3-4 June 2010
Presented at the 22nd Meeting of the NEA WPEC, Paris, France

Progress Report of Nuclear Data Experimental Activities

Ge Zhigang
China Nuclear Data Center, China Committee of Nuclear Data, China Institute of Atomic Energy
P.O.Box 275-1, Beijing 102413, P.R.China, Fax:+86-10-69357275 E-mail: gezg@ciae.ac.cn

1. Introduction

The major nuclear data project of China consists of:

Nuclear data measurement and related measurement methods study
Nuclear data evaluation and model study
Nuclear data library establish and library management
Nuclear data benchmark testing and validation

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

The facilities were used for the nuclear data measurements and studies including

- China's first experimental heavy water reactor (stopped, CIAE).
- The HI-13 tandem accelerator.(CIAE).
- 600kV-Cockcroft-Walton accelerator.(CIAE).
- 5SDH-2 tandem accelerator(CIAE).
- 4.5-MV Van de Graaff accelerator(Peking University).
- 300kV -Cockcroft-Walton accelerator(Lanzhou university).

The two new facilities at CIAE will be used for nuclear data related research.

- The China experimental fast reactor is under construction.
  (which is will be reached the critical this year)(CIAE)
- The China advanced research reactor. (neutron flux: 8×10^{14} n/cm^2·s)
  (which has been reached the critical on 13, May 2010)

2. Nuclear data measurements and related activities

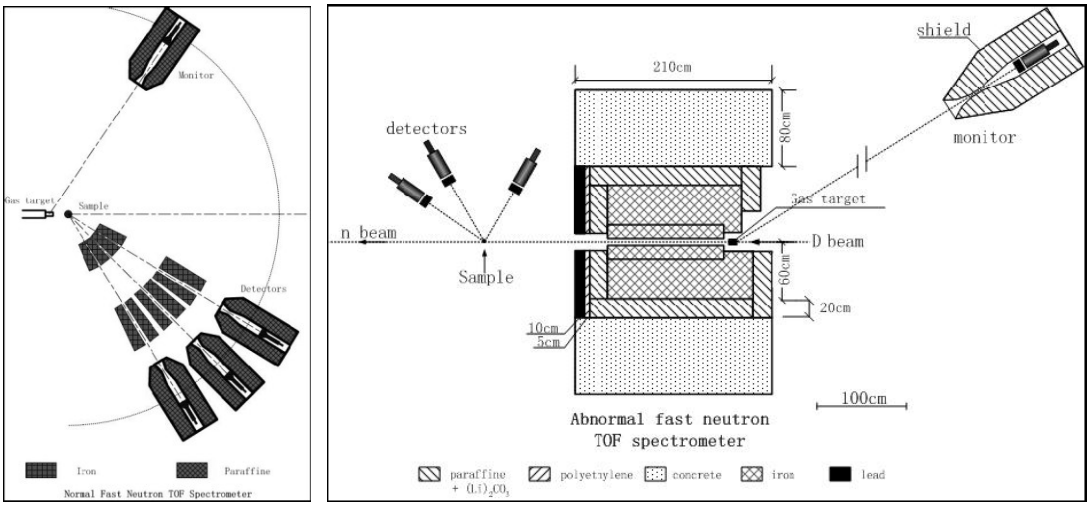
The measurements of neutron reaction and nuclear decay data performed. A lot of neutron cross section, angular distribution, neutron emission spectra, double differential cross section and nuclear decay data for a mount of nuclei have been measured and the results have been evaluated and provide to the users. Many method studies of the nuclear data measurements were performed and some study fruits of them have been used in our nuclear data measurements.

2.1 DDX measurement of ^{9}Be at 25.20 MeV

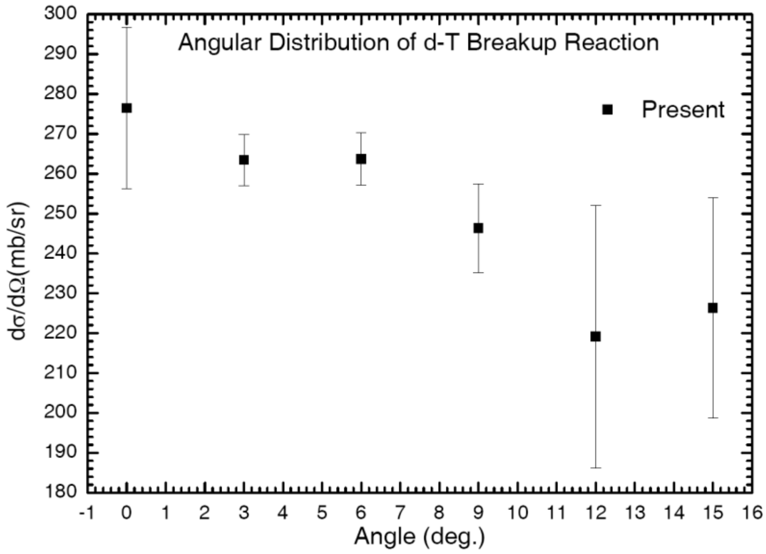
The neutron emission reactions of ^{9}Be induced by fast neutrons at 25 MeV were investigated by measuring the neutron emission double-differential cross sections. Meanwhile, the measurement results are been analysing. The experiments were carried out with the Normal Multi-detector Fast Neutron TOF Spectrometer on the HI-13 Tandem Accelerator of CIAE. A tritium gas target with 10 mm in diameter and 40 mm in length was used to generate neutrons by T(d, n) reaction. The tritium gas pressure is about 2 bar. Three liquid scintillator neutron detectors were used to detect the emitted neutron TOF spectrum . The distances from the center of gas target to the center of sample and from the center of the sample to the center of the detector are 18 cm and ~600 cm, respectively. TOF spectra at 30 angles from 15 to 160 degree were measured with gas in, sample in and out, gas out, sample in and out runs.

The d-T reaction neutron spectra with incident deuteron energy at 8.71 MeV are measured between 0 and 15 degree to obtain reduced breakup neutron energy distribution function, breakup reaction cross sections, angular differential cross sections and DDX. Moreover, the results of d-T neutron source spectra measurement are adopted to modify Monte-Carlo simulation code such as STREUER and SINENA. For the purpose of the experimental data deduction, Monte-Carlo method is employed to simulate TOF spectra, which are compared with the experimental TOF spectra. Then, the corrections for finite sample size effects, flux attenuation and multiple scattering are performed. Moreover, the measured spectra of elastic peak and continuous energy region are simulated and iterated simultaneously to solve the problem on the influence from each other. The problem on the contiminants from breakup neutrons of the d-T neutron source on secondary neutron spectra is successfully resolved. Through this data analysis processes, the final measured DDX data are obtained.

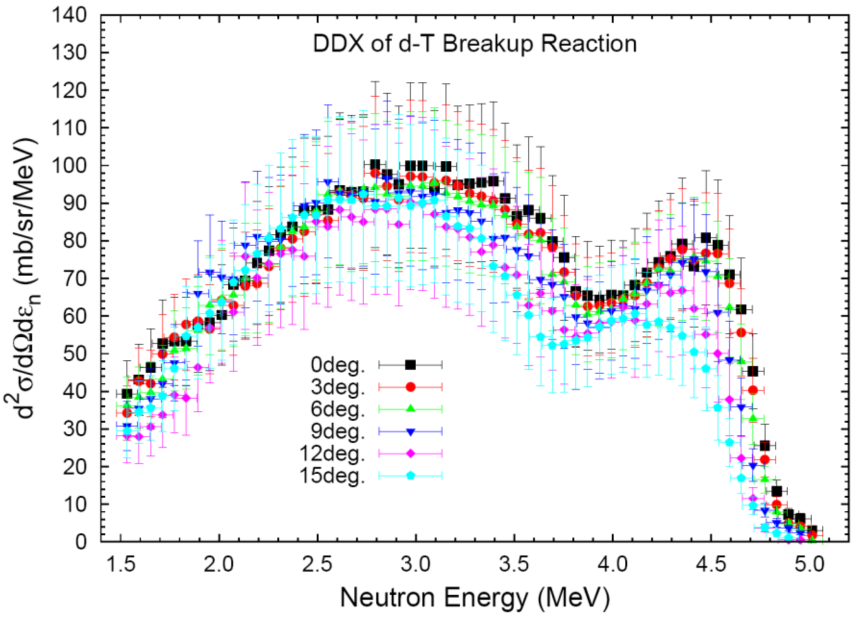
The experiment was performed with the normal fast neutron TOF spectrometer at the HI-13 Tandem Accelerator in CIAE. The diagram of the spectrometer is shown in below Fig.



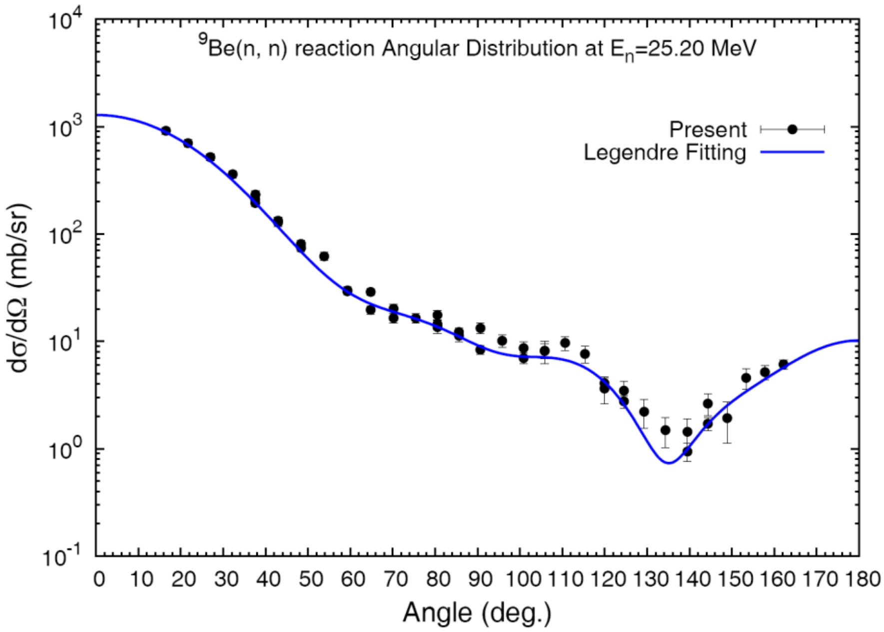
Schematic view of normal(left) and abnormal(right) fast neutron and TOF spectrometer.



d-T breakup reaction angular distribution between 0 and 15 degree



DDX of d-T breakup reaction from 0 to 15 degree.



Elastic angular distribution (including 1st ~ 5th inelastic scattering) for ^{9}Be at 25.20 MeV

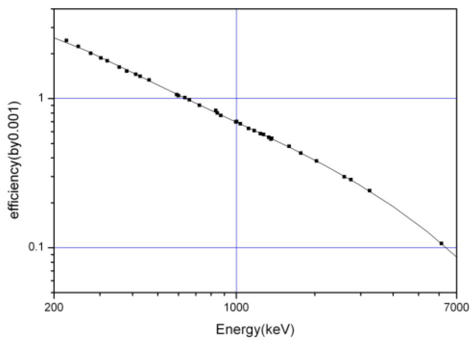
2.2 Measurement and evaluation the relative emission probabilities for high energy calibration of Ge detectors

^{56}Co and ^{66}Ga with γ-ray energies covering the range of 0.84~3.55 and 0.68~4.81MeV respectively are important radionuclides for Ge detector calibration. Their evaluated and recommended relative γ-ray emission probabilities were done based on the main measurements of D.C.Camp et al.[1] and M.E.Phelps et al.[2] before 2000. The values reported by D.C.Camp, however, were systematically lower in high energies range (by as much as 30% for the 4806 keV γ-ray of ^{66}Ga) because the conclusion has been reached that above 2500 keV Ge detector efficiency curves do not decrease linearly with energy on a log-log scale since 1975. These measurements based on the assumption of almost linear extrapolation on a log-log plot of the efficiency curve between 2500 and 5000 keV were not corrected due to no high precise measurements. The experimental data measured after 2000 and recent evaluations of C.M.Baglin et al.[3] and E.Browne et al. [4] were analyzed and compared with our present measured and evaluated values for ^{56}Co and ^{66}Ga

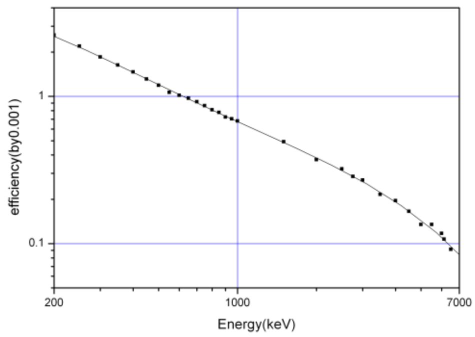
The full efficiency curve used in the present measurement can be determined by the experiment and the Monte-Carlo calculation. Below 2.75MeV the efficiency curve was based upon the experimental data. Between 2.75 and 6.13MeV the efficiency curve was obtained from the Monte-Carlo calculation which has been validated by the experimental data at low energy region and agreed perfectly with the efficiency at 6.13MeV that was determined by the ^{19}F(p, αγ)^{16}O reaction.

2.3 The experiment method study of decay data and measurement

In the past two years, the method study of decay data measurement has been performed with the examples of some shorter half-life nuclides at CIAE. Some primary results have been obtained and analyzed with the Table of Isotopes Eighth Edition for testing and checking the experimental method.

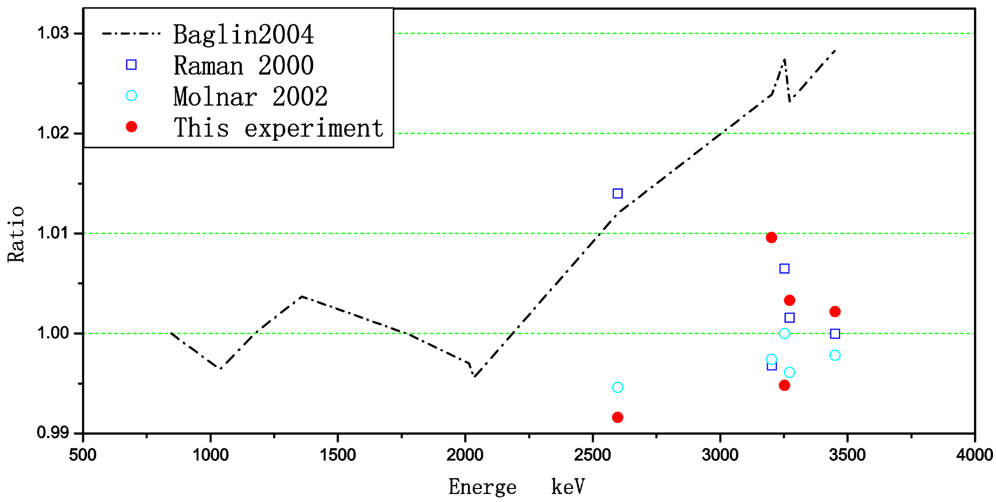


The measured efficiency curve



Comparsion of the calculated efficiency curve using EGS4 M-C code normalized at 2754keV with the measured efficiency curve

By using the efficiency curve measured above， the new relative intensities were determined for the emitted γ-rays of ^{56}Co and ^{66}Ga. The final results are presented in following Fig. and Table. It's noted that our measurements are about 2% lower than other new measurements in high energy range.



Comparison of present evaluation to Baglin's evaluation and modified measurements for ^{56}Co

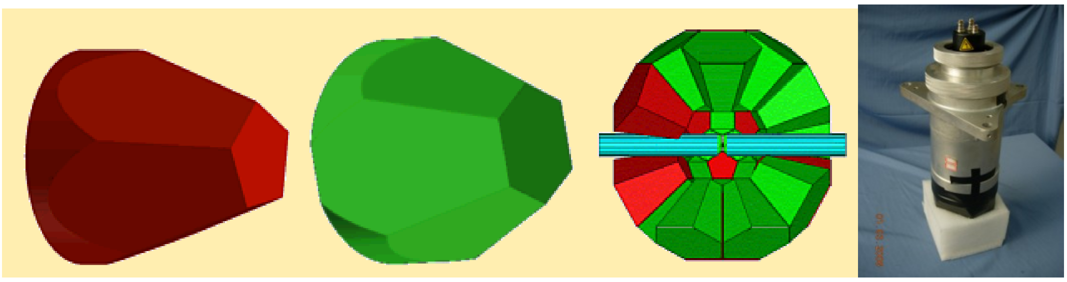
Comparison of recent measured and evaluated relative γ-ray emission probabilities for ^{66}Ga

E_γ (keV)	Measurements				Evaluations		modified values			
	Molnar[10] (Budapest)	Raman[10]	Baglin[10] (Berkeley)	Present	Browne	Present	Molnar	Raman	Baglin	Present evaluation
833.6	15.92(6)	16.02(24)	15.94(14)	15.85(17)	15.94	15.92(5)				
1039.4	100.0(3)	100.0(16)	100.0(9)	100.0(5)	100.0	100.0				
1333.2	3.171(13)	3.17(5)	3.20(3)	3.15(2)	3.16	3.17(1)				
1918.8	5.360(23)	5.33(8)	5.44(6)	5.36(4)	5.38	5.37(2)				
2189.9	14.39(6)	14.54(21)	14.50(13)	14.12(12)	14.32	14.37(5)				
2422.9	5.072(24)	5.12(8)	5.15(6)	5.17(4)	5.08	5.10(2)				
2752.3	61.34(26)	61.2(8)	61.5(6)	60.80(40)	61.35	61.22(20)*	60.60(48)	60.84(91)	60.6(9)	60.71(6)^b
3229.2	4.087(22)	4.06(8)	4.07(4)	4.00(6)	4.08	4.08(2) *	3.989(49)	4.01(9)	3.96(7)	3.99(1)^b
3381.4	3.950(23)	3.96(8)	3.99(4)	3.83(4)	3.94	3.94(2) *	3.847(52)	3.91(9)	3.87(7)	3.86(2)^b
4086.5	3.455(20)	3.38(8)	3.42(4)	3.36(5)	3.43	3.44(2) *	3.406(34)	3.35(9)	3.37(5)	3.37(1)^b
4806.6	5.04(3)	4.93(11)	5.00(7)	4.99(8)	5.03	5.02(3) *	5.06(4)	4.94(11)	4.95(7)	4.99(3)^b

2.4 GTAF(Gamma Total Absorption Facility) detector in CIAE

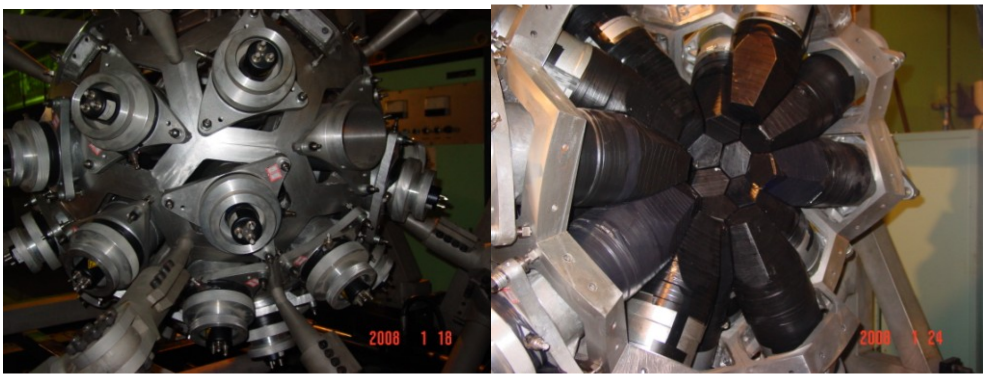
Since the requirement of the (n, γ) cross-section data is increasing strongly in ADS project, Nuclear Waste Transmutation and Nuclear Astrophysics, a new measurement method which get the (n, γ) cross-section by detecting the prompt gammas from the capture of neutrons has been set up in CIAE.

The gamma total absorption facility was chosen as our main detector. The detector consists of 42 BaF2 crystals of 15 cm length. Covering the full solid angle without any gaps requires two different crystal shapes, which can be seen in the Fig.4.   The shapes of the crystals are optimized in a way that they all cover the same solid angle, although they have different shapes. The volumes described above can be arranged to form a closed sphere with an inner radius of 10 cm and an outer radius of 25 cm.



The different crystal shapes and the all crystals together (left)and the single detector module(right)

The external support which is made by the stainless steel and the honey comb and support for crystals which are made by the Al. The construction of this system was finished last year at CIAE.



GTAF in CIAE

3. Nuclear data need in the future in China

As the development of China nuclear power, increasing of the nuclear data application in various filed, the nuclear data needs in the future in China are follows;

The covariance data in nuclear evaluated file should be improved. The kinds of covariance data for each nucleus, for example, the covariance of cross section, energy spectra, even the double-differential cross section.   The number of nuclei with the covariance data in the evaluated data file should be increased.

The model and the method of covariance data production and analyzing should be studied deeply and carefully. The international coordination on this field should be widely and the studies should be shared.

The information of the nuclear structure for some important nuclei should be measured, for example, the information of discrete level for ^{238}U, because the information is very necessary for the most nuclear data model codes which are popular used in the nuclear data evaluation now.

For the need of ADS project research, the number of nuclei should be extend in the medium-high energy data file, and the neutron energy also should be increased up to 1GeV.

The nuclear data for light nuclei, structure material are also need for the international project ITER. Although these data have been included in the FENDL and other evaluated data files, but the more accuracy and reliability are required, especially for deuterium and tritium et al.

The update, correct nuclear character information is need for the popular education and elementary application field.