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Progress of CENDL and Related Activities During 2010-2011

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I. Introduction of China Nuclear Data Activities

The goal of China nuclear data activities is supplying the nuclear data to feed the needs of the nuclear peaceful applications; which contains the nuclear power plants design, science studies, nuclear medicine application and public education et al.

The China nuclear data activities consists of nuclear data measurement and related measurement methods study, data evaluation and model study, data library establish and library management and nuclear data benchmark testing and validation.

The mainly activities are being carried out at China Nuclear Data Center(CNDC), China Institute of Atomic Energy(CIAE) and China Nuclear Data Coordination Network(CNDCN) and more than 10 institutions and universities are involved CNDCN.

II. Recent Progress of China Nuclear Data Project

2-1 CENDL project

China Evaluated Nuclear Data Library (CENDL) is a general purpose evaluated nuclear data file. The vision CENDL3.1 was released in 2009 and provided for all users by ENDF format. According to the back feed from the benchmark testing and users, some data files (MT) of CENDL-3.1 were re-evaluated in recently two years. These nuclei including the actinides ^{241}Am, ^{234,235}U, ^{237}Np, ^{233}Th and some structural materials ^{54}Fe, ^{97}Mo, ^{186}W(p,n), (p,2n) ^{208,207,206,204}Pb et al. Following Figs 1-2. show the re-evaluated results for some actinides

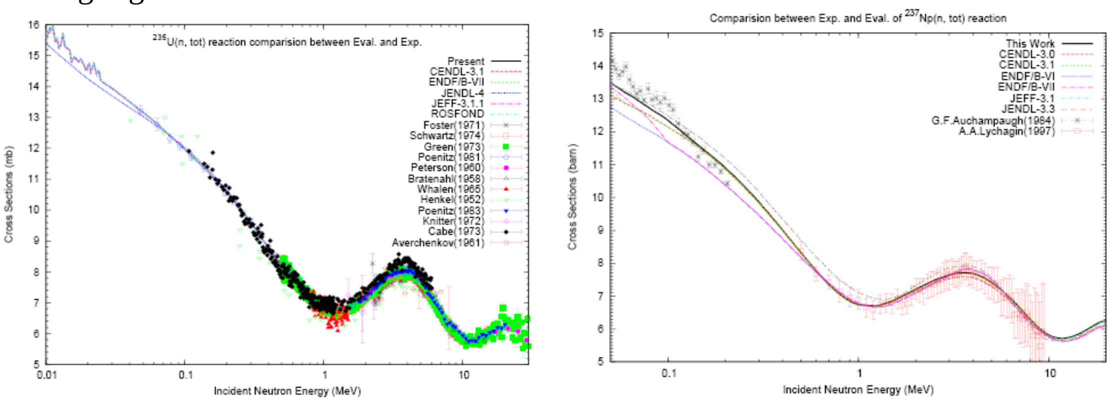

Fig.1 Comparison of re-evaluated (n,tot) CS with measured data and other evaluations for ^{235}U(lift) and ^{237}Np(right)

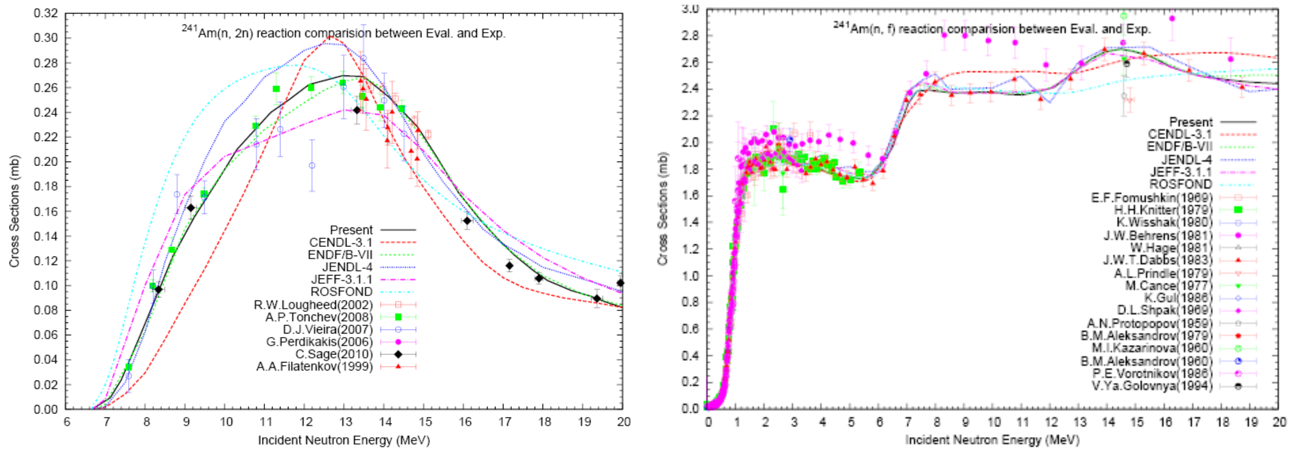

Fig. 2 Comparison of evaluated (n,2n) data for ^{241}Am (left) and comparison of CENDL-31-REV, CENDL-31， ENDF/B-VII for ^{241}Am(n, f) reaction(right)

Next CENDL will be:

- The data files re-evaluation will be continued according the updated experimental information and back feed from the benchmark testing and validation.
- The number of nuclei of next vision of CENDL will be increased from 240 up to 300 according to the user's requirements.
- The covariance files will be added for more than 30 nuclei, the high reliability covariance for important nuclei and low reliability for other will be included.
- The some sub-libraries (fission product yield data sub-library, activity cross section sub-library and charged-particle nuclear data sub-library et al.) will be re-evaluated and extended.

Decay Data Evaluation

The decay data for ^{56}Co, ^{66}Ga, ^{213}Bi, ^{213}Po, ^{217}At, ^{217}Rn, ^{221}Fr, ^{223}Fr, ^{225}Ac, ^{225}Ra, ^{231}Th, ^{234,234m}Pa, ^{235}U nuclides have been updated and recommended using available experimental data. The recommended data and evaluated comments were published in DDEP website.
Also China group has re-evaluated the main relative γ-ray intensities for ^{56}Co and ^{66}Ga considered China measurements for high energy calibration of Ge detectors.

2-2 Related Methodology Studies

- **Neutron cross section covariance evaluation**

A covariance evaluation system, COVAC (see Fig.3), is being developed in CNDC to achieve the covariance files mainly for structure and fission nuclides in CENDL. In this system, experimental data including their errors were firstly pre-analyzed and handled via available tools. In this framework, the high fidelity covariance file can be obtained with combining the theoretical and experimental uncertainties and correlations. Fig.4 show the correlation coefficient matrix of the ^{40}Ca(n, tot) cross sections obtained with COVAC system.

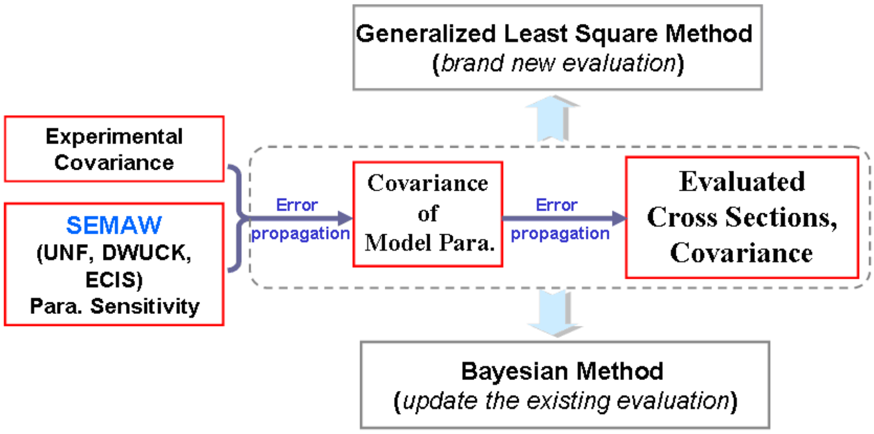

Fig 3. COVAC SYSTEM OF CNDC

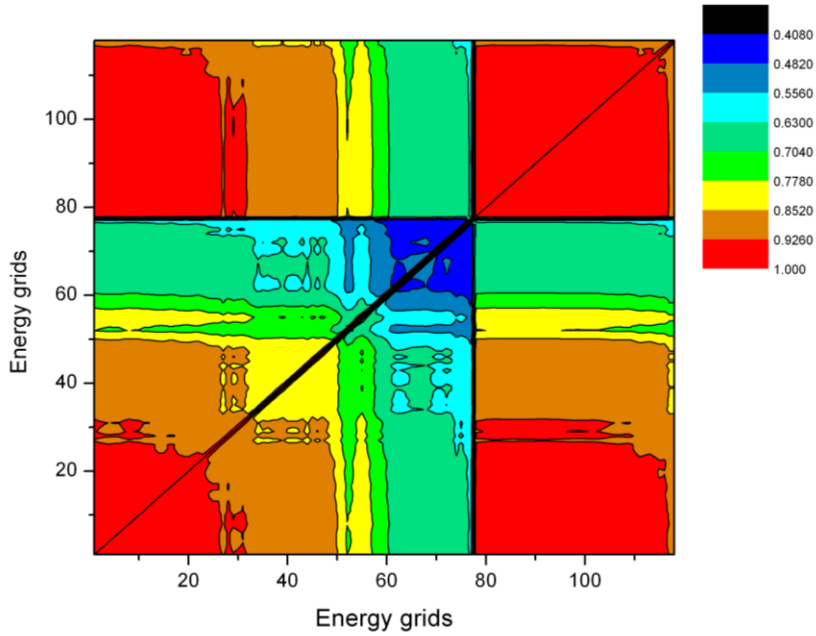

Fig 4. The correlation coefficient matrix of the ^{40}Ca(n, tot) cross sections

- **Systematic study of covariance of (n,tot) CS based on the relativistic Dirac Bruckner Hartree-Fock microscopic global OMP**

Part 1: Equivalent Covariance of Experimental (n,tot) data: **Vexp**
The global OMP were taken from the following paper:

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Relativistic nucleon optical potentials with isospin dependence in a Dirac-Brueckner-Hartree-Fock approach

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The relativistic optical model potential (OMP) for nucleon-nucleus scattering is investigated in the framework of the Dirac-Brueckner-Hartree-Fock (DBHF) approach using the Bonn-B one-boson-exchange potential for the bare nucleon-nucleon interaction. Both real and imaginary parts of isospin-dependent nucleon self-energies in the nuclear medium are derived from the DBHF approach based on the projection techniques within the subtracted T-matrix representation. The Dirac potentials as well as the corresponding Schrödinger equivalent potentials are evaluated. An improved local density approximation is employed in this analysis, where a range parameter is included to account for a finite-range correction of the nucleon-nucleon interaction. As an example the total

Covariance is evaluated through the determination method of "Least Square"

Motivation：1) explore the experimental error not reported in the literatures, especially to the correlation error; 2) study the system deviation between theoretical prediction and measurements.

Method: 1) Calculate the Ratio=s_{exp}/s_{theo}.for ^{12}C - ^{208}Pb in a certain energy region. note: ratio value is expected to be close to 1 indicating the best fit. 2）Assume the counts of ratio values follows a Gaussian shape; 3）Rough estimation for Vexp： Error1，Error2，Error3

Error1：directly adopted from EXFOR or literatures, short range error

Error2：Evaluated from Gaussian analysis for ratios,

Error3：they are middle range and long range errors respectively.

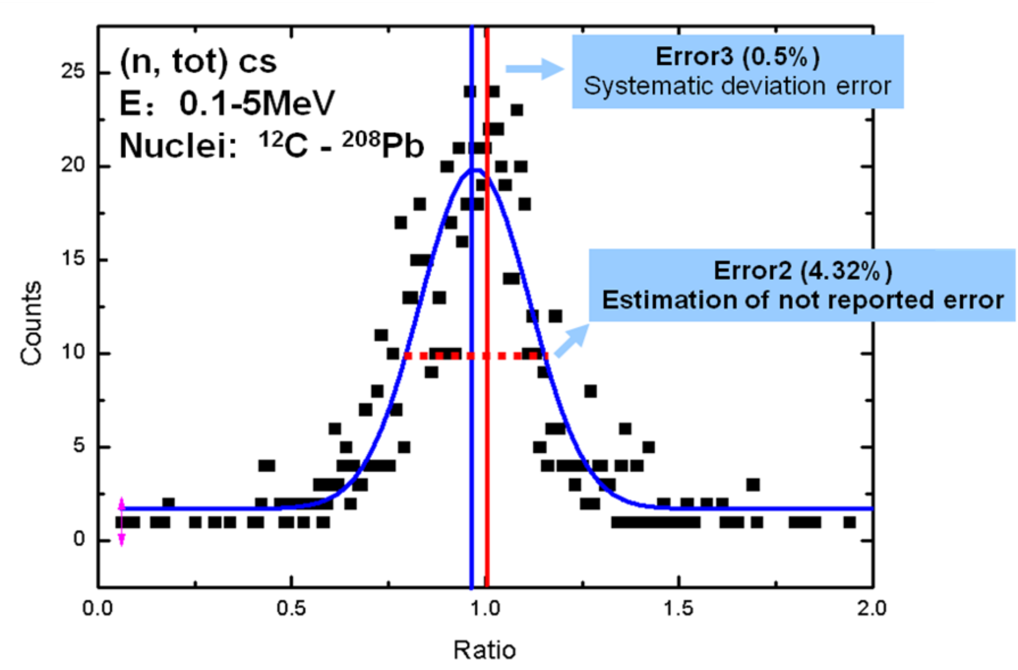

Fig. 5 The ratios of exp against calculated total CS for ^{12}C-^{208}Pb

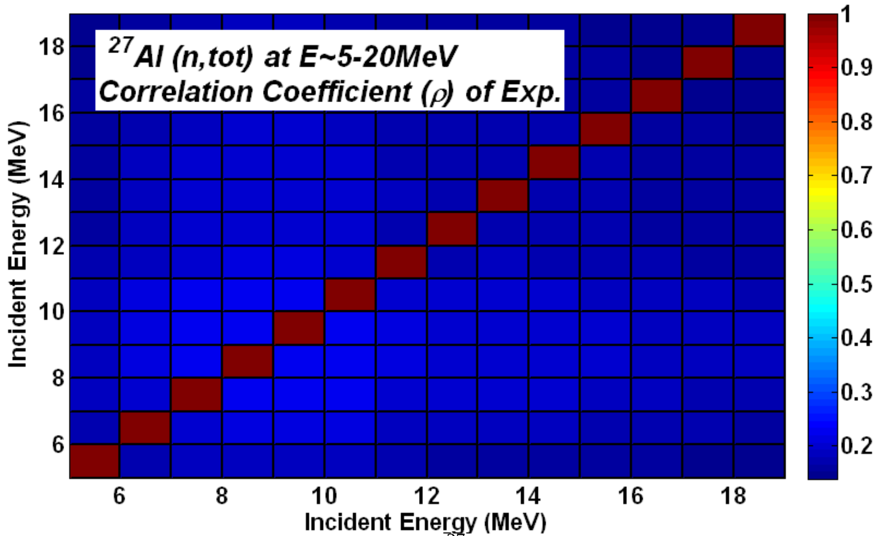

Fig.6 The correlation coefficient of exp. data for ^{27}Al(n,tot) (Diagonal elements contain Error1, Error2, Error3. Off diagonal (correlations) contain Error2, Error3)

Part2: Modification for LS formula to minimize the statistic decrease of LS method

LS:

$$\Delta\hat{C} = (F_1^T V_{\exp}^{-1} F_1)^{-1} F_1^T V_{\exp}^{-1} (Y_{\exp} - Y_{理论})$$

$$\hat{V}\mathrm{c} = (F_1^T V_{\exp}^{-1} F_1)^{-1}$$

$$\hat{Y}_{推荐} = F_2 \Delta\hat{C} + Y_{理论}$$

$$\hat{V}_{\hat{Y}_{推荐}} = \underline{a^2 N}(F_2 \hat{V}c F_2^T)$$

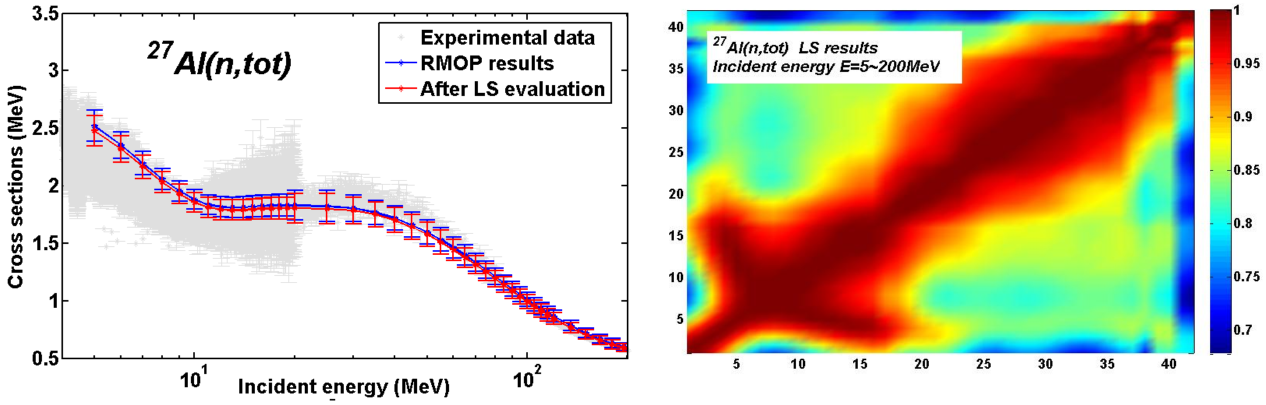

Fig. 7 This covariance is evaluated after LS calculation.

- **Nuclear data S/U method study.**

A one-dimension sensitivity/uncertainty(S/U) analysis code SENS1D, based on the generalized perturbation theory, has been developed in CNDC in 2011, which can be used for the S/U analysis of one-dimension benchmark facilities, such as Godiva, Jezebel and Flattop, with or without reflecting material. As shown in the following Fig.8. SENS1D can now calculate the explicit sensitivity coefficient of K_{eff} to several input CS data, including fission channel(n-f, nu, chi), absorption channel (n-g, n-a, n-d, n-p), scattering channel(n-el, n-inel, n-2n) and total (absorption plus scattering plus n-f), and then combine the multi-group covariance data to calculate the uncertainty of k_{eff} due to the above input CS data.

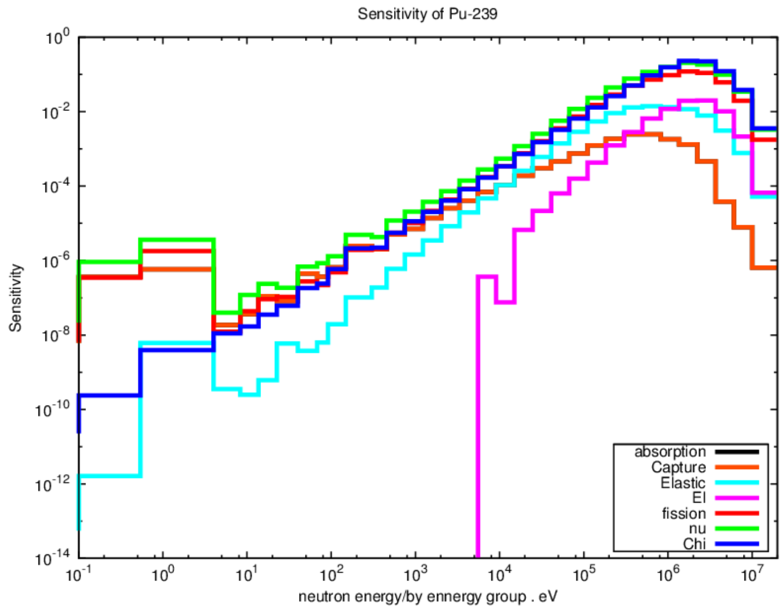

Fig. 8 Preliminary k_{eff} sensitivity coefficient of ^{239}Pu (absolute value) calculated by SENS1D.

In order to verify and test the reliability of SENS1D, the direct monte-carlo perturbation method was implemented to calculate the direct sensitivity coefficient of K_{eff}, most of whose result shows a good agreement with SENS1D, but the result of n-inel, as illustrated in Fig.9 shows a little bit difference, which can be due to the methodology difference. The same method was also implemented to calculate the sensitivity coefficient of leakage neutron spectrum of several fusion benchmark facilities, such as LLNL pulsed sphere facility, leading to a reasonable result, which can be seen in Fig.10. Furthermore, like keff, the leakage result of M-C direct perturbation calculation can be also sent to SENS1D to get the combined uncertainty.

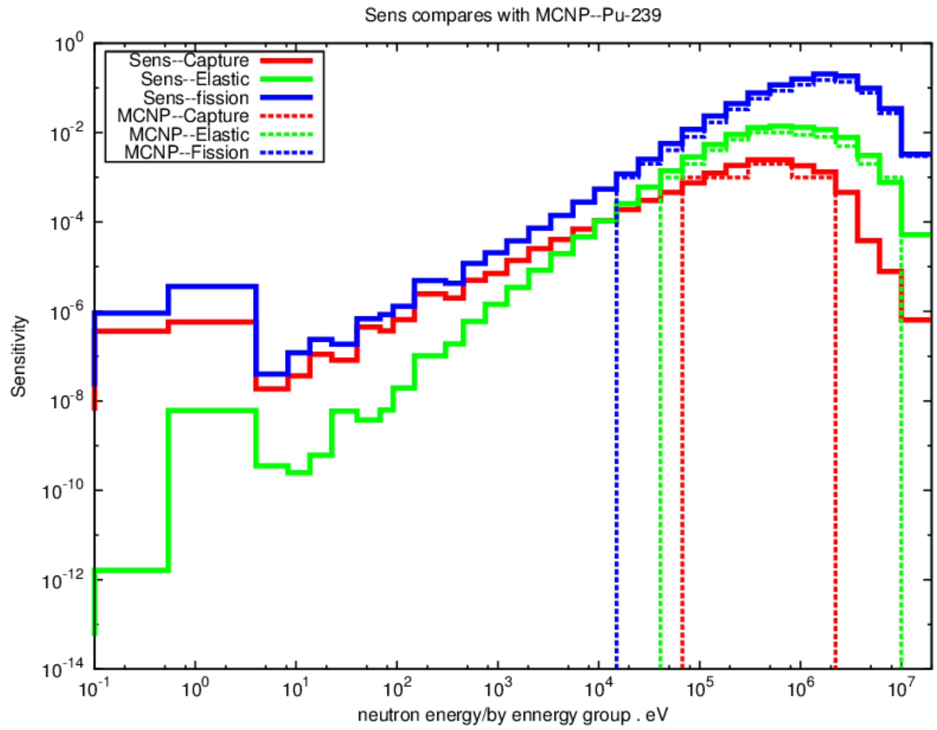

Fig. 9 Direct perturbation result of Pu-239 (absolute value)

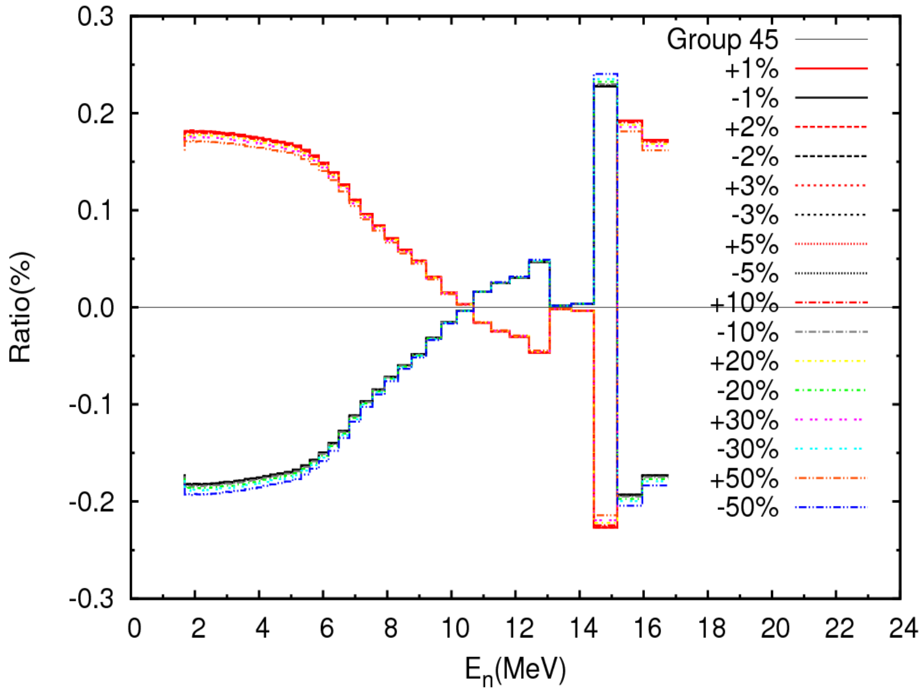

Fig. 10 Sensitivity coefficient of leakage neutron spectrum to the group 45 fission data of U-235

- **R- matrix used for light nuclei CS evaluation.**

APRML is a nuclear reaction code for calculating and fitting light nuclei cross sections, developed at CNDC and Nankai University. It is based on R-matrix theory and compiled with FORTRAN language. It can be used for calculating light nuclei cross section and angular distribution. APRML was compiled and adjusted less than a year, many mistakes and bugs have been fixed. The code has been compiled and some functions are under debugging and testing.

This code can be used for the experimental data evaluation for light nuclei reactions CS and angular distribution (two-body reactions) introduced by n,p,t, α,d,^{3}He, ^{5}He et al. Figs.11-12 give some preliminary results by this code.

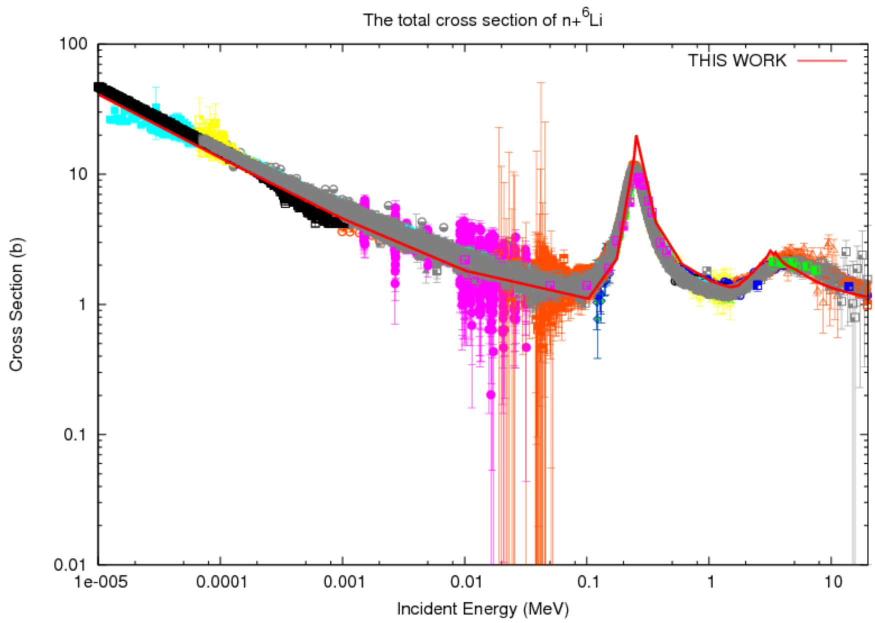

Fig.11 The comparisons of the preliminary calculation and experimental data of total CS for n+^{6}Li.

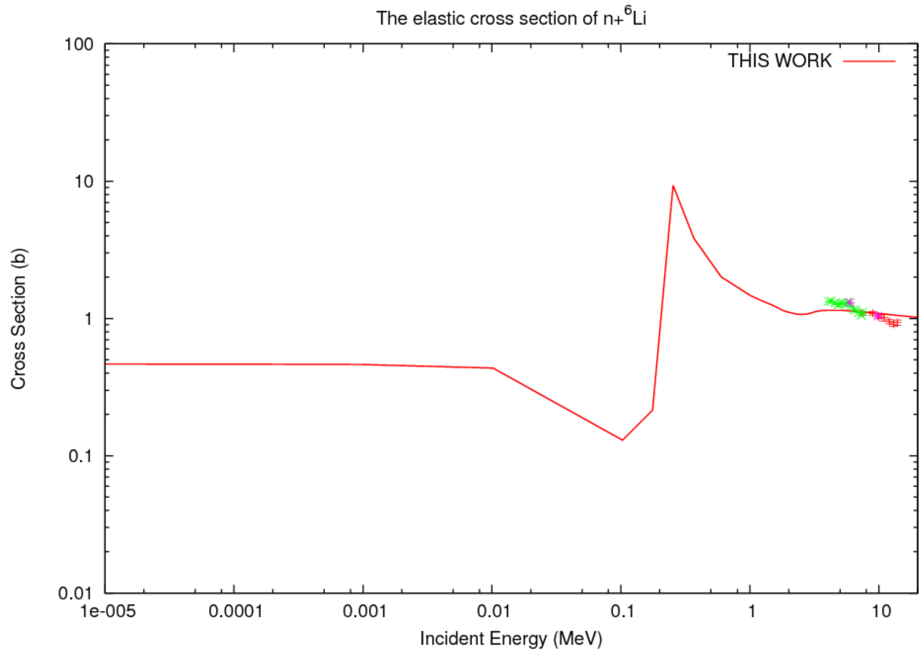

Fig.12. The comparisons of the preliminary calculation and experimental data of elastic CS for n+^{6}Li.

III. Other Nuclear Data Activities Related to CENPL Project

- The twelfth five year plan (2011-2015) of nuclear data project (incl. nuclear data evaluations and measurements) was approved and started for 2011.
- China Nuclear Data Key Library established at CIAE in 2010, which consisted of CNDC and the laboratory of nuclear data measurement of CIAE.
- Two Standing Meetings of China Nuclear Data Committee held in Beijing, in 2010 and 2011.
- 2011 Nuclear Data Conference of China was held in Beijing in 2011 Sept. and more than 100 participants from China joined this conference, more than 80 presentations received.

IV. New Generation of Nuclear Data and Library?

The problem is becoming serious because the increase of nuclear data need and the familiar experts are missing.

More nuclear data requirements including the region of nuclei, energy, accurate and the application of the nuclear data etc are proposed according the nuclear technology applications extending.

Can the existed/developing nuclear data libraries support the increasing need of nuclear applications?

Can the conventional way and technology of nuclear data produce satisfy the new nuclear data users?

What is the next generation of nuclear data for future?