# Calibration of sPHENIX Hadronic Calorimeter using Isolated Single Hadrons

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

APS DNP Meeting October 29th 2022

This work was supported by the US Department of Energy

Grant DOE-FG02-86ER-40281

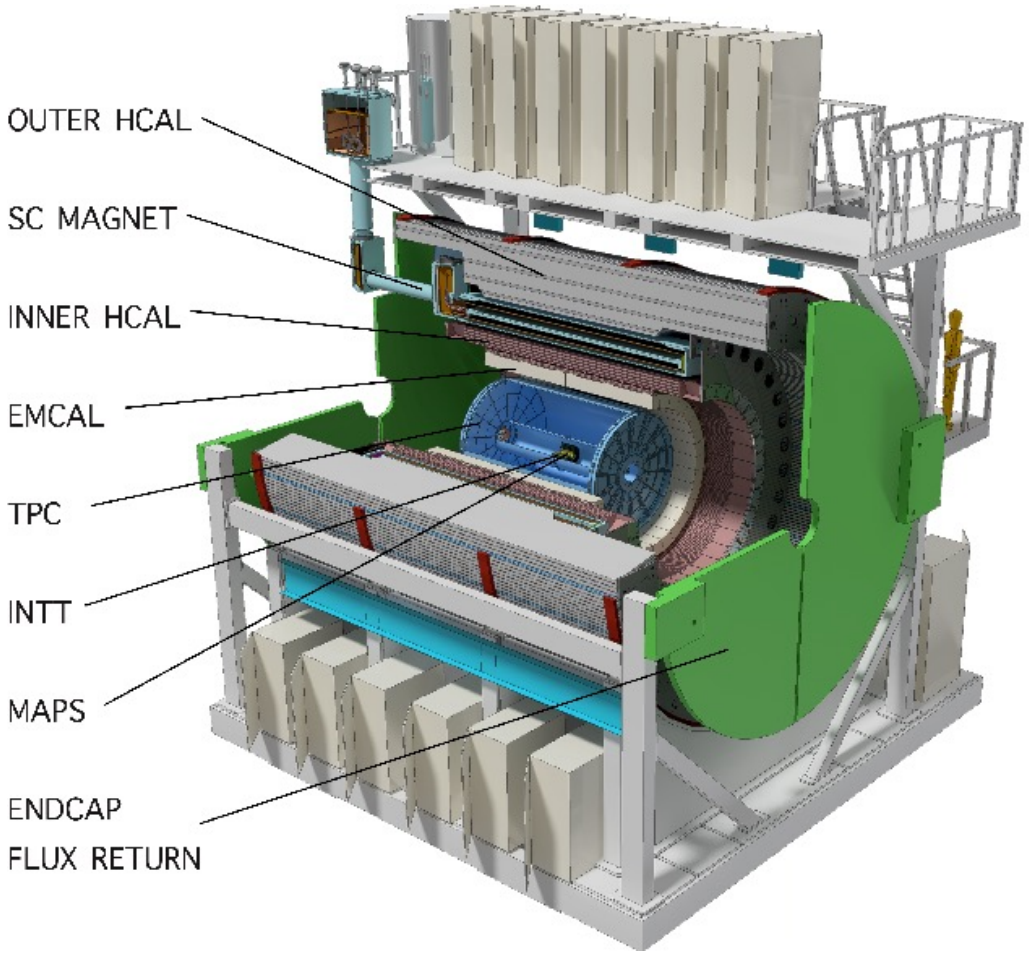
sPHENIX

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

# Motivations for this method of calibrating the sPHENIX hadronic calorimeter (Hcal)

The hadronic calorimeters will be calibrated via techniques such as Minimum Ionizing Particle (MIP) energy deposition from cosmic muons (see talks by H. Jiang and S. Li)

Additional single isolated hadron calibration can be useful as an in situ calibration by looking at the MIP signal in the particle going direction, calibrating to the hadronic and Jet Energy Scale and possibly preforming a tower-by-tower calibration on the hadronic scale



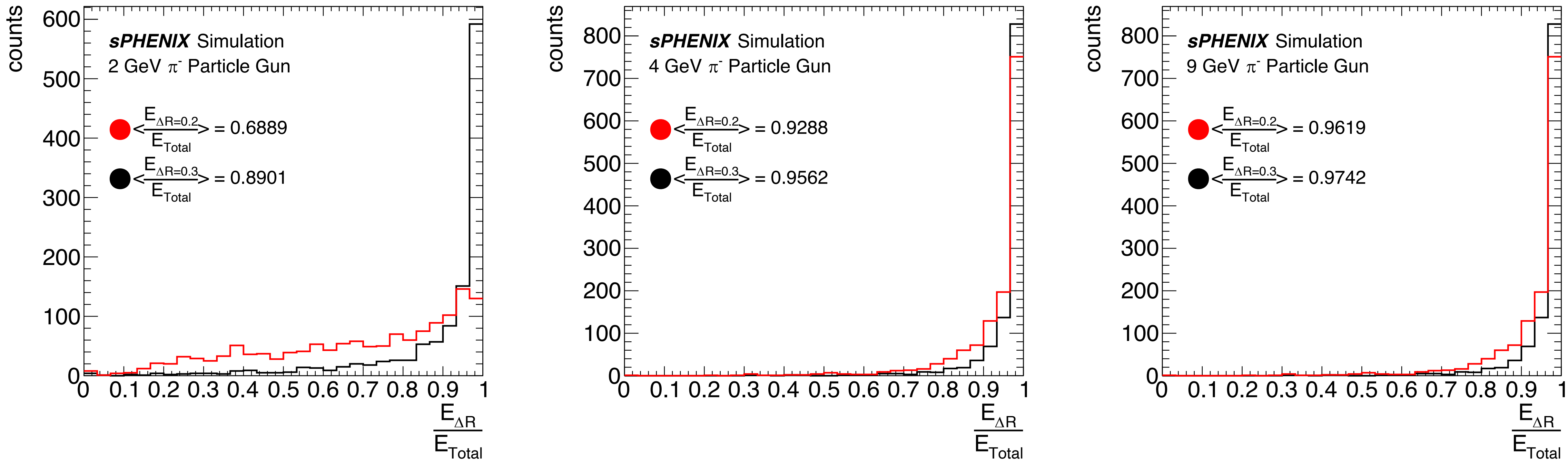
# Hadron Shower Size in Ohcal

Used $\pi^-$ particle gun of energies 2-10 GeV directed at the center of an Ohcal tower at nearly $\eta = 0$.

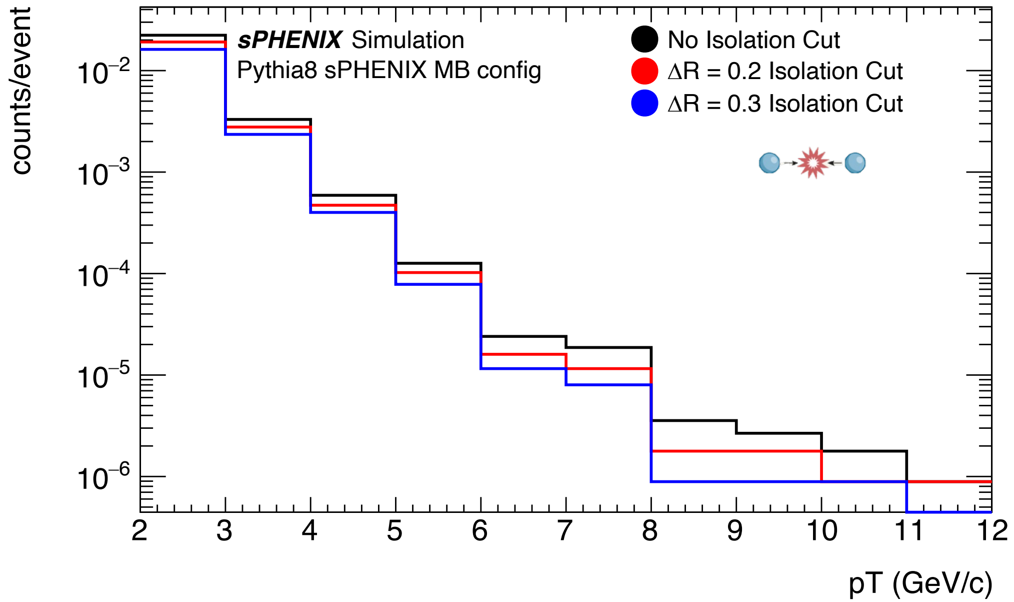
The region of towers included in the $E_{\Delta R}$ were found from $\Delta R = \sqrt{(\phi_{tower} - \phi_{particle})^2 + (\eta_{tower} - \eta_{particle})^2}$

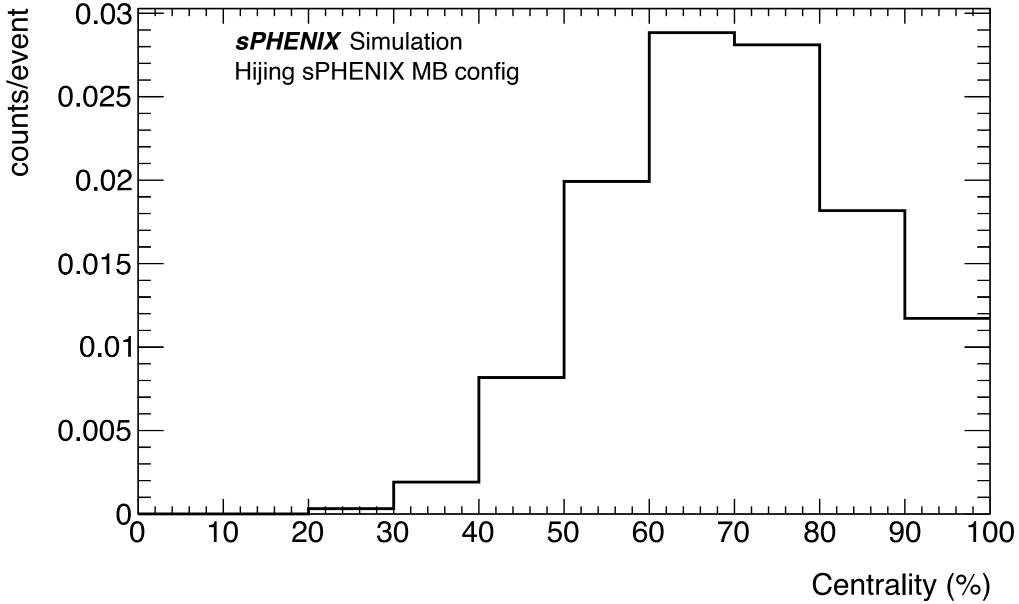
For reference, $\Delta\eta = 0.1$ and $\Delta\phi = 0.1$ for single tower in Hcals

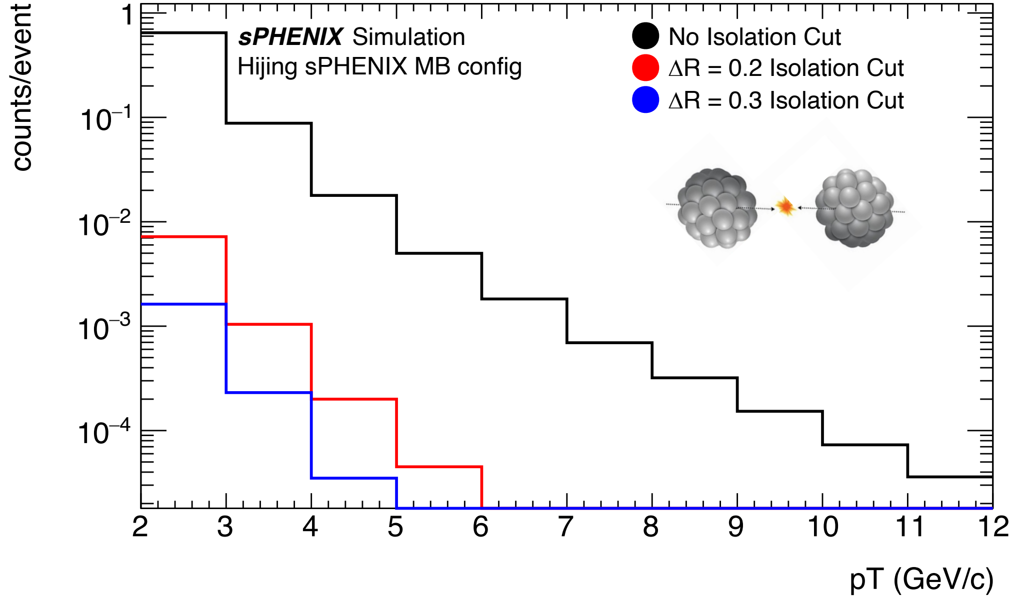
Nearly all energy deposition for $\pi^-$ with $p_T \geq 4\ GeV/c$ is contained in a tower region of radius $\Delta R = 0.2$



# Isolated high $p_T$ charged particles in Minimum Bias p+p and Au+Au




Rates of $\Delta R$=0.2 isolated particles:

| | $p_T > 2\ GeV/c$ | $p_T > 4\ GeV/c$ |
|---|---|---|
| p+p MB | 2.25% | 0.06% |
| Au+Au MB | 0.85% | 0.03% |

# Determining MIP and shower energy deposition in calorimeters

Breakdown of initial shower vertex for 4 GeV $\pi^-$ :

0.62 % MIP through detector

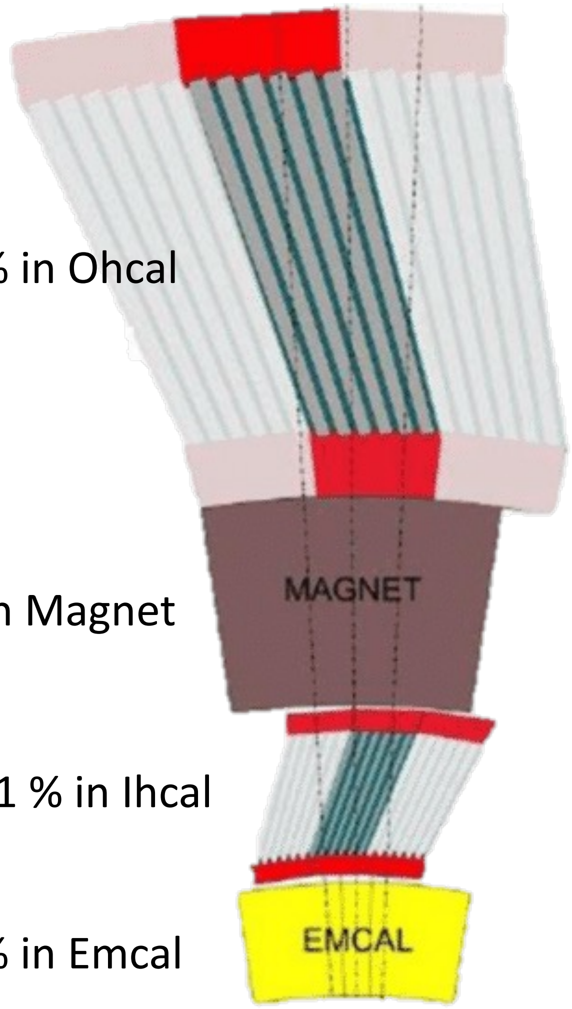
23.9 % in Ohcal

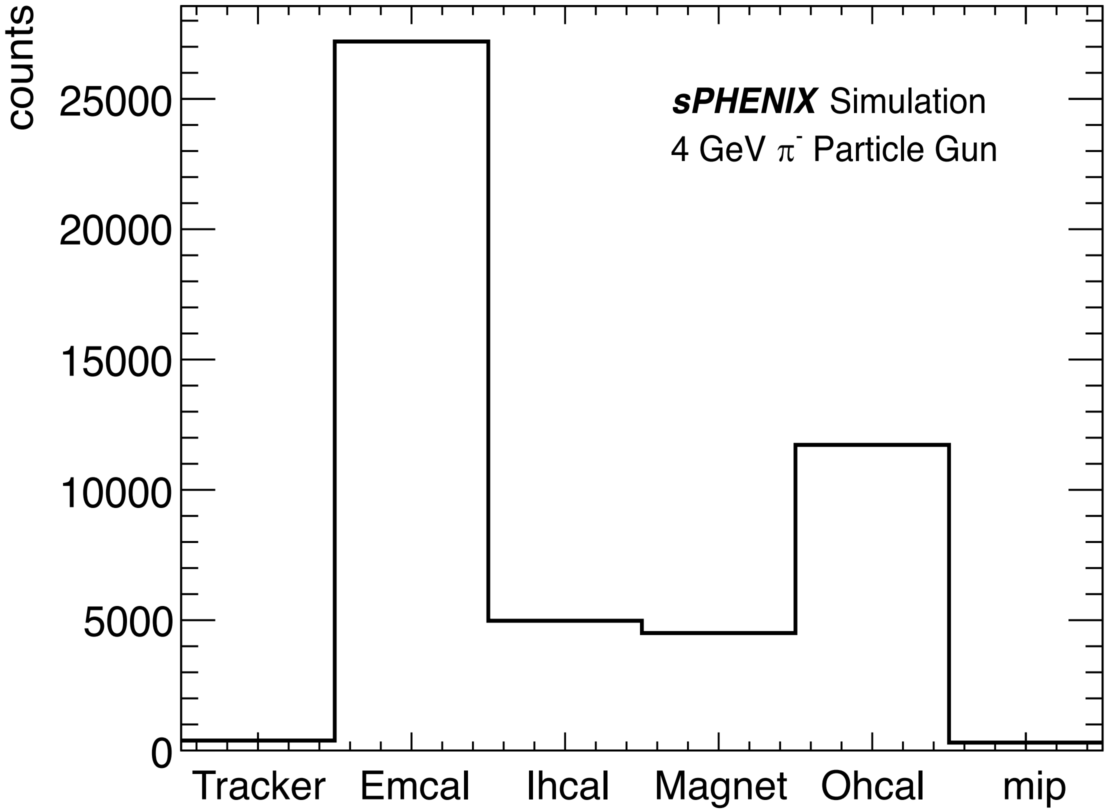
9.2 % in Magnet

10.1 % in Ihcal

55.4 % in Emcal

0.78 % before Emcal

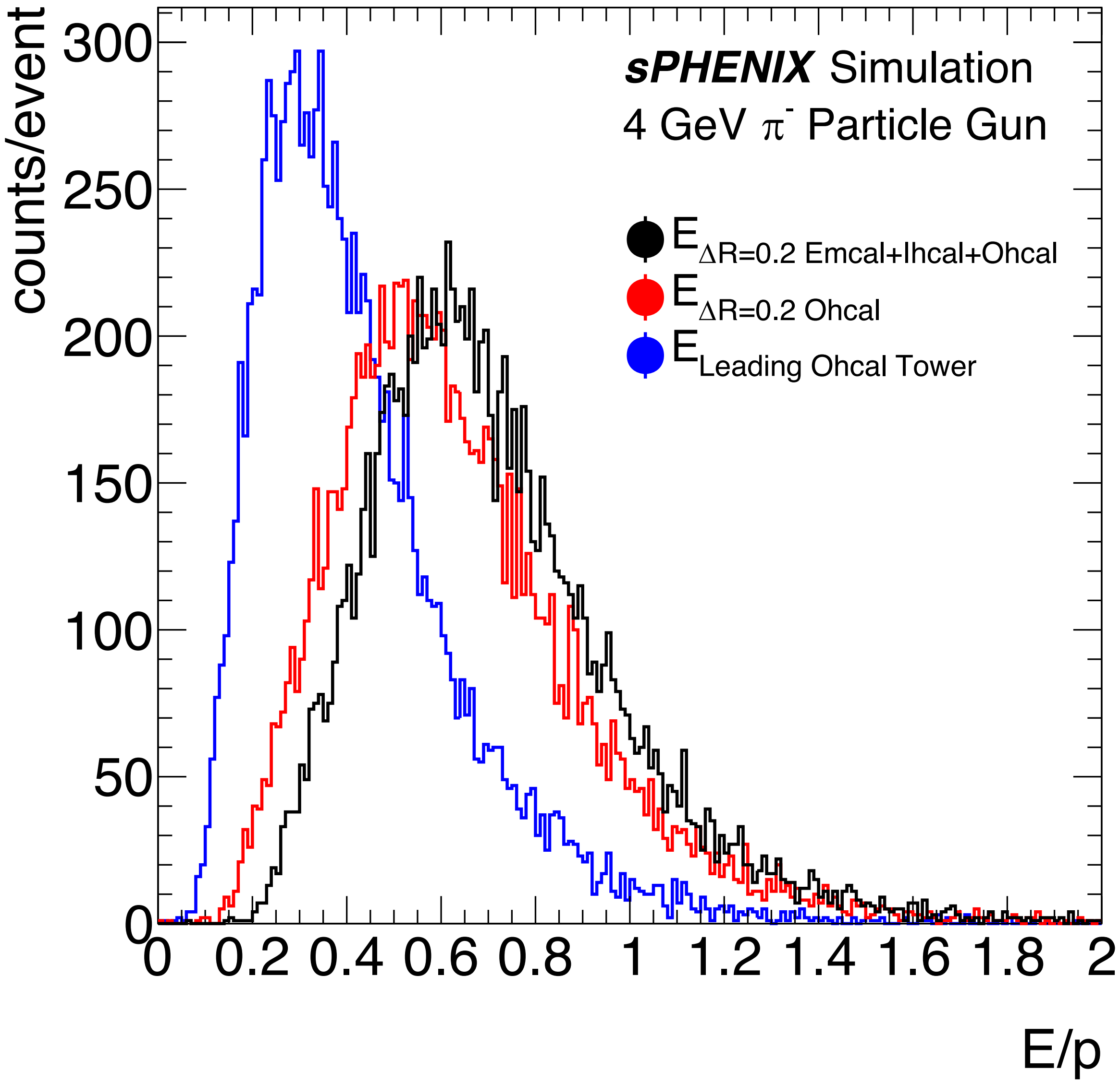


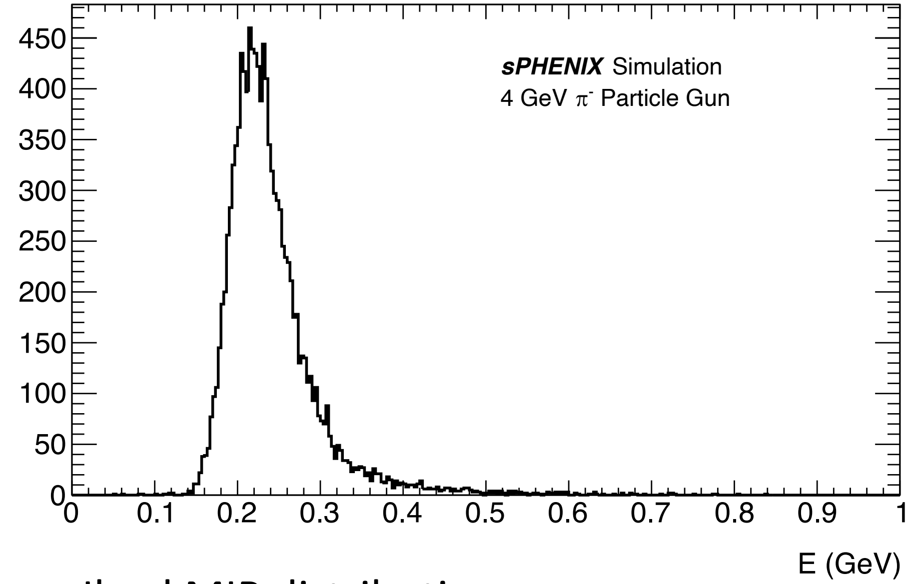

Expect 0.015 % p+p MB events to have an isolated ohcal shower from $p_T > 4\ GeV/c$ particle

Expect 0.006% Au+Au MB events to have an isolated ohcal shower from $p_T > 4\ GeV/c$ particle

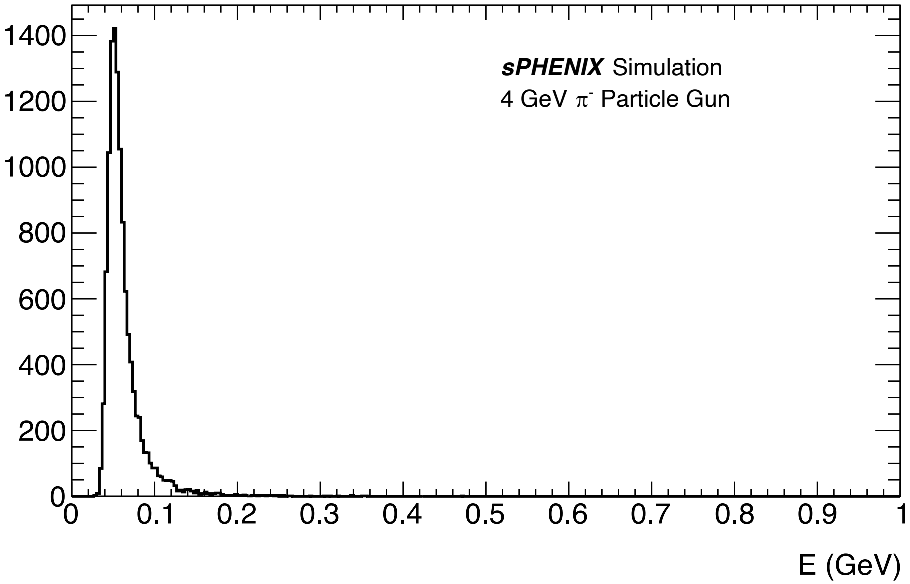
# Results of E/p for 4 GeV $\pi^-$ particle gun using this methodology



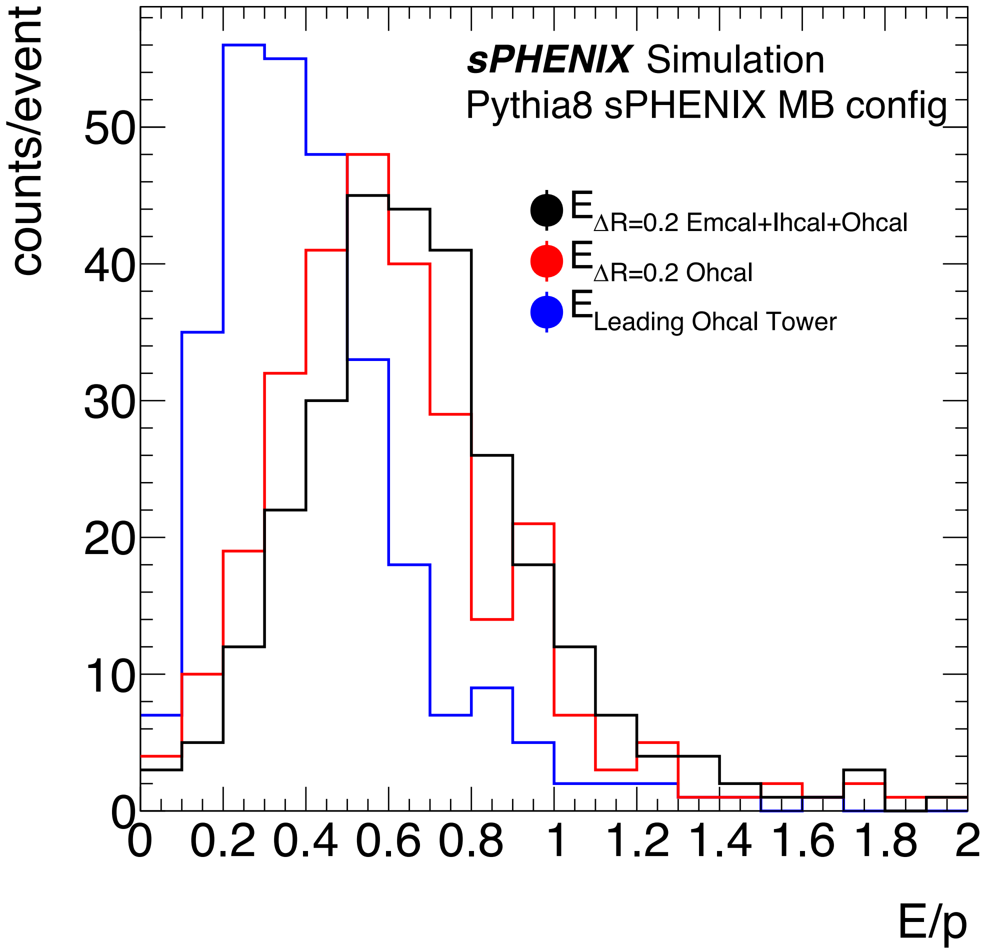

Emcal MIP distribution




Ihcal MIP distribution



# Results of E/p for isolated particles with $p_T > 4\ GeV/c$ in MB p+p




Energy distribution in 5x5 ohcal tower region (%)

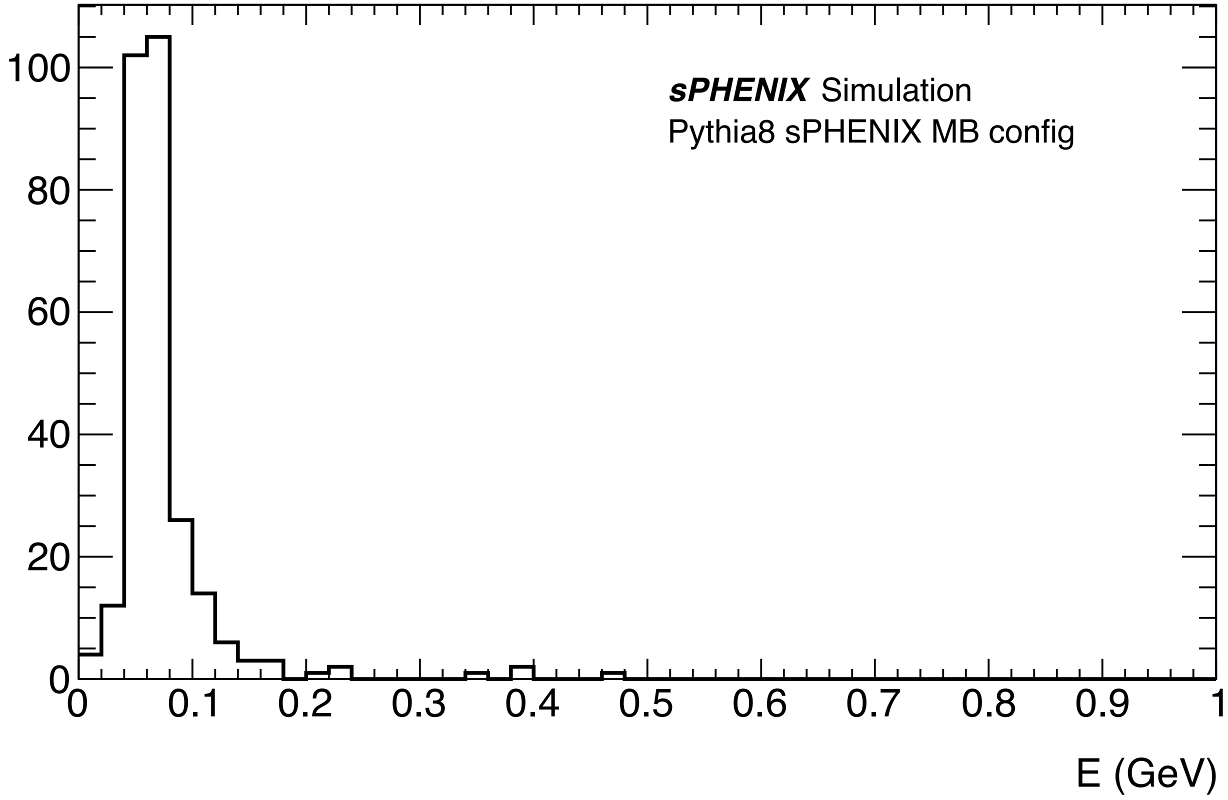
| | | | | |
|---|---|---|---|---|
| 0.06 | 0.16 | 0.25 | 0.15 | 0.06 |
| 0.19 | 1.37 | 10.3 | 1.42 | 0.19 |
| 0.42 | 4.21 | 62.8 | 4.17 | 0.42 |
| 0.26 | 1.69 | 8.27 | 1.84 | 0.27 |
| 0.1 | 0.32 | 0.58 | 0.32 | 0.1 |

From over 1.1M p+p MB events, we selected 137 ohcal shower candidates (0.013 % of events)

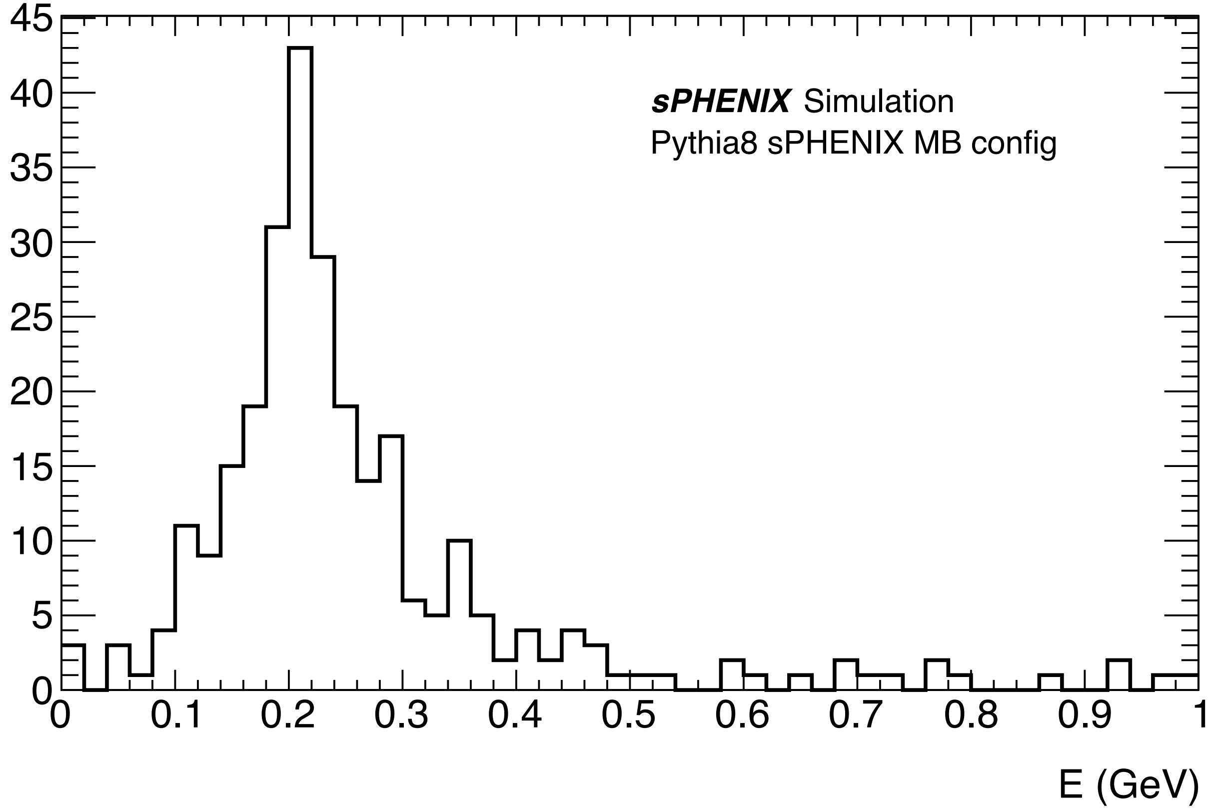
The energy distribution in the ohcal tower region (right plot) shows that an average of 62.8 % of the energy in the ohcal tower region is deposited into a single tower

# Results of MIP distributions for isolated particles with $p_T > 4\ GeV/c$ in MB p+p

Ihcal MIP distribution




Emcal MIP distribution




From events with isolated ohcal hadron showers, we were also able to isolate the MIP peaks in the Emcal and Ihcal in the isolation region, which show good agreement with the particle gun mip energy distributions

# Conclusions

- With projected number of collisions in year 1 Au+Au running of 3.7E9 events* and 0.006% of events having an isolated particle with $p_T$ > 4 GeV/c whose shower begins in the ohcal, **1.8E5 candidates for ohcal tower calibration** or **117 candidates per tower**
- With projected number of collisions in year 2 p+p running of 1.5E10 events* and 0.015 % of events having an isolated particle with $p_T$ > 4 GeV/c whose shower begins in the ohcal, **2.25E6 candidates for ohcal tower calibration** or **1465 candidates per tower**
- Further work looking into the influence of noise and fluctuations of energy deposition in ohcal hadron showers should be completed to understand the uncertainty in this method of calibration

| Year | Species | $\sqrt{s_{NN}}$ [GeV] | Cryo Weeks | Physics Weeks | Rec. Lum. $\|z\|$ <10 cm | Samp. Lum. $\|z\|$ <10 cm |
|---|---|---|---|---|---|---|
| 2023 | Au+Au | 200 | 24 (28) | 9 (13) | 3.7 (5.7) $nb^{-1}$ | 4.5 (6.9) $nb^{-1}$ |
| 2024 | $p^{\uparrow}p^{\uparrow}$ | 200 | 24 (28) | 12 (16) | 0.3 (0.4) $pb^{-1}$ [5 kHz]<br>4.5 (6.2) $pb^{-1}$ [10%-*str*] | 45 (62) $pb^{-1}$ |
| 2024 | $p^{\uparrow}$+Au | 200 | – | 5 | 0.003 $pb^{-1}$ [5 kHz]<br>0.01 $pb^{-1}$ [10%-*str*] | 0.11 $pb^{-1}$ |
| 2025 | Au+Au | 200 | 24 (28) | 20.5 (24.5) | 13 (15) $nb^{-1}$ | 21 (25) $nb^{-1}$ |

* Assumes an Au+Au Rec. Lum. of 3.7 $nb^{-1}$ and cross section of $7b$ and a p+p Rec. Lum. of 0.3 $pb^{-1}$ and cross section of $50mb$