Measurements of two-pion Femtoscopy in Au+Au Collisions at $\sqrt{s_{NN}}$ = 3.0, 3.2, 3.5, and 3.9 GeV from RHIC-STAR

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Youquan Qi (qyq@mails.ccnu.edu.cn) *for the STAR Collaboration*,
Central China Normal University

Abstract

Femtoscopic measurements are sensitive to the spatial and temporal characteristics of the particle emitting-source, allowing us to probe the properties of the matter created in heavy-ion collisions. We report the results on two-pion femtoscopy measurements in Au+Au collisions at $\sqrt{s_{NN}}$ = 3.0, 3.2, 3.5, and 3.9 GeV measured by the STAR experiment. The extracted correlation strength and HBT radii from the 3D correlation functions are presented as a function of collision energy, centrality, and pair transverse momentum.
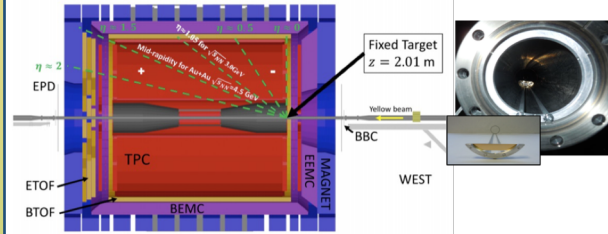
Introduction

➢ 3D two-pion correlations is sensitive to the geometry of the pion-emitting source, the duration of pion emission and the resonance decay contributions [1].

➢ If the first-order transition to QGP takes place, the time scale for pion emission is expected to increase [2].

➢ Definition of the correlation function: $c(\vec{q}) = \frac{N_{same}(\vec{q})}{D_{mixed}(\vec{q})}$. $\vec{q} = \vec{p}_2 - \vec{p}_1$; $N_{same}(\vec{q})$: pairs from same event (includes quantum statistics and final state interactions); $D_{mixed}(\vec{q})$: pairs from different events [3].

➢ Extract parameters by Bowler-Sinyukov formula [4,5]:
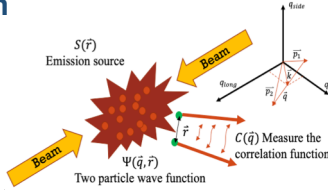
$C(q_{out}, q_{side}, q_{long}) = N[(1-\lambda) + \lambda K(q_{inv})(1 + exp(-R_{out}^2 q_{out}^2 - R_{side}^2 q_{side}^2 - R_{long}^2 q_{long}^2 - 2R_{out-long}^2 q_{out}q_{long}))]$.
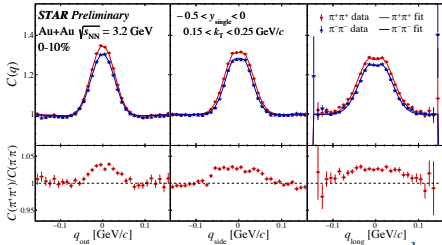
Where N: normalization constant; λ: correlation strength; $K(q_{inv}) = \int d^3 r \rho(\vec{r})|\psi_r(\vec{r}, q_{inv})|^2$ (coulomb effect).

$S(\vec{r})$ Emission source

$\Psi(\vec{q}, \vec{r})$ Two particle wave function

$C(\vec{q})$ Measure the correlation function
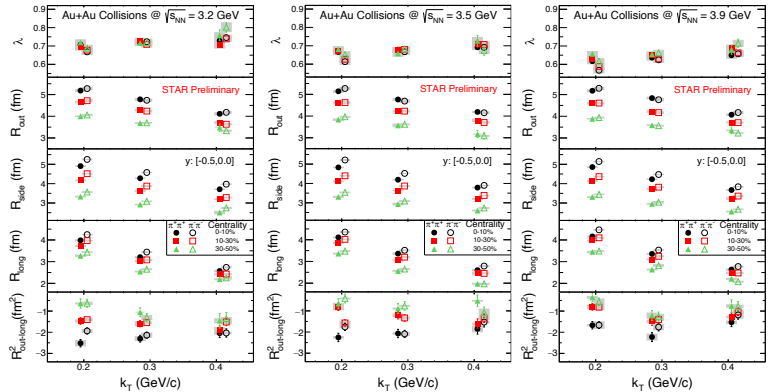
STAR Fixed-Target Setup

Fixed Target z = 2.01 m

➢ Gold target of thickness 1.93 g/cm² (0.25 mm).
➢ Located 200.7 cm from the center of the TPC.
➢ Collision energies: $\sqrt{s_{NN}}$ = 3.0 − 7.7 GeV.
➢ Extend the μ_B region up to ~720 MeV.

Correlation Functions

STAR Preliminary Au+Au $\sqrt{s_{NN}}$ = 3.2 GeV 0-10%
$-0.5 < y_{single} < 0$
$0.15 < k_T < 0.25$ GeV/c
$\pi^+\pi^+$ data — $\pi^+\pi^+$ fit
$\pi^-\pi^-$ data — $\pi^-\pi^-$ fit

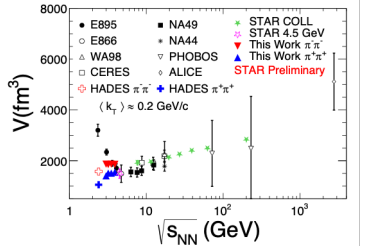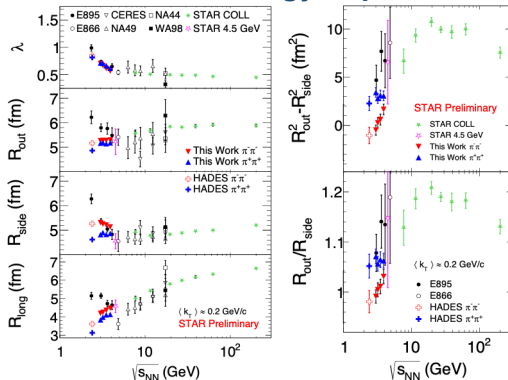$k_T = \frac{1}{2}|\vec{p}_{T1} + \vec{p}_{T2}|$

➢ λ increases from low to high k_T.

➢ Extracted radii decrease from low to high k_T and central to peripheral collisions due to the collective flow and the initial overlapping geometry.

➢ $R_{out-long}^2$ has clear centrality dependence and weak k_T dependence at mid-rapidity.

➢ Extracted R_{side} and R_{long} of $\pi^-\pi^-$ are larger than that for $\pi^+\pi^+$, most visible for the central collision and low k_T.

Centrality and k_T Dependence of Parameters

Au+Au Collisions @ $\sqrt{s_{NN}}$ = 3.2 GeV
Au+Au Collisions @ $\sqrt{s_{NN}}$ = 3.5 GeV
Au+Au Collisions @ $\sqrt{s_{NN}}$ = 3.9 GeV
STAR Preliminary
y: [-0.5,0.0]

Energy Dependence of Parameters

E895, CERES, NA44, STAR COLL, E866, NA49, WA98, STAR 4.5 GeV
This Work $\pi^-\pi^-$, This Work $\pi^+\pi^+$
HADES $\pi^-\pi^-$, HADES $\pi^+\pi^+$
STAR Preliminary

E895, E866, CERES, HADES $\pi^-\pi^-$, WA98, NA49, NA44, PHOBOS, ALICE, STAR COLL, STAR 4.5 GeV, This Work $\pi^-\pi^-$, This Work $\pi^+\pi^+$, HADES $\pi^+\pi^+$
$\langle k_T \rangle \approx 0.2$ GeV/c

➢ There are difference between $\pi^-\pi^-$ and $\pi^+\pi^+$, which may be due to the mean field and require further model study.

➢ The results of λ and R_{side} are consistent within the uncertainties compared to earlier world data and λ decreases as energy increases due to the long-lived resonances decay. R_{out} values are smaller than those from E895. R_{long} are consistent with the trend of STAR higher energy and HADES results, but opposite to the E895.

➢ The results of $R_{out}^2 - R_{side}^2$ and R_{out}/R_{side} are smaller than those from E895, but follow the trend of STAR higher energy and HADES.

➢ $V = (2\pi)^{\frac{3}{2}}R_{side}^2 R_{long}$, it varies weakly with energy and does not show a significant increase at smaller energies.

Summary

➢ We report the results on two-pion femtoscopy measurements in Au+Au collisions at $\sqrt{s_{NN}}$ = 3.0, 3.2, 3.5, and 3.9 GeV measured by the STAR experiment.

➢ We systematically discussed the dependence of the extracted physical parameters on collision energy, centrality, and k_T.

➢ We found there are differences between $\pi^-\pi^-$ and $\pi^+\pi^+$ at low energy.

➢ Except for λ, there are differences between our results and E895, especially for R_{long} and V, where the trend is opposite.

➢ Our results follow the trends of STAR higher energy and HADES.

References

[1] W. Bauer et al., Annu. Rev. Nucl. Part. Sci. 42, 77 (1992).
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[4] Yu. Sinyukov et al., Phys. Lett. B 432, 248 (1998).
[5] M. Bowler, Phys. Lett. B 270, 69 (1991).