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Abstract

The sPHENIX detector at Brookhaven National Laboratory's (BNL) Relativistic Heavy Ion Collider (RHIC) began data acquisition in 2023. Its primary objective is to investigate the microscopic properties of the Quark-Gluon Plasma (QGP) through high-precision measurements of jets and heavy flavor observables. A key feature of the sPHENIX detector is the inclusion of hadronic calorimeters (HCals) at mid-rapidity, which are essential for the jet physics program. Accurate jet reconstruction demands properly calibrated sPHENIX calorimeter systems during the entire data collection process. This study aims to build on previous cosmic testing efforts, which were conducted using individual HCal sectors in test benches, by investigating the potential for cosmic calibration with the complete sPHENIX apparatus in its data-taking position. In this poster, we will present a GEANT4-based study that employs a cosmic muon generator with a realistic zenith angle and energy distribution to examine the possibility of calibrating the HCals to the Minimum Ionizing Particle (MIP) scale using cosmic muon events. The muon rate predictions and observations will be utilized to plan routine cosmic running, ensuring the maintenance of the calibration for the lifetime of the sPHENIX experiment.

sPHENIX Hadronic Calorimeters

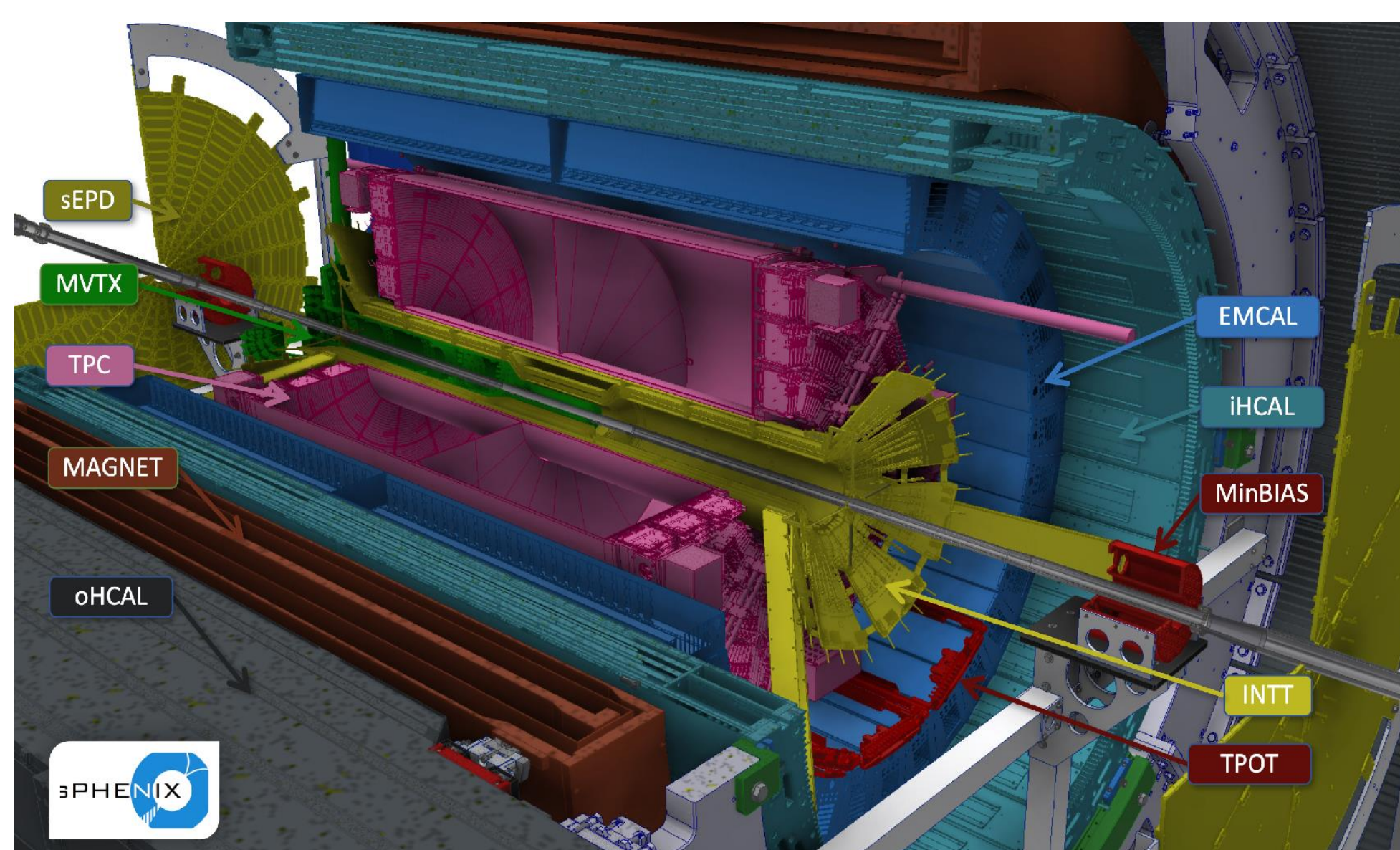
Acceptance:

$$-1.1 < \eta < 1.1$$

$$0 < \phi < 2\pi$$

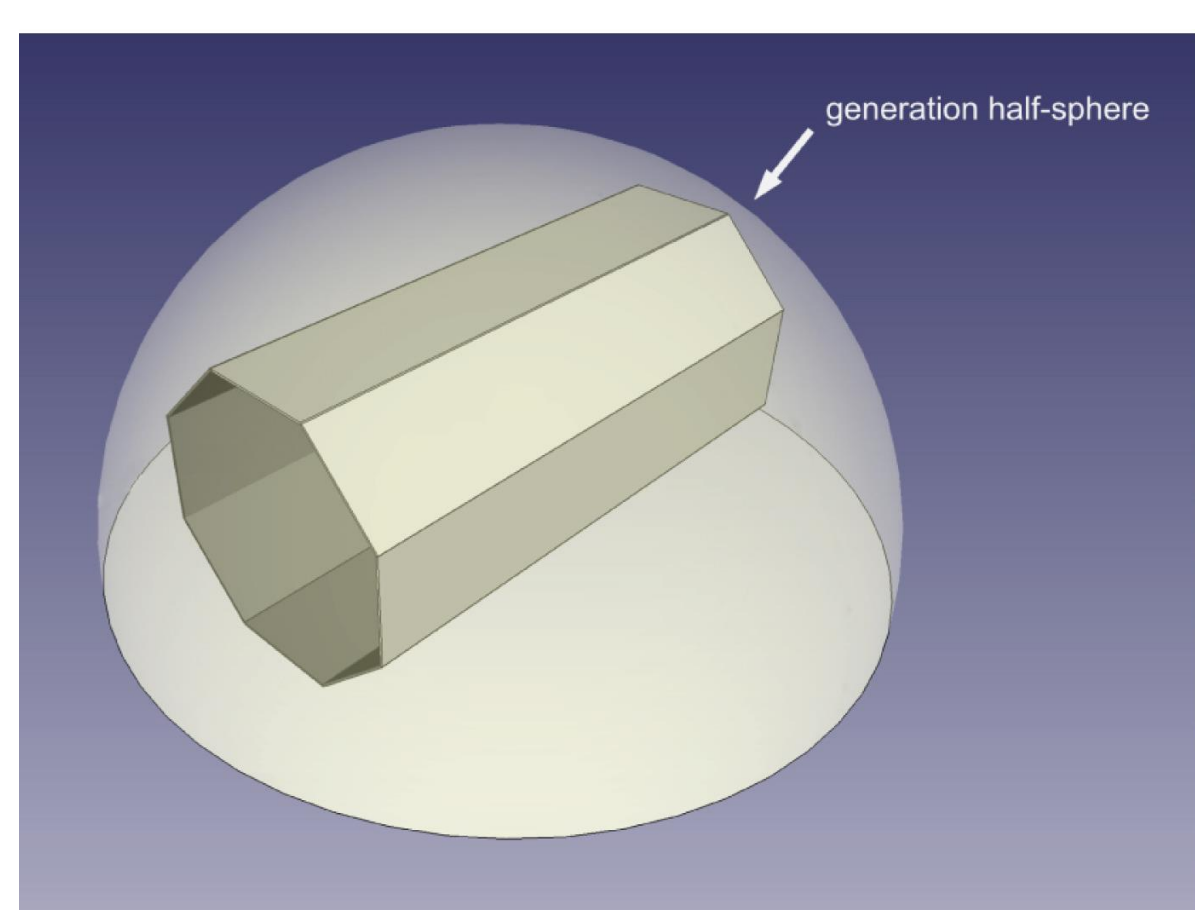
64 towers along ϕ
24 towers along η

It's important to establish initial electromagnetic energy scale calibration via cosmic muon.



Simulation Setup

- The cosmic muon generator that was used in this study was based on open-source cosmic muon generator EcoMug[1].
- The muons are generated on the surface of a half-sphere with radius of 6.5 meters covering the entire sPHENIX detector, any surface within this will receive a realistic cosmic muon flux.



Offline Muon Selection

ϕ^{twr}	< 350	> 1500	< 350
	< 350	> 500	< 350
	< 350	> 1500	< 350
	η^{twr}		

Tower Cuts(ADC)

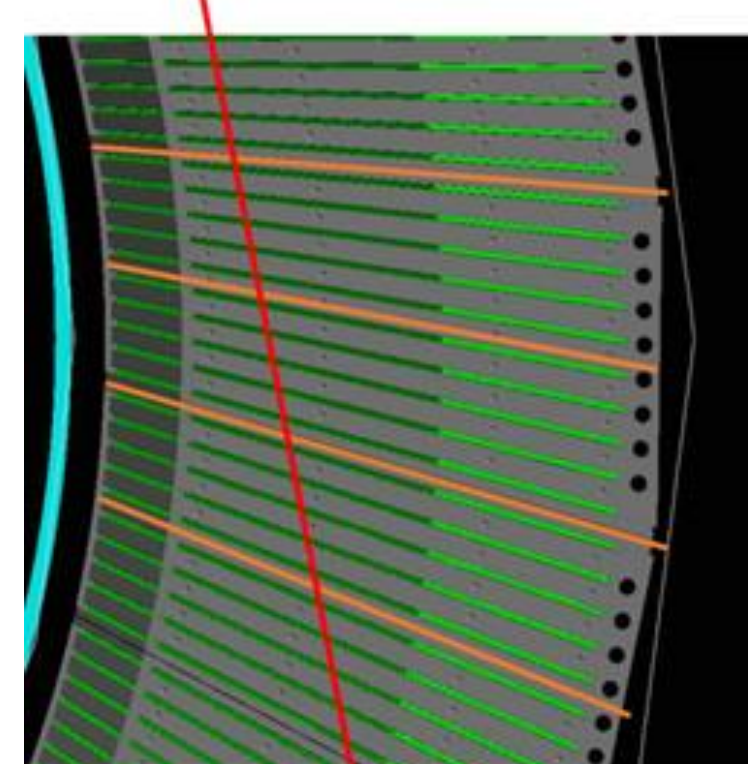
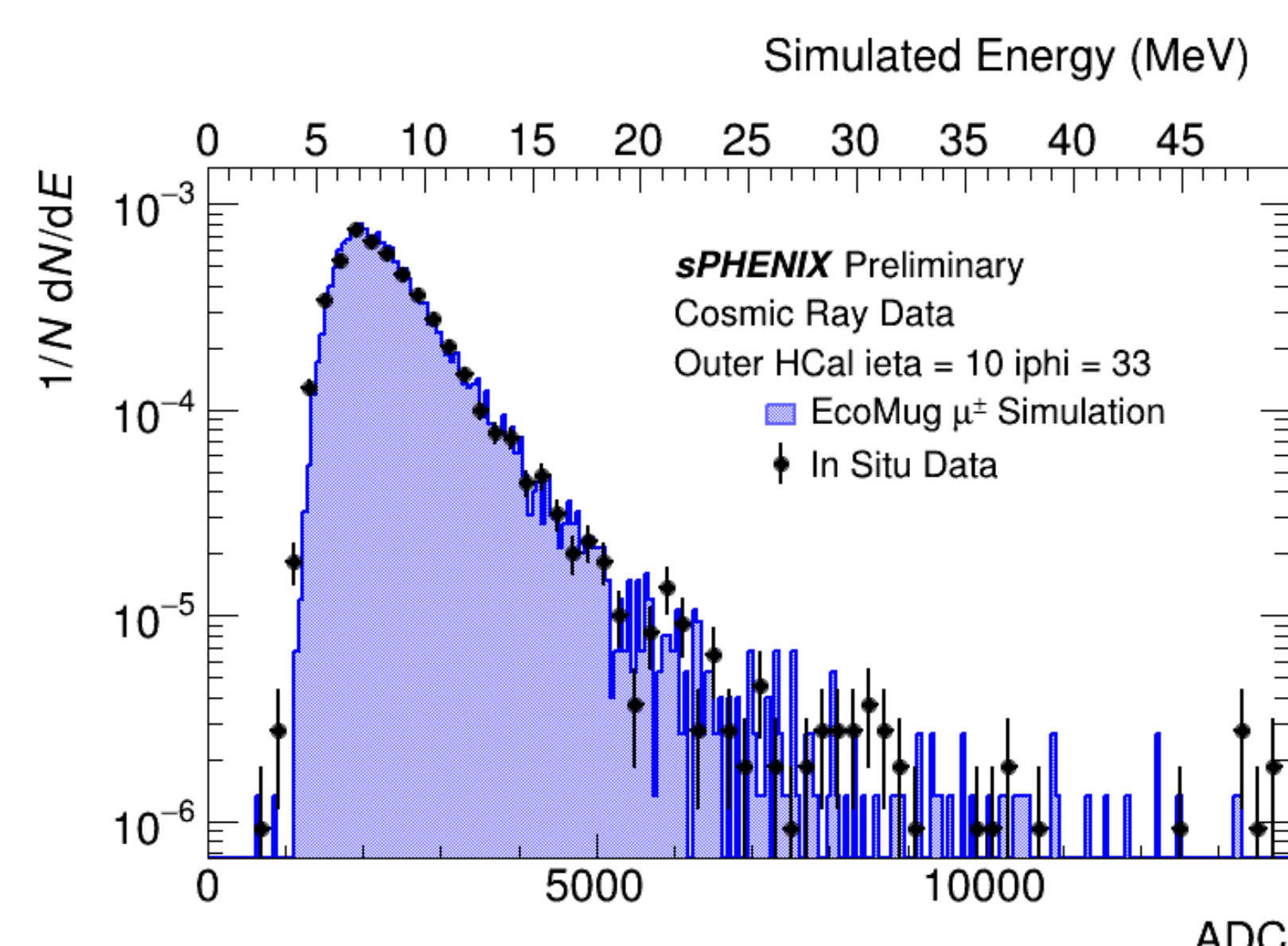


Illustration of a muon path that would pass the offline cuts

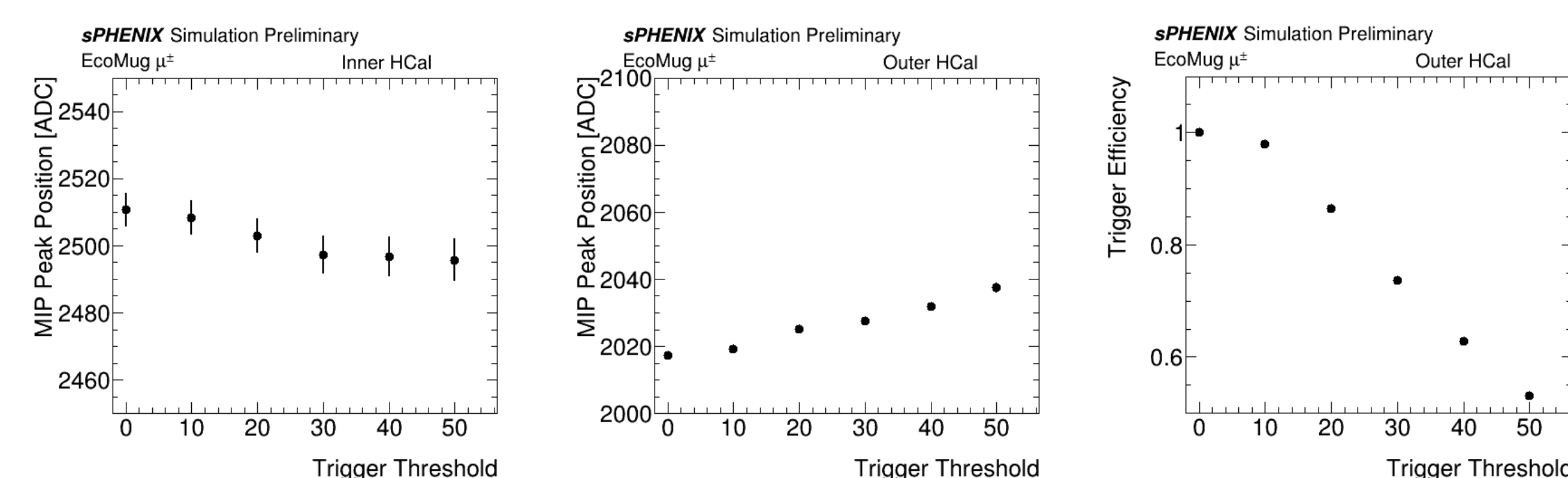
- The purpose of the offline cut is to select muon events that are roughly perpendicular to the scintillating tiles and pass through the tower of interest entirely.
- The MIP energy distribution for a single OHCAL tower after the offline selection cut demonstrates a good agreement between data and MC. The fitted peak positions of such distributions are used to derive the absolute tower-by-tower calibration (See poster 502 by Hanpu Jiang for more detail).



Cosmic Trigger Emulation

An HCal cosmic trigger emulator was employed to simulate the effect of the cosmic trigger on the collected event sample (See poster 497 by Daniel Lis for more on sPHENIX trigger):

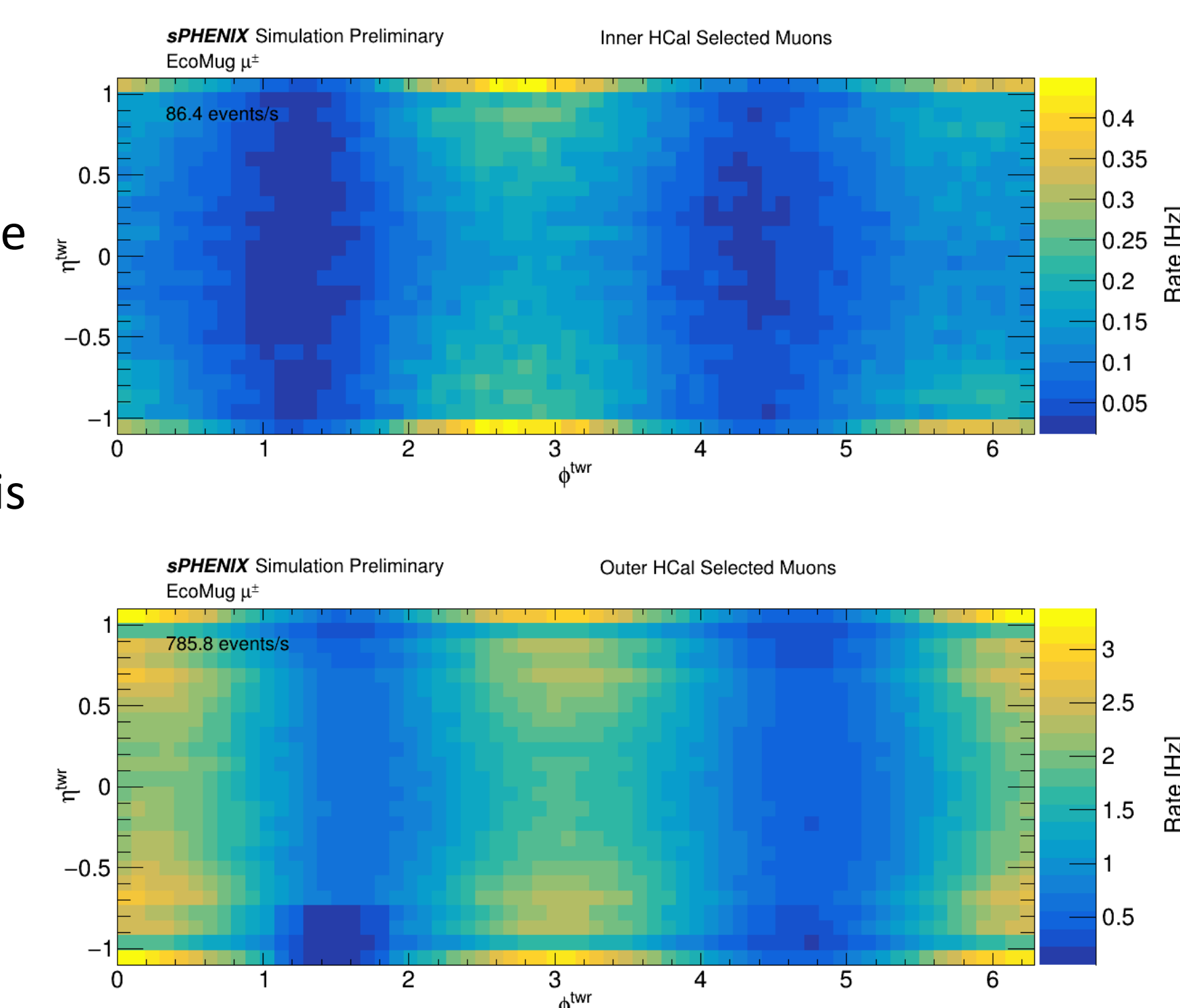
- Every G4Hit in each tower is transformed and summed into a waveform, utilizing a data-driven waveform template. The timing of the event is randomized relative to the start of the 31 time samples in the digitizers.
- This waveform is then fed into the trigger emulator, which operates on a per-beam clock basis, covering 6 time samples.
- The emulator evaluates the 2x2 sum for each tower's ADC, from which the ADC value from 6 samples prior is subtracted.
- If the sum from outer HCal, after being right-shifted by 6 bits, exceeds the established threshold, the trigger is fired.



For a trigger threshold set at 10 - the value used predominantly in our cosmic data capture - the bias was observed to be under 0.5% for the peak position, and the efficiency for the cosmic muon events passing the offline selection is close to unity.

Cosmic Muon Rate

- The good muon rate that gives well-defined MIP peaks in the OHCAL towers ranges from 0.3 - 3Hz. For IHCAL the good muon rate is from 0.03 - 0.5 Hz due to the smaller tower size.
- The ϕ dependence of the rate comes from the fact that the cut is selecting muons that are roughly perpendicular to the scintillating tiles, which for towers around $\phi = \pi/2$ (top of the barrel) and $\phi = 3\pi/2$ (bottom of the barrel) requires near-horizontal incident muon angles.



Conclusions

Through GEANT4-based simulations incorporating a realistic cosmic muon generator and a trigger emulator, we have established an accurate representation of the cosmic flux and the subsequent trigger and detector response. This simulation not only offers rate estimates for cosmic muons events but also the ability to determine the initial electromagnetic energy scale for the HCals. Such a method paves the way for routine cosmic running, ensuring consistent and accurate calibration of the sPHENIX calorimeter systems throughout the experiment's duration.

Acknowledgements

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[1]: D. Pagano et al. "EcoMug: An Efficient COsmic MUon Generator for cosmic-ray muon applications".
doi: <https://doi.org/10.1016/j.nima.2021.165732>.