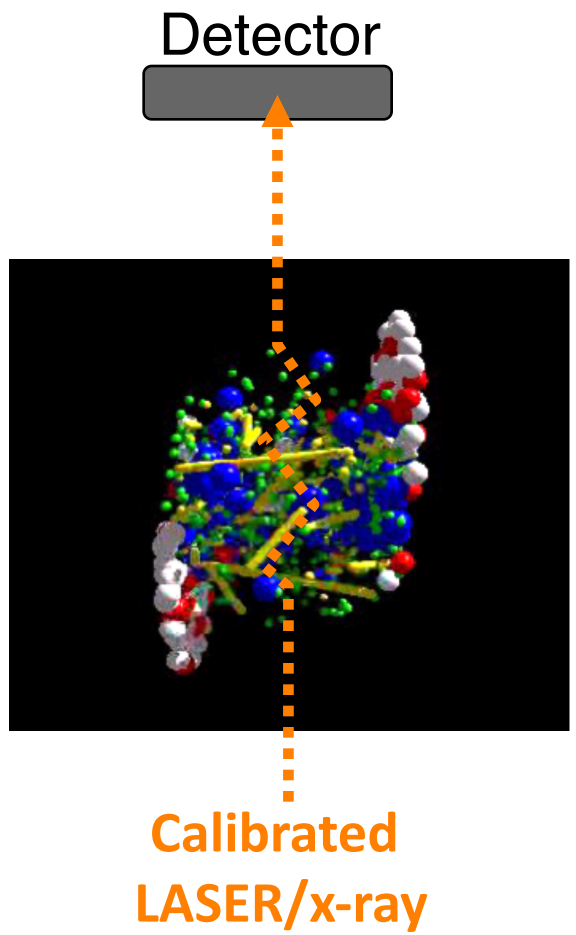
Open heavy-flavour and Jets

- as probes for the QGP -

Elena Bruna (INFN Torino)

Probing the Quark-Gluon Plasma

Goal: create a **new state of matter** with free quarks and gluons, the Quark-Gluon Plasma (QGP)
How: **colliding heavy nuclei** at high energies



Probing the Quark-Gluon Plasma

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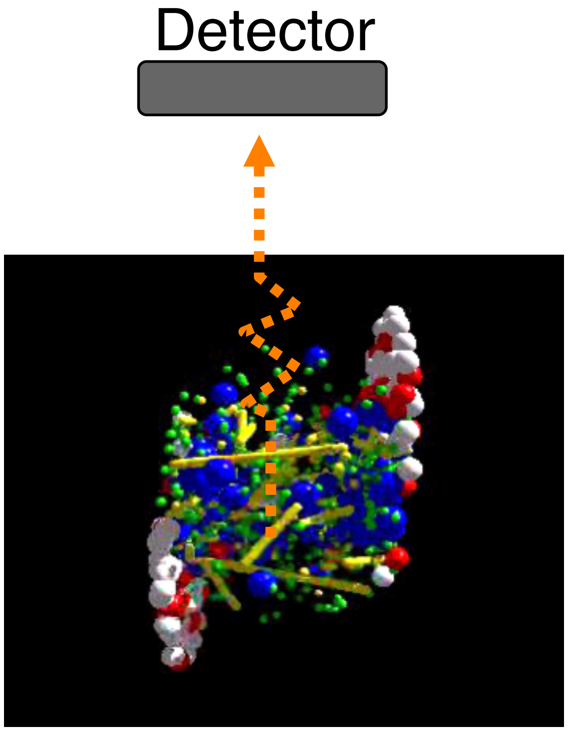
Self-generated "hard" probes



Medium Tomography!

Hard processes (jets, open and hidden charm, beauty, …) make perturbative QCD applicable
→ high momentum transfer Q^2

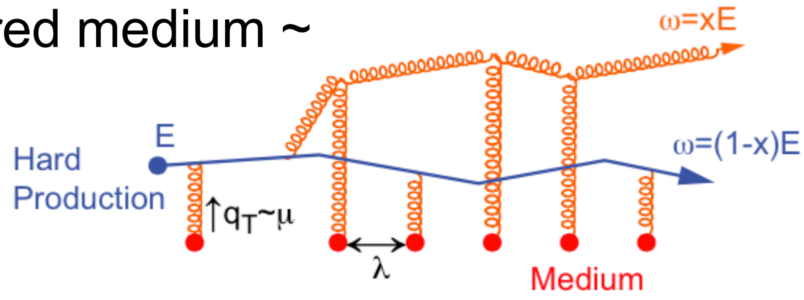
Hard processes scale as N_{bin}

Hidden charm and beauty: see R. Arnaldi's talk

Hard probes in the medium

1. Multiple final-state gluon radiation off the produced hard parton induced by the traversed dense colored medium ~ "Gluon Bremsstrahlung"

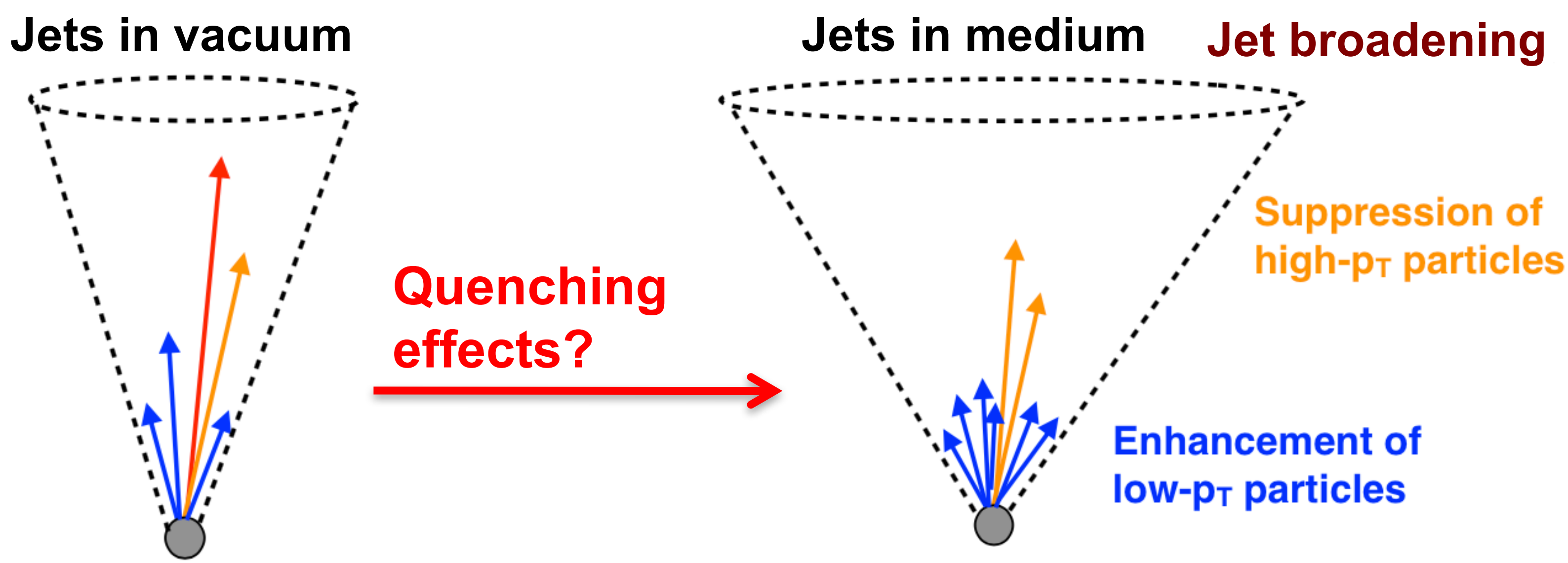
2. Energy loss by multiple elastic collisions



Effects:

-Softening of high-p_T particles

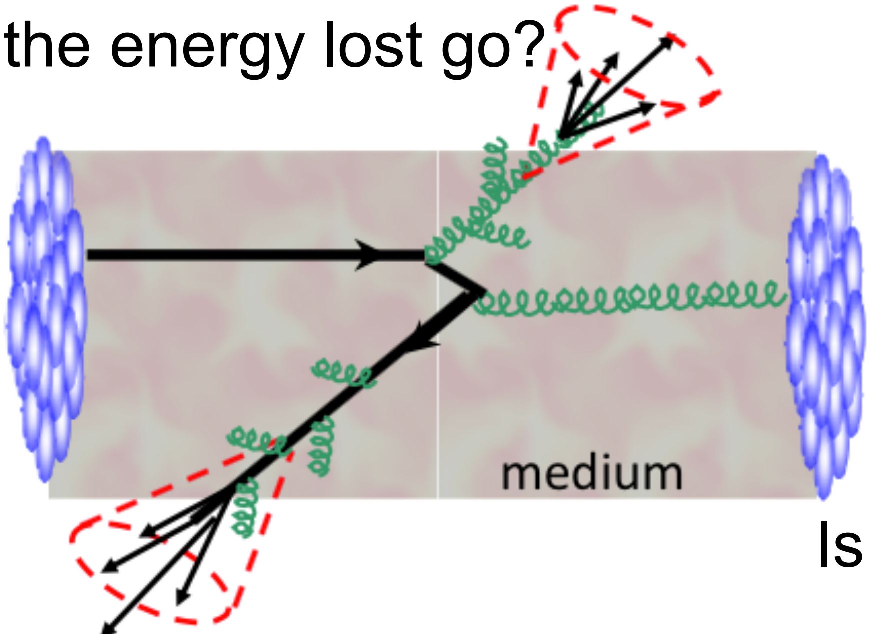
-Modification of the Jet Structure/Fragmentation Function



Jets and heavy flavours in QGP: questions to be answered

Can lost energy be recovered with jet reconstruction?

Where does the energy lost go?



Is jet structure modified?

Parton mass/colour dependence of energy loss?

$$\langle \Delta E \rangle \propto \alpha_s C_R \hat{q} L^2$$

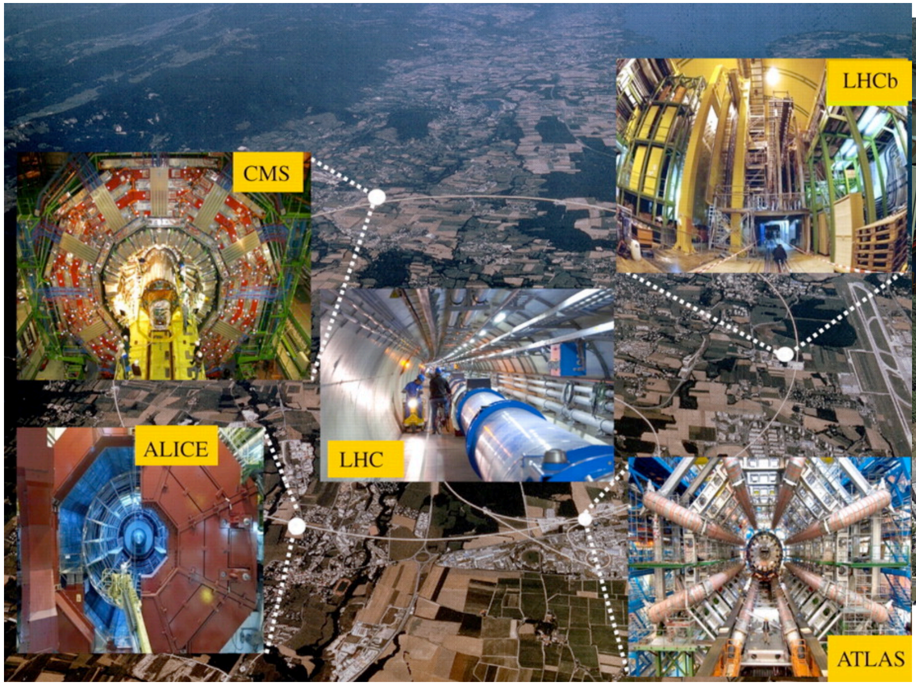
$$\Delta E_g > \Delta E_{u,d} > \Delta E_c > \Delta E_b$$

Are there initial state effect?

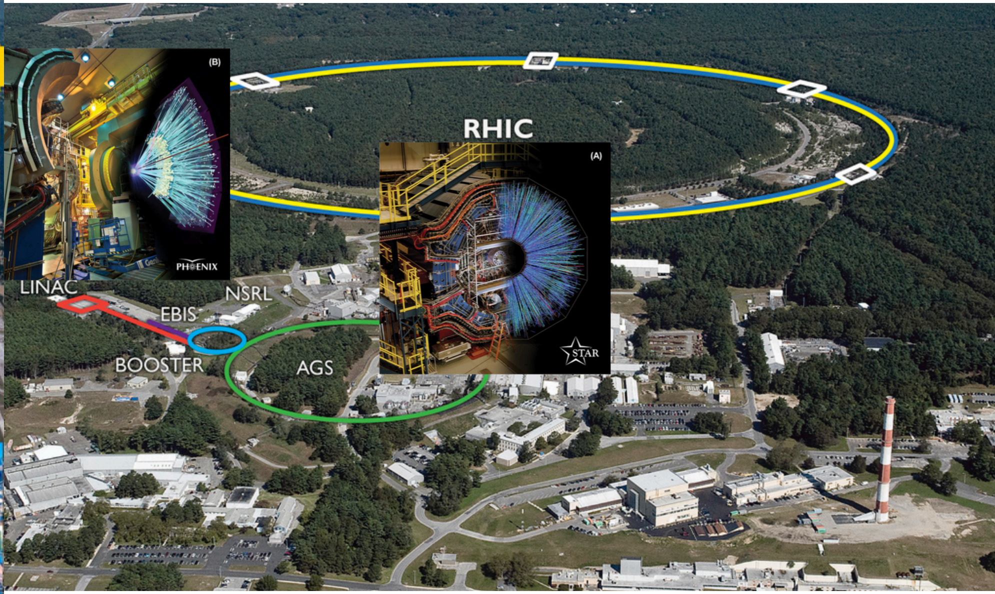
Are hard partons affected by collective expansion of the medium?

Where to study heavy-ion collisions

The Large Hadron Collider (CERN)



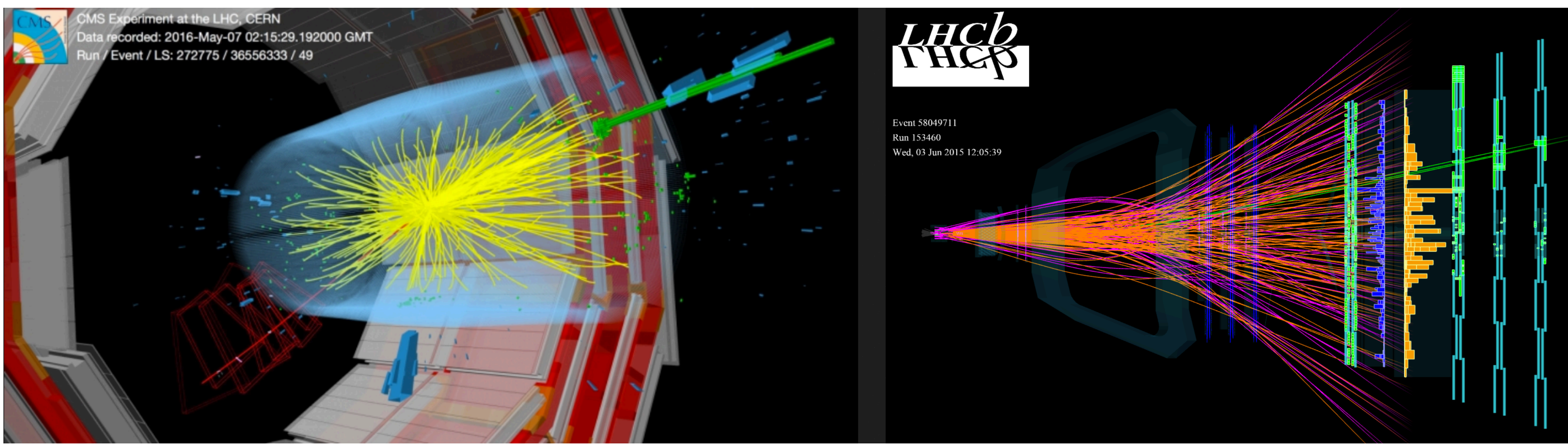
The Relativistic Heavy Ion Collider (BNL)



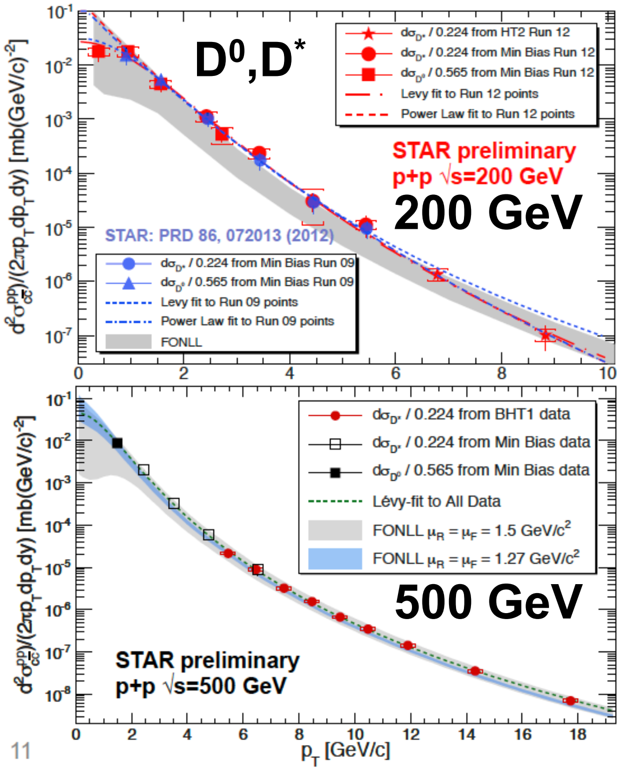
pp: 2.76, 5, 7, 8, 13 TeV
p+Pb: 5.02 TeV
Pb+Pb: 2.76, 5.02 TeV

pp: 200, 500 GeV
d+Au: 200 GeV
Au+Au, Cu+Cu: 200 GeV (and lower)

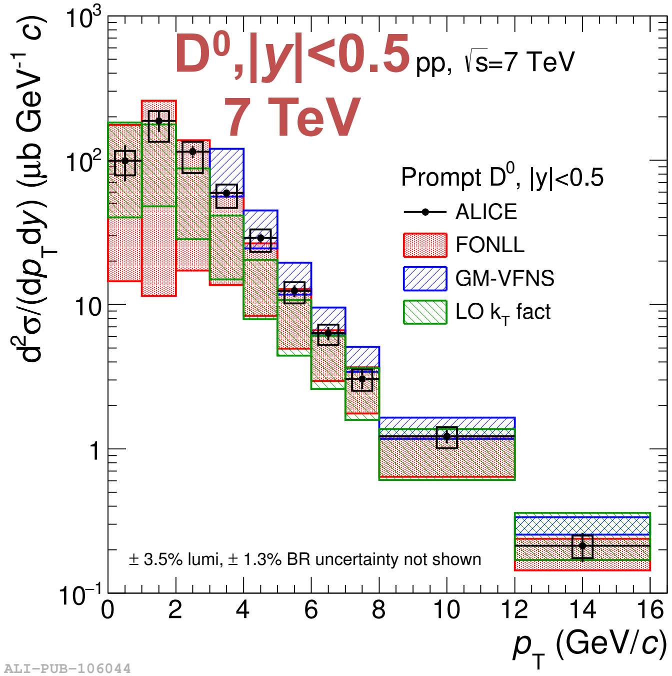
pp collisions: the benchmark system



Charm in pp: Test for pQCD and reference for pA and AA



STAR, PRD 86 (2012) 072013



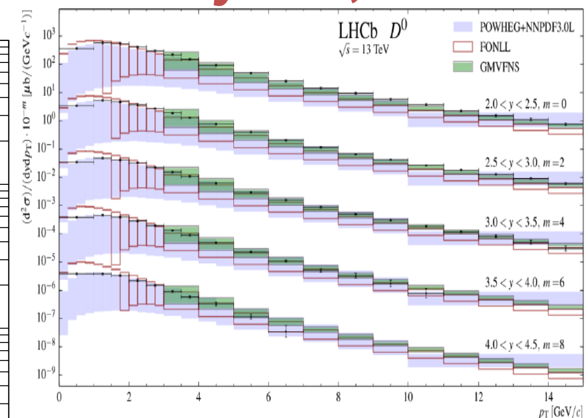
ALICE, Phys. Rev. C 94, 054908 (2016)
JHEP 1201 (2012) 128

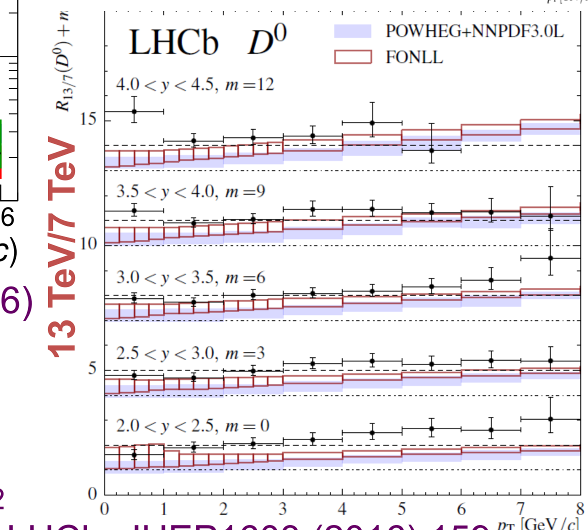
FONLL: JHEP, 1210 (2012) 137

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



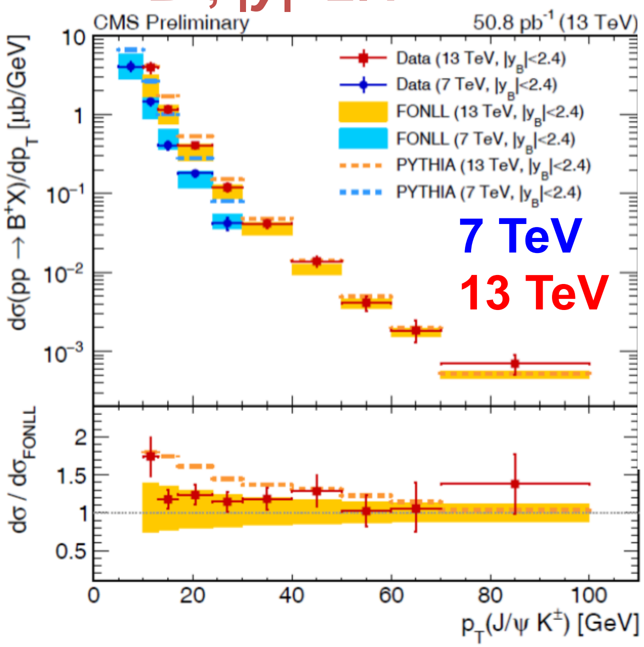


LHCb, JHEP1603 (2016) 159

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

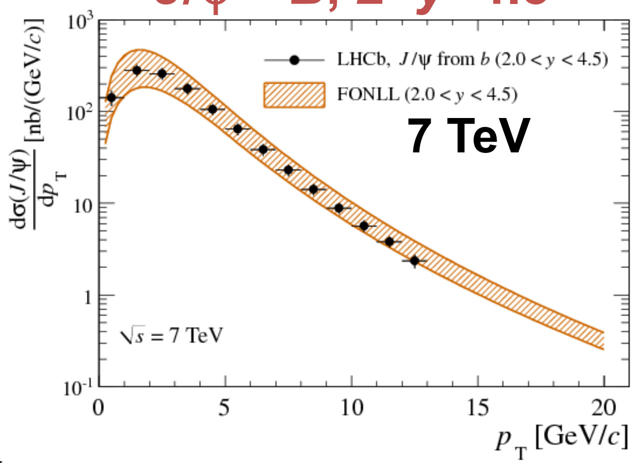
Beauty in pp: Test for pQCD and reference for pA and AA

B^+, $|y|<2.4$



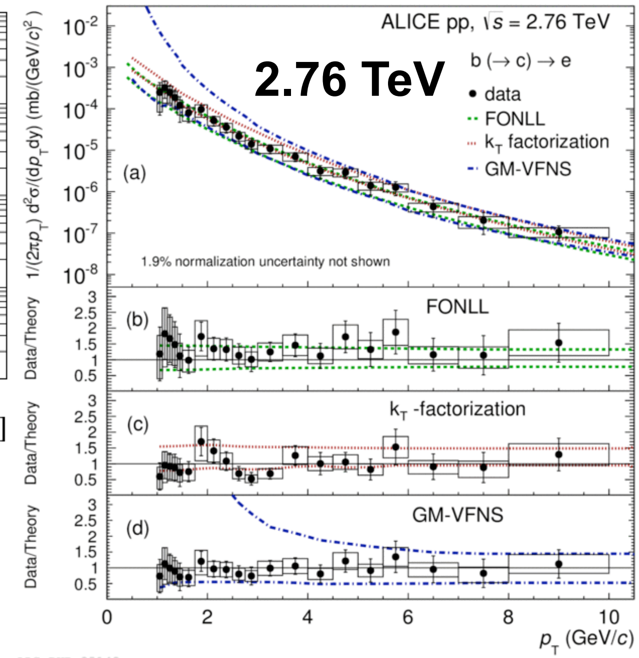
CMS, PRL 106 (2011) 112001
CMS-PAS-BPH-15-004

$J/\psi \leftarrow B$, $2<y<4.5$



LHCb, EPJ C71 (2011) 1645
JHEP 1510 (2015) 172

$b \rightarrow e$, $0<|y|<0.8$

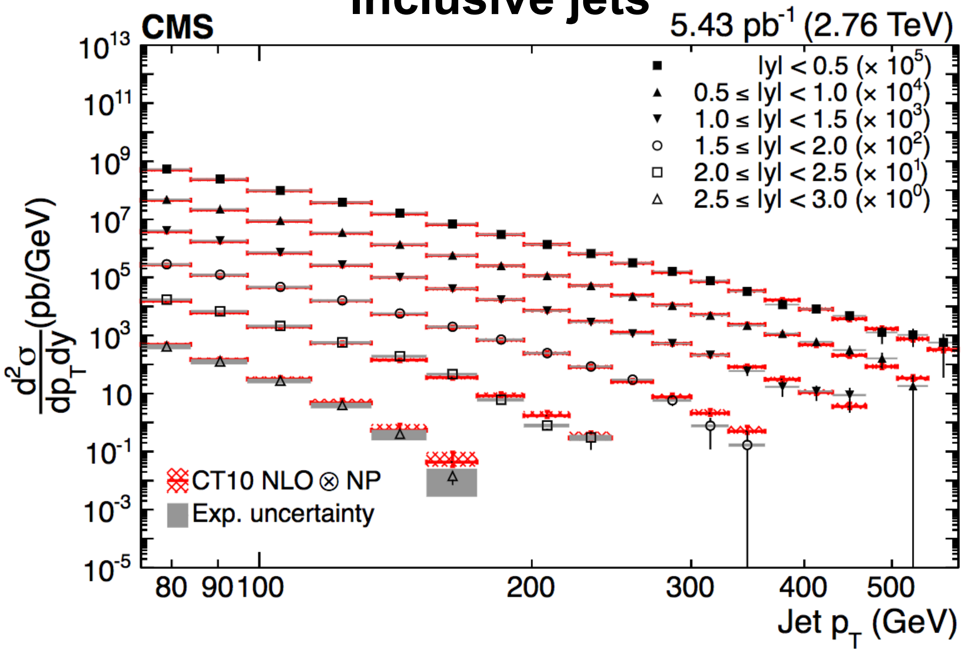


ALICE, PRD 91 (2015) 012001

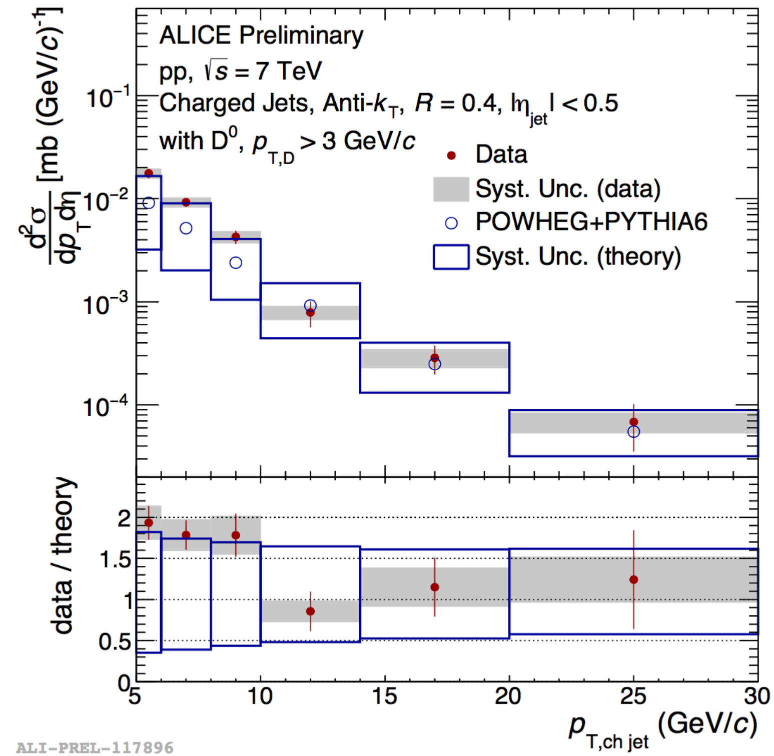
Beauty cross sections at RHIC and LHC energies well described by pQCD predictions.

Jets in pp collisions

Inclusive jets



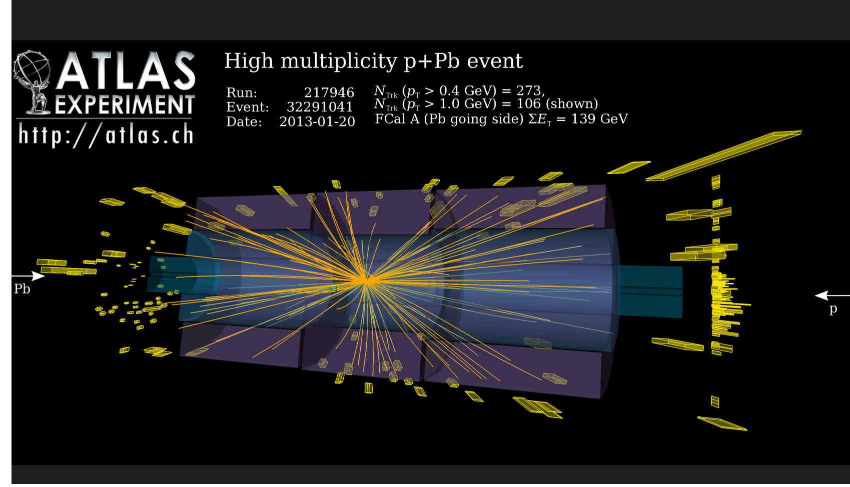
D-tagged jets



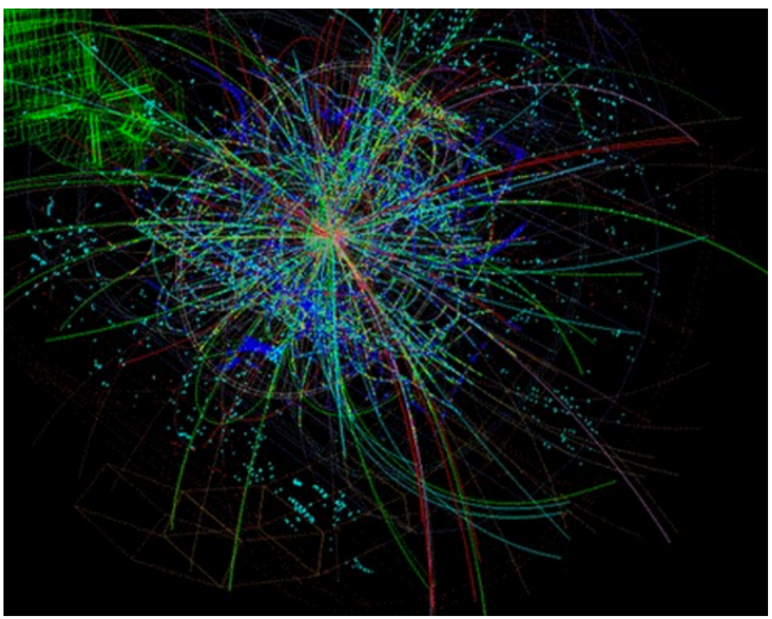
Precise inclusive jet measurements, agreement with NLO over several orders of magnitude

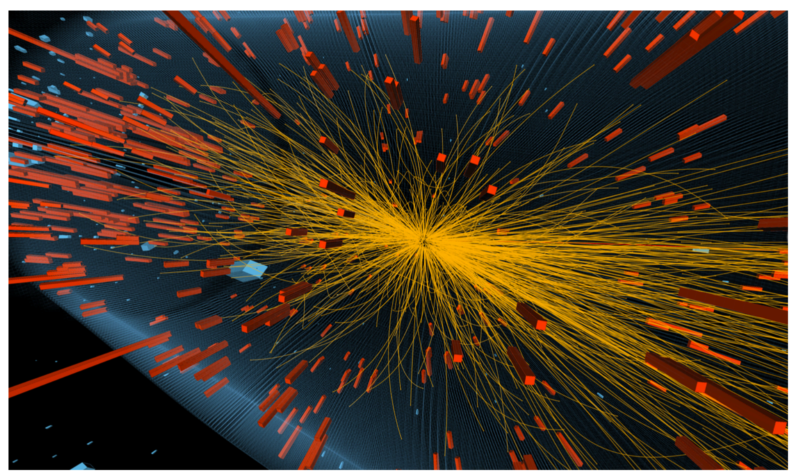
Charged jets with D^0 mesons
Measurement down to low-p_T

Measurement described by POWHEG +PYTHIA6 simulations



p-A collisions: the control experiment

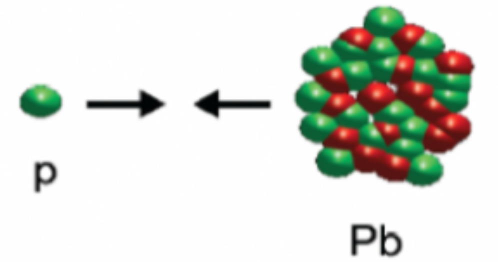




HF in pA: control experiment

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

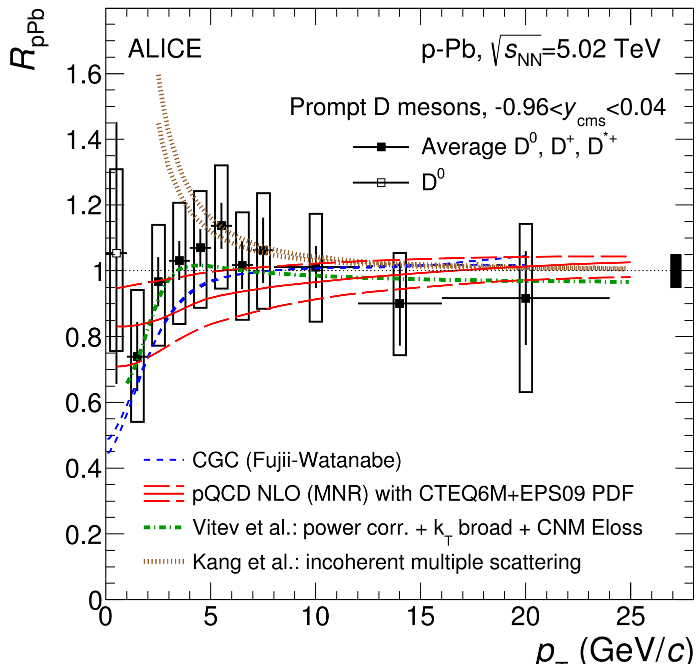
If pA is a superposition of binary pp collisions and no cold nuclear effects → R_{pPb}=1



pA a control experiment and reference for A-A collisions

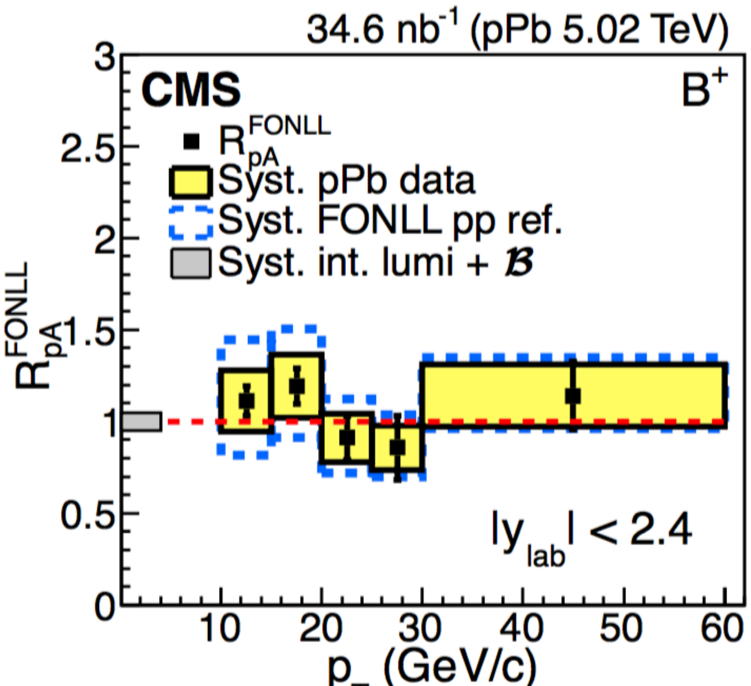
HF in pA: control experiment

D mesons



ALICE, Phys. Rev. C 94 (2016) 054908
PRL 113 (2014) 232301

B mesons



CMS, PRL 116 (2016) 032301

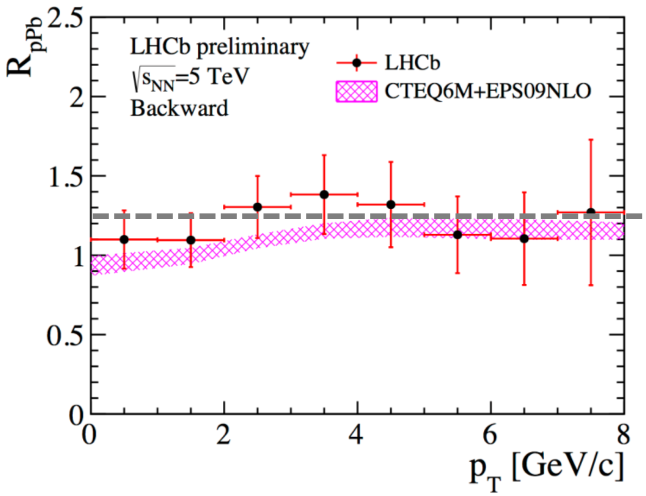
H. Fuji et al., Nucl Phys A920 (2013) 78
M. Mangano et al., Nucl. Phys. B373 (1992) 295
K. J. Eskola et al., JHEP 0904 (2009) 065
Vitev et al., Phys. Rev. C 80 (2009) 05490
Z.-B. Kang et al., Phys. Lett.B740 (2015)23

R_{pPb}~1 for D and B mesons in p-Pb collisions
Models with Cold Nuclear Matter effects describe the data within uncertainties

HF in pA: different rapidities at LHC

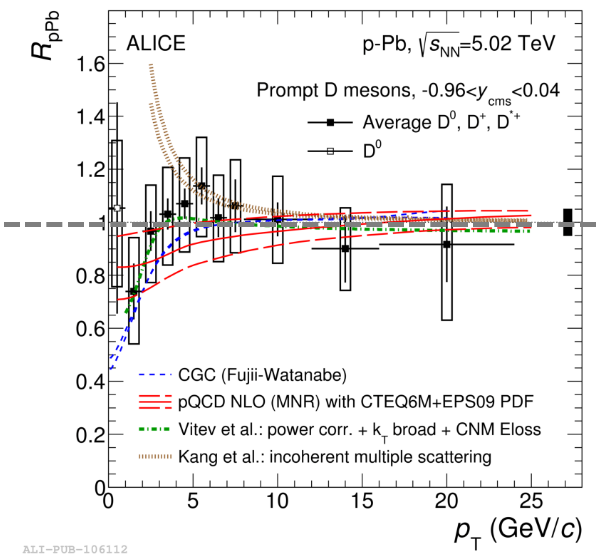
D mesons

Pb-going (backward)



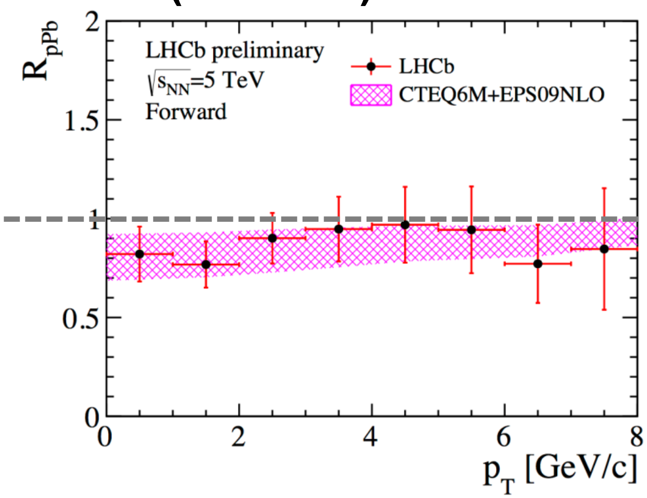
LHCb-CONF-2016-003

mid-rapidity



ALICE, PRL113 (2014), 232301
ALICE, Phys. Rev. C 94, 054908 (2016)

p-going (forward)

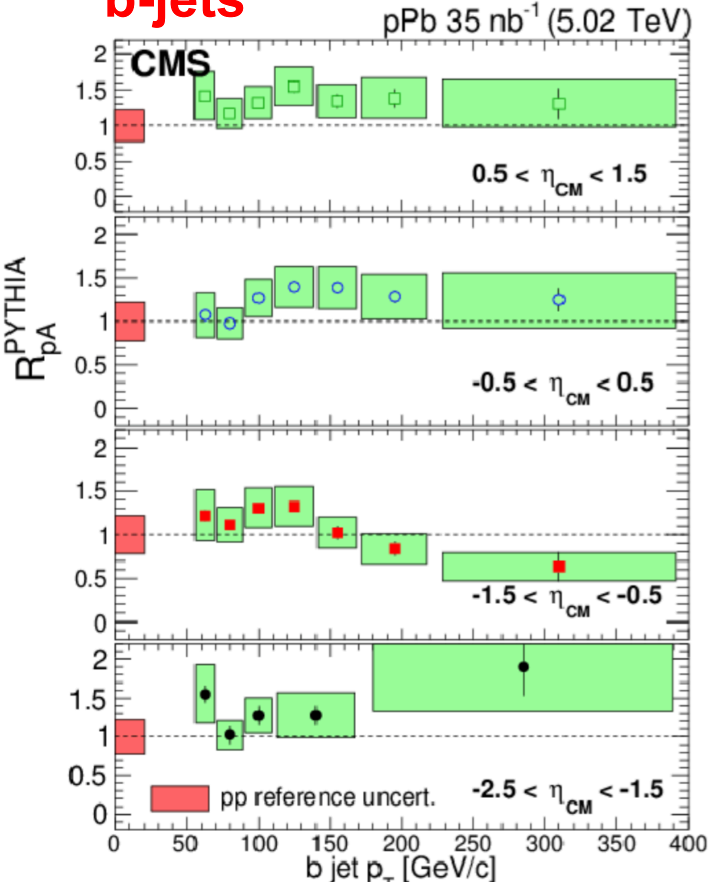


Different *x* regimes explored in different rapidity ranges with HF probes
→shadowing/saturation relevant at low p_T at the LHC

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

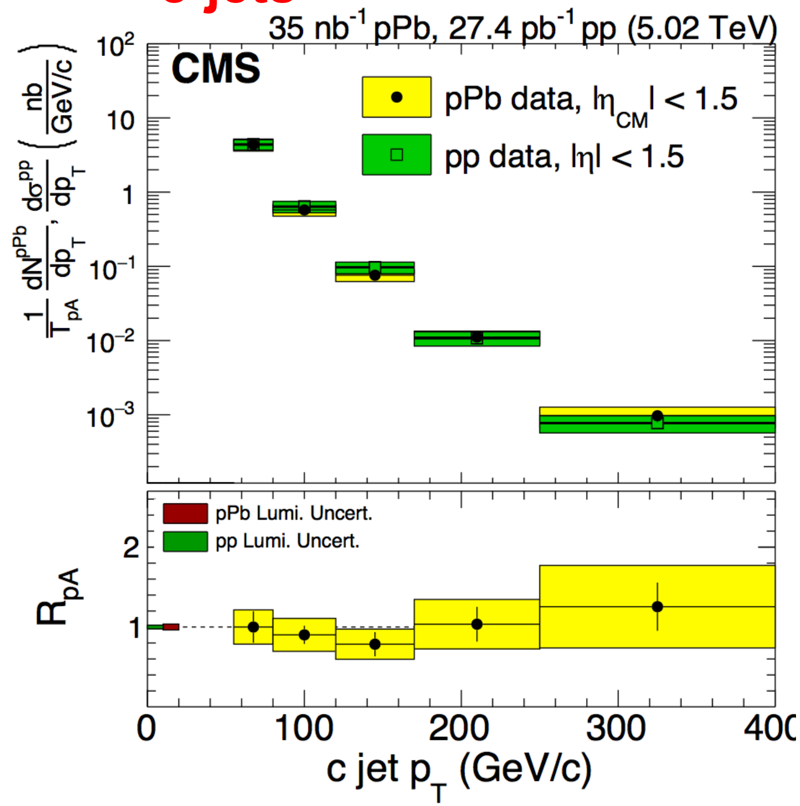
b- and c- jets in pp and p-Pb collisions

b-jets



CMS, PLB 754 (2016) 59

c-jets

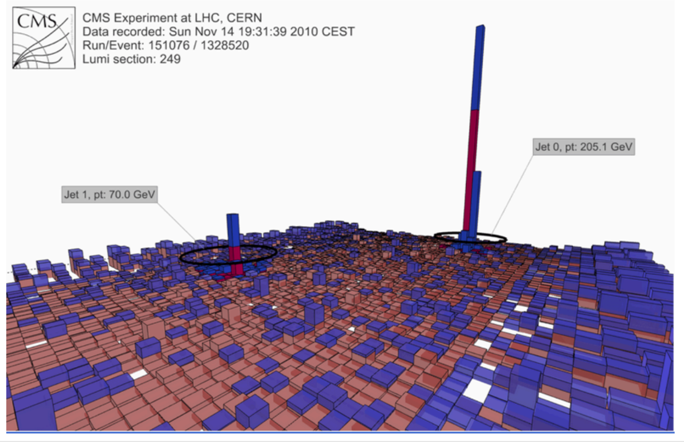


CMS, arXiv: 1612.08972

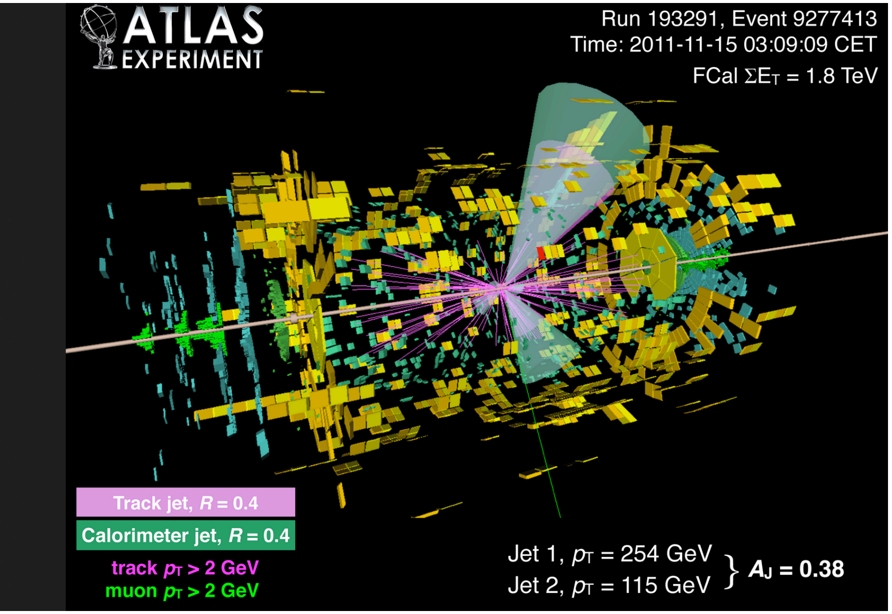
High-p_T jets tagged with charm and beauty quarks

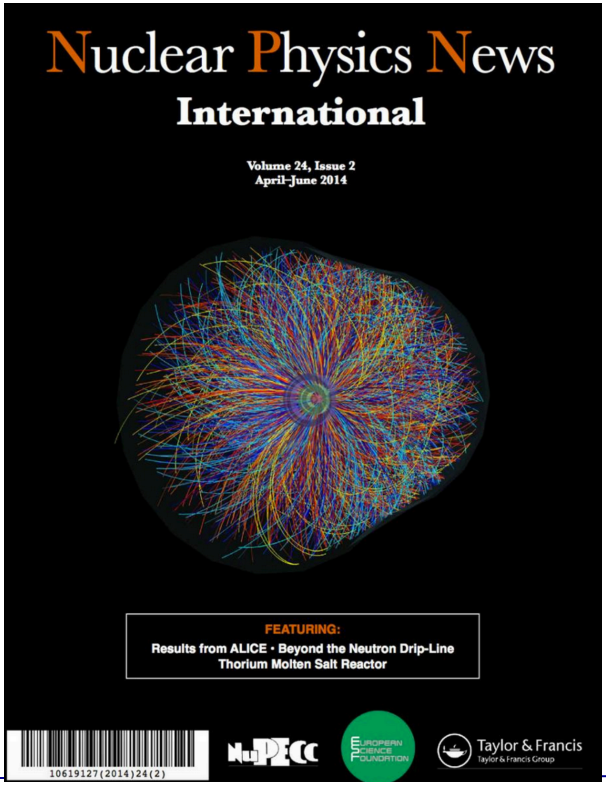
R^{PYTHIA}_{pA}(b-jets)~1, R_{pA}(c-jets)~1 within uncertainties

→No significant cold nuclear effects for jet p_T>50 GeV/c

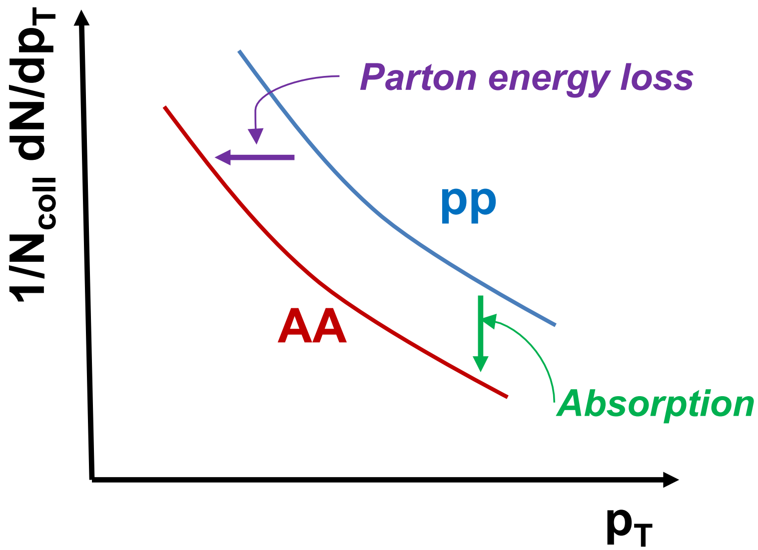


A-A collisions





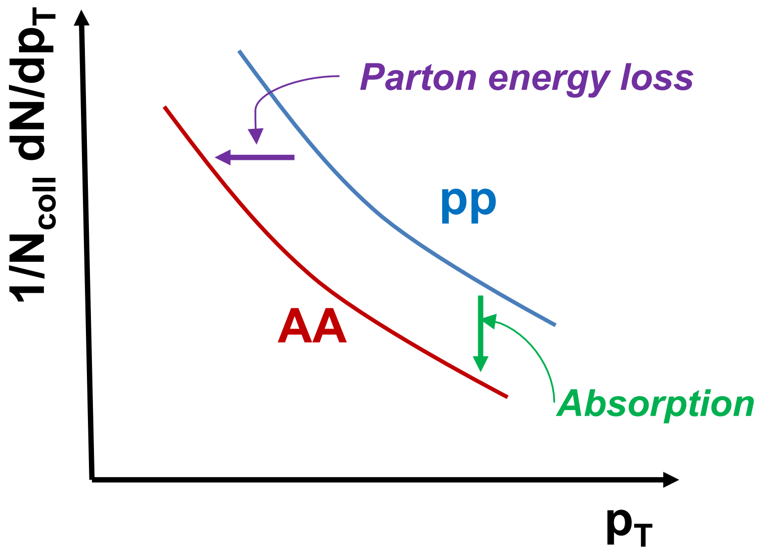
Observables of nuclear effects



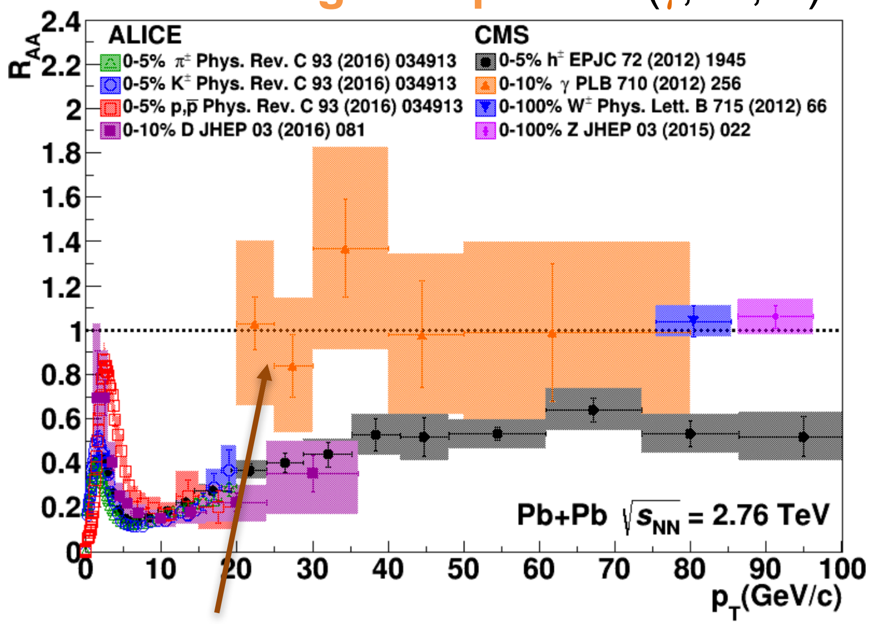
$$R_{AA}^{D}(p_T) = \frac{dN_{AA}^{D}/dp_T}{\langle T_{AA}\rangle \times d\sigma_{pp}^{D}/dp_T}$$

If R_{AA}=1 : no nuclear effects
if R_{AA}≠1 : binary scaling broken.
Energy loss gives rise to R_{AA}<1 at high p_T → Hot nuclear matter effect

Observables of nuclear effects



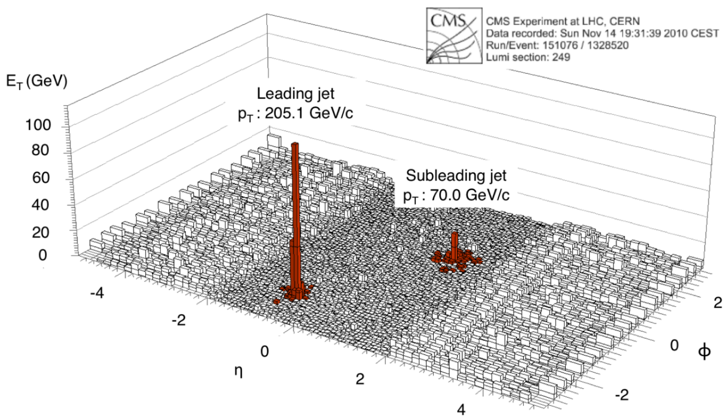
Charged particles (π,K,p,h) +
Electromagnetic probes (γ, W, Z)



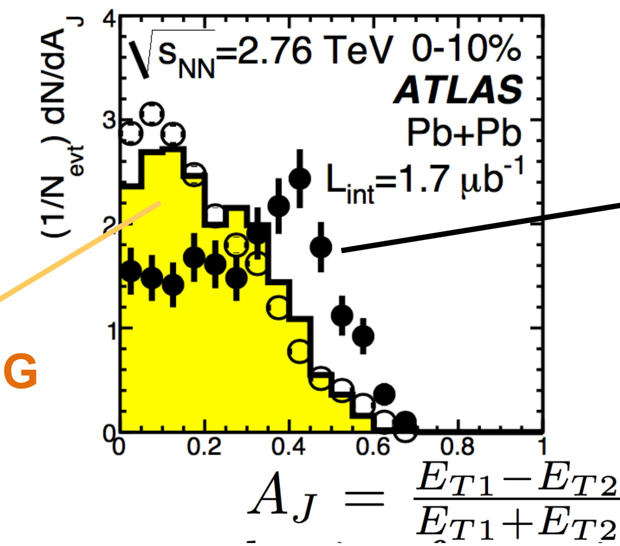
Electromagnetic probes not affected by the medium: excellent calibration tool

If $R_{AA}=1$: no nuclear effects
if $R_{AA}\neq1$: binary scaling broken.
Energy loss gives rise to $R_{AA}<1$ at high p_T → Hot nuclear matter effect

Jets in the medium

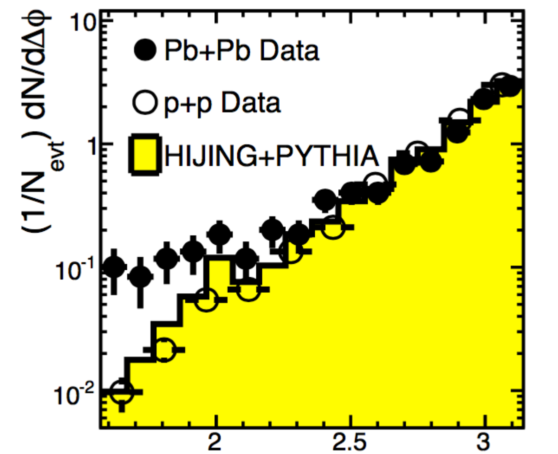


Di-jet asymmetry



0-10% Pb-Pb

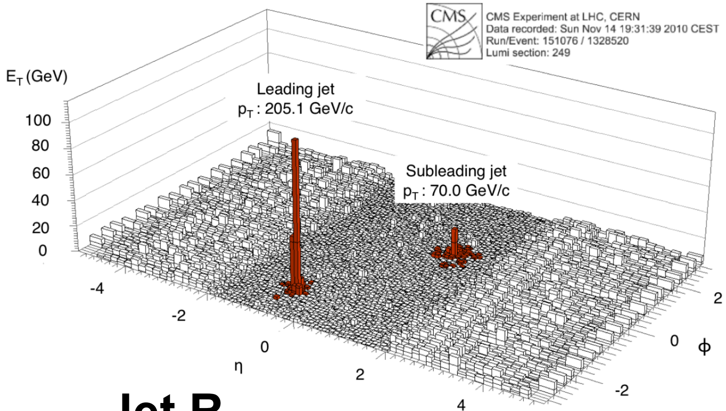
pp, HIJING



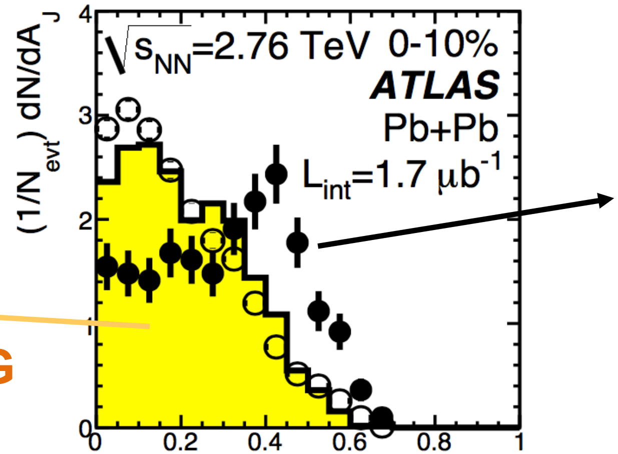
Di-jet Δϕ

Larger di-jet imbalance in Pb-Pb wrt pp

Jets in the medium

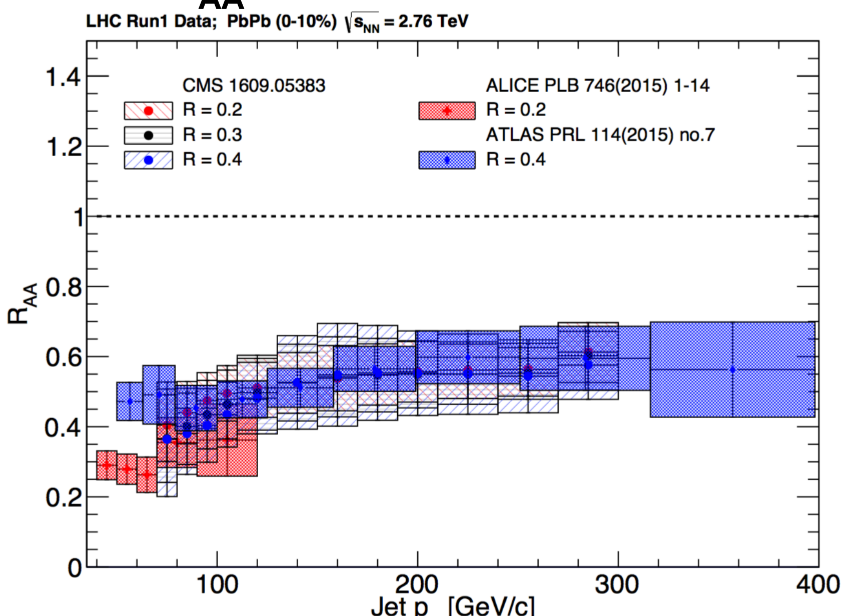


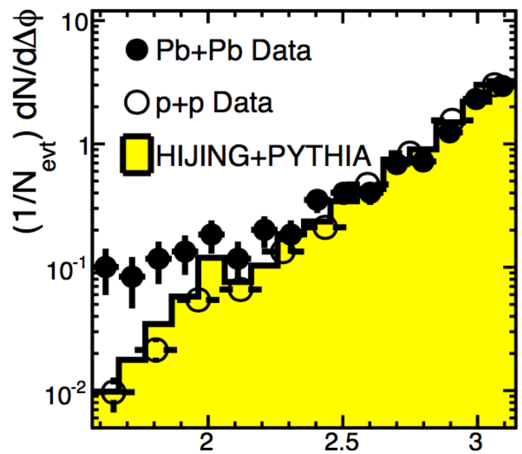
Di-jet asymmetry



$$A_J = \frac{E_{T1} - E_{T2}}{E_{T1} + E_{T2}}$$

Jet R_{AA}



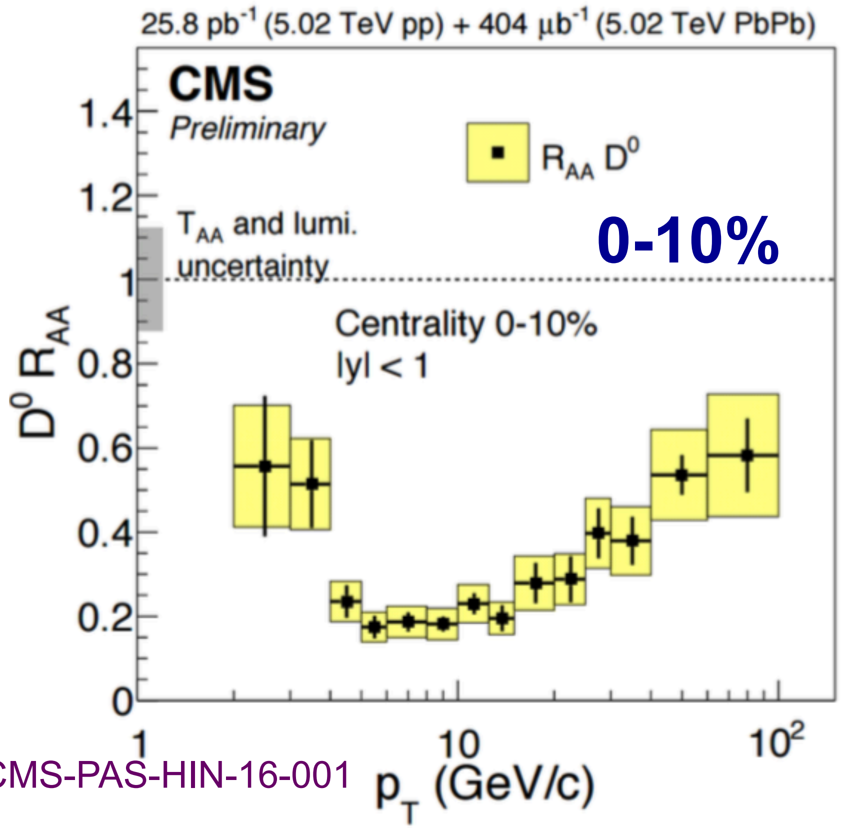


Di-jet Δφ

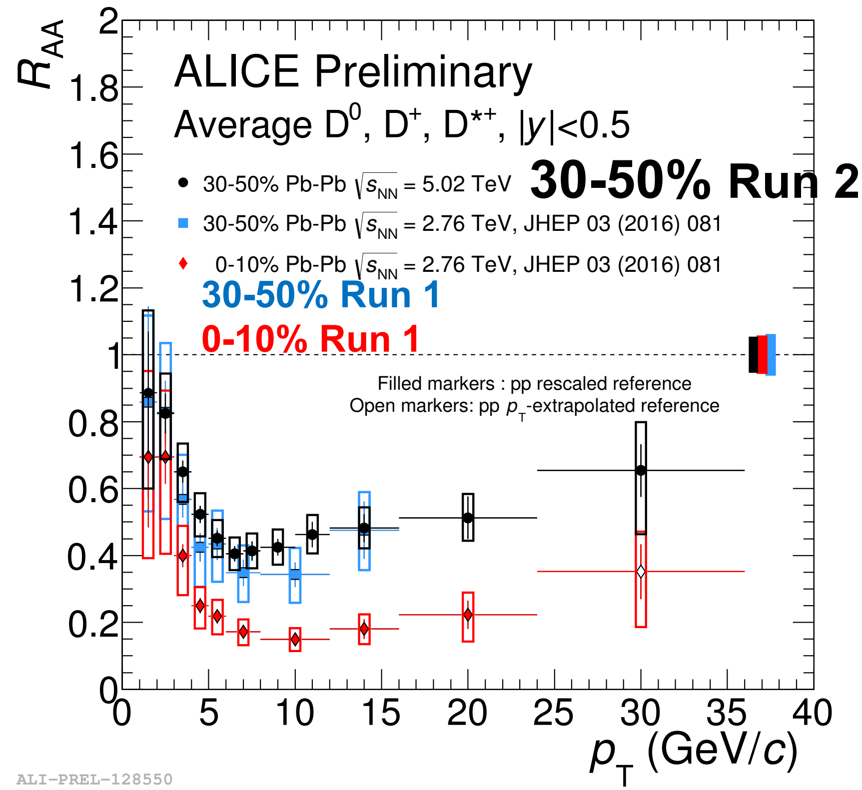
Larger di-jet imbalance in Pb-Pb wrt pp

Jet R_{AA}<1 up to very high p_T → jet energy not recovered in the cone radius

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



CMS-PAS-HIN-16-001

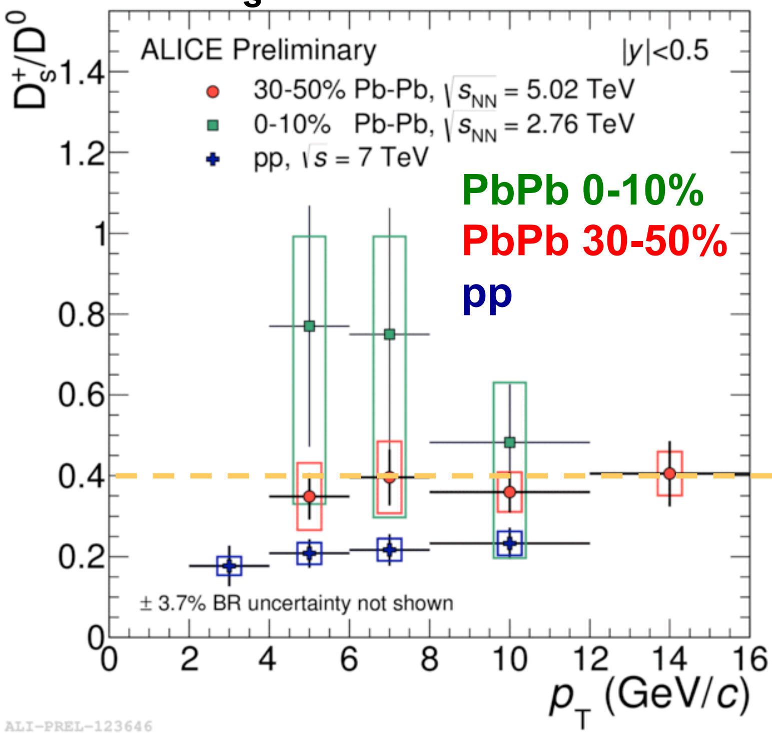


Strong suppression of D^0,D^+,D^{*+} mesons in Pb-Pb at $\sqrt{s_{NN}}$=5.02 TeV
At high p_T > 10 GeV: D^0 R_{AA} **increases** as a function of D^0 p_T

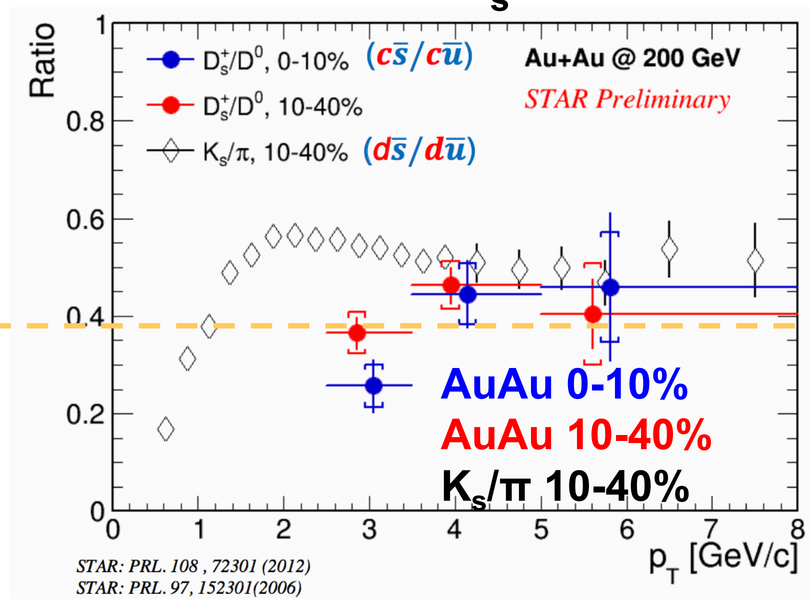
Similar suppression as in in Pb-Pb at **$\sqrt{s_{NN}}$=2.76 TeV**

D_s and Λ_c in AA collisions

D_s/D^0 at LHC



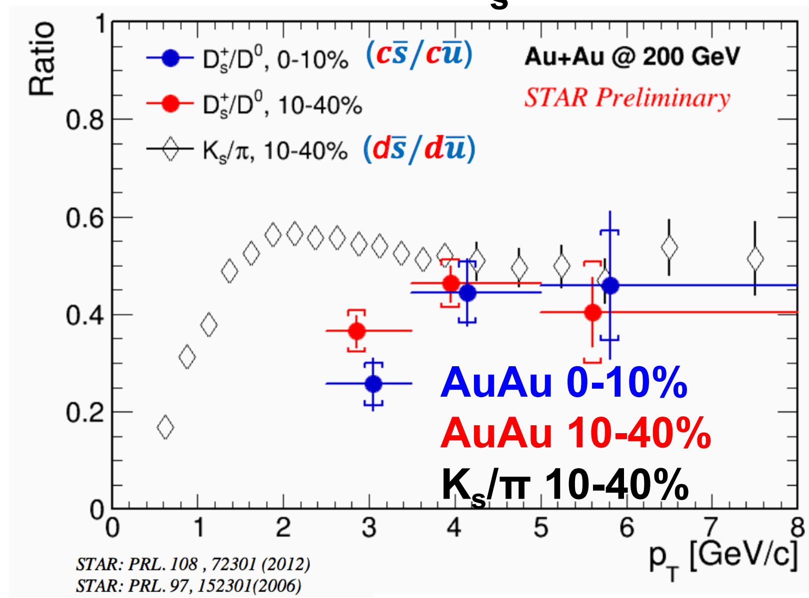
D_s/D^0 at RHIC



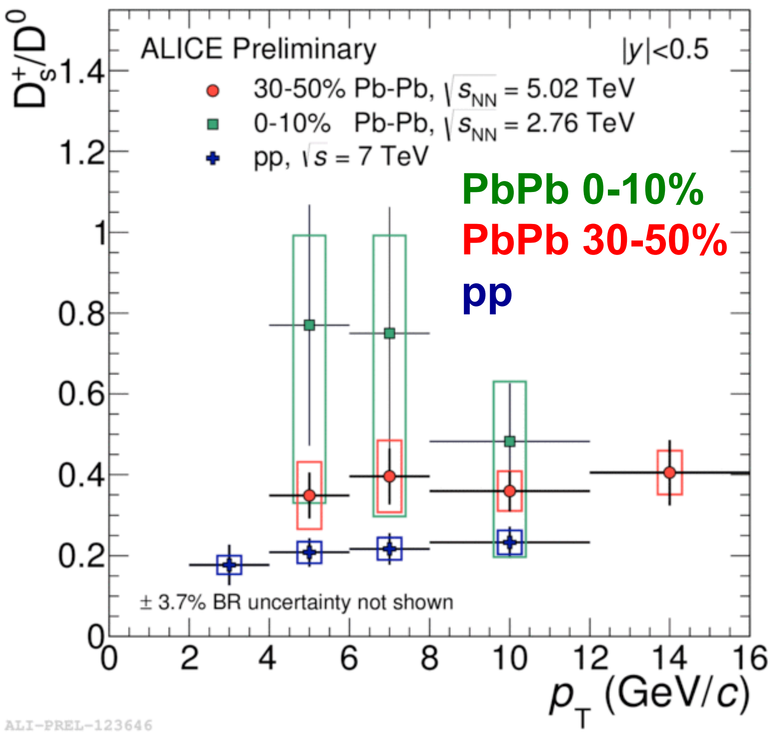
D_s/D^0 ratio: (increasing) trend from **pp** to **semi-central** to **central** Pb-Pb. Similar to RHIC energies

D_s and Λ_c in AA collisions

D_s/D^0 at RHIC



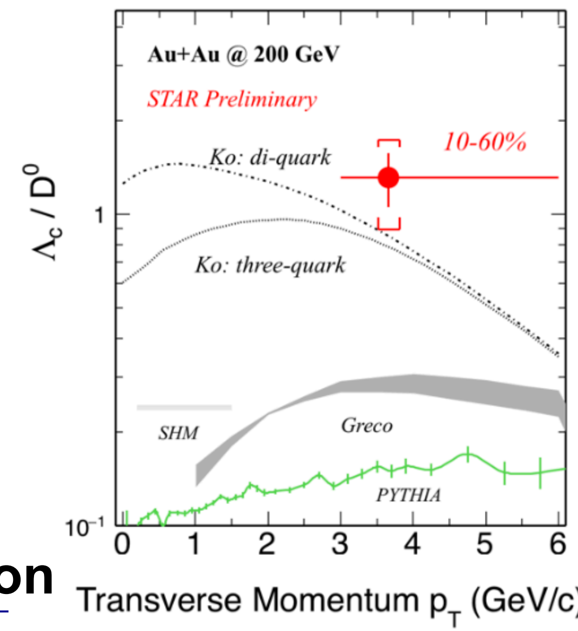
D_s/D^0 at LHC



D_s/D^0 ratio: (increasing) trend from **pp** to **semi-central** to **central** Pb-Pb. Similar to RHIC energies

First measurement of **Λ_c in AuAu collisions** !

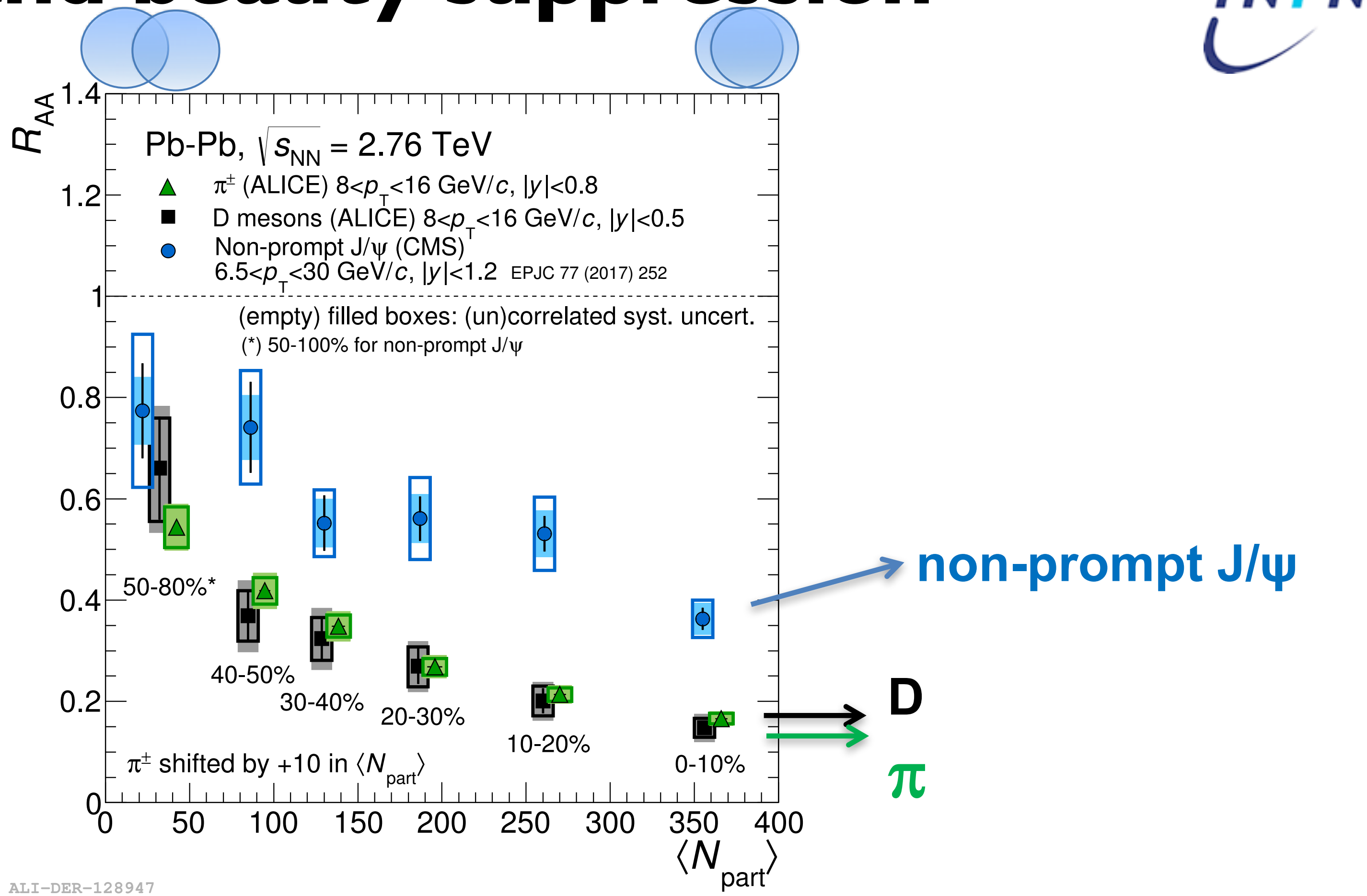
Λ_c/D^0 much higher wrt PYTHIA



More statistics needed to conclude on recombination

Charm and beauty suppression

ALICE, JHEP 1511 (2015) 205
CMS, arXiv:1610.00613

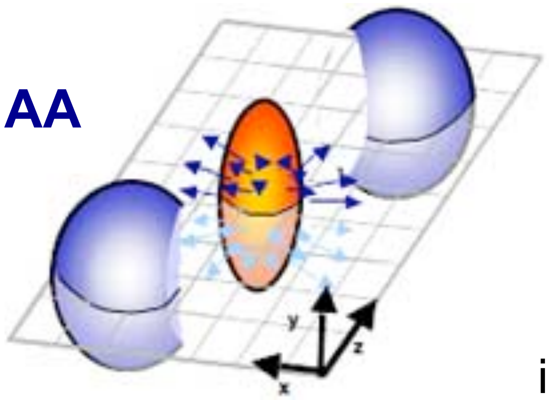


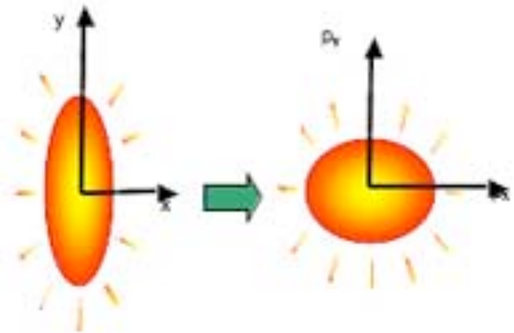
Non-prompt J/ψ vs **D**: difference between charm and beauty suppression in central collisions → parton mass dependence of in-medium energy loss

D vs **π**: different vacuum fragmentation of charm vs. light quarks and light/heavy quark p_T spectrum are relevant in the R_{AA} comparison

Heavy-flavour azimuthal anisotropy

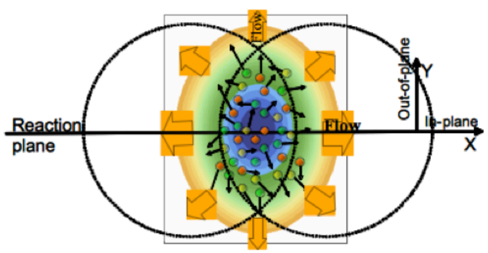
In **non-central AA collisions**:





initial spatial asymmetry → azimuthal anisotropy of final hadrons in momentum space

→non-isotropic azimuthal emission can be parametrized by:



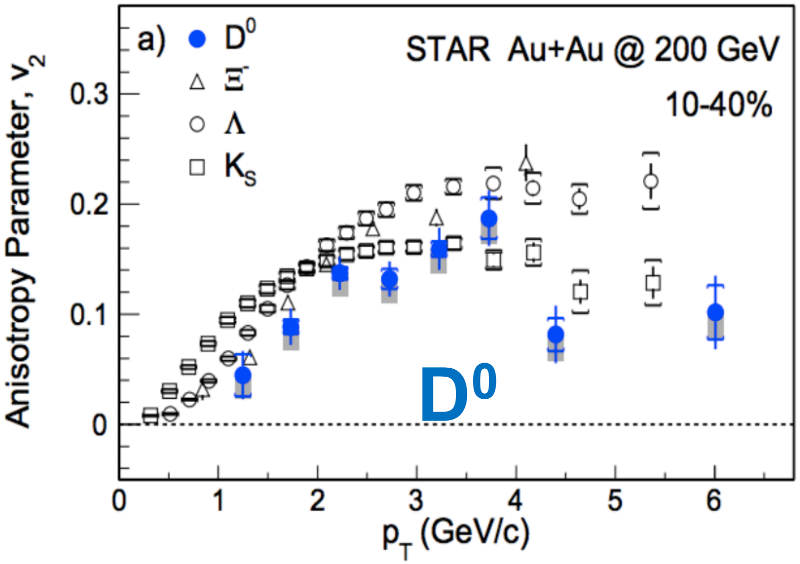
$$\frac{dN}{d\varphi} = \frac{N_0}{2\pi}\left(1 + 2v_1\cos(\varphi - \Psi_1) + 2v_2\cos[2(\varphi - \Psi_2)] + \ldots\right)$$

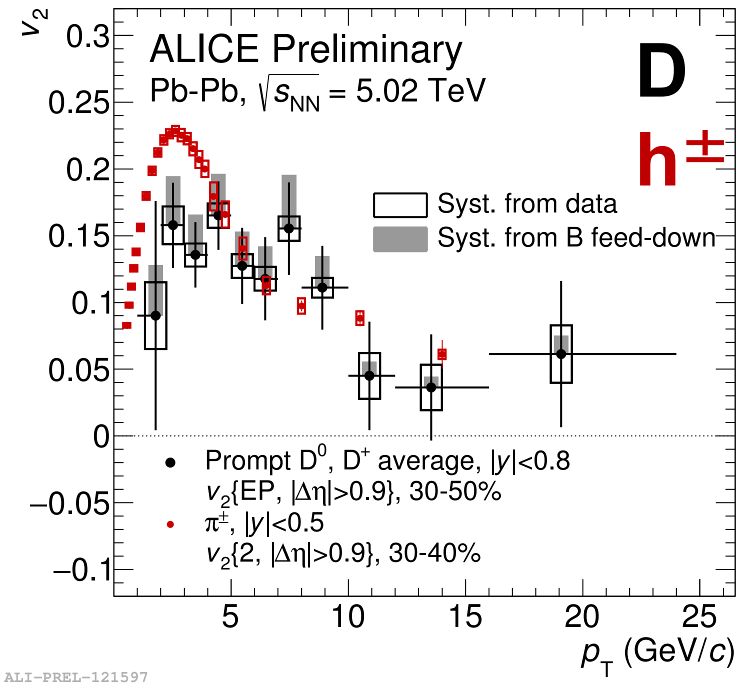
Azimuthal anisotropy originates from:

- thermalization/collective motion (low p_T)
- path-length dependence of energy loss (high p_T)

Are heavy quarks "flowing" with the medium?

D-meson v_2 at the highest energy





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?

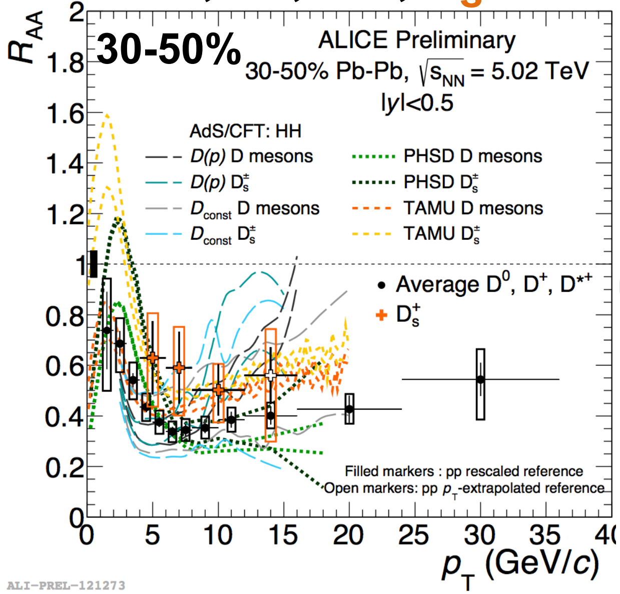
LHC: significant D-meson v_2 > 0 (30-50%)

- Low p_T: v_2 (charged hadrons) slightly higher than v_2 (D^0)
- High p_T: similar v_2 for D^0 and charged hadrons

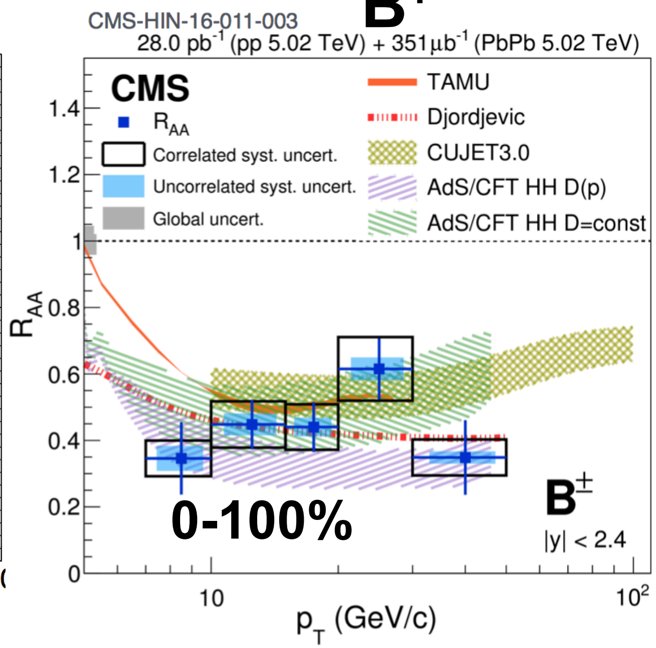
Strong interaction of charm quarks with the medium at RHIC & LHC

R_{AA} and v_2: constraints to models

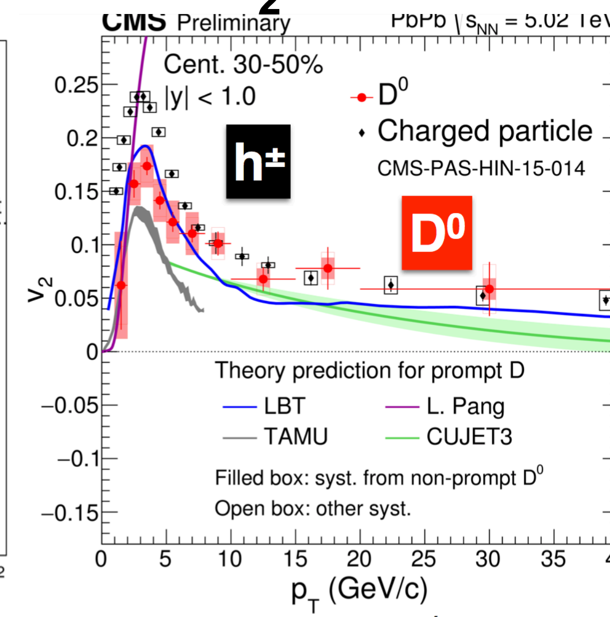
D^0, D^+, D^{*+}, D_s^+



B^+



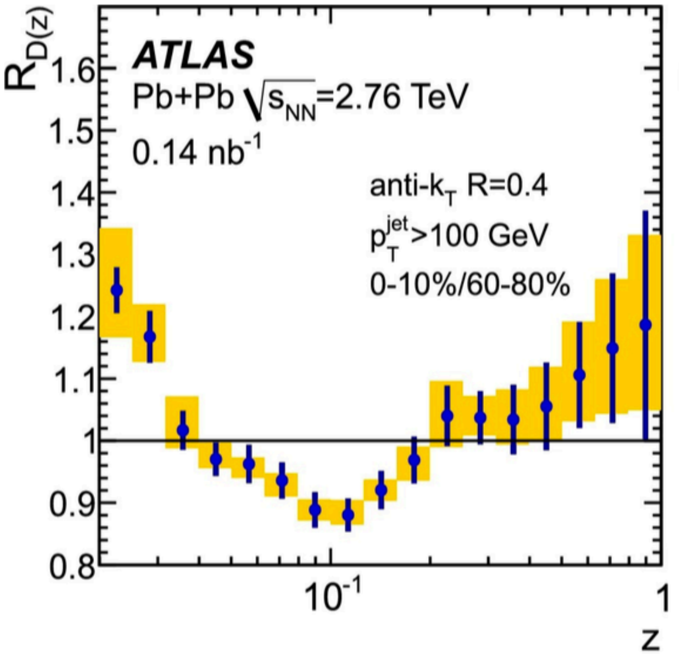
D^0 v_2



R_{AA} and v_2 results start to provide constraints to different in-medium energy loss models, and therefore to medium parameters (transport and diffusion coefficient,…)

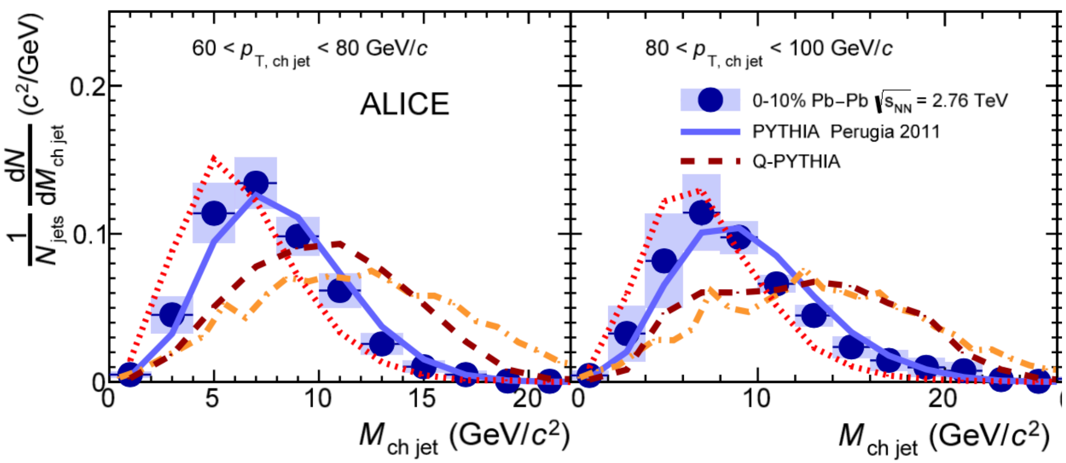
More differential observables

Investigate mechanisms of energy loss and parton-medium interaction



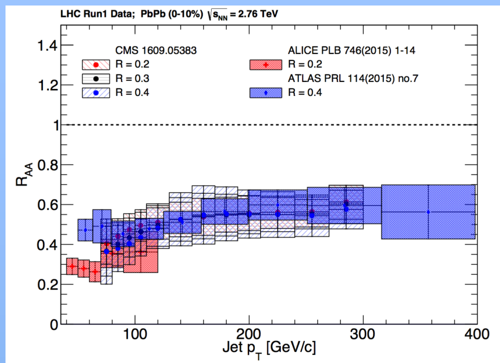
Jet fragmentation function z:
$R_{D(z)}$ = Central / peripheral Pb-Pb events

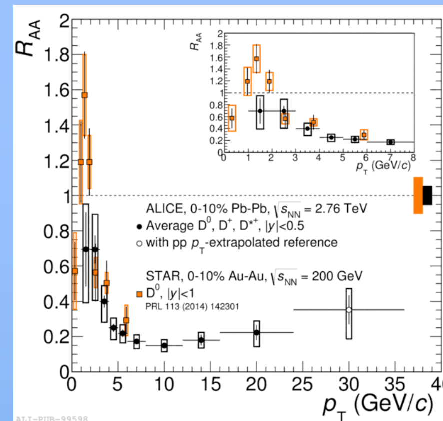
Suppression of intermediate p_T particles and enhancement at low p_T

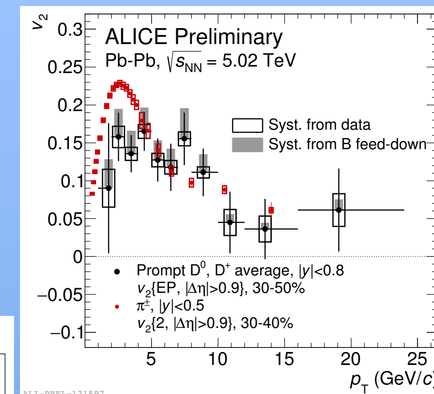


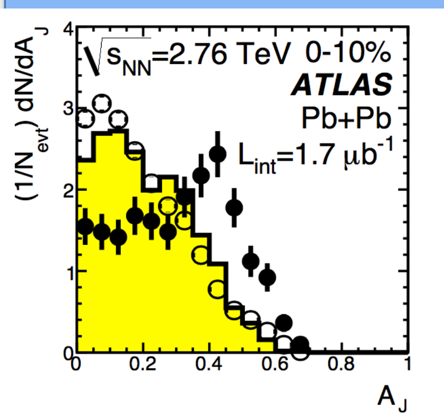
Jet **mass** measures the **"virtuality" of the jet**
Models predict **larger** jet mass due to jet-medium interactions → not observed

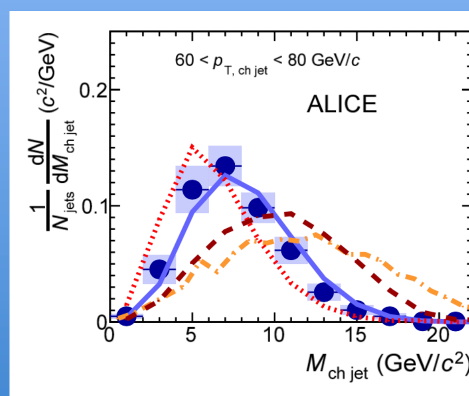
Current Status: HF and jets at RHIC and LHC

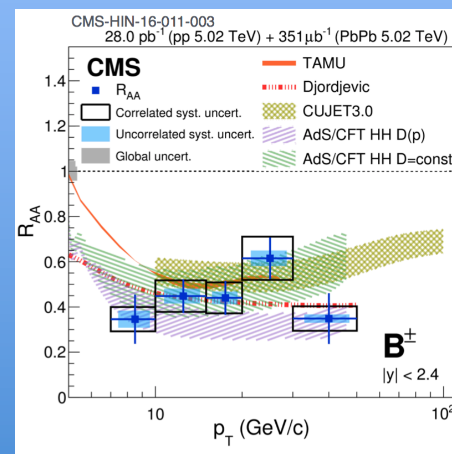












Heavy flavours and jets are unique probes to characterize medium properties at RHIC an LHC energies.

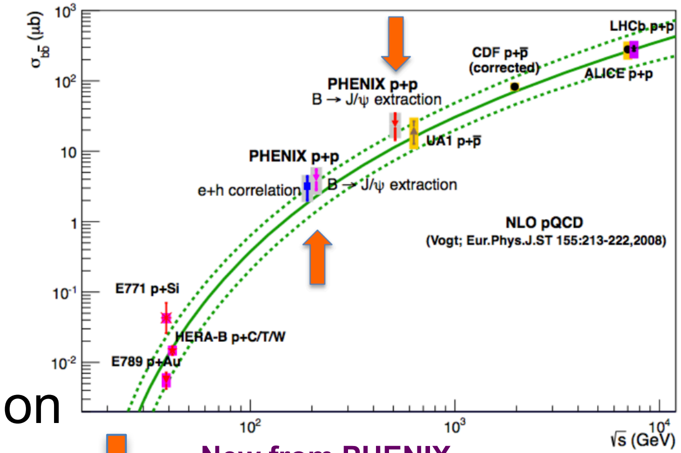
Conclusions

- Several measurements of hard probes at RHIC and LHC
  - **different energies and collision systems**
  - p(d)-A is the system to study **CNM effects**, but also different x regimes
- Jets and open charm/beauty strongly affected by the medium
  - from RHIC to LHC energies : **similar suppression at high p_T**
  - **Energy loss at large angles**
  - **Parton mass dependence** of energy loss in agreement with models
  - **positive v_2** suggests collective motion for c quarks at low p_T at RHIC and LHC
- **Next**: more precise measurements to sharpen the conclusions
  - RHIC, LHC: **new detectors and future upgrades**
  - Smaller uncertainties, new differential measurements will help to **further constrain theory** (and add information on path-length dependence of energy loss, energy loss mechanisms, medium transport coefficients, thermalization, hadronization, …)

Thank you!

Heavy Flavours in small collision systems

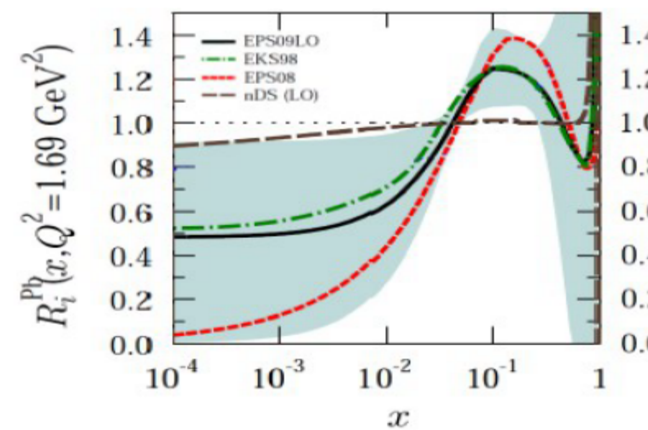
- **pp:**
  - test for pQCD
  - reference for pA and AA
  - role of Multi Parton Interactions (MPI)
  - study HF production processes and fragmentation



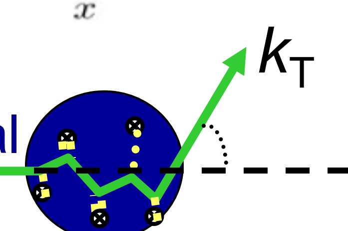
New from PHENIX
200 GeV: arXiv 1702.01085
510 GeV: arXiv 1701.01342

- **p-Pb:**
  - reference for cold nuclear matter (CNM) effects
  - initial/final-state effects
    - nPDF, saturation and more effects

      (k_T broadening, energy loss)
  - role of collision geometry/multiplicity density
  - collective effects in small systems?

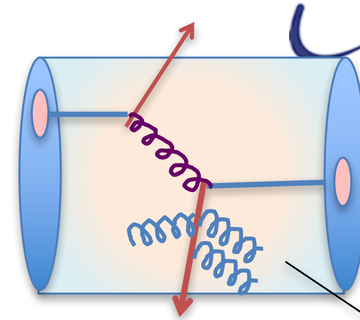


→ Experimentally: inclusive cross sections, multiplicity differential measurements and heavy-flavour correlations



Heavy Flavours in Pb-Pb collisions

- **Energy loss** of heavy-quarks in the medium:
  - modifies phase-space distribution of HQ, and of final-state observables
  - mechanisms: gluon radiation, elastic collisions
  - depends on:
    - Medium density, path-length
    - Colour-charge, parton mass



$$\langle \Delta E \rangle \propto \alpha_s C_R \hat{q} L^2$$

$$\Delta E_g > \Delta E_{u,d} > \Delta E_c > \Delta E_b$$

"dead-cone" effect in radiative energy loss
Dokshitzer and Kharzeev, PLB 519 (2001) 199.

- Do heavy flavours take part into **collective motion** of the system?
  - at low p_T → information on the transport properties of the medium, collectivity and thermalization of HQ

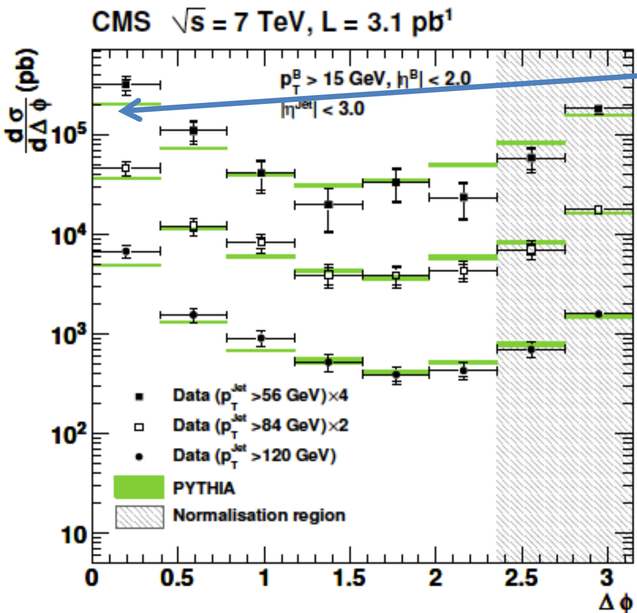
- **Hadronization** mechanism
  - role of coalescence of HQ with low-p_T light quarks in the medium

→ Experimentally: differential measurements toward a quantitative picture: charm vs beauty, correlations and jets, baryons vs mesons

Goal: extract medium properties with heavy-flavour observables

HF correlations in pp at the LHC

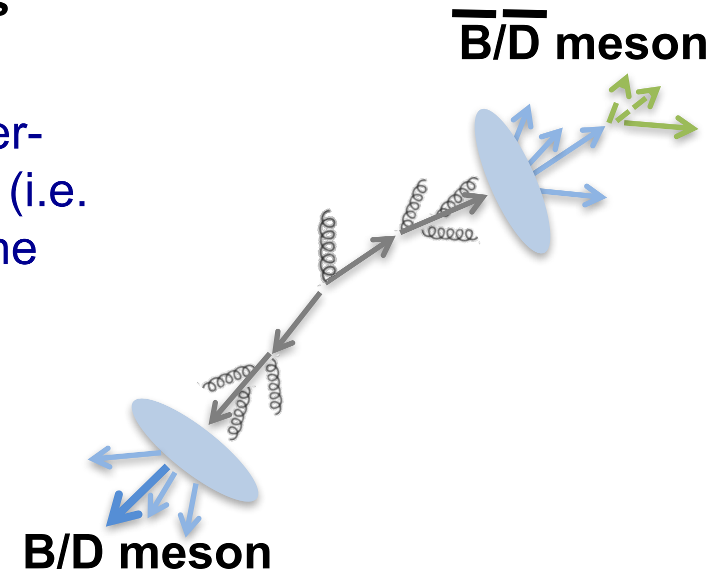
Provide constraints to MC generators about HF production mechanisms

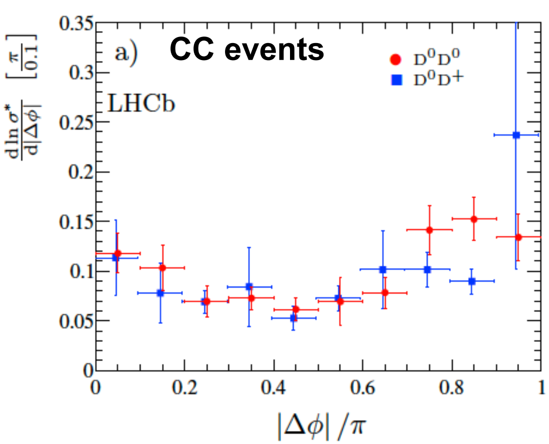


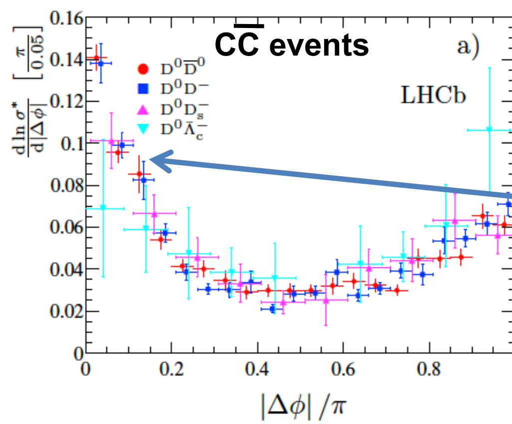
CMS, JHEP 1103:136,2011

B-Bbar correlations

Generators tend to under-predict higher-order contributions (i.e. gluon splitting) in the near side (Δϕ~0)







Azimuthal DD correlations

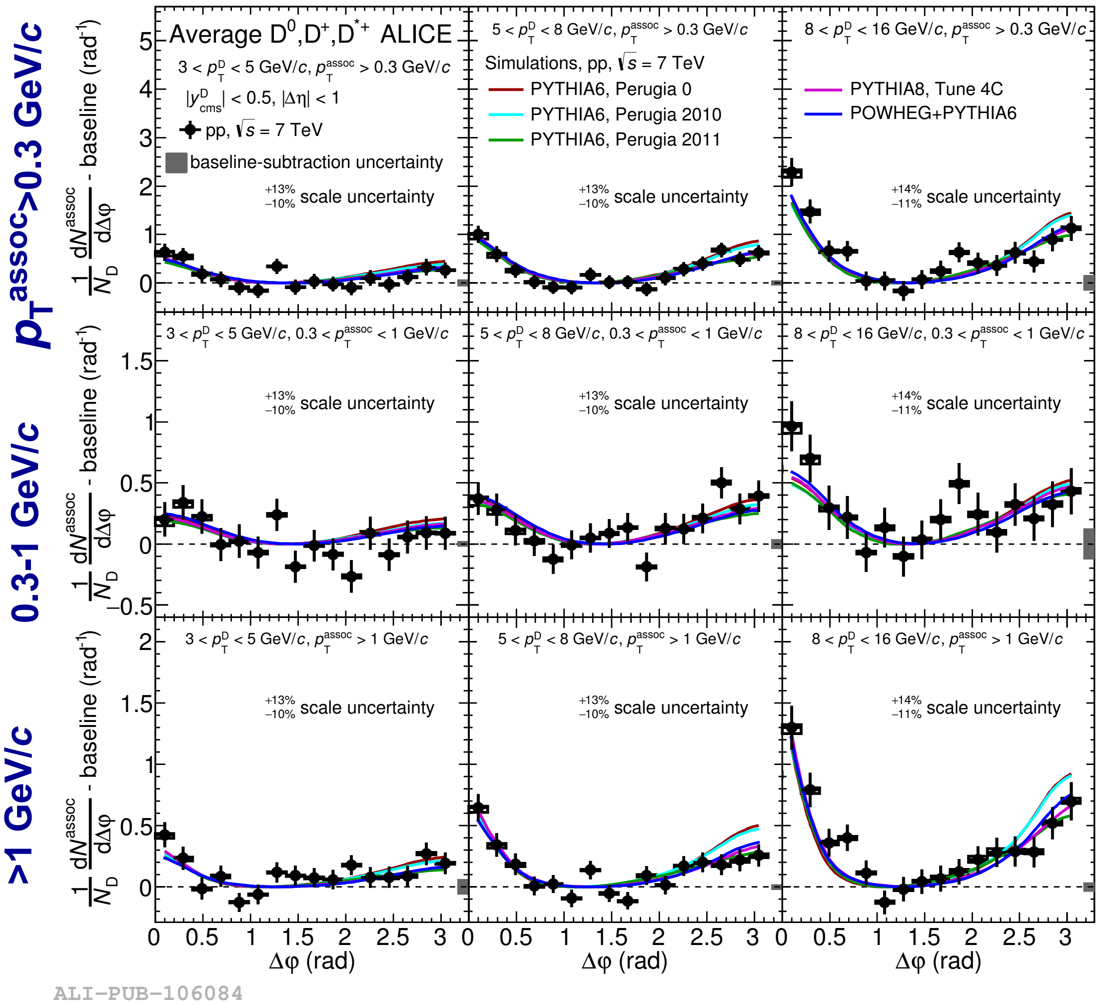
$C\overline{C}$ events have a clear enhancement at small Δϕ, consistent with gluon splitting

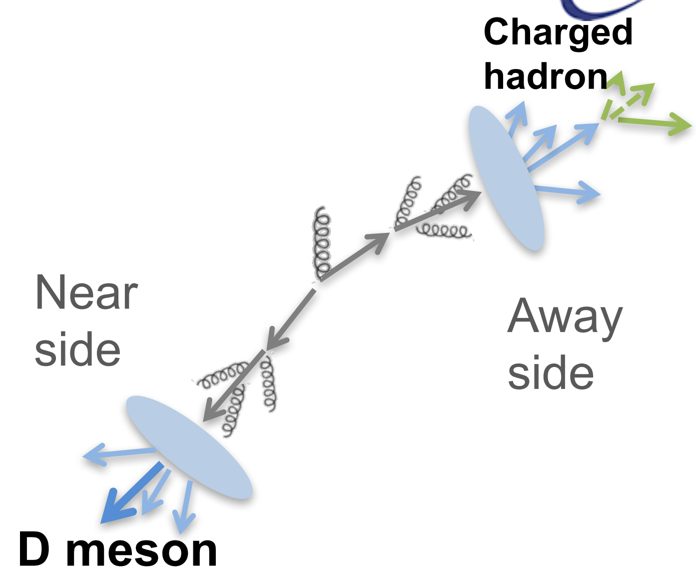
LHCb, JHEP06(2012)141

HF correlations in pp at the LHC

D-meson trigger p_T

3-5 GeV/*c*   5-8 GeV/*c*   8-16 GeV/*c*

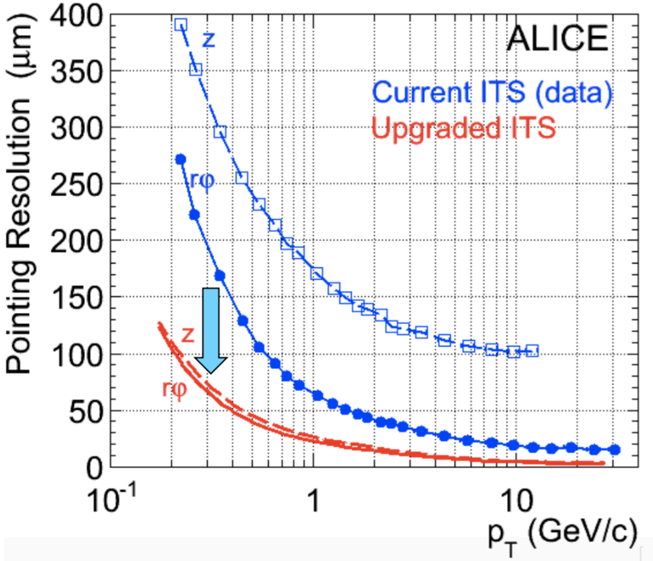




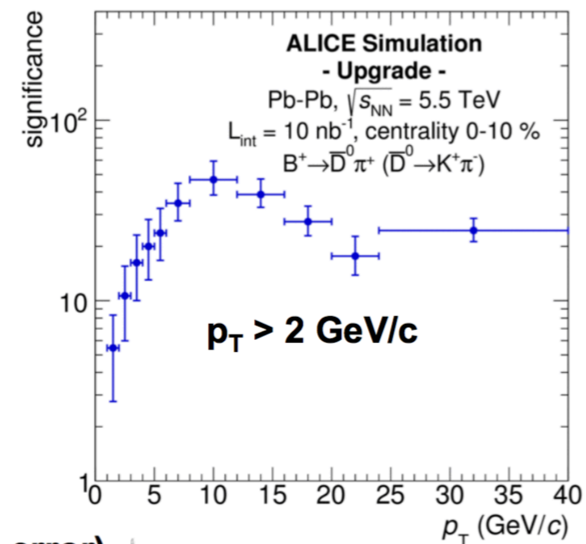
ALICE, arXiv:1605.06963

Compatible within uncertainties with expectations from different MC generators and tunes (PYTHIA6, PYTHIA8, POWHEG+PYTHIA) after baseline subtraction

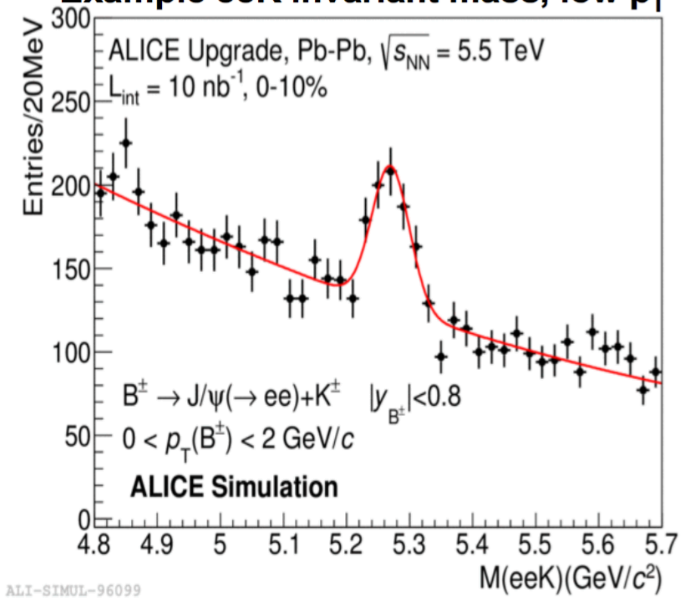
ALICE Upgraded Inner Tracking System



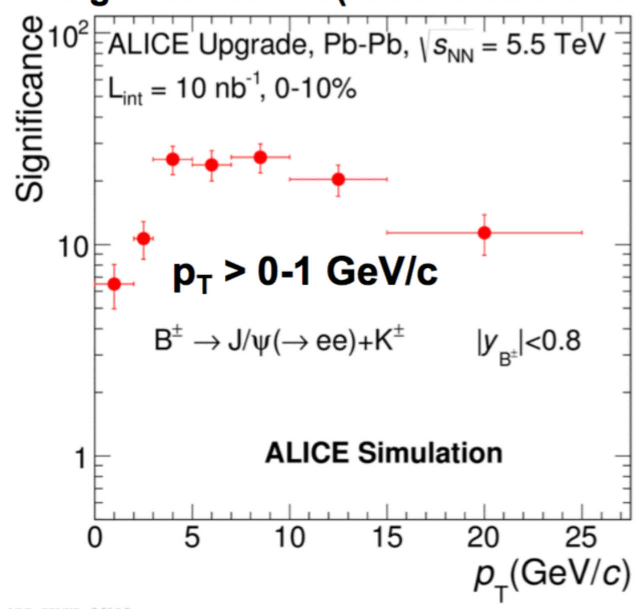
Significance = 1/(relative stat. error)



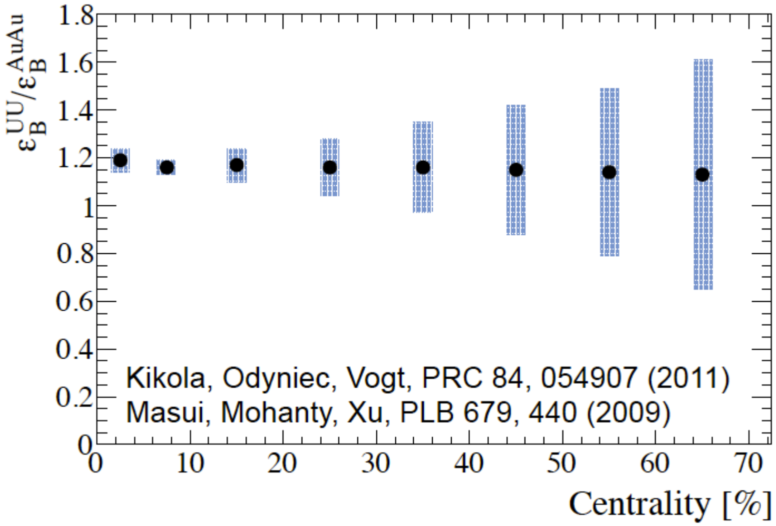
Example eeK invariant mass, low p_T



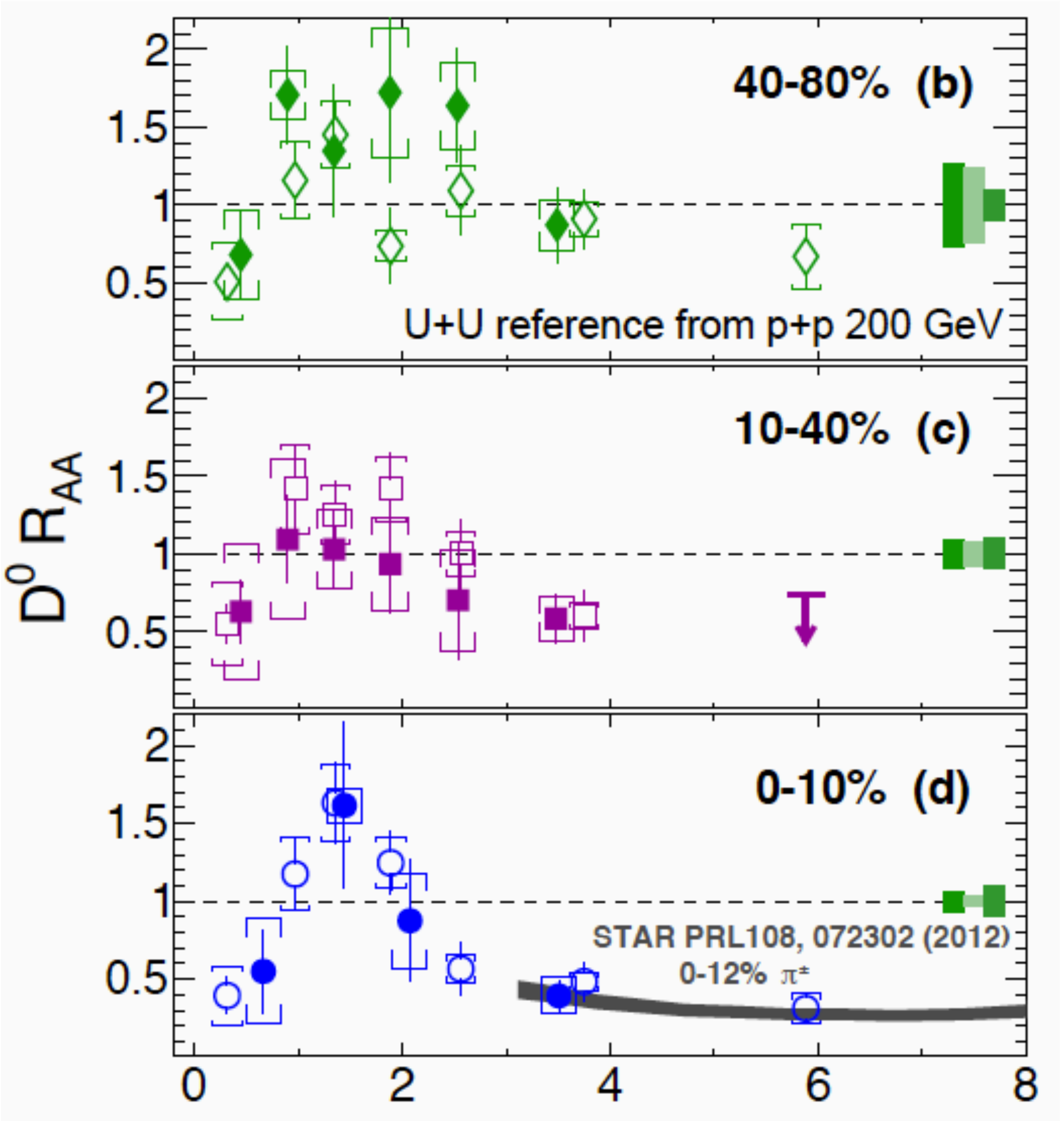
Significance = 1/(relative stat. error)



U+U at RHIC

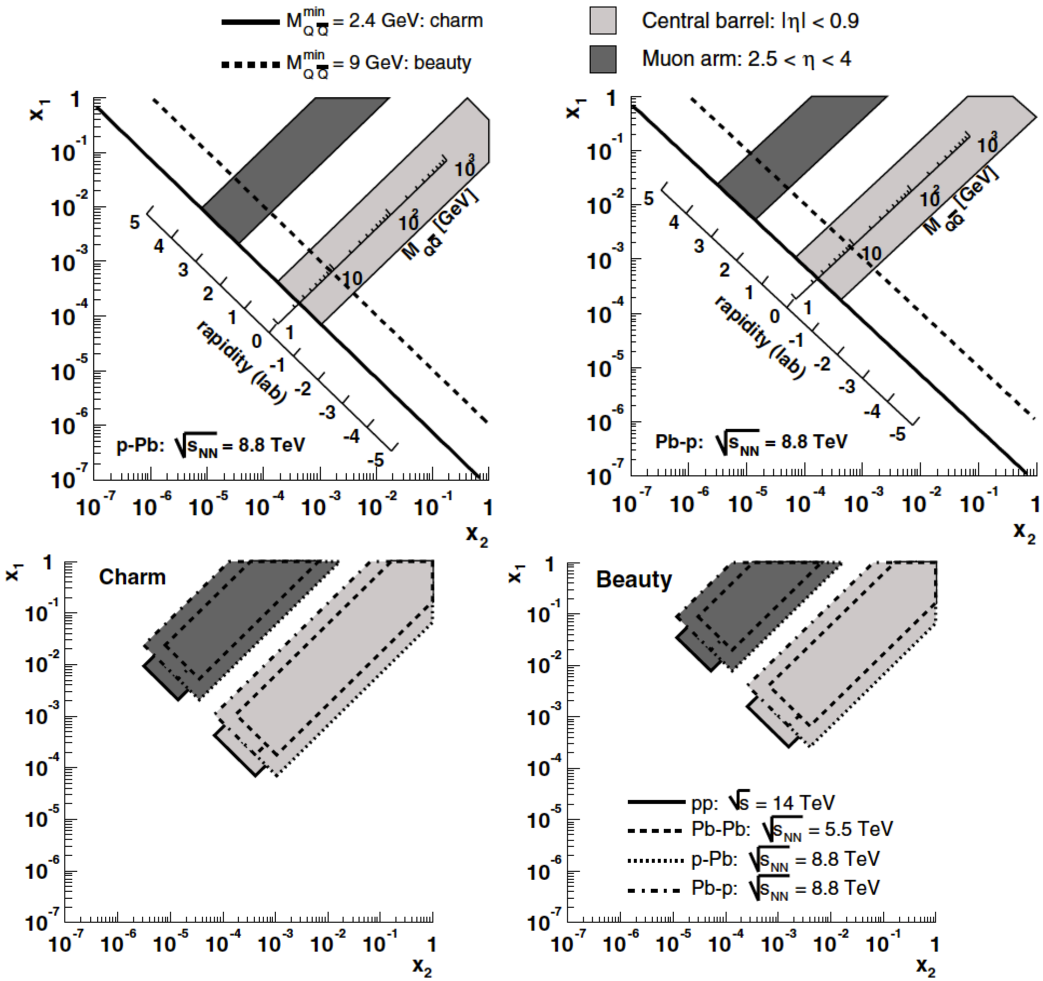


$\varepsilon_B^{UU}/\varepsilon_B^{AuAu}$
Kikola, Odyniec, Vogt, PRC 84, 054907 (2011)
Masui, Mohanty, Xu, PLB 679, 440 (2009)
Centrality [%]



D^0 R_{AA}
40-80% (b)
U+U reference from p+p 200 GeV
10-40% (c)
0-10% (d)
STAR PRL108, 072302 (2012)
0-12% $\pi^{\pm}$

x regimes at the LHC



ALICE Coll.,
J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295–2040

$$x_1 = \frac{A_1}{Z_1} \cdot \frac{M_{Q\overline{Q}}}{\sqrt{s_{pp}}} \exp\left(+y_{Q\overline{Q}}\right)$$

$$x_2 = \frac{A_2}{Z_2} \cdot \frac{M_{Q\overline{Q}}}{\sqrt{s_{pp}}} \exp\left(-y_{Q\overline{Q}}\right)$$

The LHC Probes Smallest x So Far Available

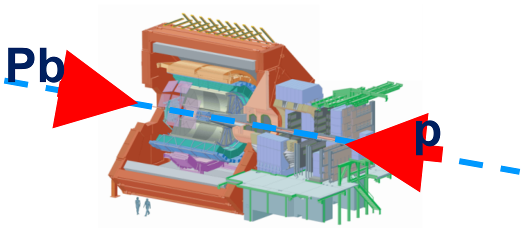
High energy pp and AA colliders probe successively smaller fractional momenta, x, of q, $\bar{q}$ and g for perturbative probes such as dijets, lepton pairs, gauge bosons or quarkonium produced at scale Q

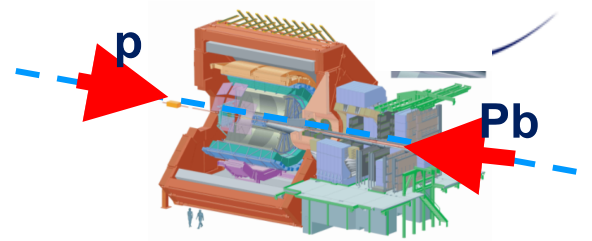
$$x_1 = \frac{Q}{\sqrt{s_{NN}}} \exp(y) \quad \text{“projectile”}$$

$$x_2 = \frac{Q}{\sqrt{s_{NN}}} \exp(-y) \quad \text{“target”}$$

At the LHC, $|y| \leq 8.6 - 9.6$, depending on $\sqrt{s_{NN}}$

HF in pA: different rapidities at LHC





$-4.46<y_{CMS}<-2.96$

$10^{-2}<x<5 \cdot 10^{-2}$

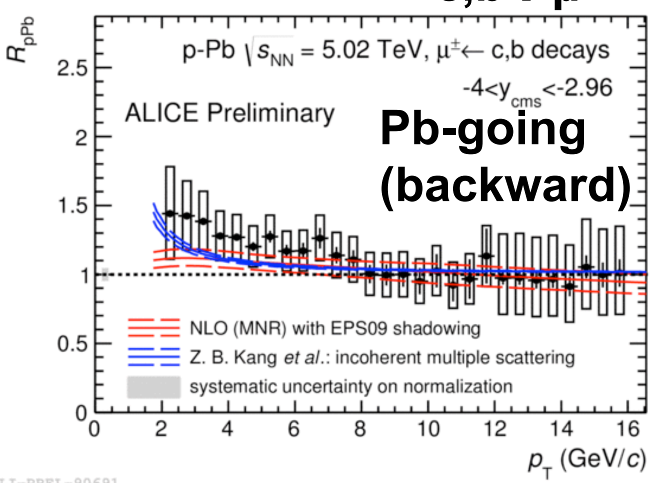
c,b→μ

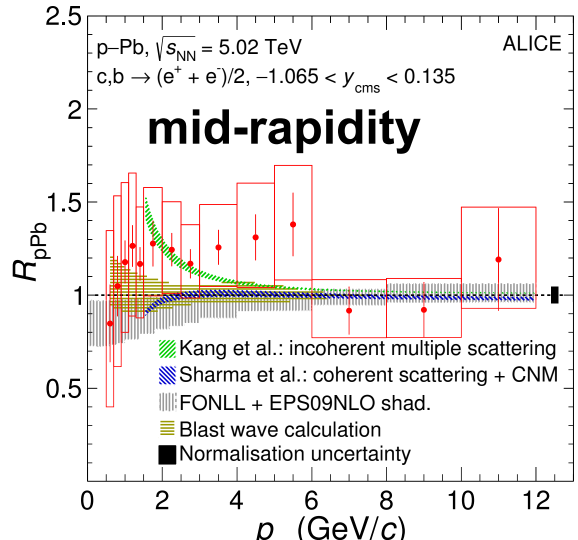
c,b→e

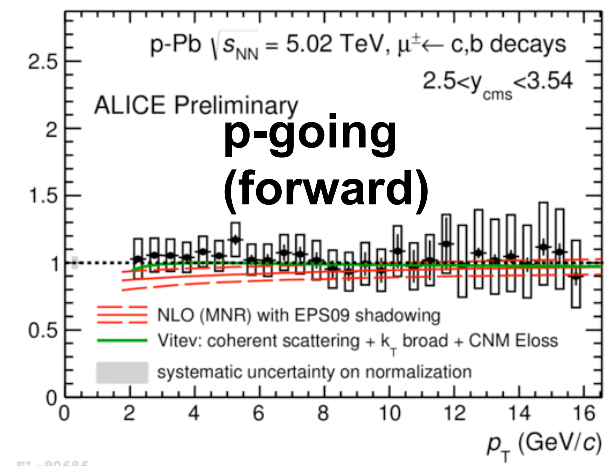
$2.03<y_{CMS}<3.53$

$10^{-5}<x<8 \cdot 10^{-5}$

c,b→μ







M. Mangano, P. Nason and G. Ridolfi, Nucl. Phys. B373 (1992) 295
K. J. Eskola, H. Paukkunen and C. A. Salgado, JHEP 0904 (2009) 065
R. Sharma, I. Vitev et al., PRC 80 (2009) 054902
Z.B. Kang et al., PLB 740 (2015) 23

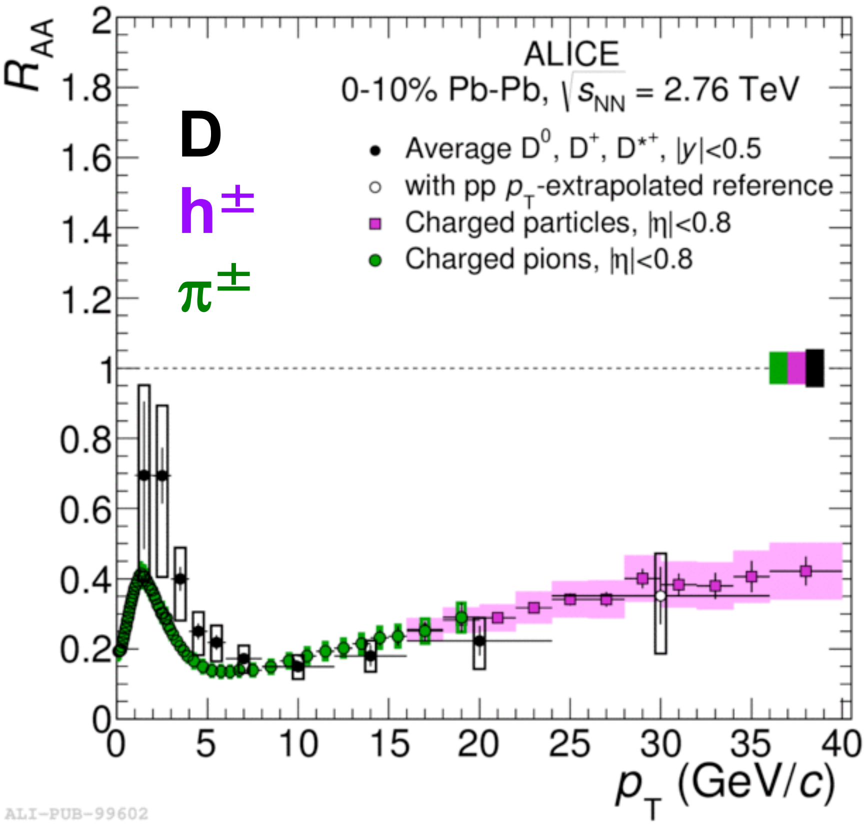
Phys. Lett. B 754 (2016) 81

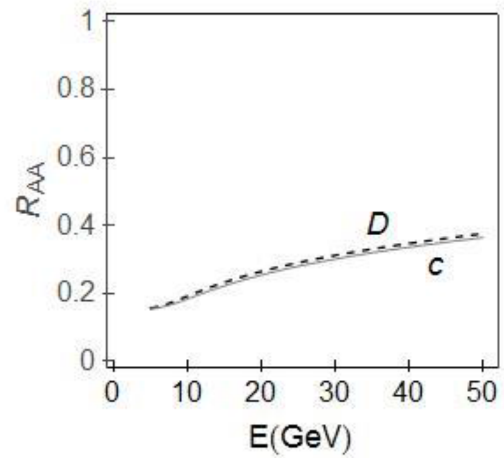
Different *x* regimes explored in different rapidity ranges with HF probes
→shadowing/saturation relevant at low p_T at the LHC

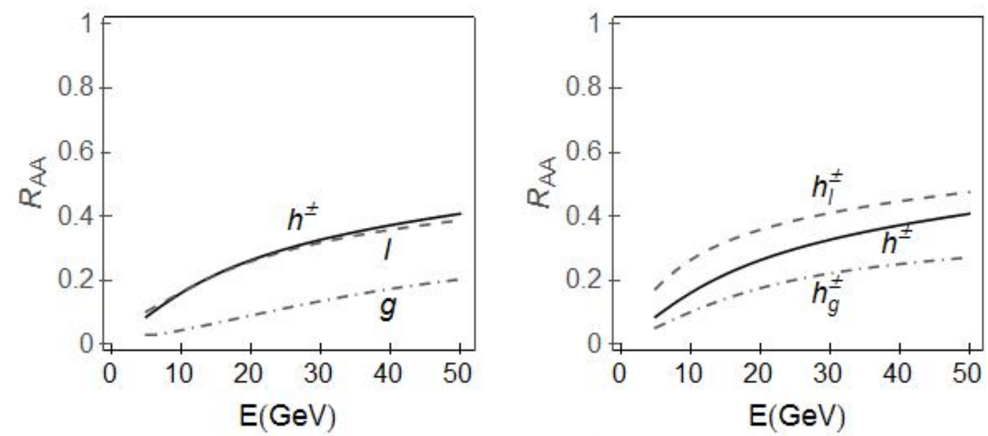
Data described within uncertainties by the models with CNM effects

R_{AA}: D mesons and charged hadrons

Mass dependence of energy loss?







M.Djordjevic, PRL 112, 042302 (2014)

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

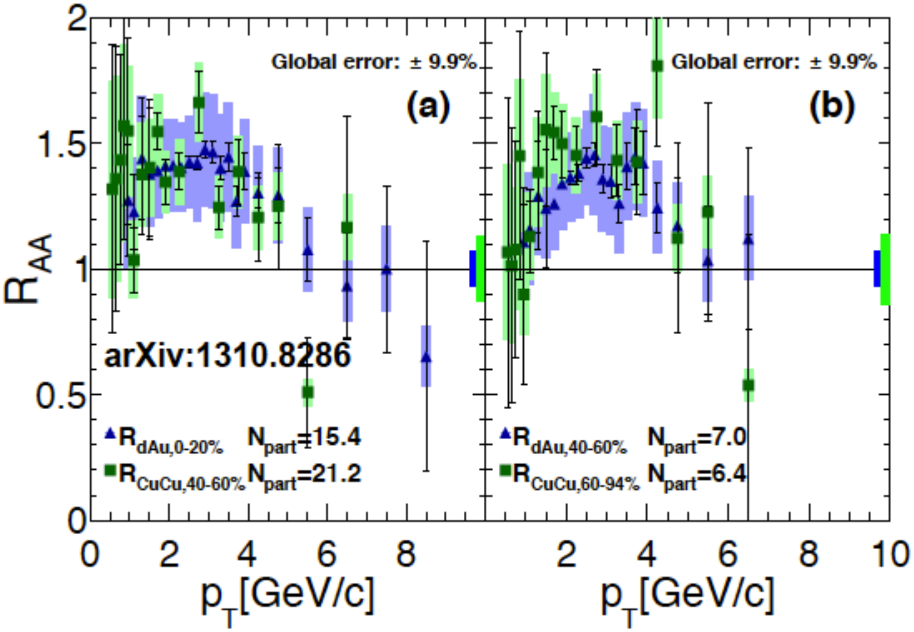
What about $\Delta E(udsg) > \Delta E(c)$? → $R_{AA}(D) > R_{AA}(\pi, h^{\pm})$

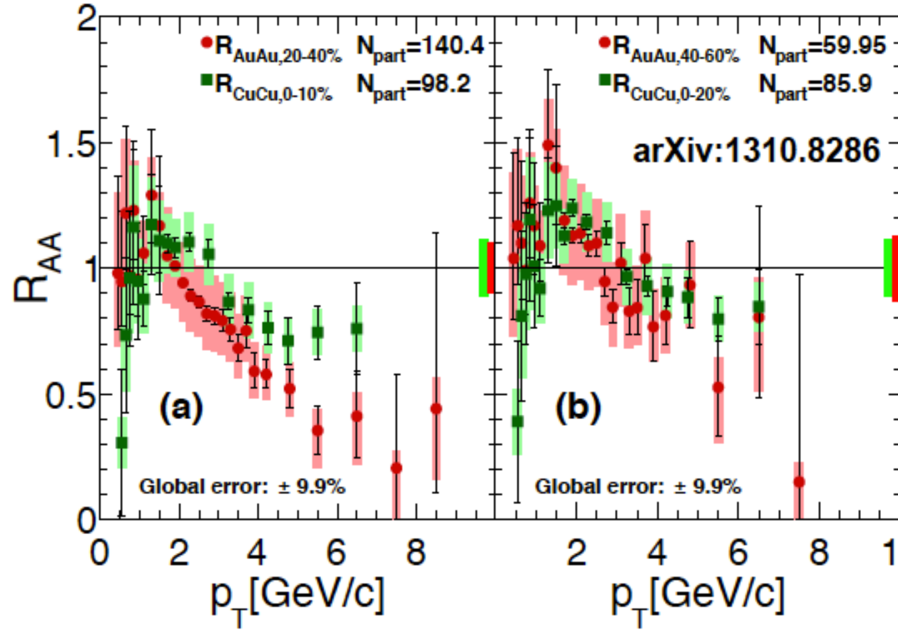
→Different quark spectra

→R_{AA}(h) affected by fragmentation

System size dependence of R_{AA} at RHIC

electrons from heavy-flavour decays



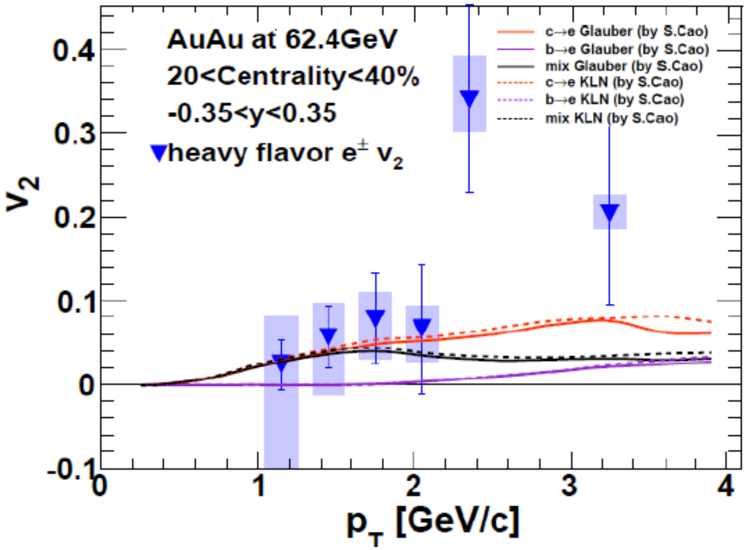


PHENIX, Phys.Rev. C90 (2014) 034903

CENTRAL d+Au ~ PERIPHERAL Cu+Cu

CENTRAL Cu+Cu ~ MID Au+Au

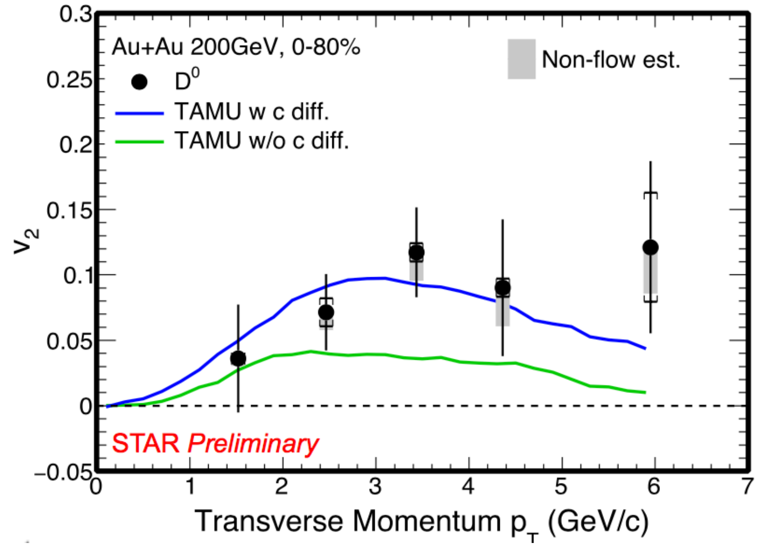
Charm collective motion at RHIC

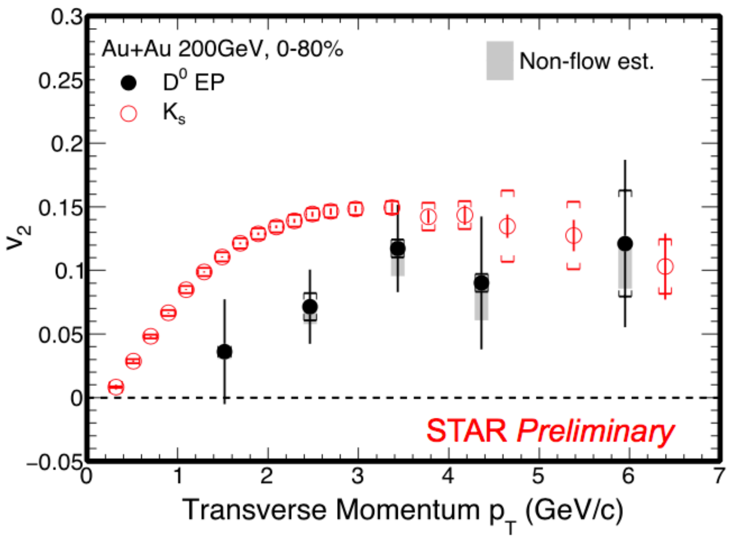


PHENIX, PRC(2015) 044907

Charm v_2 at low energy (62 GeV):

is flowing? is recombination with light quarks?



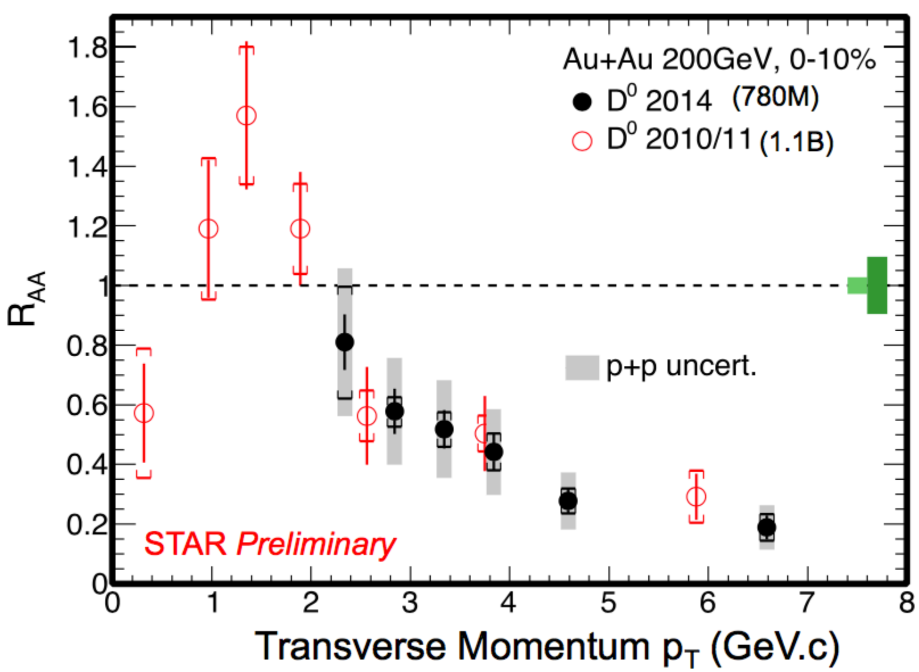


D^0 v_2>0 for p_T>2 GeV/c

- Data favour model including charm quark diffusion in the medium
- Systematically below light-hadron v_2

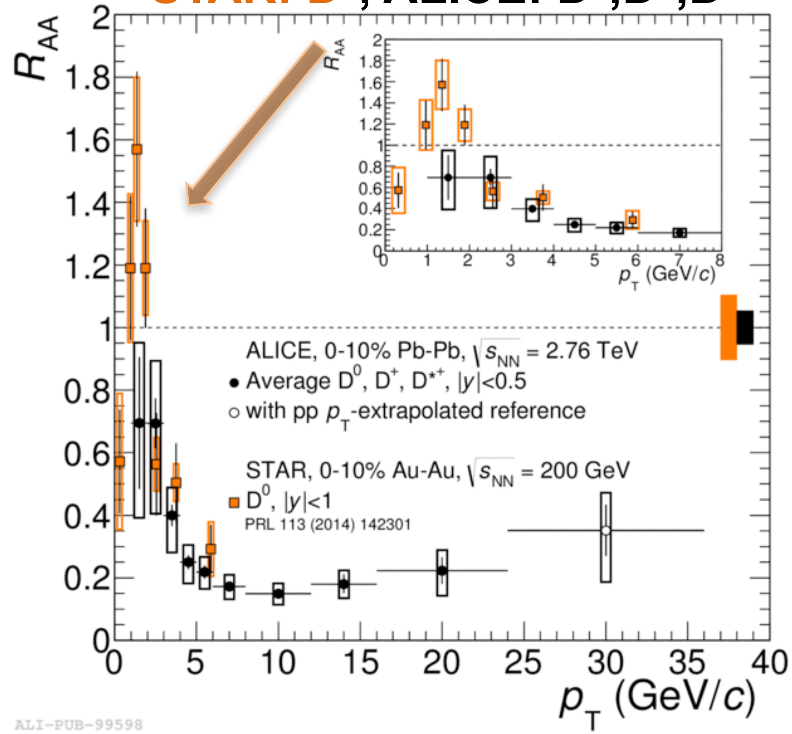
AA: comparison to RHIC energies

STAR: D⁰



STAR: PRL 113 (2014) 142301
PLB 655 (2007) 104

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



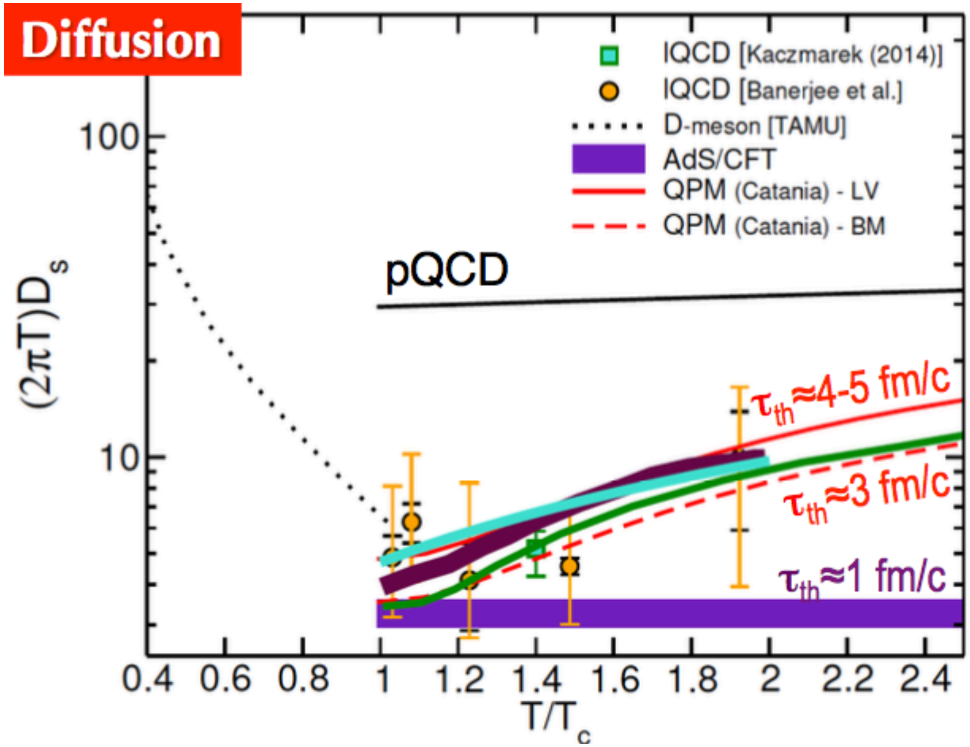
STAR, PRL113 (2014) 142301
ALICE, JHEP1603 (2016) 081

Similar suppression in central A-A collisions at high p_T

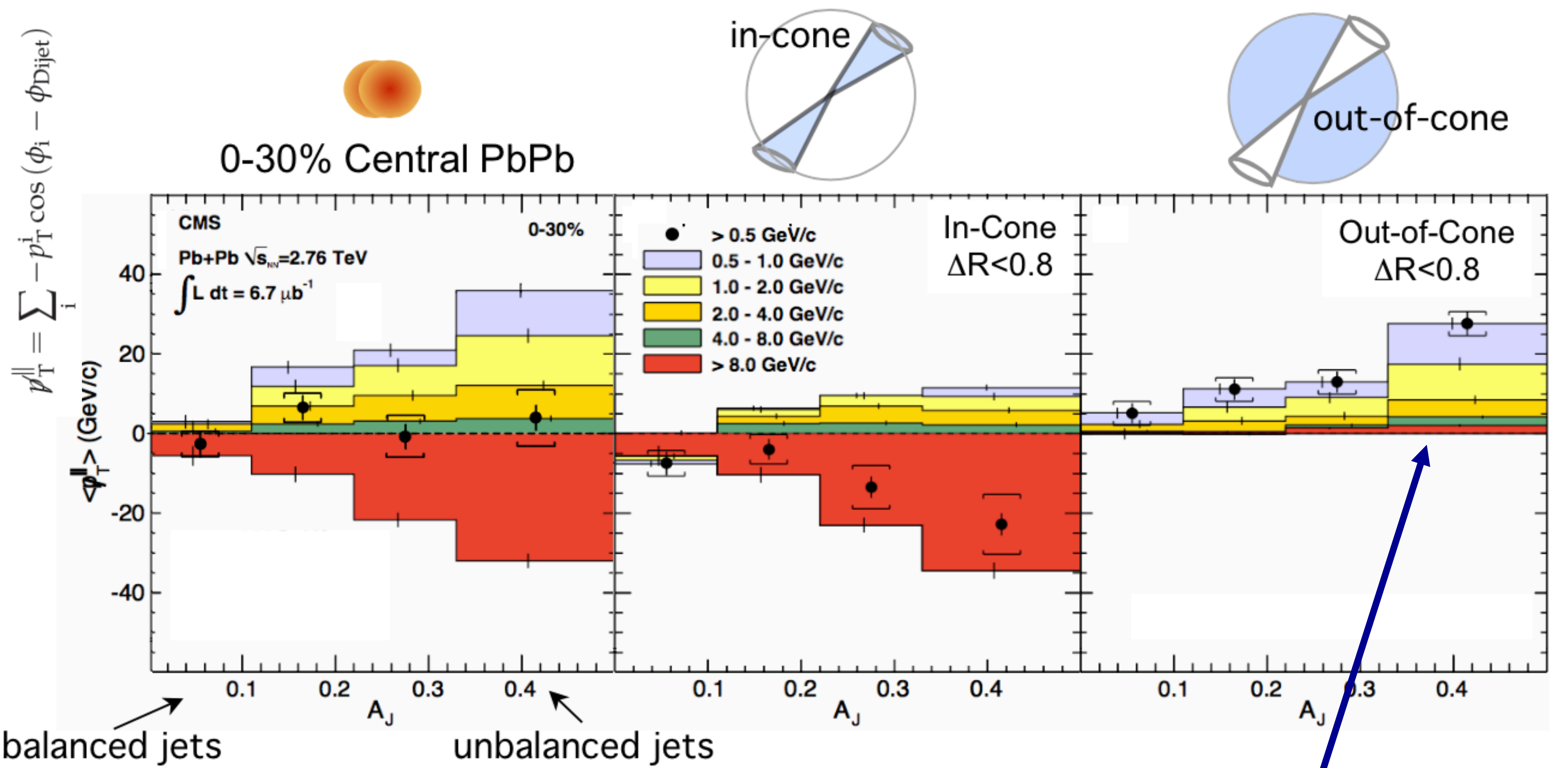
Differences at low p_T: radial flow? Shadowing? Recombination?

Crucial to go to p_T~0 at the LHC

Diffusion coefficient



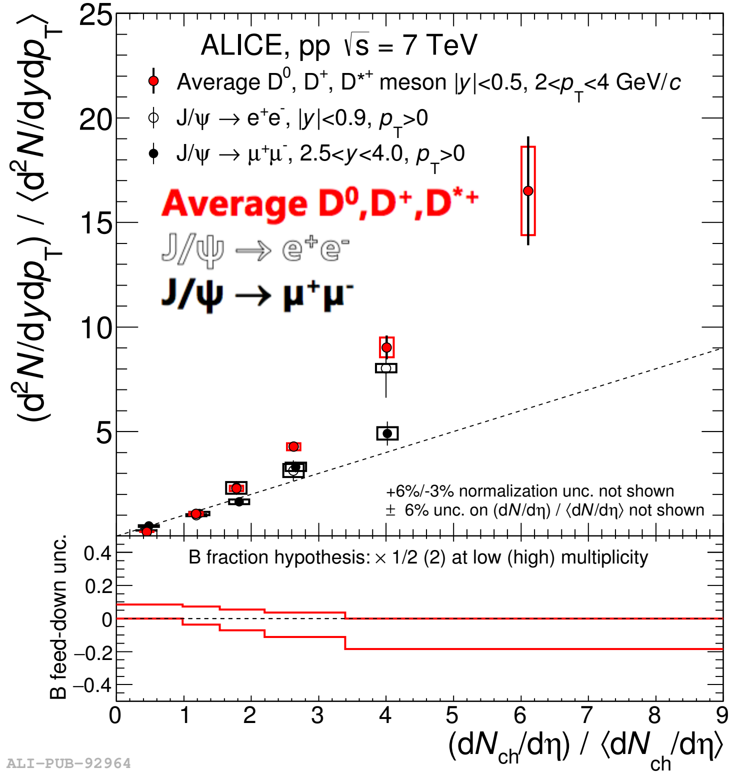
Where does the energy lost go?



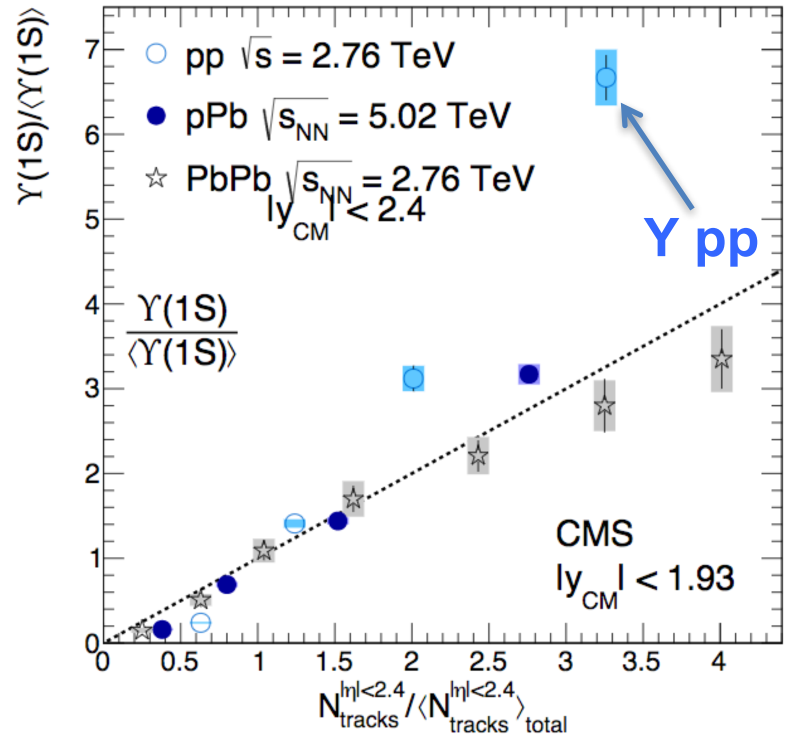
The momentum difference in the di-jet is balanced by **low p_T particles at large angles** relative to the away side jet axis

HF yields vs event multiplicity

Study the effect of multi-particle interactions (MPI) on the hard heavy-flavour scale



ALICE, Phys.Lett. B712 (2012) 165
JHEP 09 (2015) 148



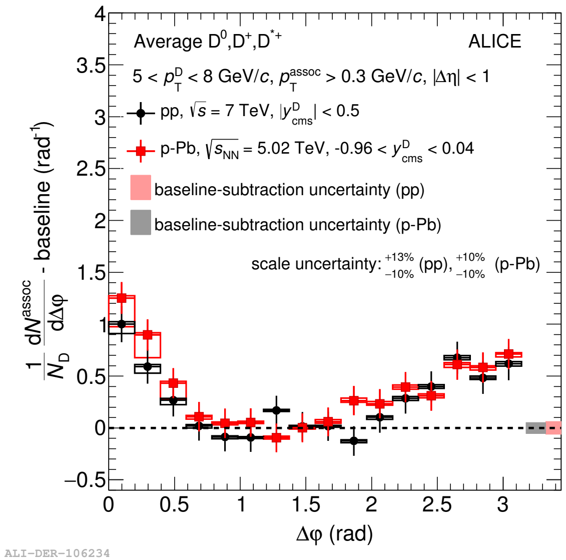
CMS, JHEP 04 (2014) 103

Increasing trend with multiplicity for **D mesons**, **J/ψ** and **Y** in pp collisions:

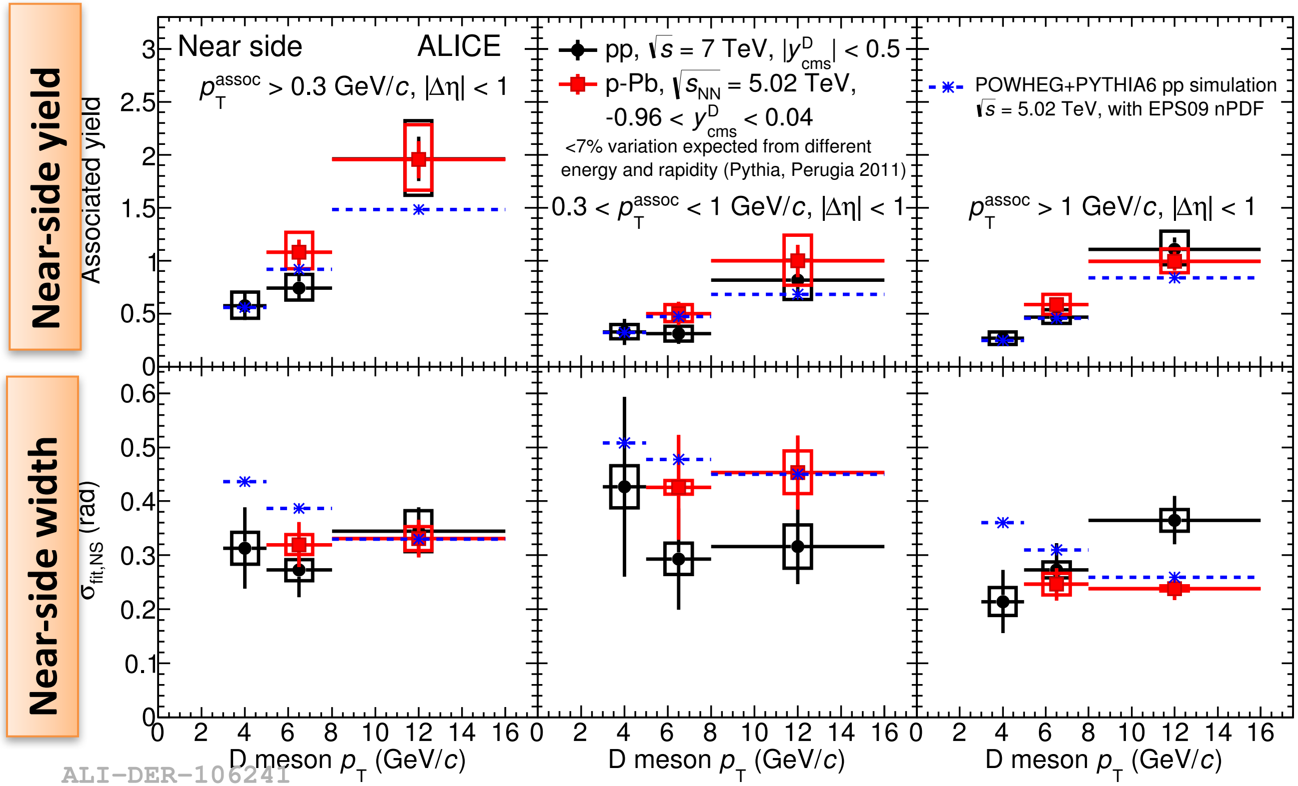
- Behaviour related to HQ production process rather than to hadronization mechanism
- MPI are dominating the high-multiplicity events and affecting heavy-flavour production

D-h correlations in pp and p-Pb

$5<p_T^D<8$ GeV/c, $p_T^{assoc}>0.3$ GeV/c



ALICE, arXiv:1605.06963

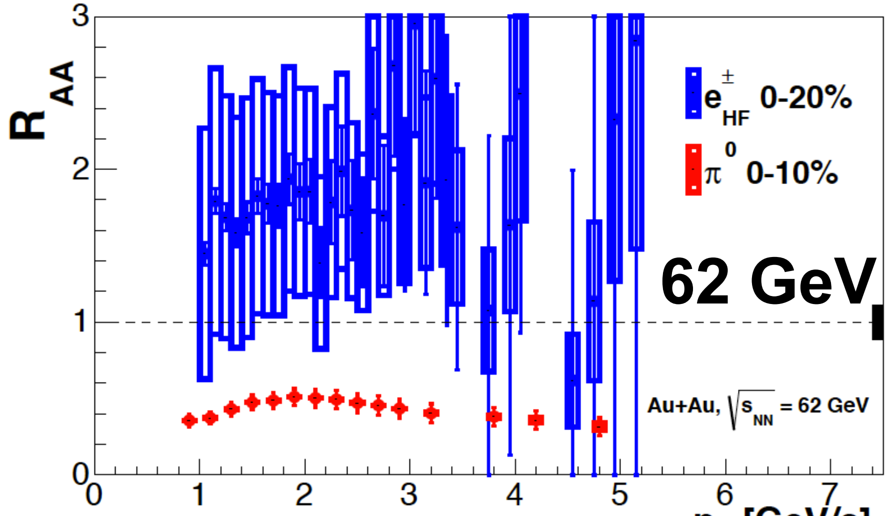


Compatibility within uncertainties between **pp collisions at √*s* = 7 TeV** and **p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV** after baseline subtraction

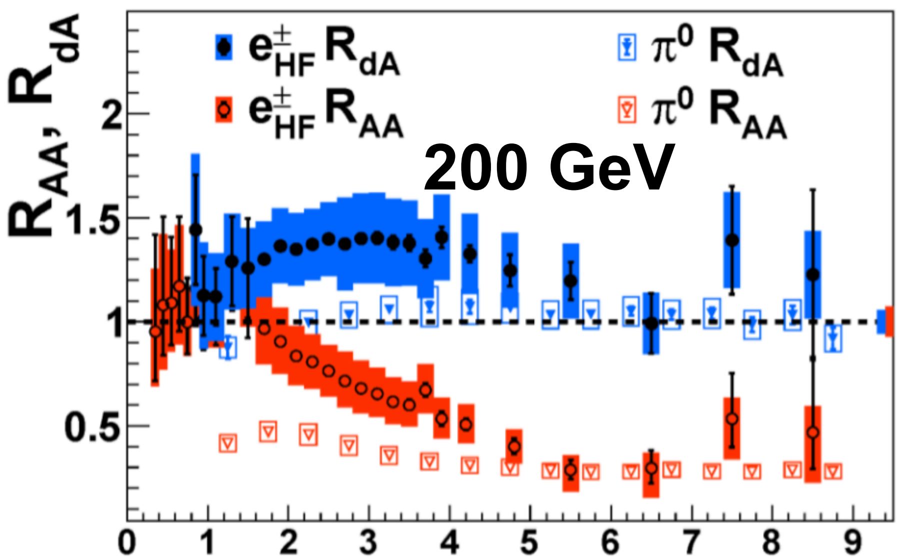
Near-side yields and widths compatible in data and simulations within uncertainties.

No modifications due to CNM effects in p-Pb seen within uncertainties

Leptons from HF hadron decays at RHIC



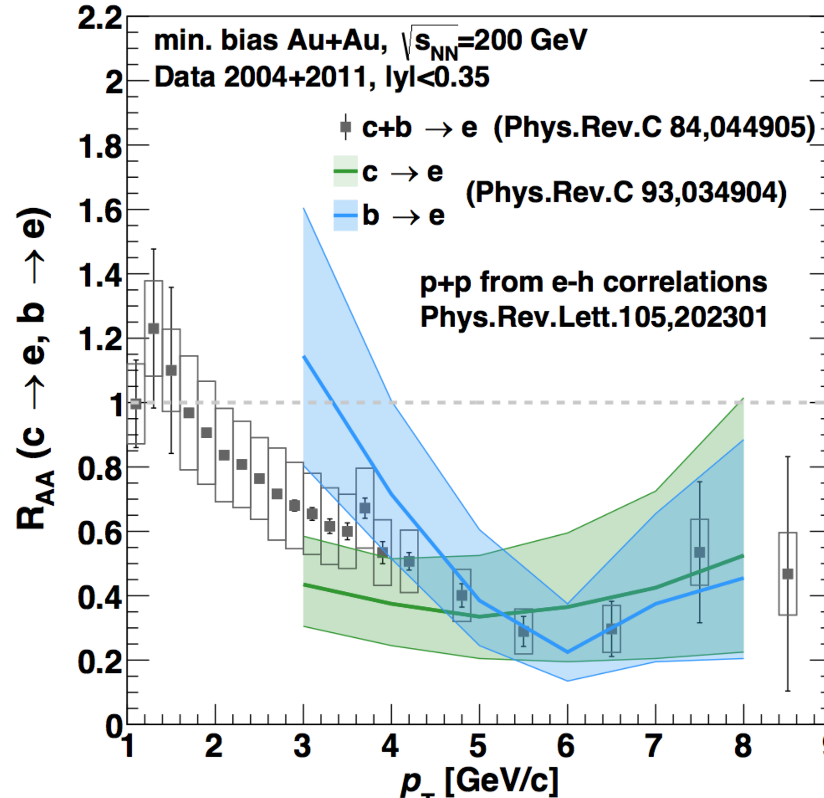
PHENIX, Phys.Rev. C91 (2015) 044907



PHENIX, PRL 109 (2012) 242301 p_T [GeV/c]

c,b→electrons

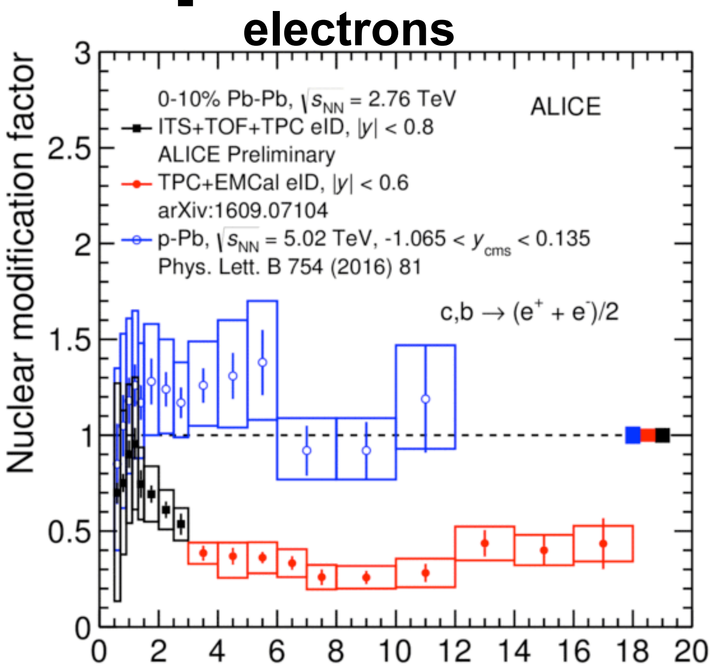
Charm and beauty separation

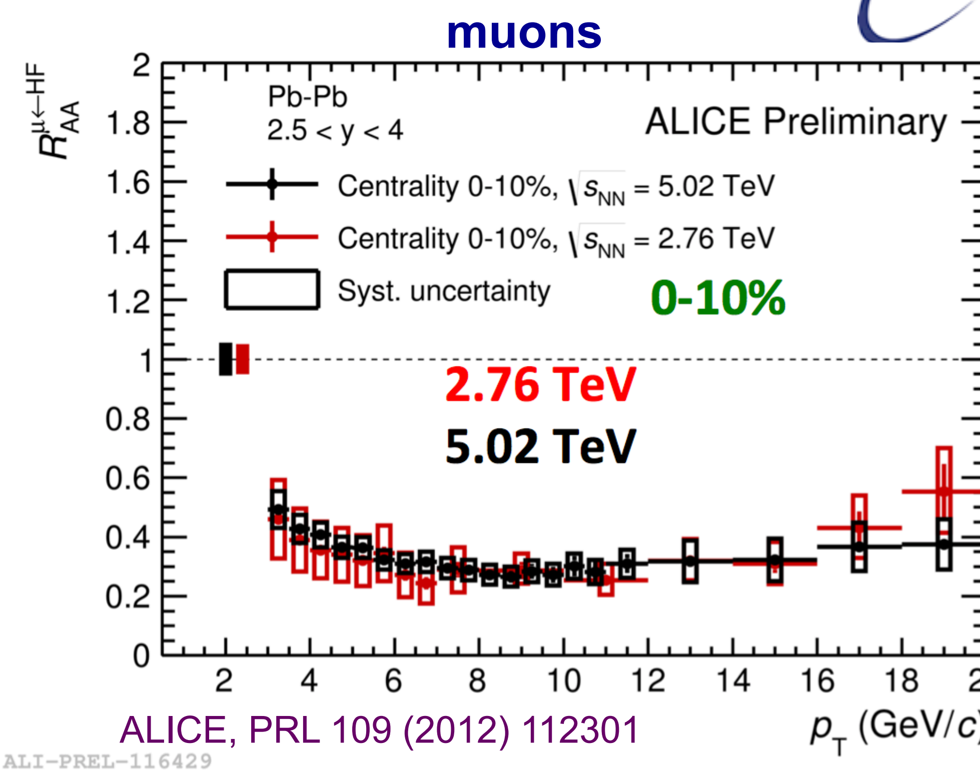


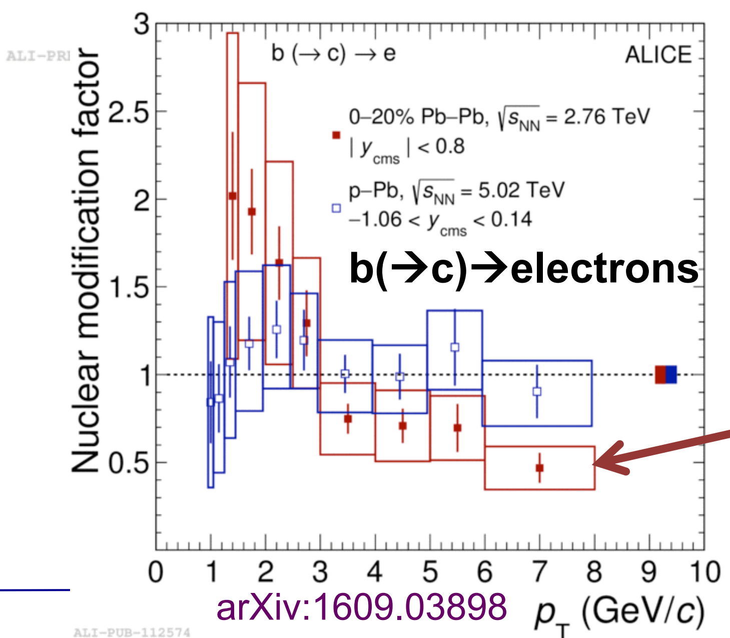
PHENIX, PRC 93 (2016) 034904

→ Expect improvement from 2014 run with x10 statistics

Leptons from HF hadron decays at LHC



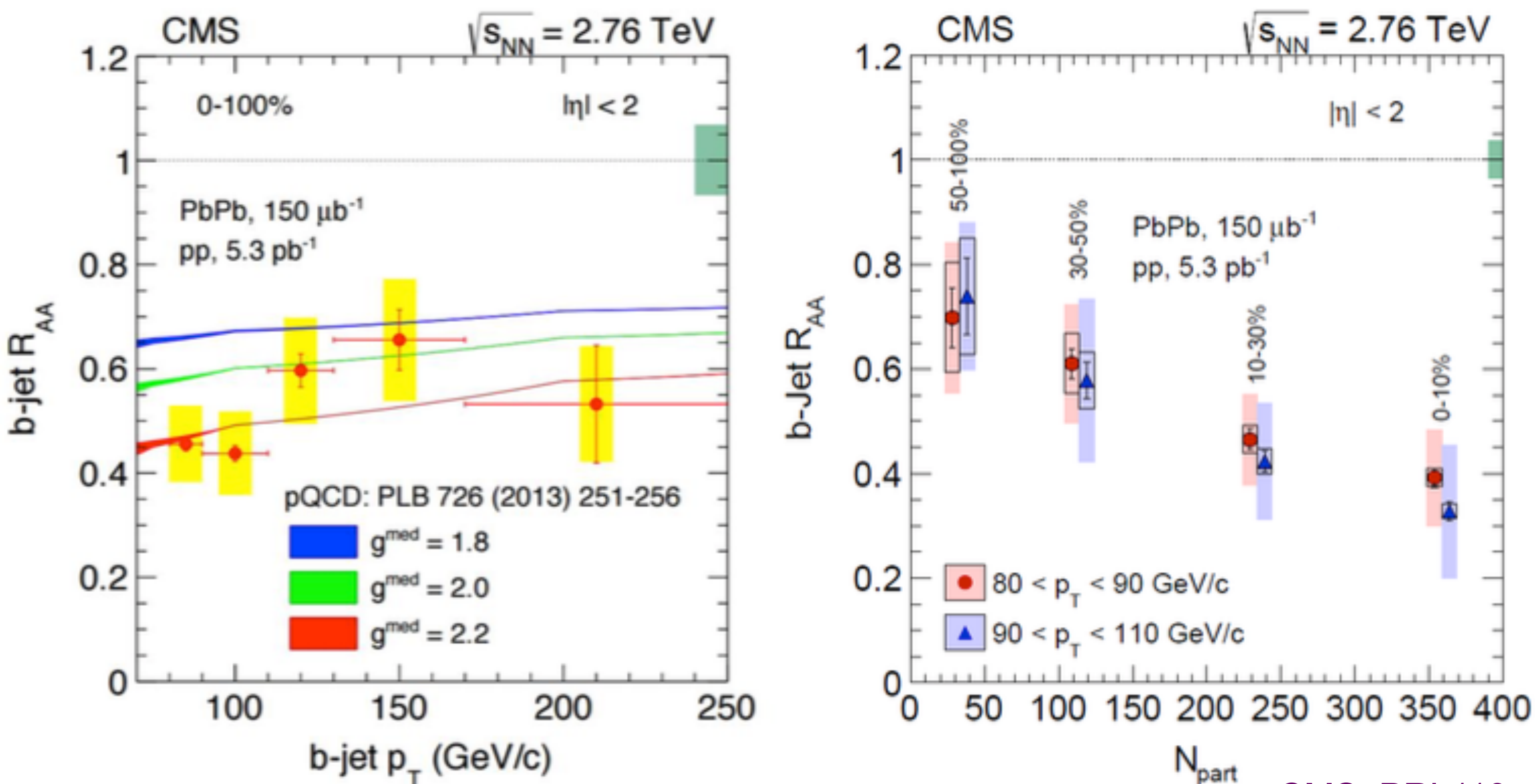




Similar suppression of **electrons and muons from heavy-flavour** hadron decays at the LHC.

Electrons from beauty-hadron decays in Pb-Pb collisions.
Hint for suppression for p_T>3 GeV/c

Beauty jets in Pb-Pb collisions



CMS, PRL113, 132301 (2014)

Quark-jets tagged in Pb-Pb collisions.

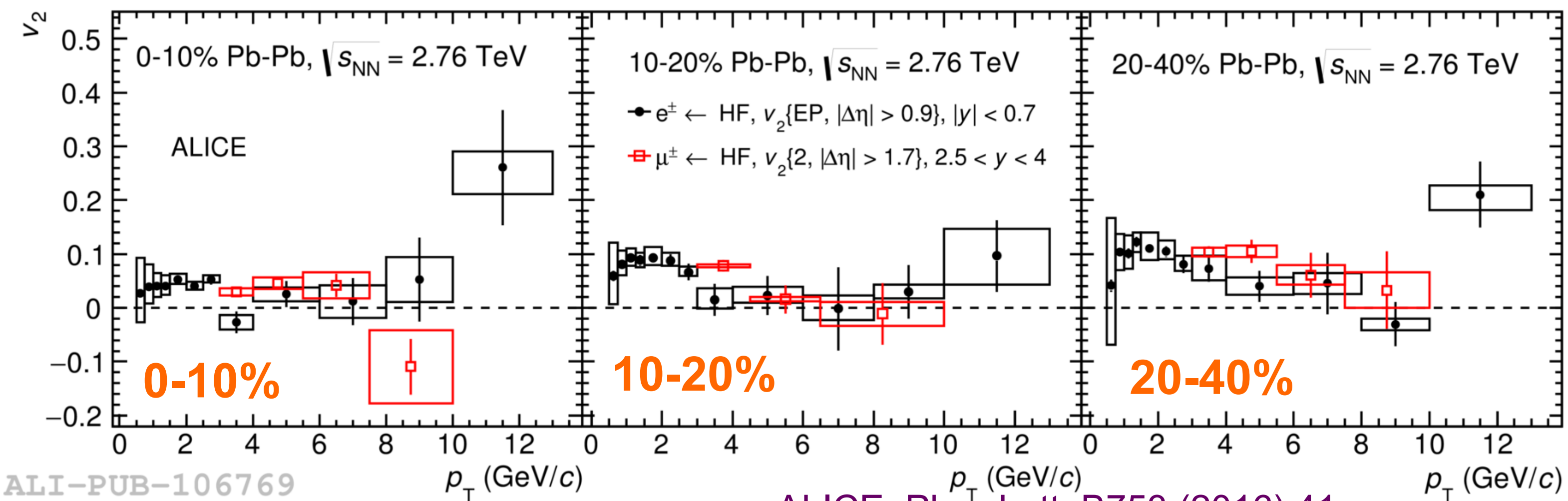
B-jet suppression increasing with centrality, **described by model with strong jet-medium coupling**, consistent with inclusive jet suppression.

Quark mass effect negligible at high jet p_T.

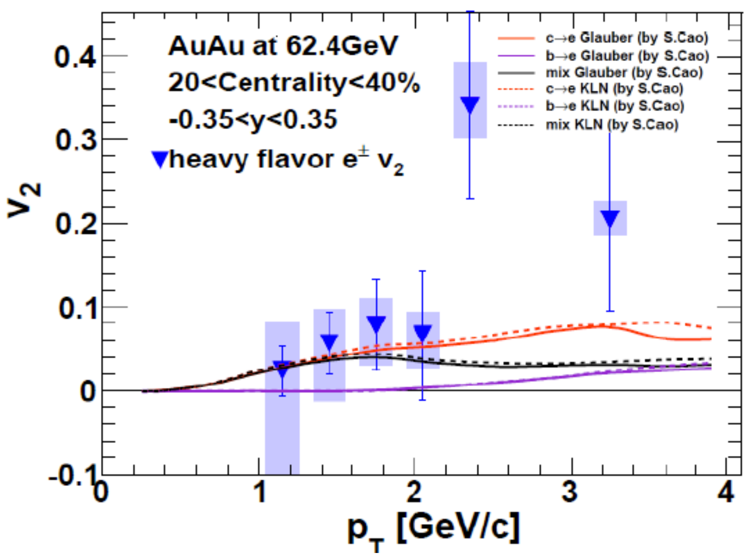
HF lepton azimuthal anisotropy

(c,b)→electrons, muons

ALICE



ALICE, Phys.Lett. B753 (2016) 41
arXiv:1606.00321



PHENIX, PRC(2015) 044907

(c,b)→electrons RHIC

Charm v_2 at low energy (62 GeV):
is flowing? is recombination with light quarks?

Measurements of Heavy Flavours at RHIC and LHC in A-A (and pp, pA)

Full reconstruction of charm meson/baryon hadronic decays

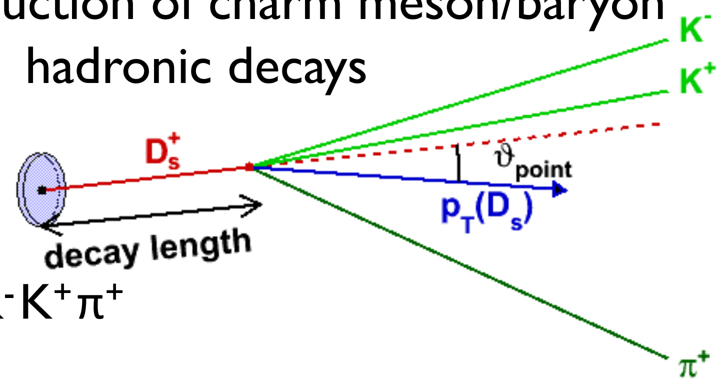
$D^0 \rightarrow K^-\pi^+$

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

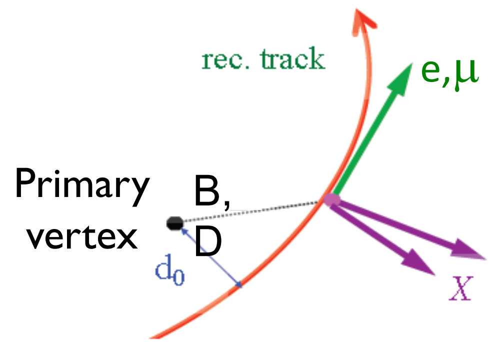
$D^{*+} \rightarrow D^0\pi^+$

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

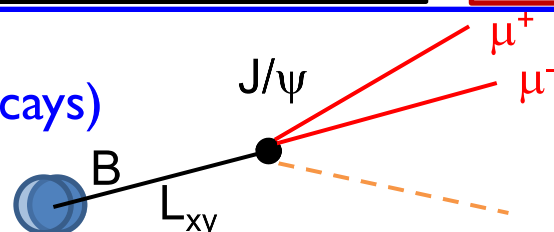
$\Lambda_c \rightarrow pK\pi$



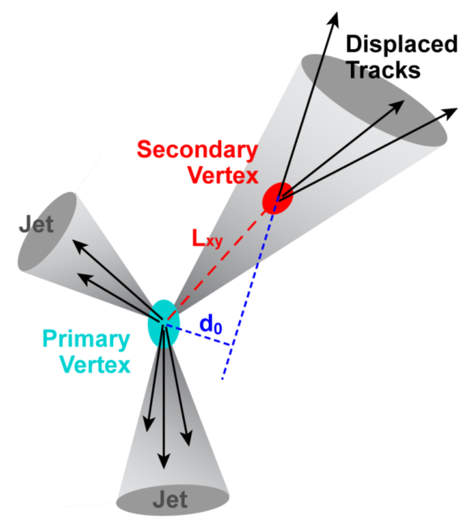
Semi-leptonic decays (charm,beauty), electrons from b



Displaced J/ψ (from B decays)



Jet b-tagging



Full reconstruction of beauty decays: **B** and **Λ_b**

$\Lambda_b \rightarrow J/\psi\ \Lambda$

$B^+ \rightarrow J/\psi\ K^+$, $J/\psi\ K\pi$

$B^0 \rightarrow J/\psi\ K^0_s$

$B_s^0 \rightarrow J/\psi\ \phi$

pp: ATLAS/CMS,LHCb

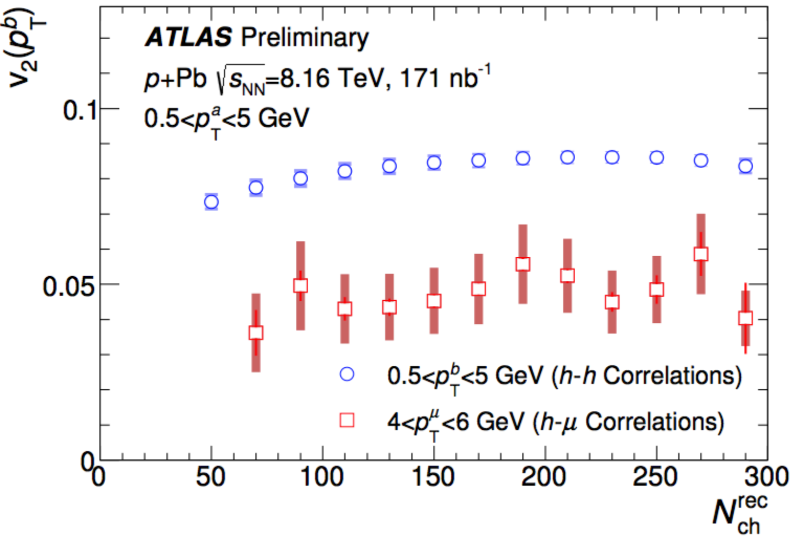
pPb (CMS) : B→ J/ψ K, π

same technique as for D mesons based on displaced vertex topologies

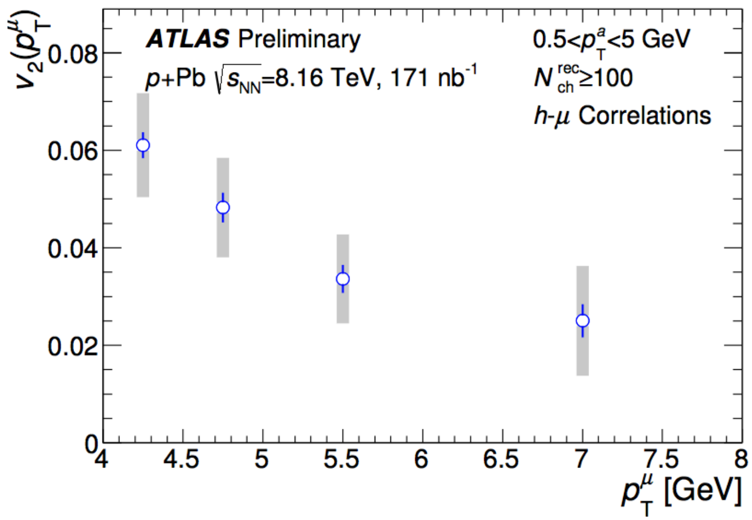
h-μ correlations in p-Pb collisions

Muons: mainly coming from heavy-flavour hadron decays

v_2 vs pPb multiplicity



v_2 vs p_T



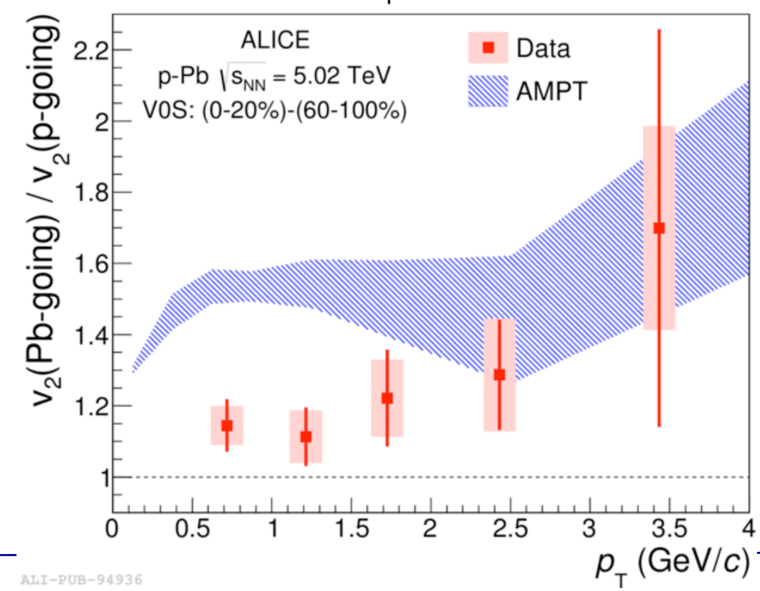
ATLAS: significant muon v_2 in pPb 8 TeV

-$v_{2\mu} \sim 0.6 \times v_{2had}$

-independent of p-Pb multiplicity

ALICE: p-Pb collisions at 5 TeV

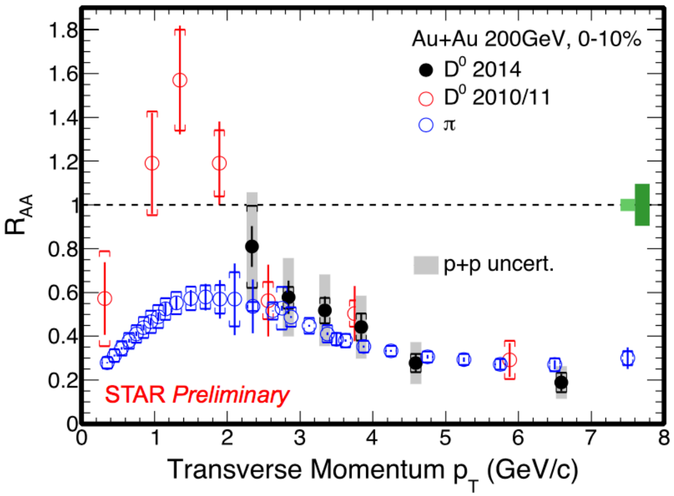
- Collective effects for high-p_T muons in
- high-multiplicity events via μ-h correlations



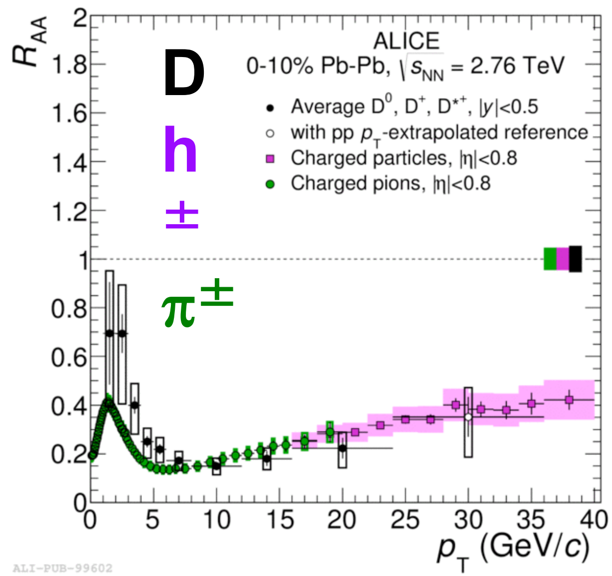
Mass/colour dependence of energy loss?

→ Compare R_{AA} of different particles: π, **D**, **B**,…

200 GeV

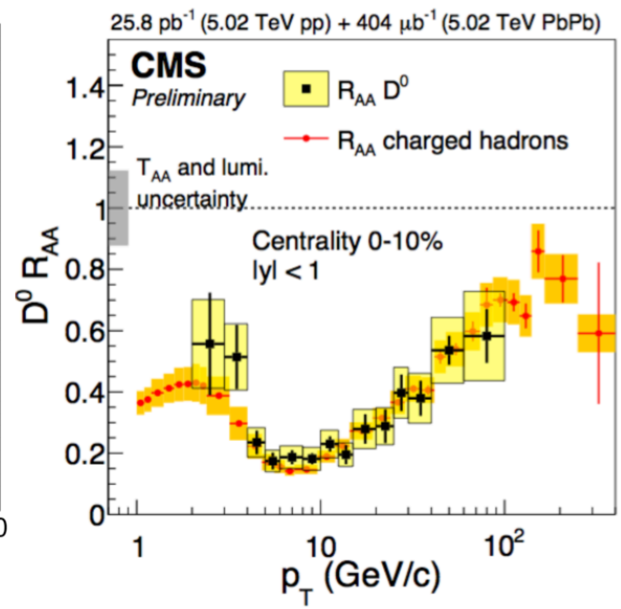


2.76 TeV



ALICE, JHEP1603 (2016) 081

5.02 TeV



R_{AA}(D)~R_{AA}(π,h±) in different AA collision energies

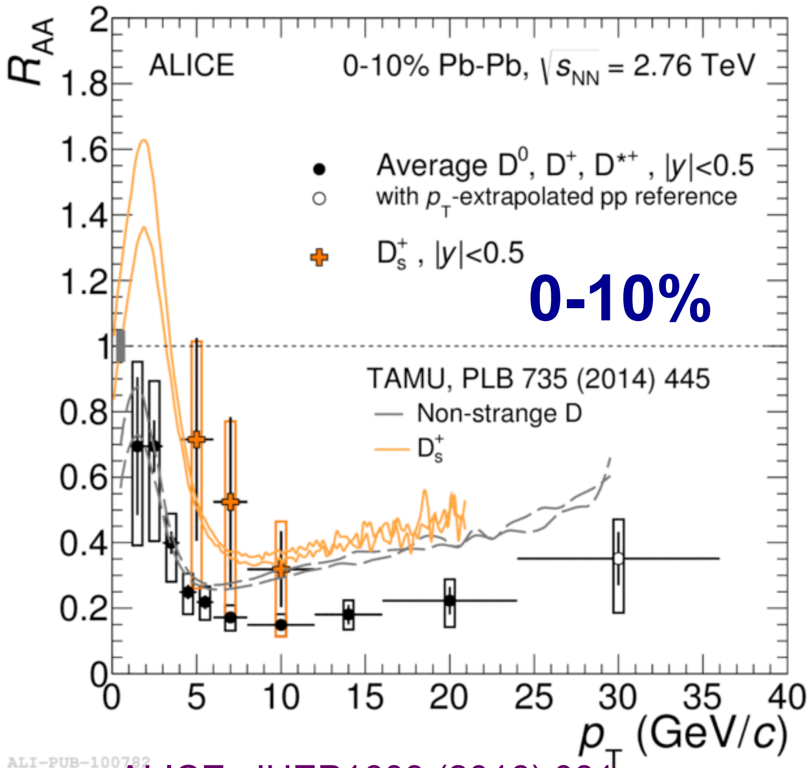
But keep in mind:

→Different quark spectra

→R_{AA}(h, π) affected by g/q fragmentation, while R_{AA}(D)~R_{AA}(c) because of harder HQ fragmentation

M.Djordjevic, PRL 112, 042302 (2014)

D mesons at LHC



ALICE, JHEP1603 (2016) 081
JHEP1603 (2016) 082

ALICE:

D^0,D^+,D^{*+},D_s^+

Strong suppression of prompt D-meson yield in central Pb-Pb collisions

- up to a factor of 5 at p_T~10 GeV/c

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

- expected if recombination plays a role in charm hadronization

Beauty and charm jets in p-Pb and Pb-Pb