Recent results on heavy quarks and leptons from the ALICE experiment

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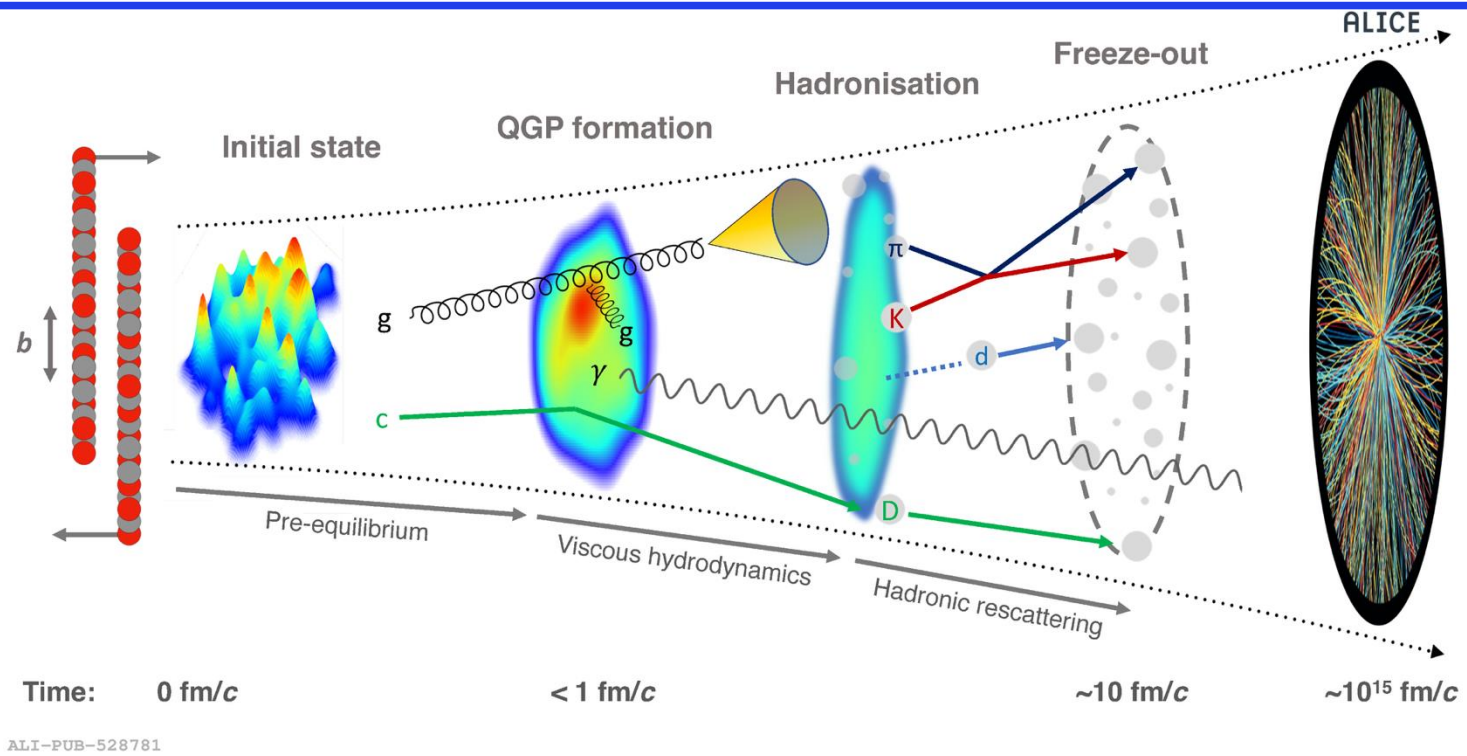
for the ALICE Collaboration

Beijing, China, 15th - 19th, Sep. 2025

ALICE

1958 University of Science and Technology of China

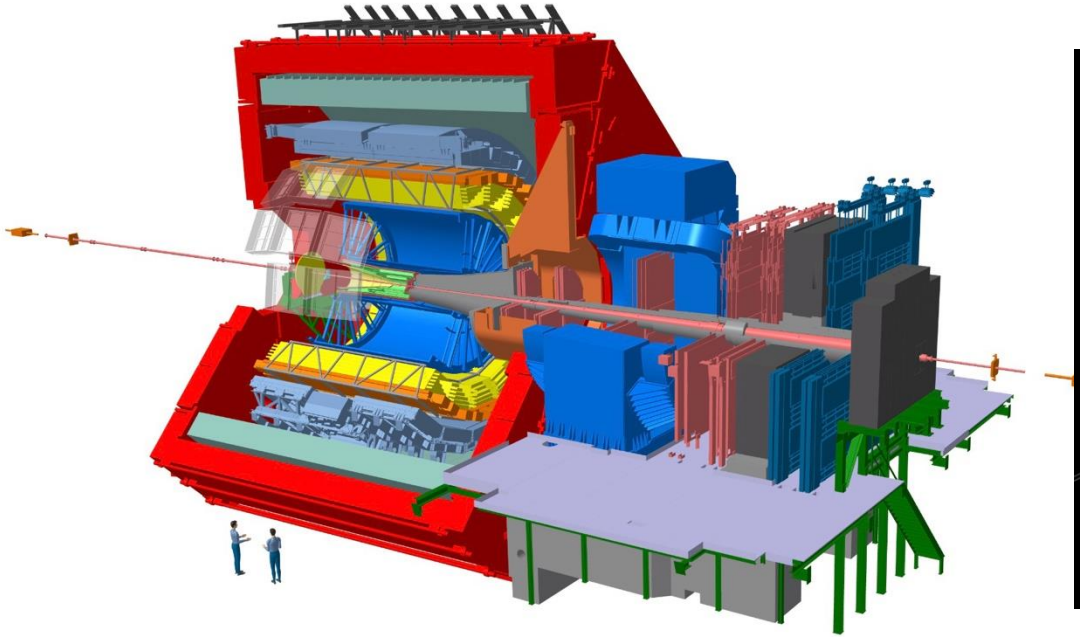
Hard probes of the heavy-ion collision



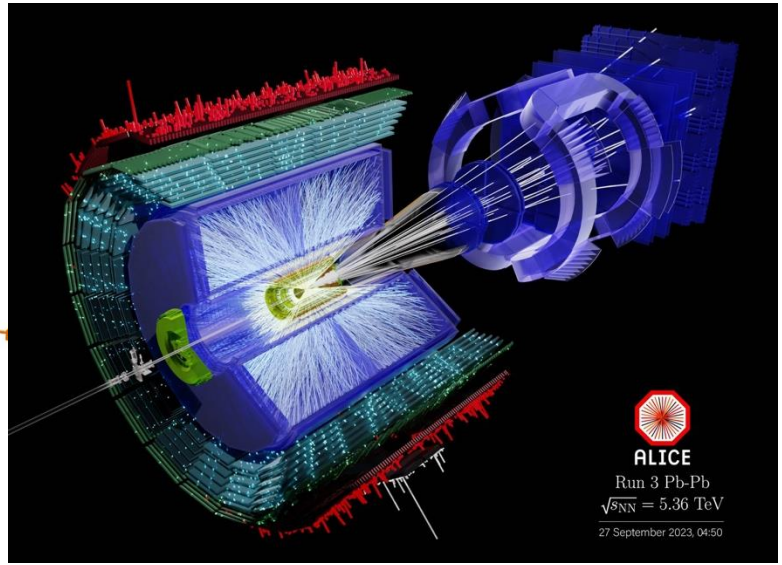
Heavy flavor, quarkonium and jets, are excellent **hard probes** to study the **initial state**, **QGP properties** and **hadronisation mechanisms in heavy-ion collisions**

ALICE, Eur. Phys. J. C 84 (2024) 813

ALICE in Run 3 (Ongoing)



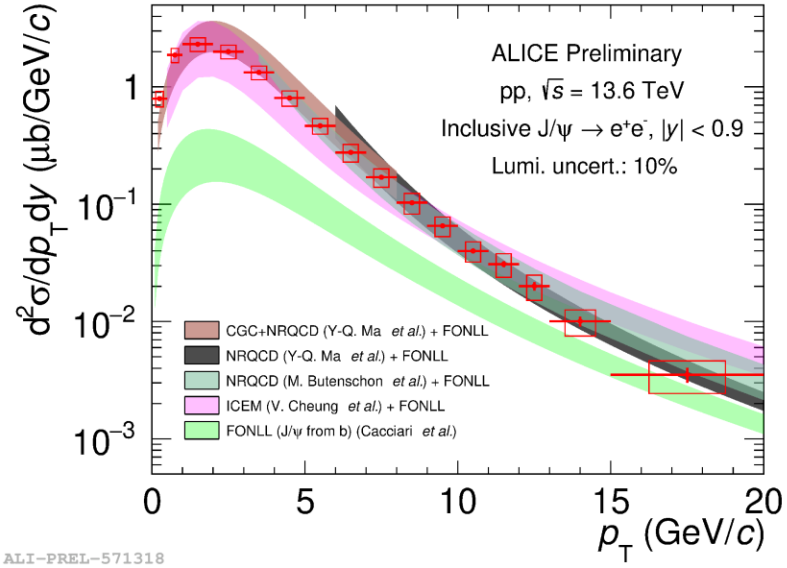
Major upgrades installed in 2019- 2021

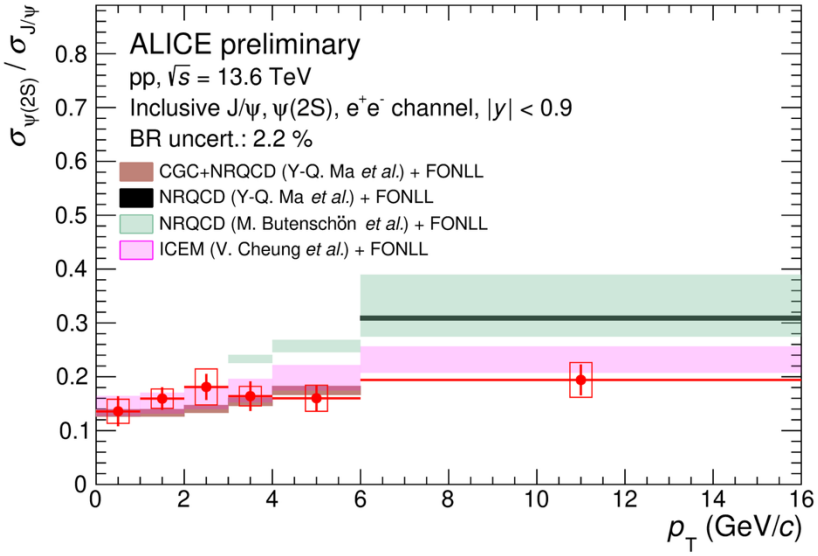


LHC LS2	LHC RUN 3	LHC LS3	LHC RUN 4	LHC LS4	LHC RUN 5 and RUN 6
2019-2021	2022-2026	2026-2029	2030-2033	2034-2035	2036-2041

Charmonia in pp collisions at $\sqrt{s}$ = 13.6 TeV

New Preliminary

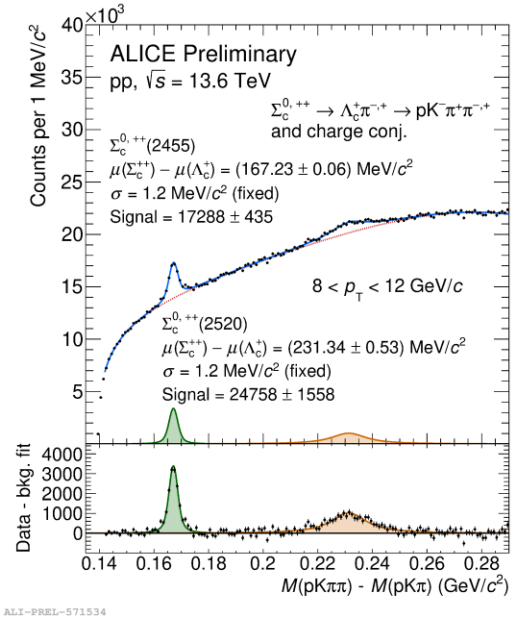




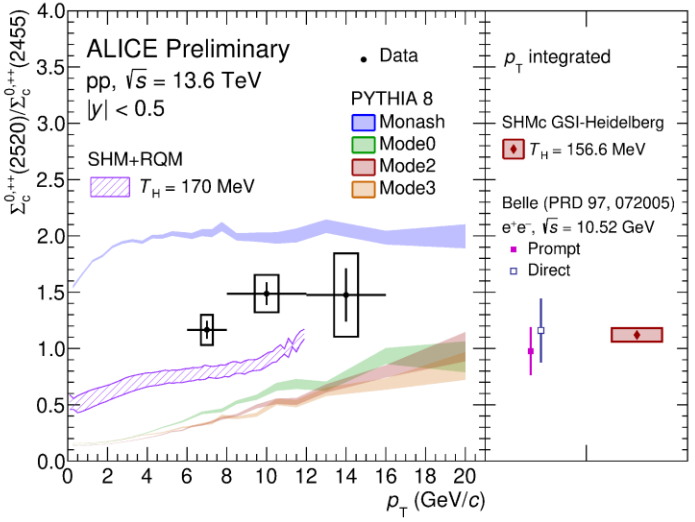
- Significantly higher integrated luminosity collected in Run 3 allows reconstruction of ψ(2S) in dielectron decay channel at midrapidity
- The data are described by ICEM and NRQCD based models coupled with FONLL to account for the non-prompt J/ψ contribution

ICEM: Y.-Q. Ma *et. al*, Phys. Rev. D 94, 114029 (2016)
NRQCD: B. A. Kniehl, *et al*, Phys. Rev. D 73, 074022 (2006)

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



New Preliminary

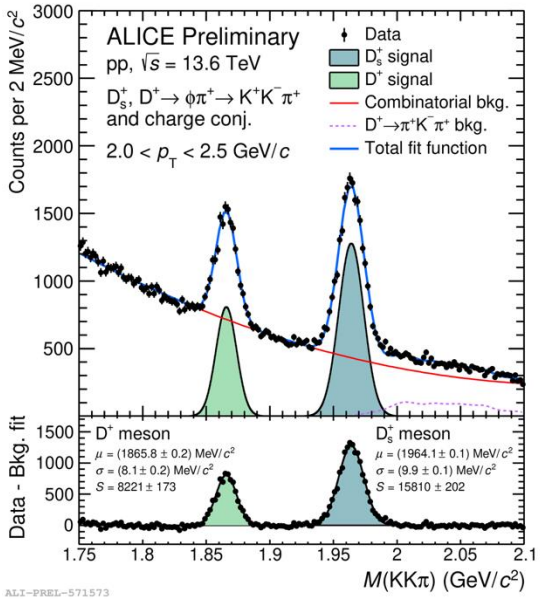


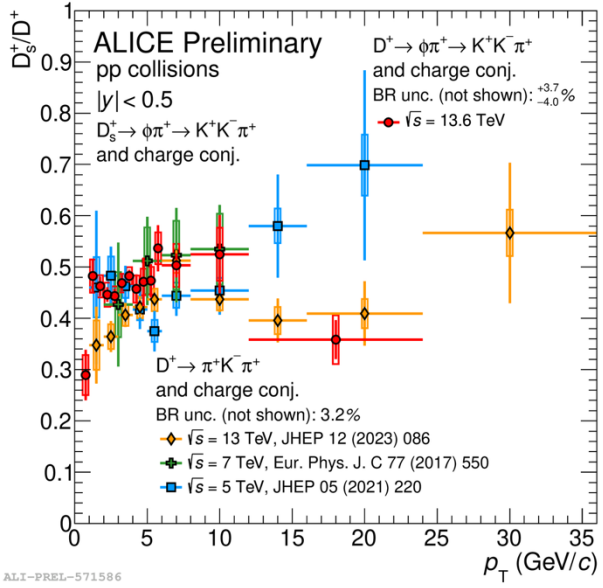
- First measurement of the production of $\sum_c^{0,++}(2520)$ relative to $\sum_c^{0,++}(2455)$ in pp collisions at $\sqrt{s}$ = 13.6 TeV
- No evidence of difference w.r.t. e^+e^- collisions (Belle) considering current uncertainties
- PYTHIA 8 Monash (default tune) overestimates the ratio, PYTHIA 8 with with additional color reconnection topologies underestimates the ratio

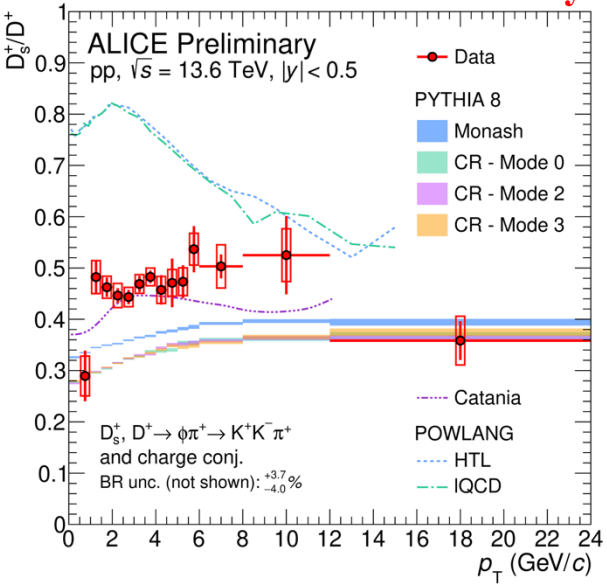
PYTHIA: EPJC 74 (2014) 8, 3024, JHEP 08 (2015) 003 GSI-SHMc:JHEP 07 (2021) 035

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

New Preliminary



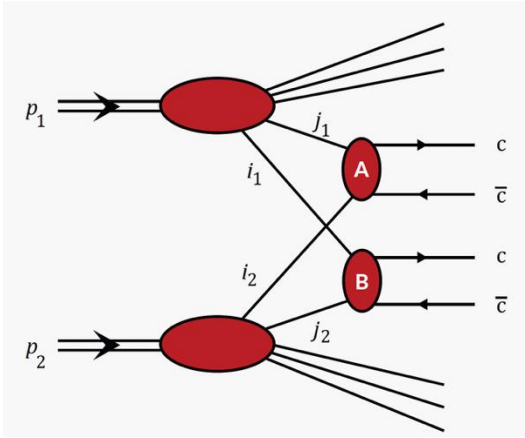




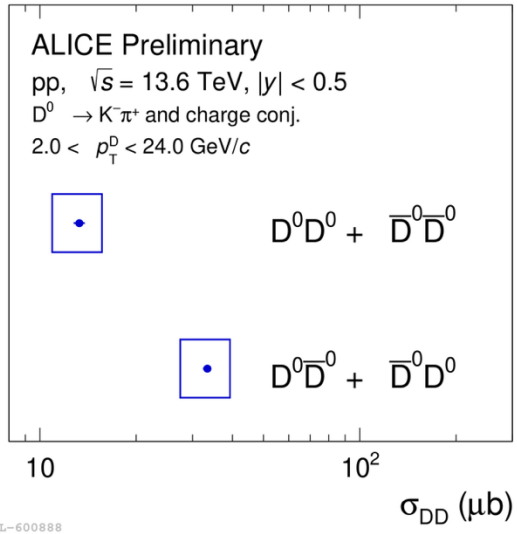
- Catania (coalescence) gives best description, while POWLANG (local color recombination) and PYTHIA (string fragmentation) can not describe the data
- No evidence of dependence of Ds^+/D^+ ratio on collision energy

Catania: Phys. Lett. B 821, 136622 (2021) POWLANG: POWLANG: PRD 109, L011501

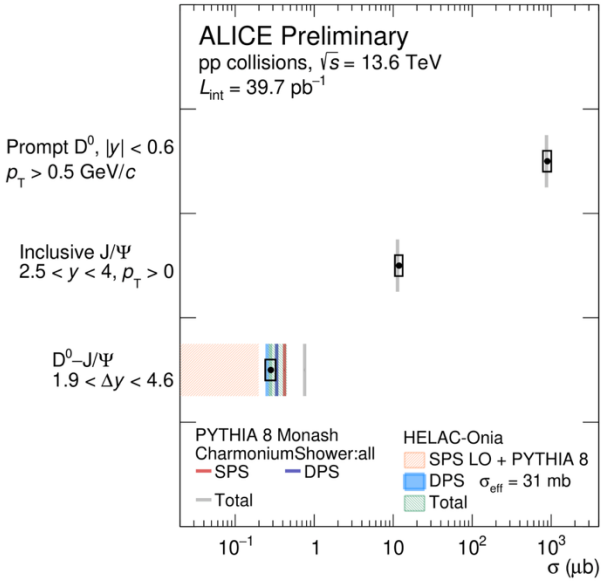
D^0D^0 and J/ψ-D^0 production associate production



$$\sigma_{\text{eff}} = \frac{m}{2} \cdot \frac{\sigma_{pp\to A} \cdot \sigma_{pp\to B}}{\sigma^{DPS}_{pp\to A+B}}$$



New Preliminary

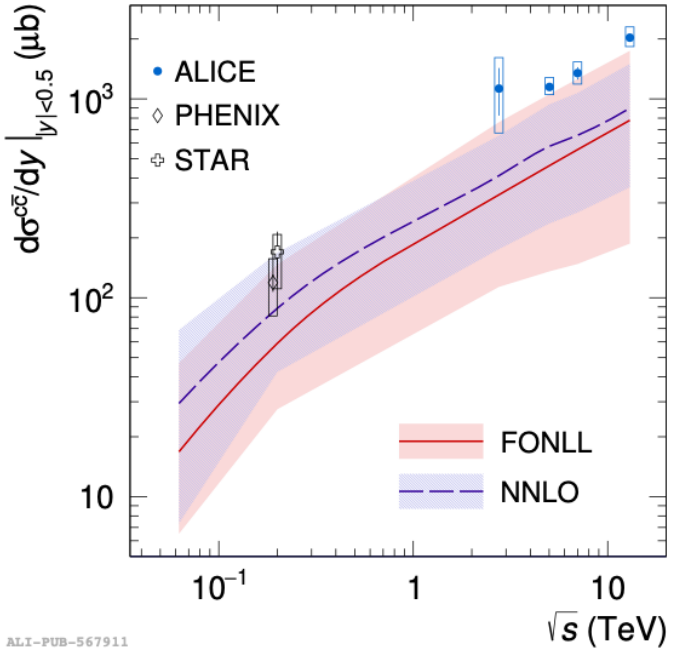


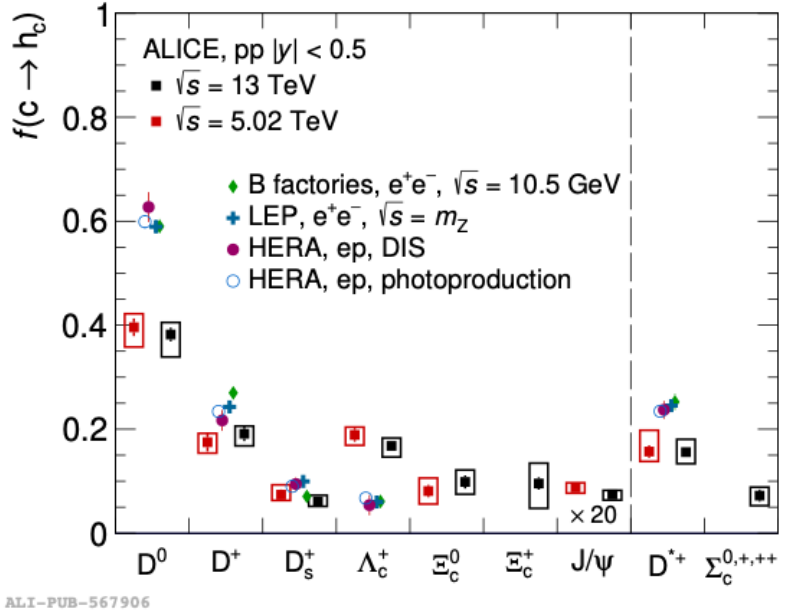
- D^0D^0 and J/ψ-D^0 production offer the possibility to compute σ_{eff}, with the very large $|\Delta y|$ available ($1.9 < |\Delta y| < 4.6$)
- PYTHIA 8: overestimates the J/ψ-D^0 cross section, HELAC-onia: reproduces the J/ψ-D cross section considering $\sigma_{\text{eff}} = 31$ mb

HELAC-onia H.-S.Shao, Comput. Phys.Commun.184,2562 (2013)

Charm production and fragmentation fractions

ALICE, JHEP 12 (2023) 086



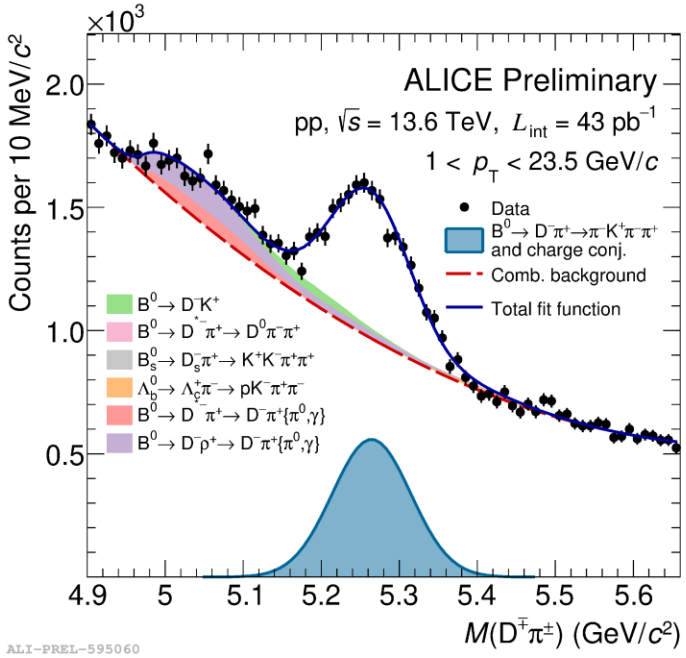


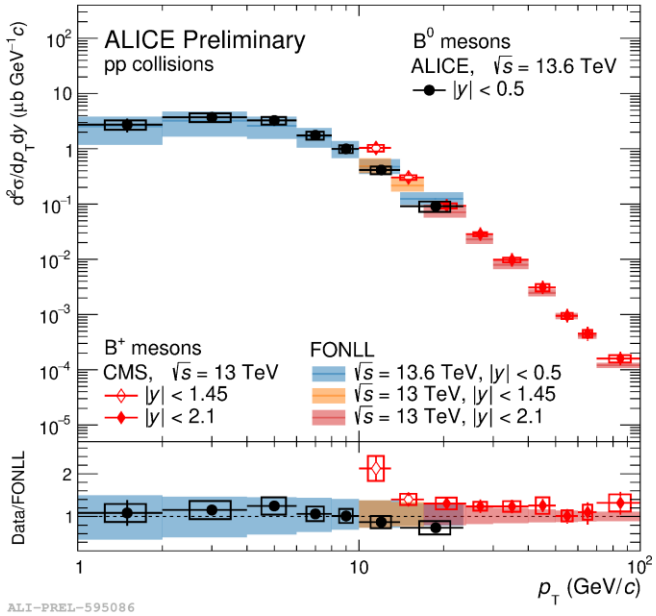
- Total charm production cross section: values at the edge of FONLL uncertainty band at midrapity
- **Charm fragmentation fractions are different** w.r.t e^+e^- and ep collisions
- **Baryon production is not fully understood**

FONLL: JHEP 05 (1998) 007

B-meson production

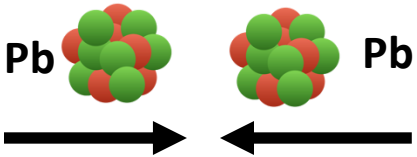
New Preliminary





- First observation of fully reconstructed open-beauty hadrons with ALICE
- New measurement extends the CMS measurement down to low p_T
- In agreement with FONLL calculations

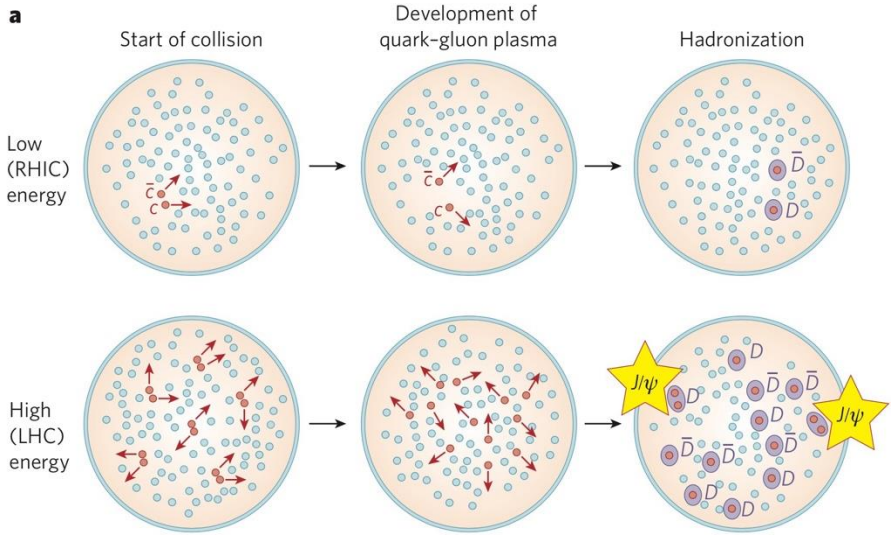
FONLL: JHEP 05 (1998) 007



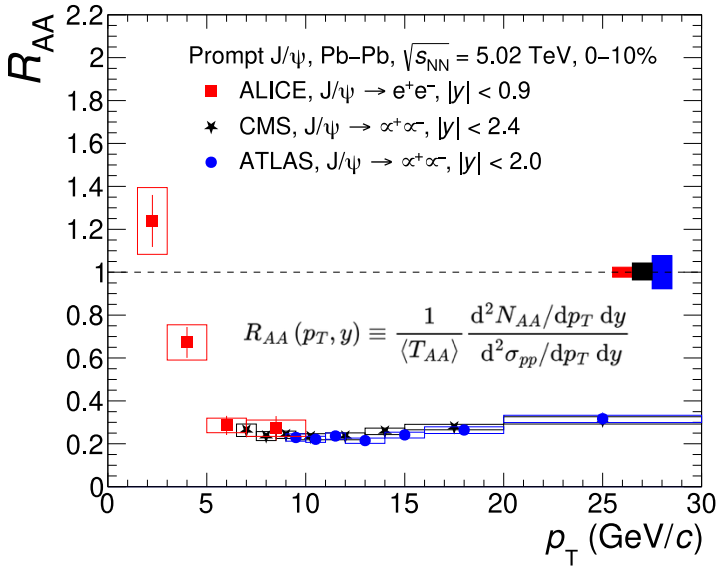
Recent results from Pb–Pb collisions

J/ψ (re-)generation Pb–Pb collisions

P. Braun-Munzinger, J. Stachel, Nature 448 (2007) 302



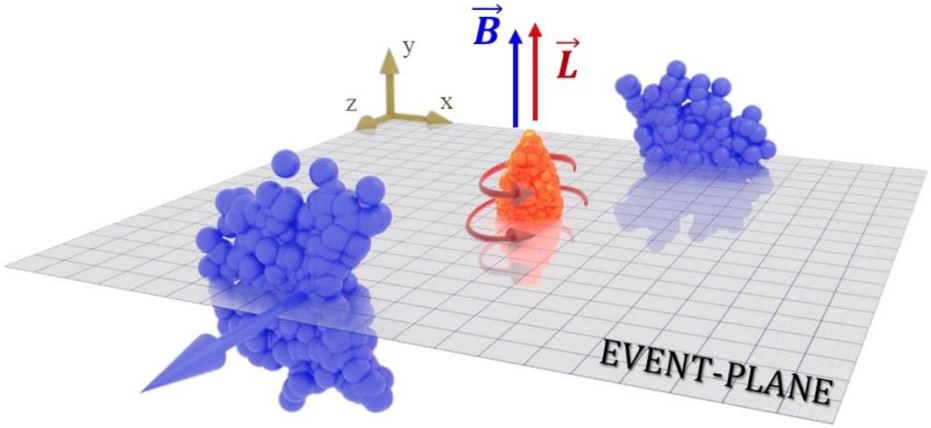
ALICE, PLB 849 (2024) 138451, JHEP 02 (2024) 066

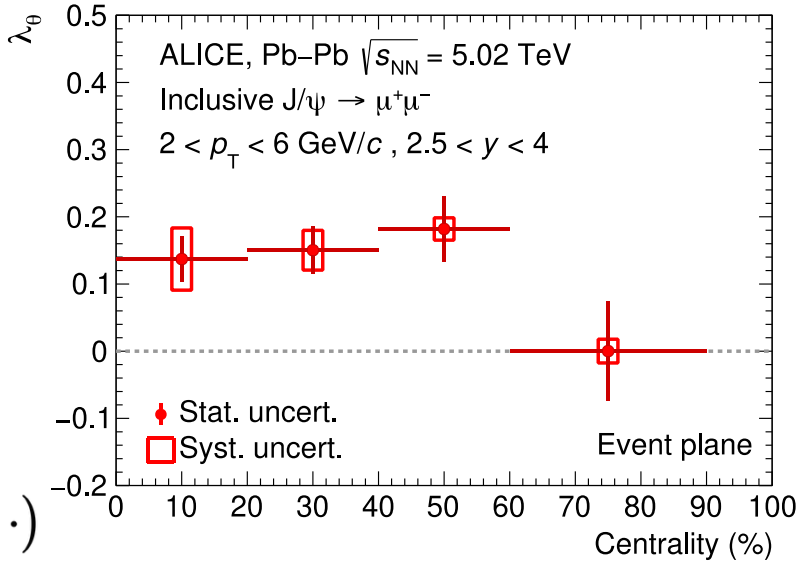


- High R_{AA} at low p_T in central collisions at midrapidity -> **evidence for J/ψ (re-)generation**
- R_{AA} extended down to p_T = 1.5 GeV/c; compatible within uncertainties with ATLAS and CMS measurements in the common p_T range

Charmonium Polarization

ALICE, PRL 131 (2023) 4, 042303



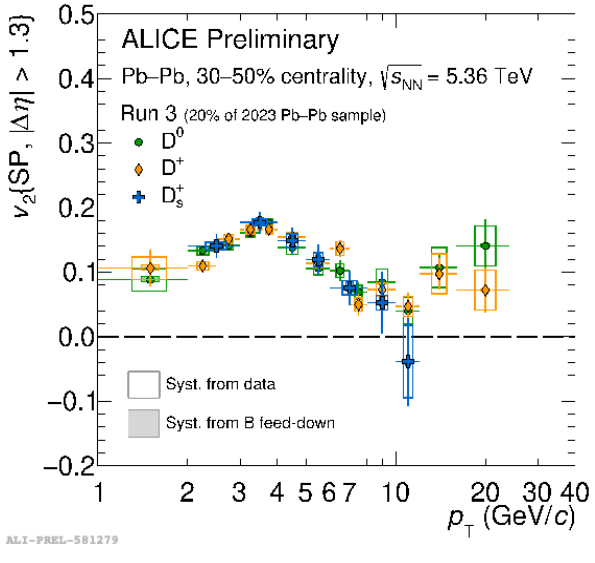


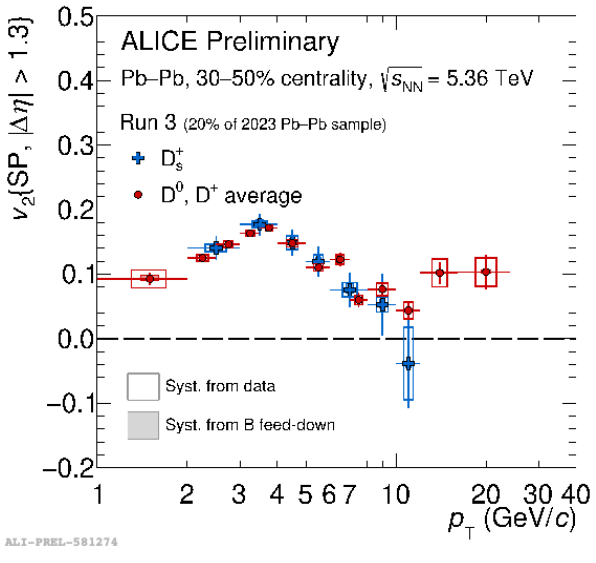
$$W(\cos\theta,\phi) \propto \frac{1}{3+\lambda_\theta} \cdot \left(1+\lambda_\theta \cos^2\theta + \cdots\right)$$

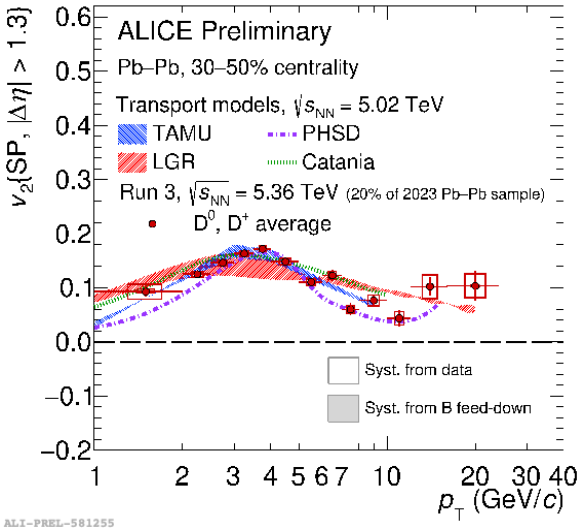
- First measurement of quarkonium polarization **w.r.t the event plane**
- Significant polarization (**~3.9σ**) observed in semicentral collisions
- Polarization measurements are ongoing at midrapidity with Run 3 data

Strange and non-strange D-mesons elliptic flow

New Preliminary





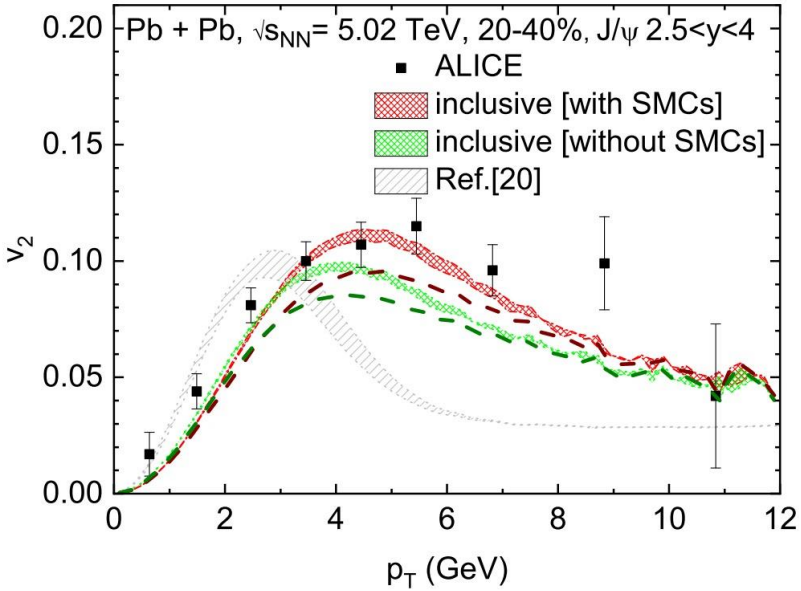


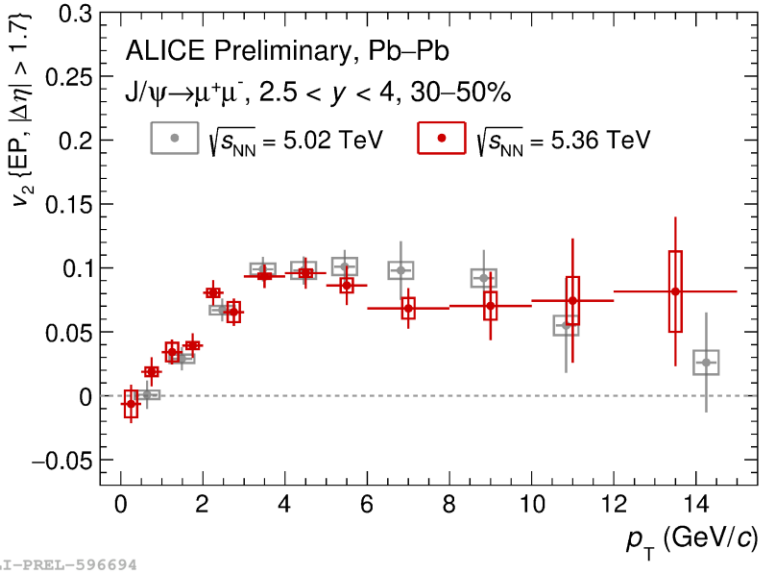
- Prompt D-meson v_2 measured using Run 3 Pb–Pb data sample
  - No significant difference between strange and non-strange D mesons
  - Strange D-meson elliptic flow reproduced by the transport models

$$\frac{dN}{d\phi} \propto 1 + 2\sum^{\infty} v_n \cos\left[n\left(\phi - \Psi_n\right)\right]$$

Charmonium elliptic flow in Run 3

New Preliminary





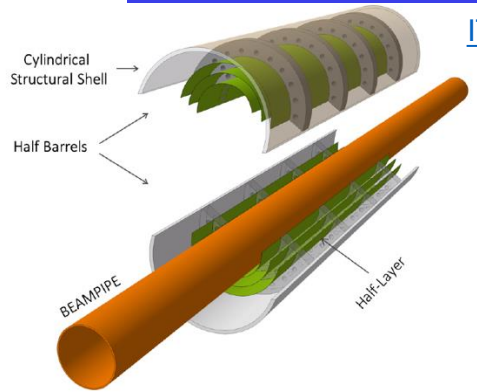
M. He, et al., PRL.128, 162301 (2022)

- The new result at forward rapidity is consistent with Run 2 measurement: statistical precision improved at low p_T
- A significant J/ψ v_2 is observed at forward rapidity, consistent with significant charm quark thermalization

Upgrading the ALICE detector (RUN 4)

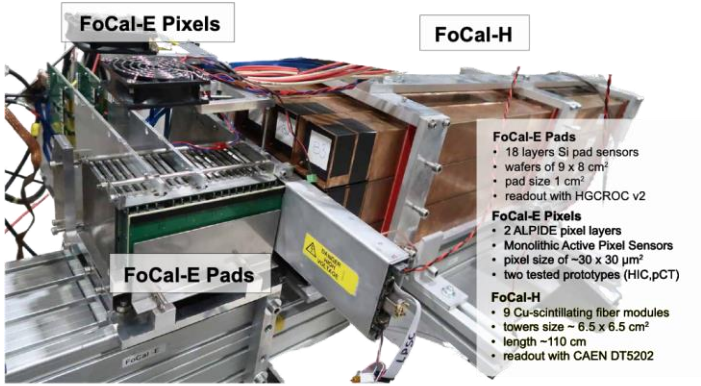
ITS upgrades: ITS 3

ITS 3 TDR



- Replacing the ITS2 inner lightweight "silicon-dominated" layers
- Innermost radius 19 mm, x2 improvement in pointing resolution
- **Improve the measurements of heavy flavor and dielectrons at midrapidity**

New detector Focal FoCal



- FoCal-E calorimeter: High-granularity Si-W, FoCal-H: Cu-scintillator
- Direct photons, π^0, jets at forward rapidity
- **Unexplored regions of small-x and low Q^2 gluons**

LHC LS2	LHC RUN 3	LHC LS3	LHC RUN 4	LHC LS4	LHC RUN 5 and RUN 6
2019-2021	2022-2026	2026-2029	2030-2033	2034-2035	2036-2041

Summary

- Significant improvement in Run 3 for several ALICE heavy-flavour measurements thanks to the detector upgrade
- Significant non-zero polarization and v_2 are observed for charm mesons
- Dominant contribution from (re-)generation for J/ψ at low p_T in central Pb–Pb collisions at LHC