Non-identical particle femtoscopy in Pb—Pb collision at $\sqrt{s_{NN}}$ = 5.02 TeV with ALICE

Pritam Chakraborty *(for the ALICE Collaboration)*
Indian Institute of Technology Bombay, India

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Introduction

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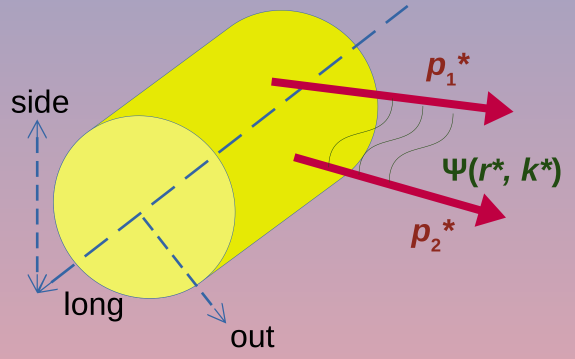
Non-identical femtoscopy

- **Source size (*R*) of the particle emitting system**
- **Emission asymmetry** ($\mu = \langle x^{light}\rangle - \langle x^{heavy}\rangle$)† **between the particles that form a pair, produced due to radial flow and thermalisation**



(*) → **Pair Rest Frame (total momentum = 0)**

Pair relative momentum → $k^* = (p_1^* - p_2^*)/2 = p_1^*$

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

$$C(k^*) \sim \frac{A(k^*)}{B(k^*)}$$ [1]

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

Extraction of femtoscopic parameters

$$C(k^*) = \int S(r^*)\, |\Psi(r^*, k^*)|^2\, dr^*$$

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

Pair interaction: includes final-state interactions (FSI) with k^* at distance r^*

Spherical harmonics representation of CF

$$C(k^*) = (4\pi)^{1/2}\, \Sigma(C_{l,m}(k^*)\; Y_{l,m}(\theta_{k^*}, \Phi_{k^*}))$$

- **k^* is decomposed into k^*_{out}, k^*_{side}, k^*_{long}** [2]

  $k^*_{out} = |k^*|\, \sin\theta_{k^*} \sin\Phi_{k^*}$

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

  $k^*_{long} = |k^*|\, \cos\theta_{k^*}$

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

[1]. A. Kisiel, Phys. Rev. C 81, 064906 (2010)
[2]. A. Kisiel, D. A. Brown, Phys. Rev. C 80, 064911 (2009)

† $\langle x\rangle$ = average emission point

Femtoscopic correlation functions for pion-kaon pairs

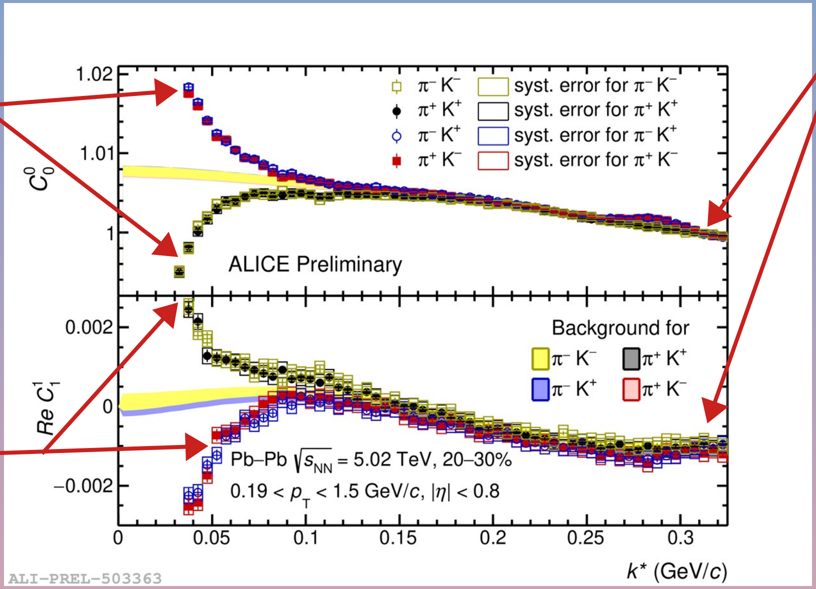
(20–30% centrality)

[1]

FSI

(Coulomb and Strong)

- **Attractive for unlike-sign pairs, repulsive for like-sign pairs**
- **Source size extraction**



- **Pair-emission asymmetry extraction**

Non-femtoscopic background (due to elliptic flow, residual correlations, etc.)

$$C_{exp}^{ij} = C_{real}^{ij} + B^{ij}$$

$$B^{ij} = a_0^{ij} + \sum_{l=1}^{5} a_l x^{(l+1)}$$

$$C_{real}^{ij} = C_{exp}^{ij} - B^{ij}$$

C_{exp} : experimental correlation function

B : 6th-order polynomial background (BG)

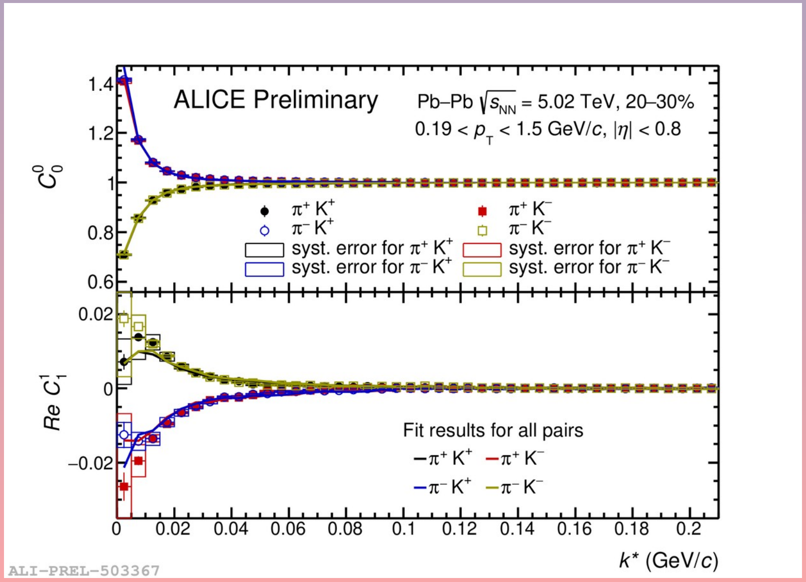
C_{real} : BG minimised correlation function

i, j : combinations of (+)ve and (-)ve pions and kaons forming pairs

All four correlation functions (separately for C_0^0 and Re C_1^1) are parameterised together with B

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

(assumed)



- **Fit results (theoretical predictions) describe the background minimised correlation functions very well**
- **R_{out} and μ_{out} extracted for each centrality class (next slide)**

[1]. A. Kisiel, Acta Phys. Polon. B 48, 717 (2017)

R_{out} and μ_{out} as the function of $\langle dN_{ch}/d\eta \rangle^{1/3}$ and $\langle m_T \rangle$

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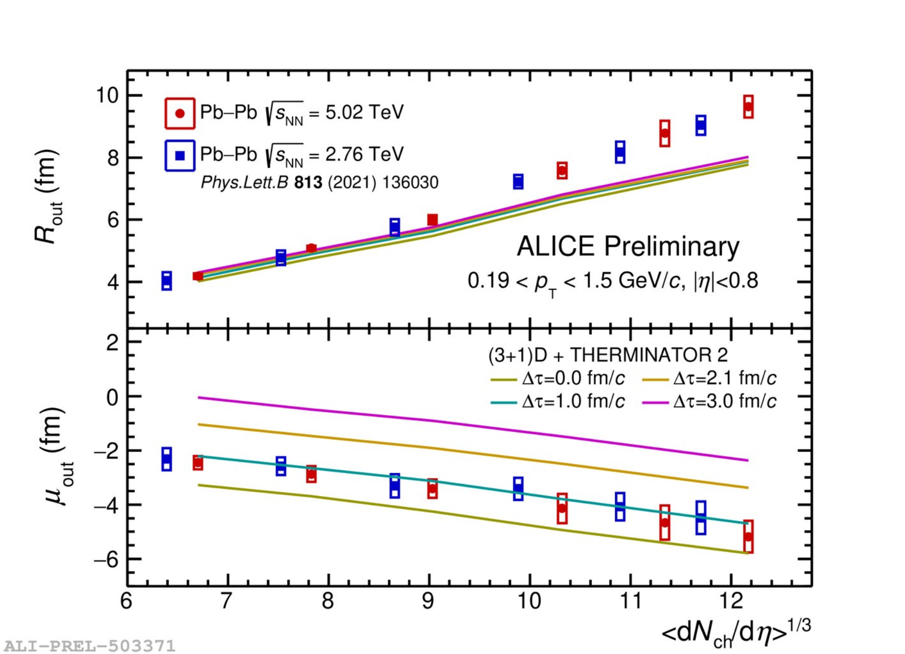
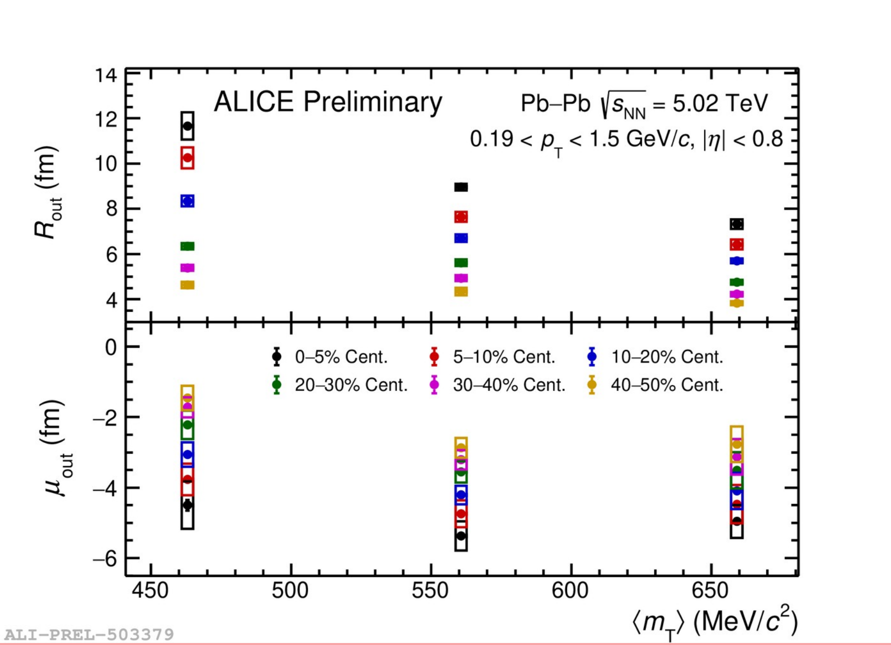
[3]

- R_{out} increases with $\langle dN_{ch}/d\eta \rangle^{1/3}$ as no. of participants increase, agrees with the predictions from (3+1)D viscous hydrodynamics + THERMINATOR 2 for peripheral events [4, 5]
- μ_{out} always negative, implies pions are always emitted closer to the center of the source, confirms the existence of the radial flow, compared with the predictions using additional delay ($\Delta\tau$) in kaon emission [1, 2, 3]
- Consistent with results at 2.76 TeV (blue markers), no energy dependence observed





- R_{out} decreases with pair-$\langle m_T \rangle$, presence of strong collective flow
- μ_{out} is lowest in smallest pair-$\langle m_T \rangle$ bin in all centrality,
- Since $\langle x_{out} \rangle \propto 1/(T/m_T)$, individual $\langle m_T \rangle$ values for π and K that are forming pairs in each pair-$\langle m_T \rangle$ bin are needed to understand the trend of μ_{out}

[1]. A. Kisiel, Phys. Rev. C 81, 064906 (2010)
[2]. A. Kisiel, Phys. Rev. C 98, 044909 (2018)
[3]. ALICE Collaboration, S. Acharya et. al., Phys. Lett. B 813 (2021) 136030
[4]. A. Kisiel et. al., Phys. Rev. C 90, 064914 (2014)
[5]. P. Chakraborty et. al., Eur. Phys. J. A 57 (2021) 338.

Summary

- μ_{out} signals the presence of radial flow
- Pions are always emitted closer to the center of the source than kaons
- R_{out} increases with centrality and decreases with pair-$\langle m_T \rangle$ due to the radial flow

...Thank you