The near-side in STAR

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Outline

• Introduction
• The *Jet* – energy, system, and particle type dependence
• The *Ridge* – energy, system, and particle type dependence
• Comparison to models
• Conclusion
Introduction
Di-hadron correlations

- Define a high-pT trigger particle
- Look at the distribution of particles relative to that trigger particle
Motivation – Jet and Ridge

- Long-range pseudorapidity ($\Delta \eta$) correlations observed by STAR in Au+Au at intermediate $p_T$
- Near side jet peak sits on plateau (Ridge)
- Significant contribution to the near-side yield in central Au+Au
Method: Yield extraction

- *Ridge* previously observed to be independent in $\Delta \eta$ in Au+Au

- To determine relative contributions, find yields for near-side, take $\Delta \Phi$ projections in
  - $-0.75 < \Delta \eta < 0.75$ *Jet + Ridge*
  - $0.75 < |\Delta \eta| < 1.75$ *Ridge*
  - $Jet = (Jet + Ridge) - Ridge \times 0.75/1.0$
  - $Ridge = yield from -1.75 < \Delta \eta < 1.75 - Jet$ yield

- Flow contributions to Jet cancel
  - $v_2$ independent of $\eta$ for $|\eta| < 1$
  - Yield: number of particles in Jet, Ridge
The Jet

Au+Au 0-10% STAR preliminary

3<p_{trigger}<4 GeV

p_{assoc} > 2 GeV

Jet

Ridge
Jet is like $p+p$

- Spectra of particles associated with Jet harder than inclusive

Putschke WWND08

$\text{P}_{\text{T,assoc}} > 2 \text{ GeV}$
Jet composition

- Baryon/meson ratios in Jet in Cu+Cu and Au+Au similar to p+p for both strange and non-strange particles

J. Bielcikova (STAR), v:0707.3100 [nucl-ex]
C. Nattrass (STAR), arXiv:0804.4683/nucl-ex
**$p_T^{\text{trigger}}$ dependence**

- No system dependence observed in the data
- Pythia 8.1 describes trends in data up to a scaling factor
  - Gets energy dependence right
  - Stronger deviations at low $p_T^{\text{trigger}}$, as expected
Pythia comparisons

- What can Pythia tell us?
  - Higher $z_T$ (lower jet energy) in 62 GeV for same $p_T^{\text{trigger}}$

$p_{\text{THat}}$ = the parameter in Pythia for the transverse momentum in the hard subprocess
**Pythia comparisons**

- What can Pythia tell us?
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Christine Nattrass (STAR), RHIC/AGS User's Meeting, June 2, 2009
$p_T^{\text{associated}}$ dependence

- No system dependence
- Pythia 8.1 slightly harder than data
- Diverges slightly from Pythia 8.1 at lower $p_T^{\text{associated}}$

\[ \sqrt{s_{NN}} = 62 \text{ GeV} \]
\[ \sqrt{s_{NN}} = 200 \text{ GeV} \]

<table>
<thead>
<tr>
<th>System</th>
<th>$317 \pm 26$</th>
<th>$445 \pm 20$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu+Cu</td>
<td>$355 \pm 21$</td>
<td>$478 \pm 8$</td>
</tr>
<tr>
<td>Au+Au</td>
<td>$469 \pm 8$</td>
<td>$469 \pm 8$</td>
</tr>
<tr>
<td>Pythia</td>
<td>$417 \pm 9$</td>
<td>$491 \pm 3$</td>
</tr>
</tbody>
</table>

J. Bielcikova (STAR), arXiv:0806.2261/nucl-ex
C. Nattrass (STAR), arXiv:0804.4683/nucl-ex
$N_{\text{part}}$ dependence

- No system dependence
- Some deviations from Pythia 8.1 with increase in $N_{\text{part}}$
  - Incomplete Ridge subtraction?
  - Jet modification at low $p_T$?

$3.0 < p_T^{\text{trigger}} < 6.0 \text{ GeV/c}$
$1.5 \text{ GeV/c} < p_T^{\text{assoc}} < p_T^{\text{trigger}}$

STAR Preliminary
Conclusions: Jet

• Particle ratios similar to p+p
  – Separation of Jet and Ridge works
  – Effects of triggers which don't come from jets small
  – Pythia can be used to estimate $z_T$ distributions, jet energy

• Pythia describes data well
  – Scaling factor needed but Pythia 8.1 is not as tuned as earlier versions
  – Energy dependence in Jet is described well in Pythia
  – Trends for $p_T^{\text{trigger}}$, $p_T^{\text{assoc}}$ dependence right

→ Jet production mechanism dominated by fragmentation
The Ridge

Au+Au 0-10% STAR preliminary

3<p_{T,trigger}<4 GeV
p_{t,assoc}>2 GeV

Ridge

Jet
Ridge is like bulk

- Spectra of particles associated with Ridge similar to inclusive

Putschke WWND08

\[ p_{T,\text{assoc}} > 2 \text{ GeV} \]
Ridge composition

- Baryon/meson ratios in Ridge similar to bulk for both strange and non-strange particles

J. Bielcikova (STAR), v:0707.3100 [nucl-ex]
C. Nattrass (STAR), arXiv:0804.4683/nucl-ex
Identified trigger: Near-side Yield vs $N_{part}$

3.0 GeV/c < $p_T^{\text{trigger}}$ 6.0 GeV/c; 1.5 GeV/c < $p_T^{\text{associated}}$ < p

Ridge yield - No trigger type dependence

Ridge yield/trigger vs $N_{part}$

**STAR preliminary**

Au+Au $\sqrt{s_{NN}}$=200 GeV from nucl-ex/0701047
Cu+Cu $\sqrt{s_{NN}}$=200 GeV from SQM2007
Data points at same $N_{part}$ offset for visibility
Ridge yield vs. pt, trig in Au+Au

- Ridge yield persists to highest trigger pt ⇒ correlated with jet production

Putschke
WWND08
Ridge vs $N_{part}$

- No system dependence at given $N_{part}$
Ridge vs $N_{\text{part}}$

- No system dependence at given $N_{\text{part}}$
- *Ridge/Jet* Ratio independent of collision energy
Jet/Ridge w.r.t. reaction plane

Feng QM08
Konzer QM09

20-60% Au+Au 200 GeV

Jet part, near-side
Ridge part, near-side

• Ridge yield decreases with $\Psi_S$. Smaller ridge yield at larger $\Psi_S$

• Jet yield approx. independent of $\Psi_S$ and comparable with d+Au

Jet yield independent of $\Psi_S$, consistent with vacuum fragmentation after energy loss and lost energy deposited in ridge, if medium is “black” out-of-plane and more “gray” in-plane for surviving jets.

Ridge asymmetric in $\Delta \phi$, consistent with surface emission...
3-particle correlations

- **Ridge** appears uniform event-by-event within STAR acceptance
- Charge sign dependence:
  - All signs the same: no *Jet*, *Ridge* only
  - Friday Plenary session talk (Netrakanti)

\[
\begin{align*}
\Delta \eta_1 &= A1-T \\
\Delta \eta_2 &= A2-T
\end{align*}
\]

\[
3<p_T^{\text{trigger}}<10 \quad 1<p_T^{\text{assoc}}<3 \quad |\Delta \phi|<0.7
\]


Christine Nattrass (STAR), RHIC/AGS User's Meeting, June 2, 2009
Conclusions: Ridge

- Extensive data on Ridge
  - Cu+Cu, Au+Au consistent at same $N_{\text{part}}$
  - $Ridge/Jet$ ratio independent of energy
  - Persists to high $p_T^{\text{trigger}}$
  - $Ridge$ looks like bulk
    - $p_T^{\text{associated}}$ dependence, particle composition
  - Appears isotropic in $\Delta \eta$
Comparisons to models
Models

• **Radial flow+trigger bias**
  – Works for one set of kinematic cuts in central Au+Au at 200 GeV
  – Need more detailed comparisons (energy dependence)
  – Model needs some refinements (momentum conservation)

• **Plasma instability**
  Anisotropic plasma, P. Romatschke, PRC,75014901 (2007)
  – So far unable to make enough Ridge without Radial flow+trigger bias
Models

- **Longitudinal flow**
  - Problems due to $\Delta \eta$ width

- **Momentum kick**
  - Fits data well, including energy dependence

- **Recombination**
  Medium heating + recombination, Chiu & Hwa, PRC72, 034903
  - No quantitative comparisons
Conclusions

- Considerable evidence that Jet is dominantly produced by fragmentation
  - Can we use this information to learn more about the Ridge?

- Several models for the Ridge, few quantitative comparisons
  - Several depend on hydrodynamics
  - Need better calculations – more quantitative, more than central Au+Au

- Future:
  - More energy dependence (RHIC beam energy scan, LHC)
  - Jet reconstruction – more detailed studies of Ridge?
  - Ridge in γ-jet correlations?