A PYTHIA Simulation Study of Direct-Photon and π^0 -Triggered Hadron Correlations in p+p Collisions at $\sqrt{s_{NN}}$= 200 GeV for the STAR Collaboration

Christopher B. Marble, Advisor: Dr. Saskia Mioduszewski

Cyclotron Institute, Texas A&M University, College Station, TX 77843

Tarleton State University, Stephenville, TX 76402

NSF Grant No. 1263281 DOE Grant No. DE-FG02-07ER41485

CYCLOTRON INSTITUTE
TEXAS A&M UNIVERSITY
http://cyclotron.tamu.edu

Abstract

Heavy-ion collisions at the Relativistic Heavy Ion Collider (RHIC) have provided evidence for the existence of a new hot and dense state of matter called the Quark-Gluon Plasma (QGP). Proton-proton (p+p) collisions provide a baseline measurement in order to understand the properties of the QGP in heavy-ion collisions. Comparisons of jet yields in Au+Au collisions to those in p+p collisions are done to determine the attenuation of hard-scattered partons in the QGP. In this study, p+p collisions are simulated at a center of mass energy $\sqrt{s_{NN}}$= 200 GeV using the PYTHIA 8.185 event generator. Jets are studied via two-particle azimuthal correlations, with the recoil jet analyzed via charged-hadron yields on the away-side ($\Delta\varphi \sim \pi$) of a π^0 or a direct-photon trigger.

The away-side charged-hadron per-trigger yields at mid-rapidity ($|\eta| > 1$), for transverse momenta $p_T^{associated} > 1.2$ GeV/c, are obtained for π^0 and direct-photon triggers for $|\eta| > 1$ and $p_T^{trigger} > 8$ GeV/c. The fraction of transverse momentum carried by triggered π^0 from its hard-scattered ancestors is studied to understand the energy imbalance between the triggered π^0 and the outgoing parton in p+p collisions. PYTHIA simulation results of the away-side charged-hadron yields, for π^0 and direct-photon triggers, are in reasonable agreement with the data collected in p+p collisions at the STAR experiment.

Motivation

- RHIC has seen evidence of QGP, but properties of QGP are still under investigation
- One way to study QGP is via hard scattered partons that are created early in high energy collisions of two nuclei
  - Hard scattering creates jets - collimated groups of hadrons
- The properties of QGP can be determined by comparing the jets from p+p collisions to those in Au+Au collisions which must pass through the QGP to be detected
- Why simulate photon + jet versus jet + jet production?
  - How well are per-trigger yields measured in p+p collisions reproduced by simulation?
  - What can simulation tell us about how much of the jet energy is carried by the trigger particle?

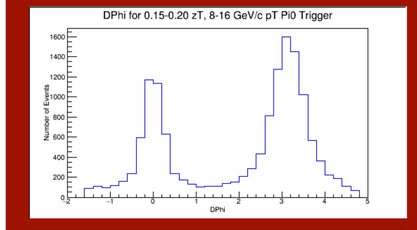
Simulation Parameters

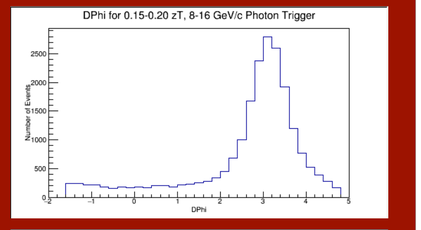
- Using the PYTHIA 8.185 event generator
- Kept events with a photon or π^0 with high transverse momentum ($p_T^{trigger} > 5$ GeV/c) and mid-pseudorapidity ($|\eta| > 1$)
- Kept associated hadrons that were charged with $p_T^{associated} > 1$ GeV/c and $|\eta| > 1$
- Initial and Final State Radiation Enabled
- pTHatMin = 4 GeV/c (Minimum invariant pT considered)
- 100M Hard QCD events simulated
  - 48426 8-16 GeV/c π^0 triggers
  - 3327 12-20 GeV/c π^0 triggers
- 1M Prompt Photon events simulated
  - 45512 8-16 GeV/c photon triggers
  - 6677 12-20 GeV/c photon triggers

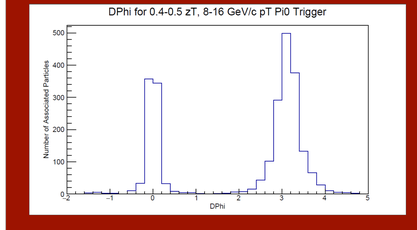
Analysis

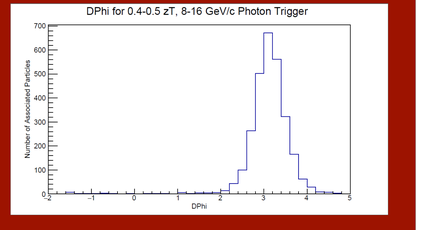
- Analyzed events with transverse trigger momentum $8 < p_T < 16$ GeV/c (previous STAR publication) or $12 < p_T < 20$ GeV/c (STAR preliminary data)
- Studied p_T of associated particles in away jet and near jet (π^0 case)
- Made separate histograms for different z_T cuts

$$zT \equiv pT^{\mathrm{assoc}}/pT^{\mathrm{trigger}}$$







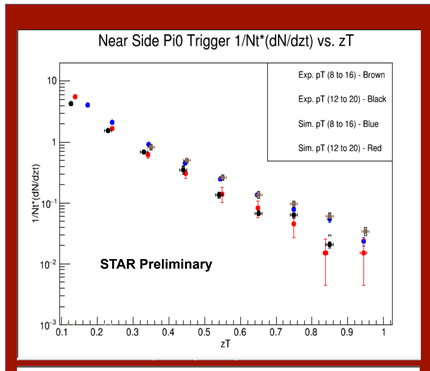


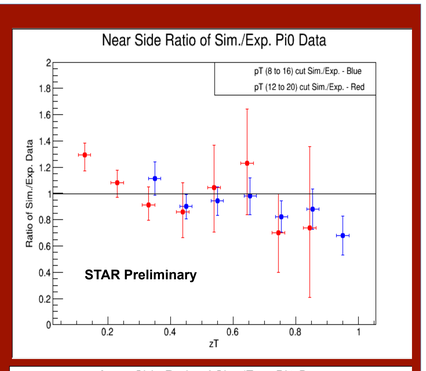
Associated particle yields as a function of the angle with respect to the trigger. Note the π^0 trigger (left) has both near and away jets while the photon trigger (right) only has an away jet. Low z_T cuts (top) have more events and higher background than higher z_T cuts (bottom).

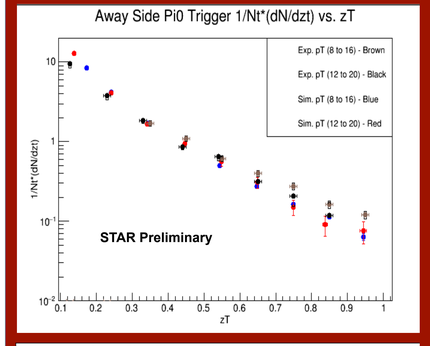
Histogram analysis procedure:

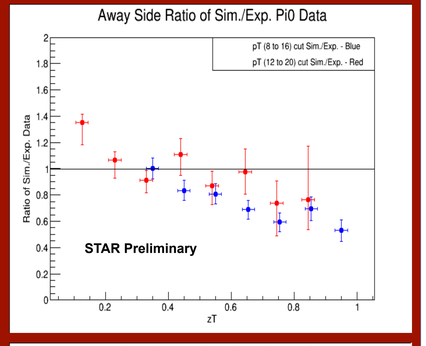
1. Integrate peaks (-1.4, 1.4) and (π -1.4, π +1.4)
2. Subtract background calculated as average over (-1.4, -0.8) and (0.8,1.4)
3. Normalize by dividing by the number of trigger particles

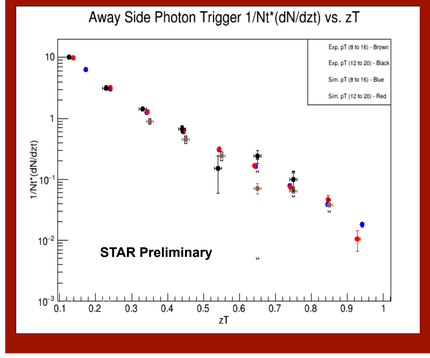
Comparison to STAR Data[1,2]

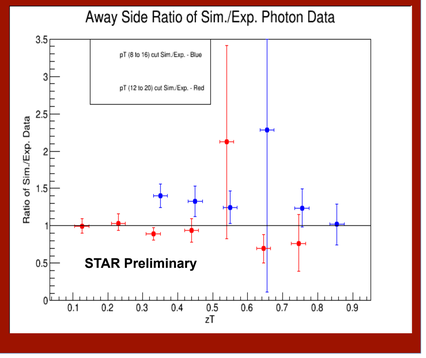








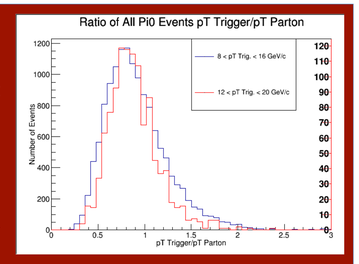


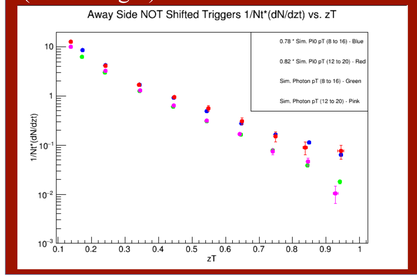


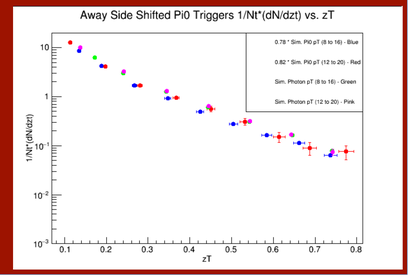
Fraction of Jet Energy Carried by Trigger

From the simulation we compare the ratio of the π^0 trigger p_T to the p_T of the scattered parton. From the graph (right) we found the peaks to be:
0.78 +/- 0.02 for 8-16 GeV/c
and 0.82 +/- 0.02 for 12-20 GeV/c

Since the photons are expected to have the same p_T as the initial hard scattered parton, the photon and π^0 yields vary significantly (below). Attempting to correct for this by shifting the π^0 zT values by 0.78 and 0.82 results in the π^0 and photon yields coming close to agreement (bottom right).







Conclusions / Future Work

- The 12-20 GeV/c simulation is in agreement with STAR Data
- The 8-16 GeV/c simulation deviates from STAR Data especially for the π^0 away jet at high-z_T
- Simulation predicts the π^0 carries a p_T of approximately 80% of the scattered parton p_T
- Understand why $p_T^{Trigger}/p_T^{Parton} > 1$ occurs frequently
- Look at effect of removing k_T (initial parton p_T) from the simulation
- Look at effect of removing Initial and Final State Radiation from the simulation

[1] 8-16 GeV/c data from: Abelev *et al.* (STAR Collaboration), Phys. Rev. C **82** (2010)

[2] 12-20 GeV/c data from: STAR Preliminary data: STAR manuscript to be submitted for publication