sPENIX Electromagnetic Calorimeter Block Evaluation

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ABSTRACT

sPHENIX is a detector under construction at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory, and will begin collecting data in February of 2023. By the collision of heavy nuclei, RHIC is capable of creating a quark-gluon plasma (QGP), a hot, dense state of unconfined quarks and gluons. Jets, collimated sprays of energetic particles, serve as important probes of the plasma, as they have been modified relative to jets in baseline proton-proton collisions because their parent partons have lost energy to the QGP. In order to provide precision measurements of jets and jet energy loss, sPHENIX has both electromagnetic and hadronic calorimetry at midrapidity. Particles will embed energy into the calorimeter blocks, and the fibers collect that energy in the form of light, which is then read out by a silicon photomultiplier (SiPM). We report a study of the EMCal's energy response to single photons measured in an sPHENIX-based GEANT4 simulation.

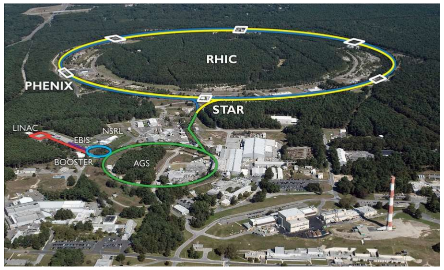


Figure 1. Aerial view of the Relativistic Heavy Ion Collider at the Brookhaven National Laboratory.

METHOD

The EM Cal prototype and photons were simulated using GEANT4 to generate data with and without the Position Dependent Correction applied. Various simulations were ran and analyzed using ROOT.

An appropriate binning system was determined to best evaluate the simulated data on ROOT. Simulated data was generated to cover a sector of the electromagnetic calorimeter with a 10% smear in either direction in phi. The investigated sector in this evaluation ranges from $-\frac{\pi}{32}$ to $\frac{\pi}{32}$ in phi and 0 to 1.1 in eta. Results are shown from $-\frac{\pi}{32}$ to $\frac{\pi}{32}$ along phi in 128 bins, and from 0 – 1.1 along phi in 384 bins. This means a sector may be viewed in 64 bins along phi and 384 bins along eta.

INTRODUCTION

sPHENIX

sPHENIX is a detector and experiment in its construction phase in the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory, and is expected to be ready to collect data in 2023. [1] Through the collision of heavy ions, Quark Gluon Plasma (QGP) will be created and its characteristics examined to better understand the Quantum Chromo Dynamic (QCD) interactions. The sPHENIX detector has many sub detectors (Figure 1) which will work together to collect large samples of jets, upsilons and heavy-flavor hadron. [1]

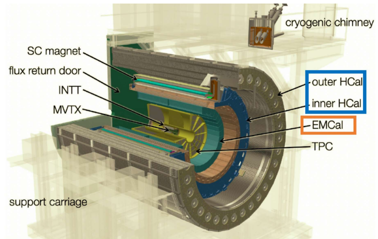
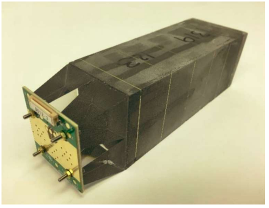


Figure 2. Schematic view of sPHENIX; the electromagnetic calorimeter being the teal inner detector.

Electromagnetic Calorimeter

The electromagnetic calorimeter (EM Cal) is the inner most calorimeter responsible for the detection and measurements of electrons, positrons, and photons in electromagnetic showers. Each EM Cal is made of tungsten powder, epoxy and scintillating fibers (Figure 3) and is tapered in two dimensions to cylindrically line the detector. [2] The tungsten stops the photon and in the photon's interaction with the tungsten, light is released. That light is then measured and turned into electrical current with its signal proportional to the amount of energy that was deposited into the tungsten.

Figure 3. One electromagnetic calorimeter block; made of a 2x2 array of towers consisting of tungsten powder, epoxy and scintillating fibers.



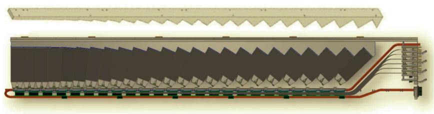


Figure 4. Side view of one sector of electromagnetic calorimeter blocks ranging from 0 to 1.1 in phi. One sector measures 4 blocks in eta by 24 blocks in phi.

RESULTS

Position Dependent Correction

A study of the electromagnetic calorimeter prototype was completed [2] which resulted in the addition of the position dependent correction and the beam profile correction. In the prototype's calibration, it was observed the beam had a different transverse profile at different energies. The calorimeter's response varies as a function of the position due to non-uniformities caused by block boundaries. In order to account for this, the Position Dependent Correction was applied to correct for the energy dependence of the beam profile. [2] The effects of the Position Dependent Correction have been evaluated with the following results.

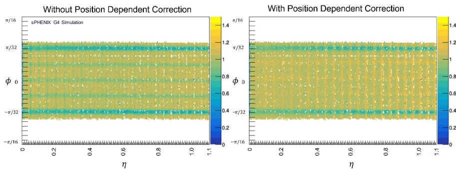


Figure 5. Histograms show a 2-D energy response of one sector of the EMCal (reconstructed energy/generated energy). The position dependent correction was applied to the to the data on the right. The position dependent correction is seen accounting for and correcting the lower energy response where the rows of EM Cal blocks meet in phi.

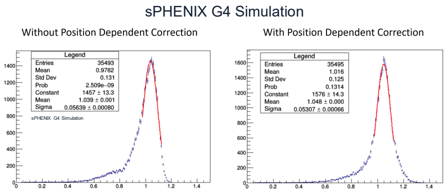


Figure 6. Histograms show energy response (reconstructed energy/generated energy) across and entire sector, on the x axis and photon count on the y axis. The correction lessens the left-hand tail of lower energy response and tightens the curve closer to 1.

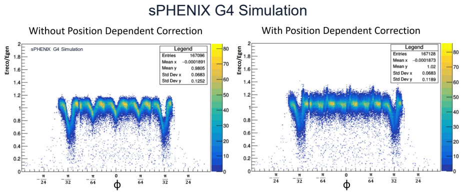


Figure 7. Histograms show the energy response of the calorimeter along phi. Left shows the uncorrected simulated data while the right shows the data with the position dependent correction applied. The four rows of EM Cal blocks can be seen in the uncorrected data with slightly lower energy response where the rows meet. The correction accounts for these areas and more accurately adjusts the calorimeter's energy response.

CONCLUSION

The results of the sPHENIX electromagnetic calorimeter block evaluation show the position dependent correction has a positive impact on the electromagnetic calorimeter's energy response. The correction eliminated the low energy response from the rows in phi where the electromagnetic blocks meet, and improved the lower energy response remain along the edges of the sector in $-\frac{\pi}{32}$ and $\frac{\pi}{32}$. The evaluation of the calorimeter's energy response and of the correction revealed excellent results and many opportunities for and future examinations.

SOURCES

[1] Kim, Y. "The Detector Development and Physics Program in sPHENIX Experiment at RHIC" Nuclear Physics A vol. 982, pp. 955-958, 2019.

[2] Aidala, C.A. et al., "Design and Beam Test Results for the 2D Projective sPHENIX Electromagnetic Calorimeter Prototype" arXiv:2003.13685v2 [physics.ins-det], 2021.

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