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AVALANCHE CHAMBER

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TEST-BEAM STUDY OF THE PERFORMANCE OF THE MICROSTRIP GAS AVALANCHE CHAMBER

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Abstract

The results of a test-beam study of the performance of the MicroStrip Gas Avalanche Chamber (MISGAC) for the detection of minimum ionizing particles are reported. A detection efficiency of 95%, a position resolution of $30\text{ }\mu\text{m}$ (RMS) and a two track resolution of $250\text{ }\mu\text{m}$ have been measured using a 9 GeV particle beam at the CERN PS. Xenon-DME and Argon-DME mixtures have been used as gas filling for a detector having a total gas thickness of 5 mm.

I. INTRODUCTION

The MicroStrip Gas Avalanche Chamber has been recently proposed as an alternative detector to solve the severe problem of tracking at the next generation of high luminosity hadron colliders [1]. This new detector aims to reproduce the structure and intensity of the electric field of the standard MWPC, but on a geometrical scale reduced by at least a factor ten [2]. This has been made possible by using a microelectronics technology (electron beam lithography) to define the field shaping electrodes with the precision of $0.1\text{ }\mu\text{m}$. Thin anodic and cathodic parallel strips were laid down on a $500\text{ }\mu\text{m}$ thick glass substrate, with a $200\text{ }\mu\text{m}$ pitch. An upper cathode seals the chamber and allows to define the drift region for ionization charges.

Fig.1 A cross section of the detector.

Fig. 1 shows a cross-section of the detector, while fig.2 shows a microphotograph of the anode-cathode structure. With a proper gas filling and applying a few hundred Volts between anodes and cathodes, the detector can reach proportional gains above 10^4 [3].

During laboratory tests with low energy X-rays sources we have shown how this detector can provide very promising performances (energy resolution $\approx 15\%$ at 6 KeV, rate capability $> 10^5\text{ counts/s mm}^2$) [4]. Aim of this paper is to present the results of the first test of this detector with a beam of minimum ionizing particles.

Fig.2 A microphotograph of the anode-cathode structure.

II. TEST-BEAM SET-UP

The test has been performed at the CERN PS using a low intensity unseparated beam of 9 GeV/c momentum. Two parallel planes of $60\text{ }\mu\text{m}$ pitch silicon microstrip chambers have been used as a position reference. The two silicon planes were positioned at a distance of 30 cm; the MISGAC has been placed in the middle with the strips parallel to the silicon microstrips and perpendicular to the beam direction. Three scintillation counters were used as a

beam defining telescope (see fig. 3). Ten cathode strips of the microstrip gas chamber were individually connected to ten charge amplifier built following the classical Radeka design [5]. The response of the amplifiers to a localized ionization (^{55}Fe X-rays) is shown in fig. 4. The total signal duration time for an extended track was 150 ns. The output of the amplifiers was sent to ten channels of a peak sensing ADC (LeCroy 2259A). A 200 ns gate signal to the ADC was provided by the scintillation counters. The data were written onto a magnetic tape for subsequent off-line analysis.

Fig.3 The test beam set-up.

Fig.4 The response of the amplifier to a localized ionization (^{55}Fe X-rays).

III. DETECTION EFFICIENCY

a) Xenon- DME filling.

The detection efficiency depends on several factors such as gas gain, the number of collision encounters, the electronics signal over noise ratio, etc. Because at the next hadron colliders the bunch crossing time will be very short (15 ns) and there will be more than one event/bunch crossing, it is very important to reduce the detector memory (i.e. the electron drift time) to reduce the detector occupancy. To reduce the electron drift-time one has to use fast gases and a short drift path. The use of a short drift path at atmospheric pressure requires the use of a gas with high cluster and ionization density. Among the noble gases Xenon has the highest ionization and cluster density (300 ion-pair/cm and 44 clusters/cm).

We started our test with a mixture of Xenon-Dimethyl Ether (90-10) at atmospheric pressure. Dimethyl-Ether (DME) is a non polymerizing gas with very good quenching properties, especially suited for operation at high particle flux [6]. The drift length was set to 5 mm. The detection efficiency measured in this conditions was 95 % with the following selection criteria:

- i) charge collected on all the cathode strips $> 2.5 \times 10^4 e^-$
- ii) charge collected on an individual strip $> 1 \times 10^4 e^-$
- iii) maximum measured coordinate difference between silicon and MISGAC $< 250 \mu\text{m}$.

Fig. 5 shows the pulse height distribution with the typical Landau shape observed with this gas filling.

Fig.5 The pulse height distribution observed with a mixture of Xenon -DME .

b) Argon-DME filling.

This mixture is well known [6] and very cheap, but the primary ionization density is only 1/3 of the Xenon mixture. To have a good efficiency we needed a higher gas gain. For this purpose we have operated the MISGAC in a different regime, i.e. with a small contribution (5-10) to the overall gain coming also from the drift region. This has been accomplished raising the drift region field to 9 KV/cm.

Fig.6 The same as fig.5 but with Argon-DME.

Fig.7 Examples of cathode charge distribution

There should be two positive side effects of the operation in this regime: i) a reduction of the time jitter (but an increase of the time delay) because the dominant ionization is the one coming from the farther region of gas which has the highest amplification, ii) reduction, for the same reason, of the expected worsening of the spatial resolution at wide angles. The measured detection efficiency for Argon-DME mixture with the same selection criteria of Xe-DME was 93%. Fig 6 shows the corresponding Landau distribution.

IV. SPATIAL RESOLUTION

a) Xenon-DME filling.

The track coordinate within the MISGAC was obtained by measuring the centroid of the cathode charge distribution. The cathode read-out should allow a position interpolation even when all primary ionization is drifted on a single anode strip. Fig. 7 shows examples of the cathode charge distribution for single events, while fig. 8 shows the histogram of frequency of number of hits (i.e. the number of strips over threshold).

The mean number of strips hit, n_{hit} , is 3.6.

The position resolution was estimated as the R.M.S width of

the distribution of the track residuals (i.e. the difference between the measured and expected coordinate). The resolution is a function of the width of the charge distribution which has a minimum of $33 \mu m$ for $n_{hit} = 3$ ($> 50\%$ of the events) (see fig. 9). The resolution for all the events is $39 \mu m$. These are upper limits, because the contribution to the overall resolution coming from the geometrical misalignment and from the silicon tracker were not unfolded. In particular, the silicon planes of the tracking system have been used for a long time within the NA-32 experiment at CERN before being moved at the test beam. The central part has been already exposed to 2×10^{12} particles [7]. The resolution in the central part has therefore degraded as result of a deformation of the electric field lines within the detector. We have estimated a contribution to the overall resolution from geometry and from the tracker of least $15-20 \mu m$. The MISGAC intrinsic resolution should therefore be in the $30 \mu m$ range. Fig. 10 shows the correlation between the silicon and the MISGAC coordinate.

Fig.8 The frequency of number of strips hit (Xe-DME).

Fig.9 The position resolution (Xe-DME).

b) Argon-DME filling.

The charge distribution is wider in this mixture relative to the Xenon mixture (see fig.11). This is probably due to the amplification process which starts already in the drift region giving a wider avalanche spread. The resolution has been measured 47 μm for all the events (see fig. 12).An indication of the good interpolation properties of the cathode read-out comes also from the differential non-linearity.

Fig.10 The correlation between the silicon and the MISGAC coordinate (Xe-DME).

Fig.11 The frequency of number of strips hit (Ar-DME).

The differential non linearity is measured by the non uniformity of the bin counts in response to an uniform illumination. Fig. 13 shows the 200 μm cell profile and the non linearity function (i.e. the derivative of the correlation function) obtained from the raw data and after correction with the algorithm of Chiba et al. [8]. A residual differential non-linearity $< 2\%$ has been measured.

V. TWO-TRACK RESOLUTION

The ability to measure as such two tracks crossing the detector at the same time depends on the width of the charge distribution. We have measured the width (R.M.S) of the charge distribution of both the gas mixtures (see fig. 14,15). The mean sigma was 125 μm for Xenon-DME and 150 μm for Argon-DME. If we define two-track resolution as two times the width of the charge distribution we obtain 250 μm and 300 μm for Xenon and Argon mixture, respectively.

Fig.12 The position resolution (Ar-DME).

Fig.13 The differential non linearity (Ar-DME).

An improvement of these figures could be obtained by a reduction of diffusion which could be achieved by a reduction of the drift length.

VI. DISCUSSION

The MicroStrip Gas Avalanche Chamber seems to maintain its promise. Tested with a beam of minimum ionizing particles, it has provided 30 μm position resolution for isolated tracks, two-tracks resolution of 250 μm, together with full detection efficiency. Its major advantages when compared with the silicon microstrip detector are:

- i) higher radiation resistance (no active medium, apart from gas which is flushed);
- ii) lower cost (one mask instead of 7-8 as for silicon and glass instead of expensive high resistivity silicon);
- iii) higher yield;
- iv) higher S/N (because of the gas amplification). The total charge available for measurement is at least a factor ten more than silicon;

v) high position resolution even with a coarse sampling (because of the charge spread due to the diffusion in gas).

Its main disadvantages are:

- i) lower position resolution (30 μm vs 10 μm);
- ii) lower two-track resolution (200 μm vs 100 μm);
- iii) expected deterioration of resolution at incident angles different from normal.

These points could be improved increasing the sampling at, for example, 125 μm and further reducing the drift length to, for example, 2 mm. Furthermore, the use of Xenon as gas filling open the way to the combined use of the MISGAC for tracking and electron identification through the detection of Transition Radiation (TR). Advantage can be taken in this

Fig.14 The width (R.M.S) of the charge distribution (Xe-DME).

Fig.15 The width (R.M.S) of the charge distribution (Ar-DME).

case from the very good energy resolution of MISGAC in detecting low energy X-rays [1] and from the fine sampling which will help to spatially separate X from delta rays. Much remains to be studied: angular dependence of position and two track resolution, further reduction of drift path, use of faster mixtures (for example Xenon-CF₄), use of integrated low-noise electronics mounted on the detector itself, ageing, double side read-out, etc.. We hope to address many of these items soon.

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