Open heavy-flavour measurements with ALICE at the LHC

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ALICE

QCD@Work – Matera – 25/06/2018

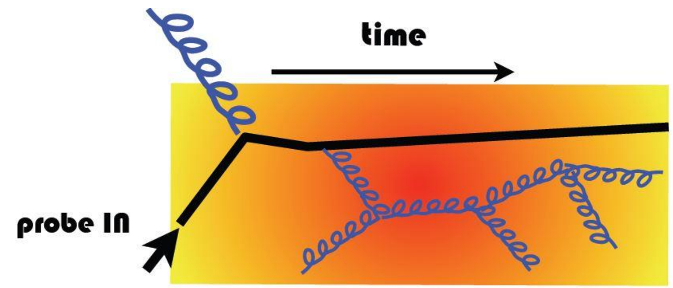
HEAVY-FLAVOUR PRODUCTION

Open heavy flavour in Pb-Pb collisions

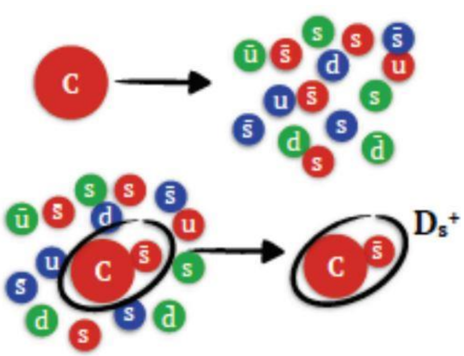
Heavy quarks experience the full evolution of the hot and dense medium produced in ultra-relativistic heavy-ion collisions → Excellent probes of the Quark-Gluon Plasma (QGP)

In particular, heavy quarks are expected to:

- Lose less energy w.r.t light quarks and gluons due to different Casimir factor and dead-cone effect
  - ➢ Microscopic study of medium and characterisation of energy loss mechanisms



- Be influenced by the collective motion of the partons inside the medium
  - ➢ Provide information on medium transport properties



- At low p_T, possibly hadronise also via coalescence:
  - ➢ Modified momentum distribution of HF hadrons
  - ➢ Enhanced v_2 of HF hadrons (light quark contribution)
  - ➢ Modified hadrochemistry (D_s^+, Λ_c^+ enhancement)

HEAVY-FLAVOUR PRODUCTION

Studies of heavy-flavour production important also in smaller systems

pp collisions

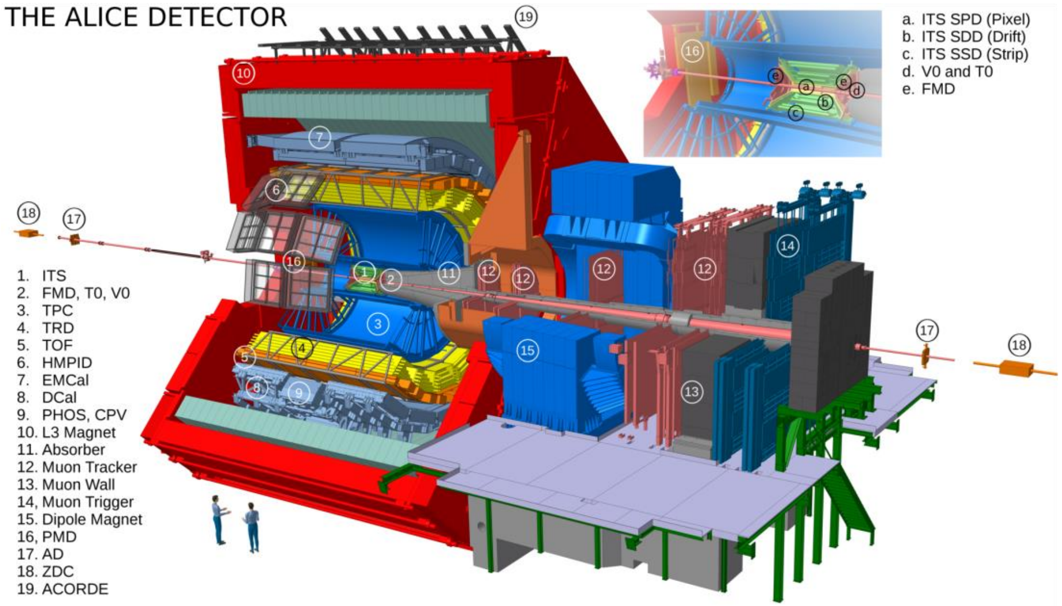
- Test and set constraints on pQCD calculations for charm and beauty quark production
- Probe parton distribution function (especially for gluons) at low values of Bjorken *x*
- Reference for studies in p-Pb and Pb-Pb collisions

p-Pb collisions

- Heavy-flavour production and kinematic properties can be modified by:
  - Cold nuclear matter effects, like shadowing, gluon saturation, Cronin effect, possible energy loss mechanisms
  - "Collective-like" effects (e.g. elliptic flow), resembling what observed in heavy-ion collisions, which is ascribed to the hydrodynamic expansion of the system

In all collision systems, **more differential measurements** (as HF correlations, jets) can provide further information than single-particle studies, and a closer access to the heavy parton properties

HEAVY-FLAVOUR RECONSTRUCTION WITH ALICE



V0: trigger + centrality/multiplicity estimation + event characterization

ZDC: centrality estimation

ITS: tracking + vertexing

TPC: tracking + PID

TOF: PID

EMCAL: high-p_T trigger + electron ID

Forward muon spectrometer: trigger + tracking

Open heavy flavour

Charmed hadrons ($|y| < 0.5$)

- $D^0 \to K^-\pi^+$
- $D^* \to D^0\pi^+ \to K^-\pi^+\pi^+$
- $D^+ \to K^-\pi^+\pi^+$
- $D^+_s \to \varphi\pi^+ \to K^-K^+\pi^+$
- $\Lambda_c^+ \to pK^-\pi^+$, $\Lambda c \to pK^0_s$, $K^0_s \to \pi^+\pi^-$
- $\Lambda_c^+ \to e^+\Lambda\nu$, $\Lambda \to p\pi^-$
- $(\Xi_b \to)\ \Xi_c^0 \to e^+\Xi^-\nu e$, $\Xi^- \to \pi^-\Lambda$

HF decay leptons

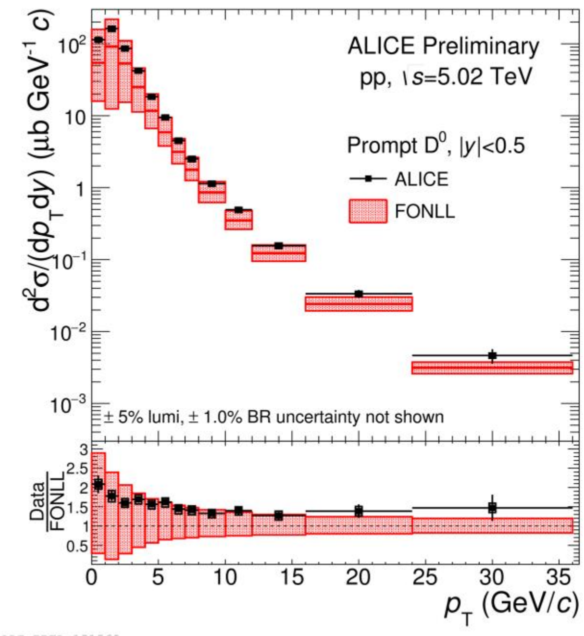
- c,b hadrons $\to$ eX ($|y| < 0.9$)
- c,b hadrons $\to$ μX ($2.5 < y < 4$)
- b $\to$ eX via impact parameter fit

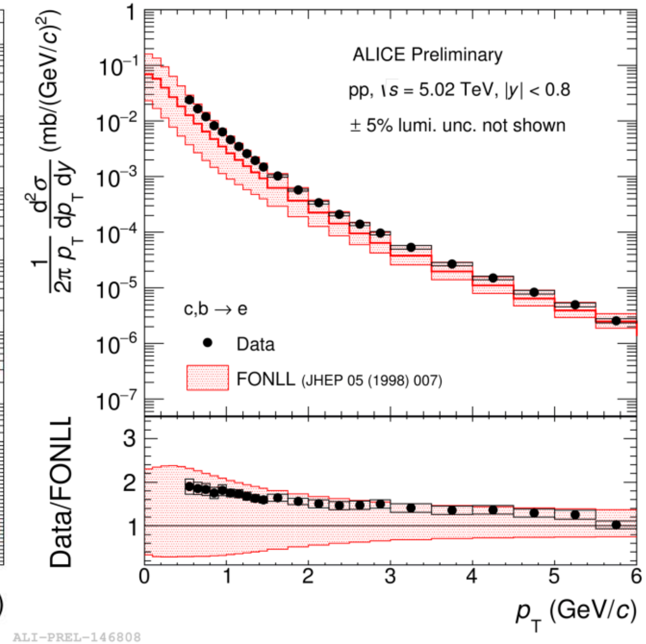
Beauty-decay J/ψ ($|y| < 0.9$)

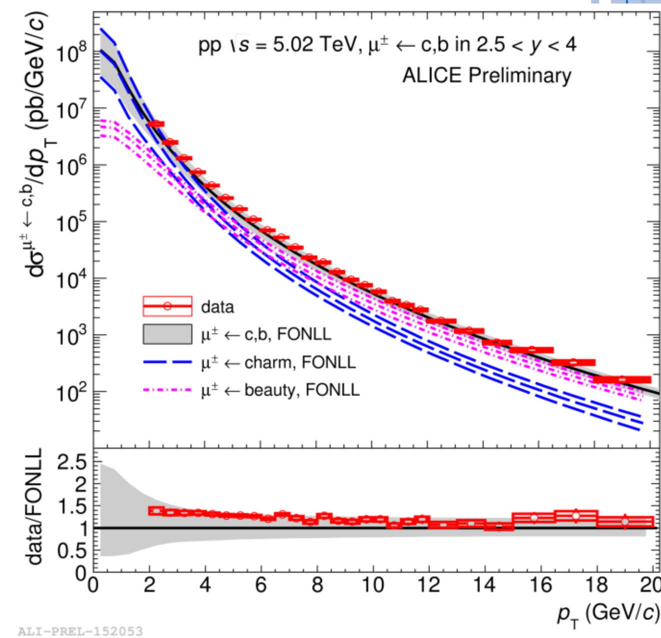
- b hadrons $\to J/\psi X$, $J/\psi \to e^+e^-$

+ open heavy-flavour jets, correlations, production vs multiplicity/centrality, ESE…

CROSS SECTIONS IN pp COLLISIONS



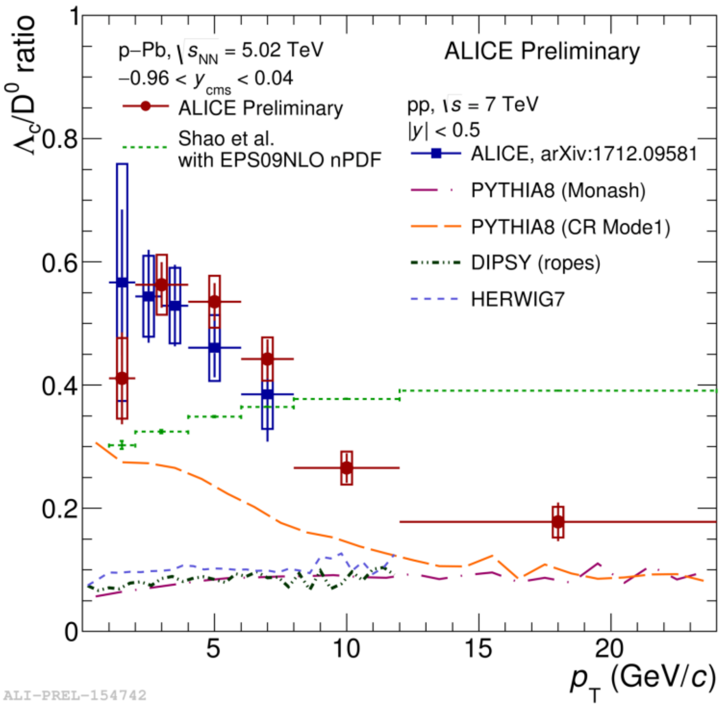


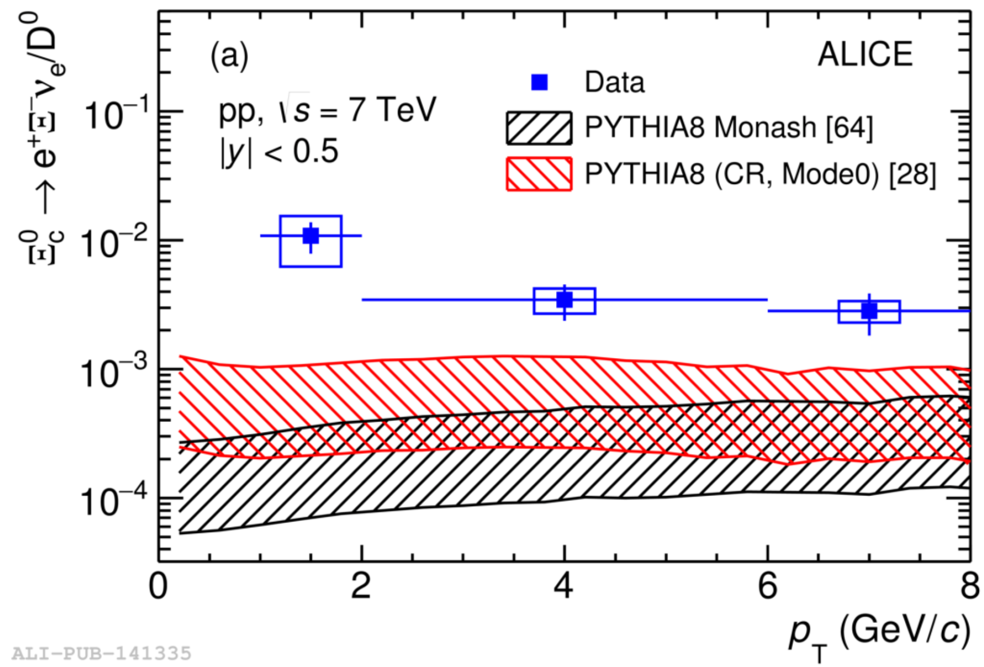


- p_T-differential production cross section of prompt D mesons and heavy-flavour decay leptons measured for several energies ($\sqrt{s}$ = 2.76, 5.02, 7, 8, 13 TeV)
- Excellent constraints for charm (+beauty) production cross section over a wide p_T interval
  - D^0 cross section down to $p_T = 0$
- All measurements are consistent with pQCD calculations, data always on upper part of FONLL uncertainty band (much larger than data uncertainties)

CHARMED BARYONS IN pp AND p-Pb

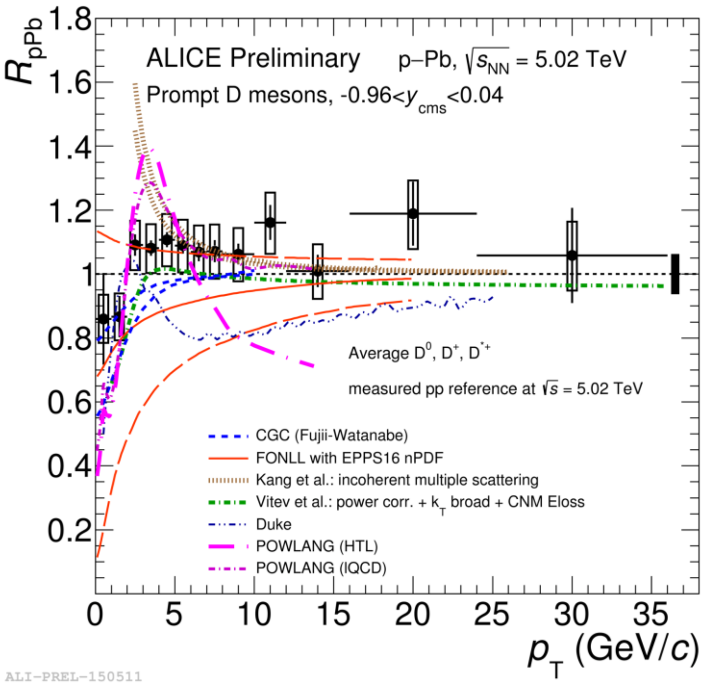
arXiv:1712.04242

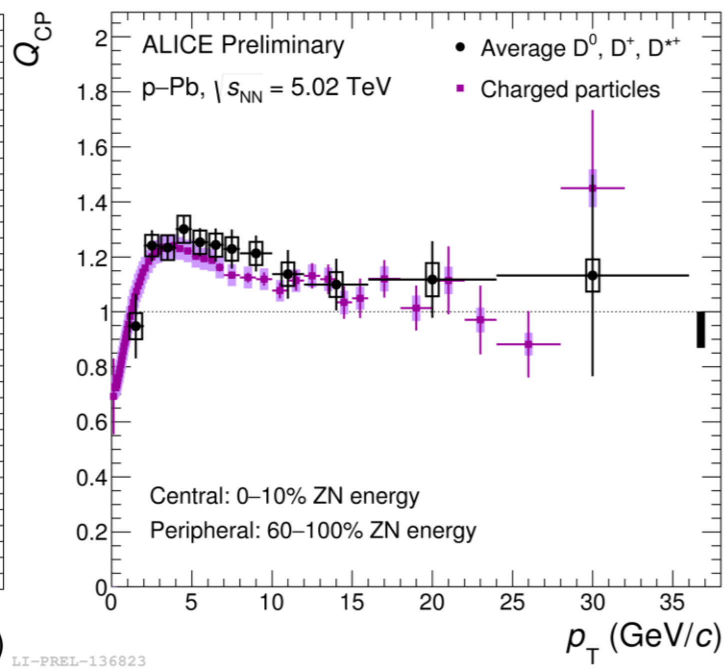




- Λ_c^+/D^0 ratios in pp and p-Pb collisions are compatible within uncertainties
  - Same p_T trend as for light flavor baryon-to-meson ratio (see backup)
- First Ξ_c^0 production measurement at the LHC
- Both Λ_c^+/D^0 and Ξ_c^0/D^0 ratios are **higher than MC expectation** (tuned on e^+e^-, e^-p data)
  - ➢ Enhanced color reconnection configuration of PYTHIA 8 is closer to data
  - ➢ Theory bands on Ξ_c^0 due to the uncertainty on the branching ratio $\Xi_c^0 \rightarrow e^+\Xi^-\nu_e$

D-MESON R_{pPb}





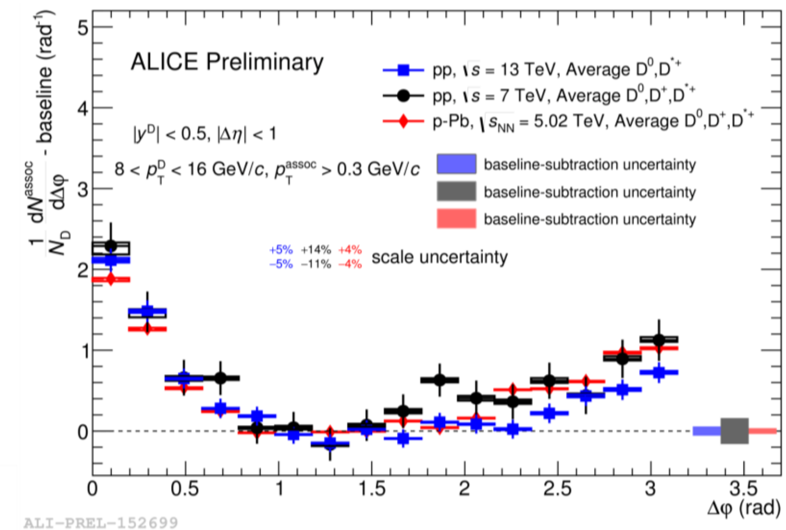
$$R_{\mathrm{pPb}} = \frac{\frac{\mathrm{d}\sigma_{\mathrm{pPb}}}{\mathrm{d}p_{\mathrm{T}}}}{A \cdot \frac{\mathrm{d}\sigma_{\mathrm{pp}}}{\mathrm{d}p_{\mathrm{T}}}}$$

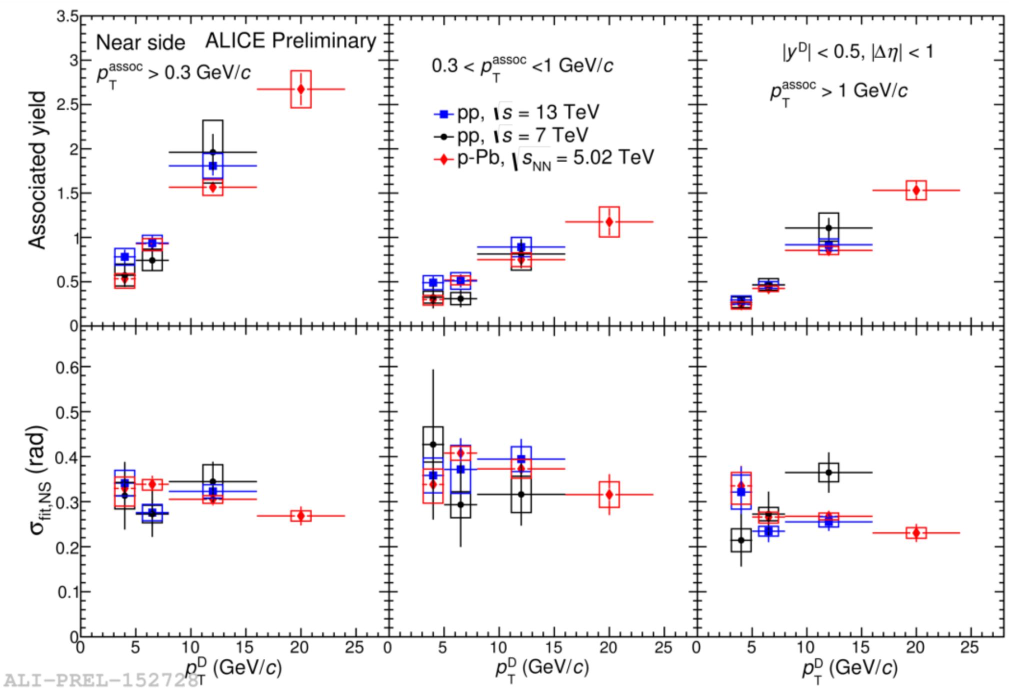
$$Q_{\mathrm{CP}} = \frac{\langle T_{\mathrm{pPb}}\rangle^{60-100} \cdot \frac{\mathrm{d}\sigma_{\mathrm{pPb}}^{0-10}}{\mathrm{d}p_{\mathrm{T}}}}{\langle T_{\mathrm{pPb}}\rangle^{0-10} \cdot \frac{\mathrm{d}\sigma_{\mathrm{pPb}}^{60-100}}{\mathrm{d}p_{\mathrm{T}}}}$$

- New preliminary results with better precision, due to reduction of uncertainties in the pp reference (2017 sample at 5 TeV)
- Non-strange D meson R_{pPb} is **compatible with unity** within uncertainties
  - Described by models including cold nuclear-matter effects and, at low p_T, by those assuming QGP formation
- Hint for D-meson "**central-to-peripheral" ratio (Q_{CP}) > 1** with 1.5σ in $2 < p_T < 8$ GeV/c
  - Initial- or final-state effect? Need theory models for its interpretation

D-h CORRELATIONS IN pp AND p-Pb

- Azimuthal correlation distributions of D mesons (average of D^0, D^+, D^{*+} mesons) with charged particles in pp and p-Pb collisions
- Characterize charm **production mechanisms** and **fragmentation** into jets and study possible modifications due to cold-nuclear-matter or medium-like effects





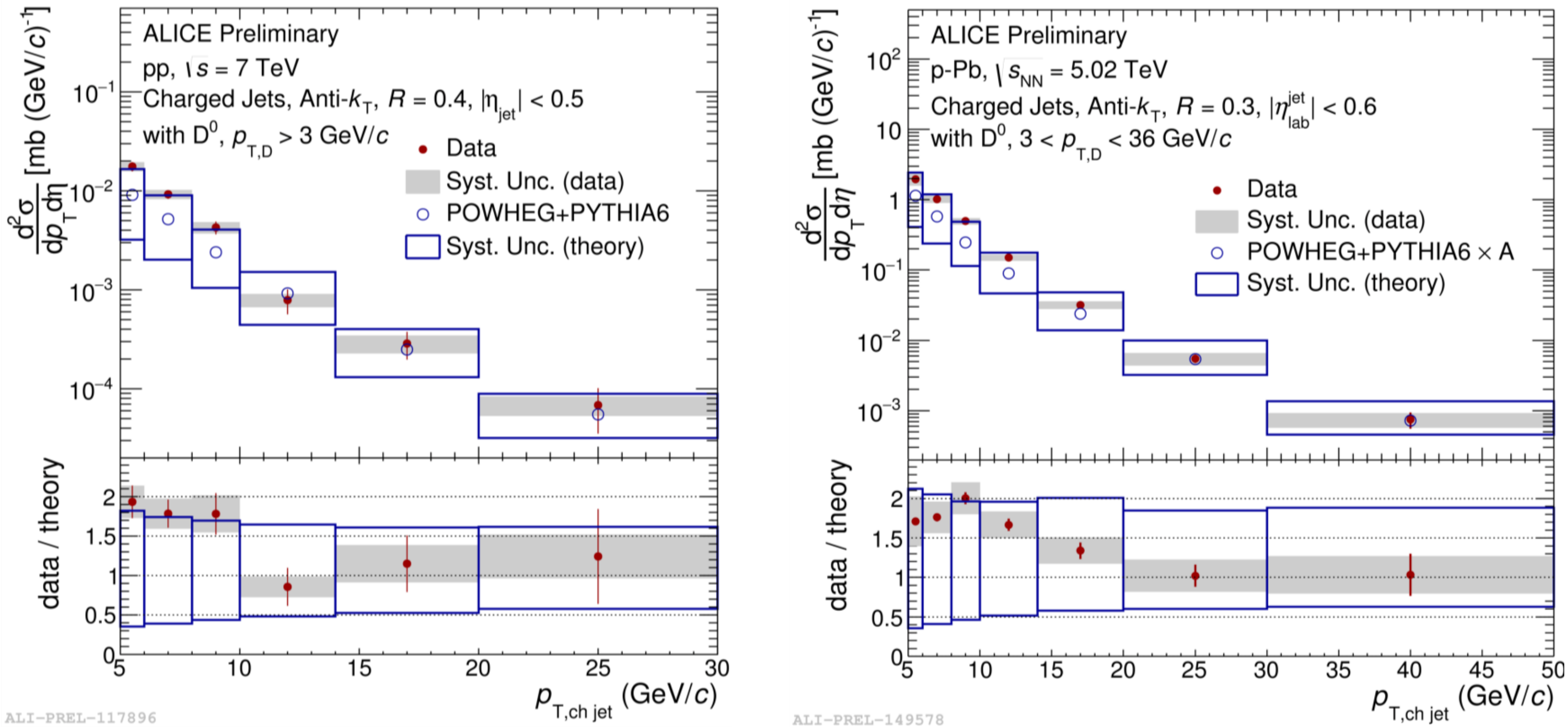
- Near-side peak yield and width extracted with two Gaussian + baseline fit to the Δφ distributions
- **Similar correlation pattern** and **near-side peak properties** in pp and p-Pb

pp@7 TeV

pp@13 TeV

p-Pb@5.02 TeV

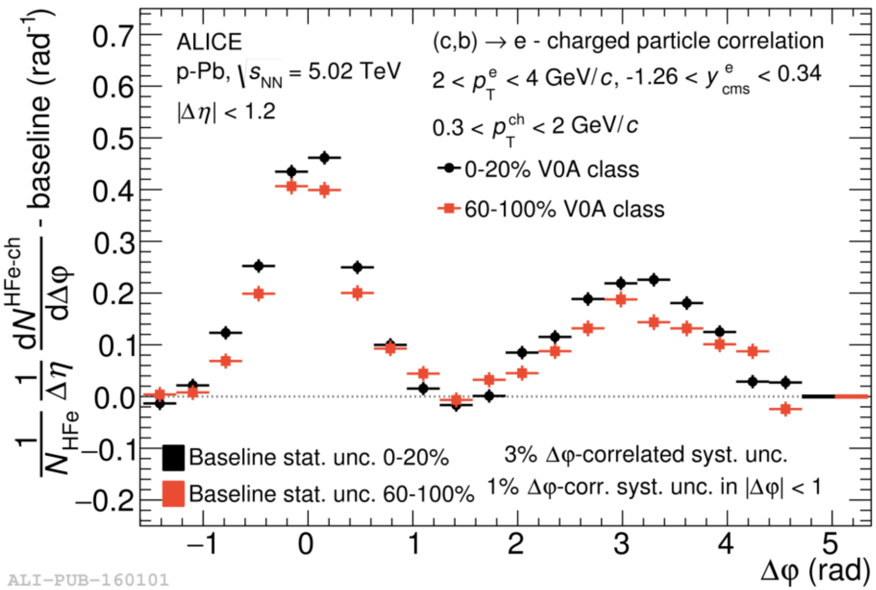
D-TAGGED JETS IN pp AND p-Pb COLLISIONS

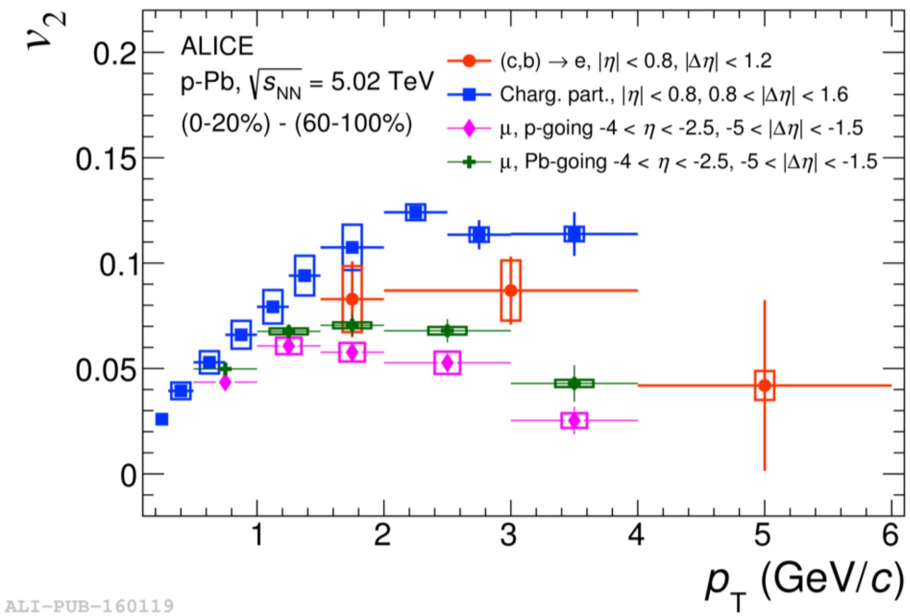


- **p_T-differential cross section** of charged jets with a reconstructed D^0 meson inside the jet cone in pp and p-Pb collisions
  - Allow a closer access to charm parton kinematics
- POWHEG+PYTHIA predictions (NLO pQCD) **describe well** the measured cross section
  - Theory uncertainties larger than data ones

HEAVY-FLAVOUR ELECTRON v_2 IN p-Pb

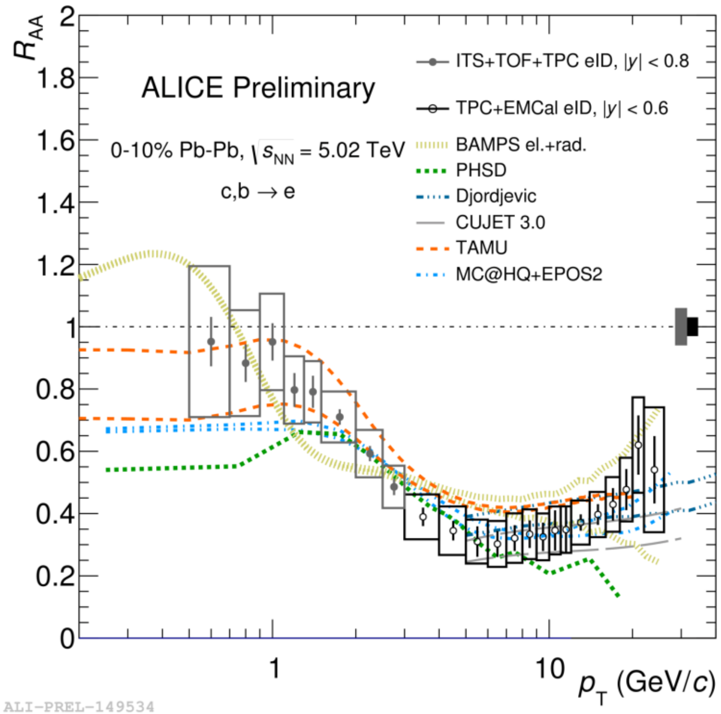
arXiv:1805.04367

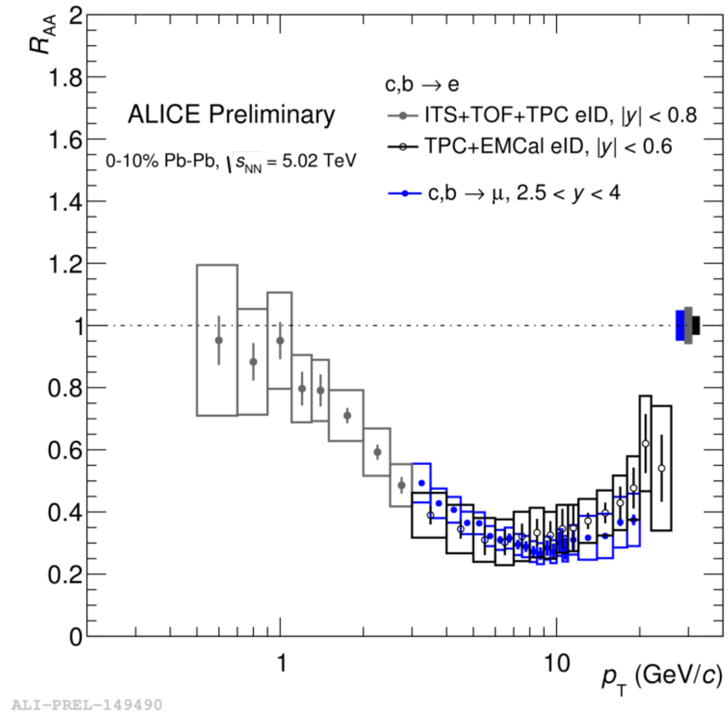




- Azimuthal correlations of heavy-flavour decay electrons with charged particles in HM (high multiplicity, 0-20%) and LM (low multiplicity, 60-100%) p-Pb collisions
- v_2 extracted from Fourier decomposition of HM – LM correlation distribution
- **Positive v_2** for heavy-flavour decay electrons (**5σ effect** for $1.5 < p_T^e < 4$ GeV/c)
  - Strength of v_2 comparable with charged-particles measurement (but different p_T ranges of original partons) and with muons (but different rapidities)
- Initial-state effect or final-state, collective effect? Need model predictions!

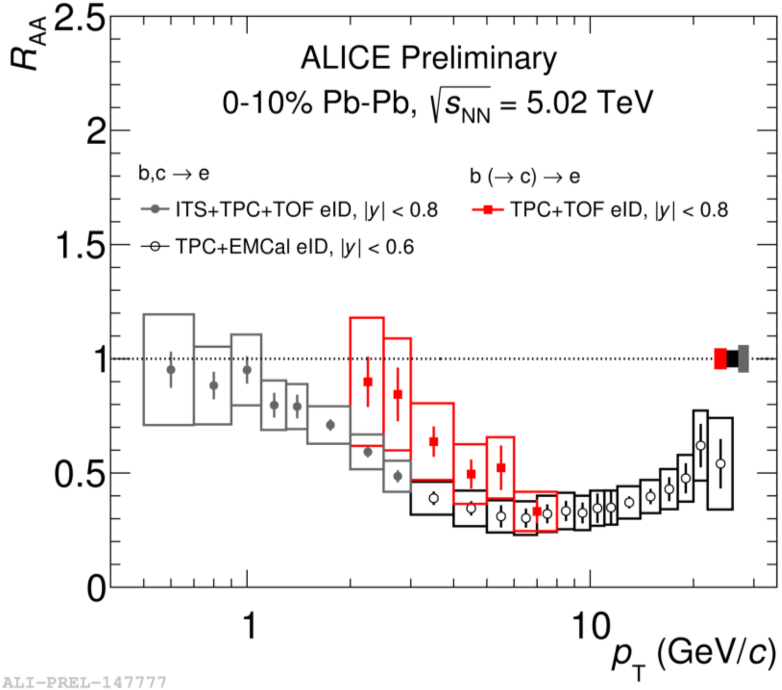
HEAVY-FLAVOUR LEPTON R_{AA}

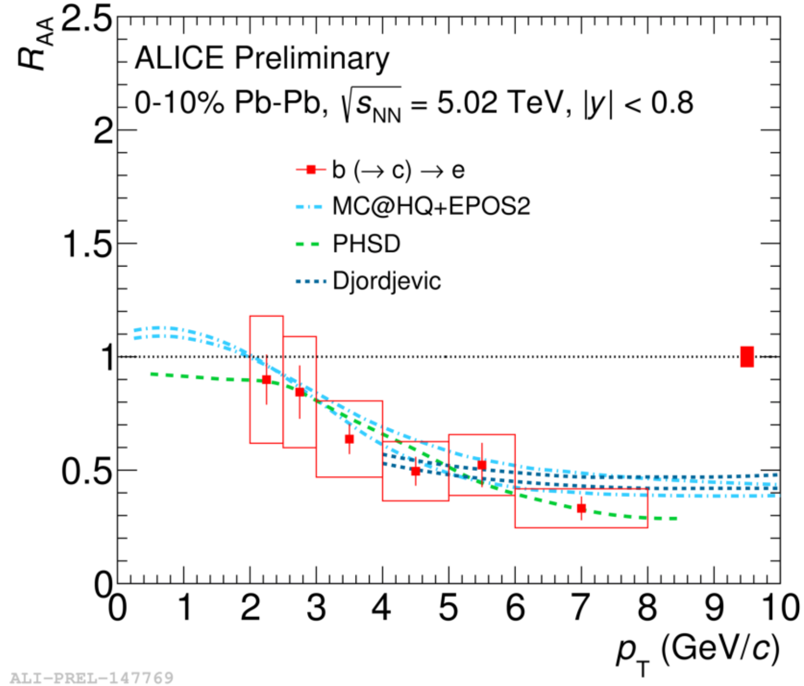




- Large suppression at high p_T in Pb-Pb collisions (factor ≈4 around 10 GeV/c)
  - No deviations from unity observed in R_{pPb} → Final-state effect induced by in-medium energy loss of hard partons
- Suppression of heavy-flavour decay muons at forward rapidity is similar to that of heavy-flavour decay electrons

BEAUTY R_{AA} MEASUREMENTS

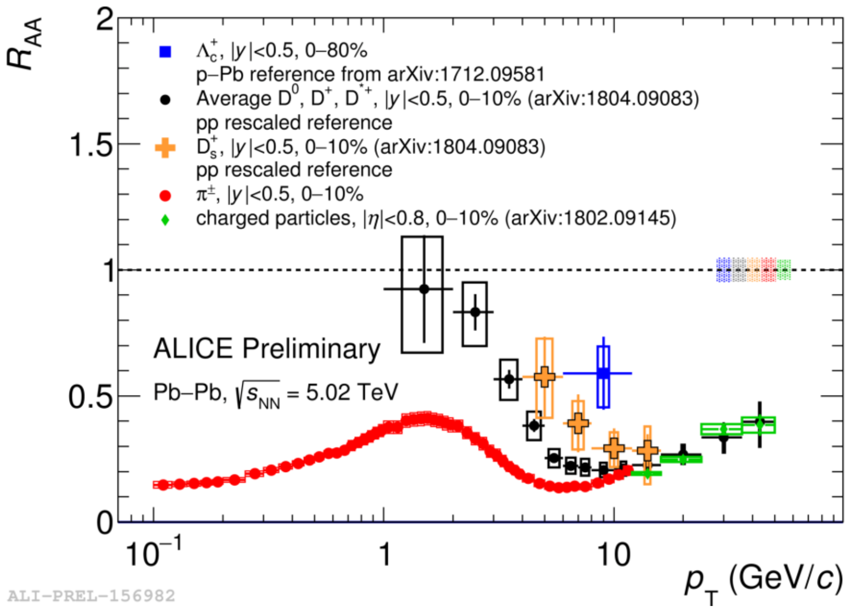


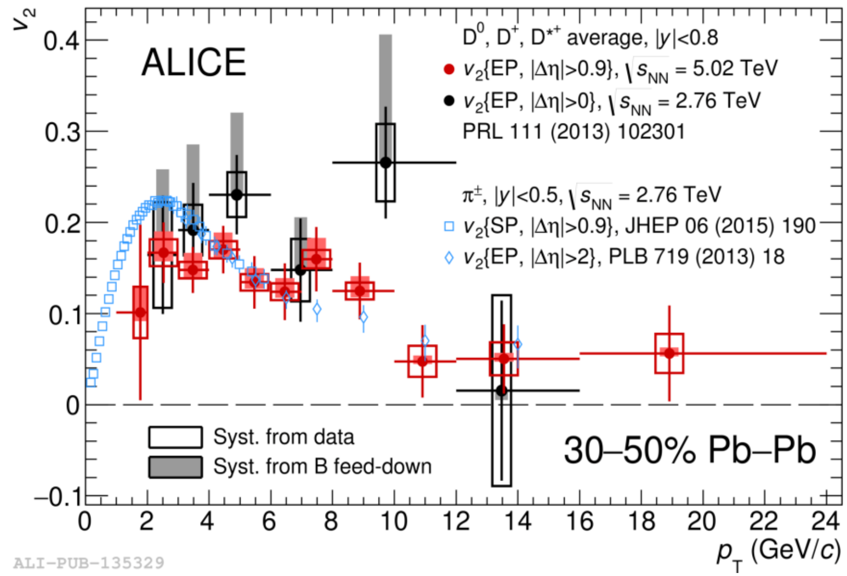


- Nuclear modification factor of beauty-decay electrons in 0-10% Pb-Pb collisions at 5.02 TeV
  - Hint of a smaller suppression for b-origin electrons than for (c+b)-origin electrons at the same electron p_T
  - Large contribution to systematic uncertainties from the rescaled pp cross section, may be reduced with direct measurement of beauty-electron production in pp at 5.02 TeV
- Models implementing **mass-dependent** energy loss mechanisms provide a good description of data within uncertainties

CHARM HADRONS R_{AA} AND v_2

ALICE, PRL 120, 102301 (2018)

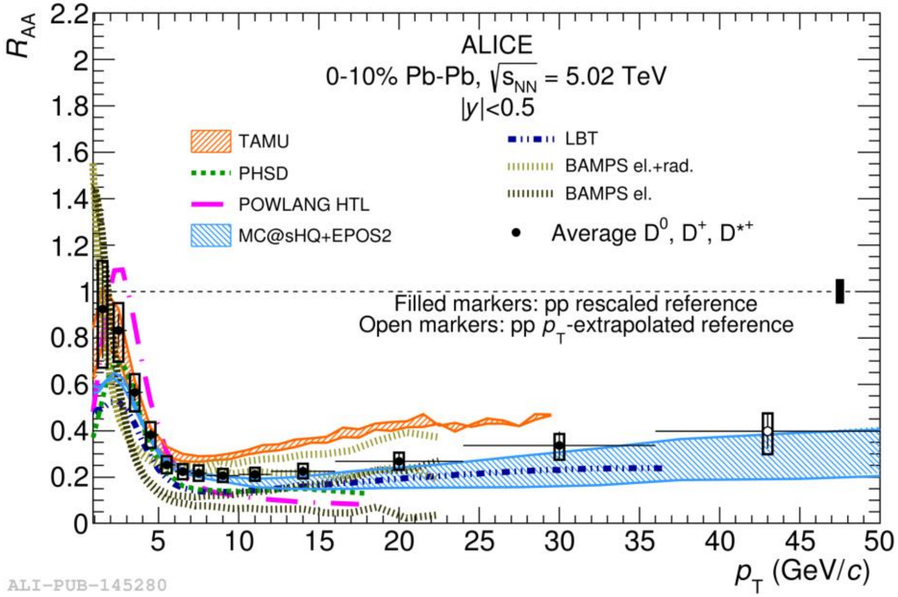




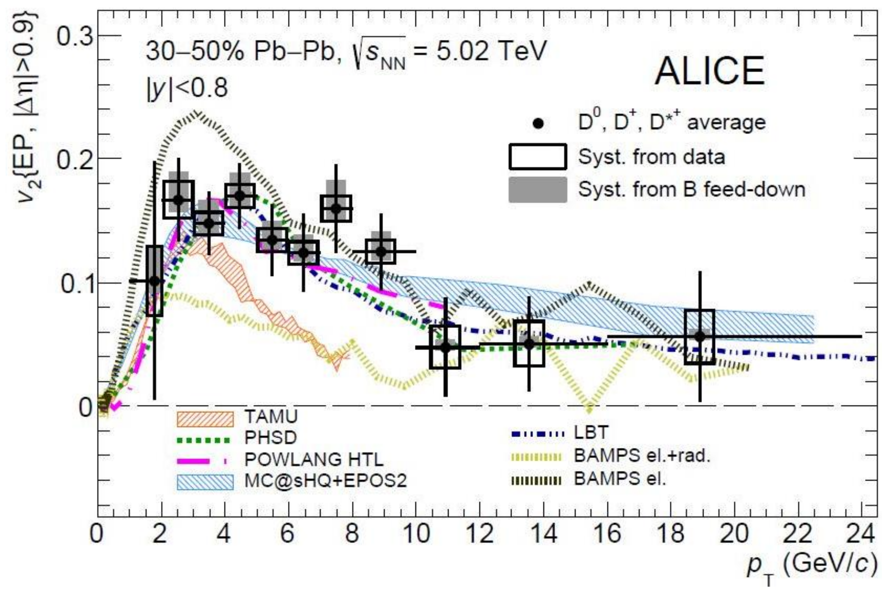
- Possible hierarchy for $R_{AA}(\Lambda_c^+$, 0-80%) > $R_{AA}(D_s^+$, 0-10%) > $R_{AA}(D^0,D^+,D^{*+}$, 0-10%)
  - From hadronisation via coalescence?
- At low p_T, R_{AA}(non-strange D) > $R_{AA}(\pi)$
  - To be interpreted with care: different fragmentation functions, initial parton p_T spectrum, radial flow contribution, N_{coll} scaling violation at low p_T for charged pions, ...
- **Positive D-meson v_2** for p_T > 2 GeV/c, with hints of $v_2(D)$ < $v_2(\pi^\pm)$ for p_T < 4 GeV/c
  - Supports the idea of charm thermalization and participation to collective motion

D-MESON R_{AA} AND v_2 VS MODELS

arXiv:1804.09083

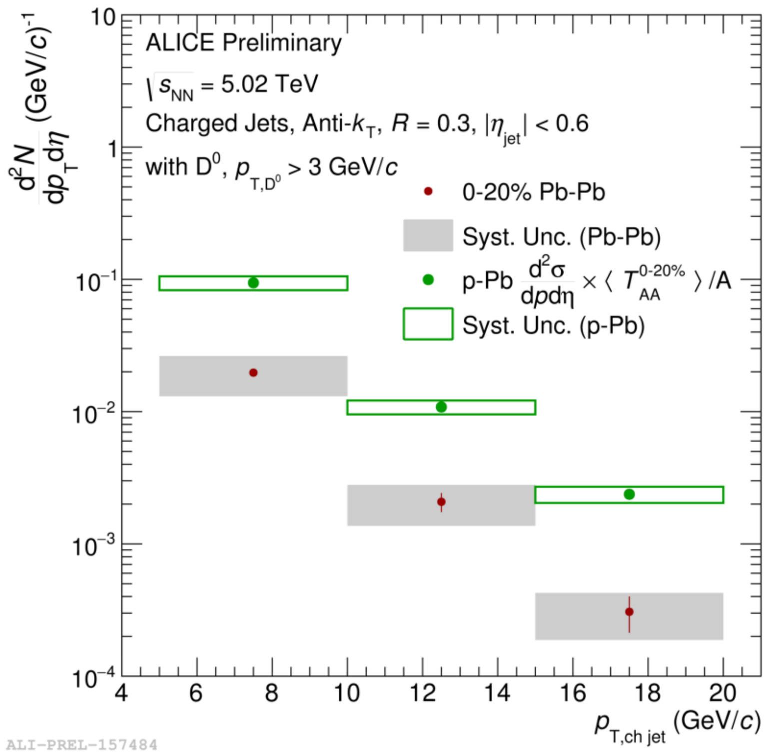


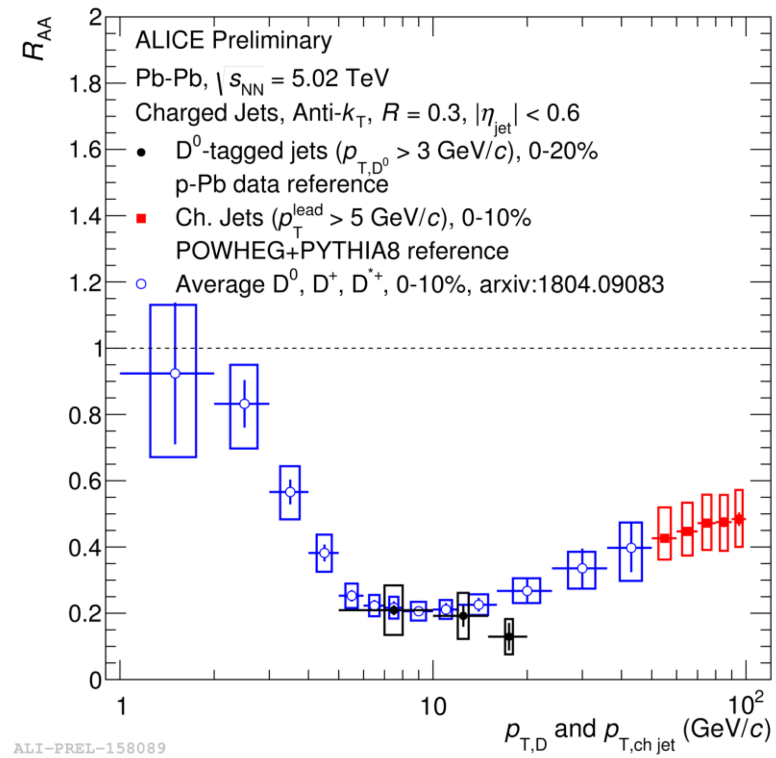
PRL 120, 102301 (2018)



- A simultaneous description of complementary observables (R_{AA} and v_2) over a wide p_T range is a challenging task: measurements allow us to set strong constraints to models
  - Models in which charm quarks pick up collective flow via **recombination** or **subsequent elastic collisions** in expanding medium better describe v_2 at low p_T. Adding **radiative energy loss** improves the R_{AA} description at high p_T but gives too low v_2 at low p_T.
  - Best v_2 description by models with diffusion coefficient $2\pi D_s(T)$ in the range **1.5-7** at T_c, with a corresponding thermalisation time **τ_{charm}~ 3-14 fm/*c***

D-TAGGED JETS IN Pb-Pb COLLISIONS





- Strong suppression of production cross section in 0-20% Pb-Pb collisions over full p_T(jet) range
- Comparison with inclusive jets difficult due to non-overlapping p_T ranges, but hint of lower R_{AA} for D jets in 5 < p_T(jet) < 20 GeV/c than inclusive jets with p_T > 50 GeV/c
  - Can address different quark/gluon jet ratio and collisional/radiative energy loss fractions
- R_{AA} comparable with single D-meson measurement: jet R_{AA} dominated by leading particle energy loss? Or a coincidence? Yet not apple-to-apple comparison (jet vs. hadron p_T scale)

CONCLUSIONS

Large set of measurements of open heavy-flavour particles in pp ($\sqrt{s}$ = 2.76, 5, 7, 8 and 13 TeV), p-Pb ($\sqrt{s_{NN}}$ = 5.02 and 8.16 TeV) and Pb-Pb ($\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV) collisions.

pp and p-Pb collisions

- Precise **p_T-differential cross section** measurements of heavy-flavour particles set strong constraints for pQCD calculations.
- **R_{pPb}** of non-strange D-mesons, D_s^+ meson and Λ_c^+ all **compatible with unity**. Other observables, as **Q_{CP} of D mesons** or **HF-decay electron v_2**, point anyway to non-negligible nuclear effects.
- Measurements of **D-h correlations** and **D-tagged jets** are well described by model predictions within uncertainties.

Pb-Pb collisions

- **Large suppression** of open heavy-flavour particles in central collisions, due to heavy-quark energy loss in the QGP.
- **Positive v_2** observed for open heavy-flavour hadrons and decay leptons: charm quarks undergo strong interaction with the QCD medium and participate to system collective motion.
- **Enhanced Λ_c^+** (and possibly **D_s^+**) production in Pb-Pb*:* coalescence in strangeness-rich environment.
- Hints of **smaller suppression** for **beauty-decay electrons** from p_T > 2 GeV/*c*.
- First measurement of **D^0-tagged jets** in Pb-Pb: large suppression observed in 0-20% collisions.

Higher precision on current observables and **more differential measurement** expected with 2018 Pb-Pb run and in the next runs after the ALICE upgrade

BACKUP SLIDES

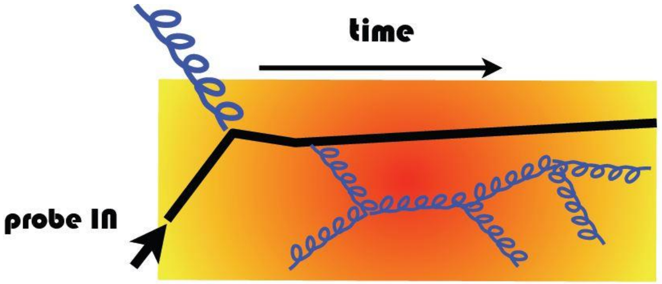
HEAVY-FLAVOUR PRODUCTION

Open heavy flavour in Pb-Pb collisions

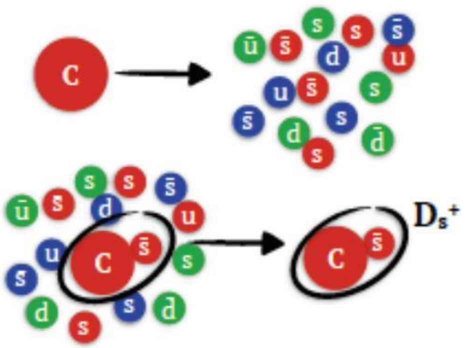
- Heavy quarks experience the full evolution of the hot and dense medium produced in ultra-relativistic heavy-ion collisions → Excellent probes of the QGP

In particular, heavy quarks are expected to:

- Lose less energy w.r.t light quarks and gluons due to different Casimir factor and dead-cone effect
  - ➢ Microscopic study of medium and characterisation of energy loss mechanisms



- Participate to some extent to the collective motion inside the medium
  - ➢ Provide information on medium transport properties ➡ ***F. Grosa's contribution***



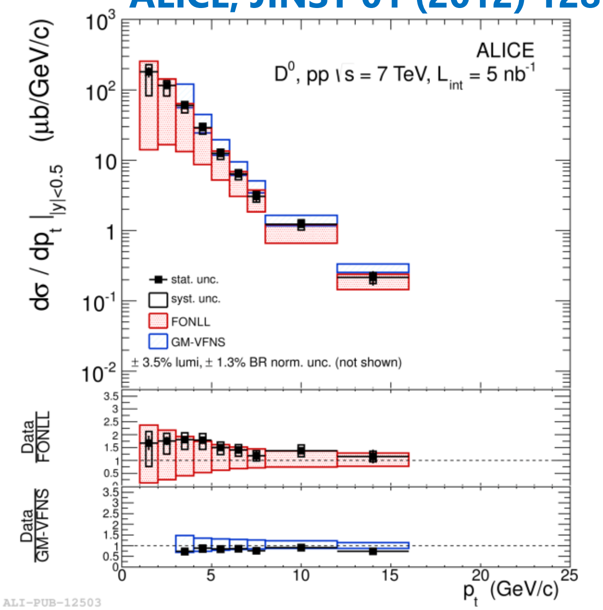
- At low p_T, possibly hadronise also via coalescence:
  - ➢ Modified momentum distribution of HF hadrons (radial flow «bump»)
  - ➢ Enhance v_2 of HF hadrons (light quark contribution)
  - ➢ Modify hadrochemistry, enhancing D_s^+, Λ_c^+ production

HEAVY-FLAVOUR PRODUCTION

ALICE

Studies of heavy-flavour production important also in smaller systems

ALICE, JINST 01 (2012) 128



pp collisions

- Test and set constraints on production mechanisms
  - Production cross section can be treated perturbatively due to the large Q^2 involved
  - pQCD-based calculations describe reasonably well open charm and beauty production at the LHC
- Probe parton distribution function (especially for gluons) at low values of Bjorken x
- Reference for studies in p-Pb and Pb-Pb collisions

p-Pb collisions

- Heavy-flavour production and kinematic properties can be modified by:
  - Cold nuclear matter effects, like shadowing, gluon saturation/color glass condensate, Cronin effect, possible energy loss mechanisms
  - “Collective-like" effects (e.g. elliptic flow), resembling what observed in heavy-ion collisions, which is ascribed to the hydrodynamic expansion of the system

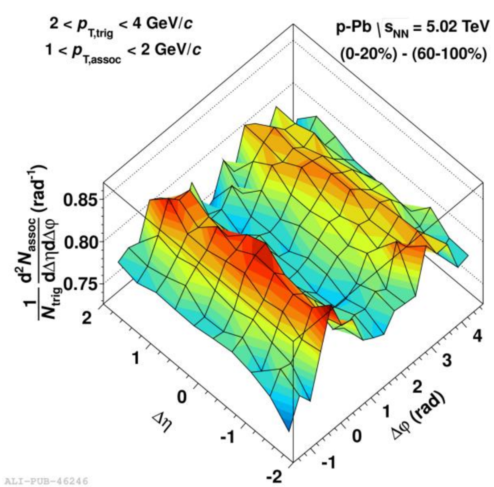
HEAVY-FLAVOUR CORRELATIONS

HF correlations: allow to gain further insight w.r.t. single-particle observables, by relating heavy-flavour particles to:

- The other tracks from the fragmentation of the same heavy quark
- The fragmentation particles from the other heavy quark in the event
- The underlying event (soft particle production)

pp collisions

- Investigate heavy-flavour quark fragmentation properties and characterize heavy-flavour jets
- Sensitivity to modeling of HQ production processes
- Reference for p-Pb and Pb-Pb results



ALICE, PLB 719 (2013) 29-41

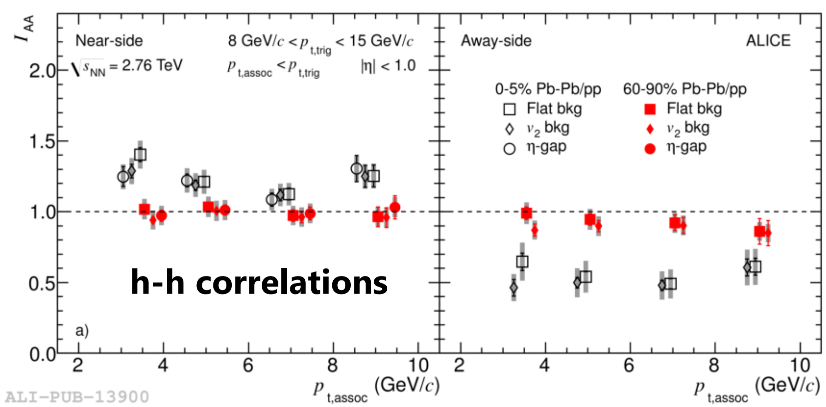
p-Pb collisions

- Investigate possible modifications of angular correlation pattern from cold nuclear matter effects
- Search for long-range ridge-like structures (double ridge), observed in di-hadron correlations, also in the heavy-flavour sector, possibly due to initial- (e.g. CGC) or final-state effects (e.g. hydrodynamics)

HEAVY-FLAVOUR CORRELATIONS

Pb-Pb collisions

- Probe the QGP effects on heavy quarks by studying how correlation distributions of heavy-flavour particles are modified w.r.t. vacuum



ALICE, PRL 108 (2012) 092301

- Add sensitivity to study contribution of radiative and collisional parton energy loss in QGP medium?

Pb-Pb @ 2.76 TeV
LO process only
→ Initial distribution: Δφ=π

For light flavour correlations:

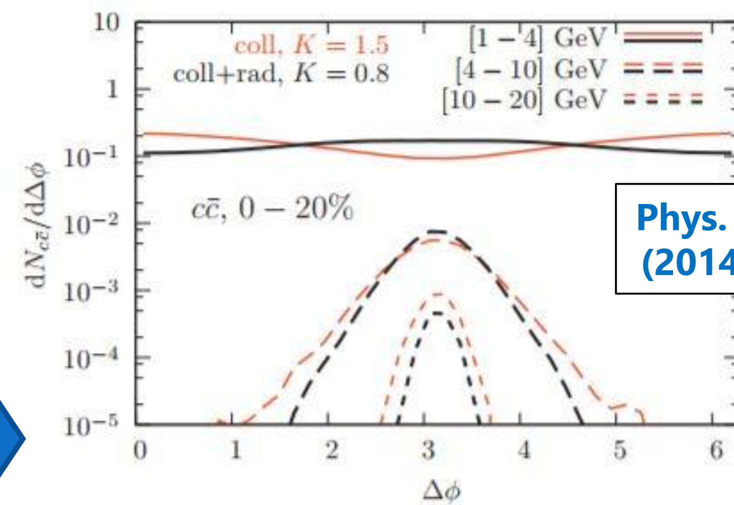
Away-side suppression at high p_T

- Path-length dependence of energy loss

Near-side peak enhancement: interplay of

- Modification to quark/gluon ratio
- Bias in partons p_T spectrum due to energy loss in medium
- Modified parton fragmentation

Note - Different fragmentation, energy loss in medium, kinematic bias between heavy and light quarks! I_{AA} not directly comparable!



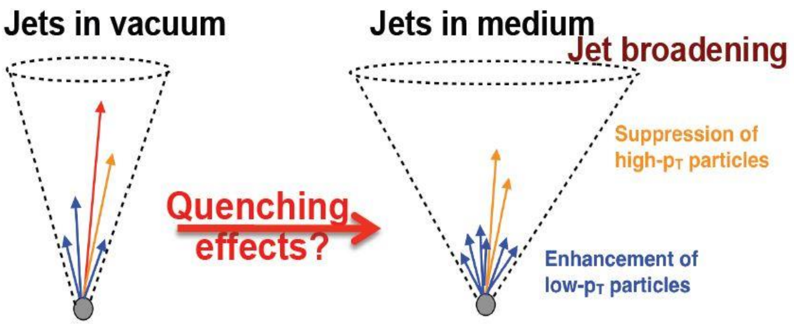
Phys. Rev. C 90 (2014) 024907

HEAVY-FLAVOUR JETS

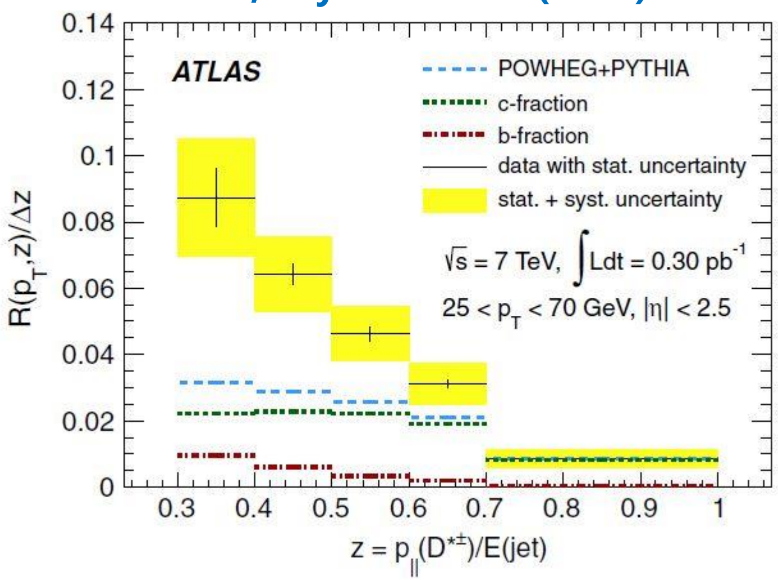
Complementary information w.r.t. correlations, seeing the parton fragments as a single object instead of as a particle ensemble

Tight connection with HF correlations also for some goals, with alternative approach:

- Spatial distribution of energy lost in the medium by heavy quarks → differences with respect to light flavour/gluon jets?



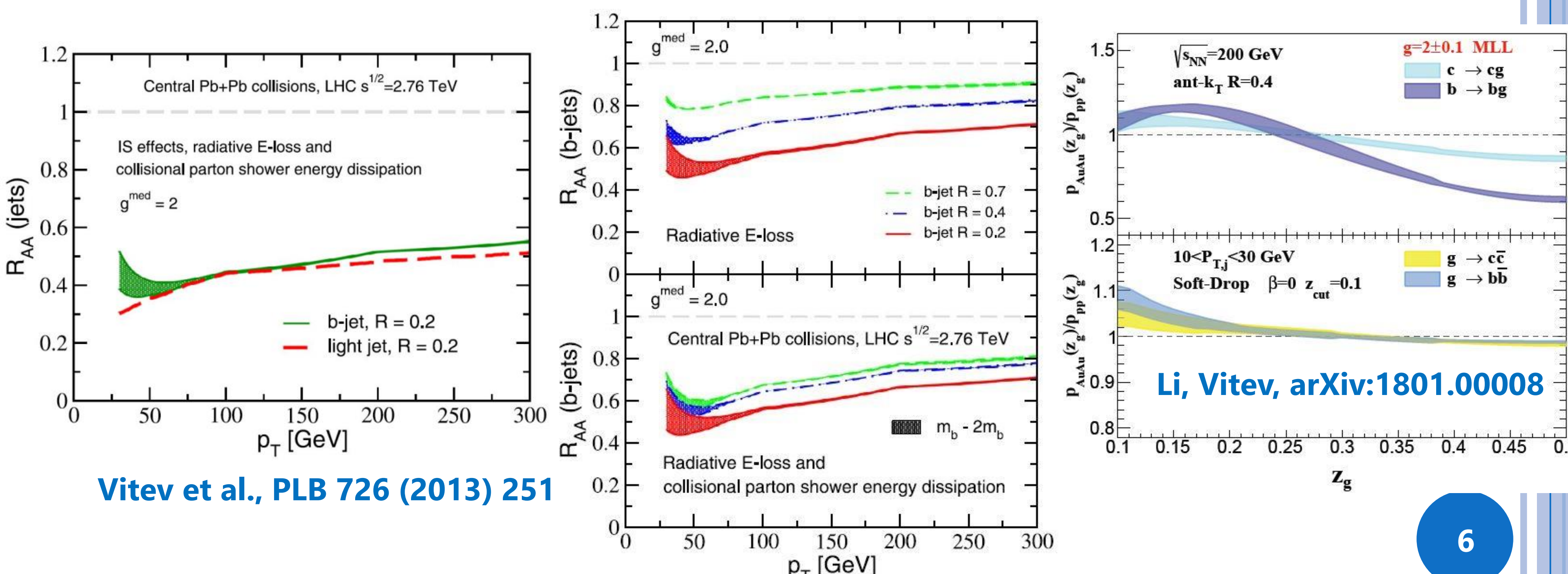
ATLAS, Phys. Rev. D85 (2012) 052005



- Jets tagged by HF hadron (D-jets, b-jets, …): study of jet momentum fraction taken by the particle and its modification in a QGP medium
- Studies important also in pp and p-Pb (reference for Pb-Pb measurements, impact of cold-nuclear-matter effects)

HEAVY-FLAVOUR JETS

- Comparison of b-jet R_{AA} with inclusive jet to investigate mass effect on medium-induced ΔE
  - ✓ Mass effects relevant for p_T < 75 GeV/c, dead-cone effect not negligible
  - ✓ Measurements vs opening radius *R* to characterize energy dissipation and possibly separate collisional and radiative energy loss
  - ✓ Energy loss in gluon splitting cases (high p_T): b-pair seen by medium as massive gluon?
  - ✓ Addressing the jet momentum sharing (via "soft drop declustering" technique) could probe the QGP-induced modifications of the heavy-flavour 1→2 jet splitting function

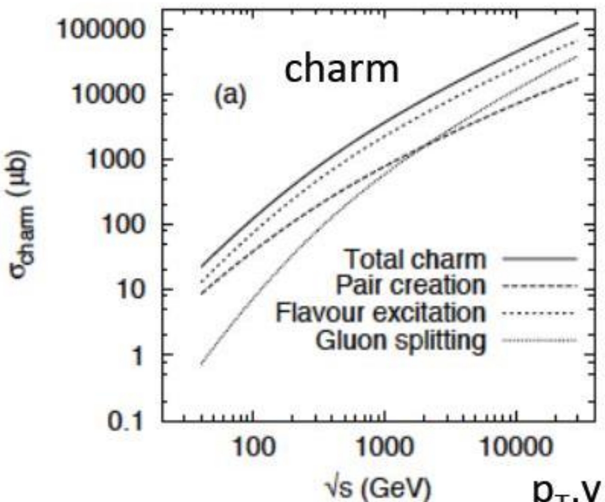


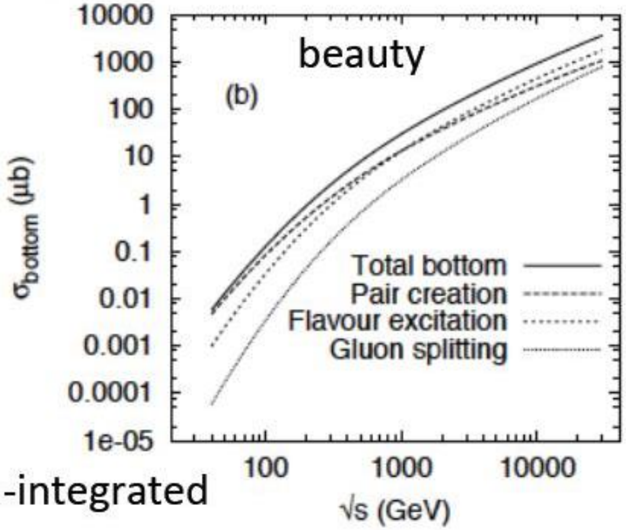
Vitev et al., PLB 726 (2013) 251

Li, Vitev, arXiv:1801.00008

HEAVY QUARK PRODUCTION

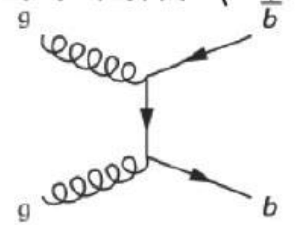
PYTHIA (E. Norrbin, T. Sjostrand, Eur.Phys.J.C17:137-161,2000)



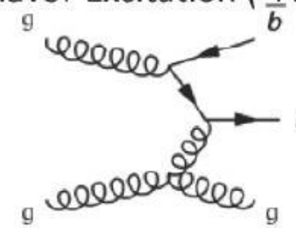


p_T,y -integrated

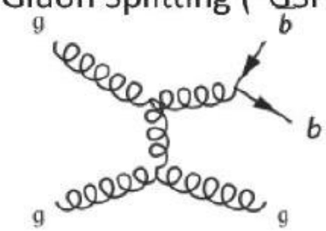
Flavor Creation ("FCR")



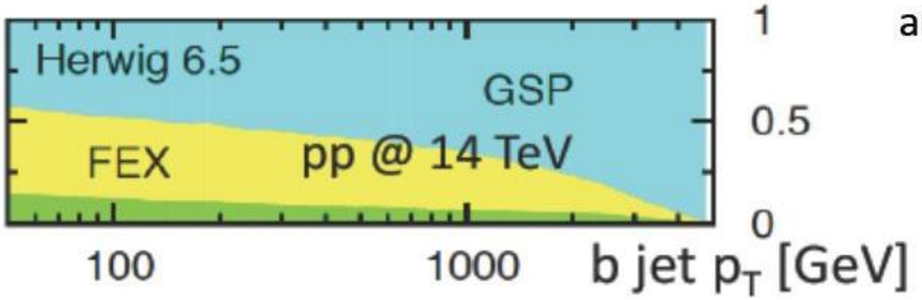
Flavor Excitation ("FEX")



Gluon Splitting ("GSP")

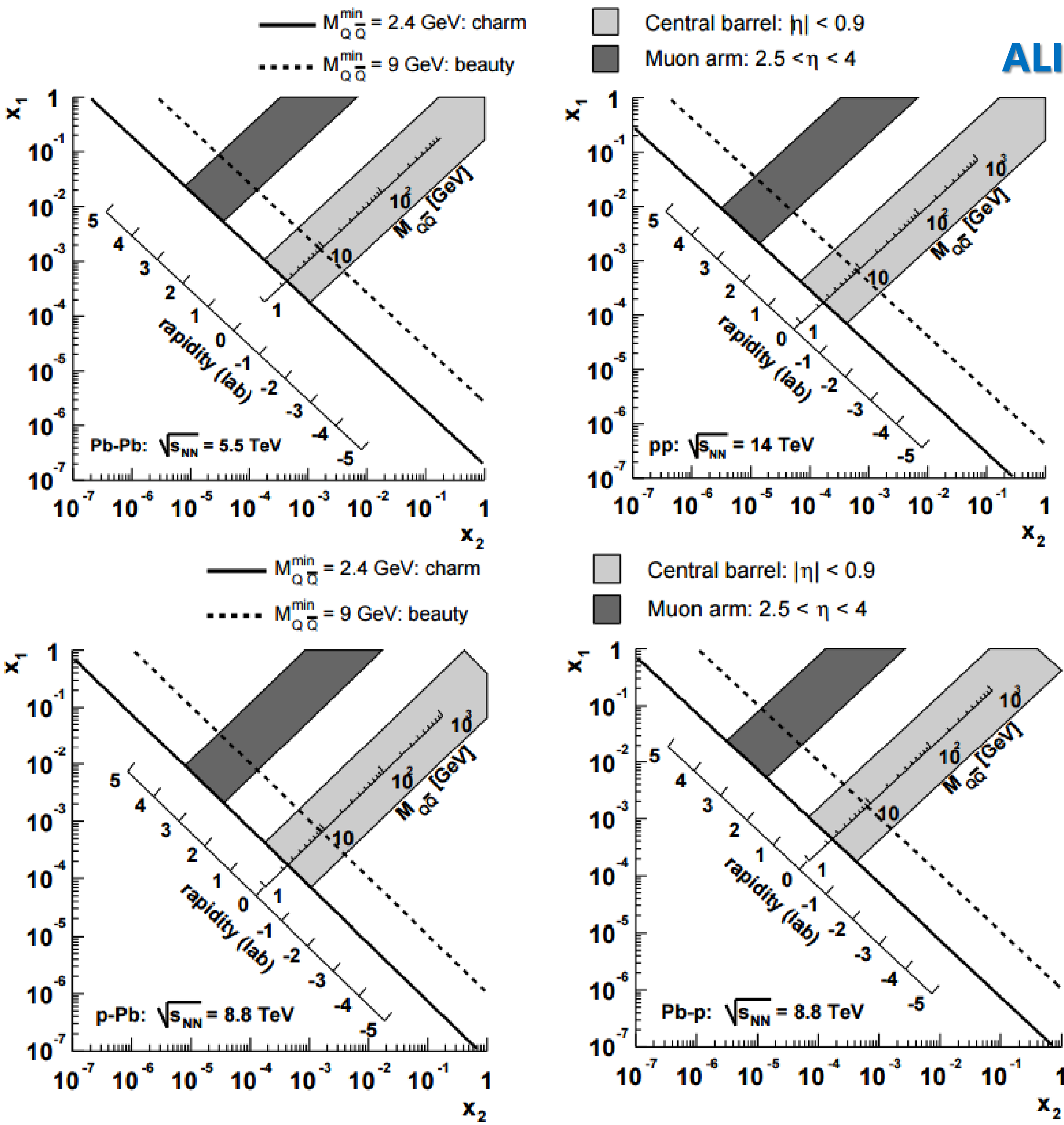


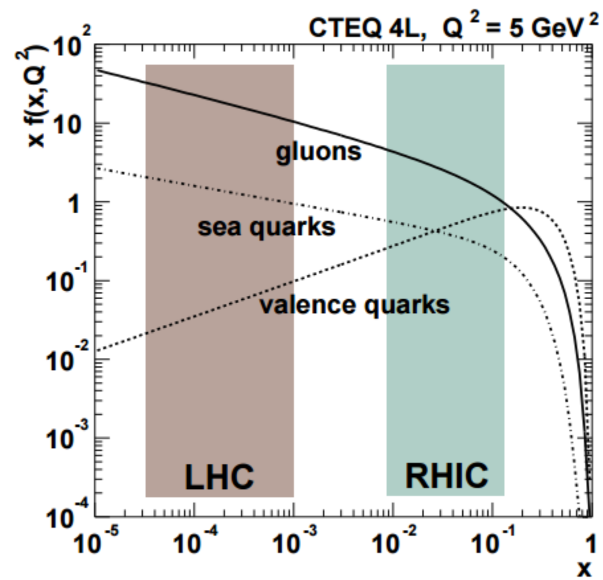
HERWIG 6.5 (A. Banfi, G. Salam, G. Zanderighi, JHEP 0707:026,2007, arXiv:0704.2999)



BJORKEN X REGIONS AT THE LHC AND PDF

ALICE, J. Phys. G, 32 (2010) 1295

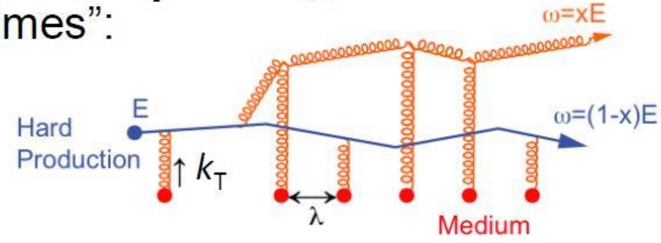




Parton Distribution Functions in CTEQ 4L parametrization, for Q^2 = 5 GeV^2

Models: low and high p_T regimes

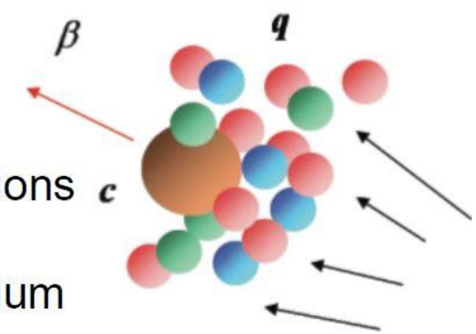
In a oversimplified scheme we can identify two “regimes”:



High p_T:

- region **dominated by radiative energy loss**
- Quantum interferences in multiple scattering important (LPM effect)
- Relevant parameter: $\hat{q} = \frac{\langle k_T^2 \rangle}{\lambda}$

pQCD-based models provide fair description



Low p_T:

- Region **dominated by “collisional” energy loss**
- Heavy quarks undergo many soft and incoherent elastic collisions **~Brownian motion**
- Goal: study how and if HQ reach the equilibrium with the medium
- Relevant parameter: **spatial diffusion coefficient, D_s**

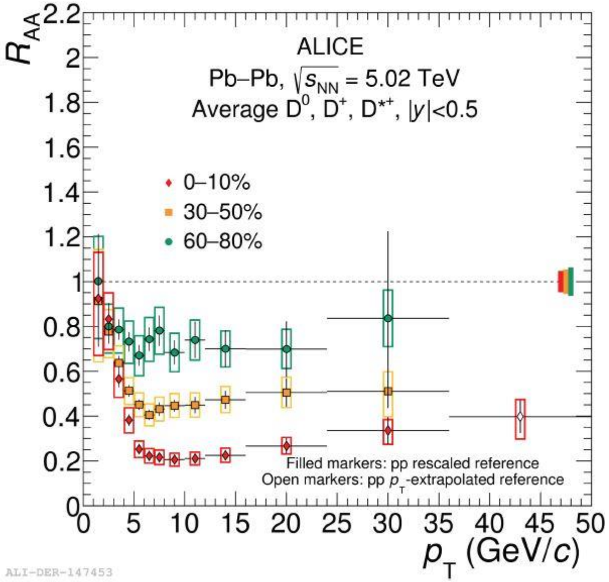
Injecting a particle at x=0 and t=0, the mean squared position at time t is: $\langle x^2(t) \rangle = 6 D_s t$

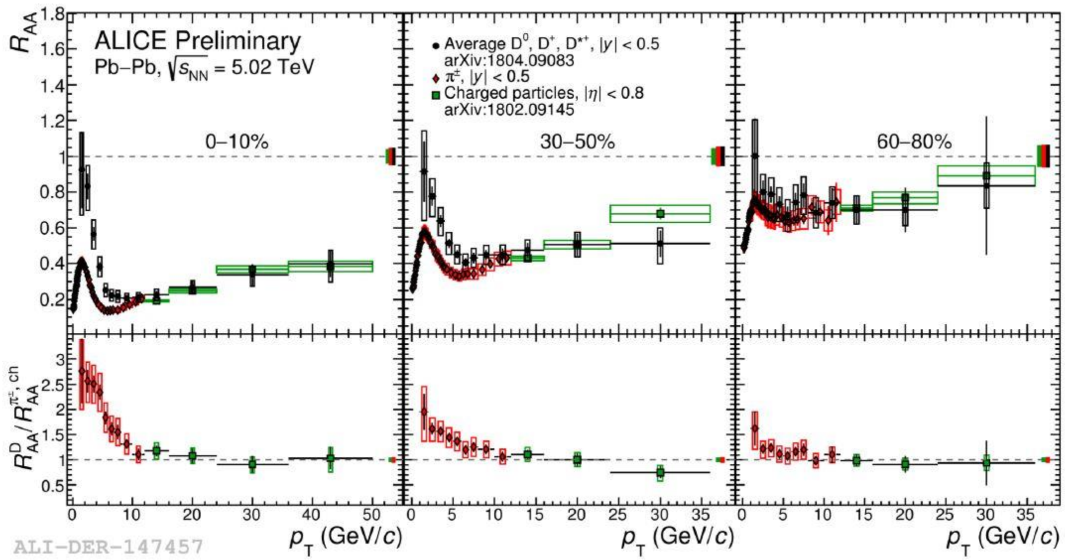
Strong coupling with the system → small D_s

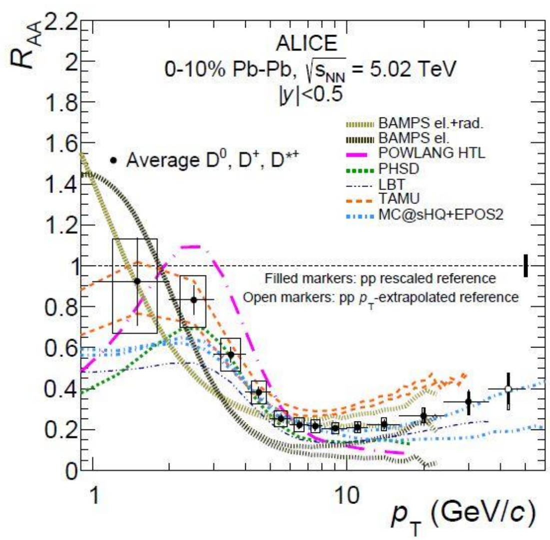
53

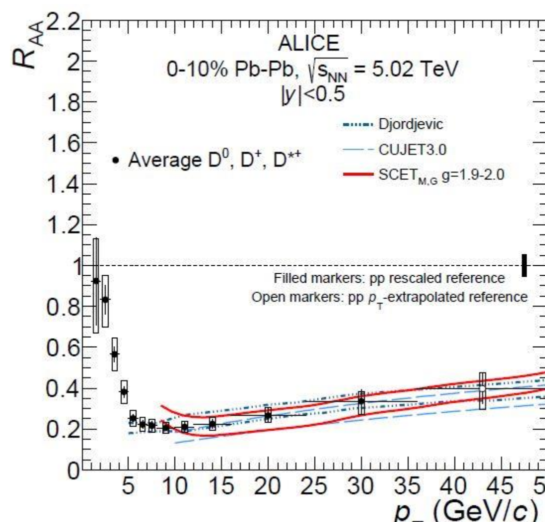
A. Rossi

FURTHER D-MESON R_{AA} RESULTS







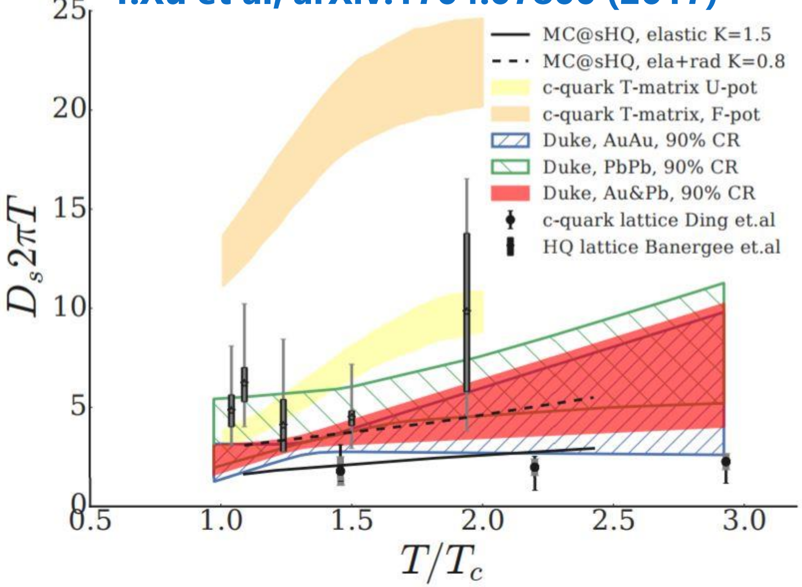


D-MESON R_{AA} - MODELS

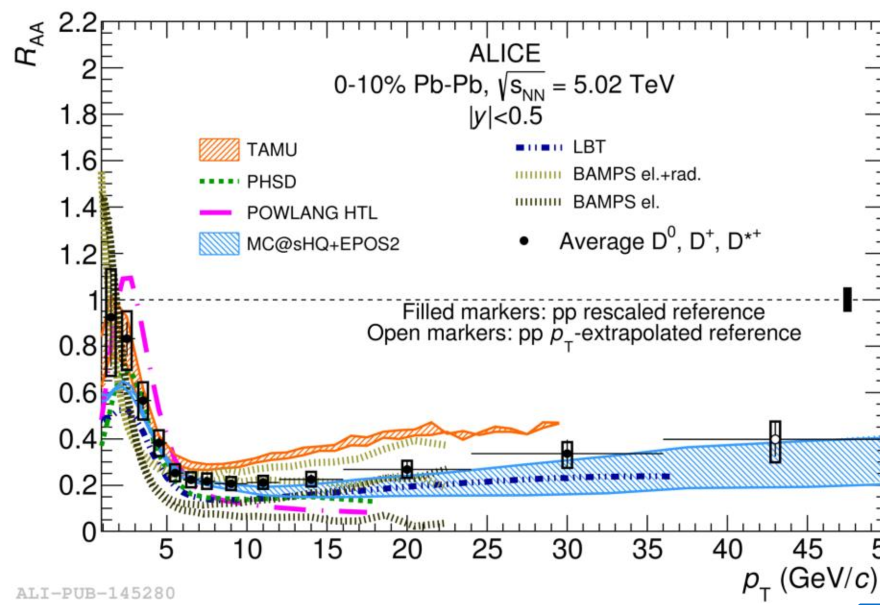
MC@sHQ+EPOS2: PR C89 (2014) 014905
Coll+Rad Eloss, recombination, EPOS-expansion
PHSD: PR C92 (2015) 1, 014910, PR C93 (2016) 3, 034906
Parton-Hadron-String Dynamics transport, coalescence
Xu, Cao, Bass: PR C88 (2013) 044907
Langevin with Coll+Rad Eloss, recombination+hydro
SCETM,G NLO: arXiv: 1610.02043
Soft Collinear Effective Theory, Bjorken expansion
Djorkevic: PR C92 (2015) 024918
Coll+Rad Eloss, recombination, finite-size hydro

POWLANG HTL: EPJ C71 (2011) 1666; JP G38 (2011) 124144
Langevin transport, Coll Eloss, recombination, hydrodynamics
AdS/CFT: JHEP 1411 (2014) 017; PR D91 (2015) 8, 085019;
Ads/CFT correspondence, Langevin Eloss + fluctuations, hydro
BAMPS: JP G 38 (2011) 124152; PL B 717 (2012) 430
Boltzmann transport, Coll. Eloss, expansion
TAMU: PL B735 (2014) 445-450
Transport, Coll. Eloss, resonant scatt. and coalescence+hydro

Y.Xu et al, arXiv:1704.07800 (2017)



Temperature dependence of the spatial diffusion coefficient Ds2πT

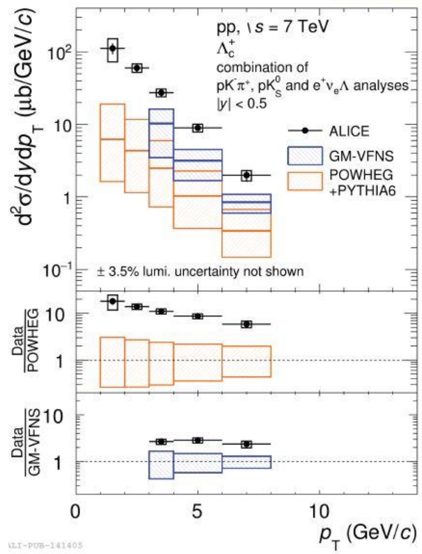


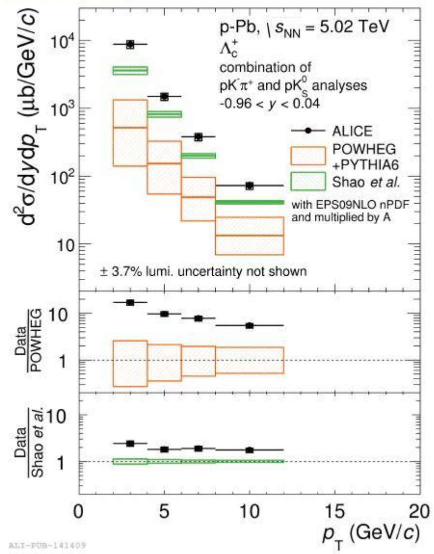
PROSPECT OF MODELS (PREDICTING R_{AA} & v_2)

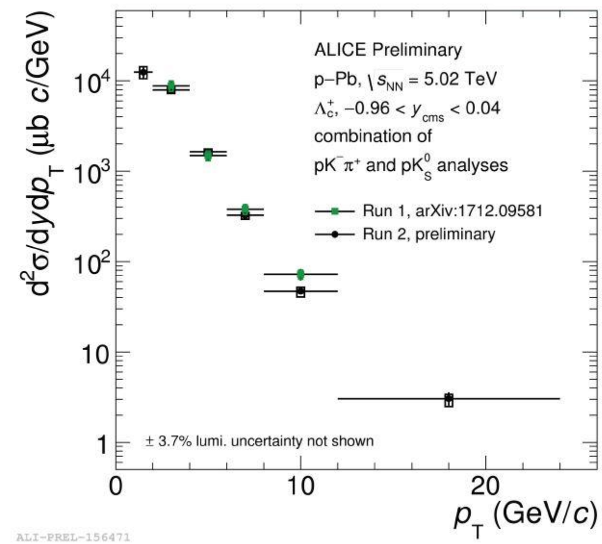
TRANSPORT MODELS	Collisional Energy loss	Radiative Energy loss	Coalescence	Hydro	nPDF
BAMPS + rad. J. Phys. G42 (2015) 115106	✓	✓	✗	✓	✗
LBT arXiv:1703.00822	✓	✓	✓	✓	✓
PHSD PRC 93 (2016) 034906	✓	✓	✓	✓	✓
POWLANG EPJC 75 (2015) 121	✓	✗	✓	✓	✓
TAMU Phys. Lett. B735 (2014) 445	✓	✗	✓	✓	✓
MC@sHQ+EPOS PRC 89 (2014) 014905	✓	✓	✓	✓	✓
pQCD Eloss MODELS	**Collisional Energy loss**	**Radiative Energy loss**	**Coalescence**	**Hydro**	**nPDF**
CUJET3.0 JHEP 02 (2016) 169	✓	✓	✗	✗	✗
Djordevic PRC 92 (2015) 024918	✓	✓	✗	✗	✓
SCET JHEP 03 (2017) 146	✓	✓	✗	✗	✓

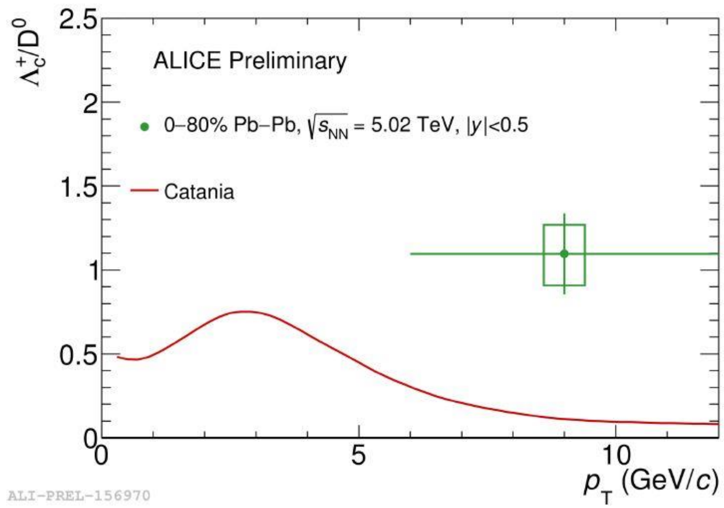
CHARMED BARYONS – ADDITIONAL PLOTS

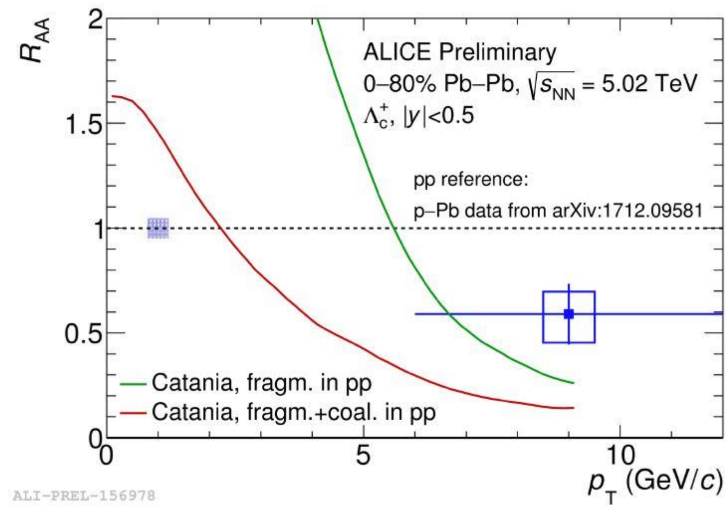
arXiv:1712.09581



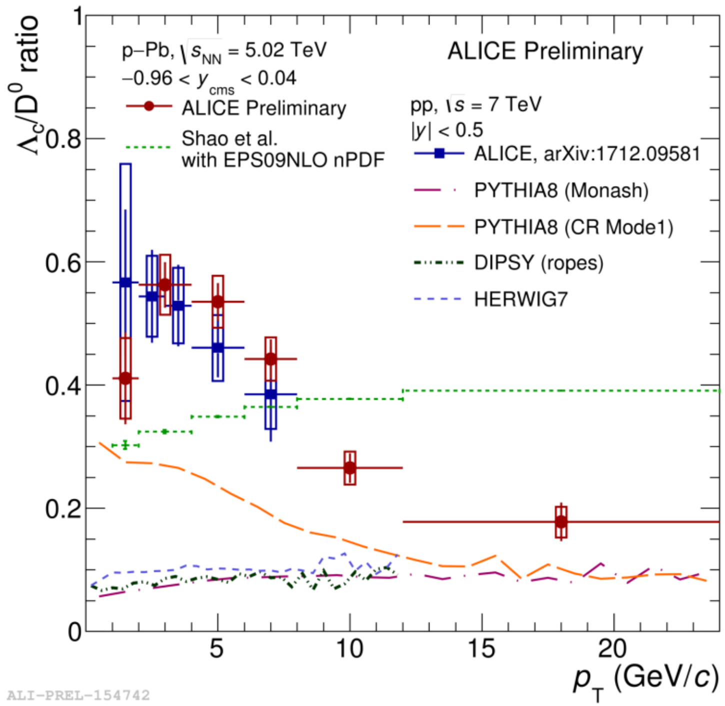


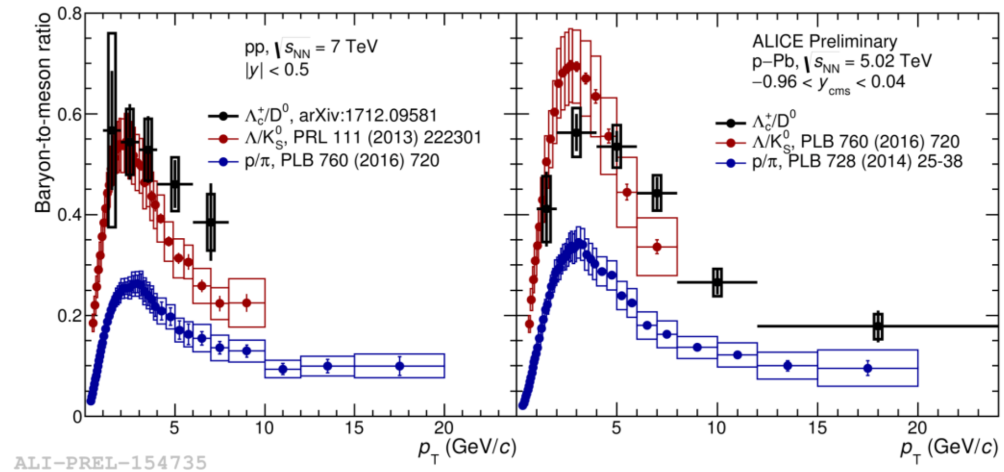






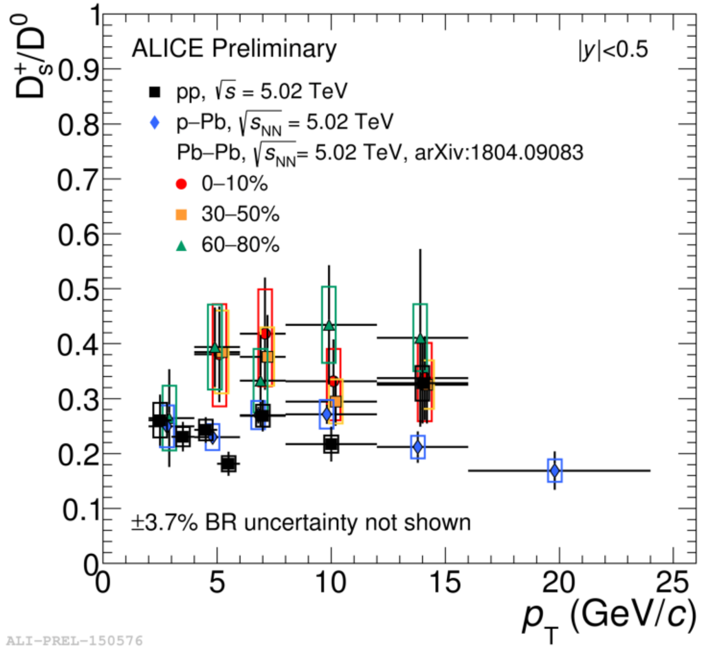
CHARMED BARYONS IN pp AND p-Pb

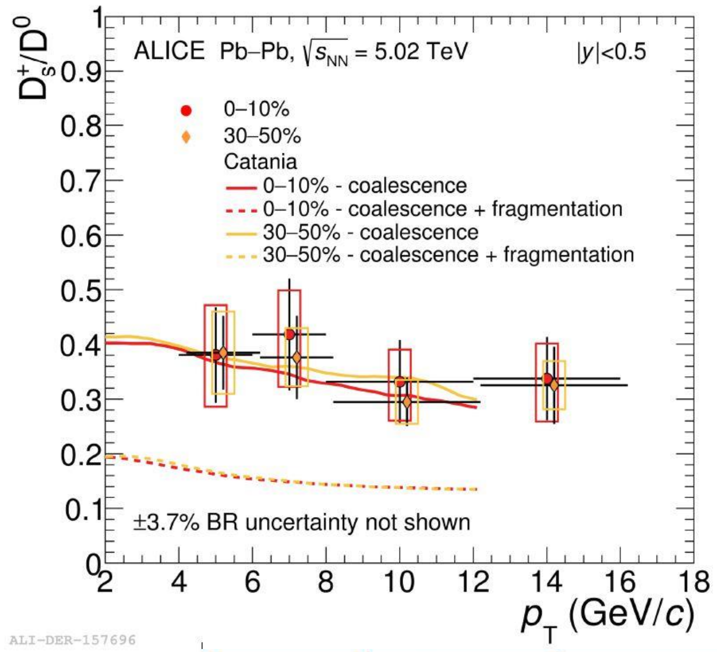




- Λ_c^+/D^0 ratios in pp and p-Pb collisions are compatible within uncertainties
  - p-Pb: decreasing values from p_T > 4 GeV/*c*, as for light flavor baryon-to-meson ratio
- First Ξ_c^0 production measurement at LHC
- Both Λ_c^+/D^0 and Ξ_c^0/D^0 ratios are **higher than MC expectation** (tuned on e^+e^-, e^-p data)
  - ➢ Enhanced color reconnection configuration of PYTHIA 8 is closer to data
  - ➢ Theory bands on Ξ_c^0 due to the uncertainty on the branching ratio $\Xi_c^0 \rightarrow e^+\Xi^-\nu_e$

CHARMED-HADRON RATIOS

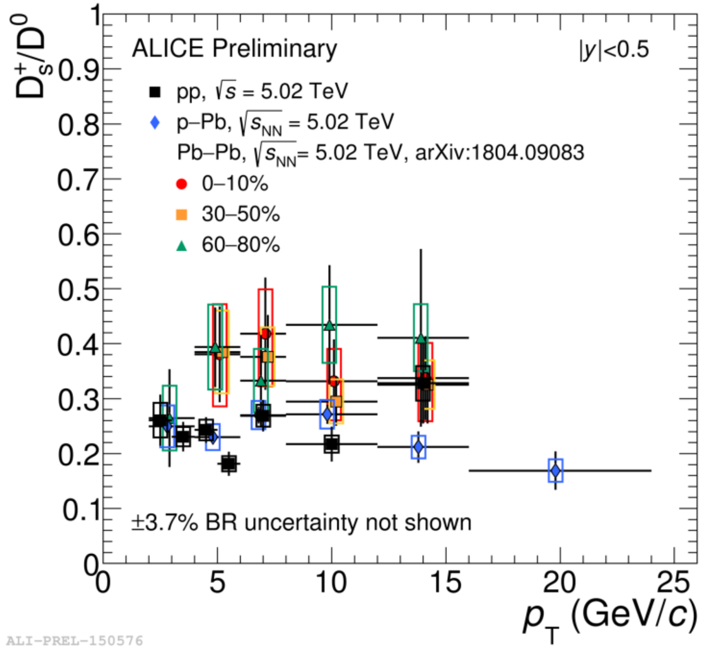


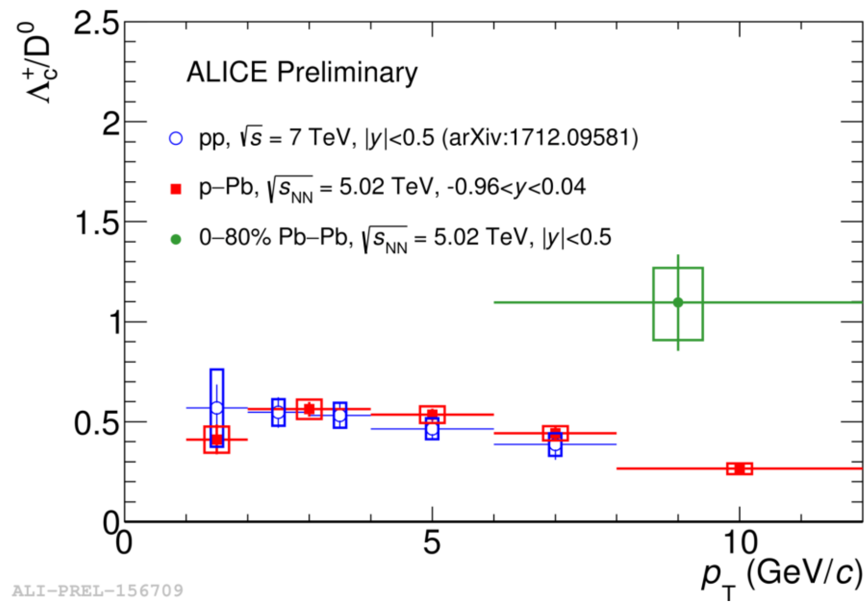


- Hint of **enhanced D_s^+ production** compared to non-strange D mesons in Pb-Pb collisions
  - No evidence of centrality dependence within uncertainties
- In Pb-Pb collisions, **Λ_c^+/D^0 ratio shows hint of enhancement** w.r.t. pp and p-Pb
  - Underestimated by model predictions

Models	System energy	Λ_c^+/D^0
Oh et al.	Au-Au (central) 200 GeV	~0.35 (p_T = 6 GeV/c)
Ghosh et al.	RHIC and LHC	0.15-0.2 (p_T = 9 GeV/c)
Das et al.	Pb-Pb (0-20%) 5.5 TeV	~0.2 (p_T = 9 GeV/c)
Plumari et al.	Pb-Pb (0-20%) 2.76 TeV	0.1-0.2 (p_T = 8 GeV/c)

CHARM HADRON RATIOS





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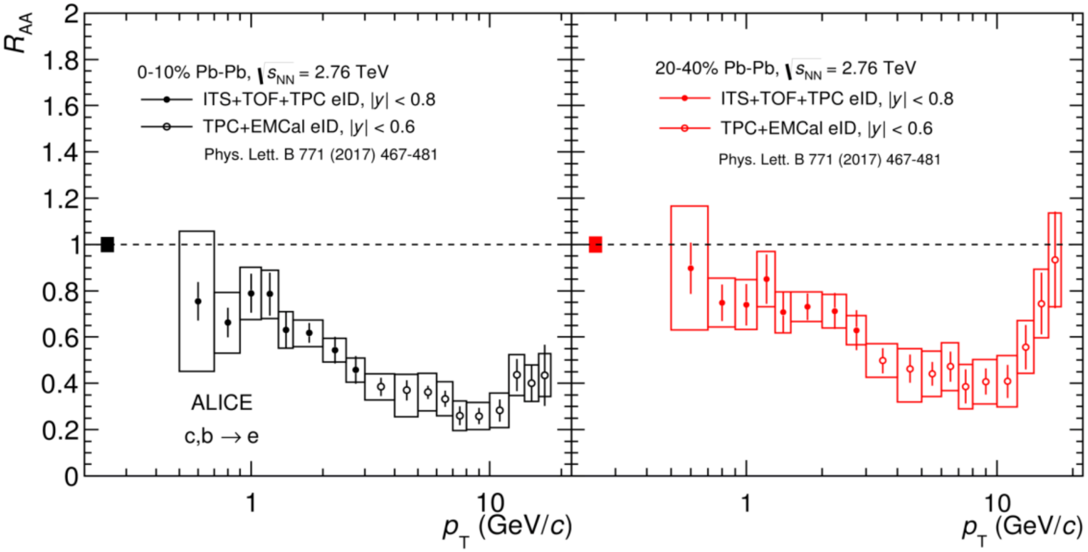
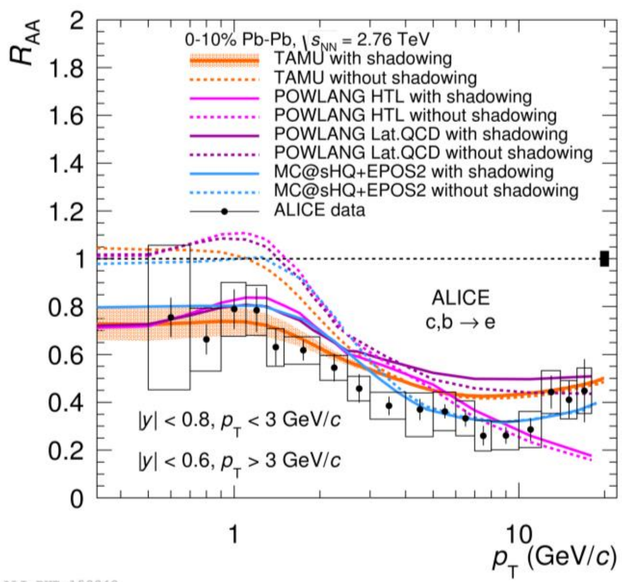
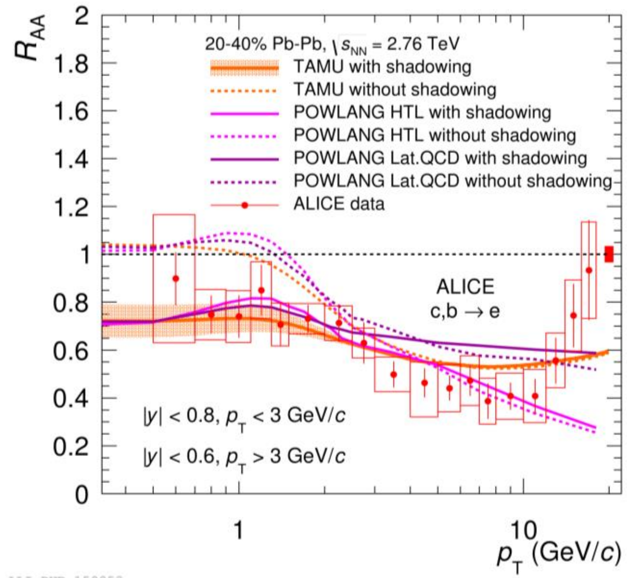
HF ELECTRON R_{AA} AT LOW p_T

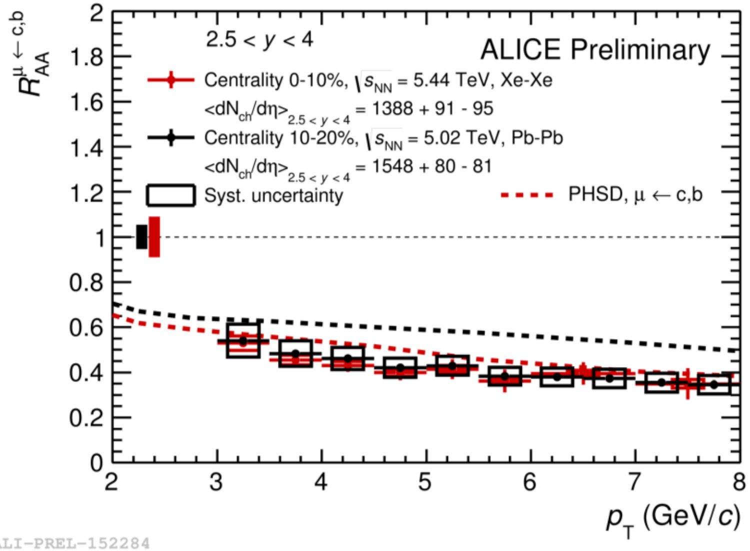


- Low-p_T data help to better constrain the total HF production cross section (less extrapolation needed) and to test initial-state effects
- Suppression better described by models including shadowing via nPDF (EPS09)

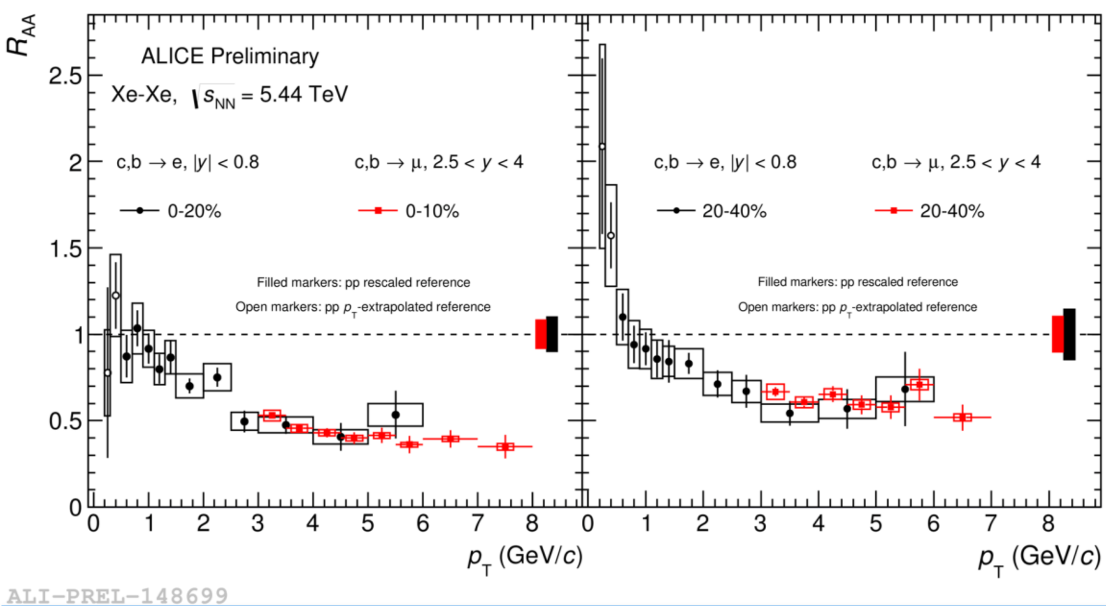




HF LEPTONS IN Xe-Xe

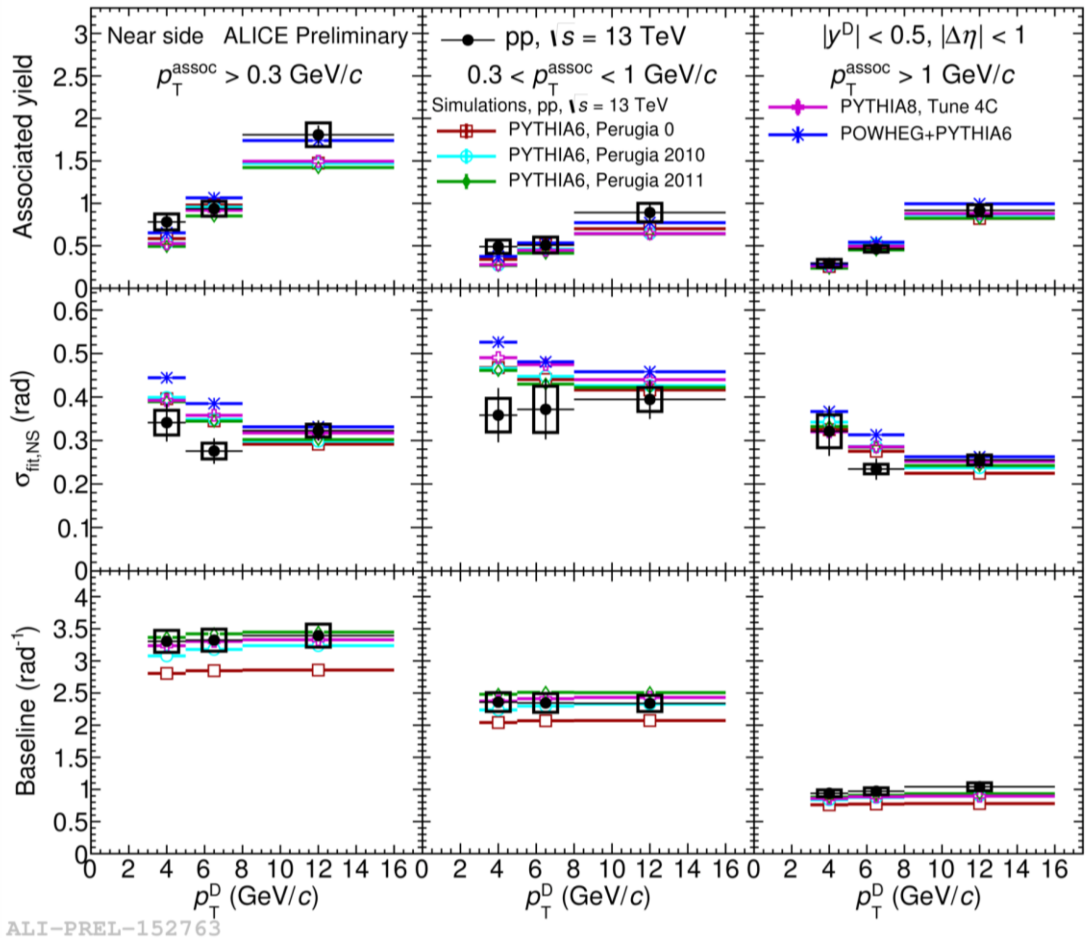


- Similar R_{AA} is observed in Xe-Xe and Pb-Pb for similar <dN/dη>
- Comparison of Pb-Pb and Xe-Xe collisions at different N_{part} or may add sensitivity to probe the path-length dependence of energy loss



- A similar suppression is observed for HF decay electrons at mid-rapidity and HF decay muons from at forward rapidity

D-h CORRELATIONS: pp VS MODELS



Comparison of near-side peak yield and width from data and Monte Carlo predictions

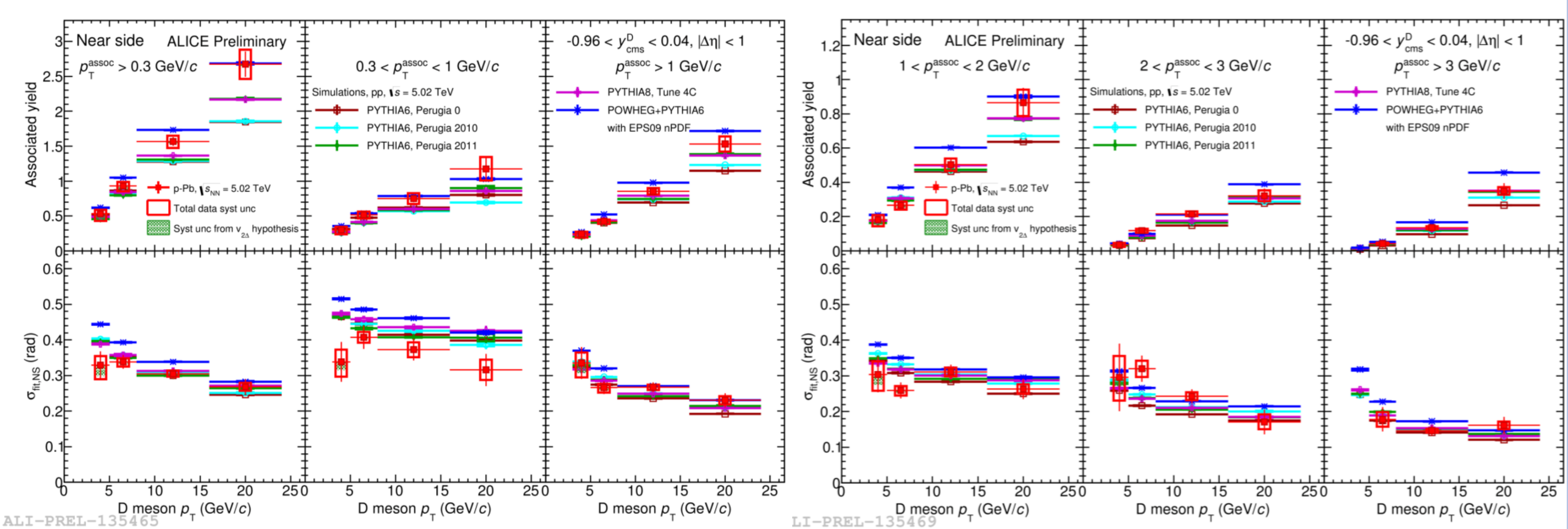
p_T(D) ranges
3-5, 5-8, 8-16 GeV/c

p_T(assoc) ranges
>0.3, 0.3-1, >1 GeV/c

- New results at 13 TeV confirm good description of data features by PYTHIA6,8, POWHEG predictions
  - Good observable to study the charm jet fragmentation modification in the QGP
- Analysis of the away-side ongoing with a x4 larger data sample

D-h CORRELATIONS: p-Pb VS MODELS

Comparison of near-side and away-side peak yields and widths to Monte Carlo predictions



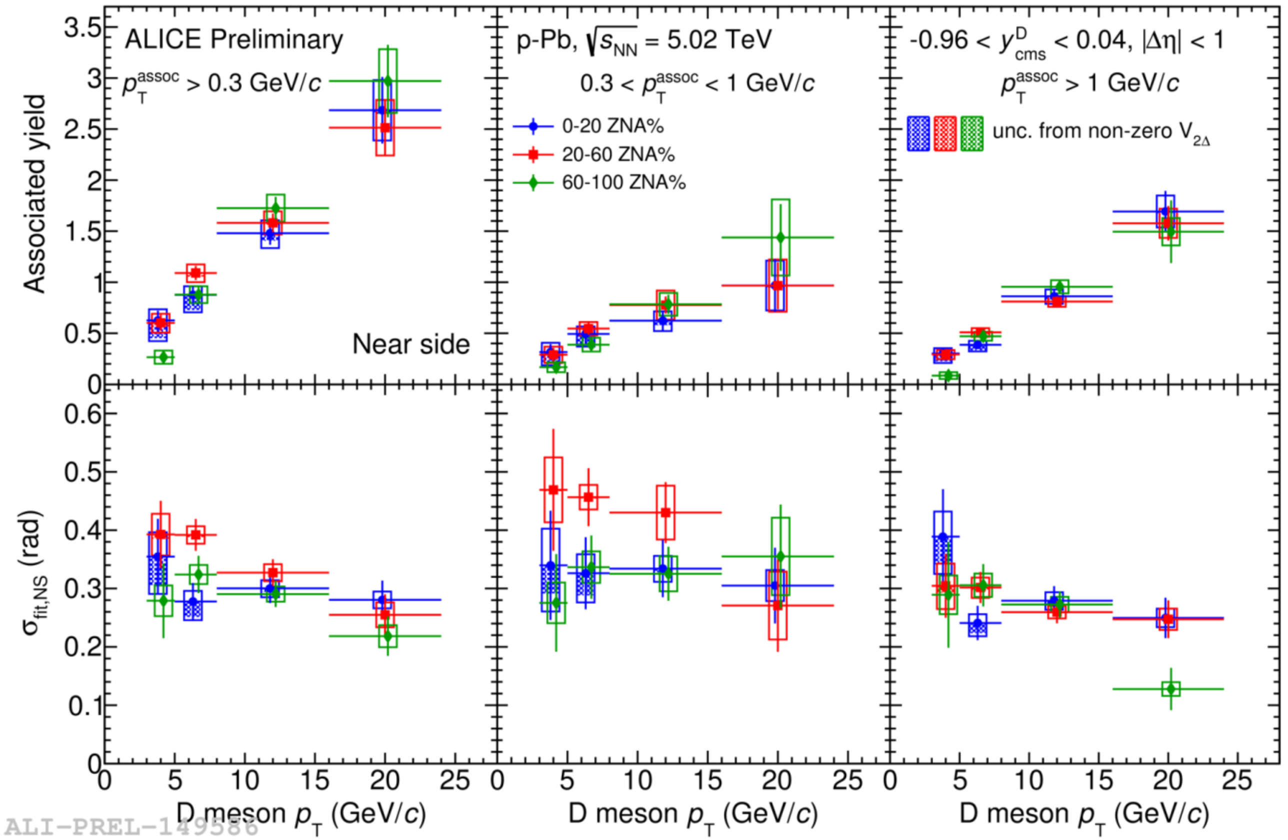
Near-side

- Best description of away-side yields given by POWHEG. Some tension with the other models at high p_T(D). POWHEG seems anyway to overpredict the peak widths.

Away-side

- Reversed hierarchy for predictions of yield and width w.r.t near-side peak. Observables sensitive to modelling production processes

D-h CORRELATIONS: p-Pb VS CENTRALITY



Comparison of near-side peak properties versus event centrality

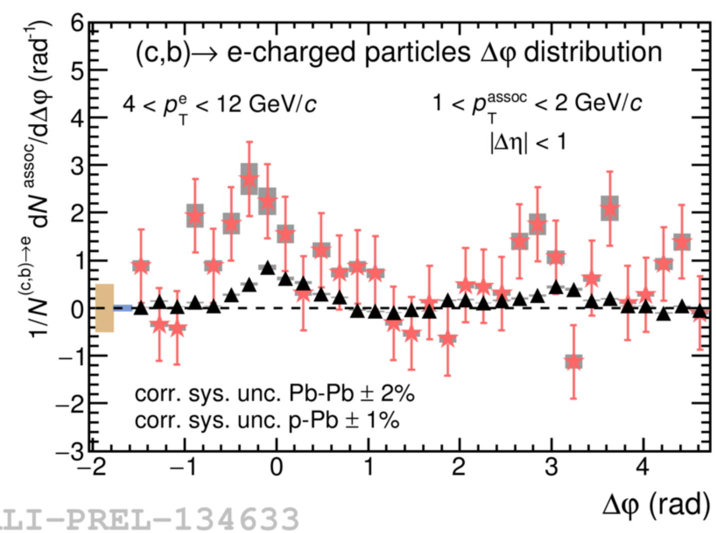
***p*$_T$(D) ranges**
3-5, 5-8, 8-16, 24 GeV/c

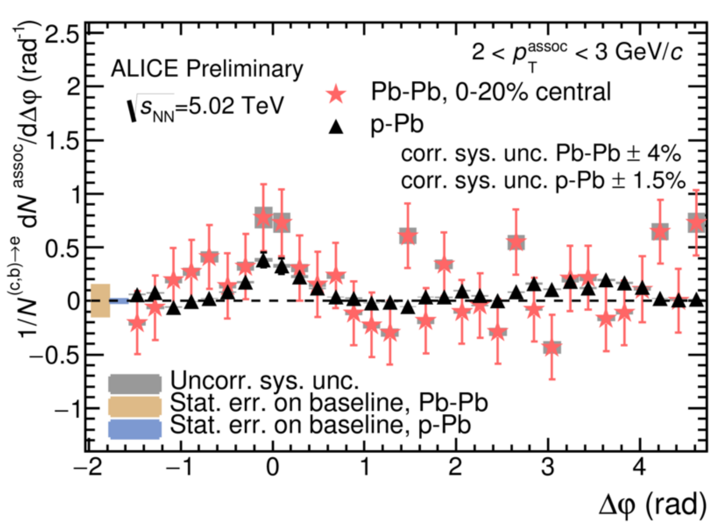
***p*$_T$(assoc) ranges**
>0.3, 0.3-1, >1 GeV/c

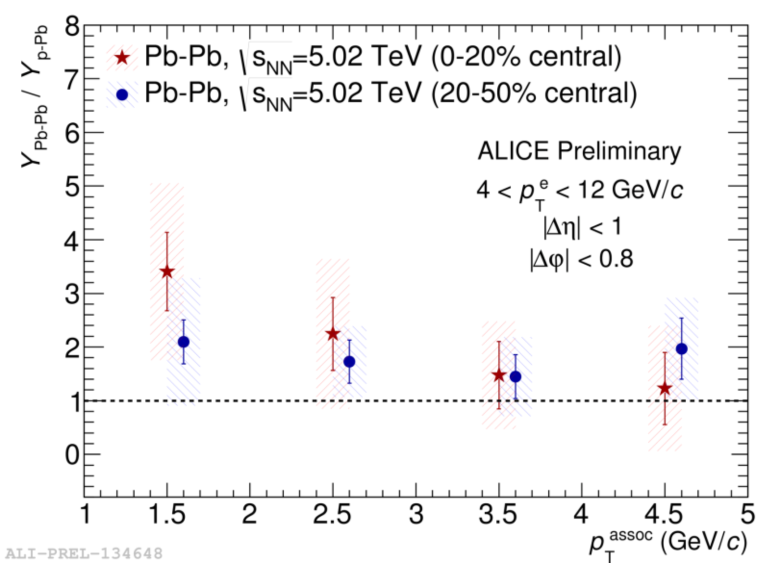
Centrality classes
0-20%, 20-60%, 60-100% (ZNA estimator)

- Charm jet fragmentation **doesn't show modifications** as a function of centrality above the current uncertainties
  - Possible flow in central p-Pb events taken into account as systematic uncertainty
- No sensitivity to extract v_2 via HM – LM subtraction with available statistics

HF ELECTRON CORRELATIONS IN Pb-Pb



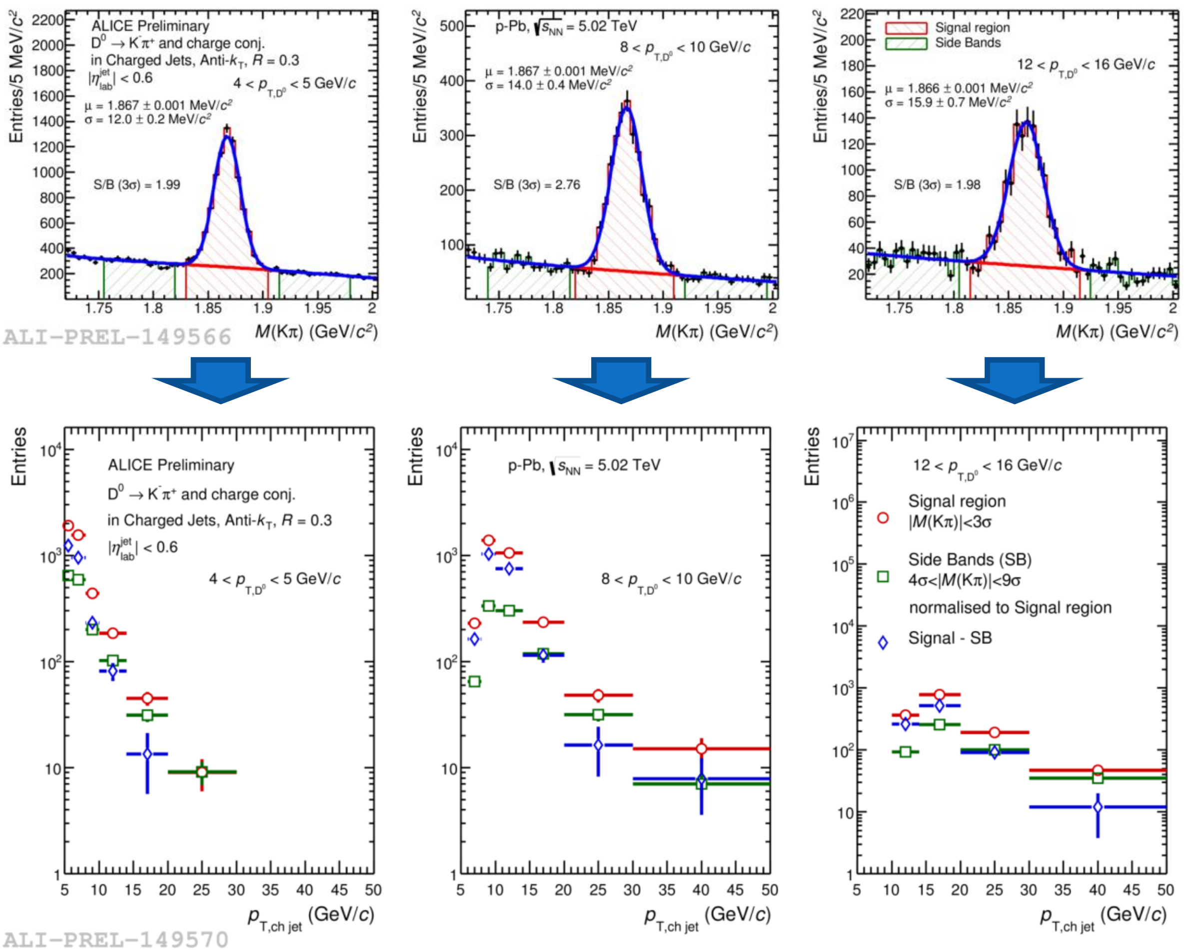




- Near-side yields from integration of correlation distribution in $|\Delta\varphi|<1$
- At low p_{T}^{assoc}, **hints of a hierarchy appear** between central Pb-Pb, peripheral Pb-Pb and p-Pb, despite large uncertainties
- Similar feature observed in h-h (see backup), interesting to have predictions from models

D-JETS: ANALYSIS STRATEGY

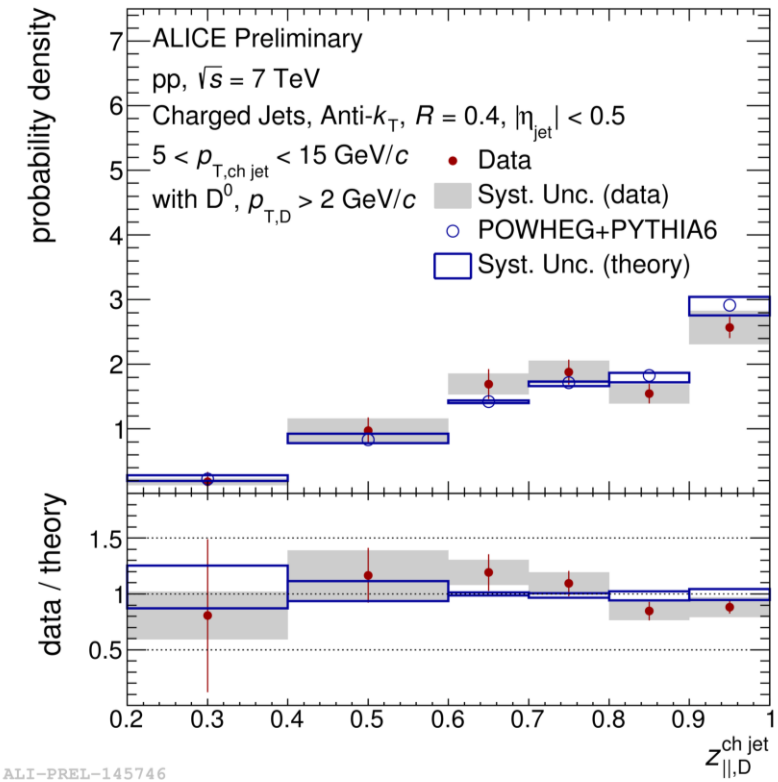
- Charged jets tagged by the presence of a reconstructed D-meson candidate inside the cone
  - Jet finder algorithm (Fastjet, anti-k_T) run for each D-meson candidate, after substituting the daughter tracks with the D-meson particle



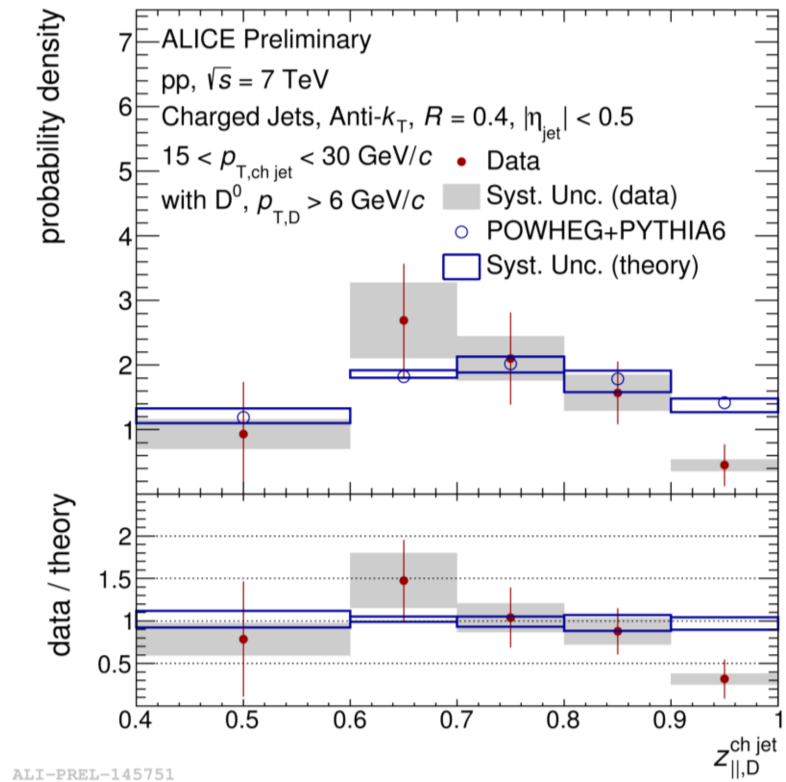
- Invariant mass study to extract D-jet raw yield
  - Background spectrum from the sidebands
- Spectrum corrected for D-jet efficiency and for beauty feed-down, exploiting folded POWHEG+PYTHIA predictions
- Corrected D-jet spectrum unfolded for detector effects and background fluctuations (in p-Pb and Pb-Pb)

D-TAGGED JET $z_{||,D}$ IN pp COLLISIONS

5 < p_T(jet) < 15 GeV/c



15 < p_T(jet) < 30 GeV/c



$$z_{||} = \frac{\vec{p}_{\text{ch jet}} \cdot \vec{p}_{\text{D}}}{\vec{p}_{\text{ch jet}} \cdot \vec{p}_{\text{ch jet}}}$$

- **Charged-jet momentum fraction** carried by D^0 meson compared to PYTHIA+POWHEG predictions, for two p_T(jet) ranges in pp collisions
- Overall, good description of data. Hint of softer fragmentation at high p_T in data w.r.t. prediction? Uncertainties are anyway still too large to conclude