Comparison of the $\pi^{\pm}K^{\pm}$ femtoscopy in Pb—Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV modeled with (3+1)D hydrodynamics + THERMINATOR 2 and iHKM

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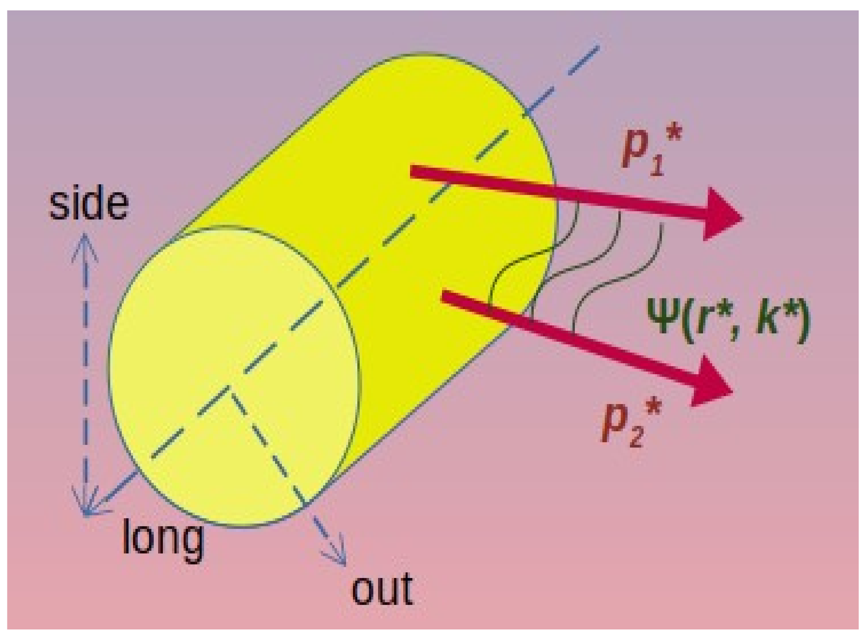
Introduction

- Non-identical particle femtoscopy is a tool to measure the space−time dimension of the particle emitting source as well as emission asymmetries between particles and Final State Interaction (FSI). [1]



[5]

Methodology

Two-particle femtoscopic correlation function (CF) (numerical)

$$C(k^*) \sim \frac{A(k^*)}{B(k^*)}$$

- $A(k^*)$: Particle-pair distribution from same events (correlated)
- $B(k^*)$: Particle-pair distribution from mixed events (uncorrelated)

Extraction of femtoscopic parameters [1]

$$C(\mathbf{k^*}) = \int S(\mathbf{r^*})\, |\Psi^2(\mathbf{r^*}, \mathbf{k^*})|\, d^3\mathbf{r^*}$$

Source function: probability of emitting a particle pair at distance *r*

Pair interaction: includes FSI with *k** at distance *r**

Spherical harmonics representation of CF [1]

$$C(k^*) = (4\pi)\, \Sigma(C_{l,m}(k^*)\, Y_{l,m}(\theta_{k^*}, \Phi_{k^*}))$$

- ***k**** is decomposed into k^*_{out}, k^*_{side}, k^*_{long}

$$k^*_{out} = |k^*| \sin\theta_{k^*} \sin\Phi_{k^*}$$
$$k^*_{side} = |k^*| \sin\theta_{k^*} \cos\Phi_{k^*}$$
$$k^*_{long} = |k^*| \cos\theta_{k^*}$$

- $Y_{l,m}(\theta_{k^*}, \Phi_{k^*})$ is calculated

Model comparison

Integrated HydroKinetic Model (iHKM) [2]

- The initial condition includes energy-density spatial distribution and anisotropic momentum distribution.
- Later, the system thermalises and evolves to nearly hydrodynamical state and then, expands continuously.
- As the system expands, the temperature reaches to $T_p \approx$ 160 MeV, from this point the system is described as hadron-resonance gas. At this stage, hadronic rescattering and resonance decay occur.
- Continuous streaming of particles from the system is considered in this model.

(3+1)D hydro + THERMINATOR 2 [1]

- The initial condition includes energy-density spatial distribution and anisotropic momentum distribution.
- The system reaches to a thermalised state and its evolution is described by ideal (3+1)D hydrodynamics.
- Due to the expansion, the system cools down to $T_f \approx$ 140 MeV and the single freeze-out (i.e. both chemical and kinetic) occurs.
- This model does not include the hadronic rescattering phase, however, propagation and decay of resonances are considered.

Femtoscopic correlation functions for pion-kaon pairs

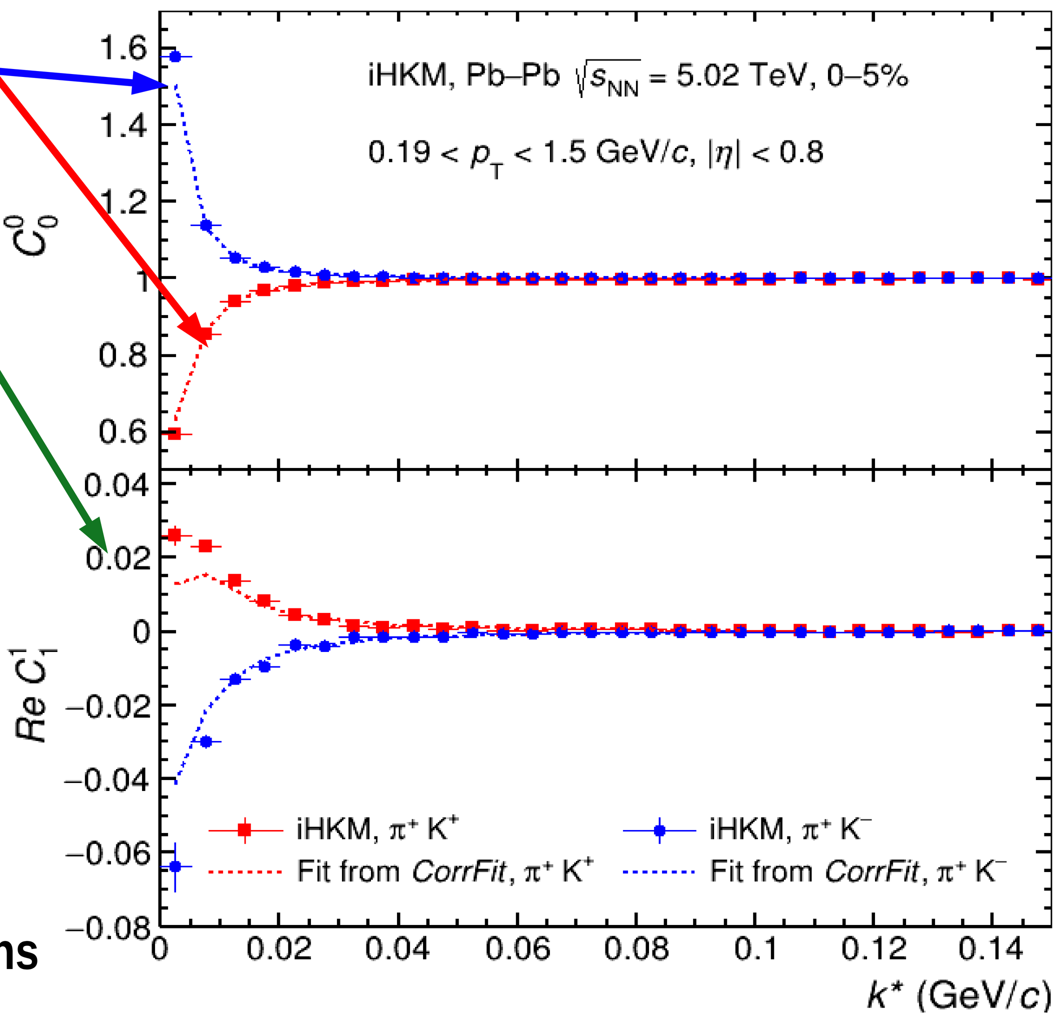
- C_0^0 : Attractive (for unlike-sign pairs) and repulsive (for like-sign pairs) Coulomb interaction, used for source size extraction
- *Re* C_1^1 : For pair-emission asymmetry extraction

assumed source function:

$$S(r) = exp\left[-\frac{(r_{out}-\mu_{out})^2}{2R_{out}^2} - \frac{r_{side}^2}{2R_{side}^2} - \frac{r_{long}^2}{2R_{long}^2}\right]$$ [4]

$r_{out}, r_{side}, r_{long}$ in LCMS → random numbers → boost to PRF, multiplied with ψ(r*, k*) → ready for χ2 test

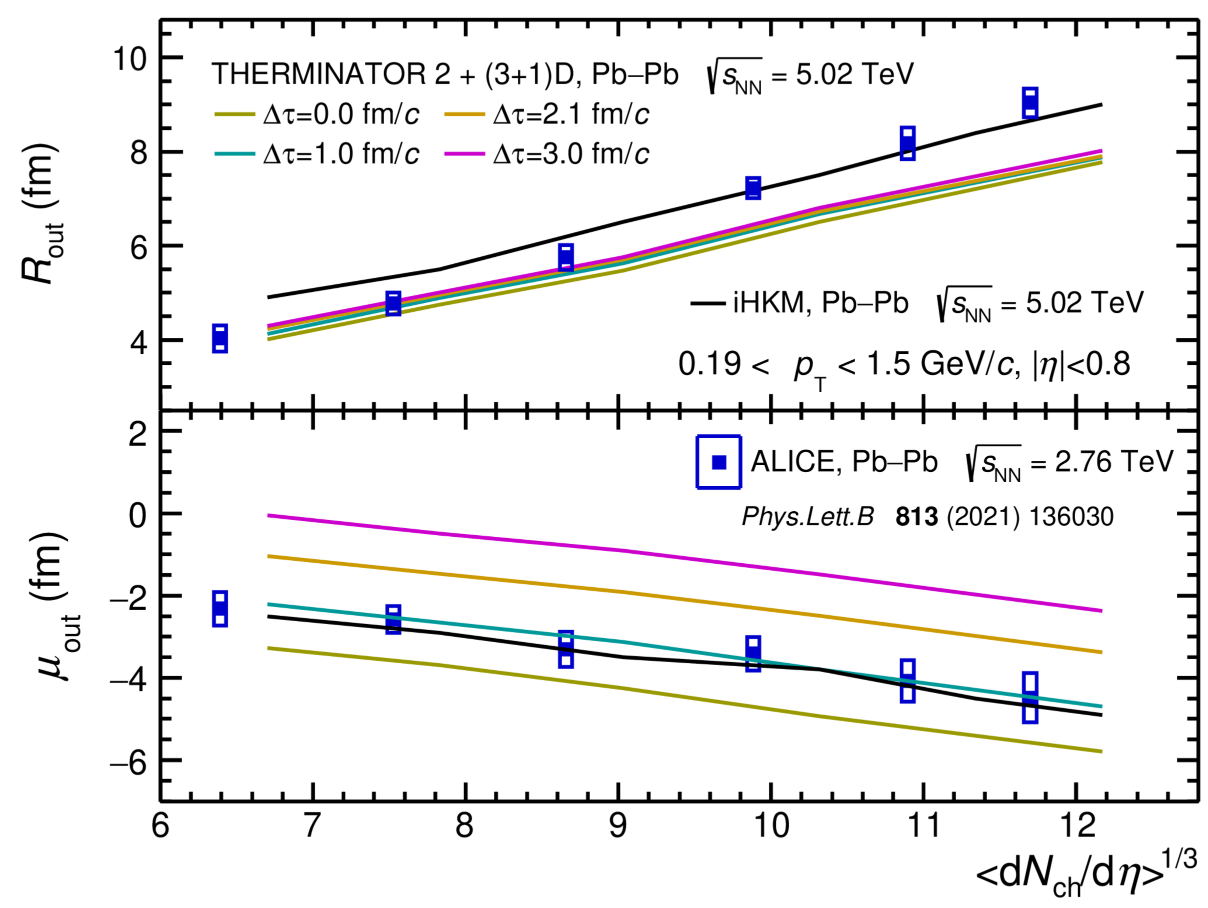
Fitting Constraints:
- $R_{side} = R_{out}$
- $R_{long} = 1.3R_{out}$

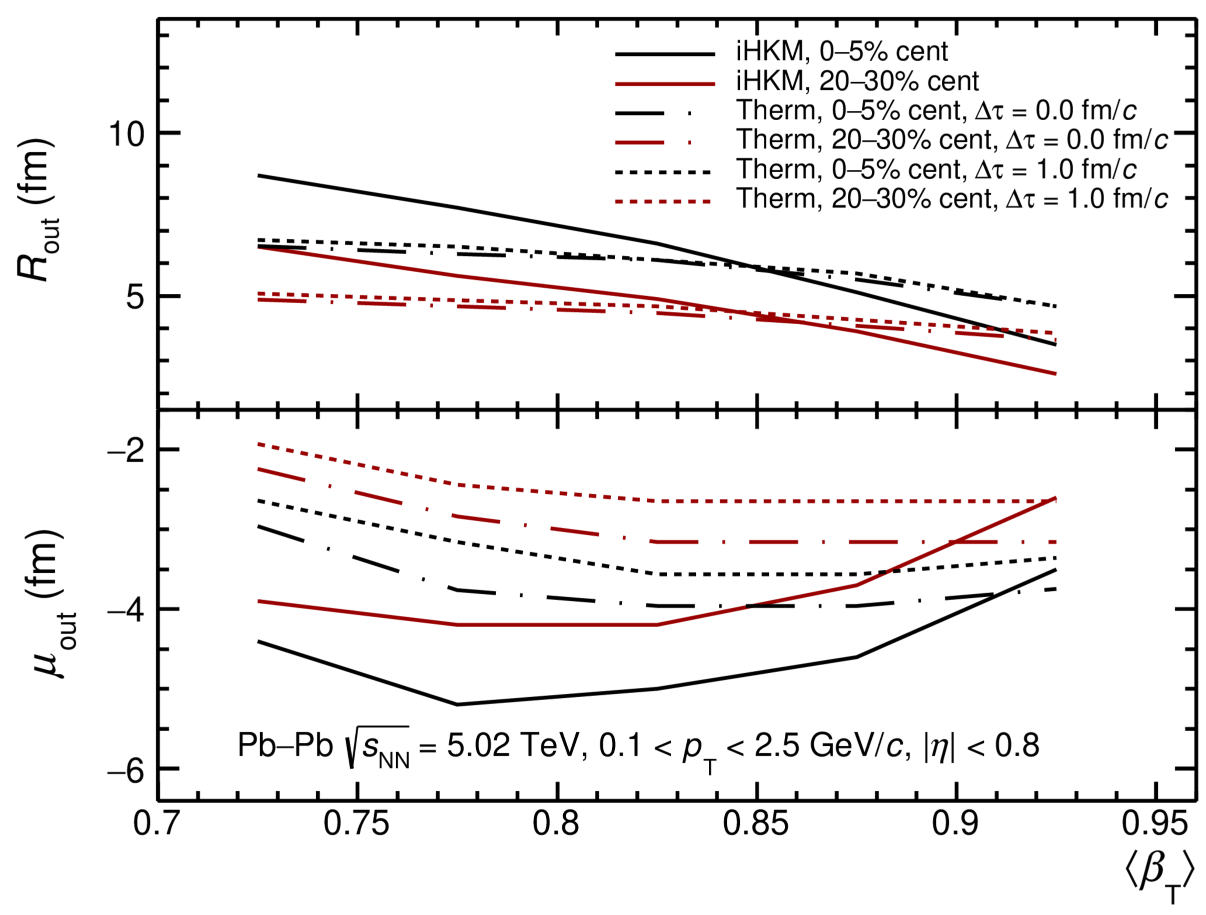


- Numerical fits from *CorrFit*[3] describe the correlation functions very well.
- R_{out} and μ_{out} extracted for each centrality and β_T class.

Results

- R_{out} increases with $\langle dN_{ch}/d\eta\rangle^{1/3}$, predictions from iHKM match with the results from the same analysis at 2.76 TeV using ALICE data at central events while the predictions THERMINATOR 2 agree within 10%.
- μ_{out} is always negative, implies pions are always emitted closer to the center of the source or later than kaons, confirms the existence of the radial flow.
- Predictions of μ_{out} from iHKM match with the 2.76 TeV ALICE results, while an additional delay of Δ = 1 fm/c in kaon emission was introduced in THERMINATOR 2 events, which matched the ALICE results (mimic the rescattering phase).





- R_{out} decreases with pair-$\langle\beta_T\rangle$, presence of strong collective flow. Slopes of R_{out} for iHKM are more steep than THERMINATOR 2 ones.
- μ_{out} first decreases and then saturates at higher pair-$\langle\beta_T\rangle$ for THERMINATOR 2, while it increases non-monotonically with pair-$\langle\beta_T\rangle$ for iHKM events.
- μ_{out} for iHKM is lower than THERMINATOR 2 events at lower pair-$\langle\beta_T\rangle$ bins.

Summary

- *μ_{out} signals the presence of radial flow, pions are always emitted closer to the center of the source or later than kaons.*
- *μ_{out} saturates at higher pair-$\langle\beta_T\rangle$ for THERMINATOR 2 while varies non monotonically for iHKM.*
- *R_{out} increases with centrality and decreases with pair-$\langle\beta_T\rangle$ due to the radial flow.*

References

[1]. A. Kisiel, Phys. Rev. C 81, 064906 (2010)
[2]. V. Yu. Naboka et al., Nucl. Phys. A, 1000 (2020), 121843
[3]. A. Kisiel, Nukleonika, 49 (suppl. 2) (2004), 81-83
[4]. ALICE Collaboration, S. Acharya et al., Phys. Lett. B 813, 136030 (2021)
[5]. P. Chakraborty (for the ALICE Collaboration), Proceedings of science, Volume 414, 2022