Enlightenment era for the three-body interactions in ALICE

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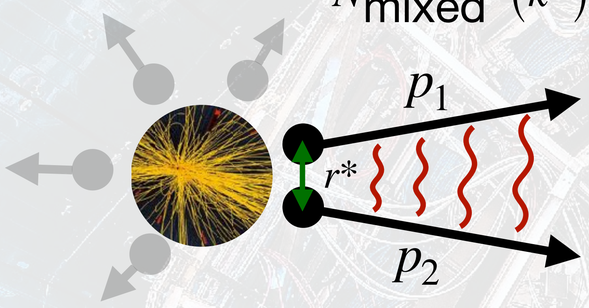
Three-Body Interactions

- Crucial to solve the hyperon puzzle
- Study of exotic bound states such as kaonic nuclei
- Extraction of the three-body interactions from (hyper-)nuclei data requires:
  - a good understanding of their shell-structure
  - spin-dependent two-body interactions
- **New experimental approaches essential to pin down the three-body interactions with less model dependency!**

Femtoscopy Technique

$$C(k^*) = \xi(k^*)\frac{N_{\text{same}}(k^*)}{N_{\text{mixed}}(k^*)} = \int S(\mathbf{r}^*)\left|\psi_{k^*}(\mathbf{r}^*)\right|^2 \mathrm{d}^3r^*$$

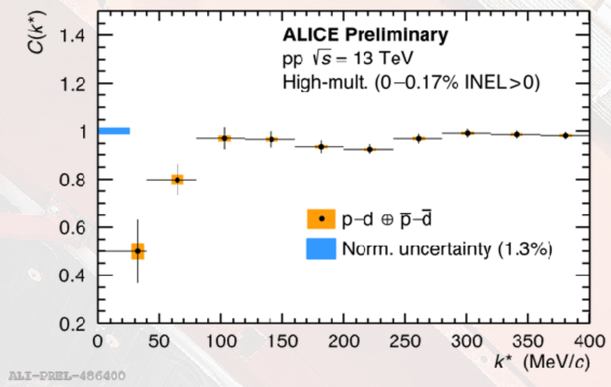


Final-state interactions
↕
Correlations in momentum space

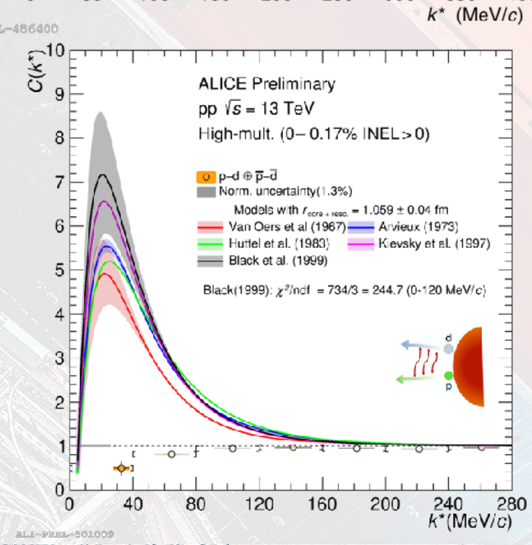
- Access to very small distances of ~1 fm in pp collisions at $\sqrt{s}$ =13 TeV [1]
- Lednický model: description of correlation function using scattering parameters [2]
- CATS: numerical Schrödinger equation solver to obtain wave-function for a given interaction potential [3]

Proton-Deuteron Interactions

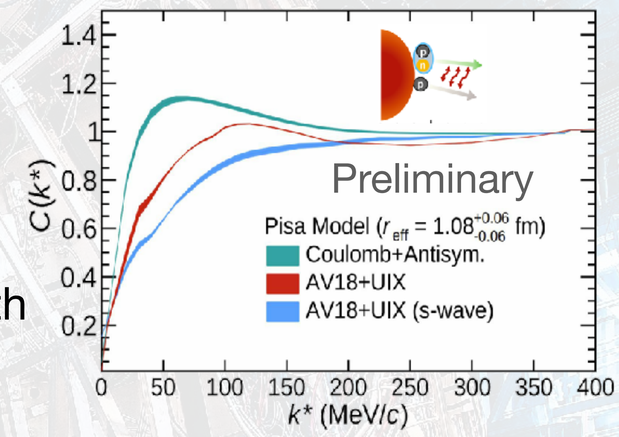
- Overall repulsive interaction observed for p-d system



- **Lednický**: point-like particles, deuteron structure not taken into account
- Using expected radius and available scattering parameters → huge discrepancy with data
- More sophisticated model needed!

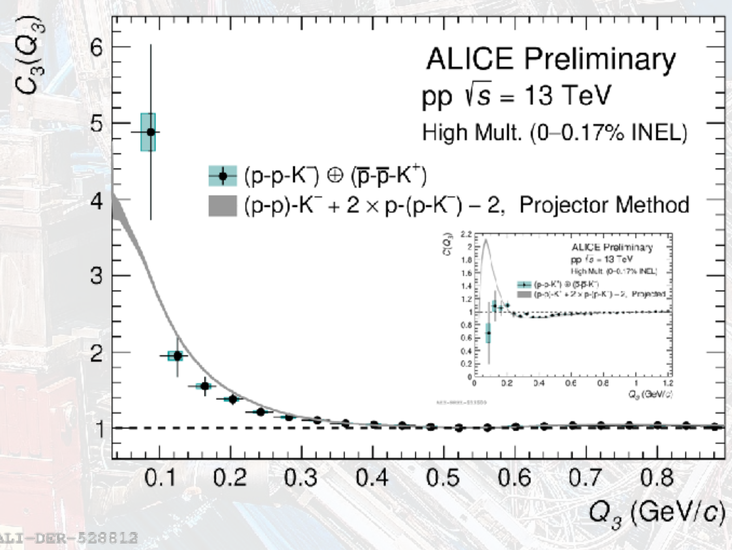


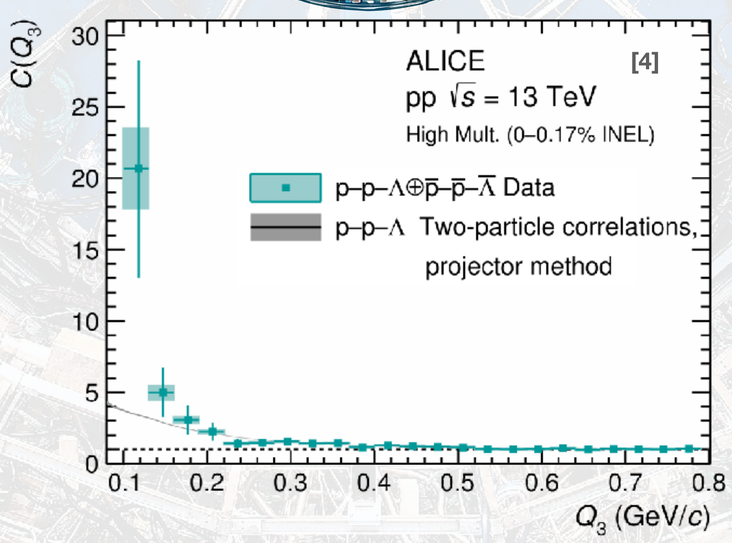
- **PISA calculation:** full wave function including three-body interactions
- Best description of data using expected radius and including both s- and p-waves

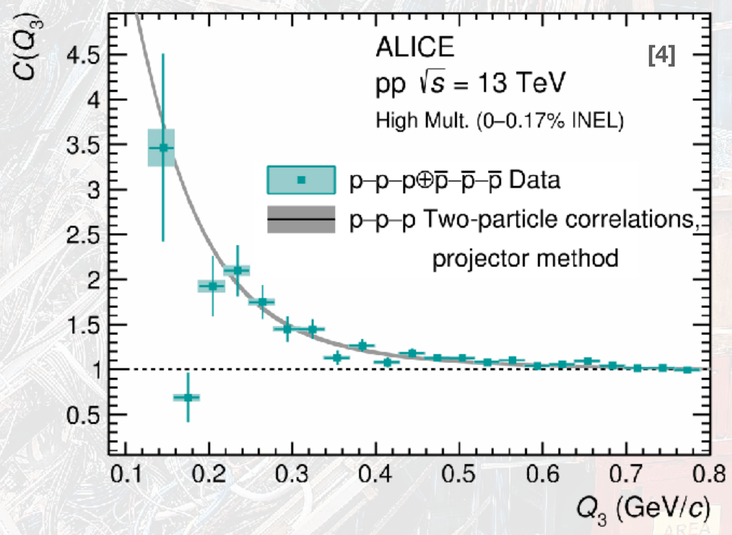


Predicted few percent sensitivity to the genuine three-body interactions!

Three-Hadron Correlations







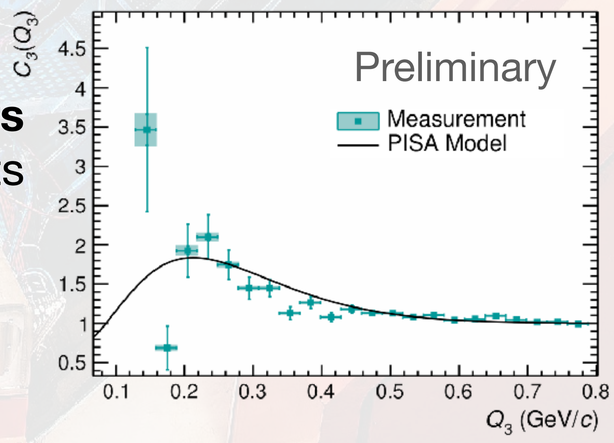
- Three-particle correlation function:

$$C(Q_3) = \xi(Q_3)\frac{N_{\text{same}}(Q_3)}{N_{\text{mixed}}(Q_3)}, \quad Q_3 = \sqrt{-q_{12}^2 - q_{23}^2 - q_{31}^2}$$

- **Projector method**: independent two-body interactions in three-body system [5]
- Good agreement with observed p-p-K⁻ (1.5 σ) and p-p-Λ (0.8 σ) correlation functions
- 6.7 σ deviation in the p-p-p system
- **Three-body calculations** need to include:
  - genuine three-body strong interaction
  - long-range Coulomb interaction
  - Pauli blocking

Outlook: Run 3 data and theory

- Preliminary PISA results qualitatively predict the observed correlation function!
- Developed offline **two- and three-body triggers** ready to record all events of interest!
- Up to x60 more triplets at Q_3<0.6 GeV/c!



Genuine three-body interactions will be accessible in Run 3!

[1] ALICE, Phys. Lett. B 811 (2020) 135849
[2] R. Lednický , Phys.Part.Nucl.40:307-352,2009
[3] Mihaylov et al., EPJC 78, 394 (2018)
[4] ALICE, arXiv:2206.03344; accepted by EPJA
[5] Del Grande et al. EPJC 82, 244 (2022)