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Cosmic ray test results of 2×4-gap MRPC

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Abstract: A new type of multi-gap resistive plate chamber (MRPC) with a structure of 2×4-gap were tested by cosmic-rays. The results show that 2×4-gap MRPCs have a lower working voltage, a longer voltage plateau, a higher efficiency and a better time resolution than traditional 6-gap MRPCs. The results show that detecting efficiency could be higher than 90% and that time resolution is about 100 ps.

Key words: MRPC; dark current; noise rate; efficiency; time resolution; ADC spectrum

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2×4 双层结构 MRPC 的宇宙线测试结果

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摘要:研制了一种新的2×4双层结构多气隙电阻板室探测器(MRPC),宇宙线测试结果表明,2×4双层结构MRPC有较低的工作电压和较长的工作坪区,探测效率90%以上,时间分辨可以达到100 ps.

关键词:MRPC;漏电流;噪声;效率;时间分辨;幅度谱

0 Introduction

The multi-gap resistive plate chamber (MRPC) has become a most favorable detector for the time of flight (TOF) measurement in heavy ion collision experiments, and some important physics results have been obtained with such type of detector [1~8]. As part of RHIC-STAR upgrade program, twenty modules of 2×4-gap MRPC were developed at USTC. In this paper, the detection efficiency, the time resolution, and the ADC spectrum of the 2×4-gap MRPC tested with the cosmic ray will be presented.

1 Materials and methods

1.1 The structure of 2×4-gap MRPC

The MRPC is a new type of gas detector first developed by the LHC-ALICE group at CERN in the late 1990's [9]. It consists of a stack of resistive plates, and nylon fishing line (220 μm in diameter) that spaces out the resistive plates to get the gap size. For a 2×4-gap MRPC, positive signals are

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derived from the top and bottom PC (print-circuit) boards and negative signals are derived from the middle PC board. We applied ±(4 000~5 000) V on the anode and cathode, but the applied voltage on 8-gap MRPC is actually 16~20 kV. All inner plates are electrically floating. The resistive plates of MRPC are float glass (bulk resistance about 5×10^{12} Ω·cm), and the thickness of the glass plates is 540 μm. The working voltage is applied to the graphite tape (surface resistance of 5×10^{5} Ω/square) on the exterior glass surface. A layer of mylar (350 μm thick) is placed between the graphite tape of HV electrode and copper readout pads. The sensitive area of the MRPC is 20×6.1 cm². There are 6 readout copper pads, with a size of 6.3×3.15 cm², each connected with a low noise fast amplifier. Gas mixture, such as Freon/isobutane (95%/5%), at 1 atm pressure flows through the chamber, which is set in a gas sealed aluminum box. Fig. 1 shows the cross-section view of the 2×4-gap MRPC.

1.2 Experimental equipment

Fig. 2 shows the test system. It is used to select cosmic-ray events. The trigger system consists of three scintillation counters with five photo-multiplier tubes (PMT). We use the coincidence signal of PMT1, PMT3 and PMT5 to as the gate signal of ADC and common stop signal of TDC. The output signals from the MRPC readout pads go through the front-end electronics:

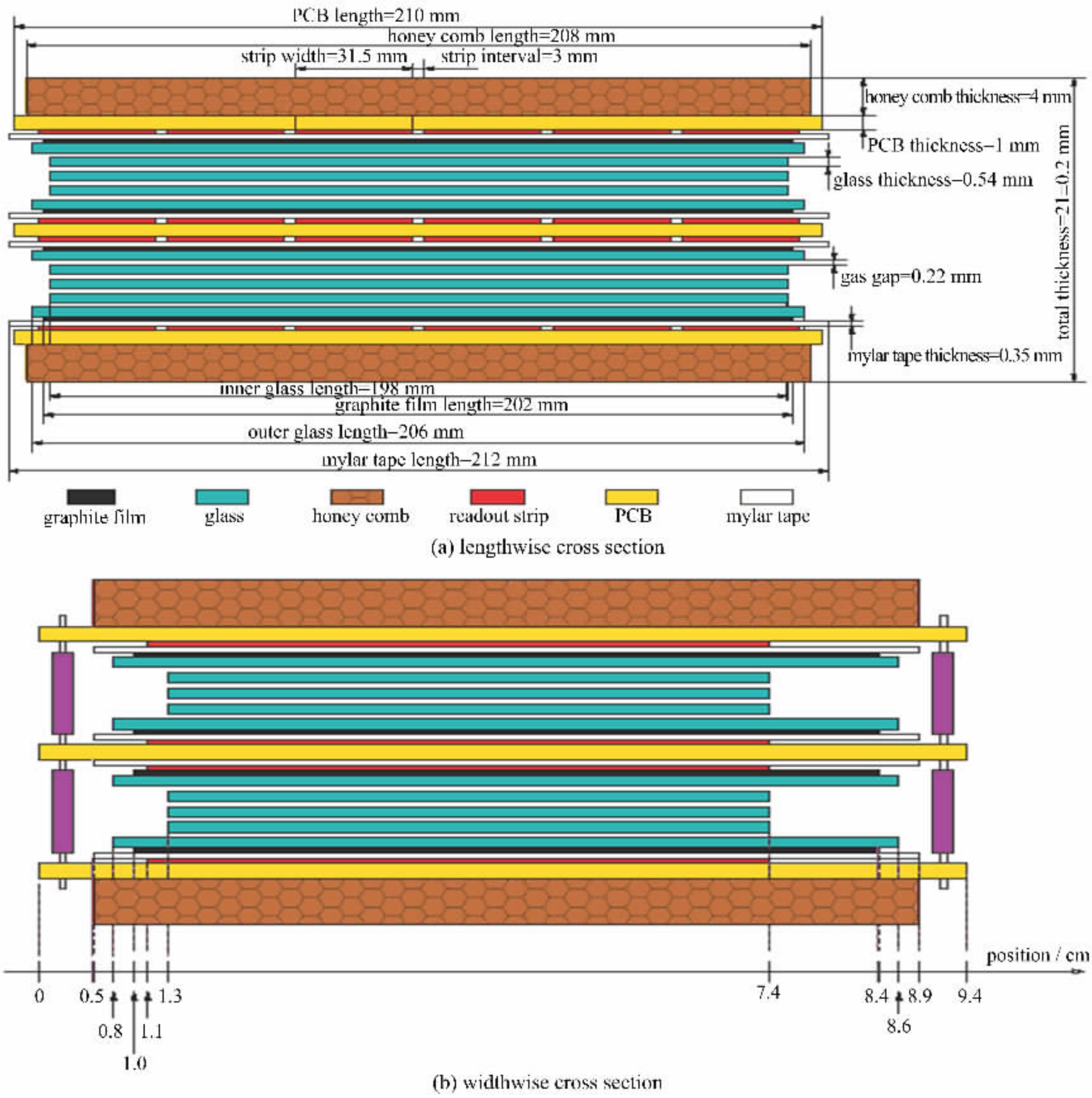

Fig. 1 Lengthwise cross section and widthwise cross section of 2×4-gap MRPC

amplifier, discriminator (the threshold is about 80 mV), and shape-amplifier, and then enter TDC.

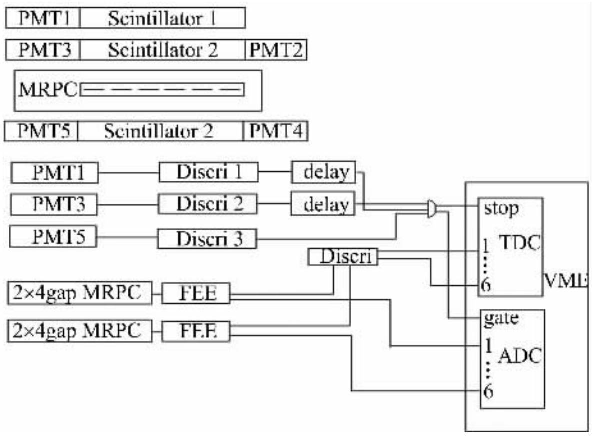

Fig. 2　Schematic diagram of cosmic ray test system

2　Test results

The gas mixture of $C_2F_4H_2$/iso-butane (95%/5%) was used for the test. The working voltage of MRPC was changed from 16.8 kV to 20 kV, and the temperature of the environment was maintained at 20 ℃. The width of the coincidence signal (gate signal) was about 100 ns. The varieties of dark current and noise rate versus the working voltage are shown in Fig. 3 and Fig. 4. For the 2×4-gas gap MRPC, dark current was not observed when the working voltage was altered from 16.8 kV to 20 kV, and the noise rate of each pad was less than 8 Hz.

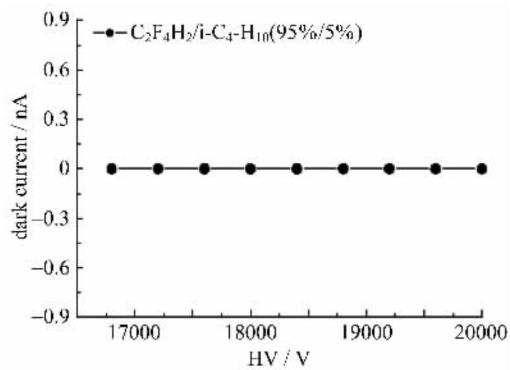

Fig. 3　Dark current vs HV

Fig. 5 gives a typical ADC spectrum where the signals with the amplitude between ADC pedestal and 1 000 channels are picked out as the avalanche signals. The ADC worked in the charge sensitive mode with a sensitivity of 0.1 pC/channel. Fig. 6 shows the small signal ratio which is defined as the ratio of the avalanche signals to the total signals registered by ADC.

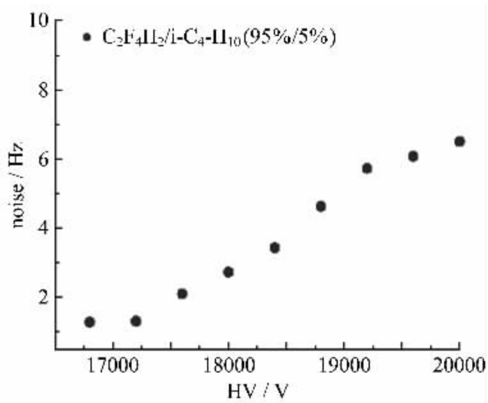

Fig. 4　Noise rate vs HV

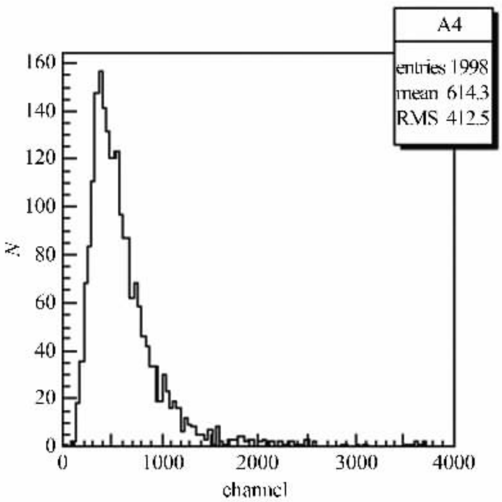

Fig. 5　ADC spectrum of one pad of MRPC at 18.4 kV

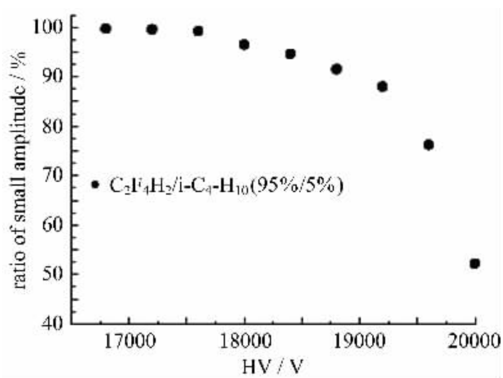

Fig. 6　Small signal ratio vs HV

The efficiency and time resolution of 2×4-gap MRPC are shown in Fig. 7. The efficiency of better than 90% and time resolution of about 100 ps can be obtained in a relative large voltage range where the voltage plateau ranges from 18 kV to 19.2 kV.

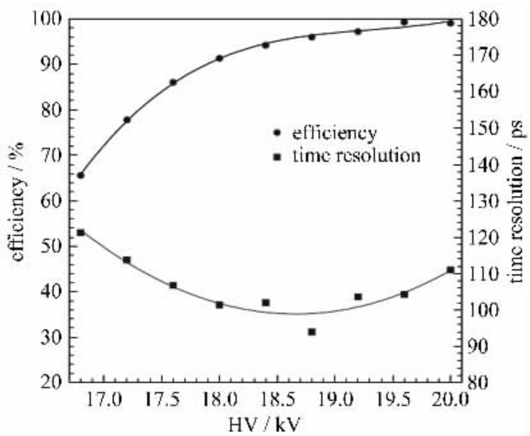

Fig. 7　Efficiency and time resolution vs HV of 2×4-gap MRPC module

Fig. 8 shows the cosmic ray test results of 6-gap MRPC. Compared with the results of 2×4-gap MRPC with 6-gap MRPC, the 2×4-gap MRPC had a better time resolution and a longer efficiency plateau. Without a tracking system, different positions where charge particles hit the read-strip would result in different times[10]. Therefore, the time resolution of 2×4-gap MRPC could be about 80 ps after the correction according to the velocity of signal propagation on the strip (45 ps/cm).

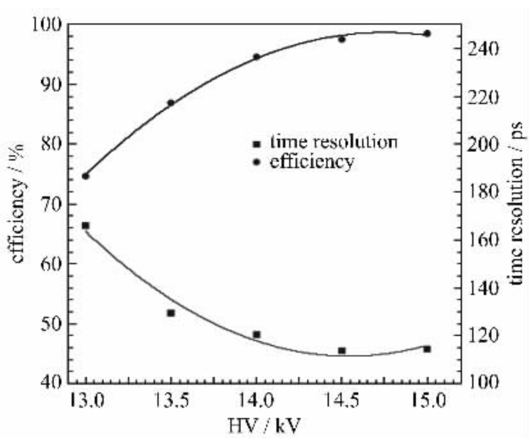

Fig. 8　Efficiency and time resolution vs HV of 6-gap MRPC module

3　Conclusion

In the cosmic ray test of 2×4-gap MRPC, the characteristics of detecting efficiency, time resolution, ADC spectrum, dark current and noise rate were obtained. These results show that the detection efficiency can be higher than 90%, and the time resolution can reach about 100 ps. The dark current is 0 nA. The noise rate of each pad is less than 8 Hz. A lower operating voltage of the 2×4-gap MRPC from ±4.5 kV to ±4.8 kV in the $C_2F_4H_2$/iso-butane (95%/5%) and longer efficiency plateau were obtained.

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