Identical-particle (pion and kaon) femtoscopy in Pb–Pb collisions at 5.02 TeV with Therminator 2 modeled with (3+1)D viscous hydrodynamics

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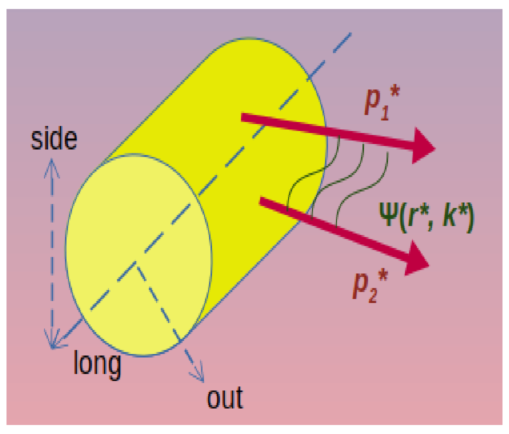
Introduction

- Femtoscopy is a technique, used to probe the space-time geometry of the system created in heavy-ion collisions using two-particle correlation function



$$C(\mathbf{k}^*) = \frac{\int S(\mathbf{r}^*, \mathbf{k}^*)\,|\Psi(\mathbf{r}^*, \mathbf{k}^*)|^2}{\int S(\mathbf{r}^*, \mathbf{k}^*)}$$

Methodology

Pair Interaction

Bosons → $\Psi_{K,\pi} = 1 + \cos(2\mathbf{k}^*\mathbf{r}^*)$

Fermions → $\Psi_p = 1 - \frac{1}{2}\cos(2\mathbf{k}^*\mathbf{r}^*)$

Source Function

3D: $$S(\mathbf{r}) \approx N\exp\left(-\frac{r_{out}^2}{4R_{out}^2} - \frac{r_{side}^2}{4R_{side}^2} - \frac{r_{long}^2}{4R_{long}^2}\right)$$

1D: $$S(\mathbf{r}^*) \approx N\exp\left(-\frac{\mathbf{r}^{*2}}{4R_{inv}^2}\right)$$

Correlation Function

3D: $$C(\mathbf{q}) = 1 + \lambda\exp(-R_{out}^2 q_{out}^2 - R_{side}^2 q_{side}^2 - R_{long}^2 q_{long}^2)$$

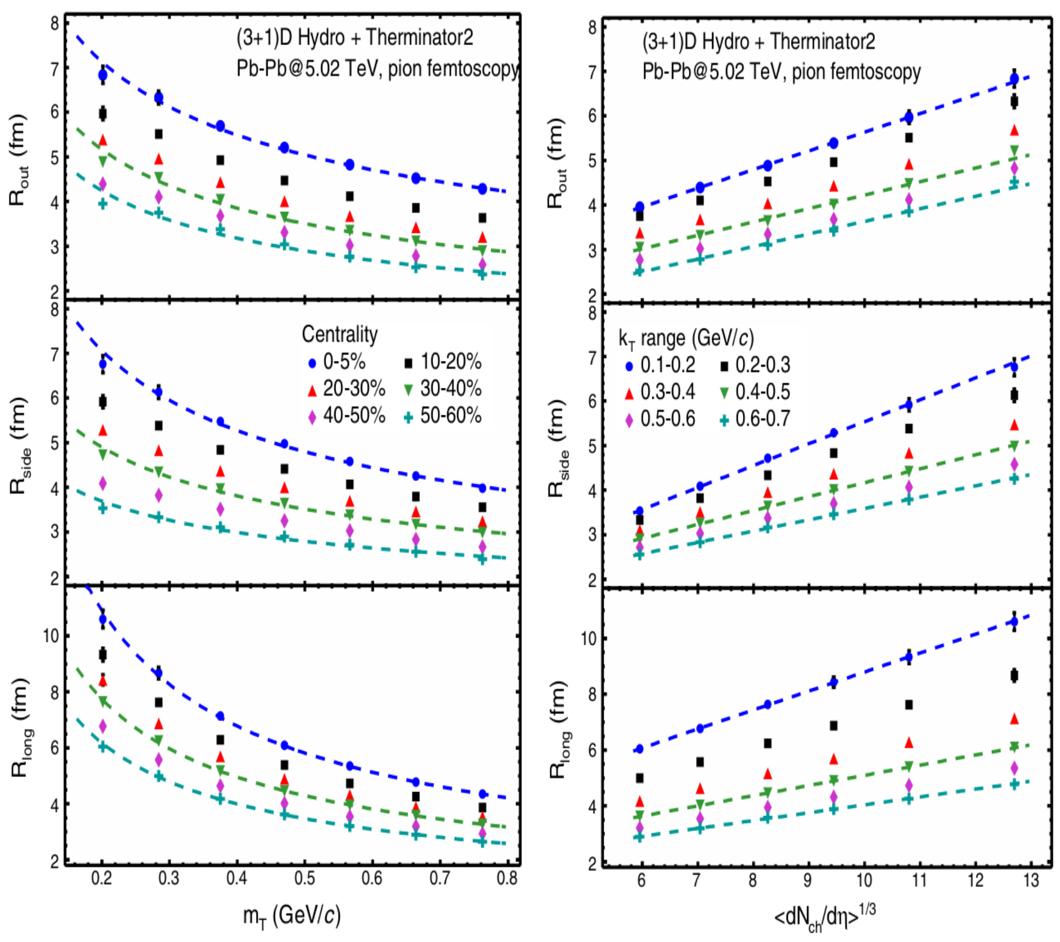
1D: $$C(q_{inv}) = 1 + \lambda\exp\left(-R_{inv}^2 q_{inv}^2\right)$$

Analysis Details

- This study focuses on the femtoscopic study of identical pions, kaons and protons in Pb-Pb events simulated using (3+1)D viscous hydrodynamics, coupled with THERMINATOR 2 at $\sqrt{s_{NN}}$ = 5.02 TeV
- The hadronic rescattering has not been considered in this model.
- The source-sizes in 3 dimensions (R_{out}, R_{side} and R_{long}) and 1 dimension (R_{inv}) are estimated in as the function of centrality (expressed as $\langle dN_{ch}/d\eta\rangle^{1/3}$) and k_T (and m_T) of the pair

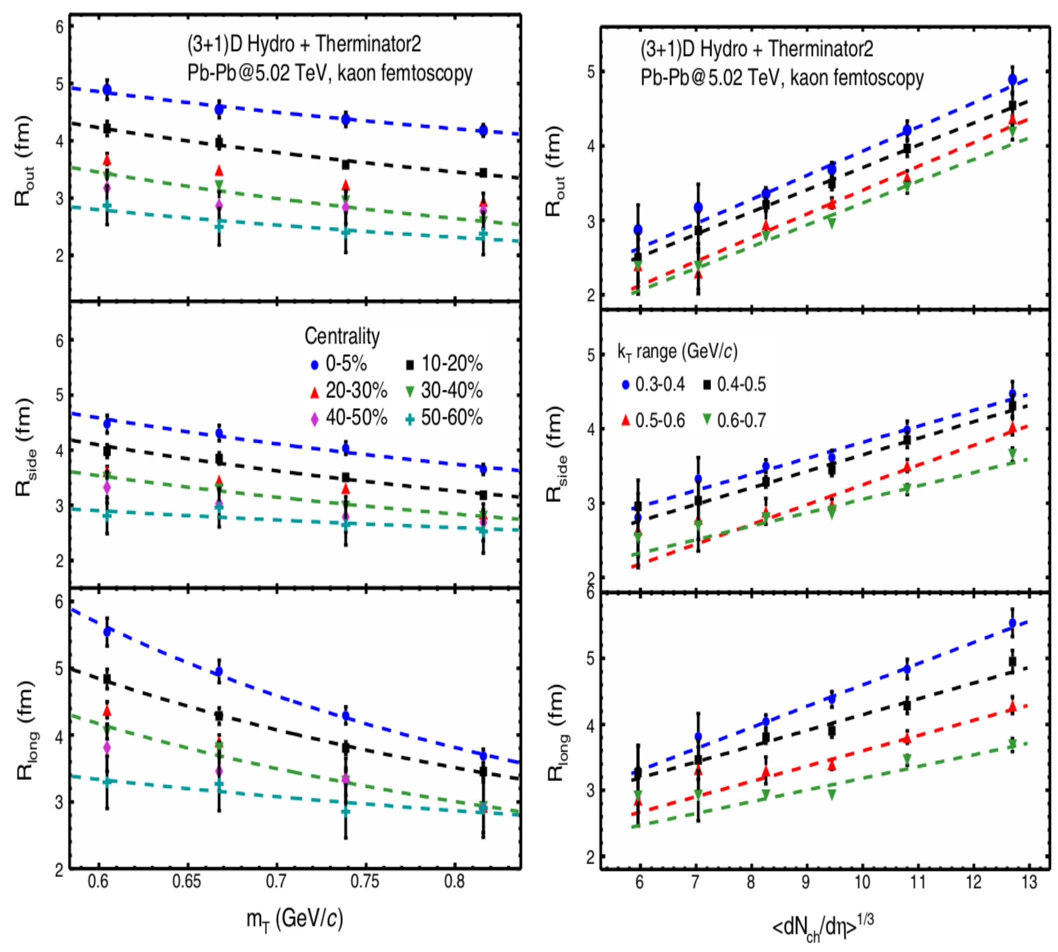
Results I

- Radii for pions in all 3 directions decrease with increasing m_T in all centralities, the trends are fitted with power-law of m_T
- R in long direction falls with increasing m_T more steeply compared to out and side direction
- Radii for pions increase with multiplicity in all k_T bins, the trends are fitted with linear-function of $\langle dN_{ch}/d\eta\rangle^{1/3}$



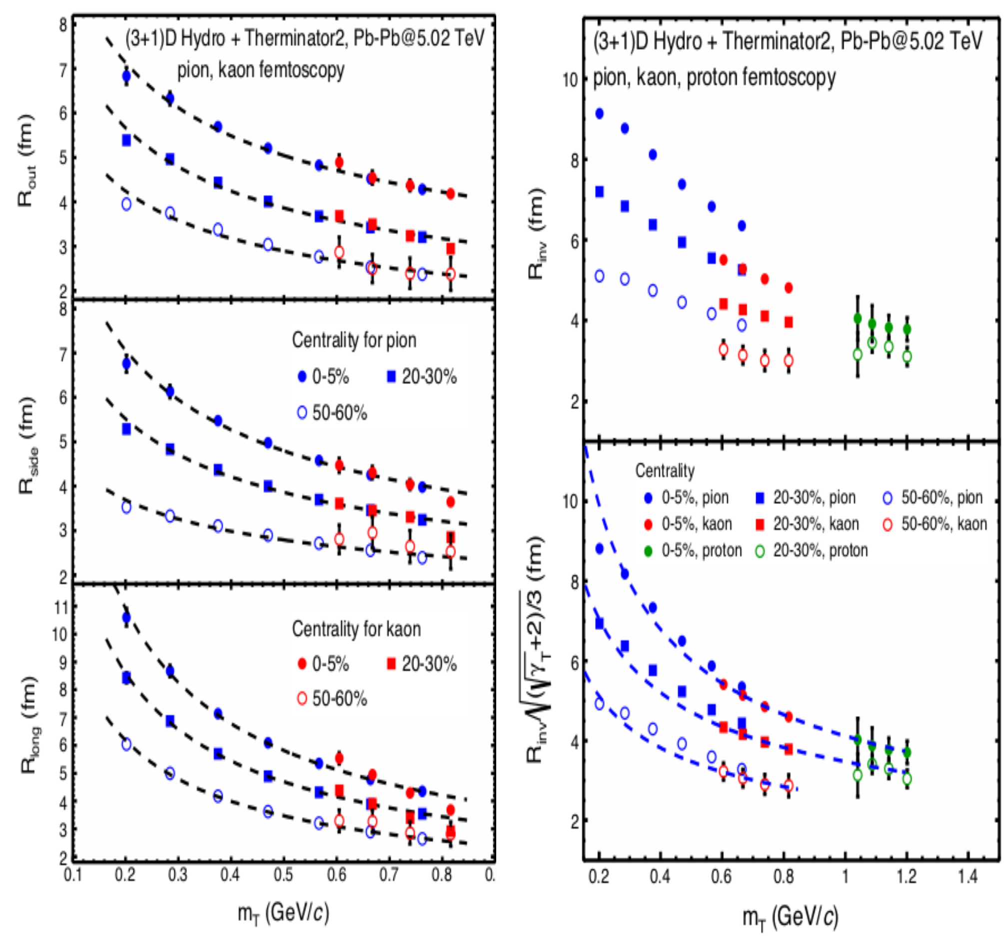
Results II

- Similar to pion femtoscopy, radii for kaons in all 3 directions also decrease with increasing m_T in all centralities and the trends are fitted with power-law of m_T
- R in long direction falls with increasing m_T more steeply compared to out and side direction
- Radii for kaons increase with multiplicity in all k_T bins, the trends are fitted with linear-function of $\langle dN_{ch}/d\eta\rangle^{1/3}$



Results III

- A common m_T scaling is approximately followed in out and side direction and slightly violated in long direction
- The slopes of 1D radii for pions, kaons and protons as the function of m_T are different.
- But a common m_T scaling is observed for different particles after scaling the radii with Lorentz boost: $f = \sqrt{(\sqrt{\gamma_T} + 2)/3}$



Summary

- The radii decrease from most central to peripheral events ans also with increasing m_T.
- For both pions and kaons, the slope of $\langle dN_{ch}/d\eta\rangle^{1/3}$ scaling of the radii is almost similar in all directions
- The m_T-scaling in out and side directions are less steeper than long direction, corresponding to the larger flow velocity
- Violation of m_T scaling corresponds to the hadronic re-scattering phase, present in the system
- A common effective scaling of 1D radii for all particles is observed after scaling the obtained radii with Lorentz factor

Reference

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4) P. Chakraborty [ALICE Collaboration], Quark Matter 2022