2018/19 Status Report of China Nuclear Data Center

GE Zhigang

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CHINA NUCLEAR DATA CENTER

I. General Information of 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.

The main tasks 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 Director

葛智刚 博士
Dr.Ge Zhigang

副主任 Deputy Directors

钱 晶 博士
Dr. Qian Jing

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.
- Nul. data calculation compilation

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 bechmarking/ 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 assistance

Evaluation Unit	Head: Dr. Huang Xiaolong	3 official staff
Theory Unit	Head: Dr. Xu Ruirui	6 official staff
Macroscopic Data Unit	Head: Dr. Liu Ping	6 official staff
Data Library Unit	Head: Dr. Shu Nengchuan	4 official staff
Secretary Office		1 official staff

- ✓ 20 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 2018/2019:

- New evaluations and re-evaluations for neutron data file for CENDL.
- Nuclear structure and decay data evaluation.
- Fission yield data evaluation.
- Photonuclear data evaluations.
- The fundamental studies of nuclear data evaluations and measurements.
- Methodological studies of nuclear data evaluation.
- Nuclear data processing code development.
- Experimental data compilations for EXFOR.
- The regular update and maintenance of IAEA/NDS mirror-site in China.
- Nuclear data services is providing to all the nuclear data users.
- ND2019 preparation.

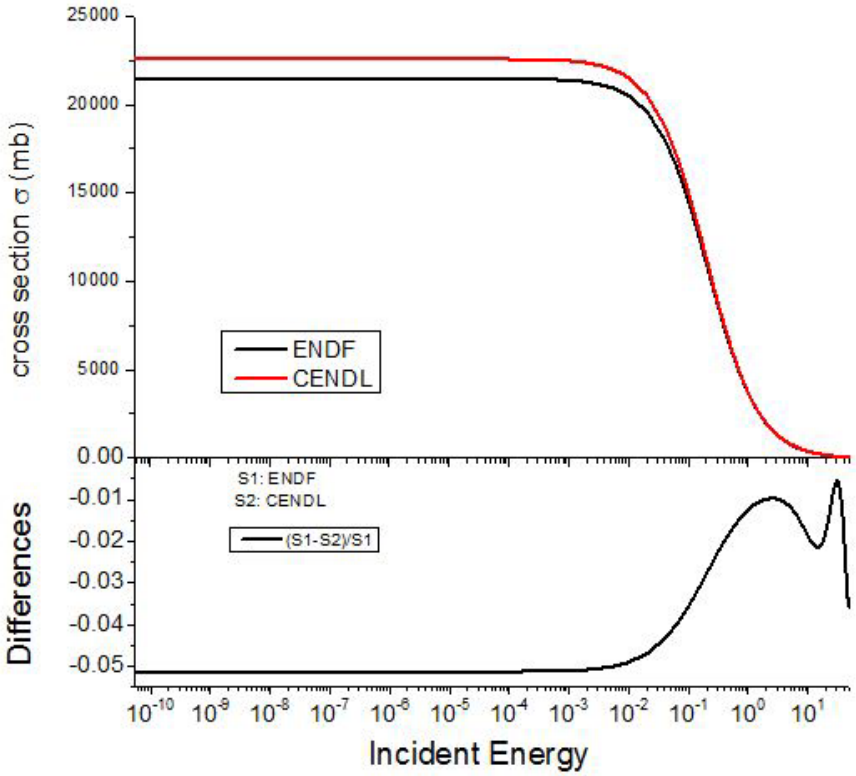
II. Nuclear Data Evaluation for CENDL

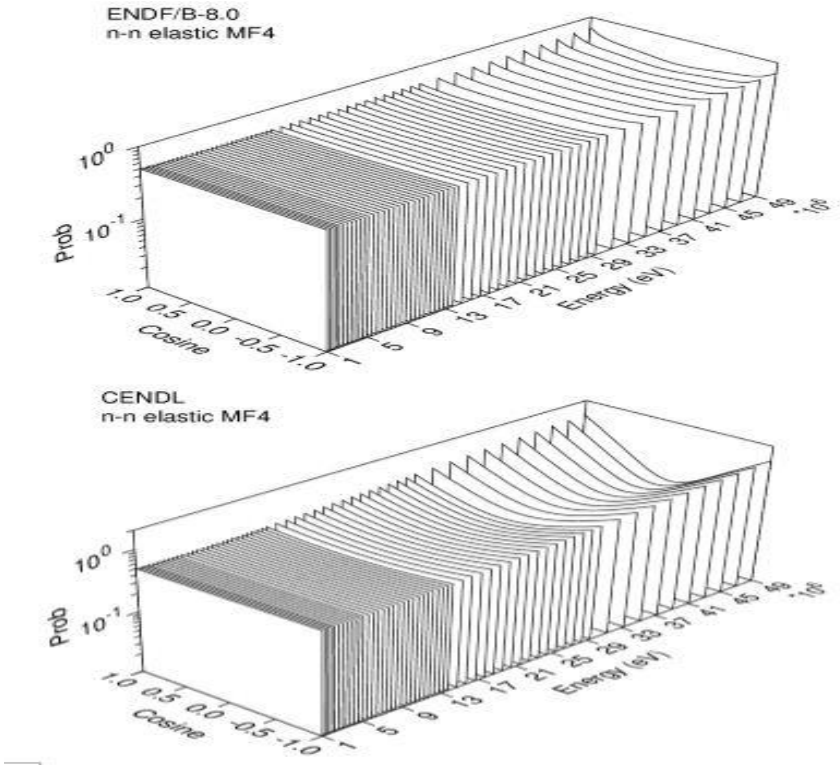
2.1 Light nuclei evaluation and model study

Some efforts have been contributed in the past to update the neutron data of light nuclei. The n-n and n-d colliding systems are calculated by considering the microscopic NN interactions, as shown in follows.

As regards the n-n system, due to the absence of neutron target, neutron-neutron scattering cannot be determined directly from experimental data. In our work, **based on the microscopic CD-Bonn one-boson-exchange nuclear force, Lippmann-Schwinger equation in momentum coordinate is solved to provide T matrix elements and phase shifts in various partial waves**. The neutron-neutron scattering cross section is calculated within S matrix theory. Results show that when incident energy up to about 10^4eV, cross sections almost keep constant. Compared with ENDF, our results are larger about 1b in low energy region. Below 10 MeV, angle distribution is near isotropy.

The n-n elastic scattering cross sections based on the CD-Bonn force

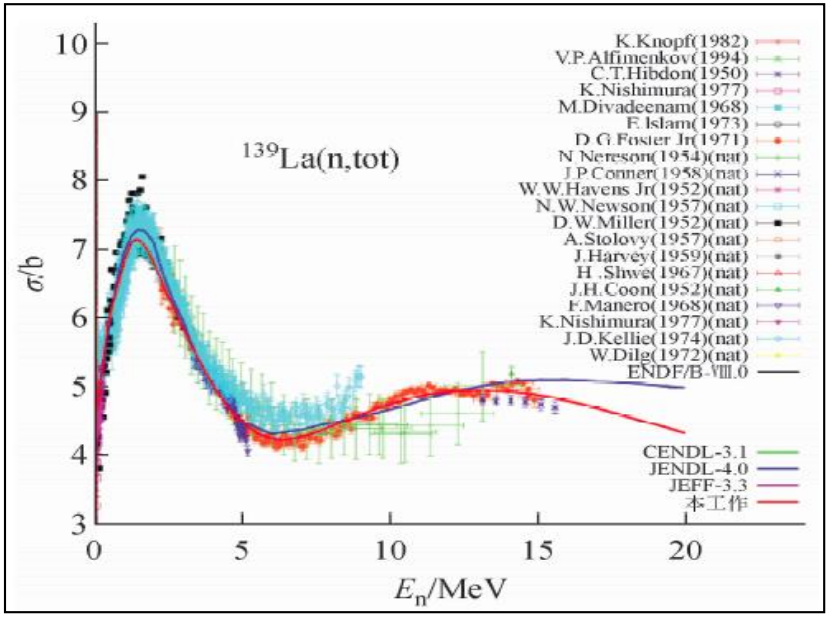


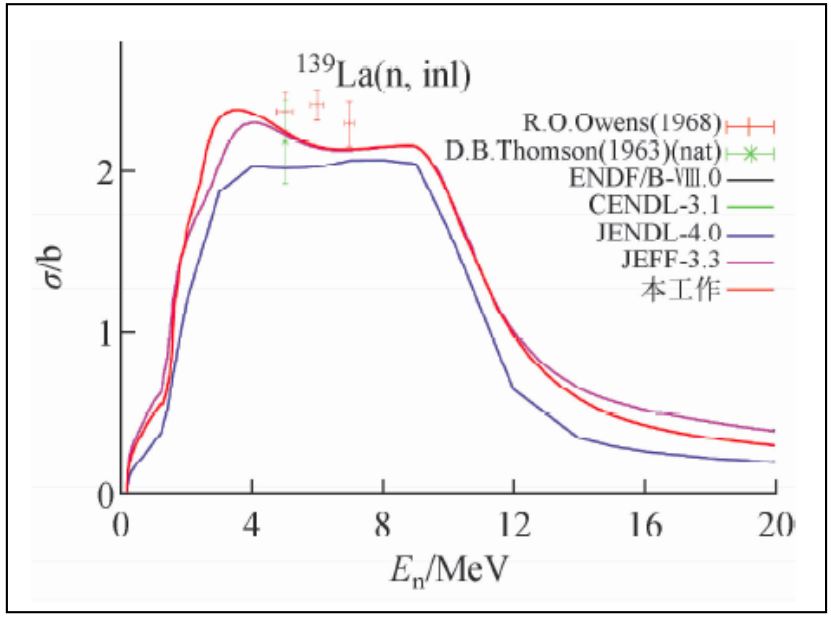


The processed elastic scattering angular distributions via the NJOY code

2.2 Medium-heavy nuclei evaluation

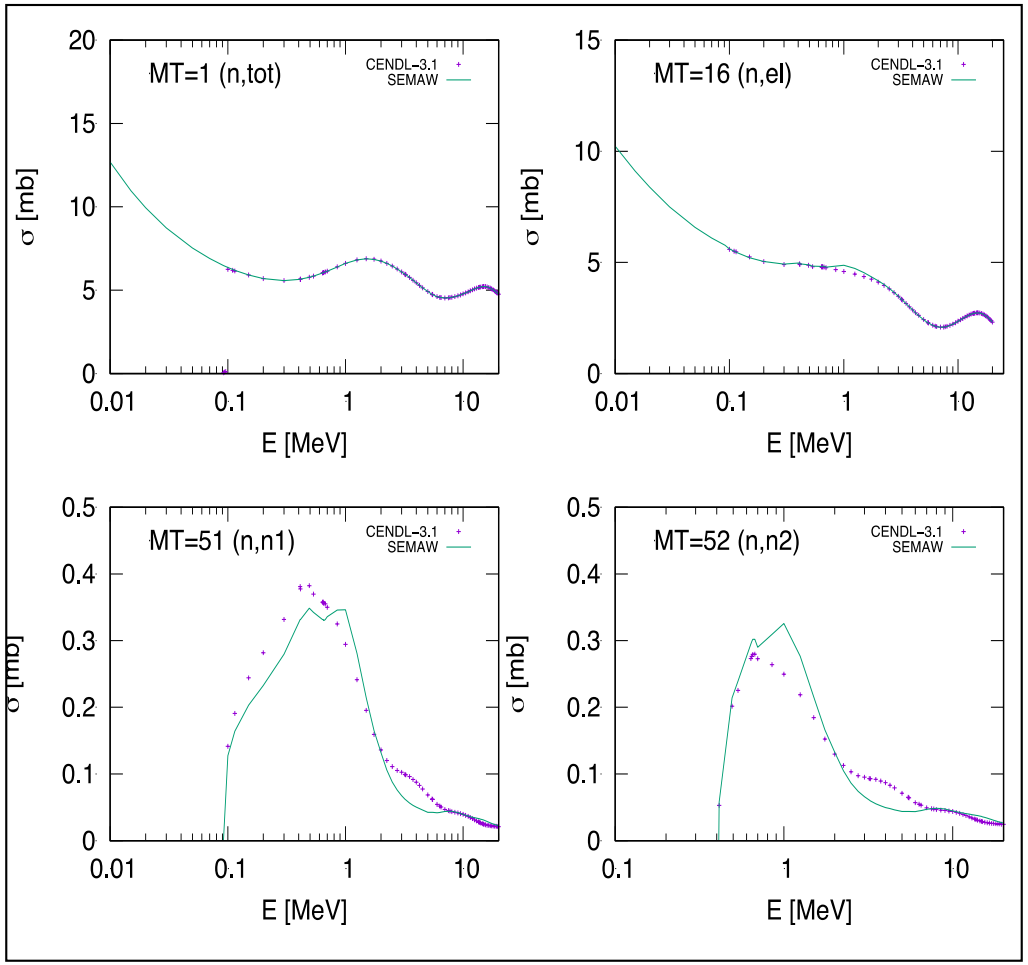
The neutron reaction data of medium-heavy nuclei (mass number around 100~200) are systematically updated in CENDL**. All the modifications are based on the calculations with the UNF code**. Parts of them are new evaluations concerning the latest measurements. The others are the systematic reproductions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





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

Secondly, 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 cross section of CENDL3.1 and the new results for n-^{147}Pm reactions

2.3 The photonuclear data evaluation at CNDC

Under the support of the **CRP Contract** No. 20466, 12 medium-heavy nuclei in the contract are finished using the new developed MEND-G code in 2018. The entire evaluation scheme in this work：

IAEA

International Atomic Energy Agency
Agence internationale de l'énergie atomique
Международное агентство по атомной энергии
Organismo Internacional de Energía Atómica

Vienna International Centre, P.O. Box 100, A-1400 Vienna, Austria
Phone: (+43 1) 2600 • Fax: (+43 1) 26007
E-mail: Official.Mail@iaea.org • Internet: http://www.iaea.org

IAEA Research Contract No: 20466

Research Contract

This Research Contract is entered into between the International Atomic Energy Agency (hereinafter referred to as the "IAEA"), an intergovernmental organization established by its Statute, whose address is Vienna International Centre, P.O. Box 100, 1400 Vienna, Austria; and the China Institute of Atomic Energy CIAE (hereinafter referred to as the "Contractor") whose address is:

China Institute of Atomic Energy CIAE
PO Box 275-59
102413 Beijing
China.

Hereinafter, the IAEA and the Contractor will also be referred to individually as a "Party" and collectively as the "Parties"

Whereas, the IAEA is authorized under its Statute and the decisions of its competent organs to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world, and this mandate includes the encouragement and assistance to research on, and the development of, practical applications of atomic energy for peaceful purposes throughout the world by, inter alia, entering into contracts for research and development; and

Whereas, the Contractor is able and willing to carry out the Research Project in cooperation with the IAEA under this Research Contract (hereinafter referred to as the "Contract").

Now, therefore, the Parties hereby agree as follows:

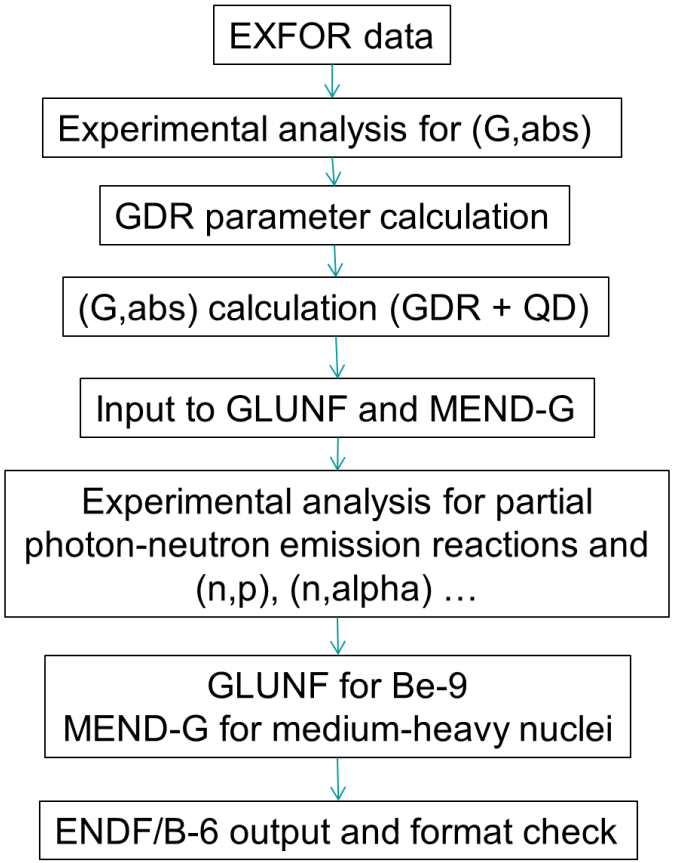
Article 1
Scope of the Research Project

1. The Contractor undertakes to perform the Research Project entitled "Calculation and Evaluation of Photonuclear Cross Sections and Y-Ray Strenght Functions for Light and Medium Heavy Nuclei" (hereinafter referred to as the "Research Project") which forms a part of the IAEA's Coordinated Research Project "F41032", entitled "Updating Photonuclear Data Library and Generating a Reference for Photon Strength Functions".

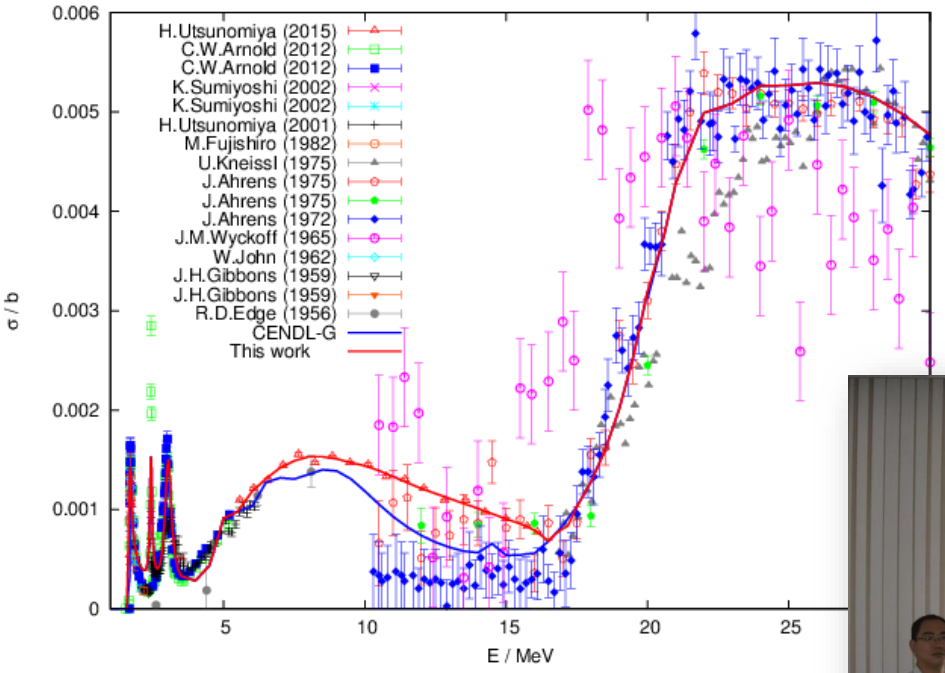
2. The Chief Scientific Investigator shall be Ms Ruirui Xu.

3. The programme of work to be performed under this Research Project shall be:

IAEA Contract with CNDC-[20466]



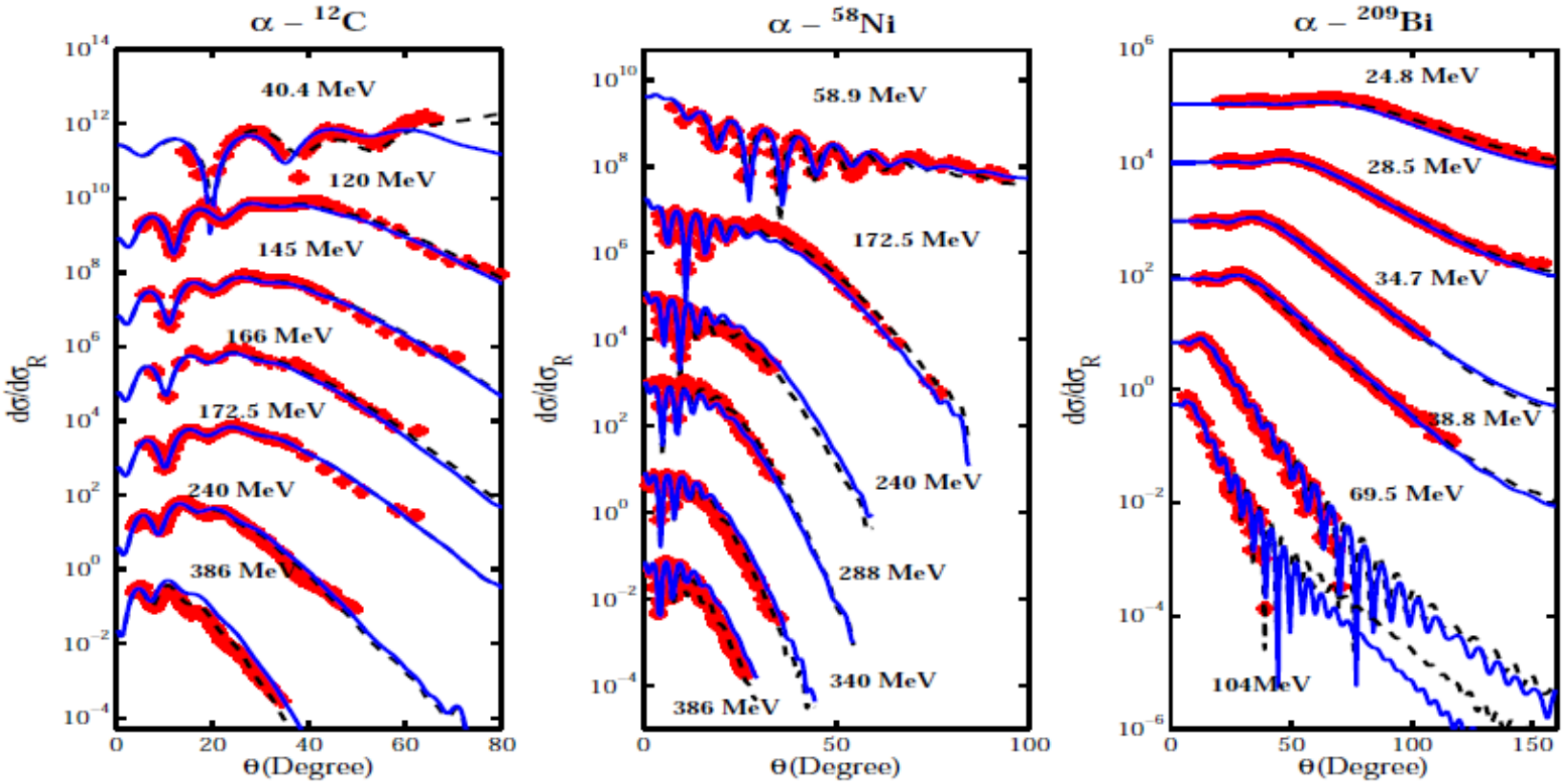
Meanwhile, a sub-library of photonuclear in the coming CENDL is also being studied recently, and 274 nuclei are contained. The obtained absorption cross sections for Be-9



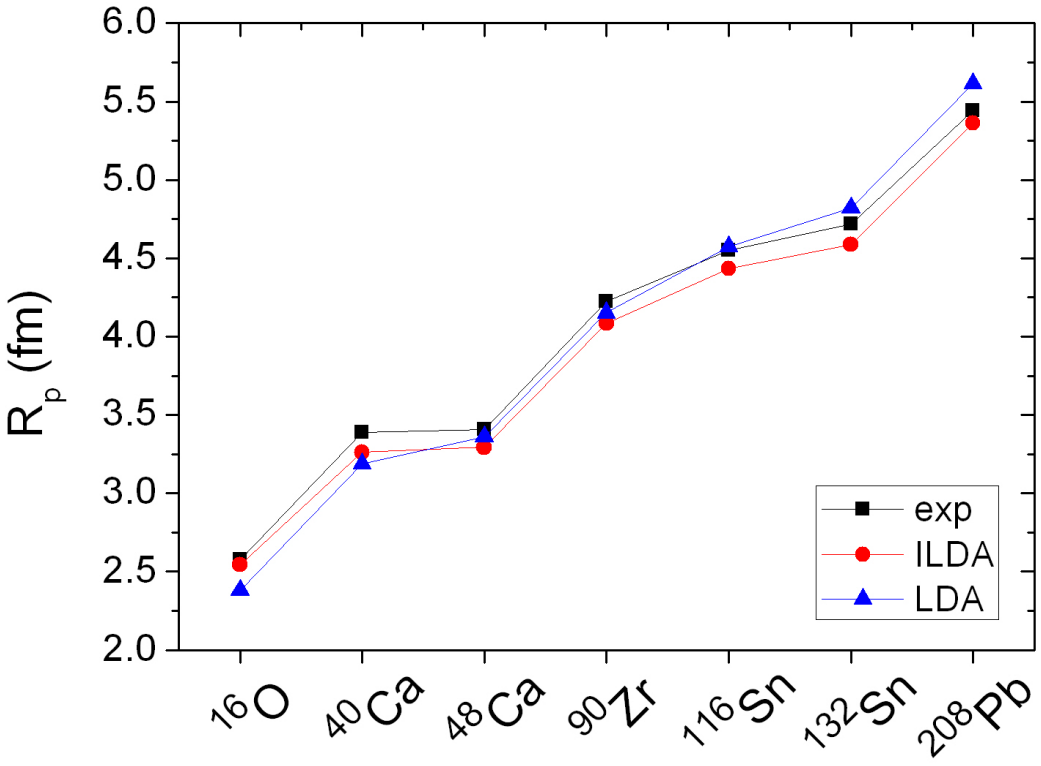
III. The fundamental studies

3.1 The microscopic optical model potential

Some microscopic nuclear reaction and structure studies are also paralleled studied at CNDC. **The microscopic a-nucleus optical model potential and the nuclear structure results based on the Dirac-Brueckner Hartree Fock approach are successfully obtained**. In our scheme, the nucleus experimental data are reproduced systematically from ^{12}C-^{208}Pb.



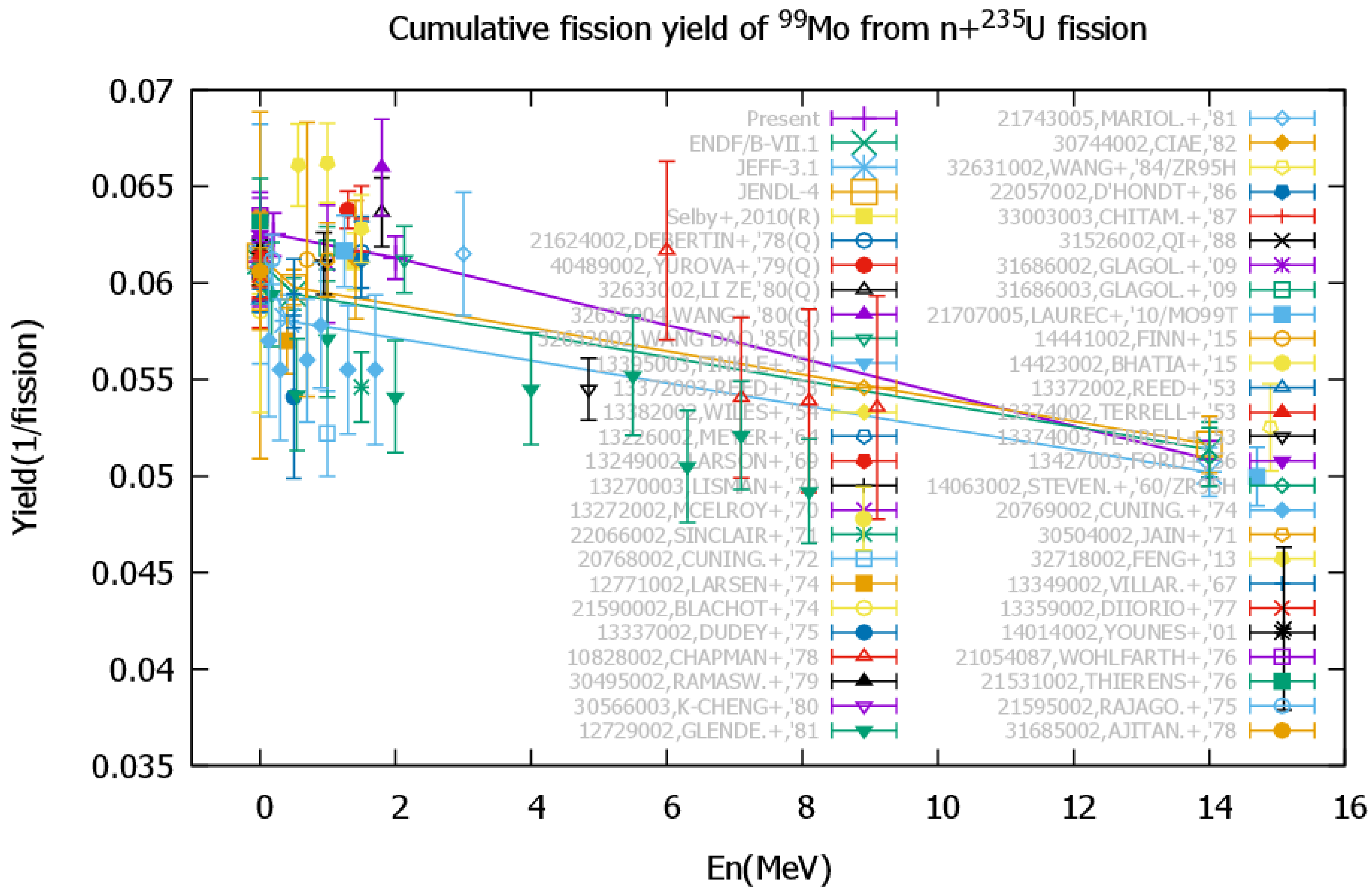
The comparisons between the calculations of ^{12}C, ^{58}Ni, ^{209}Bi and measurement



Calculations of finite nuclei binding energy and proton radius with DBHF approach

3.2 Phenomenological Method of Fission Yield and Macro-benchmark Test

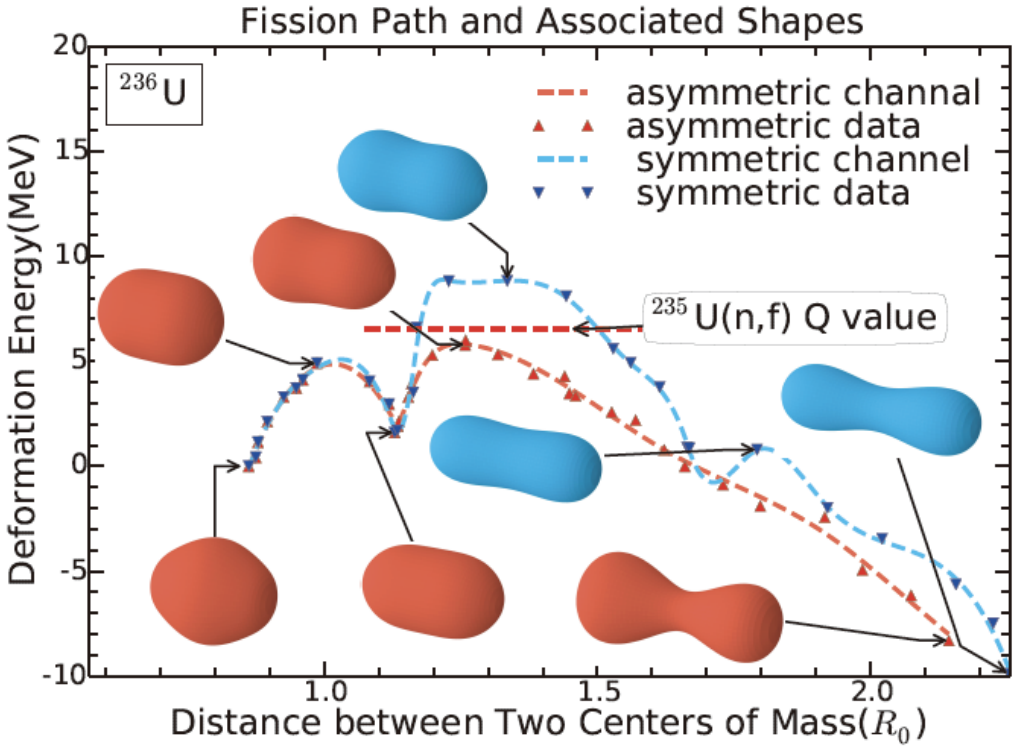
There are 49 experimental yields of ^{99}Mo, ^{99}Tc and chain yield, mainly from the United States, China and Europe. The experimental data were modified by gamma ray intensity and standard yield. After weighted averaging, the yields at thermal energy is 6.12E-2 (7.38E-4), consistent with that of ENDF/V-II.1. The yields at fission spectrum energy are quite different, ranging from 5.5 to 6.4%. Six of them are ratio, and have good consistency, which were adopted to deduced the yields, resulted 6.25 (1.8%) to 6.13 (1.8%) over the energy range of 0.2 MeV to 2 MeV, which are in accordance with the values of Selby 2011. **The yield at 14 MeV has only measured datum 6.27%, and was corrected to 5.08E-2 (9.66E-4) by normalizing with its yield at thermal energy, which is consistent with ENDF/BVII-1 and JEFF-3.1 within the uncertainties.**


Cumulative fission yield of 99Mo from n+235U fission
Yield(1/fission)
En(MeV)
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0
2
4
6
8
10
12
14
16
Present
ENDF/B-VII.1
JEFF-3.1
JENDL-4
Selby+,2010(R)
21624002,DEBERTIN+,'78(Q)
40489002,YUROVA+,'79(Q)
32633002,LI ZE,'80(Q)
32635004,WANG+,'80(Q)
32632002,WANG DAO,'85(R)
13395003,FINKLE+,'51
13372003,REED+,'53
13382002,WILES+,'54
13226002,MEYER+,'64
13249002,LARSON+,'69
13270003,LISMAN+,'70
13272002,MCELROY+,'70
22066002,SINCLAIR+,'71
20768002,CUNING.+,'72
12771002,LARSEN+,'74
21590002,BLACHOT+,'74
13337002,DUDEY+,'75
10828002,CHAPMAN+,'78
30495002,RAMASW.+,'79
30566003,K-CHENG+,'80
12729002,GLENDE.+,'81
21743005,MARIOL.+,'81
30744002,CIAE,'82
32631002,WANG+,'84/ZR95H
22057002,D'HONDT+,'86
33003003,CHITAM.+,'87
31526002,QI+,'88
31686002,GLAGOL.+,'09
31686003,GLAGOL.+,'09
21707005,LAUREC+,'10/MO99T
14441002,FINN+,'15
14423002,BHATIA+,'15
13372002,REED+,'53
13374002,TERRELL+,'53
13374003,TERRELL+,'53
13427003,FORD+,'56
14063002,STEVEN.+,'60/ZR95H
20769002,CUNING.+,'74
30504002,JAIN+,'71
32718002,FENG+,'13
13349002,VILLAR.+,'67
13359002,DIIORIO+,'77
14014002,YOUNES+,'01
21054087,WOHLFARTH+,'76
21531002,THIERENS+,'76
21595002,RAJAGO.+,'75
31685002,AJITAN.+,'78

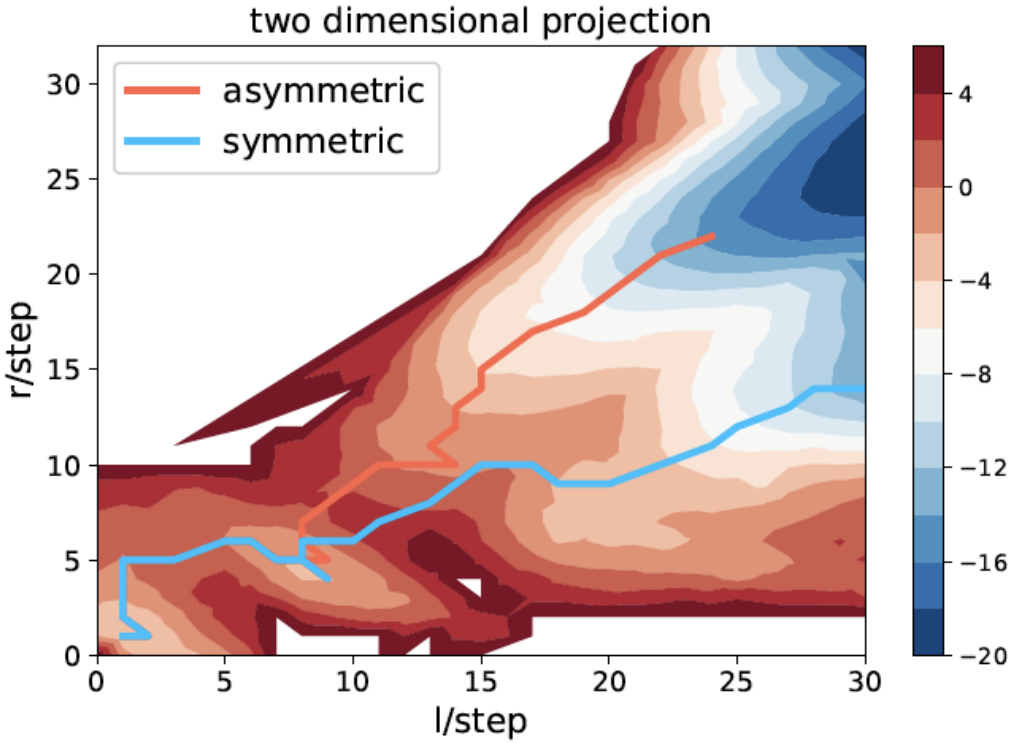
3.3 Calculations of multi-dimensional potential energy surfaces within a macroscopic-microscopic model and the study of fission dynamic processes

In the macroscopic-microscopic model, two sets of shapes are used to describe the nuclear shape. One is three-quadrature surface, which can independently describe the deformation of fragment. The other is the generalized Lawrence shape, and parameters have clearer meaning. Each of these two sets of shape parameters contains five independent variables.

Potential energy surfaces of isotopes of U and Pu elements were calculated in the five-dimensional deformation space. The asymmetric and symmetrical fission modes of actinide are obtained.

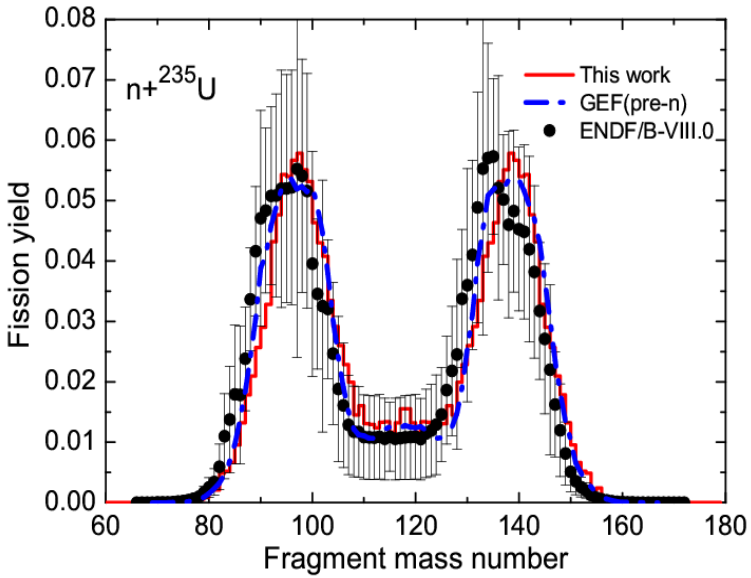


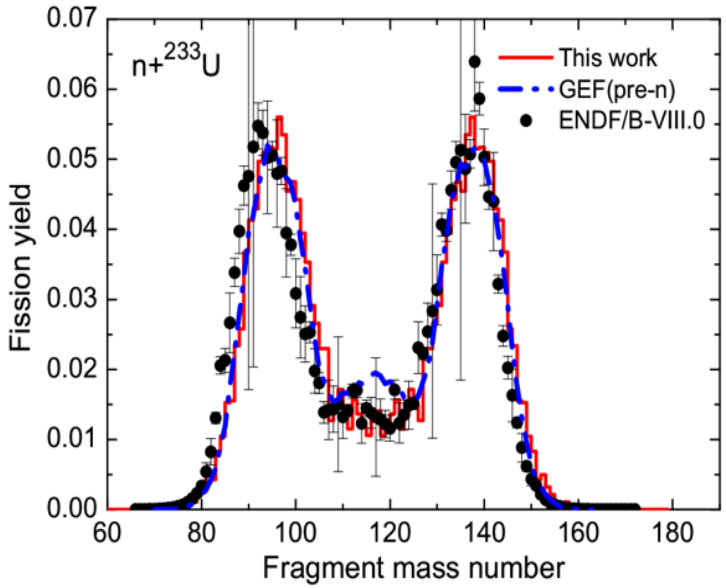
The symmetrical fission path and the asymmetrical fission path basically overlap from the ground state to the first barrier (inner barrier), but rapidly separate with the increase of deformation after the second minimum. The height of the second barrier of symmetrical fission is about 2.8 MeV higher than that of asymmetrical fission.



The difference between symmetrical fission and asymmetrical fission nuclei increases as the fission nuclei continue to elongate.

The mass distributions of 14MeV neutron induced $^{233, 235, 238}U$ and ^{239}Pu fission were calculated with Langevin equation, and the results were compared with the evaluated data of ENDF/B-VII.0 library (post-neutronmass distribution) and the results of pre-neutron mass distribution calculated by GEF.

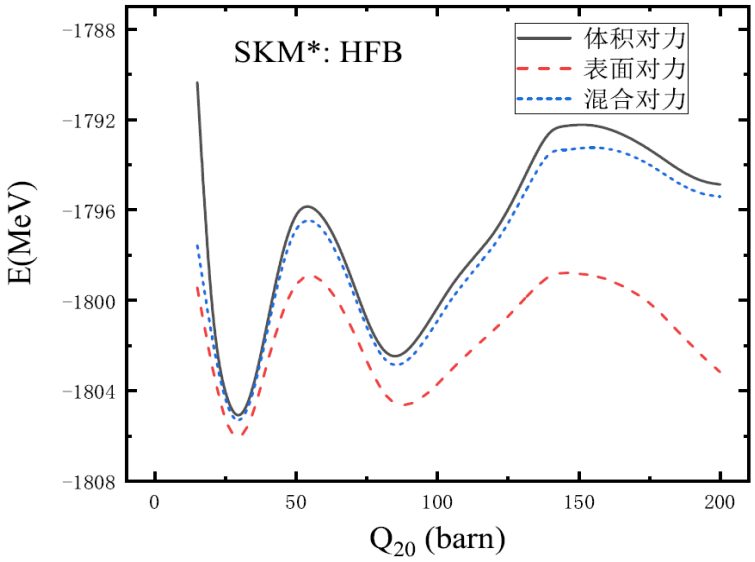


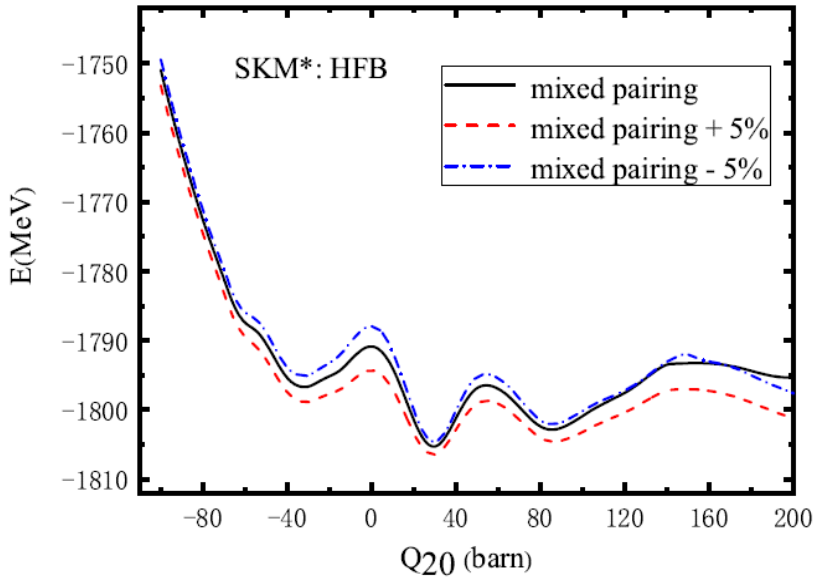


Simulation and evaluation results of n(14MeV) +$^{235,233}U$

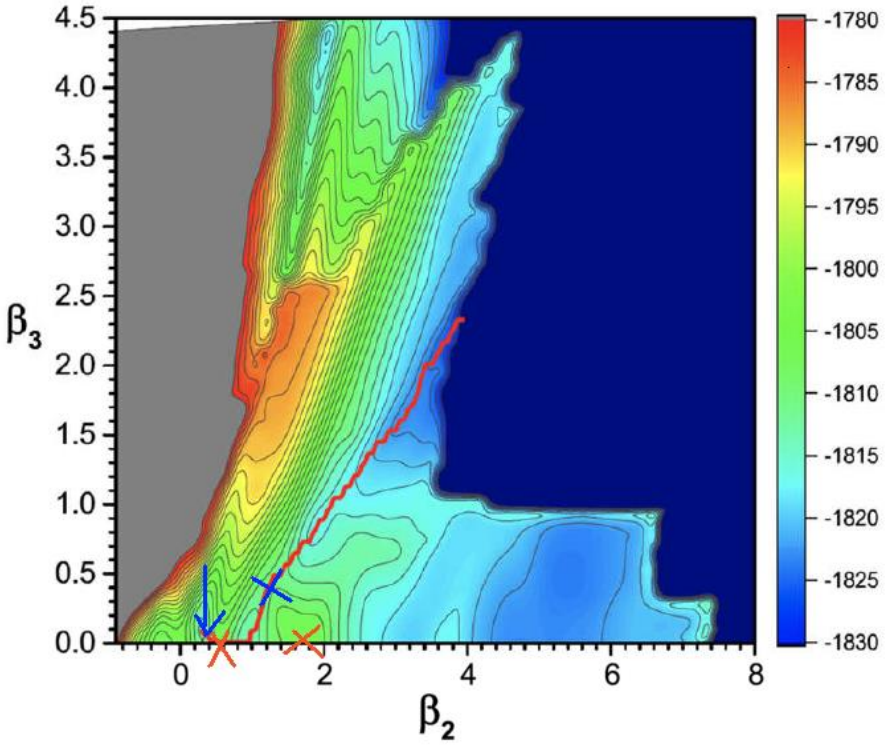
3.4 The studies on the mechanism of nuclear fission in Actinide nuclei with microscopic theories

Using the Constrained Hartee-Fock-Bogoliubov (CHFB) method based on non-relativistic energy density functional, the method and program for calculating the multidimensional potential energy surface are developed. The effects of different paring models and different paring strength on the potential energy surface are analyzed.





On the other hand, the time-dependent generated coordinate method (TDGCM) based on covariant density functional is used to study the dynamic properties of ^{240}Pu fission. The multi-dimensional fission potential energy surface and fission barrier structure are given.

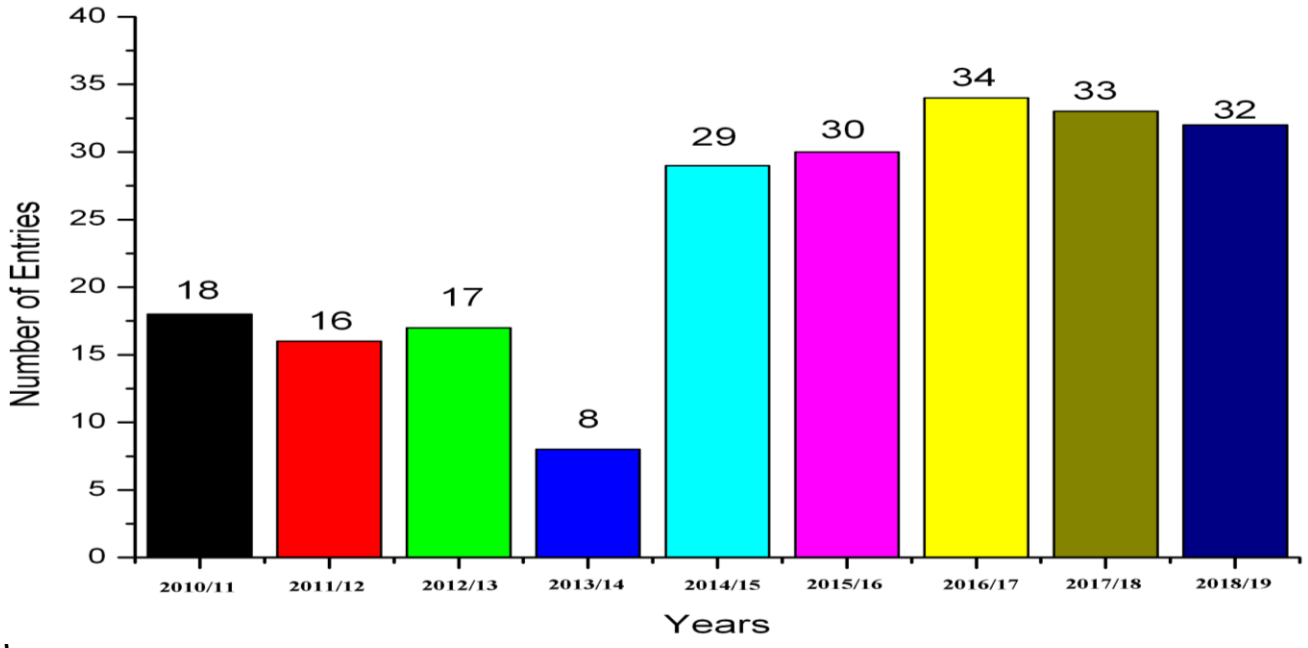


240Pu potential energy surface in (β2,β3) plane calculated with self-consistent relativistic mean field + BCS

IV. EXFOR activities at CNDC during 2018/2019

4-1. Compilation activities of EXFOR

- Since 2010, CNDC has compiled 217 EXFOR entries, which included 105 neutron and 112 charged particle entries, feedback & correction performed for more than 60 entries.
- Since the last NRDC meeting (2018-5-1), 32 new entries have been finalized and 22 entries have been revised, more than 30 articles under compiling.



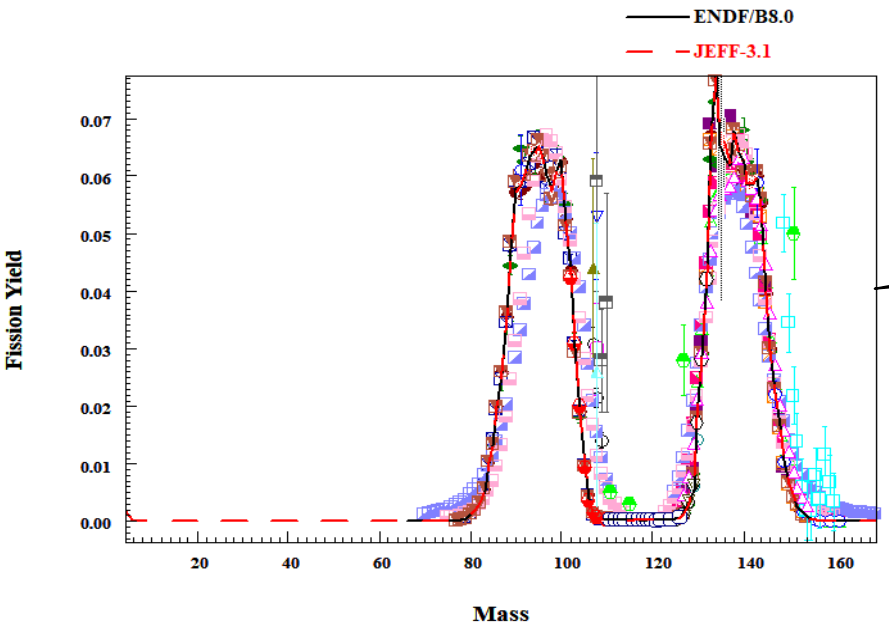
The number of the finalized EXFOR entries

4.2 Software NDPlot

NDPlot is an efficient plotting tool for nuclear data, developed by Dr. Yongli Jin (CNDC). It is not only a plotting tool for nuclear data, but also integrated application software. The latest version 0.93 beta was released in Dec.24, 2018.

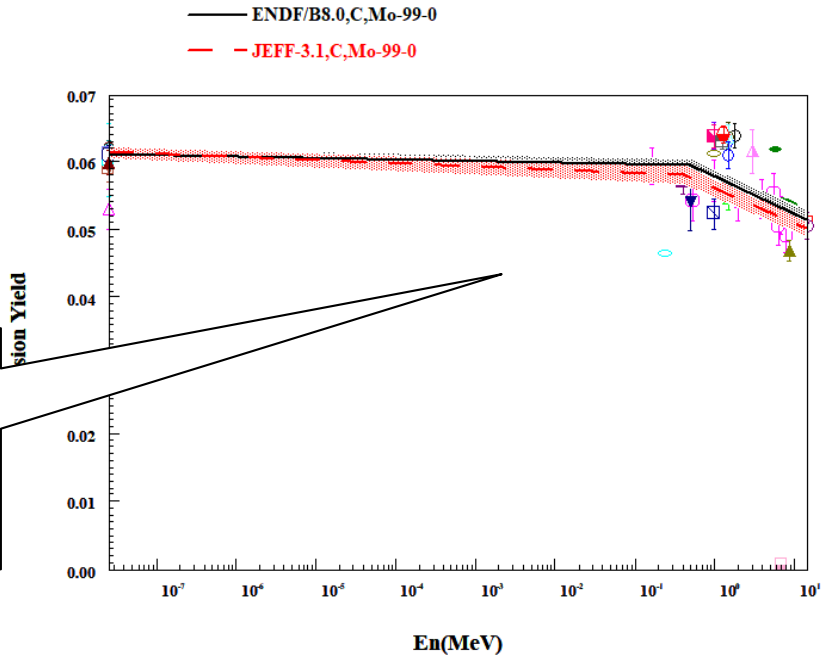
The new features added to NDPlot include:

① The ratio of cross sections can now be treated.
② Plot the chain yields and energy dependent fission yields
③ Filter fission yield data and correct the data with new gamma data.
④ Special treatment on discrete level excitation cross sections.



Chain Yield of U-235 (Thermal Energy)

Energy Dependent Fission Product Yields
U-235 (N,F)42-Mo-99,CUM,FY



4.3 Communication and Co-opetation

- Dr. Qian Jing, Dr.Wang Jimin and Dr. Jin Yongli participated in the Workshop on the Compilation of Experimental Nuclear Reaction Data, 22-25 October 2018, Vienna, Austria.

4.3 Communication and Co-opetation

- Dr.Wang Jimin and Dr. Jin Yongli participated in the 9th Asian Nuclear Reaction Database Development Workshop, 12-15 November 2018, Gyeongju, Korea.

4.3 Communication and Co-opetation

- Dr. Otsuka visited CNDC, 18-24 November 2018. More than 10 new entries were finalized, the earlier issues of “Atomic Energy Science and Technology” were scaned and the candidates of EXFOR compilation were identified.

V. Nuclear Data Service

CNDC provides the nuclear data service for institutes, universities or other requirements in China. CNDC joined the developing of Chinese basic database and established the Website of "The Database of Nuclear Physics" including experimental data (EXFOR),evaluated data, nuclear structure and decay data, astrophysical data and nuclear data for medical applications, etc. Some software can be downloaded from the website, such as GDGraph, NDPlot, and so on.

V. Nuclear Data Service

Thank you for your attention !
Comments and suggestion welcome !