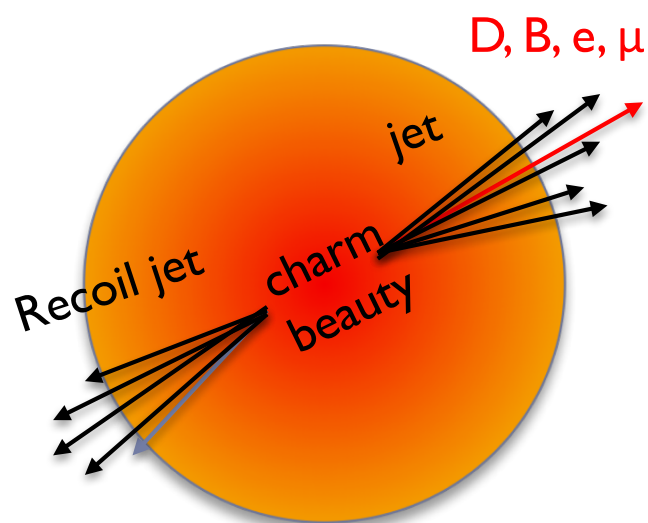


Measurement of heavy-flavour production, correlations and jets with ALICE

Shingo Sakai (Univ. of Tsukuba) for the ALICE collaboration

Heavy quarks in heavy-ion collisions

- ▶ Heavy flavour (c & b) production in heavy-ion collisions
 - ▶ Created in initial parton-parton scattering
 - ▶ Traverse and interact with the hot & dense QCD matter (QGP)
 - ▶ Ideal probe to investigate properties of QGP



[1] PLB632, 81
[2] PLB649, 139

■ Nuclear modification factor

- Sensitive to energy loss of heavy quarks via radiative [1] and collisional [2] processes
 - Mass/color dependent energy loss : $\Delta E(c) > \Delta E(b)$

■ Azimuthal anisotropy (v_2)

- Collective effects, thermalisation, hadronisation with/without coalescence at low p_T
- Path-length dependence of energy loss at high p_T

■ Jets & azimuthal correlations with charged particles

- Investigate spatial redistribution of energy loss
- Address heavy-flavour jet properties and their possible modification in the presence of QGP

Heavy-flavour signals in ALICE

■ D mesons, $|y| < 0.5$

- Direct reconstruction via displaced vertex topology

F. Grosa, HF parallel 2 (Thur. 11:30)

■ Heavy-flavour jets ($|y| < 0.5$)

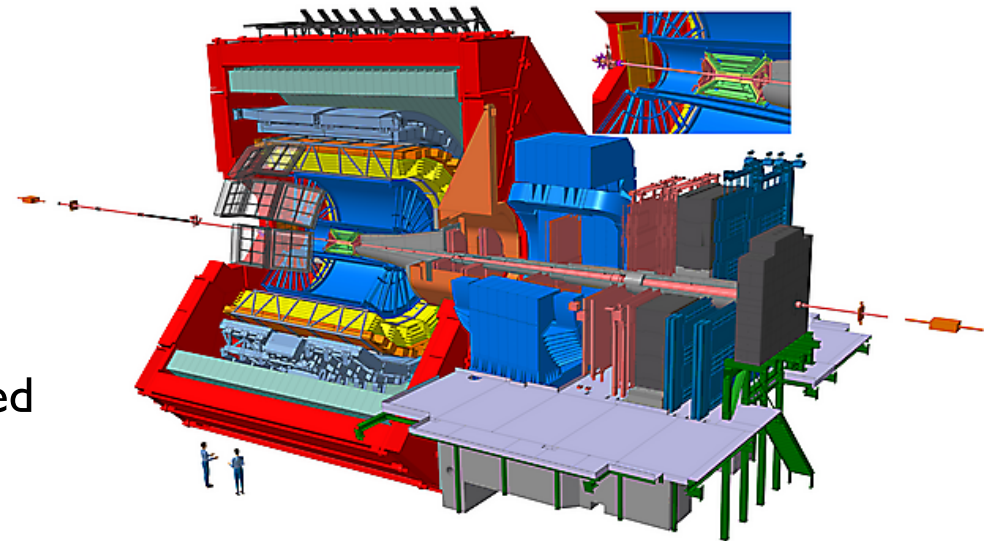
- Tagged with D mesons in reconstructed jets (via FastJet, anti- k_T)

■ Electrons from heavy-flavour hadron decays (e^{HF}), $|y| < 0.9$

- background from Dalitz decay of neutral mesons and γ conversions are subtracted via invariant mass of ee pairs
- Electrons from charm and beauty are separated by using impact parameter

■ Muons from heavy-flavour hadron decays (μ^{HF}), $2.5 < y < 4$

- background from π , K is estimated via simulations tuned with measured spectrum of backgrounds sources

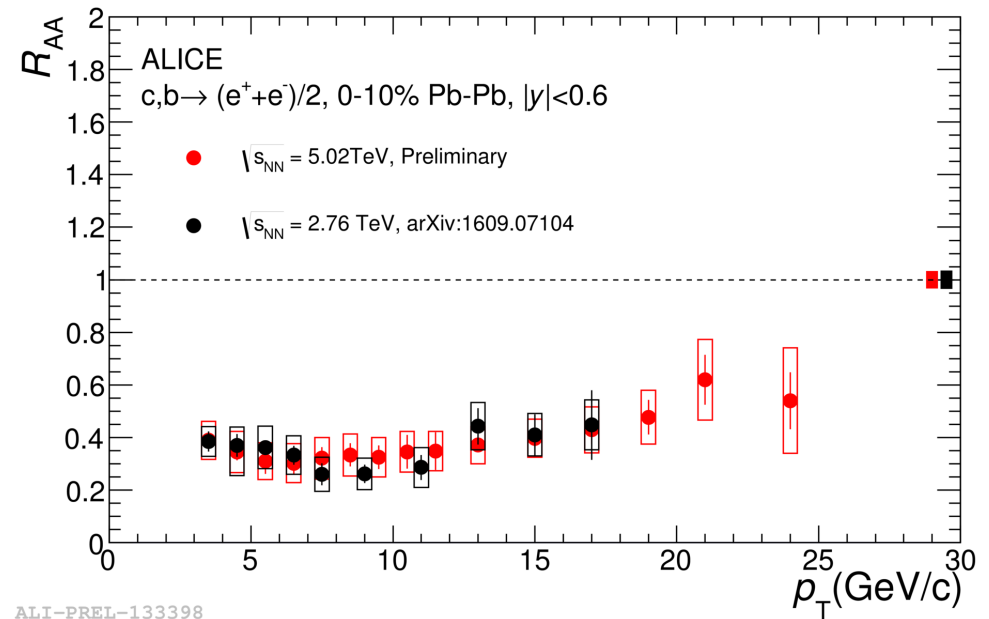
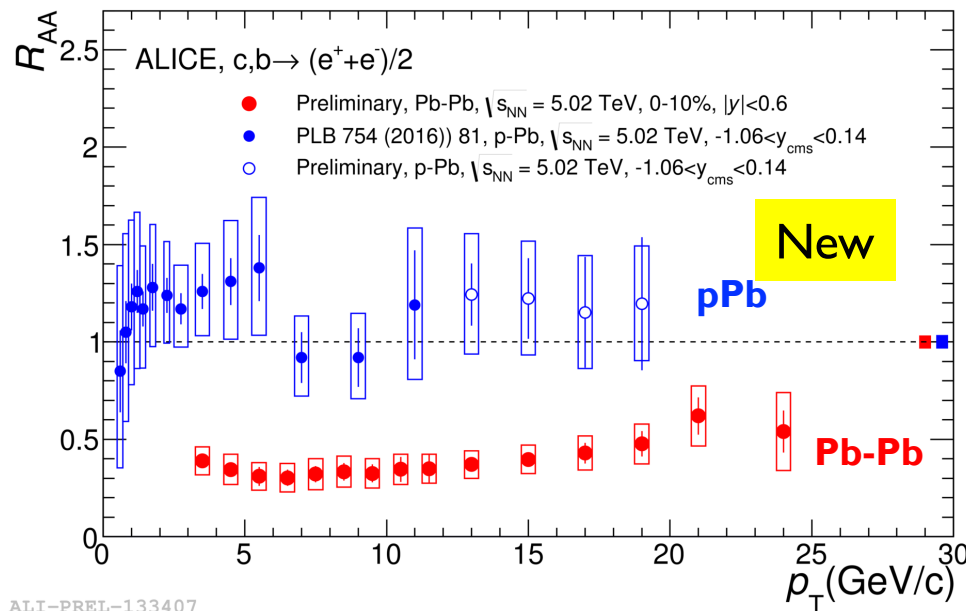




Results of e^{HF} & μ^{HF} in Pb-Pb collisions

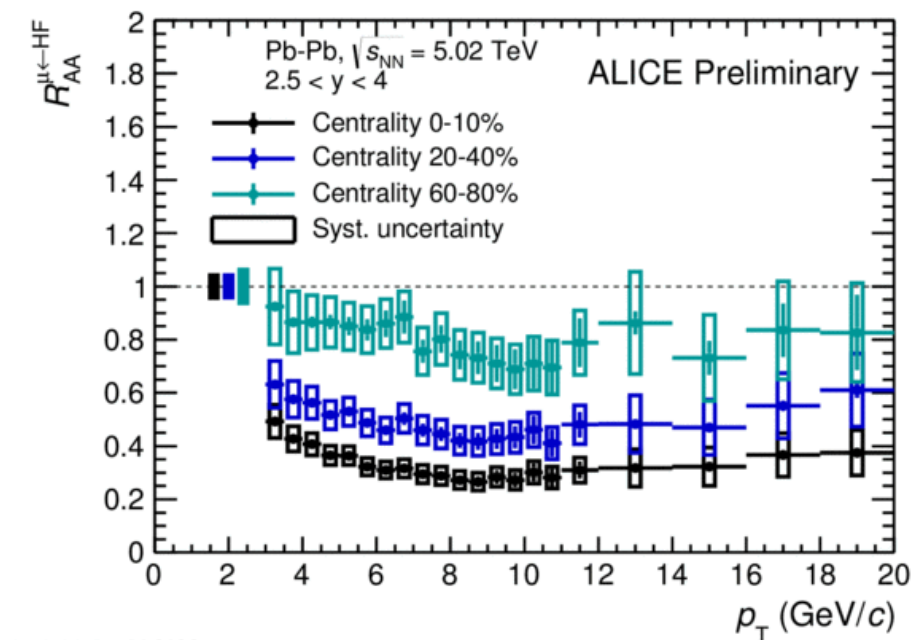
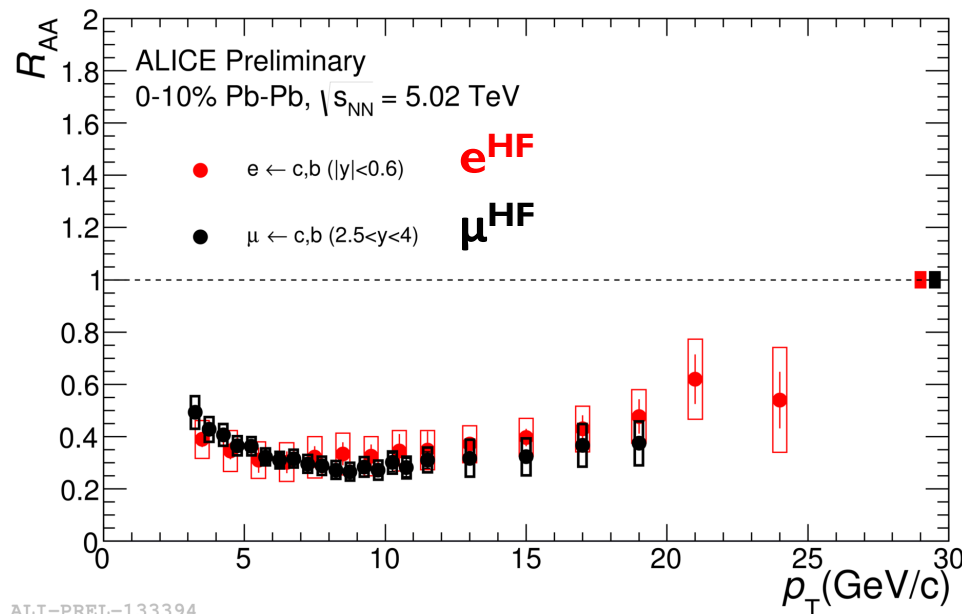
ALICE

R_{AA} of e^{HF} in Pb-Pb at 5.02 TeV



- Strong suppression of e^{HF} observed in Pb-Pb at 5.02 TeV at mid-rapidity
 - Not observed such suppression in p-Pb collisions at 5.02 TeV up to 20 GeV/c
 - The suppression is due to final-state effects, *i.e.* energy loss of heavy flavour
- High p_T e^{HF} is mainly from beauty ($p_T > 5$ GeV/c)
 - Indicates a significant energy loss of beauty in the hot & dense matter
- Similar R_{AA} of e^{HF} at 2.76 TeV and 5.02 TeV

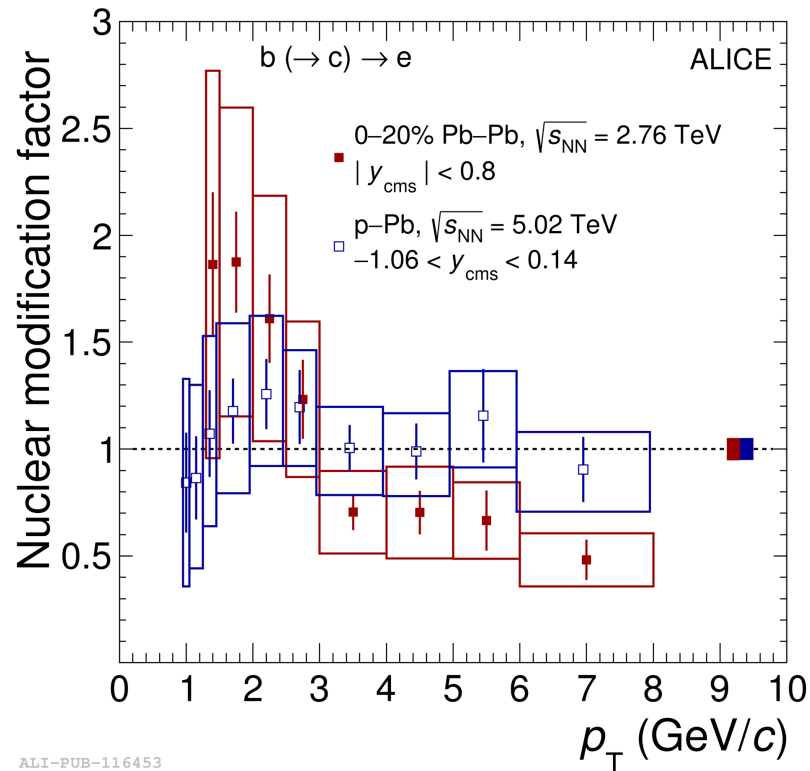
R_{AA} of μ^{HF} in Pb-Pb at 5.02 TeV



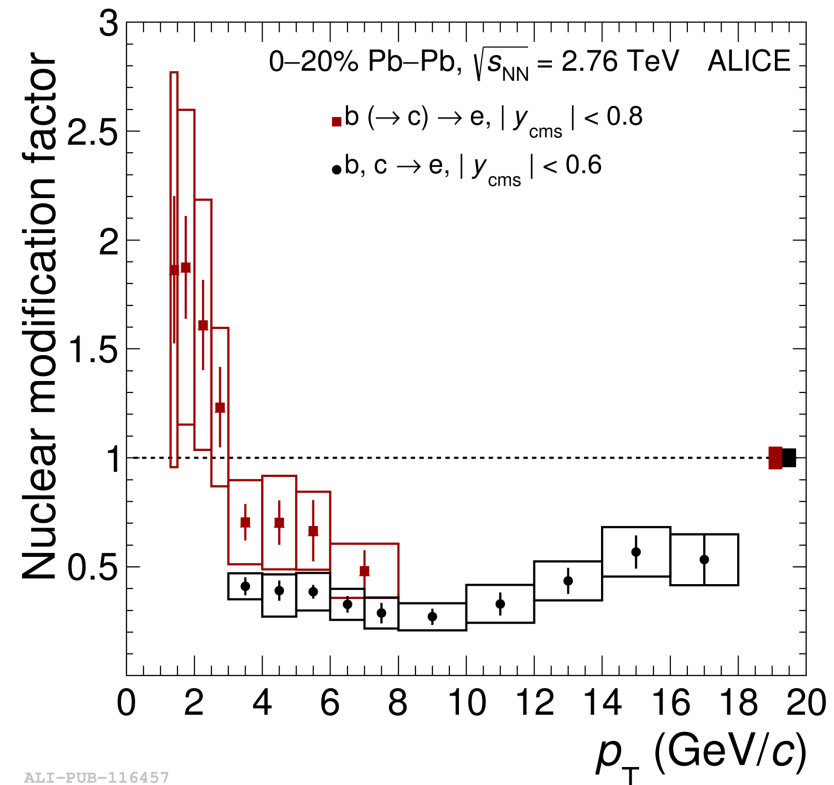
- Strong suppression of μ^{HF} observed in Pb-Pb at 5.02 TeV at forward-rapidity
- Similar suppression of e^{HF} at mid-rapidity and μ^{HF} at forward-rapidity
- Muons from beauty dominate at high p_T
- The suppression gets larger from peripheral to central collisions

Beauty decay electron R_{AA}

ALICE:arXiv:1609.03898



ALI-PUB-116453



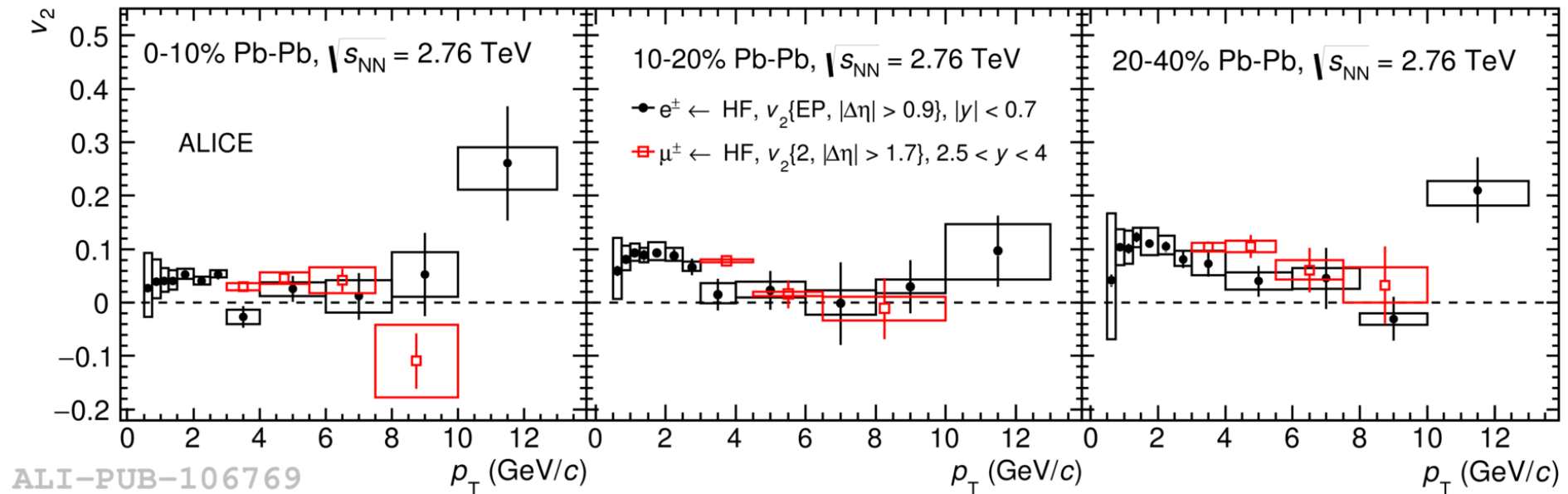
ALI-PUB-116457

- Smaller energy loss expected for beauty than for charm due to dead cone effect [1]
- Hint of smaller suppression for electrons from beauty than electrons from charm

[1] PLB519 (2001) 199

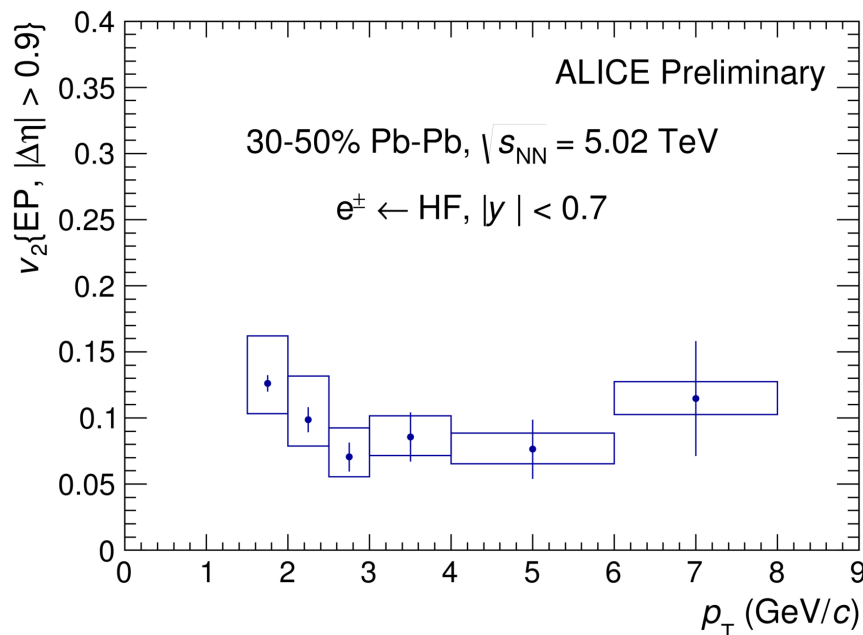
v_2 of e^{HF} & μ^{HF} in Pb-Pb collisions

e^{HF} : JHEP 09 (2016) 028, μ^{HF} : PLB 753 (2016) 41

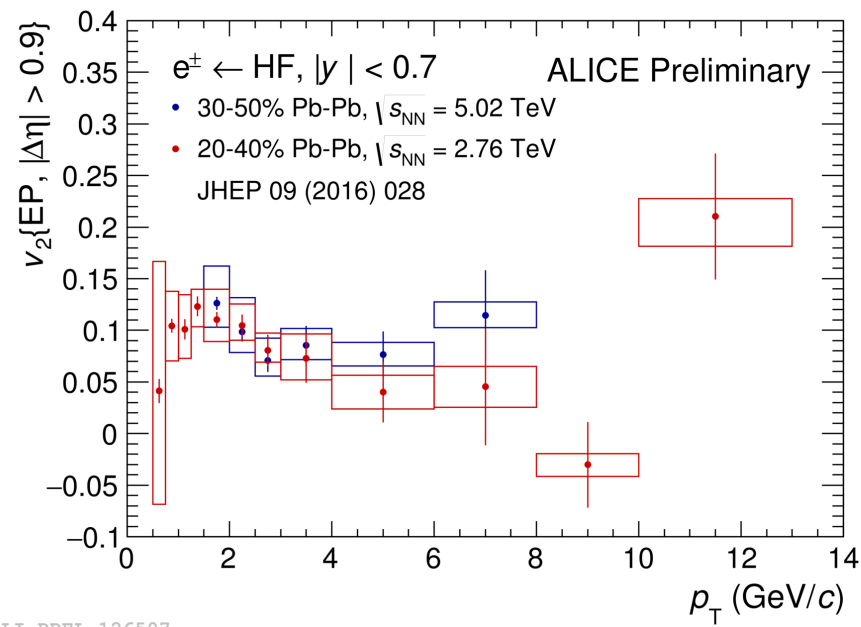


- A positive v_2 of e^{HF} is observed in mid-central (20-40%) Pb-Pb collisions at $\sqrt{s_{\text{NN}}} = 2.76$ TeV
- v_2 tends to increase from most- to mid-central collisions
- Indicates that charm quarks participate to collective motion of the system
- Similar magnitude of v_2 of μ^{HF} observed at forward rapidity
 - No dependence on rapidity is observed within uncertainties

v_2 of e^{HF} & μ^{HF} in Pb-Pb collisions



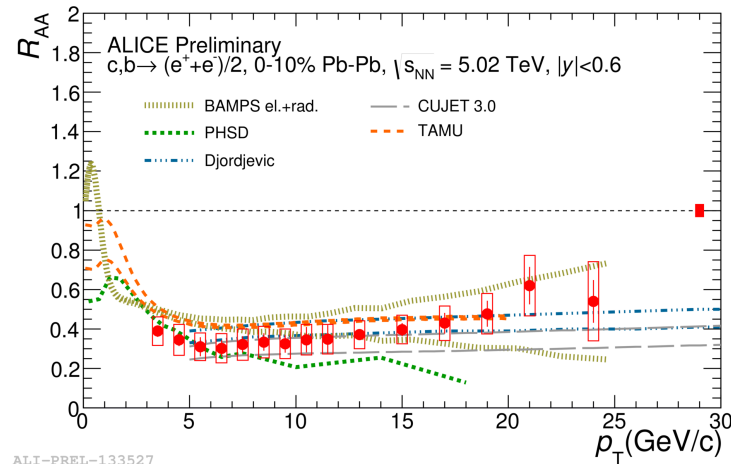
ALI-PREL-126511



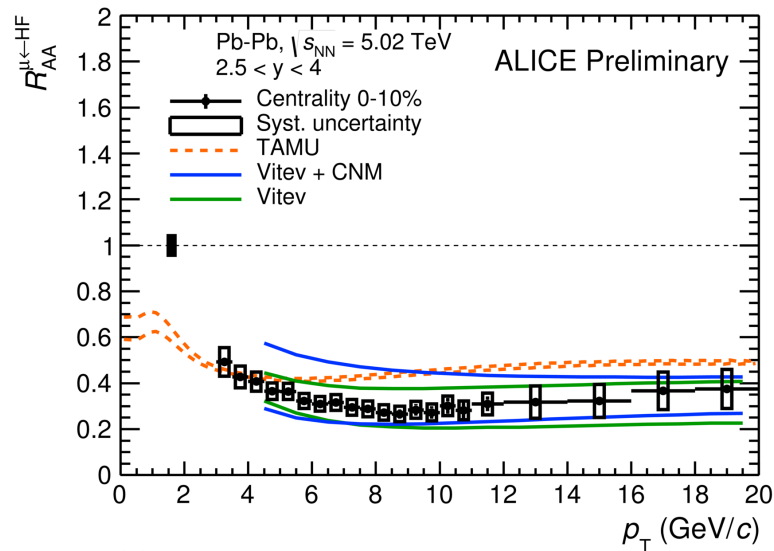
ALI-PREL-126507

- A positive v_2 of e^{HF} is observed in mid-central (20-40%) Pb-Pb collisions at $\sqrt{s_{\text{NN}}} = 2.76$ TeV
- The centrality dependence of v_2 tends to increase from most- to mid-central collisions
- Indicates charm quarks participate to collective motion of the system
- Similar magnitude of v_2 of μ^{HF} observed at forward rapidity
 - No dependence on rapidity is observed within uncertainties
- Similar v_2 measured at $\sqrt{s_{\text{NN}}} = 2.76$ TeV and 5.02 TeV

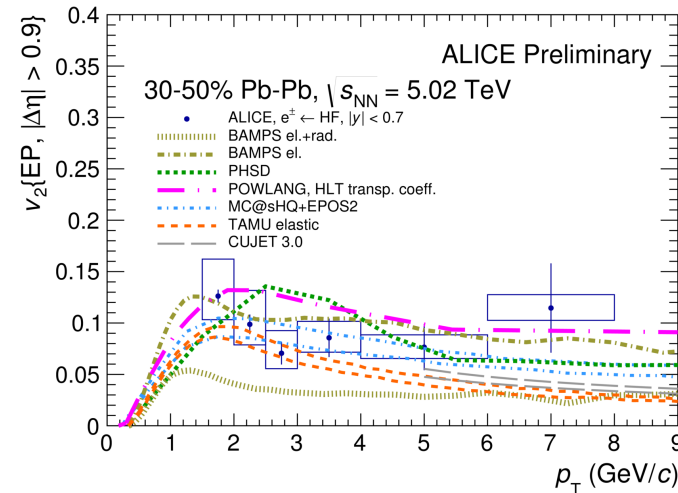
Model comparisons



ALI-PREL-133527



ALI-PREL-116437



ALI-PREL-126503

Theoretical calculations

pQCD-based energy loss models

- Djordjevic : PRC 92 (2015) 024918
- CUJET 3.0 ; PL 32 (2015) 092501
- Vitev : PLB 649 (2007) 139
- MC@sHQ+EPOS : PRC 89 (2014) 014905

Transport models

- BAMPS : JPG 42 (2015) 11
- TAMU : PLB 735 (2014) 445
- PHSD : PRC 93 (2016) 034906
- POWLANG : EPJ C 75 (2015) 121

- Models predict the large suppression of e^{HF} & μ^{HF}
- Positive v_2 expected by models

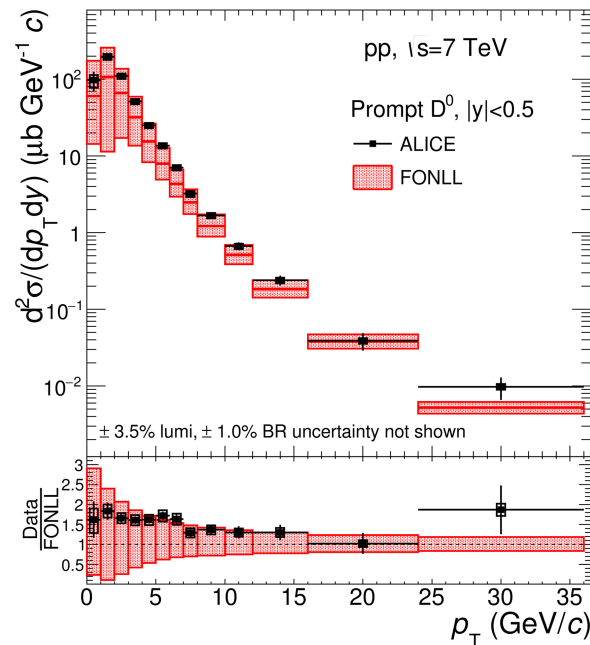


ALICE

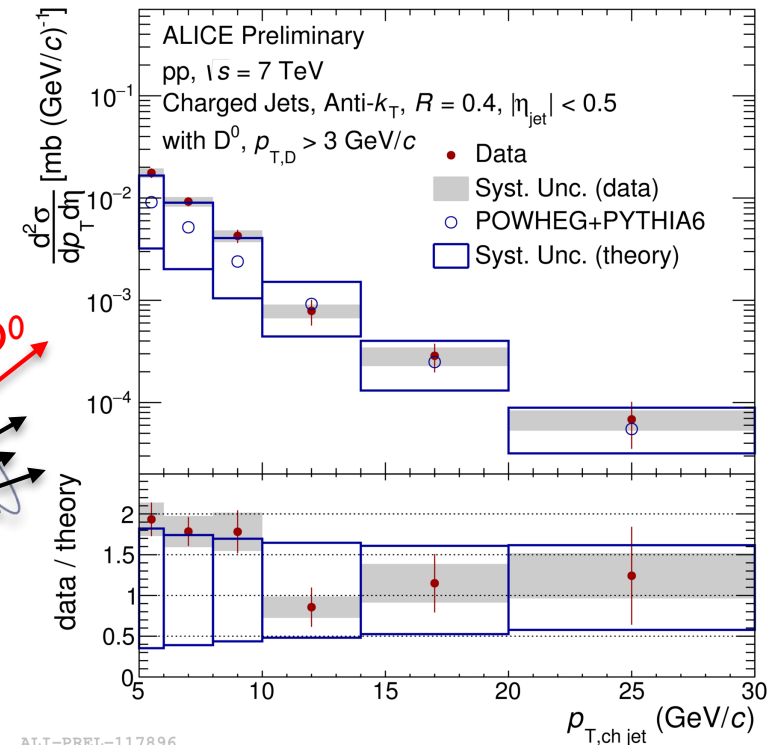
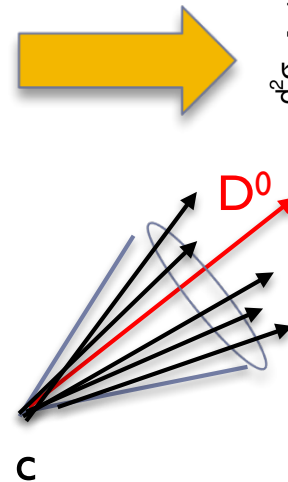
Results of heavy-flavour jets & correlation

Charm jets in pp collisions at 7 TeV

arXiv:1702.00766



ALI-PUB-125443

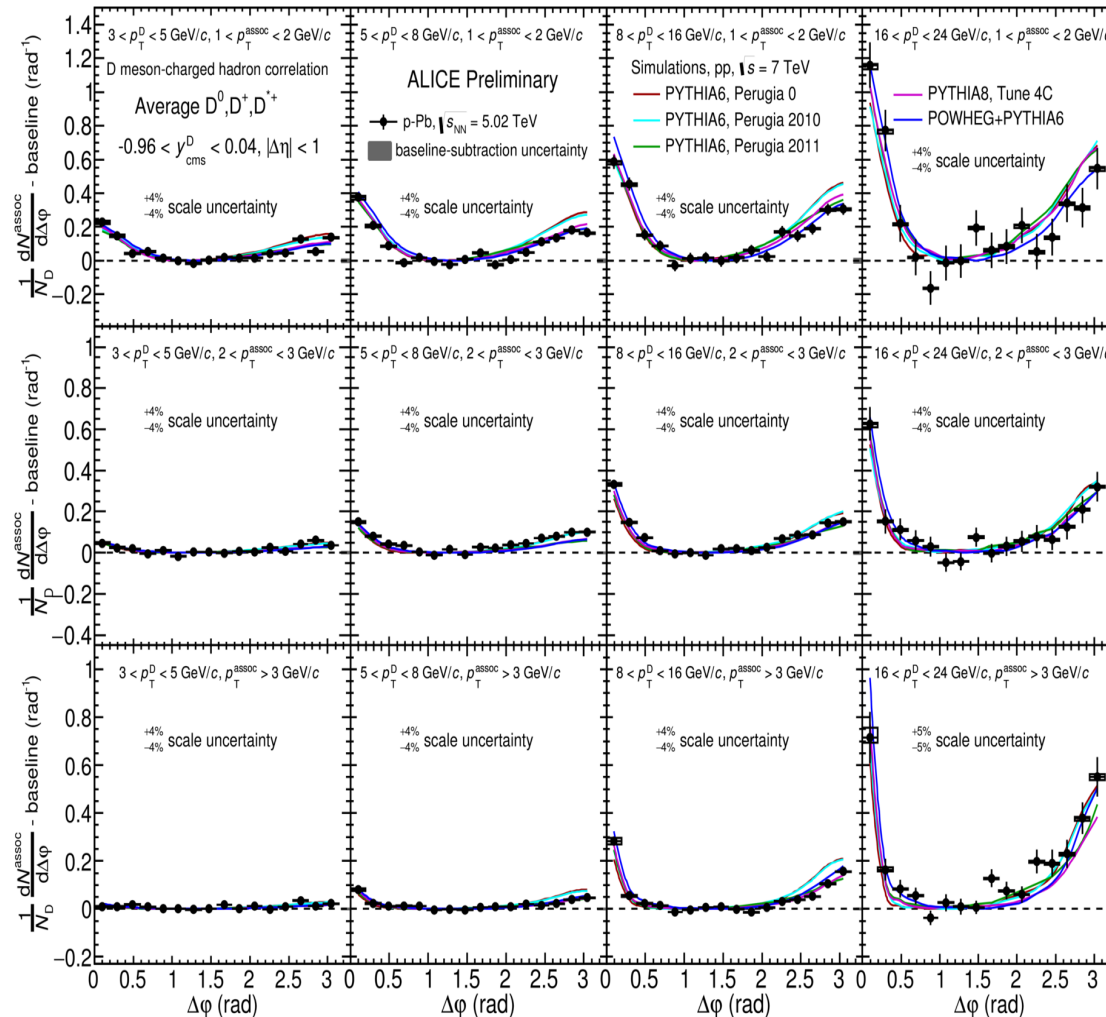


ALI-PREL-117896

- Extend measurement of charm production from D^0 to D^0 in jets to study charm jets production
 - Use fully reconstructed $D^0 \rightarrow K\pi$ decays to tag jets with charm
- Address charm jets production in pp at low p_T ($p_T > 5$ GeV/c)
 - Charm jets production is described by pQCD (POWHEG+PYTHIA)

HF correlation (D-h) in p-Pb

New result



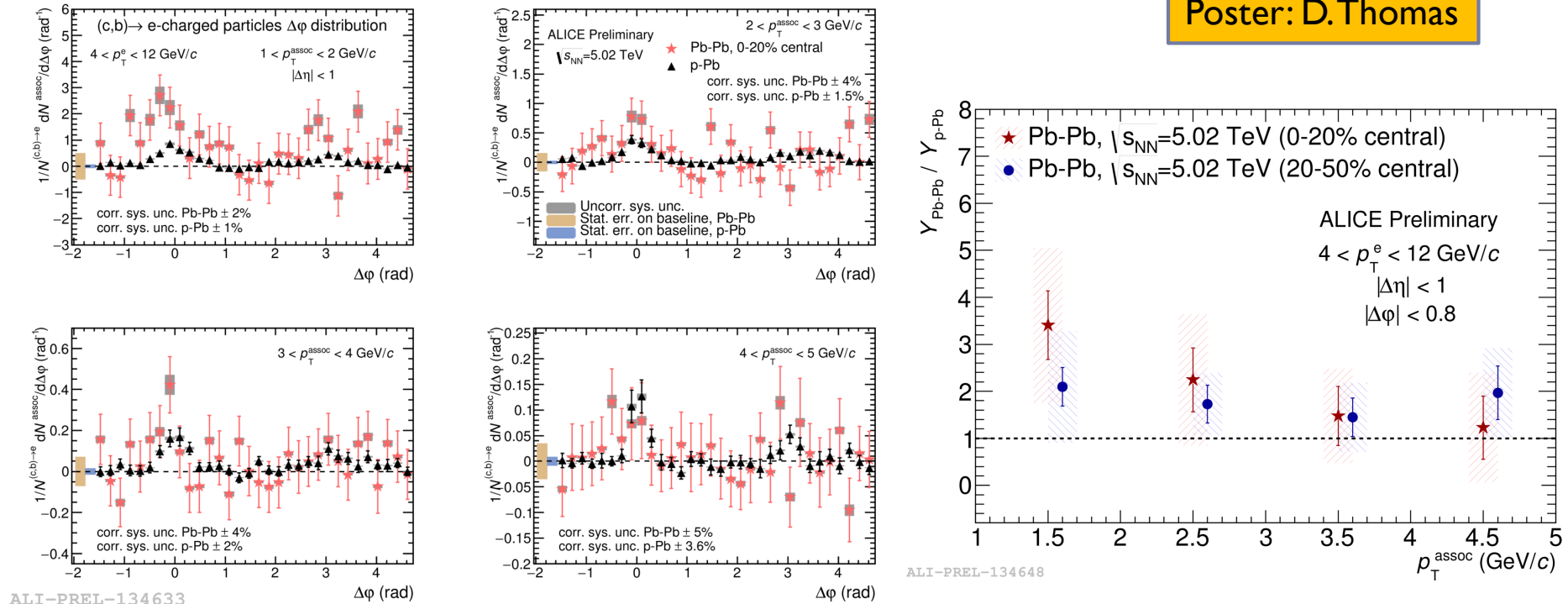
- Address charm jet properties and their possible modification due to initial or final state effects in p-Pb due to
 - Possible flow (v_2) for charm
 - Modification of fragmentation function
 - Suppression of away-side yields (recoil jets) due to energy loss
- Run2 measurement improves significantly the precision of run I data
 - EPCJ 77 245 (2017)
- Correlation function for D-h in p-Pb is described by PYTHIA and POWHEG + PYTHIA within uncertainties (direct comparison with pp in the back up)

see also e^{HF} -h correlation in pPb
Poster: H. Zanoil, D. Thomas

HF correlation function (e-h) in Pb-Pb

New

Poster: D.Thomas



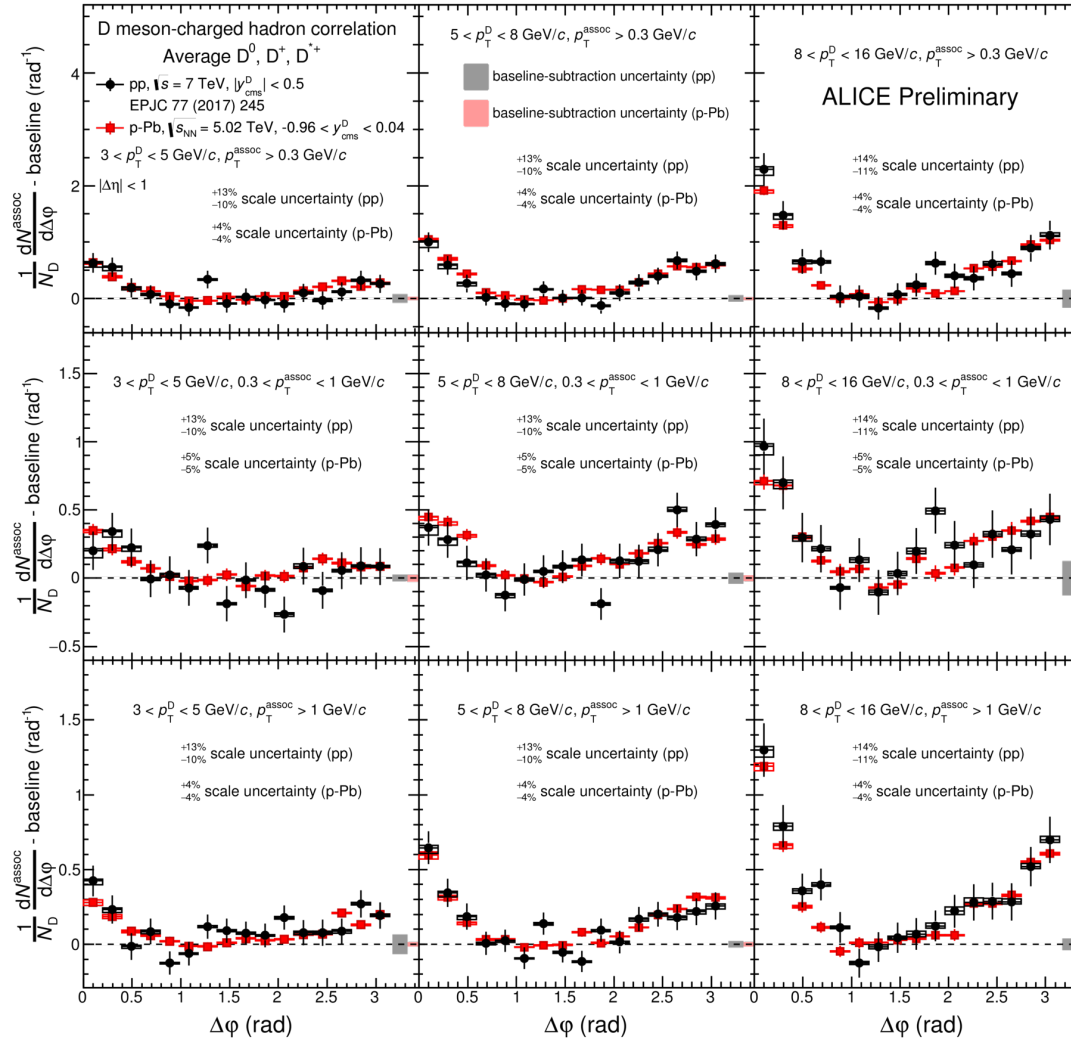
- Azimuthal correlation of e^{HF} and with charged particles in p-Pb and Pb-Pb at 5.02 TeV
 - Near-side: jets containing charm or beauty quarks
- Hint of enhancement of the yield of low- p_T associated particles in the near-side jet
 - Promising in view of next Pb-Pb runs

Summary

- ▶ **ALICE has studied heavy flavour production (charm & beauty) with various differential measurements**
 - ▶ Charm-jet production via D tagged jets in pp collisions is described by a pQCD calculation
 - ▶ No modification of azimuthal correlation between D and charged particles in p-Pb collisions (consistent with pQCD based model calculations within uncertainties)
 - ▶ A strong suppression of heavy-flavour production is observed for e^{HF} at mid-rapidity and μ^{HF} at forward-rapidity & a positive v_2 of e^{HF} in Pb-Pb at 5.02 TeV
 - ▶ Hint of enhancement of associate charged particle from heavy flavours in e^{HF} -h correlation (near-side) in Pb-Pb at 5.02 TeV
 - ▶ **Heavy flavours strongly interact with hot and dense QCD matter formed in Pb-Pb collisions**

Back up

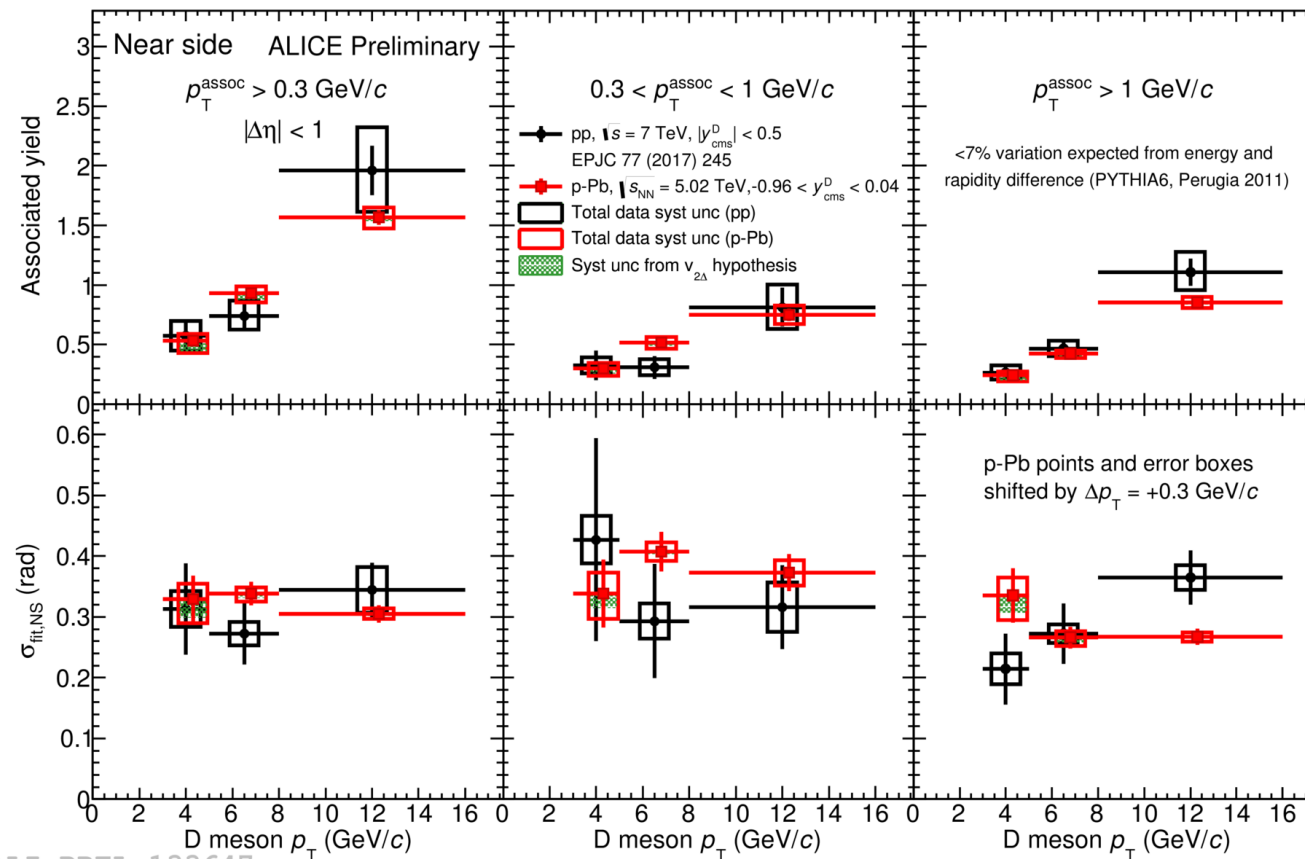
HF correlation (D-h) in pp and p-Pb



ALI-PREL-133622

HF correlation function (D-h) in pp & p-Pb

New



- Near side yields & jet width (σ) in pp and pPb are consistent within uncertainties
- No modification of fragmentation function due to cold nuclear matter effect and/or possible energy loss in small system

I_{AA} in Π^0 -h in Pb-Pb at 2.76 TeV

