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

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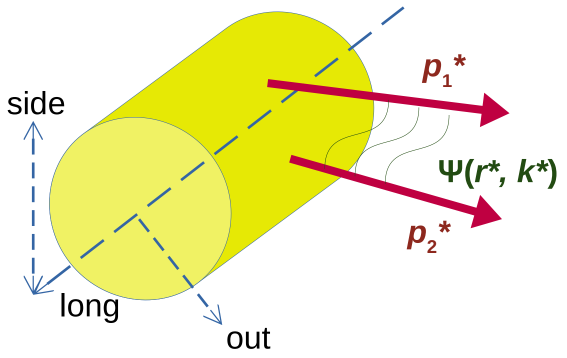
June 14, 2022

SQM2022
The 20th International Conference on Strangeness in Quark Matter
13-17 June 2022
Busan, Republic of Korea

Introduction

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 → $k^* = (p_1^* - p_2^*)/2 = p_1^*$

Theoretical Extraction of femtoscopic parameters → $C(\boldsymbol{k^*}) = \int S(\boldsymbol{r^*}) \, |\Psi(\boldsymbol{r^*}, \boldsymbol{k^*})|^2 \, d\boldsymbol{r^*}$

- **Source function: probability of emitting a particle pair at distance r^***
- **Pair interaction: includes final-state interactions (FSI) with k^* at distance r^***

Two-particle femtoscopic correlation function (CF) (experimental) → $C(\boldsymbol{k^*}) \sim \frac{A(\boldsymbol{k^*})}{B(\boldsymbol{k^*})}$ [1]

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

Spherical harmonics representation of CF → $C(\boldsymbol{k^*}) = (4\pi)^{1/2} \, \Sigma(C_{l,m}(k^*) \, Y_{l,m}(\theta_{k^*}, \Phi_{k^*}))$

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

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

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

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

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

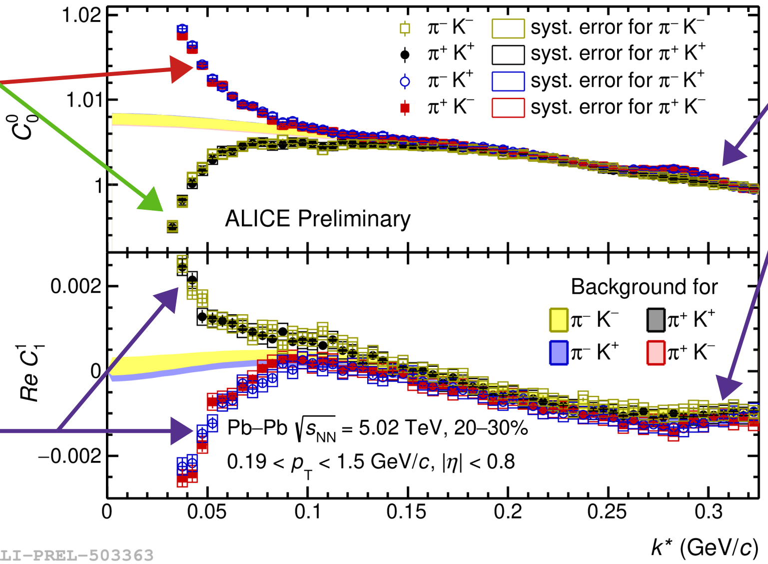
(20–30% centrality)

[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.)**

$$C^{ij}_{exp} = C^{ij}_{real} + B^{ij}$$

$$B^{ij} = a^{ij}_0 + \sum_{l=1}^{5} a_l x^{(l+1)}$$

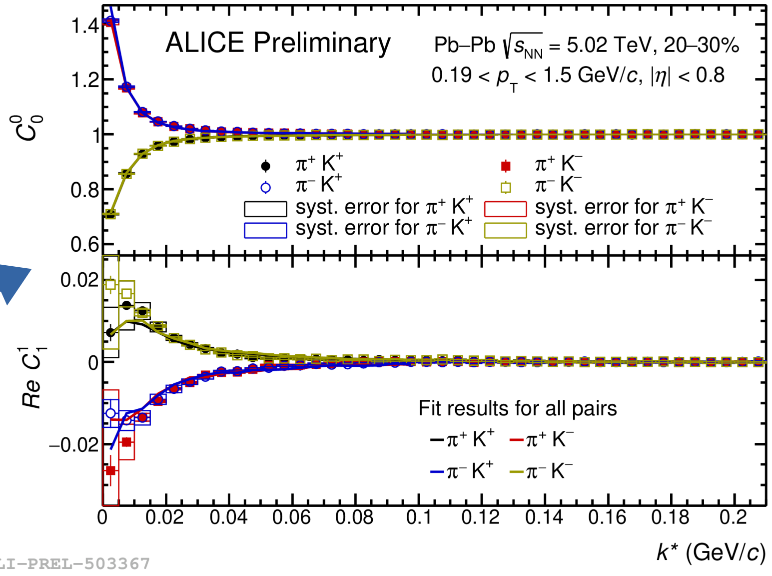
$$C^{ij}_{real} = C^{ij}_{exp} - B^{ij}$$

- 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

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

(assumed)

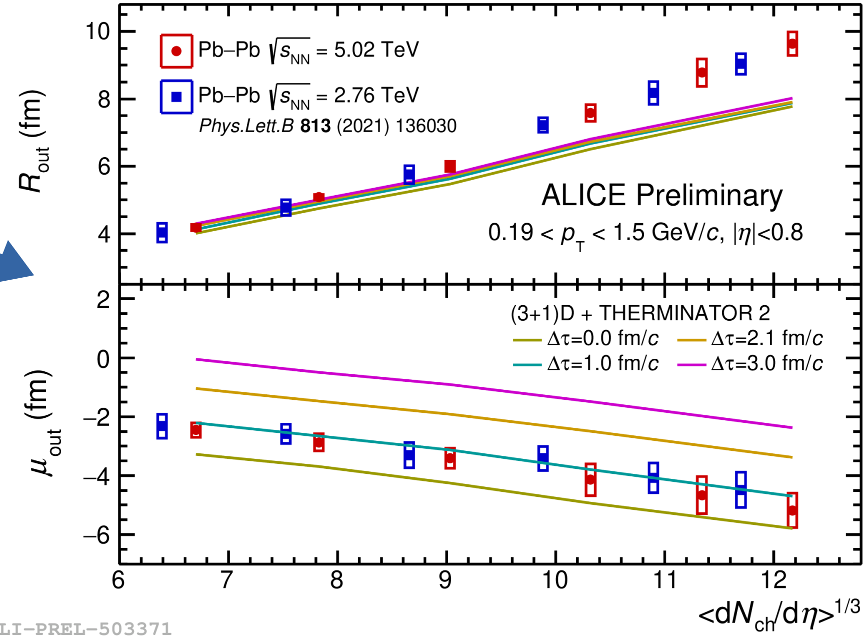


- **Fit results describe the femtoscopic correlation functions very well**
- **R_{out} and μ_{out} extracted for each centrality class (next slide)**

[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 $\langle m_T\rangle$

- R_{out} increases with $\langle dN_{ch}/d\eta\rangle^{1/3}$ as number of participants increase [3]
- R_{out} agrees with the predictions from (3+1)D viscous hydrodynamics + THERMINATOR 2 for peripheral events [4, 5]
- Negative values of μ_{out} implies pions are always emitted closer to the center of the source
- μ_{out} 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) and no energy dependence observed



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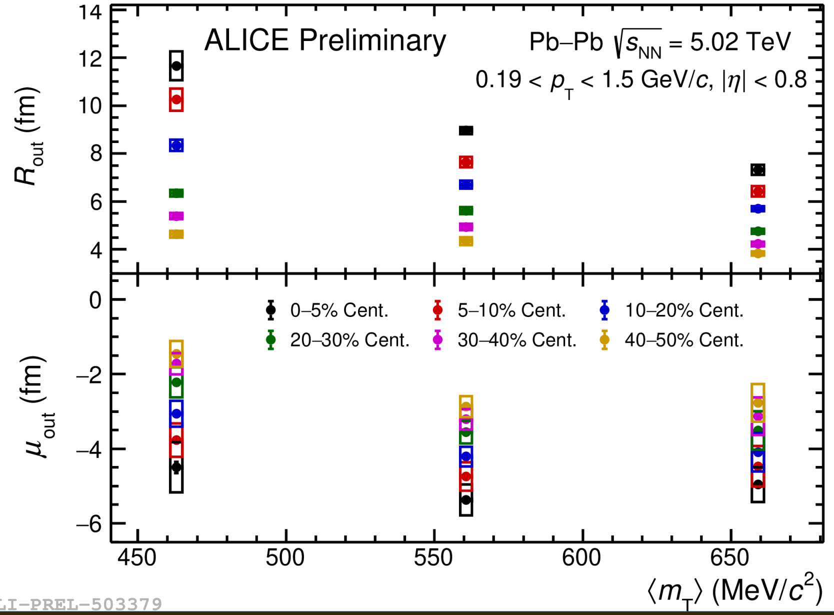

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- R_{out} decreases with pair-$\langle m_T\rangle$
- Trend of R_{out} indicates to the presence of strong collective flow
- μ_{out} is lowest in smallest pair-$\langle m_T\rangle$ bin in all centrality,
- To understand the trend of μ_{out}, $\langle m_T\rangle$ values of π and K in each pair-$\langle m_T\rangle$ bin are needed

[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

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

...Thank you