R&D of a Large-Size CsI(Tl) Detector for Neutron Induced γ-ray Measurement at the Back-n of CSNS

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CSNS
中国散裂中子源
China Spallation Neutron Source

Outlines

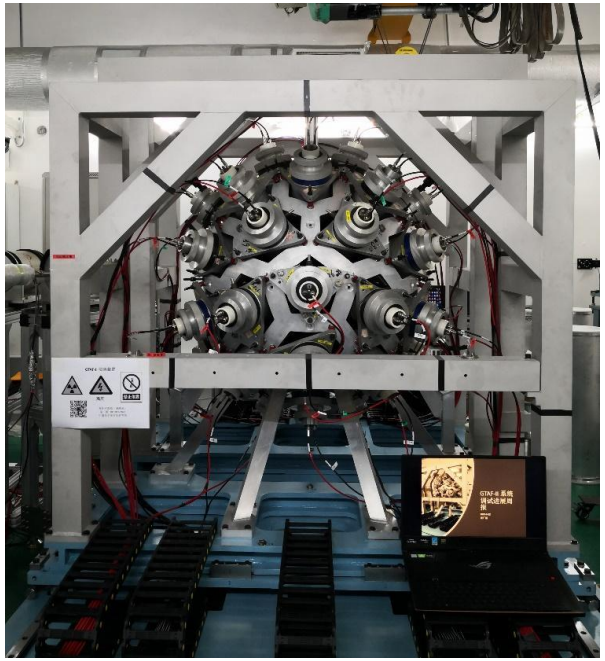
- **Introduction**
- **Assembly of the large-size CsI(Tl) Detector**
- **Performance test at lab and Back-n**
- **Summary**

Introduction

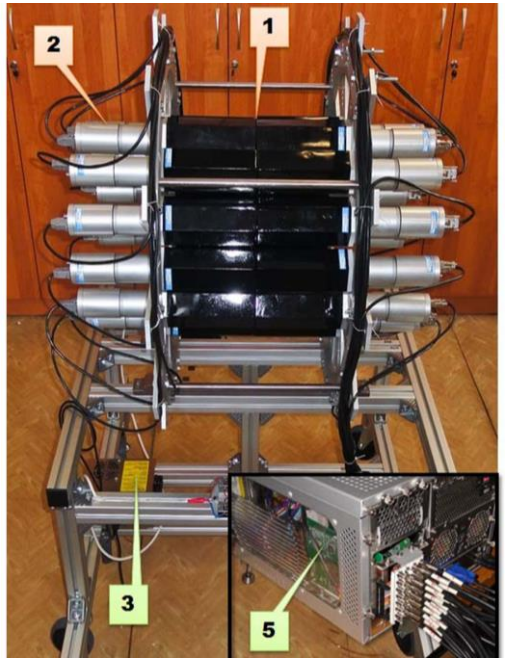
Cross-section measurement of neutron induced gamma rays plays a crucial role in nuclear physics research.

- Nuclear structure & database
- Typical detector: HpGe, BaF2, NaI, P-CsI

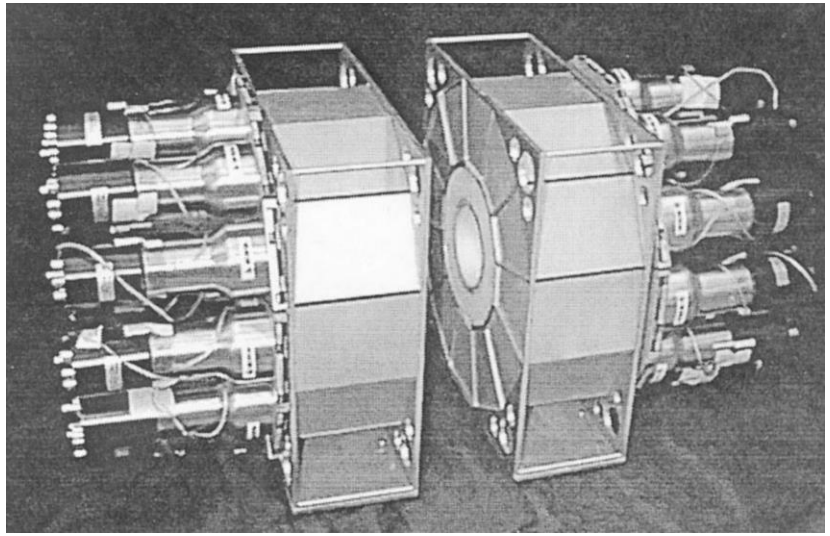
Reference:
a. GTAF · Wiki · BEAG_CSNS / share · GitLab
b. Ruskov I, Kopatch Y N, Skoy V R, et al. Experimental setup for investigation of the resonance neutron induced fission of 239Pu[J]. Physics Procedia, 2013, 47: 137-143.
c. Seestrom S J, Frankle C M, Bowman J D, et al. Apparatus for parity-violation study via capture γ-ray measurements[J]. NIM. A, 1999, 433(3): 603-613.



a. 40 BaF2 array @Back-n CSNS



b. 12 NaI array @FLNP JINR



c. 24 P-CsI array @LANCE LANL

A large-size CsI (TI) detector was proposed to measure the neutron induced γ (n-γ) at Back-n CSNS

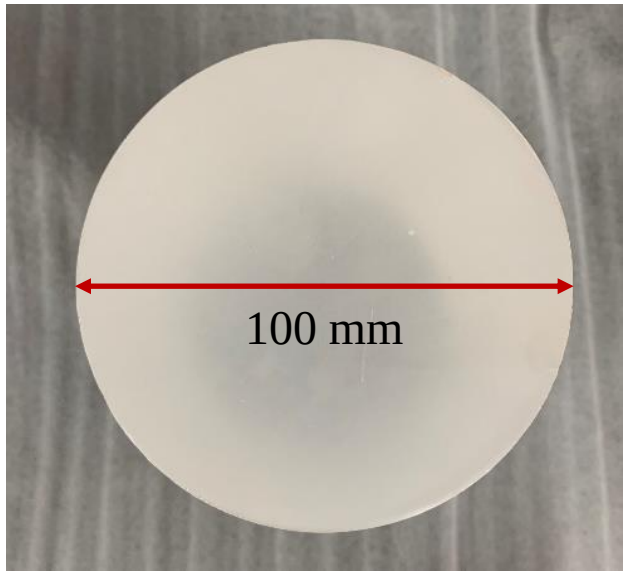
Preparation of the CsI crystal

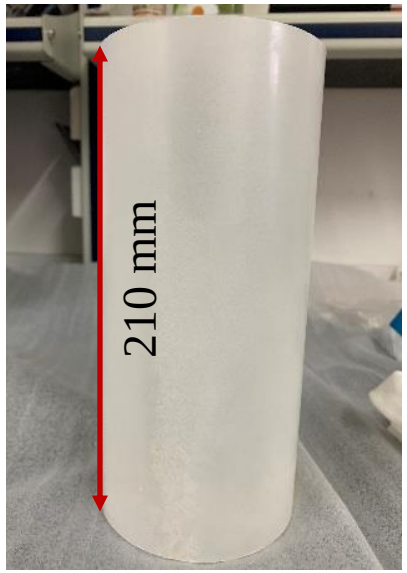
◆ CsI (TI) crystal produced by IMP

- Size: Φ100 mm and 210 mm length
- Density: 4.51 g/cm^3
- Light yield: ~50000 photons/MeV
- Fluorescence decay time: ~1 μs

- The surface of the crystal was polished to improve the optical performance
- A reflector layer was applied on the surface of CsI crystal to enhance the photon collection.

Before polishing





After polishing

Reflector layer wrapping

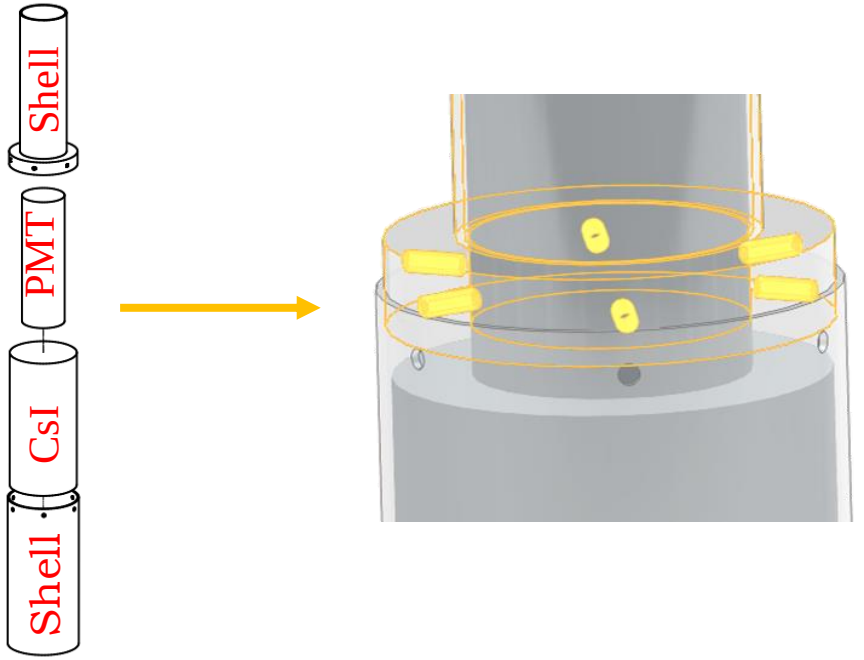
Assembly of the CsI and PMT

◆ N2021 PMT produced by North Night Vision

- Cathode size: Φ60mm
- Spectral response: 300-650 nm
- Rise time: ~2ns
- Gain: ~1e5 @2200V, 3000V max
- Maximum pulse linear current: 200 mA

N2021 PMT

- A stainless steel shell was designed to fix the PMT and CsI, also used as the light shielding.
- High-purity silicone grease was used to increase the optical coupling between the CsI and PMT.



CsI+PMT

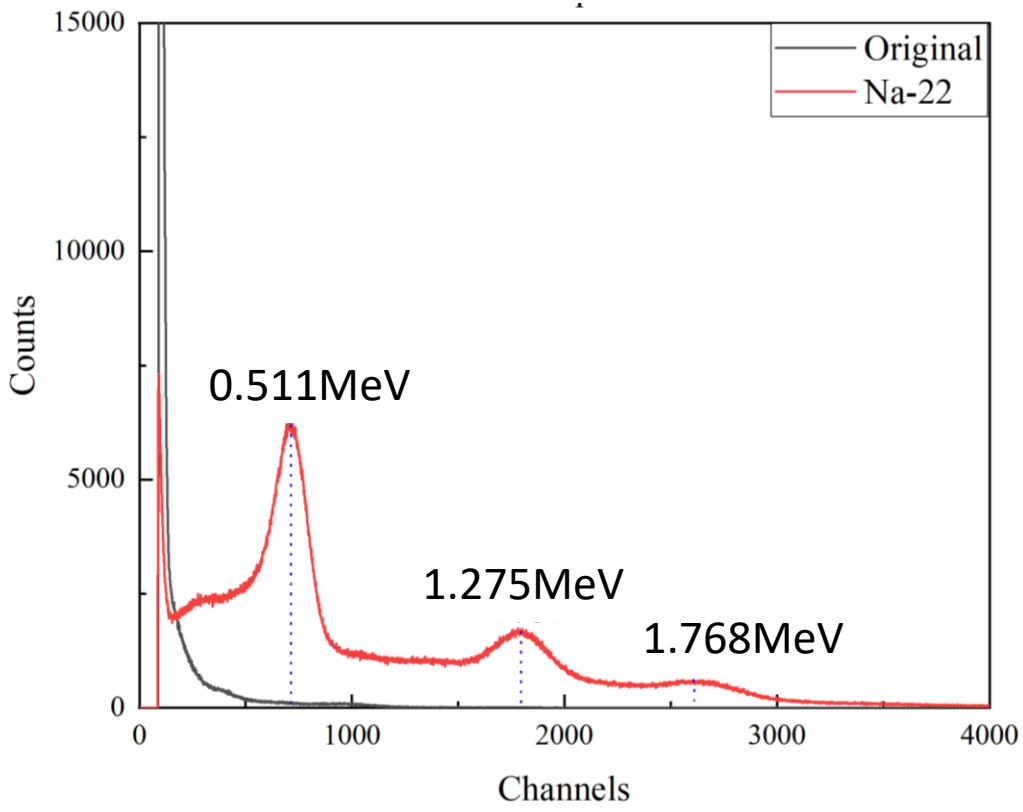
CsI detector system

Radioactive source test

◆ The waveform and energy spectrum of the detector were measured in lab with ^{22}Na source.

- The waveform can be recorded by oscilloscope with an input independence of 1MΩ.
- A MCA which integrated pre-amp and shaper-amp was used to energy spectrum measurement.

Typical waveform of CsI detector @ 1MΩ independence

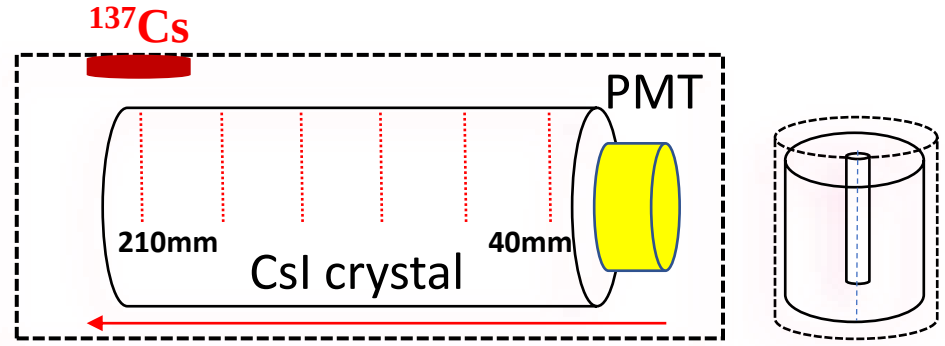


Energy spectrum of ^{22}Na

Uniformity test

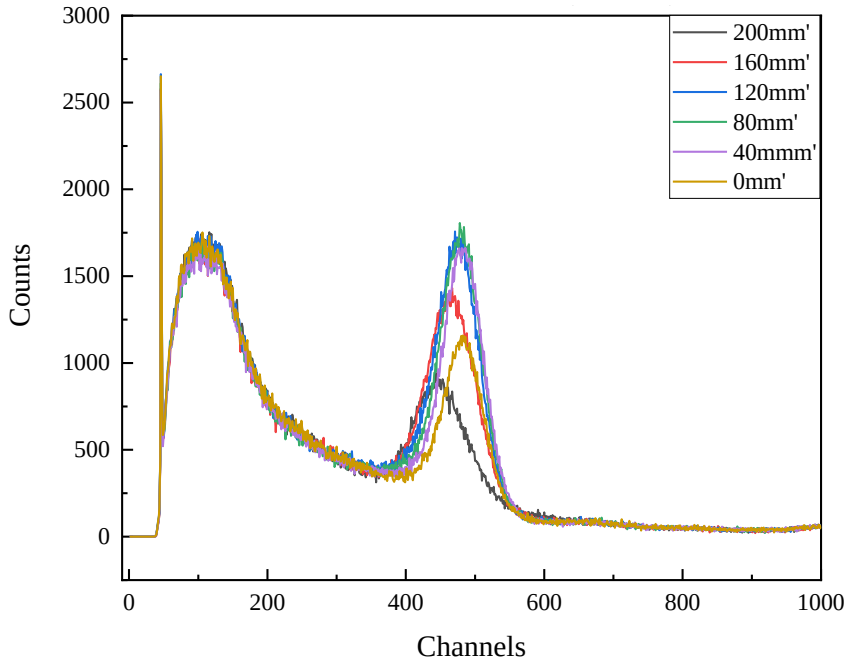
◆ The uniformity of the CsI detector was tested with ^{137}Cs source

- The energy spectrum at different position of the CsI detector were scanned with a distance of 40 mm.
- Maximum peak: ~490, Minimum peak: ~440
- Peak position Difference: ~10%

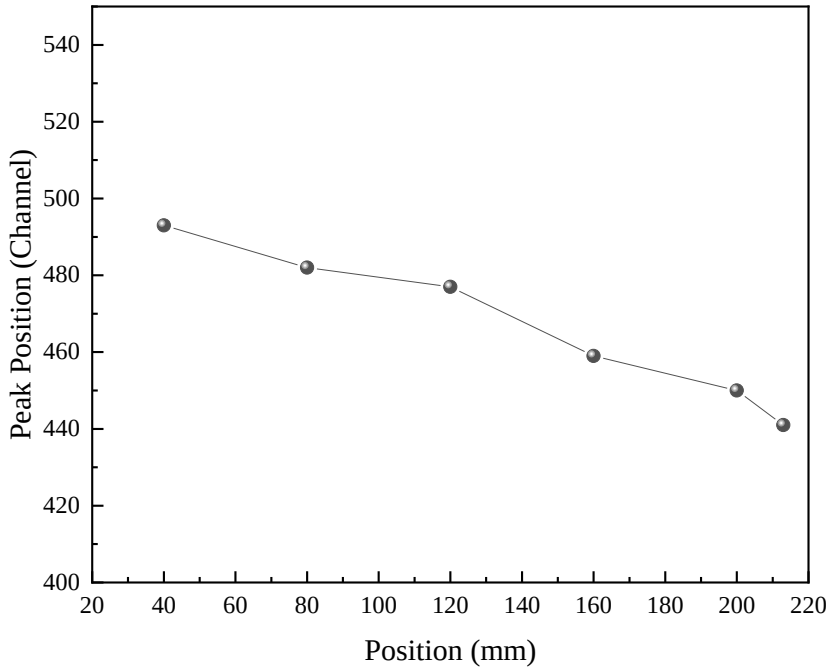


Dark box for light shielding

Collimator of source



Energy spectrum of ^{137}Cs source

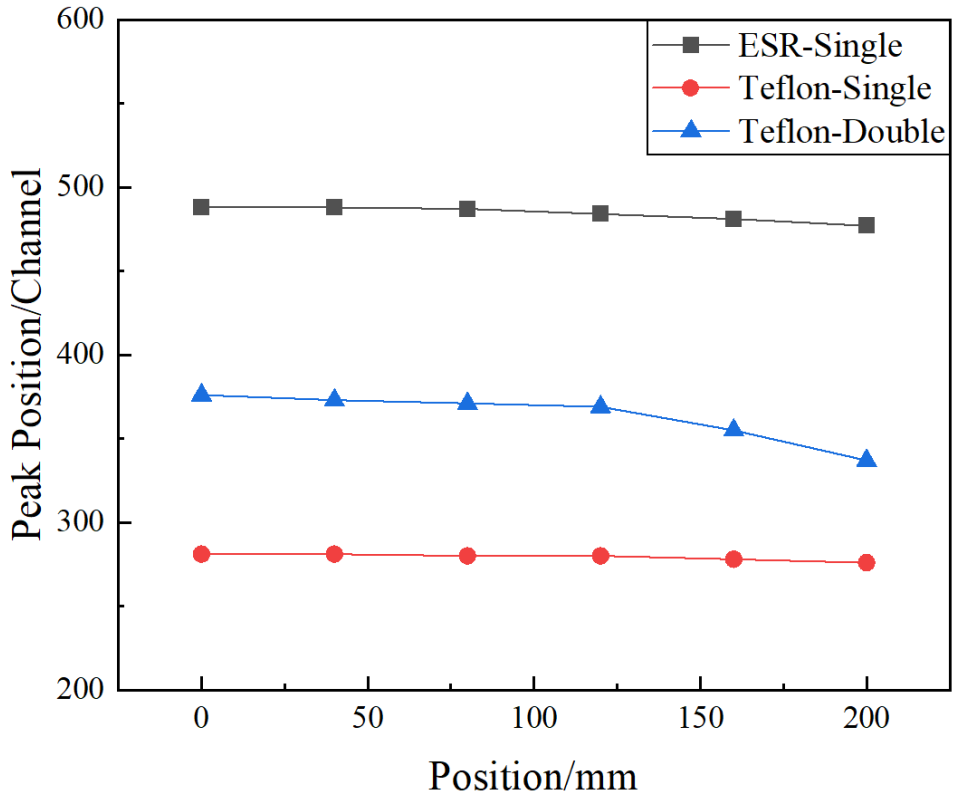


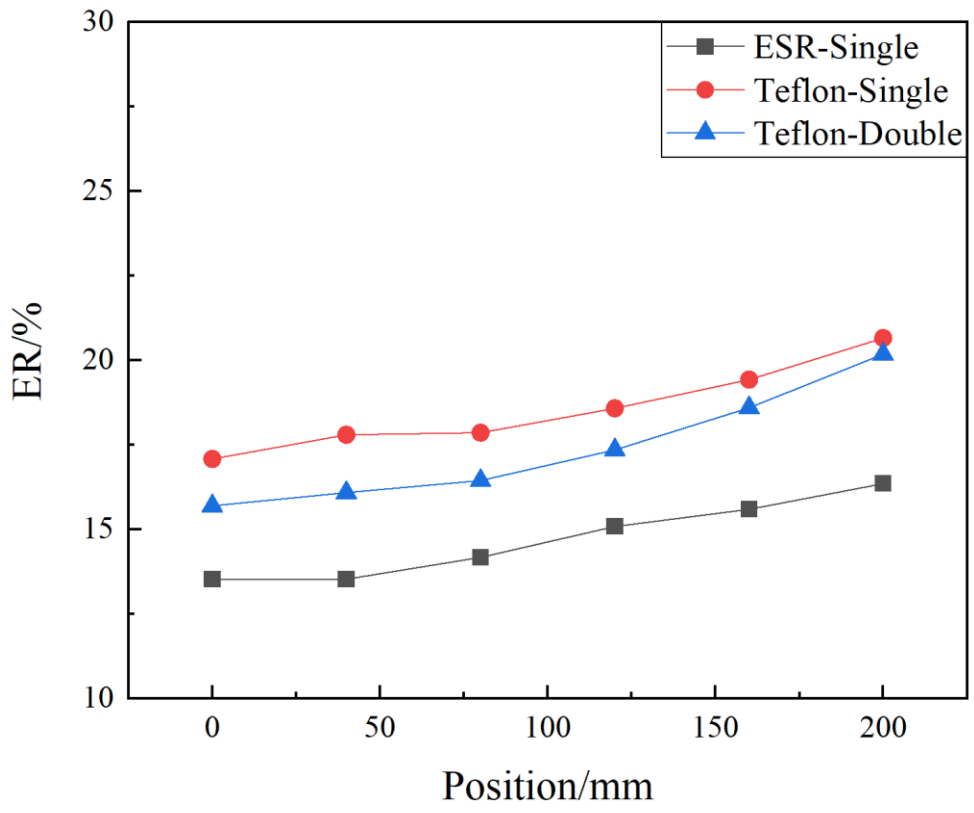
Peak vs. position

Different reflector layer

◆ The detector performance with different reflector layer were studied using uncollimated ^{137}Cs source.

- ESR (Enhanced Specular Reflector), Teflon (single and double)
- The ESR showing the maximum peak and the best energy resolution.
- An energy resolution of 12% can be achieved with 662 keV gamma rays.

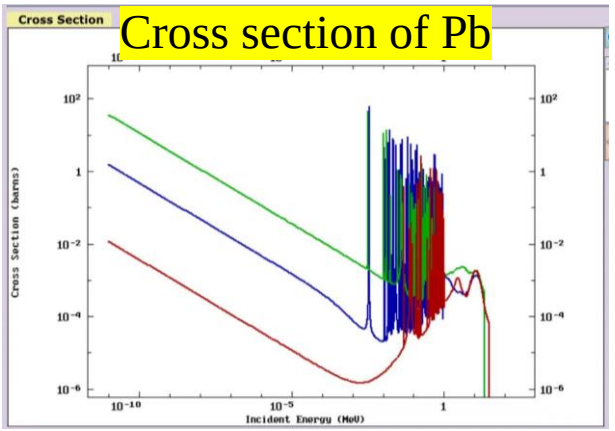


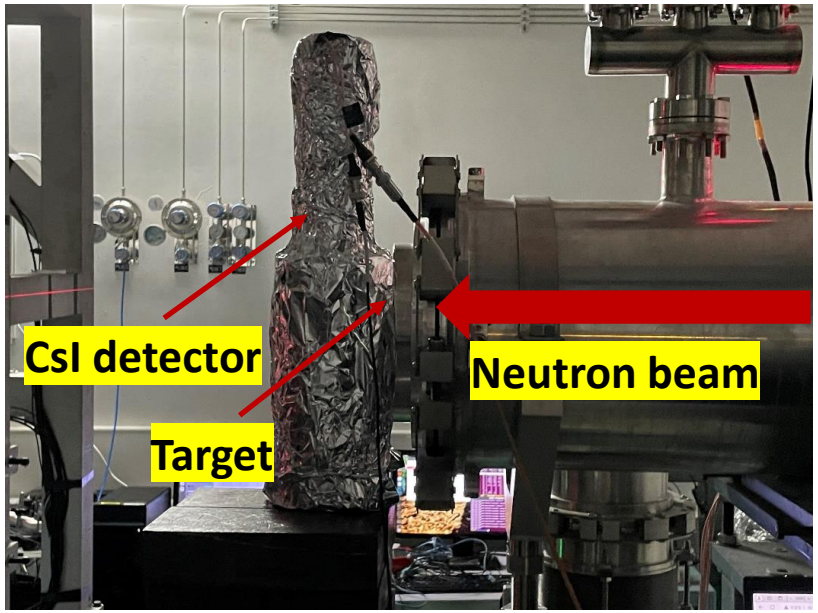


1st beam test at Back-n @2024

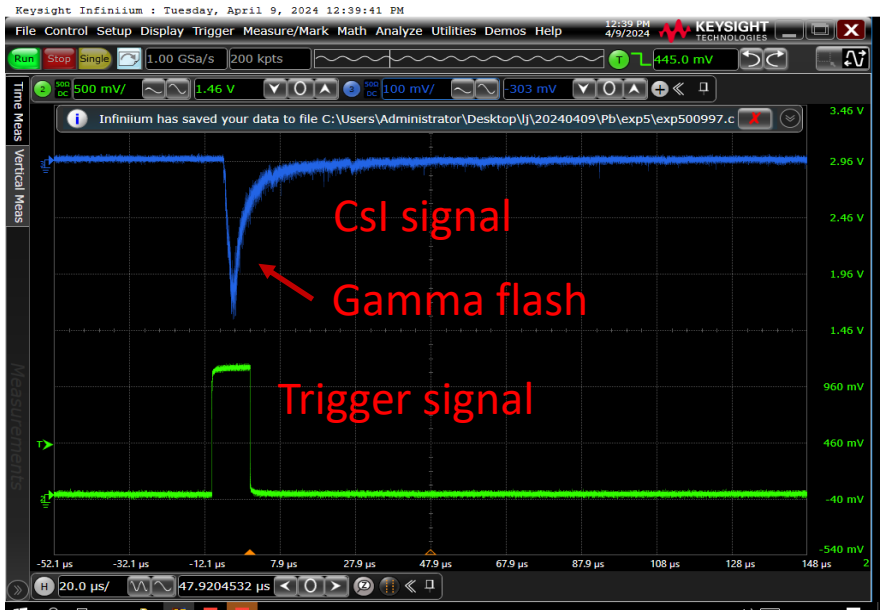
- The waveform response of the CsI detector to neutron induced γ rays was tested at Back-n

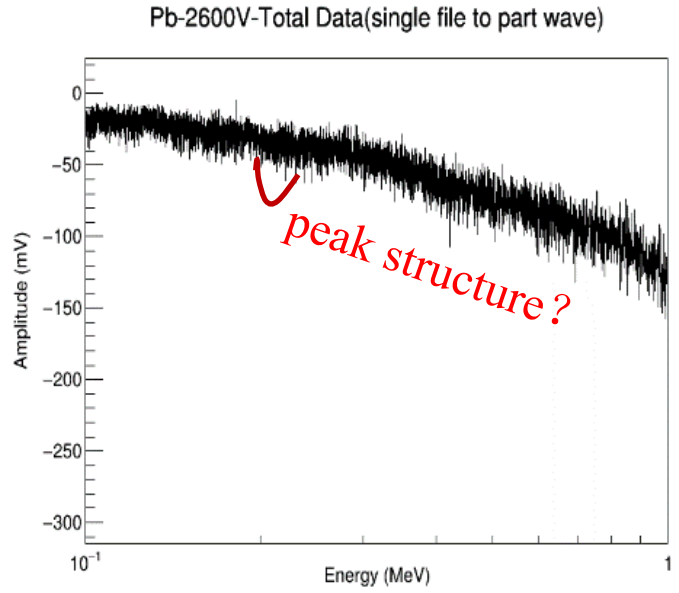
- Target: Ti & Pb
- Readout: waveform sampling by oscilloscope
- Due to the low gain of the PMT, we don't find peak structure on the waveform. The peak structure was hidden in the noise,





Experiment setup



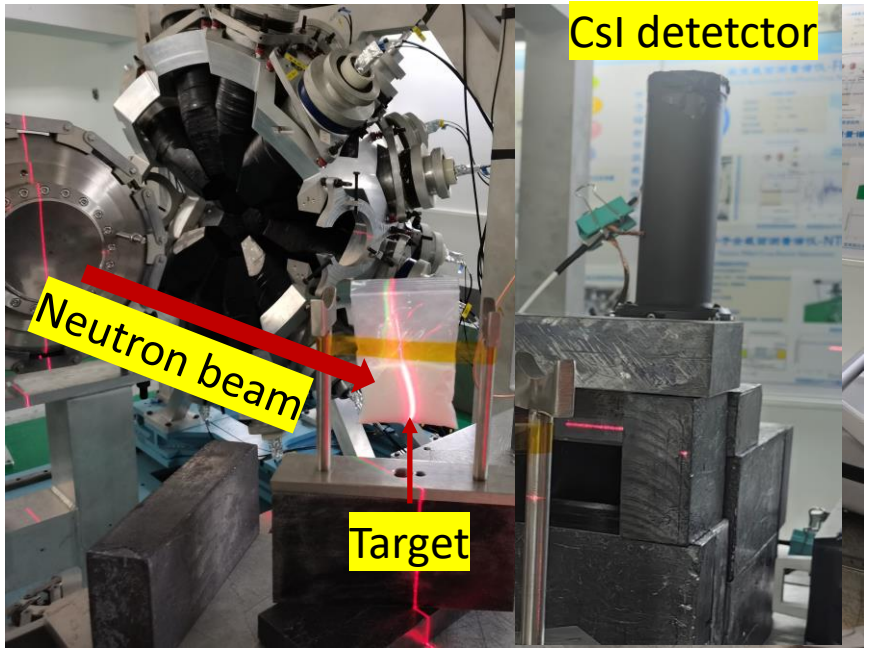


Typical signal waveform

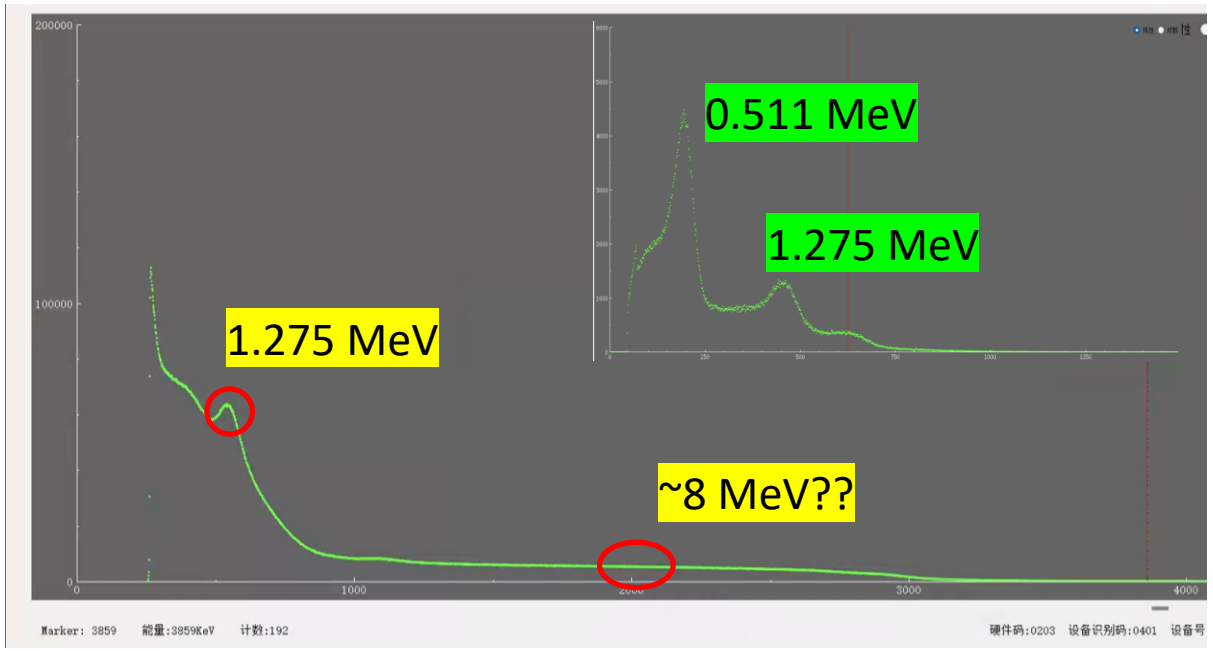
2nd beam test at back-n @2025

◆ The energy spectrum of the CsI detector to n-γ reactions was tested at Back-n

- Target: Salt in the self-sealing bag. ^{35}Cl capture neutron and emitting gamma rays ~8MeV.
- Readout: Pre-amp, Shaper-amp, MCA
- A ^{22}Na radioactive source was used to monitor the detector performance online.
- The 8MeV gamma ray should be at the channel of ~3000.



Experiment setup



Energy spectrum

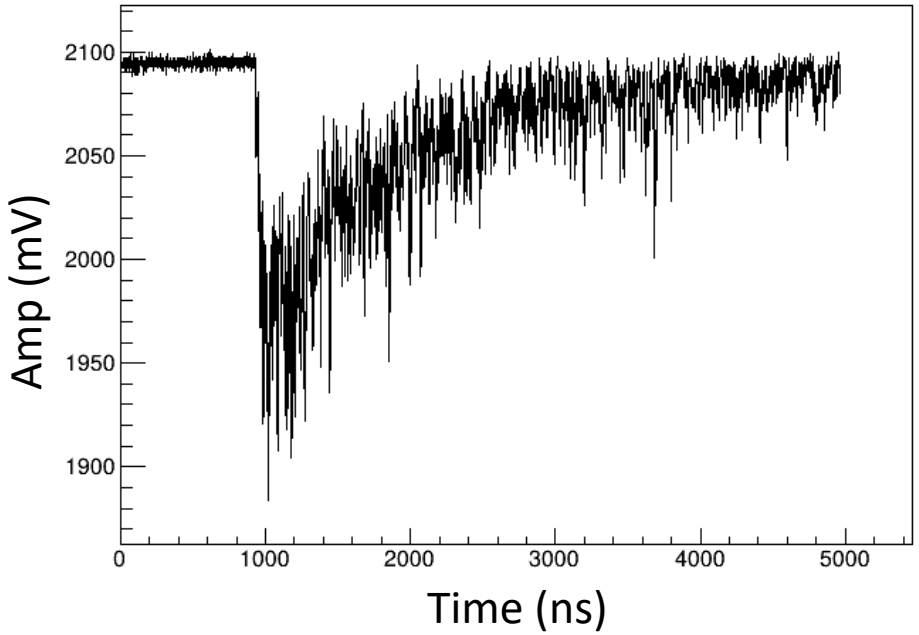
Detector optimization

◆ H1949-51 PMT produced by HAMAMATSU

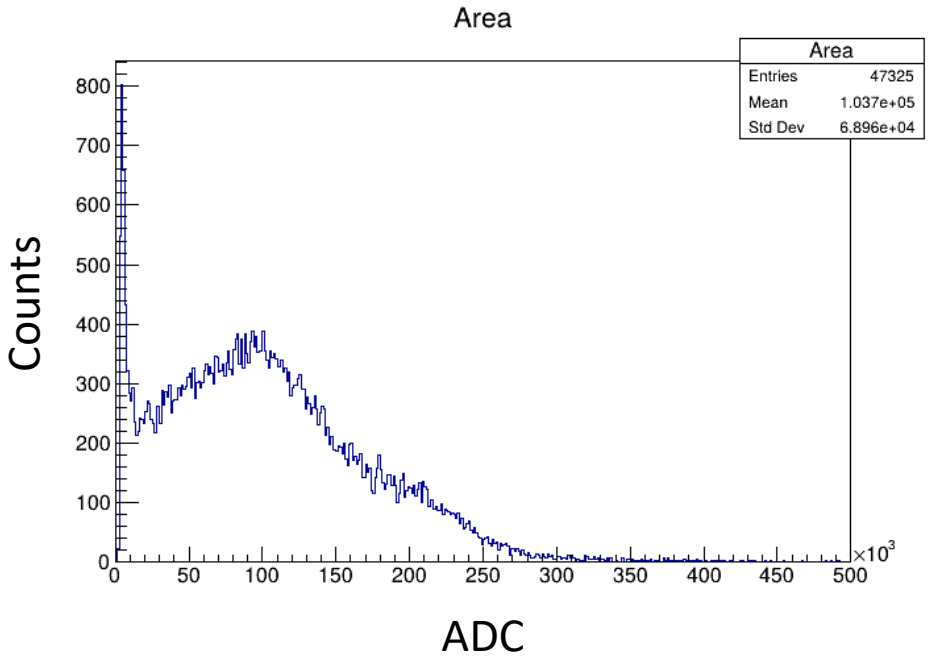
- Cathode size: Φ46mm
- Spectral response: 300-650 nm
- Rise time: ~1.3ns
- Gain: ~2e7 @2500V
- Maximum pulse linear current: 200 mA

- A higher gain PMT was used to record the waveform with the General purpose Readout Electronics at Back-n
- We plan to carry out 3rd beam test at Back-n.
- Neutron energy can be calculated by the TOF. Gamma energy can be calculated by the waveform area.

CsI + H1949-51 PMT



Typical waveform of ^{22}Na source



Waveform area distribution

Summary

- We have developed a large-size CsI detector with different PMT readout.
- Laboratory test with radioactive source have been done. The detector performance including the waveform response and energy spectrum have been measured.
- We carry out two beam test at Back-n CSNS for (n-γ) reactions measurement.
- We try to optimize the detector performance for next beam test.