Gain Uniformity tests on full scale triple GEM detectors for CMS high Eta upgrade

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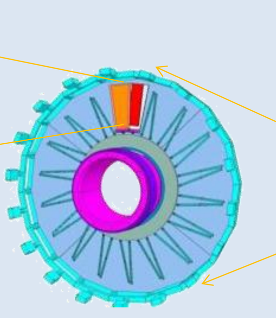
On behalf of the CMS GEM collaboration

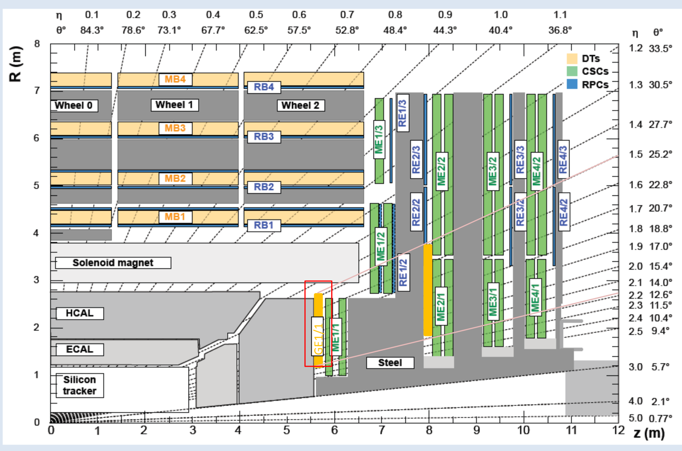
ABSTRACT

The CMS GEM collaboration has proposed an upgrade of the CMS forward muon system with triple-GEM detectors. An extensive R & D program has demonstrated that these detectors have the rate capability and radiation resistance needed to operate in the environment of the high-luminosity LHC. Moreover, their excellent position resolution will enhance the performance of muon triggering and reconstruction. These GEM detectors are the largest ones ever built. They have a trapezoidal shape, 1 m long, with parallel sides of 20 and 40 cm. It is important to insure uniform performance over the chamber area for all 144 chambers in the system. In this poster we describe a procedure for certifying the gain uniformity over the sensitive area of the detectors. An x-ray gun is used to illuminate different spots on the chamber, while the relative performance is measured in real time. We use the Scalable Readout System (SRS) which was developed by the RD51 collaboration. We describe the steps required for performance certification and we report measurements from the first full-size prototypes.

The good performances observed with a GEM based detector makes this technology an appropriate choice to equip the CMS forward muon system. In particular the CMS GEM collaboration is being prepared to equip the region 1.5 < η < 2.2.

2 slots are targeted on the endcap disks, so called GE1/1 on the following sketch. To equip this region 144 chambers have to be produced.

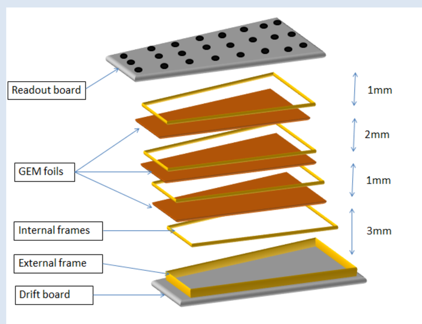


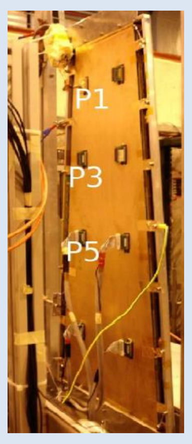


As shown on the previous pictures, the detector has a trapezoidal shape, it is 1m long and 35/55cm wide (short/long side of the trapezium). The readout is divided in 8 rows of 384 strips, each rows is read with 3 connectors of 128 channels.

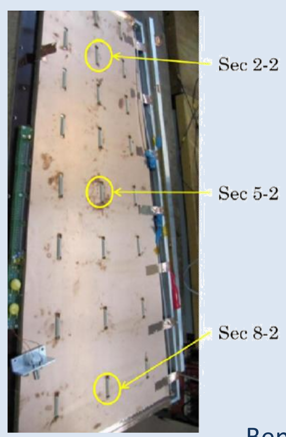
Detector working principle

The proposed detector consists of three layers of Gas Electron Multiplier, called GEM foils, which will ensure the pre-amplification of the signal. It is foreseen to run with Argon CF_4 CO_2 gas mixture (45%, 40% and 15% respectively). An external divider distributes the voltages from the drift to each foil. The particle to detect will ionize the gas present in the drift region and the primaries electrons created will drift from the drift to the readout, and will be amplified in each GEM foil. The electric fields to drift the electrons are in the order of magnitude of a few kV/cm. Inside the foils the fields will reach about 80kV/cm. In such a strong electric field the primaries electrons will be highly energetic which will allow the amplification process.





1[st] prototype



2[nd] prototype

Bench of 4 prototypes with NS2 technic

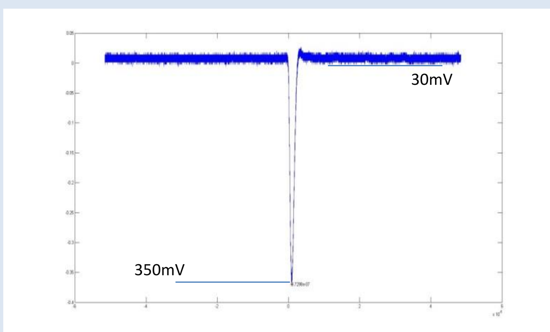
Bench of 6 prototypes for mass production preparation

Set up and signal observed

The chamber to test is illuminated with an Xray source. The output signal has a very good signal to noise ratio as shown on the picture on the right. (signal ~ 400mV noise ~ 30mV)

Xray source

Detector to test



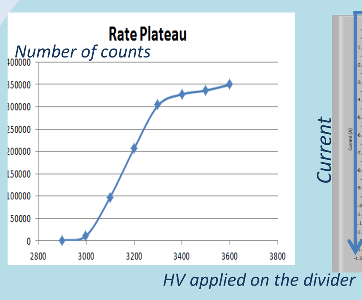
Gain measurement of the triple-GEM detector

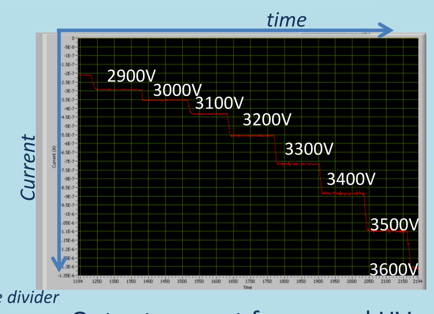
The gain of the chamber is the number of electrons created through the 3 foils by one primarie electron. The measurement is done as follow :

$$G = \frac{I_{signal}}{\#_{primaries} \times Rate \times e}$$

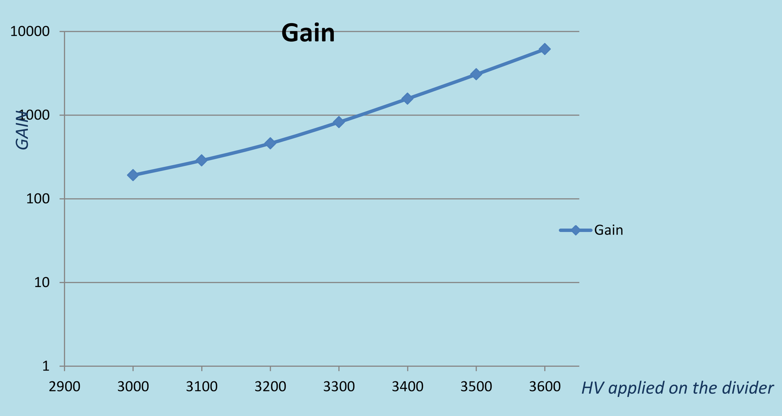
- I_{signal} is the current collected on the readout strips, measured with a picoampermeter.
- #Primaries is the number of electrons created during the ionisation. It depends on the gas mixture and the energie of the incoming particle. In this case with X-ray source we have 288 primaries electrons for Ar/CO2 and 234 for Ar/CO2/CF4.
- The Rate is measured with a discriminator and a counter.

Measurement with Ar/CO2 70%/30%



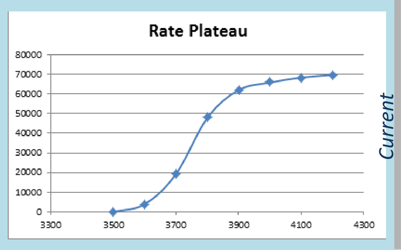


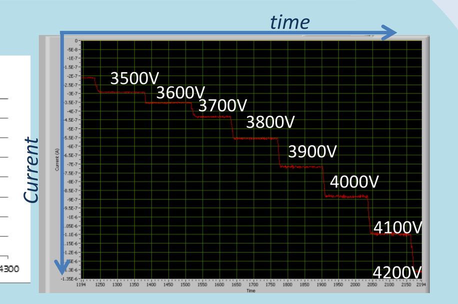
Output current for several HV values



Gain versus the voltage with Ar/CO2 (70/30)

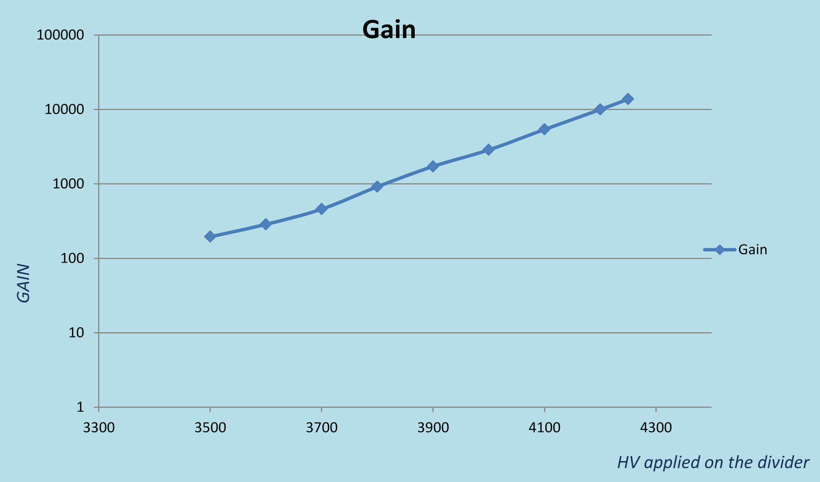
Measurement with Ar/CO2/CF4 45%/15%/40%





Output current for several HV values

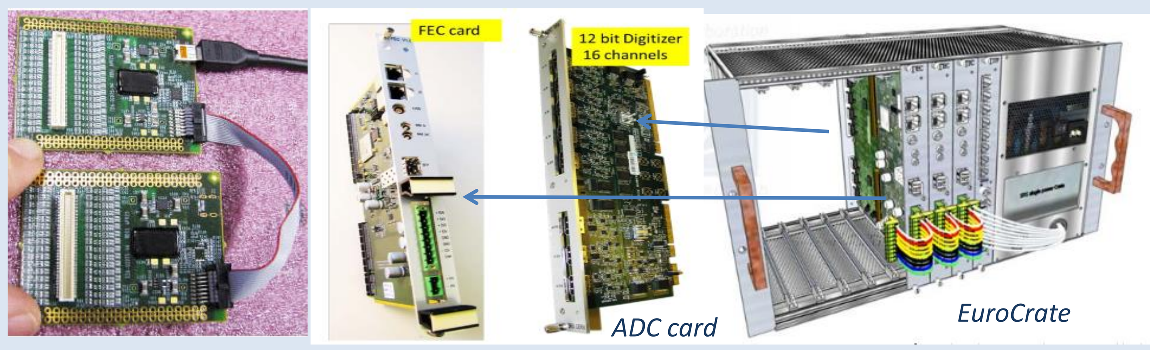
At a voltage of 3600V, the electric field on the GEM foils is about 400V and we measured a gain around 8000 which means a gain about 20 in each GEM foil.



Gain versus the voltage with Ar/CO2/CF4 (45/15/40)

The Scalable Readout System (SRS)

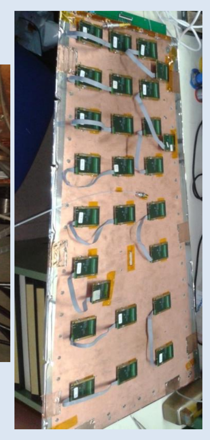
The collaboration RD51 is developing since 2009 a new analog readout electronic, the SRS system (Scalable Readout System). The minimum configuration is one APV chip read by one ADC card and one FEC card.:



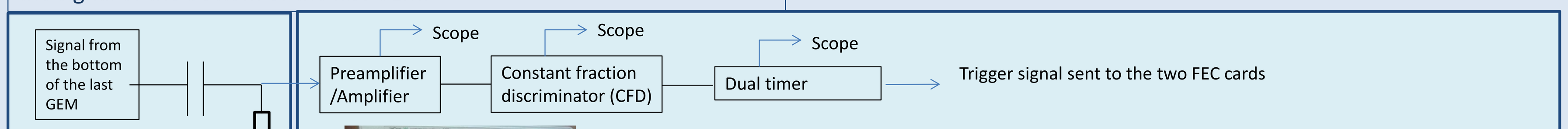
APV25 chips master and slave *FEC card (for ethernet communication)*

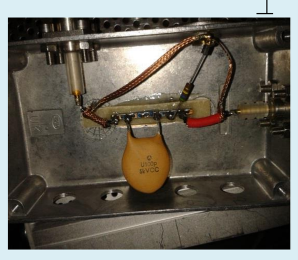
Gain uniformity measurement of the triple-GEM detector with the SRS

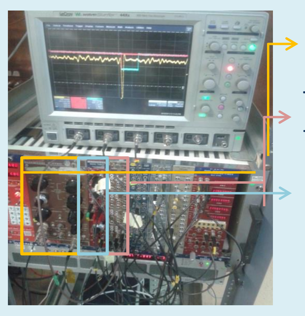
The chamber is read out with 24 APV chips via 2 FEC and ADC cards.



The APV chip needs an external trigger. To provide this trigger, we collect the signal of the bottom of the last GEM.







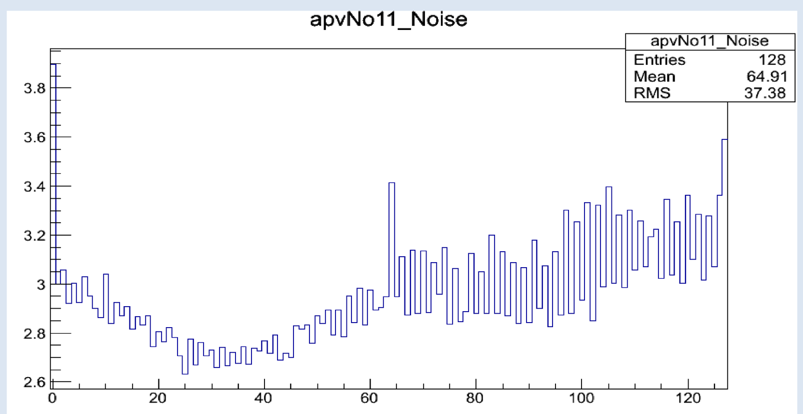
After the amplifier we can observe the signal on the bottom of the last GEM (yellow on the scope)

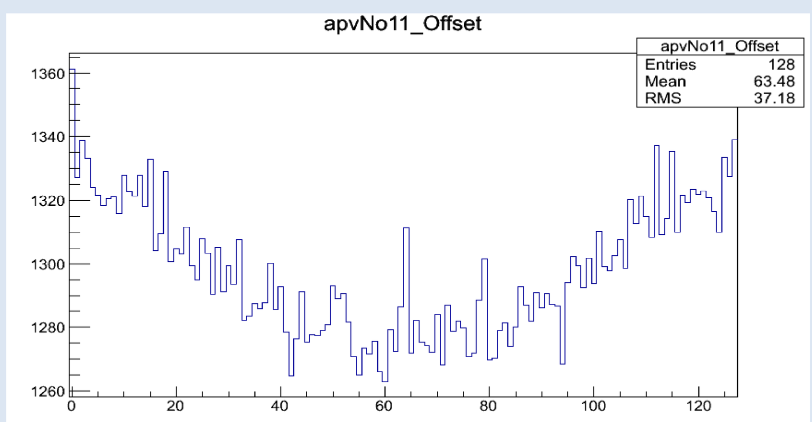
This signal is sent to the CFD, which will create a narrow gate as soon as the signal exceed the 30mV threshold.

We use a dual timer to add a veto on the gate created by the CFD to control the acquisition rate

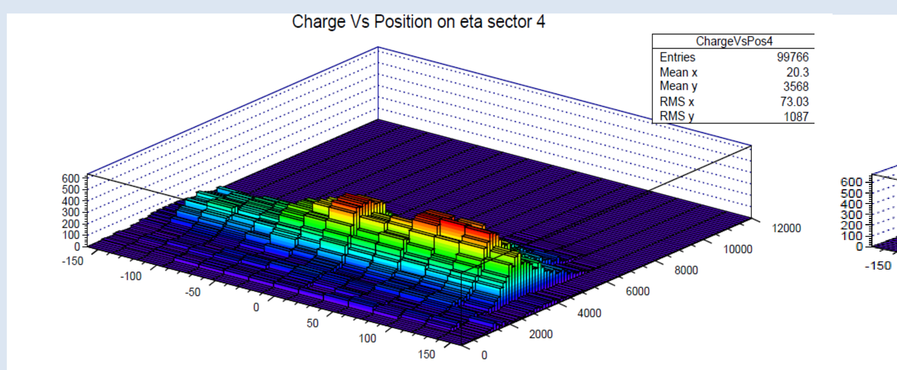
We first start a run to determine the pedestal of the signal of each APV(noise and offset). A rootfile is created with all these information for every APV.

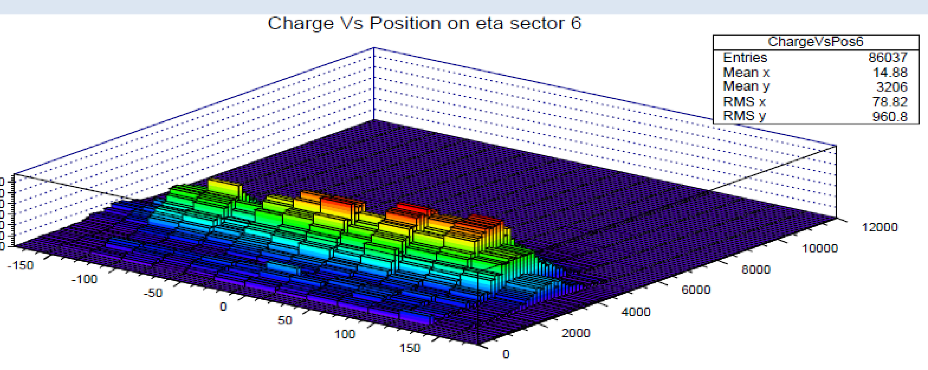
We produce a root file in which we plot the pedestal of each 24 APVs (noise and offset of the signal). On the plots below, you can see the noise and offset of ecah strips (128 for 1 APV).



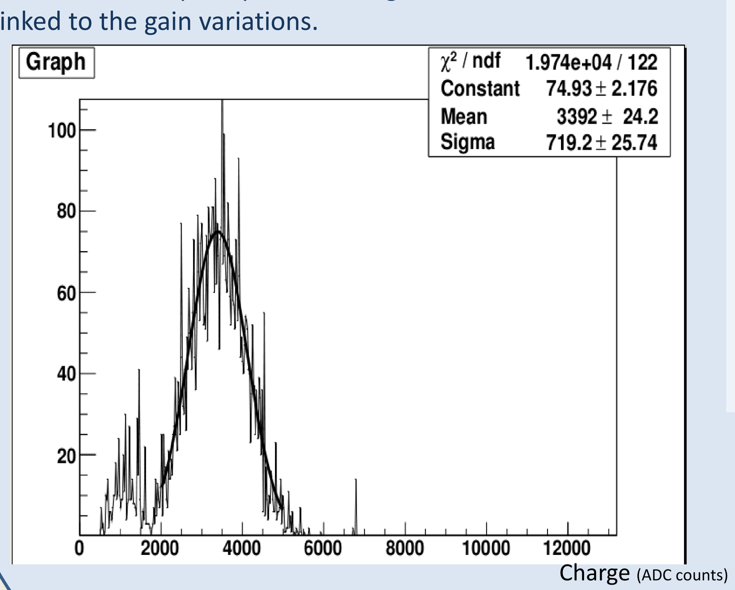


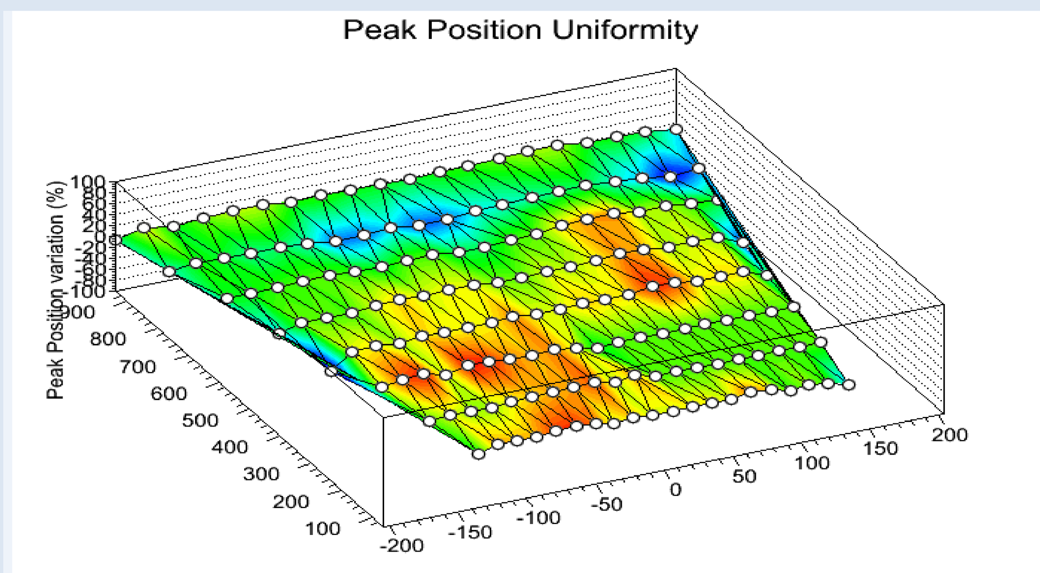
The full chamber is irradiated by an X-Ray source and the APV chips allows to record for each event the charge collected on each strips. After reconstructing the cluster informations, we can get the spectrum of the source everywhere on the chamber:





After following the peak position of this spectrum along the chamber, we can get the relative gain uniformity of the chamber. For each eta sector we compute 20 spectra. For each of them we fit the peak position. Then we can plot the variation of this peak postion along the chamber, which is linked to the gain variations.





We measured a gain variation of about 15% along the chamber with this method.

Conclusion

The triple-GEM detector allows to reach the efficiency plateau with a total gain of 8000 on the chamber, and each GEM is working far away from its limit as they run with a gain around 20. The output signal is very stable and with a very low noise. The SRS system is a powerful front-end electronic that we used successfully for a first precise measurement of the gain uniformity of the chamber. We are looking forward to test several other chambers with this method to better understand the gain uniformity. This measurement will help for the commissioning of the chambers in the CMS muon system.

Acknowledgement

Thank you to the RD51 collaboration for their facility and their equipements and special thanks to Eraldo Oliveiri for his help.

MPGD 2013, Zaragoza

1 – 6 July 2013