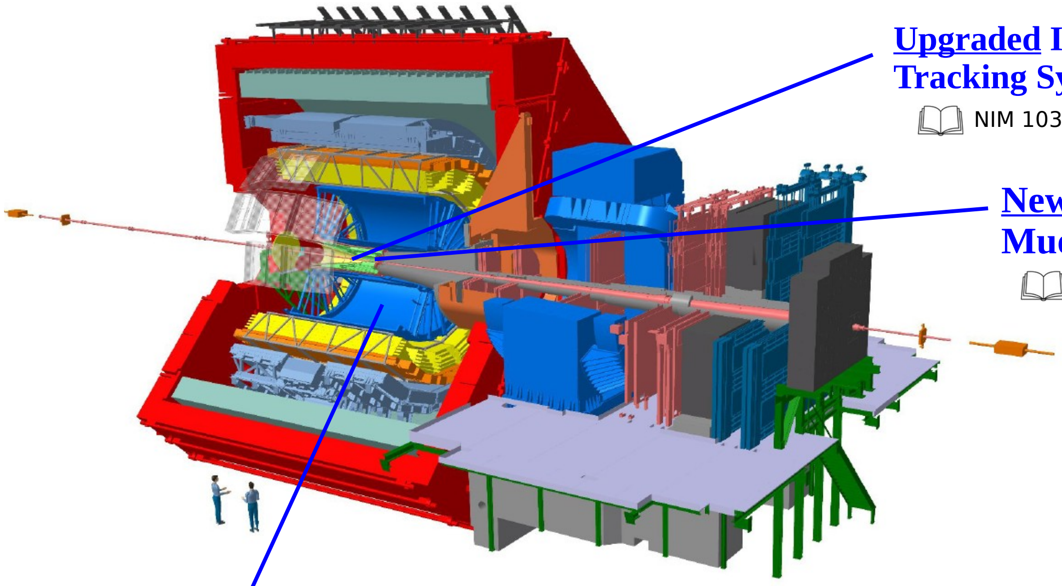
Recent results on heavy flavours and quarkonia from ALICE

Fiorella Fionda, on behalf of the ALICE Collaboration
University & INFN, Cagliari (Italy)

The 21st International Conference on Strangeness in Quark Matter
Strasbourg, France, 3-7 June, 2024

The ALICE detector in Run 3

M. Arslandok
Monday, 10:45

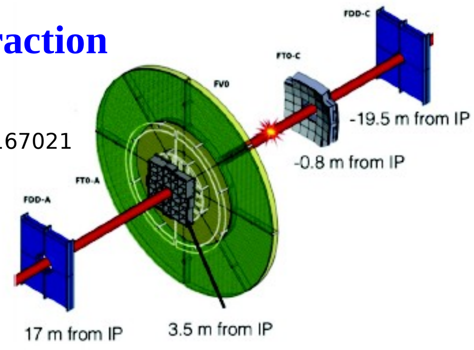


Upgraded Inner Tracking System
NIM 1032(2022)166632

New Forward Muon Tracker
CDS link

Upgraded Time Projection Chamber
JINST 16 P03022 (2021)

New Fast Interaction Trigger
NIM 1039 (2022) 167021



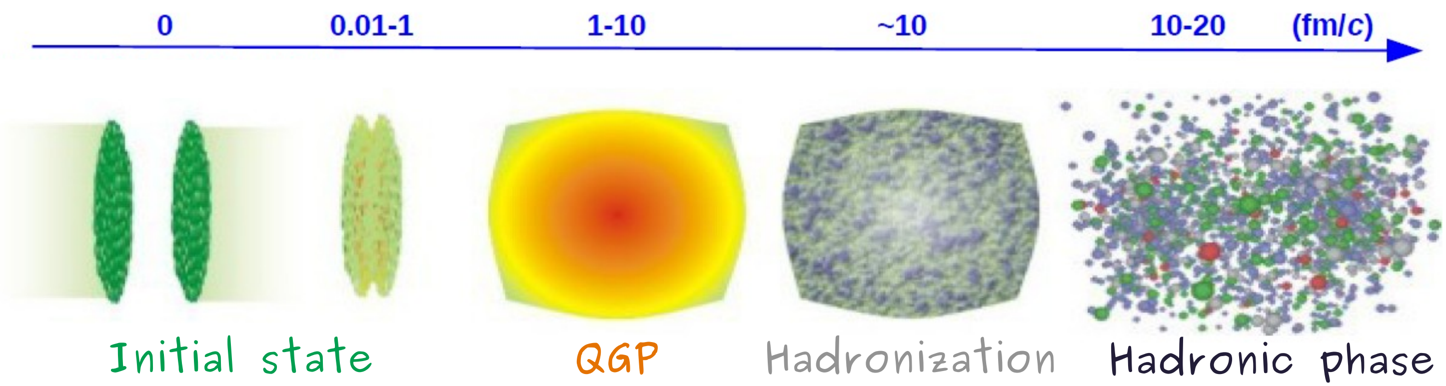
- ✔ Major upgrade of the ALICE detector in 2019-2021 JINST 19 P05062 (2024) RECENTLY PUBLISHED!
- ✔ **Continuous readout** (up to 500 kHz in pp and 50kHz in Pb-Pb) CERN-LHCC-2020-018
  - Selection of interesting physics events using high-level offline trigger selections
- ✔ **Improved pointing resolution at midrapidity** by a factor of 3 (6) in the transverse plane (beam-line direction) compared to Run 2
- ✔ **Secondary vertex reconstruction enabled at forward rapidity** for muons

The importance of heavy quarks

- In heavy-ion collisions: excellent probes to characterize precisely **initial state**, **QGP properties** and **hadronization mechanisms in medium**

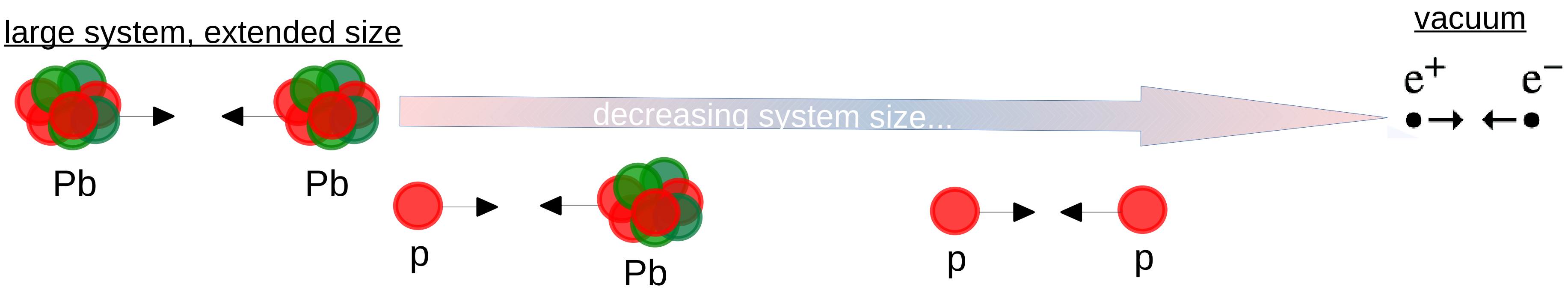
Heavy quarks

- Produced in hard partonic collisions ($\tau_{HQ} \simeq 0.05\text{-}0.1$ fm/c)
- Sensitive to the initial state
- Interaction with medium: energy loss, diffusion and thermalization



The importance of heavy quarks

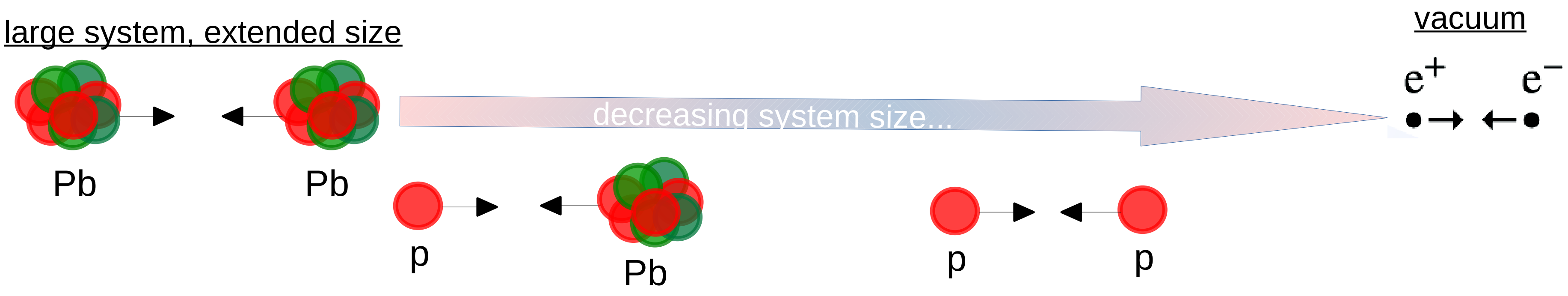
- In heavy-ion collisions: excellent probes to characterize precisely **initial state**, **QGP properties** and **hadronization mechanisms in medium**
- In small systems (pp & p–Pb)



- **Reference** for heavy-ion studies
- **Test / constrain** QCD-based models
- Insight into **multiparton interactions**
- **Collectivity** in small systems

The importance of heavy quarks

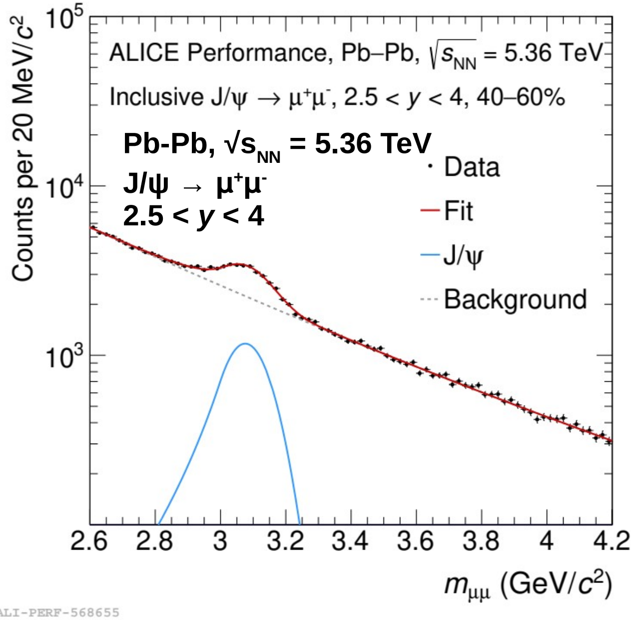
- ✔ In heavy-ion collisions: excellent probes to characterize precisely **initial state**, **QGP properties** and **hadronization mechanisms in medium**
- ✔ In small systems (pp & p–Pb)

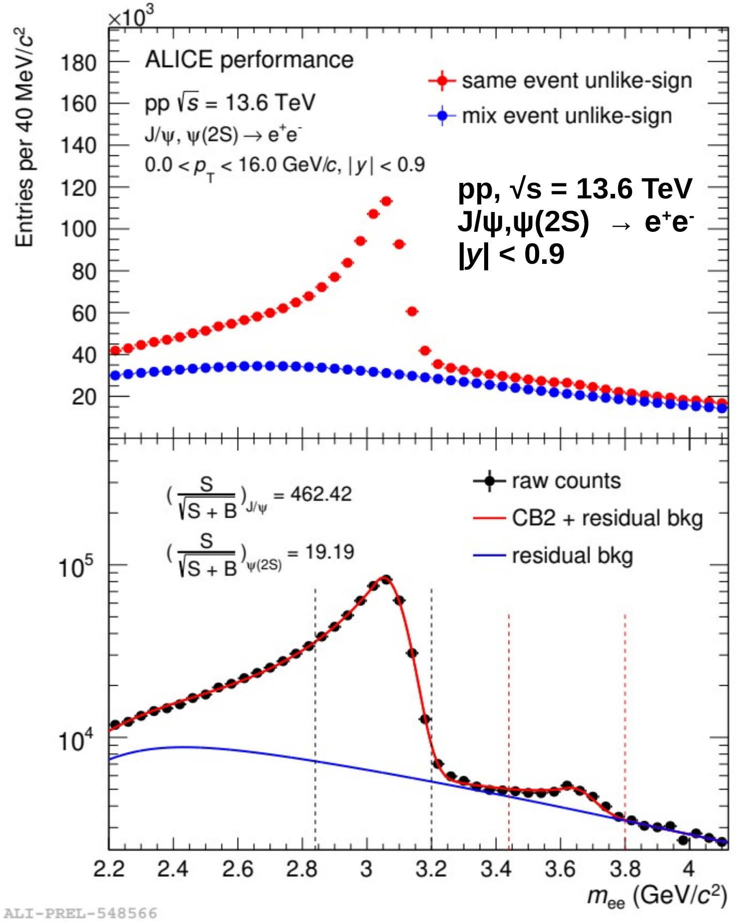


- ✔ **Reference** for heavy-ion studies
- ✔ **Test / constrain** QCD-based models
- ✔ Insight into **multiparton interactions**
- ✔ **Collectivity** in small systems

In this talk: highlights on fresh results from Run 3 and Run 2 !

Open heavy-flavour and quarkonia in ALICE

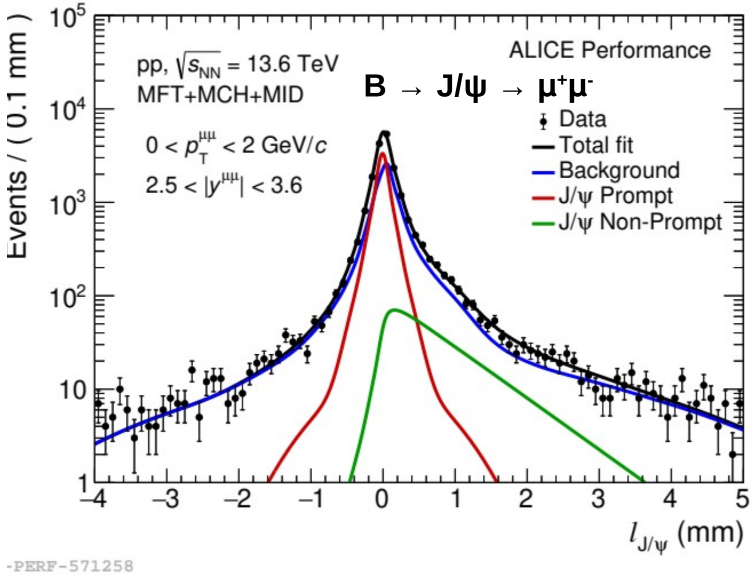




Quarkonia $\begin{cases} \Upsilon(\mathrm{nS}), \psi(\mathrm{nS}) \rightarrow \mu^+\mu^- \\ \psi(\mathrm{nS}) \rightarrow e^+e^- \end{cases}$

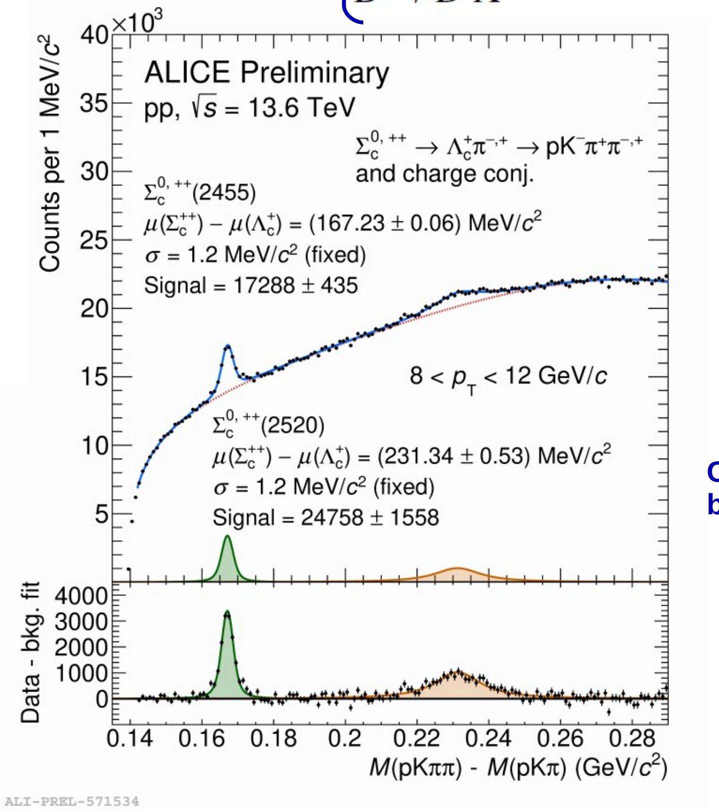
- ✔ Quarkonia reconstructed at mid and forward rapidity down to zero transverse momentum

Open heavy-flavour and quarkonia in ALICE



Open beauty

$$\begin{cases} B \to e(\mu)X \\ B \to J/\psi(\to e^+e^-)X \\ B \to J/\psi(\to \mu^+\mu^-)X \\ B \to D\,X \end{cases}$$



Open charm mesons

$$\begin{cases} D^0 \to K^-\pi^+ \\ D^+ \to K^-\pi^+\pi^+ \\ D^+ \to \phi\pi^+ \to K^-K^+\pi^+ \\ D^{*+} \to D^0\pi^+ \\ D_s^+ \to \phi\pi^+ \to K^-K^+\pi^+ \\ D \to e(\mu)X \\ D_{s1}^+ \to D^{*+}K_s^0 \\ D_{s2}^{*+} \to D^+K_s^0 \end{cases}$$

Charm baryons

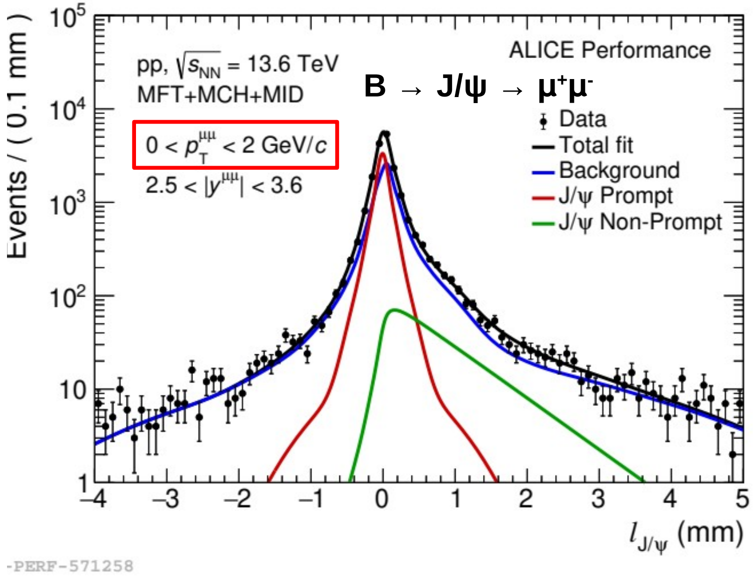
$$\begin{cases} \Lambda_c^+ \to pK_s^0 \\ \Lambda_c^+ \to pK^-\pi^+ \\ \Lambda_c^+ \to \Lambda e^+\nu_e \\ \Sigma_c^{0,++}(2455) \to \Lambda_c^+\pi^{-,+} \\ \Sigma_c^{0,++}(2520) \to \Lambda_c^+\pi^{-,+} \\ \Xi_c^0 \to \Xi^-e^+\nu_e \\ \Xi_c^0 \to \Xi^-\pi^+ \\ \Xi_c^+ \to \Xi^-\pi^+\pi^+ \\ \Omega_c^0 \to \Omega^-\pi^+ \\ \Omega_c^0 \to \Omega^-e^+\nu_e \end{cases}$$

Quarkonia

$$\begin{cases} \Upsilon(nS), \psi(nS) \to \mu^+\mu^- \\ \psi(nS) \to e^+e^- \end{cases}$$

- ✔ Quarkonia reconstructed at mid and forward rapidity down to zero transverse momentum
- ✔ Open heavy flavour hadrons reconstructed via exclusive / inclusive decay modes in wide momentum and rapidity windows !

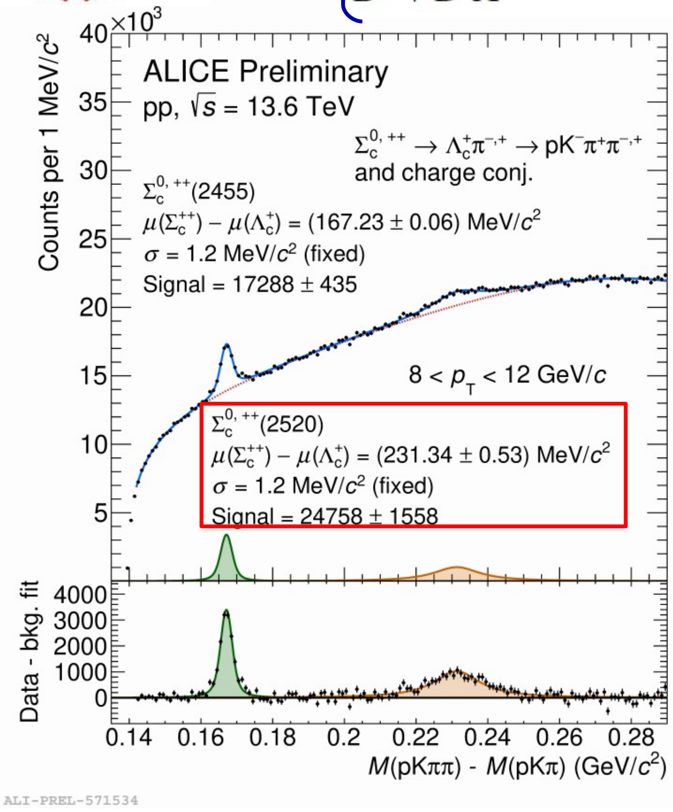
Open heavy-flavour and quarkonia in ALICE



FIRST TIME IN RUN 3!

Open beauty

$$\begin{cases} B \to e(\mu)X \\ B \to J/\psi(\to e^+e^-)X \\ B \to J/\psi(\to \mu^+\mu^-)X \\ B \to D\,X \end{cases}$$



Open charm mesons

$$\begin{cases} D^0 \to K^-\pi^+ \\ D^+ \to K^-\pi^+\pi^+ \\ D^+ \to \phi\pi^+ \to K^-K^+\pi^+ \\ D^{*+} \to D^0\pi^+ \\ D_s^+ \to \phi\pi^+ \to K^-K^+\pi^+ \\ D \to e(\mu)X \\ D_{s1}^+ \to D^{*+}K_s^0 \\ D_{s2}^{*+} \to D^+K_s^0 \end{cases}$$

Charm baryons

$$\begin{cases} \Lambda_c^+ \to pK_s^0 \\ \Lambda_c^+ \to pK^-\pi^+ \\ \Lambda_c^+ \to \Lambda e^+\nu_e \\ \Sigma_c^{0,++}(2455) \to \Lambda_c^+\pi^{-,+} \\ \Sigma_c^{0,++}(2520) \to \Lambda_c^+\pi^{-,+} \\ \Xi_c^0 \to \Xi^- e^+\nu_e \\ \Xi_c^0 \to \Xi^-\pi^+ \\ \Xi_c^+ \to \Xi^-\pi^+\pi^+ \\ \Omega_c^0 \to \Omega^-\pi^+ \\ \Omega_c^0 \to \Omega^- e^+\nu_e \end{cases}$$

Quarkonia

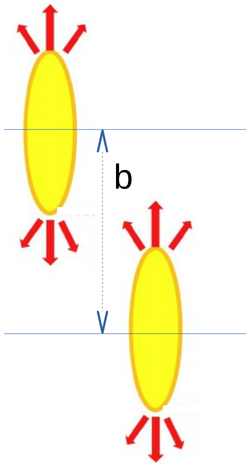
$$\begin{cases} \Upsilon(nS), \psi(nS) \to \mu^+\mu^- \\ \psi(nS) \to e^+e^- \end{cases}$$

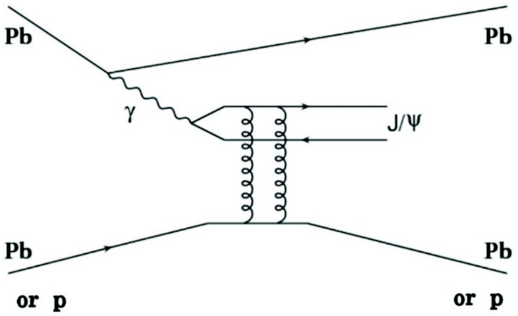
- ✔ Quarkonia reconstructed at mid and forward rapidity down to zero transverse momentum
- ✔ Open heavy flavour hadrons reconstructed via exclusive / inclusive decay modes in wide momentum and rapidity windows !

Highlights from Pb–Pb collisions

J/ψ photoproduction in peripheral Pb–Pb collisions

Ultra-peripheral Collisions (**UPC**) [***b*** **> 2R**]

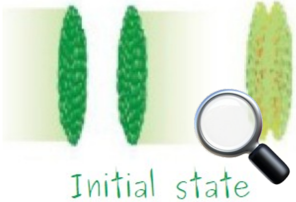


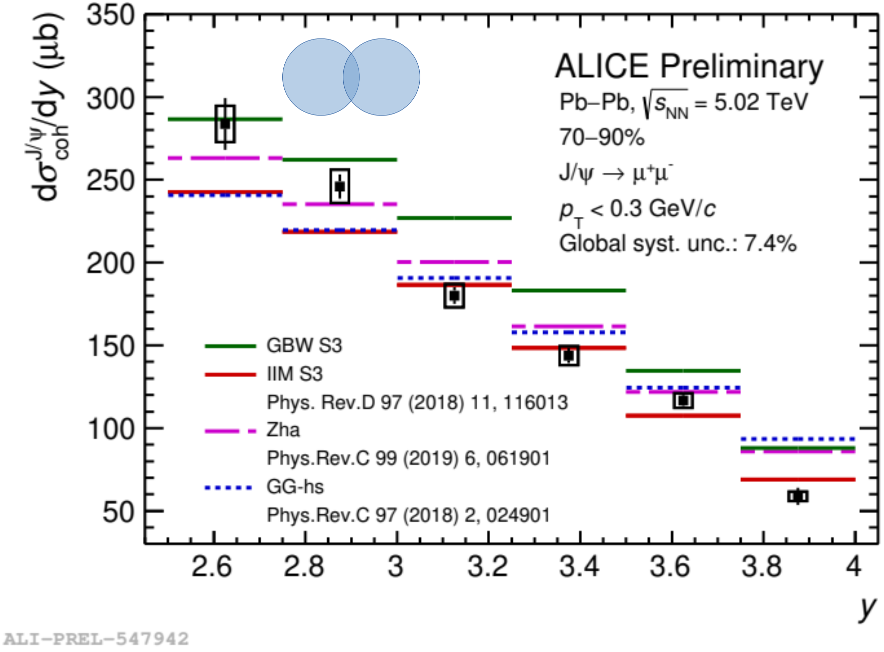


Coherent → $\langle p_T \rangle \sim 60$ MeV/c

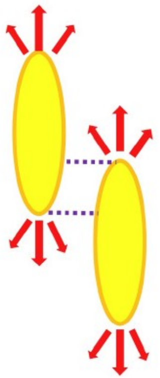
Incoherent → $\langle p_T \rangle \sim 500$ MeV/c

J/ψ photoproduction in peripheral Pb–Pb collisions

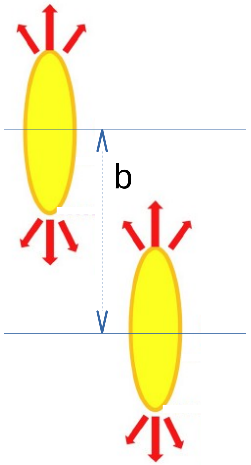


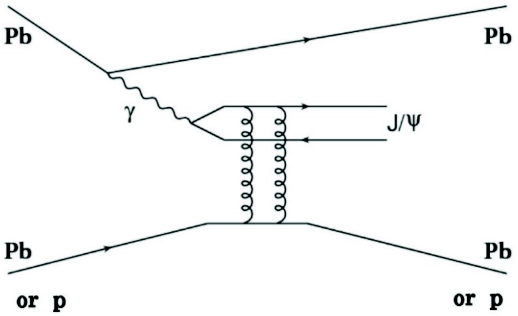


Peripheral collisions (PC) [*b* < 2R]



Ultra-peripheral Collisions (UPC) [*b* > 2R]





Coherent → $\langle p_T \rangle$ ~ 60 MeV/*c*
Incoherent → $\langle p_T \rangle$ ~ 500 MeV/*c*

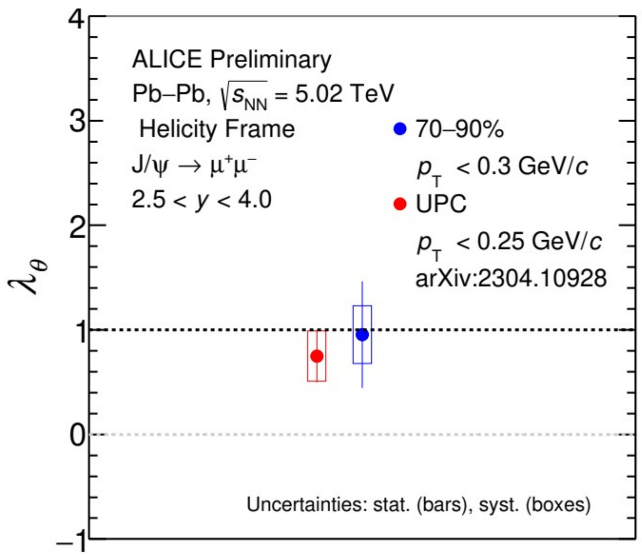
- ✔ **Strong *y*-dependence** observed for J/ψ photoproduction cross section
- ✔ Models based on vector meson photoproduction in UPC and modified for PC can **describe qualitatively but not quantitatively** the *y*-dependence

D. Mallik
Wednesday, 10:40

H. Sharma
Wednesday, 09:50

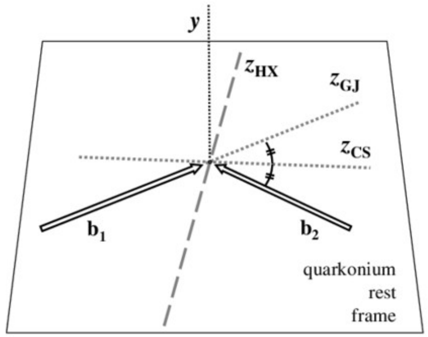
J/ψ photoproduction in peripheral Pb–Pb collisions

Initial state



ALI-PREL-546778

$$W(\theta) \propto \frac{1}{3+\lambda_\theta}\left(1+\lambda_\theta \cos^2\theta\right)$$



- ✔ **Strong *y*-dependence** observed for J/ψ photoproduction cross section
- ✔ Models based on vector meson photoproduction in UPC and modified for PC can **describe qualitatively but not quantitatively** the *y*-dependence
- ✔ **Transverse polarization** measured for inclusive J/ψ for p_{T} < 0.3 GeV/*c*, compatible with results in UPC

D. Mallik
Wednesday, 10:40

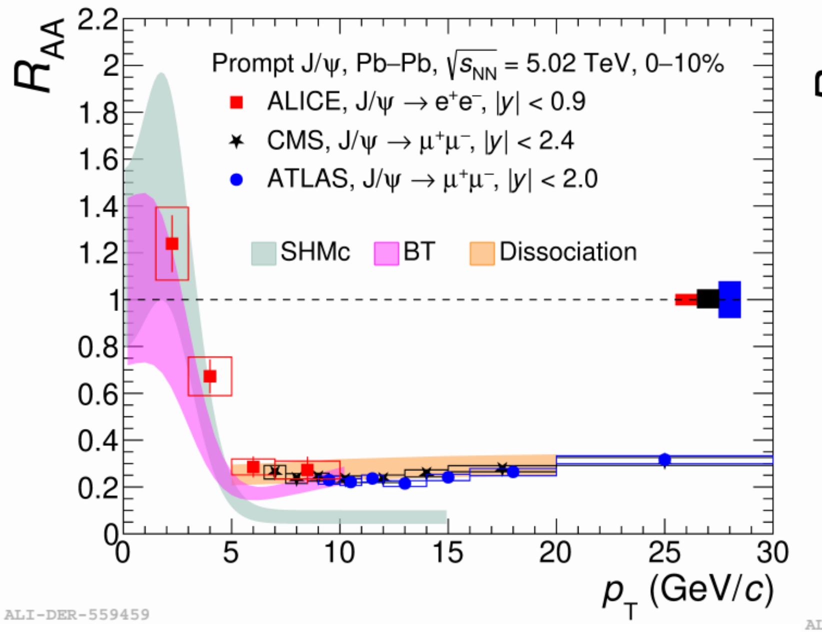
H. Sharma
Wednesday, 09:50

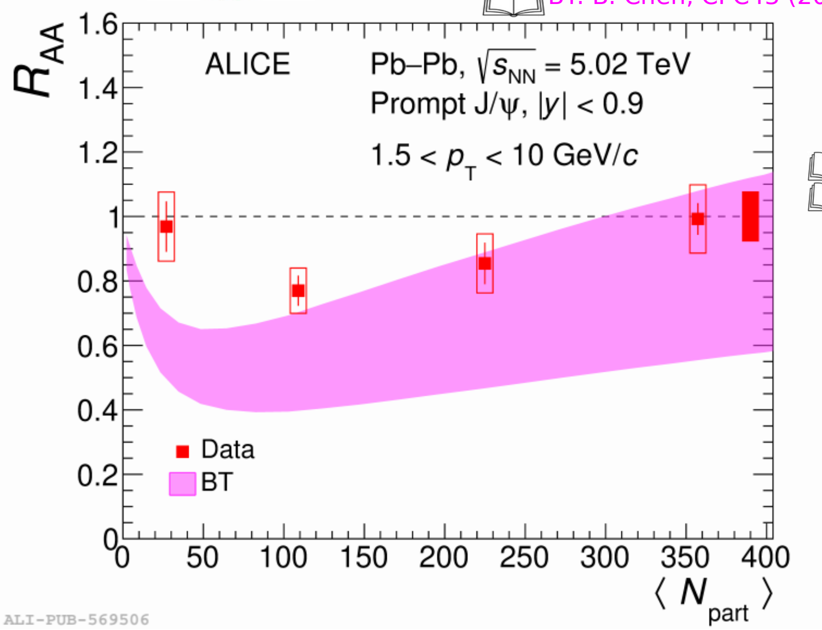
Prompt J/ψ R_{AA} in Pb–Pb collisions

JHEP 02 (2024) 066

RECENTLY PUBLISHED!

Dissociation: Vitev et al., PLB 778 (2018) 384-391
SHMc: Andronic et al., PLB 797 (2019) 134836
BT: B. Chen, CPC43 (2019) 124101





ATLAS, Eur. Phys. J. C 78 (2018) 762
CMS, Eur. Phys. J. C 78 (2018) 509

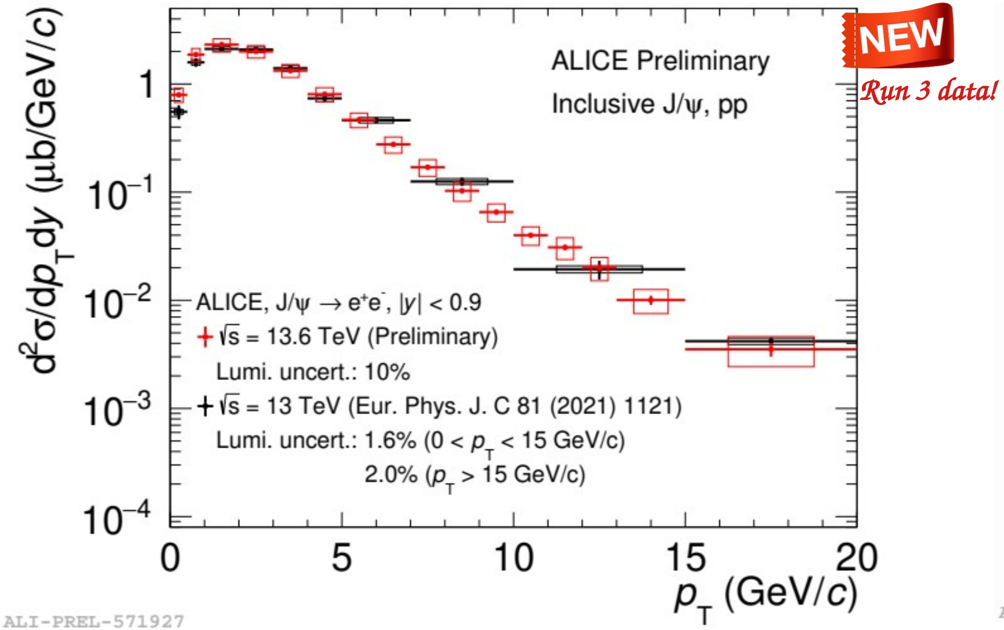
$$R_{AA} = \frac{1}{N_{coll}} \times \frac{(dN/dy)_{AA}}{(dN/dy)_{pp}}$$

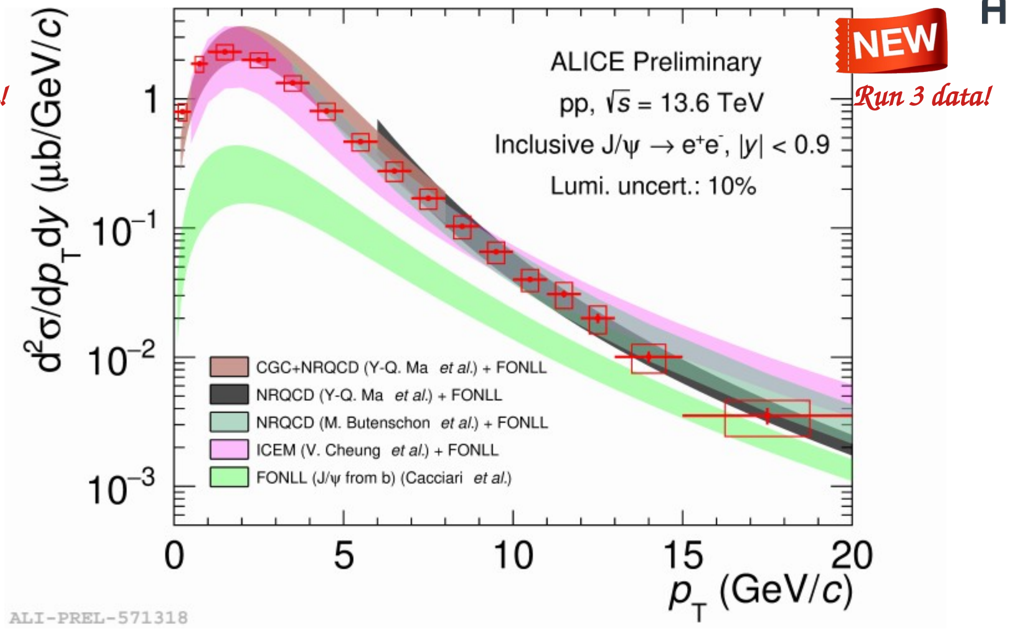
M. Coquet
Tuesday, 15:00

- ✔ p_T-differential results **compatible with** corresponding measurements from **ATLAS ad CMS** in the overlapping p_T region
- ✔ Models including **regeneration** can describe the **rising trend** towards low p_T and with increasing centrality

Highlights from pp & p–Pb collisions

Charmonia in pp collisions at √s = 13.6 TeV



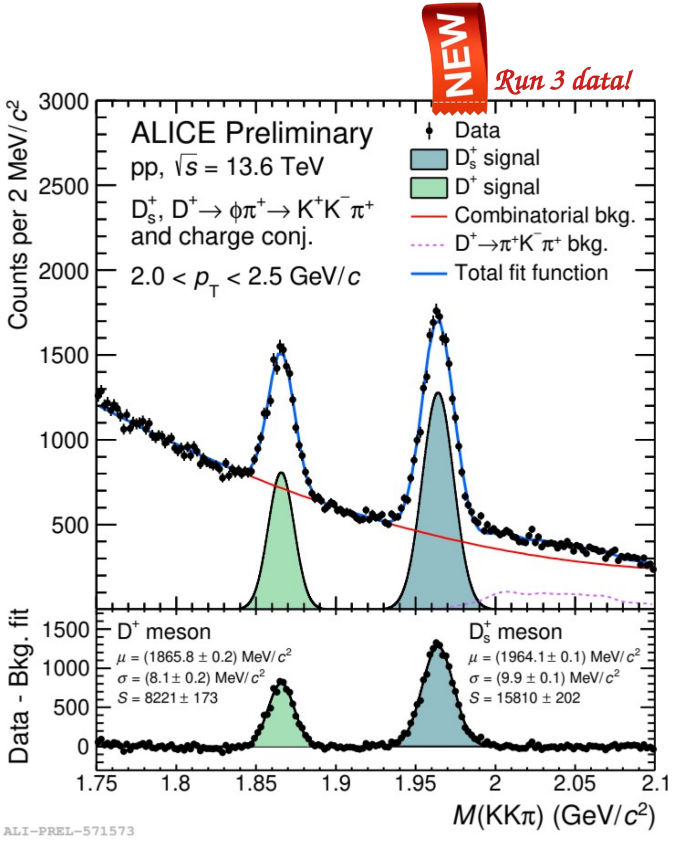


- ✔ First J/ψ cross section measurement in pp at √s = 13.6 TeV !
  - **Good agreement with corresponding Run 2 results**
  - **High granularity** thanks to the available Run 3 statistics
  - **Well described by ICEM and NRQCD based models** coupled with FONLL to account for the non-prompt J/ψ contribution

NRQCD (Ma et al): PRL 106 (2011) 042002
NRQCD+CGC (Ma et al): PRL 113 19, (2014) 192301
NRQCD (Butenshon et al): PRL 106 (2011) 022003
ICEM (Cheung, Vogt): PRD 98 11, (2018) 114029
FONLL (Cacciari et al): JHEP 05 (1998) 007

Prompt D^+_s/D^+ in pp collisions at $\sqrt{s}$ = 13.6 TeV

M. Faggin
Tuesday, 11:00

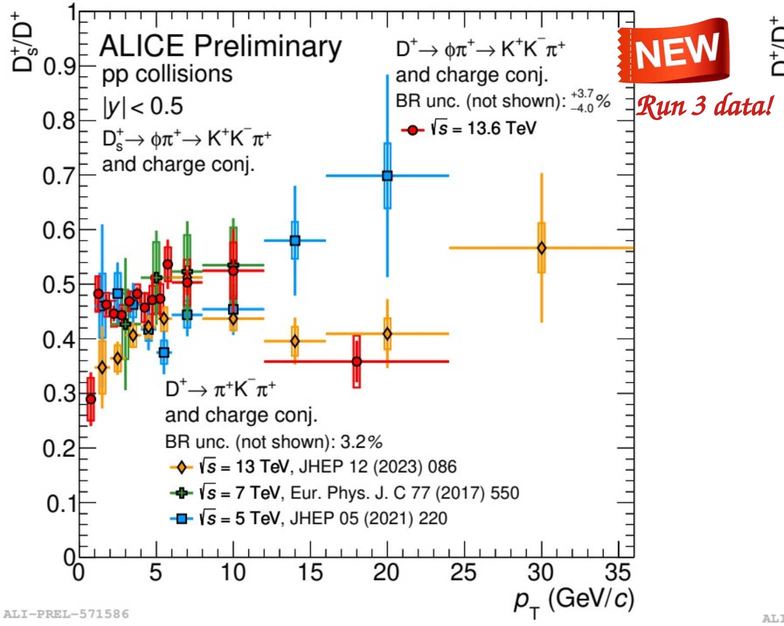


Prompt D^+_s/D^+ in pp collisions at $\sqrt{s}$ = 13.6 TeV

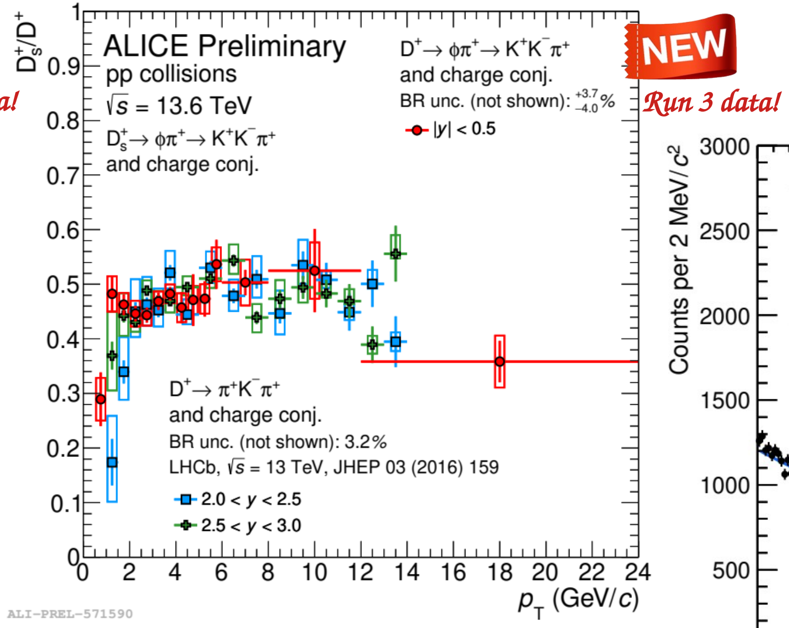
M. Faggin
Tuesday, 11:00

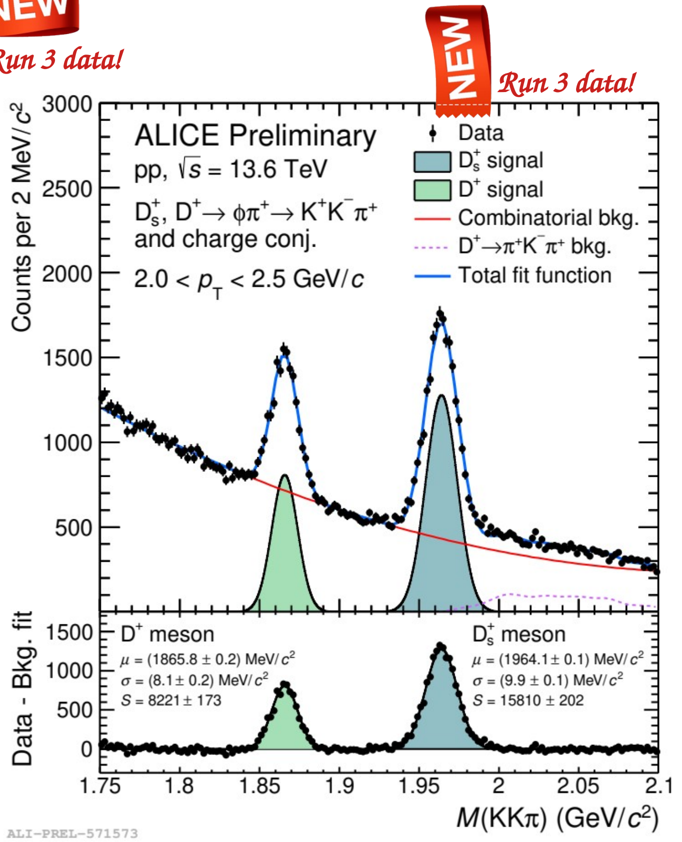
ALICE

Energy dependence



Rapidity dependence

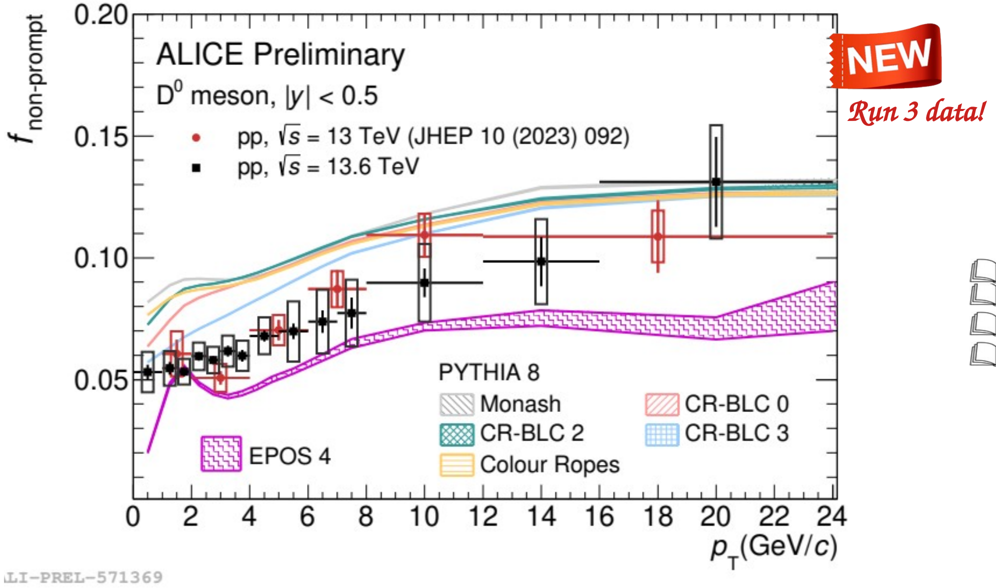




- ✔ New Run 3 measurements of **D^+_s/D^+ ratio at midrapidity** !
  - **High granular results** thanks to the significantly increased statistics
  - **Extended down to p_T = 0.5 GeV/c**
  - **Compatible with lower energy results** within uncertainties
- ✔ Comparison with LHCb results suggests **no rapidity dependence**

Non-prompt D^0 fraction in pp at 13.6 TeV

M. Zhang
Wednesday, 11:00



PYTHIA 8 (Monash): Skands et al, Eur. Phys. J. C 74 (2014)
PYTHIA 8 (CR-BLC): Christiansen and Skands, JHEP 08 (2015) 003
PYTHIA 8 (Col. Ropes): Bierlich et al., arXiv:2203.11601
EPOS4: Werner, arXiv:2301.12517

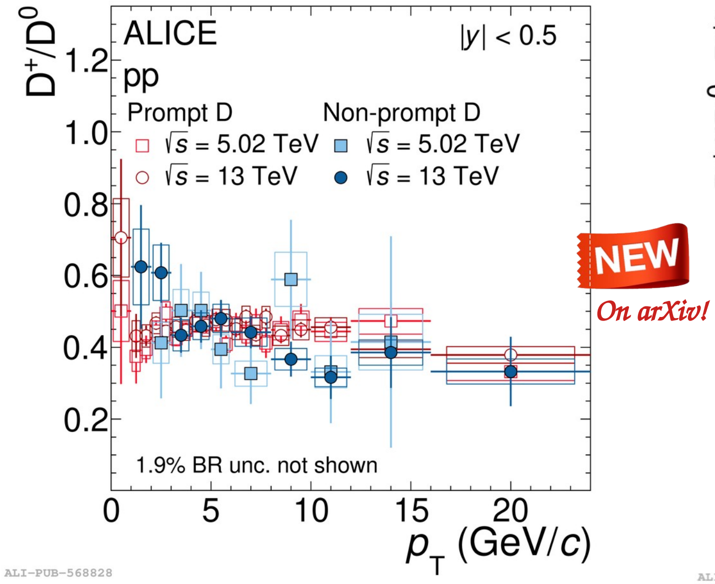
- **Non-prompt D^0 fraction** measured at **midrapidity** in pp at 13.6 TeV
  - **Compatible with results at lower energy** within uncertainties
  - Significantly **improved granularity** compared to Run 2, and measurement extended down p_T = 0
- Models either **underestimate (EPOS4)** or **overestimate (PYTHIA 8)** results → inputs for theoretical models

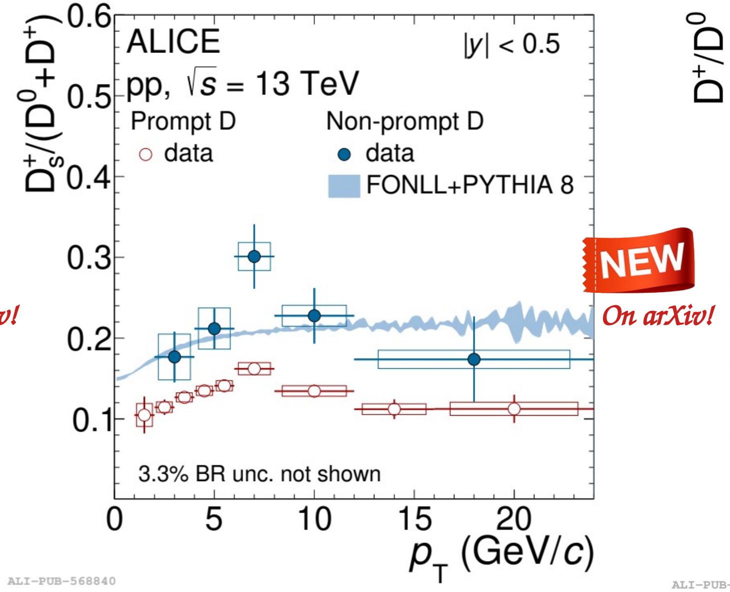
Prompt and non-prompt D meson ratios in pp collisions

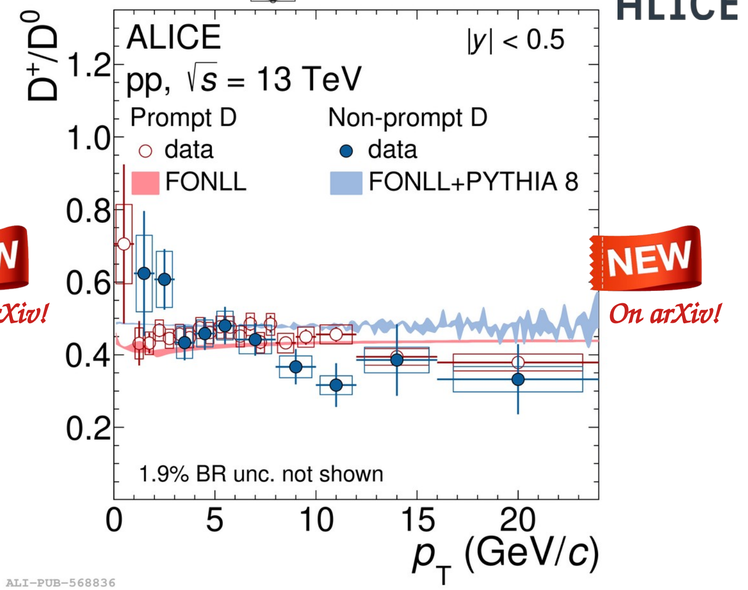
M. Faggin
Tuesday, 11:00

arXiv:2402.16417

ALICE







- **No energy dependence** observed within current uncertainties **for both prompt and non-prompt D meson ratios at midrapidity**
- **No strong p_T dependence** for measured particle ratios
- **Described by models** based on factorization approach, **employing fragmentation fractions from e^+e^-**

FONLL: Cacciari et al., JHEP 05 (1998) 007
PYTHIA 8: Skands et al., Eur. Phys. J. C 74 (2014)

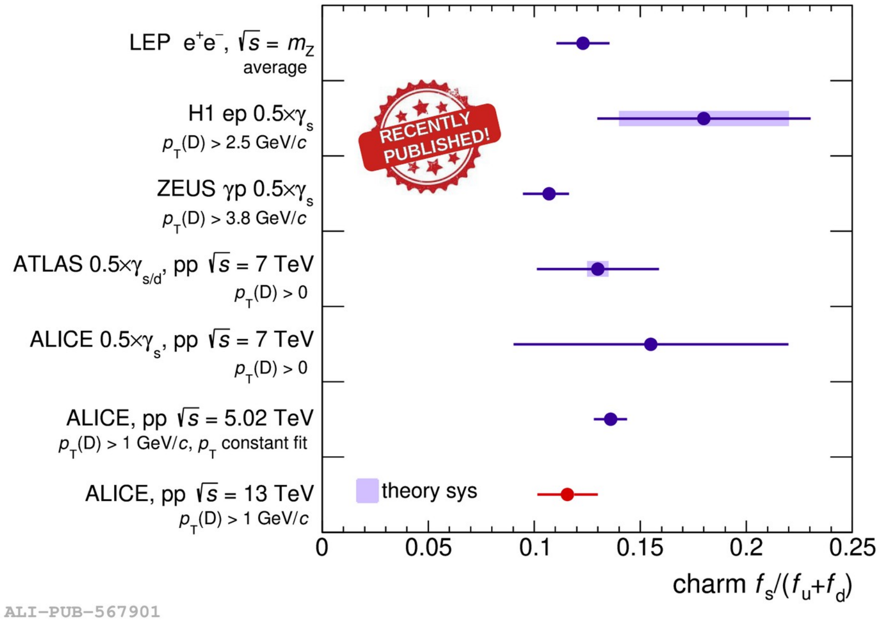
Charm and beauty strange fragmentation fractions

M. Faggin
Tuesday, 11:00

ALICE

Charm-strange FF

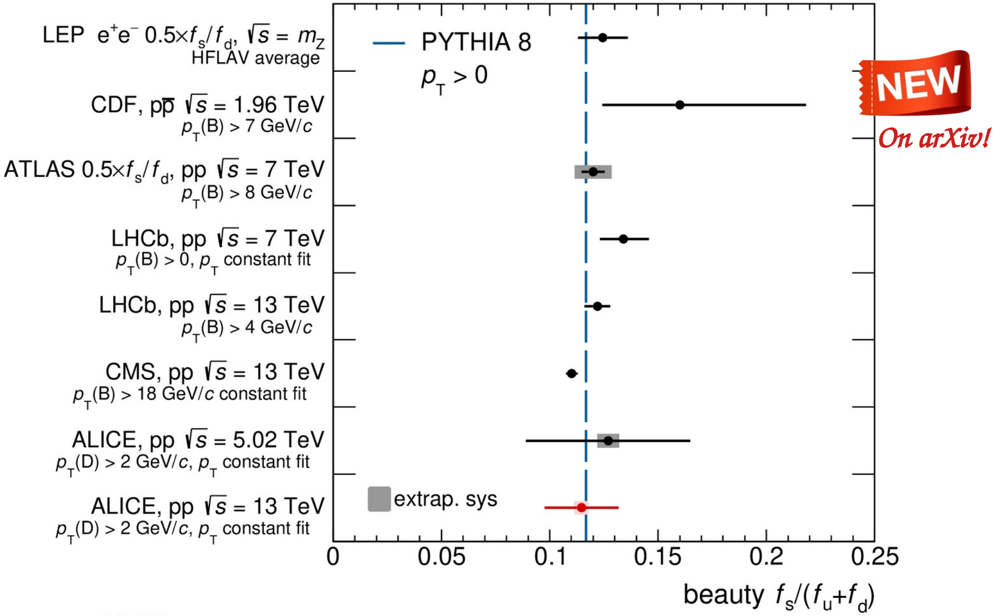
JHEP 12 (2023) 086



ALI-PUB-567901

Beauty-strange FF

arXiv:2402.16417



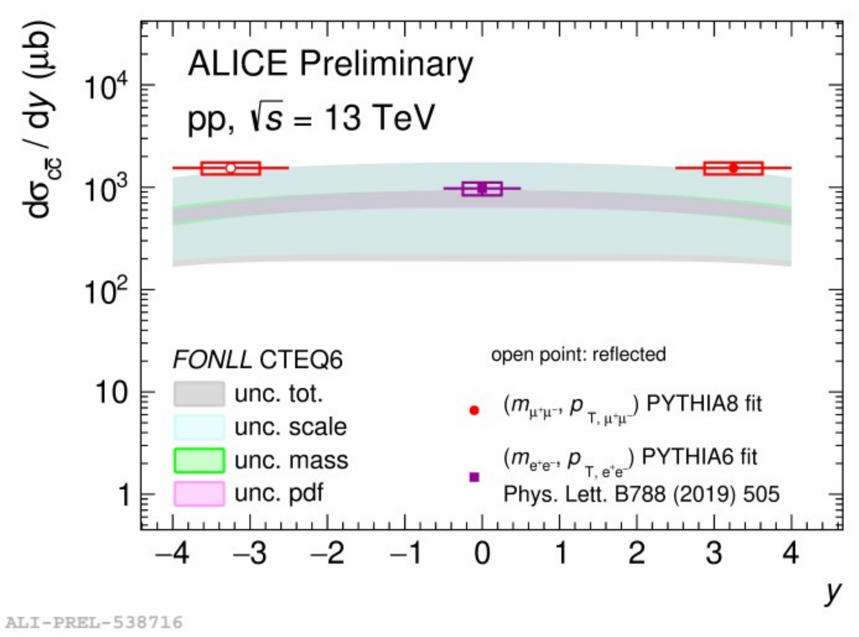
ALI-PUB-568844

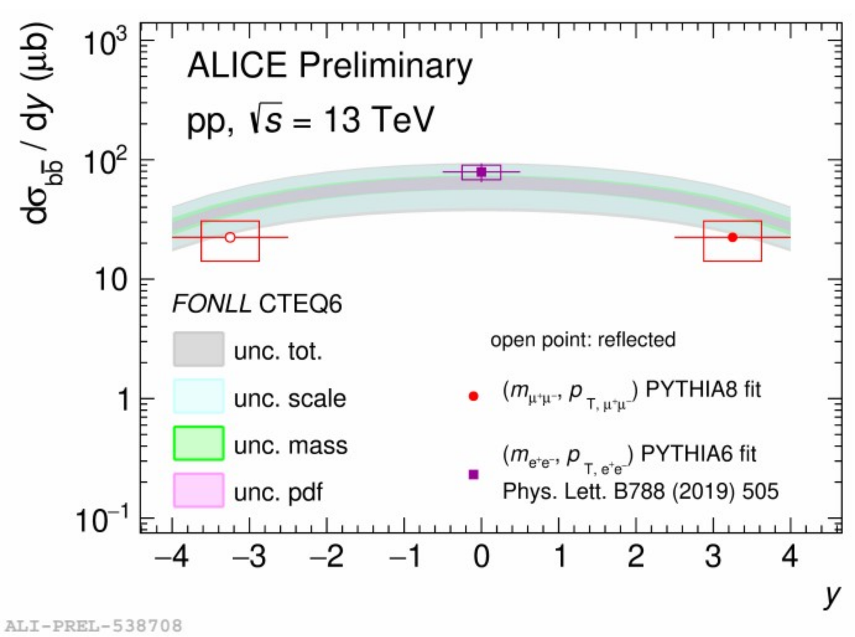
- ✔ **No** significant **energy dependence**
- ✔ **Similar values** found in **charm and beauty** sectors
- ✔ Results at the LHC **compatible** with those in other collision systems

Open heavy-flavour via high-mass dimuons in pp at √s = 13 TeV

M. Zhang
Wednesday, 11:00

ALICE





- ✔ Charm and beauty quark pair production cross sections extrapolated from **high-mass ($m_{\mu\mu}$ > 4 GeV/c^2) continuum dimuons** at **forward rapidity**
  - Simultaneous unbinned fit to $p_T^{\mu\mu}$ and $m_{\mu\mu}$ distributions from data via a cocktail of templates (estimated from PYTHIA 8) to account for the different signal and background sources
- ✔ Results **in agreement within uncertainties with FONLL**, although they lie at the upper (lower) edge of the uncertainty band for charm (beauty) cross section

FONLL: Cacciari et al., JHEP 05 (1998) 007

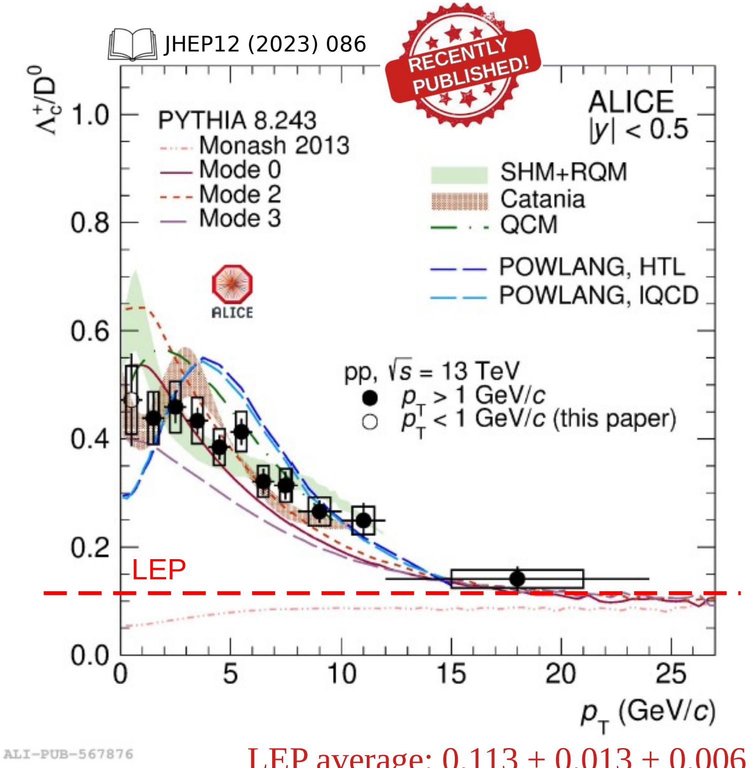
Baryon enhancement at the LHC

J. Cho
Tuesday, 09:30

ALICE

✔ Larger Λ^+_c/D^0 observed by ALICE compared to $e^+e^- \rightarrow$ **baryon enhancement** observed at the LHC !

- Models implementing several mechanisms (color reconnection, feed-down from unobserved resonant charm baryon states, quark coalescence, small expanding fireball) are able to reproduce the trend within uncertainties



LEP average: 0.113 ± 0.013 ± 0.006
[EPJC 75 (2015) 19]

PYTHIA 8 (Monash): Skands et al, Eur. Phys. J. C 74 (2014)
PYTHIA 8: Christiansen and Skands, JHEP 08 (2015) 003
SHM+RQM: He et al., PLB 795 (2019) 117-121
Catania: Greco et al., PLB 821, 136622
QCM: Song et al., EPJC (2018) 78: 344
POWLANG: Beraudo et al., arXiv:2306.02152

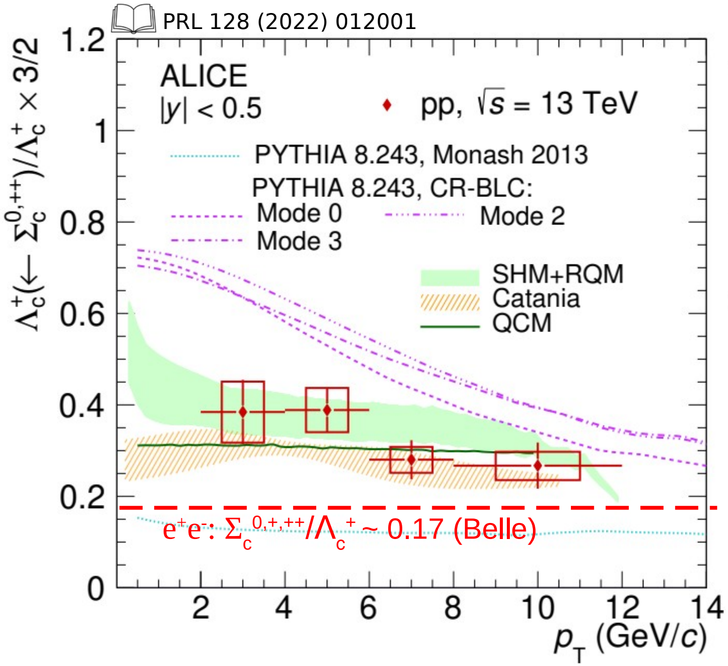
Baryon enhancement at the LHC

J. Cho
Tuesday, 09:30

- ✔ Larger Λ^+_c/D^0 observed by ALICE compared to $e^+e^- \rightarrow$ **baryon enhancement** observed at the LHC !
  - Models implementing several mechanisms (color reconnection, feed-down from unobserved resonant charm baryon states, quark coalescence, small expanding fireball) are able to reproduce the trend within uncertainties

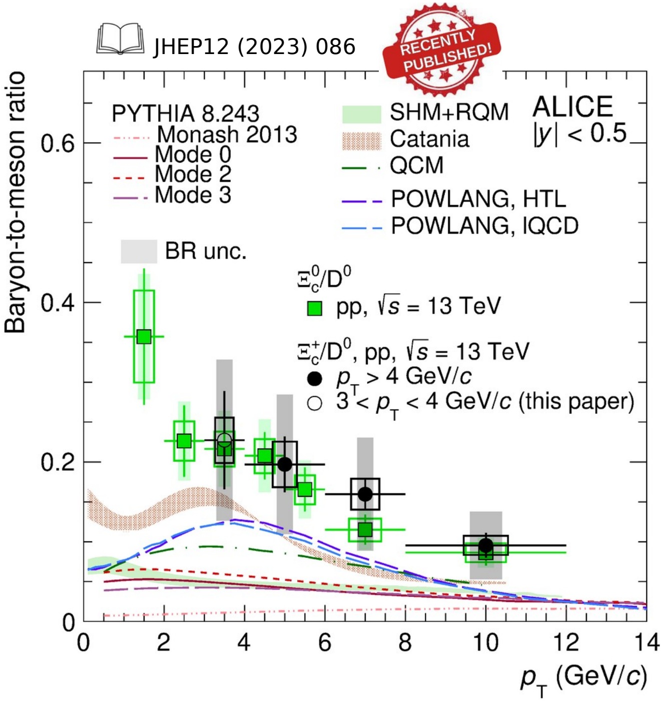
- ✔ **Tensions of available models** for reproducing Λ^+_c feed-down fraction from $\Sigma_c^{0,++}$ and Ξ_c / D^0 ratio, as well as the D^+_s/D^+ meson ratio
  → **more inputs from experimental data needed to constrain models !**

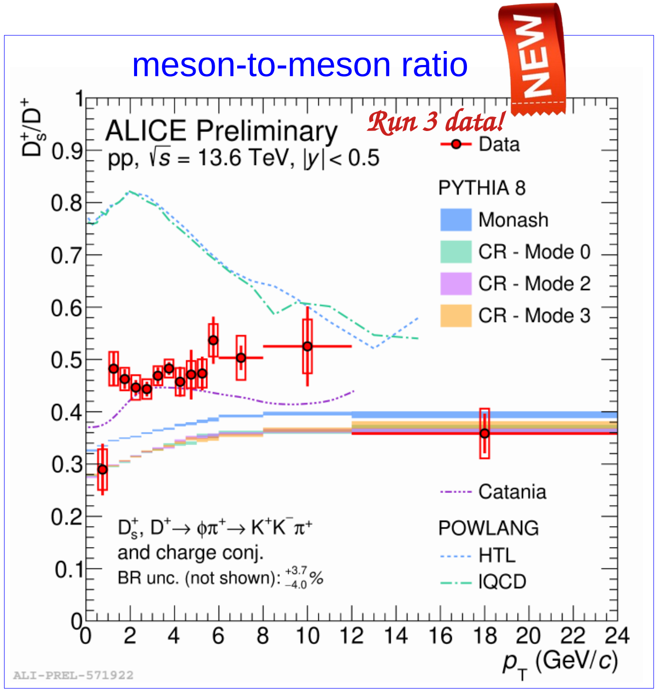
PRL 128 (2022) 012001



Belle Coll., PRD 97, 072005

JHEP12 (2023) 086



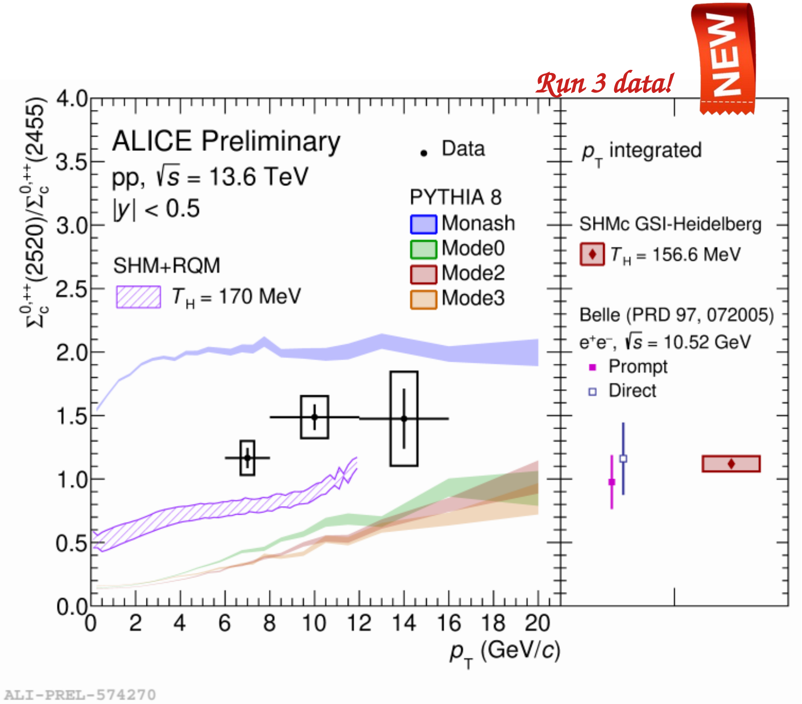


$\Sigma_c^{0,++}$ in pp collisions at √s = 13.6 TeV

J. Cho
Tuesday, 09:30

ALICE

- Relative production of $\Sigma_c^{0,++}$(2520) baryon to the ground state $\Sigma_c^{0,++}$(2455) measured in pp at 13.6 TeV
  → **first measurement at the LHC !**



- **No evidence of an enhancement** w.r.t. e^+e^- collisions considering the current uncertainties
- **SHMc describes the results** within uncertainties; **SHM+RQM predicts lower values**
- **PYTHIA 8 Monash** (default tune) **overestimates** the ratio
- **PYTHIA 8** with **CR-BLC underestimates** the ratio

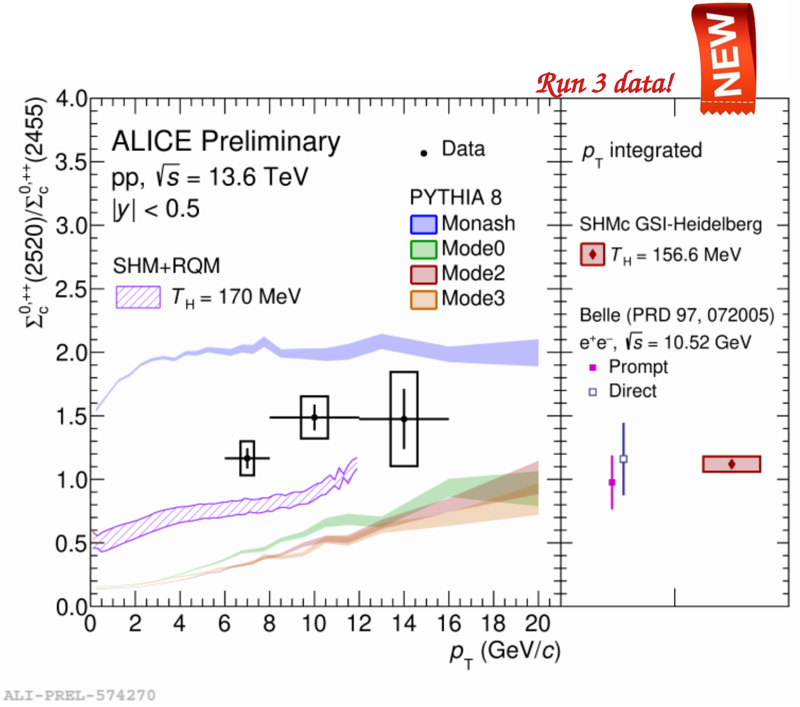
PYTHIA 8 (Monash): Skands et al., Eur. Phys. J. C 74 (2014)
PYTHIA 8 (Mode 0/2/3): Christiansen and Skands, JHEP 08 (2015) 003
SHMc: Andronic et al., PLB 797 (2019) 134836
Belle, Phys. Rev. D 97, 072005 (2018)

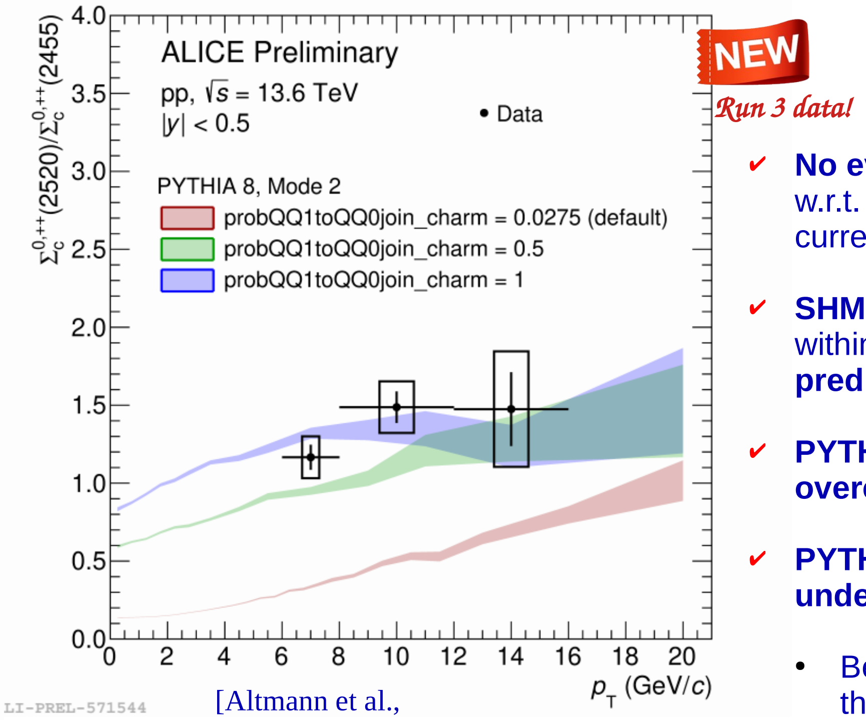
$\Sigma_c^{0,++}$ in pp collisions at $\sqrt{s}$ = 13.6 TeV

J. Cho
Tuesday, 09:30

ALICE

- ✔ Relative production of $\Sigma_c^{0,++}$(2520) baryon to the ground state $\Sigma_c^{0,++}$(2455) measured in pp at 13.6 TeV
  → **first measurement at the LHC !**



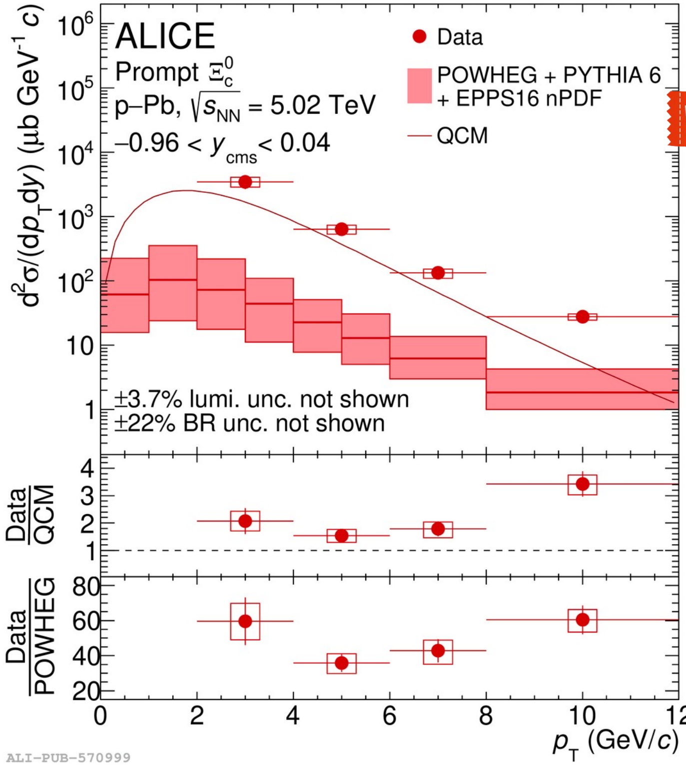


[Altmann et al., https://arxiv.org/pdf/2405.19137]

- ✔ **No evidence of an enhancement** w.r.t. e⁺e⁻ collisions considering the current uncertainties
- ✔ **SHMc describes the results** within uncertainties; **SHM+RQM predicts lower values**
- ✔ **PYTHIA 8 Monash** (default tune) **overestimates** the ratio
- ✔ **PYTHIA 8** with **CR-BLC underestimates** the ratio
  - Better agreement **after tuning** the parameter which **suppresses spin-1 w.r.t. spin-0 charm-light diquark** on Λ_c (← $\Sigma_c^{0,++}$) / Λ_c

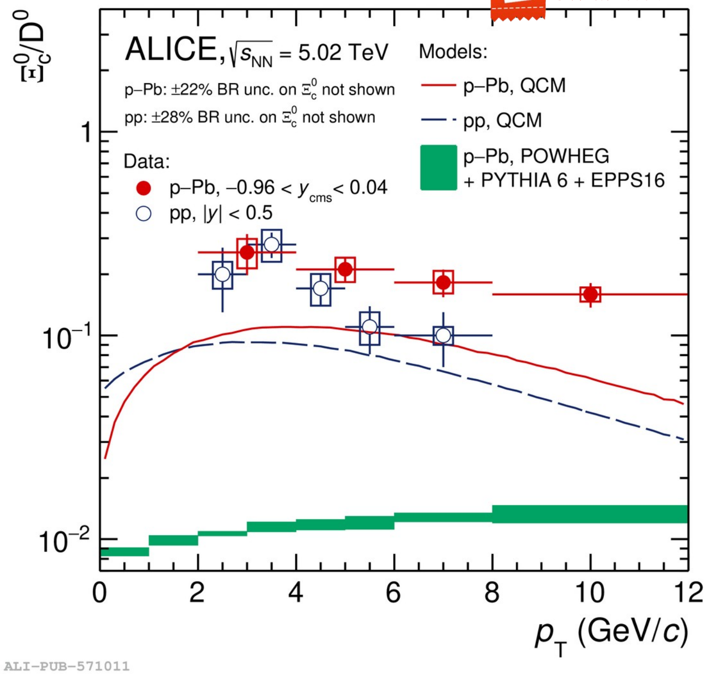
📖PYTHIA 8 (Monash): Skands et al., Eur. Phys. J. C 74 (2014)
📖PYTHIA 8 (Mode 0/2/3): Christiansen and Skands, JHEP 08 (2015) 003
📖SHMc: Andronic et al., PLB 797 (2019) 134836
📖Belle, Phys. Rev. D 97, 072005 (2018)

Ξ_c^0 production in p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV



arXiv:2405.14538

NEW
On arXiv!



NEW
On arXiv!

- ✔ POWHEG+PYTHIA 6 coupled to EPPS16 nPDF significantly underestimates Ξ_c^0 cross section
- ✔ Better agreement with QCM, however Ξ_c^0 cross section still underestimated by a factor of 2

- ✔ Baryon-to-meson ratio **compatible in pp and p–Pb collisions** within uncertainties
- ✔ **Models underpredict Ξ_c^0 / D^0 in both collision system**

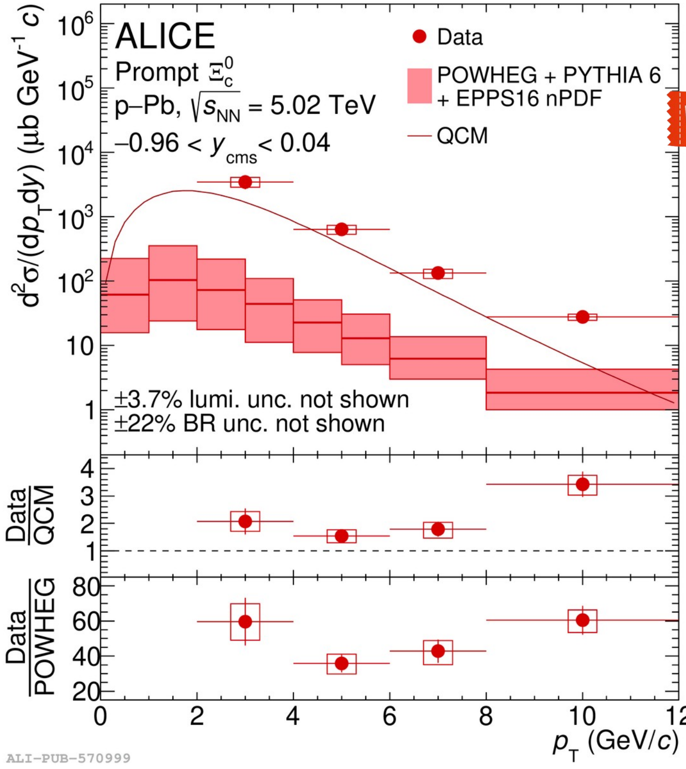
POWHEG: Banfi et al., JHEP 09 (2007) 126
PYTHIA 6: Sjostrand et al., JHEP 05 (2006) 026
QCM: Song et al., Eur. Phys. J. C 78 344 (2018)

Ξ_c^0 production in p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

A. Palasciano
Wednesday, 08:50

arXiv:2405.14538

NEW
On arXiv!

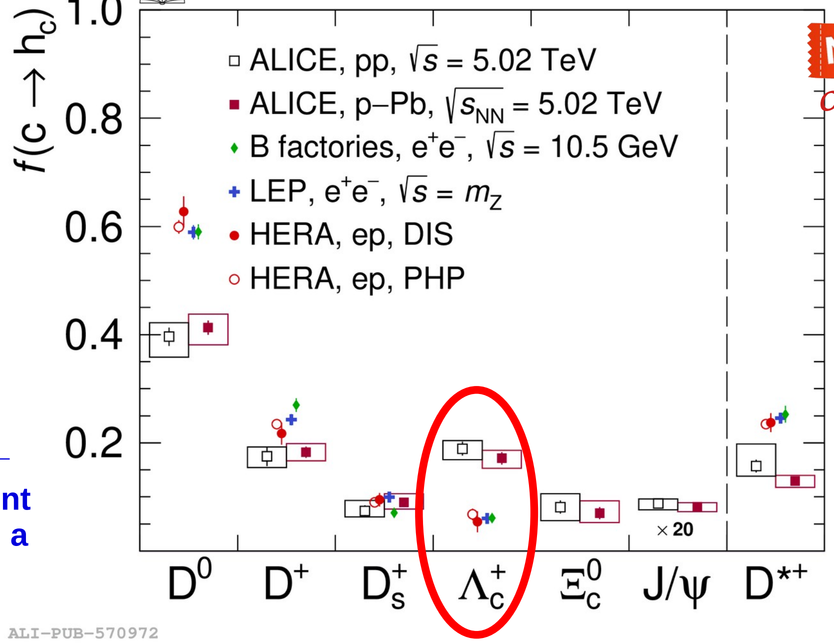


- ✔ POWHEG+PYTHIA 6 coupled to EPPS16 nPDF significantly underestimates Ξ_c^0 cross section
- ✔ Better agreement with QCM, however Ξ_c^0 cross section still underestimated by a factor of 2

- ✔ Fragmentation fractions at the LHC
  - **consistent with system size**
  - Significantly enhanced for baryons w.r.t. e^+e^- and ep → **different hadronization in a parton-rich environment**

arXiv:2405.14571

NEW
On arXiv!



POWHEG: Banfi et al., JHEP 09 (2007) 126
PYTHIA 6: Sjostrand et al., JHEP 05 (2006) 026
QCM: Song et al., Eur. Phys. J. C 78 344 (2018)

Summary & Outlook

- **Impressive collection** of new heavy-flavour physics results produced by ALICE on Run 3 and Run 2 data !
- **Efficiently Run 3 data taking** ongoing with upgraded ALICE detector
- Several **ongoing heavy-flavour analyses** on fresh collected **Pb–Pb and pp Run 3** data…

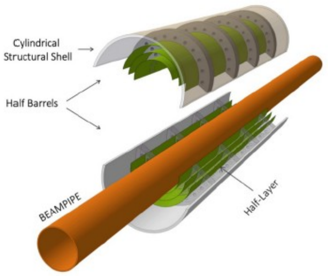
Summary & Outlook

2010-2012		2015-2018		2022-2025		2029-2032		2035-2038		2040-2041
Run I	LS1	Run 2	LS2	Run 3	LS3	Run 4	LS4	Run 5	LS5	Run 6

We are here

- **Impressive collection** of new heavy-flavour physics results produced by ALICE on Run 3 and Run 2 data !
- **Efficiently Run 3 data taking** ongoing with upgraded ALICE detector
- Several **ongoing heavy-flavour analyses** on fresh collected **Pb–Pb and pp Run 3** data…
  ...and **exciting upgrade programs** important for heavy-flavour physics...

LS3: ITS3 (and FOCAL)

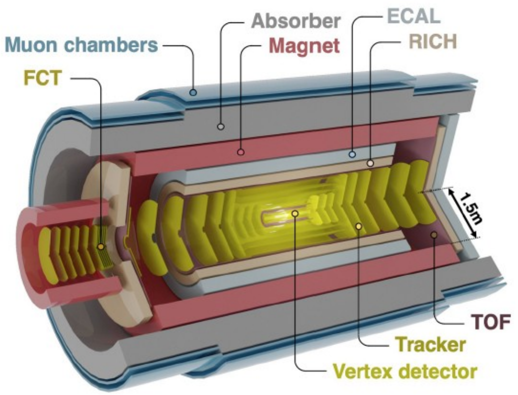


C. Wang
Tuesday, 14:20

LS4: ALICE3

G. Volpe
Tuesday, 15:20

P. Larionov
Tuesday, 15:40



...Stay tuned !

Parallel talks:

Jaeyoon Cho………..“Investigation of charm-quark hadronisation into baryons in hadronic collisions with ALICE” **[Tuesday, 09:30]**

Maurice Coquet……..“Investigating the interplay between initial hard processes and final-state effects measuring prompt and non-prompt J/ψ with ALICE” **[Tuesday, 15:00]**

Mattia Faggin………..“The role of strangeness in heavy-quark hadronisation from small to large collision systems with ALICE” **[Tuesday, 11:00]**

Dukisham Mallik…….“J/ψ photoproduction and polarization in peripheral Pb-Pb collisions with ALICE” **[Wednesday, 10:40]**

Antonio Palasciano...“Study of charm fragmentation with charm meson and baryon angular correlation measurements with ALICE” **[Wednesday, 08:50]**

Himanshu Sharma….“Investigation of early magnetic field and angular momentum in ultrarelativistic heavy-ion collisions via D^{*+}-meson spin alignment with ALICE” **[Wednesday, 09:50]**

Maolin Zhang………..“Study of charm and beauty production in hadronic collisions via muon measurements at forward rapidity with ALICE” **[Wednesday, 11:00]**

Posters:

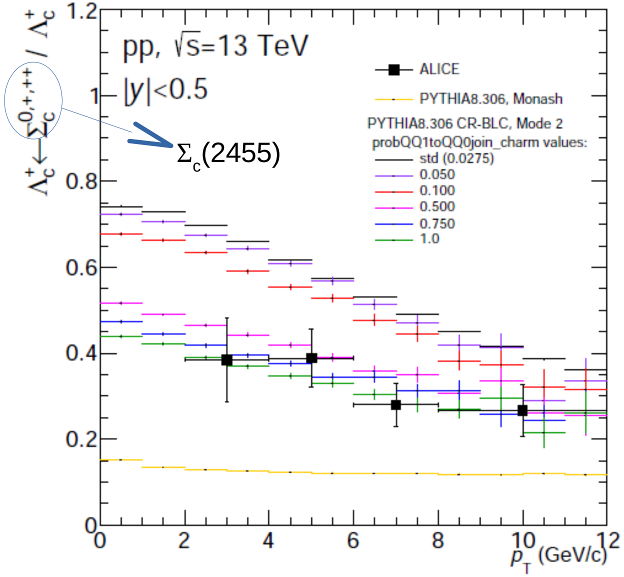
Emilie Martine Barreau – “Prompt / Non-prompt J/ψ separation performances with ALICE”
Jaeyoon Cho – “Multiplicity dependence of Ξ^{+}_{c} baryon production in pp collisions at $\sqrt{s}$ = 13 TeV with ALICE”
Tao Fang – “Ξ^{0}_{c} multiplicity dependence via hadronic decay in proton-proton collisions at $\sqrt{s}$ = 13 TeV”
Binti Sharma – “Beauty production in pp collisions at $\sqrt{s}$ = 13 TeV using the ALICE detector at the LHC”
Victor Valencia Torres – “Multi-particle cumulant J/ψ v_2 measurement in Pb–Pb with the ALICE experiment”
Josephina Rae Wright – “Investigating charm quark production in and outside jets using the ALICE detectors at the LHC”
Zhenjun Xiong – “Studying QCD production mechanisms and medium effects on quarkonia formation with ALICE”
Mingyu Zhang – “Studies of beauty-quark production, hadronisation and cold nuclear matter effects via measurements of non-prompt charm hadrons in pp and p-Pb collisions with ALICE”
Senjie Zhu – “System size dependence of collective phenomena by means of quarkonia measurements with ALICE”

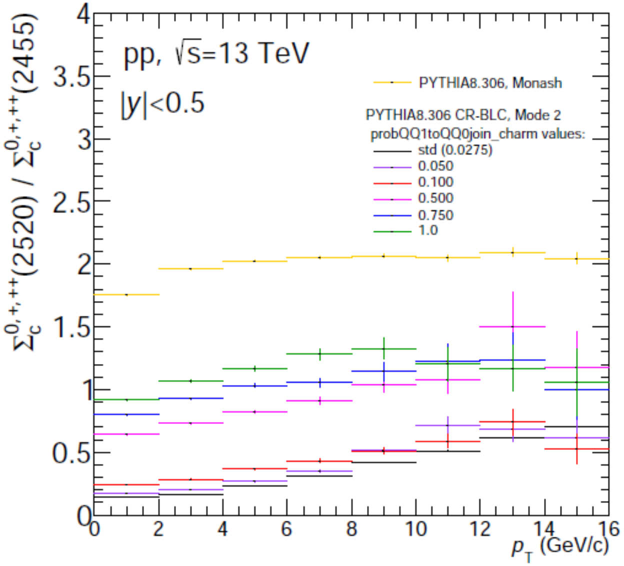
Thank you for your attention!

BACK-UP

Tuning of PYTHIA 8 QCD-based CR-BLC parameters

[Altmann et al.,https://arxiv.org/pdf/2405.19137]



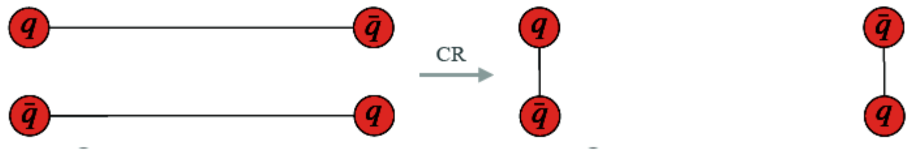


Particle	Mass (MeV/c^2)	Spin
Λ	1115.6	1/2
$\Lambda(1520)$	1519.5	3/2
Σ^0	1192.6	1/2
$\Sigma(1385)^+$	1382.8	3/2
Ξ^-	1321.4	1/2
$\Xi(1530)^0$	1531.8	3/2
Ω^-	1672.4	1/2
Λ_c^+	2286.4	1/2
$\Lambda_c(2595)^+$	2592.2	1/2
$\Lambda_c(2625)^+$	2628.1	3/2
$\Sigma_c(2455)^0$	2453.7	1/2
$\Sigma_c(2520)^0$	2518.8	3/2

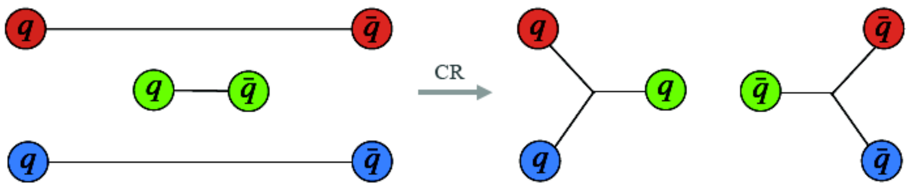
- Charm-light diquark is coupled to a quark to form a baryon
  - In ℓ = 0, spin-1 (spin-0) diquark coupled to spin ½ quark results in a baryon with spin 3/2 (½)
- Excited Λ^+_c and Σ_c states with spin=3/2 decay preferentially to Λ^+_c rather than to $\Sigma^{0,+,++}_c$ (2455) → Λ^+_c production enhanced by resonant higher mass charm baryon states
- Parameter "probQQ1toQQ0join" regulates the suppression of spin-1 w.r.t. spin-0 charm-diquarks
  - "probQQ1toQQ0join" = 1 → no suppression
  - Lower "probQQ1toQQ0join" values correspond to higher suppression
  - Values between 0.5 – 1.0 can describe the measured Λ_c feed-down from Σ_c(2455) (more precise data will help to tune the value)

Hadronization in PYTHIA 8

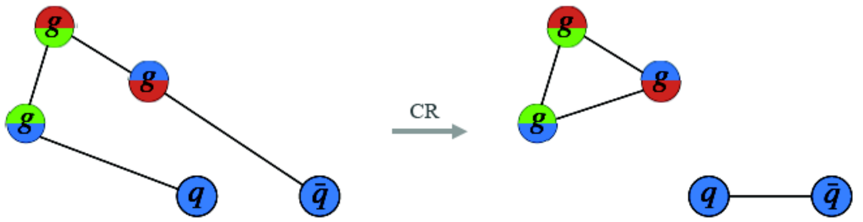
[Altmann et al.,https://arxiv.org/pdf/2405.19137]



(a) Dipole-type reconnection.



(b) Junction reconnection.



(c) Gluon-loop formation.

- ✔ Color Reconnection among partons belonging to different MPIs → In the **Leading Color** (CR-LC) limit (Monash 2013, default tune) **only “dipole” string configurations are allowed**
  - characterized by two endpoints, typically a colour and an anti-colour charge endpoint (can have any number of intermediate gluons between them which form “kinks” on the string)

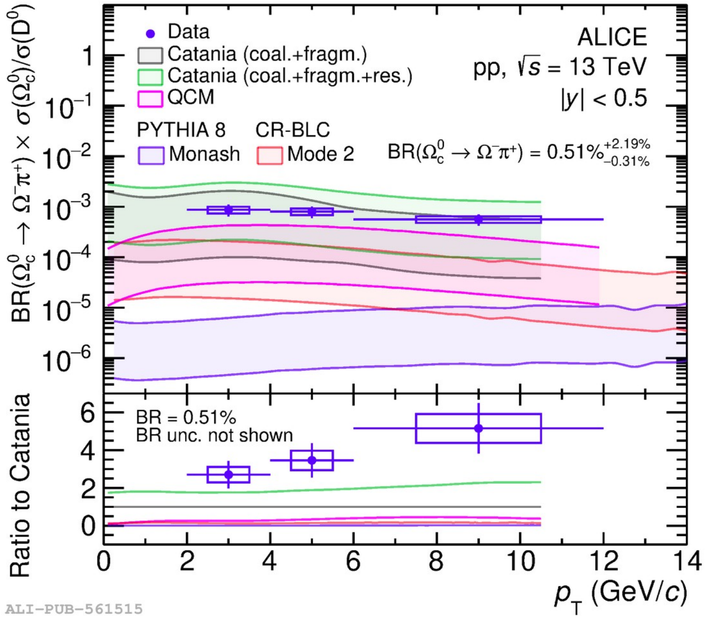
- ✔ Color Reconnection **beyond Leading Color** (CR-BLC): alternative string configurations allowed
  - **Junctions provide a new mechanisms to produce baryons** (in the LC approximation baryons are only produced via diquark creation next to a heavy-flavour endpoint)

Ω^0_c baryons production and BRs

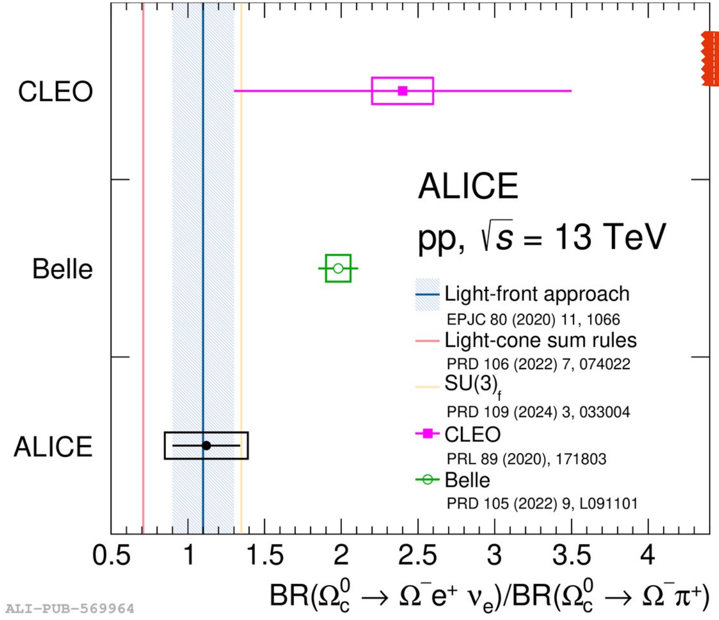
J. Cho
Tuesday, 09:30

ALICE

Phys. Lett. B 846 (2023) 137625



arXiv:2205.13993



NEW
On arXiv!

Pythia 8 (Monash): Eur. Phys. J. C 74 (2014)
Pythia 8 (CR-BLC): JHEP 08 (2015) 003
Catania: PLB 821, 136622
QCM: Eur. Phys. J. C 78 344 (2018)

- No measurement available of the absolute branching ratios for any of the decay modes of the Ω_c^0 baryon ($BR(\Omega_c^0 \rightarrow \Omega^- \pi^+)$ derived from theory calculations)
- Large BR uncertainties limit the effectiveness of the comparison with theoretical models
- Branching-fraction ratio $BR(\Omega_c^0 \rightarrow \Omega^- e^+ \nu_e)$ / $BR(\Omega_c^0 \rightarrow \Omega^- \pi^+)$ released by ALICE → in agreement within uncertainties with state of art theory calculations

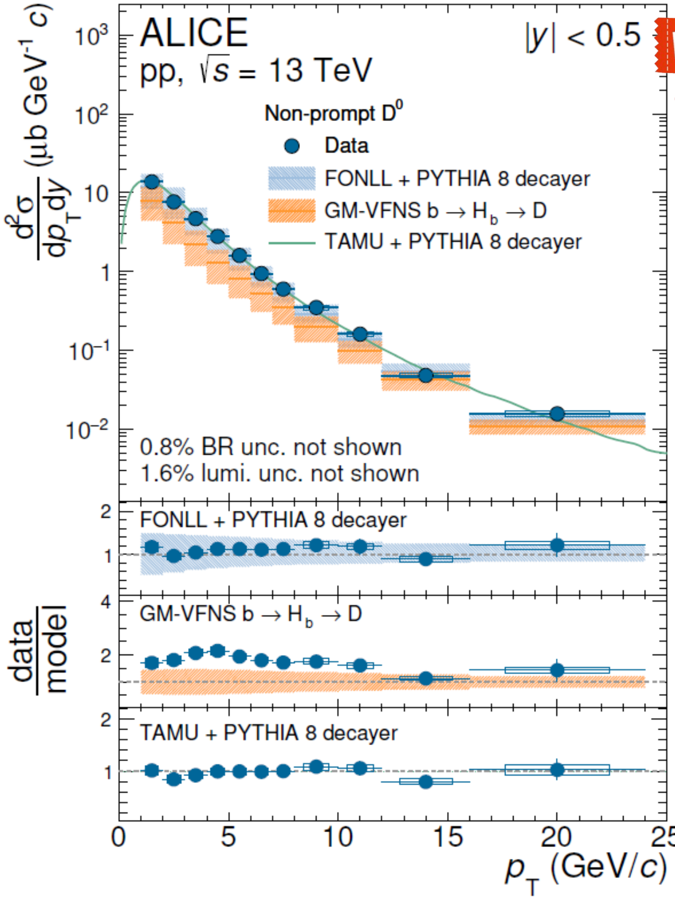
Baryon formation in current state of art models

- **Quark (re-)combination mechanism (QCM)** [QCM: Song et al., EPJC (2018) 78: 344]
  - Coalescence of charm quark and light flavour quarks close in “phase-space)”
  - Thermal weights for describing relative production of vector and scalar mesons
- **SHM + Relativistic Quark Model** [He et al., PLB 795 (2019) 117-121]
  - Hadrons formed according to thermal weights driven by mass at the freezout temperature estimated from Pb-Pb fits (156.6 MeV)
  - Significant feed-down from excited charm baryon states beyond those listed in the PDG: additional 18 Λ_c, 42 Σ_c, 62 Ξ_c, 2 Ω_c (in the PDG: 5 Λ_c, 3 Σ_c, 8 Ξ_c, 34 Ω_c)
- **Catania** [Greco et al., PLB 821, 136622]
  - Thermalised systems of light flavour quarks and gluons
  - Charm quark hadronization via fragmentation + recombination with light flavour quarks from the bulk
- **POWLANG** [Beraudo et al., arXiv:2306.02152]
  - Expanding fireball assumed in pp collisions
  - Hadronisation via recombination with light quarks
  - Charm baryon formation enhanced thanks to diquark excitations

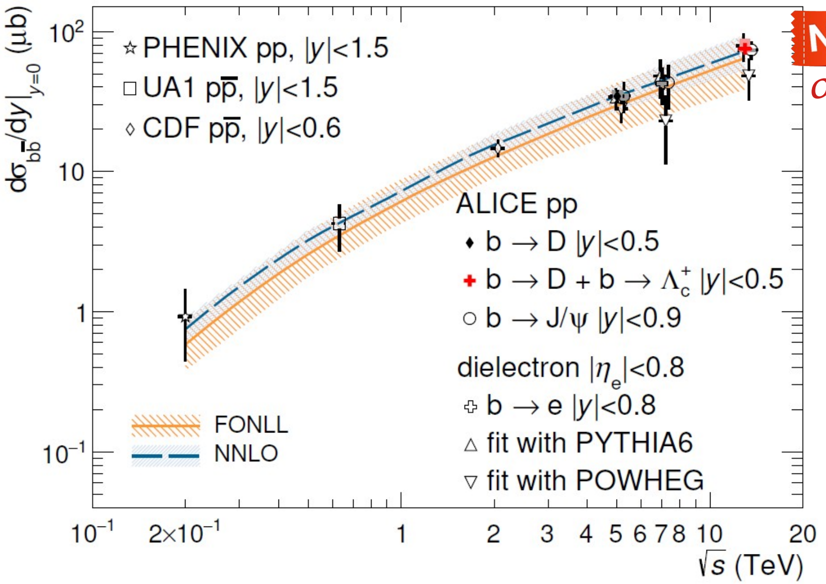
Beauty production via non-prompt D-mesons in pp at 13 TeV

arXiv:2402.16417

ALICE



NEW
On arXiv!



NEW
On arXiv!

FONLL: JHEP 05 (1998) 007
NNLO: PRL 118 (2017) 122001

✔ Beauty quark pair cross section at midrapidity extrapolated from visible cross sections of non-prompt charm hadrons

- improved precision compared to previous publication
- Dependence on √s well described by state-of-art pQCD calculations

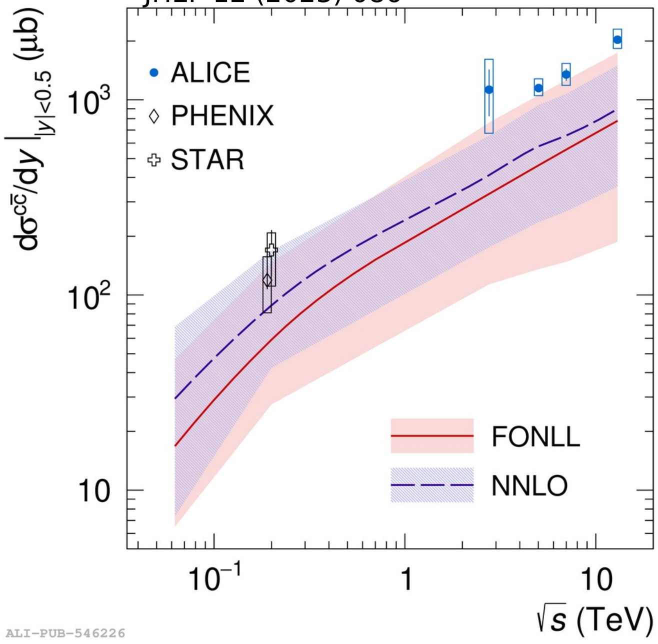
✔ Precise non-prompt D meson production cross sections computed at 13 TeV !

- well described within uncertainties by FONLL, using fragmentation fractions derived from e^+e^-
- TAMU calculations, based on a statistical hadronization approach for beauty hadron fragmentation fractions, provides also a good description

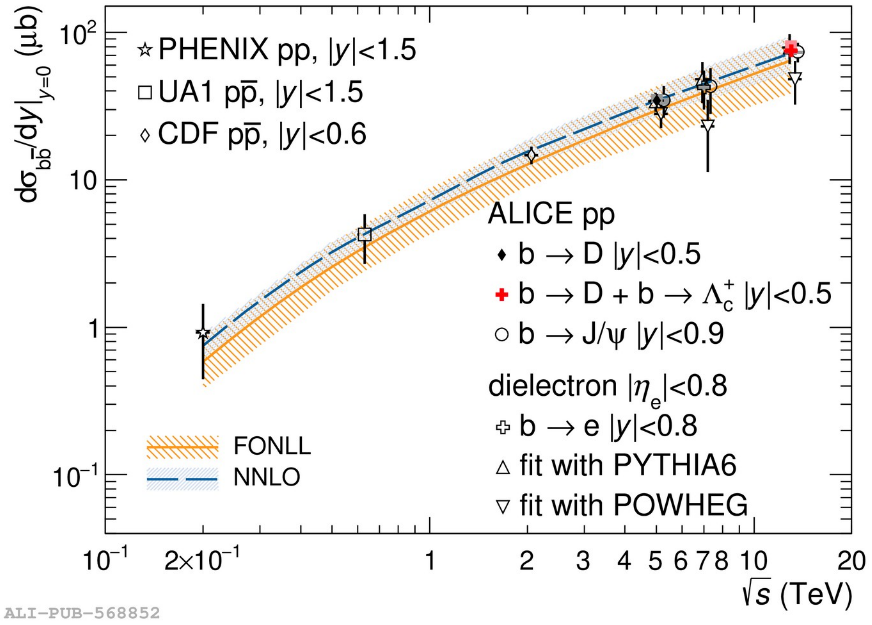
PYTHIA8: Eur. Phys. J. C 74 (2014)
GM-VFNS: JHEP 05 (2018) 196
TAMU: PRL 131 (2023) 012301

c- and b-quark pair production cross sections

JHEP 12 (2023) 086



arXiv:2402.16417

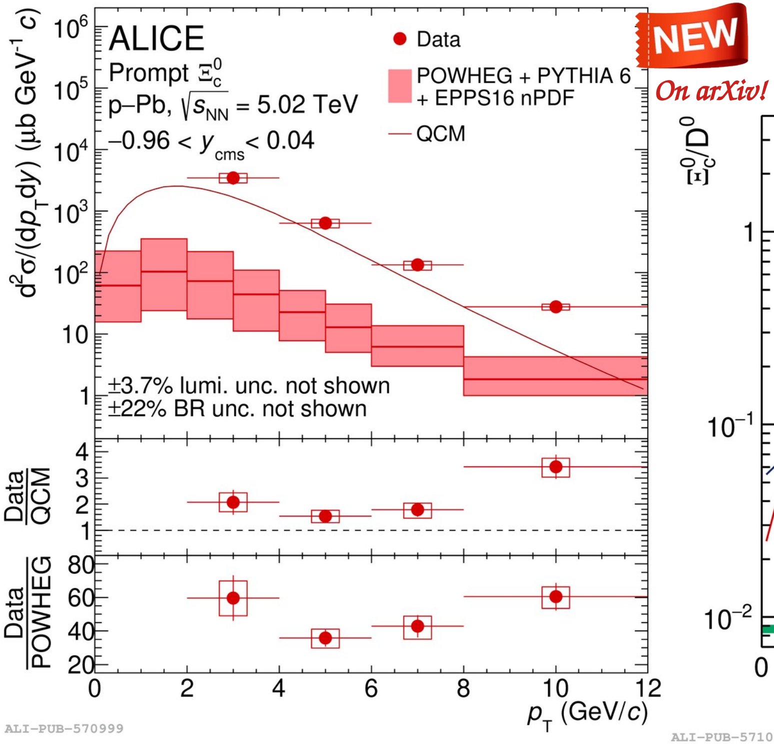


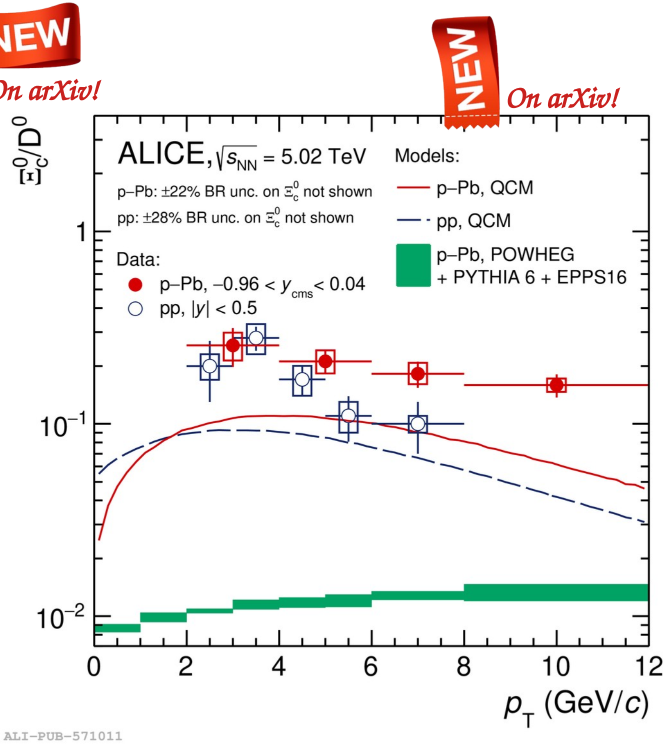
FONLL: JHEP 05 (1998) 007
NNLO: PRL 118 (2017) 122001

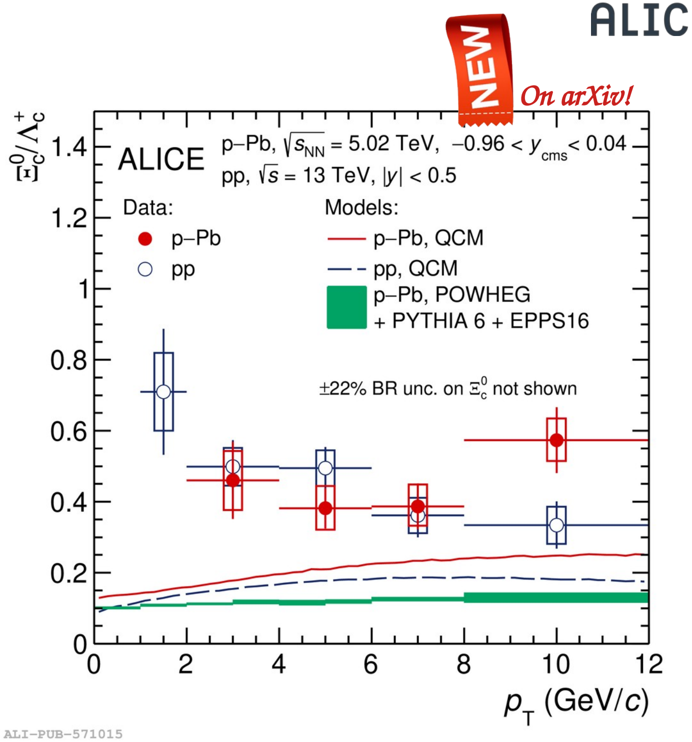
- $c\bar{c}$ cross section
  - Data on upper edge of FONLL and NNLO calculation
- $b\bar{b}$ cross section:
  - Good description by FONLL and NNLO calculations over a wide range of energy
- Less sensitive to non-perturbative hadronisation effects → excellent tools for testing pQCD based models

Ξ_c^0 production in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

arXiv:2405.14538







- ✔ POWHEG+PYTHIA6 coupled to EPPS16 nPDF significantly underestimates Ξ_c^0 cross section
- ✔ Better agreement with QCM, however Ξ_c^0 cross section still underestimated by a factor of 2
- ✔ Charm hadron ratios compatible in pp and pPb collisions within uncertainties
- ✔ Overall, models underpredict Ξ_c^0 / D^0 and Ξ_c^0 / Λ_c^+ in both collision system

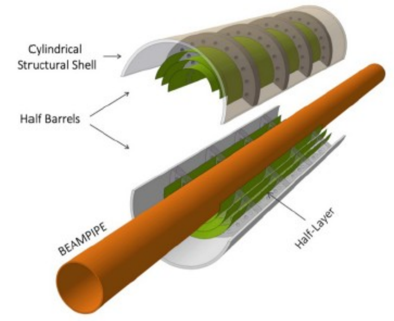
POWHEG: JHEP 09 (2007) 126
Pythia 6: JHEP 05 (2006) 026
QCM: Eur. Phys. J. C 78 344 (2018)

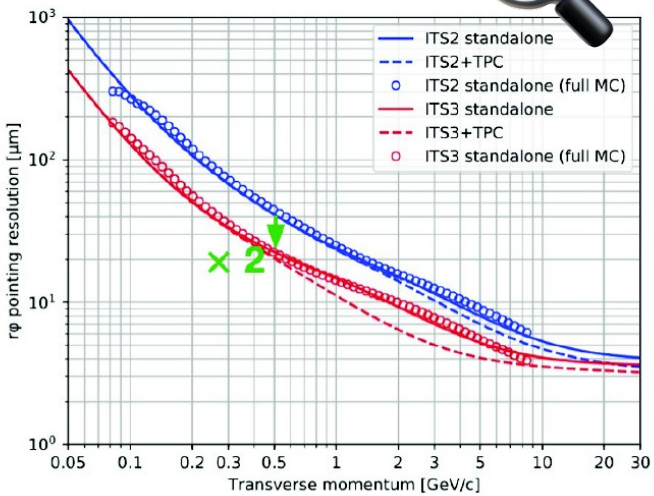
Outlook: Run4 and beyond

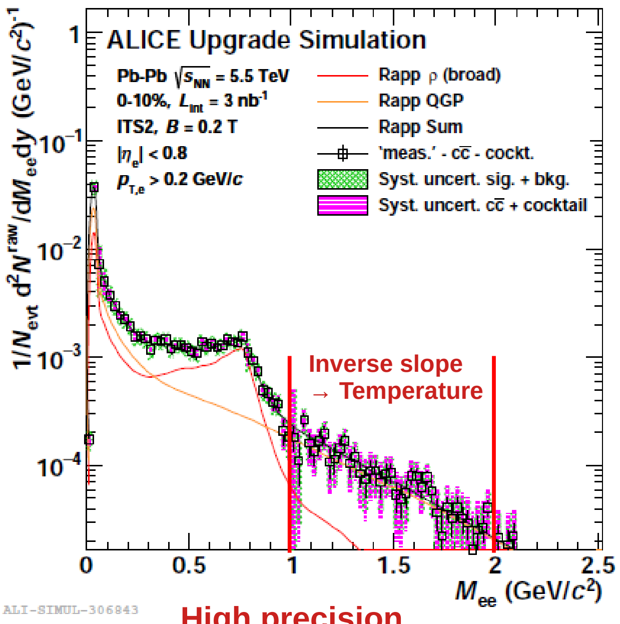
ITS3:
LoI: CERN-LHCC-2019-018
TDR: in preparation
FOCAL:
LoI: ALICE, LHCC-I-036 (2020)

2010-2012		2015-2018		2022-2025		2029-2032		2035-2038		2040-2041
Run I	LS1	Run 2	LS2	Run 3	LS3	Run 4	LS4	Run 5	LS5	Run 6

LS3: ITS3 (and FOCAL)







High precision measurement of medium temperature!

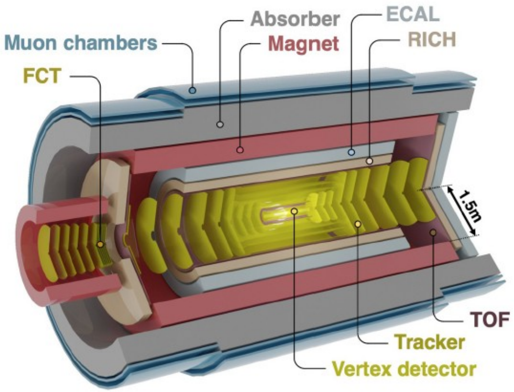
- ✔ Replacing the 3 innermost layers with new ultra-light, truly cylindrical layers
  - Reduced material budget (from 0.35% to 0.05% X_0)
  - Closer to the interaction point (from 23 to 18 mm)
- ✔ Main motivations:
  - Improve performance for **open heavy-flavour** and **dielectron** measurements

Outlook: Run4 and beyond

ALICE3:
LoI: CERN-LHCC-2022-009

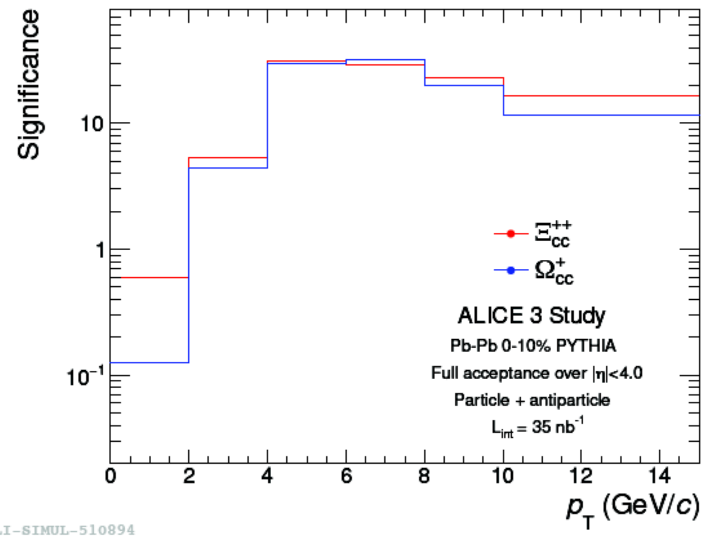
2010-2012		2015-2018		2022-2025		2029-2032		2035-2038		2040-2041
Run I	LS1	Run 2	LS2	Run 3	LS3	Run 4	LS4	Run 5	LS5	Run 6

LS4: ALICE3



- ✔ Innovative detector concept focusing on silicon technology
  - Compact and lightweight all-silicon tracker
  - Large acceptance: $-4 < \eta < 4$, $p_T > 0.02$ GeV/c
  - Continuous readout

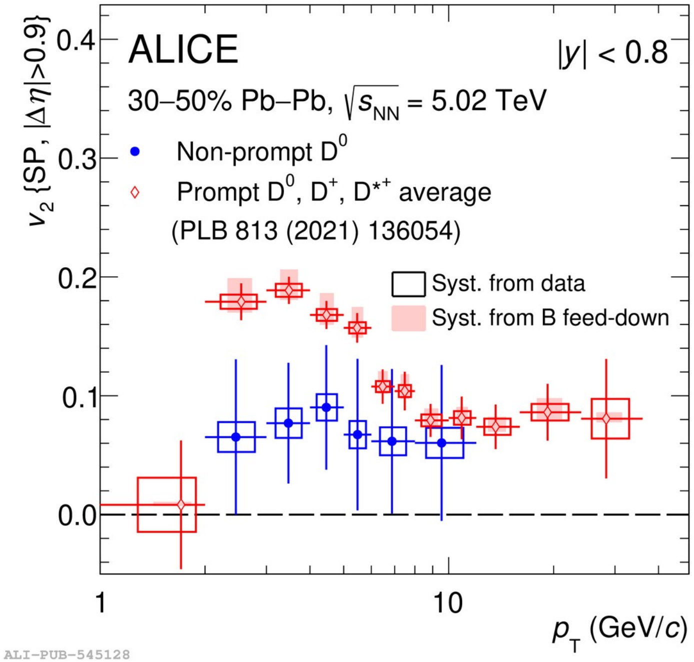
→ improved tracking and vertex performance at very low p_T
→ increased redout rate and η coverage
→ improved PID capabilities

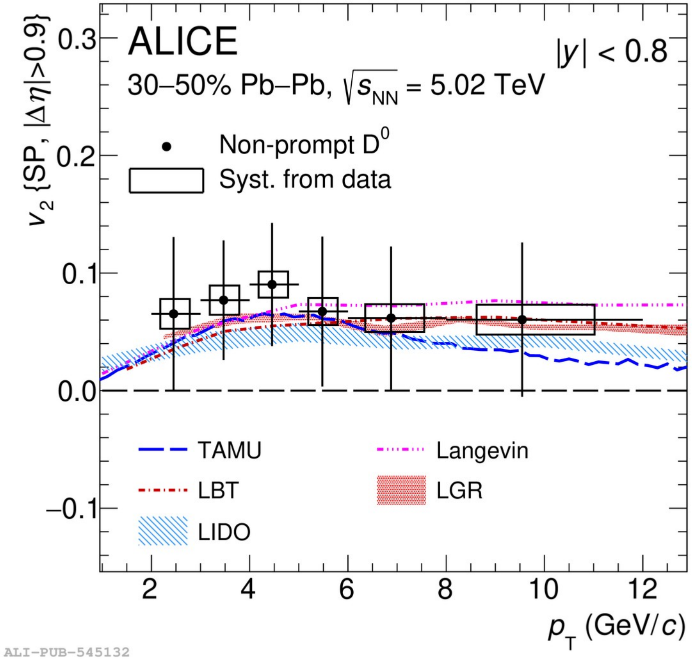


b-quark thermalization via non-prompt D^0 v_2 in Pb-Pb collisions

Eur. Phys. J. C 83 (2023) RECENTLY PUBLISHED!

M. Zhang
Wednesday, 11:00





$$\frac{dN}{d\varphi} \propto 1 + 2\sum_{n=1}^{\infty} v_n \cdot \cos[n(\varphi - \Psi_{RP})] \quad v_n = \langle \cos[n(\varphi - \Psi_{RP})]\rangle$$

- ✔ Significant v_2 measured for non-prompt D mesons (significance: 2.7*σ*)
- ✔ v_2(prompt D) > v_2(non-prompt D) with a significance of 3.2σ in $2 < p_T < 8$ GeV/*c*
- ✔ Described by models including hadronization via coalescence and fragmentation

TAMU: PLB 735 (2014) 445–450
LBT: PLB 777 (2018) 255–259
LIDO: PRC 98 (2018) 064901
Langevin: CPC 44 (2020) 114101
LGR: EPJC 80 (2020) 1113