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The effect of spacers on the performance of Micromegas detectors: A numerical investigation

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ABSTRACT

Micromegas detector is considered to be a promising candidate for a large variety of high-rate experiments. Micromegas of various geometries have already been established as appropriate for these experiments for their performances in terms of gas gain uniformity, energy and space point resolution, and their capability to efficiently pave large read-out surfaces with minimum dead zone. The present work investigates the effect of spacers on different detector characteristics of Micromegas detectors having various amplification gaps and mesh hole pitches. Numerical simulation has been used as a tool of exploration to evaluate the effect of such dielectric material on detector performance. Some of the important and fundamental characteristics such as electron transparency, gain and signal of the Micromegas detector have been estimated.

1. Introduction

Micro Pattern Gas Detectors (MPGDs) [1], a recent addition to the gas detector family, have found wide applications for tracking and triggering detectors in different experiments involving astro-particle physics, high energy physics, rare event detection, radiation imaging, etc. For example, GEM and Micromegas detectors are known to offer excellent spatial resolution, high rate capability and single photo-electron time resolution in the several nanosecond ranges.

The Micromegas (MICRO-MEsh GAseous Structure) [2] is a parallel plate device and composed of a very thin metallic micro-mesh, which separates the low-field drift region from the high-field amplification region. A set of regularly spaced dielectric pillars, called spacer [3], is required to guarantee the uniformity of the gap between the mesh and the anode plane. The use of pillars introduces one major drawback. Particles are not detected at the pillar locations and the sensitivity of the region close to the pillar may be different from the regions where there are no nearby pillars.

The Micromegas [4] detector with an amplification gap of 128 μm has been considered to be one of the good choices for a read-out system in different Time Projection Chambers (TPCs) due to its performances in terms of gain uniformity, energy and space point resolution and low ion feedback [5–8]. It is also efficient to pave large read-out surfaces with minimum dead zone. For some experiments involving low pressure operation, Micromegas detectors having larger amplification gaps are more suited [9–11]. Micromegas detectors of a wide range of amplification gaps have been studied for possible application in rare event experiments [12,13]. Detailed experimental and numerical studies on the basic performance parameters of different Micromegas detector have also been reported on earlier occasions [14,15].

In this work, numerical simulation has been used as a tool to evaluate the effect of dielectric spacer on the performance of Micromegas detectors. The study begins with the extensive computation of the electrostatic field configuration within a given device. Some of the fundamental properties like gain, electron transmission, signal on the anode plate have been estimated following detailed numerical simulation of the detector dynamics. The effect of detector geometry, such as amplification gap and mesh hole pitch on the signal, has been also studied.

2. Simulation tools

The Garfield [16,17] simulation framework has been used in the following work. This framework was augmented in 2009 through the addition of the neBEM (nearly exact Boundary Element

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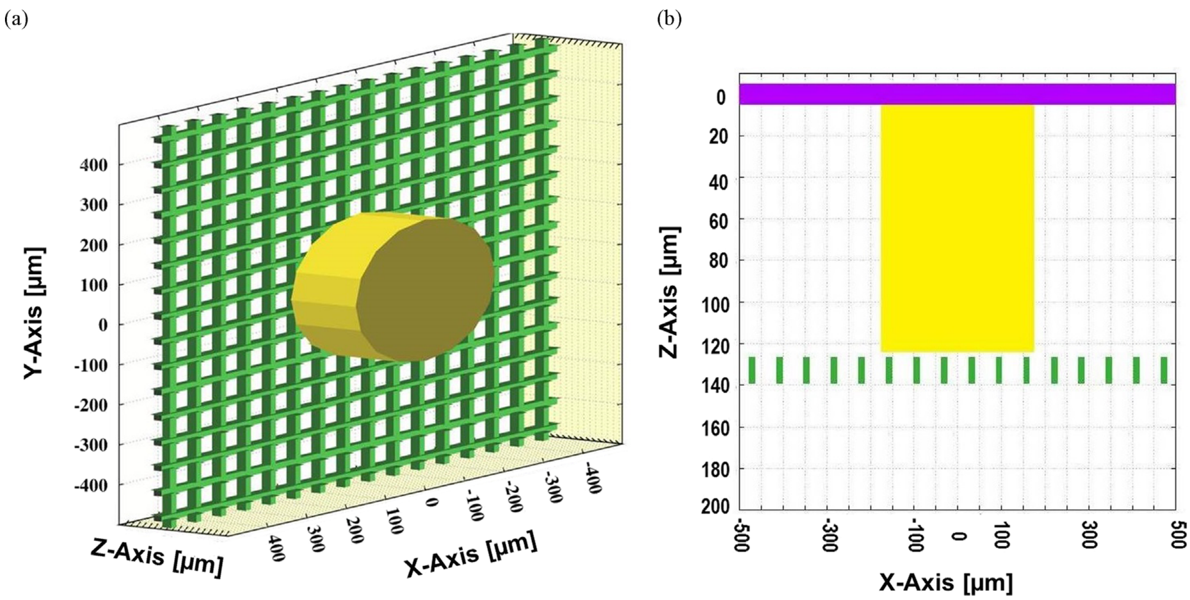

Fig. 1. Model of a Micromegas with a cylindrical spacer at the center: (a) 3D view and (b) 2D view.

Table 1
Parameters of the Micromegas detectors. All detectors have a mesh-wire diameter of 18 μm.

Detector name	Amplification gap (μm)	Mesh hole pitch (μm)
MM A	64	63
MM B	128	63
MM C	128	78
MM D	192	63

Method [18–21]) toolkit to carry out 3D electrostatic field simulation. Besides neBEM, the Garfield framework provides interfaces to HEED [22,23] for primary ionization calculation and Magboltz [24,25] for computing drift, diffusion, Townsend and attachment coefficients.

3. Results

3.1. Simulation model

For numerical simulation, Garfield has been used to model the Micromegas detector. The simulation model is given in Fig. 1. In order to reduce computational complexity, wire elements have been used to model the micro-mesh. In addition, in an actual experiment, due to the accumulation of charge, a dielectric spacer is expected to be charged up during operation. Charging up may lead to gain variations that, depending on the application, can interfere with the correct functioning of the detector. In our numerical simulation, we have not considered this effect for the present study. Also the electrostatic deformation of the mesh has not been taken into account in this numerical model.

The length of the base device along both X and Y directions has been considered to be 2 mm. A cylindrical spacer of diameter 350 μm has been placed at the center of the base device. Thus the pitch between two spacers was maintained at 2 mm. Then, this base structure has been repeated along both positive and negative X and Y directions to represent a real detector. The design parameters of the Micromegas detectors considered in this work, are mentioned in Table 1.

3.2. Electric field

The introduction of a full dielectric cylinder causes significant perturbation resulting in the increase of the field values, particularly in the regions where the cylinder touches the mesh. Fig. 2 shows the effect of such a dielectric spacer on the electric field for the Micromegas with 128 μm gap and 63 μm pitch. As is obvious from the figure, the electric field through the mesh hole near the spacer is also affected by the presence of this dielectric material. Increase in the electric field values can lead to electric discharges and thus should be avoided, as much as possible, in the detector design. Therefore, the spacer should occupy the smallest possible volume while keeping the constant amplification gap.

3.3. Drift lines, transmission and gain

To study the effects of the perturbed electric field on different detector characteristics, electron tracks of length 700 μm along the X-axis which extends over the spacer (as shown in Fig. 3) at different distances from the micro-mesh have been considered. The electrons from these predetermined tracks are then allowed to drift and multiply in the amplification region. The plot in Fig. 4 shows the drift time of these electrons versus their end points along Z-axis. As seen from Fig. 3, the drift lines get distorted and a fraction of the electrons in the presence of the spacer take a longer time to reach the anode (Fig. 4). From Figs. 3 and 4, it is also observed that significant number of electrons are lost on the spacer when the track is close to the mesh, resulting in a reduced gain. From the distant track, at 400 μm above the micro-mesh, almost all the electrons do get through, however, circumambulating the spacer and, thus, take longer drift time. This is the reason why the total gain is not reduced effectively although