

# Quality Control of Mass-Produced GEM Detectors for the CMS ME0 Muon Upgrade

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December 5, 2024





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# Introduction

- Expansion of CMS physics with LHC upgrades, the HL-LHC will expand CMS capabilities significantly, enabling new physics but posing technical challenges.
- Increased luminosity challenges in Run 3 and Run 4, the higher luminosity levels will challenge detector operations, affecting muon triggering, identification, and measurement.
- New muon detectors installation in CMS endcaps, GEM-based detectors (GE1/1, GE2/1, ME0) are being installed to tackle these challenges, with ME0 planned for 2026.
- Rigorous quality control for ME0 production, ME0 assembly and quality control are distributed globally, ensuring high standards and project success.



# Overview of the ME0 system

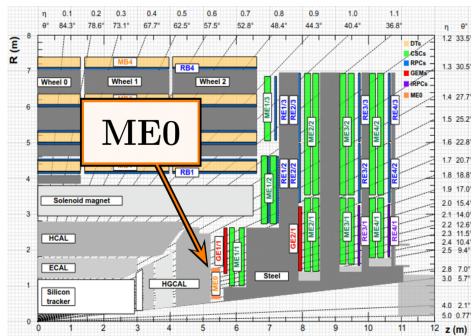


Figure: ME0 in the CMS experiment

- The Compact Muon Solenoid (CMS) experiment is one of two large general-purpose particle physics detectors built on the LHC.
- The CMS experiment is being upgraded as part of the High Luminosity Upgrade
- Three new Gas Electron Multiplier (GEM) detectors are being added to the Muon spectrometer, one of which is ME0
- It will sit in the very forward region ( $2.0 < |\eta| < 2.8$ )

# Overview of the ME0 system

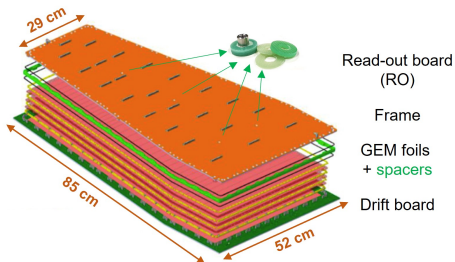


Figure: A layout of ME0 detector

- Triple-GEM technology: A gap configuration, 3/1/2/1 mm (from Drift gap)
- 18 stacks for each end-cap (36 In Total)

- 216 ME0 modules needed (245 including spares)
- ME0 is a stack of six GEM chambers

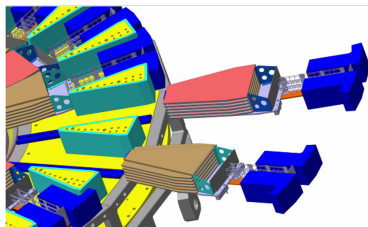
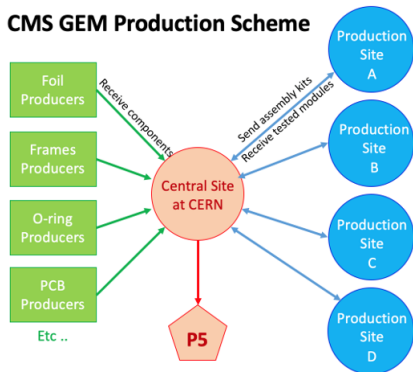


Figure: 3D drawing of the insertion of stacks of six ME0 modules

# Production Flow

## CMS GEM Production Scheme

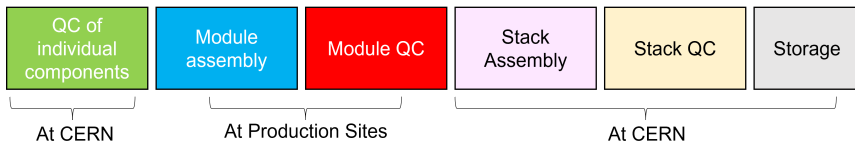


- Distribution of the production among several sites Vendors; Manufacturing of components Shipment to CERN
- CERN; Material inspection (QC1QC2) + Preparation of assembly kits + Shipment to/back from external production sites
- Production Sites; Assembly + QC2-QC5 + Database updates



# Production Flow

## Production Sequence

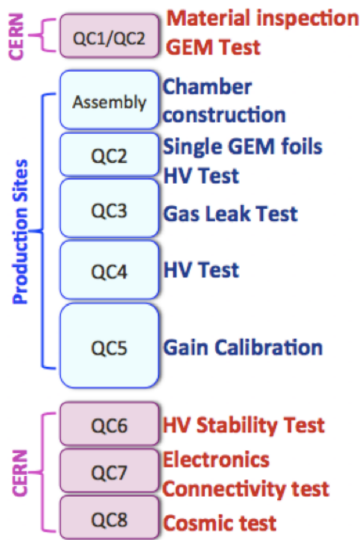


- 1 production site at CERN (with double capacity)
- 3 production + 1 QC sites in EU (Gent, Bari, Frascati, and Aachen)
- 1 production site in China (PKU)
- 2 production sites in India (Panjab Delhi)





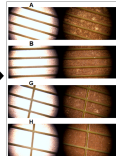
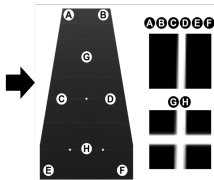
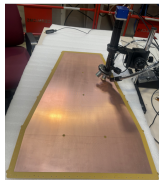
# Quality Controls



- Multi-stage QC plan (8 QC)
- Major components are pre-tested at the factory (or institute in charge) before shipment to CERN
- All components undergo in-depth acceptance test at CERN before shipment to production sites
- Final case-by-case verification at the production sites before assembly



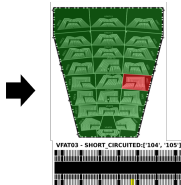
## Visual and microscopic inspection



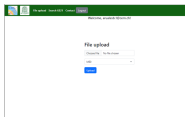
Reports are automatically generated  
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## Short circuit test

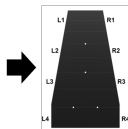
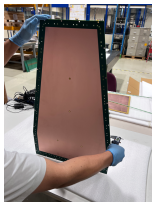


Reports are automatically generated  
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# ME0 Module - Component Test

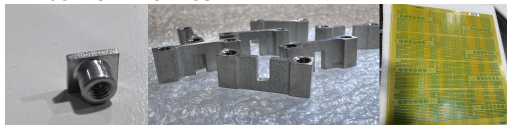
## Thickness tests



No.	Board ID	L1	L2	L3	L4	R1	R2	R3	R4	Average	STD
1	ME0-PCB-RO-B03-0001	3.06	3.06	3.05	3.05	3.05	3.05	3.06	3.09	3.06	0.01
2	ME0-PCB-RO-B03-0002	3.08	3.07	3.07	3.09	3.07	3.07	3.08	3.07	3.08	0.01
3	ME0-PCB-RO-B03-0003	3.05	3.03	3.05	3.06	3.07	3.06	3.09	3.09	3.06	0.02
4	ME0-PCB-RO-B03-0004	3.03	3.06	3.05	3.05	3.04	3.07	3.07	3.08	3.06	0.02
5	ME0-PCB-RO-B03-0005	3.05	3.06	3.07	3.06	3.08	3.09	3.08	3.07	3.07	0.01

Visual inspections and tests are performed on all components such as:

- GEM Foil
- Pullouts and T-nuts (IN)
- Internal and External Frames



# ME0 Module Assembly Status

ME0					
ID	Status	Site	Assembly date	Validation date (QC5)	Comments
ME0-MODULE-0001	QC6 Passed	904	11/04/24	11/07/2024	short circuit in GEM1 --> removed in the clean room (12 Aug), passed QC34 Oct 25
ME0-MODULE-0002	QC6 Passed	904	11/04/24	03/05/2024	
ME0-MODULE-0003	QC6 Passed	904	12/04/24	26/05/2024	
ME0-MODULE-0004	QC6 Passed	904	17/04/24	28/04/2024	
ME0-MODULE-0005	QC6 Passed	904	17/04/24	09/07/2024	Huge gas leak --> fixed after replacing ROB
ME0-MODULE-0006	QC6 Passed	904	19/04/24	14/07/2024	
ME0-MODULE-0007	QC6 Passed	904	24/04/24	05/07/2024	
ME0-MODULE-0008	QC6 Passed	904	26/04/24	30/09/2024	ROB swapped with 0038
ME0-MODULE-0009	QC6 Passed	904	30/04/24	04/06/2024	
ME0-MODULE-0010	QC6 Passed	904	02/05/24	06/06/2024	
ME0-MODULE-0011	QC6 Passed	904	14/05/24	22/06/2024	
ME0-MODULE-0012	QC6 Passed	904	06/06/24	02/07/2024	Short on G1 during assembly --> fixed & inverted pull-outs
ME0-MODULE-0013	QC6 Passed	904	18/06/24	17/07/2024	With modified T-nuts (internal frame issue)
ME0-MODULE-0014	QC6 Passed	904	25/06/24	20/07/2024	
ME0-MODULE-0015	QC5 Unl. Passed	904	26/06/24	18/09/2024	Failed QC6 (short circuit in GEM1)

## Batch 1 – 15 ME0 Modules (Completed)

- Received 15 kits of RO Drift PCB from Micropack
- 15 ME0 Modules have been assembled
  - 7 ME0 modules with CERN Foils (0001-0007)
  - 8 ME0 modules with KR Foils (0008-0015)



# ME0 Module Assembly Status

## Batch 2 – 40 ME0 Modules (Completed)

- Received 40 kits of RO Drift PCB from Micropack
- 40 ME0 Modules have been assembled
  - 18 ME0 modules in CERN
  - 4 ME0 modules in Bari
  - 8 ME0 modules in PKU
  - 3 ME0 modules in Frascati

## Batch 3 – 48 ME0 Modules (Assembly In Progress)

- Received 48 kits of RO Drift PCB from Micropack
- 11 ME0 Modules have been assembled
  - 6 ME0 modules in CERN
  - 5 ME0 modules in Ghent



# ME0 Module QC3, QC4, QC5 and QC6 Status

## Batch 1 – 15 ME0 Modules (In Progress)

Assembled	QC3	QC4	QC5 – Part 1	QC5 – Part 2	QC6
15	P: 15	P: 15	P: 15	P: 15	P: 14

## Batch 2 – 40 ME0 Modules (In Progress)

Assembled	QC3	QC4	QC5 – Part 1	QC5 – Part 2	QC6
40	P: 37	P: 34	P: 29	P: 21	P: 14

## Batch 3 – 48 ME0 Modules ( In Progress)

Assembled	QC3	QC4	QC5 – Part 1	QC5 – Part 2	QC6
11	P: 8	P: 6	P: 6	P: 6	P: 2



# QC6 - UdeA contribution

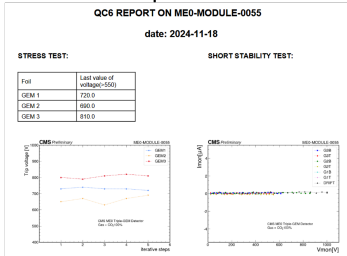
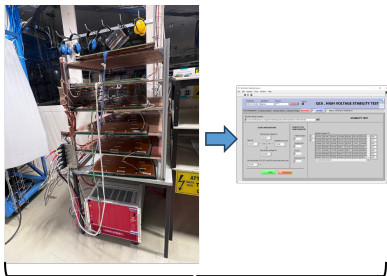


Figure: QC6 Setup

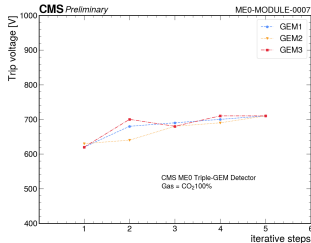


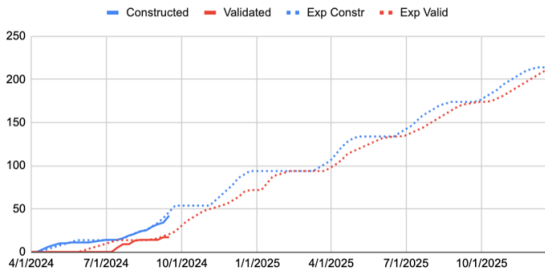
Figure: Stress Test

- 30 ME0 modules passed QC6 in 2024
- 4 ME0 modules failed QC6, 1 ME0 module was fixed and 3 ME0 modules will be fixed.



# ME0 Schedule

ME0 Production Forecast 2024-2025



- Expect 80 constructed (35%) – 65 validated (30%) by end 2024
- Total: 228 (36 stacks + 2 spare)
- Schedule:
  - 1st round July – Sep 2024
  - 2nd round Oct – Dec 2024
  - 3rd round Feb – Apr 2025
  - 4th 5th in 2025
  - 6th in 2026





# Summary

- The contributions of the University of Antioquia team in the construction of the ME0 update were presented.
- Batch 1 fully assembled, Batch 2 fully assembled, Batch 3 assembly in progress.
- Module QC3, QC4, QC5 and QC6 going smoothly.
- 2024 Production Plan:
  - Procure all materials / components in time
  - Keep module assembly rate





# Thank you!

