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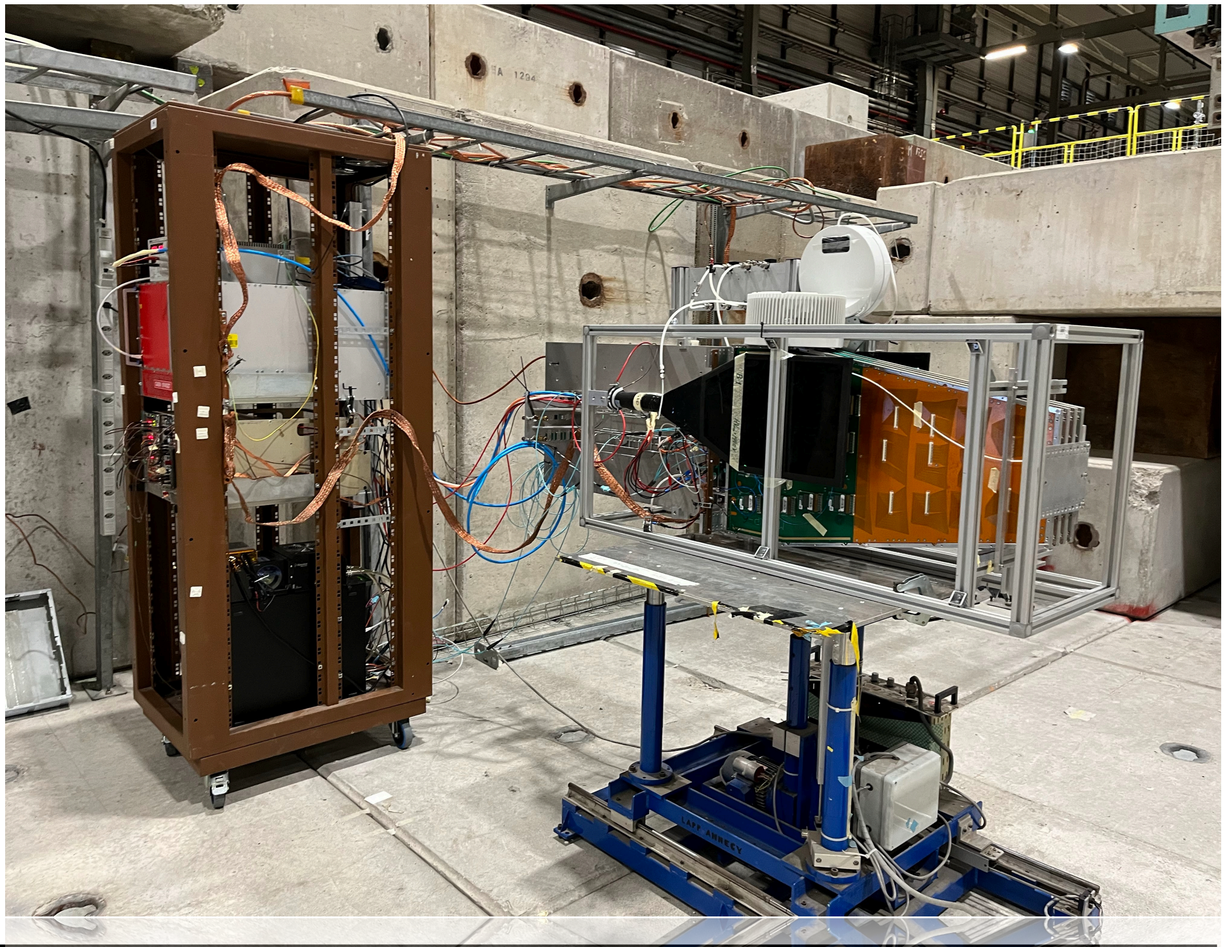
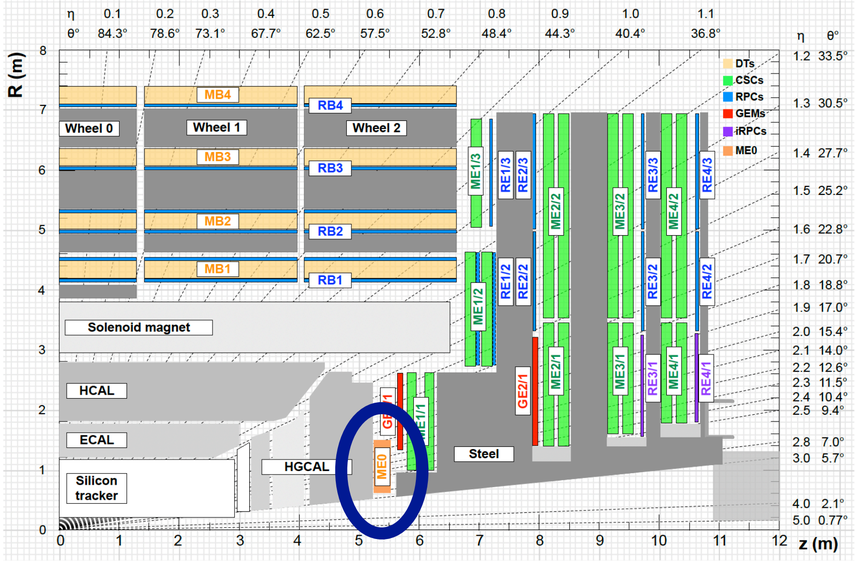
For the CMS GEM GROUP



Test beam status and plans for CMS GEM

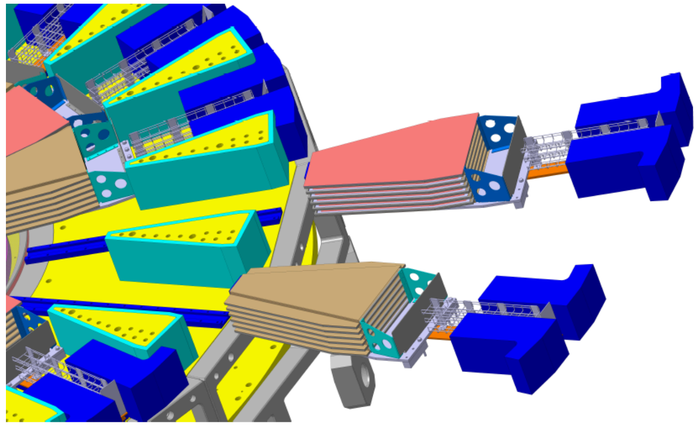
RD51 Collaboration Meeting at CERN, 4-8/12/2023 7/12/2023

A new challenge for CMS Phase-2 Upgrade: the ME0 station



Quadrant of the CMS detector with the Phase-2 Upgrade

ME0 performance validation ongoing: 3 test beams in the last 1.5 years (1 at SPS, 2 at GIF++)



3D drawing of two adjacent stacks of six ME0 modules into the endcap nose

- **HL-LHC**: p-p collisions at 5-7.5 times the nominal LHC luminosity -> 140-200 interactions per BX
- **ME0 station**:
  - it will be installed in the CMS endcap muon spectrometer
  - Extension of the pseudo-rapidity of the muon system up to $\eta = 2.8$
  - It will be able to handle background particle rates up to 150 kHz/cm^2
  - In the overall system there will be 108 modules inside 18 stacks for each endcap
  - 1 stack = 6 triple-GEM detectors
  - This structure will allow the muon segment reconstruction in standalone
- **Challenges**: the high radiation environment and the nearly-zero access for repairs because of its location behind HGCAL.

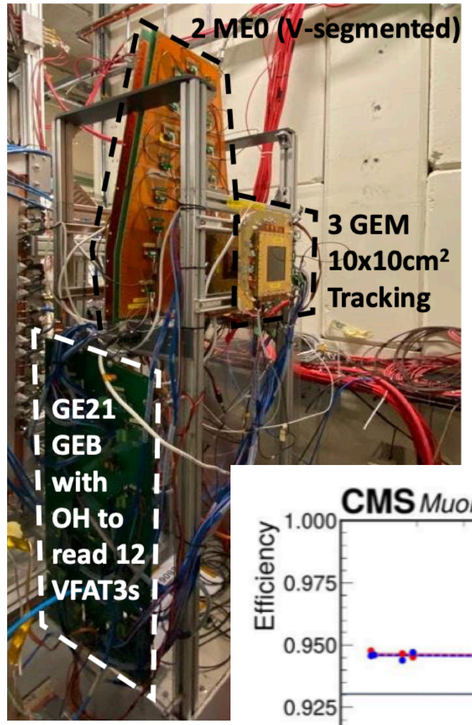
Tests beam with high background at GIF++

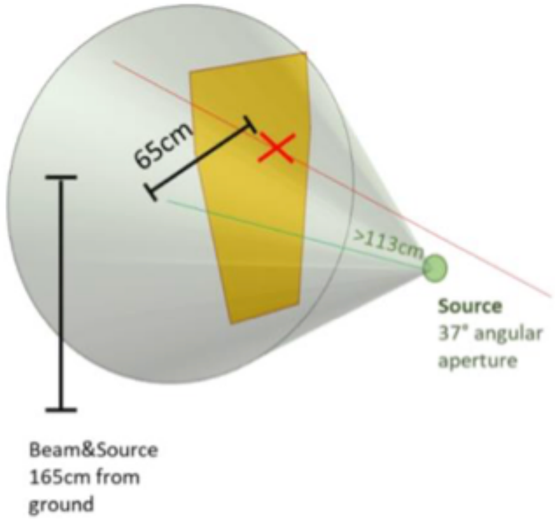
2022 - Test of two single layers

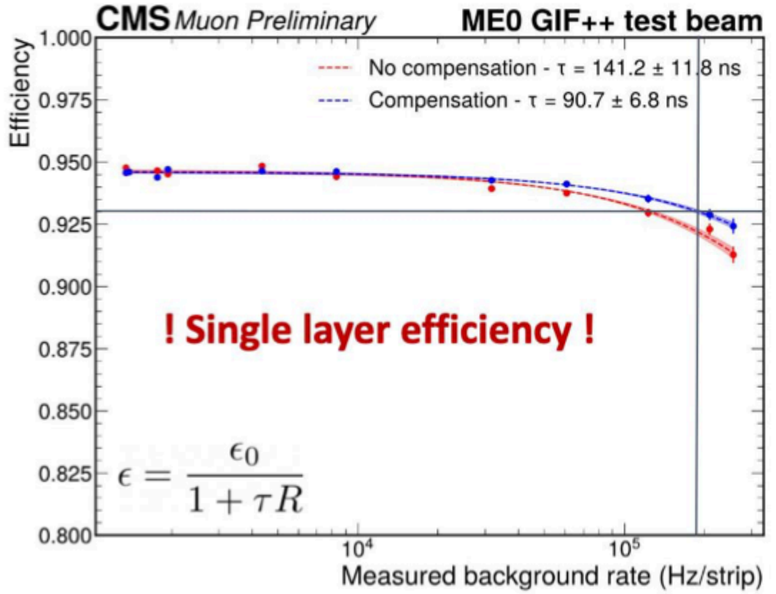
Goals:

- Demonstrate recovery of high gain under irradiation with HV compensation
- Measure efficiency under irradiation

- Source of ^{137}Cs with 14 TBq activity
- Setup as close as possible to source so that $\int Rate\ dA$ equals that at CMS, but entire module irradiation needed => minimum at ~ 113 cm
- Reached rate of 255kHz/strip vs expected 180kHz/strip at CMS



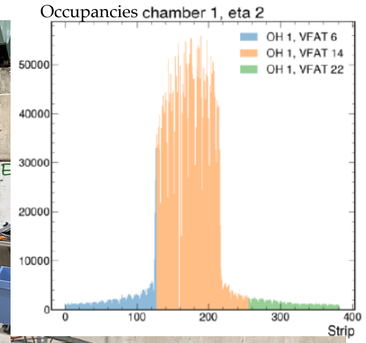


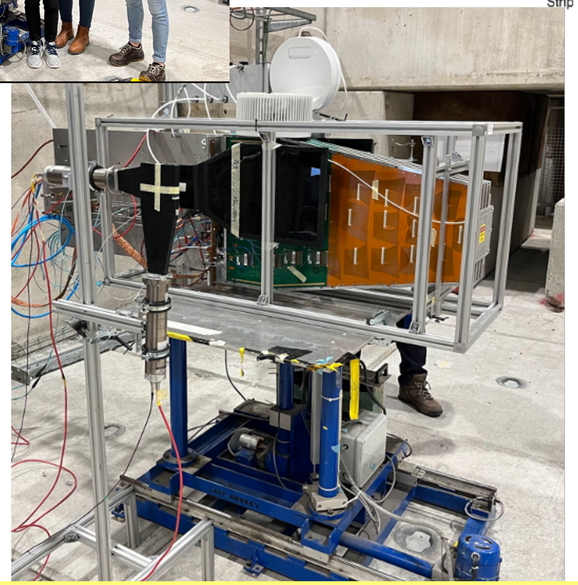


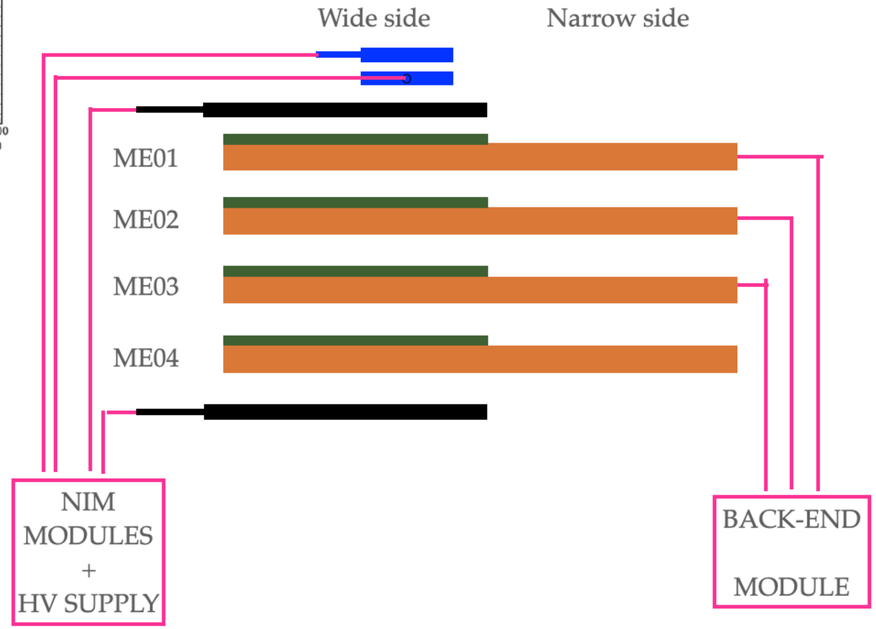
RESULT: Efficiency loss of 3% at 250kHz/strip

ME0 stack at test beam at H4

April-May 2023





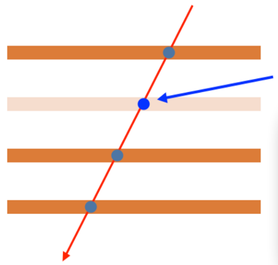


TB ME0 Stack Setup

- Moved on from single layer to proto-stack
- 4 out of 6 layers

GOAL: to demonstrate the performance of the four-layered ME0 stack operating with high-rate 80 GeV/c muon and pion beams, in particular the segment reconstruction from a MIP track.

ME0 stack at test beam
April-May 2023



HIT EXTRAPOLATION: the module under test is ignored and the reconstructed hits on the other ones are found and fitted through a **straight line.** The propagated hit is extrapolated on the chamber in question.

SPACE RESOLUTION $\sim 289\ \mu m$

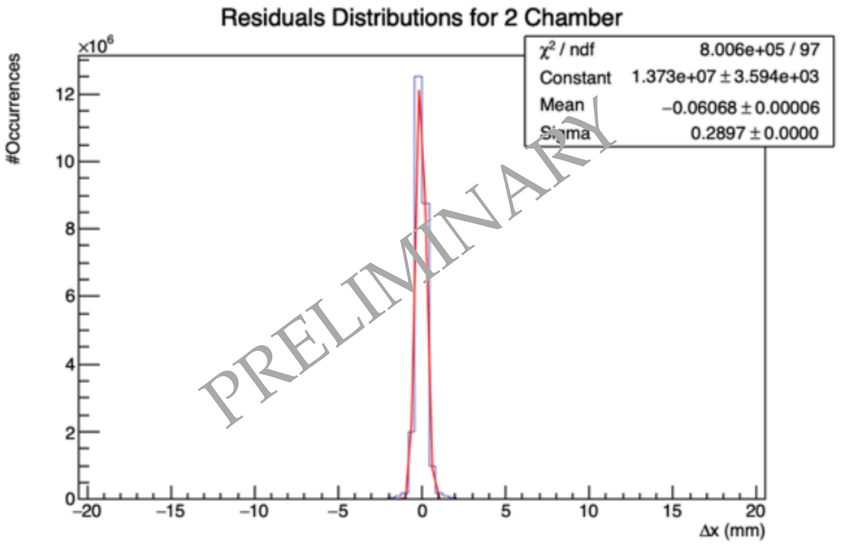
- Obtained from sigma of the Gaussian pdf fitting the **residuals distribution**
- **Residual:** distance between the extrapolated hit on a chamber and the closest reconstructed hit on the same chamber

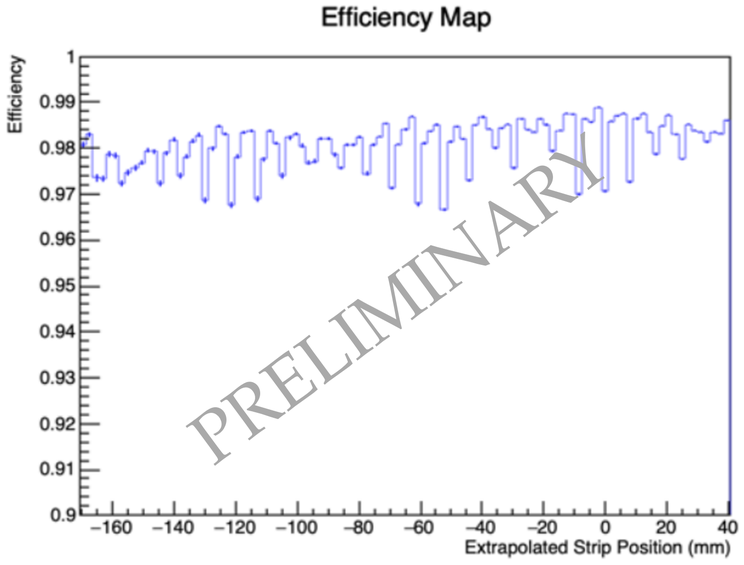
EFFICIENCY $\geq 95\ \%$

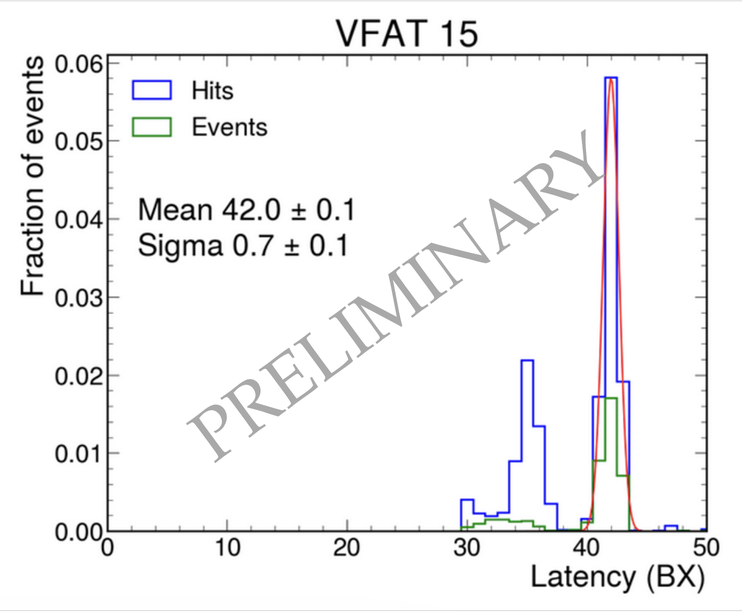
- Setting a cut at 5σ of the residual fit, we consider as **matching events** those with at least 1 hit inside that cut
- Efficiency is evaluated dividing the number of **matching events*** by the total number of events recorded in the detector

TIME RESOLUTION $\sim 16 - 17\ ns$

- VFAT with CFD does not work well with our detector
- We operate VFATs in arming mode to get the best performance we can
- Worse than TDR requirement (10ns)



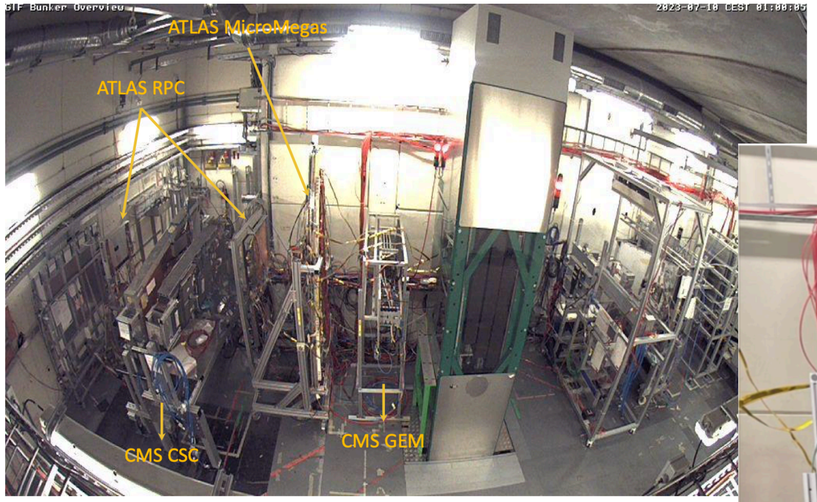




Tests beam with high background at GIF++

2023 - Test of proto-stack with 4 layers

- **Rate measurement** at different attenuation factors (source ON/ beam OFF): irradiation on half of the module surface at rate up to $150 kHz/cm^2$
- **Efficiency measurement** at different attenuation factors (source ON/beam ON)
- **Test segment reconstruction with 4 layers in high background**



Rate capability analysis ongoing

Test beam plans for 2024

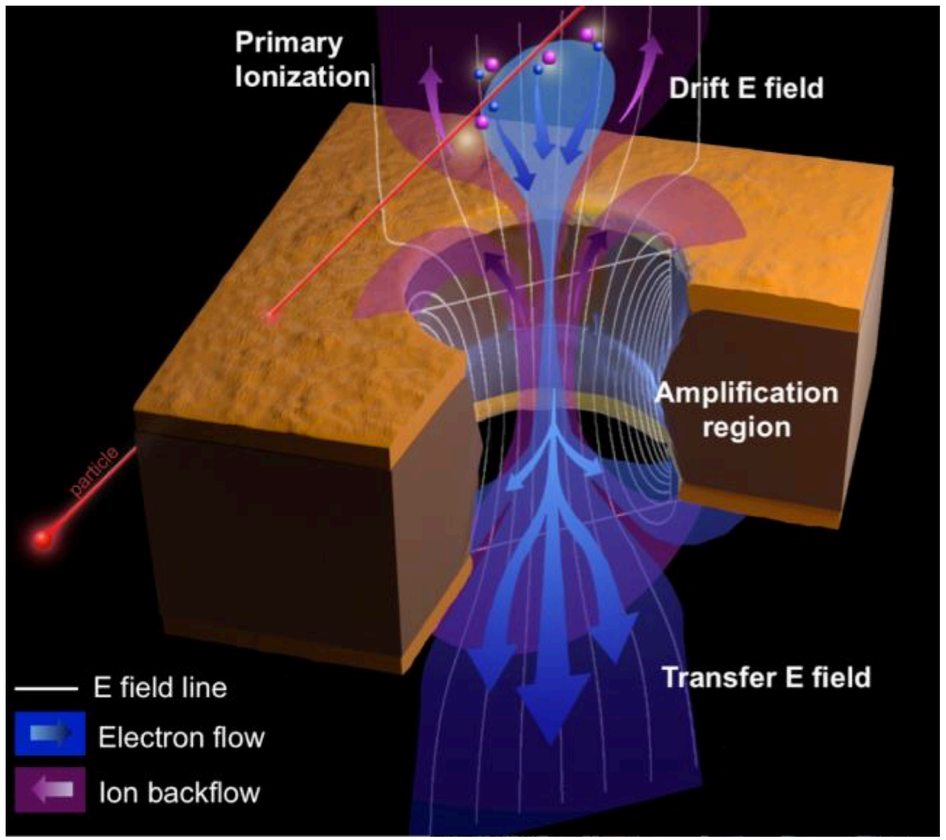
1. Complete first full ME0 stack with 6 layers beginning 2024
2. Operate the full stack (eventually with tracker) in test beam at SPS for:
   - Track reconstruction efficiency
   - Efficiency layer by layer
   - Segment time resolution
   - Put different parts of the detector in muon beam spot
   - Operate stack with final CMS back-end

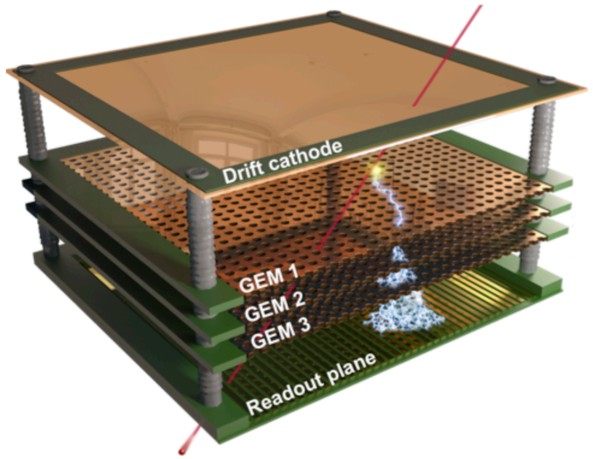
   We are planning to join RD51/DRD1 in the first test beam slot (April/May)
3. Operate the full stack with highest background

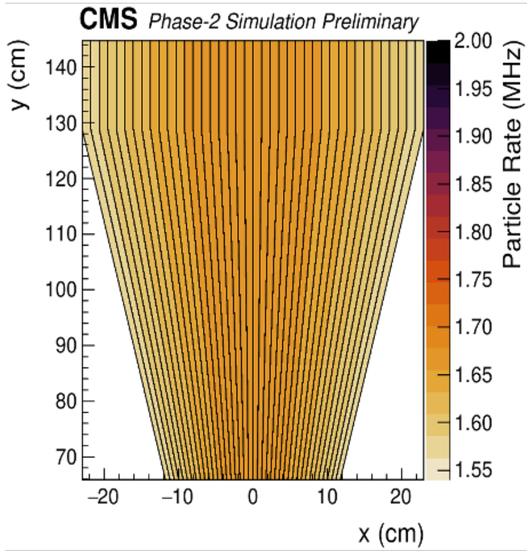
   We will have a test beam in summer and fall 2024 at the GIF++


Thanks for your attention!

ME0 detector system

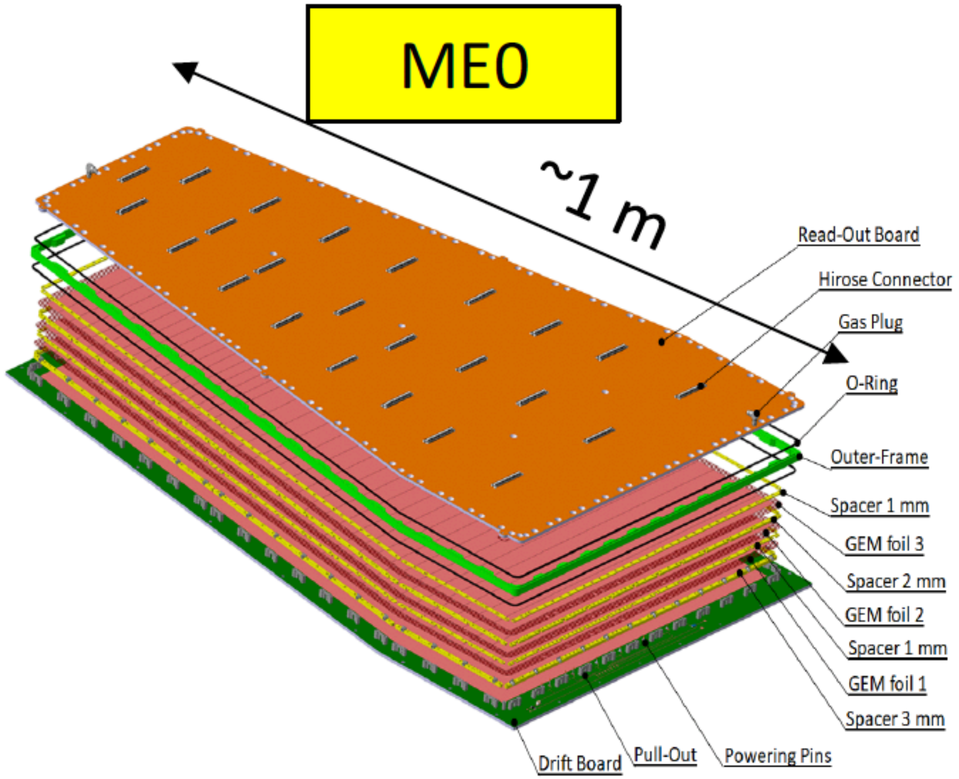


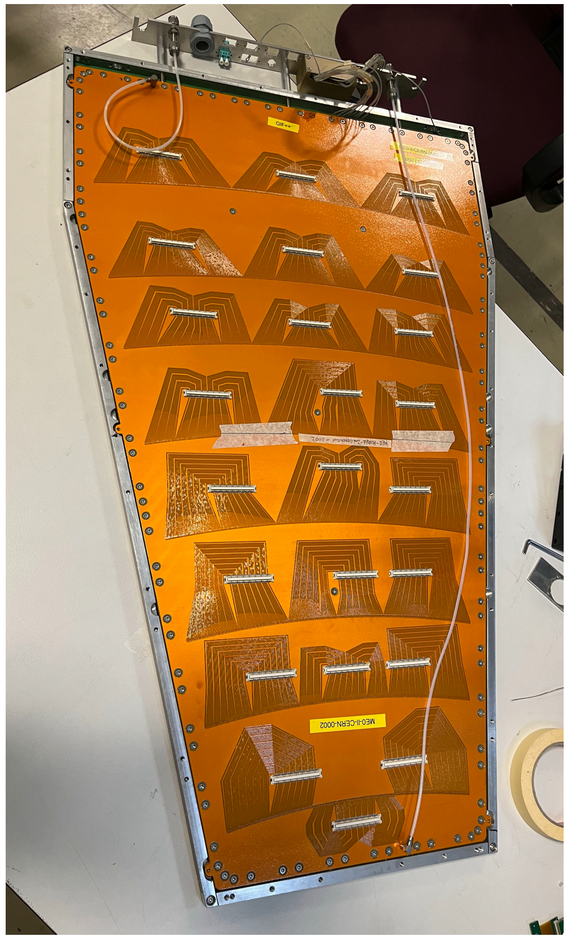




- Each ME0 stack has 6-layers of trapezoidal chambers of 78cmx(23.6–51.4)cmx1.8cm and opening angle 20.3°
- Placed at 63cm of radial distance from beam line with geometrical acceptance in $|\eta|$ between 2.03 and 2.8
- ME0 second generation: based on triple-GEM technology, with azimuthal foils HV segmentation
- It operates with 70:30 $Ar : CO_2$
- Each module is divided into 8 η-partitions, each one with 384 readout strips, and 3 ϕ -partitions
- Digital readout with VFAT3 chip, information only on ϕ coordinate

Requirements for single modules





- 97% efficiency
- Rate capability $\geq 150\ kHz \cdot cm^{-2}$
- Angular resolution $< 500\ \mu rad$
- Time resolution 8-10 ns
- Gain uniformity $\geq 15\%$
- Radiation hardness $> 7.9\ C \cdot cm^{-2}$
- Sufficiently low discharge rate