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Study on two-dimensional induced signal readout of MRPC ☆

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ABSTRACT

A kind of two-dimensional readout electrode structure for the induced signal readout of MRPC has been studied in both simulation and experiments. Several MRPC prototypes are produced and a series of test experiments have been done to compare with the result of simulation, in order to verify the simulation model. The experiment results are in good agreement with those of simulation. This method will be used to design the two-dimensional signal readout mode of MRPC in the future work.

1. Introduction

In recent decade, people pay more and more attention to antiterrorism, which calls for new technology to detect nuclear material and other explosive threats. From 2001, LANL began to study radiographic imaging with cosmic ray muons. Later in 2003, their works was published in Nature [1] and attracts lots of attention all over the world. From their posterior work as well as others', much more studies have been done and the method of muon tomography is improved [2–5]. Here we take the idea of cosmic ray imaging, and employ Multi-gap Resistive Plate Chamber (MRPC), instead of drift tube, as the detector to implement two-dimensional and/or three-dimensional muon tomography.

For muon tracking measurement, MRPC with position resolution better than 1 mm has been exploited [6]. In our previous work [7,8], we presented that the surface resistivity of high voltage provider, which also produces in the space dispersion of induced charges, will eventually affect the charge distribution on readout electrode structure. FADC-based electronics has been chosen to record the whole pulse shape of each induced current signal, in order to optimize the position resolution. In these experiments, only one-dimensional readout electrode structure was used for simplicity to focus on the main aspects of the studies. In this paper we will pay attention to the design and testing of a two-dimensional readout electrode structure of the MRPC induced signals, which has been applied for MRPC with high position resolution developed by our group.

2. Simulation of MRPC readout mode

In order to obtain the position information of incident charged particle, one has to read out the induced current signals by electron avalanche with at least two-dimensional electrode structure. Here a method of two-dimensional induced signal pickup has been developed with certain PCB technology as shown in Fig. 1. Structure of parallel long strips performs the readout of one dimension, while all the pads in a line orthogonal to the direction of the long strips are connected together on the rear surface of the PCB, to be a readout electrode structure of the other dimension. The whole readout electrode structure lies in one layer, thus saving the compensation of shielding effect between the structures of two dimensions.

Researches have been done by many groups to study the one-dimensional strip electrode structure of reading out the induced current signals of MRPC [10–12,14] and to obtain better position resolution [7,9], where theoretical and simulation analysis of the whole progress, from primary ionization to induction, have also been discussed in detail [13]. In these studies, the whole detector is considered as a plane condenser, within the carbon film as one of dielectric layers. However, not same as the usual dielectric layers, carbon film here is electrically conductive which can induce charge signals and therefore diffuses the space distribution of the induced charges when the induced charges pass through the carbon film. This will finally affect the space distribution of the induced charges on the readout electrode structure and thus needs additional consideration, which is to be discussed afterwards in simulation.

In order to do the simulation, we set the readout electrode structure as cathode, while another copper plane as anode, which is shown in Fig. 2(a). High voltage of 8000 V has been added between the anode and cathode to form the statical electric field. Then we measure the electric fluxes of strip and pad in unit area (Fig. 2(c)). If one want to get a balance distribution of the induced charges on the strips and pads, the electric fluxes passing through the strip and pad within unit area should be the same. The prototype of readout

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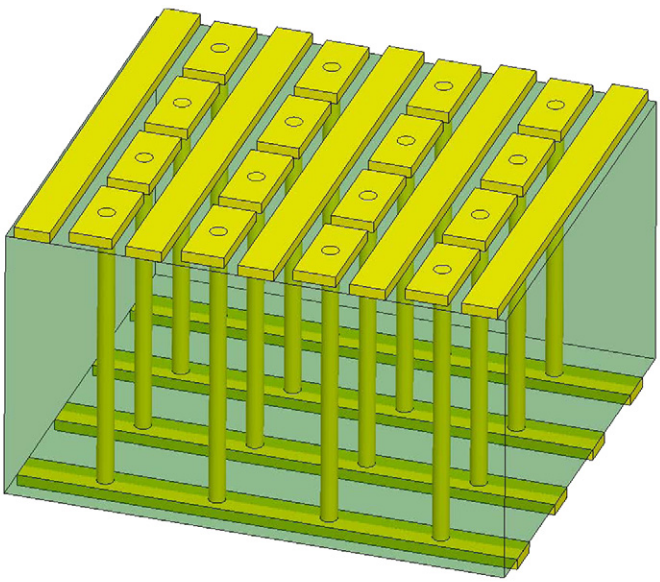

Fig. 1. Structure of readout electrode structure on PCB.

electrode structure in our simulation by Ansoft Mexwell [15] is displayed in Fig. 2. The pitch in each dimension is chosen as 2 mm. Due to the limitation of normal PCB technique, the gap between strips and pads is not less than 0.3 mm. Thus the length of pad is fixed at $2-0.3=1.7$ mm, and the only parameter to determine is the strip's or the pad's width.

A set of the strip's width is assumed from 0.45 to 0.8 mm, with the step of 0.05 mm. Fig. 3 shows the relationship between electric flux ratio and strip's width. Three fitting methods are taken to optimize the strip's width (where the ratio to be 1), which is finally determined at 0.64 mm. This result means induced charges in two dimensions will be equally diffused by carbon film. Moreover, the result yields approximately the same area of readout electrode structure in two dimensions, which is also appropriate to the induction on readout electrode structure directly by avalanched charges. It is then expected that the total induced charges in two dimensions will be roughly equal, with the strip's width of 0.64 mm.

3. Structure of the RPCs and experiment setup

MRPC is developed from RPC, as the sensitive volume divided to several gaps by floating glasses with the other parts unchanged.

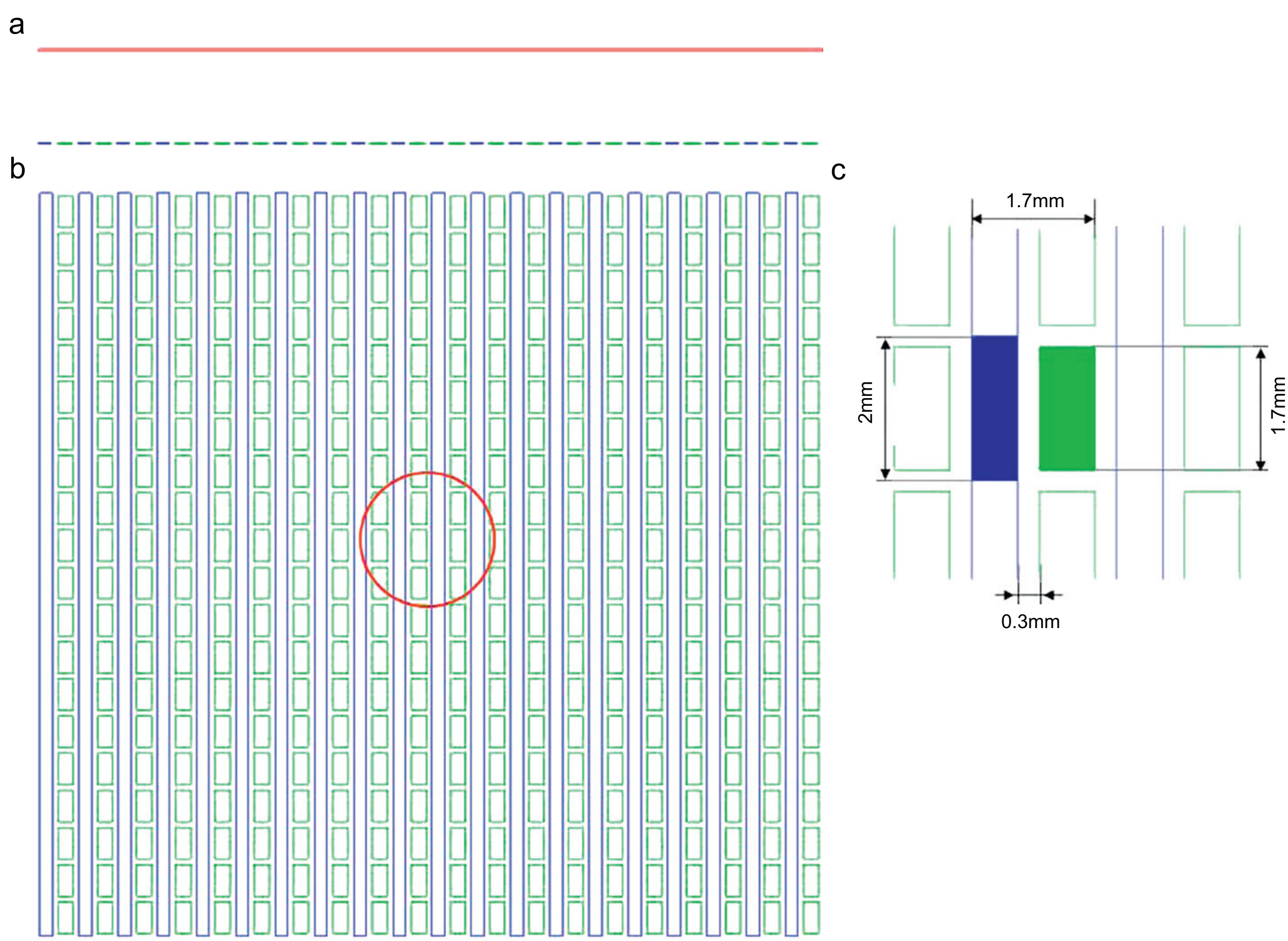

Fig. 2. Prototype of simulation (a) side view, (b) top view, (c) unit area. After simulation, we calculate the signals in the central unit area, which is shown in the red circle in (b) and is zoomed in (c). The electric fluxes of a pad (solid green box) and the related piece of strip (solid blue box) are obtained, and the ratio between them has relationship with the strip's width. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)