



PROGRESS OF CENDL PROJECT AND RELATED ACTIVITIES 2012-2013

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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

- New evaluations for CENDL new version.
- Fission yields, activation data and decay data evaluation.
- The benchmark/validation of new evaluations.
- Neutron data library evaluations and data processing for Th-U fuel cycling studies(China TMSR Project).
- Nuclear data evaluation and benchmark/validation for ADS needs (China ADS Project).
- EXFOR compilation for NRDC and structure, decay data evaluation for NSDD.
- Nuclear data methodology studies.



2-1 Neutron files evaluation progress

- The evaluation activities are going on for the new CENDL, which contain the neutron, activation and fission yields files. As some examples, following are the new evaluations for the neutron files of ^{27}Al 、 ^{48}Ti 、 ^{232}Th et al.

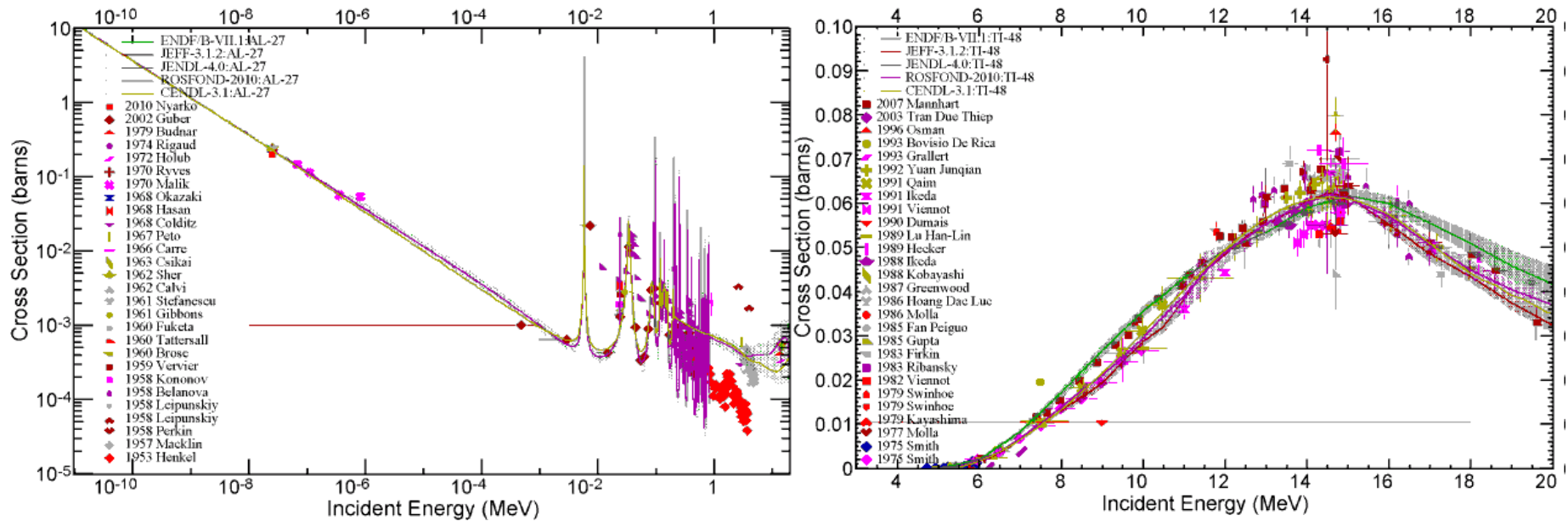


Fig.1 $^{27}\text{Al}(n, g)$ (left), $^{48}\text{Ti}(n, p)$ (right) new evaluation compared with evaluated files and exp.data.

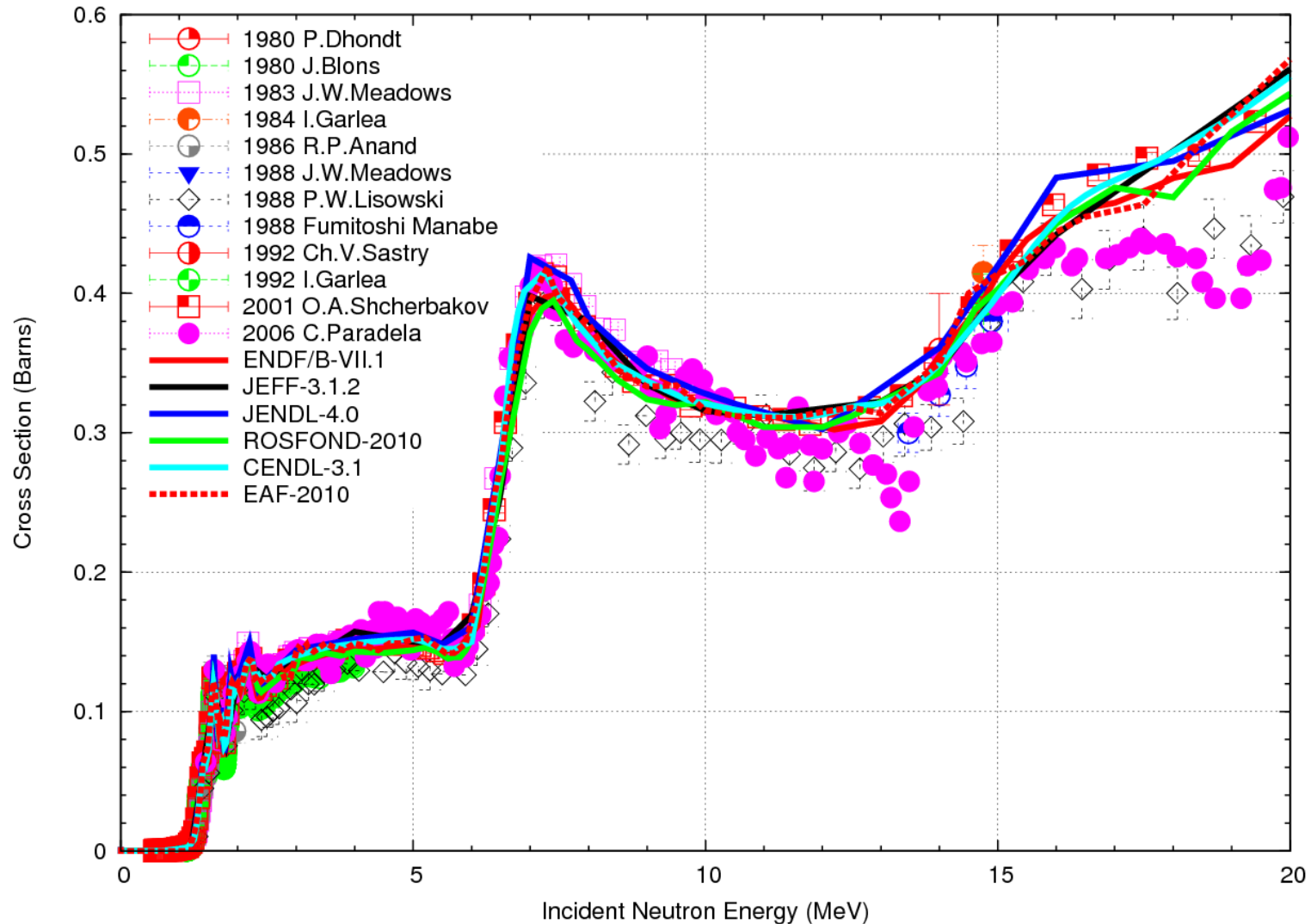


Fig.2 $^{232}\text{Th}(n, f)$ new evaluation compared with other evaluated files and exp. data.



2-2 Fission yield, Activation and Decay data Evaluation

- ^{235}U decay data evaluation which contained half-life, γ decay data, α decay data and level scheme et al., has been performed.

Tab.1 The new evaluated energies for α decay of ^{235}U (partial)

1960 Ba44	1962 Pi06	1966 Ga03	1975 Va11	1991 Ry01	2004 Da24	Calculated based on the level En and Q(α) calculations	This work
						3897.2 7	3897.2 7
		3977 10			3976 5	3975.3 7	3976 5
						3990.5 9	3990.5 9
						4013.2 8	4013.2 8
						4053.9 7	4053.9 7
		4069 10			4077	4077.5 7	4077.5 7
	4153	4140 3	4145 6		4152 5	4154.2 7	4152 5
4214	4210	4210 3	4209 4	4214.7 19	4215.8 5	4217.4 7	4214.7 19 ^b
						4219.6 7	4219.6 7
			4219 6			4227.6 7	4227.6 7
		4240 10			4248 5	4252.6 7	4248 5
	4261				4266 5	4270 4	4266 5
		4267 10				4279.3 7	4279.3 7
			4280		4282	4286.9 7	4286.9 7
		4289 10	4295			4302.1 7	4302.1 7
4320	4318	4319 3	4322 4		4322.9	4325.4 7	4322 4
4326						4327.9 7	4327.9 7

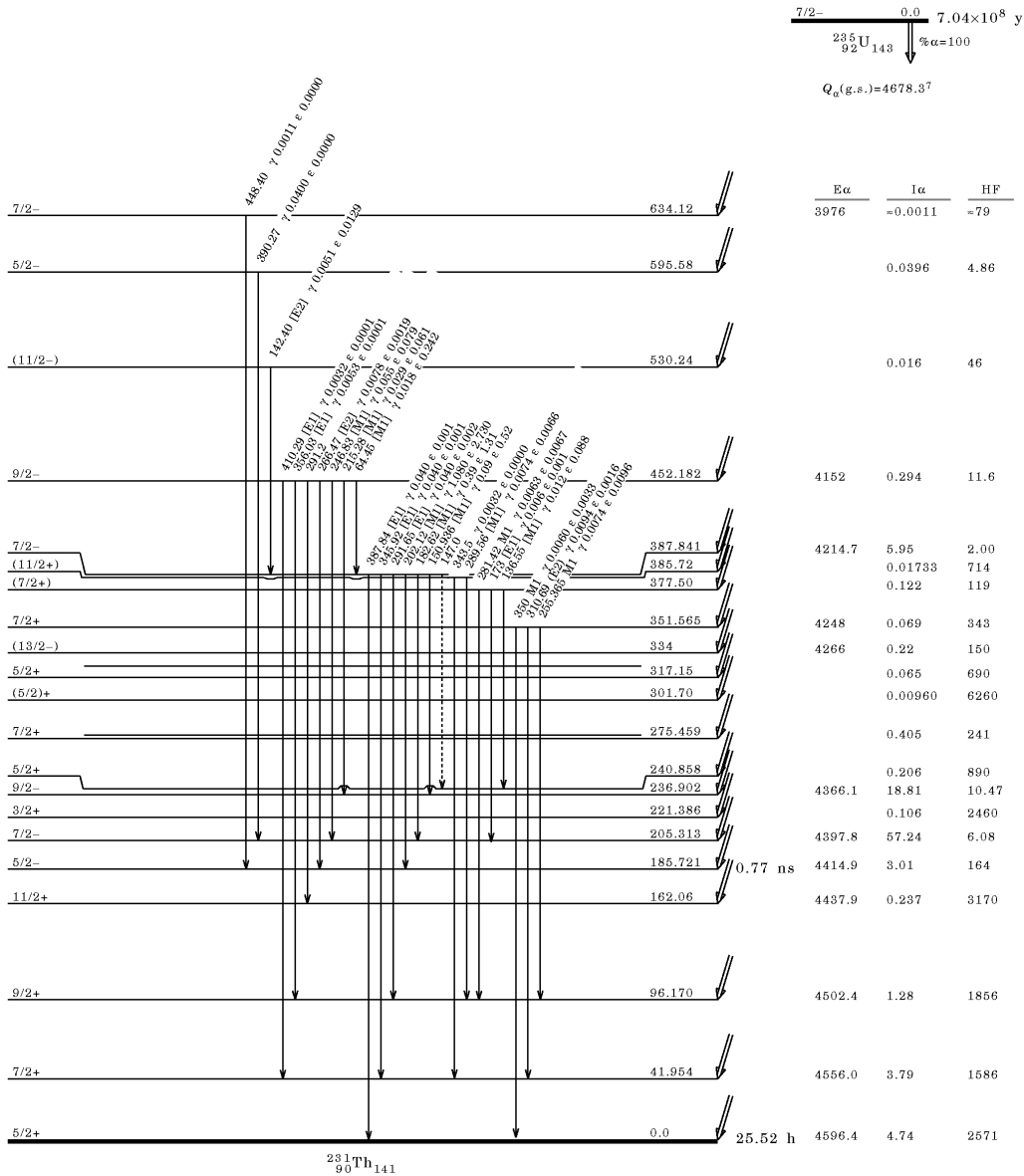


Fig.3 α Decay Level of ²³⁵U

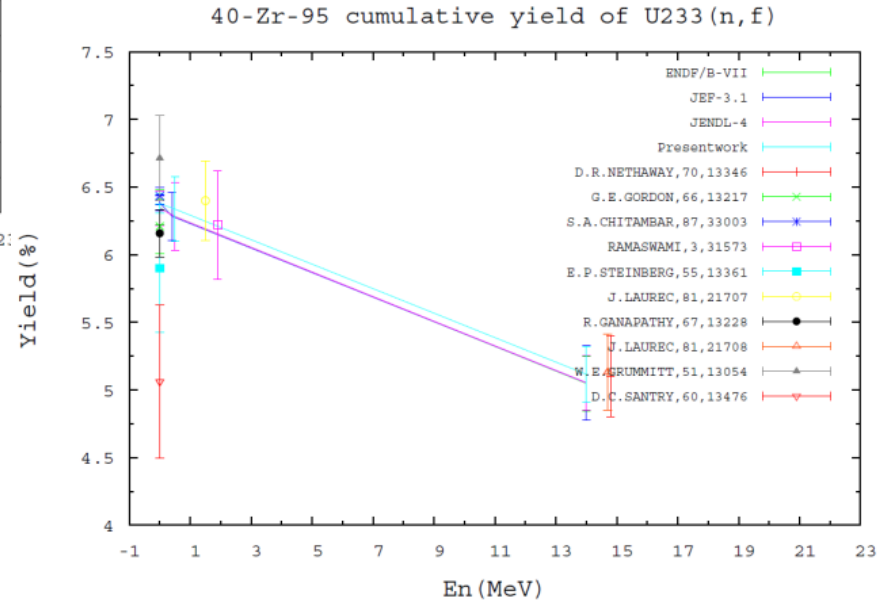
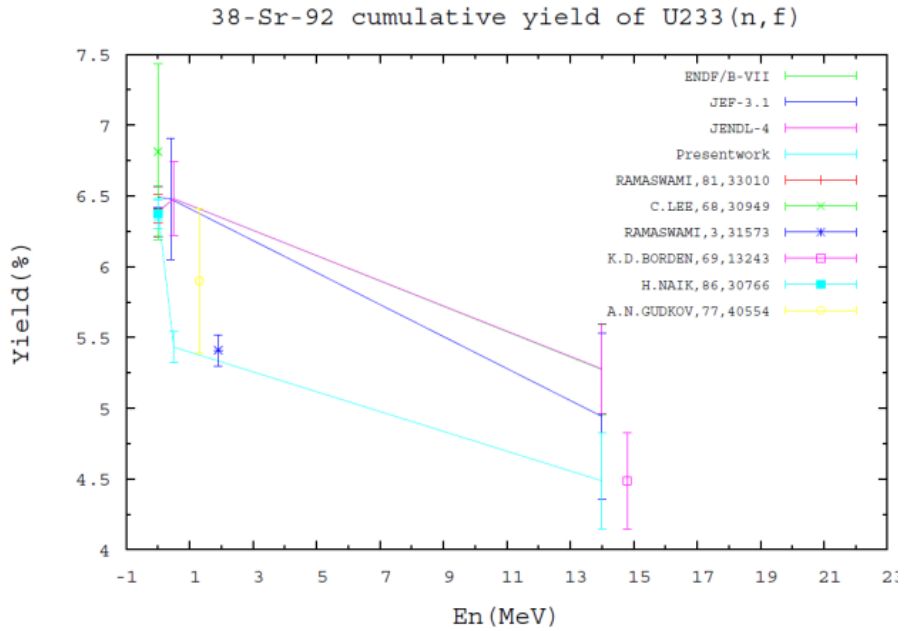


Fig. 4 $n+^{233}\text{U}$: the new evaluations for ^{92}Sr (left) and ^{95}Zr (right) compared with exp. and other files.



2-3 *The Benchmark Test for the CENDL-TSMR*

- **Generation of Nuclear Data Library for TMSR.**

Based on available evaluated nuclear data libraries, a mixed evaluated nuclear data library (CENDL-TMSR) was recommended for TMSR application, of which the materials were relatively complete and the benchmark results were relatively better. The nuclear data libraries with point or multi-group were generated using NJOY for CENDL-TMSR. In order to study the performance of CENDL-TMSR on Th-U cycle systems, the criticality and shielding benchmarks test were performed by using transport code WIMSD5B et al. CENDL-TMSR generally shows better performance in ^{233}U and ^{232}Th thermal criticality benchmarks. The differences of results are existed between the libraries for LLNL pulse sphere.

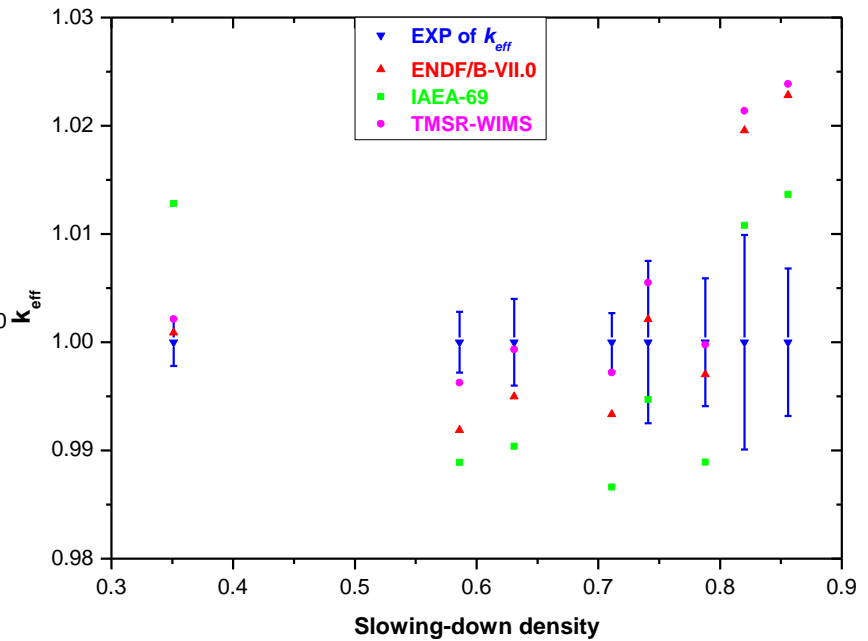
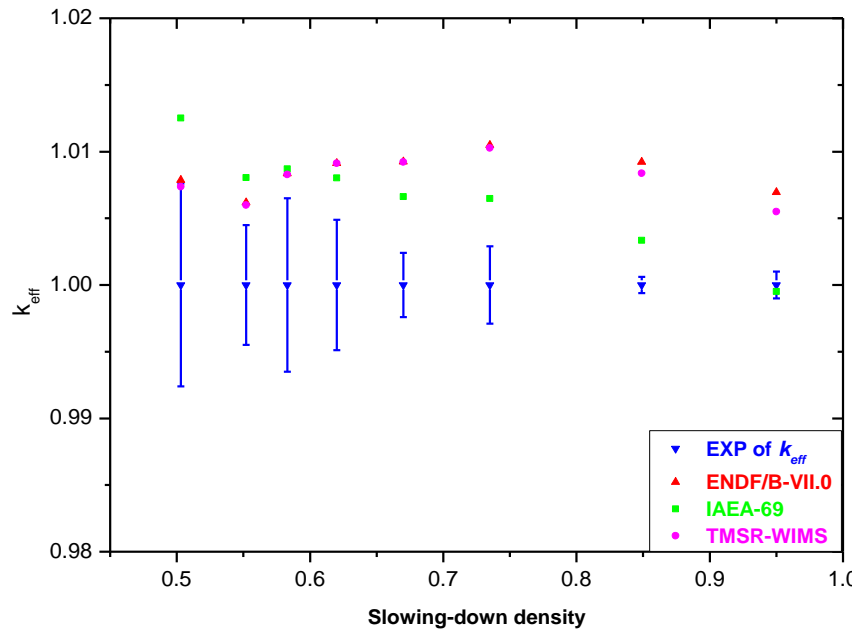


Fig.5 H₂O (left) and D₂O (right) moderated ²³³UO₂-ThO₂ critical lattices k_{eff} vs. q .

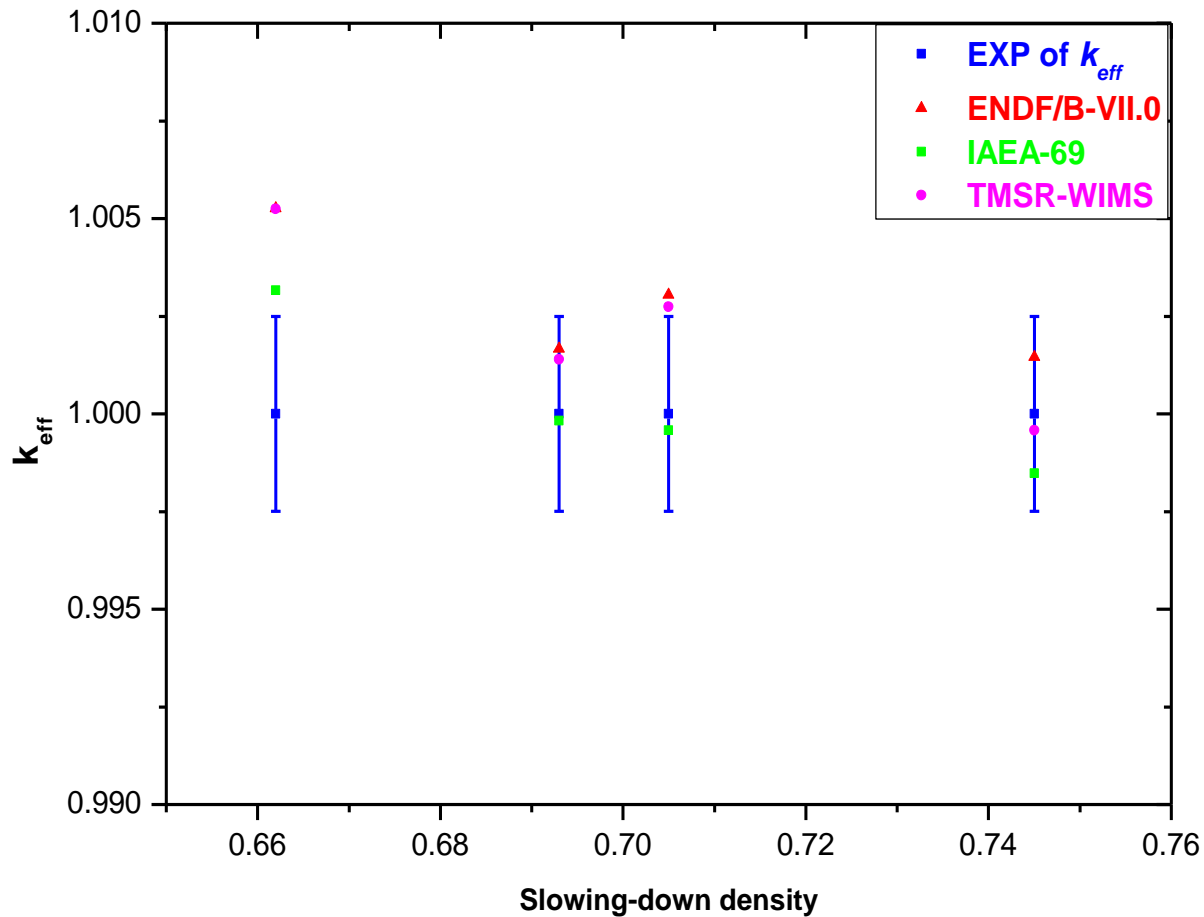


Fig.6 D₂O moderated ²³⁵UO₂-ThO₂ critical lattices k_{eff} vs.q.

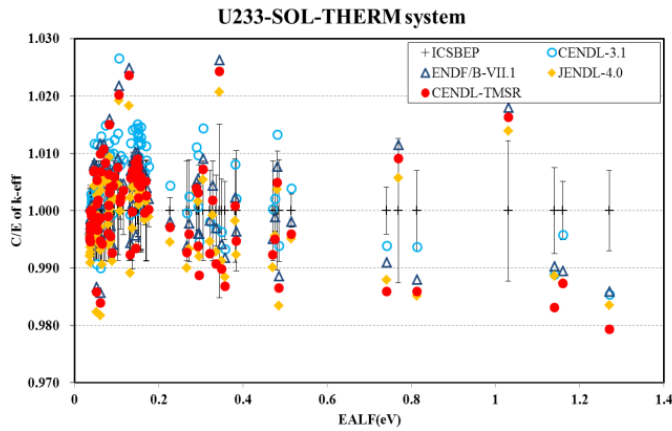


Fig.7 U233-Sol-Thermal system C/E of k_{eff} vs. EALF

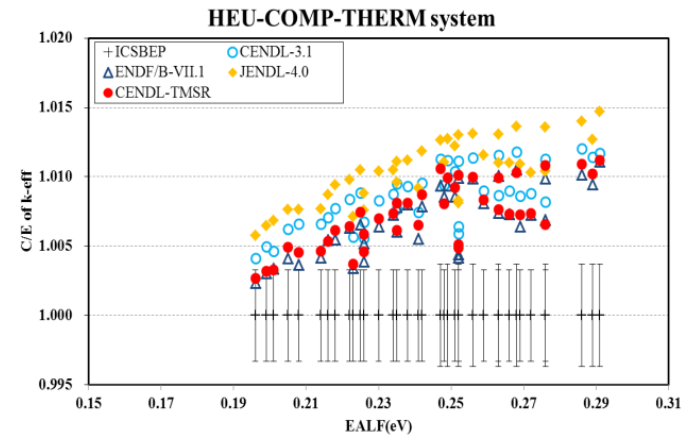


Fig.8 UO_2 and ThO_2 Thermal system C/E of k_{eff} vs. EALF

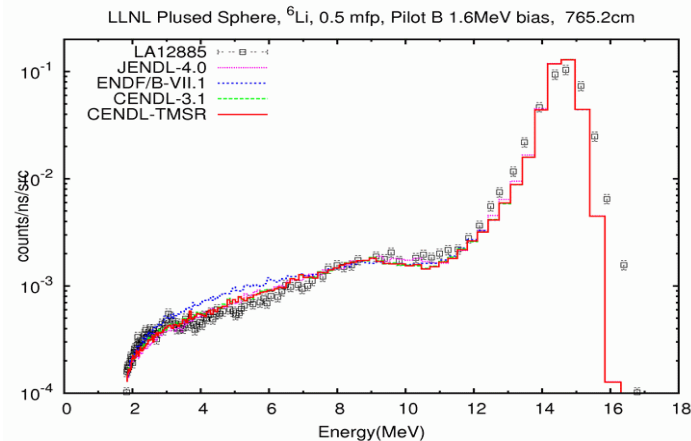


Fig.9 The neutron leakage spectrum from LLNL pulse sphere of 6Li

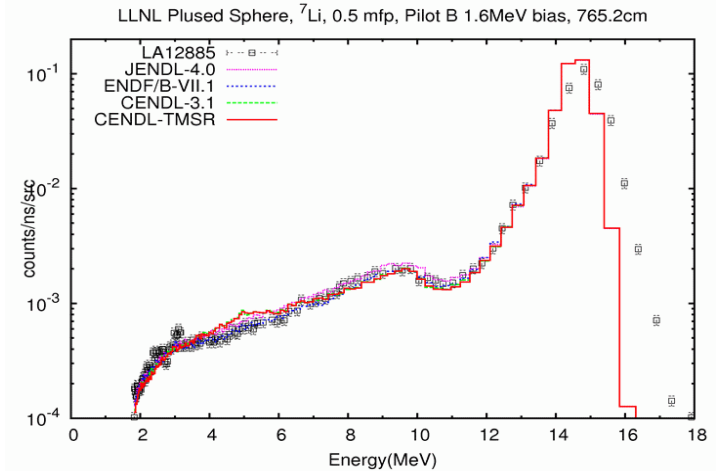


Fig.10 The neutron leakage spectrum from LLNL pulse sphere of 7Li



LLNL Plused Sphere, Be-9, 0.8 mfp, Pilot B, 765.2cm

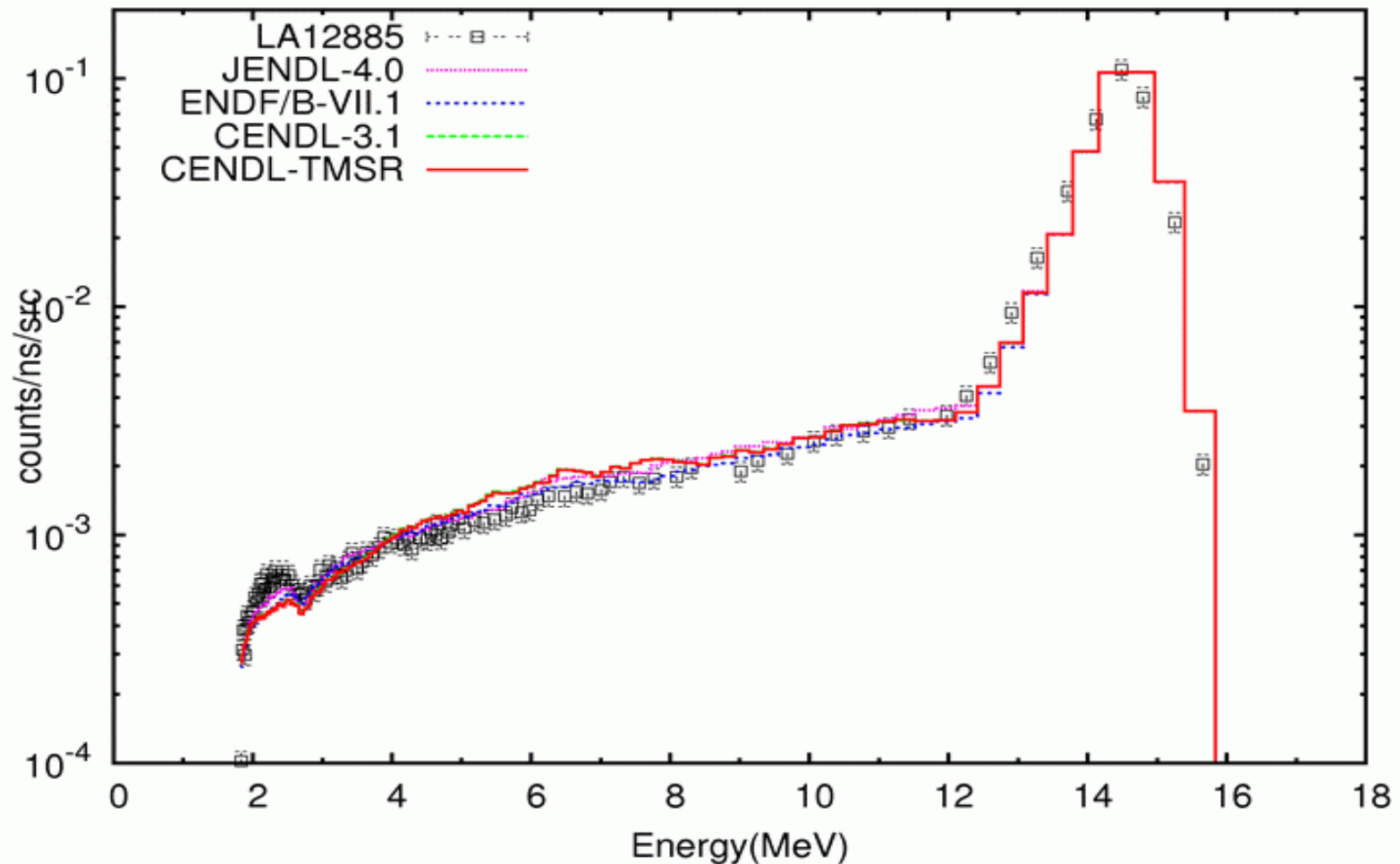


Fig.11 The neutron leakage spectrum from LLNL pulse sphere of ^9Be



2-4 The Works Nuclear Data for China ADS Project

- The investigation on status of high energy data evaluation for W、Ga.
- The comparisons of high energy proton induced reaction data for W、Ga from different evaluated data files.
- The comparisons of neutron induced reaction data for W、Ga from different evaluated data files.
- Benchmark Testing for W.

Table 2 Status of high energy data evaluation for W, Ga

W			Ga		
Evaluated data files	Particle Type	Energy, MeV	Evaluated data files	Particle Type	Energy, MeV
EAF-2010 293	neutron	60	ENDF/B-VII.1	neutron	20
IAEA-Therapeutic293	neutron	60	JENDL-4.0	neutron	20
FENDL-2.1	neutron	150	ROSFOND-2010	neutron	20
IRDF 300	neutron	150	CENDL-3.1	neutron	20
IAEA-Therapeutic273	proton	99	EAF-2010 293	neutron	60
PADF-2007	proton	150	JEF-3.2	neutron	200
ENDF/B-VII.1	neutron, proton	150,150	PADF-2007	proton	150
TENDL-2011	neutron, proton	200,200	TENDL-2012	neutron,proton	200,200
JENDL/HE-2007	neutron, proton	3000,3000	JENDL/HE-2007	neutron,proton	3000,3000

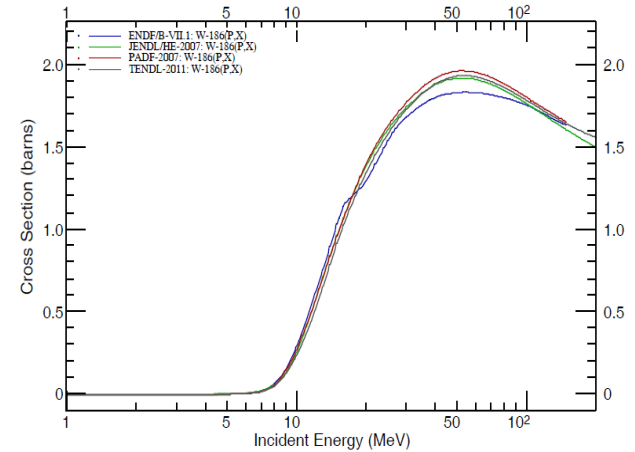
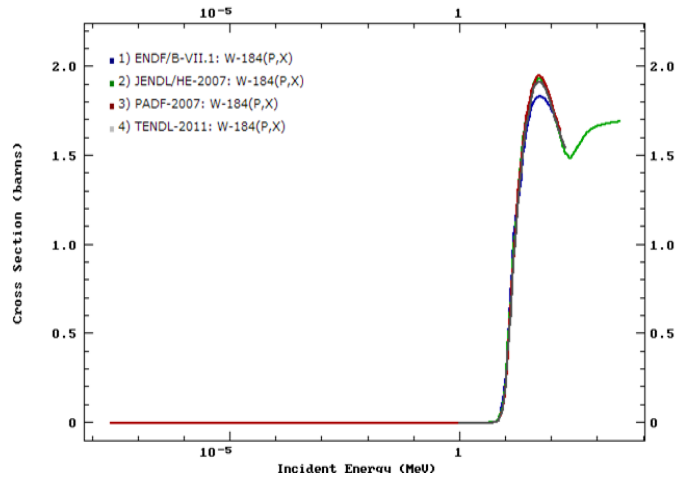


Fig.12 Comparison of $^{184}\text{W}(p,x)$ (left) and $^{186}\text{W}(p,x)$ (right) cross section

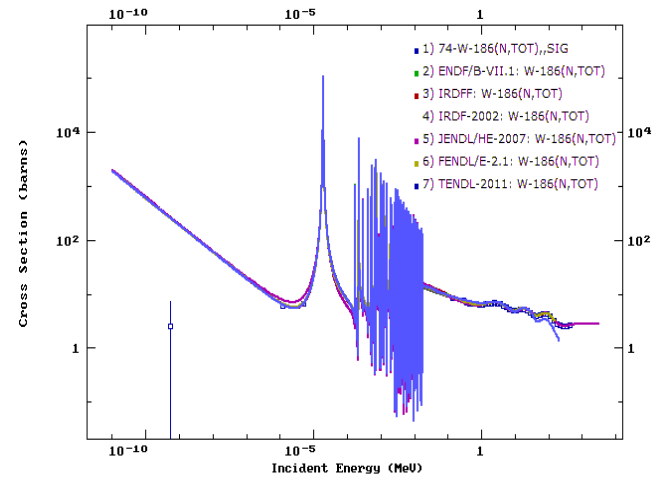
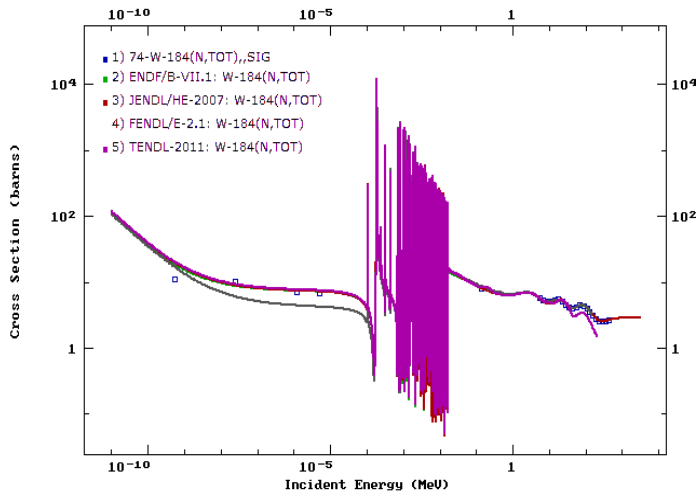


Fig.13 Comparison of $^{184}\text{W}(n,tot)$ (left) and $^{186}\text{W}(n,tot)$ (right) cross section

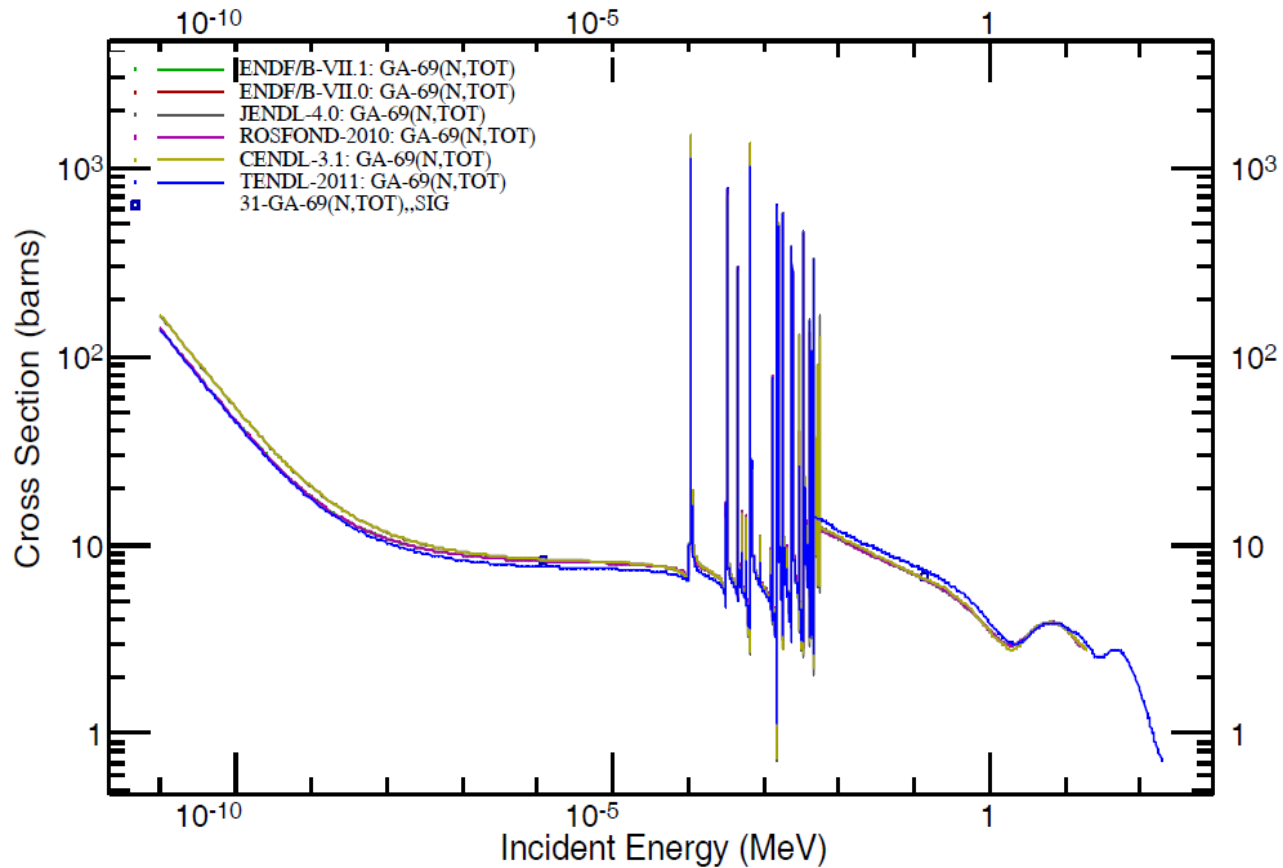


Fig.14 Comparison of ^{69}Ga (n,tot) cross section

Conclusion: It can be seen that proton induced reaction data for W from different evaluated data files are not agreement, and neutron induced reaction data for W and Ga are good agreement with different nuclear data libraries.



Benchmark test of W

•Criticality benchmarks results

Two benchmark cases HMF003 and IMF014 from ICSBEP were used. The HMF003 is tungsten-carbide-reflected high enriched uranium metal sphere assemblies, including 8, 9, 10, 11 experiments. The IMF014 is cylindrical assemblies of U metal and tungsten with aluminum reflector, including ZPR-9 assemblies 2 and 3.

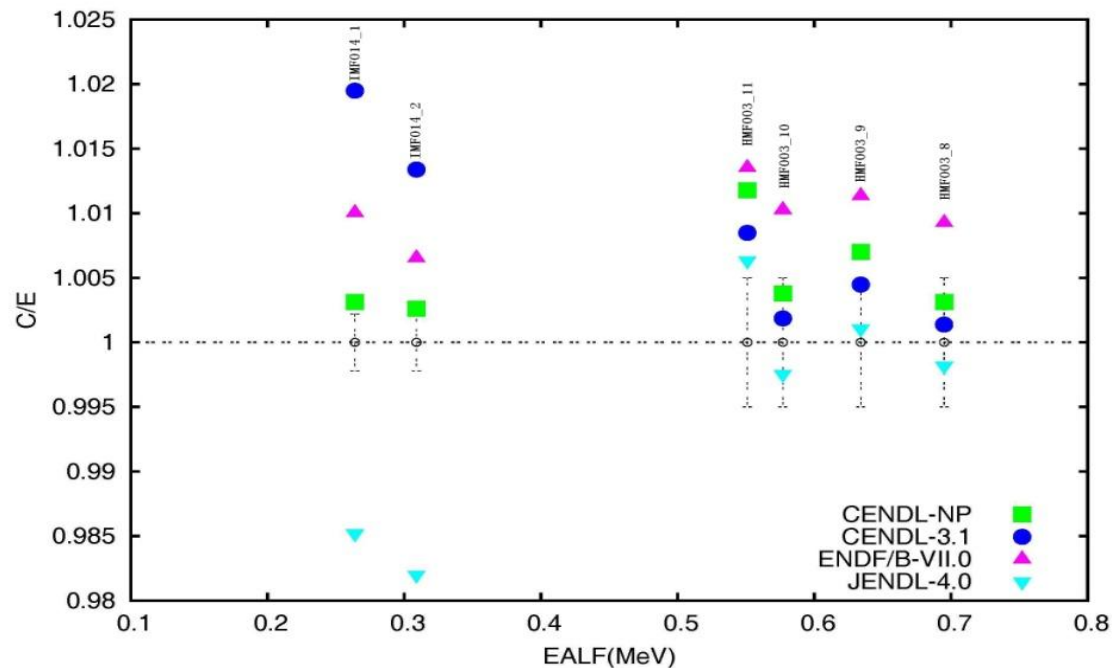


Fig.15 Comparison of k_{eff} for different evaluated data libraries



Conclusion: For IMF assemblies: the results based on CENDL-NP show good agreements with experimental values within 3‰ deviation, the results based on JENDL-4.0 were underestimated, and the results from CENDL-3.1 were overestimated 15‰-20‰. For HMF assemblies: the results from CENDL-3.1 and JENDL-4.0 show good agreements with experimental values, and the results based on ENDF/B-VII.0 were overestimated.



- **Shielding benchmarks results**
LLNL pulse ball experiment was used.

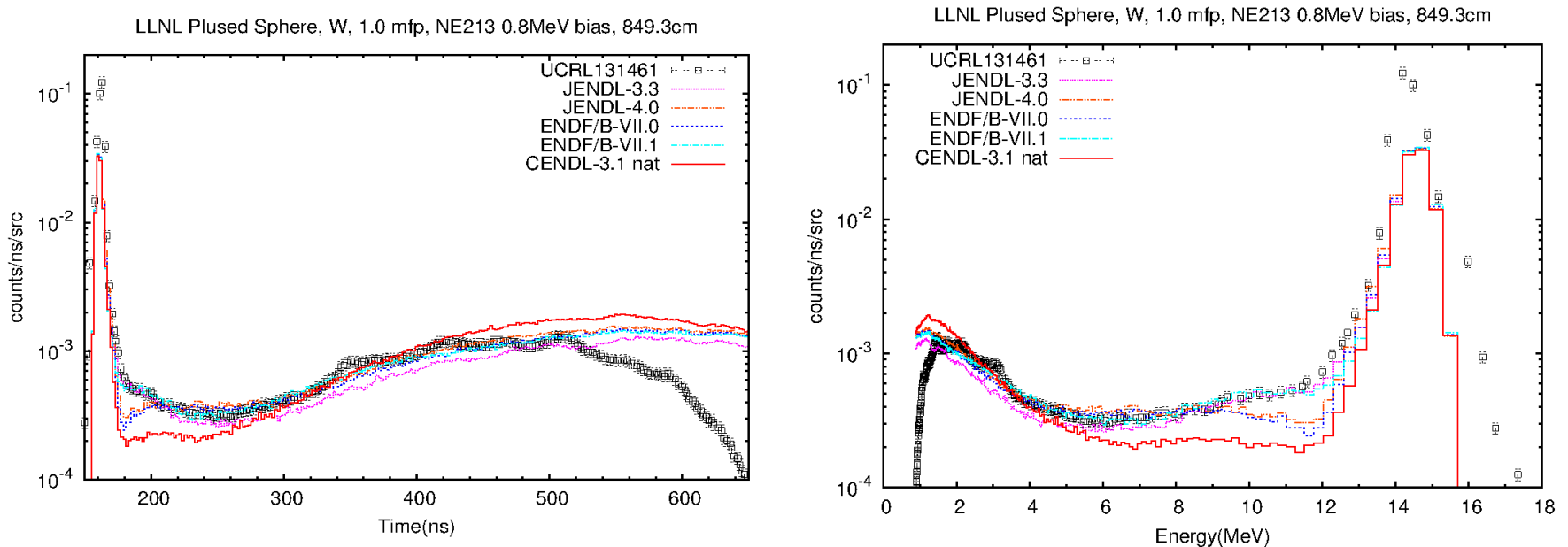


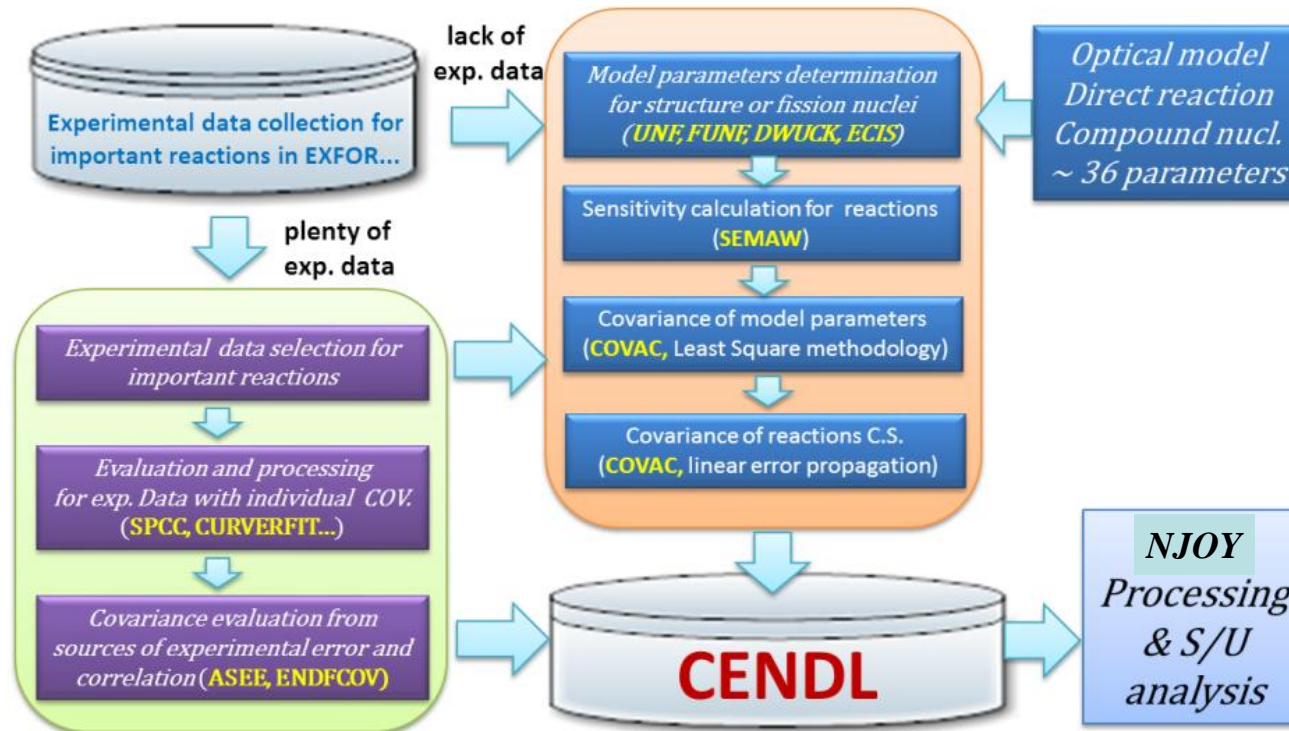
Fig.16 Tungsten pulse ball leakage neutron time of flight spectrum(left) and neutron spectrum(right).

Conclusion: There are distinct differences of results among different evaluated data libraries. In the vicinity of the 14MeV (i.e. elastic peak), the results of all evaluated data libraries were lower than the experimental values; In the 5-12 MeV range, the results from JENDL-3.3 and ENDF/B-VII.1 are closer to the experimental results, and the results of other libraries are underestimated.



III *Related Methodology Studies*

3-1 *Progress of Covariance Evaluation*



Energy: fast neutron energy region
reactions: (n, tot), (n, el), (n, γ), (n, inl), (n, p), (n, α), (n, 2n), (n, np), (n, n α), (n, 3n), (n, f)
Methodology: Least square (L-S), analysis of the sources of experimental errors (ASEE)
Codes: yellow ones in the scheme

Fig. 17 The covariance evaluation system in CNDC.



A SEE is used for the concluding and evaluating the errors and correlations extracted from the original sources of experiment facility contained in all of the experimental data available.

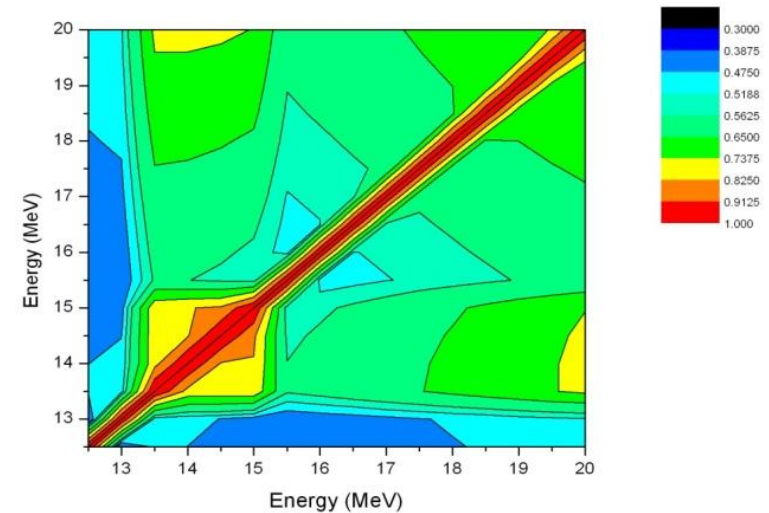
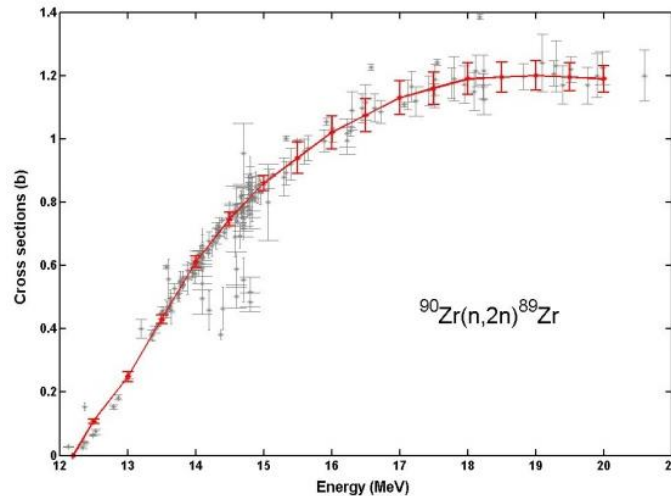


Fig.18 $^{90}\text{Zr}(n,2n)^{89}\text{Zr}$ evaluation with error(left) and coefficient of correlation(right) by ASEE

The covariance evaluations status of CENDL project:

- ^2H , ^3H , ^3He , ^{19}F , ^{55}Mn , ^{56}Fe , from the previous version of CENDL
- ^{27}Al , ^{40}Ca , ^{48}Ti , ^{58}Ni , ^{63}Cu , $^{\text{nat}}\text{Cu}$, ^{90}Zr , et al. new evaluations has been performed recently.
- ^{91}Zr , ^{92}Zr , ^{93}Zr , ^{94}Zr , ^{95}Zr , ^{96}Zr , ^{233}U , ^{235}U , ^{238}U , ^{239}Pu , evaluations are in progress.



3-2 Semi-empirical Model Study on $n+^{233}\text{U}$, ^{235}U and ^{239}Pu Fission Yields

Based upon Brosa model, the model considered the SL, SI and SII fissions, and was parameterized with 11 parameters, which were deduced by fitting to exp. data. The model could calculate mass distributions over the incident energy of 0-20 MeV, and agree exp. data well.

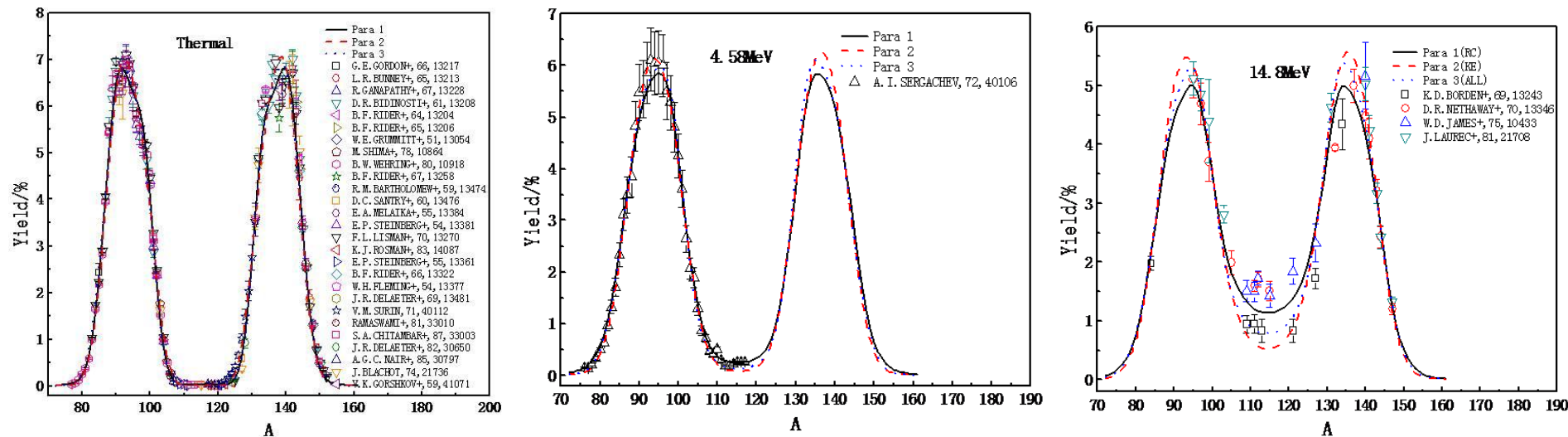


Fig.19 $n+^{233}\text{U}$, mass distributions for thermal, 4.58MeV, and 14.8MeV.

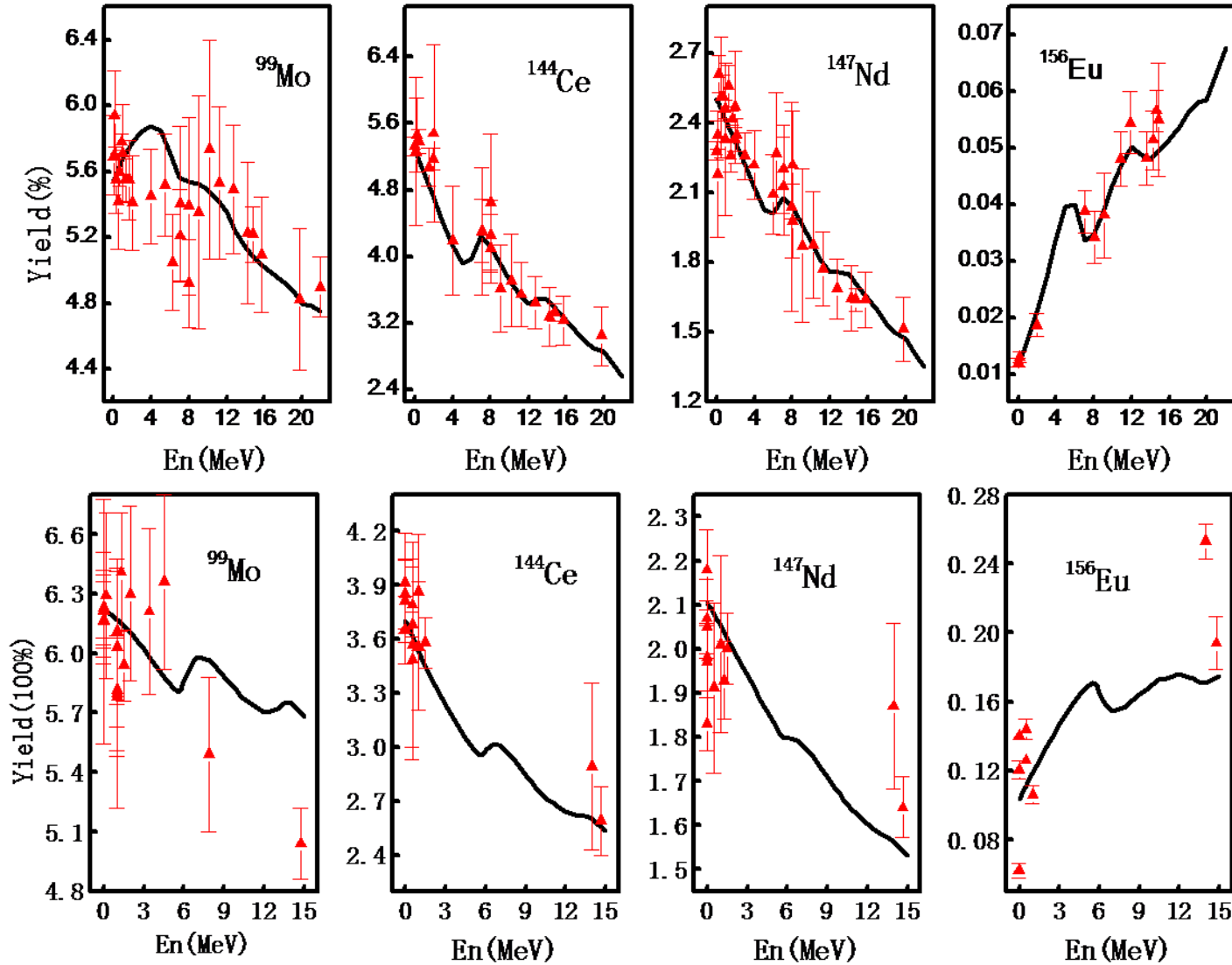


Fig.20 Yield energy dependence of the ^{235}U (up) and ^{239}Pu (down)



3-3 S/U Analysis and Data adjustment

Since 2011, CNDC has been developing S/U analysis methods and codes. The uncertainty analysis of k_{eff} for MSRE assembly was performed recently.

The uncertainty of k_{eff} simulation for MSRE due to input nuclear data is about 3‰, of which ${}^7\text{Li}$ capture and ${}^{235}\text{U}$ capture channel take the majority of uncertainty contribution, around 90% of the total uncertainty. While on the other hand, during the simulation of k_{eff} for MSRE assembly, the following input channel list have the top high sensitivities: ${}^{235}\text{U}$ fission and capture, ${}^{232}\text{Th}$ capture, ${}^{19}\text{F}$ and ${}^{58}\text{Ni}$ elastic, and ${}^{233}\text{U}$ fission.

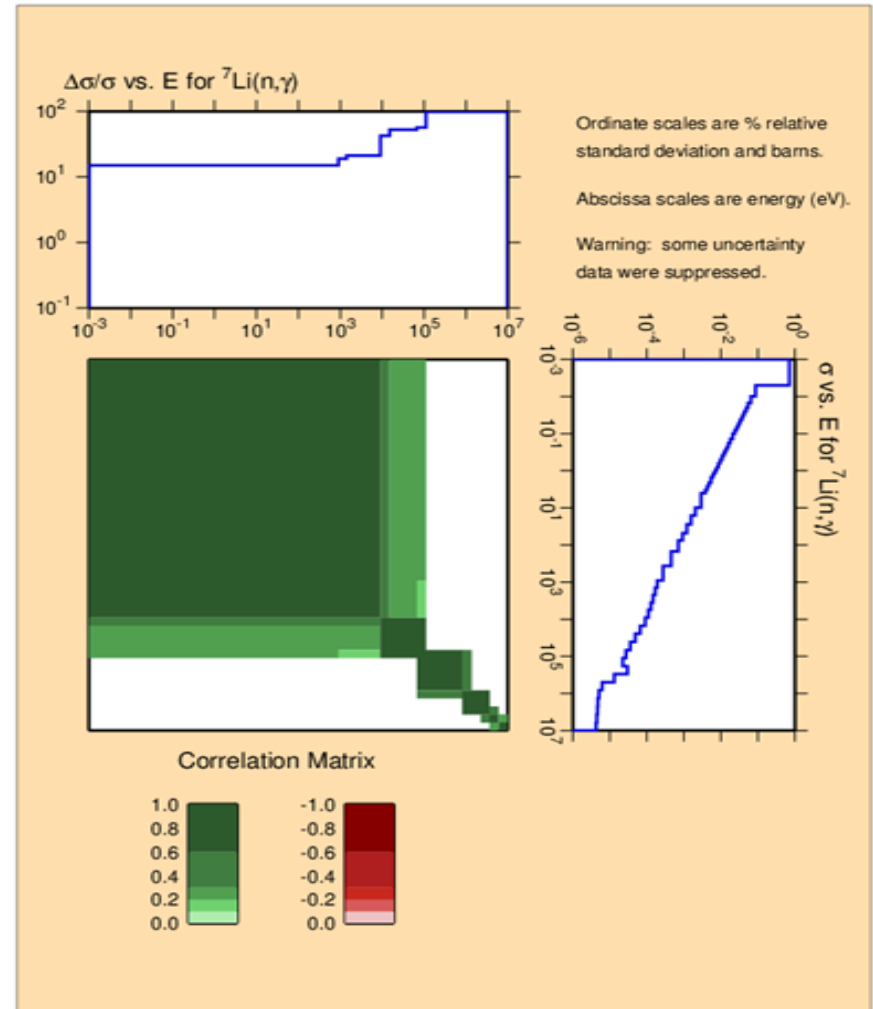
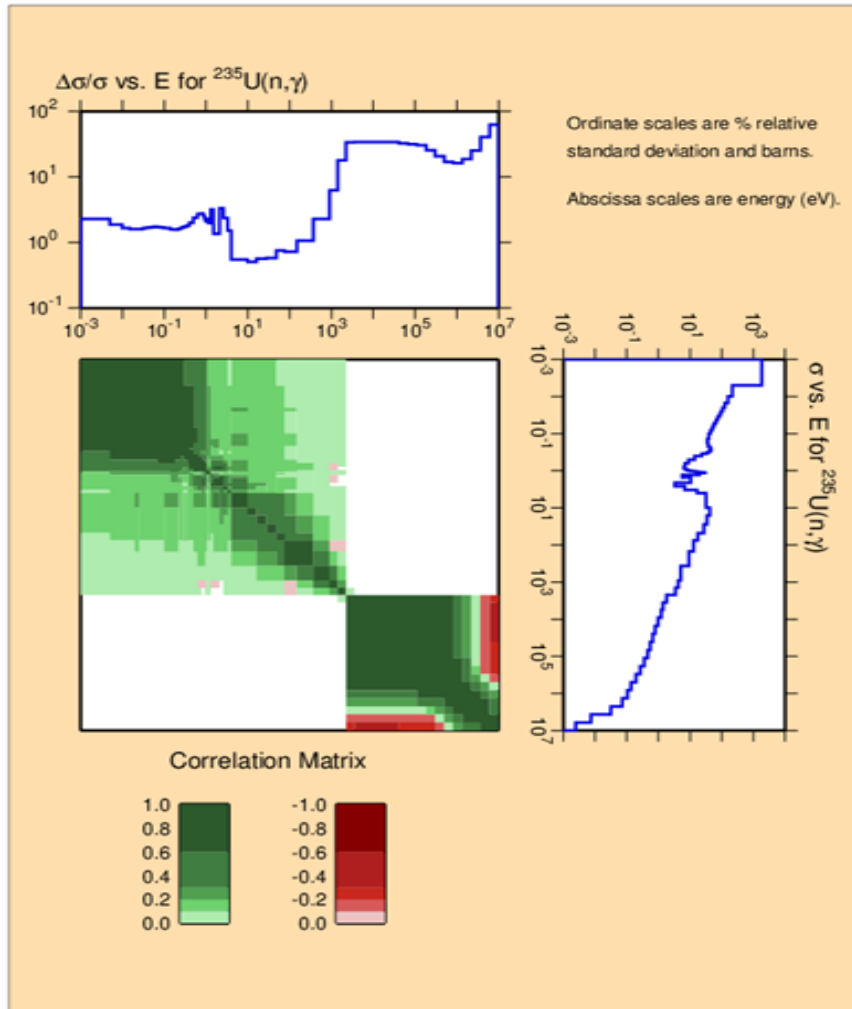


Fig.21 Group covariance data of ^{235}U and ^7Li capture

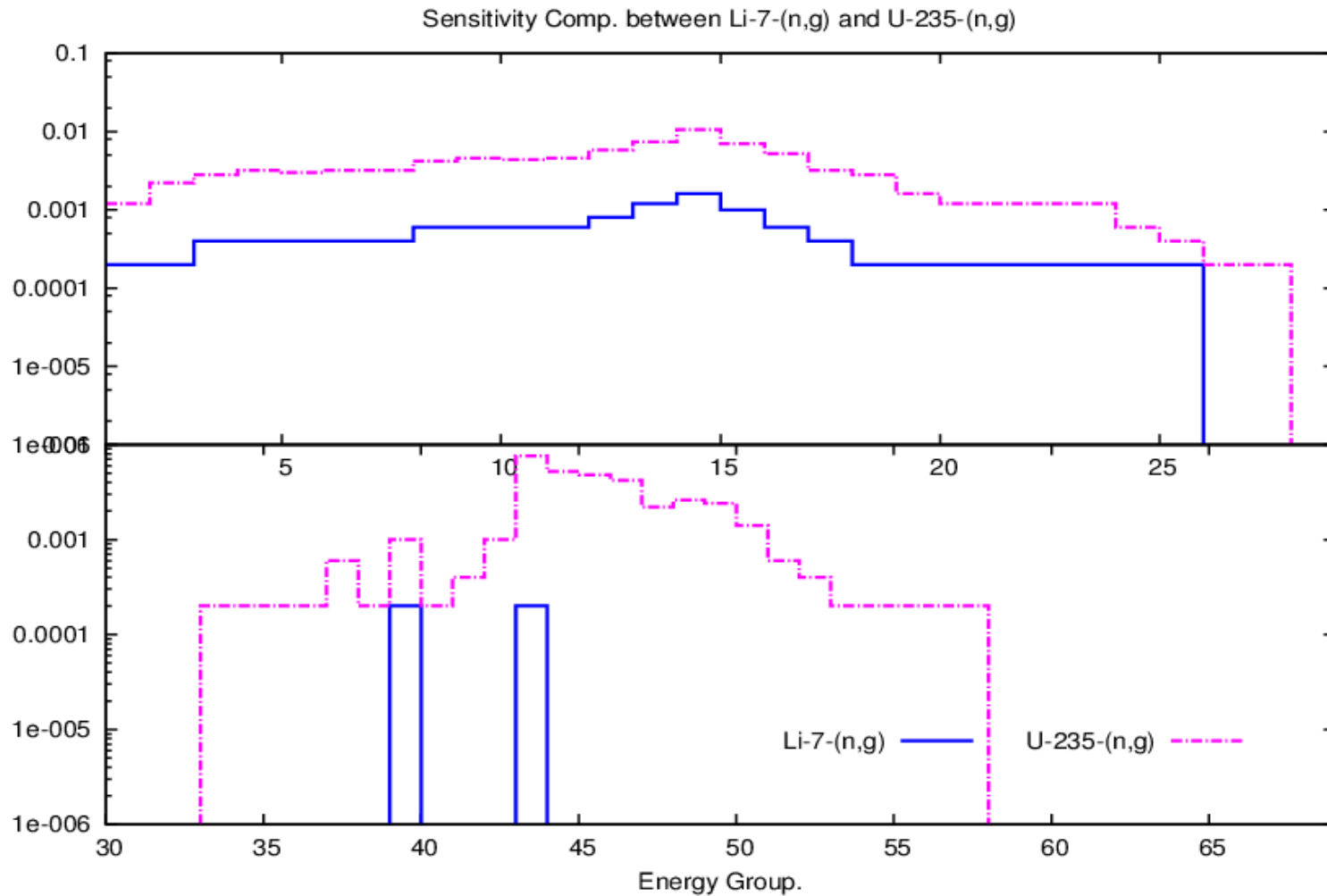


Fig.22 Sensitivity comparison of ^{235}U and ^7Li capture



3-5 EXFOR Database Compilation Progress

GDgraph Software

The updated version of the GDgraph-v5.0 and user's manual (English version) has been released and users can be download from https://www-nds.iaea.org/nrdc/nrdc_sft/.

EXFOR Compilation.

During the 2013-2014 EXFOR compile group at CNDC have finished 11 entries and 36 entries is being compiling. All these experimental information were scanned from following journals and proceedings:



IV Other Nuclear Data Activities Related to CENPL Project

- IAEA/NDS Mirror-site in China started service on 2013/08/27, regular update and maintenance are performed by NDS and CNDC.
- The 2013 standing committee meeting of China Committee of Nuclear Data was hold in Beijing on 28, Dec. 2013.
- A proposal for the establishment of the nuclear data system with white neutron sources on the CSNS has been provided.
- A proposal for a national program of the fundamental research for the nuclear data is drawing up.



***Thank you for your attention !
Comments and suggestion welcome !***