Behaviour of Small Gap plus GEM chambers in close LHC conditions

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Small Gap + GEM Chambers developped for the CMS experiment at the LHC, were exposed to a pion beam of 350 MeV at the Paul Scherrer Institut to establish their radiation hardness with respect to the operating gain. The long term stability of the gain (ageing) was then measured using an X-ray beam.

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1 Introduction

Up to end 1999, the CMS (Compact Muon Solenoid) experiment at LHC was planing to use MSGCs on a surface of about 200 m^2 in its inner tracker [1].The harsh expected environment at the 10^{34} cm^{-2} s^{-1} luminosity has led to a thorough study of the radiation hardness and long term stability of the detectors. To measure the capability of SGC+GEM to whistand such an environment, 8 detectors were exposed to a 6 kHz.mm^{-2} pion beam of 350 MeV at the Paul Scherrer Institut. The long term ageing tests were performed with a ^{55}Fe X-ray source of 6.4 keV during 2 months.

In 1996 we propose the Small Gap Chambers (SGC) as a variant of Micro-Strip Gap Chambers [2]. In this design, the anode-cathode distance is reduced to avoid the charging of the substrate under particle flux, and the edges of the strips are passivated to allow sufficient gain without sparking phenomenon. We present, in the following, the results and the improvement obtained with a GEM on top of large size substrates, as compared to previous results from small size SGCs [3].

2 Radiation hardness

2.1 Experimental set-up

8 detectors with 512 gold strips of 14 cm long [2] were exposed to the π-beam at the PSI. As compared to the small size chambers, the electronic noise was increased from 750 e^- to 1700 e^- due to the additional capacitance. In order to compensate this effect by a gain increase, a GEM (Gas Electron Multiplier) was added to the SGC as shown in figure 1, with the GEM-cathode gap equal to 1.5 mm. The GEM amplification structure consists of a thin Kapton foil plated with copper on both sides across which a potential difference is applied [4].

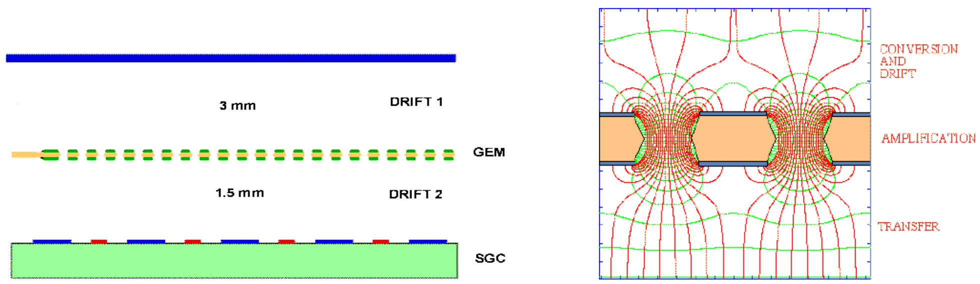

Fig. 1. a) SGC+GEM mechanics, b) Electric field in a GEM hole.

During the test, the drift volume was flushed with a gas mixture of 60 % DME and 40 % Ne. Premux chips of 128 multiplexed RC-CR amplifiers of 50 ns

[2] developped in collaboration with Thomson (France)

time constant performed the signal read-out of the anodes. The registered data included 2 ms ADC samplings of the cathode, drift and GEM currents, a monitoring of the beam intensity and a measurement of the anode signal.

2.2 Data analysis

The radiation hardness is evaluated by measuring the spark rate and the number of dead channels. According to the LHC specifications, less than 8 % of the strips must be cut in 500 days of LHC running. The 8 detectors were exposed to the 6-7 kHz.mm^{-2} pion beam during 22 days at a cathode voltage of -360 V and ΔV_{GEM}=-360 V. The gain, continuously monitored from the current measurement, was 2000 $\pm$ 300 (fig. 2) and corresponded to a signal to noise ratio S/N $\simeq$ 30 (1.5 times the minimal signal to noise ratio for full efficiency [5]).

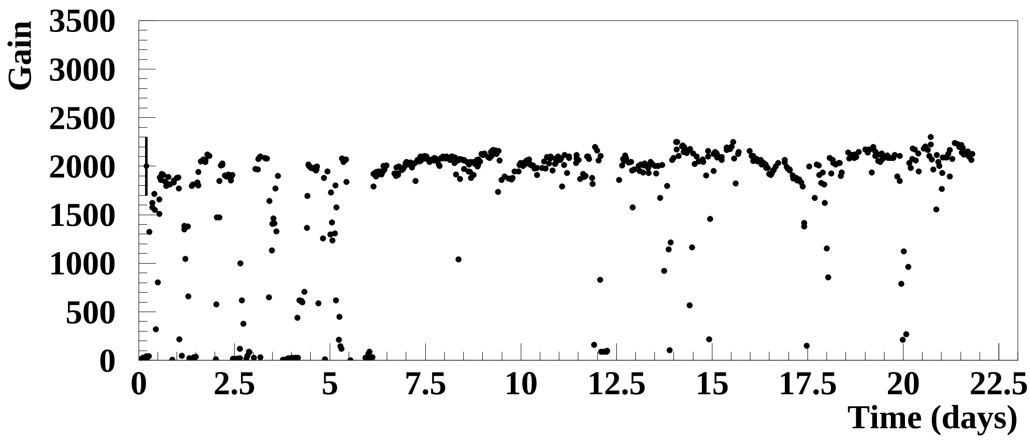

Fig. 2. Gain stability at H.I.

After this long stable running, 2 scans were performed to increase the detectors gain. One was done at a fixed ΔV_{GEM} = -360 V. The measured spark rates of the various chambers were contained in a cone (plain lines on figure 3) at least 1 order of magnitude lower at the same S/N, as compared to chambers without GEM. The second scan was performed with the ΔV_{GEM}, at a fixed V_K = -360 V, and define a second cone (dotted lines). Taking the mean values of the cones, it showed that the spark rate can be further reduce by a factor 100 at the same S/N.

During the whole beam period, the number of dead strips was monitored measuring the noise level of each channel. A drop in the noise profile of the detector indicates a strip cut while a drop of the voltage indicates a short to cathodes. At the end of the scans, the loss of channel was found compatible with the 1 to 2 cuts hardening phase found with the single SGCs (fig. 4). The linear increase of the loss with the spark rate (dashed line) can be used to extrapolate the time a chamber can whistand at high intensity. It is a

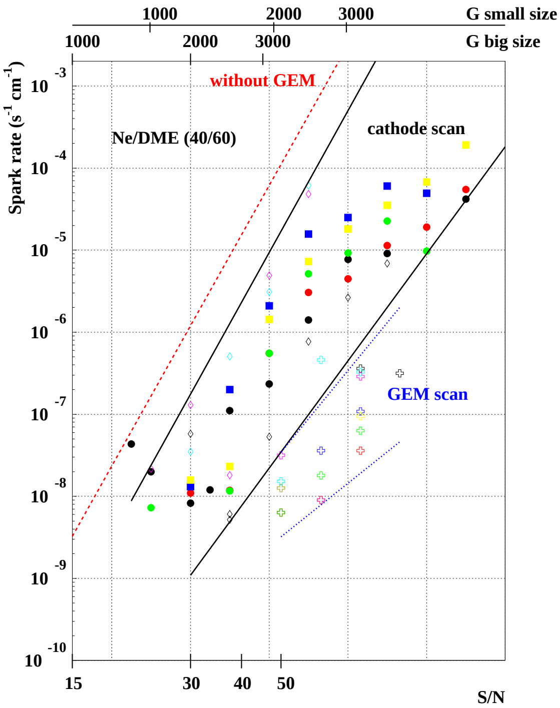

Fig. 3. Spark rate as a function of the signal to noise ratio and corresponding gain. Cathode scan (dashed line) of the chambers without GEM [3].Cathode scan with ΔV_{GEM}=-360V. GEM scan with V_K=-360V (cross symbols).(At S/N=30: V_K=-360V, ΔV_{GEM}=-360V)

pessimistic assumption if there is a saturation of the loss as observed for the SGCs but not measured here by lack of time. With such an extrapolation, we found that detectors will lose about 2 % of their strips during the 500 days at high intensity.

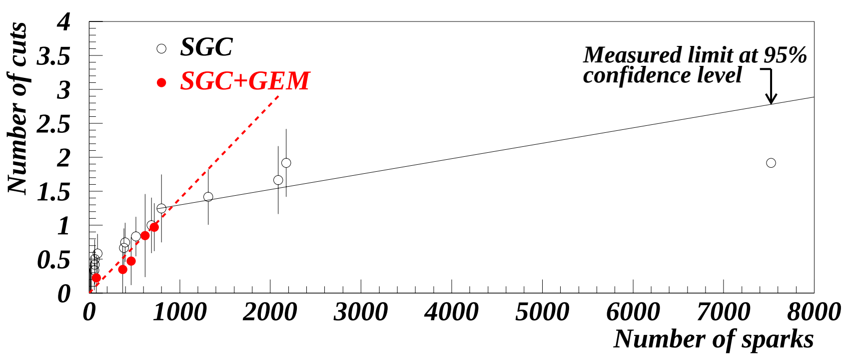

Fig. 4. Mean number of dead strips per substrate as a function of the number of sparks.

3 Ageing test

For the ageing measurement, the gain loss was estimated by the variation of the total current, measured as a function of the integrated charge per centimeter of strips. Long term tests were performed with SGCs of two sizes with and without GEM, exposed to a ^{55}Fe X-ray source of 6.4 keV. All the currents were registered with the dark current substracted regularly. To ensure the uniformity of the flux, a window smaller than the beam spot was fixed in front of the detector. Three sizes of irradiated area were used : 25 mm^2, 100 mm^2 and 9 cm^2.

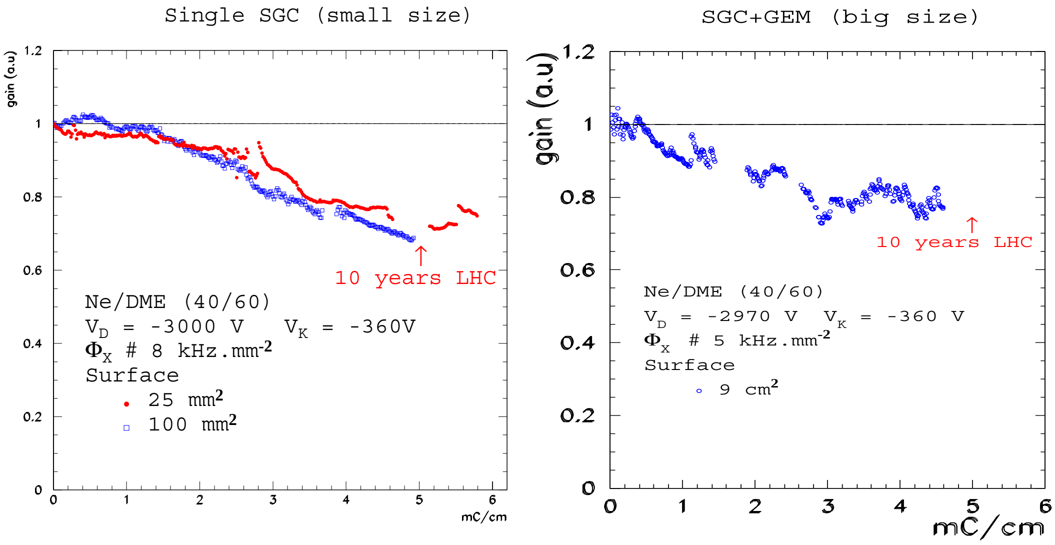

Fig. 5. Ageing of single SGC (left) and SGC+GEM (right)

Figure 5 shows the results obtained after 2 months of exposure. The same behaviour was observed with and without GEM. The loss of gain was found to be less than 25 % after 5 mC/cm equivalent to the 500 days of running at LHC.

4 Conclusions

The radiation hardness and the long term stability properties of SGC+GEMs have been established. As compared to previous results, the double amplification using a GEM was shown to significatly improve the radiation hardness at a fixed gain. 14 cm strips SGC+GEM chambers should whistand the environment of the LHC for 500 days at a gain of 2000 with less than 8 % of dead channels. This gain is 2 times the one at the begining of the efficiency plateau. The ageing results showed that the loss of gain should be less than 25 % in 10 years of LHC operation, well below the established factor 2 margin.

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