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Test and Simulation of FPMT with single chip MCP

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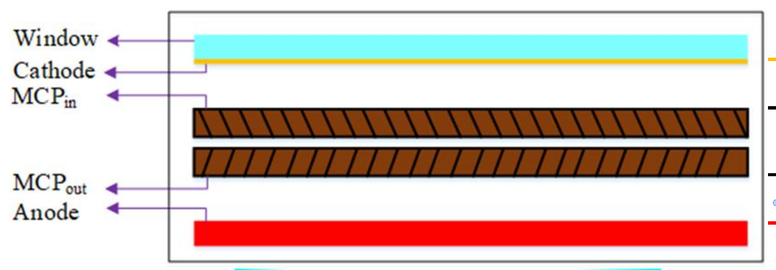
Introduction

Abstract: Micro-channel plate photomultiplier tube (MCP-PMT) is a kind of photosensitive device with single photon detection capability and great time resolution, which is also called Fast-PMT (FPMT). The MCP is the electron multiplier structure and in order to achieve single photon detection, two layers of MCPs are always used together. Due to the new-generation particle accelerators with high energy and luminosity, the time resolution of the detector is more important than single-photon detection capability. The single-chip-FPMT is expected to have a greater time resolution. Based on the CST STUDIO SUITE, the single-chip-FPMT model is built whose time performance is compared with the double-chips-FPMT model under the same parameter setting.

1.Time Resolution of FPMT

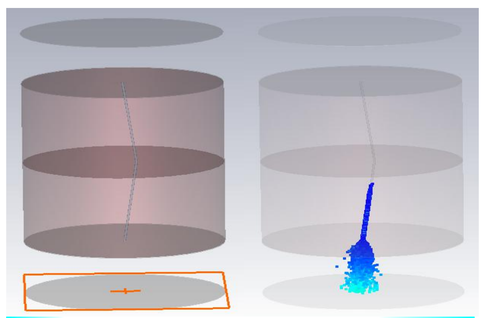


The schematic of FPMT

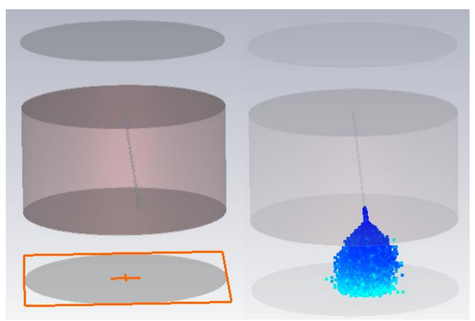
$$TTS = \sqrt{\sigma_{TT1}^2 + \sigma_{TT2}^2 + \sigma_{TT3}^2}$$

- The time resolution of FPMT itself is mainly affected by three process, focusing, multiplication and transmission process, which is represented by TT1,TT2 and TT3, respectively.
- Since the small gap and strong electric field between the cathode ,anode and the MCP, $\boldsymbol{\sigma\_TT1}$ and $\boldsymbol{\sigma\_TT2}$ is relatively small.
- The statistical fluctuation in time during multiplication process is more severe than the focusing and transmission process, for which single-chip-FPMT is expected to have greater time resolution.

2.Model Construction



Double-chips-FPMT model



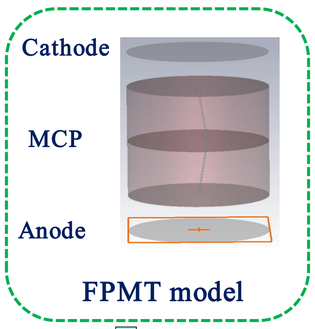
Single-chip-FPMT model

- The double-chips-FPMT model and the single-chip-FPMT model are constructed with CST.
- All the structural parameters are set based on the FPMT sample. The d is set as 6 $\boldsymbol{\mu m}$ and $\boldsymbol{\theta}$ is 8° .

Symbol	Structural Parameters
d	Diameter of each channel
θ	Oblique angle for MCP channels
D_{CM}	Distance between cathode and MCP-in
D_{AM}	Distance between anode and MCP-out
D	Distance between adjacent channels
L	Thickness of single MCP
h	Penetration depth of electrode

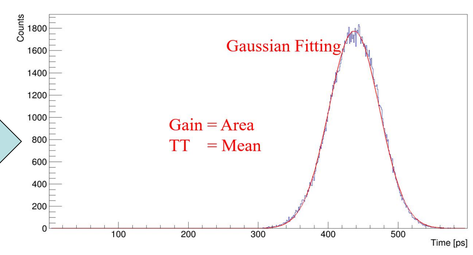
FPMT Structural Parameters

3. Available Performance Parameters



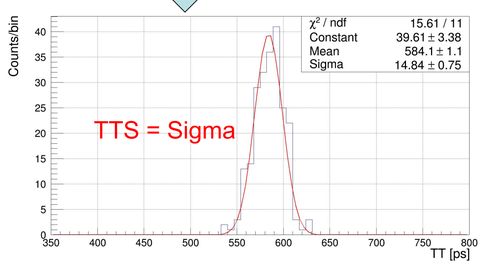
FPMT model

Single Simulation



The single-photoelectron (SPE) spectrum

Multiple Simulations



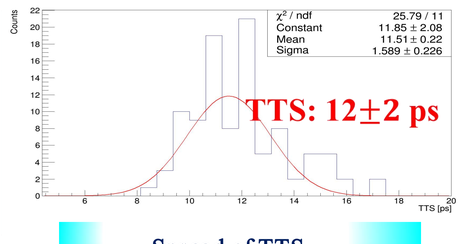
The Spread of TT

- The orange box on the anode of the FPMT model is a monitor for electrons and through single simulation, the SPE spectrum can be obtained. Through multiple simulations, the spread of TT can be obtained and TTS is the sigma.

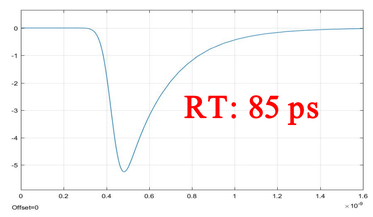
4. Simulation Results

FPMT model with double-MCPs

Gain: 2×10^5

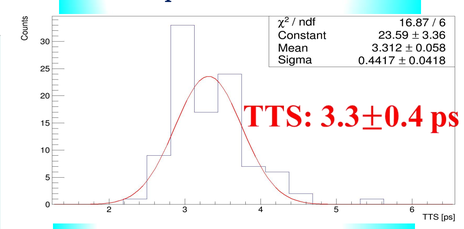


Spread of TTS

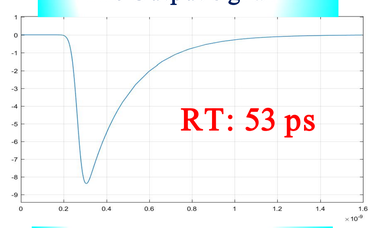


The Output signal

FPMT model with single-MCP

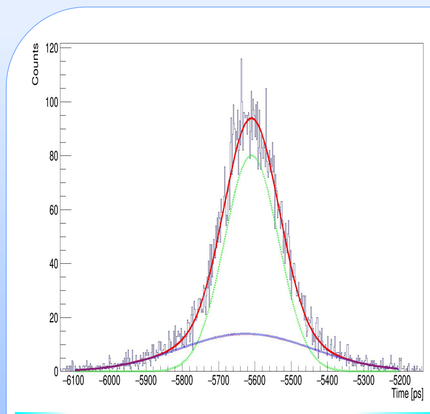


Spread of TTS

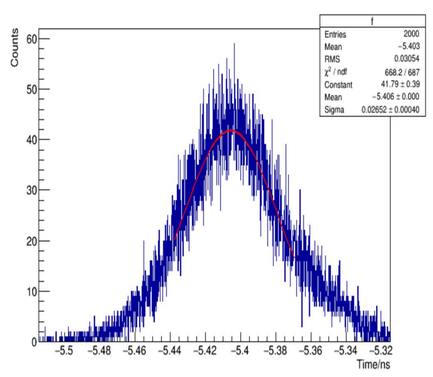


The Output signal

- Through multiple simulations, the spread of TTS is obtained and the output signal is obtained by using a equivalent circuit.



TTS@SPE for 2x2 anodes FPMT



TTS@MPE for 2x2 anodes FPMT

5. Conclusions

- Through simulations, the TTS of single-chip-FPMT is proved much better than that of the double-chips-FPMT which is in line with our expectation.
- The single-chip-FPMT can not achieve a gain of 2×10^5 now, due to the technology challenge.
- But the 2x2 anodes FPMT with double-MCPs can achieve a time resolution of 26 ps for multi-photons.
- The single-chip-FPMT under a gain of 2×10^5 is expected to achieve a better time resolution as simulated.

Acknowledgement

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