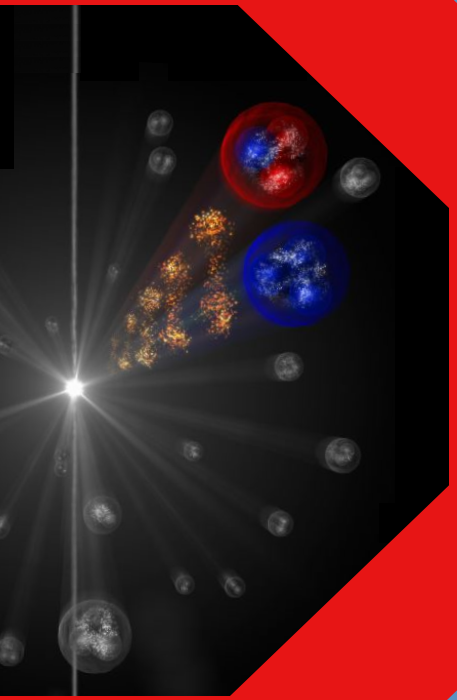


Novel constraints for the multi-strange meson-baryon interaction using correlation measurements with ALICE

Otón Vázquez Doce (INFN - Frascati) on behalf of the ALICE Collaboration

QNP2024 - The 10th International Conference on Quarks and Nuclear Physics
Barcelona, July 8th, 2024

(Multi-)strange meson-baryon systems and exotic states

Interactions between mesons and baryons involving strangeness

→ Landmark for hadron-hadron interaction studies

→ Possibility to study nature and properties of exotic states

Presence of a **rich coupled-channel dynamics**

→ Systems sharing same quantum numbers (B,S,Q) relatively close in mass

→ On- and off-shell processes from one channel to the other

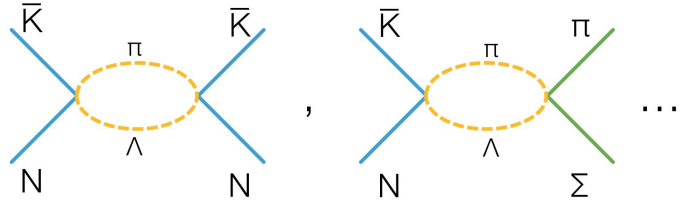
Several candidates for exotic states with **molecular nature**

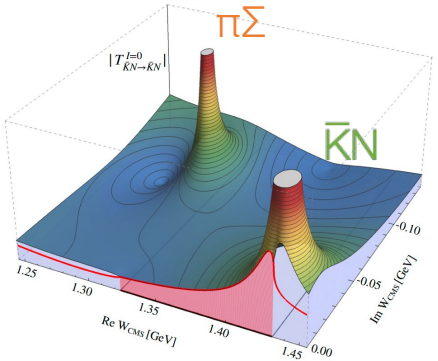
→ Typically observed close to channel thresholds

→ Main example given by the **two-pole Λ(1405) state**

J. M.M. Hall et al. Phys. Rev. Lett. 114 (2015) 13

U. G. Meißner Symmetry 12 (2020) 6, 981





M. Mai Eur. Phys. J. Spec. Top. 230, 1593–1607 (2021)

S=-1 meson-baryon interaction

Large attractive interaction in isospin I=0 channel

→ Responsible for formation of Λ(1405) below $\bar{K}N$ threshold

Scarce statistics available from scattering data above $\bar{K}N$ threshold

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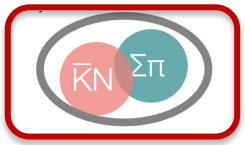
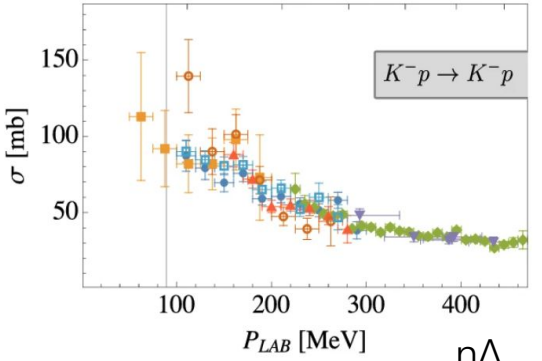
Photoproduction experiments

Λ(1405)



antiKaonic hydrogen
SIDDHARTA Coll.
PLB 704 (2011)

Scattering experiments
M. Mai Eur. Phys. J. Spec. Top. 230, 1593 (2021)



Λπ	Σπ	K̄N	ηΛ	ηΣ	KΞ	
1250-1255	1327-1337	1432-1437	1633	1740	1815	**Energy**

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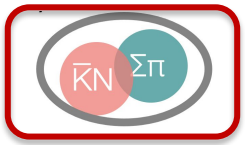

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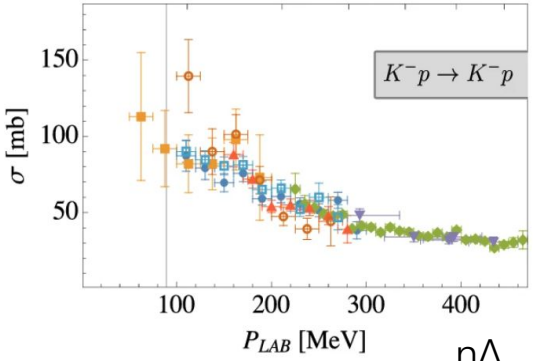
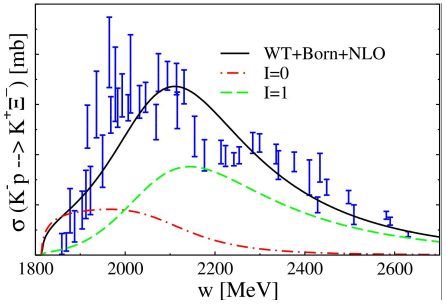


Sensitivity to I=1 component
A. Feijoo et al., Phys. Rev. C99, 035211 (2019)



Femtoscopy delivers high-precision data close to threshold and on several inelastic channels

Moving to the S=-2 sector

Scattering experiments challenging with increasing strangeness

→ Ξ(1620) lying across the $\bar{K}\Lambda$ threshold as molecular candidate, poorly known

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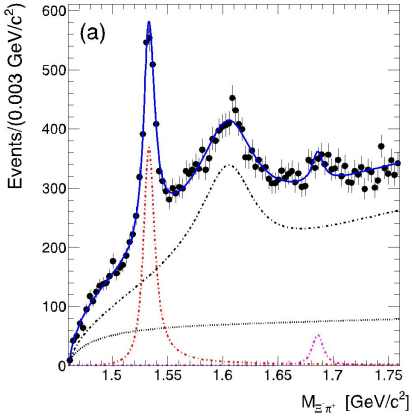
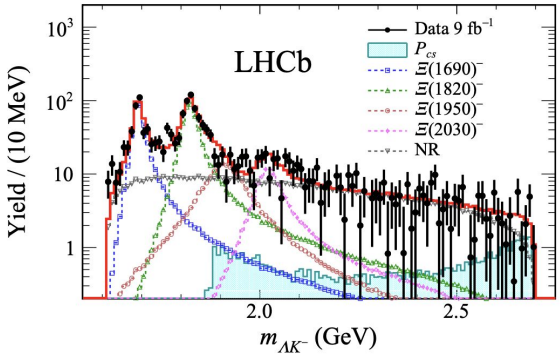
Intensive searches via spectroscopy measurements

→ Combine different production mechanisms/decay channels to reveal the nature of the state

Ξ(1620)
Belle Coll.,
Phys. Rev. Lett 122 (2019)





Ξ(1690)
LHCb Coll.
Sci. Bull. 66 (2021)

Ξπ	$\bar{K}\Lambda$	$\bar{K}\Sigma$	ηΞ	
1449-1461	1609-1613	1683-1691	1870	**Energy**

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Scattering experiments challenging with increasing strangeness

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Belle Coll.,
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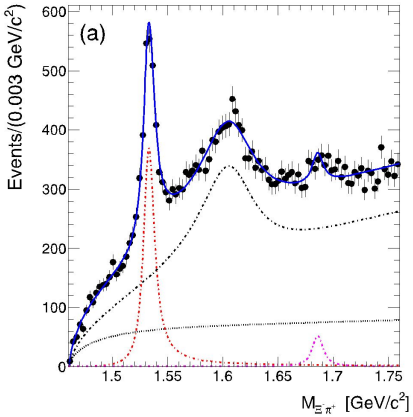

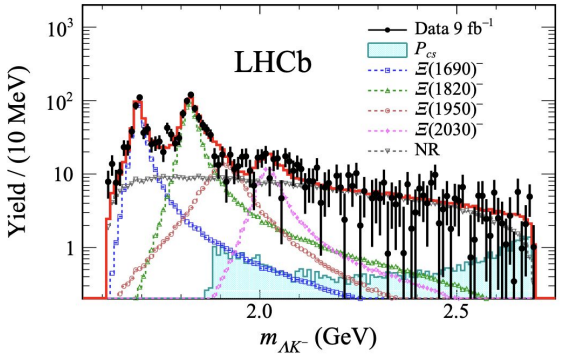

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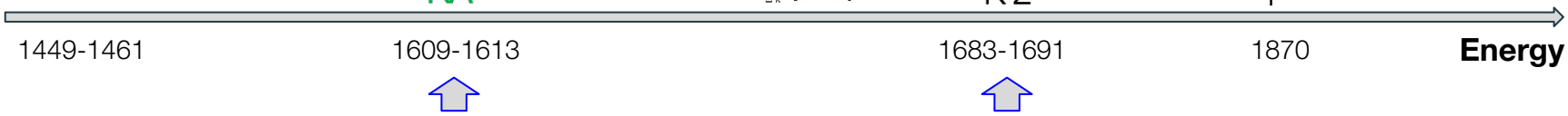


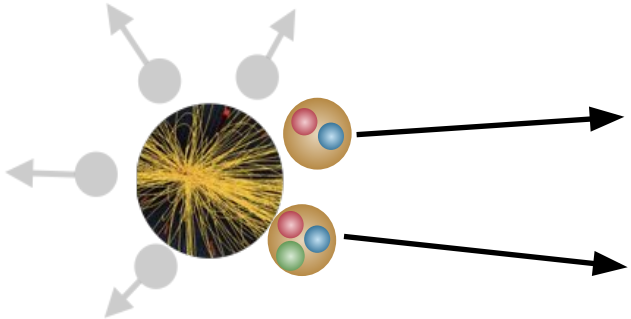
Femtoscopy approach: accessing the interaction between the constituents

The femtoscopy method in pp collisions

Accessing hadronic final-state interaction with correlation functions measured in pp collisions

M. Lisa, S. Pratt et al, Annu. Rev. Nucl. Part. Sci.. 55 (2005), 357-402, L. Fabbietti, V. Mantovani Sarti and O. Vazquez Doce Annu. Rev. Nucl. Part. Sci. 71 (2021), 377-402

$$C(k^*) = \frac{N_{\text{same}}(k^*)}{N_{\text{mixed}}(k^*)}$$



$$k^* = \frac{|\vec{p}_a^{\,*} - \vec{p}_b^{\,*}|}{2}$$

* in pair rest frame

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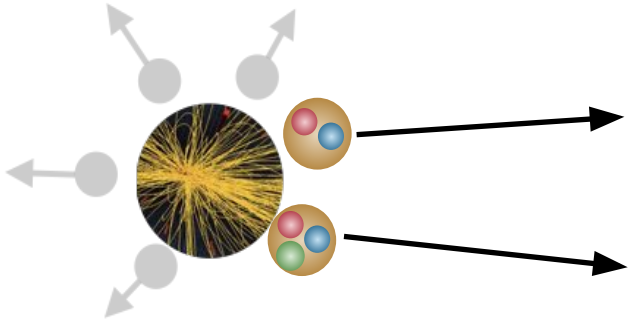

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Emitting source r^* ~1-2 fm

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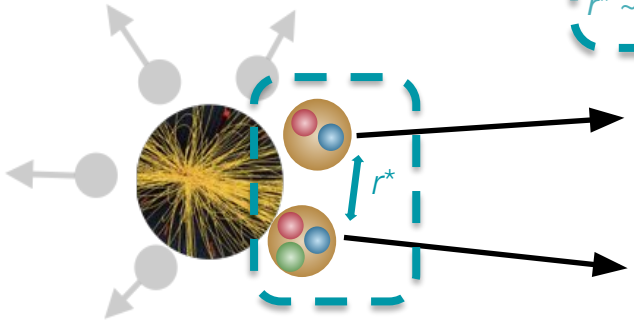

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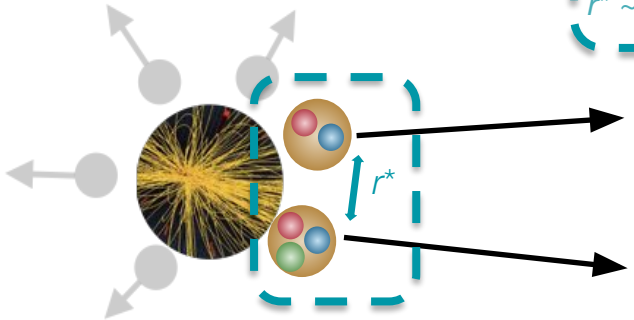

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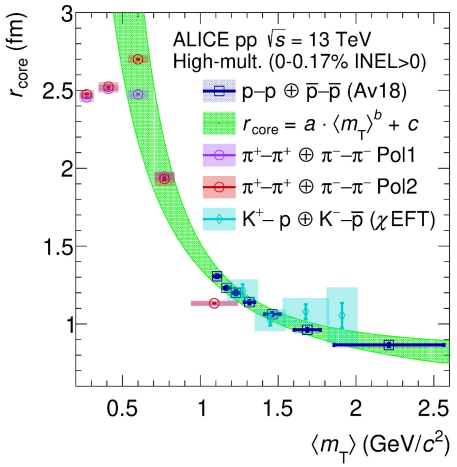
ALICE high-multiplicity (HM) pp collisions at 13 TeV
→ Emitting source anchored to p-p correlation data
→ **Interparticle distances ~1-2 fm** ALICE Coll. PLB 811 (2020)



ALICE Coll.,arXiv:2311.14527 [hep-ph]
EPJC in press

$$m_T = \sqrt{k_T^2 + m^2} \qquad k_T = \frac{1}{2}|p_{T,1} + p_{T,2}|$$

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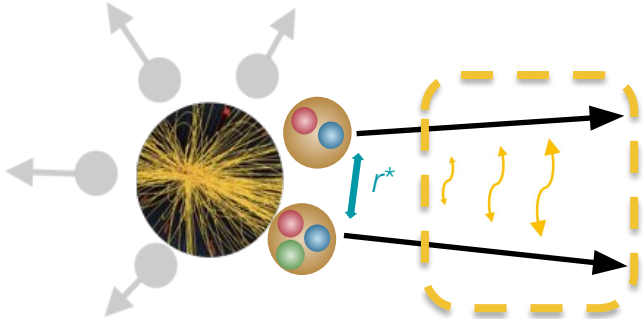
Interaction



$$k^* = \frac{|\vec{p}_a^* - \vec{p}_b^*|}{2}$$

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Scattering parameters characterizing the interaction

s-wave asymptotic wave function from scattering parameters

R. Lednicky and V.L. Lyuboshits, Sov. J. Nucl. Phys. 53 (1982) 770

Two-particle wave function

$$\Psi(k^*, \vec{r^*})$$

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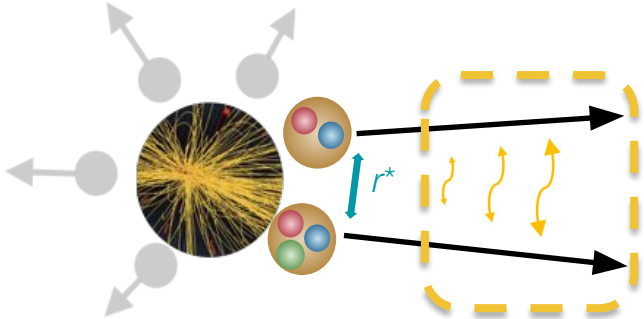

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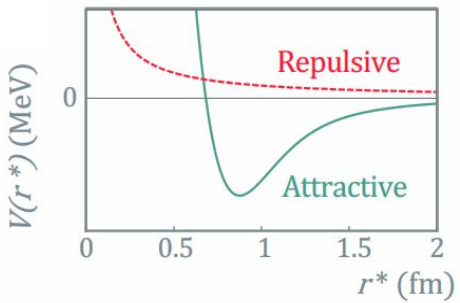

Schrödinger equation

Two-particle wave function

$\Psi(k^*, \vec{r^*})$

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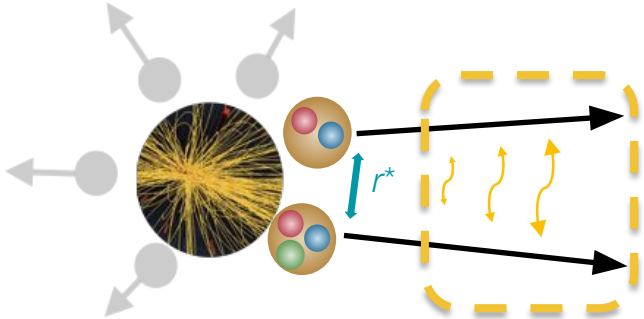
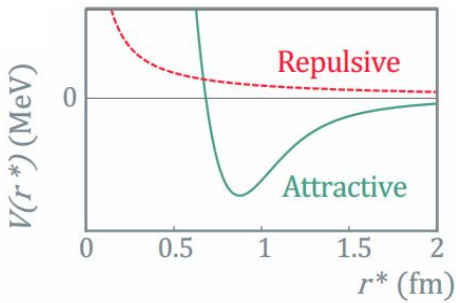
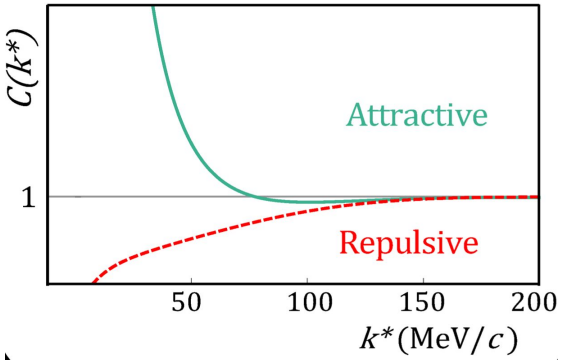




Correlation mapping 1-to-1 the nature of the interaction

ALICE Coll. Nature 588 (2020) 232-238



$$k^* = \frac{|\vec{p}_a^* - \vec{p}_b^*|}{2}$$

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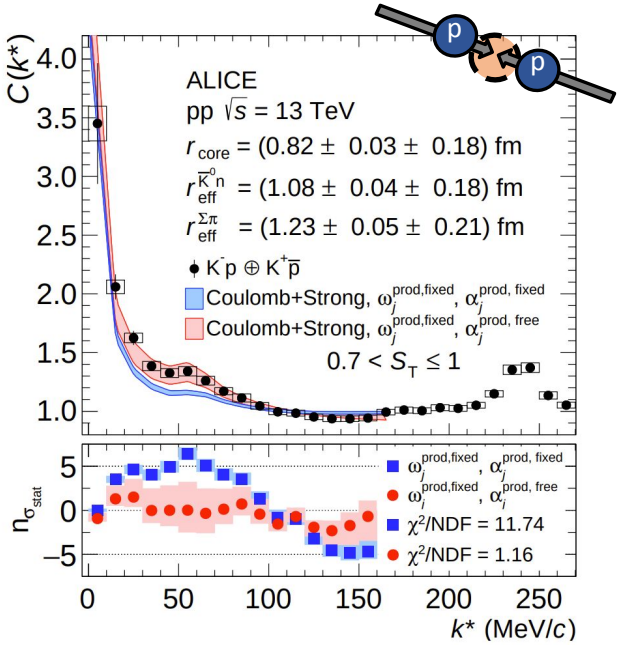
High-precision data on S=-1 sector above threshold

Femtoscopy delivers the **most precise data above K^--p threshold**
→ Crucial input for low-energy chiral effective potentials
Provides a **quantitative test of coupled channels**

Data:
ALICE Coll. Phys. Rev. Lett. 124, 092301 (2020)
ALICE Coll. Eur. Phys. J. C 83, 340 (2023)

Strong interaction: Kyoto model
K. Miyahara et al., Phys. Rev. C98, 2, (2018) 025201



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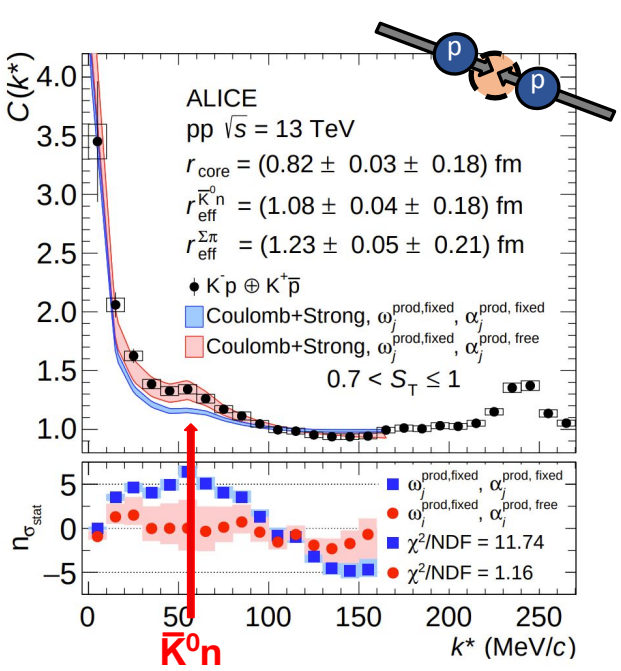

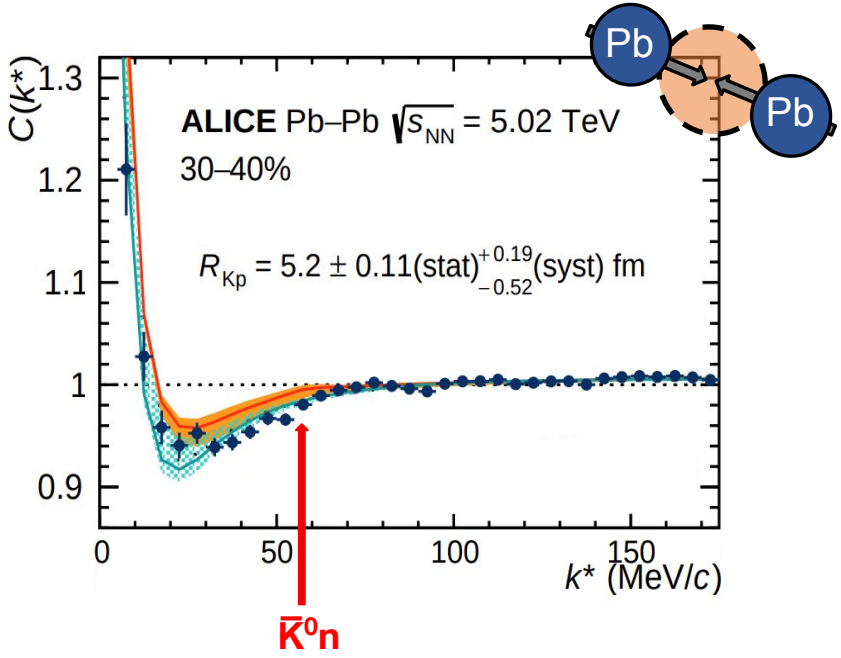

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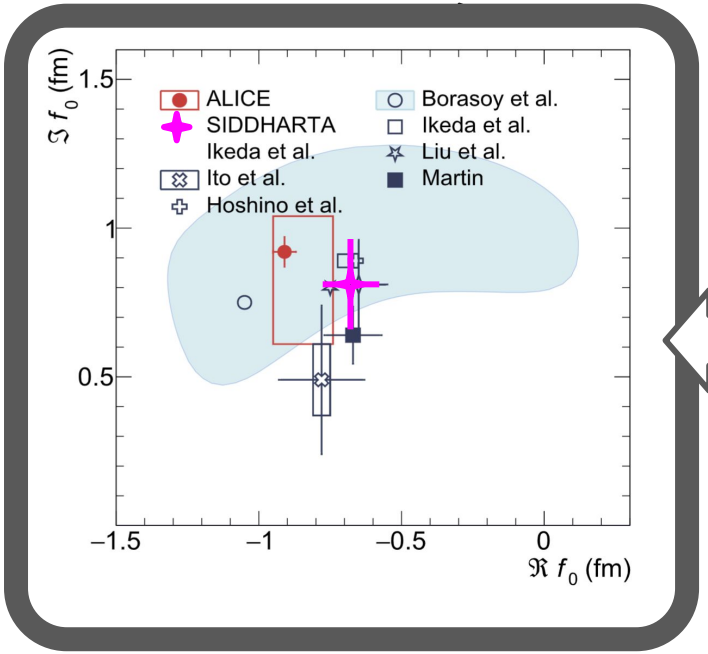
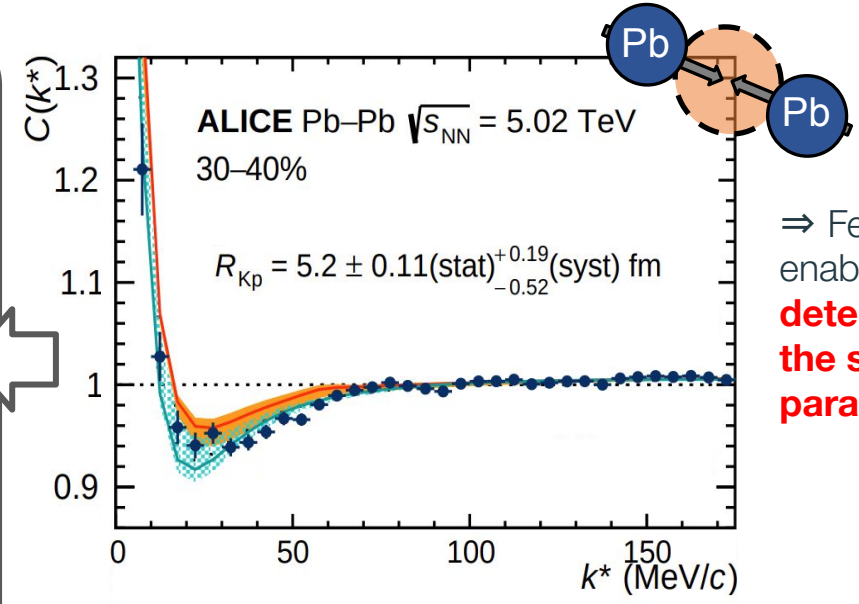




⇒ Femtoscopy data enables the **determination of the scattering parameters**

Accessing the Ξ^-K^+ system with femtoscopy

Most precise data at low momenta on the interaction between Ξ and kaons

→ Important constraints for **I=1 channel** of S=-1 meson-baryon interaction

Modeled assuming Lednický-Lyuboshits wavefunction with Coulomb (S-wave only)

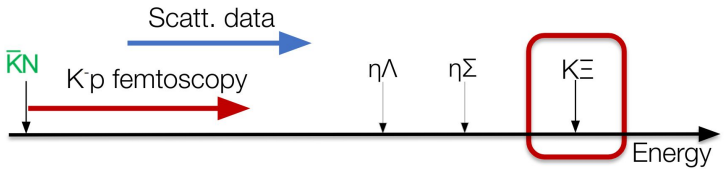
R. Lednický, Phys. Part. Nucl. 40: 307-352 (2009)

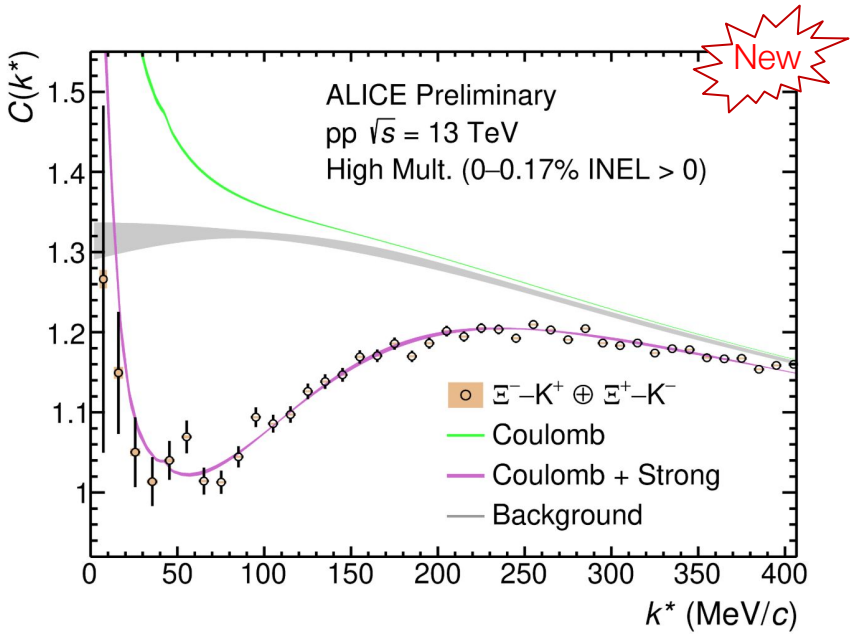
→ Coulomb + strong repulsive interaction assumption agrees with the data

Determination of scattering length from best fit

$$\Re f_0 = -0.61^{\pm 0.02(stat)}_{\pm 0.07(syst)}$$

$$\Im f_0 = \mathbf{0.41}^{\pm 0.04(stat)}_{\pm 0.11(syst)}$$





ALI-PREL-574336

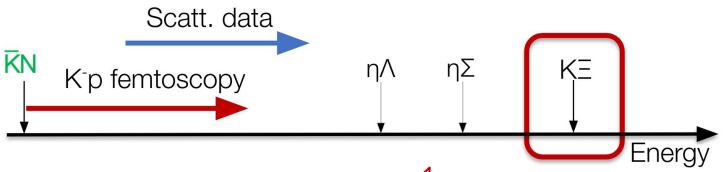
Constraining the Ξ^-K^+ scattering parameters

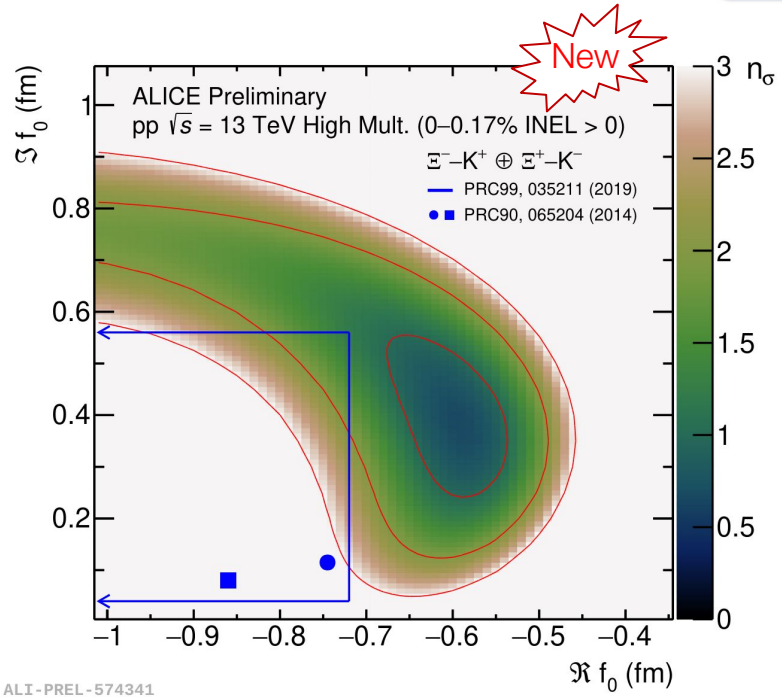
Comparison of data with modeling assuming different values of ($\Re f_0$, $\Im f_0$)

→ Delivered in terms of number of standard deviations (n_σ) in $k^* \in [0,250]$ MeV/c

Allowed values for f_0 from **state-of-the-art chiral calculations** at next-to-leading order and phenomenological potentials **constrained** to **available scattering data**

Higher precision constraints can be delivered with correlation data



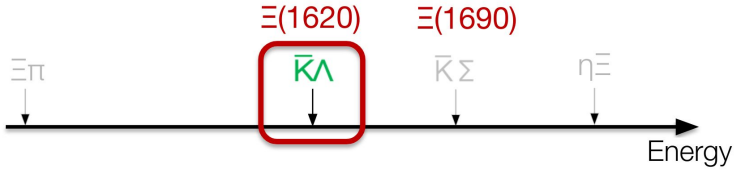


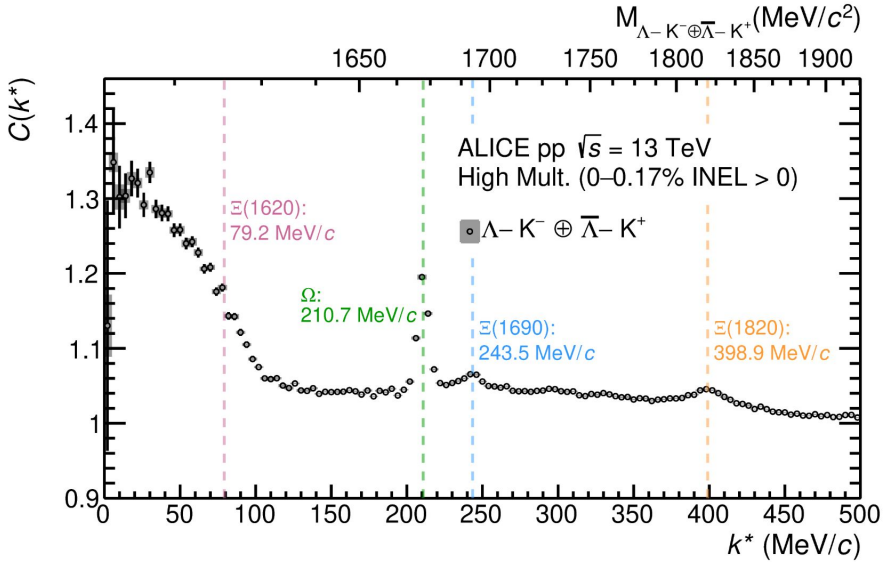
Accessing the S=-2 meson-baryon interaction

Extending previous Pb–Pb femtoscopic measurements to pp collisions

Pb–Pb: ALICE Coll. Phys. Rev. C 103 (2021)
pp: ALICE Coll. Phys. Lett. B 845 (2023) 138145

Several structures present in the measured correlation





ALI-PUB-562688

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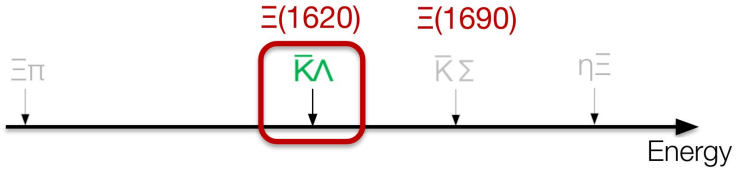
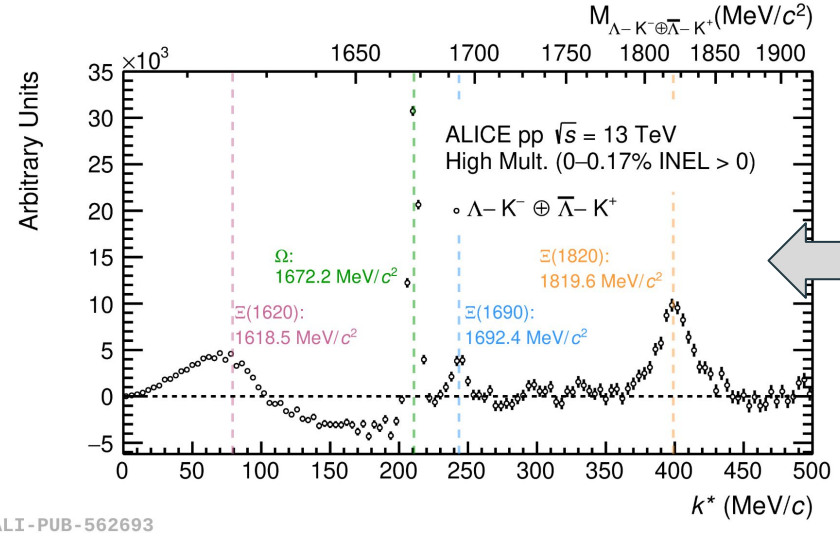
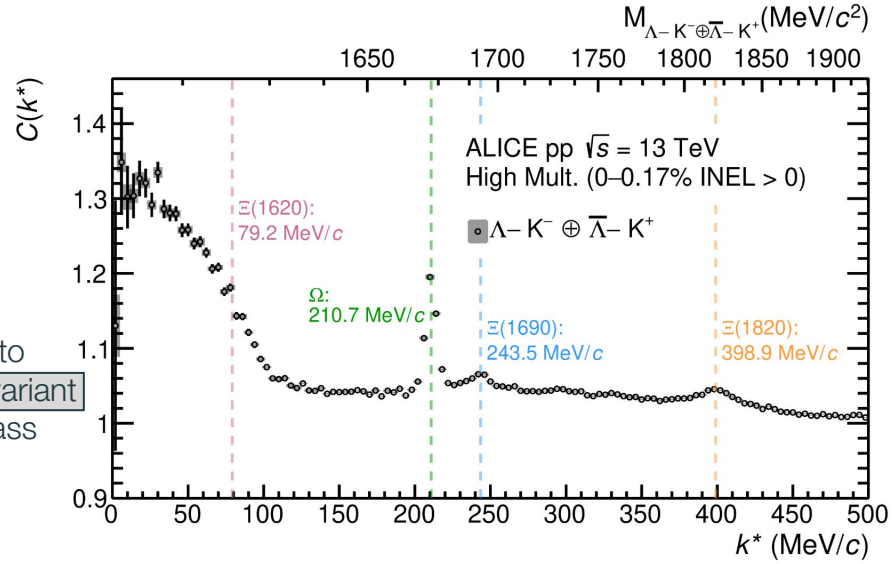


Several structures present in the measured correlation

⇒ **First experimental evidence of Ξ(1620)⟶ΛK⁻**



k^* to invariant mass



ALI-PUB-562693

ALI-PUB-562688

$K^-\Lambda$ correlations and the S=-2 meson-baryon sector

Most precise data for ΛK^- down to threshold

ALICE Coll. Phys. Lett. B 845 (2023) 138145

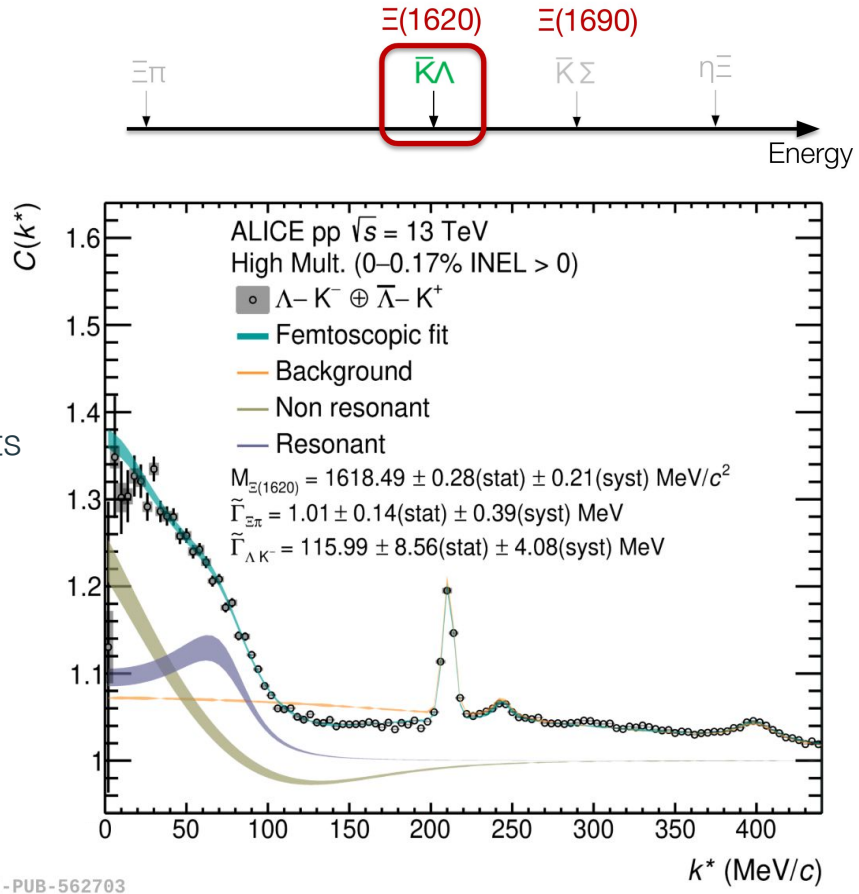
Model well reproduces the data in the whole k^* region
→ Interplay between resonant (Flatté-like) and non-resonant interaction

⇒ Ξ(1620) and Ξ(1690) properties

- Overall compatible with previous Belle and LHCb results
- Indication of a large coupling of Ξ(1620) to ΛK^-

Possibility to employ these data to **constrain effective chiral potentials** to explore this multi-strange sector

V. Mantovani Sarti et al. arXiv: 2309.08756



ALI-PUB-562703

The $\Xi^- \pi^+$ correlation in pp collisions

Most precise data for $\Xi^-\pi^+$ down to threshold

Several states visible in the measured correlation

- $\Xi(1530)^0 \rightarrow \Xi^-\pi^+$ (B.R. 100%)
- Ξ(1620) and Ξ(1690) as observed by Belle

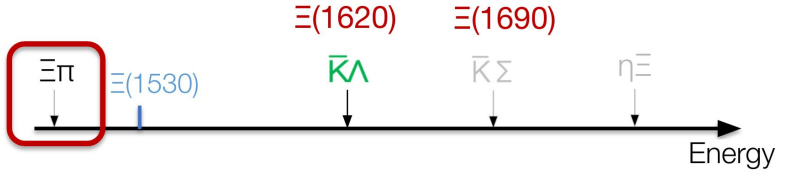
Same modeling as in Ξ^-K^+

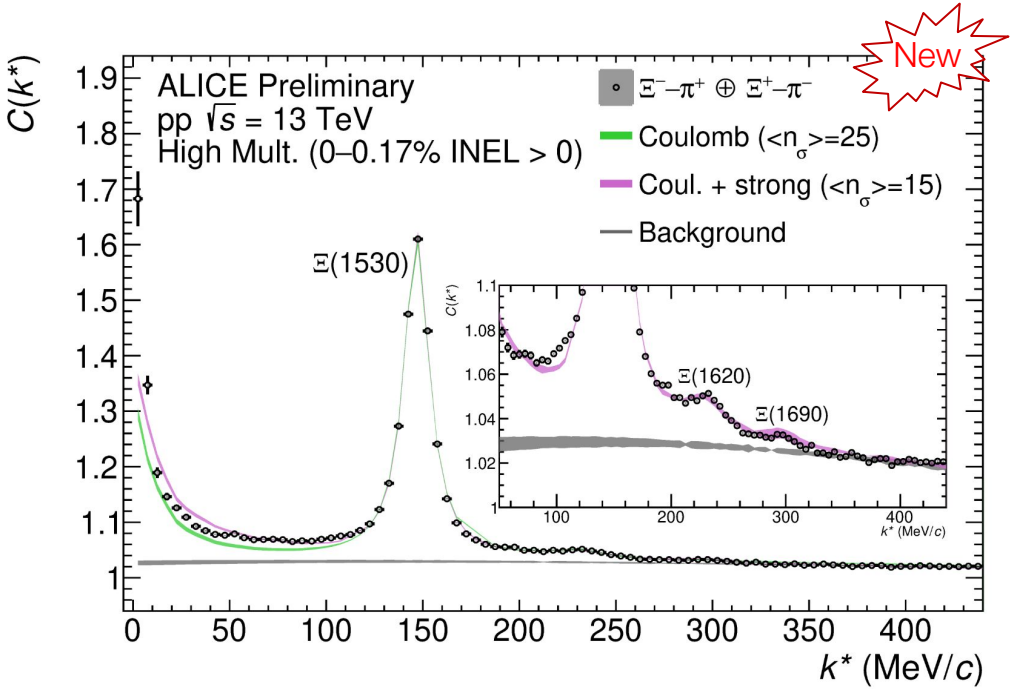
R. Lednický, Phys. Part. Nucl. 40: 307-352 (2009)

- Evidence of strong attractive interaction

Ξ(1620) and Ξ(1690) modeled with a Breit-Wigner distribution

- Mass and widths compatible with previous spectroscopic measurements





Scattering parameters for the $\Xi^-\pi^+$ interaction

Rather shallow attractive interaction

$$\Re f_0 = 0.089^{\pm 0.007(stat)}_{\pm 0.009(syst)}$$

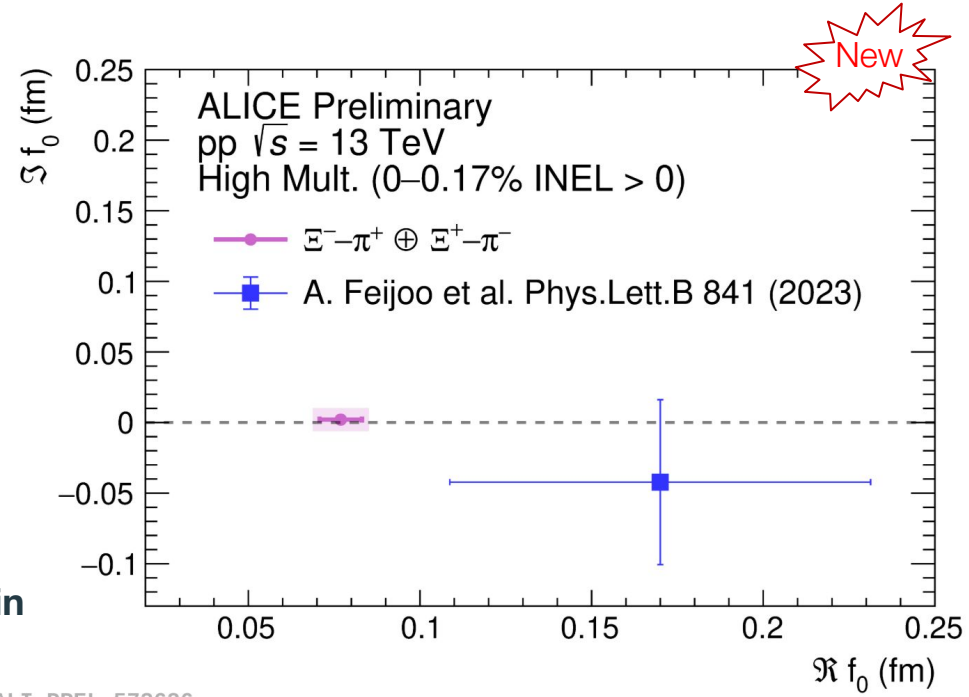
$$\Im f_0 = \mathbf{0.007}^{\pm \mathbf{0.003}(stat)}_{\pm \mathbf{0.005}(syst)}$$

Available predictions from NLO chiral potentials constrained to S=-1 data

A. Feijoo et al. Phys. Lett. B 841 (2023), 137927, Phys. Lett. B 853 (2024) 138660

- Affected by large uncertainties
- Overall compatible with our results

Novel high-precision data available to constrain this multi-strange meson-baryon sector!



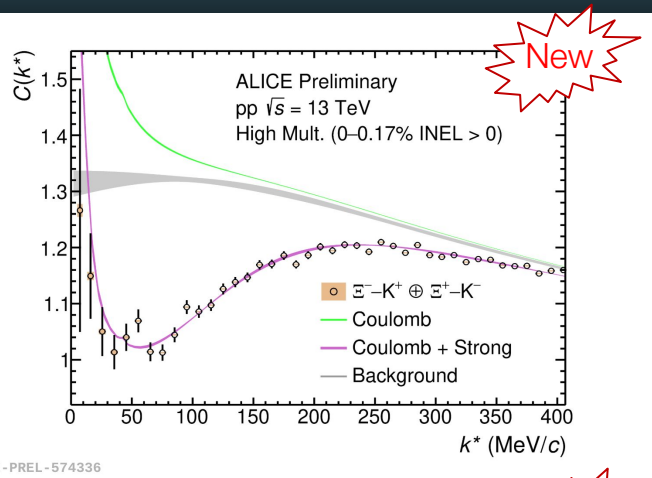
Conclusions and outlook

Most precise data on ΞK and Ξπ at low momenta available

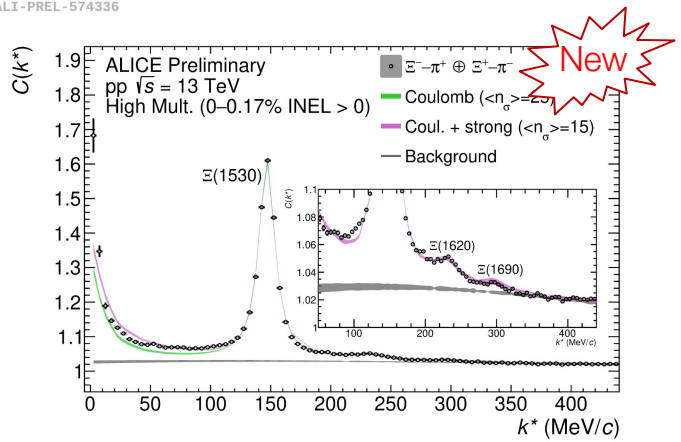
- Novel high-precision constraints on S=-1 and S=-2 baryon interactions available with correlation data
- Input for low-energy effective chiral lagrangians

Femtoscopy is a **complementary tool** to provide precision data on hadron-hadron interactions to **study exotic states**

⇒ Possibility to explore other relevant systems in these sectors with **ongoing Run 3!**



ALI-PREL-574336



ALI-PREL-573869