In The Name of GOD

Summer Student Report

CMS Muon Detectors system

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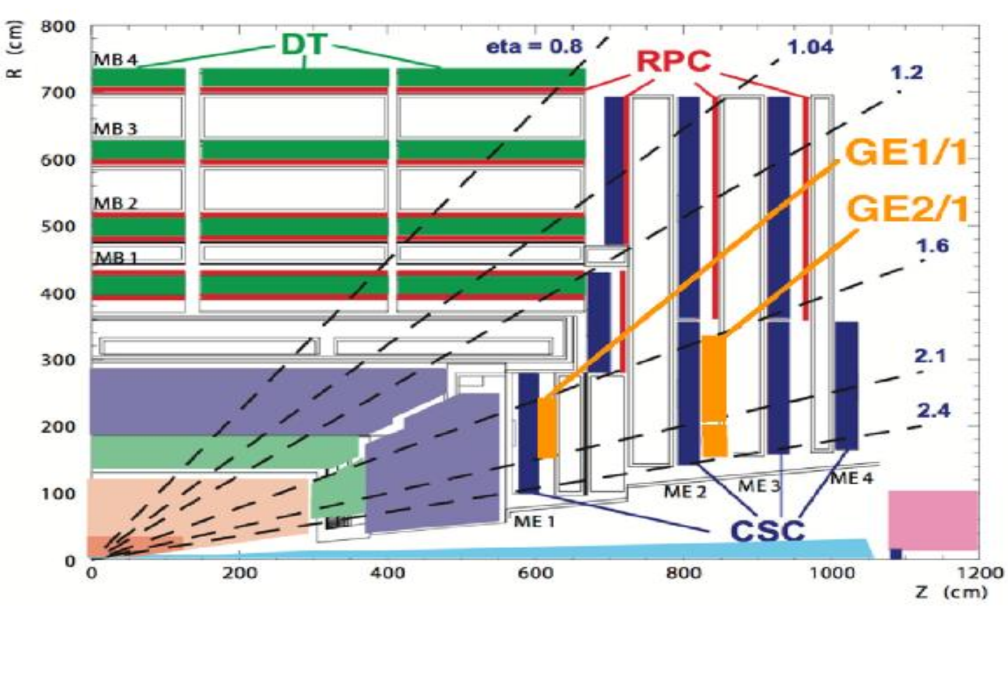
Why Muon is important?

Detecting muons is one of CMS's most important tasks. Muons are charged particles 200 times heavier than electron. They are expect to be produced in the decay of a number of potential new particles; for instance, one of the clearest "signatures" of the Higgs Boson is its decay into four muons.
muons can penetrate several metres of iron without interacting

Why 4 different kinds of Muon Detectors? Why Gaseous?

The wire based gaseous detectors are indeed not competitive with the scintillator as far as time resolution is concerned, but In total there are 1400 muon chambers:
250 drift tubes (DTs) 12 layers in the barrel region, Central coverage : $|\eta|<1.2$
540 cathode strip chambers (CSCs) 6 layers in the endcap region, Forward coverage: $0.9<|\eta|<2.4$
which these two, track the particles' positions and provide a trigger,
and 610 resistive plate chambers (RPCs) in both the barrel and the endcap Central and Forward coverage : $|\eta|<2.1$ which form a redundant trigger system, which quickly decides to keep the acquired muon data or not,
and finally, Micro-Pattern Gas Detectors (MPGDs), for instance: gas electron multiplier (GEM) in the endcap region which cover the vacant zone in the high eta: $1.6 < |\eta| < 2.4$

Because of the many layers of detector and different specialities of each type, the system is naturally robust and able to filter out background noise. These Detectors are gaseous which are fast and can measure high momentum Muons. For the initial phase of CMS, three types of gaseous detection technologies have been chosen, according to the different background rates and magnetic field the detectors have to withstand. Where neutron background is relatively small and in the 1-10 Hz/cm2 range, Drift Tube Chambers (DTs) are used. In the endcap regions where the background rate is higher and around 100-200 Hz/cm2 and the magnetic field is more intense than in the barrel, cathode strip chambers (CSCs) are selected.



How these Detectors complement to detect Muon's characteristic?

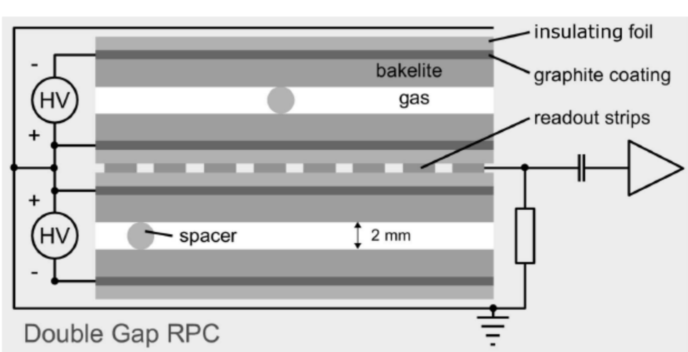
DTs and CSCs, both with self-trigger capabilities, can be used to measure the momentum and time of crossing of the muon. In addition, to assure an unambiguous bunch crossing (bx) identification and to build up a robust and redundant system, Resistive Plate Chambers (RPCs) both in the barrel and endcaps are used, providing a fast and accurate time measurement. The muon momentum resolution is extracted by combining information of the muon track from the muon system, modulated by the Global Muon Trigger with an efficiency > 96%, complemented with the more precise tracker measurement (including the vertex constraint). A momentum resolution down to 2 % is obtained for pT < 100 GeV (at all pseudo-rapidities) and 18 % for the most forward 1 TeV muon measurable by the CMS Muon spectrometer.

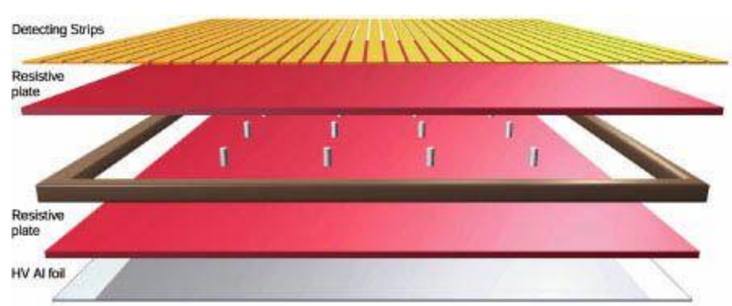
What is new with GEMs?

The forward muon upgrade will provide additional hit measurements to obtain higher efficiency and higher resolution for muons in certain pseudo-rapidity regions, providing the necessary control on the trigger rates, in addition to significant additional acceptance for muons at the trigger level. GEMs, being also a tracking devices, allows the muon pattern recognition also in partial, and even total absence, of the CSC allowing a direct measurement of the tracking performances using two independent muon systems.

RPC

the RPC trigger should efficiently detect the so called prompt muons, that is, muons that are produced very close to the collision point; particularly important are those that come from the decay of heavy particles like W±, Z0 and t quark, which will be mainly studied at high luminosity where the single muon trigger pt threshold is expected to be about 20 GeV/c. In the low luminosity LHC phase muons from J/ψ and B hadrons will also be very important and the single muon trigger pt threshold will be as low as 10 GeV/c. At the same time the RPC trigger output rate is required to be reasonably low at the threshold values reported above in order for the GMT to handle it properly and produce an output rate fitting the assigned value of about 10 kHz reserved for the single muon trigger. In this respect, one should keep in mind that prompt muons are not the only source of triggers. Muons coming from the decay of pions and kaons in the tracker or calorimeters are expected to give an important contribution.





The trigger efficiency is mainly affected by the efficiency of the chambers, their time resolution and the correct adjustment of the acceptance time gates with respect to the arrival time of the signals. On the other hand the output rate is expected to depend mainly on the intrinsic noise and the cluster size, i.e. the number of adjacent strips with signals following the crossing of an ionizing particle. Indeed, cluster size values larger than 1 strip per event result in making random coincidences more probable and in causing soft muons to be more likely recognised as harder ones.

Modes of operation:

1. Streamer
2. Avalanche

•RPCs originally conceived to work on streamer mode (up to ~100 Hz/cm2).

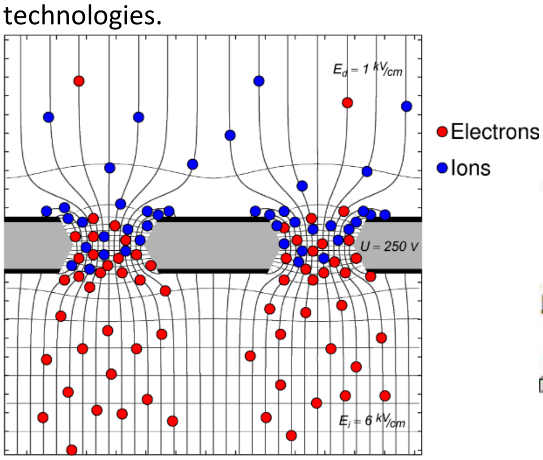
•In LHC experiments: a large neutron and gamma-ray background, producing high hit rate up to ~1000 Hz/cm2.

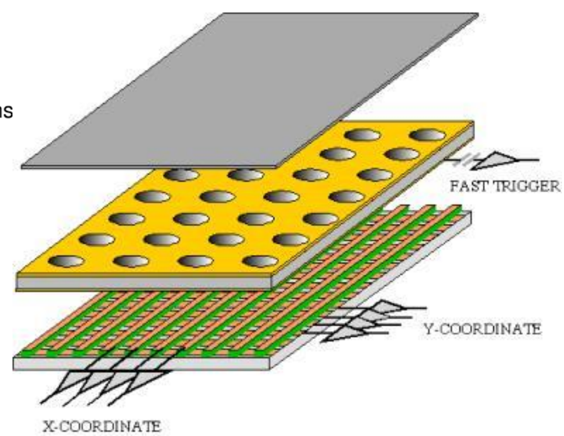
•To overcome this difficulty, RPCs will be operated in avalanche mode, using lower electric field.
•Transferring part of amplification from gas to front-end electronic.

GEMs

GEMs create the large electric field in small holes in a thin polymer sheet; the avalanche occurs inside of these holes. The resulting electrons are ejected from the sheet, and a separate system must be used to collect the electrons and guide them towards the readout.

GEMs are one of the class of micropattern gas detectors; this class includes Micromegas and other technologies.





Typical GEMs are constructed of 50-70 micrometre thick Kapton foil clad in copper on both sides. A photolithography and acid etching process makes 30-50 micrometer diameter holes through both copper layers; a second etching process extends these holes all the way through the kapton. The small holes can be made very regular and dimensionally stable. For operation, a voltage of 150-400 V is placed across the two copper layers, making large electric fields in the holes.

Under these conditions, in the presence of appropriate gases, a single electron entering any hole will create an avalanche containing 100-1000 electrons; this is the "gain" of the GEM. Since the electrons exit the back of the GEM, a second GEM placed after the first one will provide an additional stage of amplification. Many experiments use double- or triple-GEM stacks to achieve gains of one million or more.

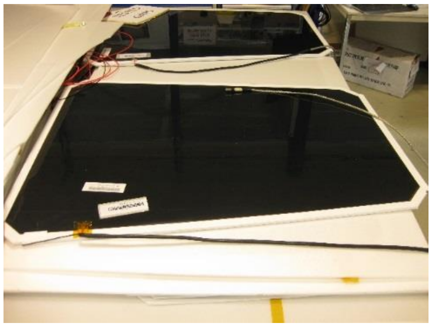
Operation of wire chambers typically involved only one voltage setting: the voltage on the wire provided both the drift field and the amplification field. A GEM-based detector requires several independent voltage settings: a drift voltage to guide electrons from the ionization point to the GEM, an amplification voltage, and an extraction/transfer voltage to guide electrons from the GEM exit to the readout plane

My Project:

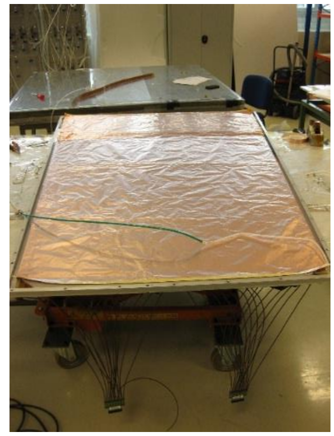
Our first works were constructing RPCs and measuring the efficiency and some other tests in the Lab 904. After that we moved to Lab 186 (TIF) to establish a new cosmic stand for testing GEM detectors.

904 ::::> leak test, Gap test, HV scans and efficiency test of RPCs.

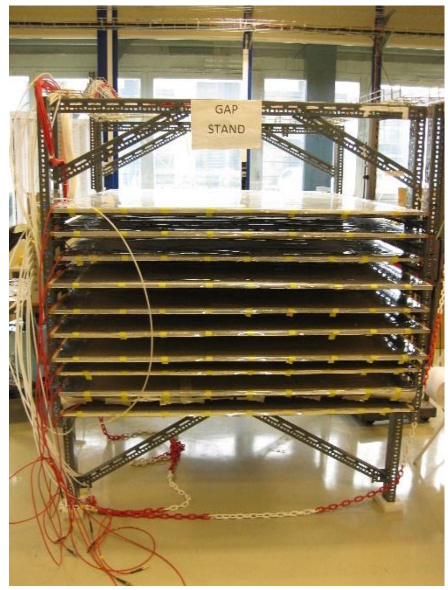
- **For building RPS's we need (components):**
  Front End Board (FEB)
  Distribution Board(DB)
  Mylar sheet
  Copper sheet
  Gas Gaps(3 type : Bottom, Top, Narrow)
  HV cables
  Gas pipe bending
  Coolant pipe pressure test
  Coaxial cable and adapter boards preparation
  Flat ribbon cable preparation
  High voltage epoxy filling



- **Test before and after construction:**
  Spacer test
  Leakage test
  Visual test
  High voltage and dark current
  FEB testing



- **The experimental setups for testing the new RPS's are:**
  High voltage power supply for gas gaps
  Low voltage power supply for front end electronics
  Gas system to inject gas mixture in chamber
  Trigger system
  Data Acquisition system
  Rack for scintillator and RPC



- **Testing procedure for new RPC's are:**

All chambers are inspected visually after assembly.
Chambers are conditioned using the gas mixture, 8 volume changes.
HV around 9 KV is applied for 24 hours (or less) and the dark current observed $\Rightarrow$ If it was more than 0.5 µA, chamber will be rejected.
HV is varied ~ 8.5 KV 9.5 KV.
More than 2000 event are taken for each HV.
From the data we can now:
Strip Occupancy $\Rightarrow$ Noisy (if more than 2) and/or dead channels, chamber will be rejected.
Efficiency $\Rightarrow$ If < 95%, chamber will be rejected
Cluster Size $\Rightarrow$ If grater than 3.0, chamber will be rejected

186 ::::> establishing new Cosmic Stands with new PMTs, remote controlling the CAEN devices in the Lab.

Triggering GEM detectors with cosmic stand for efficiency test, is needed. For this aim, there are new PMTs (H3178-51) which characterization of their assemblies are going to be tested. The operating parameters are: HV supplied to PMT anode and discriminator threshold

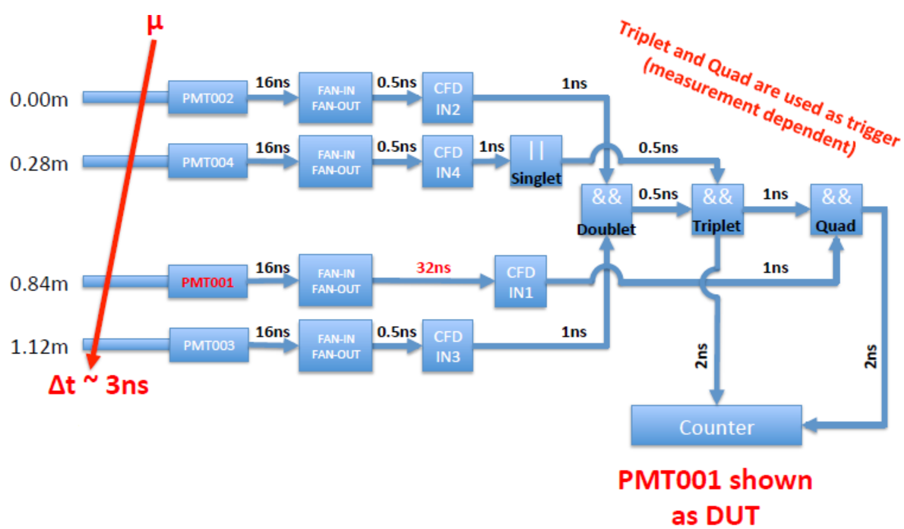
Measurements for device under test (DUT):

– Efficiency vs. HV (binned by disc threshold)
– Noise

There are 12 scintillators are all in alignment, some as DUT and some as Trigger.

The PMT characterization setup has the following equipment:

- 2 HV power supply (4 channel)
- 2 delay timer
- Quad scalar and counter timer
- logical units
- 2 CFD for threshold
- 2 linear fan in/fan out.



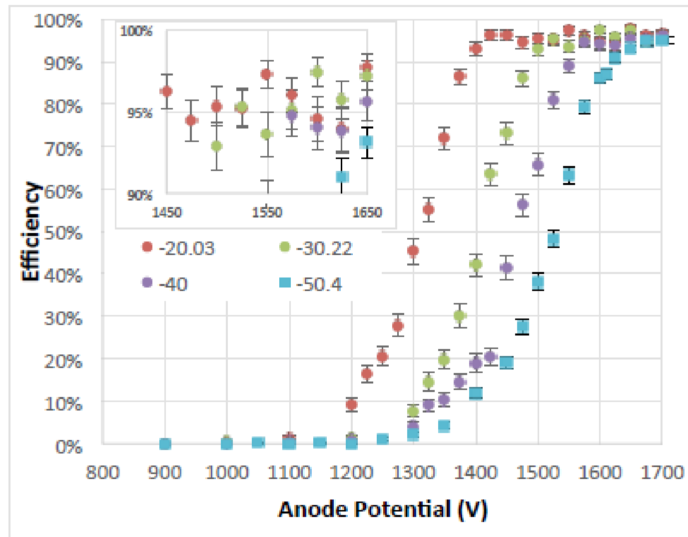
For Eff. Measurements, the procedure is the following:

- Connect Device Under Test (DUT) to Quad
- Increase the potential applied to PMT anode
- Start counter (~30 sec.)
- Record number of counts from Triplet & Quad
- Repeat above three steps until Max. voltage reached

Then by definition of efficiency and error (binomial) as

$$\varepsilon = \frac{n_{Quad}}{n_{Triplet}} \qquad \delta = \sqrt{\frac{\varepsilon(1-\varepsilon)}{n_{Triplet}}}$$

We can plot the Efficiency vs. HV (include different threshold) and observe the efficiency plateau at ~95%

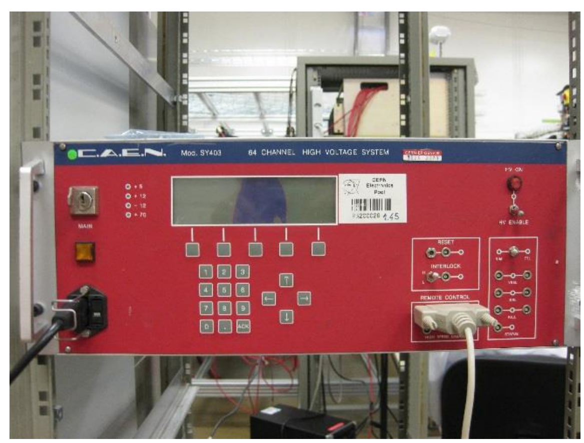


After three weeks, Efficiency curves and CFD threshold for all PMTs is determined and we are going to determine the noise level and rate for all PMTs and it's a bit complicated ....

Next step is to establish another part of cosmic stand, HV power supply for GEM detectors. There are two models of C.A.E.N power supply in the lab:

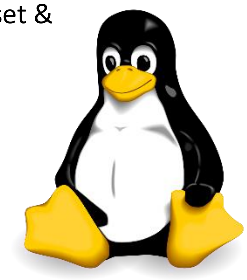
- SY403: 4*16 channels, can provide HV up to 3KV, old, RS-232c (25 pin) remote controlling serial port (MOXA serial to USB adaptor needed)
- SY1527: 8*5 channels, can provide HV up to 15KV, newer and have more adjusting and controlling options, RS-232 (9) remote controlling serial port

SY1527



SY403

Its need to control every parameter of these power supply, like Ch on/off, Vset & Vmax, Iset & IMax, Trip time, voltage rise time and fall time etc. in remote way.



So the task is to make a script code in any language like C++ or Python in Linux operating system. We used the prepared program minicom for first step but further we need to make a code with set desired parameters ready for execution via minicom.

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                     C.A.E.N.       SY403        V1.40
GROUP00             Hv_En is: On     V0-SEL     I0-SEL      Crate 01       Page 0

Channel             Vmon     Imon   HVmax      V0set    I0set    Hv    Status     Ch#
CHANNEL00          0000.1    0000    3124      1000.0    3000    Off               00
CHANNEL01          0000.0    0000    3124      0025.0    3000    Off               01
CHANNEL02          0000.0    0000    3124      1000.0    3000    Off               02
CHANNEL03          0000.3    0000    3124      1000.0    3000    Off               03
CHANNEL04          0000.0    0000    3124      1000.0    3000    Off               04
CHANNEL05          0000.2    0000    3124      1000.0    3000    Off               05
CHANNEL06          0000.0    0000    3124      1000.0    3000    Off               06
CHANNEL07          0000.0    0000    3124      1000.0    3000    Off               07
CHANNEL08          0000.0    0000    3124      1000.0    3000    Off               08
CHANNEL09          0000.0    0000    3124      1000.0    3000    Off               09
CHANNEL10          0000.0    0000    3124      1000.0    3000    Off               10
CHANNEL11          0000.0    0000    3124      1000.0    3000    Off               11
CHANNEL12          0000.0    0000    3124      1000.0    3000    Off               12
CHANNEL13          0000.0    0000    3124      0444.0    3000    Off               13
CHANNEL14          0000.4    0000    3124      1000.0    3000    Off               14
CHANNEL15          0000.0    0000    3124      1000.0    3000    Off               15

GROUP00                                      XXXX.X    XXXX    XXX

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Minicom

Finally my contract ended, but people in Lab are still working on it.
It was a great time for me to be as a summer student to gain a large amount of knowledge, and to learn lots of new things in theoretical and experimental aspects of physics.

References:

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