Jet Studies on the MPC-EX pre-shower detector upgrade to the PHENIX experiment

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Abstract

As a part of the PHENIX experiment at RHIC, we aim to perform jet and photon studies on the MPC-EX detector. The MPC-EX is pre-shower extension to the MPC (the Muon Piston Calorimeter, the current lead tungstate calorimeter), made up of interleaved Silicon mini-pad detectors and Tungsten plates. This high resolution detector adds tracking and allows for the identification of π^0s and direct photons in the rapidity range $3 < \eta < 4$. By studying direct photon and jet+photon events in simulations of protons on heavy nuclei, we aim to determine how well measurements of the Gluon Structure function can be made by the MPC-EX detector. One of the leading hypothesis to explain gluon distributions at low-x is the Color Glass Condensate.

Introduction

Experimentally, it has been shown that there is a sea of low momentum partons in addition to the stable quarks that make up a hadron. Every parton contains a fraction of their corresponding hadron's momentum. This momentum fraction is denoted as "x." The low-x gluons characteristics are not well understood. A theoretical framework to understand these low-x gluons is the Color Glass Condensate (CGC). In experiments at the Relativistic Heavy Ion Collider, when the Quark Gluon Plasma has been formed and seen in collisions of heavy nuclei, the CGC is theorized to be the initial state. [1][2]. The CGC is matter in which the momentum of the partons is so low, that their positions are uncertain over a large area [3][4]. One can visualize these partons as being spread out so that they overlap. This overlap is enhanced in a large nucleus where many nucleons are involved, and it can happen over many protons and neutrons. Overlapping gluons recombine and change their momentum distributions. This distribution is not well understood. To study this distribution, I will look at the collisions of protons on heavy nuclei. **These studies aim to determine how well the low momentum fraction of partons can be measured via direct photon and photon+jets in a detailed simulation of the MPC-EX detector.**

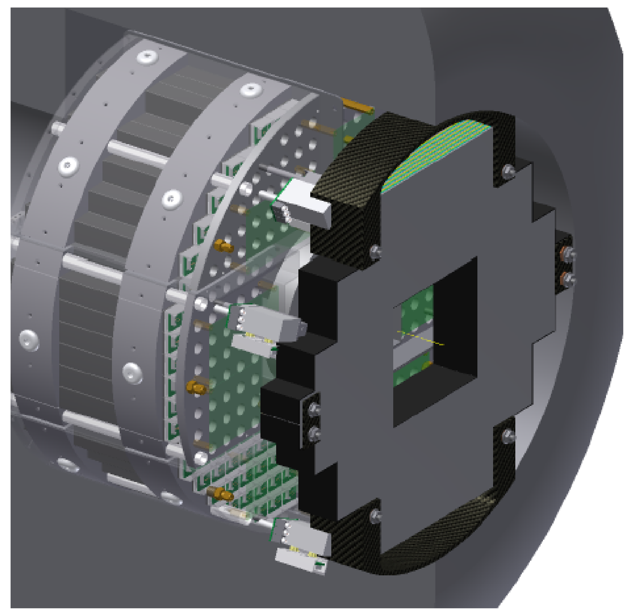

Figure 1: Render of the MPC-EX

Main Objectives

1. To find the resolution of the MPC+MPC-EX and compare to previous resolution sans extension.
2. To find the resolution of the MPC-EX over all.
3. Determine η and ϕ dependence of the photon resolutions.
4. Determine the proper energy scale factor to add the MPC and MPC-EX energies.
5. Extend this to Jet resolutions in the detector.
6. Determine Jet resolution in direct photon-Jet events.
7. Extend final analysis to proton+heavy nuclei events.

Methods

My research project is entirely simulation based. The software that is used are Monte Carlo event generators (pythia and a single particle generator) and the GEANT (GEometry ANd Tracking) based simulation package PISA. Our analysis focused on determining detector resolutions via reconstruction analysis software that can be used once real data is available.

Simulation

The event generators can simulate a variety of incident collision particles and recreate all physical processes currently substantiated in our models.

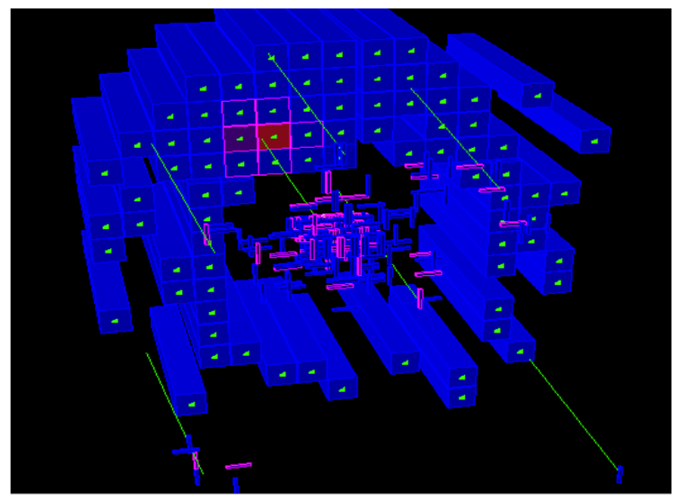

Figure 2: GEANT rendering of simulated hit in the MPC/MPC-EX

PISA is the experiment specific simulation package used in this analysis. This GEANT based software recreates our detector in the virtual world. The software takes into account the geometry and various materials of the MPC-EX.

Analysis

After simulating events, we want to obtain a rough photon resolution of the MPC-EX. We scale the output of the MPC-EX by a scale factor before adding it to the MPC energy. This scale factor is about 2.5.

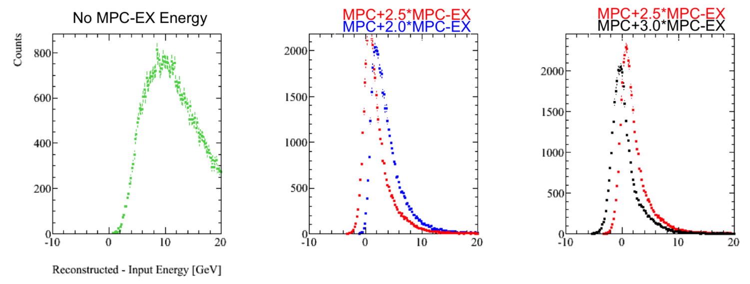

Figure 3: Scaling the MPC-EX energy by "too little" or "too much" lets us refine our scale factor to give us a better resolution

Next we look at the resolutions for the so-called "late" and "early" particle showers across a wide energy range. Where in the cartoon below we can see an "early" shower developing from the very first layer in the MPC-EX while the "late" shower only registers in the very last of the layers and has most of its energy deposited in the MPC.

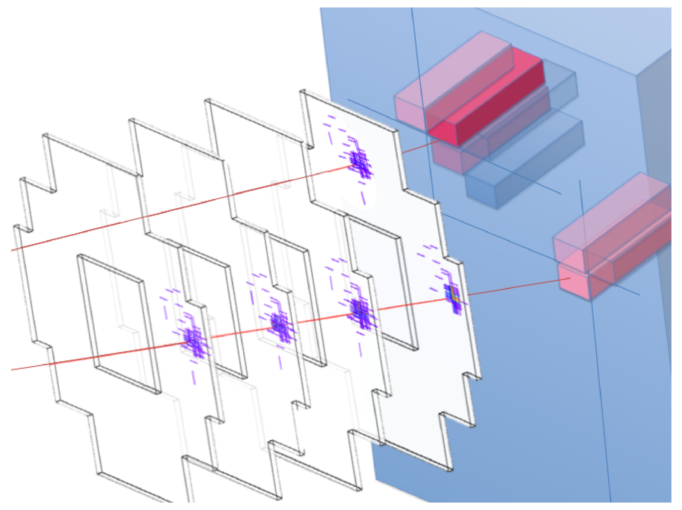

Figure 4: "Exploded" view of showers developing, both late and early, in the MPC-EX. Hits also shown in the MPC from the corresponding particle.

These resolutions are fitted with the double gaussian in equation (1)

$$f(x) = \frac{a_0}{a_2}\frac{1}{\sqrt{6.283}}e^{-0.5(\frac{x-a_1}{a_2})^2} + \frac{b_0}{b_2}\frac{1}{\sqrt{6.283}}e^{-0.5(\frac{x-(a_1+b_1)}{b_2})^2} \quad (1)$$

a_0 and b_0 are the yields of each gaussian. a_1 and b_1 are means (with b_1 as the offset of the mean of the second gaussian from the first). a_2 and b_2 are the widths of each gaussian. Plotting the widths of these peaks shows us how the resolution changes as a function of energy.

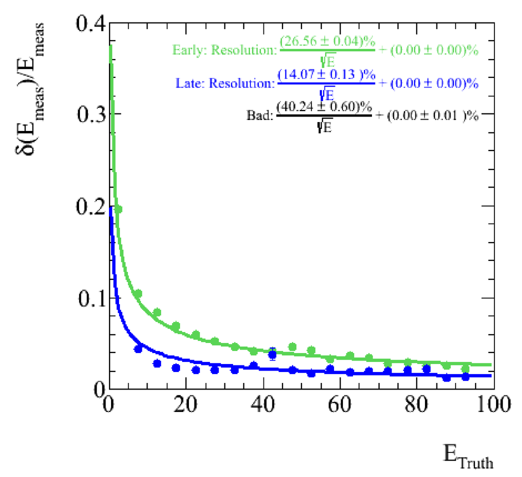

Figure 5: Energy resolution for both late and early showers (bad reconstruction is also shown)

We fit this distribution (Fig. 3, right two plots) with a convolution of a Landau + Gaussian and extract the final resolution of the detector corresponding late and early showers.

One can see from Fig. 5, that the resolution for late is better than for early showers. We then look at the η dependence. Where η is defined as $\eta = -\ln(tan\frac{\theta}{2})$. With θ being the angle between the particle's momentum and the beam axis.

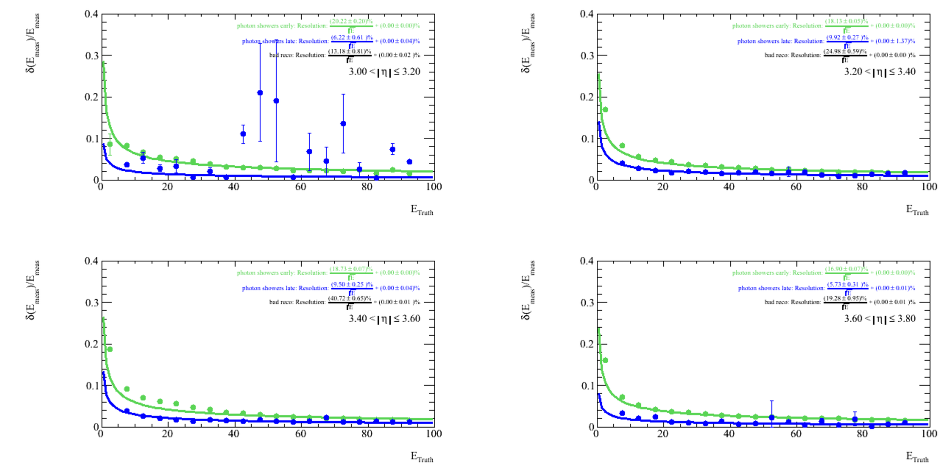

Figure 6: η dependence of energy resolution

From the above results the resolution stays consistent in the meat of the detector for both late and early showers in a rapidity range 3.2< η ≤3.6. The 3.0< η ≤3.2 range has very low statistics for late showers and we wont know how the resolution changes here until we run this over more events. The early showers do only slightly worse in this range. Then finally in the outer most η range we get some of our best resolutions. This is not expected and needs more investigation.

Conclusions & Forthcoming Research

- The resolutions are significantly better for late showers across all η.
- We think that we can use the same calibration for the MPC as before if we select out the late showering photons.
- The next big step is to extend this to direct photon+jet events, adding in jet reconstruction.

References

[1] *'Perfect' Liquid Hot Enough to be Quark Soup* **http://www.bnl.gov/rhic/news2/news.asp?a=1074&t=pr**

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