Recent Progress of Nuclear data Measurement at CIAE

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China Institute of Atomic Energy

Contents

Contents

Main purpose of ND research in China

- Nuclear energy system development
  - CIADS(Chinese Initiative Accelerator Driven System)
  - TMSR(Thorium Molten Salt Reactor)
  - Fusion reactor
  - Other new nuclear energy systems
- Nuclear science study
- Nuclear technology applications
- National security

Institutes involve in nuclear data measurement in China

中国科学院近代物理研究所
Institute of Modern Physics, Chinese Academy of Sciences

ADS related (proton induced)

中国原子能科学研究院
CHINA INSTITUTE OF ATOMIC ENERGY

Excitation function, FY, gamma production yields, DX and DDX, benchmark experiments, etc

北京大学
PEKING UNIVERSITY

(n,LCP) reaction

兰州大学
LANZHOU UNIVERSITY

Excitation function around 14 MeV

中国科学院上海应用物理研究所
SINAP
Shanghai Institute of Applied Physics, Chinese Academy of Sciences

Th-U cycle related, gamma induced reaction data

中国工程物理研究院
CHINA ACADEMY OF ENGINEERING PHYSICS

Integral experiments

SNS
中国散裂中子源
CHINA SPALLATION NEUTRON SOURCE

China Institute of Atomic Energy is one of the main base for ND research in China

Totally about 60 staff members are working in the CNDC

Research fields

Nuclear Data Measurement

Fission yield, Excitation function, DX and DDX, Gamma production cross section, Nuclear data integral experiment, etc.

Nuclear Data Evaluation and data library development:

Nuclear theory, Nuclear data evaluation, Nuclear data validation, Nuclear data service, etc.

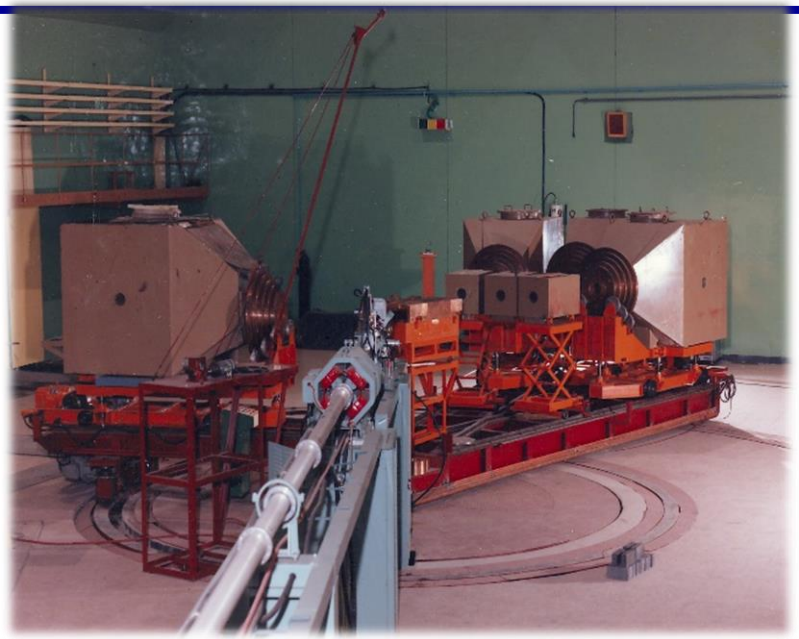
Contents

Scientific platform

Facility	Neutron energy	Flux
CARR	thermal	10^{14} n/cm^2/s
HI-13 tandem	8-26 MeV (d+D) 4-23 MeV (p+T) 22-42 MeV (d+T)	10^8 n/sr/s 10^7 n/sr/s 10^6 n/sr/s
2×1.7 MV tandem	3-6 MeV (d+D) 14-20 MeV (d+T) 0.07-2.0 MeV (p+T) 0.03-1.3 MeV (p+Li)	10^9 n/sr/s 10^8 n/sr/s 10^9 n/sr/s 10^8 n/sr/s
Neutron generator	2.5, 14 MeV	10^8, 10^{10} n/sr/s
CSNS	1 eV-200 MeV	10^7 n/cm^2/s

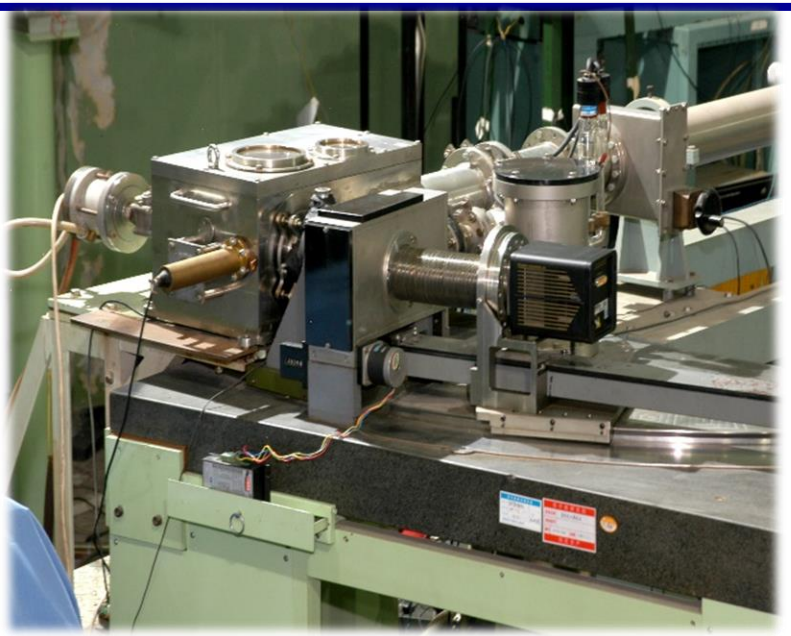
Neutron sources

Detection system



HPGe detector array

- (n,xnγ), (n,n'γ);
- Capture cross section.



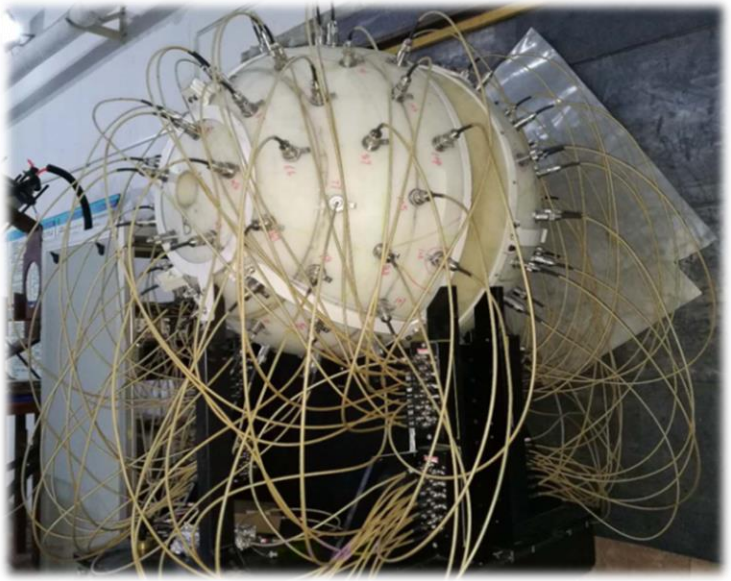
TOF spectrometer

- Fast neutron spectrum;
- Detector calibration;
- Few body physics.

Ultraviolet interferometer

- Atomic and molecular energy levels;
- Life of energy levels.

Detection system

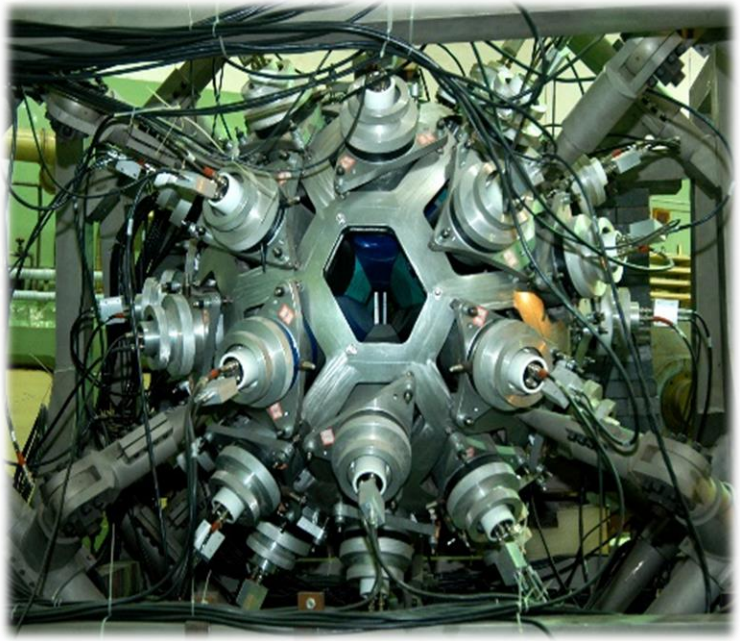


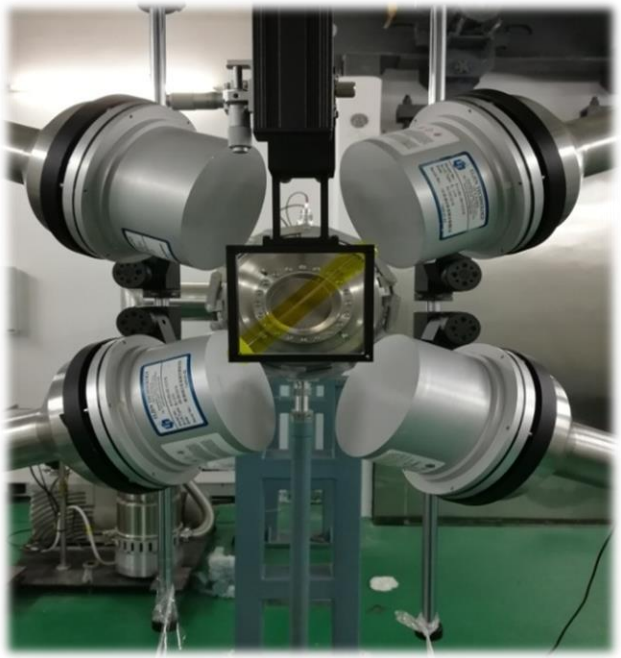
He-3 detector array

- (n,2n)、(n,3n) cross section;
- Fission neutron multiplicity;
- Neutron detection.

GTAF facility

- (n,γ)、(p,γ) cross section;
- Multiplicity of (n,γ);
- Fission gamma multiplicity.





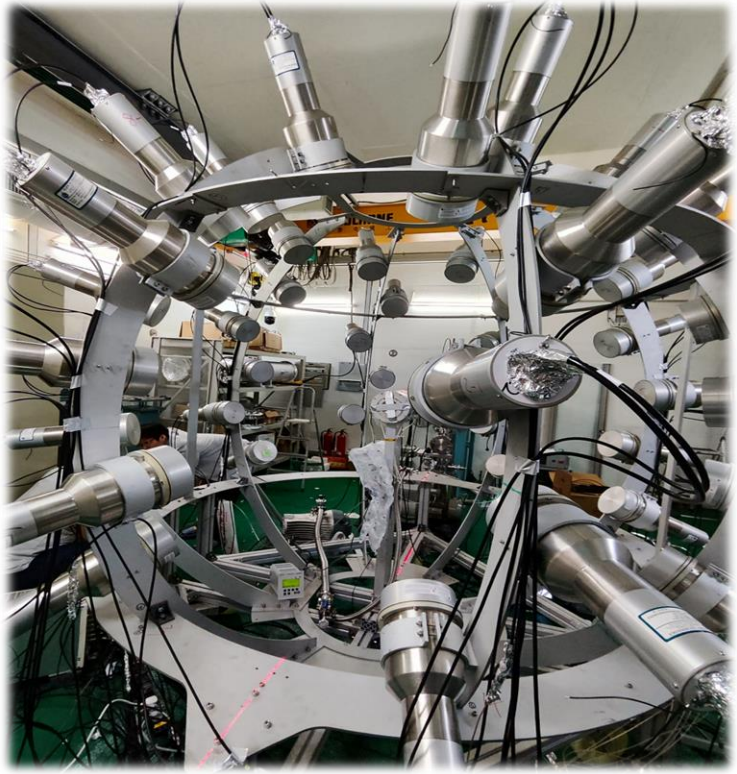
C6D6 system

(n,γ) cross section.

Detection system

FFIS

- **Fission fragment detection.**



FINDA

- **Fission neutron spectrum measurement.**

Contents

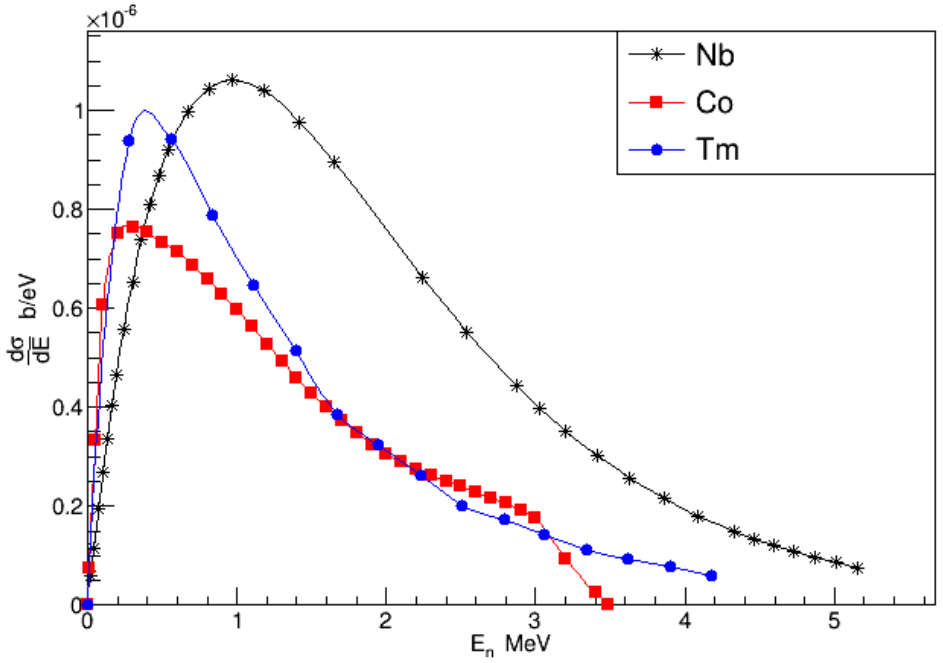
1.(n,2n) CS measurement with direct neutron detection method

- Most of the EXFOR data obtained with activation method;
- Limitations for this method: half-life of product, activity measurement.

Method	Advantage	Disadvantage
activation	Simple, high precision if the product easy to measure	Only part of nucleus can be used
Direct neutron detection	In principle can be used for all nucleus	Background control
Prompt gamma yield detection	Low background	Theoretical uncertainty
Surrogate reaction	Unstable nucleus	Theoretical uncertainty

Key issues for neutron detector:

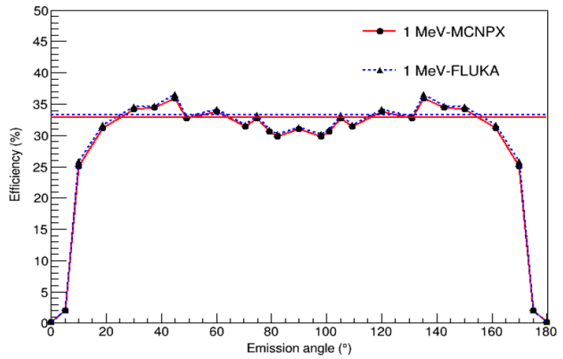
- High detection efficiency
- Low background
- Detector special and energy response are smooth.

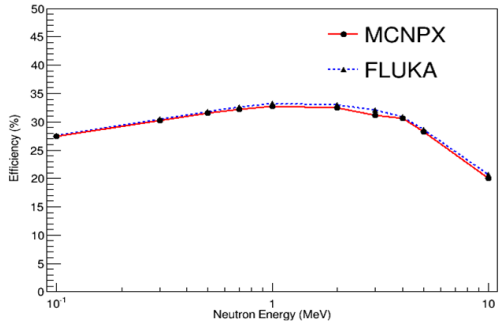


Neutron spectra from (n, 2n) reaction for different nuclei

For this purpose, a spherical 3He detection array was designed and developed.

Spherical





Barrel

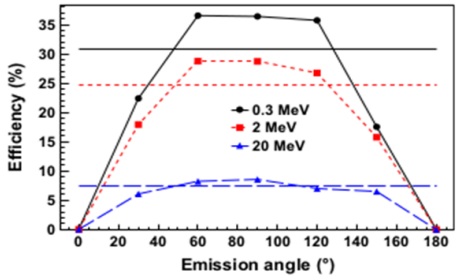


Fig. 6. Efficiency of the counter as a function of neutron emission angle relative to the beam axis for three monoenergetic neutron sources. The horizontal line represents the efficiency for an isotropic source at the same energy.

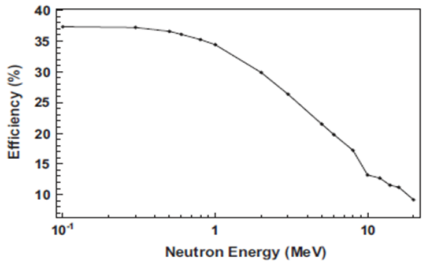
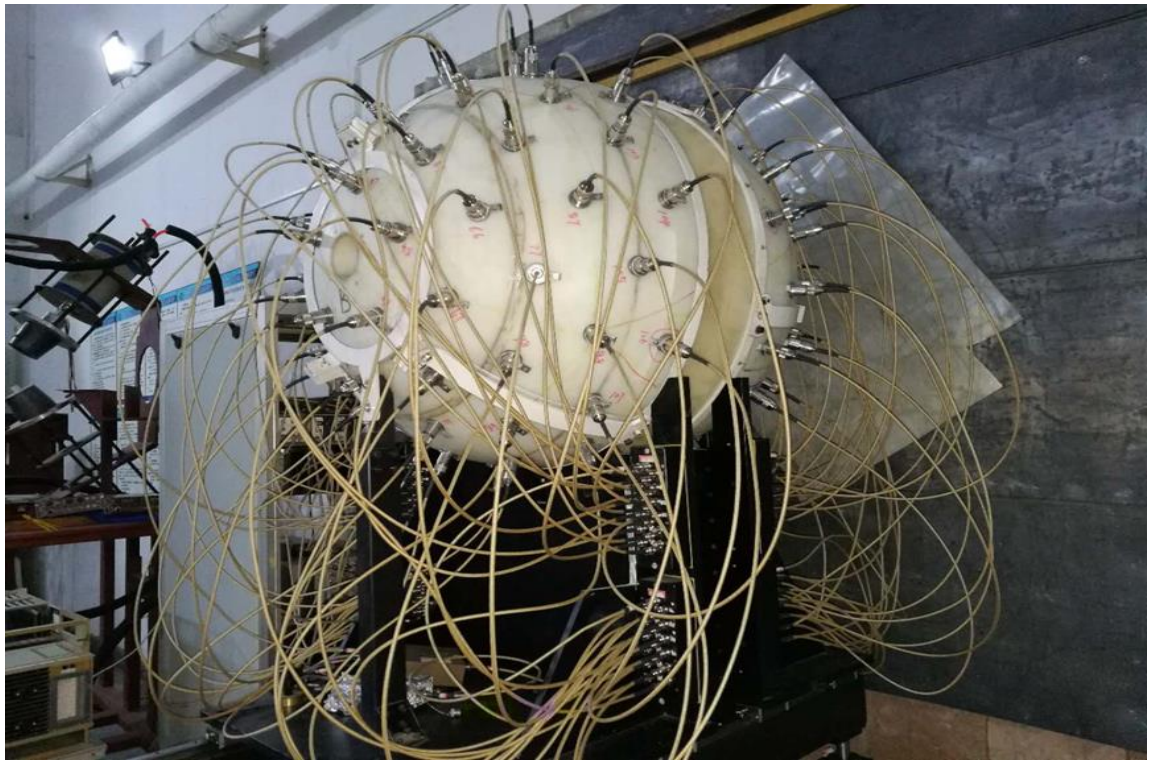


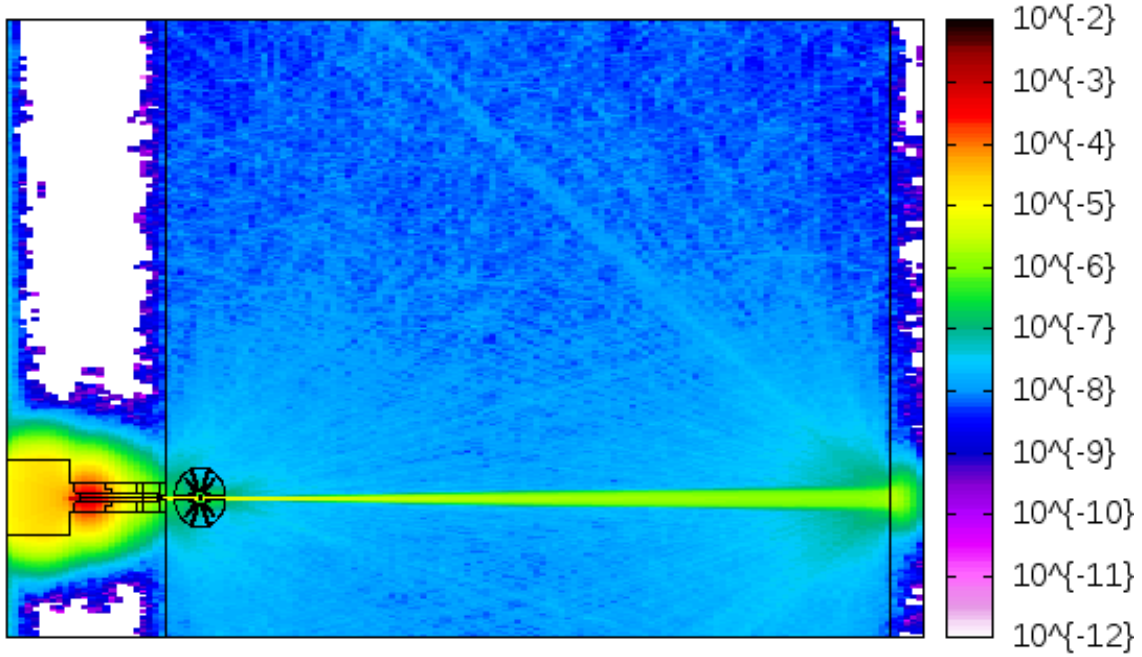
Fig. 3. Simulated neutron detection efficiency of the counter as a function of neutron energy. Calculated points are connected by linear segments for clarity.



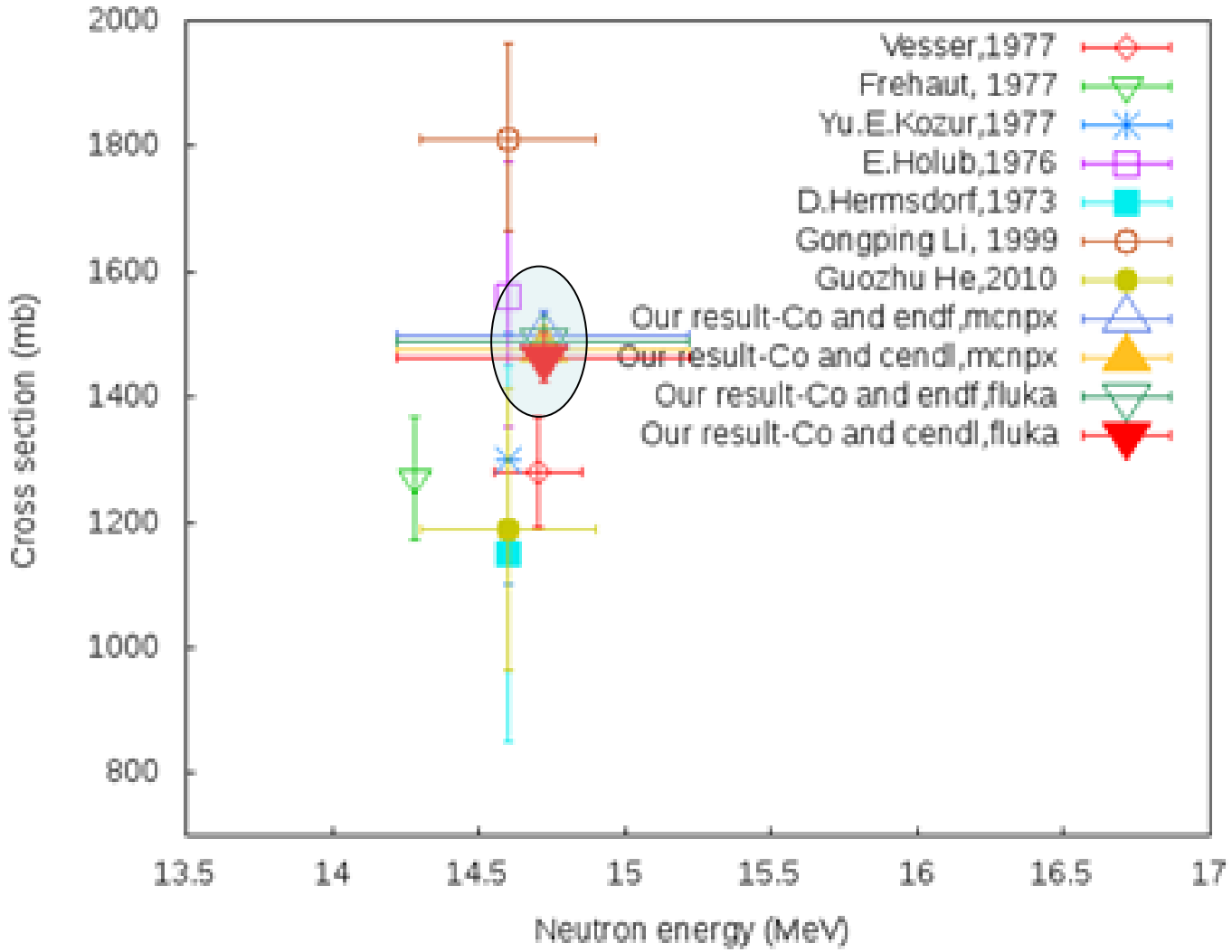
Picture of the detection array (110 3He counter)

Background control and determination:

(1) Pulsed beam (2 μs width, 1 kHZ);
(2) Shielding system;
(3) Relative measurement;
(4) Carbon sample was used to estimate accidental coincidence background.



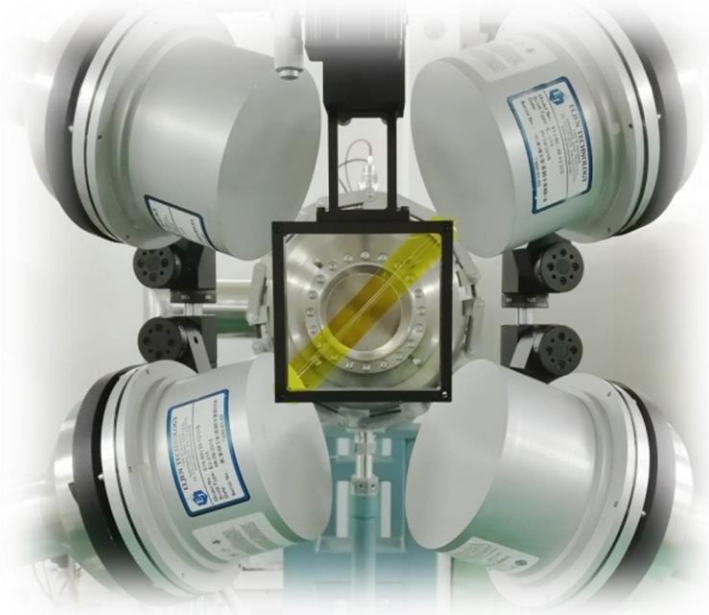
Shielding system



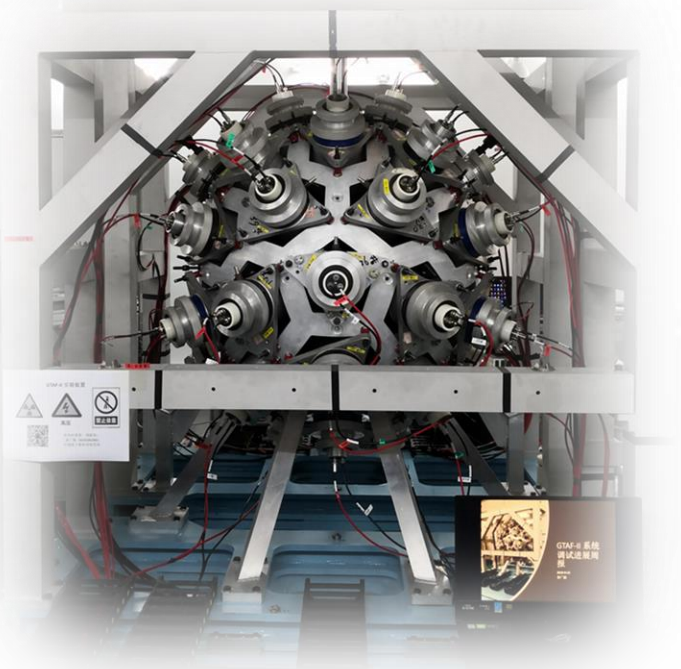
The system has been developed and used to measure the ^{93}Nb(n,2n) cross section. Good and consistent result has been obtained.

2. (n,g) cross section measurement at CSNS

CSNS is the 1st white neutron source in China, it provide a good platform for (n,g) cross section measurement.

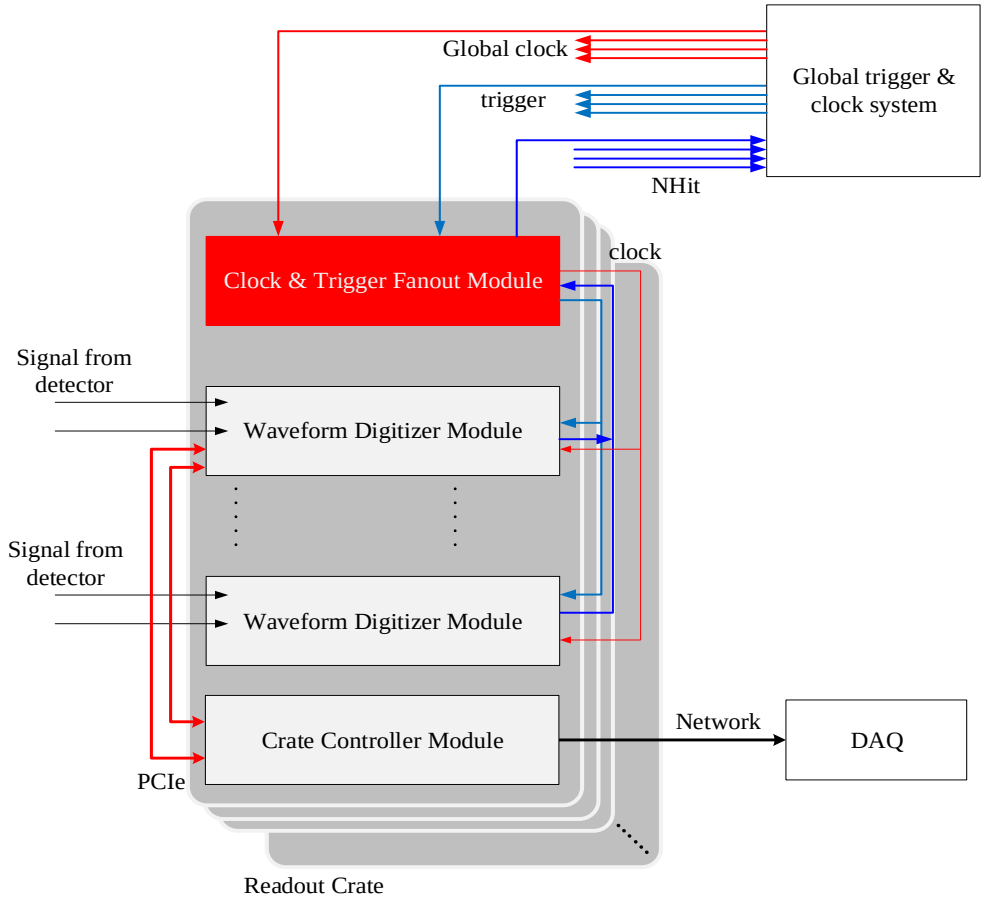


C6D6 detector



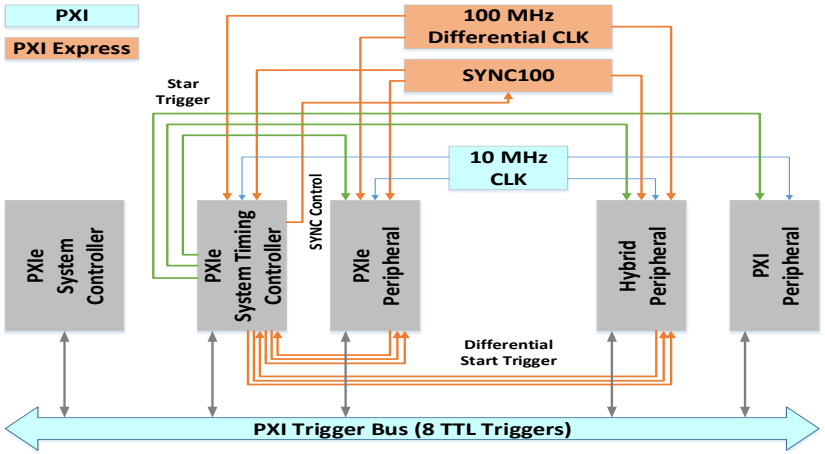
GTAF

Special designed DAQ system, waveform digitizer with 1 GS/s



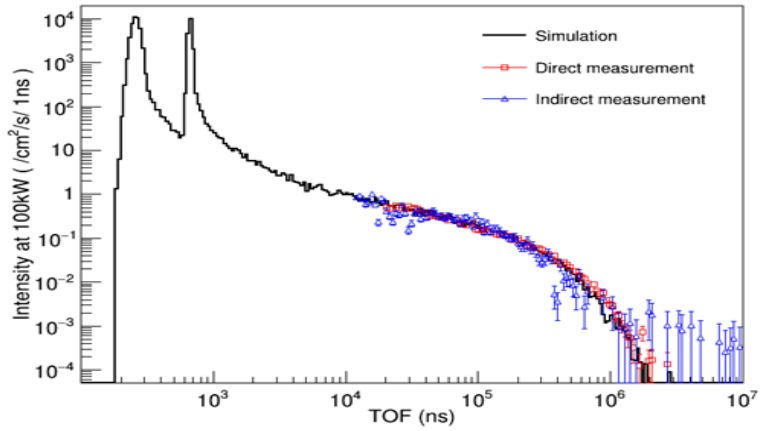
Data readout architecture

- 基于新型PXIe串行总线平台的数据读出
  - PCIe高速串行总线：
    - 多插件数据并行传输
  - 背板高性能专用差分线路：
    - 时钟及触发分发
  - 高速串行化时钟、触发融合传输：
    - 优化同步架构
  - 多机箱网络连接：
    - 可靠、灵活的分布式读出架构

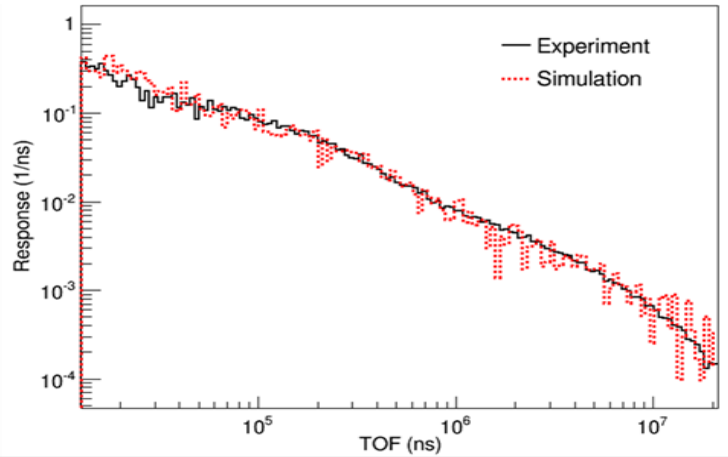


PXIE Backplane Bus

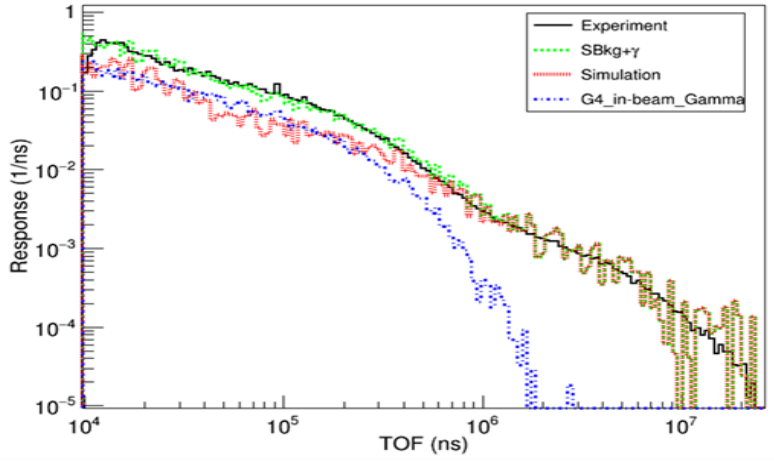
Background study



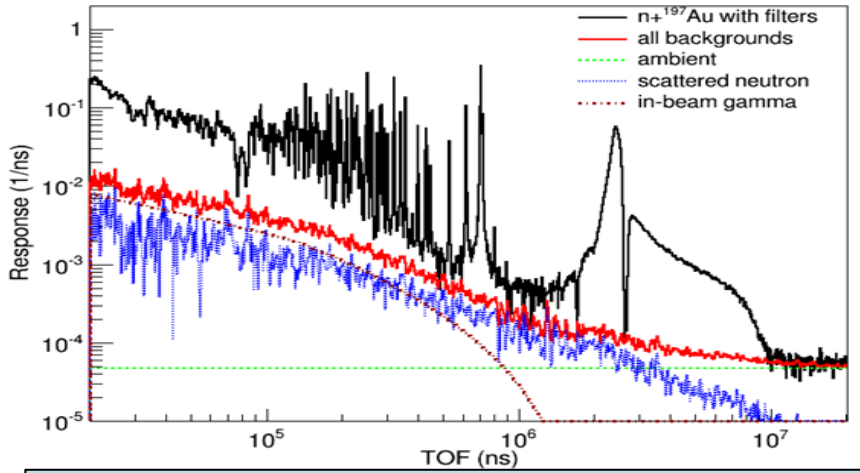
In beam gamma bg



Scatted neutron bg



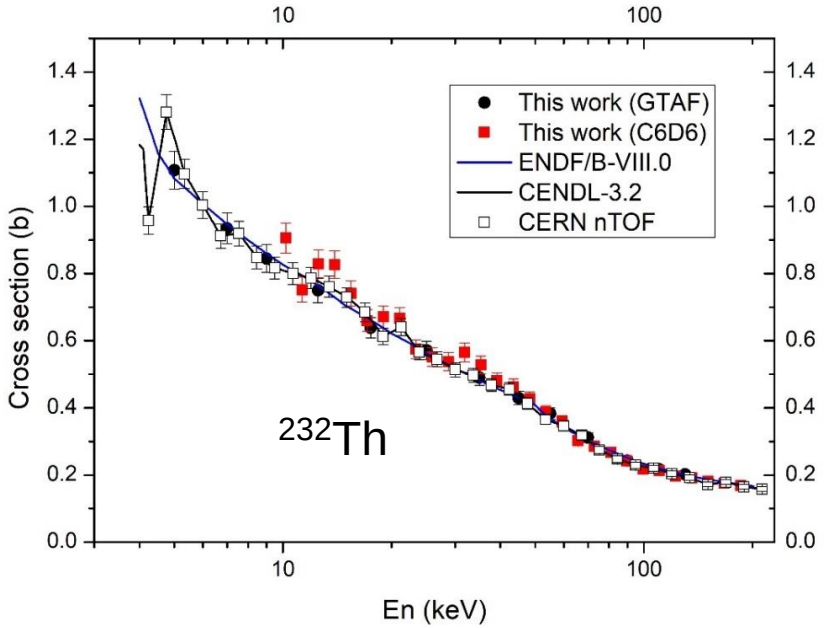
Gamma and scatted neutron bg

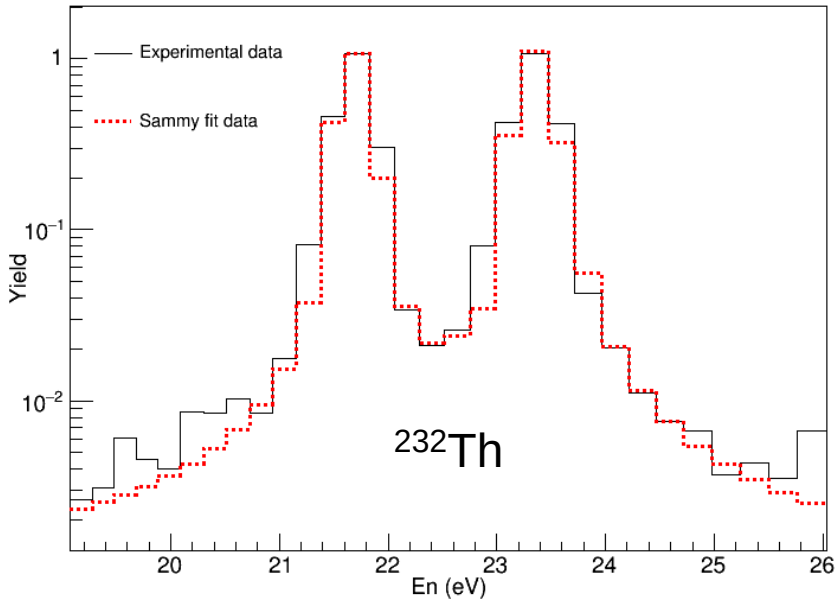


Total bg

From 2018, many measurements have been performed

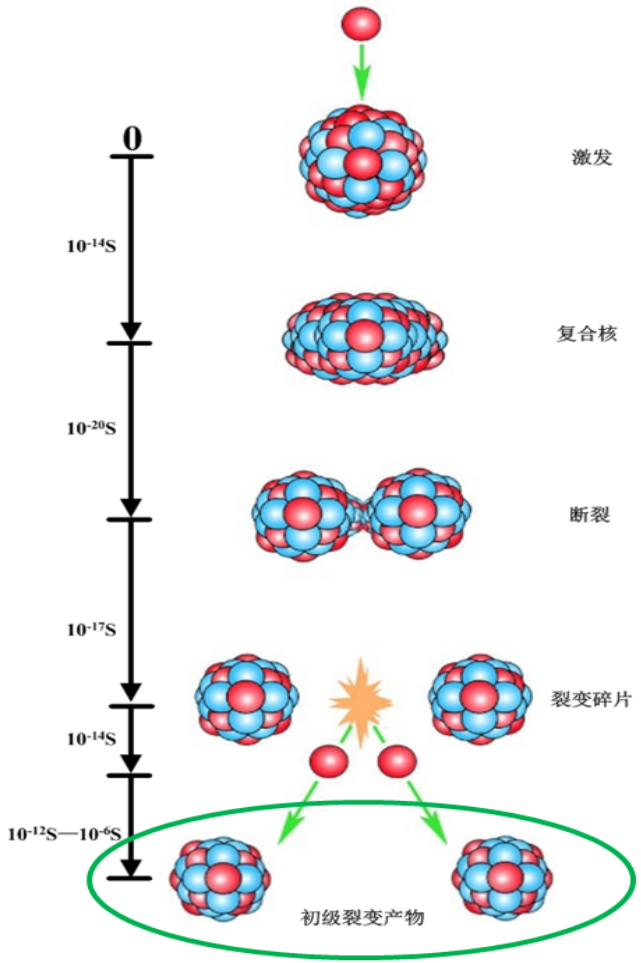
- C_6D_6: ^{169}Tm, ^{197}Au, ^{57}Fe, ^{nat}Se, ^{89}Y, ^{nat}Er/^{162}Er, ^{232}Th, ^{238}U, ^{93}Nb， ^{nat}Cu， ^{nat}Lu, $^{113\&115}$In, $^{185\&187}$Re , ^{181}Ta, $^{107\&109}$Ag, ^{165}Ho, …
- GTAF-II: ^{169}Tm, ^{93}Nb, ^{124}Xe, ^{nat}Re, …

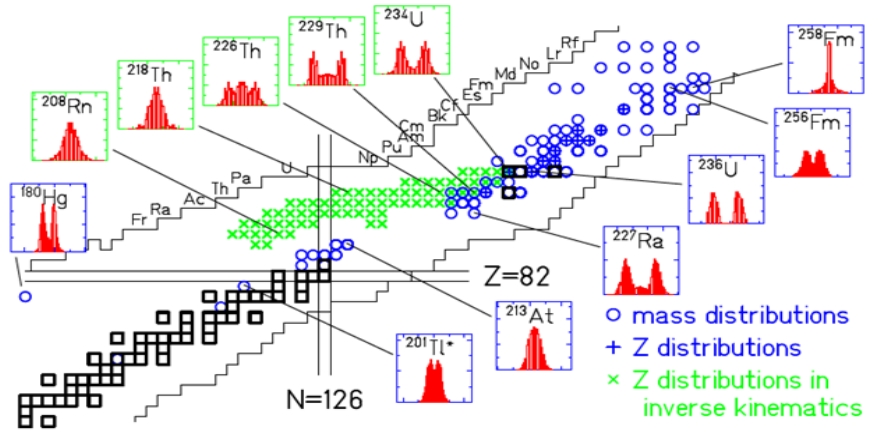




3. Fission fragment mass distribution measurement

Mass distribution is important both for fission study and applications.





原子核裂变机制
裂变微观理论模型
裂变位能曲面计算及动力学

裂变产物实验可观测量

产额数据唯象模型
全套独立产额数据
核装置设计及测试数据库

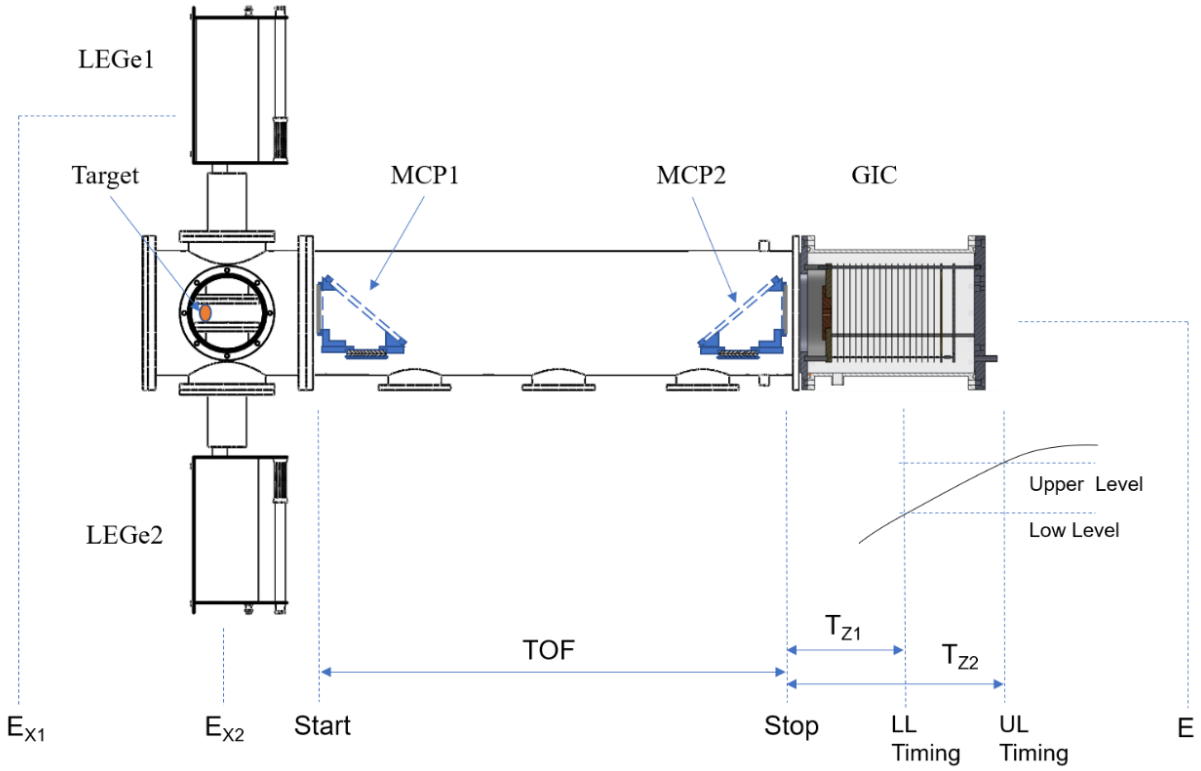
裂变产物的动能分布、角分布、质量分布、电荷分布、瞬发中子多重性、瞬发γ多重性……

The goal of this work is to build a detection system based E-v method that can obtain a mass resolution of 1 amu for light peak, and explore the possibility to obtain charge distribution.

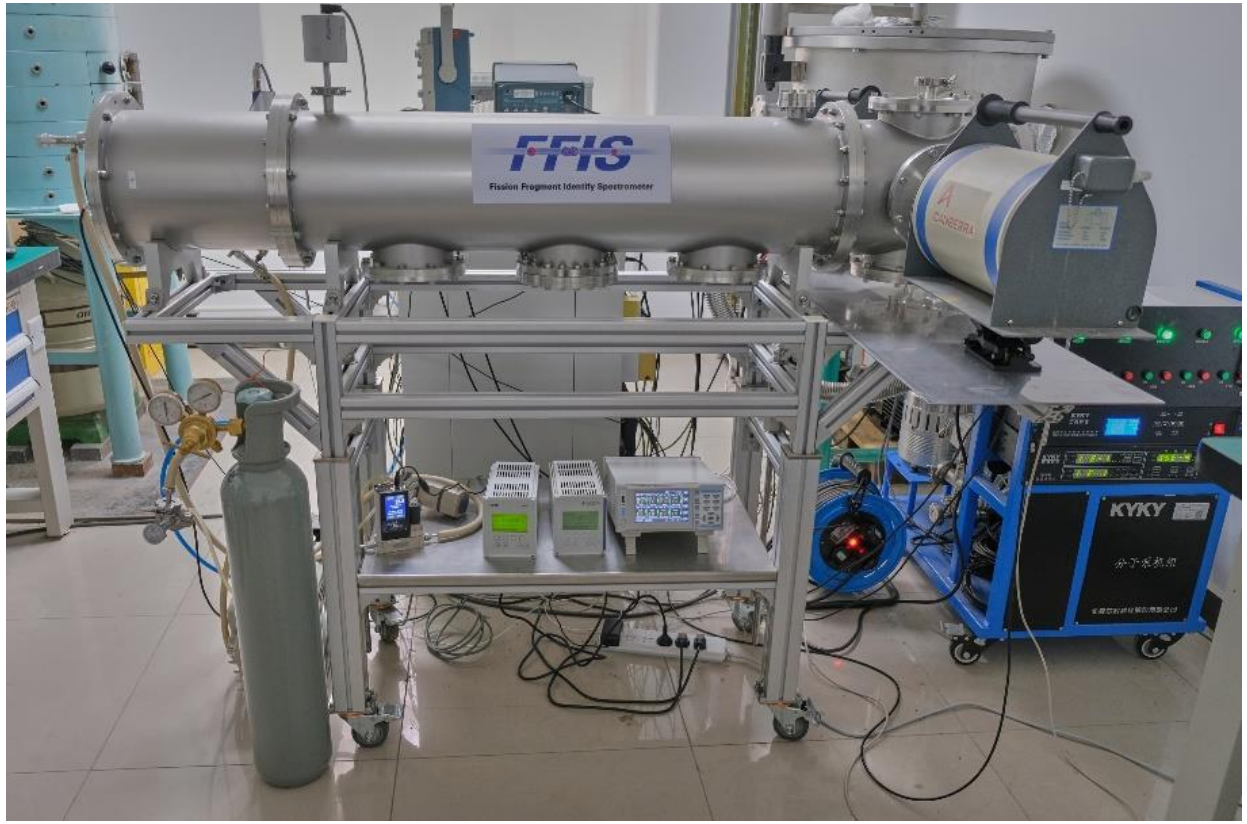
$$M = \frac{2E_k t^2}{l^2}$$

$$\frac{\Delta M}{M} = \sqrt{\left(\frac{\Delta E}{E}\right)^2 + \left(2\frac{\Delta t}{t}\right)^2 + \left(2\frac{\Delta l}{l}\right)^2} < 1\% \Longrightarrow$$

$\Delta E/E < 0.8\%$
$\Delta t/t < 0.3\%$
$\Delta l/l < 0.1\%$



The FFIS (Fission Fragment Identification Spectrometer) has been developed and tested.



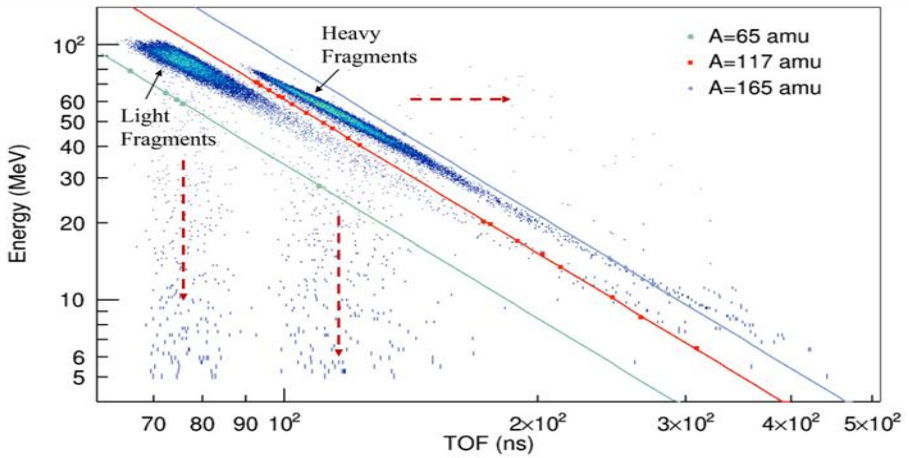
E detector: grid IC with 100 nm SiN window

TOF detector: MCP

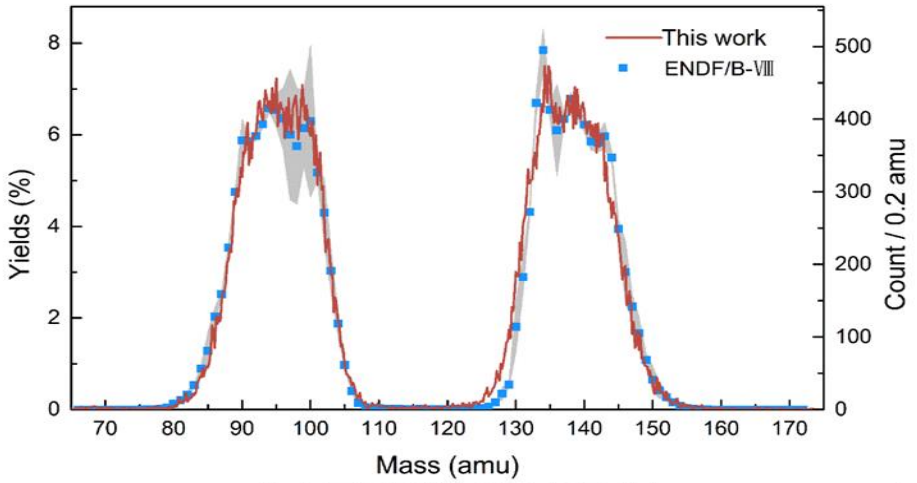
- ✓ ΔE/E < 0.8%
- ✓ Δt/t < 0.3%

1 amu resolution can be obtained !

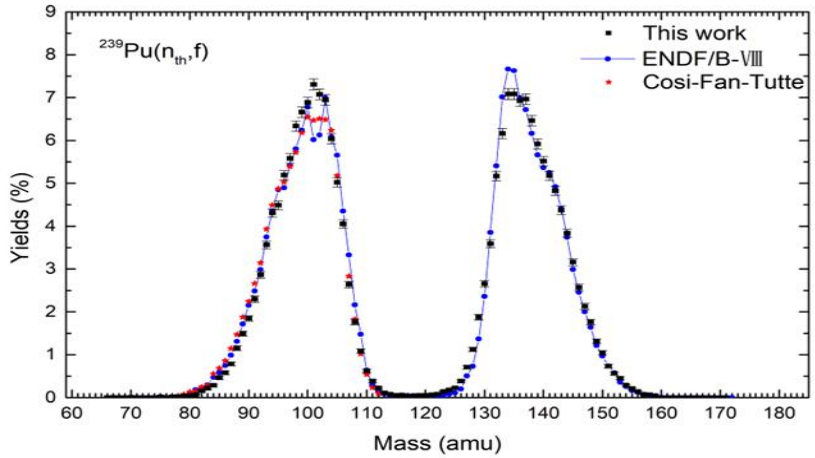
Results of $n^{th}+^{235}U$ and ^{239}Pu have been obtained



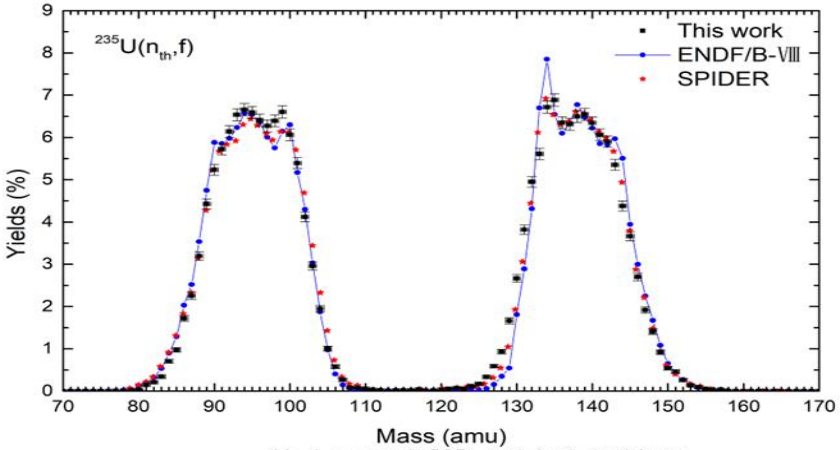
热中子诱发^{235}U裂变动能-飞行时间二维谱



热中子诱发^{235}U裂变质量分布



热中子诱发^{239}Pu裂变产额结果

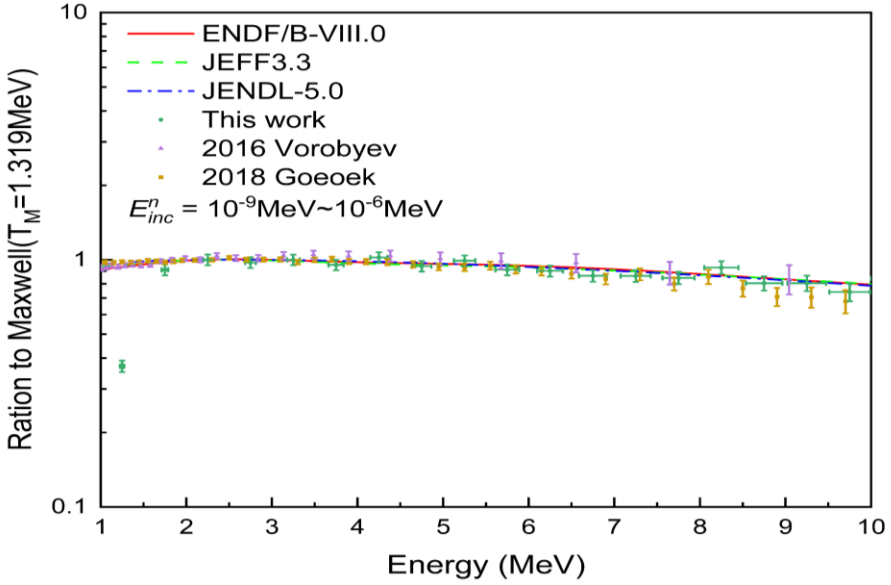


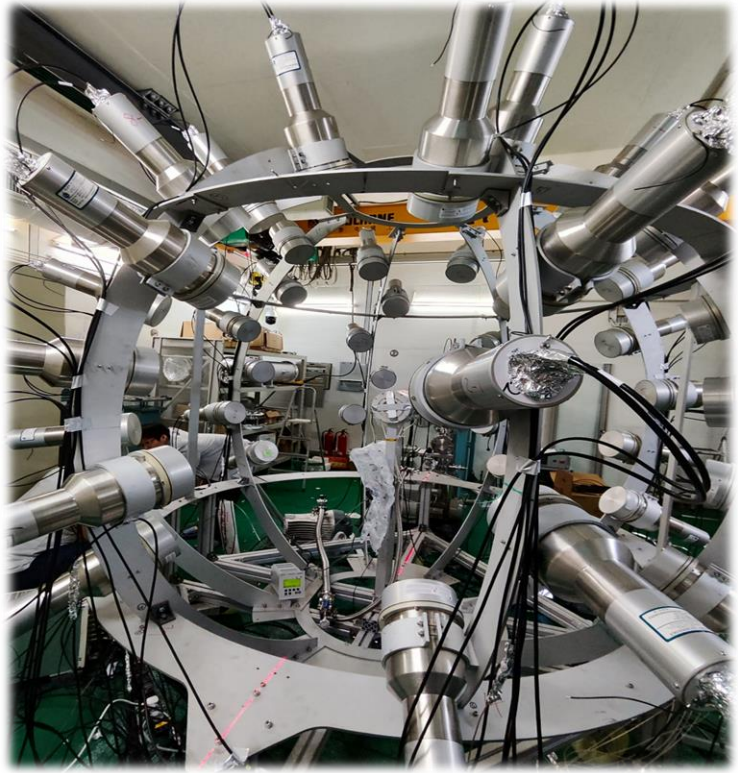
热中子诱发^{235}U裂变产额结果

4. PFNS measurement (More detail see Dr.Hanxiong Huang's presentation)

A neutron detector array consists of 48 liquid scintillators and 16 ^{6}Li glass scintillators has been developed.

Commissioning runs has been performed at CSNS and preliminary results have been obtained.





Contents

- Some recent progress of nuclear data measurement at CIAE is given in this talk.
- Thanks to the new nuclear energy system development in China, the needs for nuclear data also increase in recent years.
- New facilities such as CSNS also make more possibilities for nuclear data research.
- For our laboratory, the main purpose is to continuously improving the quality of the CENDL library.
- Collaborations are important and welcome.

Thank you for your attention !