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20 gas gaps Multigap Resistive Plate Chamber: Improved rate capability with excellent time resolution

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ABSTRACT

A 20 gas gaps multigap resistive plate chamber (MRPC) was built with thin (0.28 mm) glass sheets and 0.16 mm gas gap size. This chamber reaches 97% efficiency at 18.4 kV and a time resolution of 32 ps (sigma) at an instantaneous particle flux around 2.5 kHz/cm^2. Compared to a 6 gaps MRPC with 0.22 mm gas gap, this 20-gap MRPC shows a higher rate capability and much better time resolution. The efficiencies of the 20-gap MRPC reach 95%, 93% and 88% at instantaneous fluxes of 10 kHz/cm^2, 14.5 kHz/cm^2 and 20 kHz/cm^2, respectively. The efficiencies of the 6-gap MRPC at the same flux are 90%, 85% and 77%. The time resolution of 20-gap MRPC degrades with the increase of particle flux. However, a time resolution of 39 ps was obtained at an instantaneous flux of 10 kHz/cm^2.

1. Introduction

The multigap resistive plate chamber (MRPC) is often used as a time of flight (TOF) detector in nuclear and high energy experiments thanks to its very good timing characteristics [1]. Typically it has a time resolution between 50 and 100 ps [2]. At the future Compressed Baryonic Matter (CBM) experiment at Facility for Antiproton and Ion Research (FAIR) [3], the TOF detectors are required to work with a continuous flux on the order of 1–10 kHz/cm^2 for the outer region and 10–25 kHz/cm^2 for the central region [4]. Thus the rate capability is a key characteristic for the MRPCs used at the CBM experiment. The rate capability of the MRPC can be improved by using materials with lower bulk resistivity or electrodes with thinner thickness. For example, using low resistivity glass plates with bulk resistivity of 10^{10} Ωcm, a ten gap MRPC has an efficiency above 90% and a good time resolution (below 90 ps) at a flux of 25 kHz/cm^2 [5]. It is also shown that the reducing of gap size can enhance the rate capability of MRPC due to the reduction of avalanche charge [6]. In our previous studies, using a very small gas gap size of 0.16 mm, a time resolution of 20 ps was obtained [7]. Here we show the results of a 20 gas gaps MRPC with a gap size of 0.16 mm at different particle fluxes. This 20-gap MRPC is a very promising TOF detector that gives excellent time resolution and a high rate capability.

2. MRPC construction

Two MRPCs were constructed, 20-gap MRPC and 6-gap MRPC. For the convenience of comparison, both MRPCs have the same active area. The outer glass plates of two MRPCs have a dimension of 22×22 cm^2 with a 18×18 cm^2 voltage electrode; the inner glass plates have a dimension of 18×18 cm^2. All glass plates used to build both MRPCs are 0.28 mm thick and have a bulk resistivity of 1.3×10^{12} Ωcm at 24° C. The outer glass sheets were painted with resistive material to form a resistive electrode with a surface resistivity of 5 MΩ/□.

2.1. 20-gap MRPC

Fig. 1 shows the schematic of cross section of 20-gap MRPC. To simplify the construction of MRPC and reduce the number of total glass plates, the 20-gap MRPC has two stacks configuration instead of four stacks configuration as we used in [7]. Each stack is made with 2 outer glass plates and 9 inner glass plates. Fishing line, with diameter of 0.16 mm, is used to form a 0.16 mm gap size between the glass plates. A mylar sheet was placed between the voltage electrode and the printed circuit board (PCB) to isolate the high voltage. Three PCBs with pick up strips are used to readout the signals from 20-gap MRPC. The two resistive electrodes next to the middle PCB were connected with negative high voltage and the other two electrodes on the top and bottom layer connected to positive high voltage. Thus the 20-gap MRPC has two anode readout strip planes (top and bottom) and one cathode readout strip plane (middle). The width of the readout strip is 1 cm and the pitch is 1.2 cm. The length of the strip is 21 cm.

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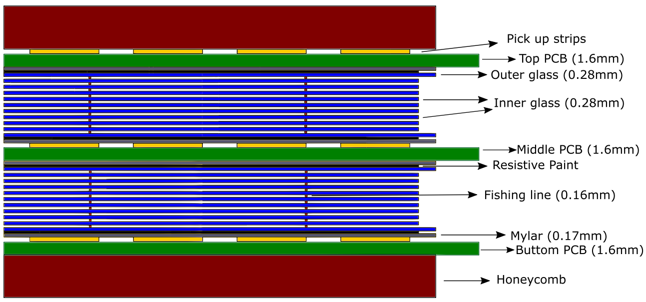

Fig. 1. Cross section of the 20-gap MRPC.

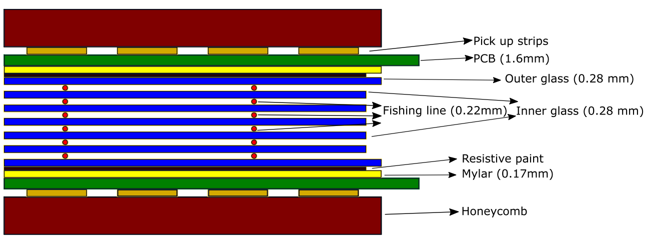

Fig. 2. Cross section of the 6-gap MRPC.

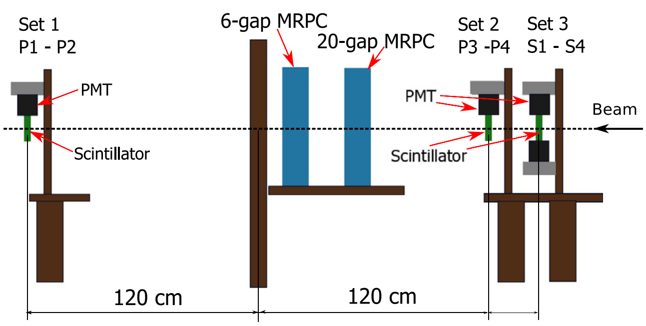

Fig. 3. The experiment setup for the MRPC test at the T10 test beam facility.

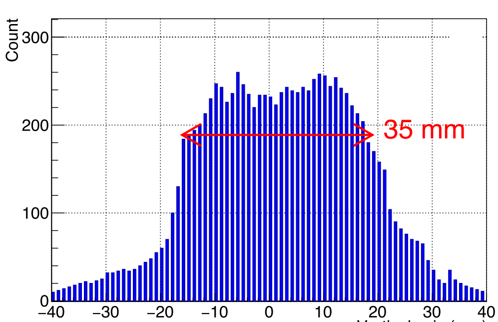

Fig. 4. The delayed wire chamber profile in vertical axis at the flux of 25 kHz/cm^2.

2.2. 6-gap MRPC

6-gap MRPC has only a single stack. Two outer glass plates and 5 inner glass plates form 6 gas gaps. The gap size of 6-gap MRPC is 0.22 mm, which is 60 μm larger than that of 20-gap MRPC. As shown in Fig. 2, the 6-gap MRPC is readout by strips located on the top and bottom PCBs. The width of the readout strip is 0.7 cm and the pitch is 0.9 cm. The length of the strip is the same as the 20-gap MRPC. Both MRPCs are supported by honeycomb and enclosed in a gas tight aluminium box.

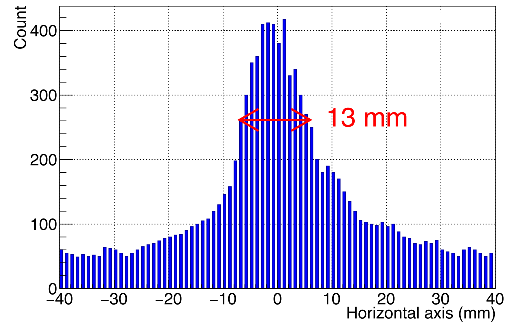

Fig. 5. The delayed wire chamber profile in horizontal axis at the flux of 25 kHz/cm^2.

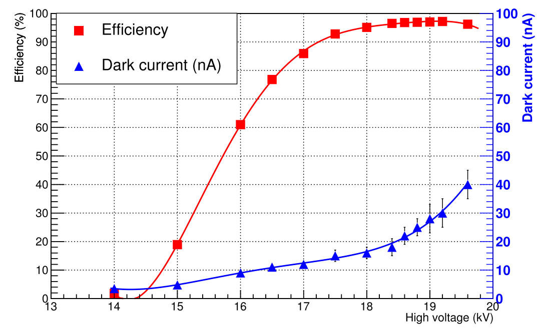

Fig. 6. The efficiency and dark current of 20-gap MRPC as a function of applied voltage with an instantaneous flux of 2.5 kHz/cm^2.

3. Experiment setup

The MRPCs were tested in T10 test beam facility at CERN [8]. Fig. 3 shows a schematic drawing of the experimental setup. The beam (mostly negative pions of 5 GeV/c momentum) had a direction perpendicular to the chamber. A gas mixture of 95% $C_2H_2F_4$ and 5% SF_6 was flowed through the chambers at a rate of 5 l/h. The size of the two scintillators of set 1 (P1, P2) is 1.2×1.2 cm^2 and set 2 (P3, P4) is 1.9×1.9 cm^2. Each scintillator of set 1 and set 2 is coupled with one photomultiplier tube (PMT). Scintillator set 3 consists of two orthogonal scintillator bars with dimension of $2 \times 2 \times 20$ cm^3. Each end of each bar is coupled to a PMT (S1, S2 for one bar, S3, S4 for the other bar). The time difference between four PMTs $((t_{S1}+t_{S2})/2-(t_{S3}+t_{S4})/2)$ has a sigma of 70 ps. This implies that the reference time of the four PMTs $((t_{S1}+t_{S2}+t_{S3}+t_{S4})/4)$ has a jitter of 35 ps. All three sets were well aligned with respect to the beam line and defined a small (1.2×1.2 cm^2) area of the beam to provide the trigger signal. The beam spill has a duration of 360 ms. By measuring the number of coincidences of set 1 and set 2 during the spill we can monitor the instantaneous flux of particles that go through the MRPCs. The beam size is measured by a wire chamber. Figs. 4 and 5 show the wire chamber profile in both vertical axis and horizontal axis at the flux of 25 kHz/cm^2. As can be seen from the wire chamber, the beam is focused on a cross section of 13 mm × 35 mm. In this spot area, the intensity varies a little. So in the small area (1.2×1.2 cm^2) we defined, the MRPC is illuminated uniformly with particles. The MRPCs were mounted on a X-Y moving table between PMT Set 1 and Set 2. This table could be positioned with a precision of 0.5 mm. By moving the table, the beam was centred in the middle of one pick up strip of the MRPC. The signals from the MRPC are discriminated by the NINO ASIC [9] and readout by WaveCatcher [10].

4. Results

4.1. Performance of MRPCs at different voltages

All results here are from T10, which has a pulsed focused beam. The flux measurement is obtained from the count rates of the scintillator sets