Open heavy-flavours: experimental view

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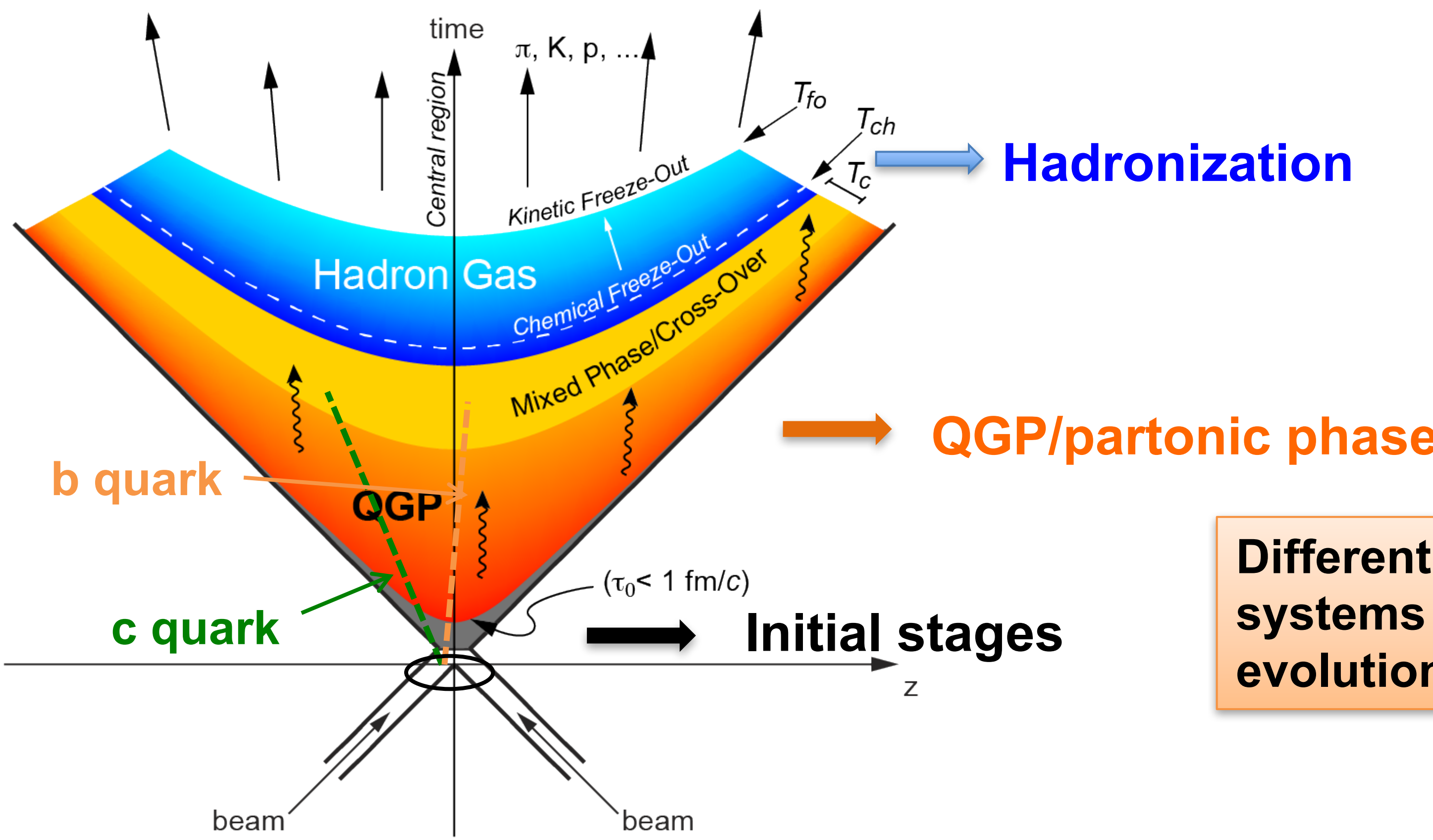
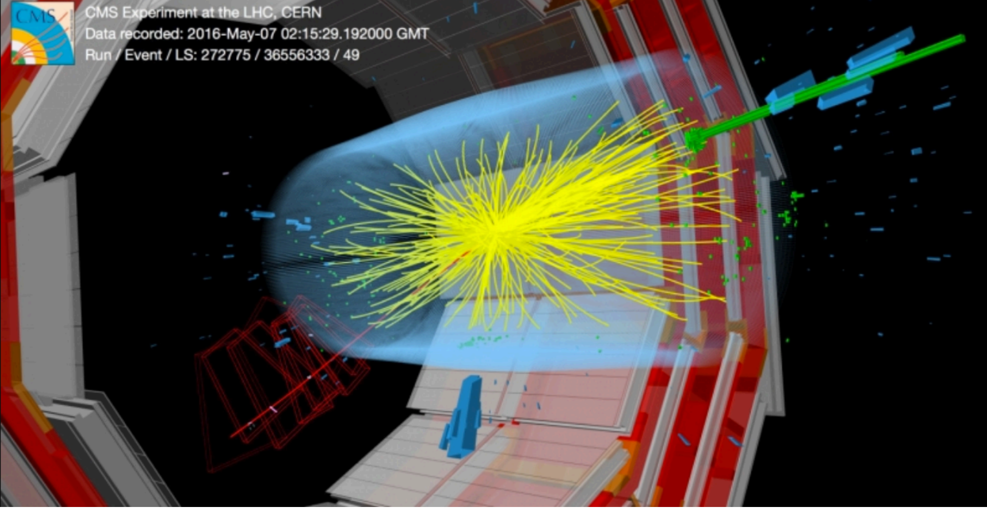
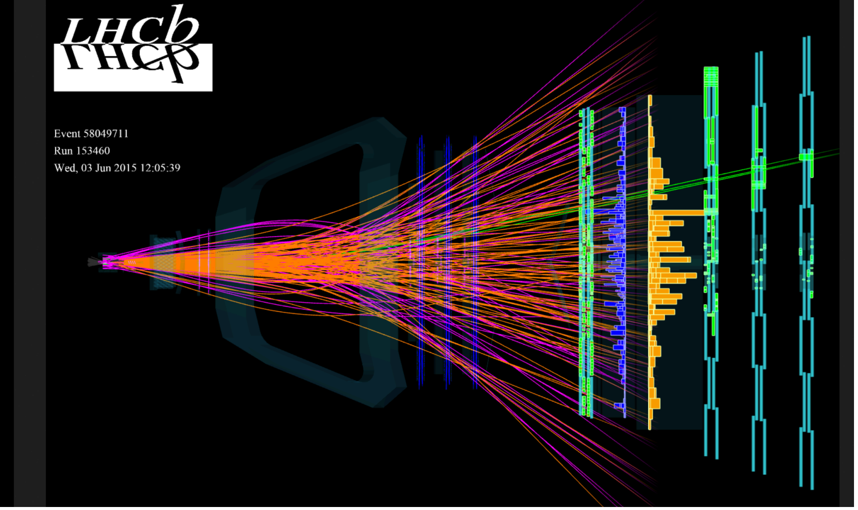
Heavy Flavours: unique probes

- Produced in initial high-Q^2 processes → calculable with pQCD
- Large mass → short formation time → experience medium evolution
  $1/2m_c$ (~0.07 fm/c) < QGP formation time (~0.1-1fm/c) << QGP life time (10 fm/c)
- Expected small rate of thermal production in the QGP ($m_{c,b} >> T$)
  – and small annihilation rate



Different collision systems probe different evolution stages !



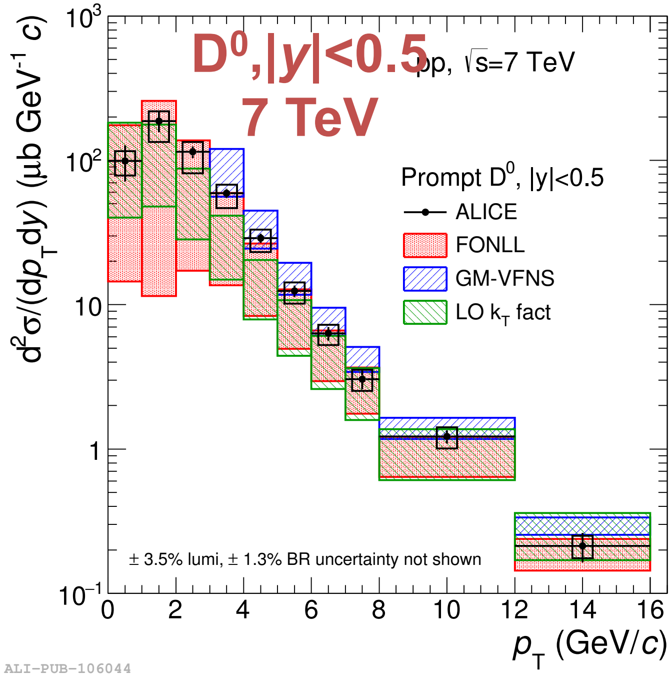


pp collisions: the benchmark system

- test for **pQCD**
- **reference** for p-A and AA

- study heavy-flavour (HF) production **processes and hadronization**

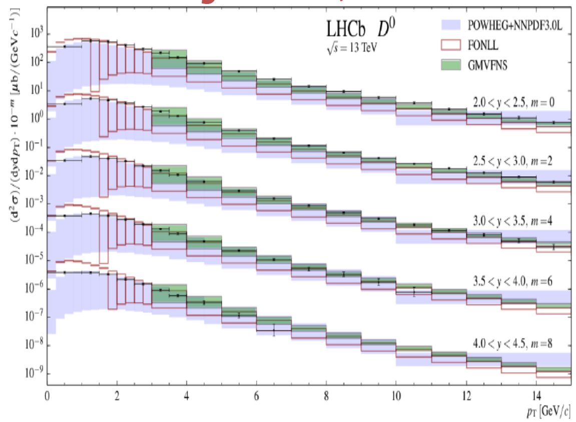
Charm and beauty in pp collisions

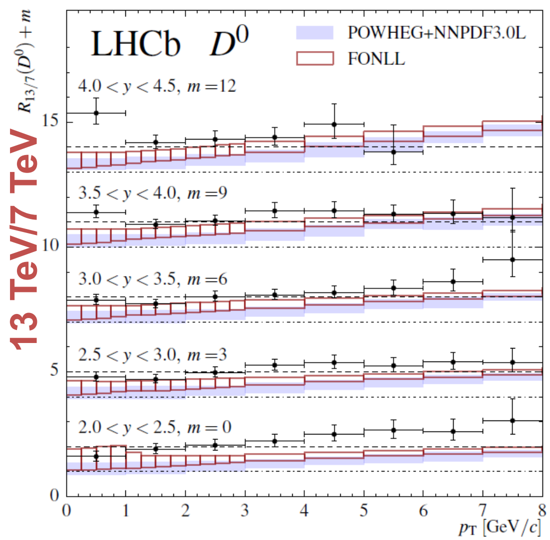


ALICE, Phys. Rev. C 94, 054908 (2016)
JHEP 1201 (2012) 128
FONLL: JHEP, 1210 (2012) 137

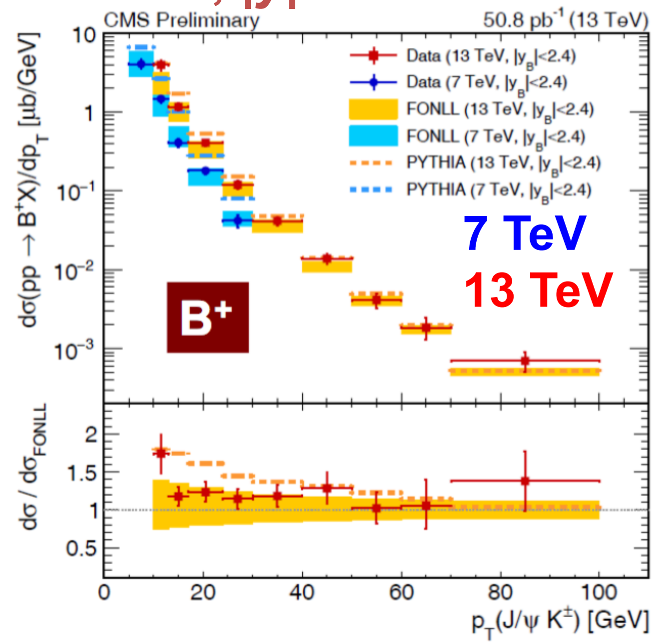
GM-VFNS: Eur.Phys.J., C72(2012)2082
Nucl. Phys. B, 872(2013) 253
LO k_T fact: Phys.Rev., D87 (2013) 094022

D^0 2<*y*<4.5, 13 TeV





B^+, |*y*|<2.4

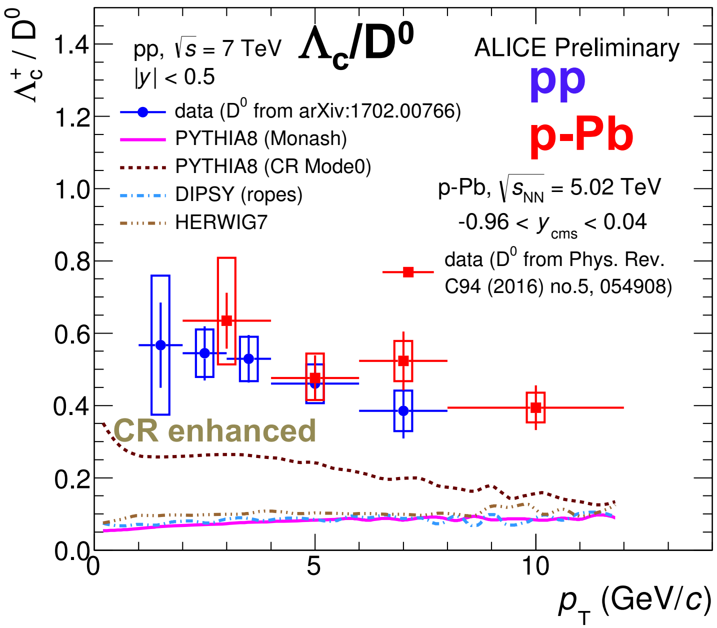


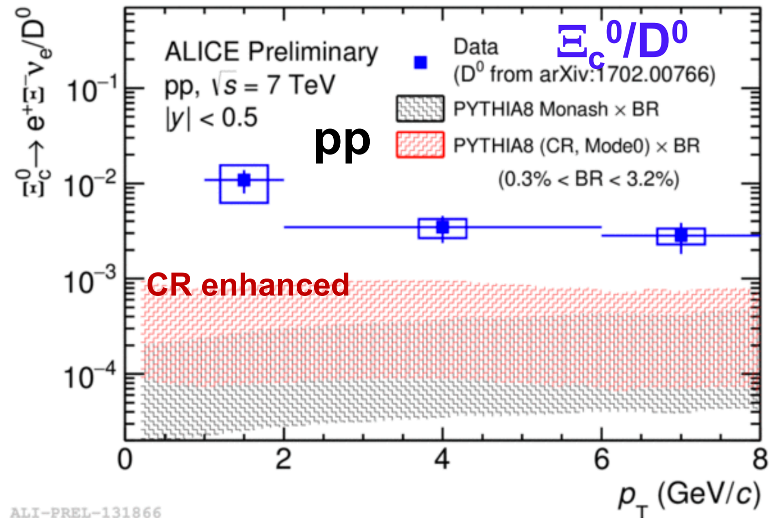
CMS, PRL 106 (2011) 112001
CMS-PAS-BPH-15-004

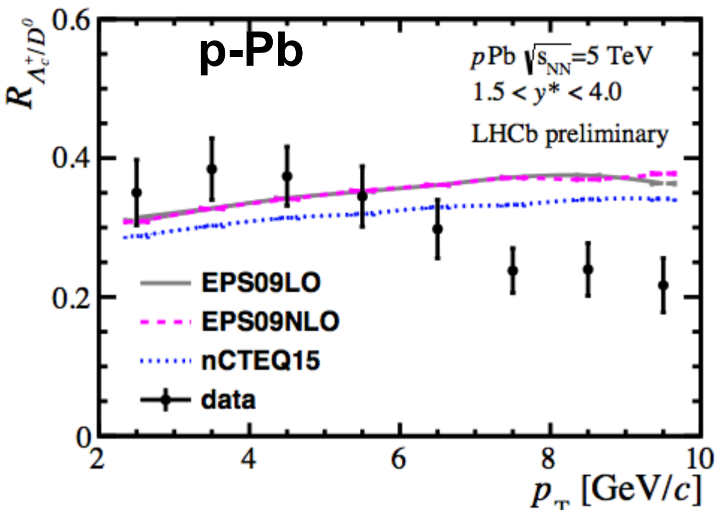
LHCb, JHEP1603 (2016) 159

Cross sections at LHC energies well **described by pQCD predictions**.
Charm cross-section on the upper side of the FONLL uncertainty band

Λ_c/D^0 and Ξ_c^0/D^0 ratios







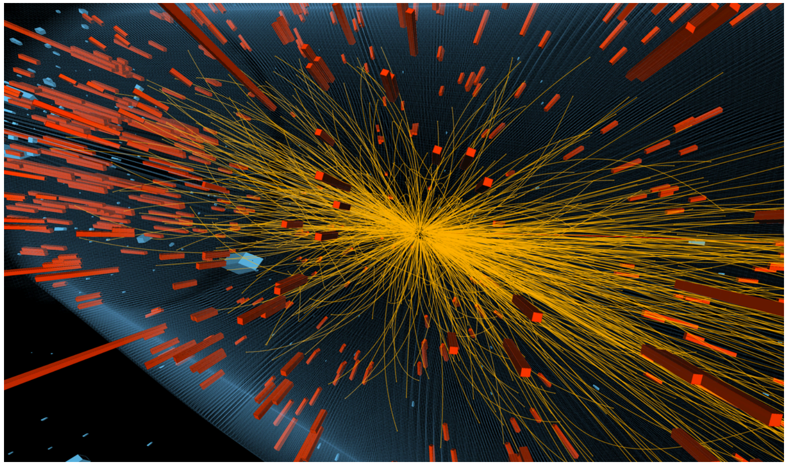
LHCb, Phys. Rev. B 871 (2013)1

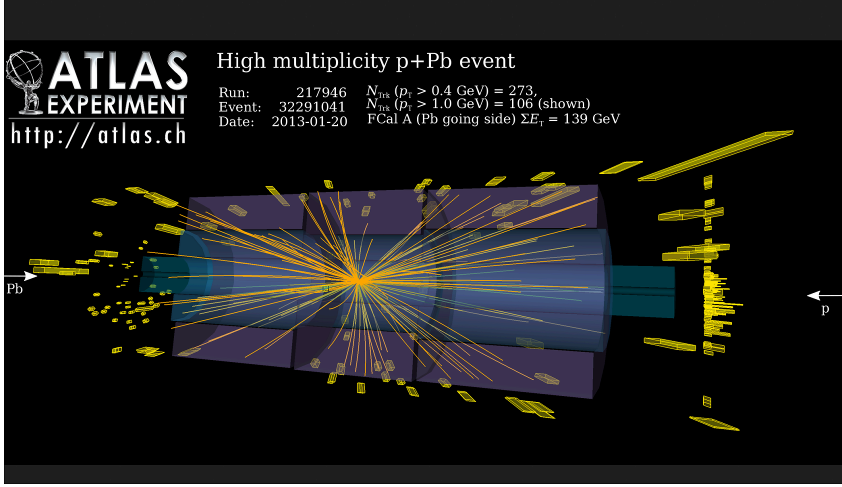
Λ_c^0 /D^0 at mid-rapidity compatible in pp and p-Pb

- higher than theoretical calculations (PYTHIA8 with enhanced color reconnection closer to data)
- slightly higher wrt Λ_c^0 /D^0 in p-Pb at forward rapidity (LHCb)

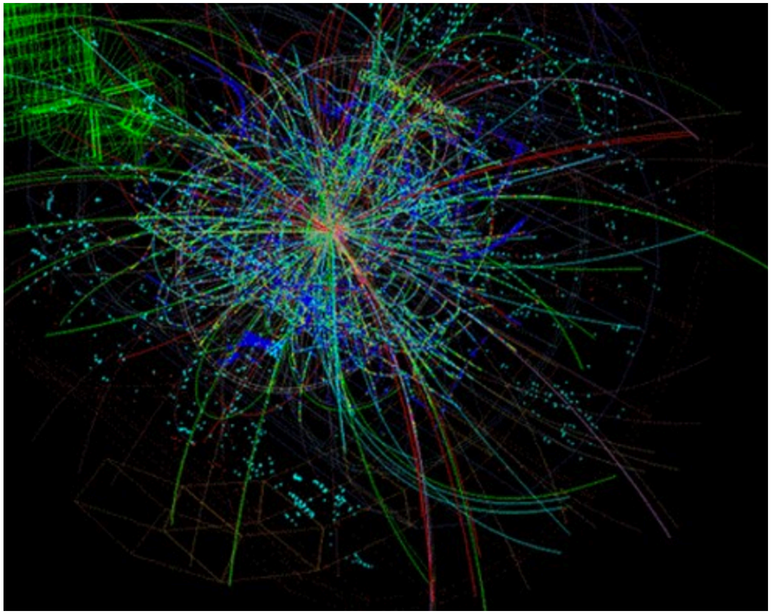
Ξ_c^0 /D^0 at mid-rapidity: higher than theoretical calculations

→ Crucial to constrain **models of charm hadronization**: current lack of knowledge about fragmentation of charm into baryons



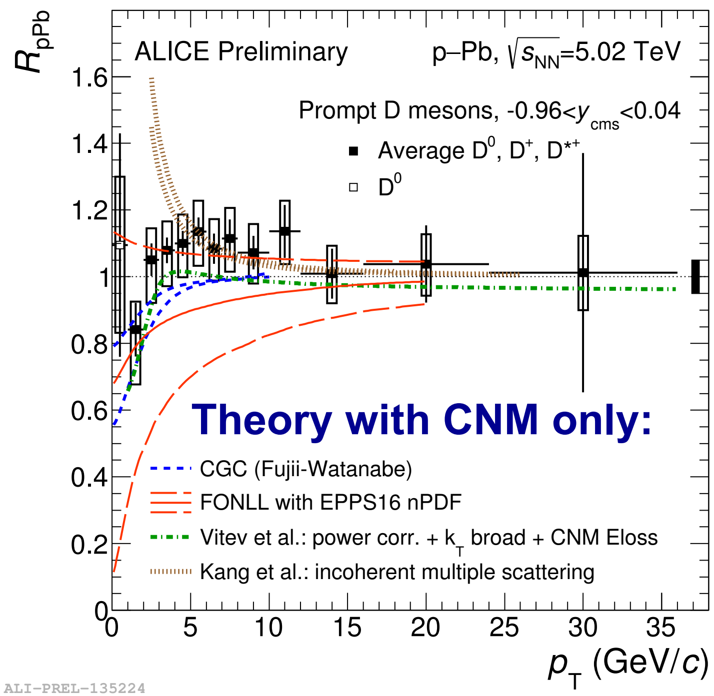


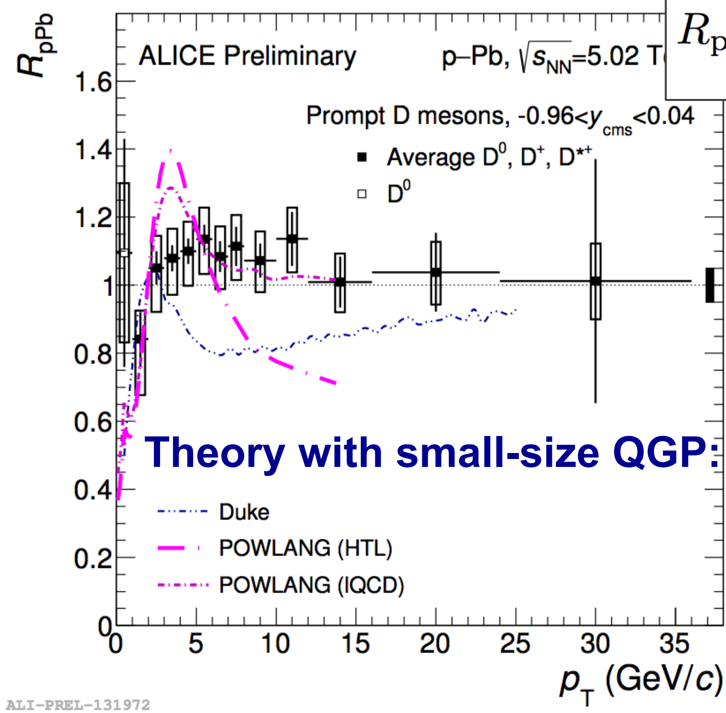
p-A collisions: the control experiment



- reference for **cold nuclear matter (CNM) effects**
  - nPDF, saturation and more effects
  - (k_T broadening, energy loss)
- role of collision geometry/multiplicity density
- **collective effects** in small systems?

HF in pA: control experiment





$$R_{pPb} = \frac{(d\sigma/dp_T)_{pPb}}{A \times (d\sigma/dp_T)_{pp}}$$

H. Fuji et al., Nucl Phys A920 (2013) 78

M. Mangano et al., Nucl. Phys. B373 (1992) 295

K. J. Eskola et al., JHEP 0904 (2009) 065, arXiv:1612.0574

Vitev et al., Phys. Rev. C 80 (2009) 05490

Z.-B. Kang et al., PLB 740 (2015)23

Y. Xu et al., arXiv:1510.07520

A. Beraudo et al., JHEP 03 (2016) 123

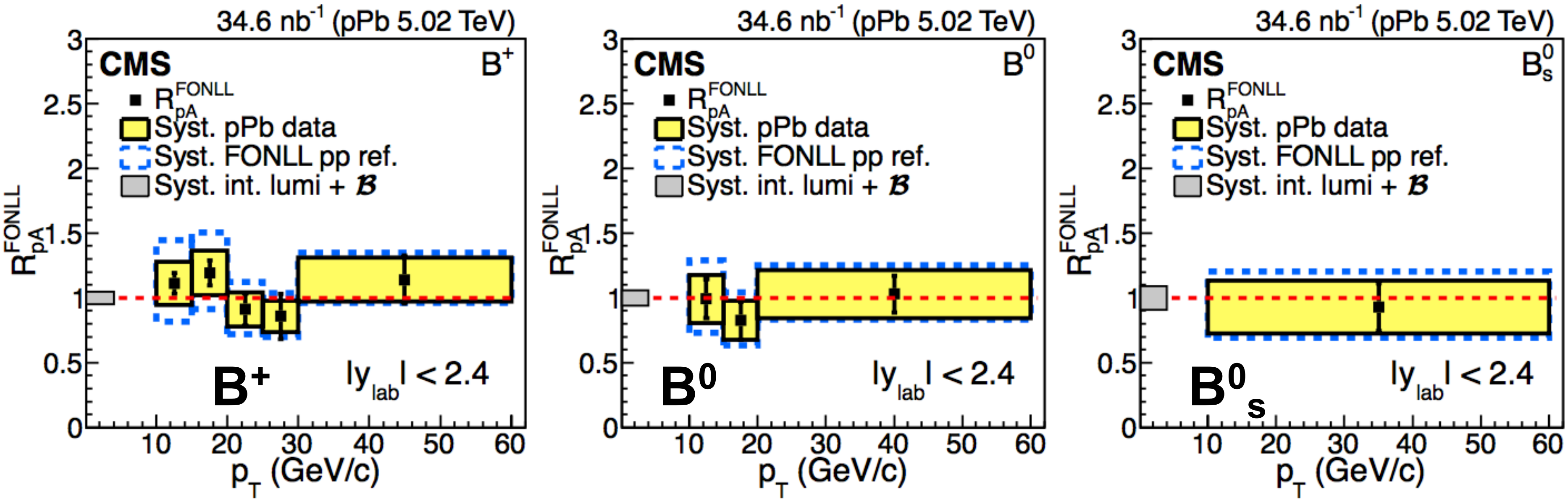
R_{pPb}~1 for D mesons in p-Pb collisions ALICE-PUBLIC 2017-008

Models with:

- **Cold Nuclear Matter** effects describe data within uncertainties
- **Incoherent scatterings** describes data for p_T> 5 GeV/c
- **Small-size QGP** can describe data at low-intermediate p_T. Suppression larger than 10% in 5<p_T<12 GeV/c disfavored

Difference between models at low p_T → more precise pp reference needed

HF in pA: control experiment

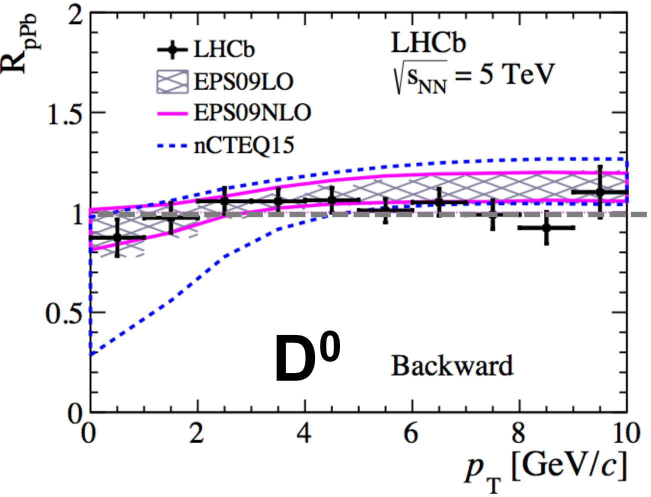


CMS, PRL 116 (2016) 032301

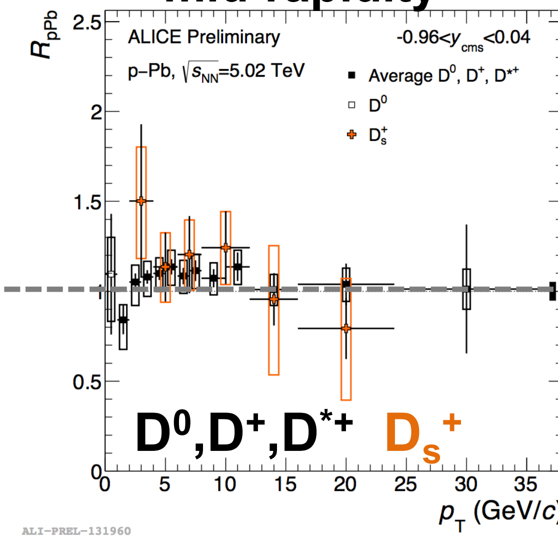
R_{pPb}~1 for B mesons in p-Pb collisions

HF in pA: different rapidities at LHC

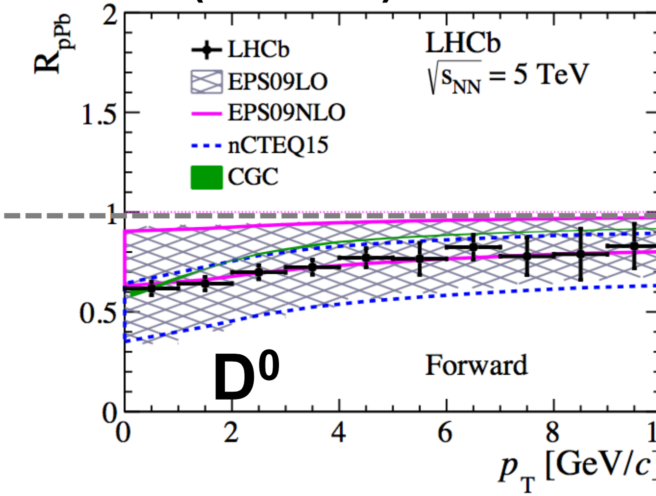
Pb-going (backward)



mid-rapidity



p-going (forward)



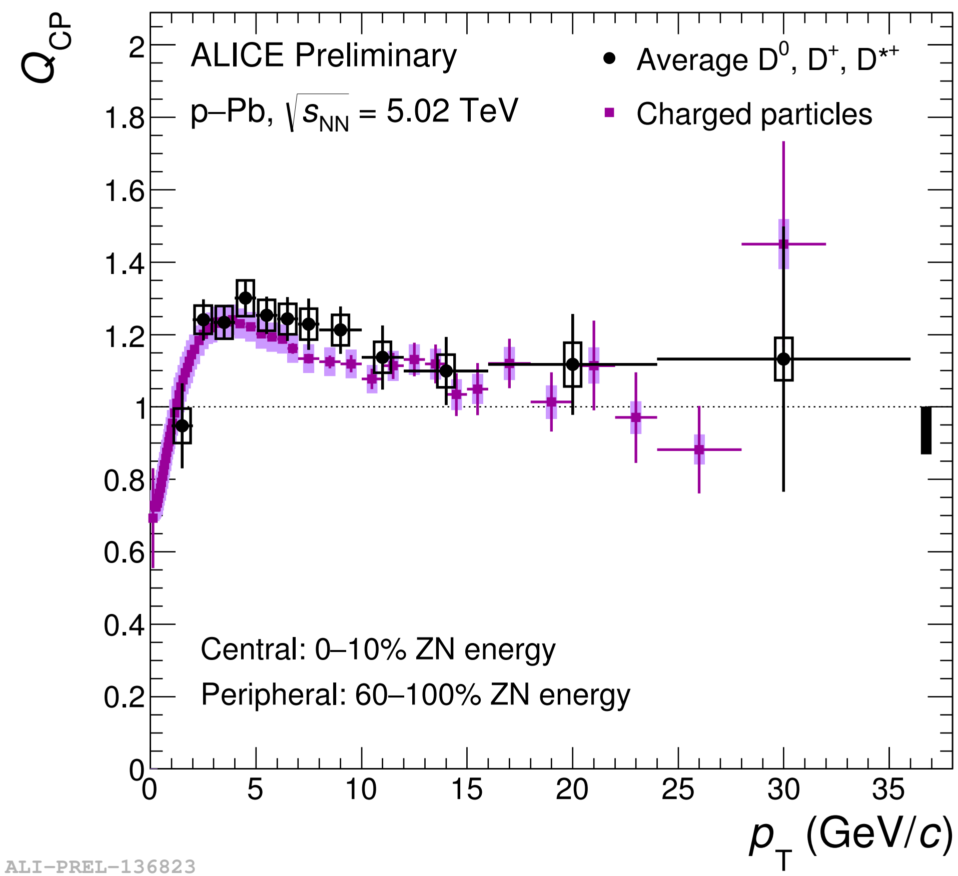
LHCb, arXiv: 1707.02750

ALICE-PUBLIC 2017-008

Different x regimes explored in different rapidity ranges with HF probes

Data described within uncertainties by the models with nPDF and other Cold Nuclear Matter effects

D-meson production in different p-Pb centrality classes



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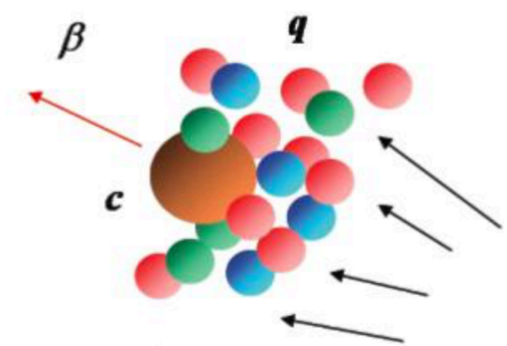
Ratio **central/peripheral Q_{CP}** (higher precision)

Q_{pPb} in for D mesons and **charged particles** agree within uncertainties

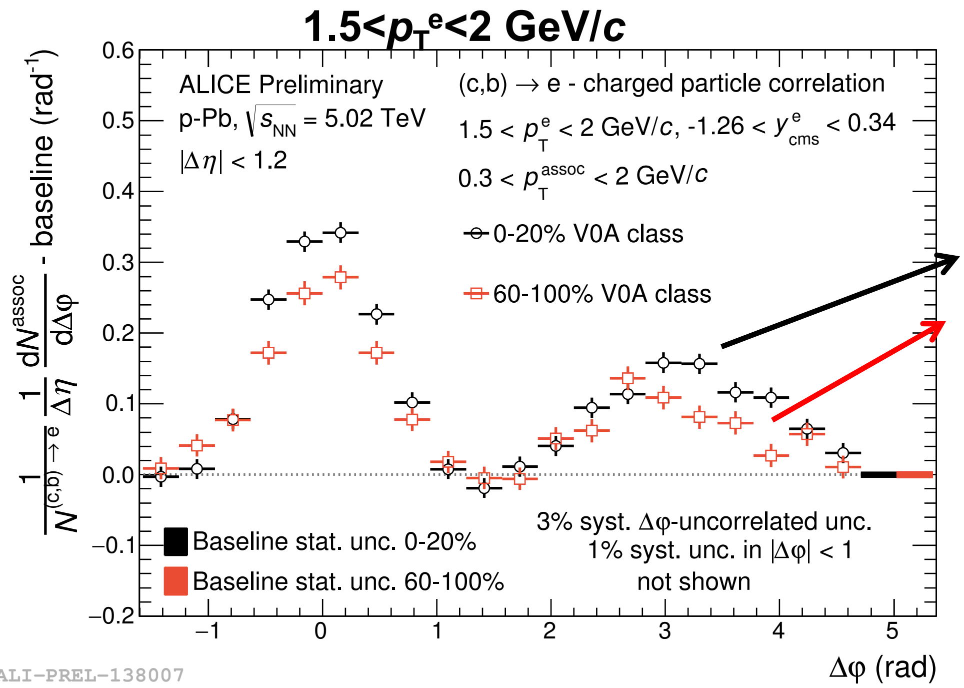
Q_{CP}>1 in 3-8 GeV/c with ~1.5 σ

$p=m\beta\gamma$



Initial- and/or final-state effects?
Collective radial flow affecting HF particles in p-Pb?

Collectivity in pPb collisions?



HFe-h correlations

p-Pb collisions in two multiplicity ranges:

0-20% (high multiplicity)

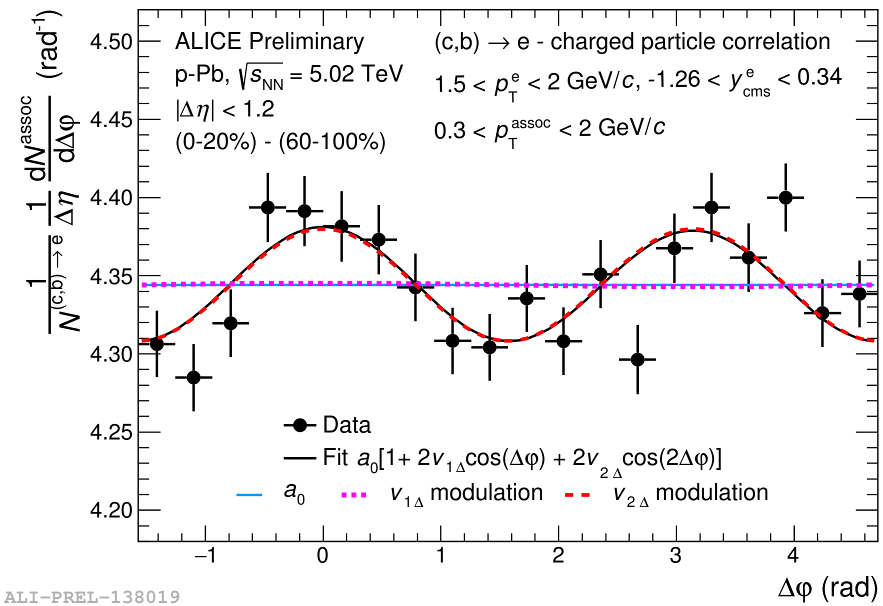
60-100% (low multiplicity)

Jet contribution reduced by subtracting low-multiplicity events

(0-20%) – (60-100%)

Collectivity in pPb collisions?

1.5<p_T^e<2 GeV/*c*

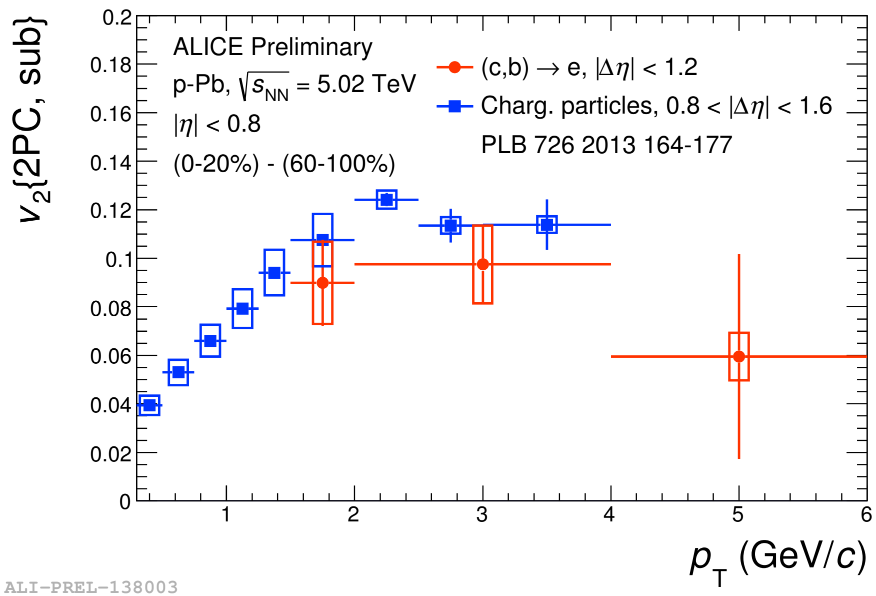


HFe-h correlations

(0-20%) – (60-100%)

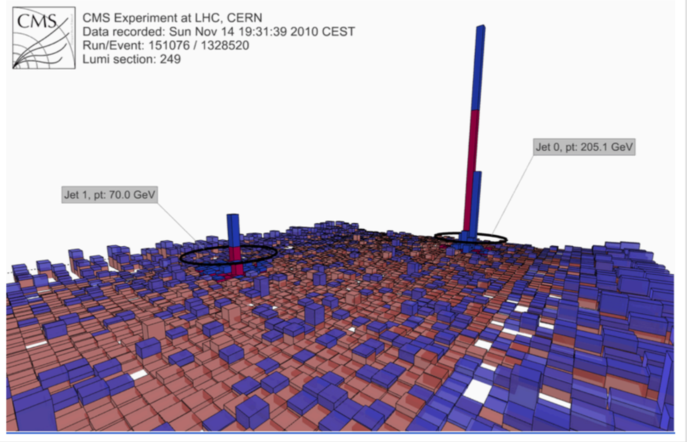
$$C_{0-20}(\Delta\varphi) - C_{60-100}(\Delta\varphi) =$$
$$a_0\,(1+2v_{1\Delta}\cos(\Delta\varphi)+2v_{2\Delta}\cos(2\Delta\varphi))$$

Positive v_2 of electrons from HF, similar to charged particles within uncertainties.

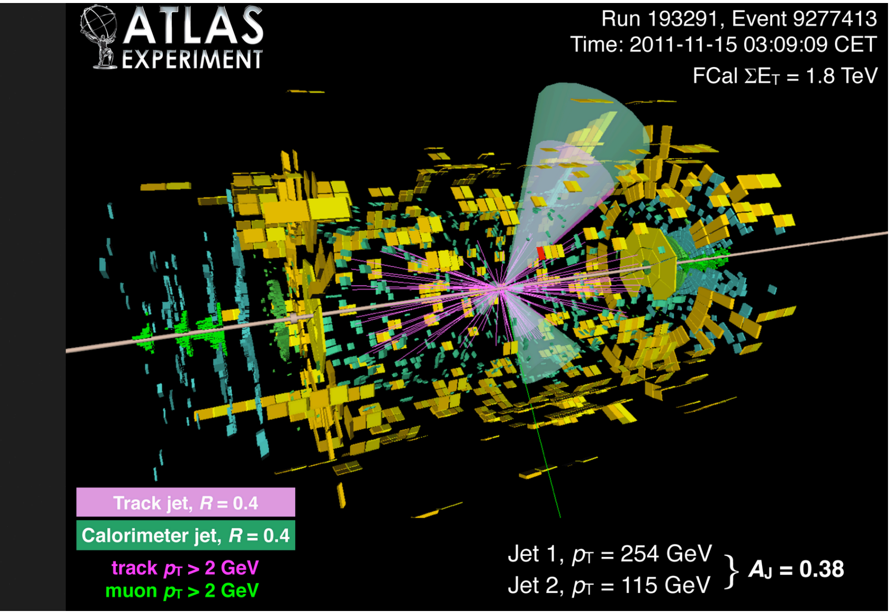


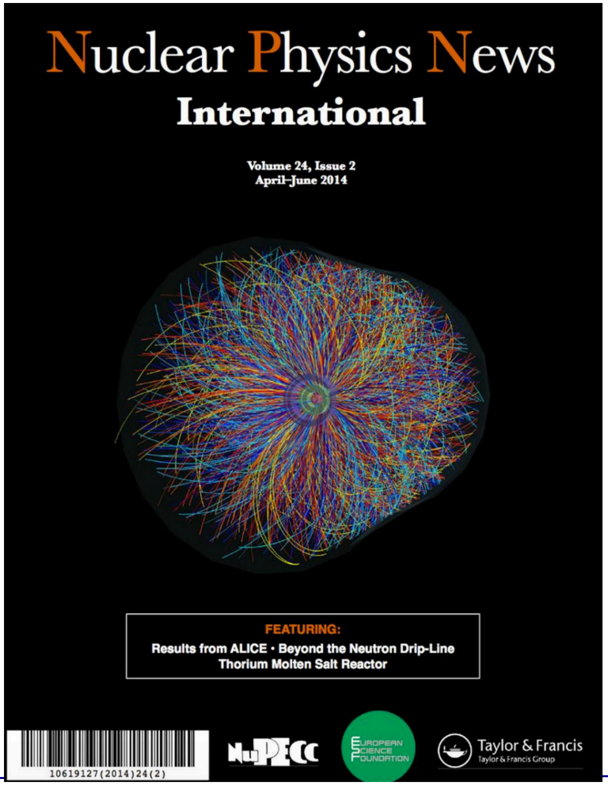
Initial-state effects, collectivity ?

B. Arbuzov et al, Eur.Phys.J. C71 (2011) 1730
K. Dusling and R. Venugopalan, arXiv:1302.7018.
S. Alderweireldt and P. Van Mechelen, arXiv:1203.2048
K. Werner et al, P.R.L. 106 (2011) 122004



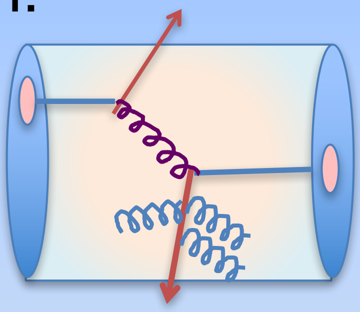
A-A collisions





Heavy Flavours in Pb-Pb collisions

Energy loss of heavy-quarks (HQ) in the medium:



- Modifies their momentum distribution, and of final-state observables
- mechanisms: gluon radiation, elastic collisions
- depends on:
  - Medium density, path-length $\langle \Delta E \rangle \propto \alpha_s C_R \hat{q} L^2$
  - Colour-charge, parton mass $\Delta E_g > \Delta E_{u,d} > \Delta E_c > \Delta E_b$

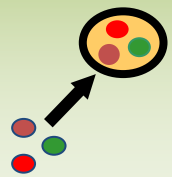
"dead-cone" effect, Dokshitzer, Kharzeev, PLB 519 (2001) 199

Collective expansion of the system

- how do HQ pick up the "flow"
- at low p_T → information on the transport properties of the medium, collectivity and thermalization of HQ

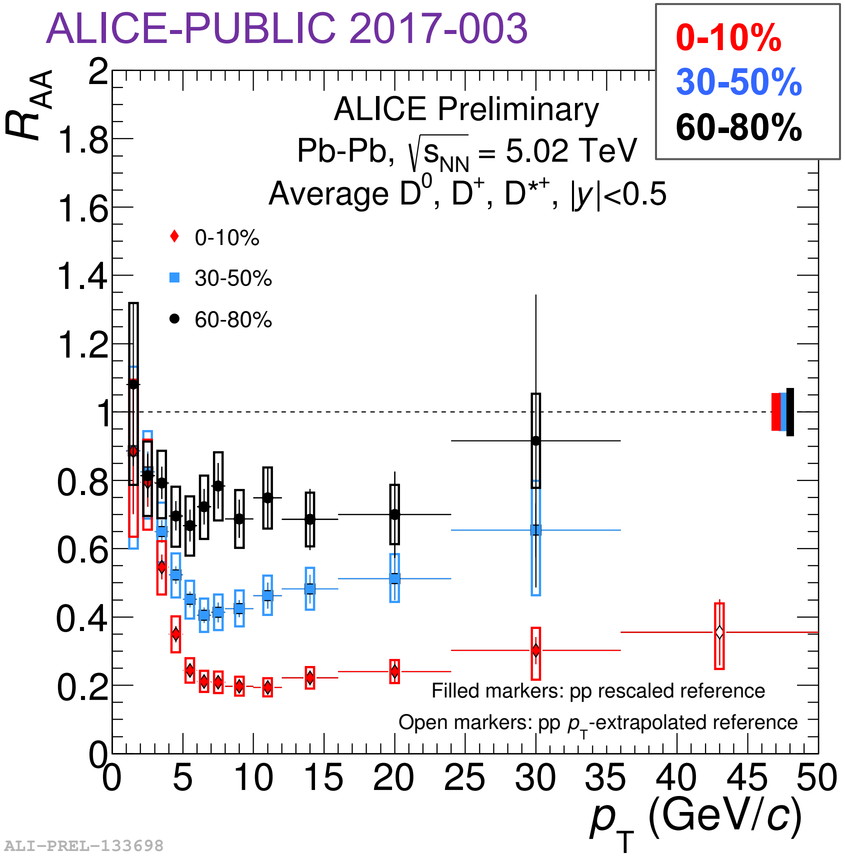
Hadronization mechanism

Fragmentation vs coalescence of heavy quarks with low-p_T light quarks in the medium, hadronic re-scattering phase

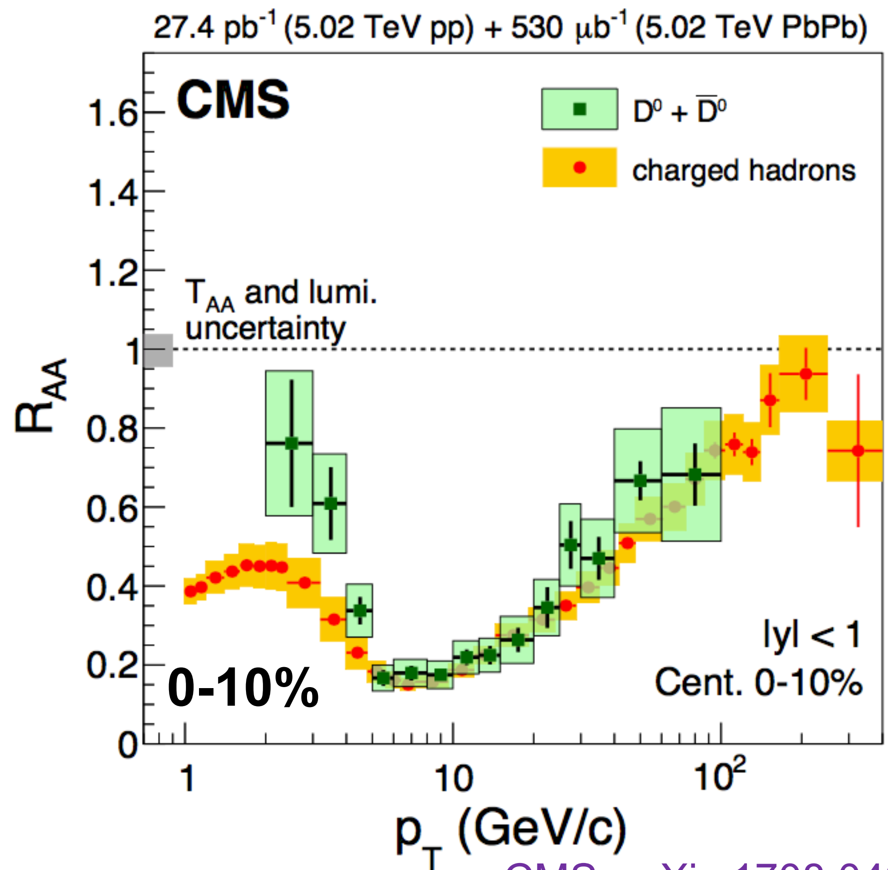


D-meson R_{AA} at LHC in Run 2

ALICE-PUBLIC 2017-003



Strong suppression of D^0,D^+,D^{*+} mesons in Pb-Pb at $\sqrt{s_{NN}}$=5.02 TeV, increasing with increasing centrality

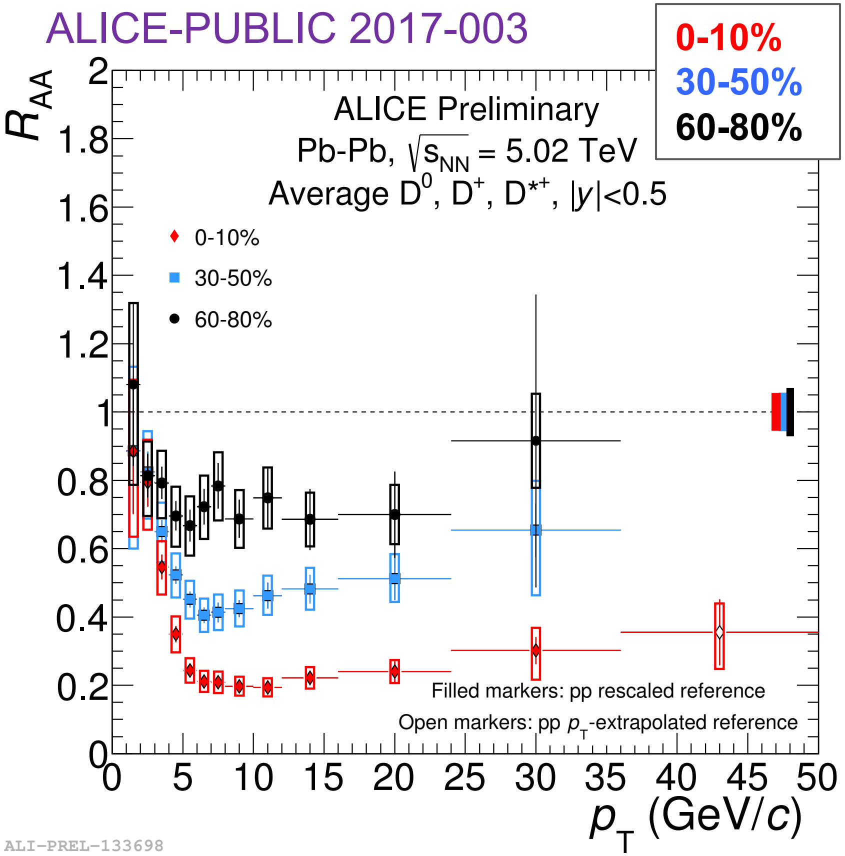


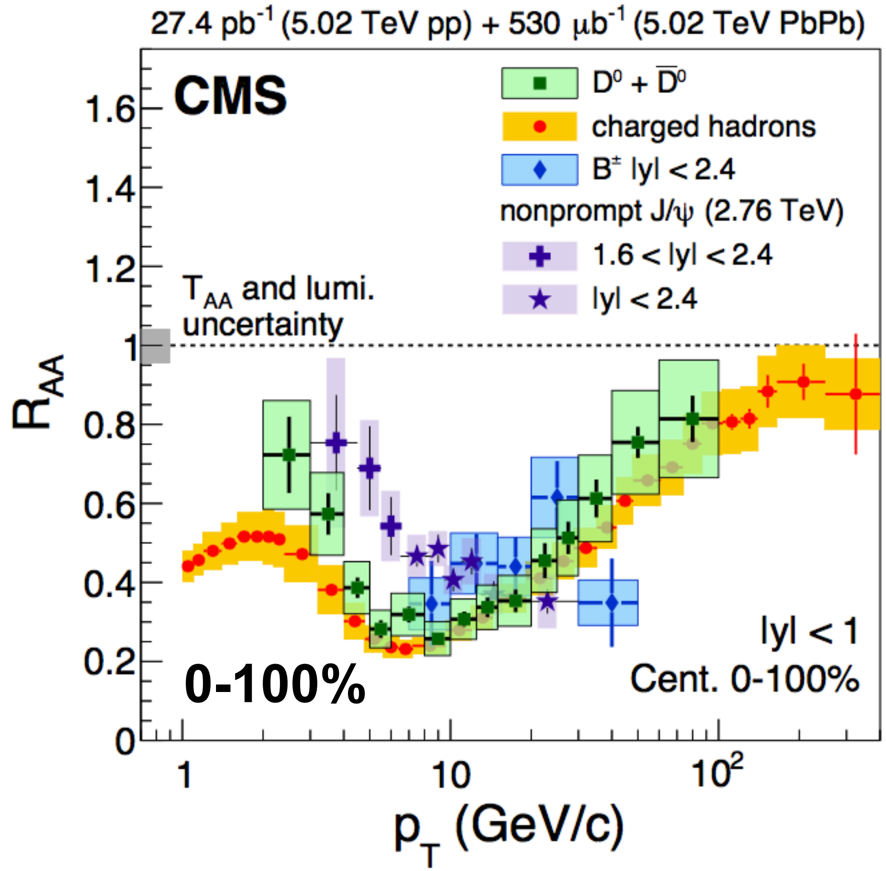
CMS, arXiv:1708.04962

Similar suppression for D and charged hadrons at high p_T. Different suppression at low p_T?

D and B R_{AA} at LHC in Run 2

ALICE-PUBLIC 2017-003





CMS, arXiv:1708.04962
arXiv:1705.04727

Strong suppression of D^0,D^+,D^{*+} mesons in Pb-Pb at $\sqrt{s_{NN}}$=5.02 TeV, increasing with increasing centrality

Similar suppression for B in the measured p_T range

D_s: sensitive to coalescence

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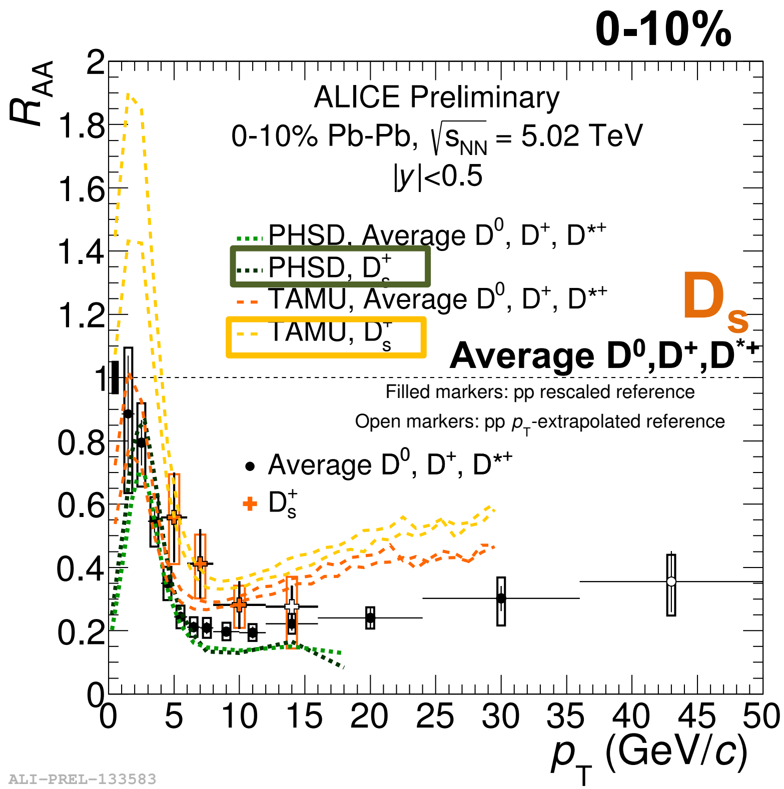


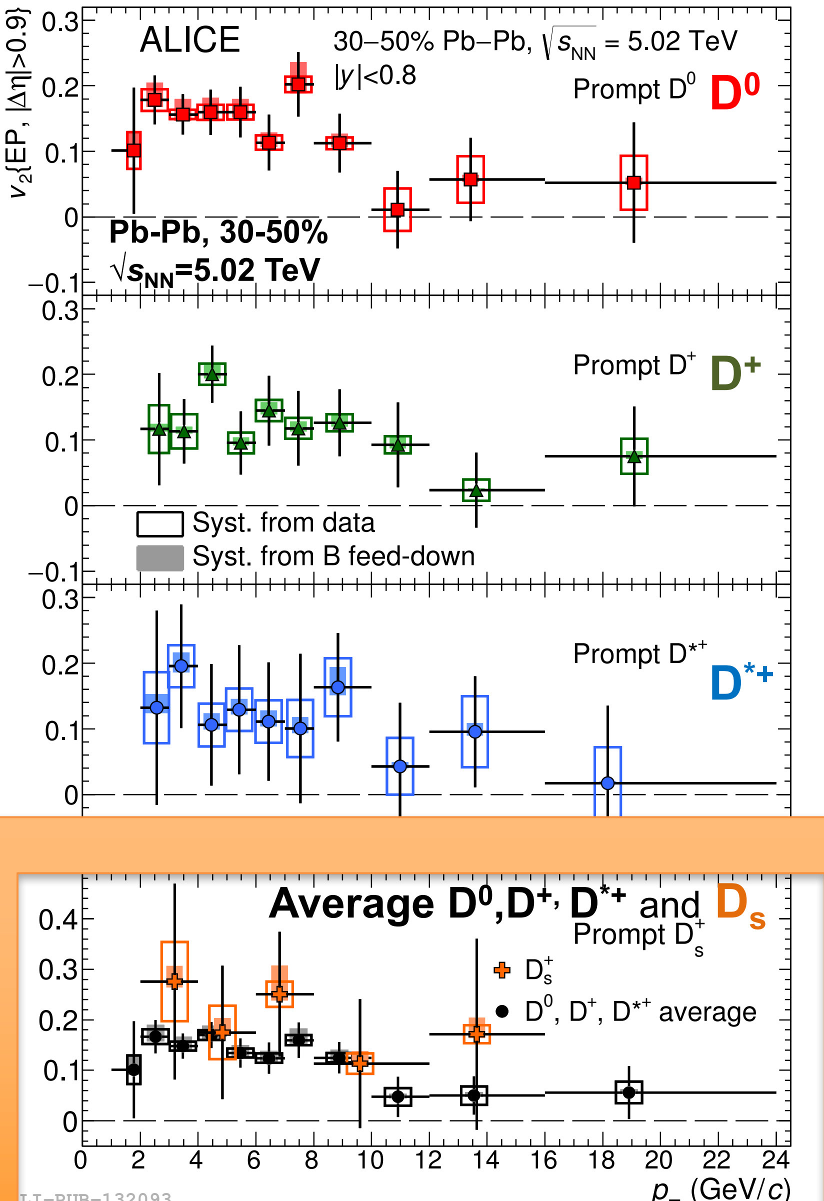
Hint for less suppression of D_s^+ than non-strange D at intermediate p_T

- expected if **recombination** with abundant strange quarks plays a role in charm hadronization

Transport models (TAMU, PHSD) predict **higher D_s R_{AA}** wrt non-strange D due to recombination with strangeness-enriched QGP

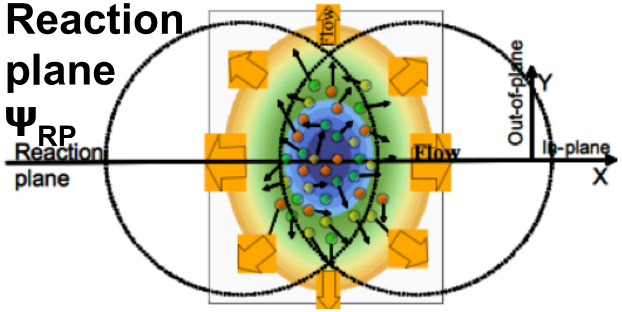
PHSD PRC 93 (2016) 034906
TAMU Phys. Lett. B735 (2014) 445

D-meson v_2 at the highest energy



ALICE, arXiv:1707.01005

Reaction plane Ψ_{RP}



$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left\{1 + \sum_{n=1}^{\infty} v_n \cos[n(\varphi - \Psi_{RP})]\right\}$$

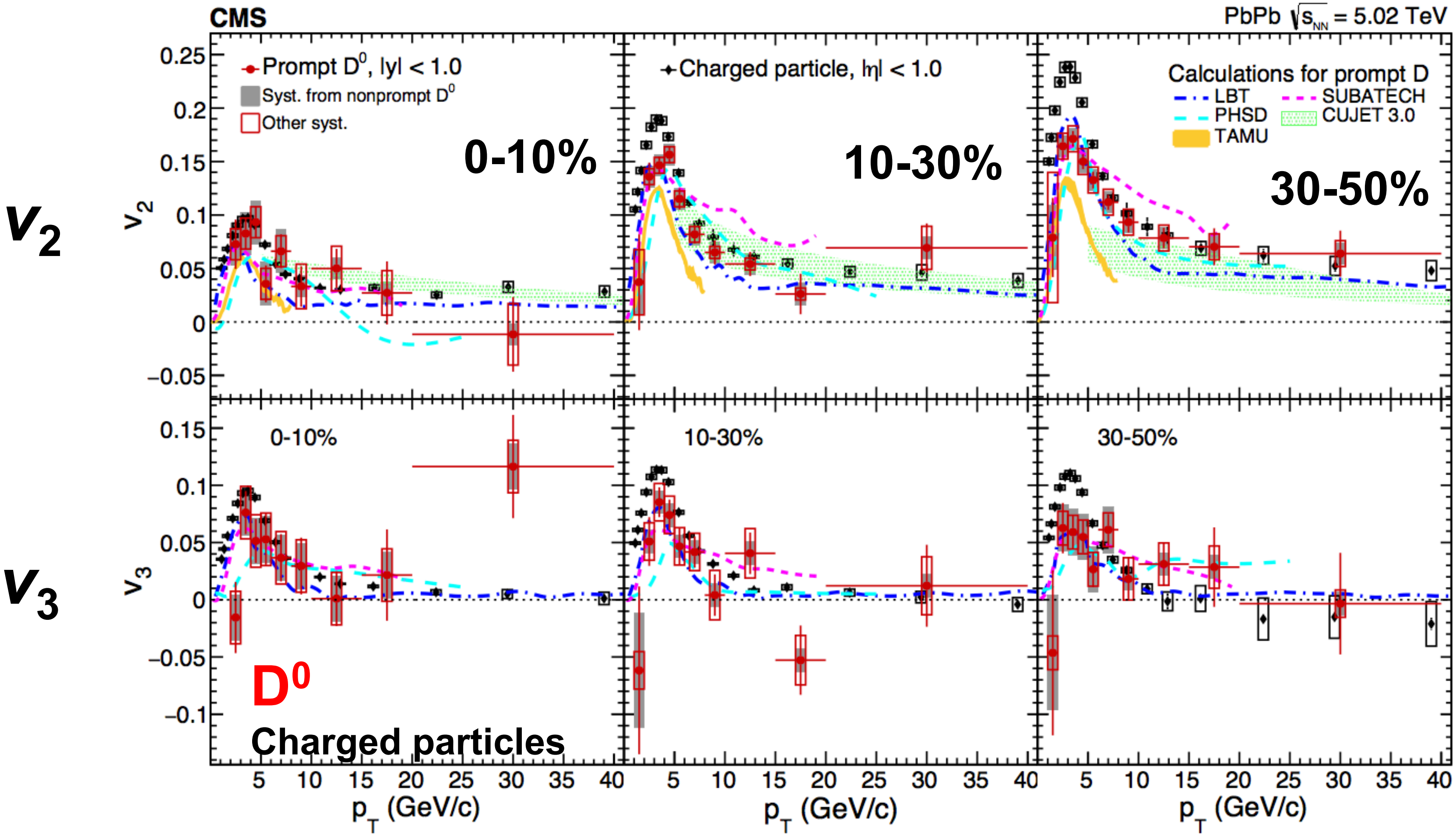
$$v_2 = \langle\cos[2(\varphi - \Psi_{RP})]\rangle$$

Compatible v_2 for D^0,D^+,D^{*+}

Average D-meson v_2>0 in 30-50%:
charm quarks interact with the medium and sensitive to its collective motion

First measurement of D_s v_2:
compatible with non-strange D-meson v_2 within uncertainties

v_2 and v_3 in different centralities



D-meson v_2 > 0 and v_3>0 in p_T<10 GeV/c decreasing with centrality

- 10-30% and 30-50%: low p_T: **v_2 (charged pions)** slightly **higher** than **v_2 (D)**
- high p_T: similar v_2 for D and charged hadrons

Event-shape engineering with D's

Measure D v_2 in events with different eccentricity to relate it to bulk v_2

Divide events on the basis of their eccentricity (q_2):

- 20% of events with **large q_2**
- 60% of events with **small q_2**

$$q_2 = \frac{|Q_2|}{\sqrt{M}}$$

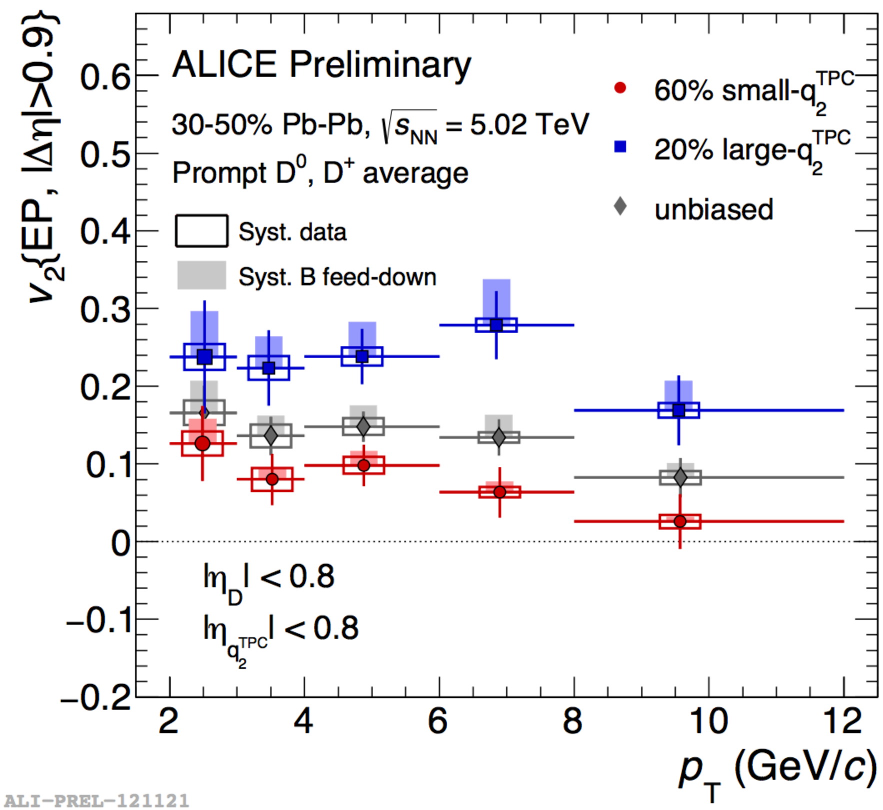
M: multiplicity

$$|Q_2| = \sqrt{Q_{2,x}^2 + Q_{2,y}^2}$$

$$Q_{2,x} = \sum_{i=1}^{M} \cos 2\varphi_i \ , \ Q_{2,y} = \sum_{i=1}^{M} \sin 2\varphi_i$$

Significant separation of D-meson v_2 in events with **large and small q_2**

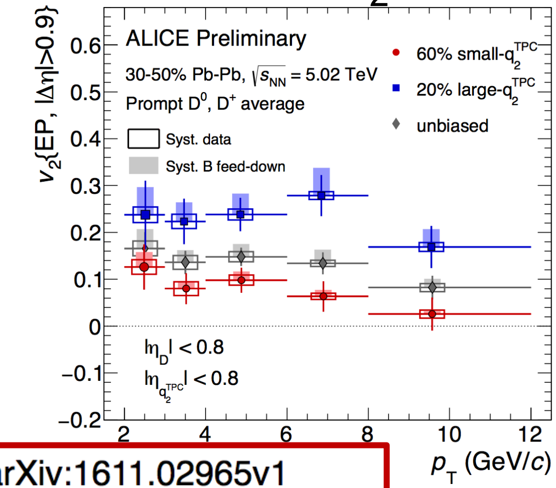
Charm sensitive to collectivity of light-hadron bulk, and by **event-by-event initial-state fluctuations**



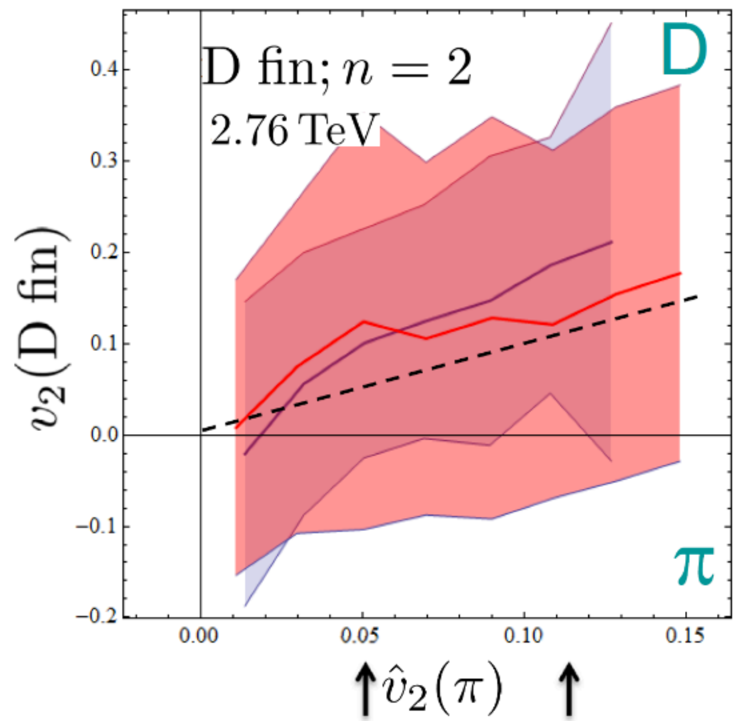
Event-shape engineering with D's

Measure D v_2 in events with different eccentricity to relate it to bulk v_2

New testing ground for theory models

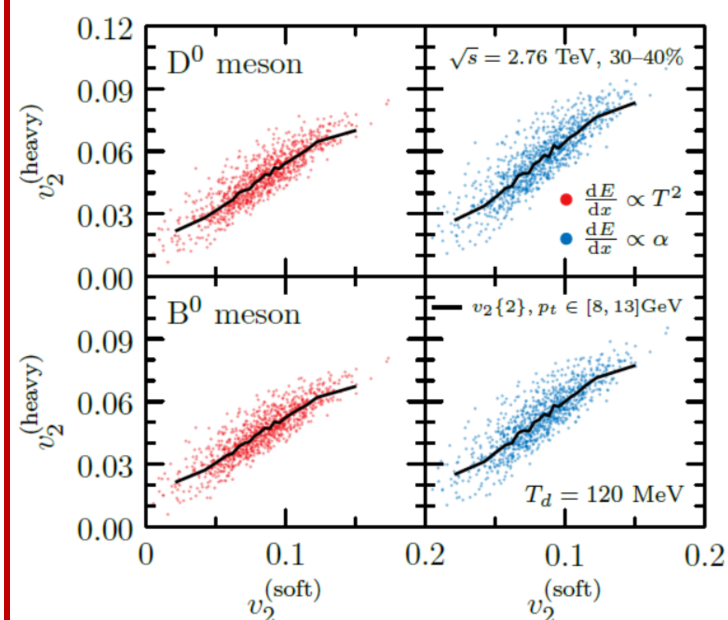


P. Gossiaux et al., arXiv:1705.02271



<60% low q_2> <20% high q_2>

Prado et al. arXiv:1611.02965v1



p_T (D/B) range 8–13 GeV

Towards a quantitative picture with model comparison

Main approaches:

pQCD-based models:

pQCD-inspired calculations of energy loss

Transport models:

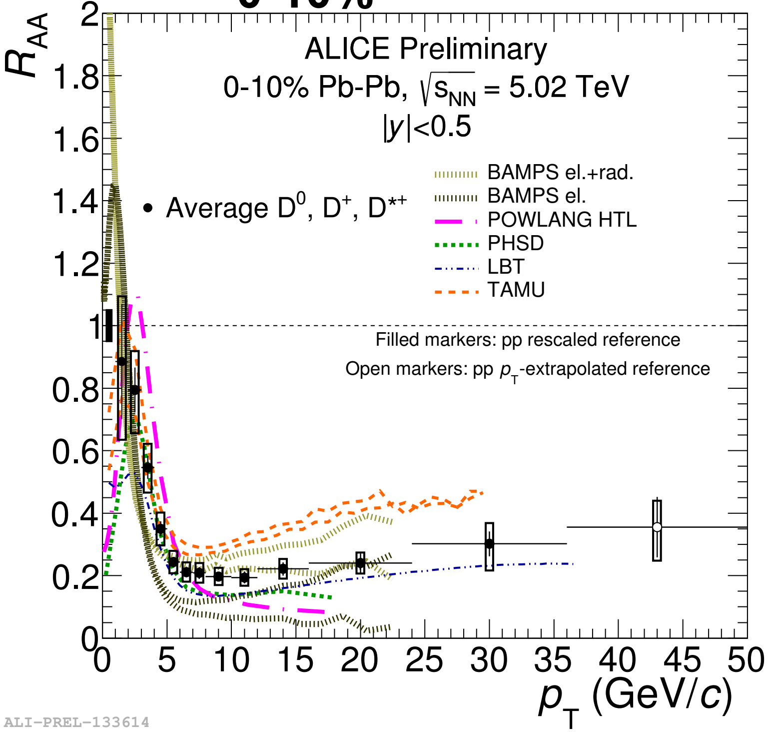
Transport of HQ through medium (i.e. Brownian motion)

HQ are characterized by spatial diffusion coefficient

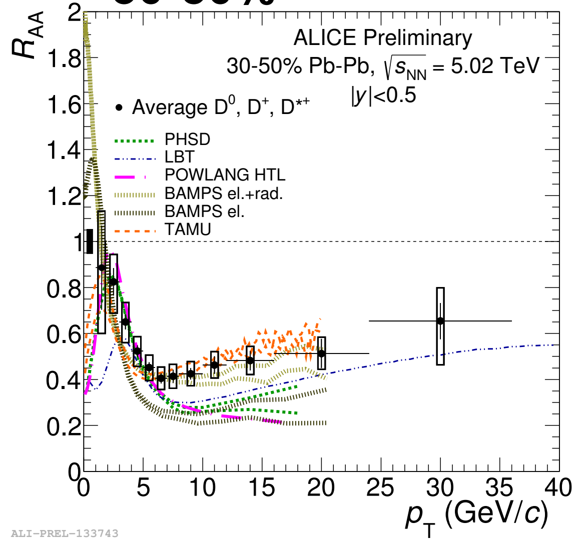
Main ingredients: **energy loss** (radiative and collisional), hadronization via vacuum fragmentation or **recombination**, **hydrodyamic** expansion, **shadowing, initial conditions**

Transport models

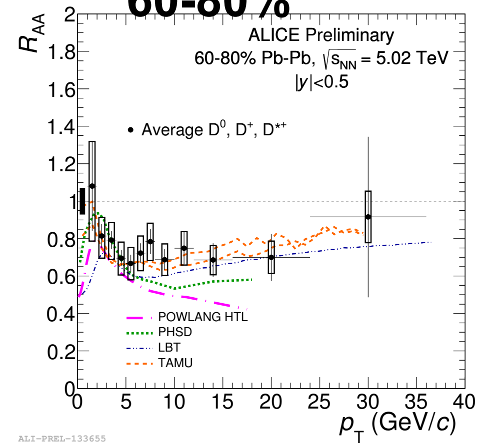
0-10%



30-50%



60-80%

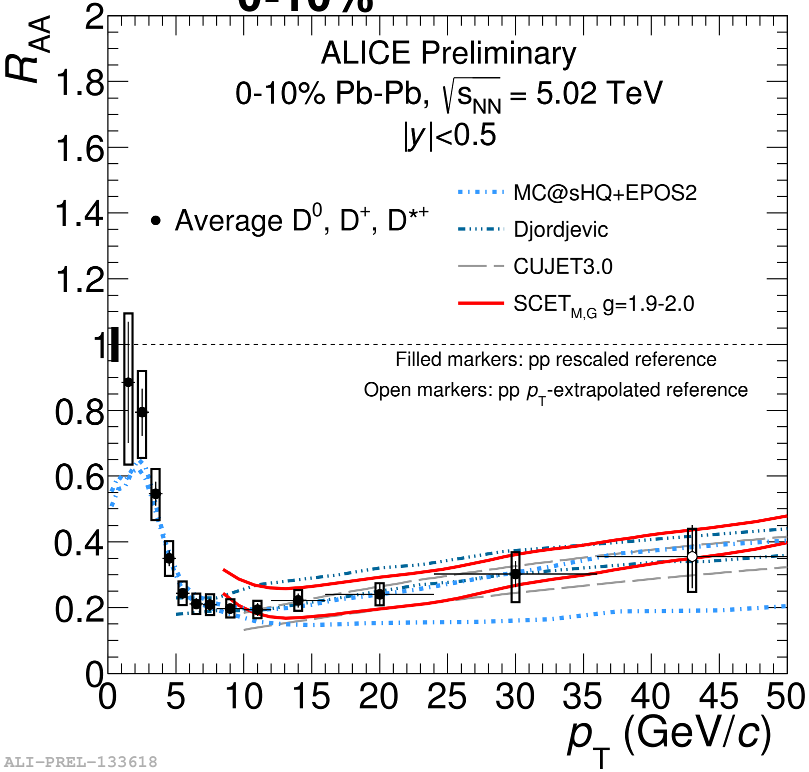


Low p_T: fairly good description with transport models → important role of recombination and elastic scatterings

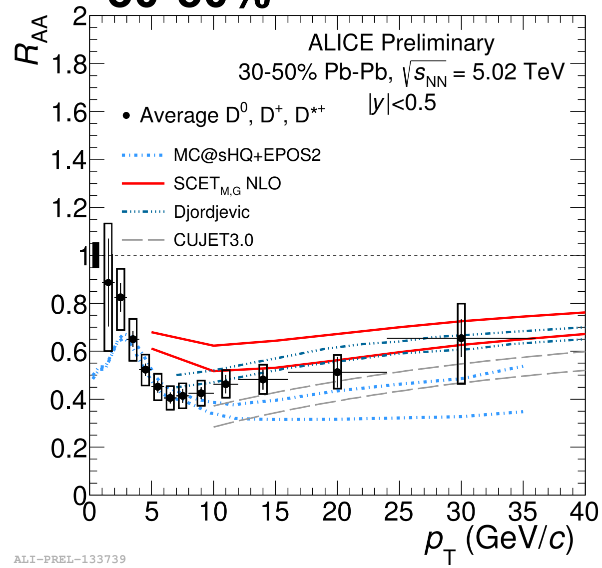
TRANSPORT MODELS	Collisional energy loss	Radiative energy loss	Recombination	Hydro/ dynamics	nPDF
BAMPS J. Phys. G42 (2015) 115106	✓	✓	✗	✓	✗
LBT arXiv:1703.00822	✓	✓	✓	✓	✓
PHSD PRC 93 (2016) 034906	✓	✗	✓	✓	✓
POWLANG EPJC 75 (2015) 121	✓	✗	✓	✓	✓
TAMU Phys. Lett. B735 (2014) 445	✓	✗	✓	✓	✓

QCD-based energy-loss models

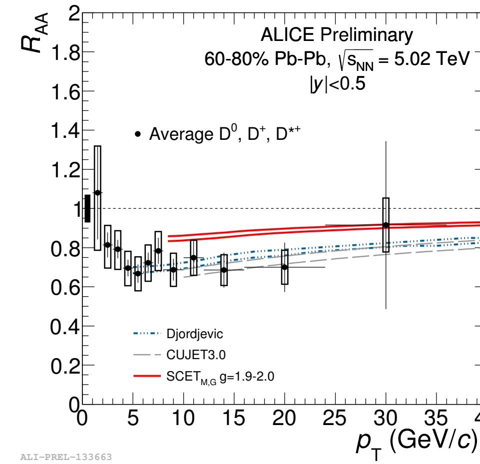
0-10%



30-50%



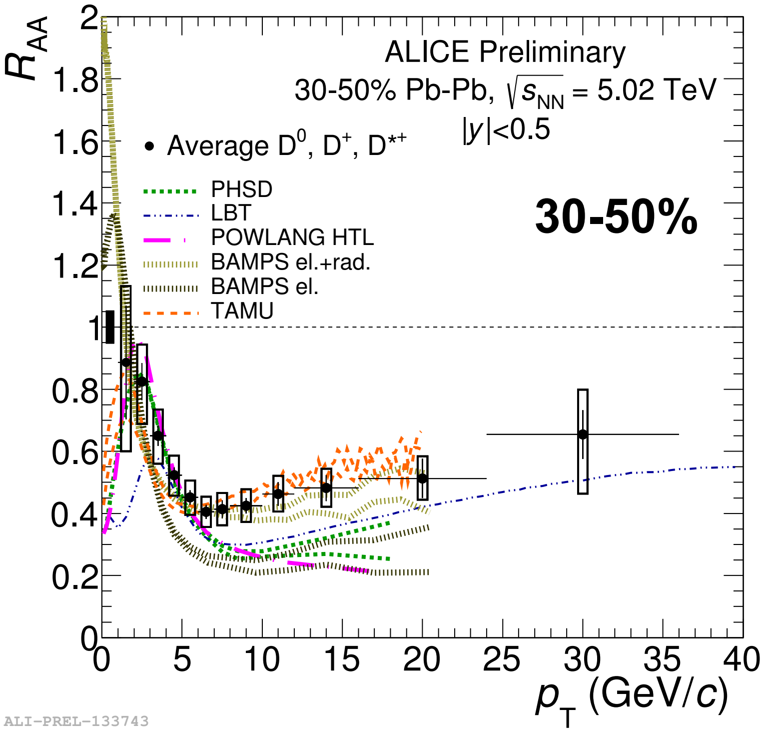
60-80%

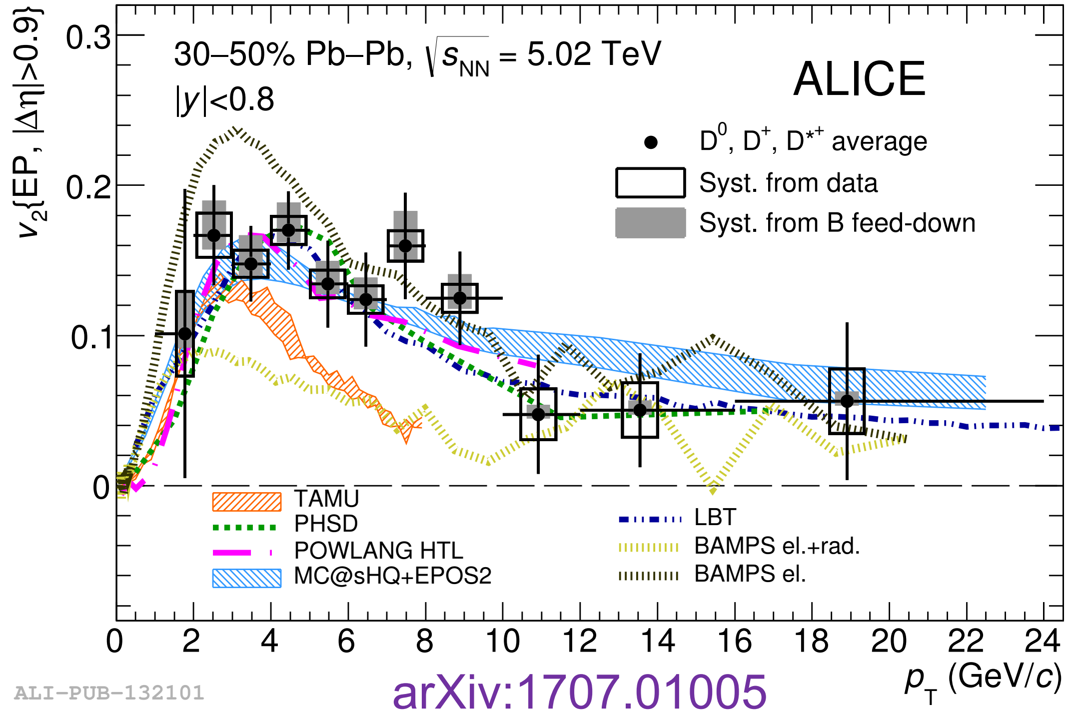


High p_T (dominated by radiative en. loss): fairly good description

QCD e-loss MODELS	Collisional energy loss	Radiative energy loss	Recombination	Hydro	nPDF
CUJET3.0 JHEP 02 (2016) 169	✓	✓	✗	✗	✗
Djordjevic PRC 92 (2015) 024918	✓	✓	✗	✗	✓
MC@sHQ+EPOS PRC 89 (2014) 014905	✓	✓	✓	✓	✓
SCET JHEP 03 (2017) 146 (in-medium association and dissociation)	✓	✓	✗	✗	✓

R_{AA} and v_2 : constraints to models





arXiv:1707.01005

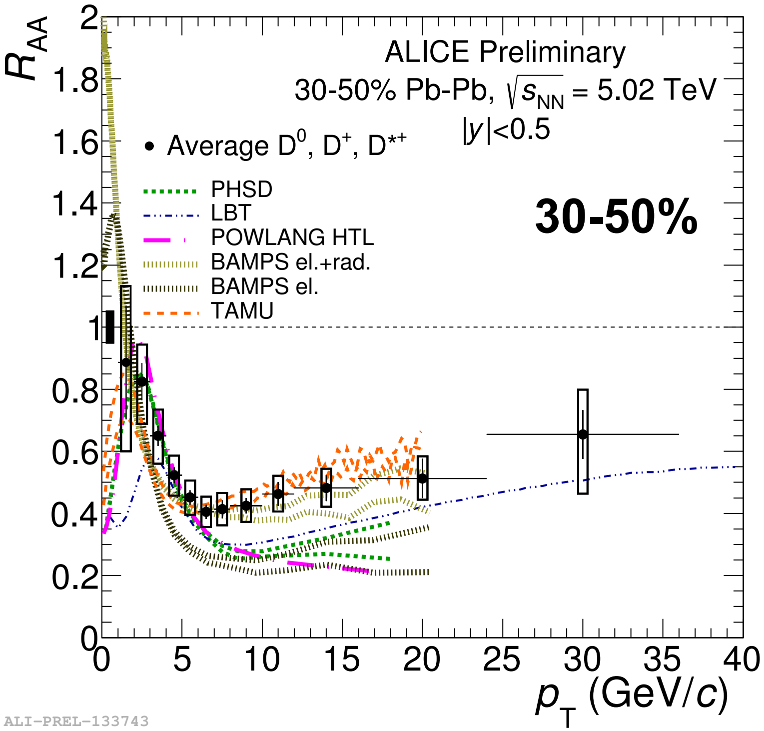
Models where charm quarks pick up collective flow via recombination and/or subsequent elastic collisions in expanding hydrodynamic medium do better at describing both R_{AA} and v_2 at low p_T (BAMPS elastic, LBT, MC@sHQ+EPOS, TAMU, POWLANG, PHSD)

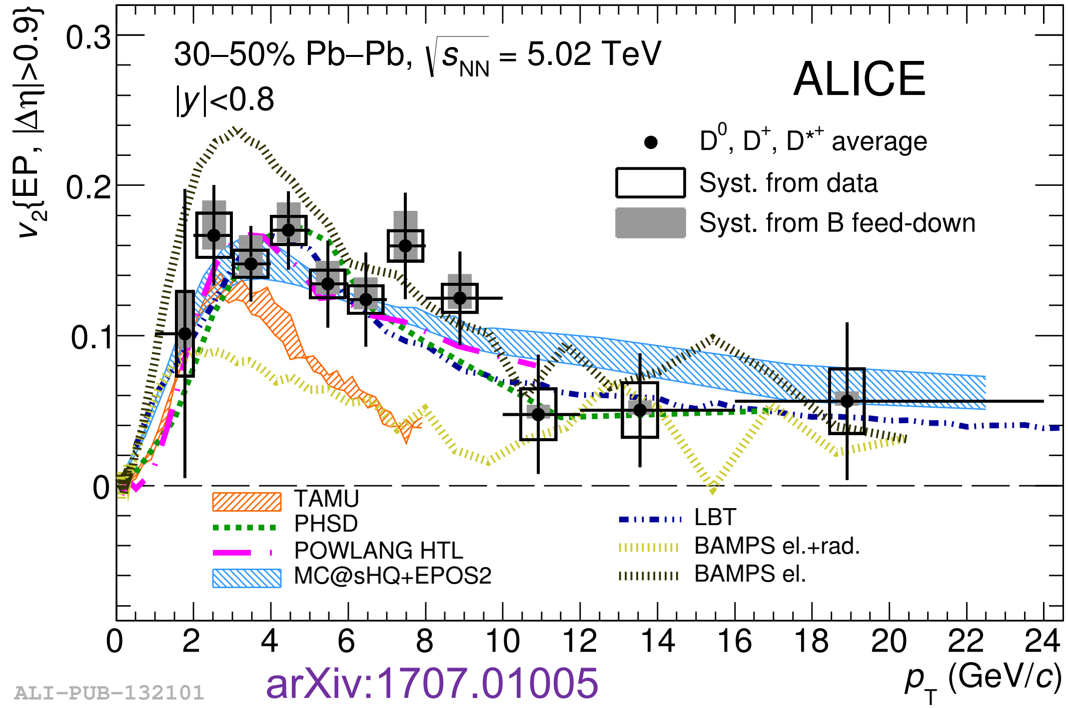
Models provide:

→ Diffusion coefficient $2\pi T D_s(T) \approx 1.5$–7 at critical temperature T_c

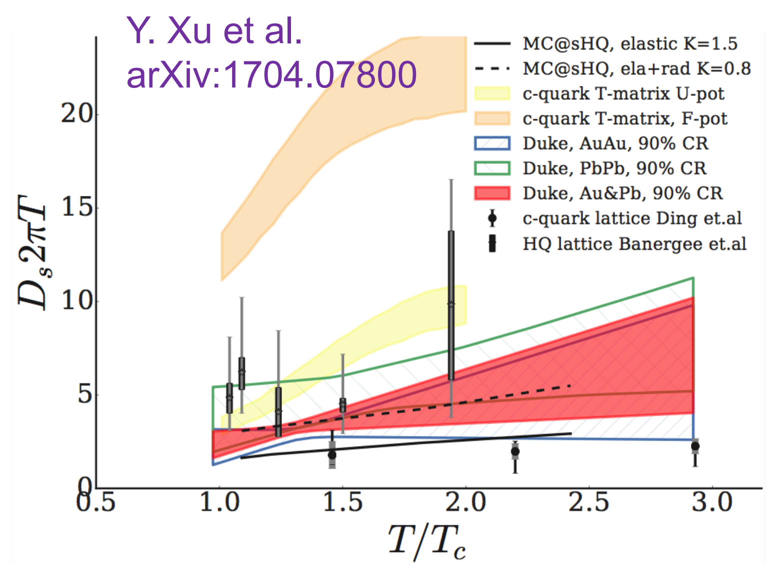
→ Charm thermalization time τ_{charm}~3-14 fm/c

R_{AA} and v_2 : constraints to models





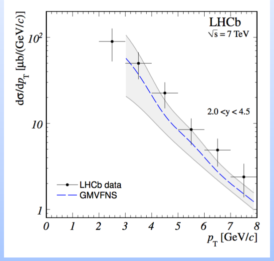
Ongoing: theoretical effort through Bayesian analysis to calibrate model parameters via model-data comparison → Find the optimal parameters that describe R_{AA} and v_2

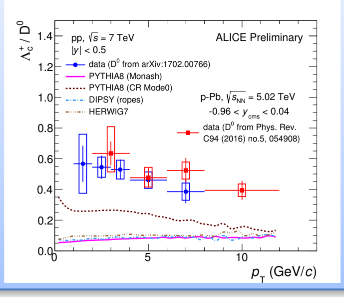


What did we learn so far ?

HF in pp:

test for pQCD (and more)

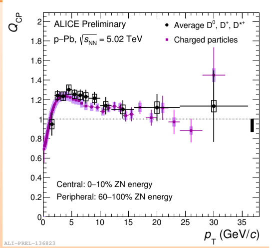


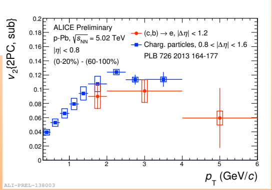


HF in p-Pb:

- HF productions seems to be different in central and peripheral collisions
- v_2 of electrons from HF hadron decays

→ **Collective motion and/or initial state effects?**

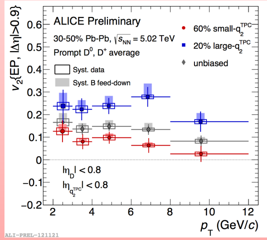


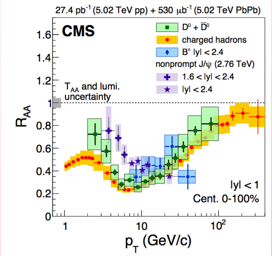


HF in Pb-Pb

- Strong modification of HF production in PbPb collisions relative to pp
- Azimuthal anisotropy → charm takes part to collectivity

→ **starting to put constraints to models !**





Ongoing/next steps with HF

QUESTIONS?

pp

QCD studies on HQ production:

→ Which mechanisms rule **interplay** between **hard processes** and **underlying event**?

→ **Charm fragmentation** properties?

p-Pb

Collective effects in small systems, also for HF ?

Pb-Pb

Mechanisms governing microscopic interactions of HQ in QGP ?

→ Contribution of **radiative and collisional energy loss**?

→ HQ **thermalization**?

→ Role of **coalescence** in hadronization?

and more…

Ongoing/next steps with HF

pp | p-Pb | Pb-Pb

QUESTIONS?

QCD studies on HQ production:
→ Which mechanisms rule **interplay** between **hard processes** and **underlying event**?
→ **Charm fragmentation** properties?

Collective effects in small systems, also for HF ?

Mechanisms governing microscopic interactions of HQ in QGP ?
→ Contribution of **radiative and collisional energy loss**?
→ HQ **thermalization**?
→ Role of **coalescence** in hadronization?

and more…

HOW

LHC Run 2, 3, 4: more statistics, new detectors and machine upgrades

Smaller uncertainties, new differential measurements to **further constrain theory**

→ A. Dainese's talk

Thank you!

Heavy flavours with ALICE

Full reconstruction of D-meson hadronic decays (prompt D mesons)

$D^0 \rightarrow K^-\pi^+$

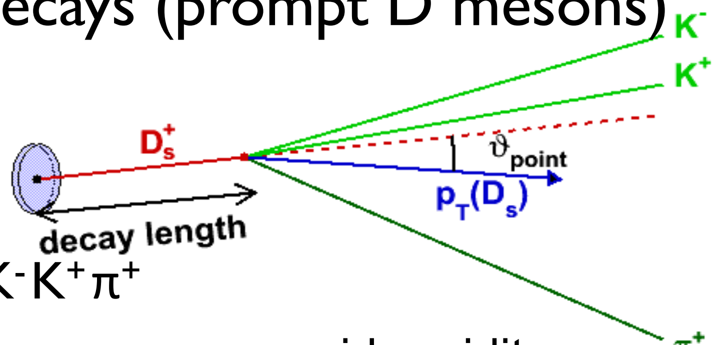
$D^+ \rightarrow K^-\pi^+\pi^+$

$D^{*+} \rightarrow D^0\pi^+$

$D_s^+ \rightarrow \phi\pi^+ \rightarrow K^-K^+\pi^+$

$\Lambda_c^+ \rightarrow pK^-\pi^+$

$\Lambda_c^+ \rightarrow pK^0_s$



mid-rapidity
$|y|<0.5$

Invariant mass analysis based on: displaced secondary vertices, topological cuts, PID

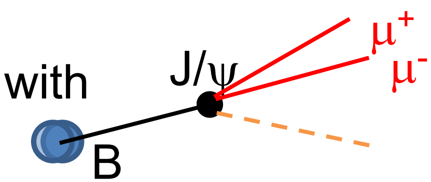
Correction for beauty feed-down (based on FONLL)

Beauty: displaced electrons, J/ψ from B

Beauty-decay electrons: $|y|<0.8$

Exploit displaced track impact parameter

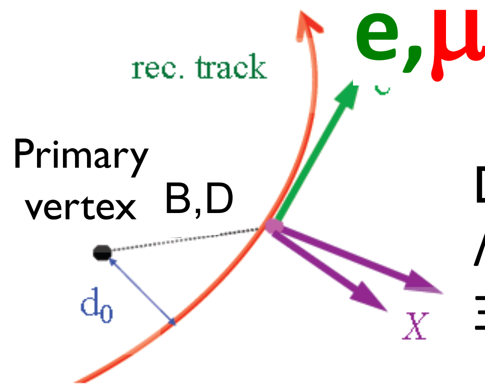
Non-prompt J/ψ measured with pseudo-proper decay length



Semi-leptonic decays (charm, beauty)

Electrons:
$|y|<0.8$

Muons:
$2.5|y|<4$



$D+B \rightarrow e,\mu$

$\Lambda_c^+ \rightarrow e^+\nu_e\Lambda$

$\Xi_c^0 \rightarrow e^+\nu_e\ \Xi^-$

Electrons: background (π^0 and η Dalitz decays, photon conversions) subtracted with invariant mass method (e+e-) and cocktail

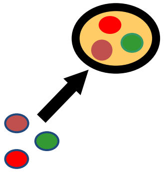
Muons: background (π,K→μ) subtracted with MC (pp) and data-tuned MC cocktail (p-Pb, Pb-Pb)

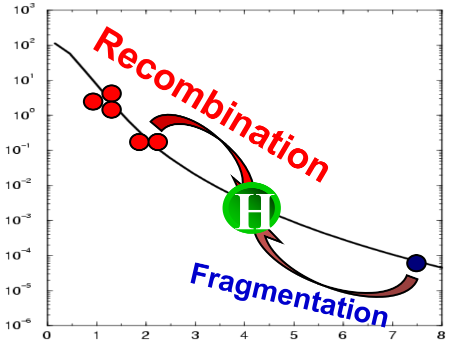
Charmed baryons

Measurements in **pp** and **p-Pb** collisions:

- Further understanding of **charm hadronization models**
  - Lack of knowledge about fragmentation of charm into baryons !

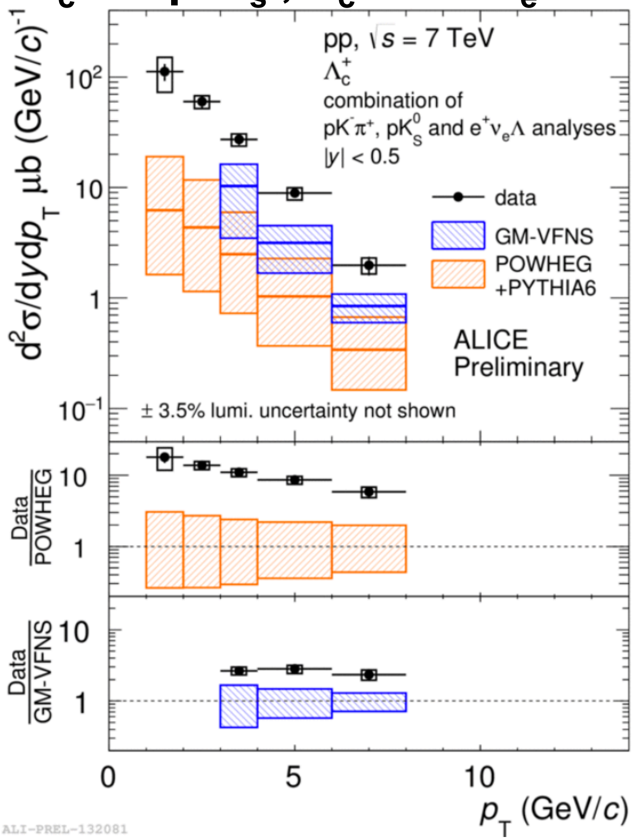
- Reference for future charmed baryon measurements in **Pb-Pb** collisions
  - Hadronization via **recombination** ?



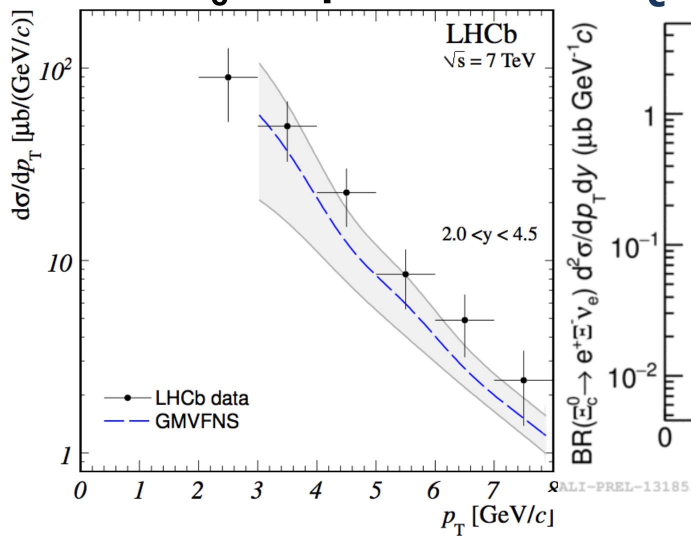


Charmed baryons

Combination of $\Lambda_c^+ \rightarrow pK^-\pi^+$
$\Lambda_c^+ \rightarrow pK^0_s$, $\Lambda_c^+ \rightarrow e^+\nu_e\Lambda$

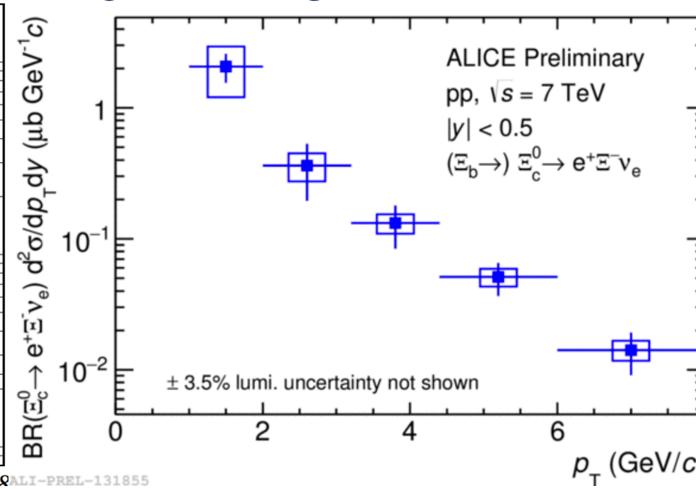


$\Lambda_c^+ \rightarrow pK^-\pi^+$



LHCb, Phys. Rev. B 871 (2013)1

$\Xi_c^0 \rightarrow e^+\nu_e\,\Xi^-$: **First at LHC**



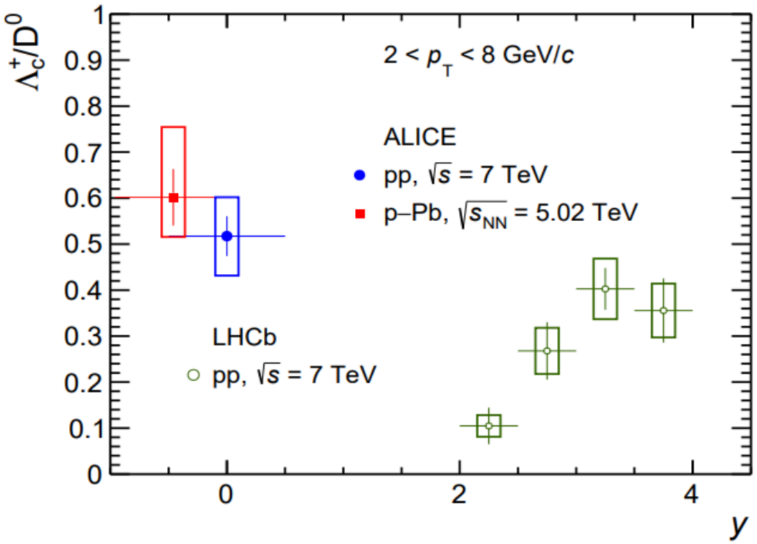
Λ_c p_T-differential cross section **underestimated** by NLO theory at mid-rapidity (ALICE):
GM-VFNS, POWHEG+PYTHIA
→ describe well D mesons
→ Fragmentation tuned to results from lower energy, e^+e^- (GM-VFNS)

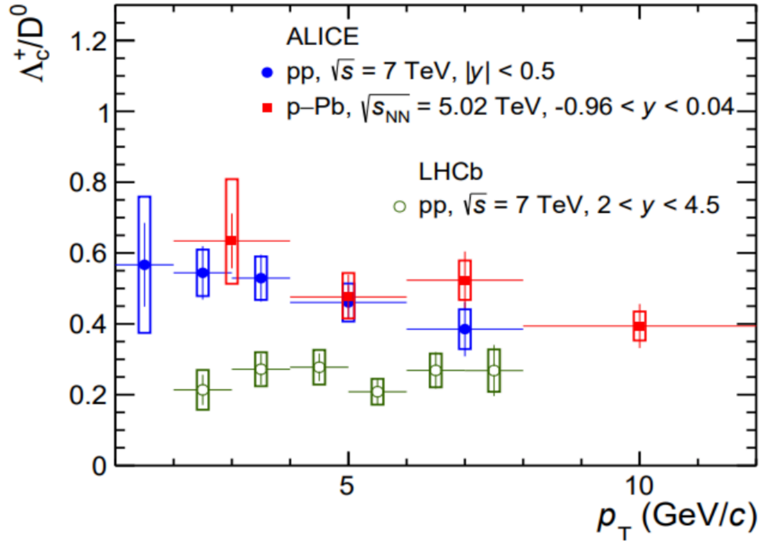
GM-VFNS: Eur. Phys. J. C41 (2005) 199–212,
Eur. Phys. J. C72 (2012) 2082
POWHEG: JHEP 06 (2010) 043

Comparison to LHCb

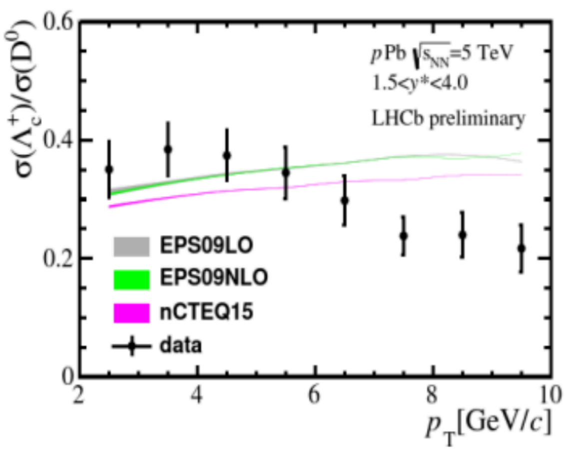
LHCb, pp

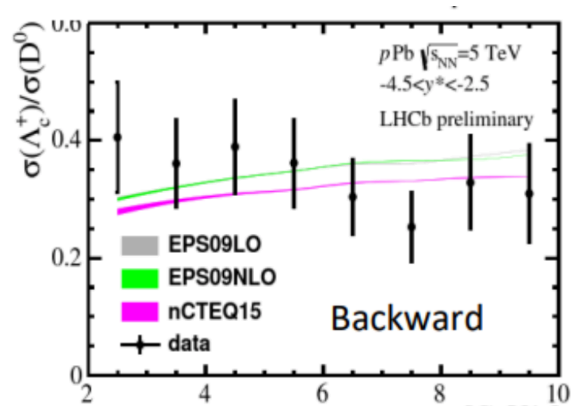
LHCb, Nucl. Phys., B871 (2013) 1-20



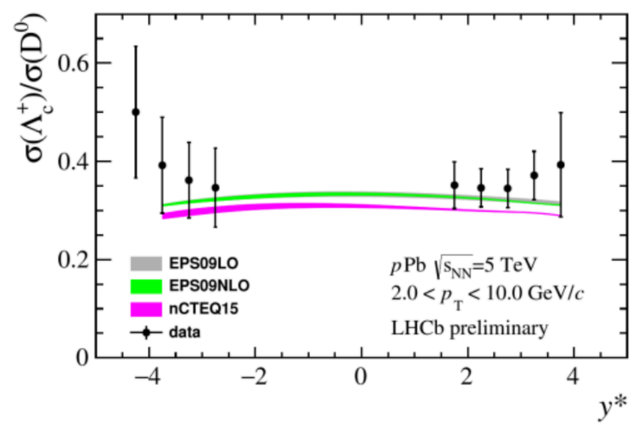


LHCb, p-Pb

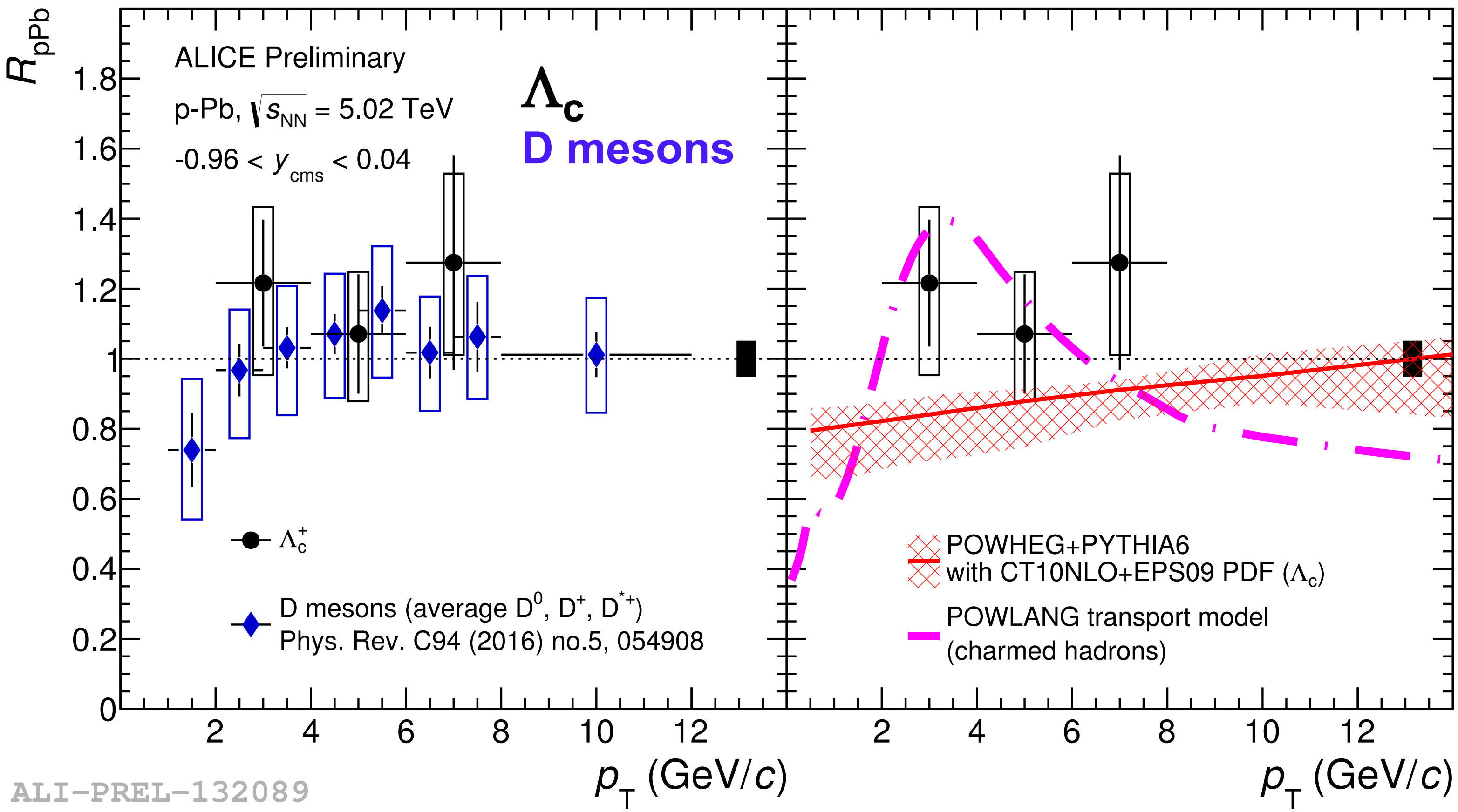




Charmed bayrons and mesons in LHCb, SQM2017



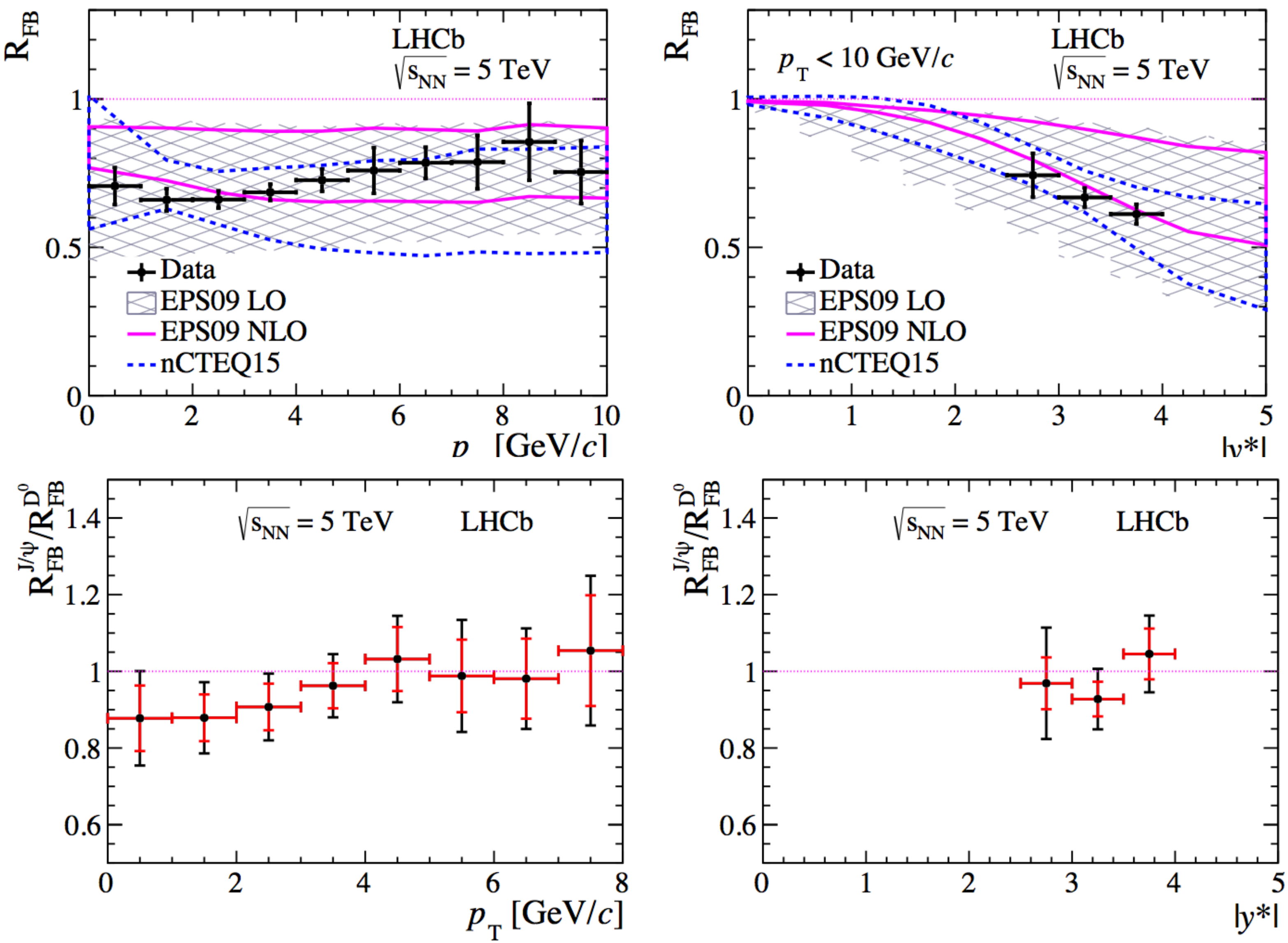
Λ_c R_{pPb}



Λ_c R_{pPb} consistent with unity, with D R_{pPb} and with models:

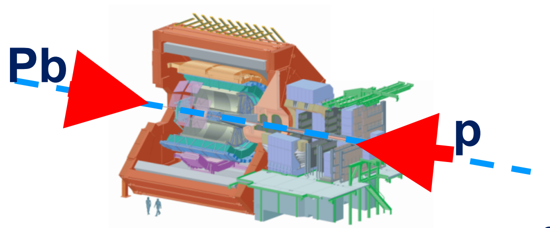
- CNM effects: POWHEG+PYTHIA with CT10NLO+EPS09 PDF
- Hot medium effects: POWLANG with small-size QGP formation, collisional en. loss

LHCb: R_{FB}

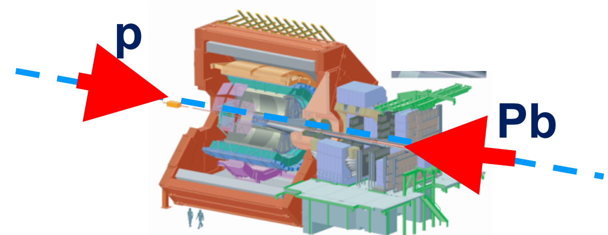


R_FB
LHCb
√s_NN = 5 TeV
Data
EPS09 LO
EPS09 NLO
nCTEQ15
p_T [GeV/c]
p_T < 10 GeV/c
|y*|
R_FB^{J/ψ}/R_FB^{D^0}

HF in pA: different rapidities

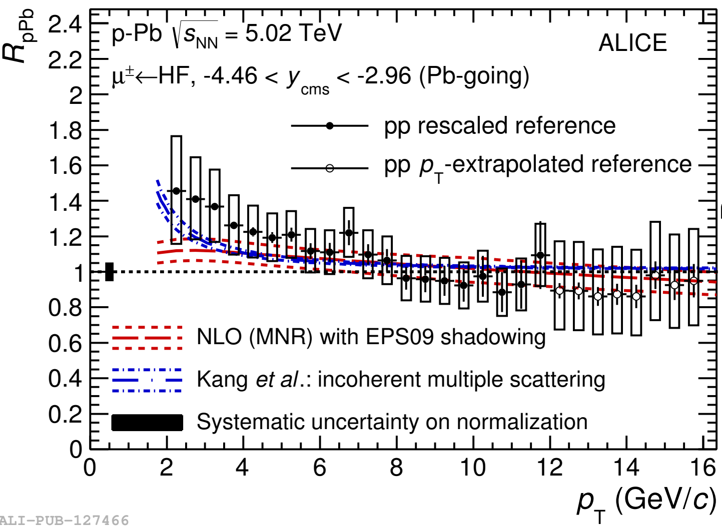


$-4.46<y_{CMS}<-2.96$ $x \sim 10^{-2}$

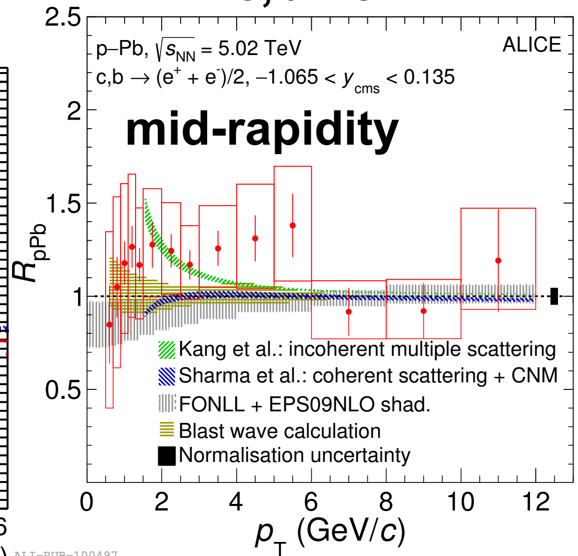


$2.03<y_{CMS}<3.53$ $x \sim 10^{-4}$

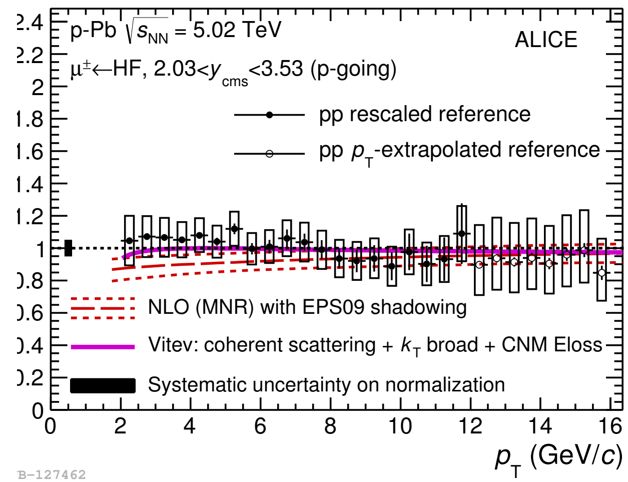
Pb-going (backward) **c,b→μ**



c,b→e



p-going (forward) **c,b→μ**



M. Mangano et al, Nucl. Phys. B373 (1992) 295
K. J. Eskola et al, JHEP 0904 (2009) 065
R. Sharma, I. Vitev et al., PRC 80 (2009) 054902
Z.B. Kang et al., PLB 740 (2015) 23

ALICE:
Phys. Lett. B 754 (2016) 81
Phys. Lett. B 770 (2017) 459

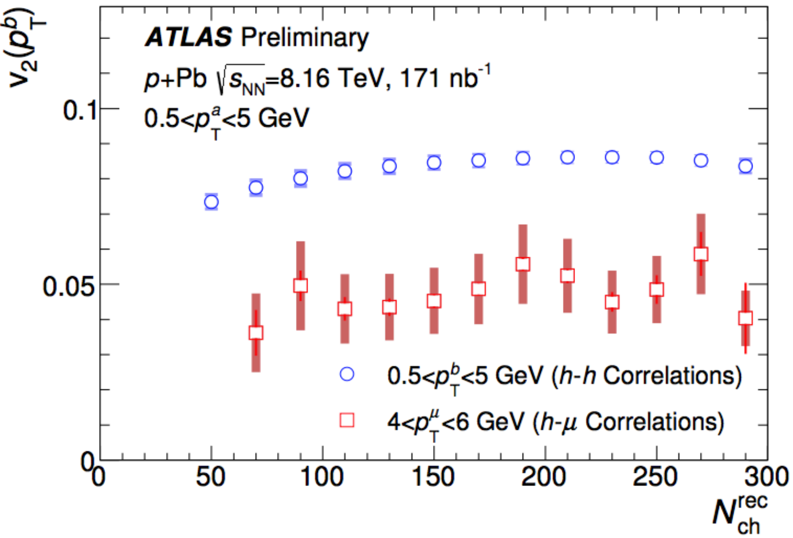
Different *x* regimes explored in different rapidity ranges
→ HF probe shadowing/saturation expected to be relevant at low p_T at the LHC

Data described within uncertainties by the models with CNM effects

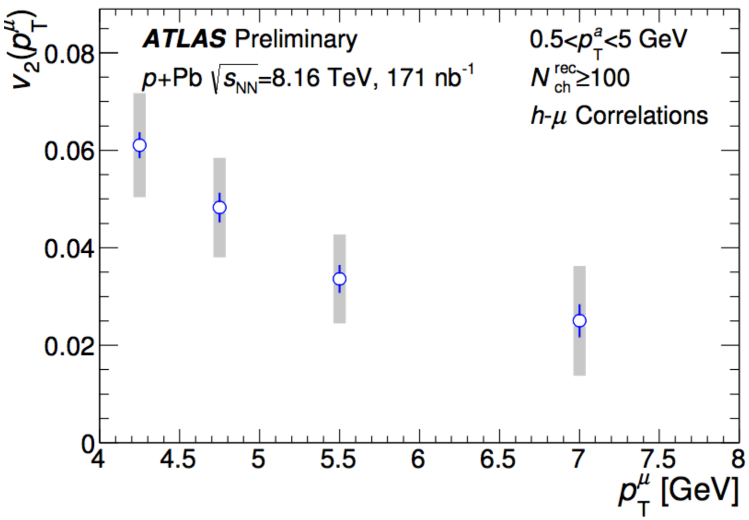
h-μ correlations in p-Pb collisions

Muons: mainly coming from heavy-flavour hadron decays

v_2 vs pPb multiplicity



v_2 vs p_T



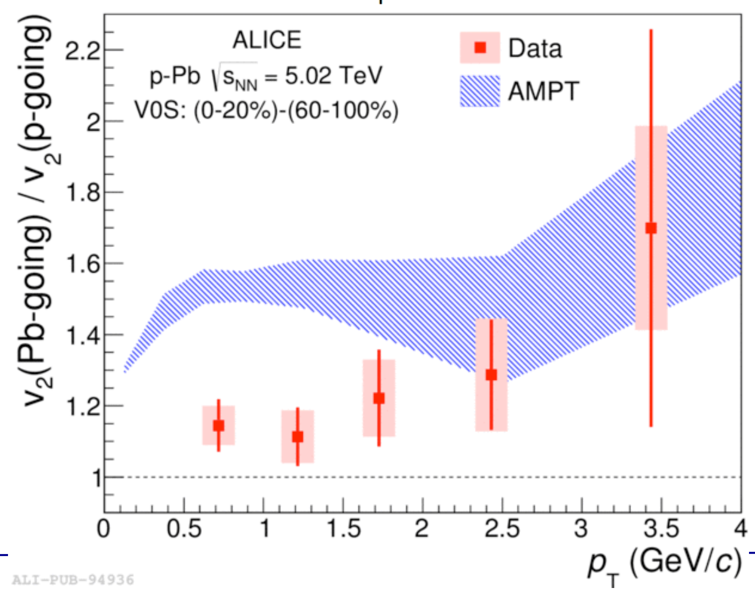
ATLAS: significant muon v_2 in pPb 8 TeV

-$v_{2\mu}$ ~ 0.6 x v_{2had}

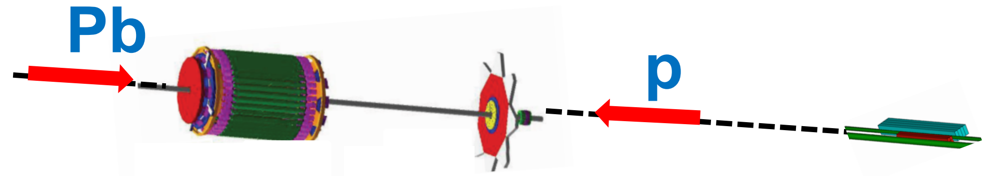
-independent of p-Pb multiplicity

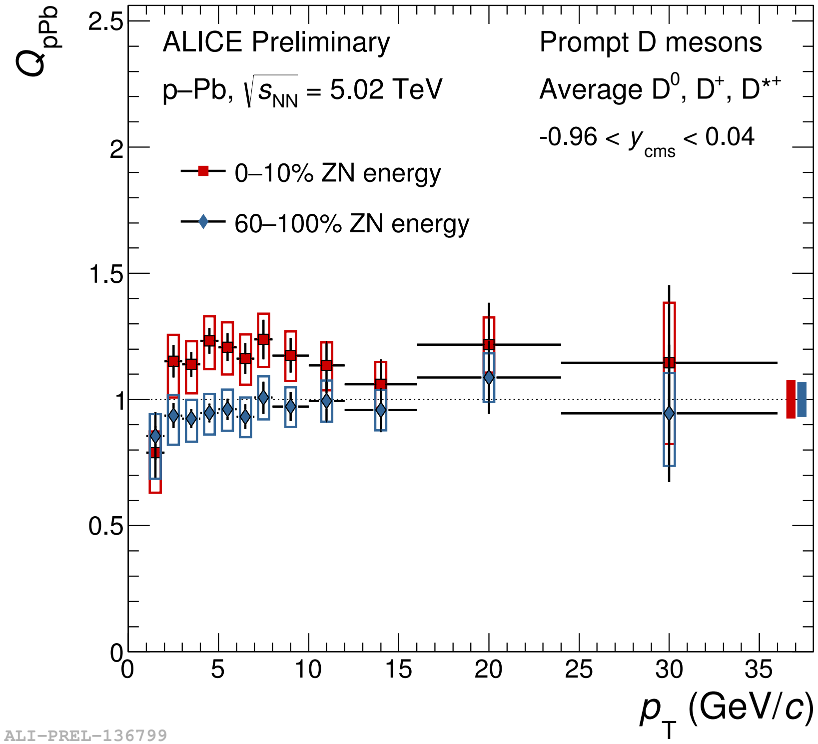
ALICE: p-Pb collisions at 5 TeV

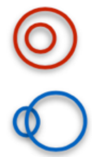
- Collective effects for high-p_T muons in
- high-multiplicity events via μ-h correlations

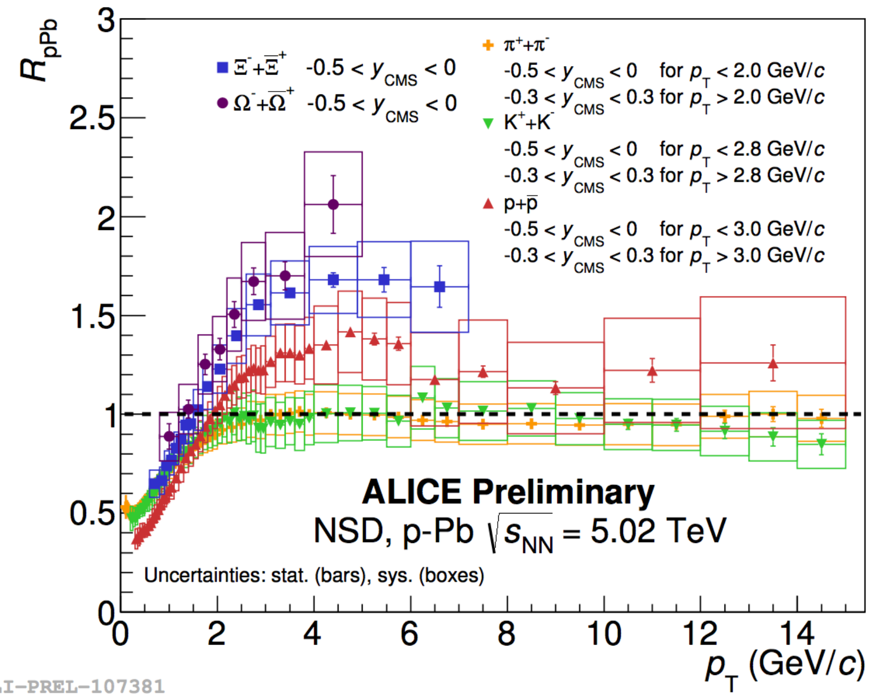


D-meson production in different p-Pb centrality classes









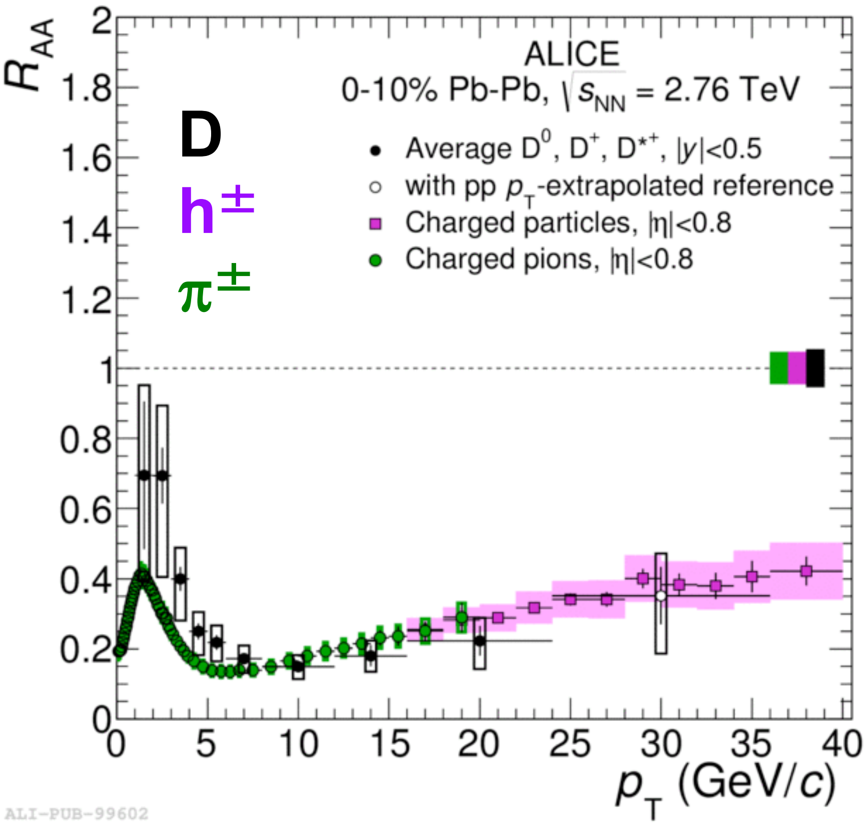
ALICE-PUBLIC 2017-008

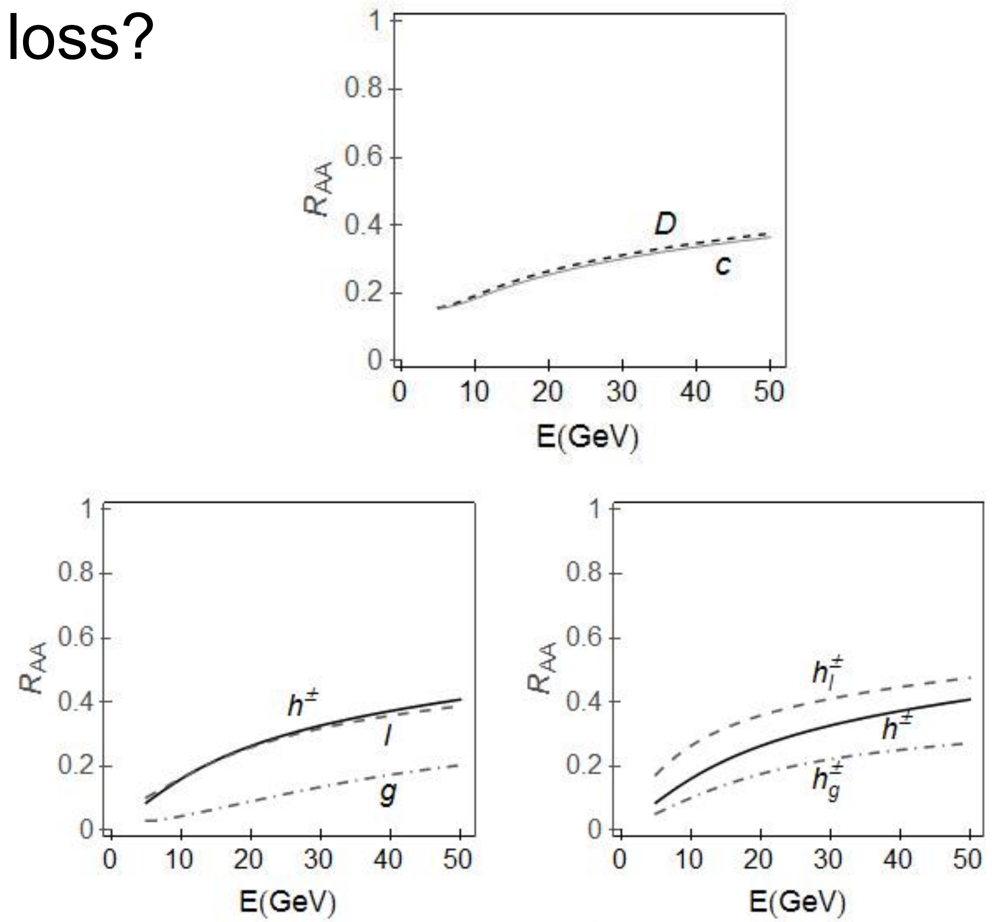
***R_{pPb}* of of primary charged** π, K, p and multi- strange baryons Ξ and Ω at mid-rapidity

→ Hint of **mass dependent** R_{pPb}

R_{AA}: D mesons and charged hadrons

Mass dependence of energy loss?





M.Djordjevic, PRL 112, 042302 (2014)

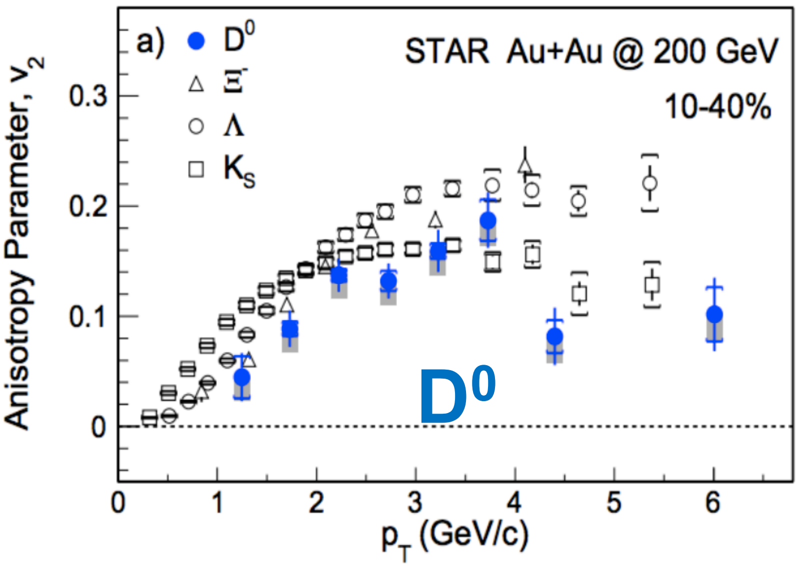
$R_{AA}(D) \sim R_{AA}(\pi, h^\pm)$?

What about $\Delta E(udsg) > \Delta E(c)$ → $R_{AA}(D) > R_{AA}(\pi, h^\pm)$

→Different quark spectra

→$R_{AA}(h)$ affected by fragmentation

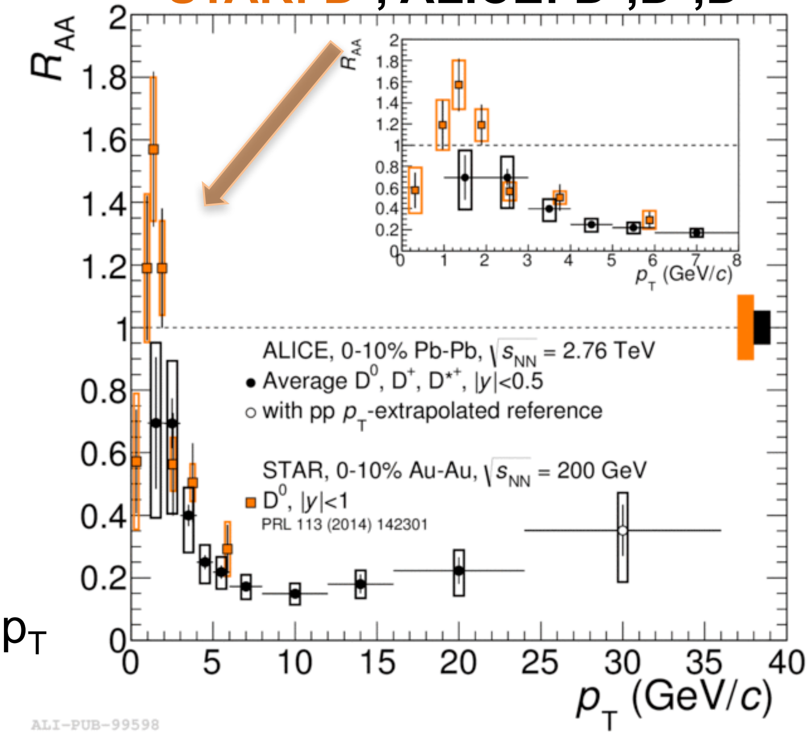
Comparison to RHIC energies



RHIC: D^0 v_2>0 for p_T>1 GeV/c (10-40%)

- tends to be below light-hadron v_2 at low p_T
- charm thermalization at RHIC?

STAR: D^0, ALICE: D^0,D^+,D^{*+}

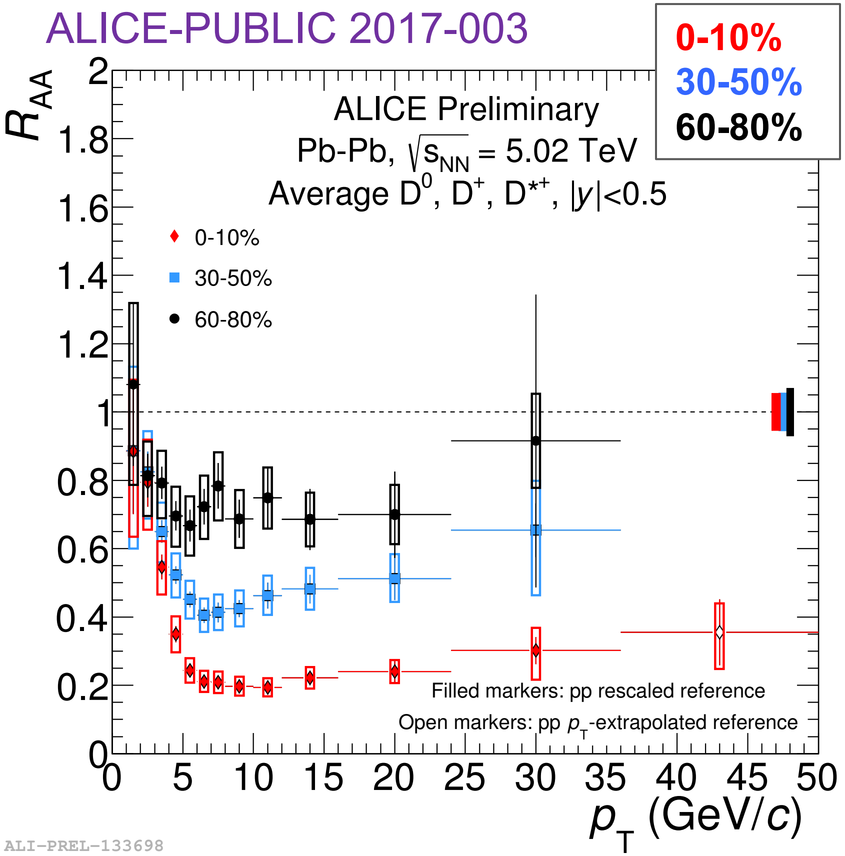


STAR, PRL113 (2014) 142301
ALICE, JHEP1603 (2016) 081

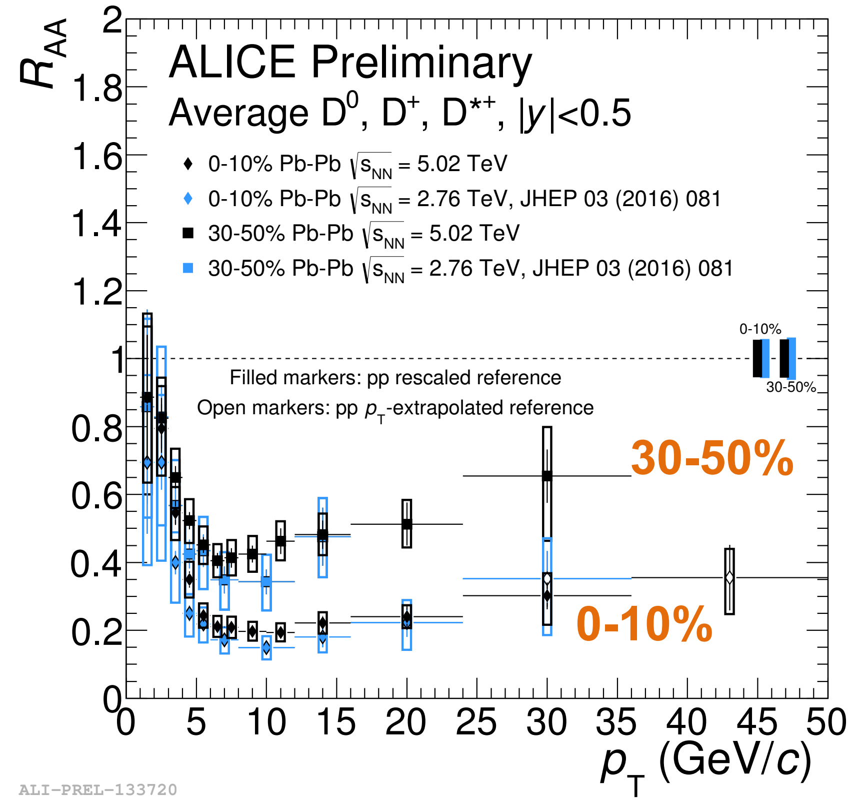
Similar suppression in central A-A collisions at high p_T
Differences at low p_T: radial flow? Shadowing? Recombination?
Crucial to go to p_T~0 at the LHC

D-meson R_{AA} at LHC in Run 2

ALICE-PUBLIC 2017-003



Strong suppression of D^0,D^+,D^{*+} mesons in Pb-Pb at $\sqrt{s_{NN}}$=5.02 TeV, increasing with increasing centrality



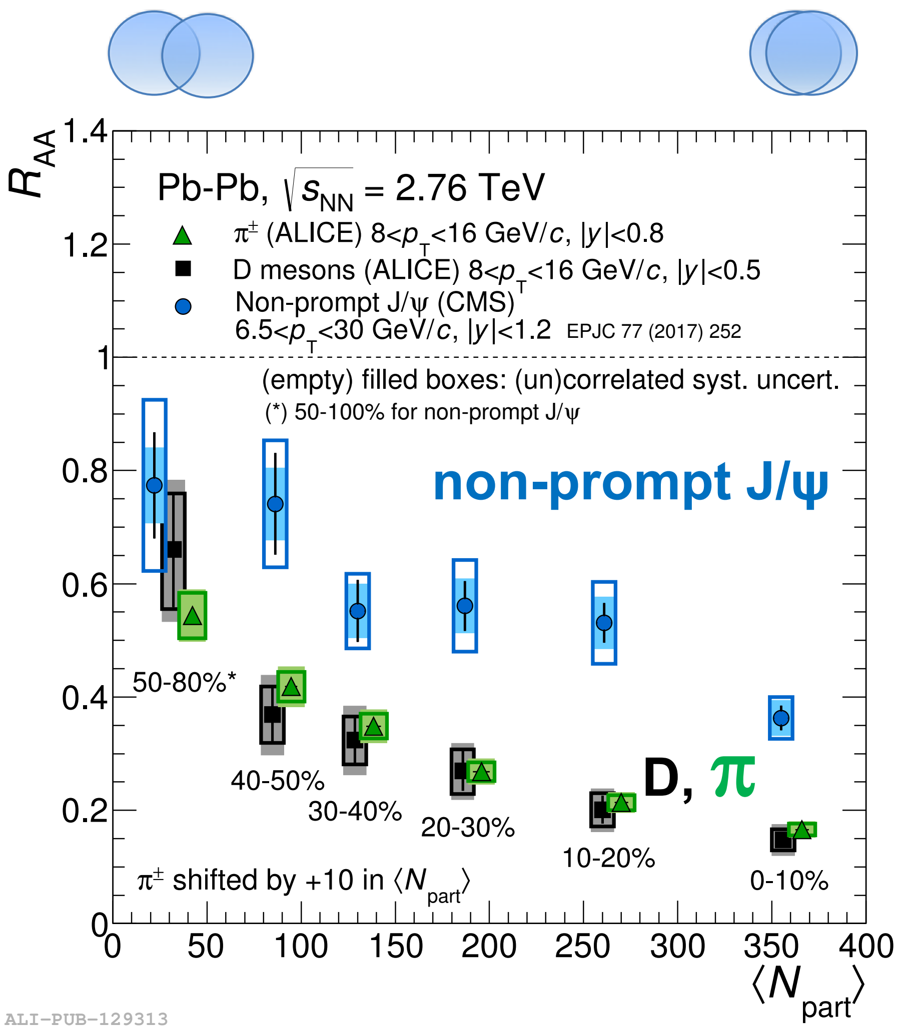
Similar suppression at **$\sqrt{s_{NN}}$=2.76 TeV** and **5.02 TeV**

Higher precision and extended p_T reach with Run 2 data → crucial to measure total charm cross section and constrain models !

Light flavour, charm and beauty R_{AA}

Test parton mass dependence of in-medium energy loss

$\Delta E(g) > \Delta E(uds) > \Delta E(c) > \Delta E(b)$? $\rightarrow R_{AA}(B) > R_{AA}(D) > R_{AA}(\pi)$



D vs **π**: similar R_{AA}, but:

- different vacuum fragmentation of charm vs. light quarks
- different light/heavy quark p_T spectra

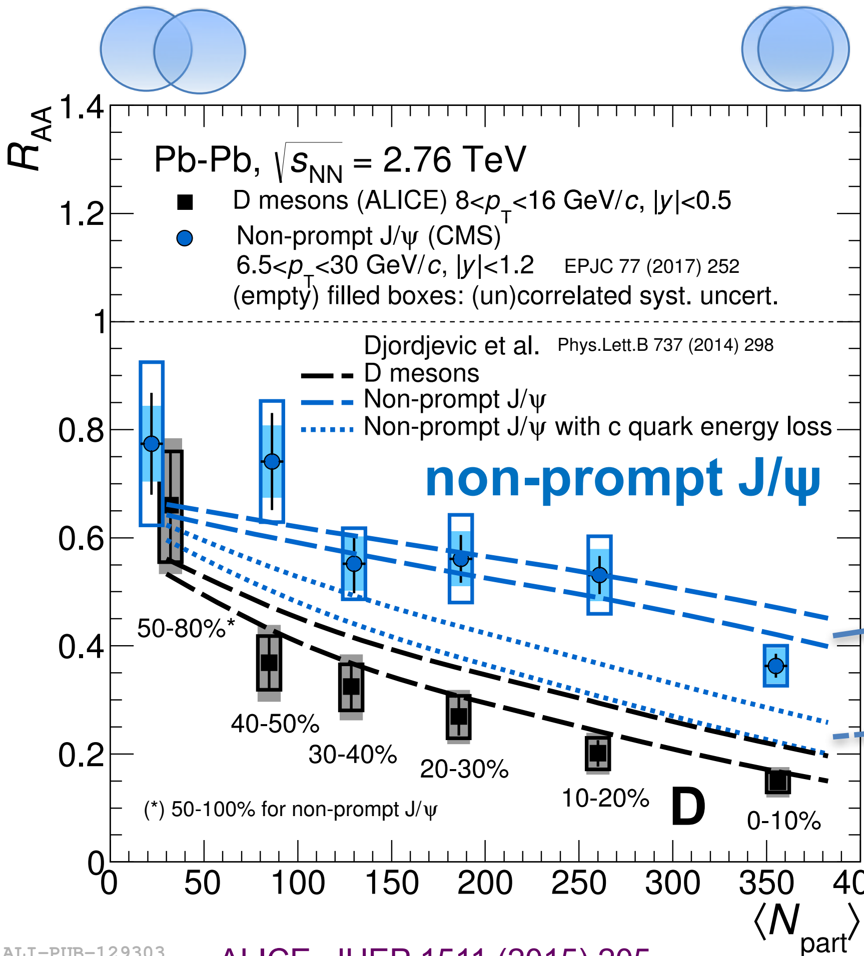
Non-prompt J/ψ vs **D**: difference between **charm** and **beauty** suppression in central collisions
→ parton mass dependence of in-medium energy loss

ALICE, JHEP 1511 (2015) 205
CMS, EPJC 77 (2017) 252

Light flavour, charm and beauty R_{AA}

Test parton mass dependence of in-medium energy loss

$\Delta E(g) > \Delta E(uds) > \Delta E(c) > \Delta E(b) \rightarrow R_{AA}(B) > R_{AA}(D) > R_{AA}(\pi)$?



ALICE, JHEP 1511 (2015) 205
CMS, EPJC 77 (2017) 252

Non-prompt J/ψ vs **D**: difference between **charm** and **beauty** suppression in central collisions → parton mass dependence of in-medium energy loss

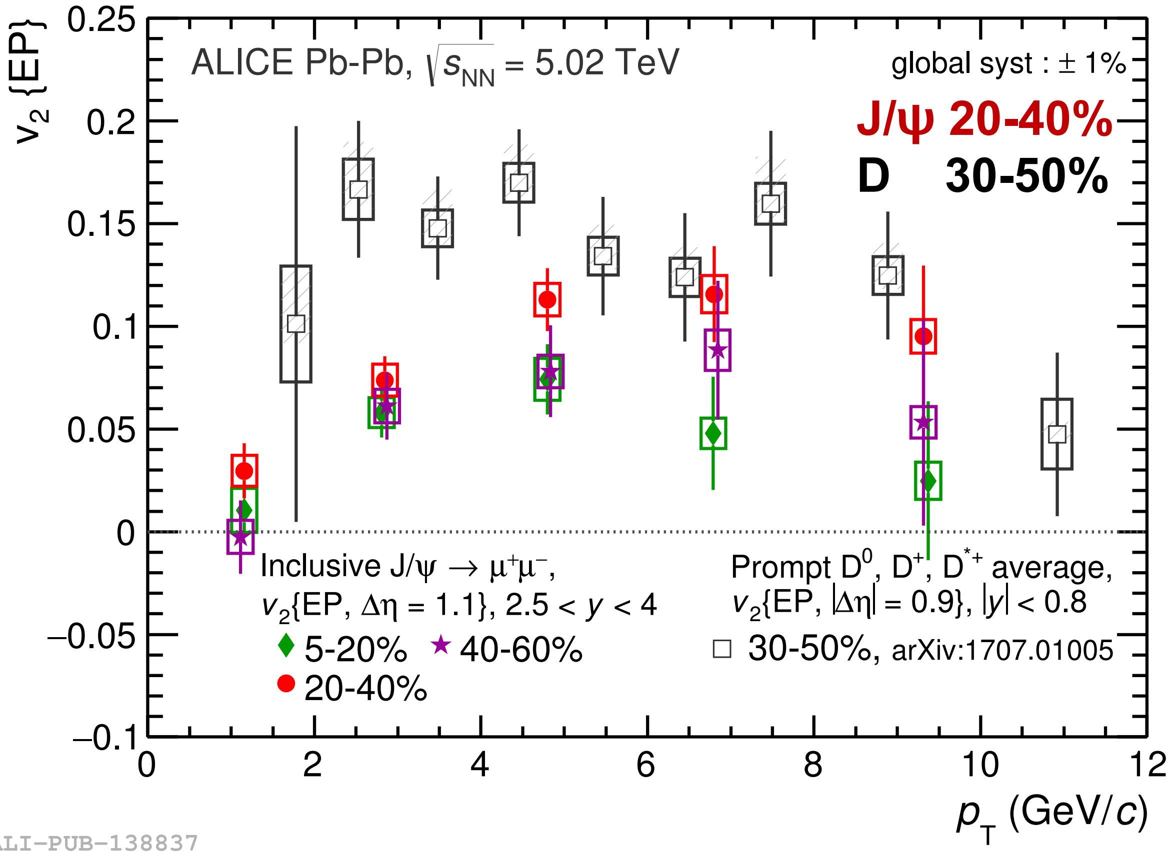
Described by **model with mass dependent energy loss**:

- **b mass** for non-prompt J/ψ
- **c mass** for non-prompt J/ψ

Difference comes from the different masses

M.Djordjevic, PRL 112, 042302 (2014)

J/ψ and D-meson elliptic flow



ALI-PUB-138837

ALICE:
arXiv:1707.01005
arXiv:1709.05260

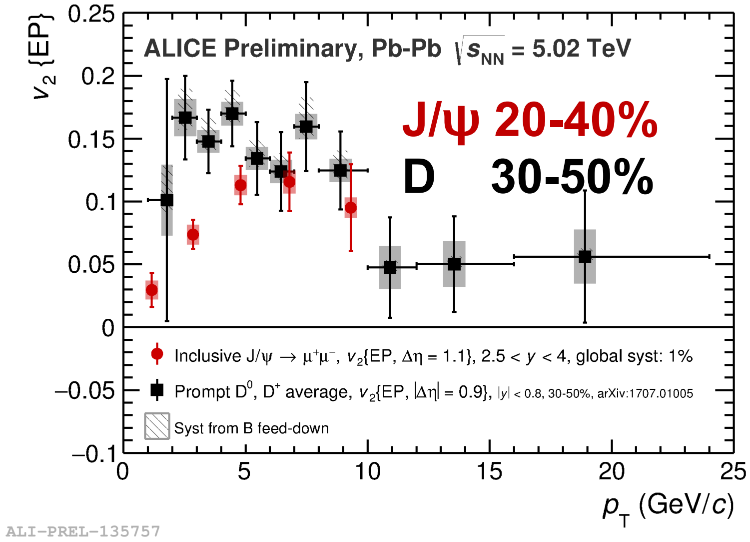
If quarkonium formed by **recombination** of $c\bar{c}$ close in phase space, and charm is "flowing"
→ $v_2(J/\psi)>0$

PRL 111 (2013) 162301

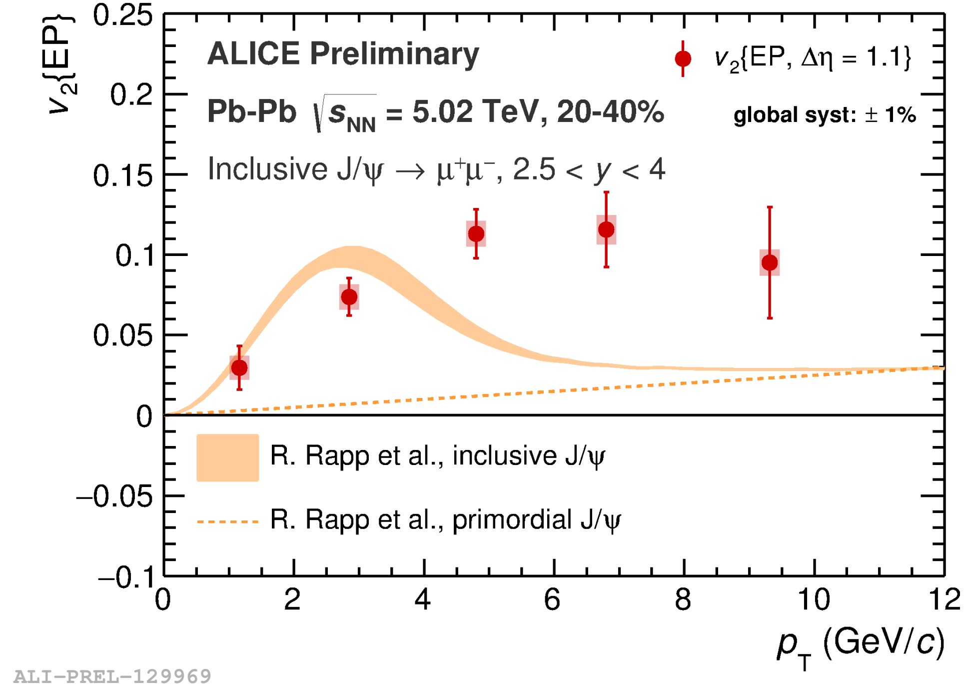
Positive J/ψ v_2 in semi-central collisions (20-40%)

Similar v_2 values for **open** and **hidden** charm
→ **Charm quarks take part in the collective motion of the system** (via subsequent collisions)

J/ψ flow

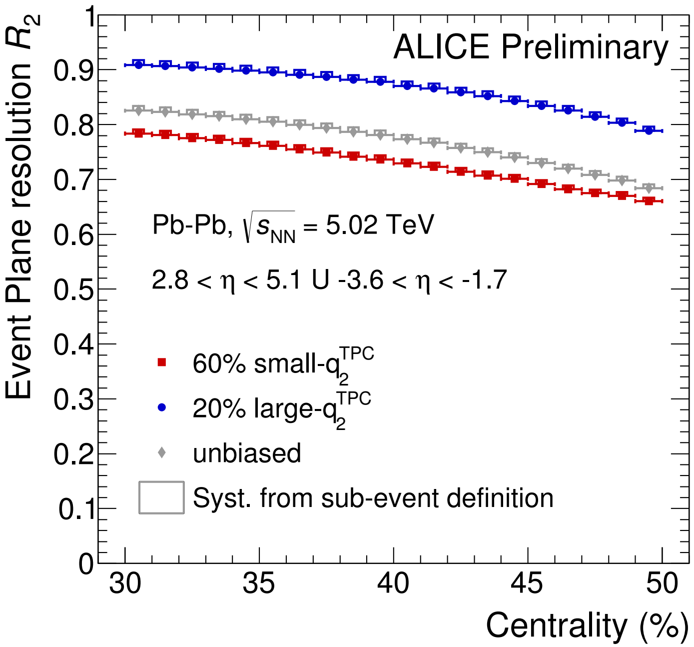


ALICE Preliminary, Pb-Pb $\sqrt{s_{NN}}$ = 5.02 TeV
J/ψ 20-40%
D 30-50%
Inclusive J/ψ → μ⁺μ⁻, v_2{EP, Δη = 1.1}, 2.5 < y < 4, global syst: 1%
Prompt D⁰, D⁺ average, v_2{EP, |Δη| = 0.9}, |y| < 0.8, 30-50%, arXiv:1707.01005
Syst from B feed-down
v_2{EP}
p_T (GeV/c)
ALI-PREL-135757

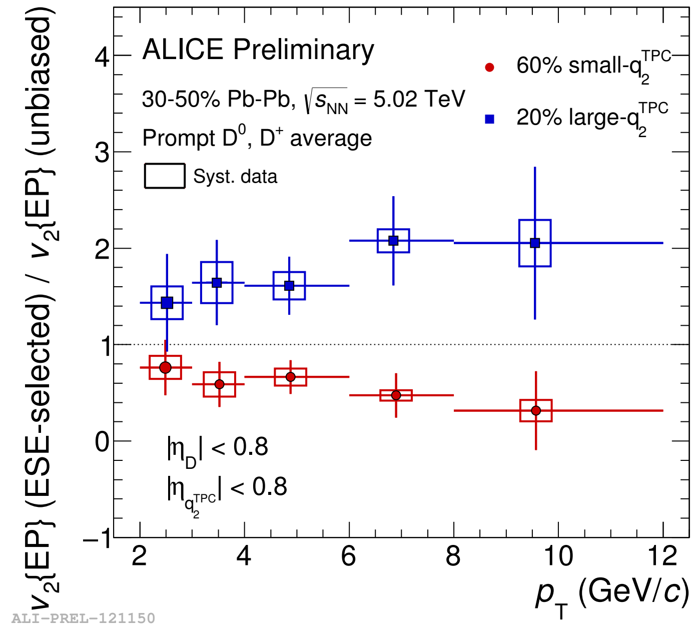


ALICE Preliminary
Pb-Pb $\sqrt{s_{NN}}$ = 5.02 TeV, 20-40%
Inclusive J/ψ → μ⁺μ⁻, 2.5 < y < 4
v_2{EP, Δη = 1.1}
global syst: ± 1%
R. Rapp et al., inclusive J/ψ
R. Rapp et al., primordial J/ψ
v_2{EP}
p_T (GeV/c)
ALI-PREL-129969

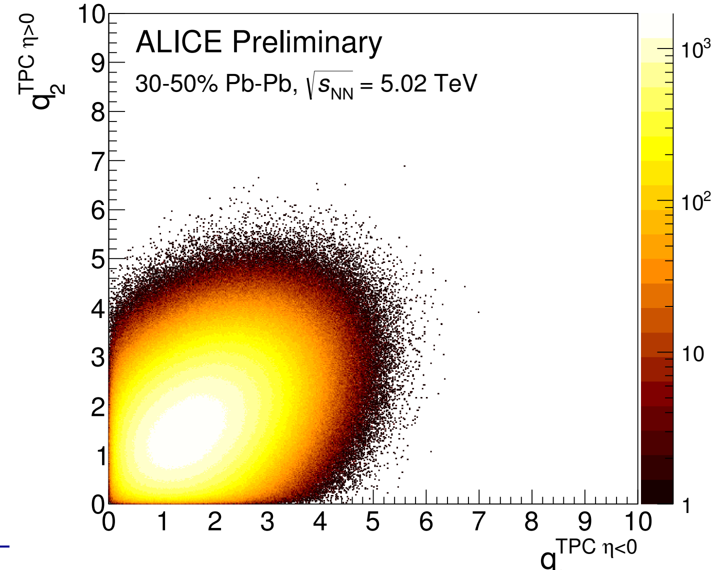
D v_2 with ESE



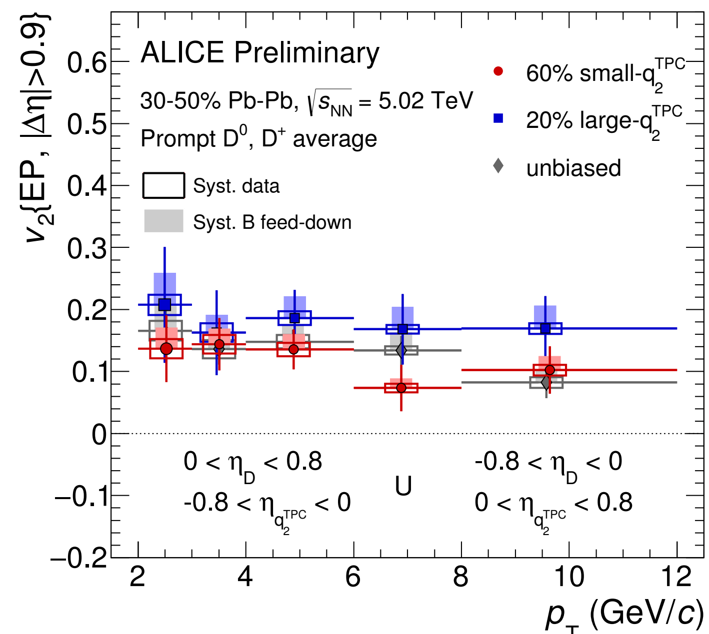
ALI-PREL-121073



ALI-PREL-121150



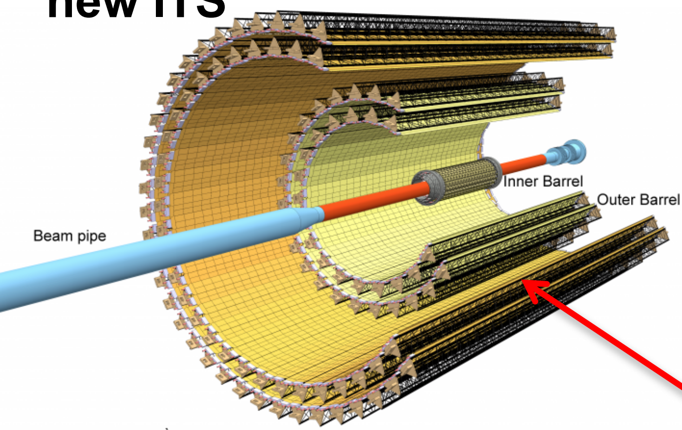
ALI-PREL-121027



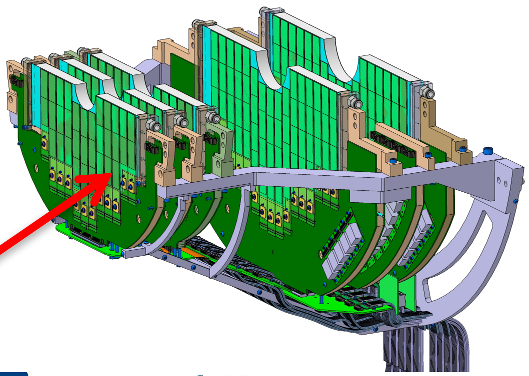
ALI-PREL-121131

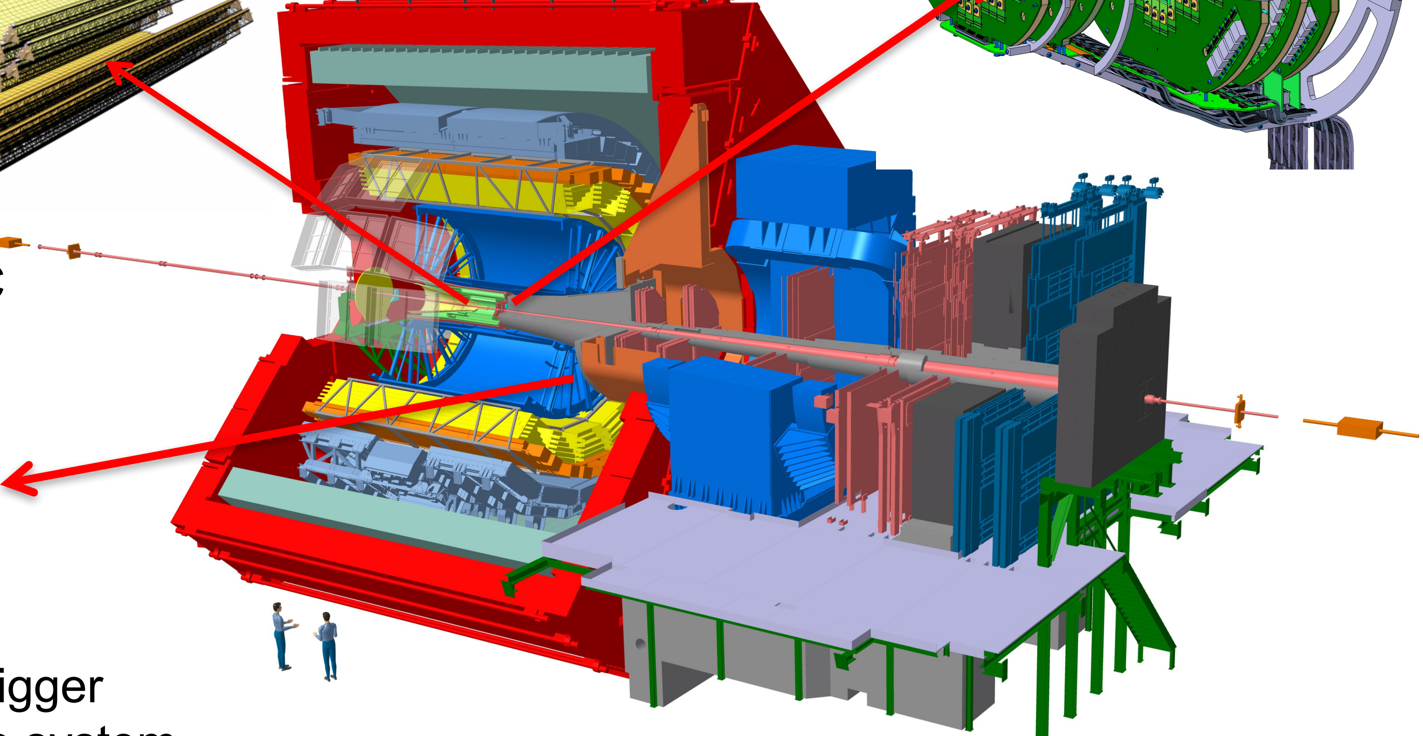
ALICE after Run-2

new ITS

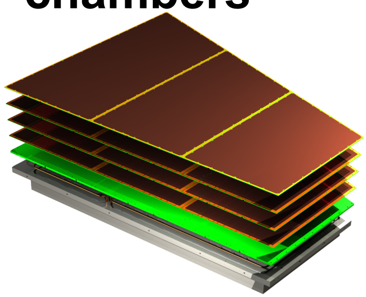


Pixel muon forward tracker





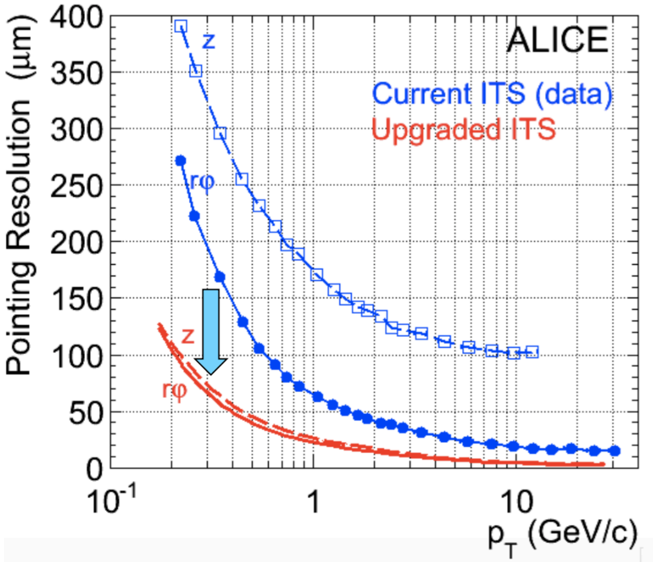
GEM-based TPC chambers



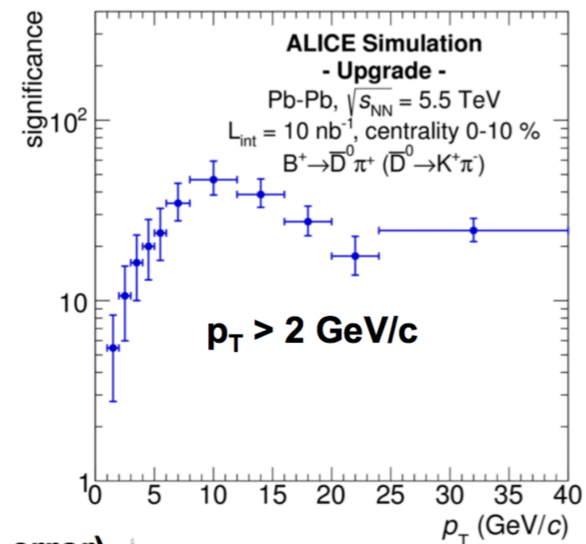
Fast Interaction Trigger
New Online-Offline system
Readout upgrade of other detectors
Goal: collect 10 nb^{-1} of min. bias Pb-Pb collisions
x100 gain w.r.t. run 1+2 for min. bias

All projects moving into production phase this year

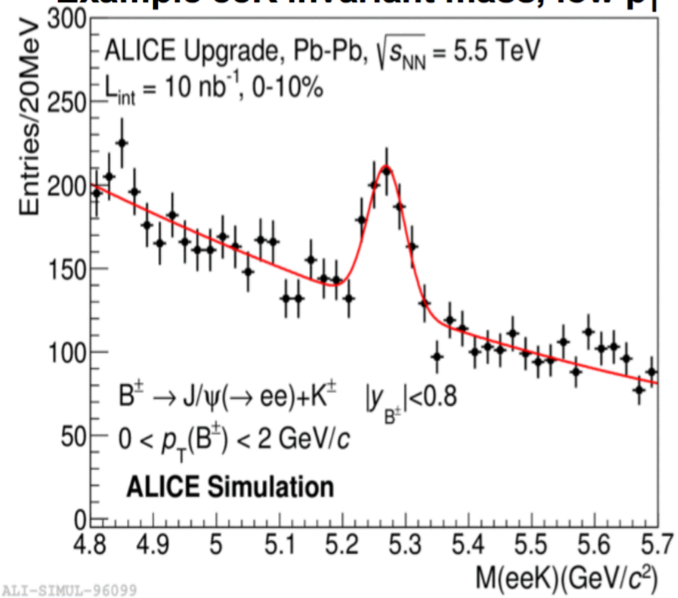
ALICE Upgraded Inner Tracking System



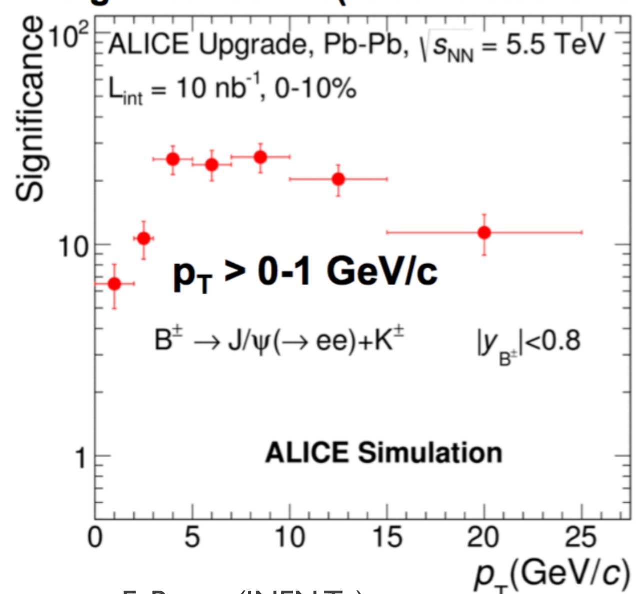
Significance = 1/(relative stat. error)



Example eeK invariant mass, low p_T

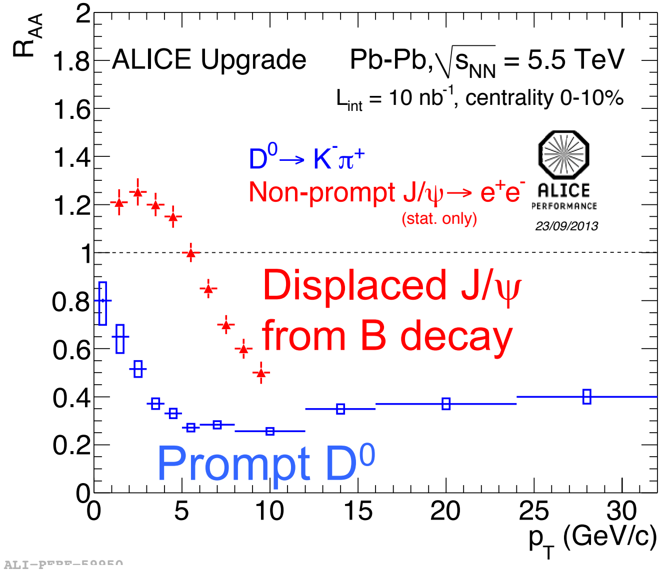


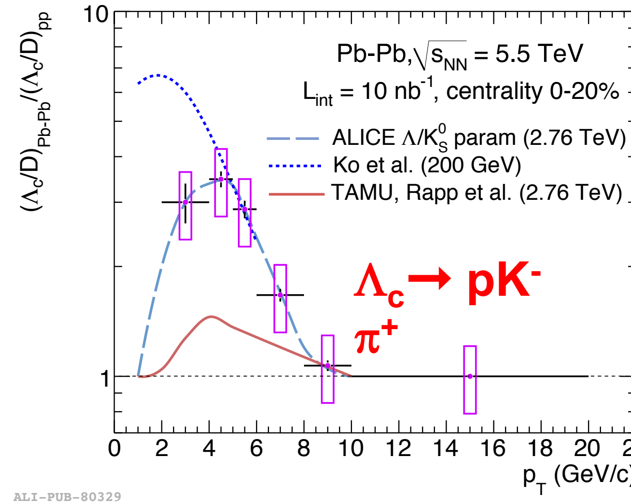
Significance = 1/(relative stat. error)

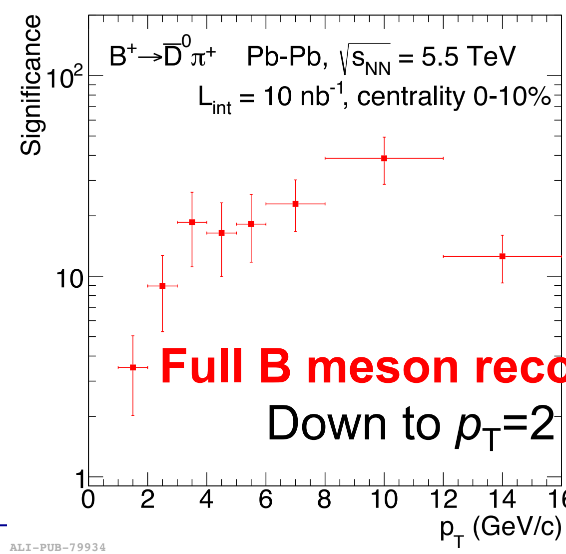


Performance examples for HF signals

Access to charm and beauty down to very low p_T







Full B meson reconstruction

Down to p_T=2 GeV/c