Operation and experimental Introduction of the CSNS Back-n

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China Spallation Neutron Source

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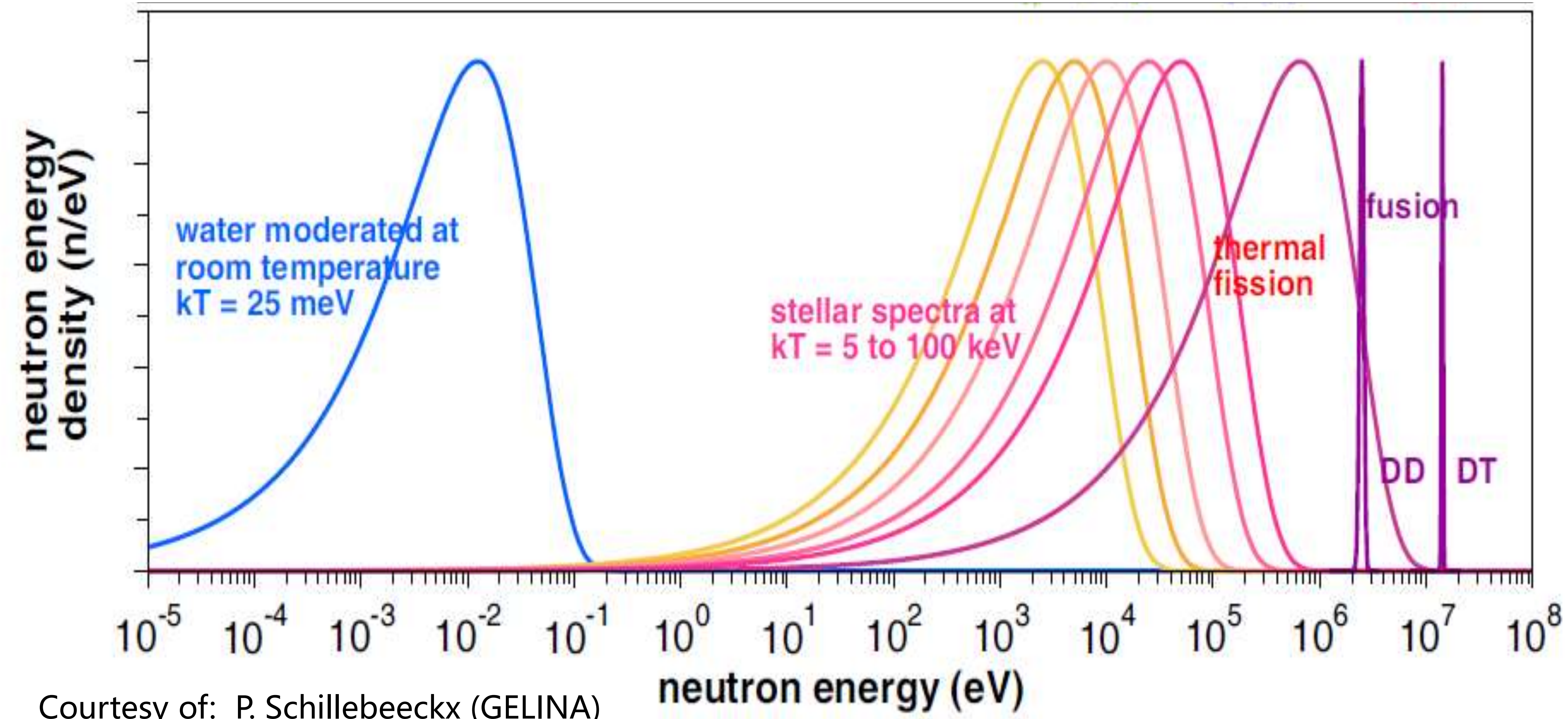
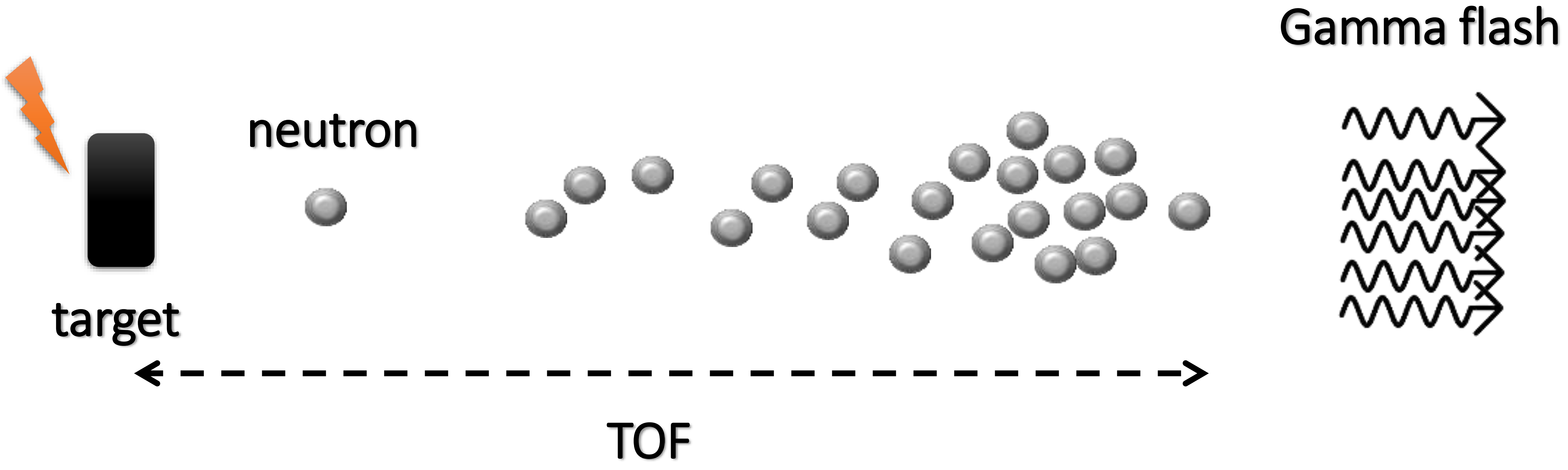
Neutron source



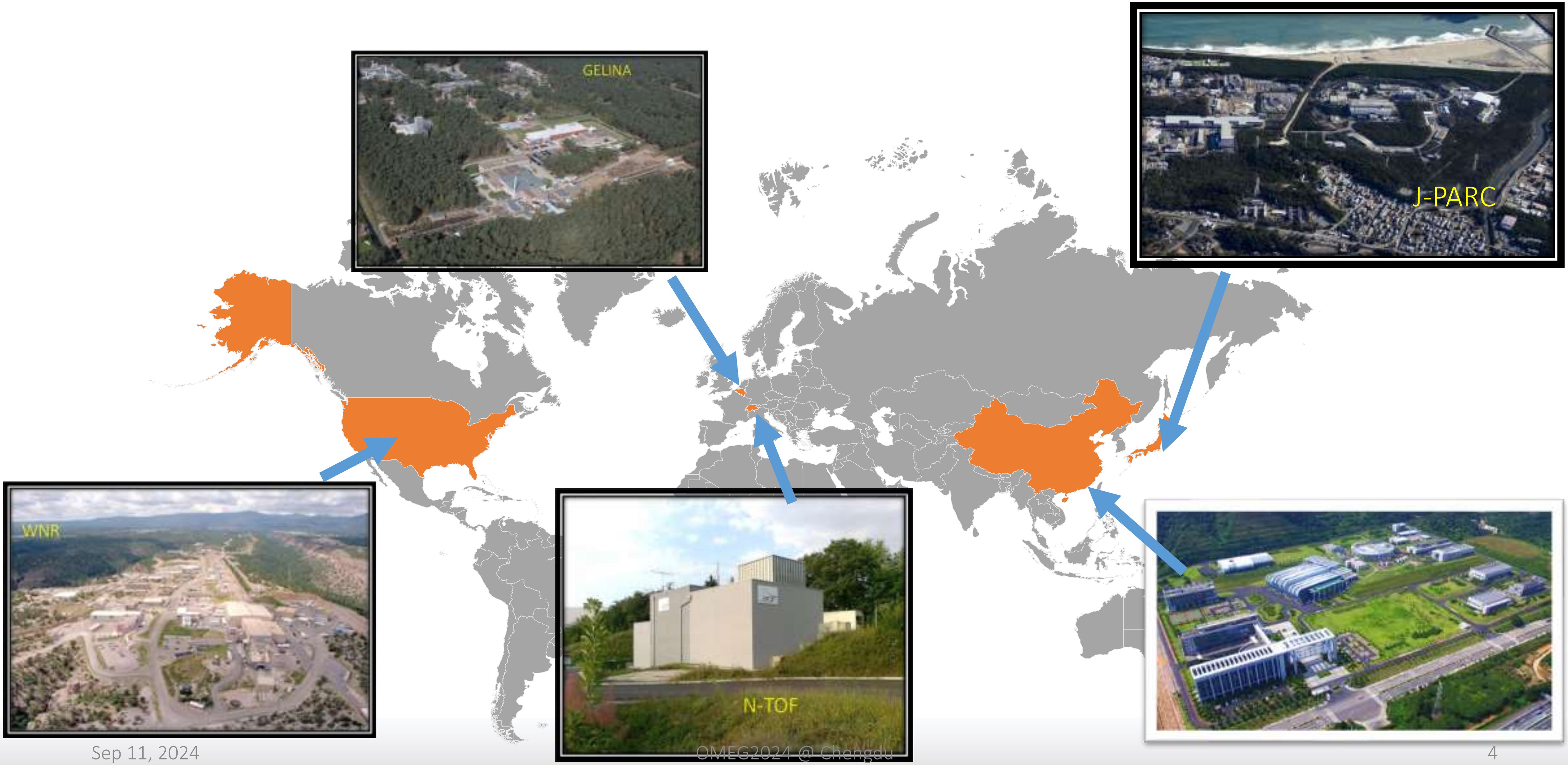
Courtesy of: P. Schillebeeckx (GELINA)

White neutron source

The name "white neutron" is derived from "white light," which indicates a broad spectrum of wavelengths. Unlike monoenergetic neutron sources, a white neutron source has a very wide energy spectrum.



White neutron sources in the world

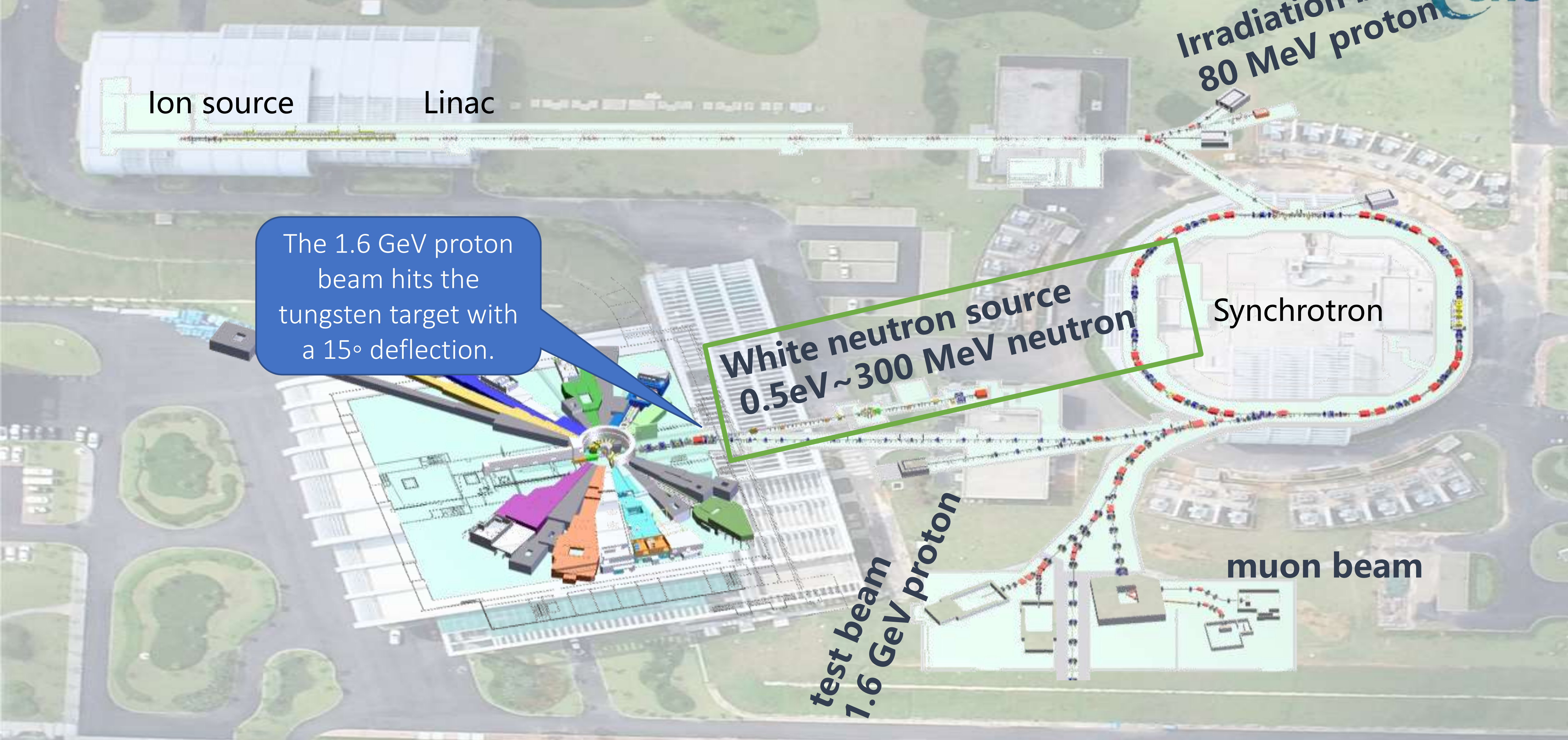


China Spallation Neutron Source

The China Spallation Neutron Source, located in Dongguan city, near Hong Kong, was running from August 28, 2017, with a budget of 2.3 billion yuan.

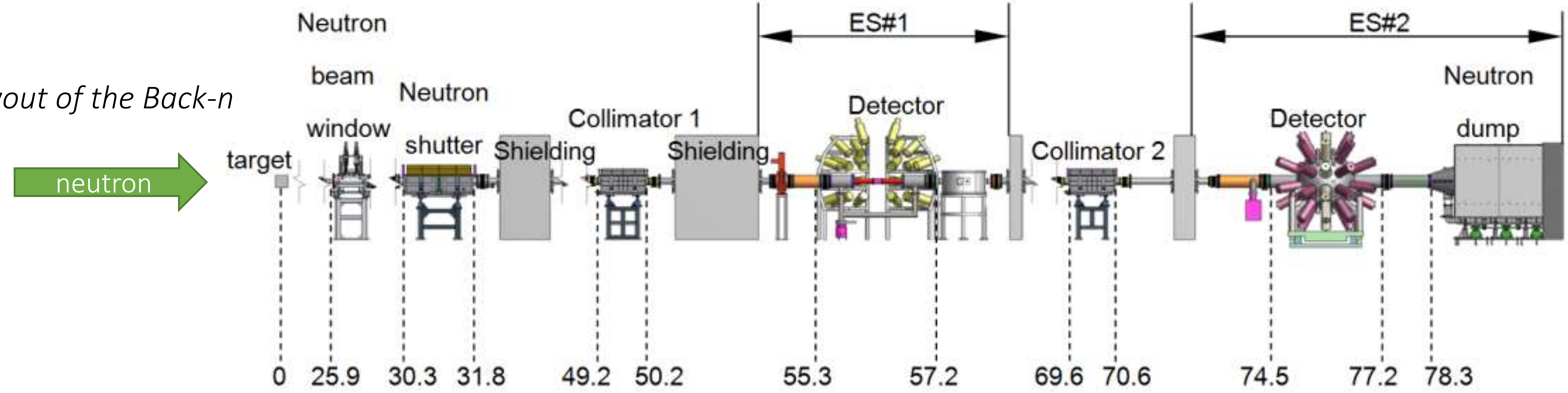
It consists of a 1.6 GeV proton accelerator with a repetition rate of 25 Hz and a beam power of 160 kW (now), will be 500 kW in next six years.

CSNS beam expansion application



Back-n

Layout of the Back-n

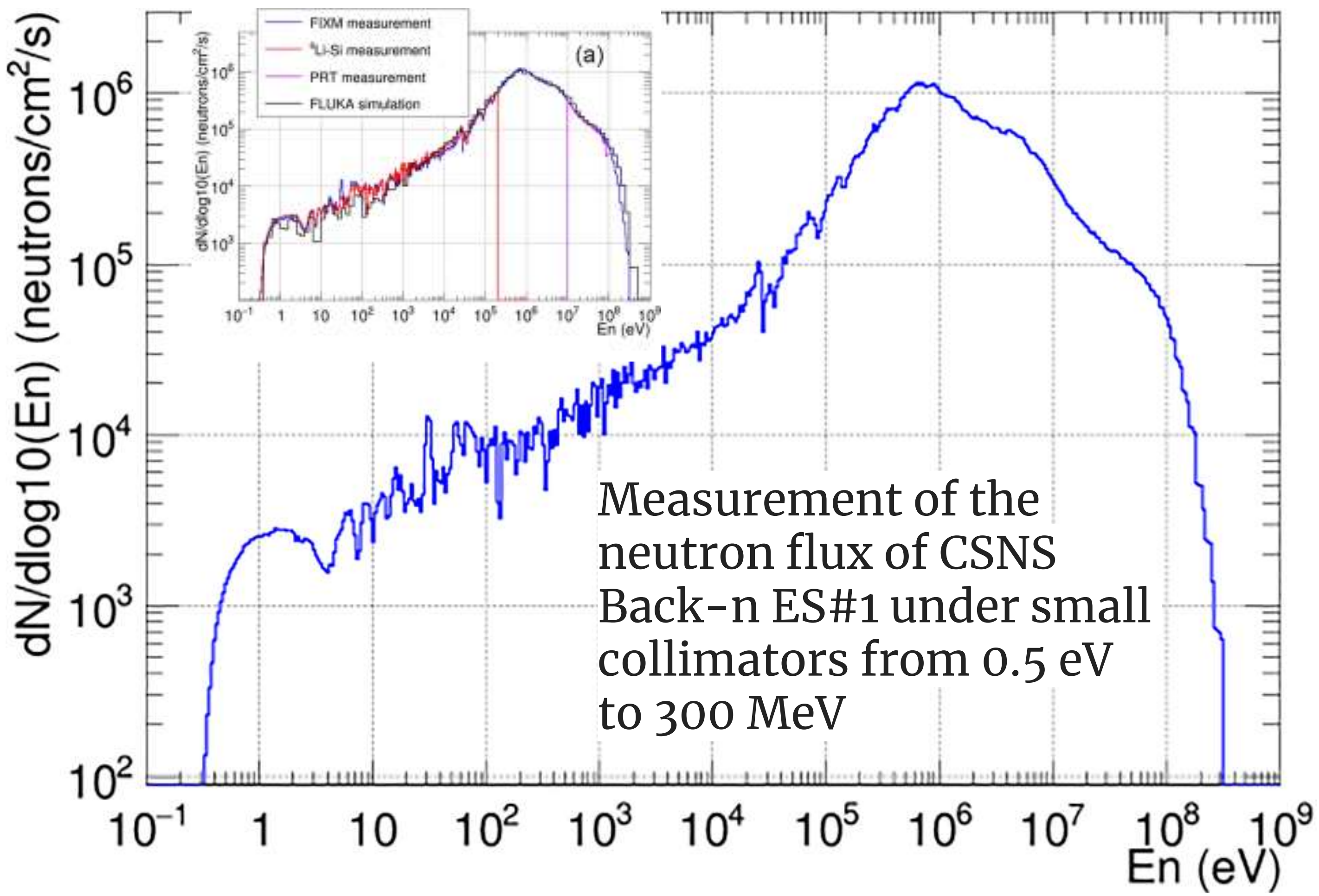


Shutter (mm)	Coll#1 (mm)	Coll#2 (mm)	ES#1 spot (mm)	ES#1 flux (n/cm^2/s)	ES#2 spot (mm)	ES#2 flux (n/cm^2/s)
Φ3	Φ15	Φ40	Φ15	1.27E5	Φ20	4.58E4
Φ12	Φ15	Φ40	Φ20	2.20E6	Φ30	7.81E5
Φ50	Φ50	Φ58	Φ50	4.33E7	Φ60	1.36E7
78×62	76×76	90×90	75×50	5.98E7	90×90	2.18E7

The back-streaming neutrons are leading to the Back-n tunnel, which has a long flight distance for the neutron time-of-flight method. Two end stations ES#1 and ES#2 are constructed for different nuclear data measurements. The ES#1 has a distance of about 55 m, and ES#2 is about 70 m from the target. Different sets of beam spots, collimator apertures and neutron fluxes at Back-n at 100 kW in proton beam power can be found in table.

1. 2017 JINST 12 P07022
2. Eur. Phys. J. A (2019) 55: 115

Back-n neutron energy spectrum measurement



Measurement of the neutron flux of CSNS Back-n ES#1 under small collimators from 0.5 eV to 300 MeV

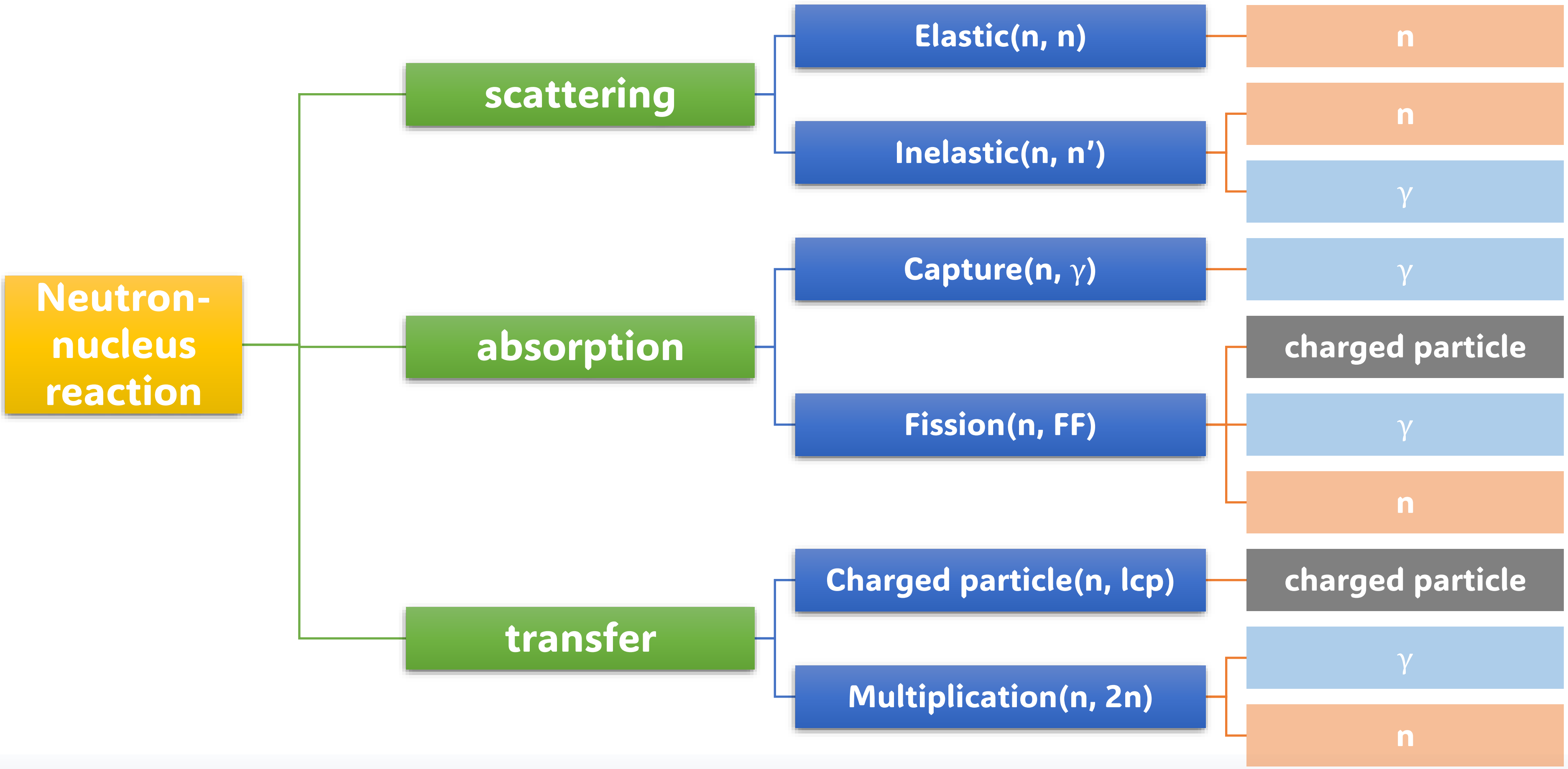
Energy range	flux (neutrons/cm^2/s)
0.1-1 eV	4.08×10^3
1-10 eV	1.79×10^4
10-100 eV	3.01×10^4
0.1-1 keV	5.01×10^4
1-10 keV	1.23×10^5
10-100 keV	4.30×10^5
0.1-1 MeV	2.98×10^6
1-10 MeV	2.77×10^6
10-200 MeV	6.21×10^5
Total	7.03×10^6

We used different reference cross-sections to measure the energy spectrum, including: (n, p), ^{6}Li(n, t), ^{235}U(n, f), ^{238}U(n, f)

Eur. Phys. J. A (2019) 55: 115
Chen, Y., Qiu, Y., Li, Q. *et al. Eur. Phys. J. A* **60**, 63 (2024).

Classification of Neutron and Nucleus Reactions

Neutron and nucleus reactions can be divided into three main categories based on the nuclear reaction process: scattering reactions, absorption reactions, and transfer reactions.



C6D6(Deuterated benzene) scintillator detector

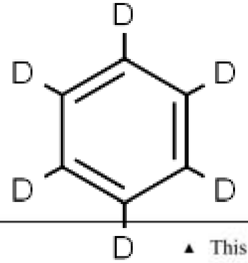


Photo of the C6D6 detector system

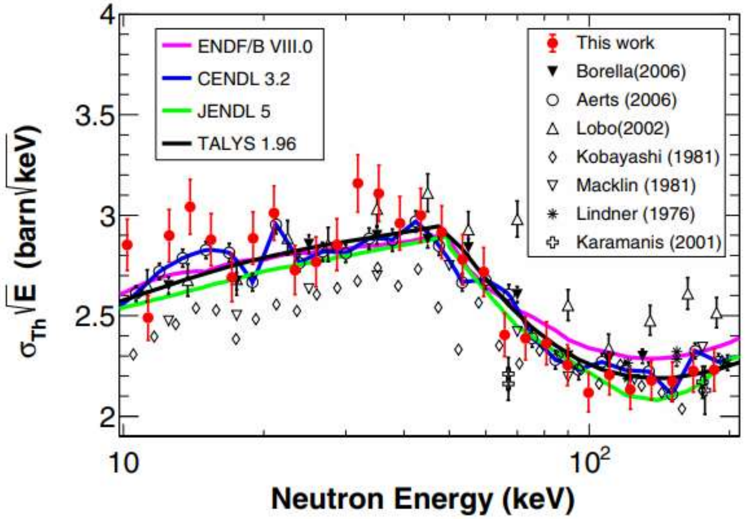


Fig. 10 The capture cross sections of ^{232}Th multiplied by the square root of the neutron energy. The uncertainty of some data sets is omitted to maintain the readability of the figure

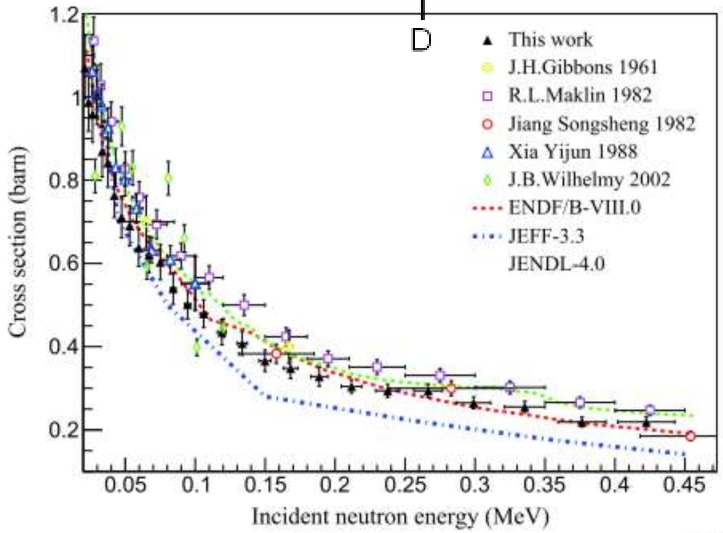


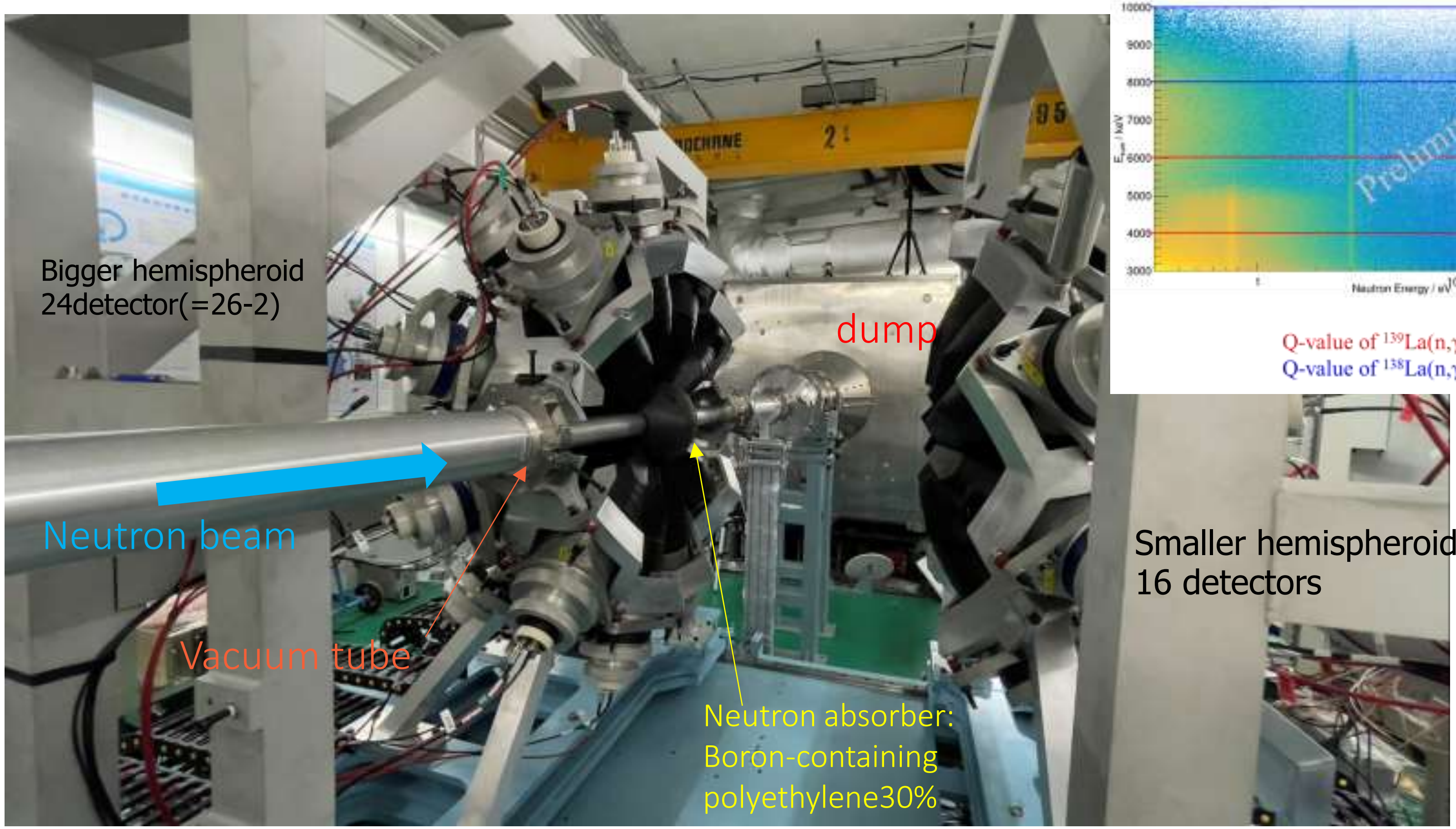
Fig. 15. (color online) The capture cross sections of ^{169}Tm obtained by the relative measurement of ^{197}Au(n,γ).

C6D6 is the most commonly used detection system for capture cross-section measurements. In the last five years, more than ten kinds of isotopes were measured by this detector, such as ^{197}Au, ^{238}U, ^{232}Th, ^{169}Tm, ^{93}Nb, ^{89}Y, ^{151,153}Eu, ^{nat}Lu, ^{nat}Cu, ^{nat}Ho, ^{nat}Tb, etc.

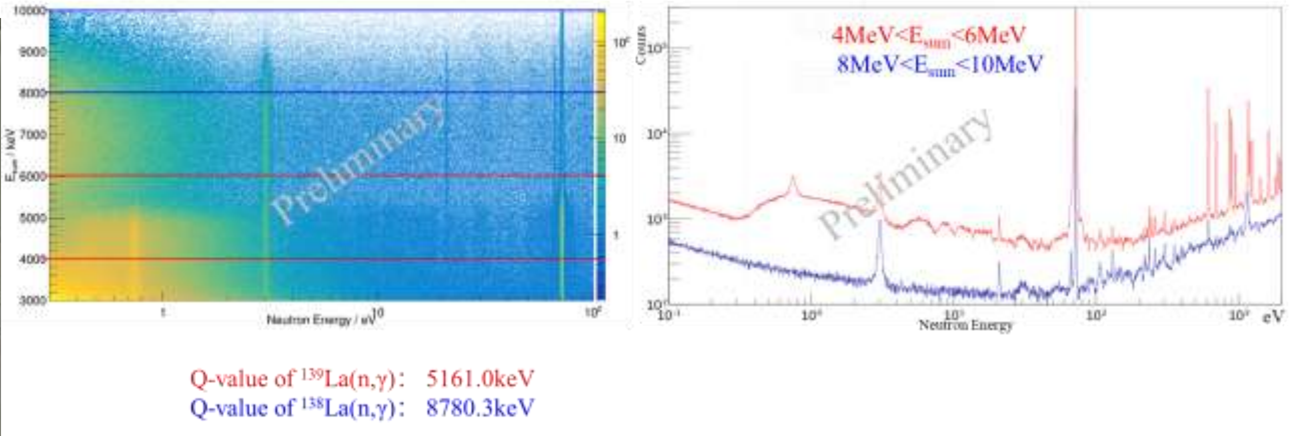
Radiation Detection Technology and Methods, 3(3): 52
Chinese Physics C, 46(4): 044002
Chinese Physics B, 31(6): 060101

Measurement of the 159Tb(n, γ) cross section at the CSNS Back-n facility by *Zhang*

GTAF (40 BaF_2 detector array)



Courtesy of: Guangyuan Luan(CIAE)

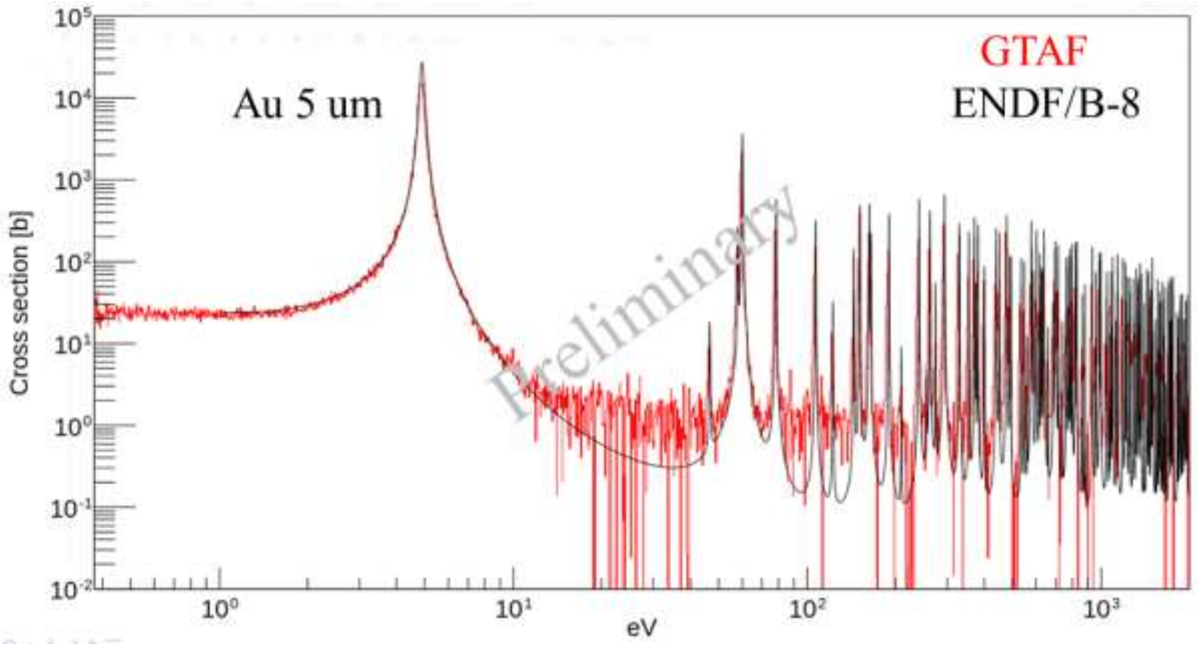


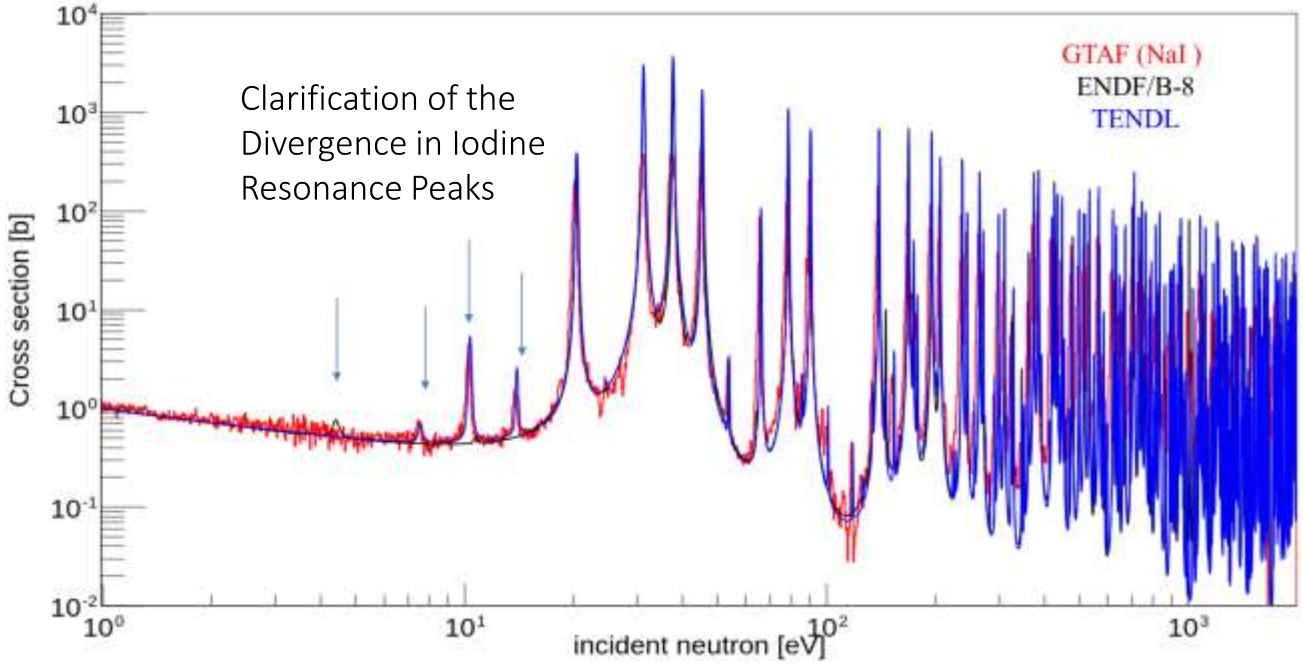
GTAF(Gamma Total Absorption Facility)

- Distinguish the resonance peaks of isotopes through gamma summation energy.
- γ multiplicity distribution, spin, and parity identification.
- Benefit for the small samples.

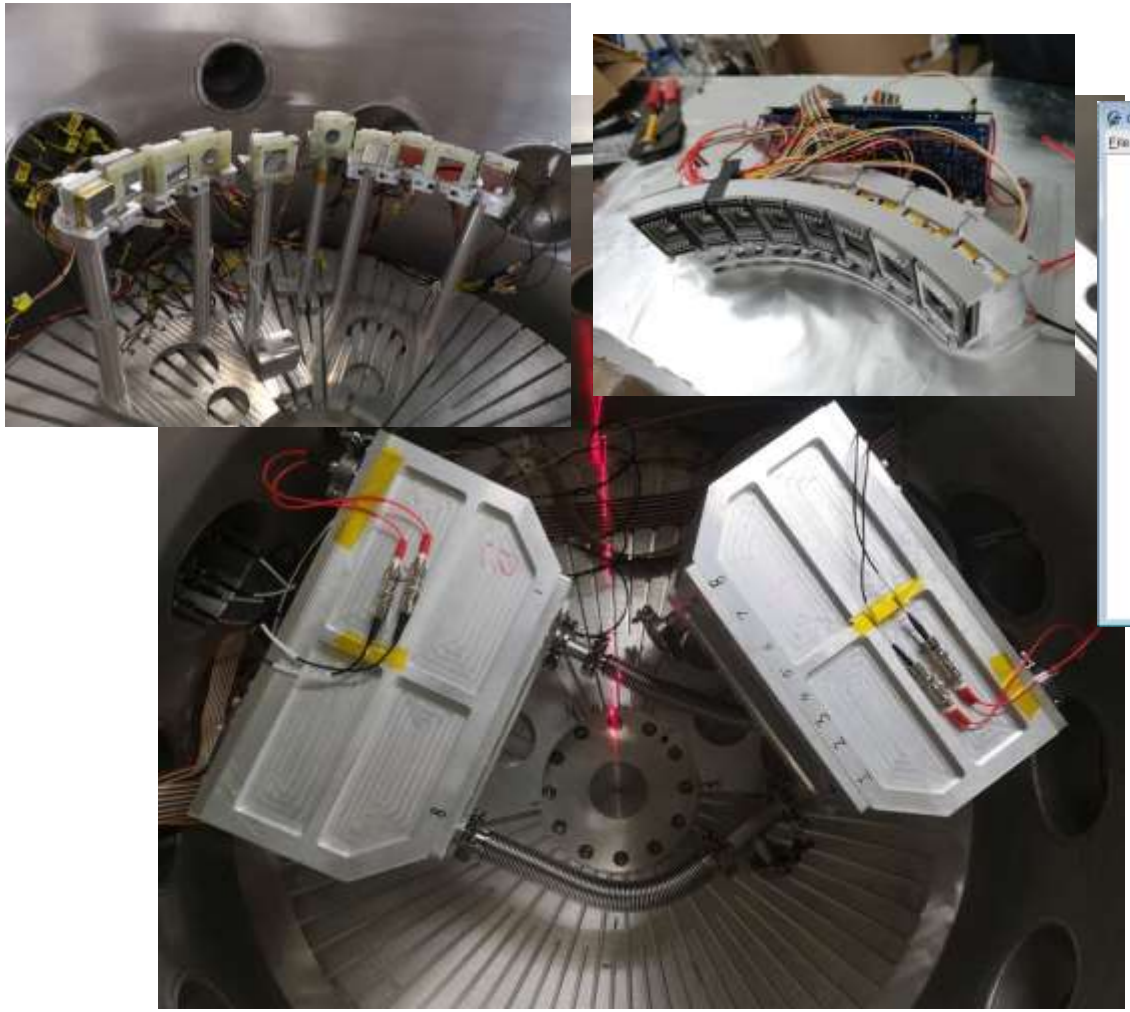
Journal of Instrumentation, 16(10): P10029

GTAF Basic Performance Test

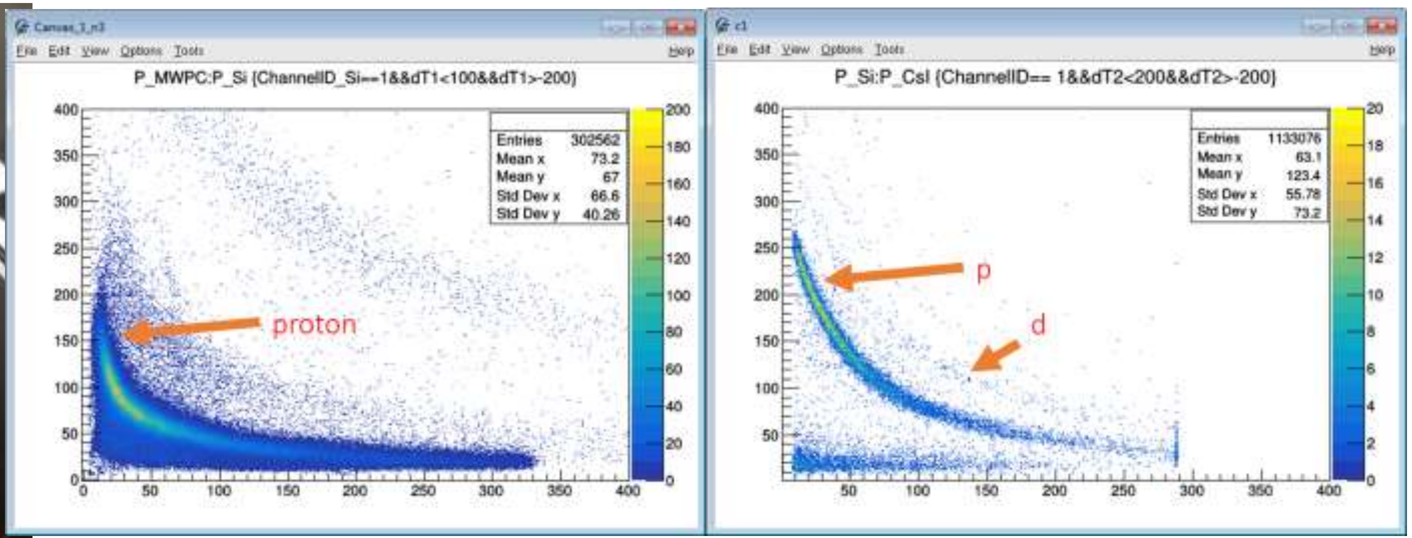




ΔE- E detector array (LPDA)



The photo of LPDA

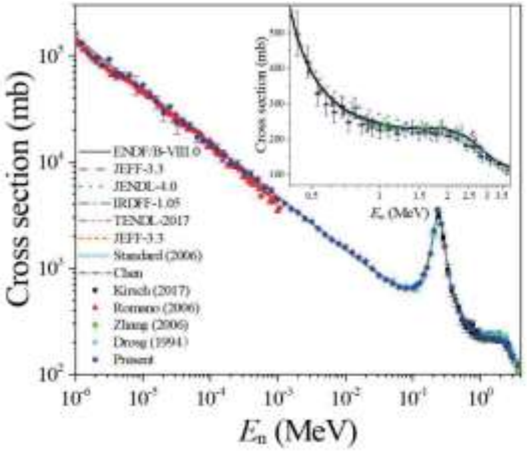


The LPMWPC (Δ*E*) vs Si-PIN (*E*) spectrum and Si-PIN (Δ*E*) vs CsI(Tl) (*E*) spectrum

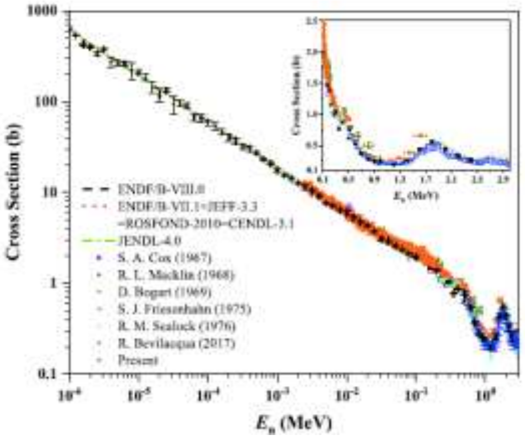
The LPDA is divided into two modules, each covering an angle of 23.5-90 degrees. It includes 8 sets of LPMWPC+Si+CsI detector telescopes, with a total of 48 channels. It was completed in June 2020.

NIMA, 973: 164126
NIMA, 981: 164343
JINST 18 P04004

LCP cross section measurements

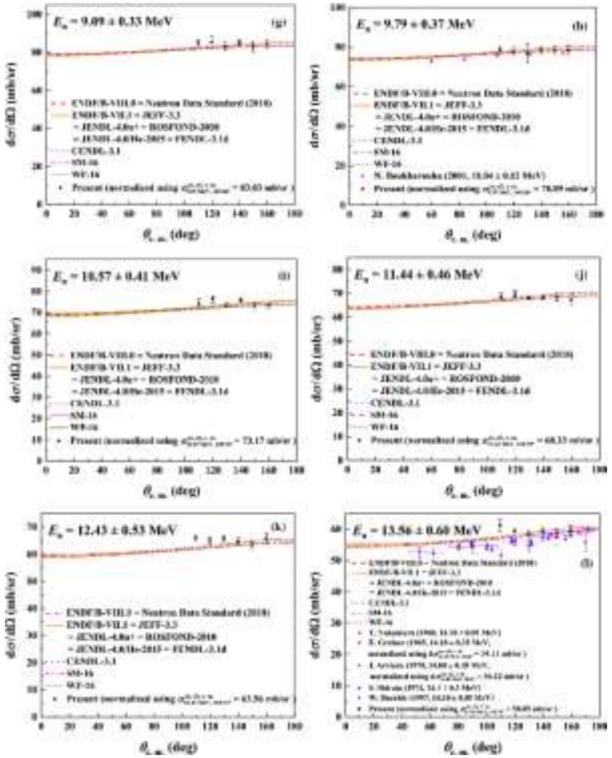


^{6}Li(n, t) α

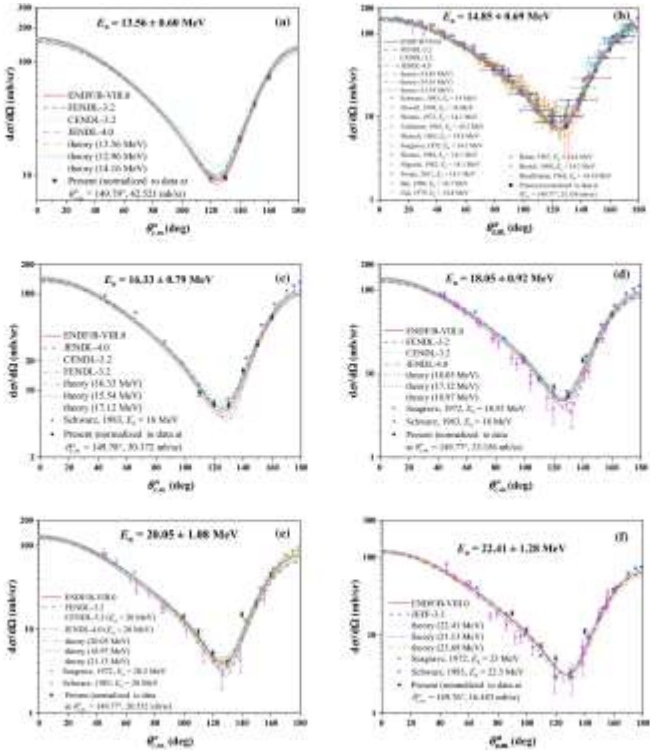


^{10}B(n, α)^{7}Li

Huaiyong Bai et al 2020 Chinese Phys. C 44 014003
H. Jiang, et al., Chin. Phys. C 43 (12) (2019) 124002
The European Physical Journal A, 57(11): 310
The European Physical Journal A, 57(1): 6



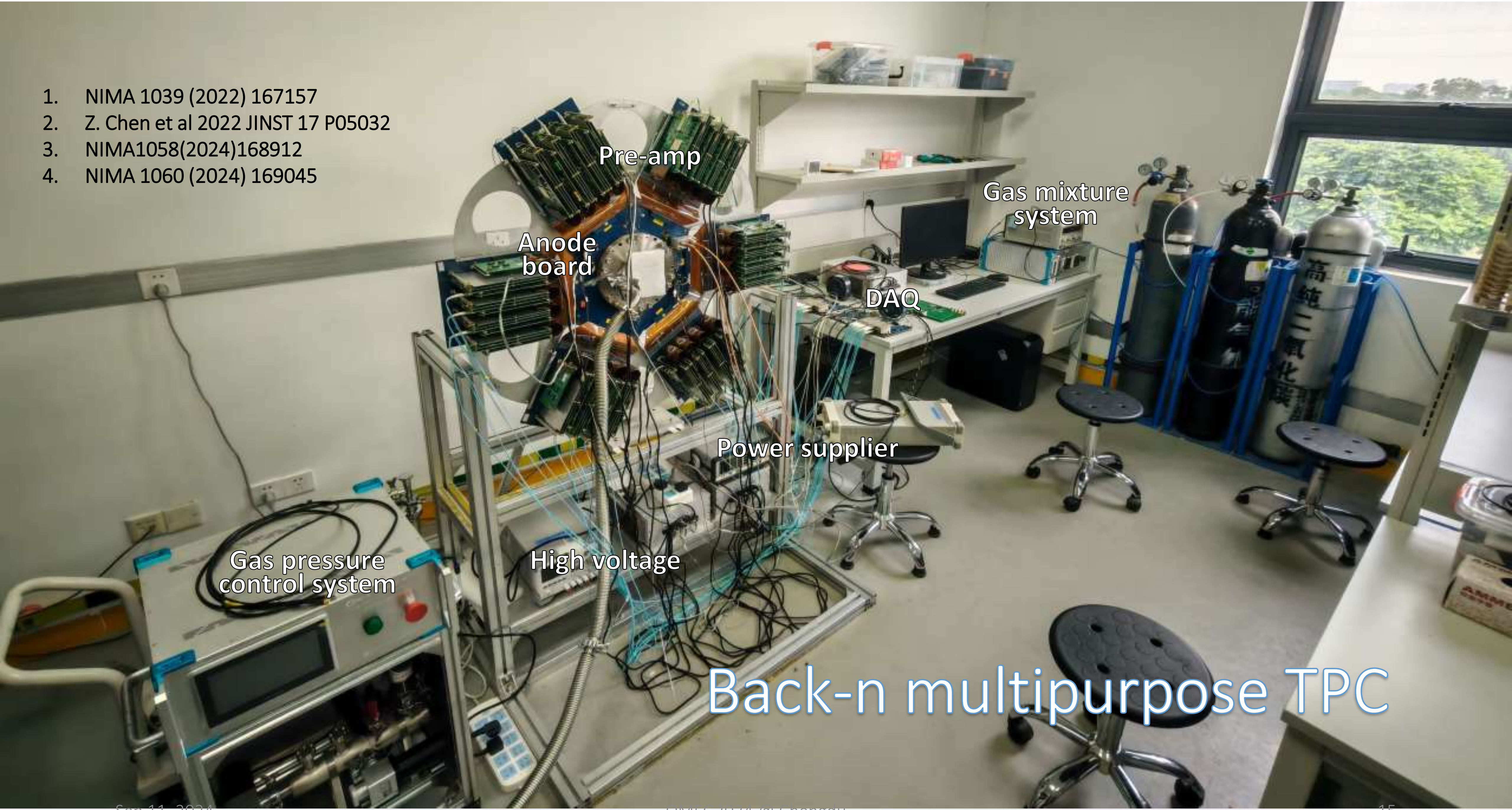
(n, p)



(n, d)

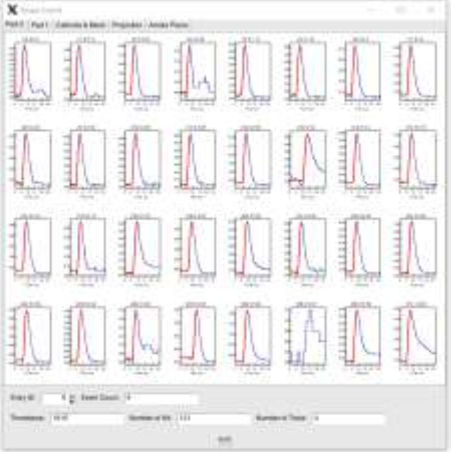
Back-n multipurpose TPC

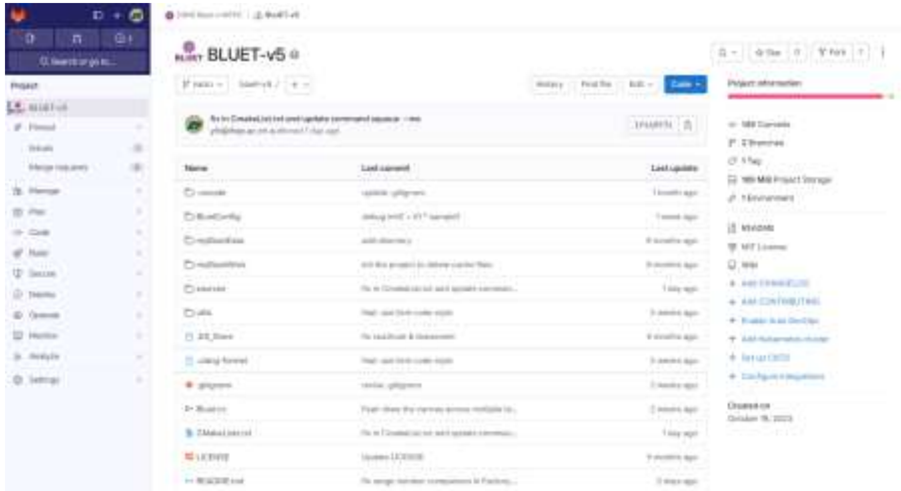
1. NIMA 1039 (2022) 167157
2. Z. Chen et al 2022 JINST 17 P05032
3. NIMA1058(2024)168912
4. NIMA 1060 (2024) 169045

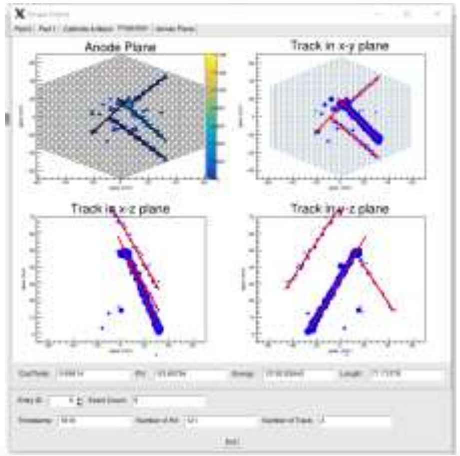


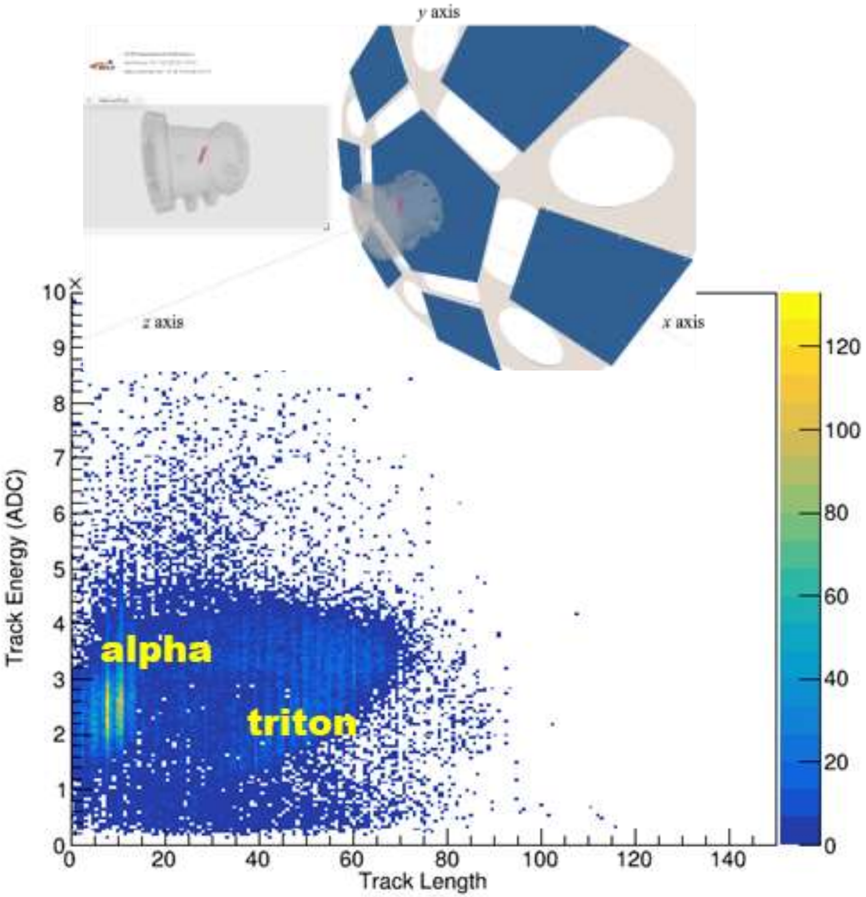
BLUET framework

- UI interface, Simulation, Waveform analysis, Event reconstruction…
- BLUET code has been upgraded to version v5, developed based on Gitlab open to everyone.

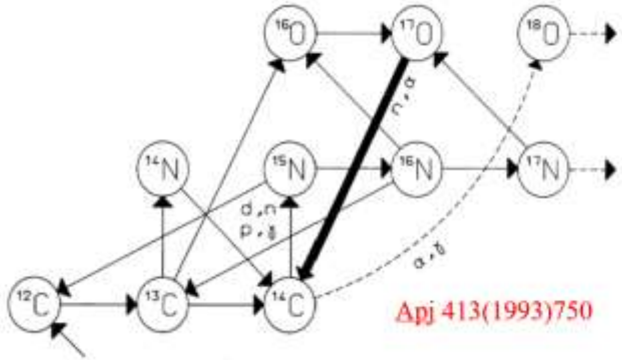




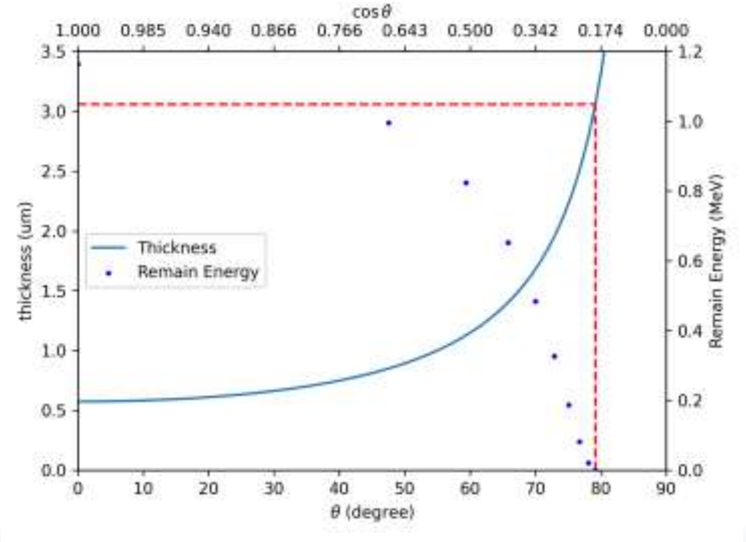


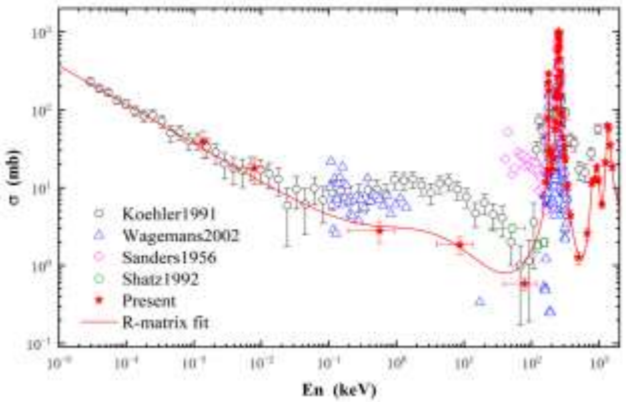


Mersurement of $^{17}O(n,\alpha)^{14}C$ with MTPC

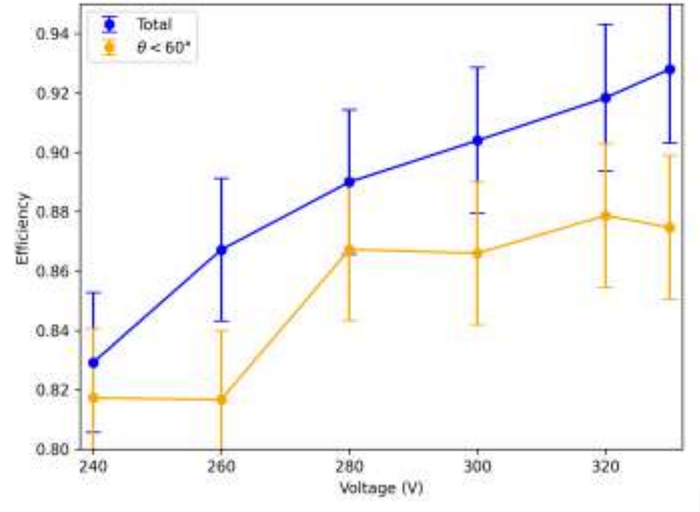


- The cross section data of $^{17}O(n,\alpha)^{14}C$ is important for the s-process in nucleosynthesis.





- The measurement of $^{17}O(n,\alpha)^{14}C$ has been conducted at CSNS Back-n with SiC array.
- The measured data in the 0.1keV~200keV is one order lower than previous results, while the statistical error is large.
- Implying the possible decreasing of reaction rate to about 1/5~1/8 compared with previous results when the $T_9<0.2$, which is cosistent with the value obtained in the AGB observation.



- MTPC works at a pressure of 0.15atm with the mixture of Ar(75%) and CO_2(25%).
- Simulation of detection efficiency at different mesh voltage.
- With the mesh voltage of 300V, the detection voltage could be about 85%.

This experiment will be started in Oct 2024.

Nuclear data measurement experiments

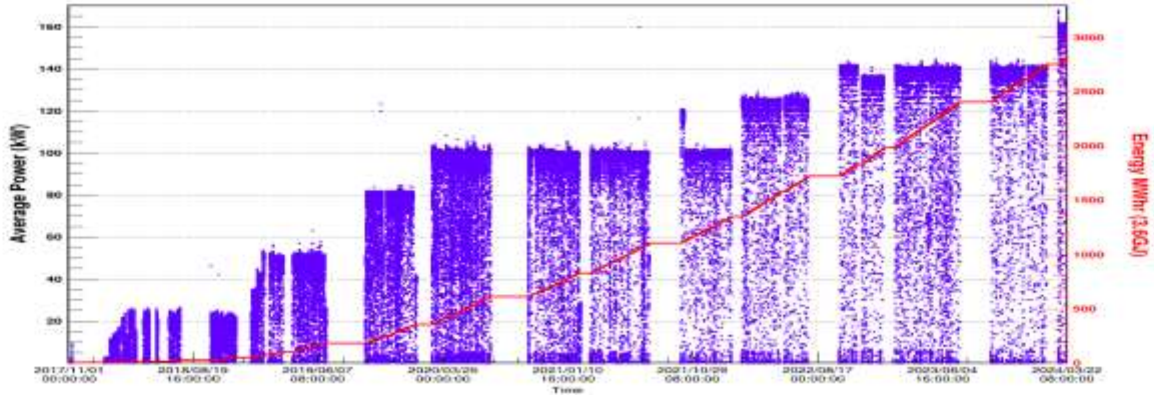
Since 2018, we have measured the neutron reaction cross sections of more than 50 nuclides and will continue to measure at a rate of over 10 nuclides per year.

- Neutron capture
  - 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, ^{nat}Yb, ^{127}I, ^{133}Cs, ^{nat}Dy, ^{103}Rh
  - GTAF-II: ^{169}Tm, ^{93}Nb , ^{nat}Re, ^{nat}Xe, ^{nat}Sn, ^{127}I, ^{nat}La
- Total cross-section
  - ^{12}C, ^{27}Al， ^{9}Be， ^{7}Li， ^{nat}Fe, **^{209}Bi, ^{nat}Pb, ^{nat}Cr, ^{9}Be, ^{169}Tm**
- Fission cross-section
  - ^{235}U, ^{238}U, ^{236}U, ^{239}Pu, ^{232}Th, ^{239}Pu, **^{236}U**
- Light charged particle emission
  - LPDA: ^{6}Li(n, x), ^{10}B(n, x), ^{63}Ni， (n-d)， ^{17}O, (n-p)， 12C(n,d)， 12C(n,α) (13C cluster)
  - TPC: ^{12}C， ^{14}N， ^{6}Li
- Inelastic cross-section (in-beam gamma)
  - ^{56}Fe (n, n’), ^{nat}Mo， ^{16}O， ^{nat}Ru， ^{nat}Lu， ^{nat}Mo， ^{nat}Ti, ^{209}Bi, ^{90}Zr, ^{55}Cr, ^{155}Eu, ^{178}Hf, ^{232}Th

展望

prospect

What can we do at Back-n?



We have almost **5000** hrs beamtime per year opening to every scientist in the world.

Back-n has the most insensitive resonance neutron flux.

In the next six years (CSNS II), the CSNS accelerator power will increase from 100 to 500 kW. The beam intensity of Back-n will increase with a factor of 5.

- ***Small reaction cross-section (mb-μb)***
- ***Important targets, which are difficult to prepare or radioactive***

Astrophysics experiments

- S-process neutron capture reaction
  - Almost all cross-sections are measurable
- Rare nuclides reactions
  - Determines the key (n, p), (n, α) and other reactions produced by a nuclide
  - **Solve the problem of anomalies in the abundance of interstellar matter and AGB stars: reaction section of 17O(n, α)14C key energy region;**
  - The 25Mg(n, α)22Ne reaction measurement (its inverse reaction is the main neutron source reaction in AGB stars, also one of the important physical targets of Jinping II).

Courtesy of: Professor Li Yunju (CIEA)

Back-n user and community

There are a total of more than 200 people from different institutions, including:

- the Institute of High Energy Physics of the Chinese Academy of Sciences
- the China Institute of Atomic Energy
- the China Academy of Engineering Physics
- the Northwest Institute of Nuclear Technology
- the University of Science and Technology of China
- Peking University
- Xi'an Jiaotong University
- Indiana University
- JINR
- ……

礼

Thanks

You are welcome mailto:*fanrr@ihep.ac.cn*