

# ***2015/16 Status Report of China Nuclear Data Center***

***GE Zhigang***

***China Nuclear Data Center(CNDC)  
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***



# I. General Information of CNDC

## *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.**

# 1-1 Information of CNDC

## 中国核数据中心组织 CNDC Organization

主任



葛智刚 博士  
Dr. Ge Zhigang

副主任 Deputy Directors



陈国长 博士  
Dr. Chen Guochang



吴海成 博士  
Dr. Wu Haicheng

### 评价组 Evaluation Unit



组长：黄小龙 博士

- 实验核数据的编纂和评价工作
- 实验数据评价方法研究
- 建立实验核数据库 (EXFOR)

Head: Dr. Huang Xiaolong

- Exp. data evaluations
- Methodological studies of exp. data eval.
- EXFOR compilation

### 理论组 Theory Unit



组长：续瑞瑞 博士

- 核数据的核反应理论基础研究。
- 中子/带电粒子核反应程序研制。
- 核数据模型计算任务。

Head: Dr. Xu Ruirui

- Nucl. data model study
- Development of nucl. data code.
- Nucl. data calculation

## 宏观组 Macroscopic Data Unit



组长：刘萍博士

Head: Dr. Liu Ping

- 评价核数据库群常数加工制作。 □ Nucl. data processing
- 评价核数据基准检验。 □ Nucl. data benchmarking/validation
- 群常数制作和宏观检验方法研究 □ Methodological of benchmarking/processing

## 数据库组 Data Library Unit



组长：舒能川博士

Head: Dr. Shu Nengchuan

- 数据评价方法研究/评价系统建立 □ Data library setup/management
- 建立计算机化中国评价核数据库 □ Evaluation system of nucl. data setup
- 计算机网络系统/用户服务。 □ Nucl. data service/user

Evaluation Unit	Head: Dr. Huang Xiaolong	4 official staff
Theory Unit	Head: Dr. Xu Ruirui	6 official staff
Macroscopic Data Unit	Head: Dr. Liu Ping	4 official staff
Data Library Unit	Head: Dr. Shu Nengchuan	5 official staff
Secretary Office		1 official staff

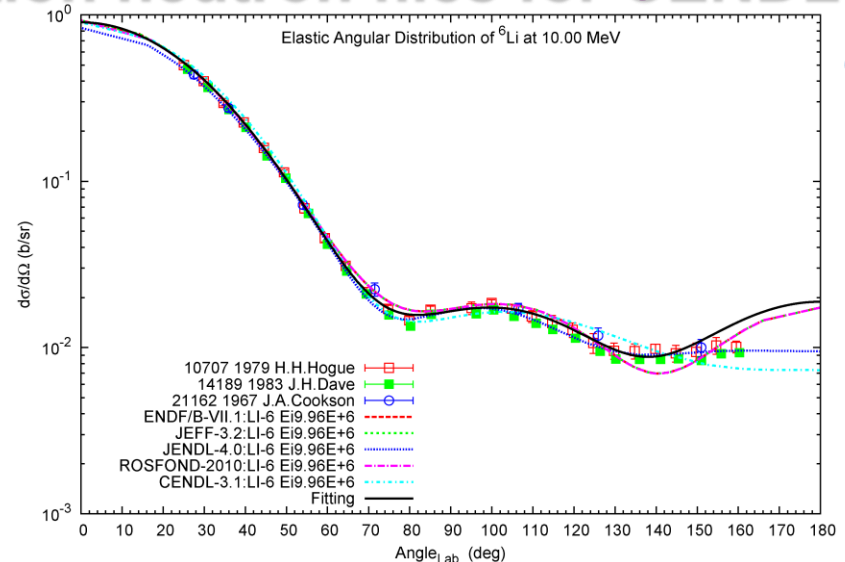
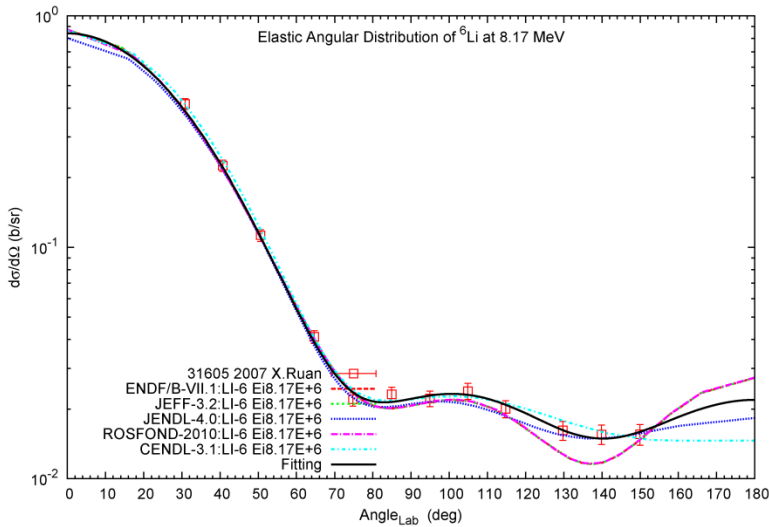
- ✓ 21 official staff + 5 students (Master 3, Ph.D 2).
- ✓ Planning to increase the official staff up to 25 in recently years.

## 1-2 Mainly tasks of CNDC in 2015/2016:

- **New evaluations and re-evaluations for neutron data file for CENDL.**
- **Nuclear structure and decay data evaluation.**
- **Update photonuclear data evaluations.**
- **Methodological studies of nuclear data evaluation.**
- **Nuclear data processing code development.**
- **Experimental data compilations for EXFOR.**
- **The fundamental studies of nuclear data evaluations/measurements.**
- **The regular update and maintenance of IAEA/NDS mirror-site in China.**
- **Nuclear data services is providing to all the nuclear data users.**

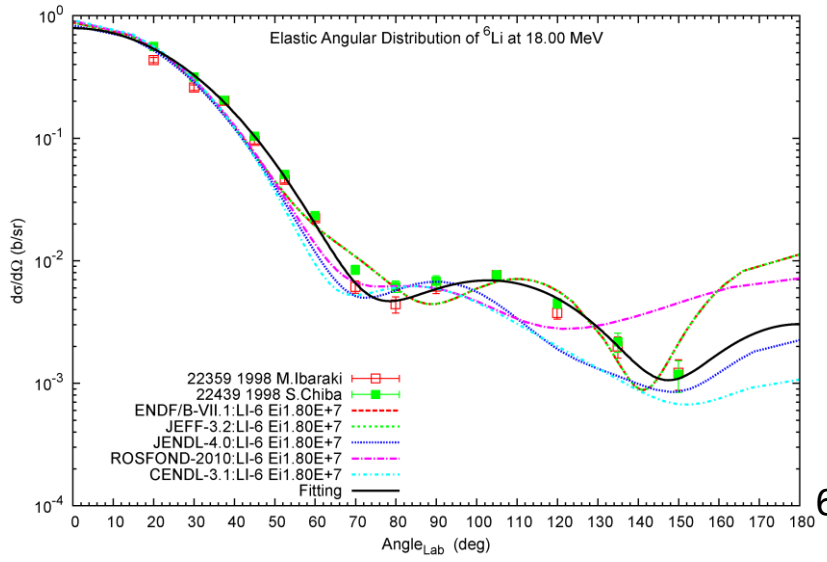
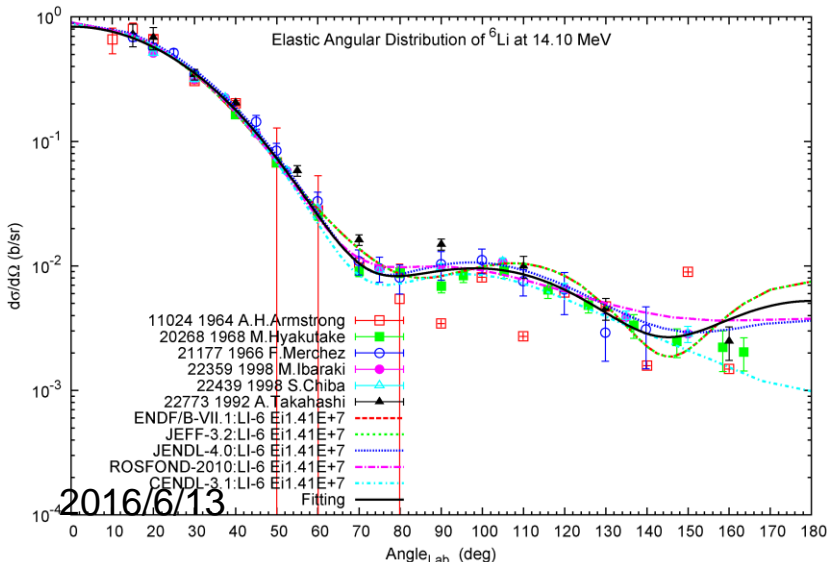
# II. Nucl Data Evaluation Methodological Studies

## 2-1 New evaluation/re-evaluation neutron files for CENDL



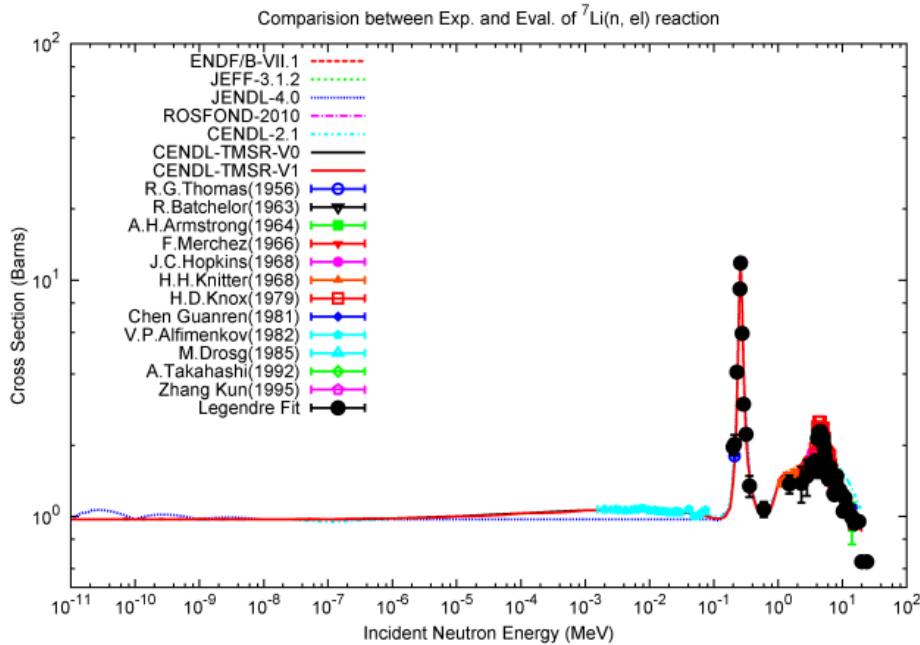
${}^6\text{Li}$

Fig.1  ${}^6\text{Li}$  elastic angular distribution compared with exp. data and other evaluated files.

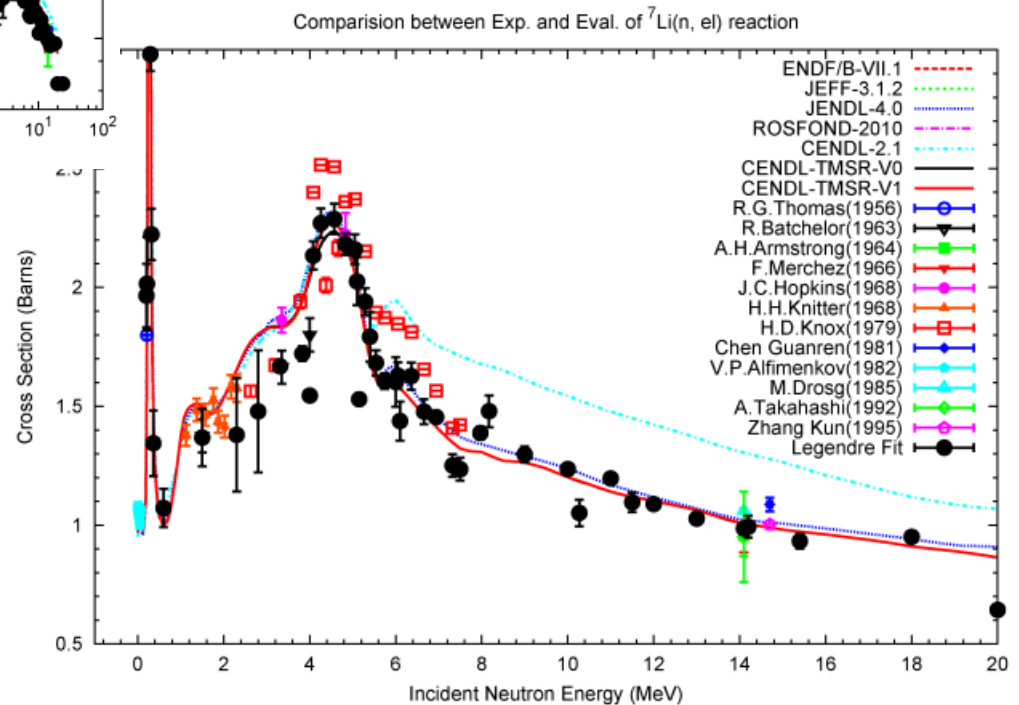


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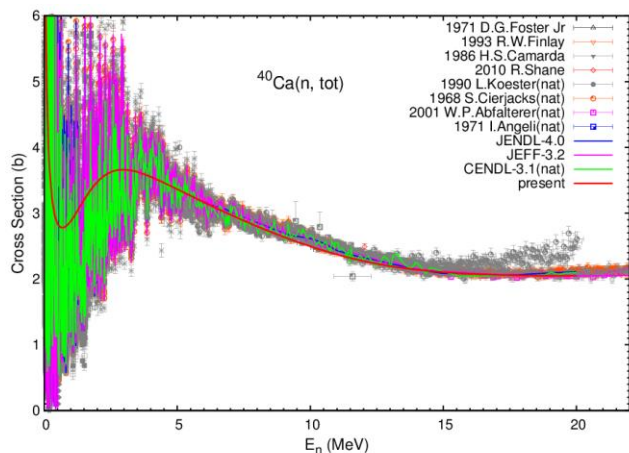
<sup>7</sup>Li



The new evaluated <sup>7</sup>Li(n,e) cross section compared with exp. data and other files.

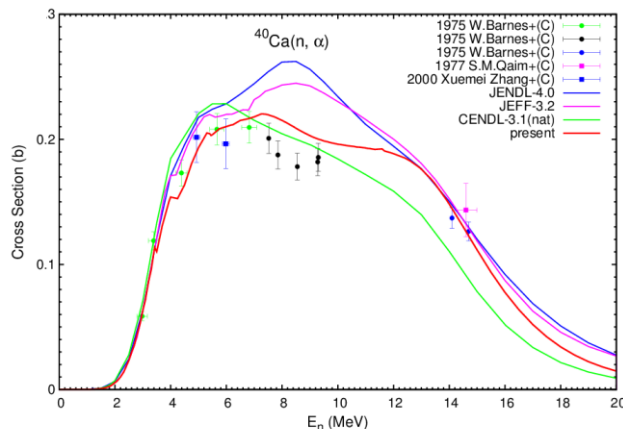


- New evaluation and covariance based on the experimental data for (n,tot) and (n,  $\alpha$ )
- Koning-Delaroche potential is utilized to calculate the neutron scattering. This function is incorporated in the latest UNF2015
- The discrete levels are adopted as the data JENDL-4



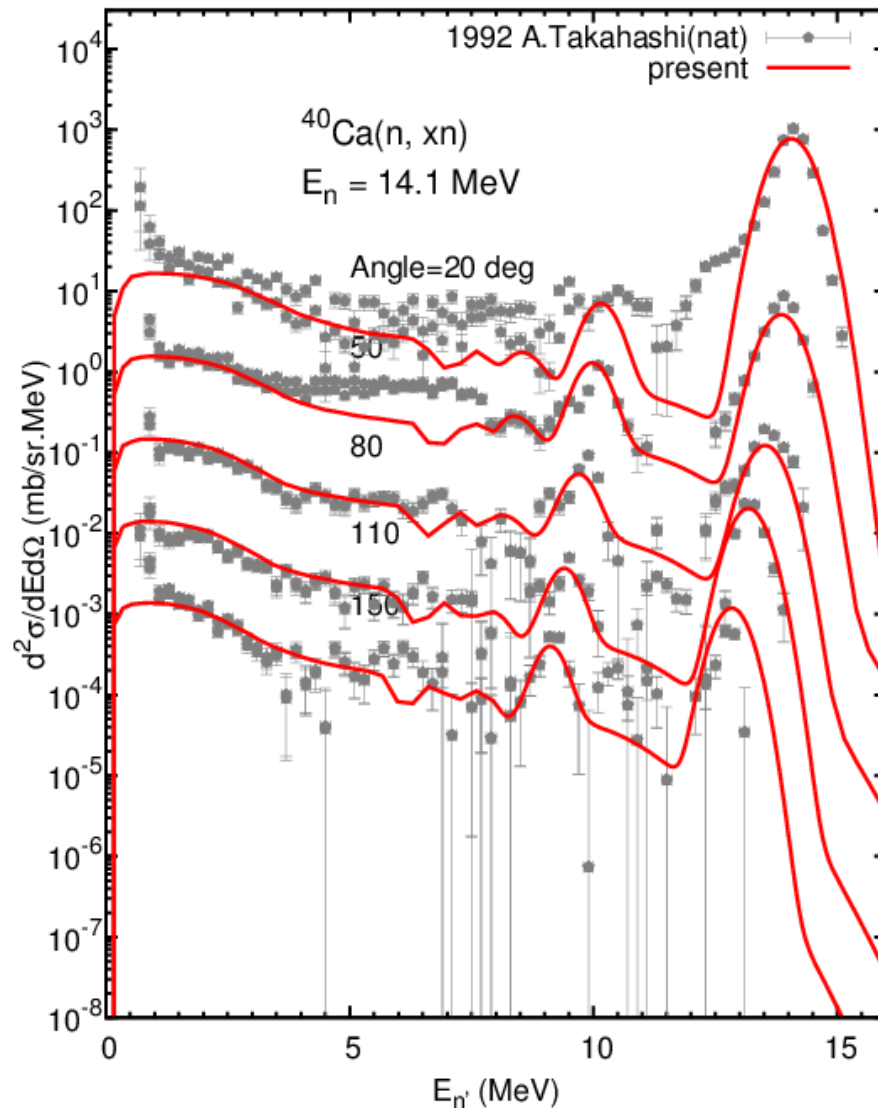
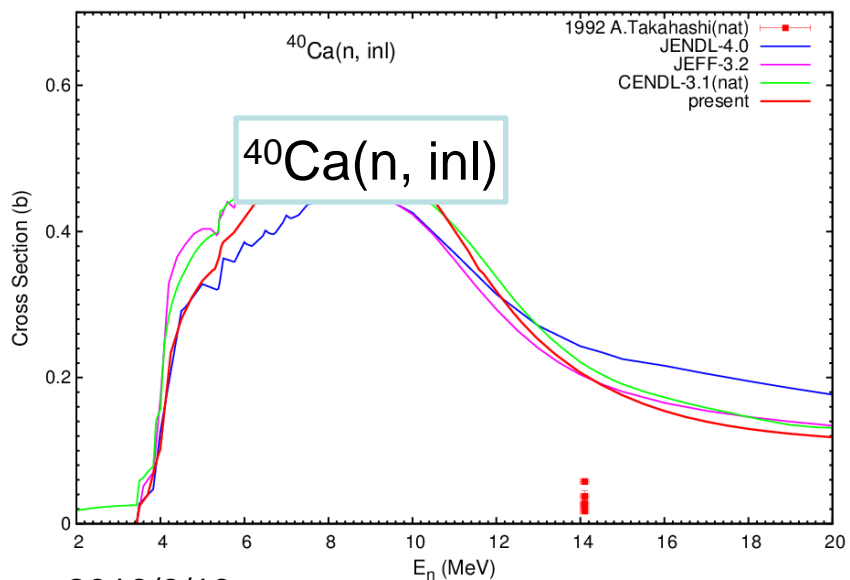
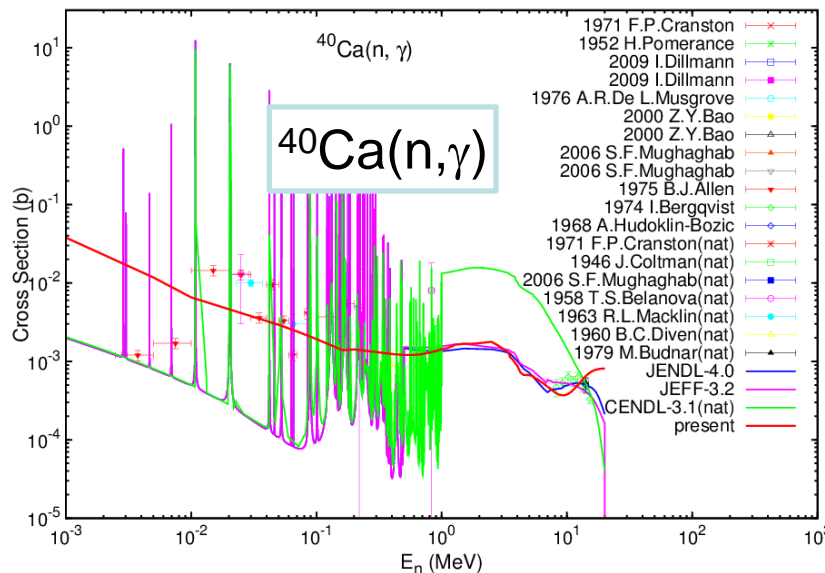
←  $^{40}\text{Ca}(n, \text{tot})$

$^{40}\text{Ca}(n, \alpha)$  →

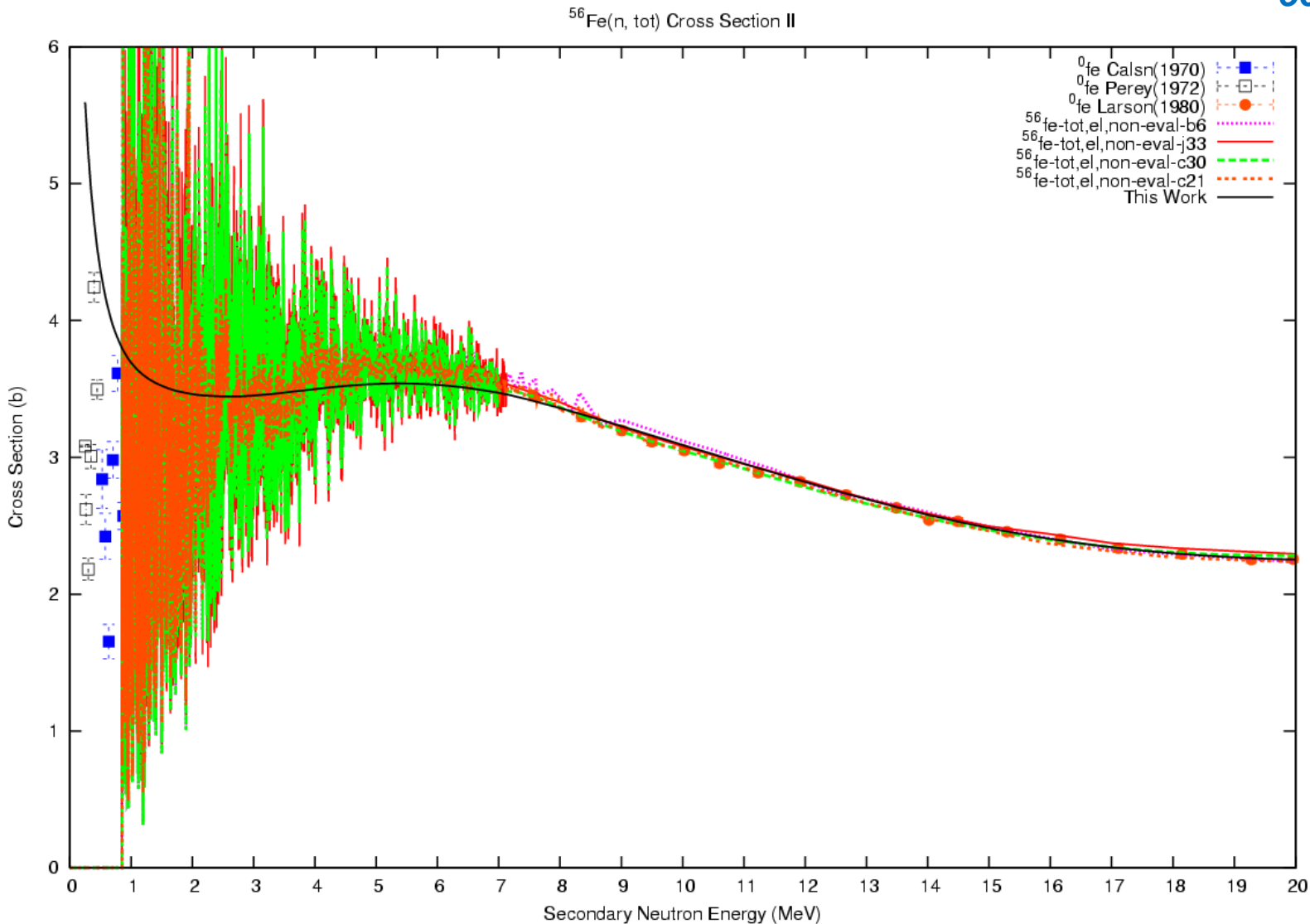


Level	Spin	Parity	DWBA
ground	0	1	0
3.35262	0	1	0
3.73669	3	-1	1
3.90438	2	1	1
4.49143	5	-1	1
5.21156	0	1	0
5.24879	2	1	1
5.2788	4	1	1
5.61352	4	-1	0
5.62941	2	1	1
5.90263	1	-1	0
6.025471	2	-1	0
6.02971	3	1	0
6.28515	3	-1	1
6.4224	2	1	1
6.50787	4	1	0
6.5428	4	1	1
6.58247	3	-1	0
6.750411	2	-1	1
6.9087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

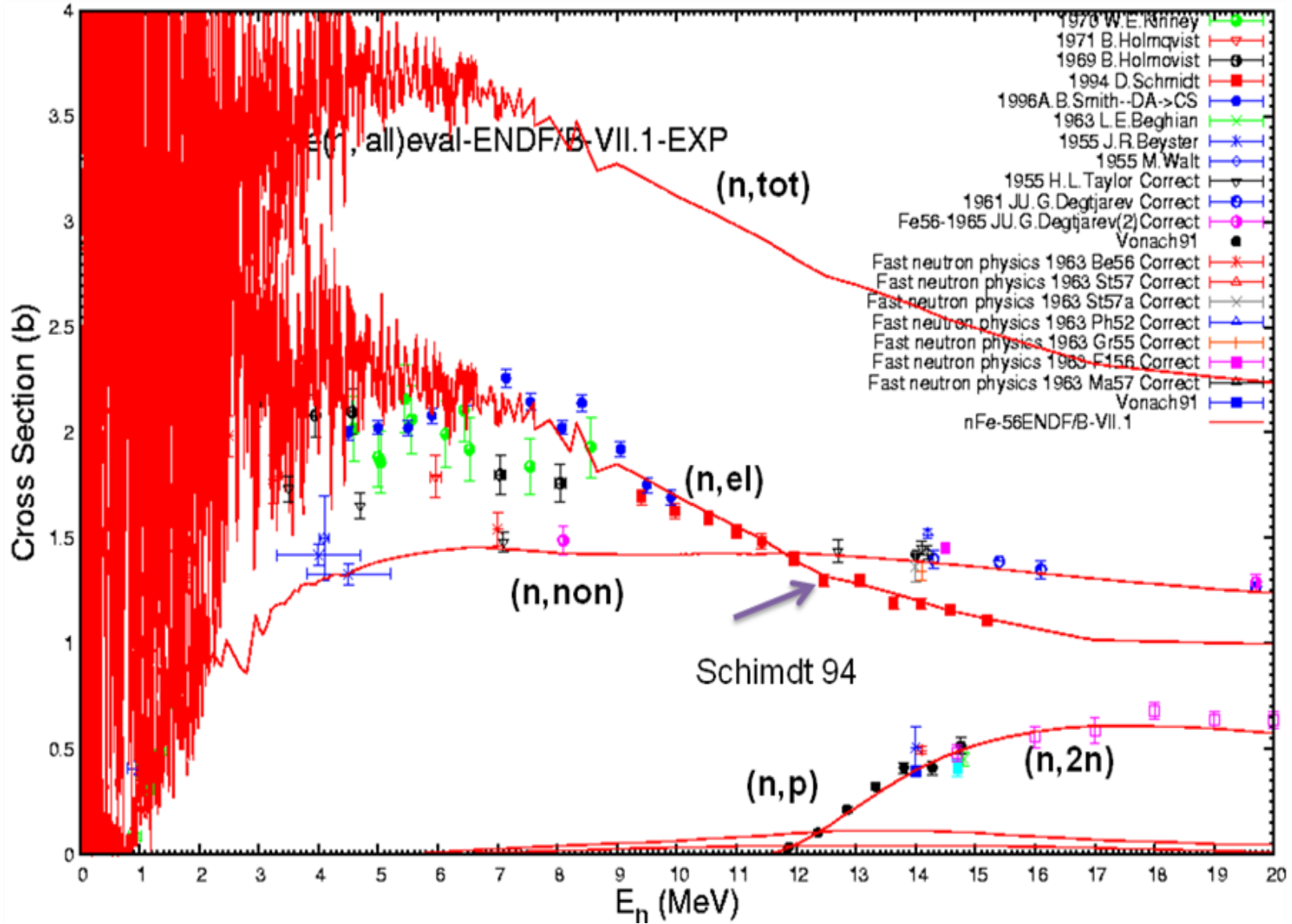




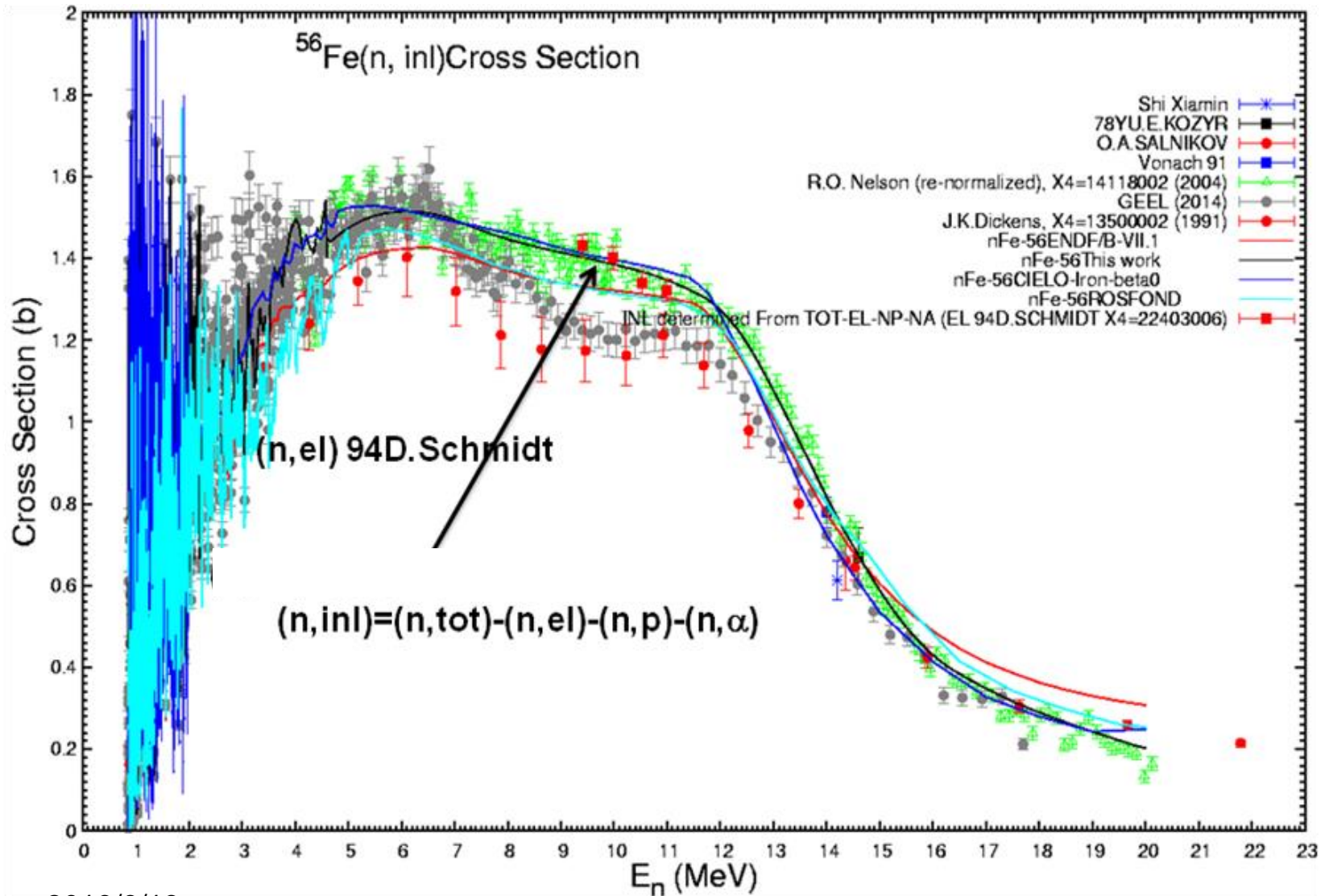
**<sup>56</sup>Fe**

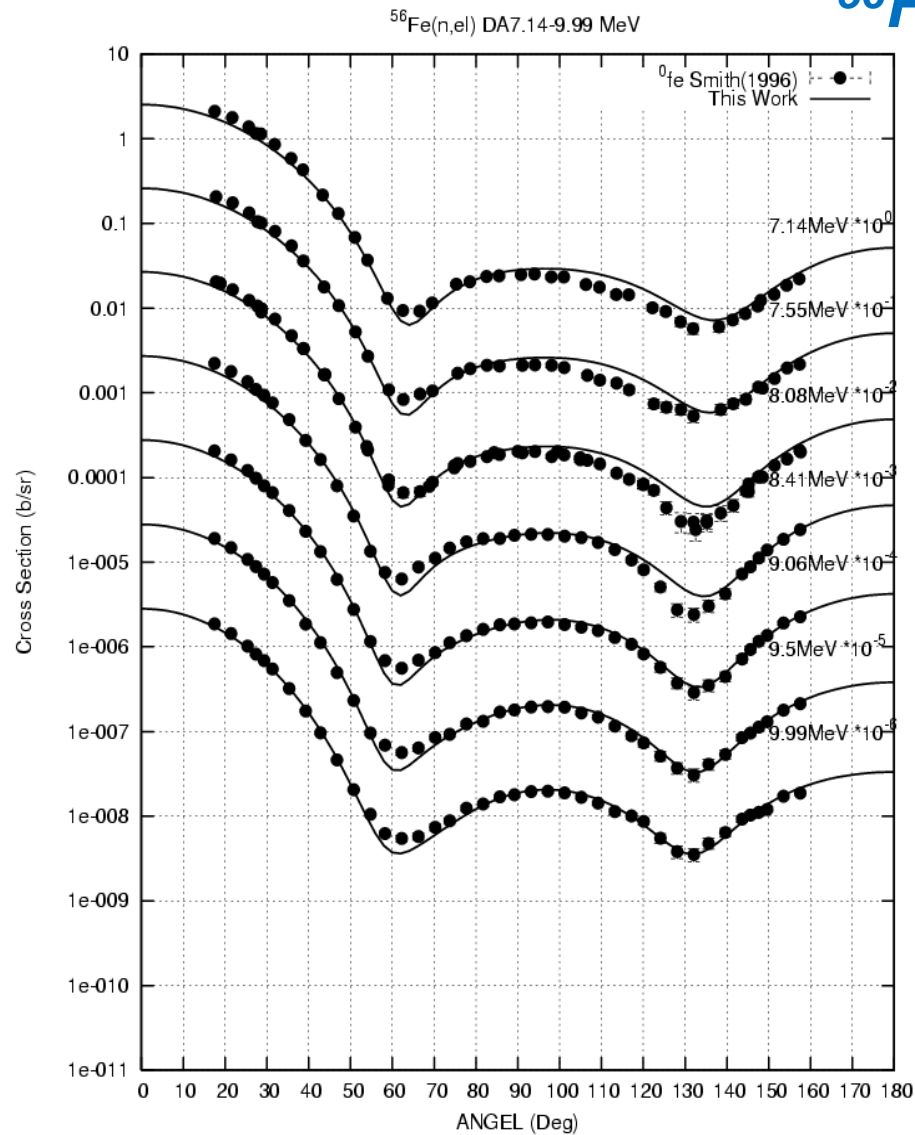
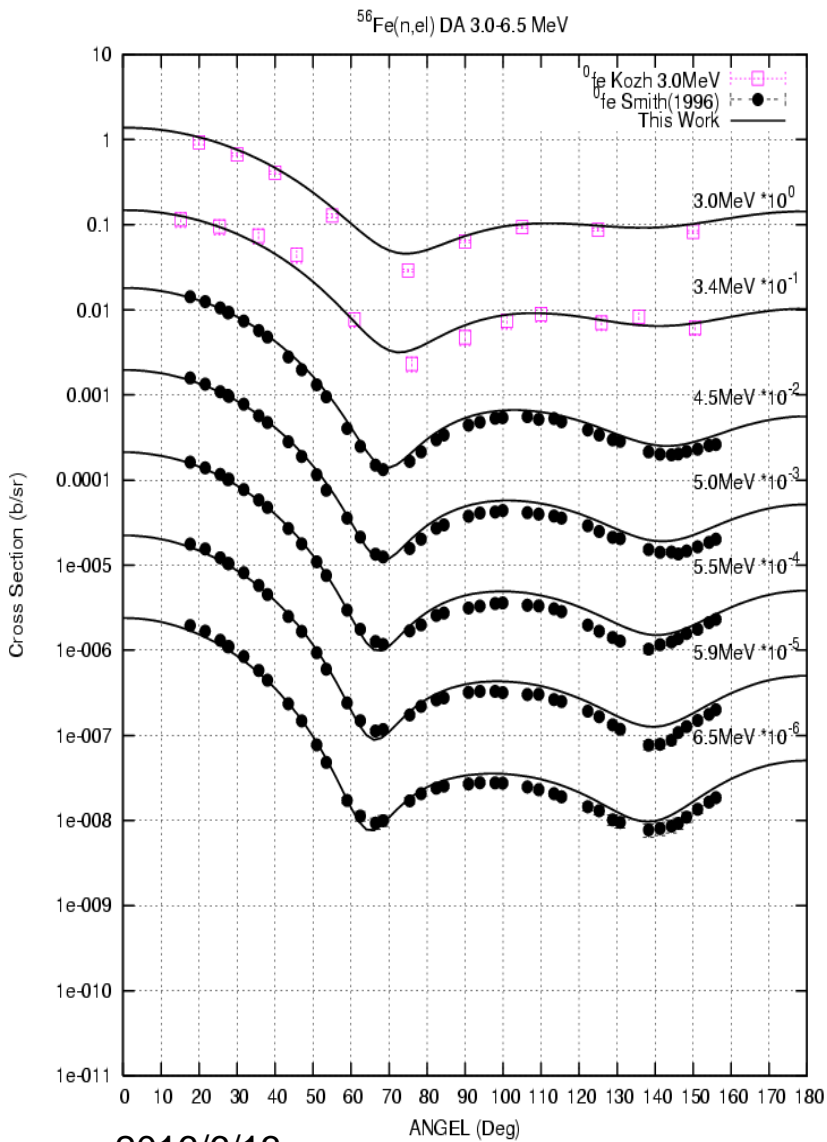


<sup>56</sup>Fe

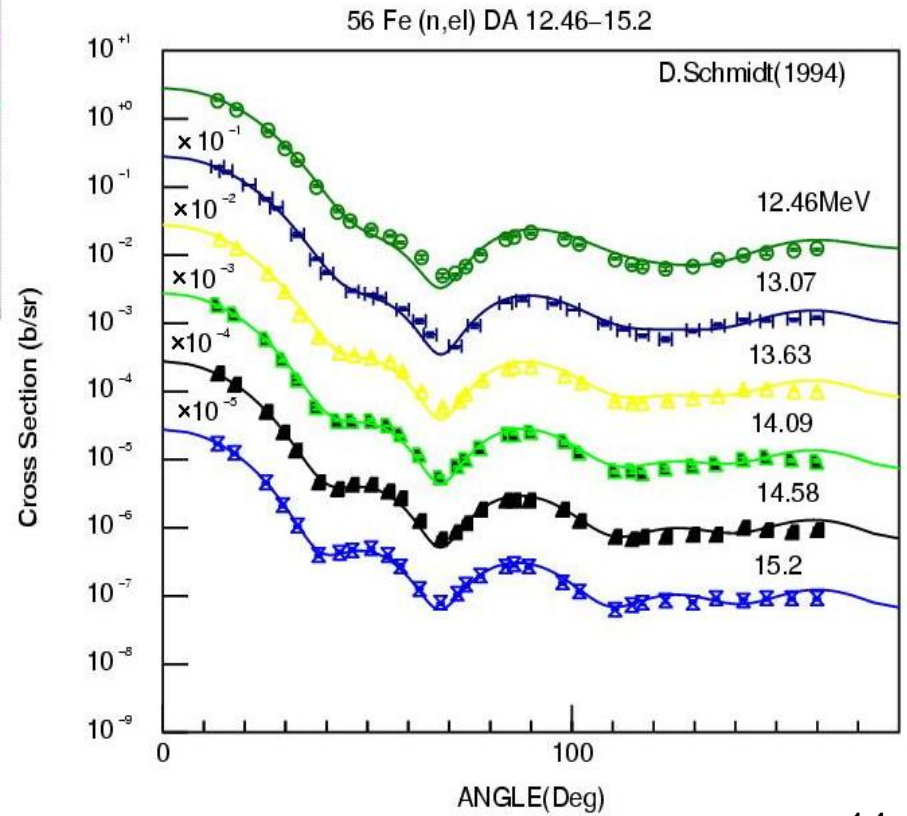
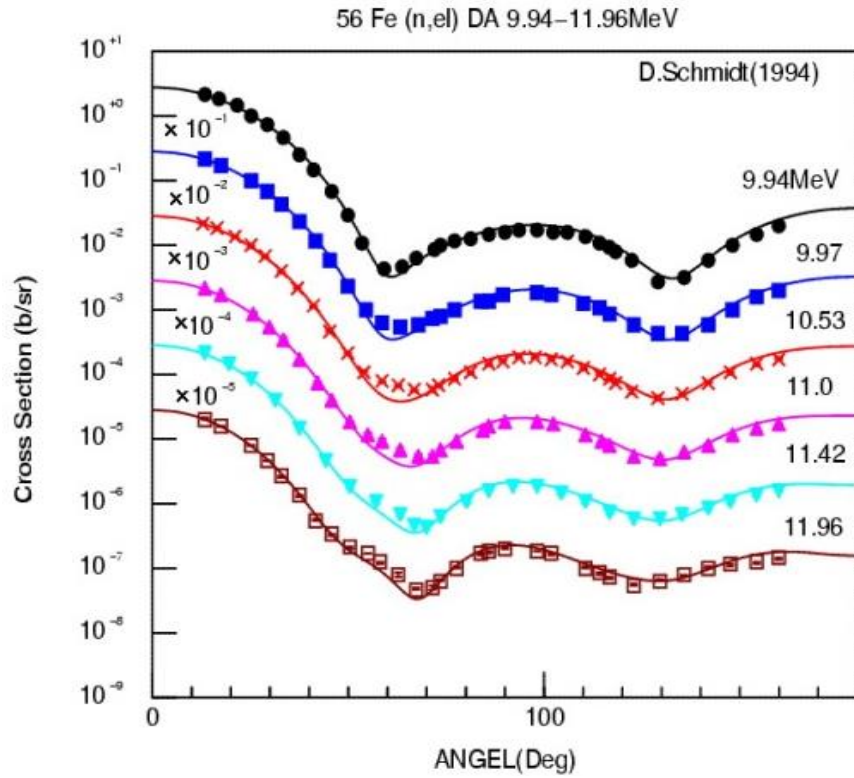


<sup>56</sup>Fe

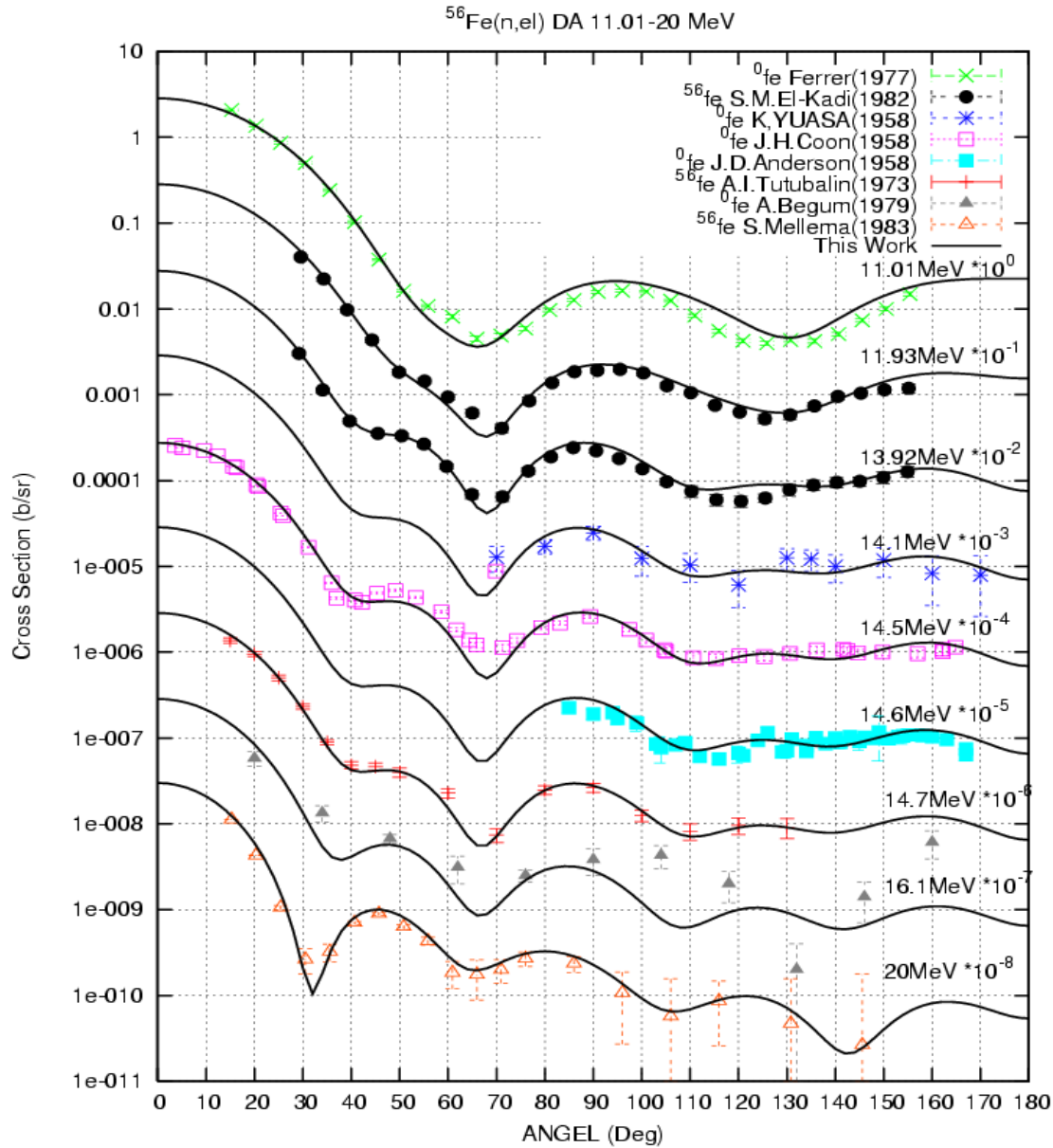


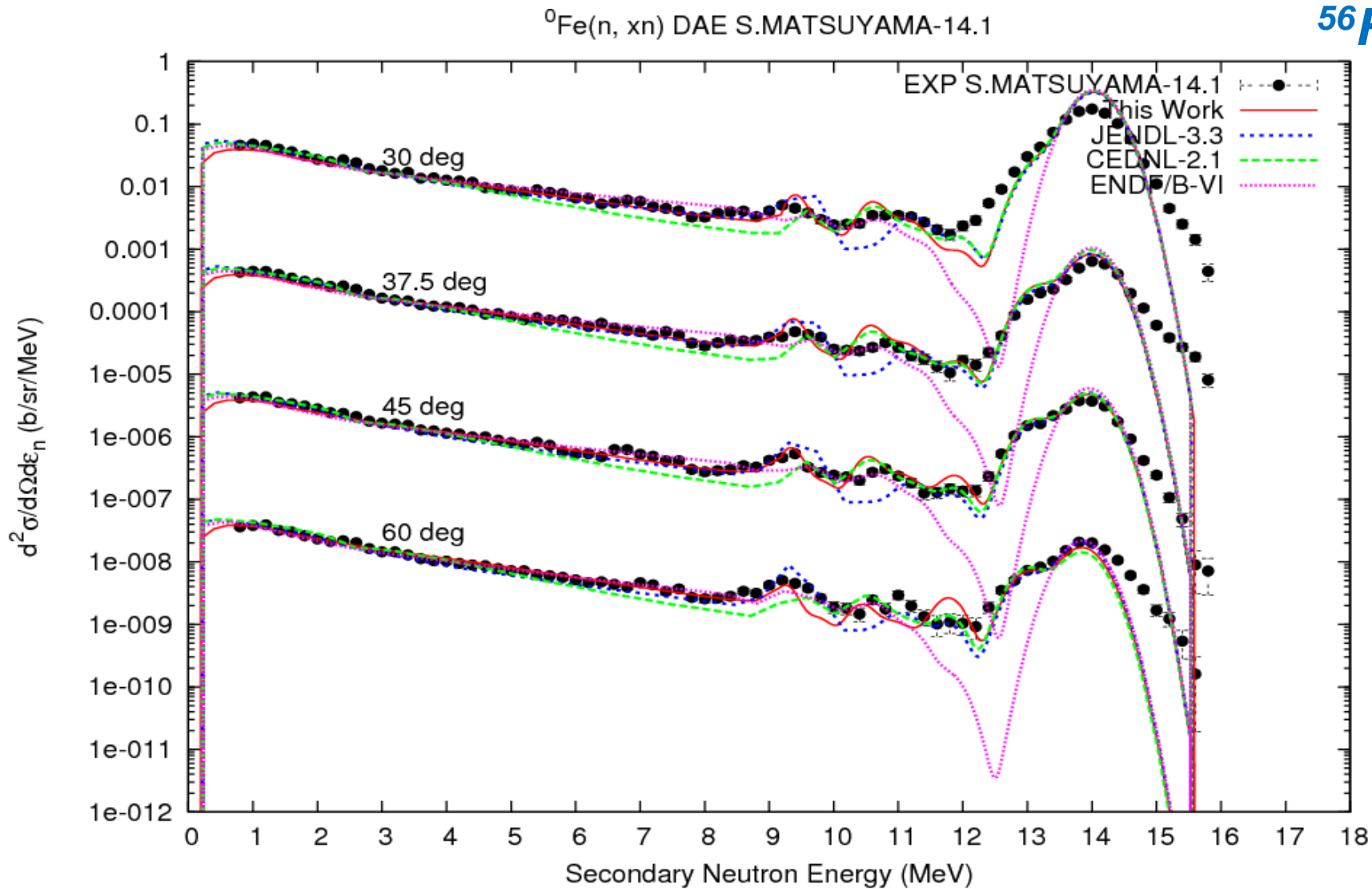


<sup>56</sup>Fe



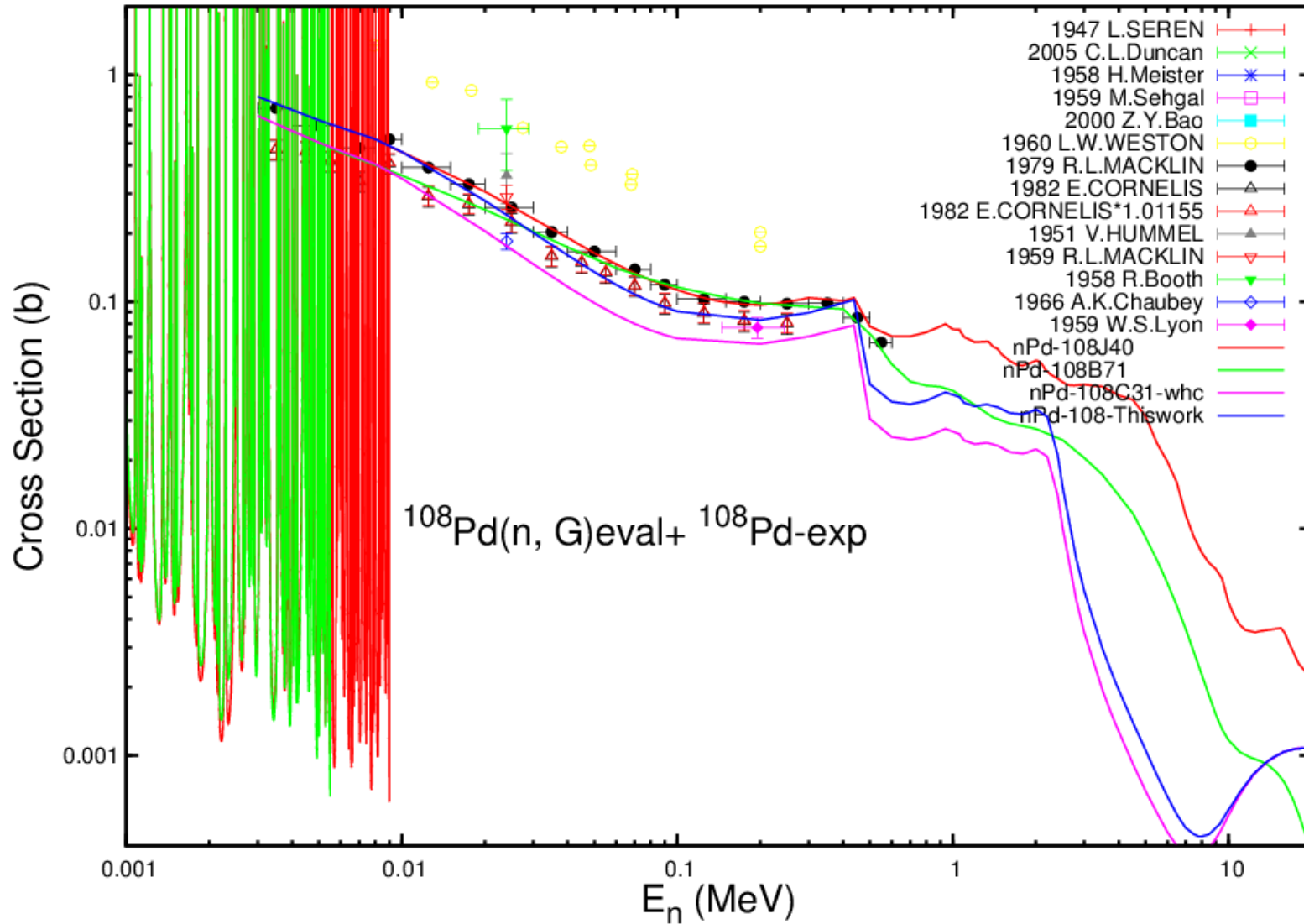
<sup>56</sup>Fe



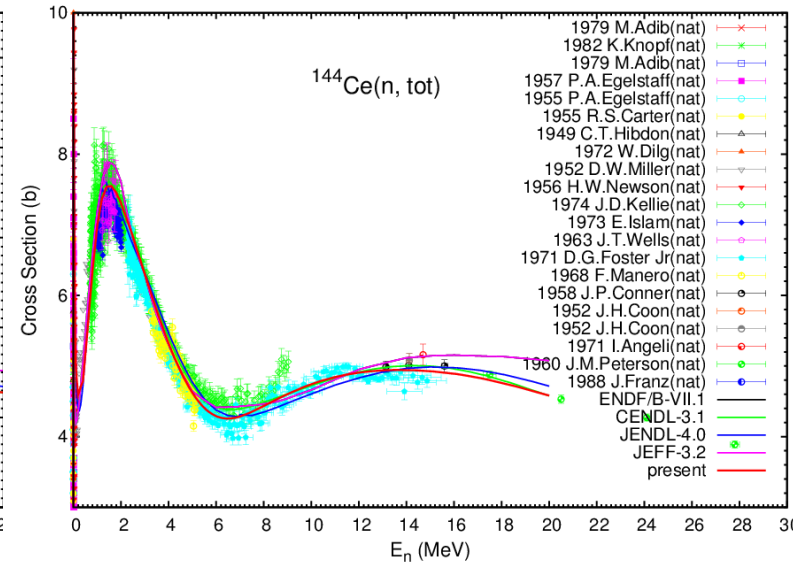
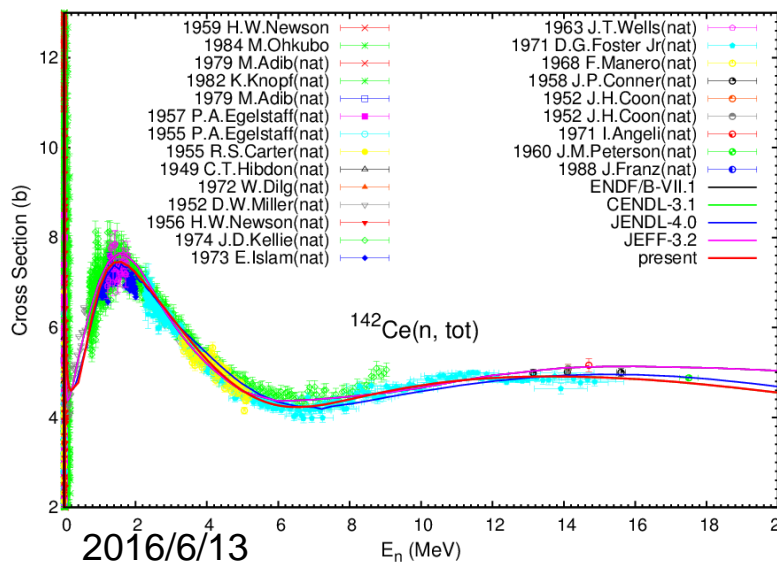
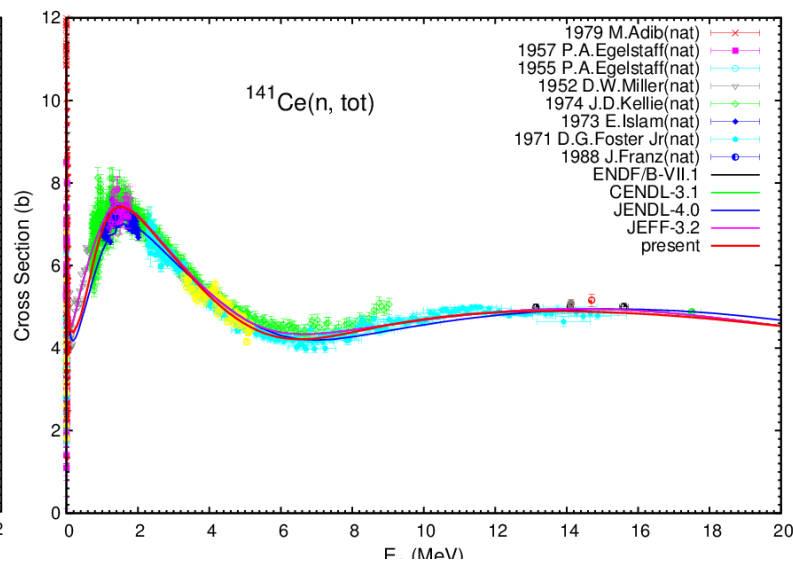
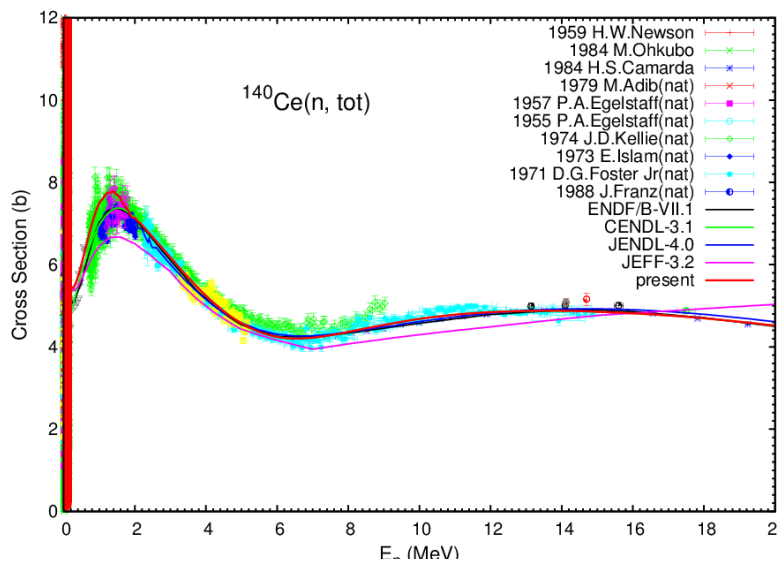




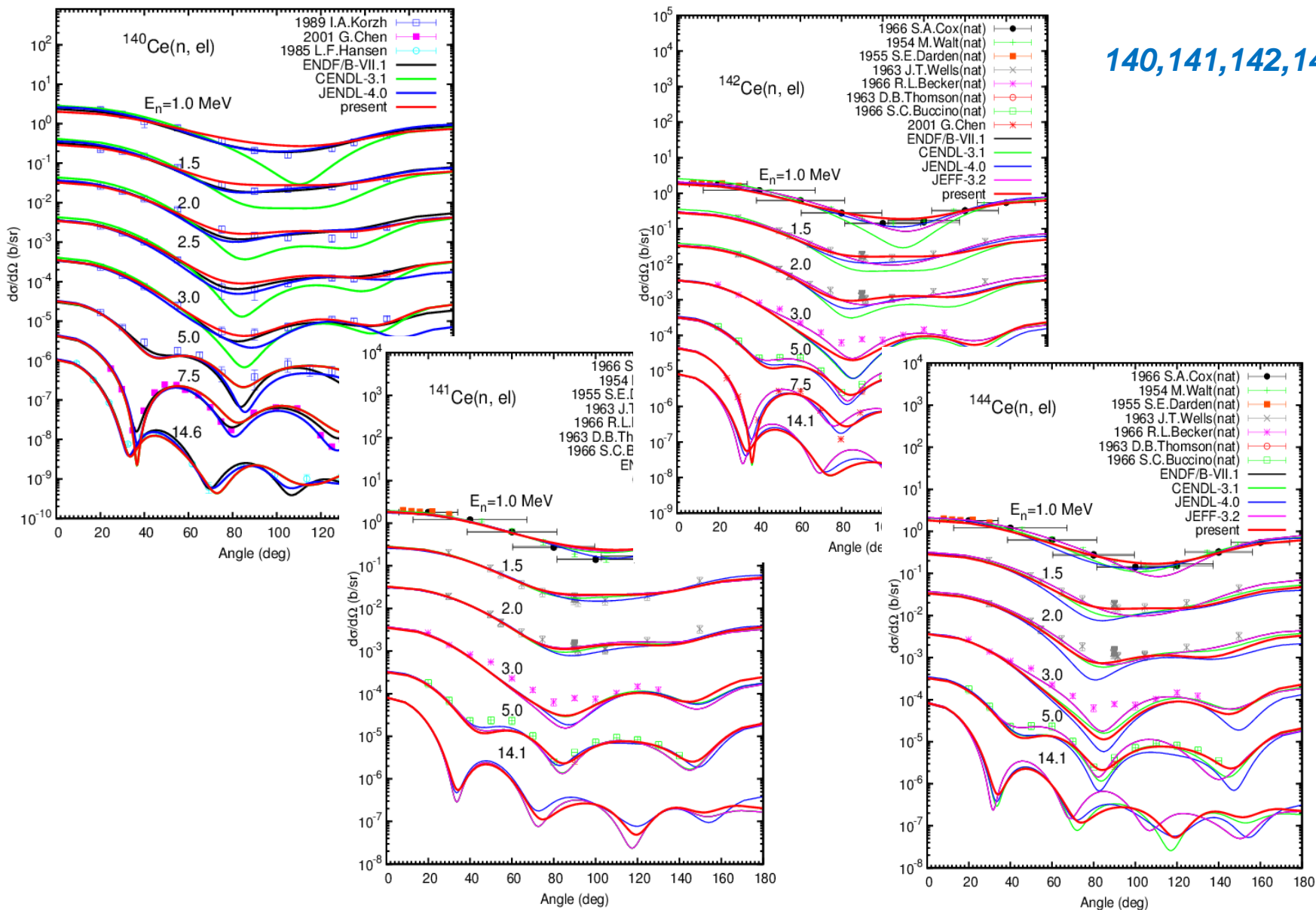
<sup>108</sup>Pd

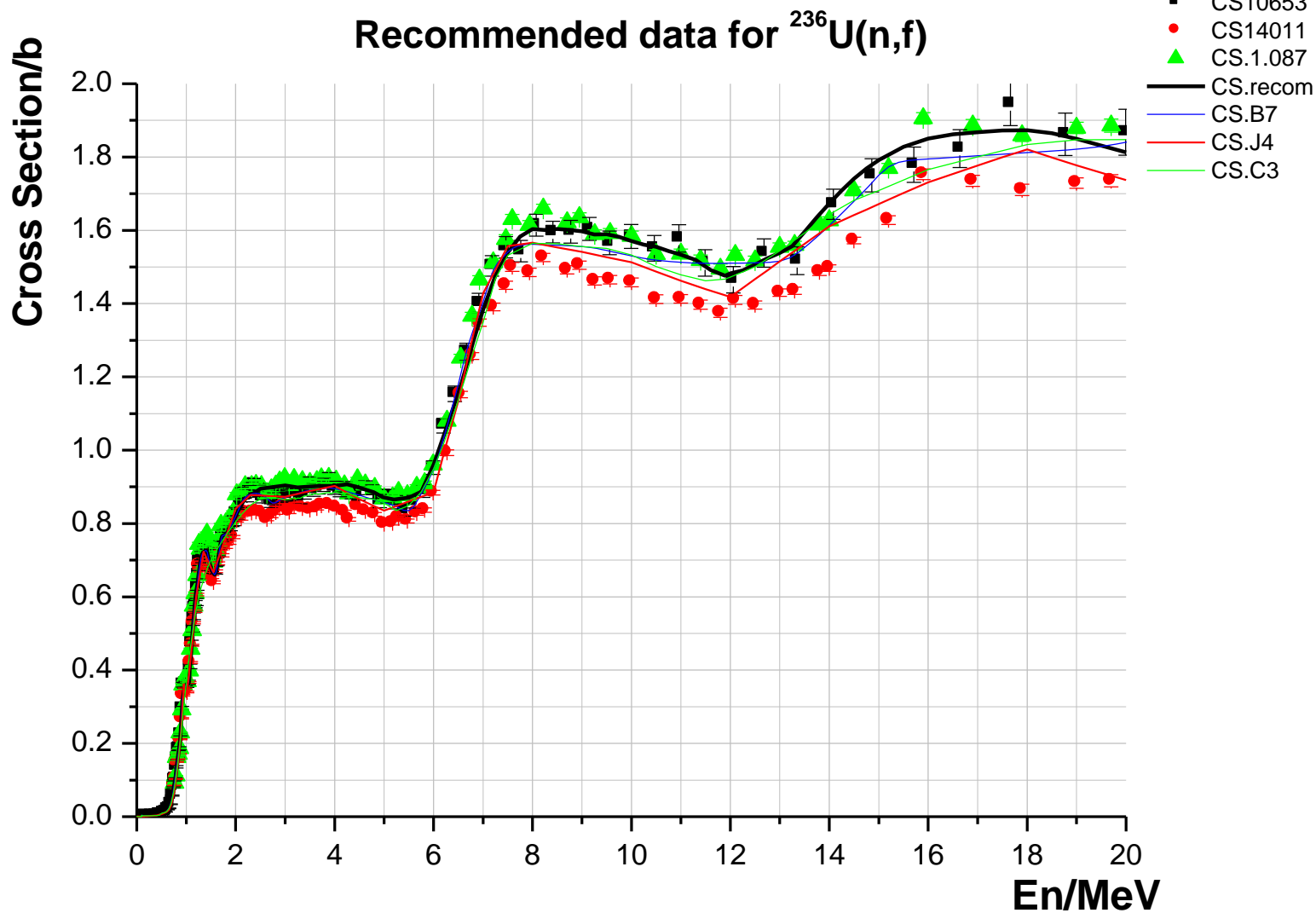


# 140,141,142,144Ce



# 140,141,142,144Ce





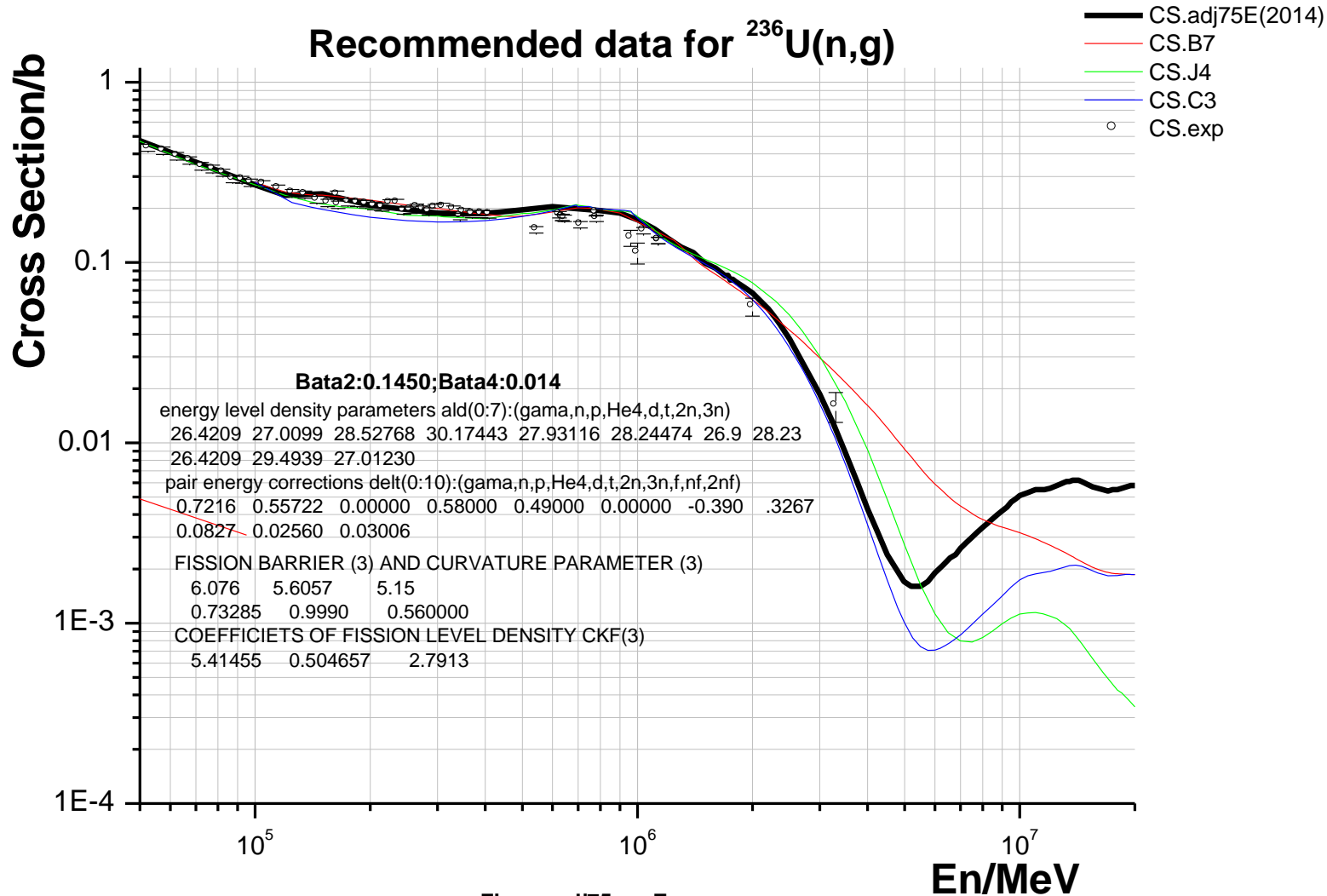
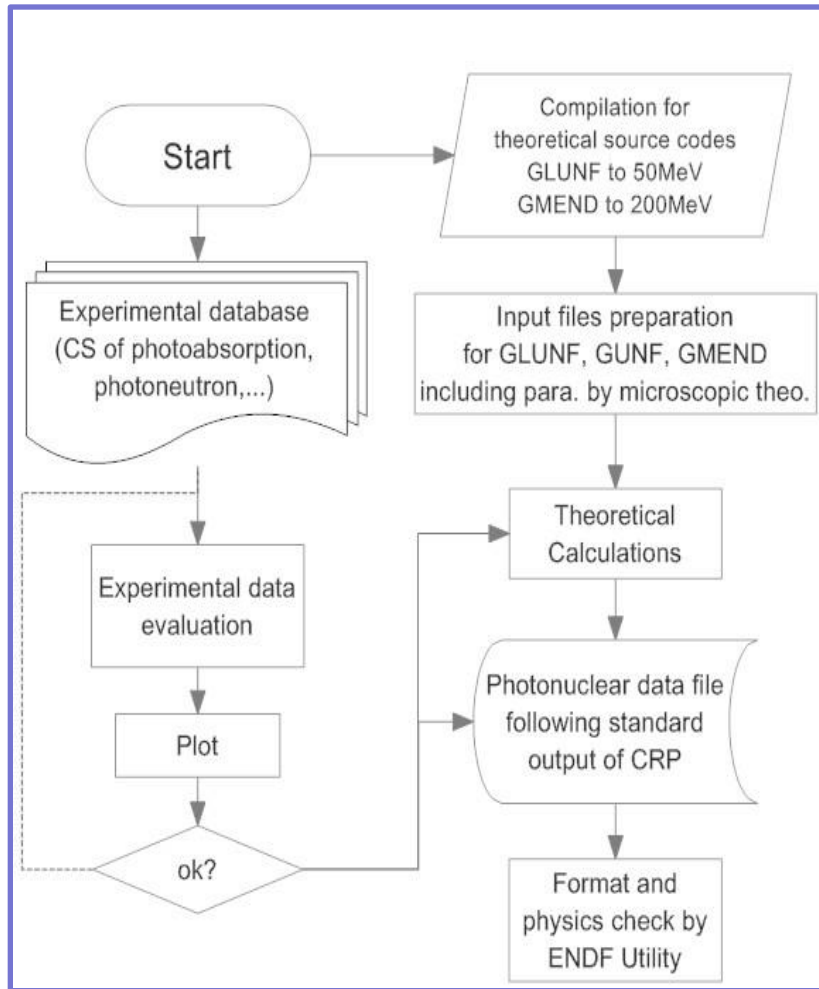


Fig:ng-adj75rec-E

## Program of photonuclear data study



- CNDC attends the latest CRP of IAEA from 2016
- The photonuclear data of light and middle-heavy nuclei are being evaluated recently, and the new experimental data evaluation and theoretical source codes compilation are being carried out so as to fulfill the requirement of CRP;
- The recommended data files would be include the calculation results by:  
GLUNF for light nuclei;  
GUNF and GMEND for middle-heavy nuclei;
- 28 nuclei are planned to involve in this CRP (nuclei in red are in this contract):  
Update  $^9\text{Be}$ ,  $^{27}\text{Al}$ ,  $^{51}\text{V}$ ,  $^{50,52,53,54}\text{Cr}$ ,  $^{54,56,57,58}\text{Fe}$ ,  $^{63,65}\text{Cu}$ ,  $^{90,91,92,94,96}\text{Zr}$ ,  $^{180,182,183,184,186}\text{W}$ ,  $^{209}\text{Bi}$ ;  
New evaluations for  $^{6,7}\text{Li}$ ,  $^{10,11}\text{B}$ ;
- The microscopic prediction for the photon strength function are performed by QRPA simultaneously.

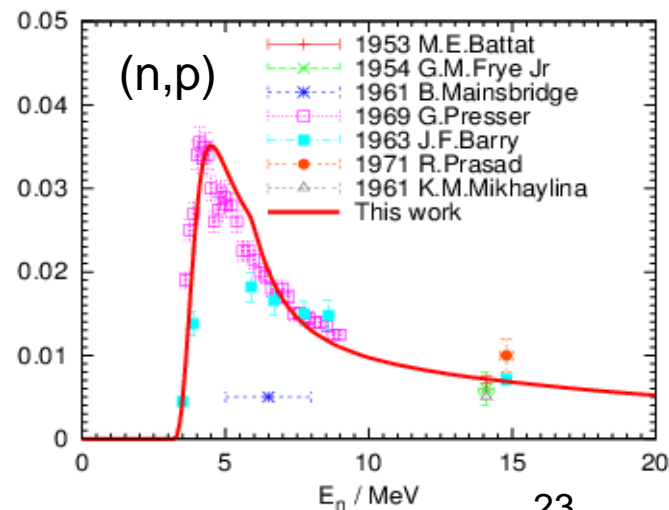
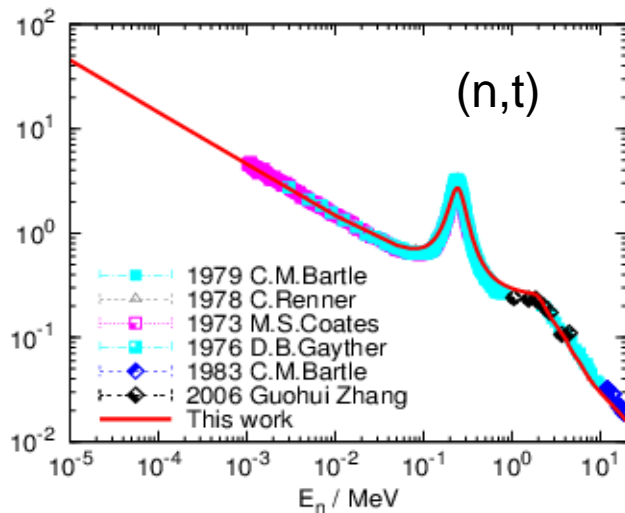
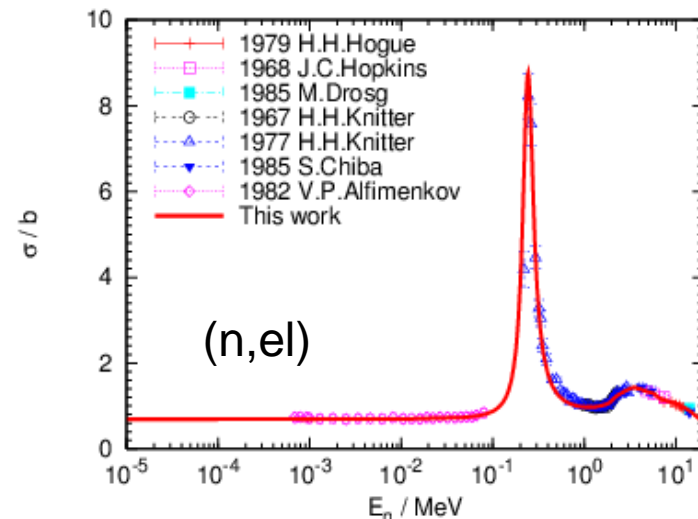
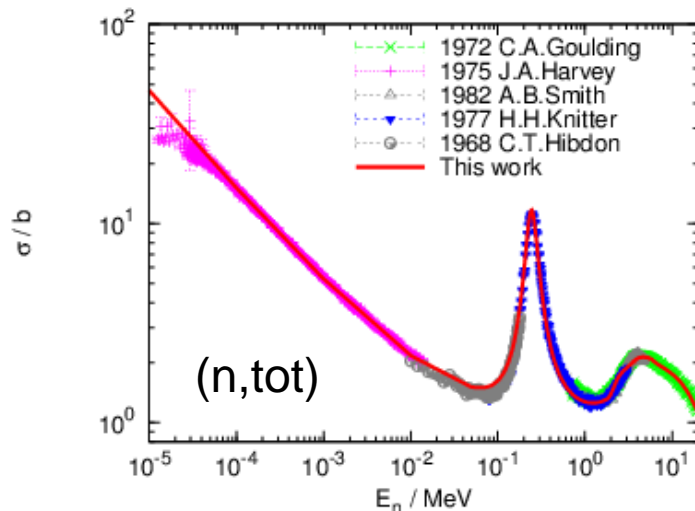
## 2-2 Methodological Studies

### For light nuclei evaluation

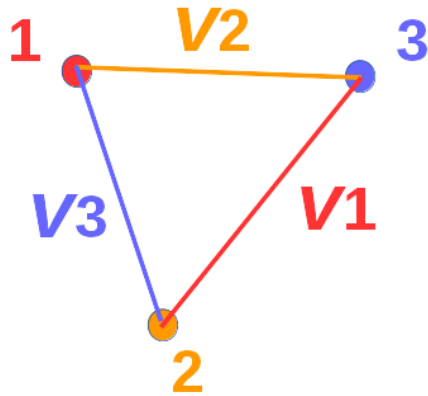
- FDRR code

a) Full and Diagonal Reduced R-matrix theory is under development to generate cross sections.

b) LUNF code is planned to apply in producing the double differential cross section.



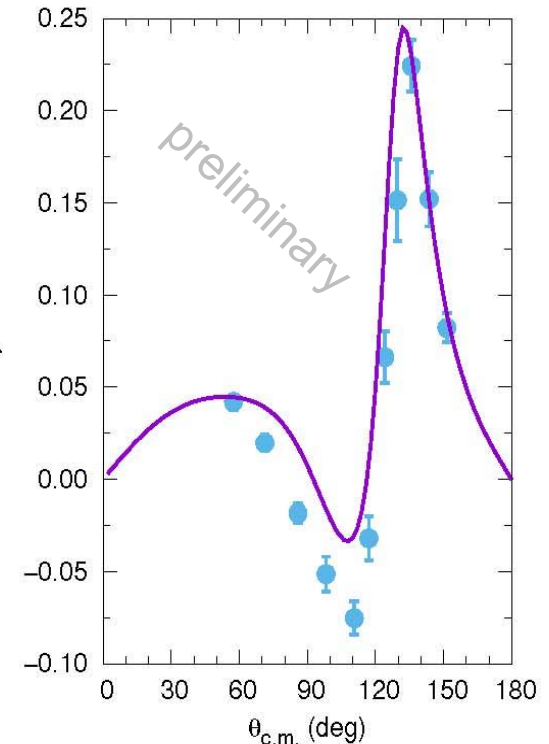
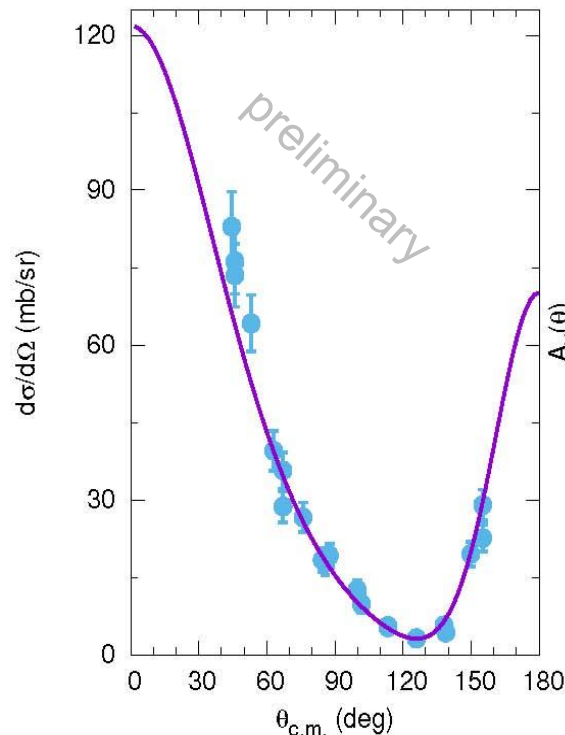
● Faddeev method for 3N reactions



n+d scattering, elastic scattering and analyzing power,  $E_n=21$  MeV, comparison with experimental data

In our present scheme:

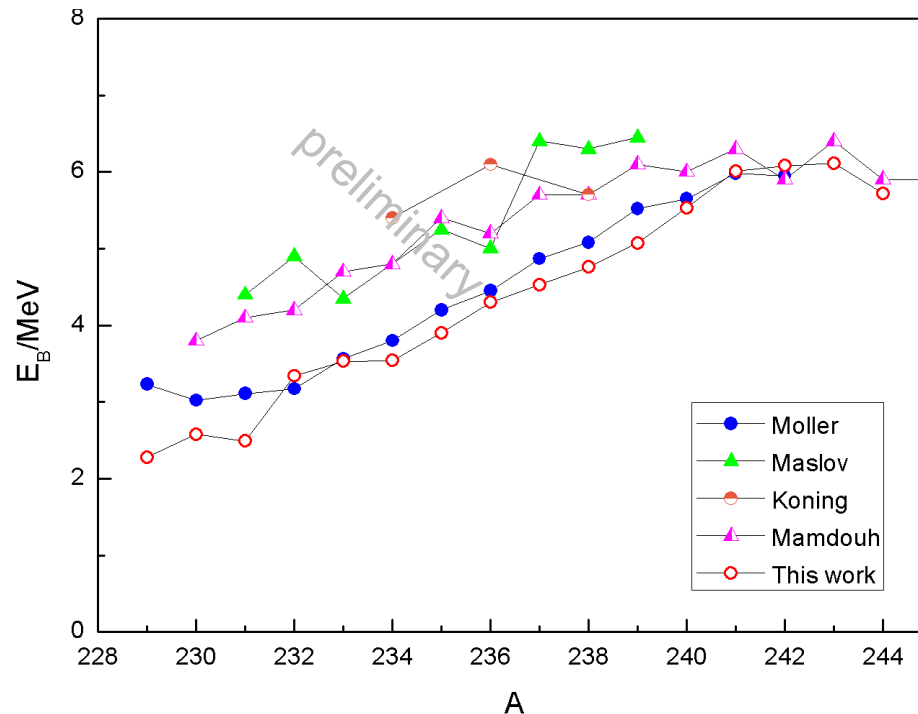
- Two-body NN interactions are adopted
- Three Jacobi coordinates are considered
- calculate elastic scattering, exchange and breakup processes on the same footing





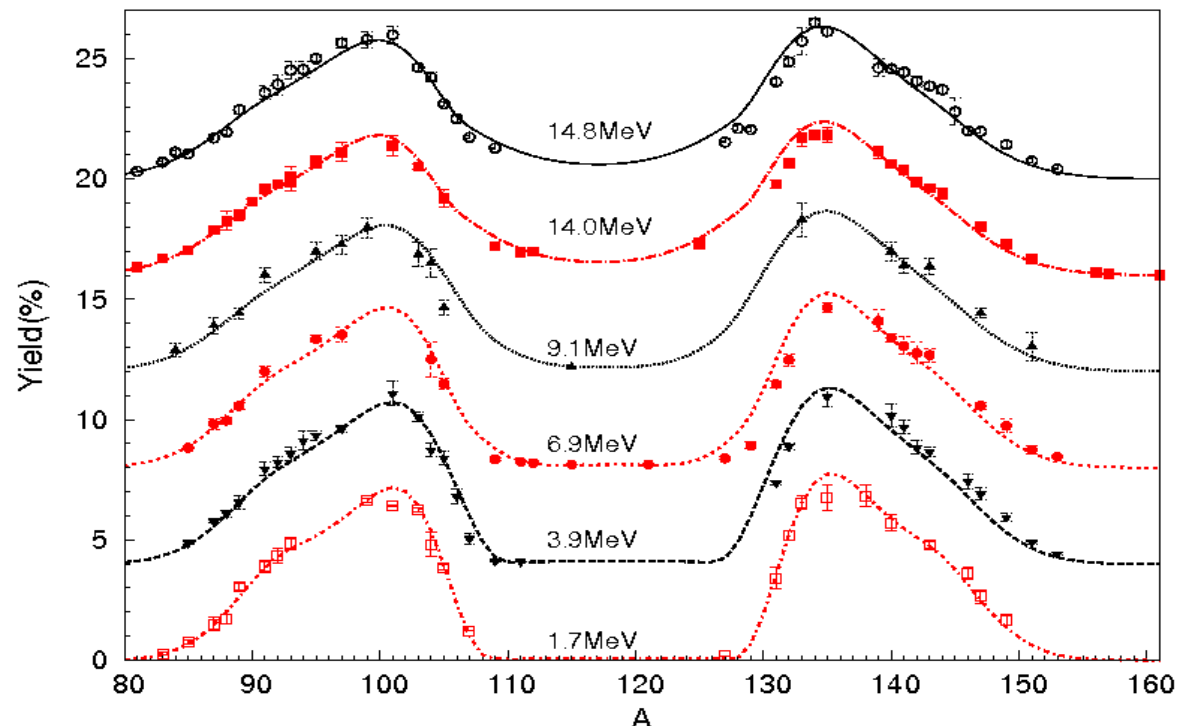
## Fission Model Study

● A primary code has been created for computing the potential surface. Improved Strutinsky shell correction model was adopted. And the Myser-Swiatchi and LSD formulae were used in the macro model; the Woods-Saxon and Folded-Yukawa potential were used in micro model. We calculated the surfaces for U and Pu isotopes, the below Fig. showed the preliminary results of fission barriers.

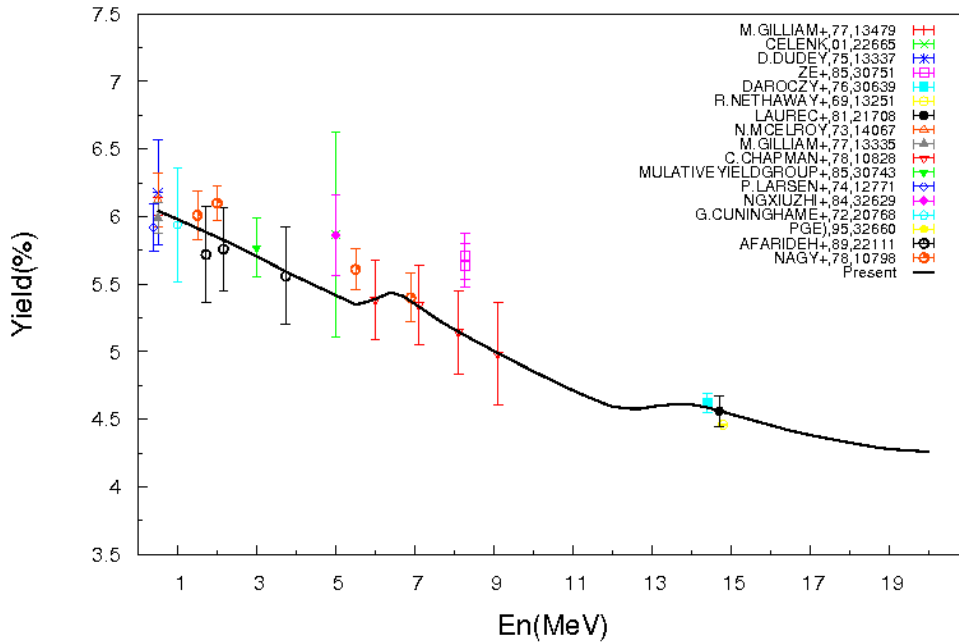


The calculated inner barriers for U isotopes and compared with other works.  
2016/6/13

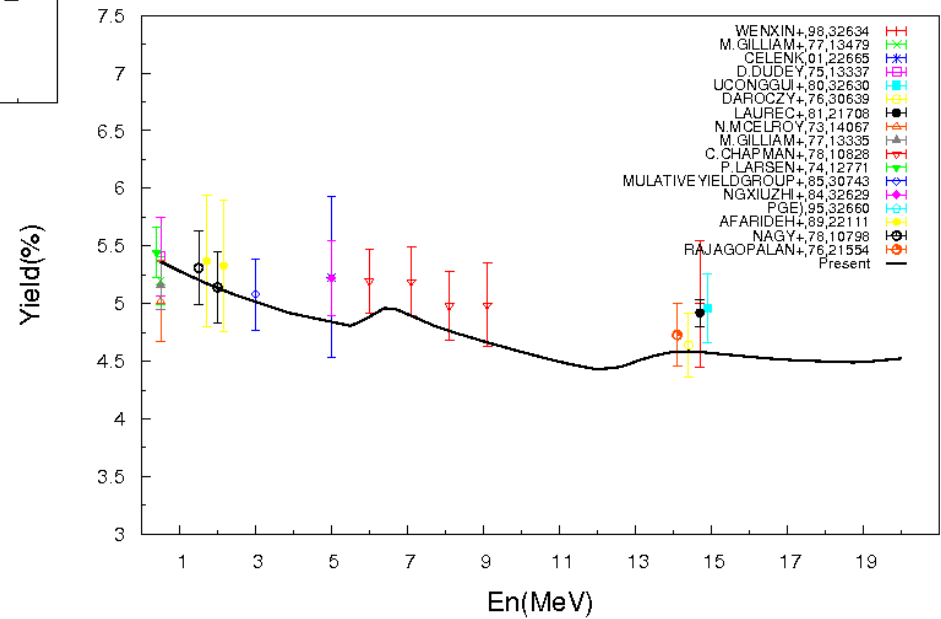
- A semi-empirical model is developed for calculating the yield mass distributions and energy dependence of  $n+^{238}\text{U}$  fission. The system potential energy included the macro-energy and 2 shell corrections, corresponding to the SL, SI and SII fission channels. Multi-chance fissions of  $(n,nf)$  and  $(n,2nf)$  were considered. The yield was expressed with a five-Gaussian-like formula with 13 parameters, which were determined by fitting to experimental. The results showed the model could well describe the mass distribution with variant incident energy and some of the yield energy-dependences.



56-Ba-140 Cumulative Yield of  $^{238}\text{U}(n,f)$



40-Zr-95 Cumulative Yield of  $^{238}\text{U}(n,f)$



# Study of global prediction of microscopic optical potential

Isospin dependent MOP in DBHF approach  
 $n, p \rightarrow {}^{12}\text{C}-{}^{208}\text{Pb}$  below 200MeV

Potential optimization through 5000 times in the global simulated annealing algorithm

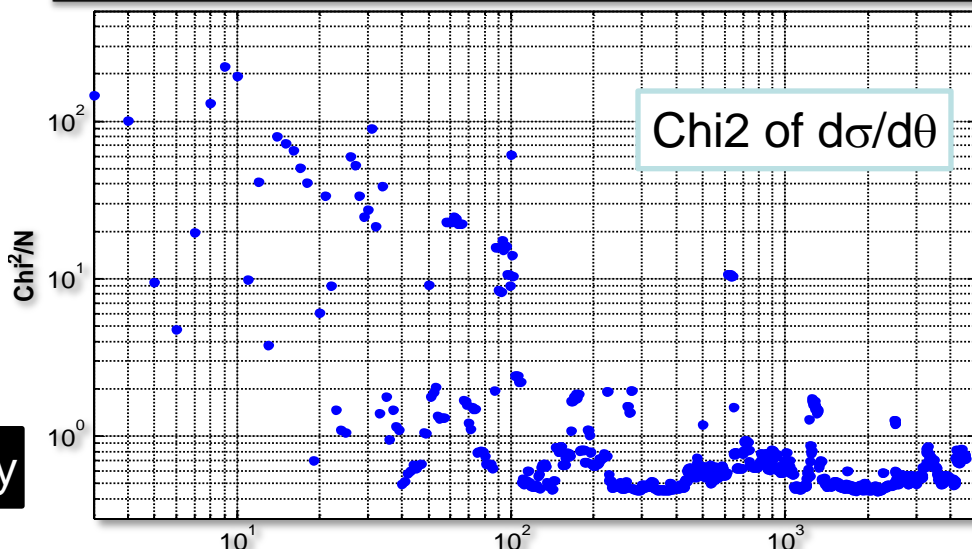
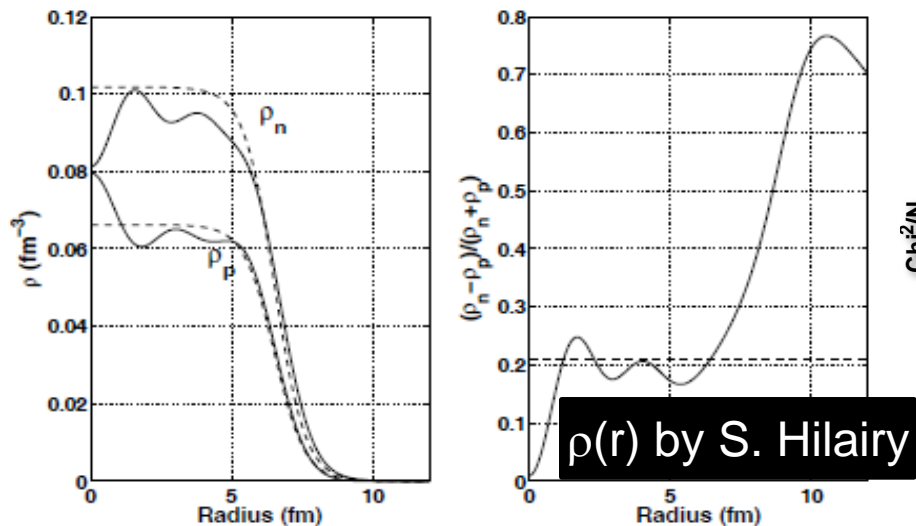
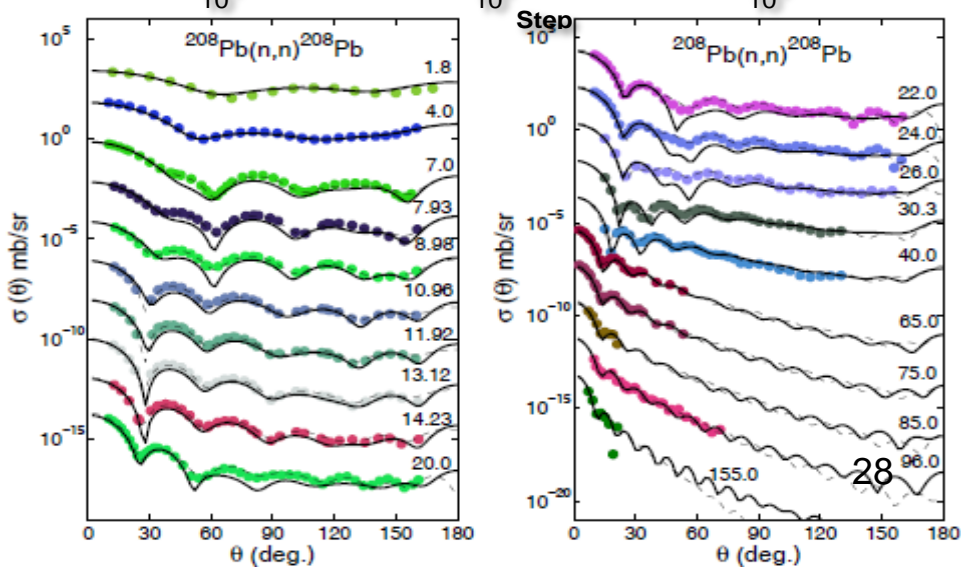


TABLE V: The  $\chi^2/N$  of  $d\sigma/d\Omega$  for  $n+{}^{12}\text{C} - {}^{40}\text{Ca}$  reactions

Nuclide	Point num. of exp.	MOP	KD
${}^{12}\text{C}$	293	3.35	2.43
${}^{14}\text{N}$	336	0.21	0.22
${}^{16}\text{O}$	309	0.91	0.66
${}^{23}\text{Na}$	221	0.31	0.22
${}^{24}\text{Mg}$	270	0.56	0.19
${}^{27}\text{Al}$	426	0.068	0.069
${}^{28}\text{Si}$	391	0.24	0.15
${}^{32}\text{S}$	388	0.22	0.07
${}^{40}\text{Ca}$	399	0.22	0.075



2016/6/13

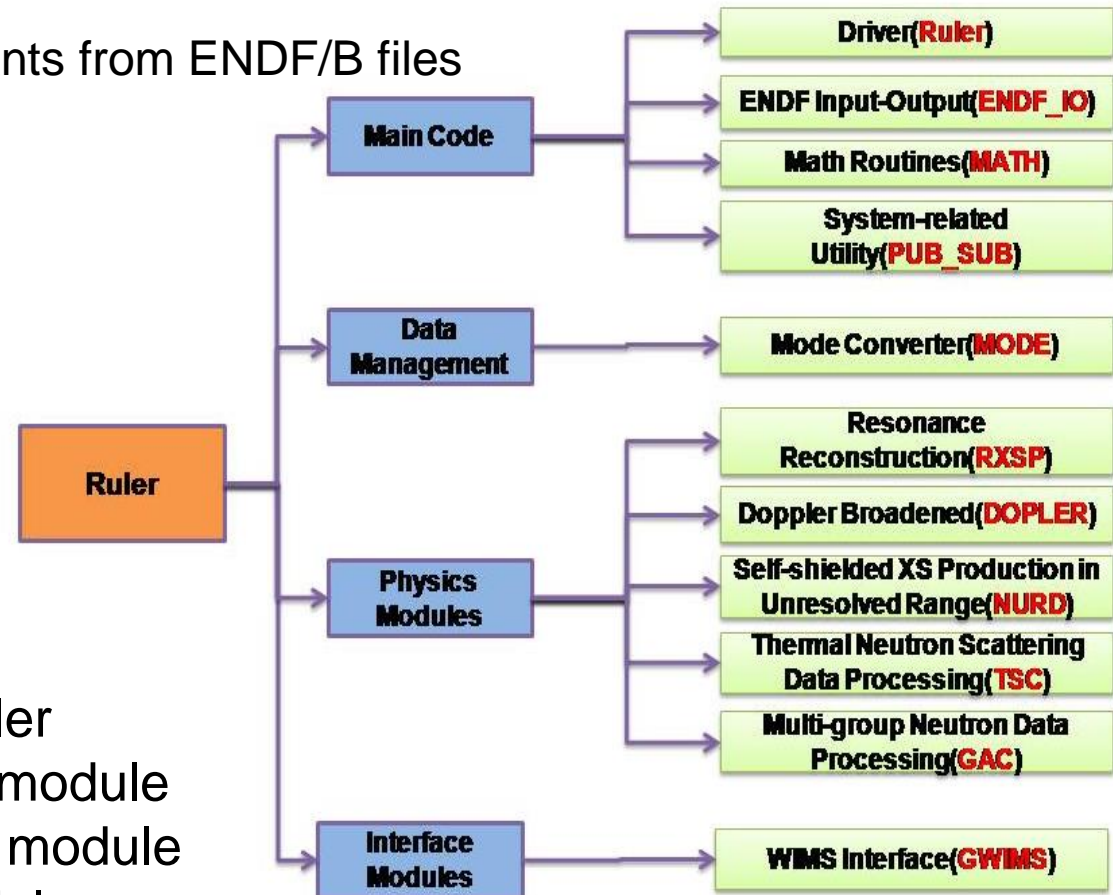
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# III. Nucl Data Processing Code Development

## Current status of Ruler

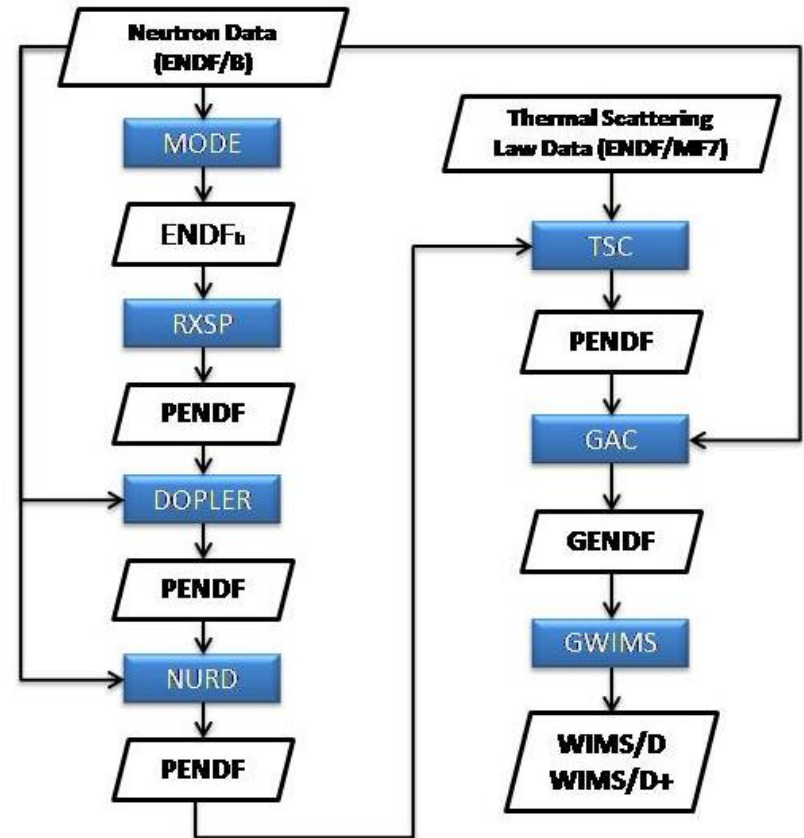
- Ruler function
  - Producing multi-group constants from ENDF/B files

- Ruler structure
  - Ruler consists of 11 modules



- Possible work to be made
  - Function extension of Ruler
    - Add photon processing module
    - Add heating processing module
    - Add more interface modules
  - Modification of ENDF\_IO module for new data format

- The characteristics of Ruler
  - Independent ENDF I/O module/library
  - Easy for maintenance and extension
  - Less computation time

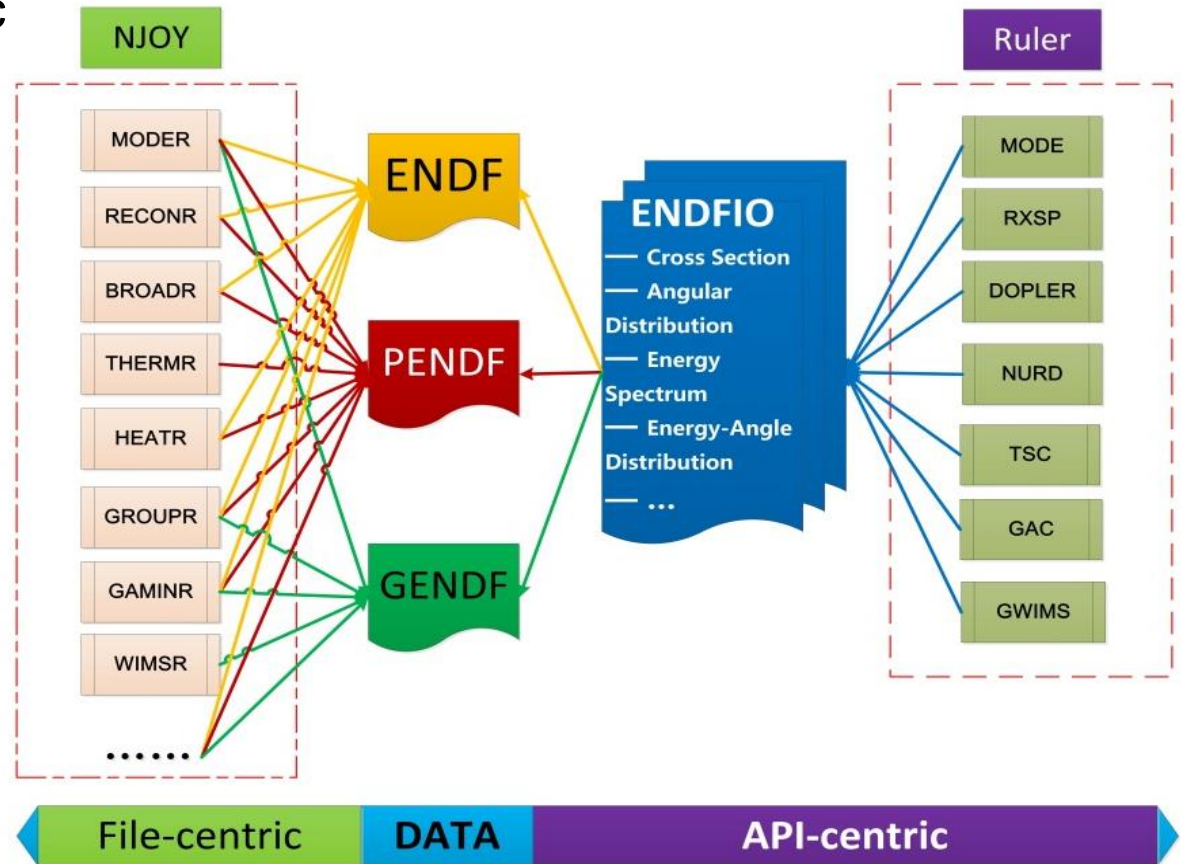


- Ruler physics
  - Ruler can be used for
    - Generating WIMS-D/WIMS-D+ format data files

- Comparison between Ruler and NJOY

- Processing way

- Ruler: API-centric
- NJOY: File-centric

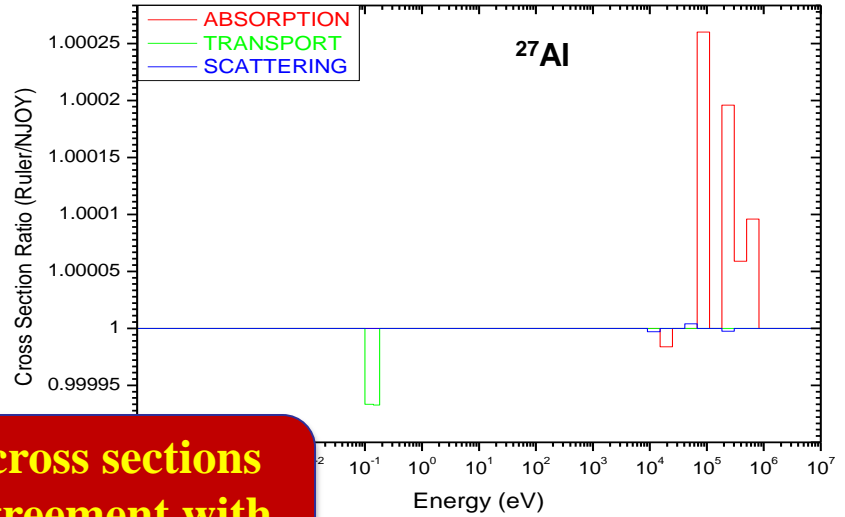
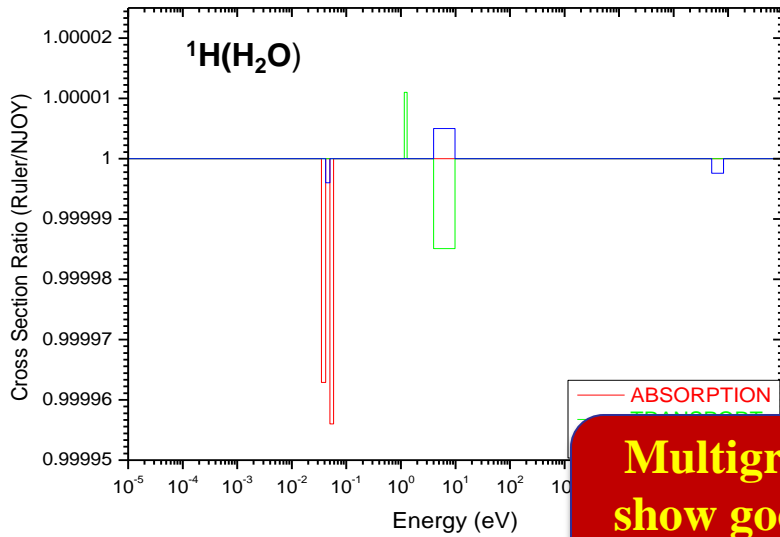


- Computation time

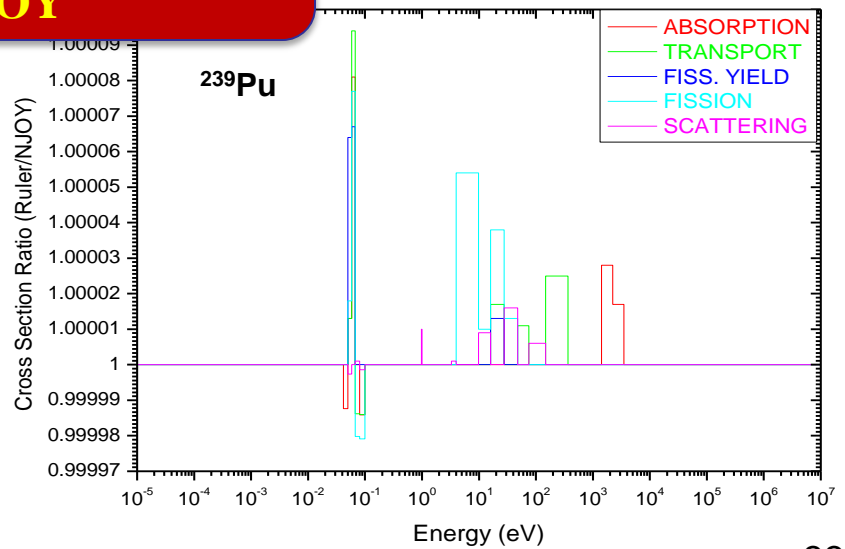
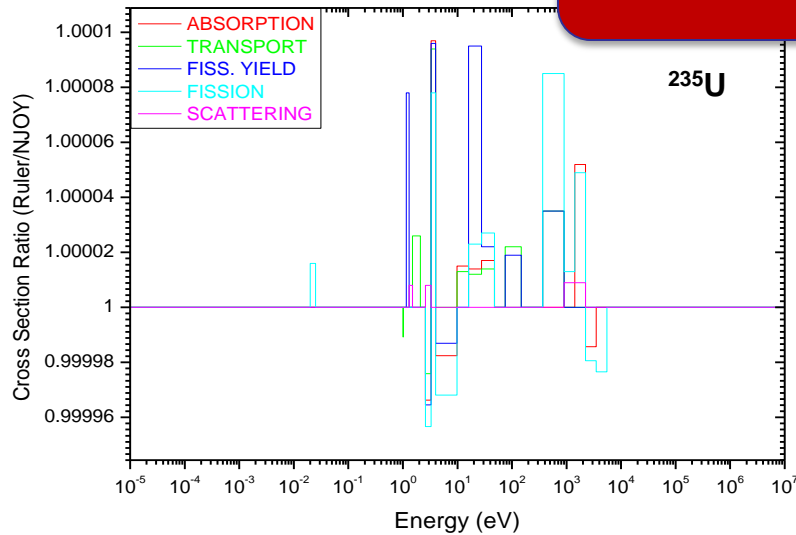
Nuclide	Running time (s)		Speed-up ratio
	NJOY	Ruler	NJOY/Ruler
1-H-H <sub>2</sub> O	152.7	104.2	1.47
1-H-ZrH	410.2	365.9	1.12
1-D-D <sub>2</sub> O	157.6	101.6	1.55
6-C	84.4		1.37
8-O-16	25.9		1.74
13-Al-27	7.0		1.63
26-Fe-56	23	19.9	1.16
36-Kr-83	5.7	3.1	1.84
42-Mo-95	7	5.7	1.23
92-U-235	247.3	187.0	1.32
92-U-238	448.6	225.3	1.99
94-Pu-239	136.7	67	2.04

Less computation time is required for Ruler





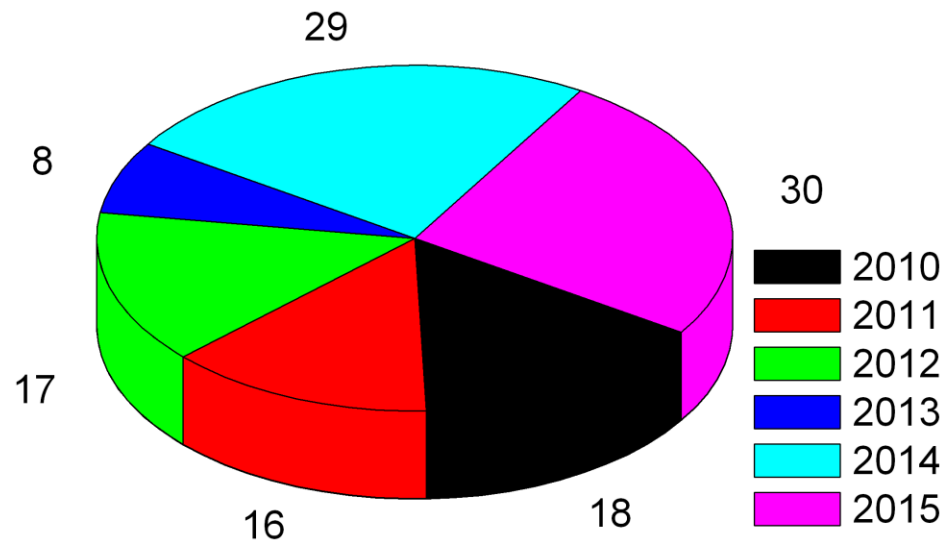
**Multigroup cross sections  
show good agreement with  
NJOY**



# III. EXFOR Compilation

During the 2015-2016 EXFOR compile group at CNDC have finished following tasks:

- a) Scan all articles about the charged particles introduced reactions published during 1978-2008 in the 《High Energy Physics and Nuclear Physics》, and find there 215 articles can be compiled for X4 database.
- b) Scan journal 2009-2015, Compiled 118 entries (charge particle: 68, neutron: 50), feedback & correction performed for more than 20 entries, more than 30 entries are compiling and more than 5 entries for checking.





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

2016/6/13

## 1-3 Activities information

- ✓ **Regular update and maintenance of IAEA/NDS mirror-site in China with the support of NDS.**
- ✓ **Foreign scientists (Drs. M.Herman, N.Otsuka, T.Kawano, et al) from NNDC, IAEA/NDS, LANL, Russia and Belarus visited CNDC last year.**
- ✓ **A symposium of the fundamental study of nuclear data held in Beijing on 31, Oct. 2014.**
- ✓ **A proposal for the fundamental study of nuclear data has been submitted to the National Natural Science Foundation of China (NSFC) and a positive response has been received from NSFC.**

## 2. Nuclear Data Evaluation and Methodological Studies

### 2-1 CENDL Project

- The evaluation activities are performing for the updating of CENDL, which contain the neutron reaction data, activation and fission yields files. As some examples, following are the new evaluations for the neutron files and activation of  $^{184}\text{W}$ ,  $^{237}\text{U}$ ,  $^{56}\text{Fe}$ .

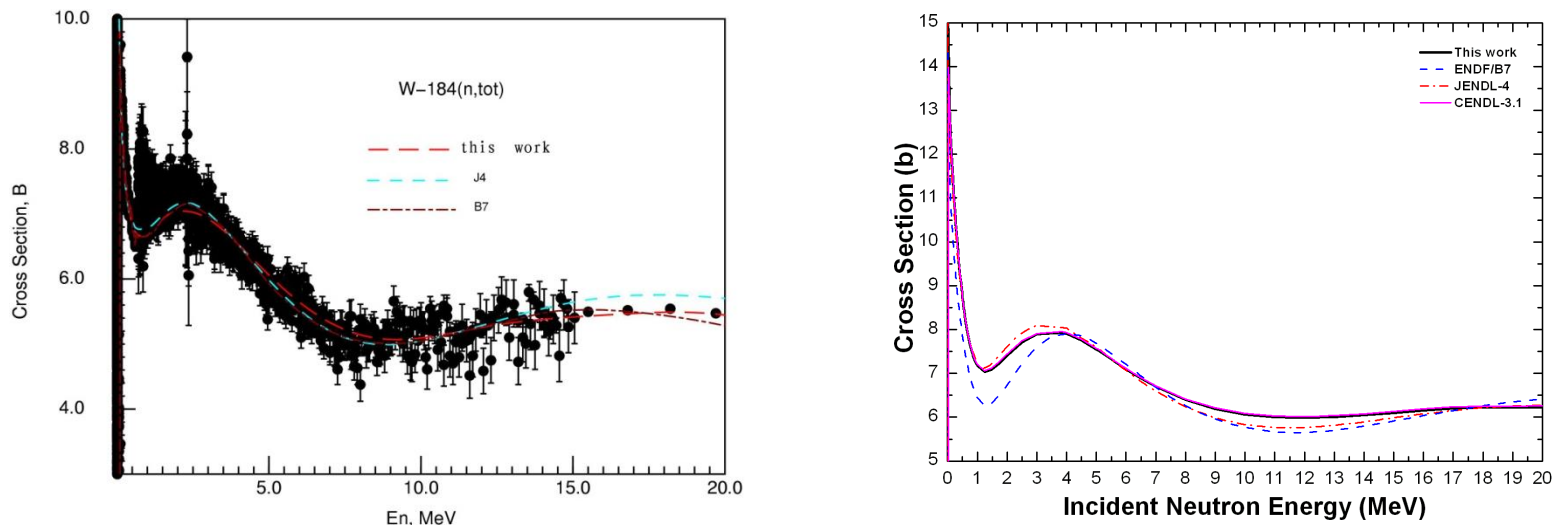


Fig.1  $^{184}\text{W}(n, \text{tot})$ (left),  $^{237}\text{U}(n, \text{tot})$  (right) new evaluation comparison with evaluated files and exp.data.

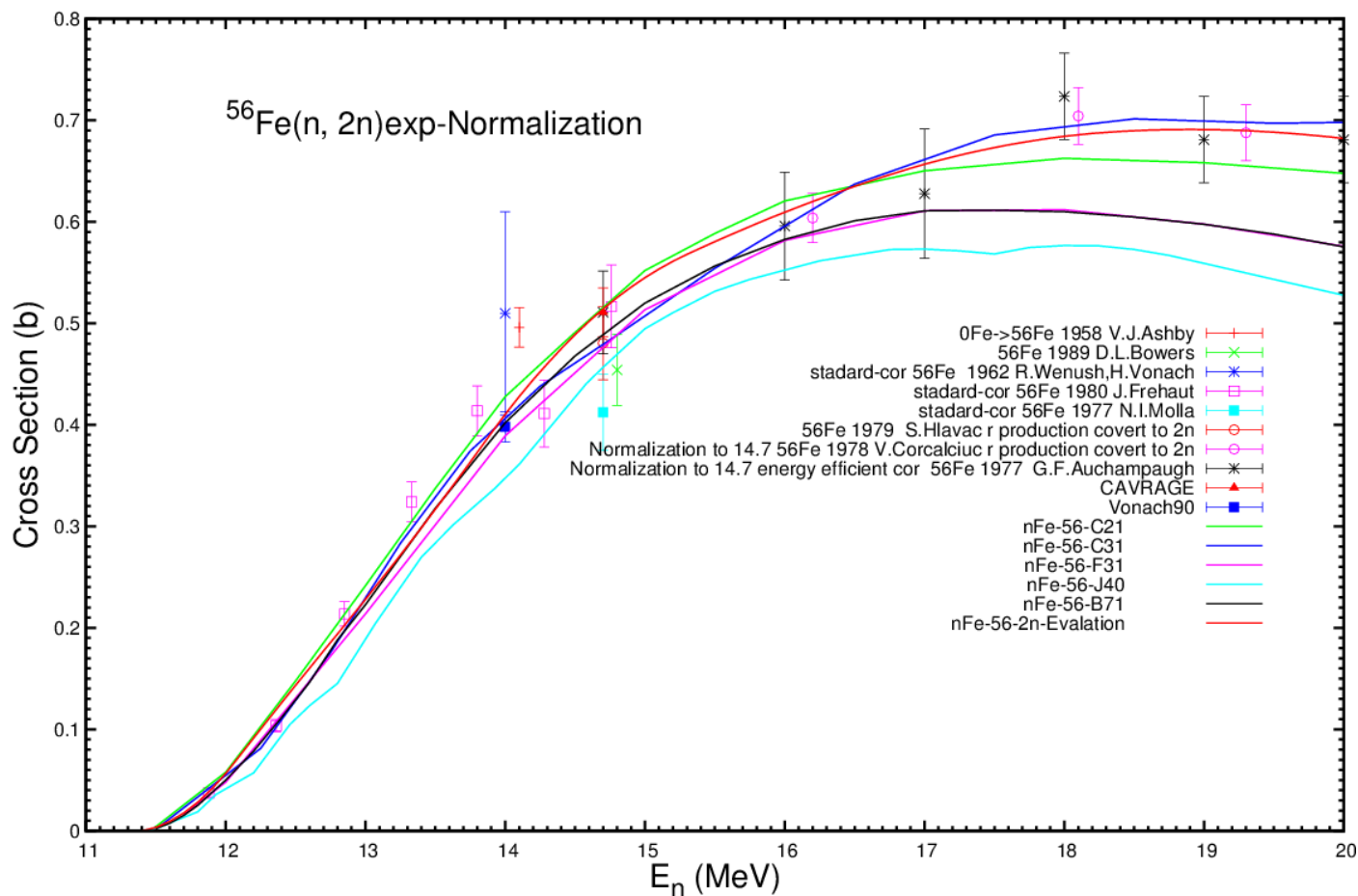


Fig.2  $^{56}\text{Fe}(n, 2n)$  new evaluation compared with exp. data.

- **The covariance evaluation (COVAC) of neutron cross section for the structure nuclei has been completed and for importance actinide is developing.**

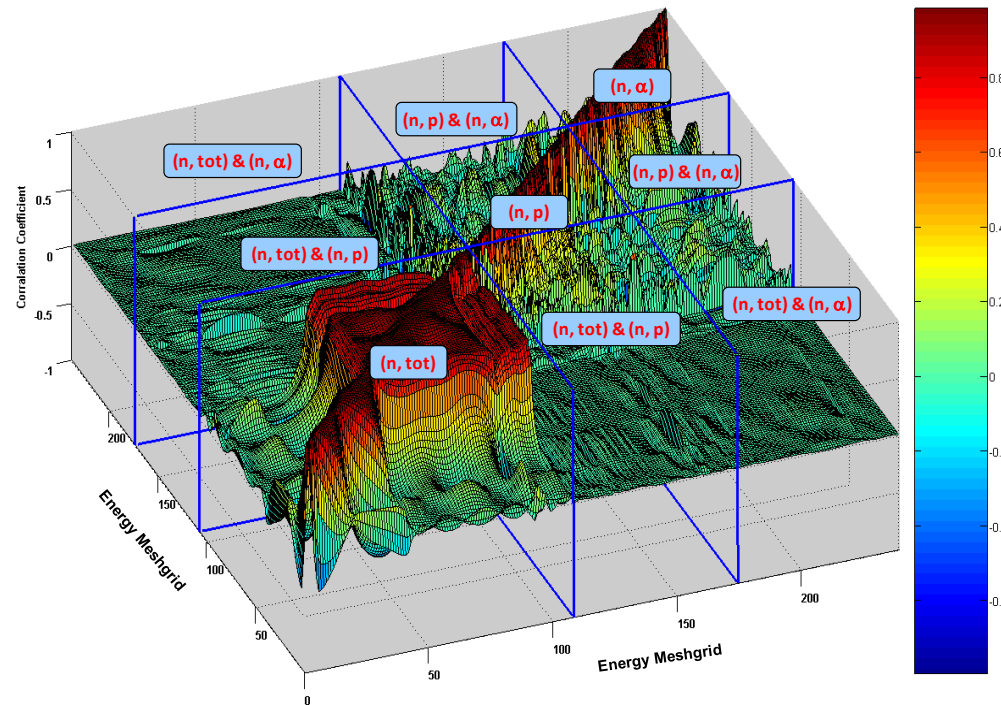


Fig.3 The updated covariance evaluations for the different reaction channels of  $n+^{48}\text{Ti}$  with COVAC system.

- A analyze system **NewS** of nuclear data uncertainty/sensitivity is developing and some preliminary results has been obtained which show as following Fig.4.

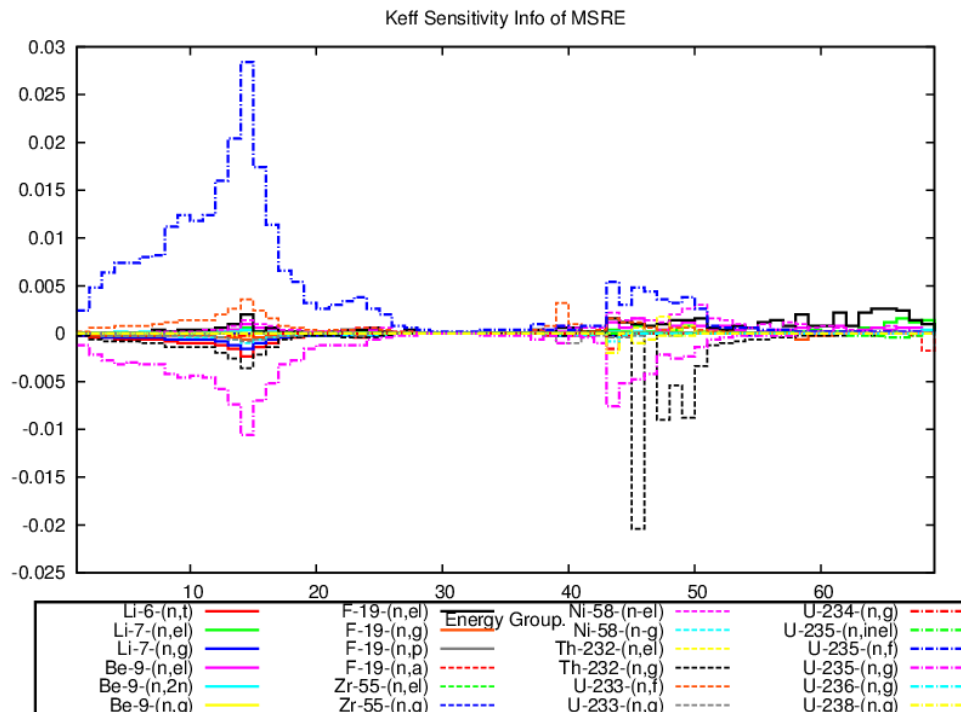


Fig.4 The  $k_{\text{eff}}$  sensitivity of preliminary analyze for the Molten Salt Reactor Experiment (MSRE) at ORNL obtained by NewS



● **Nuclear Structure and Decay Data Evaluation.**  
<sup>132</sup>I decay data evaluation which contained half-life, decay type, data and level scheme et al., has been performed.

Decay Type	Energy/keV	Intensities (absolute)/%
e Au <sub>L</sub>	3.430	1.07 4
e Au <sub>K</sub>	24.60	0.129 4
e Ce <sub>2K</sub>	102.1 4	0.014 16
e Ce <sub>3K</sub>	112.84 10	0.057 6
e Ce <sub>3L</sub>	141.95 10	0.0074 10
e Ce <sub>3M</sub>	146.26 10	0.001499
e Ce <sub>4K</sub>	149.0 3	0.021 7
e Ce <sub>10K</sub>	220.54 20	0.014 4
e Ce <sub>12K</sub>	228.34 10	0.064 6
e Ce <sub>15K</sub>	250.34 10	0.029 3
e Ce <sub>12L</sub>	257.45 10	0.0084 8

Decay Scheme

Intensities: I<sub>γ</sub> and I<sub>ce</sub> per 100 parent decays  
& Multiply placed; undivided intensity given  
@ Multiply placed; intensity suitably divided

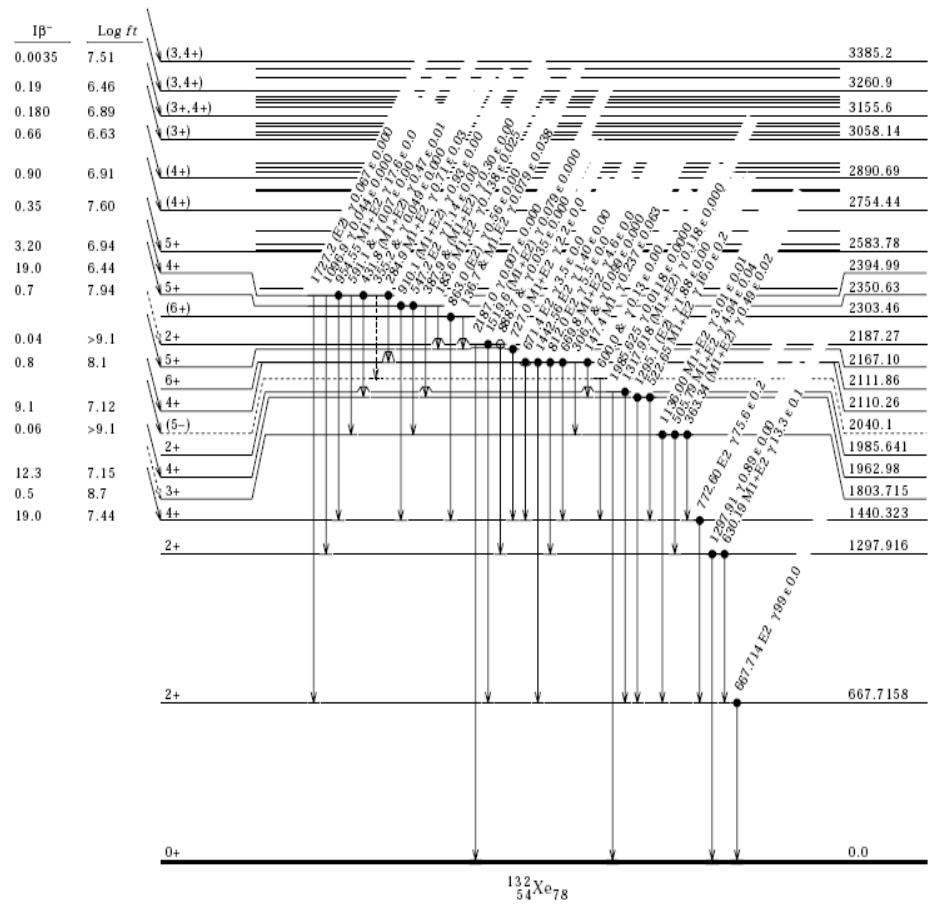
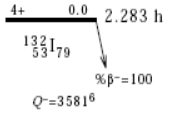
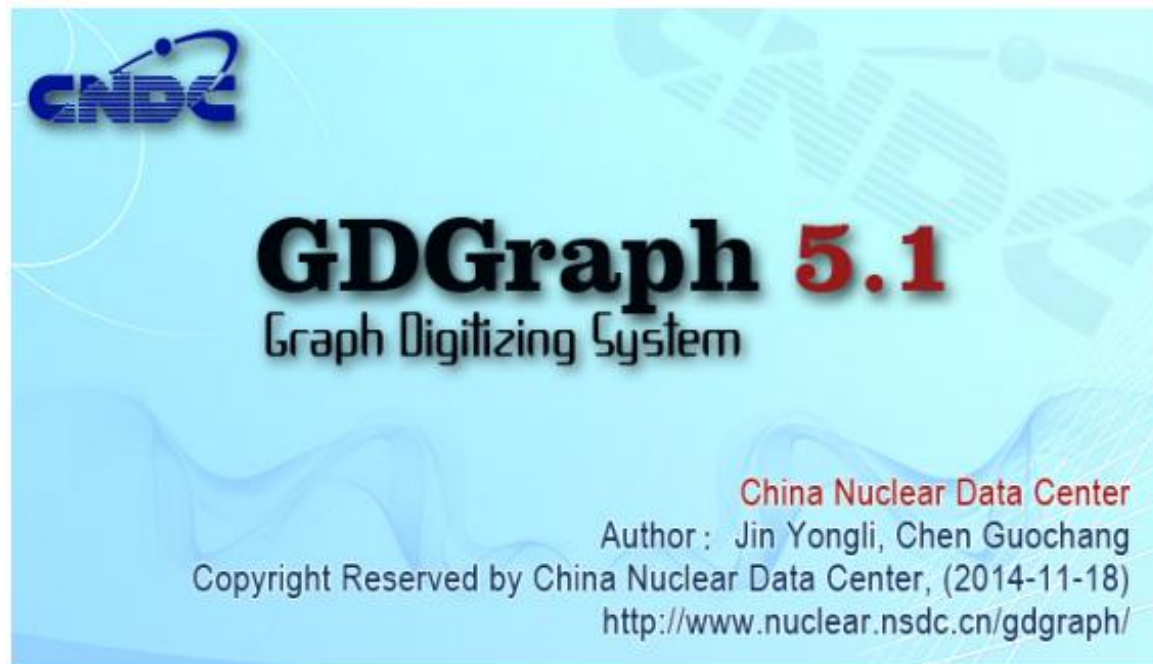


Fig.5 Decay Scheme of  $^{132}\text{I}$  (partial)

### 3. EXFOR Software and Database Compilation Progress

- **GDgraph Software**

**The upgrade of the GDgraph has been finished according to the feedbacks from the participants of workshop on EXFOR Compilation 6-10 Oct. 2014, Vienna. The updated version **GDgraph-v5.1**, and user's manual is updating.**



● **EXFOR Compilation.**

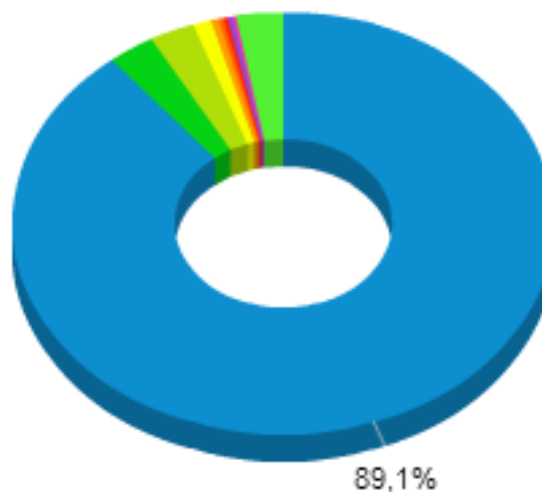
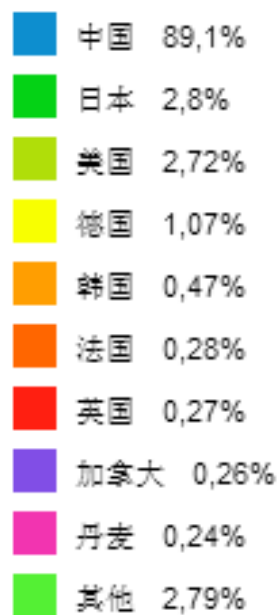
- ✓ **During the 2014-2015 EXFOR compile group at CNDC have finished following tasks:**
- ✓ **Scan all previous articles in the 《High Energy Physics and Nuclear Physics》 《Chinese Physics C》 (ENG/2007;HEN) 17,**
- ✓ **Compiled 88 entries, Feedback and correction more than 20 entries, Charge particle: 38, Neutron: 50, Compiling > 25 entries, Checking > 5**

## EXFOR compilation statue

vol,page,year	First author	Lab	Proj.	Quantity	Entry	Remark	status
8,199,1984	Kong XiangJing	NRS	a	DAP	S0078	need to digitize DA data	yes
25,304,2001	Bao ShangLian	BJG	sf	DE	32726	need to digitize data, it is a ratio between $^{248}\text{Cm}$ and $^{252}\text{Cf}$ fission count.	yes
25,834,2001	Wang HongWei	IMP	17N	CS	S0081	Need to digitize fig.5, Tab.1 is list breakup cross section.	yes
25,1165,2001	Wang QuanJin	IMP	$^8\text{B}, ^9\text{C}$	CS	S0086	Have exp. data.	yes
26,35,2002	Zhang HuYong	IMP	$^{17,18,19,20,21}\text{F}$	CS	S0097	Digitize 1 figures	yes
26,239,2002	Tian WenDong	AEP	$^{19}\text{F}$	DAE	S0099	Digitize 2 figures	yes
26,589,2002	Xu Yan-Bing	IMP	$^{18}\text{O}$	CS	<del>S0100</del>	= A0300(needn't to compile, delete)	<b>correct</b>
26,594,2002	Lu Zhao-Hui	IMP	$^{17}\text{F}, ^{18}\text{Ne}$	DA	S0101	Digitize 2 figures	yes
26,683,2002	Li Jia-Xing	IMP	$^{20}\text{Ne}$	CS	S0102	Digitize 6 figures	yes
27,206,2003	Li Zhi-Huan	IMP	$^6\text{He}$	DAE	S0103	Digitize 4 figures	yes
27,399,2003	Wu Yue-Wei	AEP	$^6\text{Li}$	CS	S0104	The same as A0608, correct A0608	<b>correct</b>
28,1256,2004	Li Jia-Xing	IMP	Many	CS	S0105	Merge S0106 to S0105, and Digitize Figure. 3. S0106 is one reaction in S0105.	yes
29,28,2005	Li Jia-Xing	IMP	$^{17}\text{Ne}$	CS	<del>S0106</del>		<b>delete</b>
29,944,2005	Li Chen	IMP	$^8\text{He}$	CS	S0107	Have exp. data	yes
29,1142,2005	Han Jian-Long	AEP	$^{19}\text{F}$	DA	S0108	The same exp. data as S0109, so merged together as one entry. Digitize 18 figures.(delete S0109)	yes
30,612,2006	Han Jian-Long	AEP	$^{19}\text{F}$	DA	<del>S0109</del>		<b>delete</b>
31,52,2007	Li Chen	IMP	$^8\text{He}$	CS	S0110	Have exp. data	yes

## **4. Nuclear data services**

**CNDC is providing the nuclear data services to all the nuclear data users in China and foreign countries and regions by the web site: <http://www.nuclear.csdb.cn> and other ways. The services for the users contains the general purpose and special purpose libraries services, and related information/technology. The statistics of the nuclear data services through the web site show as Fig.7 and Tab.3.**



The statistics (visiting and data download) of the nuclear data service. (2014-2015)

<b>Country and Region</b>	<b>Visiting</b>	<b>Request</b>	<b>Data Download(MB)</b>
CHINA	284843	476808	4901.25
JAPAN	8950	10158	78.60
U.S.A.	8689	30026	1035.64
GERMANY	3426	5269	85.34
KOREA	1496	3081	59.57
FRANCE	890	1981	87.74
U.K.	869	2940	86.63
CANADA	846	2567	91.56
DENMARK	773	2098	73.56
SWEDEN	604	1604	53.12

The statistics (visiting and data download) of the nuclear data service.( 2014-2015)





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

2016/6/13