Development of the Light charged Particle Detector Array (LPDA) at Back-n White Neutron Source

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Outline

- CSNS, “Back-n” and LPDA
- Development of LPDA in recent years (2018-2020)
  - Detectors
  - Experiments
- Summary & Acknowledgement

CSNS, "Back-n" and LPDA

In the back streaming direction of China Spallation Neutron Source (CSNS), there is a white neutron beam line that is suitable for nuclear data measurement, called "Back-n" white neutron source.

Proton beam power: 100kW energy: 1.6GeV pulse rate: 25Hz

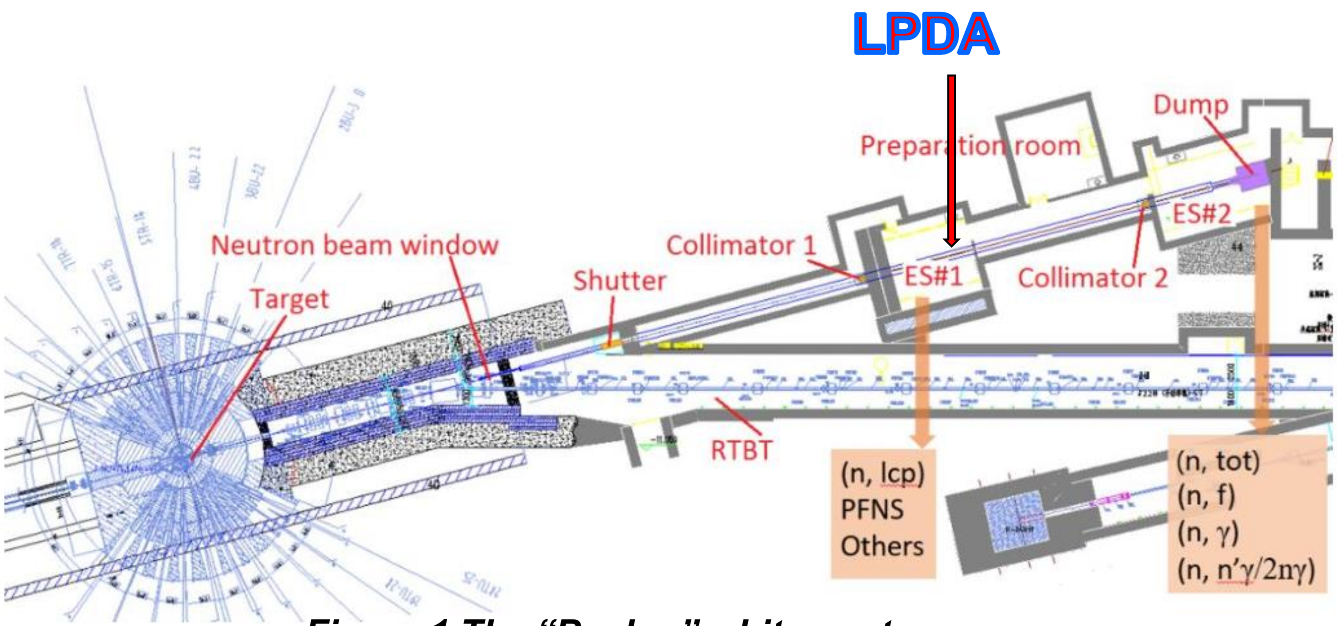


Figure 1 The "Back-n" white neutron source

CSNS, “Back-n” and LPDA

One of seven spectrometers at Back-n is Light charged Particle Detector Array (LPDA), which is used for the study of neutron induced light charged particle emission (n, lcp).

- Radius:0.5m
- Height:0.5m
- Distance(to target): 57m
- Neutron flux: 1.6×10^{7}n/cm^{2}/s

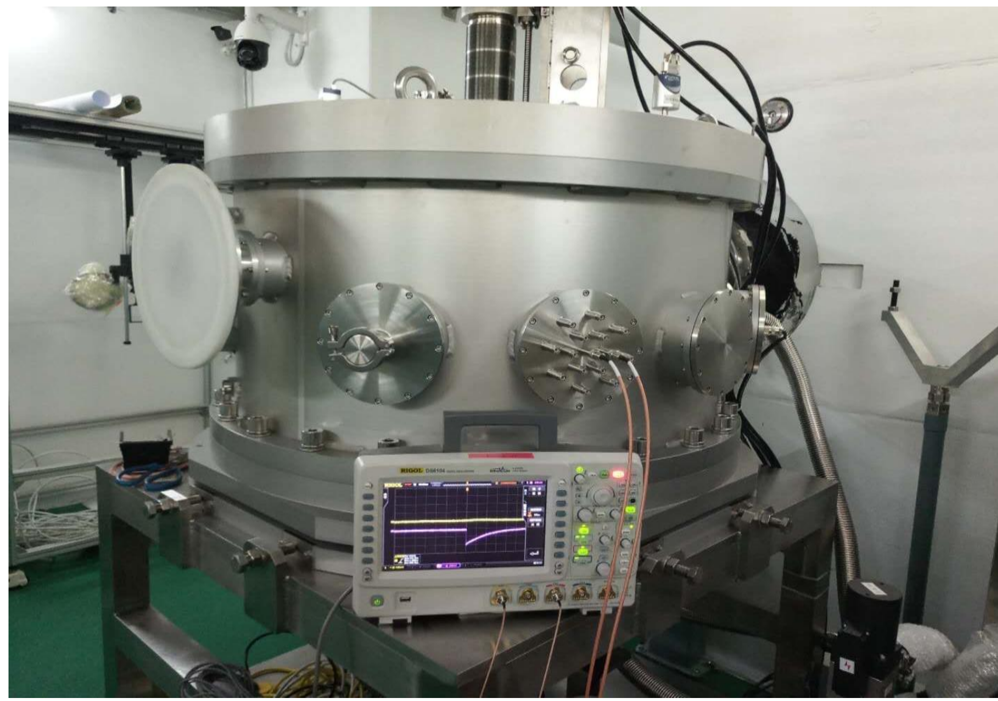


Figure 2 LPDA vacuum chamber

CSNS, "Back-n" and LPDA

A complex gas-flow control system allows precise pressure control for the vacuum chamber and the MWPC detectors. The rotatable detector support plate and sample changing systems make the experimental set-up flexible for each experiment.

The team of LPDA consists of

- Prof. Ruirui Fan et al from *Division of Accelerator Technology, Dongguan Campus, Institute of High Energy Physics (IHEP), Chinese Academy of Sciences (CAS).*
- Prof. Guohui Zhang et al from *State Key Laboratory of Nuclear Physics and Technology, School of Physics, Peking University (PKU).*

Development of LPDA in 2018

Configuration of the detectors in $^{6}Li(n, t)^{4}He$ experiment:

- 15 silicon detectors (2 cm × 2.5 cm, 500μm thick)
- 1 gridded ionization chamber (GIC)
- 3 ΔE-E detectors: each detector unit has a low pressure multi-wire proportional chamber (LPMWPC) as the low-energy (ΔE) measurement, a silicon detector unit as the total energy (E) measurement

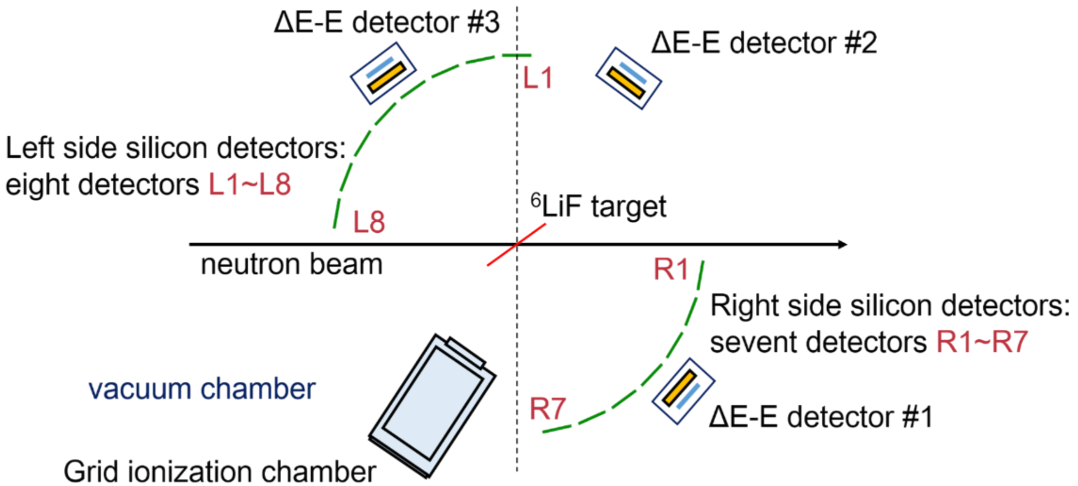


Figure 3 sketch of the configuration of the detectors

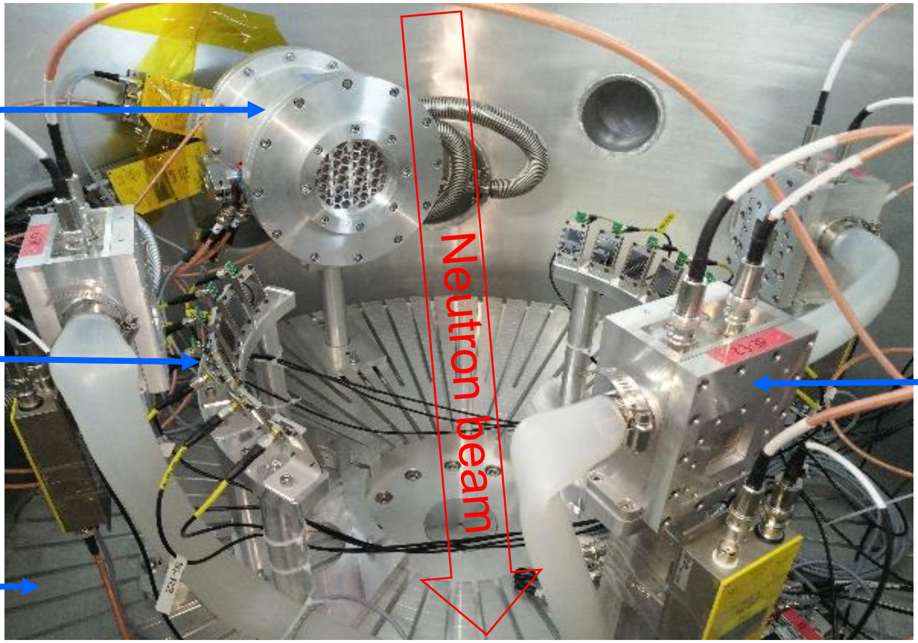
Development of LPDA in 2018

To avoid shielding the ΔE-E detectors, the centers of the silicon detectors were lower than the beam line. The angle between the normal line to each silicon detector and the horizon was 16º.

Grid ionization chamber

Silicon detectors array

rotatable detector support plate



ΔE-E detector

Figure 4 photo of the detectors in the vacuum chamber

Experiments on nuclear data measurements in 2018

The first batches of experiments on nuclear data measurements have been carried out in 2018, and the results of these experiments are published in Chinese Physics C.

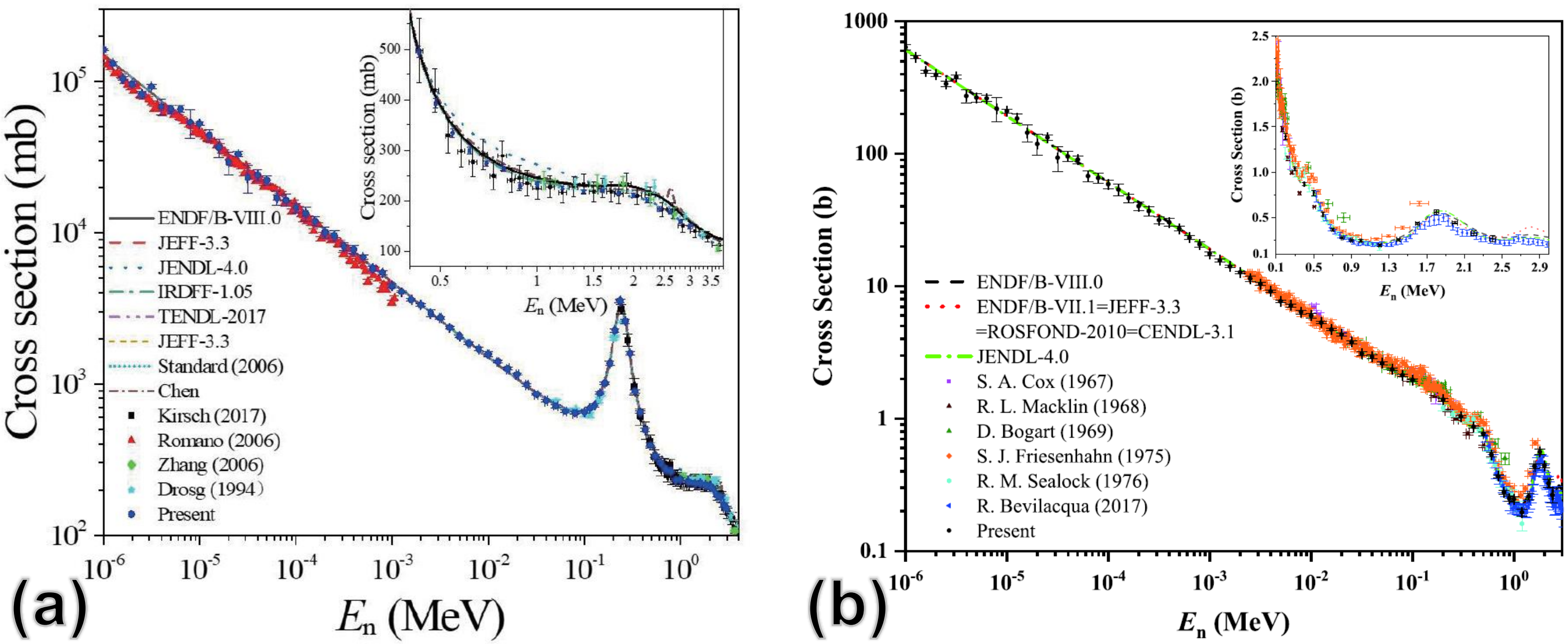
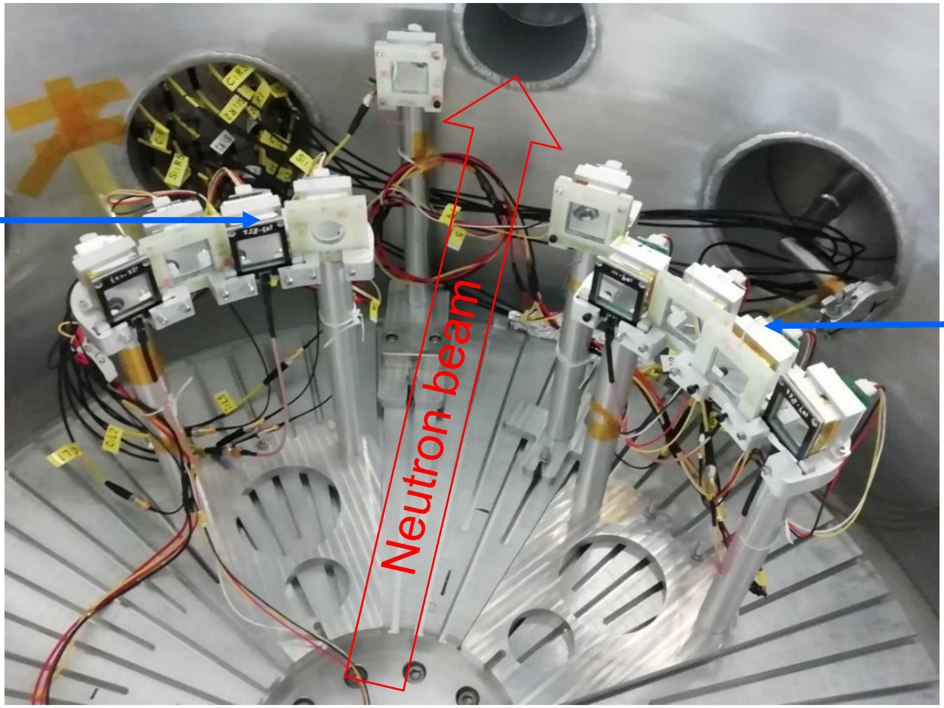


Figure 5 Results of measurement of cross section for the (a) ^{6}Li(n, t)^{4}He reaction and (b) ^{10}B(n, α)^{7}Li reaction

Development of LPDA in 2019

In the n-p elastic scattering reaction experiment, a ΔE−E telescope array were installed in the LPDA vacuum chamber. Configuration of the detectors in n-d elastic scattering reaction experiment was similar to configuration in n-p experiment.

ΔE-E detectors array



ΔE-E detectors array

Figure 6 photo of the detectors in the vacuum chamber

Development of LPDA in 2019

The ΔE detectors were the Si-PIN detectors (300 μm in thickness), and the active area of each Si-PIN detector was squared 2.5 cm in side length (except the L2 detector which was circular 2.0 cm in diameter). The E detectors were cubic (3.0 cm × 3.0 cm × 3.0 cm) CsI detectors.

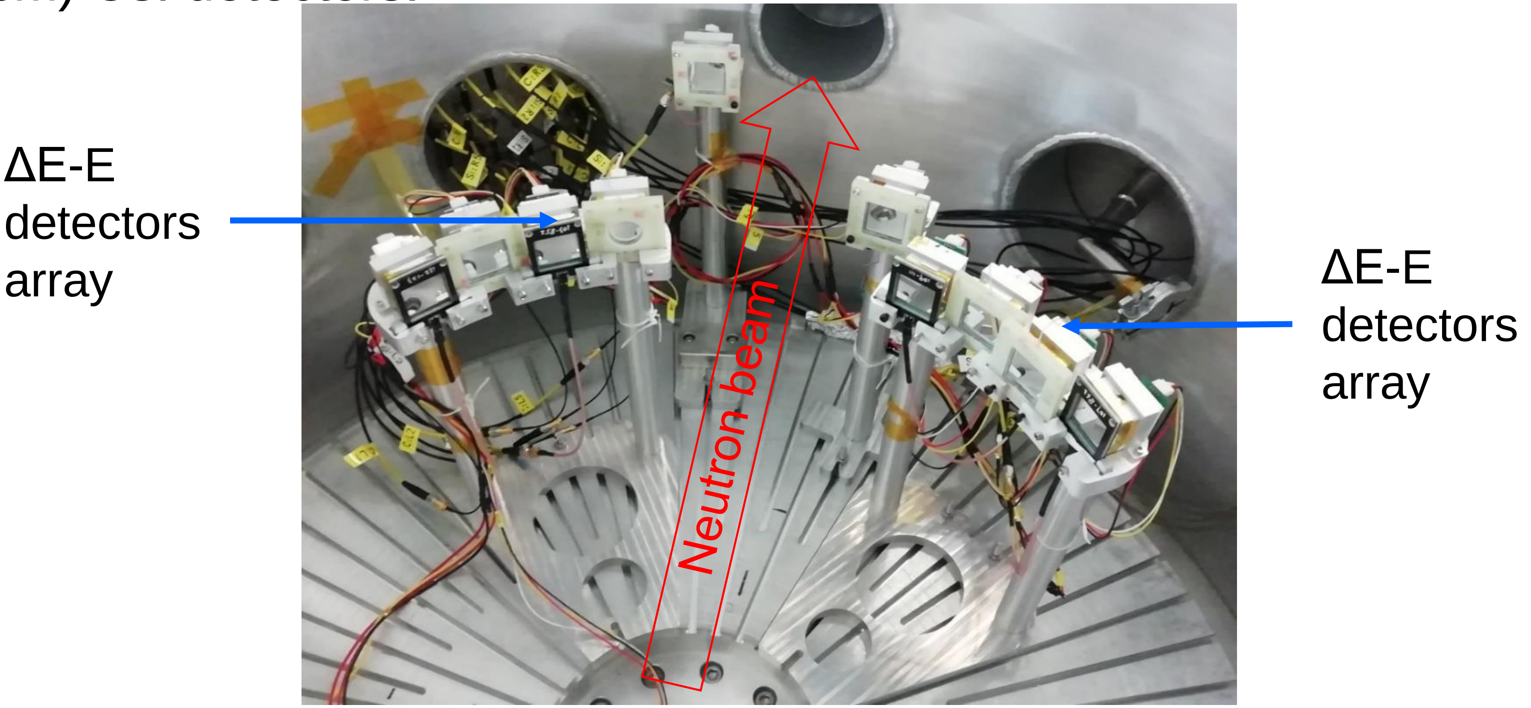
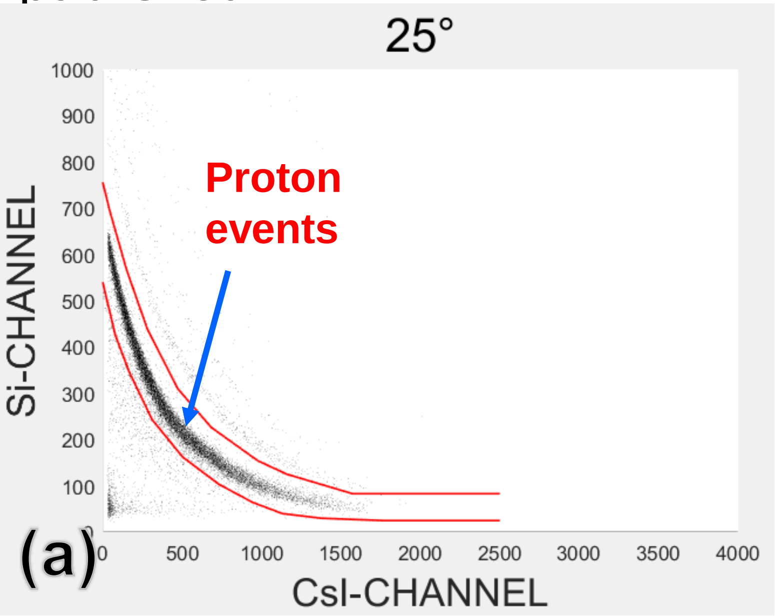


Figure 6 photo of the detectors in the vacuum chamber

Experiments on nuclear data measurements in 2019

For the particles which penetrated the Si layer and produced signals in both the Si-PIN detector and the CsI detector, the events were sorted into the ΔE−E spectrum show in Figure 7 as an example.

The results of n-p and n-d scattering reaction experiments are published.



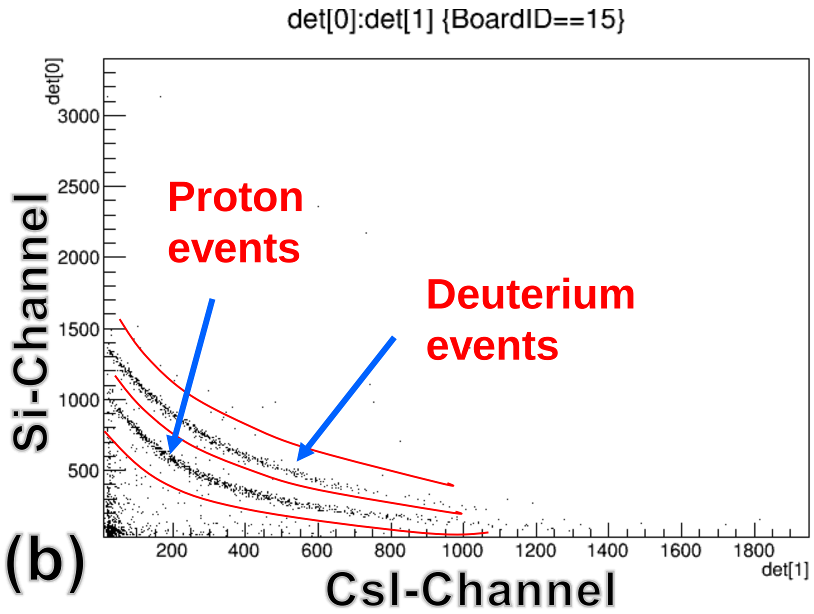


Figure 7 The ΔE−E spectrum of the R_2 ΔE−E telescope (θ_{det}=25.06) in the (a) n-p scattering reaction experiment (b) n-d scattering reaction experiment

Development of LPDA in 2020

Based on the experience and basis of the experiments in the past two years, a 16-unit ΔE-ΔE-E telescope array was constructed in 2020. This is the most complex detector system until now in LPDA.

The 16-channel telescopes are divided into two groups and installed in two sealed gas boxes. Both boxes are placed in a vacuum chamber and arranged in a fan shape to cover more solid angles.

Box B
(8 sets of ΔE-E detectors)

Target and target frame

Box A
(8 sets of ΔE-E detectors)

Figure 8 photo of the16-unit ΔE-ΔE-E telescope array

Development of LPDA in 2020

Each telescope employs a low-pressure multi-wire proportional chamber (LPMWPC) as the first stage, followed by a silicon PIN detector. A thallium activated Cesium Iodide (CsI(Tl)) crystal readout by SiPM as the total energy detector at the end of each telescope.

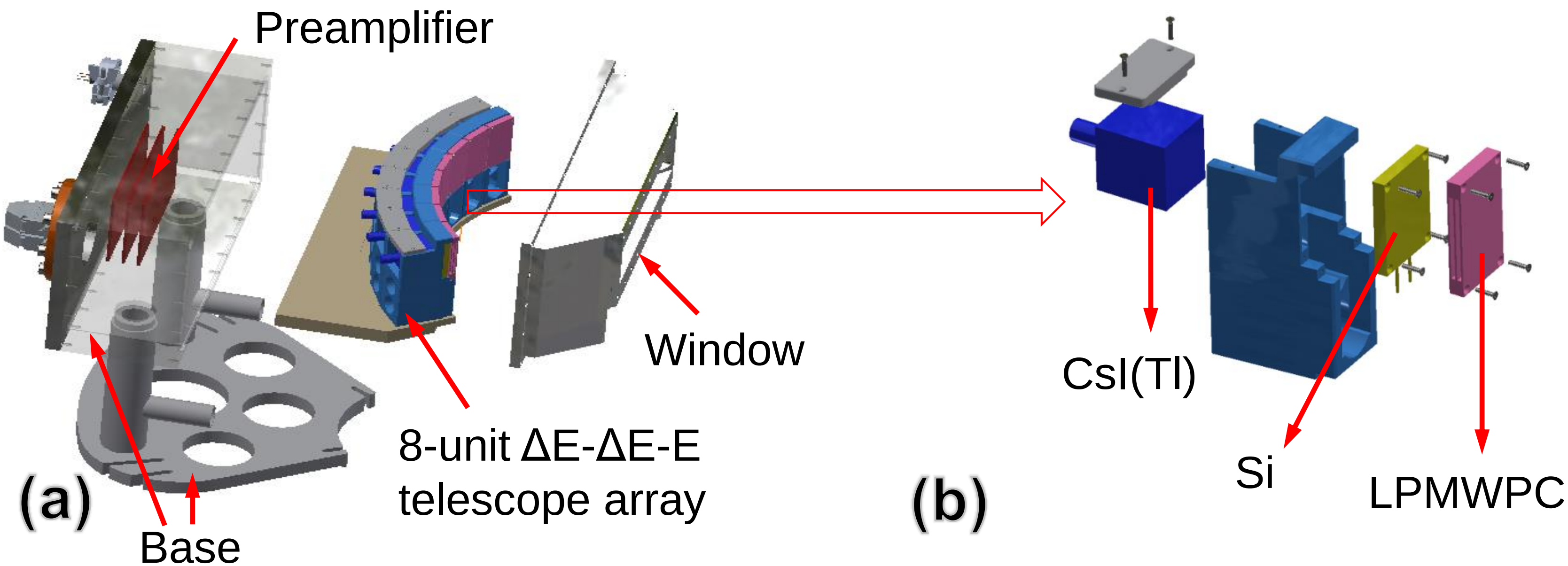


Figure 9 (a) sketch of the box (b) structure of 1 of 8-unit ΔE-ΔE-E telescope

Experiments on nuclear data measurements in 2020

With LPDA, the low-energy (n, p) scattering reaction experiment was accomplished in Oct. 2020.
The angle between the normal of each ΔE-ΔE-E telescope and that of the target are shown in Table 1.
The targets in this experiment are graphite (C target), polypropylene (CH2 target), empty and α source.

telescope number	Angle	telescope number	Angle
A1	91º	B1	29º
A2	81.5º	B2	38.5º
A3	72º	B3	48º
A4	62.5º	B4	57.5º
A5	53º	B5	67º
A6	43.5º	B6	76.5º
A7	34º	B7	86º
A8	24.5º	B8	95.5º

Table 1 The angle between the telescope and the target

Figure 10 The target in experiment

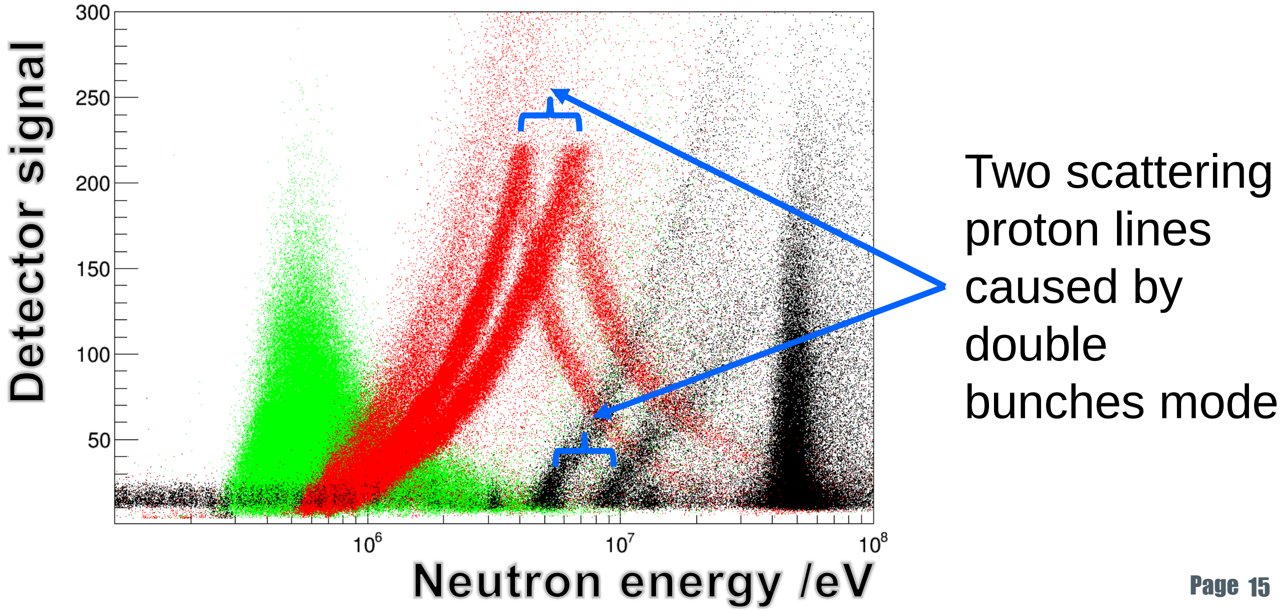
Experiments on nuclear data measurements in 2020

Detector signal of telescope A8 are shown as a example. Figure 11 is the neutron energy – detector signal spectrum with different 3 detectors.

The neutron energy is calculated by the TOF method. The double bunches mode of the CSNS accelerator causes the neutrons with different energies to reach the LPDA at the same time, leading to two scattering proton lines.

Figure 11 Detector signal of telescope A8（24.5°）

●:Signal in CsI
●:Signal in Si
●:Signal in MWPC



Experiments on nuclear data measurements in 2020

The proton events were sorted into the ΔE−E spectrum show in Figure 12 as an example, it can be clearly identified from other events in both MWPC-Si spectrum (a) and Si-CsI spectrum (b).

The next step of data analysis is going on.

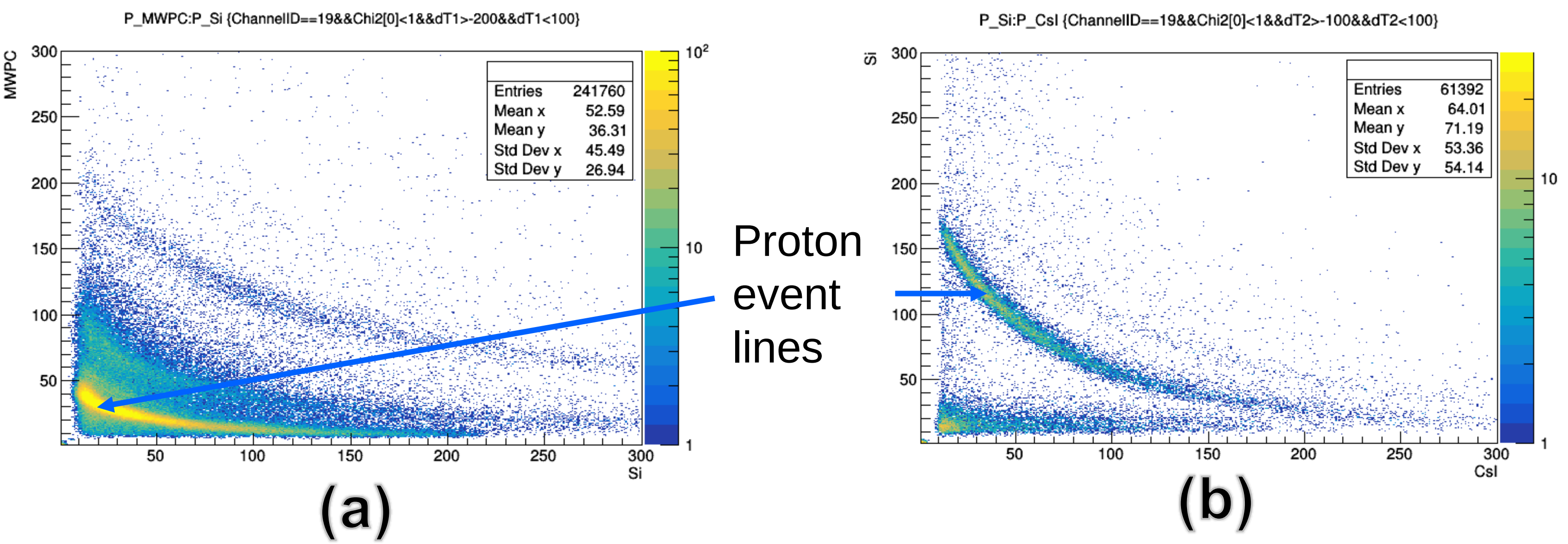


Figure 12 (a) MWPC-Si ΔE−E spectrum (b) Si-CsI ΔE−E spectrum

Summary and Acknowledgment

Although the whole system was completed in late 2020, LPDA has been employed for a number of experiments. The updated detector systems make the experimental set-up flexible for each experiment.

Thanks for the cooperation of Prof. Guohui Zhang et al from *State Key Laboratory of Nuclear Physics and Technology, School of Physics, Peking University*.

Thanks for your listening!

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