Recent heavy flavor measurements at CMS

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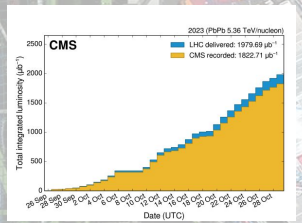
Indian Institute of Technology Madras

(On behalf of CMS collaboration)

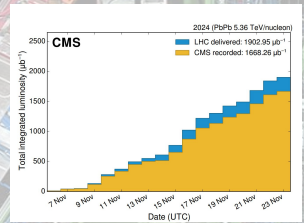
The 9th International Symposium on Heavy Flavor Production in Hadron and Nuclear Collisions

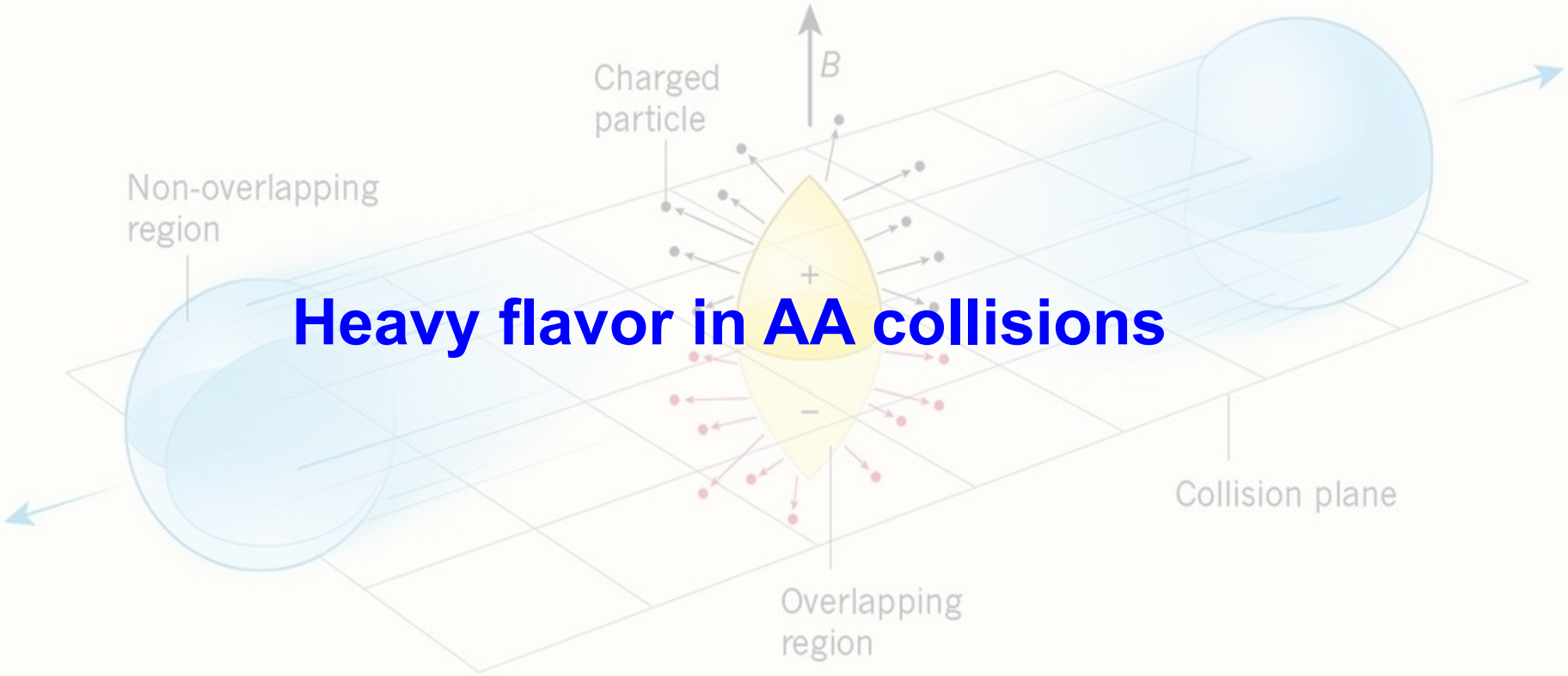
|6-11 December 2024 | Guangzhu, China |

Road map: Past, Present and Future



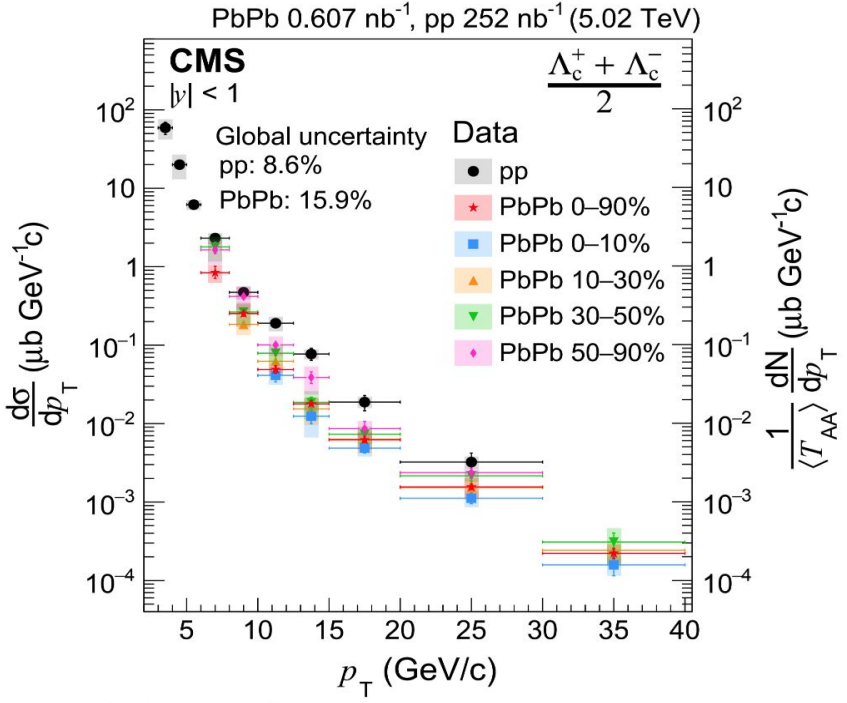
- ➔ Just arrived 2023+2024 (3.49 nb^{-1}) Run3 PbPb
- ➔ (2023+2024) PbPb ~ x6 Run2 PbPb MB events
- ➔ Great success of HI analyses with Run2 data.

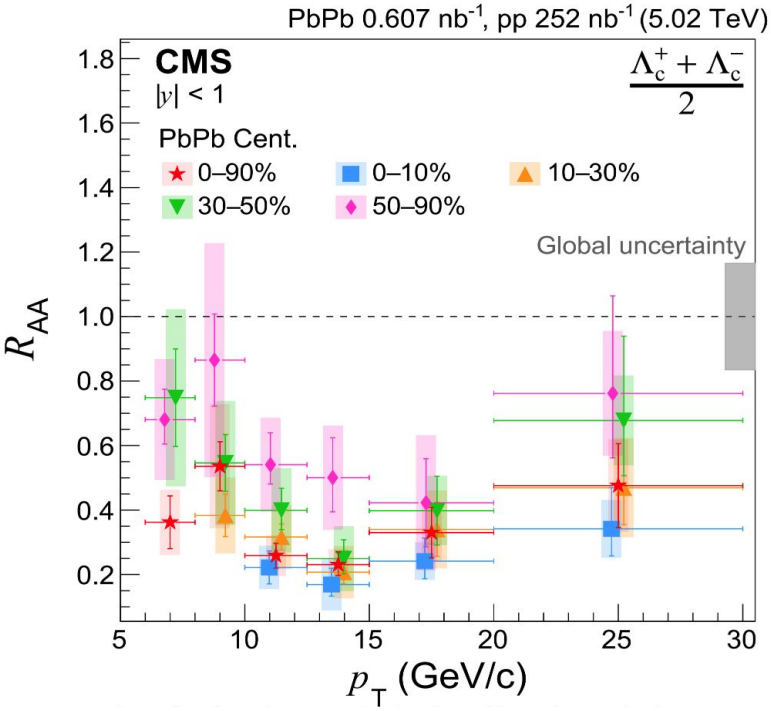




Heavy flavor in AA collisions

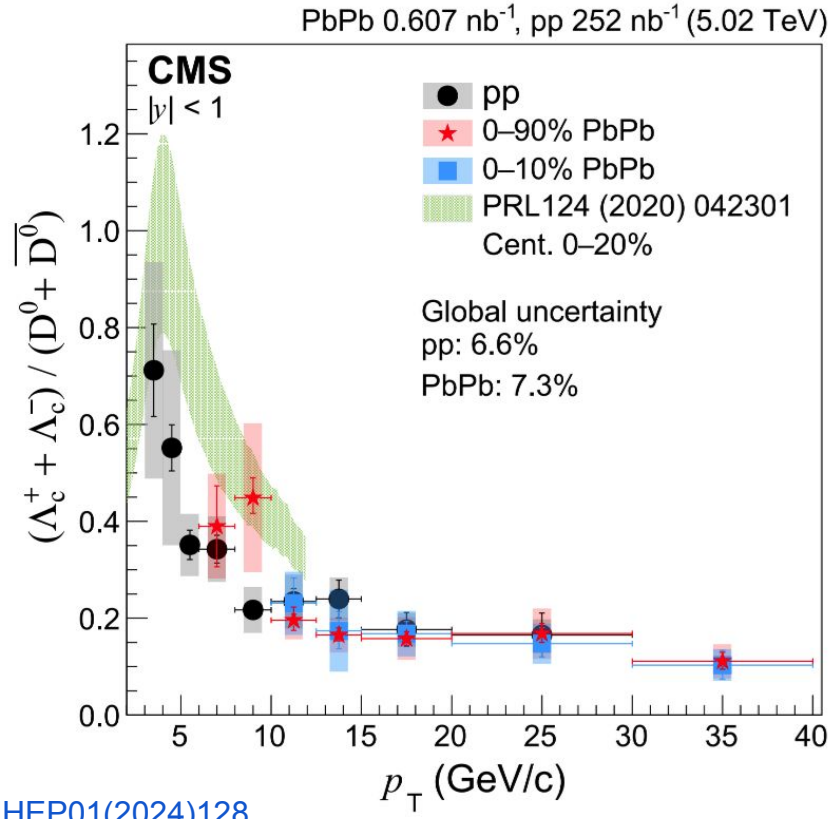
Production and R_{AA} of Λ_C





❖ **Significant suppression of Λ_c from central to peripheral** JHEP01(2024)128

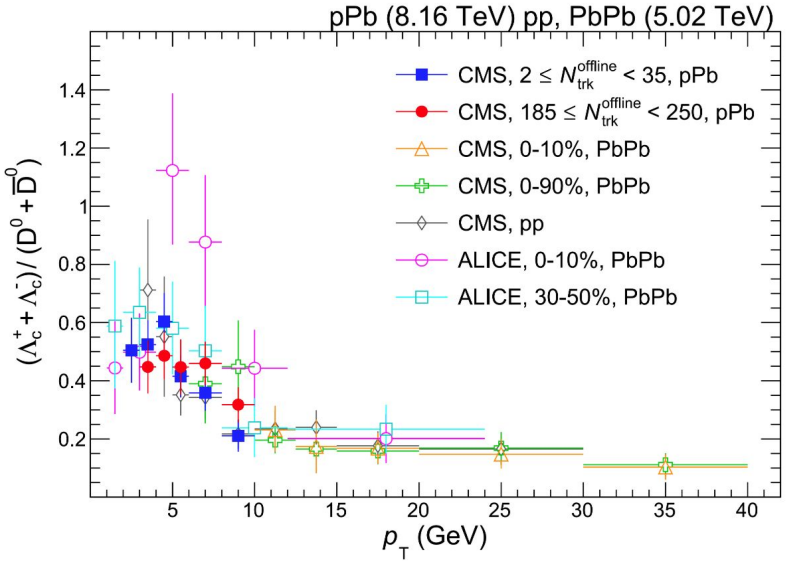
Λ_C/D^0 ratio in PbPb

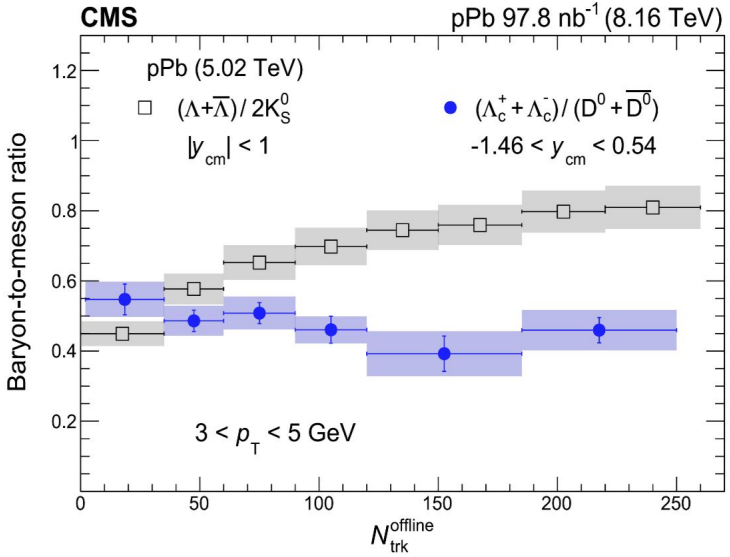


JHEP01(2024)128

- Λ_C/D^0 ratio for PbPb is consistent with pp data for p_T > 10 GeV/c.
- Coalescence process doesn't play a significant role for high p_T
- Model for PbPb collisions (0-20% centrality) almost consistent with data for p_T 10-12.5 GeV/c (0-10% centrality)

Λ_c/D^0 ratio in pPb



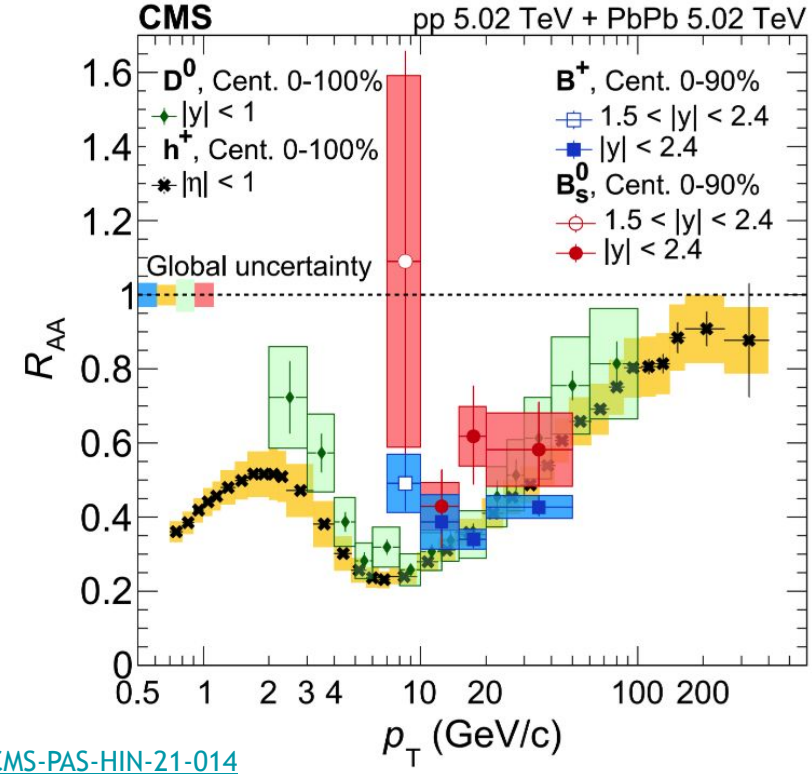


- Λ_c/D^0 ratio decreases with increasing p_T
- Consistent with pp and PbPb results

- No significant multiplicity dependence
- Differs from strange quark trend
- Coalescence process saturates early for charm quark with multiplicity

CMS-PAS-HIN-21-016

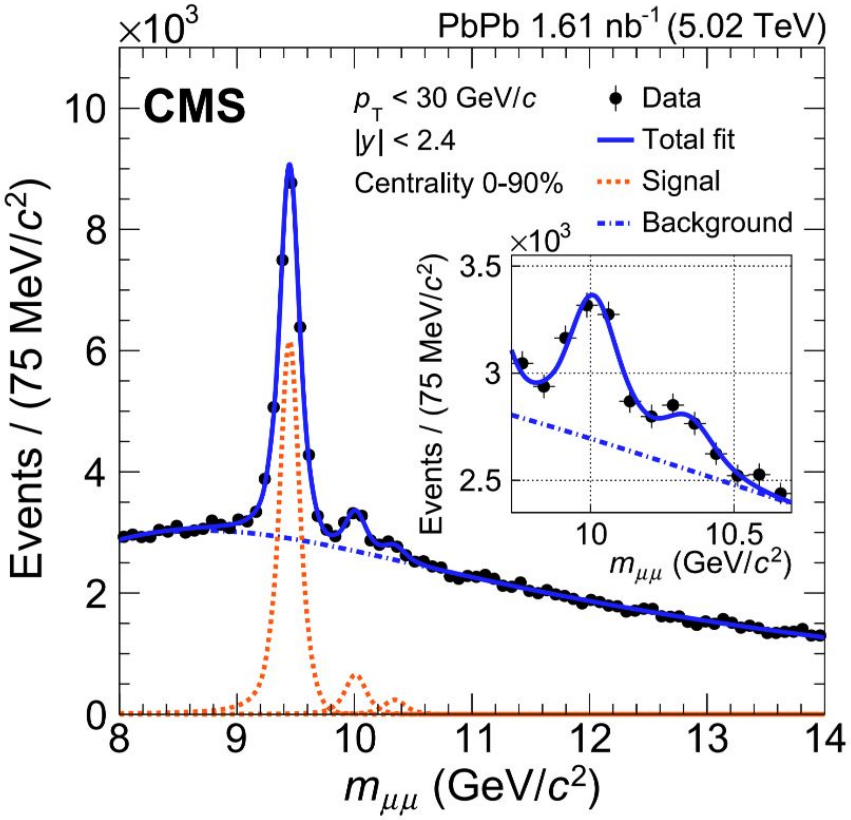
B mesons R_{AA}

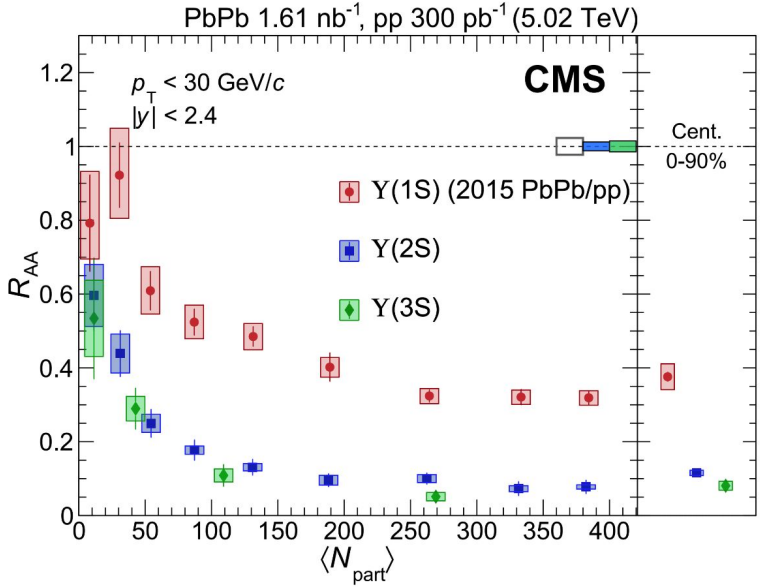


CMS-PAS-HIN-21-014

- B_s being heavier is less suppressed than B^+
- B^+ R_{AA} are consistent with charged hadrons and D^0 mesons for p_T > 10 GeV/c.
- Less suppression at lower p_T.
  - ➢ Mass dependence of parton energy loss.

Υ(nS) R_{AA}

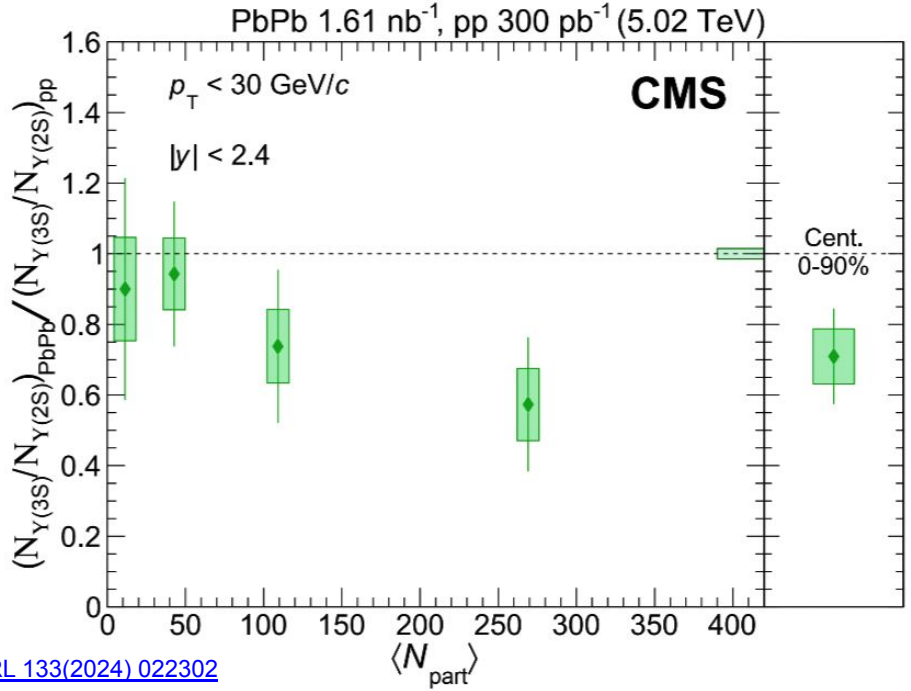


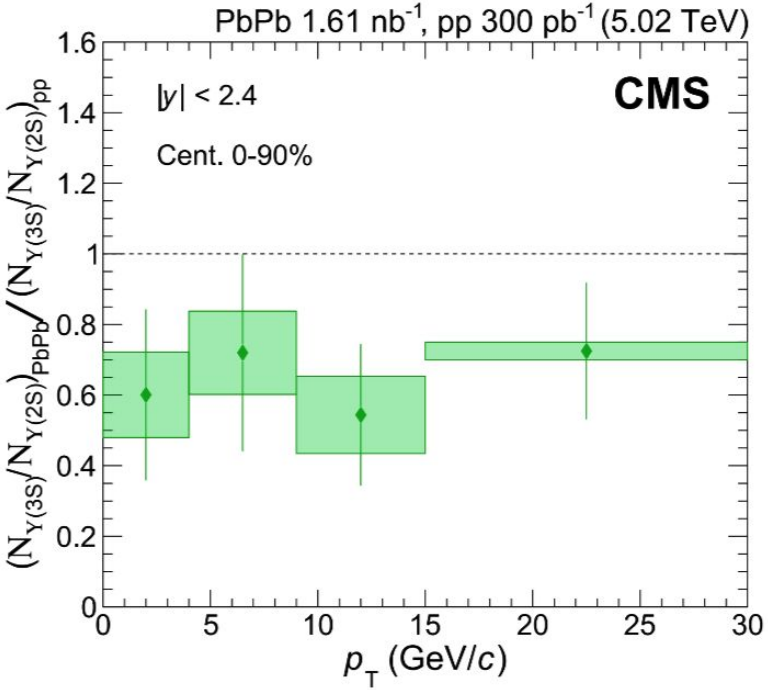


[PRL 133(2024) 022302](#)

- ❖ **First observation of Υ(3*S*) in Pb-Pb collisions in CMS, with a significance above 5σ.**
- ❖ **Both states are strongly suppressed in central Pb-Pb collisions and the entire measured p_T range.**

$N_{Y(nS)}$ Double Ratio

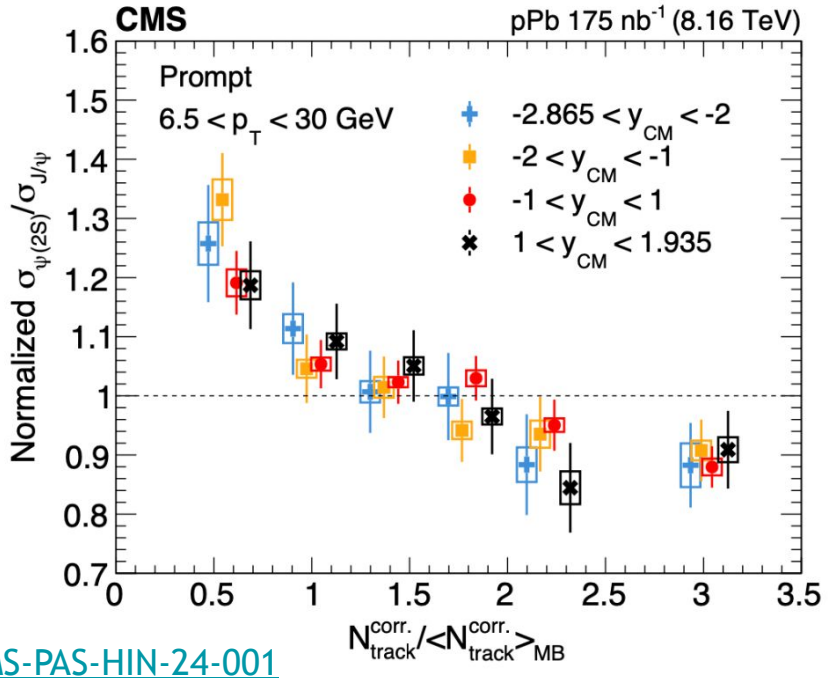


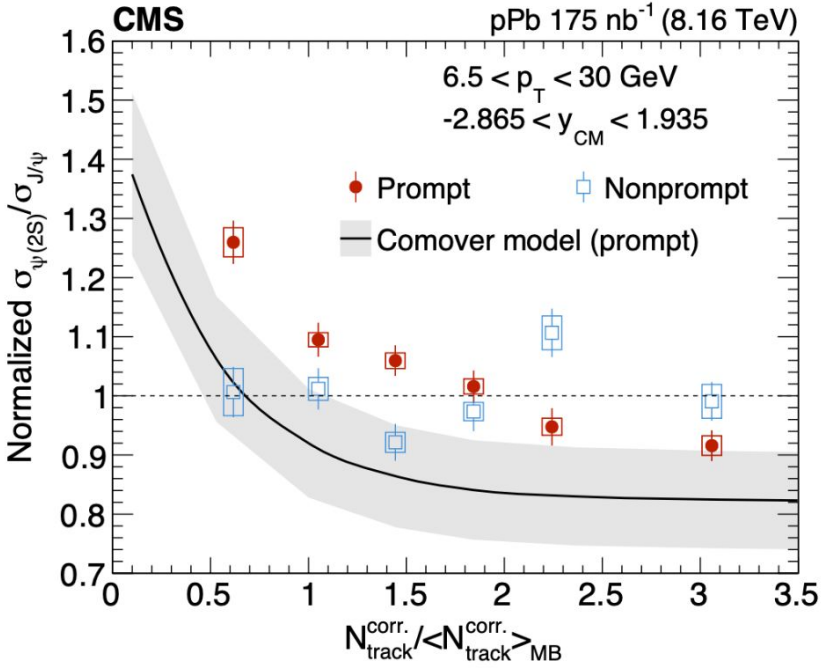


PRL 133(2024) 022302

- Stronger suppression for the $\Upsilon(3S)$ than $\Upsilon(2S)$.
- No significant dependence on p_T .

$\sigma_{\Psi(2S)}/\sigma_{J/\psi}$

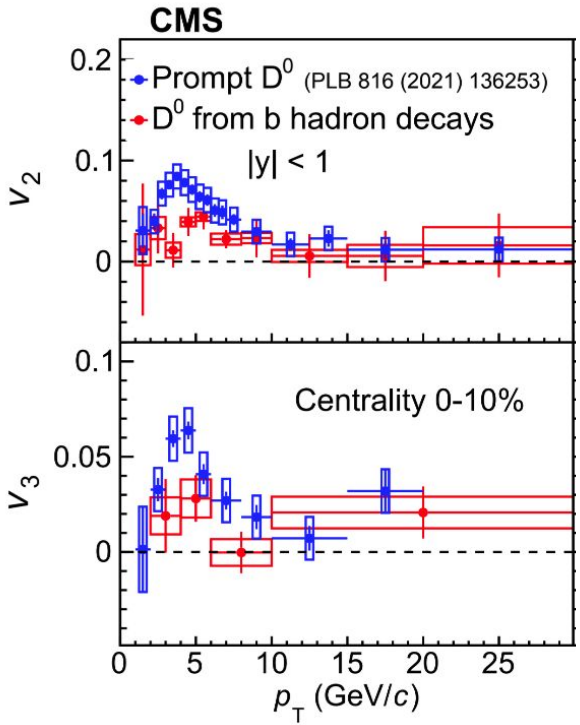




CMS-PAS-HIN-24-001

- Observed multiplicity dependence of prompt cross-section ratio.
- The measurements constrain hadronization models of heavy quarks.

Collective flow of b→ D^0

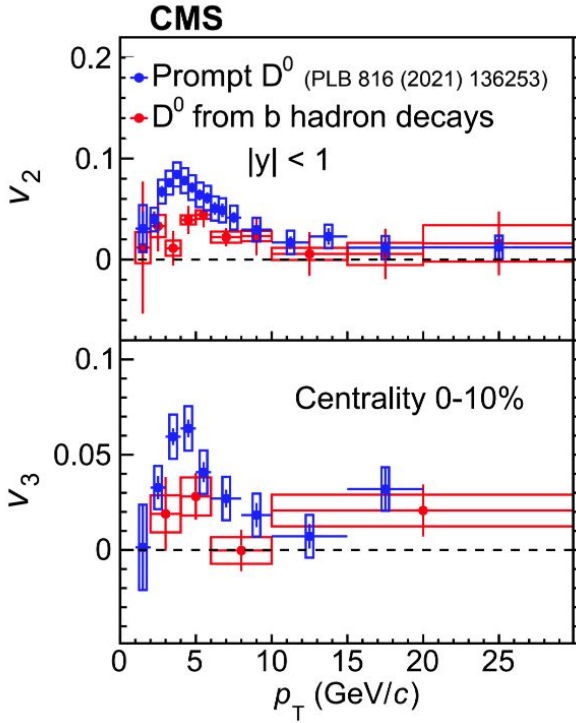


- v_2 **b→ D^0**
  - Non-zero v_2 at low p_T
  - Weak p_T dependence
- v_3 **b→ D^0**
  - Effects of initial geometry fluctuation at low p_T

PLB 850 (2024)138389

*All centrality plots are in backup

Collective flow of b→ D^0



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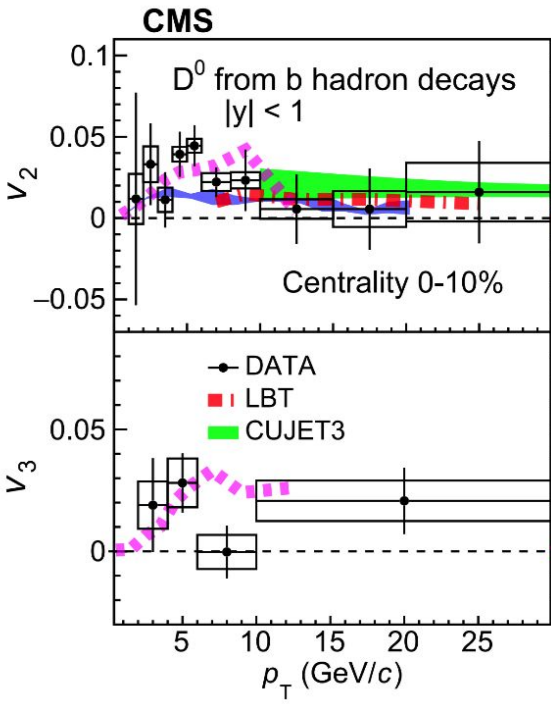
  - Weak p_T dependence
- v_3 **b→ D^0**
  - Effects of initial geometry fluctuation at low p_T
- Qualitative agreement with model predictions



PLB 850 (2024)138389

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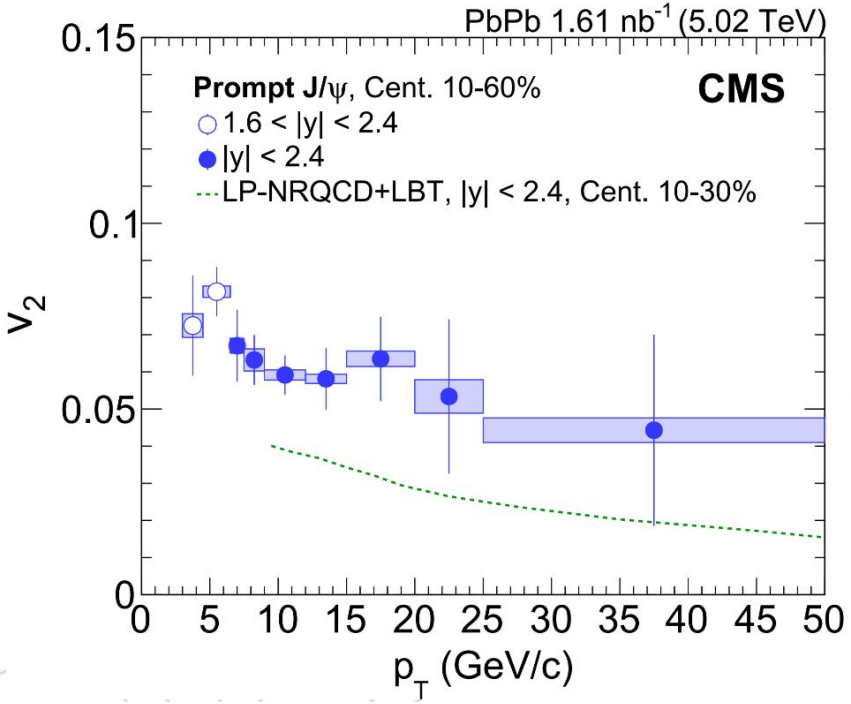
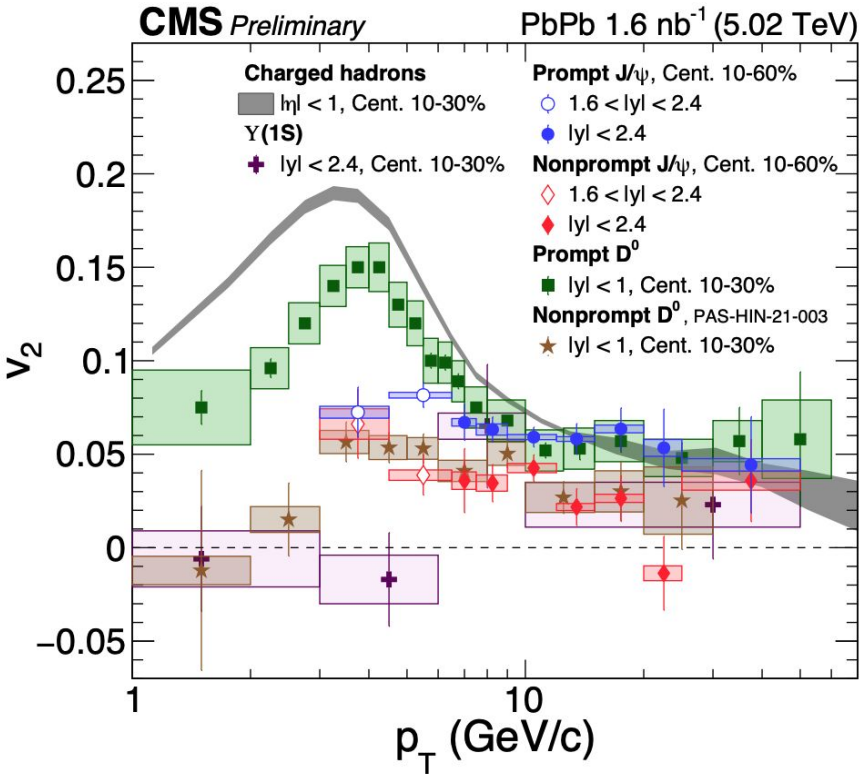
Collective flow of J/ψ



- No clear p_T dependence within uncertainty.
- Significant deviation from model predictions.
- Scope for precision improvement.

JHEP10(2023)115

CMS v_n measurements



At low p_T:

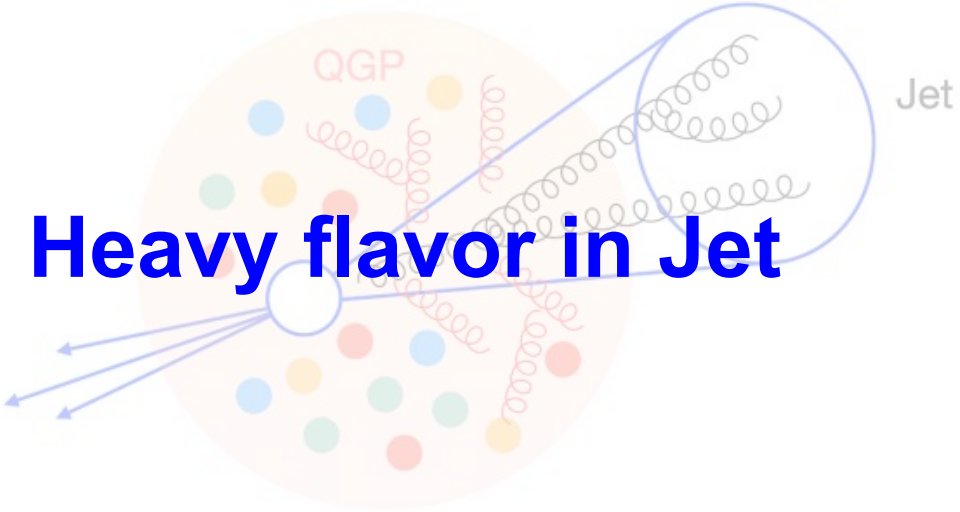
- **Beauty v_2 < Charm v_2 < Light v_2**
- Weaker collectivity of heavy quarks than light quarks.

At high p_T:

- All flavors tend to converge.
- Mass hierarchy disappears.

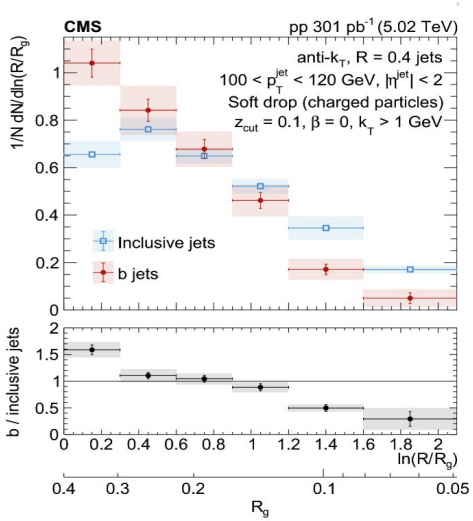
PLB 816 (2021) 136255
PLB 776 (2021) 195
PLB 850 (2024) 138389
JHEP 10 (2023) 115

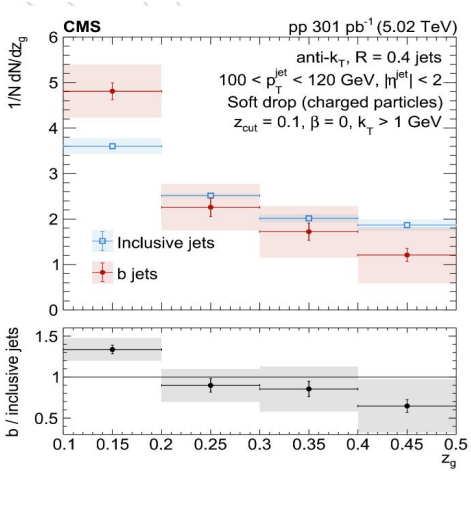
Heavy flavor in Jet

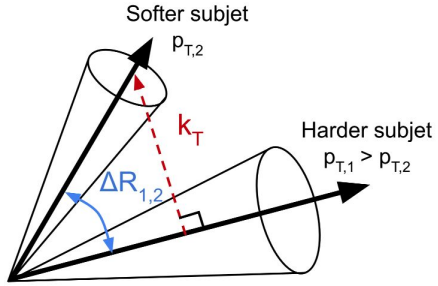


Follow for details, 8th Dec:
Lida Kalipoliti's *talk on Heavy flavor jets as probes of the QGP*

HF Jet groomed observables

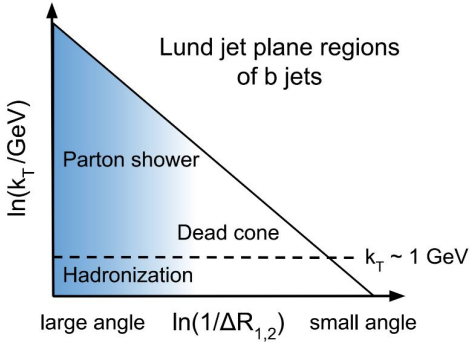




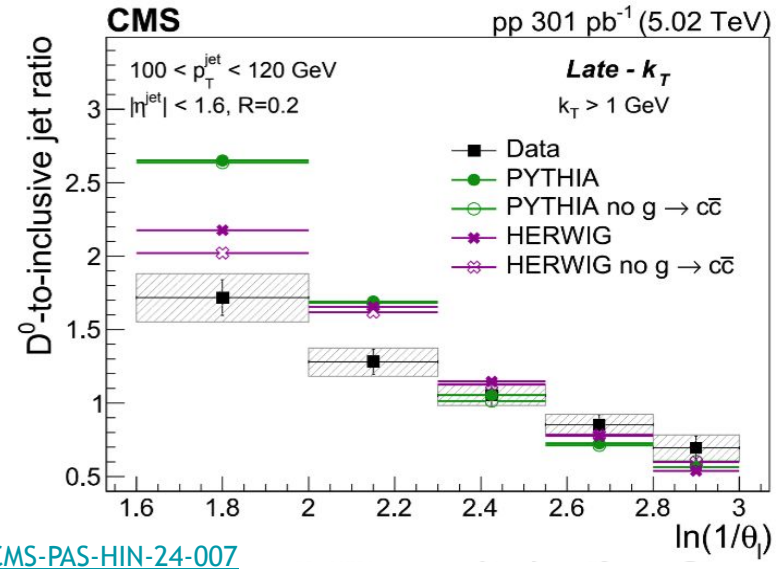


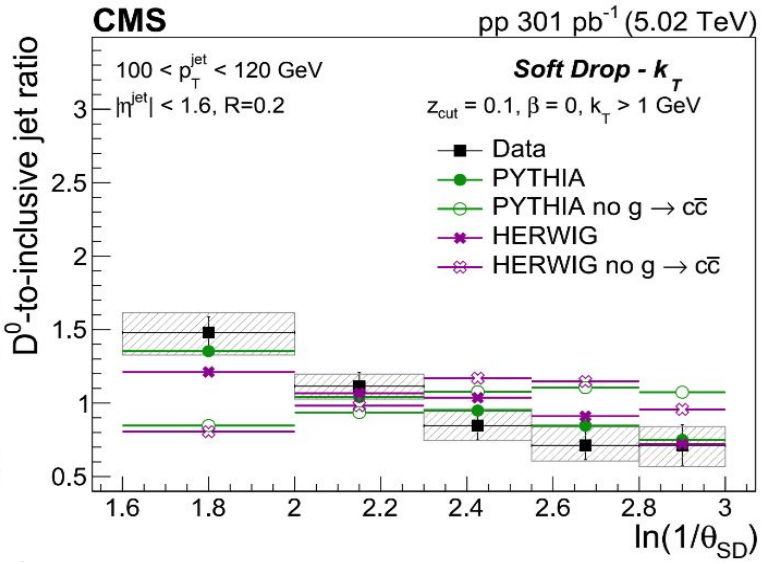
CMS-PAS-HIN-24-005

- The groomed observables **Rg (soft drop groomed jet radius)** and **Zg (groomed momentum balance)** of B-jets and inclusive jets.
- **First substructure measurement of b jets ➡ b quark mass effects.**



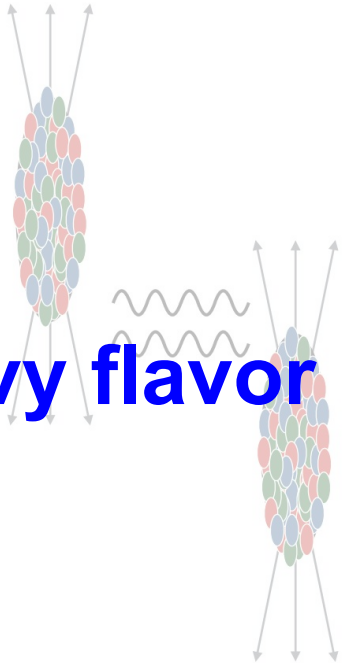
D^0/Inclusive Jet





CMS-PAS-HIN-24-007

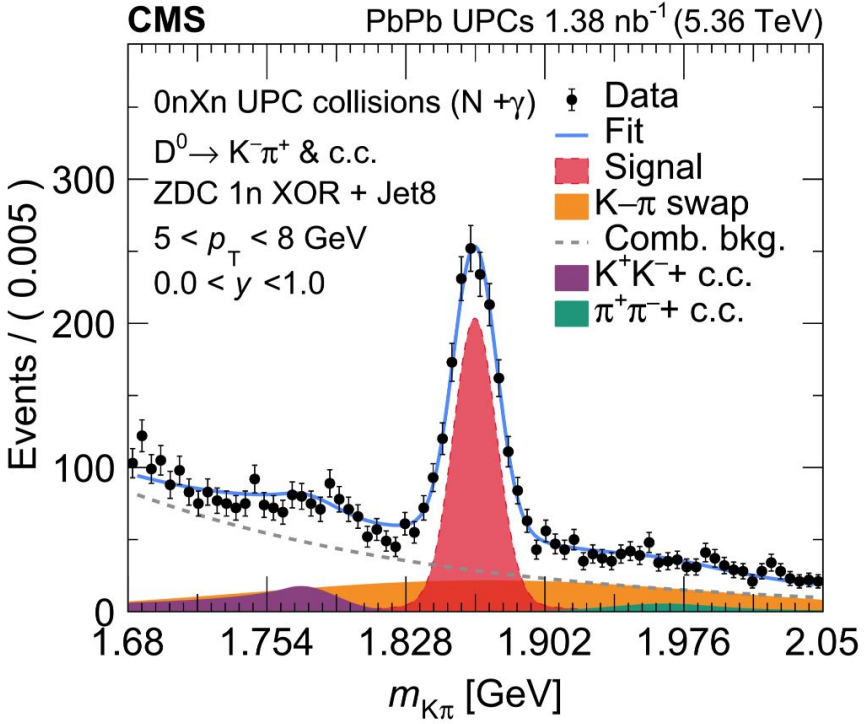
- **Jet grooming algorithms:** late-kT angle distributions and SD angle, used to study the intrajet radiation pattern.
- **The shift observed in late-k_T is consistent with the dead cone effect.**
- **The measurement set constraints on the substructure of high-p_T charm quark jets.**



Heavy flavor in UPC

Follow for details, 9th Dec:
Zaochen Ye's *talk on Heavy flavor production in UPC*

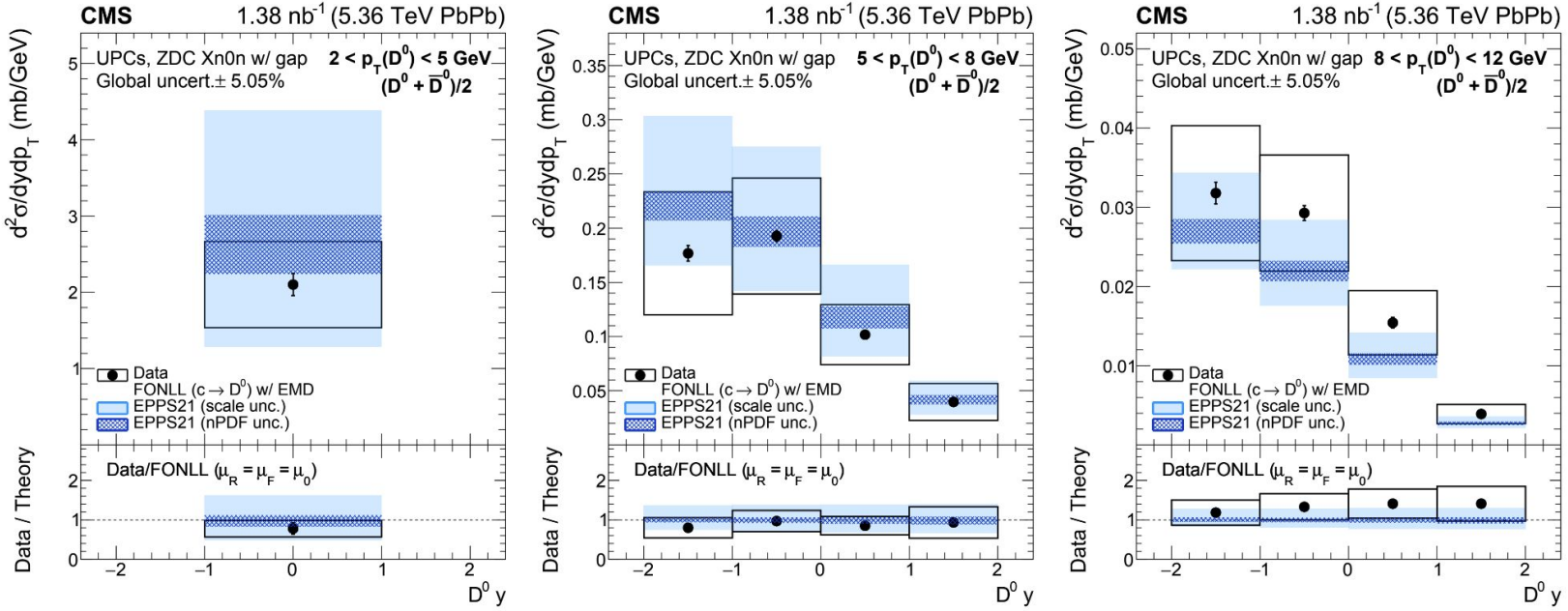
D^0 production in UPC PbPb



- Xn0n PbPb events with rapidity gap with 2023 PbPb data.
- Wide x (*partons momentum fraction*), Q^2 (*resolution of the probe*) coverage.
- Ideal probe to test the transition towards low-x nuclear matter.

CMS-PAS-HIN-24-003

D^0 production in UPC PbPb

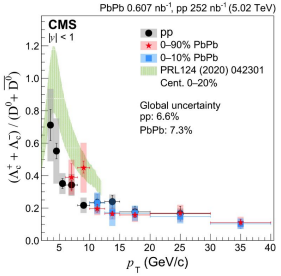


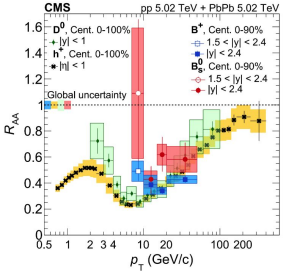
CMS-PAS-HIN-24-003

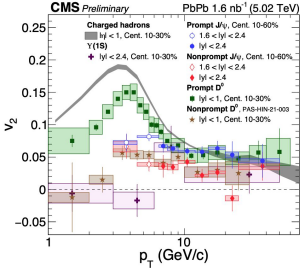
- First measurement of the cross section for photonuclear inclusive production of D^0 mesons.
- The measured cross sections are in good agreement with the theoretical calculation.

Summary

- **HF measurement in PbPb/pPb**
  - Measurement of Λ_C R_{AA}
  - Λ_C/D^0 in PbPb and pPb
  - B^+ and B_S R_{AA}
  - Y(nS) double ratio
  - Multiplicity dependence $\sigma_{\Psi(2S)}/\sigma_{J/\psi}$
  - Collective flow of b->D^0
  - Collective flow of J/ψ







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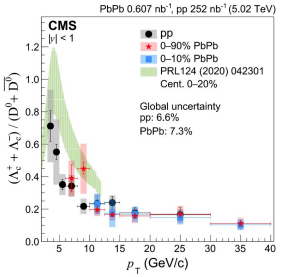
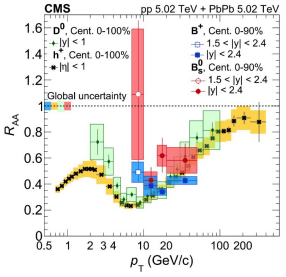
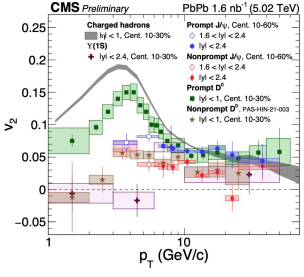
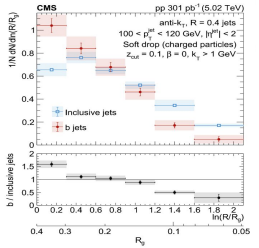
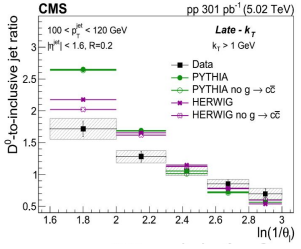
  - Rg and Zg of B and inclusive jet.
  - Ratio of the late-kT angle and SD angle for D^0 and inclusive jets.











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- ➢ Measurement of Λ_C R_{AA}
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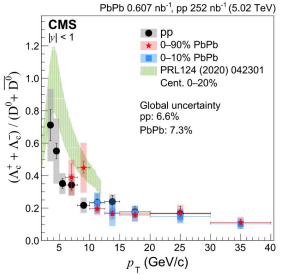
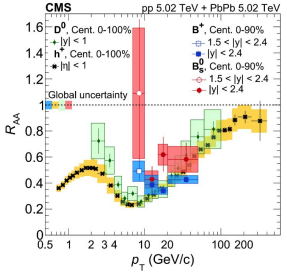
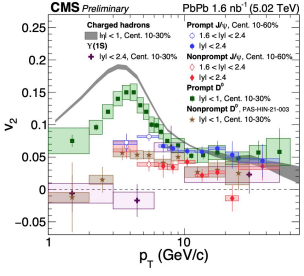
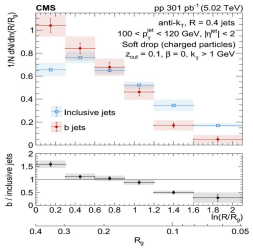
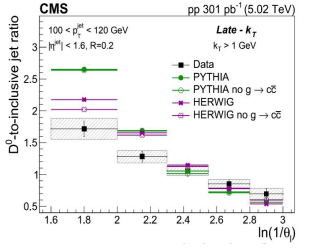
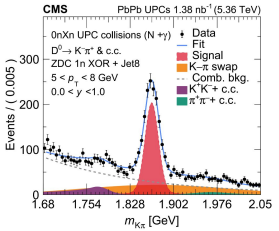


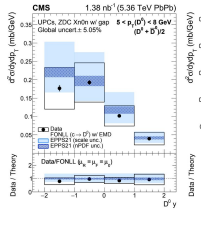


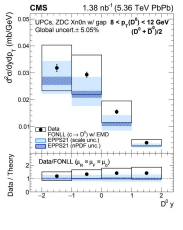












❖ HF Jets measurement

- ➢ Rg and Zg of B and inclusive jet.
- ➢ Ratio of the late-kT angle and SD angle for D^0 and inclusive jets.

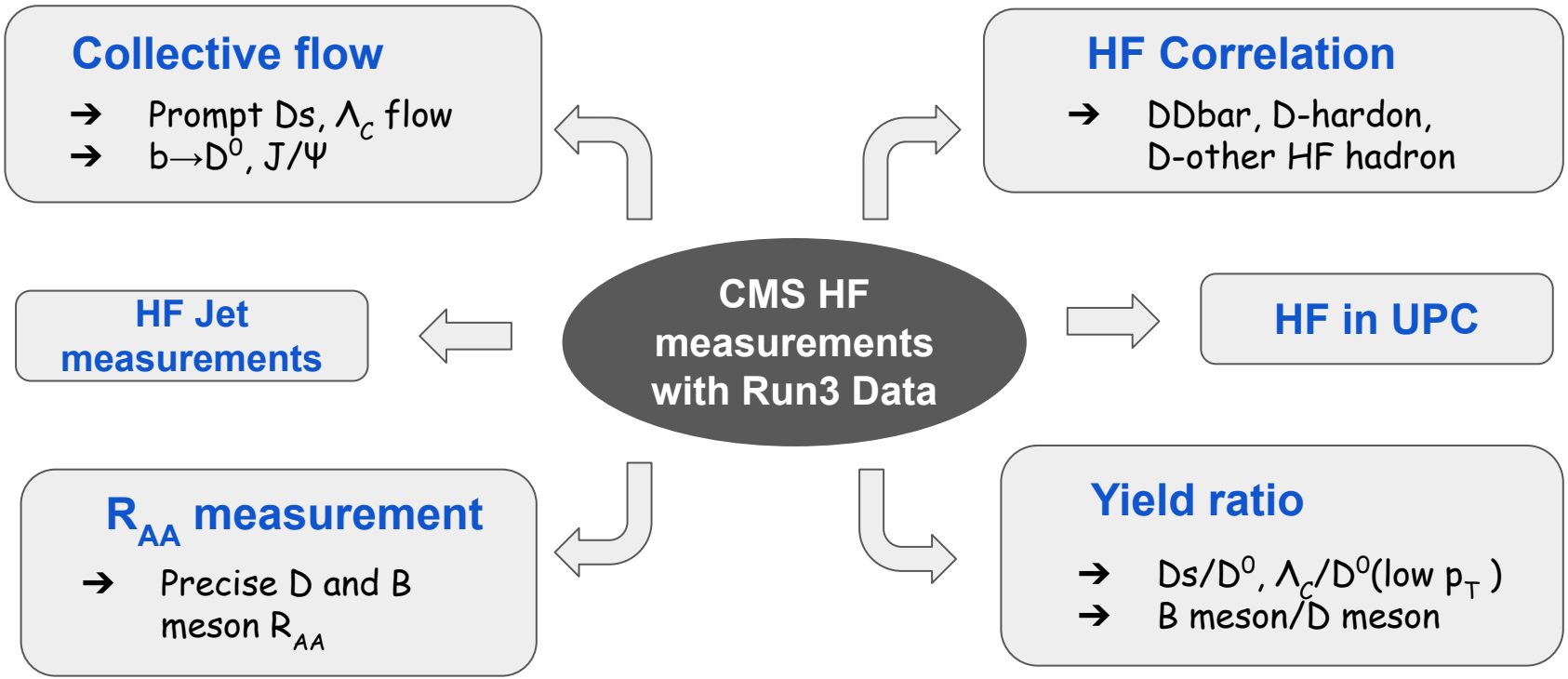
❖ HF in UPC

- ➢ First photoproduction of D^0

Some Ideas of CMS HF analyses

…Good time ahead for HF analyses with new Run3 data!

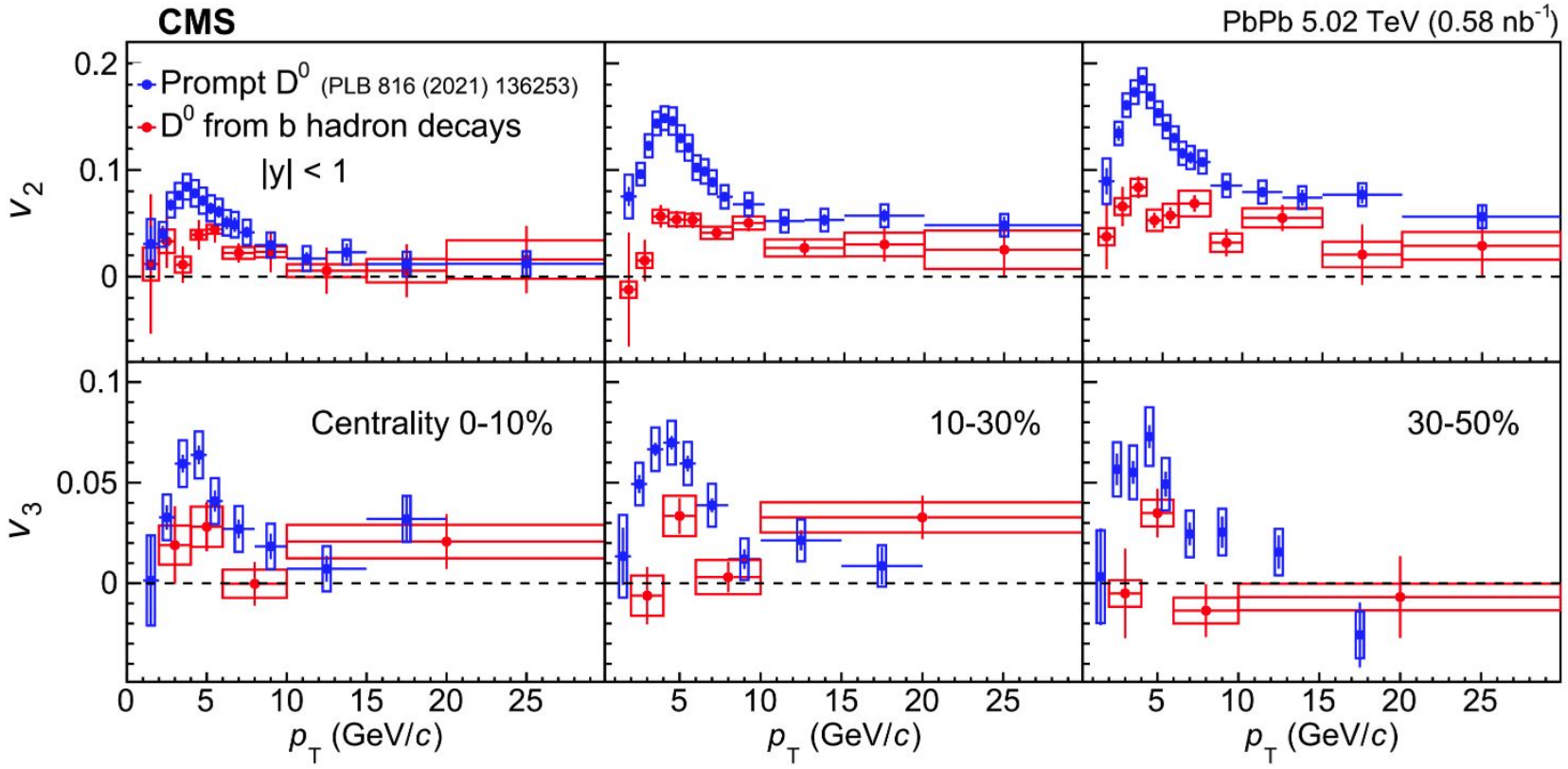
Some Ideas of CMS HF analyses



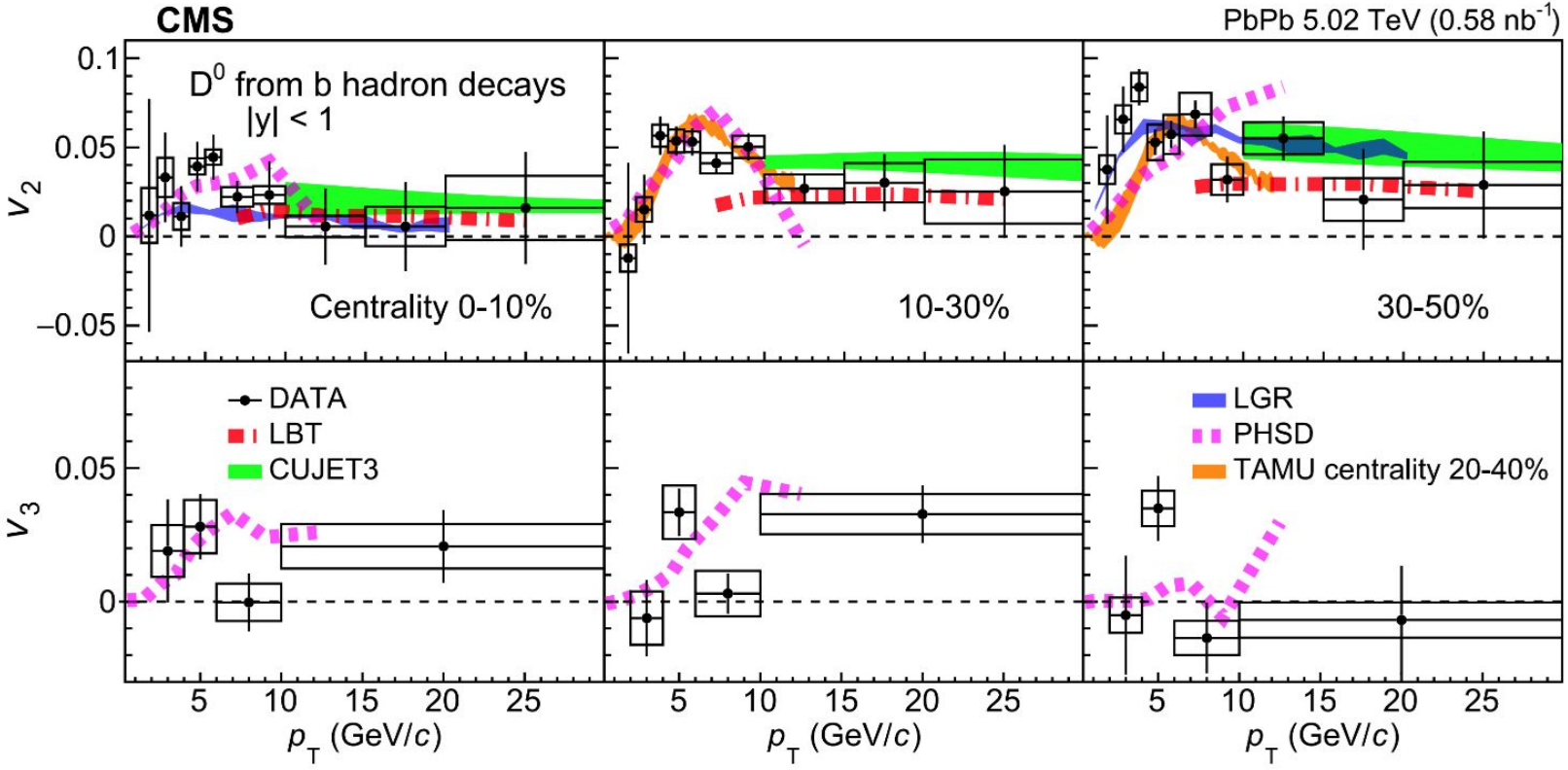

Thank You!

BACKUP

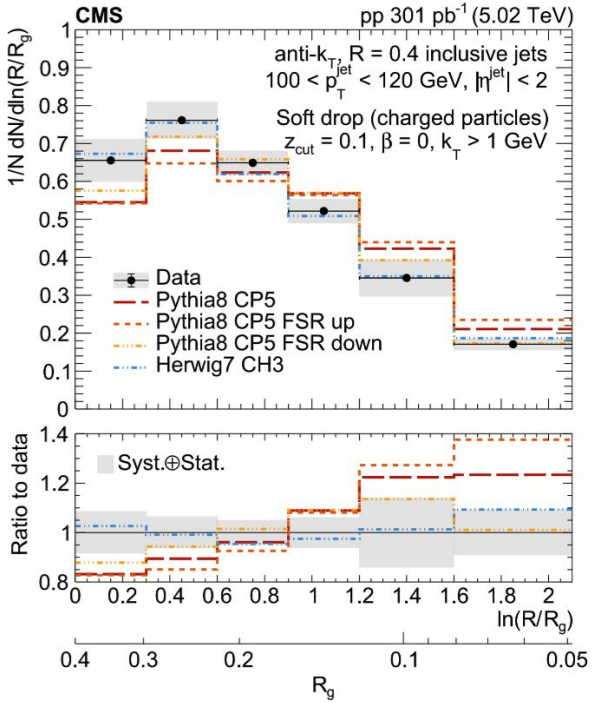
v_n measurement of non-prompt D^0

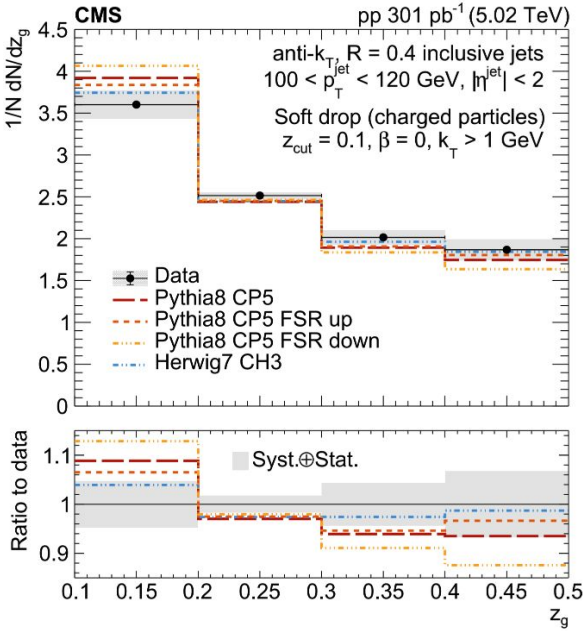


v_n measurement of b→ D^0



Heavy flavor in Jet





- Distributions of groomed substructure observables Rg (left) and zg (right) corrected to the stable-particle level for inclusive jets.
- PYTHIA8 CP5 agrees with the data within the experimental uncertainty, while HERWIG7 deviates slightly.