Measurements of open heavy flavour correlations and jets with ALICE at the LHC

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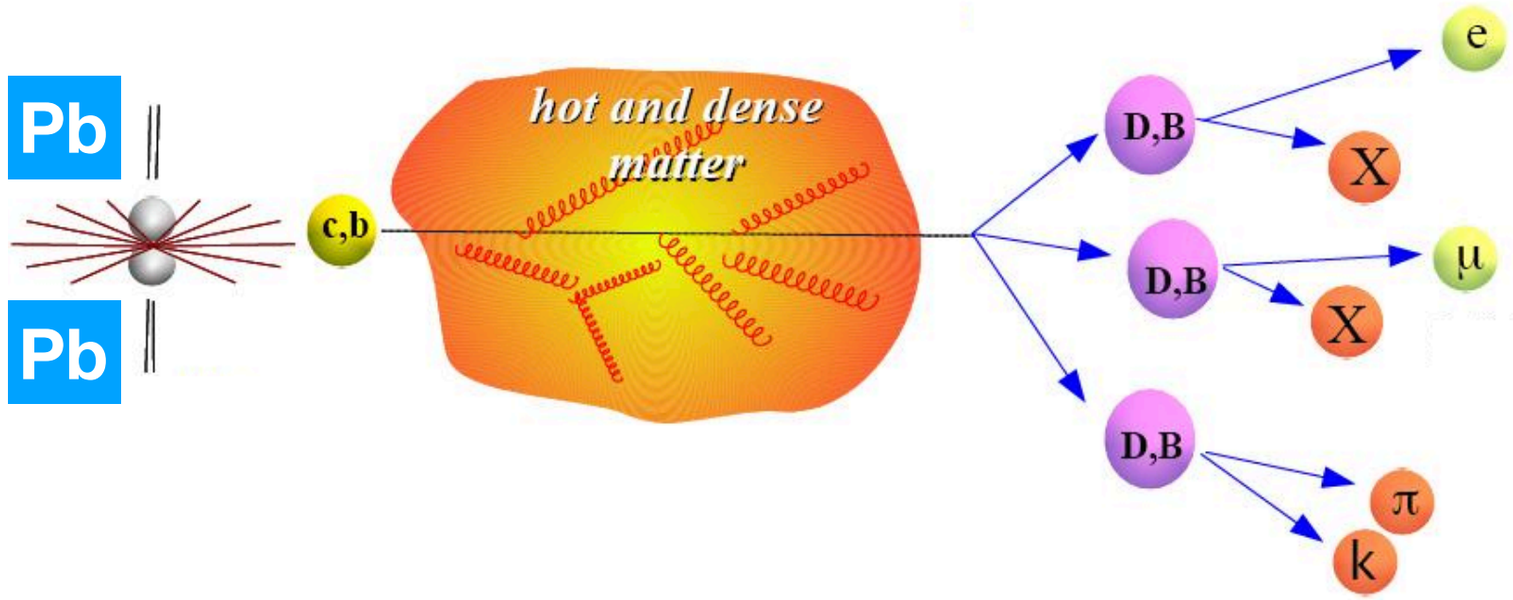
Opportunities and Challenges with Jets at LHC and beyond

10–12 Jun, 2018, Wuhan, China

- Introduction
- D-h / HFe-h correlations
- D-tagged jets
- Conclusion and prospects

Motivation

Heavy quarks (charm and beauty): powerful probes of the Quark-Gluon Plasma (QGP)



- Produced in initial hard scatterings (high Q^2) at the early stage of heavy-ion collisions: $\tau_{c/b}$ ~0.01 — 0.1 fm/c < τ_{QGP} (~0.3 fm/c)
- Production cross section calculable with pQCD (m_c, m_b ≫ Λ_{QCD})
- Experience the entire evolution of the QCD medium — probe transport properties of the deconfined medium

Motivation

Study of open heavy-quark production and jets

- pp collisions: further constraints on heavy quark production mechanisms and fragmentation, reference for pp and p–Pb collisions
- p–Pb collisions

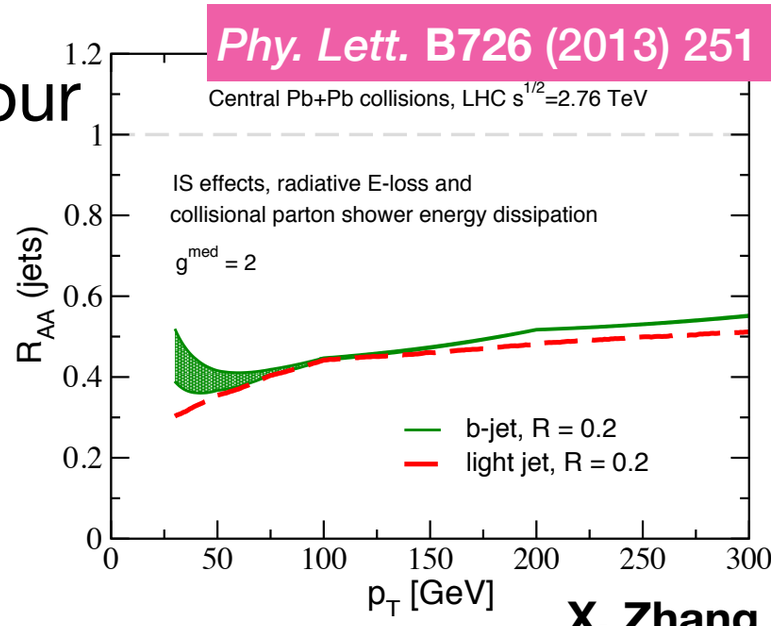
➡ Possible modifications of angular correlation pattern from cold nuclear matter effects **(open heavy-flavour elliptic flow in p–Pb collisions with ALICE [arXiv:1805.04367])**

➡ Search for long-range ridge-like structures (double ridge), observed in di-hadron correlations

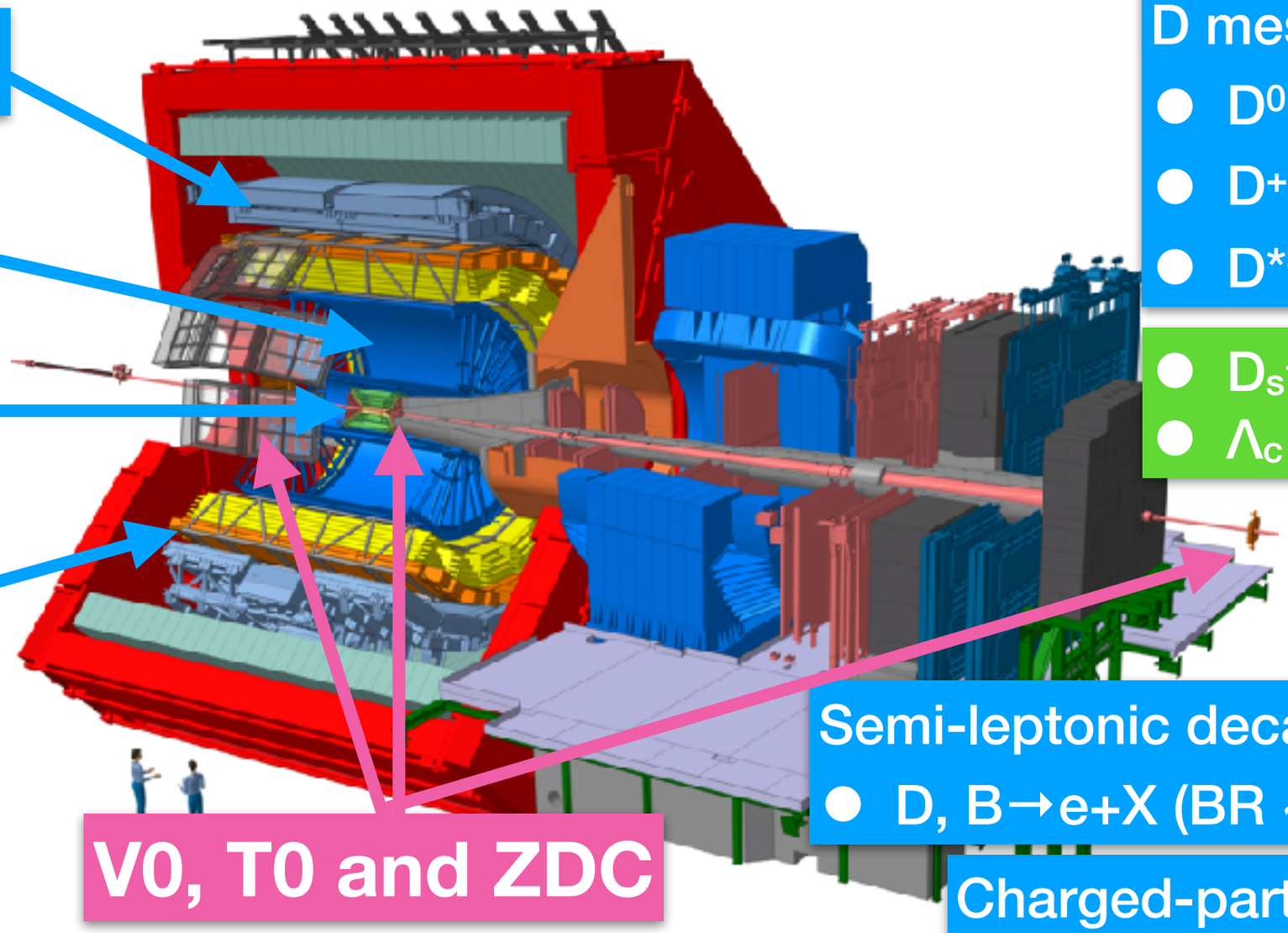
- Pb–Pb collisions: complementary to open heavy-flavour measurements

➡ Flavour dependence of the jet quenching / redistribution of the lost energy

➡ Possible modification of heavy-quark fragmentation



ALICE apparatus



D mesons (ITS, TPC, TOF)
- $D^0 \rightarrow K^-\pi^+$ (BR ~3.93%)
- $D^+ \rightarrow K^-\pi^+\pi^+$ (RB ~9.46%)
- $D^{*+} \rightarrow D^0\pi^+$ (BR ~67.7%)

- $D_s^+ \rightarrow \phi\pi^+ \rightarrow K^+K^-\pi^+$
- $\Lambda_c \rightarrow pK^-\pi^+$ (pK_s^0)

Semi-leptonic decays (TPC, TOF, EMCal)
- D, B→e+X (BR ~10%)

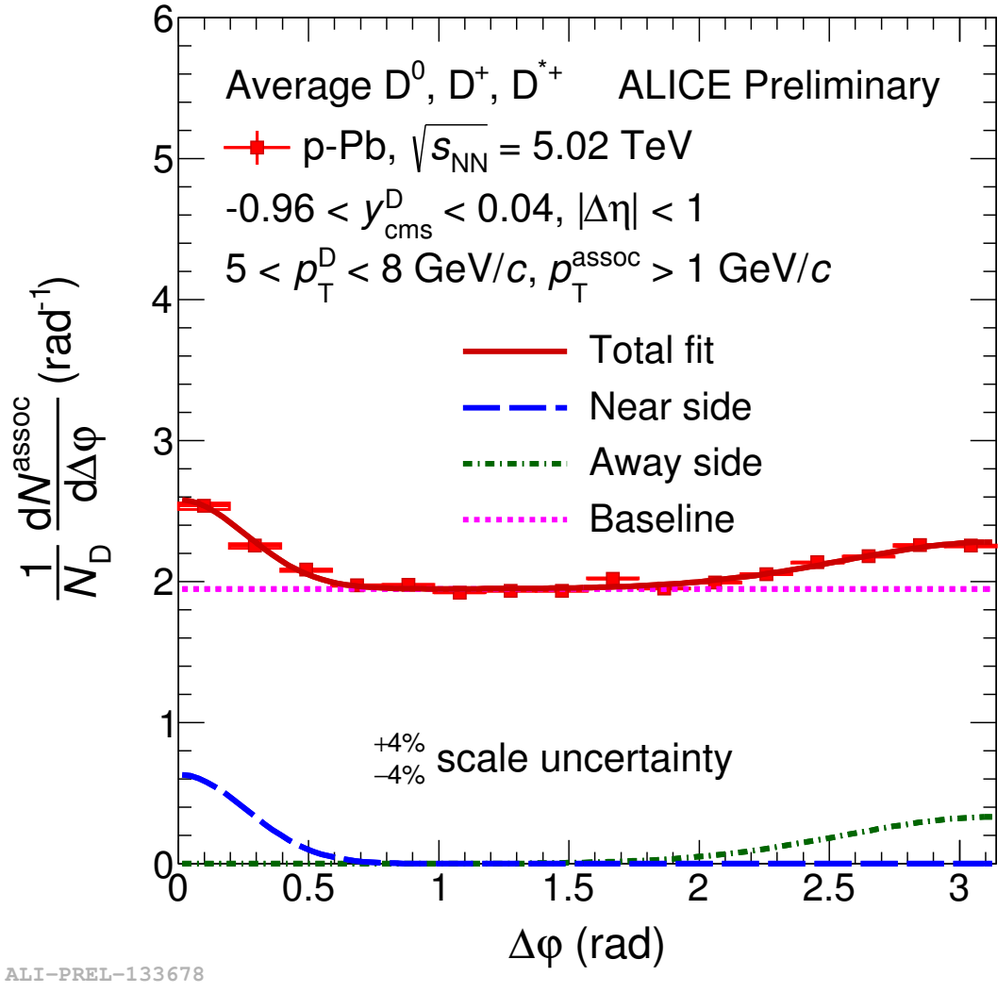
Charged-particle jets (ITS, TPC)
- Charged tracks in $|\eta|<0.9$
- anti-k_T algorithm

Mid-rapidity ($|\eta|<0.9$)
- ITS, TPC, TOF: vertexing, tracking, PID
- EMCal: high-p_T electron trigger, PID

Smaller detectors: V0, T0, ZDC
- Event trigger, characterization

Correlations between D mesons and charged hadrons

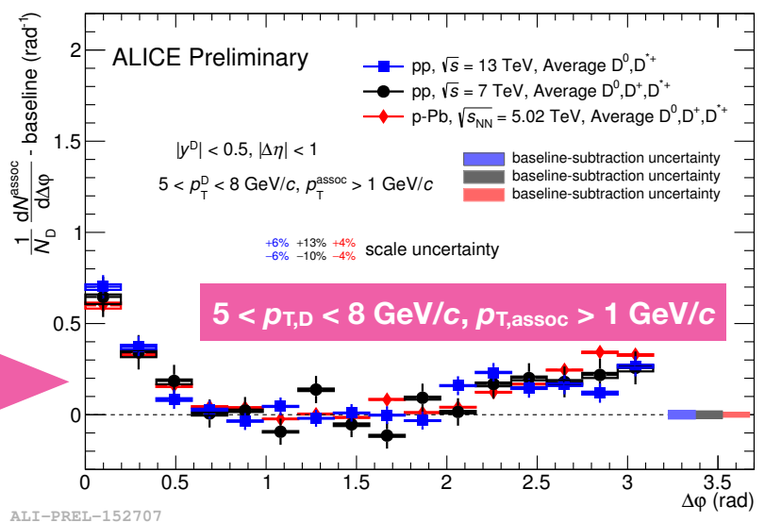
- Trigger particles: D mesons in $|y| < 0.5$ (average over D^0 and D^{*+})
- Associated particles: charged tracks with $|\Delta\eta(D,trk)| < 1$

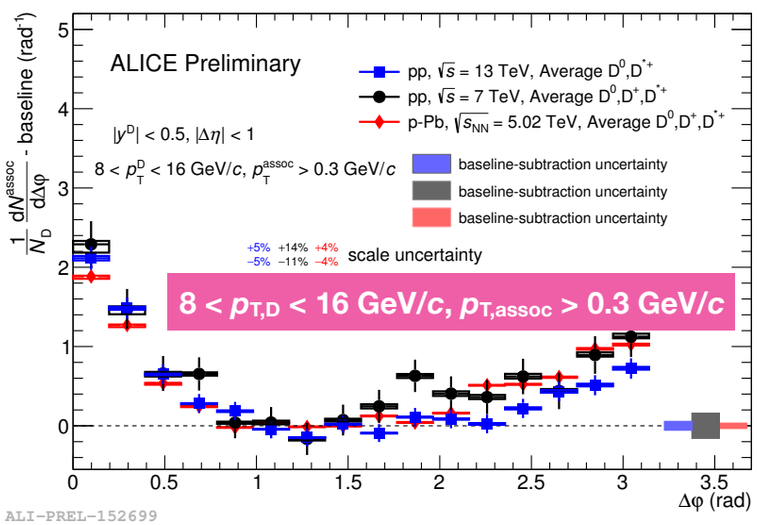


Associated particle yield extraction: combined fit with

- Two Gaussians to describe the near-side and away-side peaks
- A constant as the baseline — contribution of the underlying event

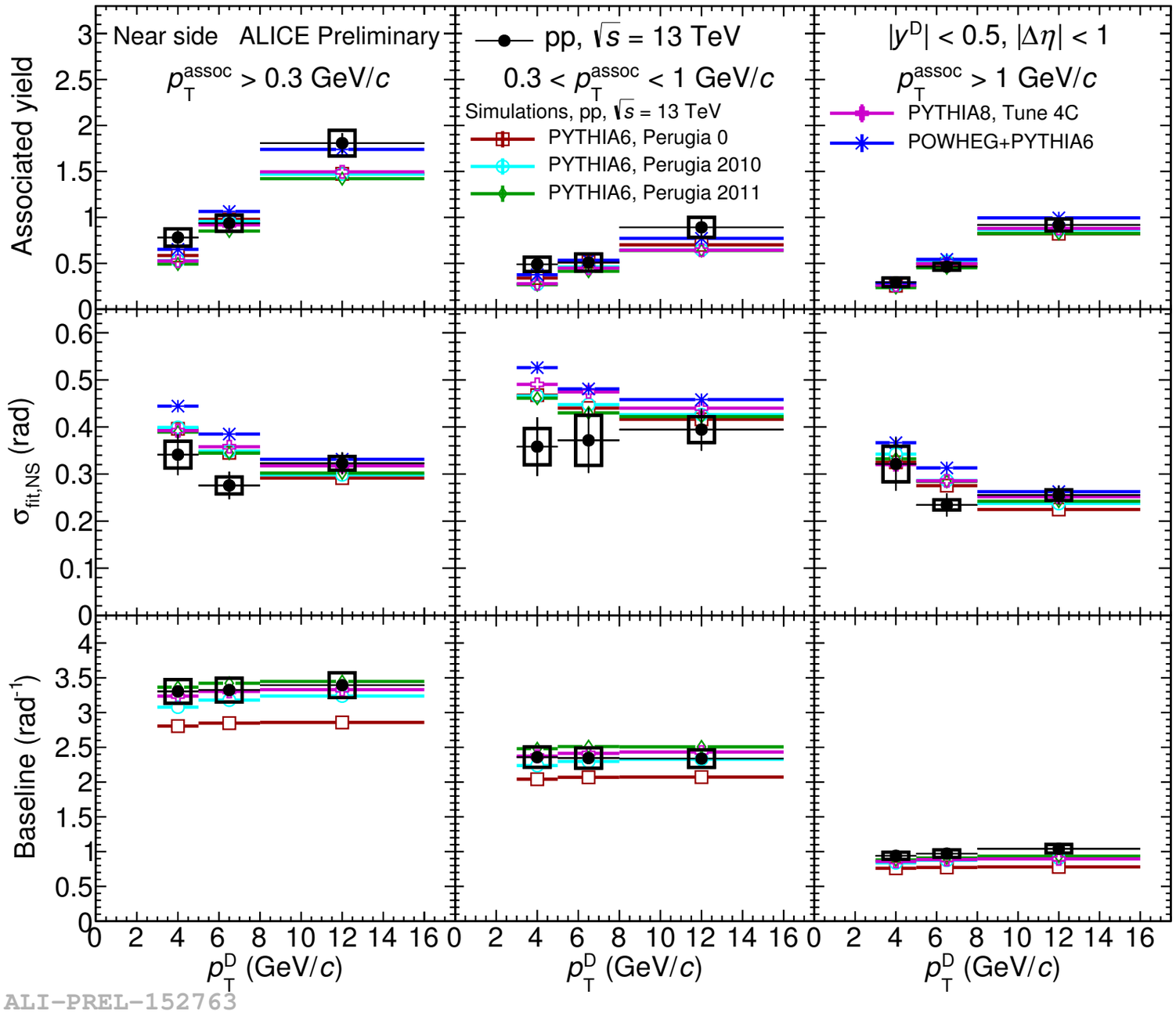
Baseline subtracted correlation distribution: no significant collision energy and system dependence





Correlations between D mesons and charged hadrons

pp at 13 TeV, near-side correlations, average over D^0 and D^{*+}



Near-side associated particle yield and width in data

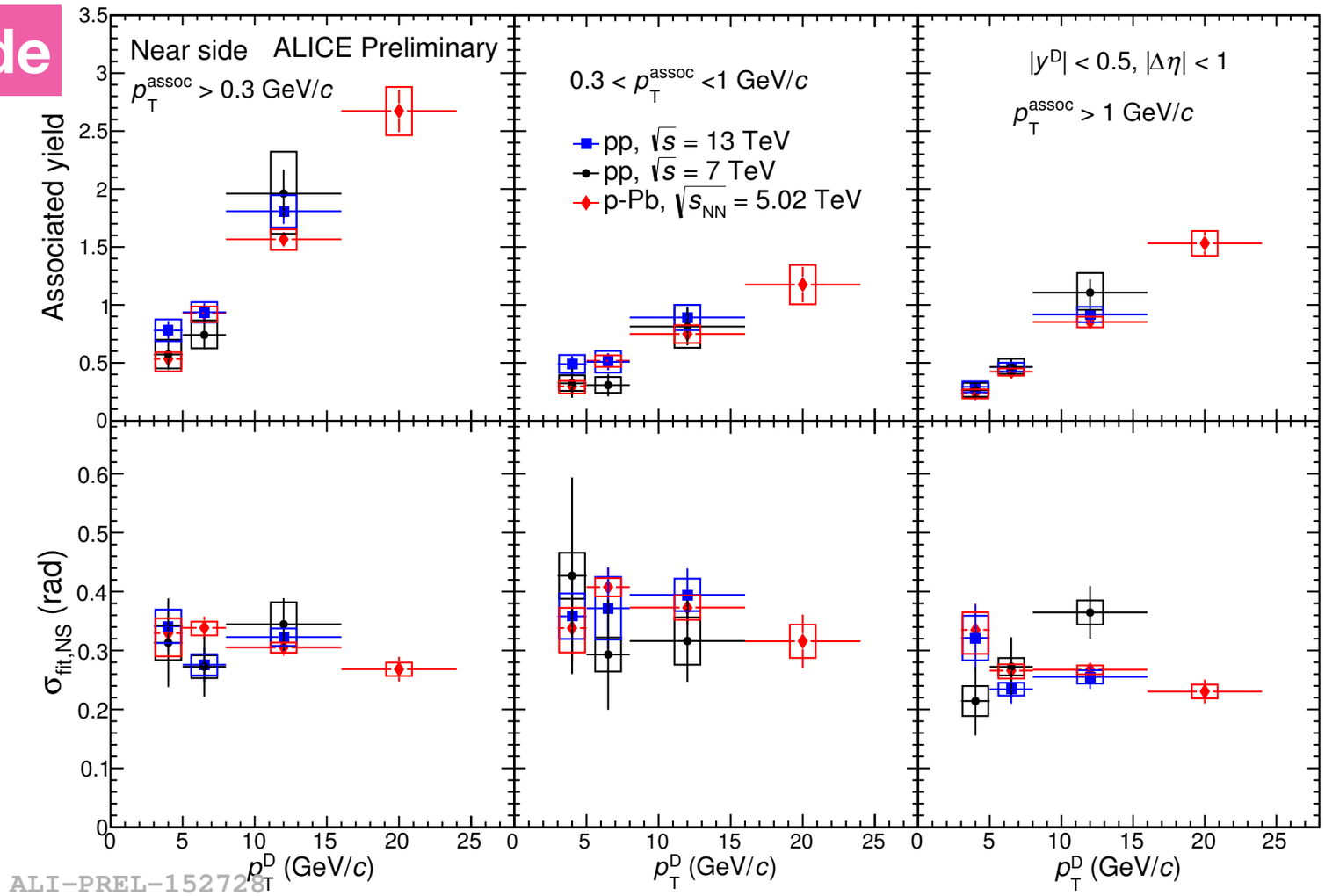
- Extracted from fits
- Consistent with model predictions within uncertainties
- Well established baseline for p–Pb and Pb–Pb collisions

Associated particle yield increases with D-meson p_T, while the width tends to decrease with D-meson p_T — higher p_T charm jets are more collimated

Correlations between D mesons and charged hadrons

p–Pb collisions at 5.02 TeV, comparison with pp at 7 and 13 TeV

Near-side



pp 7 TeV

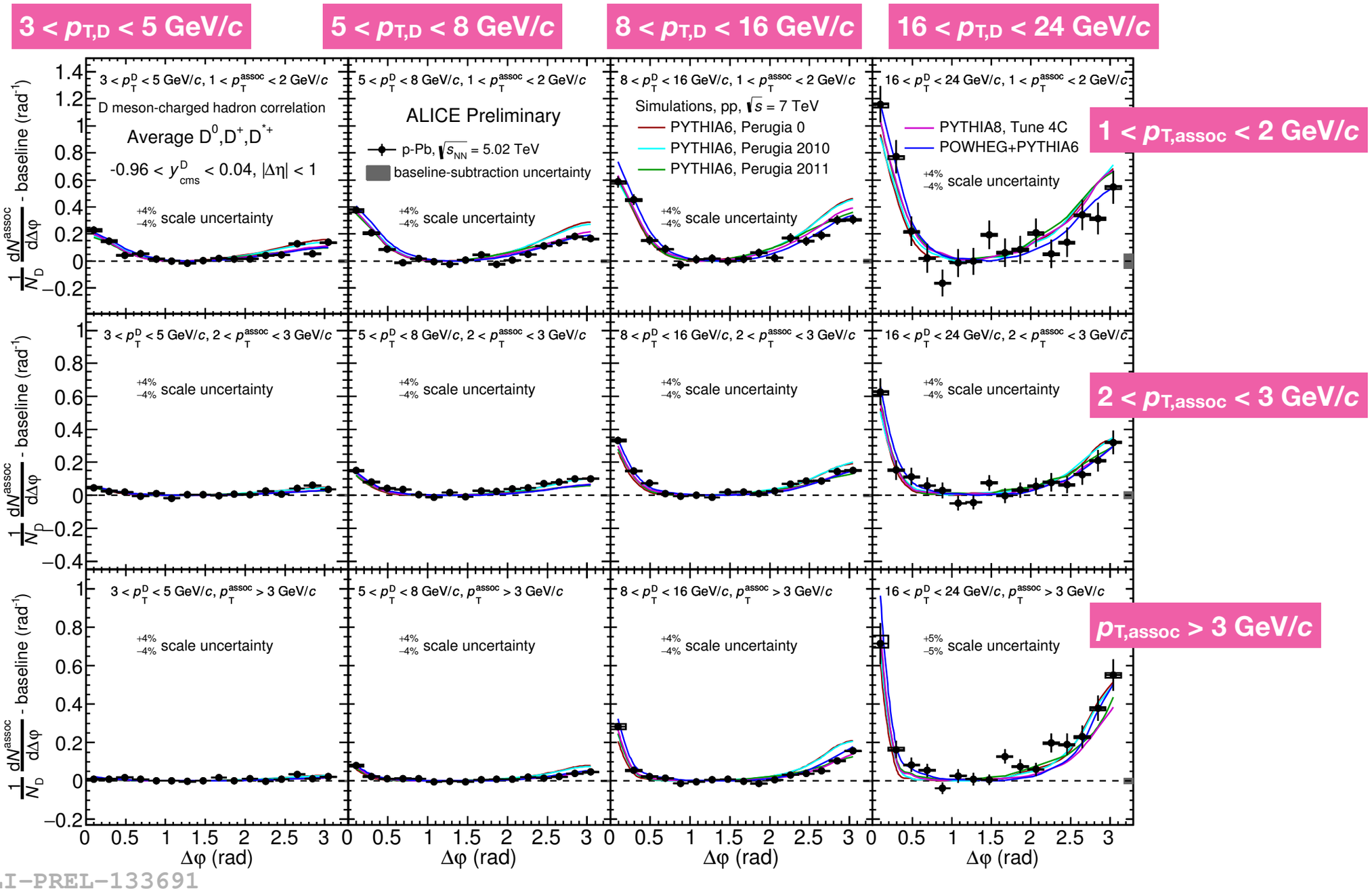
pp 13 TeV

p–Pb 5.02 TeV

- Similar near-side peak properties between collision energies and systems
- No evidence of modification due to initial- and final-state effects in p–Pb collisions within uncertainties

Correlations between D mesons and charged hadrons

p–Pb collisions at 5.02 TeV, comparison with model predictions

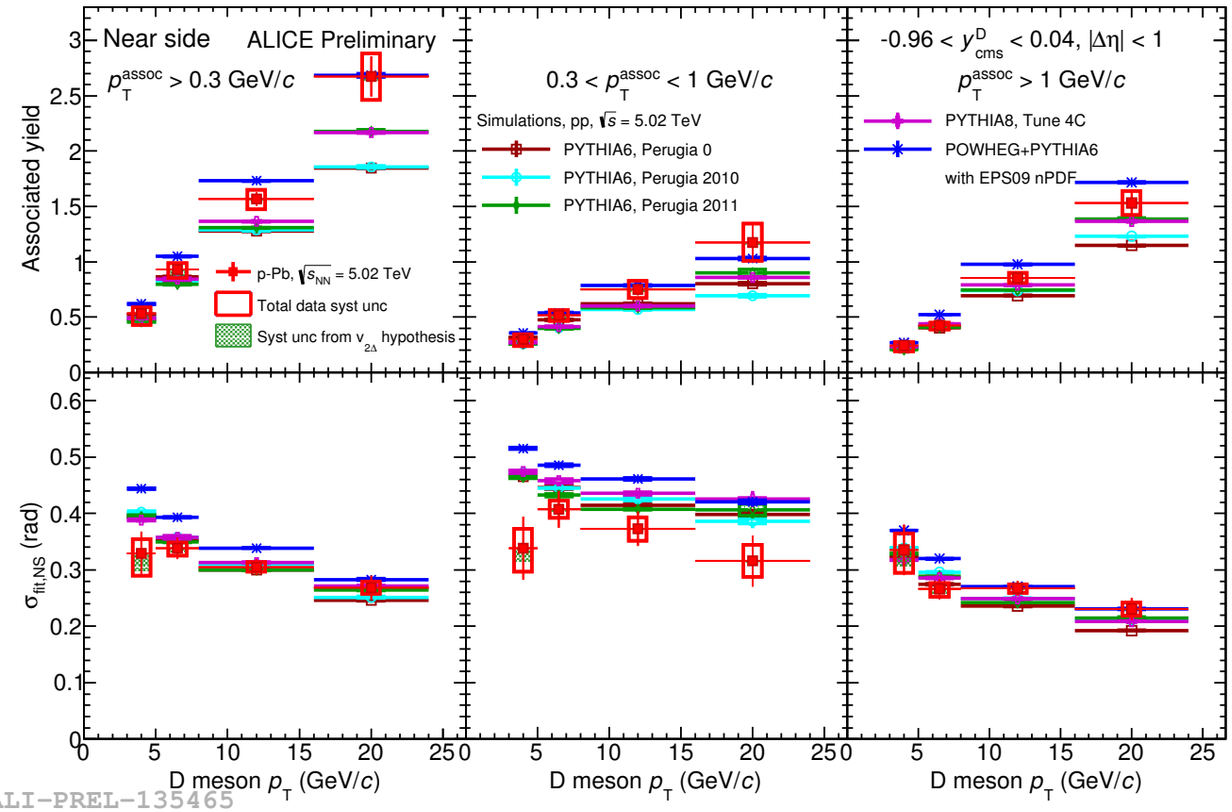


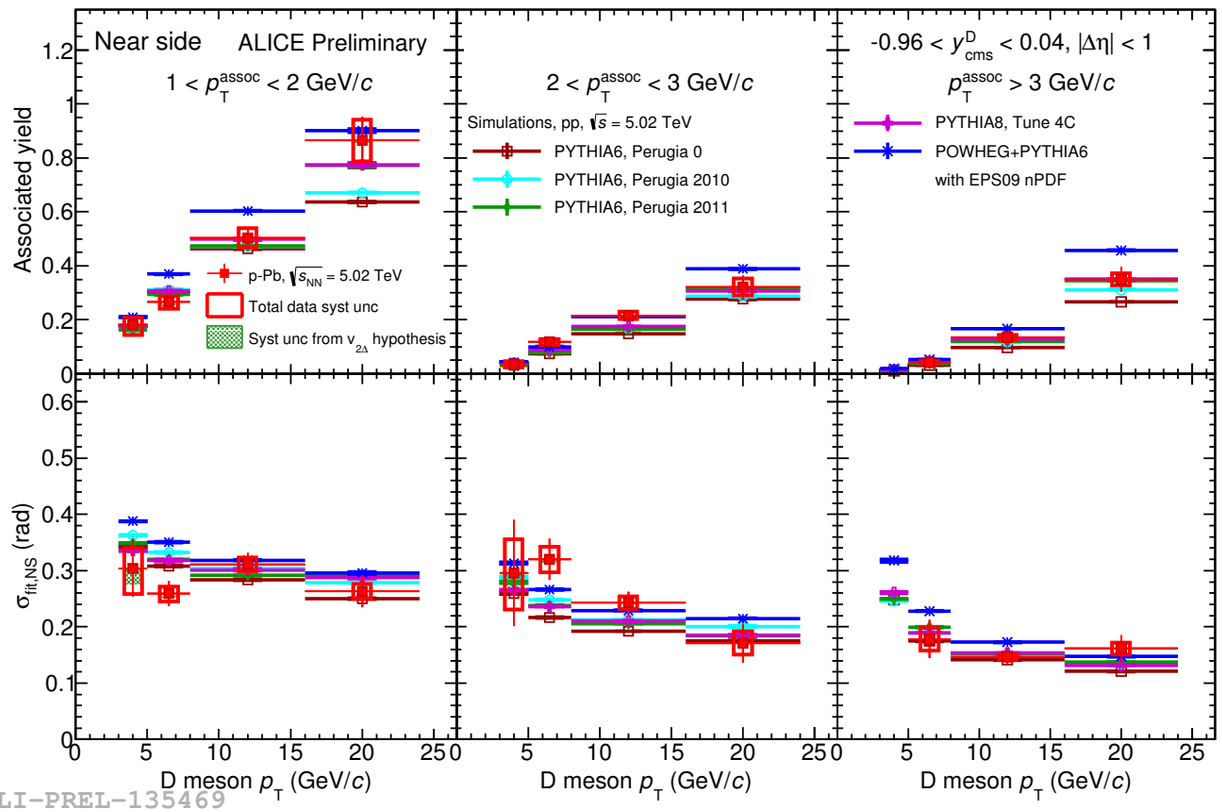
- Correlation properties are generally consistent with model predictions

Correlations between D mesons and charged hadrons

p–Pb collisions at 5.02 TeV, comparison with model predictions

Near side



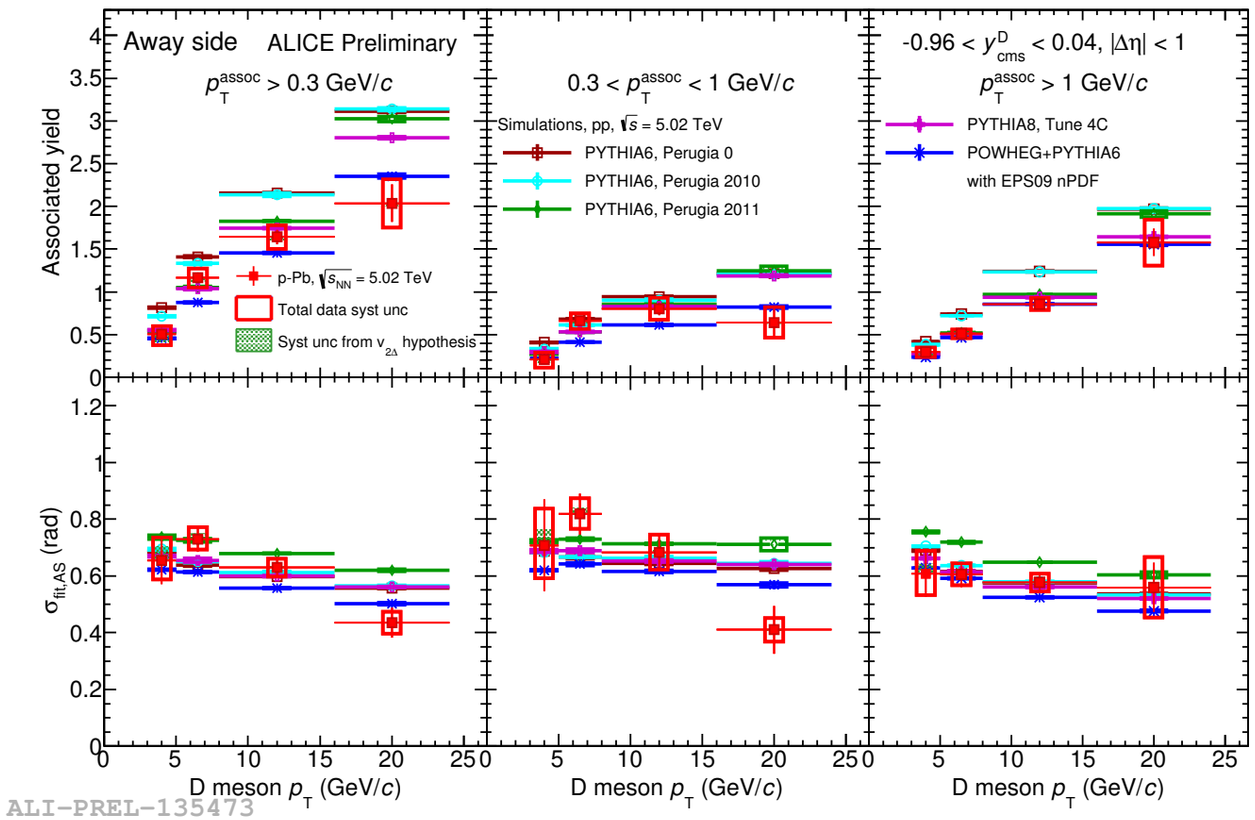


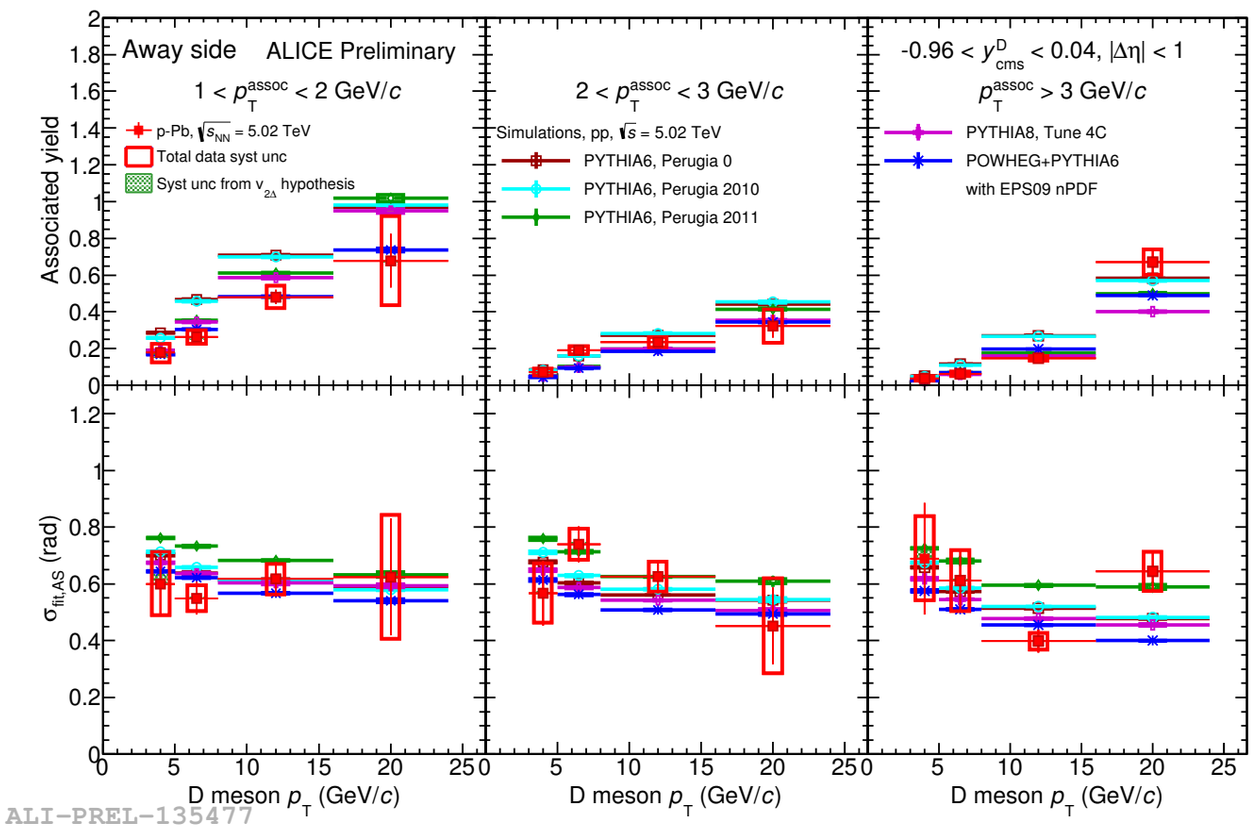
- Near-side peak properties are generally consistent with model predictions within uncertainties
- Hint of an overestimation of the width at low associated p_T with POWHEG+PYTHIA

Correlations between D mesons and charged hadrons

p–Pb collisions at 5.02 TeV, comparison with model predictions

Away side

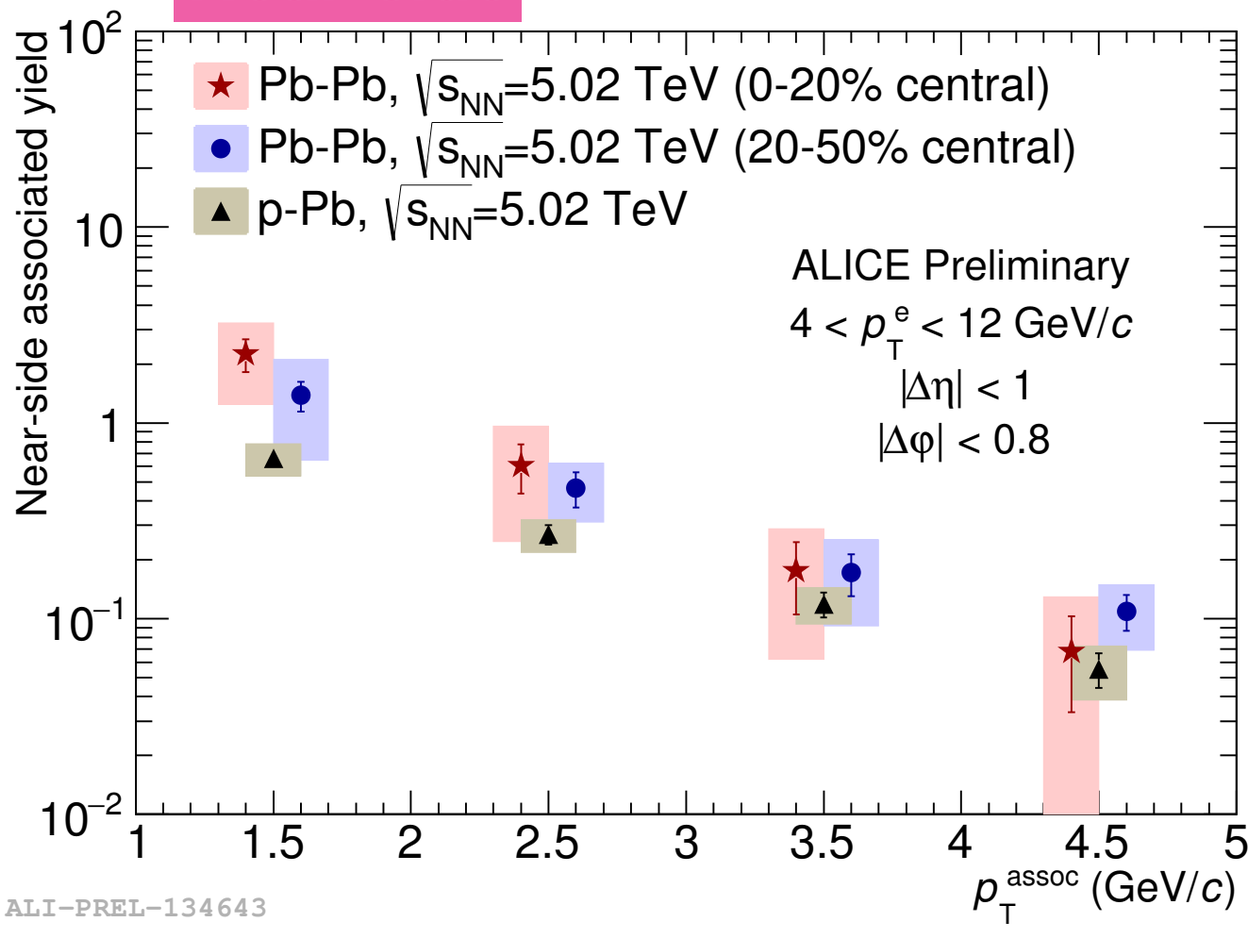


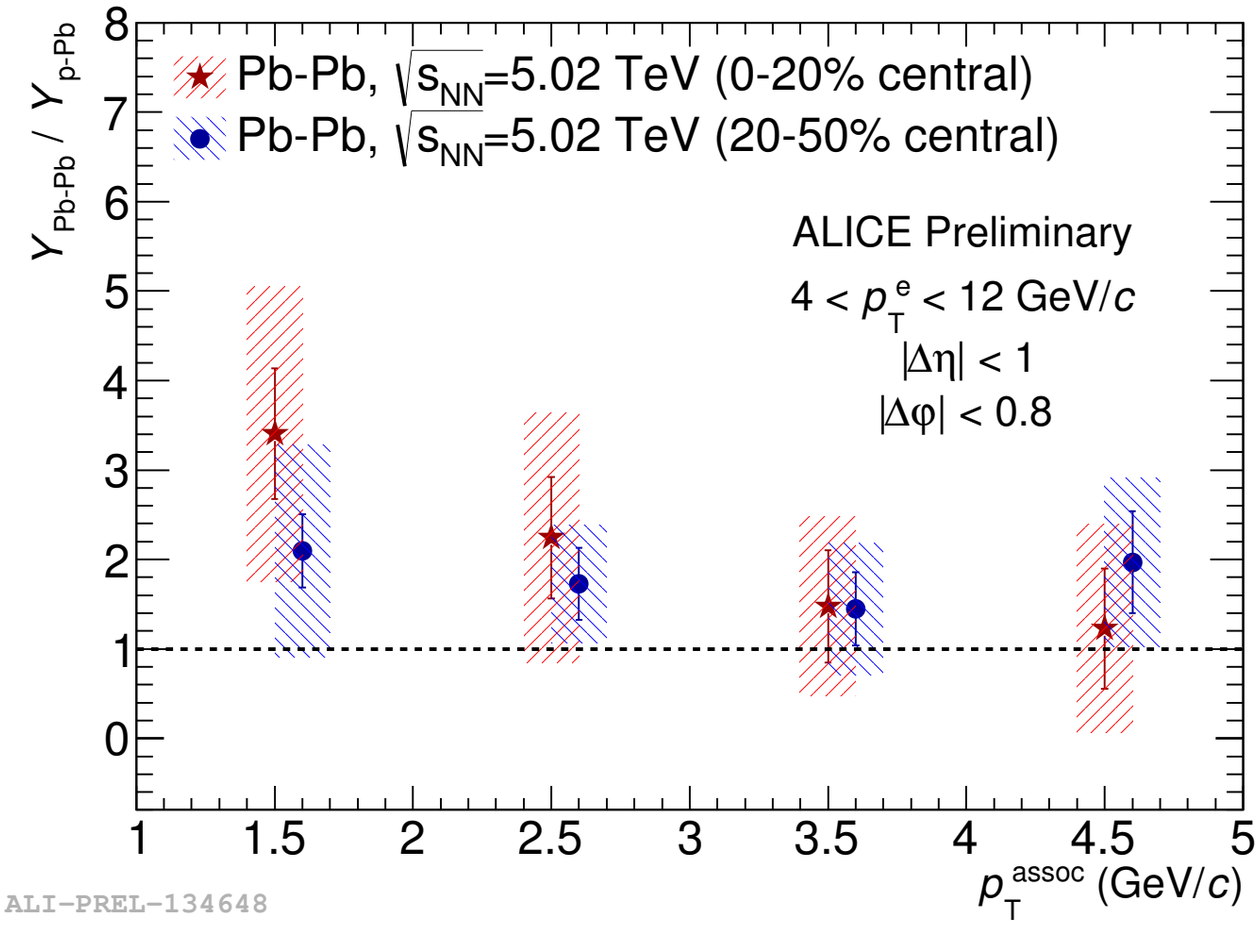


- Away-side associated yield: POWHEG+PYTHIA generally lower than data
- Peak width at away side is broader than that at near side and less sensitive to D-meson p_T

HFe–h correlations

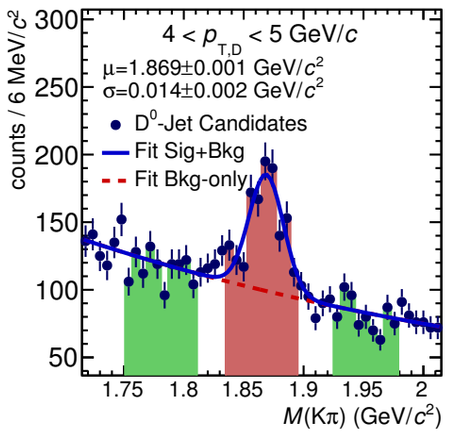
Near-side

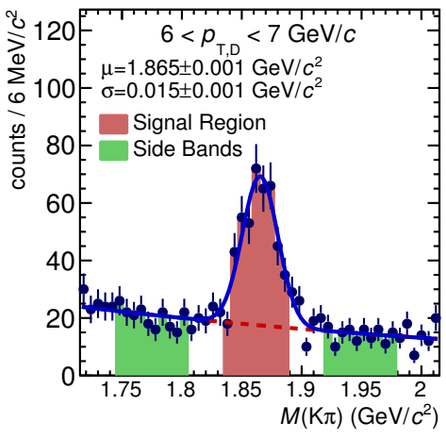


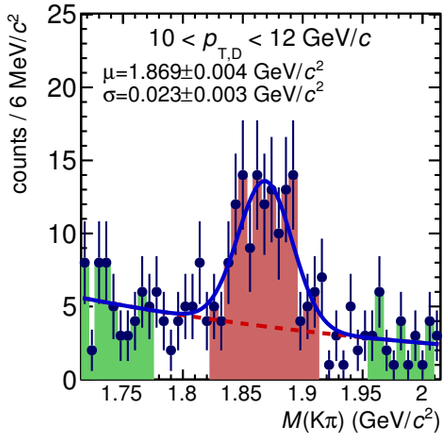


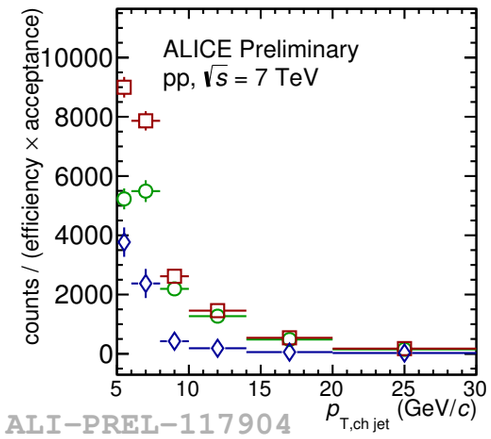
- Near-side yield in Pb–Pb collisions is consistent with that in p–Pb collisions at high associated p_T within uncertainties
- Hint of near-side yield enhancement in the 20% most central Pb–Pb collisions w. r. t. p–Pb collisions at low associated p_T — more precise measurement is expected in the next Pb–Pb run (end of 2018)

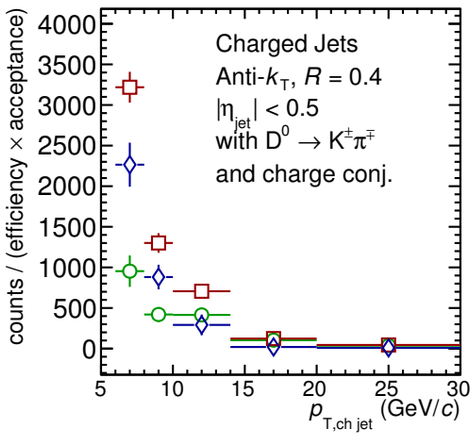
D-jet tagging

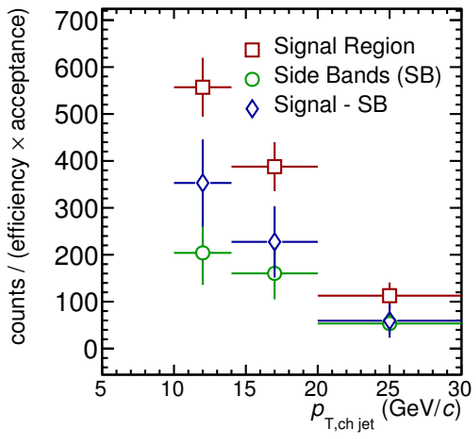












ALI-PREL-117904

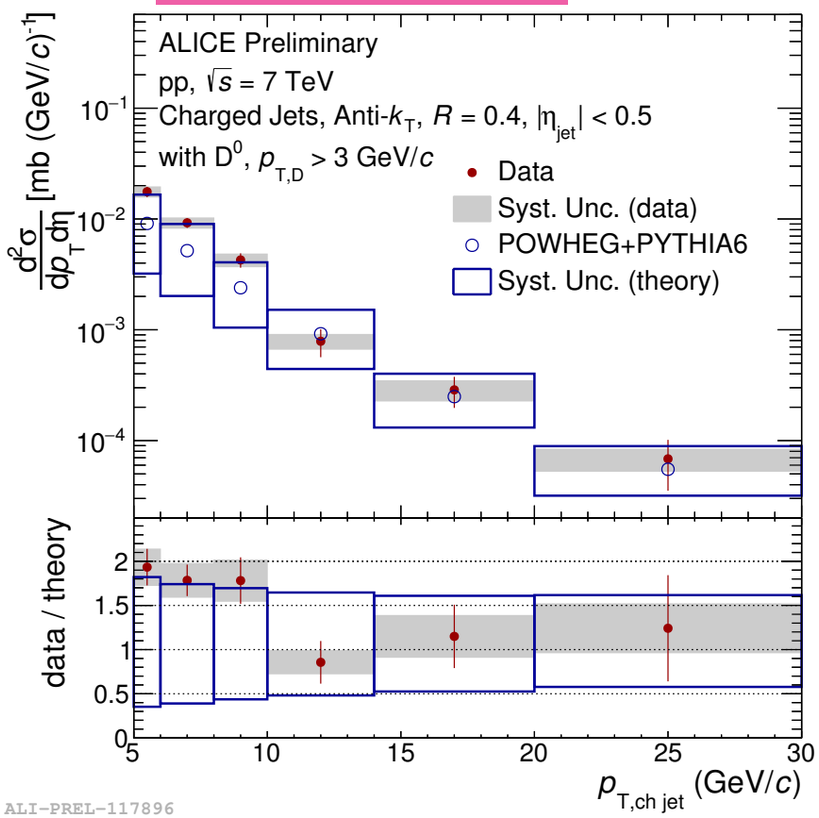
- Raw yield of D-meson tagged jets

➡ Obtained by subtracting background jets estimated in sidebands from the signal region

- Correction for D-jet efficiency and feed-down from beauty using POWHEG+PYTHIA
- Correction for detector effects and background fluctuations (p–Pb and Pb–Pb) on jet p_T spectra via unfolding

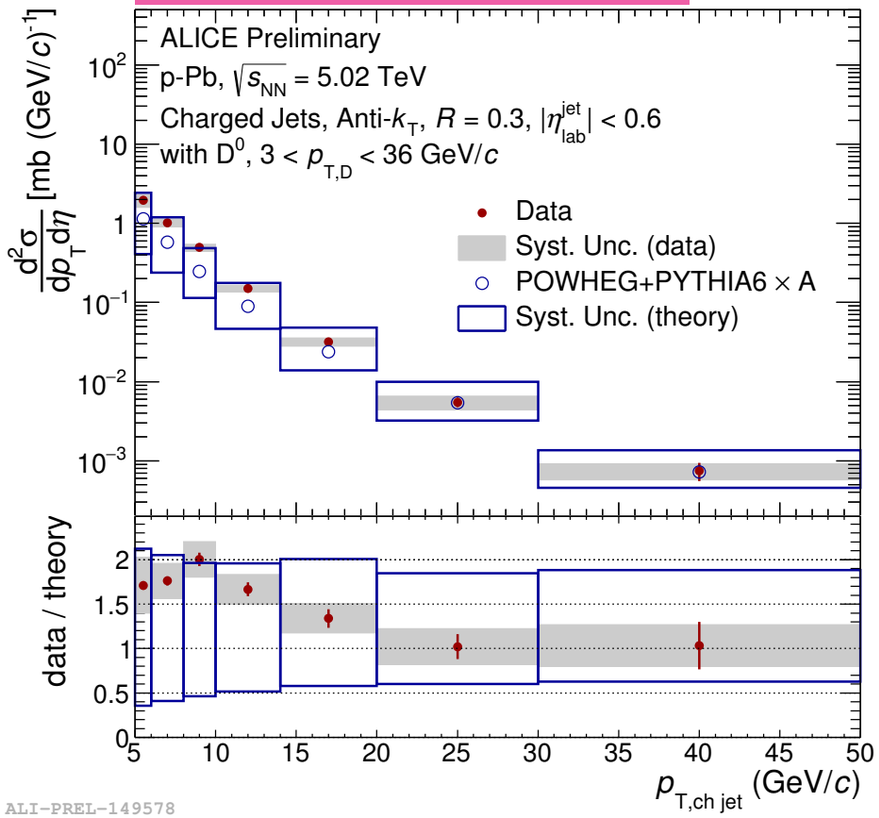
D-tagged jets in pp and p–Pb collisions

D^0-jet pp 7 TeV



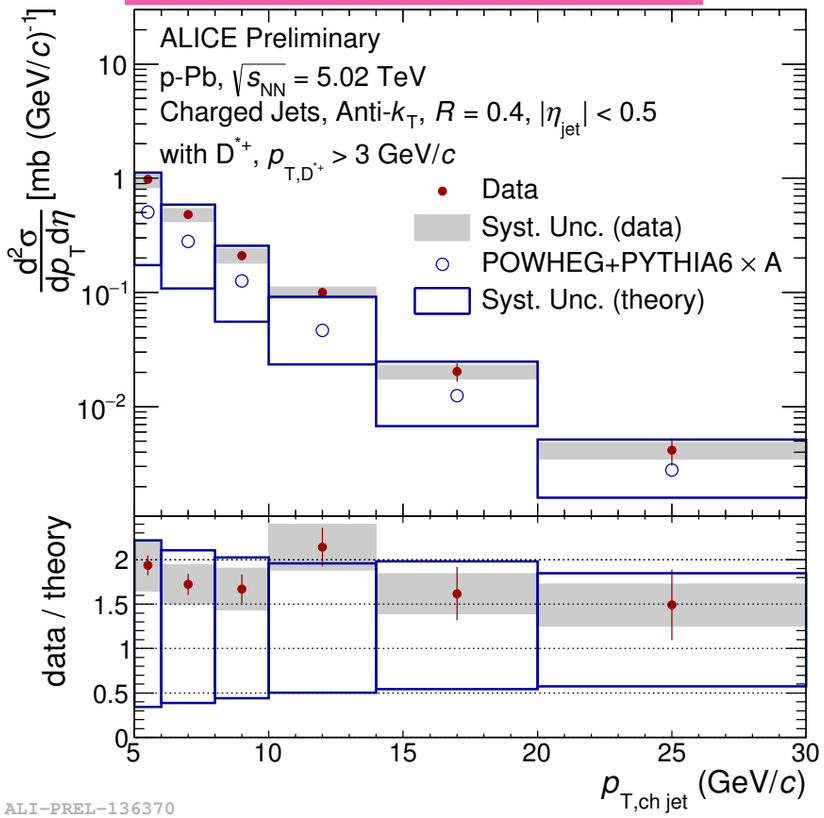
ALI-PREL-117896

D^0-jet p–Pb 5.02 TeV



ALI-PREL-149578

D^{*+}-jet p–Pb 5.02 TeV

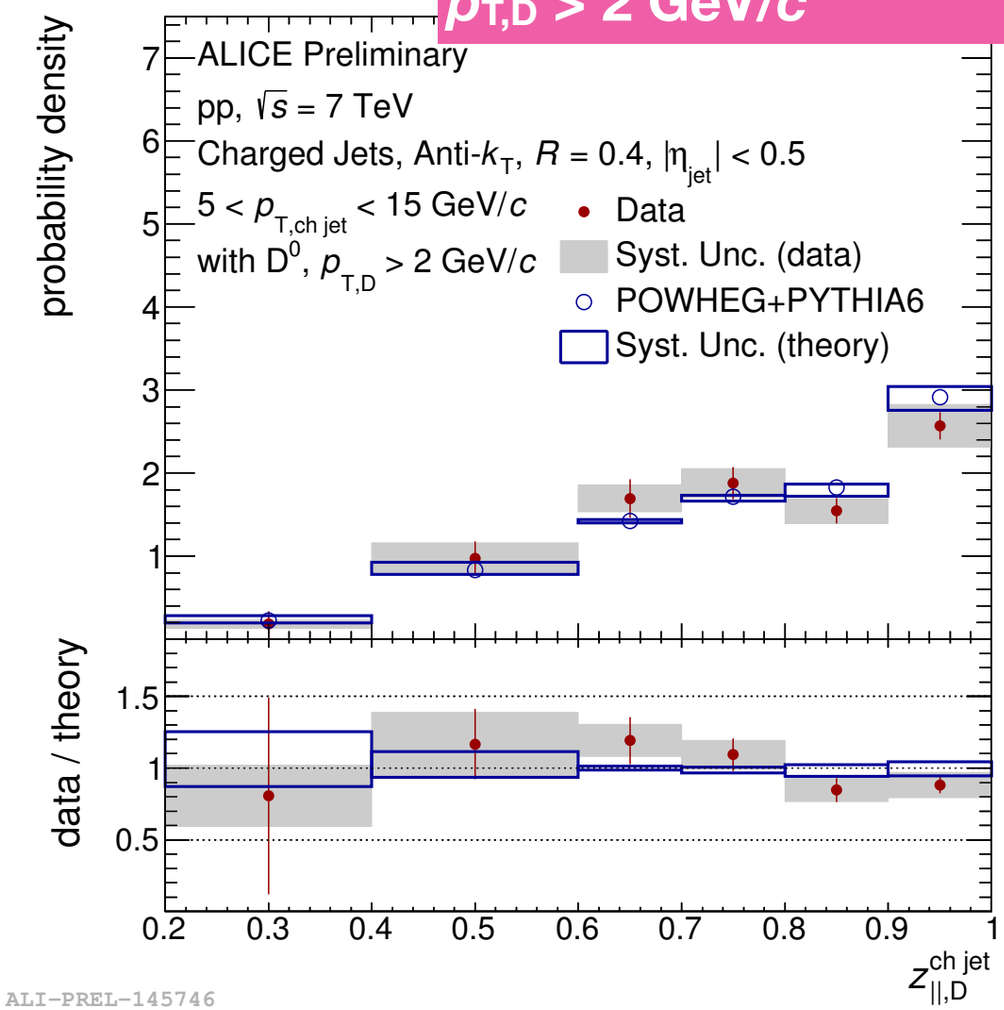


ALI-PREL-136370

- p_T-differential cross section for D^0-tagged jets in pp and p–Pb collisions and D^{*+}-tagged jets in p–Pb collisions
- Good agreement with NLO predictions (POWHEG+PYTHIA) within uncertainties in both pp and p–Pb collisions

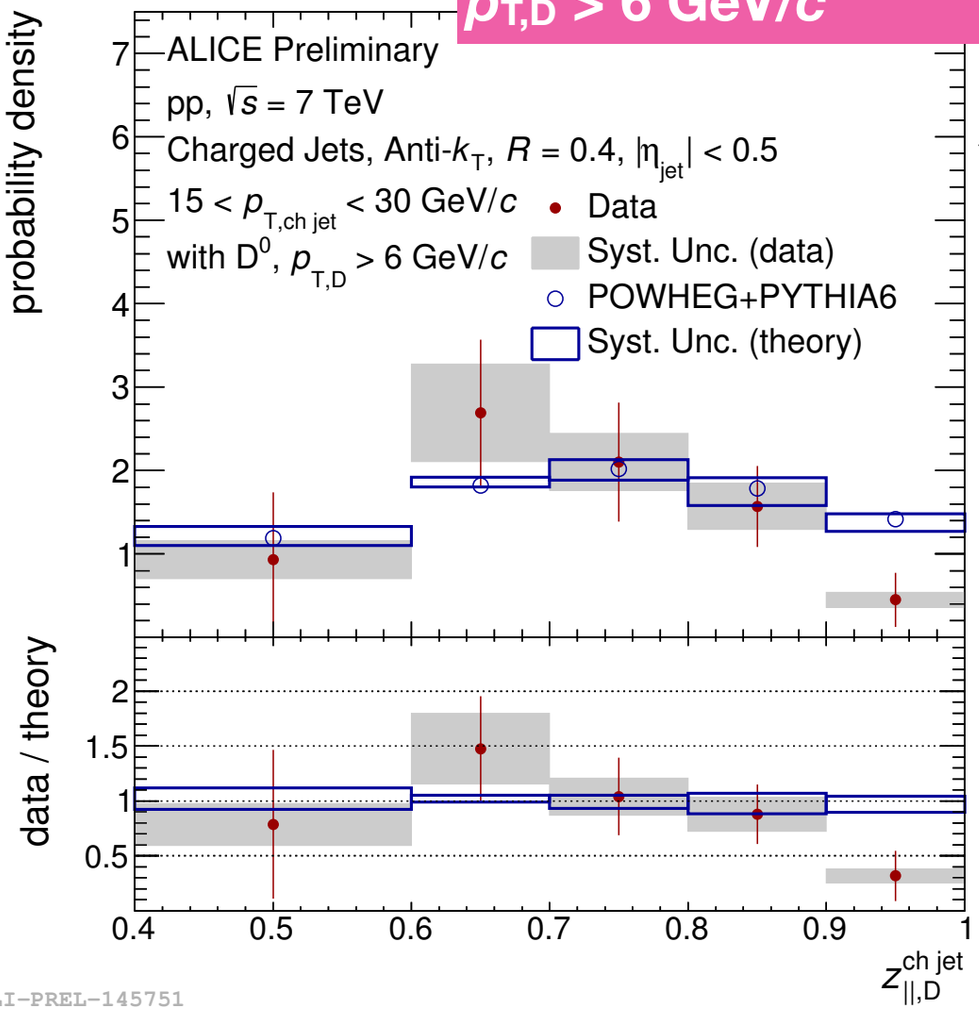
D-jet momentum fraction in pp collisions

$5 < p_{T,ch\ jet} < 15$ GeV/c
$p_{T,D} > 2$ GeV/c



ALI-PREL-145746

$15 < p_{T,ch\ jet} < 30$ GeV/c
$p_{T,D} > 6$ GeV/c

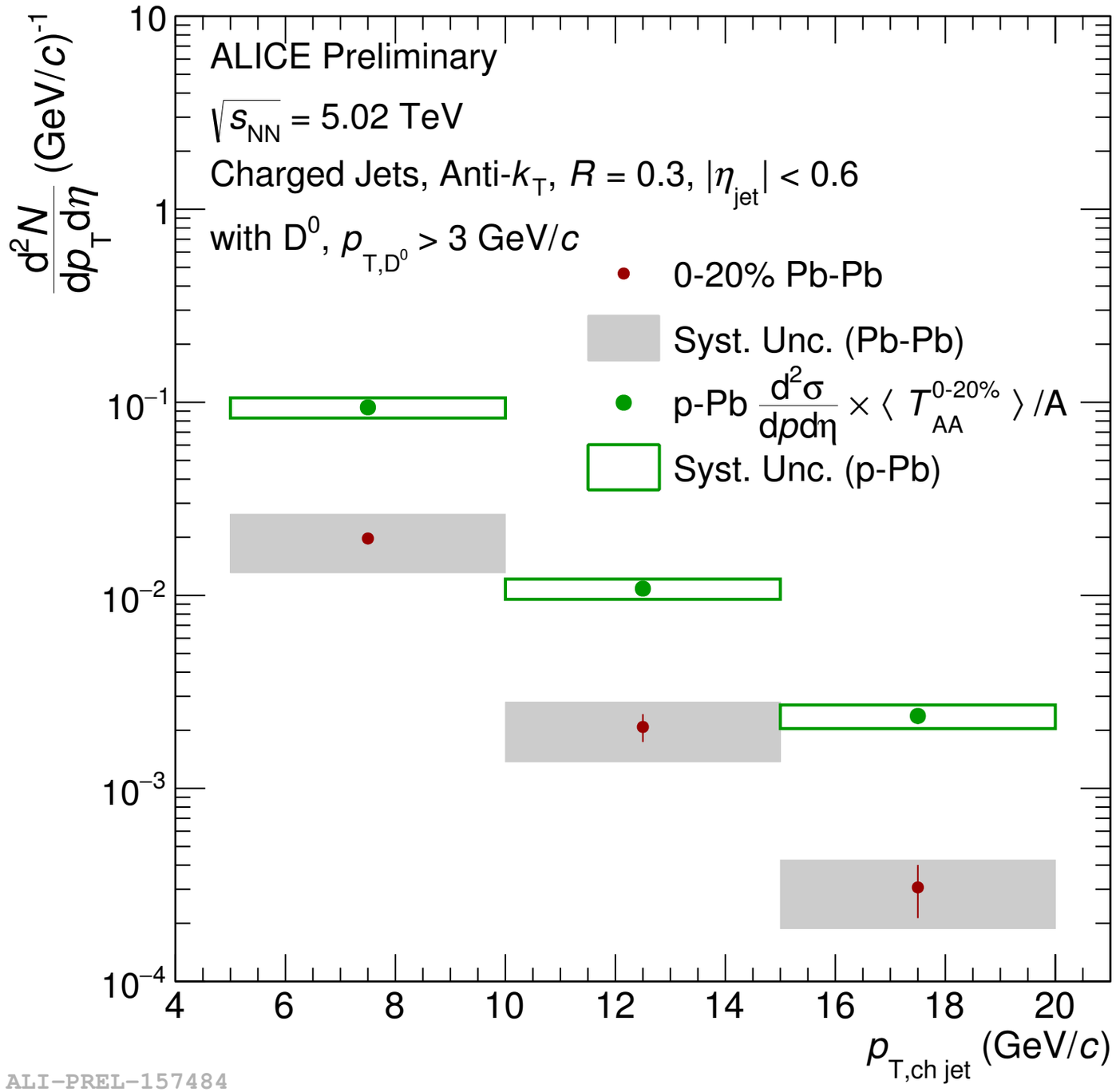


ALI-PREL-145751

$$z_{||,\mathrm{D}}^{\mathrm{ch\ jet}} = \frac{\vec{p}_{\mathrm{ch\ jet}} \cdot \vec{p}_{\mathrm{D}}}{|\vec{p}_{\mathrm{ch\ jet}}|^2}$$

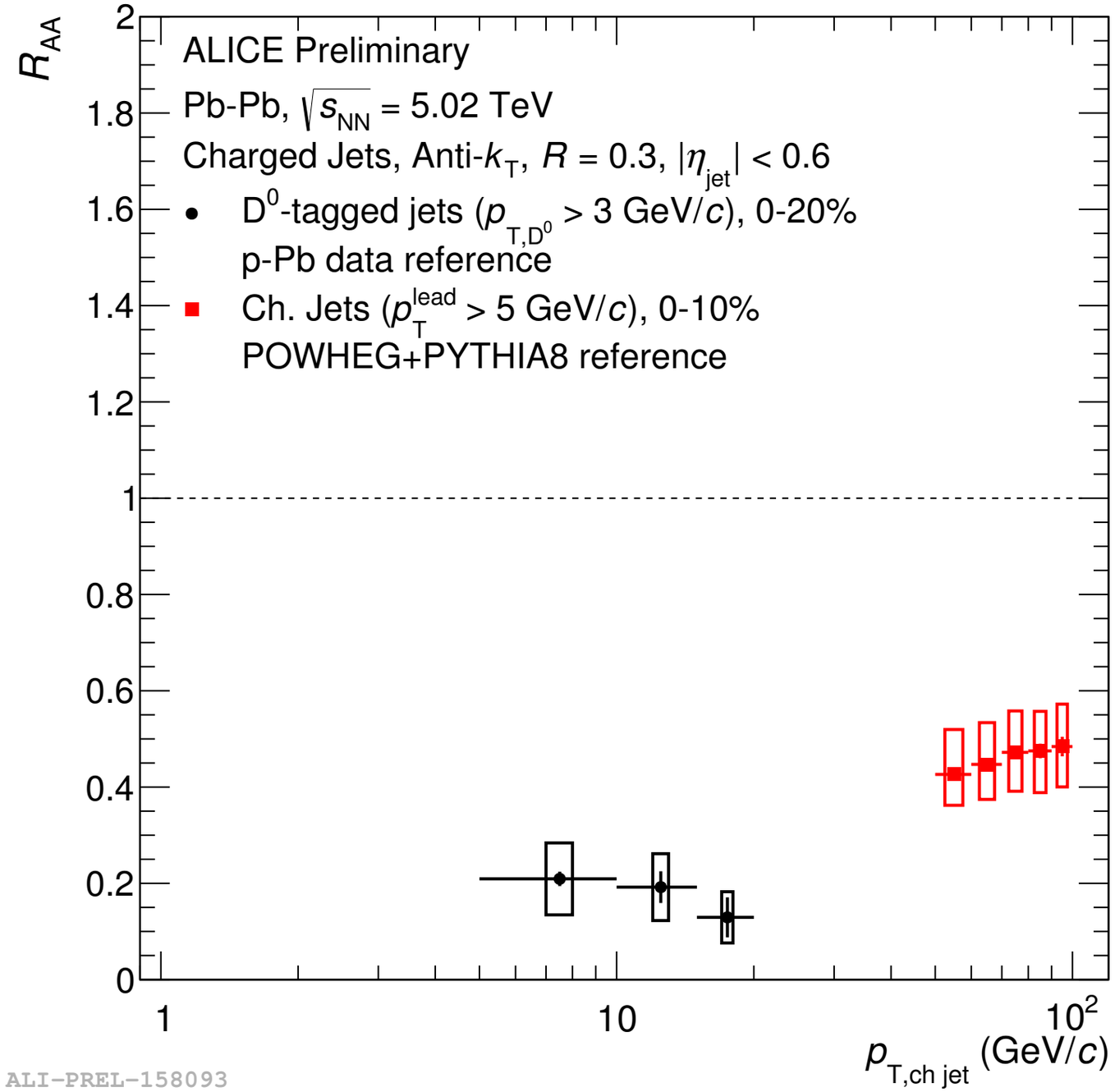
- The D^0 meson carries most of the jet momentum in the measured jet p_T interval; with a visible change of shape with jet p_T
- Good agreement with NLO predictions (POWHEG+PYTHIA6) within uncertainties

D-jets in Pb–Pb collisions



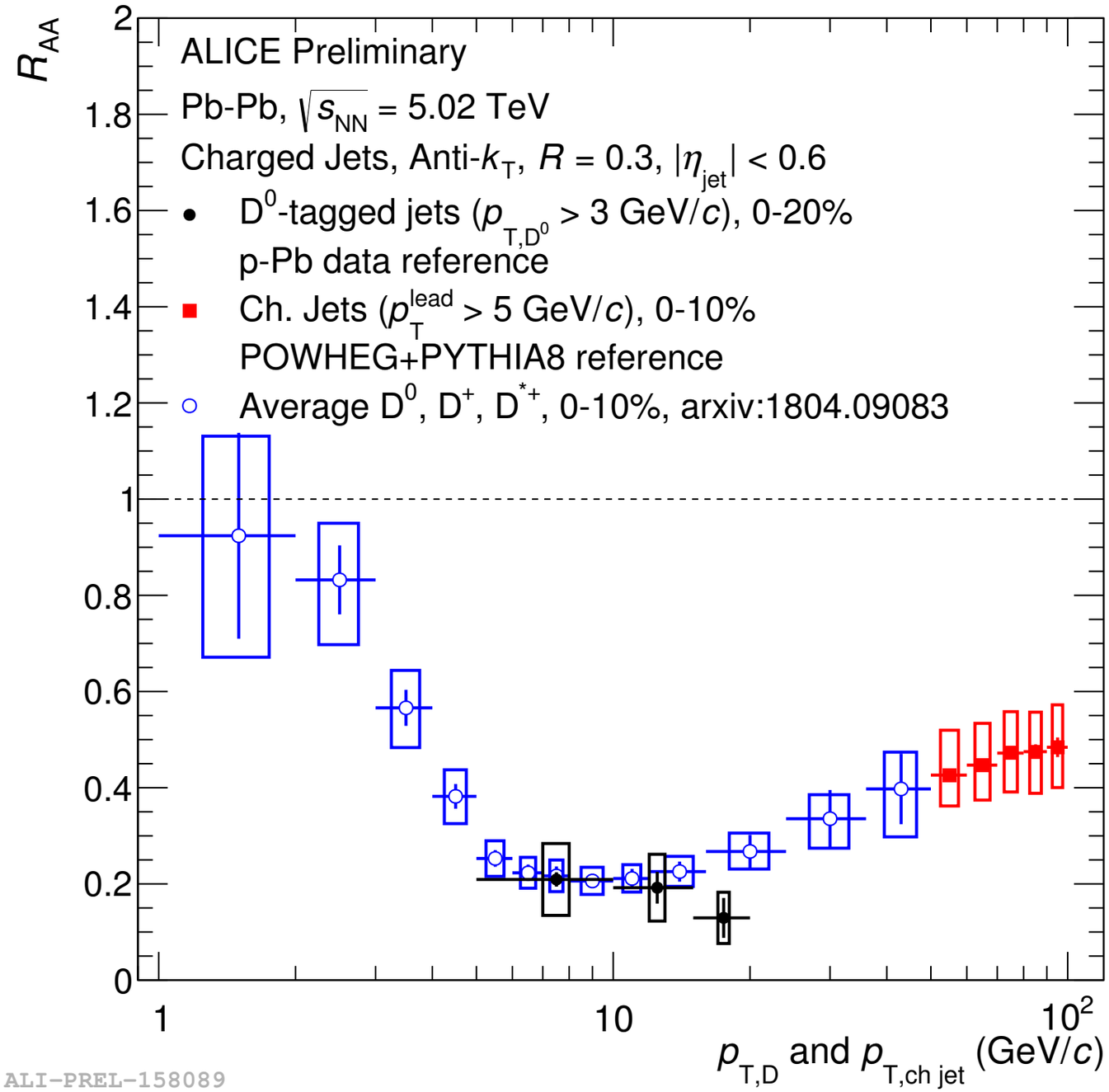
- First measurement of D-tagged jets in Pb–Pb collisions
- Measured jet p_T goes down to 5 GeV/c — improved fake jet rejection and robustness against background fluctuations
- Clear suppression of D-jet yield in Pb–Pb collisions w. r. t. p–Pb collisions

D⁰-tagged jets R_{AA} in Pb–Pb collisions



- Strong suppression of D⁰-tagged jets in the most 10% central Pb–Pb collisions
- Hint of more suppression of low p_T D⁰-tagged jets than inclusive jets at higher p_T
- D⁰-tagged jets: more quark-seeded jets compared to inclusive jets

D⁰-tagged jets R_{AA} in Pb–Pb collisions



- Strong suppression of D⁰-tagged jets in the most 10% central Pb–Pb collisions
- Hint of more suppression of low p_T D⁰-tagged jets than inclusive jets at higher p_T
- D⁰-tagged jets: more quark-seeded jets compared to inclusive jets
- Similar suppression of D⁰-jets and D mesons

- New constraint on understanding charm quark in-medium energy loss

Conclusion

- D-h correlations: compatible near-side yields and widths in pp collisions at $\sqrt{s}$ = 7, 13 TeV and p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

➡ Good agreement of near-side peak properties with MC predictions

- HFe-h correlations: hint of near-side yield enhancement in central Pb–Pb collisions

- D-tagged jets

➡ Unique opportunity to study properties of jets with a identified quark and fully reconstructed D mesons

➡ p_T-differential cross sections in pp and p–Pb collisions and D-meson jets momentum fraction in pp collisions — in agreement with POWHEG + PYTHIA6 predictions

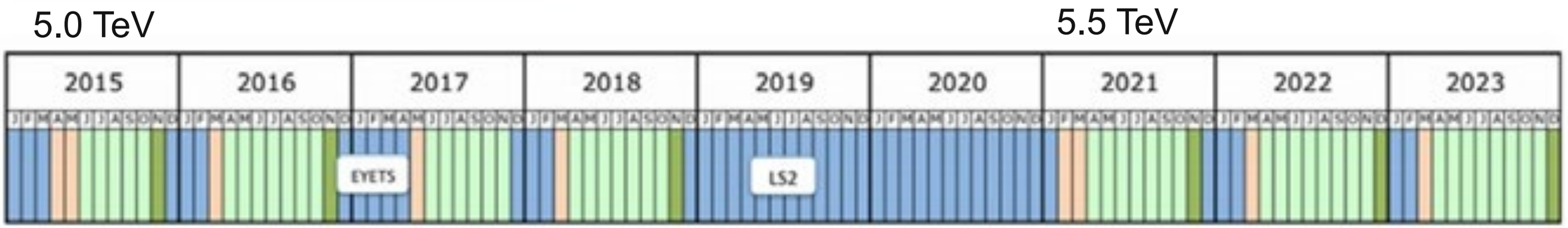
➡ First measurement of D-tagged jets in nucleus-nucleus collisions

➡ Strong suppression in central Pb–Pb collisions

Prospects: ALICE LHC RUN-III and IV

LHC roadmap: ion runs

RUN-III and RUN-IV: 2021 – 2029



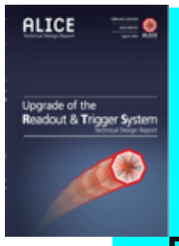
Run2 : $\mathcal{L}_{integrated}^{Pb-Pb} = 1.0\ nb^{-1}$

Run3: $\mathcal{L}_{integrated}^{Pb-Pb} = 6.0\ nb^{-1}$

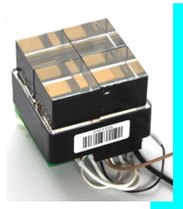
Run4 : $\mathcal{L}_{integrated}^{Pb-Pb} = 7.0\ nb^{-1}$

- 10 times higher luminosity in Pb–Pb collisions at the highest center-of-mass energy
- Possible interest on lighter ion run (Xe or Ar)

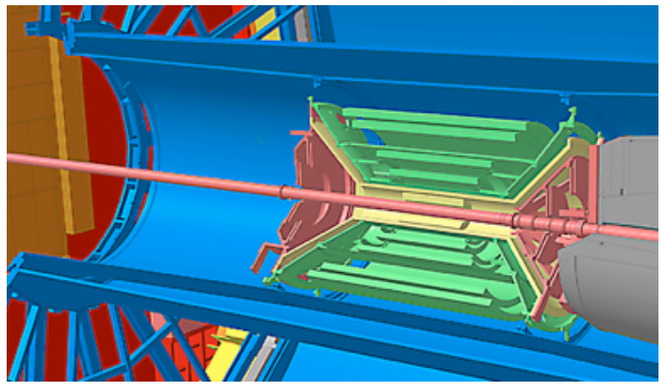
Prospects: ALICE LHC RUN-III and IV



TPC, Muon Spectrometer, TRD, TOF, PHOS, EMCAL/ DCAL, ZDC

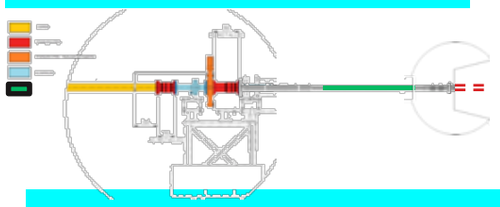


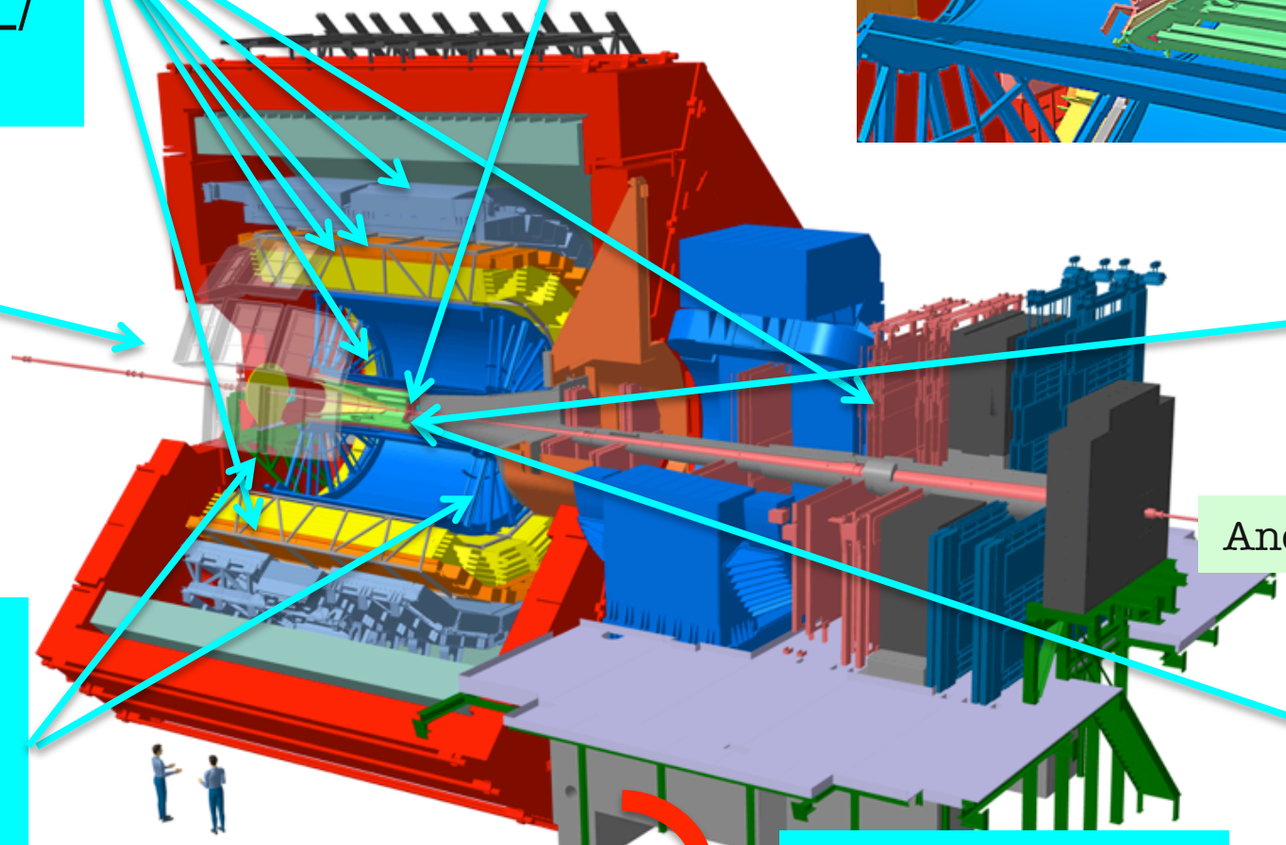
New MB trigger detector FIT



In Kwon YOO's talk

New beryllium beam-pipe smaller radius

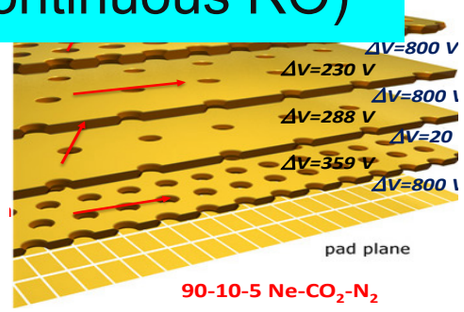




New Inner Tracking System, high resolution, low material budget

Andry RAKOTOZAFINDRABE's talk

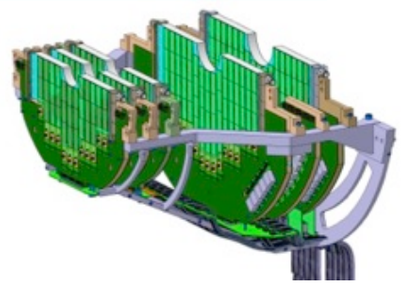
New TPC GEM Chambers (low ion backflow, continuous RO)



3.4 TBytes/s
100 GBytes/s
Online reco

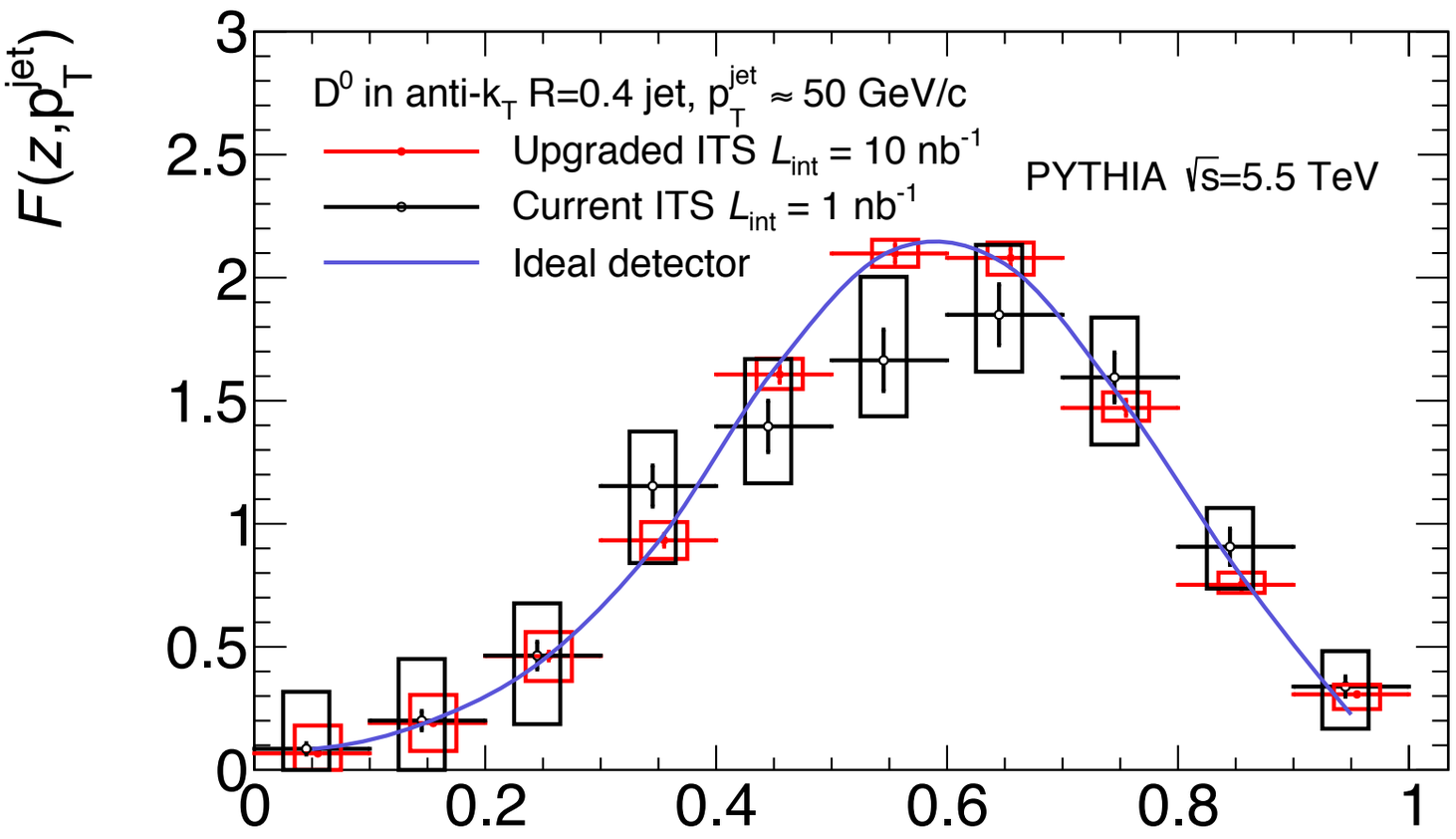
Computing O^2

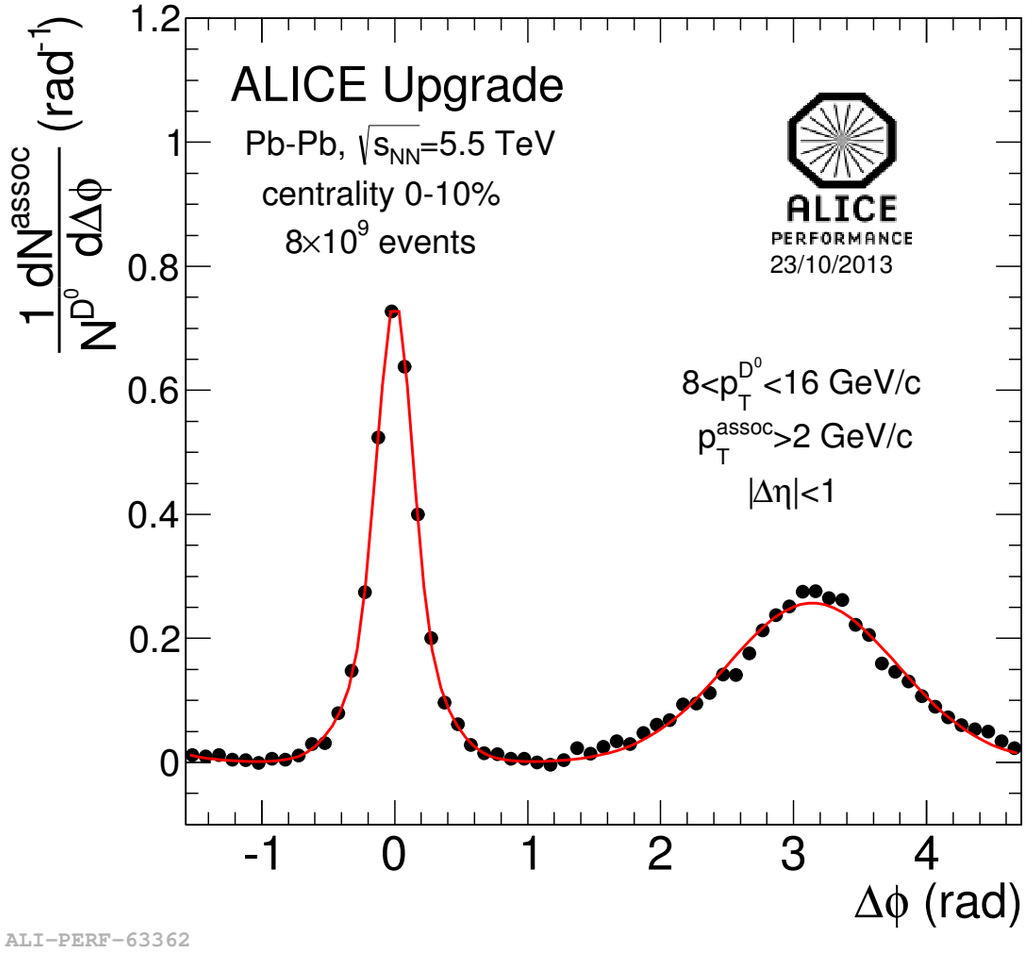
Muon Forward Tracker, high resolution, low material budget



Increase of luminosity and improve vertexing and tracking at low p_T

Prospects: ALICE LHC RUN-III and IV

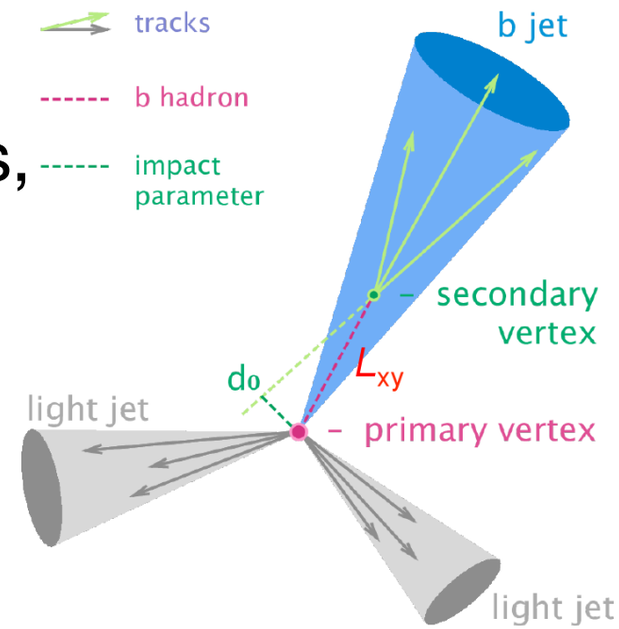


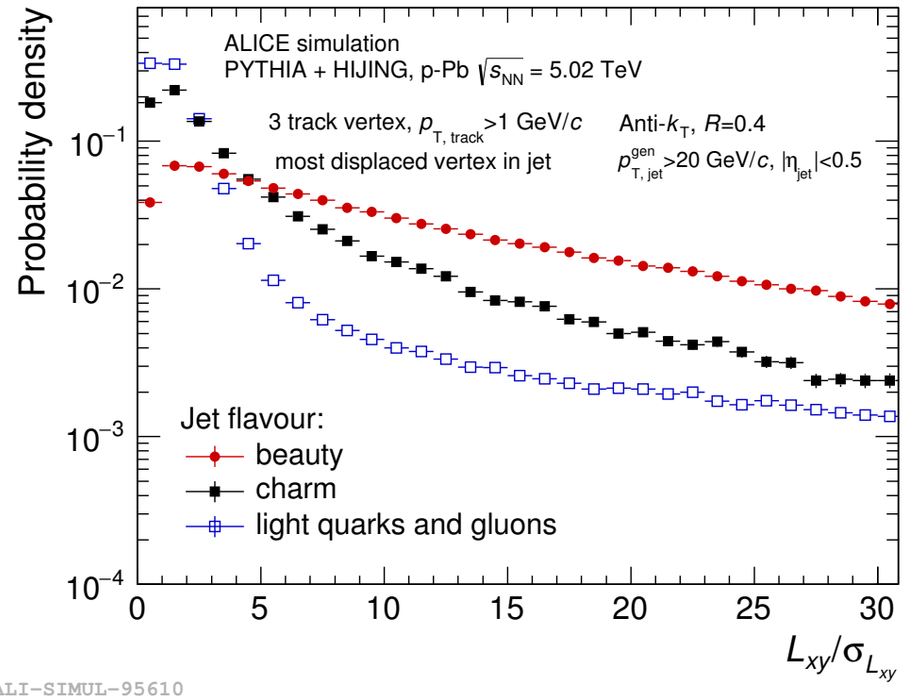


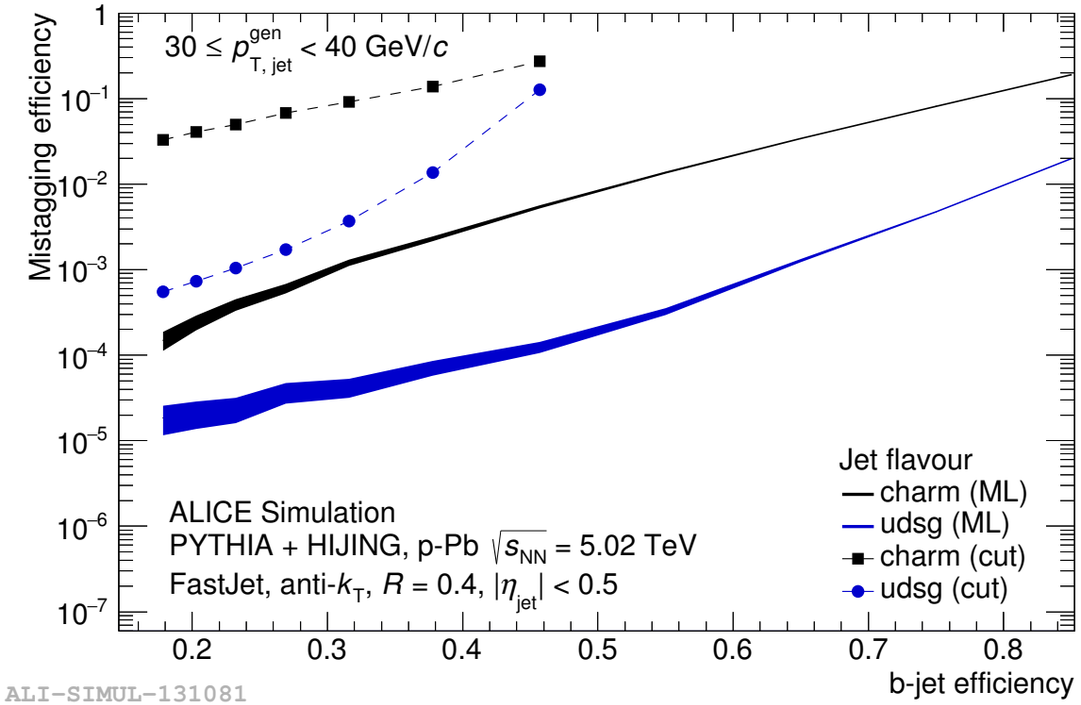
- D-meson fragmentation function and D-h correlations: improved precision on tracking resolution and D-meson reconstruction, as well as suppressed statistical fluctuations on jet p_T scale unfolding — importance of understanding gluon splitting in heavy-flavour production
- Other new physics channels: b-jets, HF-jet (sub-)structure

Prospects: b-jets with ALICE

- b-jets with ALICE: complementary to ATLAS/CMS studies, goal to reach lower p_T
- b-tagging algorithms: based on displacement from the primary vertex







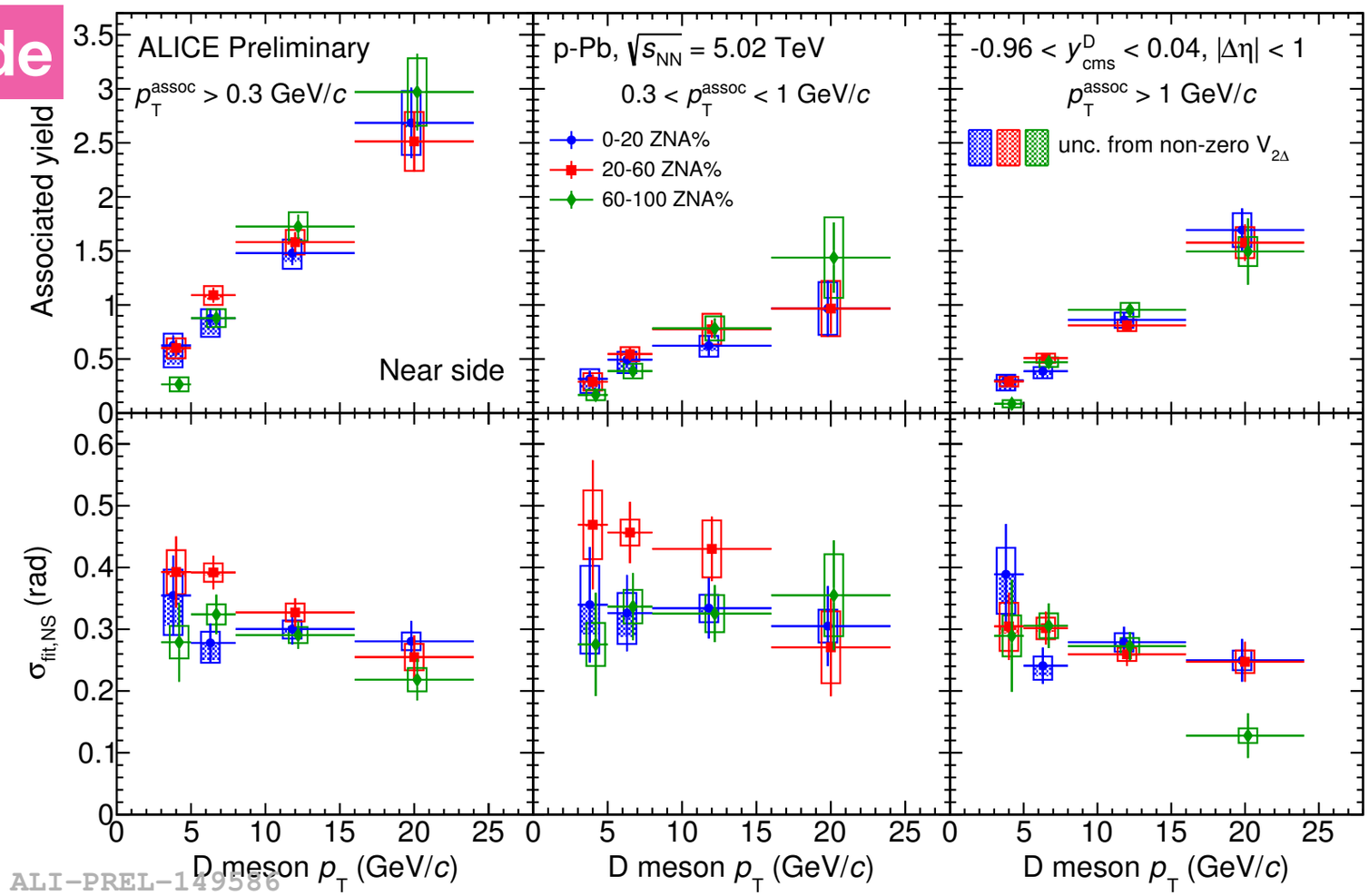
- Very promising ML-based method in pp and p–Pb collisions
- Studies will be extended to Pb–Pb collisions in RUN-III and RUN-IV

Backup

Correlations between D mesons and charged hadrons

p–Pb collisions at 5.02 TeV, results in various centrality classes

Near-side



0–20%

20–60%

60–100%

- No evidence of modification of near-side peak properties among different centrality classes within uncertainties

➡ Not enough sensitivity to extract the D-meson v_2