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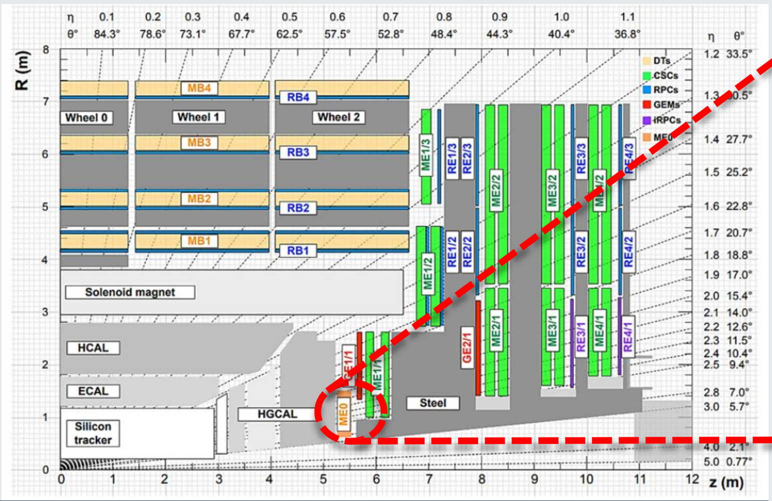
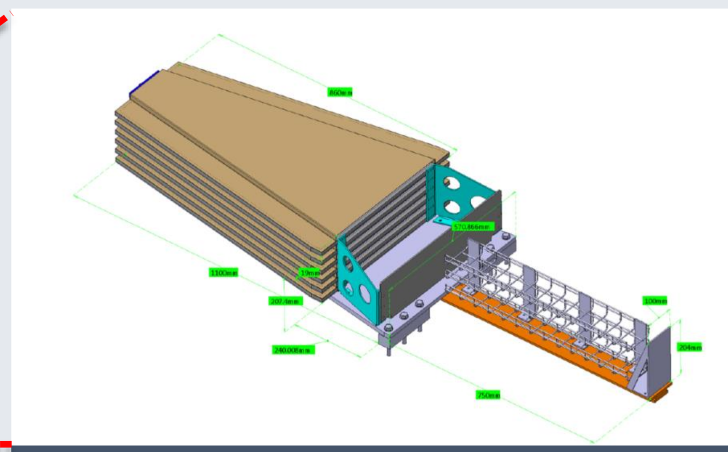
Novel GEM foil layout for high-rate particle environment in the CMS ME0 muon detector

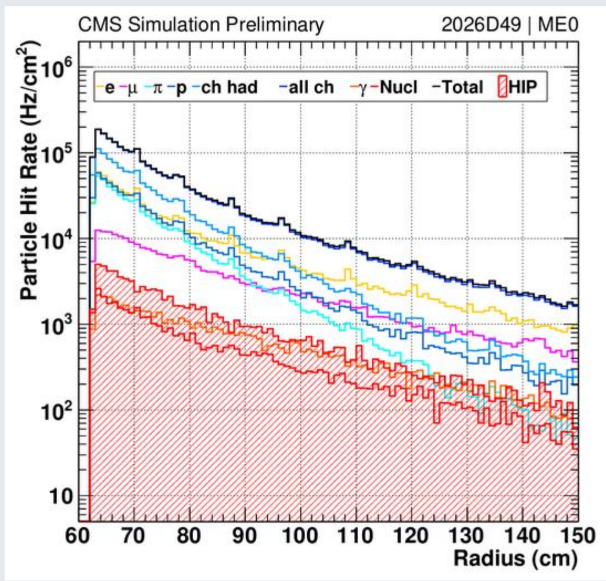
THE PHASE-II CMS MUON ENDCAP UPGRADE



Cross-sectional view of the CMS Muon System



Schematic view of ME0 stack with six triple-GEM layers



Simulation of the background particle rate expected in the ME0 station[1]

Phase II upgrade of the CMS muon system [2] : **triple-GEM** detectors

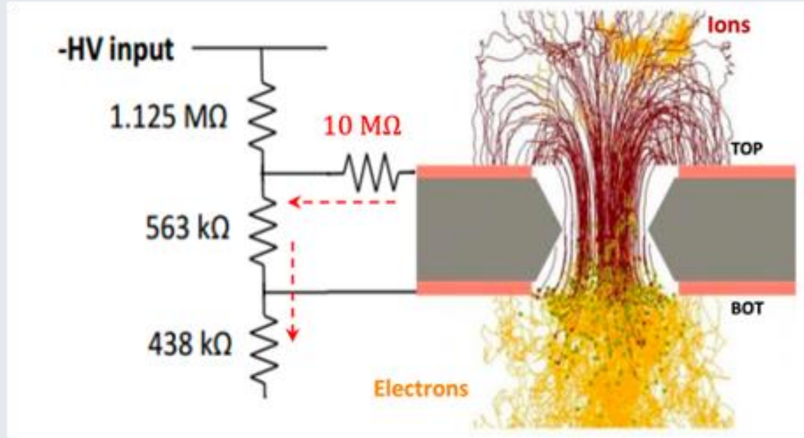
- ❑ Space resolution $< 500\ \mu\text{rad}$
- ❑ Time resolution $< 10\ \text{ns}$
- ❑ **High-rate capability** (expected hit rate up to $144\ \text{kHz/cm}^2$)

The upgrade includes:

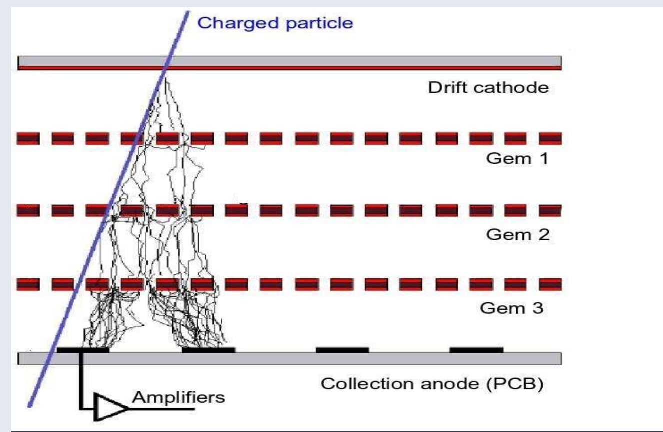
- ❑ GE1/1, $1.55 < |\eta| < 2.18$ **Installed**
- ❑ GE2/1, $1.62 < |\eta| < 2.43$ } **LS3**
- ❑ **ME0**, $2.0 < |\eta| < 2.8$ } **LS3**

The ME0 ring (**18 detectors × 6 layers × 2 endcaps**) will be the closest muon station to LHC beam line.

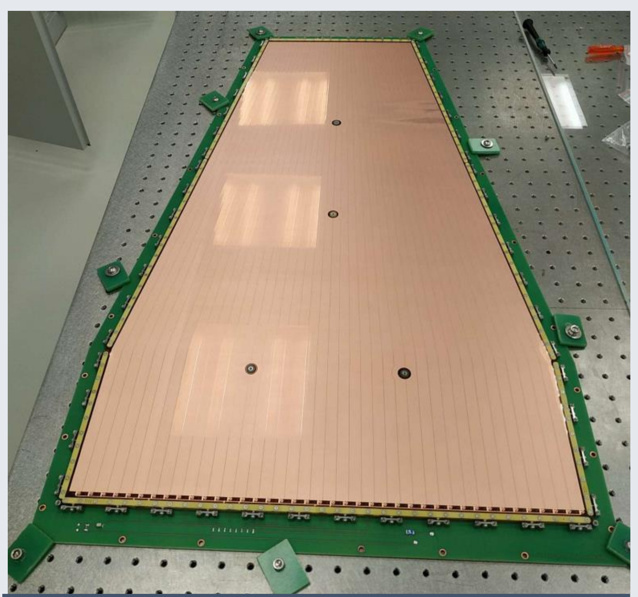
ME0 prototype



Schematic view of an avalanche in GEM holes [3]



Schematic view of an avalanche trough the three GEM foils



ME0 prototype with azimuthal segmentation [3]

GEM technology [1]

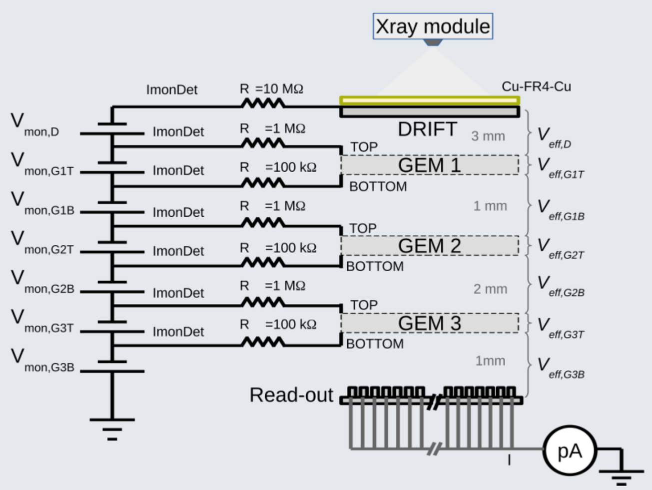
- ❑ Copper **5 μm**
- ❑ Kapton **50 μm**
- ❑ Holes density $\mathbf{50-100/mm^2}$

Possible source of gain drop at high rates

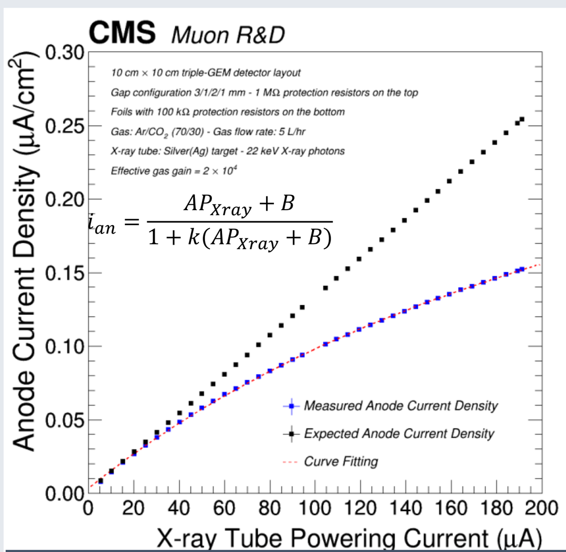
- ❑ Ion space charge
- ❑ Drop in voltage difference across GEM foil

A detailed study of rate capability and gain measurements with ME0 prototype needed

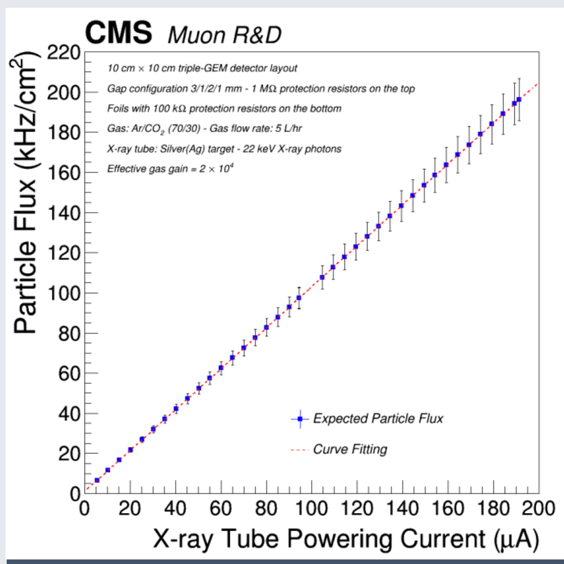
Rate measurements



Schematic view of the setup



Anode current saturation with the x-ray source current increases



Particle flux obtained by the linearization of anode current

The rate measurement have been performed with a $10x10cm^2$ **triple-GEM** detector

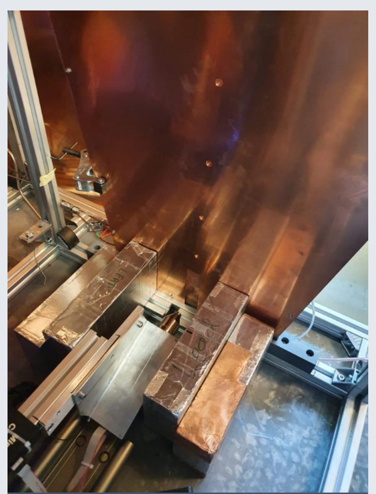
- ❑ Gas Mixture: $Ar:CO_2\ 70:30$
- ❑ HV board: **multi-channel CAEN A1515** (400pA resolution)
- ❑ Shielding layers to emulate **ME0 budget material**
- ❑ Source: two **silver-target Amptek Mini-X tubes**
- ❑ Readout: **Keithley 6487 picoammeter** ($10fA$ resolution)

Rate from linearized anode current

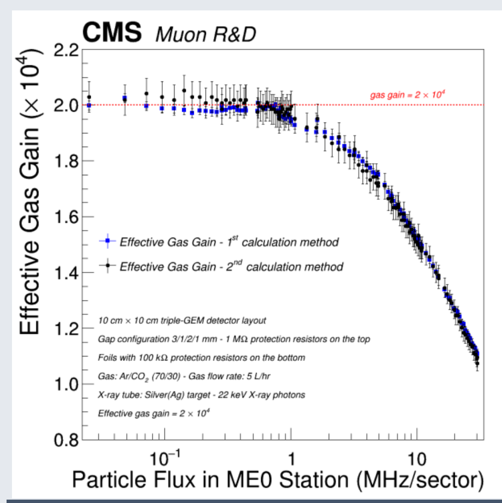
$$R = \frac{I_{linearized}(P_{Xray})}{q_e n_e g_{nominal}}$$

Where,
n_e = # primary electrons
$g_{nominal}$ = nominal detector gain measured at very low flux ($2x10^4$)

Gain measurements



Setup of the ME0 prototype irradiation



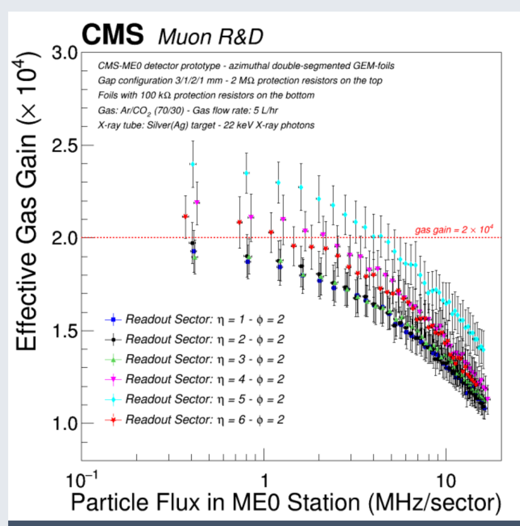
Gain measurements with the two different methods

Two different methods

1. $g_{eff} = \frac{I_{anode}(P_{Xray})}{q_e n_e R(P_{Xray})}$
2. at very low flux rate:

$$V_{eff} = V_{set} - I_{mon} R_{protection},$$

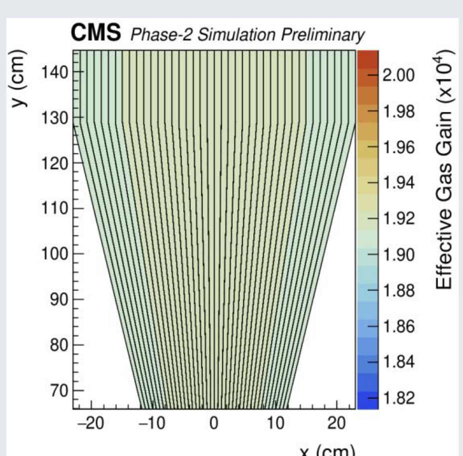
where I_{mon} is the current read by A1515 board at high flux rate.



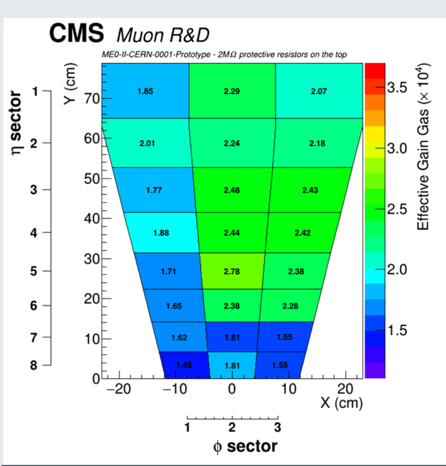
Gain measurements on ME0 prototype

- ❑ The drop of gain is mainly due to voltage drop
- ❑ The effective gain measurement at different particle flux rate has been performed on a ME0 protype detector, irradiating separatly different eta partitions

Gas gain uniformity



Simulated gain with azimuthal segmentation



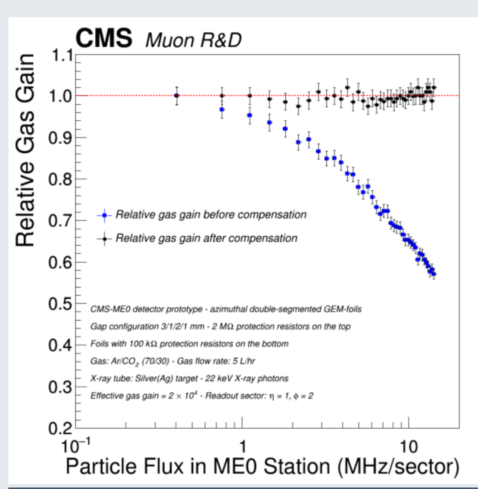
Measured gain for each sector on ME0

The μ/σ is proportional to gain variation

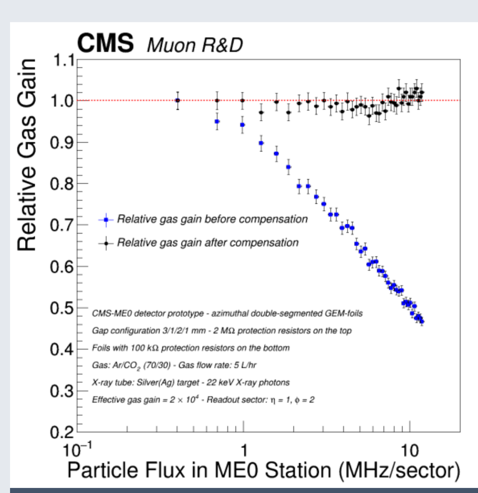
Longitudinal segmentation (GE1/1 and GE2/1)
$\frac{\mu}{\sigma} = 25\%$

Azimuthal segmentation (ME0)
$\frac{\mu}{\sigma} = 10\%$

Gain compensation



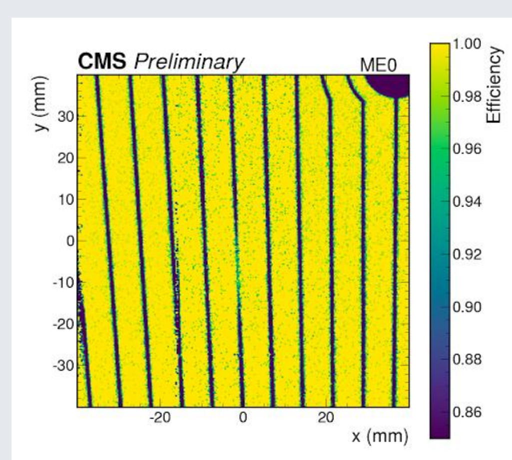
Gain compansation on ME0 prototype without HV filter



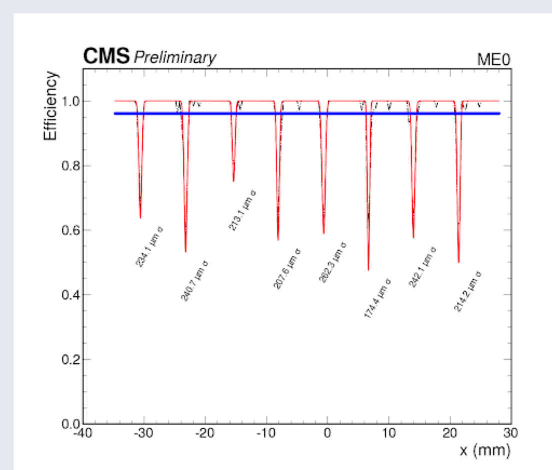
Gain measurements on ME0 prototype with HV filter

- ❑ $V^j_{eff} = V^j_{set} + I^j_{mon} R^j_{protection}$ will be applied to compansate the voltage drop (V_{set} is the previous value and I_{mon} current from CAEN Board).
- ❑ **Next**: irradiation test at GIF++

Efficiency study



Efficiency map of ME0 prototype detector



Efficiency profile of the ME0-II-CERN-0002 prototype detector

- ❑ Results from October2021 test beam
- ❑ More on the setup A.Pellecchia poster

References

[1] F. Sauli, "*GEM: A new concept for electron amplification in gas detectors*", Nucl. Instrum. Meth. A 386 (1997) 531
[2] **CMS Collaboration**, "*The Phase-2 Upgrade of the CMS Muon Detector*", cds.cern.ch/record/2283189/ .
[3] **M.Bianco et al.**, "*Rate Capability of large-area triple-GEM detectors and new foil design for the innermost station, ME0, of the CMS endcap muon system*", inspirehep.net/literature/2016685

15th Pisa meeting on advanced detectors