Centrality Dependence of Two-Particle Correlations in Heavy Ion Collisions

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Talk Roadmap

- Introduction to correlations in Phobos
- Correlations using a “trigger” track with $p_T > 2.5$ GeV/c
- Correlations between inclusive particles (no high $p_T$ cut)
- Effects of limited pseudorapidity acceptance
- Summary
* Pat Summitt: U. of Tenn. women’s basketball coach 1005 career wins!!
Correlation Measurements

Triggered Correlations:
“Trigger” particles detected in the Spectrometer (high $p_T$ trigger $0<\eta<1.5$)

Associated particles detected in a single layer of silicon
Broad $\eta$ coverage (-3<\eta<3)

No $p_T$ information !!
$p_T>7 (\pi^\pm@\eta=3)$–35 MeV/c ($\pi^\pm@\eta=0$)

Inclusive Correlations:
Pairs start with an inclusive particle detected in a single layer of silicon (-3<\eta<3)

The correlation functions are the suitably normalized ratio of signal (same-event pairs) over background (mixed-event pairs). The effect of elliptic flow is removed either by subtraction (triggered correlations) or by integrating over $\Delta\phi$ (inclusive correlations).
Correlations with $p_T > 2.5$ GeV/c Trigger

$p+p$ (PYTHIA) $\Rightarrow$ Au+Au 0-30%

$200 \text{ GeV}$

$1 \frac{d^2N_{ch}}{N_{trig} d\Delta \phi d\Delta \eta}$

$1 \frac{d^2N_{ch}}{N_{trig} d\Delta \phi d\Delta \eta}$

$p_T^{\text{trig}} > 2.5$ GeV/c
$p_T^{\text{assoc}} > 7 - 35$ MeV/c ($\pi^\pm$)

NB: PYTHIA closely matches STAR data at mid-rapidity for a similar set of $p_T$ cuts.
"Ridge" at small $\Delta \phi$: Extent in $\Delta \eta$

Long-range ridge yield

Near-side, $|\Delta \phi| < 1.0$

- Au+Au 0-30% (PHOBOS)
- p+p (PYTHIA v6.325)
- $v_2$ uncertainty
- ZYAM uncertainty

arXiv:0903.2811
Actually an Extended “Ridge” plus a Peak

\[
\frac{1}{N_{\text{trig}}} \frac{dN_{\text{ch}}}{d\Delta \eta}
\]

Near-side, \([\Delta \phi] < 1.0\)

- **Au+Au 0-30%** 
- **PYTHIA + 0.25**
- \(v_2\) uncertainty
- ZYAM uncertainty

arXiv:0903.2811
Integrated Ridge Yield: $|\Delta \eta|<1$ vs $-4<\Delta \eta<-2$

Project 2D correlation onto $\Delta \phi$ axis. Subtract out the Pythia peaks and then plot versus centrality for short- and long-range.
Integrated Ridge Yield: $|\Delta \eta| < 1$ vs $-4 < \Delta \eta < -2$

Short-range $|\Delta \eta| < 1$

Long-range $-4 < \Delta \eta < -2$

Au+Au

PYTHIA

PHOBOS

arXiv:0903.2811

0-10%

# of participant nucleons ($N_{\text{part}}$)

NEAR side

○ short-range minus PYTHIA

● long-range (PYTHIA ≈ 0)
Integrated Ridge Yield: $|\Delta \eta| < 1$ vs $-4 < \Delta \eta < -2$

Short-range
$|\Delta \eta| < 1$

Long-range
$-4 < \Delta \eta < -2$

Au+Au
200 GeV

PYTHIA

NEAR side
- short-range minus PYTHIA
- long-range (PYTHIA $\approx$ 0)

AWAY side
- short-range, long-range both minus PYTHIA

arXiv:0903.2811

$\langle \frac{1}{N_{\text{trig}}} \frac{dN_{\text{ch}}}{d\Delta \phi} \rangle$

# of participant nucleons ($N_{\text{part}}$)
Triggered Correlation Observations

Near side (small $\Delta \phi$) ridge yield extends to at least $|\Delta \eta| \sim 4$

Short-range ($|\Delta \eta| < 1$) and long-range ($-4 < \Delta \eta < -2$) ridge yields are very similar in size at all centralities

Ridge disappears for $N_{\text{part}}$ below about 80

Excess yield on the away side ($\Delta \phi \sim \pi$) is also uniform in $\Delta \eta$ and decreases for more peripheral collisions

arXiv:0903.2811
Inclusive 2-Particle Correlations

Project onto $\Delta \eta$ axis and fit with a simple parameterization of a cluster model.

- $p+p@200GeV$
- $Cu+Cu@200GeV$
- $Au+Au@200GeV$

arXiv: 0812.1172
Cluster Model Fit to Inclusive Correlations

Two-particle $\Delta \eta$ correlation function

- Cu+Cu@200GeV
- Au+Au@200GeV

(scale errors are shown as grey bands)
Cluster sizes (number of particles in a cluster) are large: Up to \( \sim 5 \) charged particles (after correction for \( \eta \) acceptance, see later discussion).
Inclusive Correlation Results

Cluster sizes (number of particles in a cluster) are large: Up to ~5 charged particles (after correction for $\eta$ acceptance, see later discussion).

Cluster size scales with fractional cross-section.

Model studies suggest that centrality dependence is due to the hadronic cascade phase and that cluster size is strongly dependent on string fragmentation parameters.
New Inclusive Correlation Result

Au+Au @ 200 GeV: Peripheral collisions

\[ R(\Delta\eta, \Delta\phi) \]

\[ R(\Delta\eta) \]
Expanded 2-Particle Correlation Result

Au+Au @ 200 GeV

Cluster size

Cluster width

N_{part} \sim 20, 50, 100, 200, 300

1 - \sigma / \sigma_0

1 - \sigma / \sigma_0
Limited $\eta$ range causes loss of correlated particles leading to *smaller* measured sizes and widths for the clusters.

For A+A data in the range $|\eta|<3$, the correction is roughly a factor of 2 for the cluster size and 40% for the cluster width.
Cluster Fits to MC in $|\eta| < 3$ and $|\eta| < 1$

Identical MC independent cluster model events thrown into different detector acceptances and then fit with the simple cluster parameterization.
MC Study of Acceptance Effect

Events from cluster model plus flow are fit with a multi-component parameterization (similar to arxiv:0806.2121v2)

MC correlation  Fit  Individual components
MC Study of Acceptance Effect

Events from cluster model plus flow are fit with a multi-component parameterization (similar to arxiv:0806.2121v2)

Note the almost complete disappearance of the 1D $\Delta \eta$ component in the reduced acceptance case

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MC Study of Acceptance Effect

Events from cluster model plus flow are fit with a multi-component parameterization (similar to arxiv:0806.2121v2)

\[ |\eta| < 3 \]

\[ |\eta| < 1 \]

Note the almost complete disappearance of the 1D \( \Delta \eta \) component in the reduced acceptance case
Summary

Correlations in Au+Au @ 200 GeV using a trigger particle with $p_T > 2.5$ GeV/c show a “ridge” of enhanced yield at small $\Delta \phi$ which extends to at least $|\Delta \eta| = 4$

- Appears to be a constant “ridge” under Pythia-like fragmentation
- Effect seems to disappear for $N_{\text{part}}$ below about 80

Inclusive 2-particle correlations suggest that particles are emitted in very large “clusters” whose size scales with the geometry of the collision as opposed to $N_{\text{part}}$

Quantitative interpretation of any correlation result needs to take into account the effect of $\eta$ acceptance

- For example comparing to models or comparing STAR & PHOBOS
Backup Slides
Construction of Correlated Yield

\[
\frac{1}{N_{\text{trig}}} \frac{d^2N_{\text{ch}}}{d\Delta\phi \, d\Delta\eta} = B(\Delta\eta) \left\{ \frac{s(\Delta\phi,\Delta\eta)}{b(\Delta\phi,\Delta\eta)} a(\Delta\eta) \left[ 1 + 2V(\Delta\eta) \cos(2\Delta\phi) \right] \right\}
\]

- **Raw correlation**: ratio of per-trigger same event pairs to mixed event pairs

- **Elliptic flow**: \( V(\Delta\eta) = <v_2^{\text{trig}}><v_2^{\text{assoc}} > \)

- **Scale factor**: accounts for small multiplicity difference between signal and mixed events

- **Normalization term**: relates flow-subtracted correlation to correlated yield

Subtraction of elliptic flow

\[ a(\Delta \eta) \left[ 1 + 2V(\Delta \eta) \cos(2\Delta \phi) \right] \]

Elliptic Flow

PHOBOS

arXiv:0903.2811

-4 < \Delta \eta < -2

-1 < \Delta \eta < 1

Long Range

Short Range

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20-25% central

![Graph showing data points and a curve, labeled as 20-25% central. The x-axis is labeled as \( \Delta \eta \).]
Pythia-Subtracted Correlation Functions

\[ \frac{1}{N_{\text{trig}}} \frac{dN_{\text{ch}}}{d\Delta \phi} \]

-1 < $\Delta \eta$ < 1
- Au+Au 0-10%
- Au+Au 40-50%

-4 < $\Delta \eta$ < -2
- PHOBOS
- Au+Au 0-10%
- Au+Au 40-50%
Pythia-Subtracted Correlation Functions

![Graph showing correlation functions with error bars and a shaded background.](image-url)
Inclusive 2-Particle Methodology

Two-particle correlation function:

\[
R(\Delta \eta, \Delta \phi) = <(n-1)\left(\frac{F_n(\Delta \eta, \Delta \phi)}{B_n(\Delta \eta, \Delta \phi)} - 1\right)> 
\]

(multiplicity independent!)

**Foreground:** \( F_n(\Delta \eta, \Delta \phi) \)
(correlated + uncorrelated pairs):

**Background:** \( B_n(\Delta \eta, \Delta \phi) \)
(uncorrelated pairs):

Secondary effects:
- \( \delta \)-electron, \( \gamma \) conversion
- MC correction for secondary effects
- Occupancy corrections in A+A

Event 1

Event 2

\( \delta \)-electron, \( \gamma \) conversion
PHOBOS
p+p@200GeV

\[ K_{\text{eff}} = \langle K \rangle + \frac{\sigma_K^2}{\langle K \rangle} \]
\[ \delta = \left( \sqrt{K(K-1)} \right) \sigma_{\eta-\eta_{\text{cluster}}} \]

\( K_{\text{eff}} \): effective cluster size

\( \delta \): cluster decay width
Expanded 2-Particle Correlation Result

Au+Au @ 200 GeV Not corrected for acceptance

Cluster size

Cluster width

N_{part}: 20  50  100  200  300

$K_{eff}^{m<3}$

1 - $\sigma/\sigma_0$

PHOBOS Au+Au 200 GeV
PHOBOS Au+Au 200 GeV, PRELIMINARY
PHOBOS p+p 200 GeV
AMPT Au+Au 200 GeV