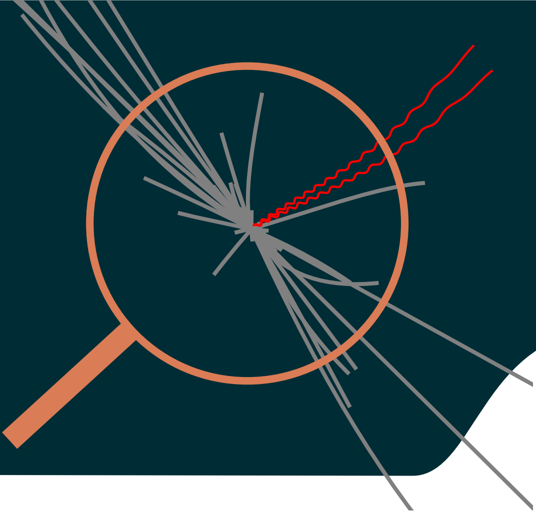


Studying the interaction between charm and light-flavor hadrons

Daniel Battistini

Technical University of Munich

Strong interaction physics of heavy flavors | Hirschegg, Austria

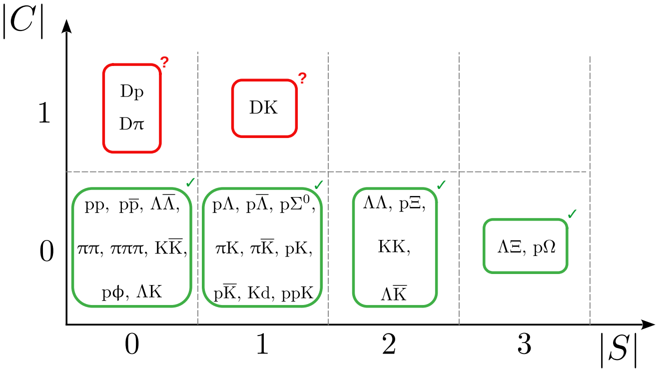
The study of hadron-hadron interactions

Light sector:

- some interactions are measured
- more challenging for large $|S|$

Charm sector: no measurement at all

- charm nuclei not found
- scattering experiments not feasible



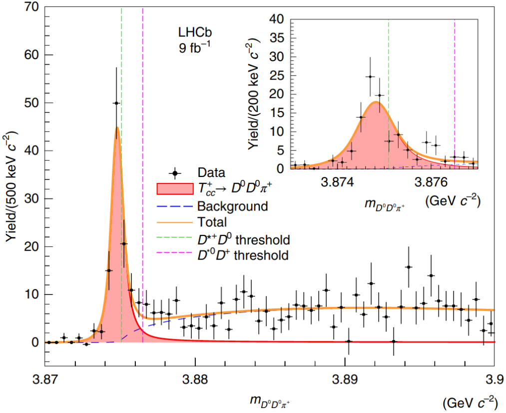
What is the nature of the exotic charm states?

Several non-conventional hadrons were discovered:

- slightly below the DD* thresholds
  → molecule candidates
- quark bags are also possible

T^{+}_{cc}: quark bag or… molecular state?

Knowledge of the D meson interactions is required



T^{+}_{cc} measurement ⇝ LHCb Coll, Nat. Com. 13 3351

Rescattering of D mesons in heavy-ion collisions

What is the impact of the rescattering on the heavy-ion observables (e.g. R_{AA})?

In heavy-ion collisions:

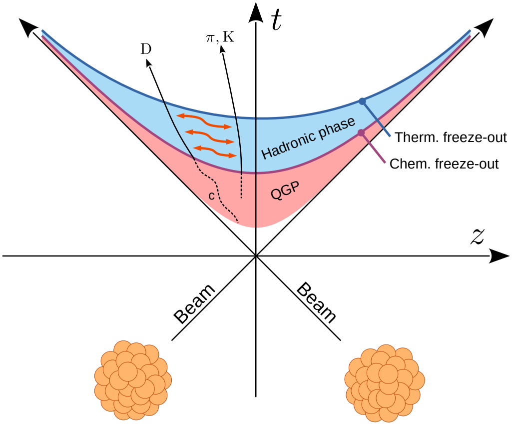
- quark–gluon plasma (QGP) formation
- system expansion and chemical freeze-out
- hadron gas

Charm hadrons are ideal QGP probes:

- experience the evolution of the system

D meson rescattering in the hadronic phase:

- interactions with light flavors are unknown
- relies on theory



Rescattering of D mesons in heavy-ion collisions

What is the impact of the rescattering on the heavy-ion observables (e.g. R_{AA})?

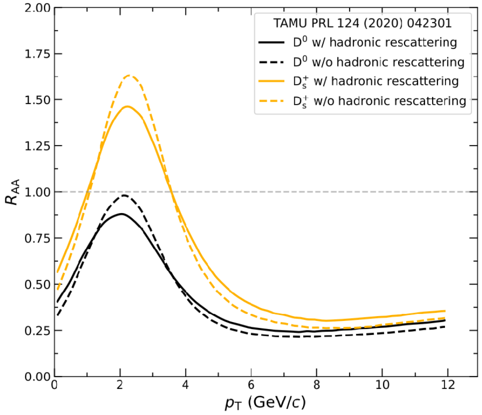
In heavy-ion collisions:

- quark–gluon plasma (QGP) formation
- system expansion and chemical freeze-out
- hadron gas

Nuclear modification factor

$$R_{\mathrm{AA}} = \frac{1}{\langle N_{\mathrm{coll}} \rangle} \frac{\mathrm{d}N_{\mathrm{AA}}/\mathrm{d}p_{\mathrm{T}}}{\mathrm{d}N_{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}}$$

- sensitive to the energy loss of the c quark
- modified by the rescattering

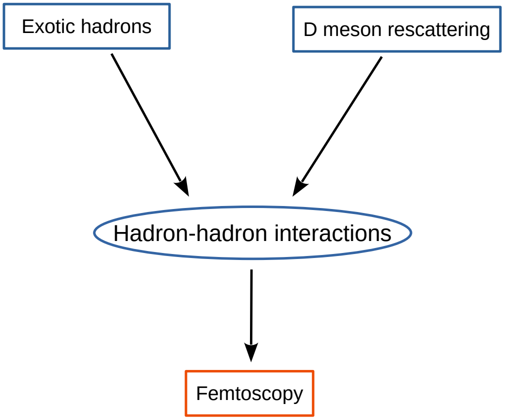


M. He and R. Rapp, PRL 124 042301

Femtoscopy as a tool to access the hadron-hadron interactions

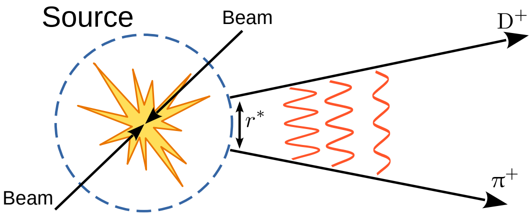
Charm-hadron interactions → femtoscopy

- the only tool to access such systems
- scattering experiments not possible
- charm nuclei not found



Femtoscopy as a tool to access the hadron-hadron interactions

Measurements performed at particle colliders (LHC)
Study the interaction at the femtometer scale



Goal: measure the interactions of D mesons with light hadrons using femtoscopy

Already employed in several works:

- pp, pΛ, $\Lambda\Lambda$: $\rightsquigarrow$ ALICE Coll., PRC 99 (2019) 2, 024001
- p$\bar{\text{p}}$, p$\bar{\Lambda}$, $\Lambda\bar{\Lambda}$: $\rightsquigarrow$ ALICE Coll., PLB 829 (2022) 137060
- ppp, ppΛ: $\rightsquigarrow$ ALICE Coll., EPJA 59 (2023) 7, 145
- ppK: $\rightsquigarrow$ ALICE Coll, EPJA 59 (2023) 12, 298
- pϕ: $\rightsquigarrow$ ALICE Coll., PRL 127 (2021) 17, 172301
- ΛK: $\rightsquigarrow$ ALICE Coll., PLB 845 (2023) 138145
- pΣ^0: $\rightsquigarrow$ ALICE Coll., PLB 805 (2020) 135419
- pK: $\rightsquigarrow$ ALICE Coll., PRL 124 (2020) 9, 092301
- pΩ: $\rightsquigarrow$ Nature 588 (2020) 232-238
- $\Lambda\Xi$: $\rightsquigarrow$ PLB 844 (2023) 137223
- pΞ: $\rightsquigarrow$ ALICE Coll., PRL 123 (2019) 11, 112002

The femtoscopy method

A correlation technique to access the strong interactions between hadrons

Observables:

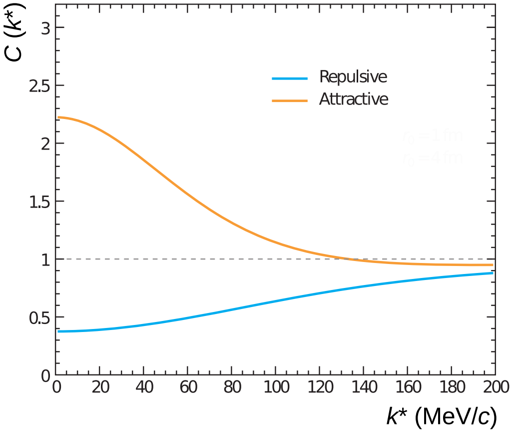
- relative momentum $k^* = |\boldsymbol{p}_{\mathrm{A}}^* - \boldsymbol{p}_{\mathrm{B}}^*|/2$
- correlation function $C(k^*)$

⇝ M. A. Lisa and S. Pratt *et al.*, ARNPS 55 357402

$$C(k^*) = \underbrace{\frac{N_{\mathrm{same}}(k^*)}{N_{\mathrm{mixed}}(k^*)}}_{\text{experiment}} = \underbrace{\int \mathrm{d}\boldsymbol{r}^*\, S(\boldsymbol{r}^*)|\Psi(\boldsymbol{r}^*, \boldsymbol{k}^*)|^2}_{\text{theory}}$$

Shape of the correlation function → interaction:

- qualitatively: attractive/repulsive
- quantitatively: scattering parameters

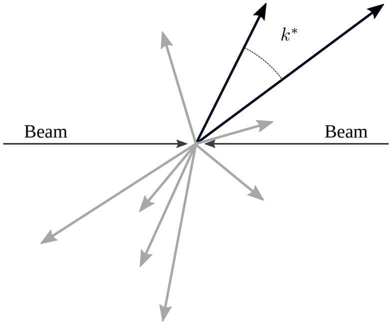


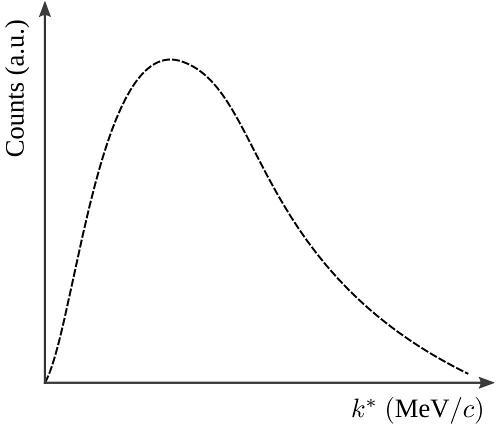
⇝ Ann. Rev. Nucl. Part. Sci. 71 (2021) 377-402

The same-event distribution

Determine $k^* = |\boldsymbol{p}_A^* - \boldsymbol{p}_B^*|/2$

- the relative momentum in the pair rest-frame



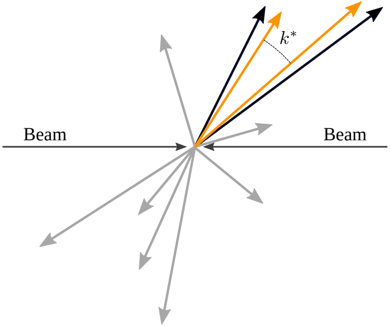


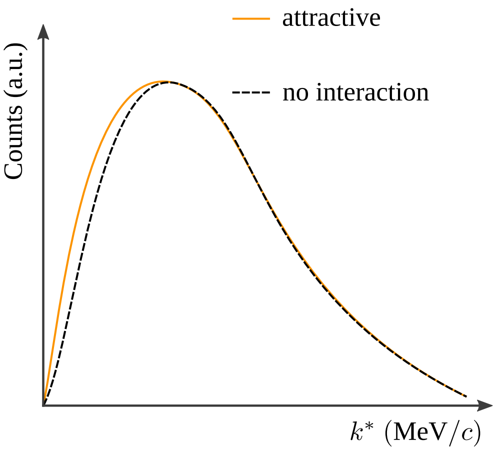
k^* is modified depending on the potential between the particles

The same-event distribution

Determine $k^* = |\boldsymbol{p}^*_\mathrm{A} - \boldsymbol{p}^*_\mathrm{B}|/2$

- the relative momentum in the pair rest-frame





k^* is modified depending on the potential between the particles

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Determine $k^* = |\boldsymbol{p}_\mathrm{A}^* - \boldsymbol{p}_\mathrm{B}^*|/2$

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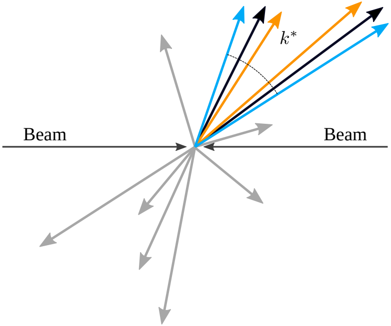
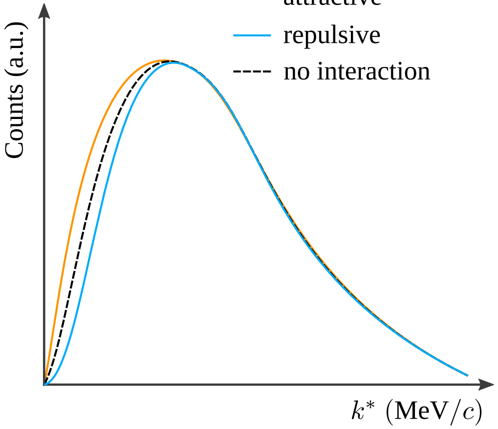


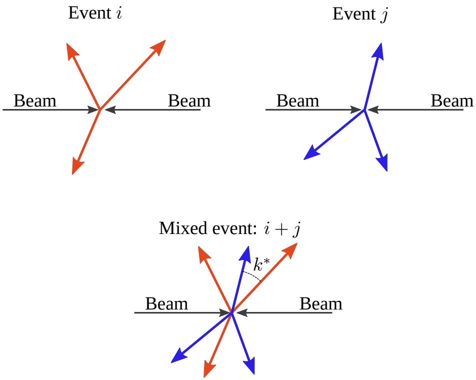


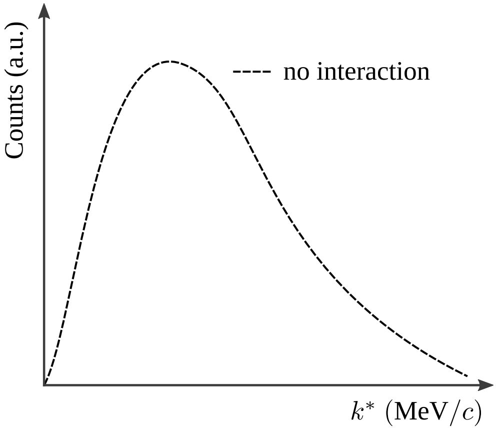
k^* is modified depending on the potential between the particles

The mixed-event distribution

Select the particles from different events:

- the interaction is removed
- underlying phase space is described



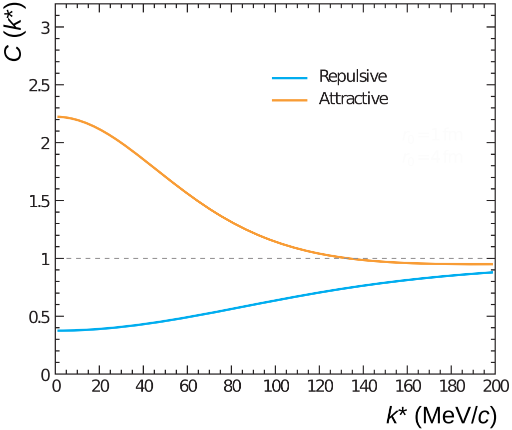


In the experiment:

- ratio of same- and mixed-event distributions

Shape of the correlation function → interaction:

$$C(k^*) = \frac{N_{\text{same}}(k^*)}{N_{\text{mixed}}(k^*)} = \begin{cases} > 1 & \text{attraction} \\ < 1 & \text{repulsion} \end{cases}$$



⇝ Ann. Rev. Nucl. Part. Sci. 71 (2021) 377-402

The source function

Theoretical definition:

$$C(k^*) = \int \mathrm{d}\boldsymbol{r}^* \, S(\boldsymbol{r}^*) |\Psi(\boldsymbol{r}^*, \boldsymbol{k}^*)|^2,$$

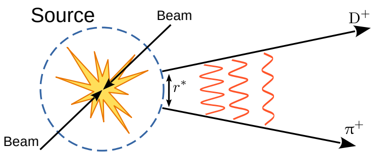
where:

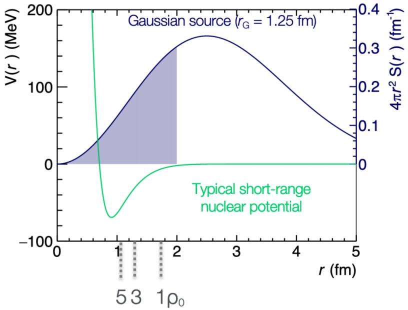
- S is the source function
- Ψ is the wave function

Source: the probability density function of r^*

Source sizes at the LHC:

- pp: $1.0 - 1.2$fm
- pPb: $1.2 - 1.8$fm
- PbPb: $4 - 10$fm





The source function

To determine the source size:

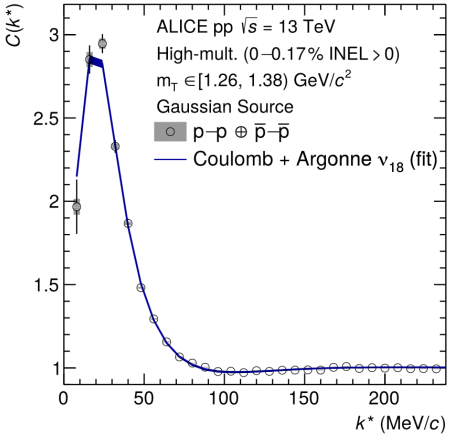
- use a potential for the pp interaction
- solve the Schrödinger equation $\to \Psi$
- fold with the source $\to C(k^*; r^*)$

$$C(k^*) = \int \mathrm{d}\boldsymbol{r}^* \, S(\boldsymbol{r}^*) |\Psi(\boldsymbol{r}^*, \boldsymbol{k}^*)|^2,$$

- fix the source size with a fit

Differential in trasnverse mass m_{T}

⇝ ALICE Coll., PLB 811 (2020) 135849



$$m_{\mathrm{T}} = \sqrt{k_{\mathrm{T}}^2 + m^2}, \quad k_{\mathrm{T}} = |\boldsymbol{p}_{\mathrm{T},1} + \boldsymbol{p}_{\mathrm{T},2}|/2$$

The source function

To determine the source size:

- use a potential for the pp interaction
- solve the Schrödinger equation $\rightarrow \Psi$
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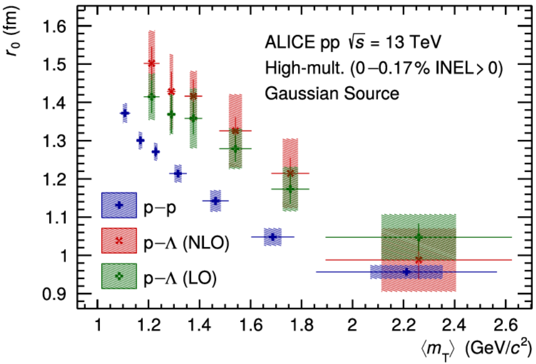
⇝ ALICE Coll., PLB 811 (2020) 135849



Differential in trasnverse mass m_{T}

$$m_{\mathrm{T}} = \sqrt{k_{\mathrm{T}}^2 + m^2}, \quad k_{\mathrm{T}} = |\boldsymbol{p}_{\mathrm{T},1} + \boldsymbol{p}_{\mathrm{T},2}|/2$$

Different systems $\rightarrow$ different sources?

- No! The contribution of resonances is missing

The contribution of resonances

Not all particles are primary

Short-living resonances ($c\tau < 5$ fm)
$\rightarrow$ enlargement of the source

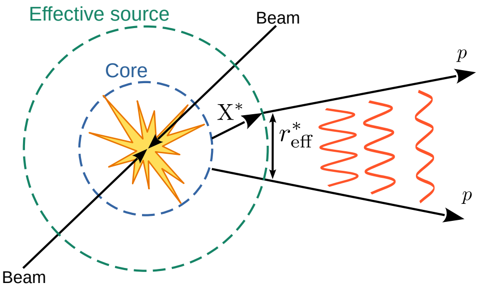
To describe the effective source size r^*_{eff}:

- angular distributions from EPOS
- yields from the statistical hadronization model

⇝ ALICE Coll., arXiv 2311.14527

⇝ ALICE Coll., PLB 811 (2020) 135849

⇝ D. Mihaylov and J. González González, EPJC 83 (2023) 7 590



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To describe the effective source size r^*_{eff}:

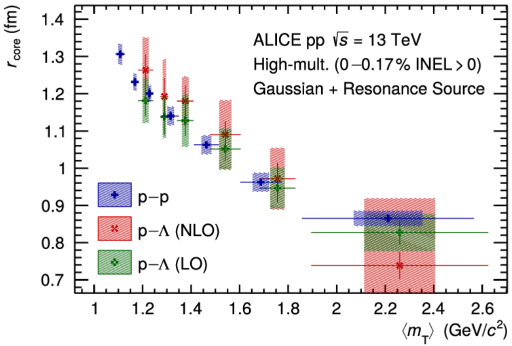
- angular distributions from EPOS
- yields from the statistical hadronization model

The source core is the same for pp and pΛ

- Assume a universal source

The framework is calibrated: new particle pairs can be studied

⇝ ALICE Coll., PLB 811 (2020) 135849



The wave function

Depends on the potential $\rightarrow$ encodes the information about the interaction

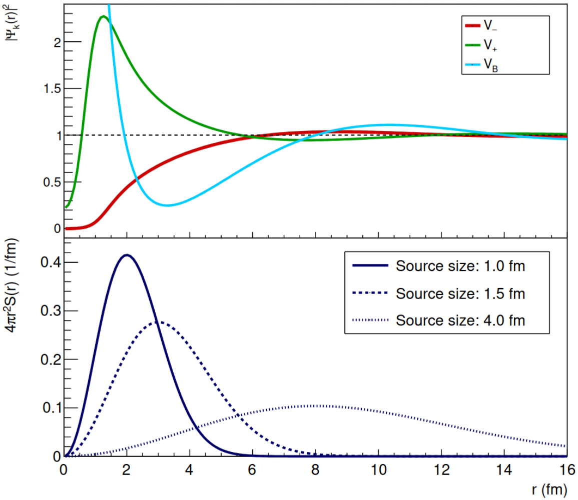
Determined numerically:

- CATS: Correlation Analysis Tool using the Schrödinger equation

  ⇝ D. L. Mihaylov *et al*, PJC 78 (2018) 5 394

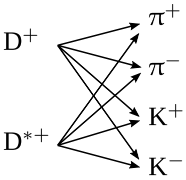
Different sources probe different regions of the wavefunctions, according to

$$C(k^*) = \int \mathrm{d}\boldsymbol{r}^* \, S(\boldsymbol{r}^*) |\Psi(\boldsymbol{r}^*, \boldsymbol{k}^*)|^2$$



Focus on:

D^-p



+ charge-conjugates

In all systems:

- Coulomb interaction
- different isospin combinations

Analyzed data:

- Run 2, collected by ALICE
  $\rightsquigarrow$ ALICE Coll., IJMP A 29 (2014) 1430044
- proton-proton collisions at $\sqrt{s} = 13\,\text{TeV}$
- high-multiplicity trigger (0.17 % of the inelastic cross section)

D meson reconstruction $\rightarrow$ hadronic decay channels:

- D^+: via $D^+ \rightarrow K^-\pi^+\pi^+$
- D^{*+}: via $D^{*+} \rightarrow D^0(\rightarrow K^-\pi^+)\pi^+$

Experimental setup

Inner Tracking System (ITS):

- tracking
- primary vertex

Time Projection Chamber (TPC):

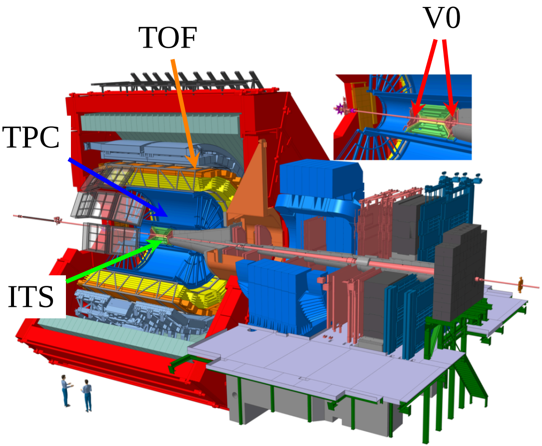
- tracking
- measurement of the momentum
- particle identification (PID)

Time of flight (TOF)

- particle identification

V0

- multiplicity estimation



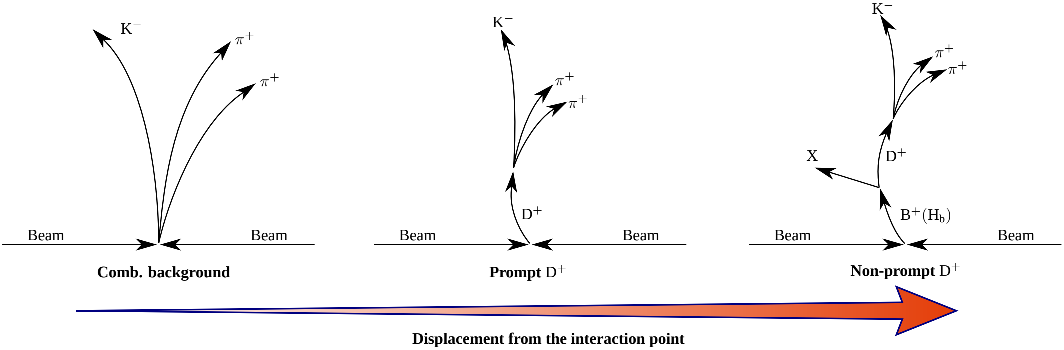
⇝ ALICE Coll., Int. J. Mod. Phys. A 29 (2014) 1430044

⇝ ALICE Coll, JINST 3 (2008) S08002

Selection of D mesons

Exploit the decay-vertex topology of the candidates

- $c\tau(\mathrm{D}) \approx 100\ \mu\mathrm{m}$
- $c\tau(\mathrm{B}) \approx 500\ \mu\mathrm{m}$



$D^{\pm}$ reconstruction performance

Machine learning algorithm based on boosted decision trees

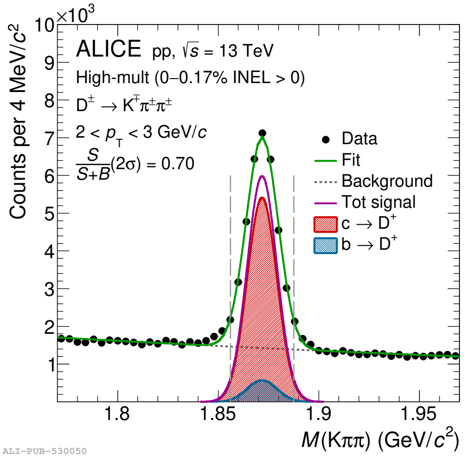
⇝ ALICE Coll., JHEP 05 (2021) 220

Selection of $D^{\pm} \rightarrow$ decay-vertex topology + PID

- from c quark hadronization (prompt)
- from beauty hadron decays (non-prompt)
- combinatorial background

Data-driven separation between prompt and non-prompt

- purity ~70%
- non-prompt fraction ~7%



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

The correlation function: genuine interaction

$\boxed{C_{\text{raw}}} = \quad \boxed{\lambda_{\text{gen}} C_{\text{gen}}}$

data | strong interaction

Primary signal particles → genuine CF

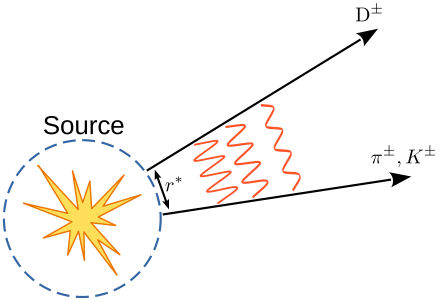
- **scattering parameters**
- formation of bound states
- ...

Source function from the universal m_{T}-scaling

⇝ ALICE Coll., PLB 811 135849

Several corrections are necessary to obtain the genuine CF

- $\text{B}^{\pm}$ decays, combinatorial background etc.



The correlation function: decays from $D^{*\pm}$ mesons

$$\boxed{C_{\text{raw}}} = \boxed{\lambda_{\text{gen}} C_{\text{gen}}} + \boxed{\lambda_{D^*} C_{D^*}}$$

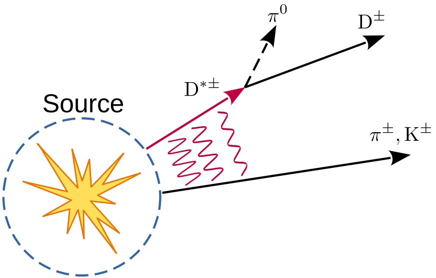
data — strong interaction — D from D*

About 30% of the $D^{\pm}$ are from $D^{*\pm}$ decay

Small Q-value $\Rightarrow \boldsymbol{p}(D^{*\pm}) \approx \boldsymbol{p}(D^{\pm})$

Modelling:

- Coulomb + strong interaction between $D^{*\pm}$ and π,K
- compute the phase space of $D^{*\pm} \to D^{\pm} + \pi^0$
- fold interaction with phase space $\to C_{D^*}$



The correlation function: flat contributions

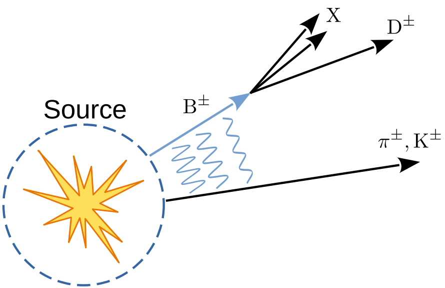
$$C_{\text{raw}} = \lambda_{\text{gen}} C_{\text{gen}} + \lambda_{\text{D}^*} C_{\text{D}^*} + \lambda_{\text{flat}}$$

data | strong interaction | D from D* | decays

Account for uncorrelated backgrounds:

- D mesons from beauty-hadron decays
- decay of long-living resonances
- misidentified particles e.g. $\pi \to$ K

Assume no correlation $\Rightarrow$ $C(k^*) = 1$



The correlation function: hadronization

$$\boxed{C_{\text{raw}}} = \boxed{C_{\text{jet-like}}}\left(\boxed{\lambda_{\text{gen}} C_{\text{gen}}} + \boxed{\lambda_{\text{D}^*} C_{\text{D}^*}} + \boxed{\lambda_{\text{flat}}}\right)$$

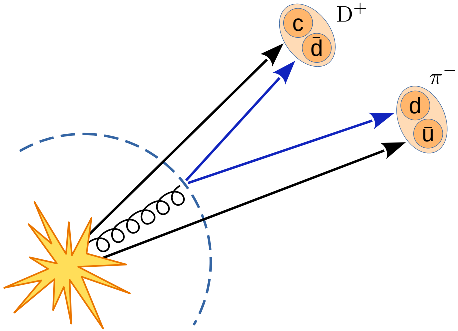
- C_{raw} → data
- $C_{\text{jet-like}}$ → hadronization
- $\lambda_{\text{gen}} C_{\text{gen}}$ → strong interaction
- $\lambda_{\text{D}^*} C_{\text{D}^*}$ → D from D*
- λ_{flat} → decays

Jet-like structures $\rightarrow$ correlation

- particles produced close in phase space

Model with MC simulations, where:

- final-state strong interaction: absent
- hadronization: present



The correlation function: combinatorial background

$$C_{\text{raw}} = \lambda_{\text{SB}} C_{\text{SB}} + C_{\text{jet-like}} \left(\lambda_{\text{gen}} C_{\text{gen}} + \lambda_{\text{D}^*} C_{\text{D}^*} + \lambda_{\text{flat}} \right)$$

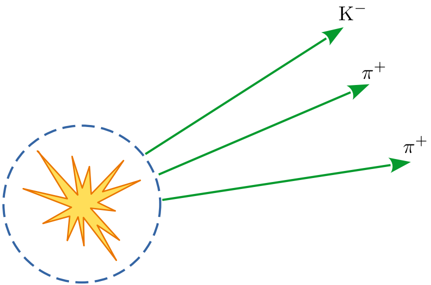
data — comb. bkg — hadronization — strong interaction — D from D* — decays

Uncorrelated π and K tracks $\rightarrow$ unphysical D mesons

- about 30% of the D candidates

Modelled with sideband (SB) analysis (data-driven):

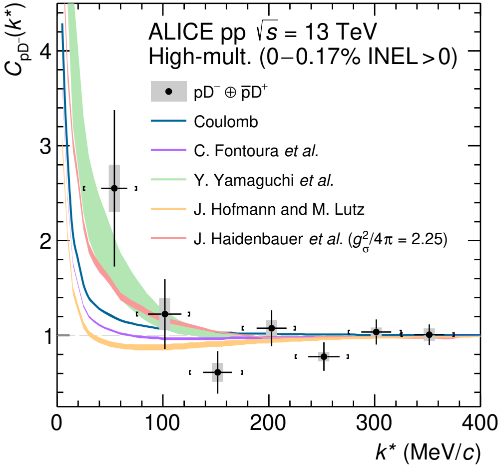
- 5σ away from the nominal $\text{D}^{\pm}$ mass
- CF with a pure background sample



The D^-p interaction

The theoretical models:

- attractive interaction
  - ⇝ J. Haidenbauer *et al*, EPJA 33 (2007) 107-117
- repulsive interaction
  - ⇝ J. Hofmann and M. Lutz, Nucl. Phys. A 763 (2005) 90-139
  - ⇝ Fontura *et al*, PRC 87 (2013) 025206
- bound state formation
  - ⇝ Yamaguchi *et al*, PRD 84 (2011) 014032



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

Gaussian potential model

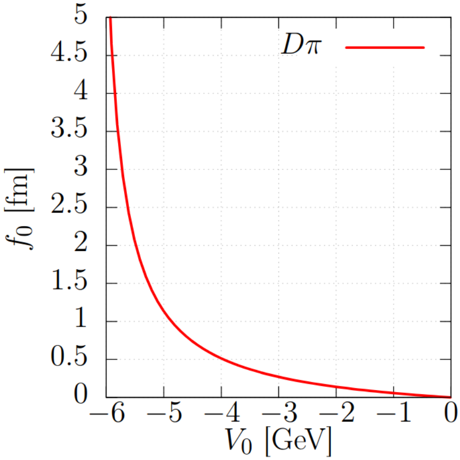
Effective potential: Gaussian potential model:

$$V(V_0, r) = V_0 e^{-(m_\rho r)^2}$$

- strength: adjustable parameter
- range: mass of the ρ meson

Coupled-channel dynamics:

- $D^+\pi^+$: no coupled channel
- $D^+\pi^-$: coupled to $D^0\pi^0$



⇝ Y. Kamiya *et al*, EPJA 58 (2022) 7, 131

The D^-p interaction

Effective potential: Gaussian potential model:

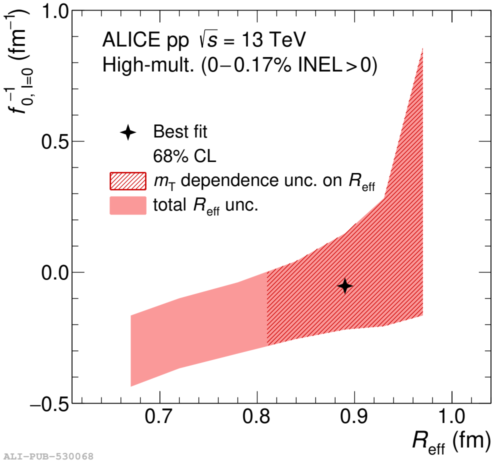
$$V(V_0, r) = V_0 e^{-(m_\rho r)^2}$$

- strength: fit parameter
- range: mass of the ρ meson

Extraction of the scattering length:

- the potential is always attractive
- The scattering length can be positive or negative

- attractive interaction
- bound state formation



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

The study of $D^{(*)}\pi$ interactions

Theoretical predictions:

- lattice QCD calculations + chiral extrapolation
  - ⇝ L. Liu et al, PRD 87 014508
  - ⇝ X.-Y. Guo et al, PRD 98 014510
  - ⇝ Z.-H. Guo et al, EPJC 79 13
- chiral perturbation theory
  - ⇝ Huang et al, PRD 15 036016
- unitarized effective field theories
  - ⇝ J. M. Torres-Rincon *et al*, arXiv 2307.02102

Potential depth tuned to reproduce the scattering lengths

Shared scattering parameters:

$$\begin{cases} a_0^{D^+\pi^+} = a_0^{I=3/2} \\ a_0^{D^+\pi^-} = \frac{1}{3}a_0^{I=3/2} + \frac{2}{3}a_0^{I=1/2} \end{cases}$$

plot not public

Comparisons with theoretical models: Dπ

Dπ scattering parameters from theoretical models

- $\rightsquigarrow$ L. Liu et al, PRD 87 014508, $\rightsquigarrow$ X.-Y. Guo et al, PRD 98 014510
- $\rightsquigarrow$ Huang et al, PRD 15 036016, $\rightsquigarrow$ Z.-H. Guo et al, EPJC 79 13
- $\rightsquigarrow$ J. M. Torres-Rincon *et al*, arXiv 2307.02102

Results:

- tension with models
- compatible with Coulomb-only interaction

plot not public

Comparisons with theoretical models: $D^{*}\pi$

$D^{*}\pi$ scattering parameters from theoretical models

$\rightsquigarrow$ J. M. Torres-Rincon *et al*, arXiv 2307.02102

Results:

- tension with models
- compatible with Coulomb-only interaction

plot not public

Extraction of the Dπ scattering parameters

Combined fit with the Gaussian potential model: $V(V_0, r) = V_0 e^{-(m_\rho r)^2}$

plot not public

$a_0^{\mathrm{pp}} = O(10), \quad a_0^{\mathrm{p}\Lambda} = O(1)$
$a_0^{\mathrm{D}\pi}(I = 3/2) = 0.01 \pm 0.02(\text{stat.}) \pm 0.01(\text{syst.})$
$a_0^{\mathrm{D}\pi}(I = 1/2) = 0.02 \pm 0.03(\text{stat.}) \pm 0.01(\text{syst.})$

Extraction of the $D^*\pi$ scattering parameters

Combined fit with the Gaussian potential model: $V(V_0, r) = V_0 e^{-(m_\rho r)^2}$

plot not public

$a_0^{pp} = O(10), \quad a_0^{p\Lambda} = O(1)$
$a_0^{D^*\pi}(I = 3/2) = 0.10 \pm 0.04(\text{stat.}) \pm 0.02(\text{syst.})$
$a_0^{D^*\pi}(I = 1/2) = 0.00 \pm 0.05(\text{stat.}) \pm 0.05(\text{syst.})$

Extraction of the $D^*\pi$ scattering parameters

$D\pi$ and $D^*\pi$ scattering parameters for the two isospin configurations

- tension with theory $\rightarrow$ why?

plot not public

Conclusions

Femtoscopy → hadron-hadron interactions

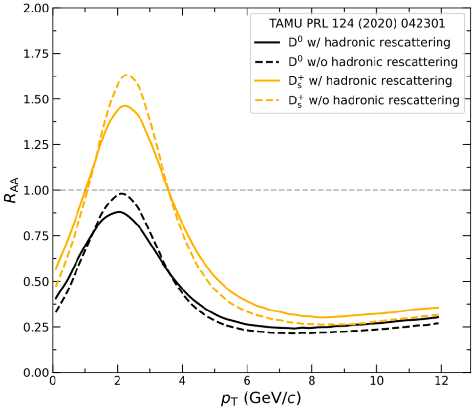
- particularly useful for charm hadrons

Results of charm femtoscopy:

- small scattering parameters → shallow interactions
- $D\pi$ and $D^*\pi$ interactions are similar
  → heavy-quark spin symmetry
- tension with theory

Conclusions:

- small effect on heavy-ion observables



Used scattering length: $a_0^{D\pi} = -0.10$ fm

⇝ M. He *et al*, PLB 701 (2011) 445-450

⇝ M. He and R. Rapp, PRL 124 (2020) 042301

Charm hadron femtoscopy during the Run 3

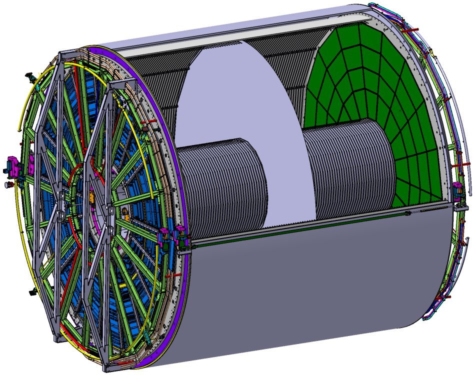
Several upgrades:

- ITS $\rightarrow$ better pointing resolution
- TPC $\rightarrow$ continuous readout
- larger luminosity: $\sim$ 100 times more statistics
- software triggers

LHC data-taking period: 2022-ongoing

The study of charm-hadrons interactions will be extended

- Λ_c^+p $\rightarrow$ charm nuclei
  - ⇝ S. Maeda *et al*, PTEP 2016 (2016) 2, 023D02
- J/Ψp $\rightarrow$ bound states
  - ⇝ G. Krein *et al*, PPNP 100 (2018) 161-210



⇝ ALICE Coll., arXiv:2302.01238

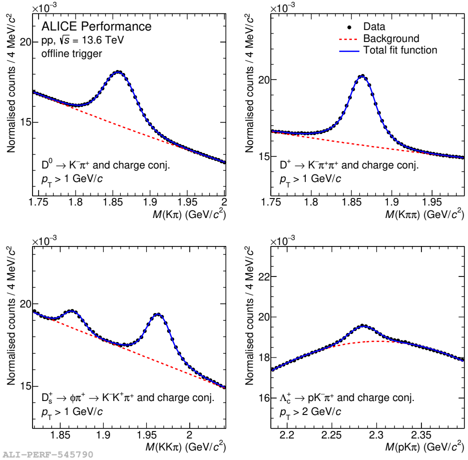
Heavy-flavor software triggers in the Run 3

Offline software triggers for:

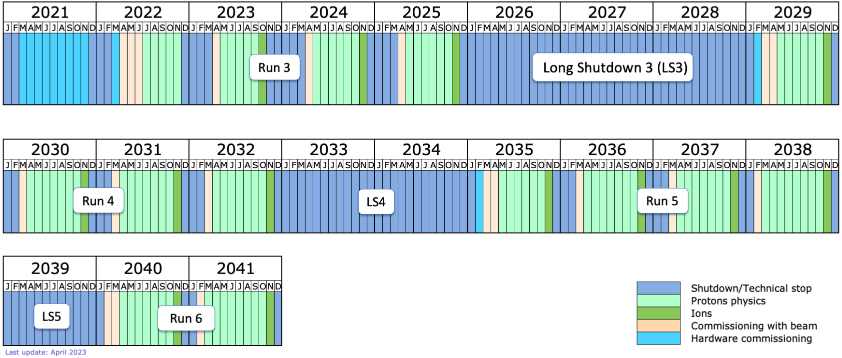
- D^0p and $\overline{D}^0$p
- $D^{\pm}$p, $D_s^{\pm}$p, and $\Lambda_c^{\pm}$p

Strategy:

- preselections on topology and kinematics
- Machine-learning selections:
  - background → discard
  - prompt → femtoscopy
  - non-prompt → beauty



The long-term LHC schedule



The ALICE experiment will end with the Run 4

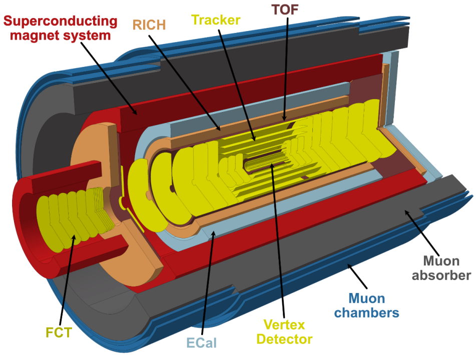
Planned for the Run 5 and Run 6: ALICE 3

⇝ ALICE Coll., arXiv:2211.02491

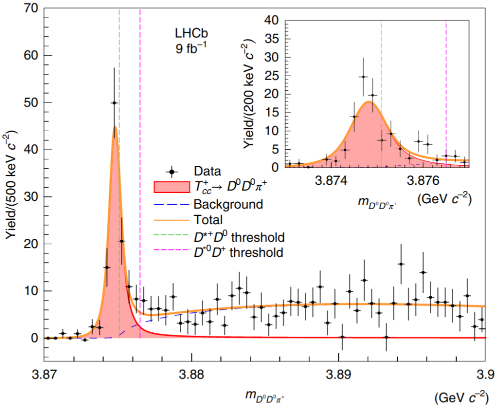
Charm hadron femtoscopy with ALICE 3

ALICE 3: ⇝ arXiv 2211.02491

- large acceptance
- low material budget
- high spatial resolution



⇝ LHCb Coll, Nat. Com. 13 3351



The study of exotic charm states will be possible

- T_{cc}^{+} could be a D^0D^* molecule

Search for bound states with femtoscopy

The T_{cc}^{+} is right below the DD^{*} thresholds

- molecule candidate

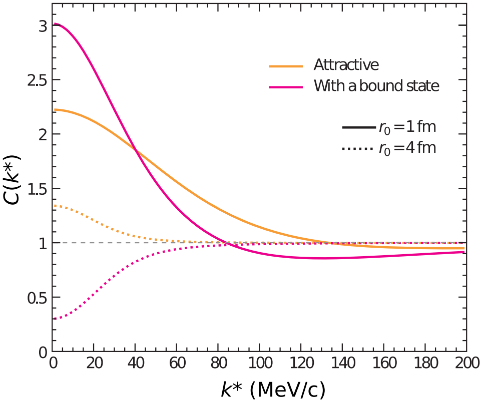
Bound states with femtoscopy

In small collision systems (pp):

- $C(k^{*}) > 1$ at small k^{*}
- $C(k^{*}) < 1$ at intermediate k^{*}

In large collision systems (pp):

- $C(k^{*}) < 1$ everywhere



Ann. Rev. Nucl. Part. Sci. 71 (2021) 377-402

Charm hadron femtoscopy with ALICE 3

The T_{cc}^{+}: a DD^{*} molecule candidate

- Binding energy ≈ 360 keV
- scattering length = $-7.16 + i1.85$ fm
  - ⇝ LHCb Coll, Nat. Com. 13 3351

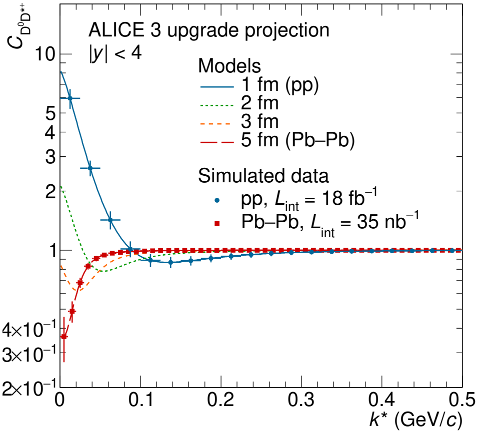
Tune the potential → mass and width of T_{cc}^{+}

⇝ Y. Kamiya *et al*, PRC 105 (2022) 1, 014915

Upgrade projection:

- pp collisions at $\sqrt{s} = 14$ TeV (Pythia 8)
- assume a Gaussian potential (with bound state)

Bound state → flip of the CF below 1



ALI-SIMUL-502575

Conclusions

The ALICE experiment is well suited for femtoscopic studies in the charm sector

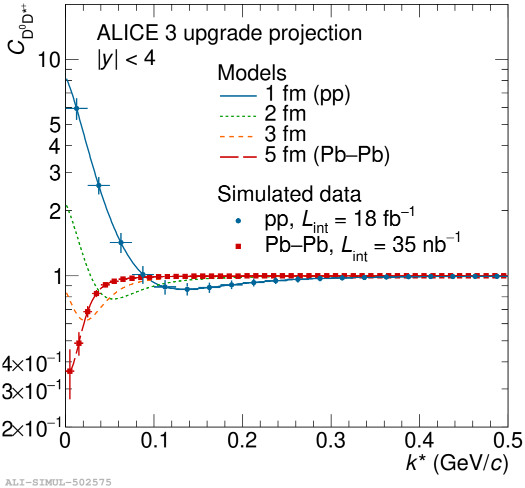
Run 3:

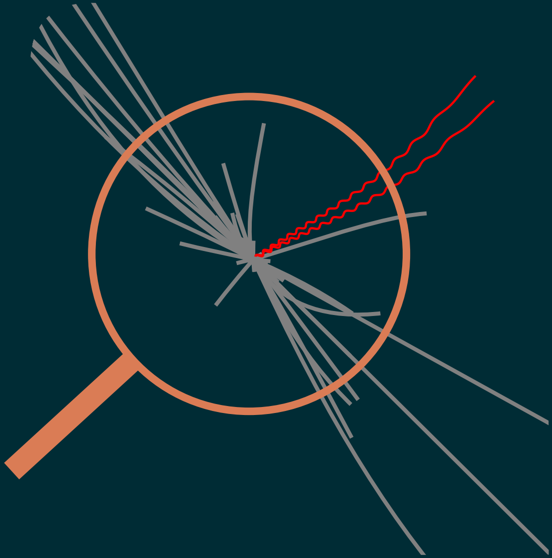
- refine the $D^{(*)}$-LF interaction measurements
- extend the studies to new particle pairs

ALICE 3:

- determine the nature of the T_{cc}^{+}

Thank you for your attention!





Additional material

Is the $D_0^*(2300)$ *a double-pole structure?*

In the strange sector:

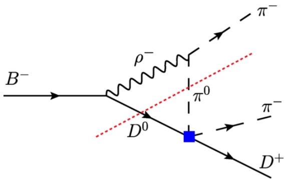
- $\Lambda(1405)$: dynamically generated state (double pole structure)

The $D_0^*(2300)$ seems to have a similar nature, from:

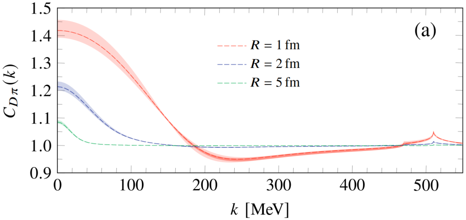
- B meson decays
- lattice calculations

⇝ A. Asokan *et al*, EPJC 83 (2023) 9, 850

$D\pi$ interaction $\rightarrow$ information about the number and position of the $D_0^*(2300)$ poles



⇝ Du *et al*, PRL 126 192001



⇝ M. Albaladejo, J. Nieves, E. Ruiz-Arriola, arXiv:2304.03107

Determination of the source

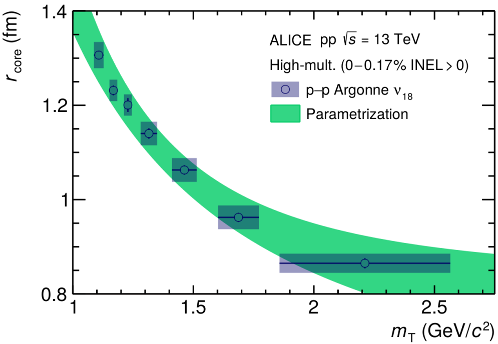
To determine r^*_{eff} for a new pair of particles:

- use the pp data (most precise)

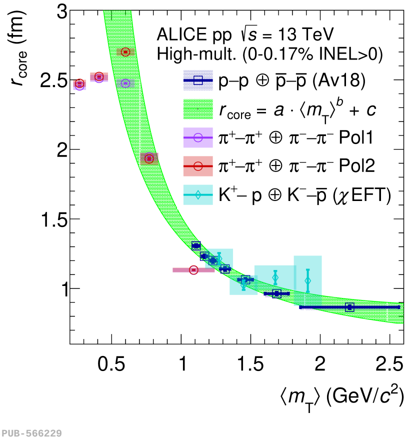
The procedure:

- compute the average m_{T} for the pair of interest
- compute the r_{core} corresponding to that m_{T}
- include the resonances
- compute the effective size r^*_{eff} of the source

Once the effective source is known, the interaction can be accessed



The universal m_T scaling



ALICE Coll., Arxiv 2311.14527

Comparisons with theoretical models: DK

DK scattering parameters from theoretical models

- ⇝ Huang et al, PRD 15 036016
- ⇝ L. Liu et al, PRD 87 014508
- ⇝ Z.-H. Guo et al, EPJC 79 13
- ⇝ X.-Y. Guo et al, PRD 98 014510
- ⇝ J. M. Torres-Rincon *et al*, arXiv 2307.02102

Results:

- compatible with all theoretical models
- Run 3 data is necessary

plot not public

Comparisons with theoretical models: $D^{*}K$

$D^{*}K$ scattering parameters from theoretical models

$\rightsquigarrow$ J. M. Torres-Rincon *et al*, arXiv 2307.02102

Results:

- compatible with the theoretical model
- Run 3 data is necessary

plot not public

Charm hadron femtoscopy with ALICE 3

The $\chi_{c1}(3872)$: molecule candidates

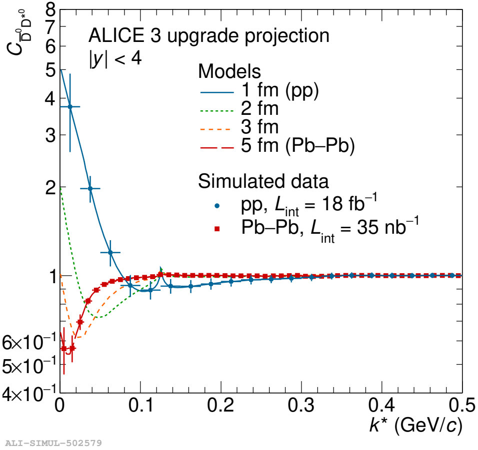
- $D^0\ \bar{D}^{*0}$ (dominant)
- $D^+\ \bar{D}^{*-}$

Assume a $D^0\ \bar{D}^{*0}$ molecule

- Binding energy $\approx$ 40 keV

Features of the CF:

- cusp at 120 MeV/c (due to $D^+\ \bar{D}^{*-}$ coupling)
- inversion of the CF for large systems
- source size dependence



Charm hadron femtoscopy with ALICE 3

The $\chi_{c1}(3872)$: molecule candidates

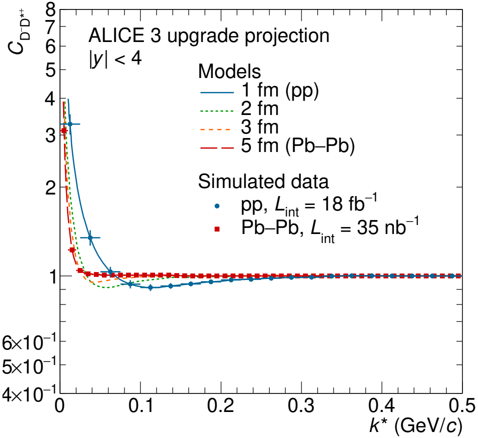
- $D^0\ \bar{D}^{*0}$ (dominant)
- $D^+\ \bar{D}^{*-}$

Assume a $D^+\ \bar{D}^{*-}$ molecule (subdominant)

- Binding energy ≈ 8 MeV

Features of the CF:

- no cusp ($D^0\ \bar{D}^{*0}$ coupling below threshold)
- no inversion of the CF for large systems
  $\approx$ no bound state
- almost no source size dependence



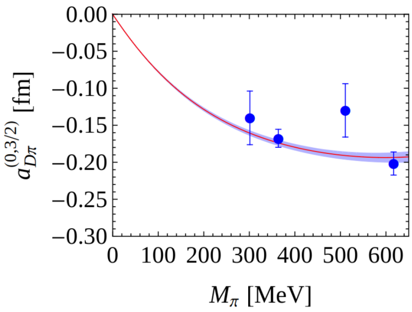
ALI-SIMUL-502583

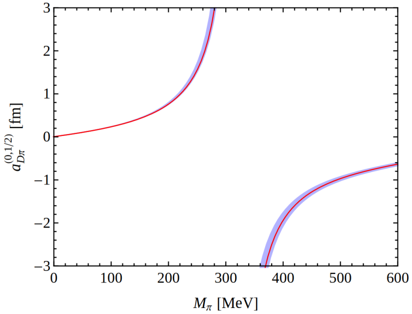
Charm hadron femtoscopy with ALICE 3

Model		a_0 (fm)	
		$D\pi(I={}^{3}\!/_{2})$	$D\pi(I={}^{1}\!/_{2})$
L. Liu *et al.*		-0.100 ± 0.002	$0.37^{+0.03}_{-0.02}$
X. Y. Guo *et al.*		-0.11	0.33
Z. H. Guo *et al.*	Fit-1B	$-0.101^{+0.005}_{-0.003}$	$0.31^{+0.01}_{-0.01}$
	Fit-2B	$-0.099^{+0.003}_{-0.004}$	$0.34^{+0.00}_{-0.03}$
B. L. Huang *et al.*		-0.06 ± 0.02	0.61 ± 0.11
J. M. Torres-Rincon *et al.*		-0.101	0.423

⇝ Huang et al, PRD 15 036016
⇝ L. Liu et al, PRD 87 014508
⇝ Z.-H. Guo et al, EPJC 79 13
⇝ X.-Y. Guo et al, PRD 98 014510
⇝ J. M. Torres-Rincon *et al*, arXiv 2307.02102

Charm hadron interaction on the lattice





⇝ L. Liu et al, PRD 87 014508