Test of a GEM Detector in the PHENIX Experiment at RHIC

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INTRODUCTION

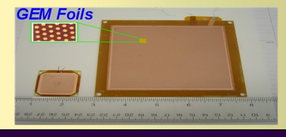
Objective

- Gas Electron Multipliers (GEM) can serve as high precision tracking detectors in a variety of high energy and nuclear physics experiments, and are currently being considered as part of a planned upgrade detector in the PHENIX experiment at RHIC.
- But...relativistic heavy ion experiments can potentally provide not only very high track multiplicities, but also severe background conditions.
- To study the use of a GEM detector in such conditions, a test was carried out of a three stage GEM detector, at PHENIX. The detector was placed in the interaction region, close to the collision point, inside the PHENIX Central Spectrometer and operated at full luminosity gold-gold collisions.
- Results are given on the stability of operation and sensitivity of the detector to beam related background using both Ar/CO_2 and pure CF_4 gas mixtures. The detector was mounted in four different orientations in an effort to simulate various possible detector geometries. The detector performance within PHENIX is compared to the typical performance in the

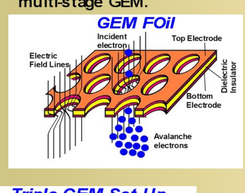
Gas Electron Multiplier (GEM)

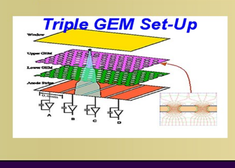
GEM Facts
- Invented by F. Sauli @ CERN in ~1995
- High precison micropattern readout detector with high/stable gain operation
- Foils are able to screen out avalancnhe induced photon mediated gas processes that limit the gain
- Very convenient geometry for various detector applications, including the possibility of multiple stages
- Applicable in high rate environments

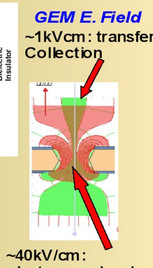
What is a GEM
- A GEM is a device capabale of amplifying the charge from an incident electron, by collecting the electron into one of many GEM holes, where an electron avalnche is triggered via a very intense elctric field. The GEM is made of 50μm thick Kapton foil with ~5μm thick copper cladding on both sides, which act as electrodes. The foil is perforated with bi-conical shaped holes on the order of 50μm in diamter and a hole spacing of 120μm.



Operation
- Once a potential of a few hundred volts is applied between the electrodes, a field develops inside the holes on the order of 40kV/cm, enough to induce rapid ionization of the detector working gas by incoming electrons. The total charge collected from the avalanche is on the order of thousands of times larger than the charge of the incident electron for a multi-stage GEM.



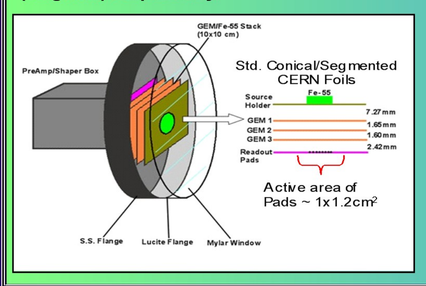


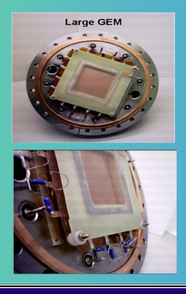


EXPERIMENT

Apparatus

- 10x10cm² Triple GEM detector with 1x1.2 cm² pad readout
- The top flange is made of lucite and a mylar window to allow the penetration of low energy particles into the gas volume, thus simulating a realistic detector.
- A 250 μCi ^{55}Fe - X-ray source allows monitoring of the gas gain
- Gas gains of ~$6x10^3$ and $3x10^3$ have easily been achieved in the lab at a voltage potential of ΔV = 360V and ΔV =495V across each foil in Ar/CO2 (4.0 grade), and CF4 (6.0grade) respectivley.





Gases Used

- Ar/CO_2 (70/30)

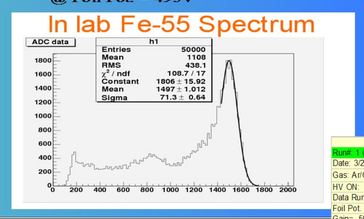
** Volt Configuration:*
DG: 0.5kV/cm
TG1:2.5kV/cm
TG2: 3.0kV/cm
IG: 3.5kV/cm

** Nominal Operating Gain:*~$6.5x10^3$ @ Foil Pot. = 360V

- CF_4

** Volt. Configuration:*
DG: 0.5kV/cm
TG1:2.5kV/cm
TG2: 3.5kV/cm
IG: 5.0kV/cm

** Nominal Operating Gain:*~$3.2x10^3$ @ Foil Pot. = 495V

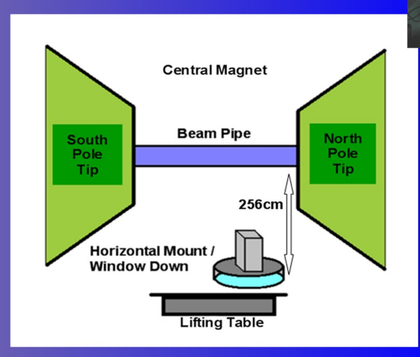


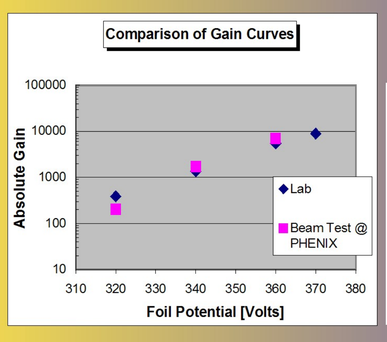
Run#: 1 (Lab)
Date: 3/2/04
Gas: Ar/CO_2 (70/30)
HV ON: 1:30 pm
Data Run: 2:50 pm
Foil Pot. = 360V
Gain: 5923 Res.= 12.2%
BEAM: N/A, ZDC = N/A
Beam Cond: N/A
Mag: N/A

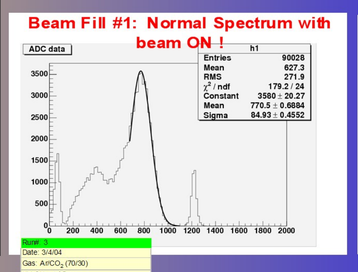
Orientation #1

Gas: Ar/CO2 (70/30)

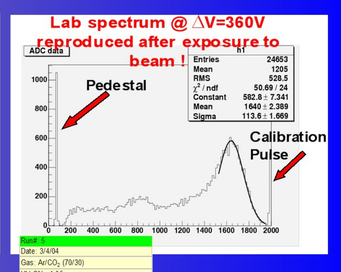
Implications:
- The detector electronics are not adversely affected by the presence of the magnetic field generated by the PHENIX central magnets.
- The detector passed the initial survival test during full luminosity RHIC A-A collisions
- In this configuration, the detector was not sensitive to beam related background, and behved as it did in the lab
- The absolute gain and the FWHM energy resolution in both beam ON and OFF conditions is comparable to lab data







Run#: 3
Date: 3/4/04
Gas: Ar/CO_2 (70/30)
HV ON: 1:05 pm
Data Run: 3:35 pm
Foil Pot. = 320V
Gain= 187 Res.= 28.2%
BEAM: OFF, Au I = 35x10⁹
Beam Cond:
Mag: ON
030404_320_8p7.txt

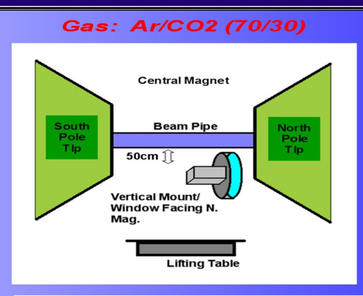


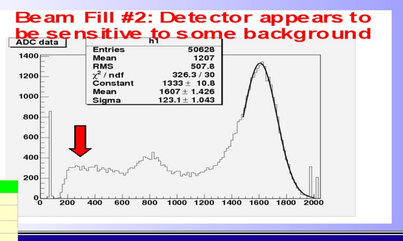
Run#: 5
Date: 3/4/04
Gas: Ar/CO_2 (70/30)
HV ON: 1:05 pm
Data Run: 6:25 pm
Foil Pot. = 360V
Gain= 6827 Res.=17.0 %
BEAM: OFF, ZDC = 0Hz
Beam Cond:
Mag: OFF
030404_360_241.txt

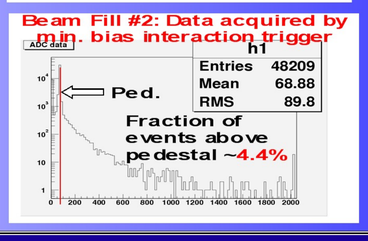
Orientation #2

Gas: Ar/CO2 (70/30)

Implications:
- Detector is sensitive to background in this configuration, with ~ 4.4% of events above pedestal (according to beam-beam triggered data) - low background rate due to small detector acceptance (1x1.2cm²)
- The gain was within expected limits, i.e. within +/-10% of the gain measured in the lab
- FWHM % reslotuon is similar to what was measured in the lab





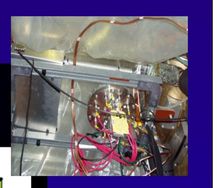


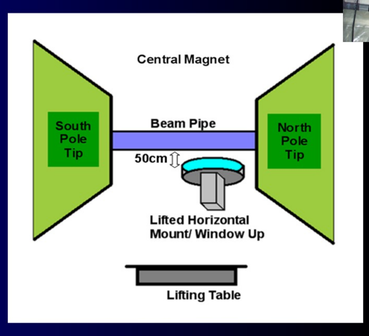
Run#: 12
Date: 3/18/04
Gas: Ar/CO_2 (70/30)
HV ON: 4:40 am
Data Run: 5:40 am
Foil Pot. = 360V
Gain= 6172 Res.= 18.9%
BEAM: ON, ZDC = 3.56kHz
Beam Cond:
Mag: ON

Orientation #3

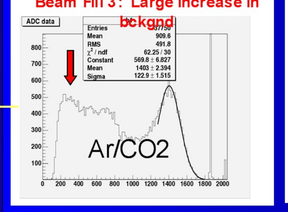
Gas: Ar/CO2 (70/30), CF4

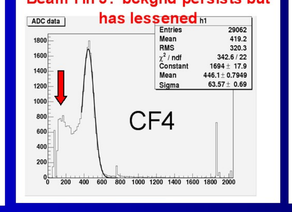
Implications:
- Orientation 3 represents approximate configuration of PHENIX HBD upgrade detector
- Large increase in background: low energy (primary charge ~ 100 e-) and does't obscure ^{55}Fe photopeak
- Ar/CO2: 4.6% of hits above ped.; CF4: 2.7%, and later 5.1% of hits above ped.
- Fluctuating background rate in both CF4 and Ar/CO2 runs may be due to changing beam conditions
- The unusally high background levels observed during fill #4 could be indicating such fluctations in the beam conditions
- The high levels of background were short-lived and the detector behaved normally thereafter (i.e in terms of abs. gain value and gain stability in time)

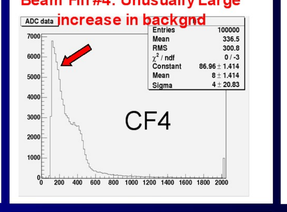


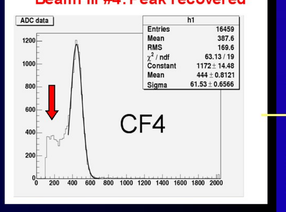


Run#: 17
Date: 3/19/04
Gas: CF_4
HV ON: 5:50 am
Data Run: 6:41 am
Foil Pot. = 495V
Gain= 3200 Res.= 39.6%
BEAM: ON, ZDC = 2.48kHz
Beam Cond:
Mag: ON



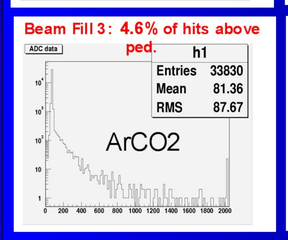


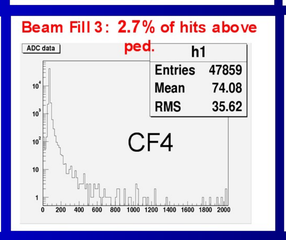


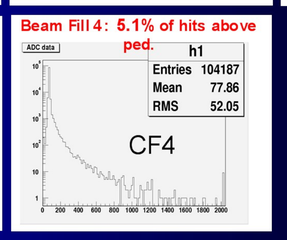


Run#: 22
Date: 3/19/04
Gas: CF_4
HV ON: 7:28 am
Data Run: 10:24 am
Foil Pot. = 495V
Gain= ? Res.= ?
BEAM: ON, ZDC = 1.77kHz
Beam Cond:
Mag: ON

Run#: 18
Date: 3/19/04
Gas: Ar/CO_2 (70/30)
HV ON: 1:00 am
Data Run: 2:13 am
Foil Pot. = 360V
Gain= 5540 Res.= 21.6%
BEAM: ON, ZDC = 1.47kHz
Beam Cond:
Mag: ON







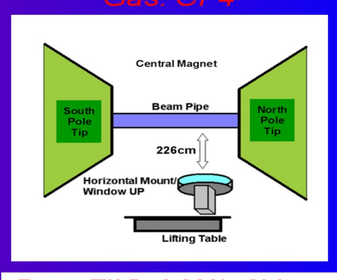
No additional beam-beam triggered data available

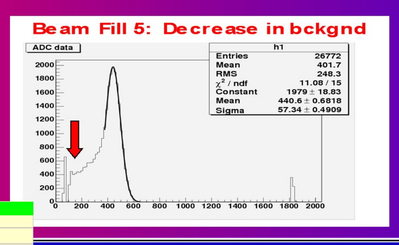
Run#: 23
Date: 3/19/04
Gas: CF_4
HV ON: 11:40 am
Data Run: 11:46 am
Foil Pot. = 495V
Gain= 3129 Res.= 38.5%
BEAM: ON, ZDC = 1.97kHz
Beam Cond:
Mag: OFF

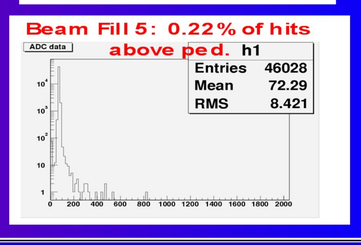
Orientation #4

Gas: CF4

Implications:
- Marked decrease in background rate, with only 0.22% of hits above pedestal
- These results strongly suggest a true correlation between the proximity of the detector to the beam pipe and the levels of background detected--> validates experiment
- GEM gain is well within expected limits (+/-10%) after tens of hours of operation inside the IR.





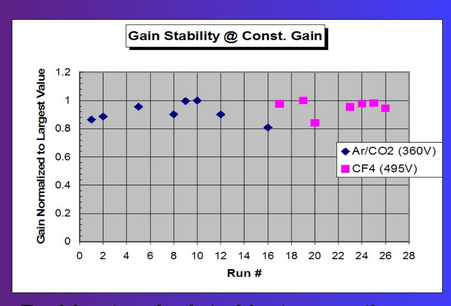


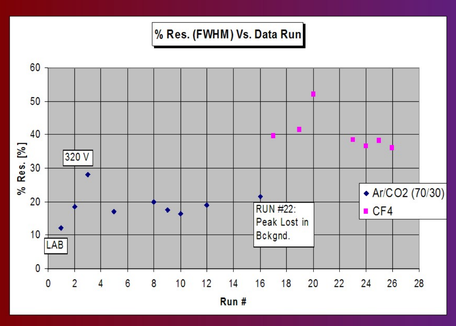
Run#: 28
Date: 3/19/04
Gas: CF_4
HV ON: 1:09 pm
Data Run: 3:24 pm
Foil Pot. = 495V
Gain= 3155 Res.= 38.2%
BEAM: ON, ZDC = 5.7kHz
Beam Cond:
Mag: ON

CONCLUSIONS

Trend in Data with respect to Run

- The gain remained stable to within +/- 10% throughout all the data runs, similar to what is experienced in a lab setting
- No significant discharging was ever observed in any of the tests





- Besides two isolated instances, the FWHM % resolution also showed consistent results throughout each test
- In the two instances where the resolution deviated from the majority of the data, the resolution was calculated from data acquired ~40min. after the HV was turned ON--the worsened resolution may be attributable to gain drift resulting from residual charging effets within the GEM foils.

Summary

- Over-all, the GEM detector exhibited trouble-free operation within the PHENIX IR, with no sparking or excessive gain instabilities.
- The single case of anamolous behavior was short-lived and may have been related to fluctuating beam conditions
- The detector was susceptible to beam related background, although the rate was relatively low (for a 1.2cm² pad array at 50cm from the beam pipe)
- The operation of the GEM and its associated electronics were not hindered by the presence of the ambient magnetic field generated by the PHENIX central magnets.
- The tests seem to indicate that the detector operated with pure CF4 was less sensitive to beam related background, than it was when operated with Ar/CO2. However, taking into account the dE/dx values for MIPs in both CF4 (~7.0keV/cm), and Ar/CO2 [70/30] (~1.4keV/cm), CF4 would be expected to be more sensitive to the ionization energy deposited by passing particles. Therefore, it is again reasonable to suspect fluctuating beam conditions (and not the detector gas) as responsible for the detector response to the observed background.

Acknowledgements: We gratefully acknowledge the Department of Energy, Division of Nuclear Physics, for their support (Contract DE-AC02-98CH10886).