Determination of hadron interaction with femtoscopy

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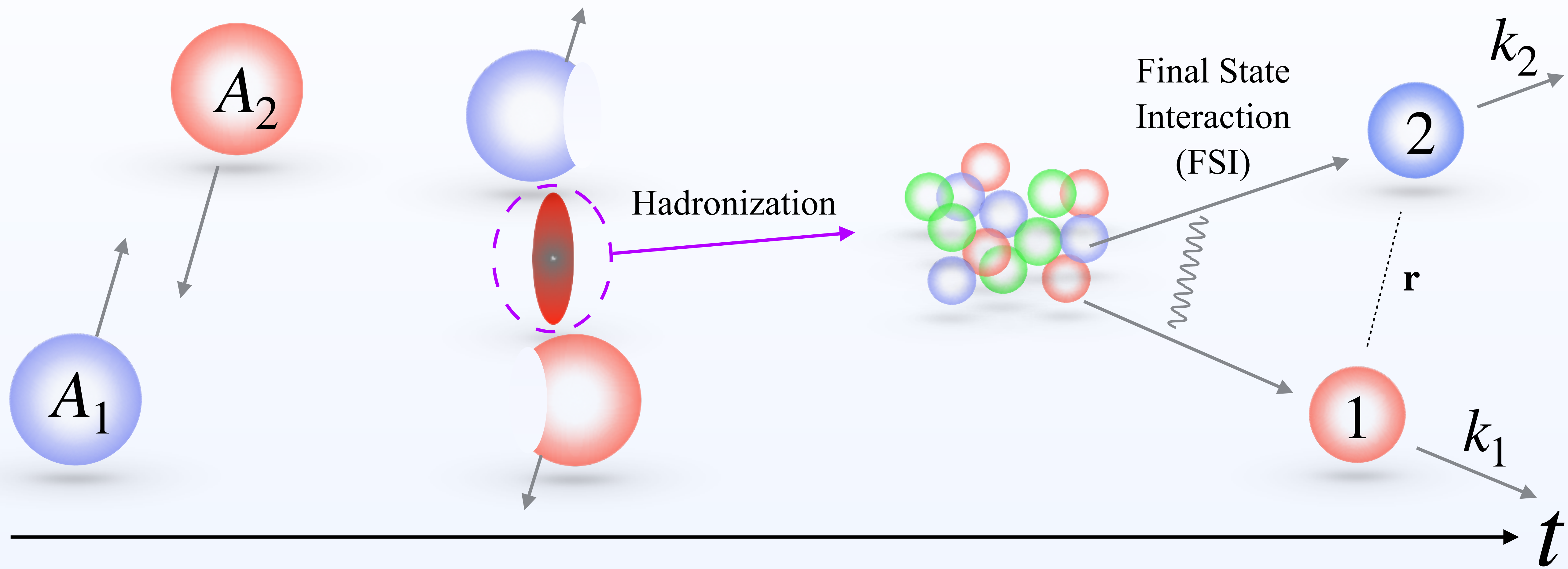
7.5.2025

Femtoscopy

- High energy nuclear collision and FSI



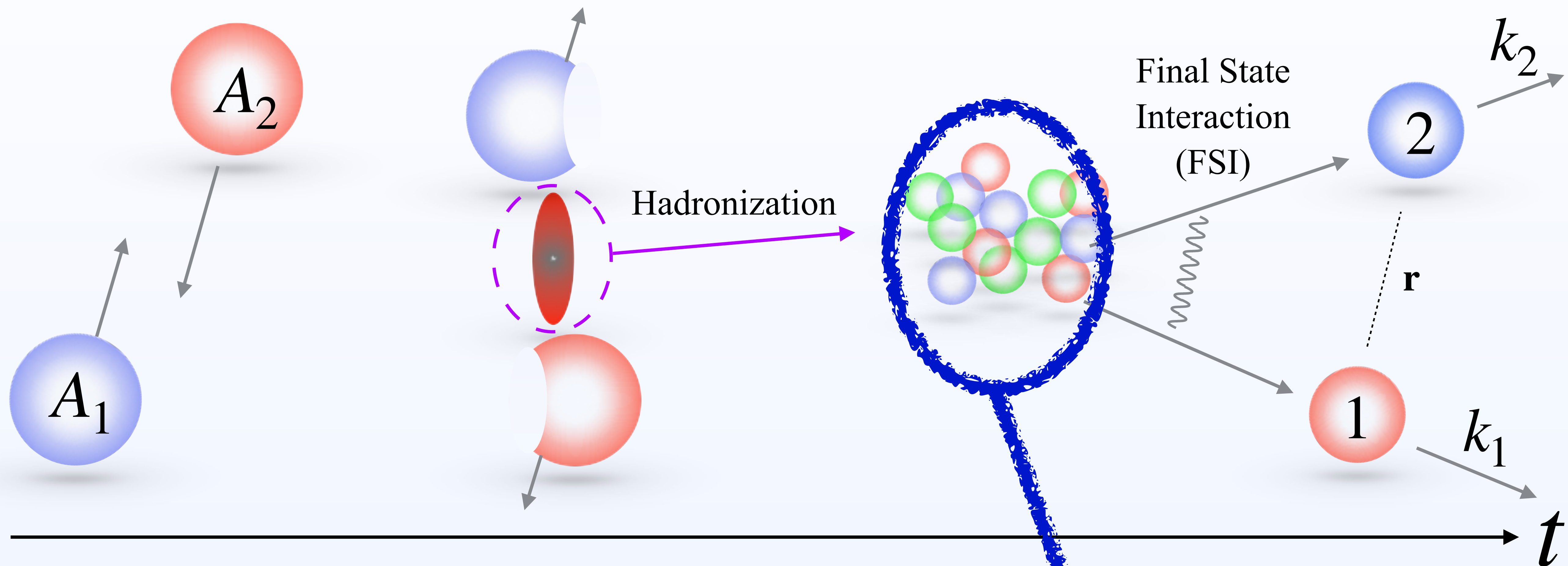
- Hadron-hadron correlation

$$C_{12}(k_1, k_2) = \frac{N_{12}(k_1, k_2)}{N_1(k_1)N_2(k_2)}$$

$$= \begin{cases} 1 & \text{(w/o correlation)} \\ \text{Others} & \text{(w/ correlation)} \end{cases}$$

Femtoscopy

- High energy nuclear collision and FSI



- Hadron-hadron correlation
  - Koonin-Pratt formula : S.E. Koonin, PLB 70 (1977) S. Pratt et. al. PRC 42 (1990)

$$C(\mathbf{q}) \simeq \int d^3\mathbf{r}\ S(\mathbf{r})\,|\varphi^{(-)}(\mathbf{q},\mathbf{r})|^2$$

$$\mathbf{q} = (m_2\mathbf{k}_1 - m_1\mathbf{k}_2)/(m_1 + m_2)$$

$S(\mathbf{r})$: Source function

$\varphi^{(-)}(\mathbf{q},\mathbf{r})$: Relative wave function

- Depends on …

  Collision detail (A_i, energy, centrality)

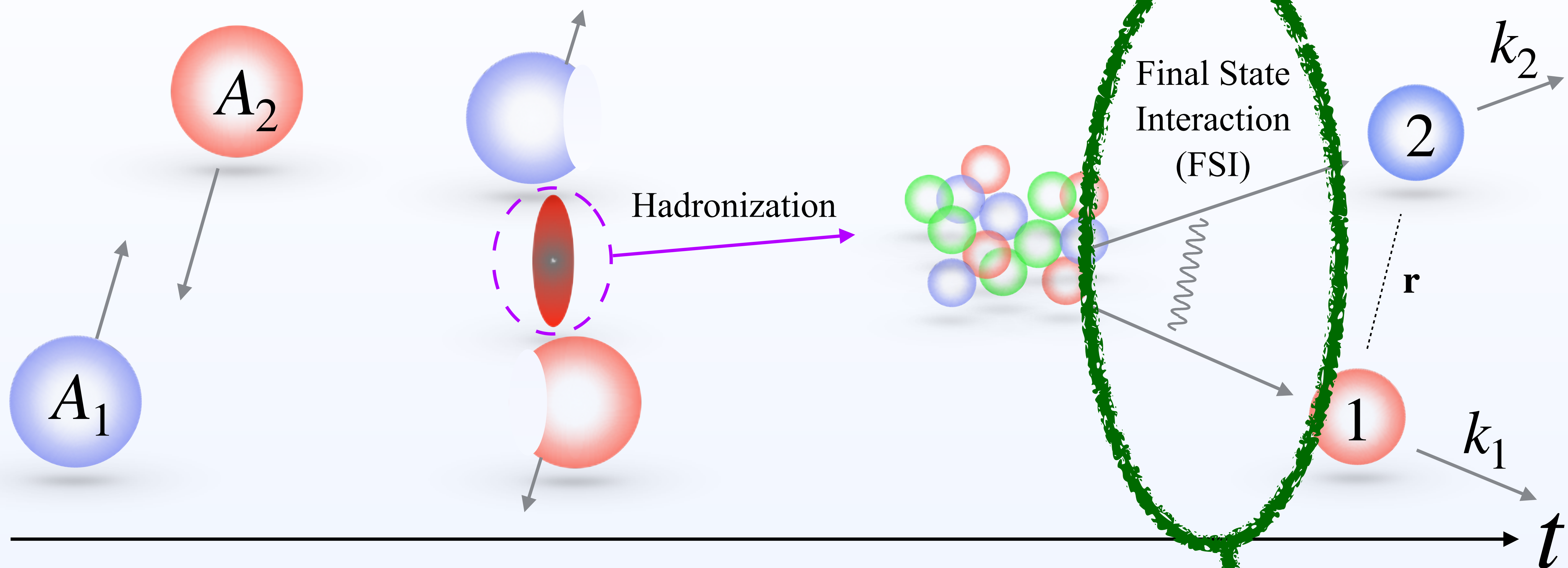
- Including information of…

  size of hadron source,

  momentum dependence, weight…

Femtoscopy

- High energy nuclear collision and FSI



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- Depends on …

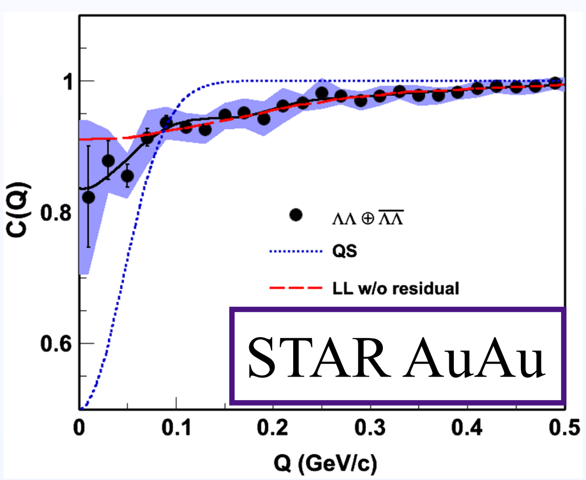
  Interaction (strong and Coulomb)

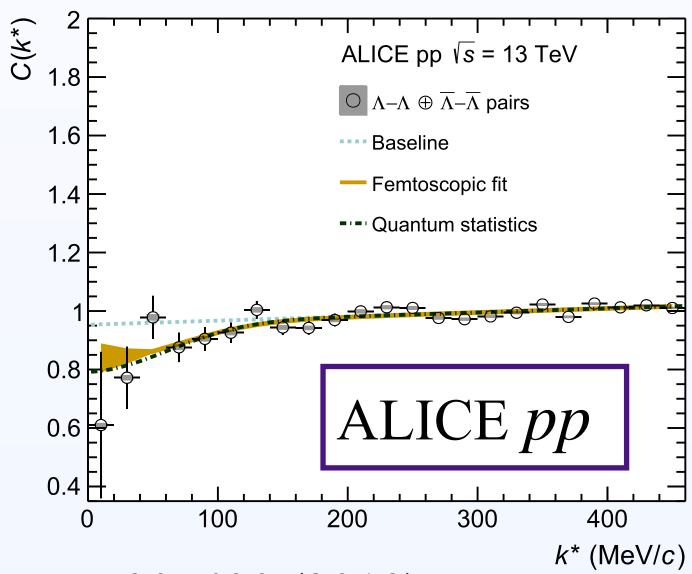
  quantum statistics (Fermion, boson)

Femtoscopic data

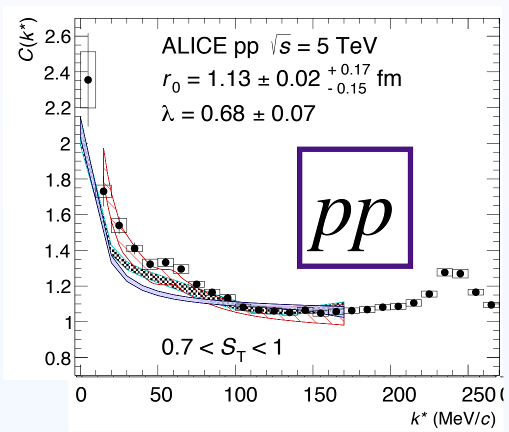
- Experimental data in various sectors

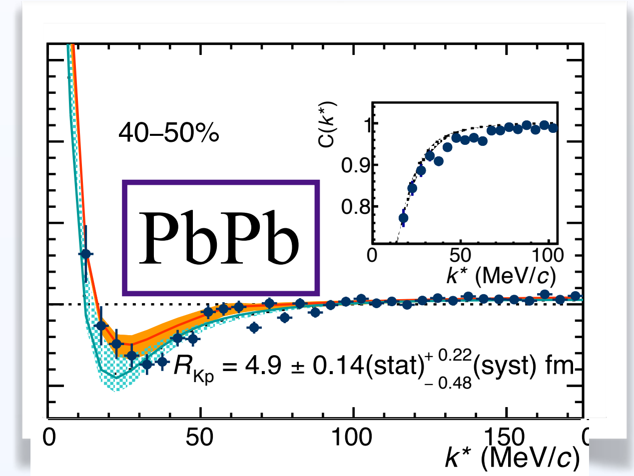
- $\Lambda\Lambda$ <u>STAR AuAu: PRL 114,022301(2015)</u>
  <u>ALICE *pp*: PLB 797 (2019) 134822</u>
  PbPb: PRC99, 024001 (2019)



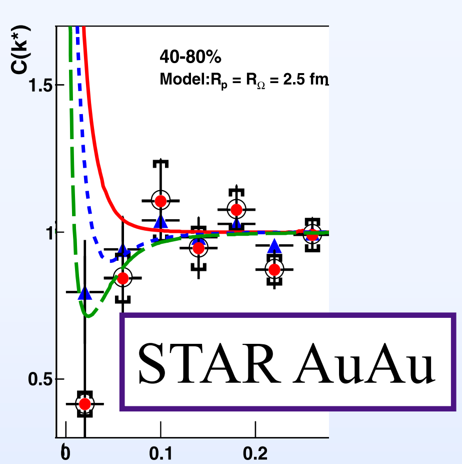


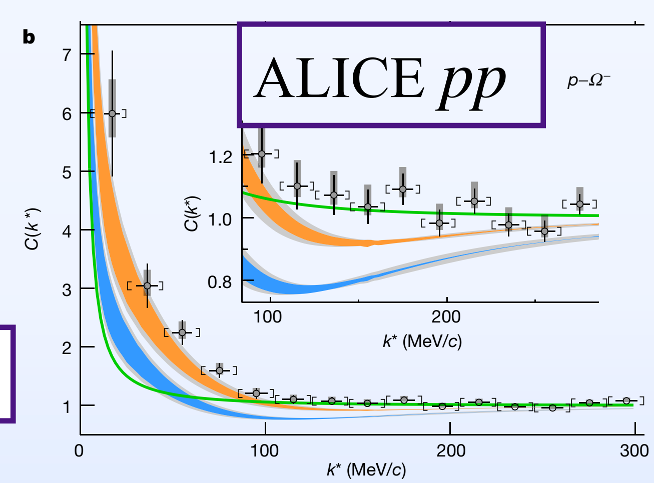
- $K^{\pm}p$ <u>ALICE *pp*: PRL 124 (2020) 9, 092301</u>
  <u>PbPb: PLB 822 (2021) 136708</u>
  STAR AuAu: NPA 982 (2019) 359



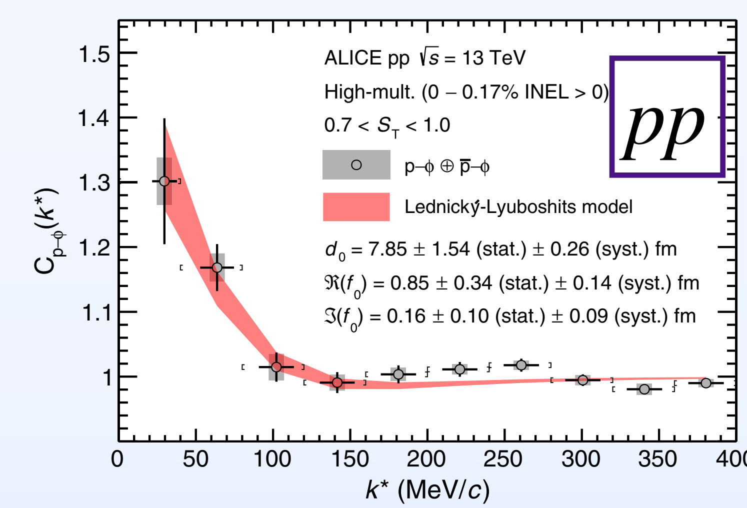


- $p\Omega$ <u>STAR AuAu: PLB 790, 490 (2019)</u>
  <u>ALICE *pp*: Nature 588 (2020) 232</u>

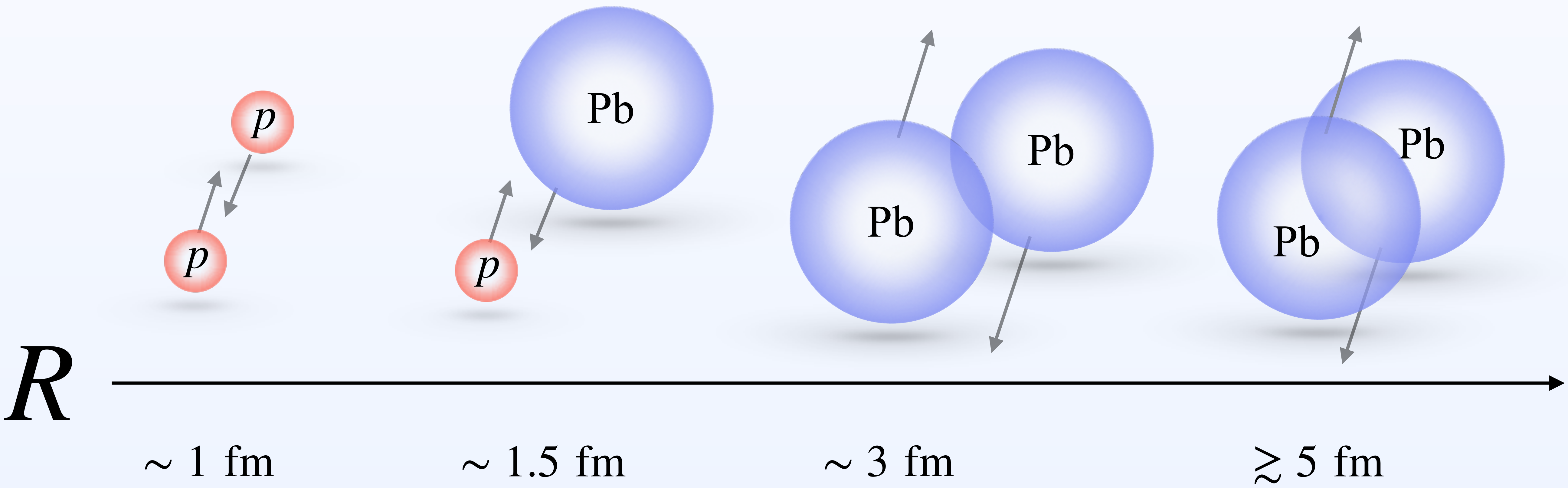




- $p\phi$ ALICE *pp*: <u>PRL 127 (2021) 17, 172301</u>



- How to control source size R
  - pp collisions
  - pPb collisions
  - PbPb collisions
    - peripheral
    - central



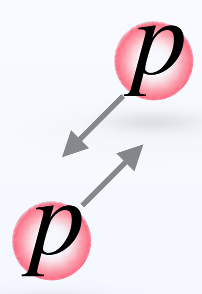
Source size dependence

- Line shapes of $C(q)$: relation to interaction

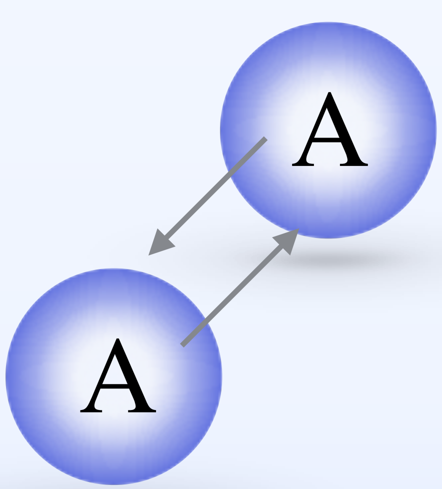
• Attractive interaction

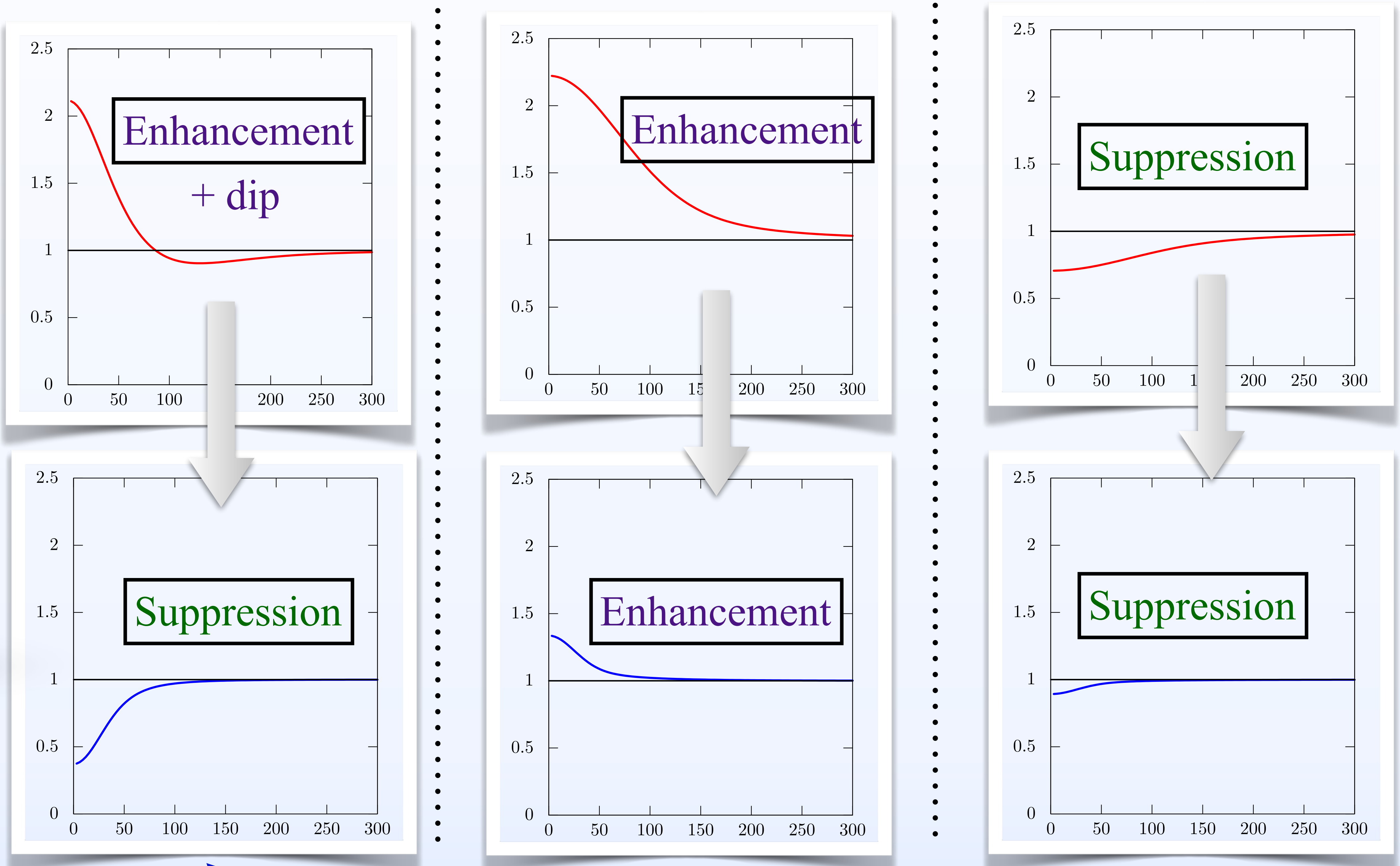
w/ bound state | w/o bound state | • Repulsive interaction

• Small source



• Large source

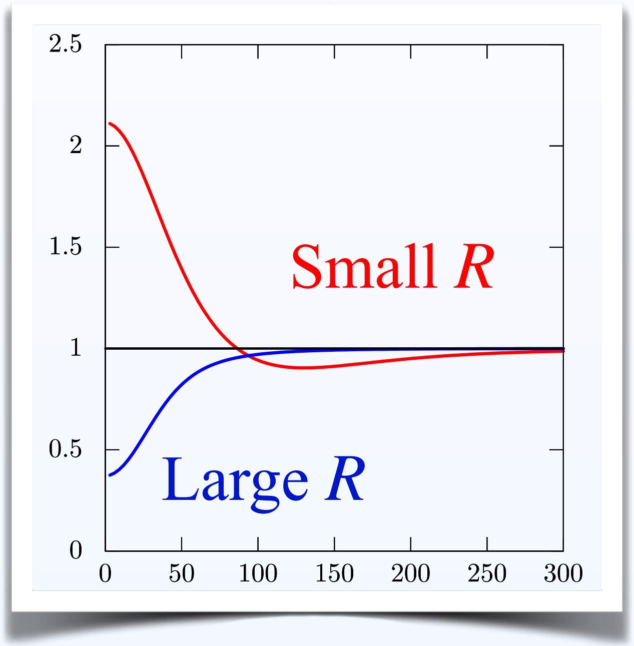




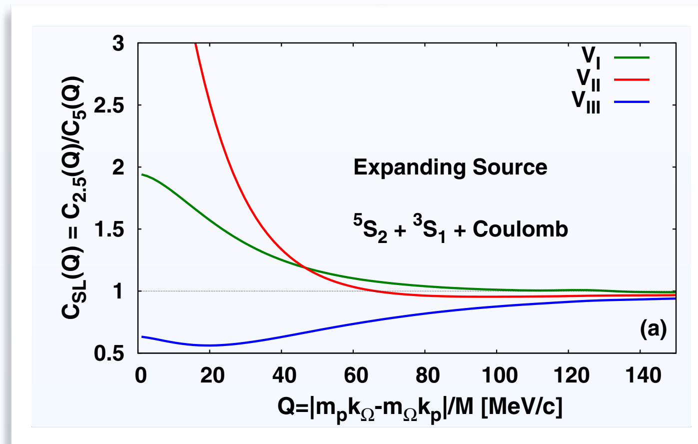
Source size dependence for typical for bound state cases!

Importance of source size dependence

- Bound state

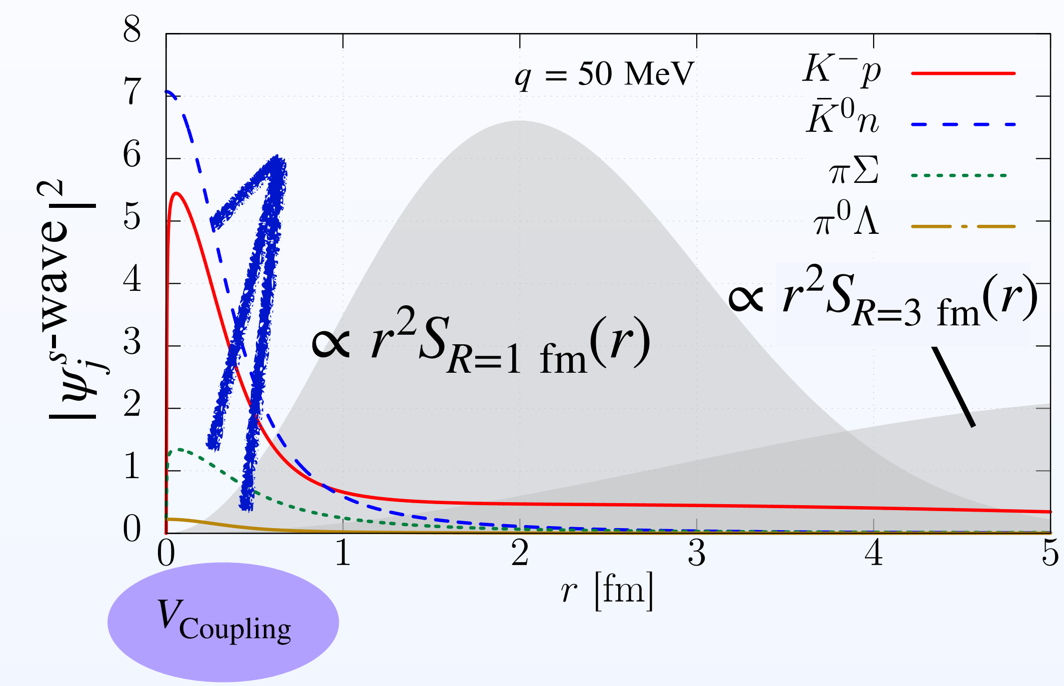


$C_{SL} = C_{\text{small } R}/C_{\text{Large } R}$



Morita et al. PRC 94 (2016)

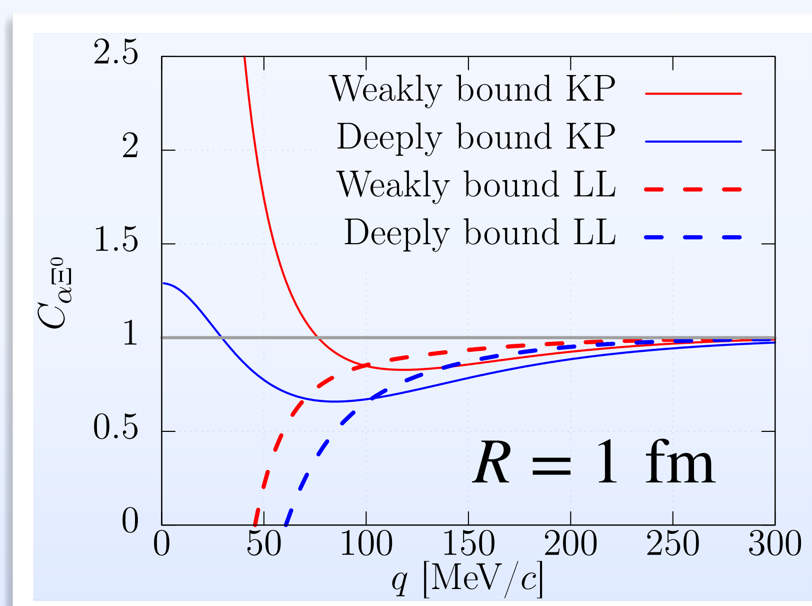
- Coupled channel effect



- More interaction detail
  - Energy dependence/potential shape

    nearby resonance, long range int.…

    —> fail of LL formula



How to construct correlation model from theory; $\mathscr{F}(q) \to C(q)$

- Using effective potential
  - Construct the eff. potential by reproducing the amplitude $\mathscr{F}$ (or threshold parameters (a_0, r_e))
  - Solving the Schrödinger eq. $\longrightarrow \varphi$
- Using half offshell T-matrix $T_l(q,k;E)$ Haidenbauer, Nuclear Physics A 981 (2019) 1–16
  - $T_l(q,k;E) \longrightarrow \varphi$

$$\tilde{\psi}(k,r) = j_l(kr) + \frac{1}{\pi}\int j_l(qr)\, dq q^2 \frac{1}{E - E_1(q) - E_2(q) + i\epsilon} T_l(q,k;E)$$

- Using Lednicky-Lyuboshitz formula
  - Approximation for the simple interaction
  - Direct relation between $C(q)$ and $\mathscr{F}(q)$

→ Comparison of model predictions and correlation data

How to extract interaction from Correlation data; $C(q) \to \mathcal{F}(q)$

- Lednicky-Lyuboshitz (LL) formula R. Lednicky, et al. Sov. J. Nucl. Phys. 35(1982).
  - Approximate φ by asymptotic wave func.(s-wave only)

$$C(\mathbf{q}) \simeq \int d^3\mathbf{r}\ S(\mathbf{r})|\varphi^{(-)}(\mathbf{q},\mathbf{r})|^2$$

$$\varphi^{(-)}(\mathbf{q},\mathbf{r}) \xrightarrow{r\to\infty} \exp(-i\mathbf{q}\cdot\mathbf{r}) + \frac{\mathcal{F}(-q)}{r}\exp(-iqr)$$

  - Use effective range expansion for amplitude $\mathcal{F}$

$$\mathcal{F}(q) = \left[\frac{1}{a_0} + \frac{r_e}{2}q^2 - iq\right]^{-1}$$

$$C(q) = 1 + \left[\frac{|\mathcal{F}(q)|^2}{2R^2}F_3\left(\frac{r_{\rm eff}}{R}\right) + \frac{2{\rm Re}\,\mathcal{F}(q)}{\sqrt{\pi}R}F_1(2qR) - \frac{{\rm Im}\,\mathcal{F}(q)}{R}F_2(2qR)\right]$$

  - Fit the data with formula

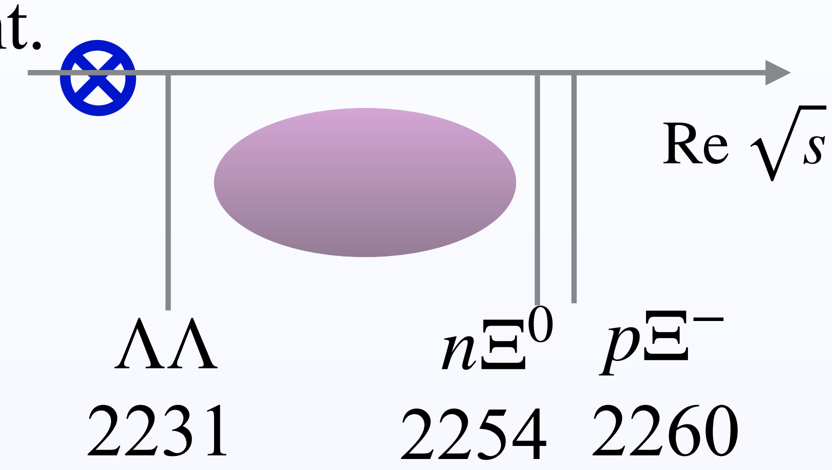
- Direct relation between $C(q)$ and $\mathcal{F}(q)$
- Difficult to introduce the detailed interaction e.g. coupled-channel
- Coulomb int. can be only introduced with Gamow factor (too crude for $C(q)$)

$N\Xi$ interaction and H-dibaryon state

- $\Lambda\Lambda$-$N\Xi$ interaction ($S = -2$) and H-dibaryon
  - $J = 0$: Unique sector in flavor Octet-Octet baryon int.

$$8 \otimes 8 = \underline{1} \oplus 8_A \oplus 8_S \oplus 10 \oplus \overline{10} \oplus 27$$

- Pauli arrowed
- Attractive color-magnetic int.



- Flavor-singlet dihyperon "H" R. L. Jaffe, PRL 38 (1977), 195.

Predicted as "single hadron" below $\Lambda\Lambda$

- Binding energy of double Λ hypernucleus

Takahashi et al., PRL87 (2001) 212502

⟶ $\Lambda\Lambda$ does NOT form (deep) bound state

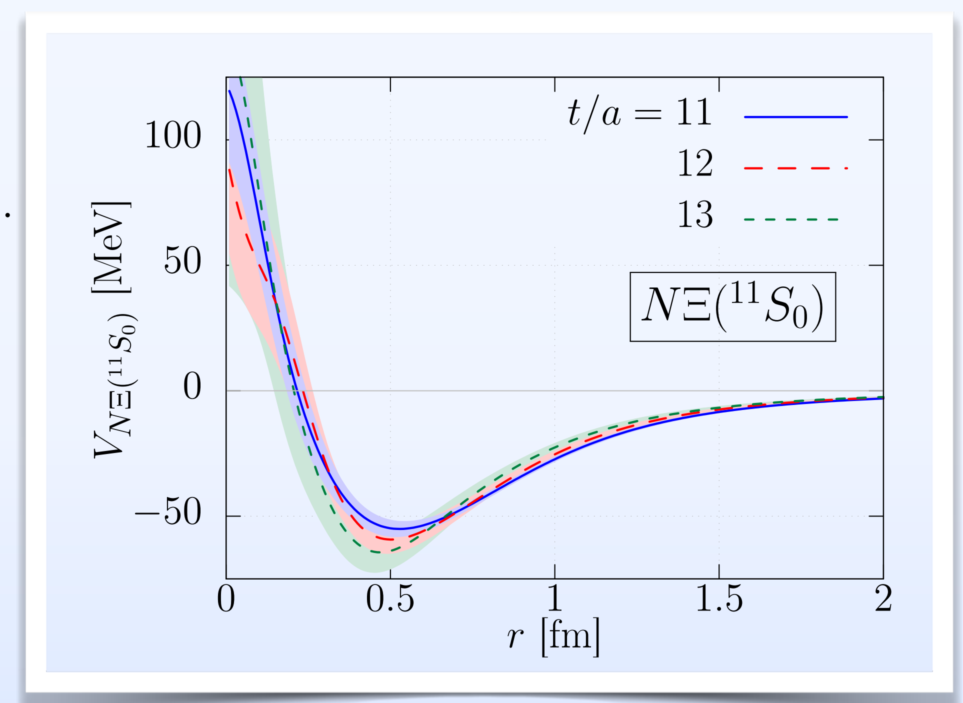
- HAL QCD $\Lambda\Lambda$-$N\Xi$ coupled-channel potential

K. Sasaki et al. [HAL QCD], NPA 998 (2020), 121737.

- Strong attraction in $J = 0$, $I = 0$ $N\Xi$ channel

$$a_0^{p\Xi^-(J=0)} = -1.21 - i1.52$$

H dibaryon state is just barely unbound.



Fate of H-dibaryon?

ΛΛ-$N\Xi$ HAL QCD potential

K. Sasaki et al. [HAL QCD], NPA 998 (2020), 121737.

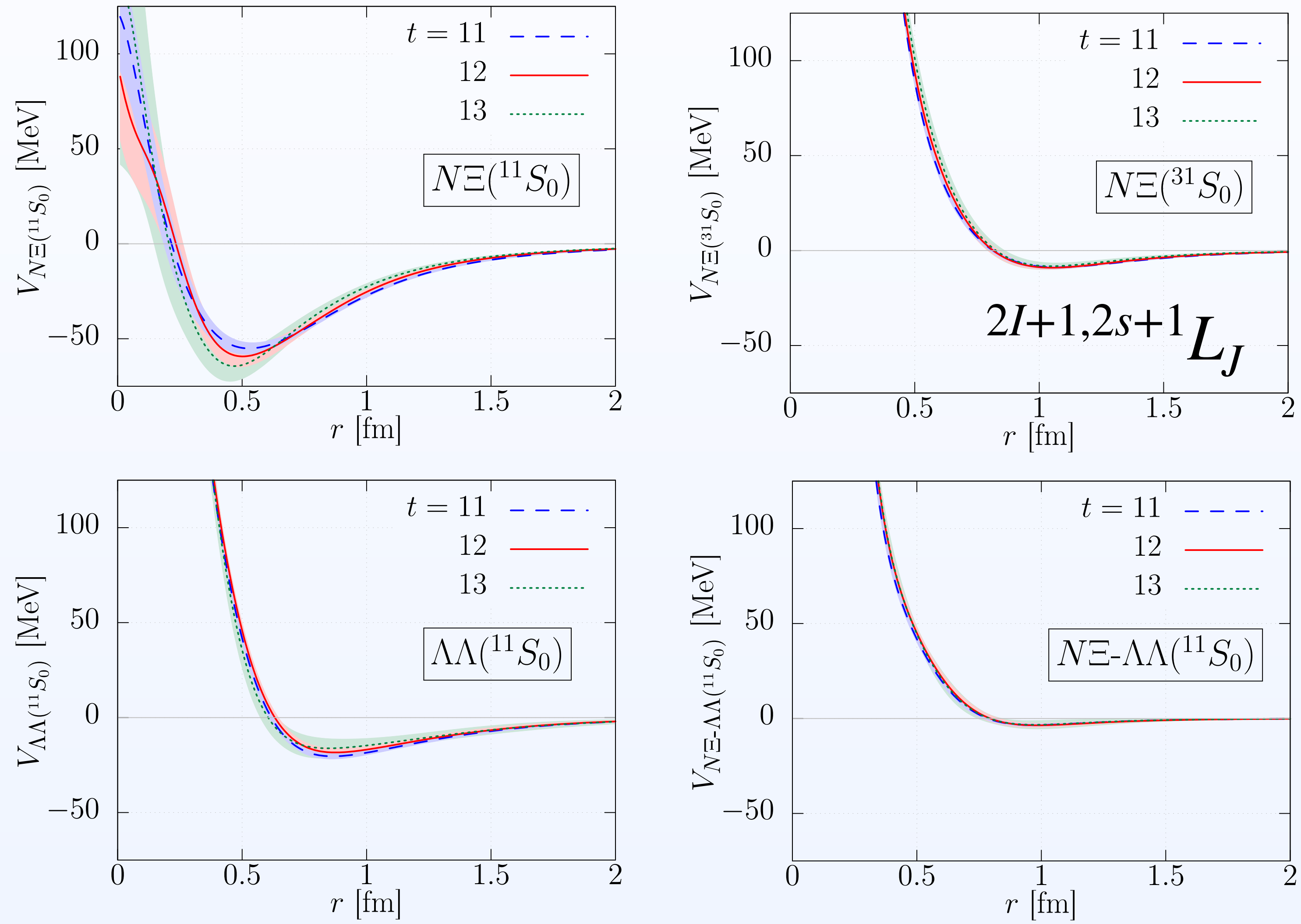
- $N\Xi$-ΛΛ HAL QCD potential
  - HAL QCD method — Ishii, Aoki, Hatsuda, PRL99 (2007) 022001; N. Ishii et al Phys. Lett. B712(2012)437

$$\langle 0|B_1B_2(t,\vec{r})\bar{I}(0)|0\rangle = A_0\Psi(\vec{r},E_0)e^{-E_0t}+\cdots$$

$\Psi(\vec{r},E_0) \rightarrow V(r)$

  - Nearly physical mass calculation

$m_\pi = 146$ MeV $m_K = 525$ MeV



- $N\Xi$-ΛΛ $J = 0$ channel
  - Strong attraction for $N\Xi$ ($I = 0$)
  - Weak attraction for ΛΛ channel
  - Weak ΛΛ-$N\Xi$ coupling
  - Solving Schrödinger eq.with physical masses

Scat. length : $a_0 \equiv -\mathscr{F}(E_{\rm th})$

Virtual pole : -3.9-i0.3 MeV (from $n\Xi^0$ thr.)

⇨ No H dibaryon state

channel		a_0 [fm]
$J=0$	$p\Xi^-$	$-1.22 \pm 0.13^{+0.08}_{-0.00} - i1.57 \pm 0.35^{+0.18}_{-0.23}$
	$n\Xi^0$	$-2.07 \pm 0.39^{+0.28}_{-0.35} - i0.14 \pm 0.08^{+0.00}_{-0.01}$
	ΛΛ	$-0.78 \pm 0.22^{+0.00}_{-0.13}$

Y. Kamiya, et al. PRC 105, 014915 (2022)

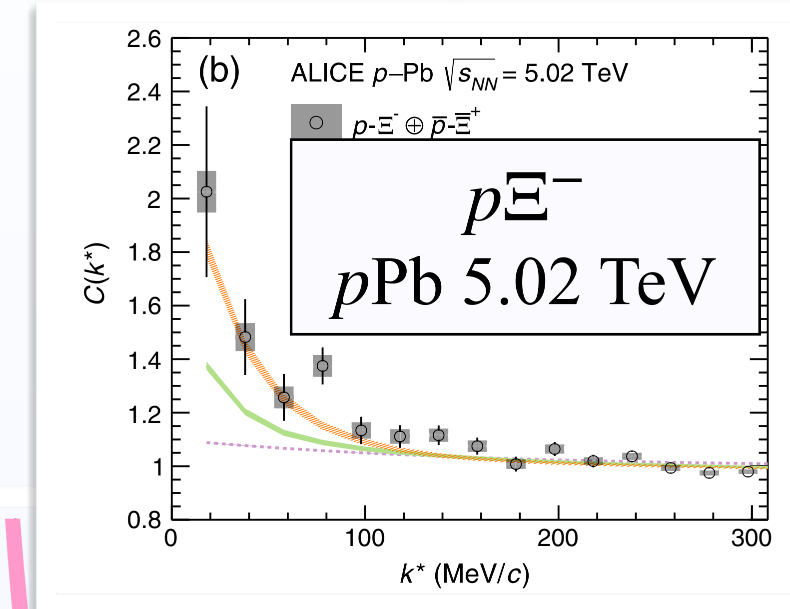
$\Lambda\Lambda$ and $p\Xi^-$ correlation function

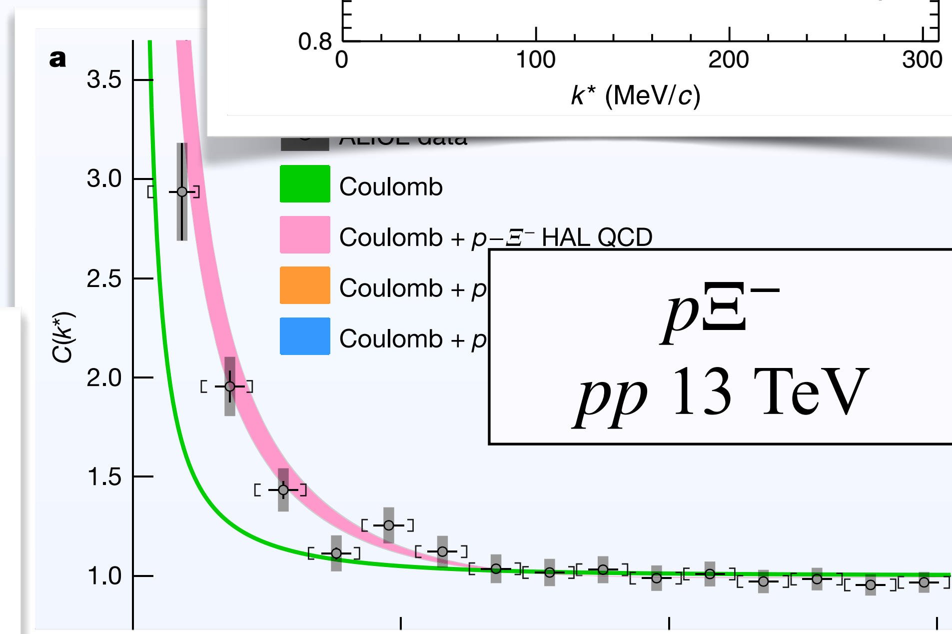
- $p\Xi^-$ and $\Lambda\Lambda$ correlation from ALICE
  - $p\Xi^-$

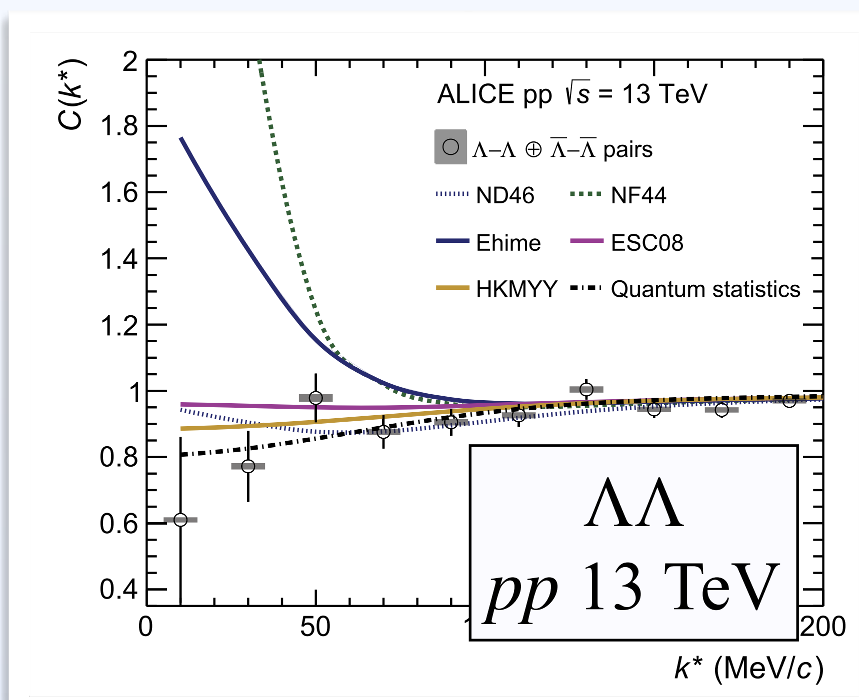
    pPb 5.02 TeV : ALICE, PRL, 123 (2019), 112002

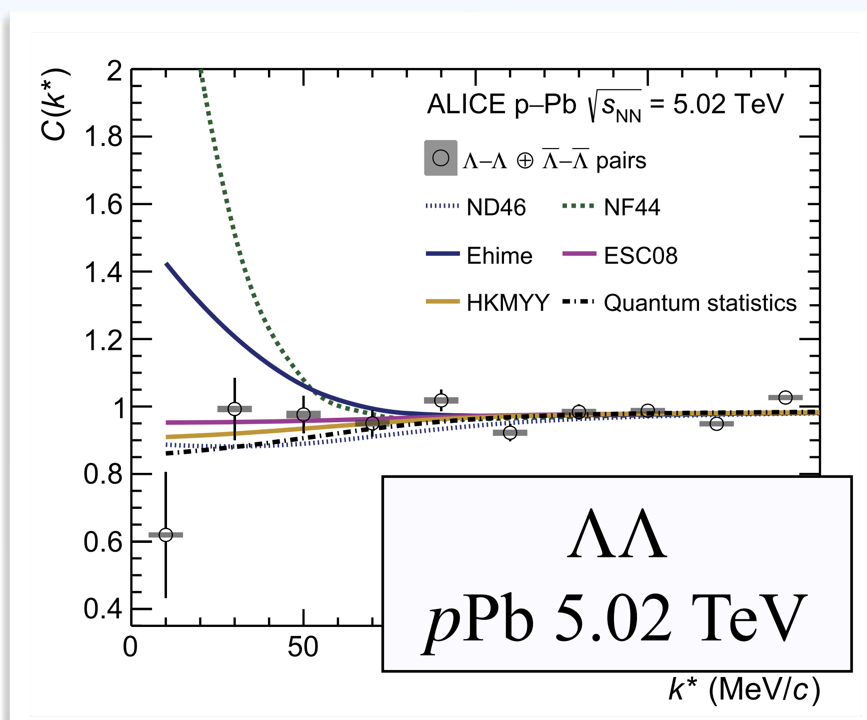
    pp 13 TeV : ALICE, Nature 588 (2020), 232-238
  - $\Lambda\Lambda$

    pPb 5.02 TeV, pp 13 TeV: S. Acharya et al. [ALICE], PLB 797 (2019).





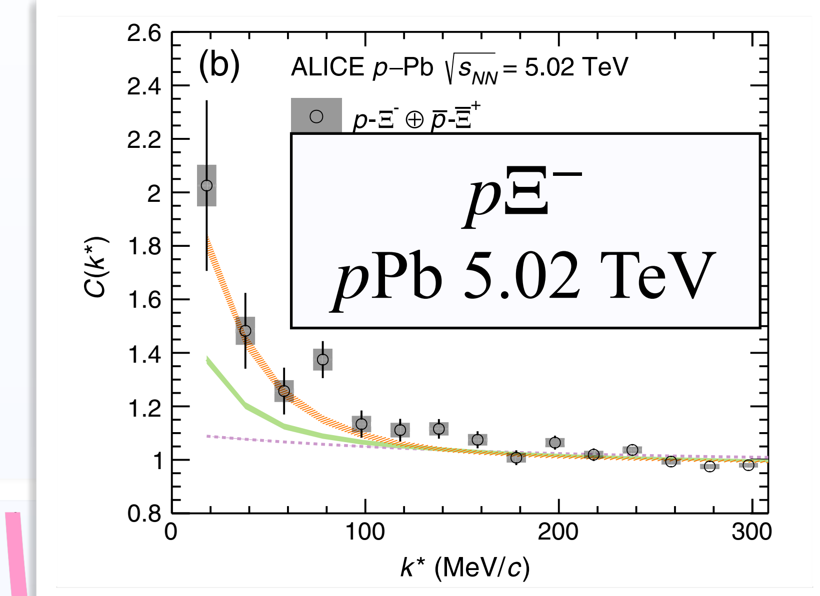


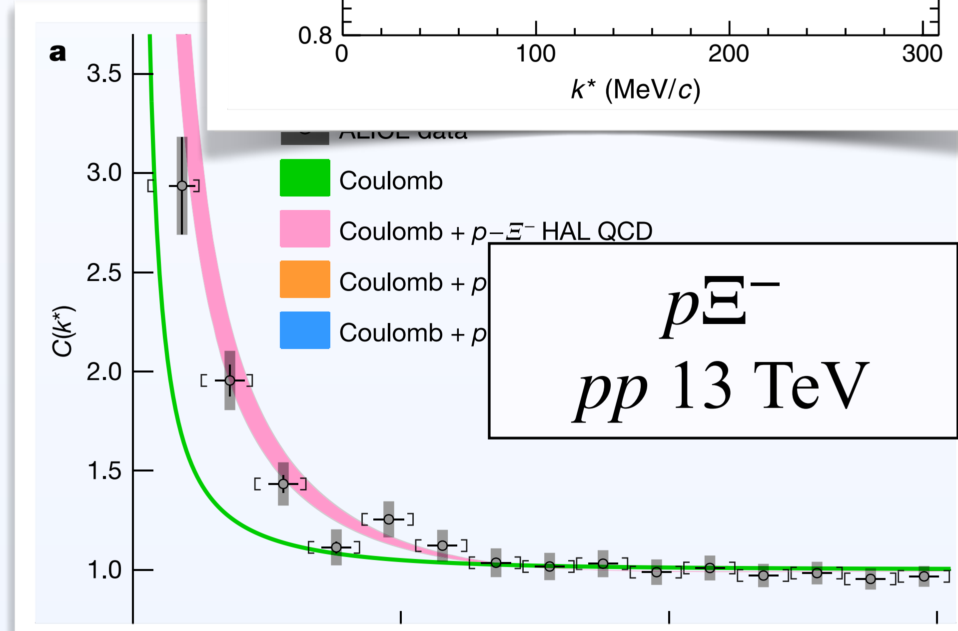


ΛΛ and $p\Xi^-$ correlation function

- $p\Xi^-$ and ΛΛ correlation from ALICE
  - $p\Xi^-$
    - pPb 5.02 TeV : ALICE, PRL, 123 (2019), 112002
    - pp 13 TeV : ALICE, Nature 588 (2020), 232-238
  - ΛΛ
    - pPb 5.02 TeV, pp 13 TeV: S. Acharya et al. [ALICE], PLB 797 (2019).
  - Our study: Systematic analysis with including
    - Coulomb interaction
    - Coupled-channel effect
    - Threshold difference

    using latest HAL QCD coupled-channel potential





- Systematic comparison to ΛΛ and $p\Xi^-$ correlation from pp and pPb collisions data from ALICE
  - Static spherical Gaussian with $R_{N\Xi} \sim R_{\Lambda\Lambda}$
  - Fitting for comparison

$$C_{\rm fit}(q) = \underline{A_{\rm non-femt}(q)} \times [1 + \underline{\lambda}(C_{\rm Theor}(q) - 1)]$$

$A_{\rm non-femt}(q) = a + bq$

$\lambda < 1$
- Miss identification
- feed-down

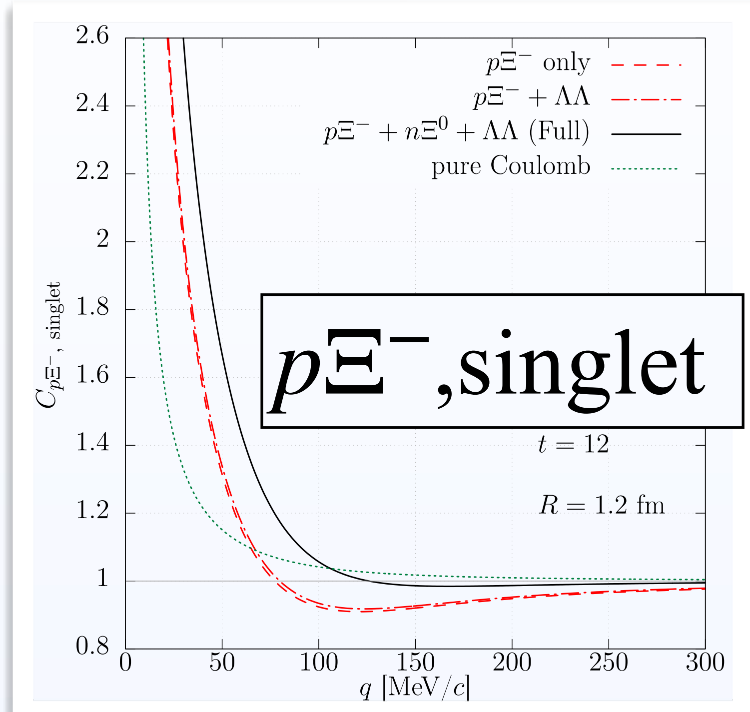
ΛΛ-$N\Xi$ interaction and ΛΛ and $p\Xi^-$ correlation function

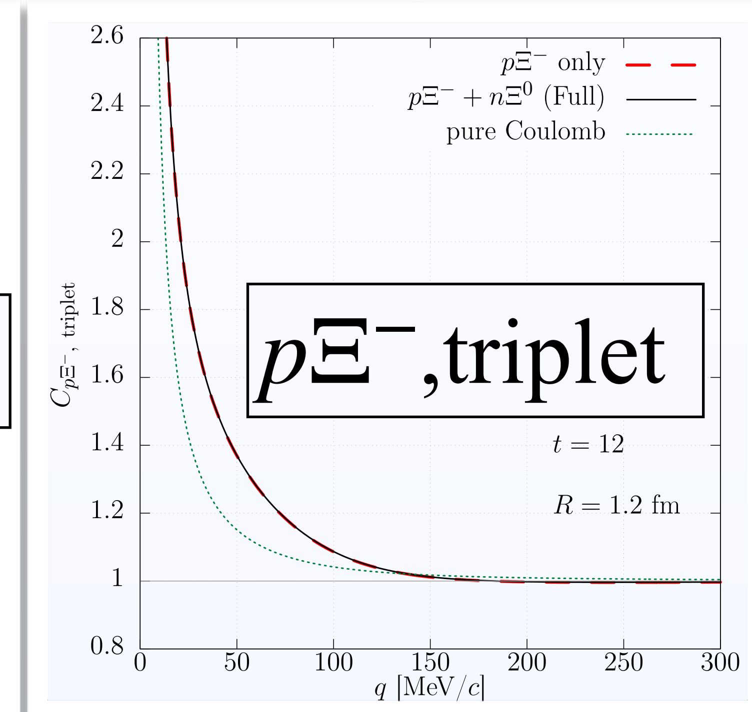
- $p\Xi^-$ correlation function

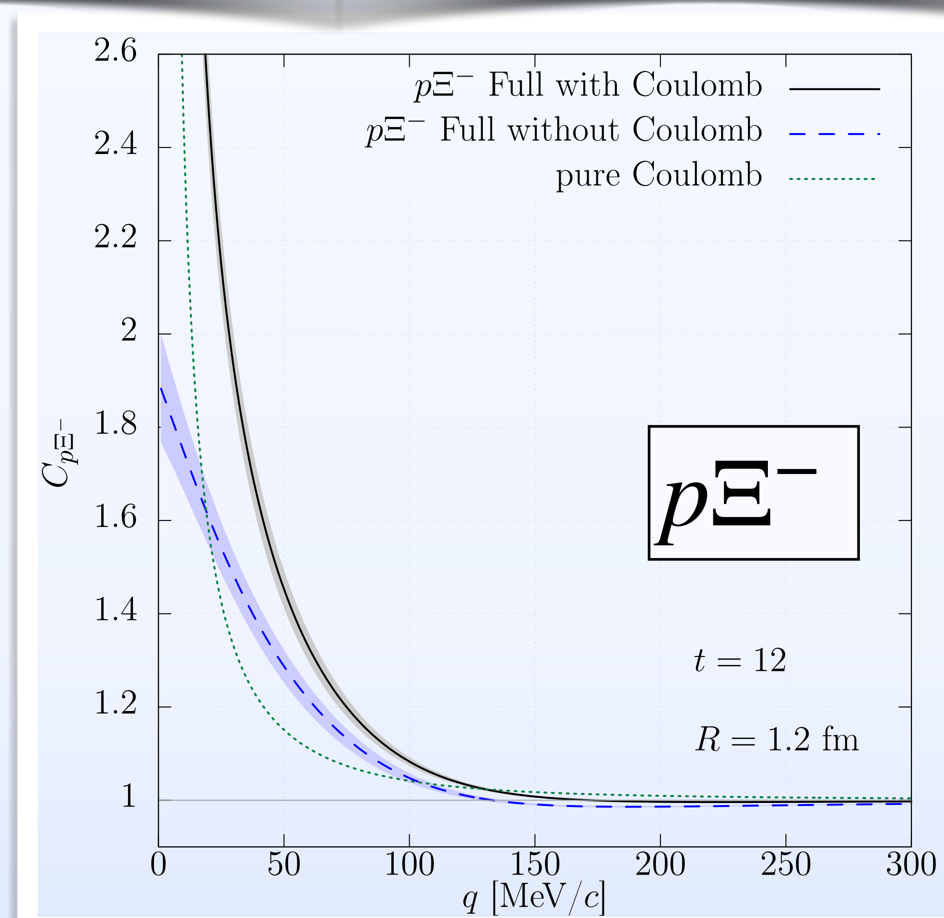
$$C_{p\Xi^-} = \frac{1}{4} C_{p\Xi^-,\text{singlet}} + \frac{3}{4} C_{p\Xi^-,\text{triplet}}$$

Couples to ΛΛ (H-dibaryon channel)

- Enhancement from pure Coulomb case
- $n\Xi^0$ source contribution
  Singlet (J=0) : sizable enhancement
  Triplet (J=1) : negligible
- ΛΛ source contribution : Negligible







$\Lambda\Lambda$-$N\Xi$ interaction and $\Lambda\Lambda$ and $p\Xi^-$ correlation function

- $\Lambda\Lambda$ correlation function

$$C_{\Lambda\Lambda} = 1 - \frac{1}{2}\underbrace{\exp(-4q^2R^2)}_{\text{Quantum statistics}} + \underbrace{\Delta C_{\Lambda\Lambda}}_{\text{Strong int.}}$$

Quantum statistics

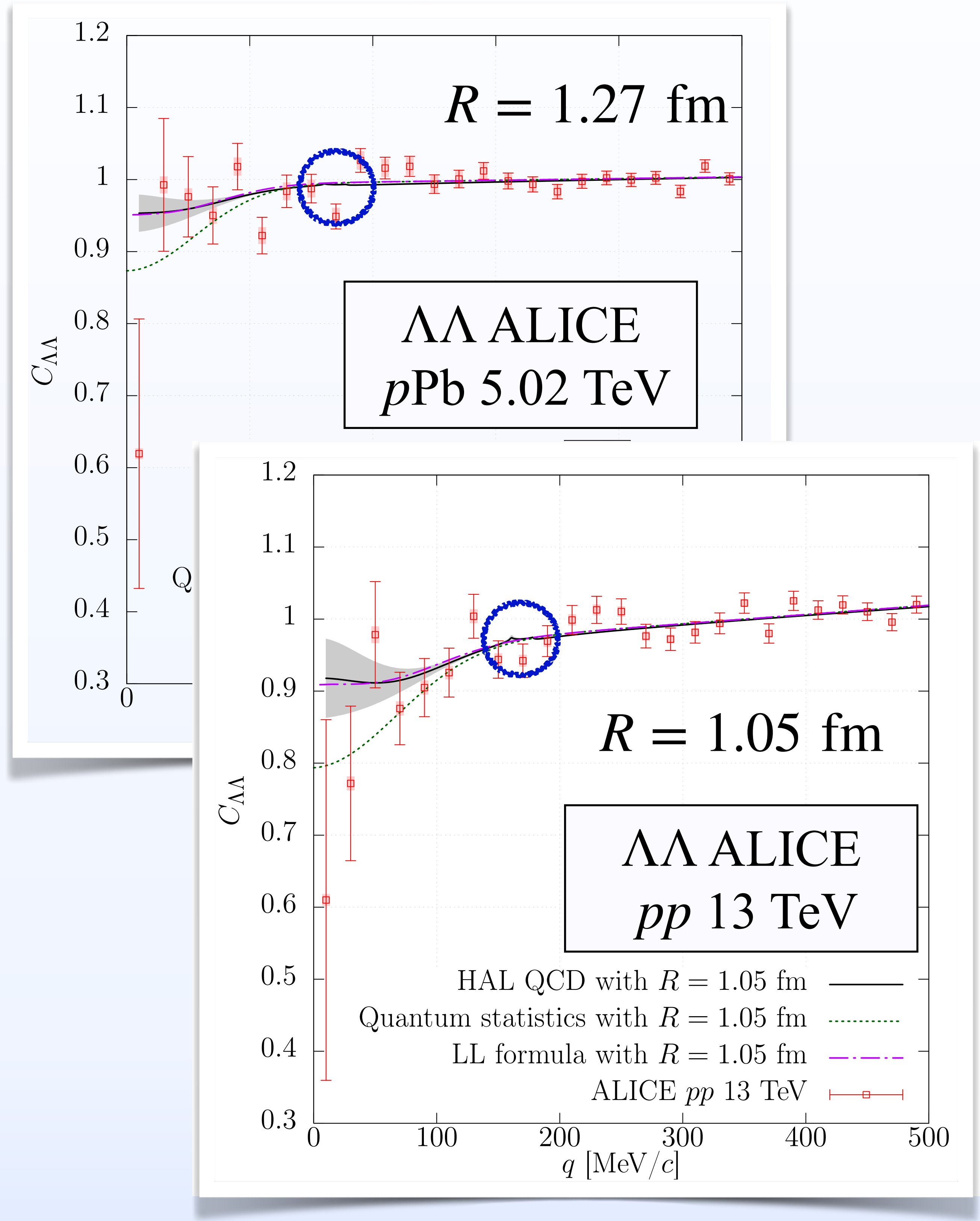
Strong int.

- Enhancement from quantum statistics
  week attractive interaction

- $N\Xi$ cusps: almost invisible
  ⟵ Due to weak coupling of $\Lambda\Lambda$-$N\Xi$

- Comparison with ALICE data
  pPb 5.02 TeV, *pp* 13 TeV collisions :
  S. Acharya et al. [ALICE], PLB 797 (2019).

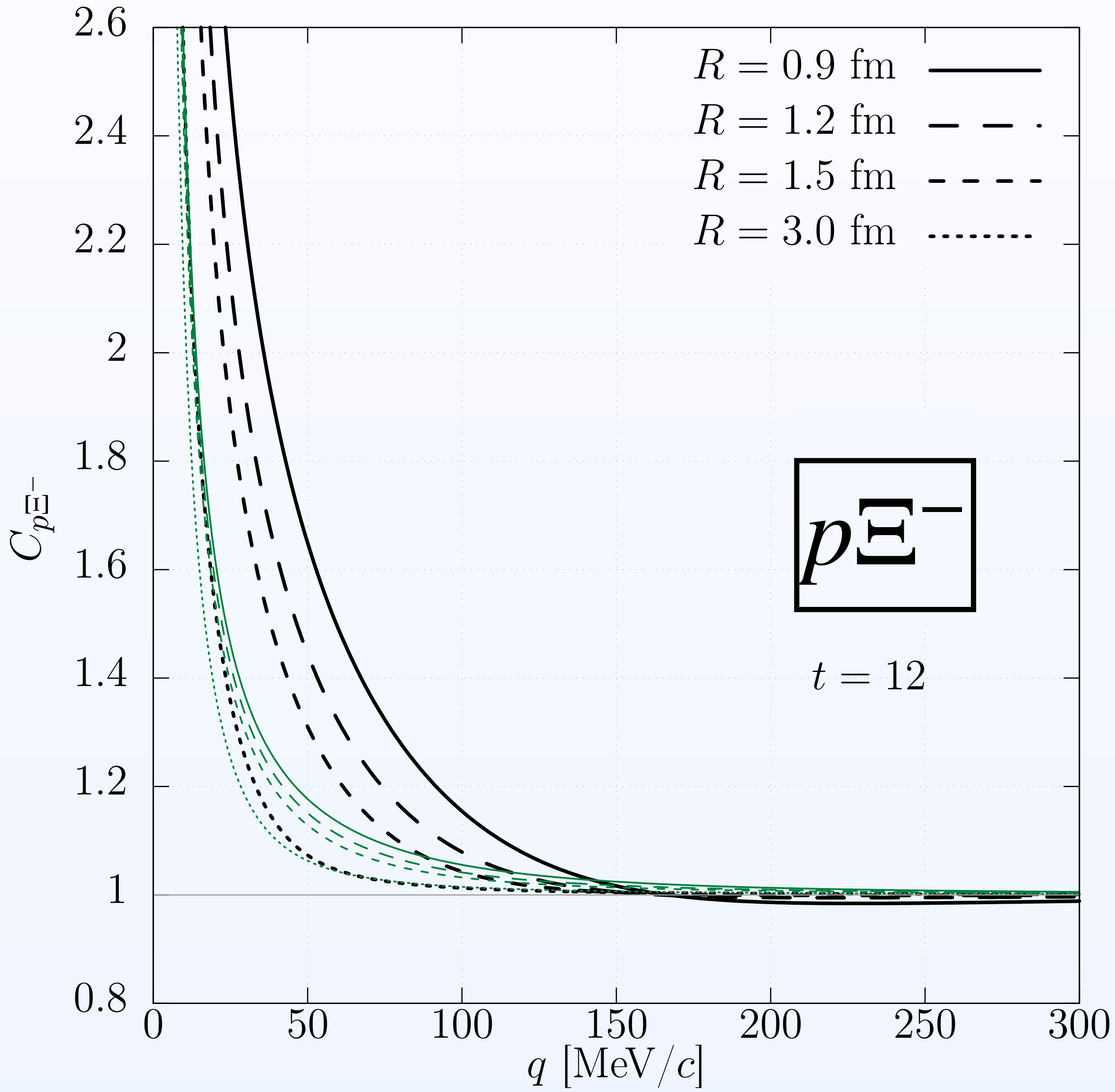
➡
- Weak attraction of $\Lambda\Lambda$ int.
- There is no signal of H-dibaryon

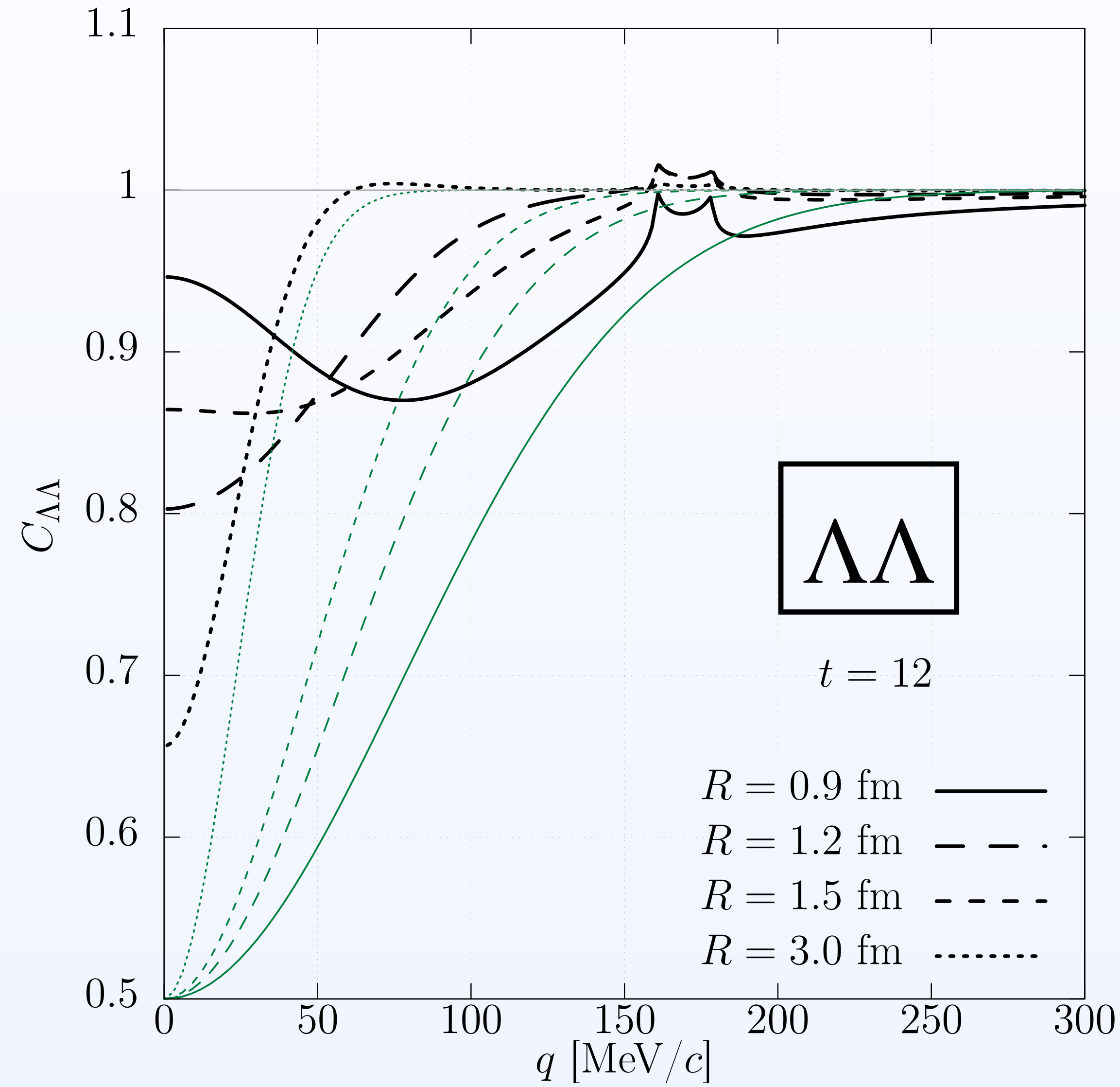


Y. Kamiya, et al. PRC 105, 014915 (2022)

ΛΛ-$N\Xi$ interaction and ΛΛ and $p\Xi^-$ correlation function

- Source size dependence





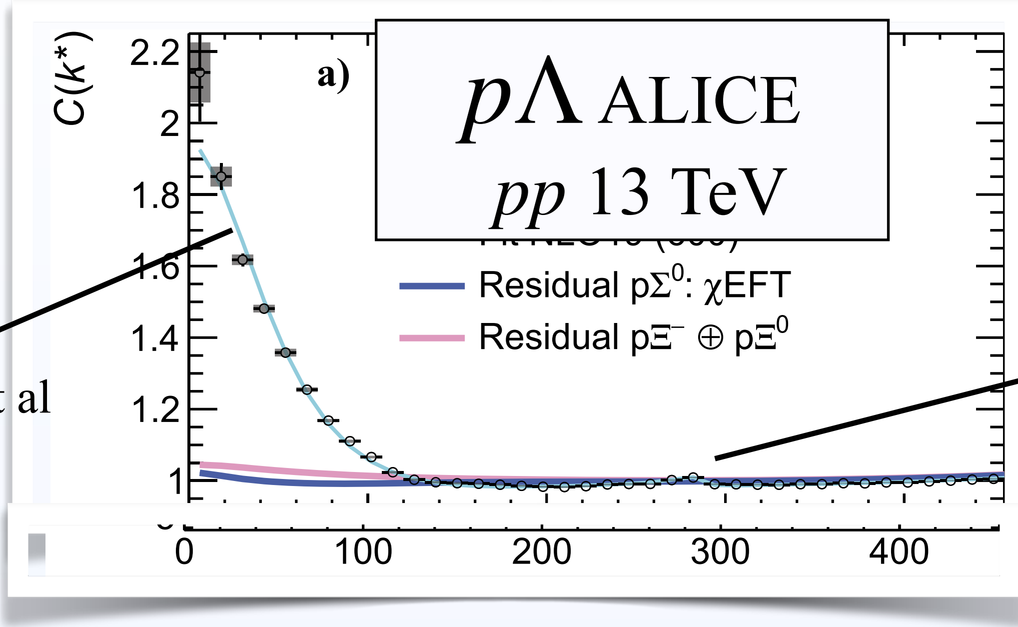
- $p\Xi^-$
  - small enhancement for large (R ~ 3 fm) case w/o any dip
- ΛΛ
  - To see source size dependence at small q is mandatory to see the week interaction

Y. Kamiya, et al. PRC 105, 014915 (2022)

Femtoscopy for $S = -1$ systems

- $p\Lambda$

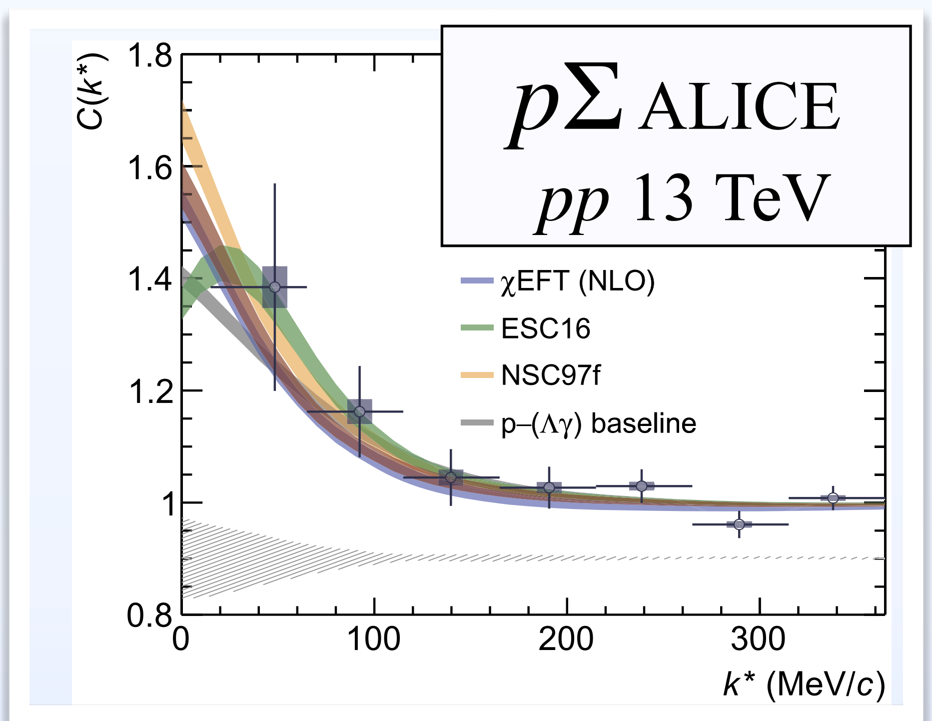
NLO 19
J. Haidenbauer, et al
EPJA 56(2020)



Cusp structure at $N\Sigma$ thresholds are also reproduced.

ALICE PLB 805 (2020) 135419

- $p\Sigma$



PLB 833 (2022) 137272

In agreement with various theoretical models.
More precise data required to distinguish them.

$d\Xi^-$ correlation function

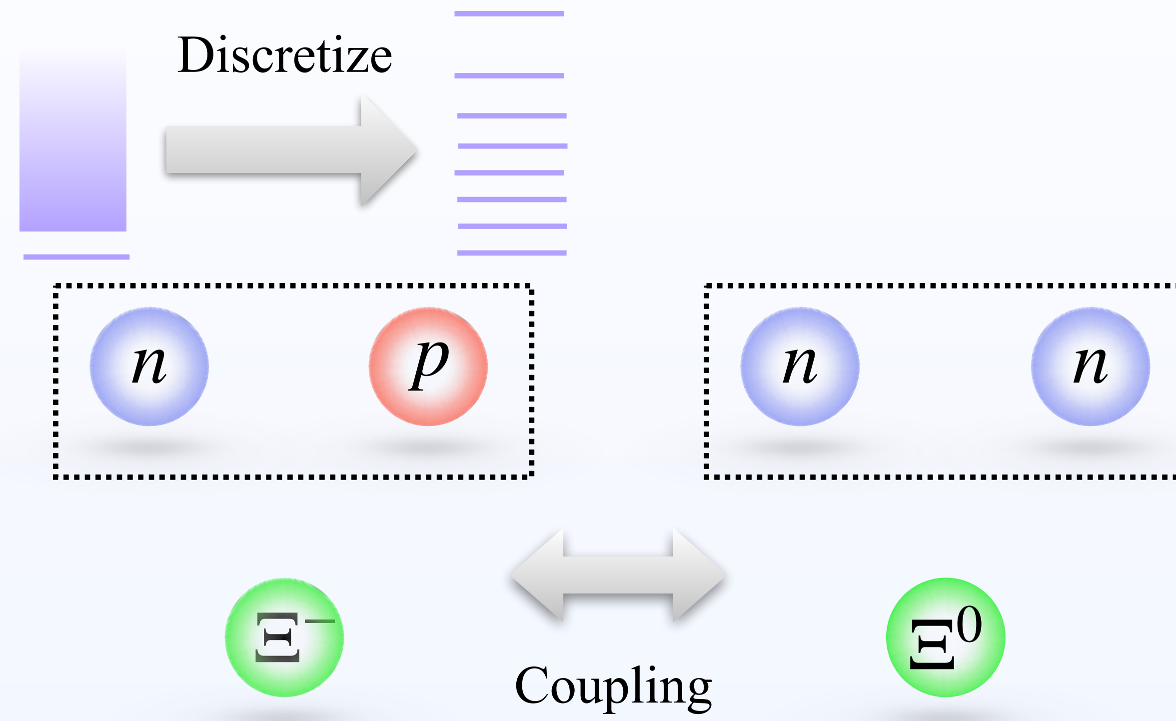
- Three body system of $d(np)\Xi$
  - Three body problem : continuum-discretized coupled-channels method (CDCC)

    N. Austern, M. Yahiro, and M. Kawai, PRL 63 2649(1989)
    N. Austern, M. Kawai, and M. Yahiro, PRC 53 314 (1996)

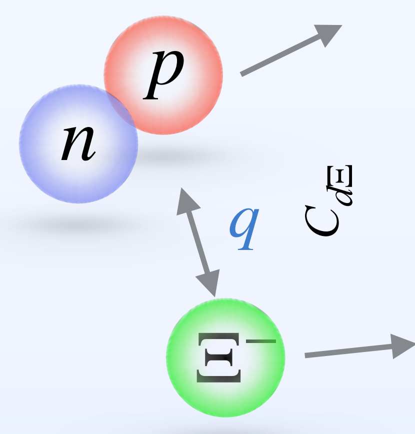
    ==> d-Ξ relative wave function
  - $N\Xi$ interaction : HAL QCD potential

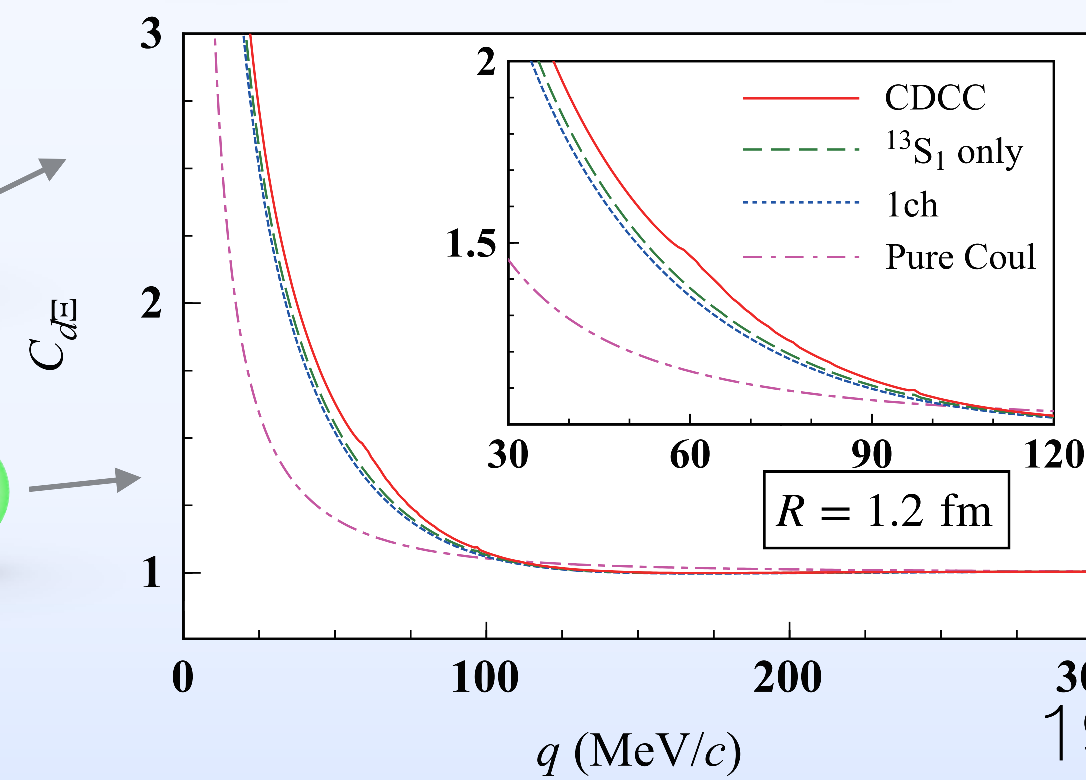
    K. Sasaki et al. [HAL QCD], NPA 998 (2020), 121737.
  - Coupling between $np\Xi^-$-$nn\Xi^0$ included

K. Ogata, T. Fukui, Y. Kamiya, and A. Ohnishi, PRC103 (2021) 6, 065205



- Theoretical model for $C_{d\Xi^-}$
  - Strong enhancement compared to pure Coulomb case
  - Coupling effect by $np\Xi^-$-$nn\Xi^0$ is estimated to be 6–8 %





Correlation with few body systems

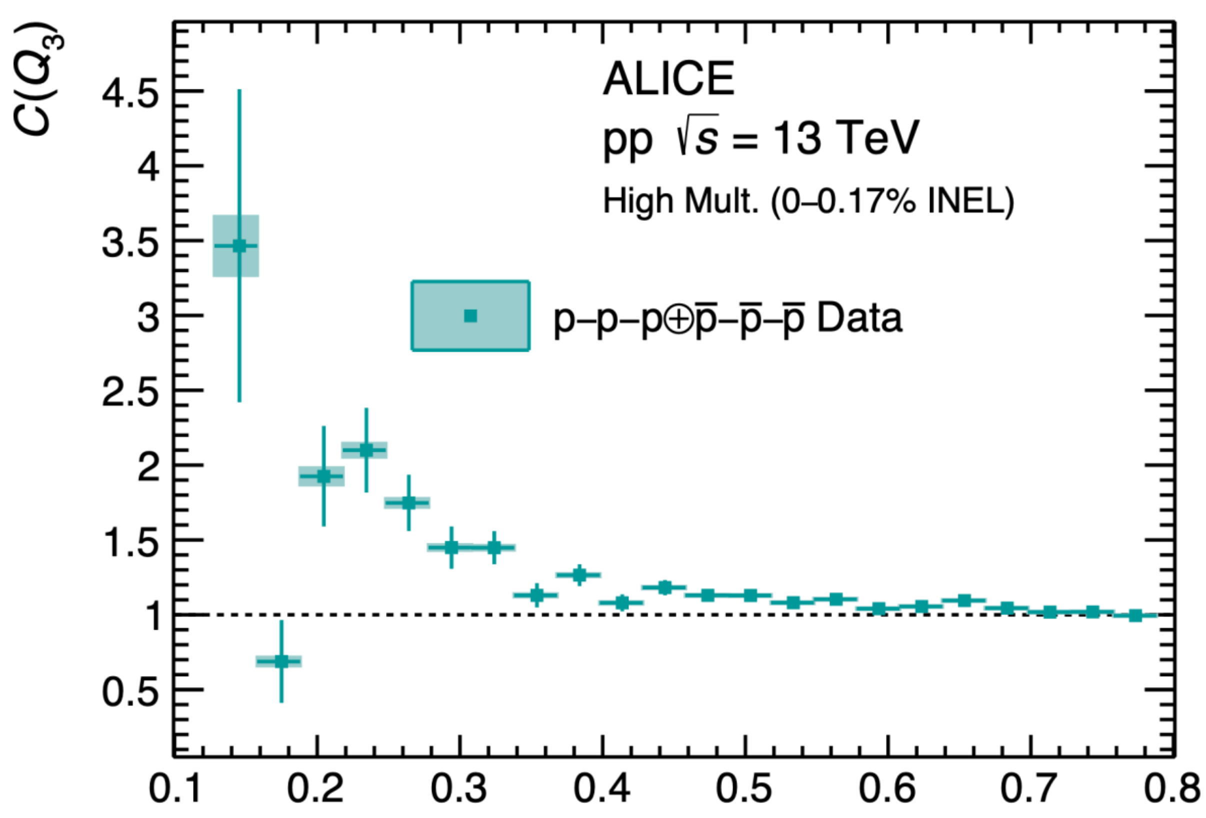
- ppp, $pp\Lambda$ correlation

Three body correlation : $C(\mathbf{p}_1, \mathbf{p}_2, \mathbf{p}_3) \equiv \frac{P(\mathbf{p}_1, \mathbf{p}_2, \mathbf{p}_3)}{P(\mathbf{p}_1)\,P(\mathbf{p}_2)\,P(\mathbf{p}_3)}$

Extension to three-particle system

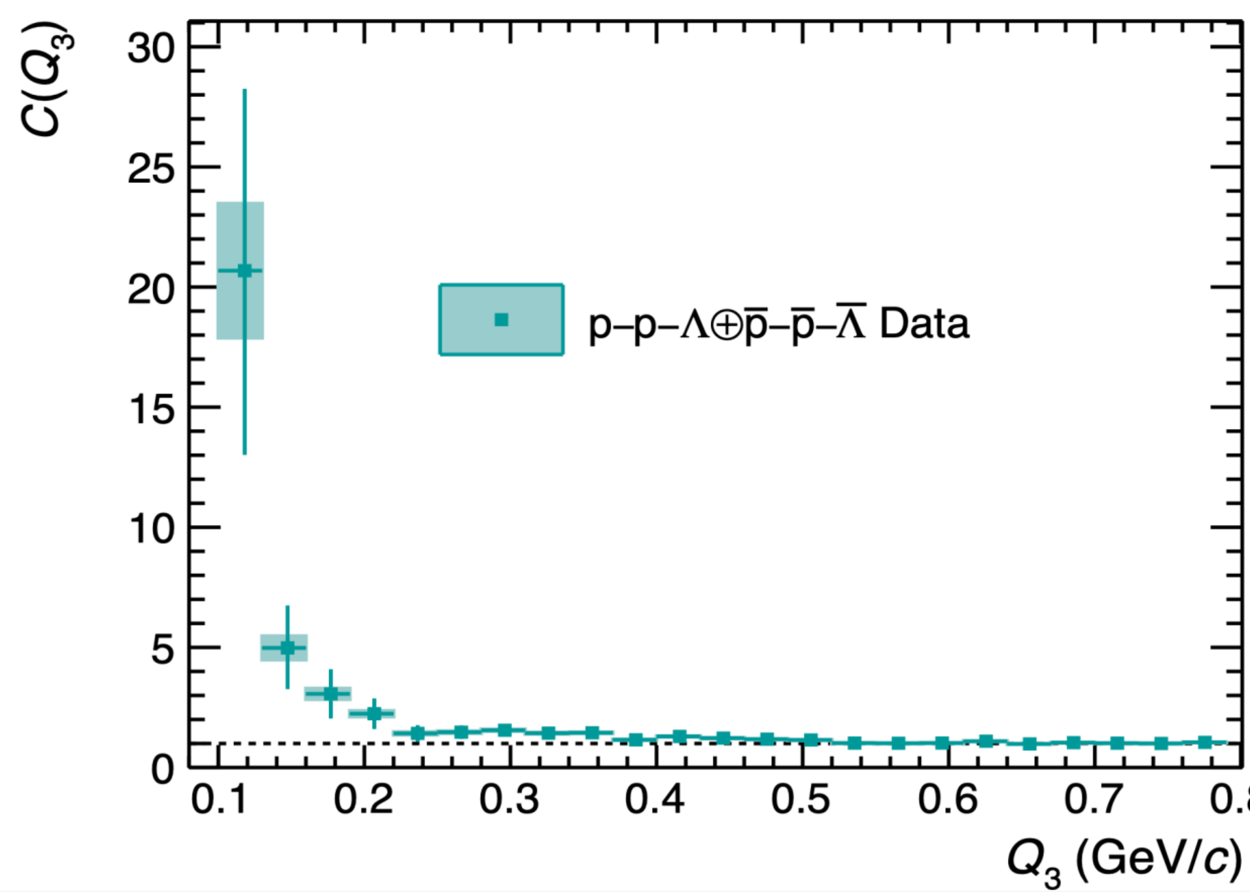
- First measurement of the free scattering of three hadrons
- Deviation from unity in p-p-p and p-p-Λ correlation functions

p-p-p



ALICE Coll., EPJ A 59, 145 (2023)

p-p-Λ

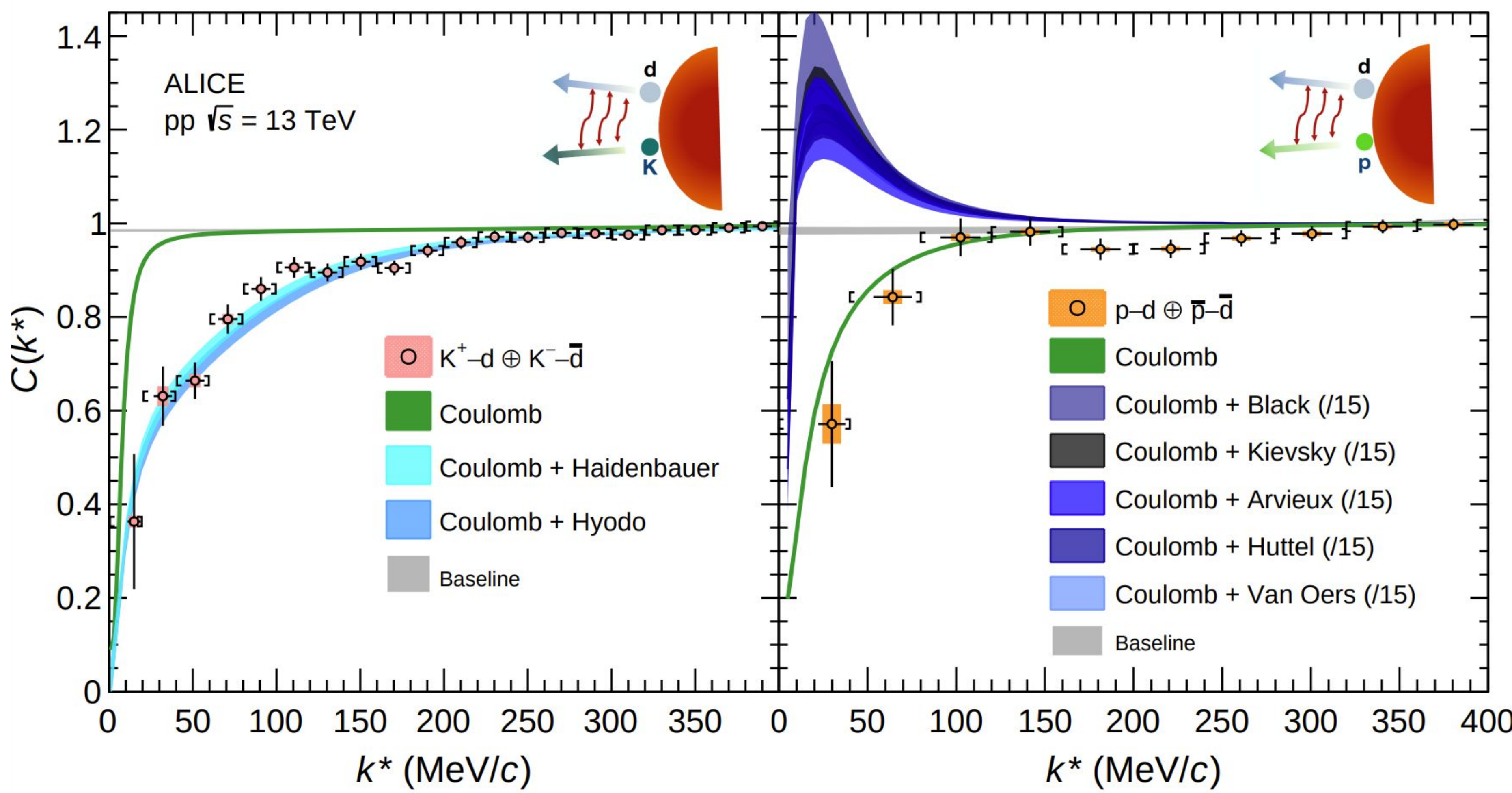


Talk slide from Raffaele Del Grande in HHIQCD 2024

Correlation with few body systems

Lednicky model vs ALICE data

ALICE



r_{K+d}=1.41±0.04 fm

r_{pd}=1.08±0.06 fm

pd model calculations scaled by 1/15

<u>Kd data well reproduced</u>

⇒ fully formed deuterons present assuming small source

<u>pd data not described</u>

⇒ pd can't be treated as effective two-body system

Considering protons, deuterons as distinguishable point-like particles leads to huge discrepancy

<u>arXiv:2206.03344</u> (ALICE)

Talk slide from Oton Vazquez Doce's in FemTUM2022

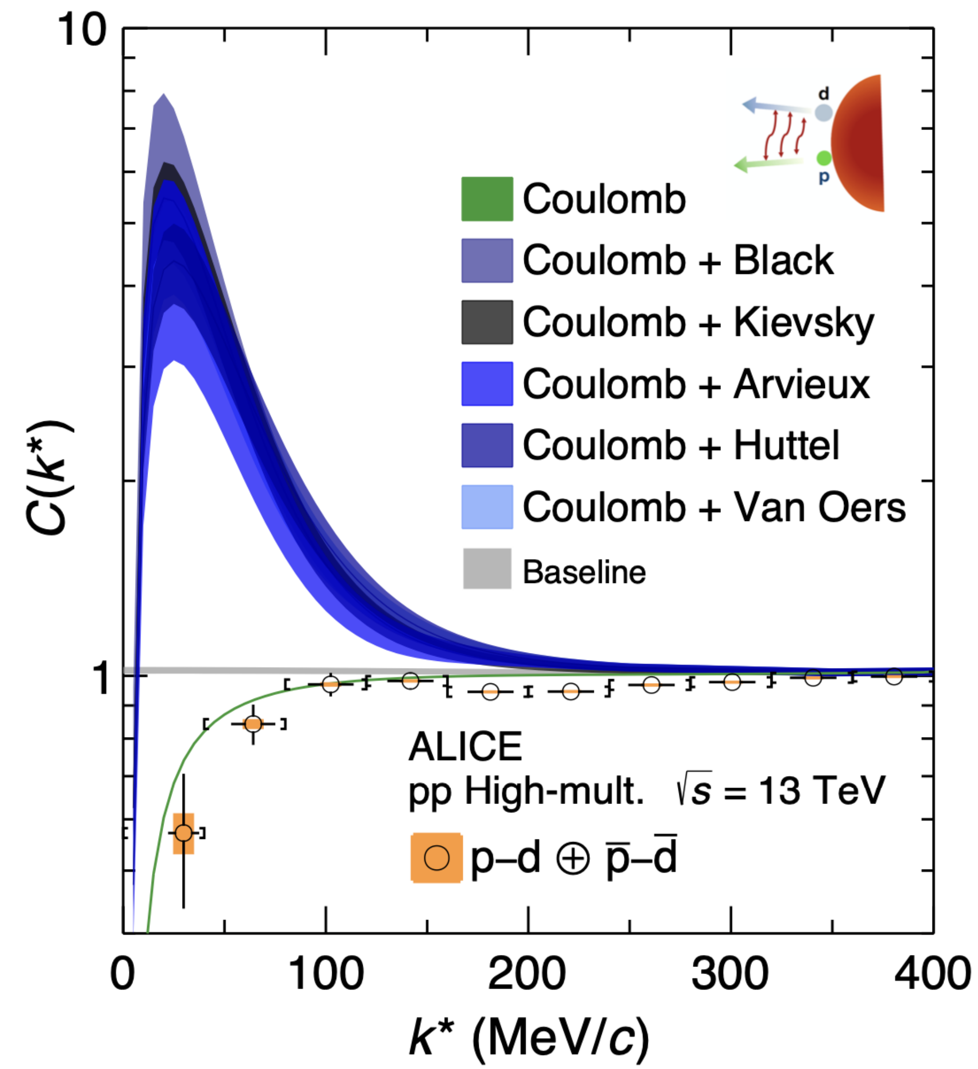
Correlation with few body systems

- *p-d* correlation

NNN using proton-deuteron correlations

- Point-like particle models anchored to scattering experiments
  W. T. H. Van Oers et al., NPA 561 (1967);
  J. Arvieux et al., NPA 221 (1973); E. Huttel et al., NPA 406 (1983);
  A. Kievsky et al., PLB 406 (1997); T. C. Black et al., PLB 471 (1999);
- Coulomb + strong interaction using Lednický model
  Lednický, R. Phys. Part. Nuclei 40, 307–352 (2009)
- Only s-wave interaction
- Source radius evaluated using the universal m_T scaling

Point-like particle description doesn't work for p-d



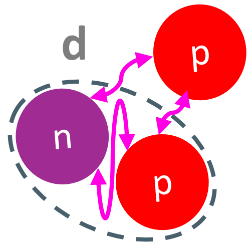
ALICE Coll. Phys. Rev. X 14, 031051 (2024)

Talk slide from Raffaele Del Grande in HHIQCD 2024

Correlation with few body systems

- *p-d* correlation

NNN using proton-deuteron correlations



- The p–d **correlation function**, assuming that p–p–n forms p–d

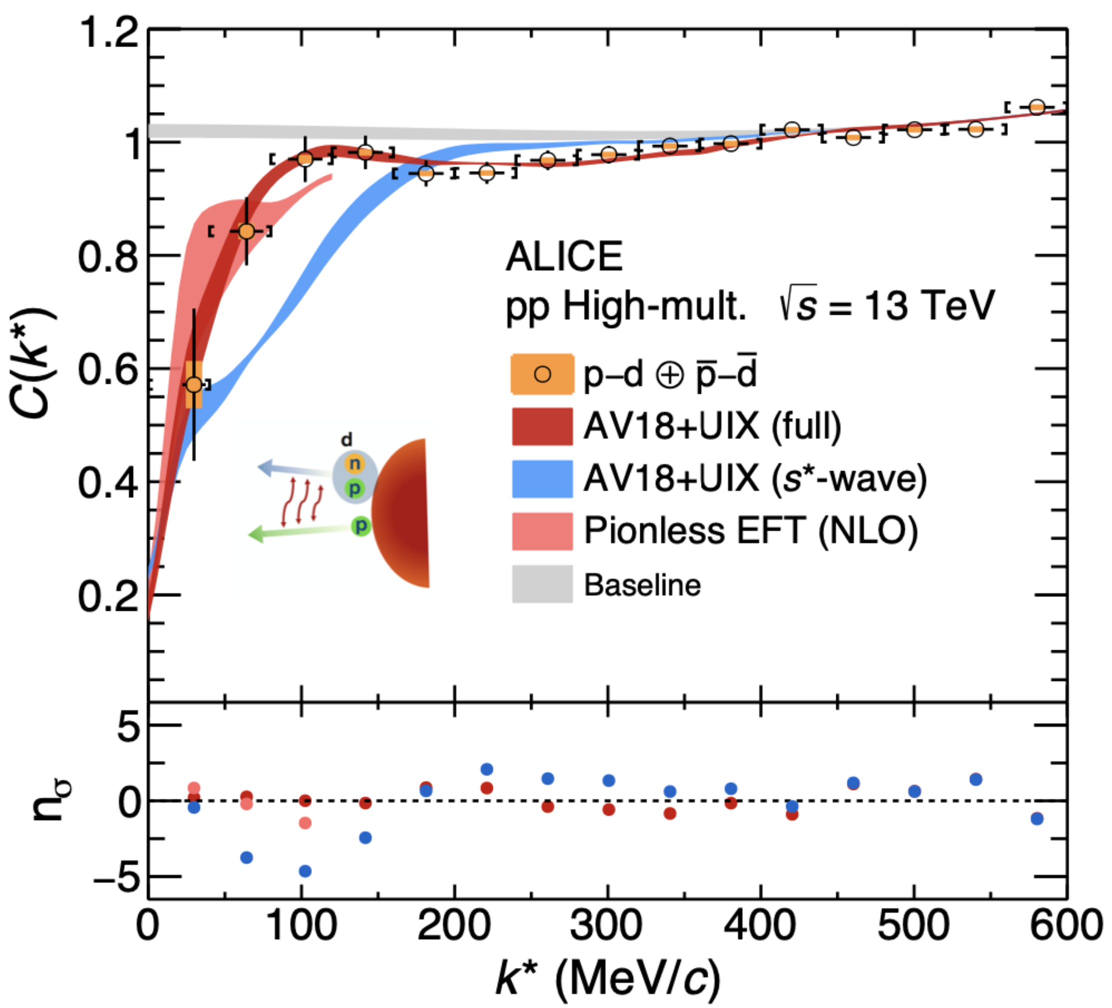
$$C_{pd}(k) = \frac{1}{A_d}\frac{1}{6}\sum_{m_1,m_2} \int d^3r_1 d^3r_2 d^3r_3 S_1(r_1)S_1(r_2)S_1(r_3)\left|\Psi_{m_1,m_2}\right|^2$$

where $S_1(r)$ is a single-particle Gaussian source and A_d is the formation probability of a deuteron

- The **three-body wavefunction** of the p–d System

$$\Psi_{m_2,m_1}(x,y) = \underbrace{\Psi^{free}_{m_2,m_1}}_{\text{Asymptotic solution}} + \underbrace{\sum_{LSJ}^{J\leq\bar{J}} \sqrt{4\pi}\, i^L\sqrt{2L+1}\, e^{i\sigma_L}\left(1m_2\tfrac{1}{2}m_1\middle|SJ_z\right)(\mathrm{L0SJ_z|JJ_z})\tilde{\Psi}_{LSJJ_z}}_{\text{Three-body dynamics}}$$

- **Hadron-nuclei correlations at the LHC can be used to study many-body dynamics**

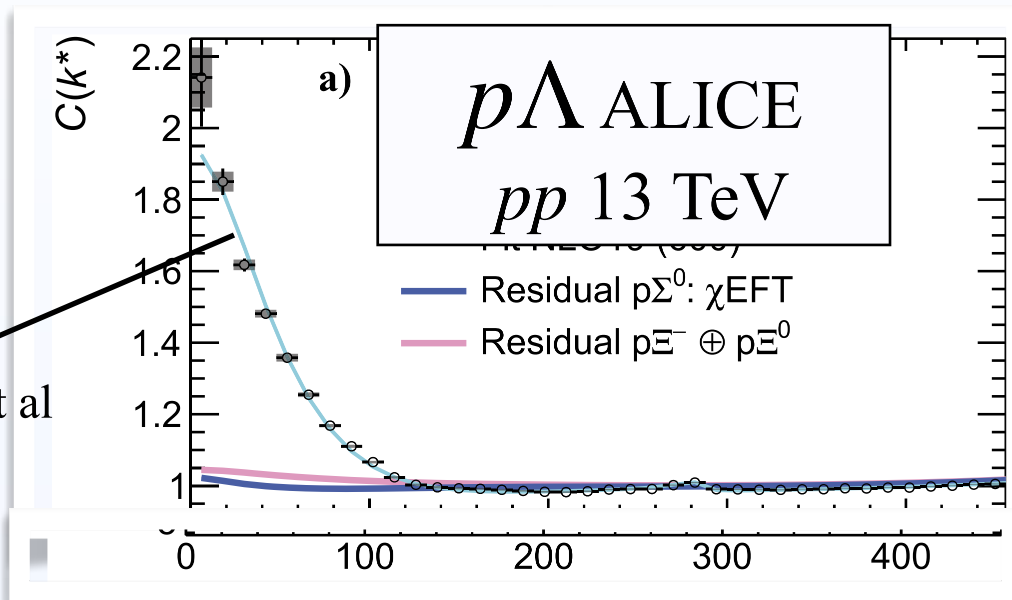


ALICE Coll. Phys. Rev. X 14, 031051 (2024)
M. Viviani et al, Phys.Rev.C 108 (2023) 6, 064002

Talk slide from Raffaele Del Grande in HHIQCD 2024

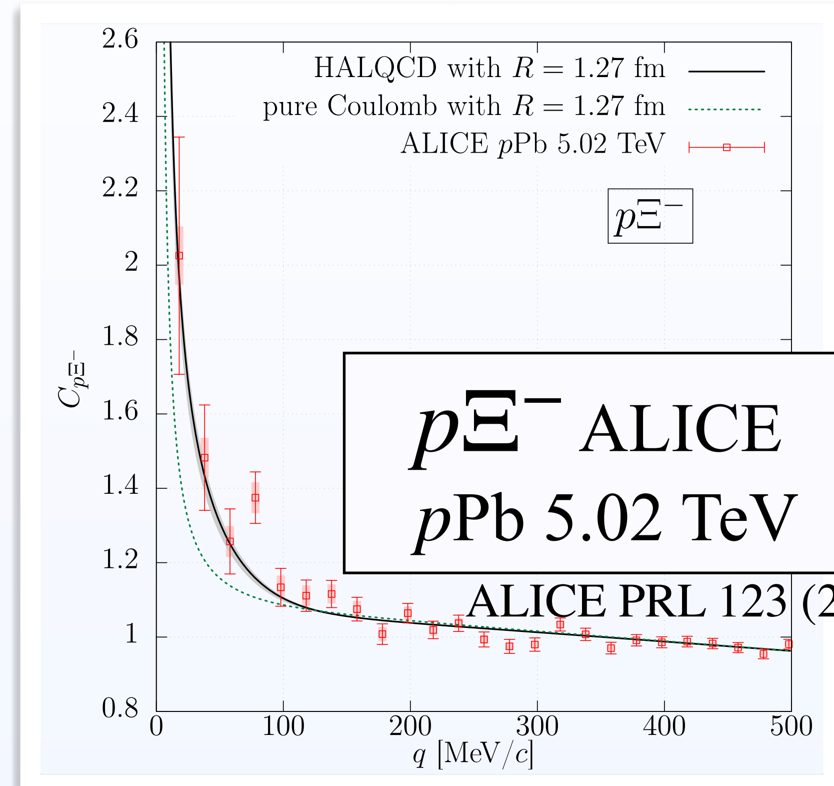
Y-α correlation

- Good agreement of Y-N correlation function



NLO 19
J. Haidenbauer, et al
EPJA 56(2020)

ALICE PLB 805 (2020) 135419

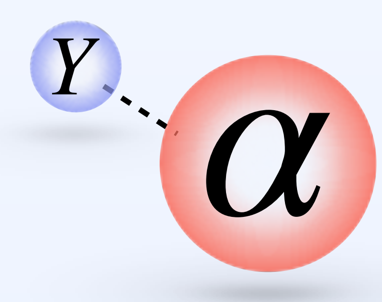


ALICE PRL 123 (2019).

Y. Kamiya, et al. PRC 105, 014915 (2022)

Y-α(^{4}He) correlation

- Large binding energy of α
  —> • Good description by two body treatment



- Y-α potential: smeared potential range
  —> • Detailed potential shape may be investigated

Further constraint on the YN(YY) int?

$\Lambda\alpha$ correlation

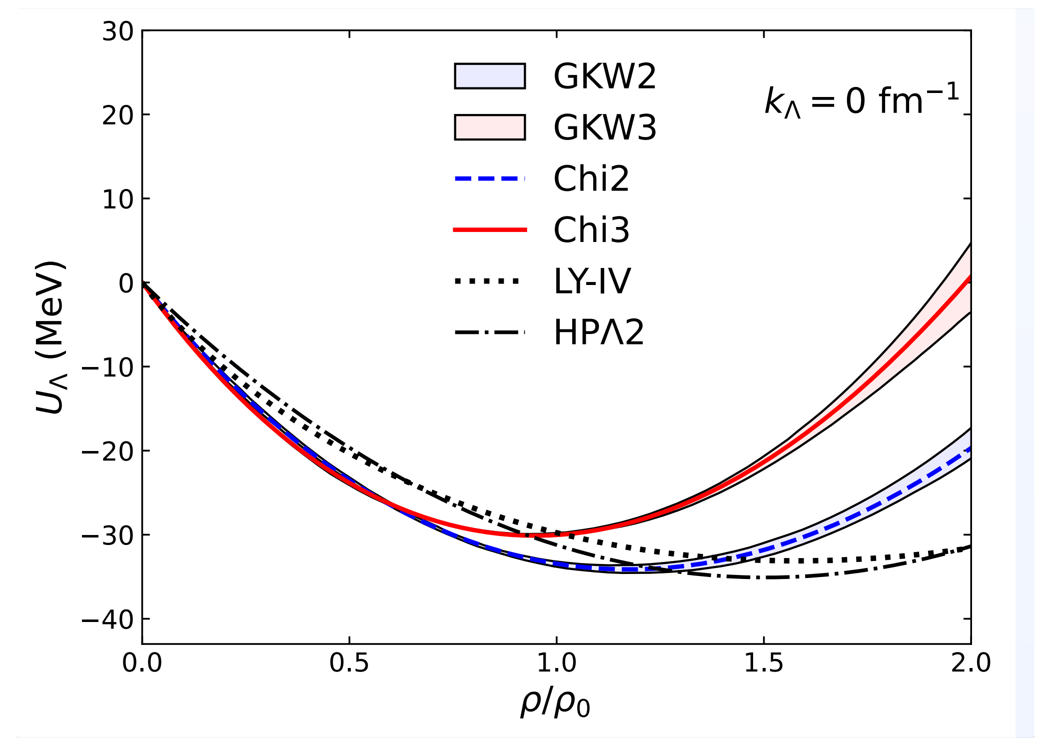
$N\Lambda$ interaction at finite density

- Chiral EFT with NLO D. Gerstung, N. Kaiser, W. Weise, EPJA 55 (2020)
  —> ΛNN three body interaction gives the additional repulsion
  —> stiffer EOS
- Chi3: Skyrme type Λ potential based on Chiral EFT with three body
  A. Jinno, K. Murase, Y. Nara, and A. Ohnishi, PRC 108 (2023) 6, 065803

$$U_\Lambda^{\mathrm{local}} = a_1^\Lambda \rho_N + a_2^\Lambda \tau_N - a_3^\Lambda \triangle \rho_N + a_4^\Lambda \rho_N^{4/3} + a_5^\Lambda \rho_N^{5/3}$$

  - Well reproduces the binding energy of Λ in hypernuclei

A. Jinno, Y. Kamiya, T. Hyodo, A. Ohnishi, PRC 110 (2024), 014001



- $N\Lambda$ potential model with different density dependence
  D. E. Lanskoy and Y. Yamamoto, PRC 55, 2330 (1997)
  N. Guleria, S. K. Dhiman, and R. Shyam, Nucl. Phys. A 886, 71 (2012)
  - HPΛ2
  - LY-IV

  Weaker desnity dependence

$\Lambda\alpha$ correlation

$\Lambda\alpha$ potential w/ Skyrme type pot.

- Nucleon density with Gaussian form:

$$\rho(r) = A(2\nu_c/\pi)^{3/2} e^{-2\nu_c r^2}$$

  - high central density ~ $2\rho_0$

- Unknown a_3^Λ: fit to reproduce the $^5_\Lambda$He experimental $E_B = 3.12$ MeV

Simple potential models

Kumagai-Fuse, S. Okabe, Y. Akaishi, PLB 345 (1995)

- Isle potential

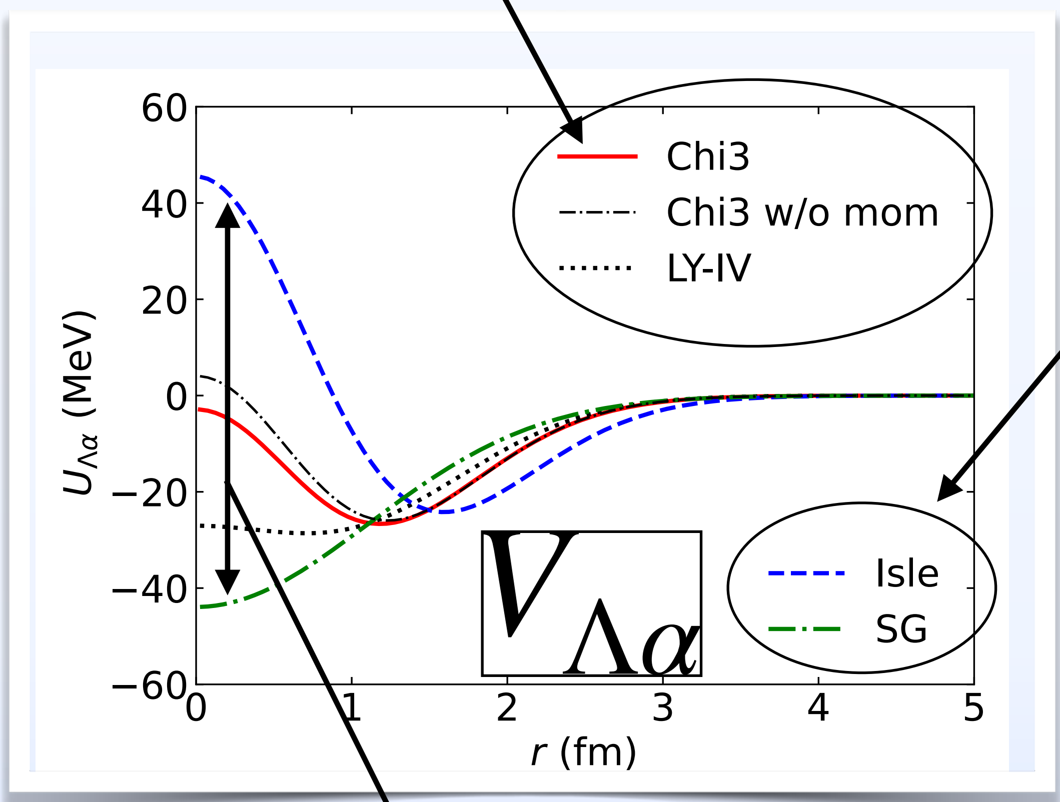
$$V(r) = V_1 e^{-r^2/b_1^2} + V_2 e^{-r^2/b_2^2}$$

repulsive core (short range) — attractive part (long range)

- Single Gaussian (Isle)

$$V(r) = Ve^{-r^2/b^2}$$

  - parameters are chosen to reproduce E_B



Large difference in strength of repulsive core

- Difference of ρ dependence of Skyrme pot. appear in the strength of repulsive core.

- Strength of repulsive core

Isle > Chi3 > LY-IV> SG (No core)

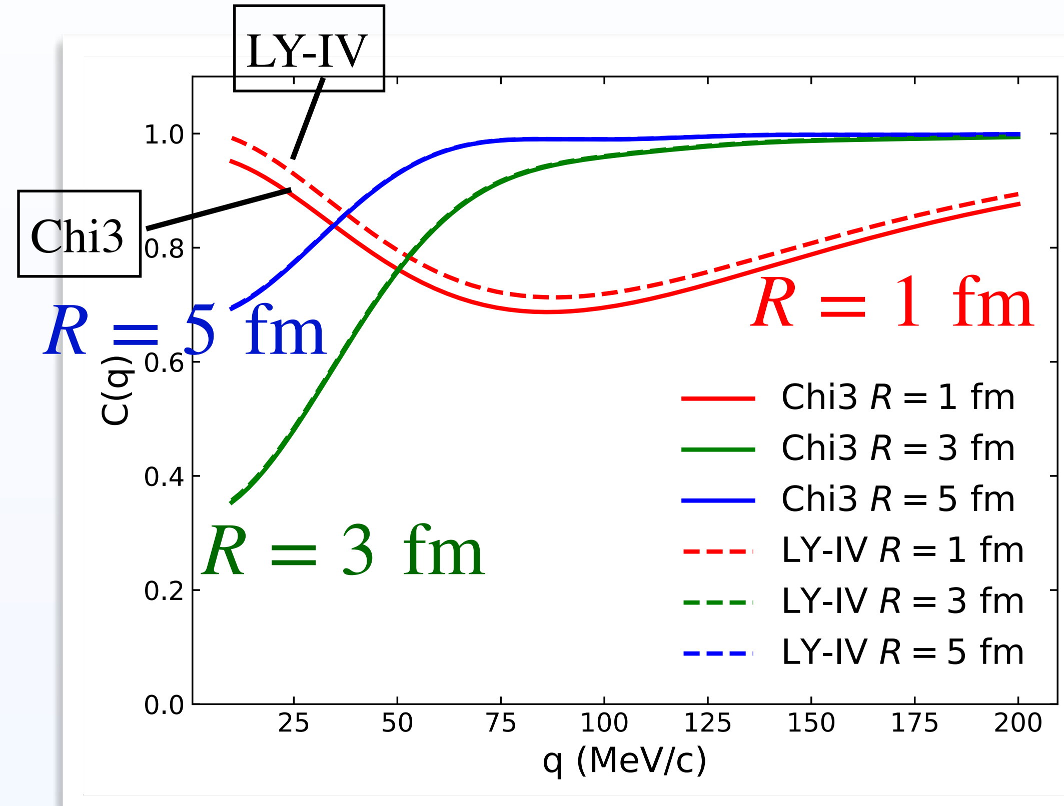
- Potential shape dependence of $C_{\Lambda\alpha}$?

Λα correlation

Source size dependence of $C_{\Lambda\alpha}$

- Characteristic lineshapes for weak binding system ($^{5}_{\Lambda}$He)
  - Dip for small source
  - Suppression for large source
- Potential difference appear only in small source results

➡ <u>Large source results are useful to check E_B of $^{5}_{\Lambda}$He</u>



Effect of repulsive core

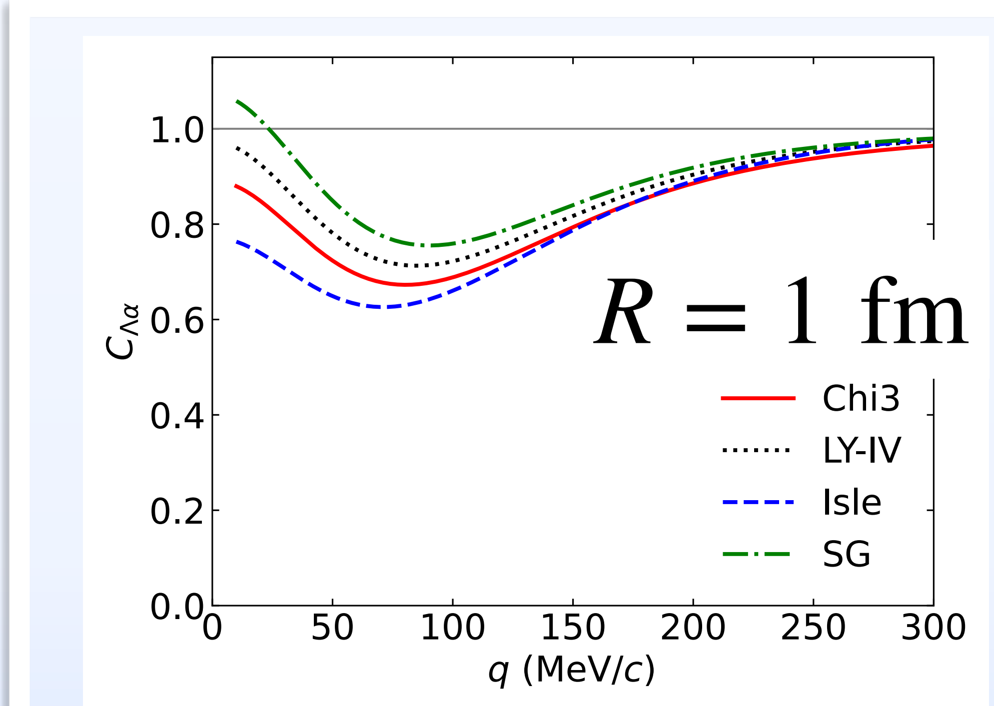
- $C(q)$ are ordered from bottom to top as

  Isle -> Chi3 -> LY-IV -> SG (No core)

  Same ordering with the strength of repulsive core

  —> Stronger core causes Stronger suppression

➡ <u>Strength of the repulsive core can be tested with $C_{\Lambda\alpha}(q)$ from small source.</u>

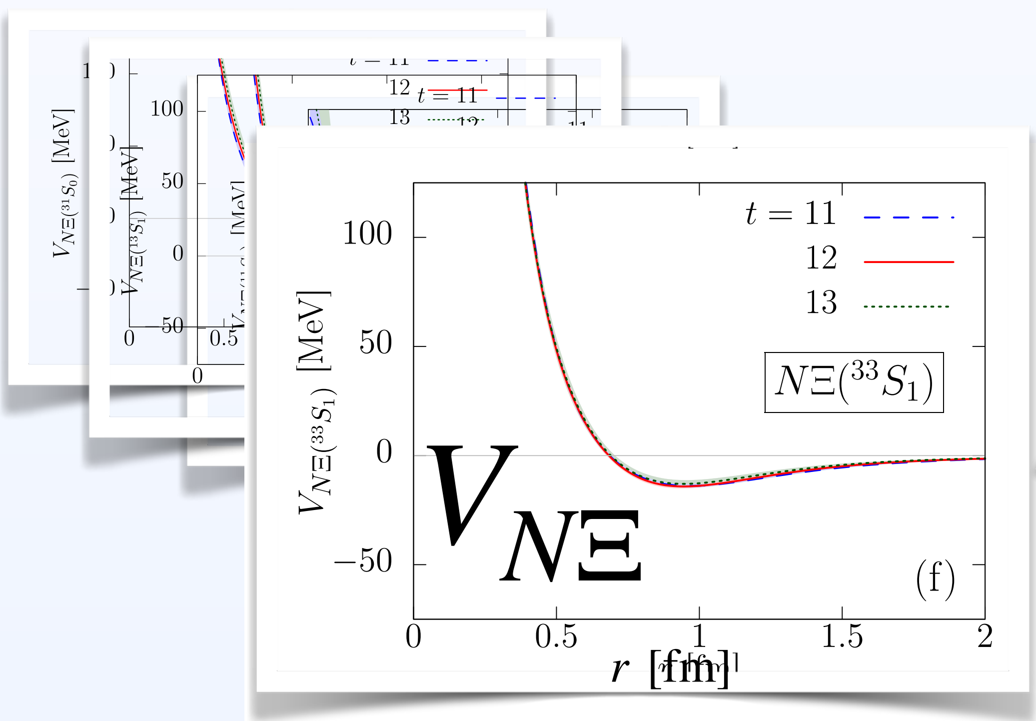


A. Jinno, Y. Kamiya, T. Hyodo, A. Ohnishi, PRC 110 (2024), 014001

$\Xi\alpha$ correlation

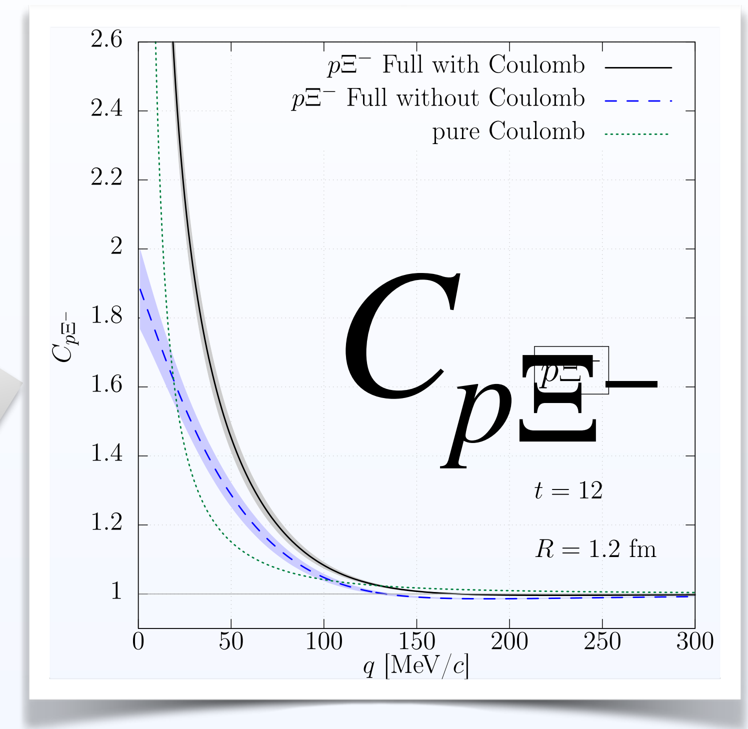
- $N\Xi$ potential and $\Xi\alpha$ potential

• HAL QCD $N\Xi$ potential
K. Sasaki et al., NPA, 121737 (2019).
4 components for s-wave : ${}^{11}S_0$, ${}^{13}S_1$, ${}^{31}S_0$, ${}^{33}S_1$



• Repulsive core
• Long tail attraction by π exchange

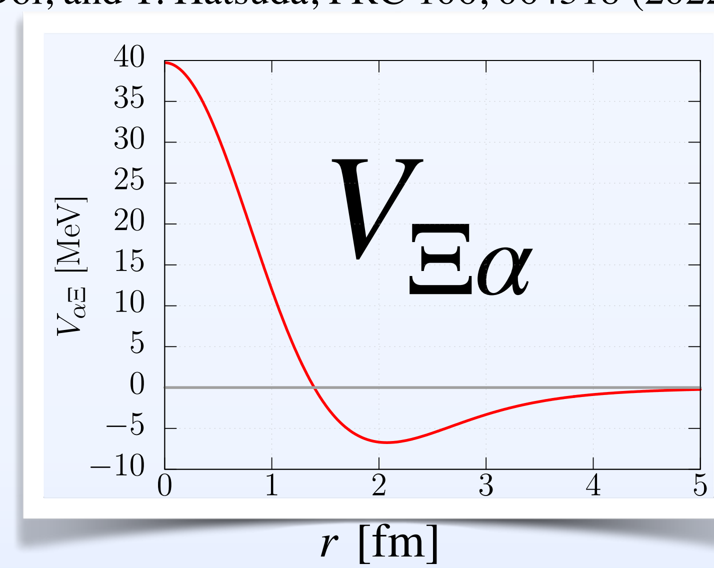
• $p\Xi^-$ correlation
$\sim [C({}^{11}S_0) + 3C({}^{13}S_1)$
$C({}^{31}S_0) + 3C({}^{33}S_1)]/8$



• Large enhancement from ${}^{11}S_0$

• Folding $\Xi\alpha$ potential
E. Hiyama, M. Isaka, T. Doi, and T. Hatsuda, PRC 106, 064318 (2022).

$[V({}^{11}S_0) + 3V({}^{13}S_1)$
$3V({}^{31}S_0) + 9V({}^{33}S_1)]/16$



• Large weight of ${}^{11}S_0$

• <u>Different channel weight</u>

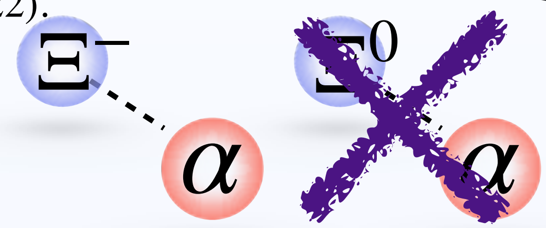
• <u>Effect of smeared repulsive core/attraction?</u>

$\Xi\alpha$ correlation

Predictions for $\Xi\alpha$ bound state: ${}^{5}_{\Xi}\mathrm{H}$

- Coulomb assisted bound state <— HAL QCD pot.
  - Bound state found only for Coulomb attractive pair
    E. Hiyama, et al PRC 106, 064318 (2022).
    K. Sasaki et al., NPA, 121737 (2019).

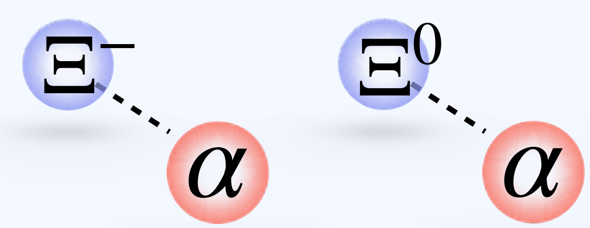
    $E_B = 0.47$ MeV



Large difference comes from ${}^{33}S_1$
H. Le, et al EPJA (2021)

- Deeper bound state <— chiral effective SU(3) pot.
  H. Le, et al EPJA (2021)

  $E_B = 2.16$ MeV

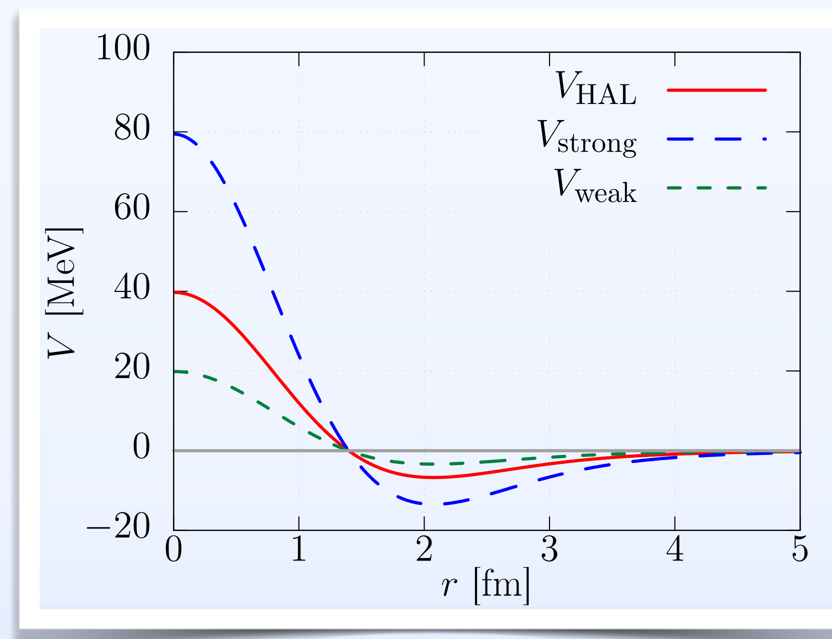


- Behavior for Coulomb assisted bound state?
- Can we distinguish ${}^{5}_{\Xi}\mathrm{H}$ with $C_{\Xi^-\alpha}$?

Folding potential and variations

- V_{HAL}: Folding potential based on $S = -2$ HAL QCD potential
  E. Hiyama, M. Isaka, T. Doi, and T. Hatsuda, PRC 106, 064318 (2022).
  K. Sasaki et al., NPA, 121737 (2019).

potential	E_B ($\Xi^0\alpha$) [MeV]	E_B ($\Xi^-\alpha$) [MeV]
VHAL	(Unbound)	0.47
Vstrong = 2 *VHAL	1.15	2.16
Vweak = VHAL /2	(Unbound)	0.18



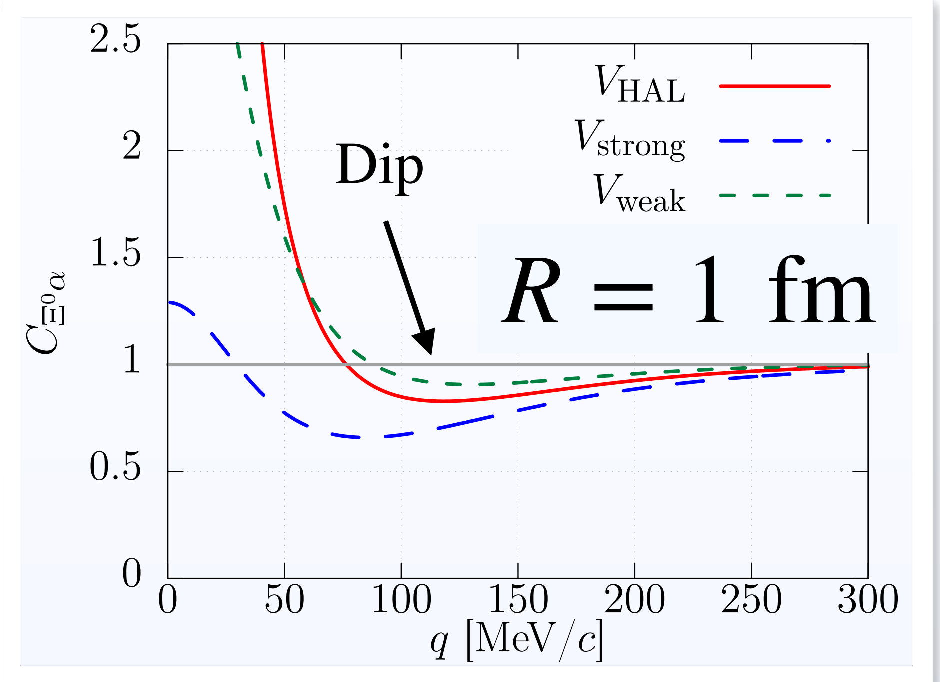
$\Xi\alpha$ correlation

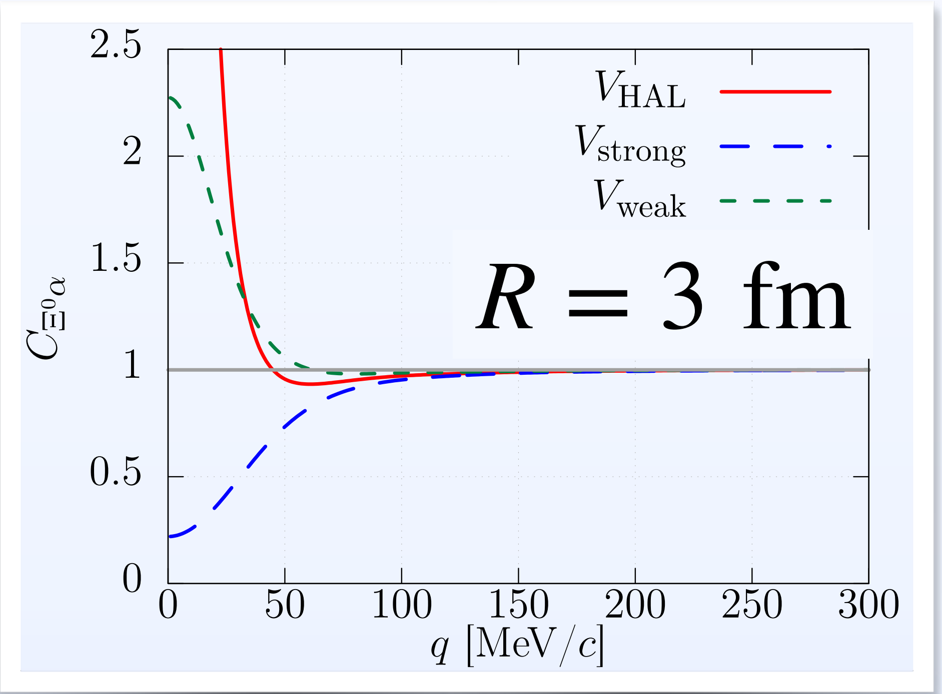
- $\Xi^0\alpha$ correlation

potential	E_B [MeV]
VHAL	(Unbound)
Vstrong	1.15
Vweak	(Unbound)

- $V_{\rm strong}$: Typical source size dependence with bound state
  - Suppression for large R
  - Enhancement and dip for for small R
- $V_{\rm HAL}$, $V_{\rm weak}$: strong enhancement
  - consistent with No ${}^{5}_{\Xi}$H
- Dip in $q \sim 100$ MeV/c for $V_{\rm HAL}$ and $V_{\rm weak}$
  - Suppression by repulsive core?

- Source size dependence can
- Effect of detailed potential shape?





Y. Kamiya, A. Jinno, T. Hyodo, A. Ohnishi, 2409.13207

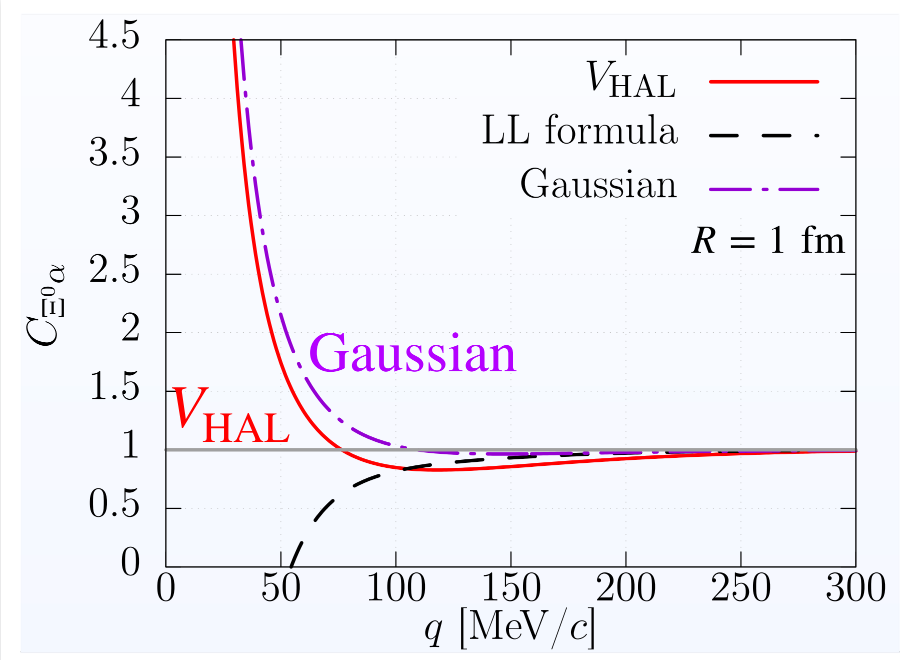
$\Xi\alpha$ correlation

- Detailed potential dependence
  - Compare the folding potential results with simpler models
  - Purely attractive Gaussian potential

$$V_{\mathrm{Gaussian}}(r) = V_0 \exp(-r^2/b^2),$$

    - Larger $C(q)$ than the folding potentials
    - No dip structure at $q \sim 100$ MeV/c

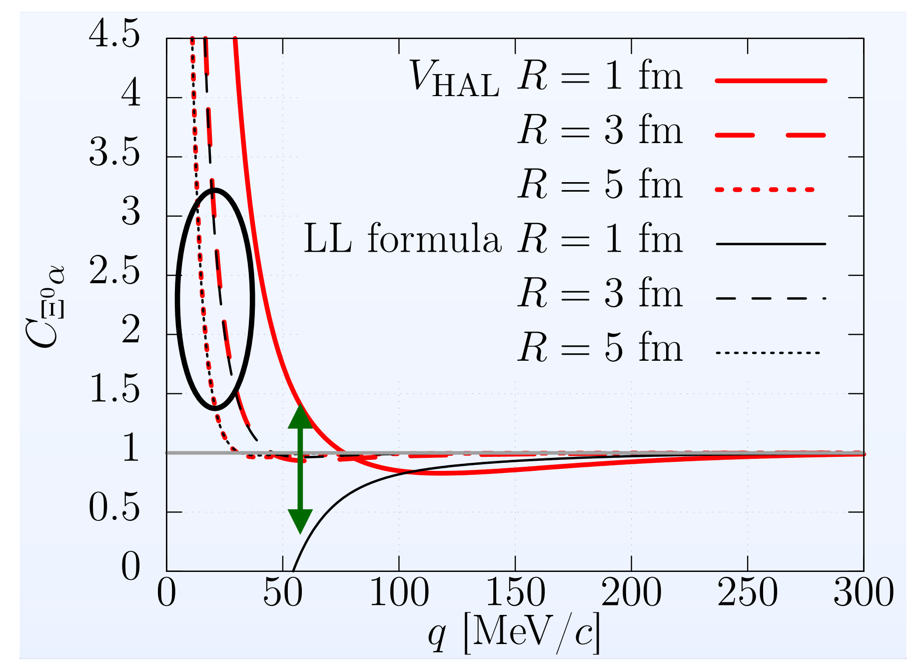
→ Repulsive core causes dip in $C_{\Xi\alpha}$!



  - Lednicky-Lyuboshitz (LL) formula
    R. Lednicky, et al. Sov. J. Nucl. Phys. 35(1982).
    - approximation by asymptotic wave function
      —> Good description for short range potential
    - Large deviation due to the large effective range for small source

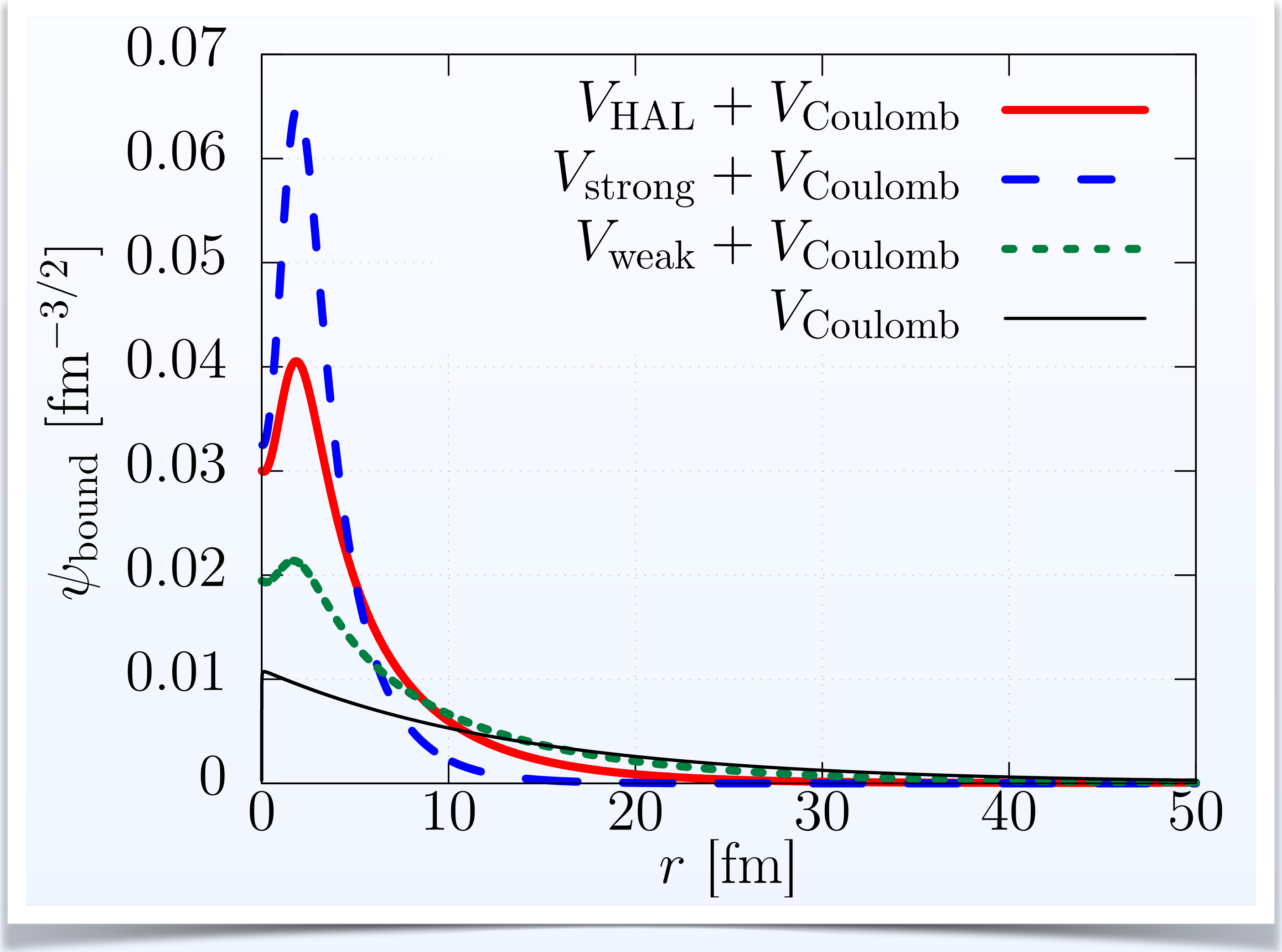
$$r_e = 4.5 \text{ fm} \quad (V_{\mathrm{HAL}})$$

→ LL formula does not work for $C(q)$ from small source.



$\Xi\alpha$ correlation

- $\Xi^{-}\alpha$ bound state and Coulomb effect



potential	<Vshort>	<VCoulomb>	***B***
VHAL	**-0.93**	-0.63	0.47
Vstrong	**-4.36**	-0.94	2.08
Vweak	-0.14	**-0.36**	0.18

[MeV]

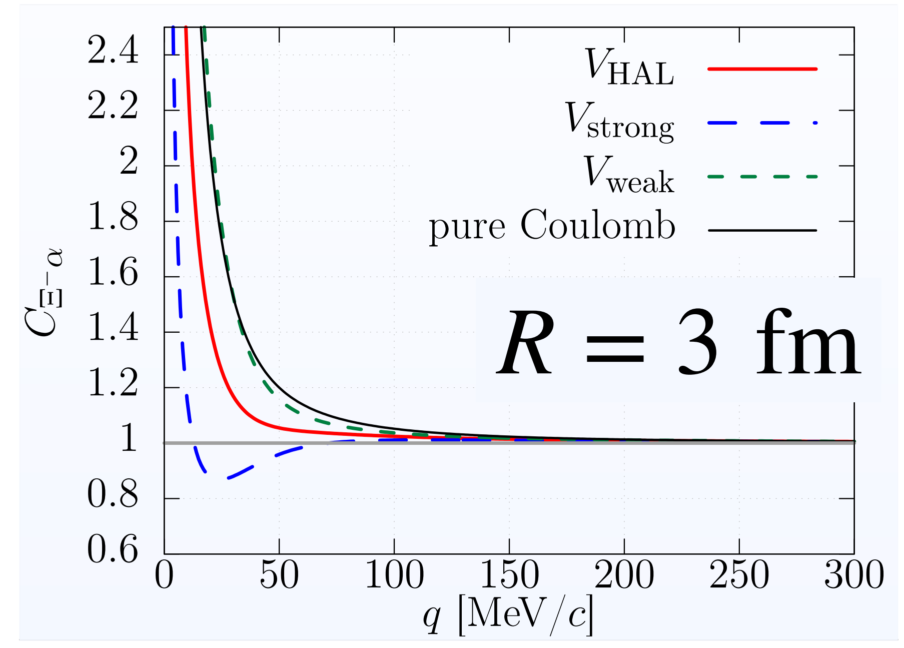
- $V_{\rm HAL}$ and $V_{\rm strong}$: W.f. strongly localized in strong int. range.
  $\rightarrow$ Short range int. is dominant.
- $V_{\rm weak}$: long range tail similar to pure Coulomb case
  $\rightarrow$ Coulomb int. is dominant.

$\Xi\alpha$ correlation

- $\Xi^{-}\alpha$ correlation

potential	E_B [MeV]
VHAL	0.47
Vstrong	2.16
Vweak	0.18

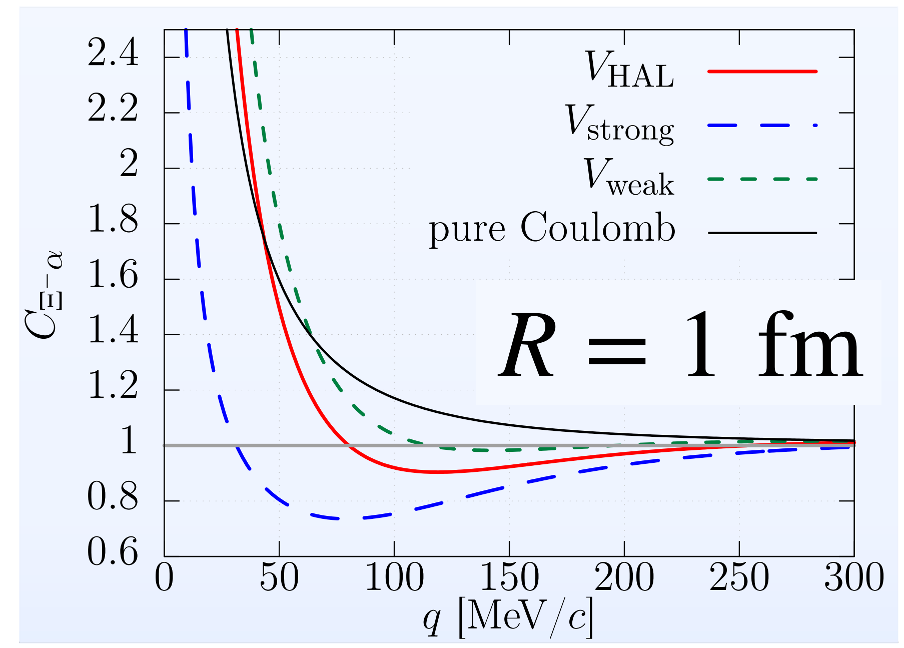
- Coulomb int. added:
  —> Strong int. effect appear as deviation from pure Coulomb
- V_{strong} and V_{weak}: Coulomb enhancement added to $C_{\Xi^0\alpha}$



- V_{HAL} : $C(q)$ with $R = 3$ fm turns to be suppressed
  —> Typical source size dependence with bound state

➡ $^{5}_{\Xi}$H can be distinguished by the source size dependence

- Dip structure at $q \sim 100$ MeV/c for $R = 1$ fm



➡ Repulsion core effect can be investigated with small source

Summary

- Femtoscopic study on the hadron interaction
  - Direct approach to the low-energy interaction
  - Sensitive to the near-threshold resonance

- $N\Xi$-$\Lambda\Lambda$
  - HAL QCD potential: Good agreement with ALICE data
  - Future data from larger source needed

- α-hyperon correlation function
  - α-hyperon correlation is useful for further constraint.
  - Correlation line related to the detailed potential shape

Thank you for your attention!

Thank you!