CMS-GEM 2022 Report
-and future-

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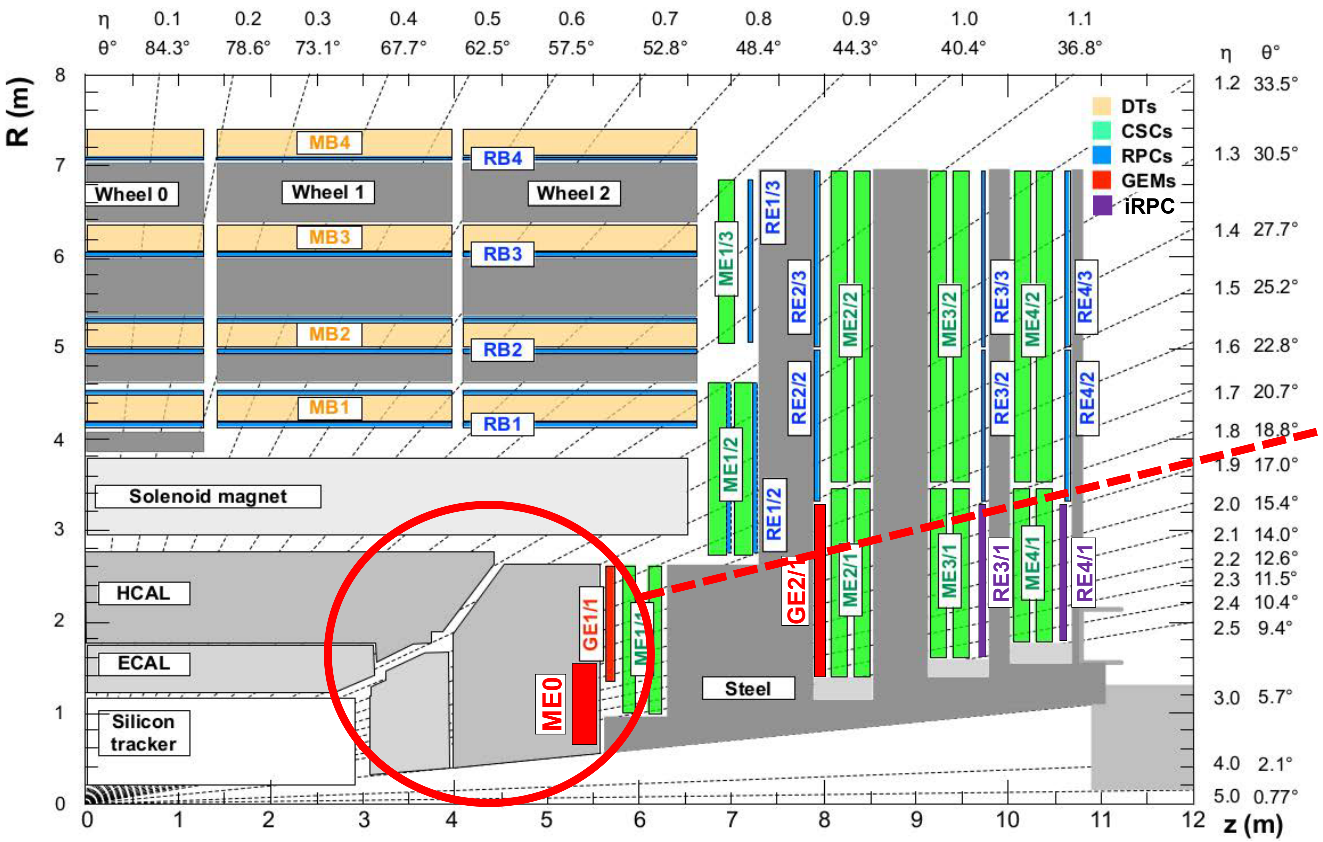
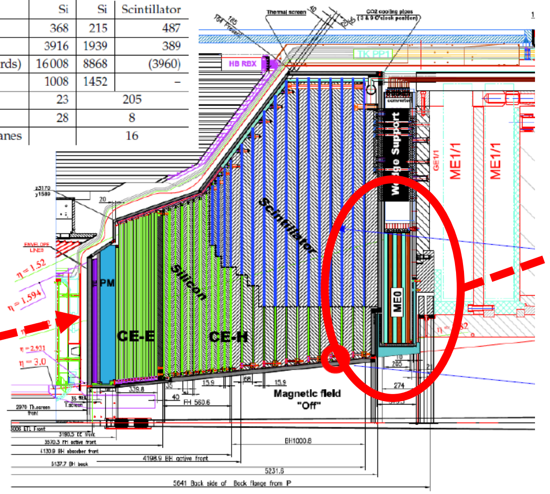
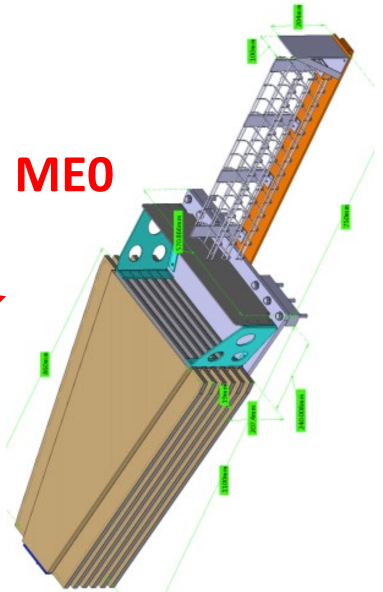
On behalf of the CMS-GEM group

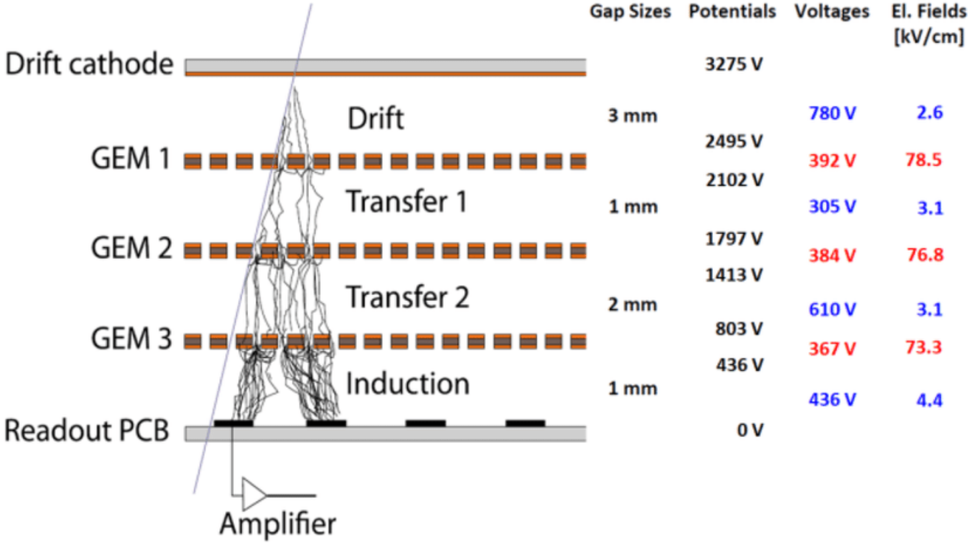
ME0 station in CMS Muon System



	CE-E	CE-H	
	Si	Si	Scintillator
Area (m^2)	368	215	487
Channels (k)	3916	1939	389
Si modules (Tileboards)	16008	8868	(3960)
Partial modules	1008	1452	–
Weight (t)	23	205	
Si-only planes	28	8	
Mixed (Si+Scint) planes		16	



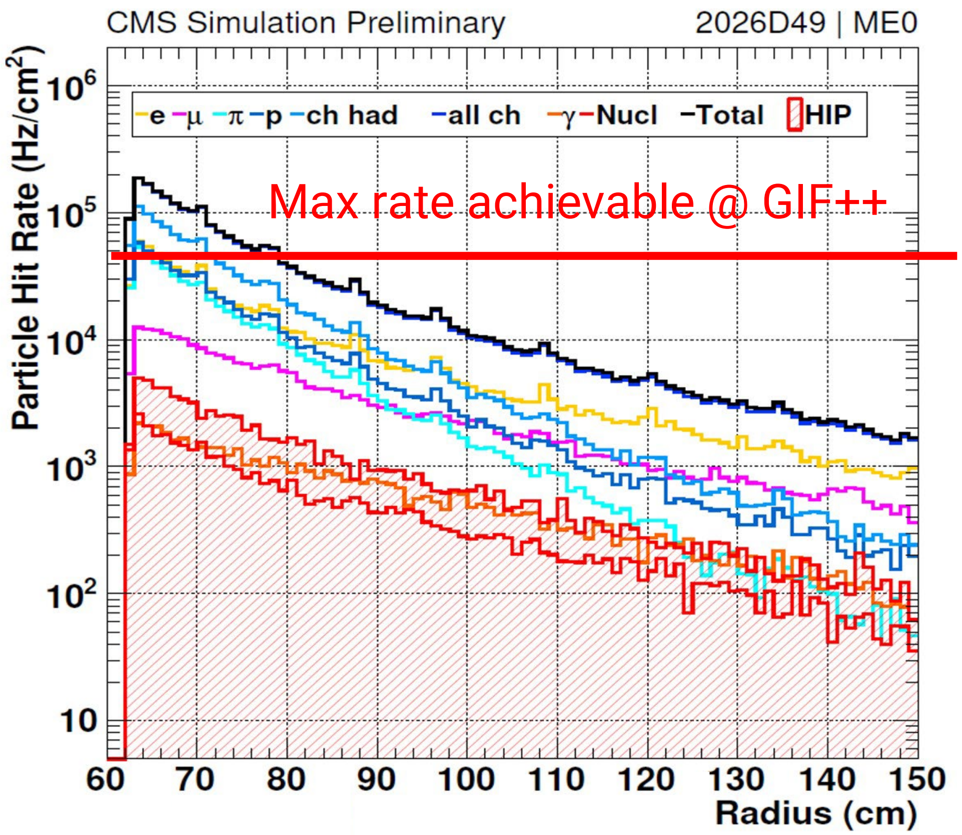




From The Phase-2 Upgrade of the CMS Muon Detectors TDR:

→ **Work in a high-rate environment: 150kHz/cm^2**

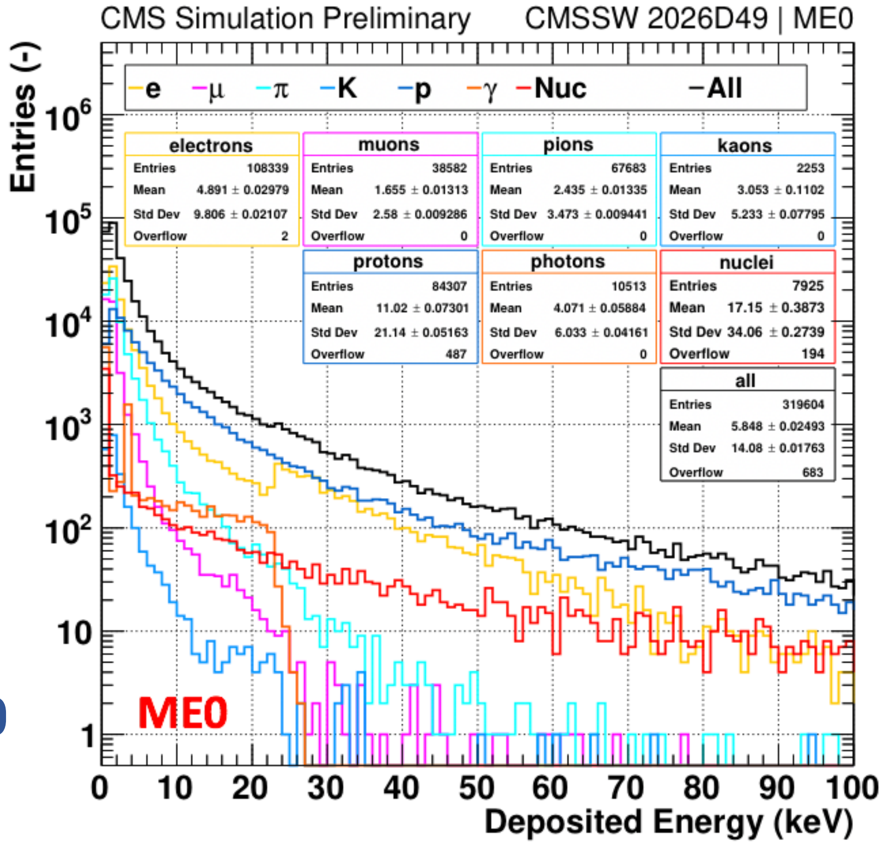
ME0 particle environment



GEANT4 simulations

- Similar results with FLUKA
- Results strongly depend on the **HGCAL design**, which is still changing

- Expected Hit Rate
  → Range [2, **144**] kHz/cm^2
- Average primary energy deposit **5.8 keV**, i.e., **200 e-ion pairs**



Demonstrating the correct operation of GEMs in such a background (highest background flux ever for a large-area gaseous detector) is one of the fundamental milestones for the ME0 project.

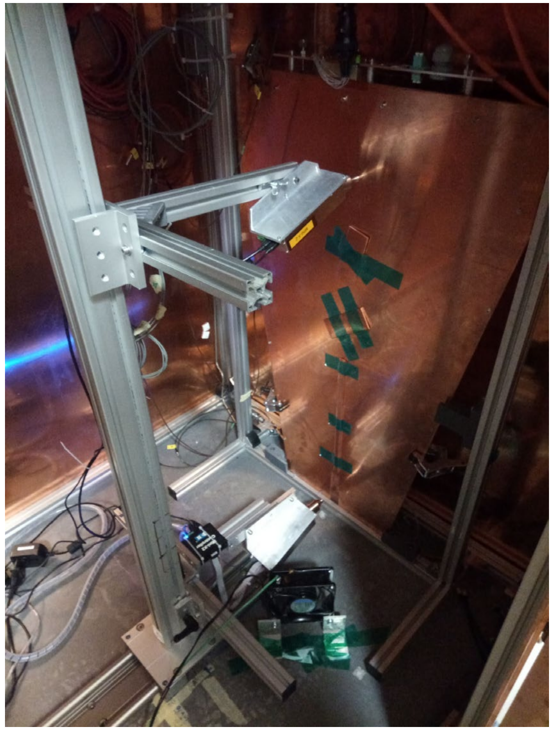
GIF++ is the most suitable place to test the GEMs rate capability

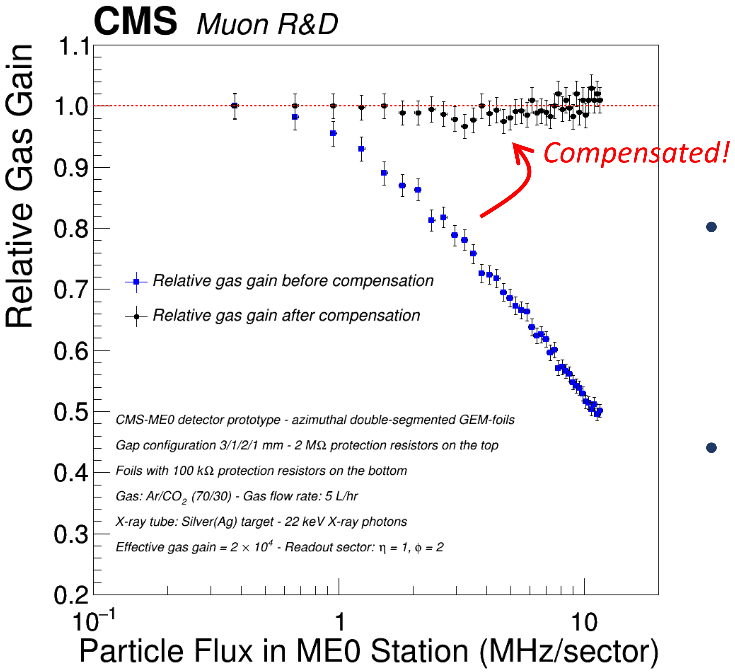
ME0 Gain loss and Compensation

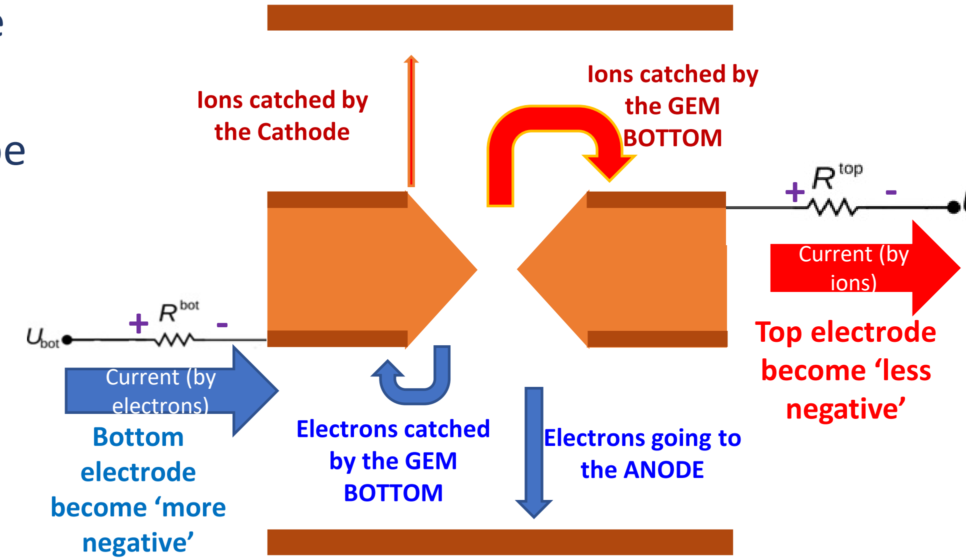
- Intrinsic rate limit in GEMs is very high due to the fast ions collection on the electrodes → **10/100 MHz/cm²**
- when a large area is irradiated, the induced current on the electrodes can be high enough **to cause a sensible voltage change** on the electrodes

$$\Delta V_{electrode} \propto R_{electode} \times \varphi \times G \times n_0$$

Flux on the electrode (φ); Number of primaries (n_0); Global electrode resistance ($R_{electode}$); Effective gain (G)







904 LAB test

- Iteratively increase the applied voltage on each GEM electrode until the effective voltage on each electrode is equal to the voltage required to operate the detector at the nominal gain
- The effective voltages on the j-th electrode are changed through the power supply according to:

$$V^j_{nominal} = V^j_{eff} = V^j_{set} - I^j_{mondet} R^j$$

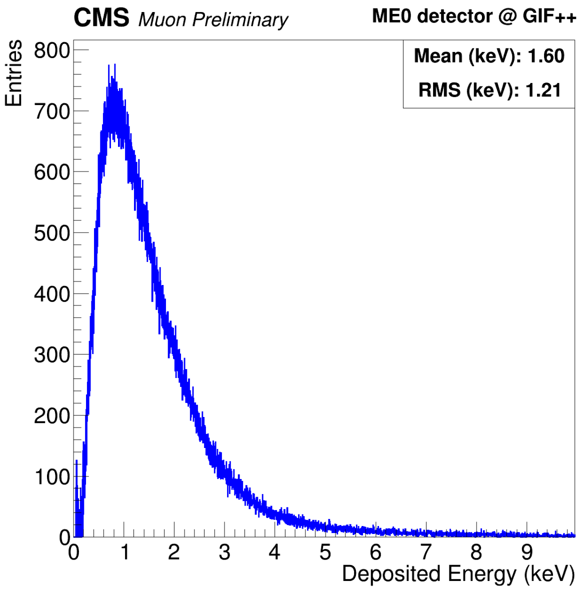
Final ME0 configuration cannot be tested @ 904 → Moving to the GIF++ facility

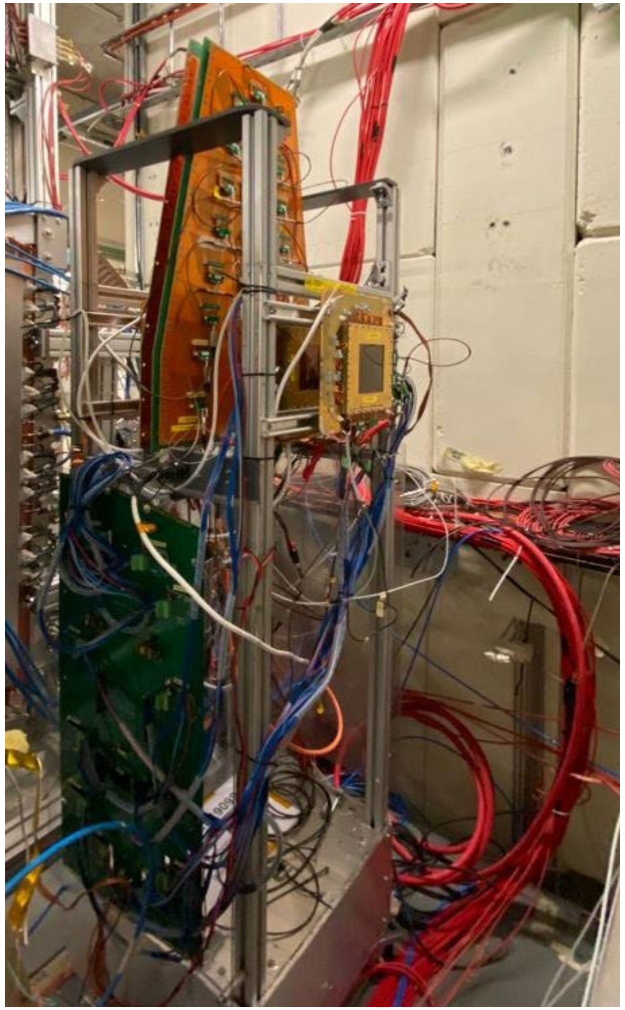
- Small irradiation area
- No HV filter resistor test

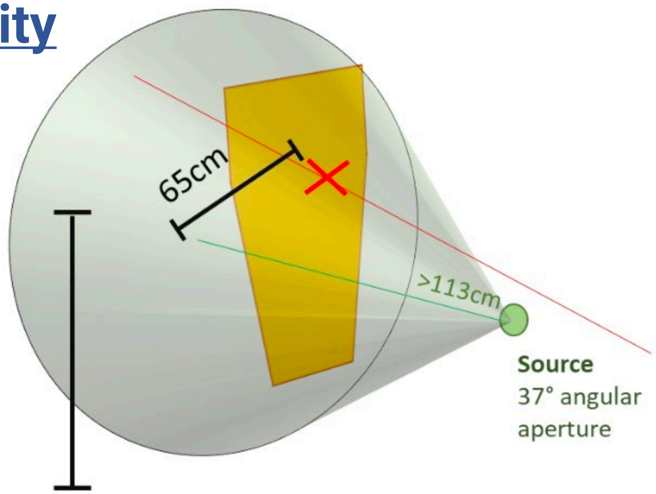
Goal 1: Demonstrate it is possible to compensate for the gain loss

→ Measure **gain loss** and **compensation** with different HV filter resistors

→ GIF++ deposited energy spectrum





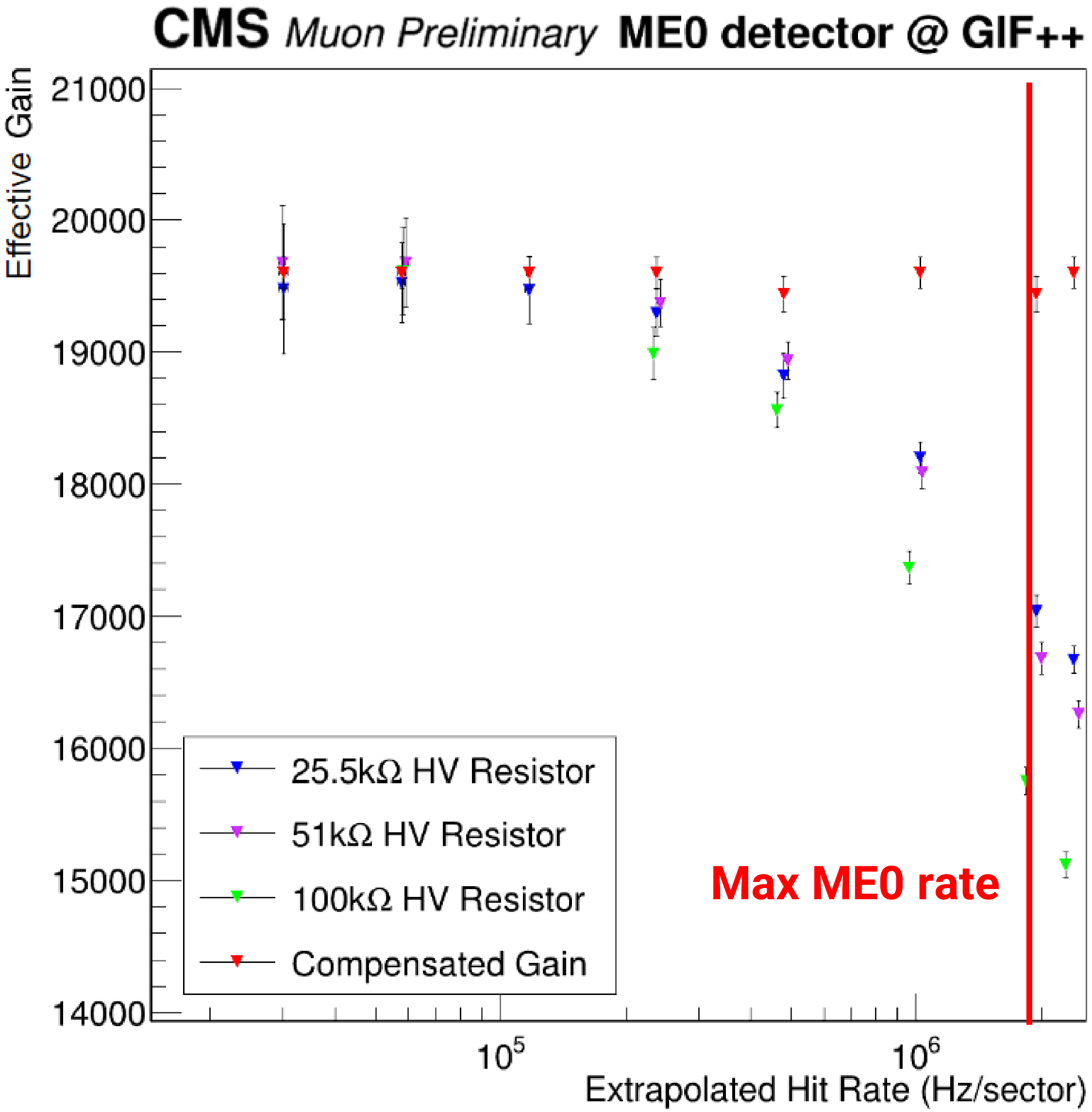


Goal 2: Measure efficiency under irradiation

→ Measure efficiency with and without compensation (different HV filter resistors)

→ **Test Beam!**

GIF++ Source Test

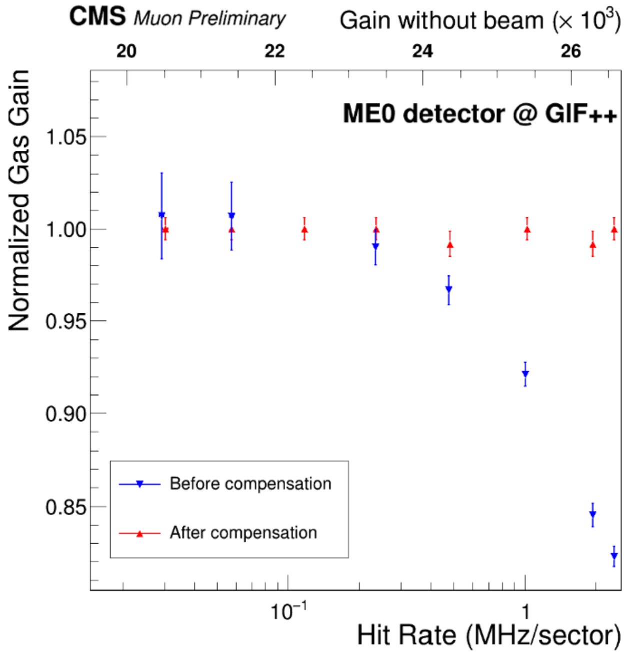


Intensive tests were carried out between February and June.

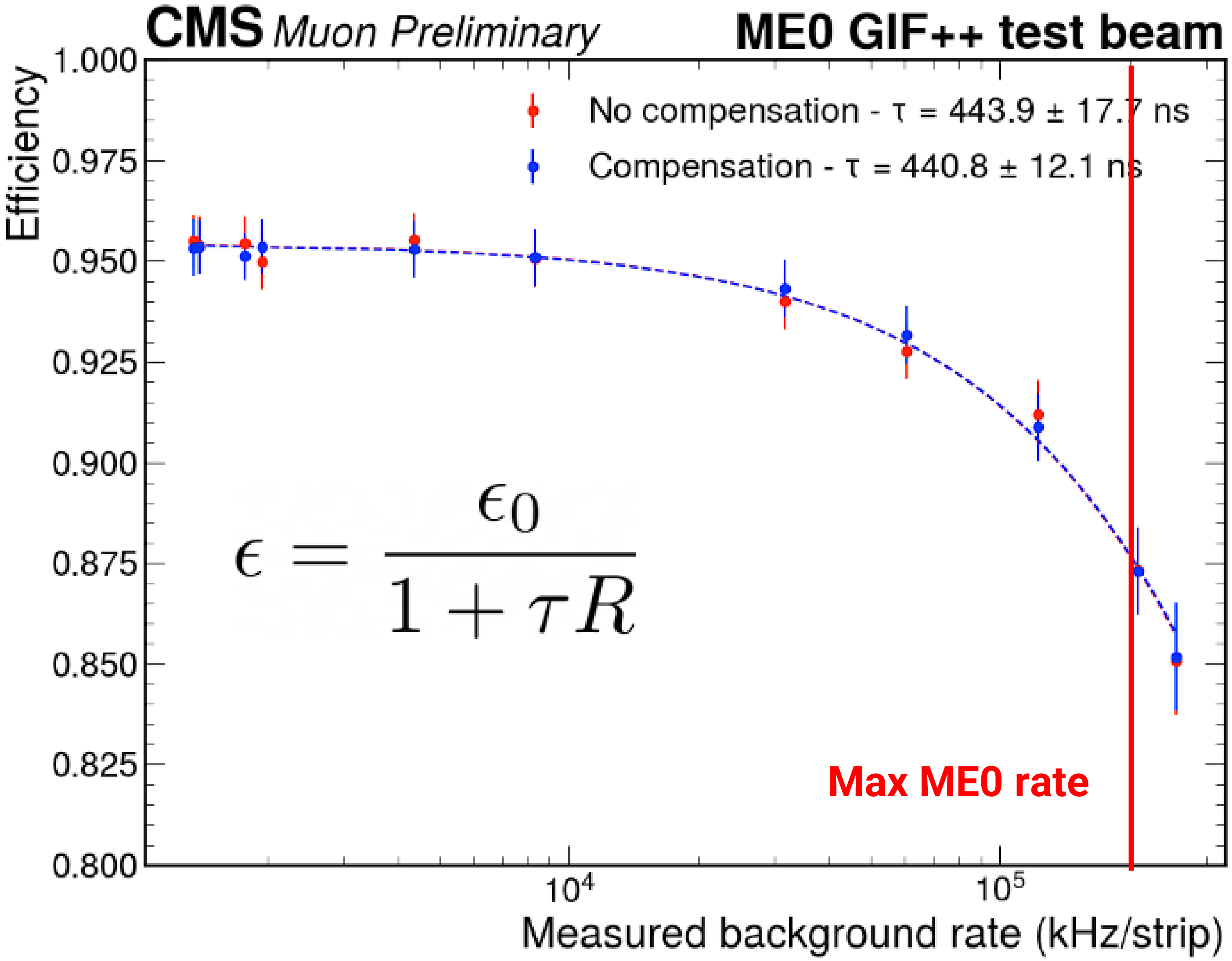
→All the foreseen tests have been done

Gain drop:
Filters are chosen among the validated ones from a discharge point of view

Compensation works perfectly in every case!



GIF++ Test Beam



Participated in July testbeam

→All the foreseen tests have been done

Efficiency loss ≈8% at max ME0 rates

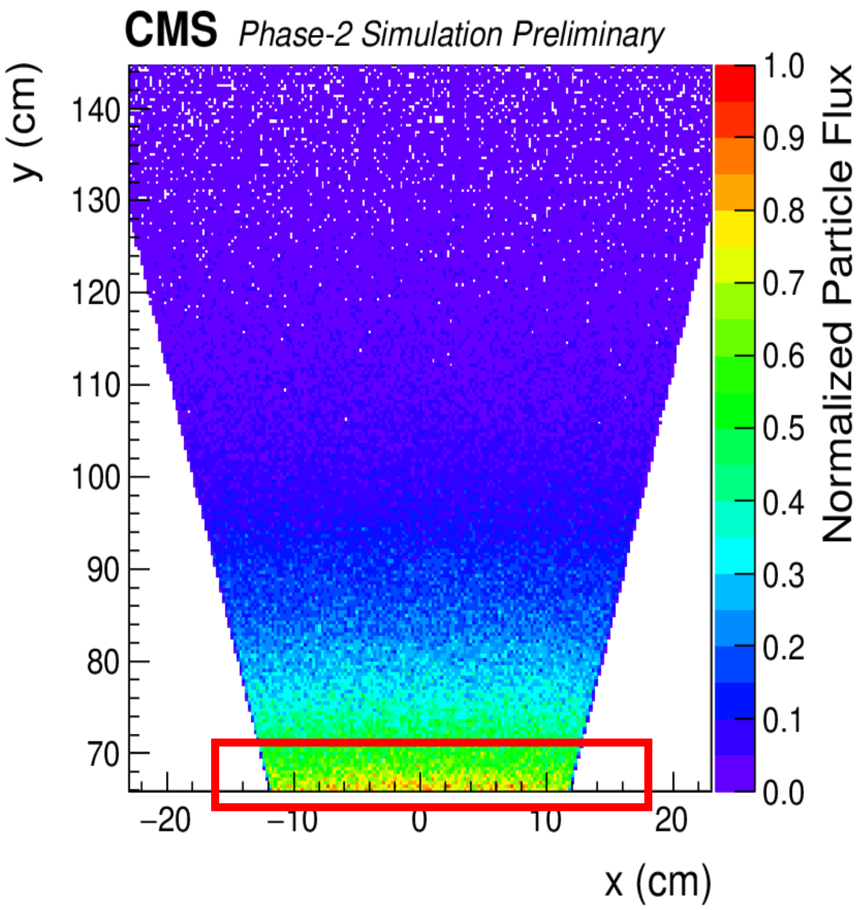
→ No influence from working point, compensation and other detector parameters

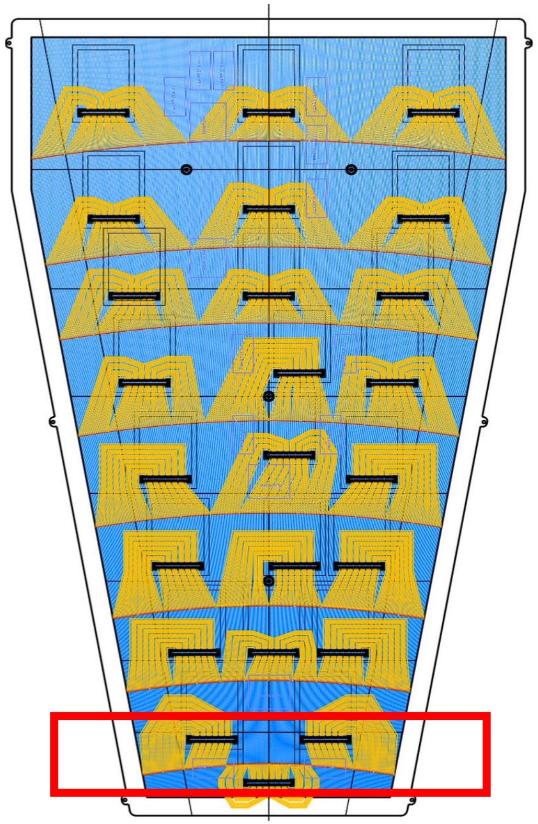
Such behaviour was not expected at the time of the test…

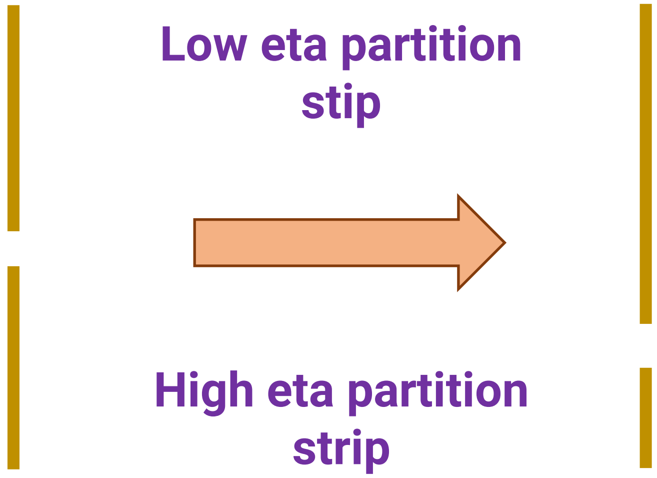
→Test in 904 lab with Xray gun confirmed the dead time measurement

→VFAT3 ASIC rate capability fully justifies the GIF++ test beam results

Mitigation strategy
-Readout board redesign-







Region of efficiency loss (≈86%) only in the highest eta partition

Baseline mitigation:

→reduce the strip length on the highest eta partition to reduce the rate on the channels

→ Increase the size of sectors that have a lower rate

***"Just"* a redesign of the readout board. It will not impact any other mechanical structure!**

Conclusion and future

GIF++ was fundamental for the 2022 R&D campaign of the CMS ME0 GEMs:

- Measure the gain loss in a CMS-like environment
- Validate the gain compensation strategy
- Final choice of the HV filter resistor
- Discovered an important loss of VFAT3 frontend efficiency
  - →400ns dead time confirmed by further measurements
  - →Mitigation strategy(ies) to be tested

CMS-GEM @ GIF++ 2023

- *-You always come back to the places where you have been happy-*
- New prototypes have to be tested **at least during one test beam**
- We'll not foresee a continuous presence at GIF++

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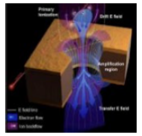

CMS-GEM

CERN, 01/12/2022, 420 contributions

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Wonderful experience strongly suggested!

We were in GIF++ for all of 2022 and didn't want to leave! We did all the tests we had to do, and all our colleagues were always helpful and happy to share knowledge (and tools). A big thanks to Giuseppe for the availability and the support, and a big thanks for the patience of our colleagues (in particular the downstream gang). An easy 5-star review, we definitely suggest GIF++ for your test beam! 😊

CMS-GEM @ GIF++ 2023

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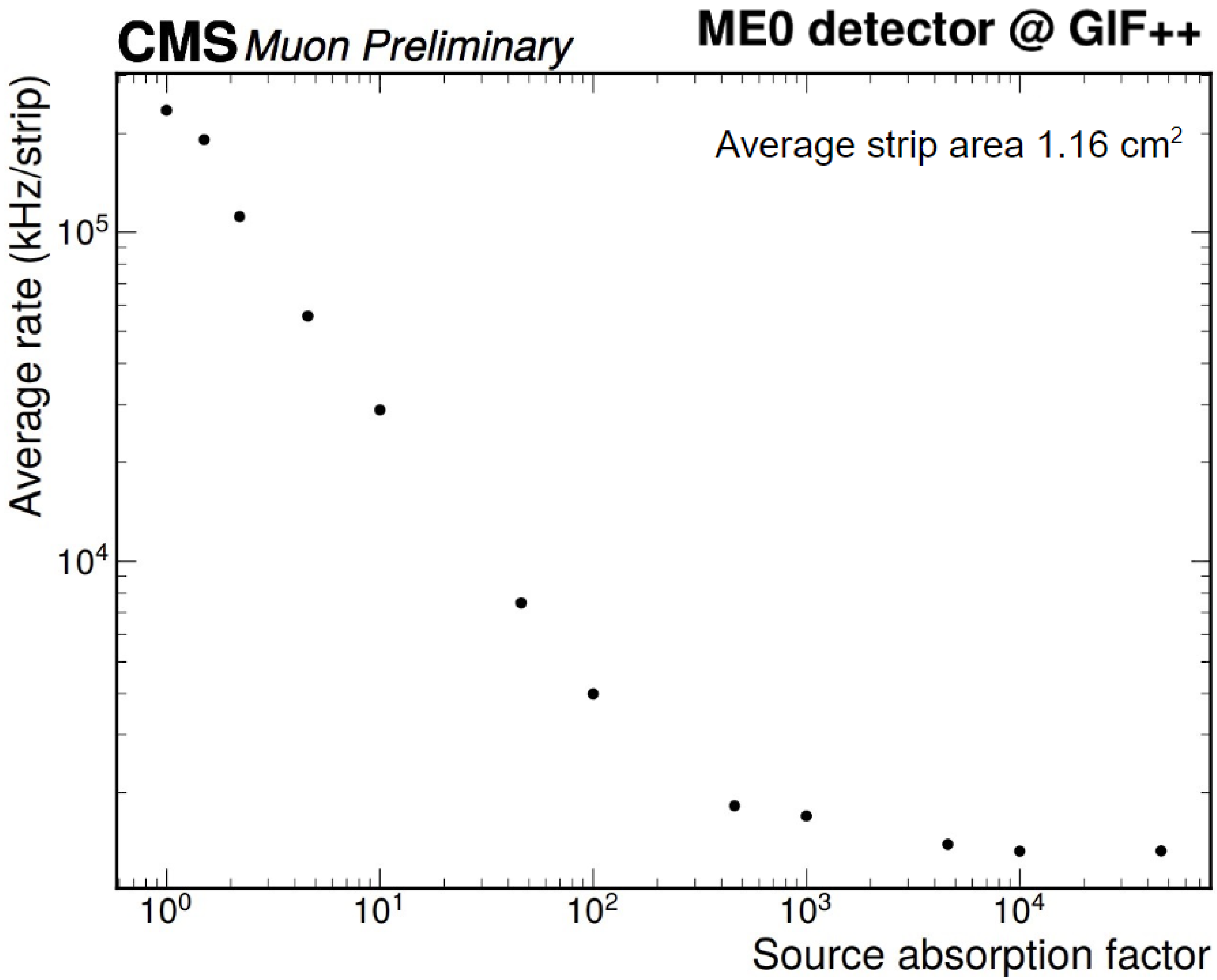
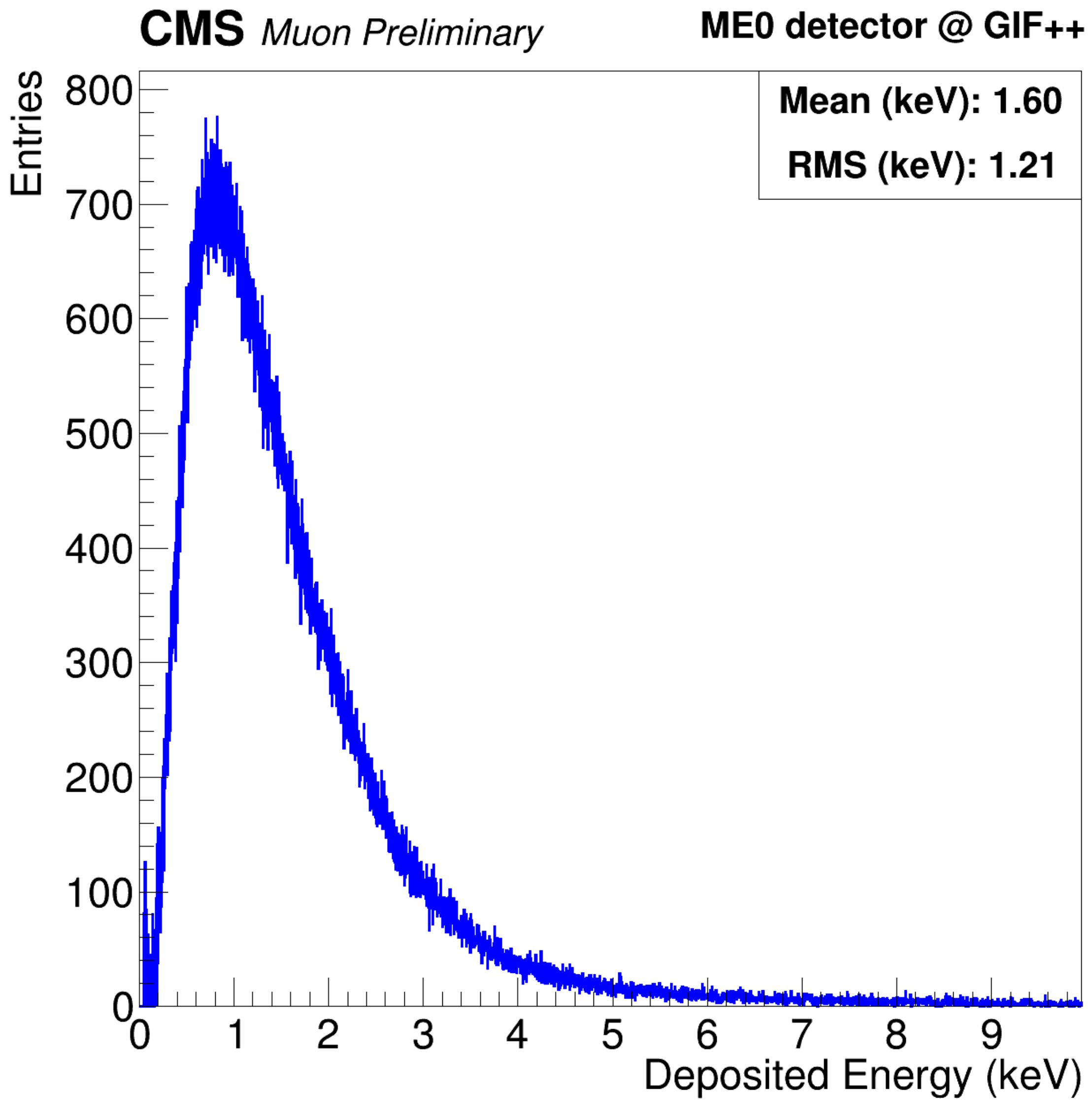
BACKUP

Measured rate vs GIF attenuation factor



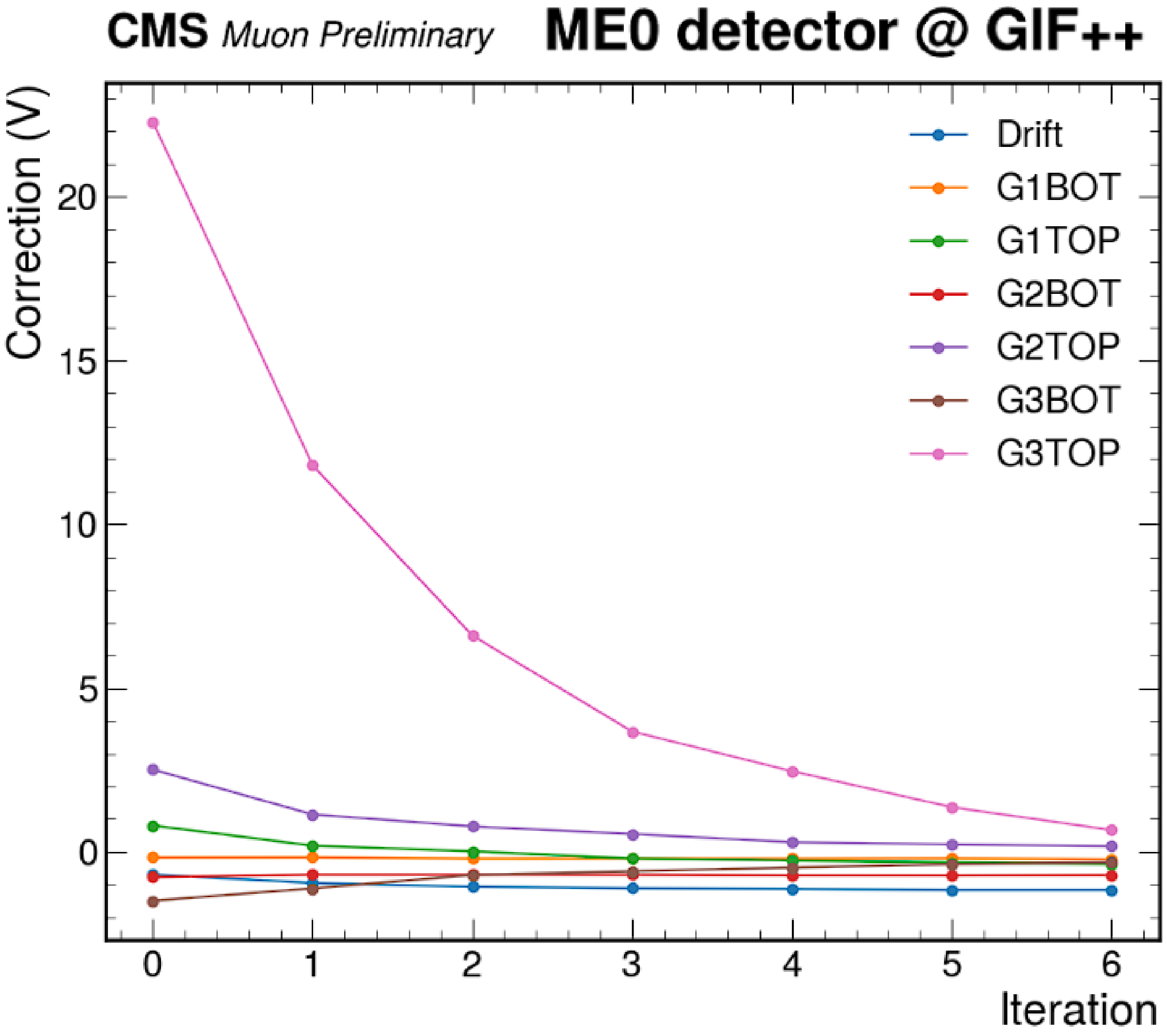
Measured background hit rate on detector as a function of the GIF++ source attenuation factor

GIF++ source spectrum on a CMS GEM



A Spectrum of the GIF++ source (662keV photons from 137Cs) deposited energy on a ME0 detector. Spectrum was acquired with a CAEN DT5720 ADC. Energy range calibrated with a 109Cd test source.

Voltage compensation steps



Every GEM electrode voltage is tuned to compensate for the voltage drop, depending on the current flowing through the electrode and the resistors applied.
The voltage of each electrode is tuned iteratively following the formula:

$$\Delta V^j = I^j_{MonDet} \; R^j$$

j-electrode, R: resistance

Where ΔV is the correction to be applied to the electrode voltage. The nominal effective voltages are reached after 5-7 interaction depending on the working parameters