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

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Outline

• Background and Motivation
• PYTHIA Simulation Conditions and Analysis
• Comparison of Simulation vs. STAR Data
• Study of pT trigger/pT parton distribution
• Future Work
Background

• Relativistic Heavy Ion Collider (RHIC) collides Au+Au at 0.99995 c.

• The collision is believed to temporarily create a new state of matter called Quark Gluon Plasma.

• Early collisions of quarks and gluons (within protons and neutrons) in the Au nuclei can result in hard scattering. However in Au+Au collisions hard scattered partons must pass through QGP.

Image from: http://www.staff.scienc.e.uu.nl/~misch101/research.htm
Motivation

• Simulation of photon + jet versus jet + jet production
  – How well are per-trigger yields measured in p+p reproduced by simulation?
  – What can simulation tell us about how much of the jet energy is carried by the trigger particle?

Image 1 from: http://inspirehep.net/record/853601/plots
Image 2 from: http://www-cdf.fnal.gov/physics/new/qcd/run2/ue/chgjet/
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Simulation Parameters

• Using the PYTHIA 8.185 event generator
• Kept events with a photon or π⁰ with a high transverse momentum (pT) > 5 GeV/c and pseudorapidity (|η|) < 1.
• Kept associated hadrons that were charged with a pT > 1 GeV/c and |η| < 1.

Image from:
http://www.quantumdiaries.org/tag/heavy-ion-physics/
Analysis

• Analyzed events with transverse trigger momentum $8 < p_T < 16$ GeV/c (previous publication) or $12 < p_T < 20$ GeV/c (current paper draft)

• Studied $p_T$ of associated particles in away jet and near jet ($\pi^0$ case).

• Made separate histograms for different $zT$ cuts

• $zT \equiv pT^{assc}/pT^{trig}$
8-16 GeV/c Histograms

Analyzed:

1. Fit two Gaussians and a uniform background.
2. Took background value and uncertainty from the fit.
3. Integrated histogram peaks (-0.63, 0.63) and (\(\pi - 0.63, \pi + 0.63\))
4. Subtracted the background
5. Normalized by dividing by the number of trigger particles.
12-20 GeV/c Histograms
Analyzed:
1. Integrated peaks (-1.4, 1.4) and ($\pi$ - 1.4, $\pi$ + 1.4)
2. Subtracted the background calculated as the average value over (-1.4, -0.8) and (0.8, 1.4)
3. Normalized by dividing by the number of trigger particles.
Compare Sim. to Exp.
blue to brown (8-16 GeV/c), red to black (12-20 GeV/c)
Reasonable agreement for both pT ranges
Compare Sim. to Exp. for the away side jet with $\pi^0$ triggers
Note: blue to brown (8-16 GeV/c) is not in agreement at high $zT$
Simulation underestimates yield for 8-16 GeV/c pT range
Reasonable agreement for 12-20 GeV/c pT range
Compare Sim. to Exp for the away side jet for photon triggers
Reasonable agreement for simulation and experiment
Away Side Ratio of Sim./Exp. Photon Data

Note: Large uncertainties caused by large uncertainties in the experimental data points
Simulation Verification

• 12-20 GeV/c simulation appears to be in agreement with the STAR Data
• 8-16 GeV/c simulation is also in agreement with STAR Data except for high-zT $\pi^0$ away jet values
• Reason is undetermined.

Now lets compare the away side jet zT yields for photon triggers versus $\pi^0$ triggers.
8-16 GeV/c Pi0 Peak: 0.77 ± 0.02
12-20 GeV/c Pi0 Peak: 0.78 ± 0.02

*where pT Parton is the pT of the away-side jet parton
Away Side No Shifted Triggers $1/Nt\pi (dN/dzT)$ vs. $zT$

Away Side Shifted Pi0 Triggers $1/Nt\pi (dN/dzT)$ vs. $zT$

$\pi^0$ simulation data
unshifted

$\pi^0$ pT 8-16 GeV/c shifted 0.77*$zT$
$\pi^0$ pT 12-20 GeV/c shifted 0.78*$zT$
Photon vs. $\pi^0$ summary

• $\pi^0$ triggers have on average approximately 80% of the pT of the scattered parton
• Correcting for this results in yields for $\pi^0$ and photon triggering that are close to agreement

Future Work

• Understand pT $\pi^0$ Trigger/pT Parton $> 1$
• Look at the effect of removing kT (intrinsic parton pT) from the $\pi^0$ simulation
• Look at the effects of removing Initial and Final State Radiation from the $\pi^0$ simulation.
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12-20 GeV/c data from: STAR Preliminary data, STAR manuscript to be submitted for publication
Extra Slides
Additional Information

• Initial and Final State Radiation Enabled
• $pT_{\text{HatMin}} = 4$ GeV/c (minimum invariant $pT$ considered)
• 500M HQCD events simulated:
  – 86502 8-16 GeV/c Pi0 Triggers
    • 307358 Associated Particles
  – 6447 12-20 GeV/c Pi0 Triggers
    • 30764 Associated Particles
• 1M Prompt Photon events simulated:
  – 45512 8-16 GeV/c Photon Triggers
    • 93292 Associated Particles
  – 6677 12-20 GeV/c Photon Triggers
    • 18432 Associated Particles
From Primary Hard Scatter: -23
From Secondary Hard Scatter: -33
From Other (Decay, Baryogenesis of quarks not involved in the hard scatter, etc.): -500
where $p_T$ Parton is the $p_T$ of the away-side jet parton

8-16 GeV/c Pi0 Peak: $0.78 \pm 0.02$

12-20 GeV/c Pi0 Peak: $0.79 \pm 0.02$
where pT Parton is the pT of the away-side jet parton

8-16 GeV/c Photon Peak: $1.07 \pm 0.02$

12-20 GeV/c Photon Peak: $1.04 \pm 0.02$
From Primary Hard Scatter: -23
From Secondary Hard Scatter: -33
From Other (Decay, Baryogenesis of quarks not involved in the hard scatter, etc.): -500
Photon Simulation without Initial and Final State Radiation (ISR and FSR), Multi-Parton Interactions (MPI) and Initial Parton $p_T (kT)$

Note: The red line completely overlaps the blue line