Calibrated Cosmic Muon simulations for the sPHENIX Hadronic Calorimeters

Shuhang Li, Hanpu Jiang, Emma McLaughlin, Blair Seidlitz, Bill Zajc

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sPHENIX Hadronic Calorimeters

Acceptance:

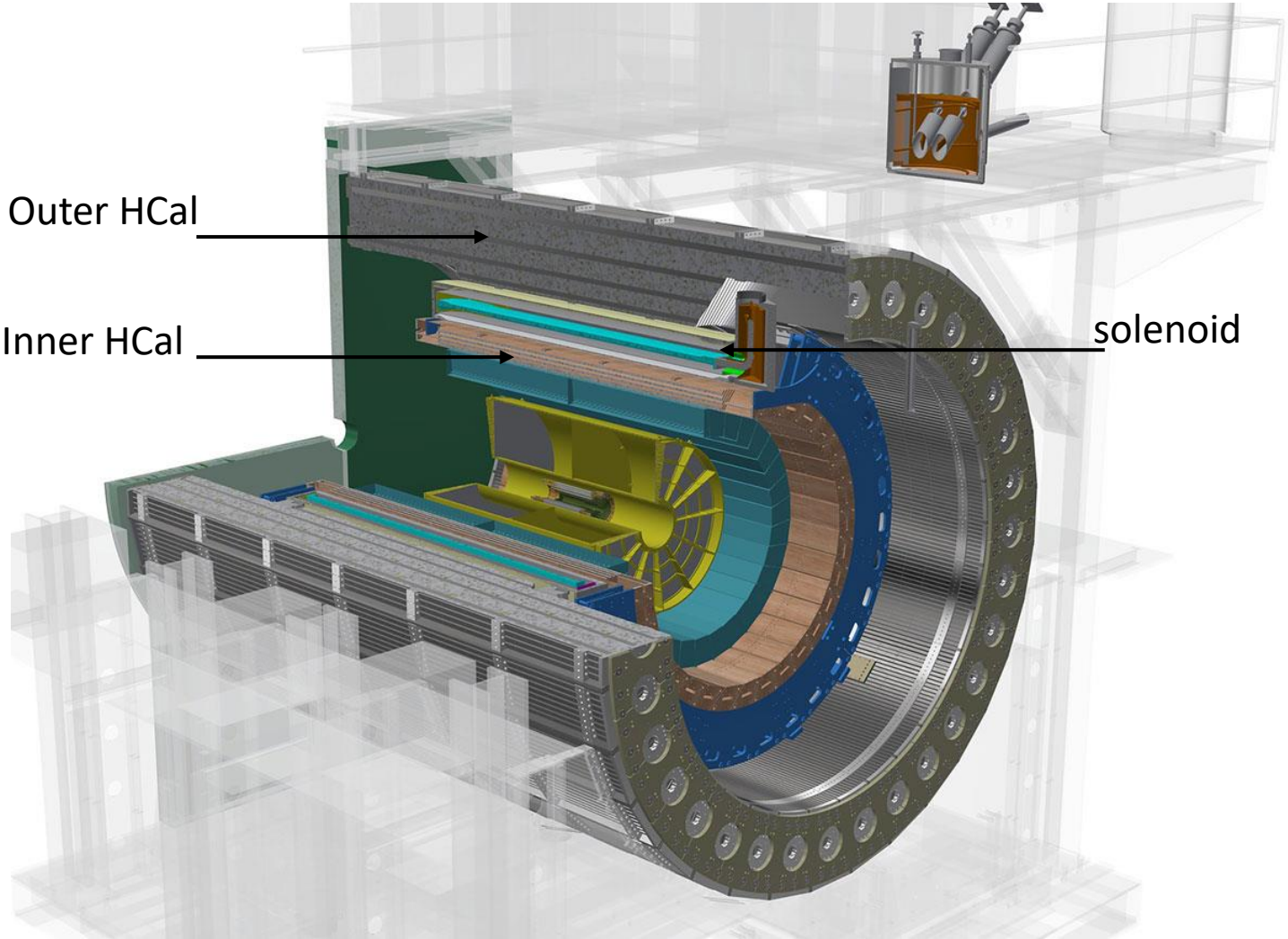
$$-1.1 < \eta < 1.1$$

$$0 < \varphi < 2\pi$$

64 towers along φ

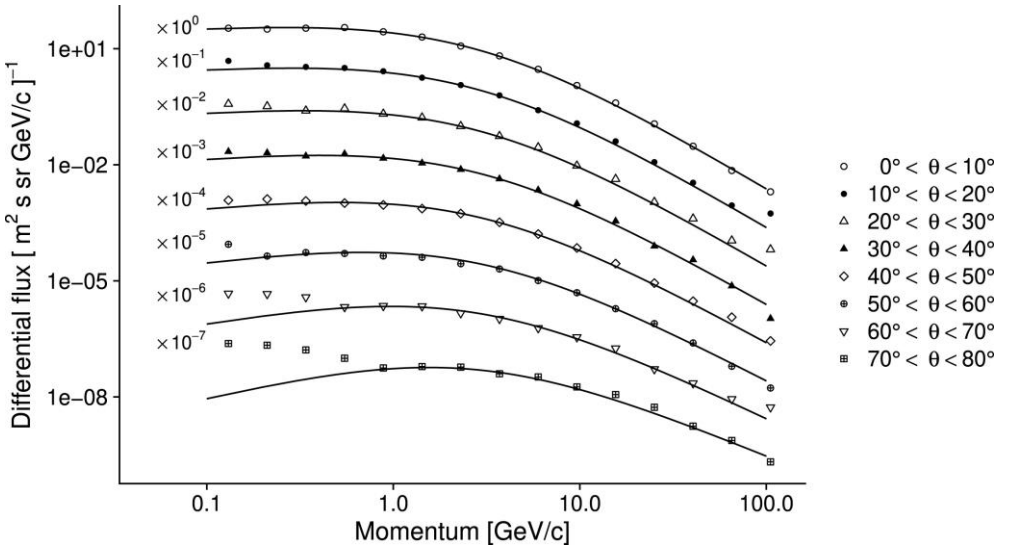
24 towers along η

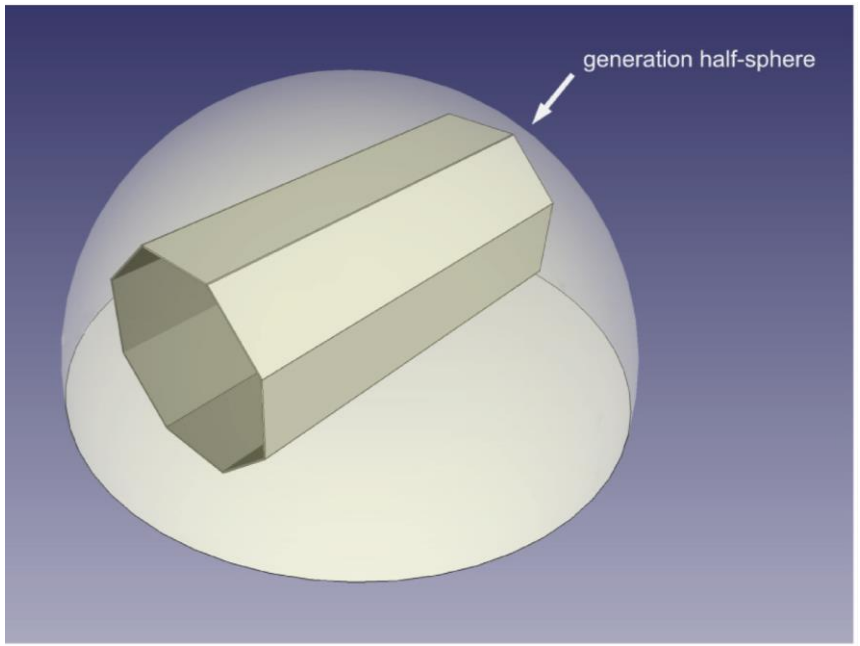
- It's important to establish absolute energy calibration via simulation.



Muon Generator & 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. The muon flux and angular distribution is realistic anywhere in the half sphere.
- The outer HCal(OHCal), inner HCal(IHCal), and the magnet was built in the GEANT4 simulation.

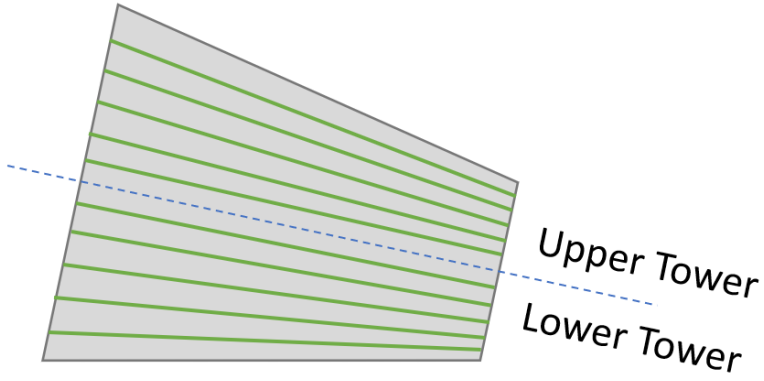




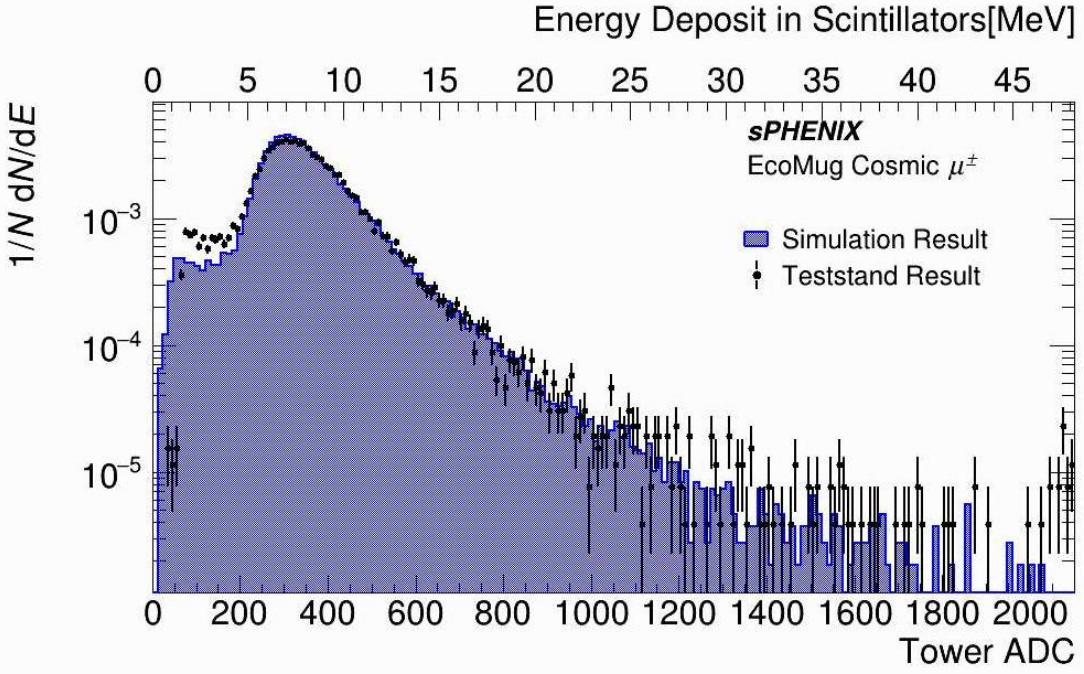
[1]: D. Pagano et al. “EcoMug: An Efficient COsmic MUon Generator for cosmic-ray muon applications”.
doi: https://doi.org/10.1016/j.nima.2021.165732.

Comparison to Test Stand Data

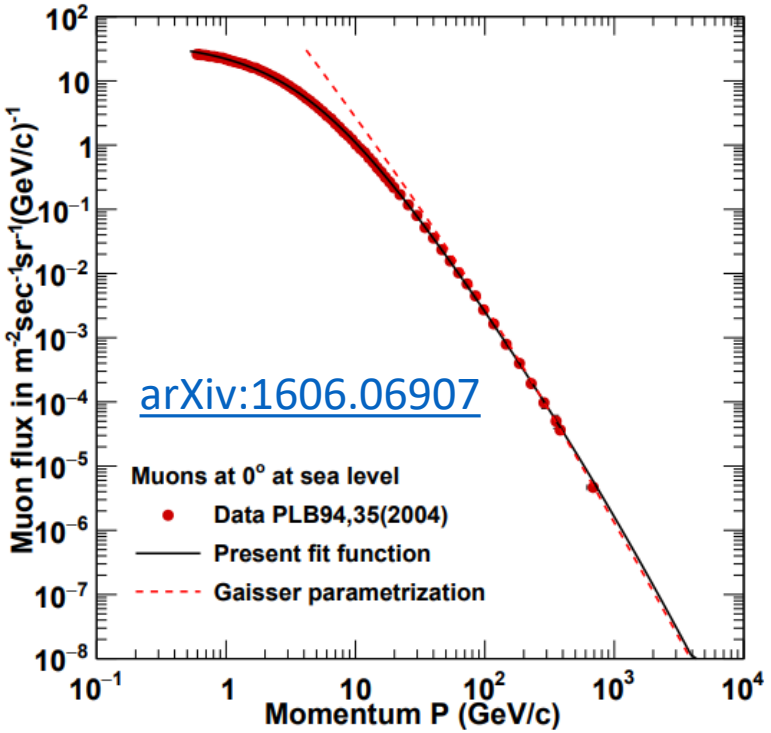
- A single OHCal sector was built in the same orientation as was used during cosmic testing, a same set of cuts are applied. This worked as a good test for the validity of the cosmic muon generator as well as the GEANT4 simulation.
- The self normalized simulated energy distribution agrees well with the test stand data.
- It's possible using cosmic simulation to establish an initial energy calibration.

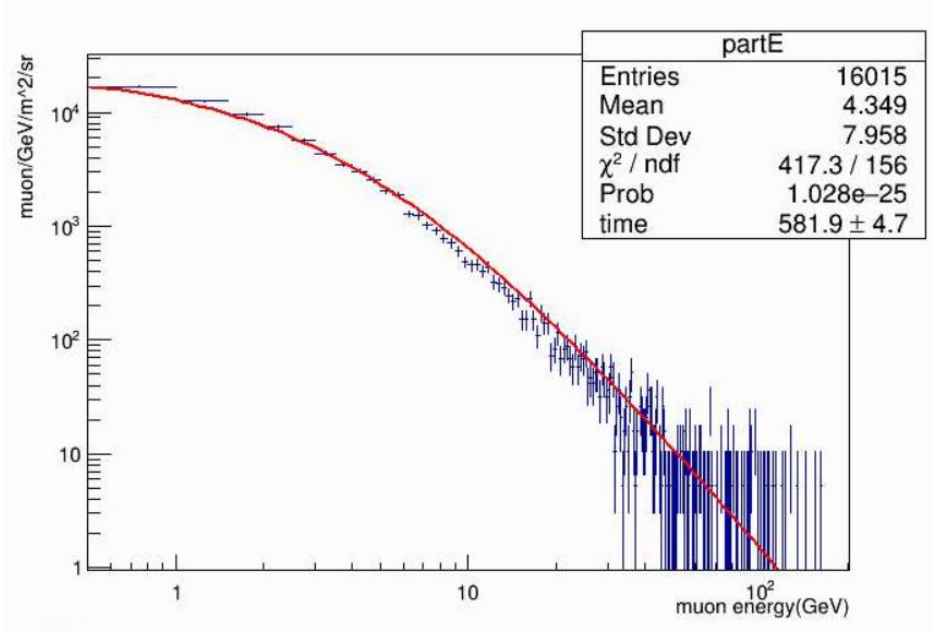


Test orientation for outer HCal



Determine the Muon Rate





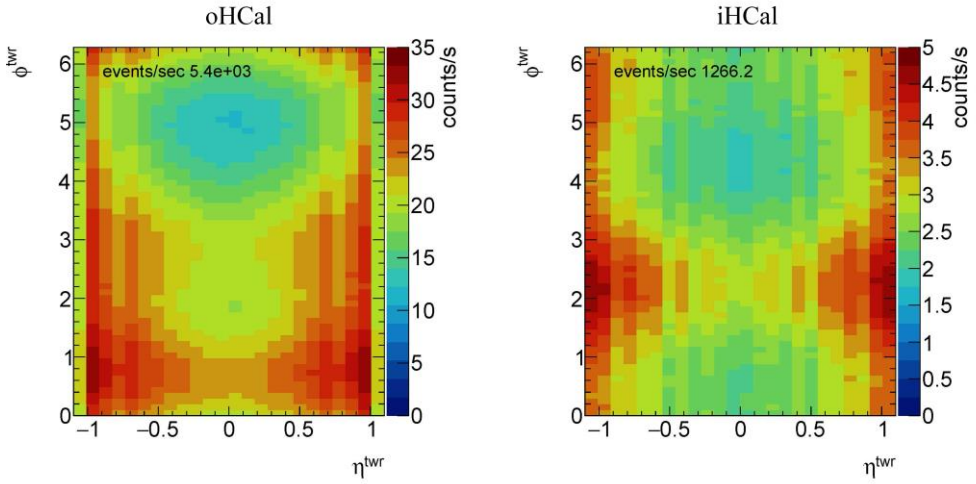
$$I(E, \theta = 0) = I_0 \; N \, (E_0 + E)^{-n} \left(1 + \frac{E}{\epsilon}\right)^{-1}$$

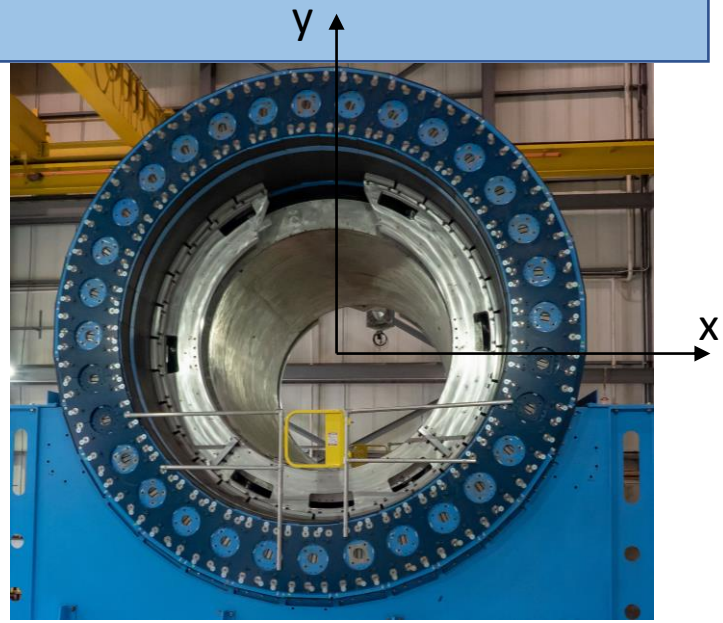
	I_0 (m^{-2} s^{-1} sr^{-1})	n	E_0 (GeV)	$1/\epsilon$ (GeV)$^{-1}$	χ^2/ndf	Data Reference
μ at 0° sea level (E>0.5 GeV)	70.7 ±0.2	3.01 ±0.01	4.29 ±0.04	1/854	128/63	Tsukuba, Japan (36.2^o N, 140.1^o W)

arXiv:1606.06907

- For the simulated muon events, the corresponding time in real-world to have the same amounts of events is determined by performing a single parameter fit to the muon energy distribution.

Muon Rate Calculation





Muon counts per second for individual towers

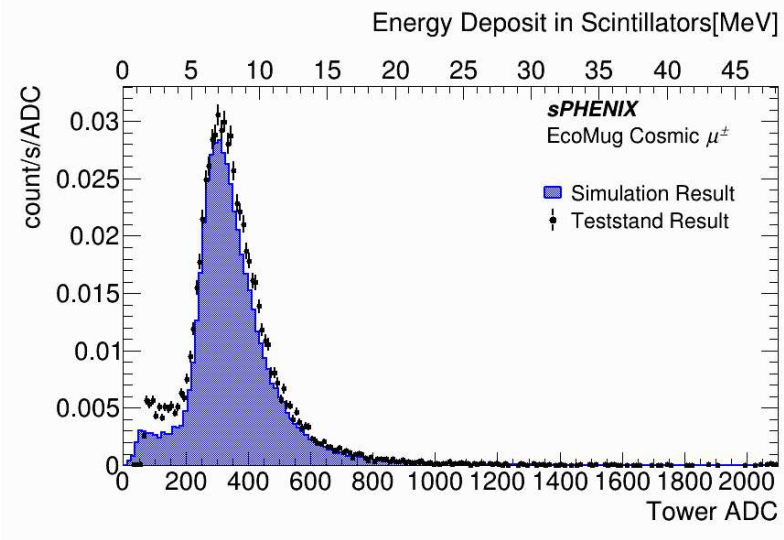
OHCal

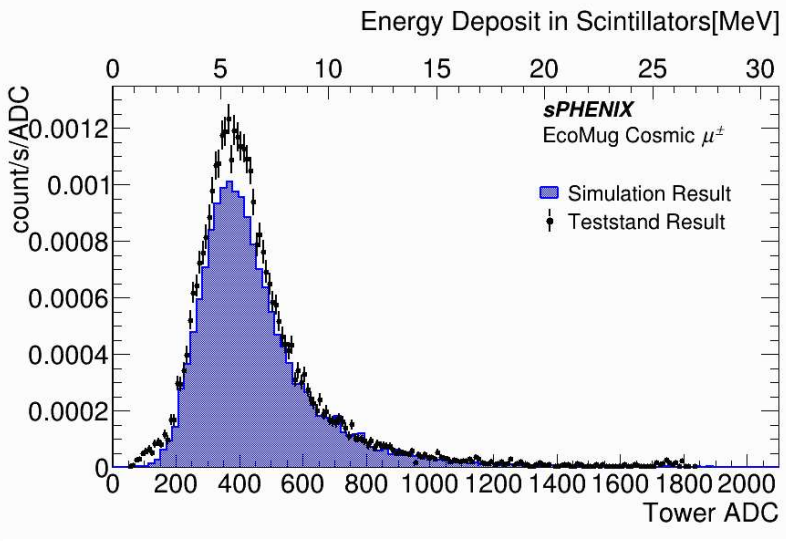
IHCal

Projective area:
IHCal 9 m^2
OHCal 36 m^2

The overall muon flux agrees with the common estimation of 1 muon/cm^2/min.

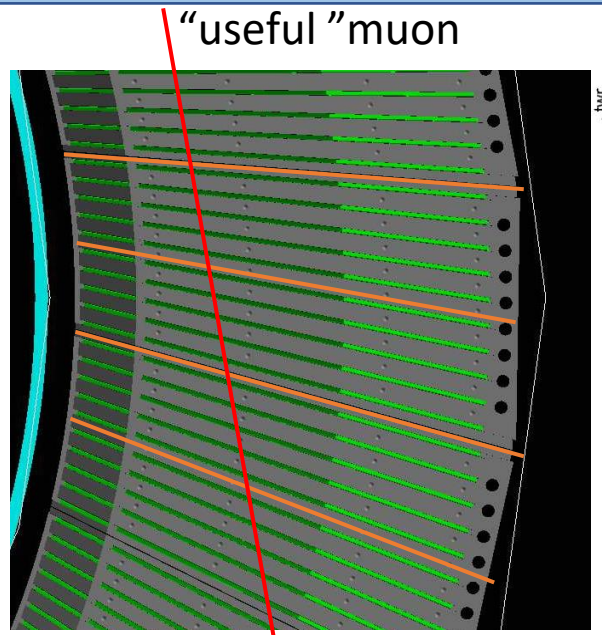
Muon rate per tower after cut agrees with test stand data within 40%.



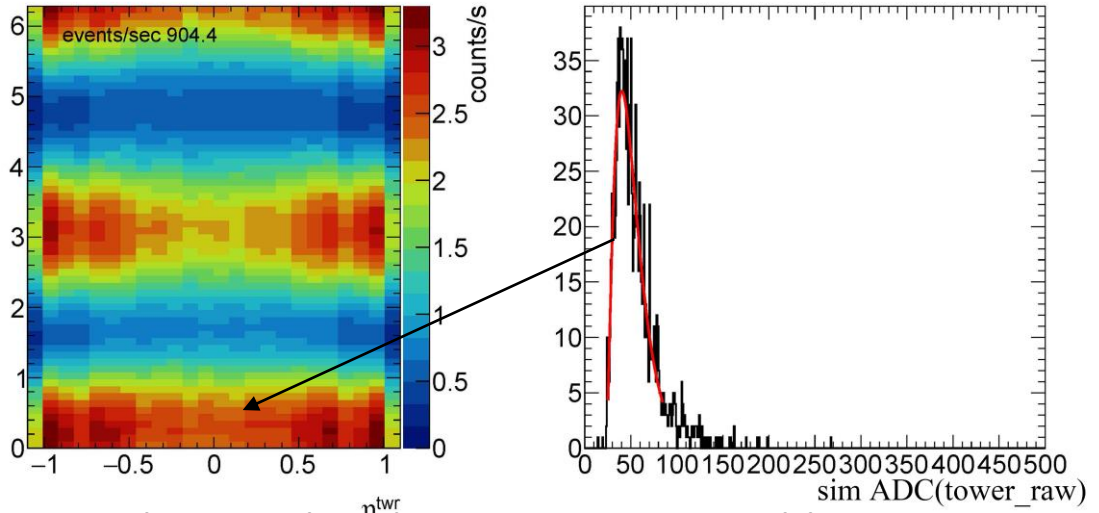


Event Selection

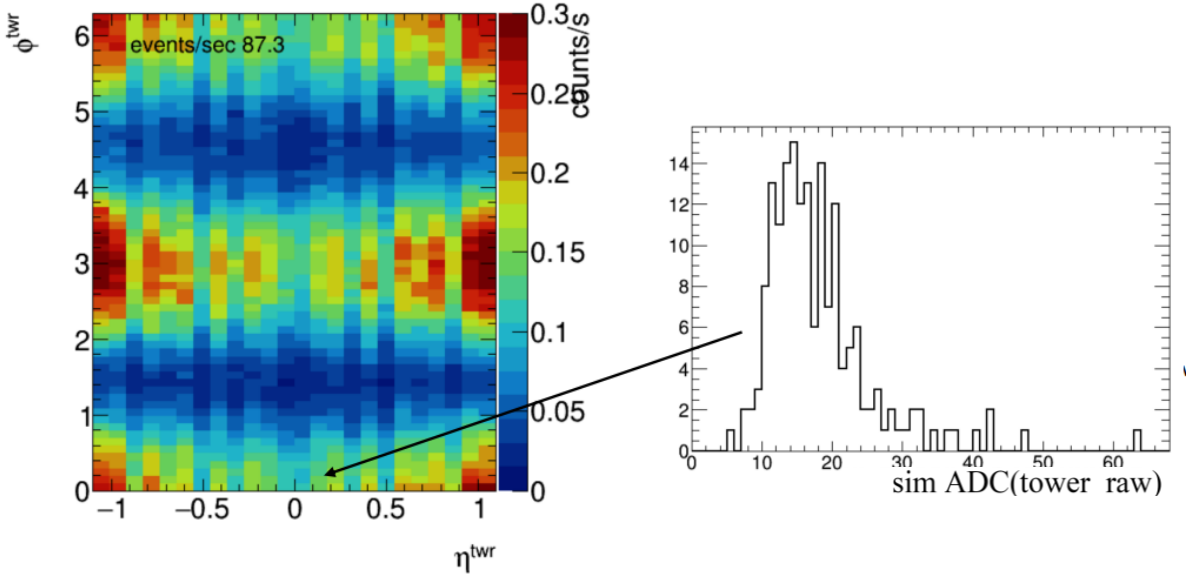
- The offline cut is determined to select muons that pass through all tiles of tower of interest.
- The rate of “useful” muon event per tower is about 0.03 Hz in the worst case, means that a useful MIP calibration peak can be developed in a 12-24 hours run. It takes one order of magnitude less time for OHCal.



OHCal, 1 simulated ADC ≈ 0.2 MeV visible energy



IHCal, 1 simulated ADC ≈ 0.4 MeV visible energy



OHCal
Tower cuts

<6	> 20	<6
<6	> 6 (Tower of interest)	<6
<6	>20	<6

φ^{twr} η^{twr}

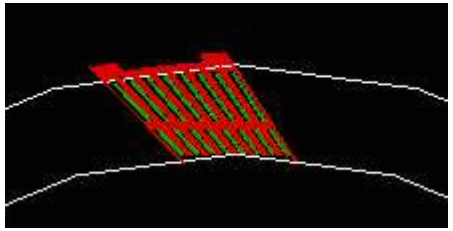
IHCal
Tower cuts

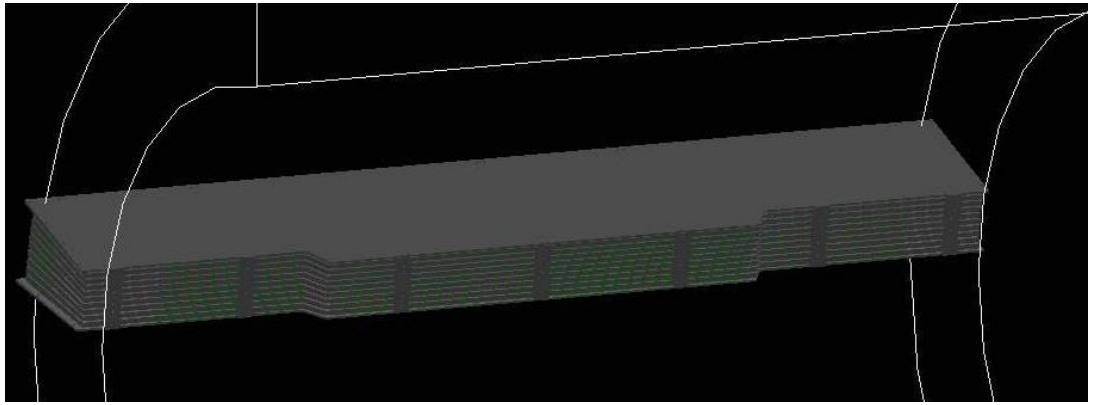
<4	> 10	<4
<4	> 4 (Tower of interest)	<4
<4	>10	<4

φ^{twr} η^{twr}

Current Developments

- A new GEANT4 setup which has a much more realistic description of the Hcal.
  - Repeat the same procedure with the new setup.
  - Build a single IHCal/OHCal sector in the simulation with the same orientation as testing.
  - “Tune” the noise in the simulation for better agreement with the cosmic testing data.
- Investigate the optimized cosmic trigger for different noise levels.
- Take cosmic event data with HCal in the data taking position.





Conclusion

- Implemented a realistic muon generator in sPHENIX simulation
- Demonstrated ability to establish E-scale using single sector simulation
- Demonstrated the possibility of using cosmic muon events as a calibration source for HCal's when the full sPHENIX apparatus is in its data-taking position.

Thanks!