In-Situ Calibration of the sPHENIX Hadronic Calorimeter using Isolated Single Hadrons

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Abstract

A first goal from early running of the sPHENIX detector, which has begun data-taking this year, is to ensure an accurate calibration of its calorimeters and a complete understanding of the uncertainties associated with these calibrations. Both of these steps are necessary for successfully achieving the physics goals of sPHENIX, especially in conducting various high-precision jet measurements with sPHENIX having the first hadronic calorimeter at mid rapidity at RHIC. This study explores measurements of the calorimetric response to single hadrons from Au+Au collisions in the sPHENIX calorimeter system, which is comprised of an electromagnetic calorimeter, followed by an inner and outer hadronic calorimeter made of aluminum and steel absorber, respectively. In this study, the momentum p of isolated tracks, those separated by a minimum distance from the nearest other tracks, are found utilizing the sPHENIX charged-particle tracking systems and are matched to calorimeter energy deposits with energy E; E/p distributions are then constructed for use in precise data-to-MC comparisons. The methodology regarding the minimization of background energy from neutral particles within the track isolation area will also be presented. These measurements can be used to understand the hadronic response and quantify the uncertainty in the calorimeter hadronic response between data and MC.

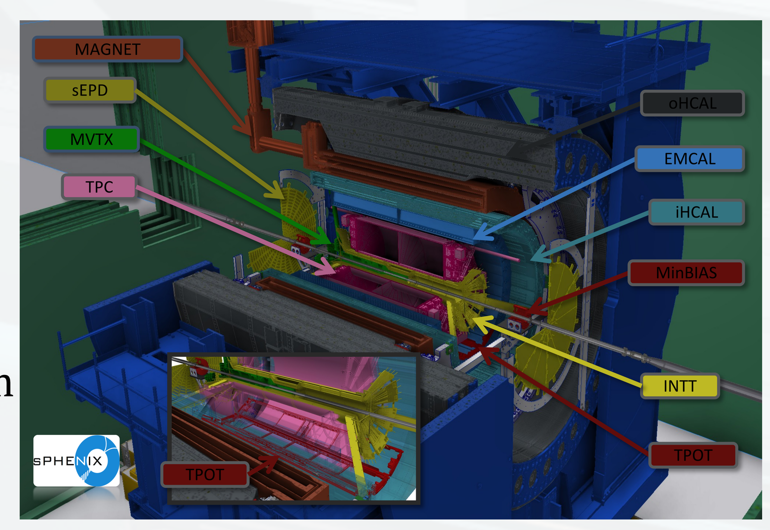
sPHENIX Detector and Calibration Efforts

sPHENIX detector has three layers of calorimetry:

1. Electromagnetic calorimeter (EMCal)
2. Inner hadronic calorimeter (IHCal)
3. Outer hadronic calorimeter (OHCal)

where the IHCal and OHCal are separated by the sPHENIX Magnet

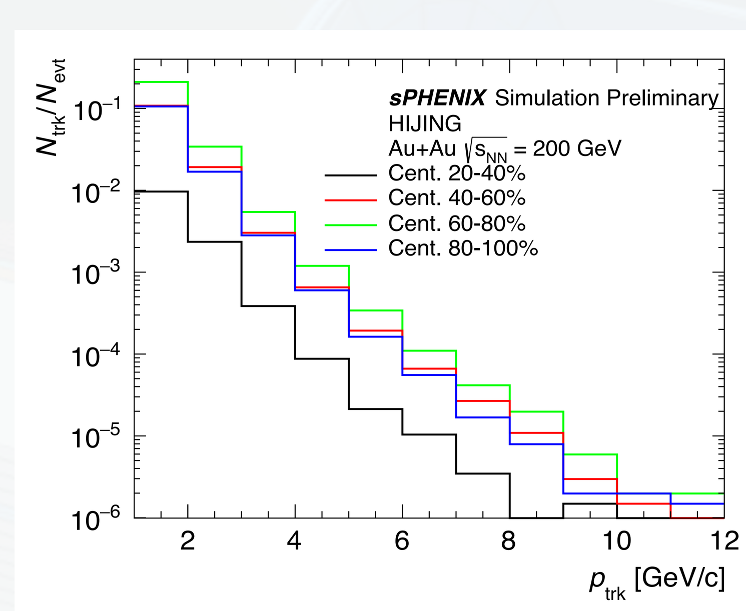
Nominal calibrations for the sPHENIX HCal system (IHCal + OHCal) have been established using cosmic muons to calibrate to the electromagnetic energy scale (see posters 501 & 502)

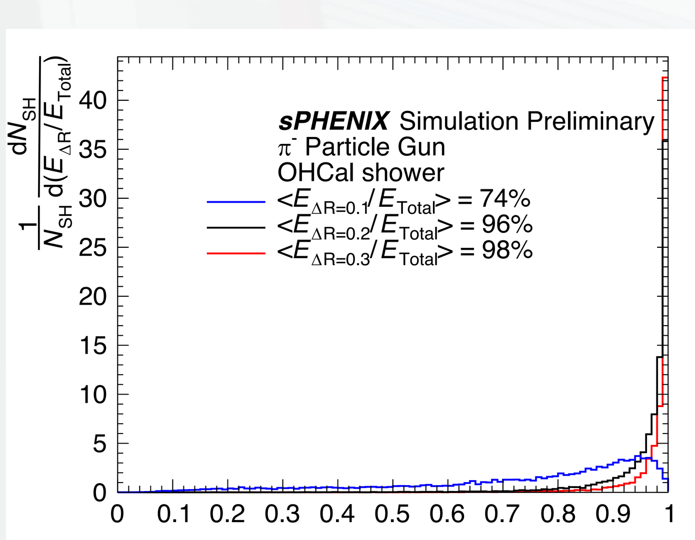


Selecting for Isolated Single Hadron Candidates

Rate of good tracks:

- Select tracks with $p_T > 1.0$ and $|\eta| < 1.0$
- Require no other track projected in the $\Delta R = 0.4$ cone around track projection point
- Apply nominal sPHENIX tracking cuts
- Isolation criterion is greatest source of statistics loss in this cut flow



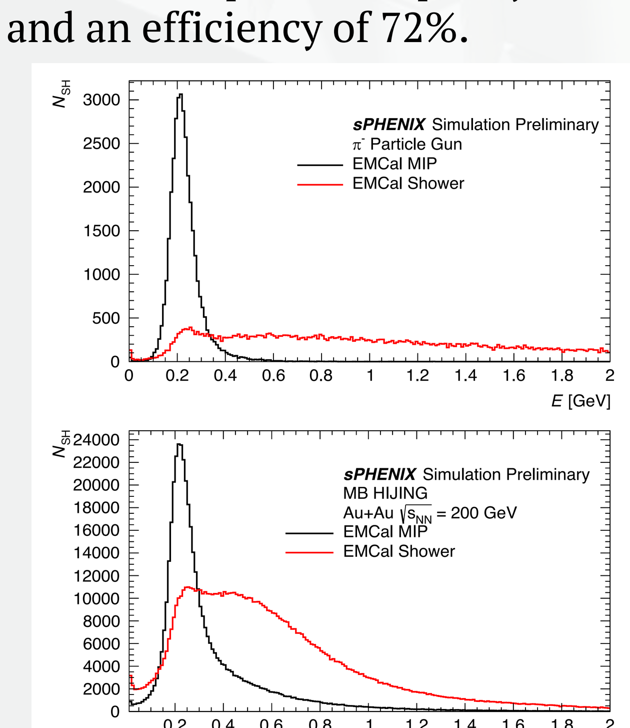


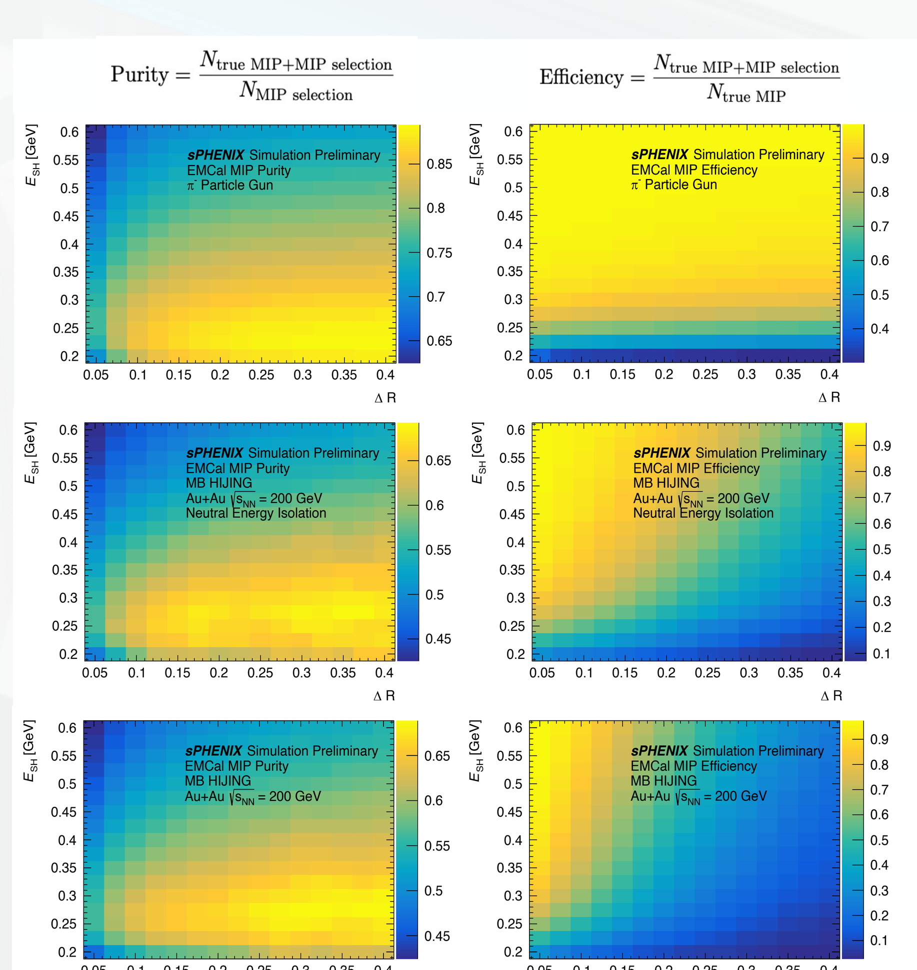
Hadron shower size:

- Using $\pi-$ particle gun, determine fraction of total energy in cones of $\Delta R = 0.1$, 0.2 and 0.3
- Energy deposition within a cone of ΔR is comprised of all calorimeter towers within ΔR of the track projection

EMCal MIP criteria:

- Optimal EMCal energy and radius cuts for selecting Hcal showering hadrons from truth information on showering vertexes of isolated single hadron candidates
- $\Delta R = 0.1$ and E = 0.35 GeV selected as the best option for the MB HIJING sample with a purity of 60% and an efficiency of 72%.





- Best separation between EMCal MIP and shower distributions in $\Delta R = 0.1$ cones (left) at around 0.35 GeV

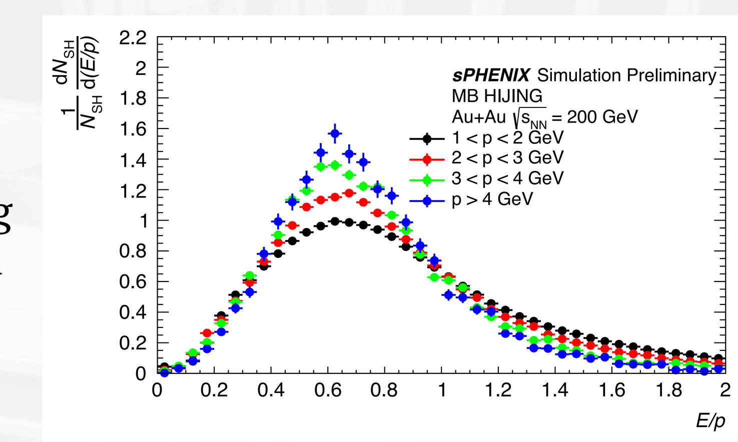
Motivations

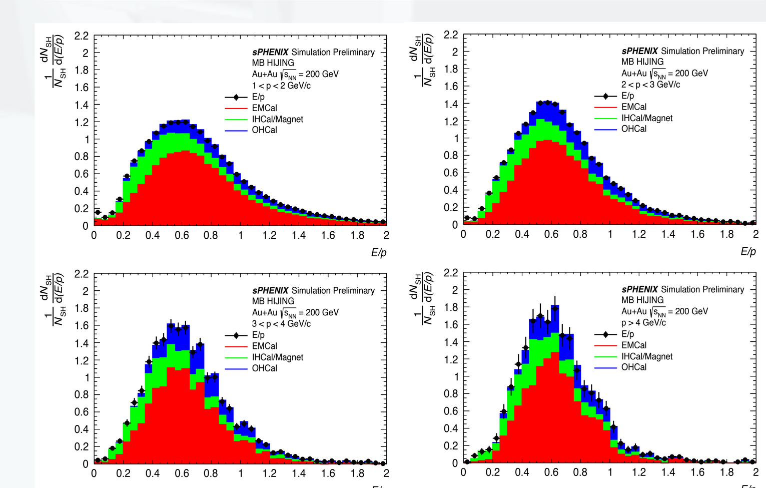
- Single hadron E/p distribution can be used to estimate the data and MC differences in the HCal's hadronic response as well as calibrate the HCal to the hadronic scale
- We select for isolated single hadrons with low energy deposition in the EMCal using the EMCal to reduce neutral energy in the track isolation cone and selecting for events which begin their showers in the Hcal
- HCal showering single hadron E/p distributions will be less susceptible to possibly overlapping EMCal calibration efforts that are currently ongoing.

E/p Measurement

Full E/p distribution:

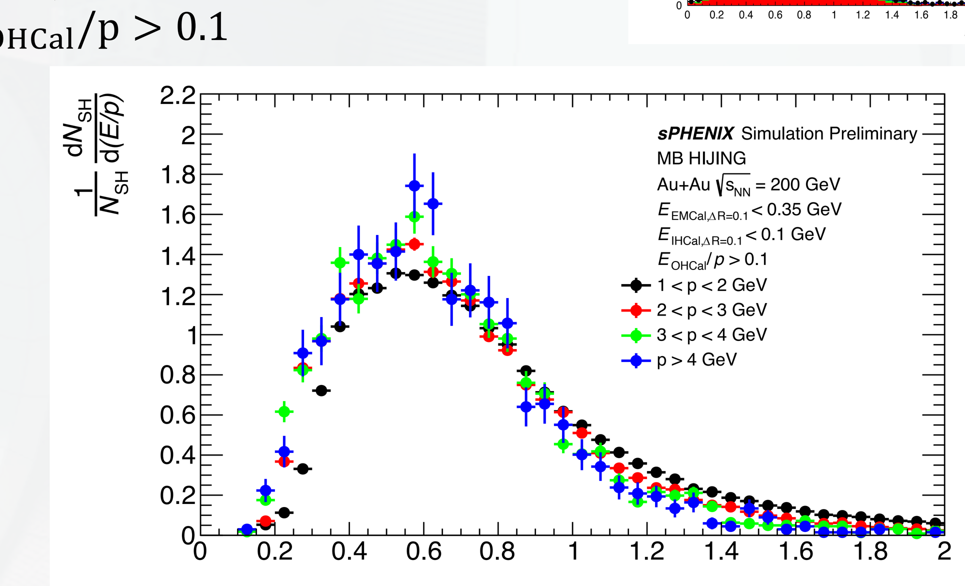
- Measure the E/p distribution by summing the energy deposition in the matched towers in all three calorimeters and dividing by the particle momentum for each isolated single hadron
- In full E/p distribution, majority of the isolated single hadrons begin showers in the EMCal, determined by shower vertex truth information in Geant4



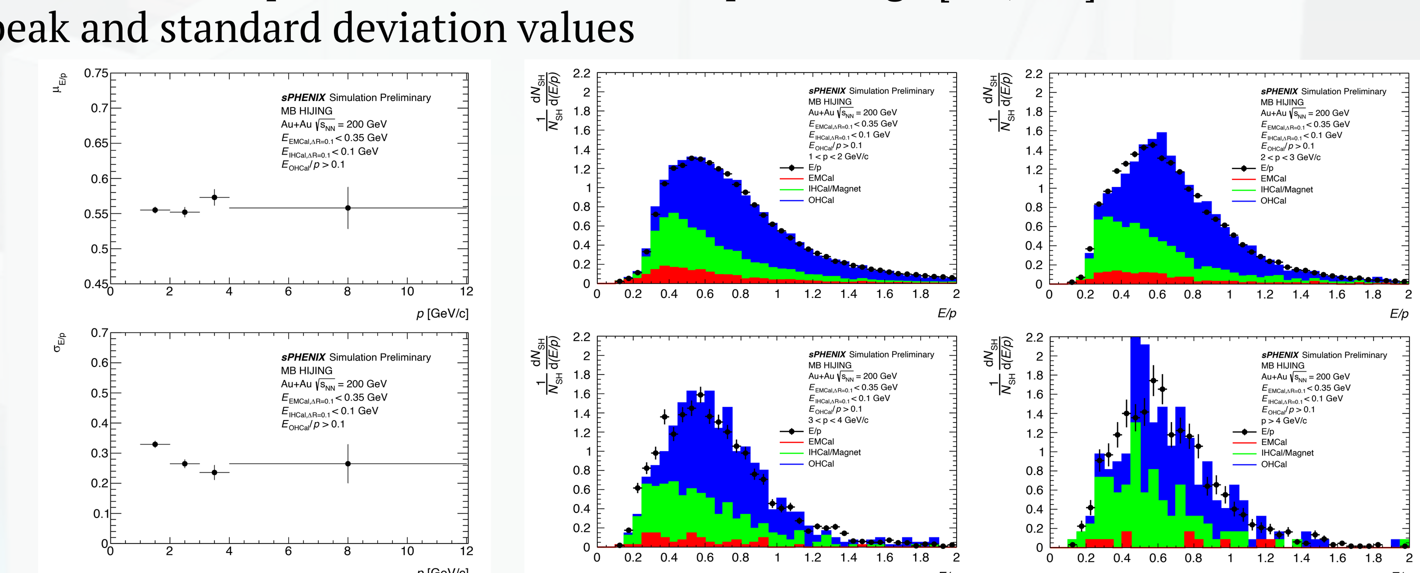


HCal shower E/p distribution:

- Select for late showering isolated single hadrons (showers beginning in the OHCal) with cuts:
  1. $E_{\mathrm{EMCal},\,\Delta R=0.1} < 0.35$ GeV
  2. $E_{\mathrm{IHCal},\,\Delta R=0.1} < 0.1$ GeV
  3. $E_{\mathrm{OHCal}}/p > 0.1$



- With cuts, fraction of isolated single hadrons with EMCal shower start in E/p distribution decreases to 10% for 1 < p < 2 GeV/c and 3% for p > 4 GeV/c
- HCal shower E/p distribution fit around peak range [0.4, 0.8] to find distribution peak and standard deviation values



Conclusions

The final E/p distribution with EMCal MIP and HCal late showering cuts should be used for comparison of the sPHENIX HCal's response differences between MC and data with current EM scale calibration

- Able to isolate the HCal response here with minimum EMCal input to the E/p distribution (90-97% purity) avoiding overlapping with EMCal calibration efforts

Full E/p distribution without the HCal late showering cuts better for the long term goal of calibrating the OHCal to the hadronic scale

- Further investigation into the underlying distributions of EMCal/IHCal/Magnet showers versus fully OHCal showers being necessary to extract the OHCal shower part of these total E/p distributions in an unbiased manner

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