2010/11 Status Report of China Nuclear Data Center

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1. General of China Nuclear Data Center

1.1 CNDC View

China Nuclear Data Center (CNDC) was established in 1975 and joined the nuclear data activities of IAEA as the national nuclear data center of China since 1984.

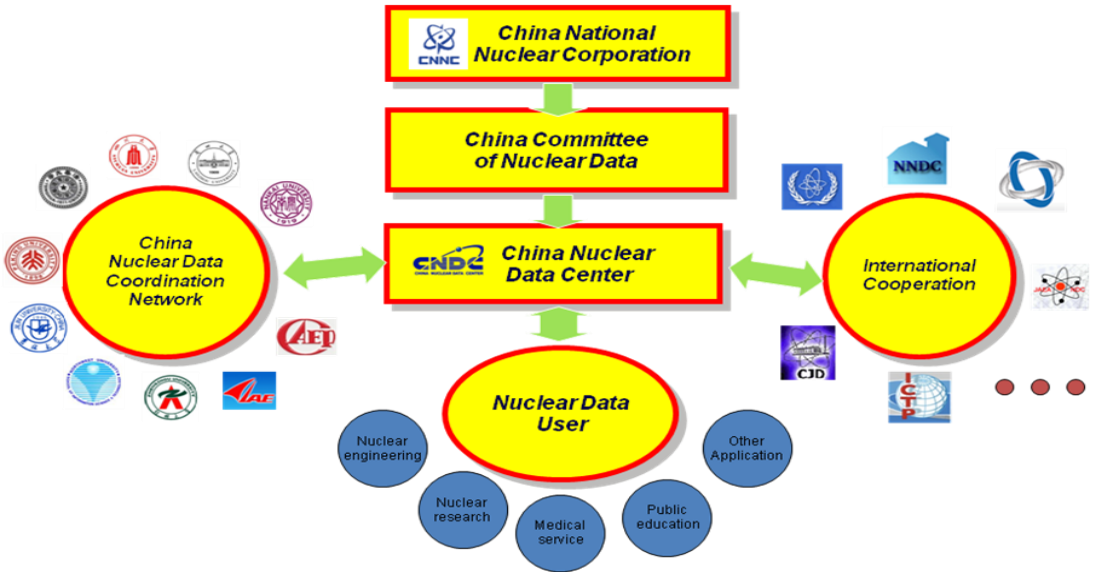
The main task of CNDC:

The nuclear data evaluations, libraries and relevant technique researches.

The exchange of nuclear data activities with IAEA, foreign nuclear data centers and agencies.

The management of domestic nuclear data activities.

The services for domestic and foreign nuclear data users.



The China Nuclear Data Activity Structure

1.2 Staff Information of CNDC

CNDC consists of the four units + an office:

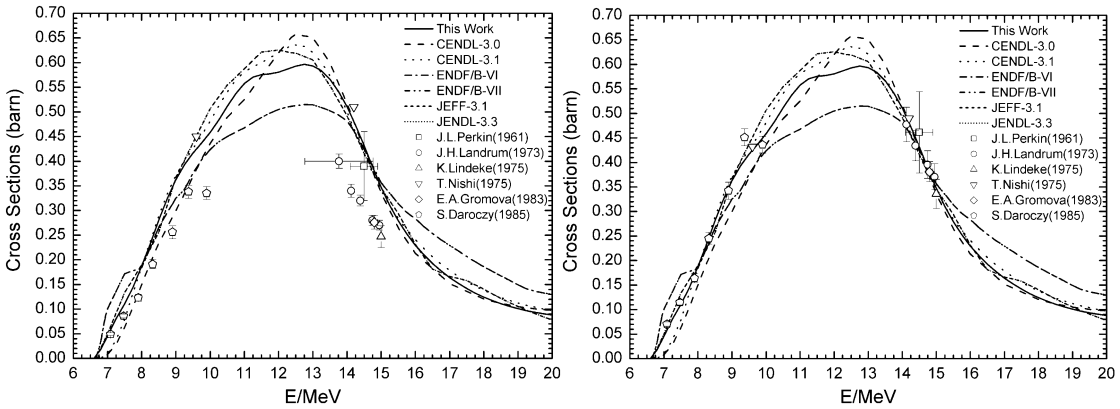
Evaluation Unit	Head: Dr. Huang Xiaolong	3 official staff
Theory Unit	Head: Dr. Ge Zhigang	7 official staff
Macroscopic Data Unit	Head: Dr. Liu Ping	5 official staff
Data Library Unit	Head: Dr. Shu Nengchuan	5 official staff
Secretary Office		2 official staff

22 official staff and 5 technical support experts (senior) working at the CNDC and 4 graduate students and 3 Ph.D students are studying at CNDC during 2010-2011.

2. Nuclear Data Evaluation and Benchmark Testing

2.1 Data Files Re-evaluation of CENDL-3.1

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.



(a) Comparison with original measured data (b) Comparison with corrected measurements

Fig.1 Comparison of evaluated data with measured data for ^{237}Np(n, 2n) reaction

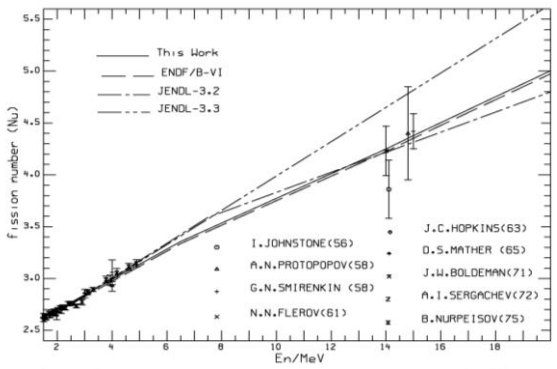


Fig. 2 Comparison of Evaluated measured data for prompt neutron number

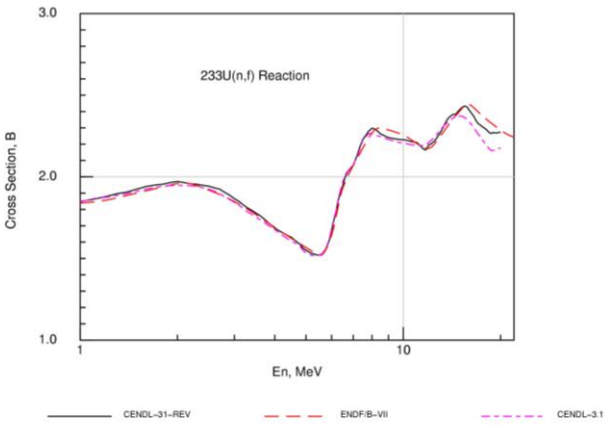


Fig. 3 Comparison of CENDL-31-REV, CENDL-31，ENDF/B-VII for ^{233}U(n, f) Reaction

2.1 Data Benchmark Testing/Validation

- **Validation of Evaluated Data Library with CSEWG benchmarks**

Several benchmarks from CSEWG were selected for validation of evaluated data files, such as CENDL-3.1, ENDF/B-VII.0, JENDL-3.3 and JENDL-4.0 vision. These cases cover fast and thermal energy spectrum. The calculated results of effective multiplication factor k_{eff} with evaluated libraries were compared with the experimental results.

Table 2 Results of LANL sphere fast assemblies

Assembly	CENDL-3.1	ENDF/B-VII.0	JENDL-3.3	JENDL-4.0	Experiment	Error
Godiva	0.99999	0.99994	1.00277	0.99746	1.0004	0.0024
BIG TEN	0.99555	0.99467	0.98495	0.98745	0.9948	0.0013
Flattop-25	1.002	1.00308	0.99837	0.99821	1	0.003
Jezebel	0.99913	0.9998	0.99746	0.99865	1	0.002
Jezebel-240	1.00018	0.99976	1.00148	0.99849	1	0.002
Flattop-Pu	0.99684	1.00105	0.99208	0.9991	1	0.003
THOR	1.00173	0.99824	1.00743	0.99792	1	6.00E-04
Jezebel-233	0.99885	0.99975	1.00415	0.99917	1	0.001
Flattop-23	0.99855	0.99918	0.99835	0.99819	1	0.0014

Table 3 Results of ORNL series assemblies

Assembly	CENDL-3.1	ENDF/B-VII.0	JENDL-3.3	JENDL-4.0	Experiment	Error
ORNL-10	1.00047	0.99941	0.99928	0.99871	1.0015	0.0026
ORNL-1	1.00103	0.99878	0.99981	0.99889	1.0012	0.0026
ORNL-2	0.99981	0.9977	0.99881	0.99805	1.0007	0.0036
ORNL-3	0.99627	0.99399	0.99487	0.99435	1.0009	0.0036
ORNL-4	0.99799	0.99587	0.99666	0.99595	1.0003	0.0036

Table 4 Results of PNL solution assemblies

Assembly	CENDL-3.1	ENDF/B-VII.0	JENDL-3.3	JENDL-4.0	Experiment	Error
PNL-1	1.01198	1.00569	1.00859	1.00749	1	0.0032
PNL-2	1.00612	1.0001	1.00376	1.00253	1	0.0065
PNL-3	1.00752	1.00562	1.00923	1.00641	1	0.0034
PNL-4	1.00527	1.00372	1.00547	1.00271	1	0.0031
PNL-5	1.00724	1.00081	1.0047	1.00334	0.9969	0.0038
PNL-6	1.00737	1.00156	1.00512	1.00314	1	0.0065
PNL-7	1.00925	1.00361	1.00689	1.005	1	0.0047
PNL-8	1.0108	1.00481	1.00821	1.00616	1	0.0032
PNL-12	1.00876	1.00368	1.00632	1.00529	1	0.0025

Table 5 Results of PNL MOX fuel assemblies

Assembly	CENDL-3.1	ENDF/B-VII.0	JENDL-3.3	JENDL-4.0	Experiment	Error
PNL-30	0.99699	1.00014	0.99613	0.99963	1.0024	0.006
PNL-31	1.00166	1.00051	1.00043	1.00292	1.0009	0.0047
PNL-32	1.00235	1.00088	1.00051	1.00217	1.0042	0.0031
PNL-33	1.00588	1.00708	1.00749	1.01016	1.0024	0.0024
PNL-34	1.00363	1.0032	1.00488	1.00412	1.0038	0.0025
PNL-35	1.00864	1.00761	1.00846	1.00785	1.0029	0.0027

- **Fast Criticality Benchmark Testing for ^{233}U**

The evaluations for ^{233}U from CENDL-3.1, ENDF/B-VII.0,JENDL-3.3 and JENDL-4.0 were tested with six U233-Metal-Fast benchmarks from ICSBEP Handbook. Total 10 criticality cases with core spectra change from hard to soft one by one, including one bare highly enriched ^{233}U core and 9 cores reflected with HEU、NU、Be and W separately. The criticality calculations were performed with Monte Carlo code MCNP4C. The ACE libraries used in the calculations were prepared with NJOY99.

Table 6 Comparison of C/E value of keff (C/E)

Case ID	EALF (MeV)	k_{eff},exp	uncertainty	C/E value of k_{eff}				Reflector
				ENDF/B-VII.0	CENDL-3.1	JENDL-3.3	JENDL-4.0	
UMF001_1	1.120	1.0000	0.0010	0.9998	0.9989	1.0034	0.9992	--
UMF002_1	1.080	1.0000	0.0010	0.9997	0.9970	1.0026	0.9985	HEU
UMF002_2	1.050	1.0000	0.0011	0.9985	0.9981	1.0035	0.9998	HEU
UMF003_1	1.080	1.0000	0.0010	0.9998	0.9983	1.0038	0.9992	NU
UMF003_2	1.070	1.0000	0.0010	0.9992	0.9984	1.0044	0.9993	NU
UMF004_1	0.999	1.0000	0.0007	1.0053	0.9941	1.0019	0.9998	W
UMF004_2	0.916	1.0000	0.0008	1.0061	0.9902	0.9987	0.9975	W
UMF005_1	0.936	1.0000	0.0030	0.9975	0.9906	0.9971	0.9961	Be
UMF005_2	0.749	1.0000	0.0030	0.9961	0.9880	0.9958	0.9957	Be
UMF006_1	1.020	0.9992	0.0014	0.9931	0.9993	1.0043	0.9990	NU

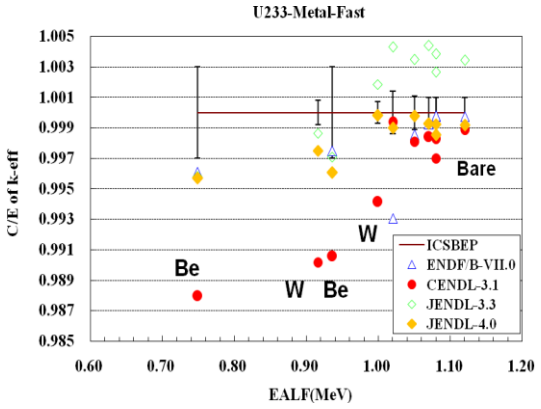


Fig.4 Comparison of C/E values of k_{eff} for UMF benchmarks

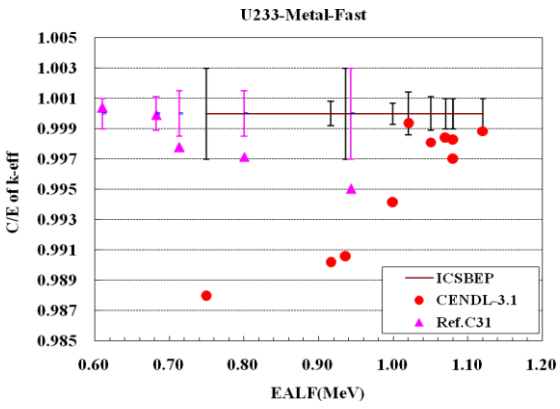


Fig.5 Comparison of C/E values of k_{eff} for test-group and reference-group

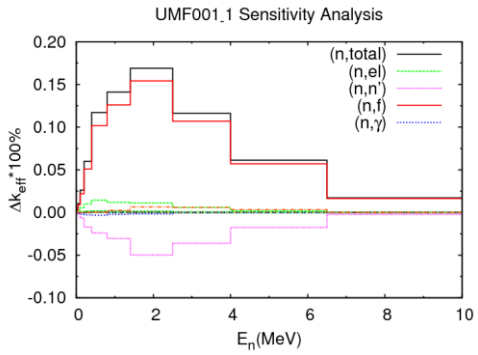


Fig.6 Sensitivity of k_{eff} to ^{233}U cross sections for UMF001_1

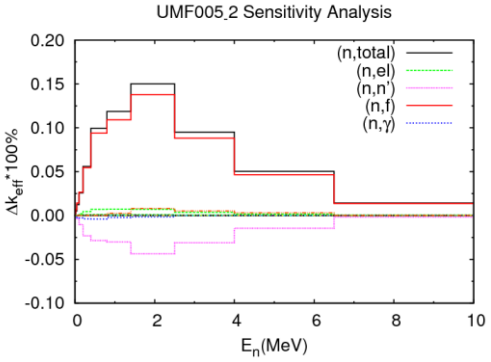


Fig.7 Sensitivity of k_{eff} to ^{233}U cross sections for UMF005_2

Finally, the analysis shows that the evaluation of $^{233}U(n,f)$ cross section in 0.5~4MeV may be underestimated in CENDL-3.1 and need to be revised by evaluators.

- **CENDL-3.1 Data Testing with LLNL Pulsed Sphere Benchmarks**

Lawrence Livermore pulsed sphere experiments were modeled for the benchmarking of CENDL-3.1. 96 different experiments on 28 different spheres, including: ^{6}Li,^{7}Li, Be, C, N, O, Al, Mg, Ti, Fe, Cu, Ta, Au, W, Pb, Nb, Sn, ^{232}Th, ^{235}U, ^{238}U, ^{239}Pu, LiD, Air, H_2O, D_2O, polythene, teflon and concrete. The calculated results were compared to experimental results, the results obtained from CENDL-2.1, ENDF/B-VII, JENDL-3.3 and JEFF-3.1 (as shown in Fig.8).

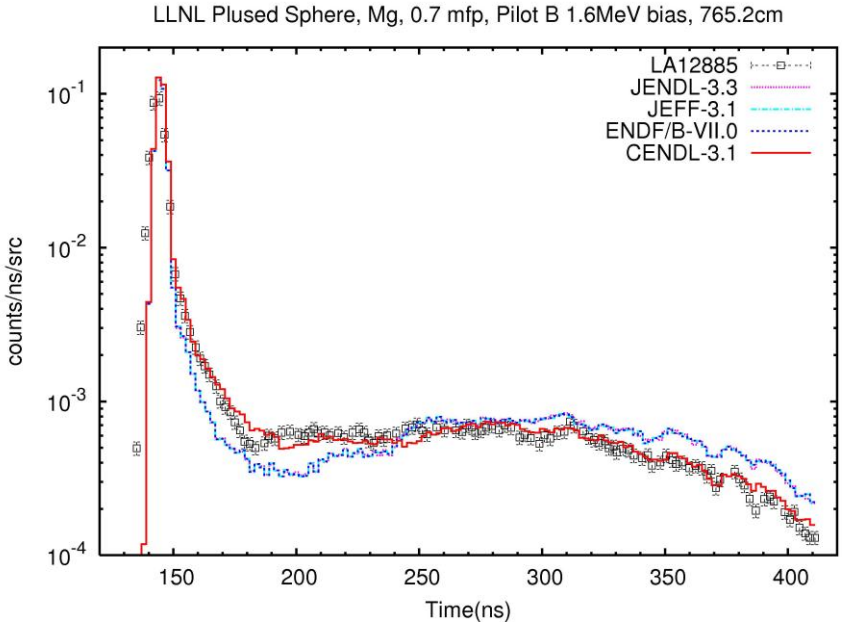


Fig.8 Neutron spectrum for the LLNL Pulsed Sphere, Mg (0.7 mfp) benchmark

The results show that the results of new release CENDL-3.1 give better results in comparison to experiment to CENDL-2.1, and close to other libraries. The light nuclei results are match the experiment well. And the results of Cu, Fe, Mg of CENDL-3.1 give better results in comparison to experiment to ENDF/B-VII. But the F, N, Ti, ^{239}Pu, Ta, Au, W, Nb of

CENDL-3.1 results give deviation results in comparison to experiment to other libraries, the evaluated nuclear data were proposed further improvements.

2.3 Methodology Studies

- **The Status of Covariance Evaluation at CNDC**

A covariance evaluation system, COVAC, 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.

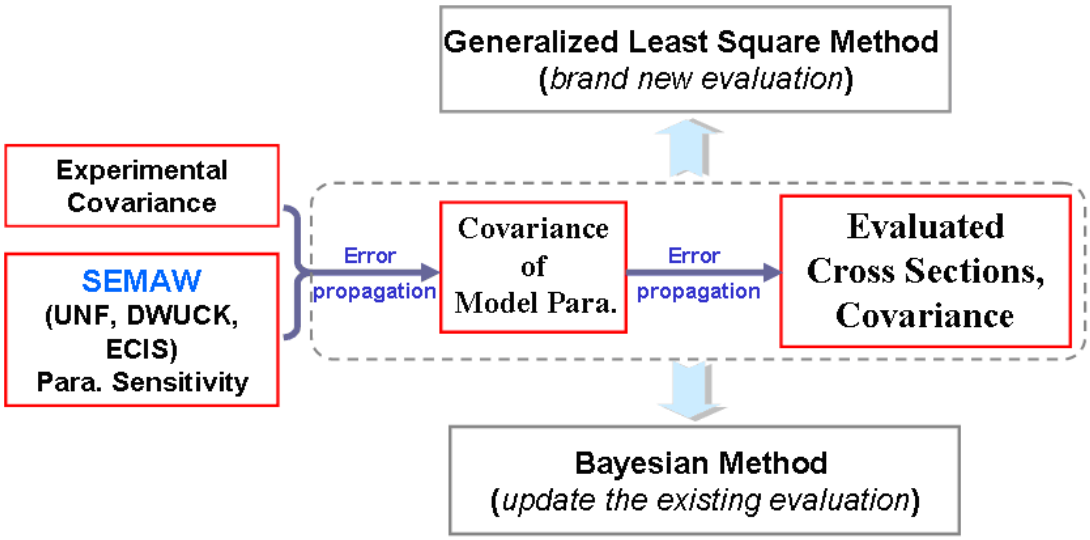


Fig. 9 COVAC SYSTEM OF CNDC

Here, ^{40}Ca(n, α) is sampled to explain the procedure.

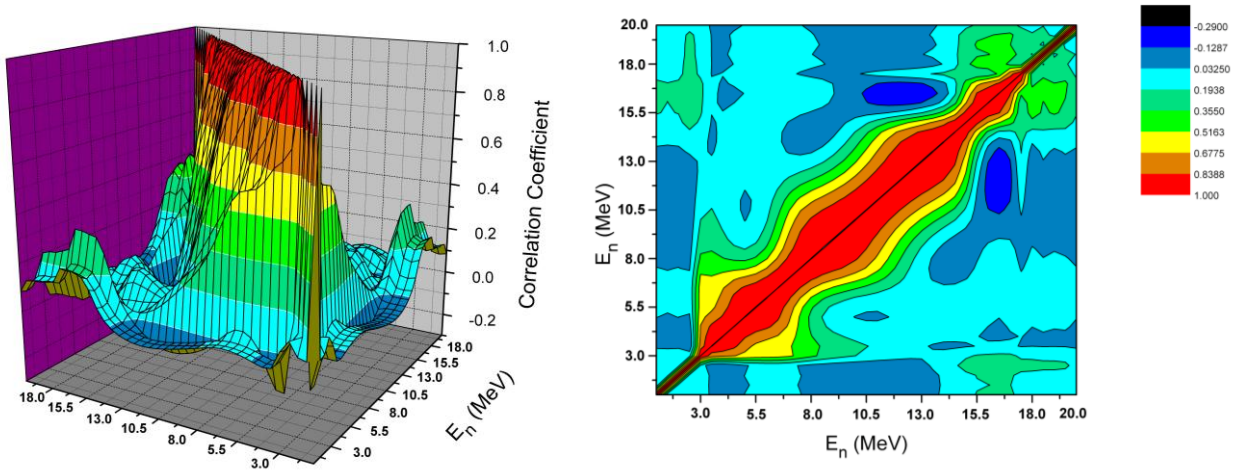


Fig.10 The correlation coefficient matrix of the ^{40}Ca(n, α) fit cross sections

- **Semi-Empirical Study on the Yield Energy Dependence of the ^{235}U + n Fission**

A semi-empirical model based upon the basic idea of Multi-Modal Random Neck-Rupture Model was applied to study the yield energy dependance of ^{235}U+n fission. The compound system energy was simplified including the macro energy and shell effects. The 11 parameters in the model were determined by fitting the evaluated experimental data. The fragment level density was determined by taking into account of the compound and fragment characters, which could improve the results. The shell effect weakened with temperature was illustrated. Prompt fission neutron and multichannel fissions were also taken into account.

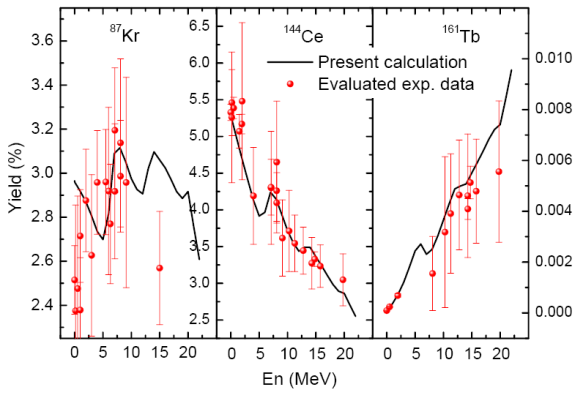


Fig.11 Yield energy-dependence of ^{87}Kr, ^{144}Ce, ^{161}Tb of ^{235}U+n fission.

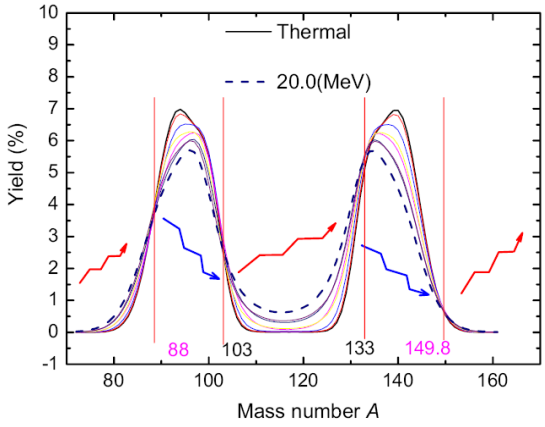
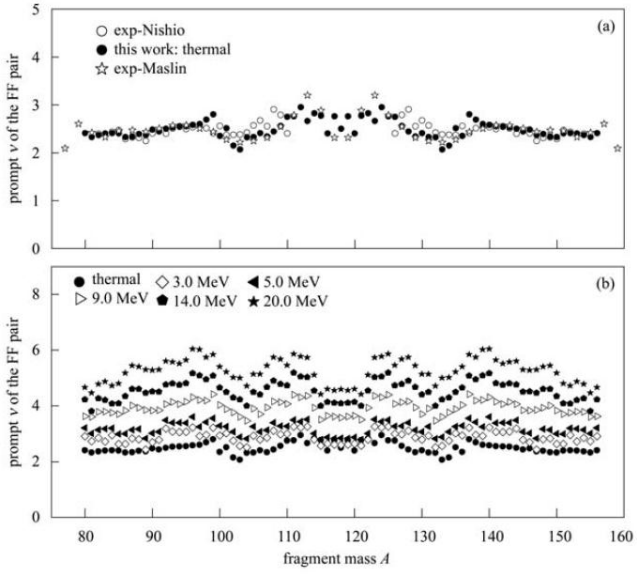


Fig.12 Mass distributions of the ^{235}U+n fission. 5 mass distribution curves from energies 0.5 MeV to 18 MeV are shown in addition to the thermal and 20 MeV curves. The arrows indicate the yields step-increased or -decreased with the energy.

- **Prompt Neutron Multiplicity Distribution for ^{235}U(n,f) at Incident Energies Up to 20 MeV**

The total excitation energy partitions between the complementary light and heavy fission fragments for the n+^{235}U fission reaction are given at incident energies up to 20 MeV. The average neutron kinetic energy $\langle\varepsilon\rangle(A)$ and the total average energies removed by γ rays $E_\gamma(A)$ as a function of fission fragment (FF) mass at different incident neutron energies are



presented. The prompt neutron multiplicity distribution $\nu(A)$ for n+^{235}U fission at different incident neutron energies are calculated. The results are checked with the total average prompt neutron multiplicities $\bar{\nu}$ and compared with the experimental and evaluated data.

Fig. 13 FF pair multiplicity of the ^{235}U(n,f) reaction at thermal neutron energy (a) and higher neutron energies (b).

- **The Systematics of (n,2n) Reaction Excitation Function**

Based on the constant temperature evaporation model taking the competition of (n,3n) reaction and the contribution of preequilibrium emission into account, the systematics formulae of (n,2n) reaction excitation function have been established. There are two systematics parameters T and $\sigma_{n,M}$ can be adjusted in the formulae. For getting the two parameters, the new evaluated data of (n,2n) reactions were adopted and fitted by means of the nonlinear least squares method. The fitted results agree fairly well with the measured data at 45≤A ≤210 below 30 MeV. Based on a body of new measurements, the reliability to predict (n,2n) reaction excitation function is improved. Hence more accurate systematics prediction for unmeasured nucleus or energy range may be provided.

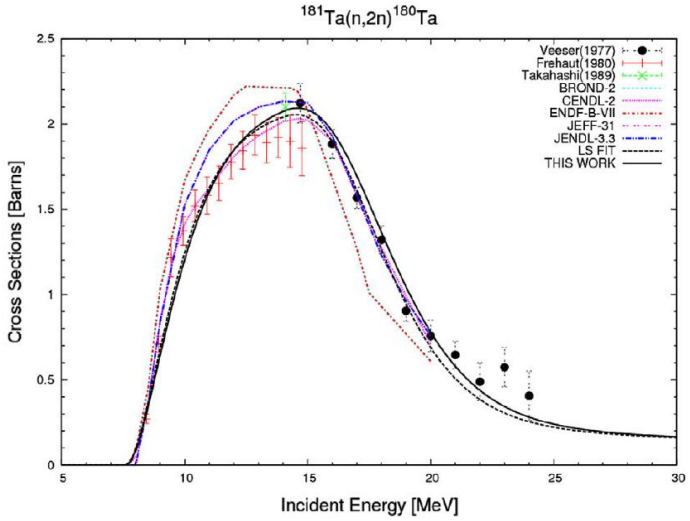


Fig.14 Excitation function of the (n,2n) reaction for ^{181}Ta.

3. EXFOR Compilation Progress

In 2010, CNDC had 23 entry compilations (2 remain from 2009, 19 from IAEA and scanned by CNDC). Up to now 18 of them have finished and 5 is being compiling (Fig.15).

An EXFOR compilation management system has been constructed in CNDC, the compilers can obtain the all information and status about their task with the system (Fig.16). The Table 7 shows the all EXFOR entries information in CNDC during recent two years.

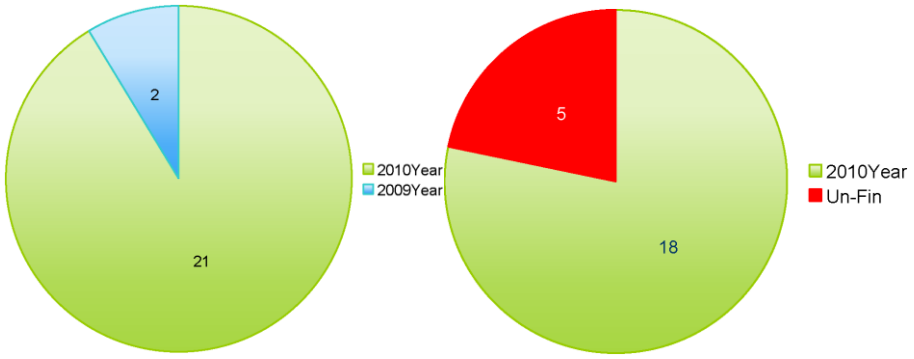


Fig. 15 the statistics of the entries of 2010 in CNDC.

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	No.	Ref.	Title	Vol.	Issue	Page	Lab	Publish date	Author	Status	Action	Delay date(m)	Compiler	Entry	Sub.
详情	1	S,JAEA-C-	Preliminary Measurement of Neutron Emission Spectra for Beryllium at 21.65 MeV	JAEA-Conf-2009-004	2009-004	169	3CPRAEP	200910	Changlin LAN	Allocated	Compiled	10	Guochang CHEN	32682	n
详情	2	S,ISINN-	Cross section measurements for the 143Nd(n,α)140Ce reaction at 4.0, 5.0 and 6.0 MeV	17	1	323	3CPRBJG	201007	Yu.M.Gledenov	Allocated	Compiled	1	Guochang CHEN	32681	n
详情	3	S,ISINN-	Cross section measurements for the 143Nd(n,α)140Ce reaction at 4.0, 5.0 and 6.0 MeV	17	1	323	3CPRBJG	201007	Yu. M. Gledenov	Allocated	Compiled	1	Guochang CHEN	32681	n
详情	4	J,RCA	Cross section measurements of (n, 2n), (n, p) and (n, α) reactions on gadolinium isotopes in the neutron energy range of 13.5 to 14.8 MeV 文献2	98	3	127	3CPRNPC	201003	Junhua Luo	Allocated	Compiled	6	Guochang CHEN	32680	n
详情	5	J,PR/C	Cross-section measurement and analysis for the 149 Sm(n,α) 146 Nd reaction at 6.0 MeV	82	1	14601	3CPRBJG	201007	Yu. M. Gledenov	Allocated	Compiled	1	Jimin WANG	32679	n
详情	6	J,NP/A	Lithium induced nuclear reactions of astrophysical interest	834	1-4	651c	3CPRAEP	201003	W.P.Liu	Allocated		7	Xi TAO	S0070	cp
详情	7	J,NP/A	Competition between fusion-fission and quasi fission processes in 32S+184W reaction	834	1-4	201c	3CPRAEP	201003	C. L. Zhang	Allocated		7		S0069	cp
详情	8	J,NP/A	Elastic resonance scattering of 13N+p and 17F+p	834	1-4	100c	3CPRAEP	201003	Y.B. Wang	Allocated		7	Xi TAO	S0068	cp
详情	9	J,NIM/B	Development of laboratory standards for AMS measurement of 237Np	268	11-12	1949	3CPRAEP	201006	Xianggao Wang	Allocated	Compiled	3	Youxiang ZHUANG	32683	n
详情	10	J,NIM/B	Measurements of the 89Y(n,γ)90mY cross-section in the neutron energy range of 13.5 - 14.6 MeV	268	9	1367	3CPRLNZ	201005	Fengqun Zhou	Allocated	Compiled	4	Youxiang ZHUANG	32678	n

Fig. 16 The EXFOR compilation management system in CNDC

Table 7. The EXFOR compilation information in CNDC

.	Ref.	Title	Vol.	Lab	Publish date	Author	Action	Delay date(m)	Compiler	Entry	Sub.
1	J,EPJ/A	Cross-section measurement for the 67Zn(n,a)64Ni reaction at 6.0 MeV	A43	3CPRBJG	201001	Guohui Zhang	Compiled		Zhendong WU	32672	n
2	J,PR/C	Investigation of discrete gamma radiation in interactions of 14.9-MeV neutrons with natural silicon by a total gamma-radiation measurement technique	82	3CPRBNU	201010	Hongyu Zhou		7	Xi TAO	32688	n
3	J,HFH	95Zr,140Ba, and 147Nd Yields from 0.57, 1.0, and 1.5 MeV Neutrons Induced Fission of 235U	32	3CPRAEP	201012	Feng Jing	Compiled	3	Guochang CHEN	32687	n
4	J,CST	Measurement of 176Hf(n,2n)175Hf Cross Section	44	3CPRNPC	201009	Zhu Chuanxin		8	Youxiang ZHUANG	32686	n
5	J,CPL	Fragmentation Cross Sections of 12C on Different Targets at Beam Energies from 50 to 100MeV/Nucleon	25	3CPRBNU	200802	BIAN Bao-An (卞宝安)		39			cp
6	J,CPL	Measurement of Angular Distribution for the 8Li(p,d)7Li Reaction	25	3CPRAEP	200802	LI Yun-Ju		39	Jimin WANG	S0072	cp
7	J,IPC	Cross-section measurements for 141Pr isotope at neutron energies from 13.5 to 14.8 MeV	79	3CPRHXU	201009	Junhua Luo	Compiled		Jimin WANG	32685	n
8	J,PR/C	Differential cross section for neutron scattering from 209Bi at 37 MeV	82	3CPRAEP	201008	Zuying Zhou	Compiled	7	Guochang CHEN	32684	n
9	J,NIM/B	Measurements of the elastic scattering cross sections for proton on T,4He	268	3CPRFUD	201008	T.Cai	Finalized		Guochang CHEN	S0071	cp
10	S,JAEA-C-	Preliminary Measurement of Neutron Emission Spectra for Beryllium at 21.65 MeV	JAEA-Conf-2009-004	3CPRAEP	200910	Changlin LAN	Compiled	10	Guochang CHEN	32682	n
11	S,ISINN-	Cross section measurements for the 143Nd(n,α)140Ce reaction at 4.0, 5.0 and 6.0 MeV	17	3CPRBJG	201007	Yu.M.Gledenov	Finalized	1	Guochang CHEN	32681	n
12	J,RCA	Cross section measurements of (n, 2n), (n, p) and (n, α) reactions on gadolinium isotopes in the neutron energy range of 13.5 to 14.8 MeV	98	3CPRNPC	201003	Junhua Luo	Finalized	6	Guochang CHEN	32680	n
13	J,PR/C	Cross-section measurement and analysis for the 149 Sm(n,α) 146 Nd reaction at 6.0 MeV	82	3CPRBJG	201007	Yu.M.Gledenov	Finalized	1	Jimin WANG	32679	n

14	J,CPL	Astrophysical Reaction Rates of the 8Li(p,\gamma)9Beg.s. Direct Capture Reaction	23	3CPRAEP	200601	SU Jun		64	Xi TAO	S0070	cp
15	J,NP/A	Competition between fusion-fission and quasi fission processes in 32S+184W reaction	834	3CPRAEP	201003	C.L.Zhang	Compiled	6	Xi TAO	S0069	cp
16	J,NP/A	Elastic resonance scattering of 13N+p and 17F+p	834	3CPRAEP	201003	Y.B.Wang		14	Xi TAO	D0477	cp
17	J,NIM/B	Development of laboratory standards for AMS measurement of 237Np	268	3CPRAEP	201006	Xianggao Wang	Finalized	3	Youxiang ZHUANG	32683	n
18	J,NIM/B	Measurements of the 89Y(n,γ)90mY cross-section in the neutron energy range of 13.5–14.6 MeV	268	3CPRLNZ	201005	Fengqun Zhou	Finalized	4	Youxiang ZHUANG	32678	n
19	J,NIM/A	Accurate determination of cross-sections for 238U (n, 2n) 237U induced by neutrons around 14 MeV	621	3CPRAEP	201009	Xianggao Wang	Finalized	3	Youxiang ZHUANG	32677	n
20	J,JRN	Measurement of neutron-induced activation cross sections of lanthanum at 14.8 MeV	283	3CPRHXU	201002	Junhua Luo	Finalized	6	Jimin WANG	32675	n
21	J,JP/G	Unusual potential behavior for the weakly bound nucleus 9Be in elastic scattering from 208Pb and 209Bi near the threshold	37	3CPRAEP	201007	N Yu	Compiling	10	Jimin WANG	S0066	cp
22	J,IPC	Cross-sections for formation of 195mPt through natPt(n,x)195mPt reaction over neutron energy range 13–15 MeV	79	3CPRLNZ	201010	Junhua Luo	Compiled		Jimin WANG	32674	n
23	J,EPJ/A	First measurement of the 2H(6He,7Li)n angular distribution and proton spectroscopic factor in 7Li	44	3CPRAEP	201004	Z.H.Li	Finalized	3	Xi TAO	S0062	cp
24	J,PR/C	Cross section of the 67Zn(n, α)64Ni reaction at 4.0, 5.0 and 6.0 MeV	43	3CPRBJG	201011	Guohui Zhang	Compiled	14	Guochang CHEN	32689	n
25	J,CPL	Neutron Spectroscopic Factors of 7Li and Astrophysical 6Li(n,g)7Li Reaction Rates	27	3CPRAEP	201005	SU Jun (苏俊)	Compiled	3	Zhendong WU	S0065	cp
26	J,CPL	Experimental Study on the Exotic Structure of 12N in RIBLL	27	3CPRLNZ	201003	LI Jia-Xing (李加兴)	Finalized	5	Guochang CHEN	S0064	cp
27	J,CPL	Excited States in 18Ne Studied via 17F+p	27	3CPRAEP	201003	JIN Sun-Jun (金孙均)	Compiled	5	Zhendong WU	S0057	cp
28	J,ARI	Cross-Section Measurement for the 95Mo(n,a)92Zr Reaction at 4.0, 5.0 and 6.0 MeV 文献 2	68	3CPRBJG	201001	Guohui ZHANG	Finalized	9	Jimin WANG	32676	n
29	J,CST	Measurement of Secondary Neutron Emission Double Differential Cross Section for Natural Iron Induced by 8.17 MeV Neutron	43	3CPRAEP	200909	Xichao RUAN	Finalized	11	Guochang CHEN	32673	n
30	J,CNPR	Study of Proton Resonances in 22Mg by Resonant Elastic Scattering of 21Na+p and Its Astrophysical Implication in 18Ne(a,p)21Na Reaction Rate	26	3CPRIMP	200907	HE Jian-jun	Compiled	13	Youxiang ZHUANG	S0060	cp
31	J,HEN	Measurement of the astrophysical S factor for the low energy 2H(d,γ)4He reaction	33	3CPRAEP	200905	Zhou jing		24	Xi TAO	S0058	cp
32	J,CPL	Quasi-Elastic Scattering of 16C from 12C at 47.5 MeV/Nucleon	26	3CPRBJG	200908	FAN Feng-Ying	Compiled	21	Youxiang ZHUANG	S0059	cp

4. Other Activities Relevant Nuclear Data

- A national key laboratory of nuclear data measurement and evaluation technology was established, which contained the nuclear data measurement laboratory in CIAE and CNDC. There are 60 official staff working the laboratory.
- A TM on the nuclear data benchmark and validation was hold in Guilin, Cuangxi Province last 15-21, Nov. 2010.
- The 2010 standing committee meeting of China Committee of Nuclear Data was hold in Beijing on 29, December 2010.
- The mirror site of IAEA/NDS is under construction in CNDC, the hardware and software are already, and the server of the mirror site is already access to Internet through CIAE. We are contacting with the IAEA/NDS to finished future task.
- The second Asian Nuclear Reaction Database Development Workshop is preparing and will be organized in Beijing this September.