

## Present Status of JENDL Project (May 2003)

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### 1. JENDL-3 revision 3 (JENDL-3.3: General Purpose File) and beyond

After 8 years of endurable revision works for JENDL-3.2 which had been released in 1994, the latest version of JENDL-3 (JENDL-3.3) was released publicly in May 2002. It contains the data for 337 nuclides in the energy range from  $10^{-5}$  eV to 20 MeV. The ENDF-6 format is adopted. The pointwise files are also constructed at 0 K and 300 K by using RESEND, RECENT, LINEAR and SIGMA1. All data are released on the WEB of our home page

<http://www.ndc.tokai.jaeri.go.jp/jendl/j33/j33.html>

or in a CD-ROM published from JAERI Nuclear Data Center (Aug. 2002)

The data improvement of JENDL-3.2 started at April 1997. Then after 5 years revision work, JENDL-3.3 has been completed by March 2002 and released in May 2002 officially as a consolidated new version of JENDL. This is a cooperative work done by JAERI NDC (Nuclear Data center) and JNDC (Japanese Nuclear Data Committee).

Some remarks of JENDL-3.3 are presented at  
<http://www.jaeri.go.jp/english/press/2002/020510>

The main features of JENDL-3.3 are summarized as follows:

1) Supply of qualified covariance data

Covariance data are supplied for major reactor constituents, such as major actinides, structural materials and main coolants, to be used for the applications of FBR, LWR and Fusion reactors. This was done so as to be able to make estimation of quantitative contribution of nuclear data uncertainty to design accuracy or safety margin. Only one nuclide (Mn-55) covariance data was supplied in the JENDL-3.2. Strong requests for this data comes from FBR reactor projects in Japan conducted by JNC (Japan Nuclear Fuel Cycle Corporation) as well as LWR reactor design group of Reactor Designs Makers in Japan.

2) Newly evaluated materials important for high burn-up application

Er isotopes are newly supplied in JENDL-3.3, because of the importance as burnable poisons in LWR in high burn-up applications.

3) Adoption of isotope evaluation policy

From this JENDL3.3, isotope evaluation policy is adopted completely, abandoning long used element evaluation policy adopted up to JENDL-3.2. Up to the previous version, natural element data was usually prepared for a natural element material (i.e., isotopes data are aggregated in one material), in parallel with this natural data we devised also isotope data in some case. In particular cases, inconsistency between natural and isotope data were alive. So as to solve this inconsistency among data we have claimed that for transport calculations in nuclear reactors, natural elements data are solely recommended to use and for dosimetry or activation applications, data given by isotopic evaluations are recommended. But there

happened miss use so much. Therefore we changed the policy. This change resulted in quality up in data expressions compared with natural evaluations.

#### 4) Enrichment of secondary gamma-ray production data

Secondary gamma-ray production data are newly incorporated for many nuclides needed in Fusion applications. The number of nuclides with gamma-ray production data was increased from 66 to 114.

#### 5) Individual Evaluation

##### a. Heavy Mass Nuclides (Modified Cross-sections)

A simultaneous evaluation of fission cross-sections for U-233, U-235, U-238, Pu-239, Pu-240 and Pu-241 was made. A least squares method was applied to selected absolute and relative measurements on the fission cross sections. Covariance matrices of the experimental data were constructed from the uncertainty information reported in the original references of each measurement.

##### b. Medium Mass Nuclides (Modified Cross-sections)

Na, Ti, Cr, Fe, Co, Ni, Nb, W isotopes are revised based on the latest high resolution measurements. As to Er-162,164,166,167,168,170 isotopes, complete new evaluation are made reflecting newly obtained capture data measured by TIT(Tokyo Institute of Technology).

#### 6) Benchmark Test

□ Group constants or MCNP/MVP Monte Carlo libraries of JENDL-3.3 were generated and used in the benchmark test. A vast benchmark tests were made for shielding performances as well as reactor physics performances in LWR, FBR and Intermediate energy reactors. Criticality calculations showed very good performances and got superior results than JENDL 3.2.

The JENDL-3.3 was released on 10<sup>th</sup> May 2002 after a long review of vast range of benchmark tests suitable for the reevaluated nuclides.

#### JENDL-4

Five year project of JENDL-4 is going to start in 2003. Prior to the start of JENDL-4 project, an adhoc group for making the road map of JENDL-4 development was set up at March 2002 in JNDC. After one year discussions among nuclear data evaluators, users from various fields especially in advanced/innovative reactors, astrophysics group, BNCT(Boron neutron capture therapy ) medical application etc, a group report will be opened in the next month. We present an outline here but this is not a final one, rather tentative one, i.e., not confirmed in the group.

We set the JENDL-4 main target as a file solving current concern on nuclear energy development such as high burn up, MOX fuels utilization, evaluations of burn-up credit and their safety assessments as well as innovative/advanced reactors seeking ultimate reliability in safety with reducing cost of fabrication. □ In the scope we also included medical or fundamental scientific applications such as BNCT, medical use of accelerators, and elemental synthesis in astrophysics. In JENDL-4, we set our goal as a supply of whole product not only JENDL-4 itself but also application libraries such as point Monte Carlo library (MVP/MCNP) library and/or group constants library produced from JENDL-4.

Contents will be enriched in the quality for actinide and FP nuclides, in the numbers for covariance data, fission product yields including prompt fission reactions, secondary gamma production data, charged particle spectra, the last one is especially required for the calculation of material damage.

Maximum energy of the file will be the same as the current one, i.e., 20 MeV. In ADS applications some materials require higher energy, only such materials will be extended up to some value of several tens MeV. Charged particle induced reactions will also be included even in limited numbers due to the requests from nuclear fusion or medical accelerator applications.

Adopted Format will be ENDF/B-7.

## 2. JENDL Special Purpose Files

The following special purpose files other than JENDL-3.3 general purpose file are being

developed in Japan. Their status is given below.

### JENDL Fusion File

The latest version of JENDL Fusion File (JFF) was released in 1999 to provide precise double-differential neutron and charged particle emission data by using MF6 representation of the ENDF-6 format. The evaluation was made for the data of H, D,  ${}^6,7\text{Li}$ ,  ${}^9\text{Be}$ ,  ${}^{12}\text{C}$ ,  ${}^{14}\text{N}$ ,  ${}^{16}\text{O}$ ,  ${}^{19}\text{F}$ ,  ${}^{27}\text{Al}$ , Si, Ca, Ti,  ${}^{51}\text{V}$ , Cr,  ${}^{55}\text{Mn}$ , Fe,  ${}^{59}\text{Co}$ , Ni, Cu, Ga,  ${}^{75}\text{As}$ , Zr,  ${}^{93}\text{Nb}$ , Mo, Sn, Sb, W, Pb and  ${}^{209}\text{Bi}$ . For H, D, Li, N and O, the data of JENDL-3.2 are directly adopted. The revision works for the nuclides excepting the light mass ones have been performed by the SINCROS-II code system which consists of GNASH, DWUCK, CASTHY and several auxiliary programs. Those results were examined by comparing with DDX measured at Tohoku and Osaka Universities. For the data of light mass nuclei, individual evaluation has been done. A lot of nuclides were adopted as FENDL-2 from this file. Formal evaluation paper was published as "Chiba S., Fukahori T., Shibata K. et. al.: JENDL Fusion File 99, J. Nucl. Sci. Technol., 39,187 (2002)".

### JENDL Actinide File

This file will provide the data of main and minor actinides about 90 nuclei (Th to Es) more than 1 day half life from 10<sup>-5</sup> eV to 20 MeV in energy. The revision work of major and minor actinides has been made and their results were reflected in JENDL-3.3. The revision work for minor actinides not reflected in JENDL-3.3 will be continued in the coming several years. The results of the reevaluation will be stored in JENDL Actinide File.

□□□ Fission and capture cross section of minor actinides given in JENDL-3.3 are compared thoroughly with other evaluated data and experimental data for the preparation of the JENDL Actinide File. The comparison was made for 32 nuclides of Th-227, 228, 229, 230, 233, 234, Pa-231, 232, 233, U-232, 234, 236, 237, Np-236, 237, 238, Pu-236, 237, 238, 242, 244, Am-241, 242, 242m, 243, Cm-242, 243, 244, 245, 246, 247, 248. Figures of compared cross sections and tables of cross sections at 0.0253 eV and resonance integrals are available in the publication of JAERI-Data/Code 2002-025: T. Nakagawa and O. Iwamoto, "Comparison of Fission and Capture Cross Sections of Minor Actinides".

Since 1994, International Science and Technology Center (ISTC) project for Measurements and Evaluation of minor actinide nuclei has been started at Institute of Physics and Power Engineering (IPPE, Obninsk Russia, #304.), V.I. Khlopin Radium Institute (KRI, St. Petersburg Russia, #183.) and Radiation Physics and Chemistry Problem Institute (RPCPI, Minsk Belarus, #b-03). After those the forth project started to measure fission cross-sections of minor actinides in medium energy range, i.e., 1 to 200 MeV by Petersburg Nuclear Physics Institute (PNPI St. Petersburg, #609.) for the coverage of JENDL High Energy File Project. Another project of actinide nuclear data evaluation for Th cycle started April 2000 (RPCPI, Minsk Belarus, #B-404). Summary record about ISTC is given in Appendix. A.

### JENDL Dosimetry File

The working group on Dosimetry cross sections in JNDC has been published a new file JENDL Dosimetry File 99 and the WG was dissolved. Cross section data of previous version, JENDL Dosimetry File 91, were revised for 33 materials and their covariance matrices were

replaced completely with new ones. Integral tests were also made. The file was released in FY99 and the data were also released with a CD-ROM, which is freely available through NDC/JAERI. Contents are 67 various reactions with point-wise and 671 group structures averaged data. An official evaluation report was published as “Kobayashi K., Iguchi T., Iwasaki S., et. al.: JENDL Dosimetry File 99 (JENDL/D-99), JAERI-1344 (2001)”.

#### JENDL Activation Cross Section File

Evaluation and compilation work for JENDL Activation Cross Section File was completed and released in March 1996 as JENDL-A96. This first version stores the data for 233 nuclei and 1246 reactions. Final report is under preparation. Revision of the files is foreseen near future considering the feedback information from the ad hoc group for threshold reaction evaluation working group in JNDC.

#### JENDL Alpha-n Data File

Evaluation and compilation work for JENDL Alpha-n Data File has been progressed by Charged Particle Nuclear Data Working Group. This file is requested from Shielding Group and/or Nuclear Criticality Safety Group especially for the applications of spent fuel transportations and stockades or reprocessing plant design. Neutron behaviors are very important for the treatment of spent fuels due to the neutrons are born from alpha emitters of minor/major actinides converted from major actinides of fuels. Total of 32 nuclides for Li-6, 7, Be-9, B-10, 11, C-12, 13, N-14, 15, O-17, 18, F-19, Na-23, Al-27, Si-28, 29, 30, Cr-50, 52, 53, 54, Fe-54, 56, 57, 58, Ni-58, 60, 61,62,64, Cu-63, 65.will be stored. UP to now except Si, isotopes evaluation is finished. A partial file was released in Feb. 2003 containing 13 nuclides from Li-6 to Na-23 out of above described 32 nuclides. All these data are available from <ftp://wwwwnc.tokai.jaeri.go.jp/www/JENDL/JENDL-AN-2003> .

#### JENDL FP Decay Data File

Evaluation and compilation work for JENDL FP Decay Data File has been completed by sub-group in Decay Heat Evaluation Working Group of JNDC. This file is a succession of former JNDC Decay Data Library compiled in private JNDC format. The newly released file is compiled in ENDF-6 Format. The file contains decay data for 1229 FP nuclides consisting of 142 stable and 1087 unstable nuclides. For each nuclides following data are given; decay modes, their Q values and branching ratios, average decay energy values of beta-rays, gamma-rays and alpha-particles and their spectral data. This file is inevitable for the decay heat calculations for the power reactors. This file was released in FY2000 and named as JENDL FP Decay Data File 2000. Official evaluation report was published as “Katakura J., et al. :JENDL FP Decay Data File 2000, JAERI-1343 (2001)”.

#### JENDL High Energy Files

The evaluation of data for high-energy neutrons and protons has been initiated in JNDC. They will make data files for neutrons up to 50 MeV and for neutrons and protons up to 3 GeV.

The former files will be used for the IFMIF project that JAERI participates. The evaluation of neutron data up to 50 MeV has been made for almost all necessary nuclides. The evaluation results for neutron are being reviewed. After review, the data will be combined with JENDL-3.3

below 20 MeV. The file release will be envisaged in FY2003.

The latter files will be used for design of accelerators, transmutation systems of high-level waste, medical applications and so on. Stored nuclides are listed in Table-1. Among the list, evaluations for first and second categories were already finished for neutron and proton induced reactions up to 3 GeV. A test data file is compiled and benchmark test is in progress. The file release will be envisaged after the benchmark test, we expect distribution starts within FY2003 for first priority nuclides.

#### JENDL PKA/KERMA File

This file stores the spectra of primary knock-on atoms (PKA) and KERMA factors. The data to be stored are created from the data files(JENDL High Energy File) up to 50 MeV made for the IFMIF project. A couple of processing codes to create the file from evaluated nuclear data file, by using the effective single particle emission approximation, have been developed and tested. The test compilation has been performed from JENDL Fusion File for the 69 isotope data except light mass nuclei below 20 MeV. The file release will be made in FY2003.

#### JENDL Photonuclear Data File

The evaluation has been finished for 46 isotopes;  $^2\text{D}$ ,  $^{12}\text{C}$ ,  $^{14}\text{N}$ ,  $^{16}\text{O}$ ,  $^{23}\text{Na}$ ,  $^{24,25,26}\text{Mg}$ ,  $^{27}\text{Al}$ ,  $^{28,29,30}\text{Si}$ ,  $^{40,48}\text{Ca}$ ,  $^{46}\text{Ti}$ ,  $^{51}\text{V}$ ,  $^{52}\text{Cr}$ ,  $^{55}\text{Mn}$ ,  $^{54,56}\text{Fe}$ ,  $^{59}\text{Co}$ ,  $^{58,60}\text{Ni}$ ,  $^{63,65}\text{Cu}$ ,  $^{90}\text{Zr}$ ,  $^{93}\text{Nb}$ ,  $^{92,94,96,98,100}\text{Mo}$ ,  $^{133}\text{Cs}$ ,  $^{160}\text{Gd}$ ,  $^{182,183,184,186}\text{W}$ ,  $^{197}\text{Au}$ ,  $^{206,207,208}\text{Pb}$ ,  $^{209}\text{Bi}$  and  $^{235,238}\text{U}$  in the gamma-ray energy range up to 140 MeV. Their compilation in the ENDF-6 format and the critical review are in progress. The file will be released in FY2003 also.

### **3. Other Activity Relating to Nuclear Data**

#### **1) ND2001: International Conference on Nuclear Data for Science and Technology**

The International Conference on Nuclear Data for Science and Technology (ND2001) was held 7-12<sup>th</sup> October 2001 at the EPOCHAL Tsukuba International Congress Center in Tsukuba, Ibaraki, Japan. The Japan Atomic Energy Research Institute (JAERI) sponsored and organized in collaboration with OECD Nuclear Energy Agency – Nuclear Science Committee (NEA/NSC) and Atomic Energy Society of Japan (AESJ) as the co-sponsors. Total of 375 scientists from 41 countries and 4 international organizations participated in the conference, of which 207 participants come from abroad. Total of 375 papers were presented including 4 keynotes and 3 summary talks in the 40 sessions; i.e., 50 invited talks, 116 oral and 202 poster contributed papers. One third of the presented papers are in the topics of Nuclear Reaction Data and Evaluated data Libraries. The other one third is devoted to the applications in energy production including ADS (accelerator driven sub-critical system) applications and Industry or Medical applications. The rest one third is devoted for forefront of Nuclear Reaction Theory, Astrophysics, Facilities for new century and steady progress in International Collaborations. An emphasis was laid down on the application of the Nuclear Data to ADS due to the increased interests in the world-wide environmental concern on nuclear high level waste. And data applications in the Astrophysics are also enthusiastically debated in connection with nuclear synthesis of the universe.

The proceedings was published on August 2002 as a supplement to Journal of Nuclear Science and Technology, a publication of Atomic Energy Society of Japan(AESJ), including all invited and contributed papers passed through peer reviews of program committee members.

## **2) The 2002 Symposium on Nuclear Data**

The 2002 Symposium on Nuclear Data was held at Tokai Research Establishment, Japan Atomic Energy Research Institute (JAERI), on 21st and 22nd of November 2002. Japanese Nuclear Data Committee and Nuclear Data Center, JAERI organized this symposium. In the oral sessions, presented were 17 papers on the release of JENDL3.3: Outline of JENDL3.3 and its Benchmark test for LWR/FBR reactors and Shielding applications, Requests and discussions about JENDL utilizations among Developers and Japanese Nuclear Industrial User Groups, International session and other topics like Neutrino Physics. In the poster session, presented were 33 papers concerning experiments, evaluations, benchmark tests and software on nuclear data. Those presented papers are compiled in the proceedings and will be published as a JAERI-conf report having INDC (JPN)-190/U (2003) report number. Total of 133 attendees including 8 foreigners (of which 2 Asian researchers invited by the organizing committee) and 85 outside JAERI were gathered. This year, due to VISA problems, three invited foreigners could not attend.

## **3) Development of Integrated Nuclear Data Utilization System for Innovative Reactors**

This is a 5 year project starting 2002 to furnish up-to-date nuclear data for the users of innovative reactor (advance reactors such as ADS, low moderation LWR, super high burn up reactors, etc) design very timely in the frame of Innovative Reactor Development Projects, in which so wide users are anticipated in Japan. This is mainly for application users representing innovative reactors, but it also act as a very strong tool for fundamental or academic users of nuclear data as well as students of universities.

So as to make available accurate and reliable latest nuclear data to users, we are developing an integrated software system called CONDUCT (Consolidated Nuclear Data Utilization, Calculation and Transfer System) functioning on the Internet. This system consists of three parts, system control part, retrieval and plotting system part, and processing and utilization system part.

System control part manages nuclear database and application programs under this system. Nuclear data database contains latest evaluated nuclear data such as JENDL-3.3, JEFF-3, ENDF/B-VI and measured data from EXFOR data base. The data retrieval and plotting system provides the numerical data files, data tables and figures that are produced from the stored experimental and/or evaluated nuclear data in the user friendly way according to the user's requests. The processing and utilization system consists of two parts: data processing and data utilization. The processing part provides the tools that create data libraries needed for reactor application codes such as MVP,MCNP,ANISN, DOT,DORT,ORIGEN2 and so on from the evaluated nuclear data. The utilization part provides the tools that make criticality and shielding benchmark calculations together with the tools tabulating and plotting numerical data.

This work is a part of "Fundamental R&D on Neutron Cross Sections for Innovative Reactors Using Advanced Radiation Measurement Technology", which is one of research tasks selected with competitions for "Innovative Nuclear Energy System Technology(INEST) Development Projects" funded by the Ministry of Education, Culture, Sports, Science and Technology(MEXT). Assigned fund for the utilization system development is about 135 million yen (1.1M\$US) out of 760million yen (6.3M\$US) in 5 years.

Table-1 Stored Nuclides in JENDL High Energy File

Priority	Nuclides (Total:122)
1 <sup>st</sup> Priority (40 nuclides)	<b>H-1, C-12, N-14, O-16, Al-27,</b> <b>Cr-50, 52, 53, 54,</b> <b>Fe-54, 56, 57, 58,</b> <b>Ni-58, 60, 61, 62, 64,</b> <b>Cu-63, 65,</b> <b>W-180, 182, 183, 184, 186, Au-197,</b> <b>Hg-196, 198, 199, 200, 201, 202, 204,</b> <b>Pb-204, 206, 207, 208, Bi-209,</b> <b>U-235, 238</b>
2 <sup>nd</sup> Priority (45 nuclides)	<b>H-2, Be-9, B-10, 11, Mg-24, 25, 26,</b> <b>Si-28, 29, 30, K-39, 41,</b> <b>Ca-40, 42, 43, 44, 46, 48,</b> <b>Ti-46, 47, 48, 49, 50, V-51, Mn-55,</b> <b>Co-59, Zr-90, 91, 92, 94, 96,</b> <b>Nb-93, Mo-92, 94, 95, 96, 97, 98, 100, Ta-181,</b> <b>Pu-238, 239, 240, 241, 242</b>
3 <sup>rd</sup> Priority (37 nuclides)	<b>Li-6, 7, C-13, F-19, Na-23, Cl-35, 37,</b> <b>Ar-35, 38, 40, Zn-64, 66, 67, 68, 70,</b> <b>Ga-69, 71, Ge-70, 72, 73, 74, 76, As-75, Y-89,</b> <b>Th-232, U-233, 234, 236, Np-237,</b> <b>Am-241, 242, 242m, 243, Cm-243, 244, 245, 246</b>

NB. **RED**: Evaluation and File Compilation Finished. (65nuclides)

. **BLUE**: Evaluation Finished. (33nuclides)

**BLACK**: Evaluation not yet Finished. (24nuclides)

## Appendix-A

Summary of ISTC project that JAERI participated with some funds, relating to the JENDL Actinide File

Objective:

.Improvement of minor actinide data for transmutation projects using actinide burner reactors or accelerator driven spallation neutron sources.

.The data needed are for  $^{237, 238}\text{Np}$ ,  $^{238, 242}\text{Pu}$ ,  $^{241, 242g, 242m, 243}\text{Am}$  and  $^{242, 243, 244, 245, 246}\text{Cm}$ .

.The corresponding data for most important cross sections should be obtained on the basis of ISTC.

ISTC projects:

- “Measurements of the fission neutron spectra for minor actinides”  
V.I.Khlopin Radium Institute (KRI St.Petersburg Russia, # 183-p)  
1995-1997
  
- .high precision measurements of the fission neutron spectra for spontaneous fission of Cm-244, -246, Pu-240 -242, and that for thermal induced fission of Cm-243, -245
  
- “Measurements and analysis of basic nuclear data for minor actinides”  
Institute of Physics and Power Engineering (IPPE Obninsk Russia, #304-p)  
1995-1996
  
- precise measurements of the fission cross sections of  
Cm-243, -244, -245, -246, -247, -248m, Am-242m, Pu-238.
- measurements of fission product yields for Np-237
- .measurements of inelastic scattering and prompt fission neutron spectra for Np-237
- .measurements of delayed neutron yields and it's 6-group constants for Np-237 fast neutron fission
- .critical comparison between evaluated data for BROND-2, JENDL-3 and ENDF/B-VI and deduction of recommended values
  
- “Evaluation of actinide nuclear data”  
Radiation Physics and Chemistry Problems Institute  
(RPCPIMinsk Belarus Russia, # b-03)  
1995-1998
  
- .complete new evaluations of neutron cross sections for Cm-243, -245 -246, Am-241, 242, 242m, 243, Np-238, Pu-238, -242.
  
- “Neutron induced fission cross-sections of some actinides heavy nuclei in energy region 1-200 MeV  
Petersburg Nuclear Physics Institute (PNPI St.Petersburg Russia, #609)



1996-1999

.measurements of neutron fission cross-section of U-233, U-238, Np-237, Th-232, Pu-239, Pb and Bi in the energy range up to 200 MeV.

Relative measurements to U-235 fission with accuracy 3-10%.

□ evaluation of above listed cross section for neutron and proton induced fissions in the energy range 20-200 MeV.

- “ Fission Cross section at Intermediate Energies“  
Petersburg Nuclear Physics Institute (PNPI St.Petersburg Russia, #1971)  
2001-2002 (Extension of #609)

.measurements of neutron fission cross-section of Pu-240, Am-243 and W in the energy range up to 200 MeV.

Relative measurements to U-235 fission with accuracy 3-10%.

□ evaluation of above listed cross section for neutron and proton induced fissions in the energy range 20-200 MeV.

Other ISTC Project relating to Nuclear Data

- “Benchmark Data on Gamma-ray Production For Fusion Application”,  
Institute of Physics and Power Engineering (IPPE Obninsk Russia, #731)  
1997-2000

□ measurements and evaluations of the benchmark data on gamma-ray production cross section in the fast neutron induced reactions for materials that are most important for fusion power applications.

Measurements anticipated are 32 structure materials at 14MeV.

(For 1<sup>st</sup> year: Li-6,-7, B-10,-11, C, N, O, Al, Si, Fe, Cu, Mo,W, Pb were measured.)

The data will be available in EXFOR Format.

Evaluations in ENDF/B-6 Format will be made for most important 20 nuclides.

- “Experimental and Theoretical Study of the Yields of Residual Product Nuclei Produced In thin Targets Irradiated by 100-2600 MeV protons”,  
Federal Scientific Center of Russia Institute for Theoretical and Experimental Physics (ITEP Moscow Russia, #839)  
1997-2000

□ Residual product nuclei measurements from spallation by high energy proton beam for thin targets of <sup>182</sup>W, <sup>183</sup>W, <sup>184</sup>W, <sup>186</sup>W, <sup>232</sup>Th, nat.U, <sup>99</sup>Tc, <sup>59</sup>Co, <sup>63</sup>Cu and <sup>65</sup>Cu .

Measured proton energies are 100, 150, 200, 800, 1000, 1200, 1400, 1600 and 2600 MeV.

To get the reference data to check the simulation code such as LAHET, ALICE, QMD, etc.

- “Nuclear Physics Investigation Aimed at the Solution of Weapon Plutonium Conversion

and Long-lived Radioactive Wastes Transmutation Problems ”,  
Russia Federal Nuclear Center All-Russia Scientific Research of Experimental Physics  
(VNIIEF Sarov Russia, #1145)  
1998-2000

- measurements of the cross sections necessary for the transmutation technologies and electro-nuclear energy production system on the basis of high-current proton accelerator.
- Cross sections of a wide range of isotopes for minor actinides of Np, Pu, Am and Cm in the fast and intermediate neutron spectra; Thermal cross section for neutron induced fission and radiative capture of Np-238( $T_{1/2} = 2.12$  d); Spectra of fast fission neutrons from Th, U, Np and Pu by 40-200 MeV protons.

- “Evaluation of actinide nuclear data”

Radiation Physics and Chemistry Problems Institute

(RPCPIMinsk Belarus Russia, # B-404)

2000-2002

.complete new evaluations of neutron cross sections for Th-232, Pa-231, Pa-233, U-232, U-233, U-234. up to 20MeV.

- new evaluations of neutron cross sections for U-238 and Pu-239 up to 150 MeV.