Operational experience with the GEM detector assembly lines for the CMS forward muon upgrade

Stefano Colafranceschi[a] and Ilaria Vai[b,c]
On behalf of the CMS Muon Group

[a]*Florida Institute of Technology, Physics and Space Sciences Department, Melbourne, FL, USA*
[b]*Department of Physics, University of Pavia, Italy*
[c]*Istituto Nazionale di Fisica Nucleare (INFN), Section of Pavia, Italy*

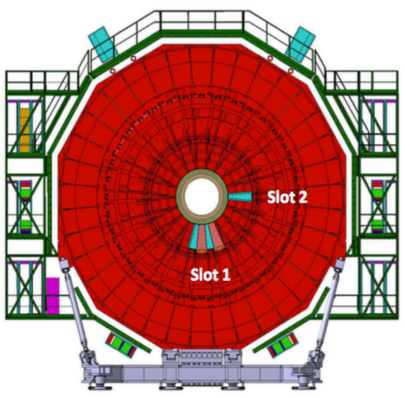
The CMS Collaboration has been developing large-area Triple-GEM detectors to be installed in the muon endcap regions of the CMS experiment in 2019 to maintain forward muon trigger and tracking performance at the HL-LHC. Ten pre-production detectors were built at CERN to commission the first assembly line and the quality controls. These were installed in the CMS detector in early 2017 and are currently participating in the 2017 LHC run. The collaboration has prepared several additional assembly and quality control lines for distributed mass production of 160 GEM detectors at various sites worldwide. During 2017, these additional production sites have been optimizing construction techniques and quality control procedures and validating them against common specifications by constructing additional pre-production detectors.

2016				2017				2018				2019
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
External Assembly Site preparation	External Assembly Site preparation	External Assembly Site preparation	External Assembly Site preparation	External Assembly Site preparation	Assembly sites validation	Start of the production	Production	Production				Installation at CMS
Detector pre-production at CERN	Detector pre-production at CERN	Detector pre-production at CERN ready	Detector pre-production installation at CMS	Detector pre-production Commissioning at CMS	Detector pre-production Commissioning at CMS	Detector pre-production Commissioning at CMS	Detector pre-production integrated in CMS	Data acquisition with detector pre-production in CMS				

Contacts: scolafranceschi@fit.edu; ilaria.vai@cern.ch

2015-2016 Ten GE1/1 Triple-GEM Pre-production detectors installed in CMS

GEM mechanical/service integration into CMS system

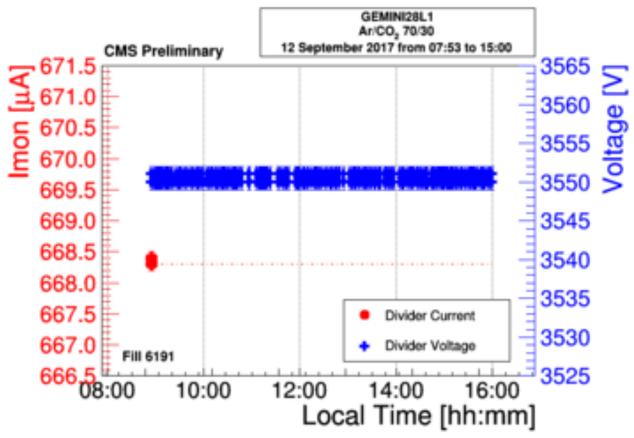


Overview of the position of the Triple-GEM chambers installed in the CMS endcap

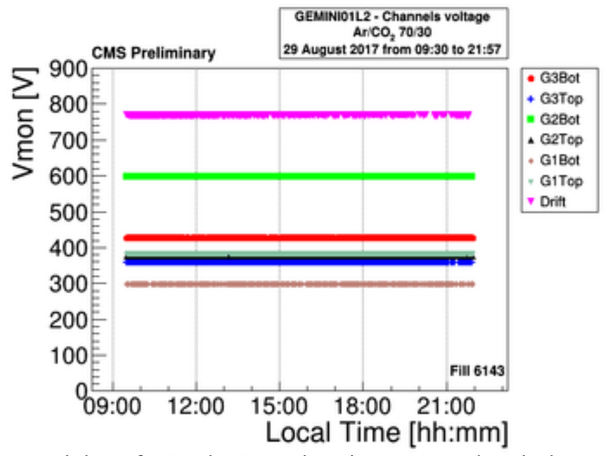
- Two GEM detectors form 1 GEMINI superchamber
- 4 GEMINI powered through a ceramic HV divider
- 1 GEMINI powered with multichannel power supply (7 HV channels per chamber)
- Readout system based on VFAT2 chip and optohybrid (OHv2b) → 3 LV channels for each chamber
- 3 Ar/CO_2 70:30 gas lines

Operational conditions of the GEM system

An overall stability on the order of 1 % or less has been observed with and without collisions.

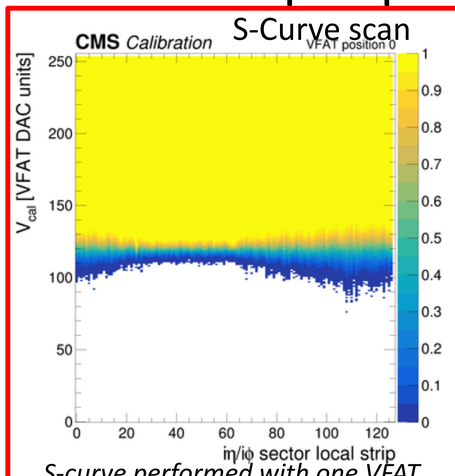


Current and Voltage stability of a Triple-GEM chamber powered through a ceramic divider over a 7 hours period during collisions.

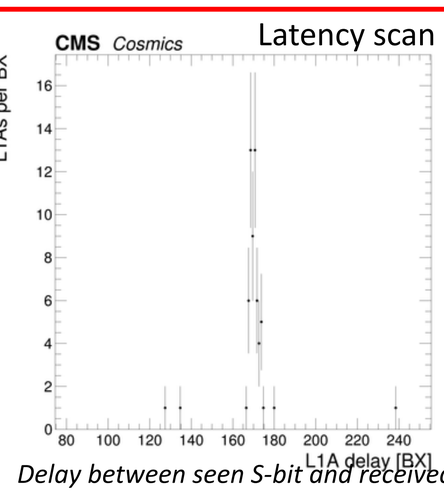


Voltage stability of a Triple-GEM chamber powered with the multichannel power supply over a 12 hours period during collisions

2017-2018 pre-production detectors being included in the central CMS operation



S-curve performed with one VFAT installed on one slice test chamber



Delay between seen S-bit and received L1A for cosmic ray muon data

Local system calibration in three main steps

- **Threshold scan**: Scan the noise of the channels as function of the applied threshold.
- **S-curves**: Scan the response of the channels to an injected pulse calibrated to a given charge at a given threshold.
- **Latency scan**: Scan the ratio of events with detected hits over the total number of events for different latency values.

CMS integration readiness

- **DAQ**: Function Manager and MiniDAQ are operational. Preparing the setup for high rate test.
- **Detector Control System**: Local version completed, integration on-going.

2017-2019 Assembly sites (*INFN-Bari, CERN, FIT, INFN-Frascati, Ghent, BARC, DELHI*) preparation

The CMS Muon collaboration has been working towards a full engineering optimization of all Quality Controls (QCs) in order to make use of independent hardware and trained personnel to ensure a fast and reliable detector production.

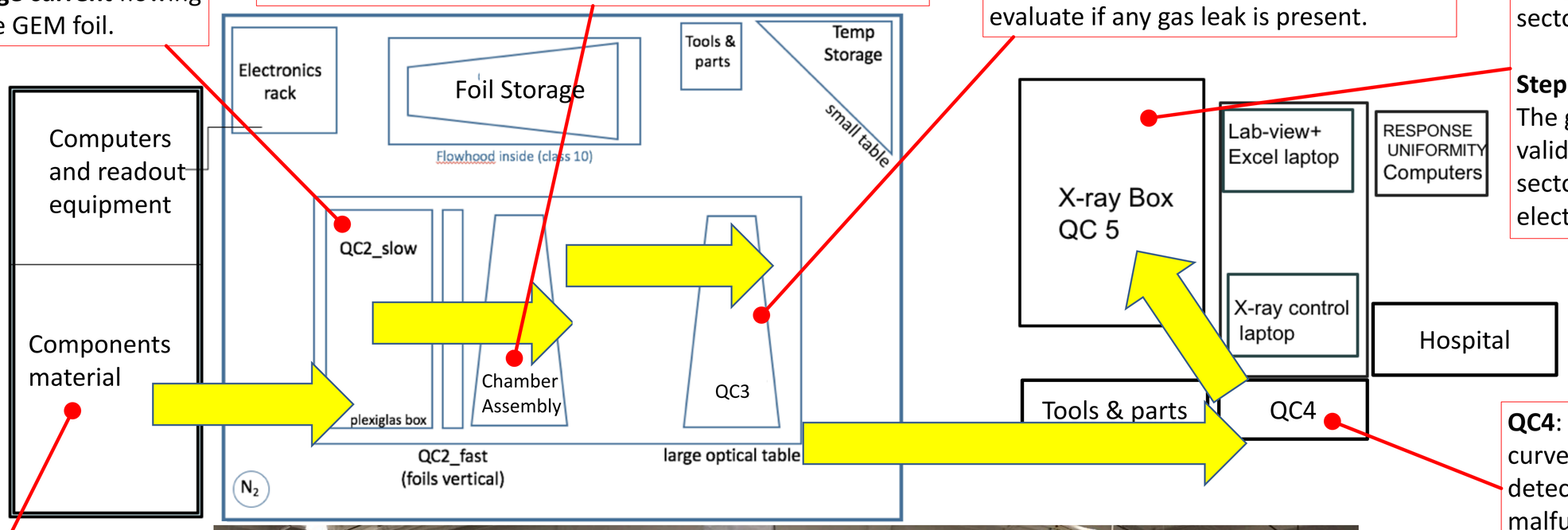
QC2: Determine the quality of a GEM foil by measuring the **leakage current** flowing across the GEM foil.

GEM foils and detector component assembly. Chamber construction is taking place simultaneously at all assembly sites with identical procedures, tools, and specifications.

QC3: The pressure drop of every detector (pressurized up to 25mbar) is monitored for 2h and recorded to evaluate if any gas leak is present.

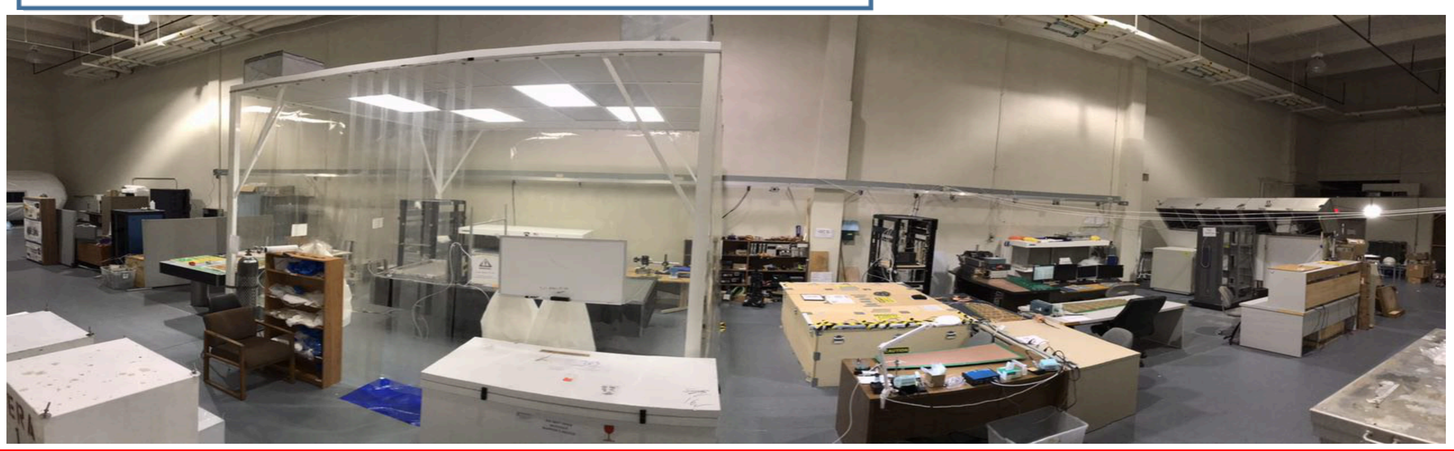
Step1) In order to establish the absolute gas gain, we measure the gain vs. HV in one readout sector using an X-ray source.

Step2)
The gas gain uniformity is validated by reading out all sectors (all strips) using SRS electronics.



QC4: Determine the *V* vs. *I* curve and rate of a GE1/1 detector to identify possible malfunctions, defects in the HV circuit, and spurious signals.

Detector components are centrally managed by CERN. Shipment box are sent by CERN to assembly sites.



Representative Assembly and QC site at Florida Institute of Technology