

Background Particle Response of CMS GEM Detectors with Run 3 Data and Simulation

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ABSTRACT

The upgrade of the High-Luminosity LHC (HL-LHC) will boost the instantaneous luminosity to $5 - 7 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$, increasing particle fluxes in the forward region of the CMS detector. The high particle flux can damage electronics and induce spurious signals. This study focuses on the GE1/1 triple-GEM detector's sensitivity to both neutral and charged background particles, performed using FLUKA and GEANT4 simulations. FLUKA provides a comprehensive description of the radiation field around the GE1/1 chambers across a broad energy spectrum. GEANT4 delivers complementary insight into the detector response based on realistic geometry, materials, and interaction processes. The results show how the detector's sensitivity changes with particle energy and incident angle, and how different configurations affect its performance. The talk also includes comparisons with CMS Run 3 data, providing valuable guidance for optimizing GEM operation under HL-LHC conditions. Moreover, this approach can be extended to other forward detectors like ME0 during the HL-LHC era.

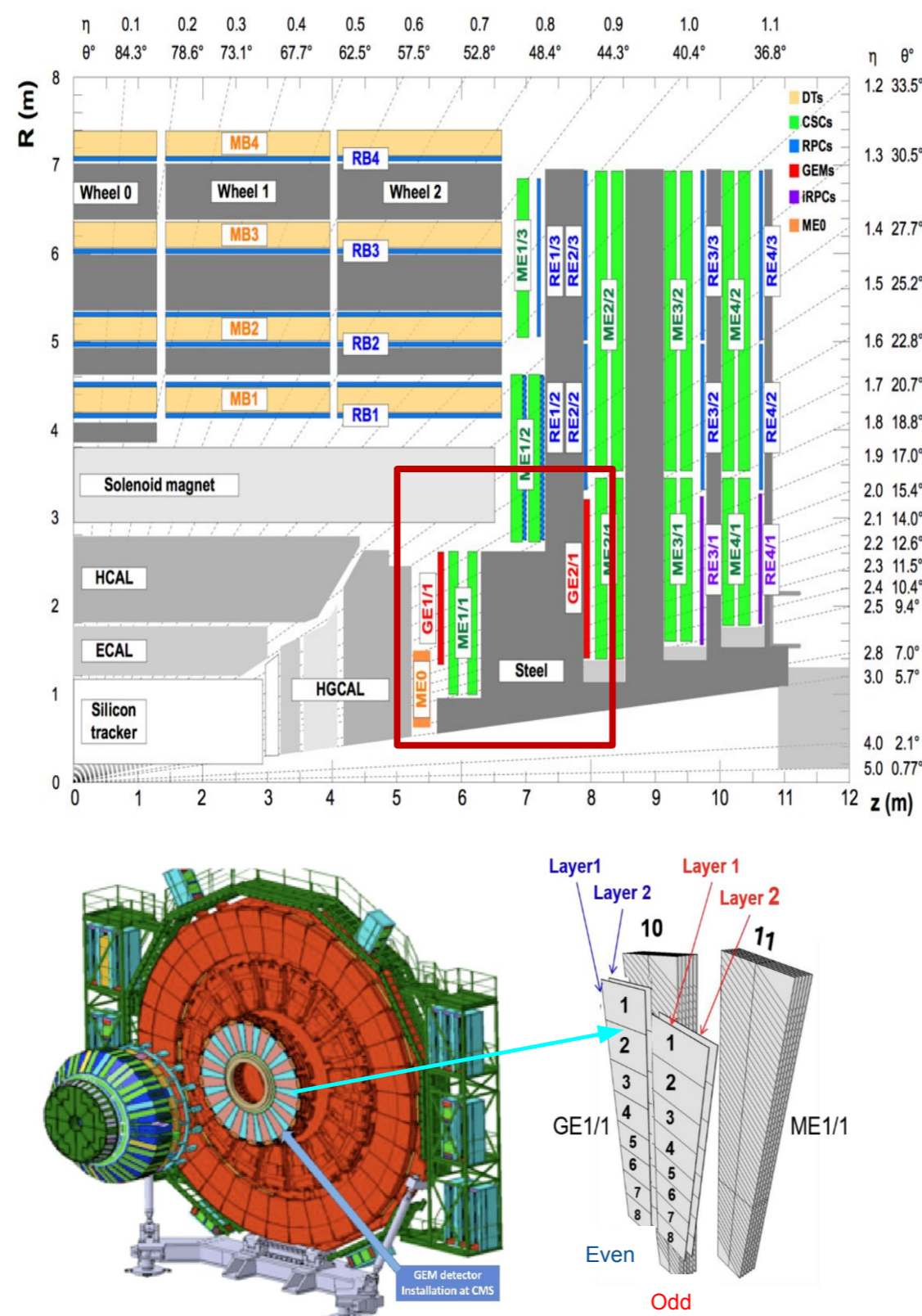
Introduction & Motivation

High-radiation environment at the LHC: colliding beams and beam-matter interactions create an intense, complex radiation field.

- Composition of background particles: Low-energy neutrons, photons (γ), electrons/positrons (e^\pm), charged hadrons (π^\pm , K^\pm , p).
- Main source of background in endcap region: Collision and HCAL gap leakage, cavern material.
- Background impact: High interaction rates can damage detector materials/electronics, create spurious hits that degrade muon reconstruction and trigger performance, and even mimic real muons, affecting physics analyses.

Overview of GE1/1 Detector

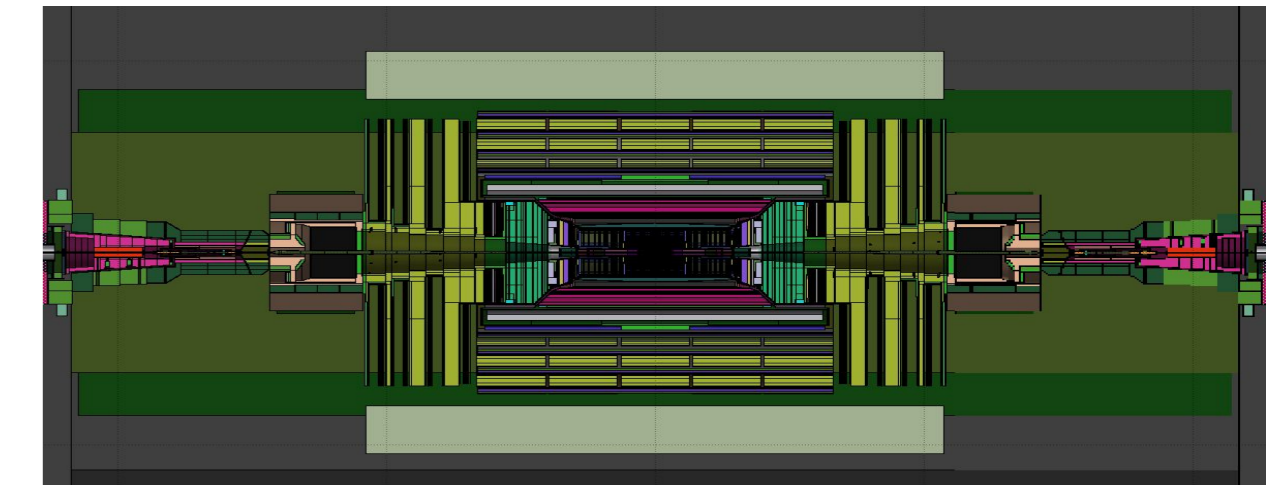
- Triple-GEM technology
- GE1/1 are installed in both +z and -z side of CMS muon endcap in front of ME1/1 (CSC).
- Coverage: $1.55 < |\eta| < 2.18$.
- 144 trapezoidal-shaped GE1/1 chambers.



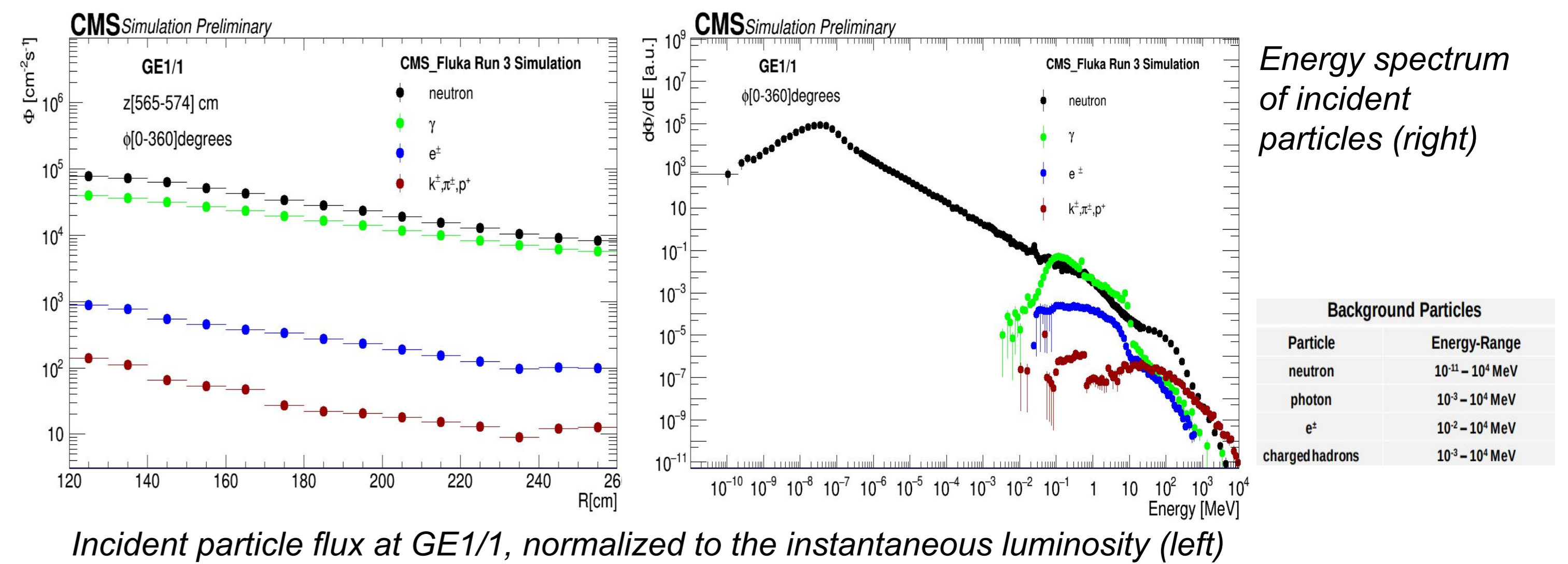
FLUKA Simulation

FLUKA simulation of CMS is performed for 6.8 TeV per beam proton-proton collision and particle fluxes, differential energy spectrum (dN/dE) for

- Luminosity $1.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
- $120 \text{ cm} < R < 260 \text{ cm}$
- $565 \text{ cm} < Z < 574 \text{ cm}$



FLUKA RUN 3 GEOMETRY v5.4.50



Incident particle flux at GE1/1, normalized to the instantaneous luminosity (left)

GEANT4 Simulation

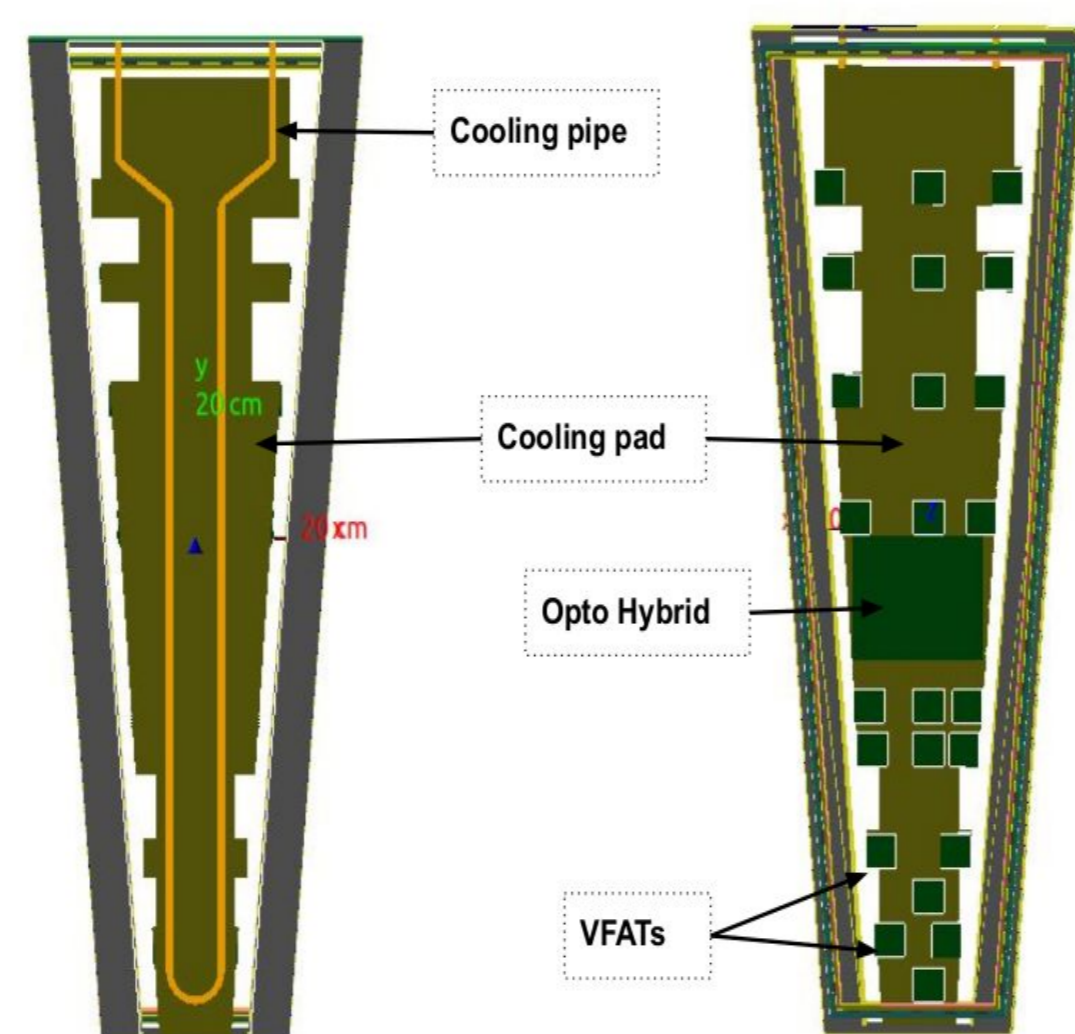
GEANT4-simulated sensitivity, defined as the probability that a particle interacts in the sensitive material and generates a signal.

$$\text{Sensitivity} = \frac{\text{Numbers of Detected Events}}{\text{Number of Events fall on the Detector Surface}}$$

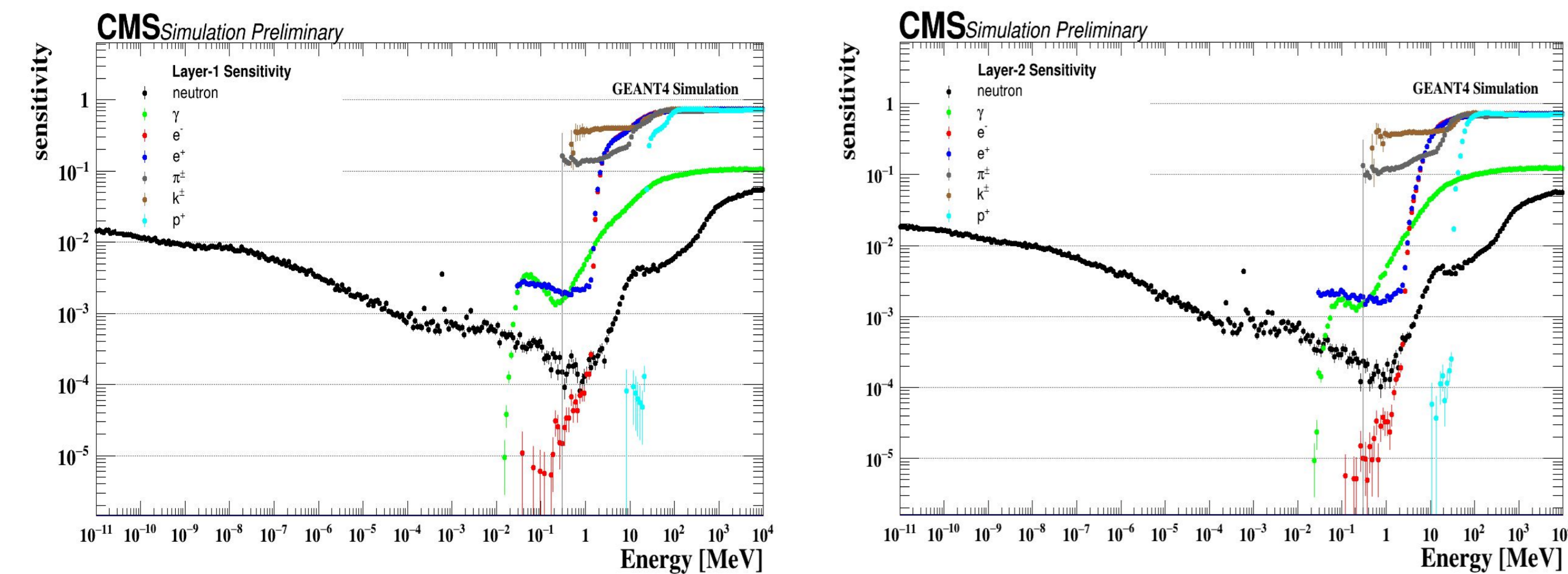
Threshold used for Triple-GEM at Gain $\sim 15,000$

Parameters	10 femtocoulomb (fC)	
	Drift Gap	Transfer-1 Gap
Minimum number of electrons in gap	5	103
Energy Thresholds	140.5 eV	2894.3 eV

(Drift & Transfer-1 Gap are used as sensitive volume)



Updated GE1/1 geometry for Run 3



Sensitivity as a function of energy for background species in layer-1 (left) and Layer-2 (right) of GE1/1 superchamber

Hit Rate Calculation

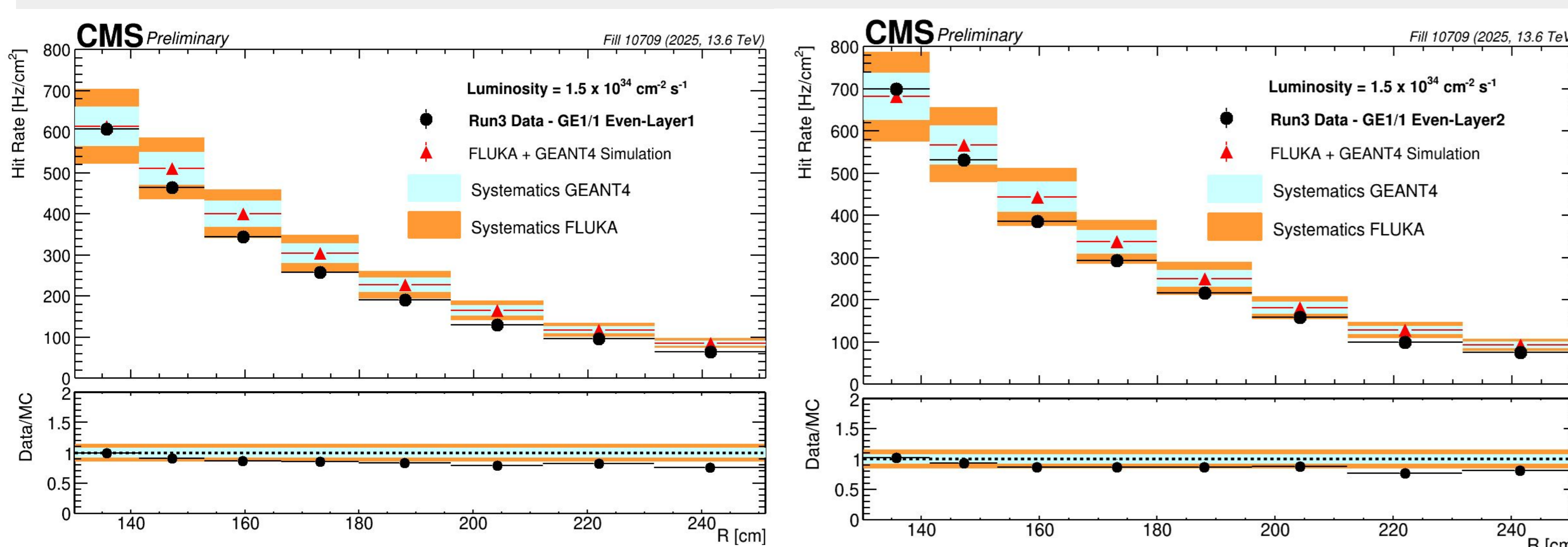
Run 3 updated study of the GE1/1 detector response to LHC background particles. The results provide background hit rate estimates for the ME0 detector ($2.0 < |\eta| < 2.8$), planned for installation before Run 4.

$$\text{Hit Rate} = \sum_{\text{type}} \text{Sensitivity}(\text{type}, E, \theta) \otimes \text{Flux}(\text{type}, E, \theta, R)$$

Particle	Sensitivity of Layer-1 (%)	Sensitivity of Layer-2 (%)
Neutron	0.70 ± 0.01	0.83 ± 0.01
Photon	0.25 ± 0.01	0.20 ± 0.01
e^\pm	1.49 ± 0.01	0.31 ± 0.01
Charged Hadron (π^\pm , K^\pm , p)	10.2 ± 0.51	9.14 ± 0.51

- Sensitivity of Layer-1 for neutrons is less as compared to Sensitivity of Layer-2 because the cooling material (Cu) slows down neutrons, increasing the interaction and the production of secondary particles that create a detectable signal in Layer-2.
- For e^\pm , and charge hadrons (more likely from interaction point), Layer-1 is more sensitive than Layer-2 as they tend to interact and get absorbed in Layer-1.

Comparison of Run 3 data and Simulation



Comparison of Run 3 data with FLUKA and GEANT4 predictions for Layer-1 (left) and Layer-2 (right) of the Even superchamber, shown as a function of radial distance. The radial coordinate R corresponds to the distance from the beamline to the center of each pseudorapidity region.

Comparison of Run 3 data with FLUKA and GEANT4 predictions for Layer-1 (left) and Layer-2 (right) of the Odd superchamber, shown as a function of radial distance.

