Azimuthal correlations with high $p_T$ multi-hadron cluster triggers in Au+Au collisions at $\sqrt{s} = 200$ GeV from STAR

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OUTLINE

Introduction / Analysis Technique

Explanation of multi-hadron trigger results

- away-side yields for different $p_T$ trigger bins:
  - 10 to 12 GeV/c, 12 to 15 GeV/c, and 15 to 18 GeV/c

- pythia predictions of away-side yields for different $p_T$ trigger bins:
  - 10 to 12 GeV/c, 12 to 15 GeV/c, and 15 to 18 GeV/c

- ratios of all single + multi-hadron away-side yields to di-hadron away-side yields

Conclusions and Outlook
Introduction

- Measuring jets in HI collisions, much more difficult than in p+p collisions
- So far our major method in sorting jets from HI events is Di-hadron correlations

We look for a **leading hadron** which we assume carries most of the energy of the jet. We make associations between the leading hadron and other tracks.
Using Di-hadron correlations we try to measure fragmentation functions - parameterizing how partons become confined hadrons.

Fragmentation function $D(z)$ depends on $z$ defined as $p_T/E_T^{jet}$.

Because we assume $p_T^{(trig)} \approx E_T^{(jet)}$ the current method of Di-hadron correlation has limited sensitivity to true fragmentation functions.

We may be able to better constrain $E_T^{jet} \sim p_T^{(trig)}$ with a multi-hadron trigger.
Analysis Technique

- Collect all seed tracks $p_T > 5.0$ GeV
- Collect all "secondary seeds" with $p_T > 2, 3, 4$ GeV/c
- Cone $R = (\Delta \eta^2 + \Delta \phi^2)^{1/2}$ centered on each seed track
- Trigger $p_T = \text{sum of all associated tracks and secondary seeds in cone}$
- Study recoil (away-side) associated yield relative to highest trigger cluster in event
- Background estimate: uniform in $\Delta \phi$, normalize with ZYAM
Analysis Technique - cont’d

* Study recoil (away-side) associated yield relative to highest trigger cluster in event

* Background estimate: uniform in $\Delta \phi$, normalize with ZYAM

* Yields extracted for $p_T$ (trig)
  * 10 to 12 GeV/c
  * 12 to 15 GeV/c
  * 15 to 18 GeV/c

* $p_T$ (assoc)
  * 3 to 4, ... 10 to 11 GeV/c
Comparison of single vs. multi-hadron trigger statistics - dAu

Allowing clusters add up to $p_T^{(trig)}$, not just requiring a single particle to carry $p_T^{(trig)}$ --> more triggers

Important to note that Multi-hadron correlations reach into lower region of jet $p_T$ as compared to Di-hadron analysis

- A 10 GeV Di-hadron trigger = a 10 GeV hadron
- A 10 GeV Multi-hadron trigger = 8 + 2 GeV, or 5+3+2 GeV, or ...
Combinatorial Background

* random combinations occur in the multi-hadron algorithm
* $p_T$ seed > 5.0 GeV/c
* we vary the minimum secondary seed $p_T$ to test the effect of combinatorial background in Au+Au
Combinatorial Background

- $R$ is defined between the multi-hadron trigger and associated track for background estimate.
- $R$ is defined between a multi-hadron trigger and associated track from another event.

- For background estimate, $R$ is defined between a multi-hadron trigger and associated track from another event.

- Minimum seed > 2.0 GeV: $R = 0.3$, $S/B = 0.2$
- Minimum seed > 3.0 GeV: $R = 0.3$, $S/B = 0.7$
- Minimum seed > 4.0 GeV: $R = 0.3$, $S/B = 2.0$

- Red = signal
- Black = untriggered background

Graphs show histograms of $dN/dR$ with varying minimum seed values.
Away Side Yields: $10 \text{ GeV/c} < p_T(\text{trig}) < 12 \text{ GeV/c}$
Min. sec. seed cut = 2.0 GeV

Data: Multi-hadrons are below Di-hadrons, likely due to the effect of random clusters bringing down the yield

Pythia: Multi-hadrons largely match Di-hadrons
Away Side Yields: \(12 \text{ GeV/c} < p_T^{(\text{trig})} < 15 \text{ GeV/c}\)

Min. sec. seed cut = 2.0 GeV

Even with an increase in \(p_T^{(\text{trig})}\)

Data: Multi-hadrons are below Di-hadrons - random clusters

Pythia: Not much change; Multi-hadrons continue to match Di-hadrons
Away Side Yields: $15 \text{ GeV/c} < p_T^{\text{trig}} < 18 \text{ GeV/c}$

Min. sec. seed cut = 2.0 GeV

A further increase in $p_T^{\text{trig}}$:

- **Data**: Multi-hadrons move up and toward Di-hadrons, because of the higher trigger $p_T$ we see less random triggers

- **Pythia**: Not much change; Di-hadrons fall slightly above Multi-hadrons
**Away Side Yields:** $10 \text{ GeV/c} < p_T^{(\text{trig})} < 12 \text{ GeV/c}$

Min. sec. seed cut = 4.0 GeV

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**Data:** Di-hadrons are below Multi-hadrons, in the Multi-hadrons we should be seeing mostly real jet triggers because of the minimum secondary seed cut of 4.0 GeV/c

**Pythia:** Multi-hadrons fall slightly above Di-hadrons
Away Side Yields: $12 \text{ GeV/c} < p_T^{(trig)} < 15 \text{ GeV/c}$
Min. sec. seed cut = 4.0 GeV

With an increase in $p_T^{(trig)}$

- Data: Di-hadrons move up to meet Multi-hadrons - pretty good matching
- Pythia: Not much change

STAR Preliminary data

- AuAu Multi-hadron Triggers
- AuAu Di-hadron Correlation

Pythia

- p+p Multi-hadron Triggers
- p+p Di-hadron Correlation
Away Side Yields: $15 \text{ GeV/c} < p_T^{(trig)} < 18 \text{ GeV/c}$
Min. sec. seed cut = $4.0 \text{ GeV}$

- A further increase in $p_T^{(trig)}$:
  - Data: Statistics are not as good, but still relatively good matching between Multi-hadrons and Di-hadrons
  - Pythia: Not much change in Multi-hadrons, Di-hadrons scatter slightly
Ratios: Single+Multi-hadron Away Side Yield to Di-hadron Away Side Yield

\[-10 \text{ GeV/c} < p_T^{\text{trig}} < 12 \text{ GeV/c} -\]

- Ratios (statistical errors only) fall around unity and are relatively flat.
- For a minimum secondary seed cut of 2.0 GeV random clusters pull the ratio down. For a minimum secondary seed cut of 4.0 GeV, the ratio is close to unity, there are much less random Multi-hadron triggers, so the ratio falls even closer to unity.
- The single+multi-hadron triggers sample same kinematics as di-hadron correlations.

![Graphs showing ratios for different secondary seed cuts]
Ratios: Single+Multi-hadron Away Side Yield to Di-hadron Away Side Yield
- $12 \text{ GeV}/c < p_T^{(\text{trig})} < 15 \text{ GeV}/c$ -

- Ratios (statistical errors only) fall around unity and are relatively flat.
- Even with a higher $p_T$ bin, with a minimum secondary seed cut of $2.0 \text{ GeV}$ random clusters pull the ratio down. With a minimum secondary seed cut of $4.0 \text{ GeV}$, the ratio is still close to unity.
- The single+multi-hadron triggers sample same kinematics as di-hadron correlations.
Ratios: Single+Multi-hadron Away Side Yield to Di-hadron Away Side Yield

- $15 \text{ GeV/c} < p_T^{(\text{trig})} < 18 \text{ GeV/c}$ -

With an even higher $p_T$ bin, the ratio with a minimum secondary seed cut of 2.0 GeV begins to fall more around unity. Though statistics are not as good, we see with a minimum secondary seed cut of 4.0 GeV, the ratio is still close to unity.

The single+multi-hadron triggers sample same kinematics as di-hadron correlations.
Conclusions and Outlook

* We have investigated Multi-hadron triggers as the next step toward full jet reconstruction ...

* We see that a cone radius of ~ 0.3 and a minimum secondary seed cut of 4.0 GeV maximizes the signal to background ratio

* The yields on the away side for Multi-hadron correlations are consistent with the yields observed via Di-hadron measurements

* Multi-hadron trigger correlations extend di-hadron correlation measurements to a lower $z_T$ range

* Method is promising, more work is needed

* Calculate corrected yield with an estimate of the background cluster yield

* Look at Multi-hadron triggers in other systems: p+p, d+Au