Results of a high intensity test beam with a large number of GEM+MSGC detector modules

Dirk Macke
on behalf of the CMS MSGC forward tracker collaboration

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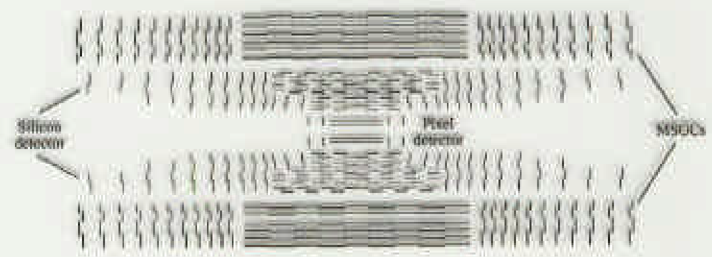
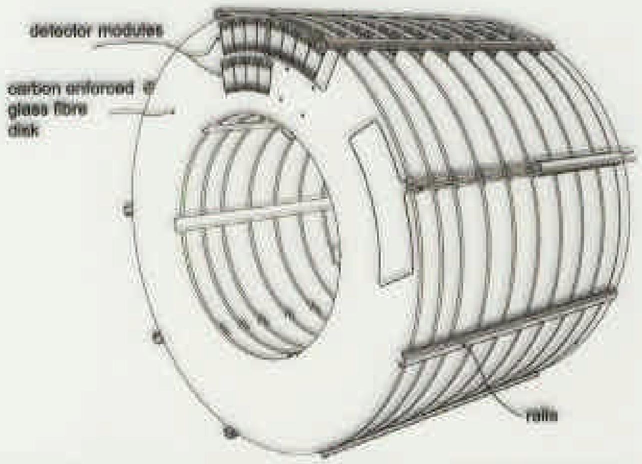
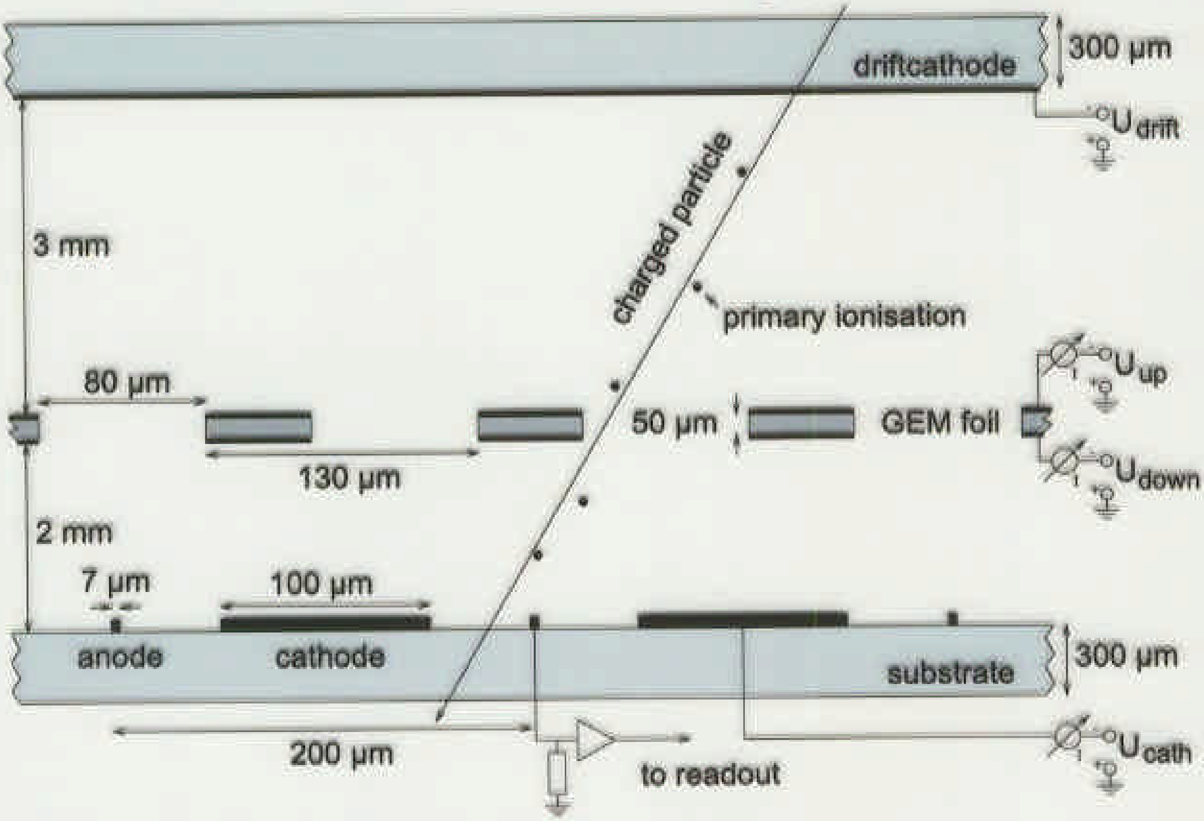
The CMS detector

- MSGCs were planned to equip the outer layers of the central tracker (r > 70cm)
- two 'supermodules' for the forward-backward part, equipped with GEM+MSGC modules
- each detector module houses four MSGC substrates





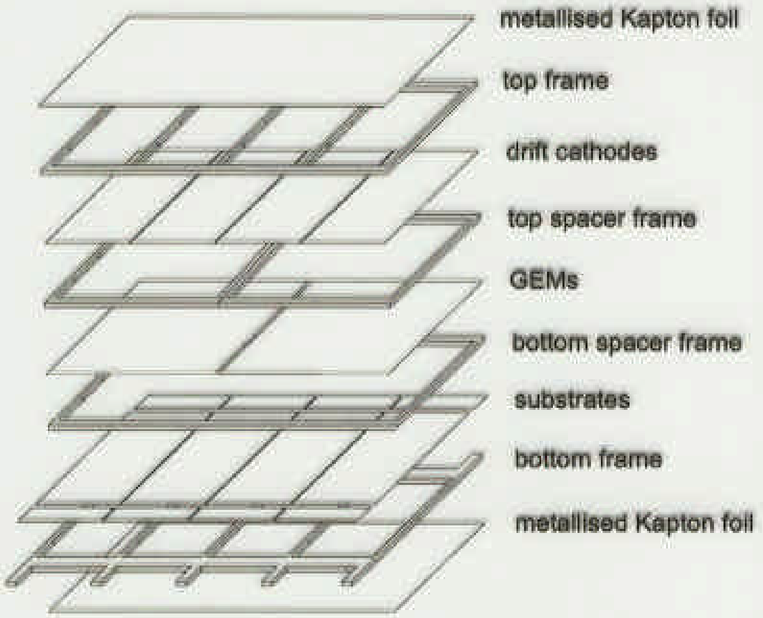
GEM+MSGC working principle



- charged particles ionise the counting gas
- electrons are transported by the drift field to the Gas Electron Multiplier (GEM)
- the GEM is a copper-clad polyimide foil with holes ($\varnothing=80\mu m$, pitch=$130\mu m$), and a potential difference between the copper layers
- the charge is amplified in the holes by avalanche processes
- the drift field below the GEM transports the charge to the Micro Strip Gas Counter (MSGC) substrate
- additional amplification between the anodes and cathodes of the MSGC, and detection of the particle signals by read out of the anodes

⇒ total amplification is shared between GEM and MSGC

CMS forward tracker modules



- four wedge shaped MSGC substrates are placed side by side in each detector module (D263 glass, Au strips, pitch=200μm at the wide side)
- a large area GEM foil covers the entire active area (50 x 15cm^2)
- 4 x 512 = 2048 channels per detector module
- PreMux128 front-end electronics

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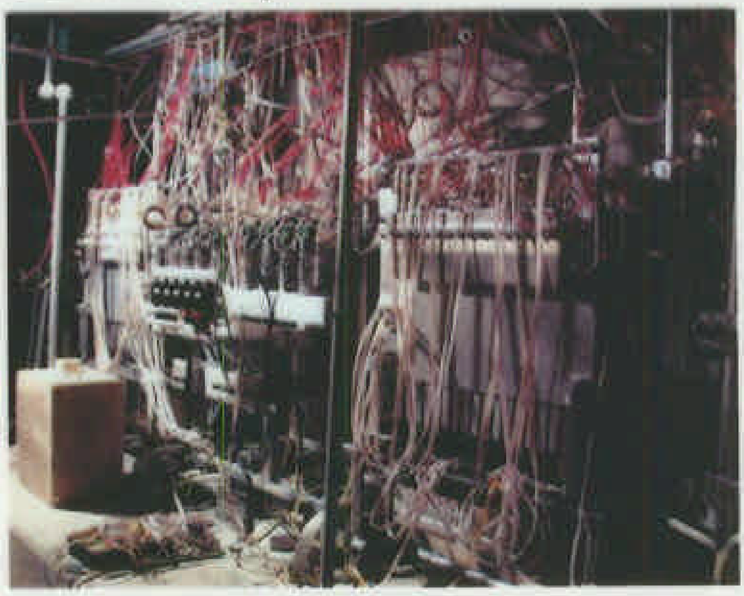
The test beam setup



- 18 detector modules with a total of 72 MSGC substrates have been built ⇒ this corresponds to 1% of the whole CMS forward MSGC tracker!
- the central two substrates were connected to the DAQ; ≈ 17.000 channels were read out
- all modules assembled and tested from August to October 1999
- the counting gas used was Ne/DME (40:60)
- tested at the Paul-Scherrer-Institute's high intensity 350MeV/c pion beam
- operation for 376h at the CMS working point (98% MIP detection efficiency) at a particle rate of ≈ 4kHz/mm^2
- currents and status of the anodes were constantly monitored for all detector modules

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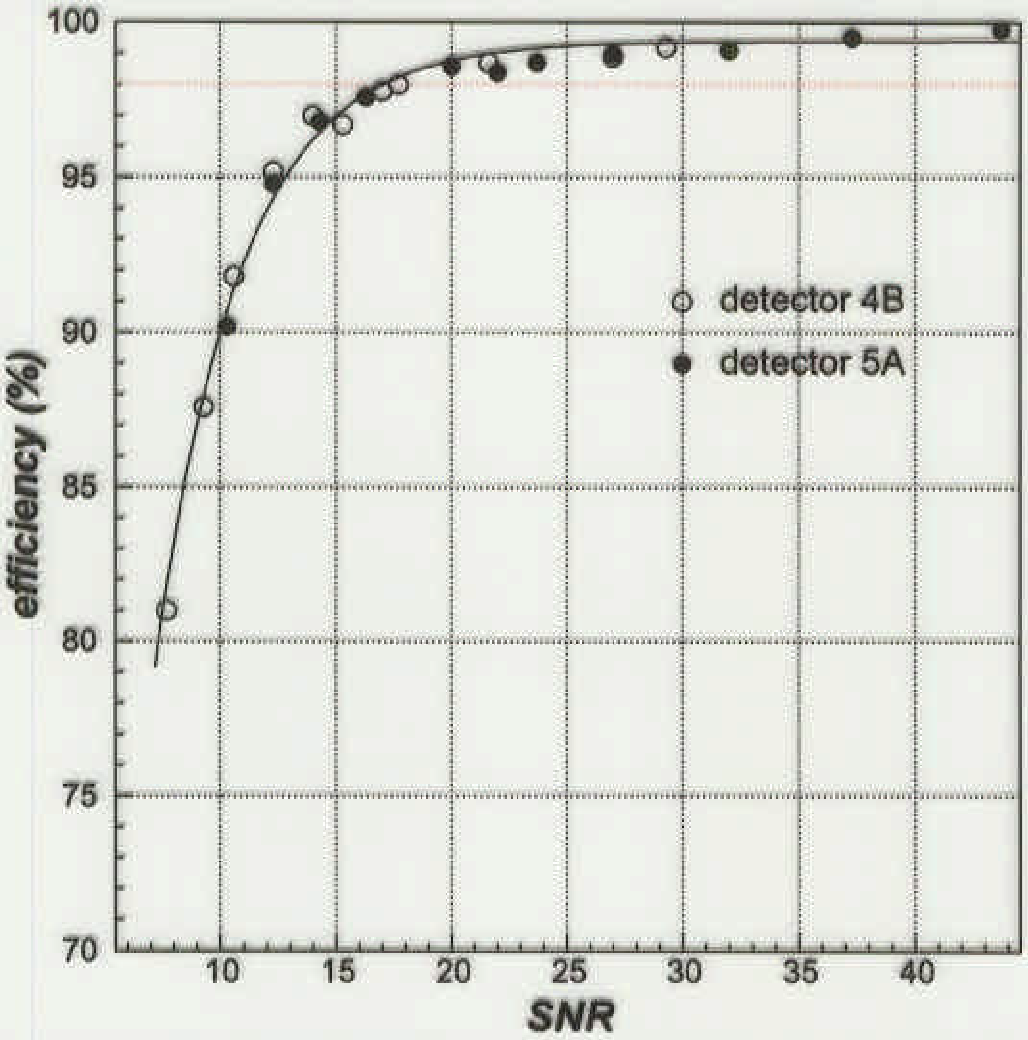
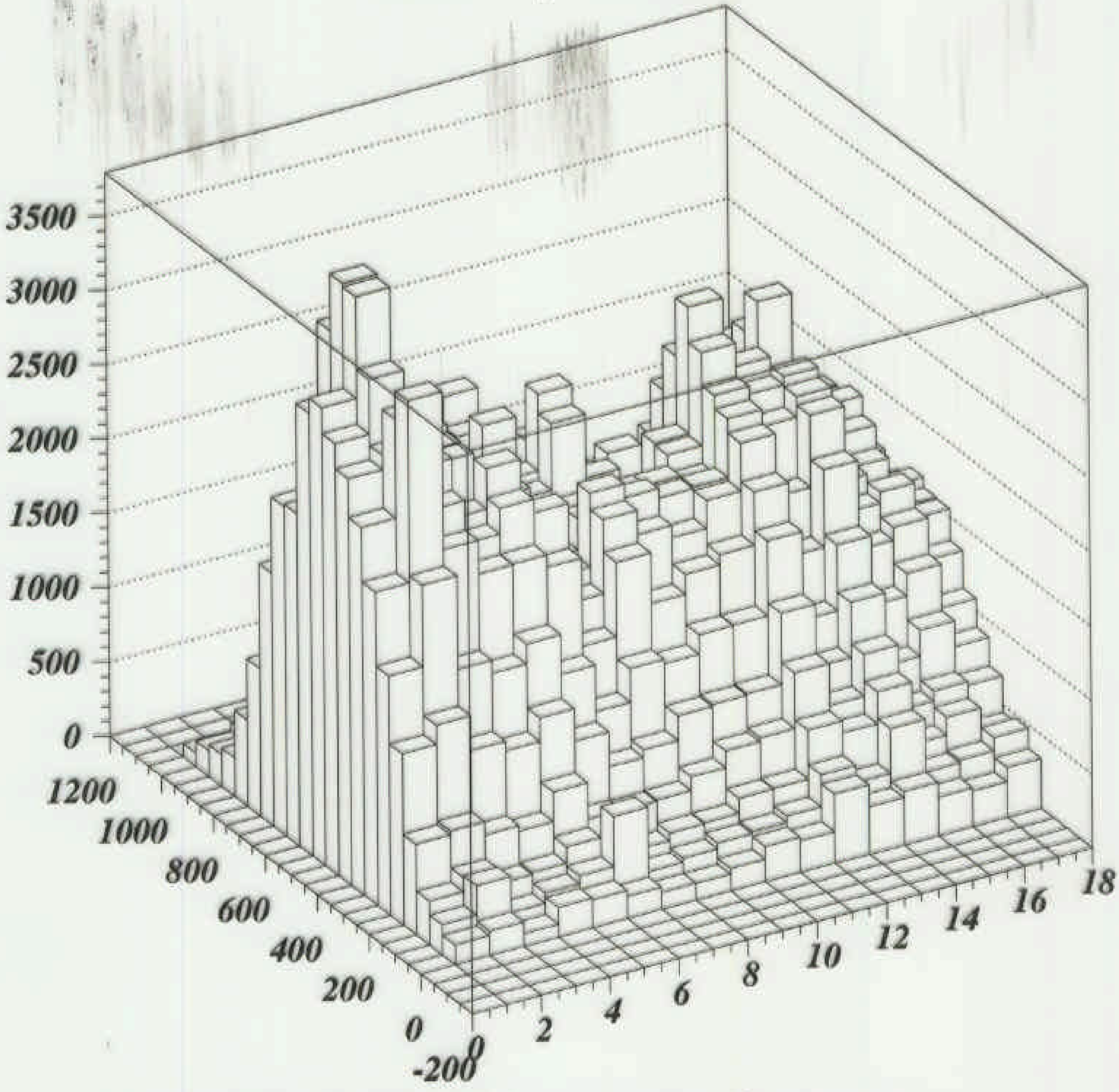
Signal-to-noise ratio and efficiency



- measurement of the efficiency of the detector modules during the test beam
- a MIP detection efficiency of 98% (required by CMS) is reached at a SNR of 17 (noise occupancy: < 2‰)
- this value has to be multiplied by 2.2 to take care of the increased noise of the next generation's front-end electronics ⇒ a SNR of 37 was set to simulate LHC/CMS running conditions

Beam profiles



- beam profiles of all detectors as they were mounted on the bench in the test beam

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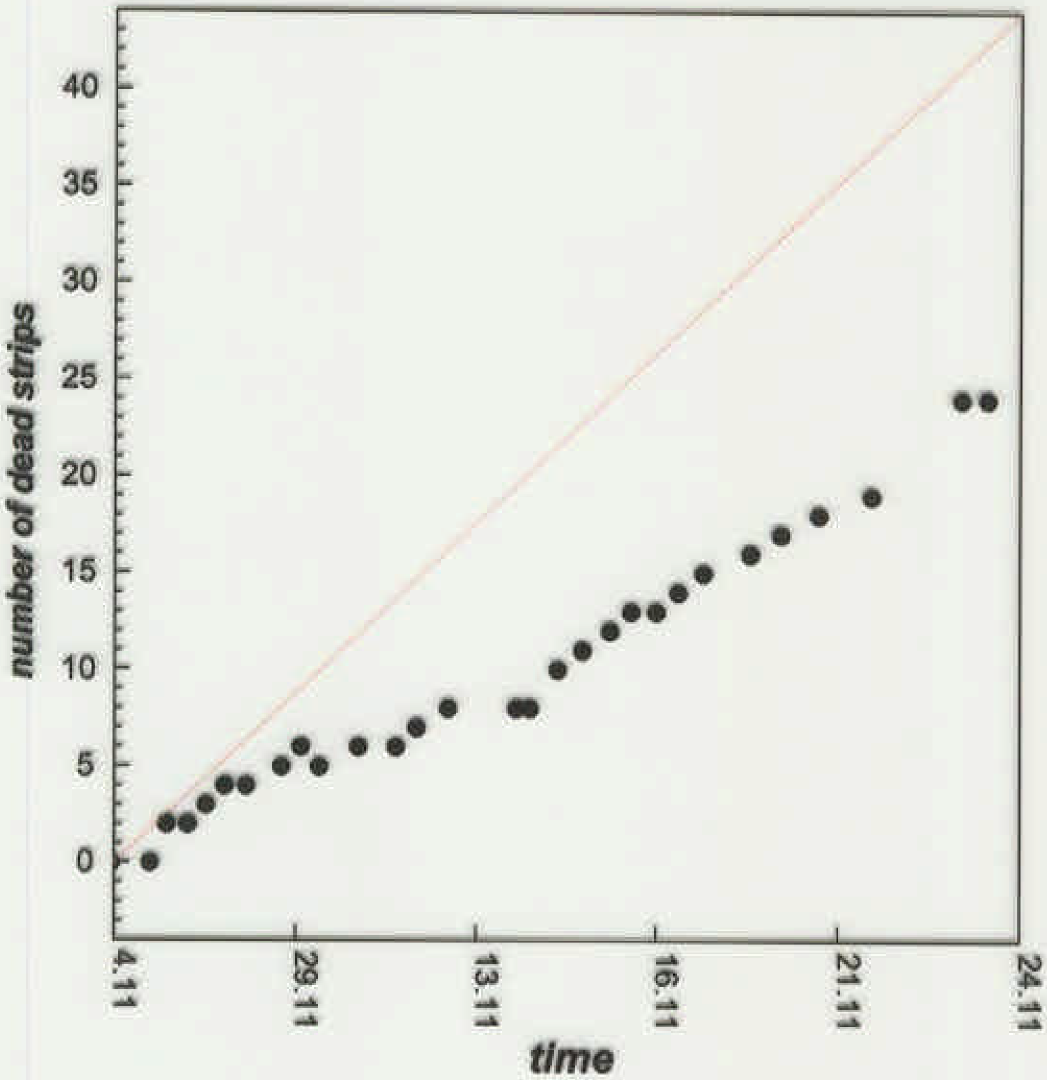
Stability in an LHC-like environment

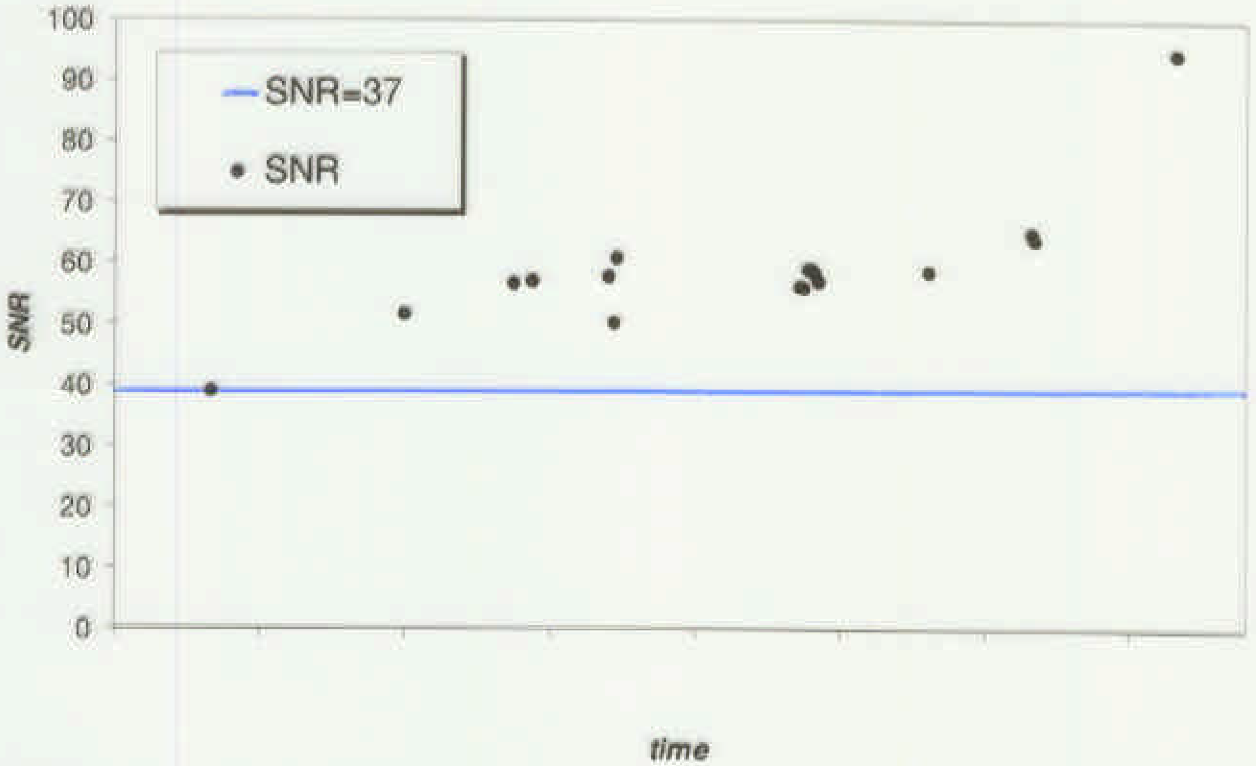


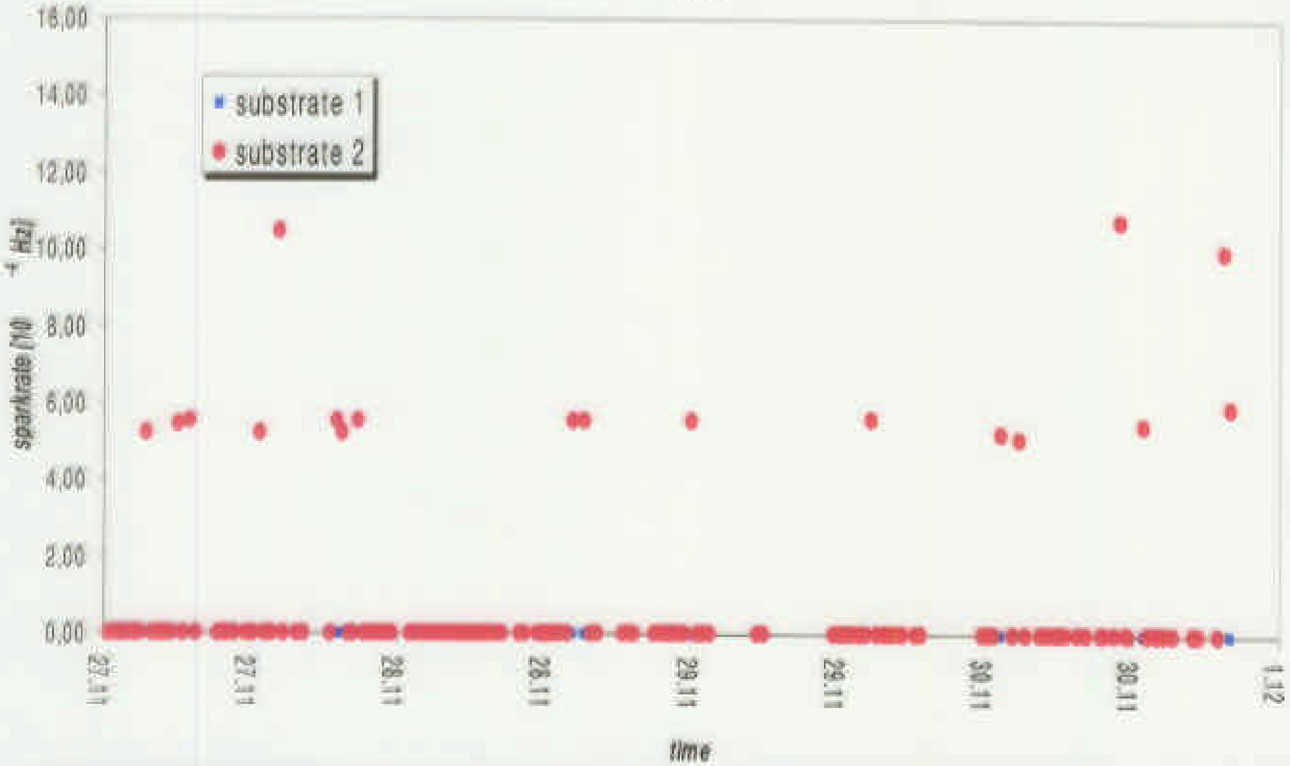
- the dotted line corresponds to a strip loss rate corresponding to 10% dead anodes after 10 years of LHC operation; the CMS track reconstruction efficiency would not be affected in that case

⇒ the loss of anodes stayed well below that margin!

- average discharge rate: 10^{-4}Hz per detector module

Performance of the detector modules





Conclusions

- GEM+MSGC detector technology was chosen as a possible solution for the CMS forward-backward MSGC tracker in 1999
- a large system of 18 detector modules with a total of 72 MSGC substrates has been successfully built and tested in a high intensity beam
- stable operation of the detectors at a LHC-like particle rate of ≈ 4kHz/mm^2 with a MIP detection efficiency of 98% has been shown
- the number of anodes lost (24 out of 17.000!) during 376h of high intensity running conditions is well below the ceiling set by the CMS requirements on track reconstruction efficiency for an extrapolated 10-year running period

⇒ all requirements imposed on GEM+MSGC detector modules by the CMS and LHC requirements could be fulfilled

- a comfortable safety margin to deal with unexpected gain fluctuations during LHC operation could be shown