Generating a Sample of π^0's and η's for Energy-Calibrating the STAR Endcap Calorimeter

- A Feasibility Study -

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Introduction

The Relativistic Heavy Ion Collider (RHIC) (Figure 1), located at Brookhaven National Laboratory is the world's only machine capable of colliding high-energy beams of polarized protons. The Solenoidal Tracker at RHIC (STAR) detector (Figure 2) utilizes these polarized-proton collisions to understand the origin of the proton spin. The **E**ndcap **E**lectro**M**agnetic **C**alorimeter (EEMC) which detects, among other particles, photons produced in proton-proton collisions and measures the photon energies within the pseudorapidity range of $1 < \eta < 2$ with a lead-scintillator sampling detector (Figure 3). Using the detected photons, most of which come from the decay of π^0 and η particles from p+p collisions, one can reconstruct the invariant mass of the π^0 or η that can then be used to energy calibrate the response of the towers in the EEMC.

Figure 1: Brookhaven National Laboratory; the RHIC Collider is highlighted at the top.

Abstract

The Solenoidal Tracker at RHIC (STAR) detector, located at Brookhaven National Laboratory, utilizes polarized-proton collisions to explore the contributions made by sea quarks and gluons to the known proton spin. An important component of STAR is the Endcap Electromagnetic Calorimeter (EEMC), which detects, among other particles, photons produced in the pseudorapidity range $1 < \eta < 2$ from beam-beam collisions and measures their energy. The quality of these energy measurements depends on accurately calibrating the energy response of the EEMC. STAR has used minimum-ionizing particles (MIPs) for this calibration. An independent energy calibration method uses reconstructed neutral pions (π^0) and etas (η) obtained, ideally, from a "clean" event sample with minimum contamination from background. By refining sample selection criteria, background is reduced, thus leaving a "clean" sample of π^0's and η's. These "clean" samples will be used to verify the energy calibration of the EEMC obtained using MIPs.

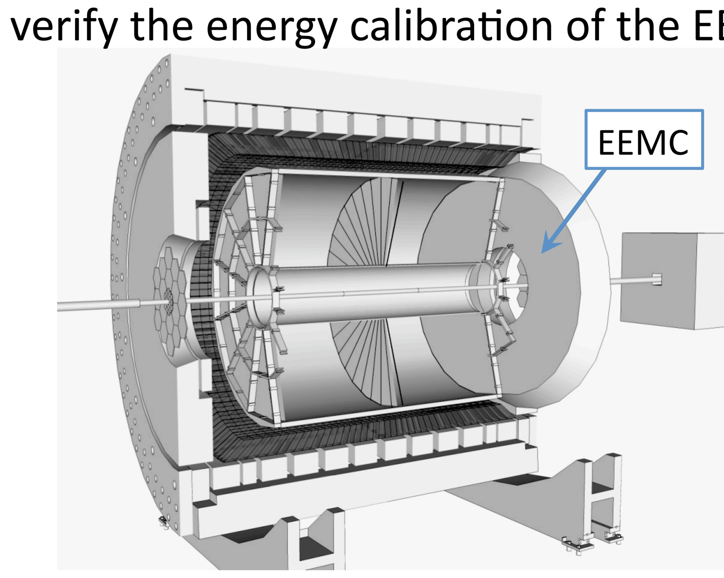

Figure 2: The STAR Detector; the EEMC is highlighted.

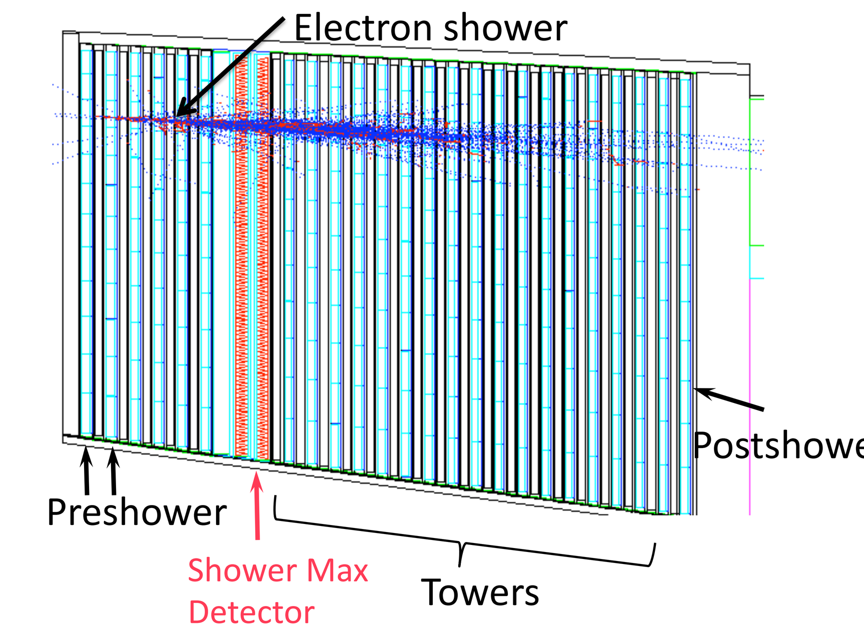

Figure 3: A cross-section of the EEMC showing the preshower, shower max detector, towers, and post shower layers. The EEMC gathers energy and position data for the electromagnetically interacting particles.

STAR summer research group.

Generating a "Clean" π^0 Sample

In a proton-proton collision, π^0 and η particles are produced and both immediately decay into two photons. The invariant masses of these decay particles are calculated by:

$$M^2_{\pi^0,\gamma} = 4E_1E_2 sin^2\left(\frac{\alpha}{2}\right)$$

where E_1 and E_2 are the energies of the photons and α is the opening angle. Background events are removed by placing cuts on parameters such as the opening angle (angle between two decay photons), the decay (Z) vertex, and the energies of the photons, thus "clean" invariant mass spectra are produced. The best estimate of the mass is then determined by fitting a Gaussian curve to the peak of the spectrum. Figures 4 and 5 are sample invariant mass spectra for π^0 particles. Figure 4 shows the invariant mass spectrum for a π^0 particle with background included. For spectra with background, a Gaussian and polynomial fit are applied. In Figure 5, the background events are removed using the cuts mentioned above. The low mass and high mass backgrounds are mostly removed by the cut on the opening angle. Figure 6 compares the estimate of the invariant mass from the data including background and the "clean" data to the pseudorapidity (η) of the pion, and we expect the mass to be independent of η and produce a flat line; however, this curve shows an η dependence, indicating that the present calibration done using minimum-ionizing-particles (MIPs) needs fine-tuning. Figure 7 shows that the mass is also dependent on time, which indicates that the tower gains may have drifted over time.

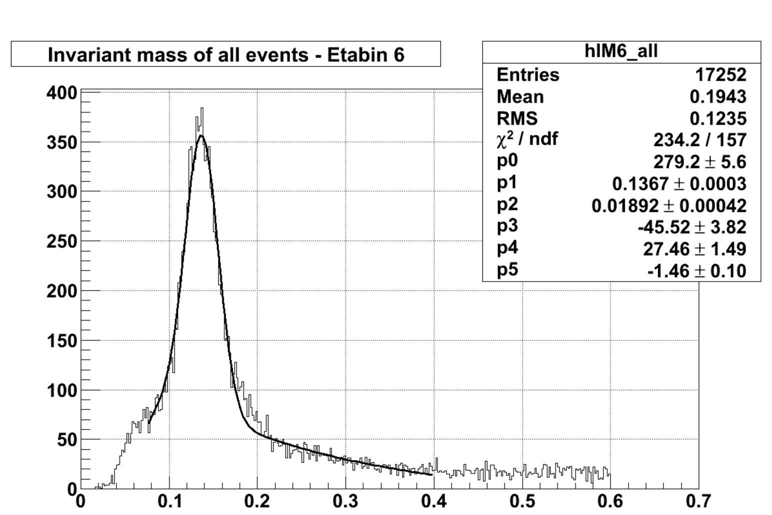

Figure 4: An invariant mass spectrum without cuts to show the π^0 peak with the background included. The spectrum has a Gaussian and polynomial fit applied.

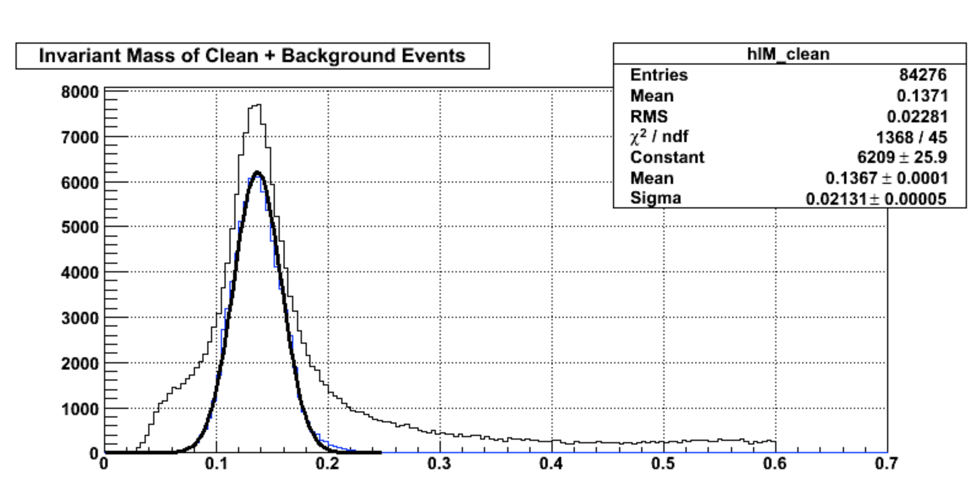

Figure 5: An invariant mass spectrum with cuts to remove background. When the background is removed, the "clean" π^0 peak remains. Most of the high and low mass background is removed by the cut on the opening angle. A Gaussian fit is then applied to the "clean" peak to closely estimate the invariant mass of the π^0.

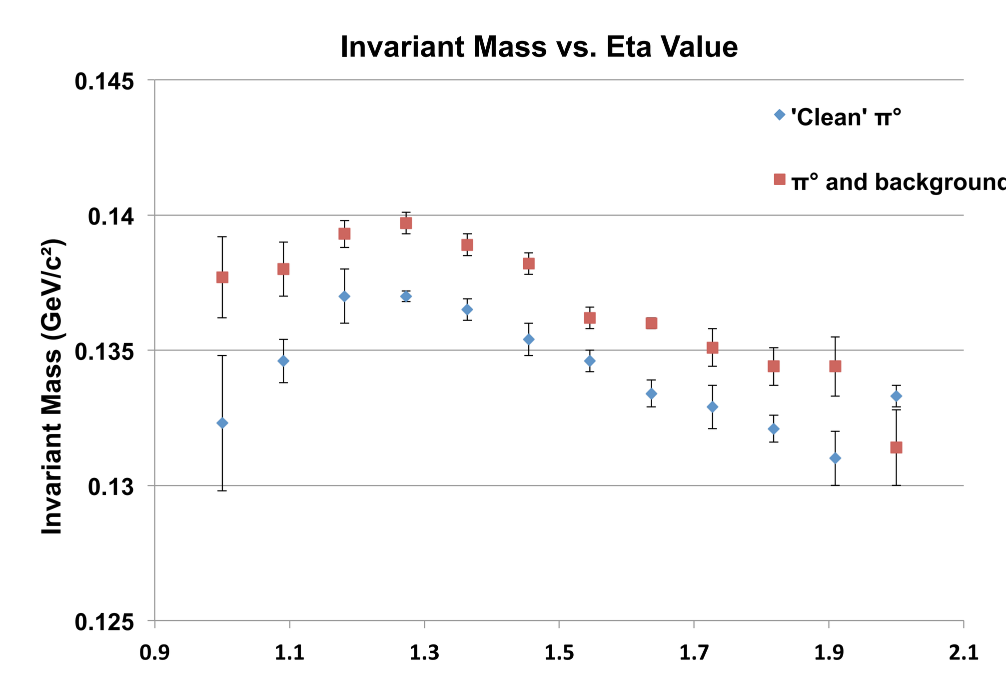

Figure 6: This plot shows measured invariant masses of "clean" and background-included π^0 's as a function of η, illustrating the η dependence. The invariant masses obtained from the two different fits show the same η dependence.

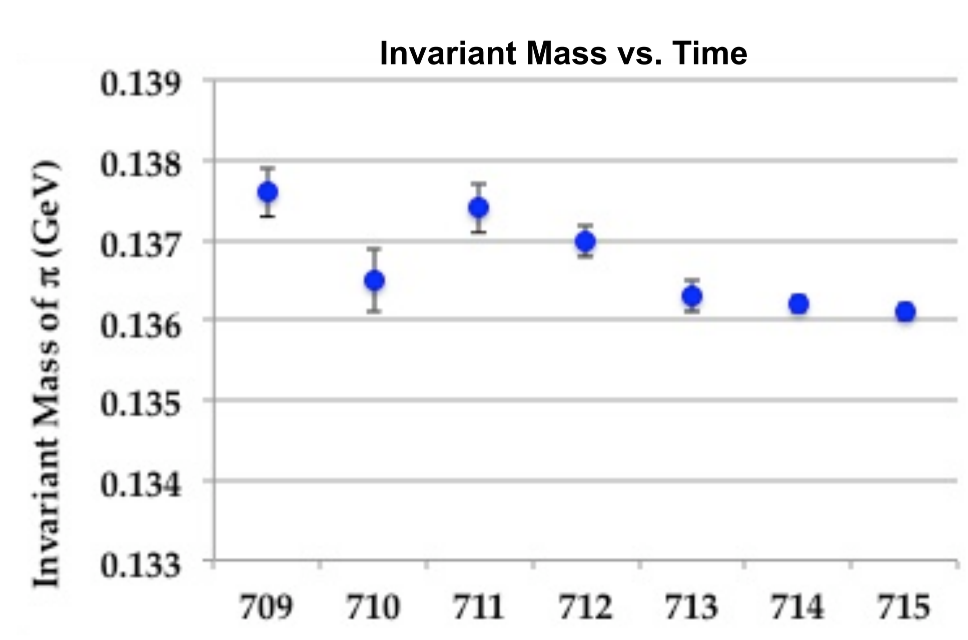

Figure 7: This plot shows measured invariant mass of "clean" π^0 as a function of the data collection dates, illustrating time dependence. The numbers on the x-axis denote the week in which the data was taken; 709 was the first week in April 2007 and 715 was the first week in June.

Generating a "Clean" η Sample

"Clean" invariant mass spectra were also produced for η particles from the same process as producing the π^0 samples. Similar to generating a "clean" π^0 sample, cuts were also placed on the opening angle, the Z vertex, and the energies of the photons. By fitting a Gaussian curve to the peak of the spectra, we determine the mass of the η particle. Since the η has a known invariant mass, we can observe whether we need to verify the EEMC calibration if the measured value has discrepancies. Figure 8 shows an invariant mass spectrum for η including the background data. When this background data is subtracted from the spectrum, the "clean" η mass spectrum remains.

Figure 8: Invariant mass spectrum with cuts to remove the background. The resulting "clean" η peak is shown with a Gaussian fit.