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Signal characteristics of a resistive-strip micromegas detector with an integrated two-dimensional readout

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ABSTRACT

In recent years, micropattern gaseous detectors, which comprise a two-dimensional readout structure within one PCB layer, received significant attention in the development of precision and cost-effective tracking detectors in medium and high energy physics experiments. In this paper, we present for the first time a systematic performance study of the signal characteristics of a resistive strip micromegas detector with a two-dimensional readout, based on test-beam and X-ray measurements. In particular, comparisons of the response of the two independent readout layers regarding their signal shapes and signal reconstruction efficiencies are presented.

1. Introduction

Since its invention in 1996 [1], the technology of micromegas detectors has been under constant development [2]. In recent years, micropattern gaseous detectors received significant attention in the development of precision and cost-effective large-scale tracking detectors for high-energy physics experiments [3,4]. The first micromegas detectors with a two-dimensional readout structure integrated within one PCB board and a resistive strip layer were developed within the RD51 [5] and MAMMA (Muon ATLAS micromegas Activity) collaborations [6]. Micromegas detectors with such a 2D readout implementation have the advantage of a reduced material budget providing also for a fixed mechanical structure of two readout layers.

A typical layout of a micromegas detector is shown in Fig. 1. A planar drift electrode and a readout electrode are separated by a gap of a few mm. While the drift electrode is covered uniformly with a conducting layer, e.g. copper, the readout electrode is usually made of a PCB board with a uniform structure of conductors, separated by insulating material. The strip width and the distance between strips can be chosen depending on the final application. The gap between the two electrodes is filled with a gas mixture (e.g. a 90:10 mixture of Ar and CO_2). A stainless steel mesh is placed at 50–100 μm above the readout electrode, defining two volumes. The volume between the drift electrode and the mesh is called drift region, the volume between mesh and PCB is the amplification region. In order to create the drift and amplification electric fields, two external voltages are applied to the drift cathode and the resistive strips. A typical electric field in the drift region is $\sim$600 V/cm. A significantly higher electric field of $\sim$50 kV/cm is applied to the amplification region. This high electric field may lead to sparks, resulting in dead-time and potential damage to the detector and the subsequent front end electronics. A resistive protection layer that consists of a thin insulator layer and resistive strips is therefore deposited on the top of the readout strips [7]. The resistive protection layer has a resistivity in the order of $\sim$ MΩ/cm and usually matches the geometry of the *x*-readout electrodes, in order to minimize a charge spread over several readout strips.

A charged particle that enters the drift region ionizes the gas atoms, producing electron-ion pairs. These electrons drift along the electric field lines to the mesh with a typical velocity of $\sim$5 cm/μs. The mesh appears transparent to the drift electrons when an adequate ratio of the electric field strength in the drift- and amplification region is chosen. Once the drift electrons reach the high electric field in the amplification region, they are accelerated sufficiently to cause a cascade of secondary electrons (avalanche) leading to an amplification factor of $\sim 10^4$ within 1 ns. These secondary electrons together with the movement of the corresponding positive ions induce a signal on the readout electrodes via a capacitive coupling to resistive strips. A detailed description of the signal formation in micromegas detectors can be found in [8].

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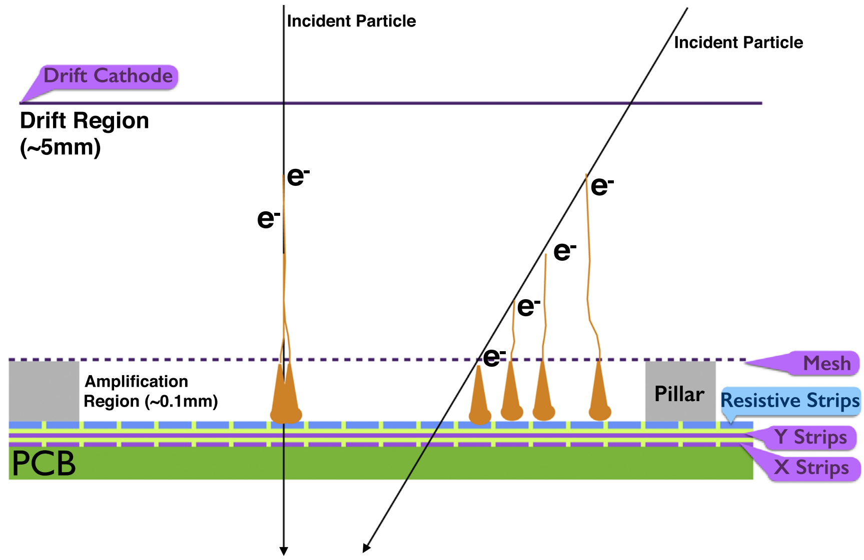

Fig. 1. Illustration of basic principle of a micromegas detector, with two incident ionizing particles. The incident particles ionize the gas atoms producing electrons that drift towards the mesh causing an electron cascade in the amplification region.

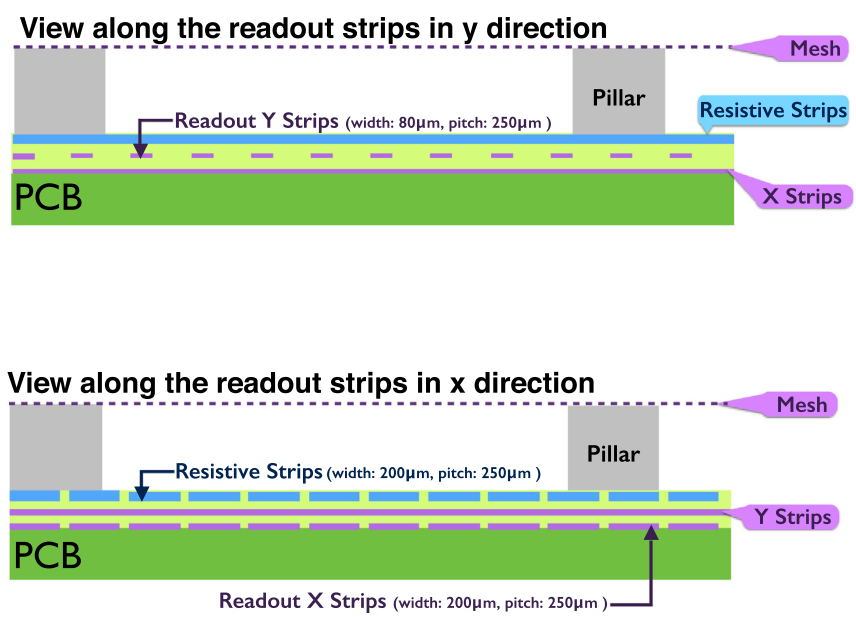

Fig. 2. Illustration of a spark protected micromegas detector with two-dimensional layout. The view is along the readout strips in *y*- (upper) and *x*-direction (lower). The resistive strips cover the upper readout layer. The first and second readout layers are separated by isolating material.

In this paper, we describe the performance of a micromegas detector with a two-dimensional readout structure. A schematic layout is illustrated in Fig. 2. In contrast to conventional micromegas detectors, this layout provides two independent readout electrodes in orthogonal directions (denoted as x and y in the following), printed on the same PCB. While previous studies [9] focused on the performance of those detector layouts for one specific configuration, we present here a comprehensive list of signal characteristics on both layers as a function of the chosen gas-mixture, amplification voltage (V_A) and the drift voltage (V_D). In particular, we compare the signal identification efficiency between the two layers and the differences in the corresponding signal shapes.

The paper is structured as follows: In Section 2, the detector layout and the experimental setups at the MAMI (Mainzer Mikrotron) accelerator and for X-ray measurements are described. The signal characteristics are described in Section 3, while the efficiency studies are presented in Section 4. A summary and concluding remarks can be found in Section 5.

2. Prototype micromegas detector and experimental conditions

The test chamber used for the studies presented here is based on a prototype detector designed by the MAMMA collaboration [9], which focuses on the development and test of large-area muon detectors for the upgrade program of the ATLAS experiment. The readout electrode comprises 360 copper readout strips in each layer with a strip pitch of 250 µm. The readout strips of the upper layer (defined as y-layer) are printed directly on top of the PCB and are covered by the resistive strips with a resistivity of $\sim$20 MΩ/cm. The lower layer (defined as x-layer) is separated from the upper layer by 70 µm of FR4, i.e. the same material used as isolating material in the