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OPTIMIZATION OF DESIGN AND BEAM TEST OF MICROSTRIP GAS CHAMBERS

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ABSTRACT

We describe recent experimental and theoretical work aimed at optimizing the geometry and the operation of micro-strip gas chambers in order to improve their performance and reliability. With the help of a simulation program, we have studied the mechanism of signal propagation and analyzed the effects on signal shape and size of resistivity of strips, grouping of biased strips and presence of a back-plane. Several detectors manufactured according to the results of the study and equipped with fast amplifiers have been installed in a test beam to study general operating characteristics, efficiency and localization accuracy; preliminary results of the data analysis are discussed.

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1. INTRODUCTION

Micro-strip gas chambers (MSGCs [1]) are an attractive choice for high resolution, high rate tracking detectors for the Large Hadron Collider, and great efforts are being made to develop the new devices [2, 3]. This paper describes some results of systematic studies aimed at improving the performance of the detectors, and in particular a signal analysis realized with an electrical model describing MSGC structures as multi-electrode distributed transmission lines. The current pulse simulating an avalanche propagates along the strips giving rise to transition processes; this results in a modification of the signals read out by the amplifiers, as well in a spread of part of the signal to neighbouring channels. The response of the detector depends on resistance of strips, inter-strip capacitance, capacitance to ground and to other electrodes.

Several medium-size MSGCs, manufactured according to the results obtained from the above studies, have been tested in a minimum ionizing charged particles beam; preliminary results on signal to noise ratio, space resolution and detection efficiency are presented.

2. OPTIMIZATION OF GEOMETRICAL AND OPERATING PARAMETERS

From previous work, a clear preference has emerged for the use of argon-dimethylether (DME) mixtures for stable, long term operation of MSGCs. It was found that a DME concentration of around 50% provides the best performance in terms of maximum attainable gain, probably the result of a compensation between the higher quenching properties of DME rich mixtures and the increase of noise due to the higher potentials required [4].

We have investigated experimentally the dependence of the discharge limit on cathode width, using a set of MSGC patterns having identical anode width and pitch (7 µm and 200 µm, respectively), and cathode strips from 60 to 170 µm. Four patterns were realized1 in gold on the same support, electron conducting glass with bulk resistivity of 109 Ω.cm. Fig. 1 shows the gain dependence on anode voltage for the four patterns, all operated in an argon-DME (50-50) gas mixture. Measurements stop for each geometry at the voltage at which, due to the appearance of discharges, the current on the power supply exceeded a pre-set limit of 20 µA. As it can be seen, the maximum gain before discharge increases for a decreasing anode to cathode gap, reaching a maximum at about 50 µm, dropping then rapidly for smaller gaps; this results suggest an optimum cathode width between 90 and 100 µm.

3. SIGNAL SIMULATION

The basic cell of the equivalent circuit used for signal analysis is shown in Fig. 2 [5]. Strip segments are simulated by a serial resistance with values depending on the length, cross section and metal of the strip; sections of cathode and anode strips are connected by an inter-strip capacitance, and each node can be also connected to a strip-to backplane capacitance (if present). To simulate a long chamber with distributed parameters, several cells can be added in series; we found however only a small dependence of the results on the number of cells if this number is greater than three. At the end of each strip, a capacitance to ground can be introduced to represent the read-out board. The signal generated by the avalanche process is simulated by two trapezoidal current sources (10 ns rise and fall time and 30 ns fwhm) between one anode and two neighbouring cathodes; the results depend only slightly on the shape of the avalanche signal. In the simulation, we have neglected the small contribution of the signals induced by the avalanche, in the real physical case, on the drift and backplane electrodes. The parameters used for the equivalent circuit correspond to the values directly measured on a MSGC plate manufactured on boro-silicate glass 300 μm thick with 2700 Å thick chromium strips, 10 μm wide anodes, 80 μm cathodes at 100 μm distance. The strips are readout by a fast amplifier with 45 ns rise time, emulating the characteristics of the RD-20 pre-amplifier [6].

We have computed (Fig. 3) for a chromium MSGC the signal peak pulse height as a function of distance from the amplifier end for different total lengths of strips, both in the case of anode (dashed lines) and cathode readout (full lines). The points with error bars represent the results of a measurement in the case of individual readout of cathode strips. On anodes the signal decreases for an avalanche moving away from the amplifier towards the far end of the strip, while for cathode readout the trend is reversed; the non-uniformity of the response is approximately the same. This surprising result is explained by the fact that, given a position of the avalanche along a cathode (anode) strip, the return current has to go through the remaining length of the neighbouring anodes (cathodes); the lower resistance of one is compensated by the higher value of the others. The figure shows also that chambers with strips up to 10 cm long can be realized with chromium strips, with a moderate non-uniformity of response, around 20%, acceptable for a tracking device.

The signal non-uniformity can be reduced by lowering the strip resistance. Fig. 4 shows the pulse height on cathodes as function of distance of the avalanche from the amplifier end for aluminium and chromium strips, in a 30 cm long chamber; presence of a backplane electrode has a small influence on signals for the lower resistivity strips.

The experimental results show that channels adjacent to the strip interested by an avalanche detect signals of reverse polarity (Fig. 5). Indeed, the return current from the avalanche has to flow through the input impedance of the neighbouring channels' amplifier in reverse direction as compared to the main strip; the number of channels detecting an inverted signals corresponds to the strips of opposite kind connected together to apply the operating potential, through a high value protection resistor. For the case of individual read-out of cathode strips, we have investigated how the number of anode (biased) strips connected in a group can affect the amplitude of the reverse signals, as well as the main signal on the central cathode strips. As expected, the opposite polarity signals detected on cathode strips adjacent to the main get smaller with the increase of the number of strips in the biased group, while the main signal increases; both reach a constant value for groups of 6 or more strips. A further reduction of the parasitic effect can be obtained adding decoupling capacitors in parallel to the protection resistors connecting each group to the power supply, thus providing additional return paths for the current; one has however to weigh the advantages of pick-up suppression with the disadvantages of an increased stored energy in case of a discharge.

4. TEST BEAM MEASUREMENTS

We have tested several MSGC detectors built according to the experience gained in the optimization studies of a minimum ionizing particles beam at CERN. The set up consists in scintillator counters for triggering, two drift chambers for beam position monitoring and three aligned micro-strip detectors; the central MSGC could be rotated around the vertical axis, perpendicular to the beam, to study inclined tracks. We have tested chambers made on different substrates: boro-silicate glass D-2632, semi-conducting glass S-89003 and D263 glass overcoated with a thin lead silicate electron conducting layer [7-10]. Electrodes are made of 2700 Å thick chromium strips with anodes 7 µm wide, cathodes 100 µm wide and 200 µm anode to anode pitch. The MSGCs used for this test4 were assembled as described in Ref. [11] with glass or Vectra thin frames and a glass 300 µm window coated with indium-tin oxide providing a 3 mm thick gas gap; the active area was 8x8 cm2. In all chambers the anodes are connected together in groups of ten, and to HV power supply through a 500 kΩ protection resistors; in each detector, 64 cathode strips are individually connected through a pitch adapter to the input of two 32-channels RD-20 PreShape32 amplifier chip with 45 ns shaping time followed by operational amplifiers (OPA 621 KU). The pulse height digitization is done with LeCroy 2282B 48-channels charge-sensing ADCs, with a 200 ns gate. Calibration of the electronics was performed using the information from the data taken with special pedestal (random) and calibration triggers; in the latter case, a known charge was injected into the preamplifiers. We have used an argon-DME (50-50) gas mixture and operating voltages of -1000 V and 570 V on the drift and anodes respectively, at a gas gain of 2.103.

After subtraction of the pedestals and gain normalization using the electronics calibration, raw data are corrected for the undershoot, as shown in Fig. 5. The procedure for cluster finding begins with the search of the strip with the highest signal in a chamber; the contribution from the neighbouring strips is then considered only if it exceeds twice the standard deviation of the noise distribution of the channel. Subsequently, hits with smaller charge are searched to take into account multi-track events, and the final hit selection is done by tracking on the basis of a c2 minimization. Fig. 6 provides the cluster size distribution for tracks perpendicular to the MSGC plane; it has a mean value of

2.8, typical for cathode readout; Fig. 7 shows the total charge distribution (sum over adjacent strips in a cluster), together with the noise spectrum obtained from the pedestal trigger data. Signal to noise ratio, defined as the most probable value of the signal divided by the standard deviation of the noise distribution, is 15.

After cluster finding, the space position of the hit in the chamber is evaluated by a centre of gravity method; tracks are defined using the two outer chambers after an iterative alignment procedure, and the correlation between predicted and measured track position in the central MSGC is used to compute the localization accuracy. A scatter plot of the correlation, Fig. 8, shows modulations with a period corresponding to the 200 μm pitch; Fig. 9 gives the distribution of the residuals in the central chamber after correction for the modulations using the simple sinusoidal fit shown in the figure. A space resolution of 39 μm rms can be estimated for a single plane of measurement.

Fig. 10 shows, for tracks perpendicular to the chamber, the dependence of the efficiency and of the noise occupancy (probability of a false hit) as a function of threshold, expressed in number of standard deviations of the noise distribution.

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FIGURE CAPTIONS

Fig. 1: Gain dependence on the anode voltage measured in MSGCs with equal anodes and pitch, and different cathode widths. The highest point in each curve corresponds to the discharge limit.

Fig. 2: Basic cell of the MSGC equivalent circuit used in the electrical simulation.

Fig. 3: Computed signal pulse height for cathode (full curves) and anode (dashed) readout as a function of the avalanche distance from the amplifier, for several lengths of chromium strips. The points with error bars correspond to measured values in a MSGC.

Fig. 4: Pulse height for cathode readout computed as a function of the distance of the avalanche from the amplifier end for chromium (full points) and aluminium (open points) strips. Dashed lines correspond to the presence of a backplane electrode.

Fig. 5: Measured signal distribution for a single avalanche (full line) and after correction for undershoot signals (dashed line).

Fig. 6: Cluster size distribution for minimum ionizing tracks perpendicular to the MSGC plate.

Fig. 7: Integral cluster charge distribution for minimum ionizing particles, and noise spectrum obtained from the pedestal trigger data. The signal over noise ratio is 15.

Fig. 8: Scatter plot of the correlation between predicted and measured position in the MSGC with cathode readout. The line represents a sine-wave fit through the data.

Fig. 9: Residuals distribution of the three-chambers straight line fitting; the corresponding single MSGC position accuracy is 39 μm rms.

Fig. 10: Dependence of the detection efficiency and noise occupancy from threshold, for minimum ionizing particles perpendicular to the chamber.

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