Two-pion Interferometry Measurements for Au+Au and Cu+Cu Systems at RHIC-PHENIX

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1. Abstract

HBT measurements are presented as a function of collision centrality and the mean transverse momentum of pion pairs, for different collision systems and beam collision energies. They provide new insights on reaction dynamics at RHIC, as well as a detailed model independent mapping of the evolution of the space-time extent of the emitting source, from RHIC to LHC.

2. HBT Method

Two-particle correlations encode information about the space-time extent of pion-emitting sources.

$$C(q) \approx \int dr\left(\Phi(r,q)^2\right) S(r,q) \qquad \text{Eq. 1}$$

r is the pair separation; *q* is the relative momentum; *S(r,q)* is the emission function; *Φ(r,q)* is a correction for Final State Interactions (FSI).
In experiment, we fit *C(q)* in 3-D with the form:

$$C_2(q_{side},q_{out},q_{long}) = 1+\lambda \exp\left(-R_{side}^2 q_{side}^2 - R_{out}^2 q_{out}^2 - R_{long}^2 q_{long}^2\right) \qquad \text{Eq. 2}$$

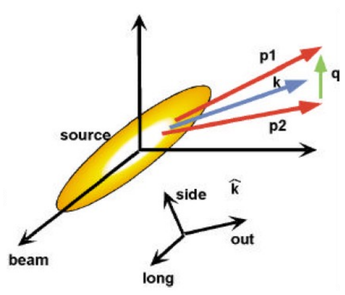

Fig. 1

$k = p_1 + p_2/2$
$q = p_1 - p_2$
$m_T = \sqrt{(k_2 + m_\pi)}$
Where m_π is the pion mass

gives

- q_{out} parallel to pair transverse momentum ⟶ R_{out} which gives source emission duration ($\Delta\tau$)
- q_{side} perpendicular to beam direction ⟶ R_{side} that provides source geometrical size, R_{geom}
- q_{long} parallel to beam direction ⟶ R_{long} that carries information on source lifetime (τ)

3. Experiment

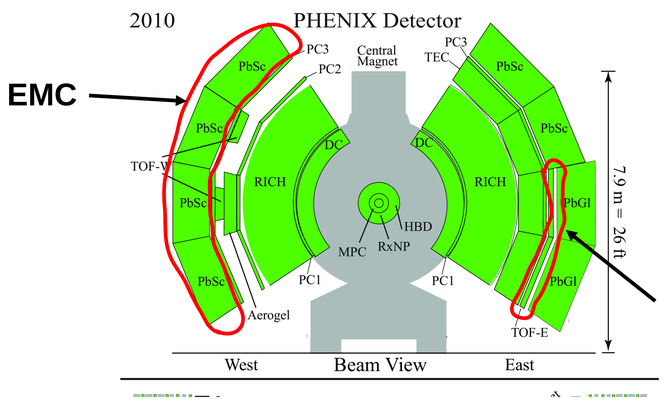

Fig. 2

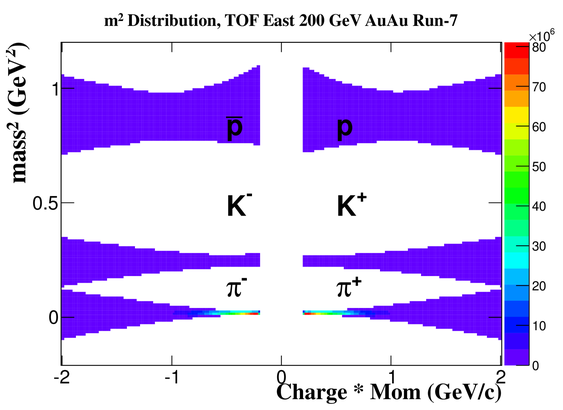

Fig. 3

Very good PID attained from EMC and TOF East

4. $\overline{R}$ Scaling of HBT Radii

$\overline{R}$ is the transverse size of the system

$$1/\overline{R} = \sqrt{\left(1/\sigma_x^2 + 1/\sigma_y^2\right)} \qquad \text{Eq. 3}$$

σ_x, σ_y : RMS widths of density distributions

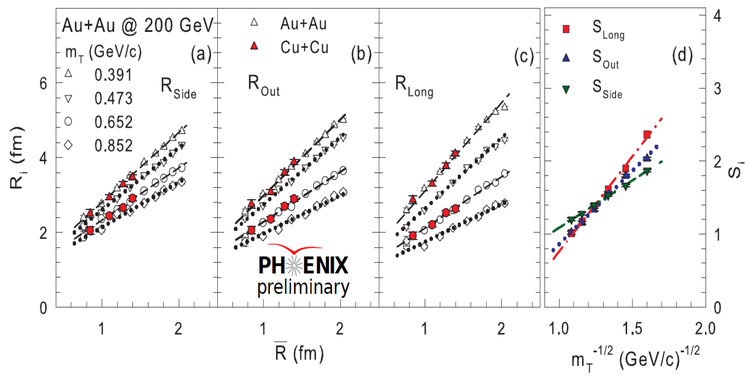

Fig. 4 (a), (b), (c) $\overline{R}$ dependence of R_{out}, R_{side}, and R_{long}. Curves are linear fits to data. (d) $1/\sqrt{m_T}$ dependence of slopes from linear fits in (a), (b), (c).

- **Au+Au and Cu+Cu similar at same m_T and $\overline{R}$**
- **Strong linear dependence of HBT radii on $\overline{R}$**
- **Decrease of slope in scaling curves for HBT radii with m_T indicative of strong influence of space-momentum correlations**

5. m_T Scaling of HBT Radii

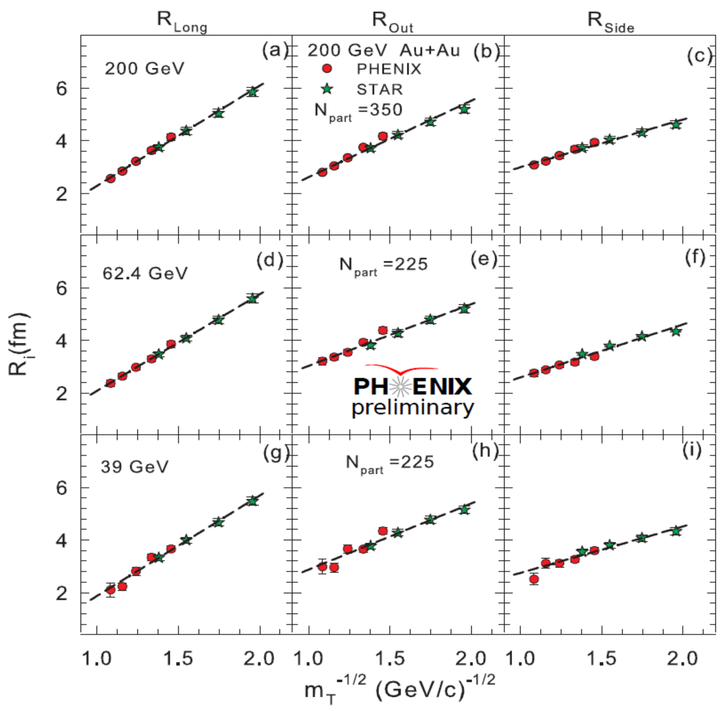

Fig. 5 PHENIX and STAR R_{out}, R_{side}, and R_{long} dependence on $1/\sqrt{m_T}$ for $\sqrt{s_{NN}}$ = 200 GeV ((a), (b), (c)); 62 GeV ((d), (e), (f)); 39 GeV ((g), (h), (I)). Curves are linear fits to data.

- **PHENIX and STAR results show a very good comparison for all HBT radii at the three energies**
- **HBT radii in all systems and energies studied scale with $1/\sqrt{m_T}$**

6. $(R_{out})^2 - R(_{side})^2$ and $(R_{side} - \sqrt{2}\overline{R})/R_{long}$

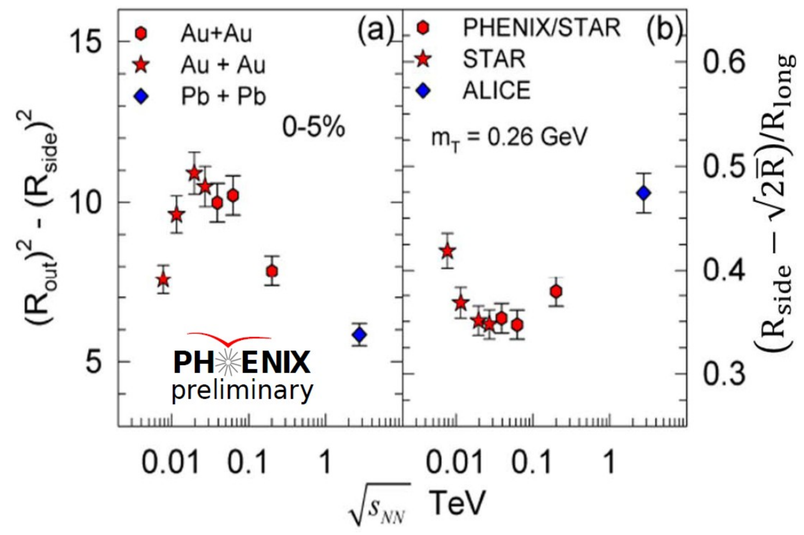

Fig. 6 (a) $(R_{out})^2 - (R_{side})^2$ and (b) $(R_{side} - \sqrt{2}\overline{R})/R_{long}$ dependence on $\sqrt{s_{NN}}$

- **$(R_{out})^2 - (R_{side})^2$ is proportional to $\Delta\tau^2$**
- **$(R_{side} - \sqrt{2}\overline{R})/R_{long}$ is expansion rate in the transverse as compared to the longitudinal**
- **$(R_{out})^2 - (R_{side})^2$ dependence on $\sqrt{s_{NN}}$ shows a maximum with a complimentary minimum in $(R_{side} - \sqrt{2}\overline{R})/R_{long}$**
- **This pattern is suggestive of decay trajectories in vicinity of critical end point (CEP)**

7. Summary and Conclusion

- **R_{out}, R_{side}, and R_{long} scale with $\overline{R}$ and m_T for all collision systems and beam energies studied**
- **Au+Au and Cu+Cu HBT radii are comparable at the same $\overline{R}$ and m_T**
- **Observed non-monotonic behavior in $\sqrt{s_{NN}}$ dependence suggests a change in reaction dynamics over small $\sqrt{s_{NN}}$ range**
- **More measurements needed in future RHIC beam energy scan to help locate CEP**

References

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Acknowledgments

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