Gain Measurement of Silicon Photomultiplier

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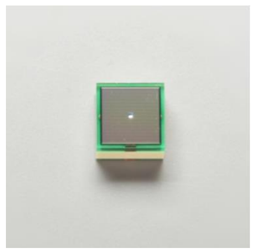
1、Introduction

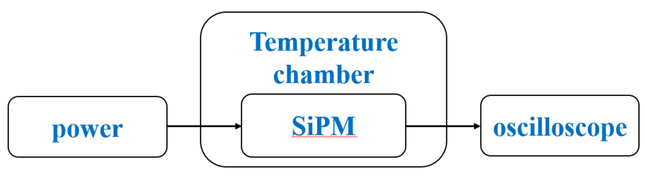
In recent years, with the development of nuclear medicine and high-energy physics. People are paying more and more attention to photon detection devices. Silicon photomultipliers (SiPMs) are emerging photon detection devices. Compared with PMT, it has the characteristics of insensitivity to an external magnetic field, more compact size, and relatively low operating voltage. This opens up a wide range of applications for SiPM in particle physics experiments such as LHCb, DarkSide, JUNO-TAO, LHAASO, and HERD. This requires testing many parameters to fully understand its behavior under various conditions. The gain test performed in this work is one of them.



2、Experiment Set-up

The main instruments involved in the experiment are as follows:

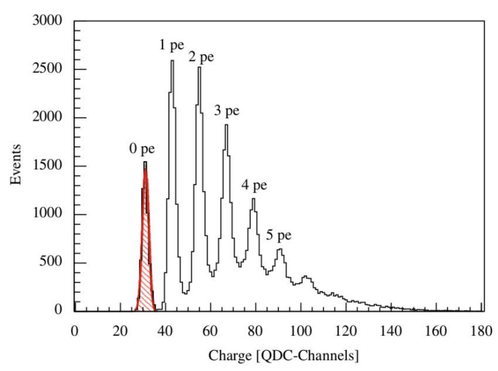
- A Tektronix 5 series mixed signal oscilloscope
- A Keithley 2231A-30-3 triple channel DC power supply
- A Hamamatsu S13360-2050VE MPPC
- A Espec GSH-64 temperature and humidity chamber

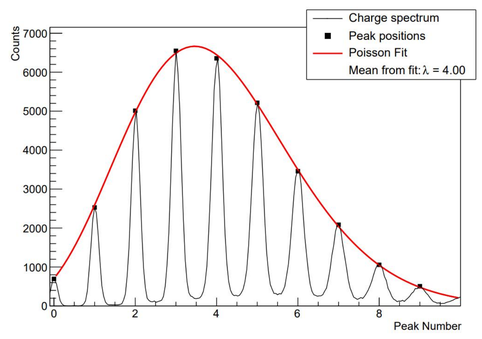


3、Theory

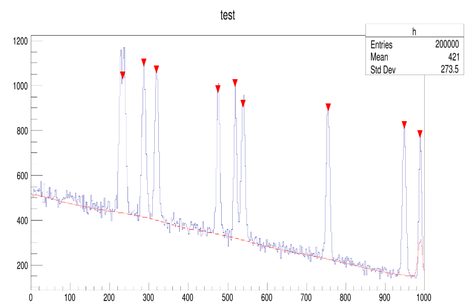
The original SiPM signal waveform information can be collected by an oscilloscope, and the corresponding charge can be calculated by integrating the waveform to obtain the charge spectrum[1].

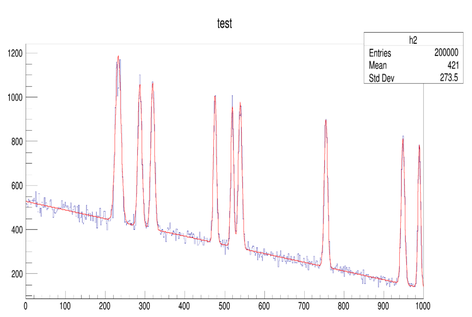
The charge spectrum was analyzed for single-photon peak charge. There are three methods:





1、Fitted with the convolution of the Poisson distribution and Gaussian[2], as shown in the two figures above.



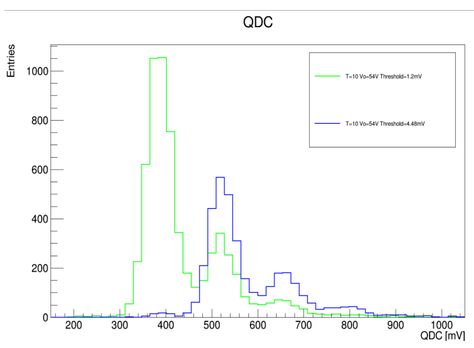


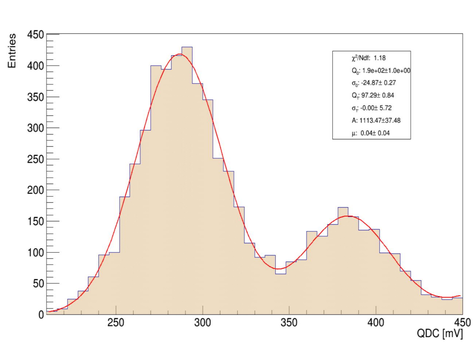
2、Use the peak finding algorithm to obtain the charge at the peak[3]

3、Fitting using a superposition of multiple Gaussians

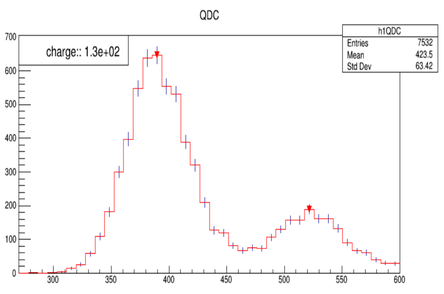
4、Analysis

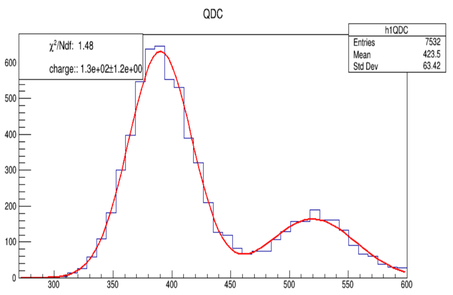
The integrated charge spectrum at different thresholds is shown on the left, and the graph on the right shows the fit of the charge spectrum using the first method.

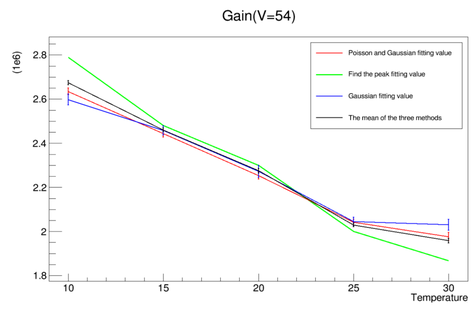


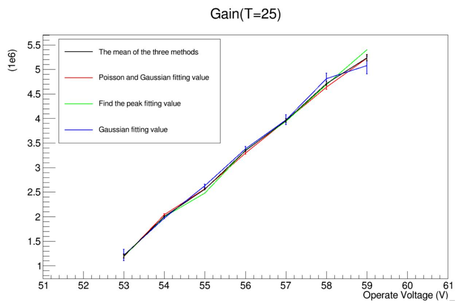


Peak finding and multi-Gaussian fitting are shown in the following two figures.

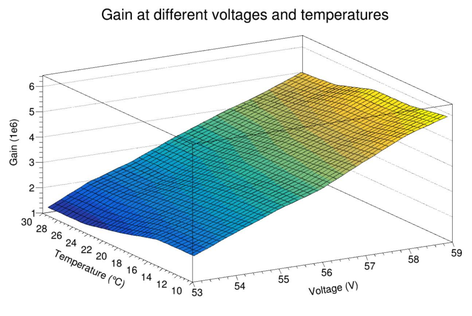


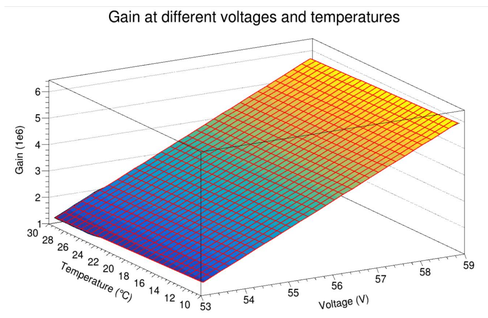






The relationship between the gain and temperature and voltage calculated by analyzing the charge spectrum using different methods is shown in the two figures. It can be seen that the gain is negatively correlated with temperature and positively correlated with voltage.





The bias correction factor can be fitted by the relationship between gain, temperature, and voltage to ensure the stability of the gain.

5、Summary and outlook

We have performed some work related to gain measurements:

1、Design gain measurement scheme and build test circuit

2、Gains were analyzed using three different methods

3、Measured the gain at different temperatures and voltages to observe its changing trend

We will continue to improve the following work:

1、Analyze bias correction factors to compensate for SiPM gain at different temperatures.

6、Reference

[1] https://www.hep.physik.uni-siegen.de/teaching/masterlab/manuals/SiPM_Manual.pdf

[2]Finocchiaro P, Pappalardo A, Cosentino L, et al. Characterization of a novel 100-channel silicon photomultiplier—Part II: Charge and time[J]. IEEE Transactions on Electron Devices, 2008, 55(10): 2765-2773

[3] https://root.cern/doc/master/peaks_8C.html