Toward EIC: an ALICE perspective

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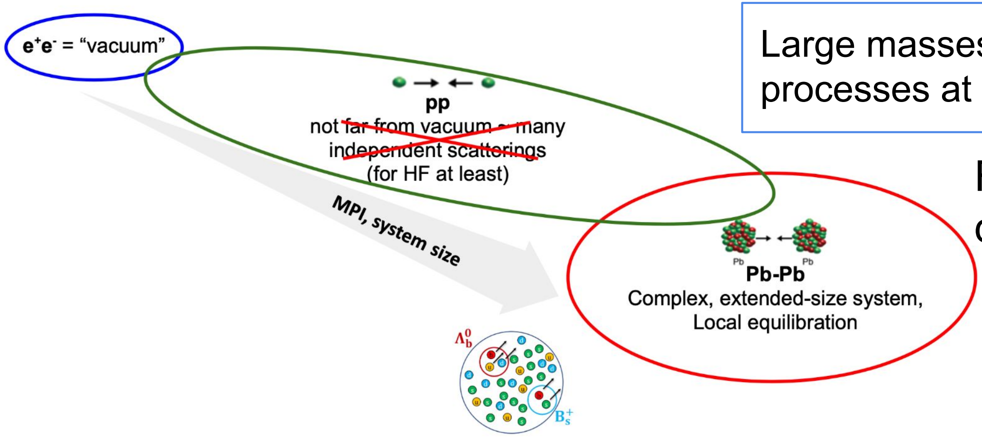
Outline

Disclaimer: this talk **does not represent a comprehensive wishlist** of what EIC could provide to better understand and complement ALICE physics.

Rather, the focus is on a series of measurements that highlighted that heavy-quark **hadronisation is not well understood, in particular baryon production,** and, contrary to expectations, already in proton-proton collisions fragmentation functions (FF) cannot be considered universal **i.e. FF universality is broken already in pp.**

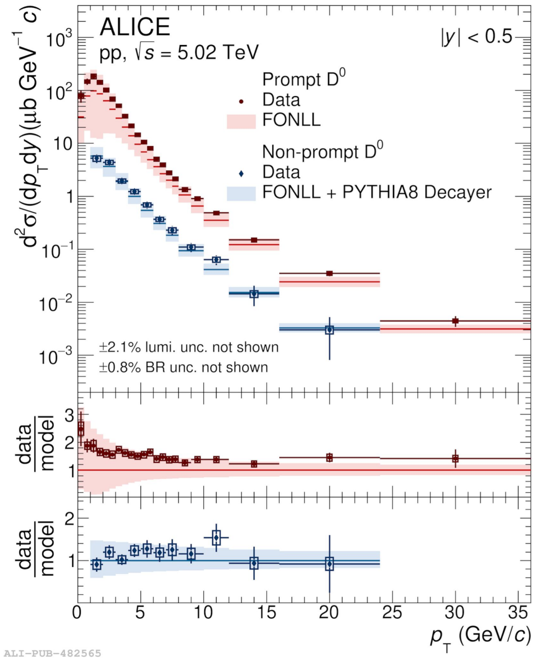
On the other hand, **charm and beauty quarks can be exploited as ideal "perturbative"** probes to study the hadronisation phase in all collision systems

Large masses → (assumed) not produced in soft processes at hadronisation (e.g. string breaking).



From vacuum-like (e^+e^-) to extended, colorful and dense systems (Pb-Pb) … **where does e-A sit?**

Factorisation: a very successful framework for HF mesons!



JHEP 05 (2021) 220 ; EPJC 79 (2019) 5, 388

FONLL: JHEP 10 (2012) 137

Prompt and non-prompt D meson production described within uncertainties by pQCD-based calculations based on factorisation approach.

Plethora of results at the LHC:

- wide p_T,y coverage
- for both charm and beauty mesons

$$\frac{d\sigma^D}{dp_T}(p_T^D;\mu_F;\mu_R)=PDF(x_1,\mu_F)\,PDF(x_2,\mu_F)\otimes\frac{d\sigma^c}{dp_T^c}(x_1,x_2;\mu_F;\mu_R)\otimes D_{c\to D}\left(z=\frac{p_D}{p_c};\mu_F\right)$$

Fragmentation functions ($D_{c->D}$) often **assumed** "**universal**": once constrained to e^+e^- and ep data they are used in different collision systems and energies.

Factorisation: a very successful framework for HF mesons!

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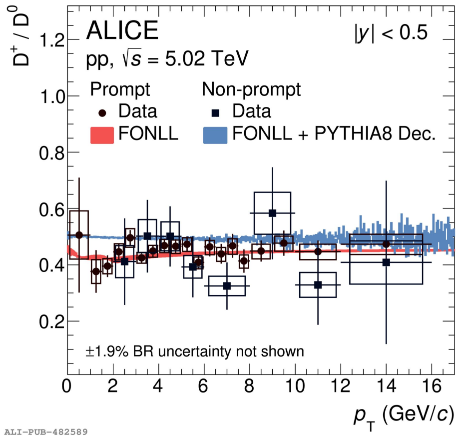
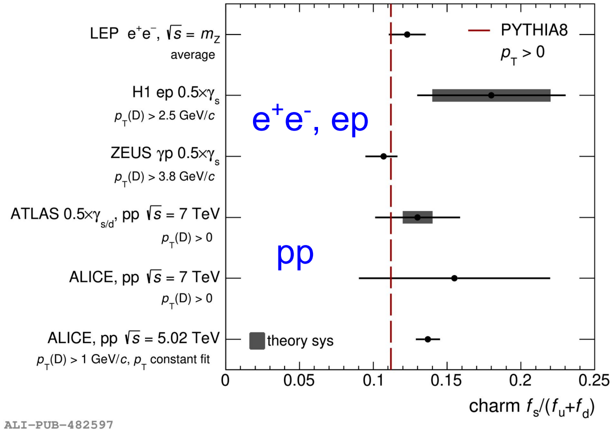
D^+/D^0



$D_s^+/(D^0+D^+)$



$$\frac{d\sigma^D}{dp_T}(p_T^D;\mu_F;\mu_R)=PDF(x_1,\mu_F)\,PDF(x_2,\mu_F)\otimes\frac{d\sigma^c}{dp_T^c}(x_1,x_2;\mu_F;\mu_R)\otimes D_{c\to D}\left(z=\frac{p_D}{p_c};\mu_F\right)$$

Fragmentation functions ($D_{c\text{->}D}$) often **assumed** "**universal**": once constrained to e^+e^- and ep data they are used in different collision systems and energies.

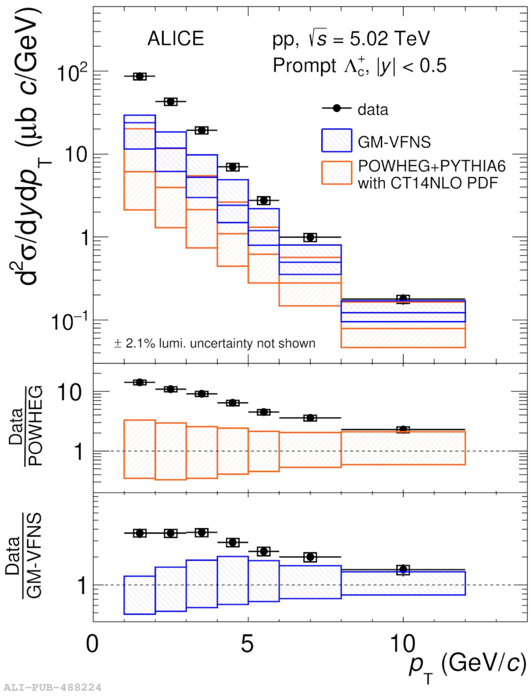
Naïve expectation: ratios of particle-species yields independent from collision system

→ holds for mesons

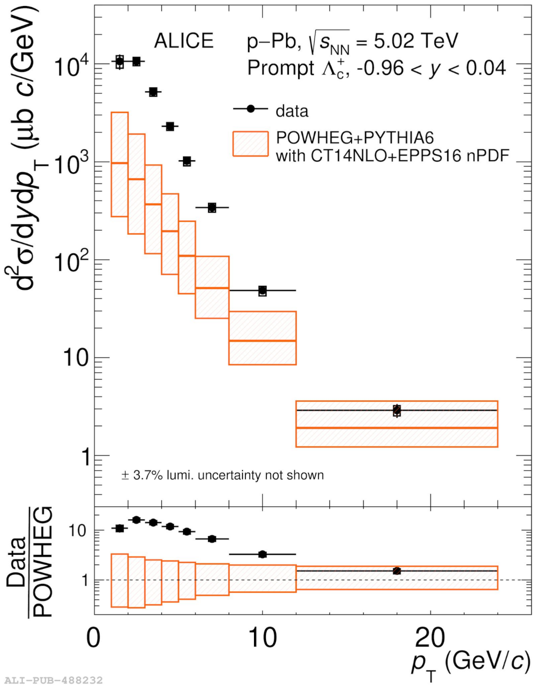
Λ_c^+ cross section in pp and p-Pb collisions at $\sqrt{s_{NN}}$= 5 TeV

PRC 104 054905 (2021)
PRL 127 202301 (2021)

pp



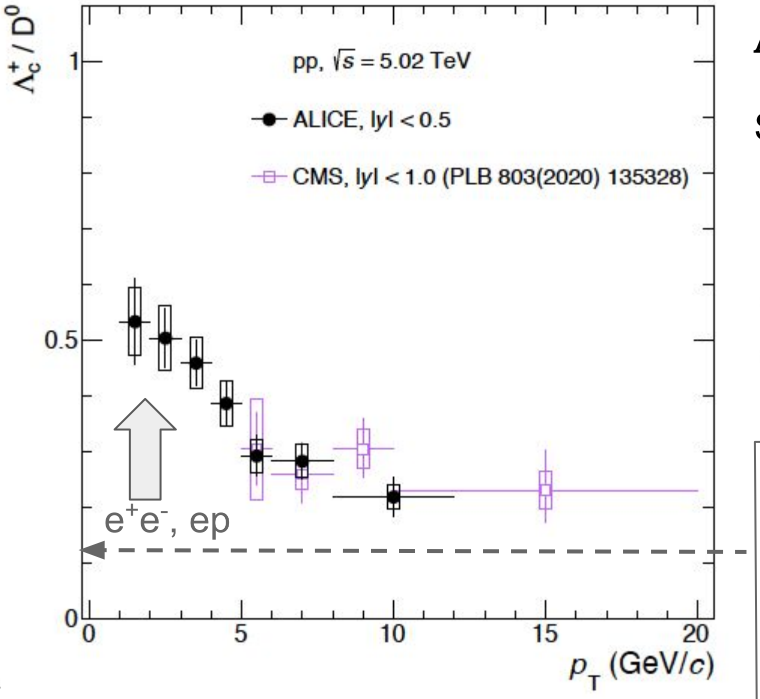
p-Pb



Λ_c^+ production significantly underestimated by pQCD-based models

GM-VFNS: PRD 101 (2020) 114021
POWHEG: JHEP 09 (2007) 126
PYTHIA6: JHEP 05 (2006) 026
CT14 NLO: Phys. Rev. D 93, 033006 (2016)

Λ_c^+/D^0 ratio in pp collisions at 5 TeV



Λ_c^+/D^0 ratio higher (x4-5) values at low p_T than e^+e^-, ep

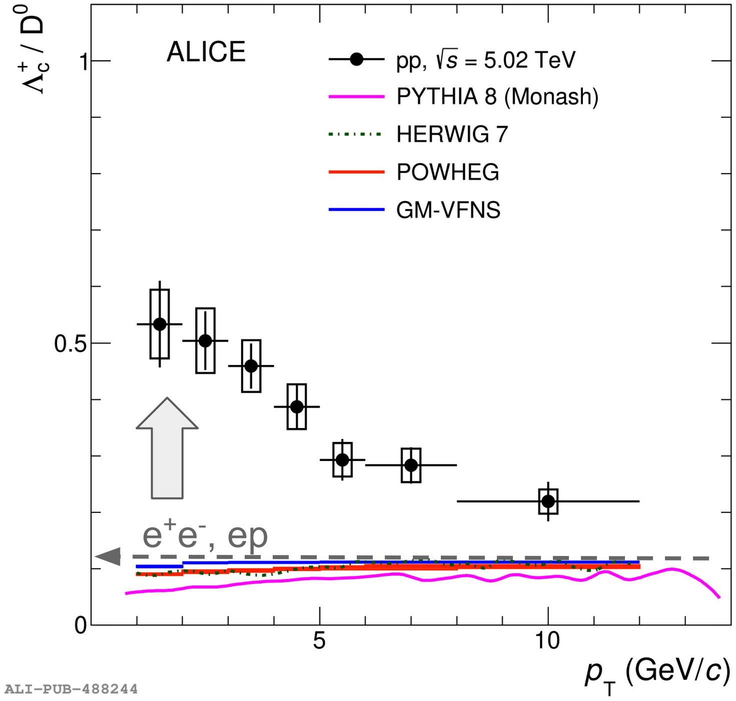
Significantly decreasing with p_T

	$\Lambda_c^+/D^0 \pm$ stat. $\pm$ syst.	System	$\sqrt{s}$ (GeV)	Notes
ALICE	$0.51 \pm 0.04 \pm 0.04\,^{+0.01}_{-0.02}$	pp	5020	$p_T > 0, \lvert y\rvert < 0.5$
ALICE	$0.43 \pm 0.03 \pm 0.05\,^{+0.05}_{-0.03}$	p–Pb	5020	$p_T > 0, -0.96 < y < 0.04$
CLEO [16]	$0.119 \pm 0.021 \pm 0.019$	e^+e^-	10.55	
ARGUS [15, 17]	0.127 ± 0.031	e^+e^-	10.55	
LEP average [18]	$0.113 \pm 0.013 \pm 0.006$	e^+e^-	91.2	
ZEUS DIS [21]	$0.124 \pm 0.034\,^{+0.025}_{-0.022}$	e^-p	320	$1 < Q^2 < 1000$ GeV^2, $0 < p_T < 10$ GeV/c, $0.02 < y < 0.7$
ZEUS γp, HERA I [19]	$0.220 \pm 0.035\,^{+0.027}_{-0.037}$	e^-p	320	$130 < W < 300$ GeV, $Q^2 < 1$ GeV^2, $p_T > 3.8$ GeV/c, $\lvert\eta\rvert < 1.6$
ZEUS γp, HERA II [20]	$0.107 \pm 0.018\,^{+0.009}_{-0.014}$	e^-p	320	$130 < W < 300$ GeV, $Q^2 < 1$ GeV^2, $p_T > 3.8$ GeV/c, $\lvert\eta\rvert < 1.6$

PRC 104 054905 (2021), arXiv:2011.06079
PRL 127 202301 (2021), arXiv:2011.06078
CMS, PLB 803 13428 (2020)

What should we expect in eA? Trivial guess would be ~ep … to be demonstrated!

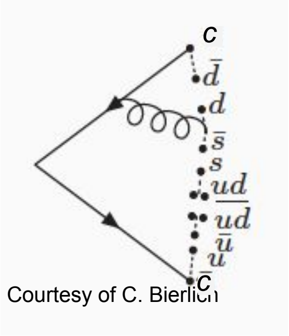
Λ_c^+/D^0 ratio in pp collisions vs. models (1)



PRC 104 054905 (2021), arXiv:2011.06079
PRL 127 202301 (2021), arXiv:2011.06078

Default PYTHIA8 (Monash, EPJC 74 (2014) 3024), standard Lund string fragmentation

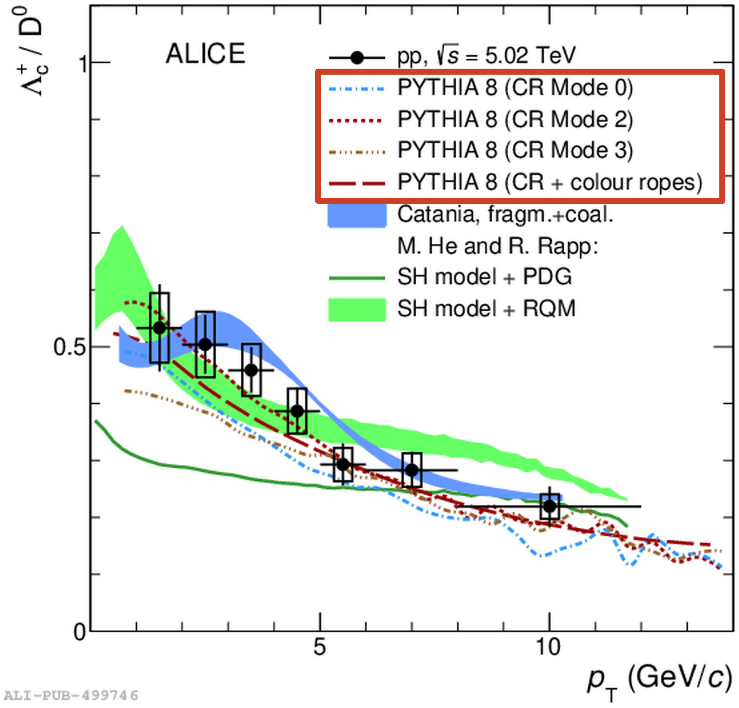
- Light quark/diquark pairs popping out from QCD color-confinement potential (← strings)
  - **Diquarks ↔ baryons**
- Hadronisation of different MPI products largely independent
- Reproduces fragmentation functions used in pQCD-based calculations



HERWIG7 (EPJC 58 (2008) 639-707), cluster hadronisation

Undershoot data by factor about 5 and do not catch p_T shape

Λ_c^+/D^0 ratio in pp collisions vs. models (2)



PRC 104 054905 (2021), arXiv:2011.06079
PRL 127 202301 (2021), arXiv:2011.06078

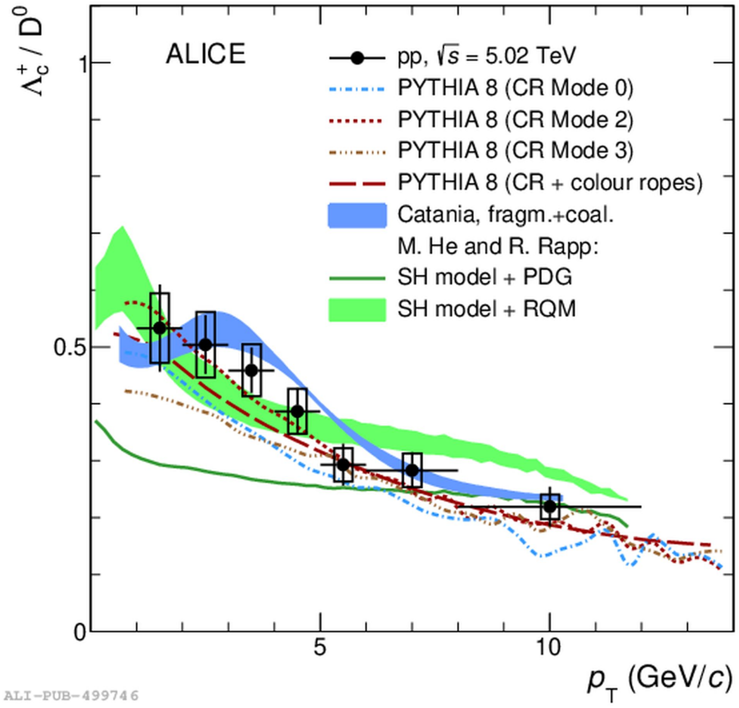
Data described by:

PYTHIA8 with String Formation beyond Leading Colour approximation (JHEP 1508 (2015) 003).
More complete and realistic (=closer to QCD) colour-reconnection (CR) scheme
- "***...between which partons do confining potentials arise?***"

Junction reconnection topologies → enhance baryons.

(b) Type II: junction-style reconnection

Λ_c^+/D^0 ratio in pp collisions vs. models (3)



PRC 104 054905 (2021), arXiv:2011.06079
PRL 127 202301 (2021), arXiv:2011.06078

Data described by:

PYTHIA8 with String Formation beyond Leading Colour

Catania model: coalescence + "vacuum" fragmentation (arxiv 2012.12001)

Expanding system of thermalised light quarks and gluons

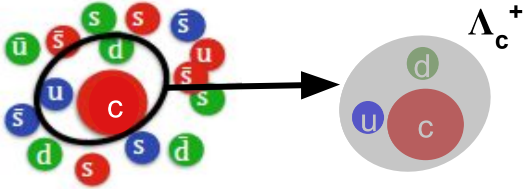
"Sudden" (fixed temperature) coalescence:

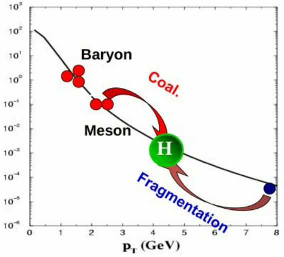
f_q = phase-space distributions of quarks in the system

$$\frac{dN_H}{dyd^2P_T} = g_H \int \prod_{i=1}^{N_q} \frac{d^3p_i}{(2\pi)^3 E_i} p_i \cdot d\sigma_i \; f_{q_i}(x_i, p_i)$$

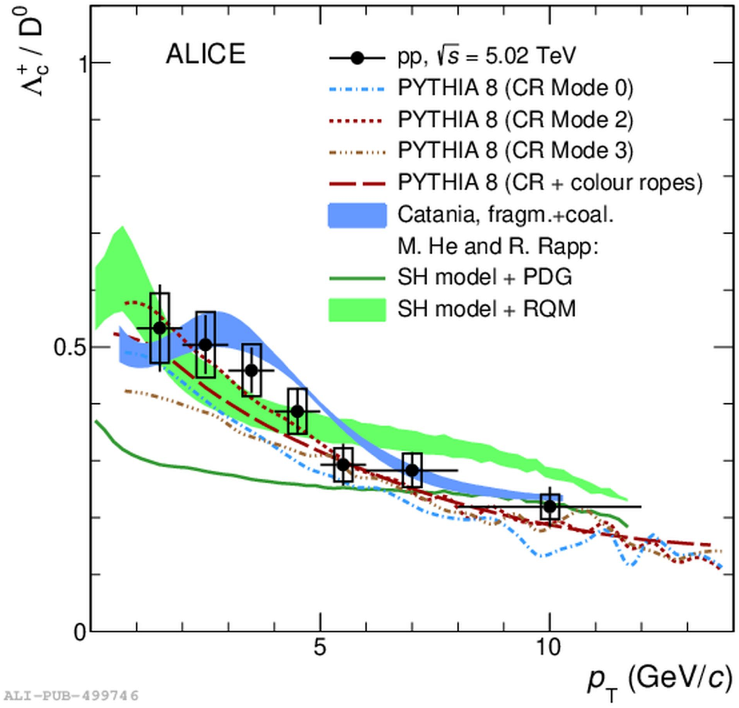
$$\times f_H(x_1 \ldots x_{N_q}, p_1 \ldots p_{N_q})\, \delta^{(2)}\left(P_T - \sum_{i=1}^{n} p_{T,i}\right)$$

f_H= phase-space distributions of quarks within hadron





Λ_c^+/D^0 ratio in pp collisions vs. models (4)



PRC 104 054905 (2021), arXiv:2011.06079
PRL 127 202301 (2021), arXiv:2011.06078

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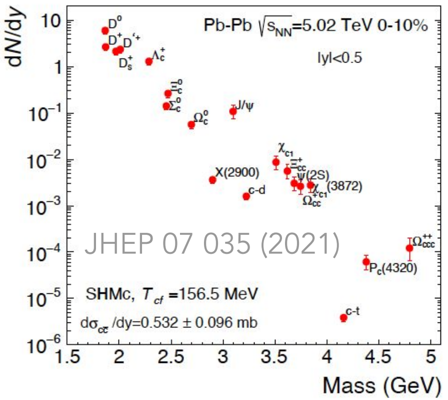
Catania model: coalescence + “vacuum” fragmentation

SH+PDG/RQM, PLB 795 117-121 (2019):
Hadron abundances based on **statistical hadronisation model** + feed-down from **augmented set of charm-baryon states** (from RQM)

→ PDG: 5 Λ_c, 3 Σ_c, 8 Ξ_c, 2 Ω_c

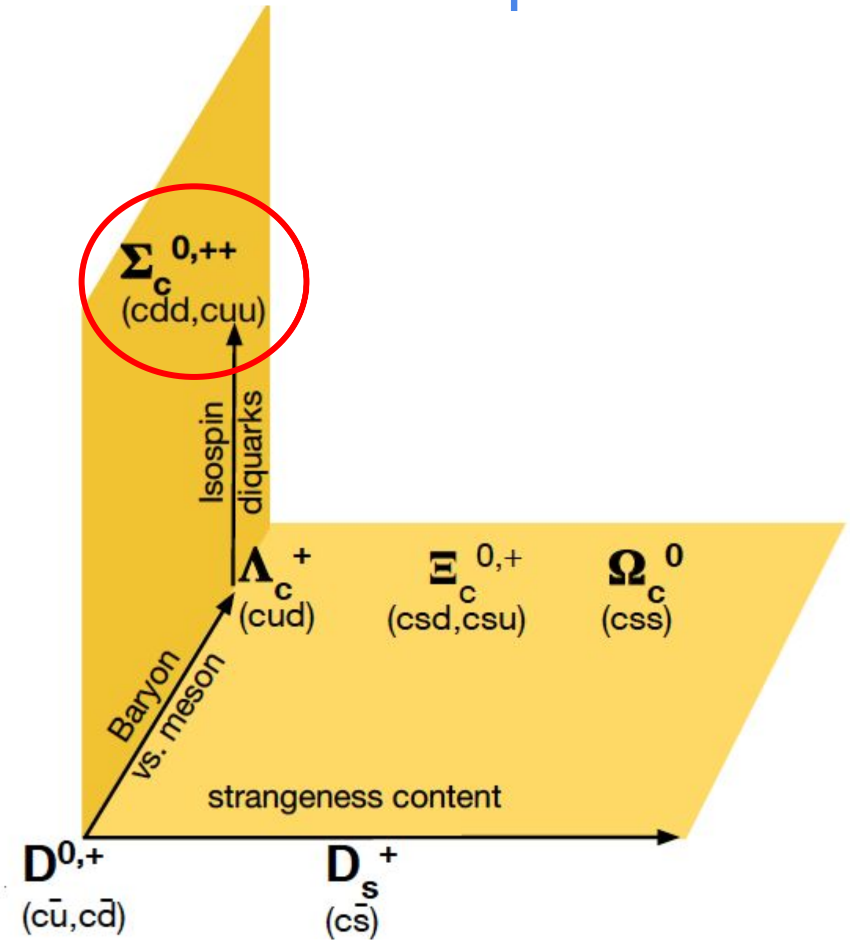
→ RQM: additional 18 Λ_c, 42 Σ_c, 62 Ξ_c, 34 Ω_c



JHEP 07 035 (2021)

Why not (easily) seen in e^+e^-?
Can they be looked for in EIC?

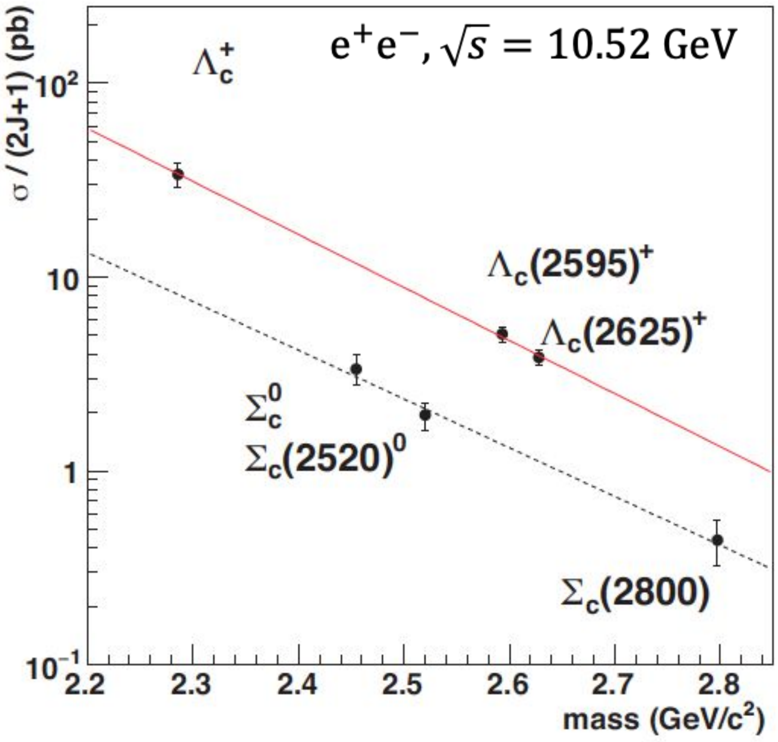
Several arrows in the quiver



Particle	Mass (GeV/c^2)
D^0	1.865
D^+	1.870
D_s^+	1.968
Λ_c^+	2.286
$\Sigma_c^{0,++}$	2.454
Ξ_c^0	2.470
Ξ_c^+	2.468
Ω_c^0	2.695

$\Sigma_c^{0,++}$ production and $\Lambda_c^+ \leftarrow \Sigma_c^{0,++}$ feedown

Belle, PRD 97, 072005 (2018)

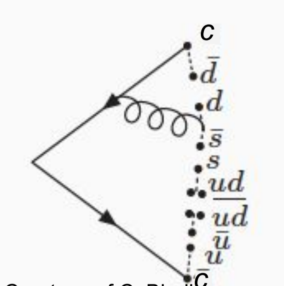


e^+e^- collisions: production of Σ_c states suppressed w.r.t. Λ_c states

In string fragmentation models charm baryons formed by combining initially produced c quarks with light-quark diquarks, produced in pair in string breaking

Λ_c (isospin = 0) needs diquark with spin = 0 $(ud)_0$
Σ_c (isospin = 1) needs diquark with spin = 1 $(ud,dd,uu)_1$

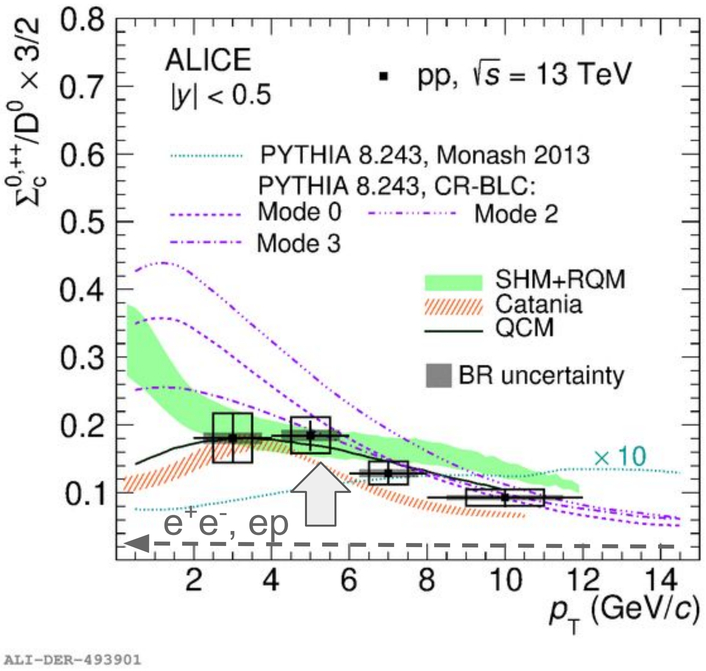
$(ud,dd,uu)_1$ larger mass than $(ud)_0$ mass → suppression

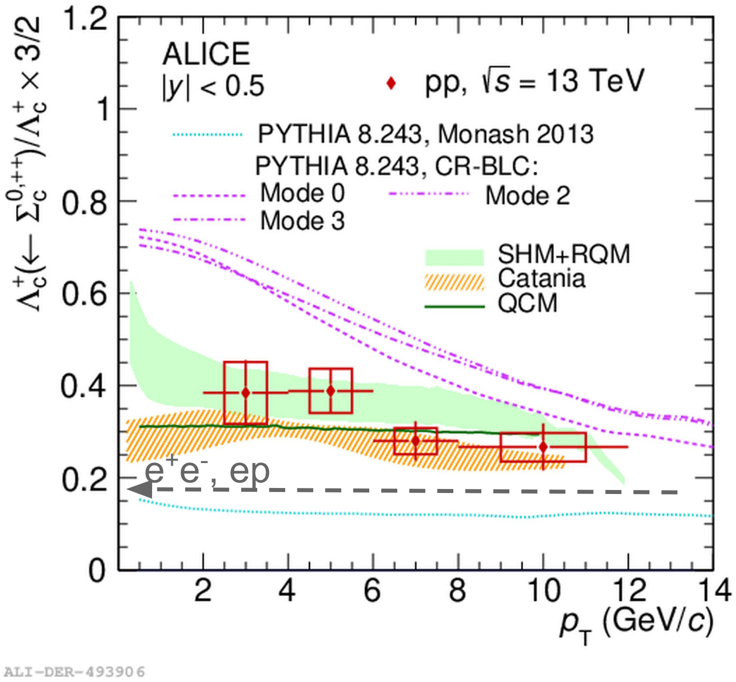


Courtesy of C. Bierlich

$\Sigma_c^{0,++}/D^0$ and $\Lambda_c^+ \leftarrow \Sigma_c^{0,+,++}$ feedown

PRL 128 (2022) 012001, arxiv 2106.08278





$\Sigma_c^{0,+,++}/D^0$ ratio significantly larger than in e^+e^- collisions

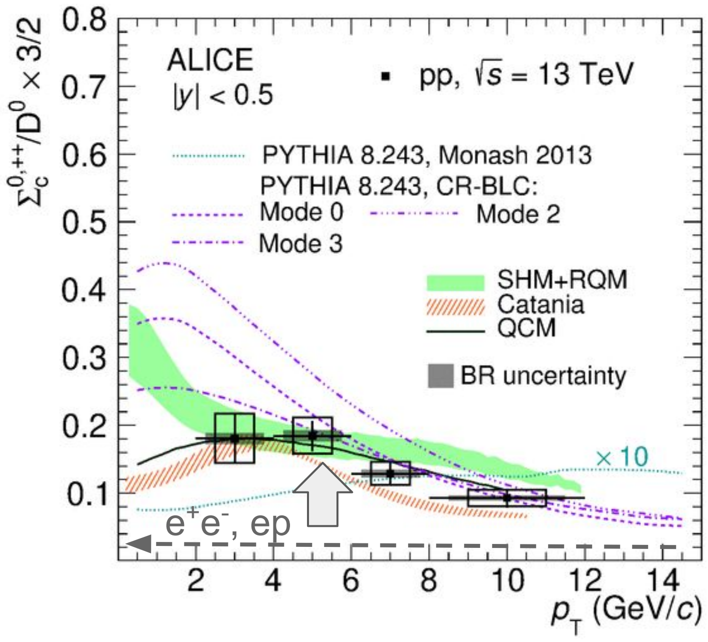
About x2 increase of $\Lambda_c^+ \leftarrow \Sigma_c^{0,+,++}$ feed-down → $\Sigma_c^{0,+,++}$ “enhancement” larger than Λ_c^+ one

→ $\Sigma_c^{0,+,++}$produced differently in pp than e^+e^- collisions

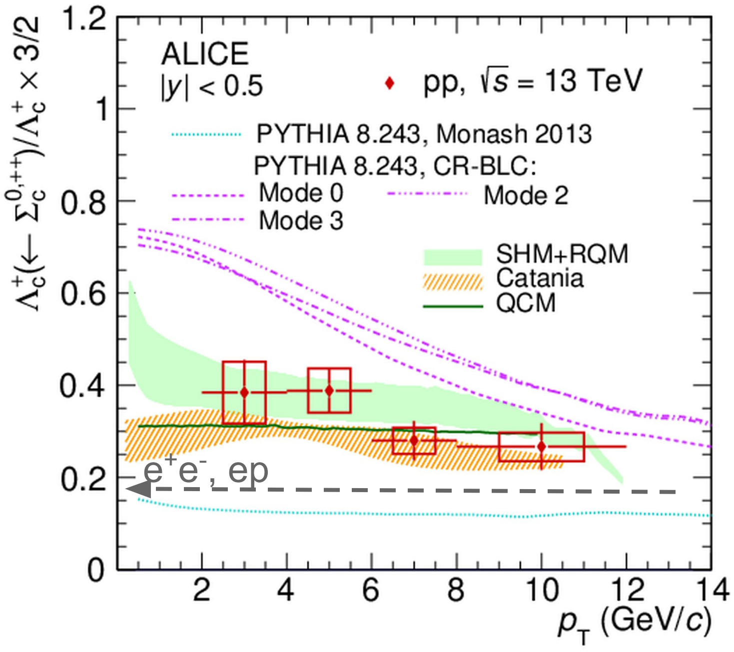
→ suppression from $(ud,dd,uu)_1$ diquark creation absent or reduced, as comparison to models suggests

$\Sigma_c^{0,++}$/D^0 and $\Lambda_c^+ \leftarrow \Sigma_c^{0,+,++}$ feedown

PRL 128 (2022) 012001, arxiv 2106.08278



ALI-DER-493901



ALI-DER-493906

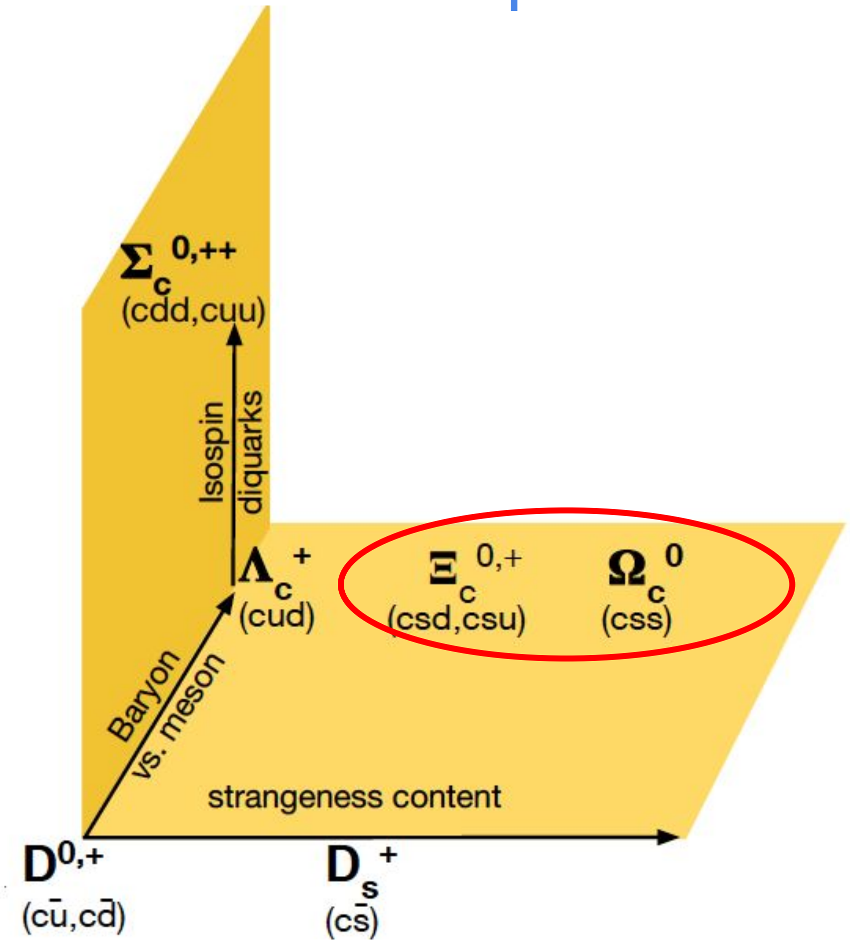
Default PYTHIA8 (Monash 2013): significantly underestimates data (worse than for Λ_c^+)

PYTHIA8 with CR beyond Leading Colour: Σ_c enhanced by junction CR topologies (n.b. heavy cu, cd diquarks)

- describes $\Sigma_c^{0,+,++}$/D^0 but overestimates $\Lambda_c^+ \leftarrow \Sigma_c^{0,+,++}$/D^0

Catania, QCM and SHM+RQM models describe both ratios

Several arrows in the quiver



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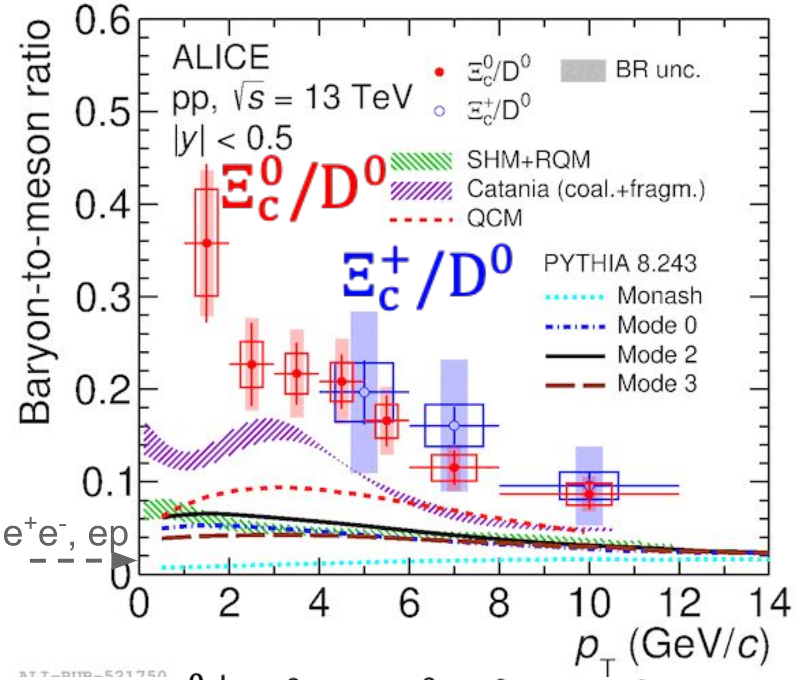
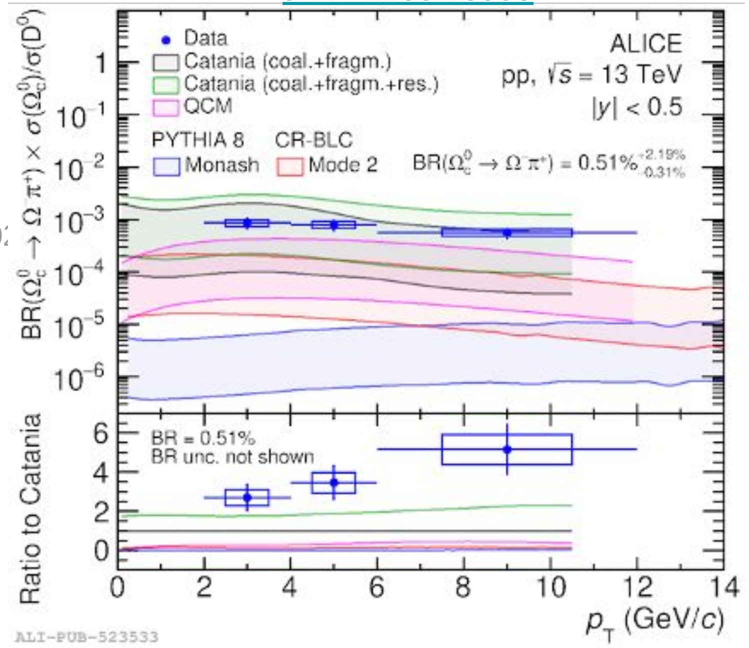
Ω_c^0	2.695

Charm-strange baryons: $\Xi_c^{0,+}$ and Ω_c^0

arXiv:2205.13993



PRL. 127 (202

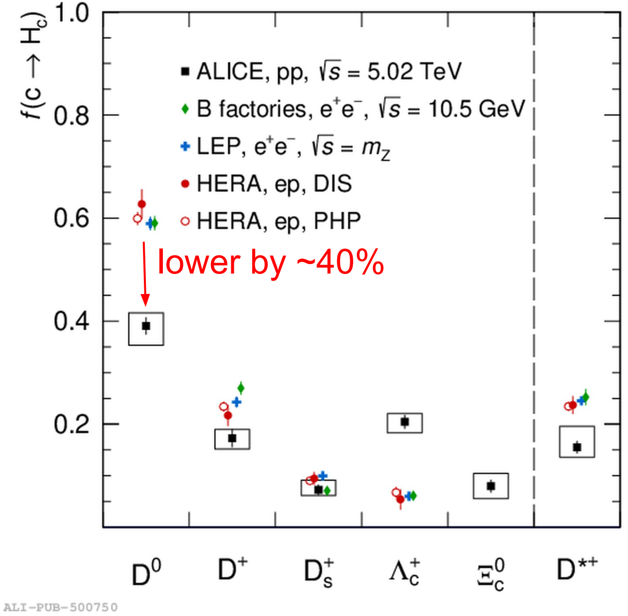


- Both $\Xi_c^{0,+}/D^0$ and Ω_c^0/D^0xBR($\Omega_c^0 \rightarrow \Omega^-\pi^+$) ratios significantly larger than in e+e- collisions
- Only **Catania** model (coalescence) close to the data.
- **PYTHIA8 with CR-BLC** (**Mode0,2,3**), **SHM+RQM, QCM** predict ratios significantly larger than what expected from e+e- and **Default PYTHIA8 (Monash)** but significantly underestimate the data.

→ Additional challenges from strange (di)quark production

Fragmentation fractions and charm cross section

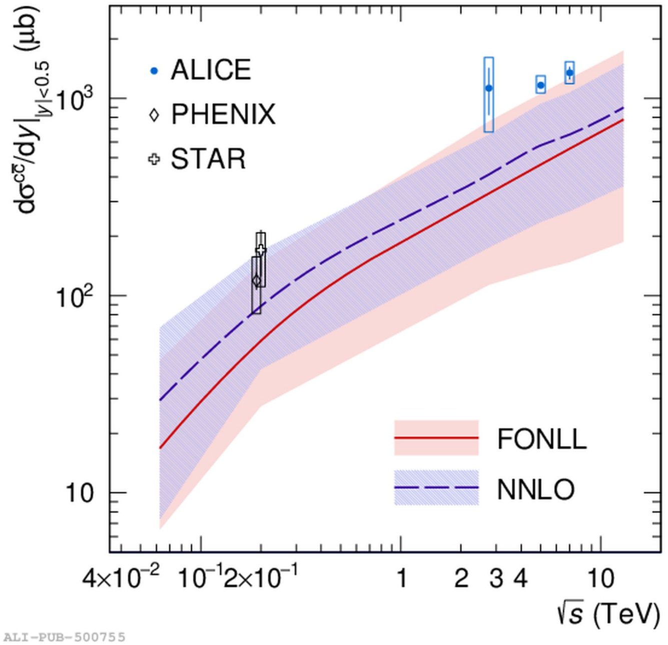
PRD 105, L011103 (2022) arxiv 2105.06335



Measured baryon-to-meson ratios imply **violation of universality of fragmentation fractions (FF) already in pp collisions**:

→ cannot rely on e^+e^- FF to get charm cross section from D meson data

→ new FF estimated from measured particle-species ratios

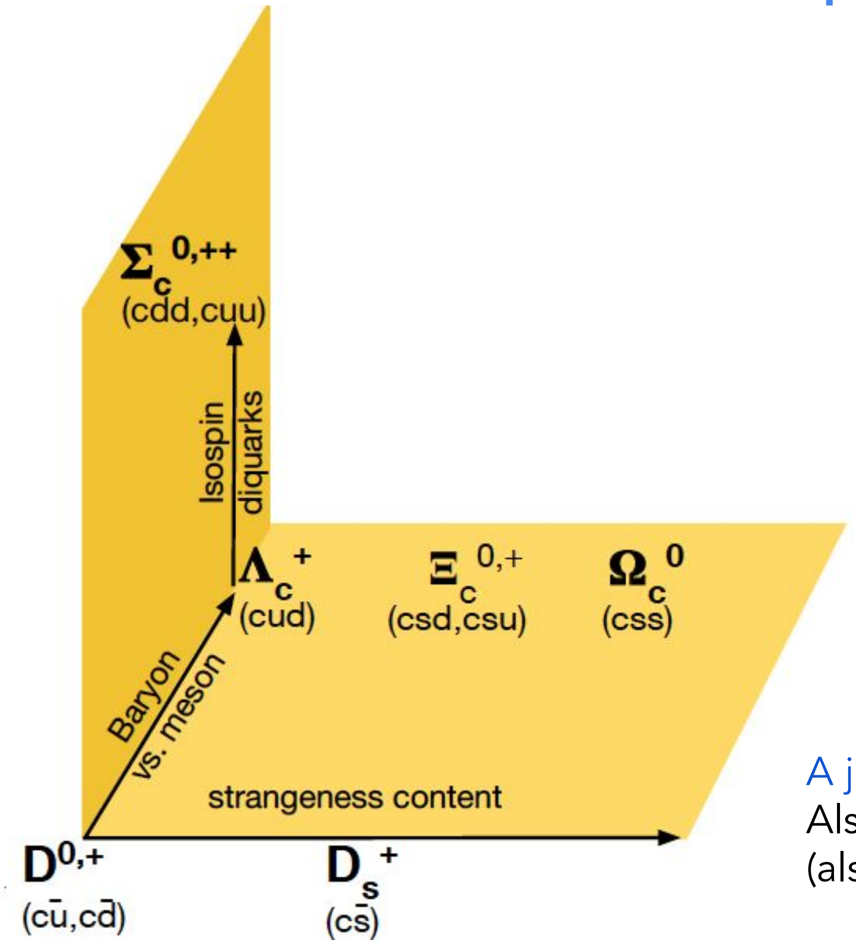


Total $c\bar{c}$ cross section at $|y|<0.5$ estimated at 5 TeV from all measured particle-species cross sections

About **40% higher values w.r.t. using e^+e^- FF**

On upper edge of FONLL and NNLO

Several arrows in the quiver



A jump in mass with beauty!
Also with non-prompt signals
(also leptons and J/Ψ)

Particle	Mass (GeV/c^2)
D^0	1.865
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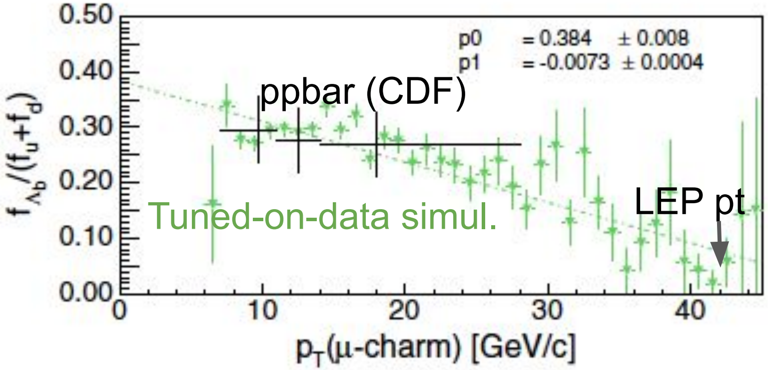
D_s^+	1.968
Λ_c^+	2.286
$\Sigma_c^{0,++}$	2.454
Ξ_c^0	2.470
Ξ_c^+	2.468
Ω_c^0	2.695
$B^{0,+}$	5.280
B_s^0	5367
Λ_b^0	5620

Beauty baryons vs. mesons at LEP, Tevatron and LHC

HFLAV, EPJC 77 (2017) 895

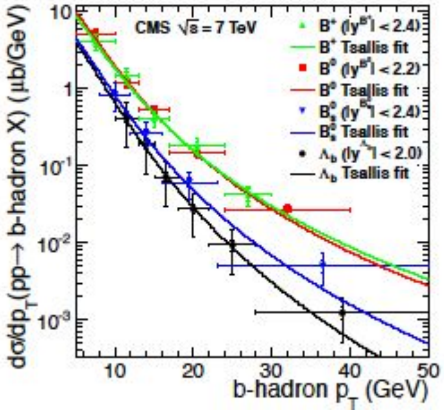
b hadron	Fraction at Z[%]	Fraction at $\bar{p}p$ [%]
B^+, B^0	41.2 ± 0.8	34.0 ± 2.1
B^0_s	8.8 ± 1.3	10.1 ± 1.5
b baryons	8.9 ± 1.2	21.8 ± 4.7



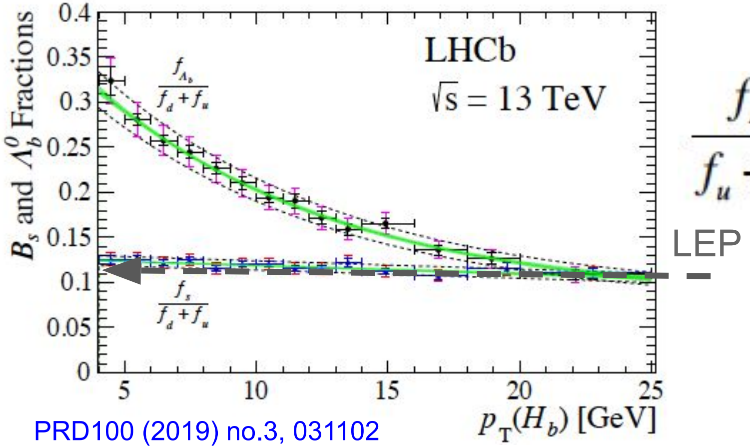
PRD 77 072003 (2008)

Suggest p_T-dependent fragmentation fraction, possibly influenced by hadronic environment

At LHC: precise Λ_b^0 measurements indicate clear dependence of baryon-to-meson ratio on p_T



CMS, PLB 714 (2012) 136



PRD100 (2019) no.3, 031102

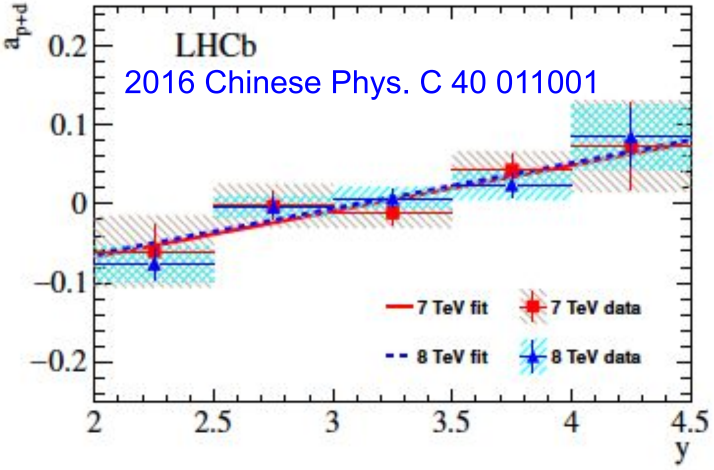
$$\frac{f_{\Lambda_b}}{f_u + f_d}$$ **at low p_T significantly higher (x3) than LEP data**

Similar trend in charm and beauty sectors

Beam remnants and drag effect, R_{AA}

Indication for a rapidity-dependent ratio of $\Lambda_b/\overline{\Lambda}_b$, suggesting some baryon-number transport from beam particles to $\Lambda_b \leftarrow$ **string drag/leading-quark effect?**

J.L. Rosner, PRD 90 014023 (2014); PRD 86 014011 (2012)

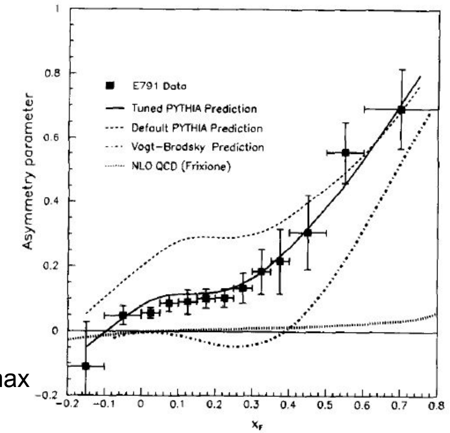


Similar effect observed for charm mesons (D^+) long ago in π-nucleus collisions (E791, E769, WA82)

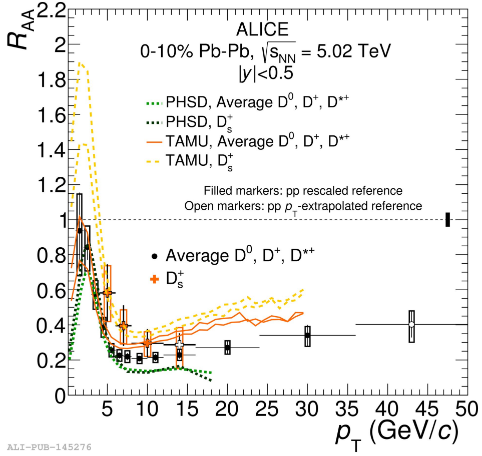
$$A(x_F, p_t^2) \equiv \frac{\sigma_L - \sigma_{NL}}{\sigma_L + \sigma_{NL}}.$$

E791, PLB 371 (1996) 157-162

$x_F = p_z/p_{z,\,max}$



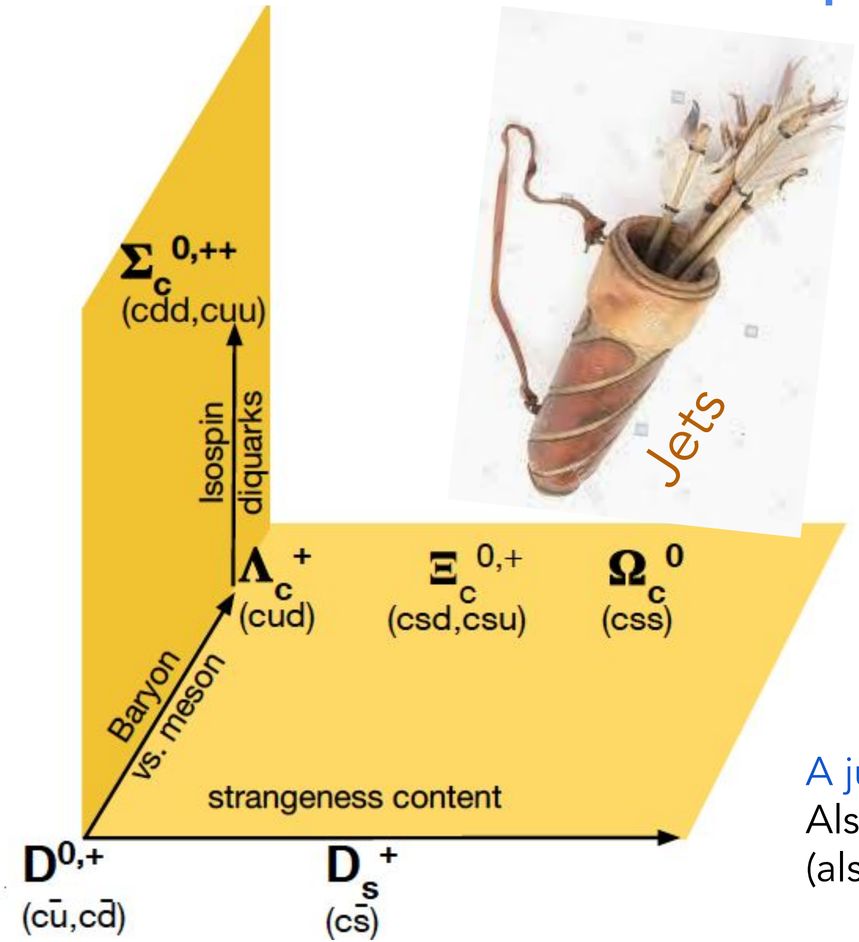
And the heavy-ion community knows that a medium matters...



Suggest that **hadronic environment plays a role**

Up to what extent? how does the hadronisation dynamics change in different systems?

Several arrows in the quiver



We can exploit multiplicity

A jump in mass with beauty!
Also with non-prompt signals (also leptons and J/Ψ)

Particle	Mass (GeV/c^2)
D^0	1.865
	1.870
	1.968
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Ω_c^0	2.695
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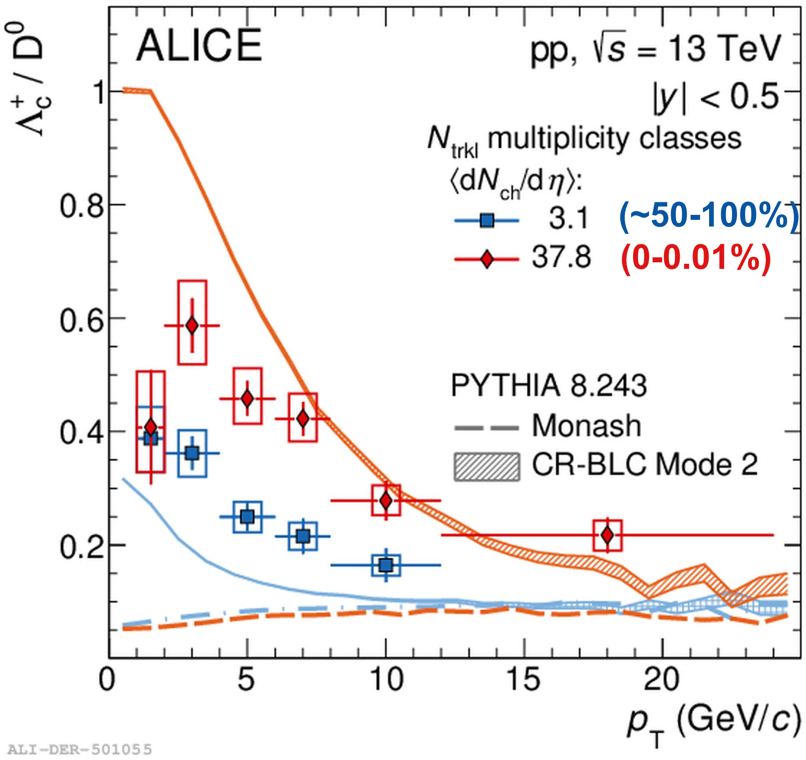
Λ_c^+/D^0 evolution with event activity: pp



PLB 829 (2022) 137065, https://arxiv.org/abs/2111.11948

Λ_c^+/D^0 increases with particle multiplicity at midrapidity

Trend expected by **PYTHIA8 with CR-BLC (Mode 2)**

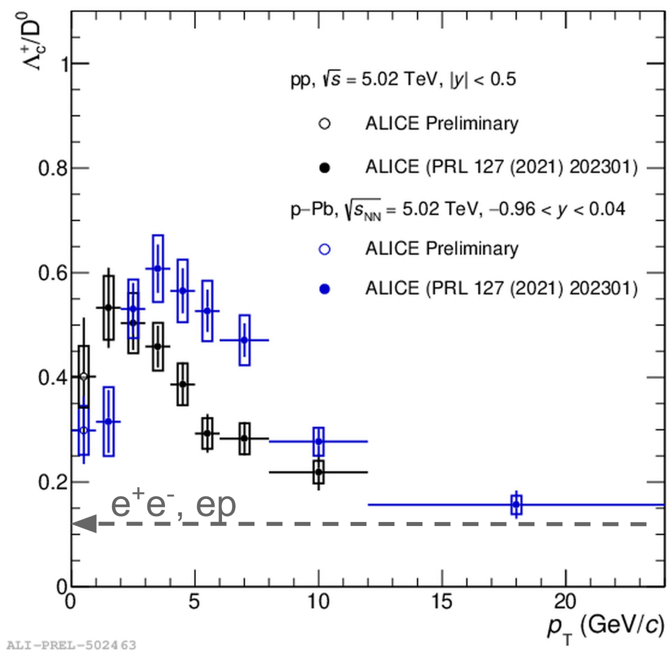
→ confirms importance of Colour Reconnection in rich partonic environments

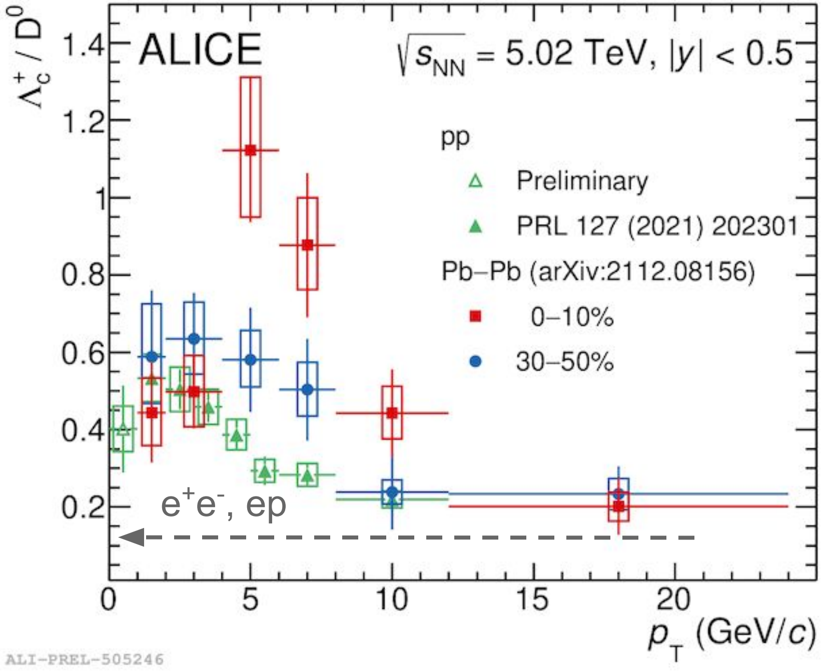
→ interplay of Color Reconnection (CR) and Multiple Parton Interactions

Do we have a smooth evolution with multiplicity from (e^+e^- to) pp to AA?

Λ_c^+/D^0 evolution with event activity: from pp to Pb-Pb

PRC 104 054905 (2021) , PRL 127 202301 (2021) , arxiv 2112.08156



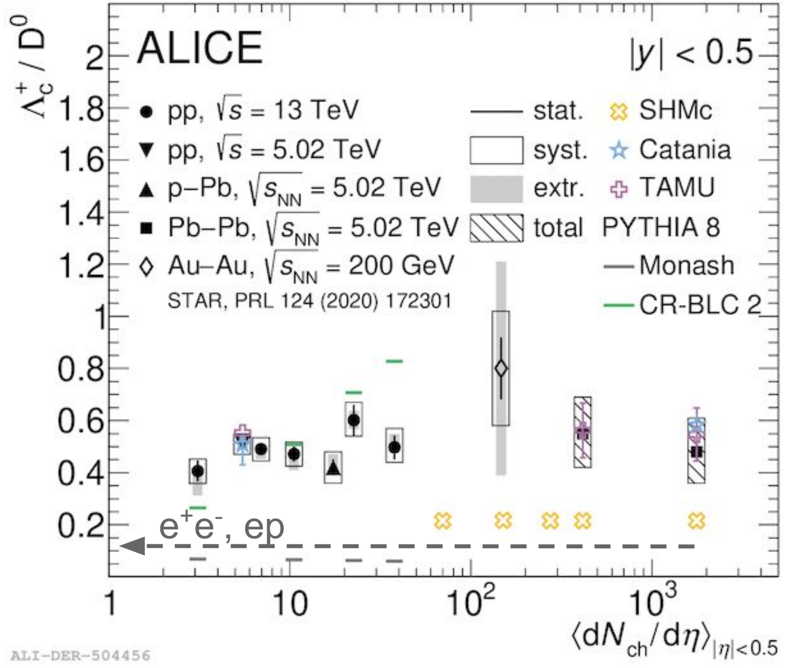


Evolution of Λ_c^+/D^0 ratio from pp to p-Pb to central Pb-Pb. Only a change of p_T shape?

- Especially at low p_T: **larger "jump" from e^+e^- to pp than from pp to Pb-Pb**
- **p-Pb in-between pp and Pb-Pb**

Λ_c^+/D^0 evolution with event activity: from pp to Pb-Pb

PRC 104 054905 (2021) , PRL 127 202301 (2021), PLB 829 (2022) 137065, arxiv 2112.08156



No evidence of evolution of p_T-integrated Λ_c^+/D^0 ratio
Data uncertainty still large

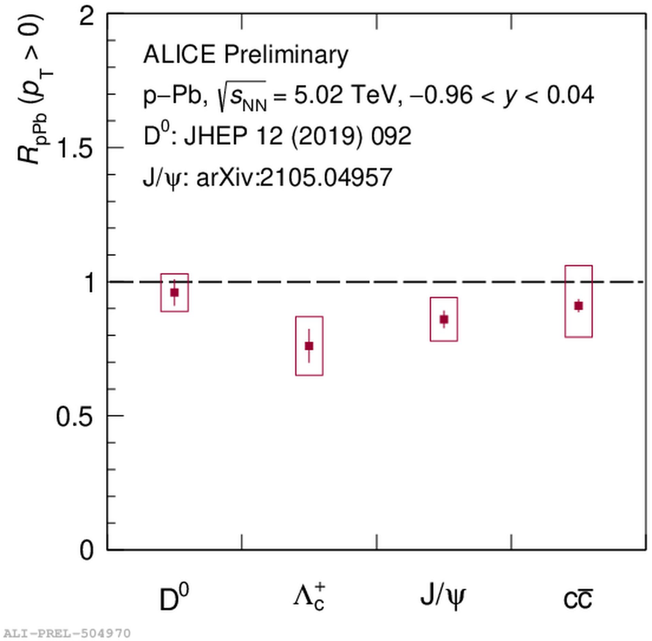
Significantly higher values than e^+e^-

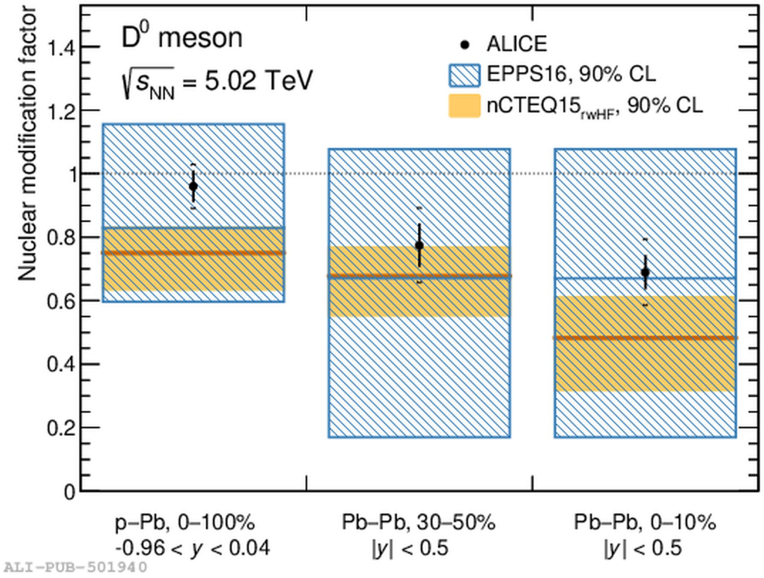
PYTHIA8 CR-BLC expects increase with mult
SHM (Pb-Pb) about flat trend but below data

… puzzling

Lowest multiplicity still to be covered (run 3): down to e^+e^-?

Side note: hadronisation, binary scaling and nPDF





Test of binary scaling for HQ requires measurements of HF-baryon production in Pb-Pb

This, along with the determination of nPDF, is important for the interpretation of HF data in Pb-Pb collisions.

Heavy flavour in our QCD laboratories

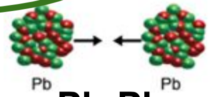
Fragmentation functions universality violated already in pp collisions
Multiple parton interactions in pp build a system rich of quarks or gluons, dense enough to alter hadronisation w.r.t. e^+e^-

e^+e^- = "vacuum"

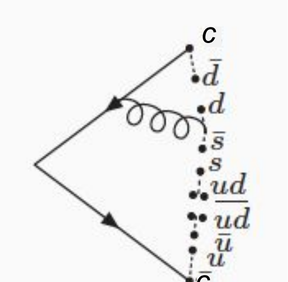
pp
~~not far from vacuum ~ many independent scatterings~~
(for HF at least)

Dynamical model
"Local" dynamical constraints
(e.g. Lund string fragmentation, quarks and diquarks popping out from QCD potential)

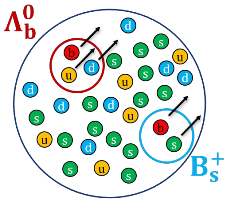
MPI, system size



Pb-Pb
Complex, extended-size system,
Local equilibration



Courtesy of C. Bierlich



(Semi)phenomenological models sufficient to describe relative particle abundances *once ingredients are tuned*?

Heavy flavour in our QCD laboratories

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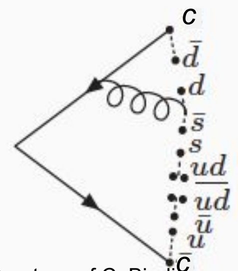
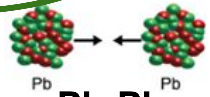


Courtesy of C. Bierlich

MPI, system size

Where does e-A sit?



Pb-Pb
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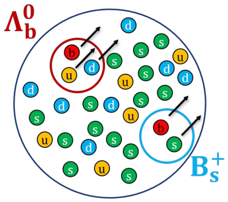
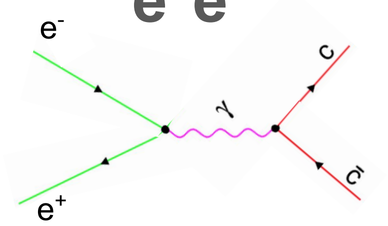
Local equilibration



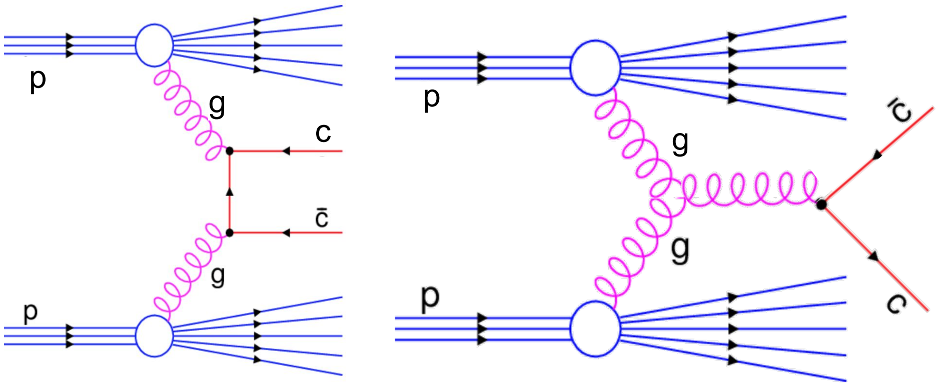
(Semi)phenomenological models sufficient to describe relative particle abundances *once ingredients are tuned*?

Different processes, different environments

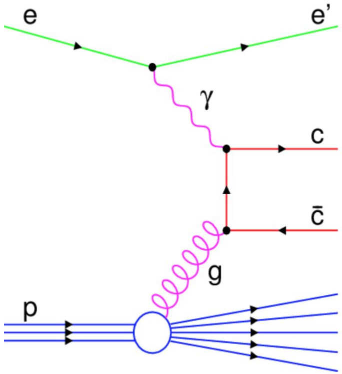
e^+e^-



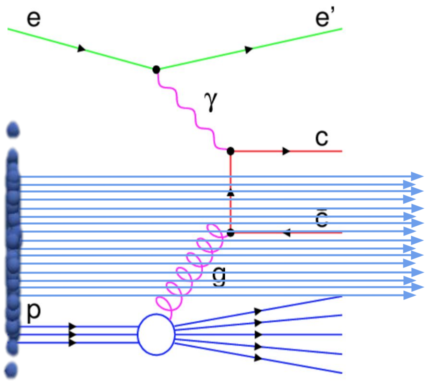
pp



ep



eA



Different production processes → different colour topologies
(sketches only some LO terms, also 3 jet events in ee and ep)

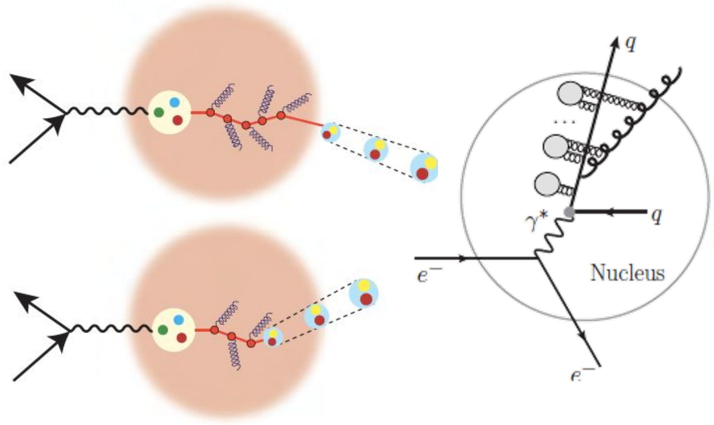
Different environments

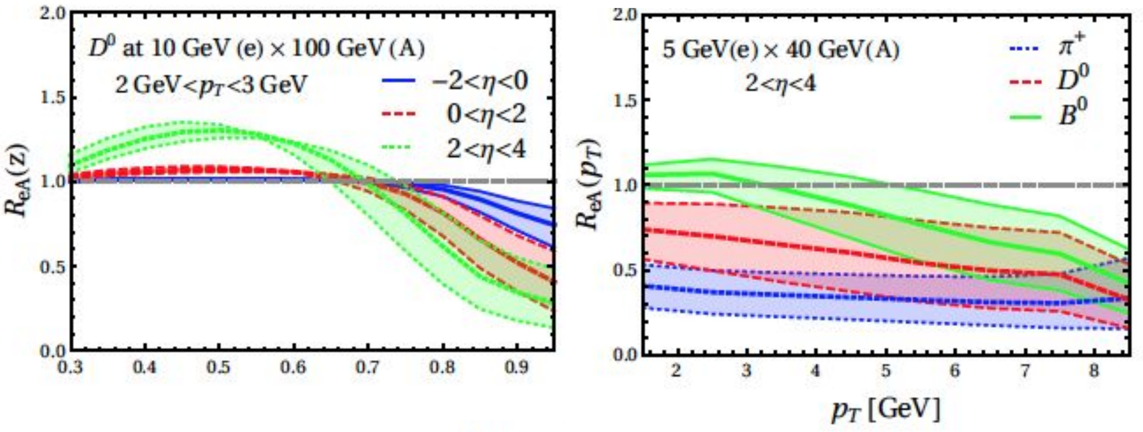
→ **different features** can be probed, also exploring phase spac
(e.g. beam remnant effects)

Possible modified fragmentation in CNM

“Cold” nuclear matter effects can alter parton shower + possible hadronic interactions

Li, Liu, Vitev arXiv:2007.10994





$$R^h_{eA}(p_T,\eta,z) = \frac{\left.\frac{N^h(p_T,\eta,z)}{N^{\rm inc}(p_T,\eta)}\right|_{\rm e+Au}}{\left.\frac{N^h(p_T,\eta,z)}{N^{\rm inc}(p_T,\eta)}\right|_{\rm e+p}}.$$

Inclusive jet spectra

Model tested on HERMES data.
Inputs also from p-Pb vs. pp at the LHC?
But one needs differential studies (e.g. vs. z, different η region, CM energies) and kinematics under control

Λ_c^+/D^0 projections for EIC

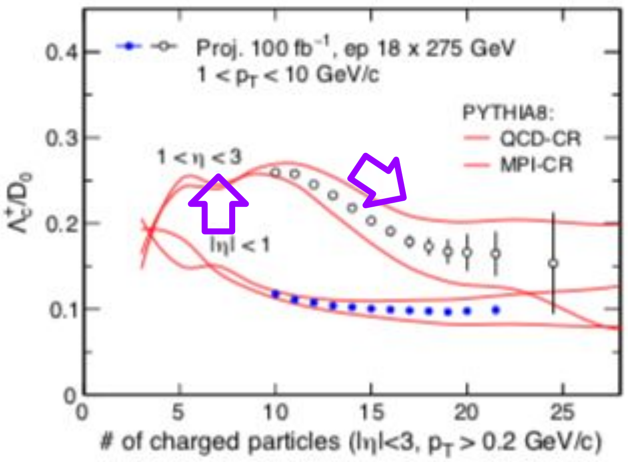


Figure 3.28: Projections for ATHENA measurements of the heavy-quark Λ_c^+ to D^0 baryon-to-meson ratio as a function of the charged track multiplicity (FastSim).

Increase from central to forward rapidity: drag effect/beam remnant?
If so, one could test

- charge asymmetry
- eta asymmetry

Decrease with increasing multiplicity: likely a fragmentation feature (fragmentation to a heavier particle reduces phase space to produce lighter particles, thus reduces multiplicity).

Not too large difference between QCD-CR and MPI-CR, expected.

Summary

- Charm and beauty LHC data indicate that hadronisation has **different features in pp than e^+e^- collisions**
- **Universality of fragmentation fractions (functions) broken** already in pp collisions (at low momenta)
  - What are the system properties and/or energy scales shaping the boundary?
- Possible existence of many undiscovered HF baryon states to be demonstrated
  - More and more states from ATLAS, CMS, LHCb (but production rates rarely reported)
  - What about searching them at EIC?

At EIC: opportunity to revisit and deepen studies done in ep at HERA in view of LHC results?

+ Extension to nuclei
  + Characterise step-by-step influence of hadronic environment on hadronisation (beam remnants, color structure, role of diquark, possible dependence on “Q^2” or relevant energy scales, etc…)
+ (not covered) possible connection between MPI-related studies at the LHC and 5D PDF (GPD)?

Potential synergies with italian communities (experimental, theory) working on spectroscopy.

T. Sjostrand summary at LHCP:

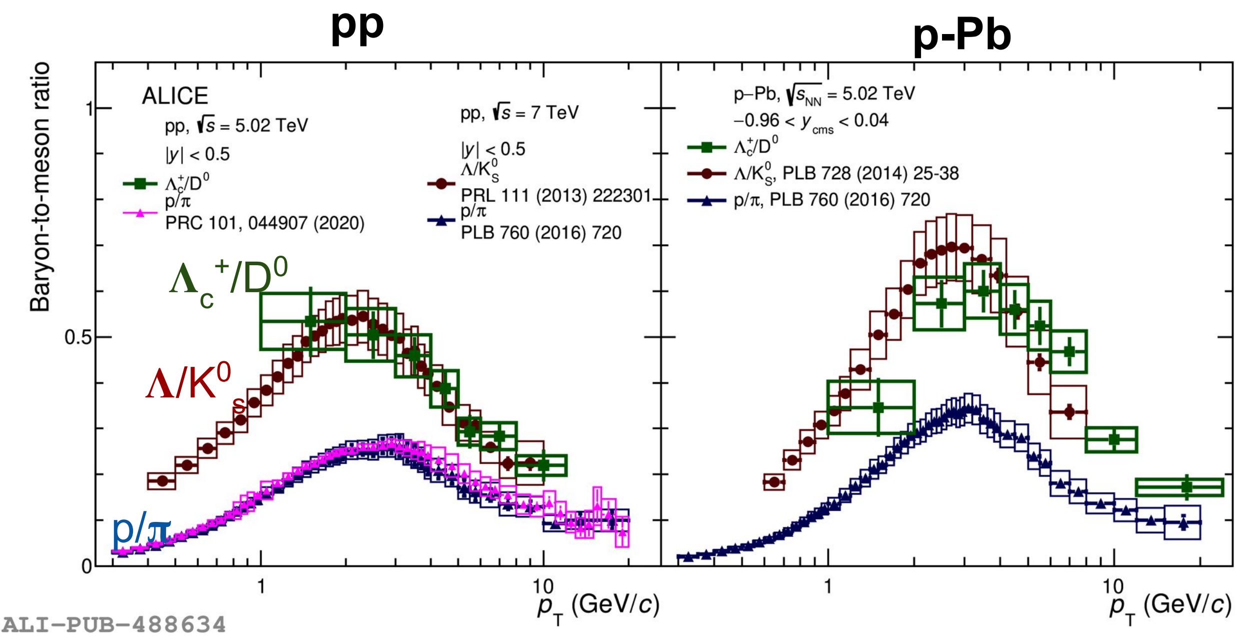
https://indico.cern.ch/event/1109611/contributions/4686977/attachments/2447285/4194251/LHCP22Sjostrand.pdf

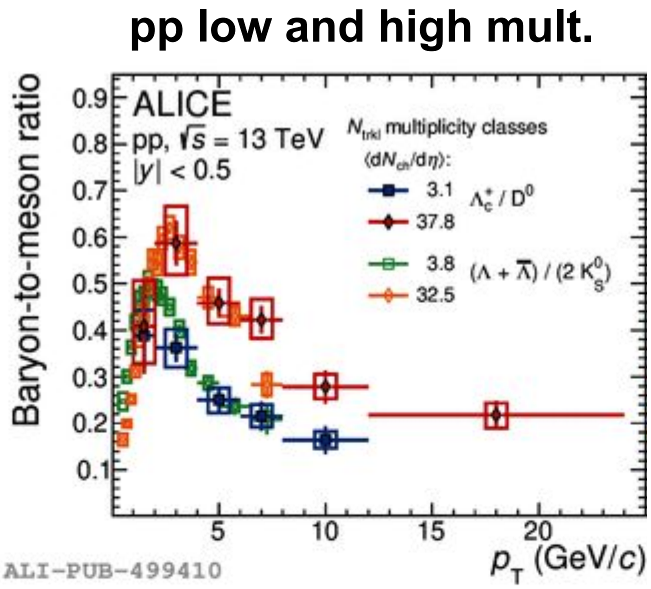
- Many poorly understood soft-physics aspects, notably
  - multiparton interactions,
  - colour reconnection, and
  - hadronization.
- LHC data has revolutionized the picture of soft physics:
  Goodbye jet universality!
- This has led to a renewed phenomenology interest:
  Welcome new mechanisms!
- Still some way to go before a new unified picture is in place, covering the evolution from e^+e^- to low-n_{ch} pp to AA.

Extra

Λ_c^+/D^0 compared with Λ/K_S^0 and p/π^+

PRC 104 054905 (2021) , PRL 127 202301 (2021), PLB 829 (2022) 137065

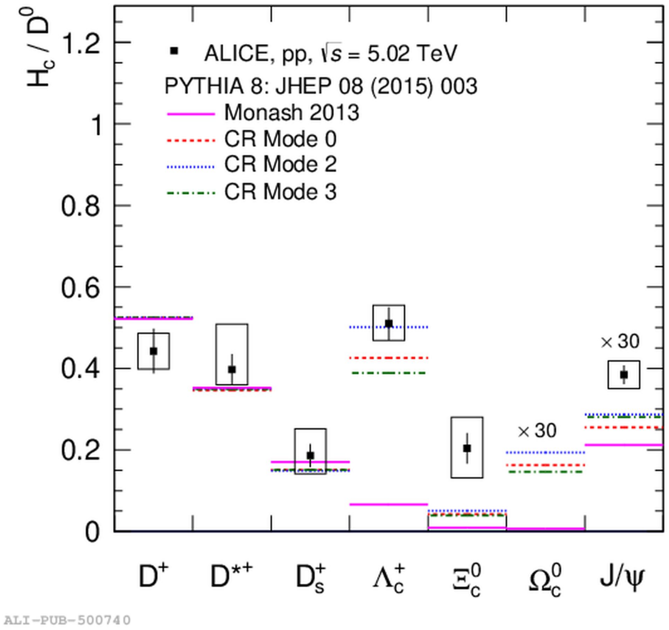


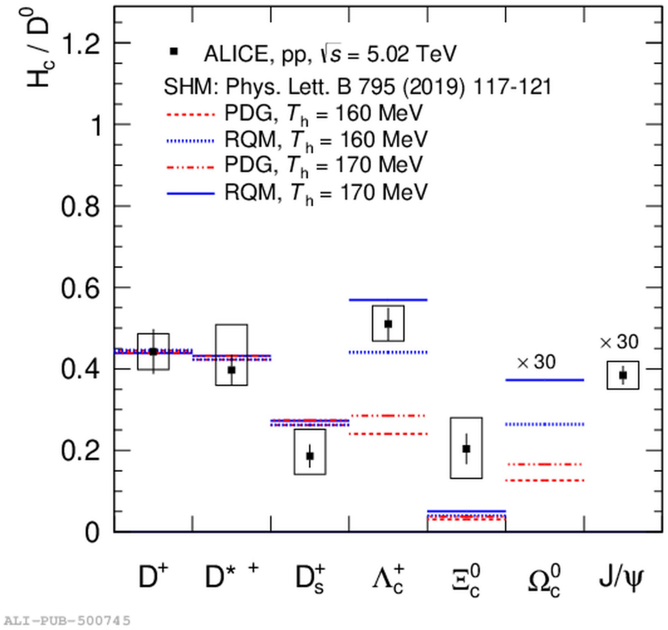


Similar p_T trend and evolution with multiplicity of baryon-to-meson ratios in light and heavy-flavour sector

Fragmentation fractions (normalised to D^0) vs. models

PRD 105, L011103 (2022) arxiv 2105.06335





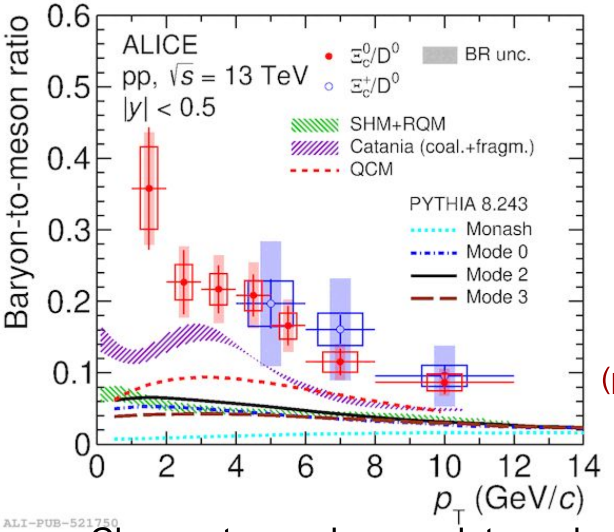
PYTHIA8: same conclusion as from p_T-differential studies.
Statistical Hadronisation Model:

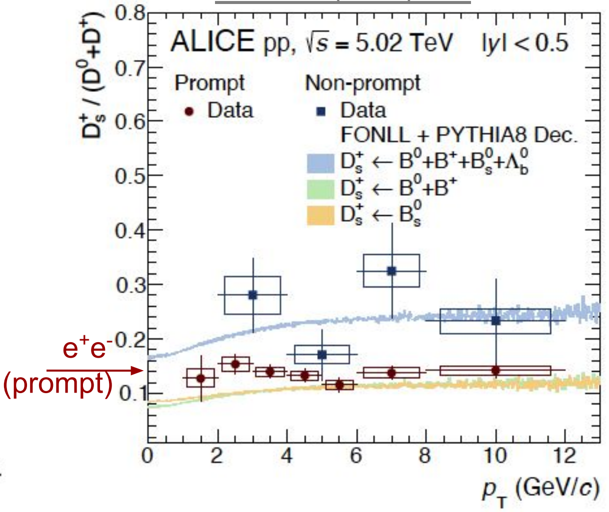
- Λ_c^+ data described only if additional baryon states from RQM assumed
- Ξ_c^0 underestimated (final assessment needs new and more precise measurement down to lower p_T)

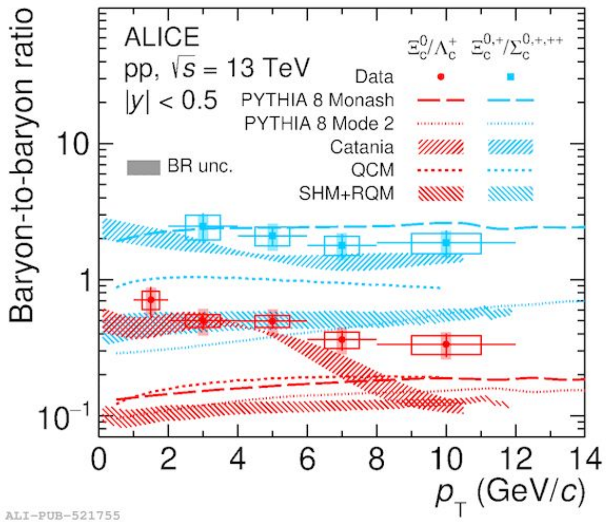
Not just a strange(ness) feature?

PRL. 127 (2021) 272001, arxiv 2105.05187

JHEP 05 (2021) 220





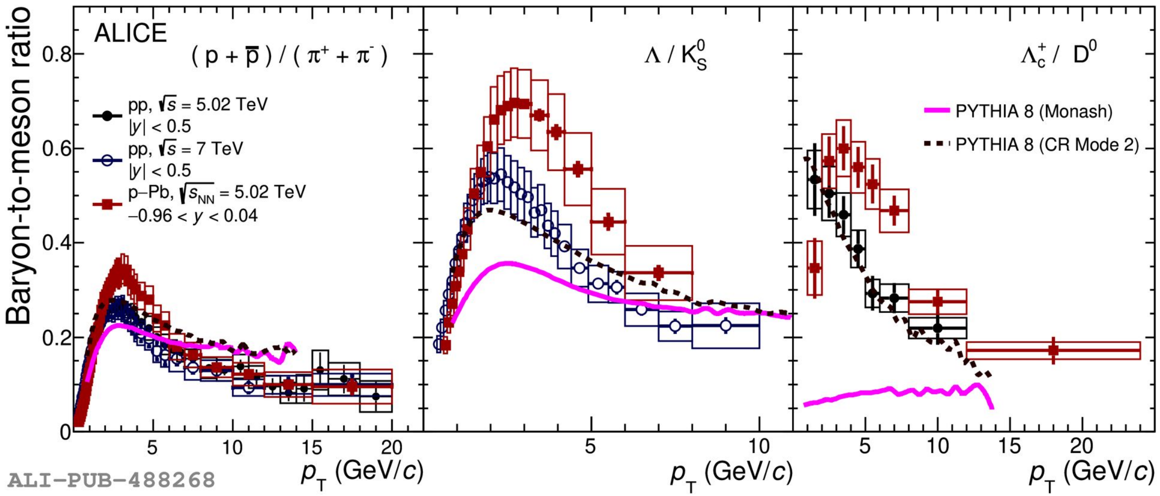


- Charm-strange baryon data underestimated by most models! Something anomalous with strange quarks?
- But $D_s^+/(D^0+D^+)$ (prompt and non-prompt) compatible with expectations from e^+e^- … **baryons are strange!**
  - Note Ξ_c^0/D^0 and Ξ_c^+/D^0 similar to D_s^+/D^0 (but large uncertainties)
- $\Xi_c^{0,+}/\Sigma_c^{0,+,++}$ ratio described by default PYTHIA8 (Monash)! (by Catania as well)
  → similar suppression in e^+e^-? Related to diquark rather than quarks?
  (note mass of spin-1 $(dd,ud,uu)_1$ diquarks might be similar to spin-0 $(us,ds)_0$ diquarks)
  Does this also connect to similarity of baryon-to-meson ratios in HF and LF sector?

- $\Xi_c^{0,+}/\Lambda_c^+$ ratio underestimated by all models

Λ_c^+/D^0 compared with Λ/K_S^0 and p/π^+

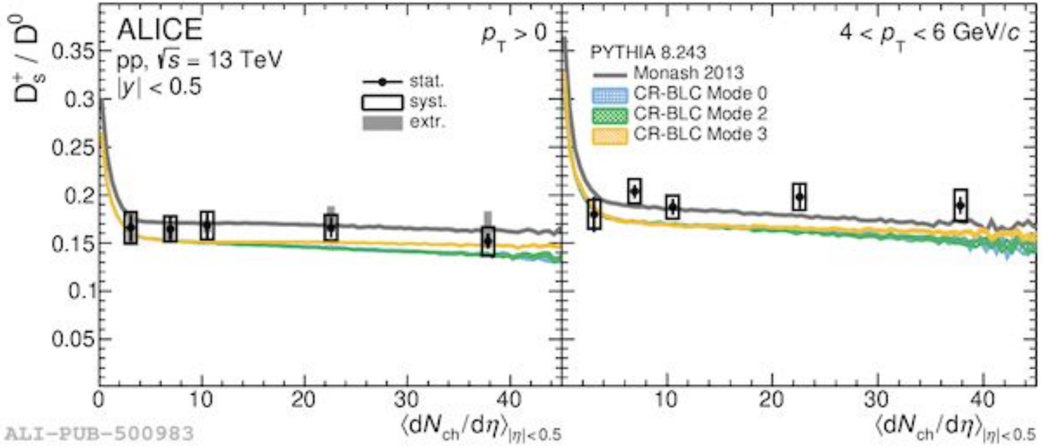
PRC 104 054905 (2021)



PYTHIA8 with CR-BLC better catching both charm and light-flavour baryon-to-meson ratios

Λ_c^+/D^0 and D_s^+/D^0 vs. multiplicity

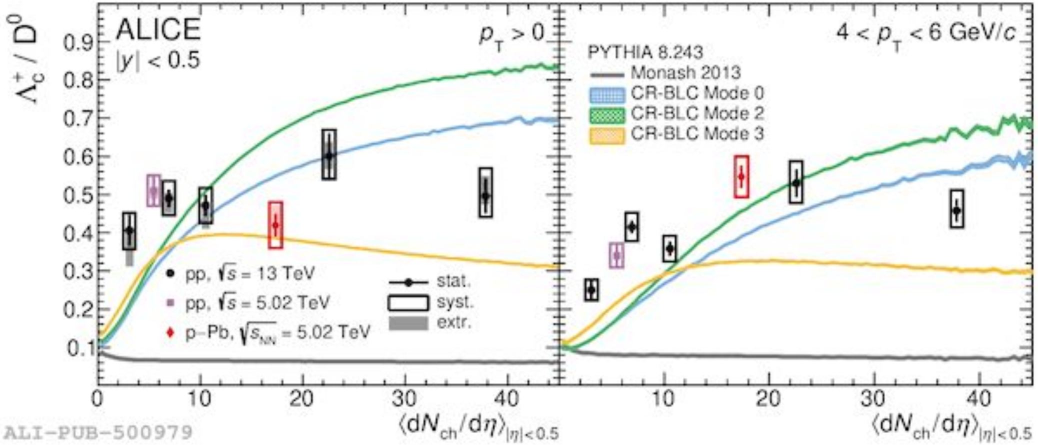
PLB 829 (2022) 137065



Both Λ_c^+/D^0 and D_s^+/D^0 p_T-integrated data do not show a significant dependence with multiplicity

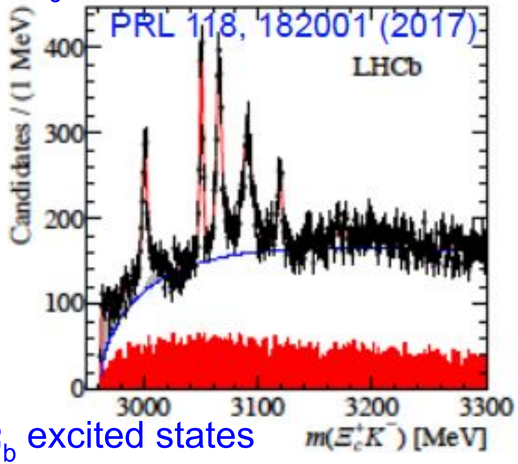
Λ_c^+/D^0 increases with multiplicity at intermediate p_T

Run 3 data needed for precise assessment

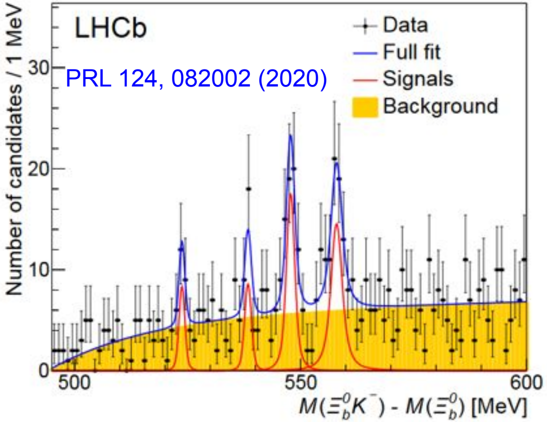


Higher-mass states: new states popping up

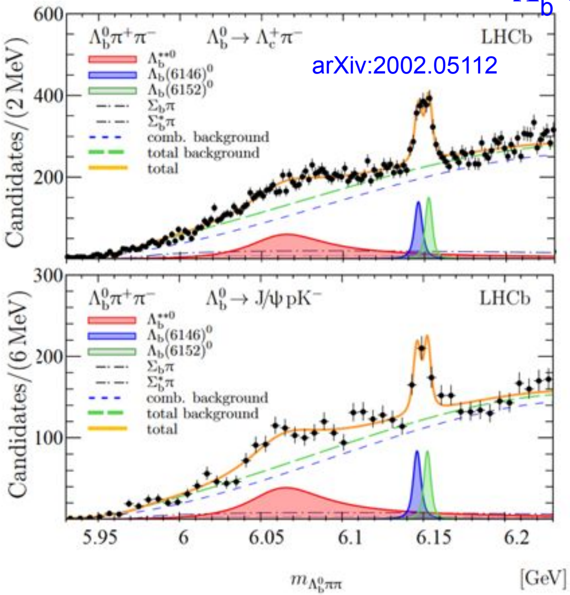
Ω_c excited states

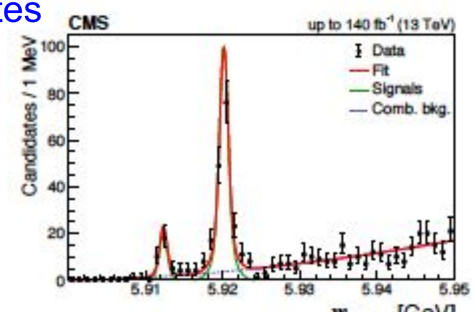


Ω_b excited states

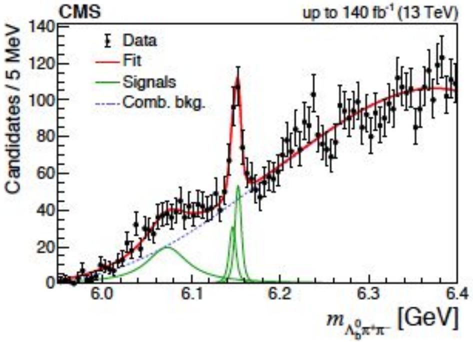


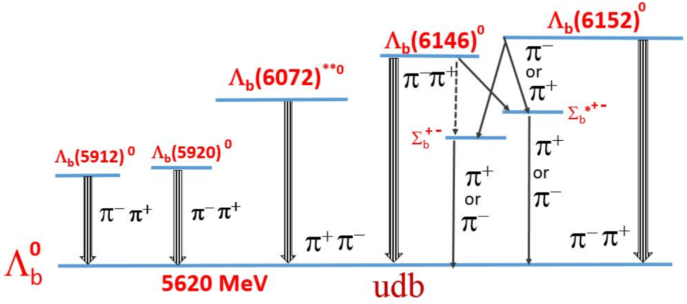
Λ_b excited states





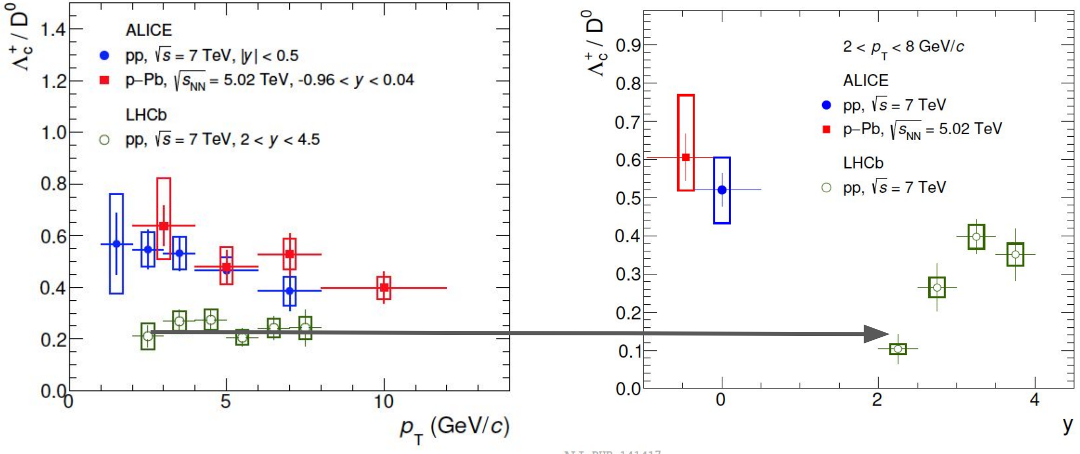
arXiv:2001.06533

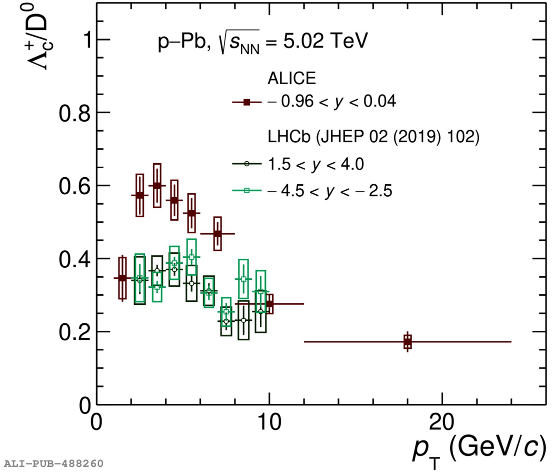


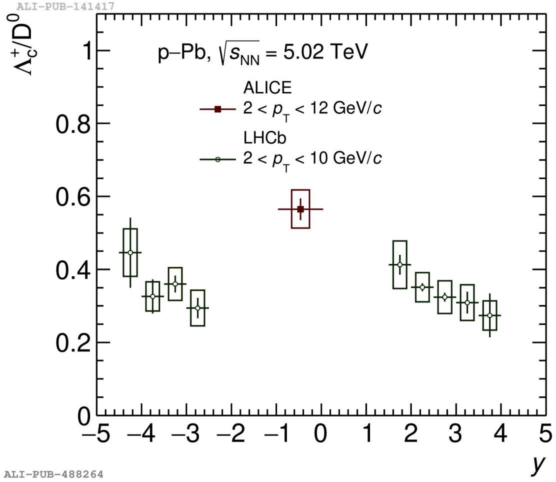


Typically not measurements of cross sections

Λ_c^+/D^0 vs. rapidity in pp and p-Pb







ALICE, JHEP 04 (2018) 108, PRC 104 054905 (2021) ,

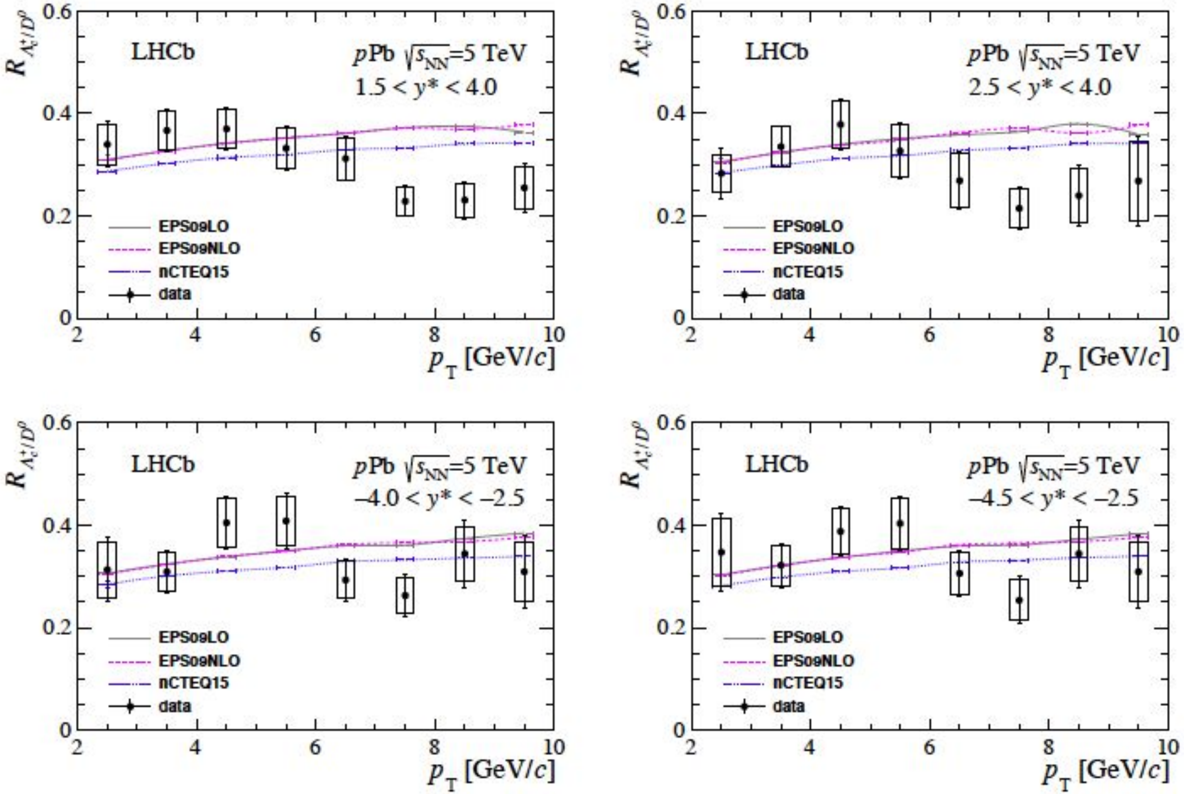
LHCb (pp), Nucl.Phys.B 871 (2013)
LHCb (p-Pb), JHEP 02 102 (2019)

Possible dependence on rapidity, especially in pp collisions

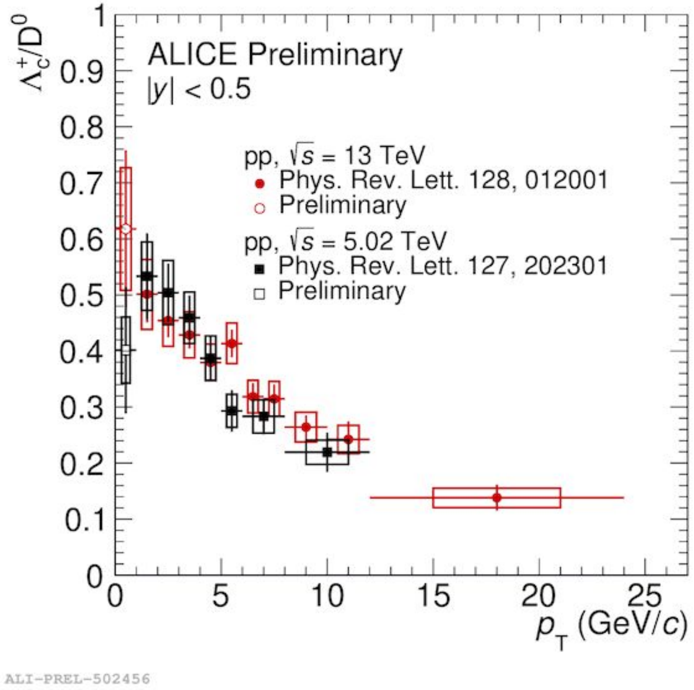
Probably run 3 data needed to clarify

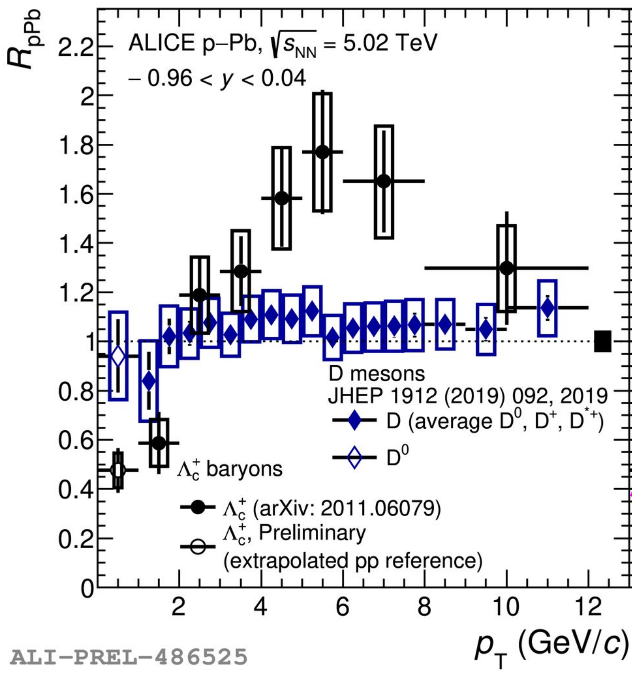
Λ_c^+/D^0 vs. rapidity in p-Pb collisions

JHEP 02 (2019) 102



More on Λ_c^+/D^0 in pp at 5, 13 TeV an in p-Pb collisions

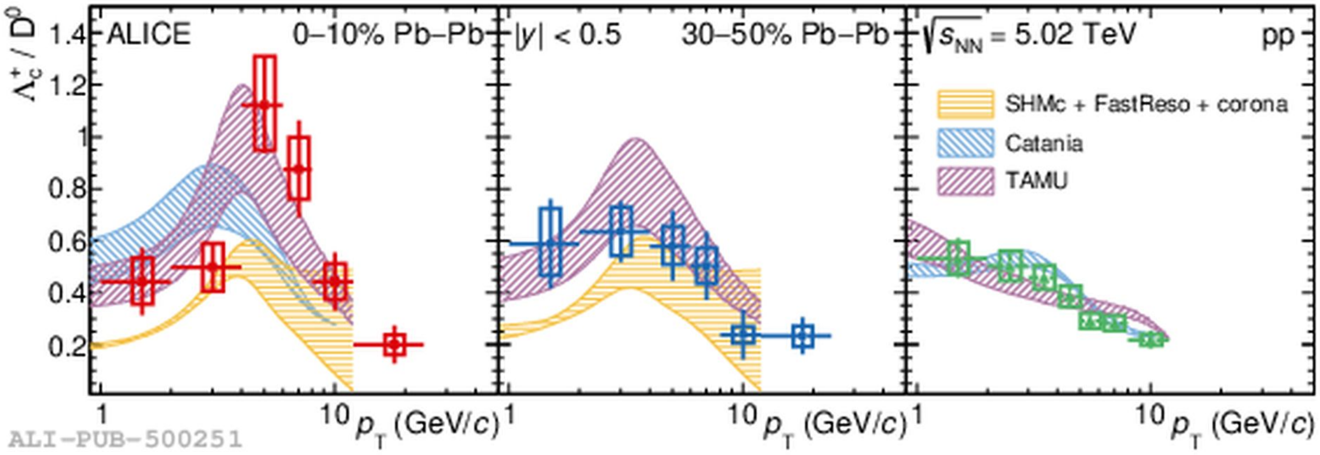




Run 3 data needed to conclude on trend below 1 GeV/*c*

More on Λ_c^+/D^0 in Pb-Pb collisions

arxiv 2112.08156



TAMU (hadronisation via Relativistic Resonant Scattering model) and Catania (sudden coalescence + fragmentation) describe data within uncertainties

SHMc + FastReso + corona tends to underestimate data

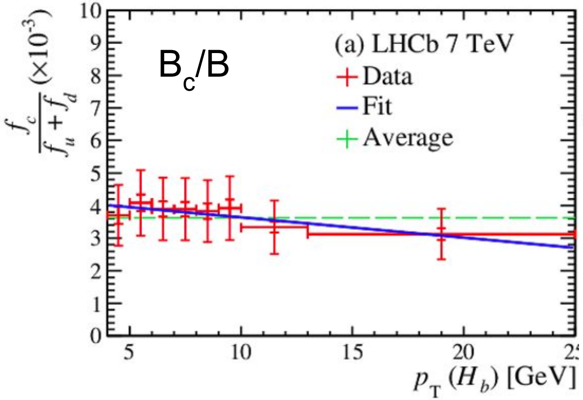
Catania, EPJC 78 4 (2018) 348
TAMU, PRL 124, 4 (2020) 042301
SHM, JHEP 07 035 (2021)

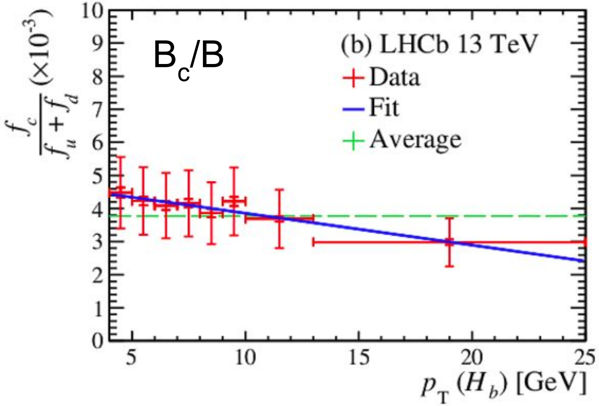
Mass effect or baryon effect?

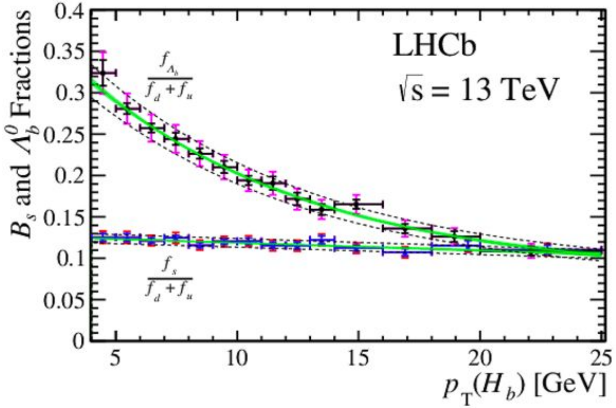
Typically baryons have larger mass
Baryon production requires the production of an antibaryon (→ an antiproton)

Energy cost larger for baryons than meson
→ impact on e^+e^- data?

Not main point: similar Λ_c/D at Z^0 and Υ peaks







B_c mass >> Λ_b mass + requires another charm meson in the event (D mass >> p mass) → even stronger constraints to phase space from B_c than Λ_b

But **B_c/B shows a much milder p_T trend (if any)** → p_T trend not related to particle mass: does this support a baryon-related effect? (caveat: feed-down, comes later)