Heavy-flavour correlations and jets with ALICE at the LHC

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on behalf of the ALICE Collaboration

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ALICE

Outline

- Motivation: Heavy Flavour
- Alice Detector
- Heavy-flavour Jets
  - Jets tagged by electrons from heavy-flavour decays
  - D^0-tagged jets
  - b-jets
- D-hadron Azimuthal Correlations
- Conclusions

Motivation: Heavy Flavour

Heavy-flavour quarks

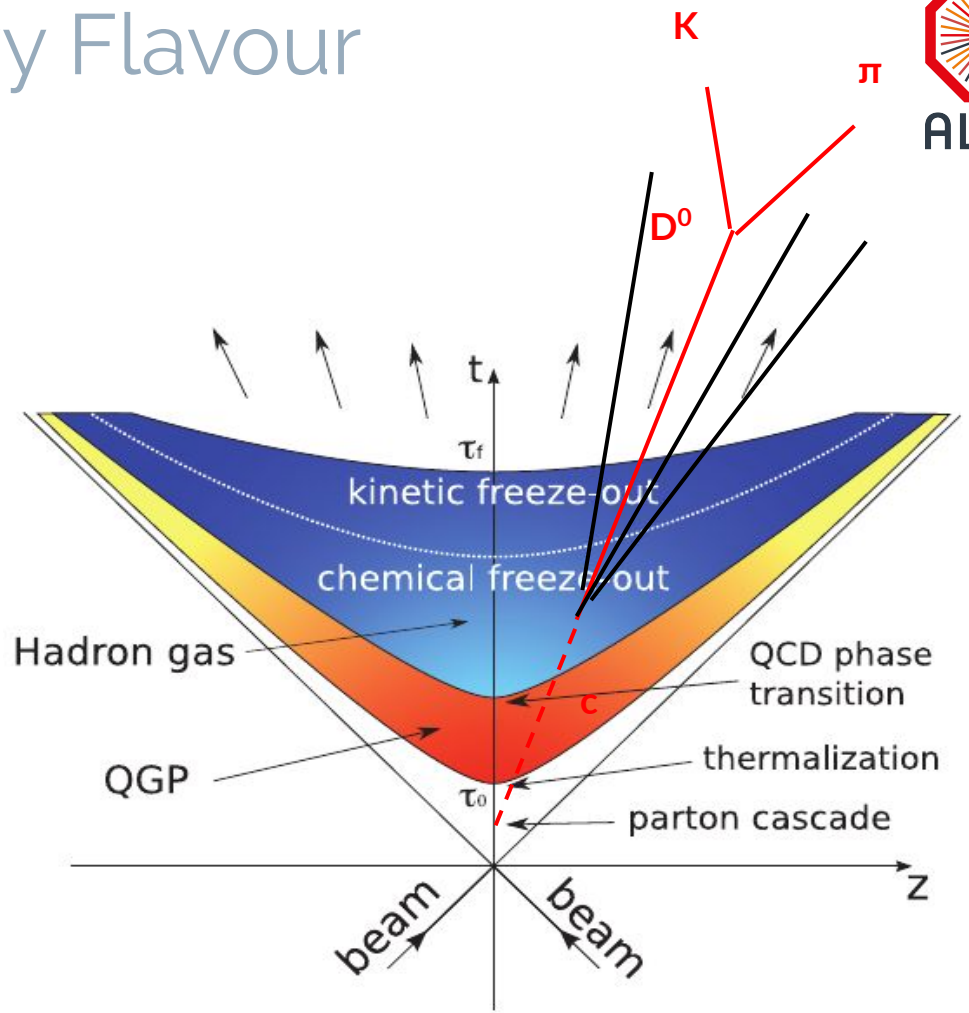
- Created in the first stages of hadronic collisions

Heavy-flavour mesons

- Production well described by FONLL calculations

Heavy-flavour jets

- Complementary information to the heavy-hadron measurements
- Fragmentation
- Jet structure and properties



Motivation: Heavy Flavour

pp collisions

- Comparison to pQCD calculations
- Fragmentation
- Reference for heavy-ions

p-Pb collisions

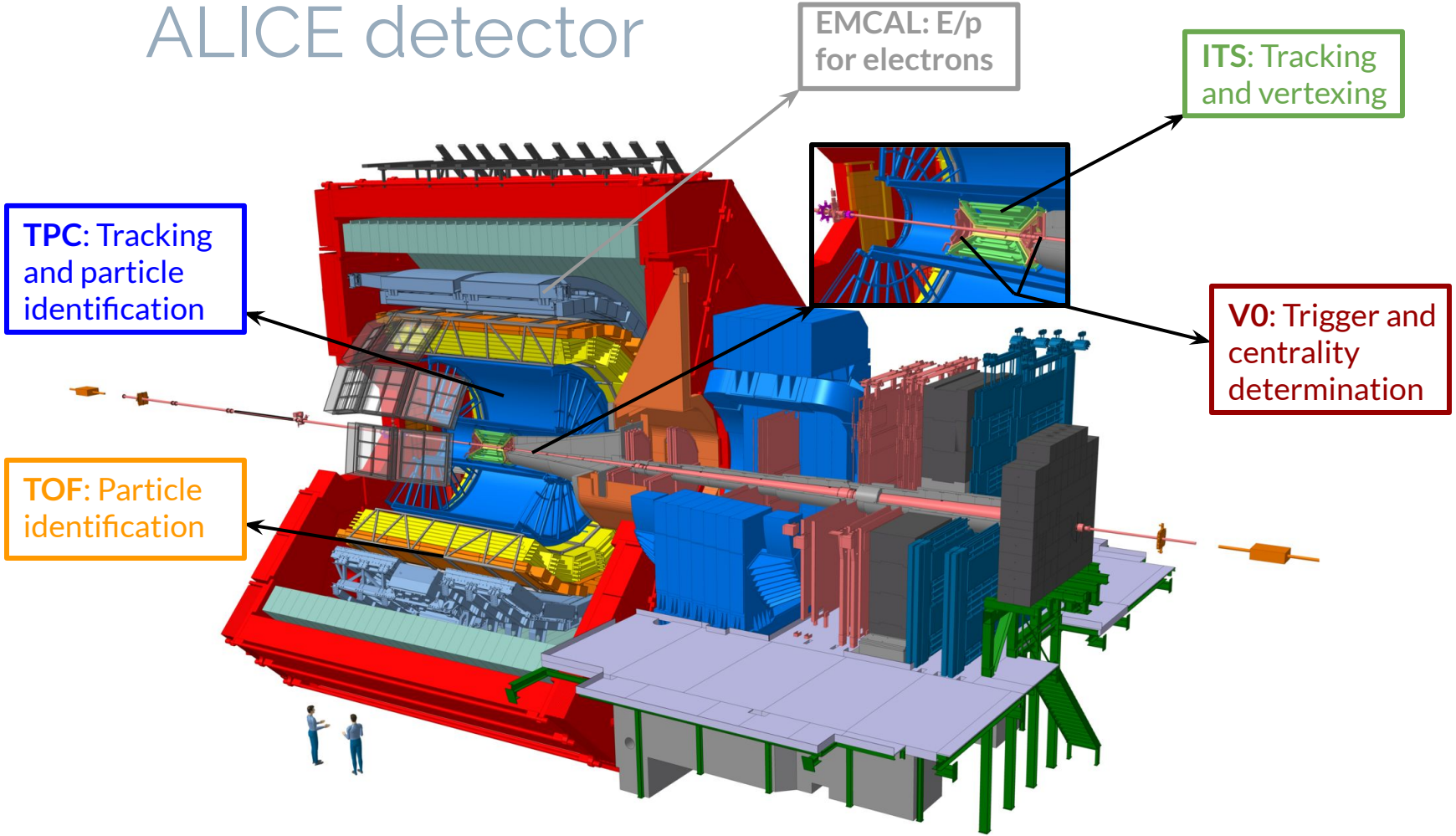
- Cold nuclear matter effects
- Collective effects?

Pb-Pb collisions

- Hot nuclear matter effects
  - Energy loss: collisional vs. radiative
  - Fragmentation in/out medium?
  - ...

$$R_{\mathrm{AA}} = \frac{1}{N_{\mathrm{coll}}} \frac{\mathrm{d}^2 N_{\mathrm{AA}}/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}{\mathrm{d}^2 N_{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}$$

ALICE detector



Heavy-Flavour Jets

Jets are reconstructed with anti-k_t algorithm using FASTJET

HFe-Jets

- Electrons from heavy-flavour decays are used to tag heavy-flavour jets

D-tagged Jets

- Tagged by fully reconstructed D^0 mesons in jets

b-Jets

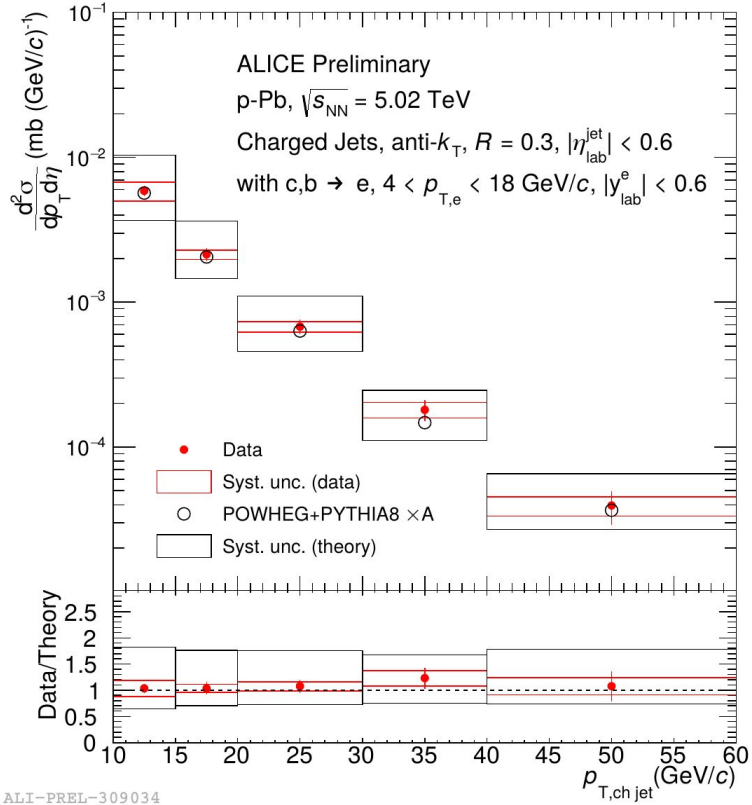
- The displacement between the primary and secondary vertices are use to identify jets coming from bottom quarks

Jets tagged by electrons from heavy-flavour decays

p-Pb collisions at 5.02 TeV

Jets tagged by electrons from HF decays

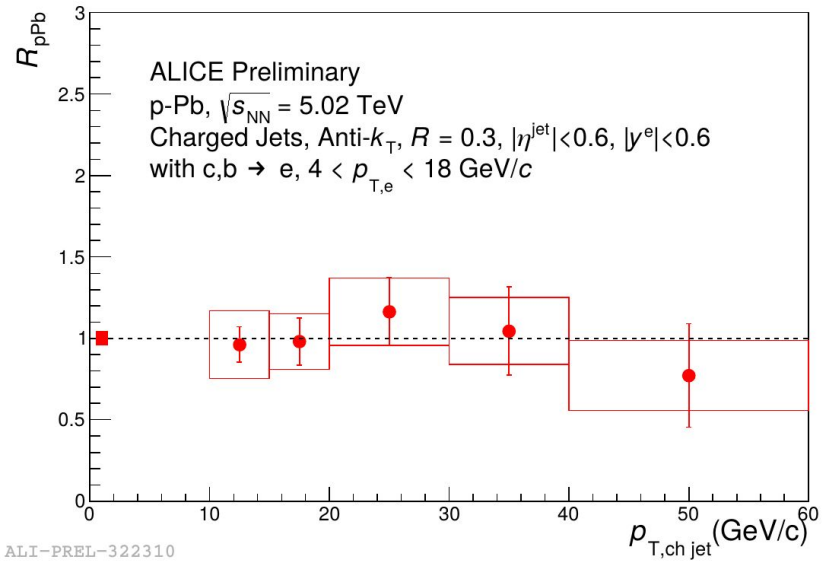
p-Pb@5.02 TeV



- p_T-differential cross-section of jets tagged by electrons coming from heavy-flavour decays
  - Charm+Bottom
- Removed contribution from Dalitz decay of light neutral meson and photon conversion
- Corrected by
  - Reconstruction efficiency
  - Detector finite resolution
- Comparison with NLO calculations using POWHEG+PYTHIA8
  - Agreement within uncertainties

Jets tagged by electrons from HF decays

p-Pb@5.02 TeV

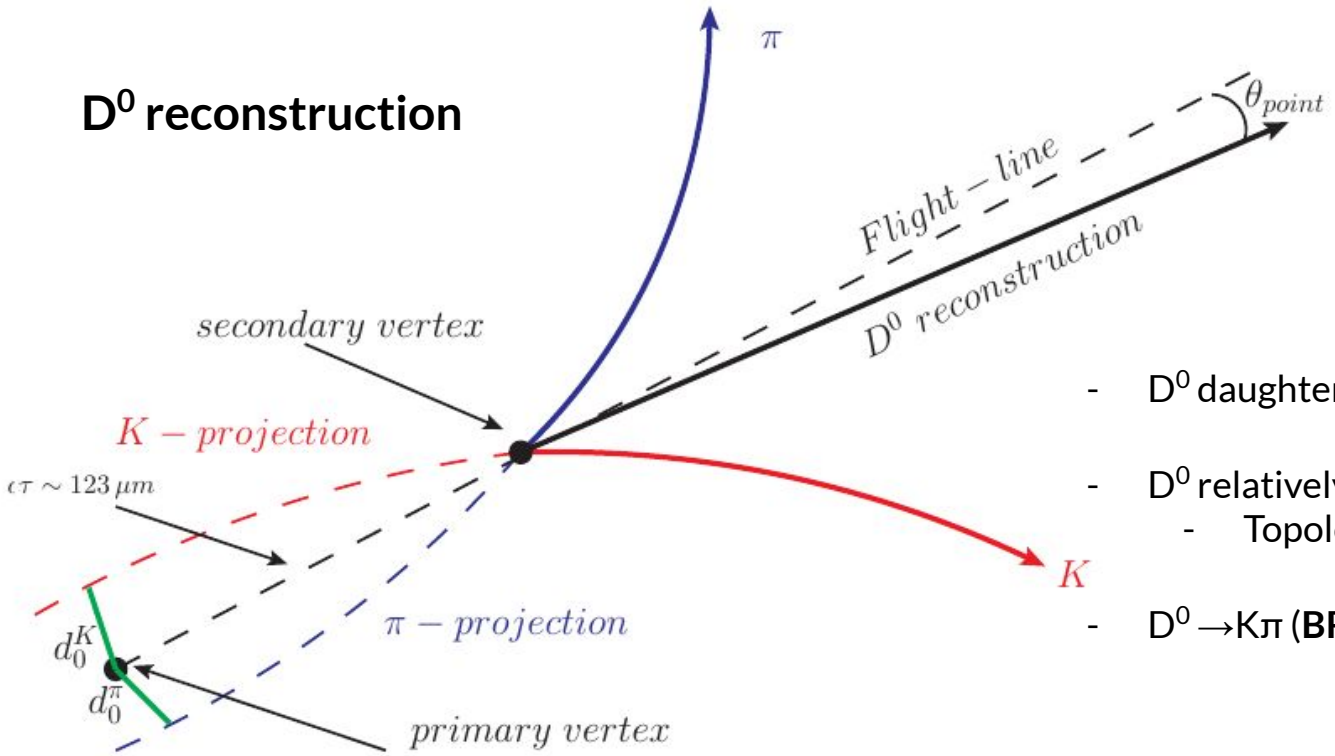


- R_{pPb} of jets tagged by electrons coming from heavy-flavour decays
- **No indication of cold nuclear matter effects**
- pp at 5.02 TeV measurement used as reference

D^0-tagged jets
pp collisions at 5.02 and 13 TeV

D^0-tagged Jets

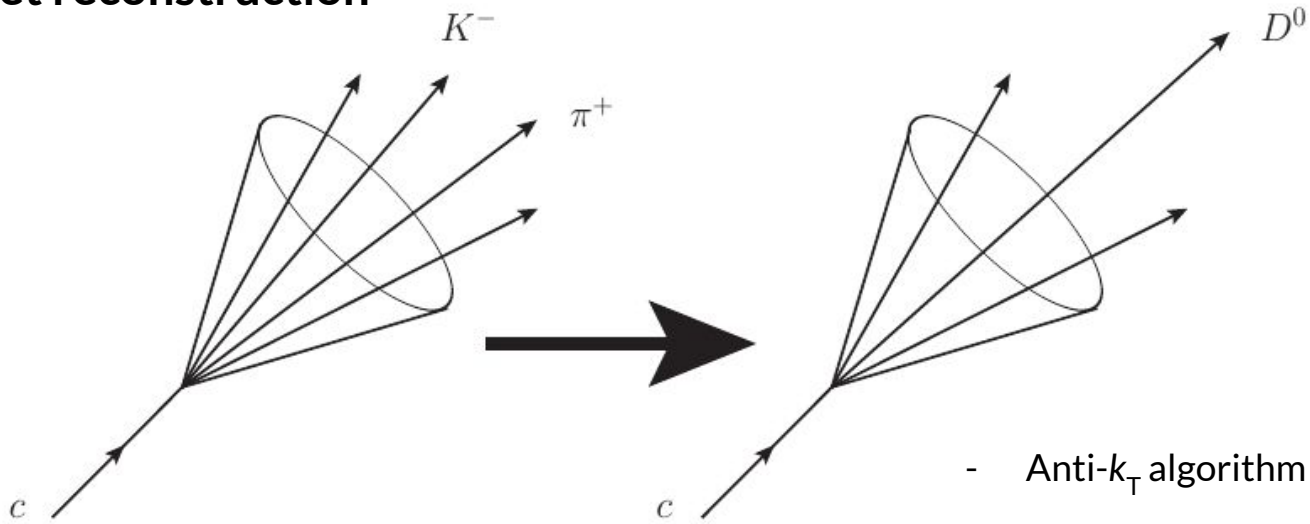
D^0 reconstruction



- D^0 daughters: particle identification
- D^0 relatively large lifetime ($c\tau$ ~ 100 μm)
  - Topological and kinematic selections
- $D^0 \rightarrow K\pi$ (**BR** ~ 3.93 %)

D^0-tagged Jets

Jet reconstruction

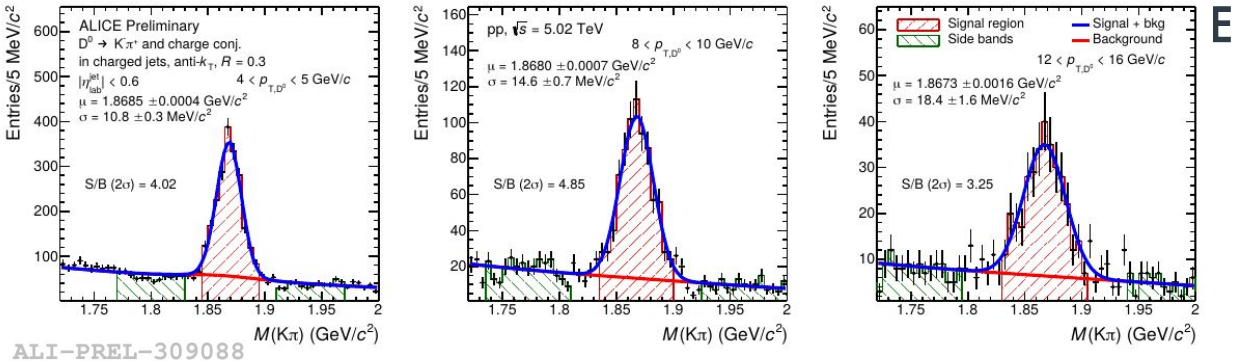


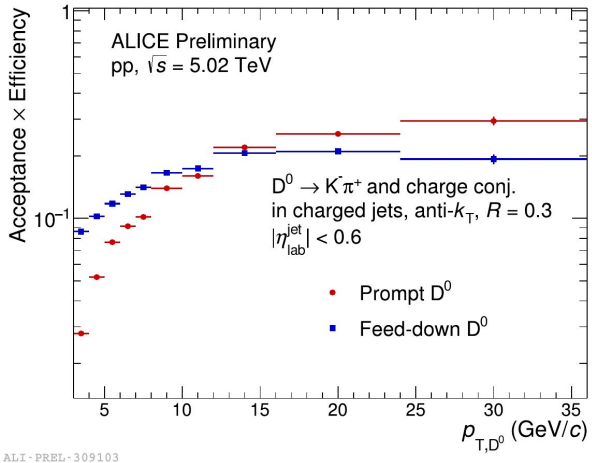
- Anti-k_T algorithm
- Charged particles
- D^0 daughters are replaced by the reconstructed 4-momentum vector

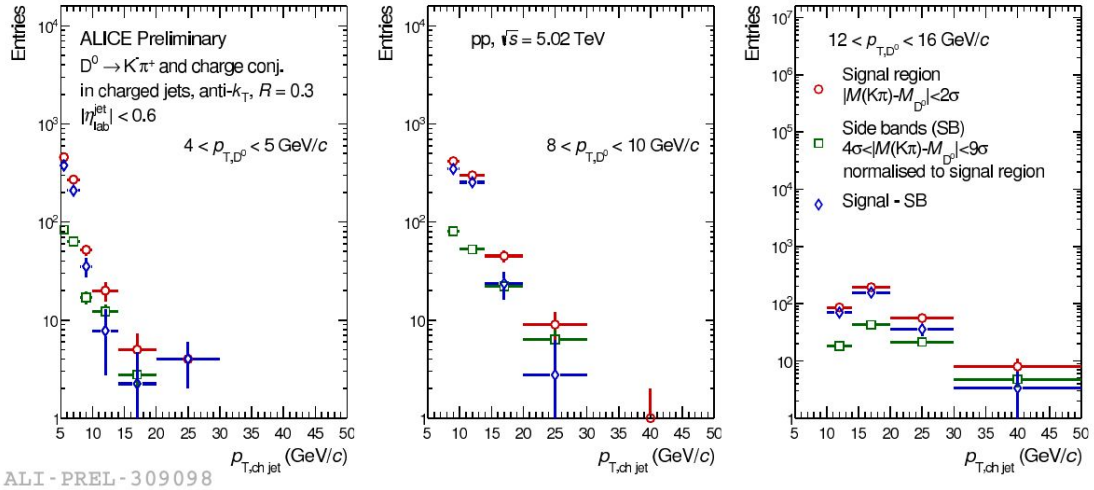
D^0-tagged jets

pp@5.02 TeV

- D^0-tagged jet signal is extracted by invariant mass analysis
- Jet $p_{T,\,raw} = p_{T,peak} - N^{*}p_{T,sideband}$
- Signal is corrected by reconstruction efficiency and <u>feed-down from bottom</u>

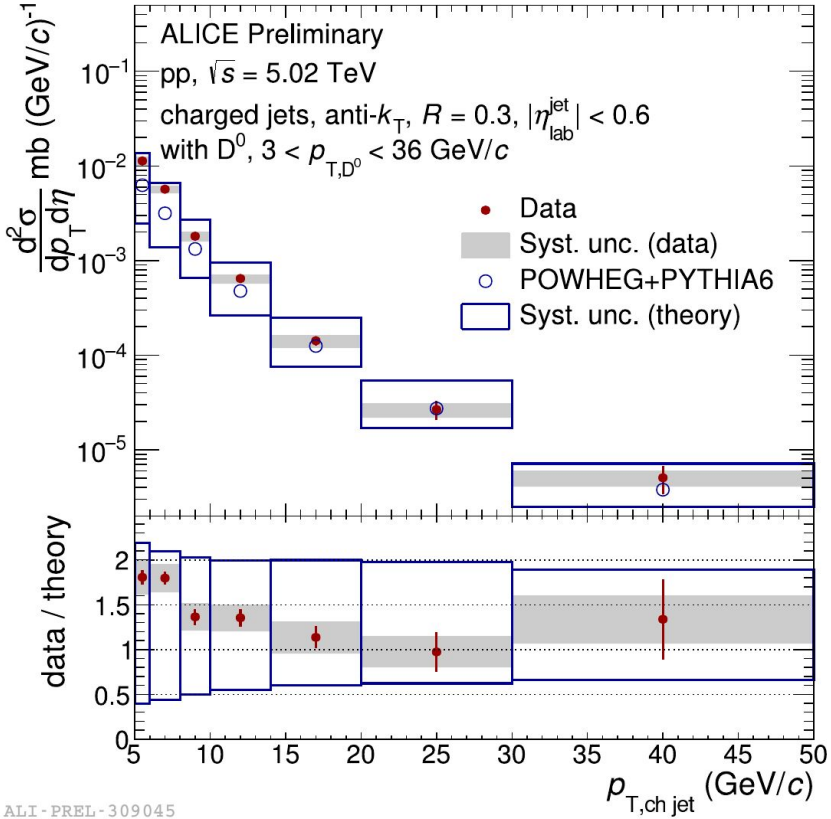






D^0-tagged jets

pp@5.02 TeV

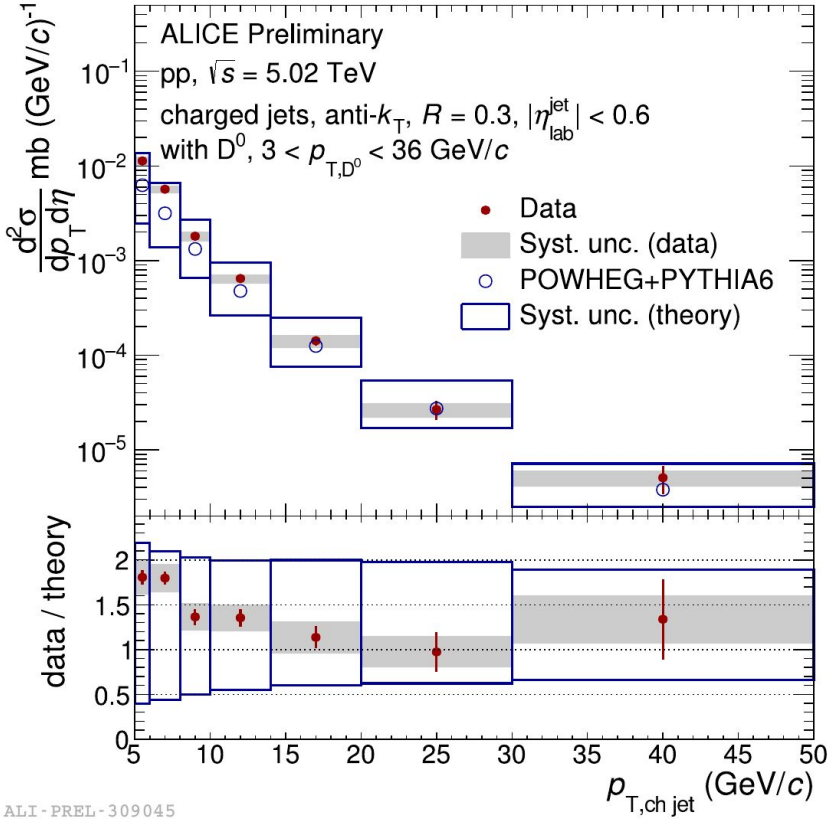


- p_T-differential D^0-tagget jet cross section

- Comparison with NLO calculations using POWHEG+PYTHIA6
  - Agreement within uncertainties

D^0-tagged jets

pp@5.02 TeV



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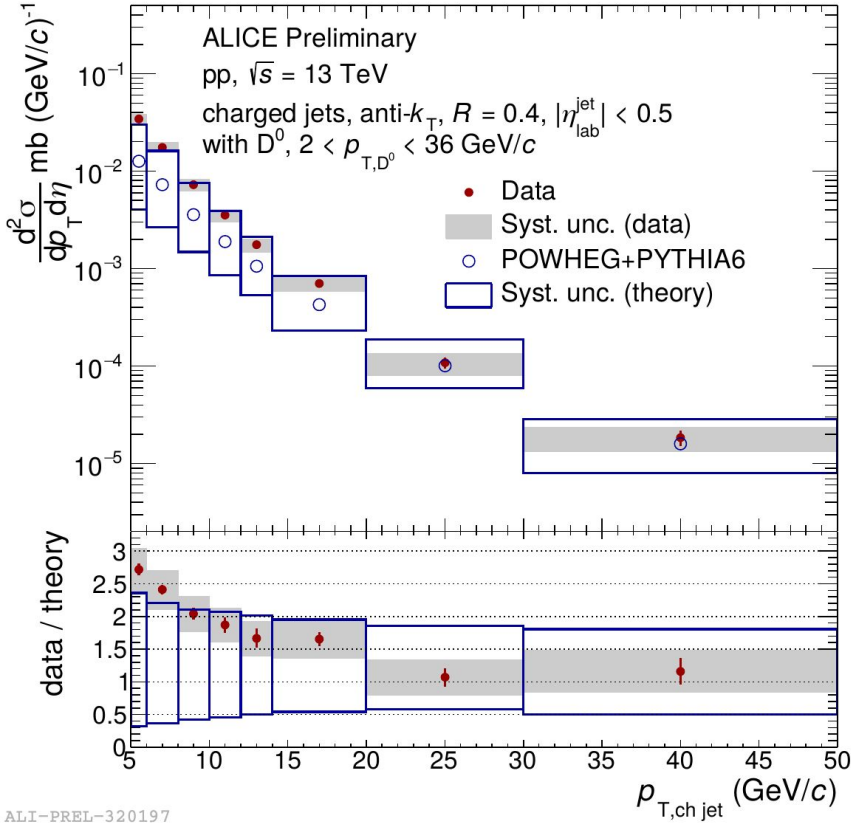
pp@13 TeV



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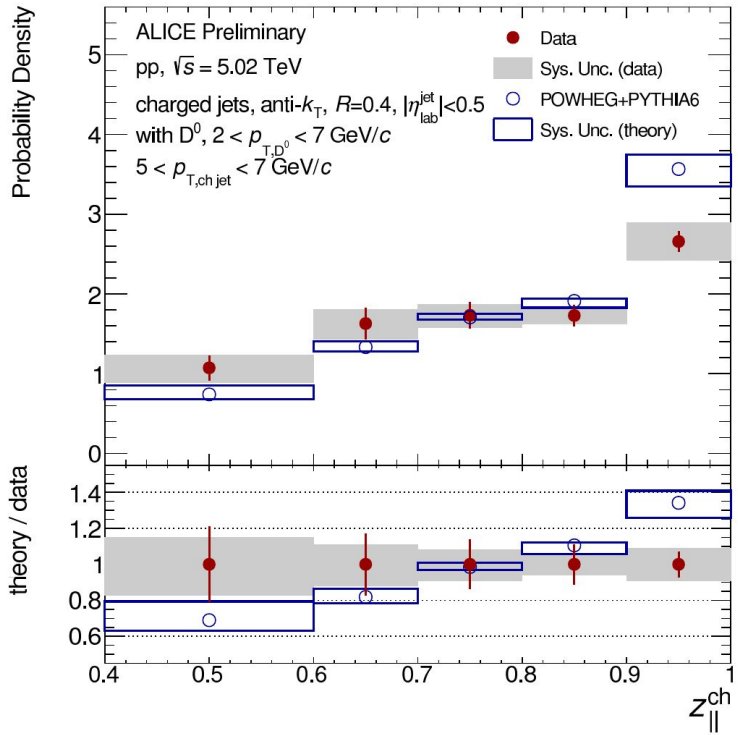
D^0-tagged jets

D^0-jet momentum fraction

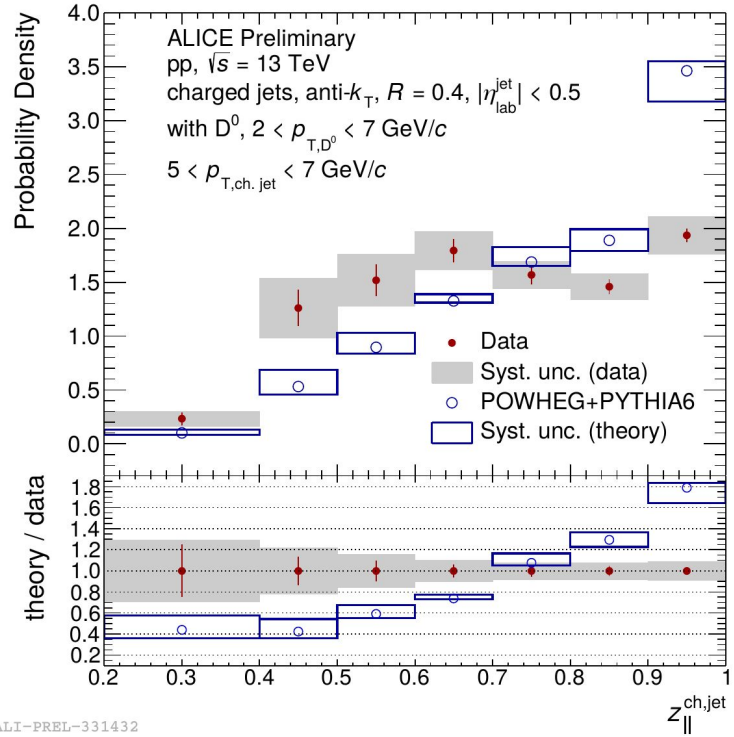
$$z_{||}^{ch} = \frac{\vec{p}_{jet}^{\,ch} \cdot \vec{p}_D}{\vec{p}_{jet}^{\,ch} \cdot \vec{p}_{jet}^{\,ch}}$$

- Both measurements give hints of a **flatter dis in comparison to POWHEG+PYTHIA6**

pp@5.02



pp@13 TeV



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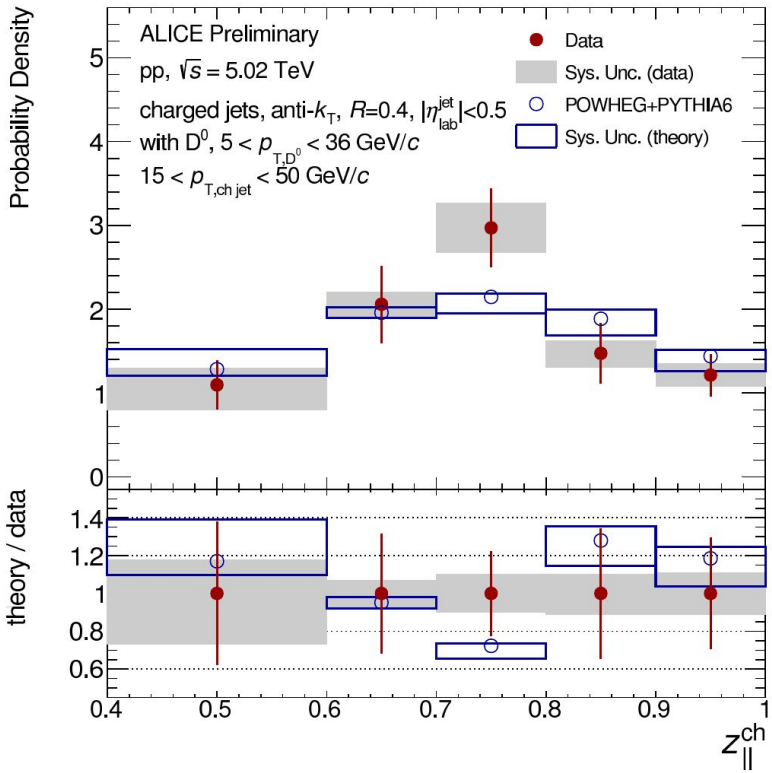
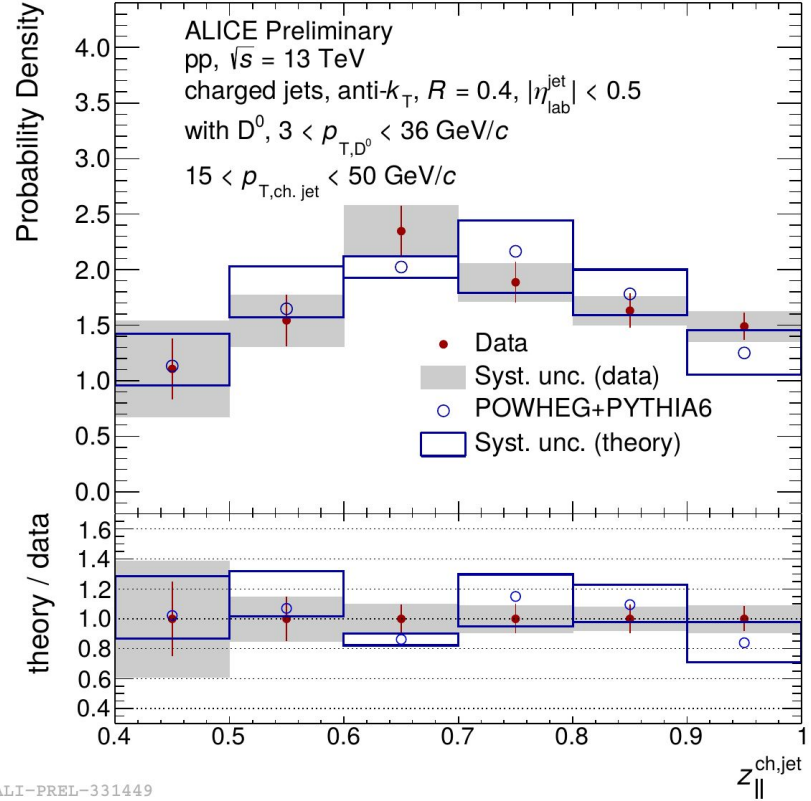
D^0-tagged jets

- The distribution is ***softer* for higher momentum jets**

pp@5.02



pp@13 TeV



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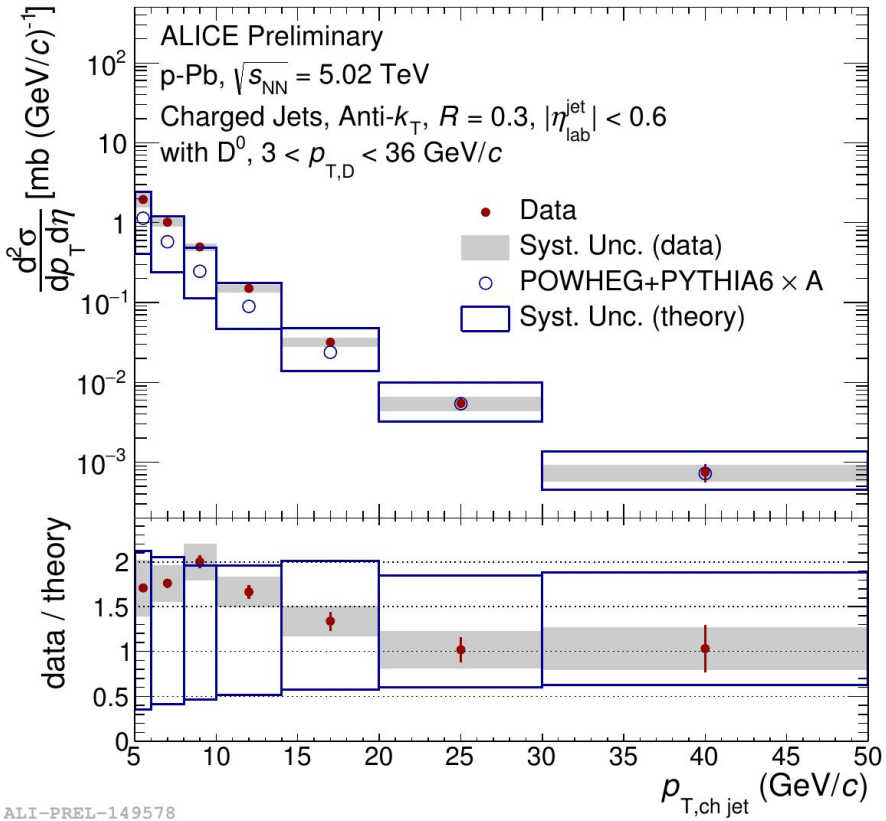
D^0-tagged jets
p-Pb collisions at 5.02 TeV

D^0-tagged jets

p-Pb@5.02 TeV



- p_T-differential D^0-tagget jet cross section
- Comparison with NLO calculations using POWHEG+PYTHIA6
  - pp simulation scaled by A
  - Agreement within uncertainties

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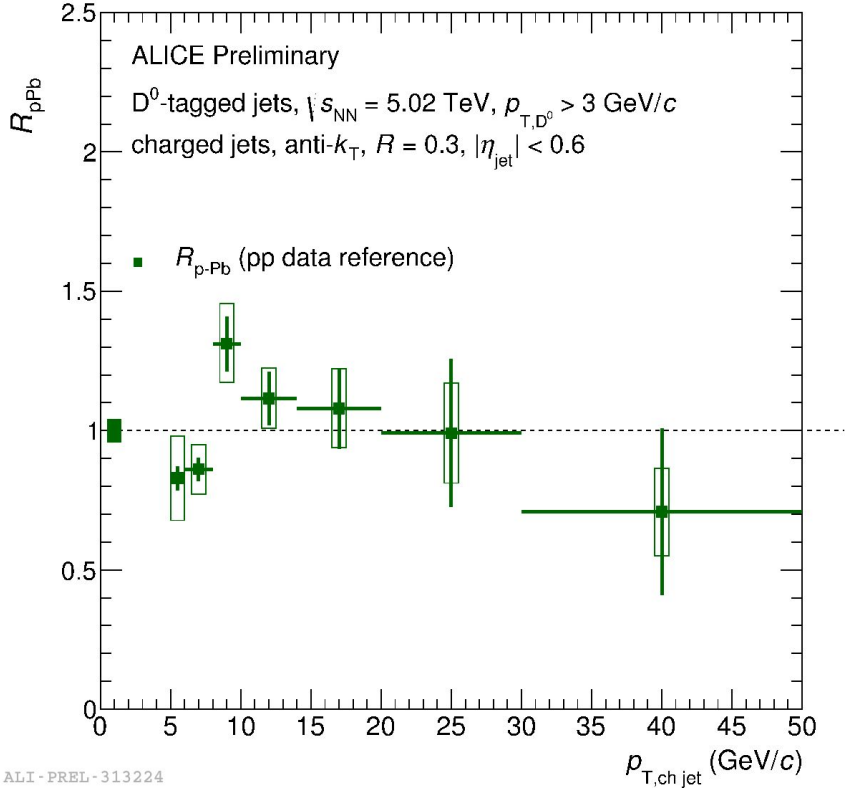
D^0-tagged jets

p-Pb@5.02 TeV



- R_{pPb} of D^0-tagged jets
- **Not sensitive to cold nuclear matter effects**
- pp at 5.02 TeV measurement used as reference

D^0-tagged jets
Pb-Pb collisions at 5.02 TeV

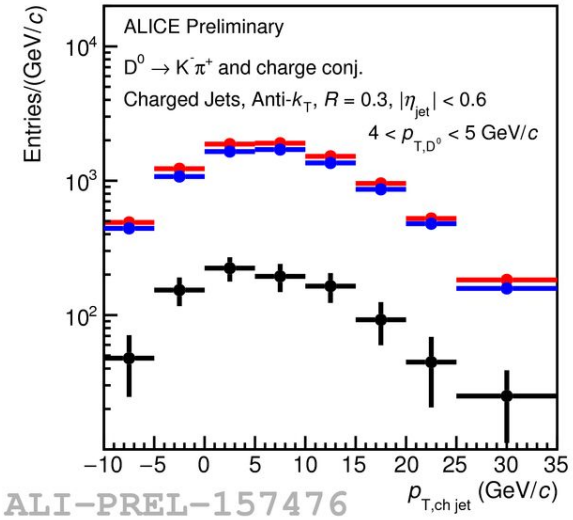
D^0-tagged jets

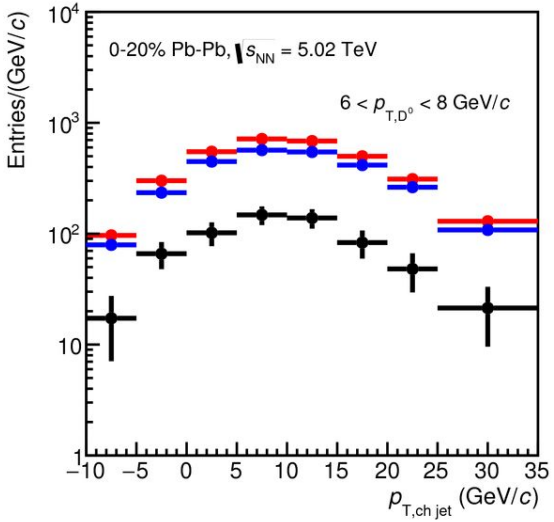
Pb-Pb@5.02 TeV

- Jet background subtracted using the median of the jet p_T density (ρ)

- Jet $p_{T,raw} = p_{T,peak} - N^* p_{T,sideband}$

$$\rho = median\left\{\frac{p_T^{jet}}{A_{jet}}\right\}$$





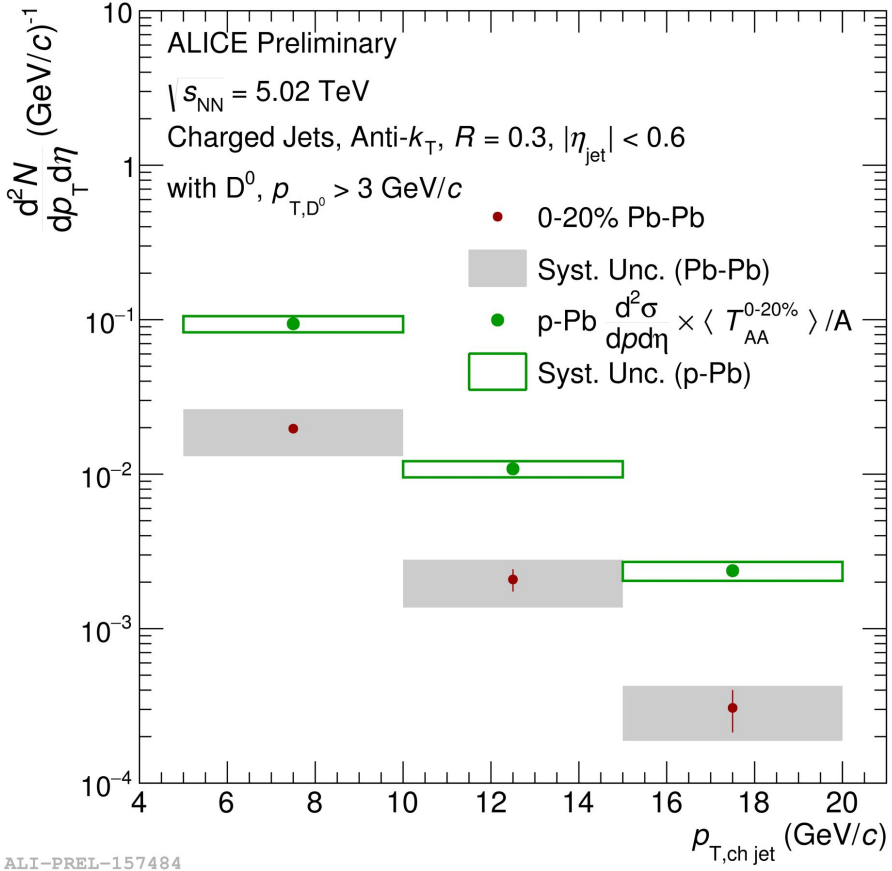
$$p_T^{corr} = p_T^{raw} - \rho A_{jet}$$

- Jet background fluctuations and detector resolution corrected by bayesian unfolding

- Monte Carlo closure tests were performed to check the stability of the unfolding procedure

D^0-tagged jets

Pb-Pb@5.02 TeV

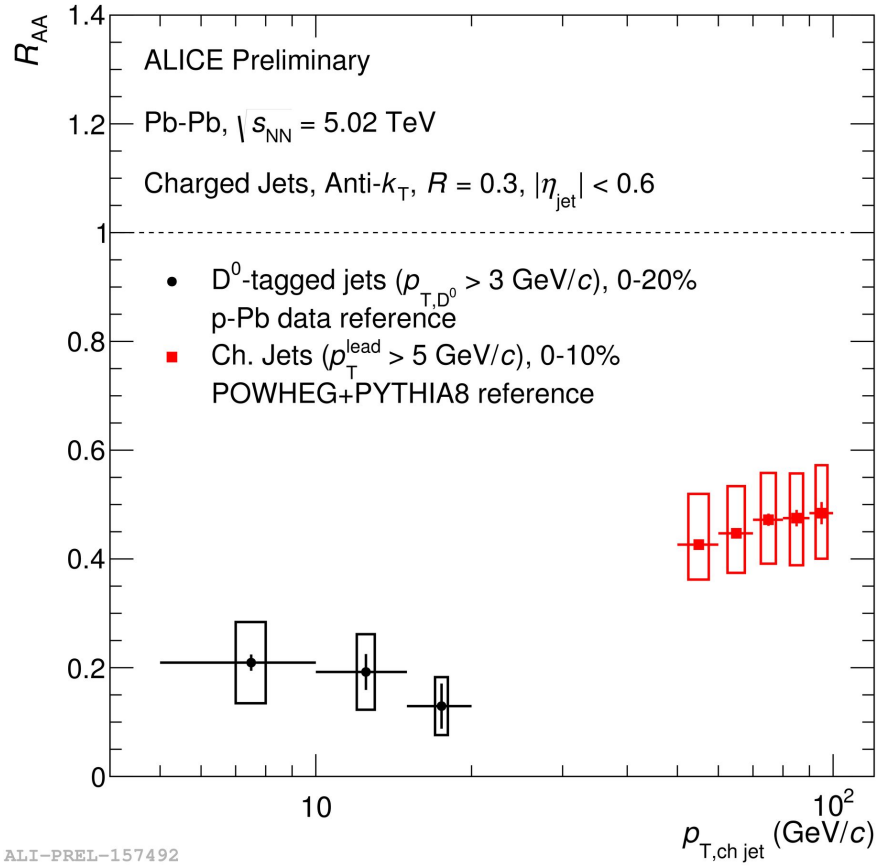


D^0-jets in Pb-Pb collisions at 5.02 TeV

- D^0 p_T > 3 GeV/c and 5 < jet p_T < 20 GeV/c
- Method **improves fake jets rejection** and jet energy scale resolution
  - Presence of heavy flavour as indication of hard scattering
- D^0-jet in p-Pb collisions at 5.02 TeV used as reference

D^0-tagged jets

Pb-Pb@5.02 TeV

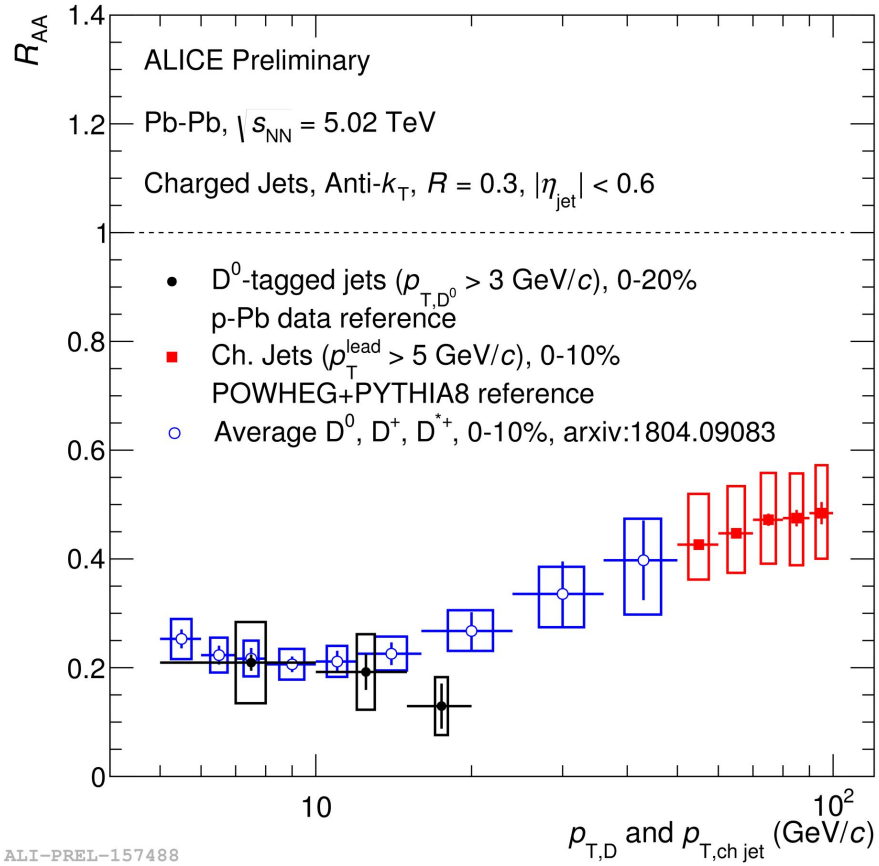


D^0-jets in Pb-Pb collisions at 5.02 TeV

- Indication of **strong suppression of D^0-jets production in central heavy-ion collisions**
- Hint of D^0-jets in 5 < jet p_T < 20 GeV/c **more suppressed than inclusive charged-particle jets** at high transverse momentum

D^0-tagged jets

Pb-Pb@5.02 TeV



D^0-jets in Pb-Pb collisions at 5.02 TeV

- Indication of **strong suppression of D^0-jets production in central heavy-ion collisions**
- Hint of D^0-jets in 5 < jet p_T < 20 GeV/c **more suppressed than inclusive charged-particle jets** at high transverse momentum
- Comparison to average R_{AA} of D^0, D^+ and D^{*+}
  - **Compatible with D^0-jets up to 15 GeV/c**

b-jets
p-Pb collisions at 5.02 TeV

b-jets

p-Pb@5.02 TeV

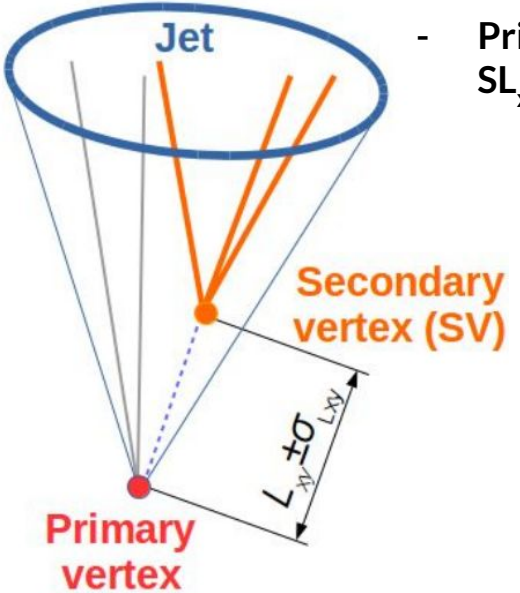
- Secondary vertex with 3 particles
- Small SV resolution
- d: DCA to the SV

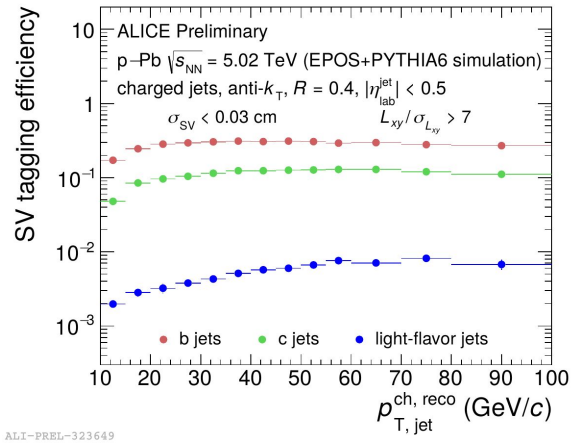
$$\sigma_{SV} = \sqrt{\sum_{i=1}^{3} d_i^2}$$

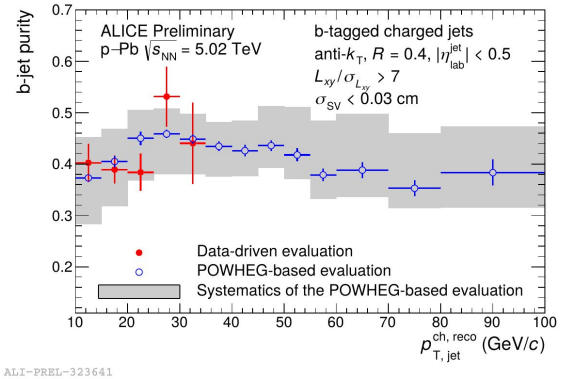
- Primary and secondary vertices separation: $SL_{xy} = L_{xy}/\sigma_{Lxy} \sim 5$ to 9
  - Tagging efficiency obtained from simulations of p-Pb collisions (PYTHIA6+EPOS)

$$\varepsilon_b\left(p_{T,\,jet}^{ch,\,reco}\right) = \frac{N_b^{selected}}{N_b^{all}}$$

  - Purity was determined using a data-driven method and using POWHEG simulations

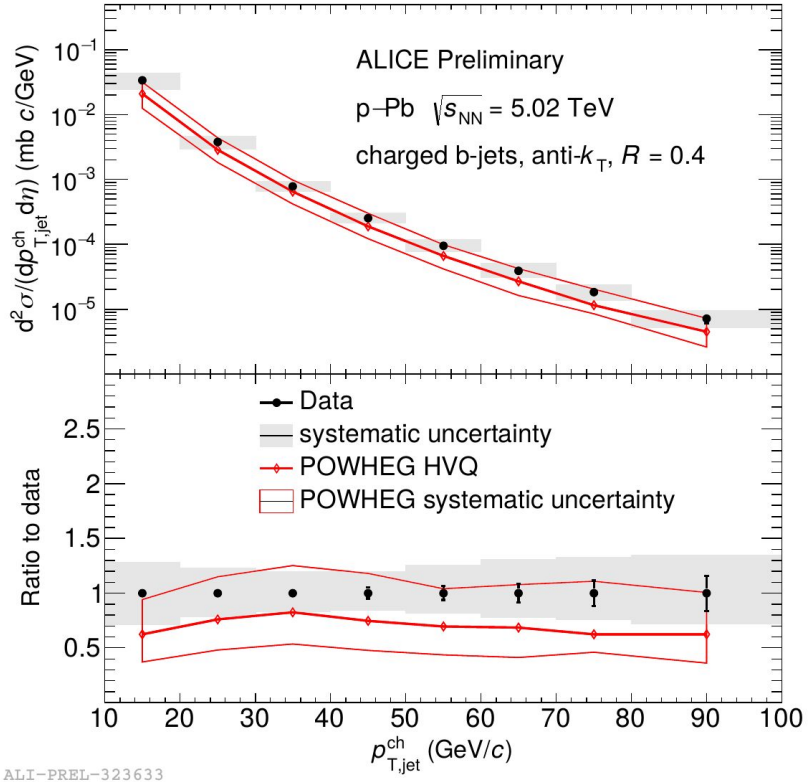






b-jets

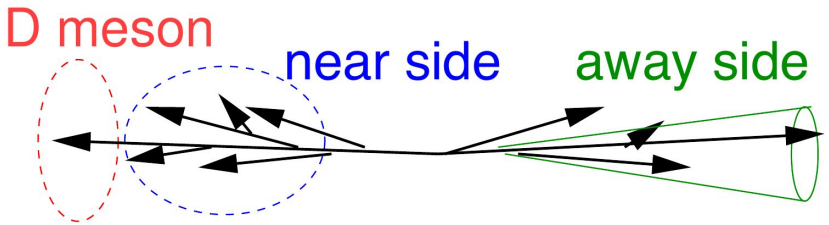
p-Pb@5.02 TeV

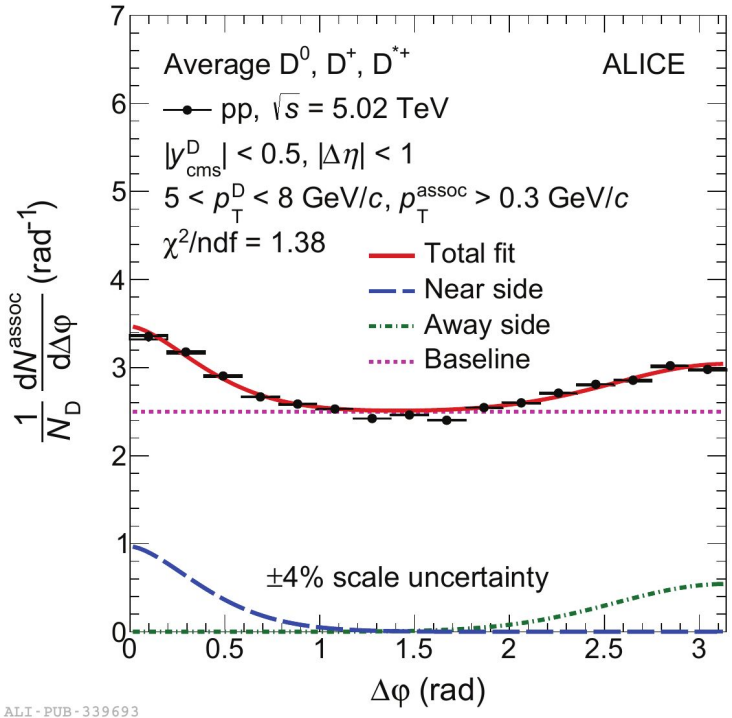


- p_T-differential cross section of jets from bottom quarks
- Corrected by SV tagging efficiency and b-jet purity
- Corrected by detector effects and jet background fluctuations
- Comparison with POWHEG HVQ
  - Data and simulation are compatible within uncertainties

D-hadron Correlations

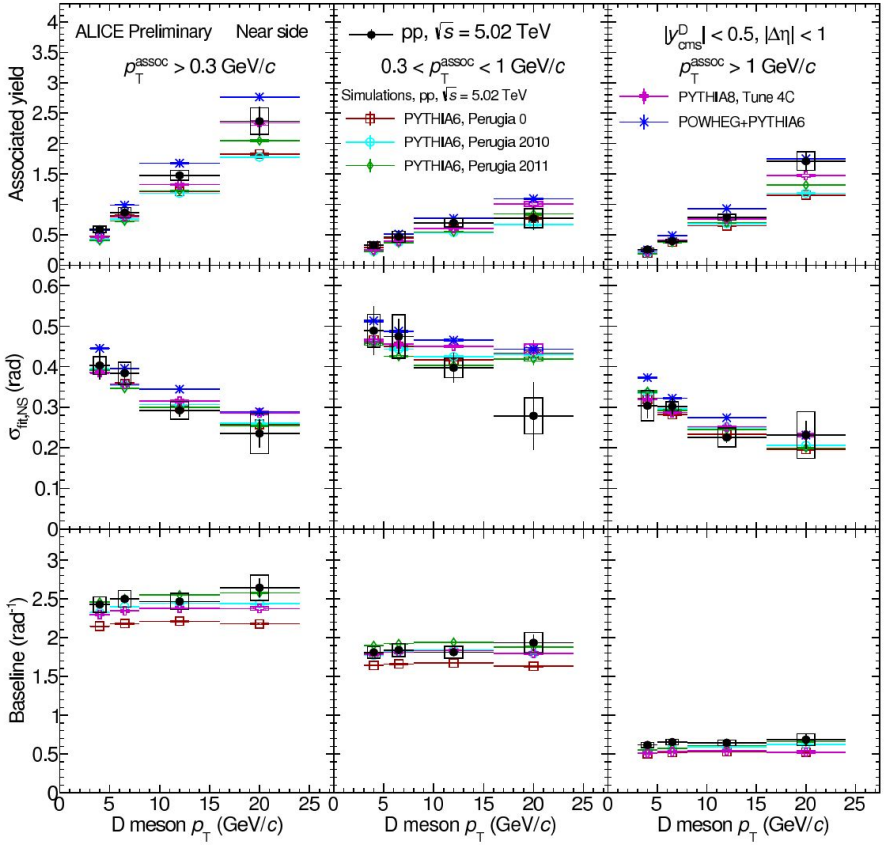
D-hadron correlations





- Complementary information to heavy-flavour jets
  - Fragmentation, spatial profile
- Corrected by
  - Finite detector acceptance (event mixing)
  - Particle reconstruction efficiency
  - B feed-down subtraction based on FONLL
- Fit with two gaussians for the peak and a constant function for the baseline

D-hadron correlations



- Comparisons between measurement and different simulations

- Yield: Charged particle multiplicity
- Width: Spatial profile of the charm jet

- **POWHEG+PYTHIA produces a better description of the data**
  - Larger associated yields and broader peaks

- PYTHIA6 with Perugia-0 underpredicts the baseline values. Other simulations reproduce it fairly well

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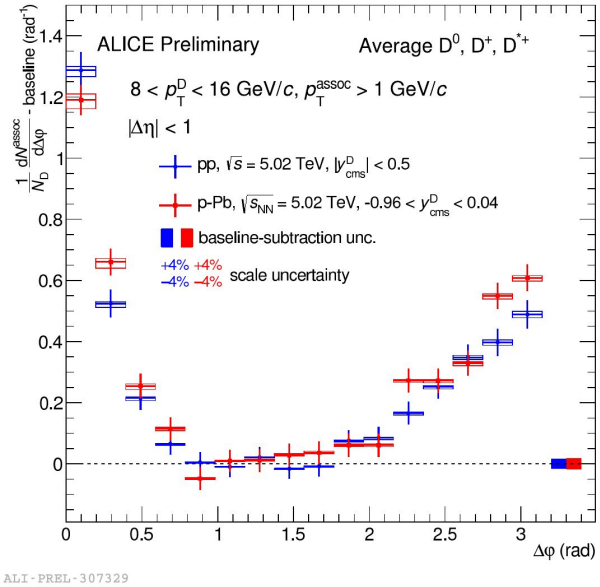
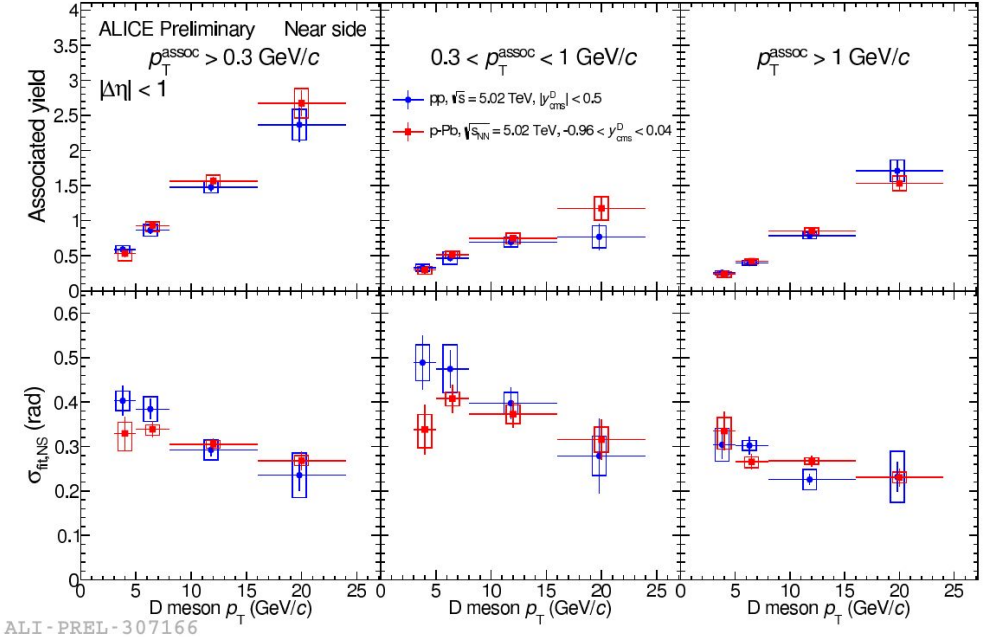
D-hadron correlations

pp vs p-Pb





For increasing D-meson p_T

- **Increase of charged particles** in the near-side peak
- Charged particles are **more collimated**

Near-side observables are compatible between the two collision systems

- **No evidences of cold nuclear matter effects**

Conclusions

Heavy-flavour jets

- p_T-differential cross section in various collision systems
  - Compatible with NLO calculations
- Momentum fraction studies in pp collisions at 5.02 and 13 TeV
  - Hint of softer fragmentation for high momentum jets
- Nuclear modification factor (R_{AA} and R_{pPb})
  - No evidence of cold nuclear matter effects
  - Evidence of strong suppression in hot medium
- Measurements of jets coming from charm and bottom

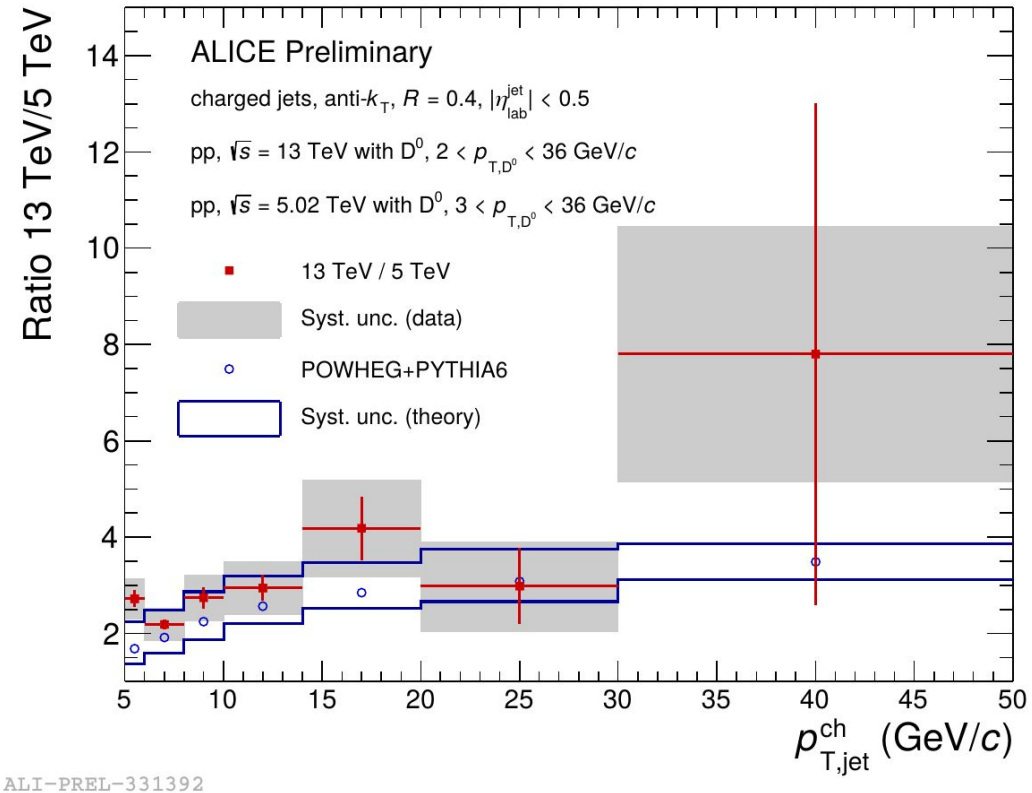
D-hadron correlations

- Characterization of the charm fragmentation
  - Near-side peak observables provide particle multiplicity and spatial distribution
- Measurements in pp and p-Pb collisions are compatible
  - No evidence of cold nuclear matter effects
- Measurements in pp collisions well described by model predictions

Backup

D^0-tagged jets

pp@5.02 and 13 TeV



- Ratio between the D^0-jet transverse momentum measurement in two different collision energies.
- The ratio is compatible to simulations using POWHEG+PYTHIA6

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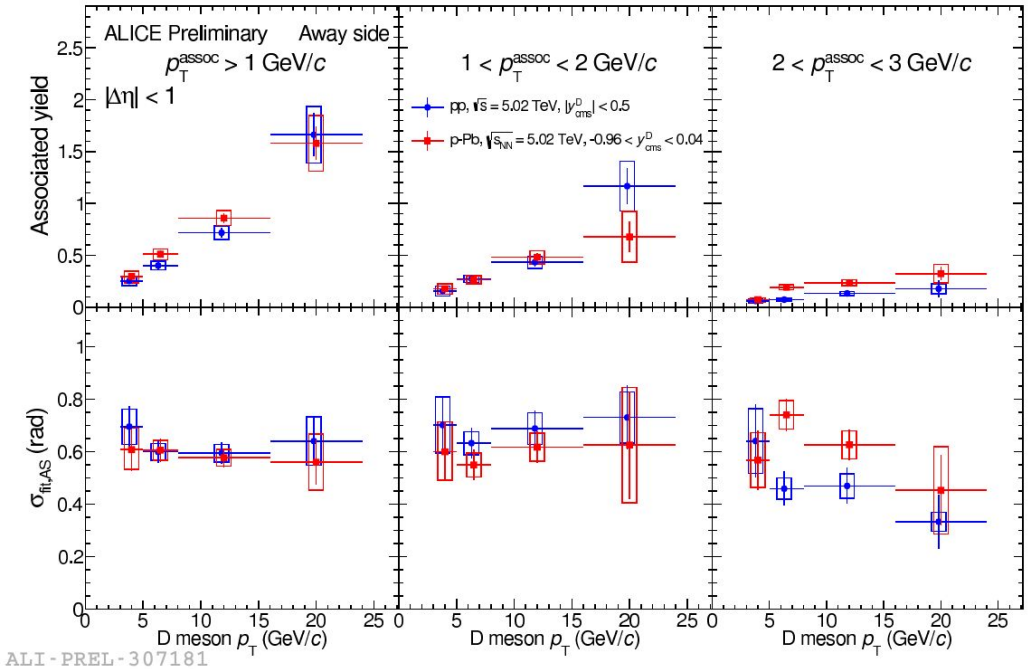
D-hadron correlations



- D-hadron correlation
- Away-side
  - Comparison between pp and p-Pb