Femtoscopic results in Au+Au and p+p from PHENIX at RHIC [1]

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Abstract

Ultra-relativistic gold-gold and proton-proton collisions are investigated in the experiments of the Relativistic Heavy Ion Collider (RHIC). In the last several years large amount of results were revealed about the matter created in these collisions. The latest PHENIX results for femtoscopy and correlations are reviewed in this paper. Bose-Einstein correlations of charged kaons in 200 GeV Au+Au collisions and of charged pions in 200 GeV p+p collisions are shown. They are both compatible with previous measurements of charged pions in gold-gold collisions, with respect to transverse mass or number of participants scaling.

1 Introduction

Ultra-relativistic collisions of Au nuclei are observed at the experiments of the Relativistic Heavy Ion Collider (RHIC) of the Brookhaven National Laboratory, New York. The aim of these experiments is to create new forms of matter that existed in Nature a few microseconds after the Big Bang, the creation of our Universe.

A consistent picture emerged after the first three years of running the RHIC experiment: the created hot matter acts like a liquid [1], not like an ideal gas some had anticipated when defining the term QGP. The nuclear modification factor is ratio of yield in Au+Au collisions over the yield in p+p collisions, scaled by the number of binary nucleus-nucleus collisions in a Au+Au collision. It has been measured for several hadron species at highest p_t, most recently η and ϕ mesons [2]. This confirms the evidence for a dense and strongly interacting matter. Direct photon measurements, which require tight control of experimental systematics over several orders of magnitude, show that high p_t photons in Au+Au collisions are not suppressed [3]. This observation makes definitive the conclusion that the suppression of high-p_t hadron production in Au+Au collisions is a final-state effect.

[1]Talk at the VI Workshop on Particle Correlations and Femtoscopy, Kiev, September 14-18, 2010.

A very important tool to understand the geometry of the matter created at RHIC is that of Bose-Einstein correlations, or otherwise interferometry of bosons. In present proceedings paper we do not detail the theory, simply refer to ref. [4]. In the next sections we will detail recent measurements about pion and kaon interferometry.

2 Kaon interferometry in Au+Au collisions

The observations of extended, non-Gaussian, source size from two-pion correlations [5] make the measurement of two-kaon correlations important for understanding the contribution from decays of long-lived resonances.

This analysis is described in detail in ref. [6]. PHENIX used ~ 600 million minimum bias events, triggered by the coincidence of the Beam-Beam Counters (BBC) and Zero-Degree Calorimeters (ZDC) with collision vertex $|z| < 30$ cm. Charged kaons were tracked and identified using the drift chamber (DC), pad chambers (PC1,PC3) and PbSc Electromagnetic Calorimeters (EMCal) to cover pseudorapidity $|\eta| < 0.35$ and azimuthal angle $\Delta\phi = 3\pi/4$. Momentum resolution in this case was $\delta p/p \simeq 0.7\% \oplus 1.0\% \times p$ (GeV/c). Backgrounds were reduced by requiring 2 σ position match between track projections and EMCal hits, and 3 σ match for PC3. Until a transverse momentum of $\sim$0.9 GeV/c kaons and pions can be separated via timing information. Above that limit PID cuts have to be introduced, the selection in this case was that we identify particles as kaons if they are within 2 σ of the theoretical mass-squared of kaons and are at least 2 σ away from the pion and also the proton mass. With this, the contamination level is $\sim$4% from pions, and $\sim$1% from protons at $p_t \sim 1.5$ GeV/c.

We find that the number of participants ($N_{part}^{1/3}$) dependence of 3D correlation radii is linear as shown on fig. 1. The transverse momentum (m_t) dependence of these radii follows the same scaling as in case of pions, predicted from hydro models, see for example [7]. In case of imaging, a non-Gaussian tail is revealed for radii greater than 10 fm. This suggests that earlier finding of large tails of pion imaged source functions are not due to resonance decays but show truly enlarged sources.

3 Pion interferometry in p+p collisions

The important measurement of Bose-Einstein correlations was extended to proton-proton systems also. See more details of this analysis in ref. [8].

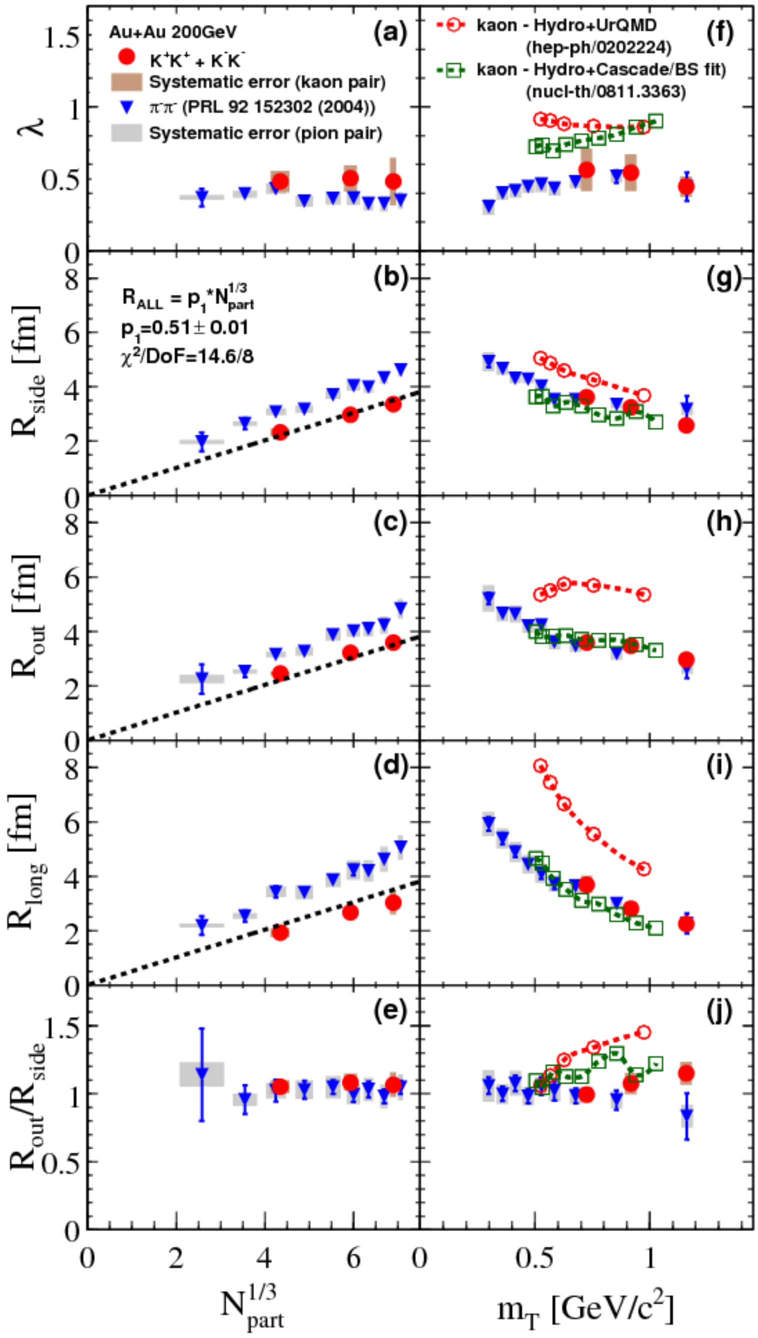

Figure 1: 3D Gaussian HBT radius parameters for charged kaon pairs are plotted as a function of $N_{\rm part}^{1/3}$ (left), and as a function of m_t (right).

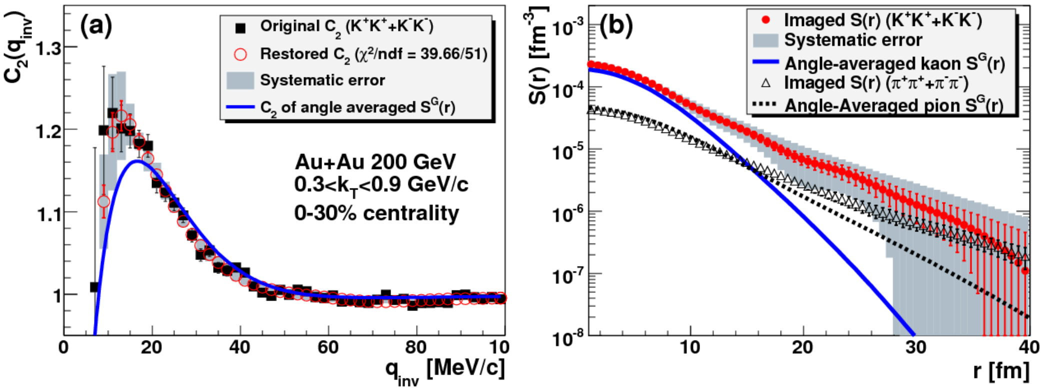

Figure 2: On the top plot, correlation functions are shown. Measurements and restored correlation functions are in nice agreement. On the bottom plot imaged kaon sources are shown. The deviation from the Gaussian is larger than in case of pions.

PHENIX analyzed roughly 2.5 million like sign pion pairs from proton-proton collisions of the 2004 and 2005 RHIC runs. Measurement techniques are similar to those described in the previous section. One-dimensional slices of the correlation function are shown in fig. 3, describable by usual HBT techniques. Extracted source sizes are shown in fig. 4. Usual m_t behavior is observed, while the $N_{part}^{1/3}$ scaling curve of Au+Au [9] data is also in accordance with the new p+p results.

4 Summary and conclusions

We measured HBT correlation functions of charged kaon pairs in Au+Au collisions and of charged pion pairs in p+p collisions. The 3D HBT radii are consistent for pions and kaons at the same number of participants and transverse mass. The 1D emission source function for kaons extracted by imaging shows a non-Gaussian tail at distances greater than 10 fm. The preliminary analysis of pion HBT correlations in p+p collisions can be analyzed via traditional 3D HBT methods. These correlation radii are also consistent with extrapolations from earlier measurements.

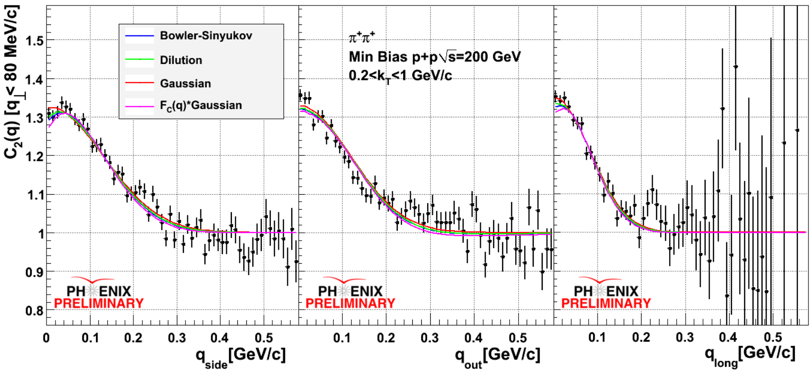

Figure 3: Slices of three dimensional two-pion correlation functions measured in proton-proton collisions.

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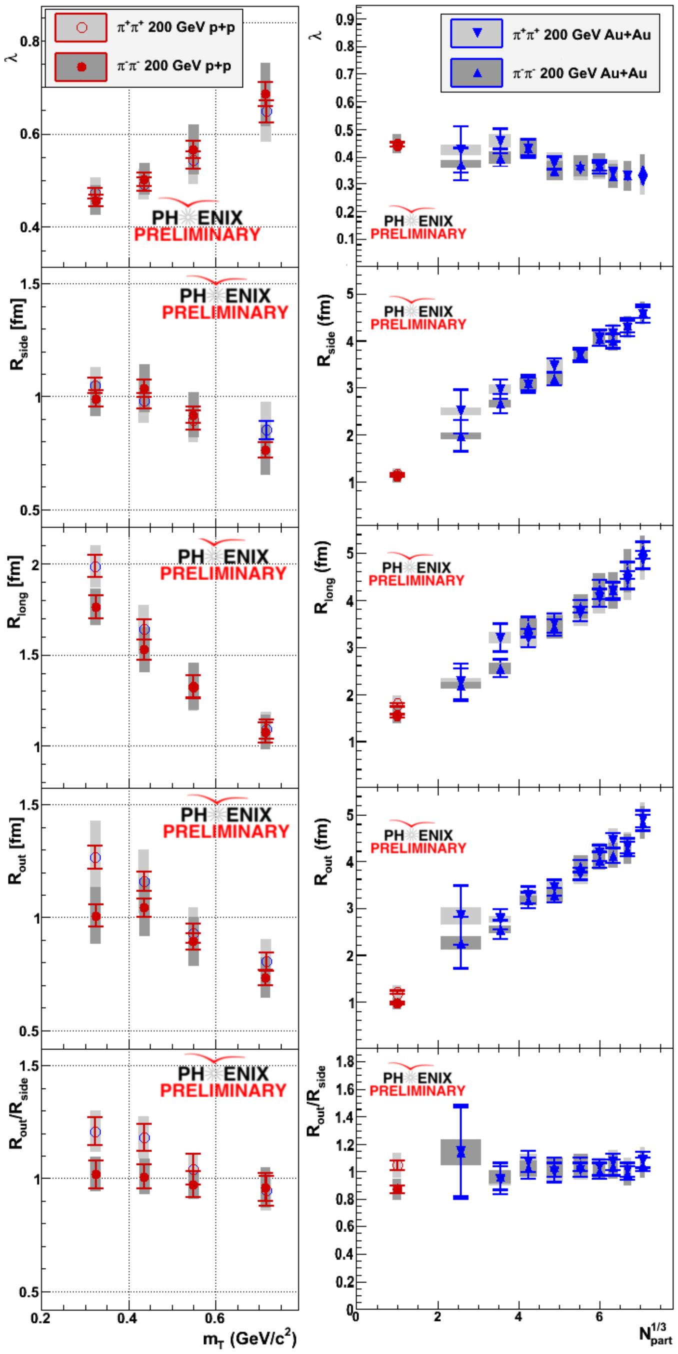

Figure 4: The transverse mass (left) and number of participants (right) dependence of correlation parameters for pion pairs proton-proton collisions. Final Au+Au HBT data is from ref. [9].