Femtoscopic studies on
proton-Ξ^- and proton-Ω^- correlations
with ALICE

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Femtoscopy

- Based on the correlation function: $C(k^*) = \dfrac{P(\vec{p_a}, \vec{p_b})}{P(\vec{p_a})P(\vec{p_b})}$

  where k^* = reduced relative momentum, with $\vec{p_a^*} + \vec{p_b^*} = 0$.

- Experimentally obtained as $C(k^*) = \mathcal{N}\dfrac{N_{Same}(k^*)}{N_{Mixed}(k^*)}$
  - Generally, the experimental correlation function accounts for the genuine correlation and it is affected by residual correlations and finite momentum resolution [1]
- Theoretically formulated as:

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

Source

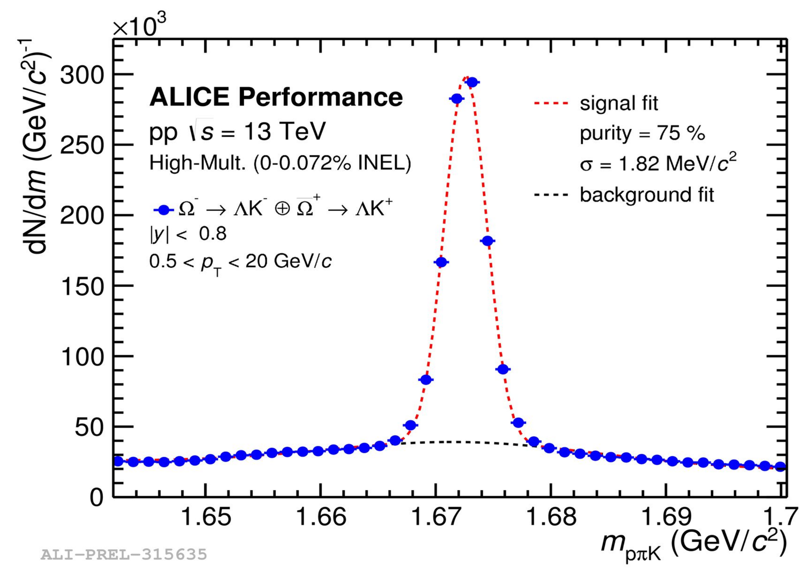
relative wave function

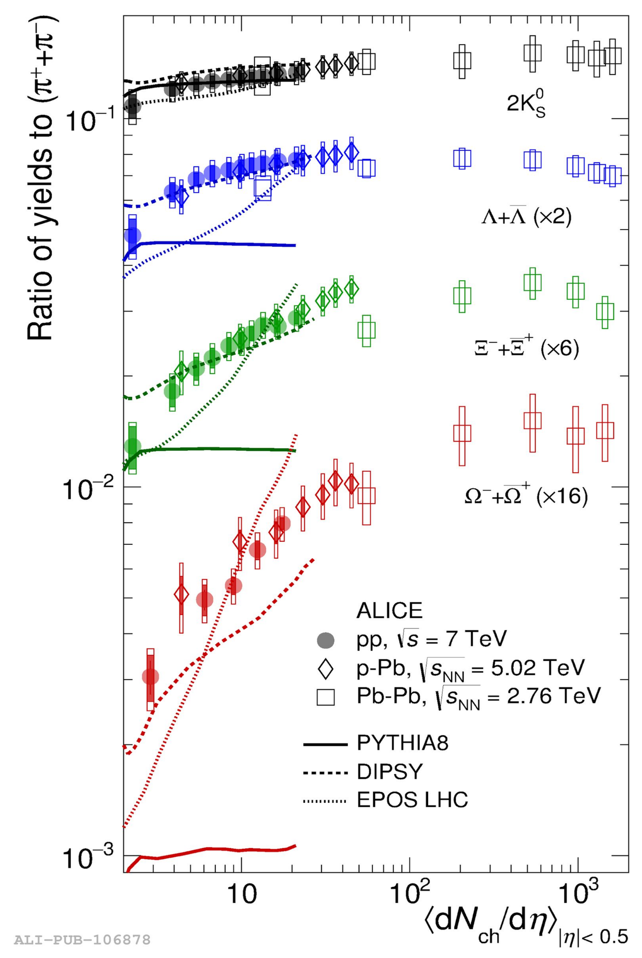
Sensitivity to the interaction potential

The theoretical correlation function is computed by CATS [2] from the shape of the local potential provided by the different models.

Data analysis

- pp collisions at $\sqrt{s}$ = 13 TeV of ALICE Run 2
  - Analyzed 10^9 events
  - High multiplicity (HM) trigger: 0.1% highest multiplicities with respect to Minimum Bias
- 9.3×10^6 $\Xi^-\oplus\Xi^+$ selected candidates
  - identified by $\Xi\rightarrow\Lambda\pi\rightarrow(p\pi)\pi$ decay. Purity 92%.
  - 3×10^4 p-$\Xi^-\oplus$p-Ξ^+ pairs at k^*<200 MeV/c
- 1.2×10^6 $\Omega^-\oplus\Omega^+$ selected candidates
  - identified by $\Omega\rightarrow\Lambda K\rightarrow(p\pi)K$ decay. Purity 75%.
  - 0.6×10^6 p-$\Omega^-\oplus$p-Ω^+ pairs (700 at k^*<100 MeV/c)

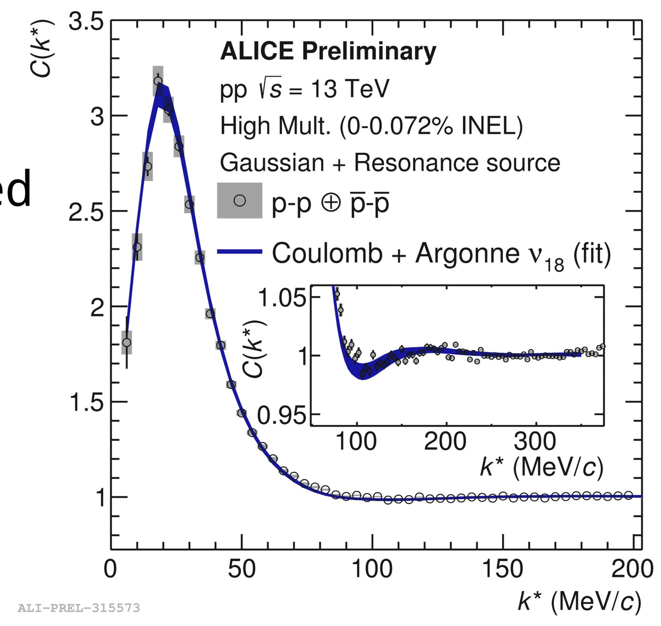




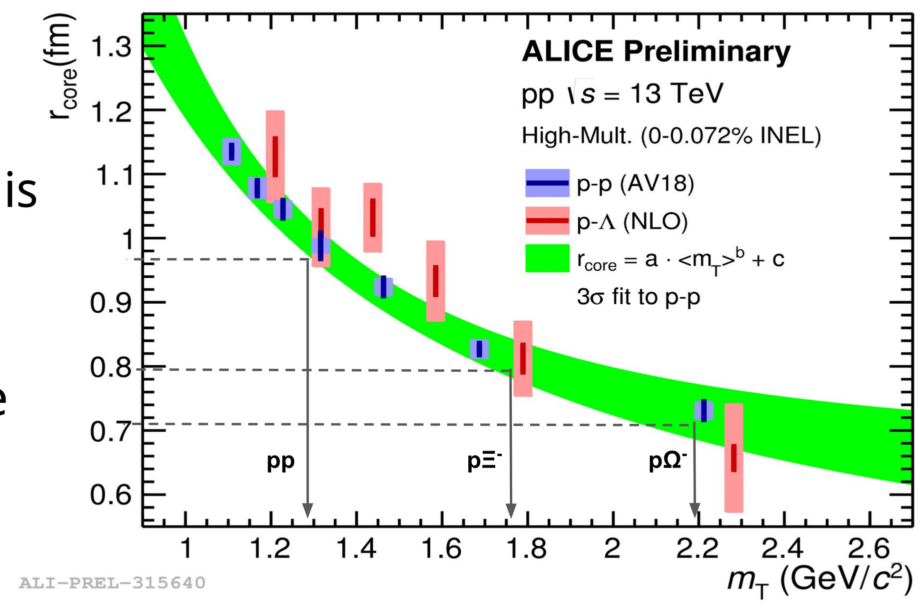
Increased yield of Ξ and Ω baryons in HM pp events [3].

Determination of the source characteristics from the p-p analysis

- Ansatz: in small collision systems the source is similar for all baryon pairs
- The size of the source core is determined from the p-p correlation function:
  - The p-p interaction is well known → determination of the source size
- Effect of strong short-lived resonances computed for all baryons (statistical hadronization model)



- The p-p femtoscopic analysis is performed differentially in <m_T> bins
- For the p-Ξ^-, p-Ω^- pairs the source size is obtained by considering the corresponding pair <m_T>
- Assume for all baryon-bayon pairs the same <m_T> dependence
  - Cross-checked by p-Λ analysis
  - resonances taken into account



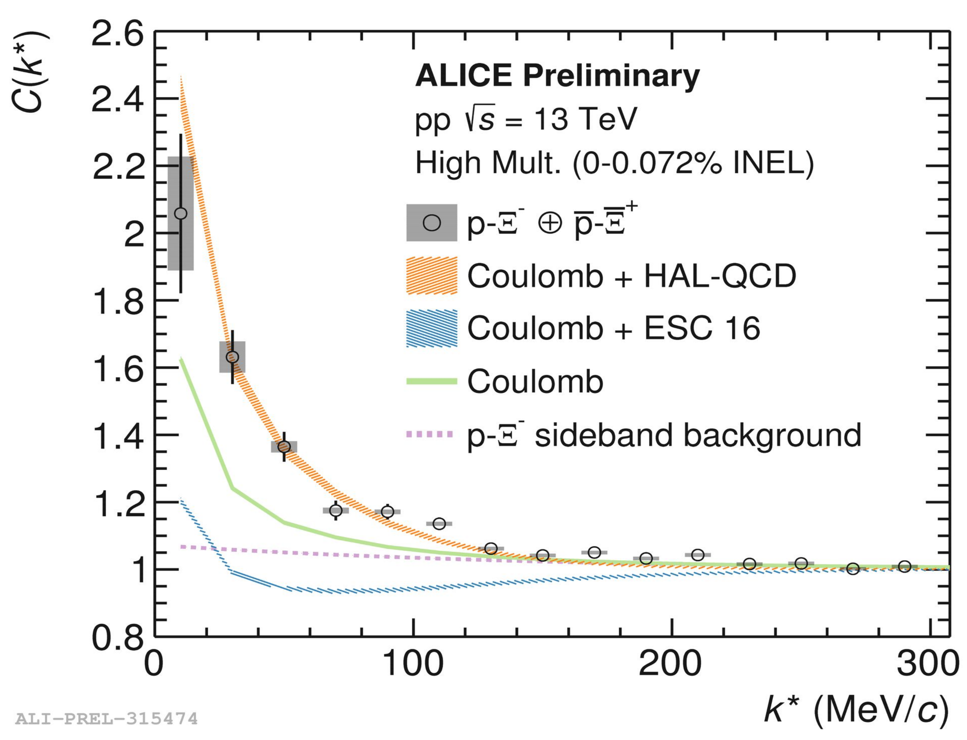
p-Ξ^-

- At which densities hyperons appears in the core of neutron stars?
  - Do Ξ take part in the picture?
  - Depends on the Ξ single particle potential in pure neutron matter, predicted to be repulsive by Lattice QCD calculations

r_{source} = 0.7 fm + resonances

ALICE data compared with:

- Lattice HAL-QCD calculations [4]
- ESC16: Meson exchange model [5]



- **Direct observation of an attractive p-Ξ^- interaction**, firstly observed by ALICE in p-Pb collisions [6]
  - Coulomb only hypothesis excluded by > 5σ
- Femtoscopic measurements sensitive to differences in potentials
  - Test of HAL-QCD model allows to apply the conclusions to the description of neutron stars ⇒ stiffer Equation of State

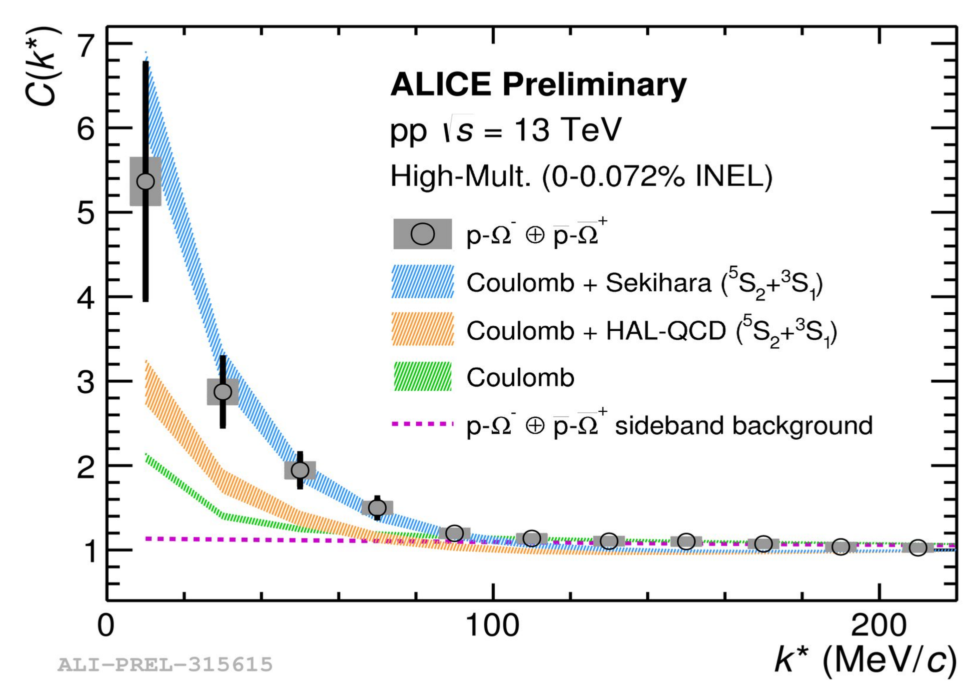
p-Ω^-

- The p-Ω interaction can only be accessed experimentally via femtoscopy
- Lattice QCD and phenomenological models predict a N-Ω interaction attractive at all distances ($^5S_2$ channel), leading to the possible existence of a NΩ di-baryon, with several different predictions for the binding energy (E_b)
- The $^3S_1$ channel is modeled by complete absorption at short distances r < 2 fm

r_{source} = 0.72 fm + resonances

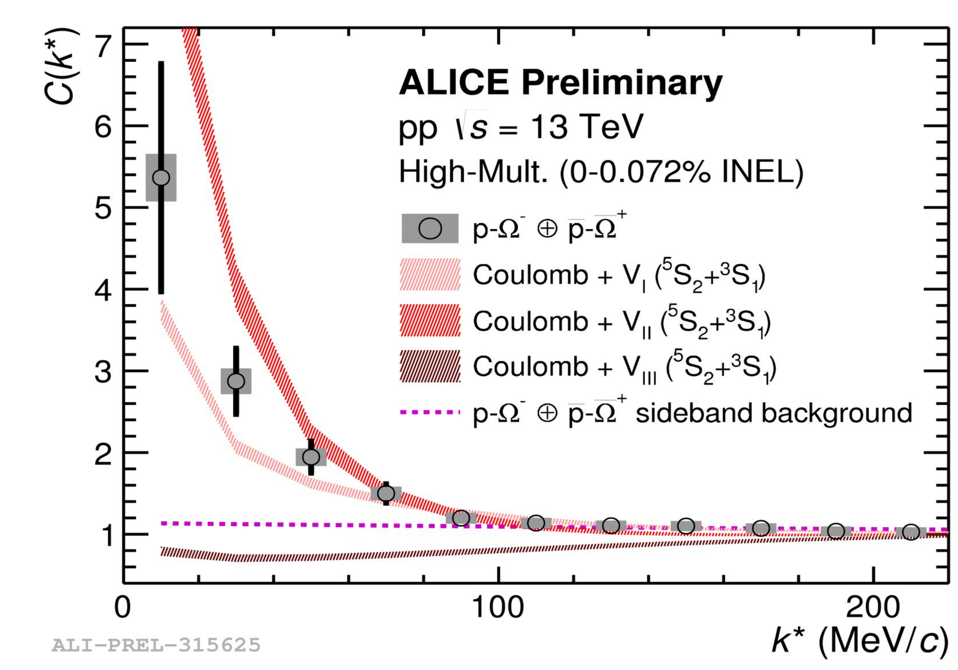
ALICE data compared with:

- Lattice HAL-QCD potential with physical quark masses [7]
  - E_b = 1.54 MeV/c^2
- Sekihara, meson exchange model [8]
  - E_b = 0.1 MeV/c^2



ALICE data compared with:

- Fits [9] to Lattice calculations (HAL-QCD [10]) with heavy quark masses:
  - V_I: No NΩ bound state
  - V_{II}: E_b = 6.3 MeV/c^2
  - V_{III}: E_b = 26.9 MeV/c^2



- The small source size of pp collisions and the high purity of the sample enhances the **sensitivity of the ALICE data to interaction parameters**
- The Coulomb-only hypothesis is excluded (~6σ) showing the strong attractive character of the interaction.
- Models predicting **large binding energies for the NΩ di-baryon are excluded by ALICE data**

References:
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