CENDL STATUS AND UPDATES

GE Zhigang

China Nuclear Data Center(CNDC)
China Nuclear Data Key Laboratory
China Committee of Nuclear Data(CCND)
China Institute of Atomic Energy(CIAE)
P.O.Box 275-41,Beijing 102413, P.R.China
E-Mail:gezg@ciae.ac.cn

Presentation for the 32nd Meeting of the NEA WPEC. 14-15 May 2020 by WebEx

1. Introduction of CENDL Project

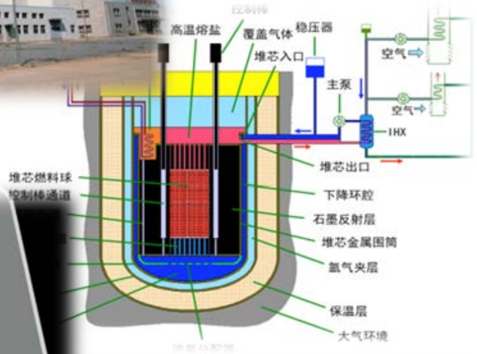
CENDL library and CENDL Project

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)

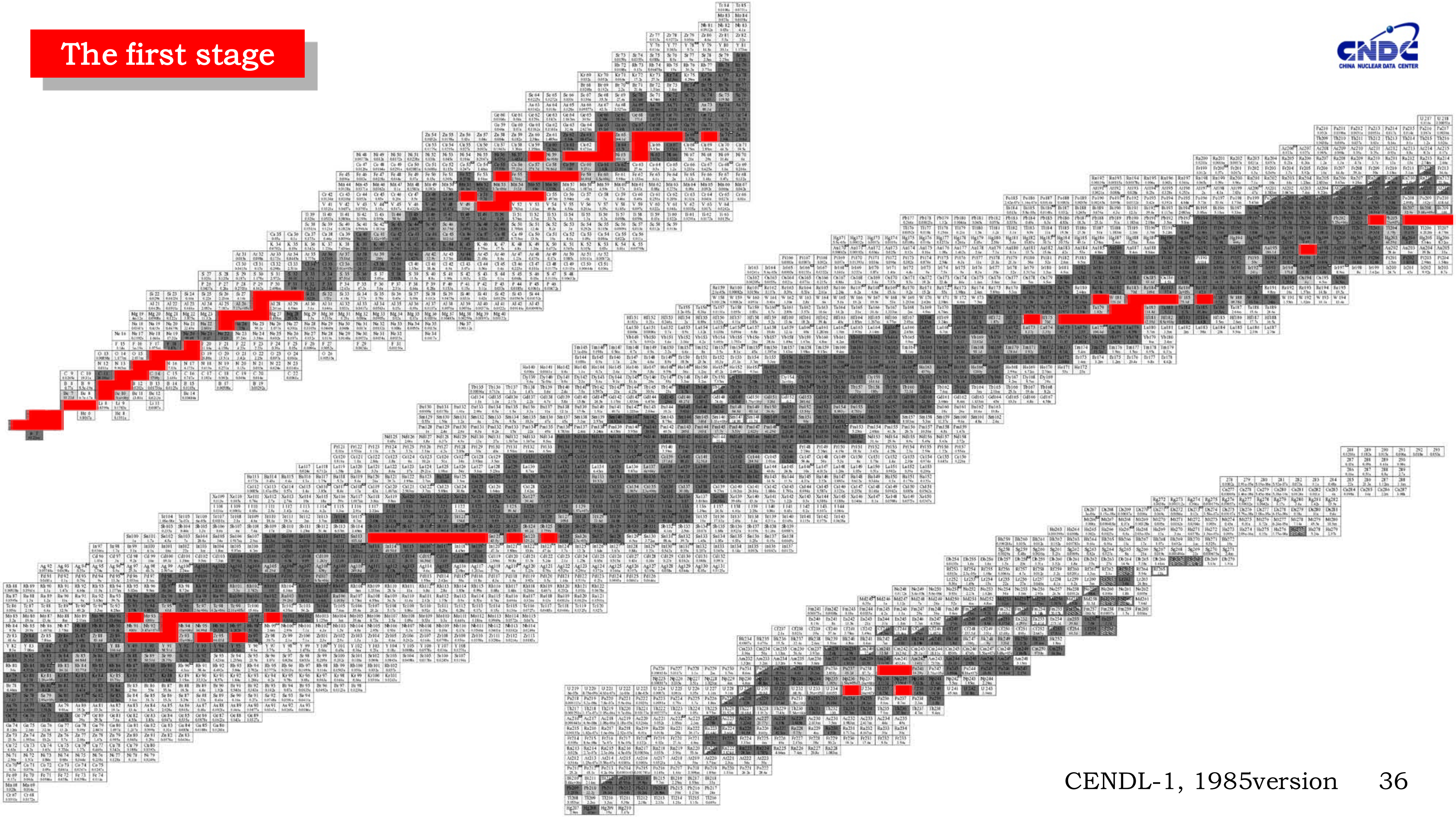
CENDL-1, 1985version 36
CENDL-2, 1992version 68
CENDL-3, 2000version 214
CENDL-3.1 2009 version 245
CENDL-3.2 2020 version 270 (May, 2020)

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



Motivated by fulfill the requirement of domestic users, a new revision of Chinese Evaluated Nuclear Data Library, CENDL3.2 has been started under the joint efforts of CENDL working group since 2010.

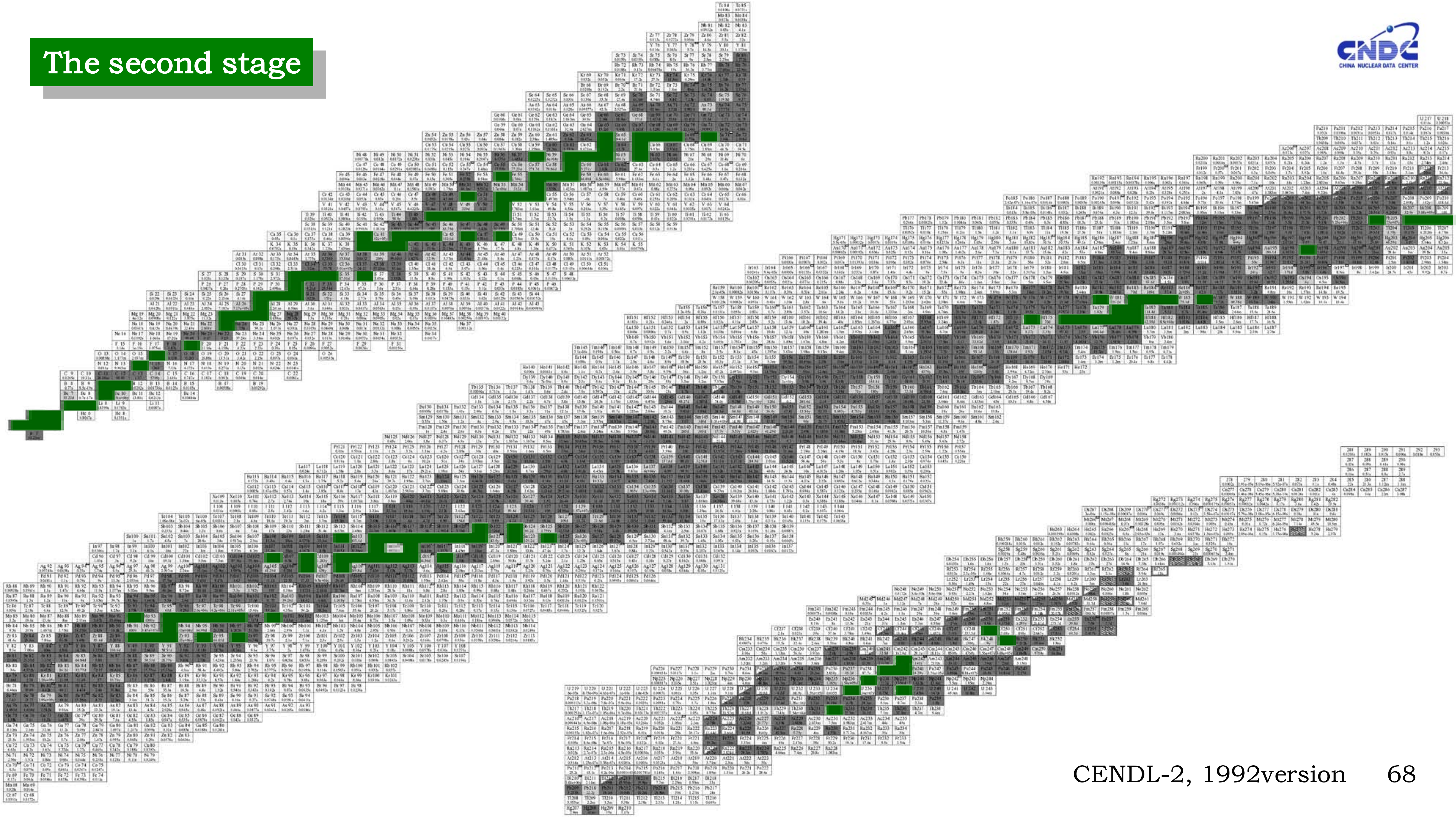
The first stage



CENDL-1, 1985version

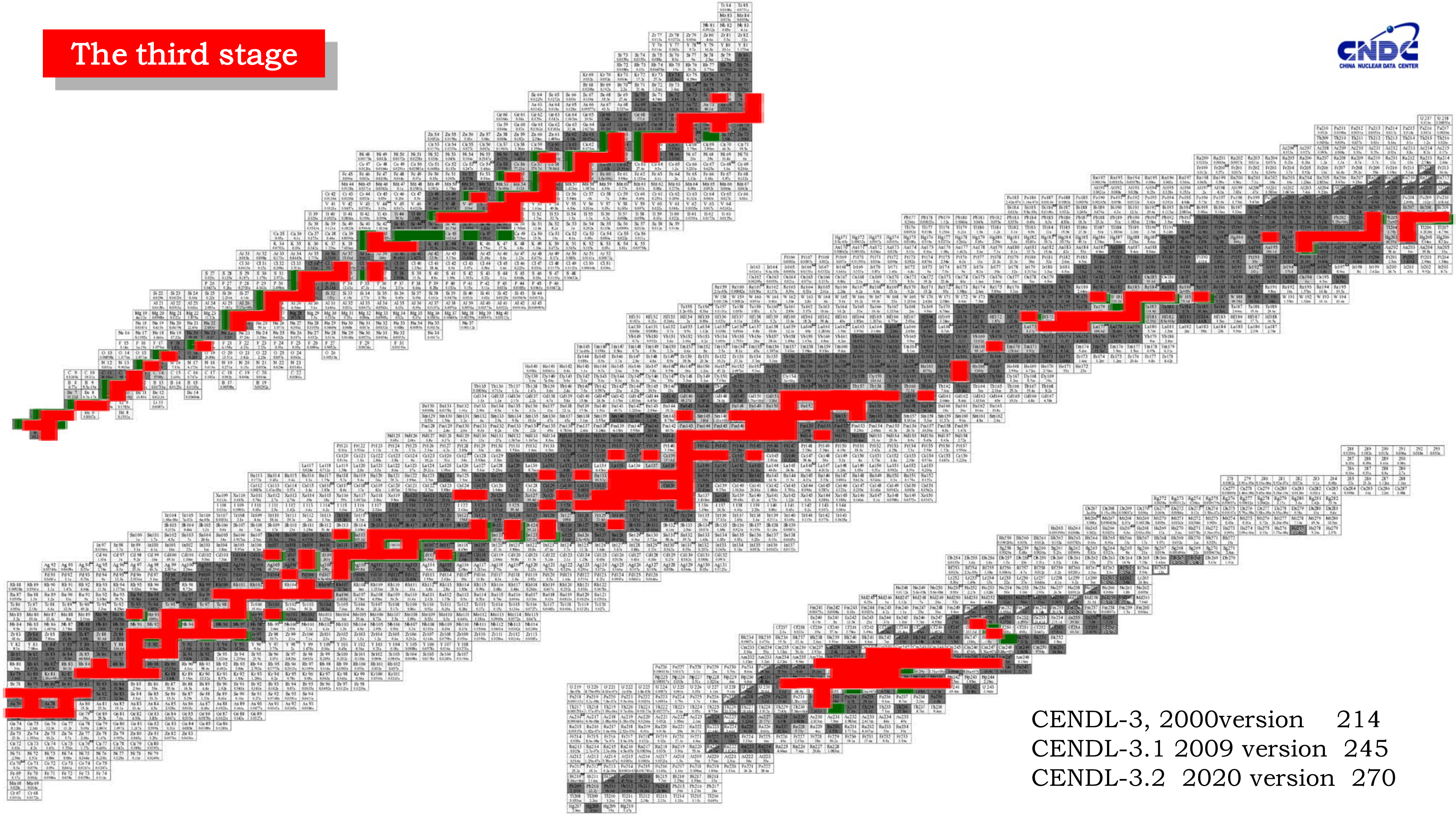
The second stage

CHINA NUCLEAR DATA CENTER



CENDL-2, 1992version

The third stage



CENDL-3, 2000version 214
CENDL-3.1 2009 version 245
CENDL-3.2 2020 version 270

2. The View of CENDL-3.2

Nucl.	Content of Nuclei in CENDL-3.2 (270)
Light Elements	n-1, $^{1\text{-}3}$H, ^{3,4}He, ^{6,7}Li, ^{9}Be, ^{10,11}B, ^{12}C, ^{14}N, ^{16}O, ^{19}F
Structural Materials	^{23}Na, $^{24\text{-}26}$Mg, ^{27}Al, $^{28\text{-}30}$Si, ^{31}P, ^{32,33,34,36}S, ^{0}Cl, ^{0}K, ^{40}Ca, $^{46\text{-}50}$Ti, ^{0}V, $^{50,52\text{-}54}$Cr, ^{55}Mn, $^{54,56\text{-}58}$Fe, ^{59}Co, $^{58,60\text{-}62,64}$Ni, ^{0,63,65}Cu, $^{64,66\text{-}68,70}$Zn, $^{90\text{-}92,94,96}$Zr, $^{92\text{-}100}$Mo, ^{0,107,109}Ag, $^{174,176\text{-}180}$Hf, ^{181}Ta, ^{180,182,183,184,186}W, ^{197}Au, ^{0}Hg, ^{0}Tl, $^{204,206\text{-}208}$Pb, ^{209}Bi
Fission Products & Medium Elements	^{69,71}Ga, $^{0,70\text{-}78}$Ge, ^{75,77,79}As, $^{74,76\text{-}80,82}$Se, ^{83,84,85,86,87,88}Kr, ^{85,87}Rb, $^{88\text{-}90}$Sr, ^{89,91}Y, ^{93,95}Zr, ^{93,95}Nb, ^{99}Tc, $^{99\text{-}105}$Ru, ^{103,105}Rh, ^{105,108}Pd, ^{0,113}Cd, ^{113,115}In, $^{112,114\text{-}120,122,124,125}$Sn, $^{121\text{-}127}$Sb, ^{130}Te, $^{127,129\text{-}131,135}$I, $^{123,124,129,131\text{-}136}$Xe, $^{133\text{-}135,137}$Cs, $^{130,132,134\text{-}138}$Ba, ^{139}La, $^{136,138,140\text{-}142,144}$Ce, ^{141}Pr, $^{142\text{-}148,150}$Nd, ^{147,148,148m,149}Pm, $^{144,147\text{-}152,154}$Sm, $^{151,153\text{-}155}$Eu, $^{152,154\text{-}158,160}$Gd, ^{164}Dy, ^{165}Ho
Actinides	^{232}Th, $^{232\text{-}241}$U, $^{236\text{-}239}$Np, $^{236\text{-}246}$Pu, $^{240\text{-}244,242m}$Am, ^{249}Bk, ^{249}Cf

2. The View of CENDL-3.2

Mass regions	The new evaluation and updation in CENDL-3.2
Light Elements (5)	n-1, ^{1,2}H, ^{6,7}Li
Structural Materials (22)	^{23}Na, ^{24}Mg, ^{27}Al, ^{32,33,34,36}S, ^{40}Ca, ^{56}Fe, ^{58}Ni, $^{64,66\text{-}68,70}$Zn, ^{93,99}Mo, ^{180,182,183,184,186}W
Fission Products & Medium Elements (30)	$^{74,76\text{-}81}$Se, ^{87,88}Kr, ^{93}Nb, ^{125}Sn, ^{124,126,127}Sb, ^{130,131}I, $^{123,124,129,131\text{-}133,134\text{-}136}$Xe, ^{139}La, $^{140\text{-}142,144}$Ce, ^{165}Ho
Actinides (15)	^{232}Th, $^{233,235\text{-}237,239\text{-}241}$U, ^{236,238}Np, ^{238,239,240,241}Pu, ^{241}Am

1、The total number of CENDL is 270. 75 evaluated and calculated covariance files including.
- ✓ 72 nuclides are newly evaluated and updated in CENDL-3.2;
- ✓ the key elements are revised based on CENDL-3.1, including the key elements **^{235}U, ^{239}Pu, ^{233}U, ^{232}Th, ^{56}Fe, ^{1}H;**
- ✓ Covariance are systematically updated for 70 fission product nuclei.

2、The incident neutron energy $E_n \leqslant 20$MeV;

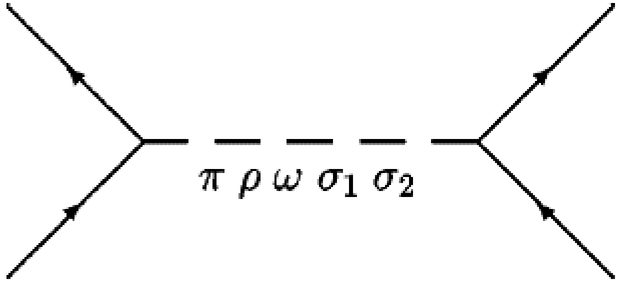
3、MF contains 1, 2, 3, 4, 5, 6, 12, 14, 15, 33.

3. CENDL-3.2 - light nuclei : n-n & n-p

Light mass: n-n & n-p data based on the microscopic N-N interaction

High precision NN potential fits about 6000 pp and np data with $\chi^2 \sim 1.0$.

CD-Bonn meson exchange nuclear force is able to explain CIB and CSB.
Low energy pp, nn and np scattering in ${}^1S_0$ channel, their a and r almost identify.



$$a_{pp} = -17.3 \pm 0.4 \text{ fm} \quad a_{nn} = -18.9 \pm 0.4 \text{ fm} \quad a_{np} = -23.74 \pm 0.02 \text{ fm}$$
$$r_{pp} = 2.85 \pm 0.04 \text{ fm} \quad r_{nn} = 2.75 \pm 0.11 \text{ fm} \quad r_{np} = 2.77 \pm 0.05 \text{ fm}$$

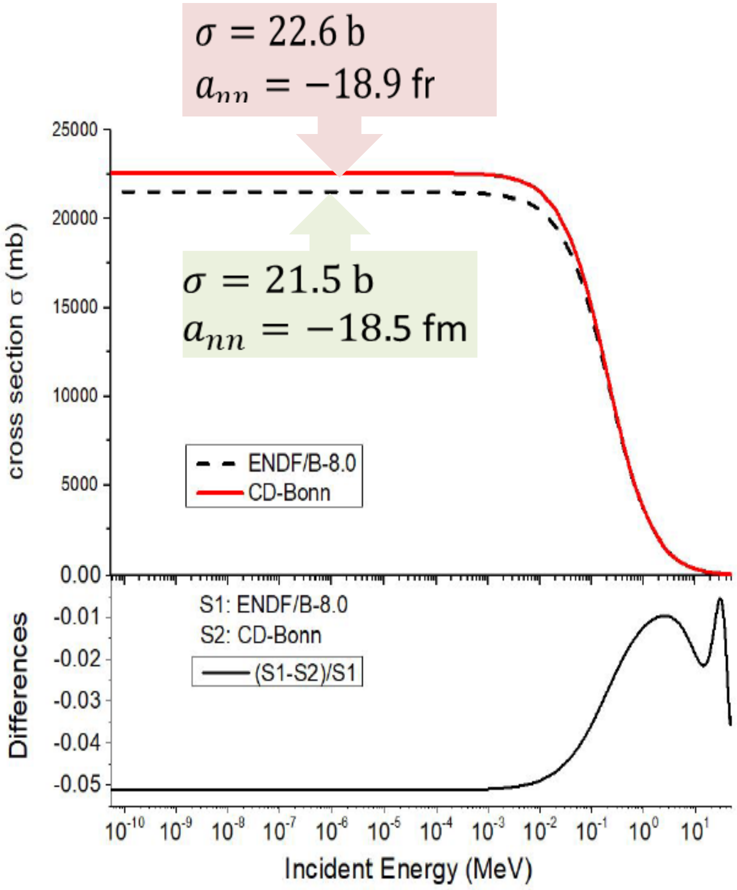
1. Solving Lippmann-Schwinger equation in momentum space to obtain phase shift δ_{lj} .
2. For spin triplet $S = 1$, coupling orbit L and spin S to provide J. 6 summation must be taken into account.

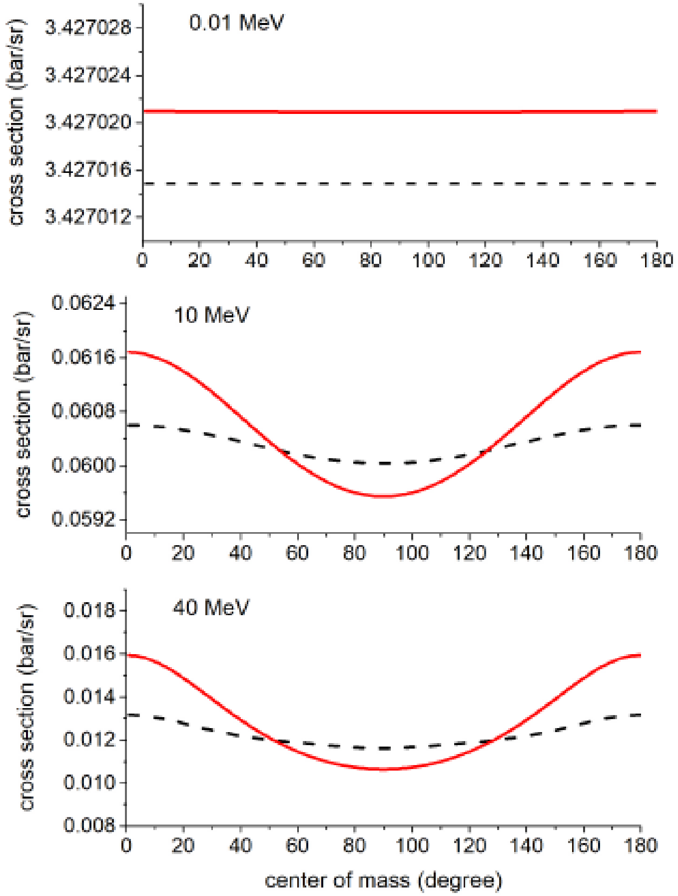
$$\frac{d^3\sigma(\theta)}{d\Omega} = \frac{1}{3k^2}\sum_{J_1}\sum_{l_1}\sum_{l_1'}\sum_{J_2}\sum_{l_2}\sum_{l_2'} i^{-l_1+l_1'+l_2-l_2'}\left(1 - S^{J_1}_{l_1' l_1}\right)^*\left(1 - S^{J_2}_{l_2' l_2}\right)K(J_1 l_1 l_1', J_2 \ldots$$

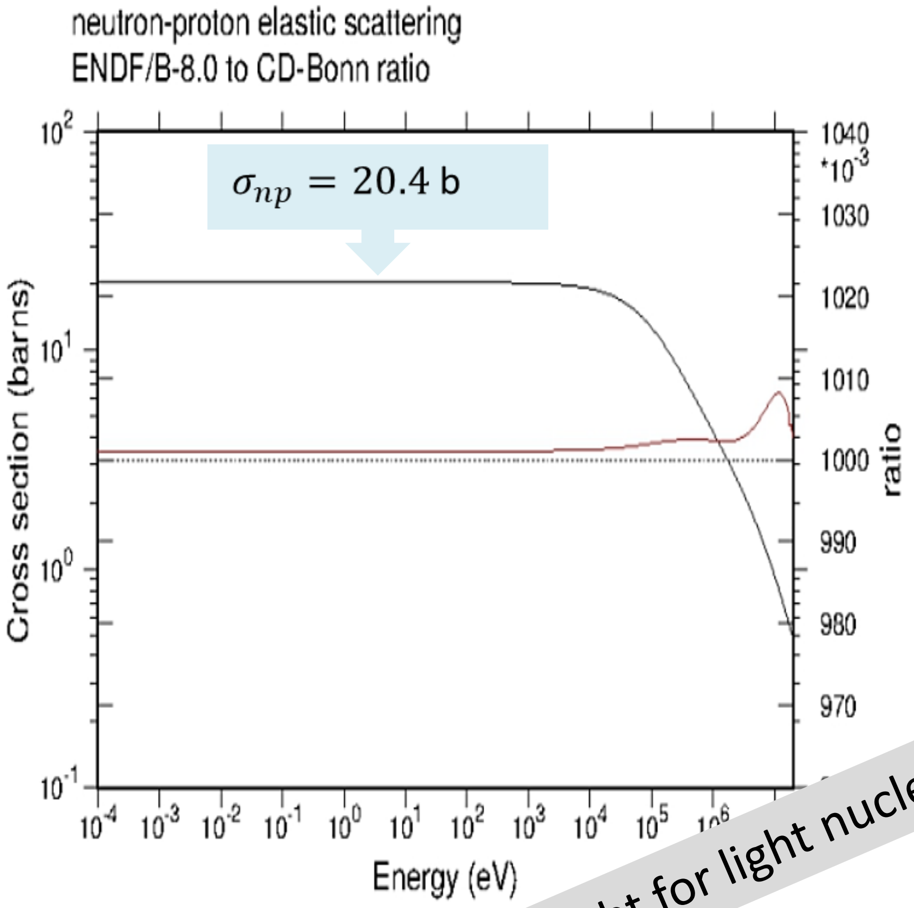
Highlight for light nuclei:

nn and np data in CENDL3.2

Comparisons of nn and np scattering cross section between ENDF/B-8.0 and CENDL-3.2





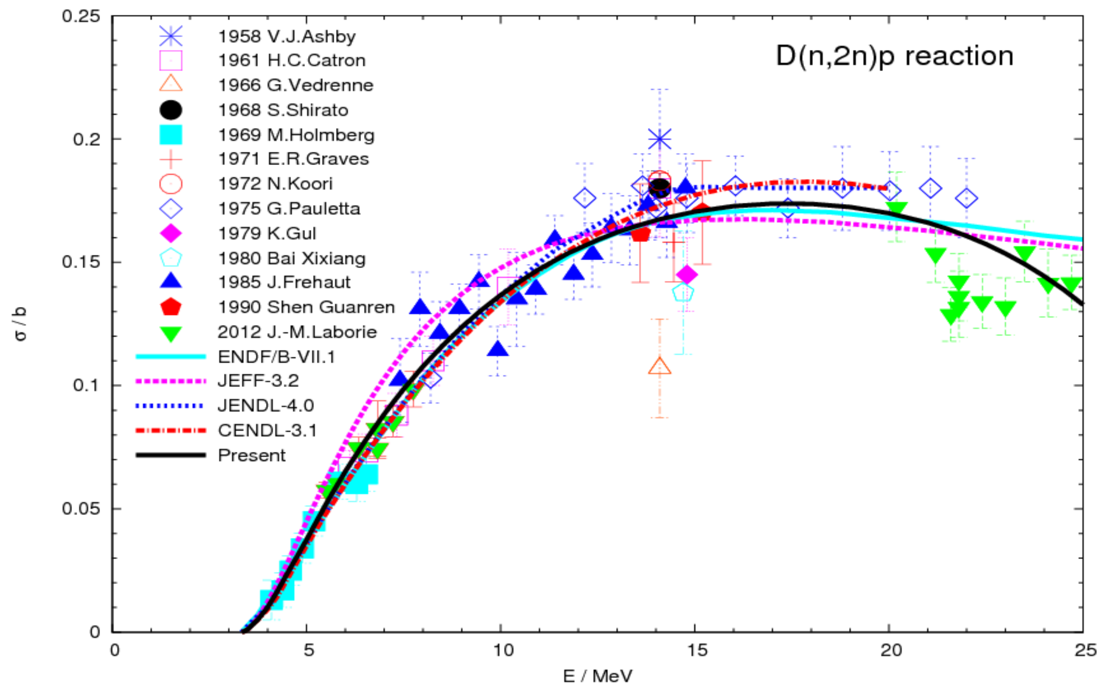


Highlight for light nuclei:

3. CENDL-3.2 - light nuclei : n-d

$$n + {}^{2}\mathrm{H}\ (\mathrm{D}) \rightarrow n + {}^{2}\mathrm{H}\ (\mathrm{D}) \quad \text{(n, el)}$$
$$\rightarrow 2n + p \quad \text{(n, 2n)}$$
$$\rightarrow \gamma + {}^{3}\mathrm{H}\ (\mathrm{T}) \quad \text{(n, γ)}$$

$$\sigma_{tot} = \sigma_{n,n} + \sigma_{n,2n} + \sigma_{n,\gamma}$$



CENDL-3.1 is adopted in CENDL-32

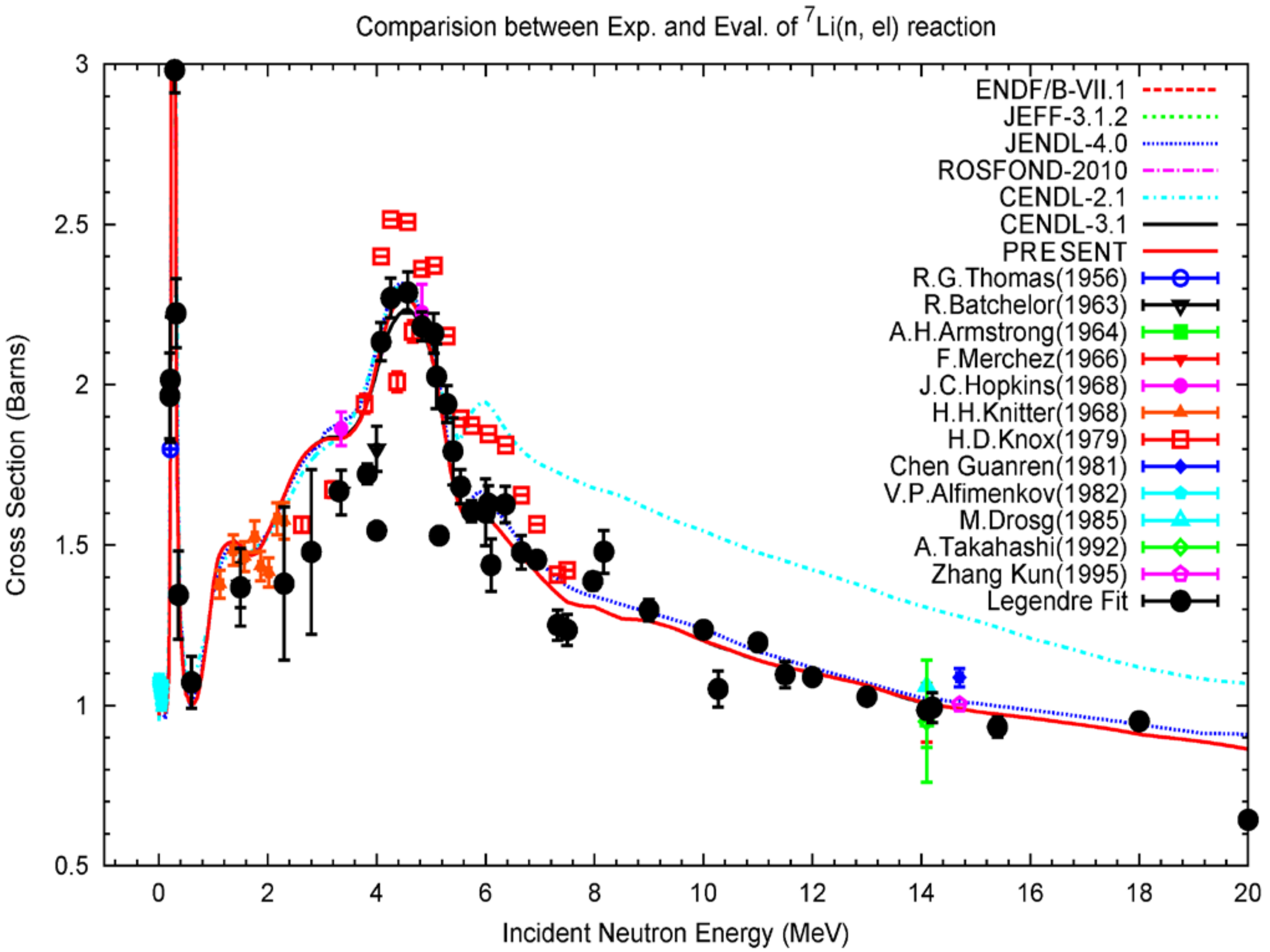
D(n,2n)p is updated considering the new experimental data:

J.M.Laborie, X.Ledoux, C.Varignon, et al. Measurement of the nutron-induced deuteron breakup reaction cross section between 5 and 25 MeV [J]. The European Physical Journal A: Hadrons and Nuclei, 2012, 48(6): 87-99. EXFOR 23036.

13 sets of experimental data are measured by **TOF and STANK,** considering the technique of particle identification to separate the proton and deuteron

3. CENDL-3.2 - light nuclei : n+^{7}Li

Experimental data evaluation are performed, and some reaction cross sections and angular distributions of neutron elastic scattering of ^{6,7}Li are updated.



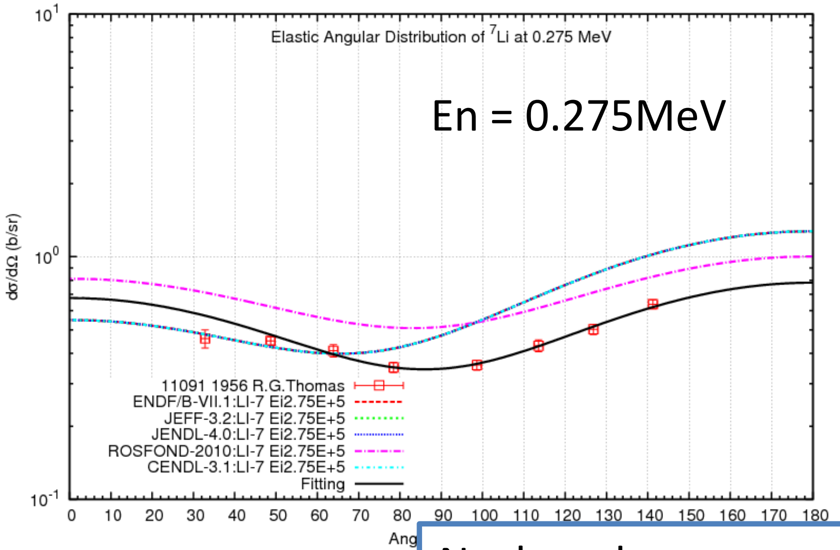
CENDL-3.1 is adopted in CENDL-32

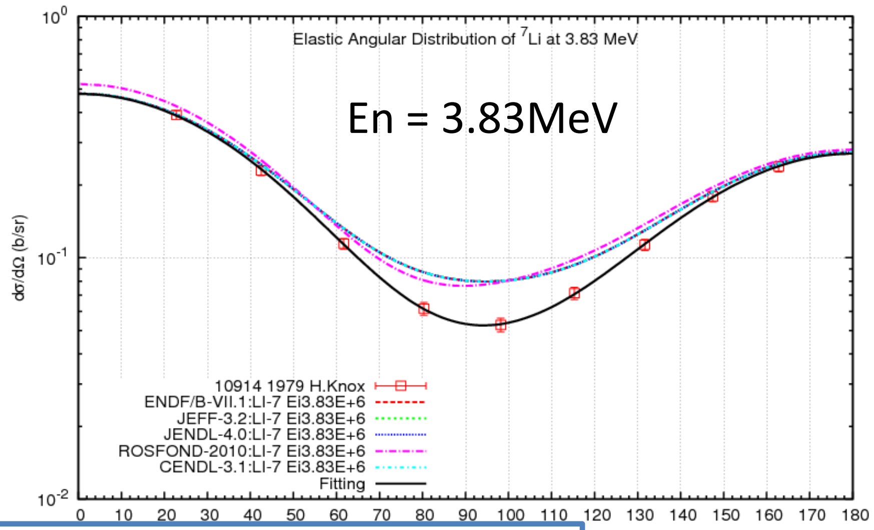
^{7}Li(n,el), (n,nt), (n,g) are updated via the new experimental data:

Channels	Q values
$\gamma+{}^{8}Li$	2.033
$n'+{}^{7}Li^{*}$	-0.4776
$d+{}^{6}He$	-7.750
$t+{}^{5}He$	-3.3362
$2n+{}^{6}Li$	-7.2490
$n,p+{}^{6}He$	-9.9740
$n,d+{}^{5}He$	-9.618
$n+t+\alpha$	-2.476
$2n,p+{}^{5}He$	-11.842
$2n+d+\alpha$	-8.724

$\sigma_{(n,\,el)}$ is derived through Legendre polynomial function fitting to the experimental data of $d\sigma/d\omega$.

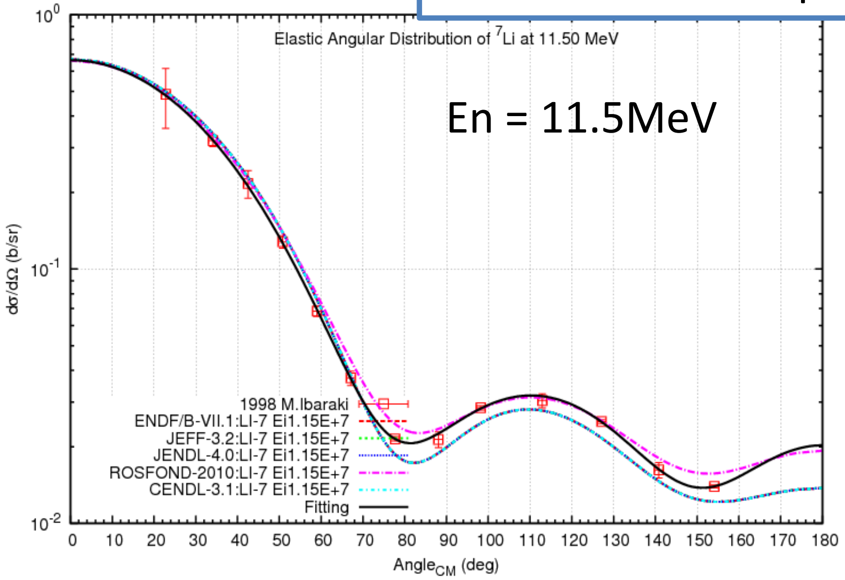
3. CENDL-3.2 - light nuclei : n+^{7}Li

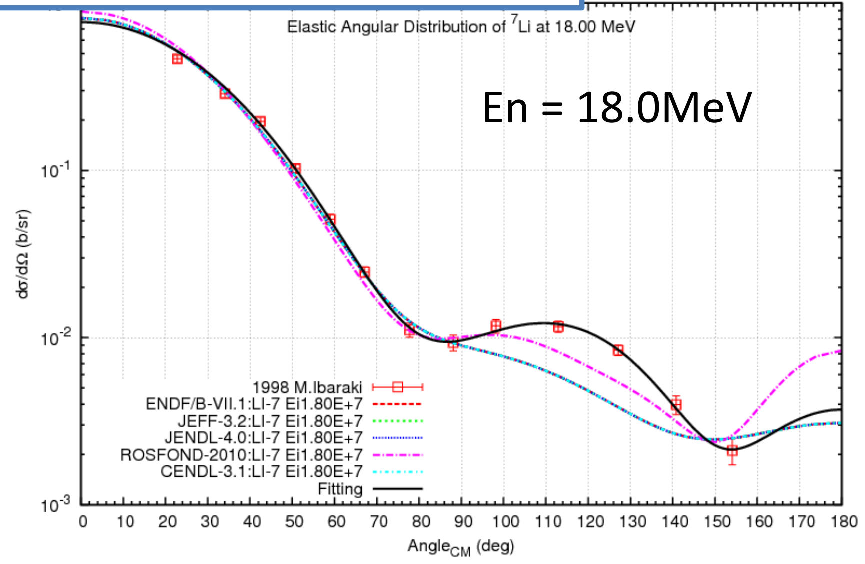




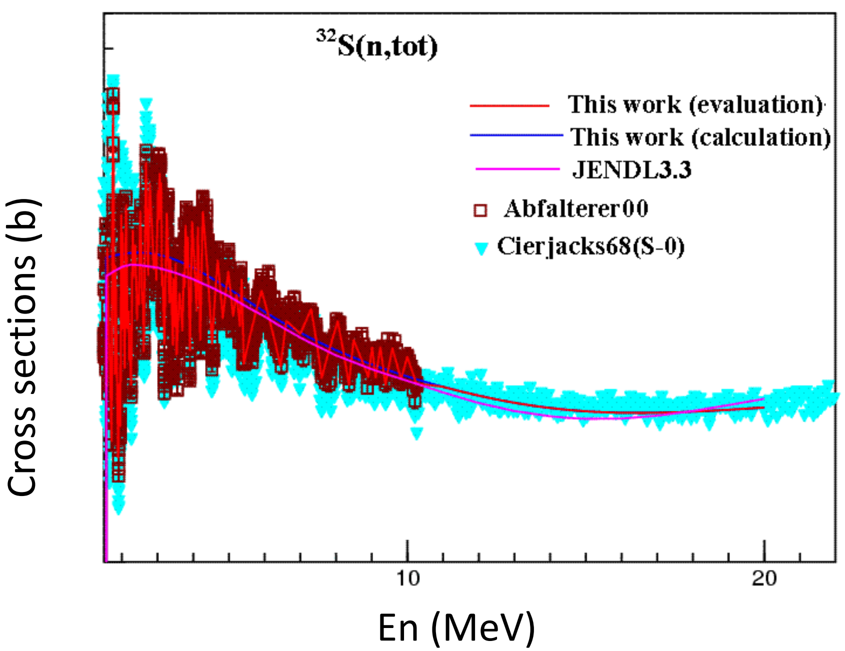
Angular distribution of elastic scattering of ^{7}Li

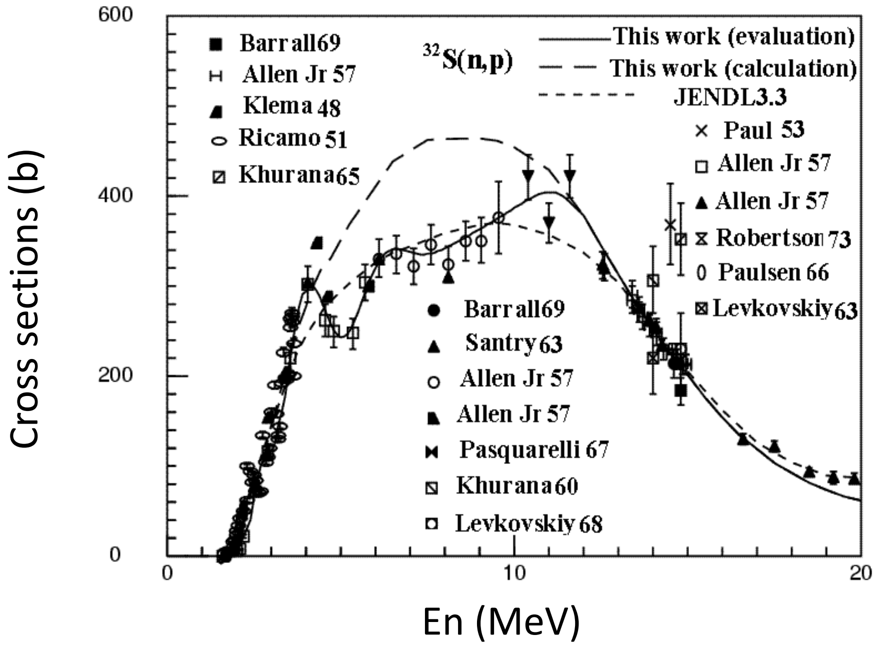
Nuclear data are updated with new Legendre fitting



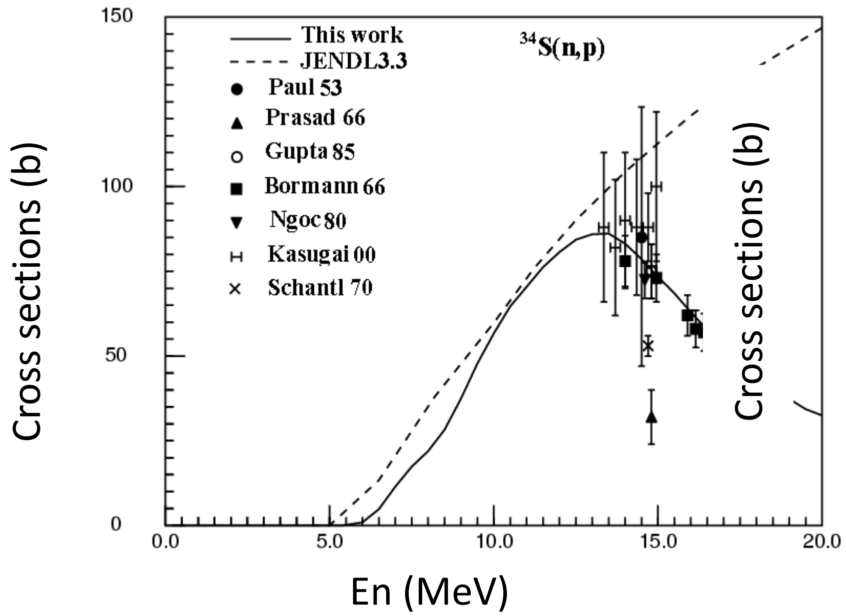


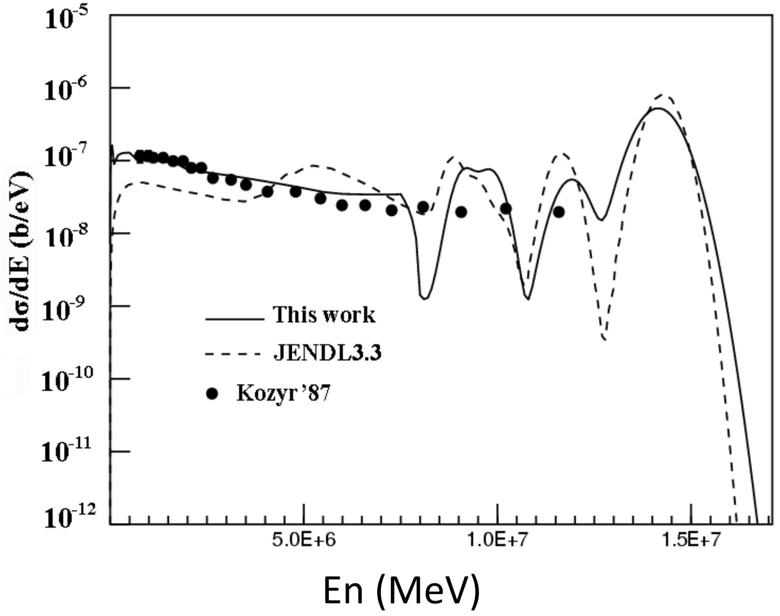
3. CENDL-3.2 – medium heavy : n+^{32}S





New calculation and evaluation are performed to the isotopes of Sulphur in CENDL-32

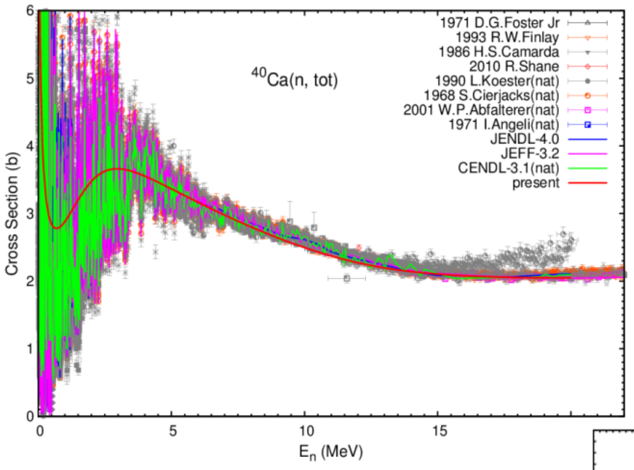




3. CENDL-3.2 – medium heavy : n+^{40}Ca

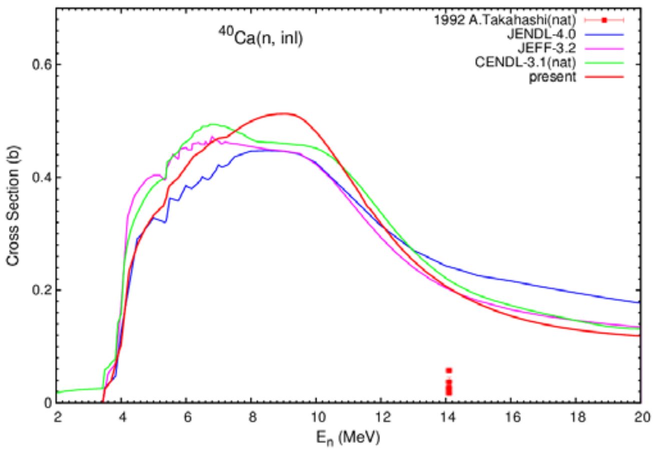
Approach:

- New evaluation and covariance based on the experimental data for (n,tot) and (n, a)
- Koning-Delaroche potential is utilized to calculate the neutron scattering. This function is incorporated in the latest UNF2015
- The discrete levels are adopted as the data JENDL-4



^{40}Ca(n,tot)

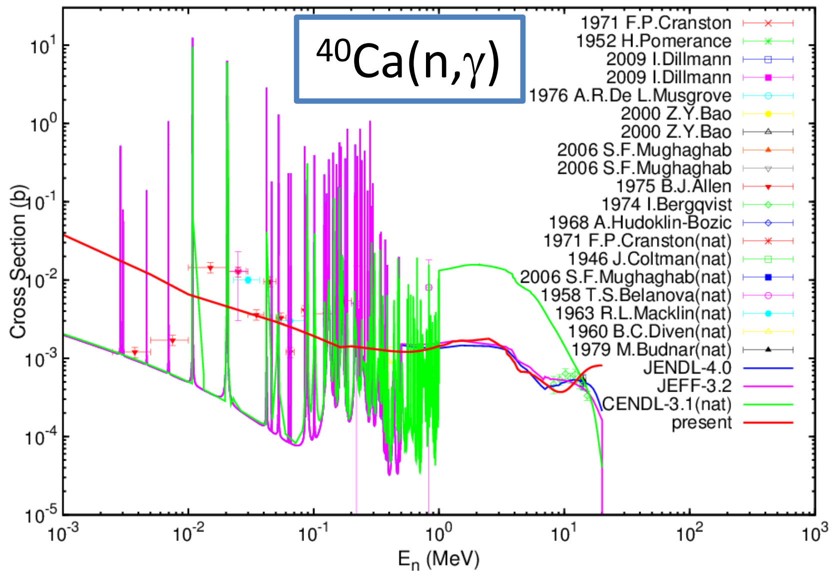
^{40}Ca(n,inl)

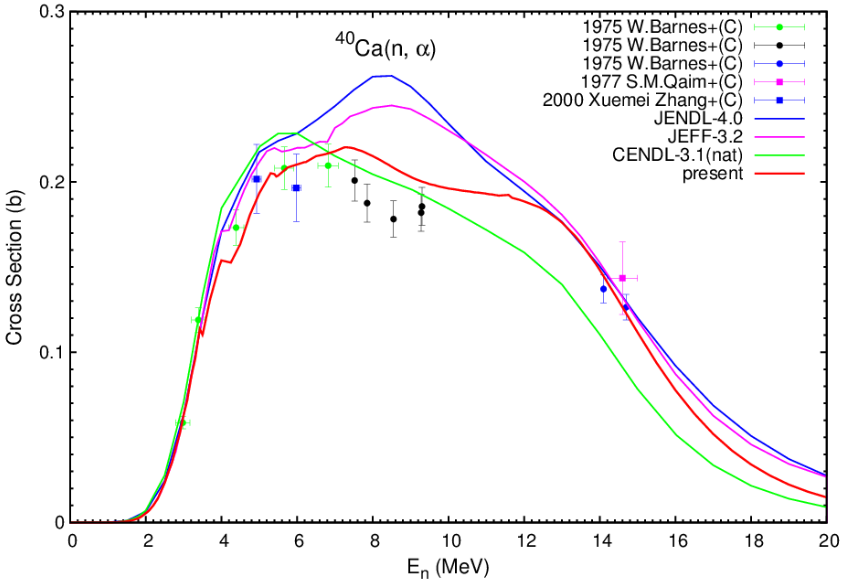


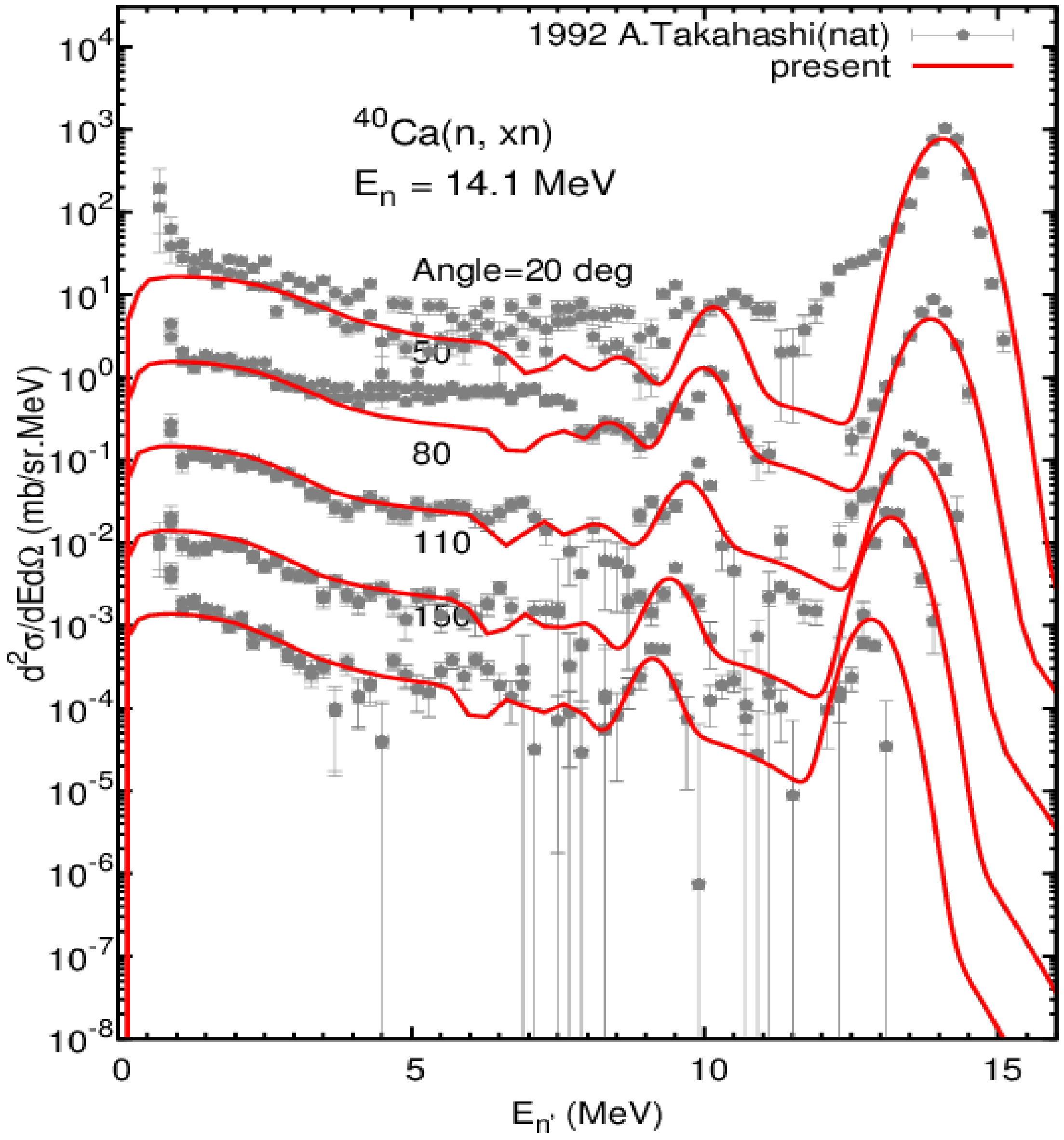
Level	Spin	Parity	DWBA
ground	0	1	0
3.35262	0	1	0
3.73669	3	-1	1
3.90438	2	1	1
4.49143	5	-1	1
5.21156	0	1	0
5.24879	2	1	1
5.2788	4	1	1
5.61352	4	-1	0
5.62941	2	1	1
5.90263	1	-1	0
6.025471	2	-1	0
6.02971	3	1	0
6.28515	3	-1	1
6.4224	2	1	1
6.50787	4	1	0
6.5428	4	1	1
6.58247	3	-1	0
6.750411	2	-1	1
6.9087	2	1	1

New calculation and evaluation are performed to the isotopes of Calcium-40 in CENDL-32

3. CENDL-3.2 – medium heavy : n+^{40}Ca

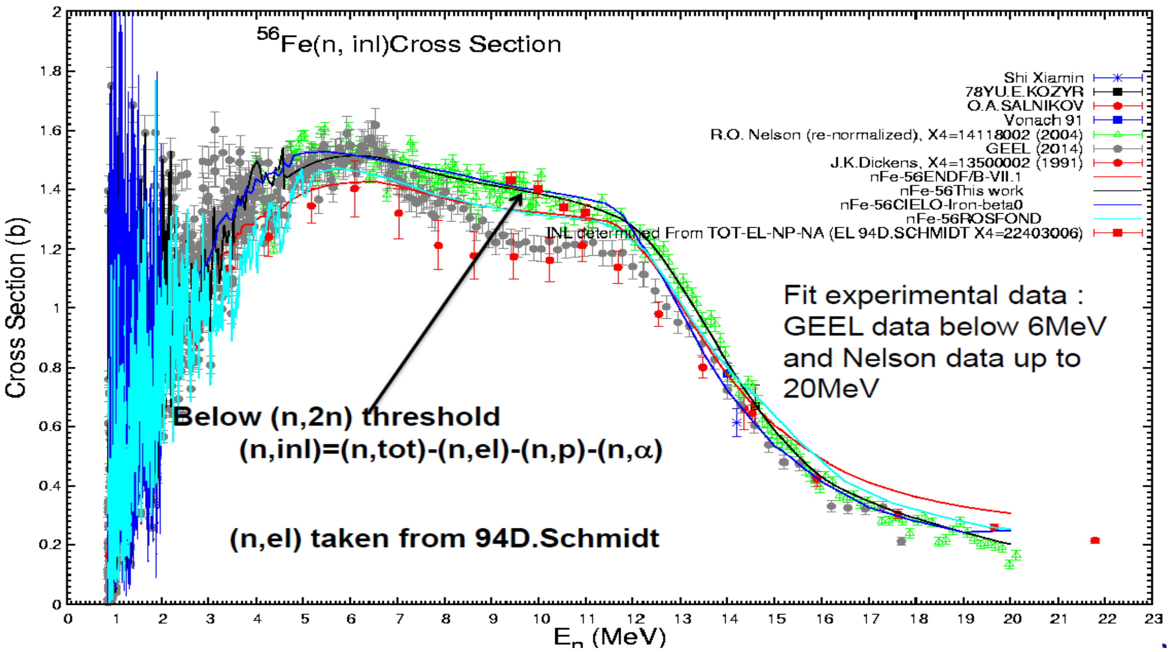


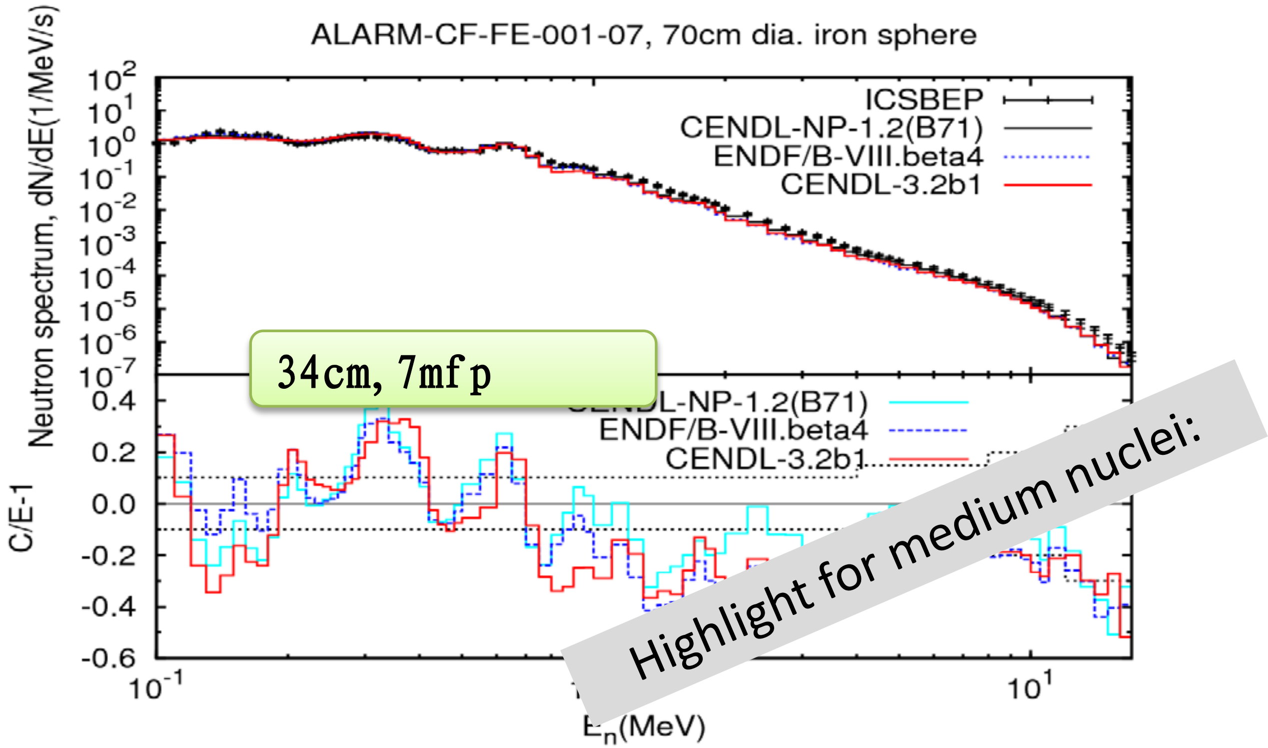




Medium-heavy nuclei: Re-evaluation of ^{56}Fe(n,inl) reaction cross section

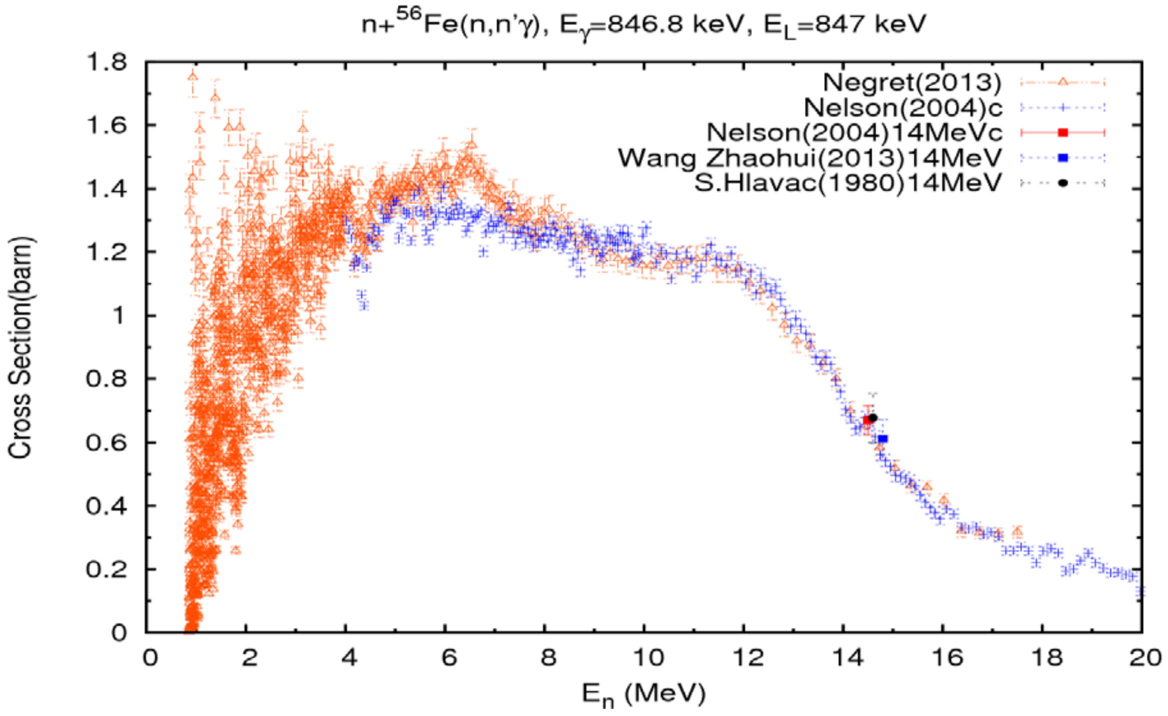
- The (n,inl) evaluation in smooth region for both B8b4 and C32b1 are based on the experimental data recommended by QIAN Jing in the CIELO project.
  - Above 6MeV, Nelson(2004) is recommended based on the (n,el) XS measured by Schmidt .
- The new evaluations of ^{56}Fe leads to a serious under prediction of neutron leakage from IPPE iron sphere.

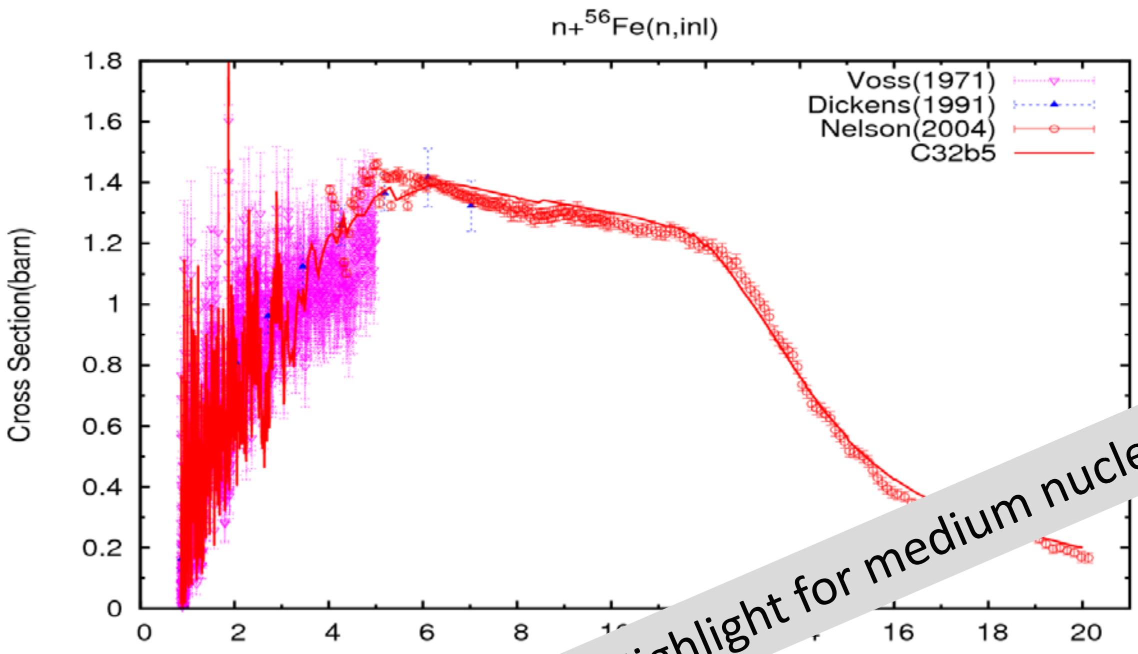




Medium-heavy nuclei: Re-evaluation of ^{56}Fe(n,inl) reaction cross section

- To solve the problem of under prediction neutron leakage in iron shielding, the experimental data of ^{56}Fe(n,inl) 847keV gamma production cross sections have been re-evaluated and a new curve for ^{56}Fe(n,inl) reaction has been evaluated.
  - Nelson(2004) was corrected based on the experiment data around 14MeV.

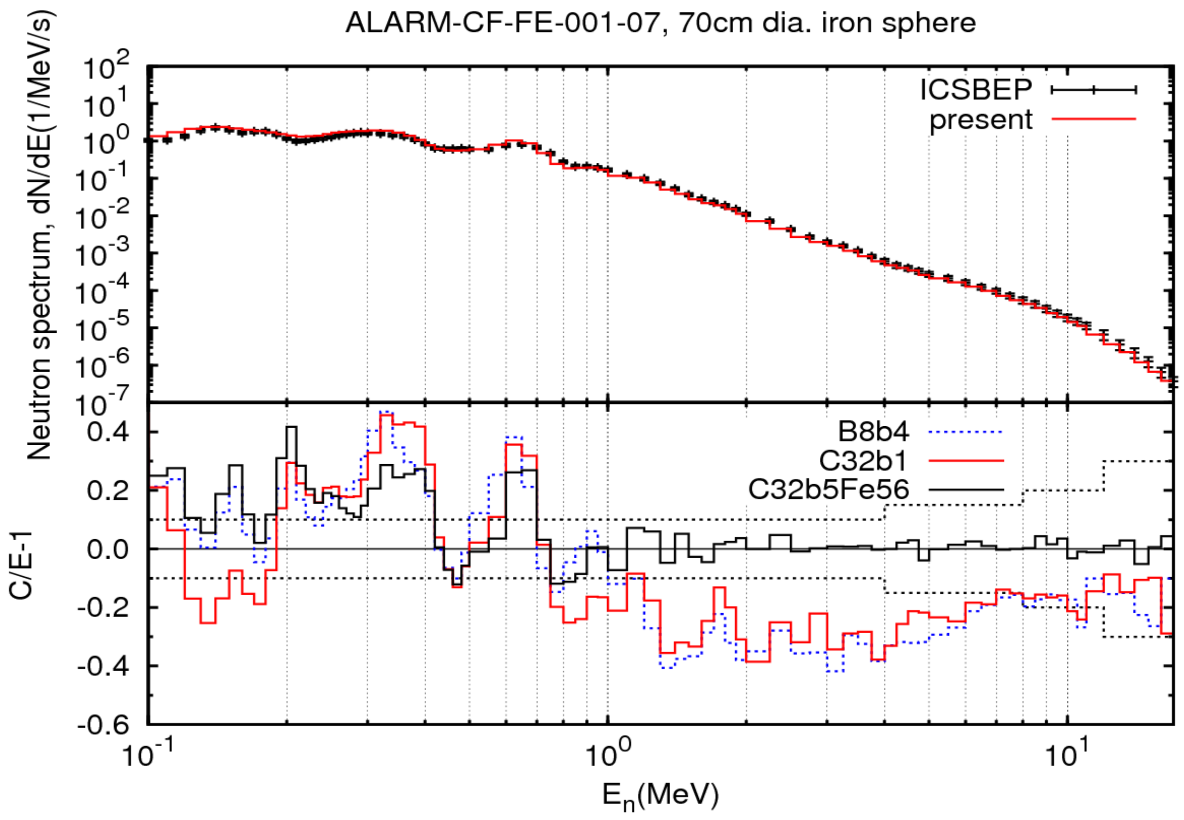


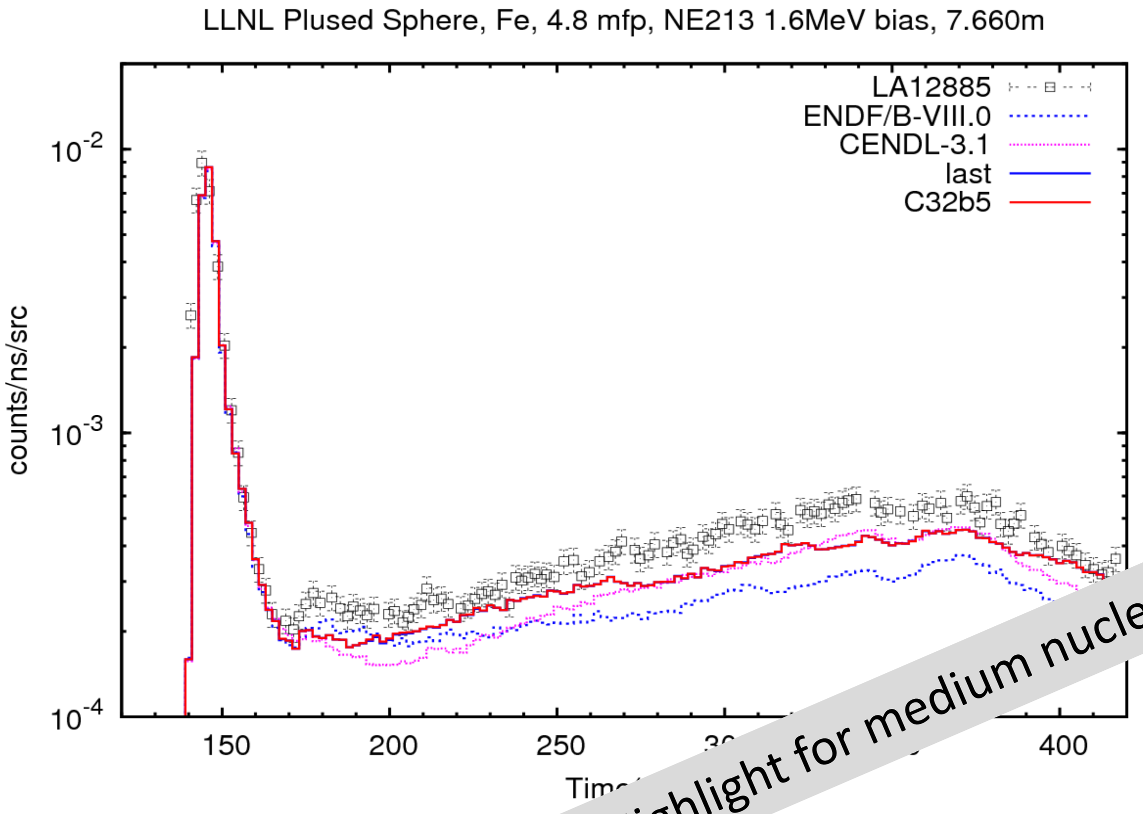


Highlight for medium nuclei:

Medium-heavy nuclei: Re-evaluation of ^{56}Fe(n,inl) reaction cross section

- Significant improvement of validation results have been achieved in testing with the 70cm dia. IPPE iron sphere and the LLNL pulsed iron sphere.



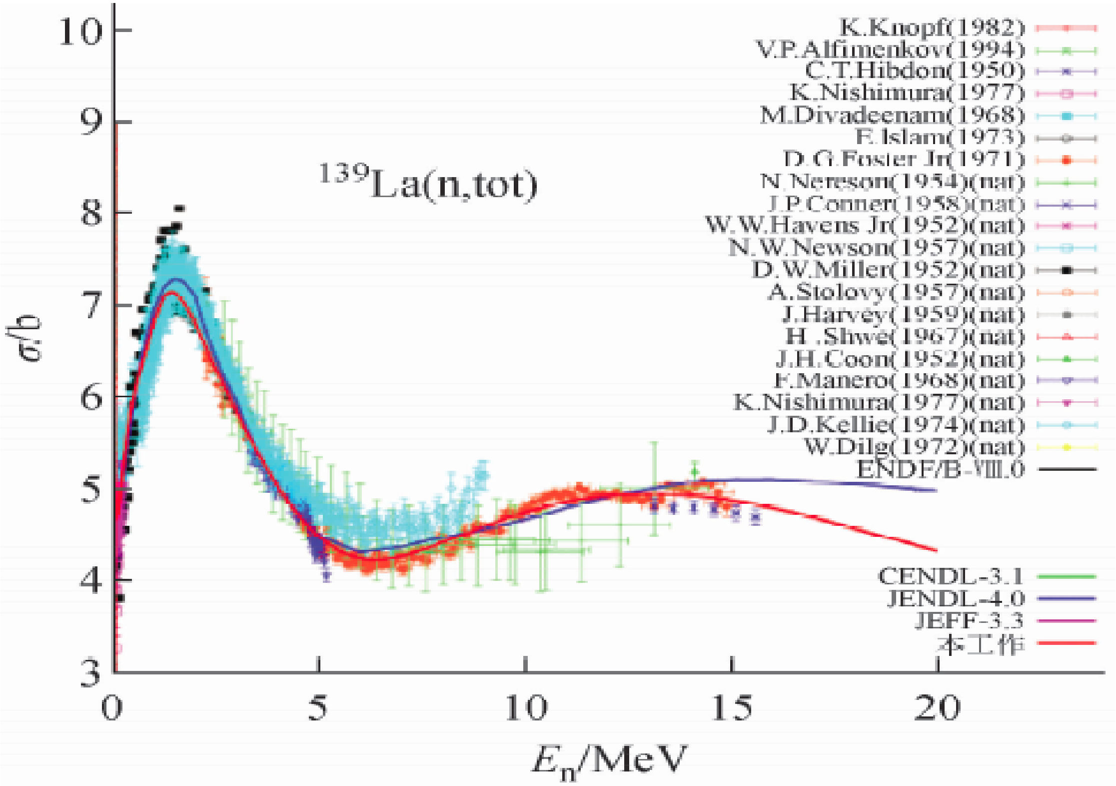


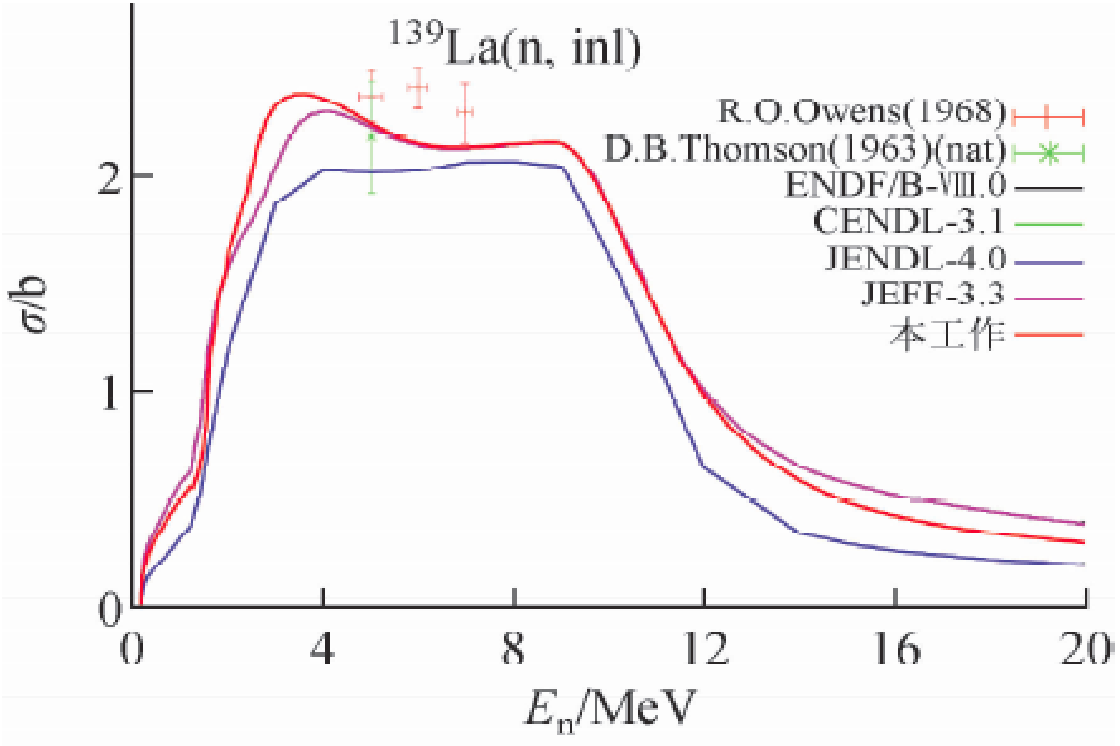
Highlight for medium nuclei:

Fission product nuclei evaluation

The neutron reaction data of medium-heavy nuclei (mass number around 100~200) are systematically updated in CENDL. **All the modifications are based on the calculations with the UNF code**. Parts of them are new evaluations concerning the latest measurements. The others are the systematic reproductions to the previous CENDL library, some odd structures are removed from previous CENDL.

The new evaluations for La-139 (n,tot),(n,inl)

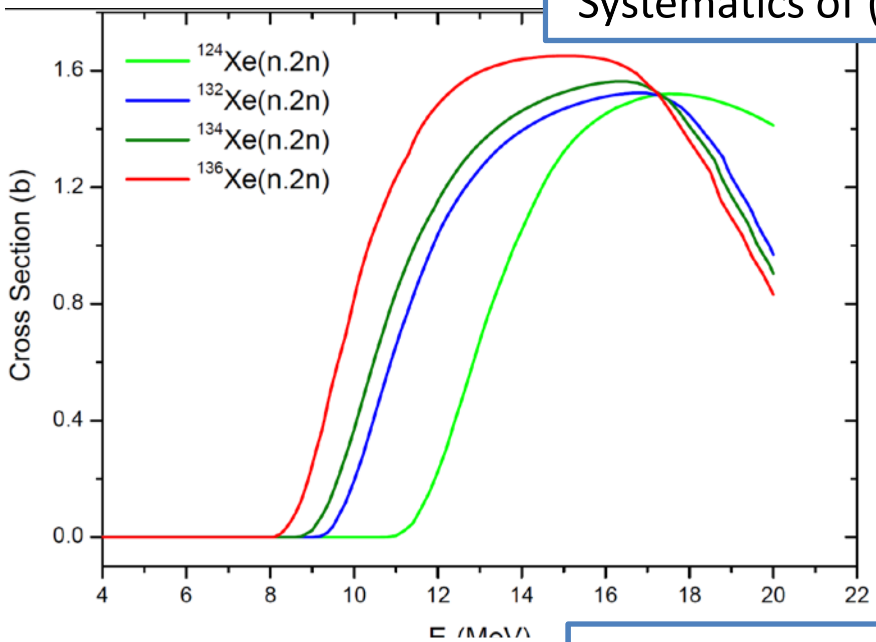


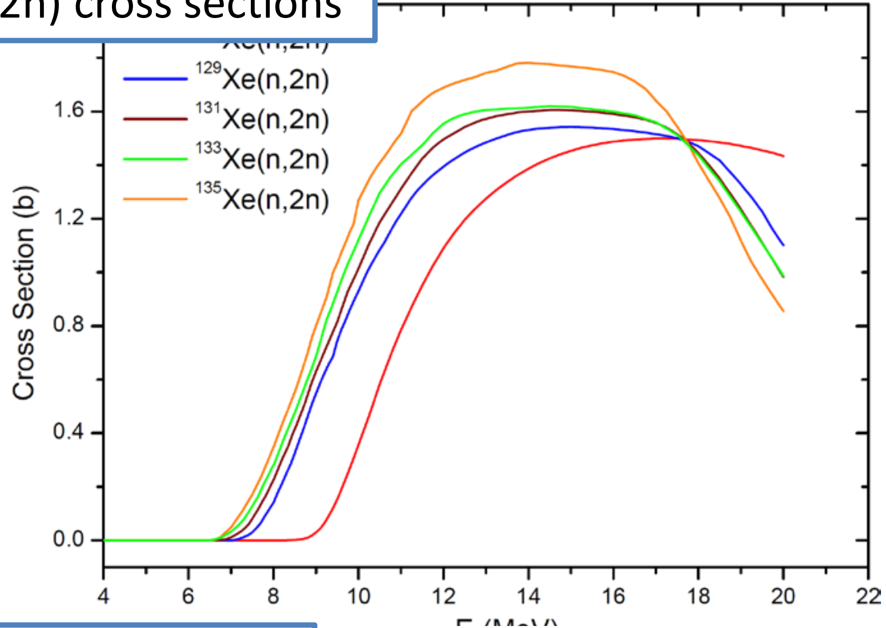


中国原子能科学研究院 CHINA INSTITUTE OF ATOMIC ENERGY

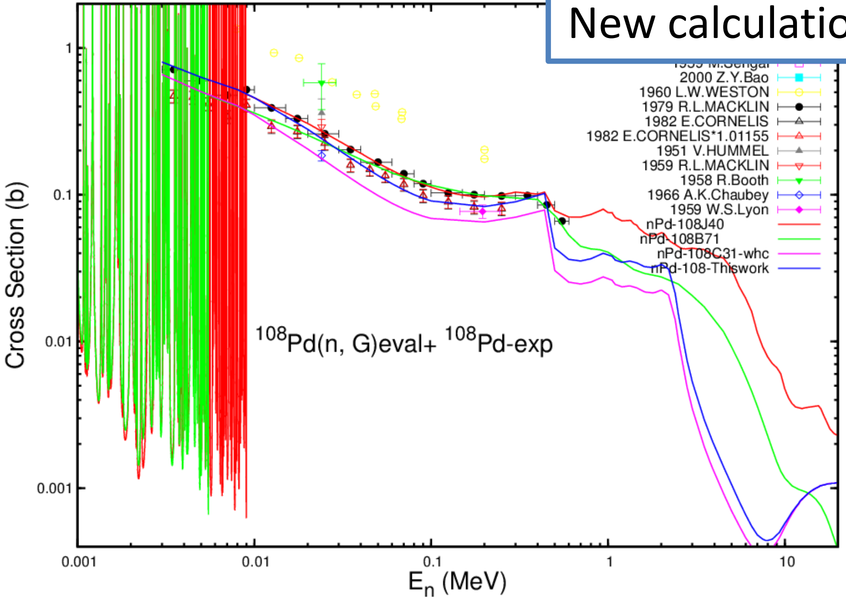
3. CENDL-3.2 – medium heavy : n+Fission product

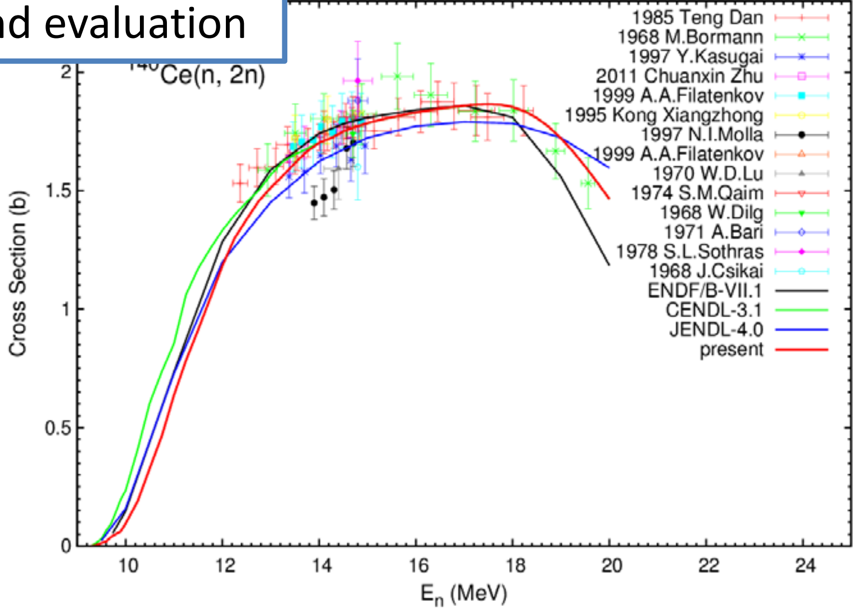
Systematics of (n,2n) cross sections





New calculation and evaluation



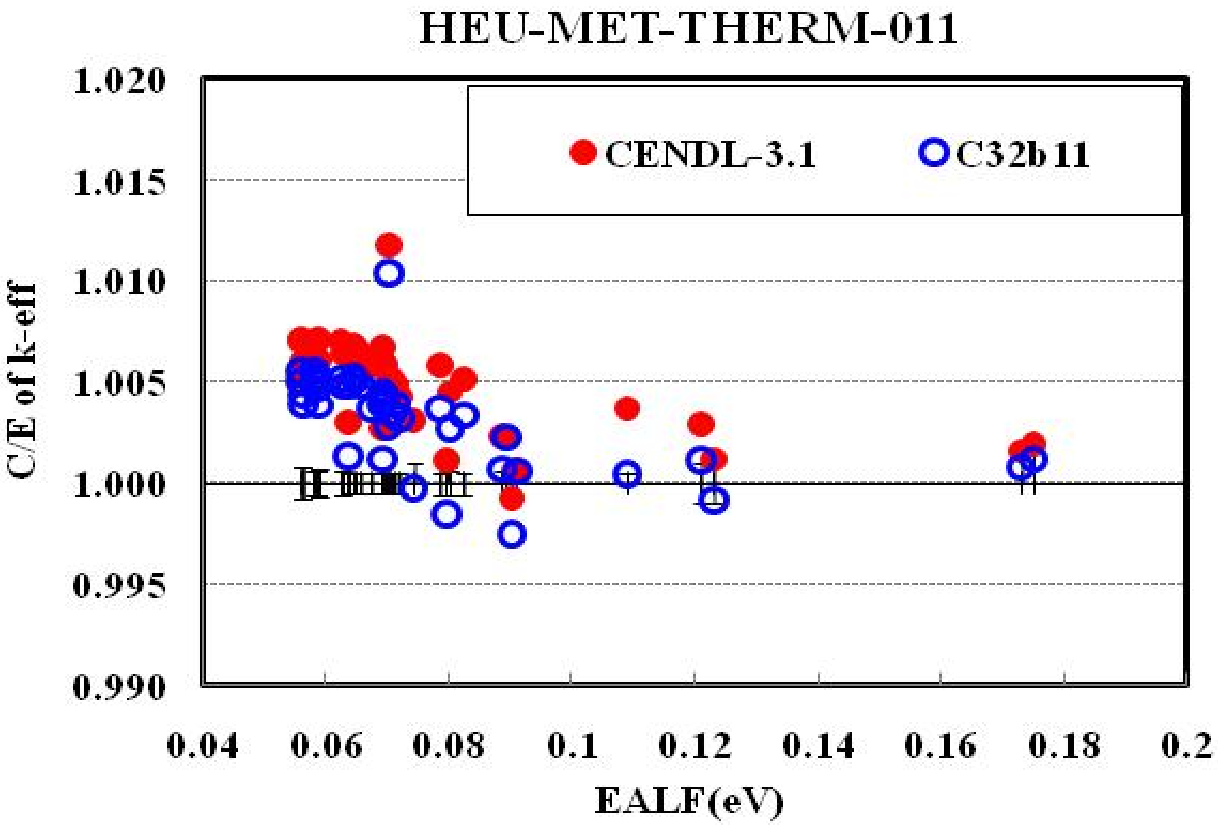


3. CENDL-3.2 – Actinides : n+^{235}U

Fission nuclei: revision of U-235

- Nubar and resonance parameters of ^{235}U(rev.C32b11) which refer as CENDL-3.2 now, were modified to reproduce the thermal quantities of the IAEA 2006 standard, which improves the prediction of keff for the HMT system.

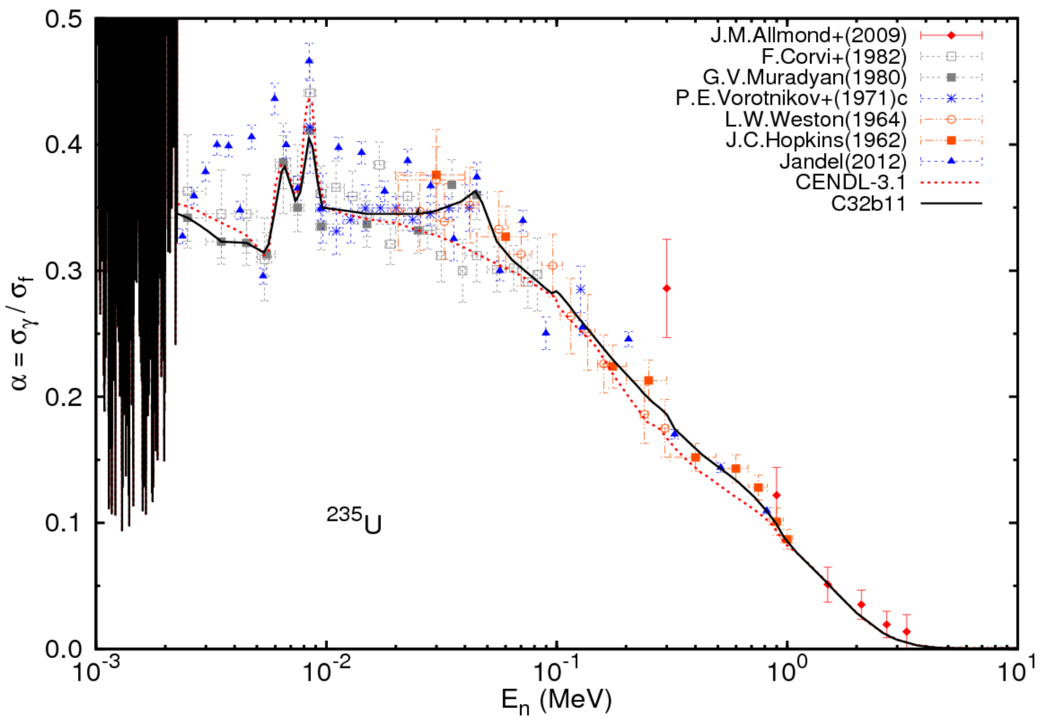
Thermal quantities	IAEA2006 standard	C32b11 evaluation	C32b11 Eval./Std.	Δ
(n,f)	584.33	5.84177E+02	-0.03%	-0.15%
(n,γ)	99.401	9.94001E+01	0.00%	0.70%
(n,el)	14.087	1.51081E+01	7.25%	-0.05%
(n,tot)	697.818	6.98685E+02	0.12%	-0.03%
G_f	0.97729	0.97667	-0.07%	0.00%
G_γ		0.99118		
G_a	0.97881	0.97878	0.00%	0.00%
ν	2.43550	2.4359	0.01%	-0.03%
η	2.08143	2.0816	0.01%	-0.16%
α	0.17011	0.17015	0.03%	0.85%

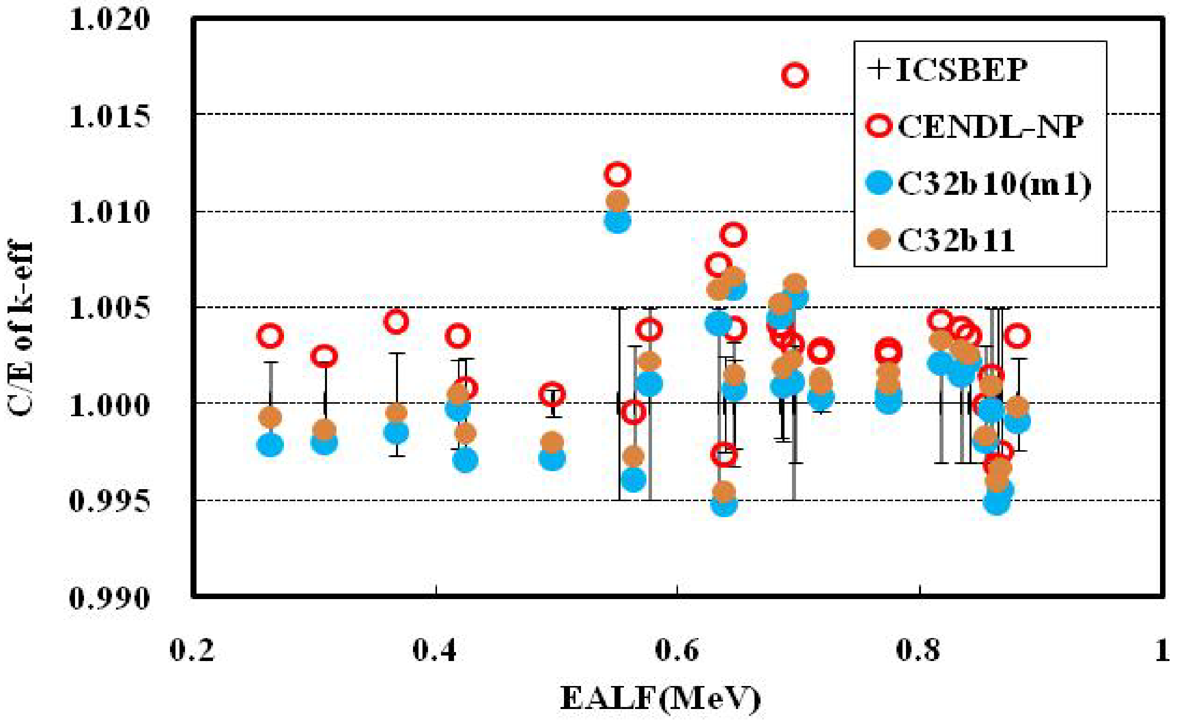


3. CENDL-3.2 – Actinides : n+^{235}U

Fission nuclei: revision of U-235

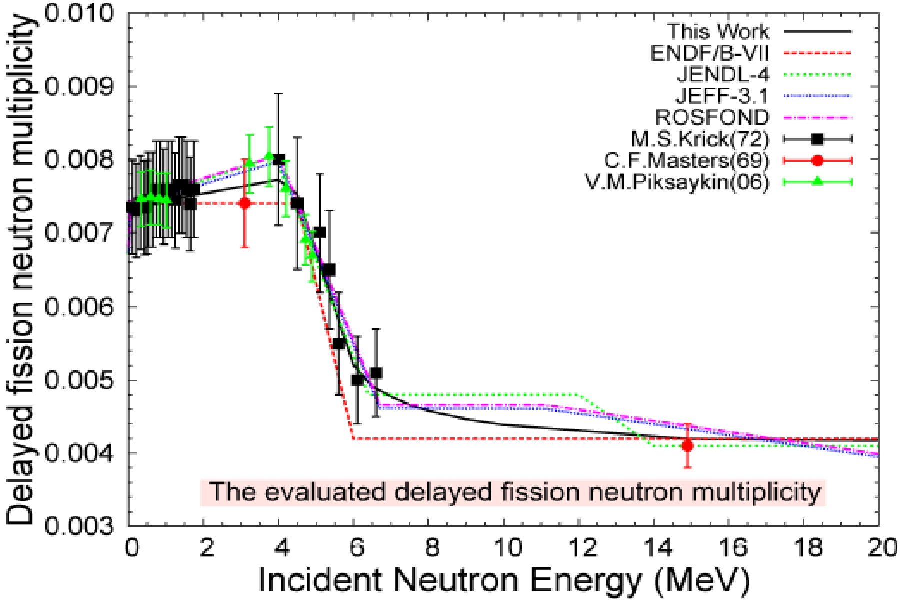
- (n,γ) cross sections were revised based on (n,f) cross sections recommended by IAEA 2006 standard and re-evaluated alpha values.
- Benchmark testing with the selected HMF, IMF and HMI cores show that the prediction of keff gets closer to 1 than before.

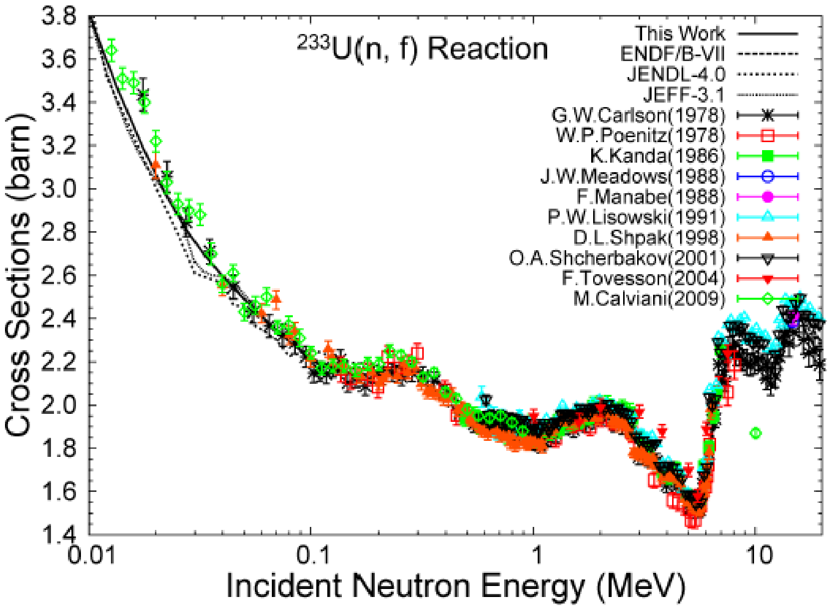


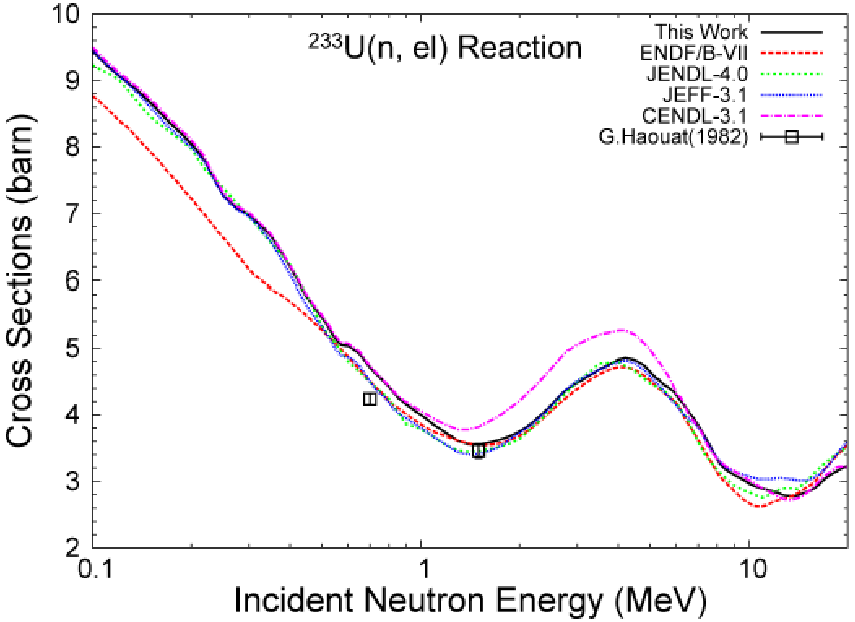


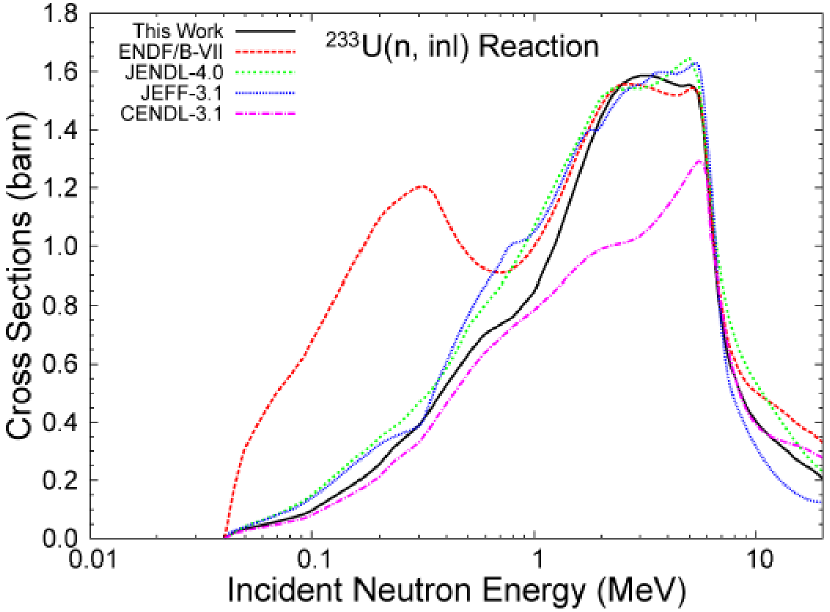
3. CENDL-3.2 – Actinides : n+^{233}U

^{233}U





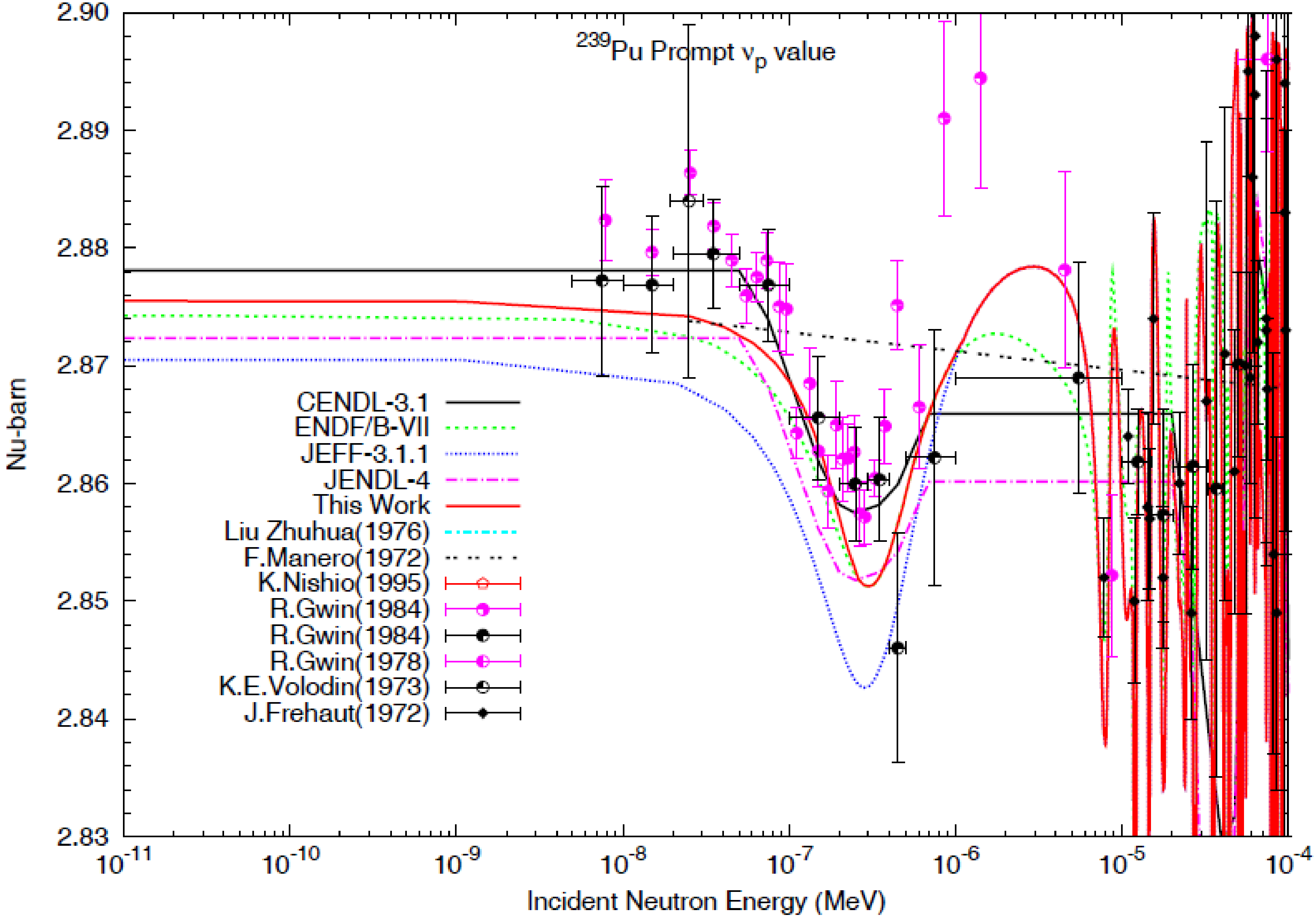




3. CENDL-3.2 – Actinides : n+^{239}U

Nu-barn experimental data evaluation for ^{239}U

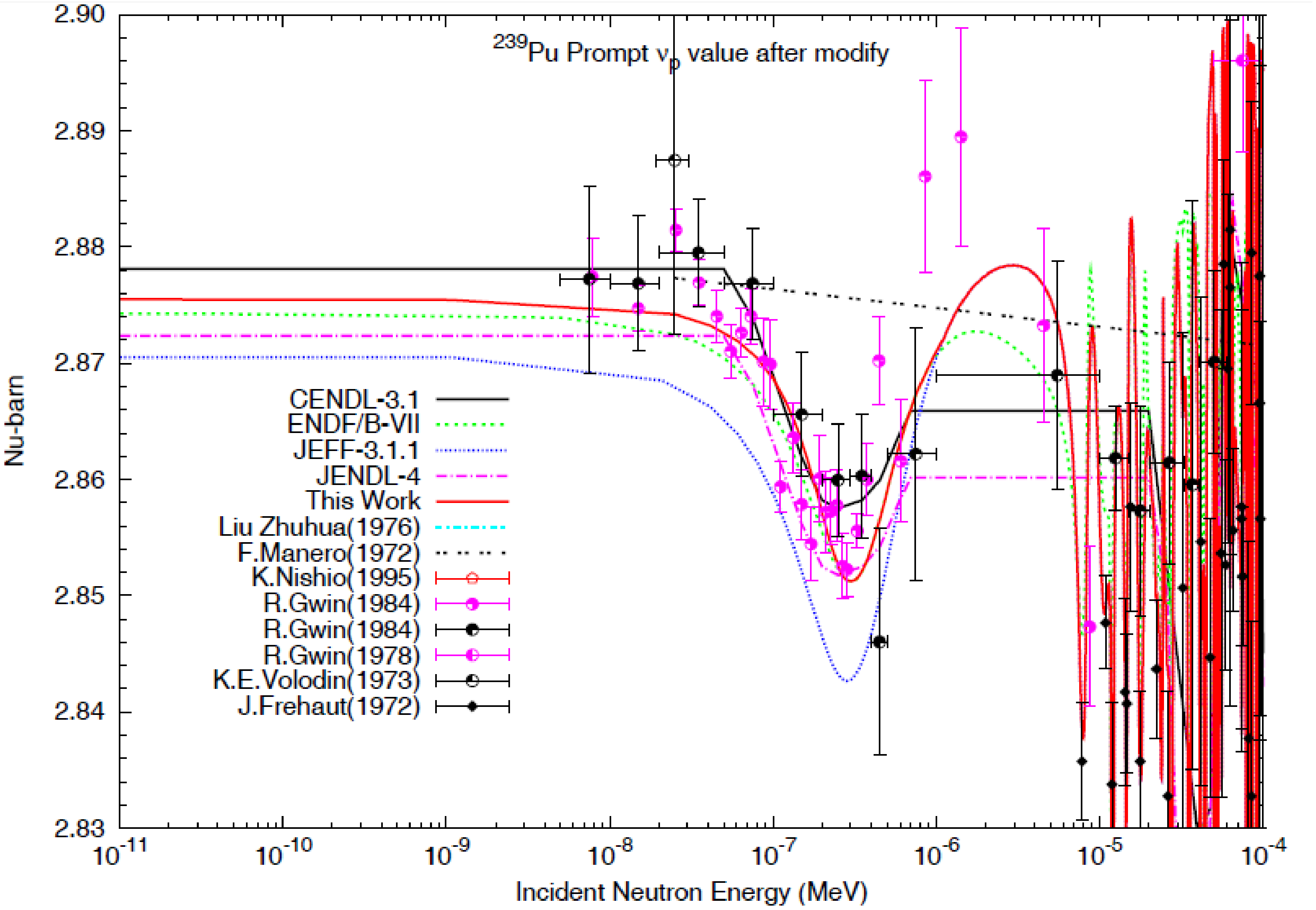
^{239}U



Before

Nu-barn experimental data evaluation for ^{239}U

^{239}U

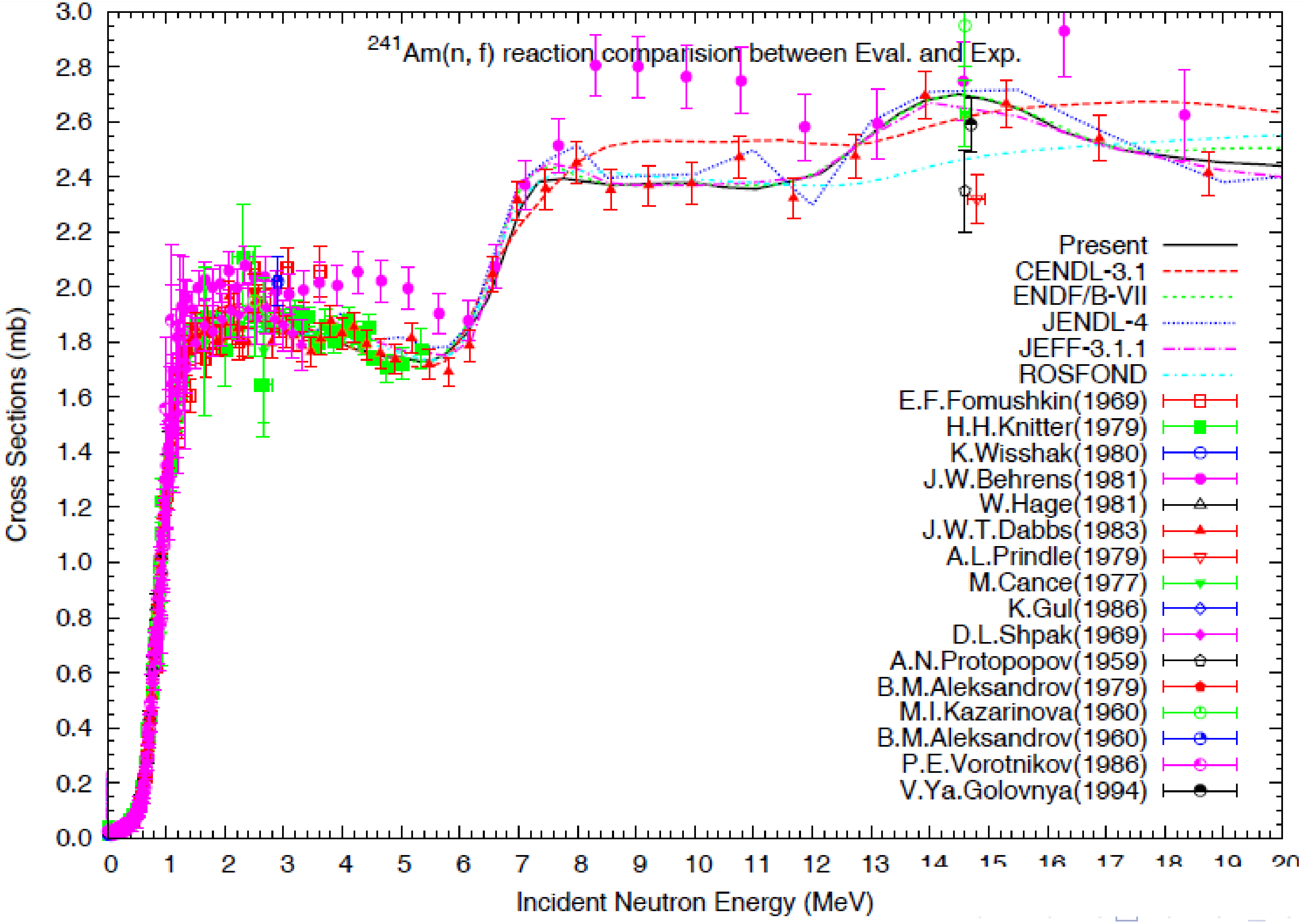


After

3. CENDL-3.2 – Actinides : n+^{241}Am

(n, fission) experimental data evaluation for ^{241}Am

^{241}Am

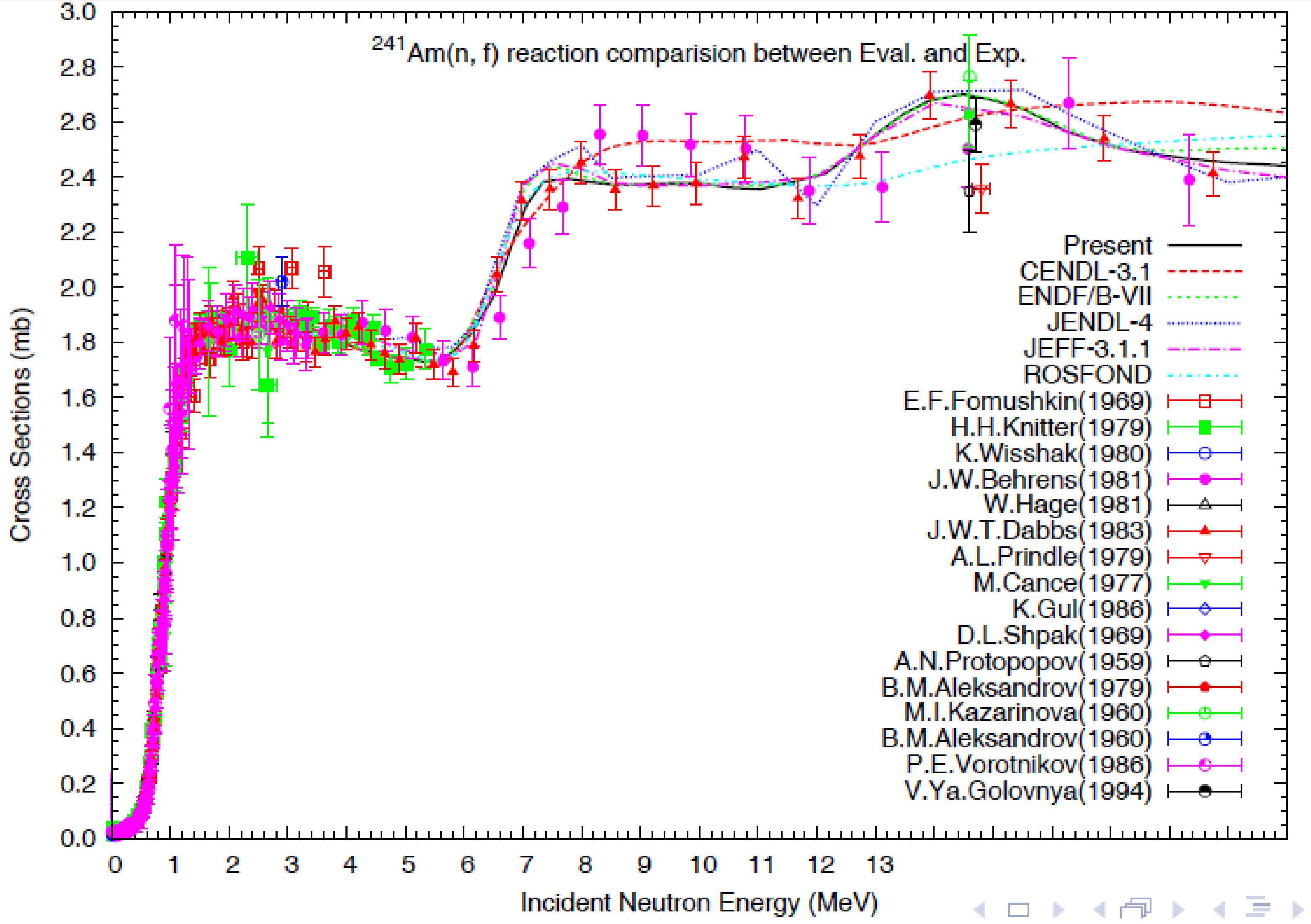


Before

3. CENDL-3.2 – Actinides : n+^{241}Am

(n, fission) experimental data evaluation for ^{241}Am

^{241}Am



After

3. CENDL-3.2 – Covariance for 70 Fis. products.

Fission product: The systematic covariance evaluation system for fission product

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

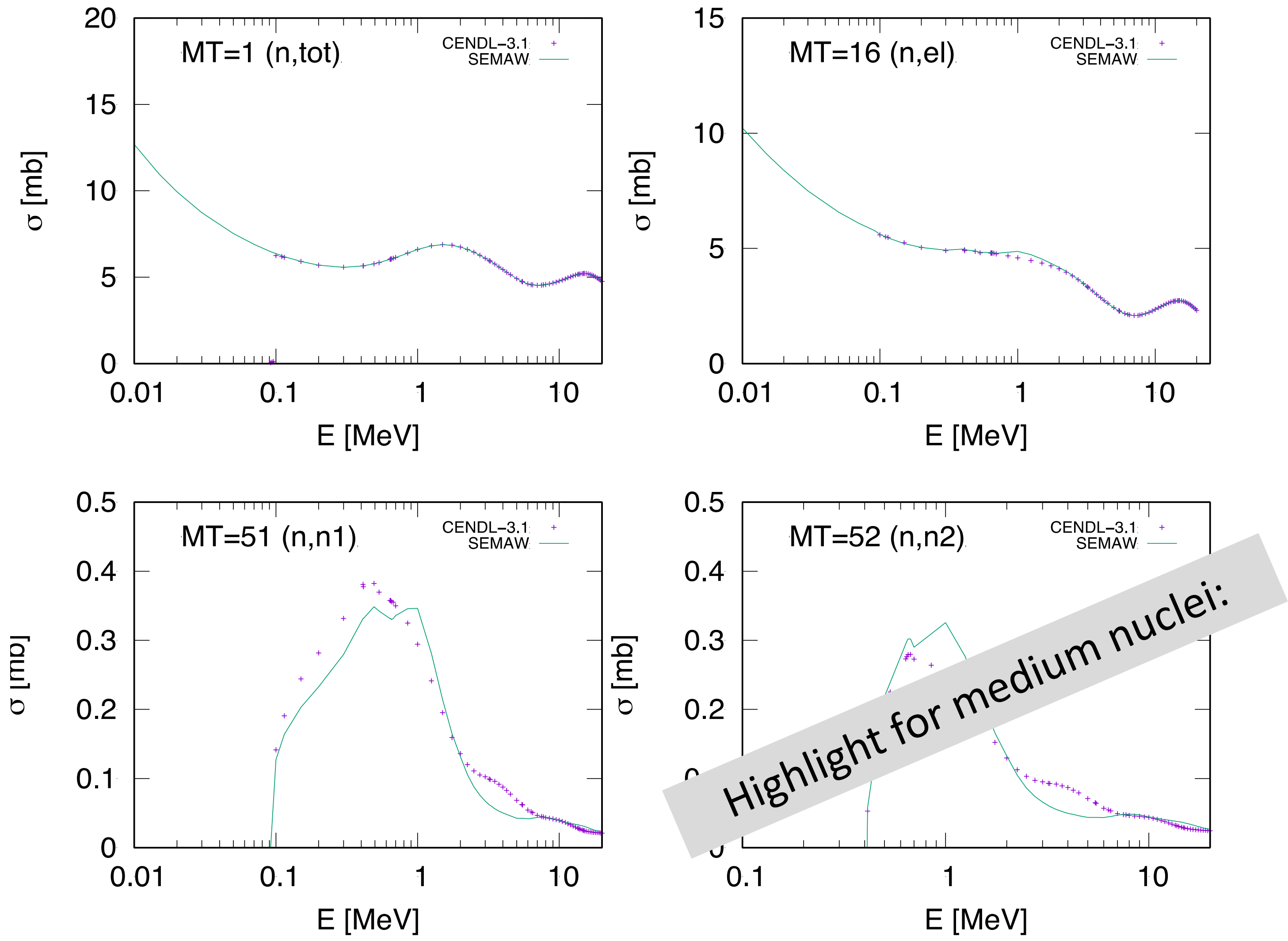
核素	输入卡	核素	输入卡	核素	输入卡
54-XE-123	SUNF	57-LA-139	SUNF	62-SM-149	SUNF
54-XE-124	SUNF	58-CE-141	SUNF	62-SM-150	SUNF
54-XE-129	SUNF	58-CE-144	SUNF	62-SM-151	SUNF
54-XE-131	SUNF	59-PR-141	SUNF	62-SM-152	SUNF
54-XE-132	SUNF	60-ND-142	SUNF	62-SM-154	SUNF
54-XE-134	SUNF	60-ND-143	SUNF	63-EU-151	SUNF
54-XE-135	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		

3. CENDL-3.2 – Covariance for 70 Fis. products.

Fission products: The nuclear reaction data re-production

with the help of MINUIT, **we have adjusted the parameters of the UNF program**, such as the parameter of the level density, pairing interaction and Giant dipole resonance of (n, gamma) channel. As shown in Figure, the dotted line is the results of the CENDL3.1, the solid line is the cross sections we have calculated with the new parameter set. For the (n,n1) and (n,n2) channel, the new parameter set gives the reasonable cross section at 8 to 10 MeV.

The comparison of CENDL-3.1 and CENDL-3.2 for n-^{147}Pm reactions

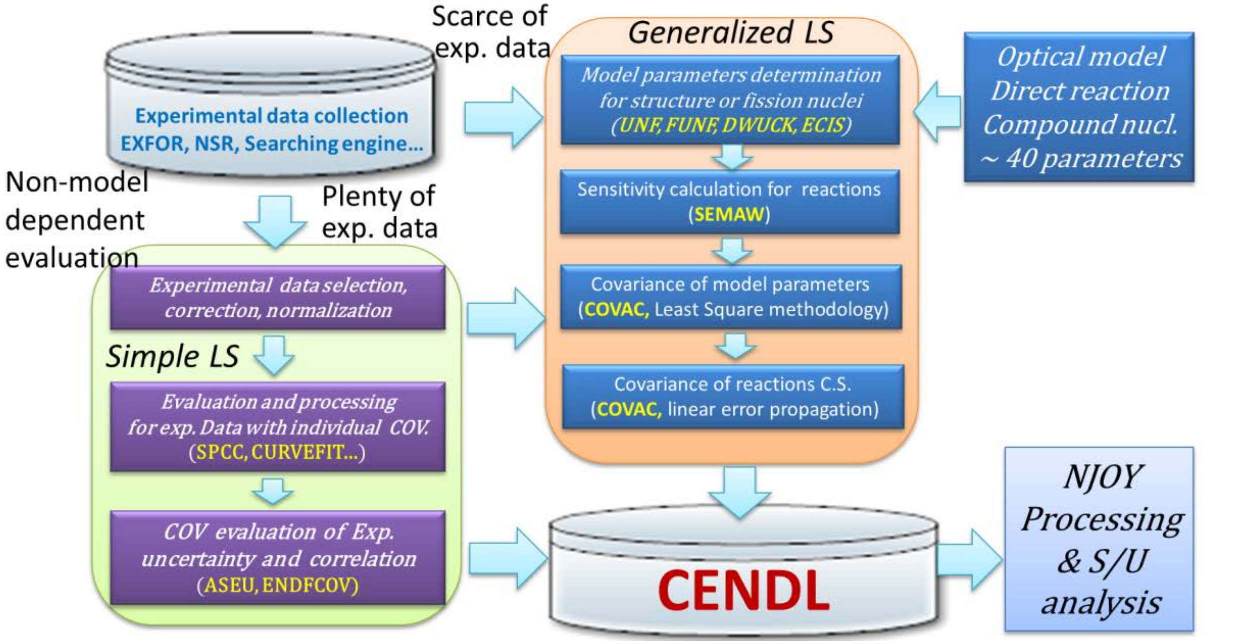


3. CENDL-3.2 – Covariance for 70 Fis. products.

Descriptions to COV scheme in CENDL-3.2:

①Tech. for non-model & model dependent
②Energies for structure & smooth regions
③COV data types for NI & NC
④Tech. deal with single & multiple measurements
⑤Tech. for parameter sensitivity selection
⑥COV matrix positive definition treatment

Deterministic approach: *Data recommendation together with COV*



(n,tot) (n,tot)	(n,tot) (n,inl)	(n,tot) (n,γ)	(n,tot) (n,p)	(n,tot) (n,d)	(n,tot) (n,t)	(n,tot) (n,2n)	(n,tot) (n,np)	(n,tot) (n,nα)
NM	(n,inl) (n,inl)	(n,inl) (n,γ)	(n,inl) (n,p)	(n,inl) (n,d)	(n,inl) (n,t)	(n,inl) (n,2n)	(n,inl) (n,np)	(n,inl) (n,nα)
		(n,γ) (n,γ)	(n,γ) (n,p)	(n,γ) (n,d)	(n,γ) (n,t)	(n,γ) (n,2n)	(n,γ) (n,np)	(n,γ) (n,nα)
			(n,p) (n,p)	(n,p) (n,d)	(n,p) (n,t)	(n,p) (n,2n)	(n,p) (n,np)	(n,p) (n,nα)
			NM	(n,d) (n,d)	(n,d) (n,t)	(n,d) (n,2n)	(n,p) (n,np)	(n,p) (n,nα)
					(n,t) (n,t)	(n,t) (n,2n)	(n,t) (n,np)	(n,t) (n,nα)
						(n,2n) (n,2n)	(n,2n) (n,np)	(n,2n) (n,nα)
9个反应道以及彼此之间的关联						NM	(n,np) (n,np)	(n,np) (n,nα)
								(n,nα) (n,nα)

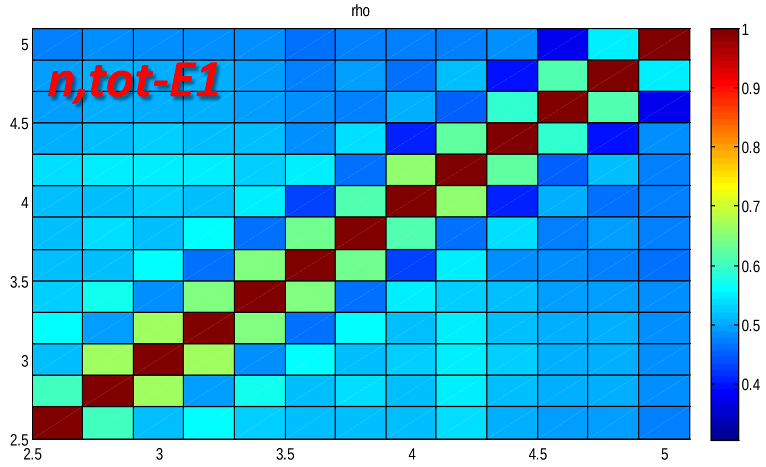
(n,tot) (n,tot)	(n,tot) (n,inl)	(n,tot) (n,γ)	(n,tot) (n,p)	(n,tot) (n,d)	(n,tot) (n,t)	(n,tot) (n,2n)	(n,tot) (n,np)	(n,tot) (n,nα)
	(n,inl) (n,inl)	(n,inl) (n,γ)	(n,inl) (n,p)	(n,inl) (n,d)	(n,inl) (n,t)	(n,inl) (n,2n)	(n,inl) (n,np)	(n,inl) (n,nα)
	MODEL	(n,γ) (n,γ)	(n,γ) (n,p)	(n,γ) (n,d)	(n,γ) (n,t)	(n,γ) (n,2n)	(n,γ) (n,np)	(n,γ) (n,nα)
		MODEL	(n,p) (n,p)	(n,p) (n,d)	(n,p) (n,t)	(n,p) (n,2n)	(n,p) (n,np)	(n,p) (n,nα)
				(n,d) (n,d)	(n,d) (n,t)	(n,d) (n,2n)	(n,p) (n,np)	(n
				MODEL	(n,t) (n,t)	(n,t) (n,2n)	(n	)
					MO	(n	p)	(n,2n) (n,nα)
9个反应道以及彼此之间的关联							(n,np) (n,np)	(n,np) (n,nα)
							MODEL	(n,nα) (n,nα)
								MODEL

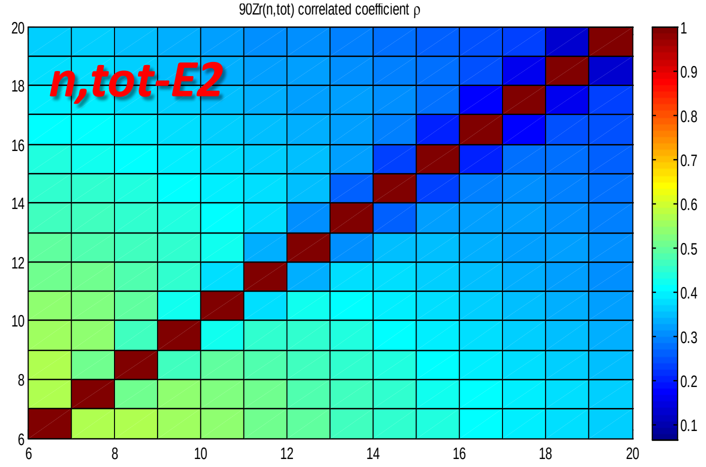
ENDF文件中，MF=32，33包含19 11行，占到Zr90全套数据文件的 %

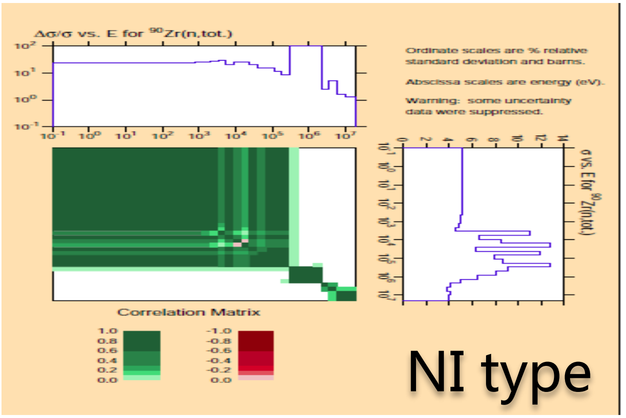
Highlight for covariance eval:

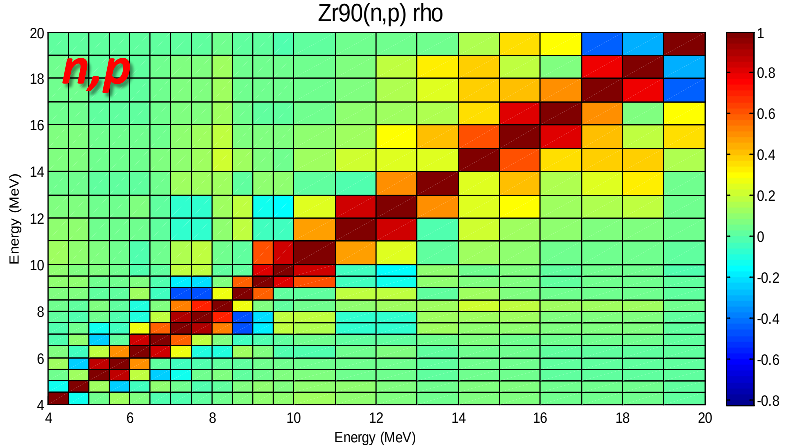
3. CENDL-3.2 – Covariance for 70 Fis. products.

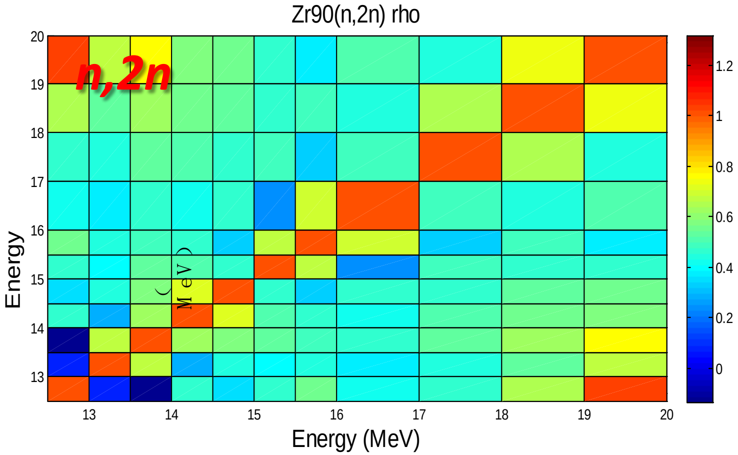
Covariance for n+^{90}Zr reaction cross sections

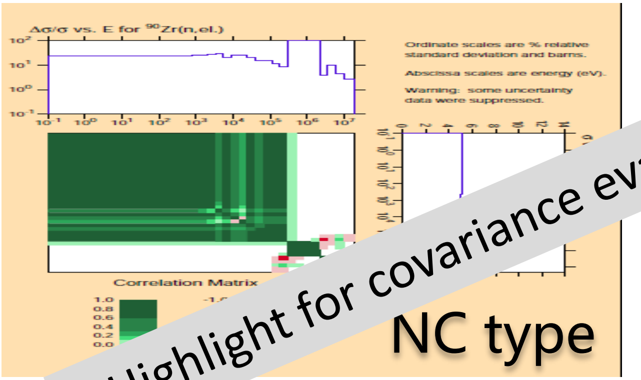












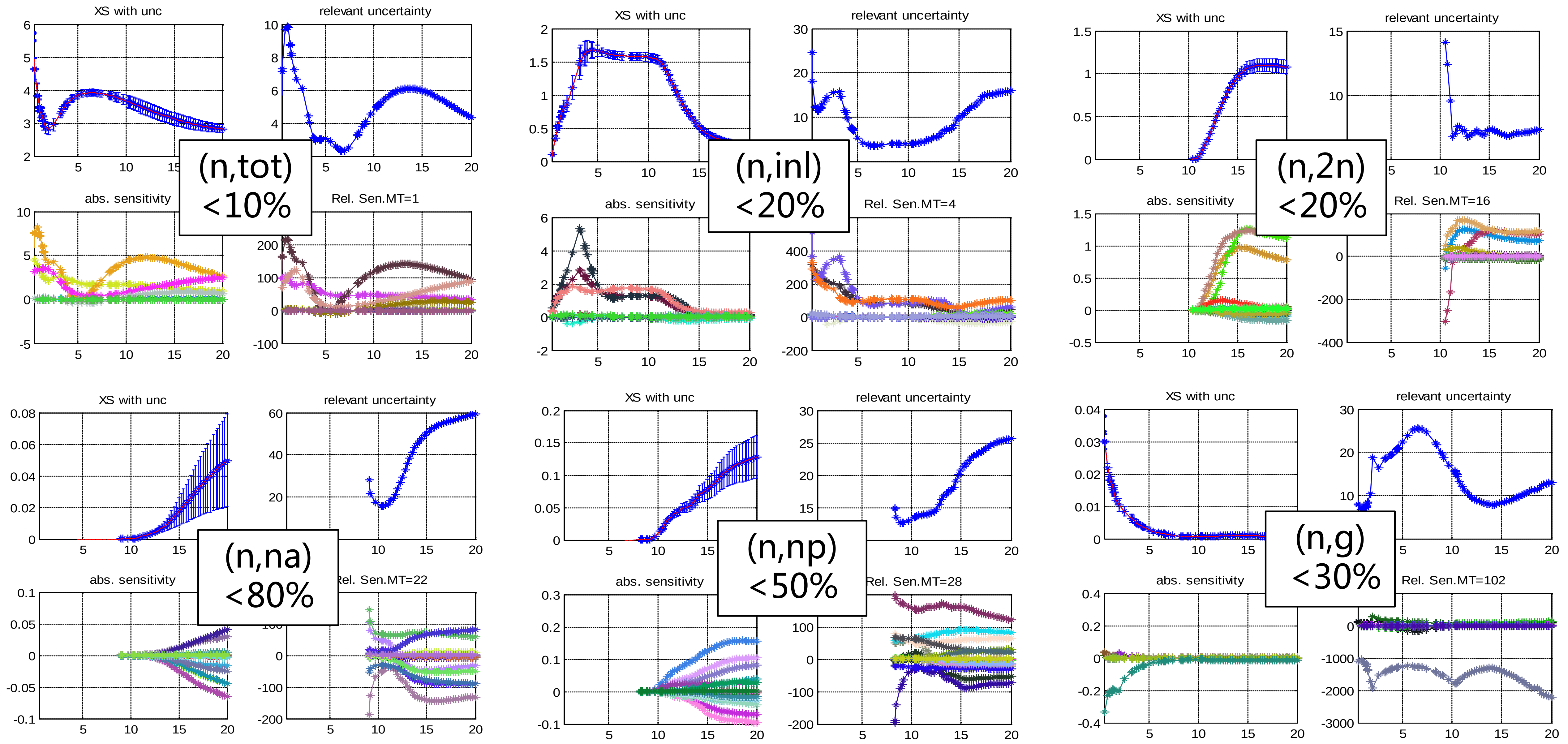
Highlight for covariance eval:

中国原子能科学研究院 CHINA INSTITUTE OF ATOMIC ENERGY 中核集团 CNNC

3. CENDL-3.2 – Covariance for 70 Fis. products.

CNDC CHINA NUCLEAR DATA CENTER

The covariance of main reactions are contained in the data file, the averaged uncertainties are about:

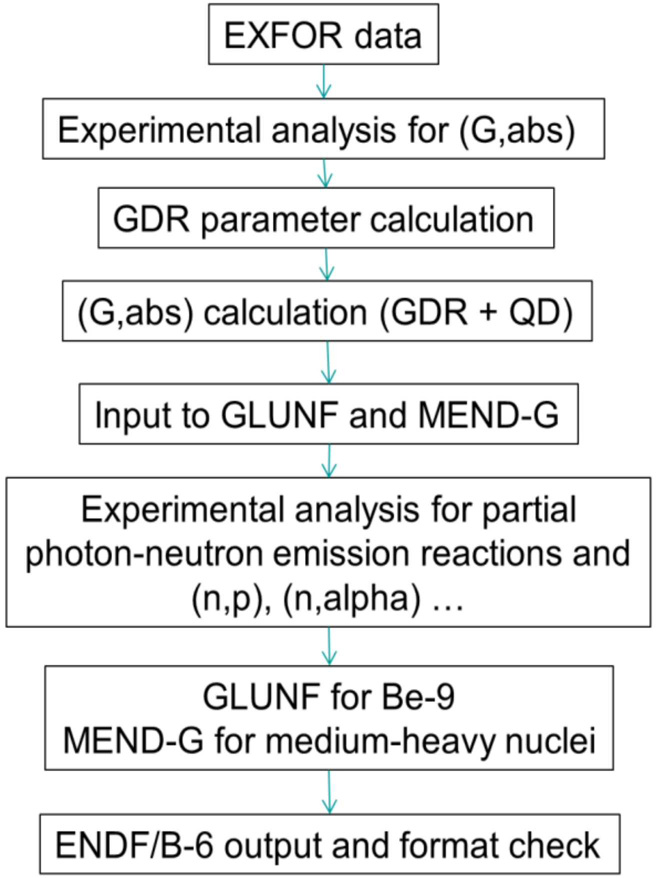


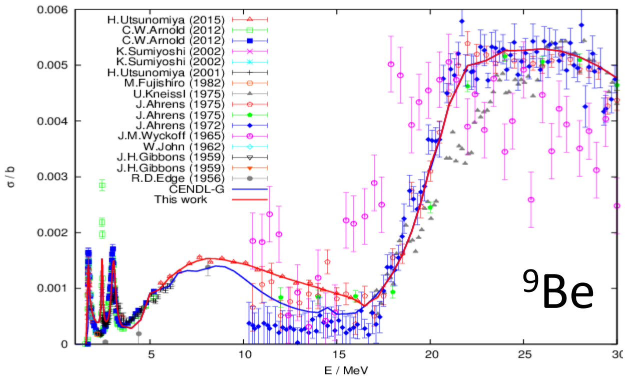
CENDL-Sub-library of photon data

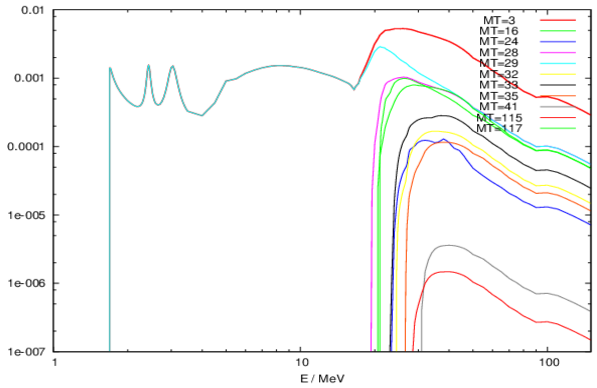
270 new evaluations have been performed based on the new GLUNF、MEND-G systems.

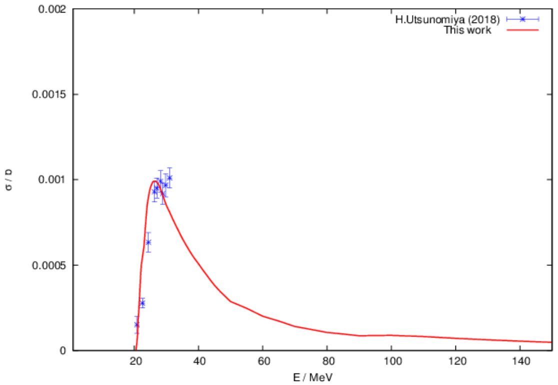
Evaluation Scheme for PD

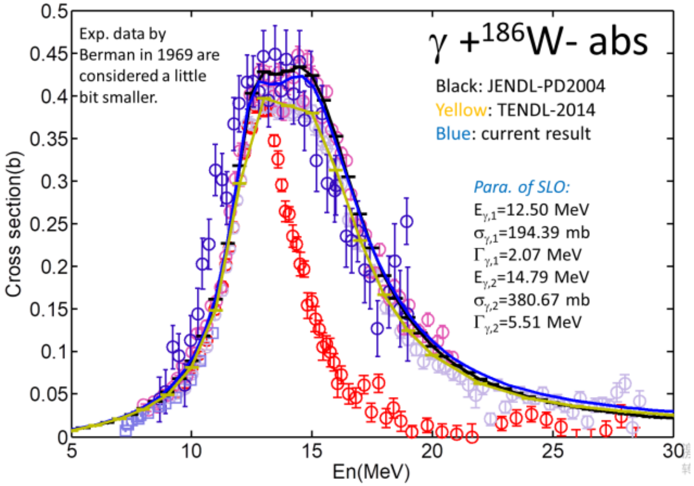
^{9}Be — ^{209}Bi 274 nuclei

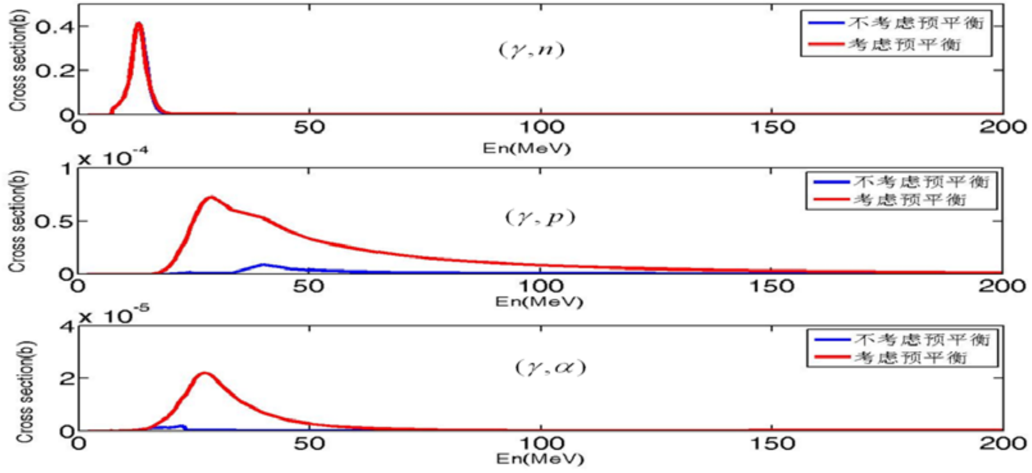






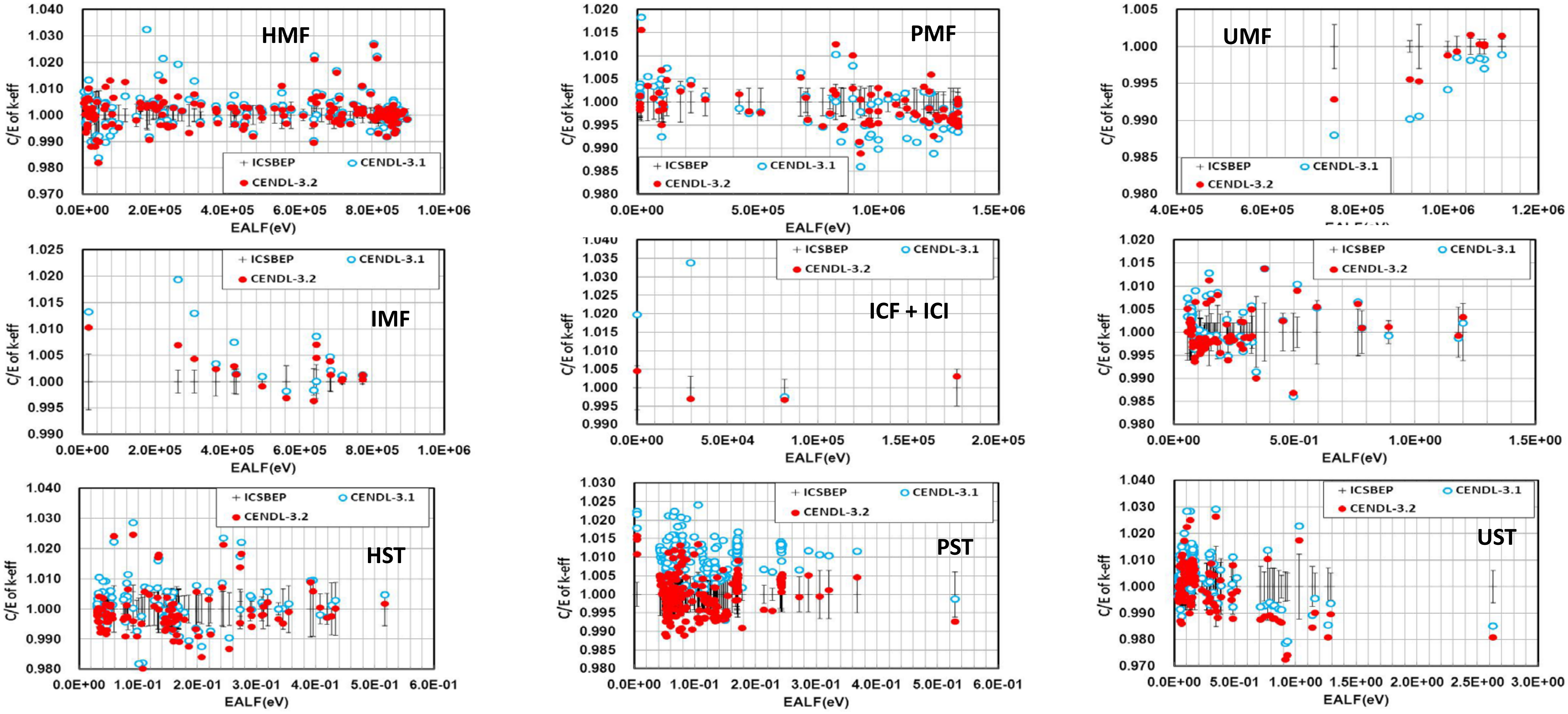






5. CENDL Validation and Application

Data validation for CENDL-3.2 via ENDITS



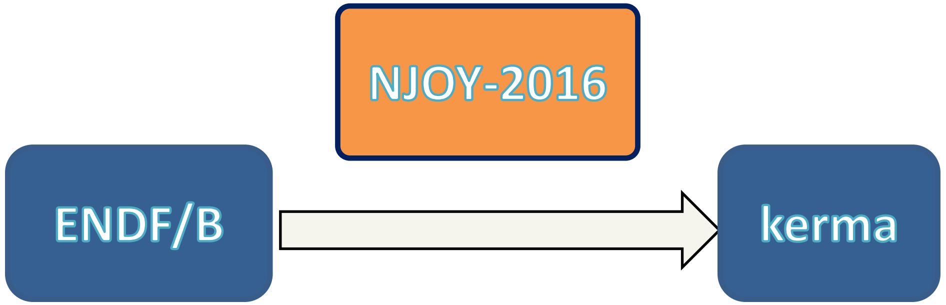
5. CENDL Validation and Application

Overall view with statistics

- CENDL-3.2 gives the best x^2 in comparison.
- The prediction for ^{235}U and Pu systems get remarkable improvement.

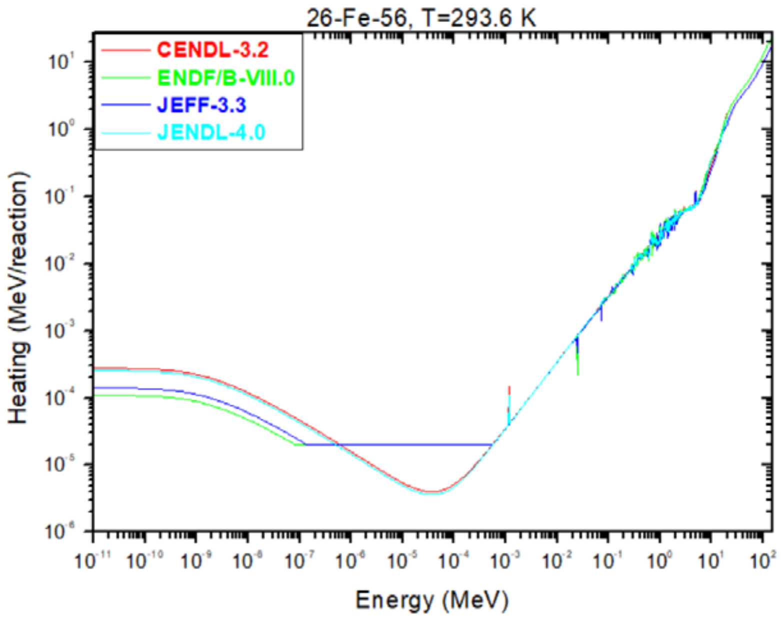
Type	Cores	Quantity	CENDL-3.2	CENDL-3.1	ENDF/B-VIII.0	JENDL-4.0	JEFF-3.3
U-235	698	C/E-1(pcm)	-13	197	-8	59	158
		STDEV	828	912	825	906	868
		χ^2	16.94	31.91	21.61	19.33	21.29
U-Pu	7	C/E-1(pcm)	155	-36	-170	-1233	176
		STDEV	277	285	225	572	221
		χ^2	20.40	11.89	5.89	249.26	4.58
Pu	388	C/E-1(pcm)	27	729	68	541	217
		STDEV	511	788	485	562	494
		χ^2	2.80	8.90	2.13	4.81	2.72
U-233	165	C/E-1(pcm)	-449	-36	-581	-649	-313
		STDEV	1206	1196	1116	1030	1120
		χ^2	5.18	6.52	4.78	4.74	4.39
All	1261	C/E-1(pcm)	-58	327	-63	106	112
		STDEV	821	958	809	914	828
		χ^2	11.03	21.33	13.28	14.19	13.24

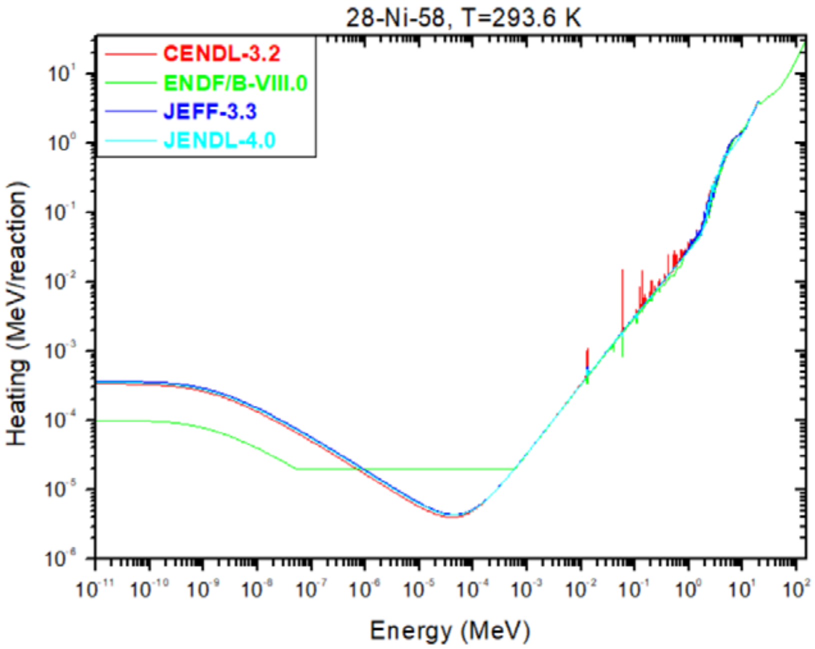
CENDL-3.2 : Kerma factors calculations

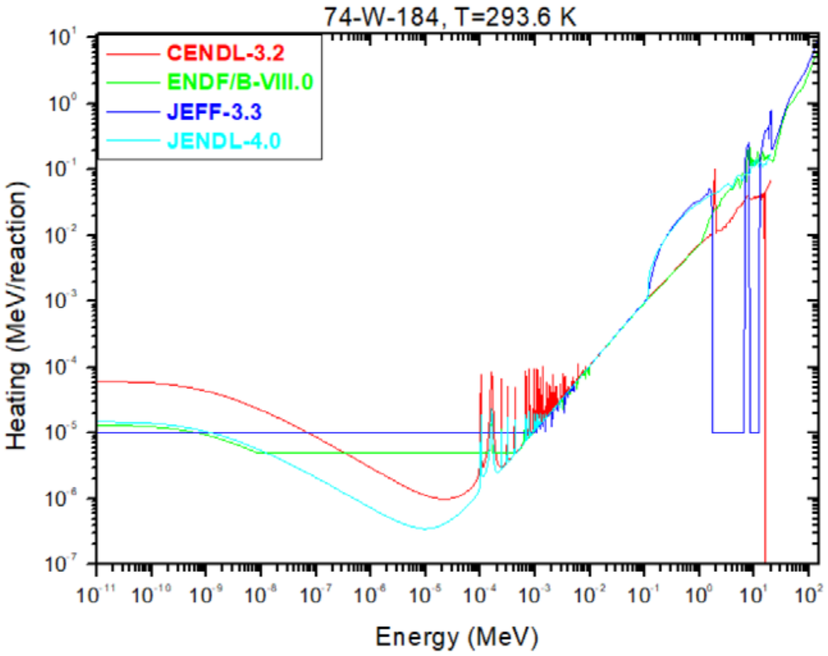


NJOY 2016 input

heatr /Add heating kerma and damage energy
-21 -23 -24/
2631 2 0 0 0 1/
443 444/ 443-total kinematic kerma







6. Conclusion & Perspective

Conclusion:

- ✓ As the main output of CENDL project, CENDL-3.2 library is built with the general purpose to provide high-quality nuclear data for the modern nuclear science, engineering and nuclear technology etc applications
- ✓ CENDL-3.2 library is constituted by neutron, fission yield, decay and activation files, which is difference comparison with previous CENDL libraries, and provide more nuclear reaction information for application.
- ✓ Comparing with previous CENDL library, the updated evaluation of nuclear reaction data for several key nuclides, such as U-235, Pu-239, U-233, Th-232, Fe-56 and et al. has been revised and improved.
- ✓ The library was tested with the criticality and shielding benchmarks with ENDITS-1.0, better results have been obtained, and used for applications for CEFR, TMSR, CAP1400, ADS, BIRF, JUNA, BISOL etc projects.
- ✓ All CENDL project also benefit from the international cooperation such as NRDC network, IAEA/CRP, OECD/WPEC and et al;
- ✓ The CENDL-3.2(C32) will be officially released at the end of May 2020.

Perspective:

CENDL- future will benefit from the issues related to the fundamental nuclear physics in nuclear data :

- ✓ Physics for Fission process
- ✓ Physics for few body theory and light nuclei
- ✓ Physics around the reaction and structure data for neutron-rich nuclei

also from they issues related to the international nuclear data measurements, evaluation, library construction :

- ✓ Measurements for key elements with better accuracy
- ✓ Modern facilities with better quality for broader beam energy region and good intensity… …
- ✓ Systematic theoretical and evaluation studies for unstable nuclei
- ✓ Uncertainty evaluation based on nuclear data
- ✓ The microscopic study applied to the ND data production

and from :

- ✓ Deeper and further international co-operation … …!