Neutron- and Proton-Induced Nuclear Data Evaluation of Thorium, Uranium and Curium isotopes for Energies up to 250 MeV

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The evaluation of neutron- and proton nuclear data for thorium-232, U-233,234,236, and Cm-243,244,245,246 isotopes have been performed at energies up to 250 MeV. Neutron data was evaluated at energies from 20 MeV to 250 MeV, and combined with the JENDL-3.3 data at 20 MeV, while proton data was obtained for energies from 1 to 250 MeV. Nuclear model parameters are largely based on the IAEA-RIPL recommendation, and adjusted to better reproduce the available measurements. The coupled channel optical model was applied to calculate the total, reaction, elastic, and direct inelastic cross sections, and to obtain the transmission coefficients. Decay of excited nuclei was described with the Hauser-Feshbach and exciton models using the GNASH code to simultaneously handle neutron, proton, deuteron, triton, helium-3, α, γ emissions and fissions. Special attention was paid on the fission cross sections for energies where experimental data are scant, using appropriate systematics and fittings. Particles and γ emission spectra after fission were calculated based on the the statistical approach of Fong, and adjusted to the experimental data using the ALICE-ASH code.

1. Introduction

Within the frame work of the JENDL high energy library, the evaluation of neutron- and proton nuclear data for thorium-232, U-233,234,236, and Cm-243,244,245,246 isotopes have been performed at energies up to 250 MeV. Neutron data was evaluated at energies from 20 MeV to 250 MeV, and combined with the JENDL-3.3 data at 20 MeV, while proton data was obtained for energies from 1 to 250 MeV.

2. Models and Codes

Nuclear model parameters are largely based on the IAEA-RIPL recommendation, and adjusted to better reproduce the available measurements. The coupled channel optical model was applied to calculate the total, reaction, elastic, and direct inelastic cross sections, and to obtain the transmission coefficients. Decay of excited nuclei was described with the Hauser-Feshbach and exciton models using the GNASH code to simultaneously handle neutron, proton, deuteron, triton, helium-3, α, γ emissions and fissions. Special attention was paid on the neutron fission cross sections to achieve continuity and consistency with the existing JENDL-3.3 evaluation using theoretical and experimental fission barriers, and fittings. Primary pre-equilibrium emission spectra of helium-3 and α-particles were calculated with the coalescence pick-up model using the ALICE/ASH code, and fed into the GNASH calculation. Particles and γ emission spectra after fission were calculated based on the the statistical approach of Fong, and adjusted to the experimental data using the ALICE-ASH code. The original frame of the procedure is based on the ECIS-GNASH code system for the evaluation of non-fissionable spherical nuclei for energies up to 150 MeV. With some modifications and expansions, JAERI Nuclear Data Center has been using it for the evaluation of JENDL High Energy File for energies up to 250 MeV. Meanwhile, for the intermediate energy evaluation of actinide nuclei, a major change was made onto it to handle the rotational coupled-channel optical model and fission. The new code system for the actinide evaluation consists of three main nuclear model codes such as the ECIS [1], GNASH [2], ALICE-ASH [3] and ALICE95Y [3] with pre-/post processors and auxiliary tools supporting them.

The ECIS code performs the coupled-channel optical model calculation to provide total, reaction, elastic, and direct inelastic cross sections, and elastic and inelastic scattering angular distributions. It is also used to produce the transmission coefficients for neutron, proton, deuteron, triton, helium-3, and alpha particles. Usually input files for various cases are prepared by PREG_ROTW with appropriate optical models. The GNASH code performs Hauser-Feshbach and exciton model calculation to handle n, p, d, t, he-3, α, and γ emission as well as fission. Original version was modified to handle 8 decay modes simultaneously including γ and fission for energies up to 250 MeV of incident neutron and proton on nuclei as heavy as up to Cm-247. The ALICE-ASH code provides precompound spectra via the hybrid and GDH models, and fission cross sections via the Bohr-Wheeler approach. The ALICE95Y code, combined with the ALICE-ASH, performs post-fission emission and fission yield calculations using statistical approach of Fong with the adjustment to experimental data.

3. Results and Comparisons

In this article, only the neutron total, proton non-elastic, and fission cross sections are presented in Figs. 1, 2, 3 and 4 compared with available measurements. More details of evaluated results and discussions will be available in [4]. As seen in Fig. 1, present evaluation of neutron total cross sections are consistent with the existing JENDL-3.3 evaluation at the neutron energy of 20 MeV. Figure 2 shows neutron-induced fission cross sections, which are continuous with the existing JENDL-3.3 evaluation except the U-234 case, and consistent with the measurements. The proton non-elastic cross sections are in Fig. 3, where the comparisons were made only for Th-232 and U–233 with the measurements. Figure 4 presents proton-induced fission cross sections, where Th-233 and U-233,234,246 cases are compared with the available measurements showing good agreements, while only theoretical results are presented for the case of Curium isotopes.

Acknowledgments

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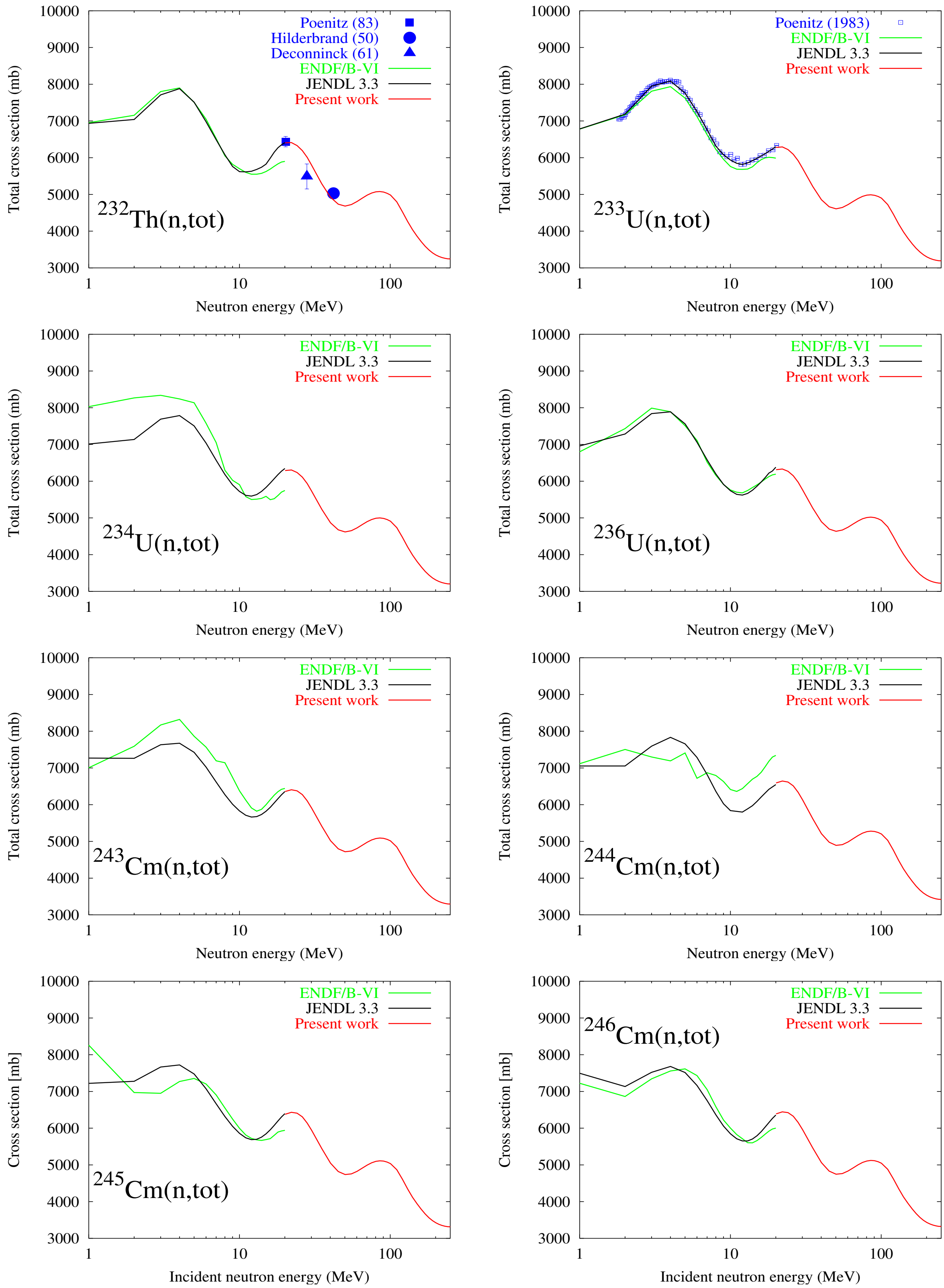

Figure 1: Evaluated neutron total cross sections for minor actinides

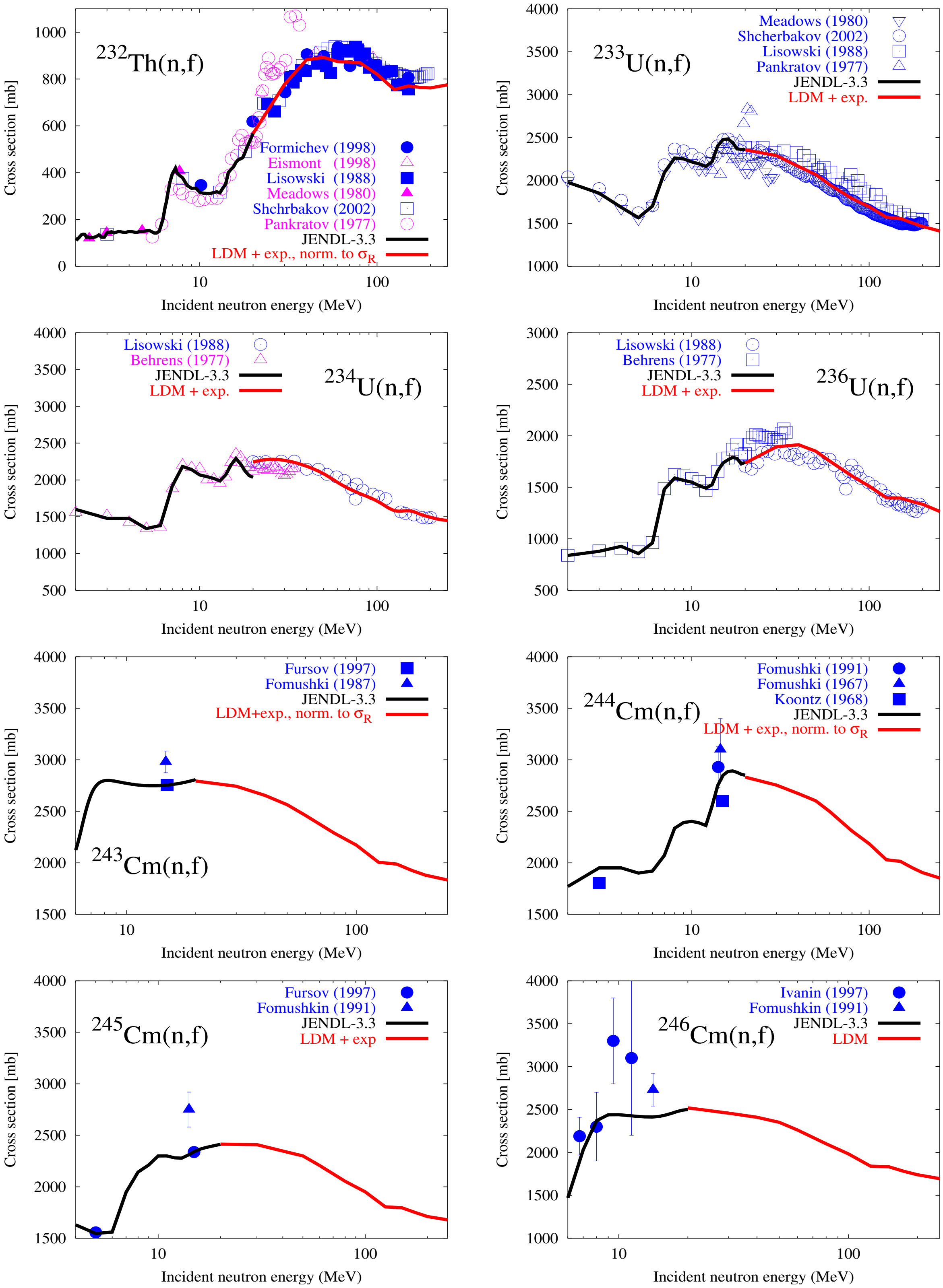

Figure 2: Evaluated neutron fission cross sections for minor actinides

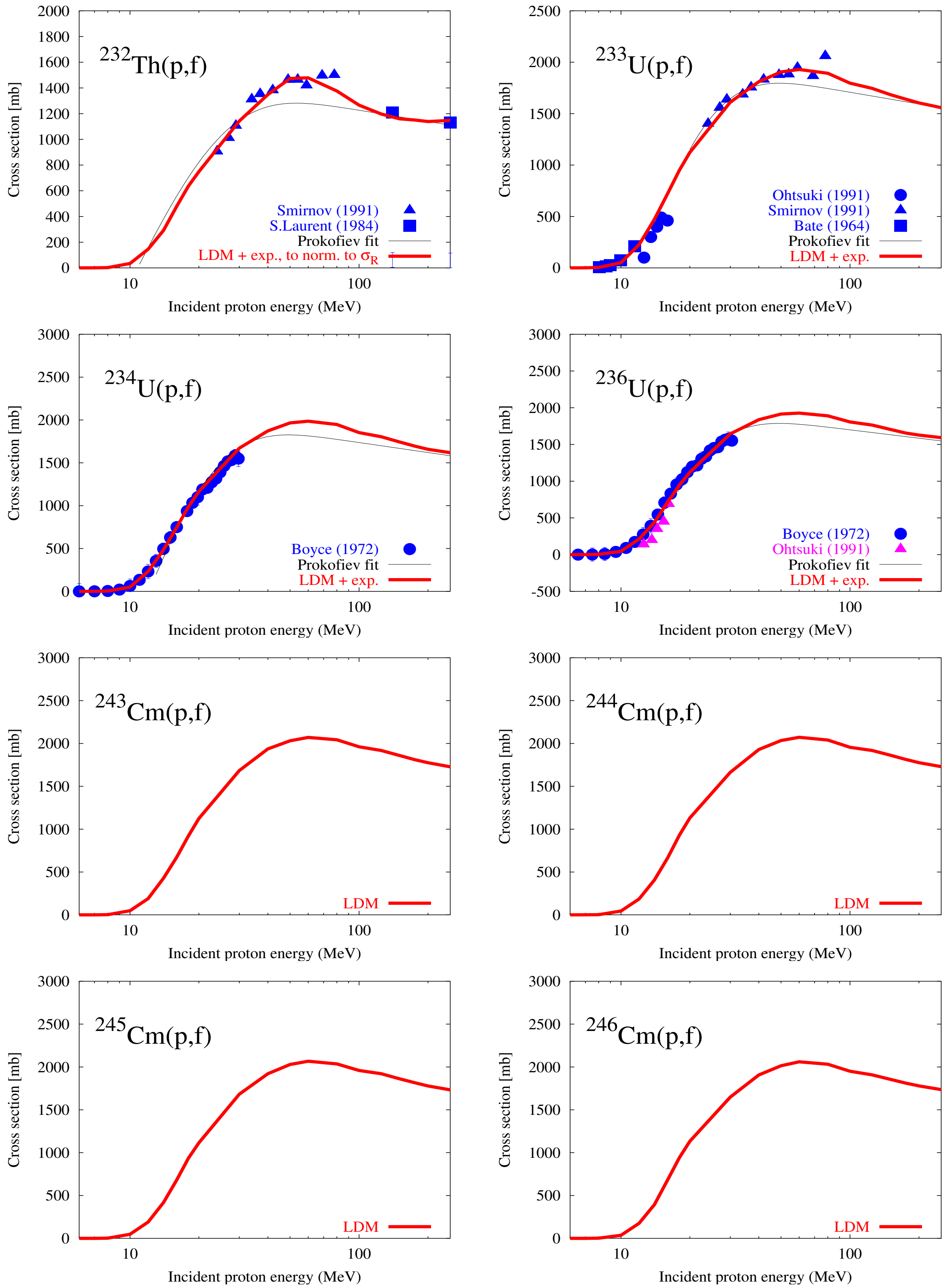

Figure 3: Evaluated proton fission cross sections for minor actinides

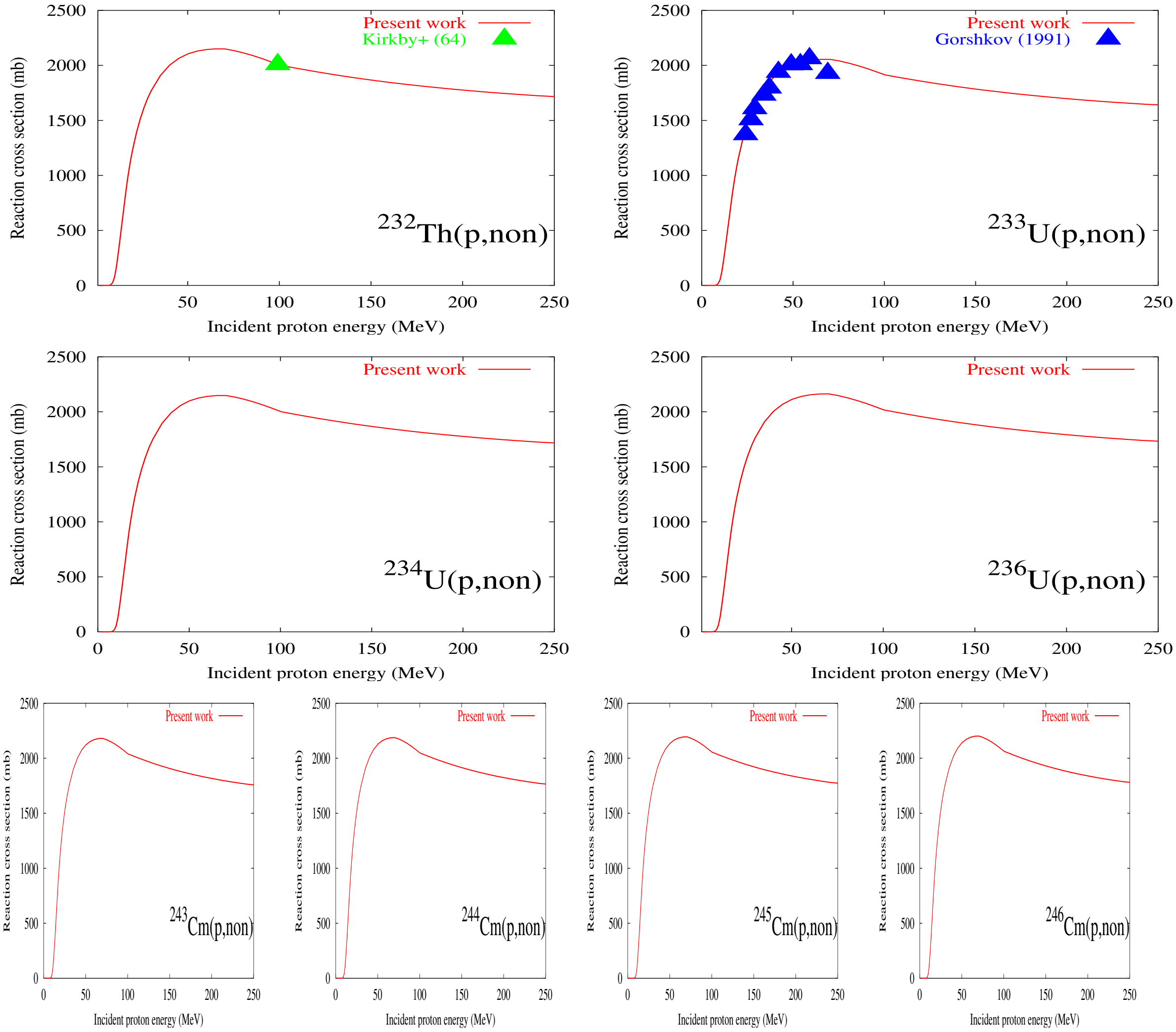

Figure 4: Evaluated proton non-elastic cross sections for minor actinides

of the authors(Y.-O. Lee) at JAERI under the Foreign Scientists Invitation System of JAERI.

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