

Test and simulation of a MICROMEGAS detector^{*}

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Abstract: We report on the recent test results of a MICROMEGAS detector in terms of position resolution, time resolution and efficiency. With a Ar+CO₂ (10%) gas mixture and a strip pitch of 200 μm an accuracy of 80 μm in sigma on the position has been measured. The time resolution is better than 20 ns and a cosmic ray detection efficiency of 94% was obtained. A Monte Carlo simulation indicates that transverse diffusion, gain fluctuation and electronic noise limit the position resolution.

Key words: position resolution, time resolution, detection efficiency, Monte Carlo simulation

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1 Introduction

MICROMEGAS as a novel micro pattern gaseous detector was introduced in 1996 [1]. It is a robust gaseous detector that can withstand electrical discharge without damage and has excellent position and time resolution. Since 1996, extensive studies have been carried out and bulk MICROMEGAS technology has been invented [2]. The technique of using an industrial woven wire mesh instead of an electroformed mesh as a grid makes the detector more robust and easier to construct. The HIRFL-CSR experiment demands high accurate tracking detectors with a large area, an alternative solution is based on the MICROMEGAS detector. This paper concentrates on the measurement results of position resolution, time resolution and detection efficiency. A Monte Carlo simulation is also developed for studying the position resolution in detail.

2 Detectors and experimental setup description

MICROMEGAS is a two-stage parallel plate aval-

anche chamber working in proportional mode. The detector consists of an anode plane, insulating spacers, a micro mesh and a drift electrode. The micro mesh separates the detector into two asymmetrical parts. The larger one is the conversion gap defined by the micro mesh and drift electrode, where primary ionization occurs. The narrow one, called an amplification gap is in between the micro mesh and the anode, which is usually about 100–200 μm with $\sim 10^4$ V/cm field, where the electrons avalanche. A detailed description can be found in previous publications [3–6]. For this measurement, a 10 cm×10 cm MICROMEGAS detector was constructed. The anode plane is made of one dimensional parallel strips with standard printed circuit board technology. The amplification gap is satisfied by stretching 160 μm diameter nylon lines every 2 mm, perpendicular to the anode strips. The micro mesh is made of 635 LPI (lines per inch) 20 μm diameter stainless steel wire. The edge of the mesh is glued to the 3 mm thick RF4 frame, which defines the activity zone of the detector. The conversion gap is ensured by the mesh frame and the drift electrode is also made of micro mesh. The measurement is performed in the Ar+CO₂(10%) gas mixture at atmospheric pressure.

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3 Test result

3.1 Position resolution

The early test with a pitch of 400 μm showed that most events fired only one strip [7] and this resulted in a loss of resolution. In order to improve it, we constructed a detector with 200 μm strip pitch anode. For a test, a mask, consisting of 10 mm thick stainless-steel slices with a 100 μm slit was set on the top of the drift electrode, parallel to the anode strips. The distance from the drift electrode was 3 mm. So only the X-rays from the ^{55}Fe source in the range of $\pm 0.6^\circ$ would pass through the slit and into the conversion gap. Most of the events fired three strips, as shown in Fig. 1, and the spatial resolution was driven from the center of gravity method, as shown in Fig. 2. The best result of 80 μm in sigma was obtained. The main factors were discussed using a Monte Carlo simulation in Section 4.

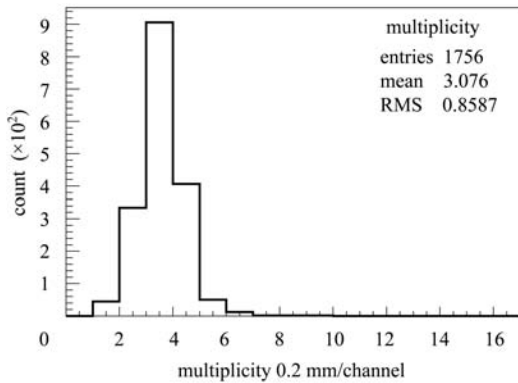


Fig. 1. Fired strip multiplicity with a micro-mesh electrode voltage of -600 V.

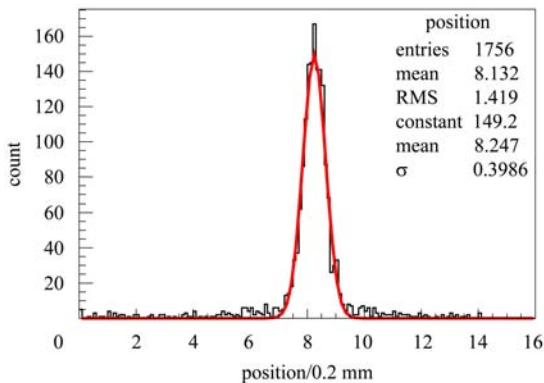


Fig. 2. Position resolution with a 0.2 mm strip pitch at a micro-mesh electrode voltage of -600 V.

3.2 Time resolution and efficiency

Time resolution is related to primary ionization fluctuation and the variations of the electron drift

distance. Usually, the first electrons to arrive show the smallest arrival time fluctuation and give a better time resolution. However, by just collecting these electrons the signals are too small to distinguish them from noise. If more electrons are collected, it would cause the signal amplitude variation and result in a time walk. Fortunately, the time walk can be corrected with the signal amplitude in off-line analysis.

For the measurement, all anode strips were connected in series, and two 5 cm \times 5 cm plastic scintillator detectors were put on the top and the bottom of the vessel. The cosmic ray signals from the anode were amplified by an ORTEC 142 A preamplifier. The fast timing pulse and E pulse were recorded by TDC and ADC respectively. Data acquisition was triggered by a signal from one of the plastic scintillator detectors. The time walk was corrected with the formula:

$$T = T_{\text{test}} - Ae^{-\frac{E}{t_0} + B}, \quad (1)$$

where, T_{test} is the time recorded by the TDC; E is the amplitude recorded by the ADC for the same event; A , B and t_0 are the fit parameters. Fig. 3 is the corrected time spectrum, and the time resolution is better than 20 ns in σ .

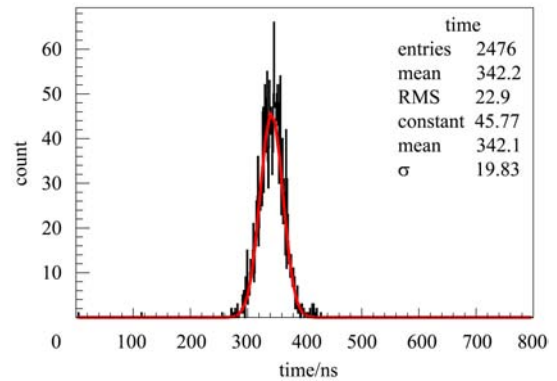


Fig. 3. Time resolution at a micro-mesh electrode voltage of -600 V.

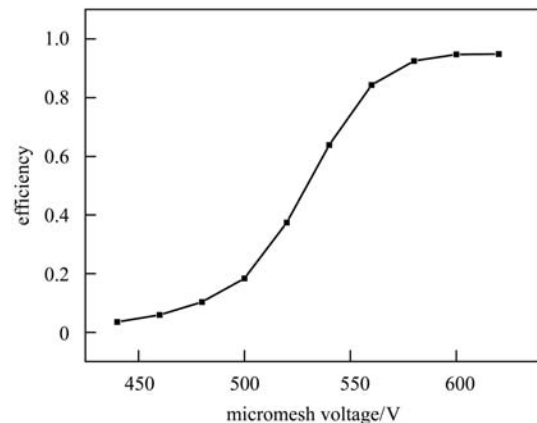


Fig. 4. Efficiency change with the micro-mesh voltage.

Detection efficiency is related to the number of electrons of primary ionization and electrons lost during drift. In the test, the drift-electrode voltage was 100 V lower than the micro mesh electrode, to decrease the electrons' loss. An efficiency of 94% was reached at a micro mesh electrode voltage of -600 V, as shown in Fig. 4.

4 Monte Carlo simulation

In order to find out the main effects that limit the position resolution of MICROMEAS, a Monte Carlo simulation has been developed. The program simulation worked in this way: the tested detector geometry parameters and a point-like particle were used to liberate electrons at the normal incidence. Each electron drifts towards the anode plane, while they shift in the x direction because of transverse diffusion. When the electrons reach the amplification gap, an avalanche happens, and the total number of electrons is determined by the gain fluctuation. The signal amplitude of each strip is related to the number of electrons that reach the region.

4.1 Transverse diffusion

The electron cloud created by the incoming particle at a height L above the anode plane will be broader when it reaches the anode, because of the scattering on the gas molecules. It is a characteristic of the gas mixture and depends on the geometry of the detector. The broader size is described by the transverse diffusion. The position where the electron reaches away from the place where ionization occurred projected onto the anode plane with a distance r given by a Gaussian distribution:

$$P(r, L) = \frac{1}{\sqrt{2\pi}D} e^{-\frac{r^2}{2D^2}}, \quad (2)$$

where $D = \sigma_T \sqrt{L}$, σ_T is the transverse diffusion coefficient. So, with one dimension σ_x is $\sigma_T / \sqrt{2}$. The position of the ionization which occurs is a random number from the drift electrode plane to the micro mesh. The transverse diffusion coefficient, from Garfield's simulation, is $220 \mu\text{m} \cdot \sqrt{\text{cm}}$. The units of L are centimeters. The position of the ionization spot is determined from the center of gravity of the electron cloud.

4.2 Strip pitch

The width of the strip pitch, w_p , is determined by the sampling frequency with an electron cloud. When the w_p is much wider than the size of the cloud distribution, only one strip gives a signal, then the position

resolution is given by $w_p / \sqrt{12}$. If the w_p is close to the size of the cloud, systematic errors are caused and they affect the position resolution. When w_p is much smaller than the cloud size, the sample is effective. Simulation indicates that if w_p is wider than $350 \mu\text{m}$ the fired strip multiplicity decreases to one. Fig. 5 shows the fired strip multiplicity as a function of the strip pitch.

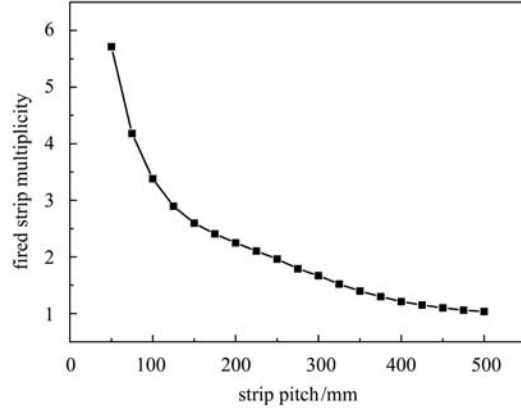


Fig. 5. Simulation fired strip multiplicity as a function of the strip pitch.

4.3 Gain fluctuation

Gain fluctuation affects the signal amplitude and confuses the gravity center of the electron cloud. It is determined by the micro mesh woven structure and diameter tolerance of the nylon line support. The total number of avalanche electrons is given by a Gaussian distribution. The Gaussian parameters are from the detector's energy resolution 26% and calculated based on the first Townsend coefficient.

4.4 Electronic noise

Usually, electronic noise is mixed in with the signals and it reduces the position accuracy. To set a higher threshold will lose some small signals and a lower threshold would include some false signals. In order to estimate the noise contribution to the position resolution, the threshold is set at 10% of the total number of avalanche electrons.

The $66 \mu\text{m}$ position resolution is predicted with $200 \mu\text{m}$ strip pitch and it includes the following contributions:

- 1) $16.8 \mu\text{m}$ from the transverse diffusion of the electrons;
- 2) $6 \mu\text{m}$ from gain fluctuation;
- 3) $3.3 \mu\text{m}$ from electronic noise.

It is worth noting that the difference between measurement and simulation is due to the slit not being absolutely parallel to the anode strip.

5 Conclusion

A 10 cm×10 cm MICROMEGAS detector has been constructed and measured with an Ar+CO²(10%) gas mixture at atmospheric pressure. Using a 200 μm strip pitch the accuracy is up to

80 μm in sigma and the time resolution is better than 20 ns. At the same time, we obtain an efficiency of 94% for the cosmic rays. Monte Carlo simulation indicates that the position resolution is determined by transverse diffusion, gain fluctuation and electronic noise.

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