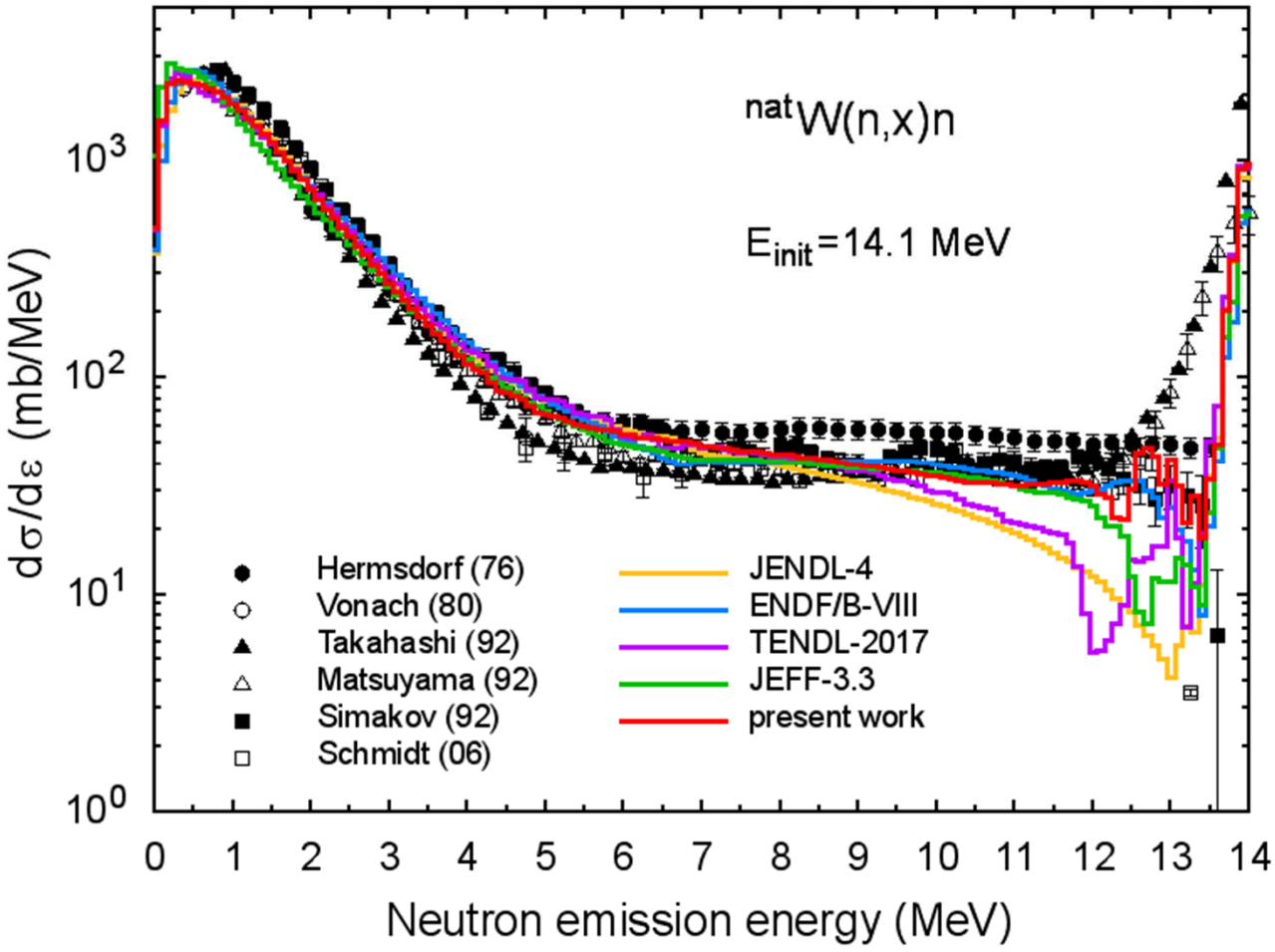




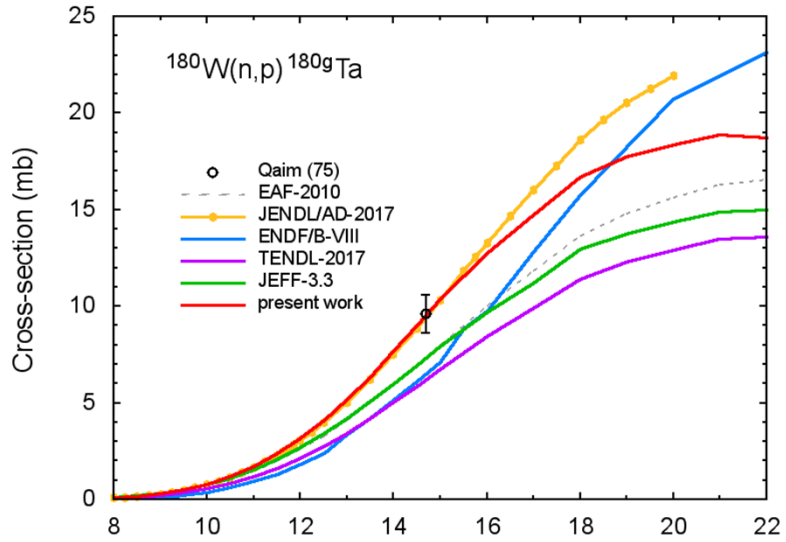


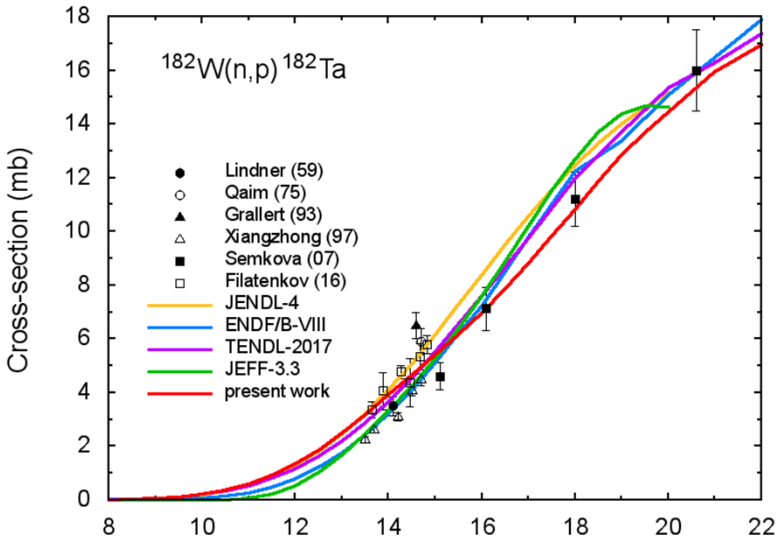


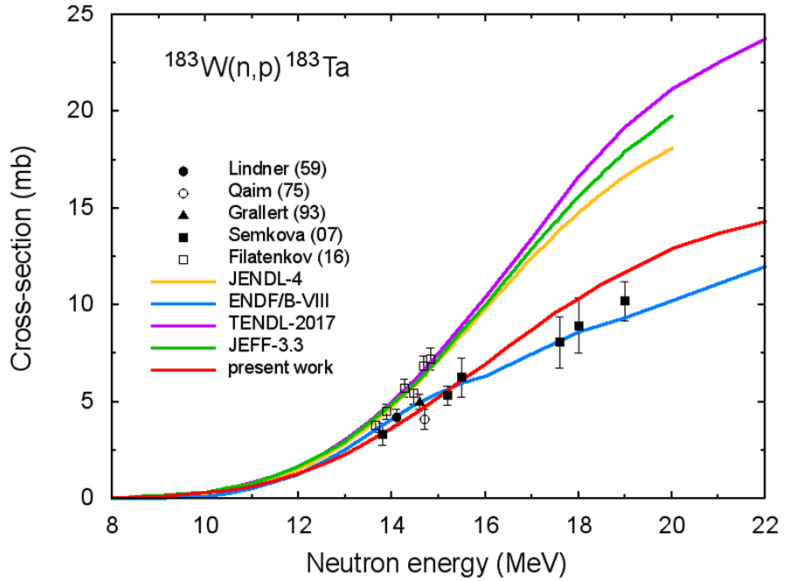
Secondary neutron energy distribution

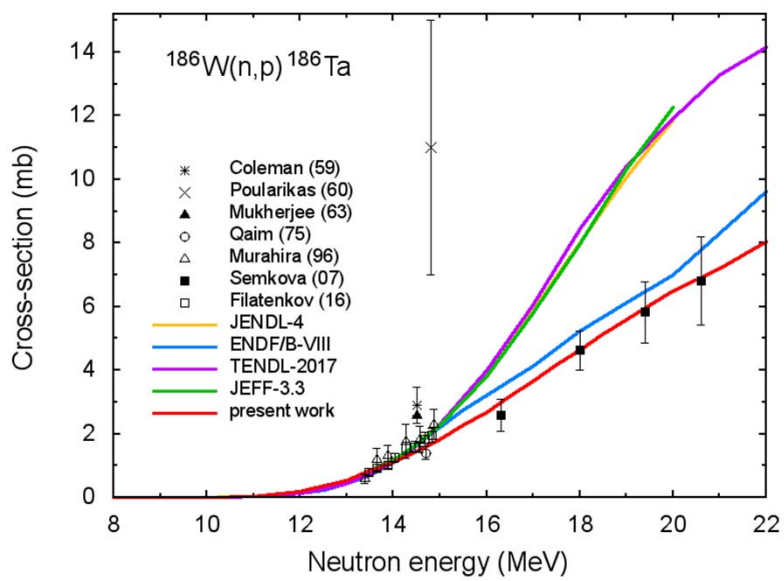


(n,p) reaction cross-section

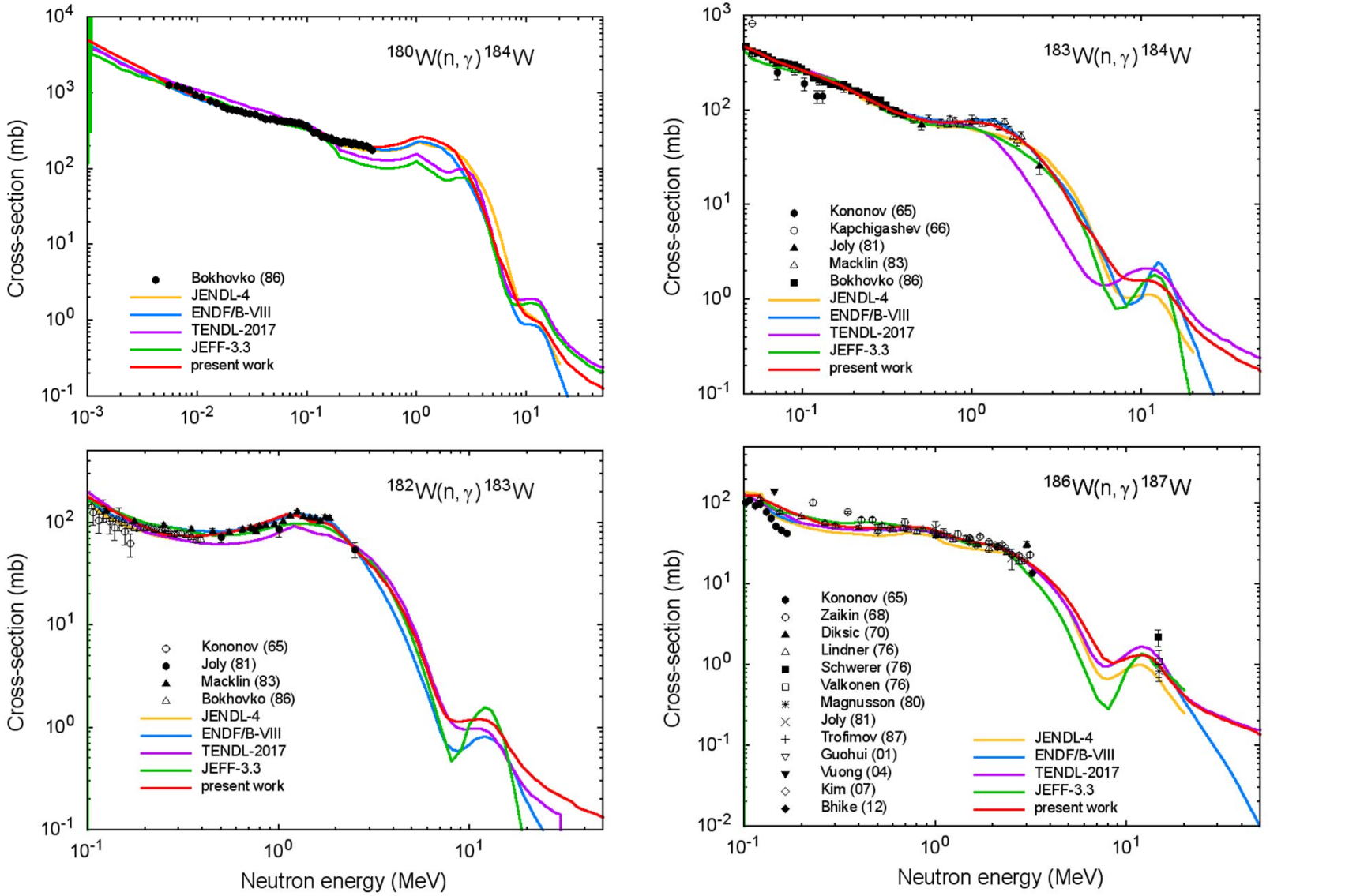




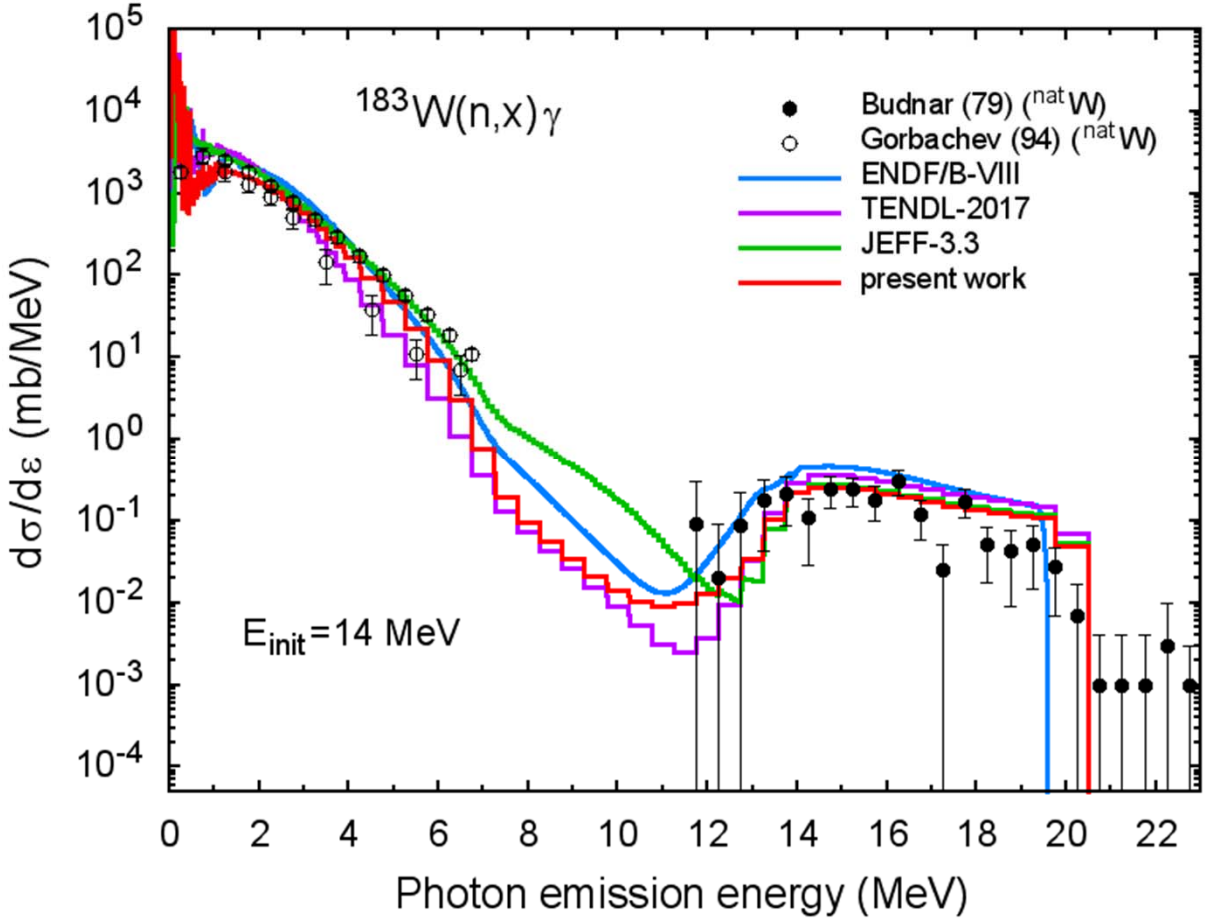




Radiative reaction cross-section

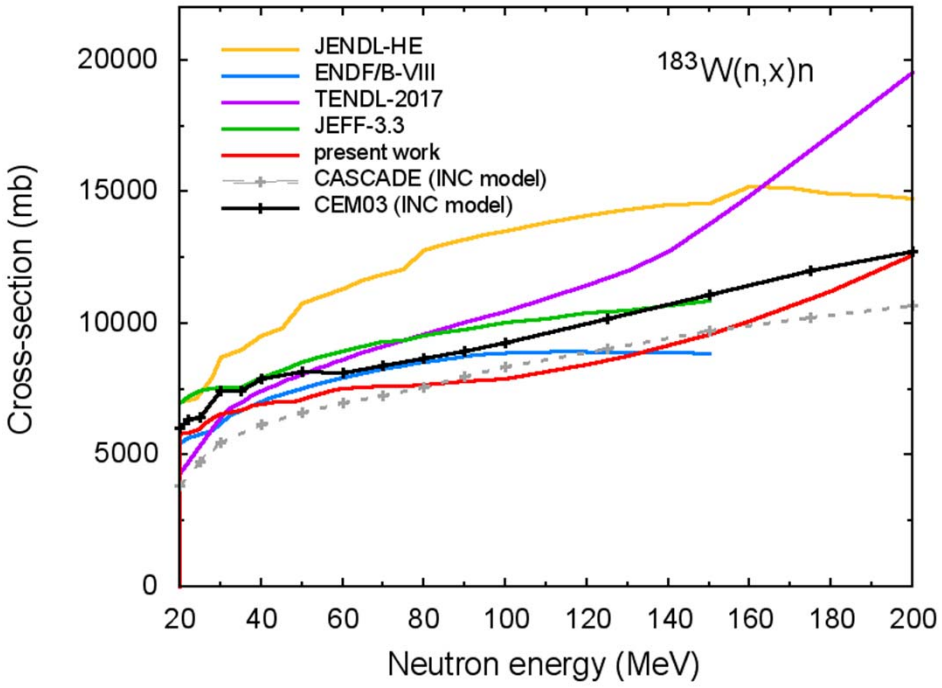


Photon energy distribution

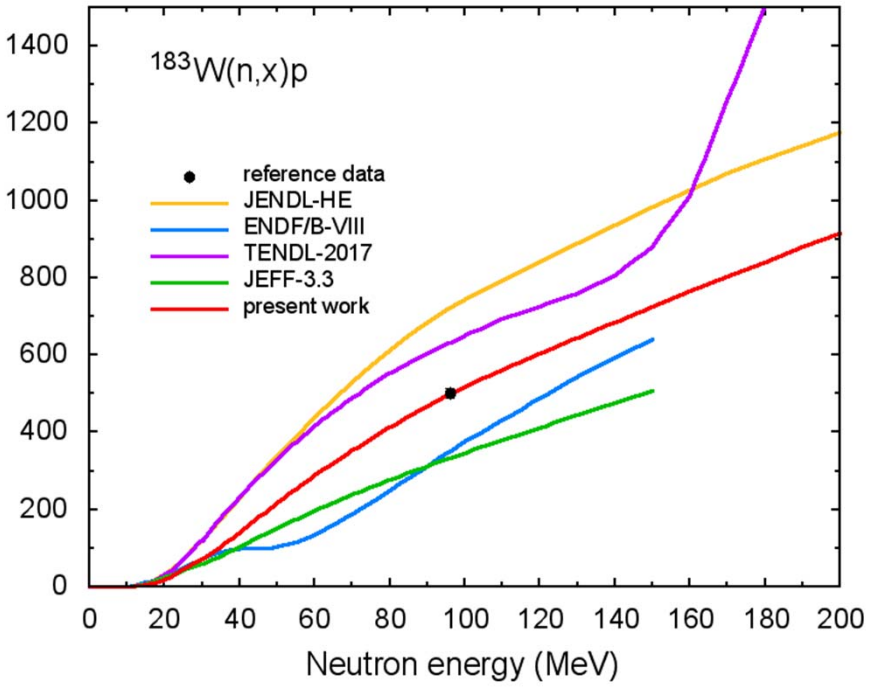


Light particle production cross-section

Neutron production cross-section

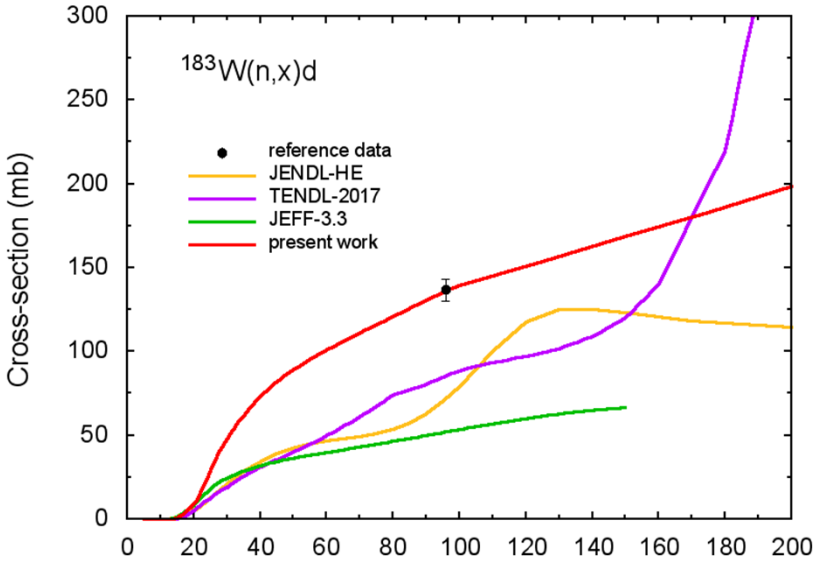


Proton production cross-section

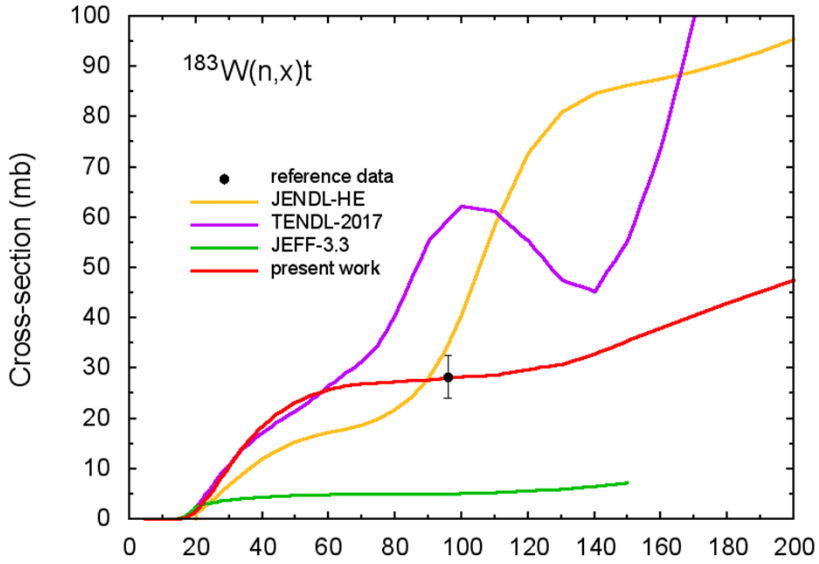


"reference data" were obtained from the evaluated A-dependence of cross-sections at fixed incident energy of primary particle: KIT Scientific Report 7660 (2014), https://www.ksp.kit.edu/9783731501770

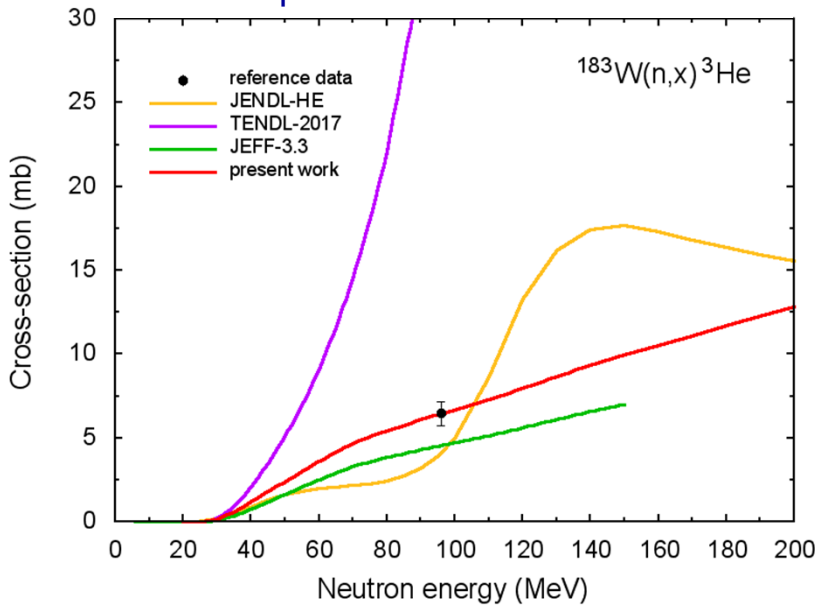
Deuteron production cross-section



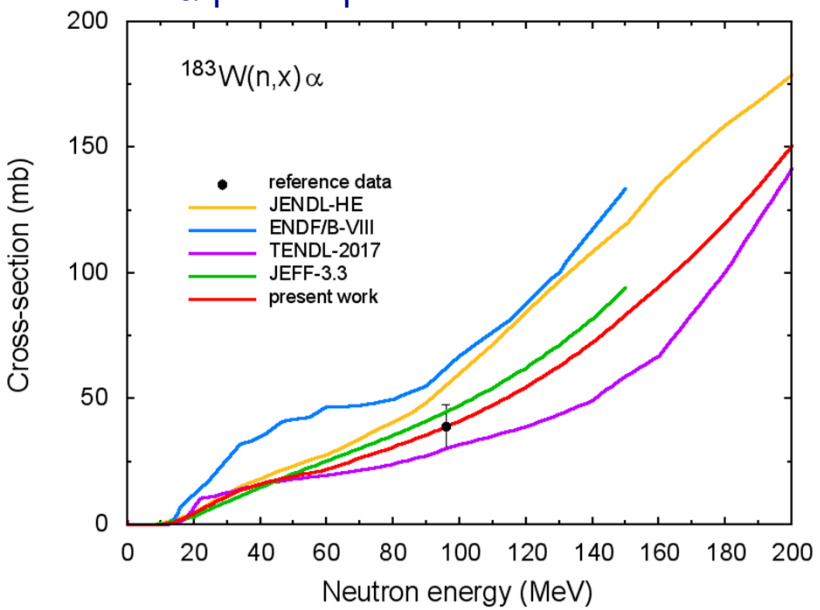
Triton production cross-section



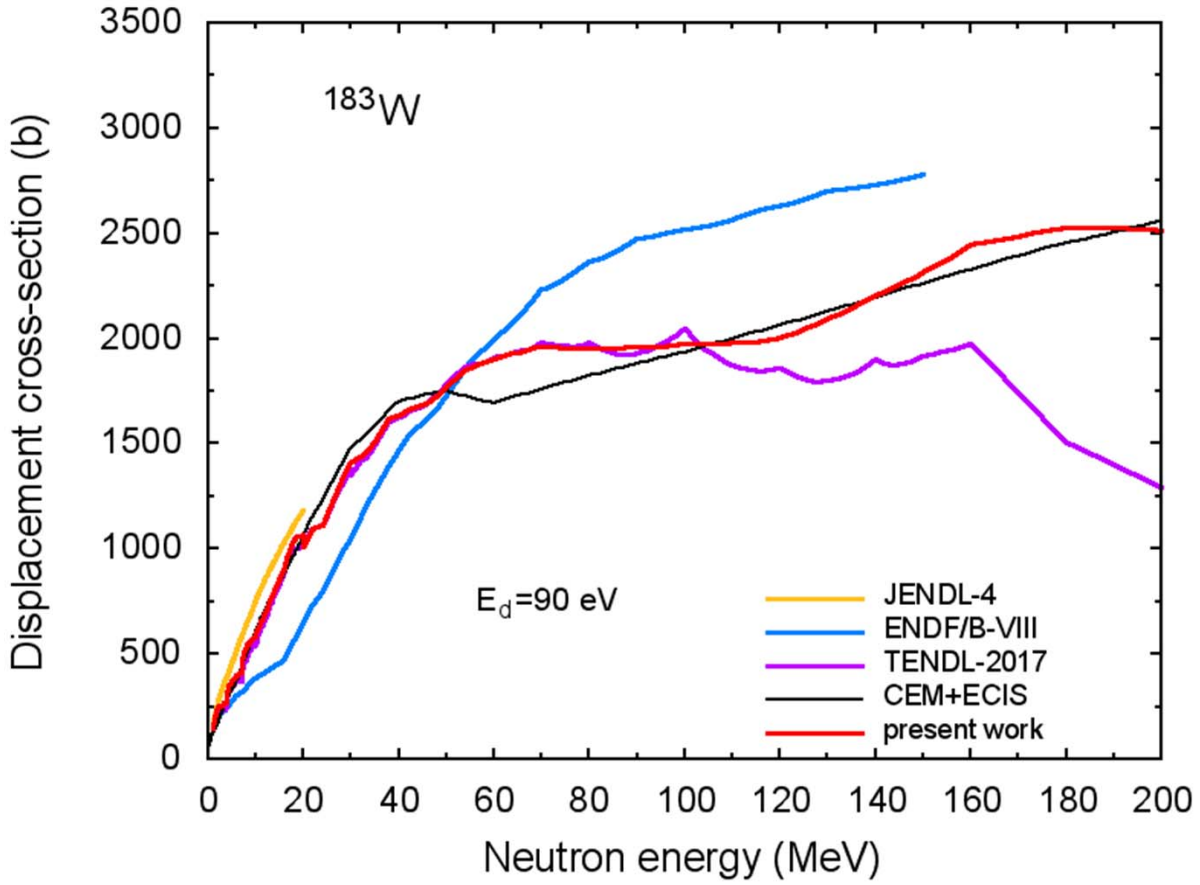
^{3}He production cross-section



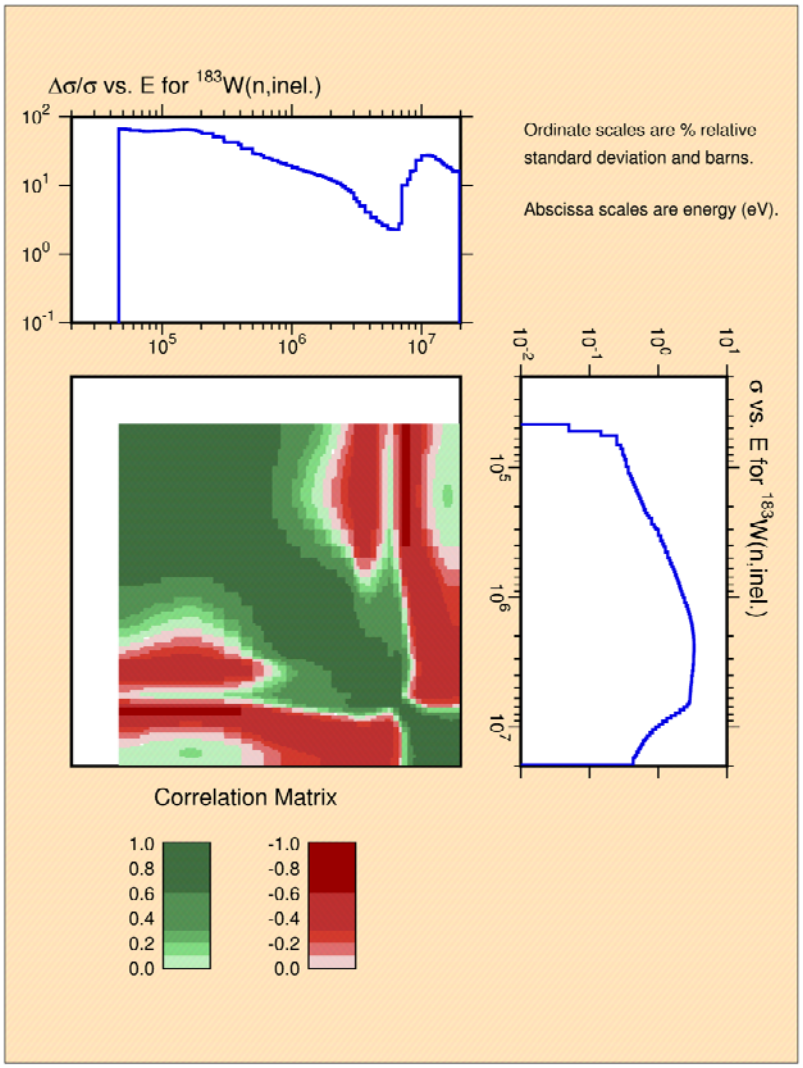
α-particle production cross-section

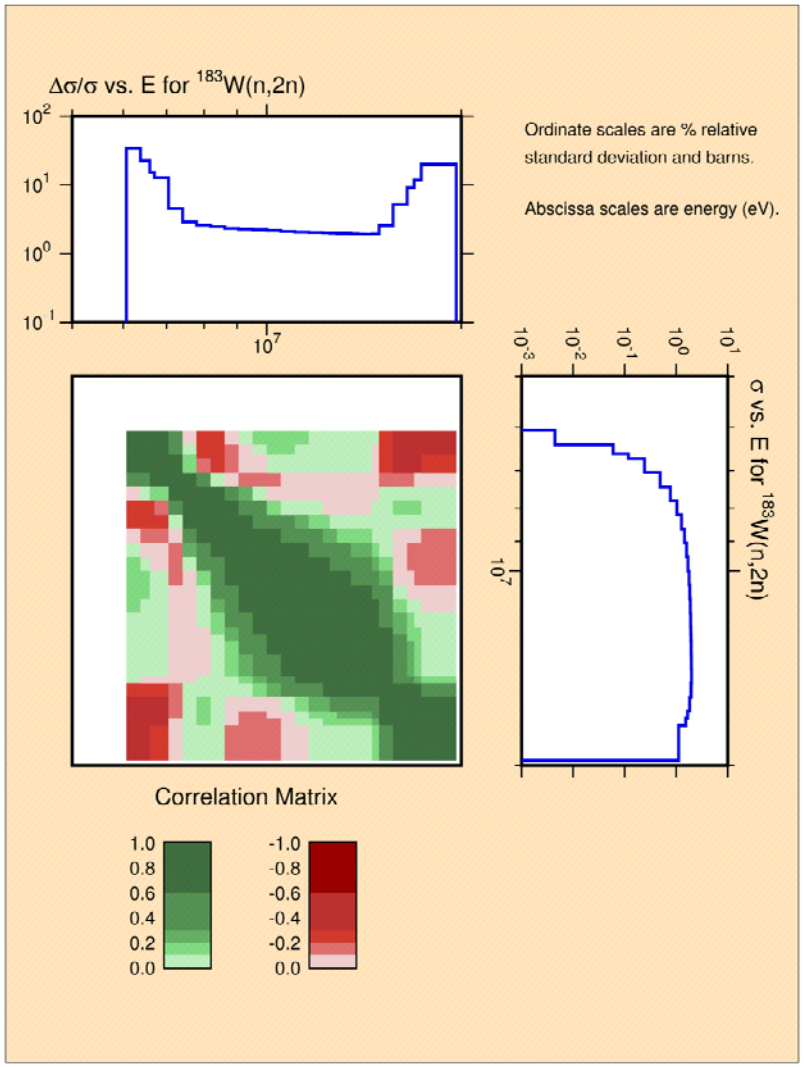


Atomic displacement cross-section



Examples of calculated covariances





Conclusions

- New evaluations for neutron cross-sections of stable W isotopes up to 200 MeV (incl. co-variance data)
- ENDF data files produced for general purpose applications- preliminary versions available
- Testing/benchmarking underway for fusion and shielding applications
- Final data files to be released by 12/2019

Acknowledgement

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