Insights into molecular states and novel constraints for strange meson-baryon interactions with correlations at LHC

V. Mantovani Sarti (TUM)

HHIQCD2024 – 21-25 October YITP, Kyoto

YITP long-term and Nishinomiya-Yukawa memorial workshop
Hadrons and Hadron Interactions in QCD 2024 (HHIQCD 2024)
-- Experiments, Effective theories, and Lattice --
14th Oct. - 15th Nov. 2024
Yukawa Institute for Theoretical Physics, Kyoto University, Japan

TUM
ORIGINS Excellence Cluster
SFB 1258 Neutrinos Dark Matter Messengers
DFG Deutsche Forschungsgemeinschaft
MA 8660/1-1

Thanks Akira.

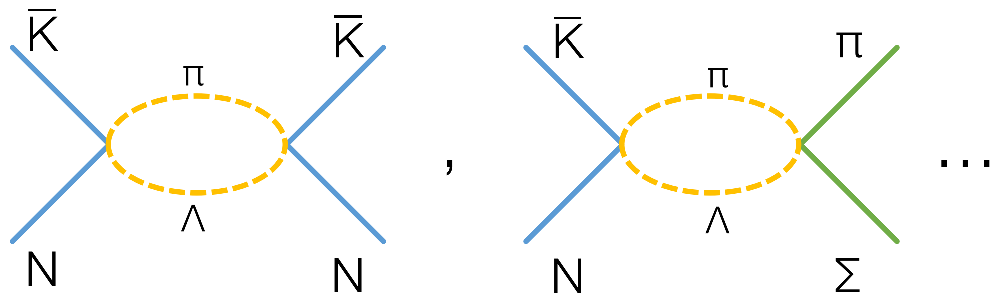
International Molecule-type Workshop "Hadron Interactions and Polarization from Lattice, Quark Model and High-Energy Collisions”
YITP Kyoto 2019

From Kyoto…to Kyoto.
In memory of Akira.

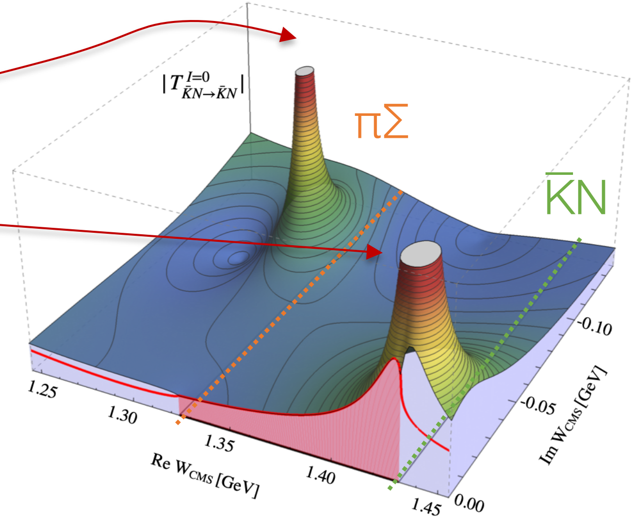
Multi-strange meson-baryon systems and exotic states

- Interactions between **mesons and baryons involving strangeness**
  - 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. PRL 114 (2015) 13
    U. G. Meißner Symmetry 12 (2020) 6, 981



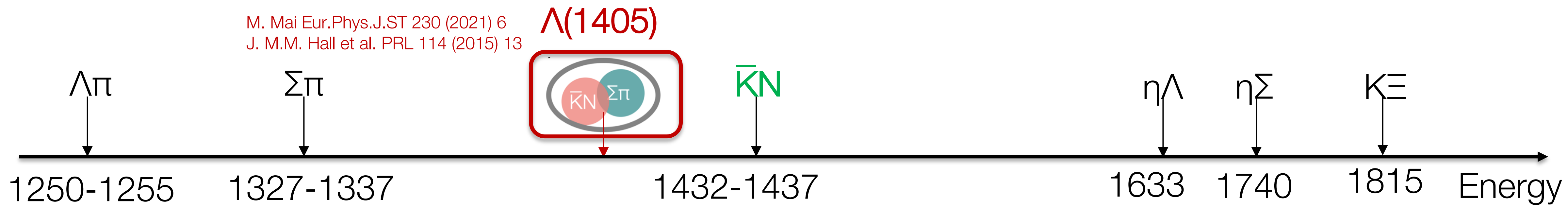
M. Mai EPJST 230 (2021) 6

Today we will focus on strange molecular states!

Strange molecular states and where to find them

Y. Kamiya Mo. 21 Oct

Interactions with rich coupled-channel dynamics → Typically observed close to channel thresholds



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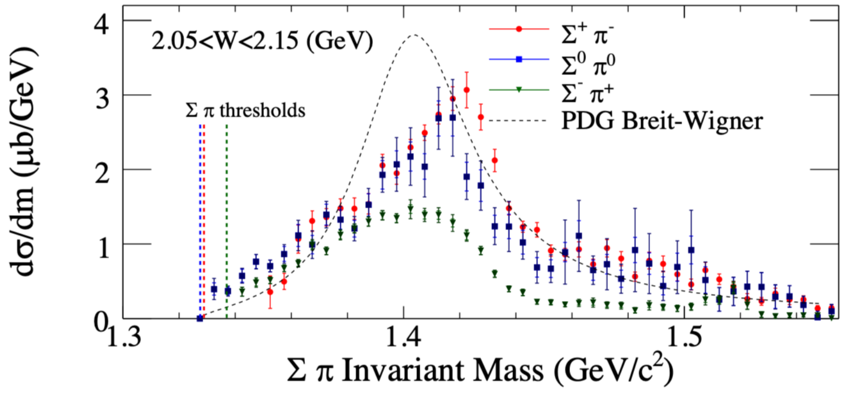
Photoproduction experiments

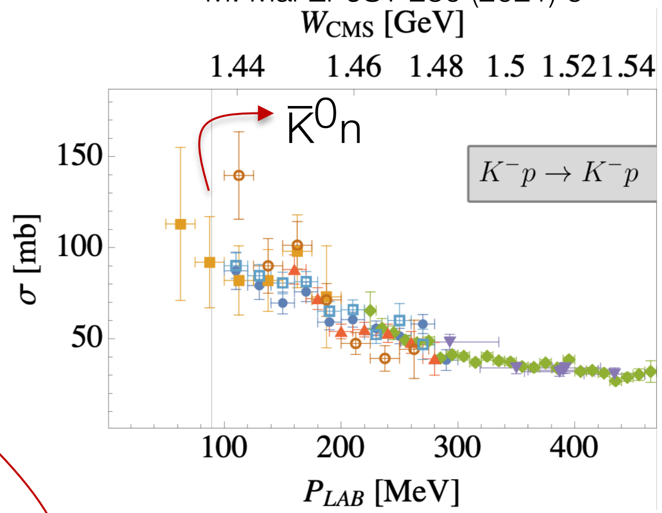
CLAS Coll. PRC 88 (2013)

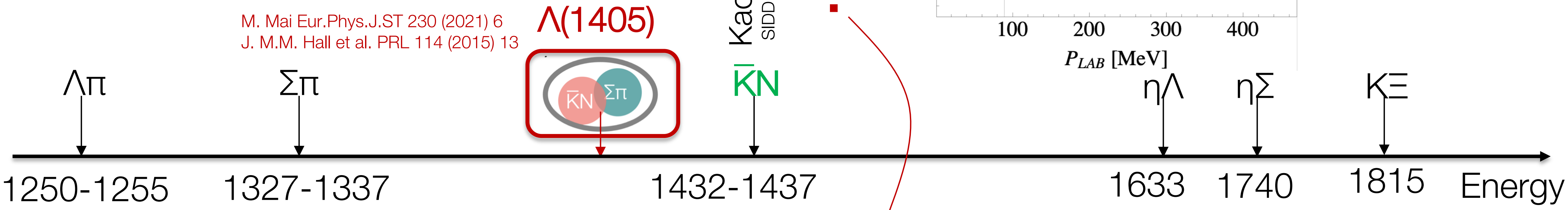


M. Mai Eur.Phys.J.ST 230 (2021) 6
J. M.M. Hall et al. PRL 114 (2015) 13

Scattering experiments

M. Mai EPJST 230 (2021) 6





Need for high-precision data close to K̄N threshold!!

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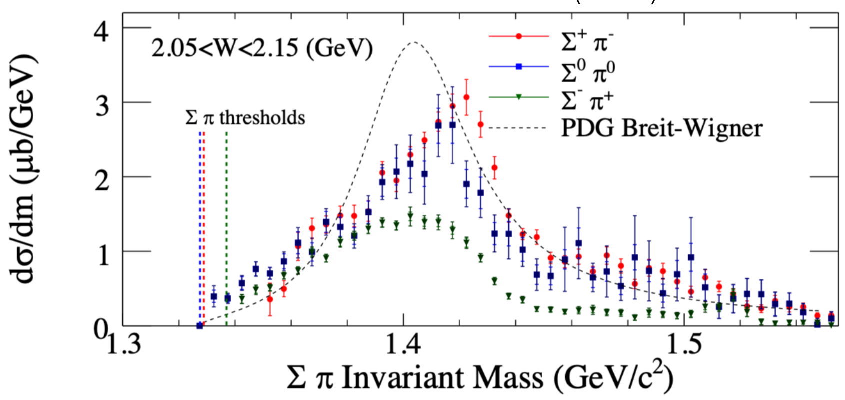
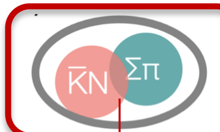


M. Mai Eur.Phys.J.ST 230 (2021) 6
J. M.M. Hall et al. PRL 114 (2015) 13

Λ(1405)

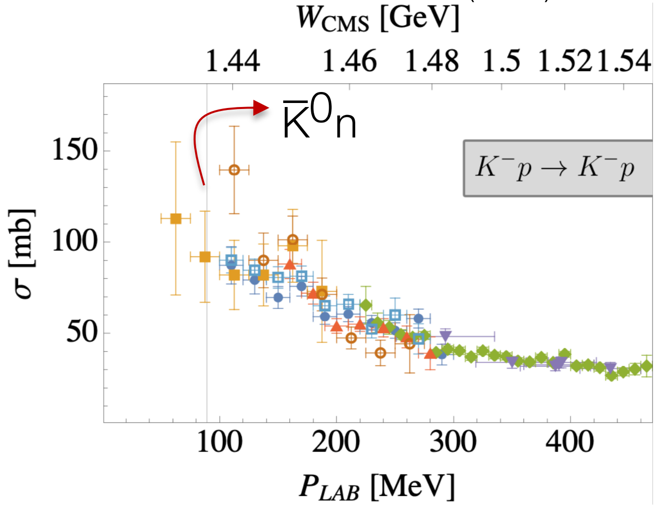


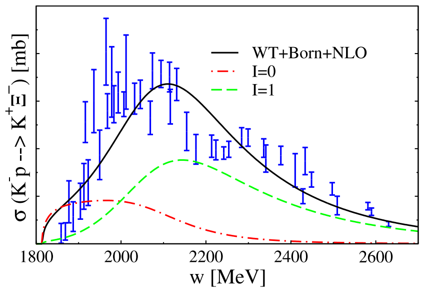
Kaonic hydrogen
SIDDHARTA PLB 704 (2011)

?

Scattering experiments

M. Mai EPJST 230 (2021) 6





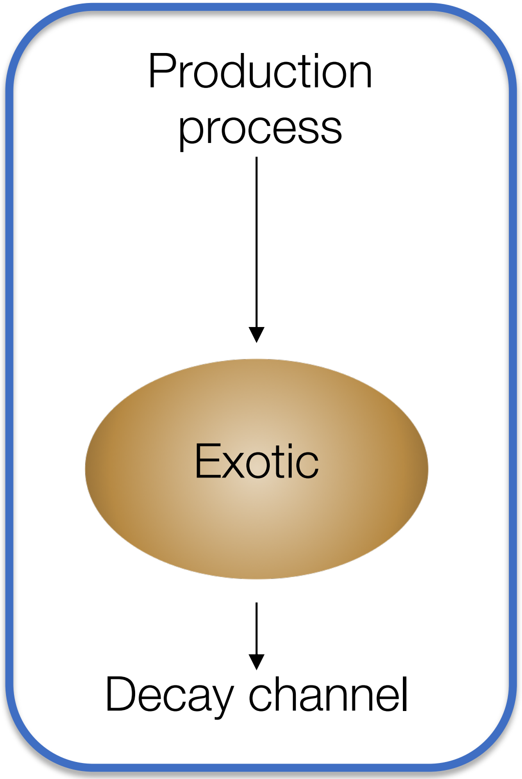
Data: K-p → X and NLO UχPT calc.
A. Feijoo, et al. PRC 99 (2019) 3

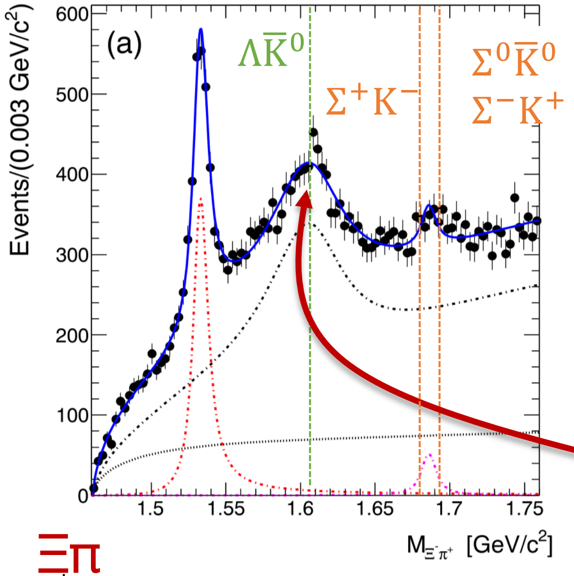
Λπ — 1250-1255
Σπ — 1327-1337
K̄N — 1432-1437
ηΛ — 1633
ηΣ — 1740
KΞ — 1815
Energy

Need for experimental constraints on as many channels as possible!

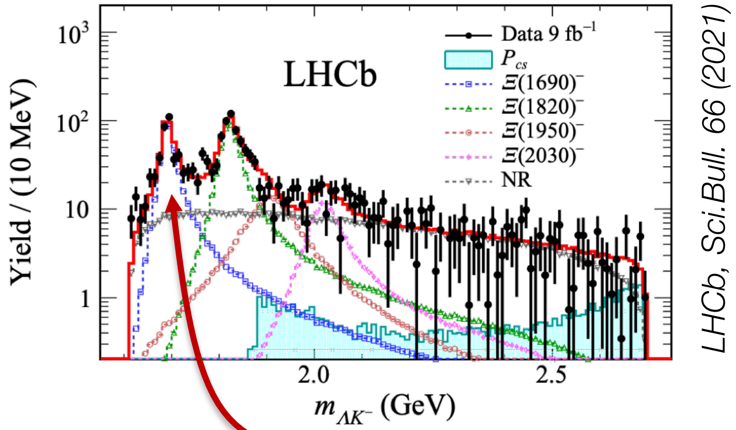
More strange molecular states and where to find them

- Scattering experiments challenging with increasing strangeness
  - $\Xi(1620)$ lying across the $\bar{K}\Lambda$ threshold as molecular candidate, poorly known
- Intensive searches via spectroscopy measurements with different production mechanism





Belle, PRL 122 (2019)



LHCb, Sci.Bull. 66 (2021)

?

?

$\Xi(1620)$

$\Xi(1690)$

$\Xi\pi$ $\bar{K}\Lambda$? $\bar{K}\Sigma$ $\eta\Xi$

1449-1461   1609-1613   1683-1691   1870   Energy

Combine different production mechanisms/decay channels to reveal the state's nature

valentina.mantovani-sarti@tum.de

More strange molecular states and where to find them

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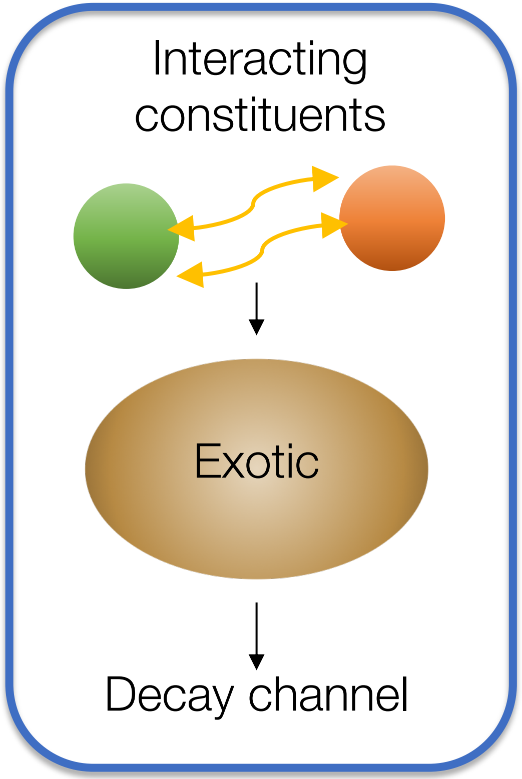
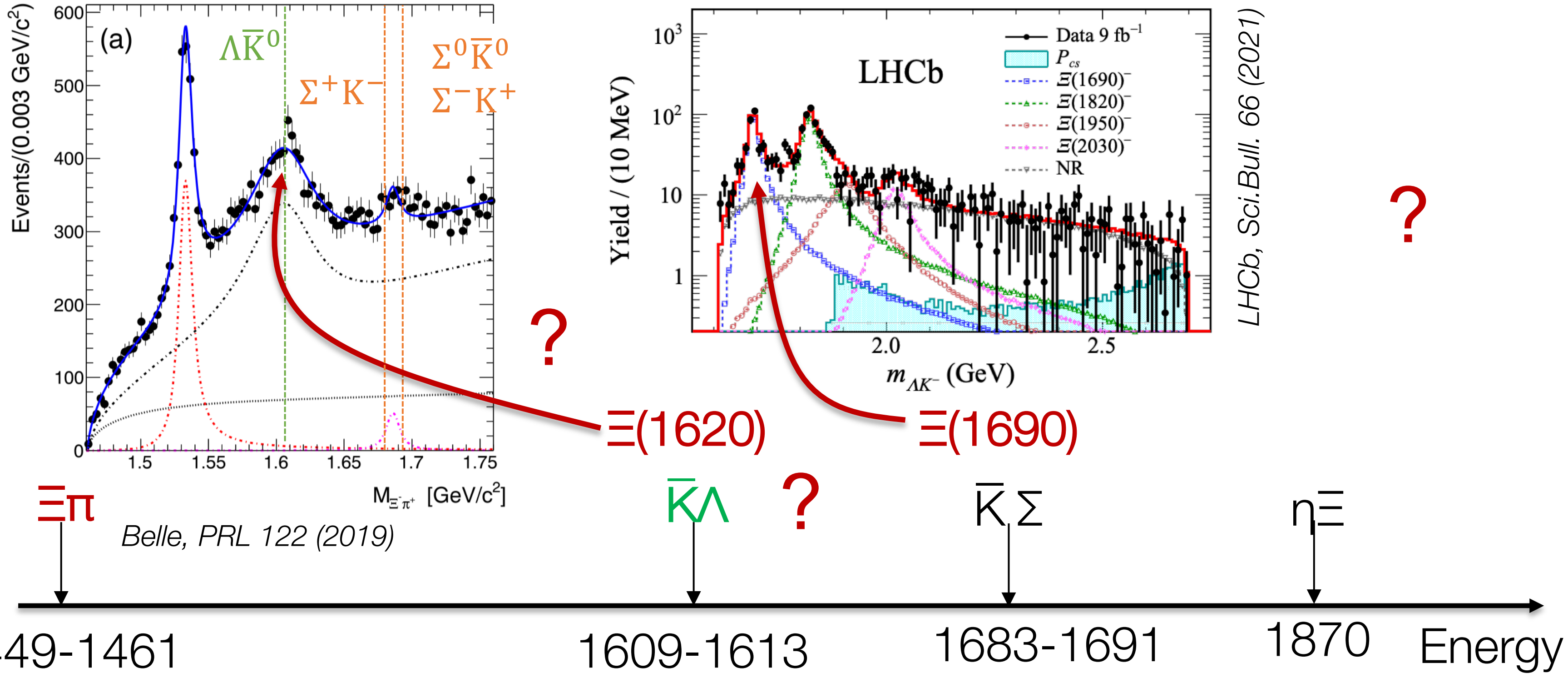
- Intensive searches via **spectroscopy measurements** with **different production mechanism**





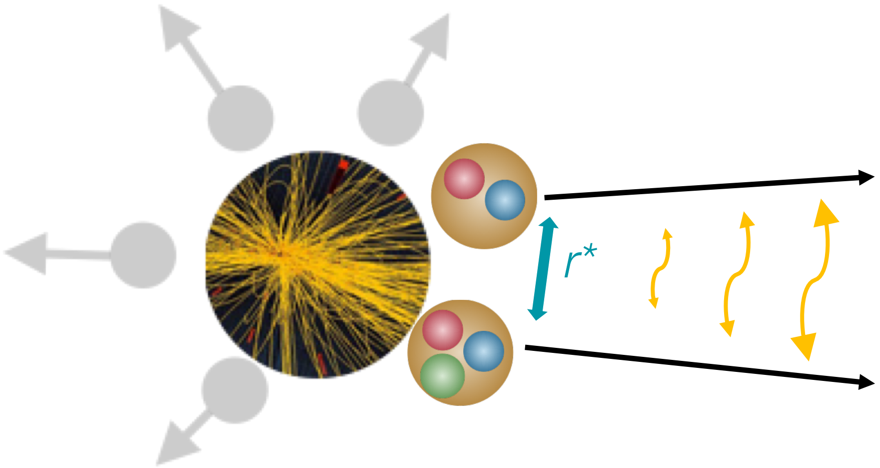
Accessing the interaction between the constituents

Investigating exotic states with correlations

- Accessing interaction between the constituents with correlation functions measured in pp collisions

  M.Lisa, S. Pratt et al, ARNPS. 55 (2005), 357-402, L. Fabbietti, VMS and O. Vazquez Doce ARNPS 71 (2021), 377-402

$$C(k^*) = \mathcal{N}(k^*)\frac{N_{\text{same}}(k^*)}{N_{\text{mixed}}(k^*)} = \int S(\vec{r}^*)\ \left|\psi(\vec{k}^*,\vec{r}^*)\right|^2 d^3\vec{r}^*$$



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Koonin-Pratt equation

S. E. Koonin, Phys. Lett. B 70, 43 (1977)

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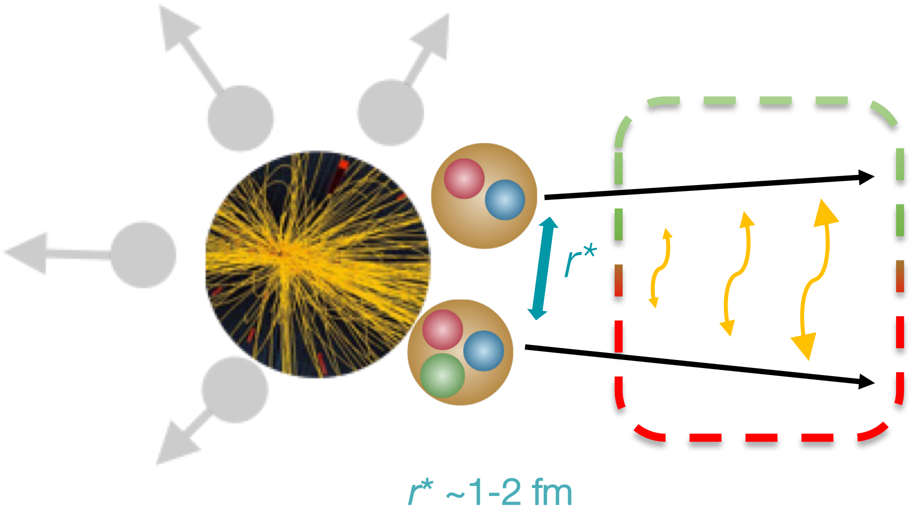
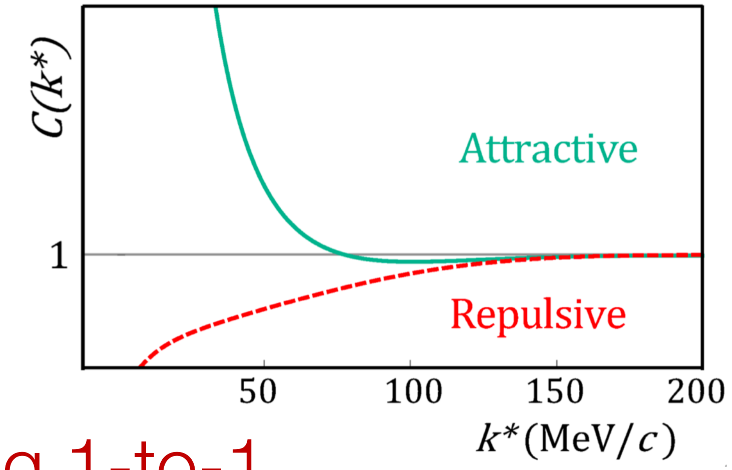
Interaction



ALICE Coll. Nature 588 (2020) 232-238



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

Investigating exotic states with correlations

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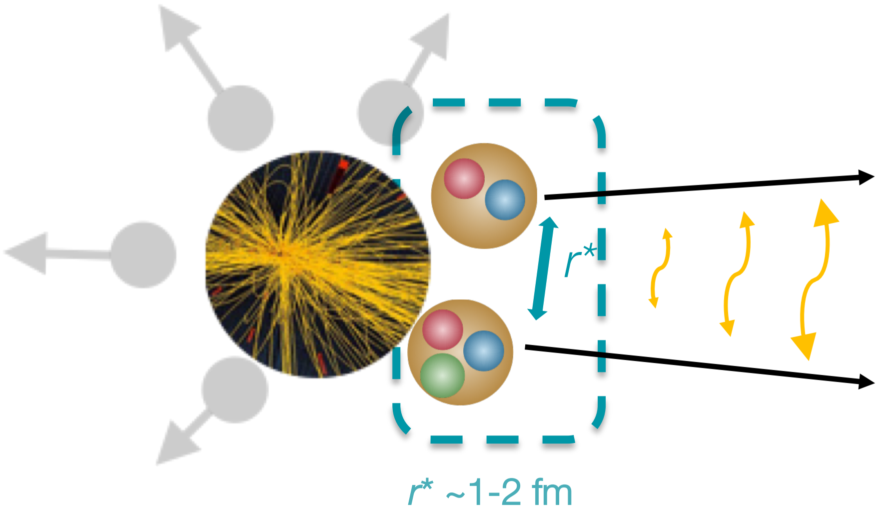
Emitting source



- It tells us on average at which relative r^*_{AB} distances the particles A and B are produced
- Acting as a probability density function in r*

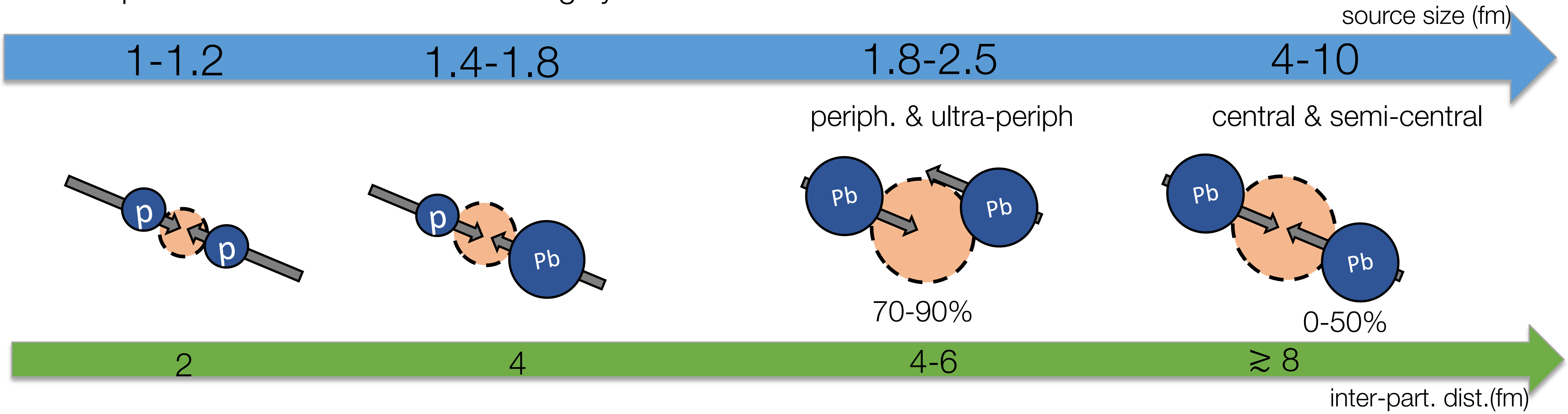
  → How much $\left|\psi(\vec{k}^*,\vec{r}^{\,*})\right|^2$ do we sample?
- It depends on the collision system

What ranges of inter-particle distances are we probing at LHC?

Small and large colliding systems at LHC: from pp to Pb-Pb

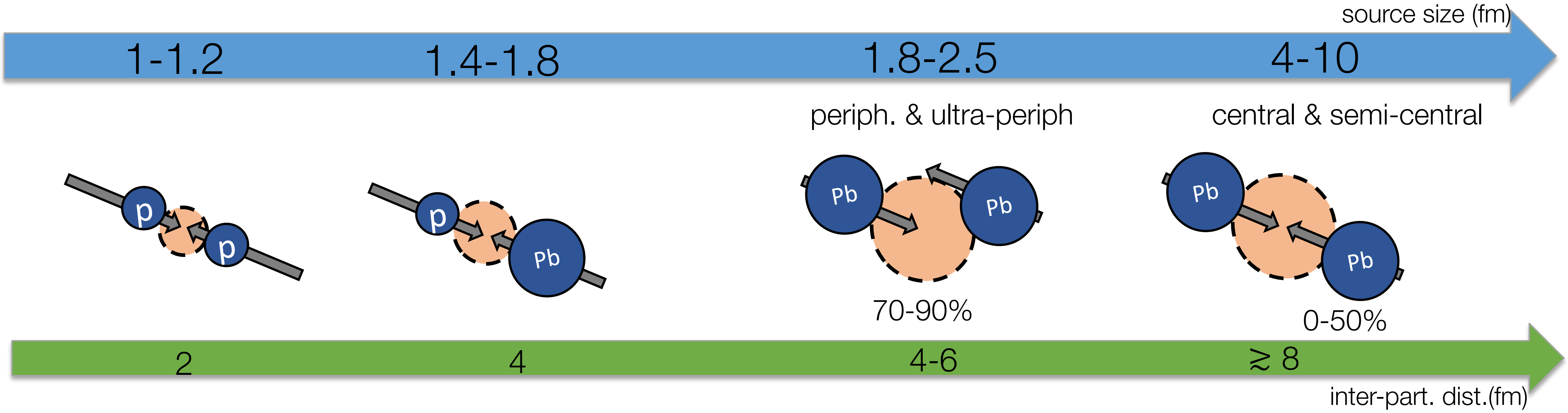
By changing the colliding system

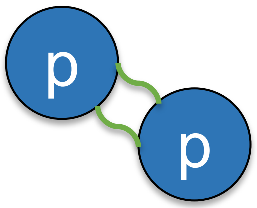
- Probe source sizes ranging from 1 fm up to 10 fm
- Interparticle distances from 2 to roughly 20 fm

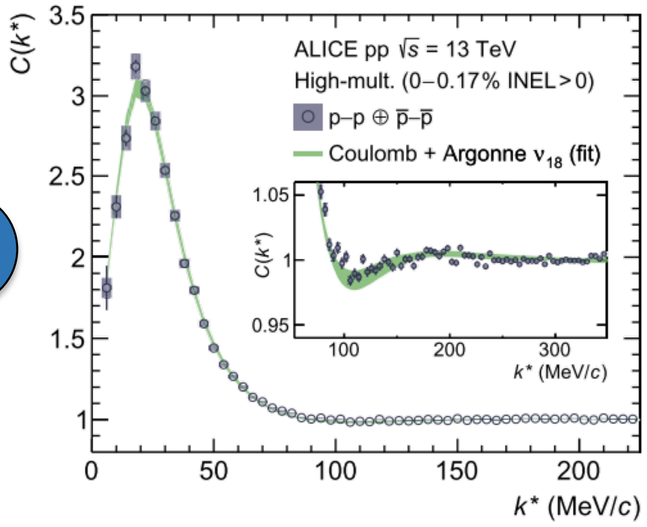


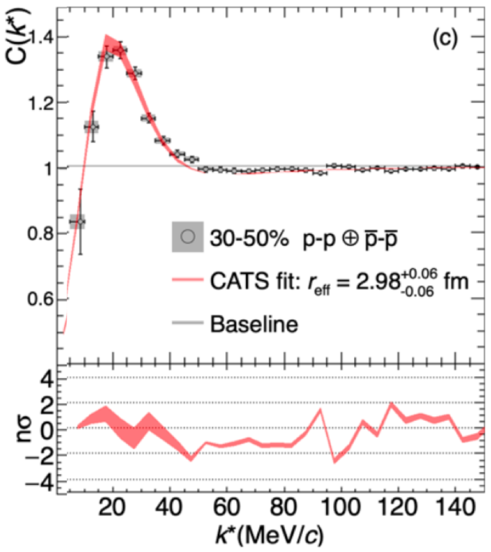
How does the signal in the correlation function changes with the source size?

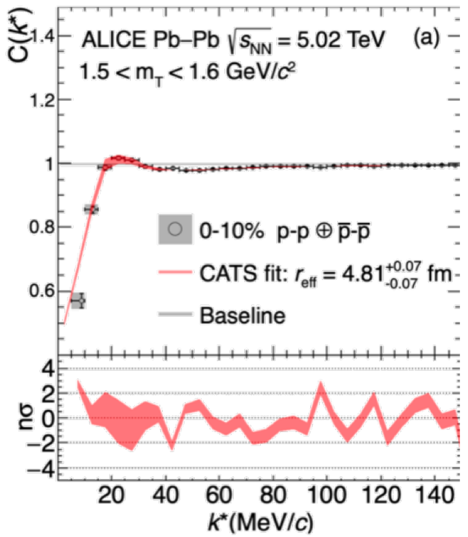
Small and large colliding systems at LHC: from pp to Pb-Pb





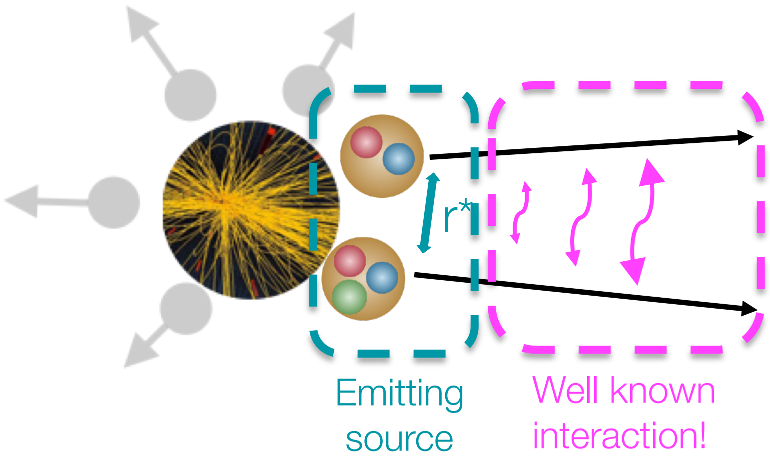






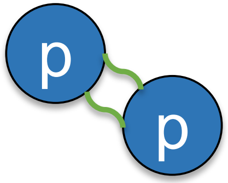
The (common) emitting source in small colliding systems

ALICE Coll. PLB 811 (2020) 135849



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

1. Fixing the source → Very well known interaction from a **pair we can easily produce at LHC**!



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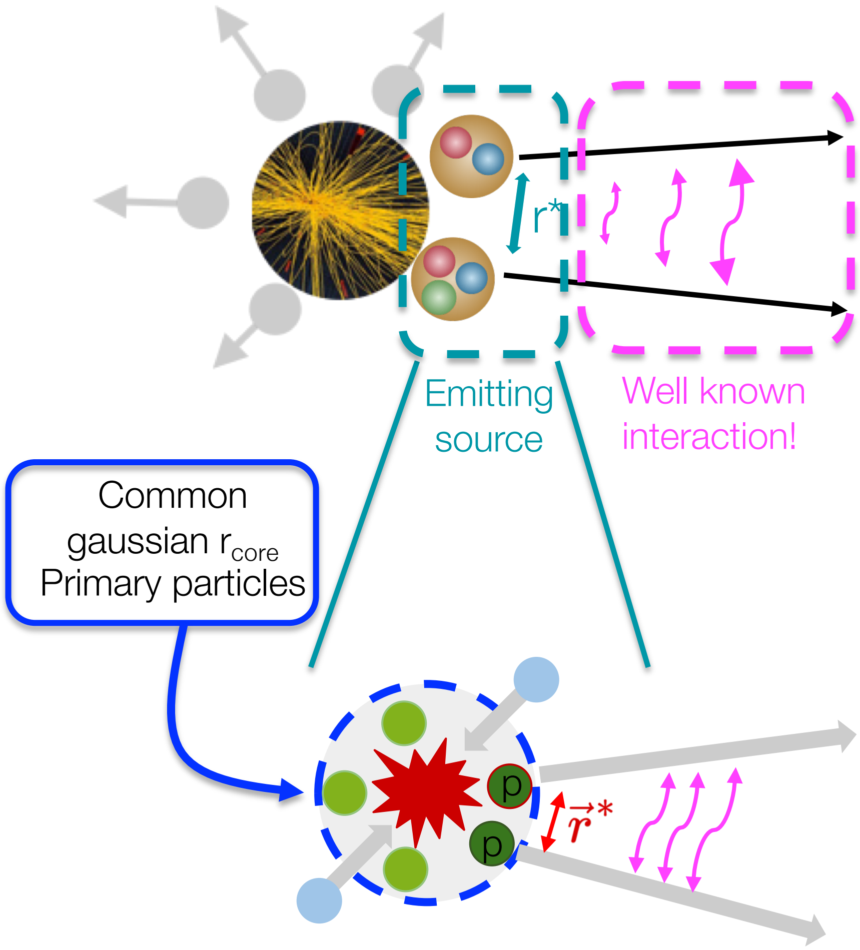

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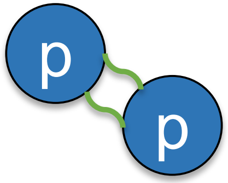

2. Modeling the source
   U. A. Wiedemann, U. W. Heinz, Phys.Rept. 319, 145-230 (1999)
   – Primary particles from common Gaussian core source
      • Observed scaling with the transverse pair mass m_{T}

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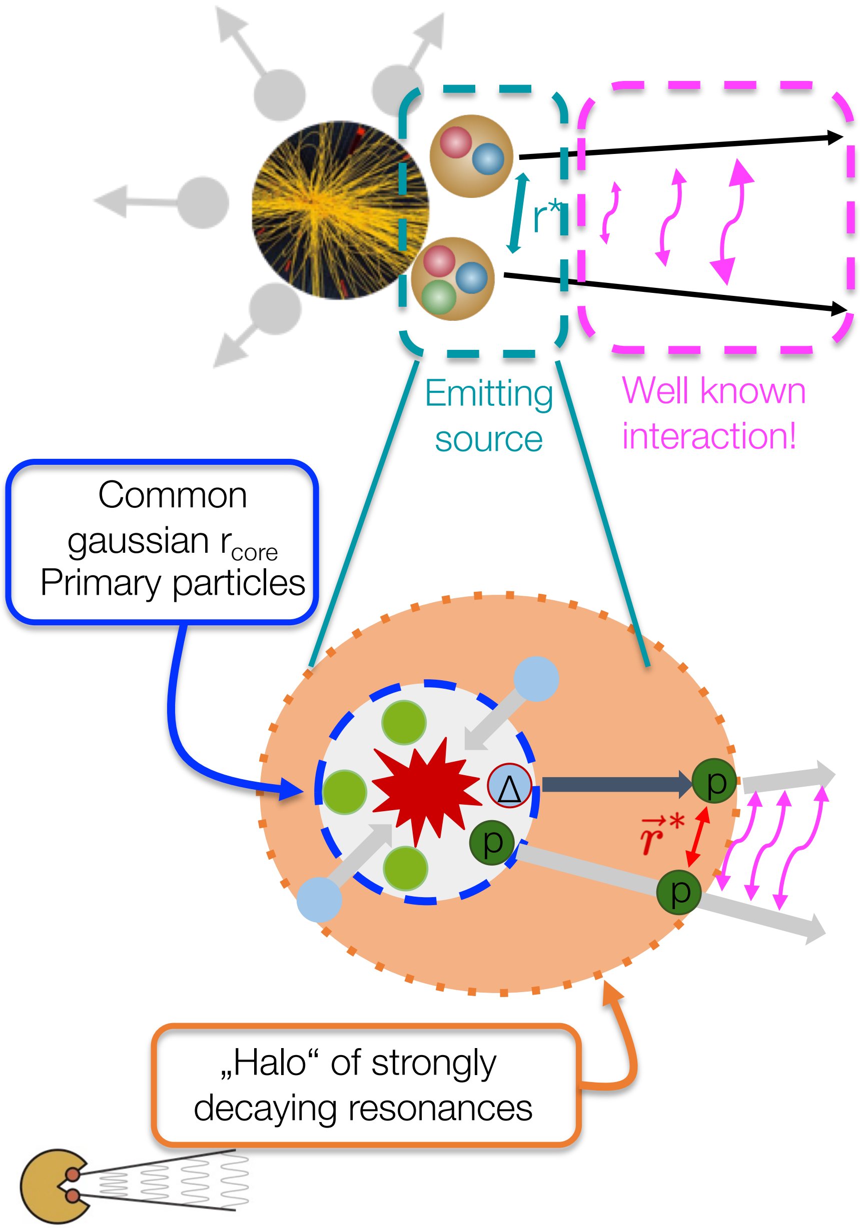

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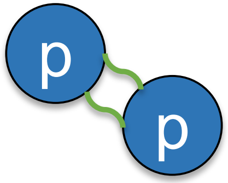

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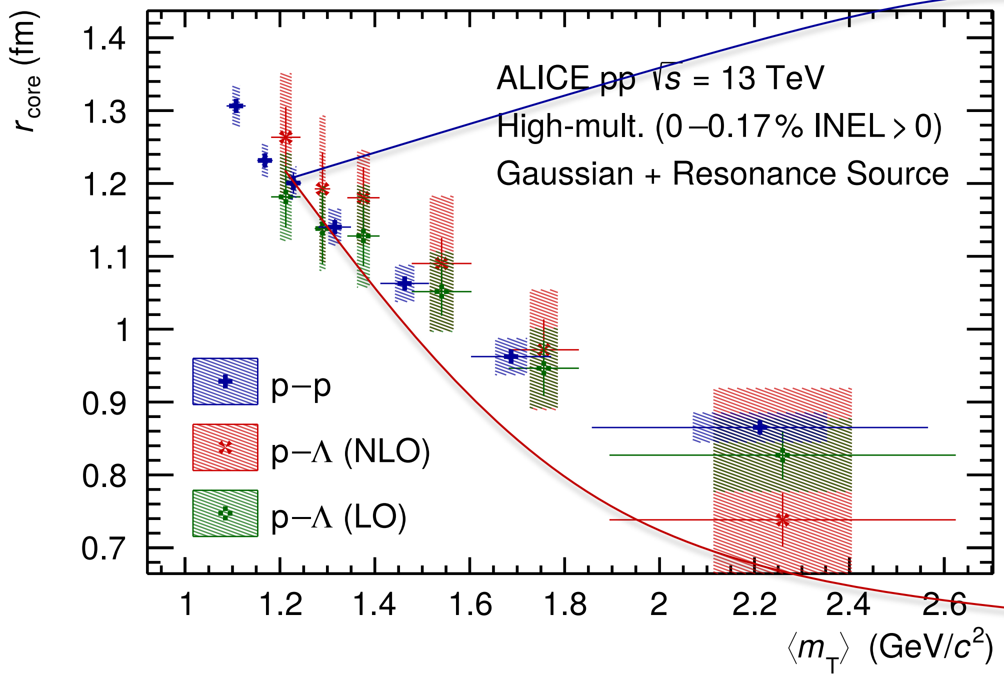
   - Primary particles from common Gaussian core source
     - Observed scaling with the transverse pair mass m_T
     - Depending only on the mass of the pair
   - Strongly decaying resonances with cτ~1-2 fm ($\Delta \rightarrow p\pi$)
     - Tail at large r^*, effect. enlarging the source
     - Depending on the particles in the pair

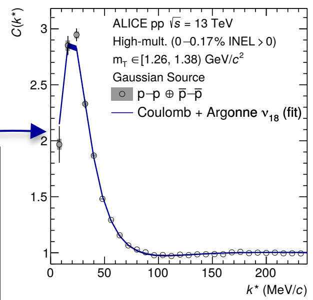
Let‘s test our source hypothesis on the data!

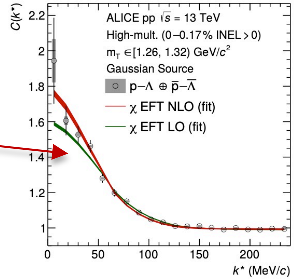
The (common) emitting source in small colliding systems

Baryon-baryon pairs

ALICE Coll. PLB 811 (2020) 135849



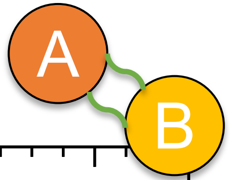


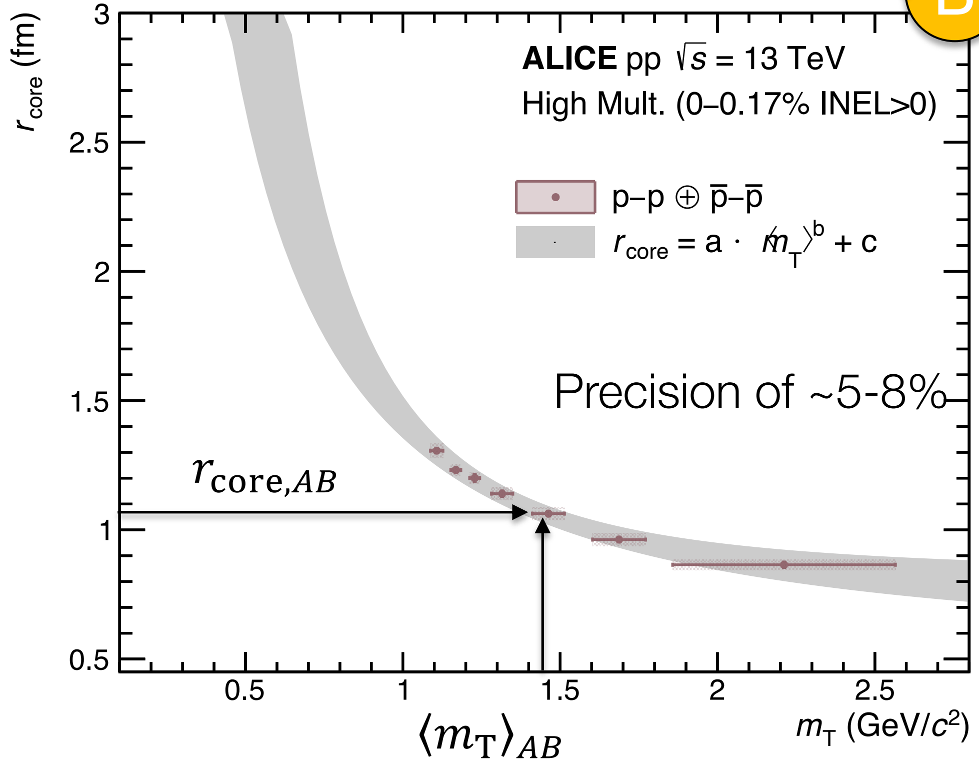


Universal scaling of core source size observed for <u>baryons</u>

Similar results obtained in Mihaylov, Gonzalez EPJC 83 (2023)

Recipe to fix the source



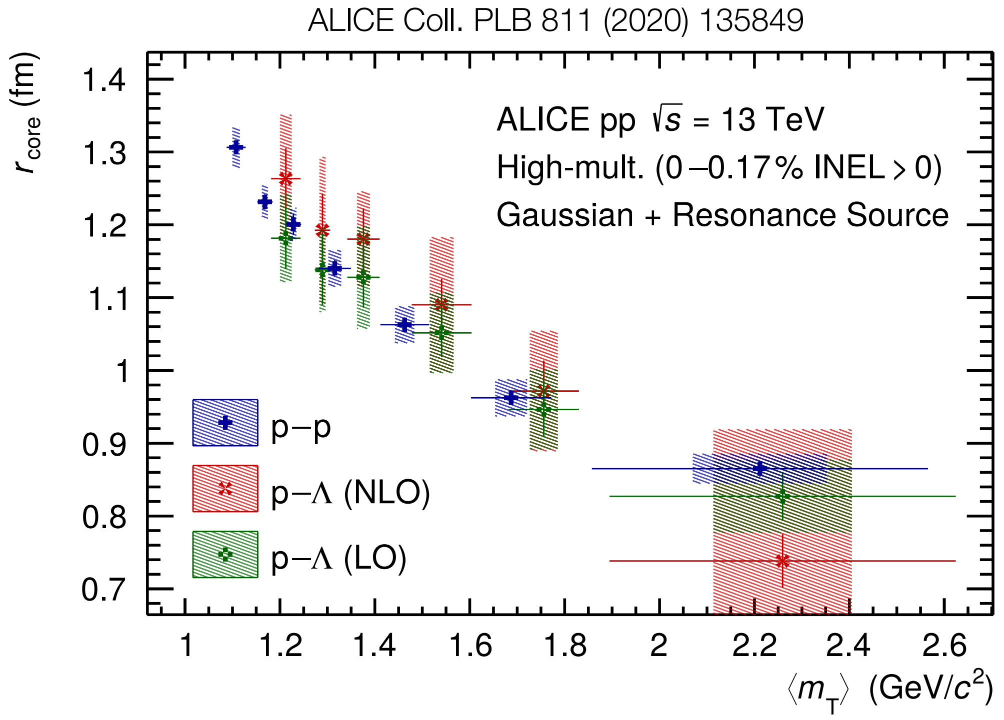


- Resonances yields and kinematics from thermal and transport models constrained to the dataset properties (e.g. multiplicity)

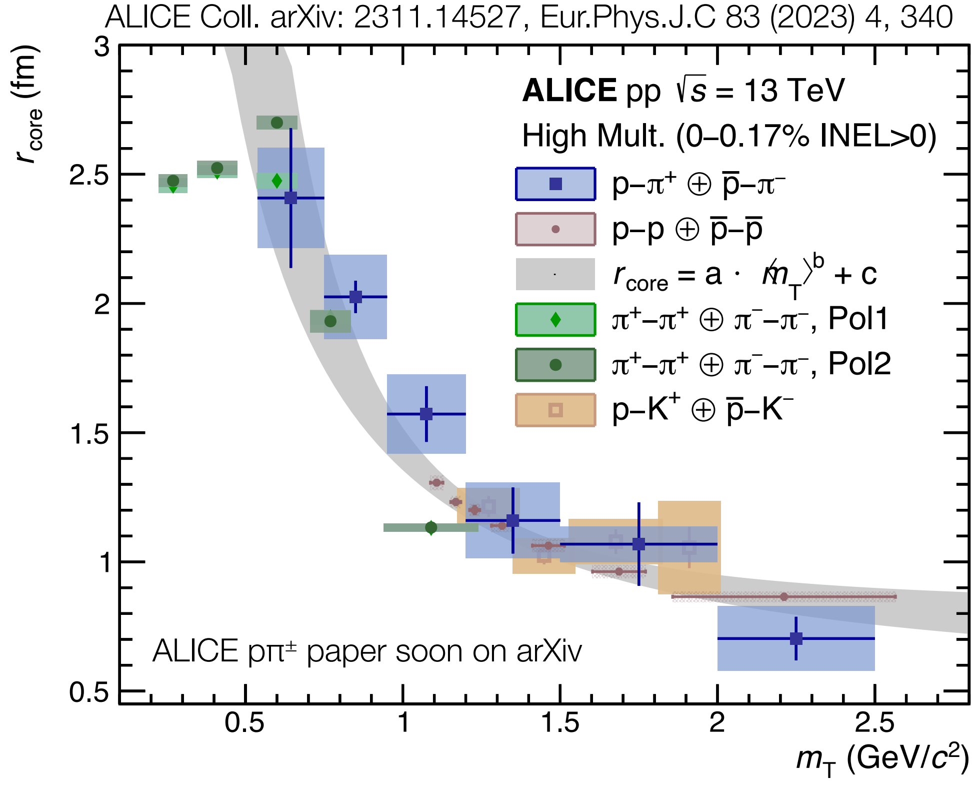
Interesting studies using a dynamical source on pϕ CF: Kuroki, Hirano arXiv:2410.01204

The (common) emitting source in small colliding systems

Baryon-baryon pairs



Meson-baryon and meson-meson pairs



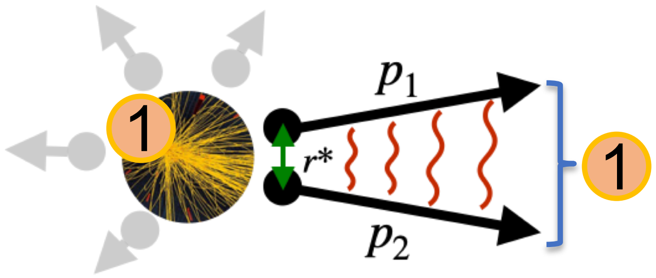
Observation of a common emitting source for hadrons in pp collisions

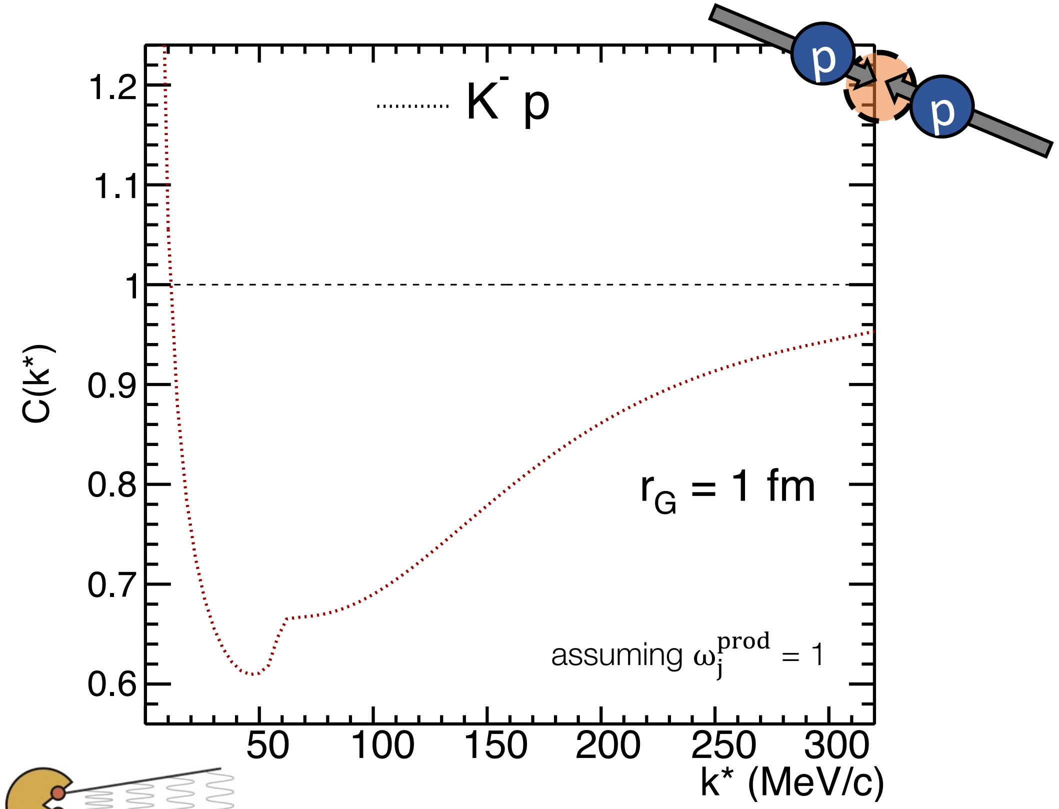
Similar approach tested on p-p correlations in Pb-Pb by ALICE will become available soon!!

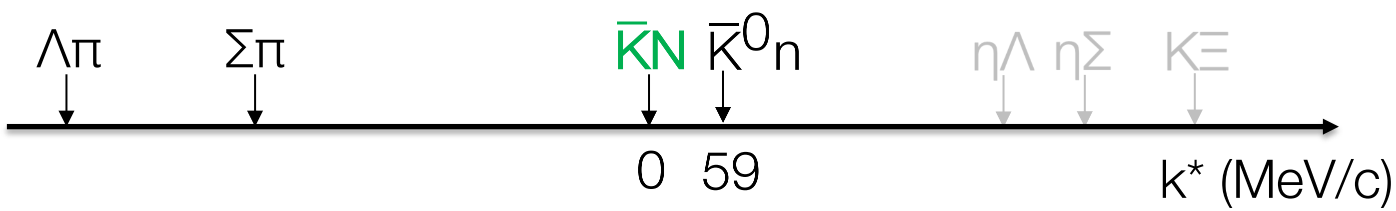
Coupled-channels dynamics in femtoscopy

$$C(k^*) = \int S_1(\vec{r}^*)\ \left|\psi_{1\to1}(\vec{k}^*, \vec{r}^*)\right|^2 d^3r^*$$

elastic
1 → 1



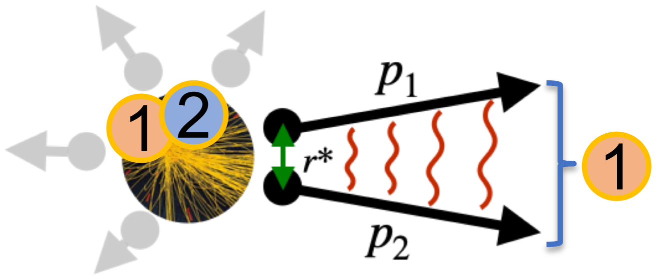


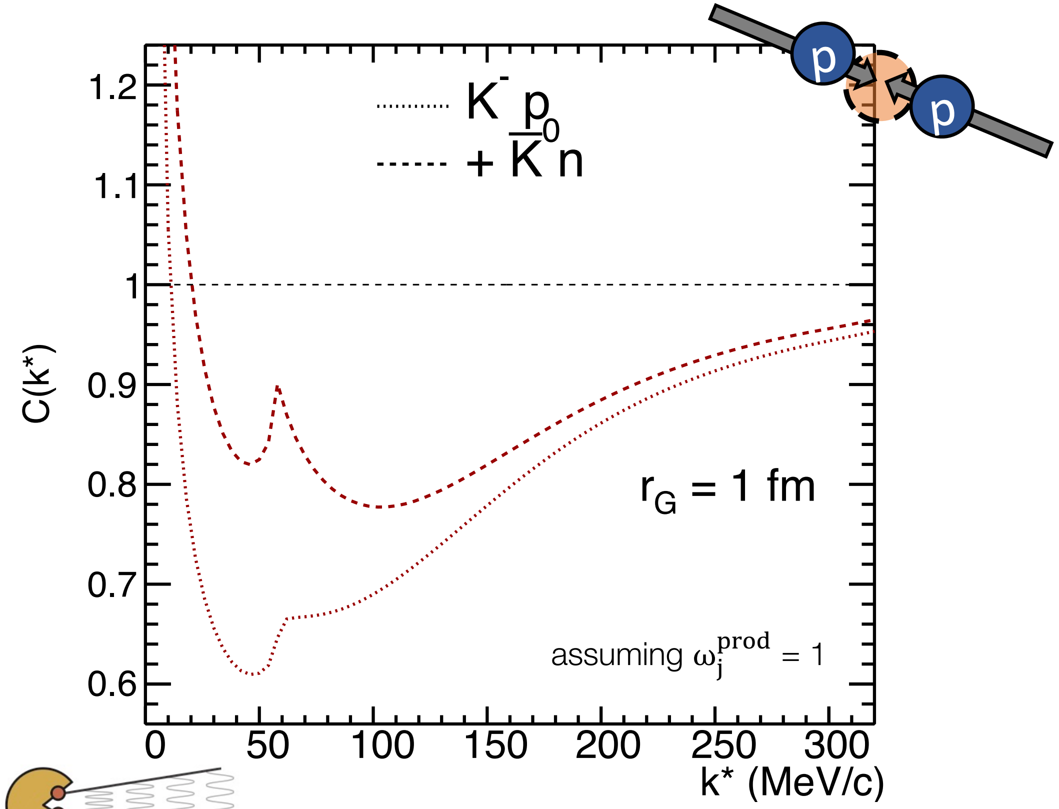


For more details: J. Haidenbauer NPA 981 (2019), Y. Kamiya et al. PRL 124 (2020)
L. Fabbietti, VMS, O. Vazquez Doce Ann.Rev.Nucl.Part.Sci. 71 (2021)

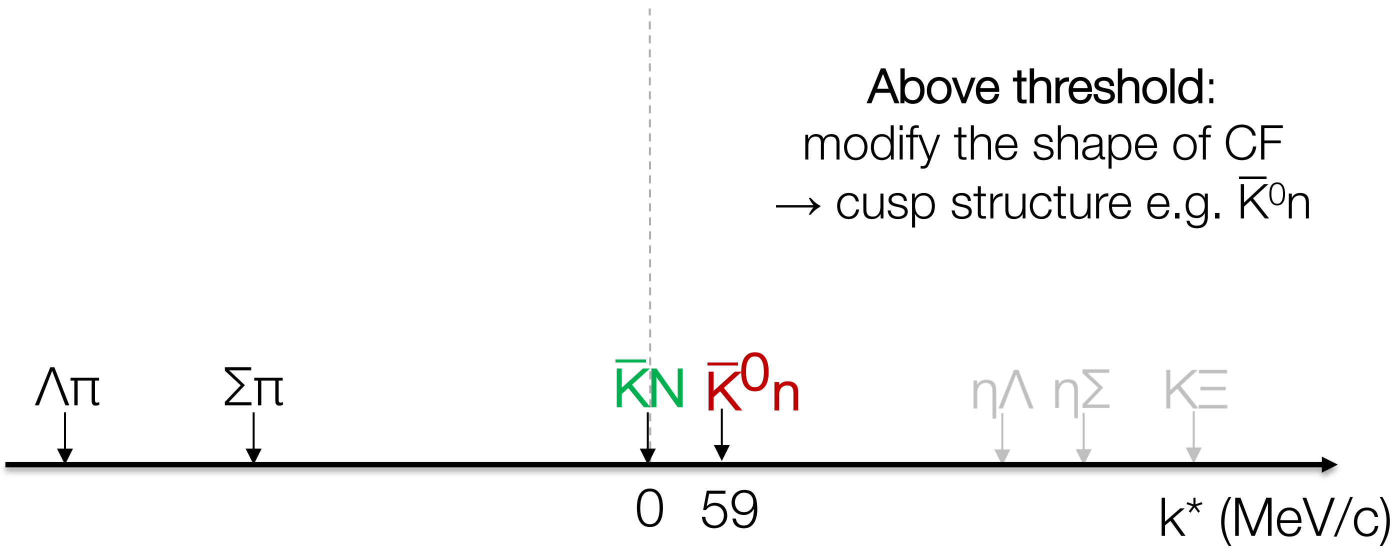
Coupled-channels dynamics in femtoscopy

$$C(k^*) = \underbrace{\int S_1(\vec{r}^*)\ \left|\psi_{1\to1}(\vec{k}^*,\vec{r}^*)\right|^2 d^3r^*}_{\text{elastic } 1\to1} + \underbrace{\sum_{j\neq1} \omega_j^{prod} \int S_j(\vec{r}^*)\ \left|\psi_{j\to1}(\vec{k}_j^*,\vec{r}^*)\right|^2 d^3r^*}_{\text{inelastic } 2,..\to1}$$





Above threshold:
modify the shape of CF
→ cusp structure e.g. $\bar{K}^0 n$



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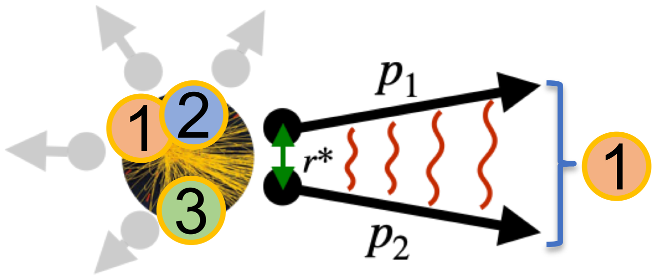
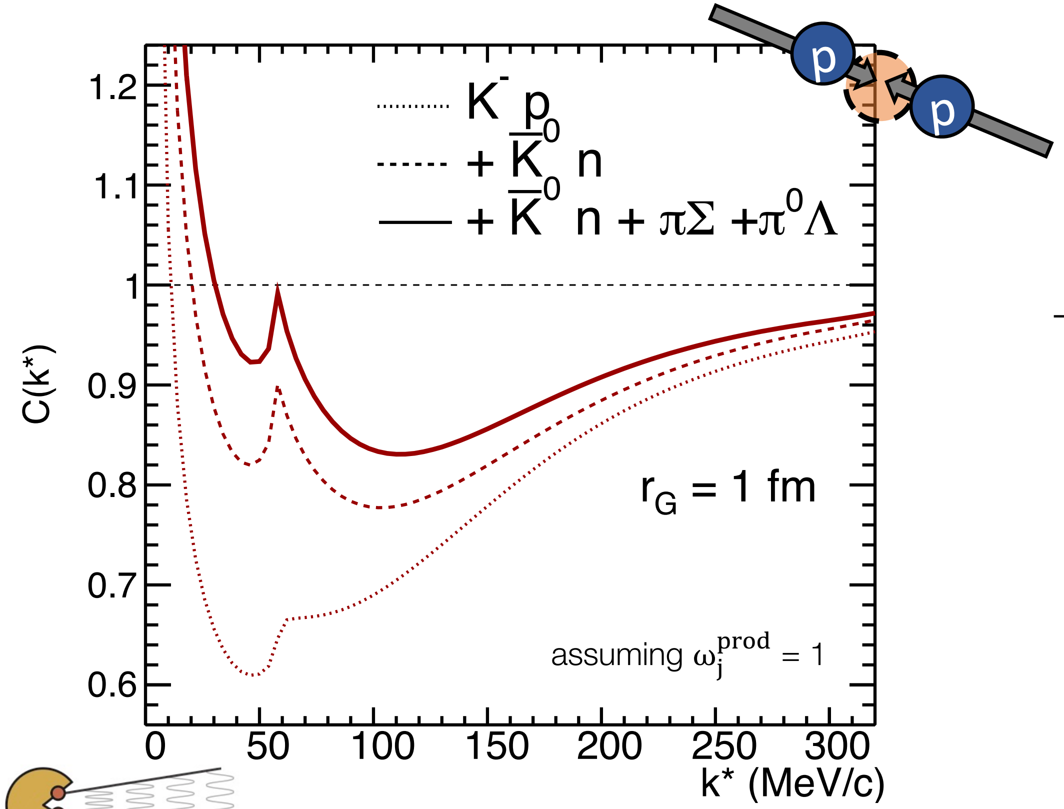
elastic
1 → 1

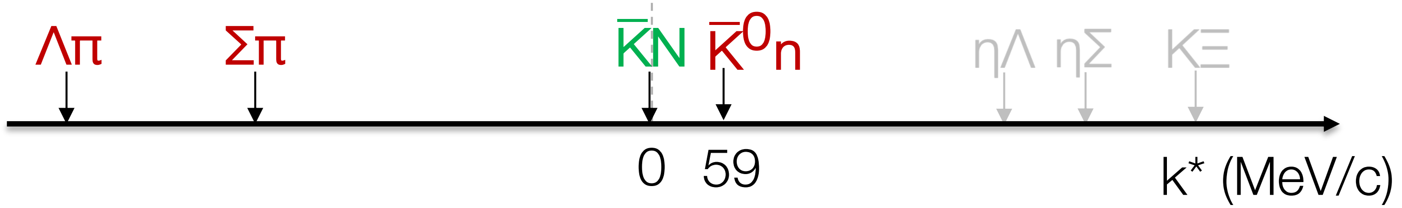
inelastic
2,3,… → 1





Below threshold:
increase the strength of CF
→ shift upward of CF e.g. Σπ

Above threshold:
modify the shape of CF
→ cusp structure e.g. $\bar{K}^0 n$



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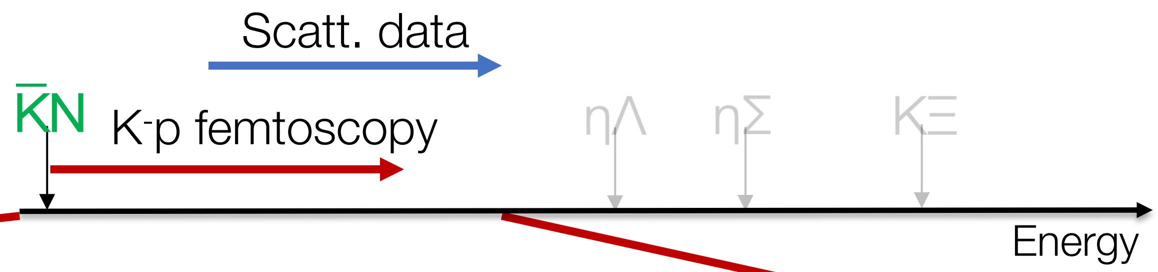
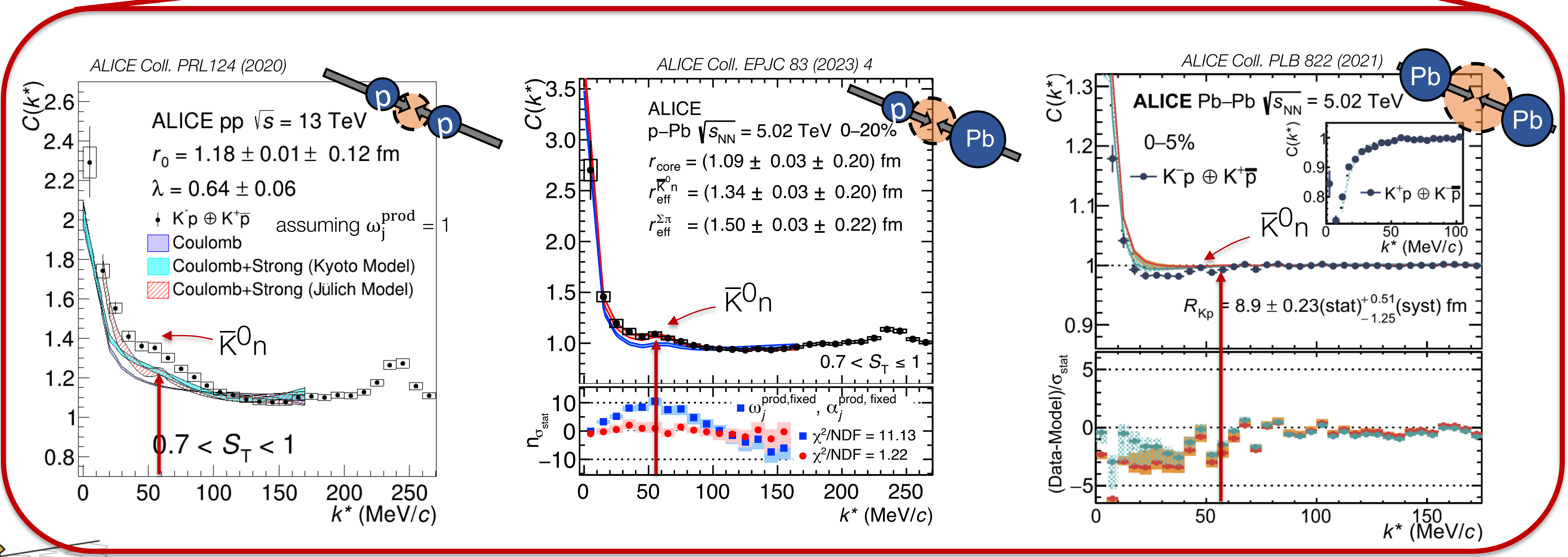
High-precision data on S=-1 sector above threshold

- Most precise data above $K^{-}p$ threshold
- Crucial input for low-energy chiral effective potentials



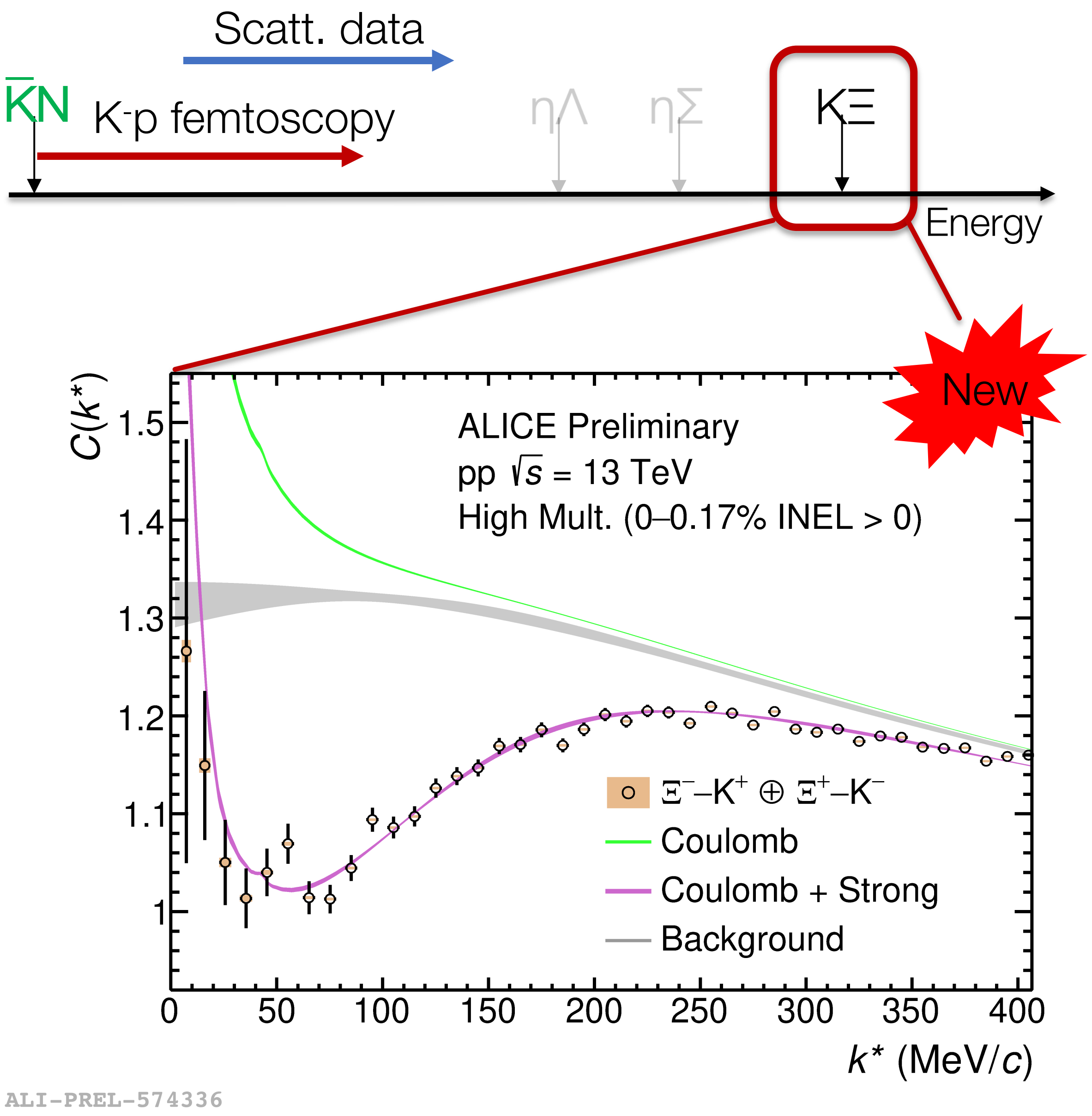


Accessing the $\Xi^{-}K^{+}$ system with femtoscopy

- **Most precise data at low momenta** on the interaction between Ξ and kaons
  - Input also for heavy Λ^* and Σ^* resonances
- Modeled assuming **Lednicky-Lyuboshits wavefunction with Coulomb (S-wave only)**
  R. Lednicky, Phys.Part.Nucl.40:307-352,2009
  - **Coulomb + strong repulsive interaction** well in agreement with the data
- Determination of scattering length from best fit

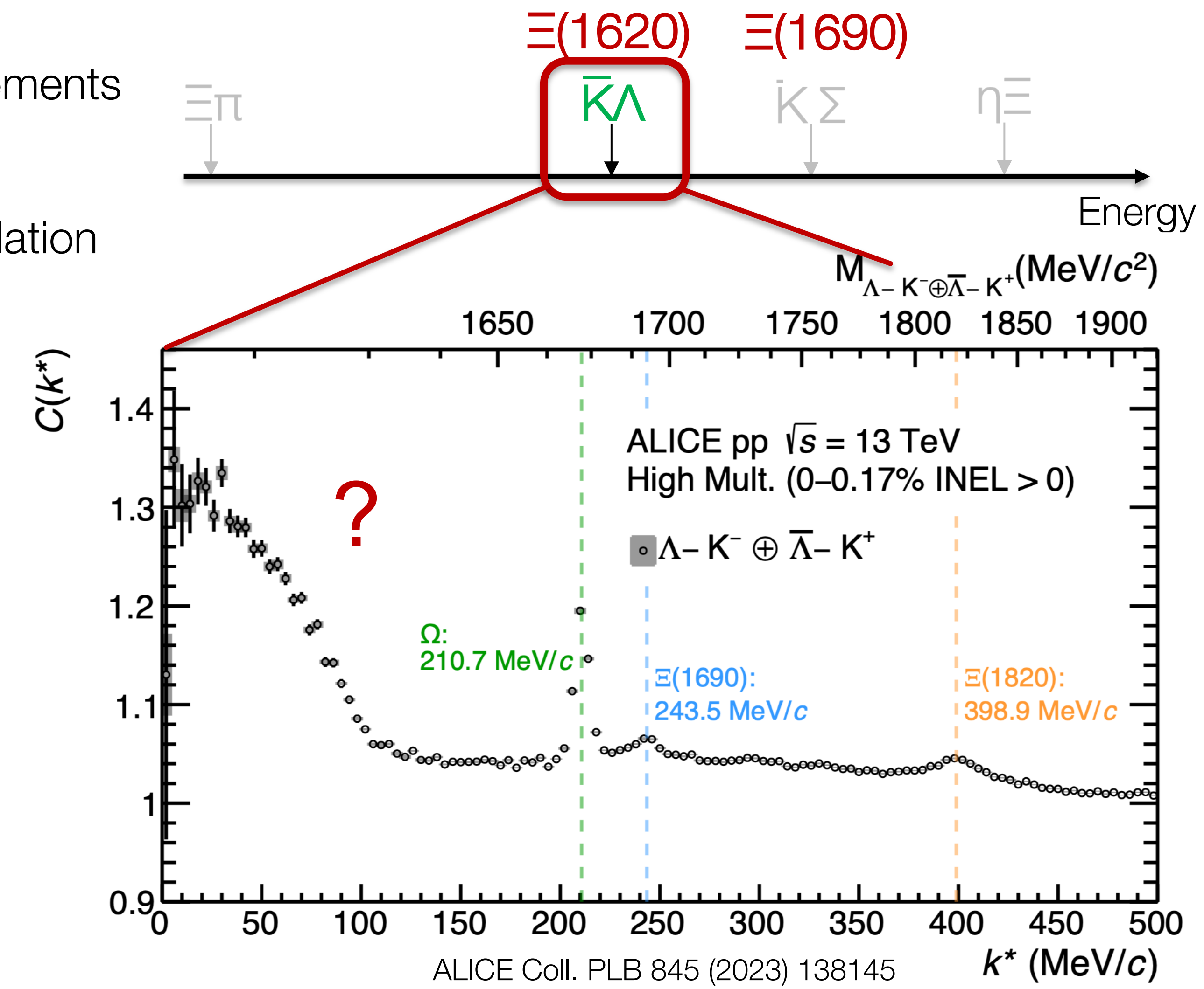
$$\Re f_0 = -0.61^{\pm 0.02(stat)}_{\pm 0.07(syst)}$$

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



Accessing the S=-2 meson-baryon interaction

- Extending previous Pb–Pb femtoscopic measurements to pp collisions
  ALICE Coll. PRC 103 (2021)
- Several structures present in the measured correlation



ALICE Coll. PLB 845 (2023) 138145

Accessing the S=-2 meson-baryon interaction

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  ALICE Coll. PRC 103 (2021)
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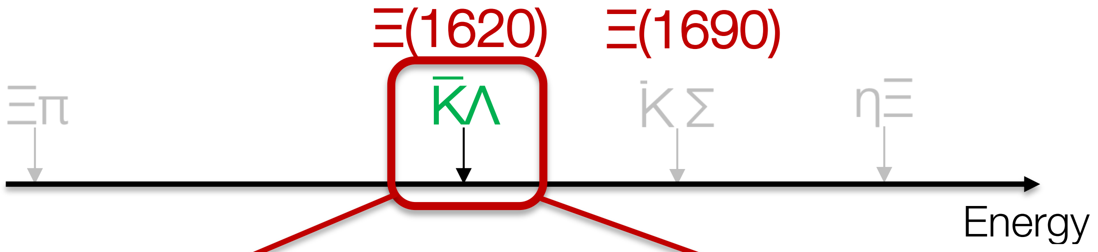
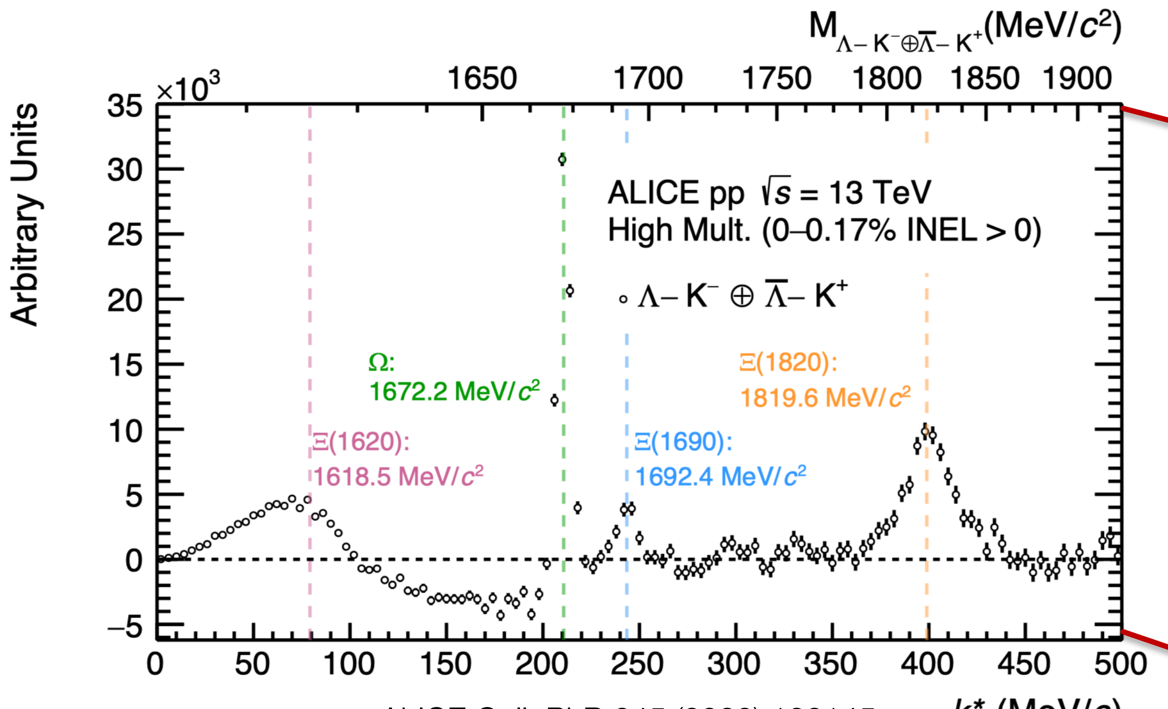
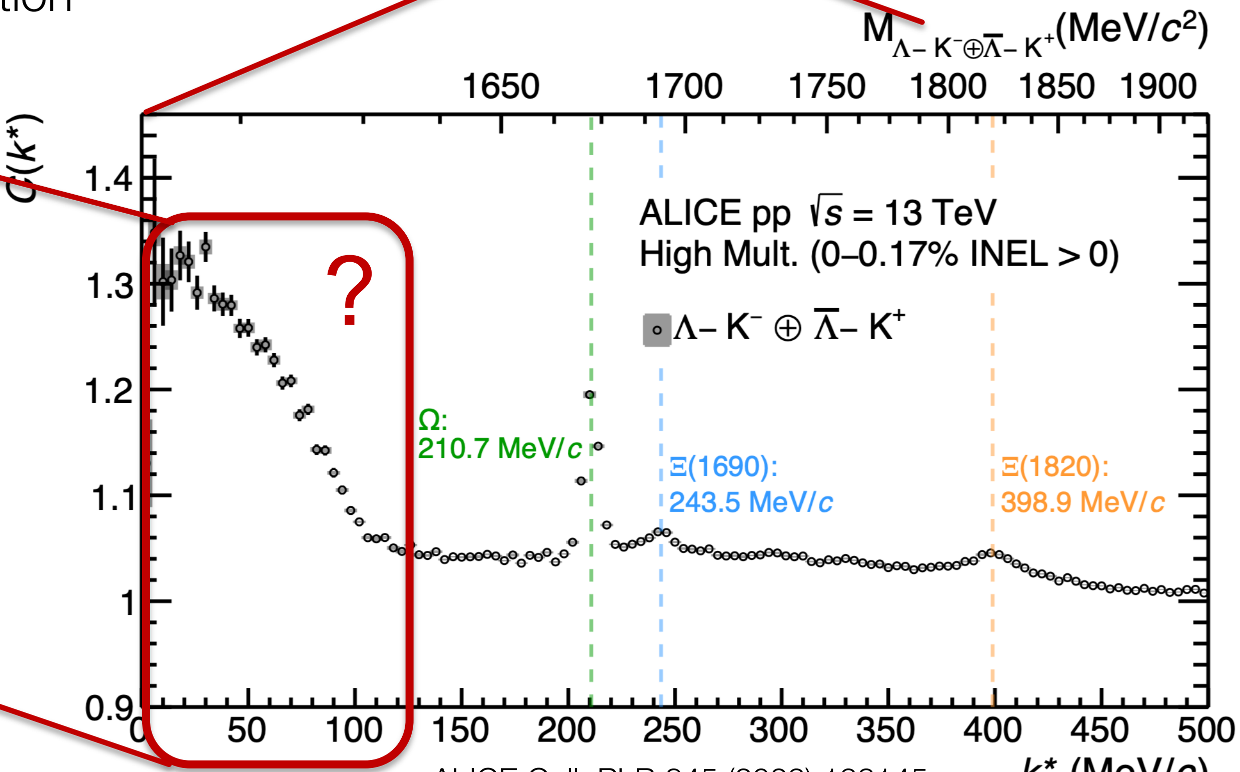




ALICE Coll. PLB 845 (2023) 138145



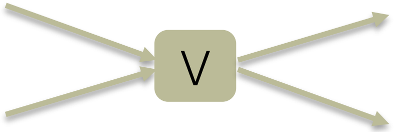
ALICE Coll. PLB 845 (2023) 138145

First experimental evidence of Ξ(1620) decay into ΛK⁻

K⁻Λ correlations and the S=-2 meson-baryon sector

- Most precise data on K⁻Λ down to zero momenta
- Data modeled assuming effective scattering amplitude[1]

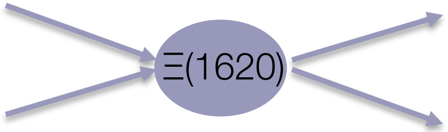
Non resonant



Assuming the effective-range expansion

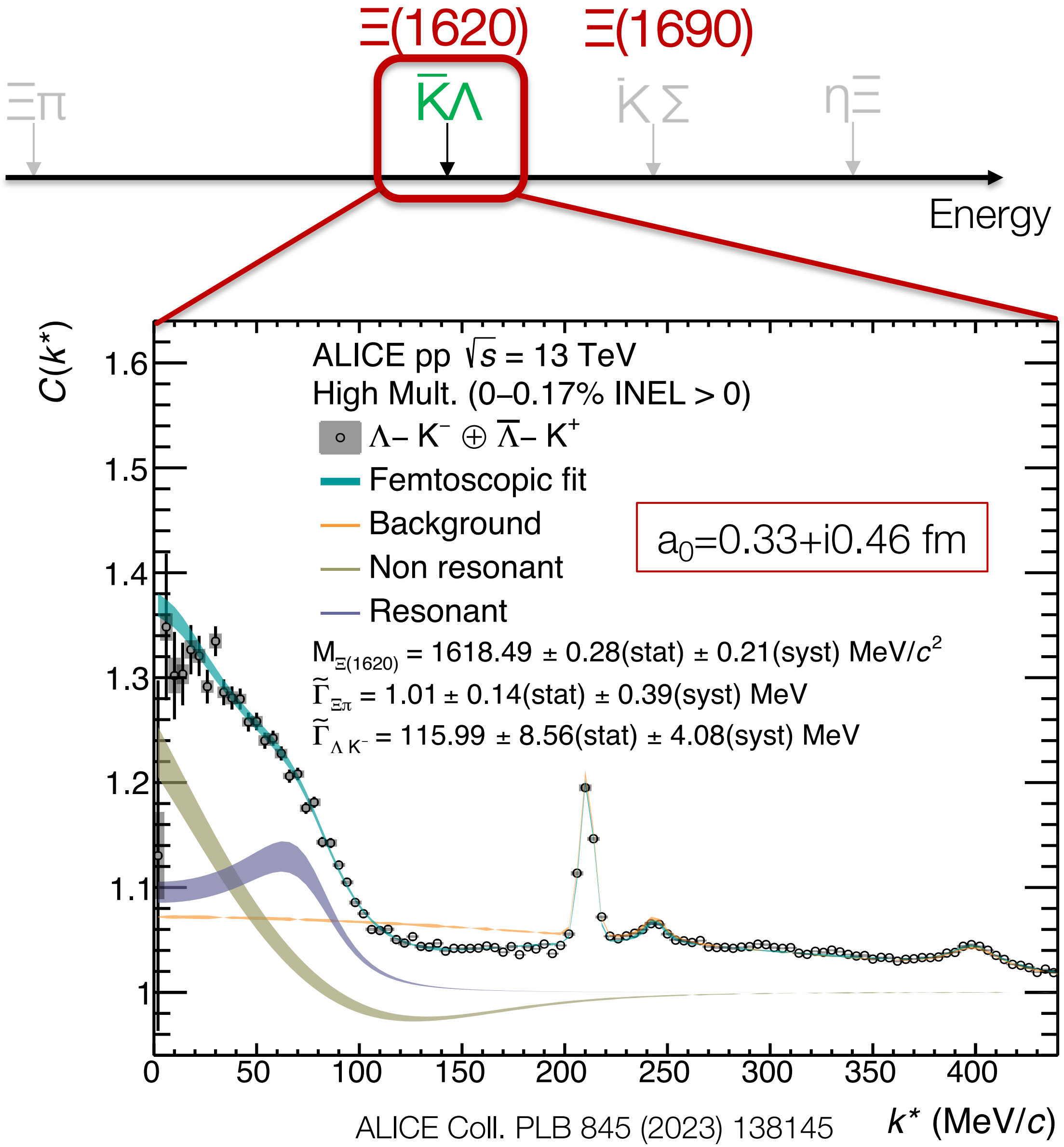
+

Resonant



Assuming a Flattè-like amplitude[2] for Ξ(1620)

- **Ξ(1620) properties** and scattering parameters overall in agreement with Belle and Pb-Pb results
  - Indication of a large coupling of Ξ(1620) to ΛK⁻



ALICE Coll. PLB 845 (2023) 138145

Can we use these femtoscopic data to constrain effective QCD models and investigate the Ξ(1620) nature?

[1] R. Lednicky, V. Lyuboshits SJNP 35 (1982)
[2] F. Giacosa et al. EPJA 57 (2021), 12, 336

Femtoscopy era in the S=-2 meson-baryon sector

- First combined effort in constraining the low-energy constants (and subtraction constants) of an effective chiral lagrangian to correlation data

$$C(k^*) = \int S_1(\vec{r}^*) \left|\psi_{1\to1}(\vec{k}^*,\vec{r}^*)\right|^2 d^3r^* + \sum_{j\neq1} \omega_j^{prod} \int S_j(\vec{r}^*) \left|\psi_{j\to1}(\vec{k}_j^*,\vec{r}^*)\right|^2 d^3r^*$$

- Wavefunctions obtained in a coupled-channel approach
  - State-of-the-art NLO effective lagrangian in UχPT
    A. Feijoo et al., PLB 841 (2023)

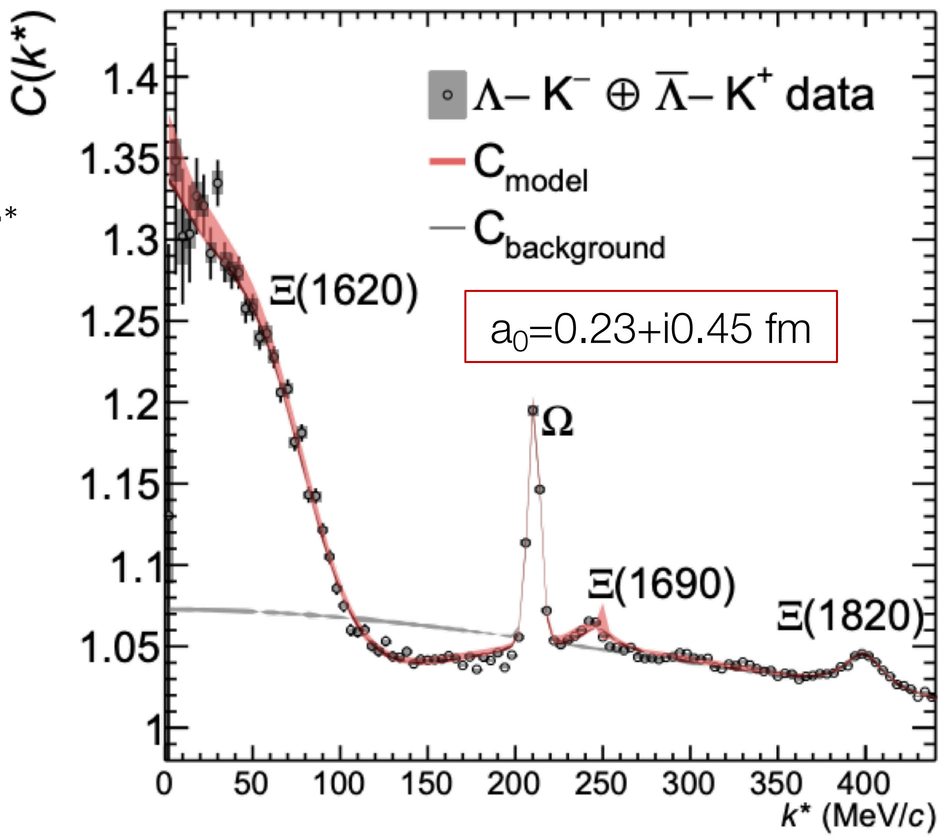
$$\mathcal{L}_{\phi B}^{(1)} = i\langle \bar{B}\gamma_\mu [D^\mu, B]\rangle - M_0\langle \bar{B}B\rangle - \frac{1}{2}D\langle \bar{B}\gamma_\mu\gamma_5\{u^\mu, B\}\rangle - \frac{1}{2}F\langle \bar{B}\gamma_\mu\gamma_5[u^\mu, B]\rangle ,$$

$$\mathcal{L}_{\phi B}^{(2)} = b_D\langle \bar{B}\{\chi_+, B\}\rangle + b_F\langle \bar{B}[\chi_+, B]\rangle + b_0\langle \bar{B}B\rangle\langle \chi_+\rangle + d_1\langle \bar{B}\{u_\mu, [u^\mu, B]\}\rangle + d_2\langle \bar{B}[u_\mu, [u^\mu, B]]\rangle + d_3\langle \bar{B}u_\mu\rangle\langle u^\mu B\rangle + d_4\langle \bar{B}B\rangle\langle u^\mu u_\mu\rangle .$$

- Data-driven estimate of ω_j^{prod} and emitting source
  ALICE Coll. Eur.Phys.J.C 83 (2023), VMS, A. Feijoo et al. arXiv: 2309.08756

- Ξ(1620) and Ξ(1690) properties overall in line with PDG and previous measurements
  - $\Gamma_{\Xi(1620)}$= 24.7 MeV, tension with Belle‘s results

VMS, A. Feijoo et al. PRD 110 (2024) 1, L011505



Work in collaboration with:
Dr. A. Feijoo, Dr. I. Vidana, Prof. A. Ramos, Prof. F. Giacosa,
Prof. T. Hyodo and Dr. Y. Kamiya

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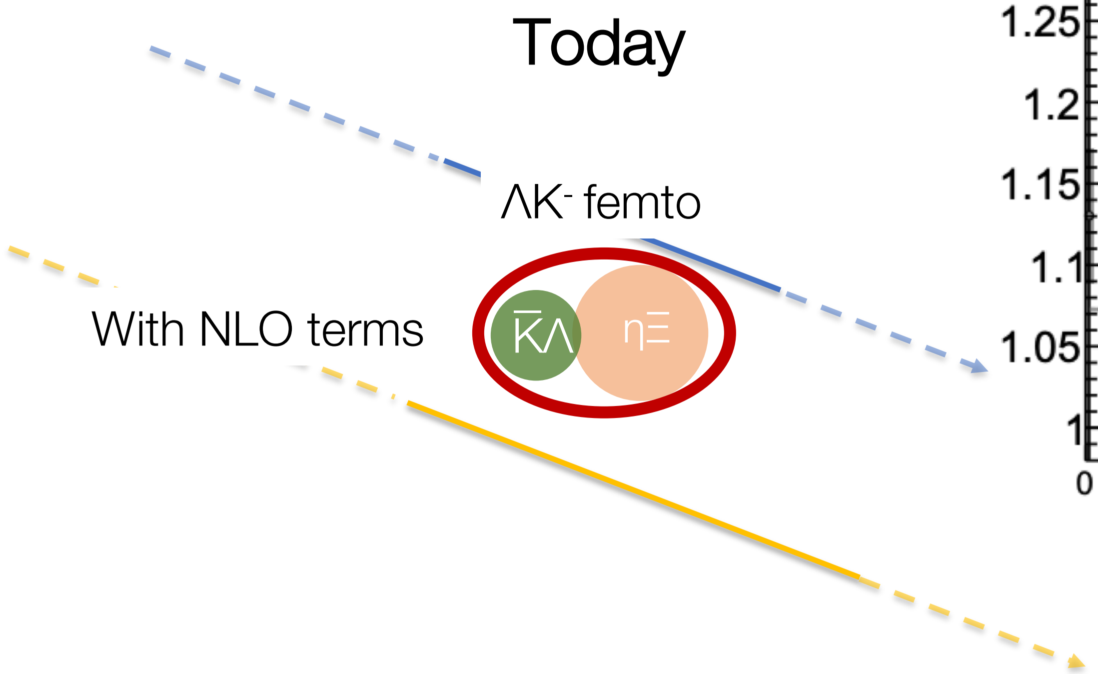
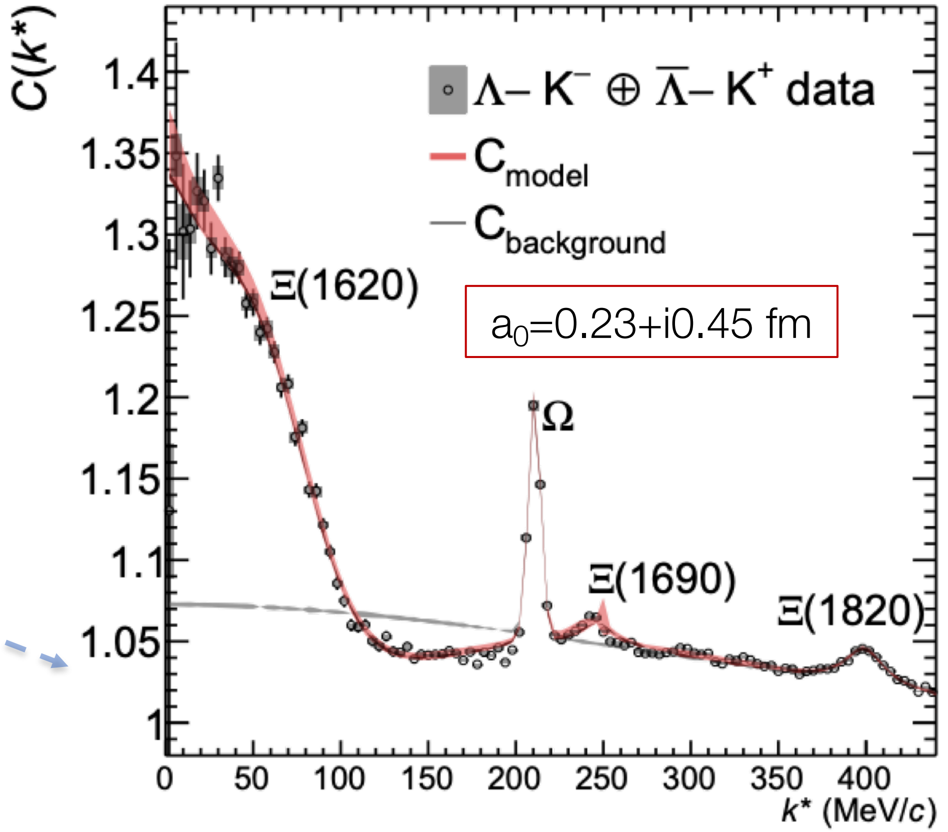
- First **combined effort in constraining** the low-energy constants (and subtraction constants) of an **effective chiral lagrangian to correlation data**



VMS, A. Feijoo et al. PRD 110 (2024) 1, L011505



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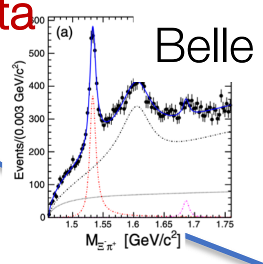
- First **combined effort in constraining** the low-energy constants (and subtraction constants) of an **effective chiral lagrangian to correlation data**



Belle Coll.

$\bar{K}\Lambda$ $\Xi\pi$

A. Ramos, E. Oset PRL 89 (2002)

Only contact terms
|S|=1 data

$\bar{K}\Lambda$ $\Xi\pi$

With NLO terms
|S|=1 data

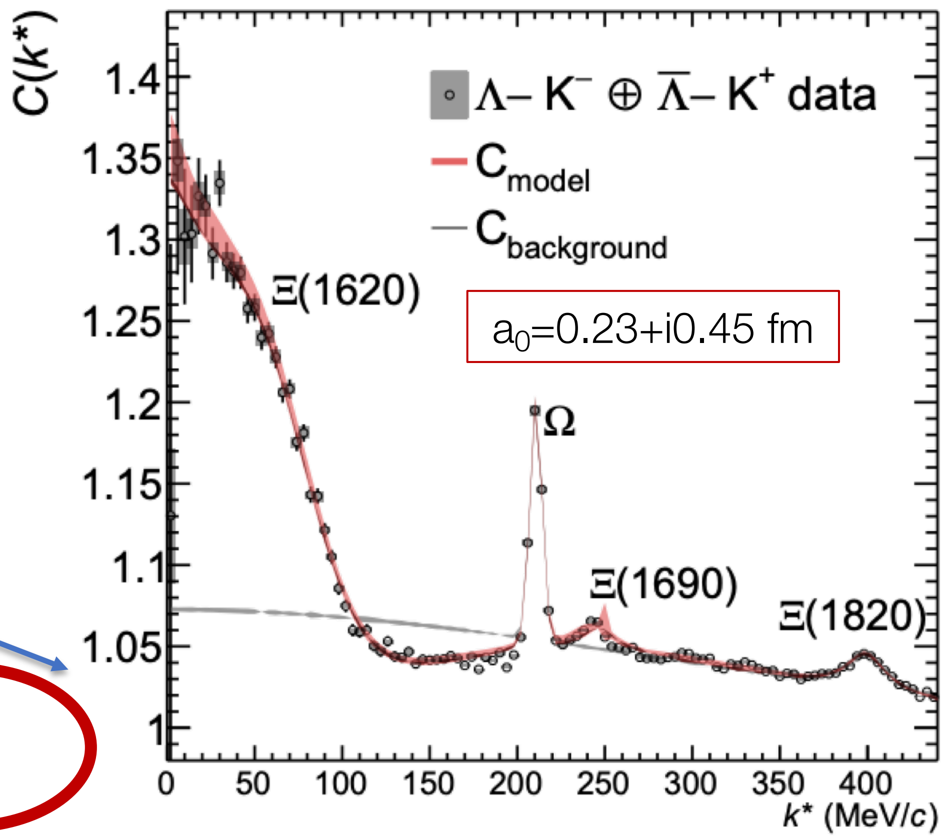
A. Feijoo et al. PLB 841 (2023)

ΛK^- femto

$\bar{K}\Lambda$ $\eta\Xi$

...

VMS, A. Feijoo et al. PRD 110 (2024) 1, L011505



Can we access other channels with correlations at LHC?

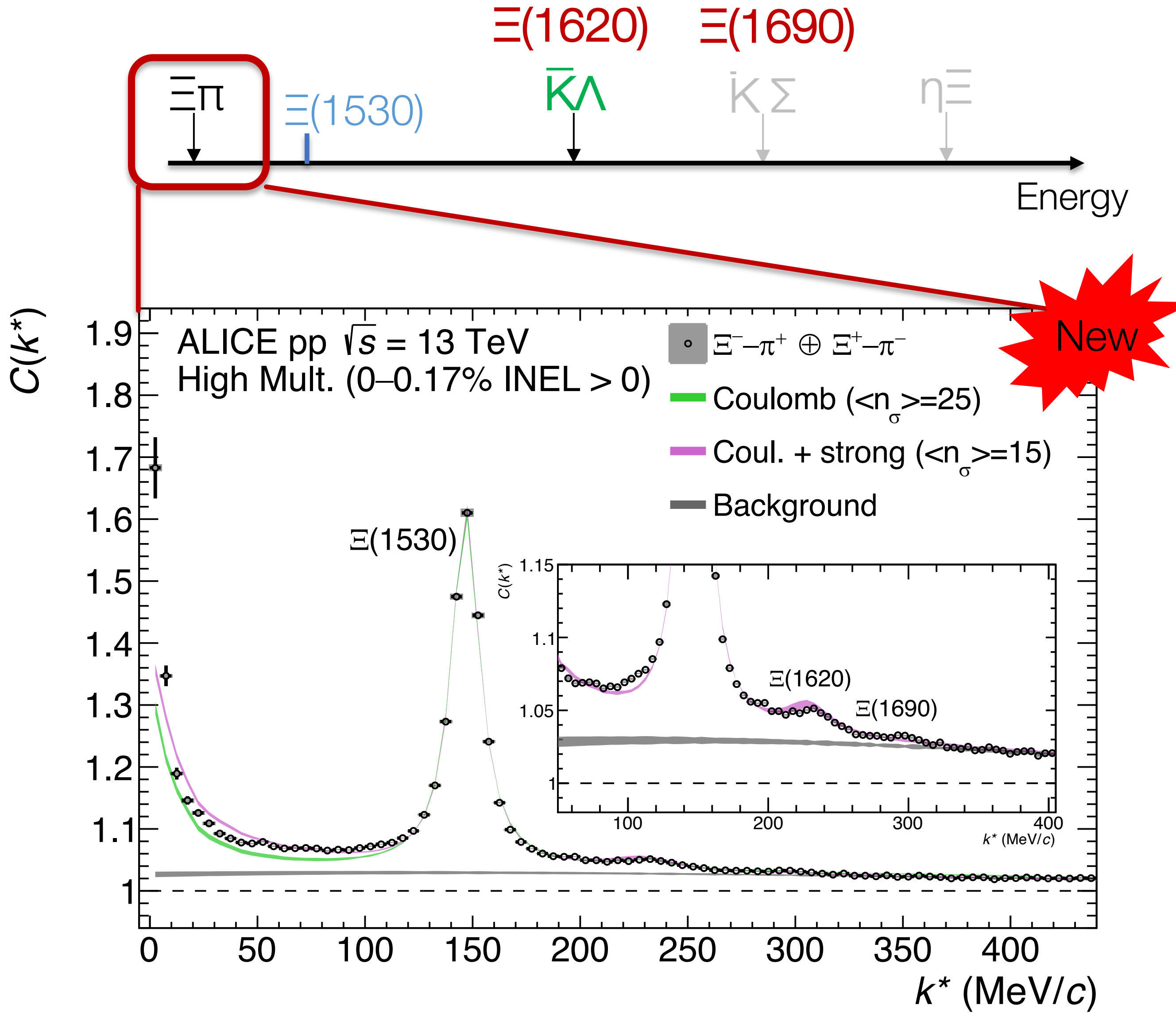
Work in collaboration with:
Dr. A. Feijoo, Dr. I. Vidana, Prof. A. Ramos, Prof. F. Giacosa,
Prof. T. Hyodo and Dr. Y. Kamiya

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

- Most precise data for $\Xi^-\pi^+$ down to threshold
- Observation of Ξ(1620) and Ξ(1690), in agreement with Belle spectroscopy data
  - Mass and widths in line with previous spectroscopic measurements
- Evidence of shallow strong attraction

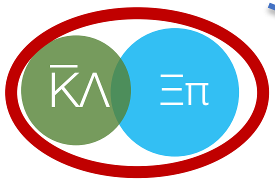
$$\Re f_0 = 0.089^{\pm 0.007(stat)}_{\pm 0.009(syst)}$$
$$\Im f_0 = \mathbf{0.007}^{\pm 0.003(stat)}_{\pm 0.005(syst)}$$

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



Towards a new femtoscopy-spectroscopy alliance!

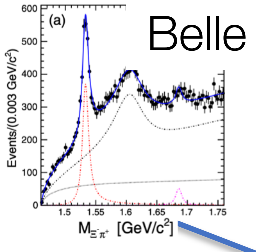
- Moving towards studies on the corresponding available spectroscopy data



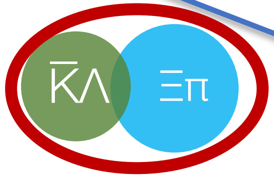
A. Ramos, E. Oset PRL 89 (2002)

Only contact terms
|S|=1 data

Belle, PRL 122 (2019)



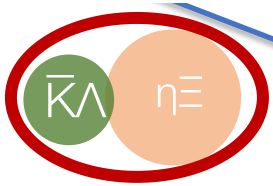
Belle Coll.



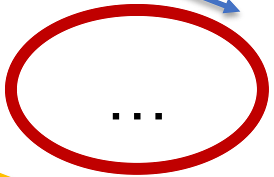
With NLO terms
|S|=1 data

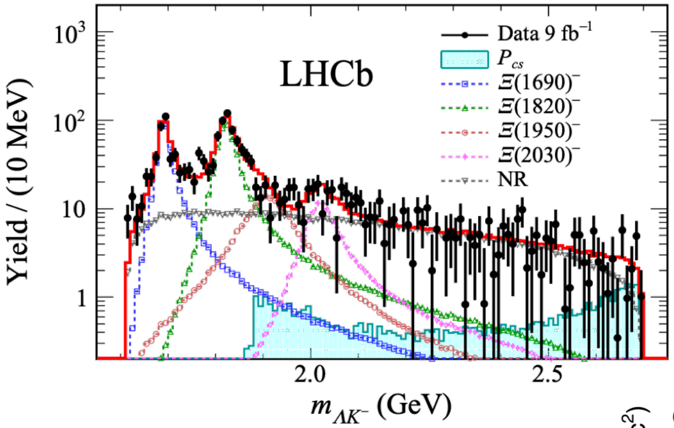
A. Feijoo et al. PLB 841 (2023)

ΛK^- femto



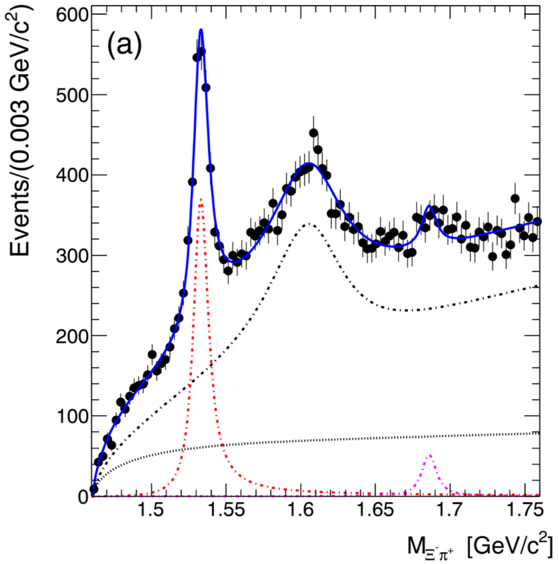
Soon
$\Xi\pi$ femto





LHCb, Sci.Bull. 66 (2021)

Work in progress on LHCb data comparison with Dr. Feijoo and BCN group



Belle, PRL 122 (2019)

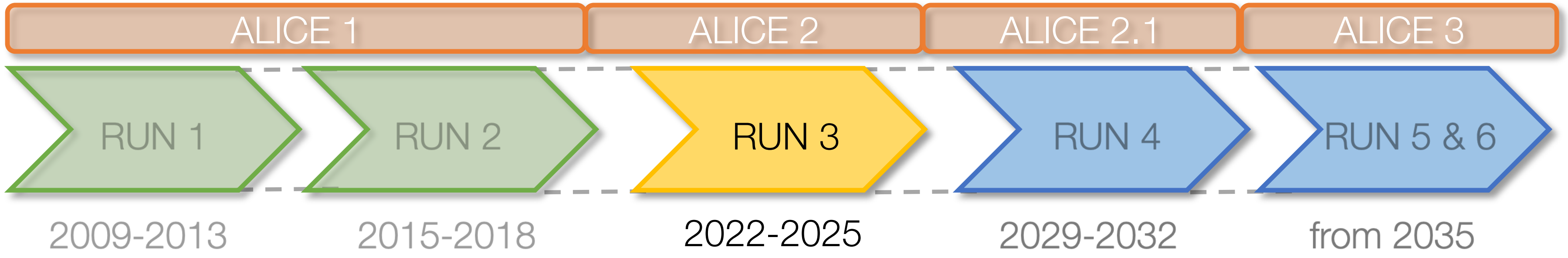
Towards a combined fit of all available data in this sector!!

(Preliminary work done on contact terms for $p\Lambda$, see backup)

Mihaylov, Haidenbauer, VMS PLB 850 (2024) 138550

Conclusions and outlooks

- 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 as a complementary tool to provide important input for **searches and studies of** exotic states



Many more correlations to come with on-going Run 3 and future LHC runs

Moving to three-body dynamics:
R. Del Grande Wed. 30 Oct

Outlooks and (soon) future with Run 3

- Soon available $\Lambda\pi^{\pm}$ correlation data!
- Possibility to reconstruct $\Sigma^{\pm}$ via kink-topology method with ITS2 in Run 3
  → Access to $\pi\Sigma$, $\overline{K}\Sigma$
- Continuing the effort to measure interactions with charm hadrons

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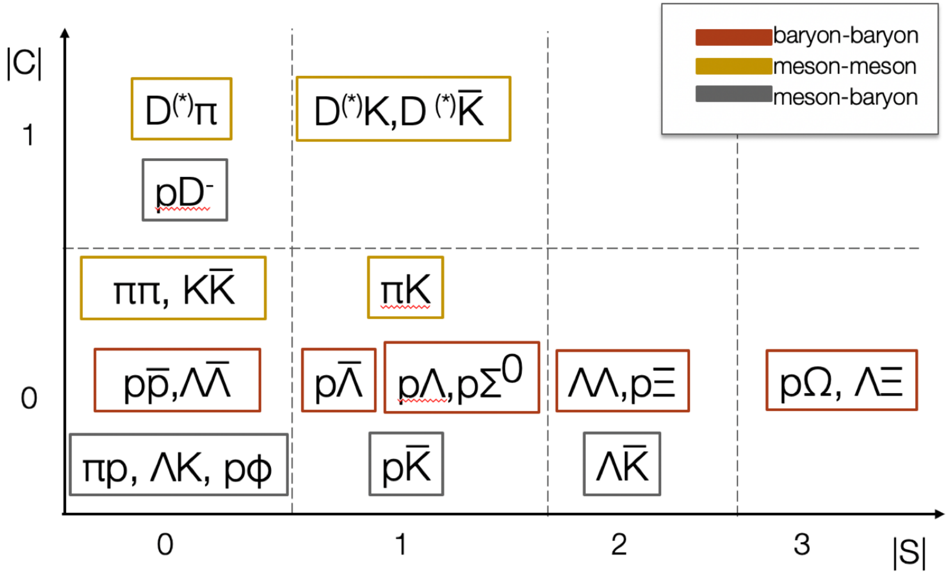
Many experimental and theoretical activities…

ALICE Collaboration:
PRC 99 (2019) 2, 024001
PLB 797 (2019) 134822
PRL 123 (2019) 112002
PRL 124 (2020) 09230
PLB 805 (2020) 135419
PLB 811 (2020) 135849
Nature 588 (2020) 232-238
PRL 127 (2021), 172301
PLB 822 (2021), 136708
PRC 103 (2021) 5, 055201
PLB 833 (2022), 137272
PLB 829 (2022), 137060
PRD 106 (2022), 5, 05201
PL B 844 (2023) 137223
EPJA 59 (2023) 145
EPJC 83 (2023) 4, 340
PLB 845 (2023) 138145
EPJA (2023) 59:298
arXiv: 2311.14527 [hep-ph]
arXiv: 2401.13541 [nucl-ex]
arXiv:2308.16120 [nucl-ex]

STAR Collaboration:
Nature 527 (2015) 345-348
PRL 114 (2015), 022301
PLB 790 (2019) 490-497

HADES Collaboration:
PRC 82 (2010) 021901
PRC 94 (2016) 2, 025201

Latest theoretical studies on exotics and correlations:
Liu et al. Phys.Rev.D 107 (2023) 7, 074019
Albaladejo et al. Phys.Rev.D 108 (2023) 1, 014020
Kemchandani et al. arXiv:2312.11811
Ikeno et al. Phys.Lett.B 847 (2023) 138281
Torres-Rincon et al. Phys.Rev.D 108 (2023) 9, 096008
Kamiya et al. Eur.Phys.J.A 58 (2022) 7, 131
Vidaña, Feijoo et al. Phys.Lett.B 846 (2023) 138201
Albaladejo, Feijoo et al. arXiv:2307.09873
Liu et al. Phys.Rev.D 108 (2023) 3, L031503
Feijoo et al. Phys.Rev.D 109 (2024) 1, 016014
Liu et al. Phys.Rev.D 109 (2024) 1, 016014
M. Z. Liu et al. arXiv: 2404.06399 [hep-ph]
Li et al. arXIv: 2311.14365 [hep-ph]
Molina et al. Phys.Rev.D 109 (2024) 5, 054002
Krein Few Body Syst. 64 (2023) 3, 42



Three-body dynamics: pd, ppp, ppΛ, pp$K^{\pm}$

pd: ALICE Coll. PRX 14 (2024) 3, 031051
ppp,ppΛ: ALICE Coll. EPJA 59, 145 (2023)
ppK: ALICE Coll. EPJA 59,12 (2023)

Theoretical papers:
M. Viviani et al, Phys.Rev.C 108 (2023) 6, 064002
A. Kievsky, et al., Phys.Rev.C 109 (2024) 3, 034006
E. Garrido et al., arXiv: 2408.01750 (2024)

Additional slides

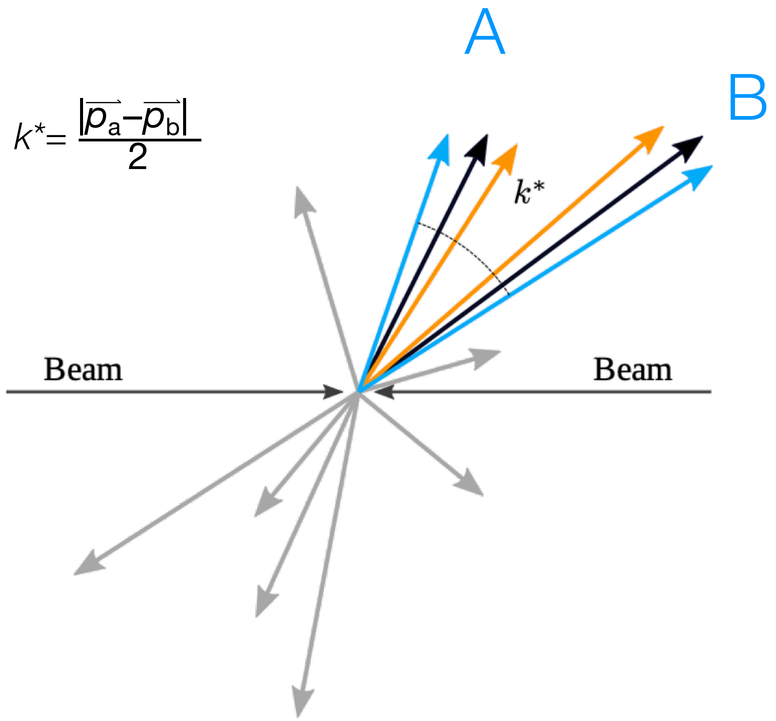
Basics of femtoscopy – Experimental definition

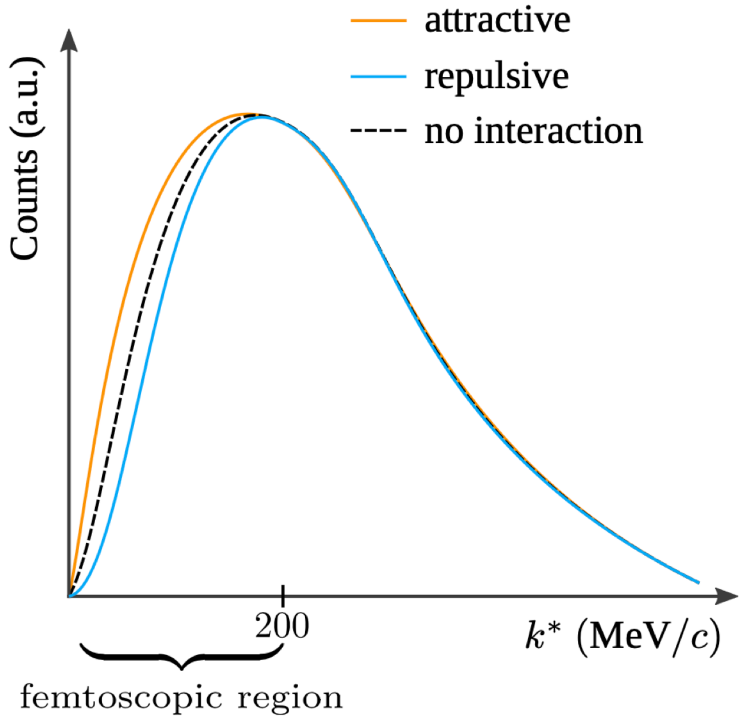
$$C(k^*) \propto \frac{N_{\mathrm{same}}(k^*)}{N_{\mathrm{mixed}}(k^*)}$$

Pairs AB produced in the same event
→ they interact!!

Particles A and B from <u>different events</u>
→ No interaction!
→ Description of the underlying <u>phase space</u>

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





A and B push each other away 💔
Less pairs at small k*

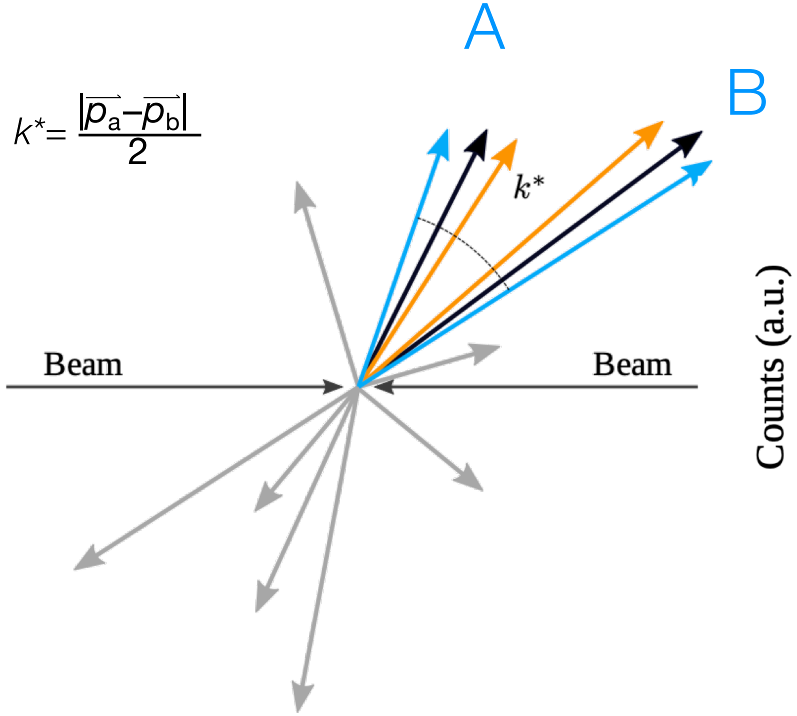
How does this translate to the correlation function?

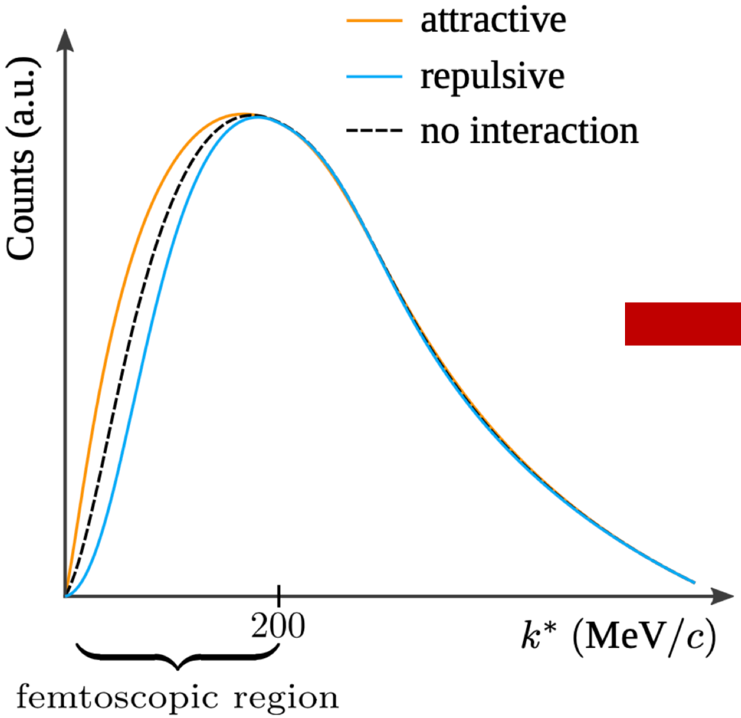
Basics of femtoscopy – Experimental definition

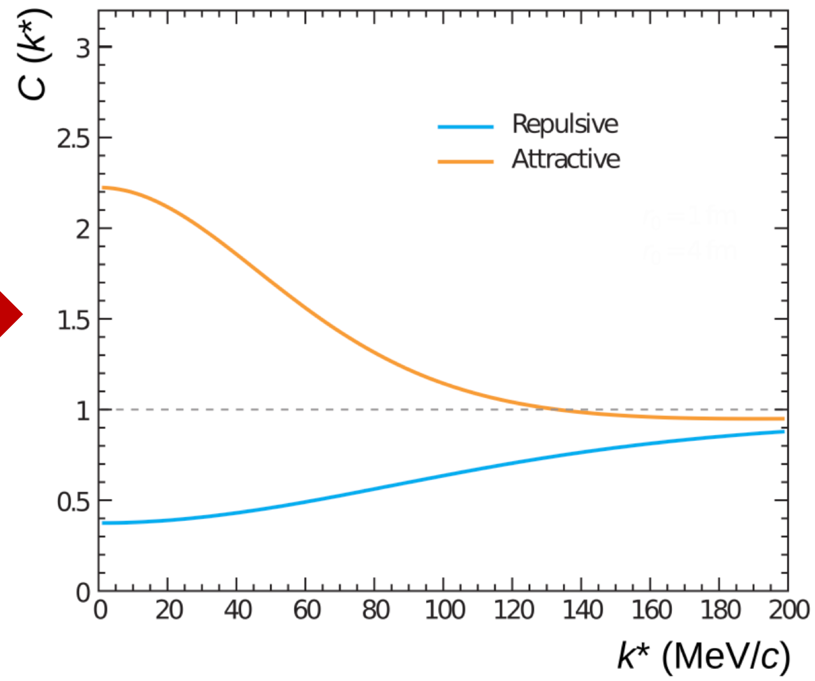
$$C(k^*) \propto \frac{N_{\mathrm{same}}(k^*)}{N_{\mathrm{mixed}}(k^*)} \begin{cases} > 1 & \text{Attractive interaction} \\ = 1 & \text{No interaction} \\ < 1 & \text{Repulsive interaction} \end{cases}$$

Mapping 1-to-1 the nature of the interaction

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

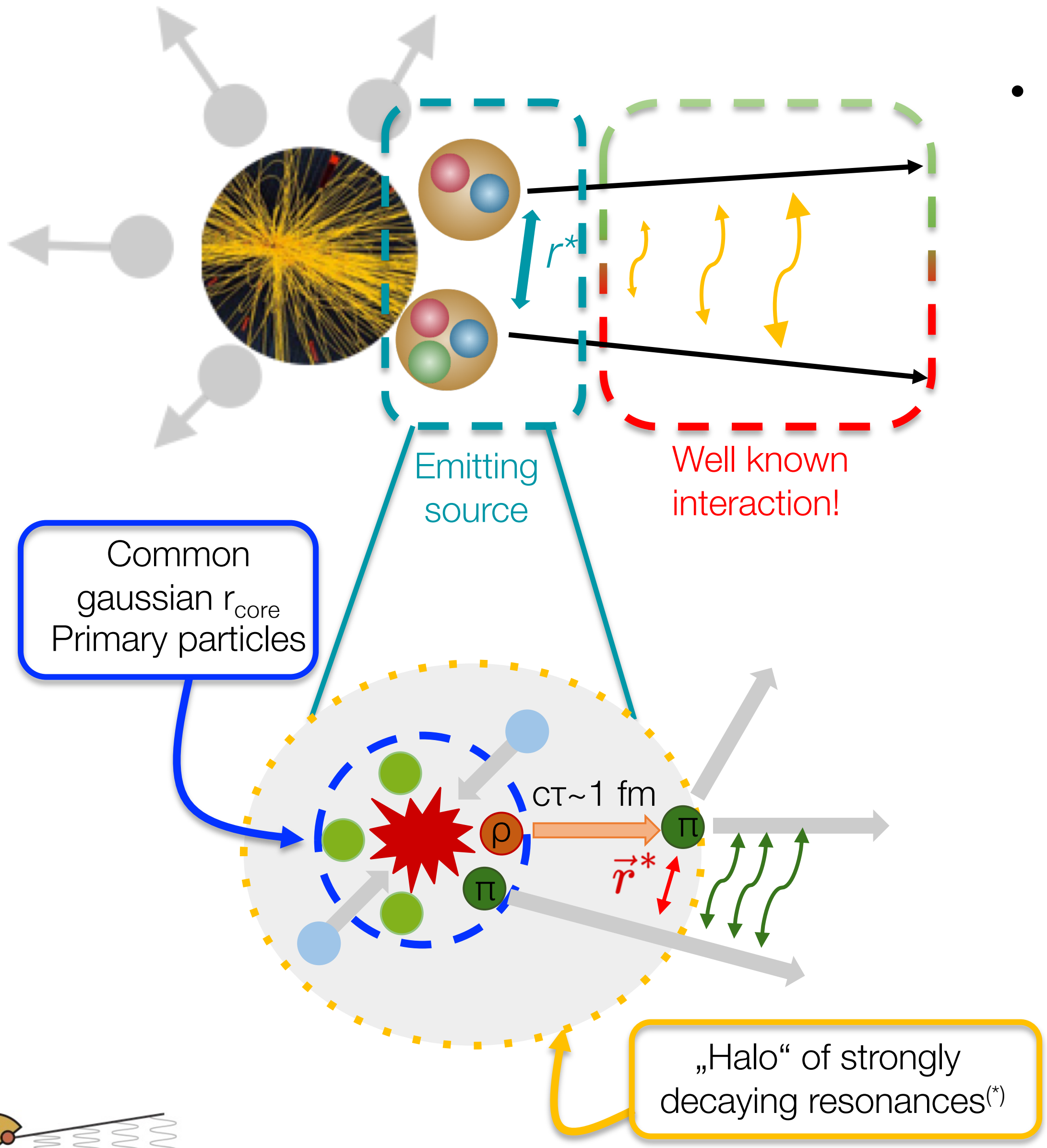






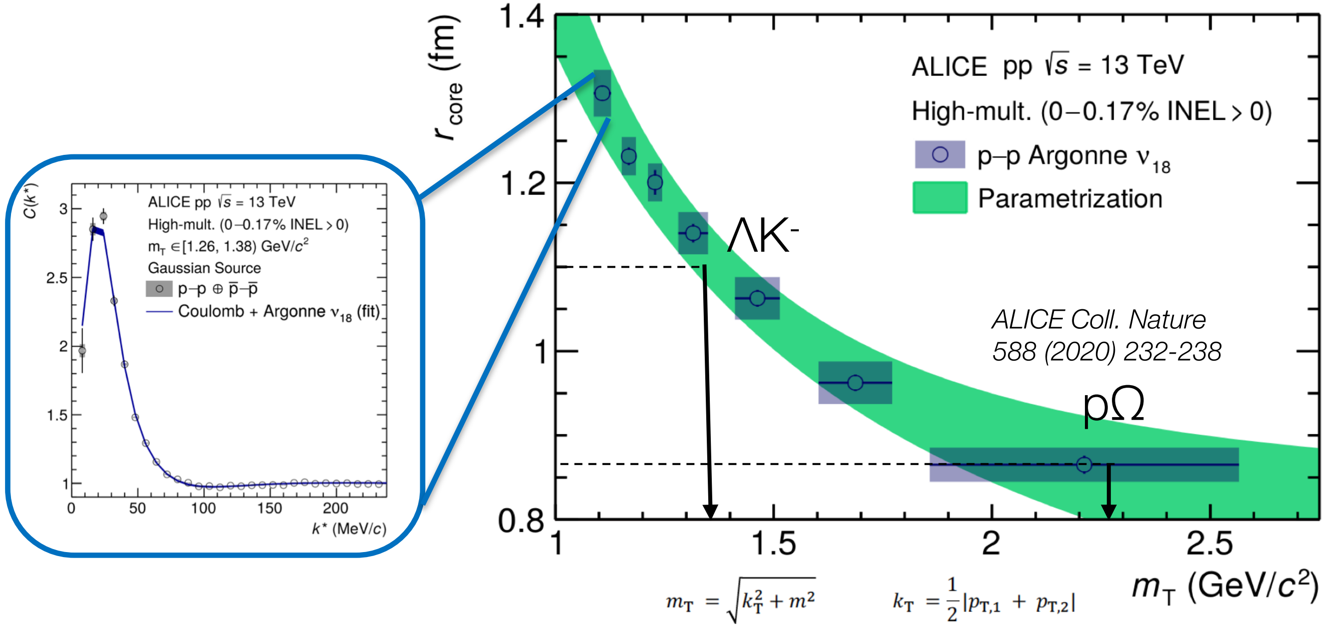
L. Fabbietti et al., Ann.Rev.Nucl.Part.Sci. 71 (2021) 377-402

The emitting source in pp collisions



- Modeled in a data-driven way using p-p correlations, most known interaction!!

Based on ALICE Coll. PLB 811 (2020) 135849
(*) U. A. Wiedemann, U. W. Heinz, Phys.Rept. 319, 145-230 (1999)



- Fixing of the source at corresponding $<m_T>$
  → Direct access to the interaction
  → Interparticle distances ~1-2 fm

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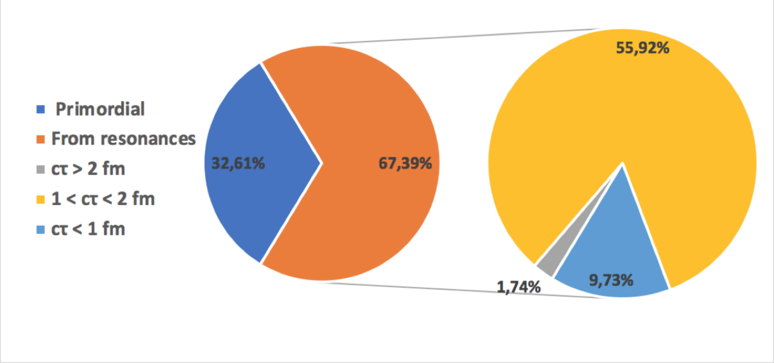
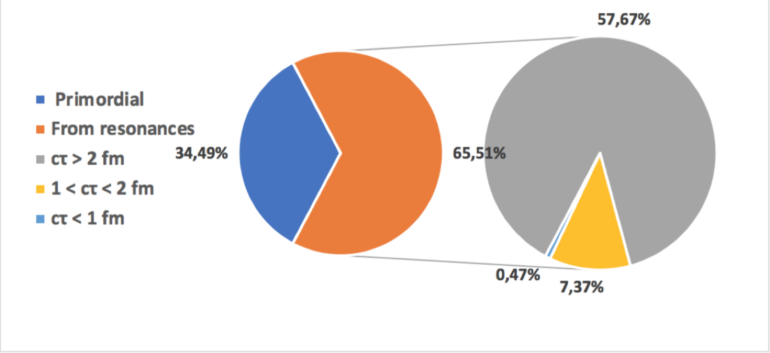
The source function - Effect of short-lived resonances

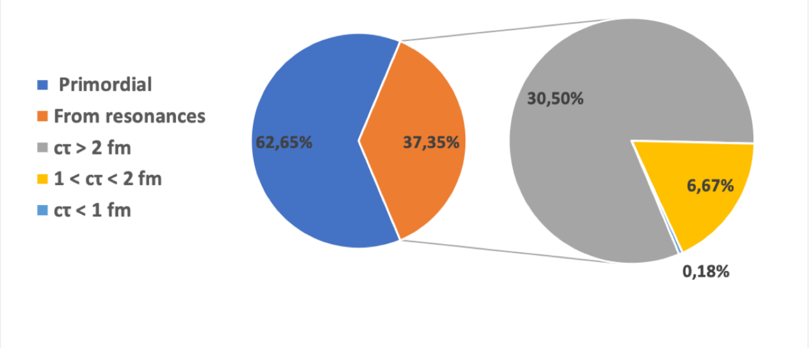
Protons



Λs



Σ^0s

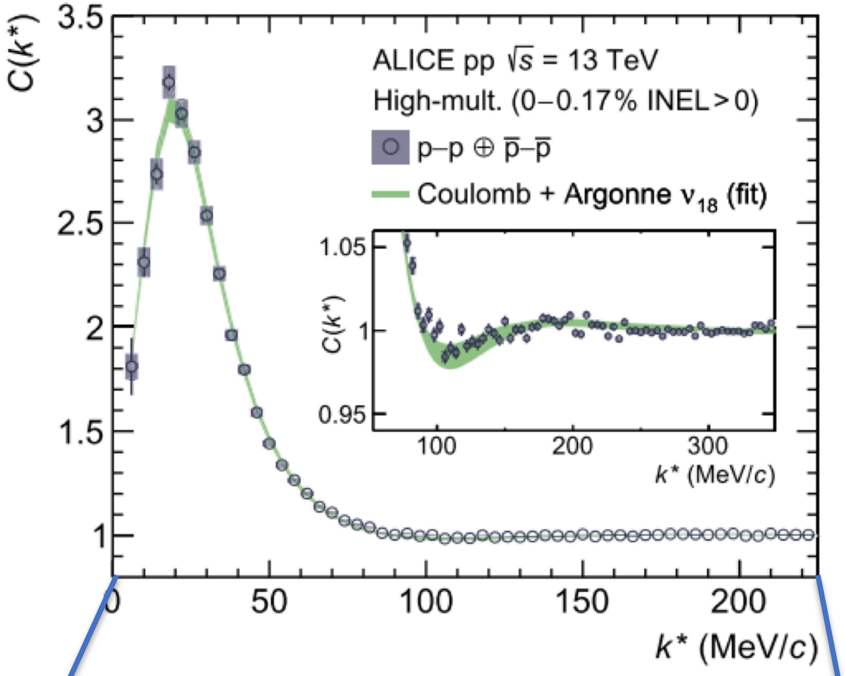


- For Ξ^- and Ω^- no contributions!
- Average mass and average cτ determined by the weighted average values of all resonances

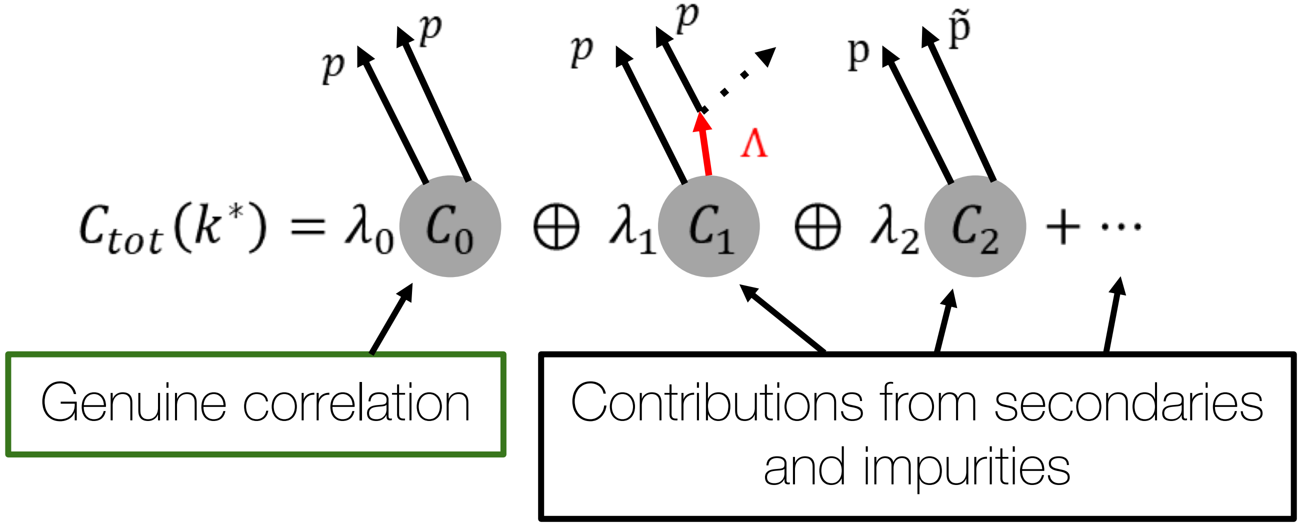
Particle	M_{res} [MeV]	τ_{res} [fm]
p	1361.52	1.65
Λ	1462.93	4.69
Σ^0	1581.73	4.28

Genuine and not genuine…that is (not) the problem!

ALICE Coll. PRC 99 (2019) no.2, 024001



Unfortunately in our p-p pairs sample we do not have only primary produced protons undergoing the genuine interaction we aim at measuring



$$C_{tot}(k^*) = \lambda_0 C_0 \oplus \lambda_1 C_1 \oplus \lambda_2 C_2 + \cdots$$

1. These residual correlations dilute the signal, need to be constrained as much as possible (modeling interaction when possible, e.g. pΛ)
2. Each contribution is weighted taking into account purity and origin of the particles in the pair

$$\lambda_i = P_{i,1} f_{i,1} \cdot P_{i,2} f_{i,2}$$

3. Both the purities and the fractions of particles coming from primary, secondaries, etc. can be determined using using Monte Carlo simulated data

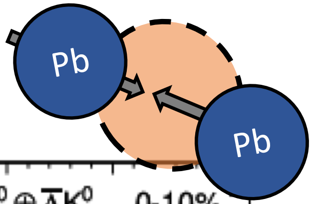
Moving to $K^-\Lambda$ correlations…

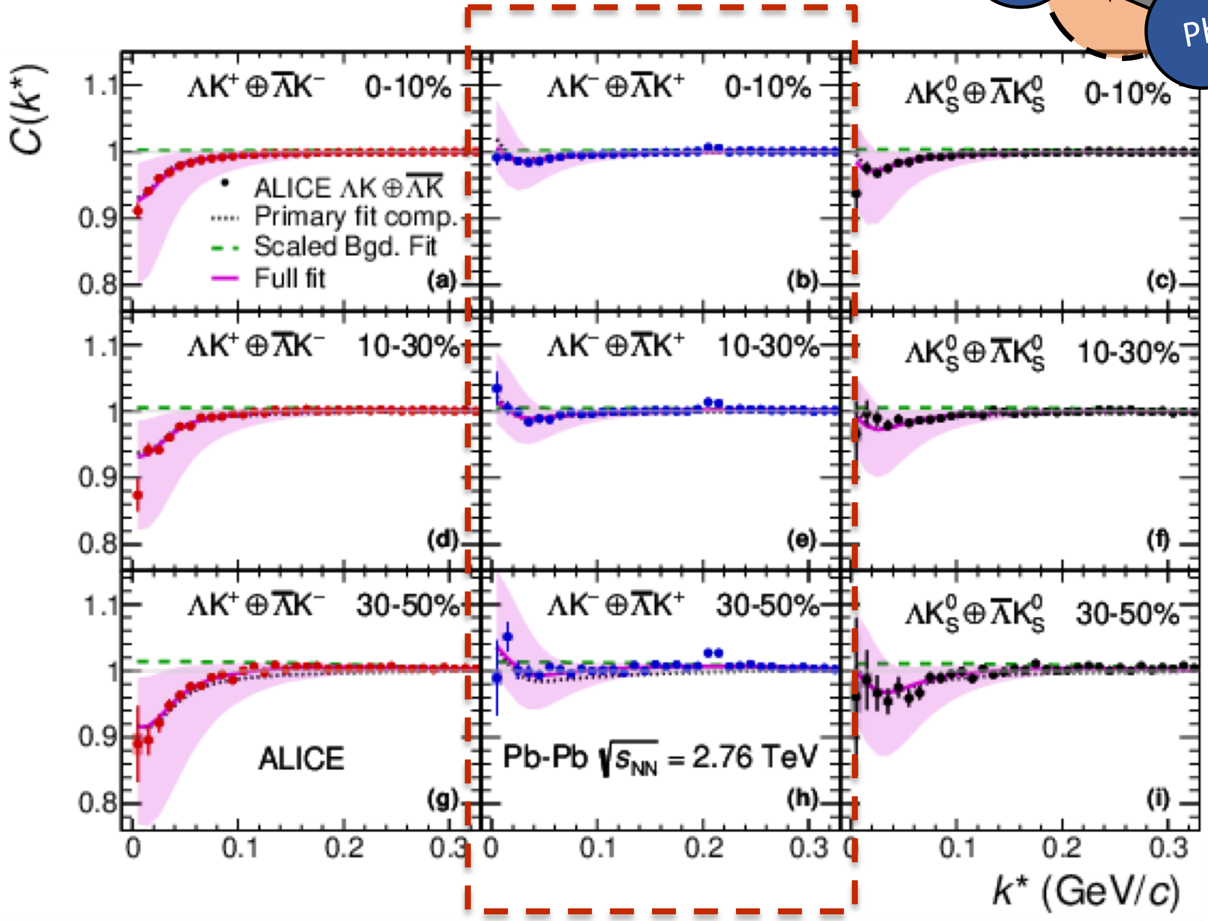
- Correlations measured in Pb-Pb collisions
  → No particular cusps or structure visible
  → First measurements of $\Lambda\overline{K}$ scattering parameters!

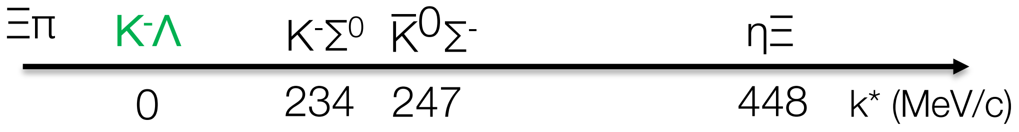
How does the correlation look like in pp collisions?

Can we shed light on the nature of Ξ(1620) and Ξ(1690) states with correlations?

ALICE Coll. PRC 103 (2021)







Fixing the source in ΛK correlations

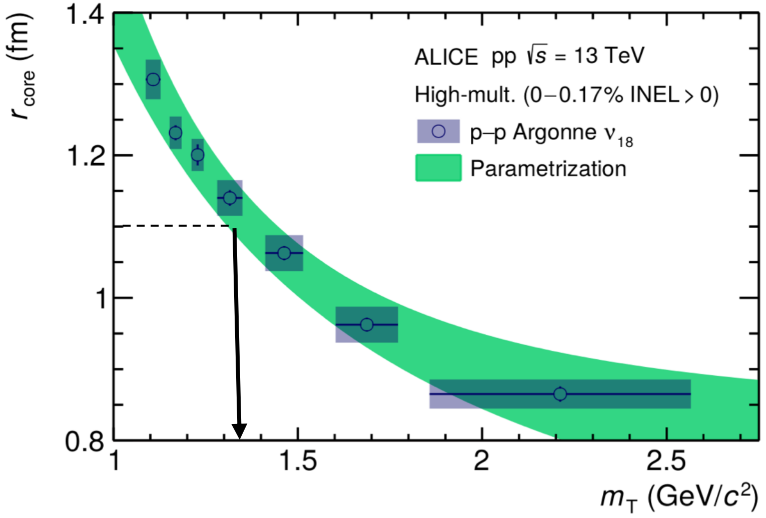
- Core-halo resonance model anchored to p-p CF
  - r_{core} = 1.11 ± 0.04 ($\langle m_T \rangle_{\Lambda K}$ = 1.35 GeV/c^2)

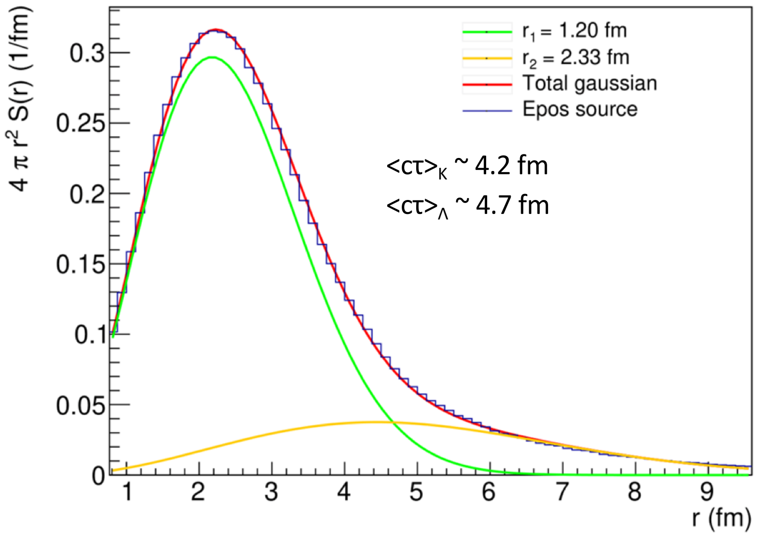
- Long-lived strongly decaying resonances feeding to Λ
  - fit with effective double gaussian

$$S_{tot}(r) = \lambda_s [\omega_S \cdot S(r_1) + (1-\omega_S) \cdot S(r_2)]$$

Parameter	Value
r_{core} [fm]	$1.11^{+0.04}_{-0.04}$
$r_{1,eff}$ [fm]	$1.202^{+0.043}_{-0.042}$
$r_{2,eff}$ [fm]	$2.330^{+0.050}_{-0.045}$
ω	$0.7993^{+0.0037}_{-0.0027}$
λ	$0.9806^{+0.0006}_{-0.0008}$

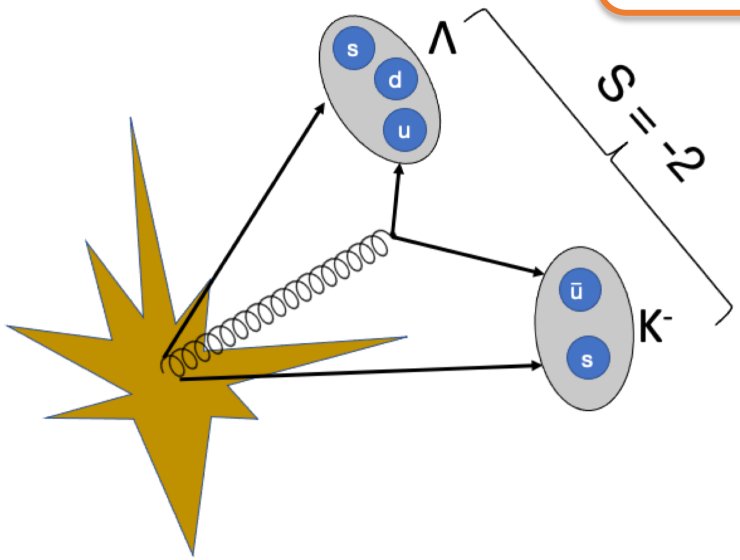
ALICE Collaboration Phys. Lett. B 811

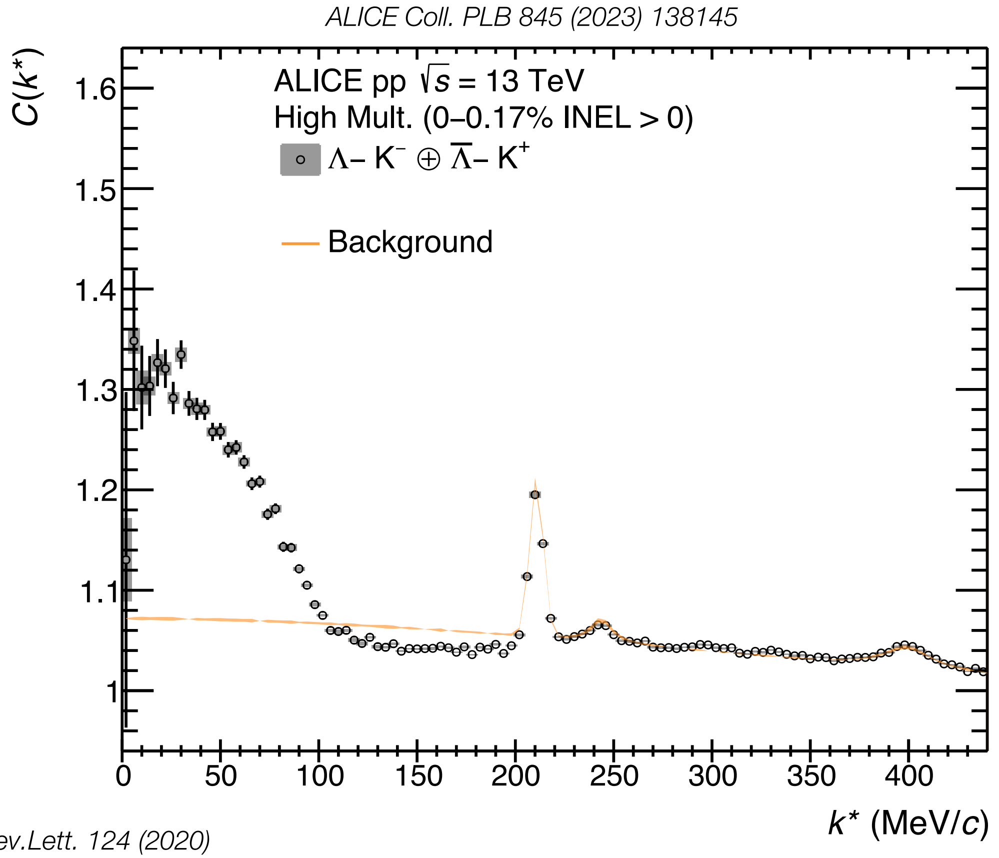




Modeling the correlation function

$$C(k^*) = N_D \cdot C_{model}(k^*) \cdot C_{bckg}(k^*)$$

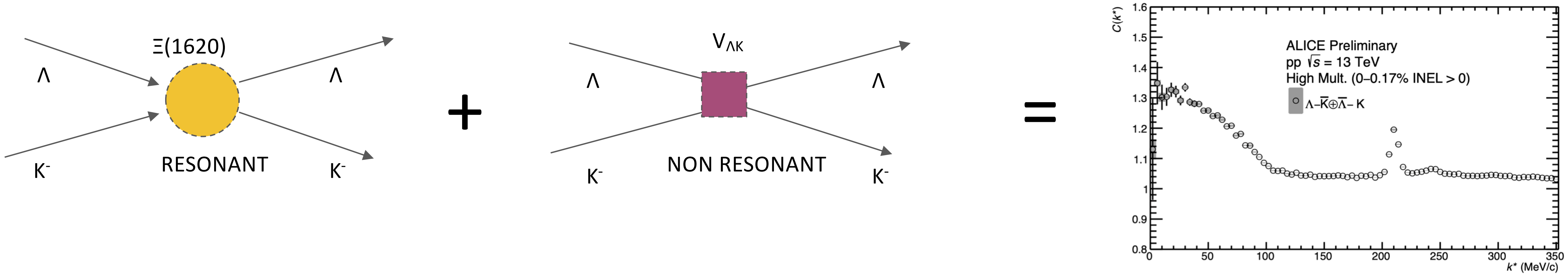




- Residual background due to initial parton scattering
  → Typically observed in meson-baryon correlations *ALICE Coll. Phys.Rev.Lett. 124 (2020)*
  → Modeled using Monte-carlo simulations

- Addition of Ω, Ξ* resonances observed in the CF modeled with BW
  → Values of (M,Γ) to be extracted with fit to the data

ΛK^- correlation: including the $\Xi(1620)$ resonance



$$C_{model}(k^*) = \lambda_{gen} C_{gen}(k^*) + \lambda_{\Xi K} C_{\Xi K}(k^*) + \lambda_{flat}$$

- Modeled with Lednicky-Lyuboshits analytical formula

$$C_{gen}(k^*) = w C_{non-res}(k^*) + (1-w) C_{res}(k^*)$$

- $C_{non-res}$ → LL with ERE scatt. amplitude
- C_{res} → LL with Flattè-like scatt. amplitude (F. Giacosa et al. Eur.Phys.J.A 57 (2021) 12, 336)

$$f(k^*) = \frac{-2\tilde{\Gamma}_2}{E^2 - M^2 + i\tilde{\Gamma}_1\sqrt{E^2 - E^2_{thr.1}} + i\tilde{\Gamma}_2\sqrt{E^2 - E^2_{thr.2}}}$$

ch. 1 = $\pi\Xi$
ch. 2 = ΛK^-

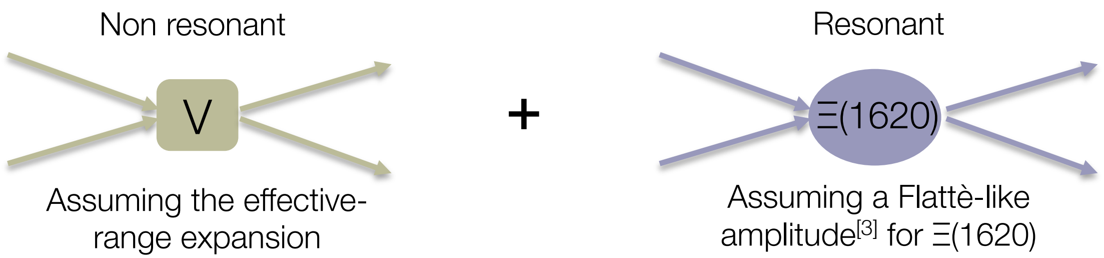
Thanks to Prof. F. Giacosa for the discussion

Modeling the correlation function

$$C(k^*) = N_D \cdot C_{model}(k^*) \cdot C_{bckg}(k^*)$$

$$\lambda_0\, C_0(k^*) + \lambda_1\, C_1(k^*) + \lambda_2\, C_1(k^*) + \cdots$$ [1]

- Genuine correlation of interest
  → Modeled with the Lednicky-Lyuboshits formula[2]



- Contributions from secondaries, impurities, etc..
  → Modeled when possible[4] or assumed flat

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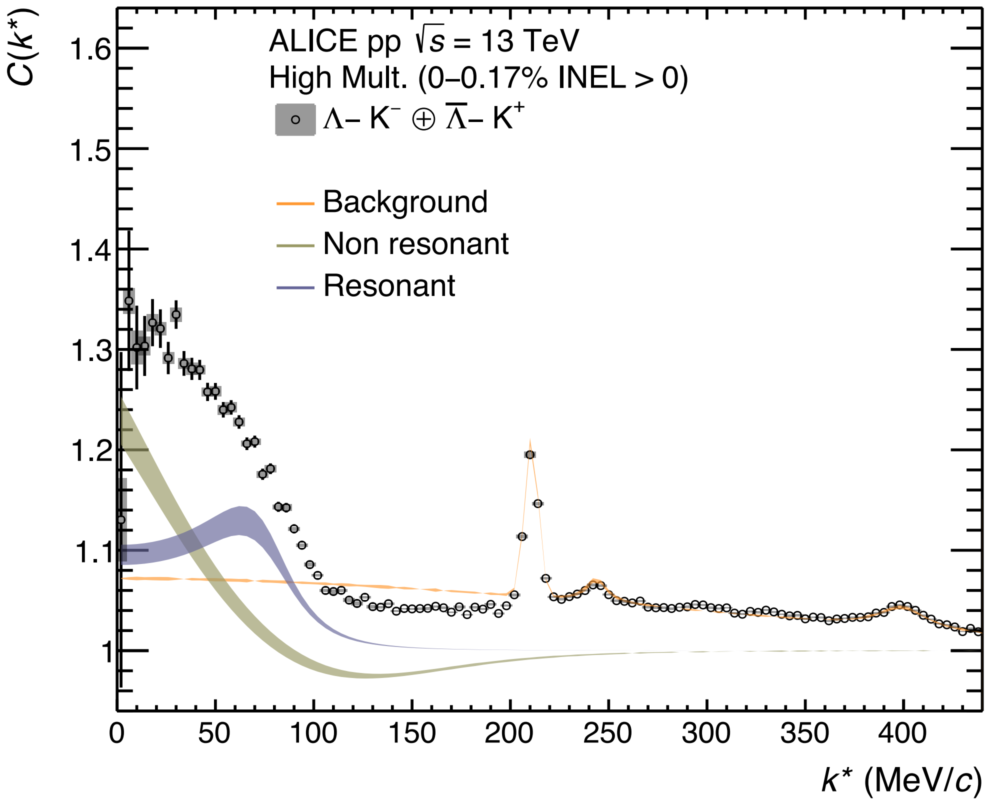

[1] ALICE coll. Phys.Rev. C99 (2019)
[2] R. Lednicky, V. Lyuboshits SJNP 35 (1982)
[2] F. Giacosa et al. EPJA 57 (2021), 12, 336
[4] CATS: D. Mihaylov et al., EPJC 78 (2018), 5, 394

Scattering parameters for ΛK^-

- Indication of an attractive non-resonant interaction
  → In agreement with ALICE Pb-Pb results[1]

- Available models far from converging on similar results

  → Parameters fixed based on SU(3) flavour symmetry, isospin symmetry

  → Mainly anchored to πN or $\bar{K}$N data

  → Ξ(1620) typically lying below threshold

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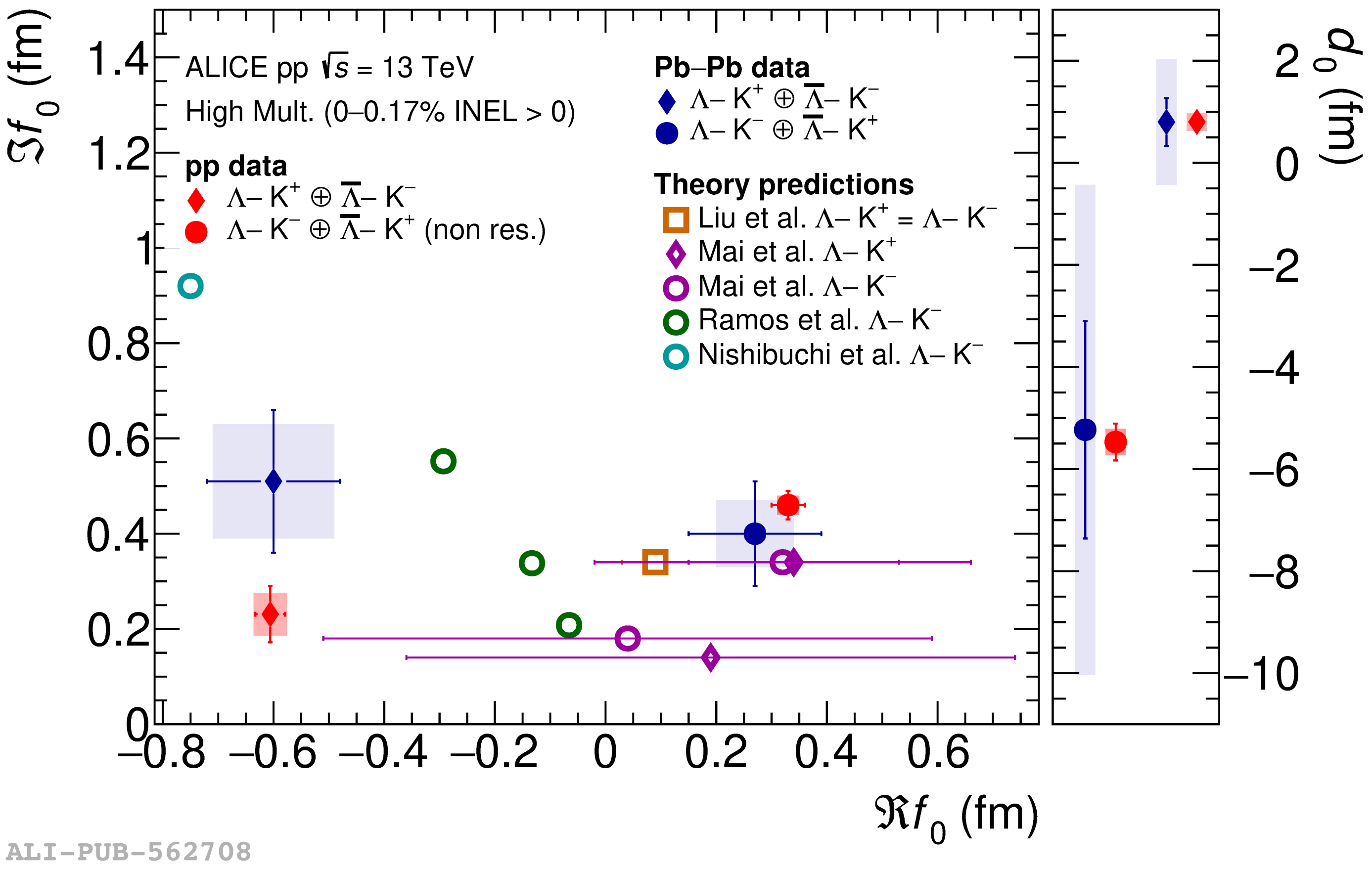


UχPT at LO: Ramos et al. PRL 89 (2002), Nishibuchi et al. EPJ Web Conf 271 (2022)
χPT at NLO: Liu et al. PRD 75 (2007), Mai et al. PRD 80 (2009)

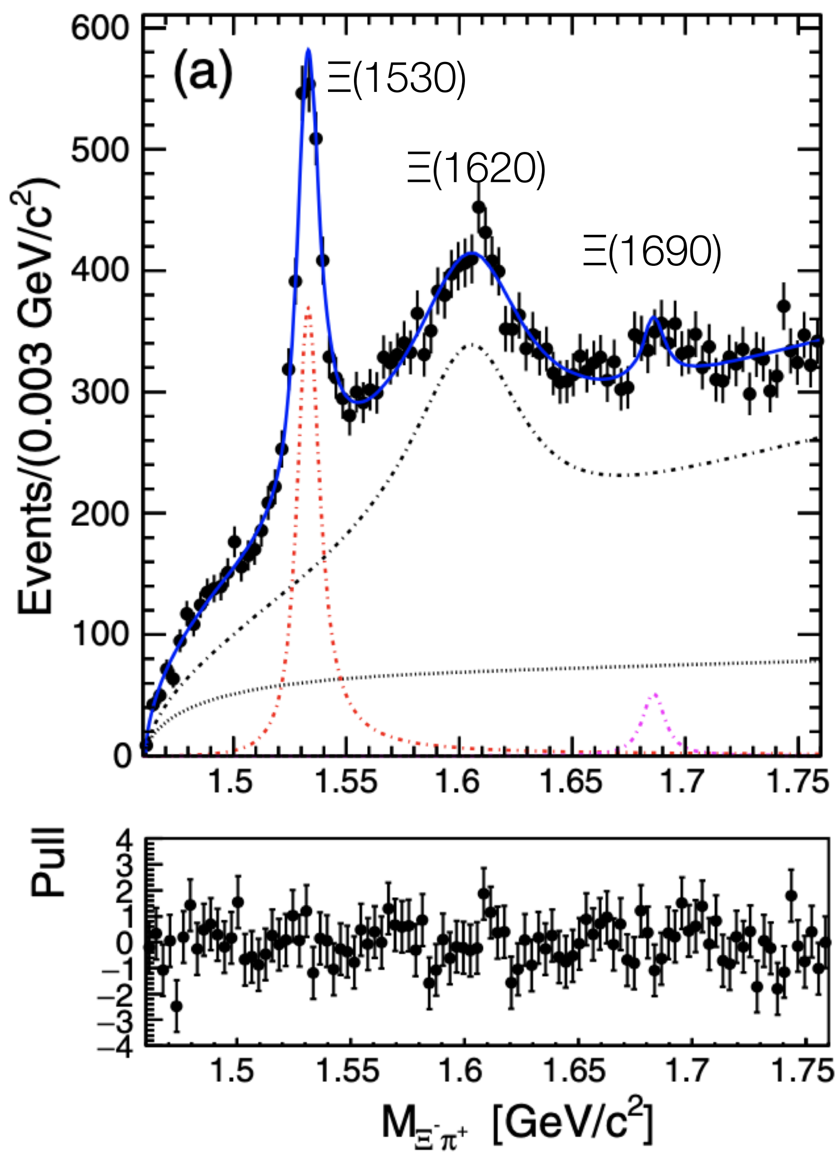
Overview on S=-2 meson-baryon sector

- **Poorly constrained experimentally**
  → Effective lagrangians anchored to S=-1 sector[1]

- **Ξ(1620)** and Ξ(1690)[2] dynamically generated states within coupled-channel models
  → Ξ(1620) observed by Belle in πΞ decay but currently only **1 star in PDG, J^P = ?$^?$, B.R. not quantit. known.**

$$M = 1610.4 \pm 6.0^{+6.1}_{-4.2}\ \mathrm{MeV},$$
$$\Gamma = 59.9 \pm 4.8^{+2.8}_{-7.1}\ \mathrm{MeV}.$$

Belle Coll. PRL 122 (2019)



[1] A. Ramos er al. PRL 89 (2002)
[2] LHCb coll. Sci.Bull. 66 (2021)
[3] A. Feijoo et al. PLB 841 (2023)

LO χPT calculations:
C. Garcia-Recio et al. PLB 582 (2004)
D. Gamermann et al. PRD 84 (2011)
T. Sekihara PTEP 2015 (9) (2015)
T. Nishibuchi and T. Hyodo, EPJ Web Conf 271 (2022)

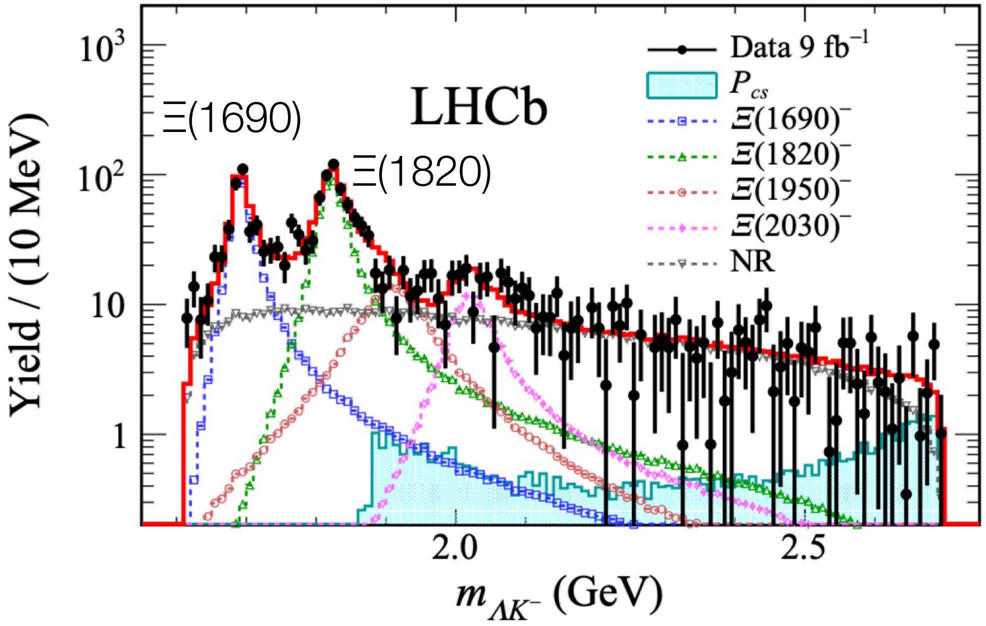
Overview on S=-2 meson-baryon sector

Belle Coll. PRL 122 (2019)

- **Poorly constrained experimentally**
  → Effective lagrangians anchored to S=-1 sector[1]

- **Ξ(1620)** and Ξ(1690)[2] dynamically generated states within coupled-channel models
  → Ξ(1690) observed by LHCb in ΛK decay, currently **3 star in PDG, J^P = ?? , B.R. not quantit. known.**

$$M = 1692.0 \pm 1.3^{+1.2}_{-0.4}\ \text{MeV},$$
$$\Gamma = 25.9 \pm 9.5^{+14.0}_{-13.5}\ \text{MeV}.$$



LHCb, Sci.Bull. 66 (2021)

- Recent development of chiral calculations at NLO[3]

[1] A. Ramos er al. PRL 89 (2002)
[2] LHCb coll. Sci.Bull. 66 (2021)
[3] A. Feijoo et al. PLB 841 (2023)

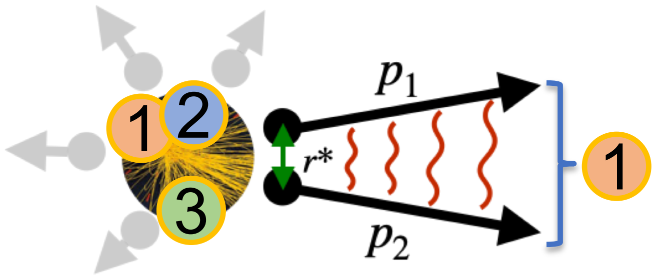
LO χPT calculations:
C. Garcia-Recio et al. PLB 582 (2004)
D. Gamermann et al. PRD 84 (2011)
T. Sekihara PTEP 2015 (9) (2015)
T. Nishibuchi and T. Hyodo, EPJ Web Conf 271 (2022)

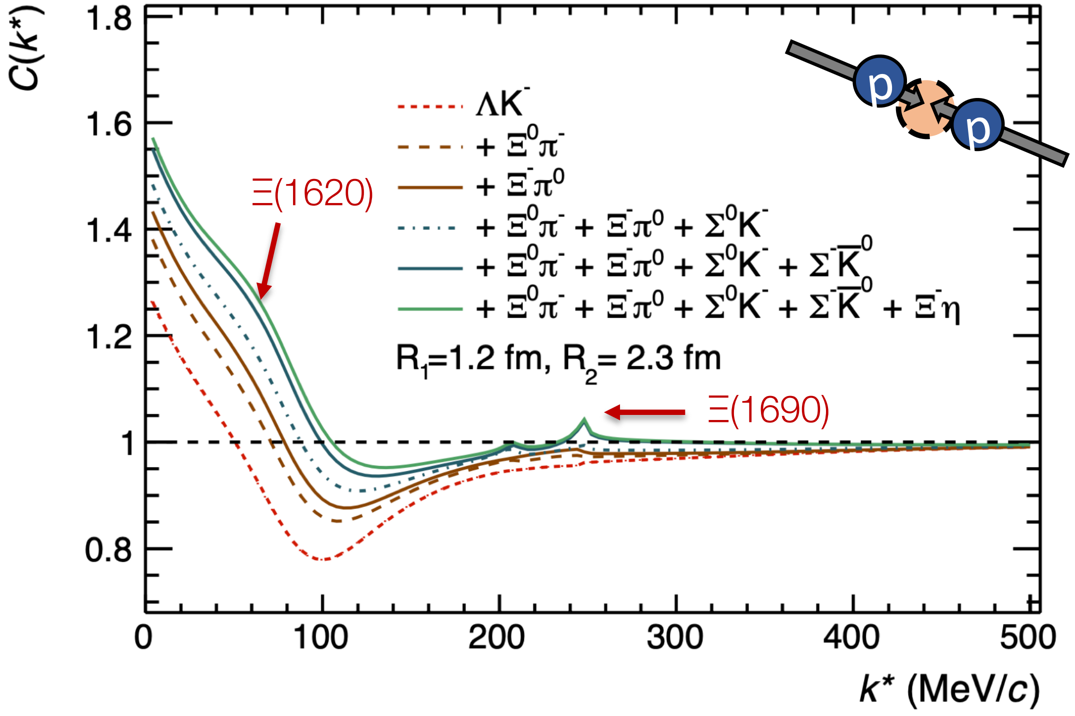
Constraining effective QCD lagrangians with correlations

$$C(k^*) = \underbrace{\int S_1(\vec{r}^*)\,\left|\psi_{1\to1}(\vec{k}^*,\vec{r}^*)\right|^2 d^3r^*}_{\text{elastic}} + \underbrace{\sum_{j\neq1}\omega_j^{\text{prod}}\int S_j(\vec{r}^*)\,\left|\psi_{j\to1}(\vec{k}_j^*,\vec{r}^*)\right|^2 d^3r^*}_{\text{inelastic}}$$

elastic
1 → 1

inelastic
2,3,… → 1





VMS, A. Feijoo et al. PRD 110 (2024) 1, L011505

Wavefunctions obtained in a coupled-channel approach

– State-of-the-art NLO effective lagrangian in UχPT
A. Feijoo et al., PLB 841 (2023)

$$\mathcal{L}^{(1)}_{\phi B} = i\langle\bar{B}\gamma_\mu[D^\mu,B]\rangle - M_0\langle\bar{B}B\rangle - \frac{1}{2}D\langle\bar{B}\gamma_\mu\gamma_5\{u^\mu,B\}\rangle - \frac{1}{2}F\langle\bar{B}\gamma_\mu\gamma_5[u^\mu,B]\rangle\,,$$

$$\mathcal{L}^{(2)}_{\phi B} = b_D\langle\bar{B}\{\chi_+,B\}\rangle + b_F\langle\bar{B}[\chi_+,B]\rangle + b_0\langle\bar{B}B\rangle\langle\chi_+\rangle + d_1\langle\bar{B}\{u_\mu,[u^\mu,B]\}\rangle + d_2\langle\bar{B}[u_\mu,[u^\mu,B]]\rangle + d_3\langle\bar{B}u_\mu\rangle\langle u^\mu B\rangle + d_4\langle\bar{B}B\rangle\langle u^\mu u_\mu\rangle\,.$$

– Ξ(1620) and Ξ(1690) dynamically generated states

Conversion weights ω_j^{prod} and source studies

– Detailed data-driven study using thermal and transport models
ALICE Coll. Eur.Phys.J.C 83 (2023), VMS, A. Feijoo et al. arXiv: 2309.08756

Constraining the S=-2 meson-baryon sector

- State-of-the-art UχPT at NLO available[1]
  - Low energy constants (LECs) fixed to S=-1 sector[2]
  - Two sets of subtraction constants (SCs) values
  - Widths of Ξ(1620) too large wrt to Belle´s results[3]

Use the high-precision femtoscopic data to fix LECs and SCs!

Work in collaboration with:
Dr. A. Feijoo, Dr. I. Vidana, Prof. A. Ramos,
Prof. F. Giacosa,
Prof. T. Hyodo and Dr. Y. Kamiya

[1] A. Feijoo et al., PLB 841 (2023)

Table 3: Comparison of the pole positions between the models: Model I and Model II (in MeV) with their couplings g_i and the corresponding modulus found in $J^P = \frac{1}{2}^-, (I,S) = (\frac{1}{2}, -2)$.

Model I	Ξ(1620)		Ξ(1690)	
M [MeV]	1599.95		1683.04	
Γ [MeV]	158.88		11.51	
	g_i	$\lvert g_i \rvert$	g_i	$\lvert g_i \rvert$
$\pi\Xi$	$2.09 + i1.00$	2.32	$-0.30 - i0.12$	0.33
$\bar{K}\Lambda$	$-2.11 - i0.09$	2.11	$-0.49 + i0.05$	0.50
$\bar{K}\Sigma$	$-0.90 + i0.34$	0.97	$1.57 - i0.24$	1.59
$\eta\Xi$	$-0.23 + i0.13$	0.26	$0.74 - i0.11$	0.74
Model II	Ξ(1620)		Ξ(1690)	
M [MeV]	1608.51		1686.17	
Γ [MeV]	170.00		29.72	
	g_i	$\lvert g_i \rvert$	g_i	$\lvert g_i \rvert$
$\pi\Xi$	$2.11 + i1.07$	2.37	$-0.36 - i0.24$	0.43
$\bar{K}\Lambda$	$-2.10 - i0.09$	2.10	$-0.81 + i0.02$	0.81
$\bar{K}\Sigma$	$-0.86 + i0.38$	0.94	$2.26 + i0.03$	2.26
$\eta\Xi$	$-0.19 + i0.12$	0.23	$1.04 - i0.07$	1.04

[2] A.Feijoo et al PRC 99 (2019)
[3] Belle coll. PRL 122 (2019)

Extension to S=-2 and Q=-1 sector

- The interaction kernel for the S=-2, Q=-1 sector can be built from the S=-2, Q=0 employing isospin symmetry arguments:

$$V_{ij}(S=-2, Q=O) \rightarrow V_{ij}(I=1/2),\ V_{ij}(I=3/2) \rightarrow V_{ij}(S=-2, Q=-1)$$

- Once again, the Bethe-Salpetter equation is solved in the same footing to get the T-matrix:

$$V_{ij} = V_{ij}^{WT} + V_{ij}^{D} + V_{ij}^{C} + V_{ij}^{NLO} \Longrightarrow T = (1 - VG)^{-1} V \Longrightarrow T_{ij}$$

ΛK^- CF data available ⟶ unprecedented opportunity to fit a model for the first time in this sector

$$C(k) \simeq 1 + \int_0^\infty 4\pi r^2 dr S_{12}(r) \Big[\sum_\beta \omega_\beta |\Psi_{\alpha\beta}(r)|^2 - |j_0(kr)|^2 \Big]$$

$$\Psi_{\alpha\beta}(r) = \delta_{\alpha\beta} j_l(k_\alpha r) + \frac{1}{\pi} \int j_l(qr) dq q^2 \frac{1}{E - E_1^\beta(q) - E_2^\beta(q) + i\epsilon} T_{\alpha\beta;l}(q, k_\alpha; E)$$

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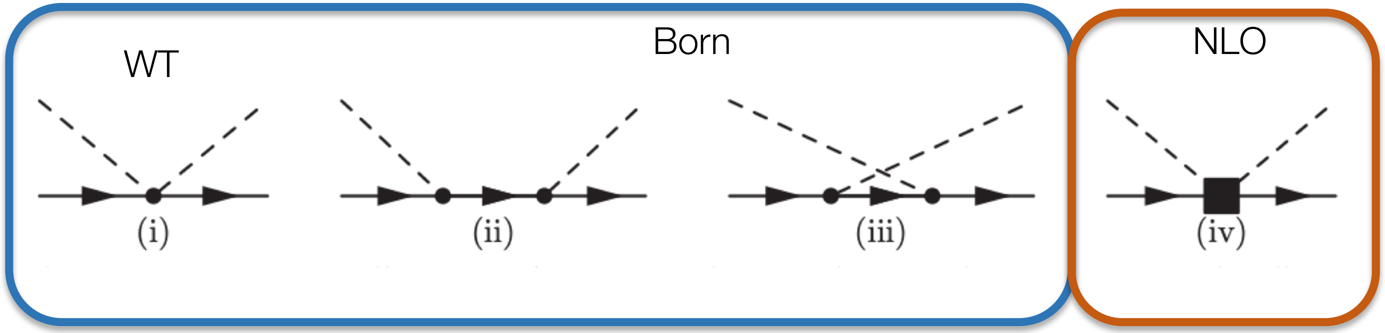
Fantastic LECs and SCs and where to find them

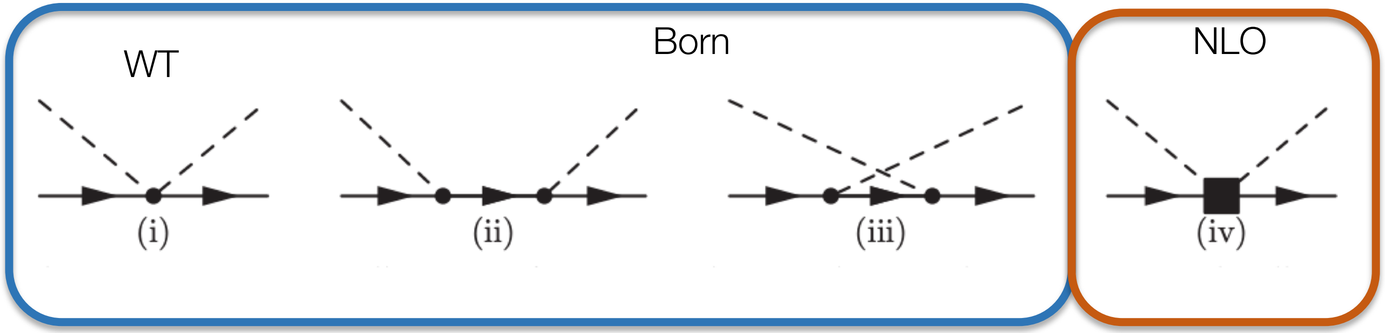


$$\mathcal{L}^{(1)}_{\phi B} = i\langle \bar{B}\gamma_\mu [D^\mu, B]\rangle - M_0\langle \bar{B}B\rangle - \frac{1}{2}D\langle \bar{B}\gamma_\mu\gamma_5\{u^\mu, B\}\rangle - \frac{1}{2}F\langle \bar{B}\gamma_\mu\gamma_5[u^\mu, B]\rangle\,,$$

$$\mathcal{L}^{(2)}_{\phi B} = b_D\langle \bar{B}\{\chi_+, B\}\rangle + b_F\langle \bar{B}[\chi_+, B]\rangle + b_0\langle \bar{B}B\rangle\langle\chi_+\rangle + d_1\langle \bar{B}\{u_\mu, [u^\mu, B]\}\rangle + d_2\langle \bar{B}[u_\mu, [u^\mu, B]]\rangle + d_3\langle \bar{B}u_\mu\rangle\langle u^\mu B\rangle + d_4\langle \bar{B}B\rangle\langle u^\mu u_\mu\rangle\,.$$

[1] A. Feijoo et al., PLB 841 (2023)

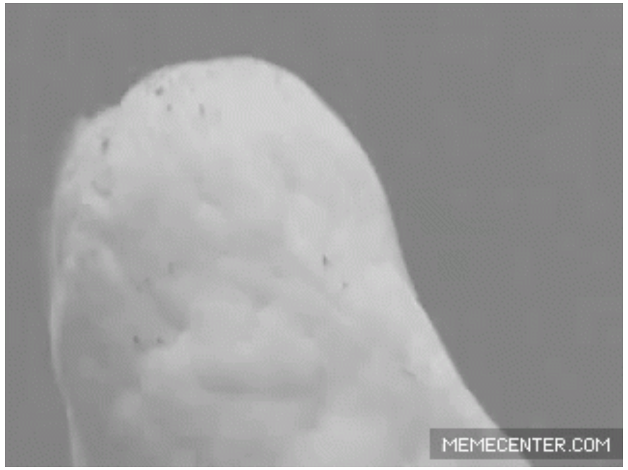
Fantastic LECs and SCs and where to find them



$$\mathcal{L}^{(1)}_{\phi B} = i\langle \bar{B}\gamma_\mu [D^\mu, B]\rangle - M_0\langle \bar{B}B\rangle - \frac{1}{2}D\langle \bar{B}\gamma_\mu\gamma_5\{u^\mu, B\}\rangle - \frac{1}{2}F\langle \bar{B}\gamma_\mu\gamma_5[u^\mu, B]\rangle\,,$$

$$\mathcal{L}^{(2)}_{\phi B} = b_D\langle \bar{B}\{\chi_+, B\}\rangle + b_F\langle \bar{B}[\chi_+, B]\rangle + b_0\langle \bar{B}B\rangle\langle\chi_+\rangle + d_1\langle \bar{B}\{u_\mu, [u^\mu, B]\}\rangle + d_2\langle \bar{B}[u_\mu, [u^\mu, B]]\rangle + d_3\langle \bar{B}u_\mu\rangle\langle u^\mu B\rangle + d_4\langle \bar{B}B\rangle\langle u^\mu u_\mu\rangle\,.$$

Overall 12 input parameters to be fixed!



[1] A. Feijoo et al., PLB 841 (2023)

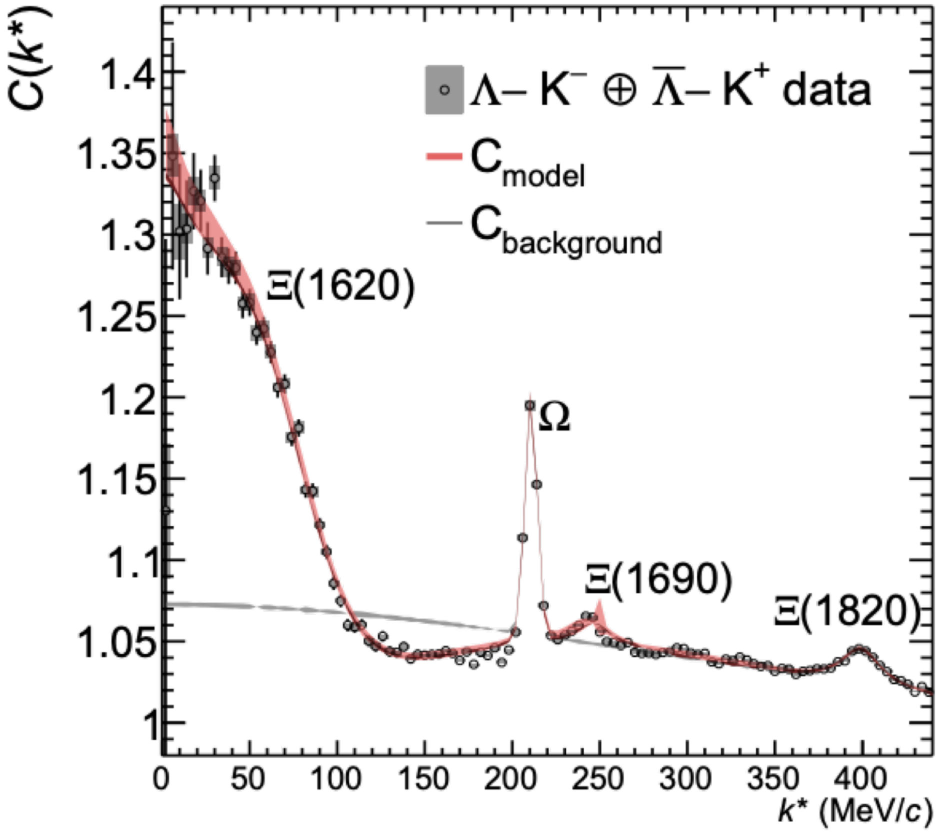
Femtoscopy era in the S=-2 meson-baryon sector

- First combined effort in constraining the input parameters of an effective chiral lagrangian to correlation data

TABLE I. Extracted fit parameters with LECs and subtraction constants of the VBC $S = -2$ meson-baryon interaction at NLO and normalization constant N_D. The bootstrap method [62–64] was employed to determine the errors of the parameters.

$a_{\Xi\pi}$	-2.96 ± 0.11
$a_{\Lambda\bar{K}}$	-1.87 ± 0.10
$a_{\Sigma\bar{K}}$	-1.32 ± 0.02
$a_{\Xi\eta}$	-2.42 ± 0.03
f/f_π	1.000 ± 0.001
b_0 [GeV^{-1}]	-2.997 ± 0.002
b_D [GeV^{-1}]	1.20 ± 0.09
b_F [GeV^{-1}]	-0.30 ± 0.12
d_1 [GeV^{-1}]	-0.69 ± 0.18
d_2 [GeV^{-1}]	-0.21 ± 0.06
d_3 [GeV^{-1}]	0.08 ± 0.20
d_4 [GeV^{-1}]	-0.39 ± 0.05
N_D	1.0015 ± 0.0004

VMS, A. Feijoo et al. PRD 110 (2024) 1, L011505



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Prof. T. Hyodo and Dr. Y. Kamiya

Femtoscopy era in the S=-2 meson-baryon sector

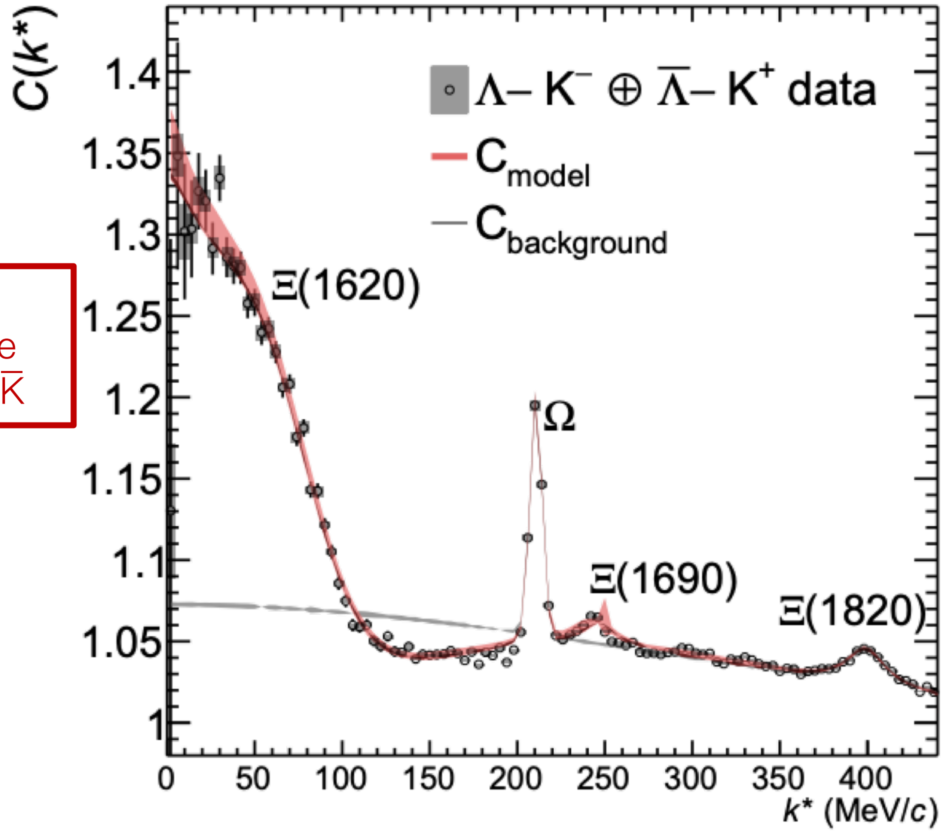
- First **combined effort in constraining** the input parameters of an **effective chiral lagrangian to correlation data**
- How does the Ξ(1620) pole scenario look like?

mass M:	1612.68 MeV		1670.28 MeV	
width Γ:	24.57 MeV		7.44 MeV	
Riemann sheet:	$(---+++)$		$(---+++)$	
	$\lvert g_i \rvert$	$\lvert g_i^2 dG/dE \rvert$	$\lvert g_i \rvert$	$\lvert g_i^2 dG/dE \rvert$
$\pi^-\Xi^0(1454)$	0.51	0.014	0.22	0.002
$\pi^0\Xi^-(1456)$	0.36	0.007	0.39	0.007
$K^-\Lambda(1609)$	0.94	0.162	0.07	0.000
$K^-\Sigma^0(1686)$	0.17	0.002	2.20	0.761
$\bar{K}^0\Sigma^-(1695)$	0.21	0.003	1.37	0.230
$\eta\Xi^-(1868)$	5.86	0.937	0.05	0.000
Experimental Ξ^*:	Ξ(1620) [18]		Ξ(1690) [56]	
mass M:	$1610.4 \pm 6.0^{+5.9}_{-3.5}$ MeV		1690 ± 10 MeV	
width Γ:	$59.9 \pm 4.8^{+2.8}_{-3.0}$ MeV		20 ± 15 MeV	

Ξ(1620) pole
Mainly molecular nature
composed of ηΞ and $\Lambda\bar{K}$

Ξ(1690) pole
Virtual state
Mainly coupled to $\bar{K}\Sigma$

VMS, A. Feijoo et al. PRD 110 (2024) 1, L011505



Work in collaboration with:
Dr. A. Feijoo, Dr. I. Vidana, Prof. A. Ramos,
Prof. F. Giacosa,
Prof. T. Hyodo and Dr. Y. Kamiya

Subtraction constants

- Unitarized scattering amplitude from Chiral Lagrangian (***WT+Born+NLO***)

$$V_{ij} = V_{ij}^{WT} + V_{ij}^{D} + V_{ij}^{C} + V_{ij}^{NLO} \Longrightarrow T = (1 - VG)^{-1}V \Longrightarrow T_{ij}$$

Only S-wave contribution is taken into account

$$G_l = \frac{2M_l}{(4\pi)^2}\left\{a_l(\mu)+\ln\frac{M_l^2}{\mu^2}+\frac{m_l^2-M_l^2+s}{2s}\ln\frac{m_l^2}{M_l^2}+\frac{q_{\rm cm}}{\sqrt{s}}\ln\left[\frac{(s+2\sqrt{s}q_{\rm cm})^2-(M_l^2-m_l^2)^2}{(s-2\sqrt{s}q_{\rm cm})^2-(M_l^2-m_l^2)^2}\right]\right\}$$

$$a_{\pi^0\Xi^0} = a_{\pi^+\Xi^-} = a_{\pi\Xi}$$

$$a_{\bar{K}^0\Lambda} = a_{\bar{K}\Lambda}$$

$$a_{\bar{K}^0\Sigma^0} = a_{K^-\Sigma^+} = a_{\bar{K}\Sigma}$$

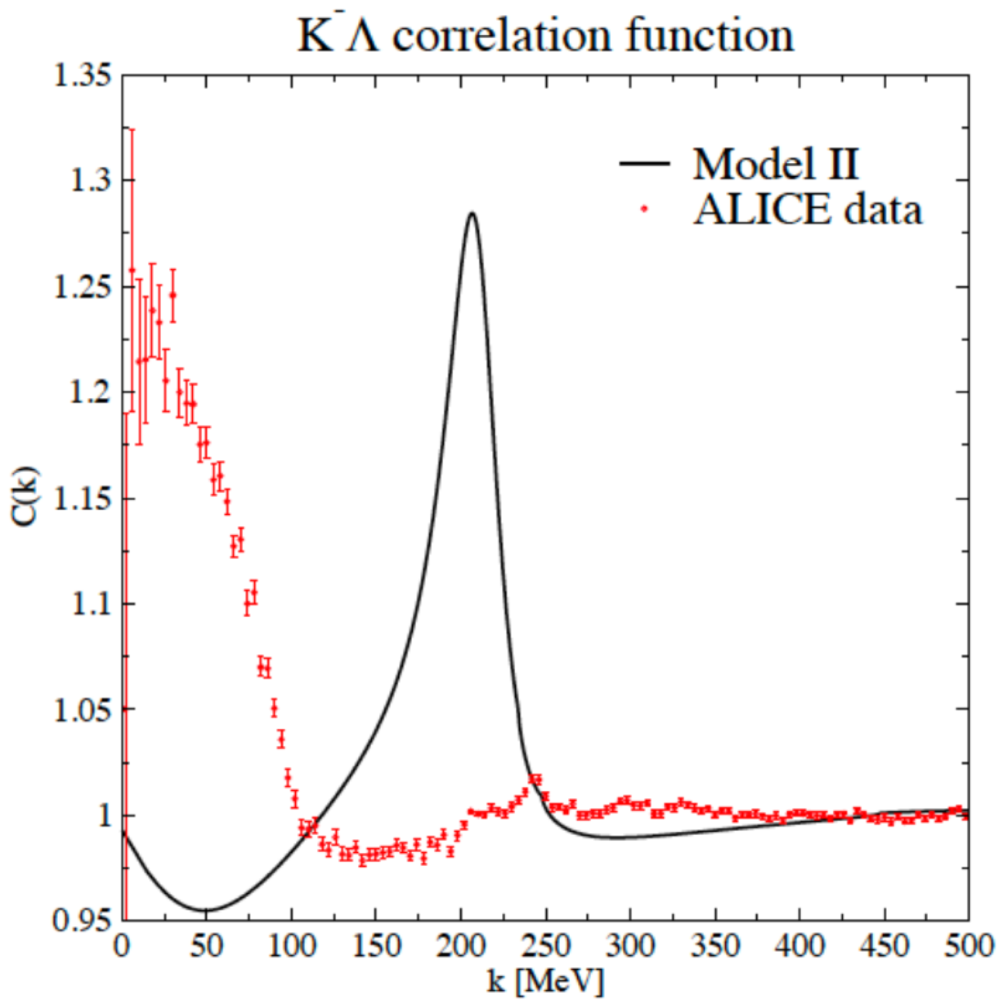
$$a_{\eta\Xi^0} = a_{\eta\Xi}$$

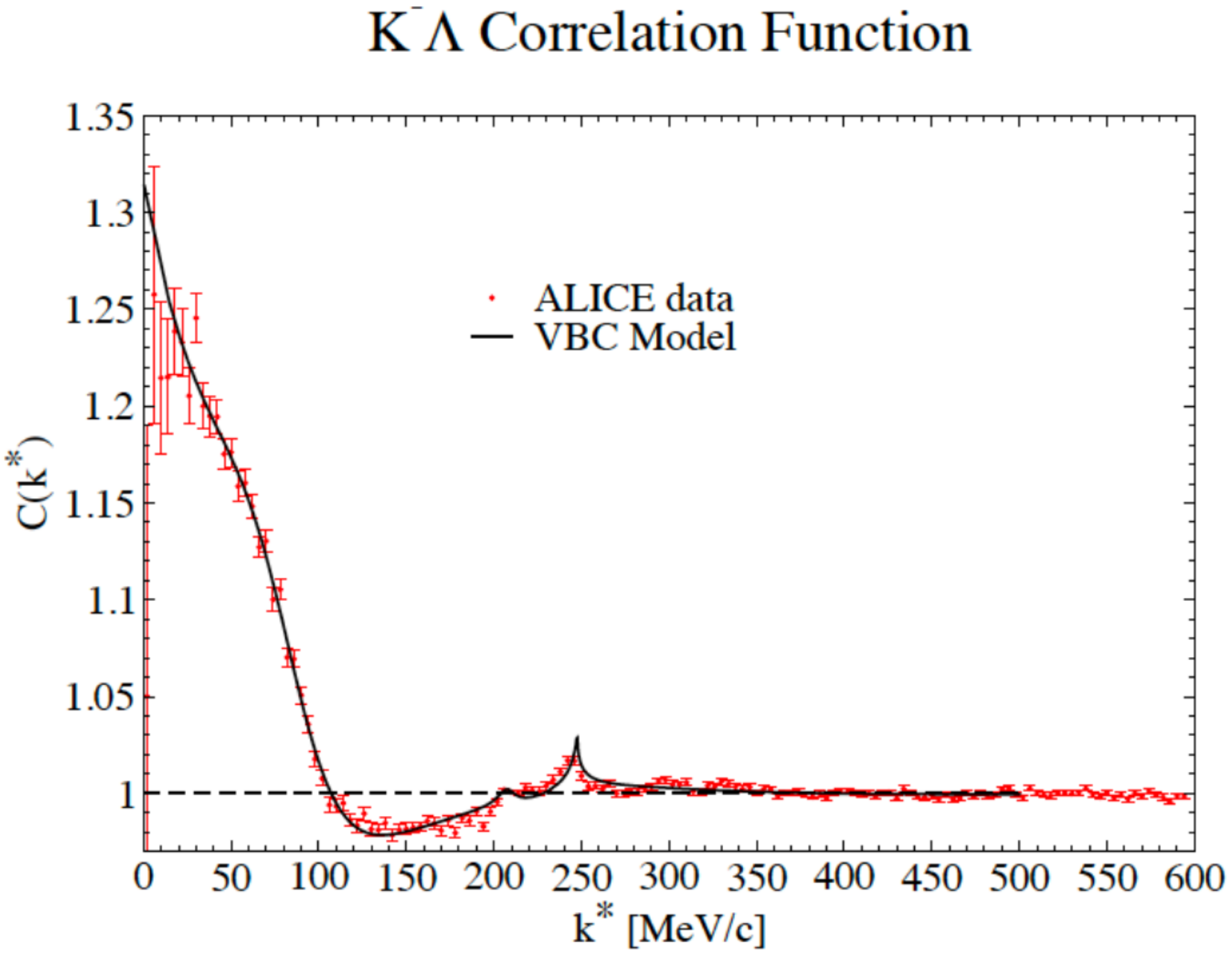
With isospin symmetry

subtraction constants for the dimensional regularization scale $\mu = 630MeV$ in all the "l" channels.

(Thanks to Dr. Feijoo)

Comparison BCN and VBC model





The ΛK⁺ correlation in pp collisions

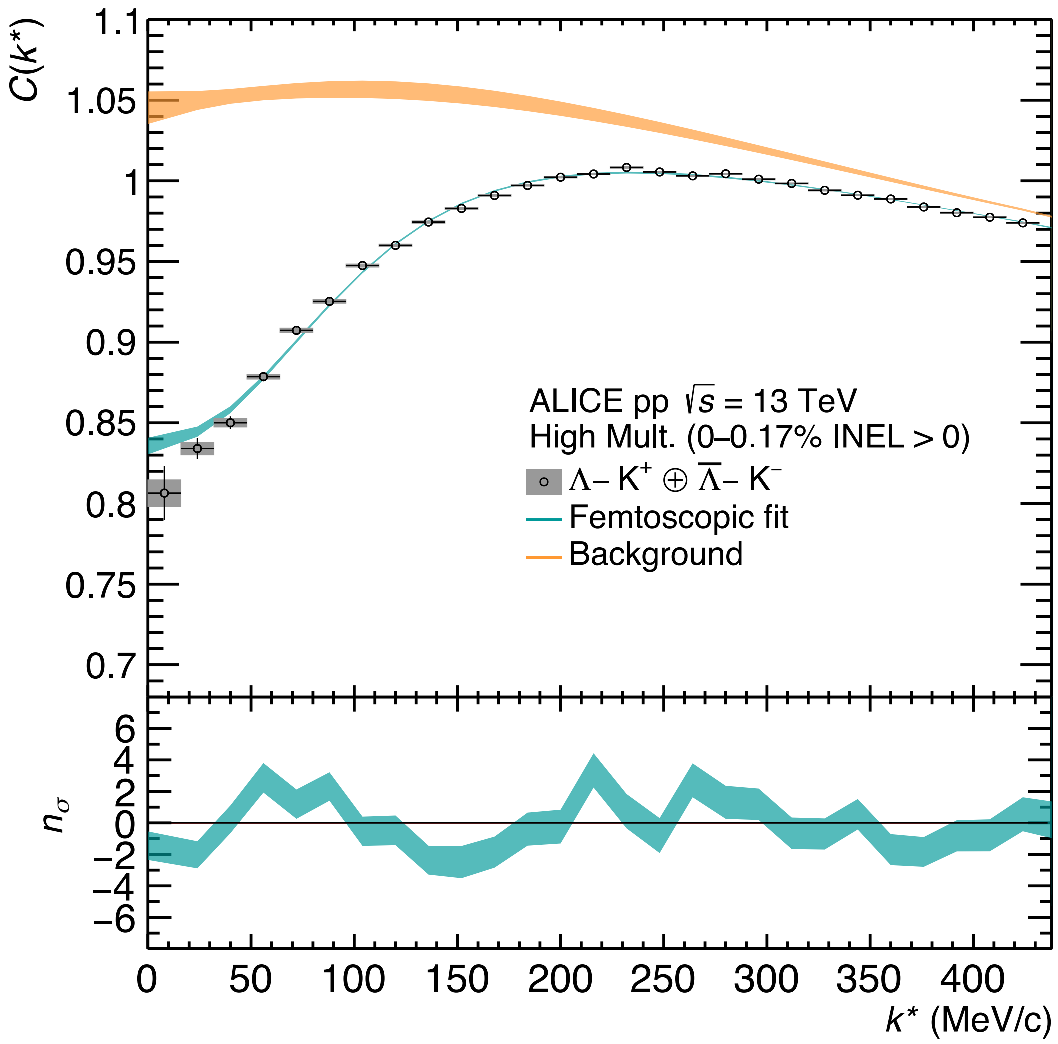
- Correlation below unity at low k* → Repulsive interaction

$$C(k^*) = N_D \cdot C_{model}(k^*) \cdot C_{bckg}(k^*)$$

- Residual background due to initial parton scattering
  → Typically observed in meson-baryon and baryon-antibaryon correlations[1,2]
  → Modeled using **Monte-carlo simulations**[2]

- Genuine correlation modeled with the Lednicky-Lyuboshits formula[2,3]
  → Assuming the **scattering amplitude** within the **effective range expansion**

ALICE Coll. PLB 845 (2023) 138145

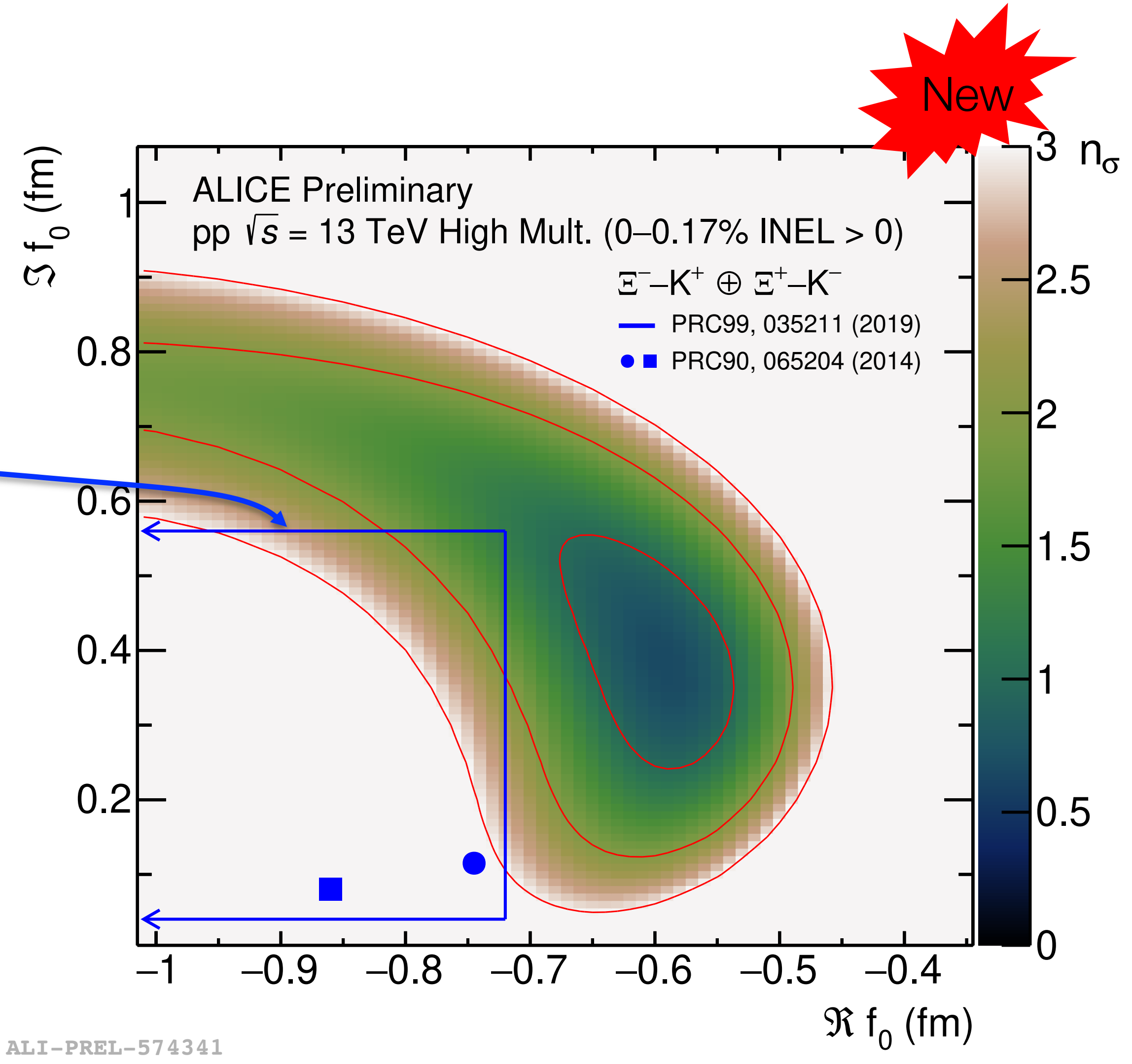


[1] ALICE Coll. Phys.Rev.Lett. 124 (2020)
[2] ALICE Coll. PLB 829 (2022)

Constraining the scattering parameters of $\Xi^{-}K^{+}$ pairs

- Comparison of data with modeling assuming different values of $(\Re f_0, \Im f_0)$
  - Delivered in terms of number of standard deviations (nσ) 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

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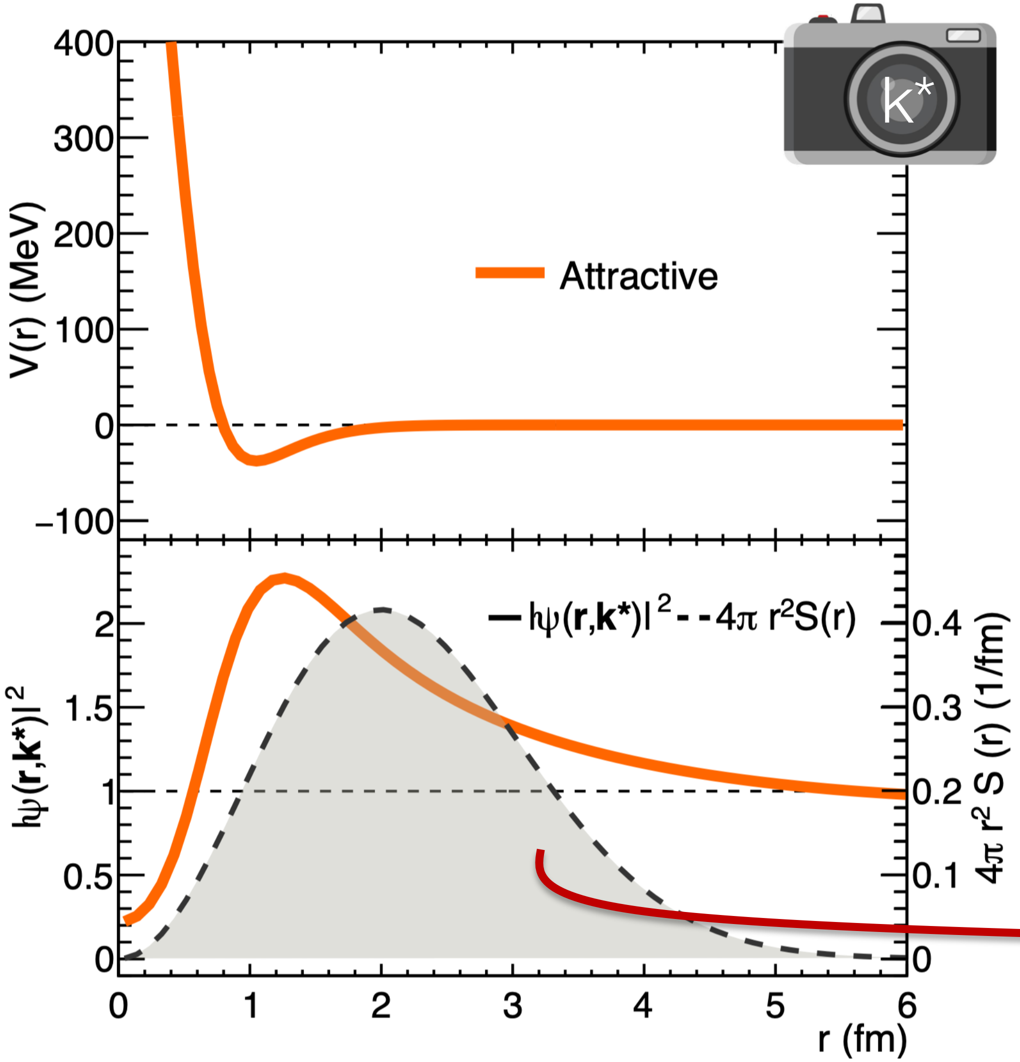
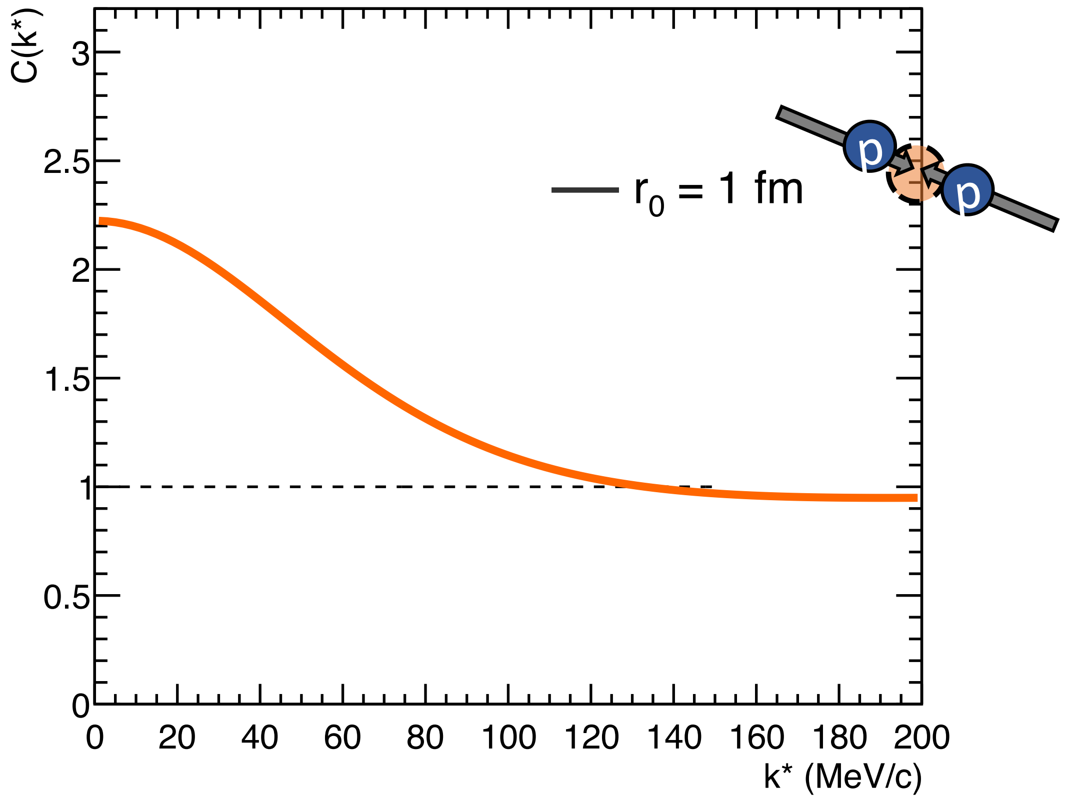
From small to large colliding systems

"What's inside the integral"



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



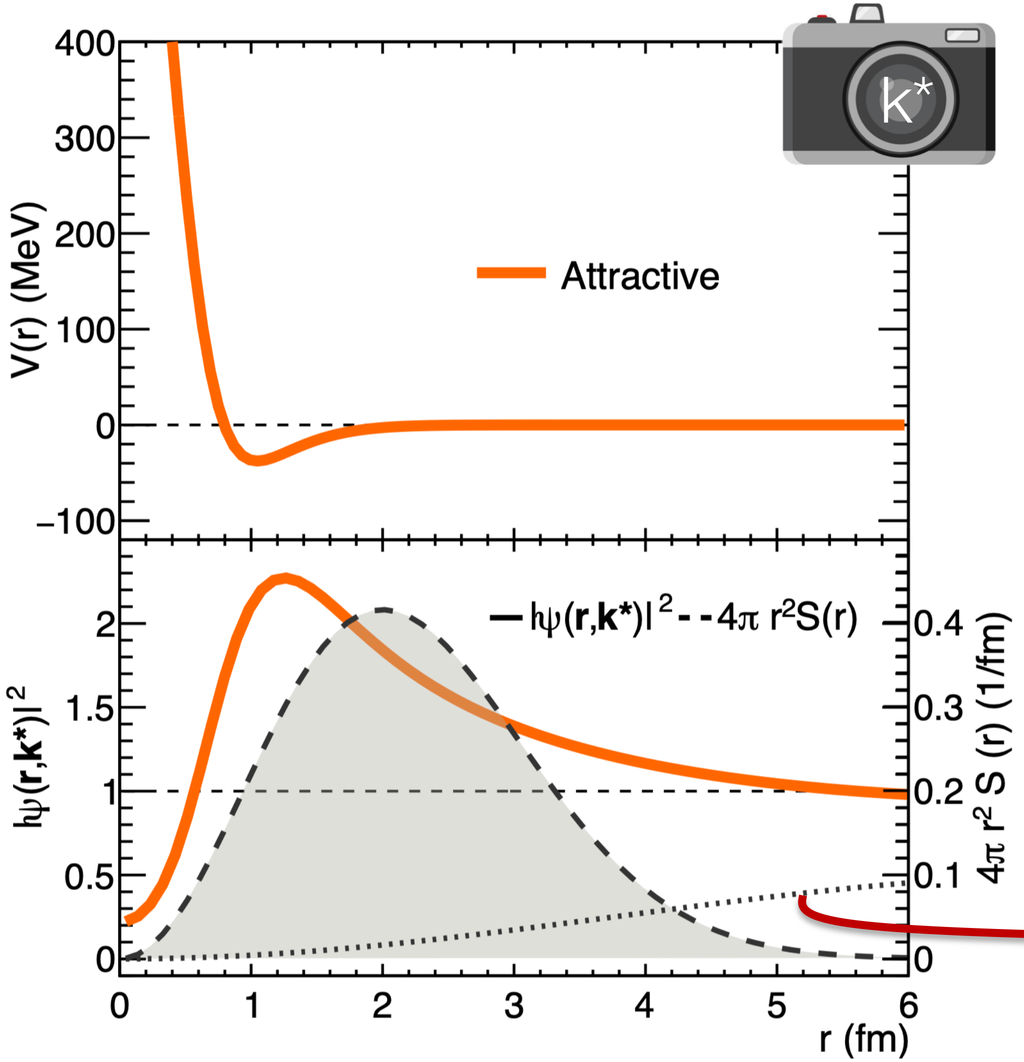
Accessing short-range dynamics in pp collisions

L. Fabbietti, VMS and O. Vazquez Doce ARNPS 71 (2021), 377-402

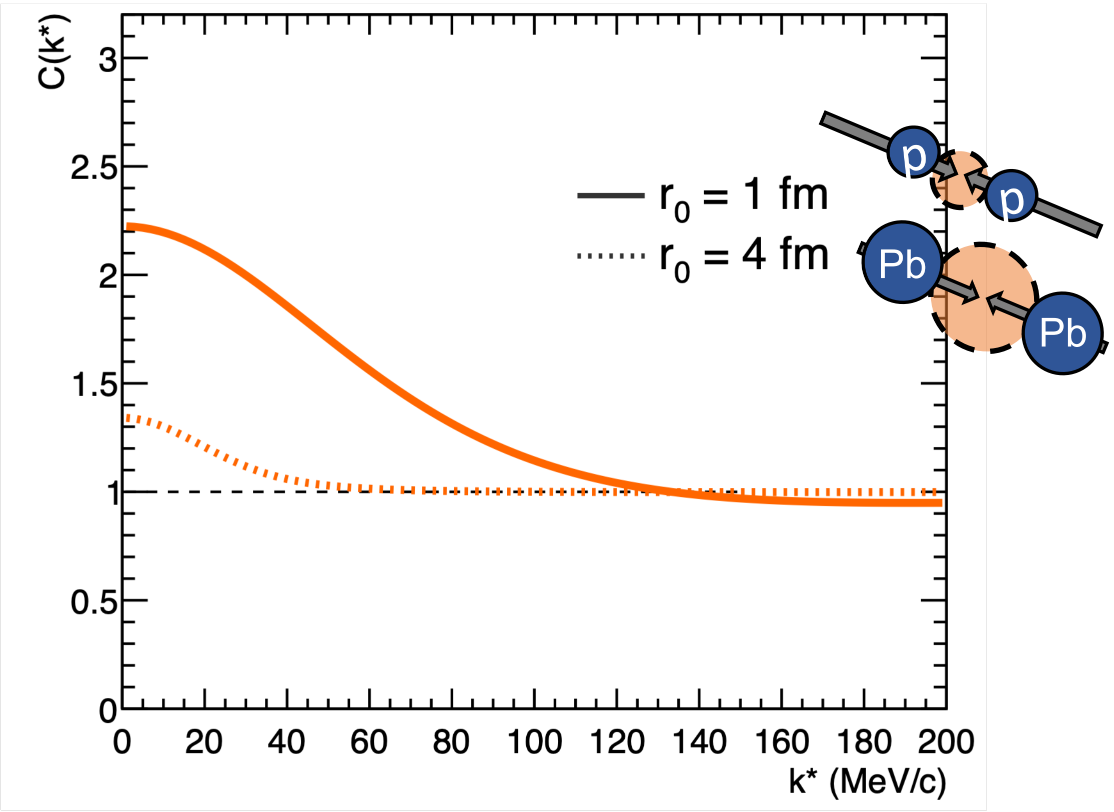
valentina.mantovani-sarti@tum.de

From small to large colliding systems

"What's inside the integral"



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

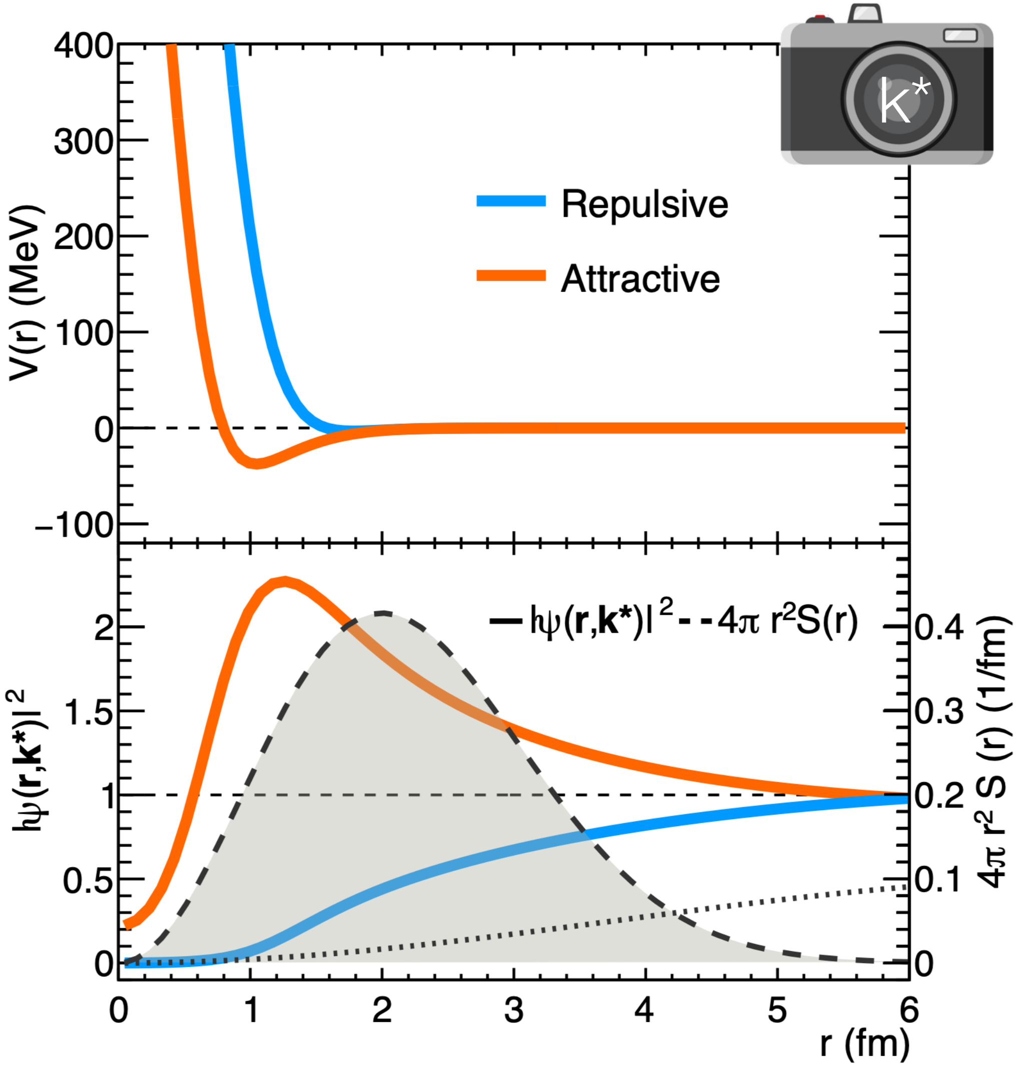


Decrease of signal strength for large source sizes

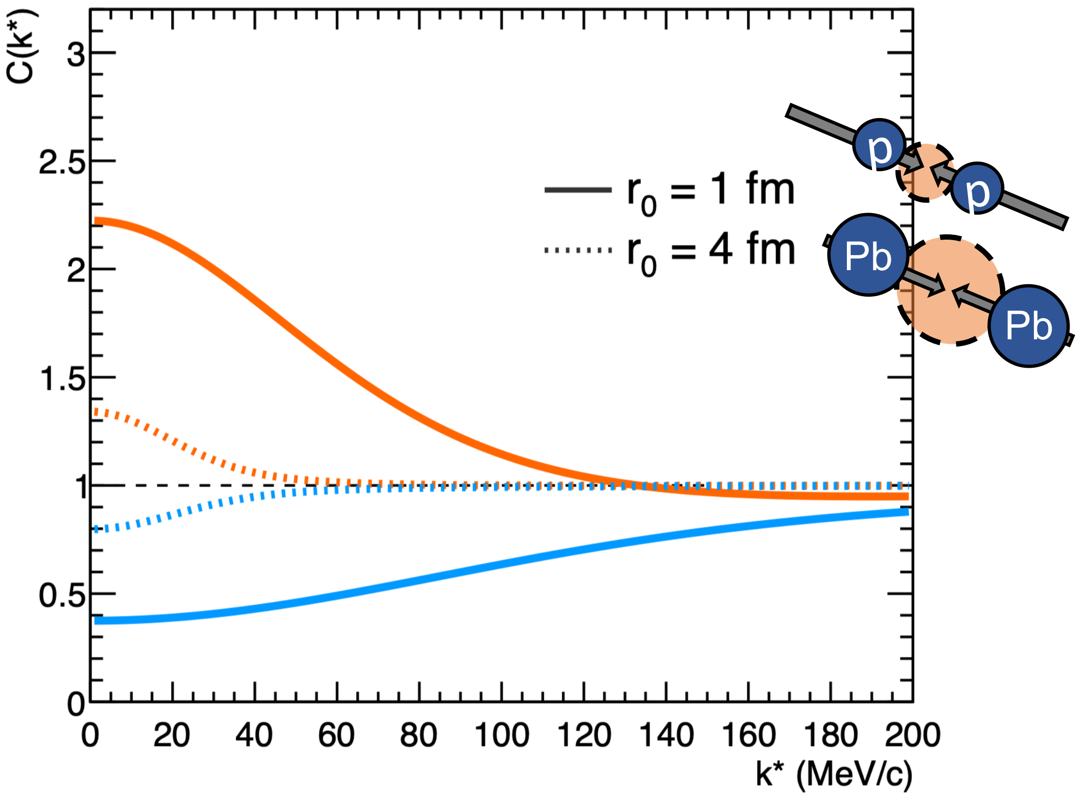
L. Fabbietti, VMS and O. Vazquez Doce ARNPS 71 (2021), 377-402

From small to large colliding systems

"What's inside the integral"



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

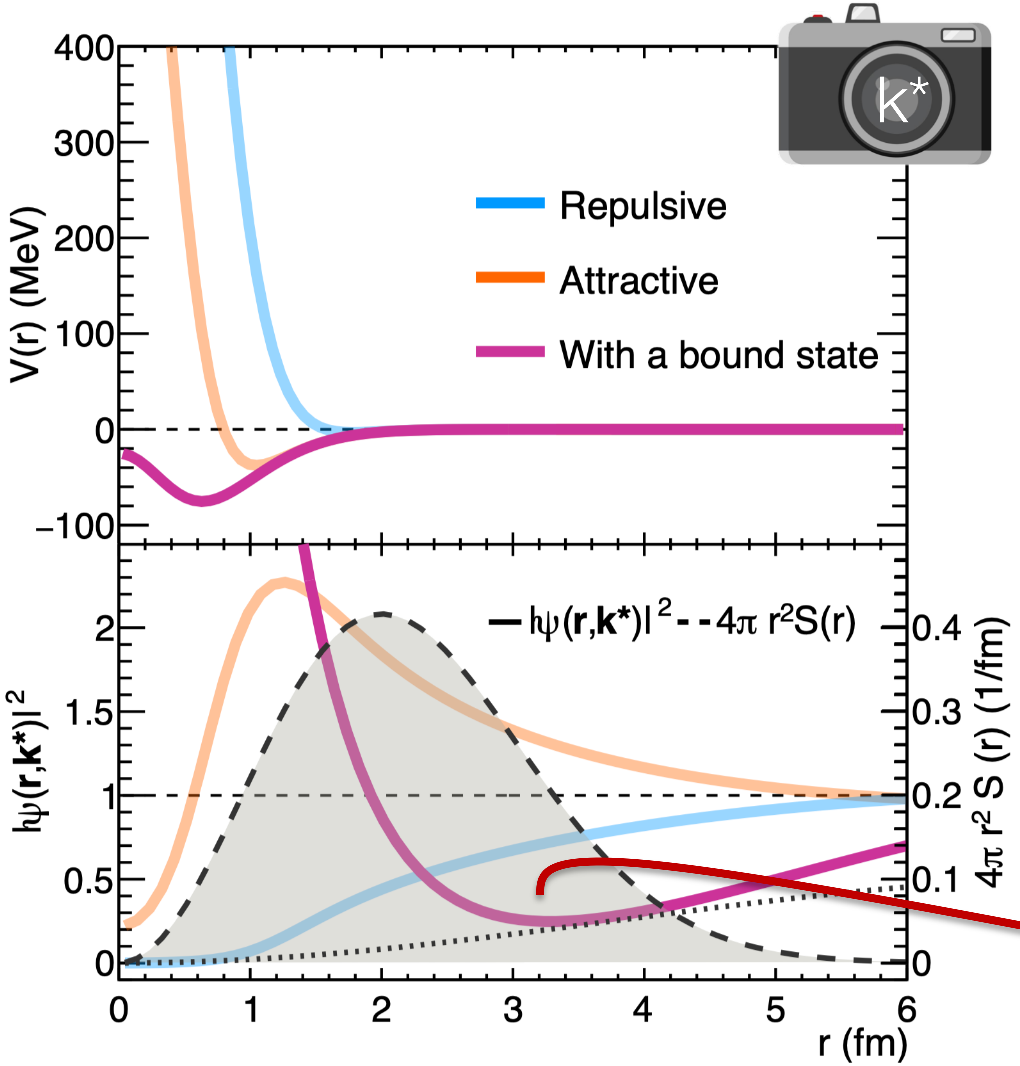


$$C(k^*) \begin{cases} > 1 & \text{Attractive (no BS)} \\ < 1 & \text{Repulsive} \end{cases}$$

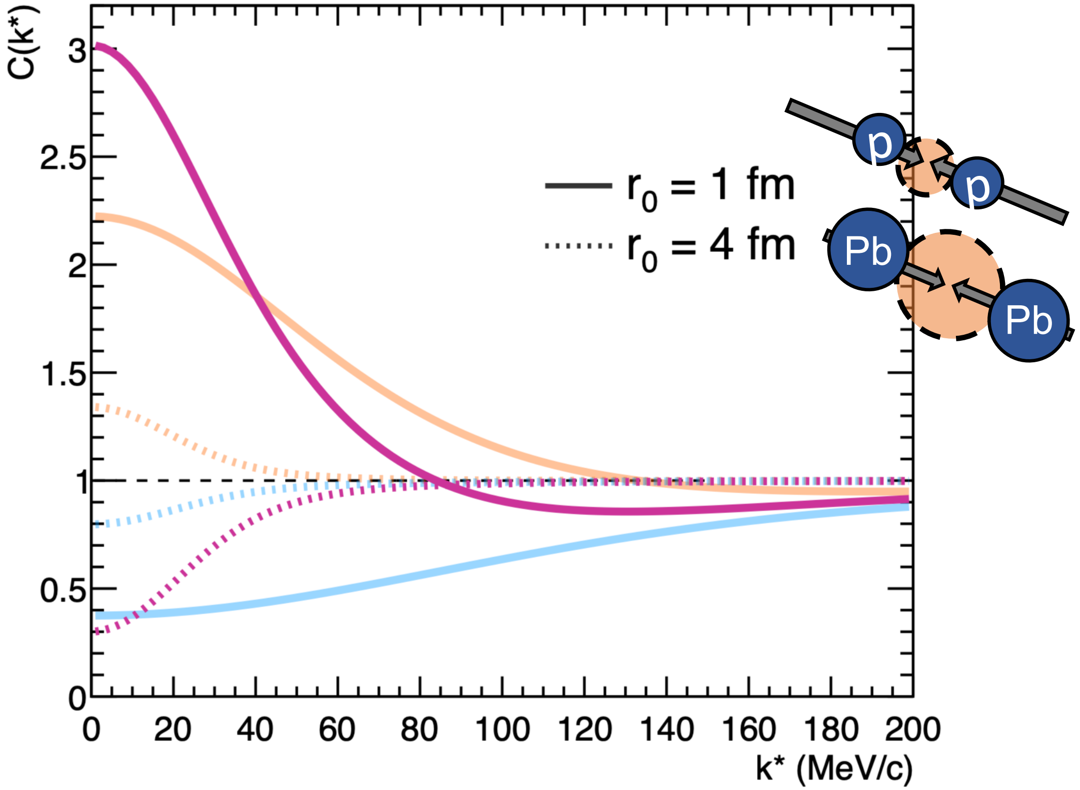
L. Fabbietti, VMS and O. Vazquez Doce ARNPS 71 (2021), 377-402

A clear signature for bound states

"What's inside the integral"



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



Correlation flips around unity when a bound state is present!

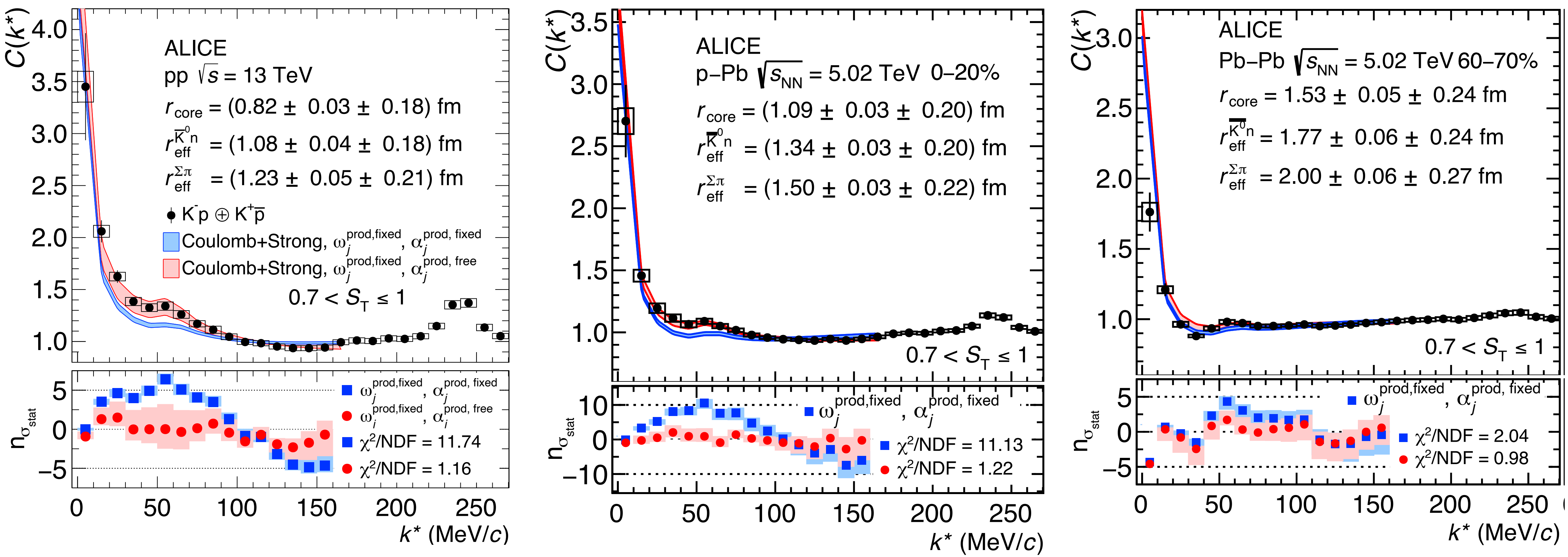
L. Fabbietti, VMS and O. Vazquez Doce ARNPS 71 (2021), 377-402

K⁻–p femtoscopy in different colliding systems

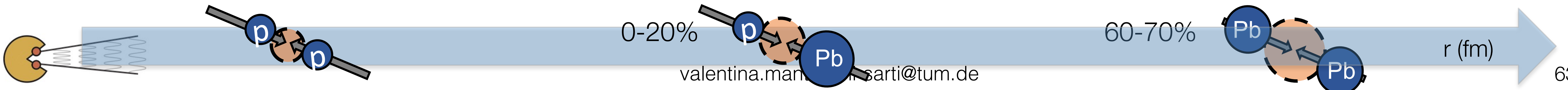
Fit the scaling factor needed for the model to reproduce the data

$$C(k^*) = \int S(r)\,\left|\psi_{1\to1}(k^*,r)\right|^2 d^3r + \sum_{j=\Sigma\pi,\bar{K}^0 n} \alpha_j \cdot \omega_j^{prod} \int S_j(r)\,\left|\psi_{j\to1}(k_j^*,r)\right|^2 d^3r$$

χEFT Kyoto model:
Ikeda et al. NPA 881 (2012), PLB706 (2011)
Kamiya et al. PRL 124 (2020)
Mihayara et al. PRC95 (2017)



ALICE Coll. Eur.Phys.J.C 83 (2023) 4, 340



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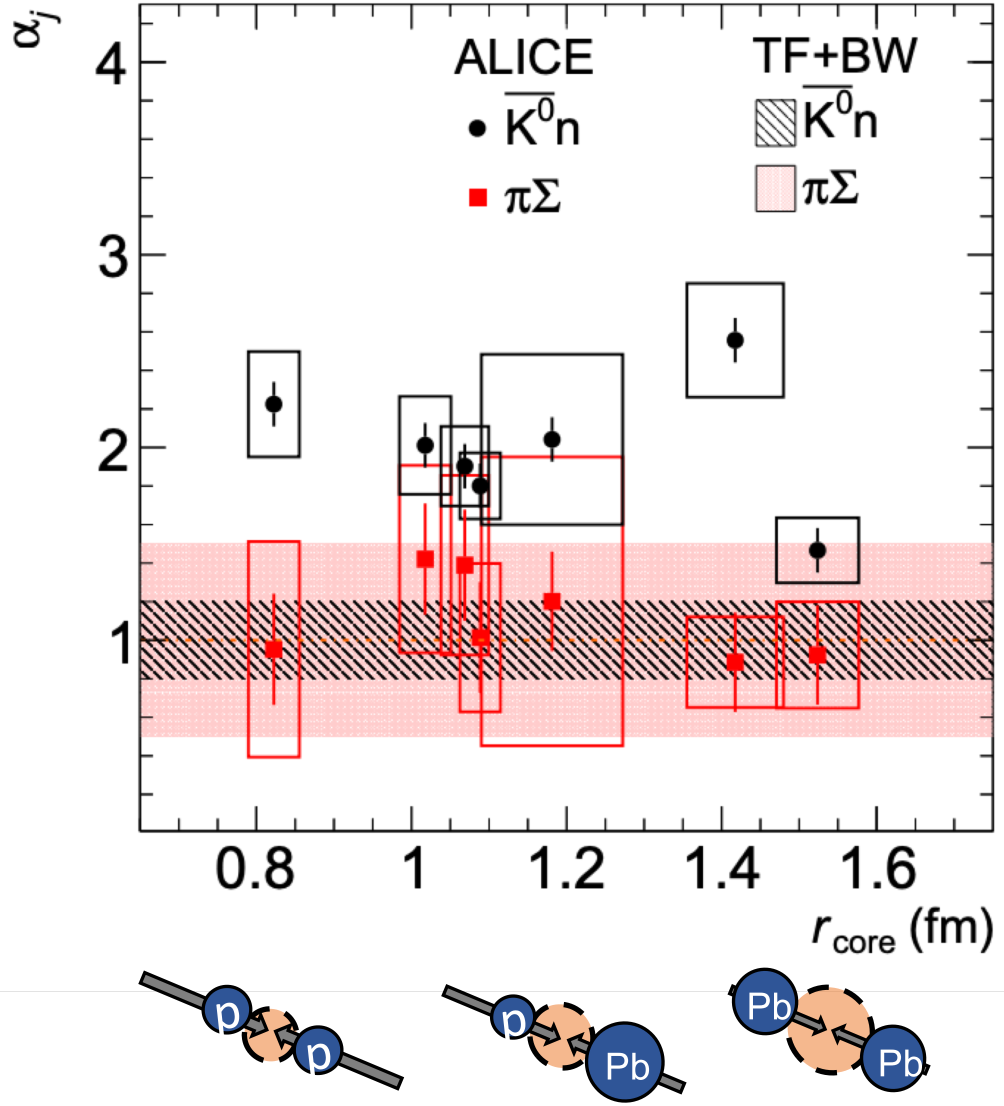
Extracted strong weights for Σπ and $\overline{K}^0$ n channels

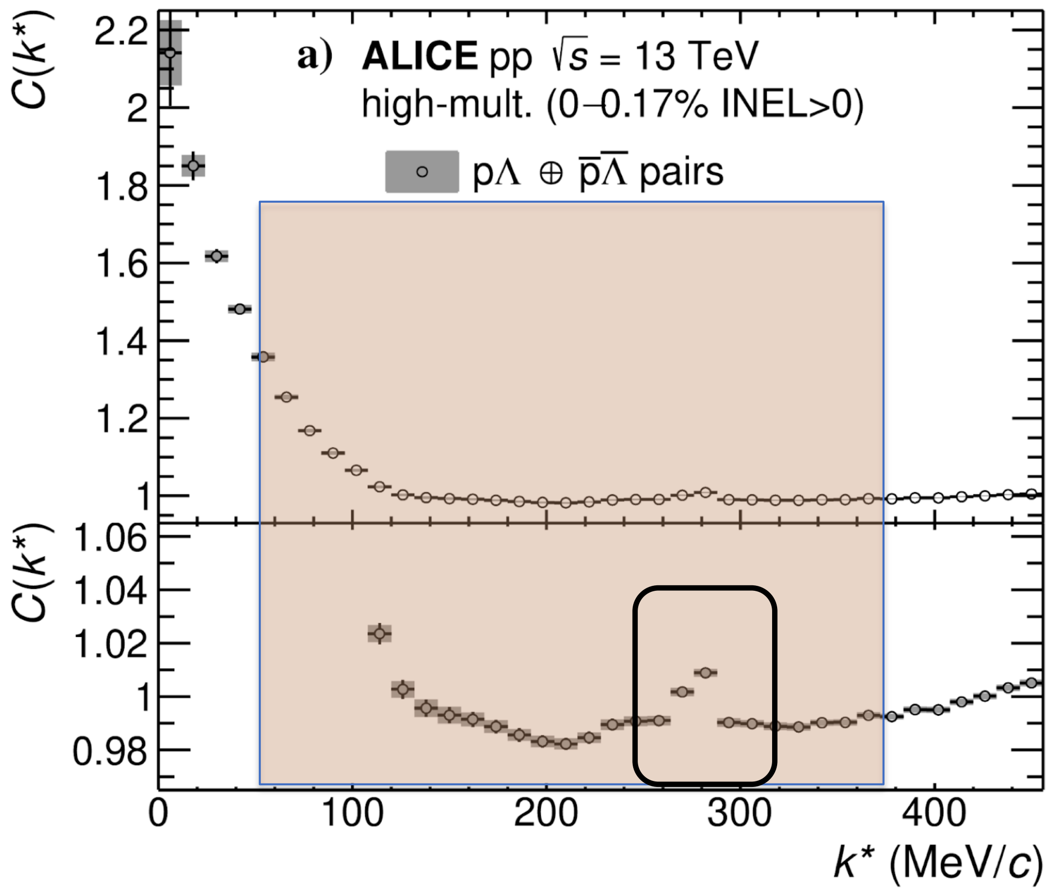
Unique constraint and direct access to $K^-p \leftrightarrow \overline{K}^0 n$ and $K^-p \leftrightarrow \Sigma\pi$ dynamics

- Σπ consistent with unity
- deviation from unity for $\overline{K}^0$ n
  - K^-p - $\overline{K}^0$ n coupling too weak in chiral potentials
  - update the scattering amplitude of KN–πΣ–πΛ system by including correlation measurements to available kaonic hydrogen and scattering data

ALICE Coll. Eur.Phys.J.C 83 (2023) 4, 340

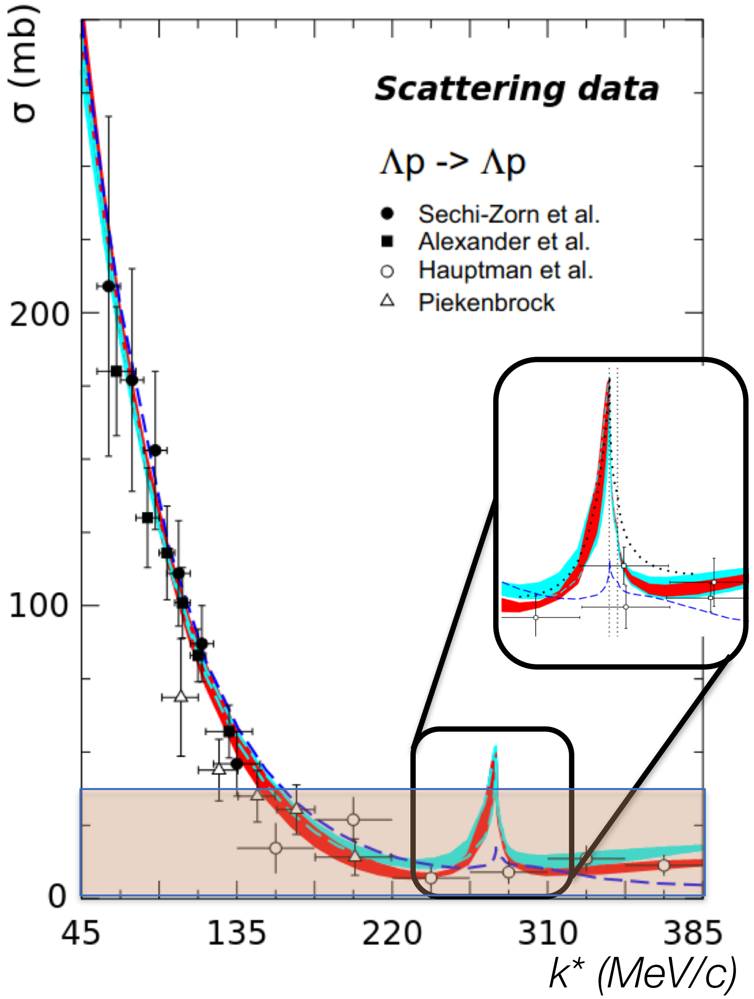


High-precision data on ΛN-ΣN interaction at LHC



ALICE Coll. PLB 833 (2022), 137272

- Extension of kinematic range
- Measurement down to zero momentum
- Factor 20 improved precision in data (<1%)
- First experimental evidence of ΣN cusp in 2-body channel

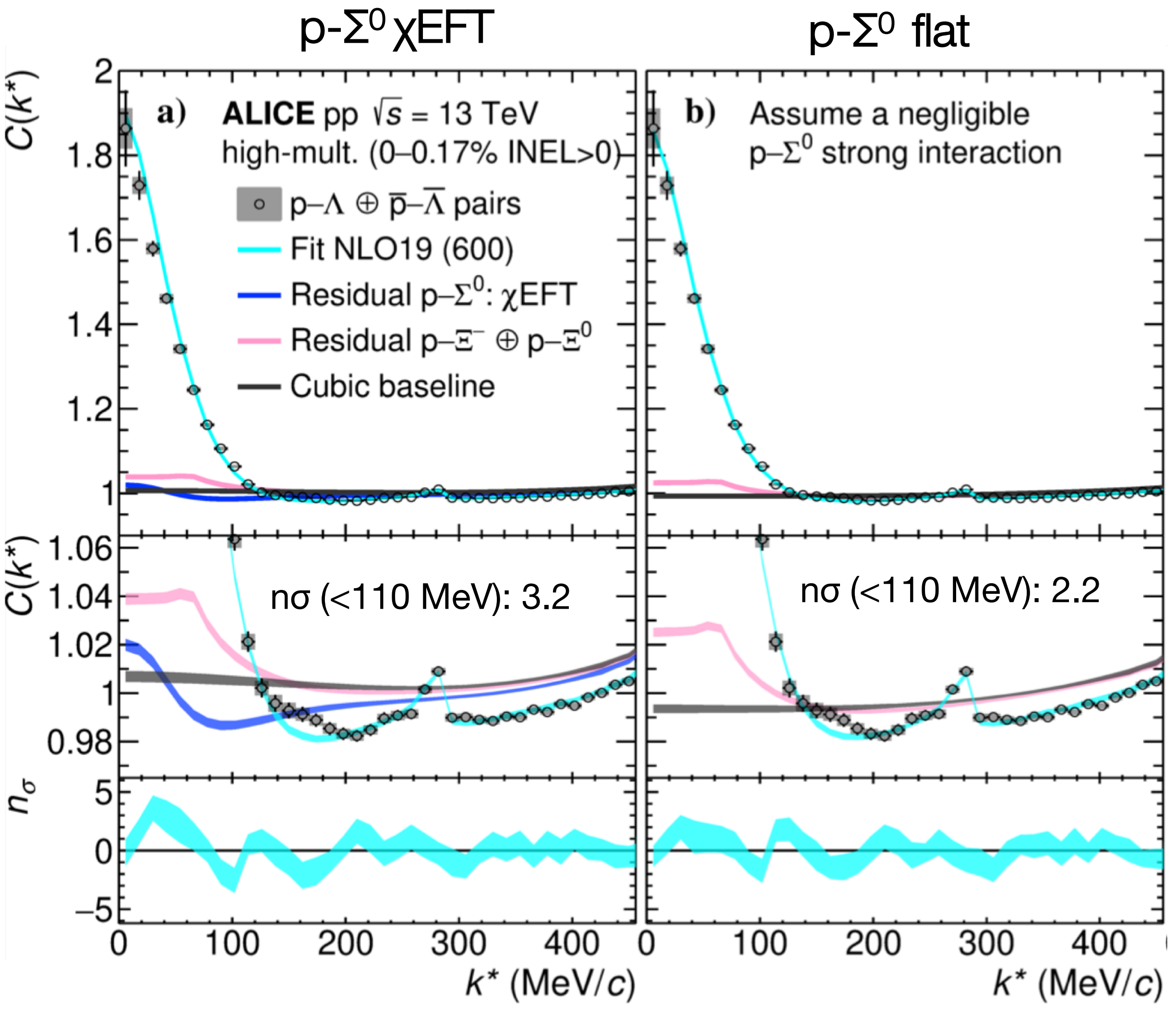


High-precision data on ΛN-ΣN interaction at LHC

- New scenario arising for ΛN-ΣN interaction
  - NLO19 potentials favoured
  - Sensitivity to residual p-Σ^0 interaction
  - Crucial input from several measurements:
    → p$\Sigma^{+,-}$ correlations in LHC Run 2/Run 3
    → p$\Sigma^{+,-}$ scattering data J-PARC E40

- Deviations with correlation data observed

First-ever combined analysis using available pΛ scattering and correlation data



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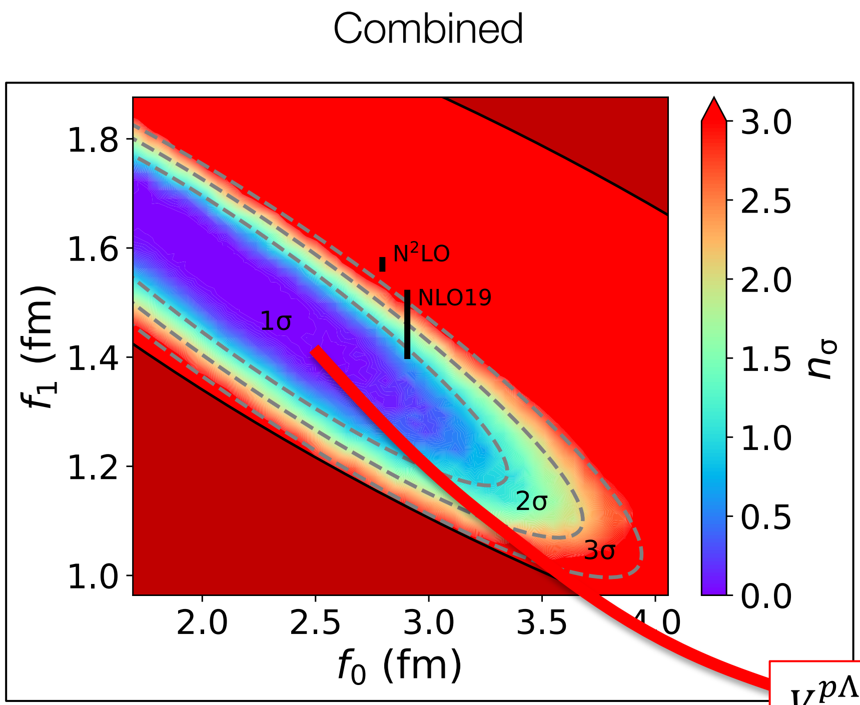
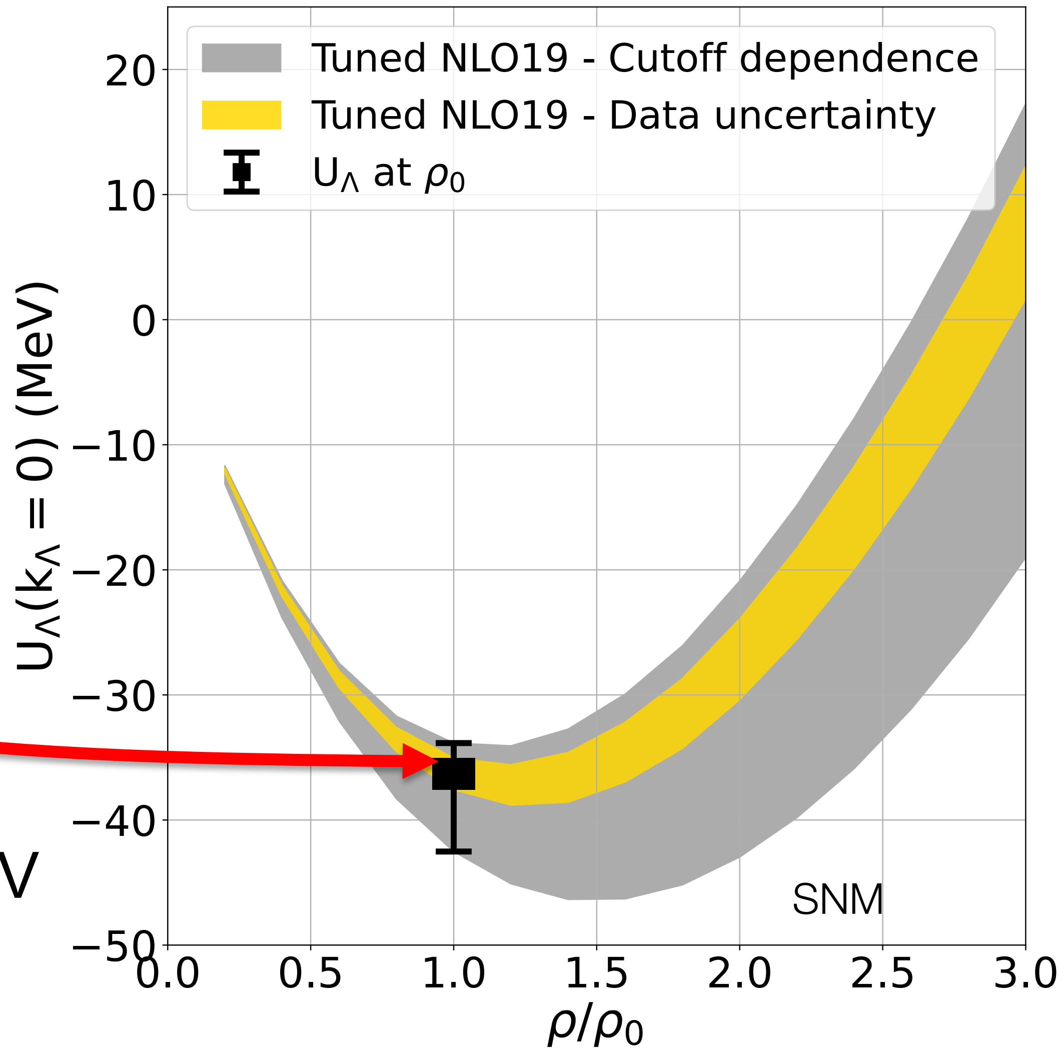
Quantifying the two-body contribution of U_Λ



$V^{p\Lambda}_{NLO19}$ in mom. space via G-matrix approach

D. Mihaylov, J. Haidenbauer and VMS PLB 850 (2024) 138550



$$U^{2BF}_{\Lambda}(\rho_0) = -36.3 \pm 1.3(stat)^{+2.5}_{-6.2}(syst)\ \text{MeV}$$

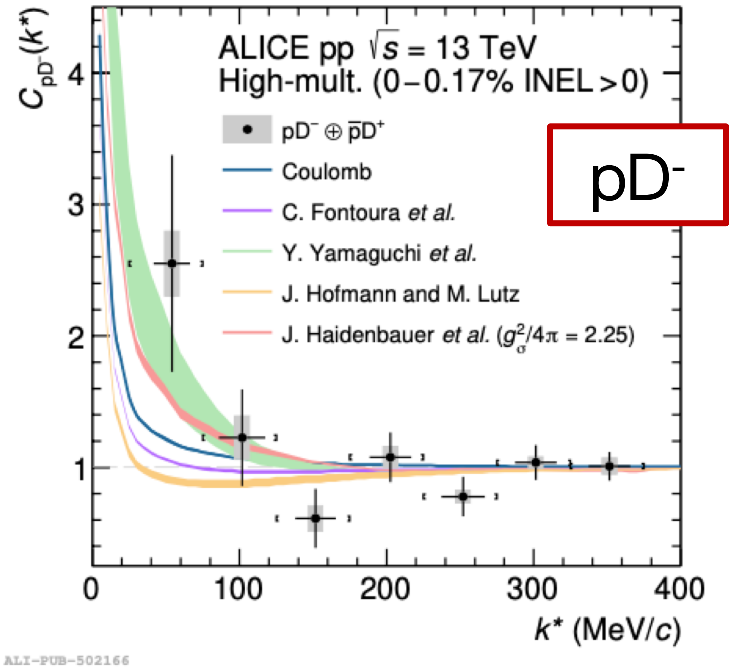
pΛ scattering parameters from combined fit

Table 1
Summary table showing the compatibility of different scattering parameters to the femtocsopy data ($n\sigma_{fmt}$), scattering data ($n\sigma_{sct}$) as well as the combined analysis from the present work ($n\sigma_{tot}$). If the combined estimator $n\sigma_{tot}$ is considered, solutions ii, v and vii represent a set of "best" solutions.

Usmani parameterization	f_0 (fm)	f_1 (fm)	$n\sigma_{fmt}$	$n\sigma_{sct}$	$n\sigma_{tot}$
NLO13(600)	2.91	1.54	5.2	0.0	4.6
NLO19(600)	2.91	1.41	1.7	0.4	1.1
N^2LO(550)	2.79	1.58	5.4	0.0	4.8
i	2.10	1.44	0.2	2.1	1.0
ii	**2.10**	**1.56**	**0.0**	**0.9**	**0.0**
iii	2.10	1.66	1.8	0.2	1.0
iv	2.50	1.32	0.2	2.2	1.1
v	**2.50**	**1.46**	**0.2**	**0.8**	**0.0**
vi	2.50	1.55	1.8	0.2	1.0
vii	**2.91**	**1.32**	**0.1**	**1.5**	**0.3**
viii	3.34	1.18	1.2	0.9	1.0

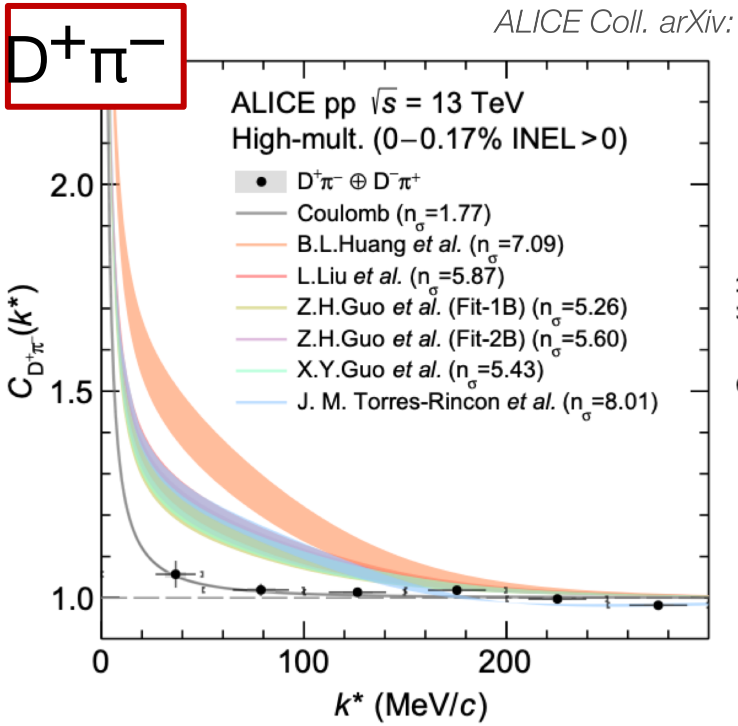
Accessing the interaction between light and charm hadrons

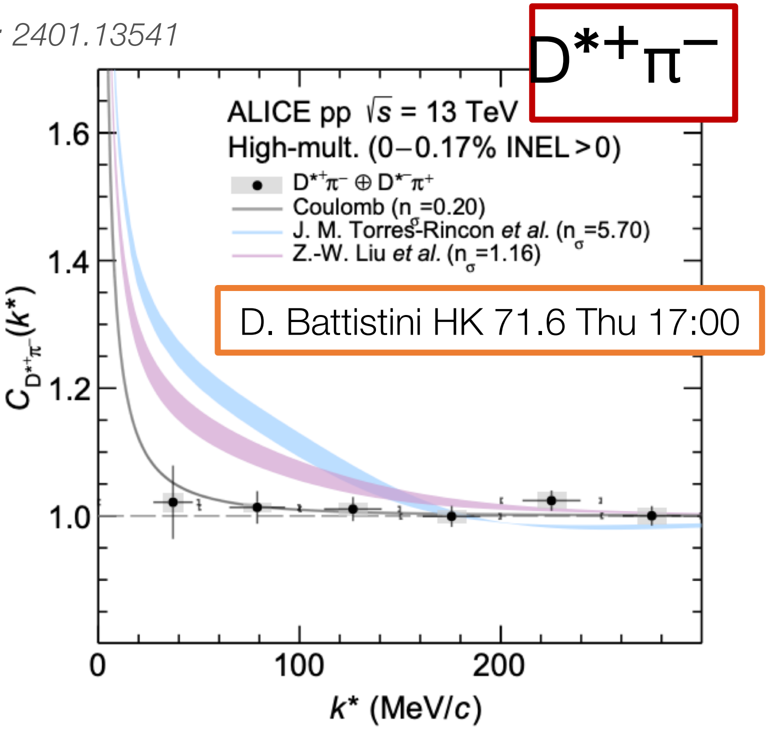
ALICE Coll. PRD 106 (2022), 5, 052010



- **First measurements of interaction between D(*) mesons and light hadrons**
  - Several predictions of exotic states, crucial input for charm nuclei and heavy-flavor observables in heavy-ions
- **Femtoscopy can be extended to the charm sector**
  - More results to come with the LHC Run 3 and Run 4 statistics

ALICE Coll. arXiv: 2401.13541





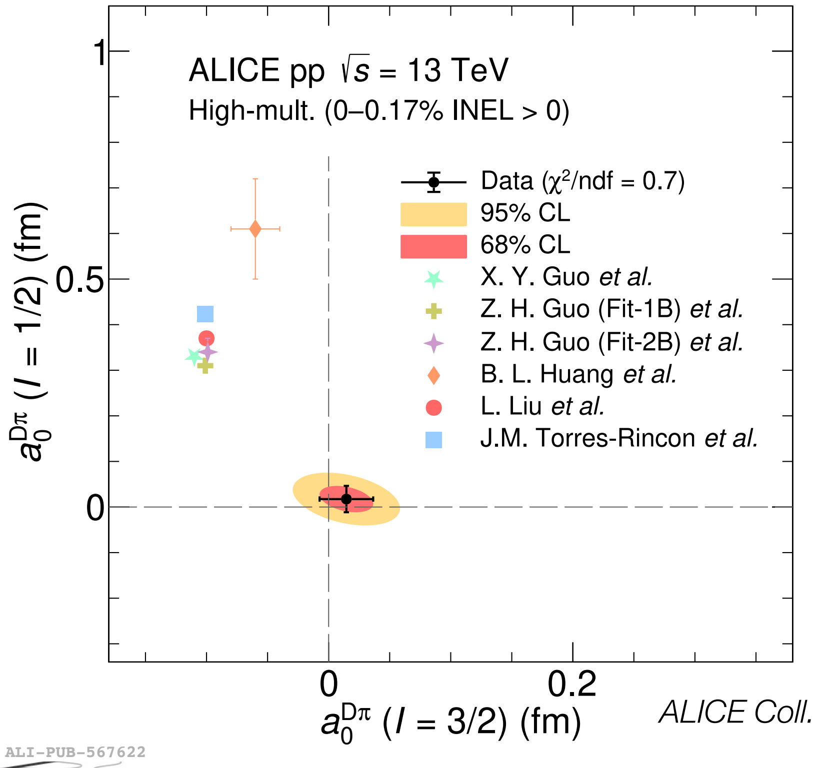
D. Battistini HK 71.6 Thu 17:00

Moving towards a charming future

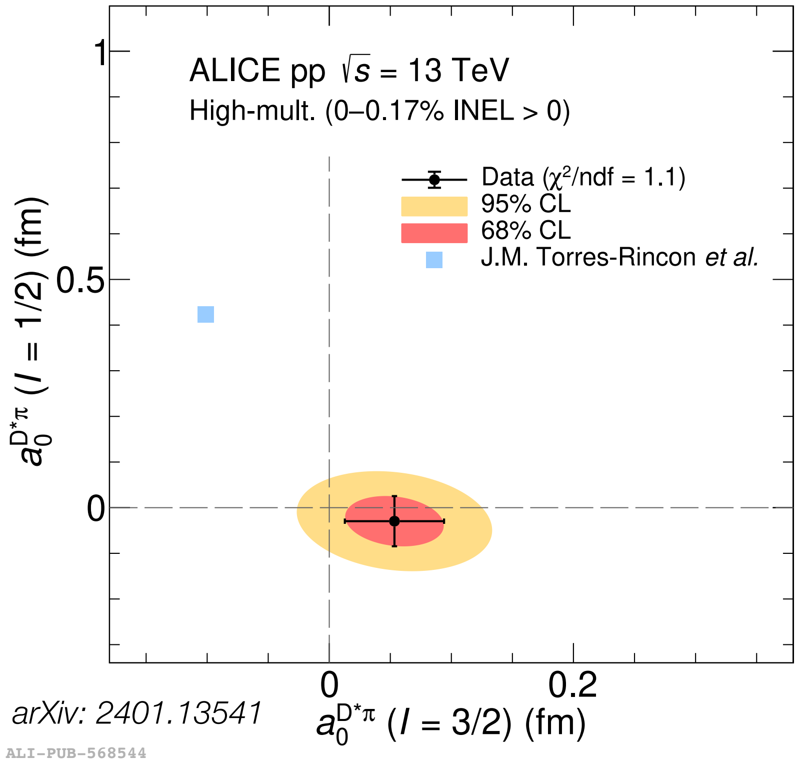
Measuring the scattering length for Dπ and D*π systems

- Extracted **scattering lengths compatible with zero**
  → No influence of the hadronic phase on heavy-flavour observables in heavy-ions
- Tension with available theoretical models
  → Novel possibility to constrain effective QCD models in the charm sector!

Dπ system



D*π system



ALICE Coll. arXiv: 2401.13541

First experimental constraints available for $D^{(*)}$ - light mesons dynamics

Accessing the strong interaction with charm hadrons

- First measurement of the genuine correlation between protons and D^- mesons
  → Important input in studies and searches for charm nuclear states[1]
- Comparison with available models
  → Indication of an attractive interaction
  → Compatible also with the formation of bound state

ALICE coll. PRD 106 (2022), 5, 052010

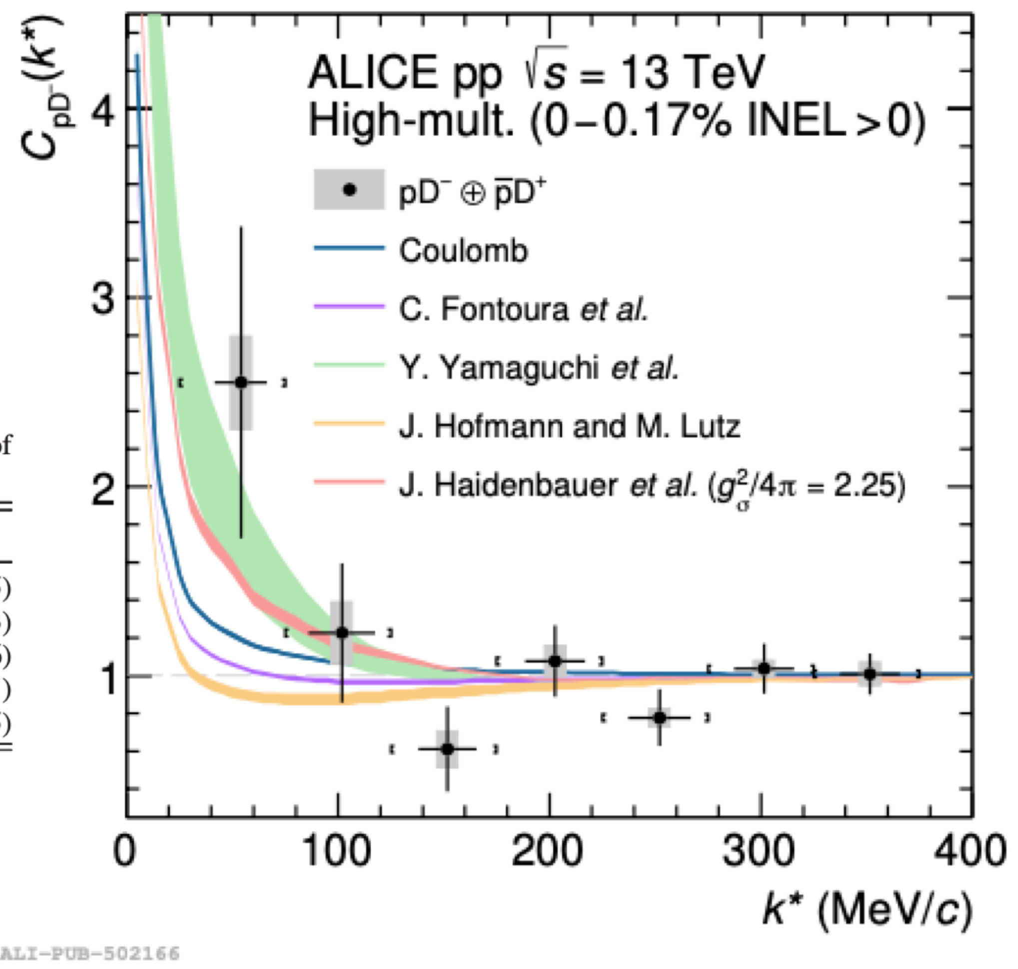


TABLE I. Scattering parameters of the different theoretical models for the $N\bar{D}$ interaction [22–25] and degree of consistency with the experimental data computed in the range $k^* < 200$ MeV/c.

Model	$f_0(\mathrm{I}=0)$	$f_0(\mathrm{I}=1)$	n_σ
Coulomb			(1.1–1.5)
Haidenbauer *et al.* [22] ($g_\sigma^2/4\pi = 2.25$)	0.67	0.04	(0.8–1.3)
Hofmann and Lutz [23]	−0.16	−0.26	(1.3–1.6)
Yamaguchi *et al.* [25]	−4.38	−0.07	(0.6–1.1)
Fontoura *et al.* [24]	0.16	−0.25	(1.1–1.5)

[1] A. Hosaka et al. Prog. Part. Nucl. Phys. 96 (2017), 6, 062C01