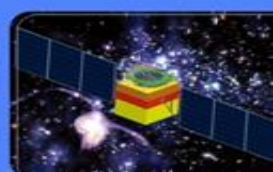


超快光电倍增管在全球束流测试的情况

WWW.IHEP.CAS.CN



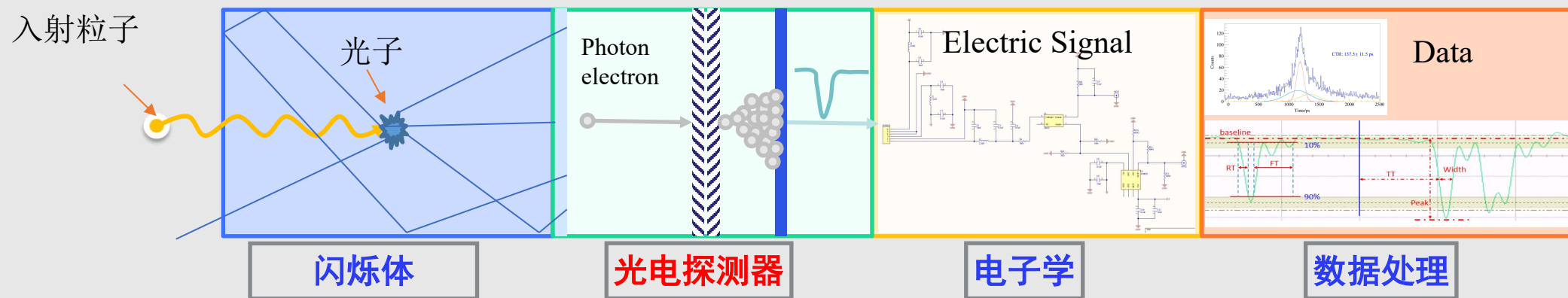
陈灵玥、钱森、吴琪、马丽双

The Institute of High Energy Physics, CAS

2025. 8.16

- 1. 超快光电倍增管 (FPMT) 简介
- 2. CSNS 质子束流实验
- 3. Fermi 质子束流实验
- 4. CERN muon束流实验
- 5. KEK 电子束流实验
- 6. CERN 质子束流实验计划

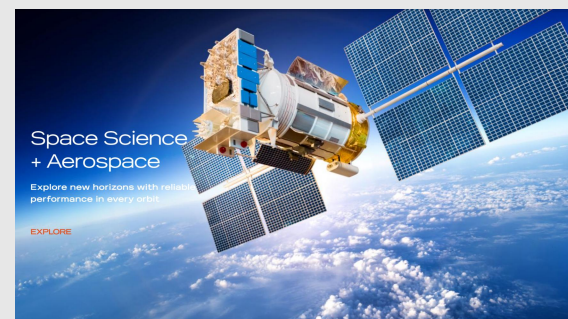
1 超快光电倍增管简介



分析仪器



医疗成像



空天物理



高能物理

1 超快光电倍增管简介

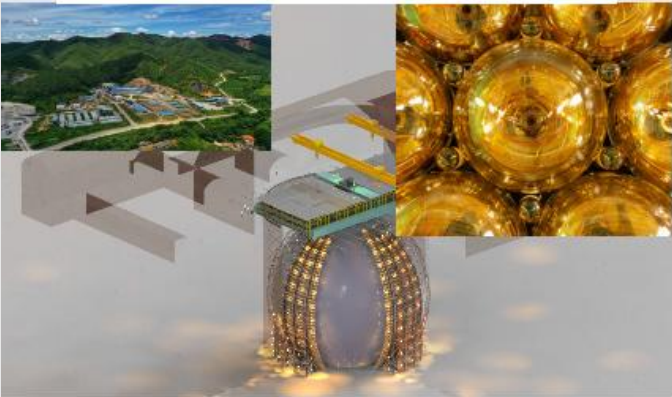
		FPMT	LPMT
MCP		2" MCP-PMT ✓	20" MCP-PMT ✓

PMT合作组:

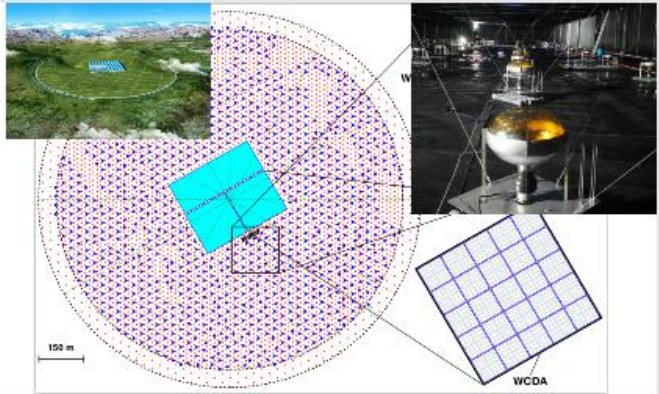
LPMT: 2009-2019;

FPMT: 2020-2025;

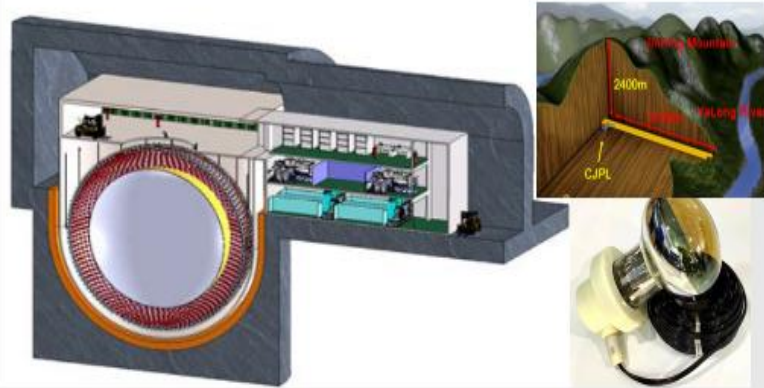
JUNO: 20" PMT: 15000 Pics, 75%



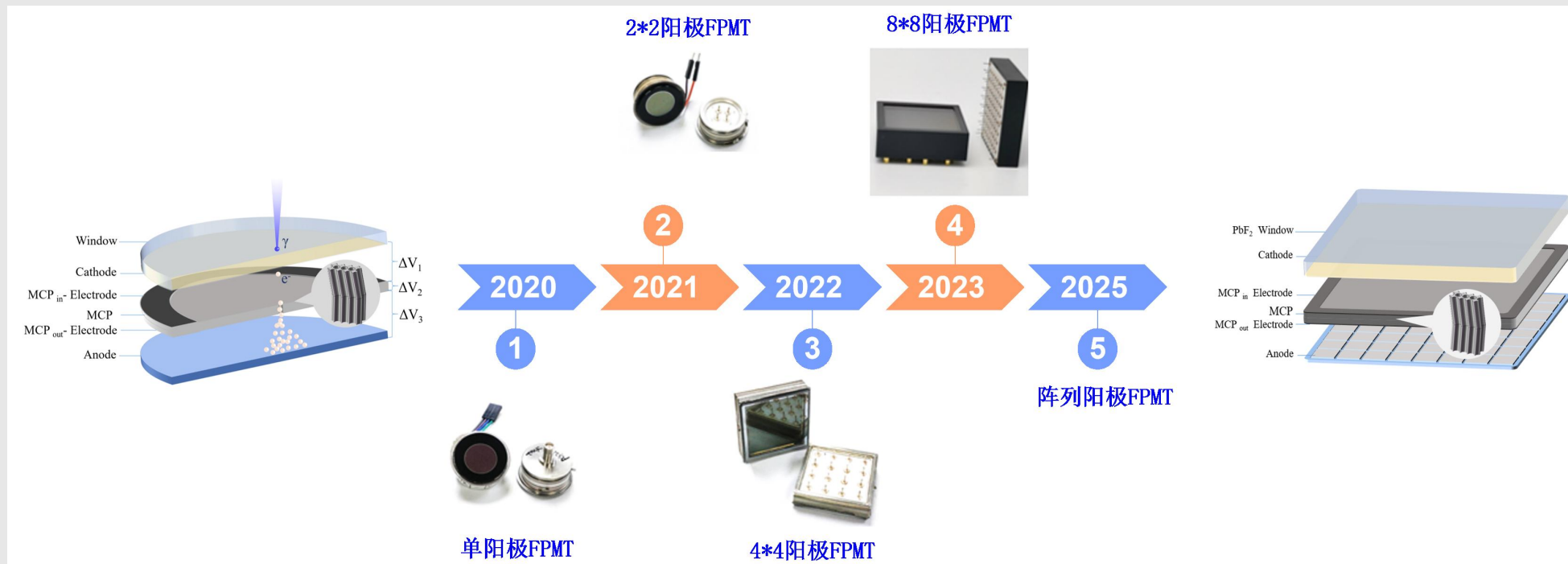
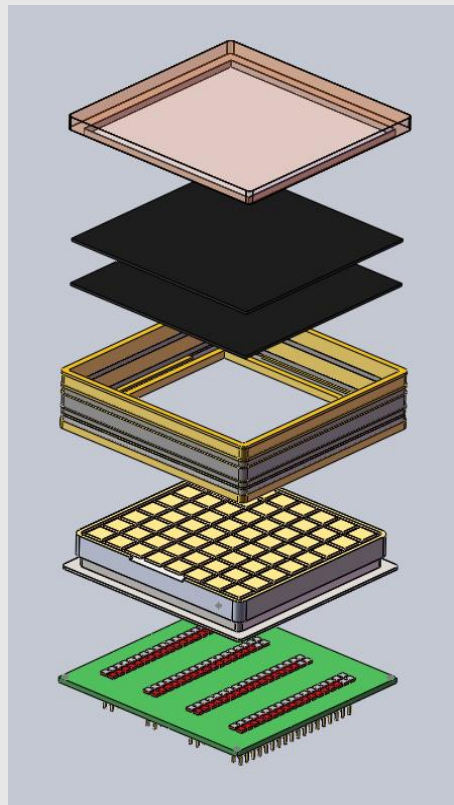
LHAASO: 20" PMT: 2700 Pics, 100%



✓ The FAST 8" MCP-PMT for JNE



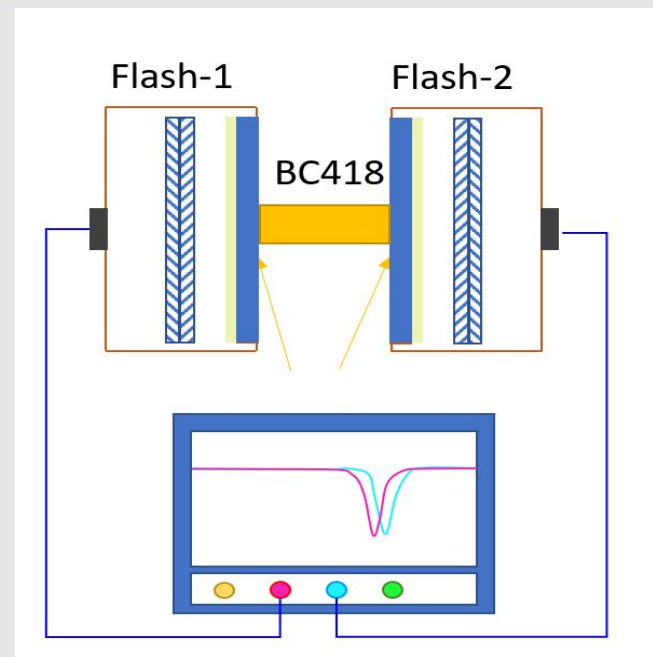
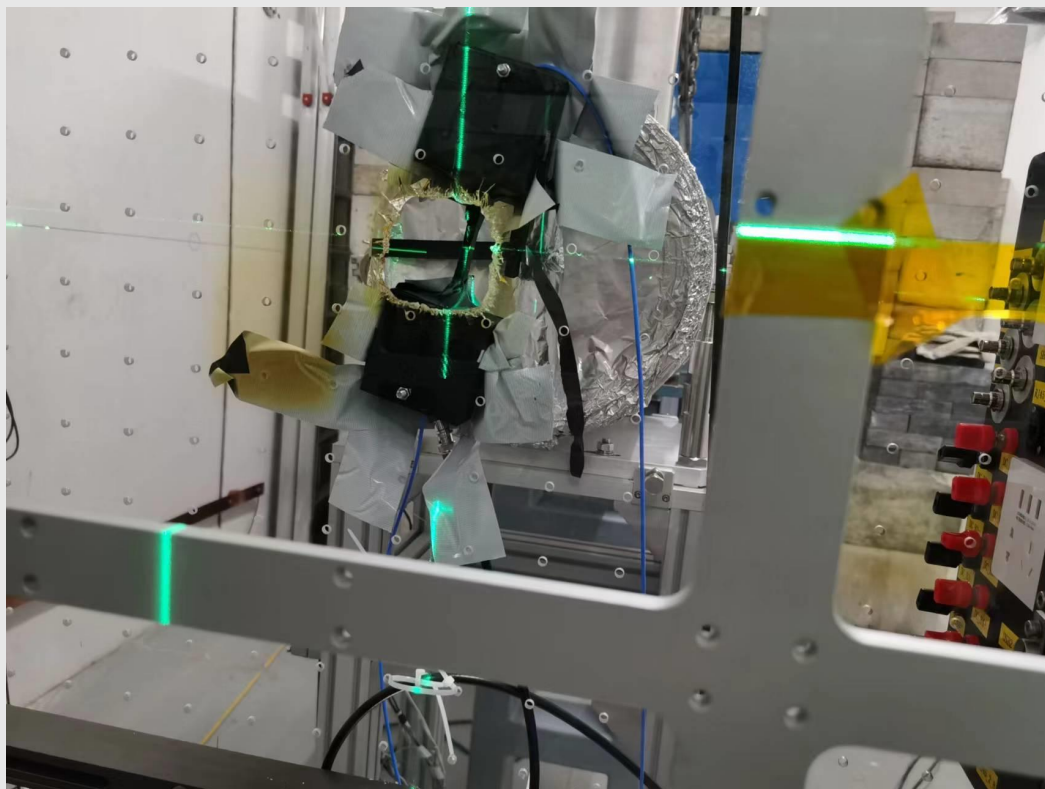
1 超快光电倍增管简介



自2020年以来，从单阳极到多阳极，合作组成功研发了一系列FPMT，尤其是对单阳极和8×8阳极FPMT的性能进行了不断改进。我们选取多种超快闪烁体与FPMT耦合，在多种束流条件下测试其符合时间分辨（Coincidence Time Resolution, CTR）性能。

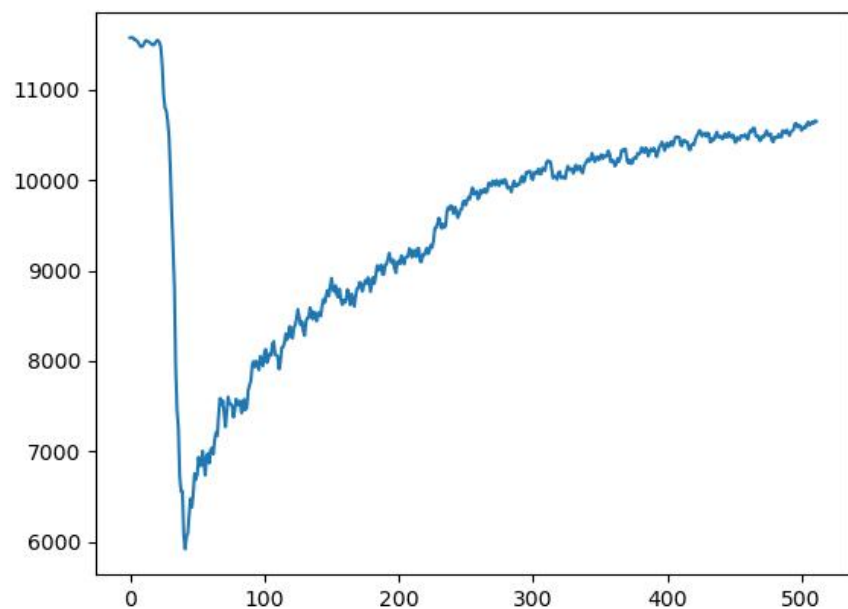
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2 CSNS 质子束流实验

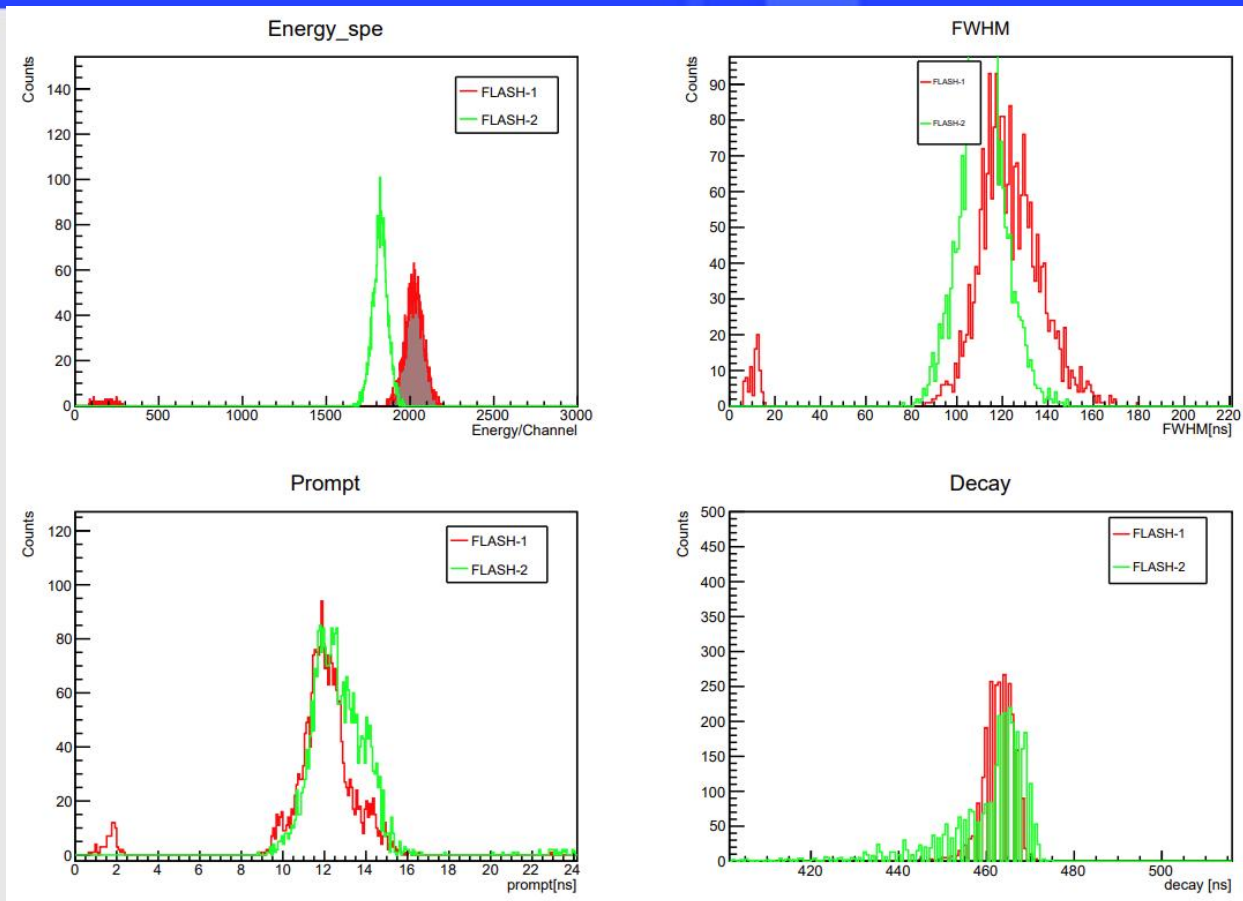


- CSNS 80MeV 质子束流测试
- 测试闪烁体: BC418
- PMT: 单阳极FPMT
- DAQ card (1GSa/s sampling rate)
- 实验时间: 2022.11

2 CSNS 质子束流实验

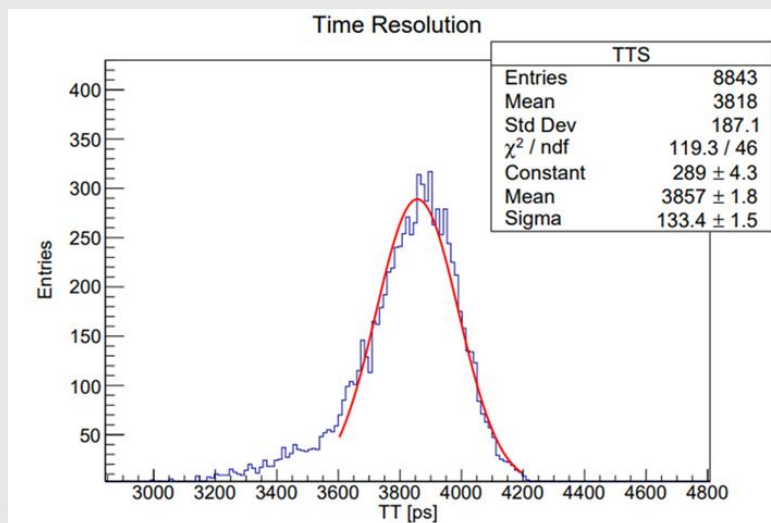
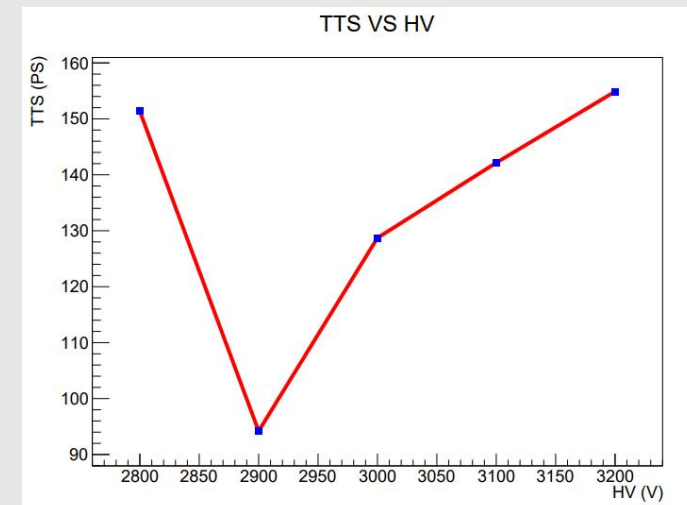
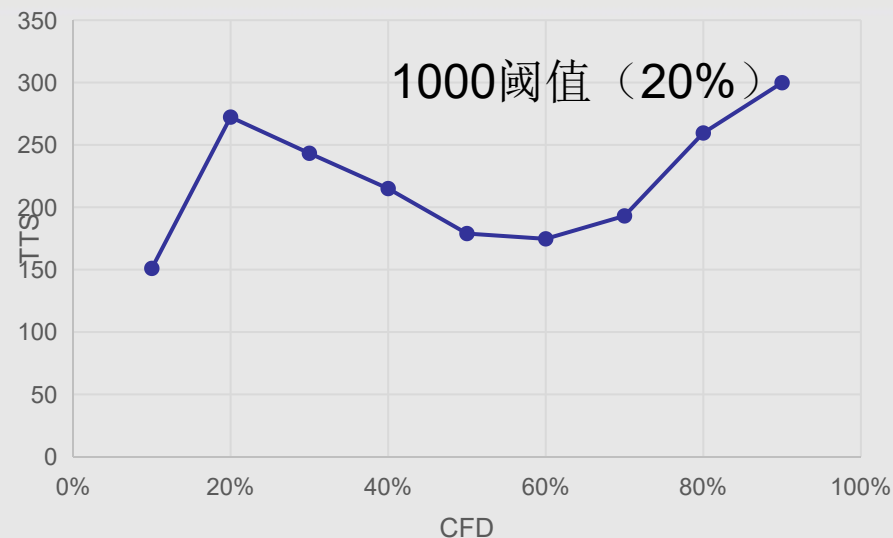
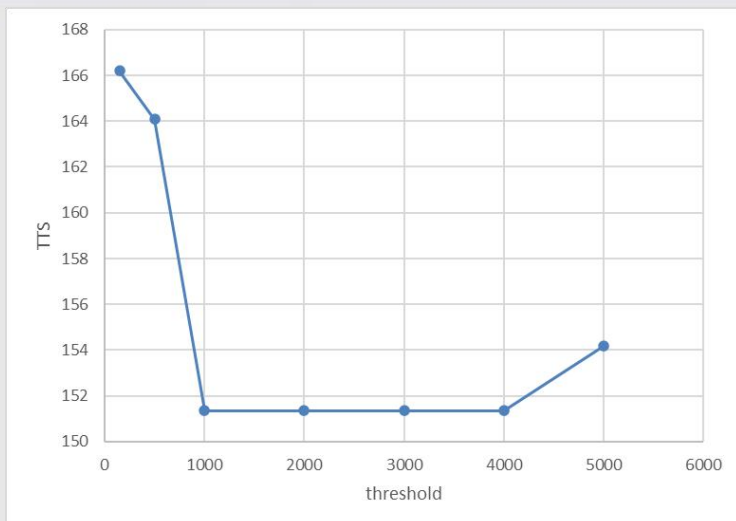


典型波形



	FWHM	Prompt	Decay
FPMT1	120 ns	12 ns	470 ns
FPMT2	110 ns	11 ns	470 ns

2 CSNS 质子束流实验



通过调整阈值、定时比例以及FPMT高压，得到**最佳CTR**：

$$\sigma = 133.4 \text{ ps}$$

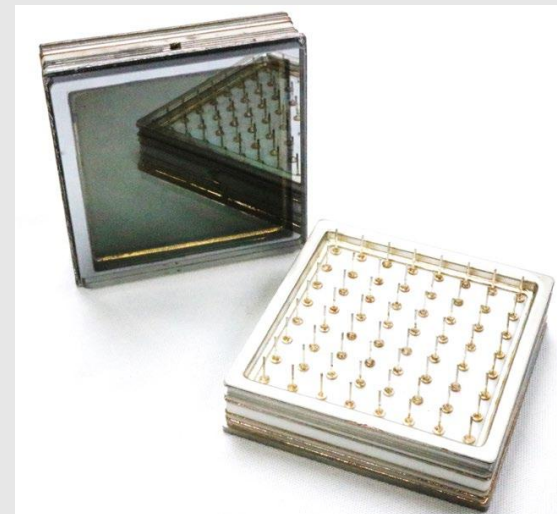
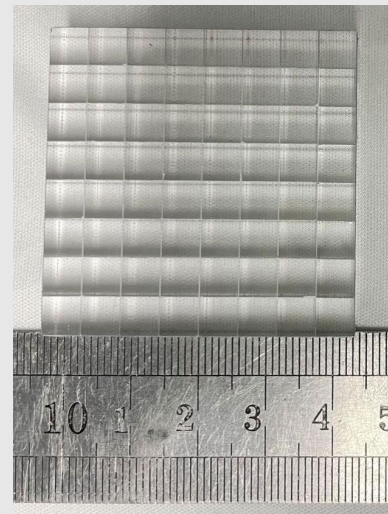
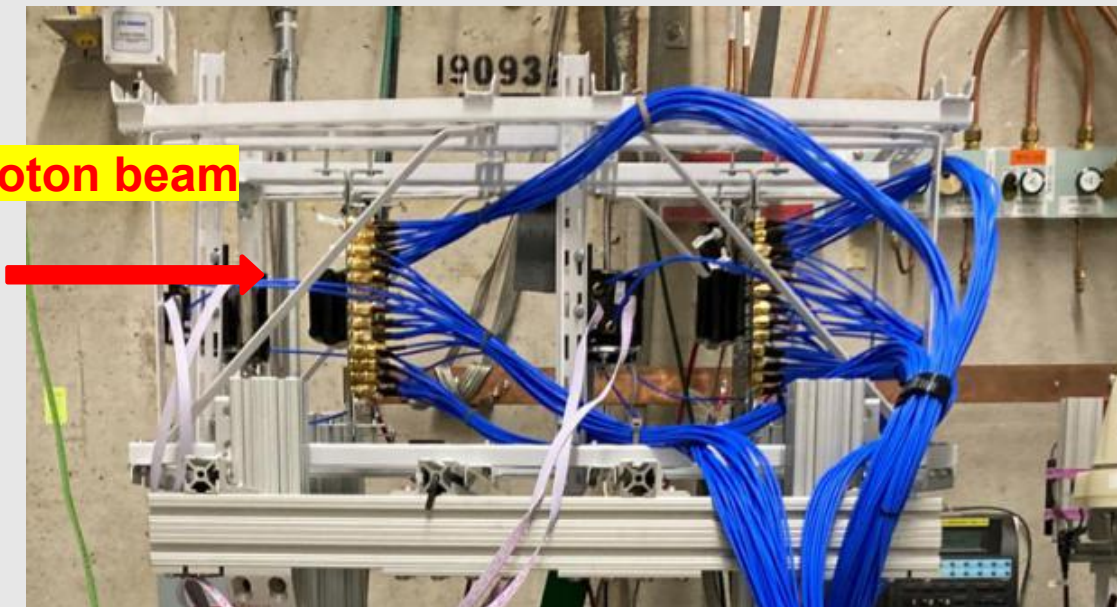
受采集卡采样率影响，测得符合时间分辨较高。

目录

- 1. 超快光电倍增管 (FPMT) 简介
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3 Fermi 质子束流实验

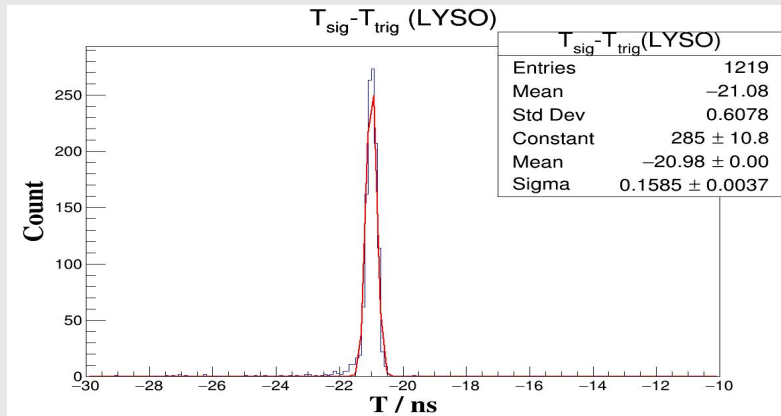
120GeV Proton beam



- Fermi 120GeV质子束流测试。
- 样管采用普通光窗8*8 FPMT
- 测试晶体：LYSO、BGO
- DAQ：CAEN V1742 (时间分辨)~50ps;
- 实验时间：2023.09

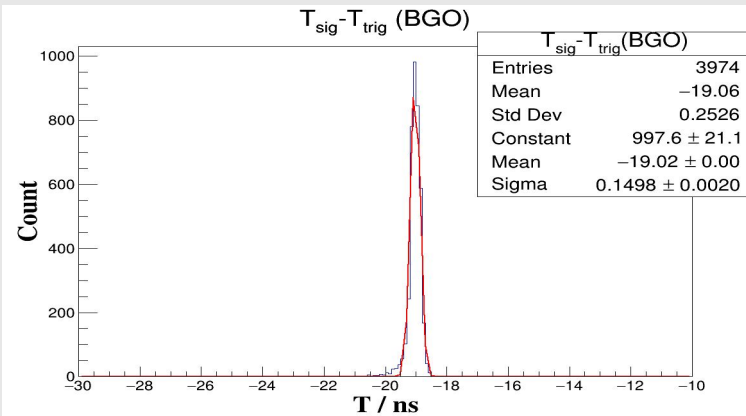
Ref: NIMA 1064 (2024) 169373

3 Fermi 质子束流实验



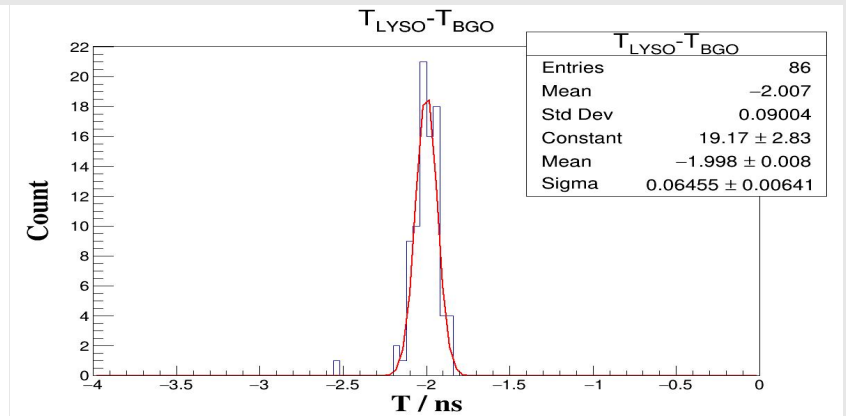
➤ LYSO single channel
Time Resolution

Sigma: 158.5 ps



➤ BGO single channel
Time Resolution

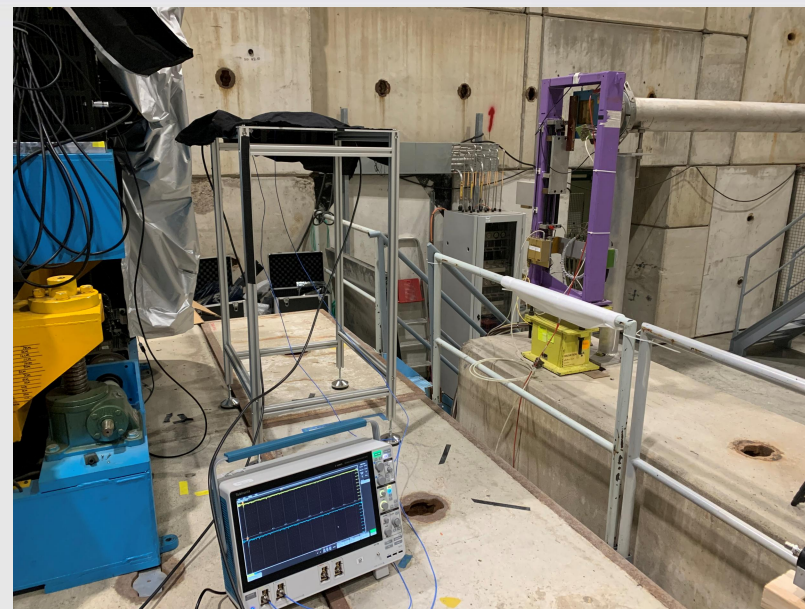
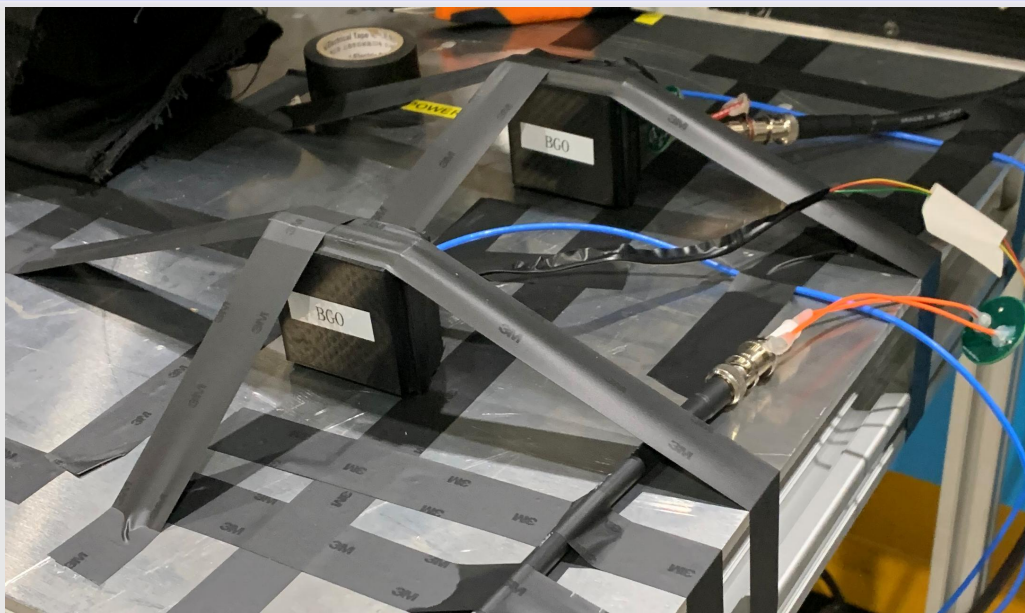
Sigma: 149.8 ps



➤ LYSO & BGO
Coincidence Time jitter ~64 ps
Single tube Time jitter ~45ps

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4 CERN muon束流实验



- CERN 108GeV muon束流测试。
- 样管采用普通光窗8*8 FPMT
- 对多块晶体材料阵列进行测试，包括切伦科夫光材料和闪烁光材料
- 测试系统采用高采样示波器带宽为6GHz，采样率为15Gs/s
- 实验时间：2023.01

Ref: NIMA 1064 (2024) 169373

4.1 实验设置

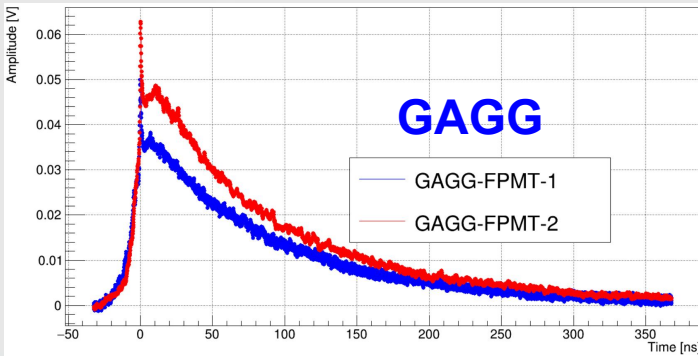
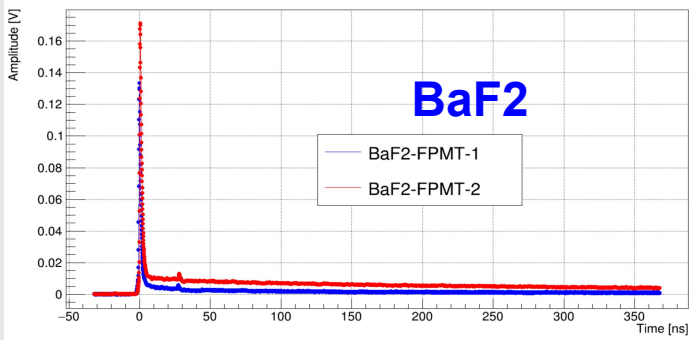
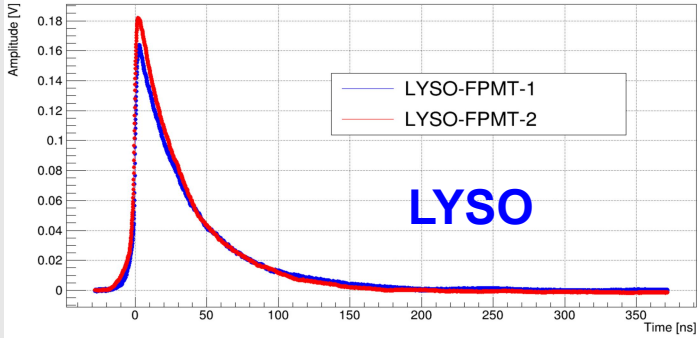
FPMT性能参数

	Code	HV [V]	Gain	P/V	Amplitude @SPE [mV]	RT [ps]	FT [ps]	TTS @SPE [ps]	TTS @MPE [ps]
FPMT1	5006	-1600	2.4E6	10.8	30 mV	390	640	47.2	10.4
FPMT2	5001	-1500	3.9E6	18.6	45 mV	334	660	38.5	9.1

闪烁体性能参数

	LY[Ph/MeV]	Decay Time[ns]	Emission Peak[nm]
LYSO	30000	40	420
BaF ₂	6000	0.6&620	300
GAGG	50000	50	560
Pb Glass	Cherenkov Radiation		
Quartz Glass			

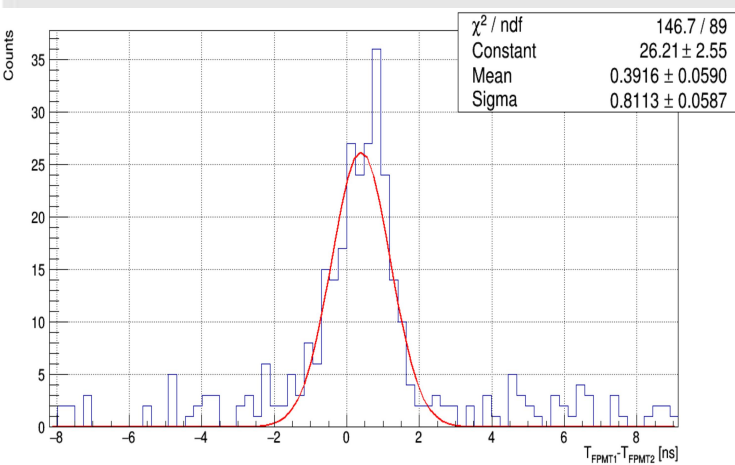
4.2 闪烁晶体



	LY	Decay	Peak [nm]
LYSO	30000	40	420
BaF ₂	6000	0.6&620	300
GAGG	50000	50	560

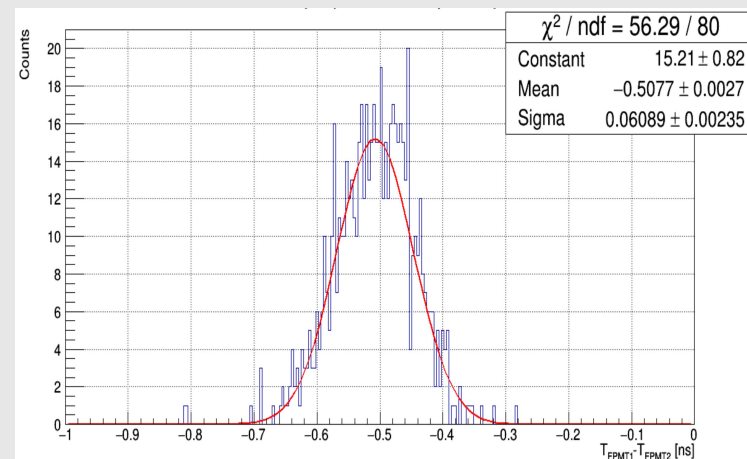
LYSO	Amplitude [mV]	RT [ps]	FT [ps]
FPMT1	210	4633	5224
FPMT2	215	5282	5772
BaF ₂	Amplitude [mV]	RT [ps]	FT [ps]
FPMT1	143	438	2310
FPMT2	142	471	2080
GAGG	Amplitude [mV]	RT [ps]	FT [ps]
FPMT1	63	428	1052
FPMT2	78	447	1413

4.2 闪烁晶体



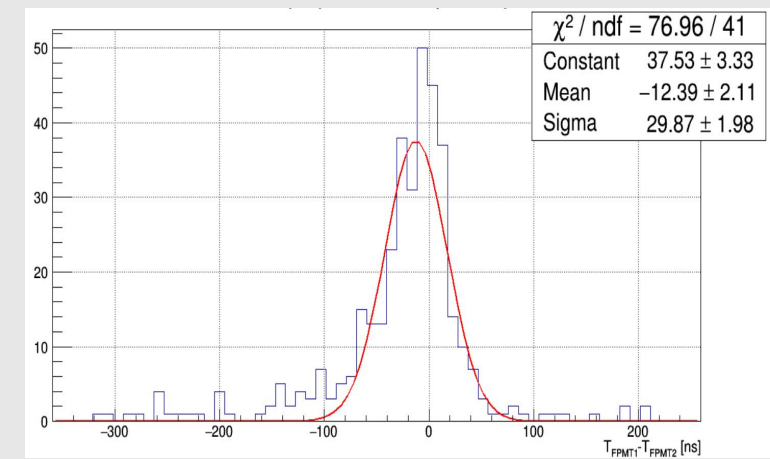
LYSO

CTR = 811 ps



BaF₂

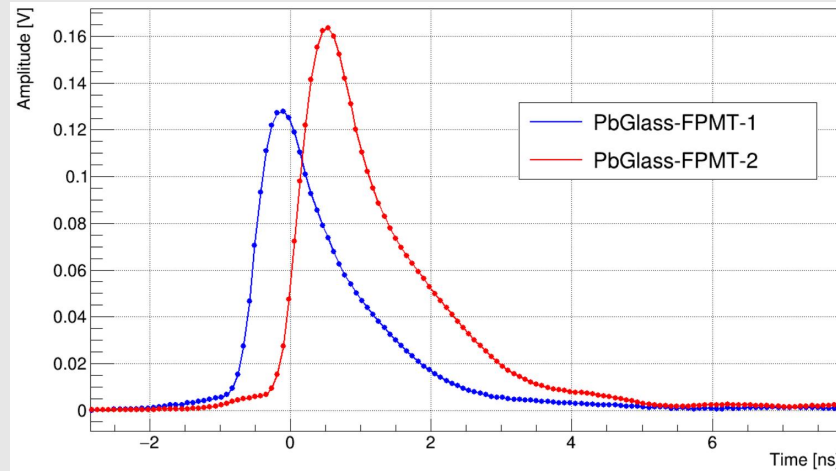
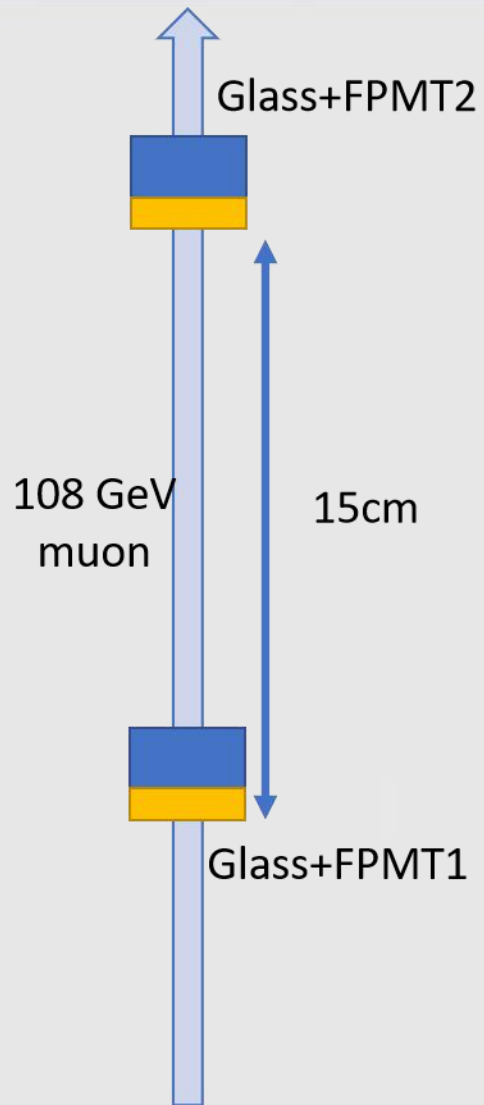
CTR = 61 ps



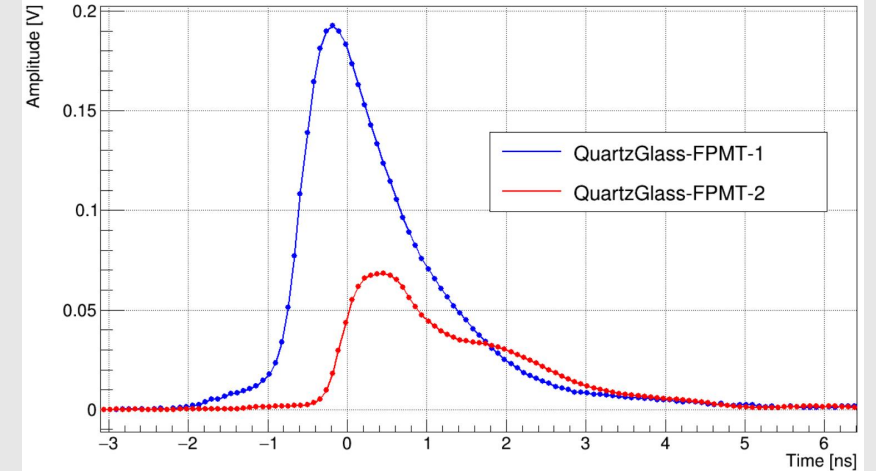
GAGG

CTR = 30 ns

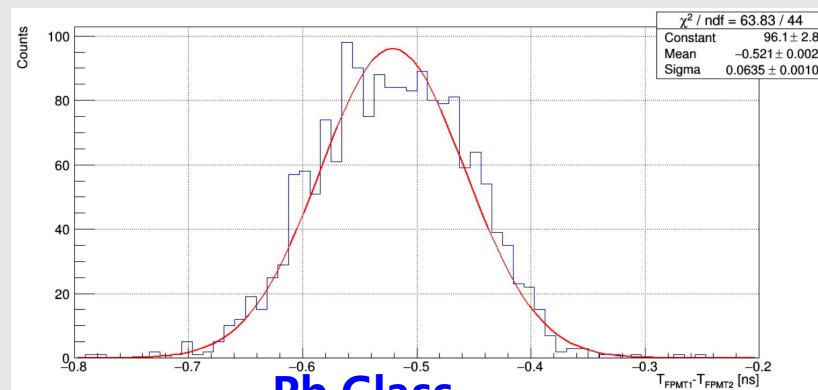
4.3 Pb Glass & Quartz Glass



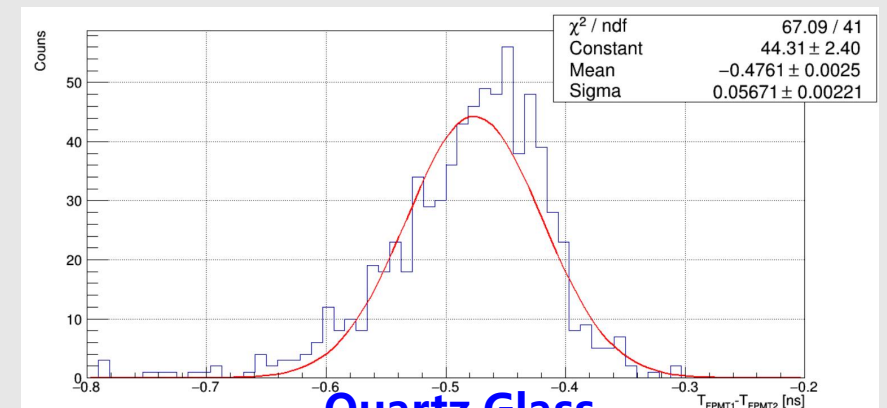
平均波形



平均波形



Pb Glass
CTR = 64 ps



Quartz Glass
CTR = 57 ps

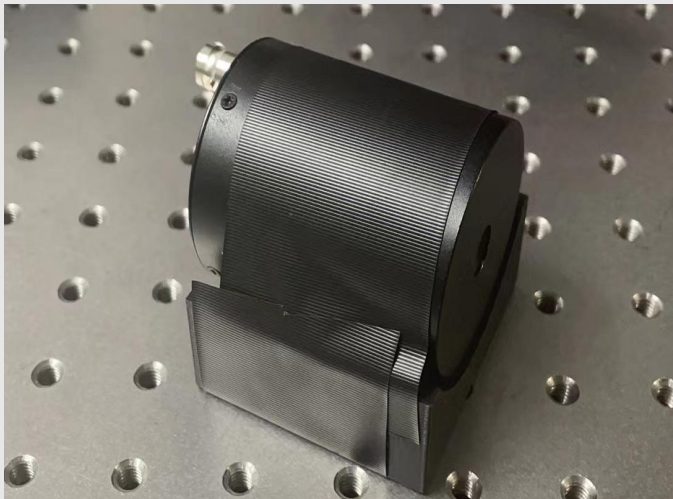
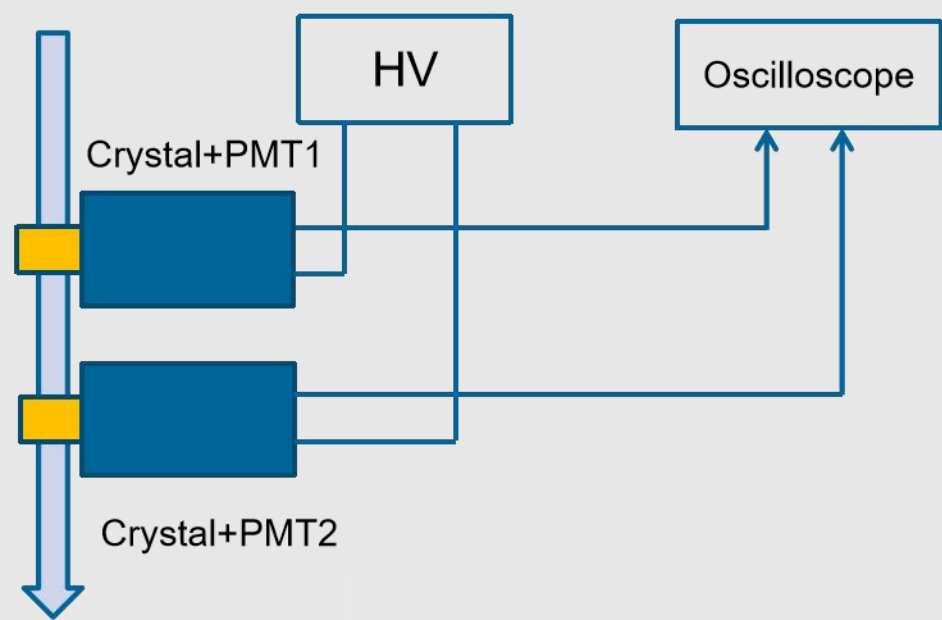
4.4 小结

	LY [Ph/MeV]	Decay Time [ns]	Emission Peak [nm]	Amplitude [mV]	RT [ns]	CTR [ps]
LYSO	30000	40	420	213	4958	811
BaF ₂	6000	0.6&620	300	142	455	61
GAGG	50000	50	560	71	438	30,000
Pb Glass	Cherenkov Radiation			168	383	64
Quartz Glass				165	364	57

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5 KEK 电子束流实验

5 GeV
electron



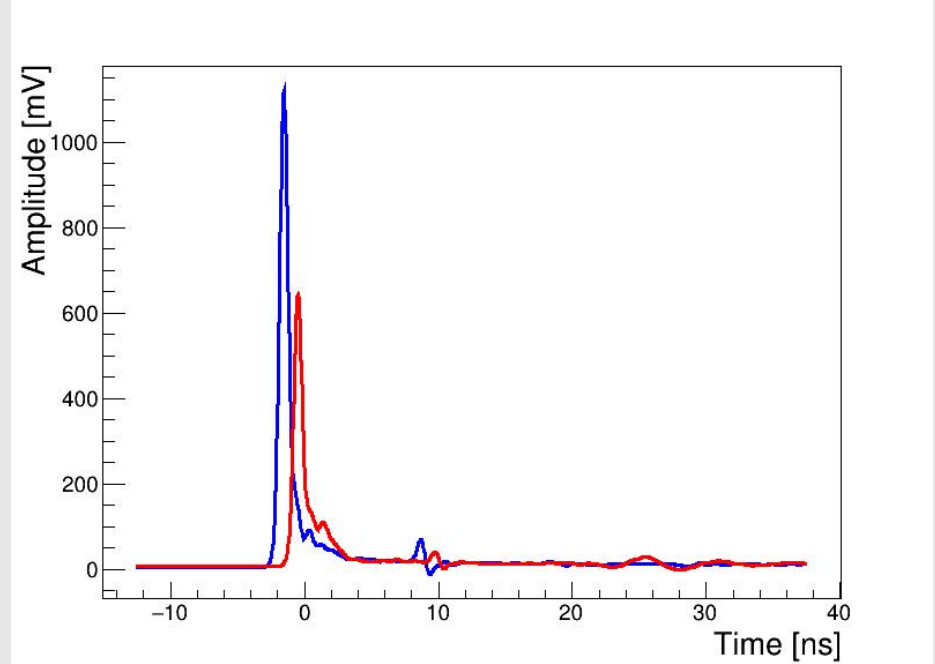
- KEK 5GeV电子束流实验
- 测试晶体: BaF
- PMT: 单阳极 FPMT
- 测试系统采用20Gs/s高采样示波器
- 实验时间: 2025.05

	HV	RT	FT	Peak	Pulse_wid	Gain	P/V	TTS@SPE
FPMT1	2750	220.4 ps	523.8 ps	62.3 mV	435.9 ps	3.8E6	13.0	26.9 ps
FPMT2	1800	229.9 ps	641.6 ps	50.9 mV	395 ps	3.2E6	32.2	24.6 ps

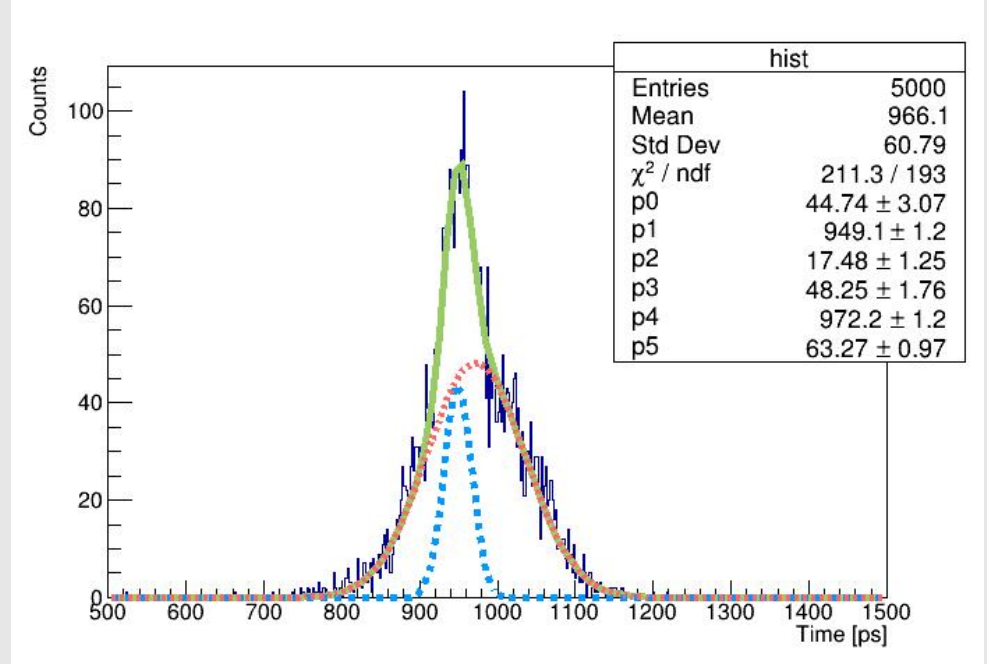
5 KEK 电子束流实验

	LY	Decay	Peak [nm]
BaF ₂	6000	0.6 & 620	300

	Amplitude [mV]	RT [ps]
FPMT1	1286	454.7
FPMT2	701.9	470.3



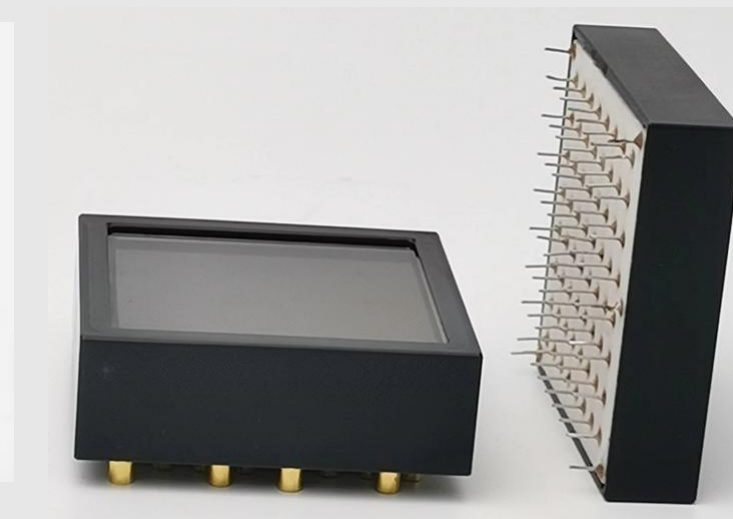
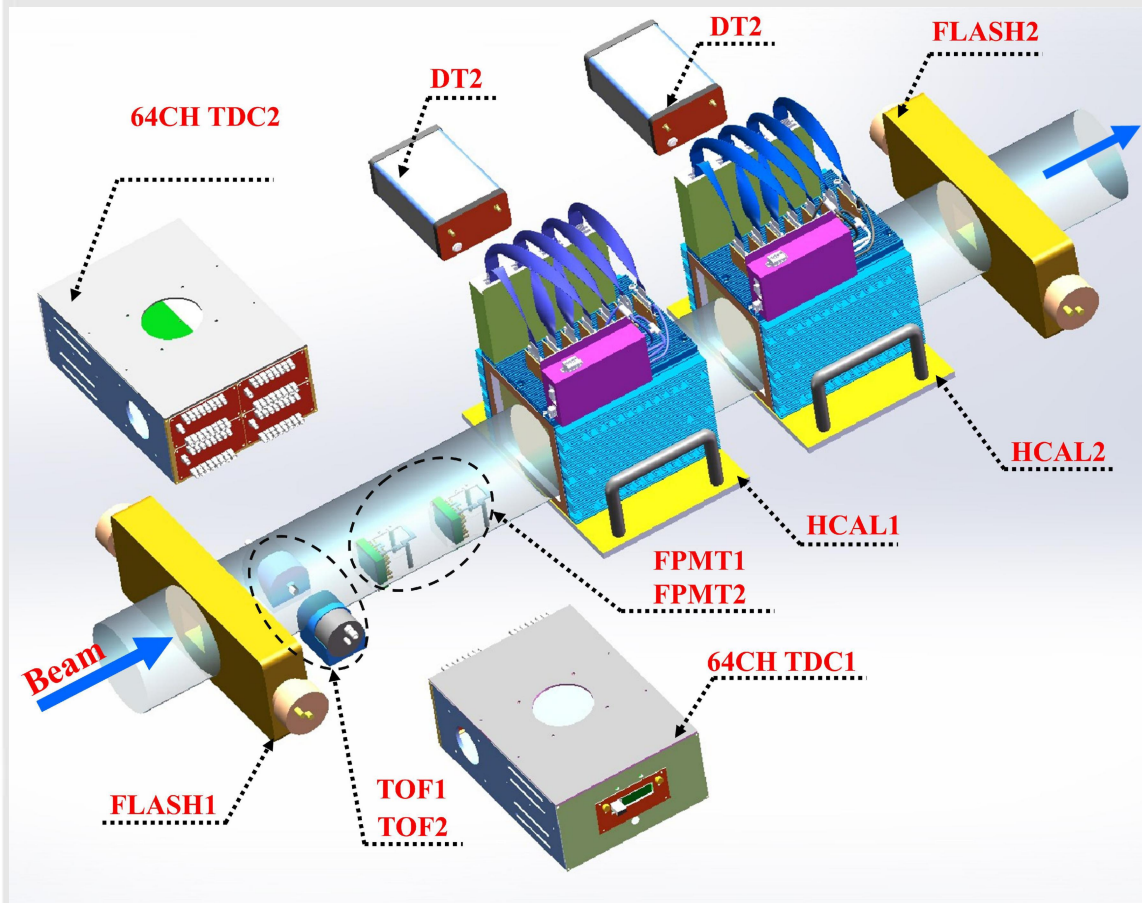
平均波形



➤ BaF₂ 符合时间
Sigma = 60.8 ps

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6 CERN 质子束流实验计划



- CERN 180GeV质子束流实验
- 测试晶体：BaF、BGO等
- PMT: 单阳极 FPMT、 8×8 阳极FPMT
- 测试系统采用20Gs/s高采样示波器
- 实验时间： 2025.10

Thanks!