ID: #114-A

How to improve the performance of the fast timing detector

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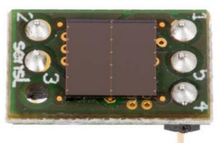
22nd IEEE Real Time Conference

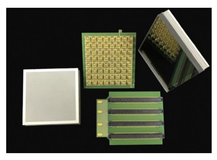
Introduction

The Fast timing detector is widely used for its picosecond (ps) level time resolution, such as the small MCP-PMTs with about 50 ps@ SPE, some fast SiPM with about 100ps@SPE. The transit time spread (TTS) describes the distribution of transit time and characterizes the time resolution of PMT (MCP-PMT, SiPM). The test results of the Fast timing detector will be affected by the light source, the electronic device board, the DAQ system, etc. In this manuscript, some comparative test results will be shown and discussed on the factors affecting the performance of the fast timing detector.

1.The Fast timing Photodetector



SiPM



Multi-anode MCP-PMT

Photodetector	SiPM	MCP-PMT
Product	SenSL J30035	Photek MAPMT253
QE@400nm	PDE: 47%	~20%
CE		>90%
Operating voltage	26.7V	3500V
Gain	10^6	10^6
Dark counts	~50KHz/mm^2	<3Hz/mm^2
Rise time @SPE	1ns -> 90ps	~200ps
TTS@SPE(σ)	1ns ->~60ps	~40ps

Several types of photodetectors could have the fast timing resolution, such as the Multi-anode MCP-PMTs and some special SiPMs, of which the characteristics is shown in the table. We test them and design the timing detector with them for better timing resolution.

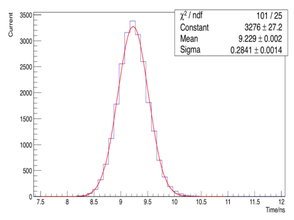
2.The Influencing factors by the Light Source

Signal Generator
Tektronix AFG3102C

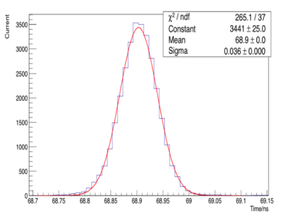
Picosecond Laser
Advanced Laser Diode Systems

	RT/ns	FT/ns	TTS/ps
LD (Width=10ns)	1.58	3.12	284.1
PS (Width=40ps)	0.36	1.18	36

Time-related parameters of MCP-PMT under different light sources in SPE



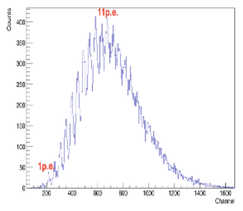
TTS @Picosecond Laser

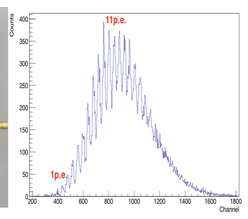


TTS @Signal Generator

The performance of the light source has a more obvious impact on TTS. The TTS measured with the ps light source is obviously better.

3. The Influencing factors by the Electronics Board





The different power driver circuit operating the same SiPM for the same photon signal

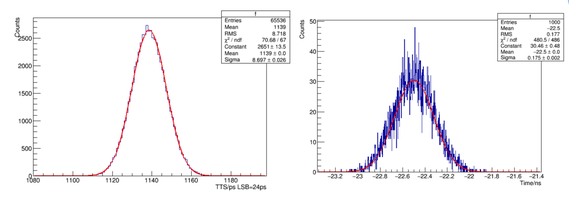
Modules	1 p.e. ER	2 p.e. ER	3p.e. ER	RT/ns	FT/ns	TTS/ps
D.B.	13.31%	13.03%	15.17%	1.52	17.13	313
E.B.	14.45%	14.32%	16.44%	1.25	13.75	65

The figures and table above show the charge spectrum and time performance of the same SiPM under the same light source using different power drive boards. The TTS measured with D.B(left, by Hamamatsu) is 313ps and the result tested with EB（right, by our lab) is 65ps, the time performance is significantly improved.

4. The Influencing factors by the DAQ

Portable VME-DAQ
Mesytec Digital Pulse Processor

The Oscilloscope
Lecroy HDO9404-MS

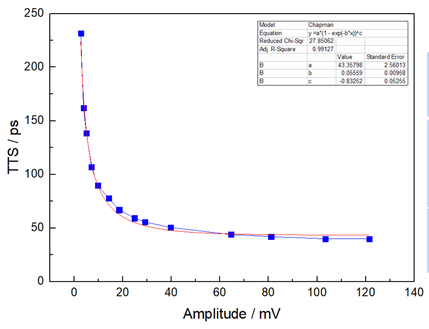


TTS test of H8500 by VME and oscilloscope

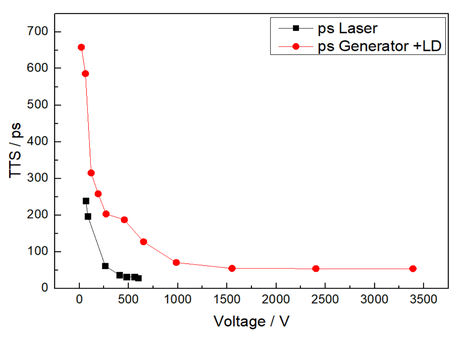
	Bandwidth	Sampling Rate	TTS/ps
Portable VME-DAQ	500MHz	80MHz	209
Oscilloscope	4GHz	40Gs/s	175

DAQ with different bandwith will also impact the time performance of fast timing detectors. The table shows the difference of two kinds of DAQ and the TTS testing results. The Oscilloscope obtain and analyze the waveform data directly, but the VEM-DAQ stratched the waveform firstly and then analyze them by the software.

5. The Influencing factors by the light intensity



	SiPM	MCP-PMT
TTS@ ps Laser	40ps	28ps
TTS@ LD	-	53ps

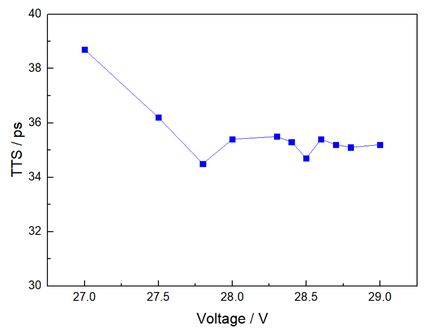


TTS of SiPM under different light intensities

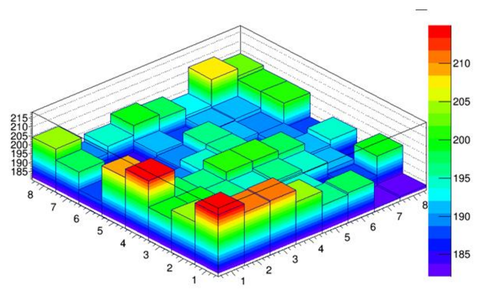
TTS of MCP-PMT under different light intensities

Both the TTS of SiPM and MCP-PMT, are affected by the light intensity. With enough photons, the TTS of both SiPM and FPMT will reach stable value， the Limited Time Resolution, the best TTS data of the PMT.

6.Others



TTS of SiPM under different driving voltages



TTS uniformity of PMT

- ***The driving voltage of SiPM also affects its TTS, so the voltage needs to be optimized during testing.***
- ***For multi-anode PMT, the uniformity of TTS is also an important factor affecting the overall time performance of PMT.***

Acknowledgement

This paper was supported by National Natural Science Foundation of China (No.11675205, No.11675196)，Foundation of State Key Laboratory of Particle Detection and Electronics (SKLPDE-ZZ-201902), Program of Science &Technology Service Network of Chinese Academy of Science, Youth Innovation Promotion Association CAS. Thanks to the cooperation of Ning Zhe, Wang Zhigang, Zhang Yinhong, Zhu Yao, Hu Qianyu, Guo Hao, Wu Qi, Zhang Lingfeng, Yan Min, Peng Shuo .

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