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Progress of Nuclear Data Measurement in China during 2010-2011

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I. Introduction of China Nuclear Data Activities

The goal of China nuclear data activities is supplying the nuclear data to feed the needs of the nuclear peaceful applications, which contains the nuclear reactor design, science study, nuclear medicine application and public education et al.

The China nuclear data activities consists of nuclear data measurement and related measurement methods development, data evaluation and model study, data library establishment and library management and nuclear data benchmark testing and validation.

The mainly activities are being carried out at China Nuclear Data Center(CNDC), China Institute of Atomic Energy(CIAE) and China Nuclear Data Coordination Network(CNDCN) and more than 10 institutions and universities are involved in CNDCN.

The facilities used for the nuclear data measurements and studies include China's first experimental heavy water reactor(it was shut down two years ago), the HI-13 tandem accelerator, 600kV-Cockcroft-Walton accelerator and 5SDH-2 2×1.7MV tandem accelerator at CIAE. The 4.5-MV Van de Graaff accelerator at Peking University and 300kV -Cockcroft-Walton accelerator at Lanzhou university.

In addition, the China Experimental Fast Reactor (CEFR, 65 MW) reached critical on 21 June 2010, and China Advanced Research Reactor (CARR, 60MW, neutron flux: 8×10^{14}n/cm2·s), which has reached critical on 13, May 2010 at CIAE, will also be used for nuclear data related research.

II. Recent Progress of Nuclear Data Measurement in China

- **The secondary neutron emission double-differential cross section measurement for ^{9}Be and D**

The measurement of the double-differential cross sections (DDXs) of ^{9}Be at 22 and 25 MeV neutron energies has been finished and the measurement of DDXs of D at 8, 10, 12 MeV is undergoing at CIAE. These measurements are performed with the multi-detedtor fast neutron TOF spectrometer at the HI-13 Tandem Accelerator in CIAE. The diagram of the spectrometer is shown in following Fig.1

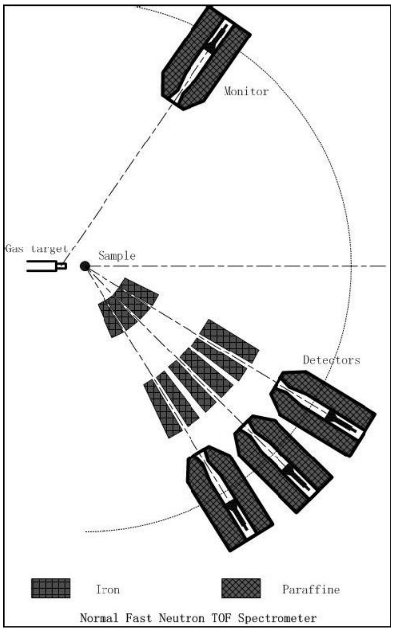


Fig. Schematic view of the multi-detector fast neutron and TOF spectrometer.

LUNF code based on the Hauser-Feshbach and exciton model for light nuclei was used to describe the DDXs of $n+^{9}Be$. The comparison between the model calculation and measurement is shown in fig.2.

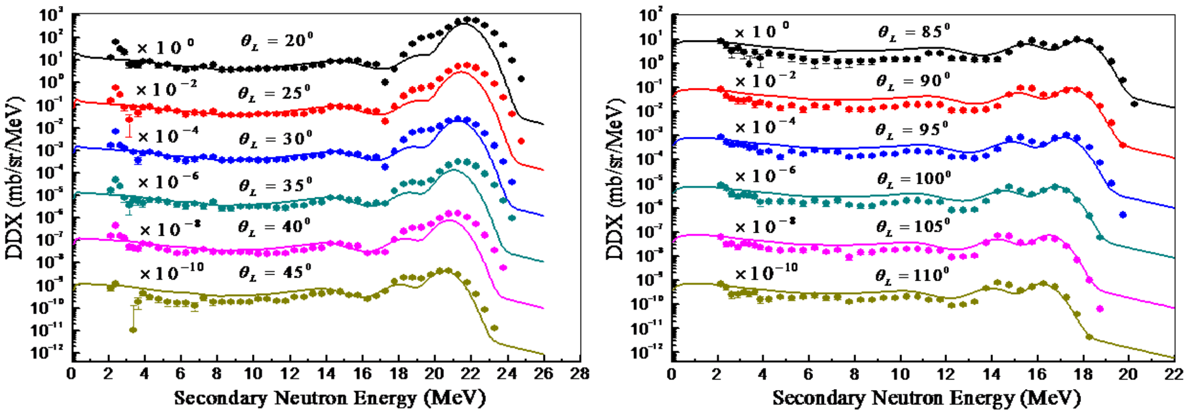


Fig.2 Part of DDX result for Be at 22 MeV

- **$^{69}Ga(n,2n)^{68}Ga$ cross section measurement**

This measurement was performed with the 600kV-Cockcroft-Walton accelerator in CIAE at the neutron energy of 14.9MeV. Based on the measurement, the existing experimental data of $^{69}Ga(n,2n)^{68}Ga$ cross section were reevaluated and improved based on CENDL-3.1

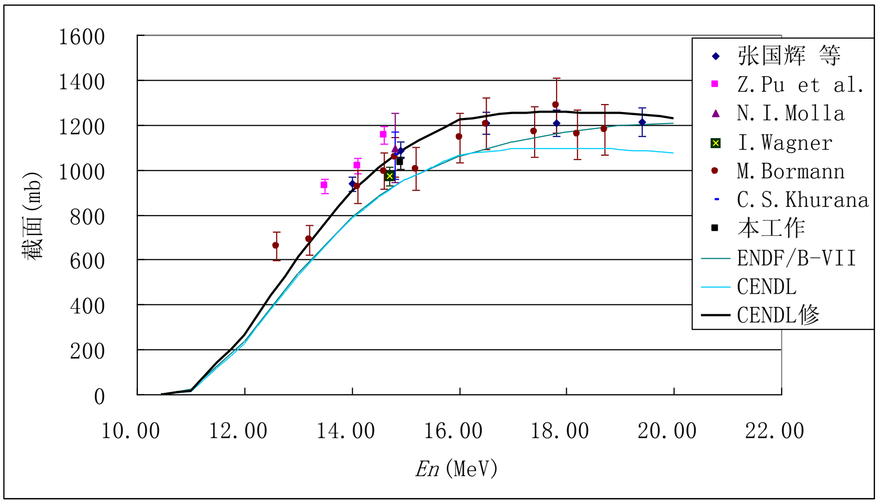


Fig.3 Measured result of $^{69}Ga(n,2n)^{68}Ga$ cross section, and compared with other measurement and evaluations

- **Fission yield measurement**

The fission yields of ^{235}U、^{239}Pu at thermal neutron energy and ^{232}Th at 14MeV neutron energy were measured at CIAE in recent years. The absolute fission rate was monitored with a double-fission chamber. Fission product activities were measured by a HPGe γ-ray spectrometer. The measured data were compared with ENDF/B-6 and Mills' measured results and the CNDC's evaluation. This work was required by the CENDL project and the study on the Th-U fuel cycle and MSR system. The following Tables show part of the measured results and comparisons.

Table 1 Thermal neutron induced ^{239}Pu fission

Nuclei	Eγ(keV)	CumFY(%) (stat. error)	Uncertainty (%)	Evaluated value (%)	
				ENDF/B-6	Mills(1995)
Rb-88	1836.0	1.320±0.029	3.8	1.329±0.027	1.291±0.025
Y-95	954.0	4.692±0.075	4.6	4.692±1.079	4.962±0.099
Mo-101	2032.1	6.127±0.139	5.3	6.007±0.661	6.268±0.138
Tc-101	306.8	6.100±0.039	3.6	6.019±0.662	
Cs-138g	1435.9	6.243±0.058	3.9	5.924±0.355	6.094±0.140
La-142	641.3	4.738±0.011	3.2	4.925±0.034	4.967±0.055

Table 2 Thermal neutron induced ^{235}U fission

Nuclei	E γ(keV)	BR(%)	FY(%)	UC	CNDC	UC
Kr-85m	304.87	13.7	1.288	0.023	1.291	0.027
Kr-87	402.6	49.6	2.837	0.075	2.558	0.026
Kr-88	2392	34.6	3.52	0.12	3.438	0.094
Xe-135mi	526.5	80.5	0.114	0.009	0.178	0.011
Xe-135mc	526.5	80.5	1.049	0.012	1.102	0.015
Xe-135g	249.8	90.2	6.63	0.18	6.529	0.138
Xe-138	1768.2	16.7	6.62	0.22	6.297	0.088

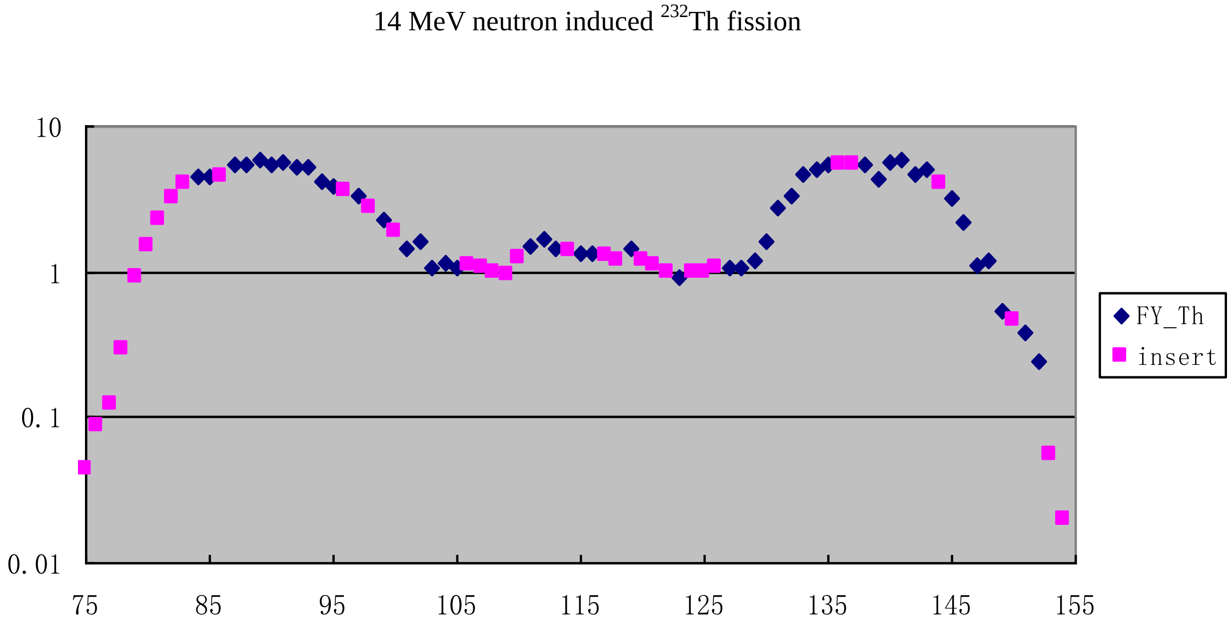


Fig.4 Fission yields of 14 MeV neutron induced ^{232}Th fission

- **Nuclear data measurement with AMS**

The AMS measurement system was established at the HI-13 Tandem Accelerator in CIAE, which contains the AMS injector system and two beam lines (see Fig.5).

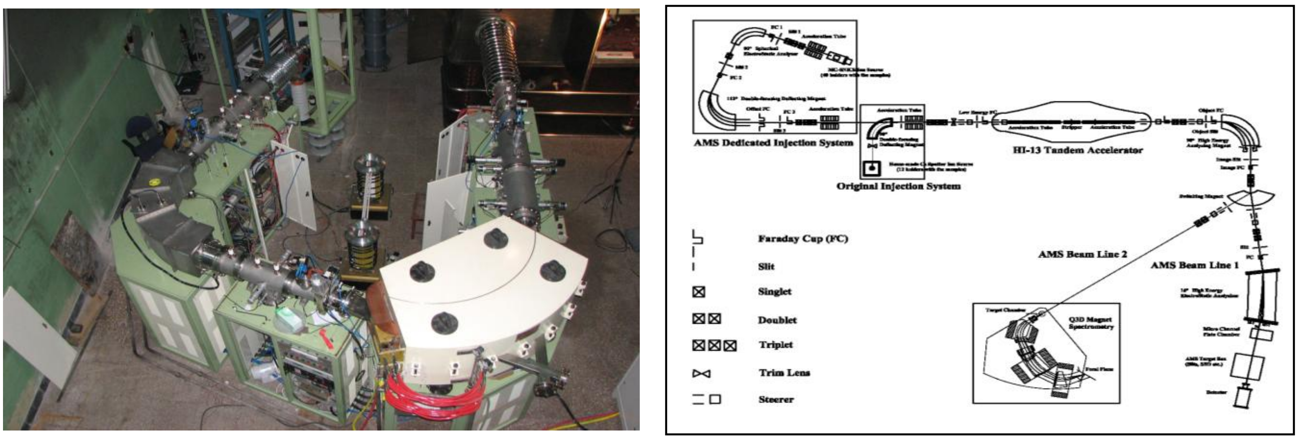
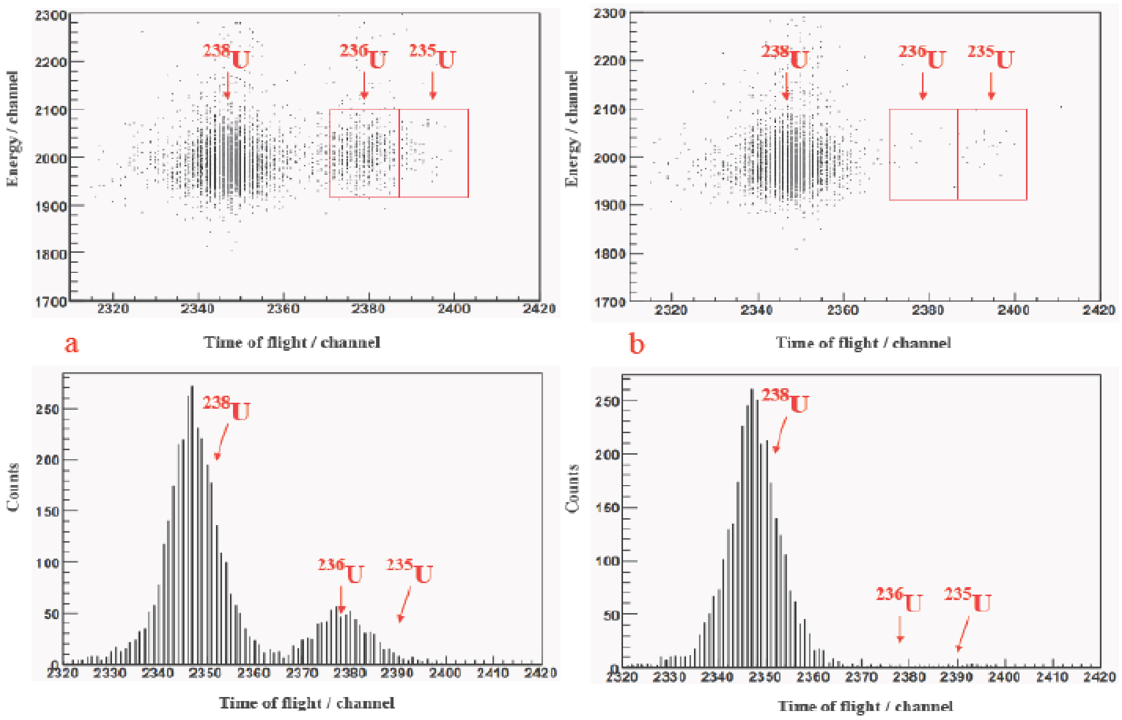


Fig.5 AMS injector system (left) and AMS system layout (right) in CIAE.

The ^{93}Nb(n,2n)^{92}Nb and ^{238}U(n,3n)^{236}U reactions were measured with the AMS system, after the samples were irradiated with 14MeV neutrons at the 600kV-Cockcroft-Walton accelerator. Irradiation condition is: T(d, n)^{4}He reaction neutron source, deuteron beam current: ~0.5mA, deuteron beam energy:300KeV, thickness of Ti-T$_{1.5}$ target:~1mg/cm^2 ; neutron yield:~3× 10^{10} n.s^{-1} and irradiation time: ~200h.



(a) ^{236}U dilution standard sample (Sample 2) with a ^{236}U/^{238}U ratio of (4.6±0.4)×10^{-8}, (b) natural uranium sample (Sample 3) with a ^{236}U/^{238}U ratio of (4.8±0.7)×10^{-10}

Fig.6 Mesured spectrum for ^{238}U(n,3n)^{236}U reaction

The preliminary result of ^{238}U(n,3n)^{236}U and ^{93}Nb(n，2n)^{92}Nb^{g} reaction cross sections were obtained with 729±224 mb for ^{93}Nb(n，2n)^{92}Nb^{g}, 550mb at 14.65MeV and 490mb at 14.18MeV.for ^{238}U(n,3n)^{236}U, respectively.

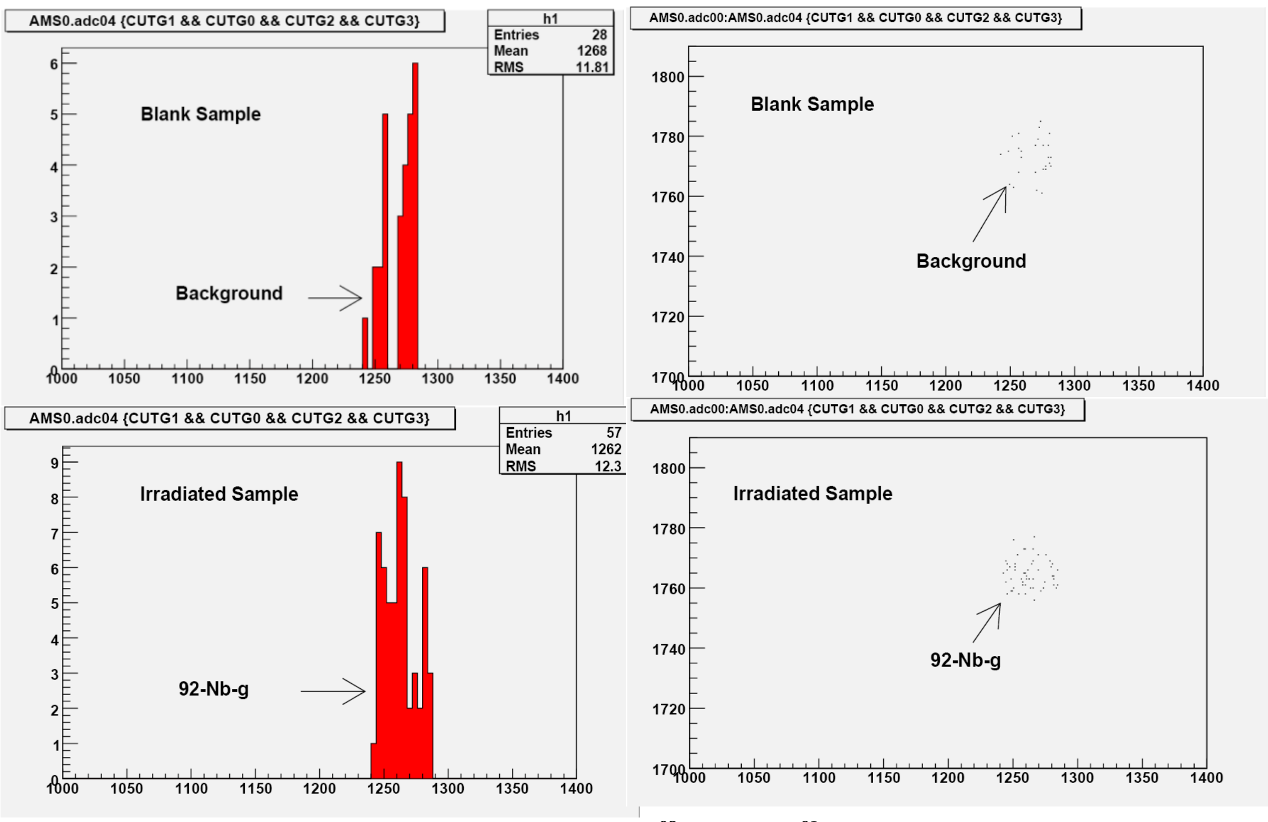


Fig.7 Mesured spectrum for ^{93}Nb(n，2n)^{92}Nb^{g} reaction

- **(n,x) measurement at Peking University**

The reaction cross sections of ^{149}Sm(n,α)、 ^{64,67}Zn(n,α) and ^{10}B(n,α) were measured with the 4.5 MV Van de Graaff accelerator of Peking University with monoenergetic neutrons produced via the ^{2}H(*d*,*n*)^{3}He reaction using a deuterium gas target. Alpha particles were detected with a double-section gridded ionization chamber having two back-to-back samples attached to the common cathode. Absolute neutron flux was measured using a small ^{238}U fission chamber and monitored by a BF_3 long counter. The measured results were compared with TALYS calculations, evaluated data and other measurements.

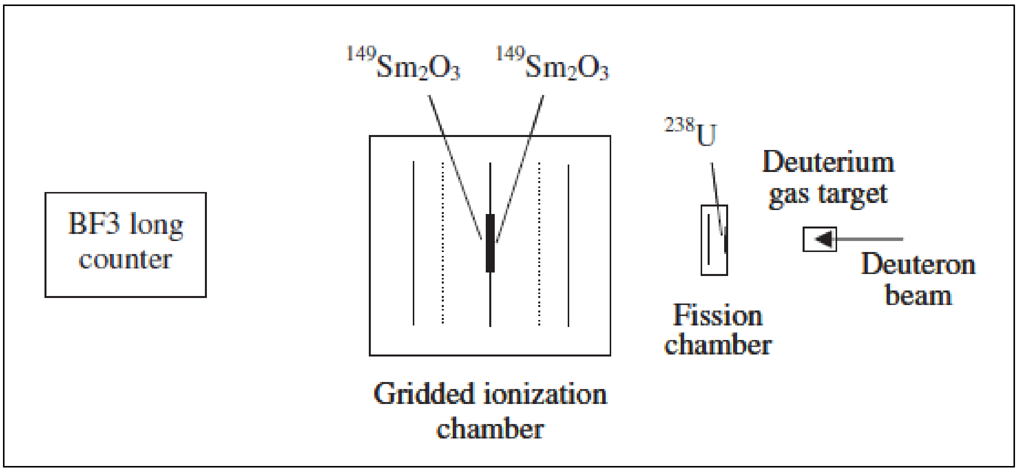


Fig.8 Experimental apparatus of (n,x) measurement at Peking University.

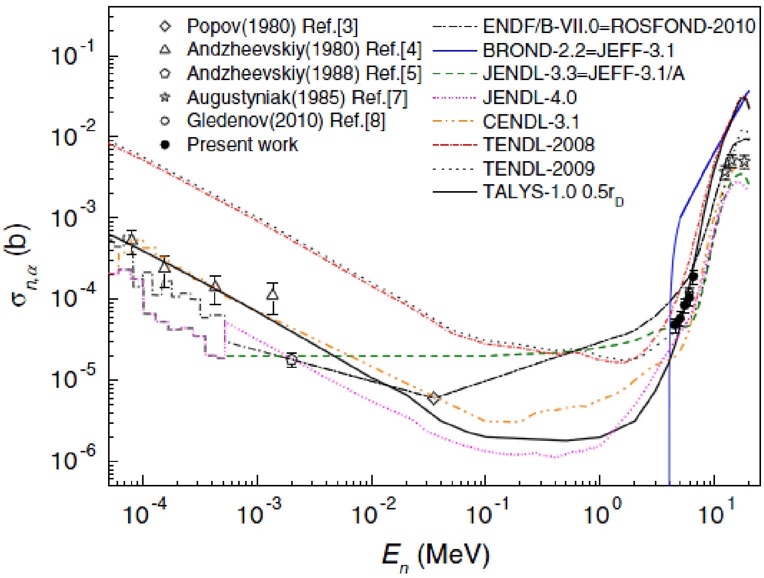


Fig.9 Present cross sections of the ^{149}Sm(n, α)^{146}Nd reaction compared with evaluated files and TALYS code calculations.

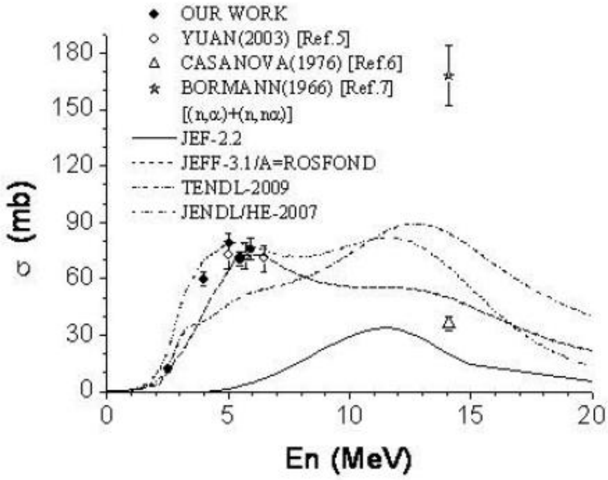


Fig.10 Present cross sections of the $^{64}Zn(n, \alpha)^{61}Ni$ reaction compared with existing data

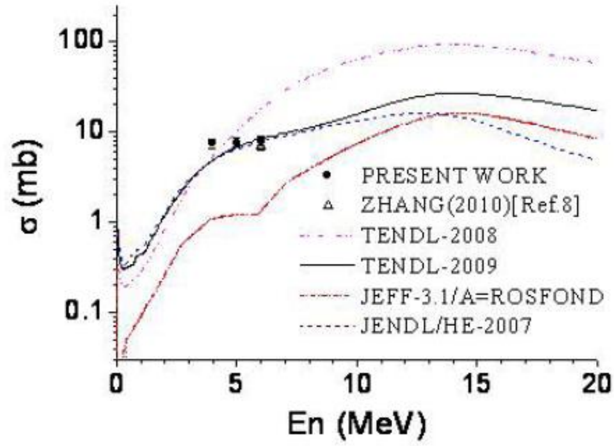


Fig.11 Present cross sections of the $^{67}Zn(n, \alpha)^{64}Ni$ reaction compared with existing data

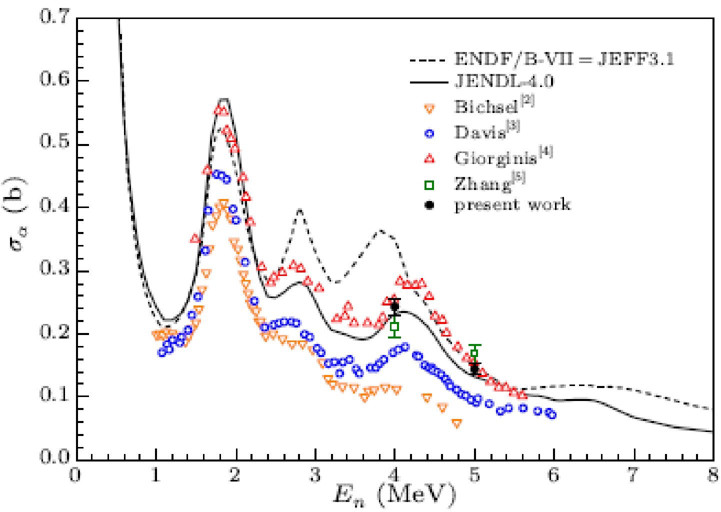


Fig.12 Present cross sections of the $^{10}B(n, \alpha)^{7}Li$ reaction compared with previous measurements and evaluations.

- **Excitation function around 14 MeV at Lanzhou University**

Several short life products measurements were performed with the 300kV -Cockcroft-Walton accelerator at Lanzhou University. The following nuclei of (n,2n), (n,α) and (n,p) cross sections were measured and the results are compared with previous measurements.

Table 3 The reactions measured at Lanzhou University recently years.

Nuclei	Reactions	Half life（m）
W	^{180}W(n,2n)^{179m}W	6.40
	^{186}W(n,2n)^{185m}W	1.67
Ho	^{165}Ho(n,2n)^{164m}Ho	37.5
	^{165}Ho(n, a)^{162}Tb	7.60
Ge	^{70}Ge(n, p)^{70}Ga	21.14
	^{74}Ge(n, p)^{74}Ga	8.12
Pd	^{108}Pd(n, p)^{107}Rh	6.0
	^{110}Pd(n, a)^{107}Ru	3.75
Ni	^{64}Ni(n, a)^{61}Fe	5.98
V	^{51}V(n, p)^{51}Ti	5.76
Yb	^{174}Yb(n, p)^{174}Tm	5.40

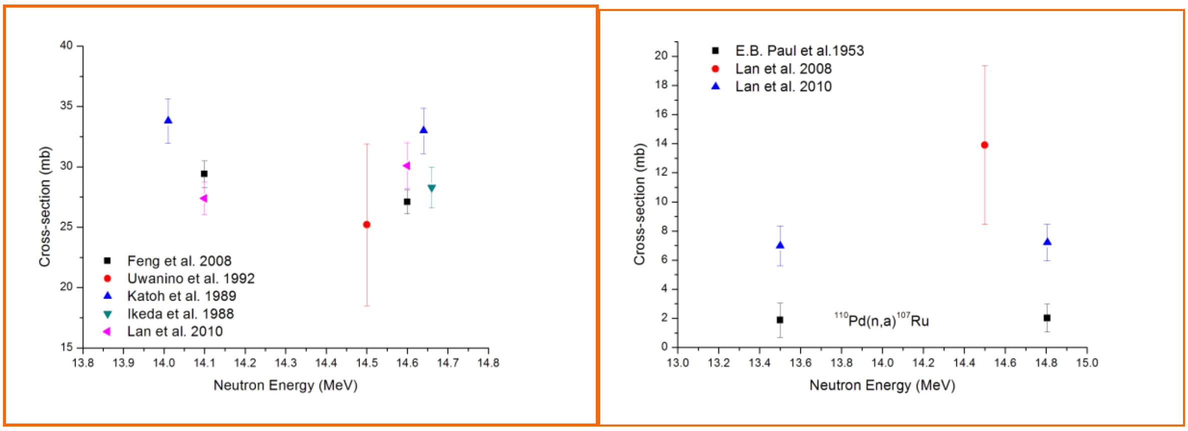


Fig.13 ^{51}V(n,p)^{51}Ti(left) and ^{110}Pd(n,α)^{107}Ru(right) reaction cross sections compared with other measurements.

III. Conclusion

Substantial progress on nuclear data measurement has been made in China in recent years.