PROGRESS OF CENDL PROJECT AND RELATED ACTIVITIES 2011-2012

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CHINA NUCLEAR DATA CENTER

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.***

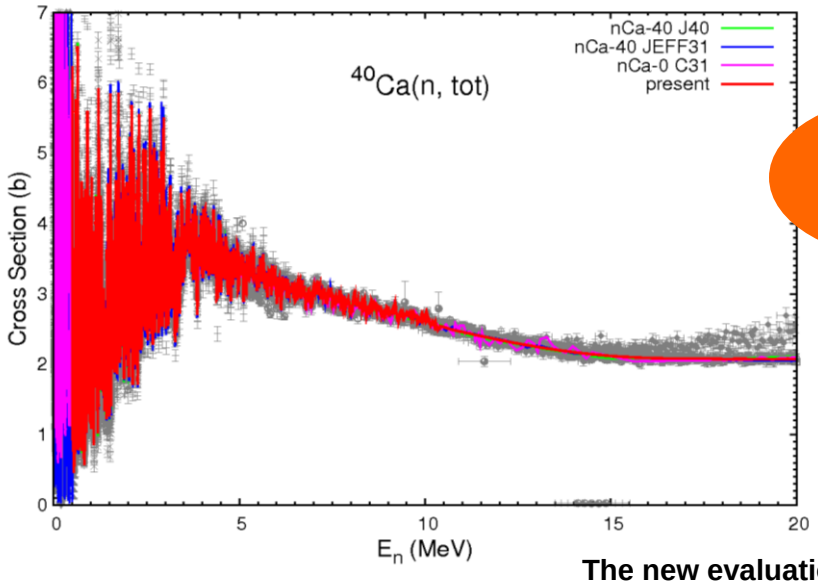
II. Recent Progress of China Nuclear Data Project

Mainly Tasks of CNDC in 2011-2012:

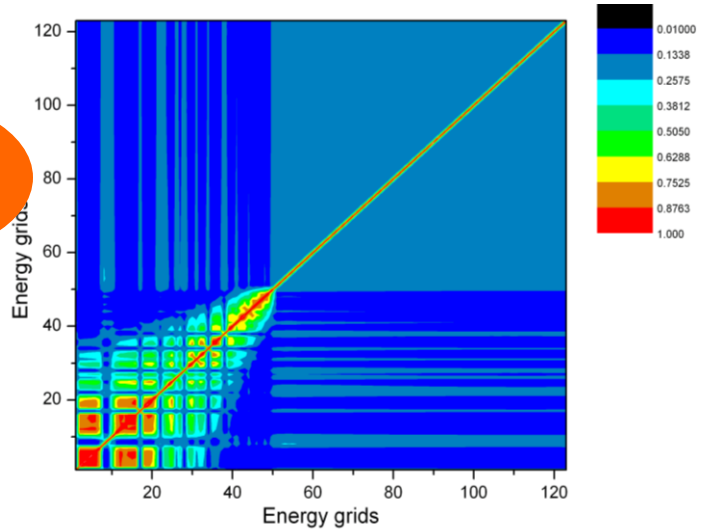
- *New evaluations for the next version of CENDL.*
- *Neutron data library evaluations and data processing for Th-U fuel cycling studies(Chinese TMSR Project).*
- *Nuclear data evaluation and benchmark/validation for ADS needs(Chinese ADS Project).*
- *Nuclear structure and decay data evaluation for ENDSF.*
- *EXFOR compilation for NRDC.*
- *Nuclear data methodology studies.*
- *The benchmark/validation of nuclear data libraries (CENDL-3.1, ENDF/B-VII, JENDL-4 and JEFF etc.).*

2-1 CENDL Project

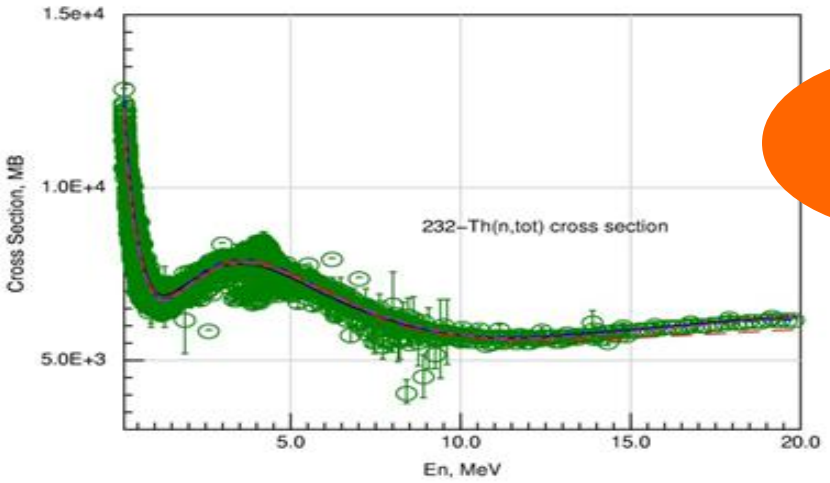
- ***The CENDL-3.2 is the next output results of CENDL project which consists of the neutron reaction sub-library, the activation sub-library, decay data sub-library and fission yield sub-library. CENDL-3.2 can be used for the nuclear engineering, nuclear medicine and nuclear science etc. fields.***
- ***The evaluation activities (including the neutron file, fission product yield and activation sub-libraries) of CENDL-3.2 are performing according to the updated need from users, new nuclear data evaluation methodologies and experimental information.***
- ***The mainly contribution of CENDL-3.2 are being carried out at CNDC, China Institute of Atomic Energy and China Nuclear Data Coordination Network(CNDCN) and international collaboration.***



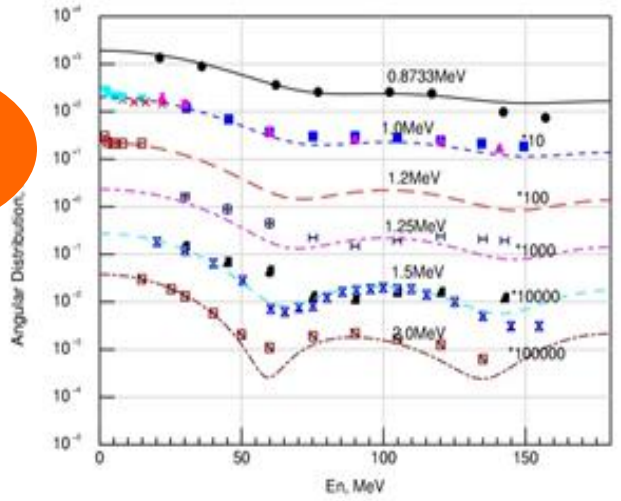
^{40}Ca



The new evaluation(preliminary) of the ^{40}Ca(n,tot) CS and its covariance file and n+^{232}Th for CENDL-3.2.



^{232}Th



2-2 An Evaluated Nuclear Data Library (CENDL-TSMR) (preliminary)

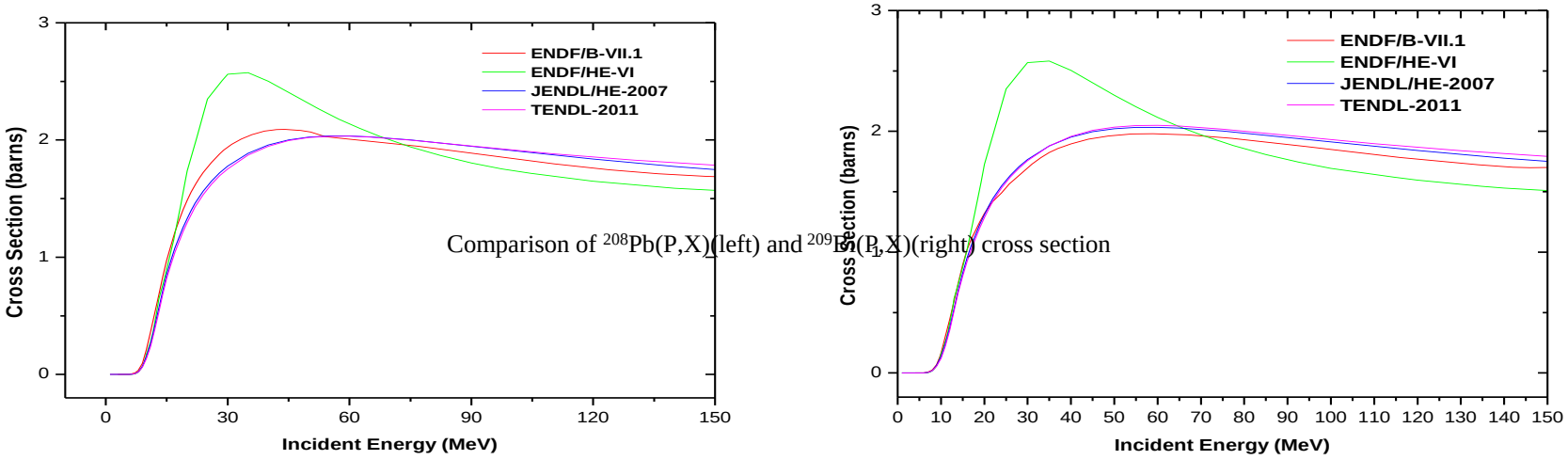
- *The CENDL-TSMR is used for Th-U experimental reactor design which contained 400 nuclei (CENDL-3.1, ENDF/B-VII.0, VII.1, JENDL-4.0, JEFF-3.1, IAEA/ADS-2.0)*
- *CENDL-TSMR also contained 21 thermal neutron scattering evaluations, and electro-atomic evaluations for 100 materials (take from ENDF/B-VII.1).*

	Material	No.
Light nuclei	^{1,2,3}H、^{3,4}He、^{6,7}Li、^{9}Be、^{10,11}B、^{12}C、^{14,15}N、^{16,17}O、^{19}F	16
Structure and FP	^{22,23}Na、^{24,25,26}Mg、^{27}Al、^{28,29,30}Si、^{31}P、^{0,32,33,34,36}S、^{35,37}Cl、^{36,38,40}Ar、^{39,40,41}K、^{40,42,43,44,46,48}Ca、^{45}Sc、^{46,47,48,49,50}Ti、^{0}V、^{50,52,53,54}Cr、^{55}Mn、^{54,56,57,58}Fe、^{59}Co、^{58,60,61,62,64}Ni、^{0,63,65}Cu、^{0}Zn、^{69,71}Ga、^{70,72,73,74,76}Ge、^{74,75,77,79}As、^{74,76,77,78,79,80,82}Se、^{79,81}Br、^{78,80,82,83,84,85,86}Kr、^{85,86,87}Rb、^{84,86,87,88,89,90}Sr、^{89,90,91}Y、^{90,91,92,93,94,95,96}Zr、^{93,94,95}Nb、^{92,94,95,96,97,98,99,100}Mo、^{99}Tc、^{96,98,99,100,101,102,103,104,105,106}Ru、^{103,105}Rh、^{102,104,105,106,107,108,110}Pd、^{107,109,110m,111}Ag、^{106,108,110,111,112,113,114,115m,116}Cd、^{113,115}In、^{112,113,114,115,116,117,} ^{118,119,120,122,123,124,125,126}Sn、^{121,123,124,125,126}Sb、^{120,122,123,124,125,126,127m,128,129m,} ^{130,132}Te、^{127,129,130,131,135}I、^{123,124,126,128,129,130,131,132,133,134,135,136}Xe、^{133,134,135,} ^{136,137}Cs、^{130,132,133,134,135,136,137,138,140}Ba、^{138,139,140}La、^{136,138,139,140,141,142,} ^{143,144}Ce、^{141,142,143}Pr、^{142,143,144,145,146,147,148,150}Nd、^{147,148,148m,149,151}Pm、^{144,147,148,149,150,151,152,153,154}Sm、^{151,152,153,154,155,156,157}Eu、^{152,153,154,155,156,157,158,} ^{160}Gd、^{159,160}Tb、^{156,158,160,161,162,163,164}Dy、^{165,Ho166m}Ho、^{162,164,166,167,168,170}Er、^{175,176}Lu、^{174,176,177,178,179,180}Hf、^{181,182}Ta、^{180,182,183,184,186}W、^{185,187}Re、^{191,193}Ir、^{197}Au、^{196,198,199,200,201,202,204}Hg、^{204,206,207,208}Pb、^{209}Bi	310
Heavy nuclei	^{223,224,225,226}Ra、^{225,226,227}Ac、^{227,228,229,230,231,232,233,234}Th、^{230,231,232,233}Pa、^{232,233,234,235,236,237,238,239,240,241}U、^{235,236,237,238,239}Np、^{236,237,238,239,240,241,242,243,} ^{244,246}Pu、^{240,241,242,242m,243,244,244m}Am、^{240,241,242,243,244,245,246,247,248,249,250}Cm、^{249,250}Bk、^{249,250,251,252,253,254}Cf、^{253,254,255}Es、^{255}Fm	74
Total		400

2-3 Benchmark Testing of Nuclear Data Files for Chinese ADS

- ***The investigation on status of high energy nuclear data for Pb、Bi、W etc. .***
- ***The comparisons of high energy proton induced reaction data for Pb、Bi、W from different nuclear data libraries.***
- ***Experimental investigation on ADS.***
- ***Benchmark calculation and analyses on ADS.***

1) Comparisons of high energy nuclear data files



Comparison of ^{208}Pb(P,X)(left) and ^{209}Bi(P,X)(right) cross section

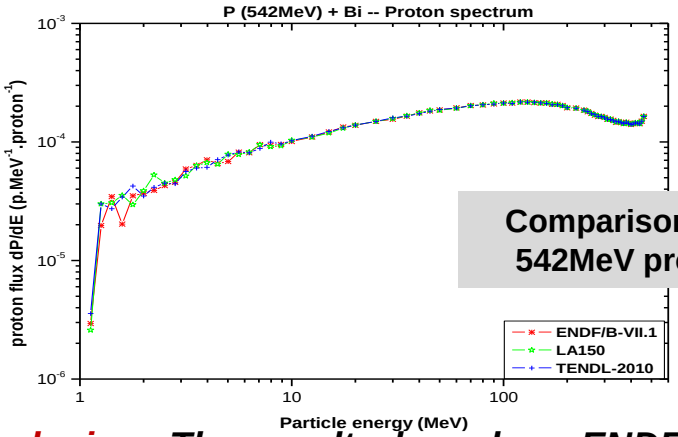
Conclusion: ***The proton induced reaction data for Pb、Bi、W from different nuclear data libraries are not agreement, but neutron induced reaction data for Pb、Bi、W are good agreement with different nuclear data libraries.***

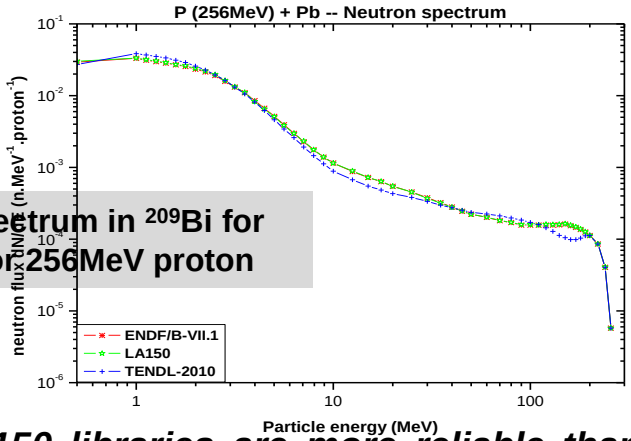
2) Benchmark calculation and analyses on ADS

Nuclear data libraries (H-energy), ENDF/B-VII.1: Neutron and proton up to 150MeV, LA150: Neutron and proton up to 150MeV, TENDL-2010: Neutron and proton up to 200MeV, are used to perform the benchmark calculation.

Table Characterization of partial experimental benchmark on ADS

Benchmark	Particle type	Particle energy	Target material	Assembly type
YALINA Booster	n		Lead	Sub-critical assembly
SAD	p	660MeV	Lead & Lead-Bismuth Eutectic	
TARC	p	2.75GeV，1.73GeV	Lead	
JAEA-ADS	p	1.5GeV	Lead-Bismuth Eutectic	Pb+Bi cooling
TEF-P	p	Max beam:~10 W(~10^{12}n/s)	Lead-Bismuth Eutectic	Pb+Bi cooling
TEF-T	p	Max beam:~10 W(~10^{12}n/s)	Lead-Bismuth Eutectic	
KUCA	D-T n	14 MeV	T	Critical assembly
KUCA	p	150MeV	Lead	



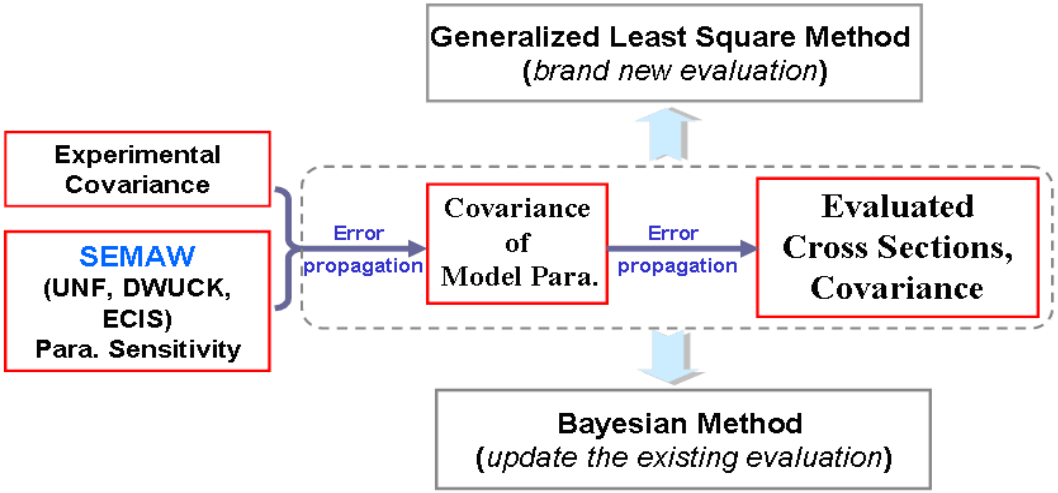


Comparison of proton spectrum in ^{209}Bi for 542MeV proton and Pb for 256MeV proton

Conclusion: ***The results based on ENDF/B-VII.1, LA150 libraries are more reliable than those results based on TENDL-2010. The largest differences between the libraries are the evaluated data for ENDF/B-VII.1, LA150, and calculation data for TENDL-2010. Further improvement is needed in high energy proton induced reaction data and neutron induced reaction data of Pb.***

III. Related Methodology Studies

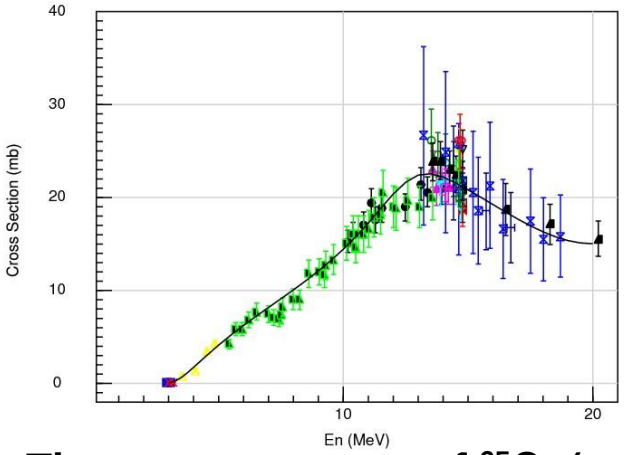
3-1 Neutron Cross Section Covariance Evaluation



The sensitivity calculation of the model parameters can be done by the SEMAW code, and now we are focusing to establish a method to construct covariance from the experimental information for structure nuclei and actinides. Following items are studying;

1) to obtain the error information from different methods(TOF, Activation…) of measurements.
2) to derive the systematic errors and statistic errors from exp. data.
3) to determine the correlated errors in exp. data evaluation.

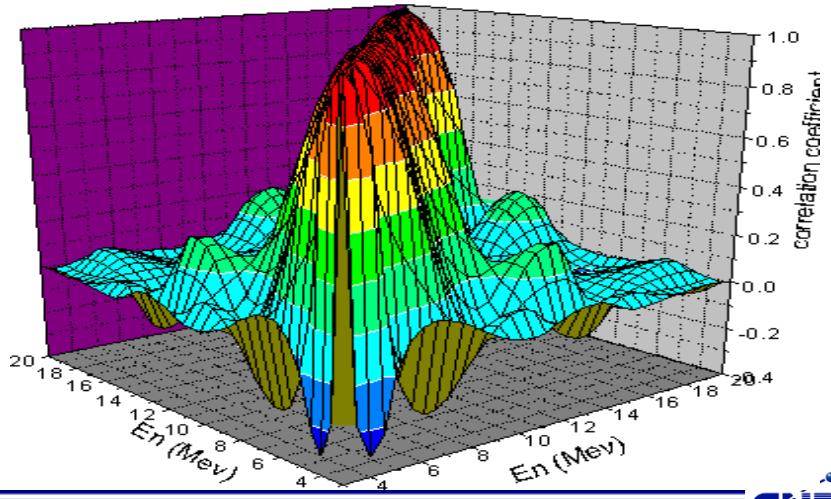
As an example, the covariance evaluation of experimental data for ^{65}Cu(n,p) measurements by activation has been performed. The errors of standard cross sections, detector efficiency, branching ratios of γ(or β) and uncertainties of target thickness etc. were considered and analysed as correlated elements.



Year	Author	Energy (MeV)	points	Sys. Error (%)	Sources of Sys errors(%)
2007	W.Mannhart+	10.2~14.0	10	1.72	Standard: 1.5，Percentage of isotopes
2004 2000	T.Shimizu+	2.90~3.09 3.00~3.20	2	6.29	Neutron flux: 0.4, sample mass: 0.1, thickness: 0.6, detection: 5.5, standard: 3
1999	A.A.Filatenkov+	13.6~14.8	7	2.6	Normalization
1994	N.I.Molla+	13.9~14.7	4	3.1	Sample mass: 1, flux: 1, others: 0.65, Norm.: 2.6
1980	P.N.Ngoc+	13.66~14.7	6	5.98	Sample mass, purity: 2, standard: 5, normalization: 2.5
1965	D.C.Santry+	5.45~13.6	31	3.12	Geometry: 1, BG: 0.5, flux: 0.5, breakup: 0.5, ^{65}Ni, ^{32}P correction: 2

The measurements of ^{65}Cu(n, p) cross sections in En≤20MeV(fig.) and exp. error evaluation of some measurements(table)

The present correlation coefficient of ^{65}Cu(n, p)



3-2 Evaluation Method for Light Nuclei Based on R-Matrix Theory

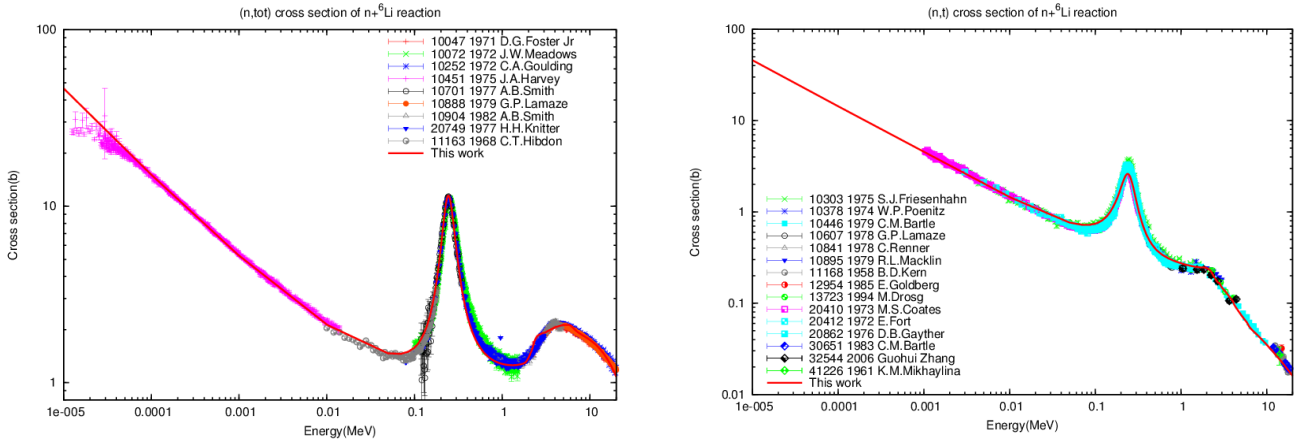
A Full and Diagonal Reduced R-matrix(FDRR) Four kinds of R-matrix formalism are included in FDRR code:

- ***Full (un-approximated) R-matrix formalism including un-diagonal elements (the general R-matrix theory);***
- ***The un-diagonal elements are keeping for retained channels but only diagonal elements are keeping for eliminated channels;***
- ***The reduced R-matrix theory(similar with the method used in RAC code);***
- ***Reich-Moore R-matrix theory.***

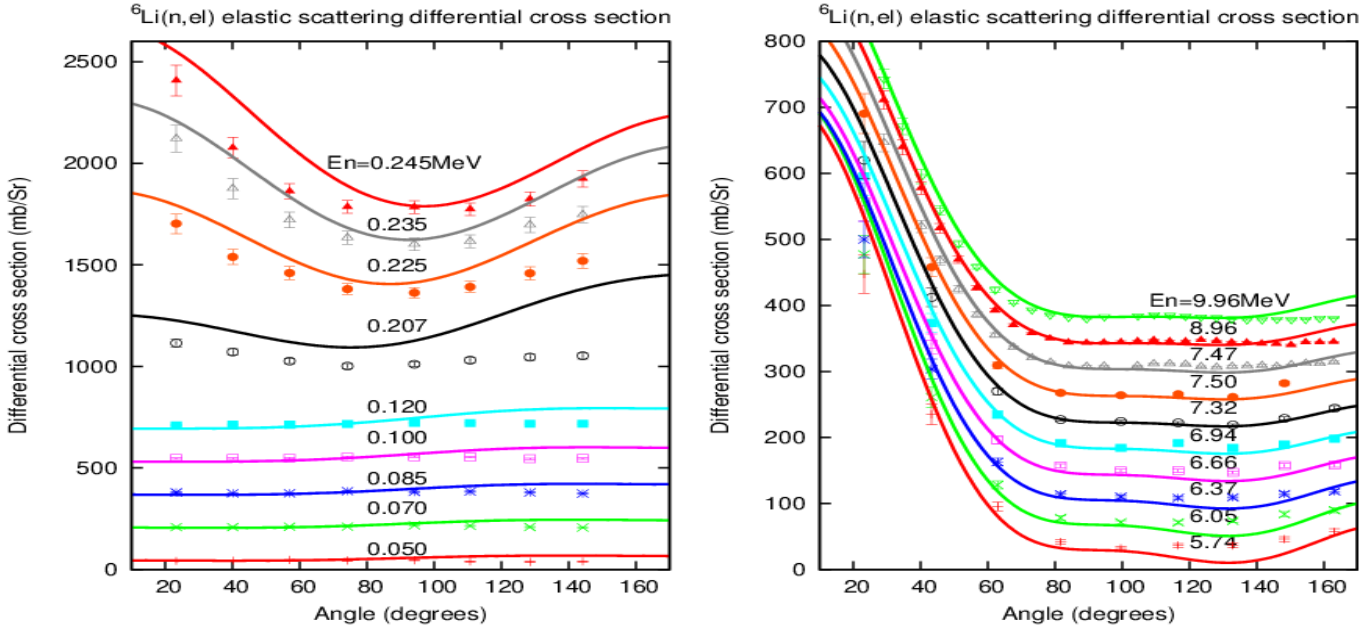
The S-L coupling S-matrix theory is used in FDRR code. The same compound nuclei uses one set of parameters and auto adjusting the resonance width parameters.

All reaction channels(cross sections, angular distributions, analyzing power) which have the same compound nucleus are considered simultaneously including 3-body channels and those channels which has no experimental data.

As an example, following figures show the calculating and fitting results used FDRR code for n+^{6}Li reactions below 20 MeV.

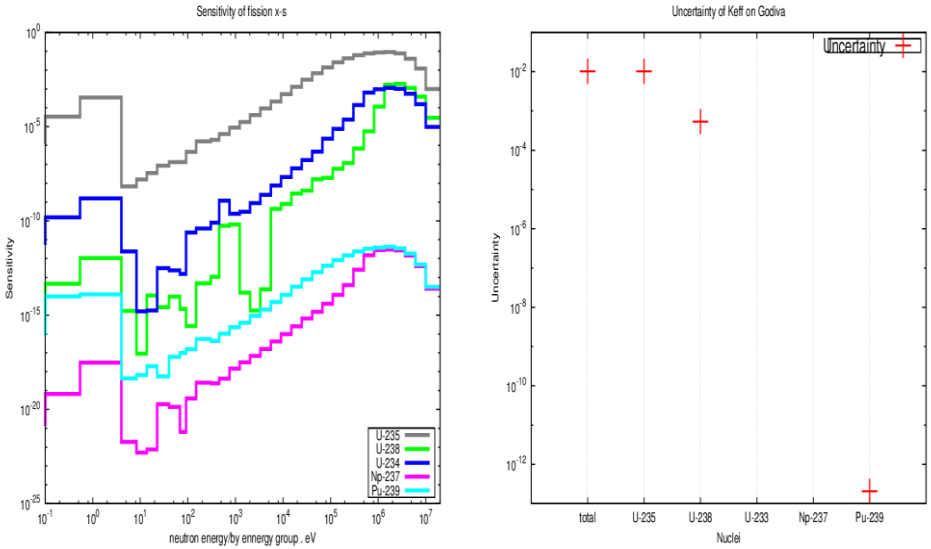


The comparisons of the preliminary calculation and exp. data of the total CS (left) and (n,t)(right) for n+^{6}Li.



The comparisons of the preliminary calculation and exp. of the angular distributions of ^{6}Li(n,el)

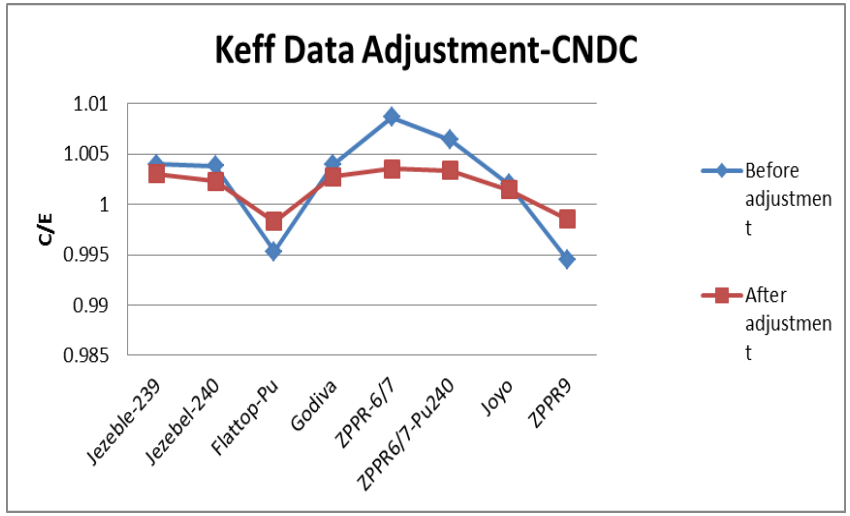
3-3 S/U Analysis and Data Adjustment



S/U analysis of Godiva

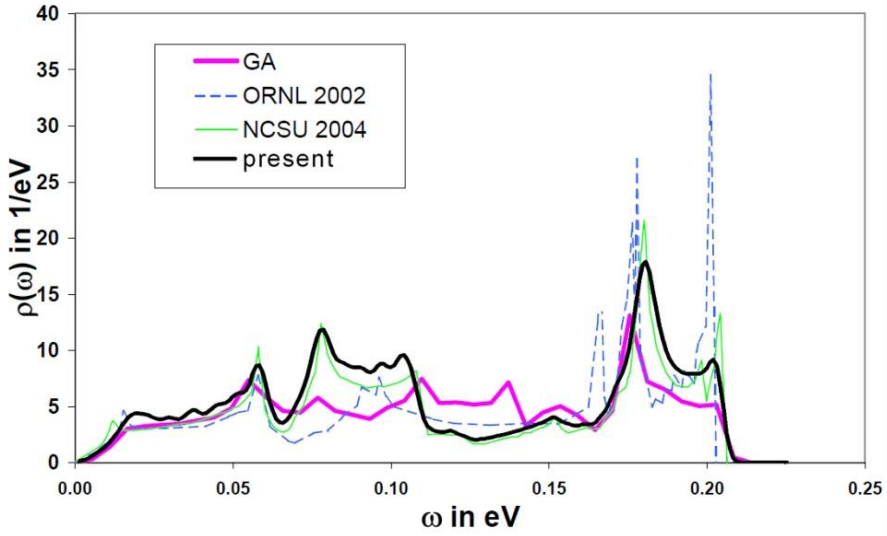
CNDC has been developing S/U analysis methods and codes. A new code system SENS is under development which will combine both MC and GPT to analyse S/U of target integral parameters. Now 1D module for k_{eff} has been done, and 1D module for reaction rate and 2D module is under testing.

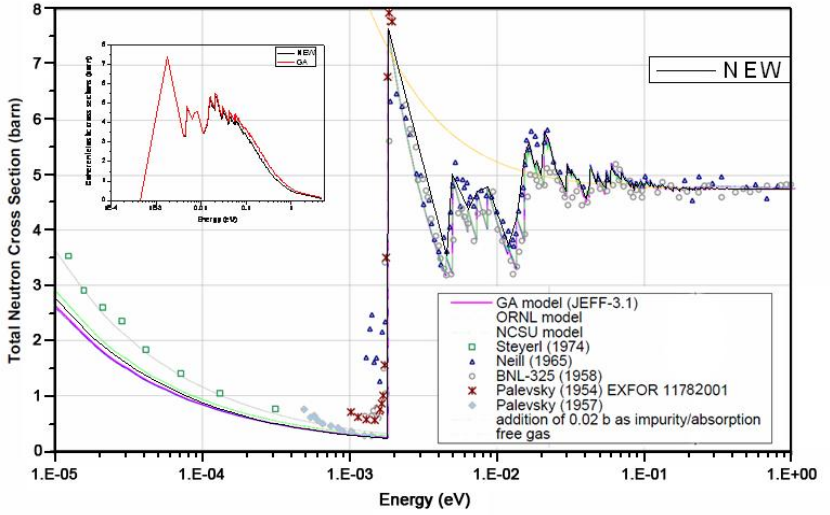
Basing on S/U analysis and Bayesian methods, the data adjustment method was also developed, which is also part of the work for sub-group 33. The k_{eff} results before and after adjustment for several facilities.



3-4 Thermal Neutron Scattering Data Study

- ✓ ***According to the future establishment of the thermal neutron scattering data file for CENDL project. The study of methodology on scattering data stated from last year.***
- ✓ ***The ab initio methods, linear response theory(VASP, WIEN2K, FROPHON, PHONONPY..) are used for the frequency distribution. LEAPR module of NJOY is used for the neutron scattering calculation.***
- ✓ ***Following Fig. shows the frequency distribution of graphite based on the central force dynamical theory with ab initio 144 atoms of the hexagonal graphite lattice(code:VASP+FROPHON).***





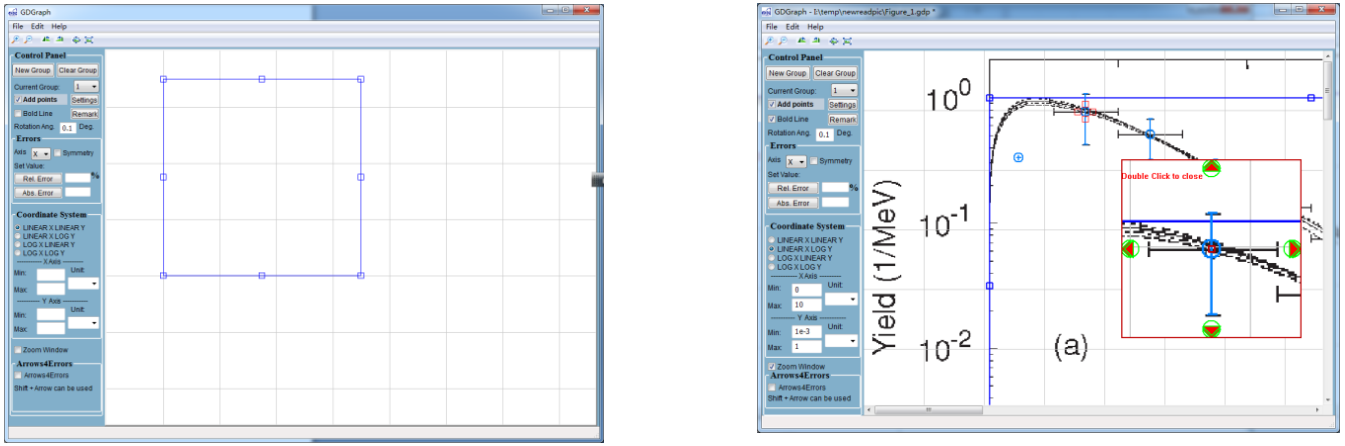
Frequency distribution calculated by VASP+FROPHON(left) and total CS calculated by LEAR module.(right) for graphite(preliminary).

3-5 EXFOR Database Compilation Progress

GDgraph Software

A series of digitization software(GDgraph) have been developed, and GDgraph-v4.4 was participated in the Benchmarking of the Digitization Software organized by IAEA/NDS last year.

A new vision of the GDgraph-v5.0 has been developed, and some new functions ware added. The user's manual of GDgraph-v5.0 is preparing. GDgraph-v5.0 will be available.



The working windows of GDgraph (partial)

EXFOR Compilation.

CNDC have finished 17 compilations (neutron: 14, charge particle: 3 and 14 have been included in X4 database); 11 compilations (Neutron: 3 and Charge particle: 8) are compiling. All these experiments were finished by Chinese and published in the following journals and proceedings:

IV. Other Nuclear Data Activities Related to CENPL Project

- **2012 Conference on Nuclear Data Benchmark/Processing and Application** *was held in Hangzhou city on Nov. 4-9, 2012 and more than 69 participants from China attended this conference, more than 39 presentations received.*
- **The 2012 Standing Committee Meeting of China Committee of Nuclear Data** *was hold in Beijing on 26, Dec. 2012.*
- **3rd Asian Nuclear Reaction Database Development Workshop** *held in 27-29 Aug. 2012 Pohang, Korea. Participants from China, Japan, Korea, India, Kazakhstan, Vietnam and IAEA/NDS. 23 presentations provided .*
- **The International Collaborations on Nuclear Data** *with IAEA, NEA and other foreign institutions(IAEA-CRP, WPEC-Subgroups and CIELO Project etc.).*

Thank you for your attention !
Comments and suggestion welcome !