Proton Femtoscopy in ALICE

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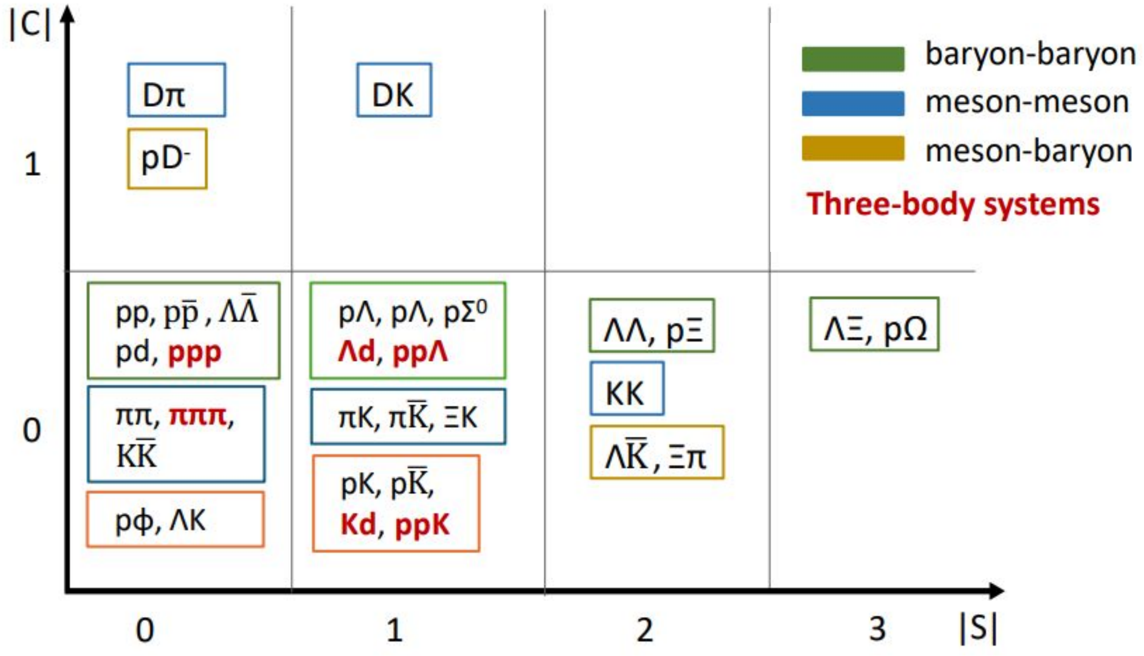
Several femtoscopy measurements by ALICE at the LHC

- ALICE experiment has provided unprecedented precise input for the study of hadronic interactions

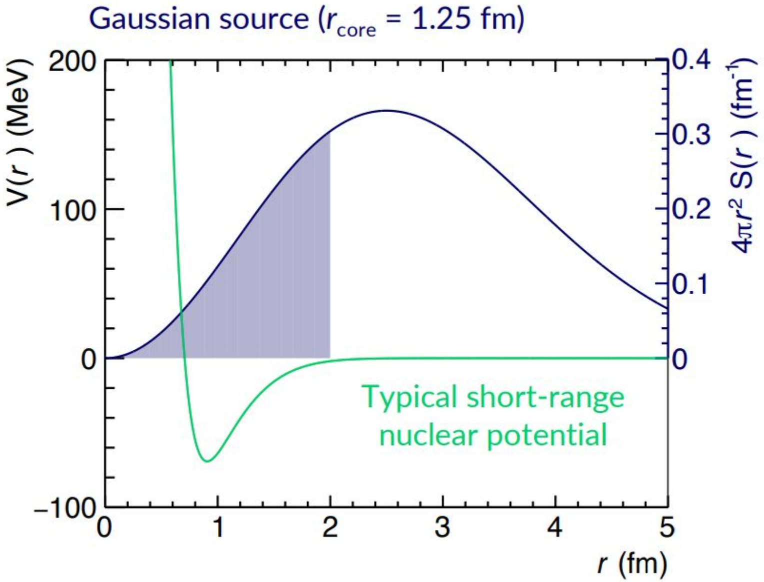


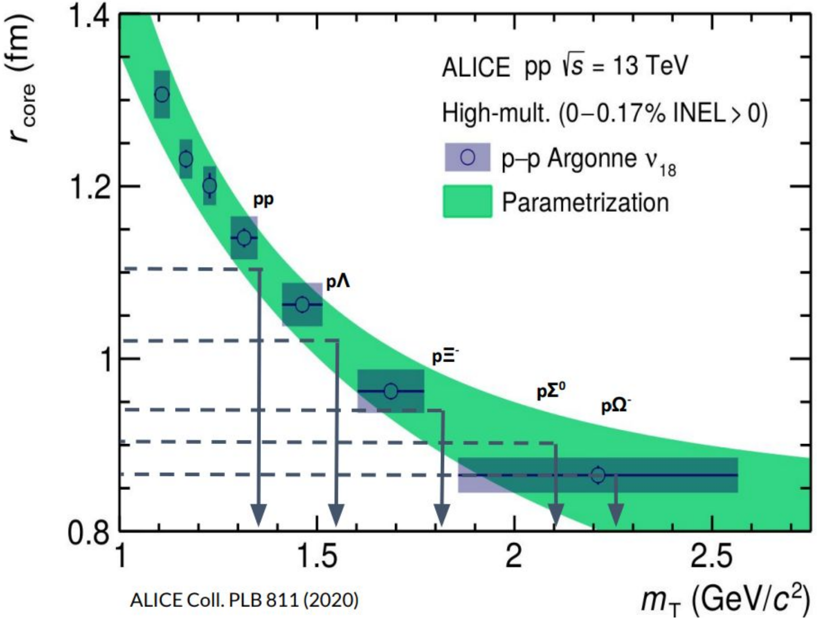
List of ALICE femtoscopy measurements

PRC 99 (2019) 2, 024001	p–p, p–Λ, Λ–Λ (methods)
PLB 797 (2019), 134822	Λ–Λ
PRL 123 (2019), 112002	p–Ξ
PRL 124 (2020) 092301	p–K
PLB 805 (2020), 135419	p–Σ0
PLB 811 (2020), 135849	p–p, p–Λ
Nature 588 (2020) 232-238	p–Ξ, p–Ω
PRL 127 (2021), 172301	p–ϕ
PLB 822 (2021) 136708	p–K
PRC 103 (2021) 5, 055201	Λ–K
PLB 833 (2022), 137272	p–Λ
PLB 829 (2022), 137060	baryon–(anti)baryon
PRD 106 (2022) 5, 052010	p–D
PLB 833 (2022) 137335	K0–K0, Kch–K0
PLB 844 (2022), 137223	Λ–Ξ
EPJA 59 (2023) 7, 145	p–p–p, p–p–Λ
EPJA 59 (2023) 12, 298	p–p–K
EPJC 83 (2023) 4, 340	p–K
PLB 845 (2023), 138145	Λ–K
PRX 14 (2024) 3, 031051	p–d, K–d

Source determination

- Small particle-emitting source created in pp collisions at the LHC
- Source size provide information on the scale of the interaction region
- Constrain source with common m_T scaling





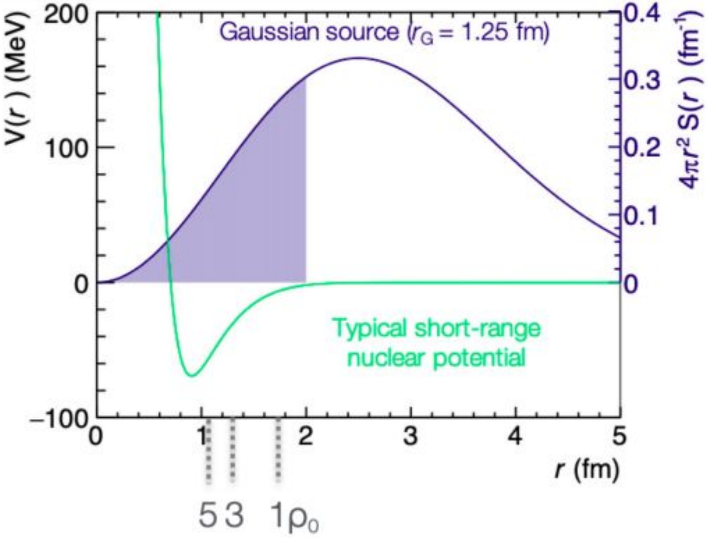
ALICE Coll. PLB 811 (2020)

Source determination

- The emitting source function used to describe the p-p correlation function

$$C(k^*) = \int S(\vec{r})\left|\psi(\vec{k}^*,\vec{r})\right|^2 d^3\vec{r}$$

measured known interaction



- The **source function** is parameterised by the **gaussian parameterization**

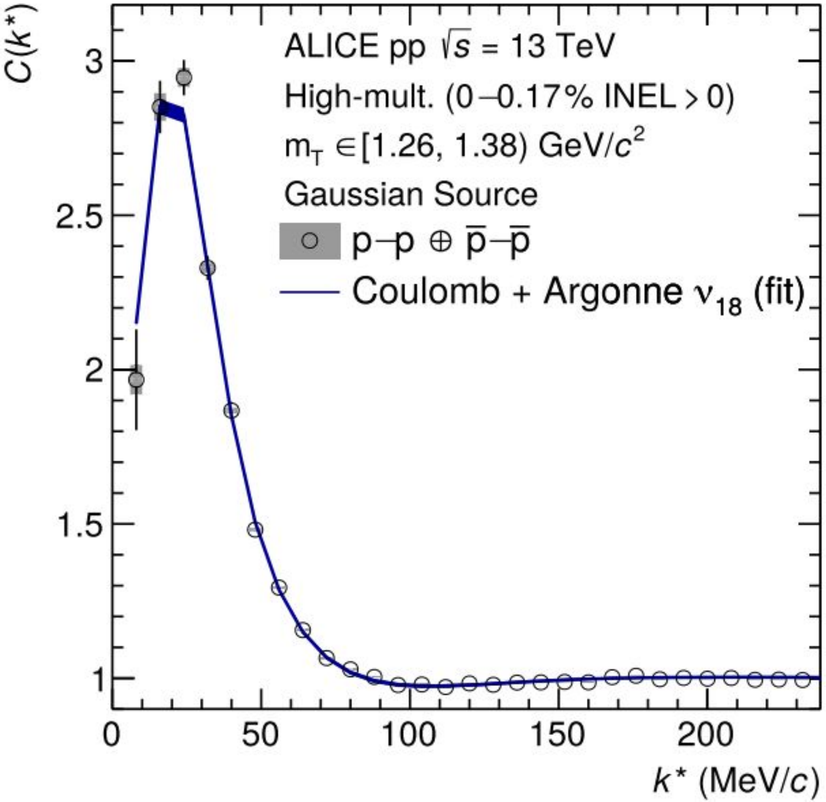
$$S(r) = \frac{1}{(4\pi r_{core}^2)^{3/2}} \exp\left(-\frac{r^2}{4 r_{core}^2}\right) \times$$ Effect of short lived resonances (cτ ~ 1 fm)

- Small particle-emitting source created in pp collisions at the LHC

ALICE Coll., PLB, 811(2020, 135849), ALICE Coll., arXiv:2311.14527

- **One global source for all hadrons**

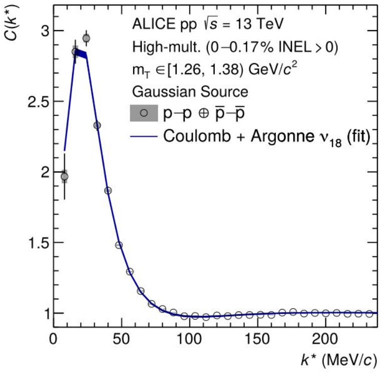
p-p source in pp collisions in ALICE at the LHC

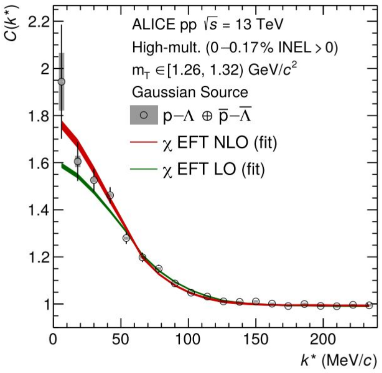


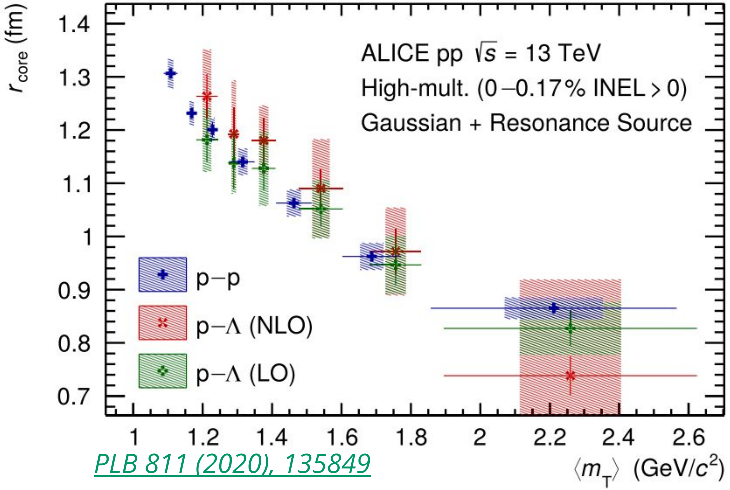
PLB 811 (2020), 135849

- Gaussian source used to study the p-p and p-Λ source size
- Argone AV18 + Coulomb potentials used to calculate the two particle wave function
- Two particle wave function as solution to Schrodinger's equation
  → by using **CATS** (Correlation Analysis Tool using the Schrodinger equation) framework

Source measurement in pp collisions in ALICE at the LHC







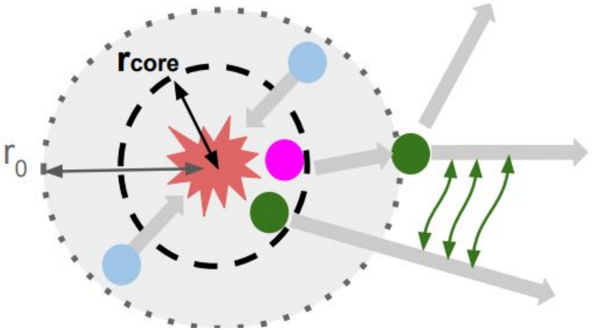
PLB 811 (2020), 135849

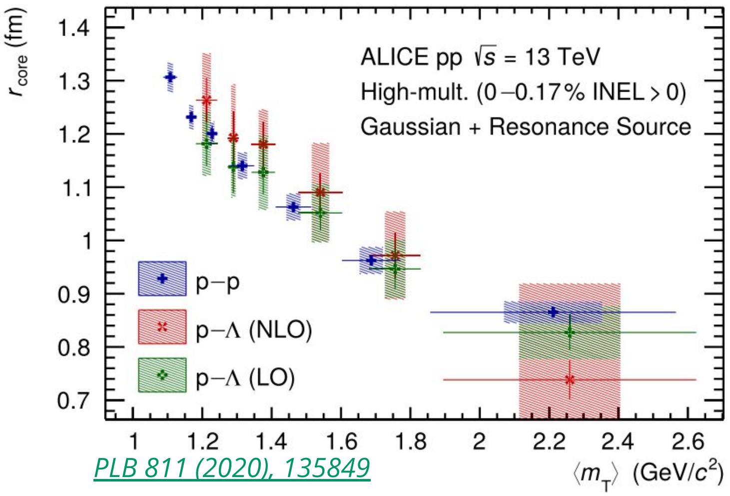
- Gaussian source used to study the p-p and p-Λ source size
- Observed to follows m_T scaling
- Different source size (core radius) for different species
- Here, an assumption is made that the Gaussian "primordial core" is common for all the species but modifies from short lived hadronic resonances.

→ protons (⅔ fraction of all) comes from resonance decay (Δ, heavier-Δ, N*, Λ resonances)

→ similarly, Λ comes from resonance decay (prominently via Σ resonances, heavier-Δ, N*, Σ resonances)

Common baryon source in pp collisions

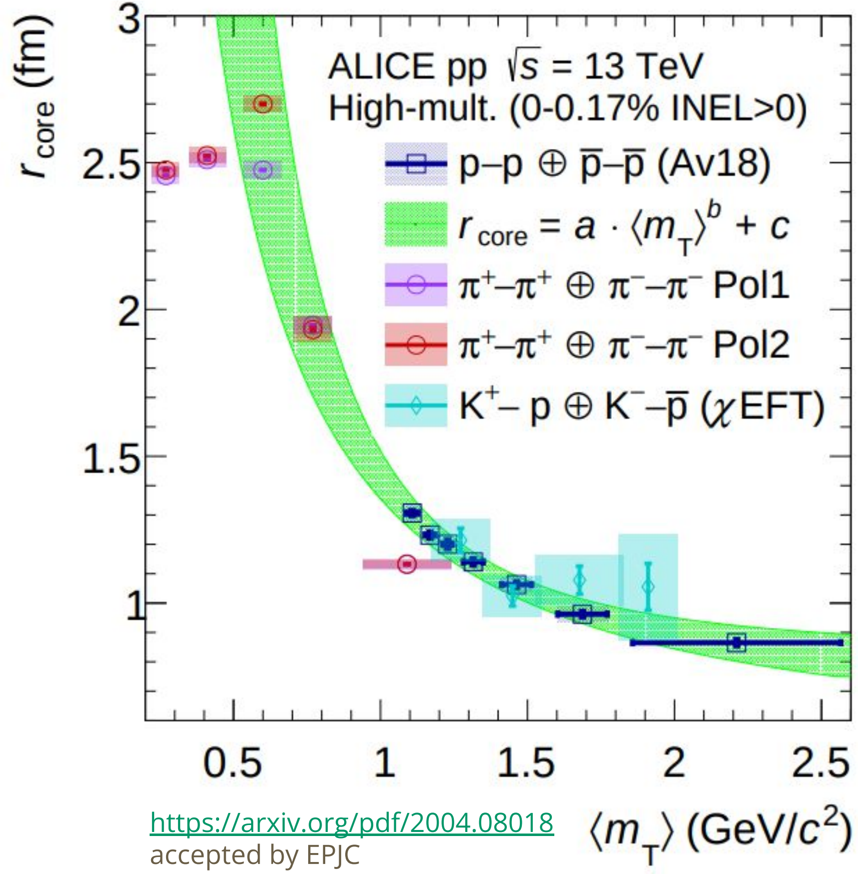


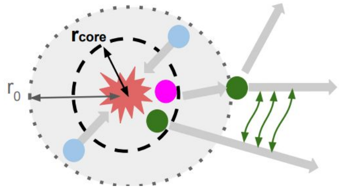


PLB 811 (2020), 135849

- Gaussian source used to study the p-p and p-Λ source size
- Observed to follows m_T scaling
- Different source size (core radius) for different species
- Any baryon pair should follows this m_T scaling
  → source size can be extracted based on the m_T of the measured pairs
  → way to allows for precisely studying the strong interactions

Universal source for all the hadrons

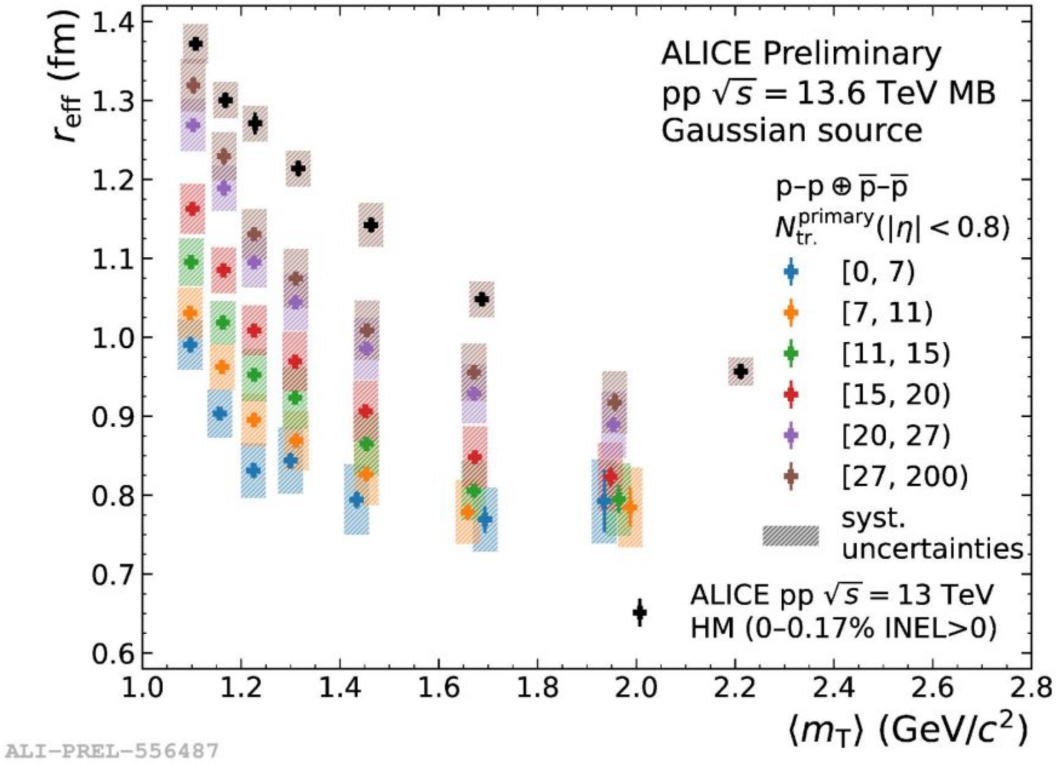




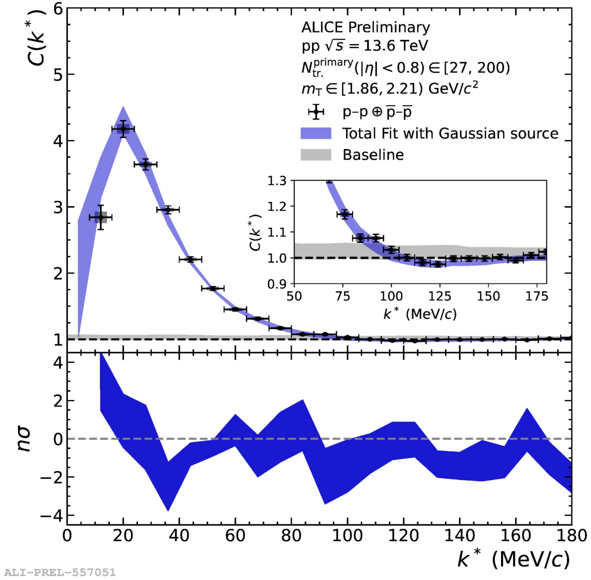
- Gaussian core radius (r_core) results for protons, pions and kaon-proton pairs in High-multiplicity pp collisions at 13 TeV
- Remarkable agreement of r_core for meson-meson and meson-baryon pairs with the m_T scaling of the source size.
- Additional support for the scenario of a common emitting source for all hadrons in small system

https://arxiv.org/pdf/2004.08018
accepted by EPJC

Source measurement in pp collisions in ALICE - RUN3

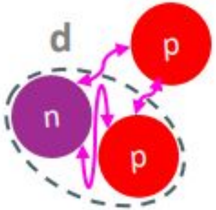


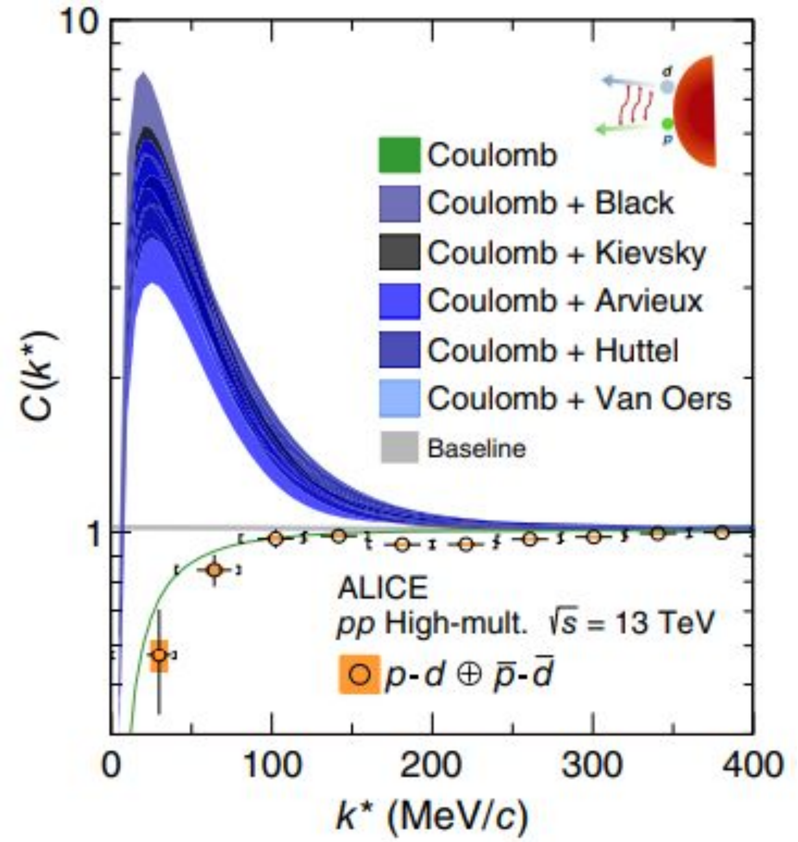
- Recent RUN3 results at pp collisions at 13.6 TeV
- Study multiplicity dependence
- Observed m_T scaling



PRX 14 (2024) 3, 031051

p-d correlation in pp collisions in ALICE at the LHC





- P-d as an effective two-body →used LL approach
- Source size = 1.08 ± 0.06 fm
- Strong interaction is constrained from scattering measurements
- Picture of two-point like particle does not work
- Need of three-body calculations accounting for p-pn dynamics

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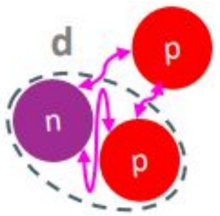
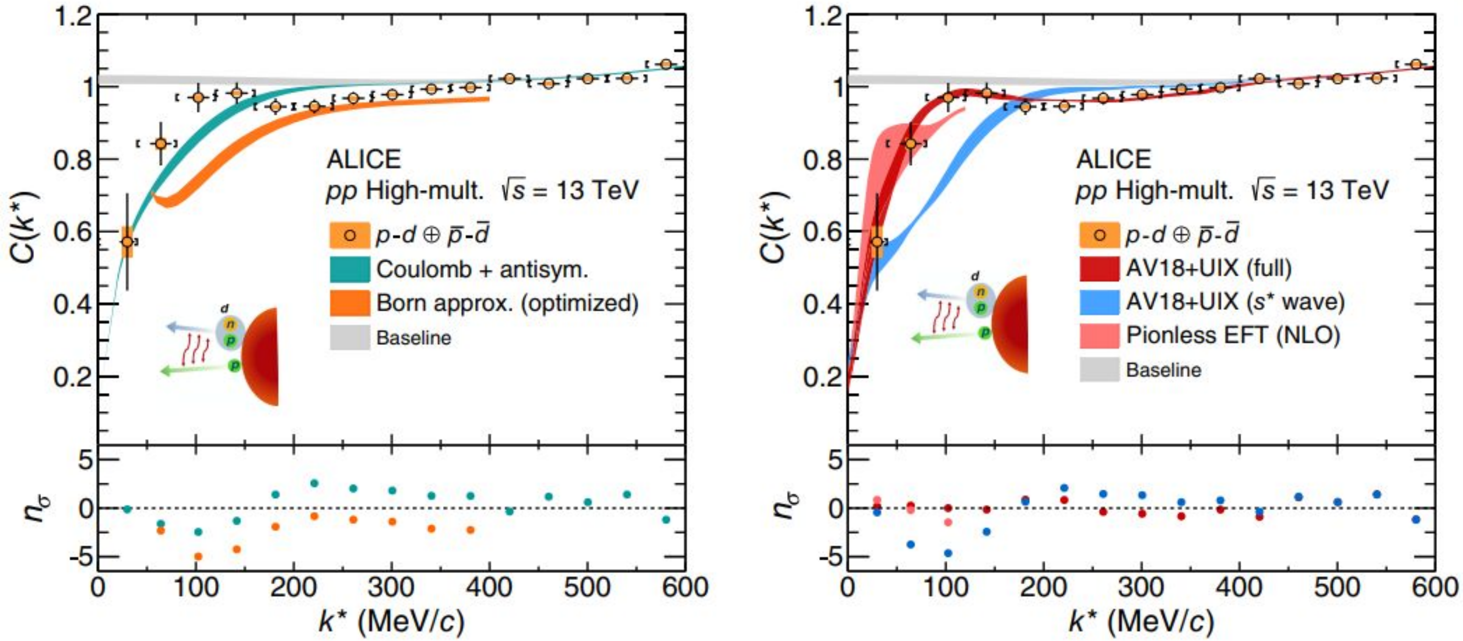
p-d correlation in pp collisions in ALICE at the LHC





- Deuteron treated as composite object, only full three-body calculation accounts for internal structure of deuteron can explain the data (Av18-NN + Urbana IX-NNN + Quantum statistics)
- The argonne AV18 potential is used for the calculation, 5% uncertainty to three-body forces
- Hadron-nuclei correlations at the LHC can be used to study many-body dynamics

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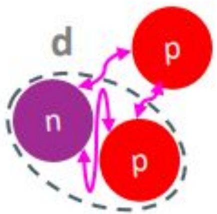
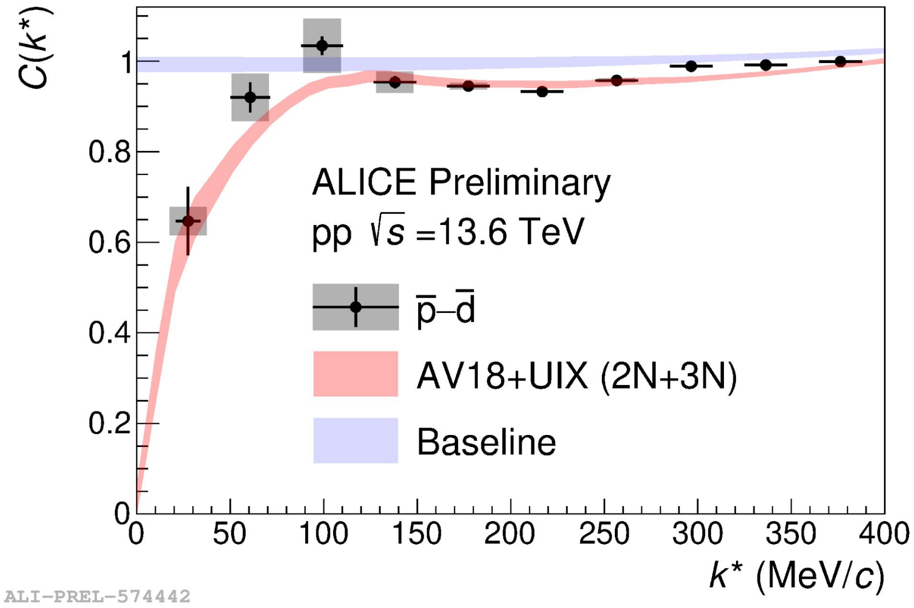
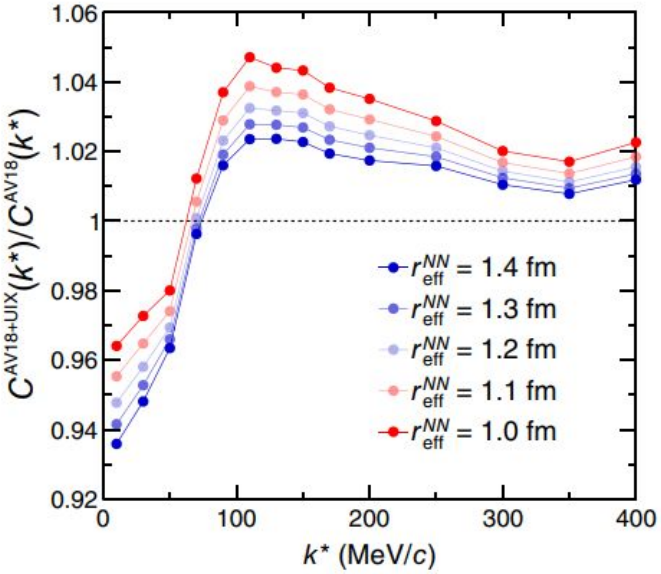
p-d correlation in pp collisions in ALICE - RUN3



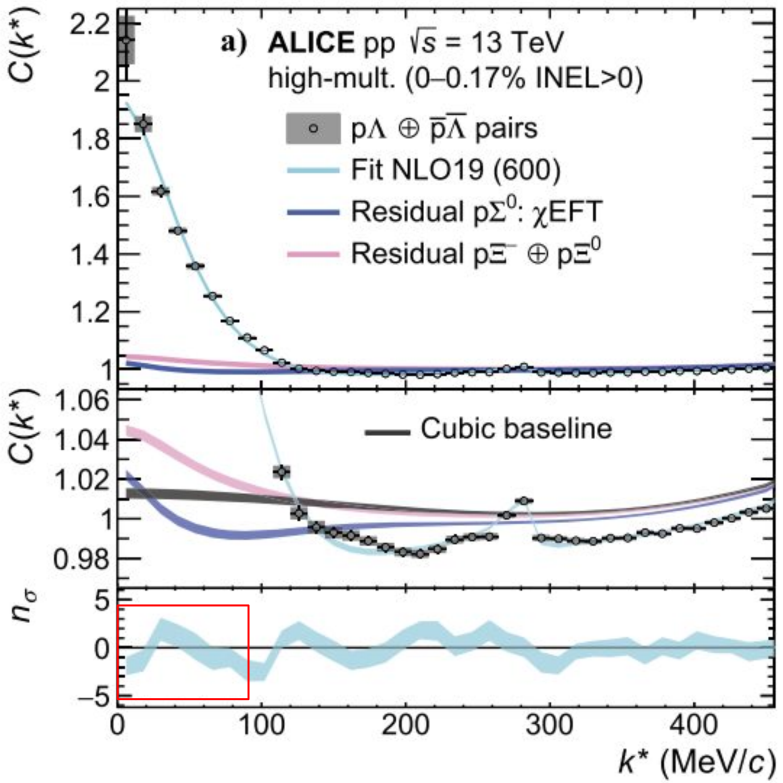




- Only full three-body calculation accounts for internal structure of deuteron can explain the data (NN + NNN + Quantum statistics)
- Analysed Run3 data at 13.6 TeV, promising results, possibility of m_T-differential analysis
- Expected uncertainty to three-body forces upto 1%

PLB 833 (2022), 137272

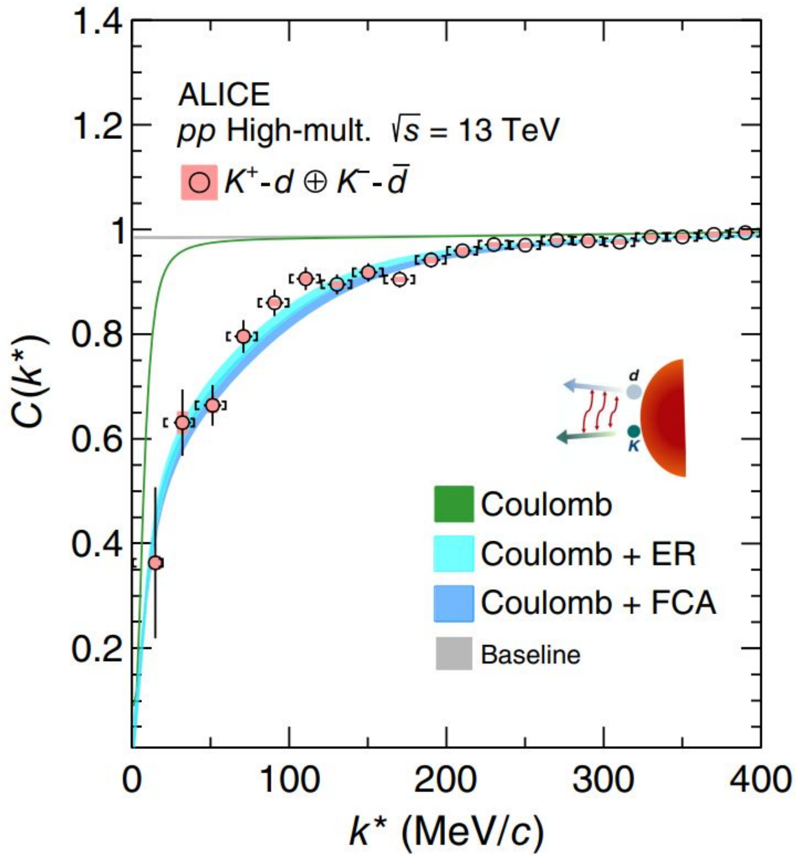
p-Λ correlation in pp collisions in ALICE at the LHC



- Gaussian source (modelled by CATS) with chiral magnetic field theory potentials
- Sensitive to different ΣN coupling strength
- Next to leading order (NLO19) is favoured within $n_\sigma = 3.2$
- Attractive interaction of Λ at large density

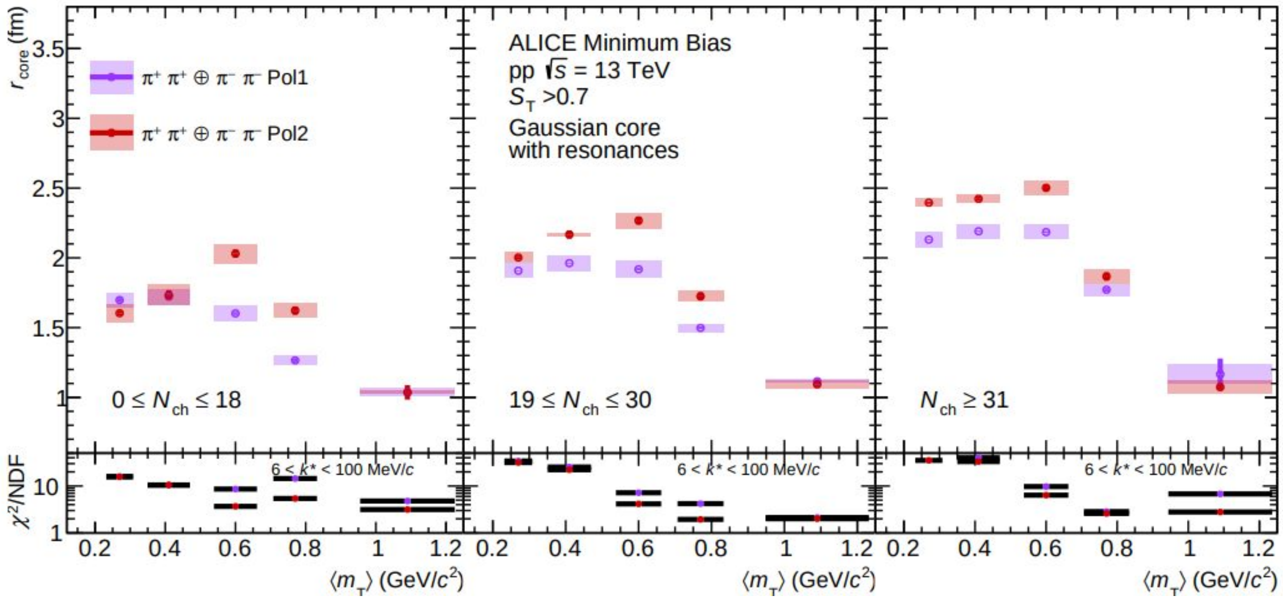
PRX 14 (2024) 3, 031051

K-d correlation in pp collisions in ALICE at the LHC



- K-d as an effective two-body system by using LL approach
- Source size = 1.35 + 0.04 - 0.05 fm
- First measurement in pp collisions
- Deuterons are produced in shorter distances together with hadrons

Source size increases with increasing multiplicity



- Attempt of multiplicity dependent source size measurement
- Innovative behaviour of growing r_core with increasing multiplicity
- Scaling of r_core with increasing m_T
- Saturation of source size below 600 MeV/c^2

https://arxiv.org/pdf/2004.08018
accepted by EPJC

Thank you for your attention!