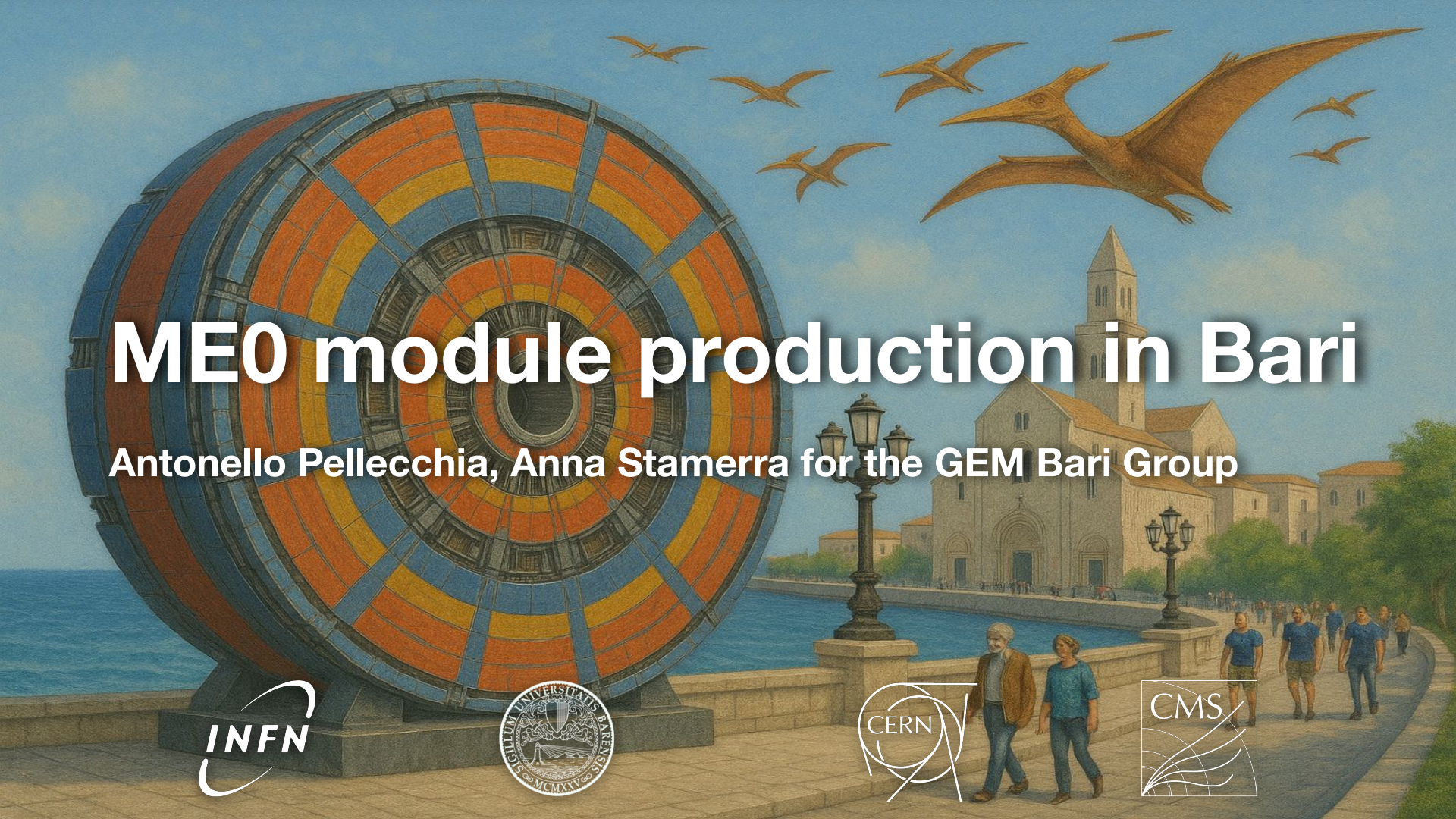

ME0 module production in Bari
Antonello Pellecchia, Anna Stamerra for the GEM Bari Group
INFN
CERN
CMS

Who we are

The CMS GEM group in Bari

- 7 staff
- 3 post-docs
- 5 PhD students

Piet Verwilligen
Upgrade coordinator

Luigi Longo
Hardware coordinator

Anna Stamerra
Bari site manager

Francesco Licciulli
Deputy electronics coordinator

Antonello Pellecchia
Deputy run coordinator

Leading roles in the GEM project: from **TDR** studies to coordinating **design**, **production** and **operations**

Expertise in GEM production

- GE1/1 : 18 chambers produced and qualified in Bari in 2018
- GE2/1 : 36 M1 modules produced and qualified in Bari in 2022

2016 GE1/1 production

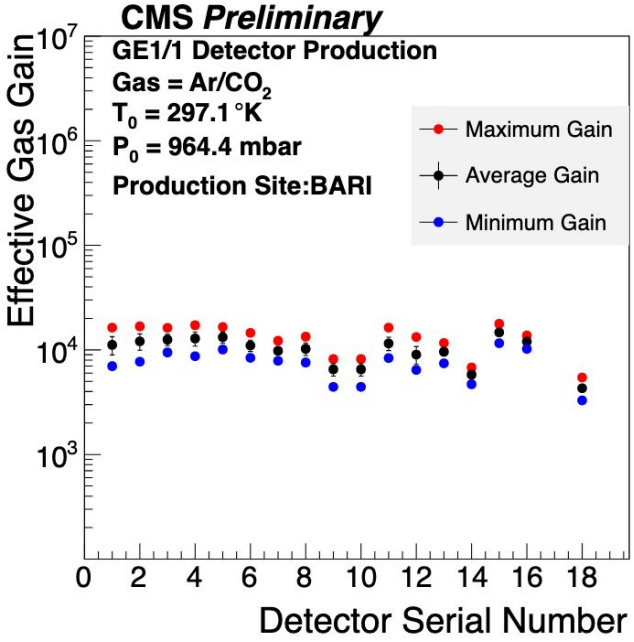
2018 GE2/1 prototype construction

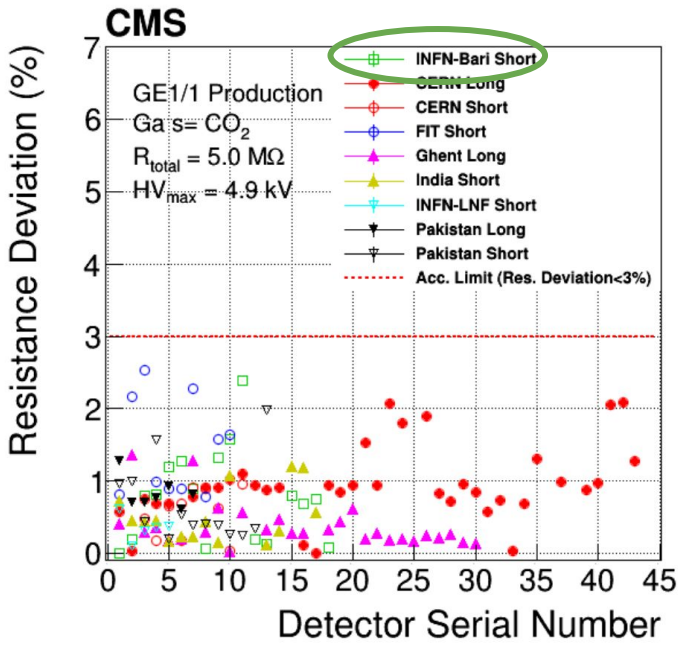
2022 GE2/1 production

GE1/1 production in Bari

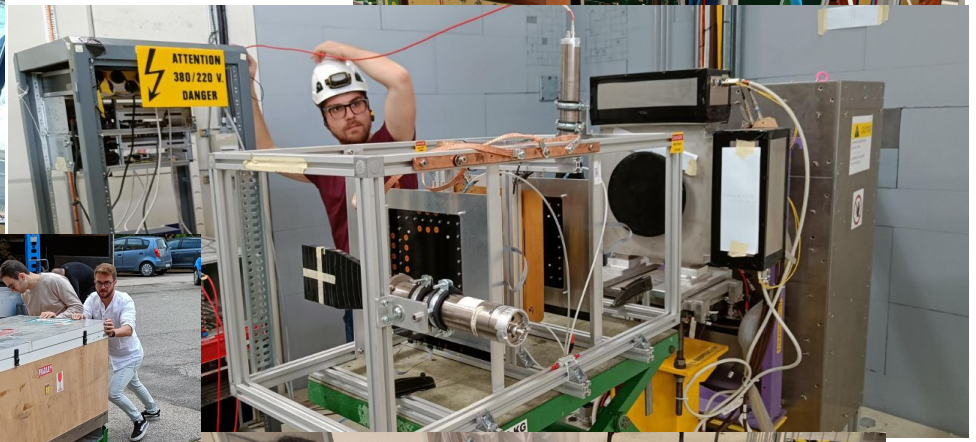
Positive feedback from GE1/1 chambers produced in Bari, both from QC results and operational experience in 904 and P5

«Le camere di Bari sono sempre molto cazzute»





… but also test beam campaigns



GE2/1 and ME0 performance

Since 2021, Bari has led the **design optimization and performance studies** of GE2/1 and ME0:

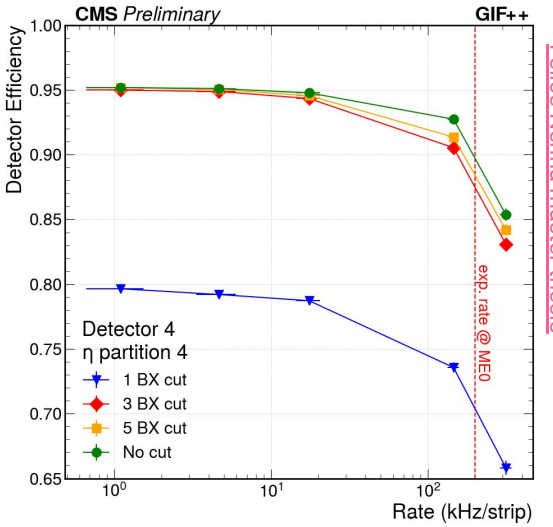
- Optimization of ME0 design for **high rates**

  Detector able to cope with background rates up to 150 kHz/cm^2

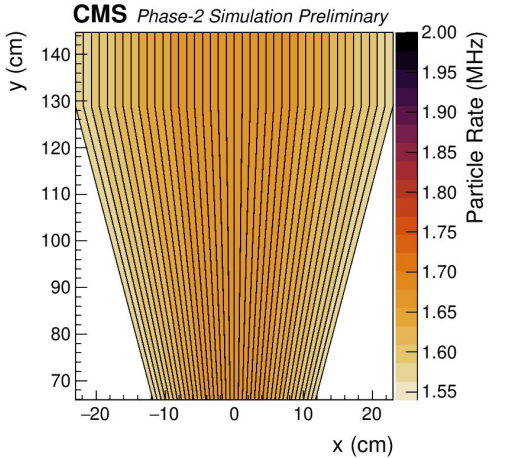
- Electronics **integration and performance** of GE2/1 and ME0 with test beams
- Performance validation with particle beams in high background rates

  *Detector + electronics operated **up to several MHz/cm^2***

	TDR requirement	Measured
Efficiency	97%	95%
Rate capability	50 kHz/cm^2	> 150 kHz/cm^2
Space resolution	< 500 μrad	200 μrad
Time resolution	8 - 10 ns	10 ns
Longevity	8 C/cm^2	> 8 C/cm^2



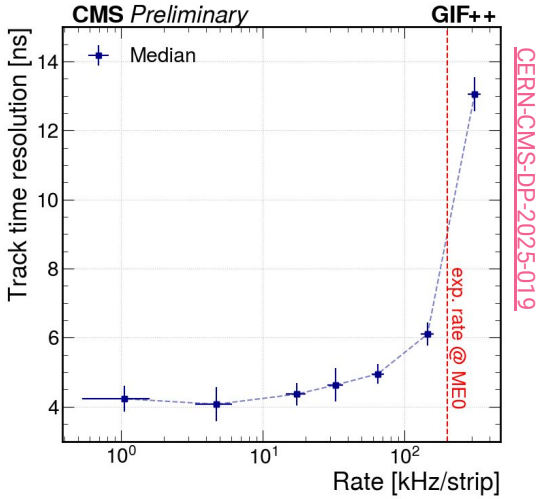
Felice Nenna master thesis

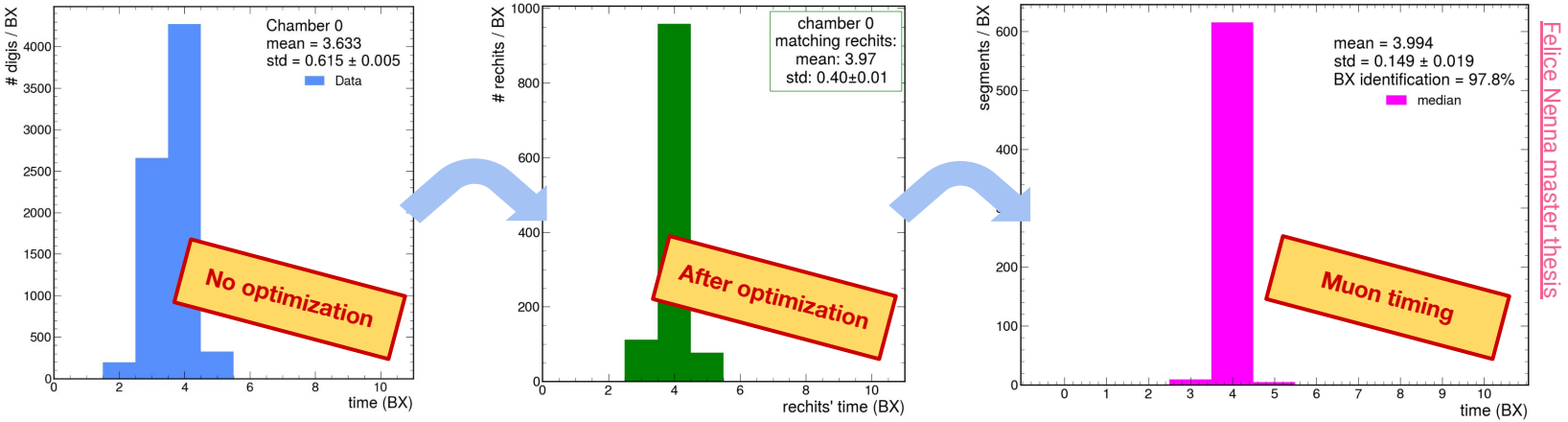


CMS-CR-2021-268

ME0 system integration

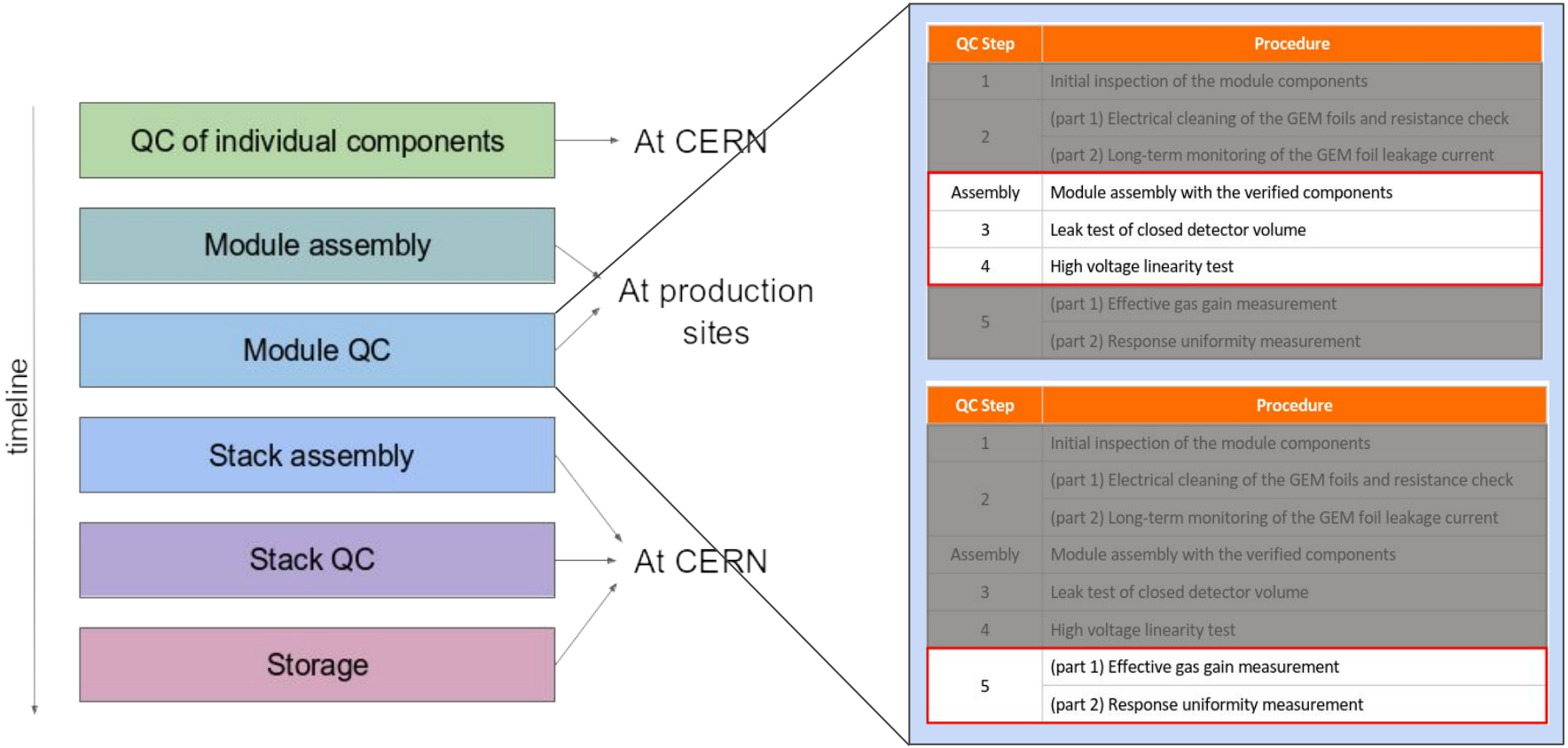
- From detector performance to full **stack integration**: demonstrated muon tracking from ME0 stacks in laboratory and with particle beams
- Involvement and **leadership from Bari group**: organized 5 test beam campaigns, participated with a team of **10 physicists**
- 1 PhD **thesis**, 3 master **theses**





Lessons learnt super useful also for GE1/1 performance improvements in Run 3!

ME0 production scheme



QC Step	Procedure
1	Initial inspection of the module components
2	(part 1) Electrical cleaning of the GEM foils and resistance check
	(part 2) Long-term monitoring of the GEM foil leakage current
Assembly	Module assembly with the verified components
3	Leak test of closed detector volume
4	High voltage linearity test
5	(part 1) Effective gas gain measurement
	(part 2) Response uniformity measurement

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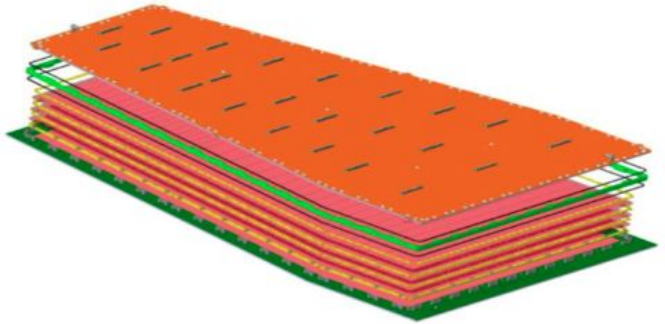
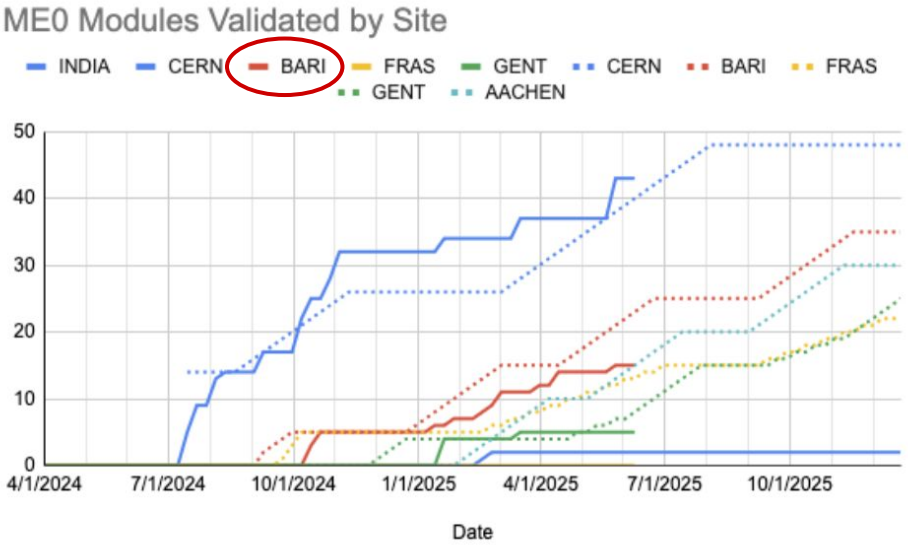
ME0 production schedule

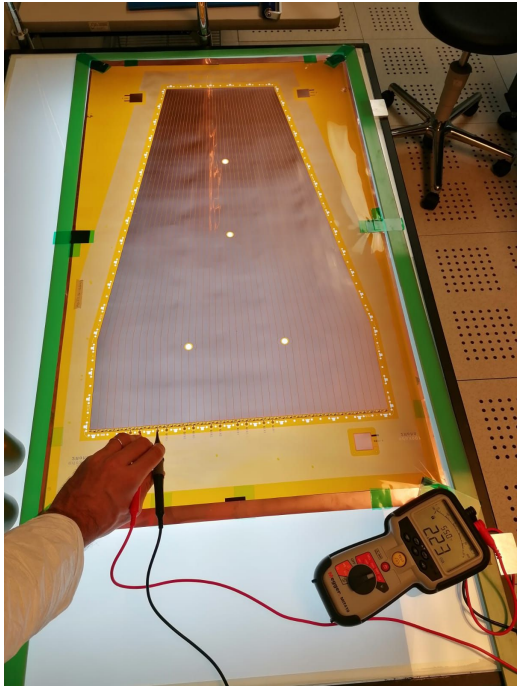


ME0 modules produced in Bari so far: **15/50**

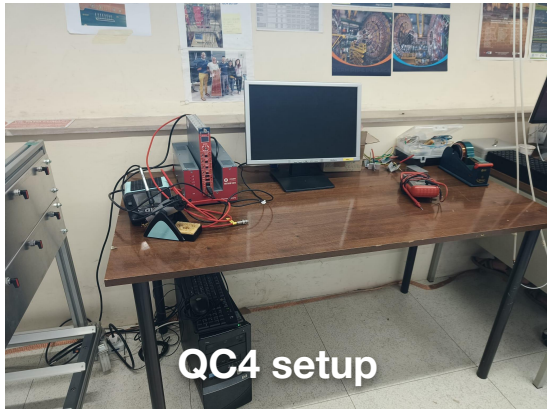
- 1st round of production: July – September 2024
  - 5 high quality chambers produced and tested up to QC5
- 2nd round: January - May 2025
  - 10 chambers produced and tested up to QC5
- 3rd round: from July 2025
  - 10 chambers to be produced
- 4th round: December 2025

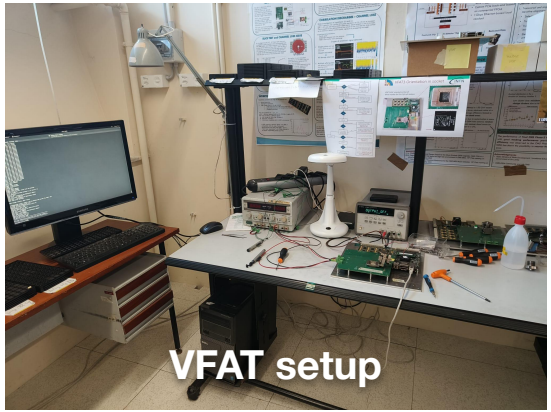


ME0 production: assembly in clean room



The GEM lab

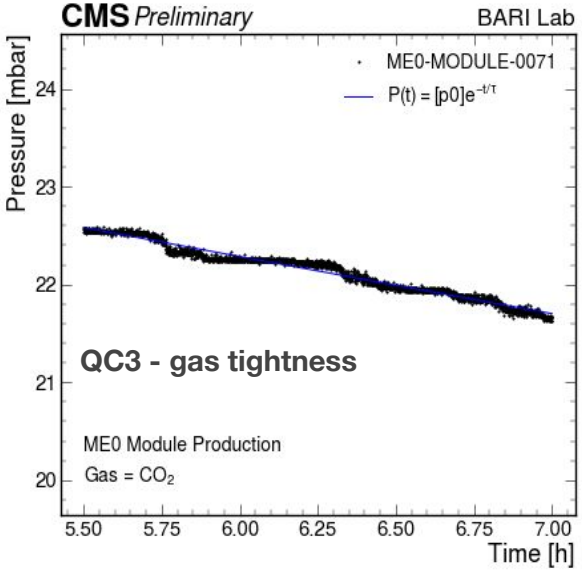


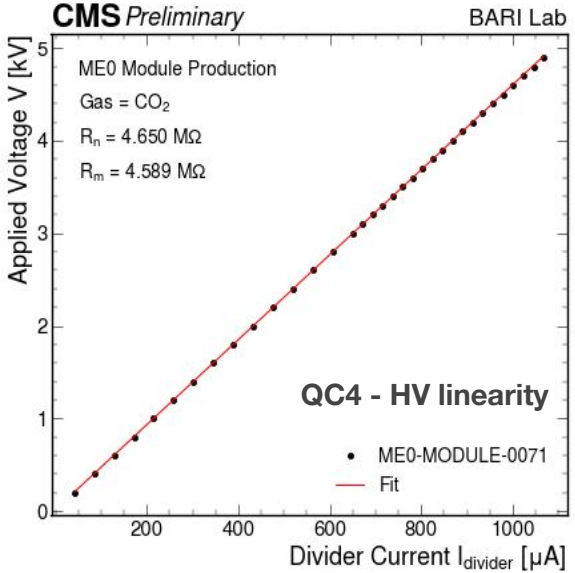


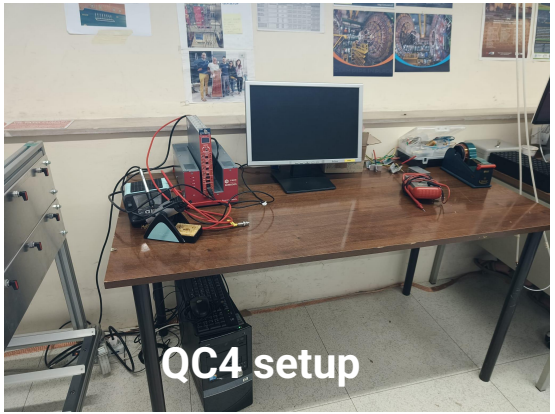
- 1 week per module with organized shift:
  - Assembly in clean room
  - Quality controls
- 3 people for assembly

  3 physicists or 2 physicists + 1 technician
- 2 people for QCs

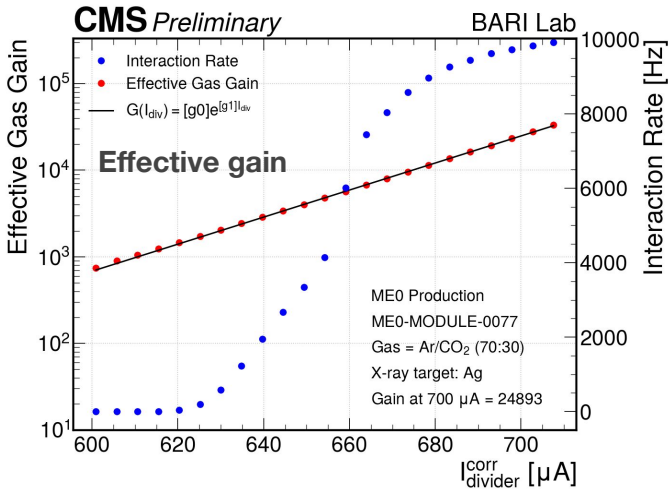
ME0 production: Quality controls

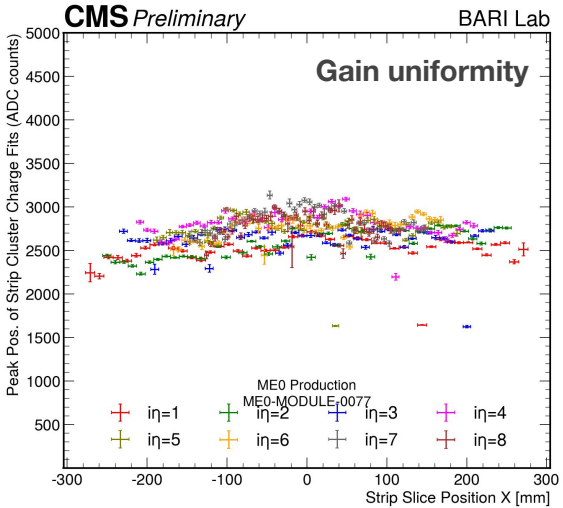


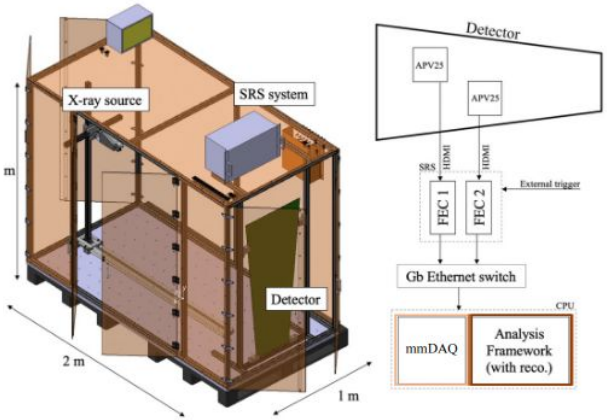




ME0 production: Quality controls

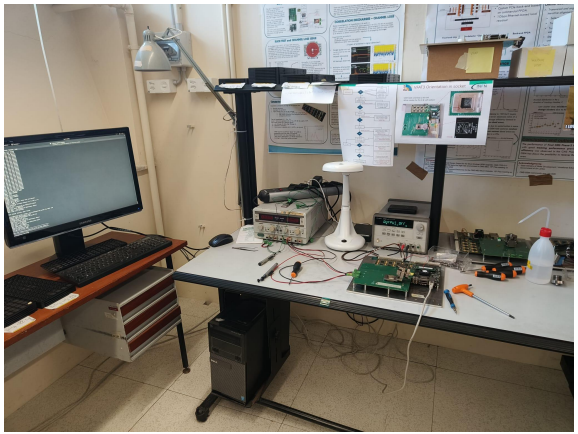


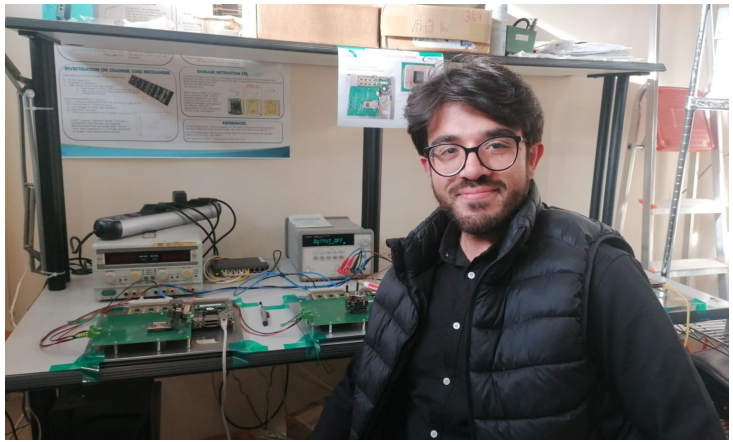




VFAT testing

- Electronics for GEM detectors designed by INFN Bari (F. Loddo, G. de Robertis, F. Licciulli)
- Setup for testing in Bari (MOSAIC + Test Board)
- 10 k chips packaged
    - 8000 for ME0, 2000 for GE21

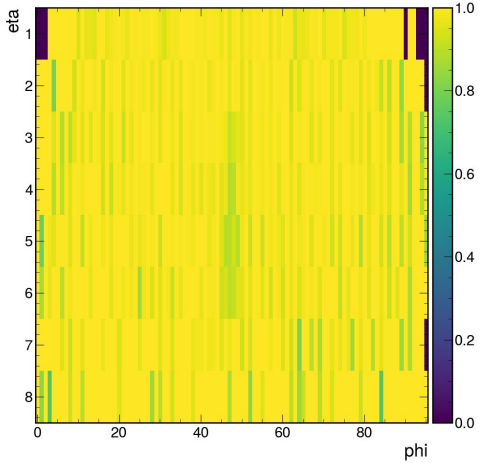


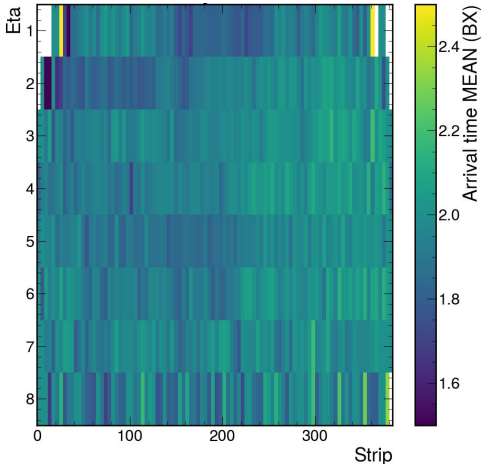


ME0 stack at CERN: assembly and testing

1. QC7: **on-detector electronics** testing (GBT phases, noise, …)
2. Stack **assembly**: 100% of 4 stacks so far assembled by Bari PhD student (Donato Troiano)
3. QC8: stack **testing with cosmic** rays with full services (DCS, cooling, …), electronics (front-end & back-end), DAQ

   Analysis and procedures **established by Bari** team (P. Verwilligen, F. Nenna)

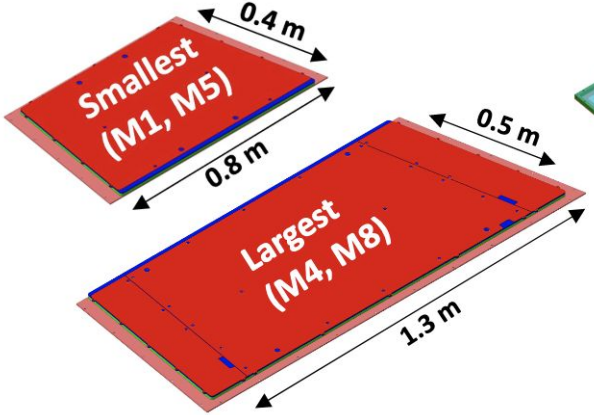




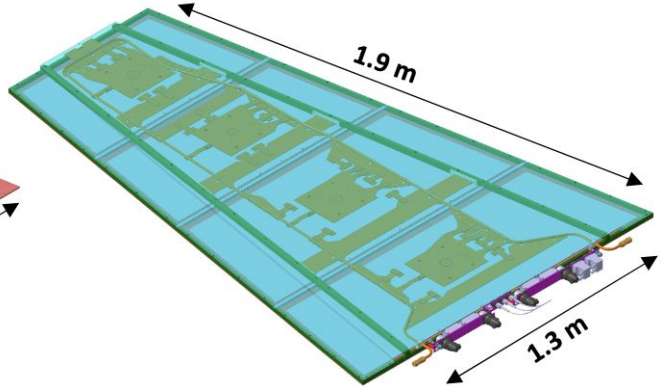

DIMMI QUANDO

Backup

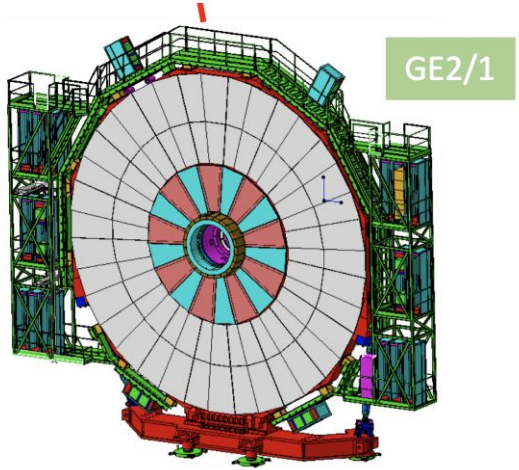
GE2/1 detector



8 slightly different triple-GEM modules
(M1 to M8)

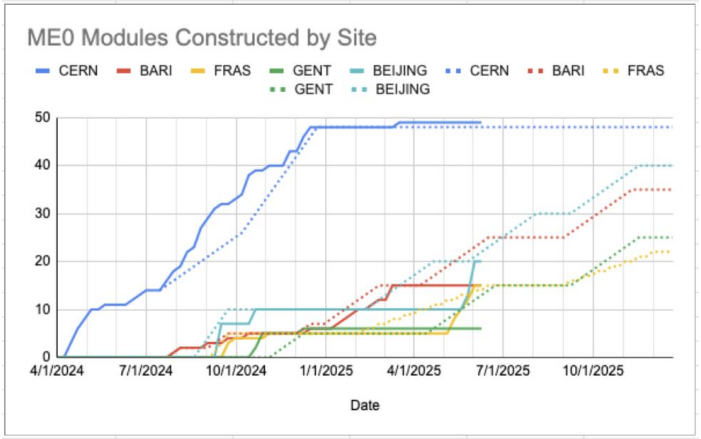


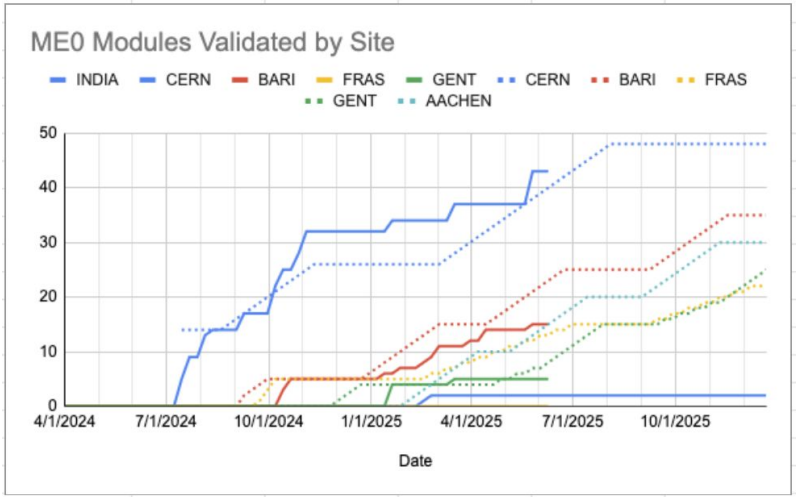
BACK-type (M1 to M4) and FRONT-type
(M5 to M8) chambers



Pseudo-rapidity coverage $1.62 < |\eta| < 2.43$

ME0 production





ME0 production: Quality controls

In Bari, well-defined routine for QCs, with automatized setup for measurements

ME0 production: Quality controls

At production sites:

QC2: GEM foil integrity (during assembly)

QC3 - QC4 : detector integrity

- gas tightness, HV stability

QC5: detector performance

- Effective gain and uniformity response in Ar/C02 70/30

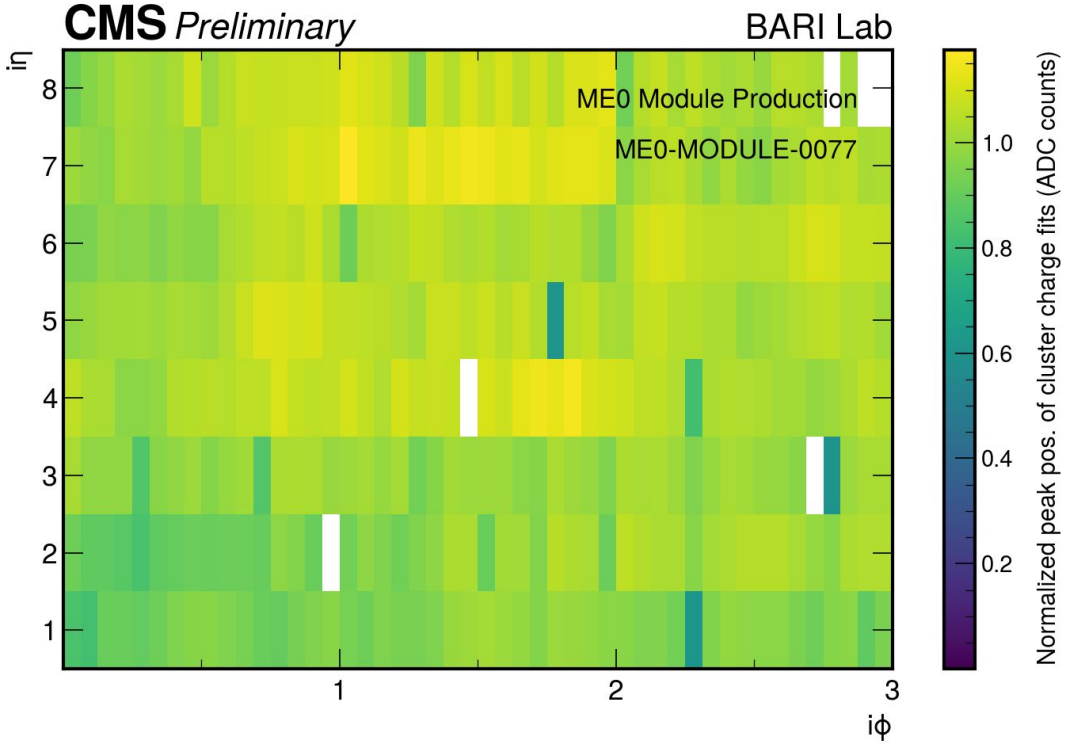
At CERN:

QC6 / QC7 / QC8

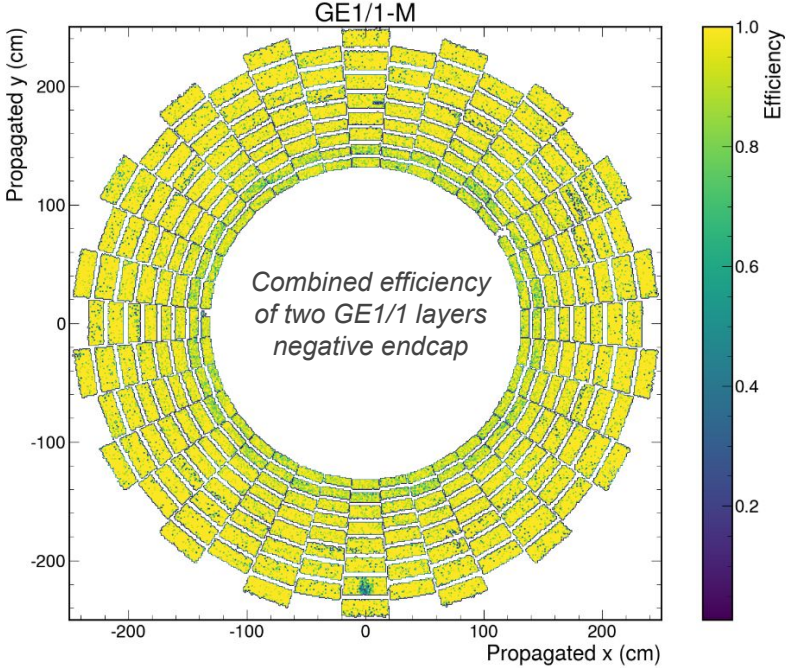
- HV stability, electronics integration, cosmic stand

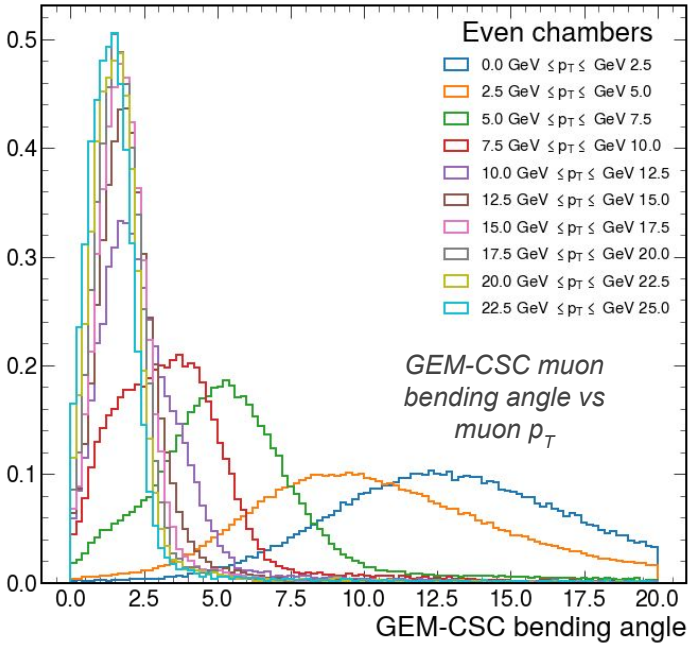
In Bari, well-defined routine for QCs, with automatized setup for measurements

- ~ 1 week per module with organized shift for
  - assembly in clean room
  - quality controls
- 3 people to assembly
- 2 people for qcs


CMS Preliminary
BARI Lab
ME0 Module Production
ME0-MODULE-0077
iη
iϕ
Normalized peak pos. of cluster charge fits (ADC counts)
1.0
0.8
0.6
0.4
0.2

GE1/1 trigger performance in Run 3

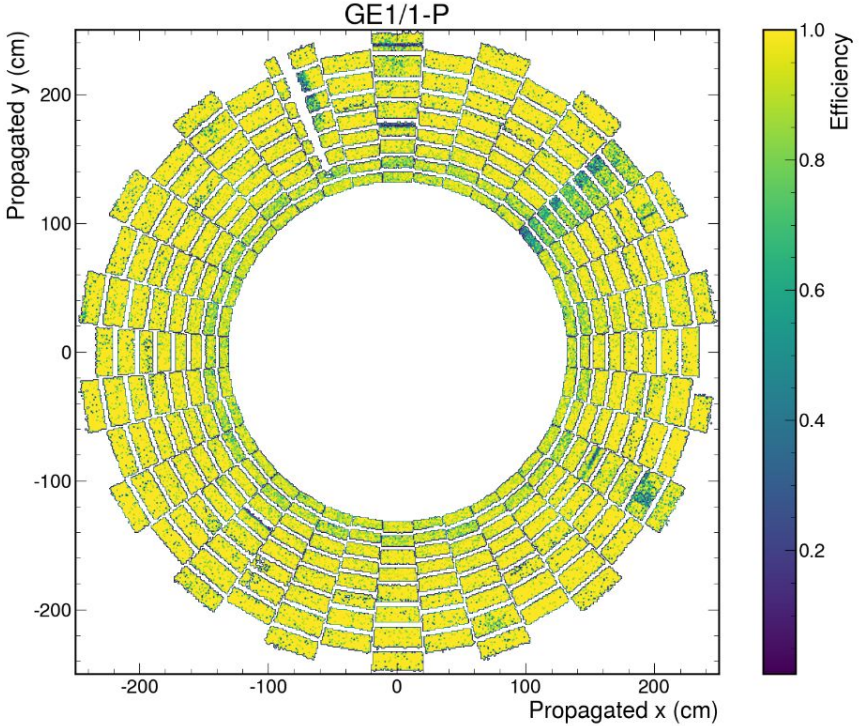


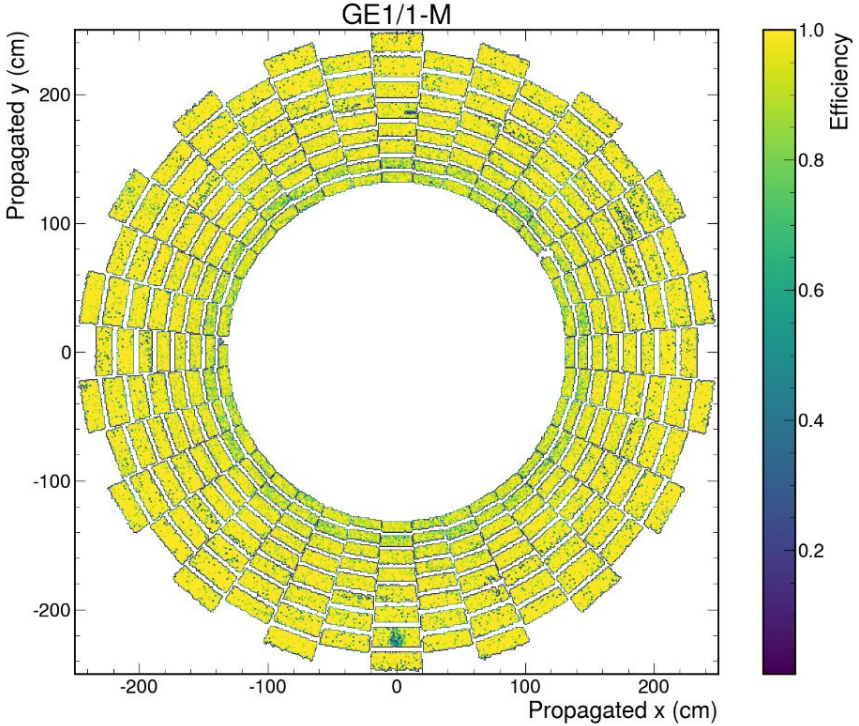


We are responsible of measuring the GE1/1 **trigger primitive performance** and optimizing the detector during operation to maintain a high data quality:

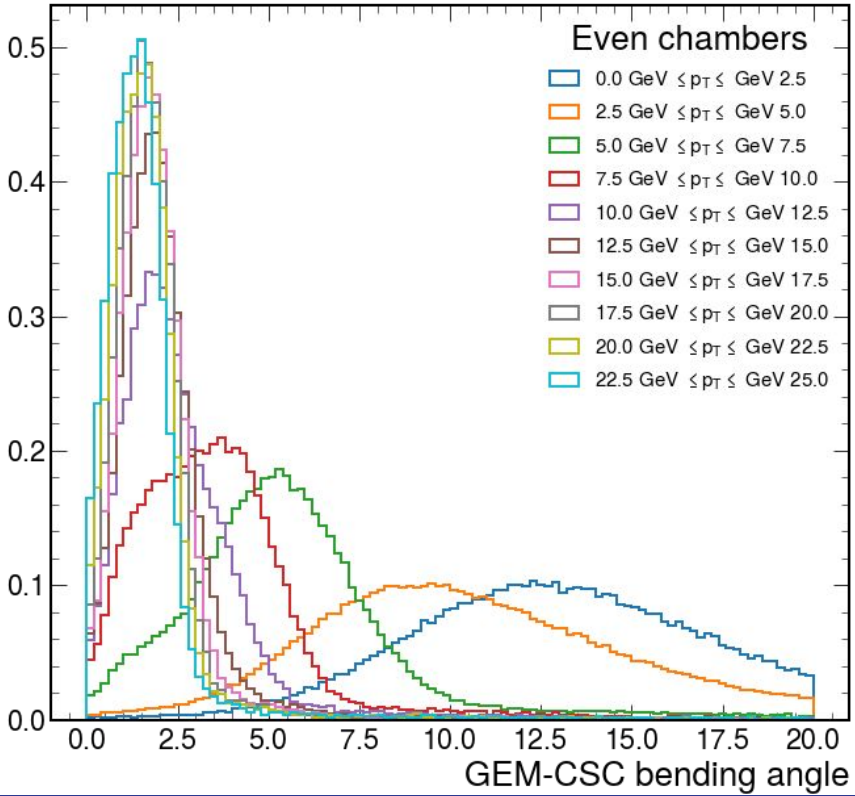
- **Excellent efficiency** overall, thanks to redundancy (OR) of two GEM layers
- Ongoing **optimization** with good progress (~17-12 ns) of **time resolution** for best matching efficiency with CSC ME1/1 station
- GEM-CSC **bending angle is a good discriminant** for low-p_T muons, **to be exploited in the next implementation of the EMTF algorithms**

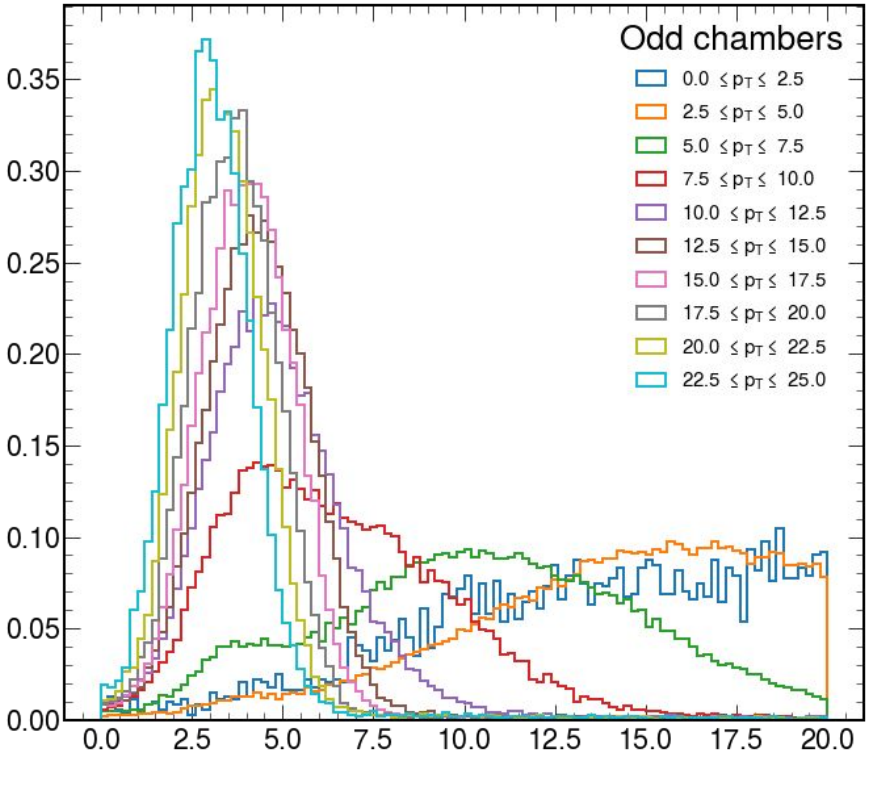
Backup


GE1/1-P
Propagated y (cm)
Propagated x (cm)
Efficiency
1.0
0.8
0.6
0.4
0.2
200
100
0
-100
-200

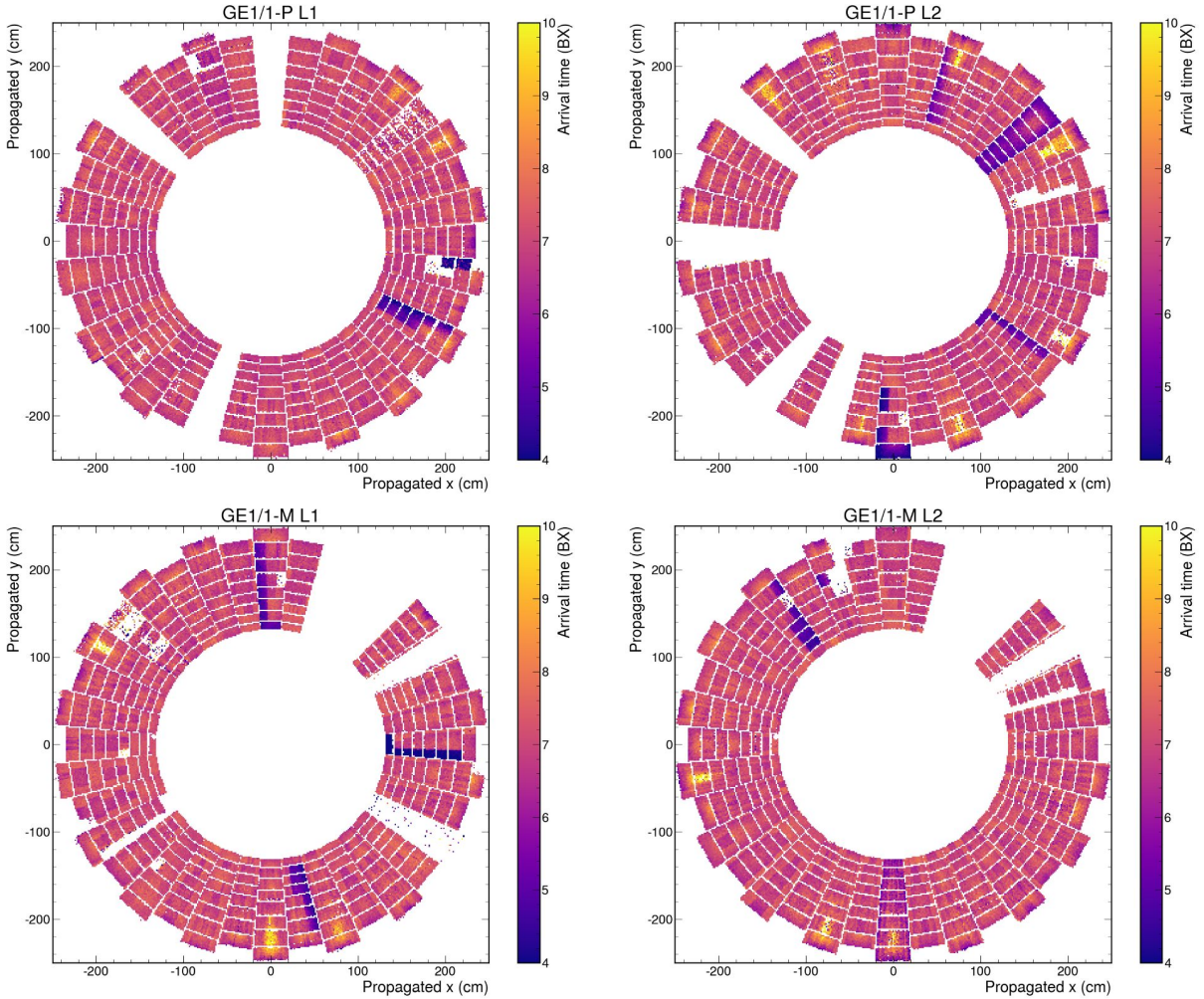

GE1/1-M
Propagated y (cm)
Propagated x (cm)
Efficiency
1.0
0.8
0.6
0.4
0.2
200
100
0
-100
-200

Backup

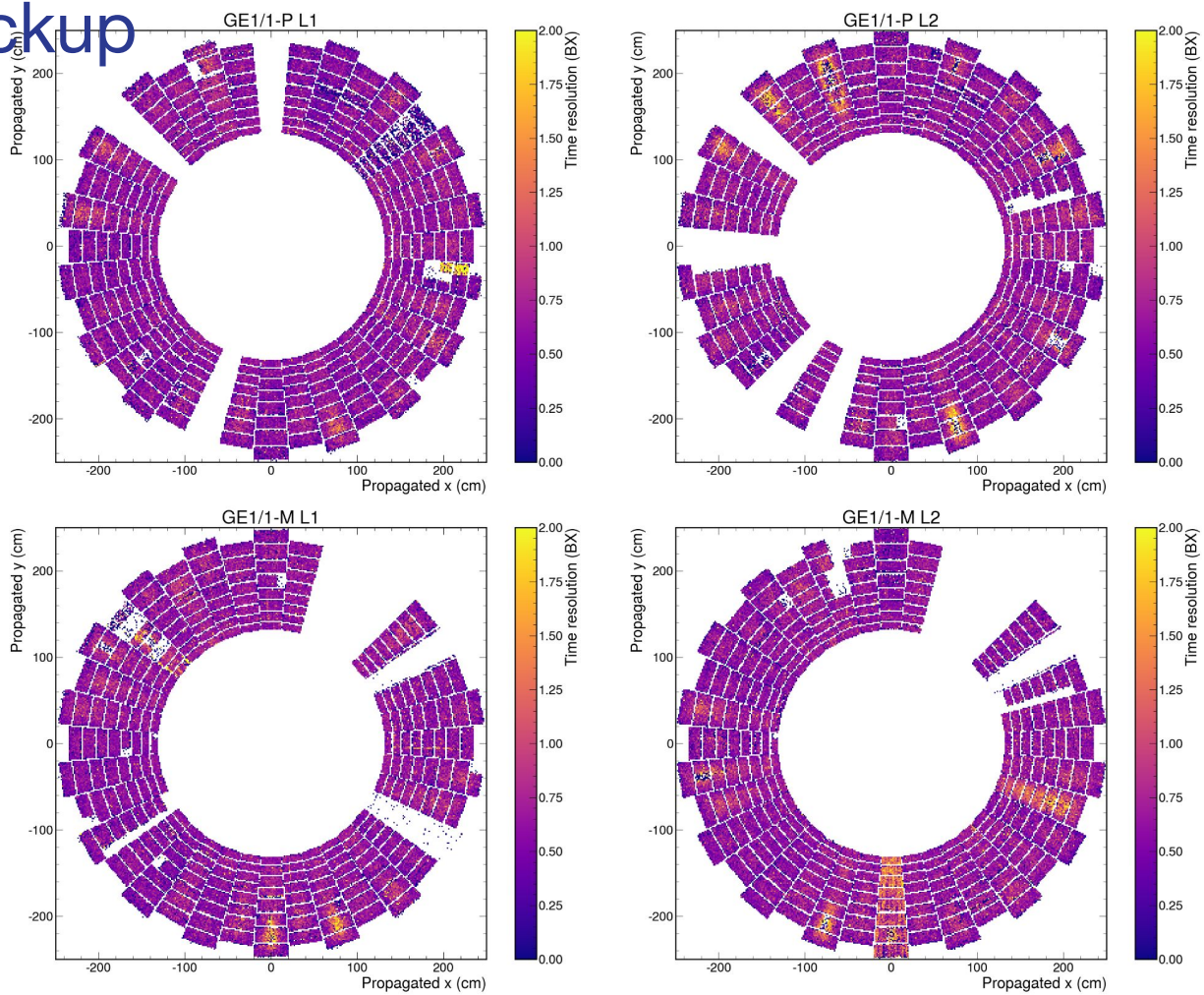

Even chambers
0.0 GeV ≤ p_T ≤ GeV 2.5
2.5 GeV ≤ p_T ≤ GeV 5.0
5.0 GeV ≤ p_T ≤ GeV 7.5
7.5 GeV ≤ p_T ≤ GeV 10.0
10.0 GeV ≤ p_T ≤ GeV 12.5
12.5 GeV ≤ p_T ≤ GeV 15.0
15.0 GeV ≤ p_T ≤ GeV 17.5
17.5 GeV ≤ p_T ≤ GeV 20.0
20.0 GeV ≤ p_T ≤ GeV 22.5
22.5 GeV ≤ p_T ≤ GeV 25.0
0.0
0.1
0.2
0.3
0.4
0.5
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
GEM-CSC bending angle


Odd chambers
0.0 ≤ p_T ≤ 2.5
2.5 ≤ p_T ≤ 5.0
5.0 ≤ p_T ≤ 7.5
7.5 ≤ p_T ≤ 10.0
10.0 ≤ p_T ≤ 12.5
12.5 ≤ p_T ≤ 15.0
15.0 ≤ p_T ≤ 17.5
17.5 ≤ p_T ≤ 20.0
20.0 ≤ p_T ≤ 22.5
22.5 ≤ p_T ≤ 25.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0

Ba


GE1/1-P L1
GE1/1-P L2
GE1/1-M L1
GE1/1-M L2
Propagated y (cm)
Propagated x (cm)
Arrival time (BX)
-200
-100
0
100
200
4
5
6
7
8
9
10

Backup


GE1/1-P L1
GE1/1-P L2
GE1/1-M L1
GE1/1-M L2
Propagated y (cm)
Propagated x (cm)
Time resolution (BX)
-200
-100
0
100
200
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00