Nuclear Data Measurements in Russia

B.I.Fursov, A.V.Ignatyuk, B.D.Kuzminov

Institute of Physics and Power Engineering, Obninsk, Russia

Main activity on nuclear data in Russia during the last years was concentrated on a revision of most important neutron data for advanced nuclear reactors and a formation of the new version of the BROND-3 library. A large attention was also spent to accumulation of data required for a nuclear waste transmutation of the basis of accelerator driven systems. The following data have been obtained:

Measurements at IPPE (Obninsk)

i) Prompt fission-neutron spectra for ^{238}U have been measured early at incident neutron energies 3, 5, 7, 13, and 14.7. Similar measurements were recently performed at energies 16 and 18 MeV. Dependence of the average fission-neutron energy on the excitation energy of fissioning nucleus was estimated (Fig. 1). The values of average energies do not exceed 2.05 MeV at highest energies of incident neutrons and their saw-like changes are strongly correlated with a step-like structure of the fission cross sections.

ii) Total and relative group yields of delayed neutrons, as well as the corresponding group half-life times were measured for ^{233}U at the incident neutron energies from 1 to 18 MeV and for ^{238}U and ^{239}Pu at energies between 14 and 18 MeV. Evaluations were made for the energy dependence of delayed-neutron yields for ^{235}U, ^{238}U, ^{237}Np,and ^{239}Pu. It is shown that the average half-life times of delayed neutrons essentially differ in the energy region 14-18 MeV from evaluations included in current data libraries (Fig. 2). The energy dependence of group half-life times of delayed neutrons was also measured for ^{241}Am at the incident neutron energy region between 0.75 and 5 MeV.

iii) The leakage neutron spectra from thick vanadium, lead and bismuth spheres were measured for 14 MeV neutrons and the ^{252}Cf(sf) neutron source. The spectra obtained are used now for testing the corresponding neutron data files.

iv) Preliminary measurements of the fission cross sections at the region of unresolved resonances were performed for ^{232}Th, ^{235}U, ^{237}Np, ^{239}Pu, and ^{245}Cm on the basis of the new lead-slowing-down spectrometer at the Institute of Nuclear Research RAN (Troitsk). The planned future measurements should essentially reduce uncertainties of experimental data on the fission cross sections of minor actinides at the region of unresolved resonances.

v) The transmission and self-indication functions were measured for Rh, Ho, W, Nb, Mo, Pb, Sn, In, Sm on the IBR spectrometer (JINR, Dubna) at neutron energies between 0.01 and 100 keV. The total neutron cross-sections and resonance shielding effects are estimated and compared with the current data-library evaluations.

Measurements at the Radium Institute (St.Petersburg):

i) During the last years, the measurements of neutron-induced fission cross-sections of actinides have been performed at high energies on the GNEIS facility (PINP, Gatchina). New series of experiments have been recently made for ^{240}Pu, ^{243}Am and ^{nat}W in the energy range of incident neutrons from 1 MeV to 200 MeV. The measurements were performed using the multiplate ionization chamber and time-of-flight technique. The results of this measurement are shown in Fig. 3 and 4 in comparison with some previous data. Uncertainties of new data are about 3-4% for all energies above 1 MeV. Detailed analysis of possible systematic errors is under consideration. The work is performed in the frame of the Project ISTC-1971.

ii) The neutron spectra have been measured for the proton-induced fission of ^{232}Th, ^{235}U, ^{238}U, and ^{237}Np at energies 50 and 96 MeV. The data obtained for ^{238}U and ^{237}Np are shown in Fig. 5. The anisotropy of neutron emission in backward-forward directions was estimated for neutrons with energies above 9 MeV. The data obtained were compared with the intranuclear cascade model (INCM) calculations. It was found that high-energy cascade neutrons give an essential contribution to the prompt-fission neutron multiplicity. The work was supported by the Project ISTC-1145.

Measurements at the VNIIEF (Sarov)

i) Measurements of the effective fission cross sections for Np, Pu, Am, and Cm isotopes were performed for neutron spectra of the MSB-1 and MSB-2 salt-blankets installed on the critical facility FKBN-2M, the fast-pulse reactor BIGR, and the thermal reactor MAKET. The fission-chamber technique, developed and widely applied at the VNIIEF, was used for all these measurements. The data obtained are compared in Table 1 with the cross sections calculated for current evaluated data-files (the TENDL library). Essential differences, observed for ^{244}Pu, ^{242}Am, ^{246}Cm, and ^{247}Cm, indicate on needs of a revision of the corresponding files in the region of unresolved neutron resonances. The work was carried out in the frame of the Project ISTC-1145.

ii) Measurements of the thermal cross sections for ^{232}Pa were performed on the IRT reactor (MIFI). The values were obtained (655$\pm$69) b for the capture cross section, (977±75) b for the fission cross section and (915±320) b for the fission resonance integral. The results obtained differ essentially from the available recommended data (464 ±95) b and (760±100) b for the capture and fission cross sections, respectively. The work was also supported by the Project ISTC-1145.

Measurements at the ITEP (Moscow)

i) The neutron spectra from thick W and Na targets irradiated by 0.8 GeV protons were studied on the ITEP accelerator. The results obtained are shown in Fig. 6. The comparison between the new data and previous ones shows differences about 20-30%, which should be considered as a systematic uncertainty of neutron spectra data for thick targets. Experimental data were compared with the results of a simulation by the widely used cascade-model codes. The work was performed in the frame of the Project ISTC-1145.

ii) Large amount of data on the cumulative yields of spallation and fission products was obtained during the last year for the targets of ^{206}Pb, ^{207}Pb, and ^{208}Pb irradiated by protons with energies from 70 MeV to 2.6 GeV. The corresponding data for ^{208}Pb at energies 1 GeV and 150 MeV are compared in Fig. 7 with INCM calculations. Although none of widely used codes provides a detailed description of current data, the adjustment of model parameters improves essentially the predictive accuracy of INCM calculations. This activity is developing under the Project ISTC-2002.

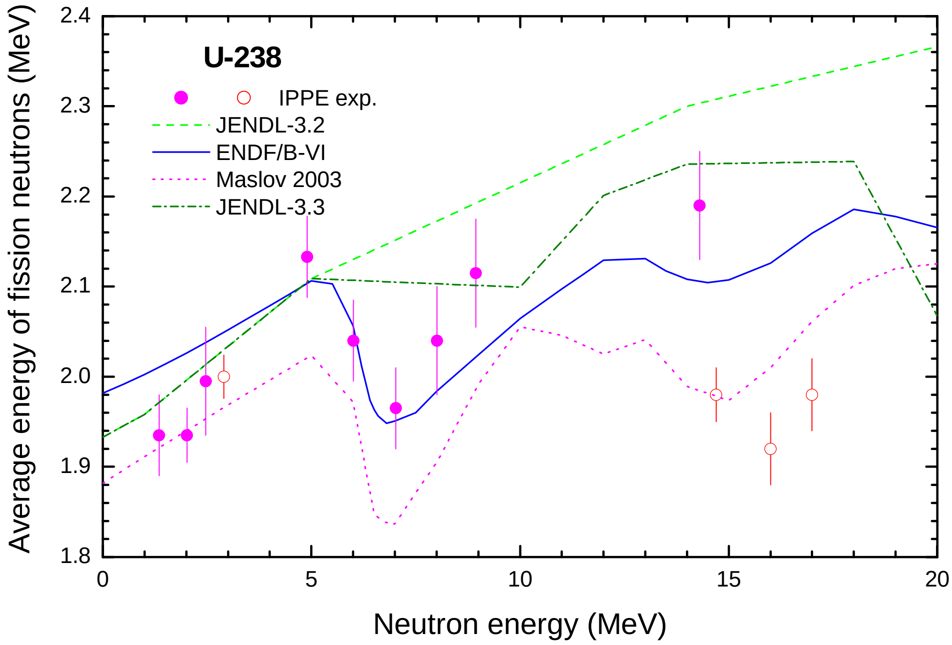

Fig. 1. Experimental data on the average energies of prompt-fission neutrons in comparison with various evaluations

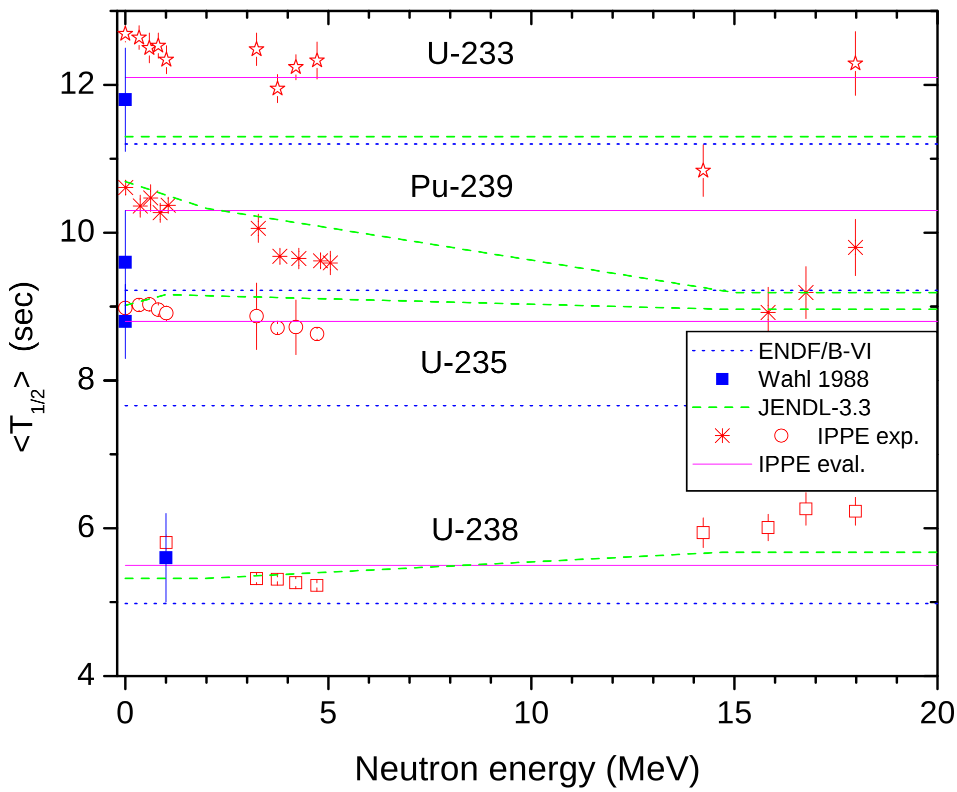

Fig. 2. Experimental data on the average half-life time of delayed neutrons in comparison with various evaluations

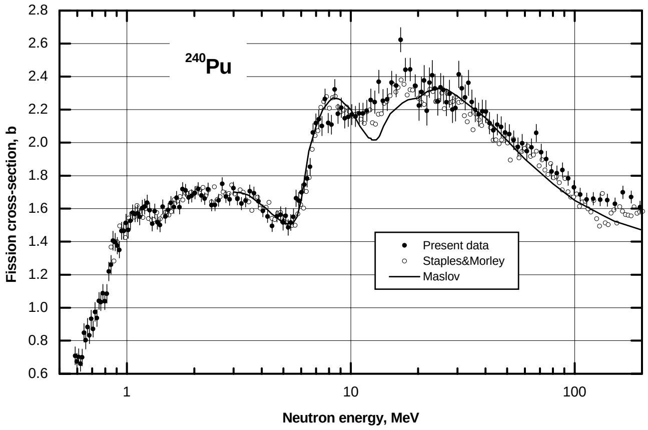

Fig. 3. Fission cross-section of ^{240}Pu in the energy range up to 200 MeV.

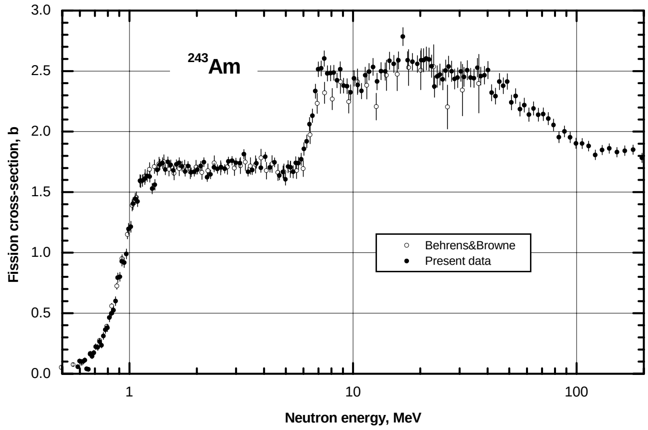

Fig. 4. Fission cross-section of ^{243}Am in the energy range up to 200 MeV.

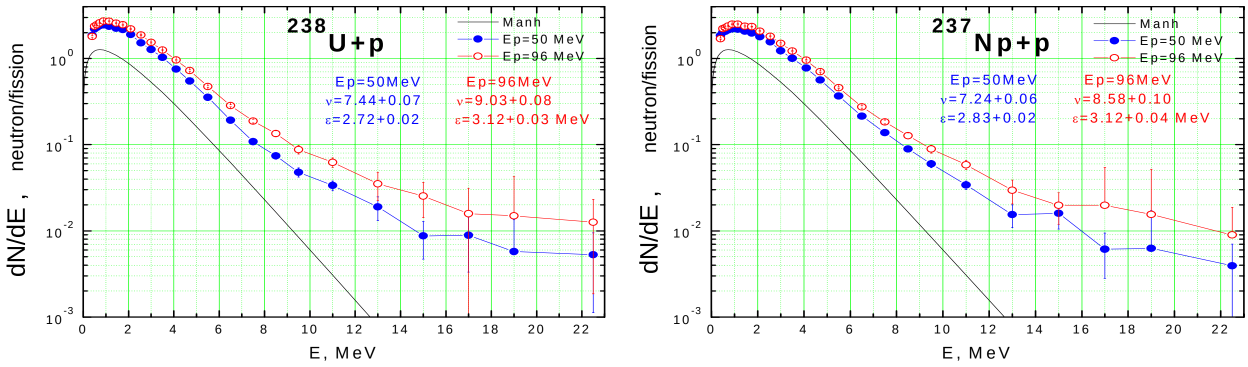

Fig. 5. Fission neutron spectra for the ^{238}U(p,f) reaction at the proton energies of 50 and 96 MeV

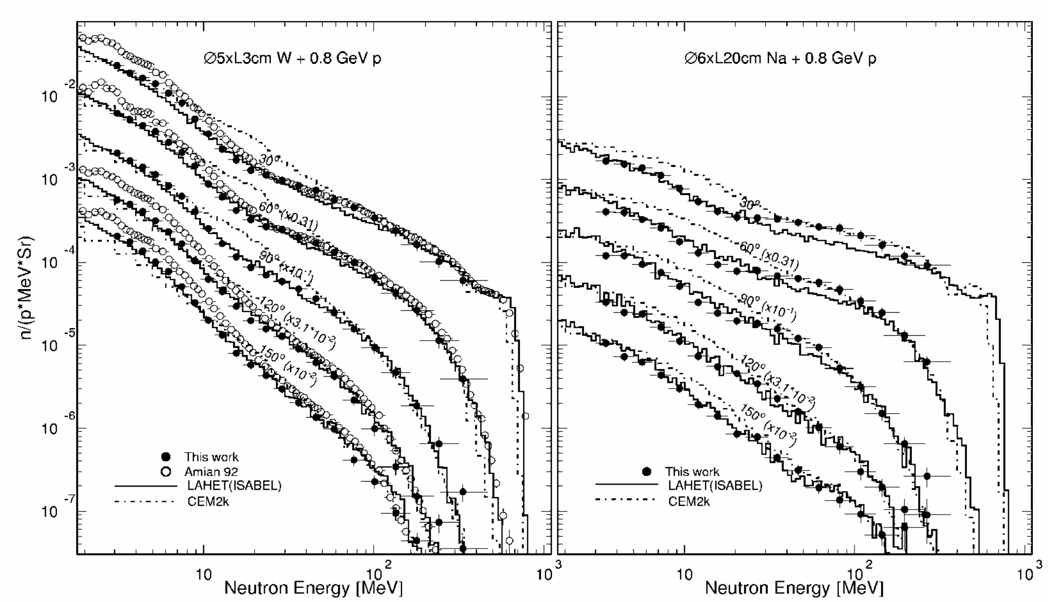

Fig. 6. Double differential neutron spectra measured for the W-slab ∅5xL2.935 cm (the left-hand panel) and ∅6xL20-cm Na (the right-hand panel) irradiated by the 0.8 protons together with INCM calculations

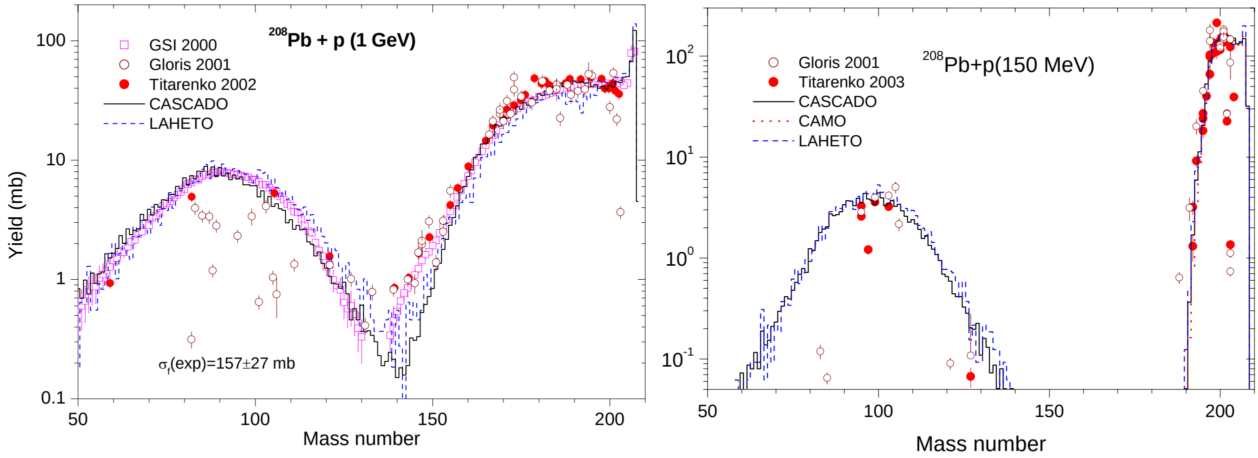

Fig. 7 Experimental data on the residual-mass distribution (open squares) and residual cumulative yields (solid and open circles) for the ^{208}Pb+p reaction at various energies in comparison with cascade-model calculations

Table 1. Comparison between the effective fission cross sections, measured for the salt blanket models MSB-1 and MSB-2 on the fast pulse-reactor BIGR and the FKBN-2M facility, and the cross sections calculated with the TENDL library.

Isotope	BIGR						FKBN-2M					
	MSB-1			MSB-2			MSB-1			MSB-2		
	$\sigma_{f\ exp}$	$\sigma_{f\ calc}$	$\sigma_{f\ exp}/\sigma_{f\ calc}$	$\sigma_{f\ exp}$	$\sigma_{f\ calc}$	$\sigma_{f\ exp}/\sigma_{f\ calc}$	$\sigma_{f\ exp}$	$\sigma_{f\ calc}$	$\sigma_{f\ exp}/\sigma_{f\ calc}$	$\sigma_{f\ exp}$	$\sigma_{f\ calc}$	$\sigma_{f\ exp}/\sigma_{f\ calc}$
^{235}U	2.539(94)	2.5389	1.000	2.205(82)	2.2058	1.000	1.449(54)	1.4488	1.000	1.460(54)	1.4597	1.000
^{238}U							0.104(04)	0.1217	0.855	0.108(05)	0.1219	0.886
^{237}Np							0.744(29)	0.7100	1.049	0.765(29)	0.7042	1.086
^{238}Pu	1.414(55)	1.5111	0.936	1.284(50)	1.3987	0.918						
^{239}Pu	2.917(110)	2.7997	1.063	2.475(94)	2.5647	0.965	1.746(65)	1.6952	1.030	1.772(66)	1.7005	1.042
^{240}Pu	0.614(30)	0.5701	1.072	0.543(27)	0.5534	0.986	0.704(34)	0.7505	0.939	0.734(37)	0.7452	0.985
^{241}Pu	3.506(214)	3.7925	0.925	2.848(188)	3.2391	0.759						
^{242}Pu	0.490(20)	0.4376	1.119	0.481(20)	0.4211	1.142						
^{244}Pu	0.599(45)	0.3860	1.552	0.571(39)	0.3709	1.540						
^{241}Am	0.678(26)	0.5060	1.329	0.573(22)	0.4830	1.187	0.788(31)	0.6777	1.153	0.791(31)	0.6737	1.169
^{242m}Am	7.982(480)	6.5002	1.228	6.099(366)	5.2008	1.173	3.090(170)	2.3109	1.337	3.116(168)	2.3263	1.340
^{243}Am	0.444(22)	0.4035	1.101	0.452(22)	0.3837	1.178						
^{243}Cm	6.177(297)	6.1119	1.011	4.945(242)	4.7704	1.262	2.911(140)	2.3059	1.262	2.727(134)	2.3198	1.175
^{244}Cm	0.716(34)	0.6675	1.073									
^{245}Cm	3.986(191)	4.2761	0.932	3.262(156)	3.5332	0.923	2.203(106)	2.0517	1.074	2.249(106)	2.0655	1.089
^{246}Cm	0.652(33)	0.4764	1.369									
^{247}Cm	3.981(219)	3.3193	1.199	2.265(131)	2.7947	0.811						
^{248}Cm	0.625(36)	0.5669	1.103									