Benchmark experiment on slab iron for validation of evaluated nuclear data

Content

Experimental arrangement

Measure the neutron leakage spectrum from slab samples for different angles by Time-of-Flight technique with a 14 MeV D-T neutron source

Pulse Frequency: 1.5MHz;

Pulse Width: about 1.5ns;

Neutron Yield: about 2×10^{9}

Flight Distance: about 8m

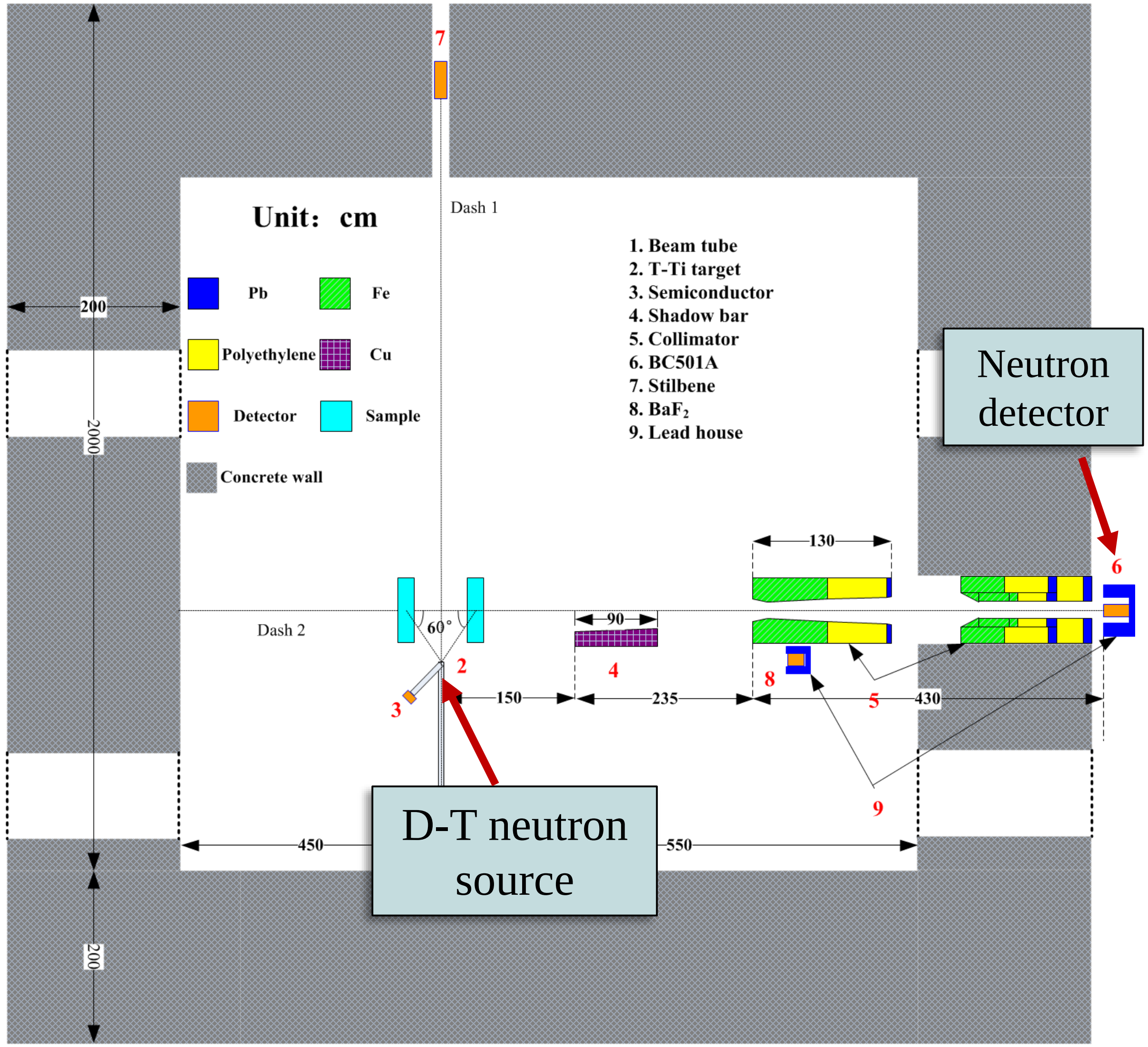

Fig. 1 Experimental arrangement for benchmark validation at CIAE

The neutron source

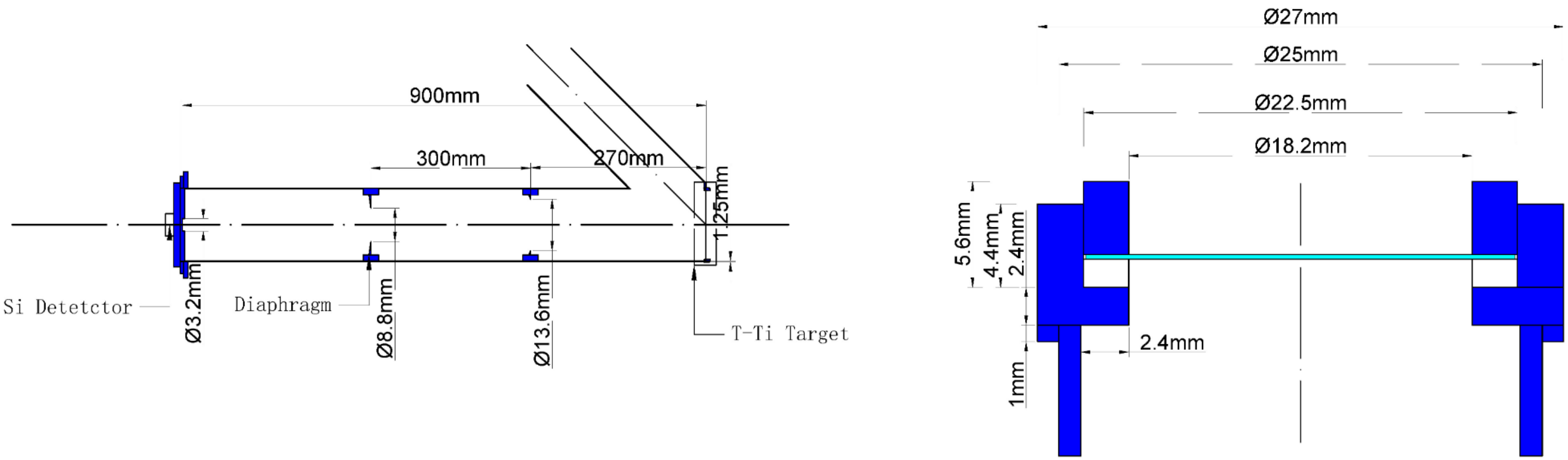

Fig. 2 The detailed dimensions with the T-Ti target

- ✓ **The source neutron yield at the target position can be estimated by the following equations:**

$$N_n = \frac{N_\alpha \times A_\alpha \times \sigma_{tot}}{\Delta\Omega \times \sigma(\theta)}$$

$$\Delta\Omega = \frac{\pi \times r^2}{L^2}$$

The Samples

Table.1 The integral experiments on iron have been performed at CIAE

Sample	Area （cm）	Thickness （cm）	Density (g/cm^3)	Angle （°）
Fe	Φ13	5,10,15	7.86	60,120
Fe	30×30	5,10,15	7.86	60,120

Table.2 The compositions of the sample (in weight)

Nuclide	Fe	Si	C	Mn	Al	Impurity（Pb+Sn +Bi Cu+S+P）
mass ratio	99.900%	0.03%	0.015%	0.02%	0.02%	0.015%

The electronics

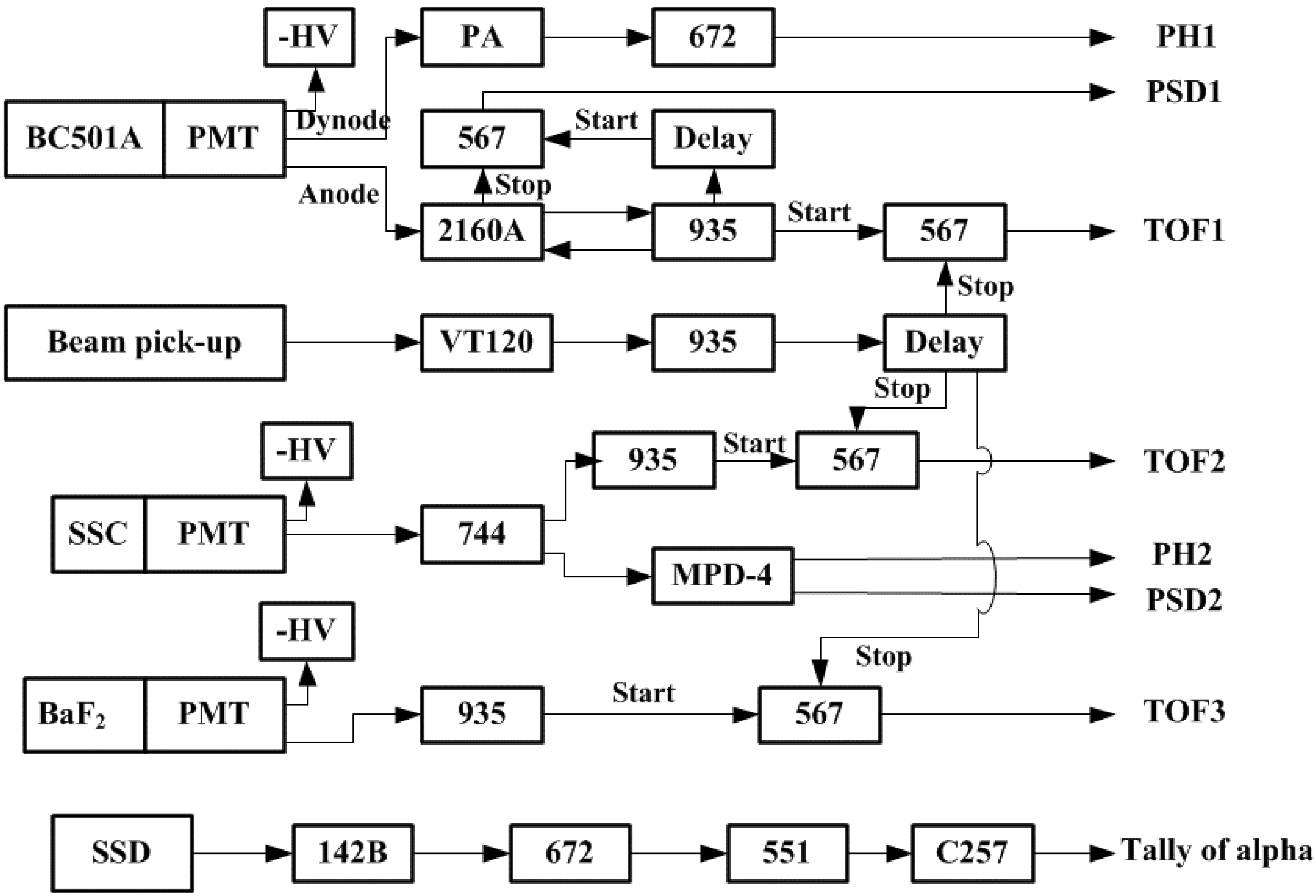

Fig. 3 Block diagram of the electronic circuit for the experiment

The neutron detector efficiency

1、Use double scintillation detector to measure relative detection efficiency of BC501A;

2、Use D-D neutron source to measure absolute detection efficiency of BC501A

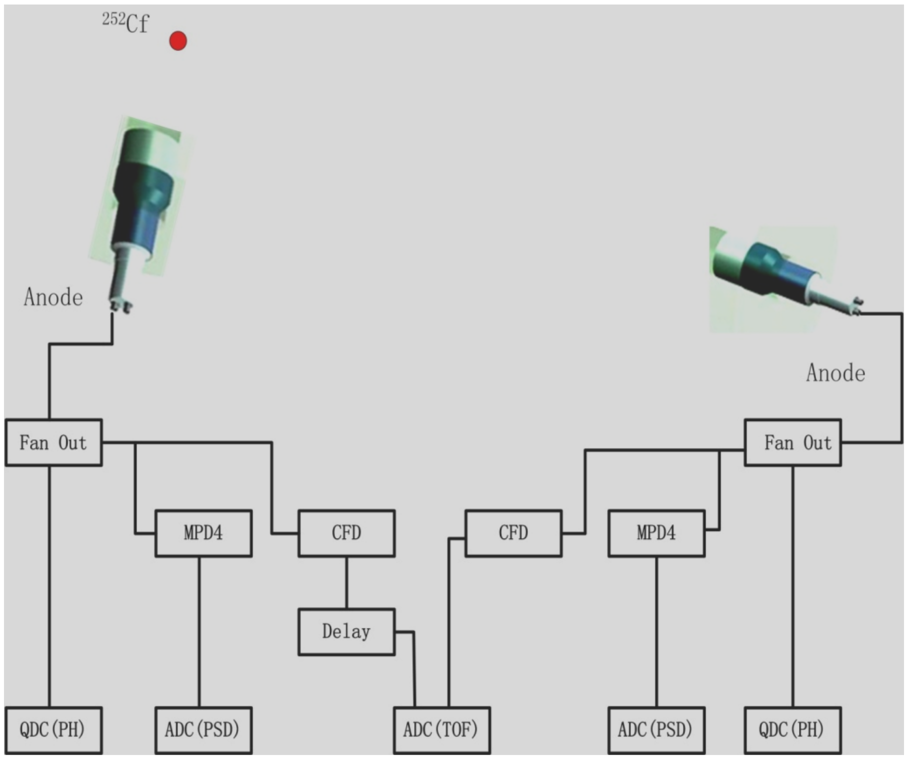

Fig.4 Experimental arrangement for relative detection efficiency calibration

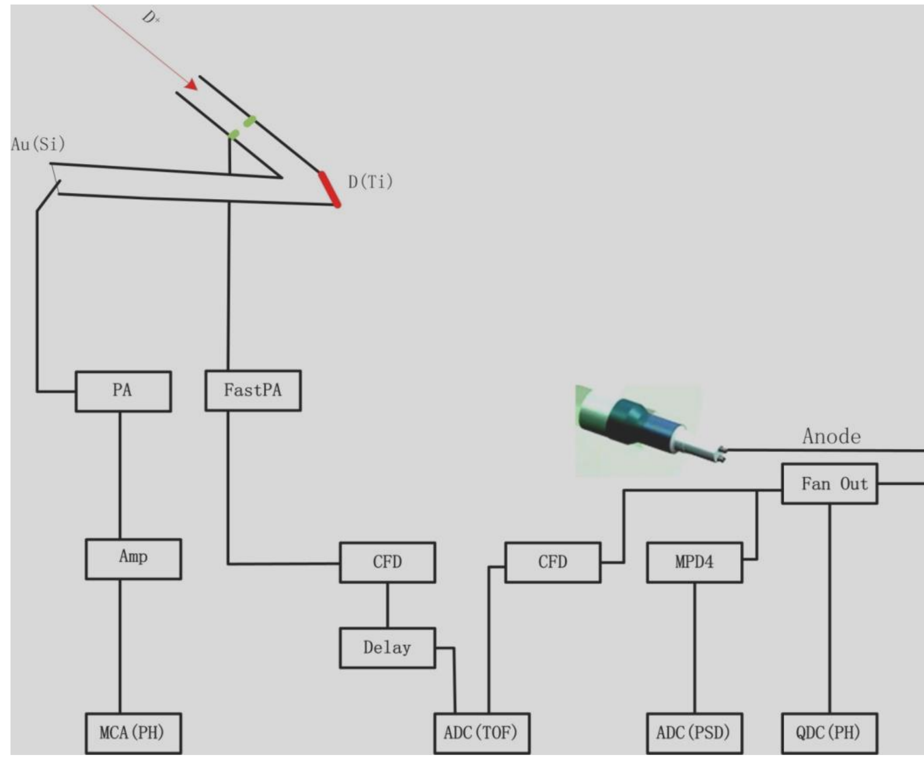

Fig.5 Experimental arrangement for absolute detection efficiency calibration

The neutron detector efficiency

3、Use NEFF code to simulate detection efficiency curve

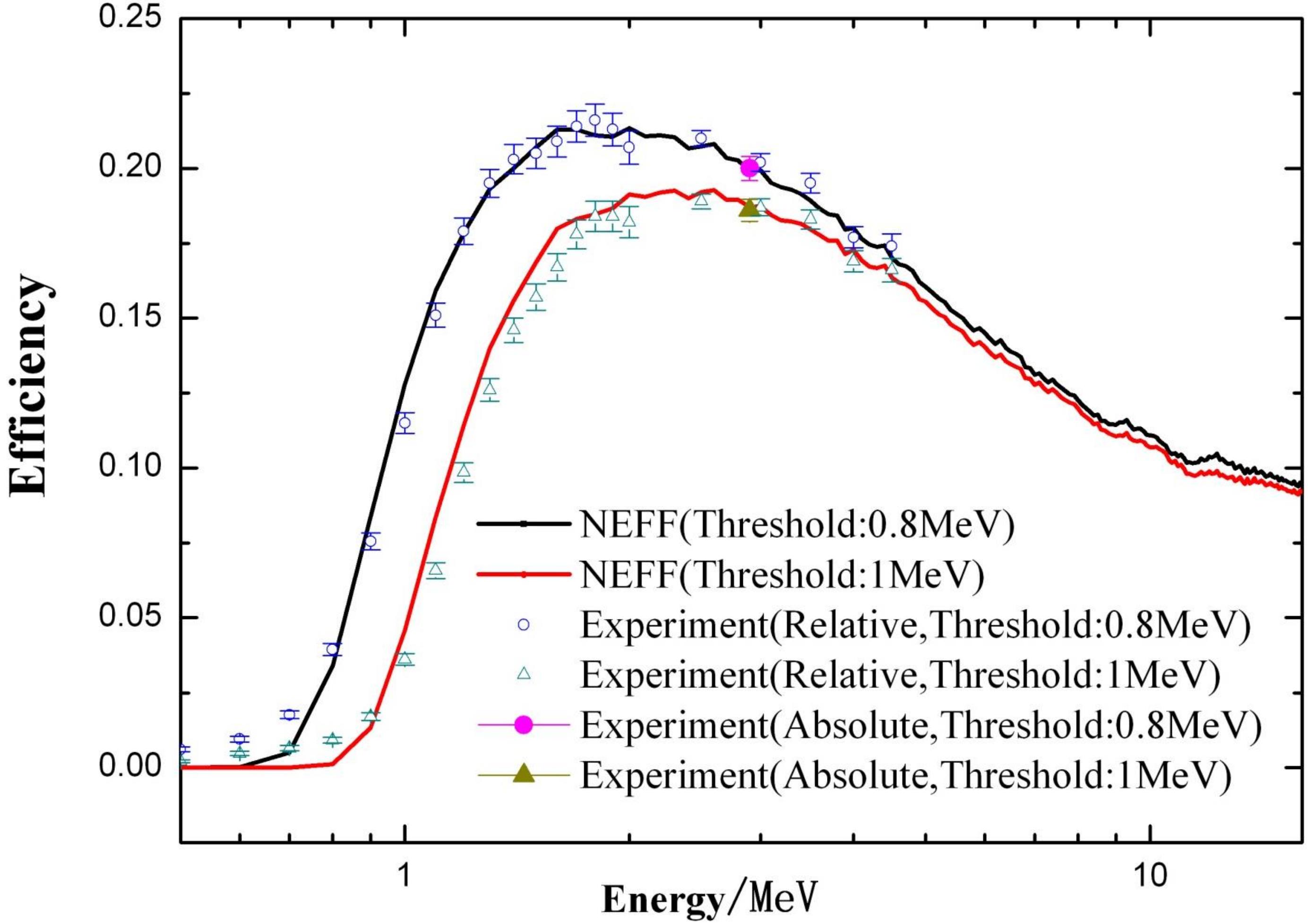

Fig.6 The detection efficiency with different thresholds

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System verification with standard sample

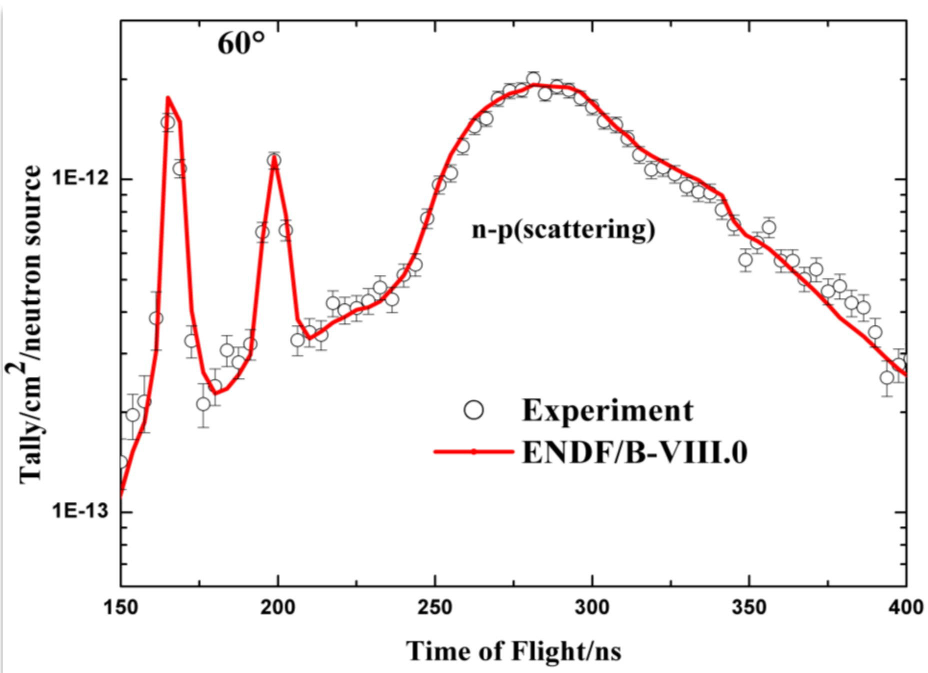

Fig.7 Leakage neutron spectra from polyethylene sample of Φ13cm×6cm at 60°

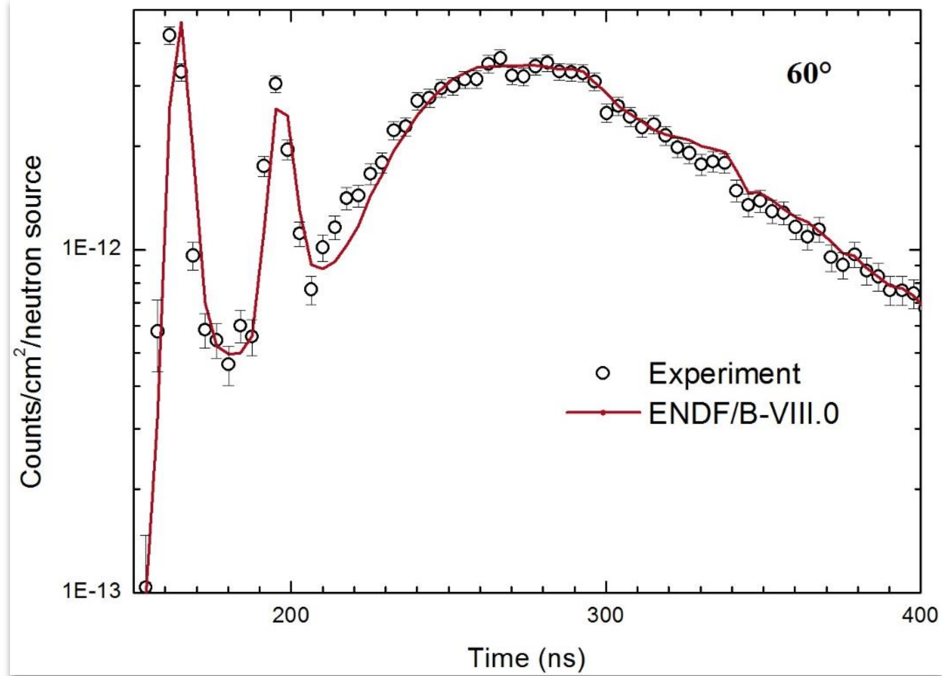

Fig.8 Leakage neutron spectra from polyethylene sample of 30cm×30cm×6cm at 60°

sample	n-p scattering (Experiment)	n-p scattering (Calculation)	C/E
Φ13cm×6cm	4.269E-11	4.349E-11	1.019
30cm×30cm×6cm	9.360E-11	9.619E-11	1.015

These results indicate that the experimental apparatus work well.

Uncertainties of experimental data

The measured spectra were normalized by the n-p scattering with equation bellow,

$$\frac{N_B^e}{N_n} = \frac{N_B^e}{N_\alpha^B \times B^1} = \frac{N_B^e \times N_p^c \times N_\alpha^p}{N_p^e \times N_\alpha^B}$$

Where N_B^e is the number of neutrons per time bin, N_α^B is the number of associated alpha particles detected for other sample in beam

Table.3 The uncertainties of the present experiment

Statistical Uncertainty		Systematic Uncertainty	
N_B^e	<0.5%	relative neutron detection efficiency	<3%
N_P^c	<0.5%		
N_P^e	<0.5%	scattering angle ambiguity	<1%
N_α^p	<0.5%		
N_α^B	<0.5%		

Monte Carlo simulation

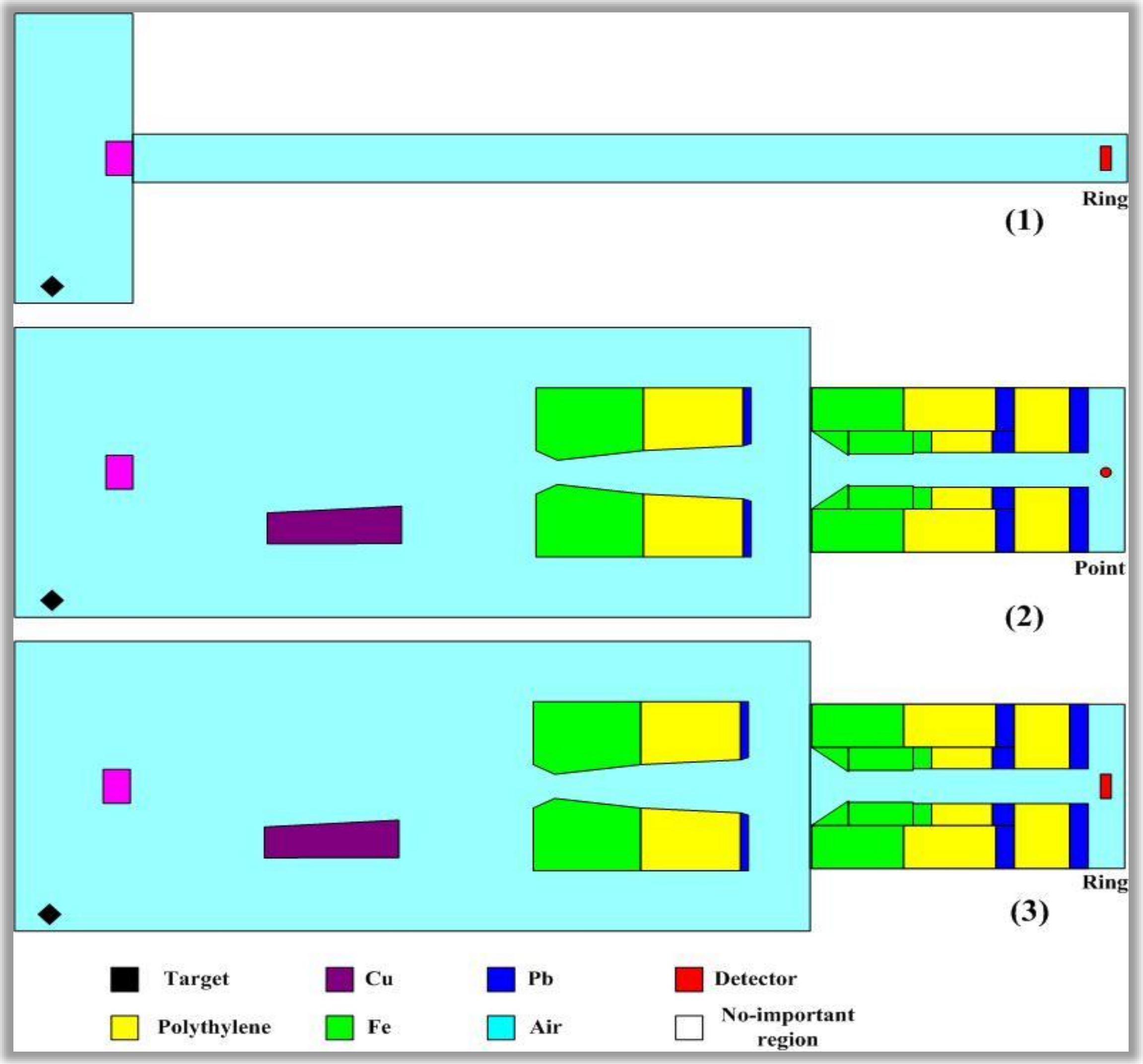

Fig.9 The models were used in MCNP simulation

Simple model
Ring detector

Complex model
point detector

Complex model
Ring detector

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Monte Carlo simulation

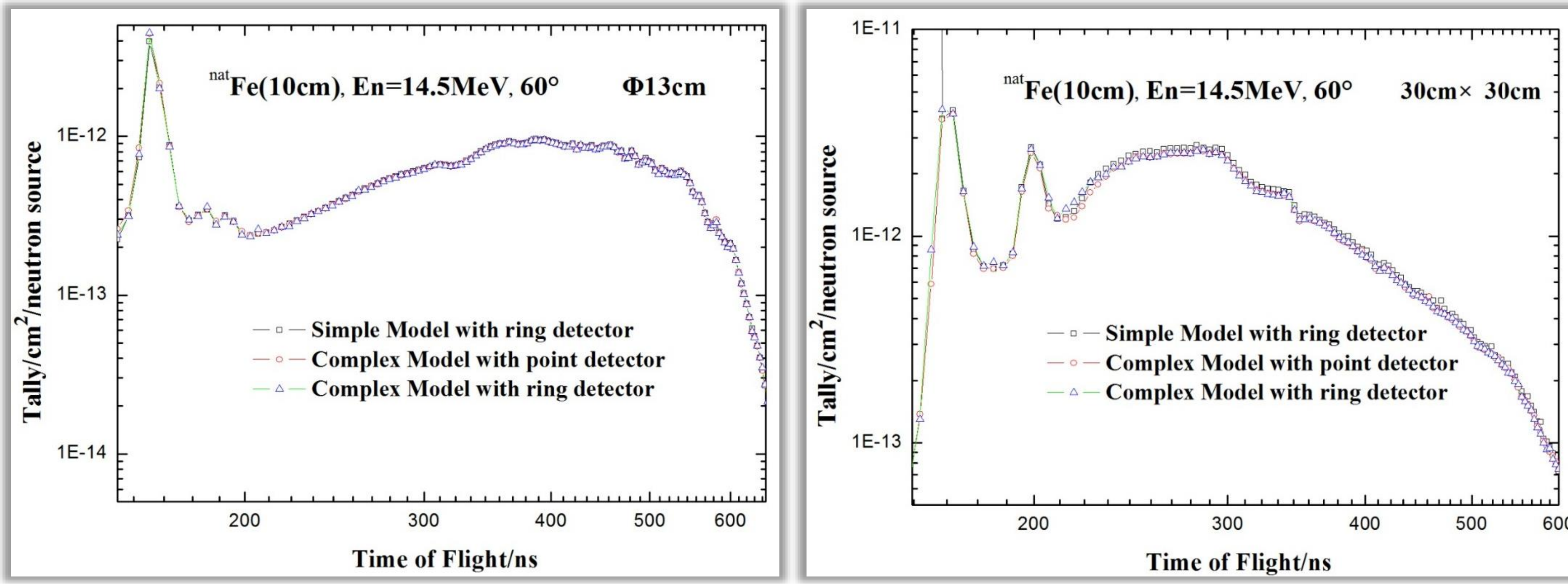

Fig.10 The simulation results from different models; Φ13cm(left), 30cm×30cm(right)

- ✓ **Φ13cm : Simple model with ring detector**
- ✓ **30cm×30cm: Complex model with ring detector**

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Monte Carlo simulation of experimental details

1、Use the neutron flight time spectrum as an input spectrum;

2、Source neutron TOF spectra at different times were simulated by MCNP code;

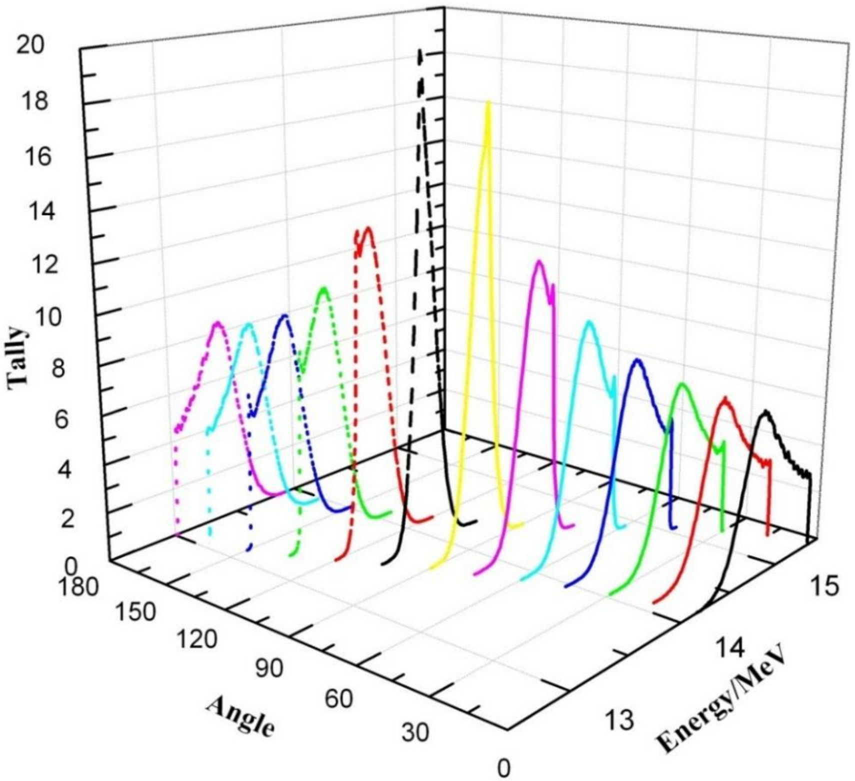

Fig.11 The angle dependent energy distribution of the source neutrons(by TARGET code)

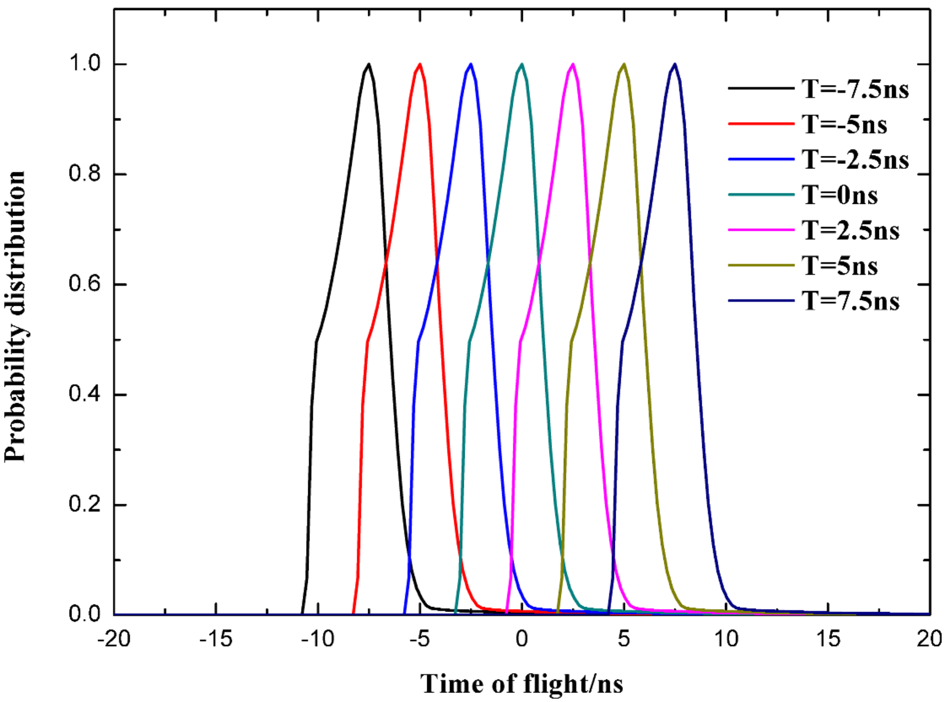

Fig.12 TOF spectra of neutron source at 0° and 8m with different generation time

Monte Carlo simulation of experimental details

3、Use the γ TOF spectrum as a default spectrum

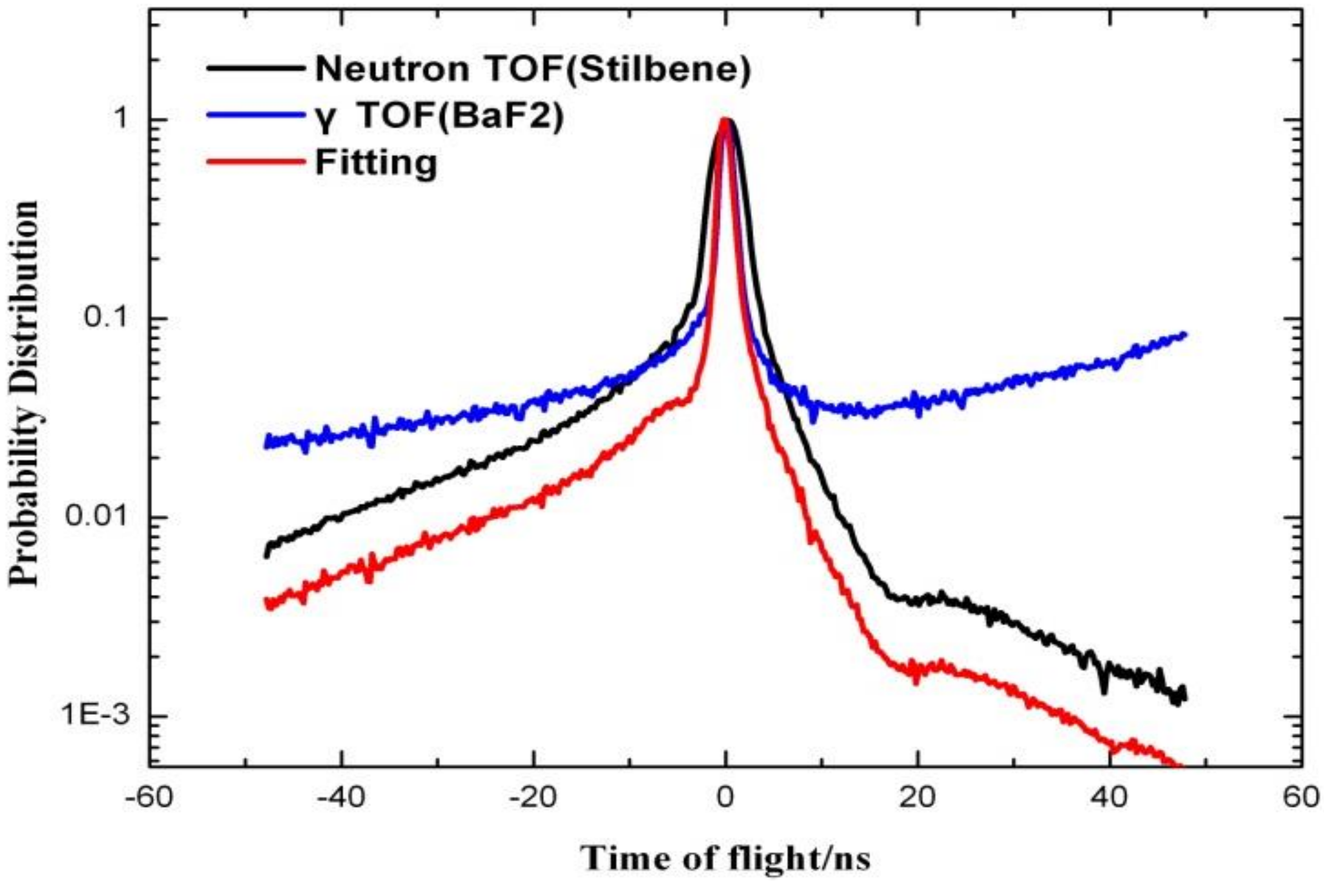

Fig.13 Comparison of the fitting result with the neutron spectrum and the γ spectrum

The results

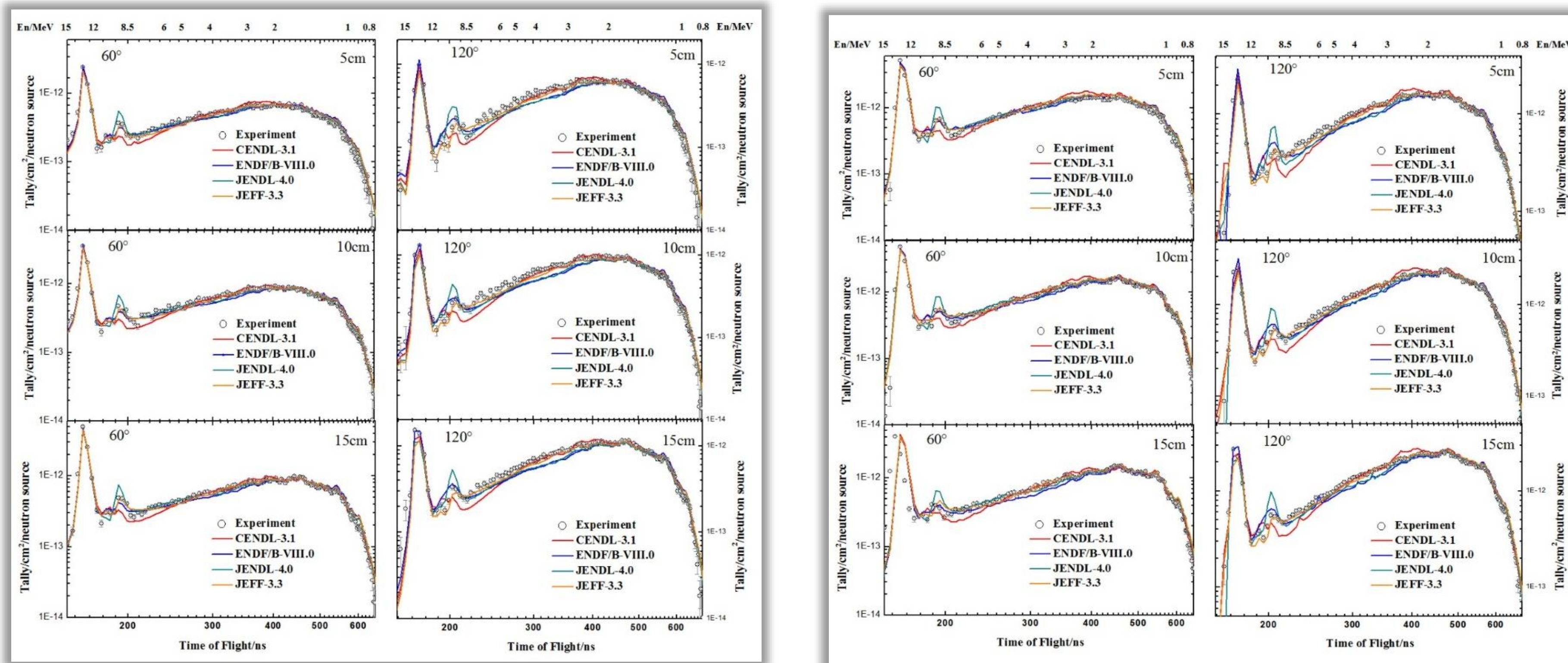

Fig.14 The comparison of measured and calculated leakage neutron spectra; Φ13cm(left), 30cm×30cm(right)

- **The calculation results with different libraries are different from the experimental results in some energy region, especially the high-energy region.**

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The results

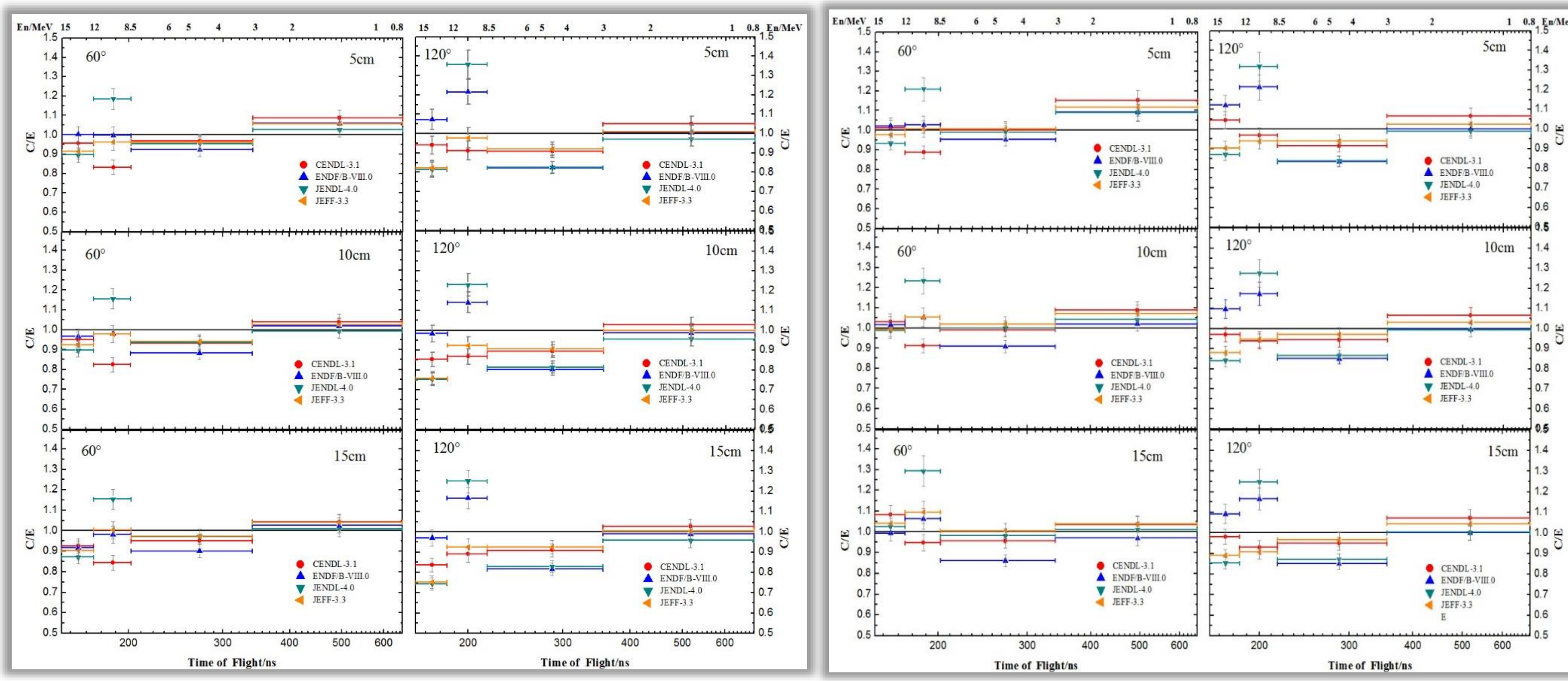
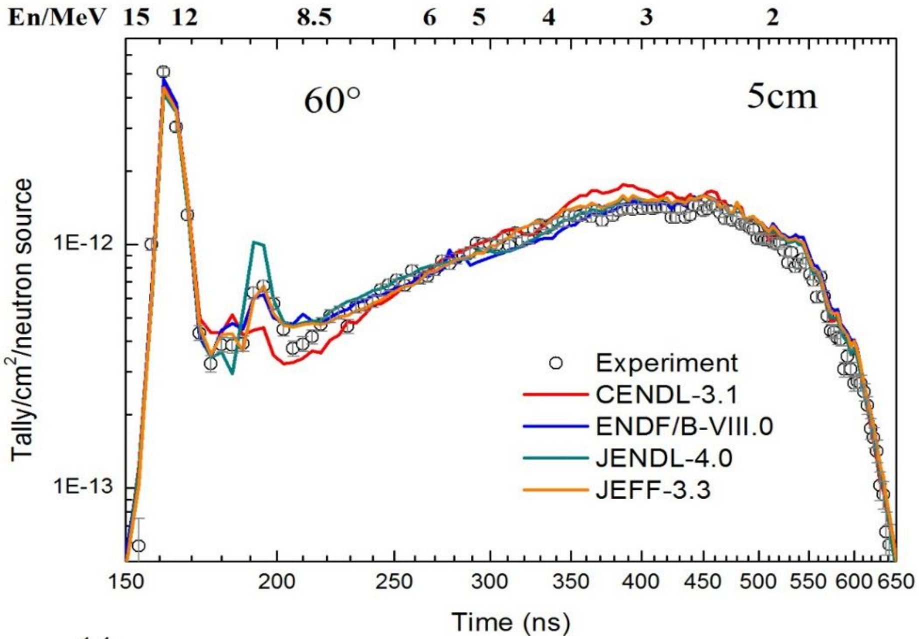
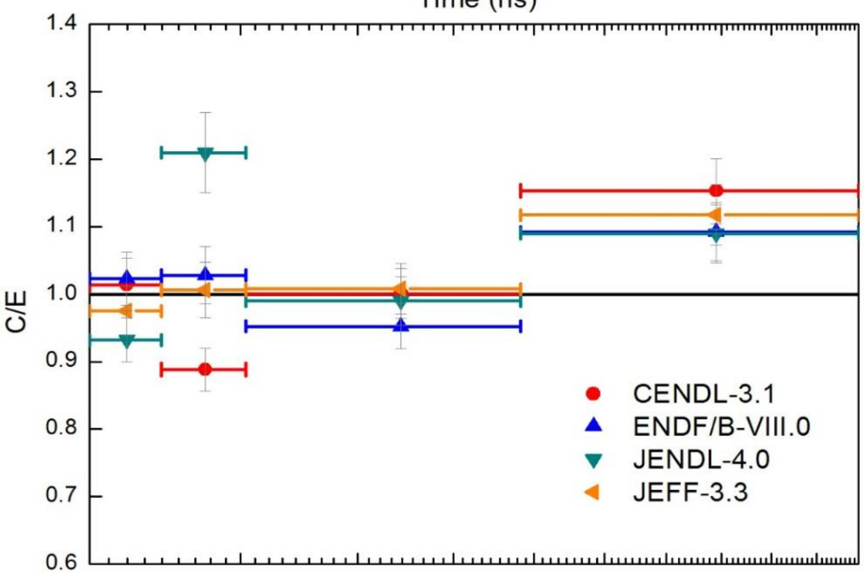


Fig.15 The The C/E values integrated over the specified energy ranges; Φ13cm(left), 30cm×30cm(right)

The results





➢ **12-16 MeV, the elastic scattering region**

Calculated scattering peaks with the ENDF/B-VIII.0 library well reproduce the experimental ones, CENDL-3.1, JENDL-4.0 and JEFF-3.3 underestimated at 120°

➢ **8.5-12MeV, the discrete inelastic scattering**

The results with JENDL-4.0 library are overestimated around 25% at both 60° and 120° . At 60° , the results with the CENDL-3.1 library are underestimated around 10%, and at 120° , the results with the ENDF/B-VIII.0 are overestimated by more than 15%.

➢ **3-8.5 MeV, the continuous inelastic scattering**

The calculated results with four libraries agree with the experiment within 10% at 60° , while the results with the ENDF/B-VIII.0 and JENDL-4.0 libraries are underestimated about 15% at 120° .

➢ **0.8-3 MeV**

The calculated results from all libraries agree with the experimental ones within 10%

Analysis and Discussion

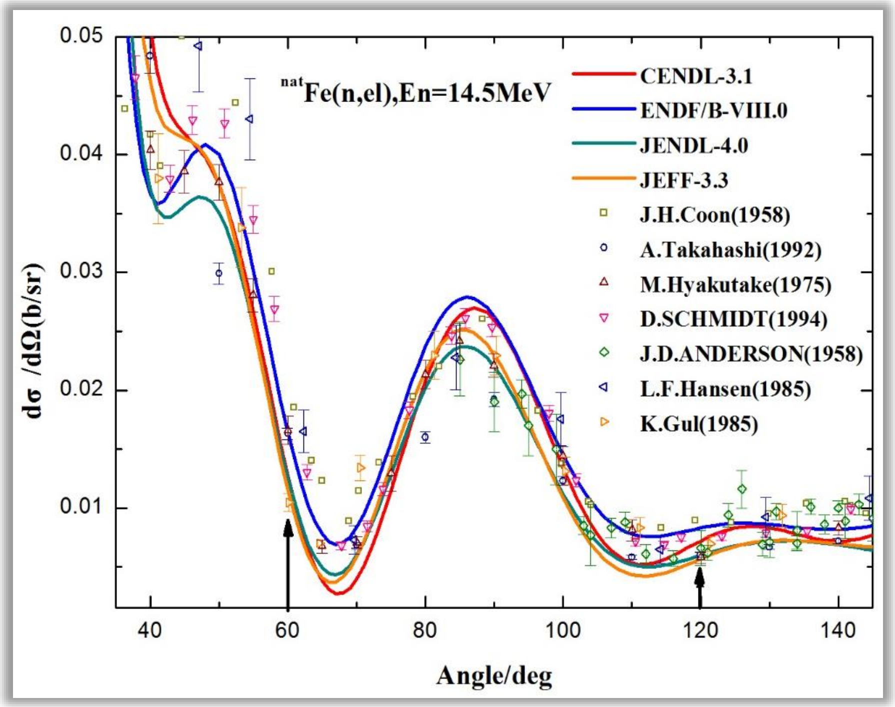


Fig.16 The angular distributions of the neutron elastic scattering

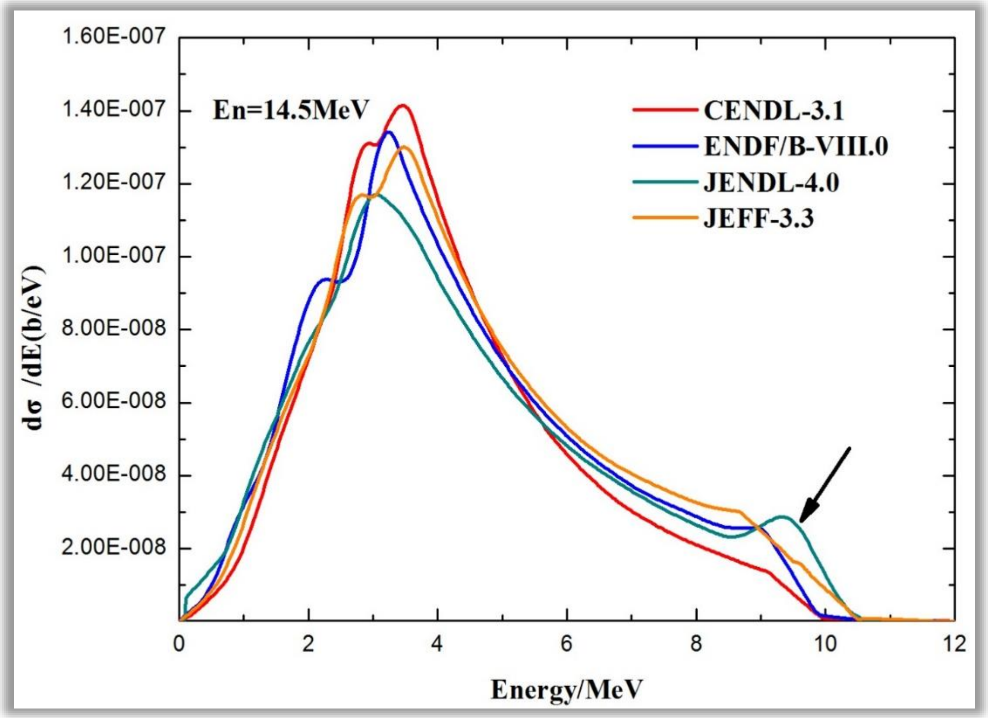


Fig.17 the continuum inelastic scattering