Performance of two different modules of long-strip multi-gap resistive plate chamber

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Abstract Long-strip multi-gap resistive plate chamber (LMRPC) were built with (Module 1) or without (Module 2) adhesive tapes and silicones. Their performances were investigated by working gas mixtures of different gradient contents (Test 1: 94% freon, 5% iso-butane and 1% SF_6; Test 2: 90% freon, 5% iso-butane and 5% SF_6). Both the modules achieved 100% efficiency, with time resolutions of 75 and 70 ps. Comparatively, the Module 1 works with a lower applied HV at the higher noise level, and time resolution was not influenced greatly by the adhesive tapes and silicones.

Key words Resistive Plate Chamber, Time of flight, Tape, Silicone, Glue, Performance, Noise

1 Introduction

Multi-gap resistive plate chambers (MRPCs) for accurate time-of-flight (TOF) measurements were introduced in 1990s[1]. Being insensitive to magnetic fields, inexpensive and simple to build, and better than scintillators, MRPCs are widely used in TOF system at medium and high energy physics experiments, such as the STAR (Solenoidal Tracker At RHIC) experiment at the RHIC (Relativistic Heavy Ion Collider)[2], and some other experiments[3–6]. A large-area and cost-effective Muon Telescope Detector (MTD) at mid-rapidity has been proposed to improve STAR capability for direct identification muon decay from quarkonia[7]. The MTD with the low occupancy is constructed by the long-strip MRPC (LMRPC) technology, instead of smaller pad MRPCs, in the STAR TOF system[7]. With this design, the number of electronic channels can be reduced, and the hit position along a strip can be obtained by the time differences at the two ends of the strips. Among the prototypes developed for large-area implementation of the MTD[8], some were assembled with adhesive tapes and silicones to solidify the constructions and avoid sparking, while others were mounted without any adhesive tape and silicone. And effects of adhesive tapes and silicones on the detector performances can be studied.

In this paper, we report an experiment setup and the results of systematic cosmic-ray tests. The LMRPC modules with tapes and silicones can work at lower HVs in the higher noise level and more complicated construction procedure, and time resolution is not affected greatly by the tapes and silicones.

2 Structure of the module

A schematic side view of the detector structure is shown in Fig.1. The seven glass plates, in thicknesses of 0.7–1.1 mm and volume resistivity of 10^{12}–10^{13} Ω·cm, are interleaved with 250-μm gaps and nylon monofilament fishing lines. By using a sprayer moving in a constant speed, the external surface of outer glass plates has been coated by colloidal graphite paint to form the HV cathode and anode, with the surface resistivity of ~5 MΩ/□. The high voltage is applied to

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the long edges of the painted electrodes by a piece of self-adhesive copper of 10 mm×50 mm. The active area of the module, defined by the inner glass plates, is 52 cm×90 cm. The twelve strip pairs, in periods of 3.8 cm + 0.6 cm, pick up the signals. A Mylar layer of 0.18 mm thickness is placed between the graphite paint and read-out PCB (printed circuit board), so as to insulate the HV electrodes and the read-out strips. Fiber glass-reinforced honeycomb plates are placed on the outer surfaces of PC board to support the device and keep it rigid.

Gas mixtures of primarily freon R134A with admixtures of iso-butane and SF_6 are used as the working gas. The primary ionization in the gas gaps following traversal charged particles through the detector undergoes Townsend avalanche multiplication due to the electric fields in the gaps. The avalanche electrons move to produce image charge signals in the pick-up strips. The signals input to the front-end electronics (FEE) are the total avalanche signals in gas gaps. The outputs of FEE (the same FEE used for the STAR TOF prototype "TOFr"[9]) are digitized by VME based CAEN V792 (for charge) and CAEN 775E (for time).

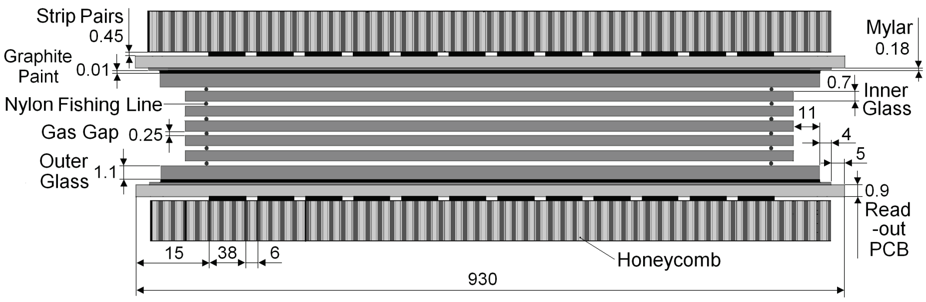

Fig.1 The structure of the LMRPC module.

Two LMRPC modules were built, Module 1 with double coated adhesive tapes and silicones (Fig. 2), while Module 2 with none. For Module 1, the PCB, Mylar layer and graphite painting layer are separated by 3M 9690 double coated tapes[10], and the circumambience of the graphite layer is protected by CAF 4 Rhodorsil Silicones[11].

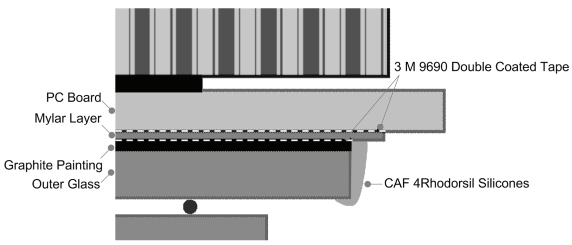

Fig.2 Schematic view of the LMRPC Module 1.

3 Cosmic ray test system setup and results

In the cosmic ray test, three 20 cm×5 cm×5 cm and two 4 cm×2 cm×1 cm scintillators were used. As shown in Fig.3, two large and one small scintillator were above the LMRPC module; and the rest were below the module. Seven photomultiplier tubes, PMT0–6, were connected to the scintillators. PMT0 and PMT3 coincidence signals provide the trigger for the ADC gate and the TDC stop signal. PMT1–PMT4 provides reference time for the LMRPC measurement. The same setup was used for cosmic ray test of the STAR TOF MRPC detectors[12]. When measuring the module efficiency, the area subtended by the two small scintillators was smaller than that of an LMRPC strip.

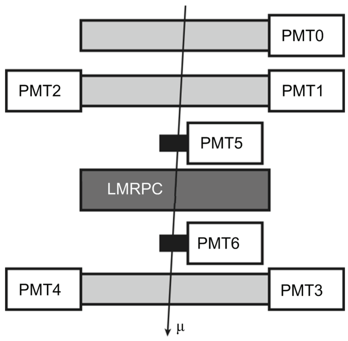

Fig.3 Layout of the cosmic-ray test system.

To eliminate the jitter of TDC stop signal, time resolution of the LMRPC module is processed as follows:

(1) The reference time is given by $t_0 = (t_1 + t_2 - t_3 - t_4)/4$, where t_1 to t_4 are provided by PMT1 to PMT4, respectively. A slewing correction using Eq.(1) is done for q_1 to q_4 (charges measured on PMT1 to PMT4).

$$t = p[0]+p[1]/q^{1/2}+p[2]/q+p[3]q \qquad (1)$$

(2) The measured time of LMRPC module is given by $t_m = [(t_{m1}-t_{m2})/2]-(t_1+t_2+t_3+t_4)/4$, where t_{m1} and t_{m2} are the time measured by strips at two ends of the LMRPC module. A slewing correction using Eq.(1) is done for $q_1 - q_4$ and $(q_{m1}+q_{m2})/2$ (average charge for two ends of the measured strip).

(3) The time resolution is given by. Eq.(2),

$$\delta_t = (\delta_{tm}^2 - \delta_{t0}^2)^{1/2} \qquad (2)$$

where, δ_{tm} and δ_{t0} are the time resolution of LMRPC measured time and reference time respectively.

Figure 4 shows examples of the reference time and measured time of LMRPC. Before and after slewing correction, resolutions of the reference time are 56.0 and 37.0 ps. The resolutions for the measured time of LMRPC are 84.9 and 76.5 ps after slewing correction and by solving Eq.(2).

Both LMRPC modules underwent two tests with gas mixtures of different gradient contents: Test I, 94% freon, 5% iso-butane and 1% SF_6; and Test II, 90% freon, 5% iso-butane, and 5% SF_6. The efficiency, time resolution and noise of the LMRPC modules were measured.

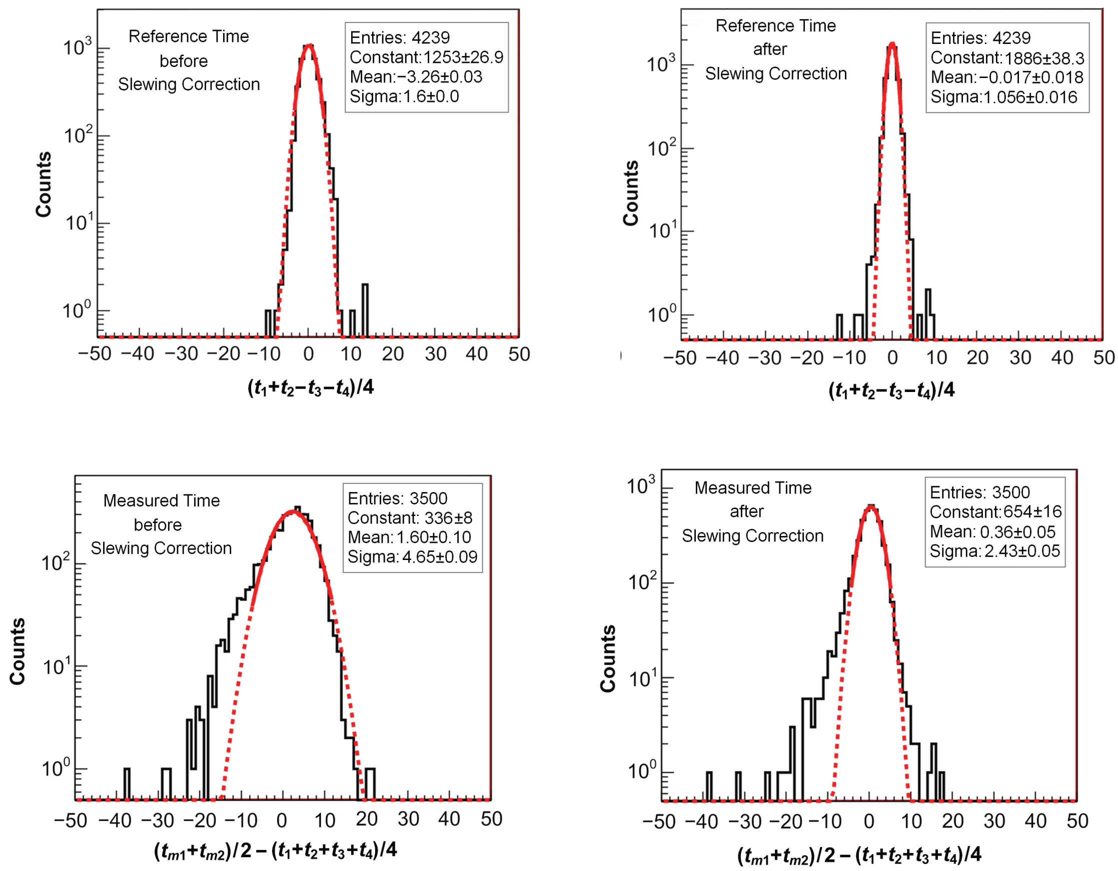

Fig.4 Distributions of the reference time and LMRPC-measured time before and after slewing correction (35 ps per channel).

Figure 5 shows test results of the two modules. The efficiency, time resolution and noise level are given as a function of the electric field intensity (E), which is the applied HV divided by the total thickness of the gas gaps (6×0.025 cm). In Test I, both the modules achieved 100% efficiency at high E. The efficiency was over 90 % at ≥ 89.3 kV/cm (HV≥|6.70| kV) for Module 1; and at ≥97.9 kV/cm (HV≥|7.34| kV) for Module 2. The time resolution was around 75 ps for both modules. The electric field intensity to achieve 90% efficiency for Module 1 was 8.6 kV/cm (HV of 0.65 kV) lower than Module 2, but the noise level of Module 1 was 90 Hz at 90% efficiency in comparison to 60 Hz of Module 2.

The results of Test II were similar to Test I. As shown in Fig.6, the two modules had efficiency around 100% at high electric field. The 90% efficiency was seen at 90.4 kV/cm (HV= ±6.78 kV) for Module 1;

and 100 kV/cm (HV= ±7.5 kV) for Module 2. The time resolution was around 70 ps for both modules. The electric field intensity to achieve 90% efficiency for Module 1 was 9.6 kV/cm (HV of 0.72 kV) lower than Module 2, while noise level of Module 1 was 80 Hz at 90% efficiency but it was 50 Hz for Module 2.

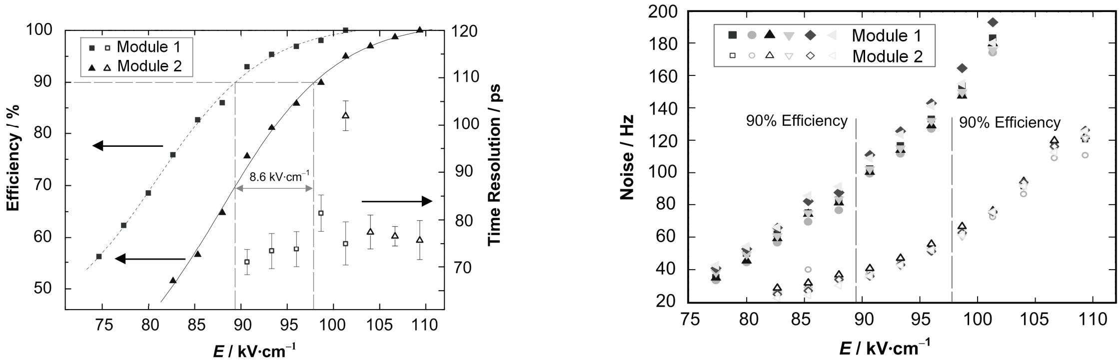

Fig.5 Eficiency, time resolution and noise level of the two modules, as a function of the electric field intensity, in Test I.

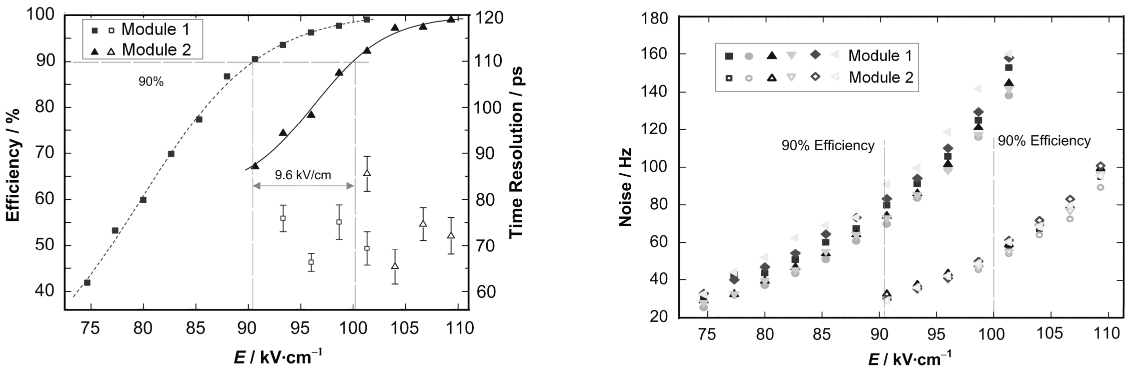

Fig.6 Efficiency, time resolution and noise level of the two modules, as a function of the electric field intensity, in Test II.

4 Conclusions

Performance of the LMRPCs with (Module 1) or without (Module 2) adhesive tapes and silicones were investigated in Tests I and II with gas mixtures of different gradient contents, However, the LMRPC modules performed rather similarly in the two tests.

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