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R&D of Fast Timing MCP-PMT with PbF_2 window

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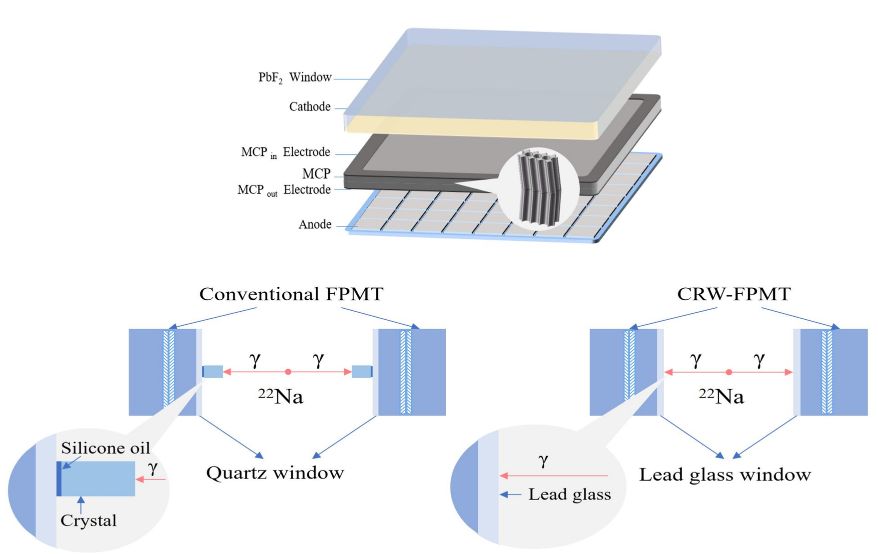
Introduction

The timing performance of photodetector is a critical parameter for the development of Radiation Imaging Detectors based on Time Of Flight (TOF) technique, notably in applications like TOF Positron Emission Tomography (TOF-PET). The small size Microchannel Plate Photomultiplier (MCP-PMT), also referred to as Fast timing MCP-PMT (FPMT), is a popular candidate photodetector of TOF-PET for its high gain, good detection efficiency, single photon detect ability, magnetic field resistance, ultimately its good time resolution.

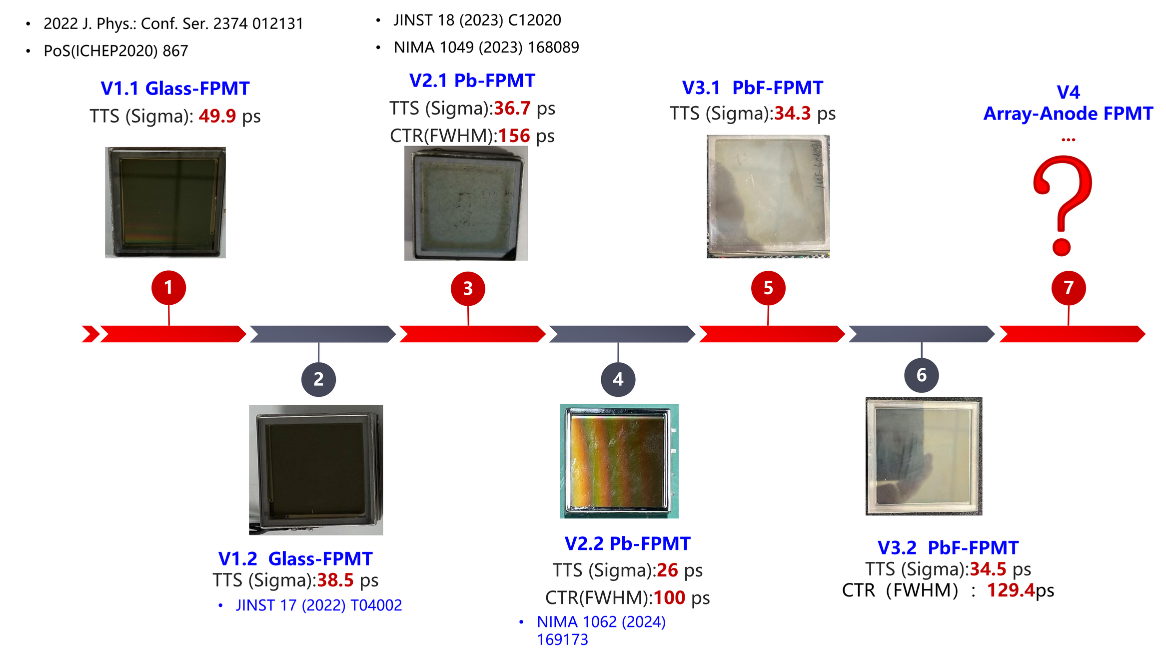
Using the Cherenkov radiator as the light window directly can eliminate the optical interface between the radiator and conventional MCP-PMT, and Cherenkov light will be directly converted into photoelectrons, thus improving the CTR of Cherenkov TOF-PET. PbF_2 is a favoured Cherenkov radiator for its high refractive index, high density and pure Cherenkov radiation. Starting from 2020, the MCP-PMT workgroup has completed the development of FPMT from Glass window FPMT (Glass-FPMT) to Pb Glass window FPMT (Pb-FPMT), and ultimately advanced to PbF_2 window FPMT (PbF-FPMT). The structure of the PbF-FPMT was optimized to achieve a better time resolution. The performance of PbF-FPMT at SPE mode and the CTR of a pair of PbF-FPMT were evaluated.

1. Development of PbF-FPMT

- Using the Cherenkov radiator as the light window directly can improve the CTR of Cherenkov TOF-PET.
- PbF_2 is a favoured Cherenkov radiator for its high refractive index, high density and pure Cherenkov radiation.
- Starting from 2020, Our team has completed the development of FPMT from Glass window FPMT (Glass-FPMT) to Pb Glass window FPMT (Pb-FPMT), and ultimately advanced to PbF_2 window FPMT (PbF-FPMT).

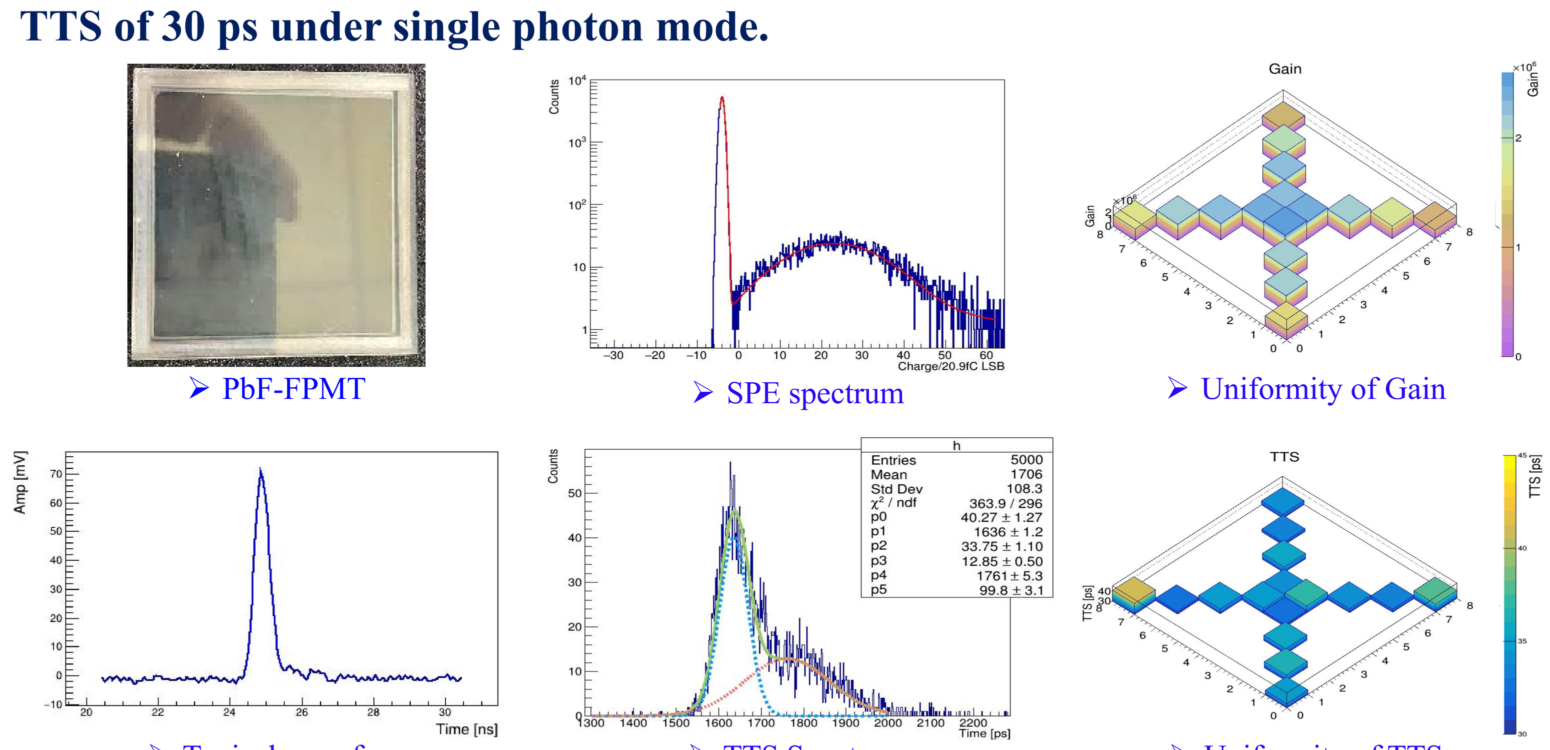


	PbF_2	$PbWO_4$
Index of refraction (λ=400 nm)	1.8	2.3
Density (g/cm³)	7.77	8.28
Cherenkov threshold for e^- (keV)	104	56
Optical transmission cutoff wavelength (nm)	250	350
Scintillation light yield (photons/MeV)	-	200
Scintillation decay time (ns)	-	6/30
440.Scintillation emission peak (nm)	-	440/530



2. Performance of PbF-FPMT

- Reducing the spacing between the photocathode and the MCP can effectively improve the TTS .
- The structure of the PbF-FPMT was optimized to achieve a RT less than 300 ps and a TTS of 30 ps under single photon mode.



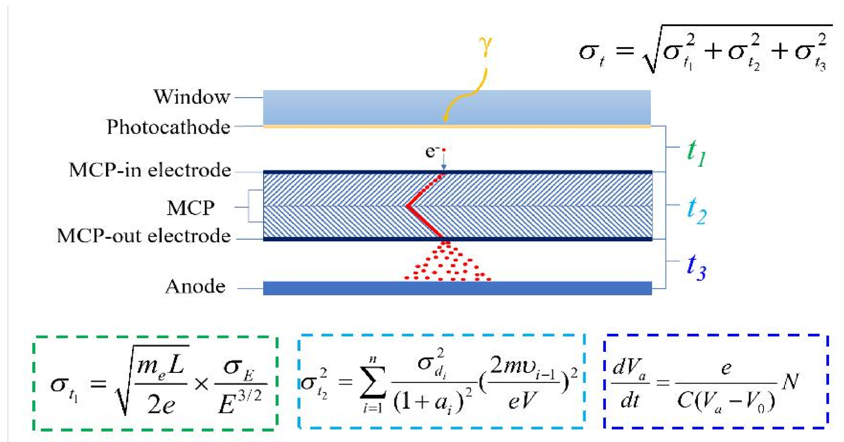
➢ PbF-FPMT ➢ SPE spectrum ➢ Uniformity of Gain

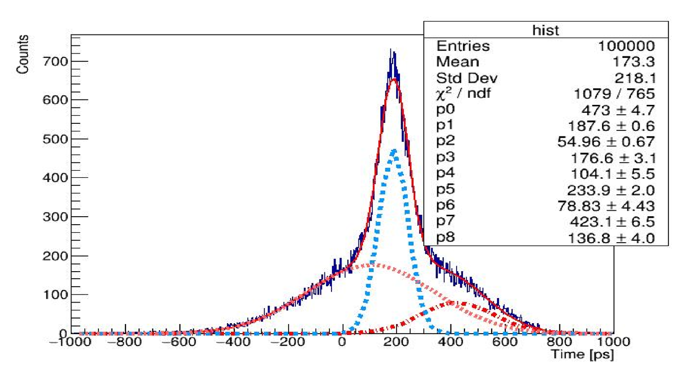
➢ Typical waveform ➢ TTS Spectrum ➢ Uniformity of TTS

	HV(V)	Gain	P/V	Peak(mV)	RT (ps)	FT (ps)	Width (ps)	TTS (ps)
PbF-FPMT	1420	3.5E6	9.5	57.4	277.6	309.8	449.5	33.75

3. CTR of PbF-FPMT

- Using the PbF_2 as the light window directly to produce more Cherenkov photons.
- Using step window insted of flat window structrue to reduce the spacing between the photocathode and the MCP





PbF-FPMT

CTR= 129.2±1.6 ps

	HV(V)	Gain	P/V	Peak(mV)	RT(ps)	FT(ps)	Width(ps)	TTS(ps)
PbF-FPMT-1#	1500	2.6E6	23.9	46.4	284.8	242.8	427.6	34.5
PbF-FPMT-2#	1420	3.5E6	9.5	57.4	277.6	309.8	449.5	33.75

4. Conclusions

- The PbF-FPMT has been successfully developed by the MCP-PMT workgroup.
- The structure of the PbF-FPMT was optimized to achieve a RT less than 300 ps and a TTS of 30 ps under single photon mode.
- The direct use of PbF_2 as the optical window eliminate the optical interface between the radiator and the detector, significantly enhances the number of Cherenkov photons and the multi-anode structure enables a great spatial resolution. The CTR of the PbF-FPMT can reach 129.2±1.6 ps.

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