DAQ and online control system for new GEM detectors in the endcap muon system of the CMS experiment

José D. Ruiz-Álvarez
on behalf of the CMS Collaboration

August 4, 2016
<table>
<thead>
<tr>
<th></th>
<th>Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gas Electron Multiplier detector at CMS experiment: GE1/1</td>
</tr>
<tr>
<td>2</td>
<td>Electronics</td>
</tr>
<tr>
<td>3</td>
<td>Data format</td>
</tr>
<tr>
<td>4</td>
<td>Online data acquisition system</td>
</tr>
<tr>
<td>5</td>
<td>Conclusions</td>
</tr>
</tbody>
</table>
## Gas Electron Multiplier detector at CMS experiment

### GE1/1 Gap Sizes

<table>
<thead>
<tr>
<th>GE1/1 Gap Sizes</th>
<th>Typical Potentials</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 mm</td>
<td>3200 V</td>
</tr>
<tr>
<td>2 mm</td>
<td>2430 V</td>
</tr>
<tr>
<td>1 mm</td>
<td>2050 V</td>
</tr>
<tr>
<td>2 mm</td>
<td>1750 V</td>
</tr>
<tr>
<td>1 mm</td>
<td>1380 V</td>
</tr>
<tr>
<td>1 mm</td>
<td>780 V</td>
</tr>
<tr>
<td>1 mm</td>
<td>430 V</td>
</tr>
<tr>
<td>0 V</td>
<td>0 V</td>
</tr>
</tbody>
</table>

### Typical Voltages

<table>
<thead>
<tr>
<th>Typical Voltages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1380 V</td>
</tr>
<tr>
<td>780 V</td>
</tr>
<tr>
<td>430 V</td>
</tr>
<tr>
<td>0 V</td>
</tr>
</tbody>
</table>

### Typical El. Fields [kV/cm]

<table>
<thead>
<tr>
<th>Typical El. Fields</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3</td>
</tr>
<tr>
<td>3.0</td>
</tr>
<tr>
<td>2.6</td>
</tr>
<tr>
<td>62.0</td>
</tr>
<tr>
<td>64.0</td>
</tr>
<tr>
<td>3.0</td>
</tr>
<tr>
<td>60.0</td>
</tr>
</tbody>
</table>

### Drift cathode

- GEM 1
- GEM 2
- GEM 3
- Readout PCB
- Induction
- Transfer 1
- Transfer 2
- Drift
- Amplifier

### GEM 1/1 Parameters

- 70 µm
- 140 µm

---

**Figure Description:**
- left: SEM image of GEM foil, showing typical diameters.
- center: Schematic of GEM detector setup with labeled components.
- right: Diagram illustrating the GEM detector setup with potential and field distribution.
Overview of the CMS GEM electronics system.
More details can be found at Brian Dorney and Cesare Calabria posters:
6 August, 18:00

*New gas electron-multiplier detectors for the innermost stations of the endcap muon system of the CMS experiment: design, prototype performance, and installation*
http://indico.cern.ch/event/432527/contributions/1071758/

*New micropattern gas detectors for the endcap muon system of the CMS experiment at the high-luminosity LHC*
http://indico.cern.ch/event/432527/contributions/1071768/
Front-end electronics

VFAT
- Readout strips connected to VFAT
- 128 channels
- Preamplifier, shaper and fraction discriminator (for VFAT3)
- Currently working with VFAT2, VFAT3 under development
- 24 VFAT chips per GE1/1 chamber

Optohybrid
- Interface between on-detector and off-detector electronics
- Concentrate the 24 readout sectors
- Two optical lines: Tracking and Trigger, tracking configuration, control commands
Back-end electronics

AMC (Advanced Mezzanine Card)
- Depending on card, up to 76 optical transceivers and receivers
- Operation capabilities at least 10 Gbps
- Currently testing GLIB (Gigabit Link Interface Board) and CTP7 (Calorimeter Trigger Processor)
- SDRAM buffer → data quality

AMC13
- Interface to CMS DAQ and TTC

μTCA
- Interface between detector and CMS DAQ
- Currently supporting 10 GB/s data throughput with IPbus and fiber DAQ outputs.
- With standard MCH module
VFAT (Data packet) \( e^{- \text{link}} \) GBT at OH (8 VFATs x GBT) (Serialize data) \( \text{optical link} \) AMC card \( \mu\text{TCA backplane} \)

Firmware: Implementation of common protocols (GBT and IPbus) and set of flags for warnings and errors
XDAQ - Generics

Software platform designed specifically for the development of distributed data acquisition systems.

XMAS alarm propagation
XDAQ

GEM supervisor

Managers

AMC13
AMC
OH

Scan routines

Threshold
Latency
HV

Database Readout

Data processing and visualization (Light DQM)

Database
Readout
GEM online system

GEM supervisor

- HTML application
- Actions: configure, start, stop, halt, ...
- Just clicking buttons on a web page
Component managers

- Piece of code to manage each DAQ component
- OH, AMC13, AMC
- Fully configurable from a xml file
- Monitoring component status
Scan routines

Calibration scans

- Directly done from AMC13
- Latency scan, Threshold scan, High voltage scan
Conclusions

- New GEM system to be installed in CMS during 2019-2020 upgrade
- Several additional tools under development: DQM, python-based CLI, Node.js webdaq, LightDQM web-interface
- Getting ready for slice test (beginning 2017 → Installation of 2 to 4 superchambers at CMS)
- Currently testing and doing quality control at CERN (2 locations) and remote locations (Brussels, Rice U., TAMU, Fermilab)
Source of figures


BACKUP
CMS L1 trigger rate with GE1/1

Figure 1.2: Level 1 muon trigger rates before and after the GE1/1 upgrade at a luminosity of $2 \times 10^{34}$ cm$^{-2}$ s$^{-1}$, for constant efficiency of 94%. MS1/1 denotes the first endcap muon station Level 1 trigger in both cases, i.e. with CSC-only or with the combination CSC and GEM trigger information. With the addition of GE1/1, the bending angle between the two stations can be used and the trigger rate is greatly reduced.
Performance
## Gas Electron Multiplier detector at CMS experiment

### Triple-GEM

<table>
<thead>
<tr>
<th>GE1/1 Gap Sizes</th>
<th>Typical Potentials</th>
<th>Typical Voltages</th>
<th>Typical El. Fields [kV/cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 mm</td>
<td>3200 V</td>
<td>770 V</td>
<td>2.6</td>
</tr>
<tr>
<td>1 mm</td>
<td>2430 V</td>
<td>380 V</td>
<td>64.0</td>
</tr>
<tr>
<td></td>
<td>2050 V</td>
<td>300 V</td>
<td>3.0</td>
</tr>
<tr>
<td>2 mm</td>
<td>1750 V</td>
<td>370 V</td>
<td>62.0</td>
</tr>
<tr>
<td></td>
<td>1380 V</td>
<td>600 V</td>
<td>3.0</td>
</tr>
<tr>
<td>1 mm</td>
<td>780 V</td>
<td>350 V</td>
<td>60.0</td>
</tr>
<tr>
<td></td>
<td>430 V</td>
<td>430 V</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>0 V</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[Diagram showing the components of the Triple-GEM detector.]
GE1/1 development and upgrade schedule
GEM Endcap: GE1/1
GEM Electronic Board (GEB)

Left: External face of the readout board of the GE1/1 detectors. Right: Internal face of the readout board with the readout strips.
Light DQM

Thanks to Robert King for the diagram.