Construction and beam test analysis of GE1/1 prototype III gaseous electron multiplier (GEM) detector

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Outline

• Motivation
• Gas Electron Multiplier (GEM) detectors
• Construction of GE1/1 prototype III GEM detector
• Beam test setup at FNAL
• Different scenarios used for test
• Results:
  ➢ Uniformity, efficiency and resolution
• Conclusion
• Future plans
Motivation

• Long shutdown Phase II of CMS experiment at CERN LHC involves forward muon endcap region upgrade

• Technology will be used is Gas Electron Multiplier (GEM)
  ➢ In the form for 1m long GEM detectors
  ➢ Provides fast triggering
  ➢ Precise tracking
  ➢ It will help to improve overall muon trigger

• Florida Tech is planning to make huge contribution in this upgrade project by producing 40 GEM detectors(app. 25% of the detectors)

Source: Topic-of-the-Week Seminars, LHC Physics Center at Fermilab - Marcus Hohlmann
Gas Electron Multiplier (GEM) Detector

- It is micro pattern gas detector (MPGD)
- Consists of GEM foil that is made up of kapton foil coated with copper on both sides and has array of holes which are equidistant usually 140\(\mu\)m
- High voltage is applied across foils, which creates avalanche of electrons through holes
- Provides good efficiency and spatial resolution
- Provide a gain of \(10^4\) with gas mixture of Ar/CO\(_2\)

Triple GEM configuration:
Most popular and reliable

Murtas, F.: “Development of a gaseous detector based on Gas Electron Multiplier (GEM) Technology

Source: http://gdd.web.cern.ch/GDD/
Source: http://www.flc.desy.de/tpc/basicsgem.php
Construction of GE1/1 Prototype III

Total assembly time 3 Hrs 40 mins with 2 people

Step I
GEM foils assembly with inner frames

Stack of GEM foils with inner frames ready to place on drift electrode

Step II
Stretching GEM foils by providing tension

Stretched GEM foils with inner and outer frames

Readout board
8 $\eta$-sectors with each 384 radial strips

GEM detector w/ APV connected
FNAL Test Beam Setup

Tracker Voltage: 4200V
Gas mixture: Ar/CO2

CMS Detector

Trackers

Beam 32GeV

0 deg inclination

7 deg inclination

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Different Scenarios used for test

**HV scan**
- Operating plateau voltage
- Efficiency at different voltages

- Range of voltages: 2900V-3300V

**Position scan**
- Overall performance of the detector
  - Uniformity, Cluster Size, Efficiency

- Voltages: 3250V

Sector 5 used for HV scan
Results: HV scan

- **Gaussian beam profile for Hit Distribution at 3100V**
- **Beam profile remain same**
- **Charge Distribution (fitted by Landau dist. at 3100V)**
- **Charge Vs High Voltage**
  - Cluster charge increases with voltage
- **Cluster Size vs. High Voltage**
  - Cluster size increases with voltage
- **Cluster size at 3100V**
- **Error is less than 1 %**
  - Error bars are smaller than marker size
Results: HV Scan

- Operating efficiency obtained using sigmoid fit is 97.8%

Error is less than 1%
Error bars are smaller than marker size
Results: Position Scan

Beam Profile

- Width of beam profile decreases from eta1 to 7 as width of strip increases

Cluster Size vs. Eta sectors

- Cluster size remains same for all eta sectors

Charge uniformity looks consistent for all three APV positions

Upper and lower APV 0 deg inclination

- Error is less than 1 %

Middle APV 7deg inclination

- Error bars are smaller than marker size

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Results: Position Scan

- Overall efficiency of the detector for all sectors is consistent with operating efficiency we found out in HV scan which approximately 98%

Error is less than 1%
Error bars are smaller than marker size

Uneven stretching near sector 7
Conclusion

- Detection efficiency for GE1/1 prototype detector III form HV scan is 97.8% which is consistent with overall efficiency
- Charge uniformity is consistent for all three APV position as well as for different angle inclination.
- Future Work
- Find the spatial resolution of the detector and study the tracking information
Thank you!
Triple GEM detector

• Most popular and reliable configuration is Triple GEM configuration
• Consists of stack of 3 GEM foils between the drift and readout
• Several experiments use Ar/CO₂ gas mixture in 70:30
• Advantages of using this gas
  • Non flammable
  • Chemically stable
  • Fast electron drift velocity
  • Provides high gain

Murtas, F.: “Development of a gaseous detector based on Gas Electron Multiplier (GEM) Technology
Backup

• Studied the hit distribution, charge distribution and cluster size for HV scan and Position scan

• Evaluates the efficiency from cluster multiplicity (CM)

\[
\text{efficiency} = \frac{N1}{(N - N2)}
\]

Where, N1: No. of events with CM≥1 for given sector
N: Total no. of events
N2: sum of the no. of events with CM≥1 for other sectors