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Study on the performance of large area MRPC with high position resolution ☆

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ABSTRACT

Multi-gap resistive plate chamber (MRPC), which is mostly developed in high energy physics domain with excellent time resolution, is also highlighted in imaging applications. A set of 50 cm × 50 cm large area MRPC with high position resolution was successfully developed by our group and different experiments have been done to test its performances. Cosmic ray muons were used to do the test and proper high voltage and working gas were chosen. Data analysis indicates its good detection efficiency and good position resolution, which encourages further study of its application in RPC-PET and muon tomography.

1. Introduction

In 2003, a new form of cosmic ray muon radiography, which is based on the multiple Coulomb scattering of muons when passing through materials, was proposed by LANL for detection and 3D imaging of dense high-*Z* objects [1–3]. By tracking the scattering angles of incoming and outgoing muons one by one with two groups of detectors with sub-millimeter-scale high position resolution, one can scan the density distribution of materials, especially heavy nuclear materials in the sensitive space between the two groups of detectors. In their study, drift chambers were used for precise measurement of muon tracks, and many exciting and inspiring results have been achieved. In this paper, a kind of large area multi-gap resistive plate chamber (MRPC) with high position resolution is studied for the possible application in muon tomography.

2. Structure of the MRPC

As shown in Fig. 1, the MRPC detector is composed of two parallel resistive plate electrodes with five gas gaps divided by four resistive floating glasses with bulk resistivity of about $10^{12}\ \Omega\,\mathrm{cm}$, while Nylon fishing lines are used to hold the thickness of gas gap. Each gap has a width of 0.33 mm, so the total sensitive thickness is about 1.7 mm. High voltage is applied on the carbon film (surface resistivity of $4\times10^5\Omega/\square$) to provide homogeneous electric field, and outside of the carbon film, separated by a layer of 350 μm−thick Mylar film, is the readout module on PCB to pick up induced signals. A kind of two-dimensional readout method with strips and pads has been developed for the MRPC detector. The readout pitch is set to 2 mm for both *X* and *Y* dimension.

The detailed structure of the readout electrodes is shown in Fig. 2. A method of two-dimensional read out electrode has been developed with certain PCB technology. All the pads in a line orthogonal to strips are connected together on the rear surface of the PCB. Thus the two-dimensional readout structure can pick up the induced signal when an avalanche occurs in the gas gaps of MRPC. The width of the long strip is 0.64 mm. The pad has a dimension of 1.7 mm × 0.76 mm. The internal width between the strip and pad is 0.3 mm, and the same width is for neighboring pads.

The prototype large area MRPC has the dimension of 500 mm × 500 mm and effective region is about 440 mm × 440 mm. The number of readout channels in each dimension is 222 with the pitch of 2 mm. Due to the limited number of electronic channels; we just use 80 channels of electronics to study the performance of the prototype MRPC.

3. Test experiment

3.1. Experiment setup

Cosmic ray muons were used as the charged particle source to test the performance of the MRPC. The induced current signals from every detector channel were picked up by a current-sensitive preamplifier and then fed into a home-made main amplifier and FADC for digitization. The DAQ system was based on VME bus, and a PowerPC (Motorola MVME5100) interface was used for taking data. The experimental setup was designed to use triggering for signal selection. The trigger came from a coincident output of two scintillators that were served as cosmic ray telescopes for muon

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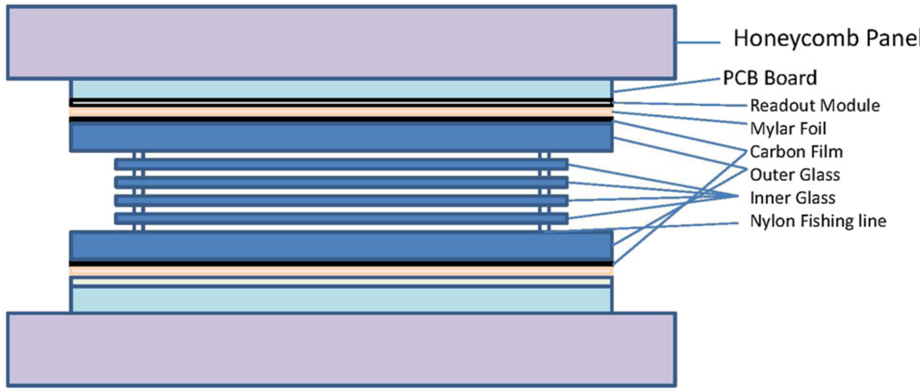

Fig. 1. The structure of the prototype MRPC detector.

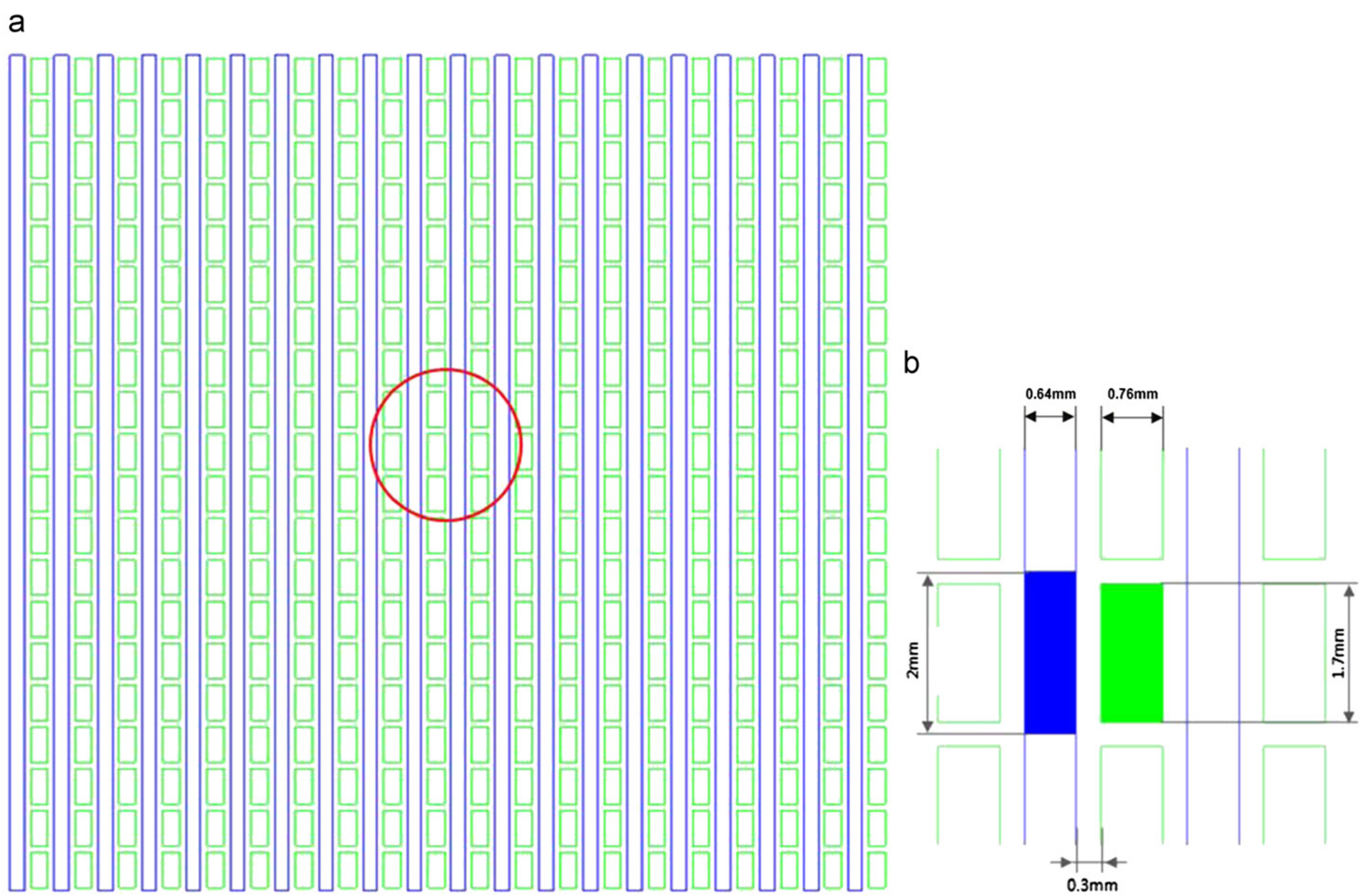

Fig. 2. (a) Structure of readout electrode, (b) unit area.

tracking. The DAQ system recorded the current pulse shapes from all the channels when the system is triggered. Fig. 3 shows the schematic layout of the experimental setup. The induced charges from several adjoined strips describe the space distribution of the induced charge of an MRPC detector. The position of the incident muon can be obtained by applying the charge center method with signals from several adjoined strips both in two dimensions.

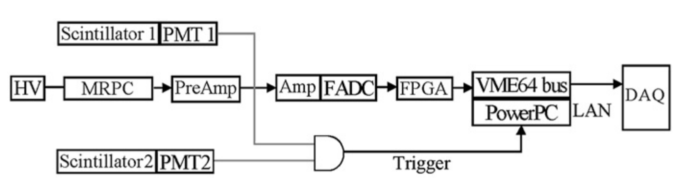

Fig. 3. The schematic layout of experimental setup for MRPC.

3.2. Operating gas

The gas mixture of three ingredients has been used as the working gas as follows: F134a, iso-butane, and sulfur hexafluoride. The contents of each gas will be changed to get optimum performance of MRPC. Fig. 4 shows curves of efficiency versus high voltage for the MRPC. The maximum efficiency, including both