



中国科学院高能物理研究所  
*Institute of High Energy Physics*  
*Chinese Academy of Sciences*



The Chinese Academy  
of Sciences

# Study on the Possibility of Neutron Gamma Discrimination in GAGG Crystal

**Reporter:** Ma Lishuang, Guo Hao

**Tutor:** Qian Sen, Wang Zhigang

[qians@ihep.ac.cn](mailto:qians@ihep.ac.cn)

26th. May. 2021

International  
Conference  
on Technology and  
Instrumentation  
in Particle Physics



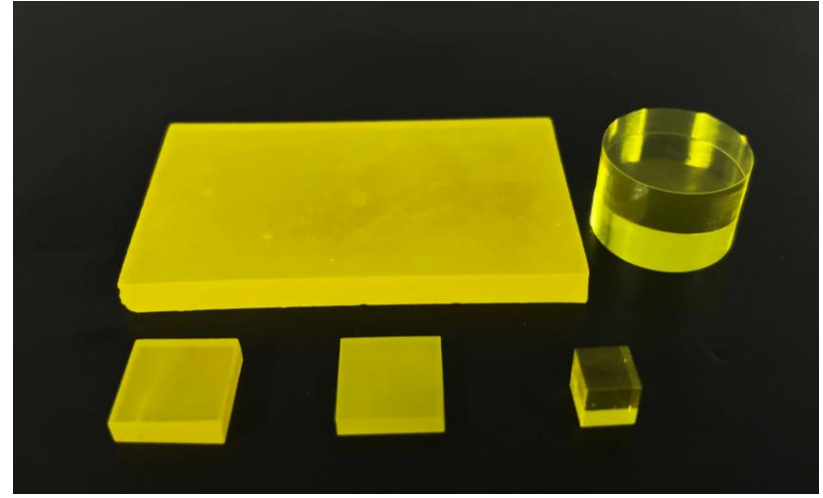
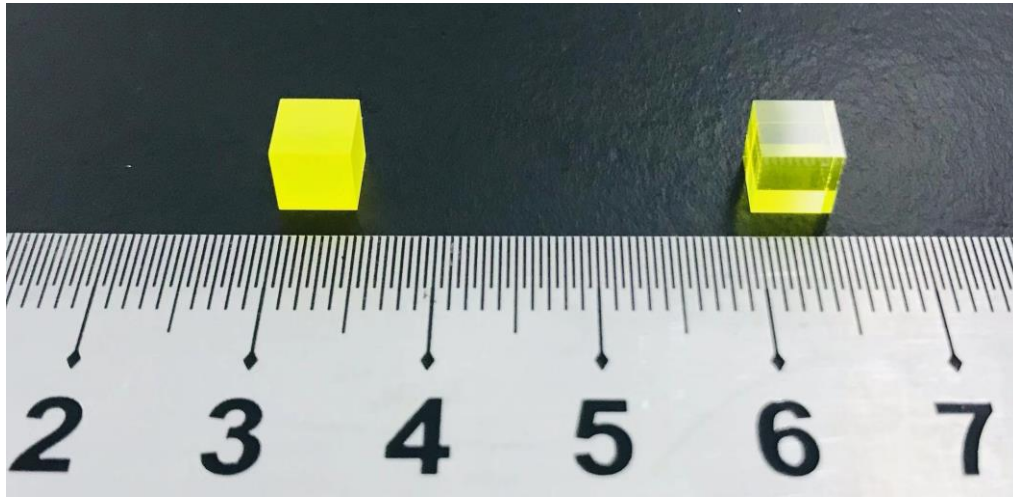
# **Content**

**1. Introduction of GAGG Crystal**

**2. GAGG thermal neutron detection**

**3. N/ $\gamma$  discrimination based on GAGG**

# ➤ 1. Introduction of GAGG Crystal



GAGG(Ce) - Gadolinium Aluminium Gallium Garnet ( $\text{Gd}_3\text{Al}_2\text{Ga}_3\text{O}_{12}$ ), doped with Ce is a newly developed scintillator. It is one of the brightest available scintillators with an emission peak at 500~550nm. The Light yield and decay time will be influent by the ratio of Gadolinium and Gallium.

Variant	Photons/MeV	Decay Time(ns)
High Light Yield	60000	<150
Balanced	50000	<90
Fast Decay	40000	<50

## ➤ 1.2 Performance Compare of GAGG

--Performance comparison of GAGG crystals from different manufacturers

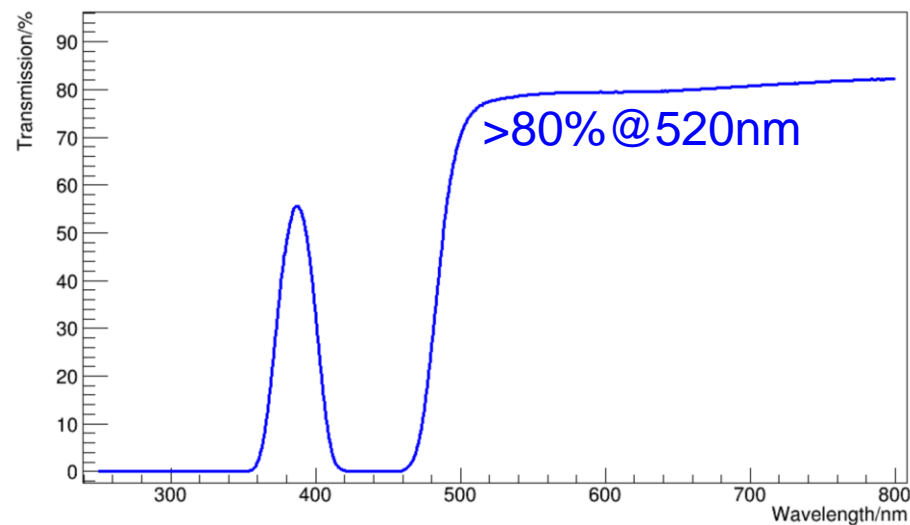
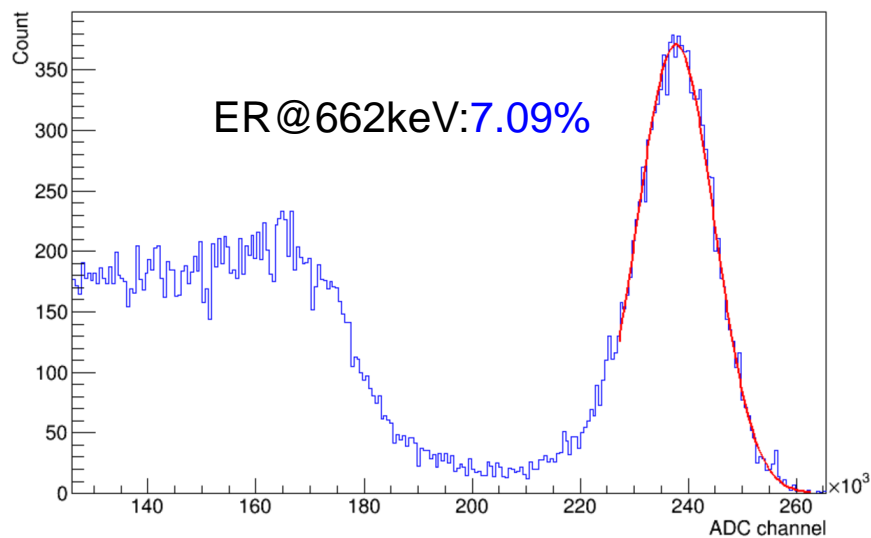
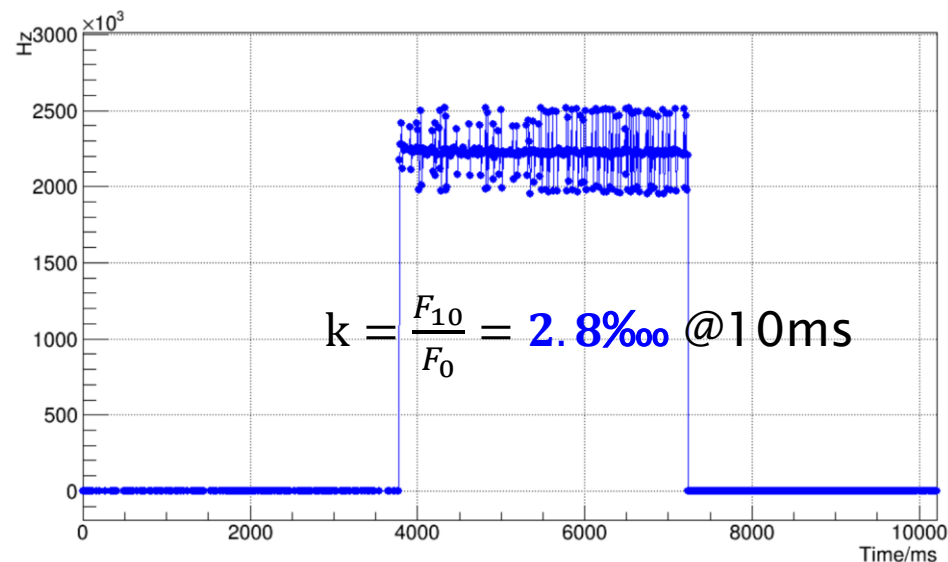
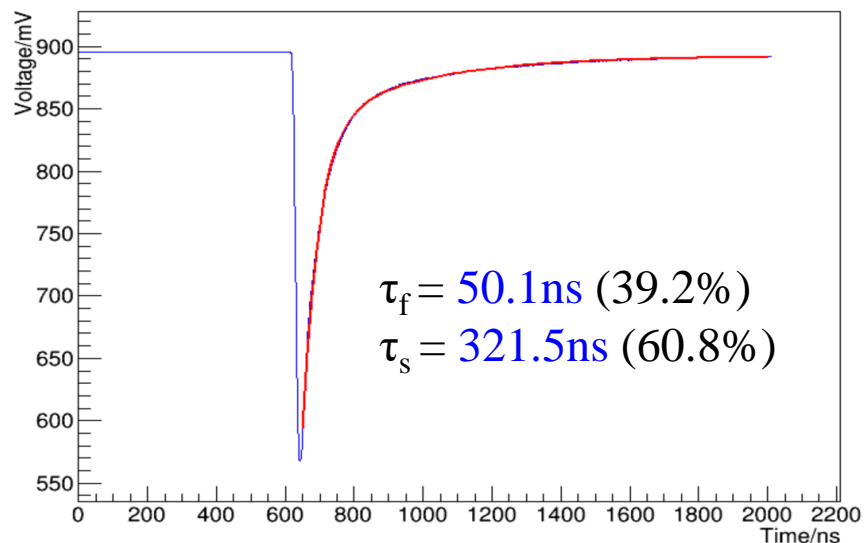
	FURUKAWA(Japan) <sup>ref1</sup>	Advatech(UK) <sup>ref2</sup>	Sample Crystals <sup>ref3</sup>
Density(g/cm <sup>3</sup> )	6.63	6.63	6.63
Light yield (photon/MeV)	57,000	40000~60000	31405
Decay time (ns)	88 (91%) 258 (9%)	50~150	50.1(39.2%) 321.5(60.8%)
Peak emission (nm)	520	520	530,560
Energy resolution (%@662keV)	5.2 (5x5x5mm <sup>3</sup> with APD)	5.2±0.1	7.1 (5x5x5mm <sup>3</sup> with SiPM)
Melting point (°C)	1,850	1850	1850
Hygroscopic	No	No	NO

Ref1: K. Kamada, T. Yanagida, J. Pejchal, M. Nikl, T. Endo, K. Tsutsumi, Y. Fujimoto, A. Fukabori, A. Yoshikawa *IEEE Trans. Nucl. Sci.*, 59 (2012), pp. 2112-2115

Ref2: [https://www.advatech-uk.co.uk/gagg\\_ce.html](https://www.advatech-uk.co.uk/gagg_ce.html)

Ref3: Sample crystal from Chinese company, tested in our lab.

## ➤ 1.3 Performance Test of GAGG



Transmittance @ 520nm 5

# Content

1. Introduction of GAGG Crystal

**2. GAGG thermal neutron detection**

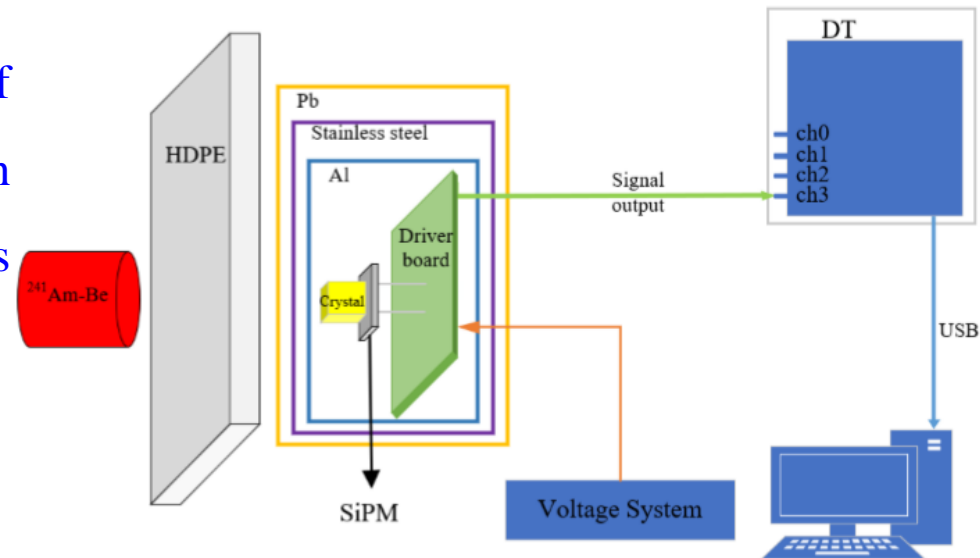
3. N/γ discrimination based on GAGG

## ➤ 2.1 Thermal neutron detection of GAGG

--The thermal neutron capture cross section of Gd isotope is as high as **255,000 kbarn**, which is the largest thermal neutron reaction cross section among known nuclides.

### Measurement condition :

- Crystal size: 6\*6\*1mm GAGG crystal
- Threshold: 40mV
- Detector: 75 $\mu$ m MPPC H
- Sampling time : 18h
- Radioactive source:  $^{252}\text{Cf}$  \  $^{241}\text{Am Be}$
- 1 layer moderator
- No lead brick

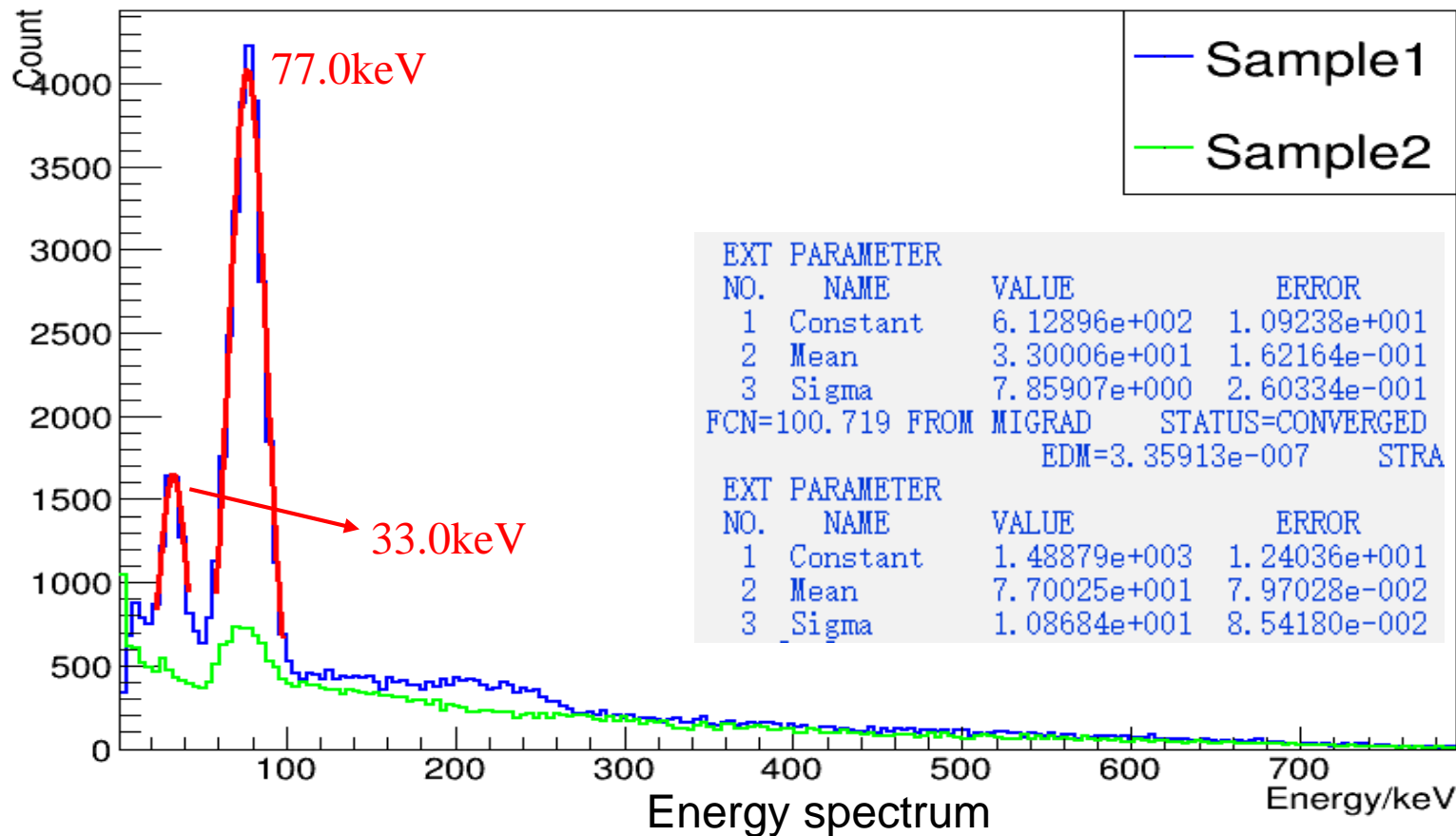


Experimental principle and device diagram



Thermal neutron experiment test site

## ➤ 2.2 GAGG crystal neutron detection test results



- Sample1 is thermal neutron, Sample2 is background;
- A Gd-containing scintillator will generate 33keV internal conversion electrons and 44keV Gd KX rays, resulting in a 77keV scintillation peak
- The ratio of the number of thermal neutron events to the number of background events at 77keV is 5.65 .
- Prove that GAGG crystal can be used for thermal neutron detection



# Content

1. Introduction of GAGG Crystal

2. GAGG thermal neutron detection

**3. N/ $\gamma$  discrimination based on GAGG**

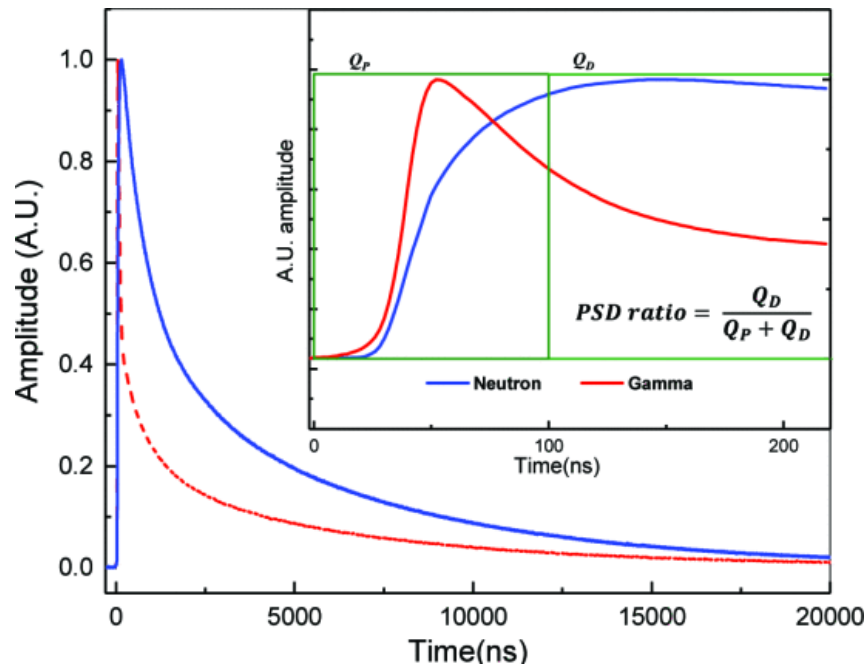
## ➤ 3.1 N/γ discrimination based on PSD

Pulse Shape Discriminator, PSD

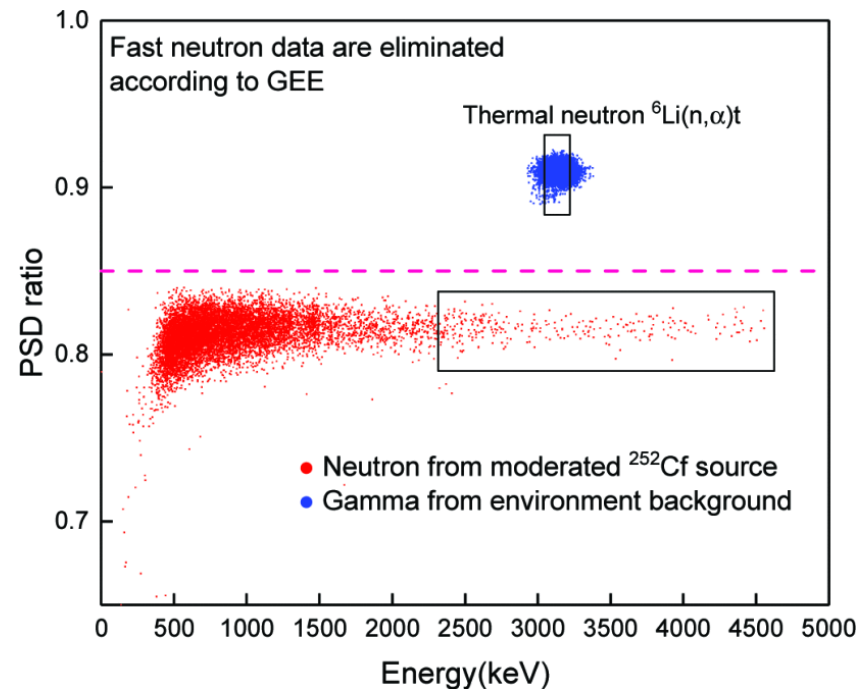
**Long integration:** Integrate the entire waveform ( $Q_D$ )

**Short integration:** intercept part of the waveform and perform partial charge integration( $Q_P$ )

**Charge PSD algorithm:** 
$$PSD\ ratio = \frac{Q_D}{Q_P + Q_D}$$

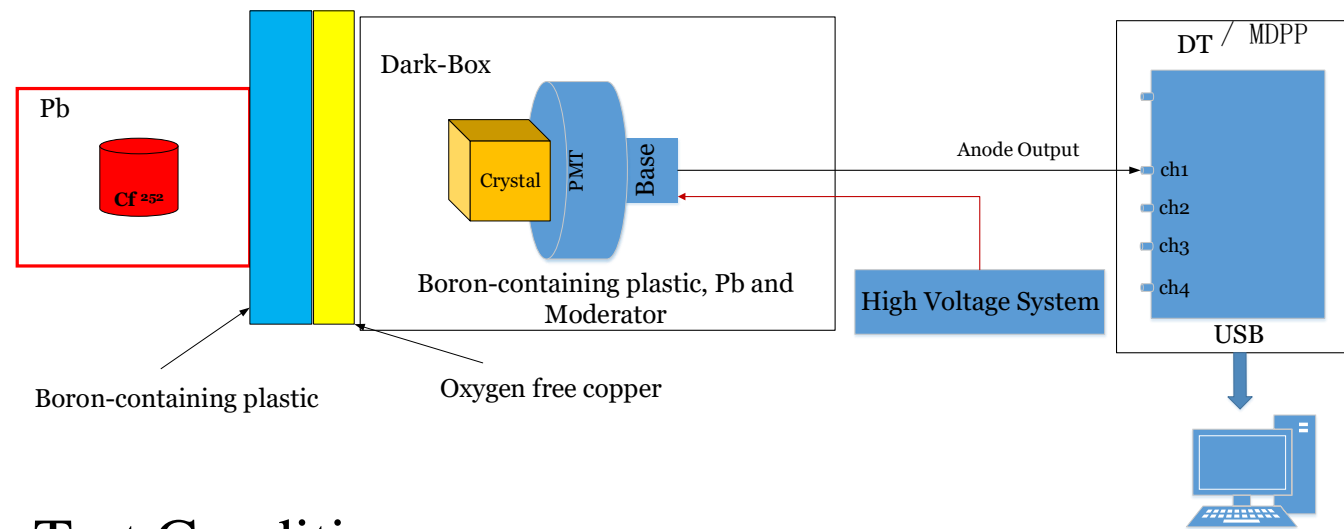


Normalized and averaged neutron and gamma-ray pulses.



Neutron and gamma-ray PSD ratio distribution. Squared area is used to calculate the FOM

## ➤ 3.2 Setup of the experiment



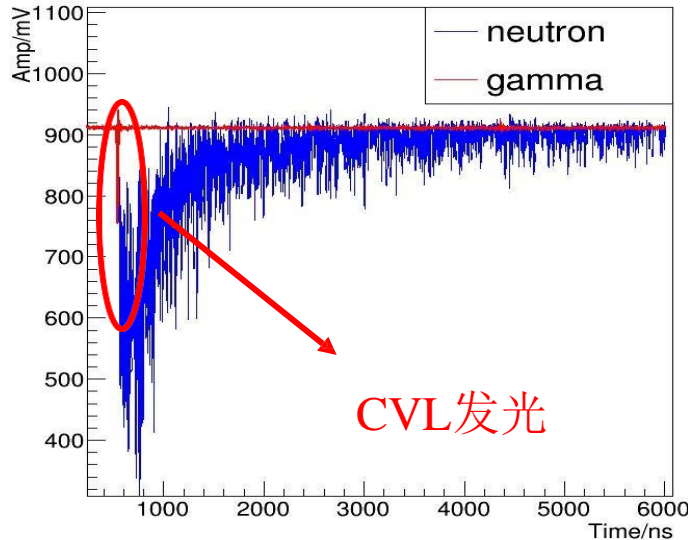
PMT type	XP2020
HV	-1700V
TTS	ns-level
RT	>1ns

### Test Conditions:

- Crystal: GAGG / CLYC
- PMT: XP2020 -1700V@SPE
- Source: Cf-252
- DAQ: DT5751 / MDPP
- Background: lead brick + boron-containing plastic + oxygen-free copper
- Silicone oil is used to couple crystal and PMT

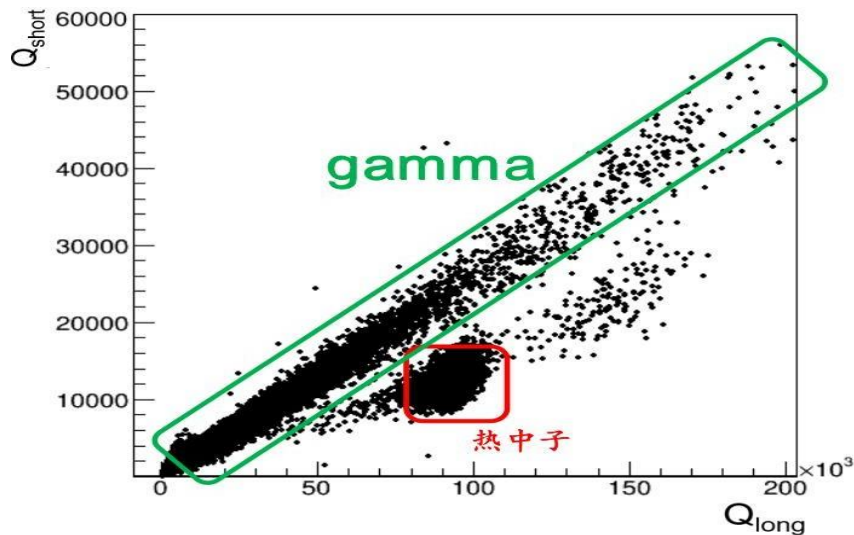
	DT5751	MDPP
Time resolution	~1ns	24ps
Waveform acquisition	yes	No
QDC	yes	yes
TDC	yes	yes

### ➤ 3.3 CLYC crystal N/γ discrimination by PSD

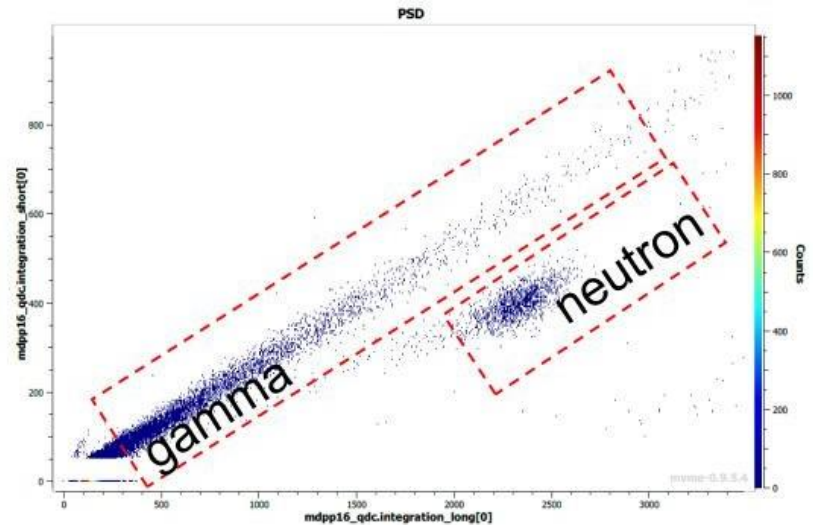


- CLYC can produce CVL (Core to Valence Luminescence) luminescence with a decay time of no more than **2 ns** under gamma ray excitation, but there is no CVL luminescence under neutron excitation.
- The  $^6\text{Li}$  isotope CLYC crystal can be used to detect thermal neutrons, and the  $^7\text{Li}$  isotope crystal can be used for fast neutron measurement.

Neutron/γ waveform of CLYC tested in our lab

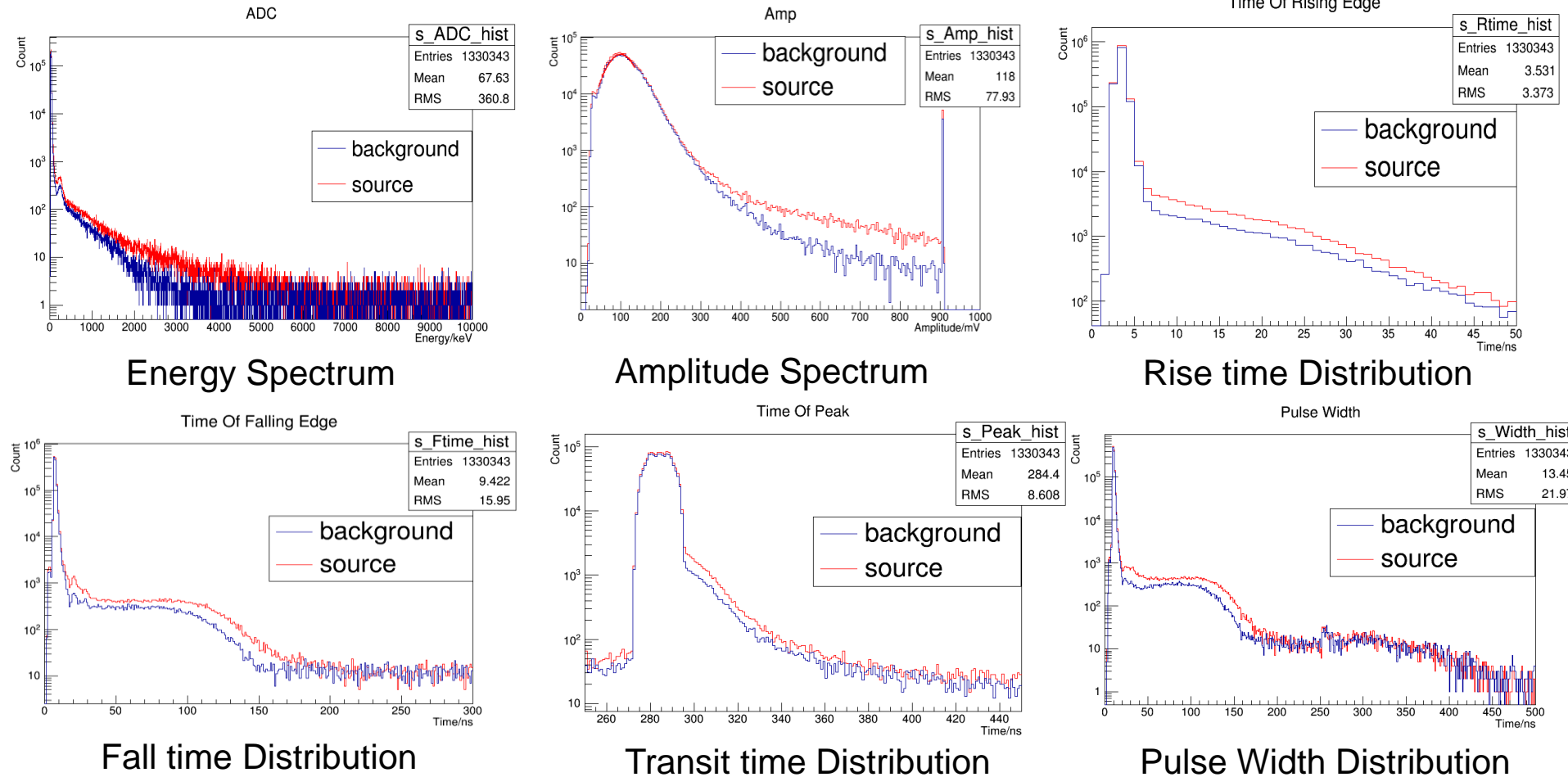


PSD result tested by DT  
(time resolution 1ns)



PSD result tested by MDPP  
(time resolution 24ps)

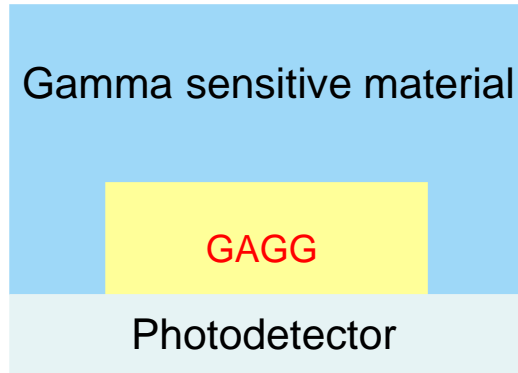
## ➤ 3.4 Result of GAGG coped with PMT



The analysis shows that there are obvious differences in Energy spectrum; there is no obvious difference between background and active waveforms.

**NOTE:** The background in the figure represents the background data; source represents the data of the interaction between  $^{252}\text{Cf}$  and the crystal

## ➤ 3.5 N/ $\gamma$ discrimination using composite crystal



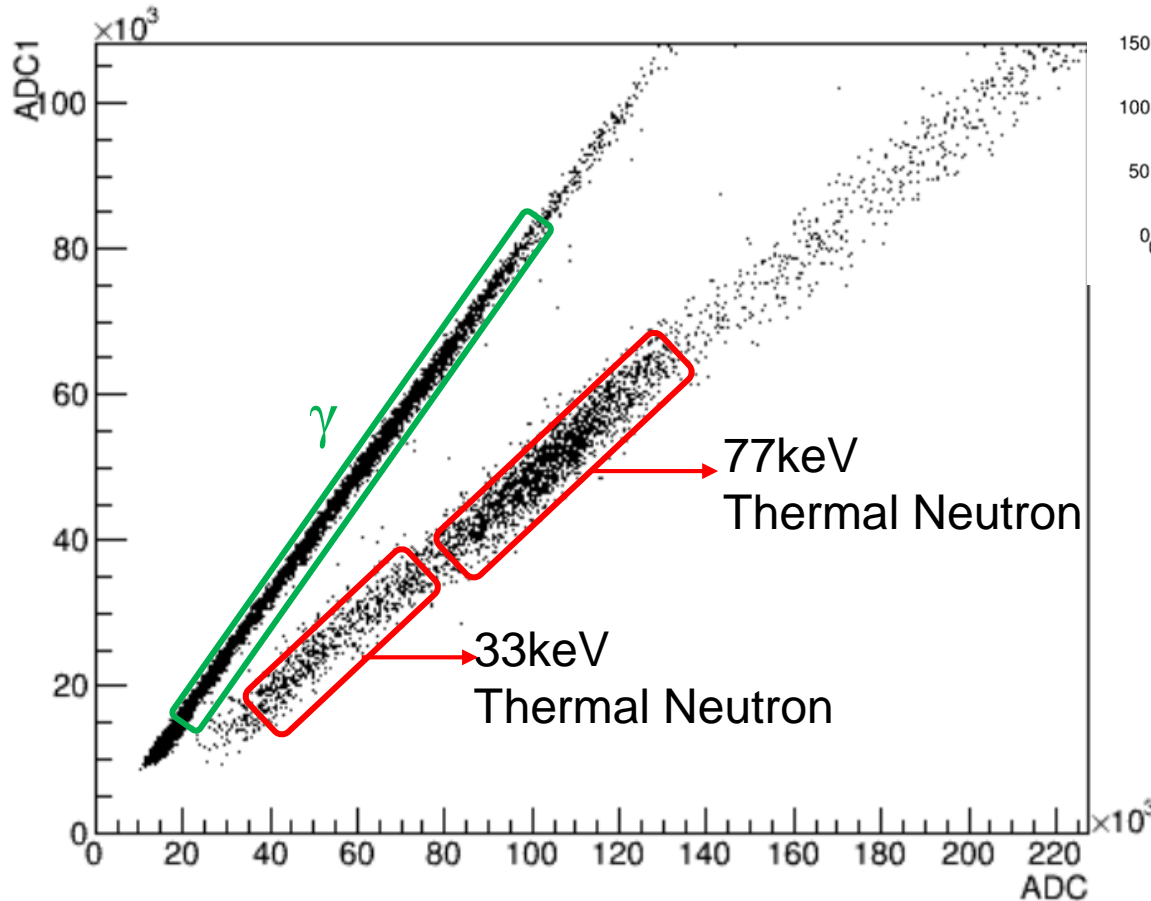
- A thermal neutron detector: This detector is composed of two crystals stacked and nested, and the scintillation light signals of the two crystals are read out by the same photoelectric device such as SiPM or PMT. Among them, GAGG:Ce crystals are thin, 0.2mm~ 1 mm or even thinner, and are used to detect thermal neutron signals.

### **Uses of Gamma Sensitive crystals:**

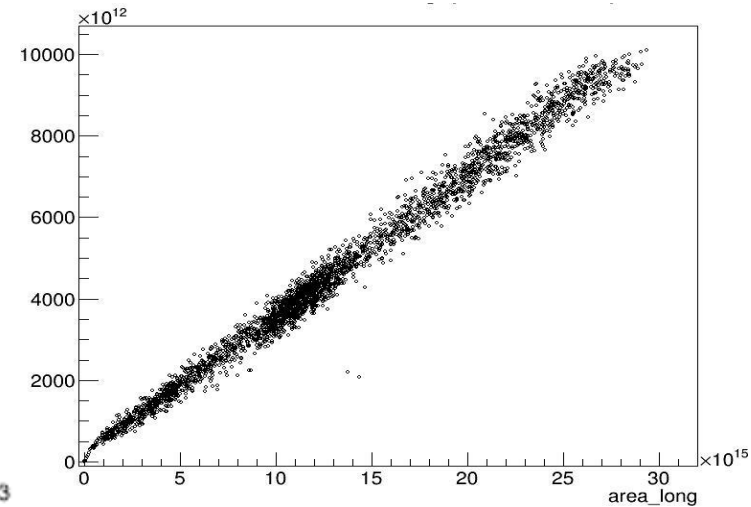
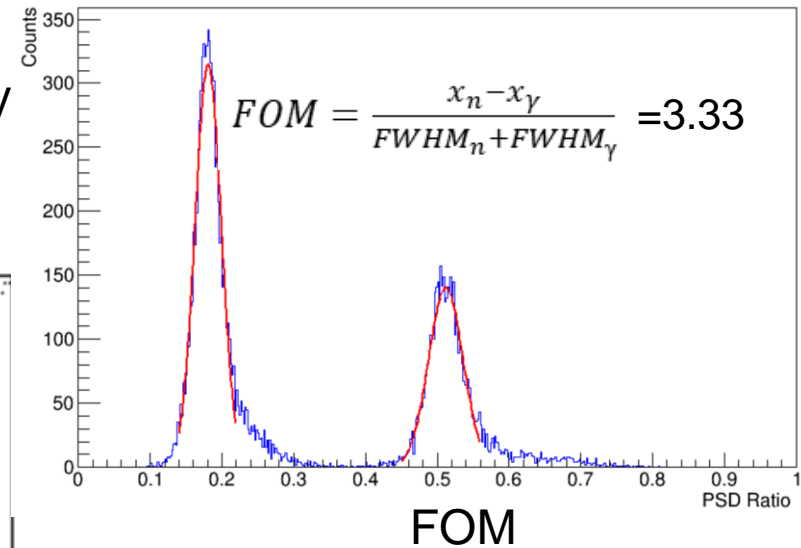
- Detect the gamma signal accompanied by thermal neutrons, and realize the counting of gamma signals
- It is used to shield low-energy gamma signals and achieve full absorption of low-energy gamma rays to prevent them from depositing energy in the GAGG:Ce crystal.

## ➤ 3.6 N/γ discrimination using composite crystal

- The composite crystal has achieved N/γ discrimination, and thermal neutrons at 33keV and 77keV can also be resolved.



PSD result of composite GAGG crystal



PSD result of Single GAGG crystal

## ➤ 4. Summary

- The neutron experiment of a single GAGG crystal verifies that thermal neutrons can be detected by GAGG.
- We used the method of composite crystals to realize the N/  $\gamma$  identification based on PSD method.
- The next step is to use fast timing PMT coupled with GAGG single crystal for PSD based on time information.



**THANK YOU!**