

Recent open heavy flavor and charmonium measurements from ALICE experiment

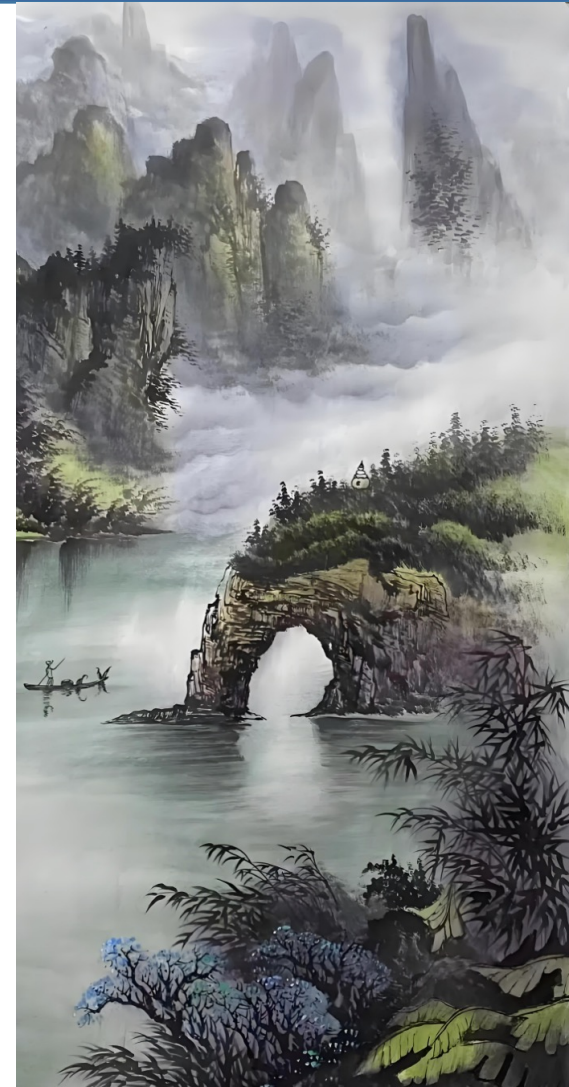
Yifei Zhang

University of Science and Technology of China



Guilin, a beautiful city with such charming landscape!

October 26, 2025



Outline

- ✧ **Introduction**
- ✧ **HF production in pp collisions**
- ✧ **HF production in Pb-Pb collisions**
- ✧ **Summary and outlook**

Outline

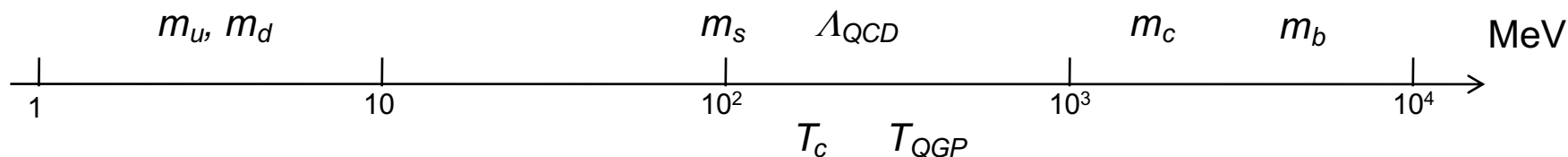
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Introduction

◆ pp collisions:

Key features: Produced early in the history of HIC / Calculable by pQCD

Observables: Cross sections / Hadronisation / Baseline for HIC ...



perturbative QCD:

$$\sigma^{pp \rightarrow Q\bar{Q}} = \int_0^1 dx_1 dx_2 \sum_{i,j} f_i(x_1, Q^2) f_j(x_2, Q^2) \sigma^{ij \rightarrow Q\bar{Q}}(x_1, x_2, Q^2)$$

Nucl. Phys. B263 (1986) 37.

Nucl. Phys. B151 (1979) 429.

Introduction

✧ pp collisions:

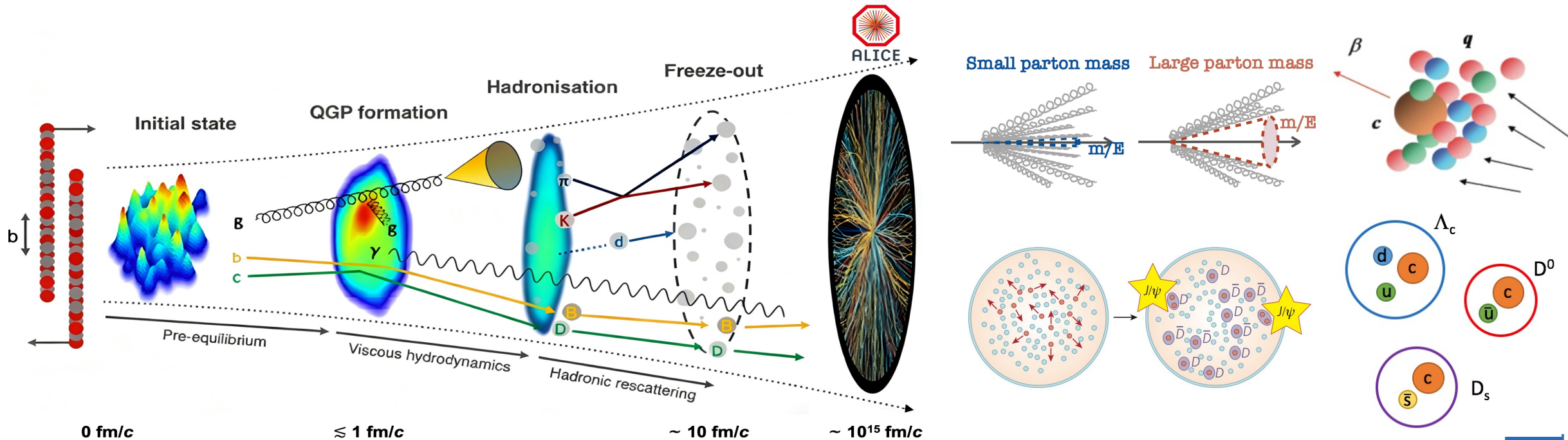
Key features: Produced early in the history of HIC / Calculable by pQCD

Observables: Cross sections / Hadronisation / Baseline for HIC ...

✧ Pb-Pb collisions:

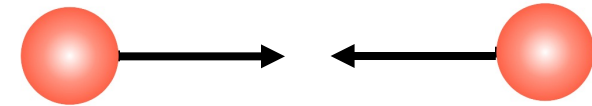
Key features: Witness of the system evolution / Sensitive to medium properties

Observables: Energy loss / Flow / Hadronisation / Polarization ...



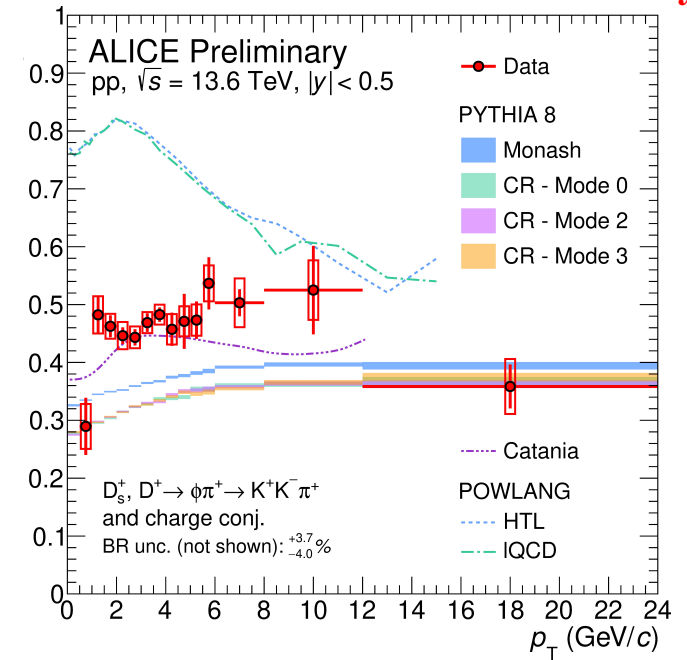
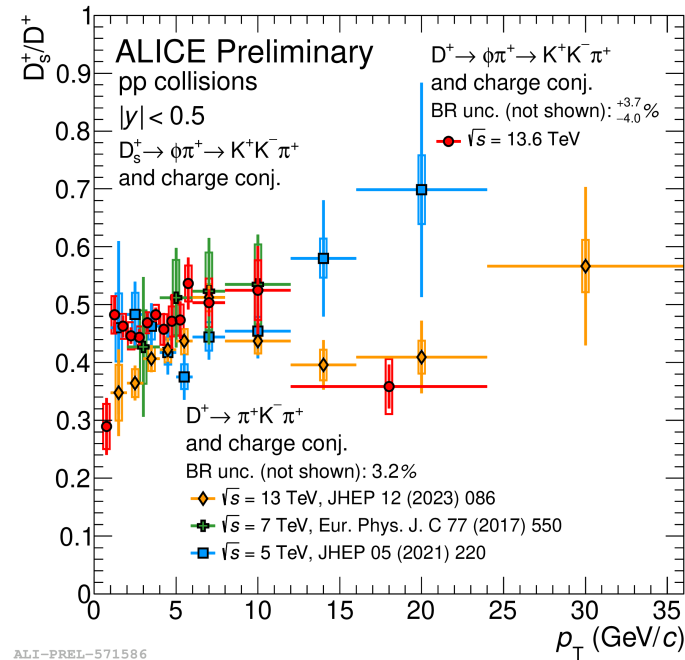
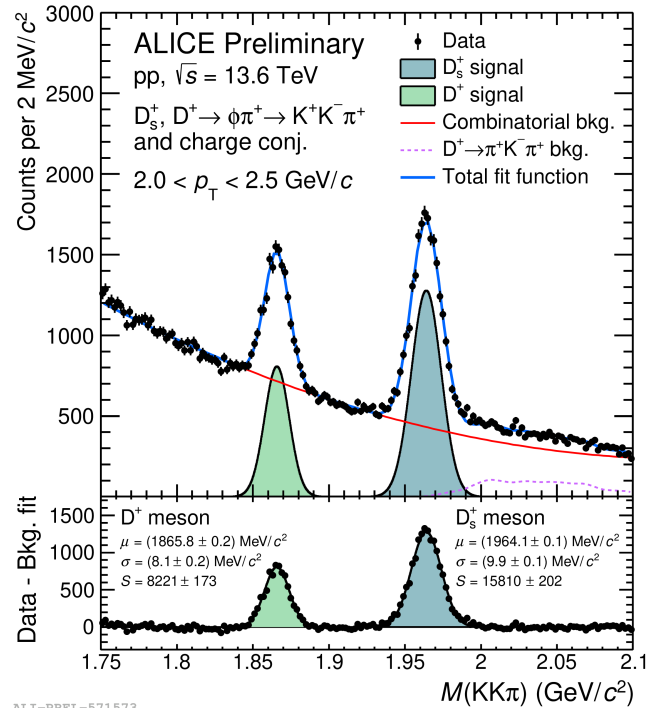
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Prompt D_s^+ and D^+ in pp collisions at $\sqrt{s} = 13.6$ TeV

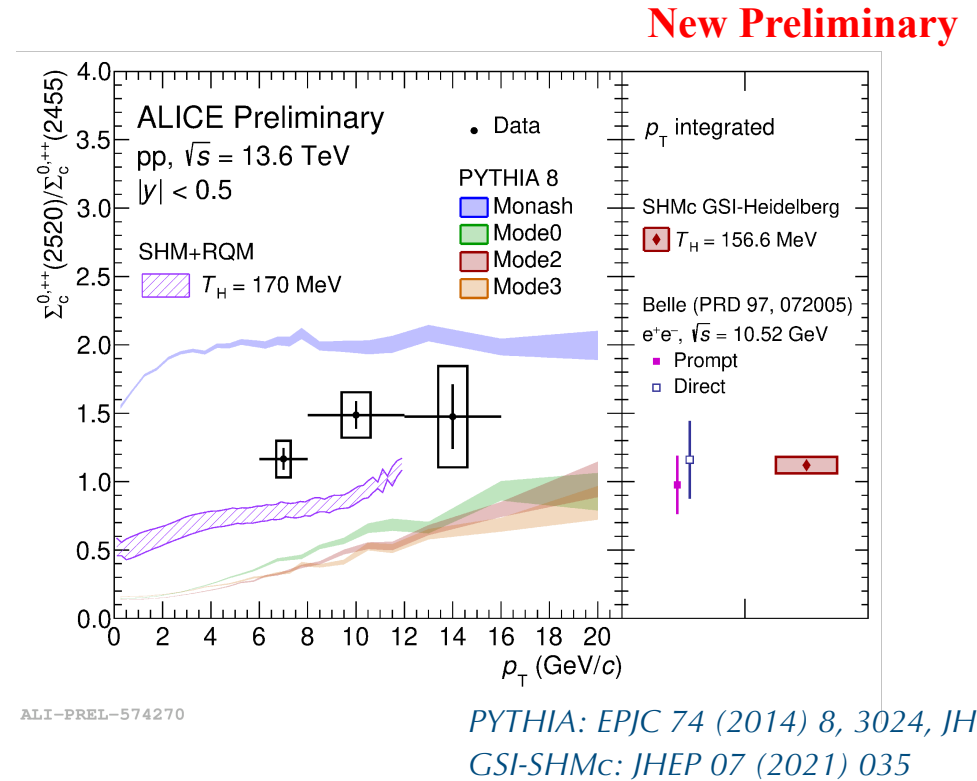
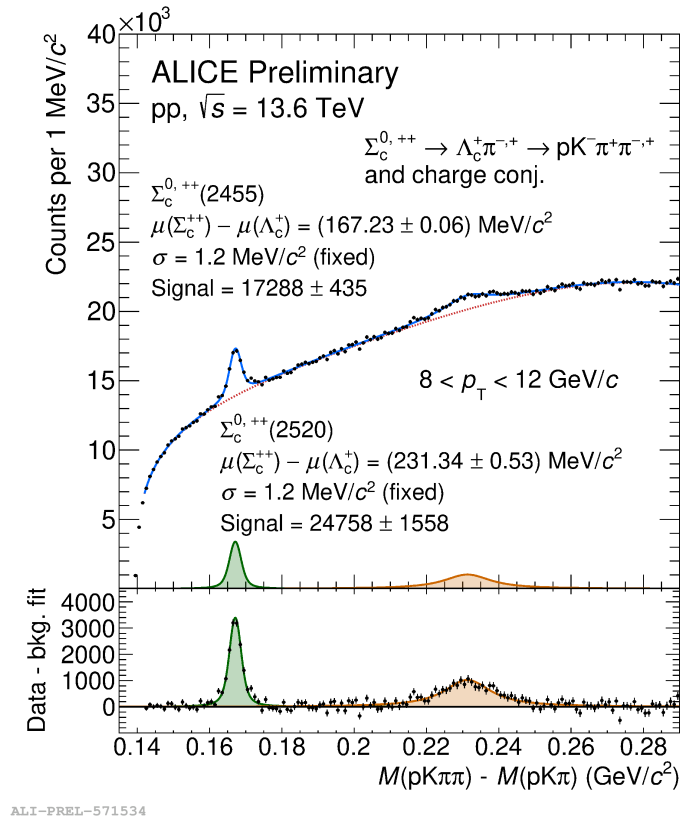
New Preliminary



Catania: PLB 821 (2021) 136622
POWLANG: PRD 109, L011501

- First measurement in pp collisions at $\sqrt{s} = 13.6$ TeV down to $p_T = 0$
- Improved precision for strangeness production in charm sector in small system.
- No obvious collision energy dependence observed.
- Catania (coalescence) gives best description, while POWLANG (local color recombination) and PYTHIA (string fragmentation) can not describe the data

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

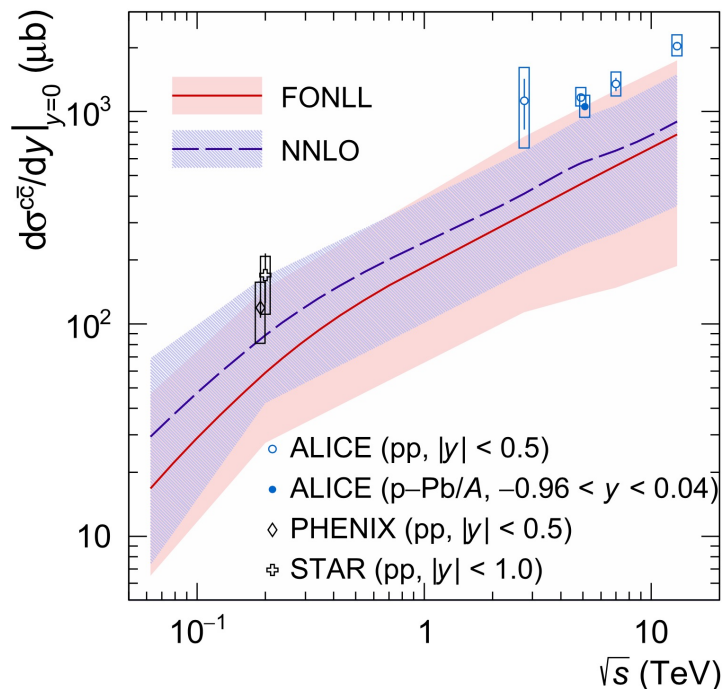


- ✦ First measurement of $\Sigma_c^{0,++}(2520)$ relative to $\Sigma_c^{0,++}(2455)$ in pp collisions at $\sqrt{s} = 13.6$ TeV
- ✦ No obvious difference w.r.t. e^+e^- collisions (Belle) within uncertainties
- ✦ PYTHIA 8 Monash (default tune) overestimates the ratio, PYTHIA 8 with additional color reconnection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

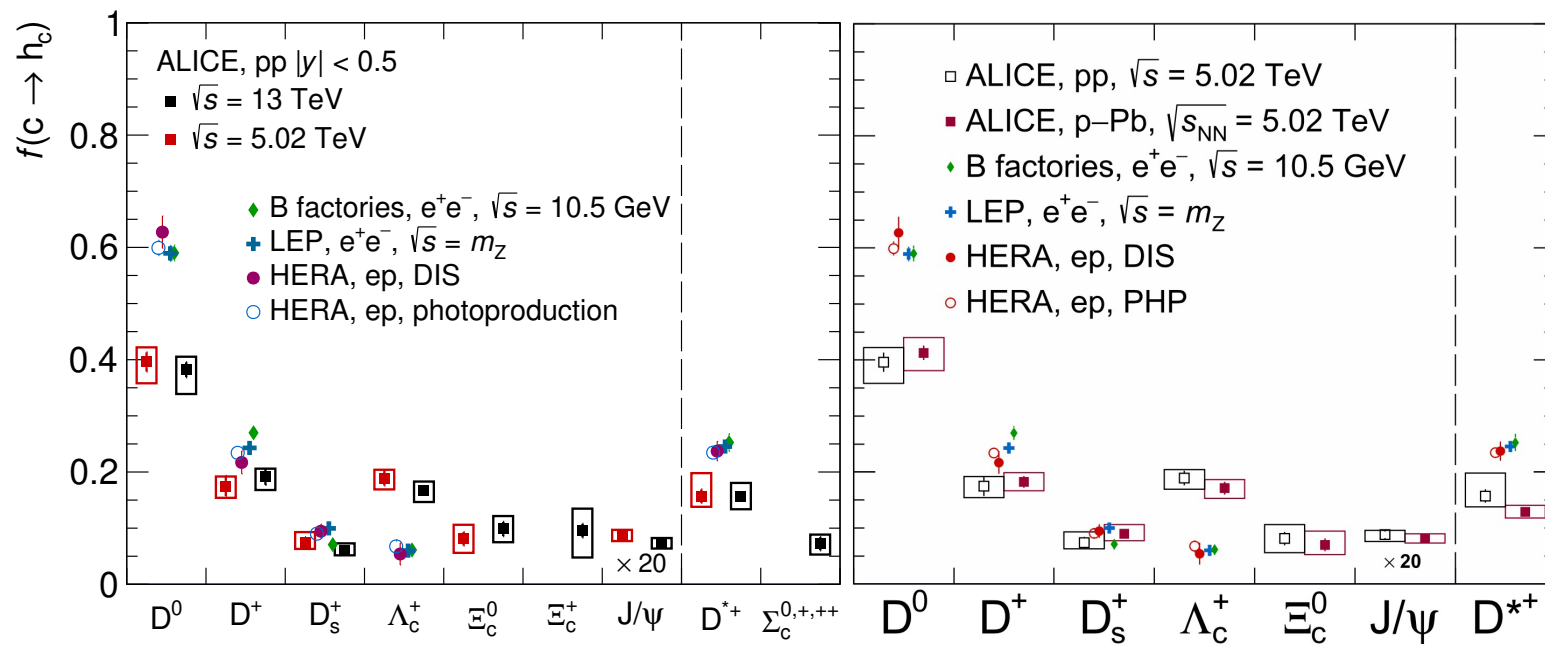
Charm production and fragmentation fractions

ALICE, EPJC 84 (2024) 1286

FONLL: JHEP 05 (1998) 007



ALICE, JHEP 12 (2023) 086

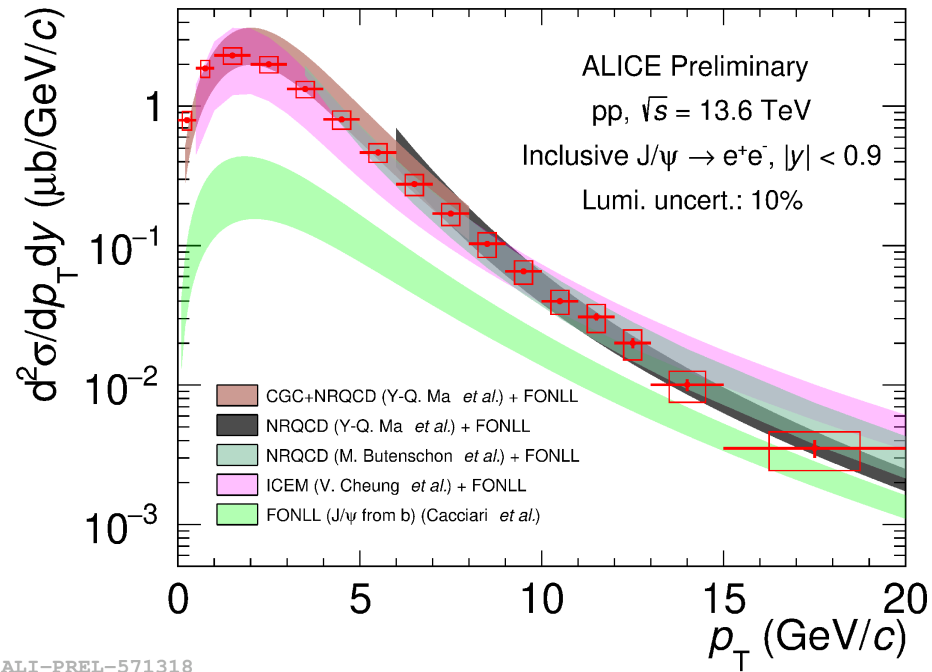


Total charm production cross section: consistent with FONLL upper limit at midrapidity.

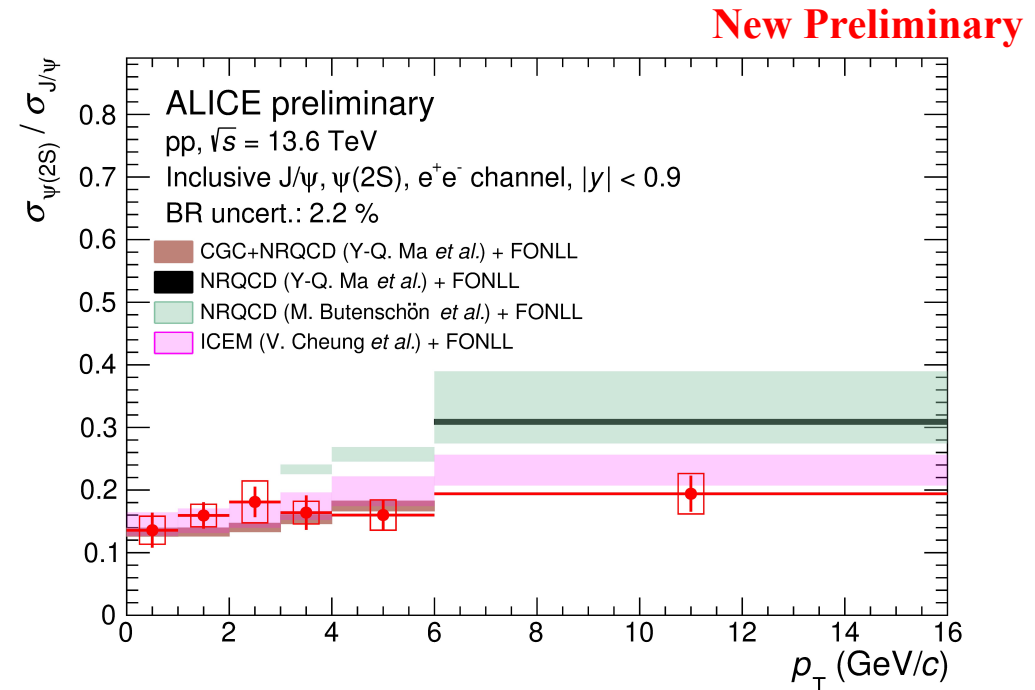
Charm fragmentation fractions:

- ✧ No obvious collision energy dependence.
- ✧ Data from pp and p-Pb collisions are consistent within uncertainties.
- ✧ **Different** w.r.t e^+e^- and ep collisions. **Baryon enhancement in small system** not fully understood.

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



ALI-PREL-571318



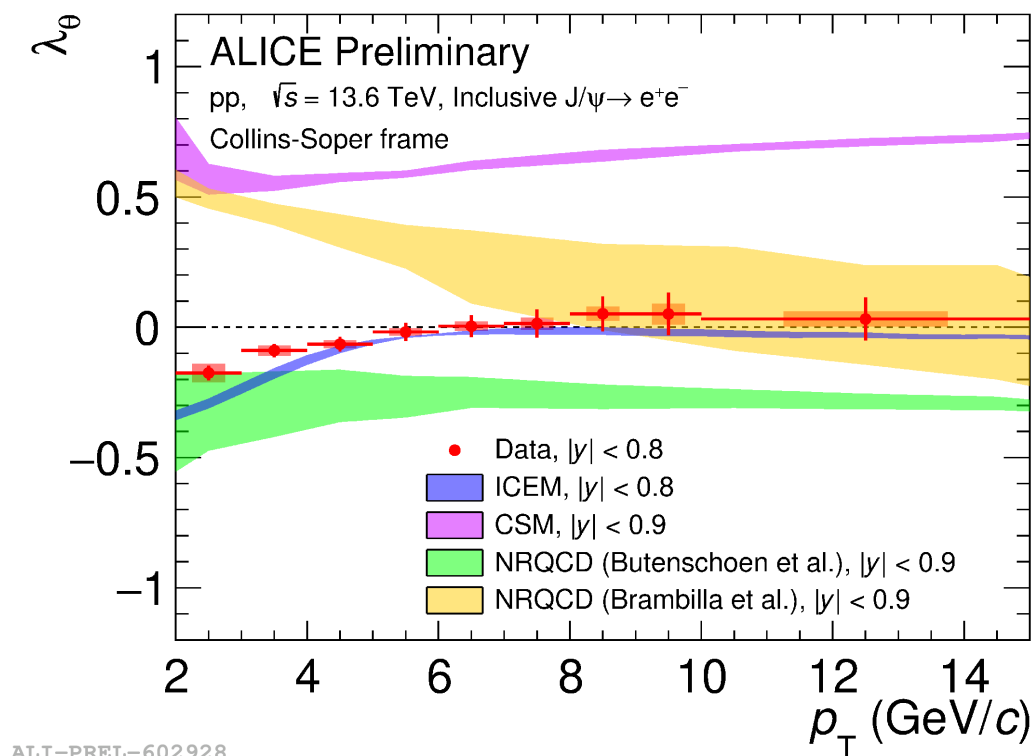
ICEM: Y.-Q. Ma *et al.*, PRD 94 (2016) 114029

NRQCD: B. A. Kniehl, *et al.*, PRD 73 (2006) 074022

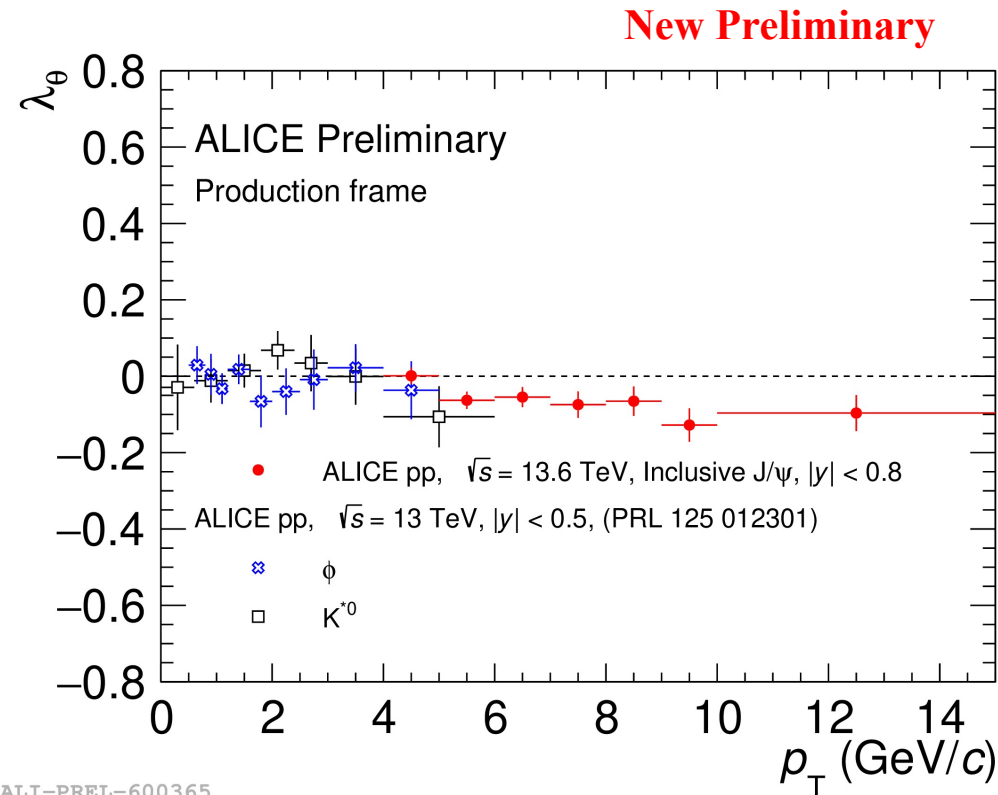
- ✦ Precision measurements of J/ψ and $\psi(2S)$ at midrapidity with significantly higher statistics collected in Run 3.
- ✦ The data are described by ICEM and NRQCD based models coupled with FONLL to account for the non-prompt J/ψ contribution.

See Liang Dong's poster

Charmonium polarization in pp collisions



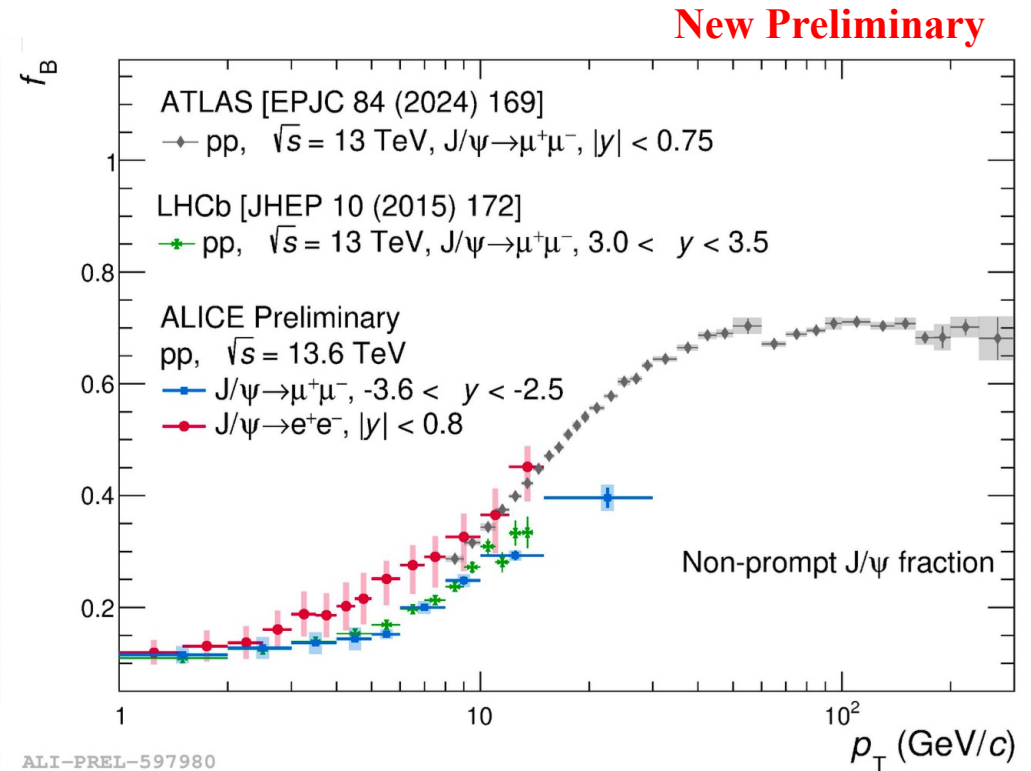
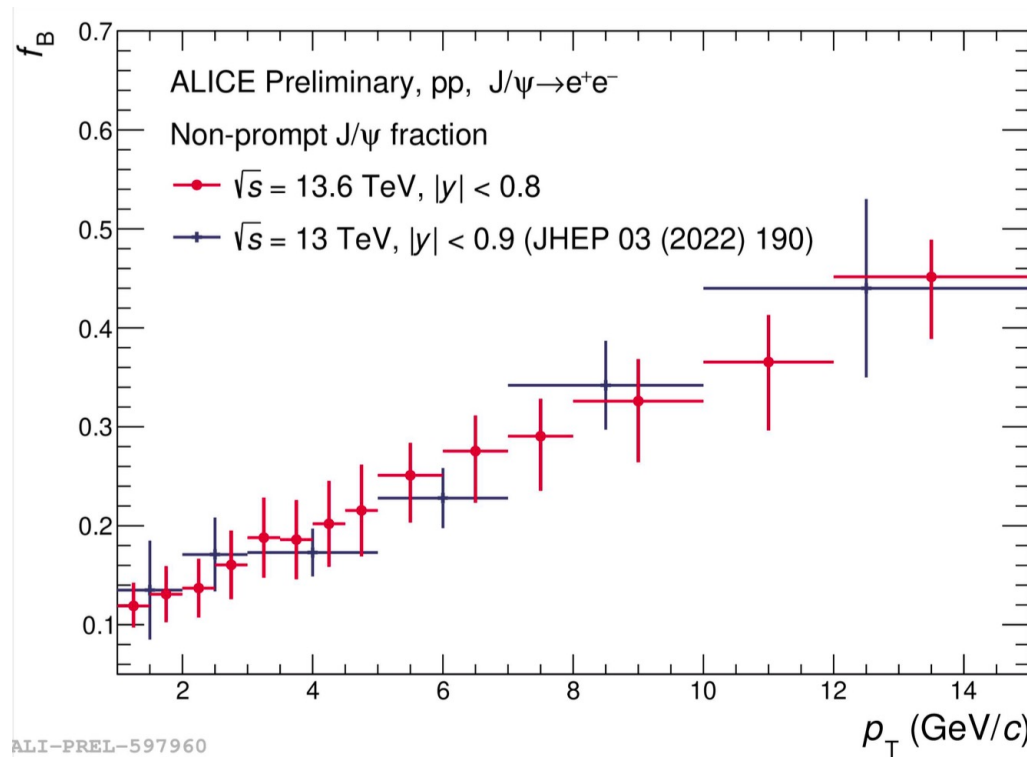
ALI-PREL-602928



ALI-PREL-600365

- ✧ Hint of non-zero signals for CS / Production frame at low / high p_T , respectively.
- ✧ The data can be described by the ICESM calculations.

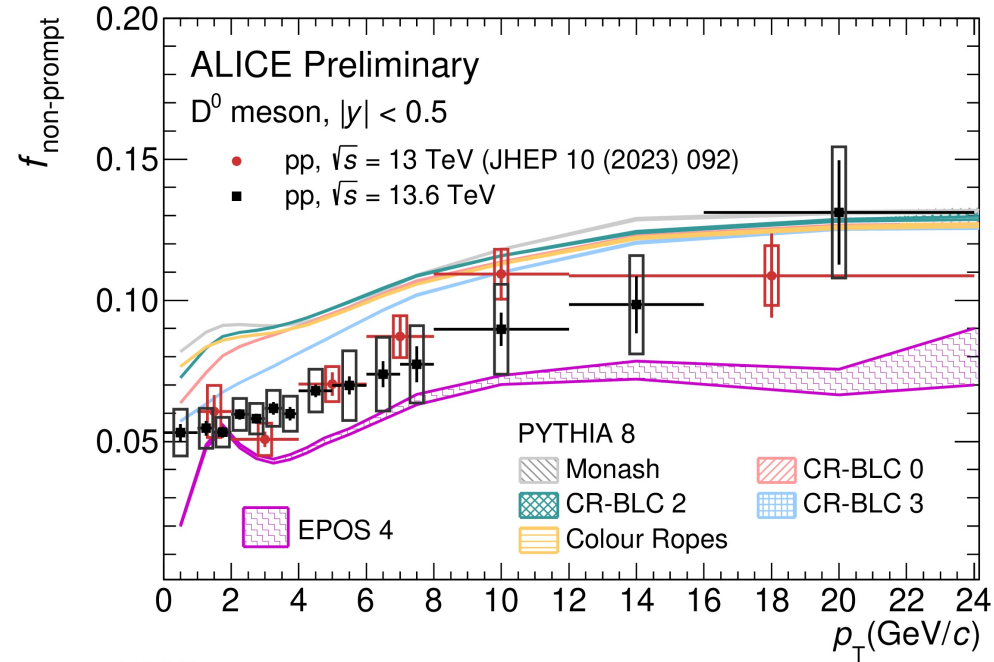
Non-prompt J/ψ in pp collisions



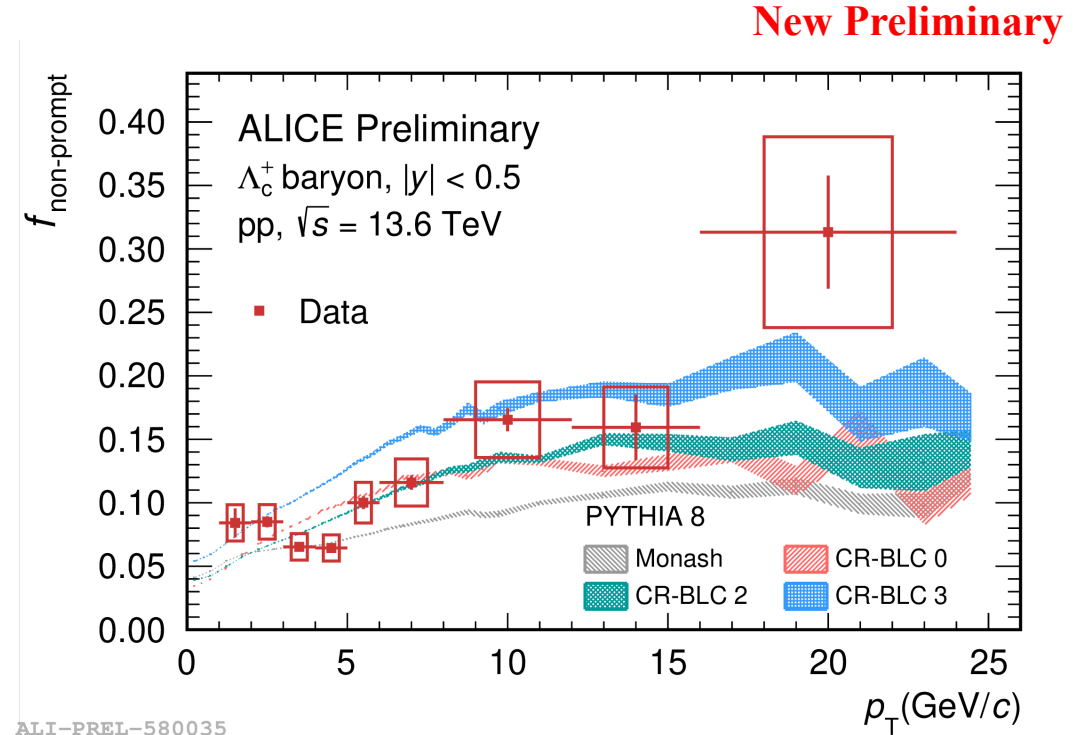
See Liang Dong 's poster

- ✦ Improved statistics from Run 3. Consistent with Run 2 result at midrapidity.
- ✦ Systematically different from forward rapidity at intermediate p_T region.

Non-prompt D^0 and Λ_c^+ in pp collisions



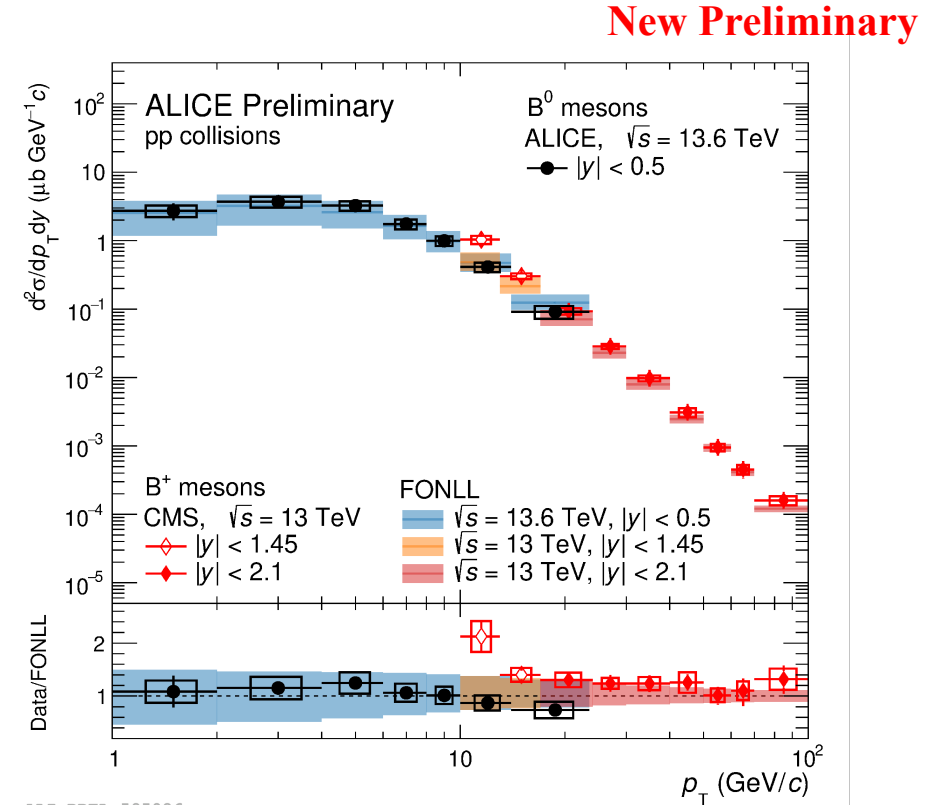
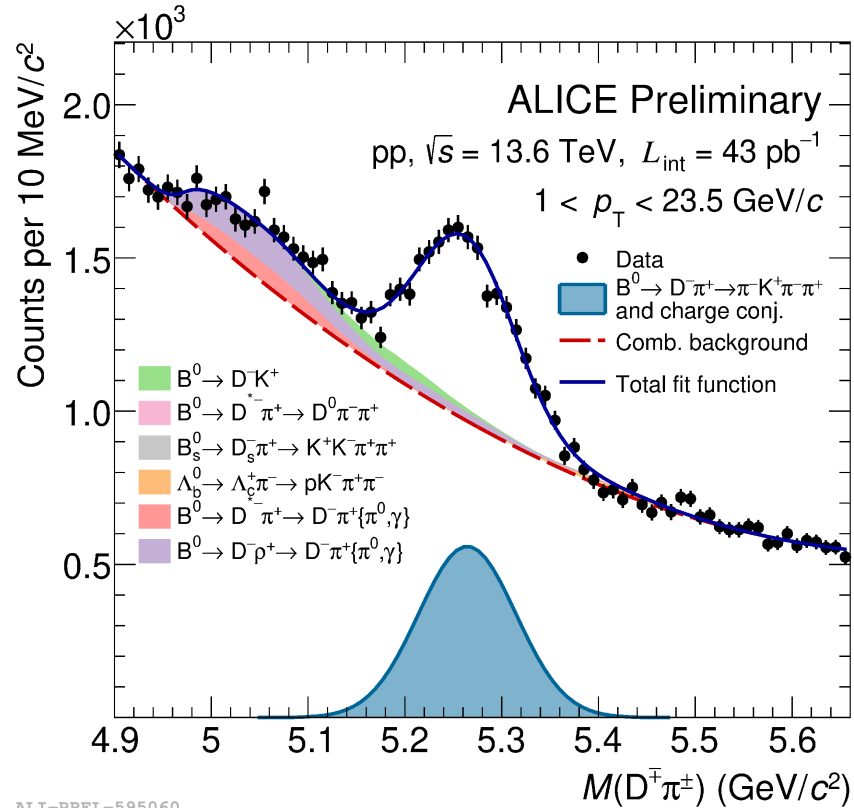
ALI-PREL-571369



ALI-PREL-580035

- ◆ Non-prompt D^0 and Λ_c^+ fractions measured extended down to $p_T = 0$ and 1 GeV/c, respectively
- ◆ Models can not describe D^0 and Λ_c^+ data simultaneously. Pythia color reconnection tuning reproduces Λ_c^+ result better.

Direct B^0 reconstruction in pp collisions

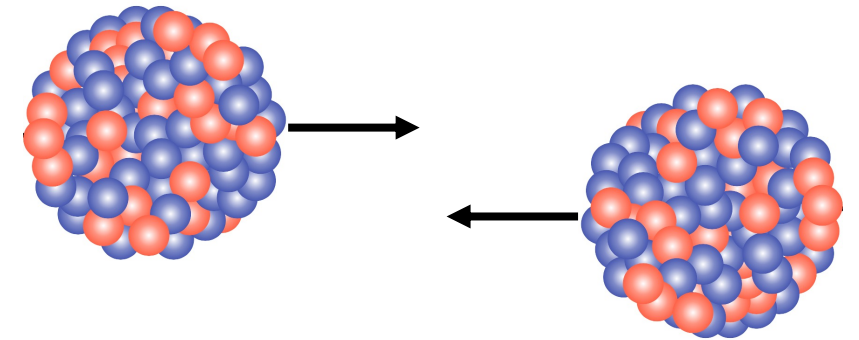


FONLL: JHEP 05 (1998) 007

- ✦ First direct observation of B^0 meson via hadronic decay reconstruction in ALICE
- ✦ New measurement widely extends the CMS result down to $p_T = 1 \text{ GeV}/c$
- ✦ In good agreement with FONLL calculations

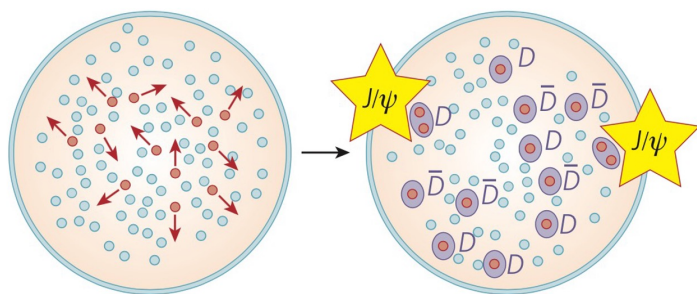
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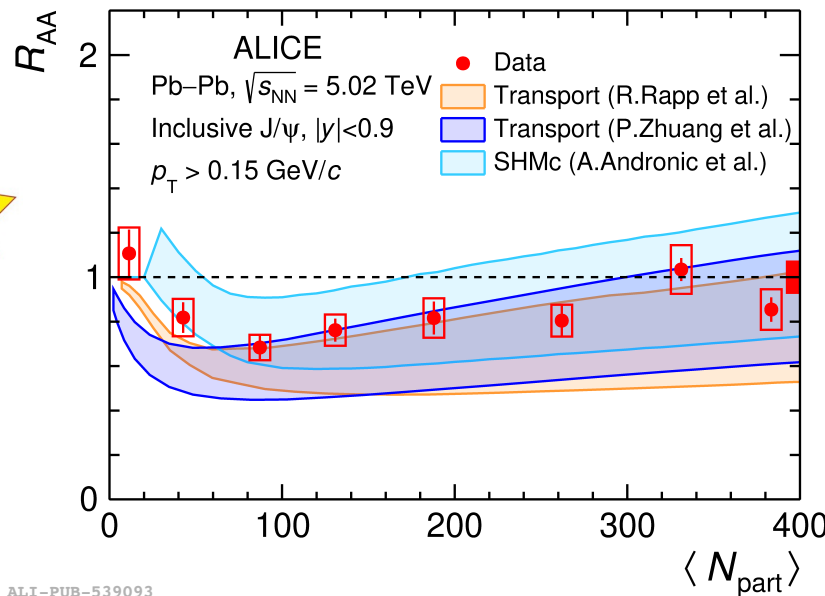


Inclusive J/ψ R_{AA}

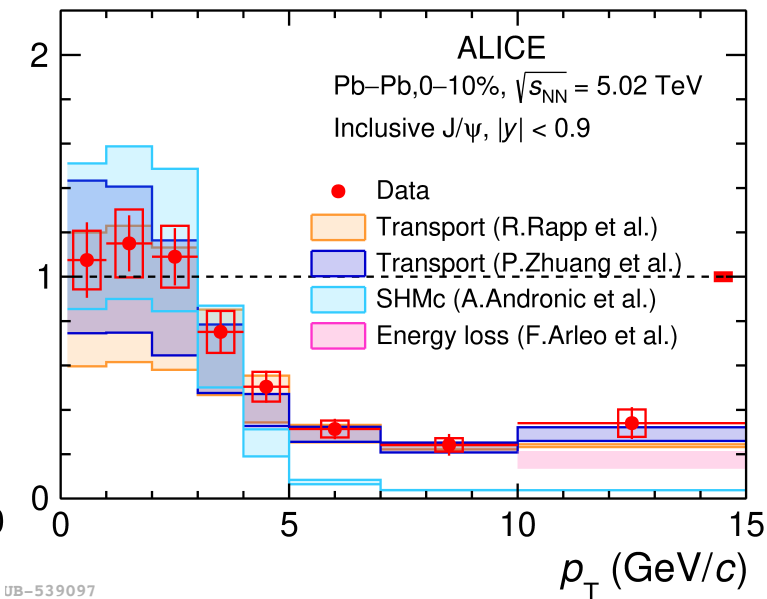
ALICE, PLB 849 (2024) 138451



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



ALI-PUB-539093



UB-539097

Du, X. et al., NPA 943, 147–158 (2015)
Zhou, K., et al., PRC 89, 054911 (2014)
Andronic, A, et al, PLB 797, 134836 (2019)

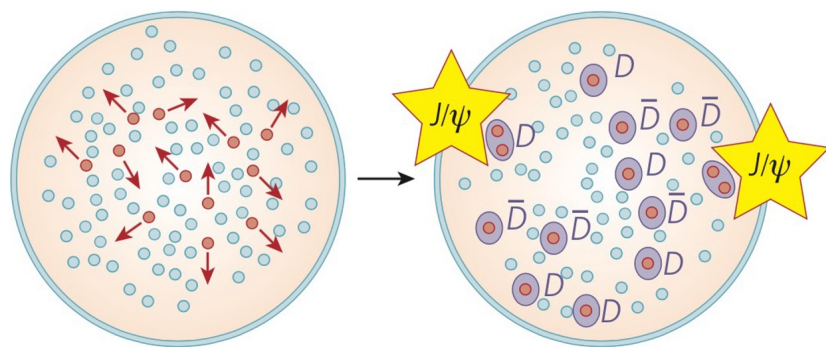
Xiaozhi Bai's talk on Oct. 26

✧ Evidence for J/ψ (re-)generation in central collisions.

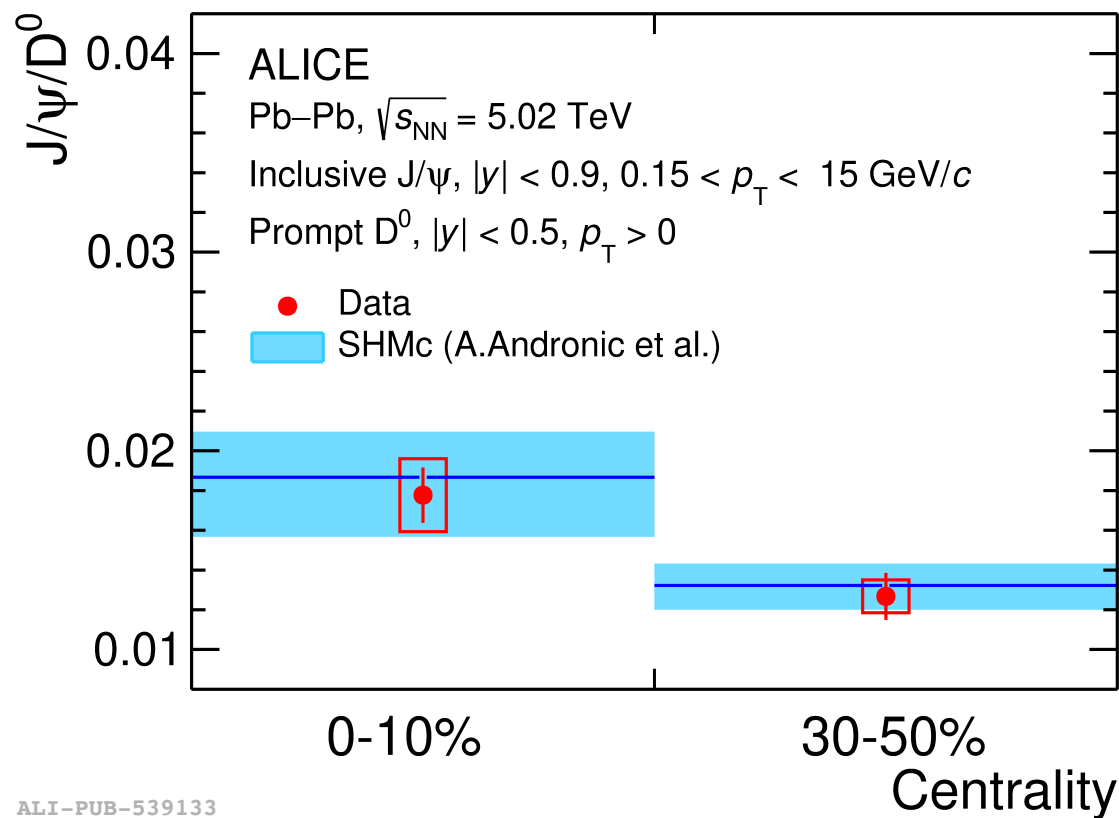
✧ All models can describe the integrated yield but suffer from large uncertainties. Differentially SHMc underestimates data at high p_T .

J/ ψ -to- D^0 ratio in Pb–Pb collisions

ALICE, PLB 849 (2024) 138451



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



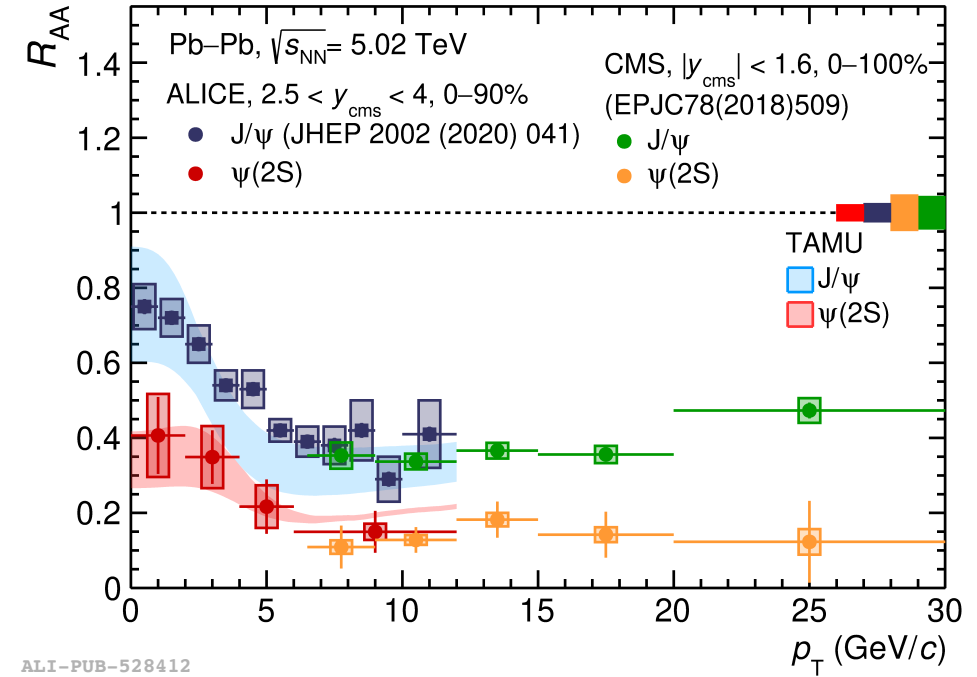
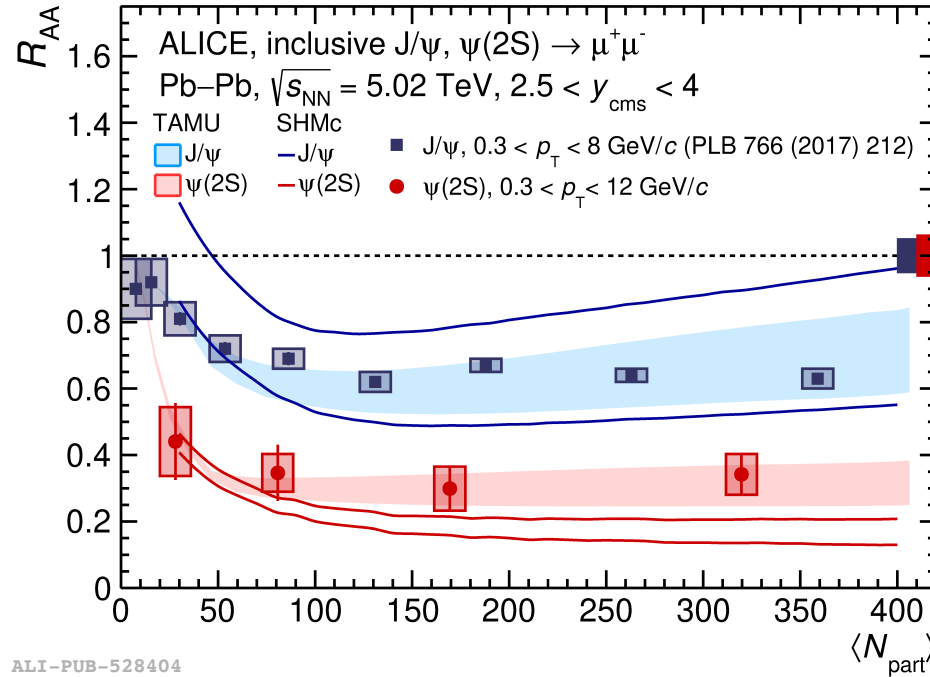
SHMc
Andronic, A, et al,
PLB 797, 134836 (2019)

ALI-PUB-539133

- ✦ Sensitive to hadronization mechanisms for open and hidden charm hadrons
- ✦ The centrality-dependent trend of the J/ ψ to D^0 ratio consistent with SHMc prediction considering the increase of charm abundance towards most central collisions.

Sequential suppression of charmonia R_{AA}

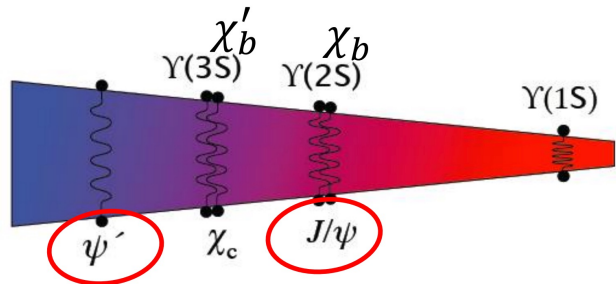
ALICE, PRL 132, 042301(2024)



(TAMU) X. Du, et al., NPA943,147-158(2015)

(SHMc) A. Andronic, et al., PLB797,134836(2019)

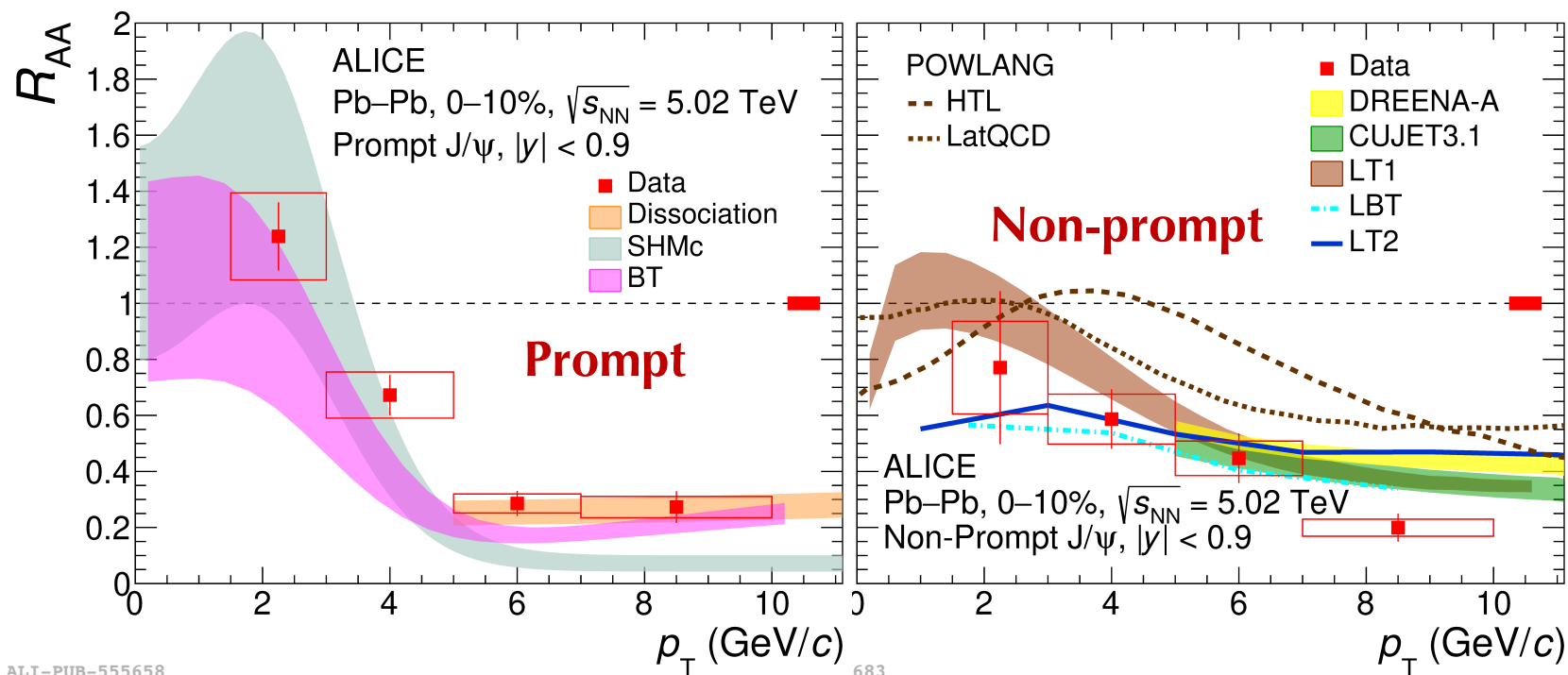
Xiaozhi Bai's talk on Oct. 26



- ✦ A **larger suppression** of the $\psi(2S)$ w.r.t the J/ψ is observed
- ✦ The $\psi(2S)$ R_{AA} increases at low p_T , which is a **hint of $\psi(2S)$ regeneration**
- ✦ The TAMU model describes data better than SHMc in central collisions

Non-prompt and prompt J/ψ R_{AA}

ALICE, JHEP 02 (2024) 066



DREENA-A:

Front. Phys. 10:957019 (2022),

Phys. Rev. C 105, L021901

CUJET3.1: *CPC 43 (2019) 044101*

LT1: *PRC107, 054917(2023)*

LBT: *PLB838(2023) 137733*

LBT2: *EPJC 81 848 (2021) 1035*

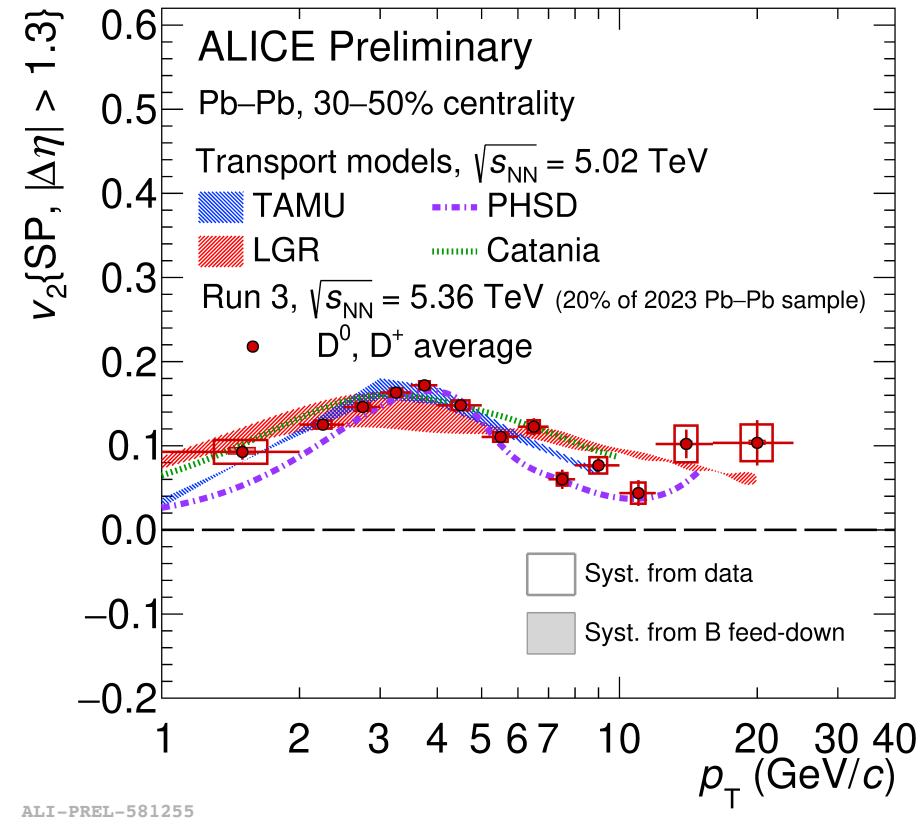
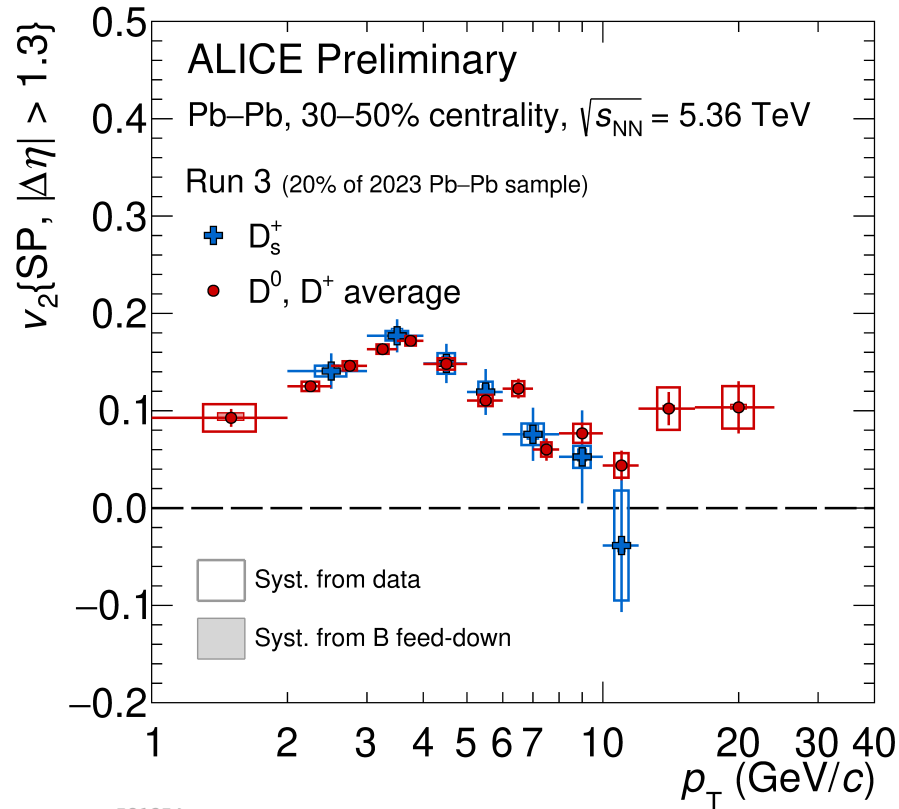
Dissociation: PLB 778 (2018) 384-391

SHMc: *PLB 797 (2019) 134836*

BT: *CPC43 (2019) 124101*

- ✧ The SHMc model and transport microscopic calculations that include a contribution from **regeneration** are compatible with the measured **prompt J/ψ R_{AA} at low p_T**
- ✧ **Non-prompt J/ψ R_{AA}** is described within uncertainties by models implementing **collisional and radiative energy loss** contributions. POWLANG with only collisional contributions, overestimate data.
- ✧ Hint of **no regeneration** contribution of non-prompt J/ψ compared with prompt J/ψ.

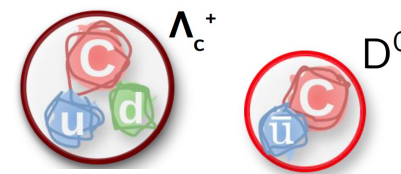
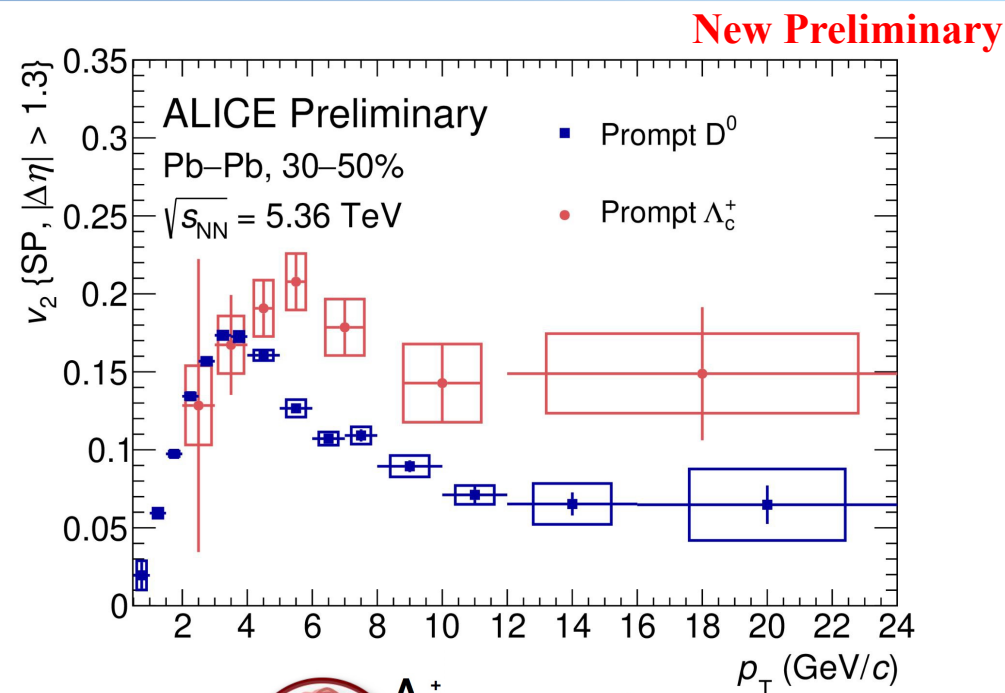
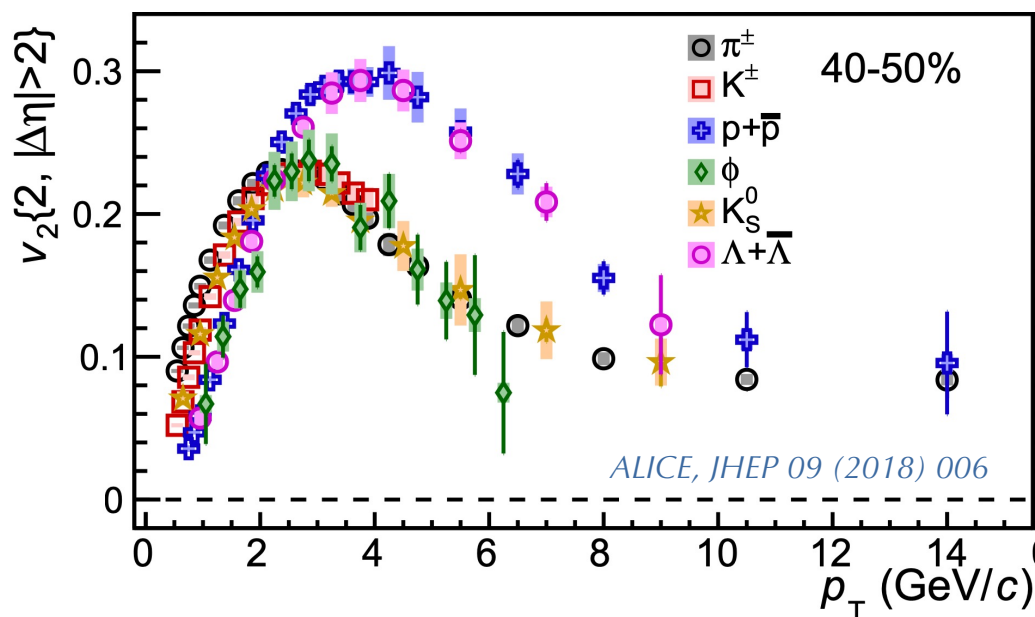
Strange and non-strange D-mesons elliptic flow



Prompt D-meson v_2 measured using Run 3 Pb–Pb data sample

- ✦ No significant difference between strange and non-strange D mesons
- ✦ Data reproduced by the transport models with hydro evolution + coalescence hadronization

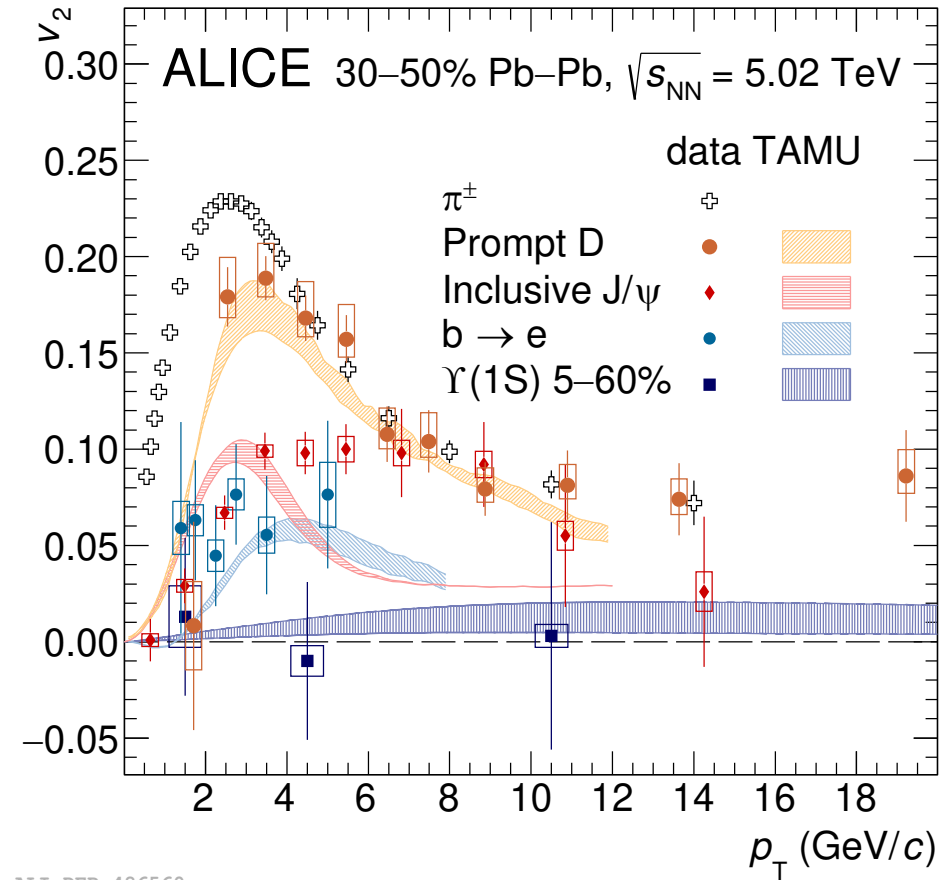
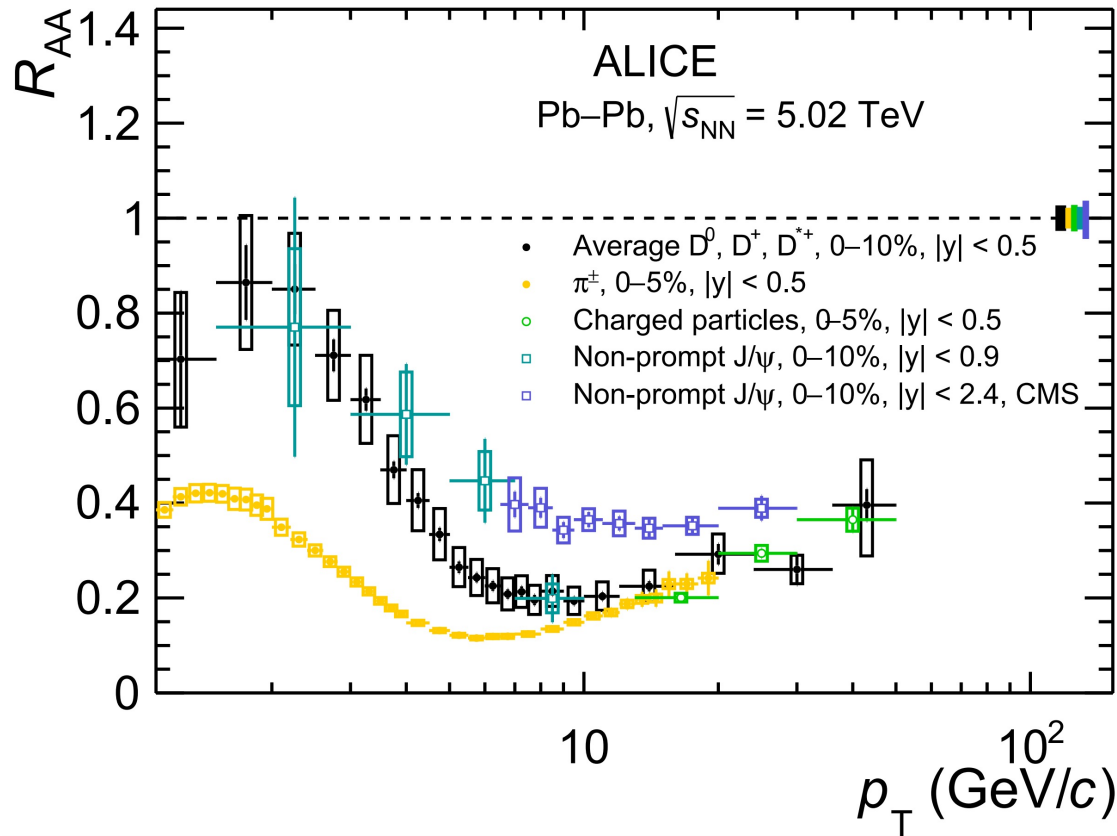
Charm baryon/meson v_2 splitting



Xiaoming Zhang's
talk on Oct. 25

- ✦ First prompt charm-baryon v_2 measurement in heavy-ion collisions
- ✦ Compatible within uncertainties with D^0 in the low p_T , $v_2(\Lambda_c^+) > v_2(D^0)$ with 3.6σ in the intermediate p_T , **evidence of charmed baryon/meson splitting, insensitive to flavors.**

Flavor dependence of R_{AA} and v_2

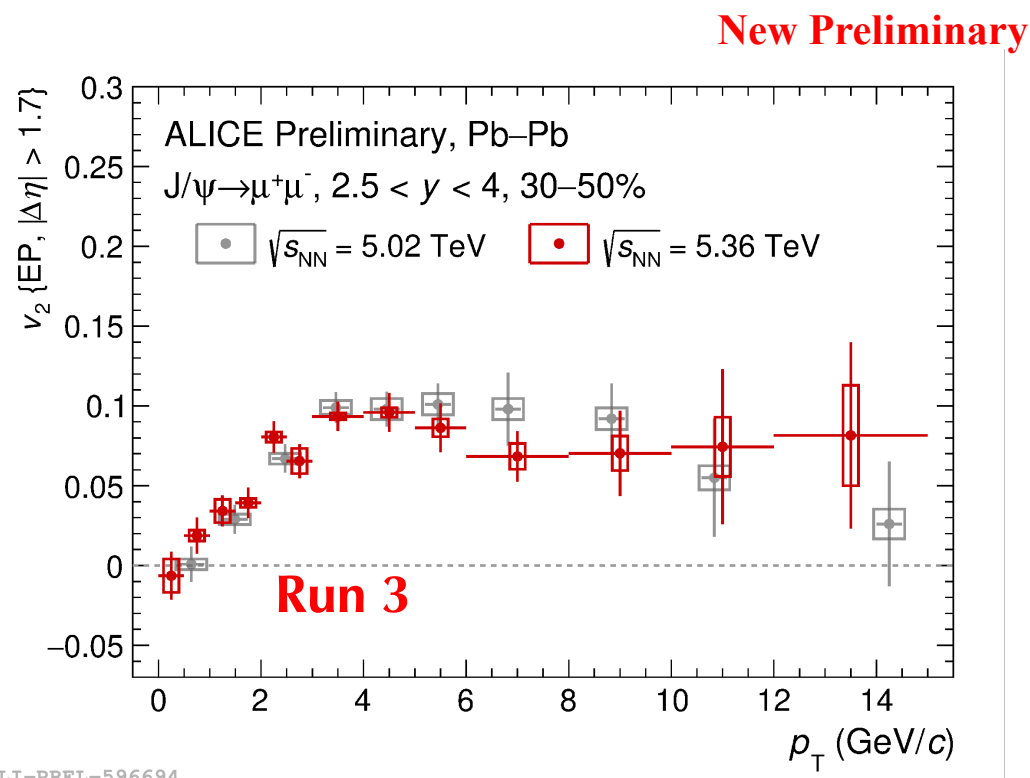
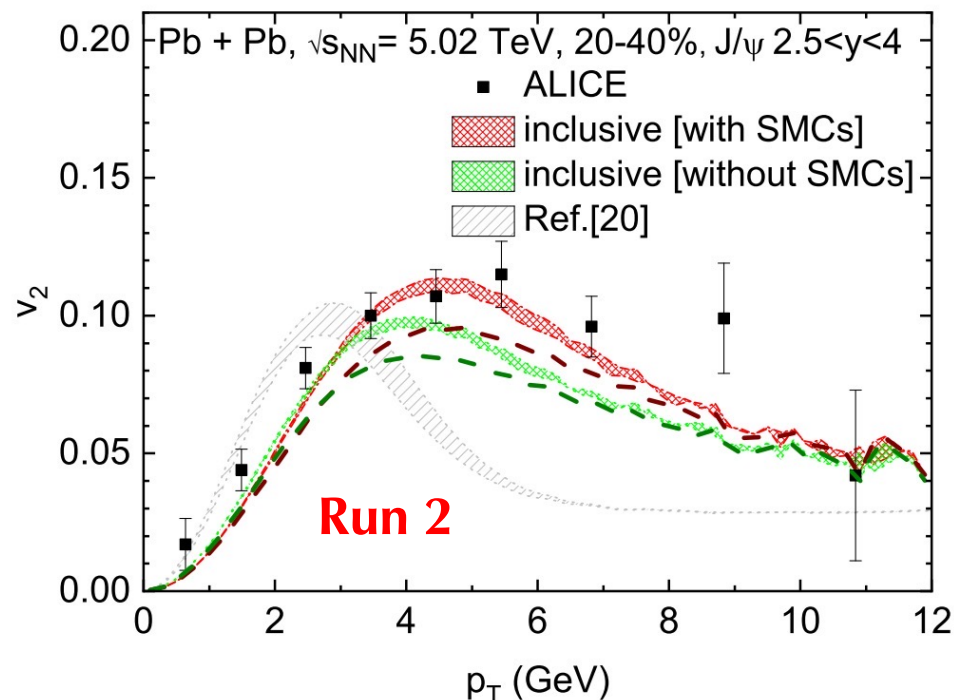


ALI-DER-486560

- ✦ Clear mass/charge dependent energy loss and elliptic flow observed at 5.02 TeV Pb-Pb collisions.
- ✦ Strong coupling with the medium and test thermalization degree with different quark mass.

Inclusive J/ψ elliptic flow

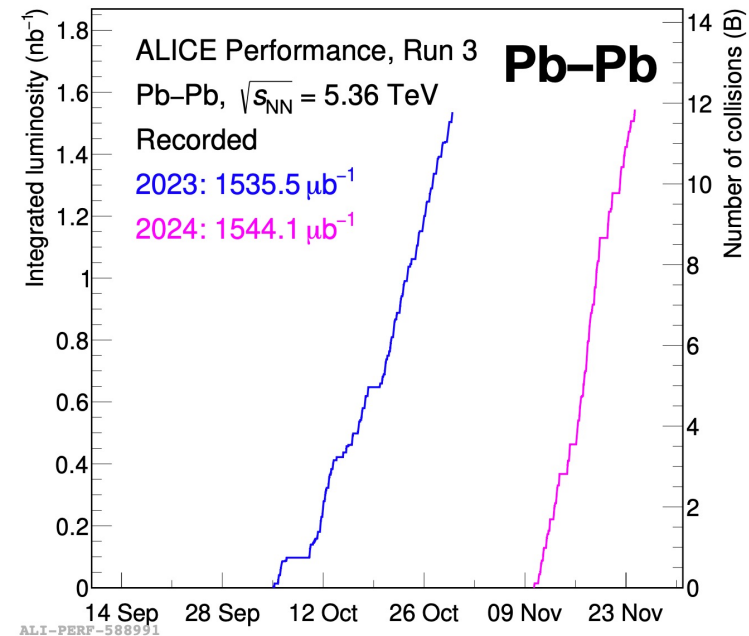
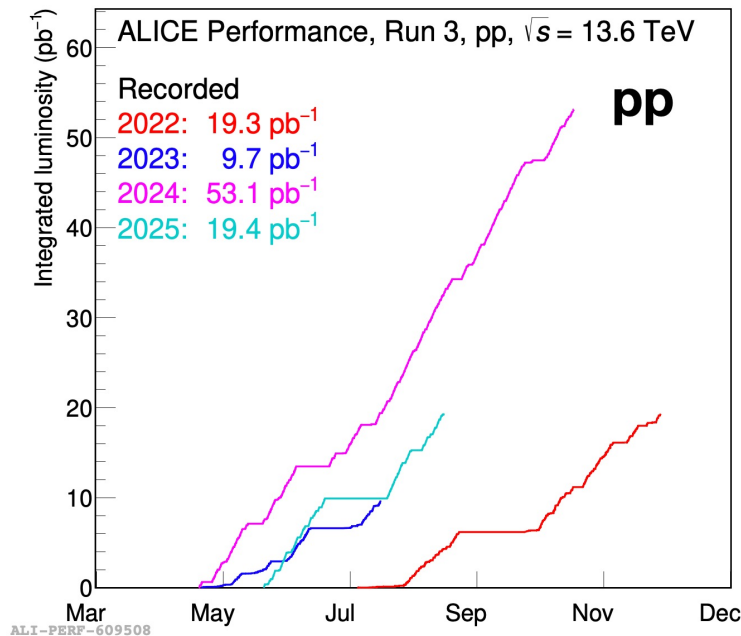
Model: M. He, et al., PRL.128, 162301 (2022)



- ✧ 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, how it is built up need further understanding.
- ✧ Resonance recombination model + SMC describes data, can it also explain result at mid-rapidity?

Summary and outlook

- Some new results with significantly improved precision of OHF and charmonium measurements in pp and Pb-Pb collisions have been achieved.
- We expect more anticipated results coming soon from Run 3 pp (Pb-Pb) data with x1600 (x70) more statistics than Run 1+2.



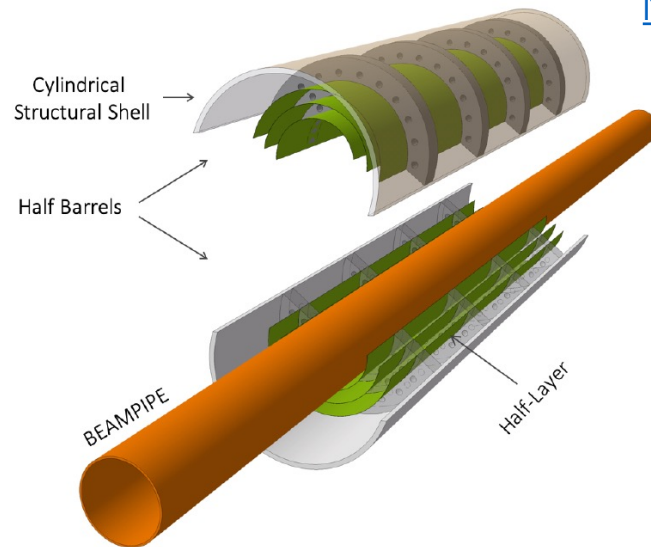
Upgrading the ALICE detector (RUN 4)

LHC LS-3 2026 – 2029

LHC Run4 2030 – 2033

ITS upgrades: ITS 3

[ITS 3 TDR](#)

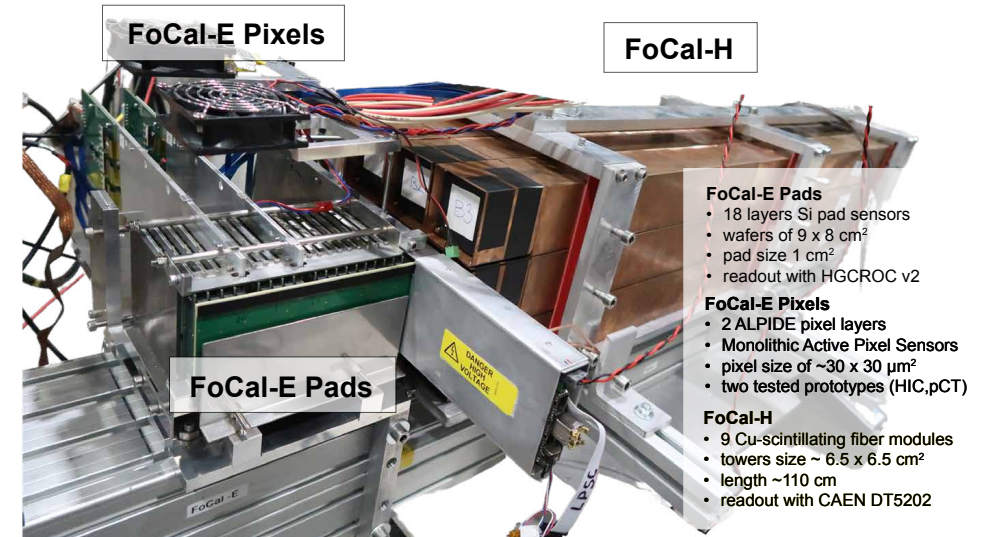


Wafer-scale, ultra-thin, truly cylindrical pixel sensors with minimum material budget.

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 Pads**
 - 18 layers Si pad sensors
 - wafers of 9 x 8 cm²
 - pad size 1 cm²
 - readout with HGCROC v2
- FoCal-E Pixels**
 - 2 ALPIDE pixel layers
 - Monolithic Active Pixel Sensors
 - pixel size of ~30 x 30 μm^2
 - two tested prototypes (HIC, pCT)
- FoCal-H**
 - 9 Cu-scintillating fiber modules
 - towers size ~ 6.5 x 6.5 cm²
 - length ~110 cm
 - readout with CAEN DT5202

FoCal-E calorimeter: High-granularity Si-W, FoCal-H: Cu-scintillator

Electron/photons, π^0 , jets at forward rapidity

Unexplored regions of small-x and low Q^2 gluons

Expect better signals for HF

Wenbin Zhao's talk on Oct. 25



桂林山水甲天下
碧玉罗裙青可参

Guilin's landscape tops the world
Its emerald jade and silken blues like **charm** and
beauty invite contemplation and wonder.