with mass number $A < 20$ can be well achieved using ETF in the future experiments.

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5 - 4 Effect of Different Connection Modes of Multiple Silicon Photomultipliers on the Output Signal Shapes

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Silicon photomultipliers (SiPMs) have obtained a growing attention as an alternative to the traditional photomultiplier tubes in application on the fast detection of scintillation light thanks to their compactness, low cost, low operating voltage, high gain, high photon detection efficiency, excellent resolution for single photon detection, and insensitivity to magnetic fields[1]. In considering larger detector sizes, however, the main drawback of the SiPM readout is their small active area. Devices with an active area in the range between 1 and 36 mm^2 are now widely available. Usually, the small size of SiPMs can be compensated by using several SiPMs connected in parallel or in series, which is equivalent to a single large SiPM from the circuit viewpoint. In this report the effect of different connections on the shapes of output signals will be discussed.

The schematics of the setups for measuring the signals of plastic scintillators coupled with one SiPM, two SiPMs in parallel, and two SiPMs in series are shown in Fig.1(a), (b), and (c), respectively. The 50 mm×50 mm×3 mm EJ232Q-0.5% scintillator sheets wrapped in Tyvek were used in the test. The Hamamatsu S13360-3050PE SiPMs, each of which has an active area of 3 mm×3 mm, were optically coupled to the scintillator with optical grease. The output signals were sampled with a digital oscilloscope Tektronix MSO 5204B with a sampling rate up to 10 Gs/s. An Ortec 710 module was used to bias the SiPMs. The bias voltages shown in Fig. 1 correspond to an overvoltage of about 3 V for each of SiPMs.

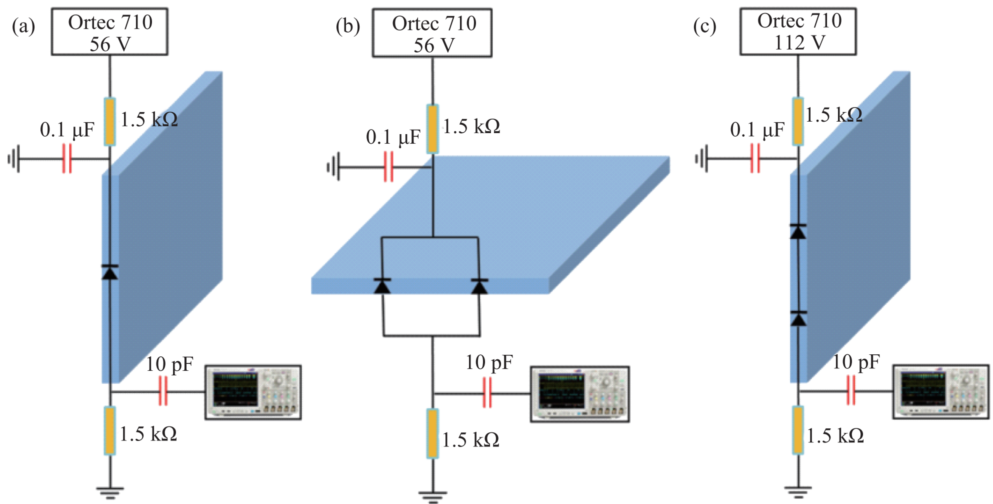

Fig. 1 (color online) Schematics of the setups for measuring the signals with different SiPM connections. (a) A single SiPM. (b) Two SiPMs connected in parallel. (c) Two SiPMs connected in series.

The scintillator was irradiated by cosmic rays under test, and the typical output signals with different SiPM connections are shown in Fig. 2(a). The rise times (10% to 90%) and the full width at half maximum (FWHM) of the output signals have been extracted and shown in Fig. 2(b) and (c), respectively. It can be seen that the signals from the series connection have faster rise times and narrower widths than that from a single SiPM. This is contrast to the case of parallel connection, where the signal rise times become slower and the widths become wider. This is due to the reduction of the total capacitance of the series circuit. The fast rise times and narrow widths are of particular importance for optimizing the time resolution in high counting rate experiments. A disadvantage is that the reduced capacitance will decrease the signal size which is proportional to the capacitance times the overvoltage[1]. However, our results show that the signal amplitudes with the series connection are larger than that with the parallel connection as shown in Fig. 2 (d). This may be caused by a larger overvoltage in the series connection from the circuit analysis. Therefore, the series connection of multiple SiPMs should be recommended for time measurement.

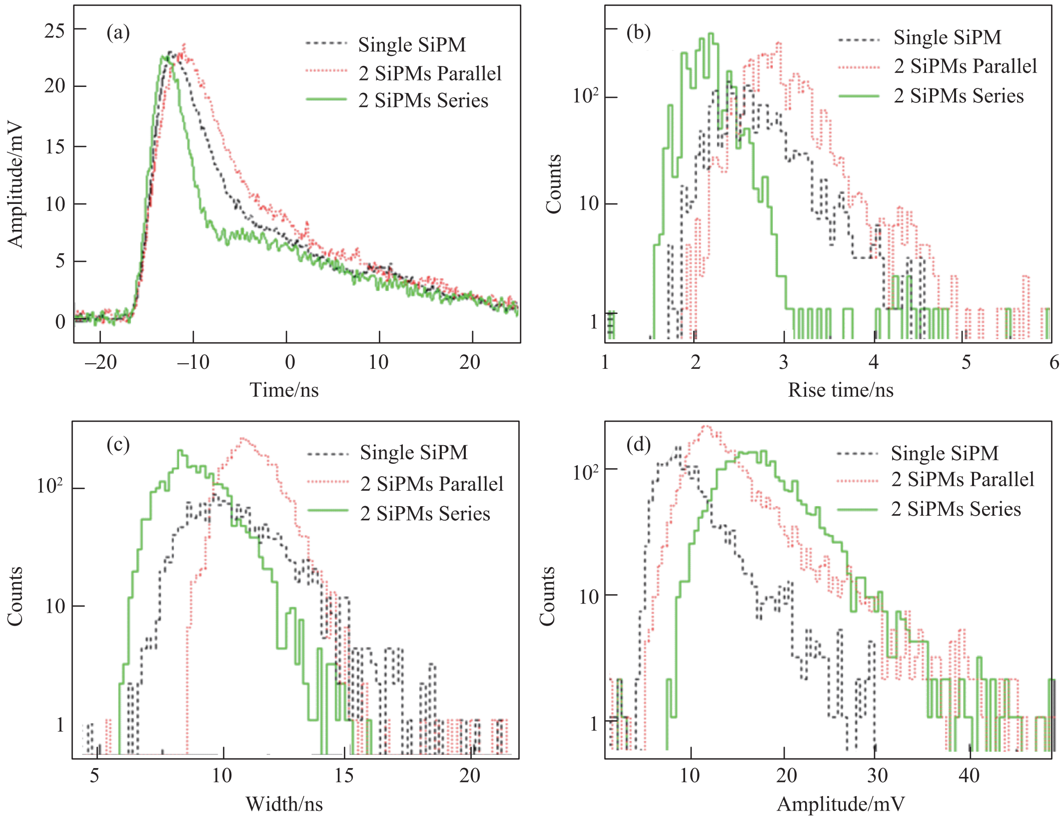

Fig. 2 (color online) Test results with cosmic rays. The signal shapes, the rise time distributions, the width distributions, and the amplitude distributions with different SiPM connections are shown in (a), (b), (c), and (d), respectively.

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