Recent results from femtoscopic studies with ALICE at LHC

9th International Workshop on Multiple Partonic Interactions at the LHC
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Ashutosh Kumar Pandey for the ALICE collaboration

(IIT BOMBAY)

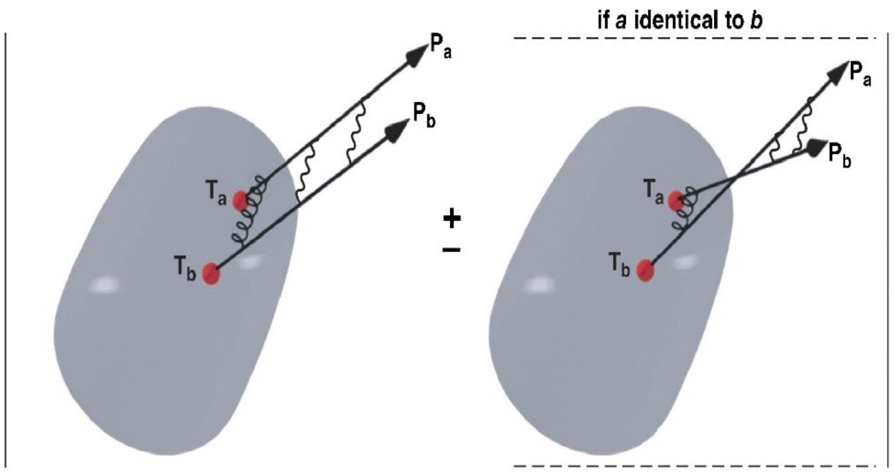
Outline

- Introduction
- Correlation Function
- Results from identical mesons femtoscopy
- Correlation from Strong Interaction
- Baryon-baryon and baryon-antibaryon femtoscopy
- Summary

Introduction

Two particle correlation function is defined as:

$$C_2 = \frac{P_2(p_a, p_b)}{P_1(p_a)P_1(p_b)}$$



Lisa MA, et al. 2005.
Annu. Rev. Nucl. Part. Sci. 55:357–402

$P_2(p_a,p_b)$ – probability of detection of particles with momentum p_a and p_b close in phase space

$P_1(p_i)$ – probability of detection of particle with momentum p_i

Femtoscopic measurements

- Probe space-time characteristics of the source using particle correlations in momentum space

- Main sources of correlations:

➡ **Quantum statistics (QS)**

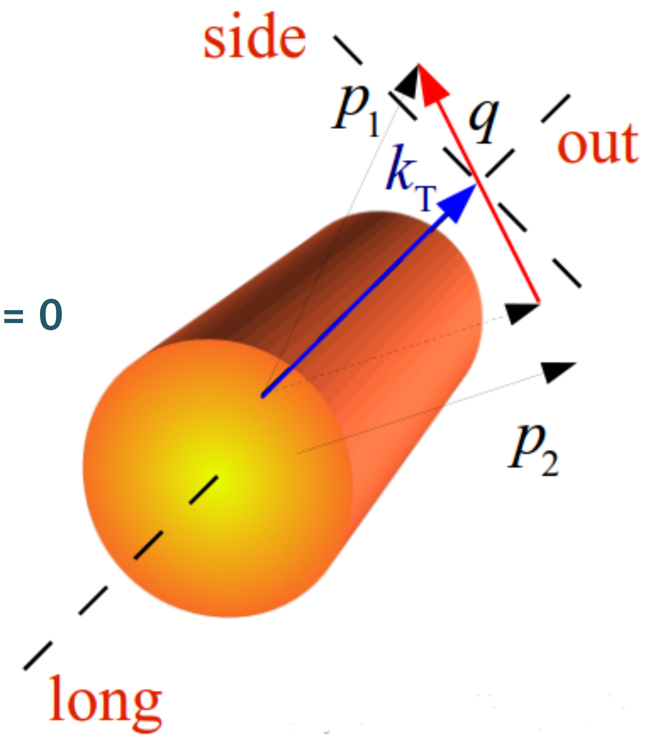
- bosons - Bose-Einstein quantum statistics
- fermions - Fermi-Dirac quantum statistics

➡ **Final-state interactions (FSI)**

- strong interaction
- Coulomb interaction (repulsion/attraction)

Relevant Co-ordinate system

- **side** is interpreted as **geometric size**
- **out** gives info on **emission process**
- **long** is used for **emission time approx.**



Longitudinal co-moving system (LCMS):

A rest frame moving along the beam direction such that $P_z = 0$

$$V_{long} = (P_0 V_z - P_z V_0)/M_T$$

$$V_{side} = (P_x V_y - P_y V_x)/P_T$$

$$V_{out} = (P_x V_x + P_y V_y)/P_T$$

Pair rest frame (PRF):

$$V'_{out} = \frac{M_{inv}}{M_T}\frac{(P_x V_x + P_y V_y)}{P_T} - \frac{P_T}{M_T M_{inv}} P.V,\ V'_{side} = V_{side},\ V'_{long} = V_{long}$$

Where $M_T^2 = P_0^2 - P_z^2$, $P_T^2 = P_x^2 + P_y^2$ and $M_{inv}^2 = P^2$

$k_T = (p_{T1} + p_{T2})/2$, $\mathbf{q} = \mathbf{p_2} - \mathbf{p_1}$

Experimental Correlation function

$$\mathbf{C(q)} = \frac{\mathbf{S(q)}}{\mathbf{B(q)}}$$

- **S(q) -** distribution of q of pairs from same events (signal)
- B**(q) -** distribution of q of pairs from different events (background)

where q : relative momentum of the pair particles ($p_b - p_a$)

Fit function for identical charged pions:

Bowler-Sinyukov formula -

$$C(q) = N[(1-\lambda) + \lambda K(q_{inv})(1 + G(q))]$$

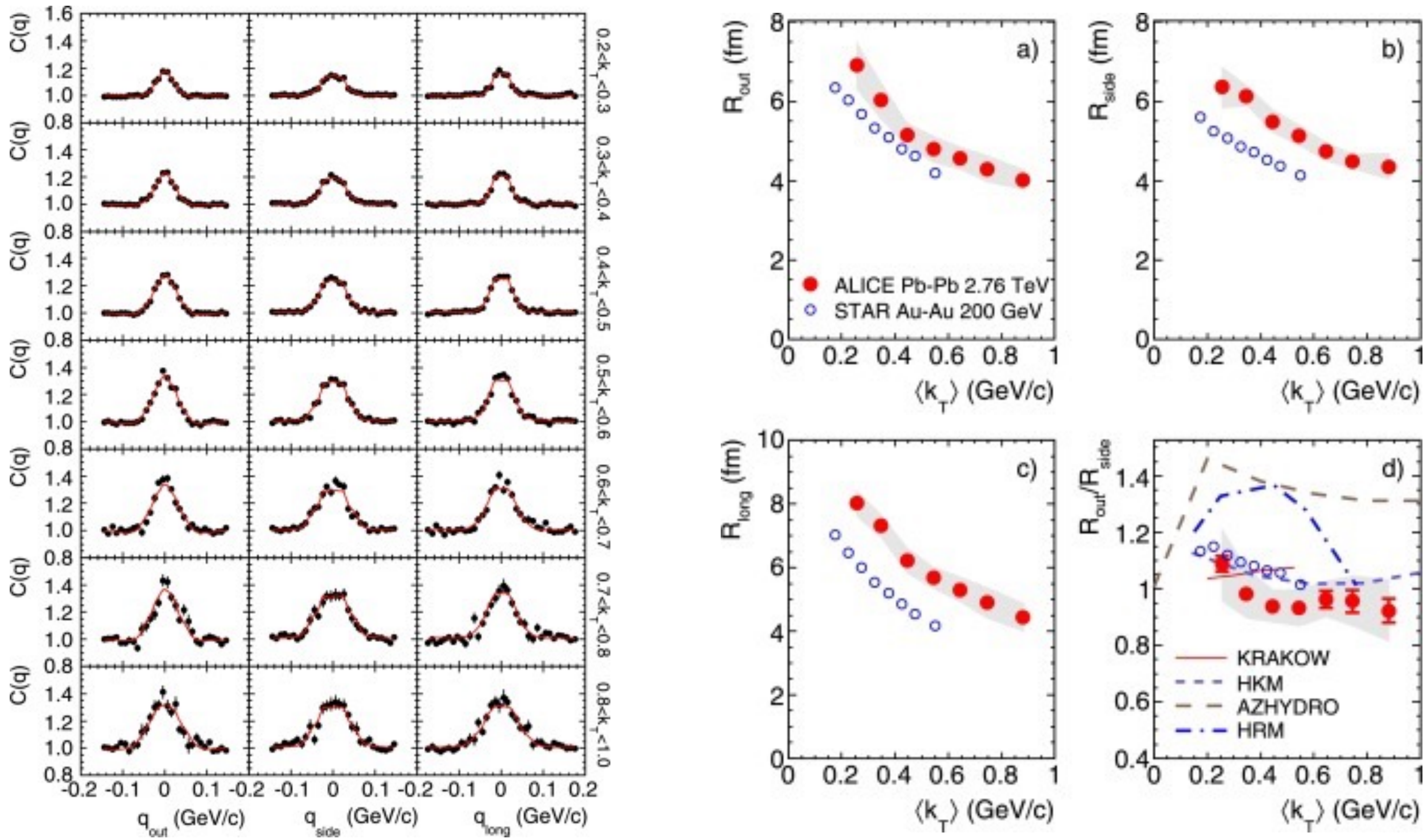
$$G(q) = exp(-R_{out}^2 q_{out}^2 - R_{side}^2 q_{side}^2 - R_{long}^2 q_{long}^2)$$

⋆ λ correlation strength,

⋆K(q_{inv}) - squared Coulomb wave function averaged over a spherical source

Results (I)

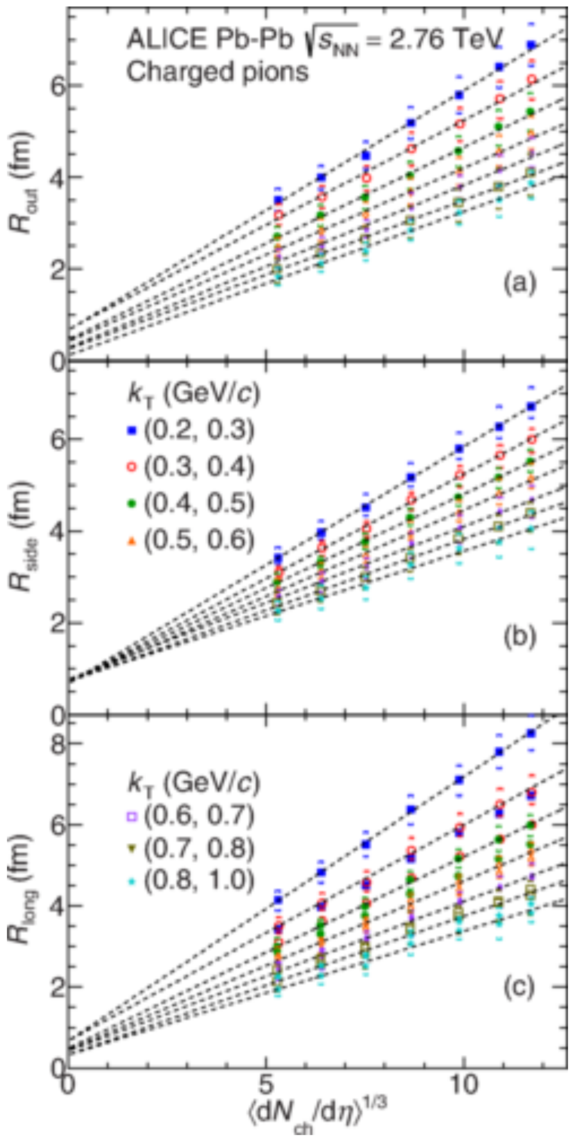
Identical pion-pion femtoscopy



- Source radii decrease with increasing average transverse momentum
- R_{out} and R_{side} are equal within systematic error

Results (II)

Identical pion-pion femtoscopy (cont.)



$$R \propto N^{1/3}$$

$$R^3 \propto V \propto N$$

$$\frac{N}{V} = \rho \;\; \text{(constant)}$$

"This proves that the initial geometry of the collision does influence the final measured radii and must be taken into account in any scaling arguments."

Correlation from strong interaction

$$C(q) = \int S(r)|\psi(q,r)|^2 d^4 r$$

q = $2k^*$

- $C(q)$ → measured correlation
- $S(r)$ → emission function (source size/shape)
- $\psi(q,r)$ → pair wave function (includes cross section)

$$\psi = exp(-ik * r) + f\frac{exp(ik^* r)}{r}$$

s-wave scattering approximation

$$f^{-1}(k^*) = \frac{1}{f_0} + \frac{1}{2} d_0 k^{*2} - ik^*$$

effective range approximation

For only Strong Final State Interaction:

$$C(k^*) = 1 + \sum_S \rho_S \left[\frac{1}{2} \left| \frac{f^S(k^*)}{R} \right|^2 \left(1 - \frac{d_0^S}{2\sqrt{\pi}R} \right) + \frac{2\Re f^S(k^*)}{\sqrt{\pi}R} F_1(2k^*R) - \frac{\Im f^S(k^*)}{R} F_2(2k^*R) \right]$$

ρ_S → spin fractions

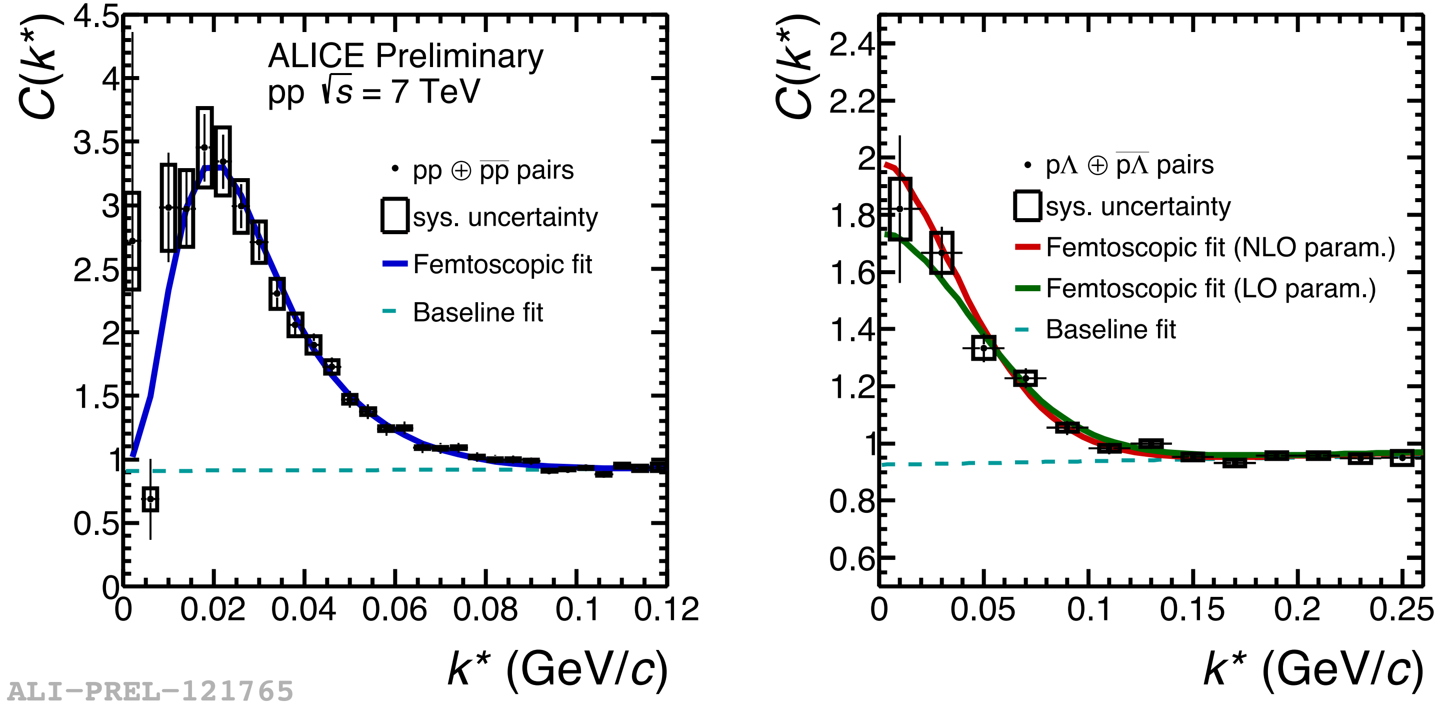
Lednicky, Lyuboshitz, Sov. J. Nucl. Phys., 35, 770 (1982)

- The correlation function is finally characterised by **three parameters**:
  - **radius** R, **scattering length** f_0 and **effective radius** d_0
  - Cross-section **σ** (at low k*) is simply: **σ** = $4\pi|f|^2$

$$F_1(z) = \int_0^z \chi e^{\chi^2 - z^2}/z dz$$
$$F_2(z) = (1 - e^{-z})/z$$

Results (III)

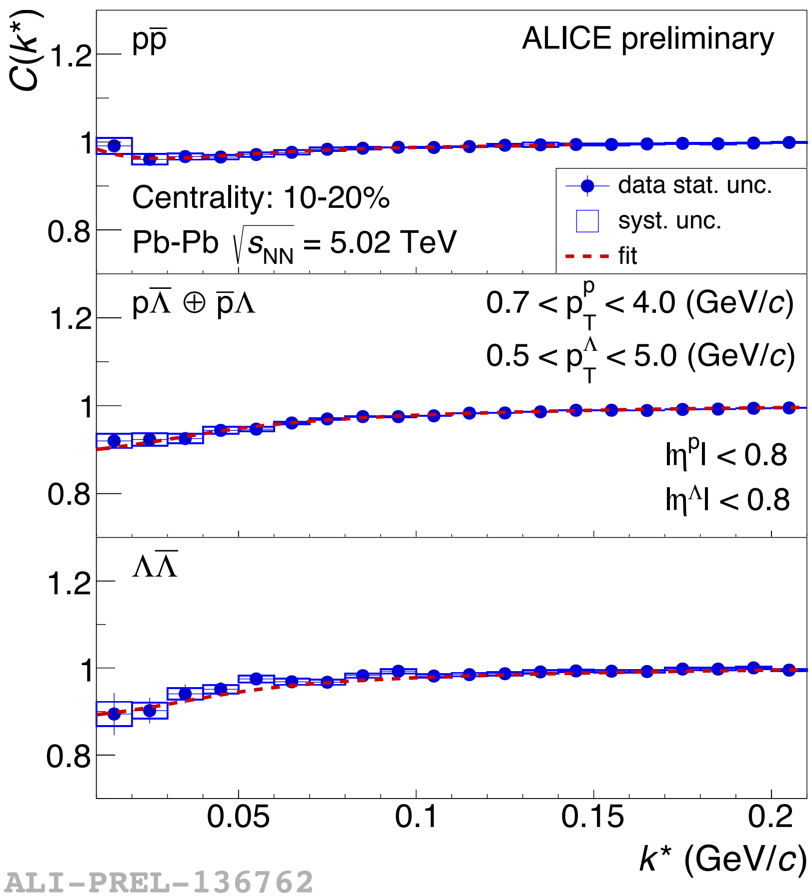
Baryon-baryon femtoscopy

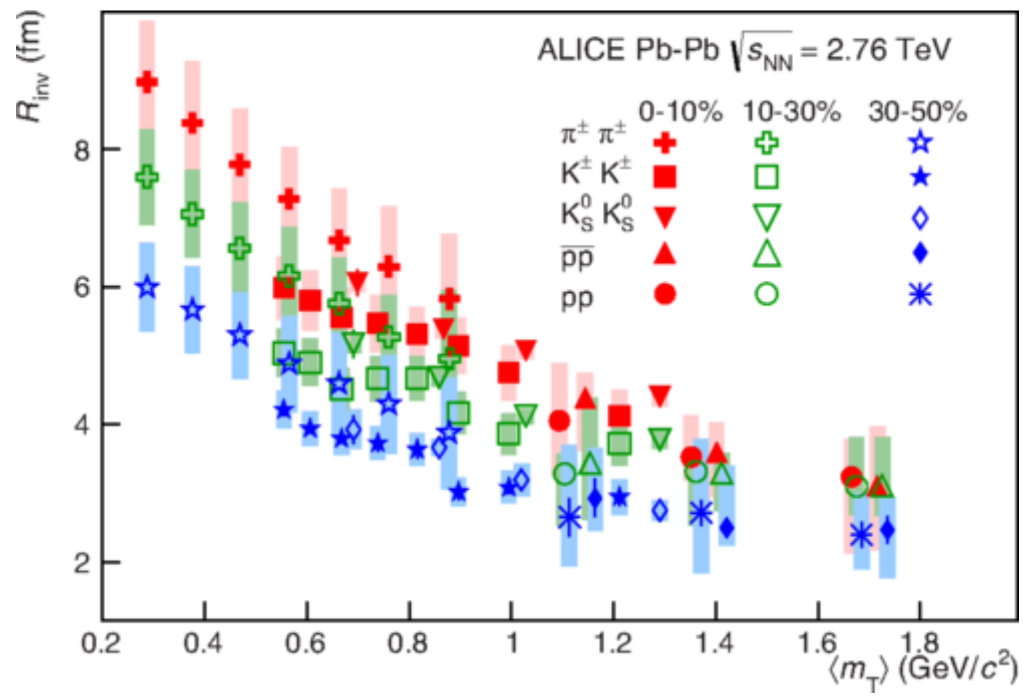


extracted source size : R = 1.31 ± 0.02 fm

Results (IV)

Baryon-antibaryon femtoscopy

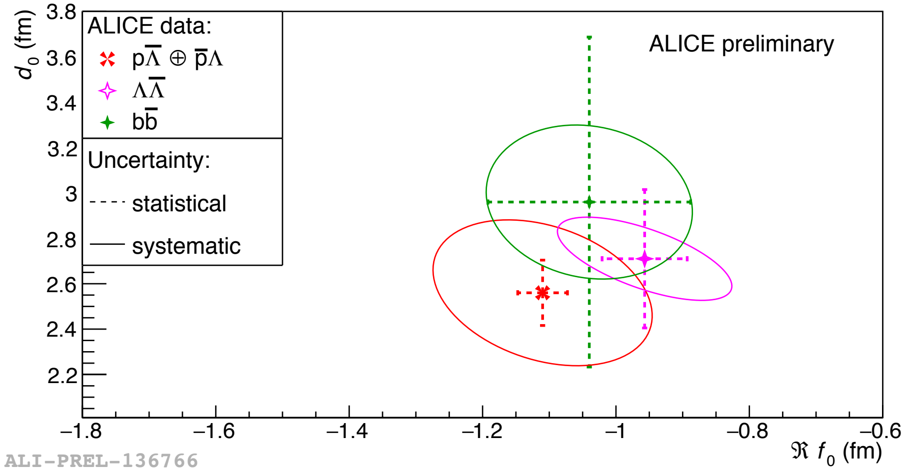


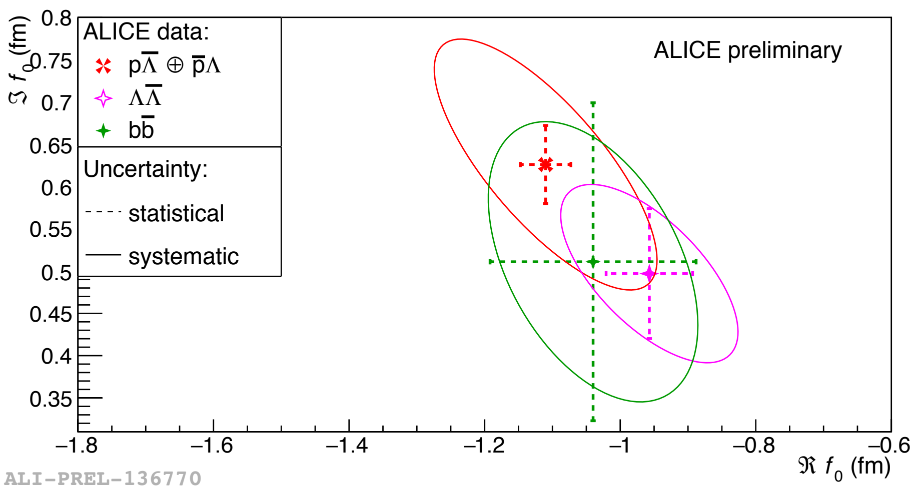


- Radii fall with m_T - sign of hydrodynamic collectivity
- Radii fall with centrality class

Results (V)

Baryon-antibaryon femtoscopy (cont.)

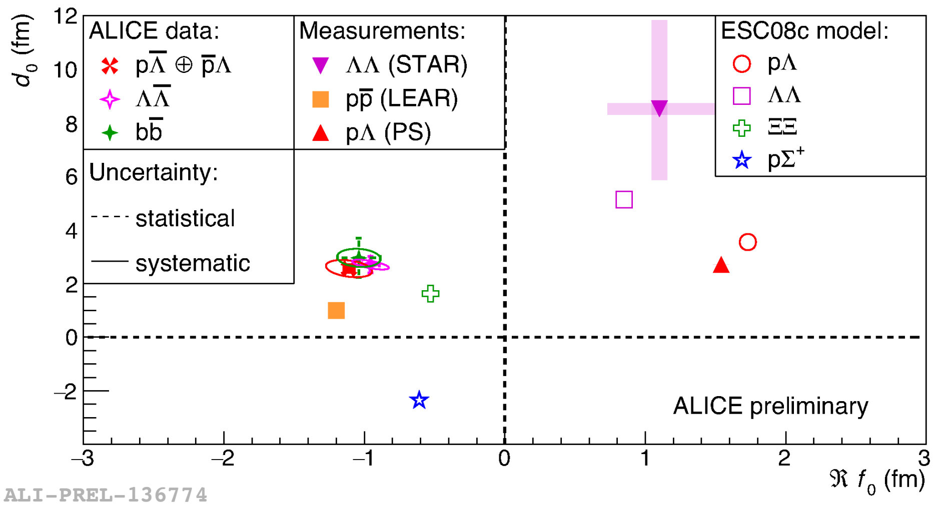


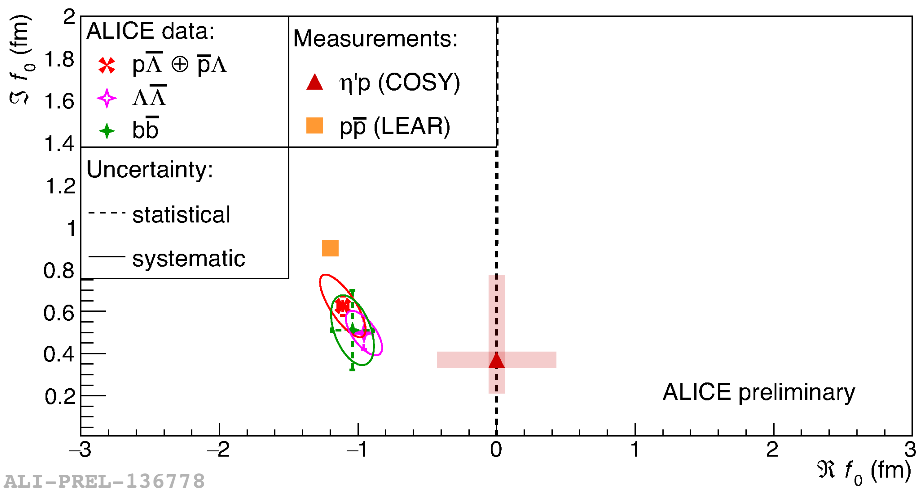


- Interaction parameters are measurable
- Scattering parameters for **all baryon-antibaryon pairs are similar to each other**
- We observe a **negative real part of scattering length** - repulsive strong interaction or creation of a bound state (existence of baryon-antibaryon bound states?)
- Significant **positive imaginary part of scattering length** - presence of a non-elastic channel - annihilation

Results (VI)

Baryon-antibaryon femtoscopy (cont.)





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Summary

- **Results from identical pion-pion and kaon-kaon femtoscopy at 2.76 TeV Pb-Pb data have been shown**
- **Radii in out, side and long direction decrease with increasing average transverse momentum of the pairs for both pions and kaons**
- **ALICE can probe strong interaction cross section with femtoscopy**
- **Femtoscopic correlation functions of baryons sensitive to strong interaction potential, including annihilation, possible $b\bar{b}$ bound states?**

THANK YOU

Backup