33rd Meeting of the Working Party on International Nuclear Data Evaluation Co-operation (WPEC)
13-14 May 2021 Zoom Videoconference

Status Report of CENDL Project（2021）

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CHINA NUCLEAR DATA CENTER

I. General Information of CNDC

1.1 About CNDC

CNDC

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. As a window, CNDC has been open to the world since 1978. and CNDC has established a good cooperative relationship with the IAEA, OECD/NEA, and major nuclear data centers and institutions in the world.

The current main task of CNDC:

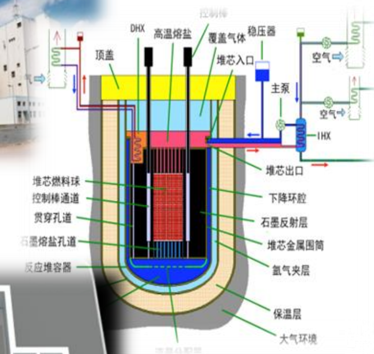
- ✓ The management of domestic nuclear data activities.
- ✓ The nuclear data evaluations, libraries and relevant methodology studies.
- ✓ Nuclear data measurements and methodology studies
- ✓ The exchange of nuclear data activities with IAEA, foreign nuclear data centers and agencies.
- ✓ The services for domestic and foreign nuclear data application users.

1.2 Mainly tasks of CNDC in 2020/2021:

- Validation, benchmarking for CENDL-3.2. and release.
- Photonuclear data modeling, evaluations, structure and decay data evaluation and library establishment.
- Methodological studies of nuclear data evaluation(incl. theoretical and experimental for fission process…).
- Nuclear data measurements and related methodological studies.
- The compilations for EXFOR.
- Nuclear data services is providing to all the nuclear data users.
- Proposal of the next Five Years Plan (2021-2025) for nuclear data (CENDL Project).
- ND2019 post activities.

II. CENDL Project

Based on the measurements and evaluations collaborated with China Nuclear Data Coordination Network, the main output of CENDL project is the CENDL library.



Chinese Evaluated Nuclear Data Library (CENDL project)

CENDL-1, 1985version 36

CENDL-2, 1992version 68

CENDL-3, 2000version 214

CENDL-3.1 2009 version 245

CENDL-3.2 2019 version 272 (June 12.2020)

Nuclear Structure and Decay Data Library (NSDD)

Fission Product Yield Data Library (FPYD)

Charged-Particle Nuclear Data Library (CPND)

Neutron Activation Dosimetry Data Library

Other Data Library……

III. CENDL-3.2 and CENDL-PD

2.1 CENDL-3.2 released on June 12.2020

As a general purpose evaluated nuclear database, Chinese Evaluated Nuclear Data Library (CENDL) is not only an output of more-than-forty-year domestic cooperation under the name of CENDL Library Project via China Nuclear Data Coordination Network (CNDCN), but also a product of international collaborations, especially under the multi-lateral framework of IAEA and OECD/NEA/WPEC.

Coordinated by China Nuclear Data Center (CNDC) during 2015-2019, CENDL-3.2 is the latest release of CENDL. With ENDF-6 formatted neutron reaction data for a total number of 272 materials, CENDL-3.2 is expected to meet general requirements for diversified scenarios of peaceful use of nuclear power and nuclear technology application.

The data for 135 materials are totally new or partly updated evaluations, while the other 137 materials were inherited and adopted as it was from previous version, CENDL-3.1.

Table 1. Nuclides List and Major Updates for CENDL-3.2

Newly Evaluated and Partly Updated (135 Nuclides)

Newly Evaluated (58 Nuclides):

n-1, H-1, Na-23, Al-27, S-32, S-33, S-34, S-36, Ca-40, Fe-56, Ni-58, Zn-64, Zn-66, Zn-67, Zn-68, Zn-70, Se-74, Se-76, Se-77, Se-78, Se-79, Se-80, Se-82, Kr-87, Kr-88, Mo-93, Mo-99, Sn-126, Sn-128, Sb-124, Sb-127, I-130, I-131, Xe-123, Xe-124[b], Xe-129, Xe-131, Xe-132[b], Xe-133, Xe-134[b], Xe-135[b], Xe-136, La-139[b], Ce-140, Ce-141[b], Ce-142, Ce-144[b], Ho-165, W-180, W-182, W-183, W-184, W-186, U-236, U-240, Np-236, Pu-238, Am-241.

Partly Updated (77 Nuclides):

H-2, Li-7, Ti-48, Ga-69[b], Ga-71[b], Ge-71[b], Ge-73[b], Ge-74[b], Ge-75[b], Ge-76[b], Ge-77[b], Ge-78[b], As-75[b], As-77[b], As-79[b], Sr-89[b], Y-89[b], Y-91[b], Zr-93[b], Zr-95[b], Nb-93, Nb-95[b], Tc-99[b], Ru-99[b], Ru-100[b], Ru-101[b], Ru-103[b], Ru-104[b], Ru-105[b], Rh-103[b], Rh-105[b], Pd-105[b], Pd-108[b], Cd-113[b], Sb-121[b], Sb-125[b], I-127[b], I-129[b], I-135[b], Cs-133[b], Cs-135[b], Cs-137[b], Ba-130[b], Ba-134[b], Ba-135[b], Ba-136[b], Ba-137[b], Ba-138[b], Pr-141[b], Nd-143[b], Nd-145[b], Nd-146[b], Nd-148[b], Pm-147[b], Pm-148[b], Pm-149[b], Sm-150[b], Sm-151[b], Eu-151[b], Eu-153[b], Eu-155[b], Gd-154[b], Gd-155[b], Gd-156[b], Gd-157[b], Gd-158[b], Gd-160[b], Th-232, U-233, U-235[c], U-237, U-238[c], U-239, Np-237, Np-239, Pu-240, Pu-241[c].

Inherited from CENDL-3.1 (137 Nuclides):

H-3, He-3, He-4, Li-6, Be-9, B-10, B-11, C-12, N-14, O-16, F-19, Mg-24, Mg-25, Mg-26, Si-28, Si-29, Si-30, P-31, Cl-0, K-0, Ca-0, Ti-46, Ti-47, Ti-49, Ti-50, V-0, Cr-50, Cr-52, Cr-53, Cr-54, Mn-55, Fe-54, Fe-57, Fe-58, Co-59, Ni-60, Ni-61, Ni-62, Ni-64, Cu-0, Cu-63, Cu-65, Ge-0, Ge-70, Ge-72, Kr-83, Kr-84, Kr-85, Kr-86, Rb-85, Rb-87, Sr-88, Sr-90, Zr-90, Zr-91, Zr-92, Zr-94, Zr-96, Mo-92, Mo-94, Mo-95, Mo-96, Mo-97, Mo-98, Mo-100, Ru-102, Ag-0, Ag-107, Ag-109, Cd-0, In-113, In-115, Sn-0, Sn-112, Sn-114, Sn-115, Sn-116, Sn-117, Sn-118, Sn-119, Sn-120, Sn-122, Sn-124, Sb-123, Te-130, Cs-134, Ba-132, Ce-136, Ce-138, Nd-142, Nd-144, Nd-147, Nd-150, Pm-148m, Sm-144, Sm-147, Sm-148, Sm-149, Sm-152, Sm-154, Eu-154, Gd-152, Dy-164, Hf-174, Hf-176, Hf-177, Hf-178, Hf-179, Hf-180, Ta-181, Au-197, Hg-0, Tl-0, Pb-204, Pb-206, Pb-207, Pb-208, Bi-209, U-232, U-234, U-241, Np-238, Pu-236, Pu-237, Pu-239, Pu-242, Pu-243, Pu-244, Pu-245, Pu-246, Am-240, Am-242, Am-242m, Am-243, Am-244, Bk-249, Cf-249.

a. Total data size of CENDL-3.2: 392MB.
b. Covariance added.
c. Beta-delayed fission gamma spectrum (MT=460) added.

In order to verify the physical rationality, systematic comparisons between CENDL-3.2 and other major evaluated libraries (ENDF, JENDL, JEFF and TENDL…) as well as experimental data available have been implemented. Moreover, the benchmarking test of CENDL-3.2 was performed with ENDITS-1.0, an integrated benchmarking test system including 1233 criticality benchmark configurations.

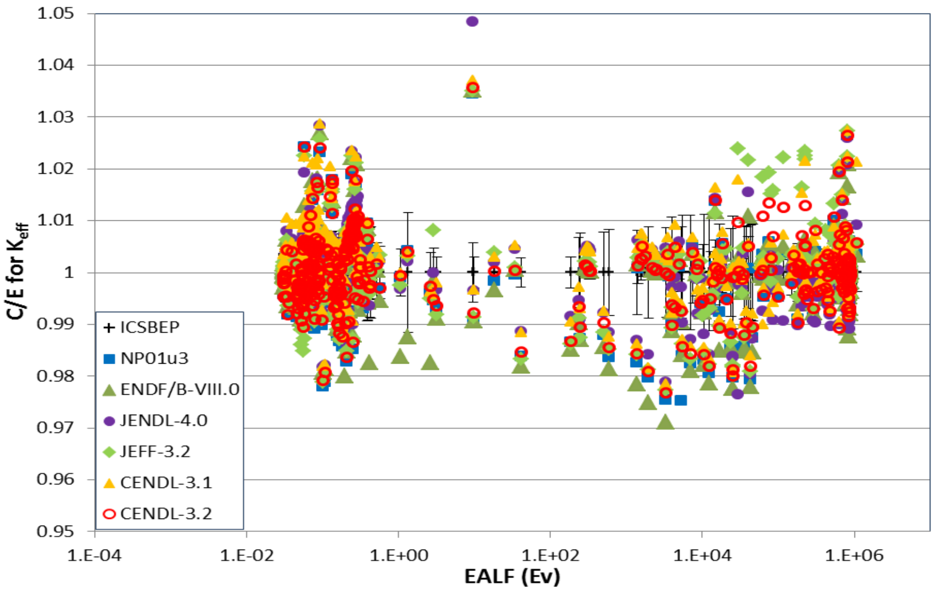


Fig. 1 Results for HEU systems

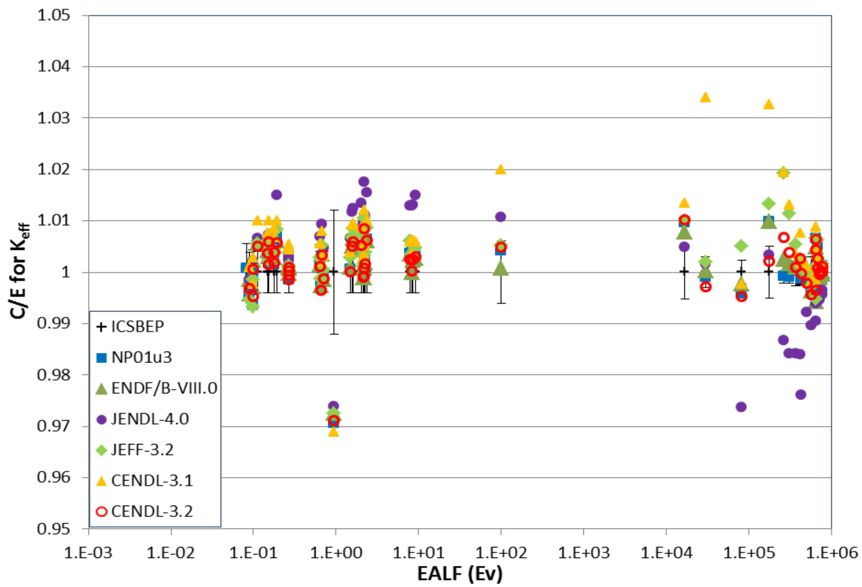


Fig. 2 Results for IEU systems

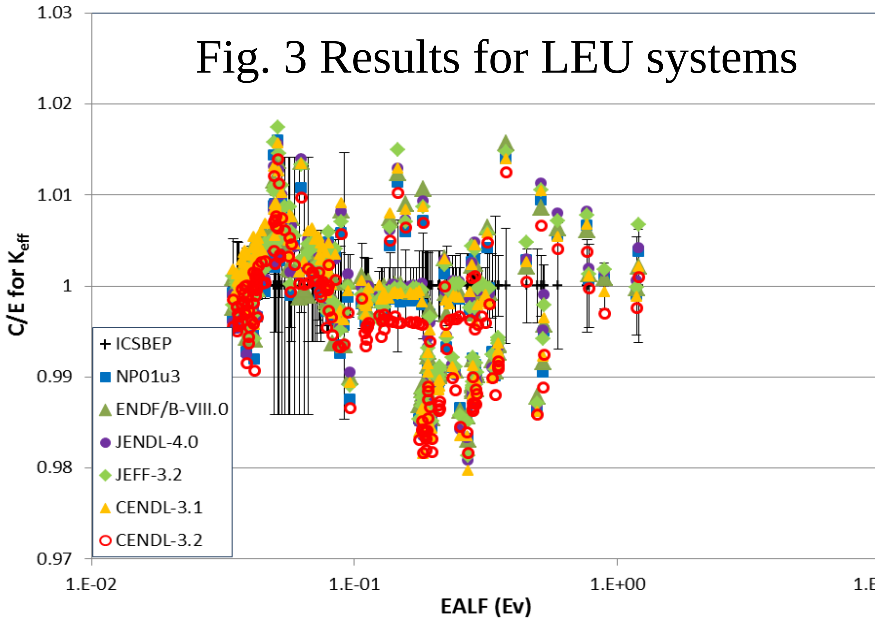


Fig. 3 Results for LEU systems
C/E for Keff
EALF (Ev)
ICSBEP
NP01u3
ENDF/B-VIII.0
JENDL-4.0
JEFF-3.2
CENDL-3.1
CENDL-3.2

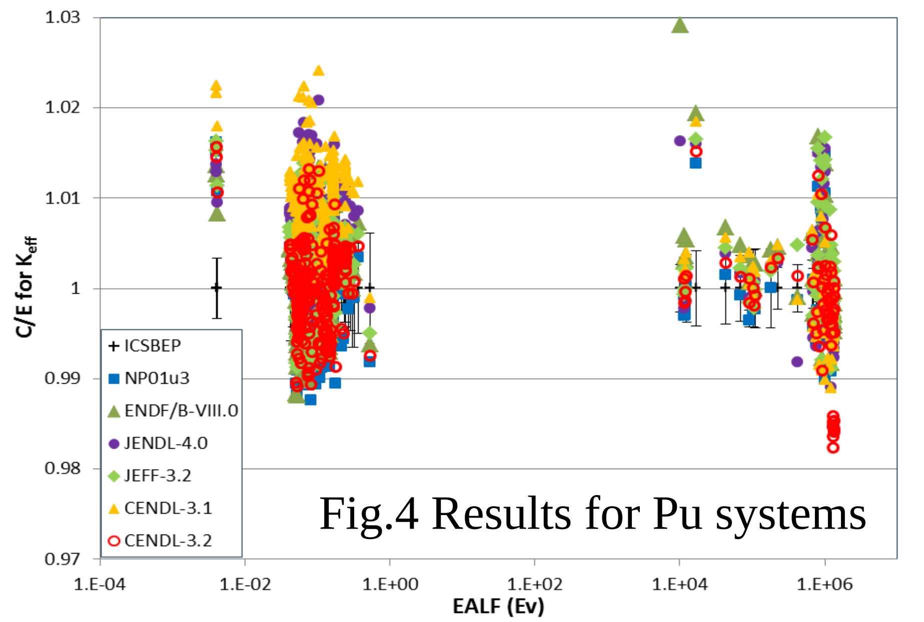


Fig.4 Results for Pu systems
C/E for Keff
EALF (Ev)
ICSBEP
NP01u3
ENDF/B-VIII.0
JENDL-4.0
JEFF-3.2
CENDL-3.1
CENDL-3.2

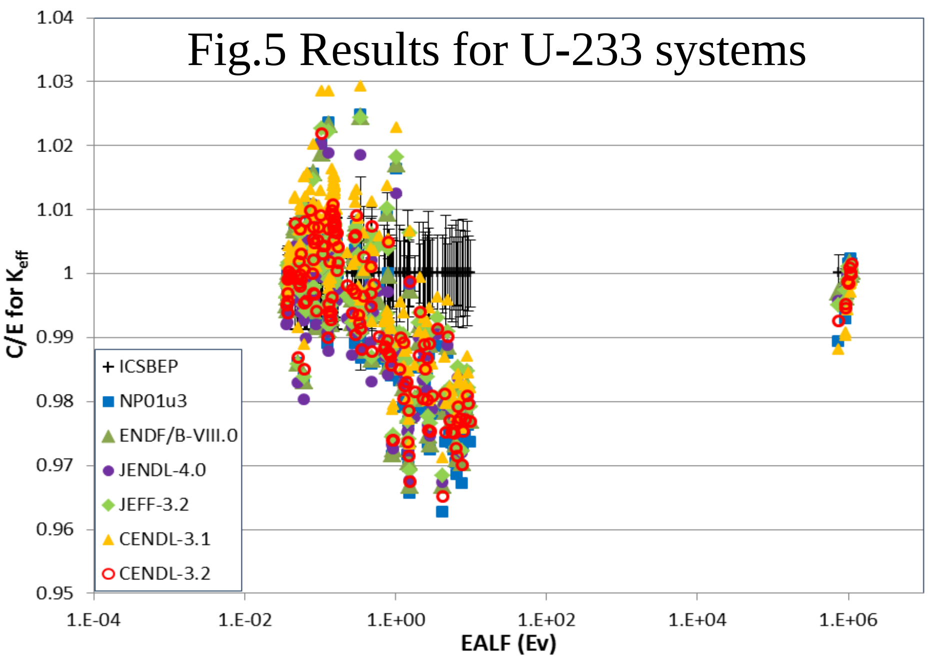


Fig.5 Results for U-233 systems
C/E for Keff
EALF (Ev)
ICSBEP
NP01u3
ENDF/B-VIII.0
JENDL-4.0
JEFF-3.2
CENDL-3.1
CENDL-3.2

Table 2. The average values of C/E-1, standard deviation and χ^2

Type	Casess	Quantity	ENDF/B-VIII.0	JENDL-4.0	JEFF-3.2	CENDL-3.1	CENDL-3.2
U-235	686	C/E-1 (pcm)	-20	26	62	182	-84
		STDEV	703	772	750	779	758
		χ^2	12.32	13.56	12.41	23.94	9.66
U-Pu	7	C/E-1 (pcm)	-170	-1233	122	-36	88
		STDEV	225	572	414	285	283
		χ^2	5.89	249.26	35.51	11.89	16.81
Pu	376	C/E-1 (pcm)	93	554	210	764	4
		STDEV	488	561	504	769	554
		χ^2	2.26	4.91	2.80	9.05	3.27
U-233	164	C/E-1 (pcm)	-547	-653	-378	-42	-579
		STDEV	1127	1031	1091	1197	1139
		χ^2	4.81	4.77	4.27	6.49	5.30
All	1233	C/E-1 (pcm)	-56	89	49	328	-119
		STDEV	745	849	762	892	782
		χ^2	8.21	11.09	8.53	17.01	7.17

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Progress in Nuclear Energy 136 (2021) 103727

Contents lists available at ScienceDirect

Progress in Nuclear Energy

journal homepage: http://www.elsevier.com/locate/pnucene

ELSEVIER

Performance of CENDL-3.2 evaluated nuclear data library for t
shielding benchmarks

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ARTICLE INFO

Keywords:
CENDL-3.2
Iron-88
PCA-Replica
HBR-2
NECP-Atlas
NECP-Hydra

ABSTRACT

The latest CENDL-3.2 evaluated nuclear data library was release
CENDL-3.2 in shielding benchmarks, a broad-group shielding libr

Hindawi
Science and Technology of Nuclear Installations
Volume 2021, Article ID 6633366, 13 pages
https://doi.org/10.1155/2021/6633366

Research Article

Verification of CENDL-3.2 Nuclear Data on VENUS-3 Shielding Benchmark by ARES Transport Code

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/ 2021; Published 5 February 2021

ibrary is deemed as an important achievement in the field of nuclear data research
iry to the shielding calculation of PWR and analyze the influence of multigroup
lation, ARES-MACXS module is used to process the MATXS format multigroup
igroup working cross sections for PWR shielding calculation. VENUS-3 exper-
ry. It is often used to test the ability of the advanced transport calculation method
uate the accuracy of cross-section library. Different cross-section parameters are
ark, and equivalent neutron flux of ^{58}Ni(n,p)^{58}Co, ^{115}In(n,n')^{115m}In and ^{27}Al(n,α)
ata provided by the benchmark report. The numerical results demonstrate that
ilculated results and the experimental results are within 20%, which satisfies the
3.2 is suitable for PWR shielding calculation. The comparison of various cross-

Annals of Nuclear Energy 158 (2021) 108238

Contents lists available at ScienceDirect

Annals of Nuclear Energy

journal homepage: www.elsevier.com/locate/anucene

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Application of CENDL-3.2 and ENDF/B-VIII.0 on the reactor physics simulation of PWR

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ARTICLE INFO

Article history:
Received 1 December 2020
Received in revised form 27 February 2021
Accepted 3 March 2021

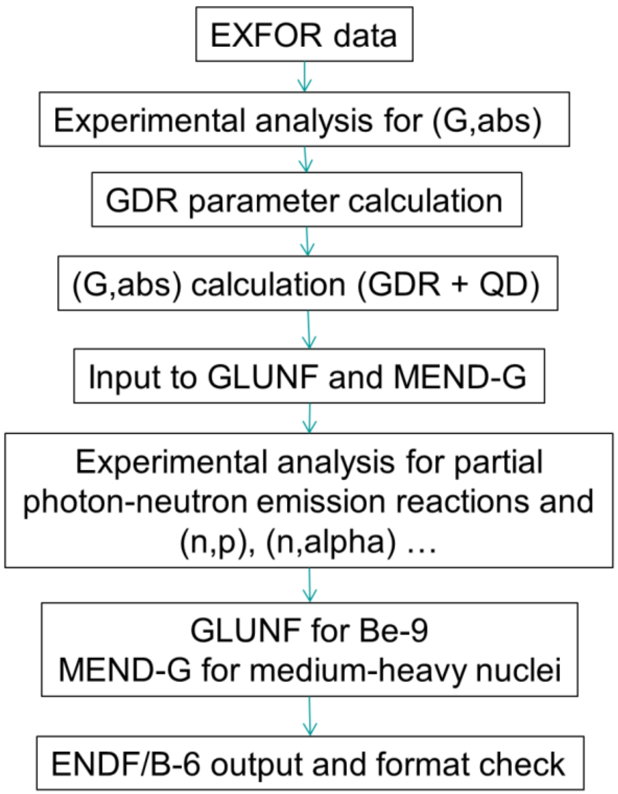
Keywords:
CENDL-3.2
ENDF/B-VIII.0
CNP-1000
NECP-Atlas
LOCUST/SPARK

ABSTRACT

The latest CENDL and ENDF/B evaluated nuclear data libraries was released in 2020 and 2018, respectively. To apply CENDL-3.2 and ENDF/B-VIII.0 in the reactor physic simulations of pressurized water reactor (PWR), the CNP-1000 PWR, which is an improved GEN-II PWR and operated in Fuqing Nuclear Power Plant in China, is simulated using these two libraries. The key parameters during the startup physics tests and power operation in the first three fuel cycles of the CNP-1000 reactor have been simulated and compared with corresponding measurement values. The numerical results show that ENDF/B-VIII.0 performs better in several parameters of the startup physics tests than ENDF/B-VII.0; the cross-section data in CENDL-3.2 is competent in the engineering application of PWR.

2.2 CENDL-PD for the photonuclear data will be released soon

1. CENDL-PD has been evaluated and it will be released soon, which contained photonuclear data for 266 nuclei.
2. The global estimation based on various Lorentzian model for all elements is performed;
3. The calculation for the competing photonuclear data is performed based on MEND-G and GUNF codes for light nuclei.



Scheme of photonuclear data evaluation at CNDC.

Reaction scheme

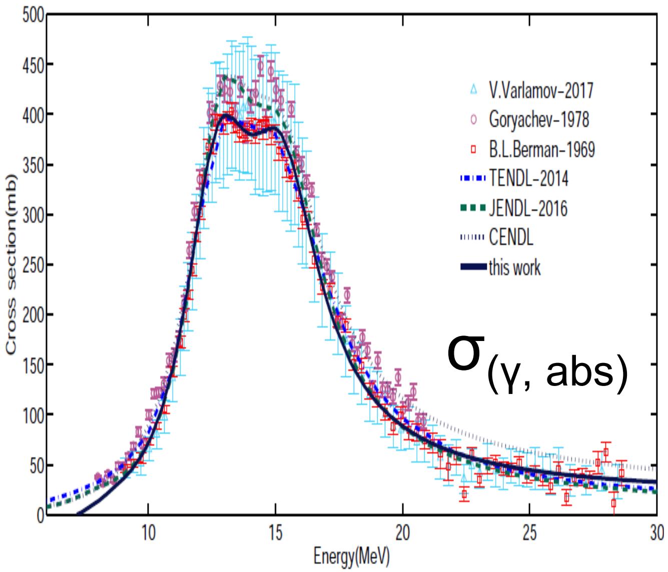
次数	Particles	Total reaction number
1	n,p,α,d,t,He-3	6
2	n,p,α,d,t,He-3	$6^2=36$
3	n,p,α,d,t,He-3	$6^3=216$
4	n,p,α,d,t,He-3	$6^4=1296$
5	n,p,α,d	6^4X4=5184
6	n,p,α,d	6^4X4^2=20736
7	n,p,α,d	6^4X4^3=82944
8	n,p,α	6^4X4^3X3=248832
9	n,p,α	6^4X4^3X3^2=746496
10	n,p,α	6^4X4^3X3^3=2239488
11	n,p	6^4X4^3X3^3X2=4478976
12	n,p	6^4X4^3X3^3X2^2=8957952
13	n,p	6^4X4^3X3^3X2^3=17915904
14	n,p	6^4X4^3X3^3X2^4=35831808
15	n,p	6^4X4^3X3^3X2^5=71663616
16	n,p	6^4X4^3X3^3X2^6=143327232
17	n,p	6^4X4^3X3^3X2^7=286654464
18	n,p	6^4X4^3X3^3X2^8=573308928

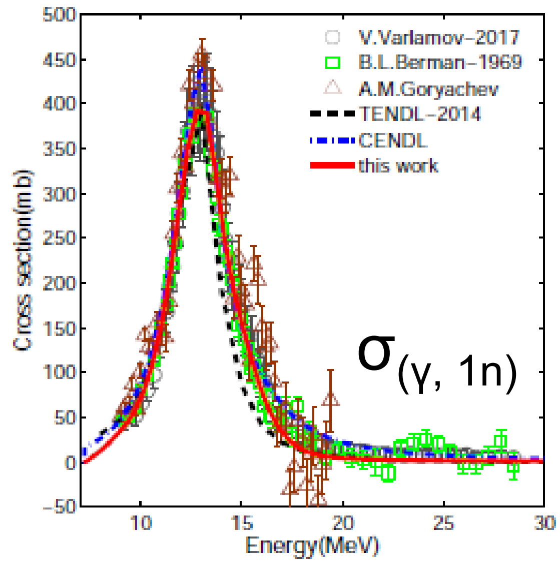
The evaluation for photonuclear data -W isotopes

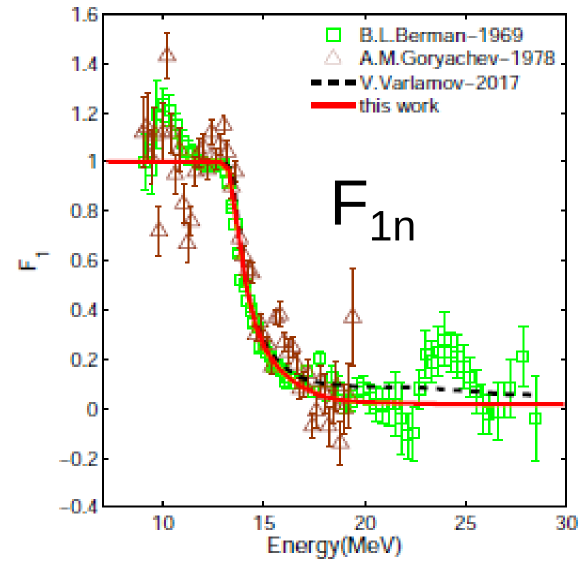
The experimental data of γ + ^{180,182,183,184,186}W

Nuclide	Author/Ref.	Reaction Type	Energy(MeV)	Year
^{182}W	G.M.Gurevich+	(γ, abs)	8.53 - 20.7	1981
	A.M.Goryachev+	(γ, n)+(γ, np)+(γ, 2n)	8.02 - 20.8	1978
^{184}W	G.M.Gurevich+	(γ, abs)	8.53 - 20.7	1981
	A.M.Goryachev+	(γ, x)n	9.0 - 19.4	1973
	A.M.Goryachev+	(γ, n)+(γ, np)+(γ, 2n)	8.02 - 20.8	1978
^{186}W	Berman+	(γ, x)n	9.1 - 28.5	1969
		(γ, x)n,unw.	9.1 - 28.5	1969
		(γ, n)+(γ, np)	9.1 - 28.5	1969
		(γ, 2n)+(γ, 2np)	9.1 - 28.5	1969
		(γ, 3n)	9.1 - 28.5	1969
	A.M.Goryachev+	(γ, x)n	9.0 - 19.4	1973
		(γ, x)n,unw.,deriv.	9.0 - 19.0	1973
	A.M.Goryachev+	(γ, n)+(γ, np)+(γ, 2n)	8.02 - 20.8	1978
	G.M.Gurevich+	(γ, abs)	8.67 - 19.7	1981
	P.Mohr+	(γ, n)	7.26 - 10.9	2004

Experimental data for γ + W isotopes are measured mainly for ^{186}W below 30MeV.

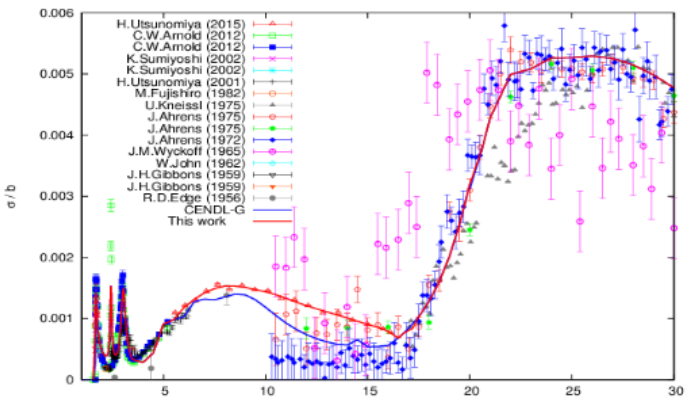




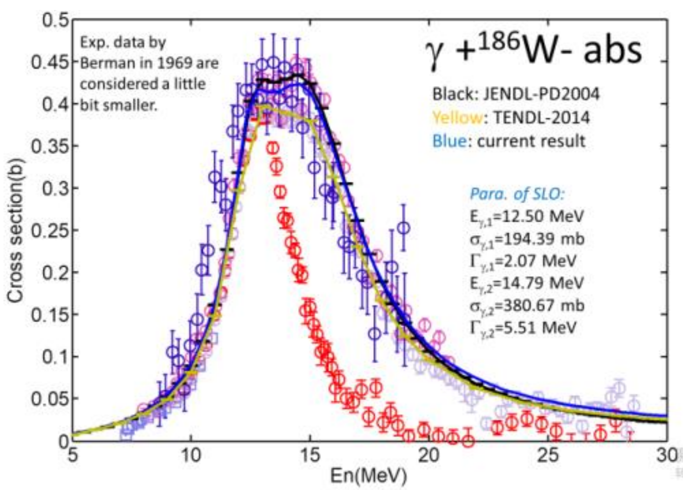


- The evaluated (γ, abs) with SMLO are based on the data by Berman and Varlamov's;
- The competing photonuclear reactions are calculated with MEND-G, and separate photon-neutron cross sections and physics criteria Fi are estimated.

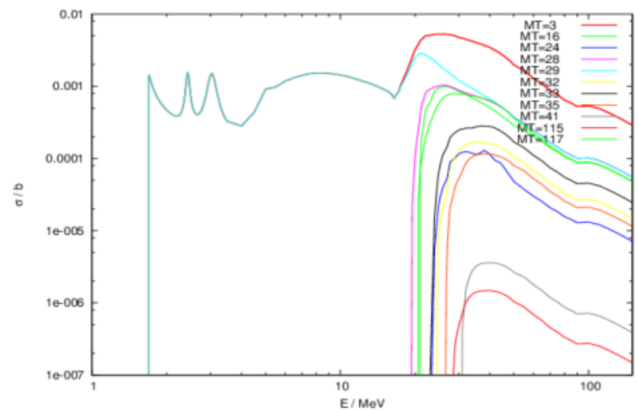
^{9}Be — ^{209}Bi 266 nuclei

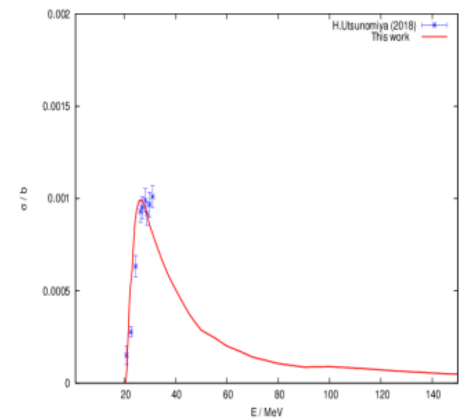


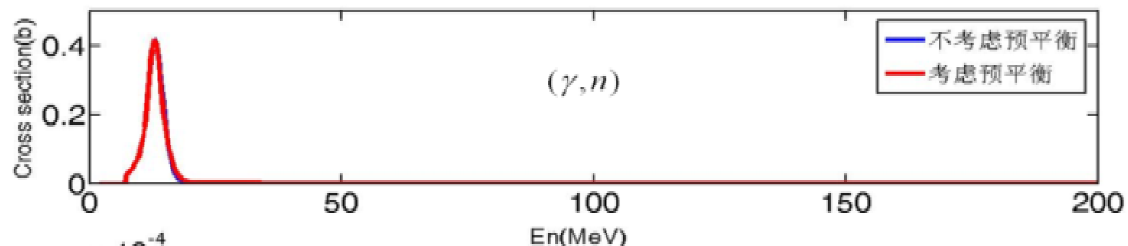
^{9}Be

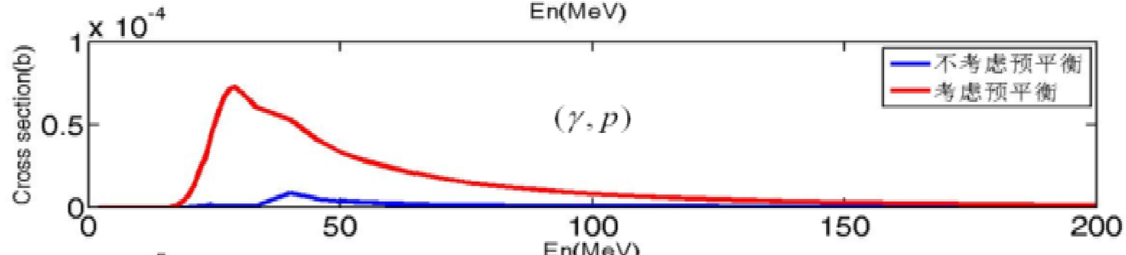


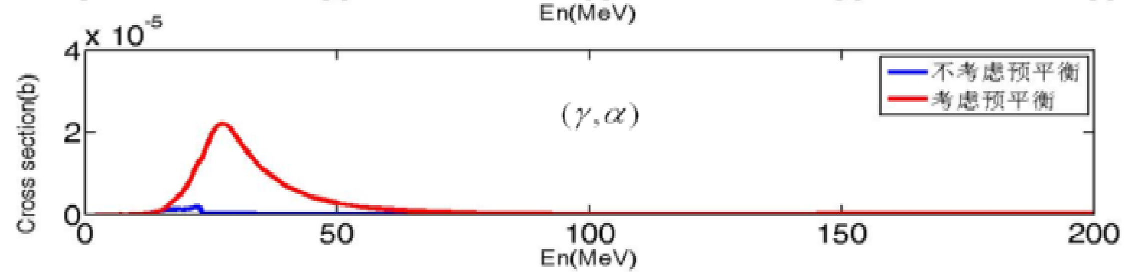
^{186}W





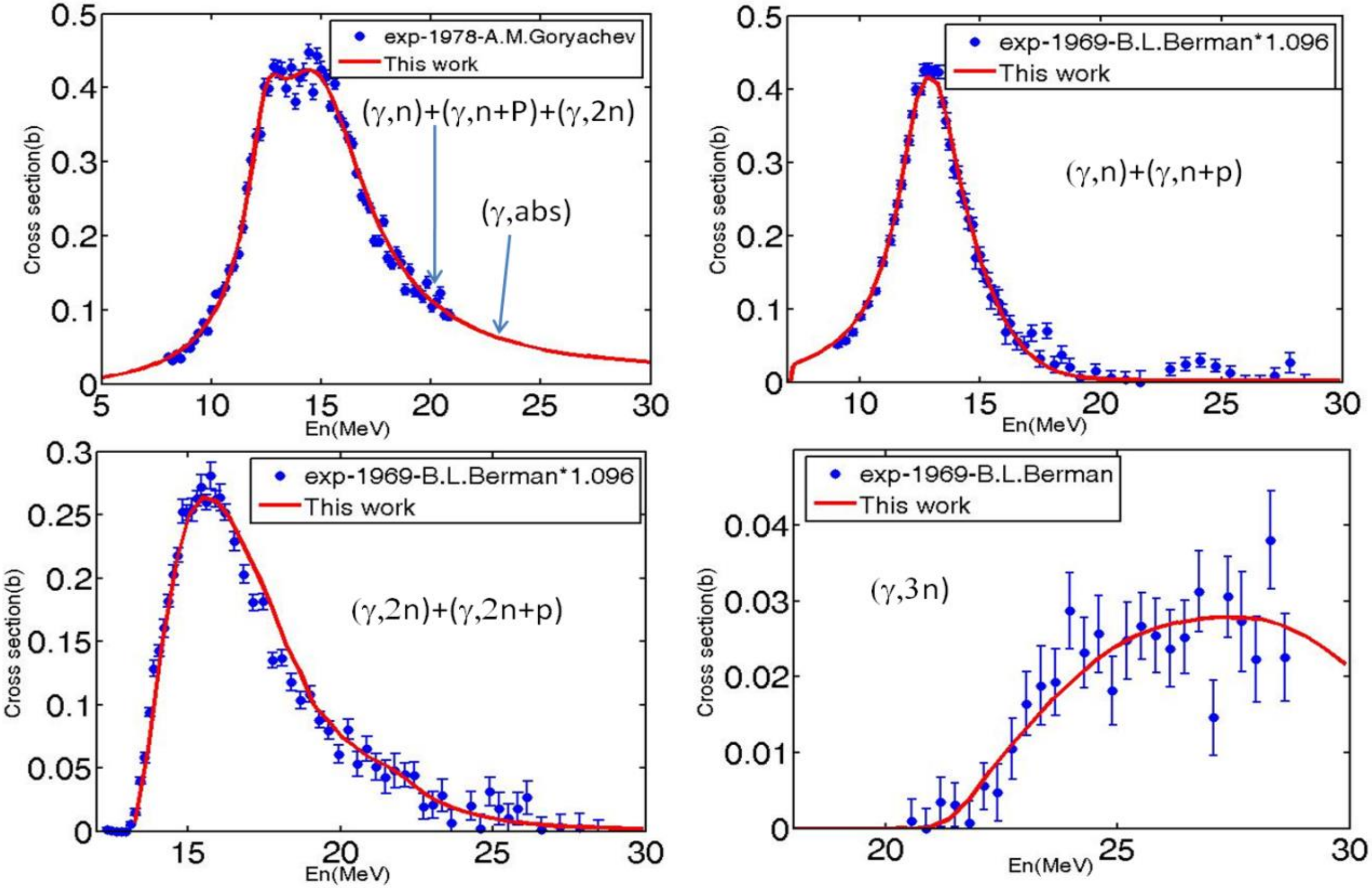






Single Lorentz formula+ GMEND parameters optimized

$\gamma + {}^{186}W$



Main neutron outgoing cal. results

LD Par.	**p \ n**	**1**	**2**	**3**
	0	**25.999000**	**15.031723**	**19.108256**
Pair Par.	**p \ n**	**1**	**2**	**3**
	0	**0.988**	**0.869**	**0.89**

III. Improvement of UNF code for medium heavy & and fission nuclei

A function of the batch calculations of UNF for the medium heavy nuclei has been added

Calculation system for FP nuclei (CENDL-3.1 to 3.2)	
sunf2unf.pl	Convert sunf->unf
Batchcal	Produce unf.newunf
batchmincard.pl	Auto-produce inputs SEMAW.in, DPPMI.in, Min.in，sys.dat, exp
Correctmin	Correct the energy margin of min.in
get14MevCSInl	Produce the direct reaction cross section based on
batchmincard14.pl	Adjust DWUCK para. to fit 14MeV
NDPlot	Plot the figures for 10 reactions

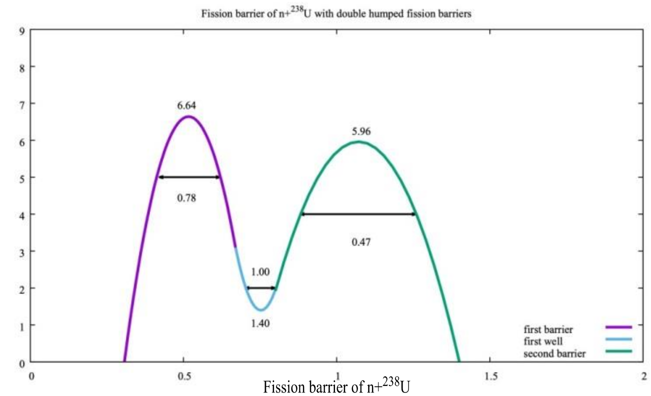
核素	输入卡	核素	输入卡	核素	输入卡	核素	输入卡
12-MG-24	UNF	32-GE-70	UNF	39-Y-89	SUNF	44-RU-102	SUNF
12-MG-25	UNF	32-GE-71	UNF	39-Y-91	SUNF	44-RU-103	SUNF
12-MG-26	UNF	32-GE-72	UNF	40-ZR-90	UNF	44-RU-104	SUNF
14-SI-28	UNF	32-GE-73	UNF	40-ZR-91	UNF	44-RU-105	SUNF
20-CA-40	UNF	32-GE-74	UNF	40-ZR-92	UNF	44-RU-99	SUNF
22-TI-46	UNF	32-GE-75	UNF	40-ZR-93	SUNF	45-RH-103	SUNF
22-TI-47	UNF	32-GE-76	UNF	40-ZR-94	UNF	45-RH-105	SUNF
22-TI-48	UNF	32-GE-77	UNF	40-ZR-95	SUNF	46-PD-105	SUNF
22-TI-49	UNF	32-GE-78	UNF	40-ZR-96	UNF	46-PD-108	SUNF
22-TI-50	UNF	33-AS-75	UNF	41-NB-93	SUNF	48-CD-113	SUNF
28-NI-58	UNF	33-AS-77	UNF	41-NB-95	SUNF	49-IN-113	UNF
28-NI-60	UNF	33-AS-79	UNF	42-MO-100	UNF	49-IN-115	UNF
28-NI-61	UNF	36-KR-83	SUNF	42-MO-92	UNF	51-SB-121	SUNF
28-NI-62	UNF	36-KR-84	SUNF	42-MO-94	UNF	51-SB-123	SUNF
28-NI-64	UNF	36-KR-85	SUNF	42-MO-96	UNF	51-SB-125	UNF
29-CU-63	UNF	36-KR-86	SUNF	42-MO-98	UNF	52-TE-130	SUNF
29-CU-65	UNF	38-SR-88	SUNF	43-TC-99	SUNF	53-I-127	SUNF
31-GA-69	UNF	38-SR-89	SUNF	44-RU-100	SUNF	53-I-129	UNF
31-GA-71	UNF	38-SR-90	SUNF	44-RU-101	SUNF	53-I-135	SUNF

核素	输入卡	核素	输入卡	核素	输入卡
54-XE-123	SUNF	57-LA-139	SUNF	62-SM-149	SUNF
54-XE-124	SUNF	58-CE-141	SUNF	62-SM-150	SUNF
54-XE-129	SUNF	58-CE-144	SUNF	62-SM-151	SUNF
54-XE-131	SUNF	59-PR-141	SUNF	62-SM-152	SUNF
54-XE-132	SUNF	60-ND-142	SUNF	62-SM-154	SUNF
54-XE-134	SUNF	60-ND-143	SUNF	63-EU-151	SUNF
54-XE-135	SUNF	60-ND-144	SUNF	63-EU-153	SUNF
54-XE-136	SUNF	60-ND-145	SUNF	63-EU-154	SUNF
55-CS-133	SUNF	60-ND-146	SUNF	63-EU-155	SUNF
55-CS-134	SUNF	60-ND-147	SUNF	64-GD-152	SUNF
55-CS-135	SUNF	60-ND-148	SUNF	64-GD-154	SUNF
55-CS-137	SUNF	60-ND-150	SUNF	64-GD-155	SUNF
56-BA-130	SUNF	61-PM-147	SUNF	64-GD-156	SUNF
56-BA-132	SUNF	61-PM-148	SUNF	64-GD-157	SUNF
56-BA-134	SUNF	61-PM-148m	UNF	64-GD-158	SUNF
56-BA-135	SUNF	61-PM-149	SUNF	64-GD-160	SUNF
56-BA-136	SUNF	62-SM-144	SUNF	66-DY-164	SUNF
56-BA-137	SUNF	62-SM-147	SUNF		
56-BA-138	SUNF	62-SM-148	SUNF		

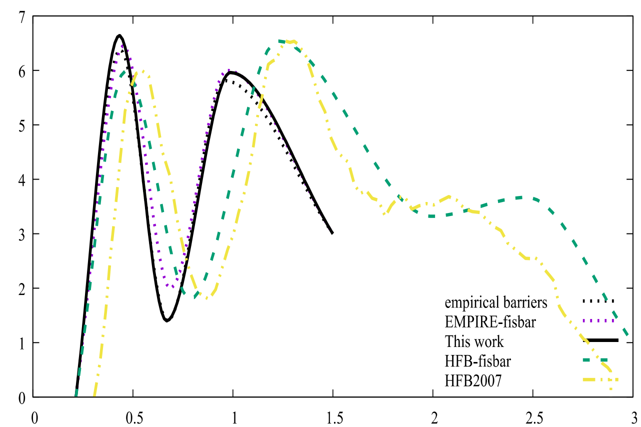
New fission reaction code — FUNF-2020

\+ Multi-humped fission

The multiple humped fission barrier((phenomenological) , have successfully incorporated recently into nuclear reaction code FUNF-2020, and some preliminary results for n+238U are obtained based on this code, FUNF-2020 will be used for the actinides modeling in our future neutron data evaluation according to the present results



$n+^{238}U$



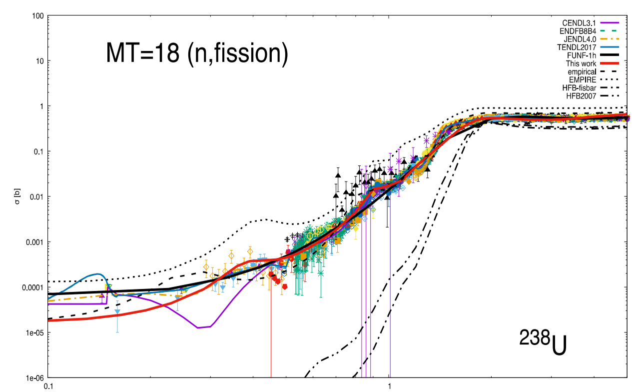
The chief model parameters are listed as follows:

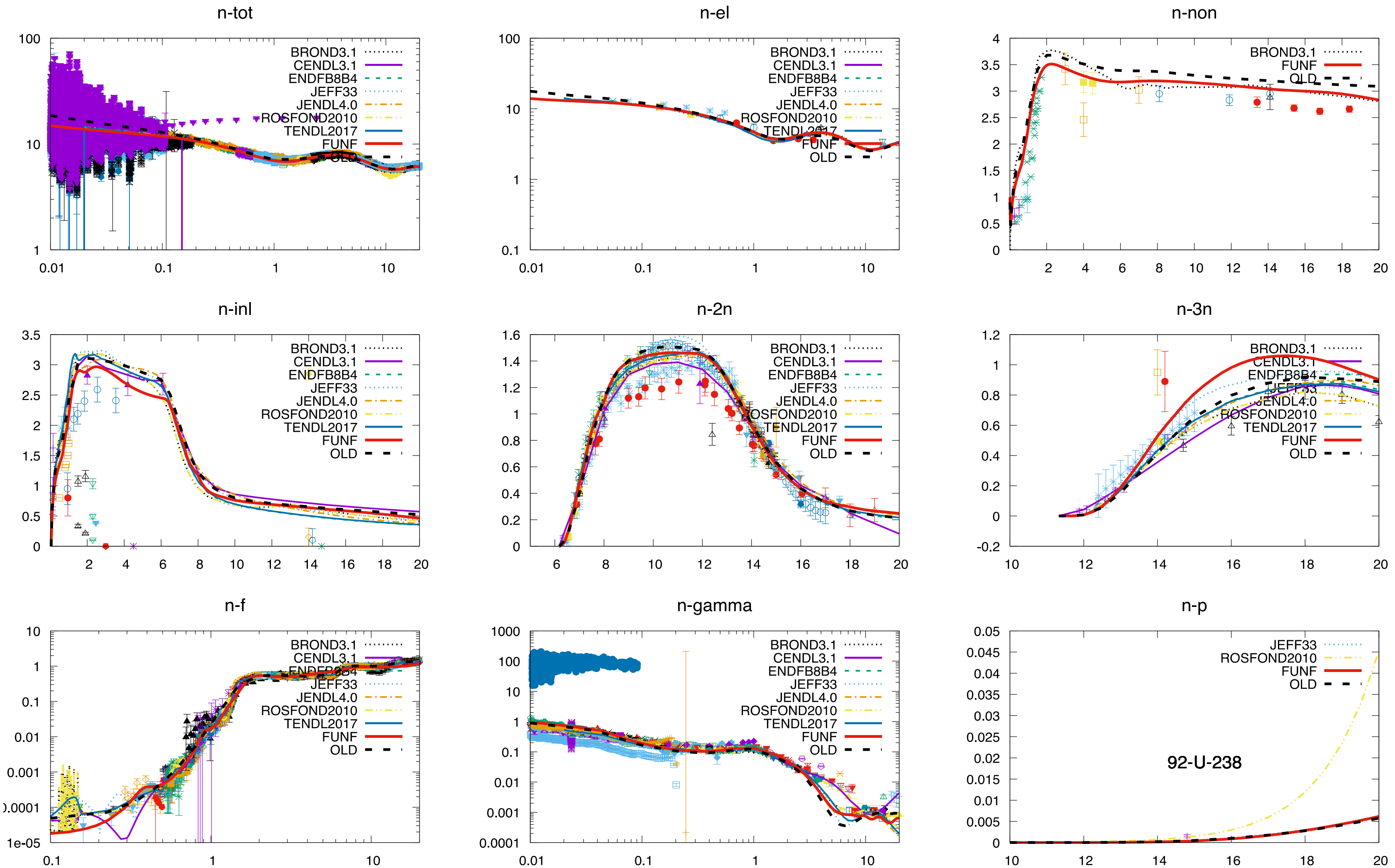
	n,inl	n,2n	n,3n	n,gamma
Level Density	23.87	28.62	31.73	28.16
Paring Correction	0.409	0.201	0.0283	0.0283

Table 1 The parameter of level density and pairing correction for (n,inl), (n,2n), (n,3n) and (n,gamma) channels

	Height	Width	Level density	Pairing correction
(n,f) inner	6.64	0.78	34.77	-0.997
(n,f) outer	5.96	0.47	26.83	-0.149
(n,f) well	1.40	1.00		
(n,nf)	5.13	0.15	25.10	1.014
(n,2nf)	6.07	1.39	41.39	0.560

Table 2 The parameters of fission barriers and level density for (n,f), (n,nf) and (n,2nf) channels.

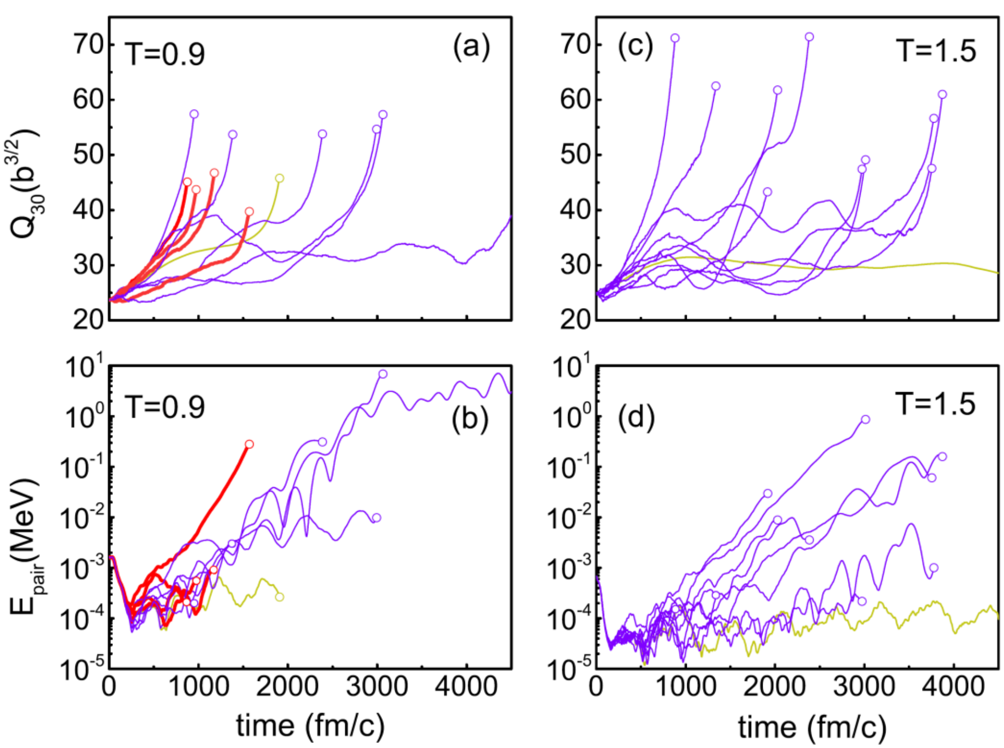


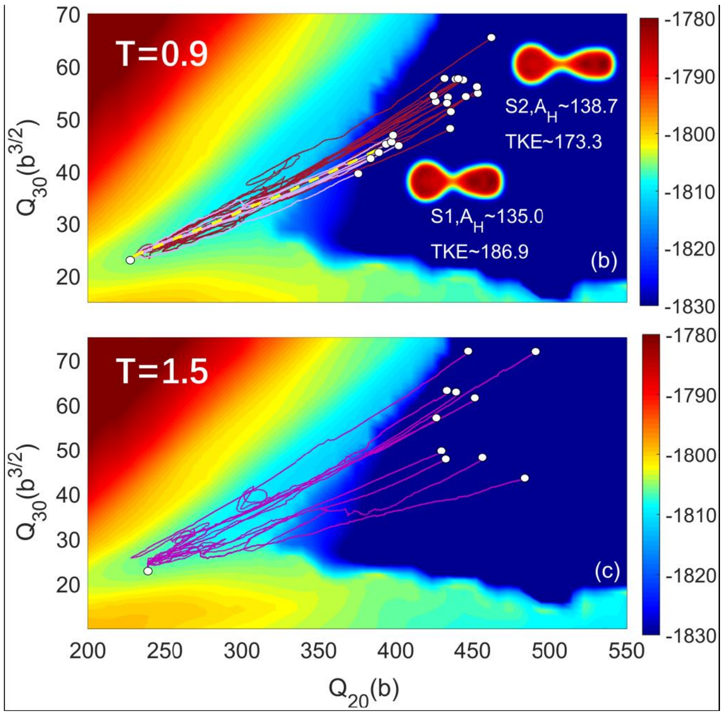


The major cross section for n+^{238}U as a function of neutron energy. The experimental data taken from EXFOR. The red solid line is the new result, and the black dashed line is our previous result using a single-humped fission barrier. The evaluated data from ENDF/B-VIII.0, JENDL-4.0 and JEFF-3.3 are also compared in the figures.

IV. Fundamental theory study for fission data

The real-time fission dynamics from low-energy to high excitations in the compound nucleus ^{240}Pu with the TD-Hartree-Fock + BCS +thermal fluctuations was studied.





At high excitations, the random thermal fluctuations is indispensable to drive fission.

The obtained FY and TKE with fluctuations can be divided into two asymmetric scission channels, namely, S1 and S2, which explain well experimental results and give microscopic support to the Brosa model.

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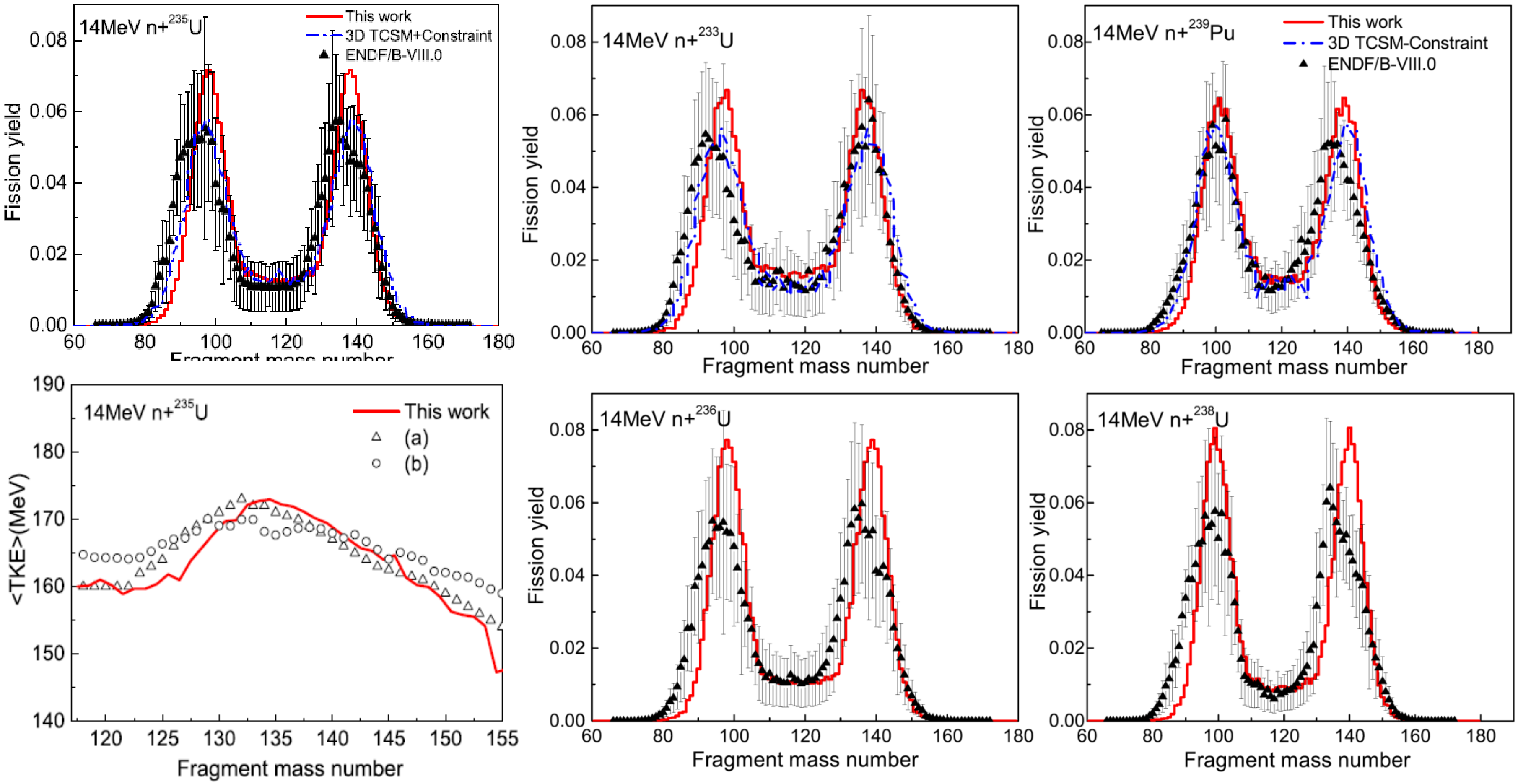
The Langevin approach is extendedly applied to study the dynamical process of nuclear fission within the Fourier shape parametrization.



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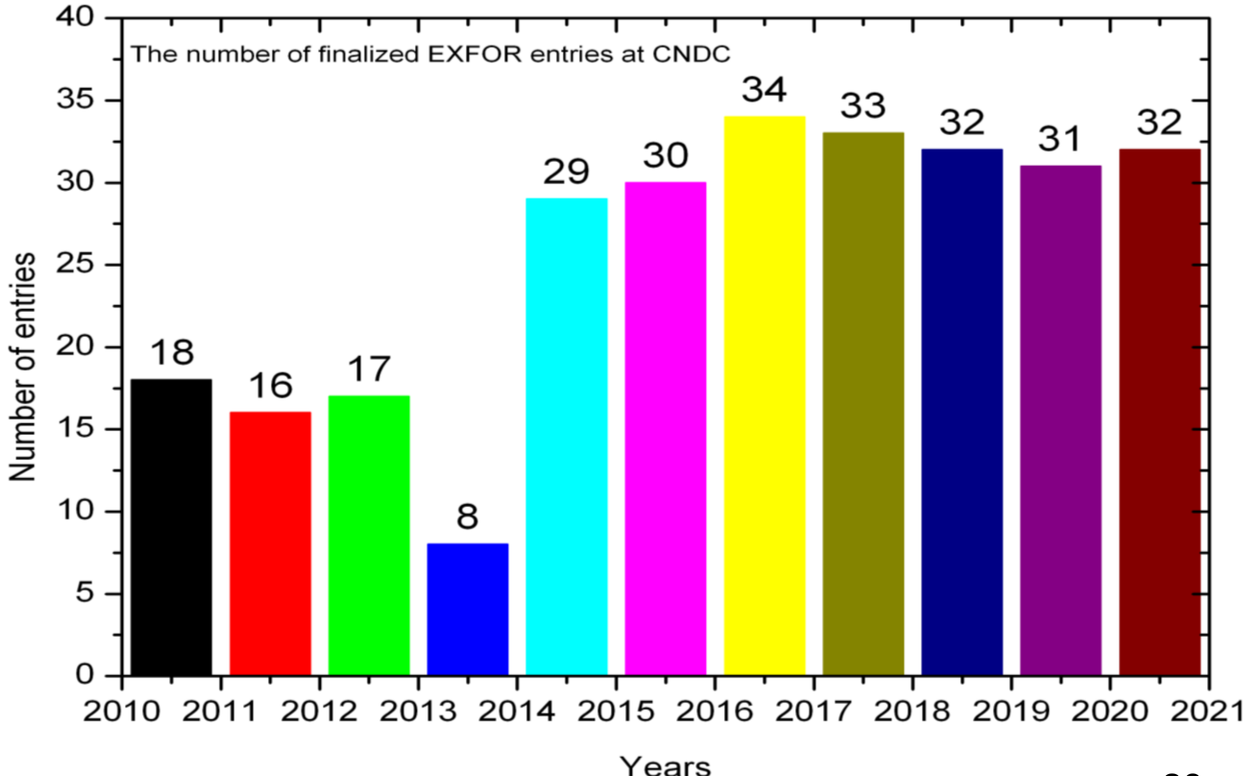
IV. EXFOR activities

- **Compilation**

➢ more than 410 entries were compiled at CNDC. Since 2010, more than 280 entries were finalized, which included 142 neutron and 138 charged particle entries. Feedback and correction performed for more than 100 entries.

➢ Since the last NRDC meeting (April 2019), 63 new entries have been finalized and 26 entries have been revised, more than 87 articles under compiling.



Thank you for your attention !
Comments and suggestion welcome !