Pion Interferometry in Heavy Ion Collisions at RHIC

Z. W. Lin, C. M. Ko, and S. Pal

Particle interferometry based on the Hanbury-Brown Twiss (HBT) effect can provide information not only on the spatial extent of an emission source but also on its expansion velocity and emission duration [1], [2], [3]. In particular, the long emission time resulting from the quark-gluon plasma to hadronic matter phase transition in the initial stage of heavy ion collisions is expected to lead to a much larger radius parameter along the direction of the total momentum of detected two particles than that perpendicular to both this direction and the beam direction. Using a multiphase transport model (AMPT) [4] that includes both the initial partonic and final hadronic interactions, we have studied the partonic effect on the pion interferometry in heavy ion collisions at RHIC [5].

From the emission function, which is given by the space-time and momentum distribution of particles at freezeout in the AMPT model, we can evaluate the correlation function $C(\mathbf{Q},\mathbf{K})$ of two identical pions including their Coulomb interaction. Here, **Q** and **K** are the relative and total momenta of the two pions. The six-dimension correlation function is usually shown as a function of the invariant momentum $(Q_{inv} = \sqrt{-Q^2})$ or as a function of the projection of the relative momentum in the "out-side-long" coordinates, defined by the beam direction (Q_{long}), the direction along the total transverse momentum of the two pions (Q_{out}), and the direction orthogonal to the above two directions (Q_{side}). In Fig. 1, we show the one-dimensional projections of the correlation function for mid-rapidity pions with transverse momentum $125 < p_\perp < 225\, MeV/c$ in Au+Au collisions at $\sqrt{s} = 130\, AGeV$. Also shown is the measured π^- correlation function by the STAR collaboration without correcting the effect due to Coulomb interaction [6]. In the figure, the results from the default AMPT model, which includes only minijet partons in the partonic stage and uses a parton scattering cross section of $\sigma_p = 3\, mb$ are shown by the dash-dotted curves, while other curves are from the extended AMPT model, which includes also partons from melting the excited strings in the partonic stage, but different values of parton scattering cross section. It is seen that with string melting both

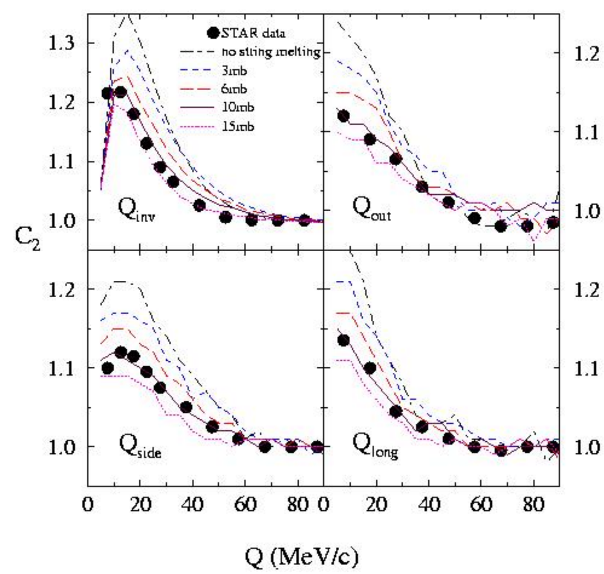

Figure 1: Correlation functions for midrapidity pions from central Au+Au collisions at $\sqrt{s} = 130\, AGeV$. Coulomb-uncorrected correlation functions from the STAR collaboration [6] for low p_T π^- at midrapidity from central collisions are shown by filled circles. Dash-dotted curves are results from the default AMPT model, while other curves are from the extended AMPT model with string melting and various values for the parton scattering cross section.

the width of the Q_{inv} correlation function and its height decrease with increasing σ_p. To reproduce the measured one-dimensional correlation functions from the STAR collaboration, we need a parton scattering cross section of about 10 mb in the extended AMPT model with string melting.

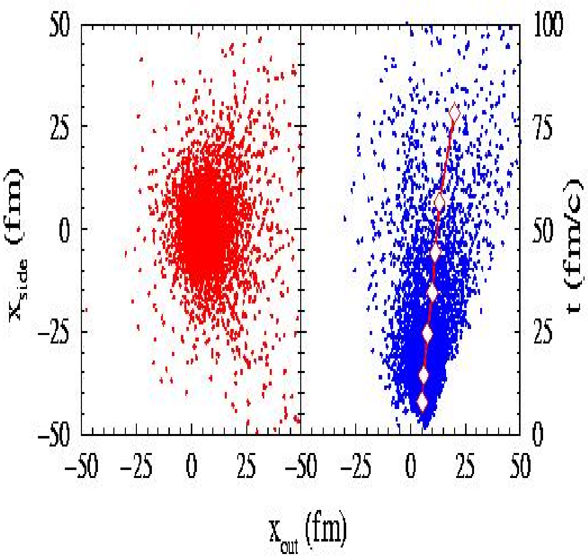

Figure 2: Distribution of the emission source from the AMPT model for midrapidity pions with $125 < p_\perp < 225\,MeV/c$ in the $x_{out} - x_{side}$ (upper panel) and $x_{out} - t$ (lower panel) spaces.

In Fig. 2, we show the distribution of the emission source from the AMPT model for midrapidity pions with $125 < p_\perp < 225\,MeV/c$ in the $x_{out} - x_{side}$ and $x_{out} - t$ spaces. It is seen that the emission source shows a large halo around a central core. The halo consists of not only pions from decays of long-lived resonances such as the ω, but also thermal pions. The latter contribution to the halo becomes increasingly important when the collective expansion velocity of the source is large as a result of increasing parton cross section. The emission source also shows a strong correlation between x_{out} and t, with the width of its x_{out} distribution increasing with the emission time t. As a result, the source radii R_{out}, R_{side}, and R_{long} estimated from the curvature of the correlation function at $Q = 0$ is a factor of 2 to 3 larger than the radius parameters obtained from fitting the correlation function by a Gaussian function in the relative momentum of the pion pair. Furthermore, the ratio R_{out} / R_{side} obtained from the emission function has a value between 1.0 and 1.3 and is larger than that from the radius parameters extracted from the Gaussian fit to the correlation function, which is much closer to 1. Our study thus demonstrates the sensitivity of two-pion correlation function on the partonic dynamics during the early stage of heavy ion collisions. The study of pion interferometry thus helps to confirm the formation of the partonic matter at RHIC and to study its properties.

References

[1] S. Pratt, Phys. Rev. D **33**, 1314 (1986).

[2] G. Bertsch, M. Gong, and M. Tohyama, Phys. Rev. C **37**, 1896 (1988).

[3] D. H. Rischke and M. Gyulassy, Nucl. Phys. **A608**, 479 (1996).

[4] B. Zhang, C. M. Ko, B. A. Li, and Z. W. Lin, Phys. Rev. C **61**, 067901 (2000); Z. W. Lin, S. Pal, C. M. Ko, B A. Li, and B. Zhang, *ibid*. **64**, 011902 (2001); Nucl. Phys. **A698**, 375c (2002).

[5] Z. W. Lin, C. M. Ko, and S. Pal, nucl-th/0204054.

[6] C. Adler *et al*., (STAR Collaboration), Phys. Rev. Lett. **87**, 082301 (2001).