Performance of a Large-Area Triple-GEM Detector in a Particle Beam

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on behalf of the GEM Collaboration (GEMs for CMS)

gas electron multiplier (GEM) micro-pattern gas detector (MPGD)
GEM Collaboration (GEMs for CMS)

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motivation for GEM detectors in CMS

existing CMS forward muon systems:
  cathode strip chambers, $0.8 < |\eta| < 2.4$
  resistive plate chambers, $|\eta| < 1.6$

dual detection systems for high trigger and reconstruction efficiency

after LHC upgrade (>2016), luminosity $\sim 10^{34} \text{ cm}^{-2} \text{ sec}^{-1}$

increased track density due to large # of interactions per bunch crossing

complete and preserve dual system concept
RPC Endcap Muon System

Reduced RE system $|\eta| < 1.6$

$\eta = 2.4$

<table>
<thead>
<tr>
<th>STAGED</th>
<th>RE 1/1</th>
<th>RE 1/2</th>
<th>RE 1/3</th>
<th>RE 2/1</th>
<th>RE 2/2</th>
<th>RE 2/3</th>
<th>RE 3/1</th>
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<th>RE 4/1</th>
<th>RE 4/2</th>
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<tbody>
<tr>
<td>No. of chambers</td>
<td>36*2</td>
<td>36*2</td>
<td>36*2</td>
<td>18*2</td>
<td>36*2</td>
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View of First Endcap Station
time resolution ~4 ns adequate for 25 ns interval between bunch crossings

L in range $10^{34} - 10^{35}$ cm$^{-2}$s$^{-1}$ gives high-η charged particle flux 0.5k to 30k cm$^{-2}$s$^{-1}$

operation with non-flammable Ar/CO$_2$ gas mixture is highly desirable in the limited-access environment

HV discharges at low rate and are non-destructive allowing long-term (10 year) stable operation

need to verify that large-area chamber will have only small gain loss after accumulated charge of 0.05 to 30 C/cm$^2$, expected after 10 years, depending on the integrated luminosity
Gain after irradiation of small area prototype*

detector properties:
  triple-GEM
  10cm×10cm
  128 strips with 0.8 mm pitch (1-d readout)
  Ar/CO$_2$ 90:10 mixture

X-ray source with Cu target

initial gain ~2300 at 3550 V

<5% gain reduction after 20 C cm$^{-2}$ exposure

trapezoidal geometry, 990mm × (220 − 455) mm
single mask GEM foils, readout 0.8 – 1.6 mm strip pitch

Large area prototype “GE1/1” construction*

Gas mixture: Ar/CO2 (70/30)
Gas flow: ~ 5 l/h
Large area prototype “GE1/1” construction*

100 cm² per HV sector

compact HV divider boards with surface mount components
GE1/1 tested in 150 GeV extracted beam

setup in RD51 area of H4 SPS
150 GeV μ/π test beam, Oct. 2010

4 η sectors with 2 φ sections

8 front-end readout boards with 128 channel VFAT chip

multi-conductor cables to common DAQ board
VFAT* front-end electronics

GE1/1 read out by single VFAT chip
VFAT properties:
  CERN-designed ASIC
  front-end readout of silicon and gas detectors
  128 channels; each channel:
    two-stage preamplifier
    comparator with adjustable threshold
    binary output
  fabrication process: 0.25 micron line-width CMOS
  chip size 9.4 × 7.6 mm²
  programmable “OR” function over region of inputs for trigger
  current use with GEM and CSC detectors in TOTEM experiment

Beam test spatial resolution results

small-area GEMs measure hit position in large-area GEM

spatial resolution of 0.29 mm measured in region with average strip pitch of 1.1 mm

expected resolution of 0.31 mm for single-strip clusters using $1/\sqrt{12}$ of average strip pitch

<table>
<thead>
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<th>deltaX</th>
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<tr>
<td>Entries 9152</td>
</tr>
<tr>
<td>Mean -0.0467</td>
</tr>
<tr>
<td>RMS 0.7155</td>
</tr>
<tr>
<td>$\chi^2 / \text{ndf}$ 205 / 37</td>
</tr>
<tr>
<td>Constant $1113 \pm 15.7$</td>
</tr>
<tr>
<td>Mean $-0.0354 \pm 0.0032$</td>
</tr>
<tr>
<td>Sigma $0.2888 \pm 0.0025$</td>
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Beam test efficiency results

efficiency \sim 98\% at full operating voltage
Current activity

new prototype chamber with 3/1/2/1 mm gaps

old and new prototypes set up in H4 beam with 3 T magnetic field

operation in progress
Summary

Triple-GEM detectors are an excellent candidate for a new small-angle ($|\eta| > 1.6$) muon system in an upgraded CMS.

A large area (1m×0.5m) prototype was operated in a secondary test beam at CERN in Oct. 2010.

Spatial resolution of ~300 microns is demonstrated with efficiency ~98%.

Two large area chambers are currently installed in the test beam inside a 3T magnetic field.