Test and Simulation of FPMT with single chip MCP

Wu Qi, QIAN Sen*
State Key Laboratory of Particle Detection and Electronics
Institute of High Energy Physics, Chinese Academy of Sciences

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 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, σ_TT1 and σ_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

- 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 μm and θ is 8°.

3. Available Performance Parameters

- 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

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

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 $2 \times 10^5$ 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 $2 \times 10^5$ is expected to achieve a better time resolution as simulated.

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 Zhiping, Zhang Yinmeng, Zhu Yao, Hu Qianyu, Guo Hao, Ma Lishuang, Zhang Lingfeng, Yan Min, Peng Shuo. Corresponding author: QIAN Sen qians@ihep.ac.cn