System size dependence of di-hadron correlations with identified strange particles in STAR at RHIC

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STAR Collaboration
Outline

- Motivation
  - Interesting phenomena at intermediate $p_T$
  - Baryon/meson differences

- Method

- Comparisons of systems and energy

- Comparisons of unidentified to strange

- Conclusions

<table>
<thead>
<tr>
<th>System</th>
<th>Energy</th>
<th>Number of events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Au+Au</td>
<td>200</td>
<td>24M central</td>
</tr>
<tr>
<td>Cu+Cu</td>
<td>200</td>
<td>34M</td>
</tr>
<tr>
<td>Au+Au</td>
<td>62</td>
<td>16M</td>
</tr>
<tr>
<td>Cu+Cu</td>
<td>62</td>
<td>24M</td>
</tr>
</tbody>
</table>
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
- Jet harder than Ridge; Ridge closer to bulk
Ridge production mechanisms

- **Radiated gluons, broadened by**
  - Anisotropic plasma, P. Romatschke, PRC,75014901 (2007)

- **Momentum-kick model**

- **Medium heating + recombination**
  - Chiu & Hwa, PRC72, 034903

- **Radial flow + trigger bias**
Method: Yield extraction

- **Ridge** previously observed to be independent of $\Delta \eta$ in Au+Au
- Yield = number of associated particles/trigger particle
- To determine relative contributions, find yields for near-side, take $\Delta \Phi$ projections in
  - $-0.75 < \Delta \eta < 0.75$ \textit{Jet} + Ridge
  - $0.75 < |\Delta \eta| < 1.75$ Ridge
- $\text{Jet} = (\text{Jet}+\text{Ridge}) - \text{Ridge} \times 0.75/1.0$
- $\text{Ridge} = \text{yield from}$ $-1.75 < \Delta \eta < 1.75 - \text{Jet}$ yield
- Flow contributions to jet cancel
- $v_2$ independent of $\eta$ for $|\eta| < 1$


Unidentified particle correlations
Jet yield vs $p_T^{\text{trigger}}$

- Jet yield rises with $p_T^{\text{trigger}}$ in h-h
  - Central Au+Au and Cu+Cu jet yields comparable
- Similar trend for $\sqrt{s_{NN}}=62$ GeV

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Cu+Cu $\sqrt{s_{NN}}=200$ GeV from C. Nattrass (STAR), SQM2007
Data points at same $p_T^{\text{trigger}}$ offset for visibility
Near-side Yield vs N\_part

- **Jet yield**
  - $\sqrt{s_{NN}} = 200$ GeV:
    - Nearly independent of N\_part
  - $\sqrt{s_{NN}} = 62$ GeV
    - Also nearly independent of N\_part
  - Yield/trigger smaller

\[ 3.0 \text{ GeV/c} < \pT^{\text{trigger}} < 6.0 \text{ GeV/c}; \quad 1.5 \text{ GeV/c} < \pT^{\text{associated}} < \pT^{\text{trigger}} \]
p_T-distribution of associated particles

200 GeV

- Jet spectra similar in Cu+Cu, Au +Au

62 GeV

- Au+Au and Cu+Cu Jet similar
  - Softer than 200 GeV

<table>
<thead>
<tr>
<th>System</th>
<th>Energy</th>
<th>T(Jet) MeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Au+Au</td>
<td>200 GeV</td>
<td>478 ± 4</td>
</tr>
<tr>
<td>Cu+Cu</td>
<td>200 GeV</td>
<td>445 ± 20</td>
</tr>
<tr>
<td>Au+Au</td>
<td>62 GeV</td>
<td>317 ± 26</td>
</tr>
<tr>
<td>Cu+Cu</td>
<td>62 GeV</td>
<td>355 ± 21</td>
</tr>
</tbody>
</table>

√s_{NN}=200 GeV  Au+Au 0-10% Cu+Cu: 0-54%
√s_{NN}=62 GeV  Au+Au 0-80% Cu+Cu: 0-60%

Nattrass (STAR), SQM2007

Fits assuming 1/p_T dN/dp_T = A p_T exp(-p_T/T)
Ridge yield

- 200 GeV
  - No Ridge in d+Au
  - Increases with $N_{\text{part}}$
  - Cu+Cu consistent with Au+Au
- 62 GeV
  - Also increases with $N_{\text{part}}$ in $\sqrt{s_{NN}} = 62$ GeV
  - yield/trigger smaller

Jet yields: 10% error added h triggers to account for track merging d+Au, Au+Au $\sqrt{s_{NN}} = 200$ GeV from J. Bielcikova (STAR), J.Phys.G34:S929-930,2007
Cu+Cu $\sqrt{s_{NN}} = 200$ GeV from C. Nattrass (STAR), SQM2007
Near-side Yield vs $N_{part}$

- **Ridge yield**
  - 200 GeV
    - No Ridge in d+Au
    - Increases with $N_{part}$
    - Cu+Cu consistent with Au+Au
  - 62 GeV
    - Also increases with $N_{part}$ in $\sqrt{s_{NN}} = 62$ GeV
    - yield/trigger smaller

Jet yields: 10% error added h triggers to account for track merging
d+Au, Au+Au $\sqrt{s_{NN}} = 200$ GeV from J. Bielcikova (STAR),
Cu+Cu $\sqrt{s_{NN}} = 200$ GeV from C. Nattrass (STAR), SQM2007
Ridge/Jet Ratio

- Ridge/Jet ratio independent of energy, system

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

$\text{Au+Au } \sqrt{s_{\text{NN}}} = 200 \text{ GeV}$ from J. Bielcikova (STAR), J.Phys.G34:S929-930,2007

$\text{Cu+Cu } \sqrt{s_{\text{NN}}} = 62 \text{ GeV}$ from C. Nattrass (STAR), SQM2007
Jet: No dependence on system, falls off faster in $\sqrt{s_{NN}} = 62$ GeV.

Ridge: No dependence on system, increasing with $N_{\text{part}}$.

Ridge/Jet ratio the same at $\sqrt{s_{NN}} = 62,200$ GeV.
Identified particle correlations
Motivation

- Identified trigger particles
  - Effect of leading particle mass, flavor

- Identified associated particles
  - Probe Jet and Ridge composition
Jet yield vs $p_T^{\text{trigger}}$

\[ \text{Cu+Cu} \sqrt{s_{\text{NN}}} = 200 \text{ GeV, 0-54\%} \]
\[ 1.5 < p_T^{\text{associated}} < p_T^{\text{trigger}} \]

STAR Preliminary

Jet yields: 10\% error added to $V^0$ and $h$ triggers to account for track merging, 15\% to $\Xi$ triggers

No significant trigger type dependence

- Note: Additional systematic error due to loss of tracks at small $\Delta \eta, \Delta \phi$ not yet quantified

Au+Au @ 200 GeV, (0-10)\%

\[ 1.5 \text{ GeV/c} < p_T^{\text{associated}} < p_T^{\text{trigger}} \]

No significant trigger type dependence

- Note: Additional systematic error due to loss of tracks at small $\Delta \eta, \Delta \phi$ not yet quantified

Au+Au $\sqrt{s_{\text{NN}}} = 200$ GeV from J. Bielcikova (STAR), J.Phys.G34:S929-930,2007

Data points at same $p_T^{\text{trigger}}$ offset for visibility

Jet yields: 10\% error added to $V^0$ and $h$ triggers to account for track merging, 15\% to $\Xi$ triggers
Near-side Yield vs N\_\text{part}

3.0 GeV/c < p\_\text{trigger} < 6.0 GeV/c; 1.5 GeV/c < p\_\text{associated} < p\_\text{trigger} 

\text{Jet yield -}

- No significant trigger type dependence

Jet yields: 10% error added to V\_0 and h triggers to account for track merging, 15% to \Xi triggers


Cu+Cu \sqrt{s_{NN}} = 200 GeV from C. Nattrass (STAR), SQM2007
No significant trigger type dependence

\[ \sqrt{s_{NN}} = 200 \text{ GeV} \quad \text{Au+Au 0-10\% Cu+Cu: 0-54\%} \]
\[ \sqrt{s_{NN}} = 62 \text{ GeV} \quad \text{Au+Au 0-80\% Cu+Cu: 0-60\%} \]

J. Bielcikova (STAR),
Nattrass (STAR) - QM2007

\[ \frac{1}{N_{\text{trigger}}} \frac{1}{p_{T}} \frac{dN}{dp_{T}} = A p_{T} \exp(-p_{T}/T) \]
Near-side Yield vs $N_{\text{part}}$

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

**Ridge yield** -

- Large systematic errors
- No significant difference? Depends on how correlated systematic errors ($v_2$) are

Data points at same $N_{\text{part}}$ offset for visibility
Jet yields: 10% error added to $V^0$ and $h$ triggers to account for track merging, 15% to $\Xi$ triggers
$v_2$ errors shown only for $h$-$h$. $K^0_S$-$h$ error bars comparable to $h$-$h$. $\Lambda$-$h$ and $\Xi$-$h$ errors roughly 1.5 times as large as $h$-$h$.

Cu+Cu $\sqrt{s_{NN}}=200$ GeV from C. Nattrass (STAR), SQM2007


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Quark Matter 2008
\( p_T \)-distribution of associated particles

- No significant trigger type dependence
- Systematic errors under investigation
- Jet:
  - loss of tracks at small \( \Delta \eta, \Delta \phi \)
- Ridge subtraction
- Ridge:
  - systematic error from \( v_2 \)

\[ \sqrt{s_{NN}} = 200 \text{ GeV} \quad \text{Au+Au 0-10\% Cu+Cu: 0-54\%} \]
\[ \sqrt{s_{NN}} = 62 \text{ GeV} \quad \text{Au+Au 0-80\% Cu+Cu: 0-60\%} \]

Nattrass (STAR) SQM2007

\[ \sqrt{s} = 200 \text{ GeV} \quad \text{Au+Au} \]
\[ \langle \Lambda + \bar{\Lambda} \rangle/2 \text{-h} \]
\[ K^0_s \text{-h} \]

No significant trigger type dependence
Systematic errors under investigation
Jet:
loss of tracks at small \( \Delta \eta, \Delta \phi \)
Ridge subtraction
Ridge:
systematic error from \( v_2 \)
Ridge production mechanisms

- **Radiated gluons, broadened by**
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Do particles in Ridge look like bulk? Look at dependence on particle type


**STAR**
$p_T^{\text{trigger}}$ of identified associated yield

**Jet:** \((\bar{\Lambda}+\Lambda)/2K_0^S \approx 0.5\) in both systems

**Particle ratios in Jet similar to those in p+p**
$\left( \frac{\bar{\Lambda} + \Lambda}{2} \right) / 2K^0_S \approx 0.5$

independent of $p_T$
$p_T^{\text{trigger}}$ of identified associated yield

**Identified associated**

- Ridge: $(\bar{\Lambda} + \Lambda)/2K_S^0 \approx 1$
- Note: systematic error due to $v_2$ not shown
$p_T^{\text{trigger}}$ of identified associated yield

Particle ratios in Jet similar to those in p+p
Identified summary

**Identified trigger**

No significant dependence on trigger particle?

**Identified associated**

Jet looks like p+p

Ridge looks more like bulk?
Conclusions - Near-side

• Energy dependence:
  - Ridge present at $\sqrt{s_{NN}} = 62$ GeV
  - Both Jet and Ridge yields smaller at $\sqrt{s_{NN}} = 62$ GeV than $\sqrt{s_{NN}} = 200$ GeV
  - Ridge/Jet Ratio independent of collision energy

• Identified trigger particles:
  - No significant dependence on trigger type

• Identified associated particles:
  - Jet ($\bar{\Lambda} + \Lambda)/2K^0_s$ similar to p+p
  - Ridge ($\bar{\Lambda} + \Lambda)/2K^0_s$ similar to bulk?
Outlook

• More Au+Au $\sqrt{s_{NN}} = 200$ GeV from Year 7 – 4x statistics, EMC-triggered data
  - Allow separation of Jet and Ridge components of $\Omega$ triggered correlations?

Away side ( $\bar{\Lambda}+\Lambda$)/2$K^0_s$

Poster
Jiaxu Zuo
STAR Collaboration

Argonne National Laboratory - University of Birmingham - Brookhaven National Laboratory - California Institute of Technology - University of California, Davis - University of California - University of California, Los Angeles - Carnegie Mellon University - University of Illinois at Chicago - Creighton University - Nuclear Physics Institute Prague - Laboratory for High Energy (JINR) - Particle Physics Laboratory (JINR) - University of Frankfurt - Institute of Physics, Bhubaneswar - Indian Institute of Technology, Mumbai - Indiana University, Bloomington - Institut de Recherches Subatomiques - University of Jammu - Kent State University - Institute of Modern Physics, Lanzhou - Lawrence Berkeley National Laboratory - Massachusetts Institute of Technology - Max-Planck-Institut fuer Physik - Michigan State University - Moscow Engineering Physics Institute - City College of New York - NIKHEF and Utrecht University - Ohio State University, Columbus - Panjab University - Pennsylvania State University - Institute of High Energy Physics, Protvino, Russia - Purdue University - Pusan National University, Pusan, Republic of Korea - University of Rajasthan, Jaipur - Rice University - Universidade de Sao Paulo - University of Science & Technology of China - Shanghai Institute of Applied Physics - SUBATECH, Nantes, France - Texas A&M University - University of Texas - Tsinghua University - Valparaiso University - Variable Energy Cyclotron Centre, Kolkata, India - Warsaw University of Technology - University of Washington - Wayne State University - Institute of Particle Physics, ČCNU (HZNU), Wuhan - Yale University - University of Zagreb
“Large acceptance hadronic detector”
Ridge in other systems and energies

- Ridge also present at $\sqrt{s_{NN}} = 62$ GeV
- Lower statistics
- Weaker signal
- Apply method as done for $\sqrt{s_{NN}} = 200$ GeV