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High Rate Tests of Microstrip Gas Chambers for CMS

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MicroStrip Gas Chambers (MSGC's) have been proposed for equipping the outer region of the tracker of the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC). The MSGC's have undergone extensive development and tests during the last few years and their performance is well established. An important issue that has to be addressed to date is whether MSGC's can maintain their characteristics after a long exposure to an intense flux of particles, similar to LHC. We report results from the most recent beam test addressing this topic.

1. INTRODUCTION

MSGC's, due to their capability of offering a very cost-efficient solution for covering a large surface of a tracker with high granularity, have been chosen as the baseline technology for the CMS tracker [1]. Many tests in particle beams as well as irradiation with radioactive and X-ray sources have established the capabilities of this technology, and have shown that MSGC's meet the stringent performance criteria of the CMS inner tracker. The main characteristics are briefly summarized in the next section.

What has not been fully investigated yet, is the robustness of the chambers in a high-rate environment with heavily ionizing particles, which they will be exposed to at the LHC at their design location of $70-115$ cm from the beam pipe. In this region the expected particle flux, contributed mainly by minimum ionizing particles, varies from 1 to 5 kHz/mm^2 [2]. Highly ionizing nuclear fragments (HIP) produced in the interaction of hadrons in the structure of the chamber may reach the amplification region and induce a streamer in the chamber. In extreme cases the streamer catalyzes a discharge which may damage the micro pattern structure. In order to address the question of survivability, tests in a beam providing such conditions began in Summer 1997 [8] and continued in 1998. This paper presents the outcome of the latter test.

2. DESCRIPTION OF THE MSGC

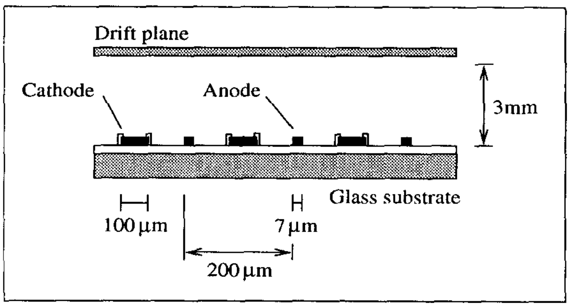

Figure 1. Schematic cross section of an MSGC.

The MSGC prototypes are built according to

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the CMS baseline specifications [3]. The gold strip micro pattern (Fig. 1) is etched on a 300 μm thick substrate made of DESAG 263 glass, coated with a thin ($\sim$ 1 μm) layer of Pestov glass [4]. The resistivity of the semiconductive film is $\sim 10^{16}$ $\Omega/\Box$. The anode and cathode strips are 10 cm long and 7 μm and 100 μm wide, respectively. Their thickness is 0.5 μm, the pitch of the pattern is 200 μm.

A thin layer of Polyimide is deposited with precision on the edge of the detector. Two patterns for this "passivation" have been developed, the standard and the advanced passivation. The former consists of applying a thin film of polyimide with a width of 0.6 mm orthogonal to the strips across their ends, the latter adds a 3 μm thick layer of polyimide onto the edges of the cathodes, over their entire length. This approach allows to work at a higher voltage by reducing the chance of field extraction of electrons, and thus sparks, initiated from the cathodes.

Above the substrate there is a 3 mm thick gap filled with a gas mixture of 40% neon and 60% DME, in which a traversing minimum ionizing particle creates $\sim$ 20 e^-/ion pairs. The gas volume is sealed with a PEEK (Poly Ether Ether Ketone) frame and a metallized PEEK cover, which serves as the drift cathode. The chamber volume with 512 anode and cathode strips covers an active surface of 10×10 cm^2.

The anode signals are read out by PREMUX chips [5] (shaping time $\sim$50 ns) and digitized with a Sirocco flash ADC [6]. For CMS, a hit reconstruction efficiency of more than 98.5% is required, which can be achieved by working at a signal-to-noise ratio $S/N = 20$ [3], defined as the ratio of total cluster charge to average noise of one strip in the cluster. The PREMUX electronics used to date differs from the electronics that will be used in CMS, which will be built with radiation hard technology and feature a deconvolution circuit in order to make bunch crossing identification at LHC frequencies possible. Since the deconvolution is expected to decrease the signal-to-noise ratio by a factor 2.2, today's chambers have to be operated at a $S/N = 44$ to allow comparison with the nominal working point to be used at the LHC. The necessary gain of $\sim$ 1700 [8] is obtained operating at $V_{cathode} = 520$ V and $V_{drift} = 3500$ V in a Ne-DME 40-60 gas mixture. Previous tests [7] have proven that in this operating condition the intrinsic track resolution is 30 – 40 μm.

3. EXPERIMENTAL SETUP

One detector among the MSGC prototypes irradiated at the Paul Scherrer Institute (PSI) in 1997 [9] was chosen to undergo a second period of tests at PSI, under the same conditions. At the πM1 facility, a 350 MeV π^+ beam was tuned to illuminate the whole active surface of 10×10 cm^2 of the detectors. The flux of the beam was estimated to be $\sim$ 5 kHz/mm^2 in the center of the chamber and about a factor 2 lower in the regions at the detector edge. Triggering and rate measurements were performed using a coincidence of a 0.5×2 cm^2 and a 0.5×10 cm^2 sized scintillation counter.

The beam composition with a contamination of a few percent of protons and its intensity are comparable to LHC conditions [2]. The beam structure is very similar to the LHC: Considering machine stops, we had almost 7 full days of LHC-like irradiation at the minimum radius of 70 cm. Taking into account the dose the MSGC's have experienced at PSI in 1997, the prototype that continued testing has been exposed to a total dose equivalent to 14 full days of operation at the LHC.

4. DATA ANALYSIS

Fig. 2a shows the beam profile as measured by the chamber. Out of the 512 strips, 10 are not performing, which is still below the maximum number of misbehaving wires of 2% that would be acceptable for a module installed in CMS. The last but one group of 16 anodes did not record any particles. This is due to the fact that during the extensive transport this chamber has undergone, one connection supplying the high voltage to the corresponding group of 16 cathodes was damaged.

Fig. 2b shows the noise of each anode strip. The capacity of a strip contributes to the total

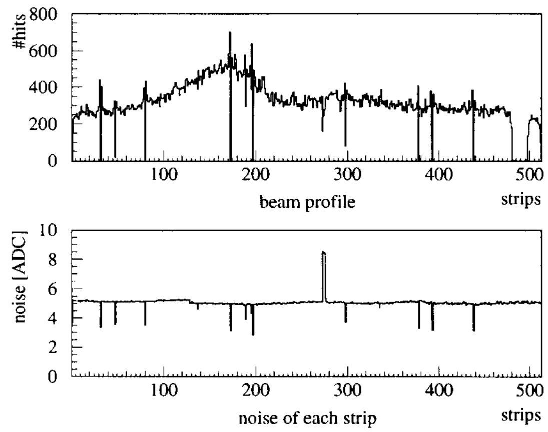

Figure 2. Beam profile of the 350 MeV π^+ beam at PSI as measured by the MSGC and noise of each of the 512 channels of the MSGC.

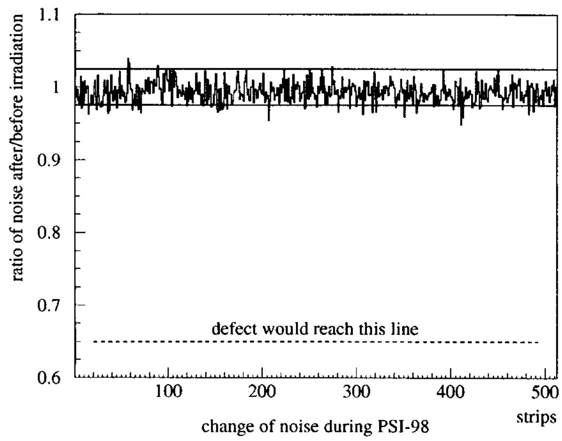

Figure 3. Ratio of noise before and after irradiation of each of the 512 strips. Fluctuations are within the statistical errors.

noise of the read out channel. If a strip breaks, the noise is reduced. Thus a measurement of noise gives a clear evidence for the integrity of the corresponding anode strip. After a comparison of Fig. 2a and Fig. 2b we can clearly state that a decrease of noise of a strip indicates a degradation of its performance. Fig. 3 shows the ratio of noise measured at the end of the test beam period and the noise measured before irradiation. Within statistical limits, no worsening of the chamber performance can be identified, and most of all, no strip losses are observed. In fact, a damaged strip would show a change of up to 30% in Fig. 3, where only fluctuations of 3% are recorded.

To investigate further the operational stability and robustness of the chamber, the cathode voltage was increased up to $V_{cath} = 590\ V$ (Fig. 4 and Fig. 5). The detector behaved as expected and the beam profile it measured and Landau spectrum of the signal distribution after the scan were unchanged. No deviation from the exponential increase of the gain with V_{cath} was observed.

During the whole running period the drift and cathodic currents (I_{drift}, I_{cath}) were monitored, in order to detect spontaneous or particle induced streamers. The frequency of these spikes in the currents was around one per day when operating at the nominal values, and no indication of damage of the micro pattern could be found.

Assuming that 10 years of running at LHC is equivalent to $5\times10^7 s$ at the maximum luminosity [2], the chamber has received 1/40 of the expected LHC dose. Thus, having observed less than one damaged strip, we can expect less than 40 damaged strips per module at LHC, which is less than 8 % of the total number of strips.

5. CONCLUSIONS

The MSGC's developed for CMS have shown to be well suited for application at the LHC in terms of resolution and hit finding efficiency. Their survivability in the expected radiation environment with high rates and large fluxes of heavily ionizing particles is, of course, of crucial importance. Two periods of testing at intensities comparable to LHC-like rates, amounting to a total time of almost two weeks of continuous irradiation at nominal gain and above have left the detector undamaged, and have demonstrated a very stable oper-

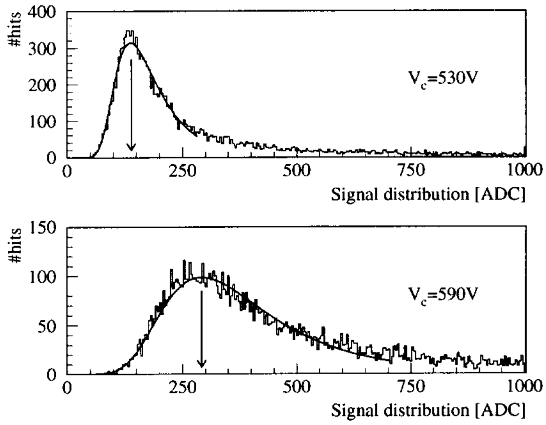

Figure 4. Landau distribution of energy loss of mainly MIP's in the detector. The spectrum is shown for two different gains, corresponding to different V_{cath} during the voltage scan.

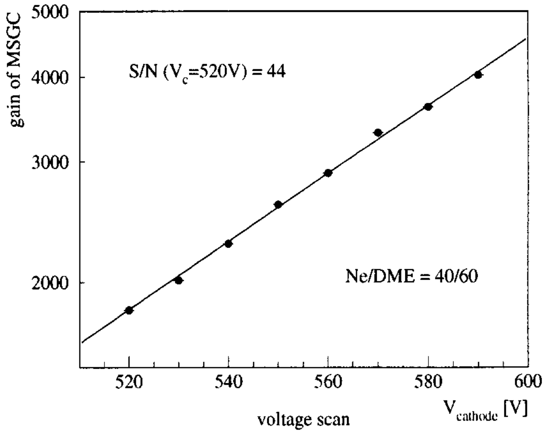

Figure 5. Gain versus V_{cath}. No significant deviation from the expected exponential dependence of the gain on V_{cath} is observed.

ation of the device.

A future test at PSI is aimed at giving a quantitative statement with an accuracy on the 1%-level of how big the influence on detector operation after ten years at the LHC would be. This beam test has shown this number to be less than 8 %. To date one can confirm that the MSGC technology is well suited for CMS.

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