First Results on Two-Particle Correlations
Determined by PHENIX

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Why study particle correlations?
(Preaching to the choir)

• Measures the relative spatial-temporal separation at the point of last interaction
  – Sensitive to relative separation in phase space of pairs at freeze-out

\[ C_2 = \frac{A(q)}{B(q)} = 1 + |\tilde{\rho}(q)|^2 \]

Assuming a chaotic source with no dynamical correlations and no final state interactions the resulting correlation function is rather straightforward:

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But Beware!!

• “C₂ depends on more variables than you can think of.”
  – Anonymous HBT expert

• In particular
  – Dynamical correlations
  – Lorentz kinematics

Be careful with assumptions of symmetric and static sources!!

**This first figure unabashedly stolen from M. Lisa**

\[ R_S^2 + \beta^2 \tau^2 = R_O^2 \]
Agenda

• First PHENIX HBT results from Run 1.

• Proof of principle – capability of PHENIX to perform these measurements
  – PID capabilities and analysis
  – 1D correlations
  – Bertsch-Pratt 3D fit to $R_{OSL}$
  – Confirm dependencies of $R$ on $k_t$

• Comparisons and Conclusions

• A glance at future capabilities.

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Particle identification

- For this analysis: \( \pi = \)
  - 2 \( \sigma \) within \( \pi \) peak
  - 3 \( \sigma \) away from \( K \) peak
  - 180 < \( p \) < 2000 MeV/c

"Particle identification capability of the PHENIX experiment"
H. Hamagaki
Pair Acceptance

- Acceptance about time-of-flight wall restricts correlation measurement to $y_{\text{pair}} < 0.3$
- PHENIX excellent PID allows pair reconstruction to very high $k_t$
  - $\Rightarrow$ larger statistics of year-2 will allow high $k_t$ 3D measurements

$$\langle k_t \rangle \equiv \frac{1}{2} \sqrt{(p_{x1} + p_{x2})^2 + (p_{y1} + p_{y2})^2} = 350 \text{MeV}$$
• Finite acceptance in $\delta y$ and $\delta \phi$ $\Rightarrow$ finite $q_{T \text{side}}$ and $q_{\text{long}}$ reach.

• Excellent particle identification to large $p$ $\Rightarrow$ large $q_{\text{Tout}}$ bite.
q acceptance

![Graphs showing q acceptance with q_{T_{side}} < 100 MeV and q_{T_{out}} < 100 MeV](image_url)
Centrality

- All data presented today are for ‘minimum bias collisions’ (i.e. only with trigger on $z_{vtx}$)
- However: finite detector + minimum bias sample + pairs requirement
  
  - $\Rightarrow$ bias towards central collisions in min bias sample
- Truly a central event sample
$Q_{\text{inv}}$ distributions

- Full coulomb correction...
  - Analytic coulomb correction assumes $R(Q_{\text{inv}})$ source
  - Resulting radii independent of $R_{Q_{\text{inv}}}$ input within ~10%

- $Q_{\text{inv}}$ => measurement of relative separation of the pair in the pair rest frame
  - Acceptance dependent!!

PHENIX Preliminary

$Q_{\text{inv}}$ (MeV/c)

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Bertsch-Pratt Fit Results

\[ R_1 = 6.7 \pm 0.9 \]
\[ R_{\text{Tside}} = 5.8 \pm 1.5 \]
\[ R_{\text{Tout}} = 5.49 \pm 0.54 \]
\[ \Lambda = 0.493 \pm 0.061 \]

\[ R_1 = 4.0 \pm 1.2 \]
\[ R_{\text{Tside}} = 7.9 \pm 1.1 \]
\[ R_{\text{Tout}} = 6.23 \pm 0.54 \]
\[ \Lambda = 0.493 \pm 0.050 \]
1D correlations

- Full coulomb correction
- $q \rightarrow$ Measure of relative separation of pair in the rest frame of the collision.

PHENIX Preliminary

$\langle k_i \rangle = 195\text{MeV}$

$R = 6.0 \pm 0.8$

$\lambda = 0.38 \pm 0.08$

$\pi^- \pi^-$

$\langle k_i \rangle = 307\text{MeV}$

$R = 4.8 \pm 0.5$

$\lambda = 0.48 \pm 0.08$

$\langle k_i \rangle = 524\text{MeV}$

$R = 3.7 \pm 0.6$

$\lambda = 0.37 \pm 0.09$

$\pi^- \pi^-$

$q (\text{MeV}/c)$

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As a function of $k_t$

- $k_t$ dependence is well behaved

- Measured relative separation of pions from source expected to decrease versus $k_t$ possibly due to collective behavior of source or resonance contributions.
Comparisons

- No indication of large volumes
- Comparable results to SPS and preliminary STAR with similar $<k_t>$/centrality
  - Not exactly the same, so be careful…
- Perhaps indicative of same effective freeze-out due to convolution of
  - larger source and
  - stronger dynamical correlations / high flow velocities / resonances(?)

△ Star Preliminary (M. Lisa)
▲ NA44
▼ NA49
★ E866
△ E895
● PHENIX Preliminary
Conclusions*

• First measured $\pi^+/\pi^-$ correlation function from PHENIX at RHIC including most Run 1 dataset:
  
  – 1D correlation looks well behaved $\Rightarrow$ used to determine coulomb correction.
  – 3D correlation comparable to SPS published and STAR preliminary results when comparing similar $k_t$ bins
  – Dependencies of R1 and Rs on beam energy are gradual and well behaved.
  – No indication of long lived source in correlation function
    • But be careful what you conclude from that…

• First proof-of-principle methodology -- looking forward to increased statistics and systematic studies…

* Don’t leave yet, I still have 3 more slides…
For the future...

- **This year**
  - Complete systematic studies of $\pi^+/\pi^-$ correlations
  - $h^+h^- \pi^-p, \pi^-K$ (1D)
  - with EMCAL:
    - $\pi\pi, KK, pp$ (1D)

- **Next year**
  - 100x statistics $\Rightarrow$
    - $\pi$ vs centrality and $k_t$
    - $pp, KK$
  - with EMCAL
    - anti-neutron, $\pi^0$ (?)

- **In general**
  - Are there other methods we can use to extract info from correlations? $\Rightarrow$

Coherent interpretation of source size
Other methods

– Explicit inversion of correlation function to deduce relative separation of pairs at freeze-out.

– How sensitive is this method to the source?
  
  • Can we learn more than just the RMS?
  • Extract multi-D source parameters?
  • Systematic studies underway.

See poster by D. Brown

Figure and studies by Mike Heffner

Brown and Danielewicz nucl-th/0010108

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