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Tests of CMS MSGC modules at PSI

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Abstract

The CMS experiment, to be installed at the future $p-p$ collider LHC at CERN, foresees the use of Micro-Strip Gas Counters (MSGC's) for the outer layers of its central tracker. Present developments focus on the reliability of MSGC's in the harsh radiation environment imposed by the LHC. This paper reports on tests of two baseline CMS MSGC's identical to those foreseen for the barrel part of the tracker, in a high intensity π-beam at the Paul Scherrer Institute (PSI), in april 1999.

1 Introduction

The CMS experiment foresees the use of MSGC's for the outer layers of its central tracker, located at distances between 70 and 120 cm from the beam pipe [1]. The MSGC's of the innermost layer will be exposed to a flux of 4.10^3 minimum ionizing particles (MIP's) per second per mm^2 and of up to 10^4 neutrons per second per mm^2. Most of these particles are hadrons, which may generate heavily ionizing particles (HIP's) in the counters by nuclear interactions with detector material. HIP's can in turn induce streamers and discharges, the energy of which is large enough to damage the strip pattern.

Triggered by the studies of [2], stability of operation and robustness of MSGC's exposed to heavily ionizing particles have become a subject of thorough investigation. The CMS MSGC community has therefore planned a large scale test (i.e. milestone test 2) in october - november 1999 to assess the survivability of the detectors at the LHC. In this report we describe the program of the milestone test, as well as a preliminary test in which 2 MSGC's, identical to those that will be used in the barrel part of the CMS tracker, have been exposed to the PSI π-beam for two weeks.

2 Milestone test

The milestone test is defined as follows:

1. 25 barrel detectors of 12.5 cm striplength, and 12 forward modules equipped with 4 substrates, 2 of which being read out, shall be exposed to the PSI π-beam for 360 hours at maximum beam intensity;
2. the detectors have to be operated at a gas gain corresponding to a detection efficiency for MIP's higher than 98% at the LHC;
3. the number of strips broken at the end of the test must be below 30 for each detector type (barrel and forward), i.e. 0.23% of the total number of strips.

The PSI machine provides a continuous beam of 350 MeV/c pions, with a maximum intensity of about 7.10^3 Hz/mm^2 in the centre of the beam spot. Simulation studies [3] have shown that the spectrum of energy deposited in the chamber by such a beam - and thus the spectrum of ionization charge produced in the chamber - is very similar to what is expected in CMS. A period of 360 hours (1.3×10^6 s) in the PSI beam corresponds to as much operation time in CMS for the innermost MSGC's. As the LHC is expected to run for 5×10^7 s, requirement (iii) ensures that the fraction of dead strips be less than 10% at the end of operation of the collider.

3 Test setup

Preliminary tests are being conducted at PSI by the CMS MSGC community in order to assess the quality of our MSGC production process. We describe here the results of a test of 2 barrel MSGC's performed in april 1999. The 2 chambers, labelled PP1 and PP2, comprise 512 anode strips of 12.5 cm active length. The substrates are made by Cetev. They are composed of DESAG AF45 glass of 300 μm thickness, covered with a 1 μm thick layer of Schott S8900 semiconductive glass. Gold, patterned by a lift-off technique, is used as a strip metal. The edges of the cathode strips are passivated by 8 μm wide polyimide lines. The chambers are assembled by Laben. The gas mixture used is DME-Ne 2:1.

The anode signals are amplified and readout by Premux chips and digitized by CAEN Sirocco ADC's. This allows monitoring of the chamber gain and Signal-to-Noise ratio S/N. The definition of S/N used here is the most probable value of the distribution of the ratio between the cluster charge, Q_{cl}, and the average noise of the strips included in the cluster, N_s. A $S/N = 14$ ensures 98% detection efficiency for MIP's. However, the chambers are operated

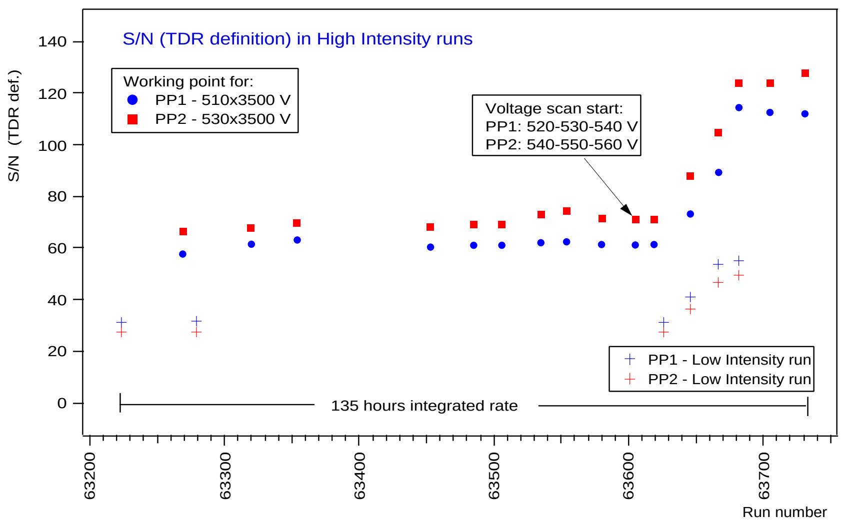

Figure 1: S/N ratio vs. run number in chambers PP1 and PP2.

at $S/N \geq 28$ in order to compensate for the 50% loss of S/N foreseen for the final readout chip (APV-M). In chamber PP1, only 384 anodes are read out because of the failure of 1 Premux chip.

The currents drawn by the cathode strips of each chamber are measured every 2 ms with nanoamperemeters. Sparks with a charge as small as 1 nC can be detected. In order to select sparks which could be harmful to the strips, a lower cut of 32 nC is applied to the spark charge. This threshold corresponds to 80% of the charge released by the complete discharge of 1 cathode group (40 nC).

4 Results

4.1 S/N ratio

Figure 1 shows S/N of the 2 chambers as a function of run number, for a period of 135 h at maximum beam intensity. Low intensity runs were also taken at regular intervals, with a beam intensity of 50 Hz/mm^2. The figure shows that stable operation at $S/N \geq 28$ is achieved at a drift voltage V_d of -3500 V and cathode strip voltages V_c of -510 V and -530 V for PP1 and PP2 respectively.

A difference in S/N of about a factor 2 is visible between low and high intensity runs. This is due to the fact that, at high intensity, we are not able to select the cluster produced by the particle that has triggered data acquisition, out of the numerous clusters reconstructed per chamber (8 - 10 on average). We chose the one with the largest Q_{cl}/N_s ratio, which biases S/N towards higher values. A few low intensity runs, in which only 1 MIP signal is recorded per trigger, are thus needed in order to check the actual S/N ratio.

At the end of the beam period, V_c was increased by 30 V in steps of 10 V in order to reach $S/N \geq 56$ at low intensity, i.e. twice the nominal value. The chambers were operated stably for 13 h at these settings, but showed an increase of the discharge rate and one anode strip was destroyed by a spark (see below).

4.2 Spark rate

Figure 2 shows the rate of cathode block discharges, in counts per hour of exposure at maximum beam intensity, vs. run number. It remains well below 1 per hour per chamber for most of the test period. When operating chamber PP2 at twice the nominal S/N, the spark rate increases to 2/h. As 1 strip was destroyed in chamber PP2 at this setting, it is considered the end of the S/N safety range. The chambers have thus a factor 2 gain margin.

4.3 Strip loss

Broken strips are searched for after every run by looking at holes in the beam profile and at electronics channels with a noise rms below the average value. No strip was broken while operating the chambers at $S/N = 28$. One strip was lost in chamber PP2 after 13 h at $S/N = 56$.

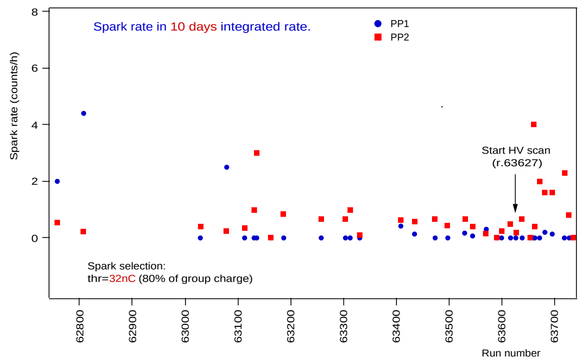

Figure 2: Spark rate vs. run number in chambers PP1 and PP2.

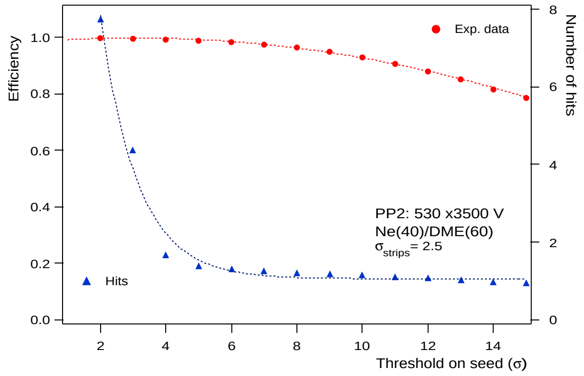

Figure 3: Detection efficiency and number of clusters reconstructed in chamber PP2 vs. cut on the charge of the strip carrying the largest signal in a cluster.

4.4 Detection efficiency

The detection efficiency in PP2 is estimated in low intensity runs by reconstructing a track in 4 other counters (2 MSGC's and 2 Groove+GEM chambers [4]) and requiring at least one cluster in PP2. Figure 3 shows the detection efficiency and the number of clusters reconstructed in PP2 as a function of the threshold applied on the charge of the strip carrying the largest signal in a cluster. The threshold is expressed in units of strip noise. When applying a cut ranging from 4 to 8, the detection efficiency remains above 98% with a tolerable number of noise hits (less than 1 per chamber). This indicates that there is enough gain margin to accomodate for the 50% loss in S/N expected with the final electronics.

4.5 Charging

When switching the beam from high to low intensity, a slow increase of S/N is noticed in both chambers. It rises from 28 to about 33 in 3 hours, then levels off. When switching back to high intensity, the chamber gain drops in about 1 hour, as seen from the electrode currents, then stabilises. Although charging did not prevent the chambers from operating correctly, this effect is not fully understood yet and deserves further study.

5 Conclusions

Two CMS MSGC's have been tested in a high intensity π-beam at PSI. They were operated at a gas gain corresponding to 98% detection efficiency for MIP's at the LHC. After 135 h at a beam intensity corresponding to the irradiation rate at the innermost MSGC layer in CMS, the counters showed no sign of high voltage instability and did not lose any of the 896 active strips. Extrapolation of these results to the CMS MSGC milestone test of october - november 1999 is very encouraging as to the success of the milestone test.

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