First measurement of properties of strong interaction between (anti-)deuterons and charged kaons in Pb–Pb collisions with ALICE

Wioleta Rzęsa (Warsaw University of Technology)
on behalf of the ALICE Collaboration

Motivation

The effective interaction between hadrons with different quark contents is still an open topic in nuclear physics. Since the low-energy processes of QCD cannot be described with perturbation theory, experimental data are essential to constrain the currently available effective theories.

Picture of strong interaction

$K^{\pm}d$ strong interaction

$K^{\pm}d$ scattering parameters

- very poorly known theoretically,
- never measured before.

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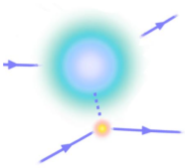
Picture of strong interaction

The K^-d study can enable the **full isospin dependence of the interaction** to be determined for the first time, which is a fundamental problem in the strangeness sector in the low-energy regime of QCD.

A measurement of K^-d strong interaction parameters is awaited for more than 40 years!

Experimental techniques that can be used to access hadron–hadron interaction

Scattering experiments



- Scattering cross sections.

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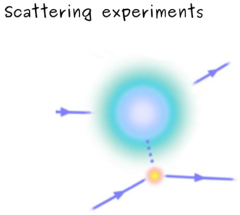

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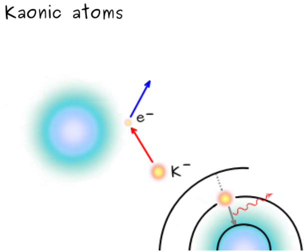
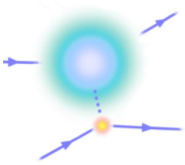


- SIDDHARTA-2 experiment created for $K^{-}d$ measurements. **Ongoing.**

Experimental techniques that can be used to access hadron–hadron interaction

Scattering experiments



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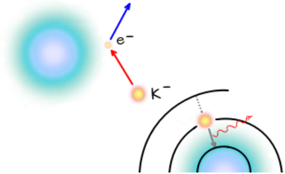
Kaonic atoms



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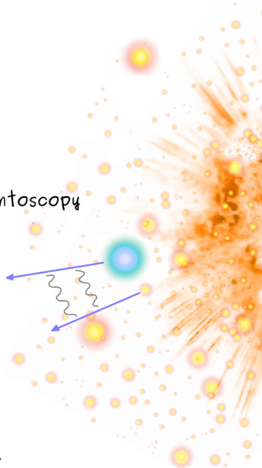
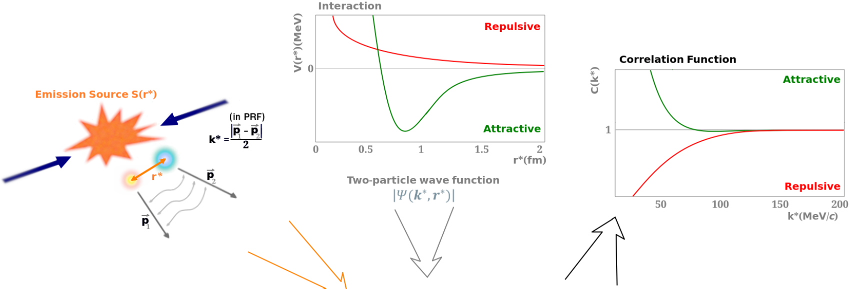
Femtoscopy



- This study!

Methodology



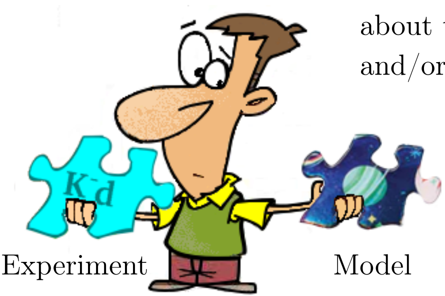
$$C(k^*) = \int S(r^*) \; |\Psi(k^*, r^*)|^2 \, d^3r^* = \xi(k^*) \cdot \frac{N_{\text{same}}(k^*)}{N_{\text{mixed}}(k^*)}$$

- **Femtoscopy** is a technique to study the space–time characteristics of the particle-emitting source using correlation function (CF) in momentum space.
- **CF** is a convolution of the source function and wave function (the latter for non-identical particles combines strong and/or Coulomb forces).

A magic power of femtoscopy

$$C(k^*) = \int S(r^*) \, |\Psi(k^*, r^*)|^2 \, d^3r^* = \xi(k^*) \cdot \frac{N_{\mathrm{same}}(k^*)}{N_{\mathrm{mixed}}(k^*)}$$

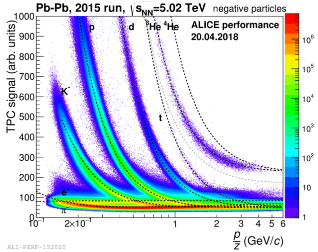
We can compare experimental correlation functions with available models and conclude about their parameterisation, i.e.: source and/or interaction parameters.

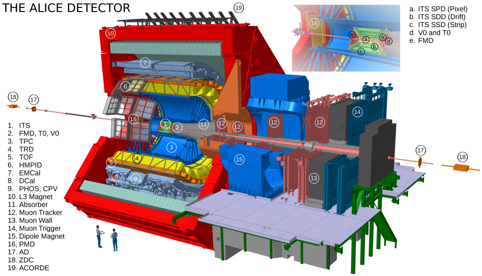


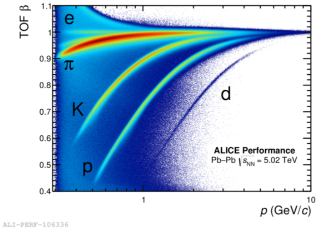
We need: experimental data
and models.

Data

- Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV.
- $\mathrm{K}^{\pm}\mathrm{d}/\ \mathrm{K}^{\pm}\overline{\mathrm{d}}$ correlation functions.
- 3 centrality intervals: 0–10%, 10–30%, 30–50%.
- Momentum reconstruction via TPC detector.
- Particle identification via TPC, TOF detectors.







Modeling correlation functions

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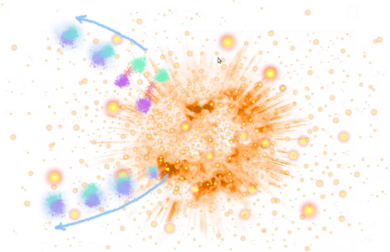
- What size?
- (Anti-)deuterons' production mechanism?



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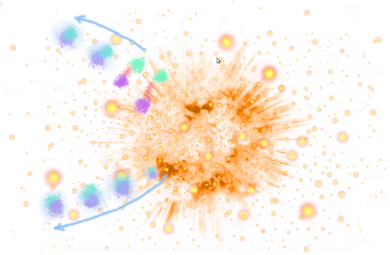
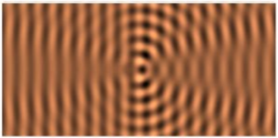
- How to calculate $\Psi(k^*, r^*)$?
- f_0 - scattering length?
- d_0 - effective range?





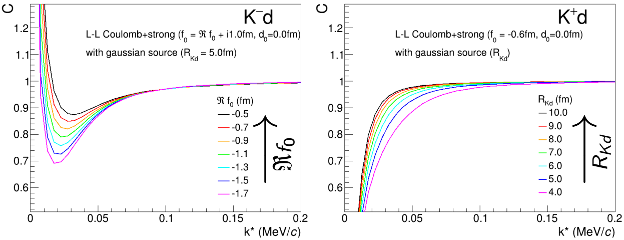
Modeling correlation functions

- Theoretical CFs modeled with Lednický-Lyuboshitz approach [1] with the assumptions:
  - gaussian source,
  - zero effective-range approximation of the interaction, $d_0 = 0.0$ fm.
- Numerical calculation of theoretical CFs for different fit parameters.

Examples of modeled CFs for different values of fit parameters

Fit parameters:

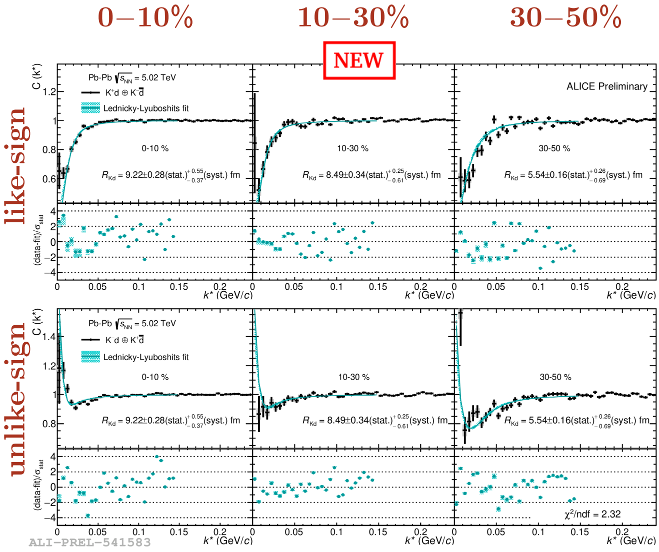
- source radii (R_{Kd})
- scattering lengths (f_0):
  - $K^- d$ ($\Re$, $\Im$)
  - $K^+ d$ ($\Re$)



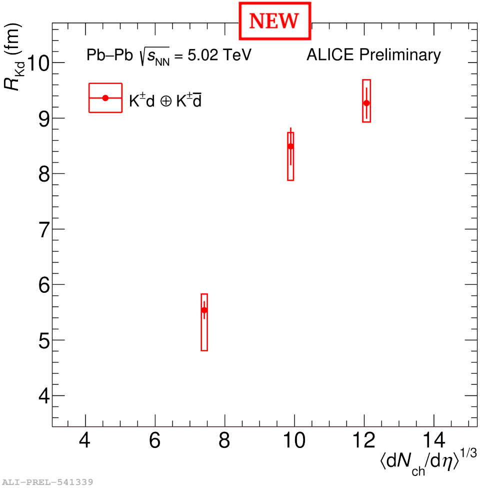
[1] Lednický, R. and Lyuboshits, V. L., Final state interaction effect on pairing correlations between particles with small relative momenta, Yad. Fiz. 35 (1981).

Kd in Pb–Pb with L-L fit

- Simultaneous fit to 6 CFs.
- Source radii from like- and unlike-sign pairs:
  - one R_{Kd} per centrality.
- Scattering lengths from three centralites:
  - one $f_0(\Re,\Im)$ for unlike-sign pairs,
  - one $f_0(\Re)$ for like-sign pairs.



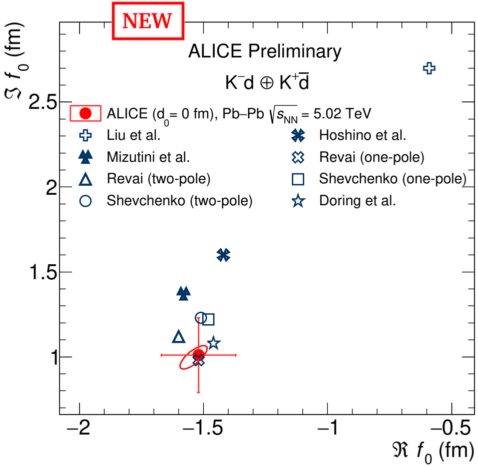
Kd radii



- 3 radii for 3 centralities (the same radius for all particle pairs).
- Source size increases with multiplicity.

$K^- d$ scattering length

- $\Re f_0$ and $\Im f_0$ are in agreement with most of the available calculations.



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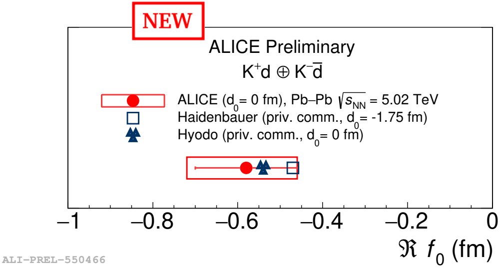
K^+d scattering length

- $\Re f_0$ is in agreement with available calculations.



Summary

- First measurement of Kd correlation functions and 1D radii in heavy-ion collisions.
- First measurements of $K^{-}d$ and $K^{+}d$ scattering lengths:
  - $\Longrightarrow$ In agreement (within uncertainties) with many $K^{-}d$ predictions and with the two currently available $K^{+}d$ calculations.
  - $\Longrightarrow$ Obtained values play a crucial role in constraining the scattering parameters for future theoretical studies.

Thank you for your attention!