Open heavy-flavor measurements with ALICE at the LHC

R. Bailhache on behalf of the ALICE Collaboration

SQM
DUBNA 2015

Outline

- Open heavy-flavor physics
- The ALICE open heavy-flavor program
- Selection of Run 1 results:
  - pp collisions
  - Pb-Pb collisions
  - p-Pb collisions
- Conclusion and Outlook for Run 2 and Run 3

Heavy-flavor cross sections

Charm: $m \sim 1.5$ GeV/c^2

Beauty: $m \sim 4.5$ GeV/c^2

- Charm and beauty quarks are produced in hard scatterings with large Q^2

➡ Production cross sections calculable with perturbative QCD

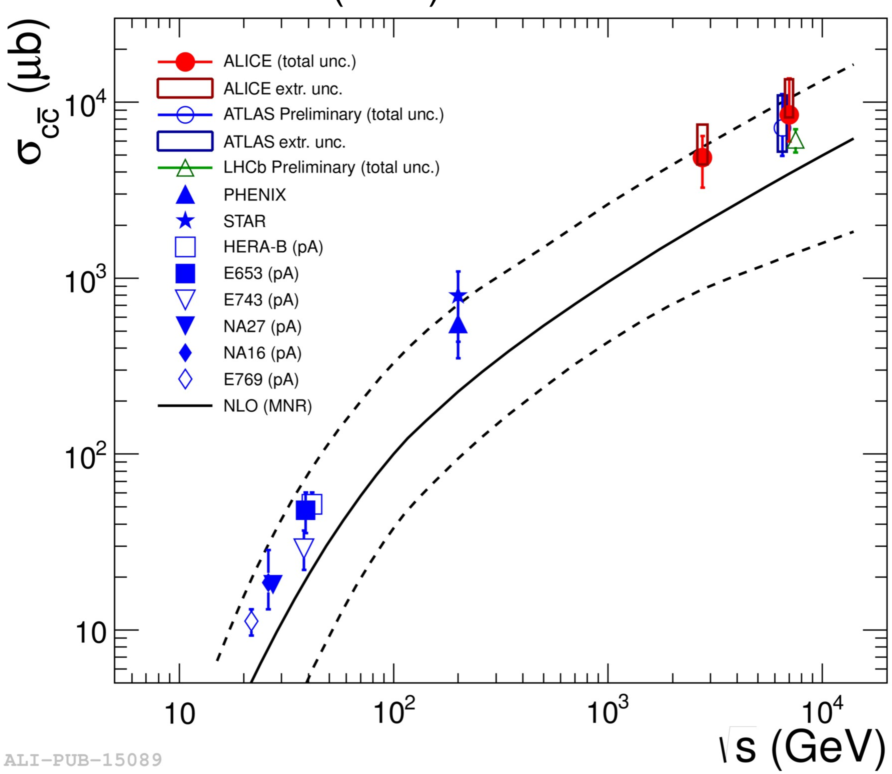
- Abundant production of heavy quarks at the LHC

Increase in $\sigma_{Q\bar{Q}}$ from RHIC to the LHC:

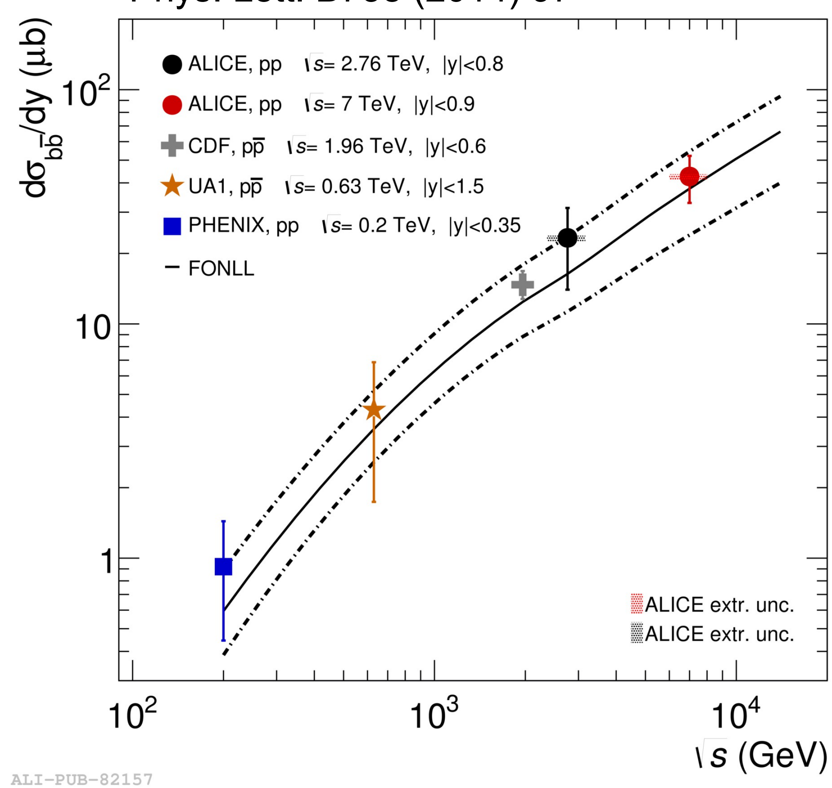
$\sim 10^*\sigma_{c\bar{c}}$ (RHIC)

$\sim 50^*\sigma_{b\bar{b}}$ (RHIC)

JHEP 1207 (2012) 191



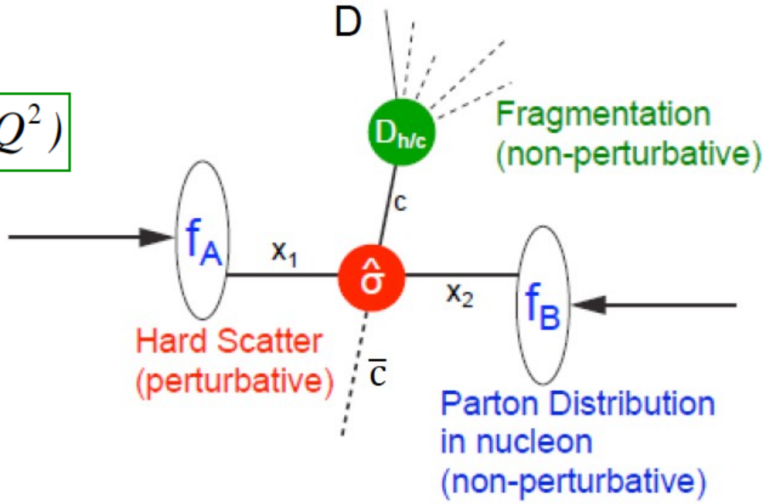
Phys. Lett. B738 (2014) 97



Open heavy flavor in pp collisions

- Precision test of pQCD calculations based on the factorization approach:

$$\sigma_{hh \to Hx} = PDF(x_a, Q^2) PDF(x_b, Q^2) \otimes \sigma_{ab \to q\bar{q}} \otimes D_{q \to H}(z_q, Q^2)$$



Mangano et al., Nucl. Phys. B373 (1992) 295
Cacciari et al., JHEP 05 (1998) 007
Kniehl et al., PRD 71 (2005) 014018
Jung et al., JHEP 1101 (2011) 085

→ Measure total and differential production cross sections

- More differential measurements → deeper insight into charm production
  - Azimuthal-correlation measurements: quark fragmentation and different $Q\bar{Q}$ production mechanisms leading to different angular correlations of Q and $\bar{Q}$
  - Heavy-flavor production as function of charged-particle multiplicity: role of multi-parton interactions

- Provide a reference for p-Pb and Pb-Pb collisions

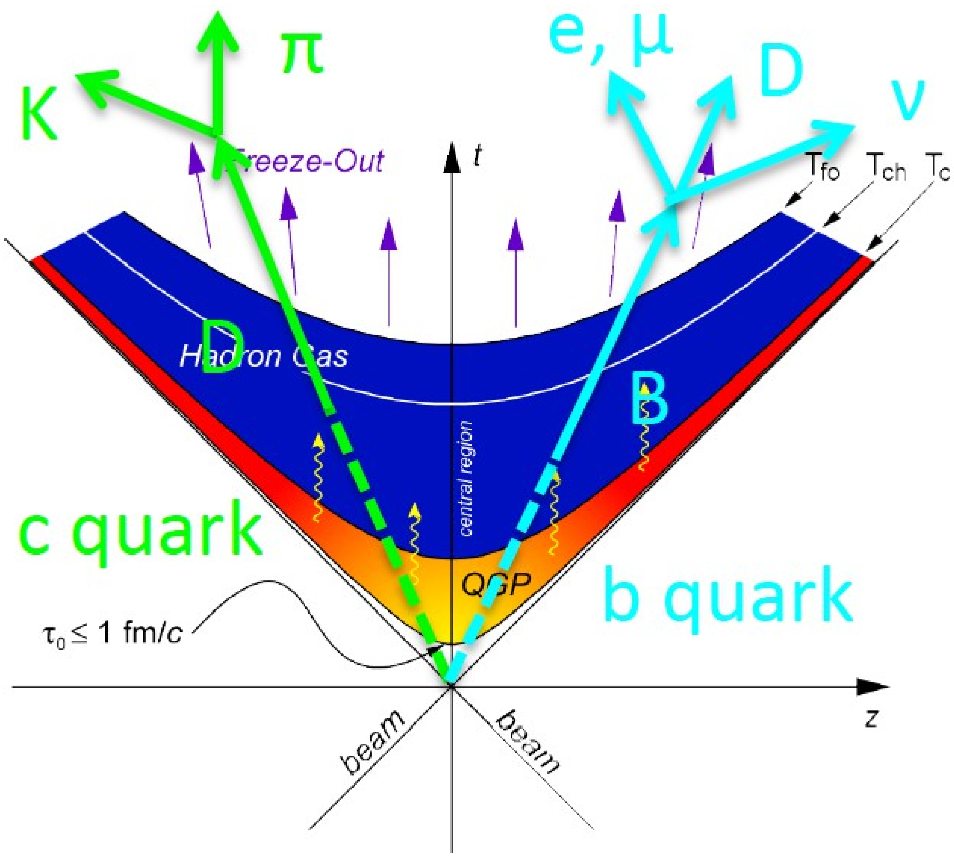
Open heavy flavor in heavy-ion collisions

- Heavy quarks produced at the early stage of the collision: formation time of $c\bar{c}$ pairs: $1/(2m_c) = 0.08$ fm/c

- Expected formation time of the QGP ≤ 0.1 fm/c
- Expected lifetime of the QGP: 10 fm/c

- Flavor conserved by the strong interaction

→ **Heavy quarks experience the full evolution of the deconfined medium**



Main questions:
- **Parton energy loss in the QGP**
- **Participation of the heavy quarks in the collective expansion of the medium**

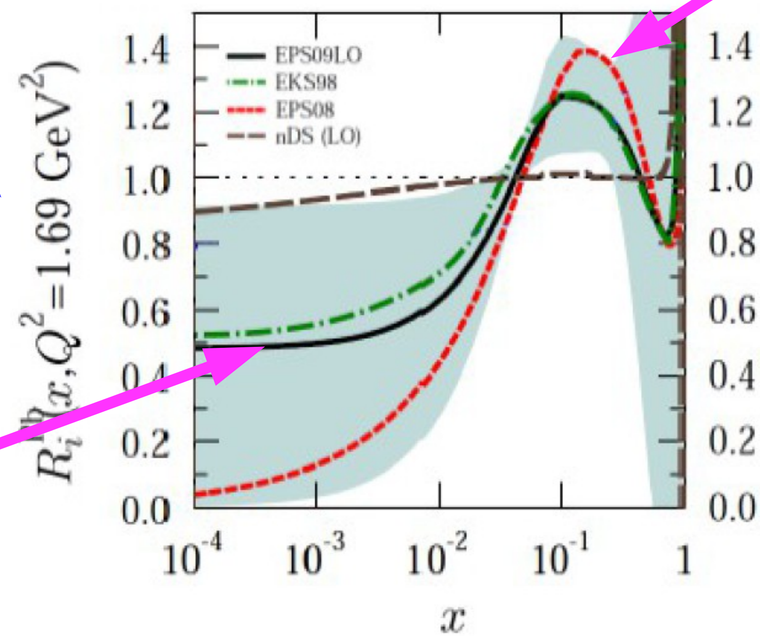
Open heavy flavor in p-Pb collisions

Study cold nuclear matter effects
to disentangle them from hot and dense matter effects in Pb-Pb collisions

Ratio of the Parton Distribution Function (here for gluons) in the nucleus and in nucleons

Anti-shadowing

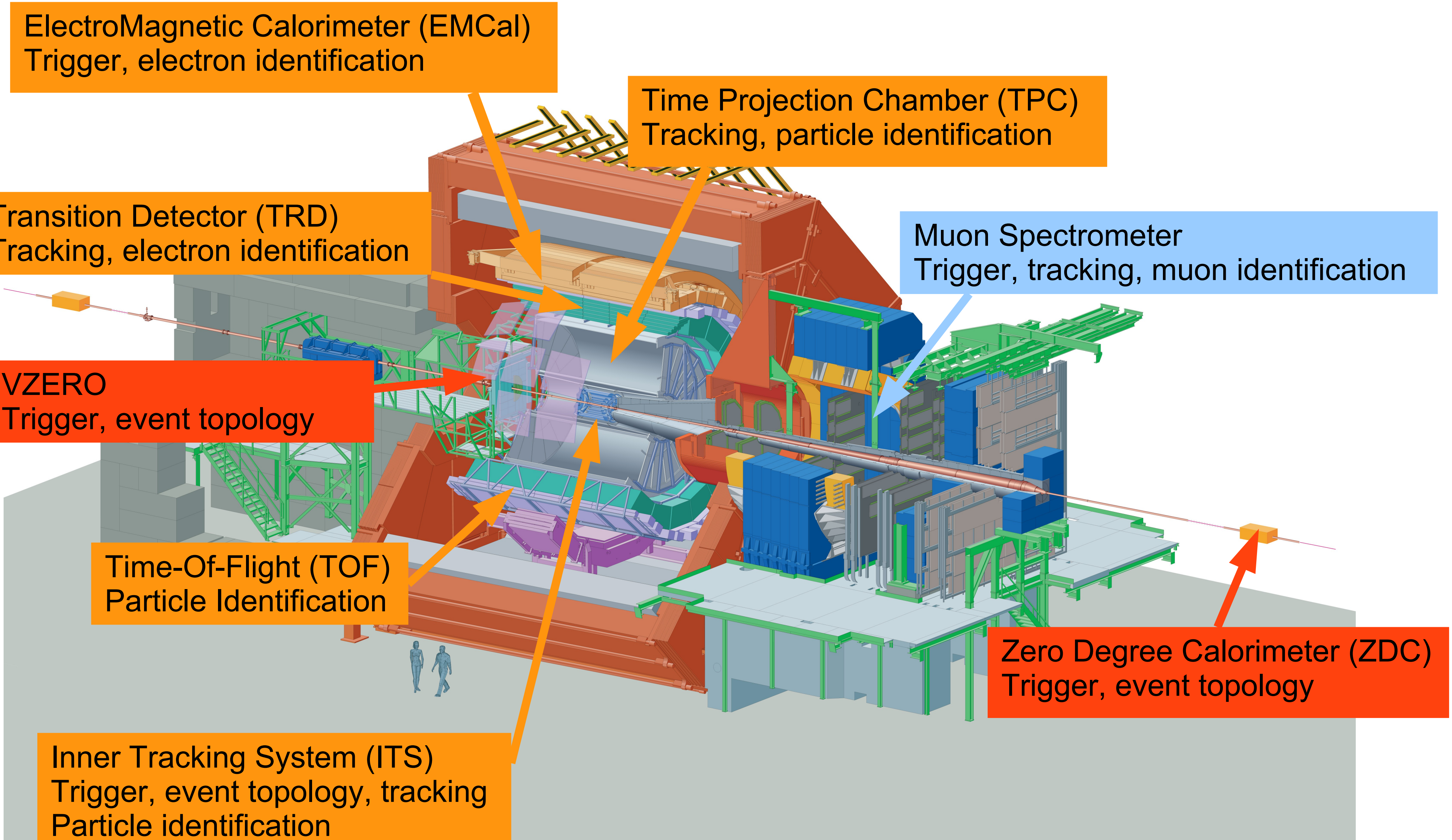
JHEP 0904 (2009) 65



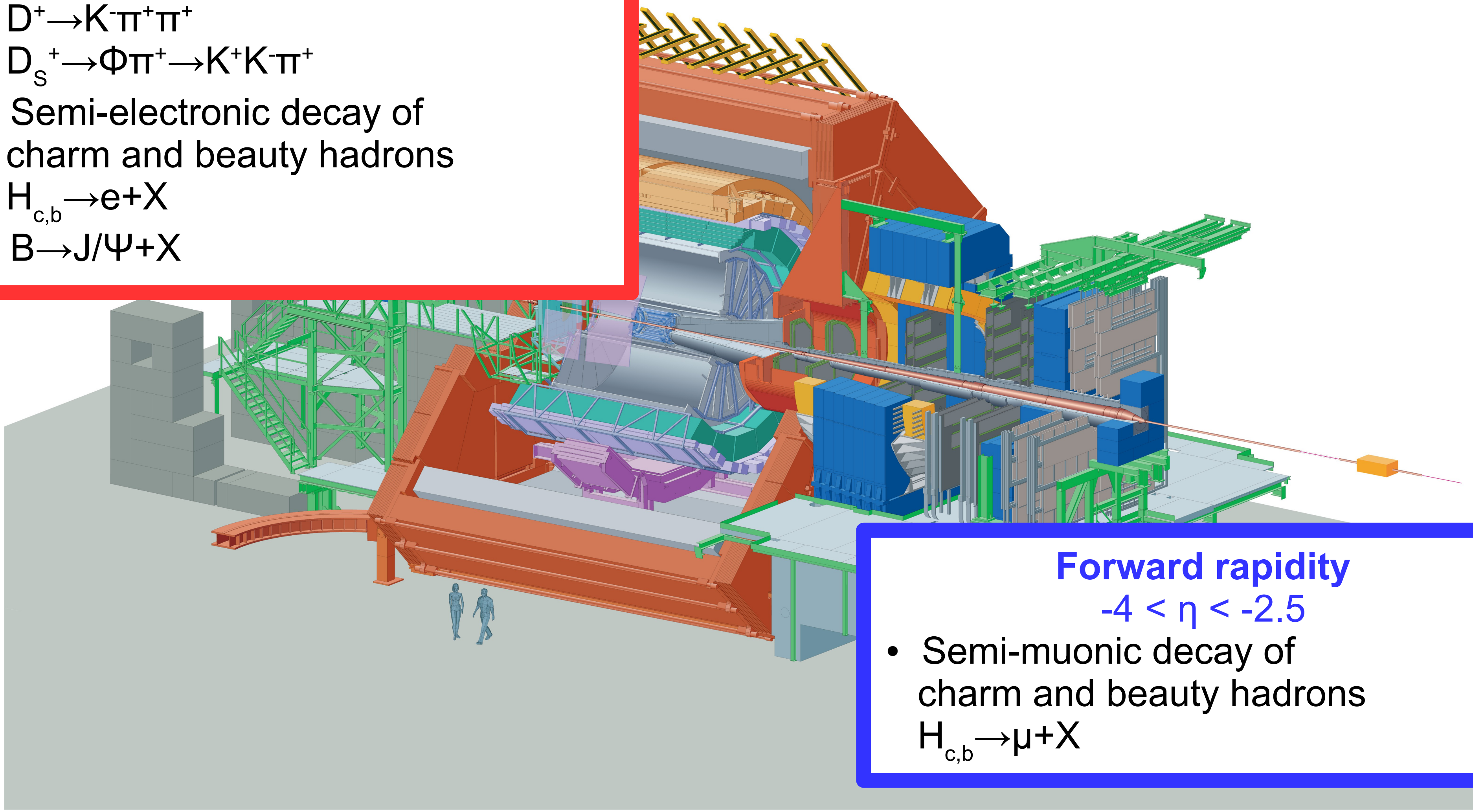
Shadowing

- Modification of the parton distributions in nuclei
  Shadowing / gluon saturation (Color Glass Condensate CGC) at low Bjorken *x*
  JHEP 0904 (2009) 65, NPA 920 (2013) 78
- k_T-broadening from multiple soft scatterings Vitev,PRC 75 (2007) 064906
- Partonic energy loss from initial- and final-state radiation
- Investigate potential final-state effects

ALICE at the LHC



The ALICE open heavy-flavor program



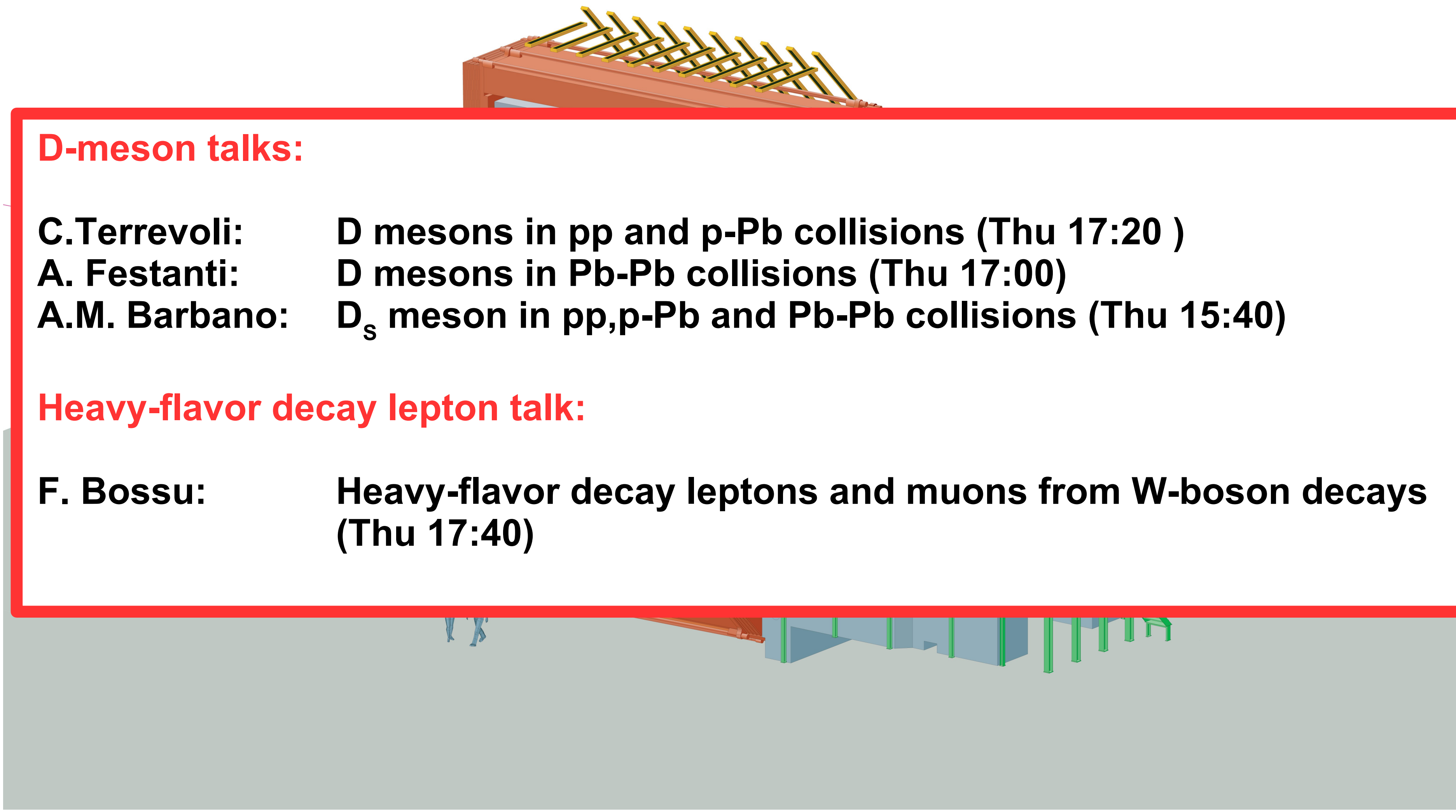
Mid rapidity
$-0.9 < \eta < 0.9$

- Hadronic decay of charm hadrons:
  $D^0 \to K^-\pi^+$ $D^{*+} \to D^0\pi^+$
  $D^+ \to K^-\pi^+\pi^+$
  $D_s^+ \to \Phi\pi^+ \to K^+K^-\pi^+$
- Semi-electronic decay of charm and beauty hadrons
  $H_{c,b} \to e+X$
- $B \to J/\Psi + X$

Forward rapidity
$-4 < \eta < -2.5$

- Semi-muonic decay of charm and beauty hadrons
  $H_{c,b} \to \mu + X$

The ALICE open heavy-flavor program



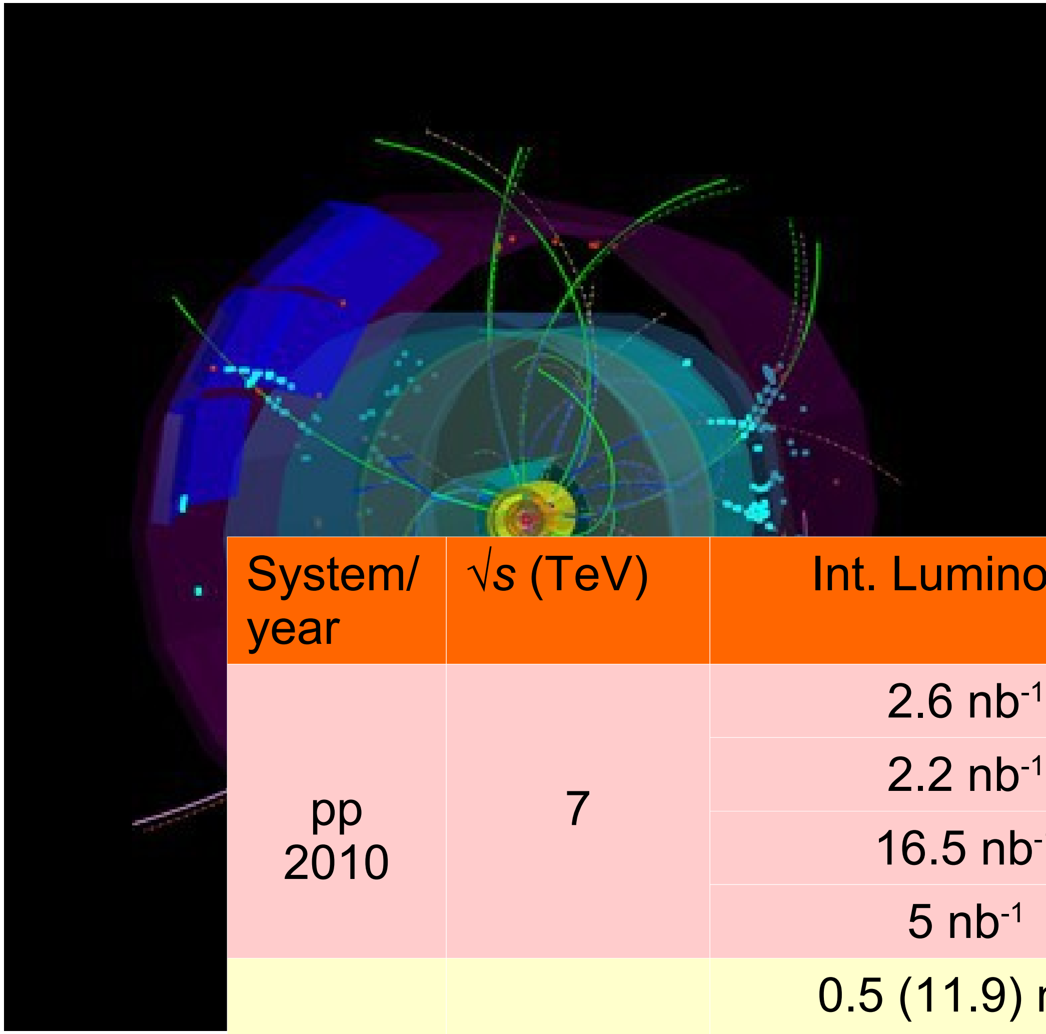
D-meson talks:

C.Terrevoli: D mesons in pp and p-Pb collisions (Thu 17:20)
A. Festanti: D mesons in Pb-Pb collisions (Thu 17:00)
A.M. Barbano: D_s meson in pp,p-Pb and Pb-Pb collisions (Thu 15:40)

Heavy-flavor decay lepton talk:

F. Bossu: Heavy-flavor decay leptons and muons from W-boson decays (Thu 17:40)

pp collisions



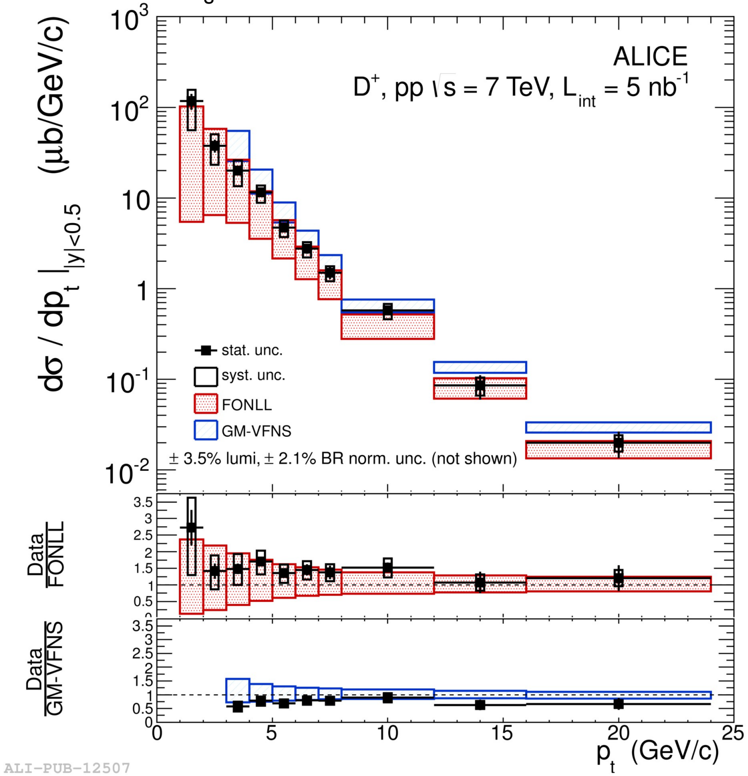
System/ year	√s (TeV)	Int. Luminosity	Analysis
pp 2010	7	2.6 nb^{-1}	Heavy-flavor decay electrons
		2.2 nb^{-1}	Beauty-decay electrons
		16.5 nb^{-1}	Heavy-flavor decay muons
		5 nb^{-1}	D mesons
pp 2011	2.76	0.5 (11.9) nb^{-1}	Heavy-flavor and beauty-decay electrons minimum-bias (EMCal trigger)
		19 nb^{-1}	Heavy-flavor decay muons
		1.1 nb^{-1}	D mesons

Charm and heavy-flavor decay leptons

pp collisions at $\sqrt{s}$ = 7 TeV

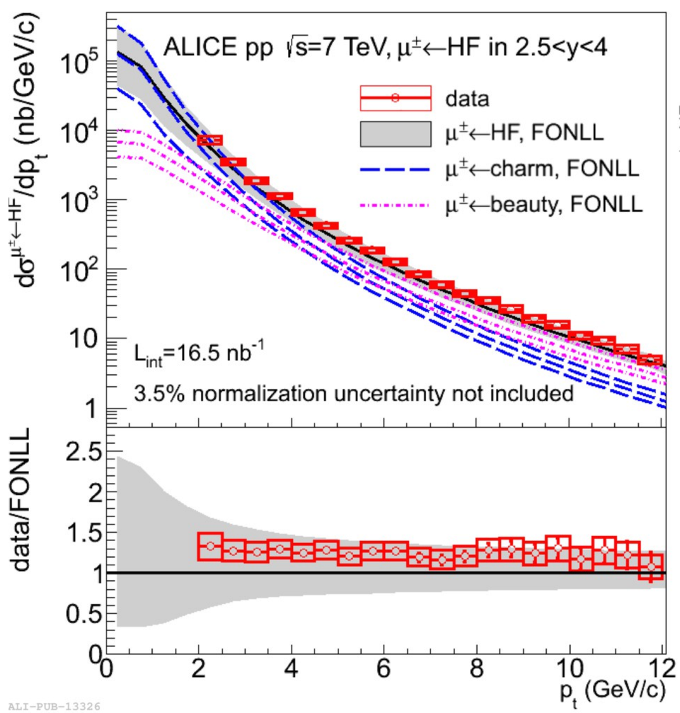
D mesons

JHEP 1201 (2012) 128
D_s in PLB 178 (2012) 279



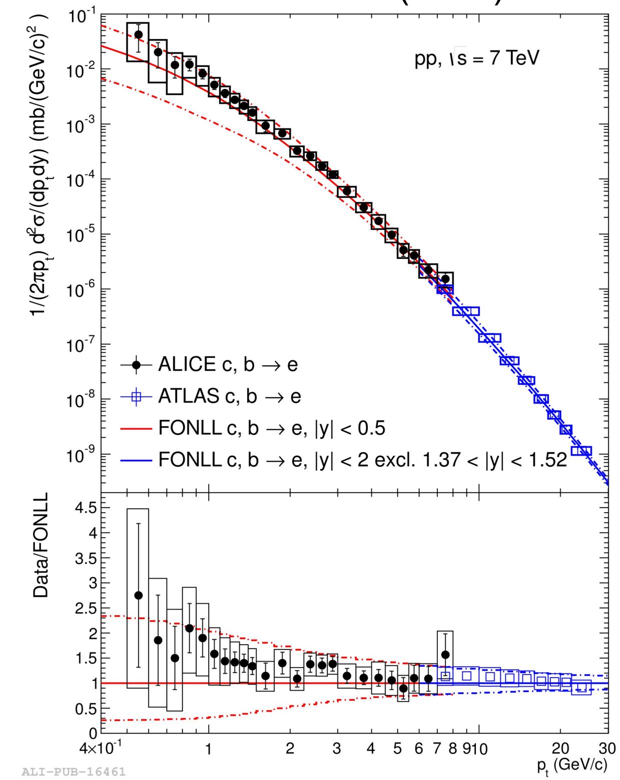
Heavy-flavor decay muons

PLB 708 (2012) 265



Heavy-flavor decay electrons

ALICE: PRD 86 (2012) 11200
ATLAS: PLB 707 (2012) 438



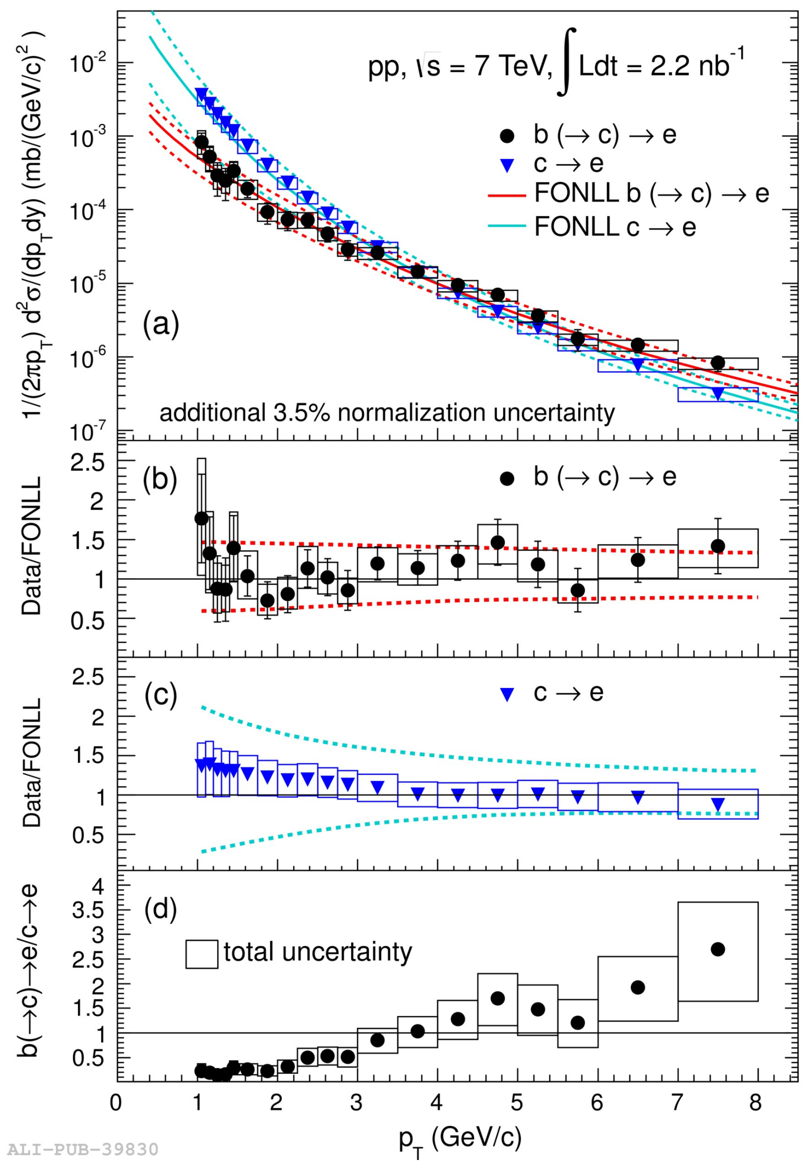
- pQCD calculations describe the data within uncertainties
  FONLL: JHEP 1210 (2012) 37; GM-VFNS: EPJ C72 (2012) 2082; k_T-factorization: PRD 87 (2013) 094022
- Measurement of the heavy-flavor decay electrons complementary to the ATLAS results
- Similar situation at $\sqrt{s}$ = 2.76 TeV

Beauty-decay electrons

Phys. Lett. B721 (2013) 13-23

pp collisions at $\sqrt{s}$ = 7 TeV

- Separate charm from beauty-decay electrons
- Good description of the data by FONLL calculations
  FONLL: JHEP 1210 (2012) 37
- Similar situation at $\sqrt{s}$ = 2.76 TeV



Talk by F. Bossu

D meson-hadron azimuthal correlations

Measure azimuthal correlations of D mesons and charged hadrons

pp collisions at $\sqrt{s}$ = 7 TeV

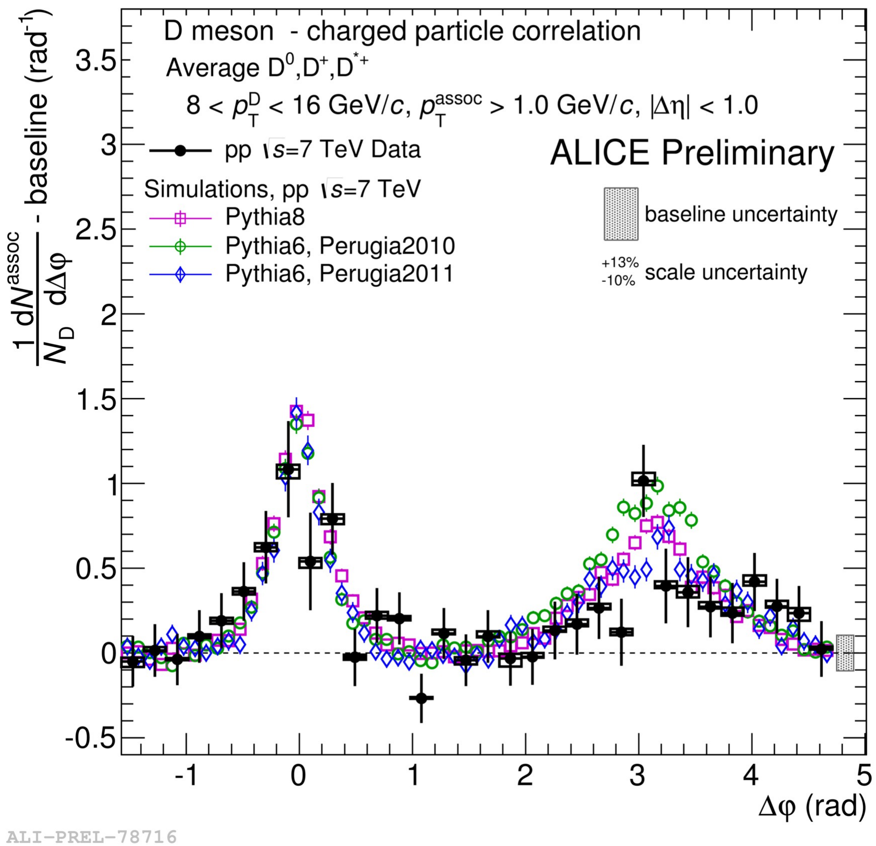
$8 < p_T^D < 16$ GeV/c
$p_T^{assoc} > 1$ GeV/c

Sensitive to:

- Quark fragmentation
- $c\bar{c}$ production mechanisms

- Different PYTHIA tunes consistent with the measurement within uncertainties

- Expect smaller statistical errors with data from Run 2

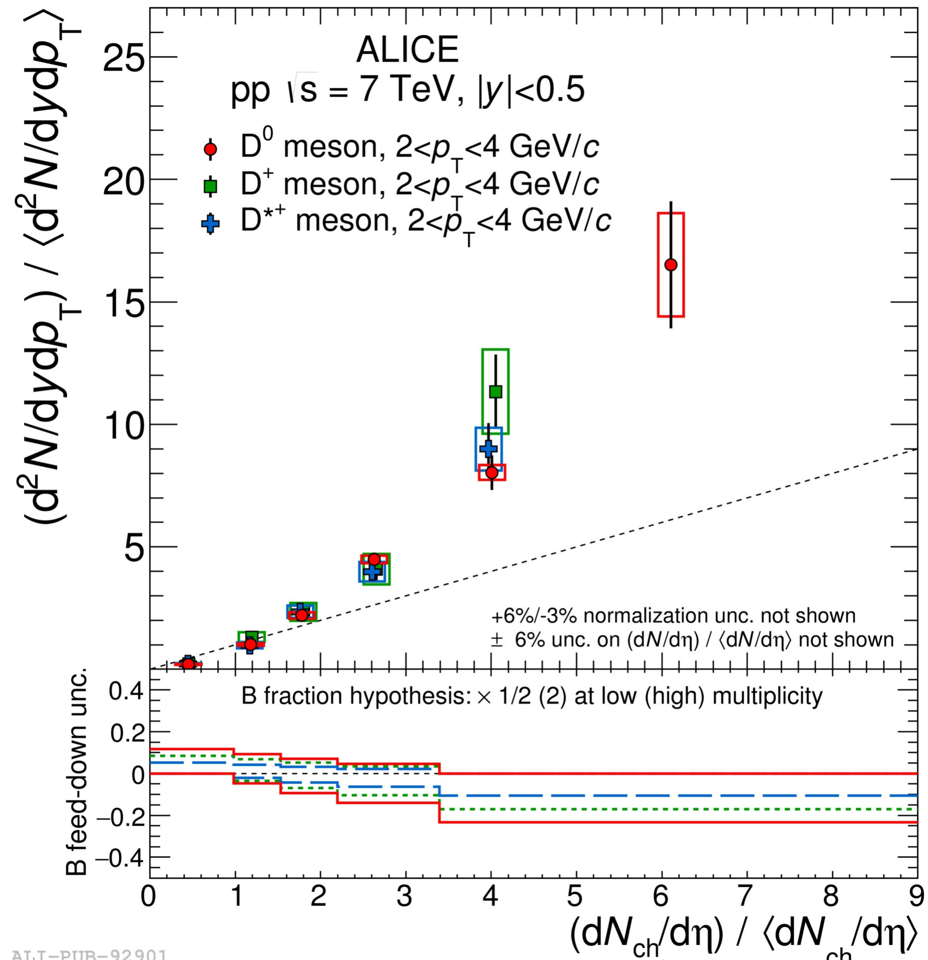


Multiplicity dependence of D-meson production

pp collisions at $\sqrt{s}$ = 7 TeV

Self-normalized D-meson yields

arXiv: 1505.00664



Relative charged-particle multiplicity

Sensitive to:

- Interplay between hard and soft processes
- Multi-Parton Interactions (MPI)

D-meson per-event yields increase with charged-particle multiplicity

- Faster than linear increase
- D^0, D^+, D^{*+} compatible within uncertainties

Talk by C. Terrevoli

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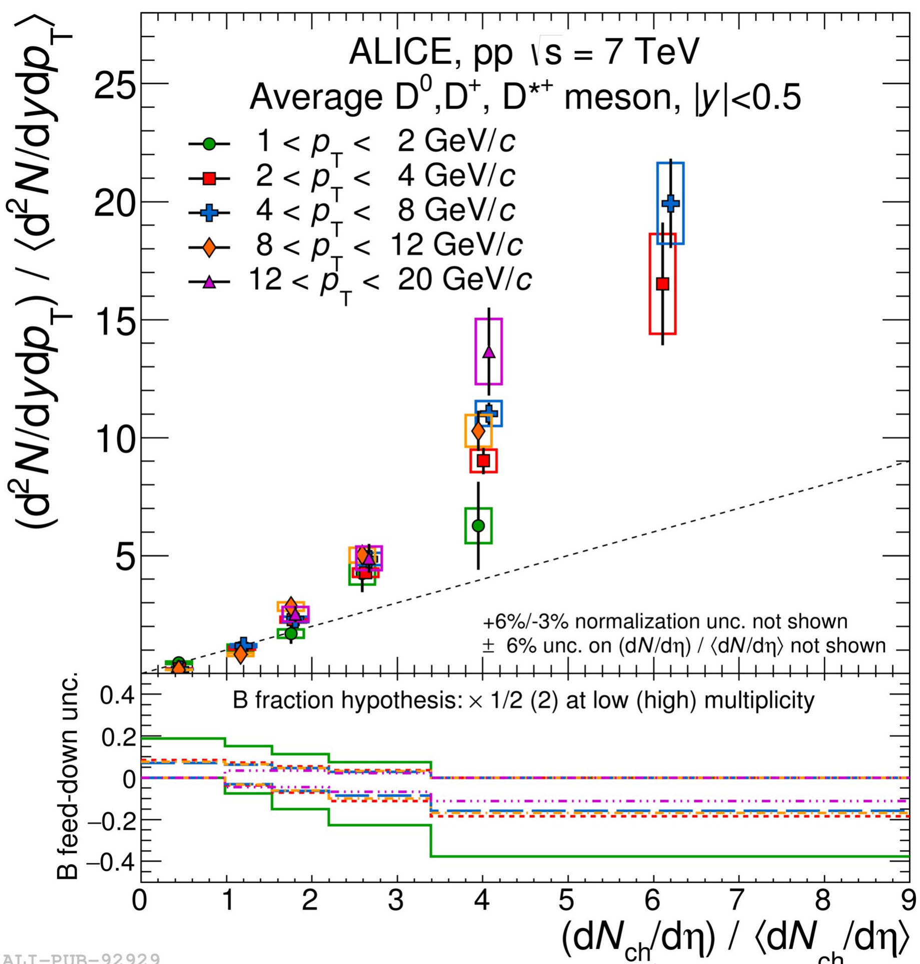

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- No p_T dependence observed within uncertainties

Talk by C. Terrevoli

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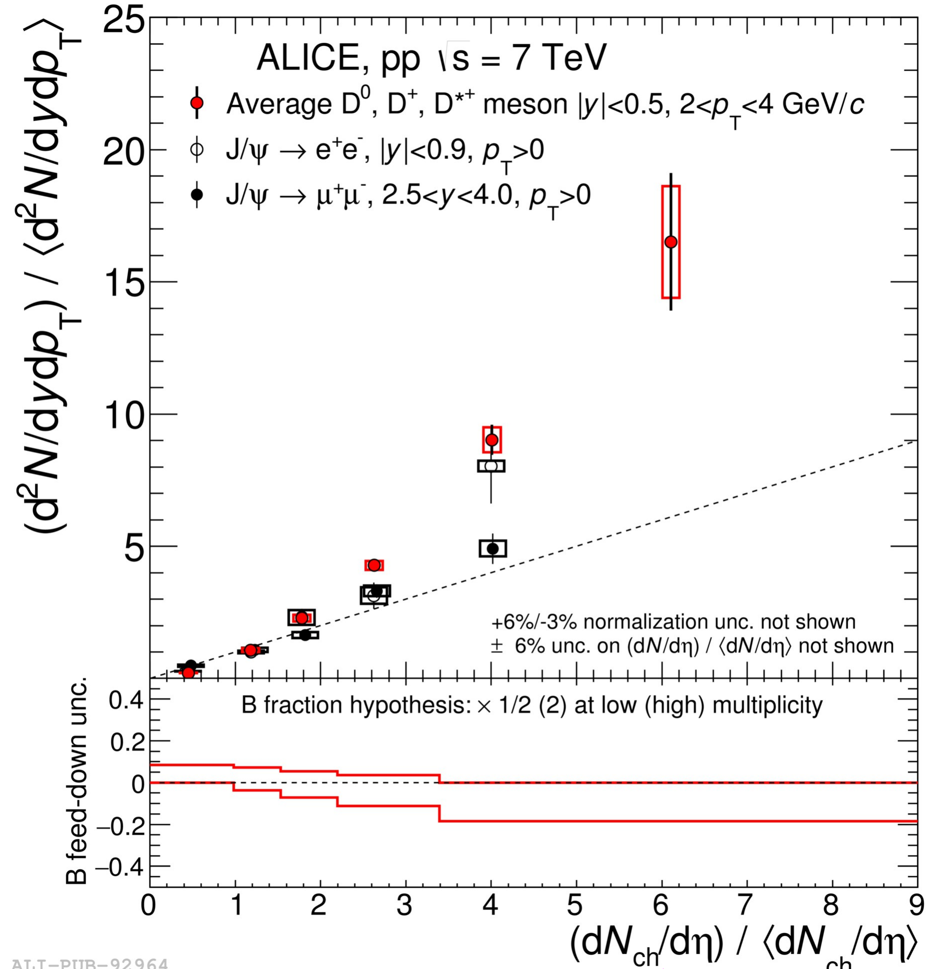


Relative charged-particle multiplicity

Sensitive to:

- Interplay between hard and soft processes
- Multi-Parton Interactions (MPI)

D-meson per-event yields increase with charged-particle multiplicity

- Faster than linear increase
- D^0, D^+, D^{*+} compatible within uncertainties
- No p_T dependence observed within uncertainties
- Similar trend observed for inclusive J/Ψ

Talk by C. Terrevoli

Multiplicity dependence of D-meson production

pp collisions at $\sqrt{s}$ = 7 TeV

Comparison with models:

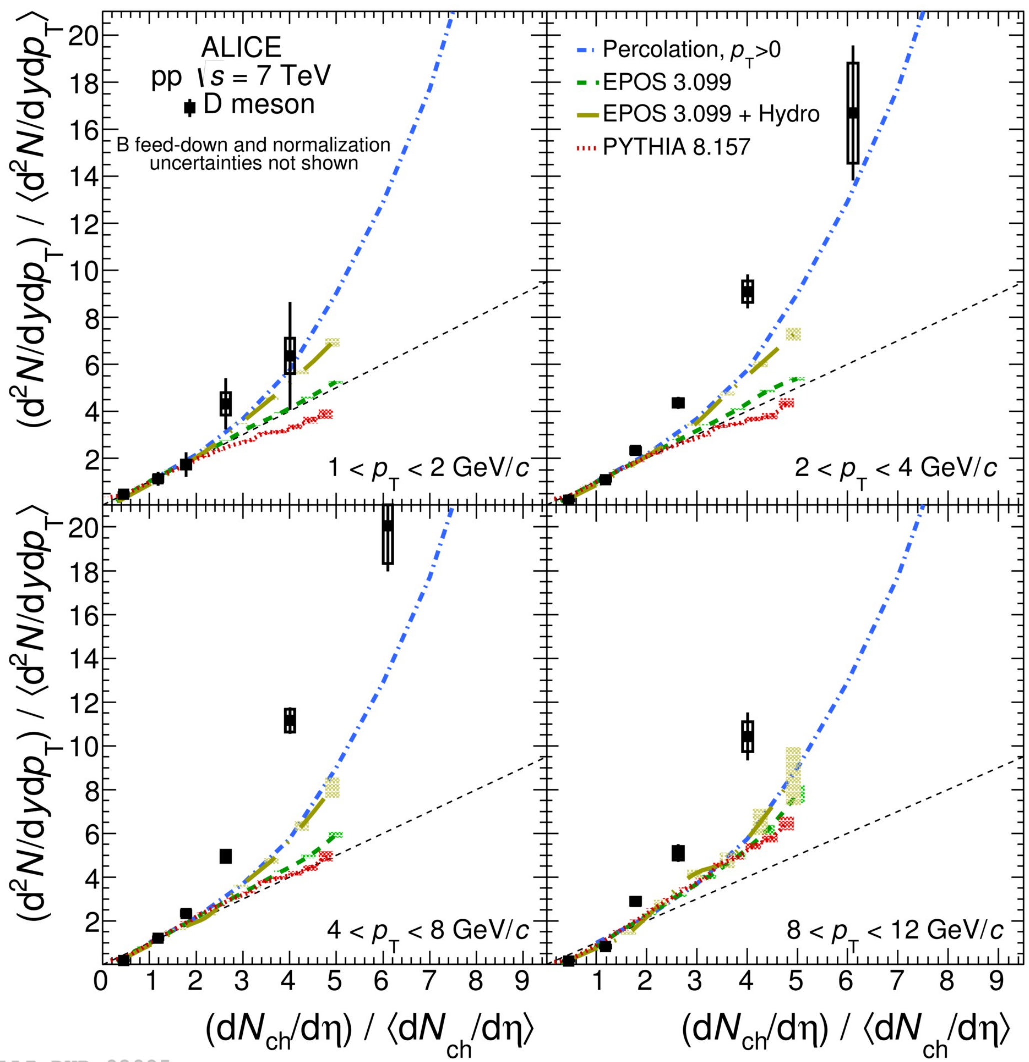
- Percolation
  Elementary sources of particle production: color ropes/strings (closed to MPI)
  Ferreiro, Pajares, PRC 86 (2012) 034903

- EPOS 3.099 initial conditions:
  Gribov-Regge multiple scattering, saturation scale, hadronization via string fragmentation, number of MPI related to multiplicity
  EPOS 3.099 + hydrodynamical evolution
  Werner et al., PRC 89 (2014) 064903

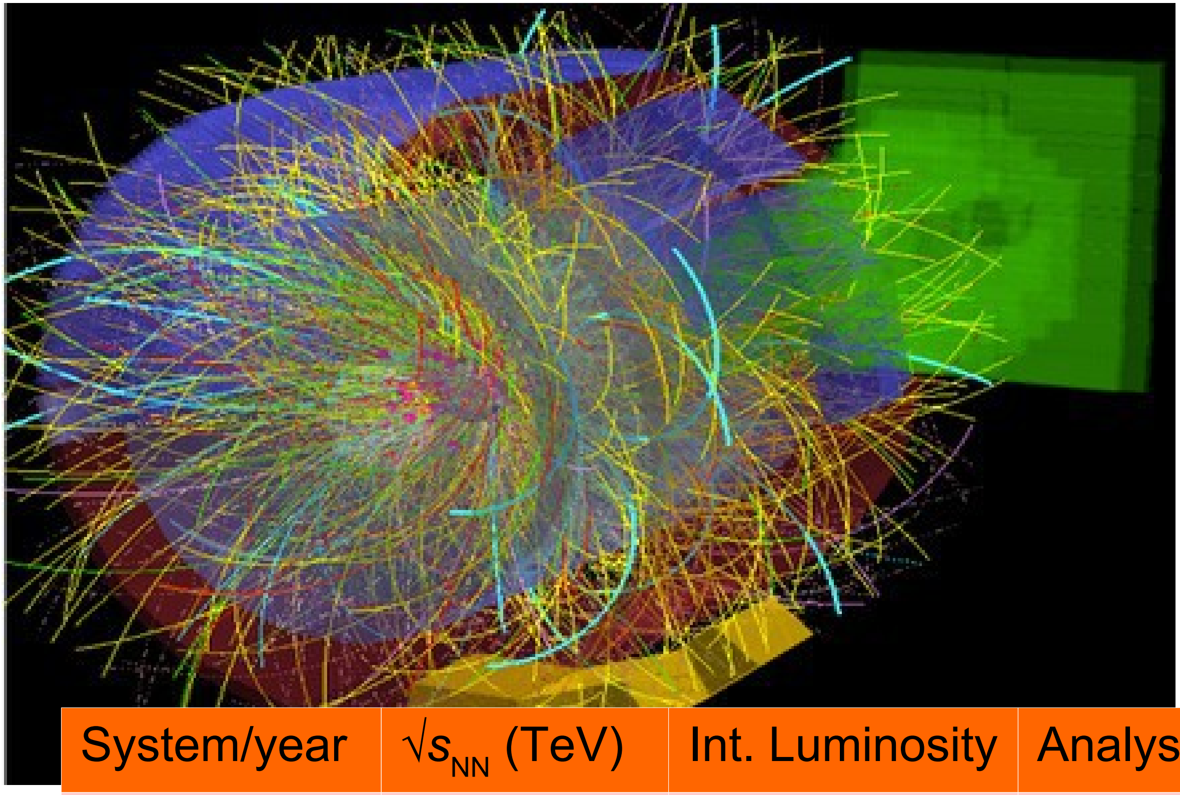
- PYTHIA 8
  Soft-QCD tune with color reconnections, multi-parton interactions, initial and final-state radiations

Talk by C. Terrevoli

arXiv: 1505.00664



Pb-Pb collisions

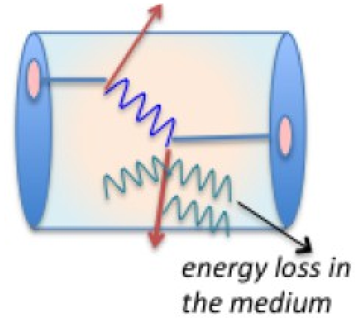


System/year	$\sqrt{s_{NN}}$ (TeV)	Int. Luminosity	Analysis
Pb-Pb 2010	2.76	2 μb^{-1}	Heavy-flavor and beauty-decay electrons
		2.7 μb^{-1}	Heavy-flavor decay muons
		2.12 μb^{-1}	D mesons
Pb-Pb 2011	2.76	21 (37) μb^{-1}	Analyses with central trigger (EMCal trigger)
		6 (34) μb^{-1}	Analyses with semi-peripheral trigger (EMCal trigger)

In-medium parton energy loss

- Collisional and radiative parton energy loss in the medium
- Energy loss depends on:
  - Color charge $\Delta E_g > \Delta E_{u,d,s}$
  - Parton mass $\Delta E_c > \Delta E_b$

  Expect the ordering at the parton level:
  $\Delta E_g > \Delta E_{u,d,s} > \Delta E_c > \Delta E_b$

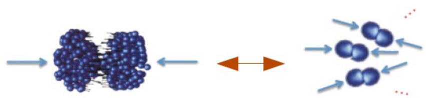


- Modification of the measured spectra quantified by the nuclear modification factor:

$$R_{AA}(p_T) = \frac{dN_{AA} / dp_T}{d\sigma_{pp} / dp_T} \cdot \frac{1}{\langle T_{AA} \rangle}$$

pp reference

T_{AA}, nuclear overlap function



$R_{AA} = 1$ binary scaling
$R_{AA} \neq 1$ medium effect

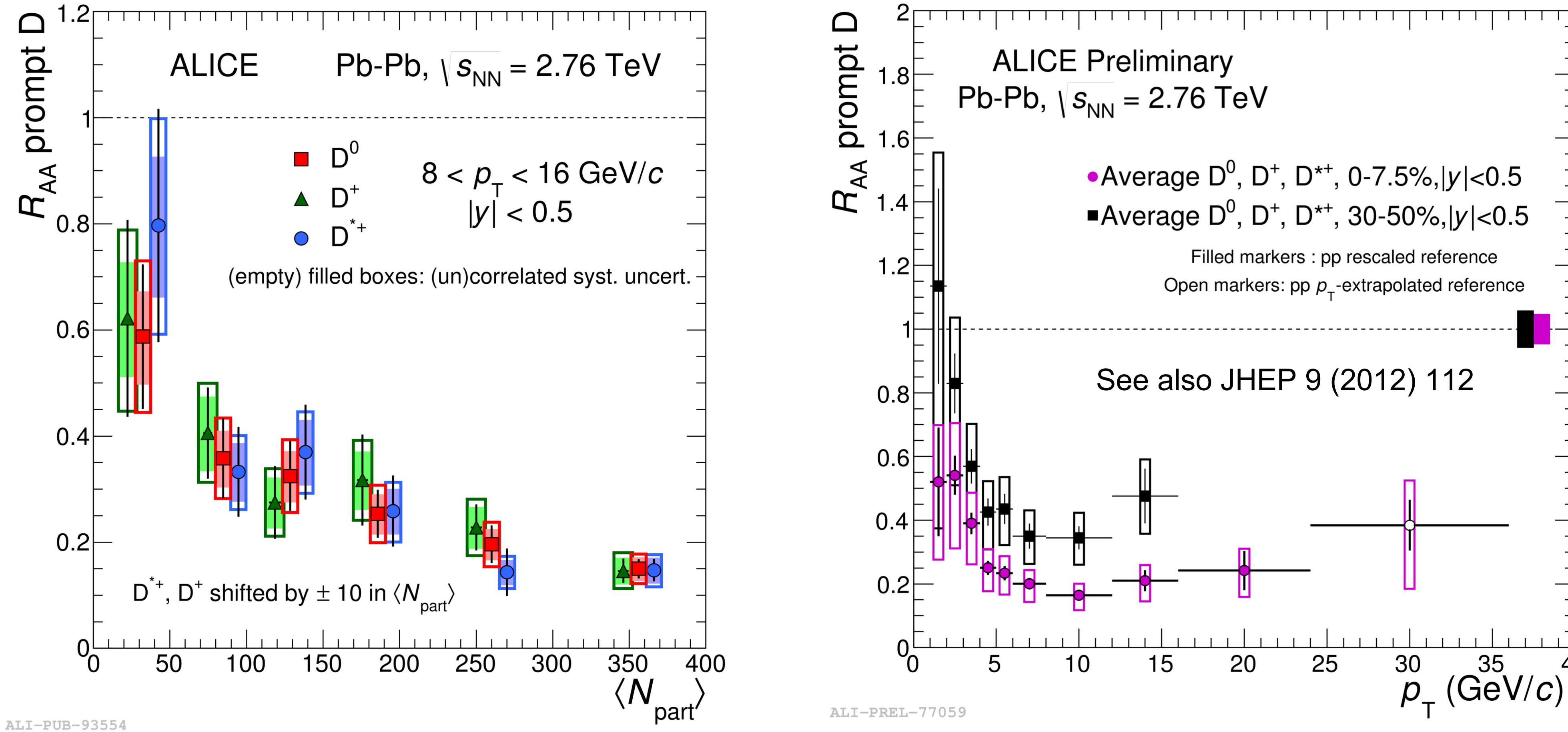
- Naive expectation: $R_{AA}(\pi) > R_{AA}(D) > R_{AA}(B)$

  More complicated due to different production kinematics and fragmentation of light and heavy quarks

Nuclear modification factors of D mesons

R_{AA} of D mesons as function of collision centrality and p_T

arXiv: 1506.06604 [nucl-ex]

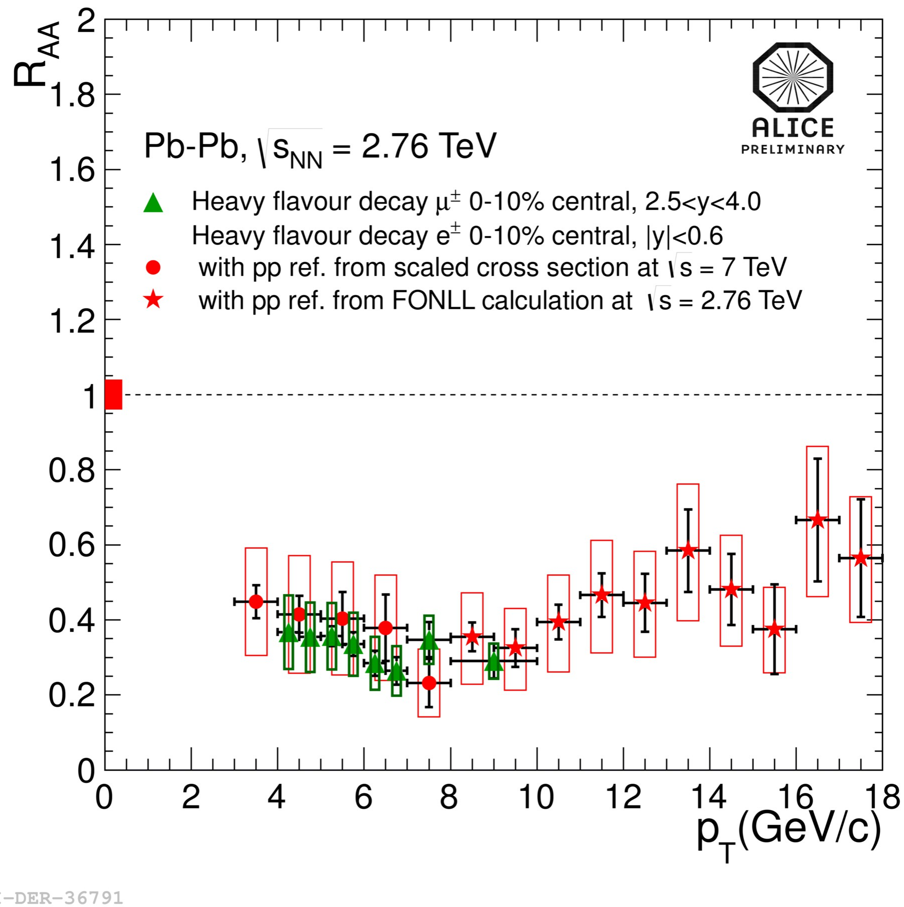


Talk by A. Festanti

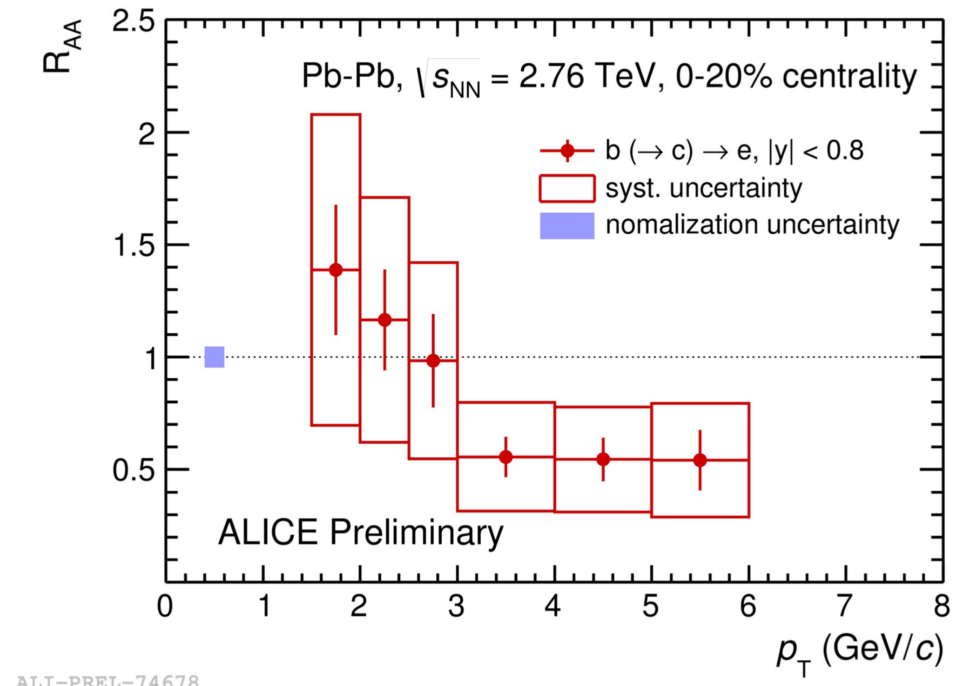
- Strong suppression of high-p_T D mesons in central collisions
- Where does the energy lost end up ? Low-p_T measurements crucial in all systems

Leptons from heavy-flavor decays

μ ← c,b   2.5<*y*< 4.0
e ← c,b |*y*|<0.6



Beauty-decay electron, |*y*|<0.8



Talk by F. Bossu

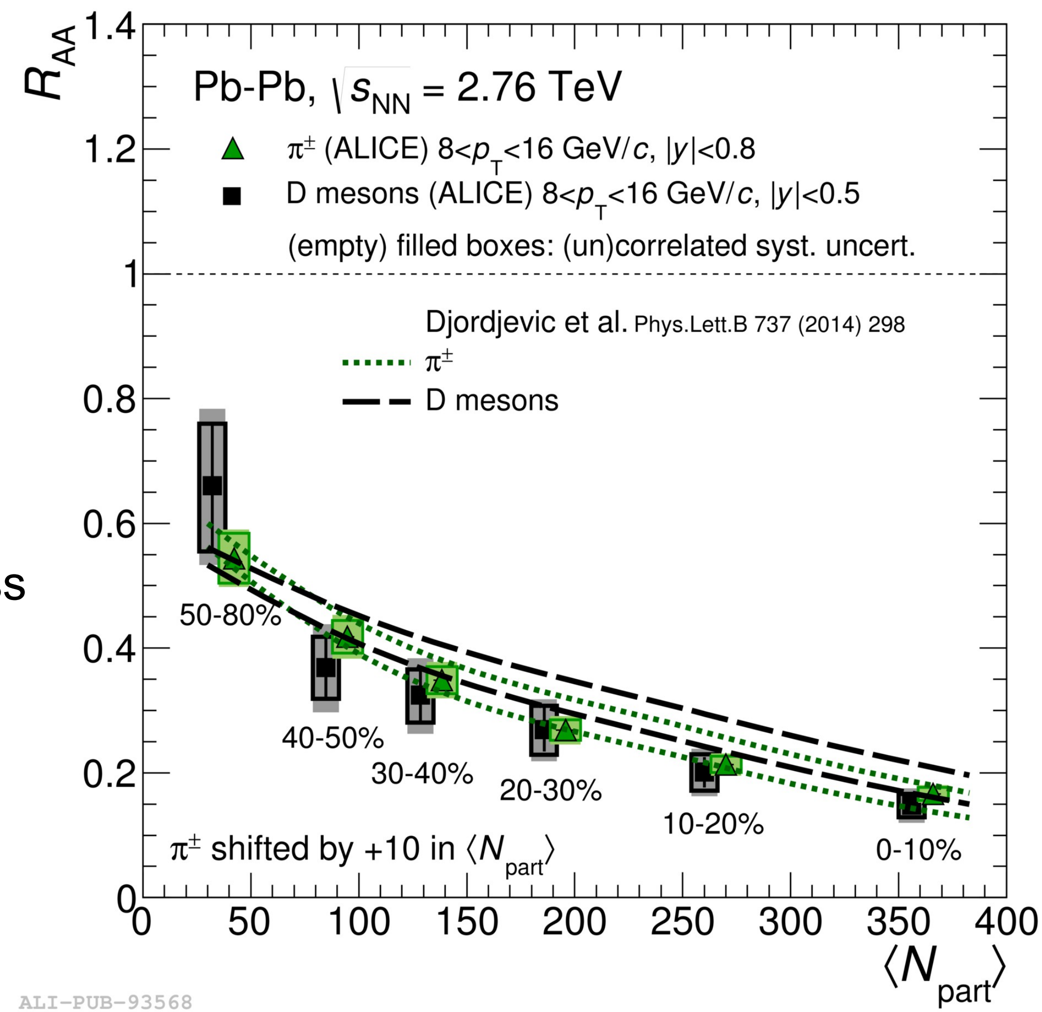
- Suppression of heavy-flavor decay leptons similar at mid rapidity and forward rapidity
- Hint for suppression of beauty-decay electrons for p_T > 3 GeV/c

Color-charge dependence of parton energy loss

Talk by A. Festanti

arXiv: 1506.06604 [nucl-ex]

$R_{AA}(\pi) \sim R_{AA}$ (D)



- Model reproduces the data.
  Djordjevic, PL B734(2014)286

- Combination of:
  - Color-charge dependent parton energy loss
  - Different p_T shape
  - Different fragmentation

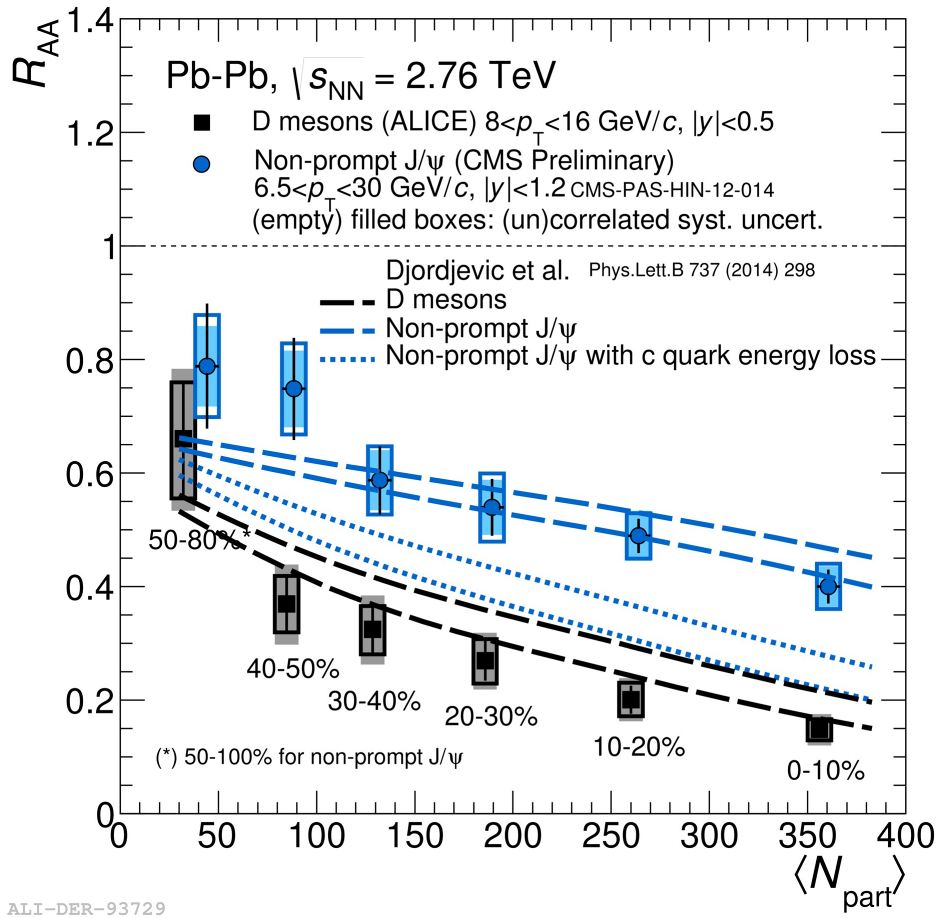
Mass dependence of parton energy loss

Talk by A. Festanti

$R_{AA}(J/\Psi \leftarrow B) > R_{AA}(D)$

ALICE: arXiv: 1506.06604 [nucl-ex]
CMS Preliminary: CMS-PAS-HIN-12-014
See also CMS: JHEP 05 (2012) 063

- Similar kinematic region: $\langle p_T^D \rangle \sim \langle p_T^B \rangle$
- Quark mass used in the model crucial to reproduce the data
  Djordjevic, PL B734(2014)286
- Similar pattern from other calculations
  TAMU elastic: arXiv:1401.3817 [nucl-th]
  MC@sHQ+EPOS2: Phys. Rec. C89 (2014) 014905
  BAMPS: J.Phys.G38 (2011) 124152
  WHDG: J.Phys.G38 (2011) 124114
  Vitev et al., Phys.Rev.C80 (2009) 054902



Mass dependence of parton energy loss

Talk by A. Festanti

R_{AA}(J/Ψ←B) > R_{AA}(D)

ALICE: arXiv: 1506.06604 [nucl-ex]
CMS Preliminary: CMS-PAS-HIN-12-014
See also CMS: JHEP 05 (2012) 063

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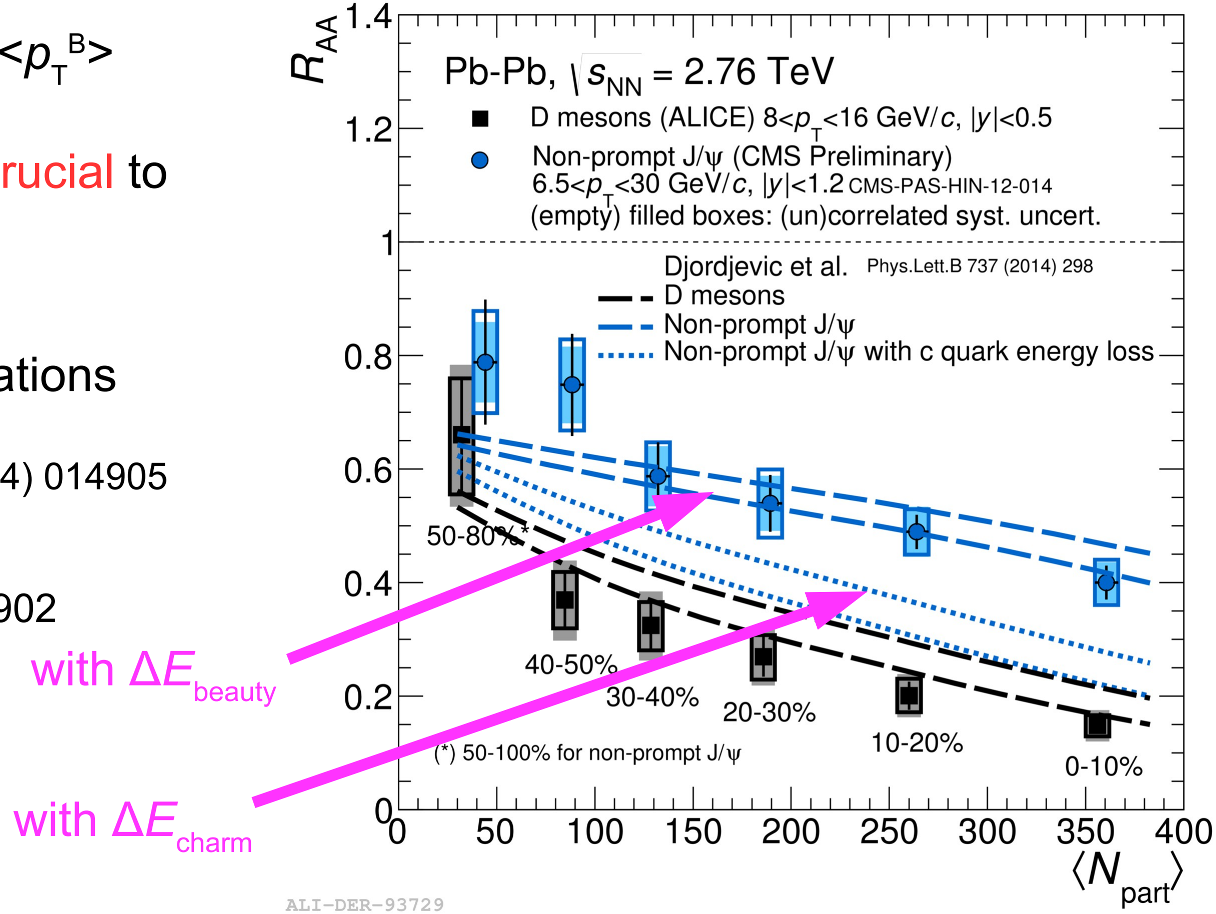
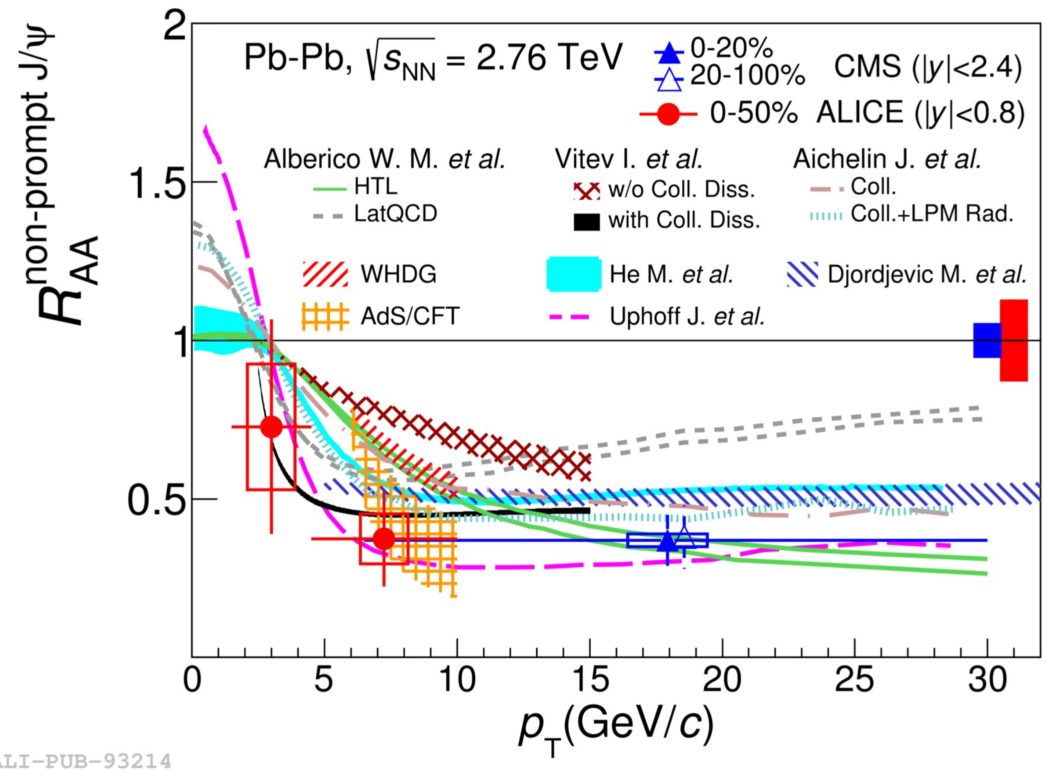
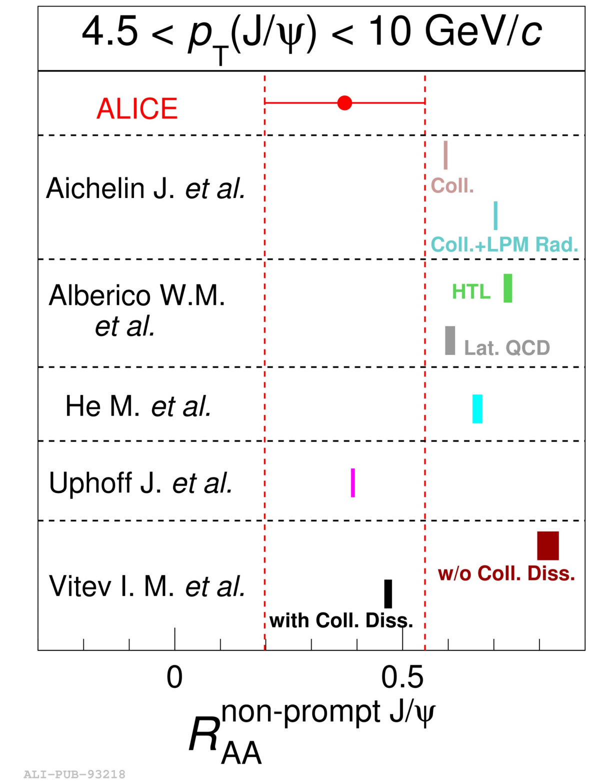


Non-prompt J/Ψ from ALICE

ALICE: arXiv: 1504.07151v2 [nucl-ex]
CMS: JHEP 05 (2012) 063





ALICE measurements at low p_T complementary to CMS results
Measured R_{AA} seems to be overestimated by some models in 4.5 < p_T(J/Ψ) < 10 GeV/c
More precise data needed to discriminate among models

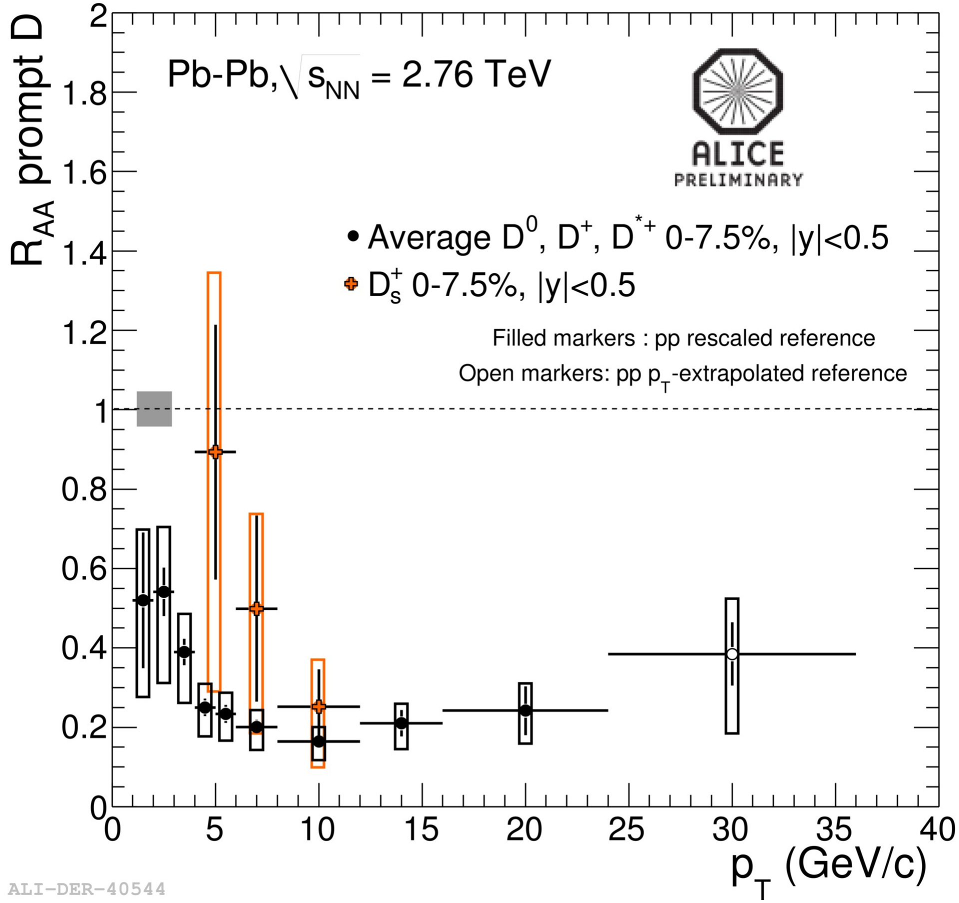
Ads/CFT: Maldacena et al., Int. J. Theor. Phys. 38 (1999) 1113–1133, Gubser et al., Phys. Lett. B428 (1998) 105–114; Aichelin et al., Phys. Rev. D89 no. 7, (2014) 074018, Nucl. Phys. A931 (2014) 581–585; Alberico et al., Eur. Phys. J. C71(2011) 1666, Eur. Phys. J.C73 (2013) 2481; Djordjevic et al., arXiv:1307.4098; He et al., Phys. Lett. B735 (2014) 445–450; Uphoff et al., Phys. Lett. B717 (2012) 430–435; Vitev et al., Phys. Rev. C80 (2009) 054902, Phys. Rev. C87 (2013) 044905; WHDG: Nucl. Phys. A784 (2007) 426–442

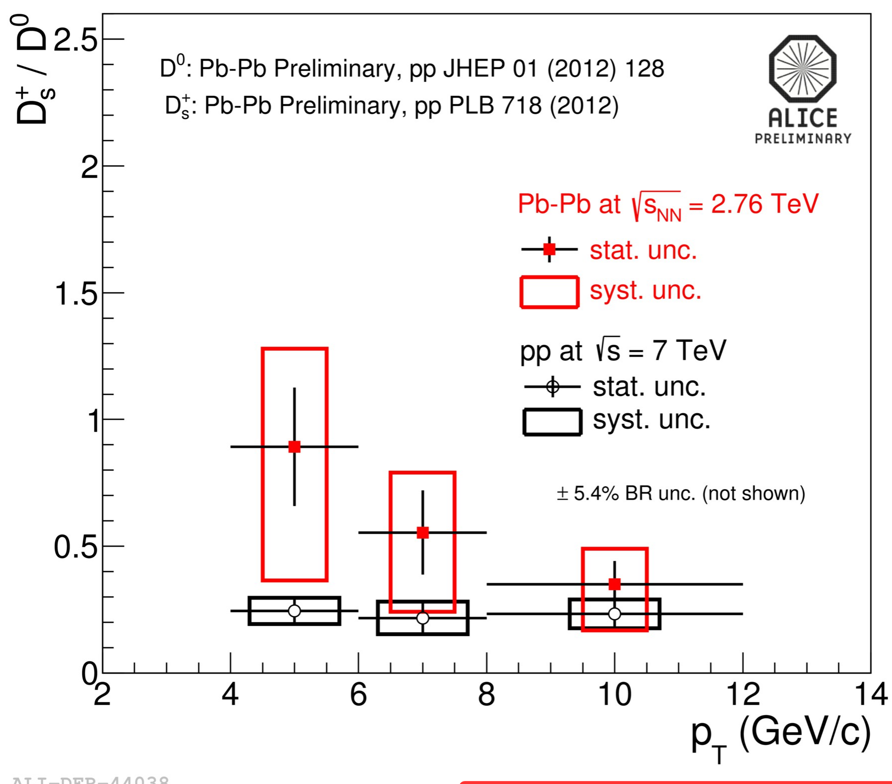
Lifting of strangeness suppression

Expect an enhancement of strange D meson, D_s, compared to non-strange D mesons:

- In-medium strangeness enhancement
- Hadronization via recombination

He et al. PRL 110 (2013) 112301
Andronic et al. PLB 659 (2008) 149
Kuznetsova, Rafelski EPJ C51 (2007) 113



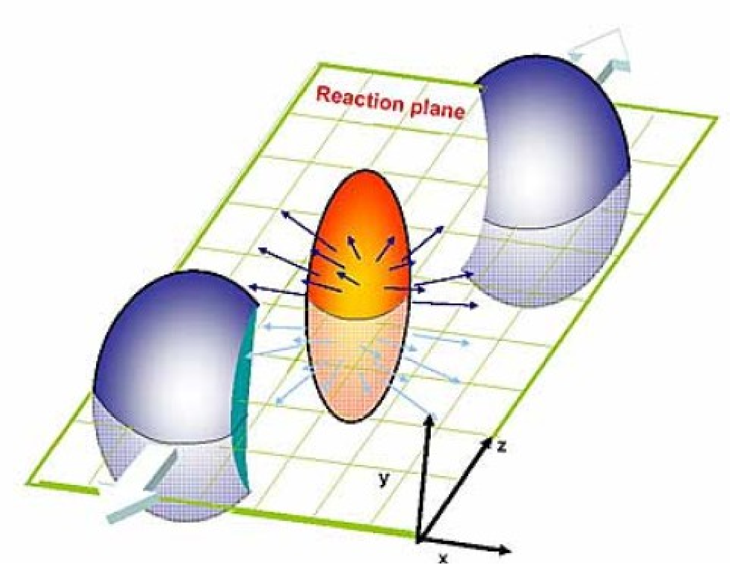


- D_s compatible with average D mesons within uncertainties
- Hint for an enhancement at low p_T

Talk by A.M. Barbano
Results also in 20-50%

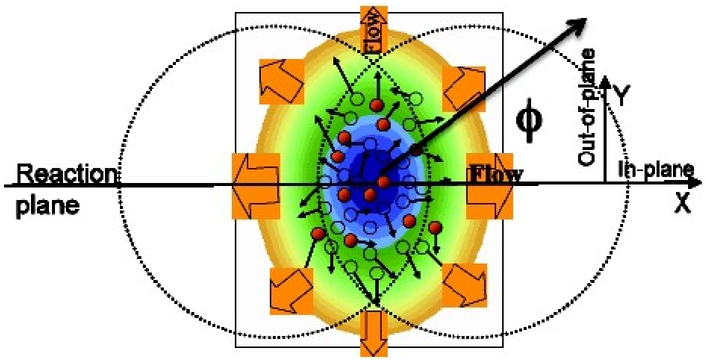
Collectivity? Elliptic-flow measurements

- Initial spatial asymmetry in semi-central collisions
  → Converted into azimuthal anisotropy of final hadron yields via interactions in the medium



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

Elliptic flow v_2 = second Fourier coefficient



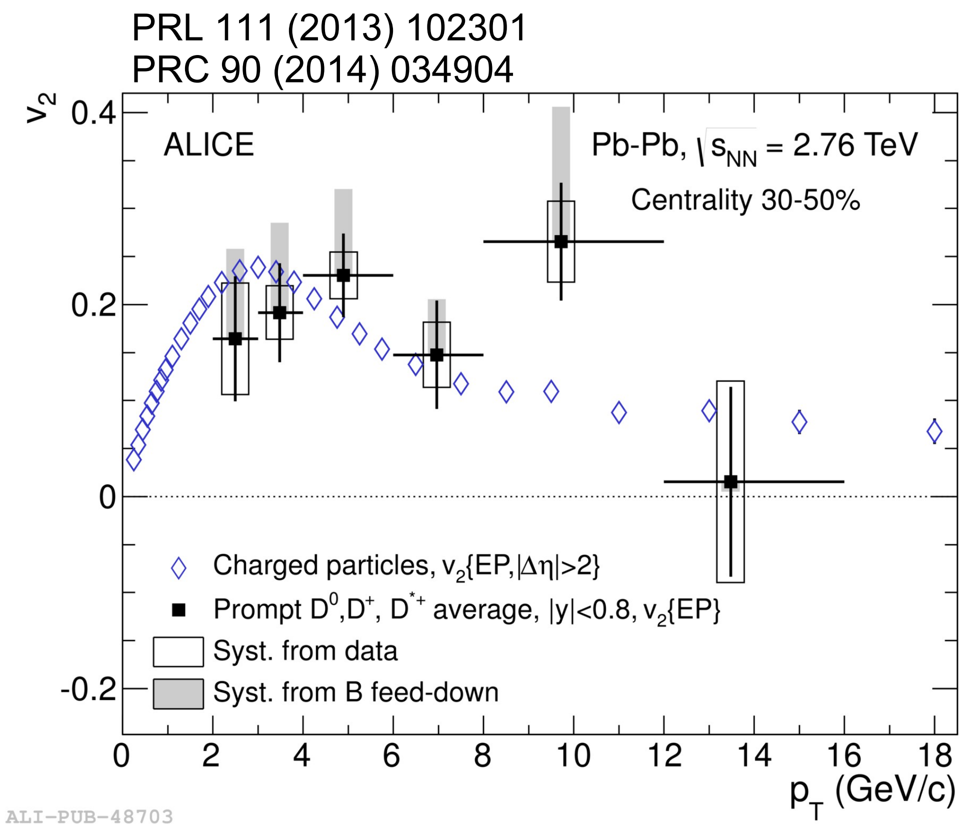
- Participation of charm quarks in the collective motion of the medium: $v_2 > 0$ at low p_T
- Path-length dependence of energy loss at high p_T

Heavy-flavor elliptic flow

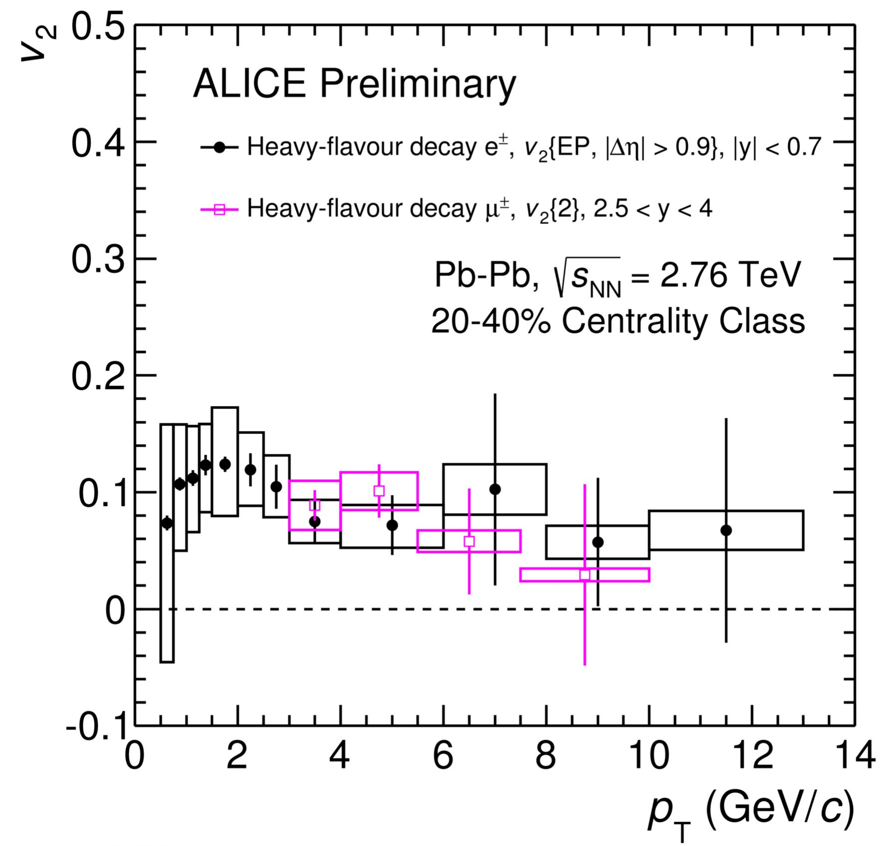
Talk by A. Festanti

Talk by F. Bossu

v_2(D) ~ v_2(charged particles)



v_2(e←b,c) at mid rapidity
~ v_2(μ←b,c) at foward rapidity

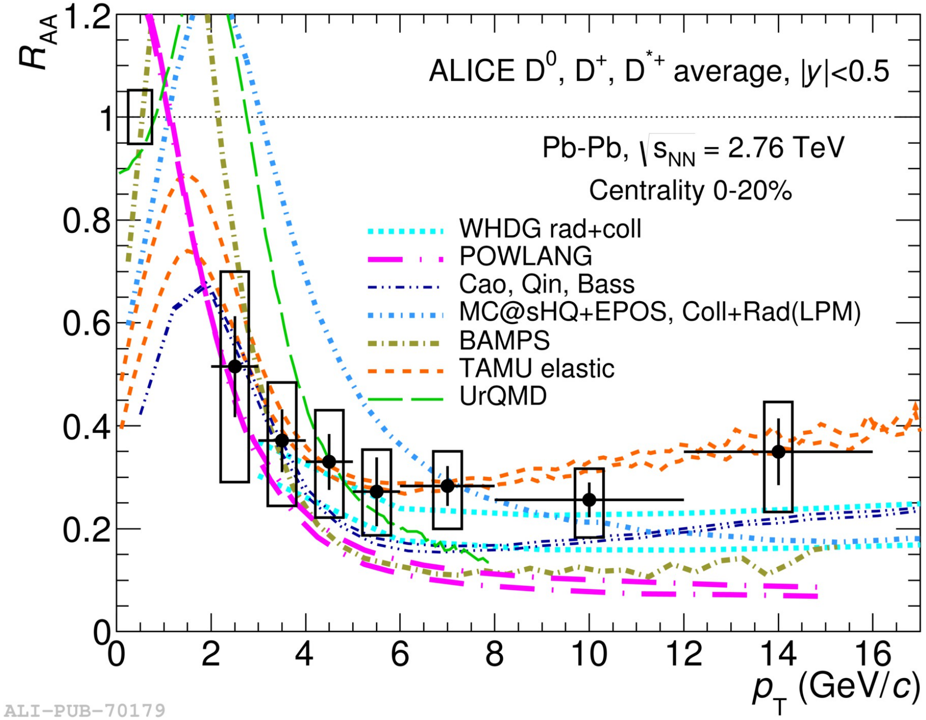


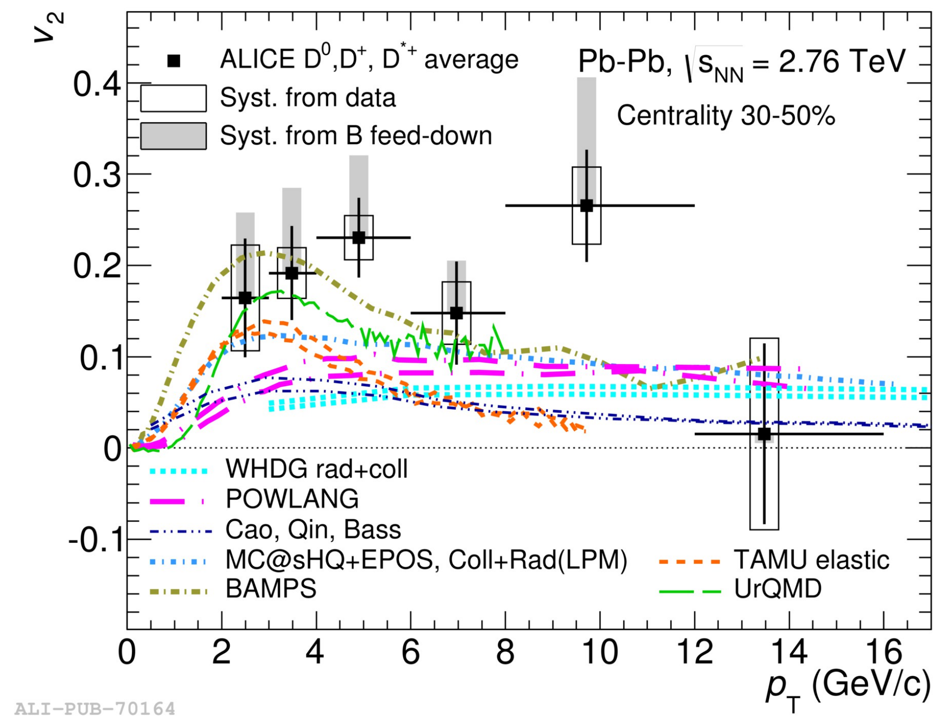
- Positive v_2 of D mesons (5.7σ effect in 2<p_T< 6 GeV/c), heavy-flavor decay electrons (3σ effect in 2<p_T<3 GeV/c) and muons (3σ effect in 3<p_T<5 GeV/c)
- Hint for participation of charm in the collective expansion of the medium

Comparison with models

Talk by A. Festanti

PRL 111 (2013) 102301
PRC 90 (2014) 034904

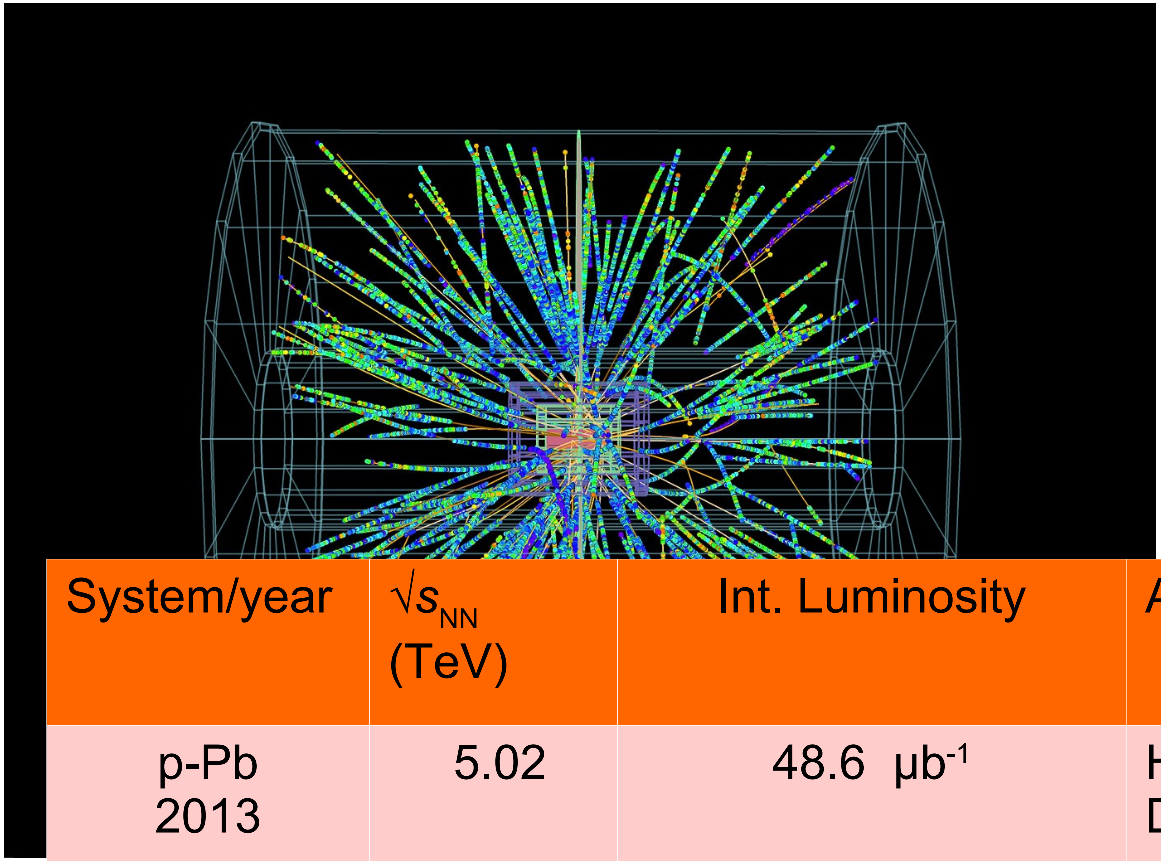




Simultaneously description of v_2 and R_{AA} challenging for the models

WHDG: Nucl. Phys. A 872 (2011) 265; MC@sHQ+EPOS, Coll+Rad(LPM): Phys. Rec. C89 (2004) 014905; TAMU elastic: arXiv:1401.3817 [nucl-th]; POWLANG: Eur. Phys. J. C71 (201) 1666, J.Phys. G 38 (2011) 124144; BAMPS: Phys. Rev. C 84 (2011) 024908; J. Phys. G38 (2011) 124152 Phys. Lett. B 717 (2012) 430;arXiv:1310.3597v1[hep-ph] ; UrQMD: arXiv:1211.6912[hep-ph]; J. Phys.Conf. Ser. 426 (2013) 012032; Cao, Qin, Bass: Phys. Rev. C 88 (2013) 044907

p-Pb collisions



System/year	$\sqrt{s_{NN}}$ (TeV)	Int. Luminosity	Analysis
p-Pb 2013	5.02	48.6 μb^{-1}	Heavy-flavor and beauty-decay electrons D mesons
p-Pb 2013	5.02	196 μb^{-1} (4.9×10^{3} μb^{-1})	Heavy-flavor decay muons with Muon Single Low triggered (with Muon Single High triggered)
Pb-p 2013	5.02	254 μb^{-1} (5.8×10^{3} μb^{-1})	Heavy-flavor decay muons with Muon Single Low triggered (with Muon Single High triggered)

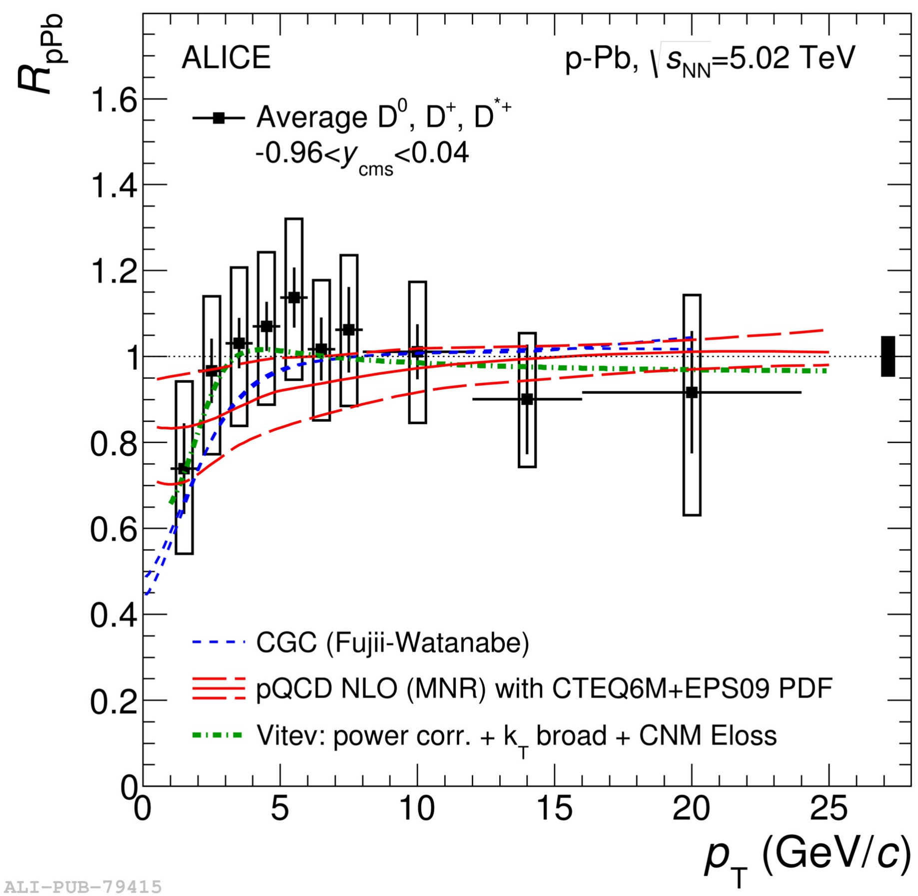
D-meson R_{pPb}

$$R_{pPb}(p_T) = \frac{d\sigma_{pPb} / dp_T}{d\sigma_{pp} / dp_T} \cdot \frac{1}{A}$$

- R_{pPb} of D mesons compatible with unity within uncertainties

- R_{pPb} described by:
  - MNR pQCD calculation with EPS09 parametrization of shadowing
    NPB 373 (1992) 295, JHEP 0904 (2009) 065
  - Vitev – coherent scattering, k_T-broadening and energy loss in cold nuclear matter
    PRC 75 (2007) 064906
  - CGC – color glass condensate
    NPA 920 (2013) 78

Phys. Rev. Lett. 113 (2014) 232301



Talk by C. Terrevoli

Heavy-flavor decay lepton R_{pPb}

Talk by F. Bossu

Mid rapidity

Forward rapidity

Backward rapidity

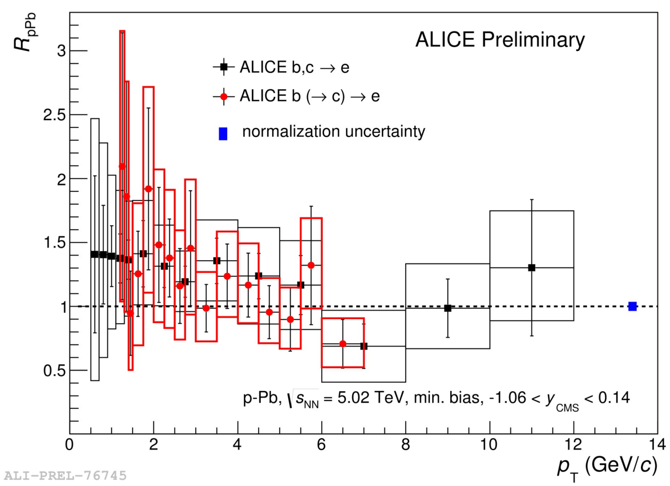
Heavy-flavor decay electrons
Beauty-decay electrons

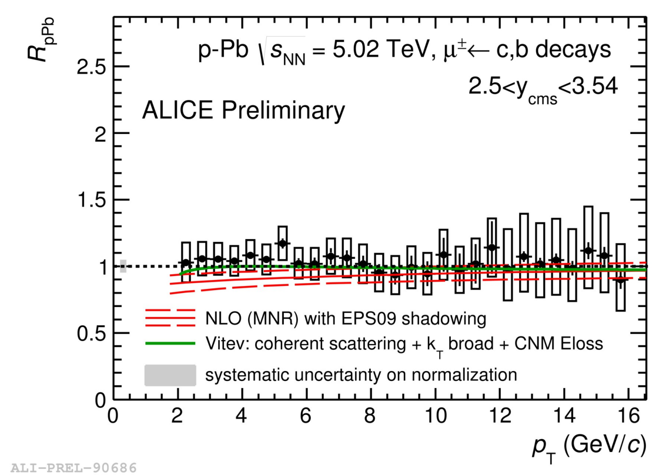
Probe low Bjorken x

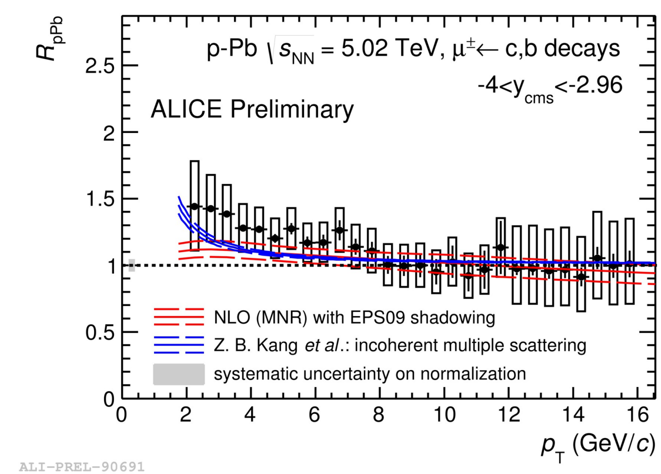
Heavy-flavor decay muons

Probe high Bjorken x

Heavy-flavor decay muons

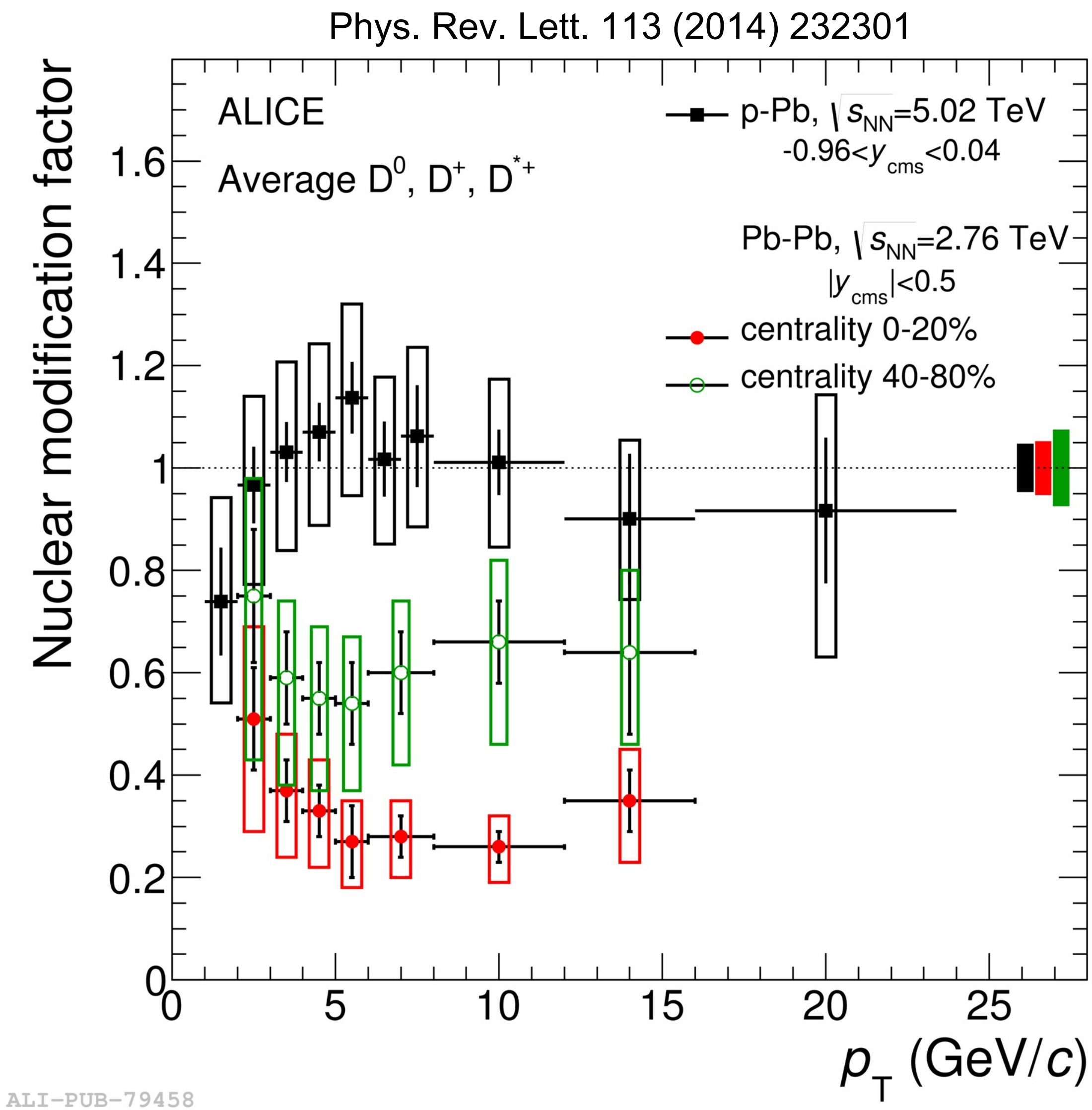






- Cold nuclear matter effects don't lead to a strong suppression in the measured p_T range
- Data described within uncertainties by models which include cold nuclear matter effects
  MNR pQCD calculation with EPS09 parametrization of shadowing NPB 373 (1992) 295, JHEP 0904 (2009) 065
  Vitev: coherent scattering, k_T-broadening and energy loss in cold nuclear matter PRC 75 (2007) 064906
  Z. B. Kang et al.: incoherent multiple scattering PLB 740 (2015) 23

$R_{pPb}\,(p_T)$ compared to $R_{AA}(p_T)$



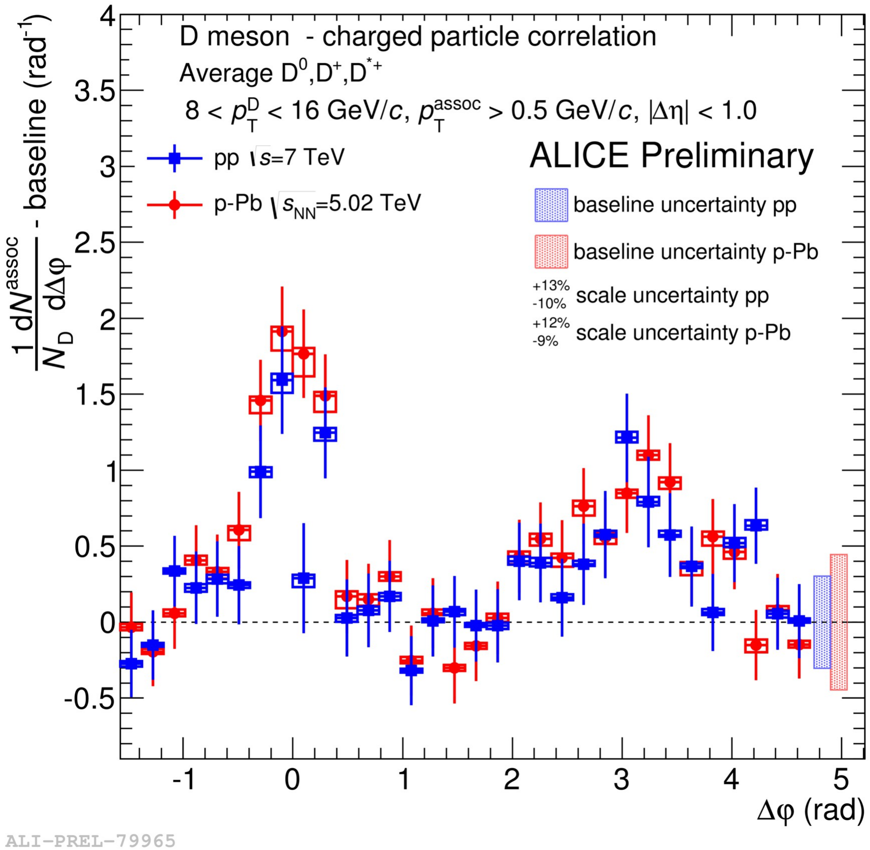
Talk by C. Terrevoli

The suppression at high p_T in Pb-Pb collisions is a final-state effect

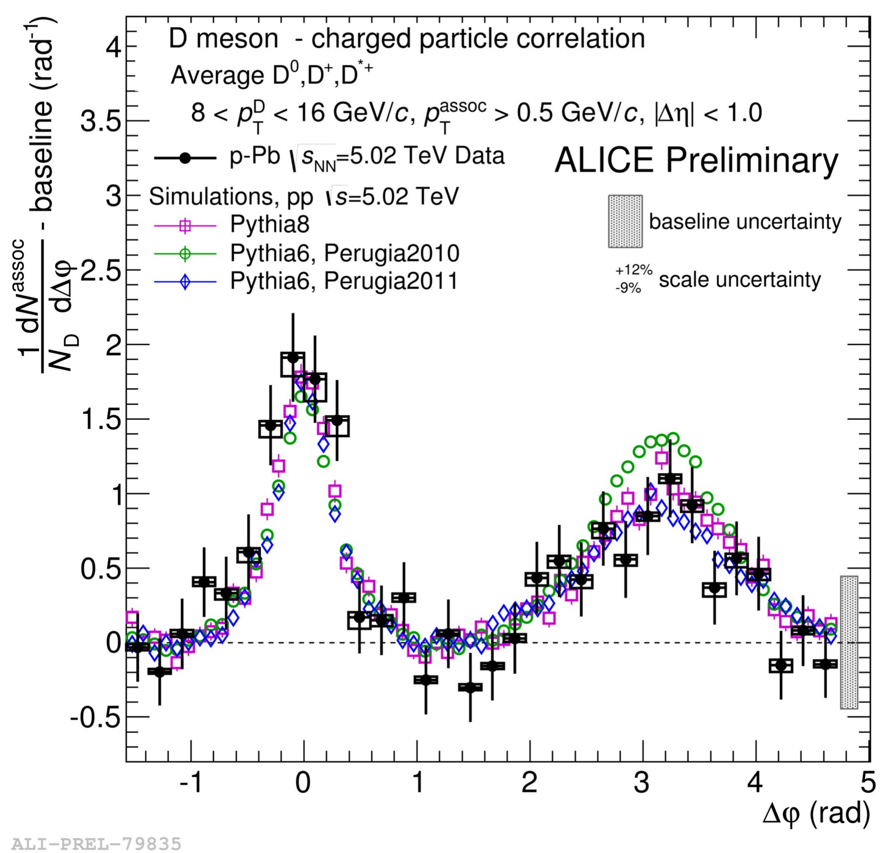
Same conclusion for the other channels

D meson – hadron correlations

D meson – charged particle correlations in pp and p-Pb collisions



D meson – charged particle correlations in p-Pb collisions compared to PYTHIA tunes

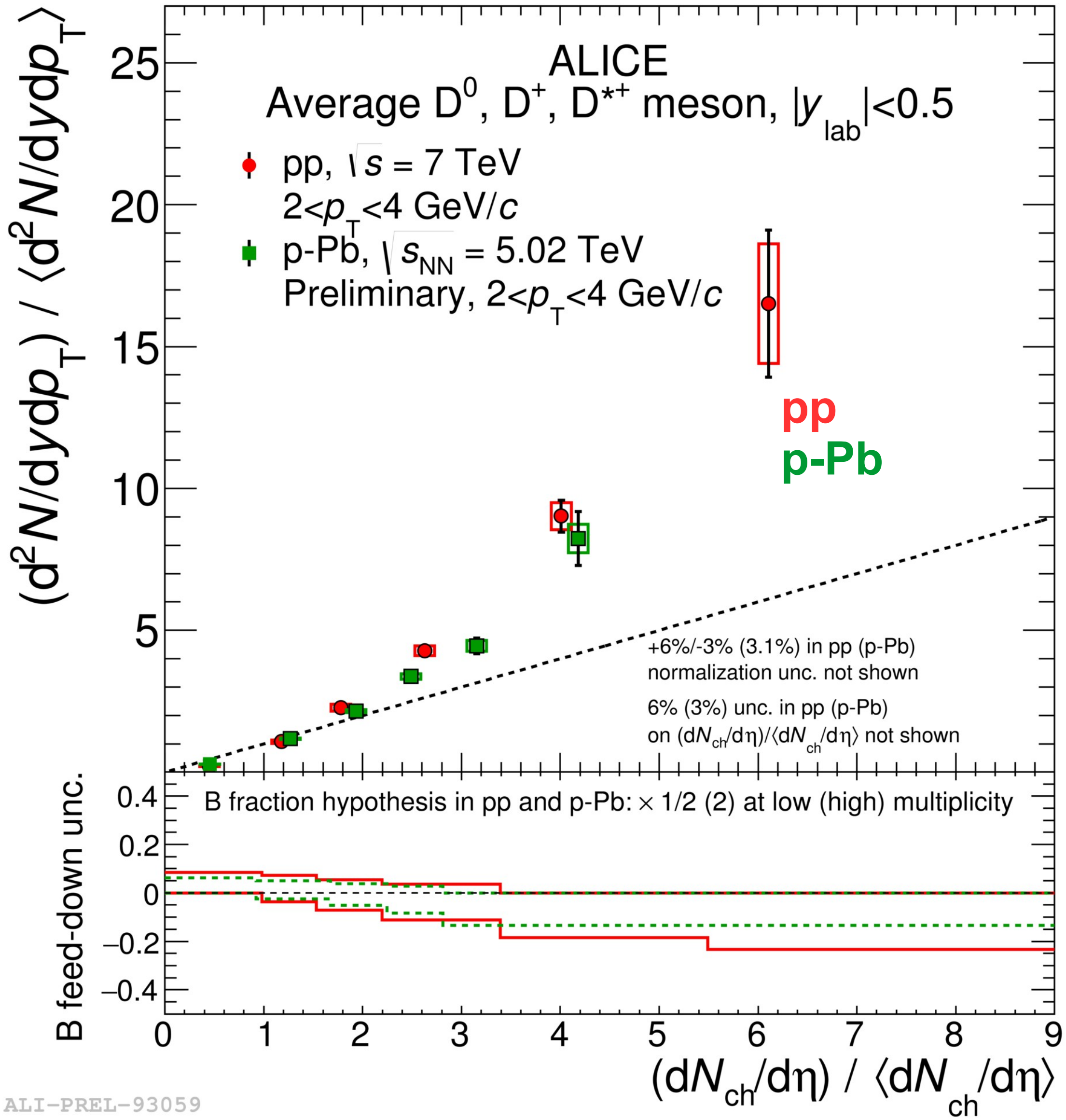


- Distributions in p-Pb and pp are similar after baseline subtraction
- Within uncertainties p-Pb results consistent with various PYTHIA tunes
- Statistics of Run 2 will allow better constraints of model calculations

Multiplicity dependence of D-meson production

Talk by C. Terrevoli

- Similar trend in pp and p-Pb collisions but:
  - Multi-parton interactions in pp collisions
  - Multiple nucleon-nucleon collisions in p-Pb collisions



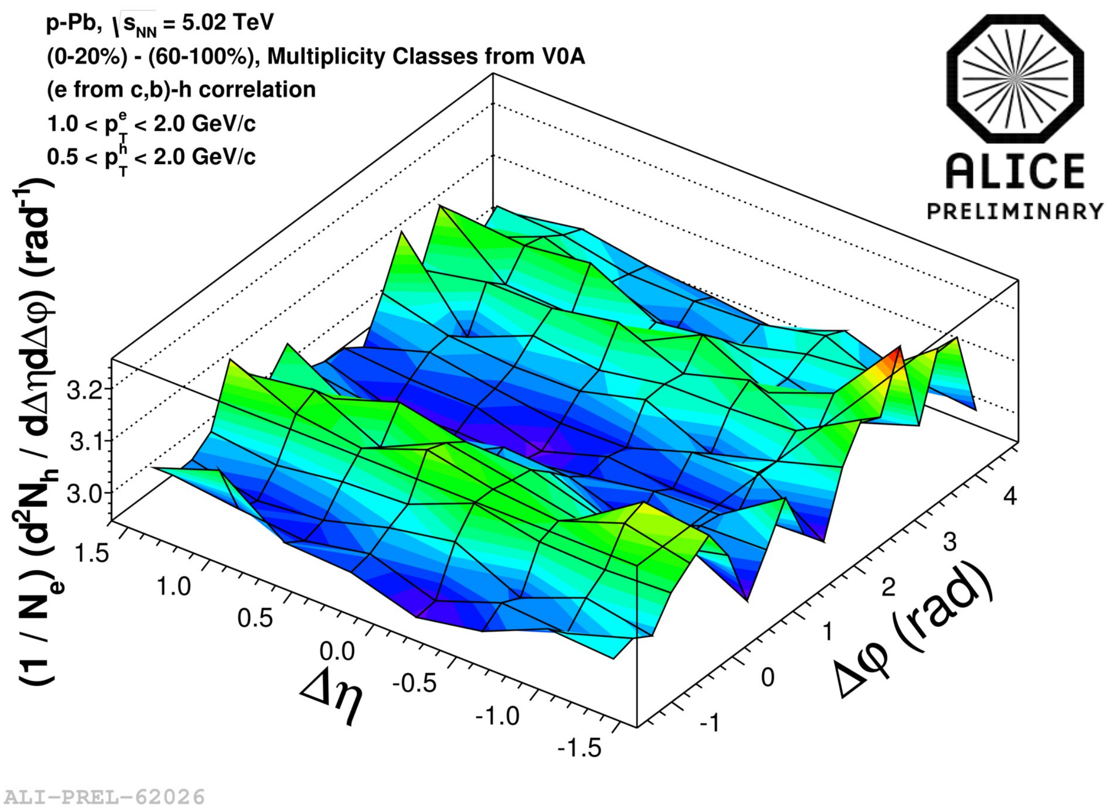
Heavy-flavor decay electron–hadron correlation

Measure angular correlations of heavy-flavor decay electrons and charged hadrons

$1.0 < p_T^e < 2$ GeV/c
$0.5 < p_T^h < 2.0$ GeV/c

Angular correlations
in high-multiplicity events (0-20%)
-
Angular correlations
in low-multiplicity events (60-100%)

To remove jet correlations



- Indication for double-ridge structure, as observed for light-flavor two-particle correlations
  PLB 719 (2013) 29, PLB 726 (2013) 164
- Heavy flavor possibly affected by the processes potentially leading to long-range correlations in Δη of light-flavor hadrons:
  - Initial state: CGC arXiv:1302.7018
  - Final state: Hydrodynamics PLB 718 (2013) 1557

Talk by F. Bossu

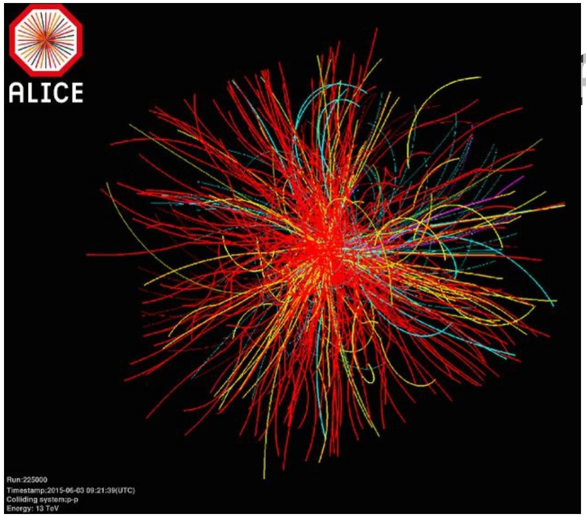
Conclusion

- In Pb-Pb collisions:
  - Heavy quarks probe the transport properties of the QGP in heavy-ion collisions
  - Run 1 measurements provide insight into the properties of the QGP matter
    - $R_{AA}(\pi) \sim R_{AA}(D) < R_{AA}(J/\Psi \leftarrow B)$ related to $\Delta E_g > \Delta E_{u,d,s} > \Delta E_c > \Delta E_b$
    - Heavy-flavor $v_2 > 0$ indicates that charm quarks participate in the collective expansion at low p_T
- In pp collisions:
  - pQCD calculations describe the data
  - Further studies of charm production via D meson-hadron correlations and multiplicity-dependence studies
- In p-Pb collisions:
  - Cold nuclear matter effects don't lead to a strong suppression in the measured p_T range
  - Double-ridge structure observed in electron-hadron azimuthal correlations at low p_T: CGC, hydrodynamic expansion, some other mechanisms ?

Outlook

Run 2 2015-2018

On going



- Higher energies (pp at $\sqrt{s}$=13TeV, Pb-Pb at $\sqrt{s_{NN}}$=5.1TeV) and higher interaction rates
- Larger data sample compared to Run 1
- Extend p_T range (down to p_T=0 and towards high p_T)
- More precise measurements of azimuthal correlations, beauty and heavy flavor in jets
- Study hadronization of heavy quarks: measure baryons and D_s

Run 3 2020-2023

New ITS, new TPC readout, Muon Forward Tracker (MFT)
high-rate readout upgrade for all detectors

- Improve p_T reach and precision of the current measurements
  ➡Distinguish between models
- Beauty measurements:
  - Displaced D mesons
  - Separate charm and beauty at forward y with the MFT
  - Direct measurement of B hadrons

Plenary talk by A. Dainese (Sat 10:00)
Talk by F. Fionda (Thu 18:00)

Back-up

D-meson reconstruction at mid rapidity

Displaced decay vertices ($|\eta|<0.9$)

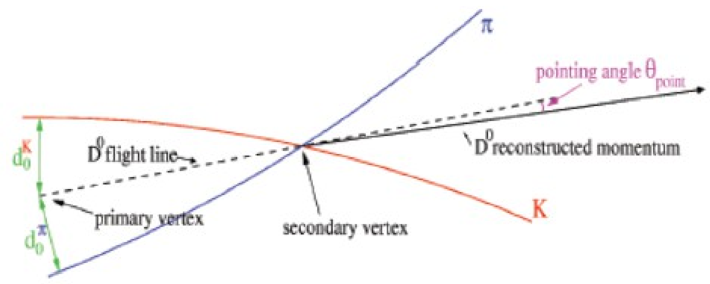
$D^0 \rightarrow K^- \pi^+$ ($c\tau$=123 μm)

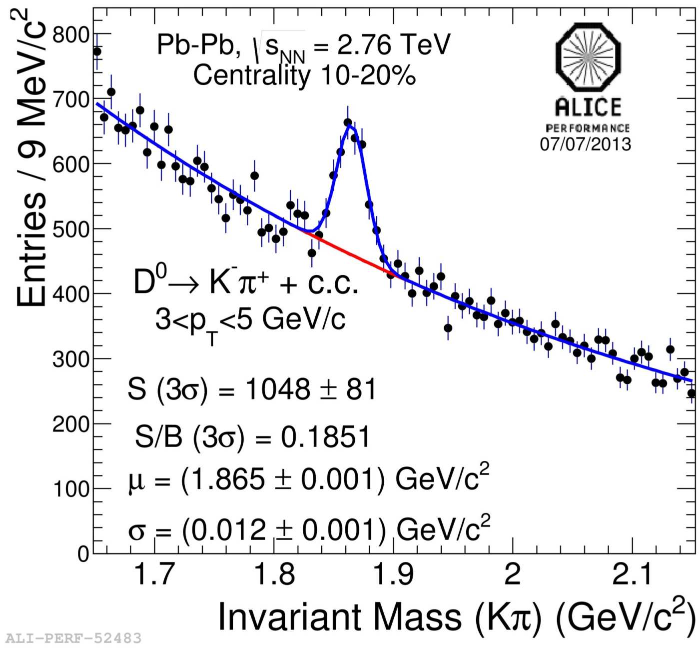
$D^+ \rightarrow K^- \pi^+ \pi^+$ ($c\tau$=312 μm)

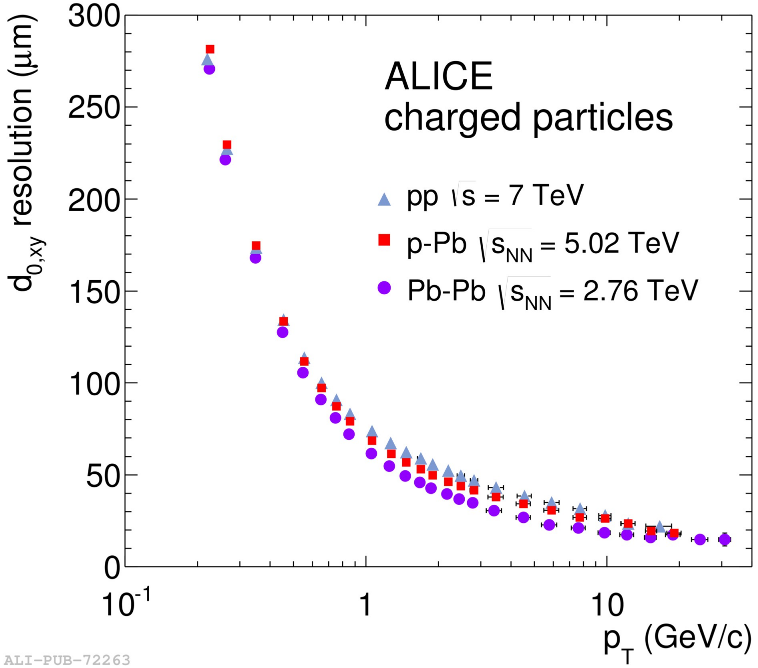
$D_S^+ \rightarrow \varphi \pi^+ \rightarrow K^+ K^- \pi^+$ ($c\tau$=150 μm)

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

$\Lambda_c \rightarrow p K^- \pi^+, p K_s^0$ ($c\tau$=60 μm)







Int. J. Mod. Phys. A 29 (2014) 1430044

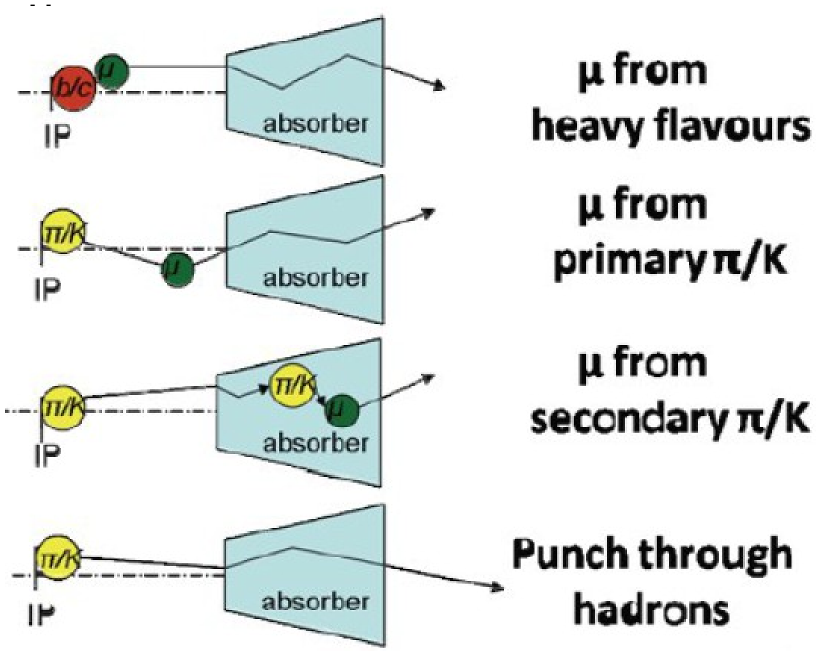
- Reconstruction and selection of secondary vertex topologies away from the primary vertex
  - PID (TPC and TOF) to reduce the combinatorial background, specially at low p_T
  - Invariant mass analysis to extract the signal

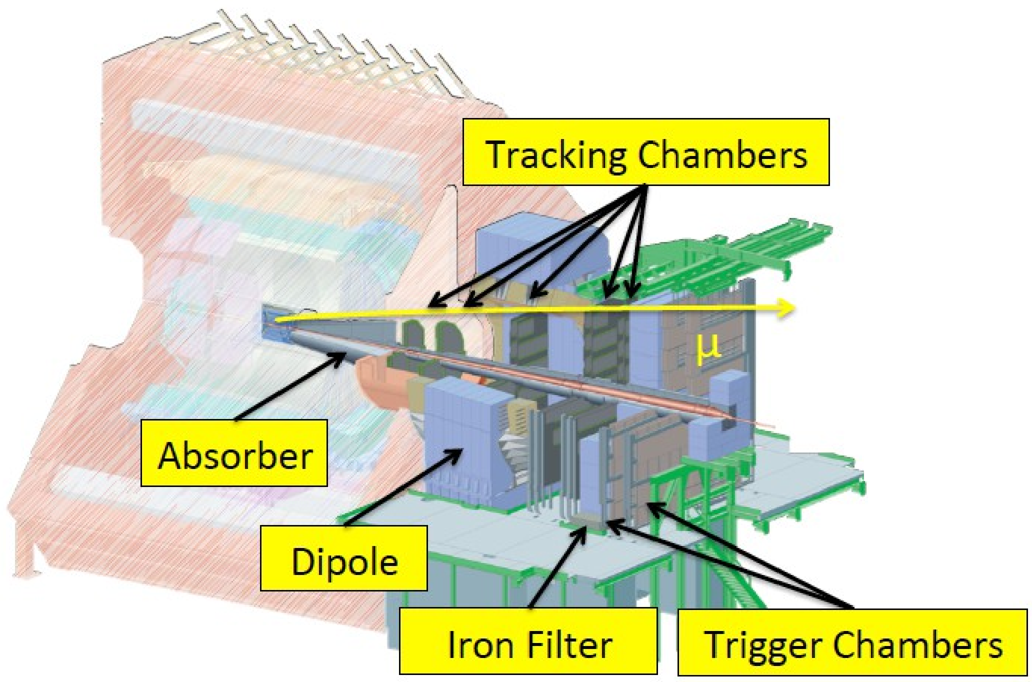
Heavy-flavor decay muons at forward rapidity

Track selection:

- Acceptance and geometrical cuts:
  Select tracks in the acceptance of the spectrometer
- Muon trigger matching:
  Reject hadrons that cross the absorber
- Pointing angle to the vertex:
  Remove beam-gas events and particles produced in the absorber

→ Remaining main background:

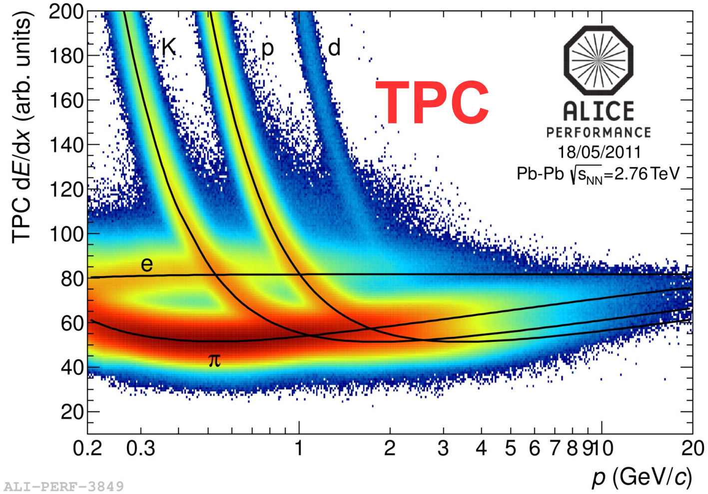


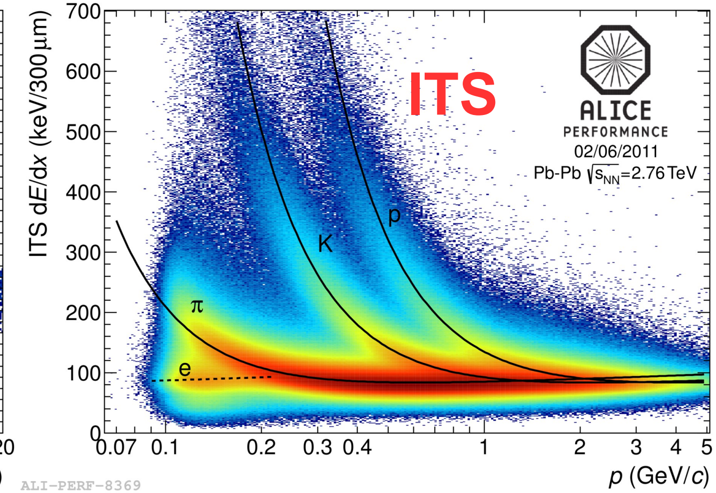


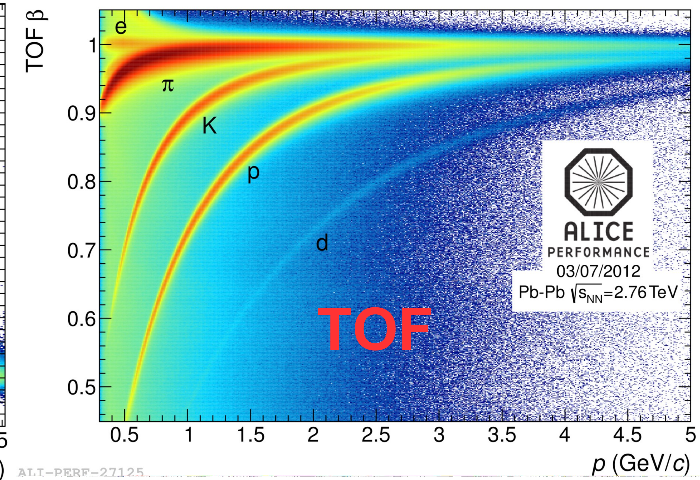
Heavy-flavor decay electrons at mid rapidity

Electron identification based on:

- ITS-TPC-TOF at low and intermediate p_T
- TPC-EMCal at high p_T

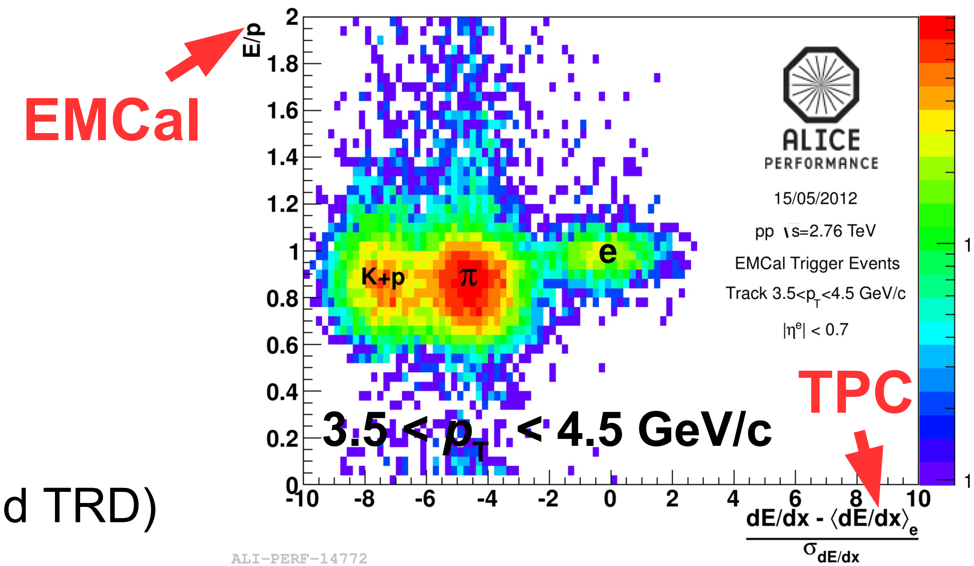






Non heavy-flavor background
from photonic sources subtracted by:

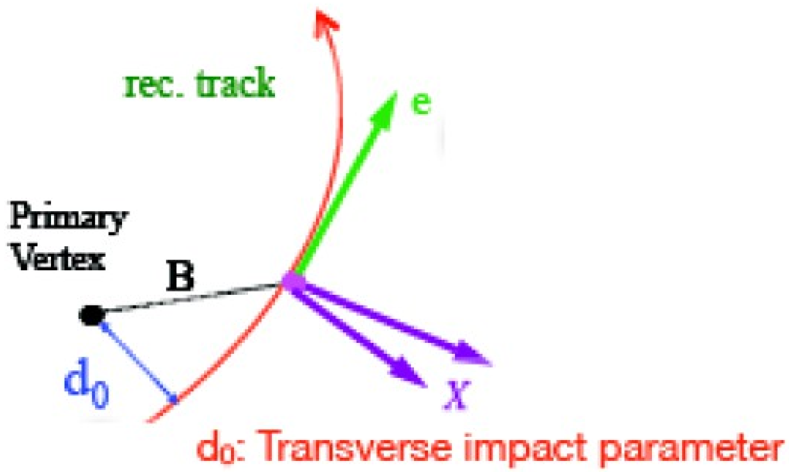
- Cocktail method
- Photonic background reconstruction



MB triggers and electron triggers with EMCal (and TRD)

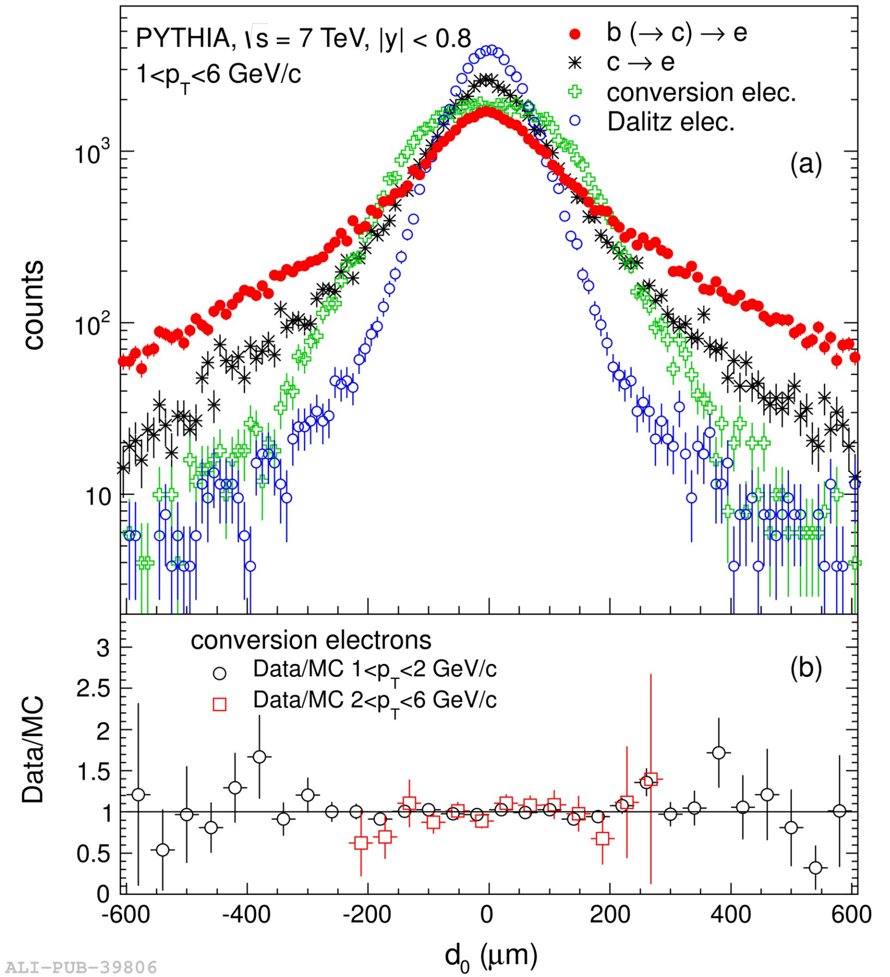
Beauty-decay electrons at mid rapidity

Beauty hadrons have large lifetime ($c\tau$ ~ 500 μm)
➡ broad d_0 distribution of decay electrons



Apply a minimum d_0 cut or fit the d_0 distribution

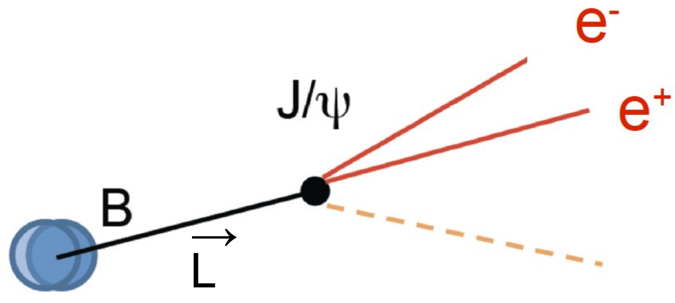
Phys. Lett B721 (2013) 13-23



Other method in pp collisions:
Electron-hadron Δφ correlation (wider for beauty-decay electrons than for charm-decay electrons)

Beauty via non-prompt J/psi at mid rapidity

- Measure displaced J/Ψ from beauty-hadron decays
- Simultaneous fit to invariant mass and pseudo-proper decay length (*x*) distributions

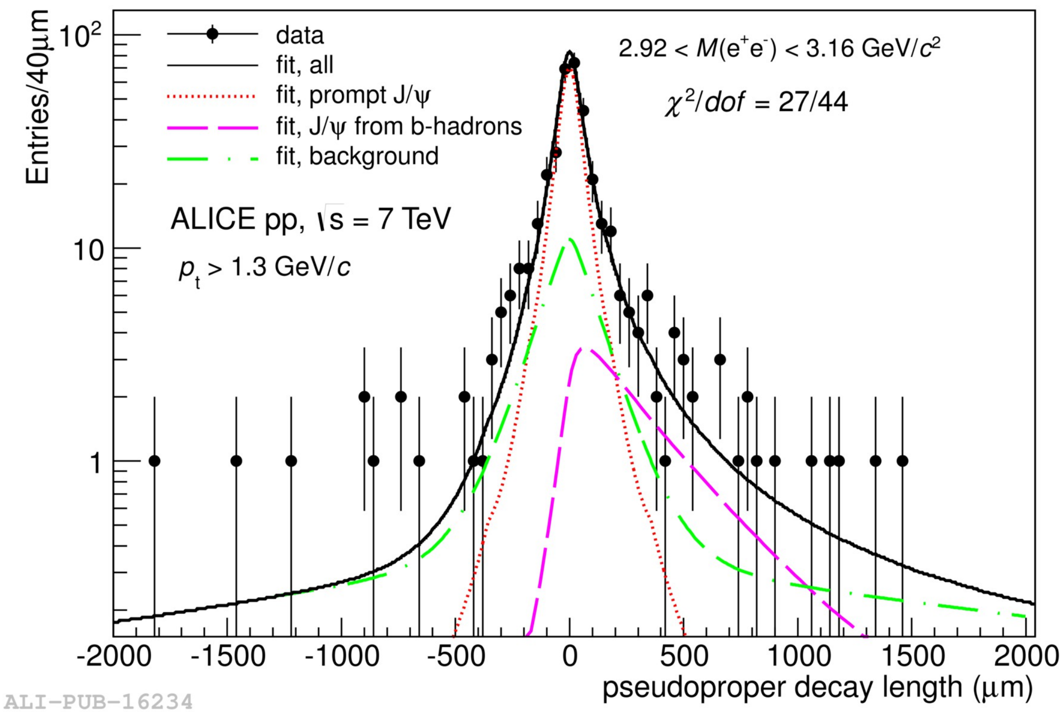


$$L_{xy} = \vec{L} \cdot \frac{\vec{p}_T^{\,J/\Psi}}{|\vec{p}_T^{\,J/\Psi}|}$$

$$x = L_{xy} \cdot \frac{M_{J/\Psi} \cdot c}{p_T^{J/\Psi}}$$

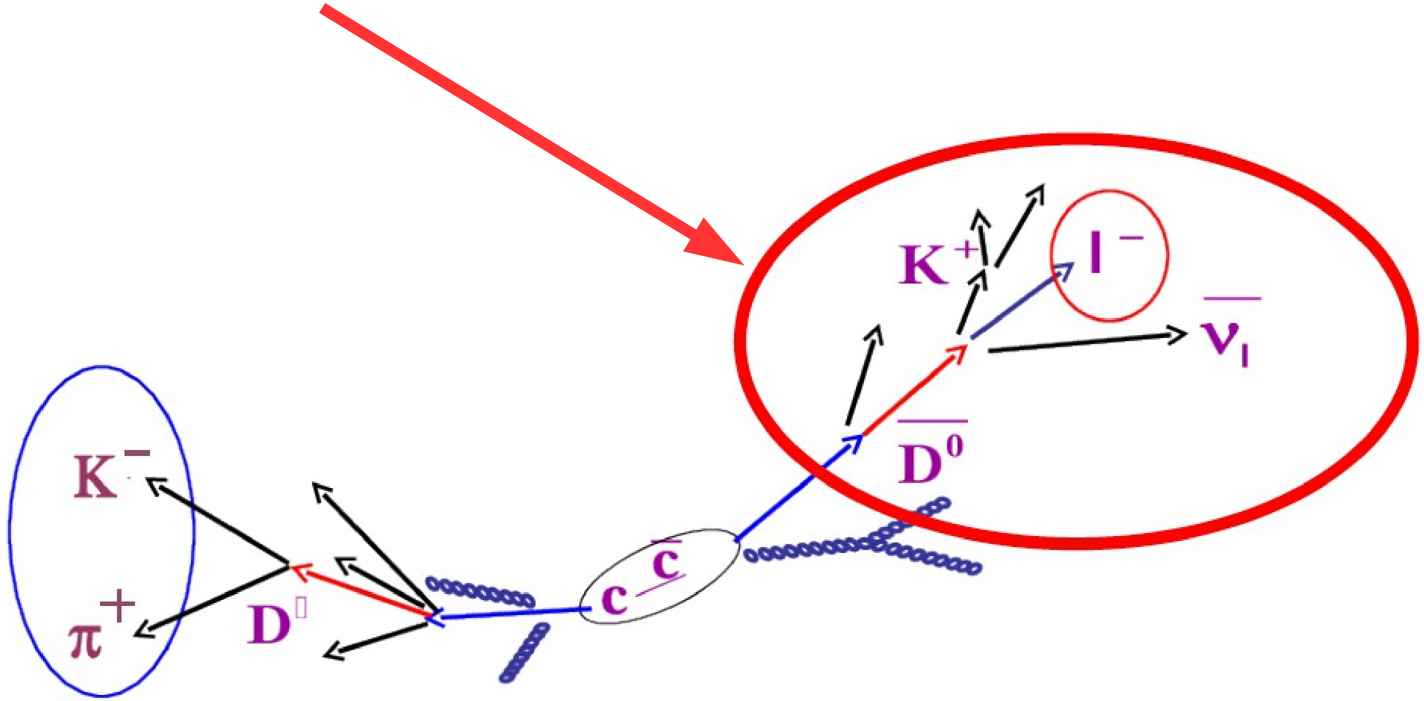
$M_{J/\Psi}$, J/ψ mass from the PDG

JHEP 11 (2012) 065



Semileptonic decays

Measure the $c\bar{c}$ and $b\bar{b}$ production cross sections through semi-leptonic decays of open charm and open beauty hadrons:



Branching Ratios:

c→l+X	9.6%
b→l+X	11%
b→c→l+X	10%

In ALICE:
Electrons at mid rapidity
Muons at forward rapidity

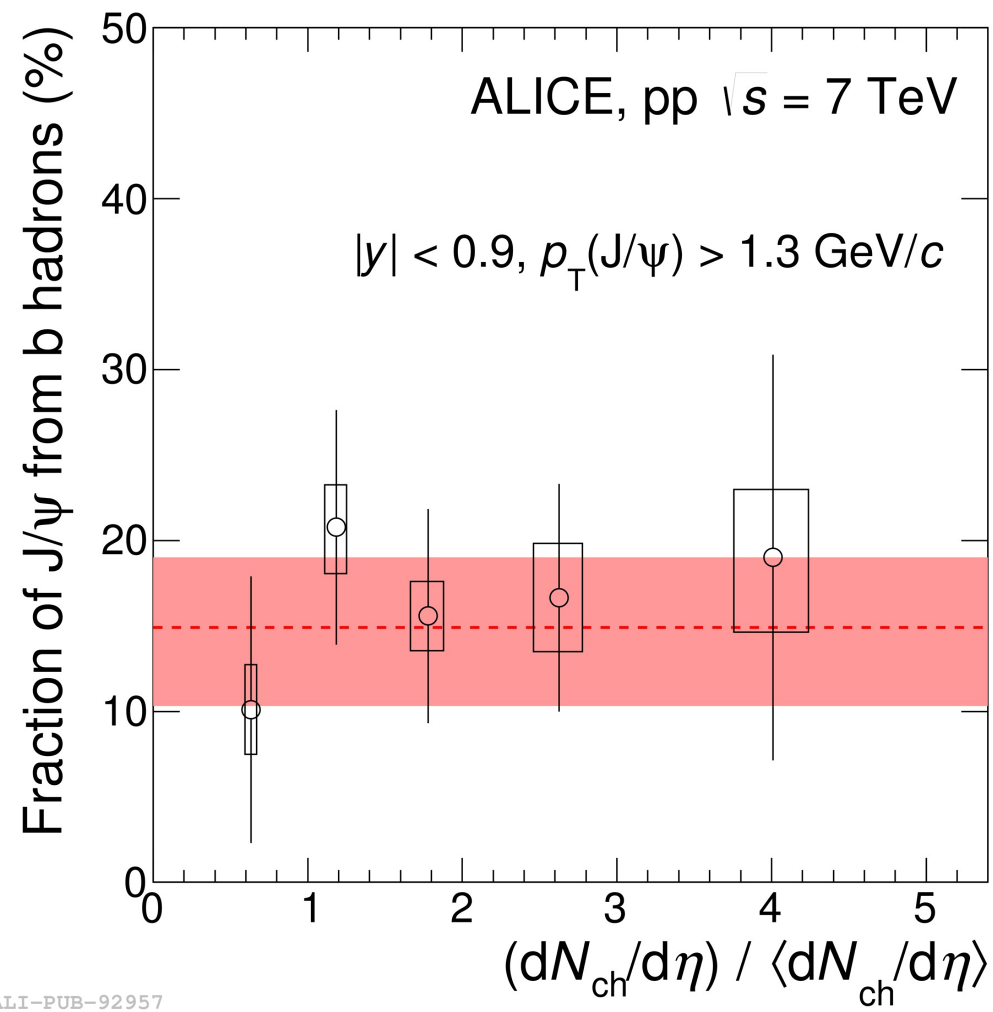
Multiplicity dependence of D-meson production

pp collisions at $\sqrt{s}$ = 7 TeV

arXiv: 1505.00664

Sensitive to:

- Interplay between hard and soft processes
- Multi-Parton Interactions (MPI)



D-meson per-event yields increase with charged-particle multiplicity

- Faster than linear increase
- D^0, D^+, D^{*+} compatible within uncertainties
- No p_T dependence observed within uncertainties
- Similar trend observed for inclusive J/Ψ and non-prompt J/Ψ from B-hadron decays

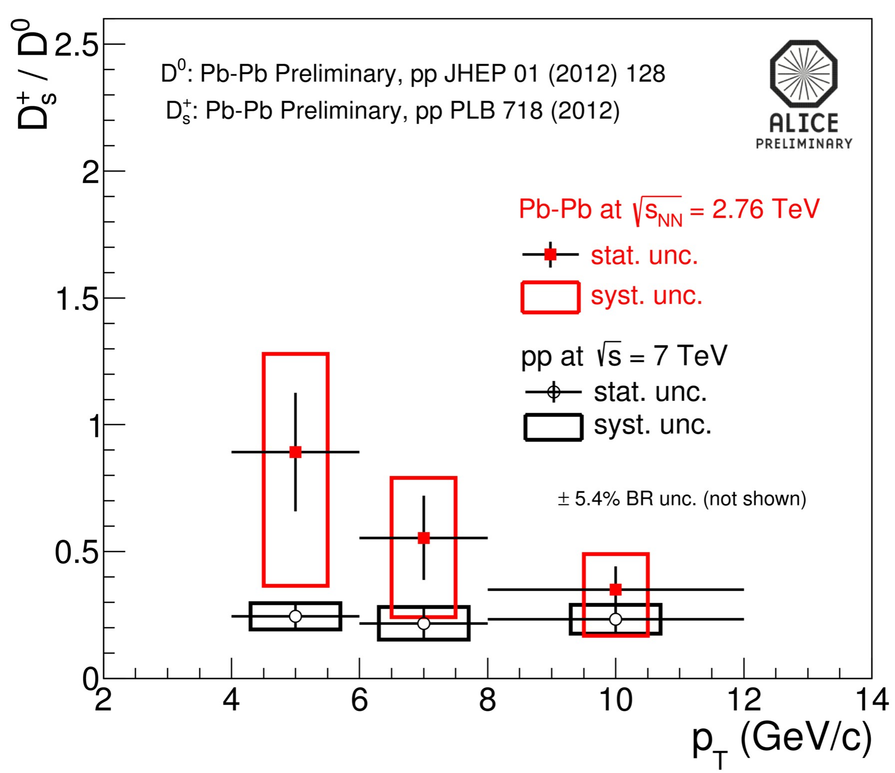
Talk by C. Terrevoli

Lifting of strangeness suppression

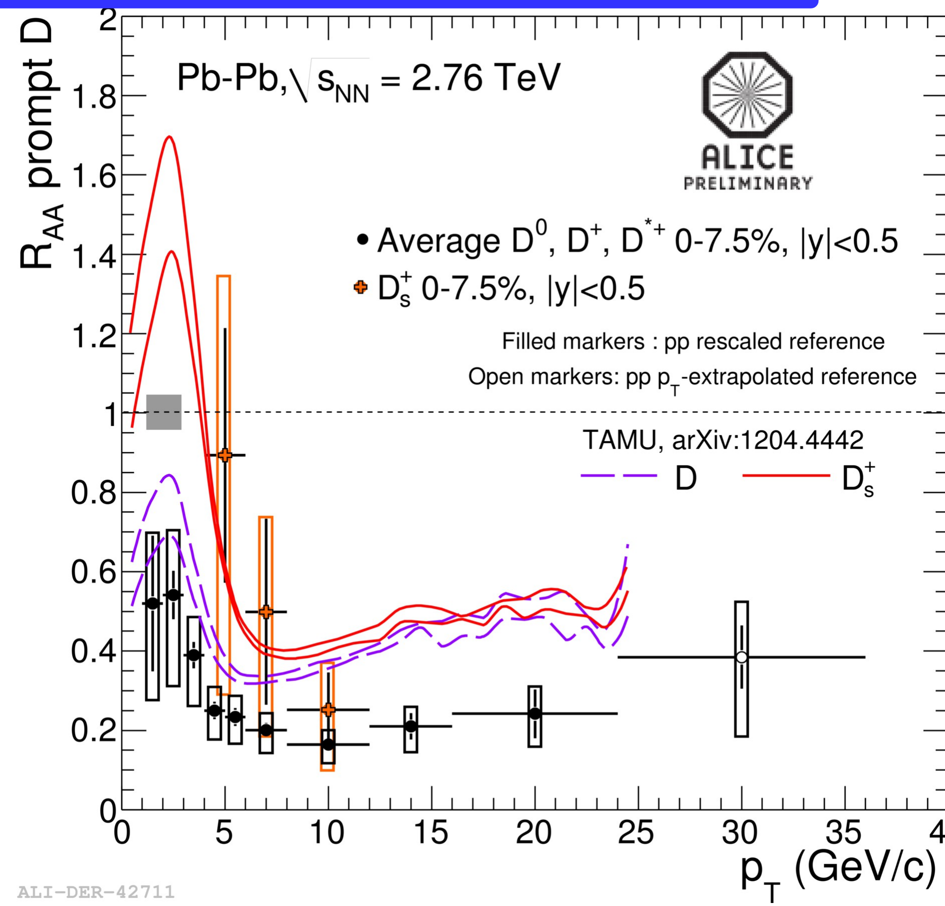
Expect an enhancement of strange D meson, D_s, compared to non-strange D mesons:

- In-medium strangeness enhancement
- Hadronization via recombination

He et al. PRL 110 (2013) 112301
Andronic et al. PLB 659 (2008) 149
Kuznetsova, Rafelski EPJ C51 (2007) 113



ALI-DER-44038



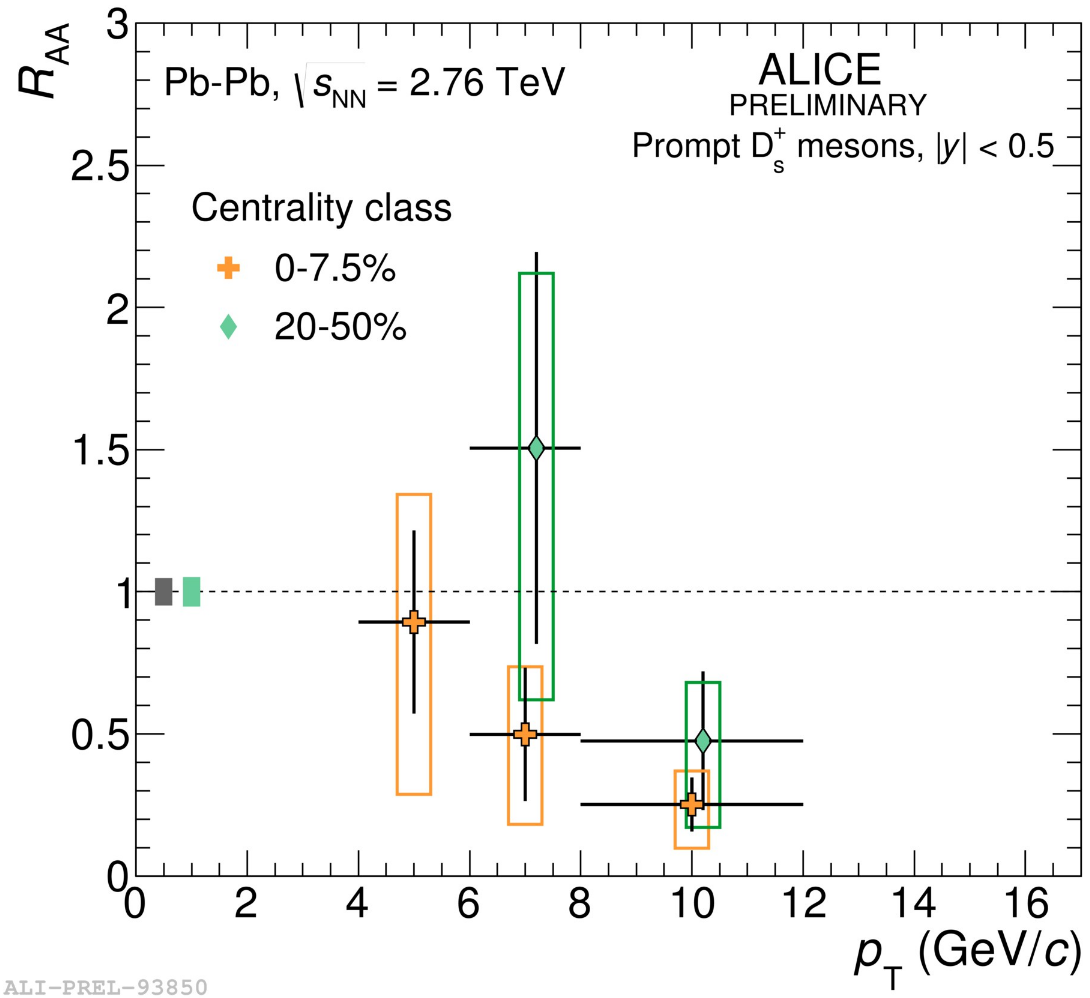
ALI-DER-42711

- D_s compatible with average D mesons within uncertainties
- Hint for an enhancement at low p_T

Talk by A.M. Barbano
Results also in 20-50%

Lifting of strangeness suppression

Talk by A.M. Barbano



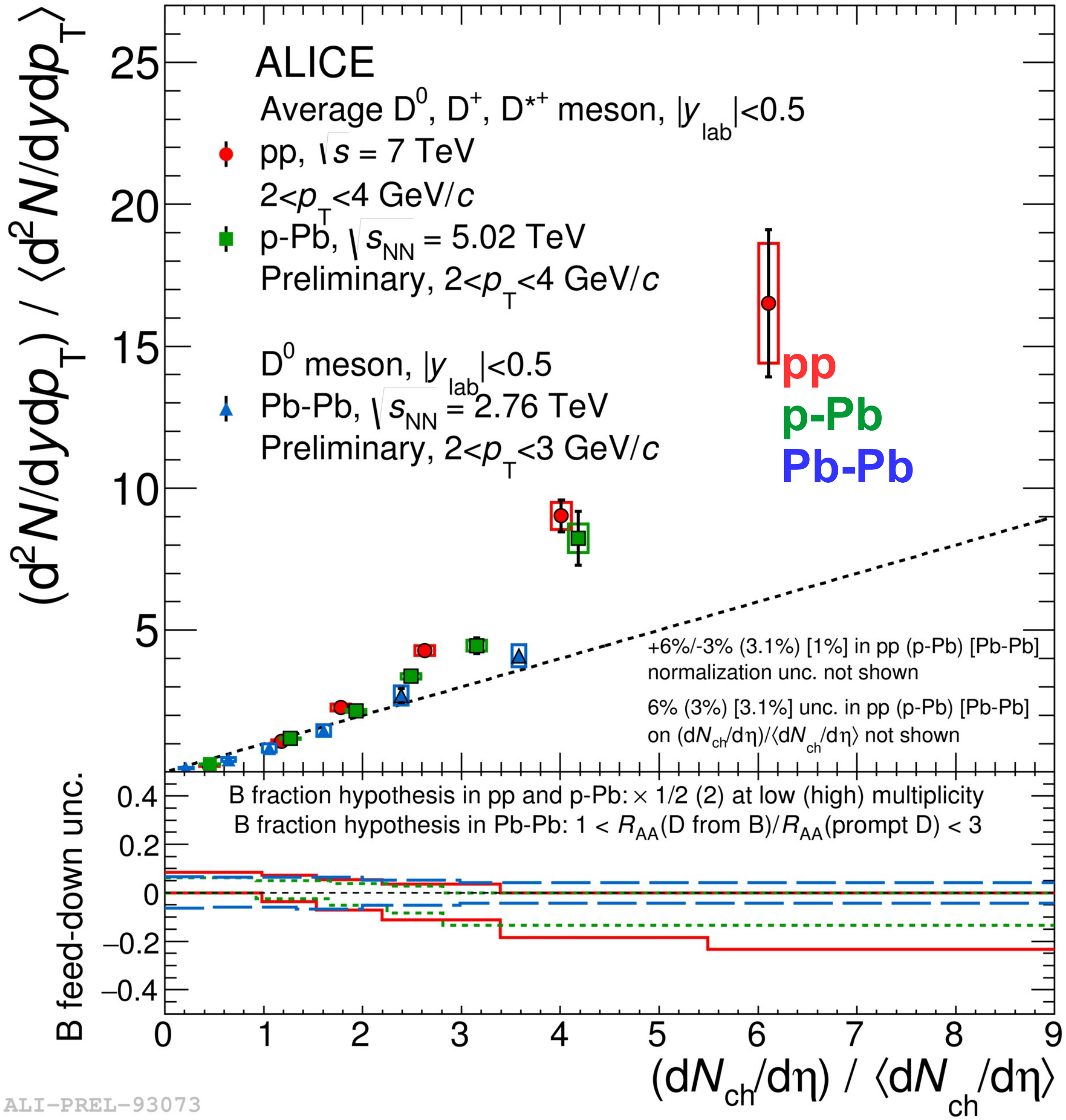
Multiplicity dependence of D-meson production

- Similar trend in pp collisions and p-Pb collisions but:
  - Multi-parton interactions in pp collisions
  - Multiple nucleon-nucleon collisions in p-Pb collisions

- In Pb-Pb collisions:

  In medium parton-energy loss + radial flow modify the p_T distribution of D mesons in a centrality/multiplicity dependent way

Talk by C. Terrevoli

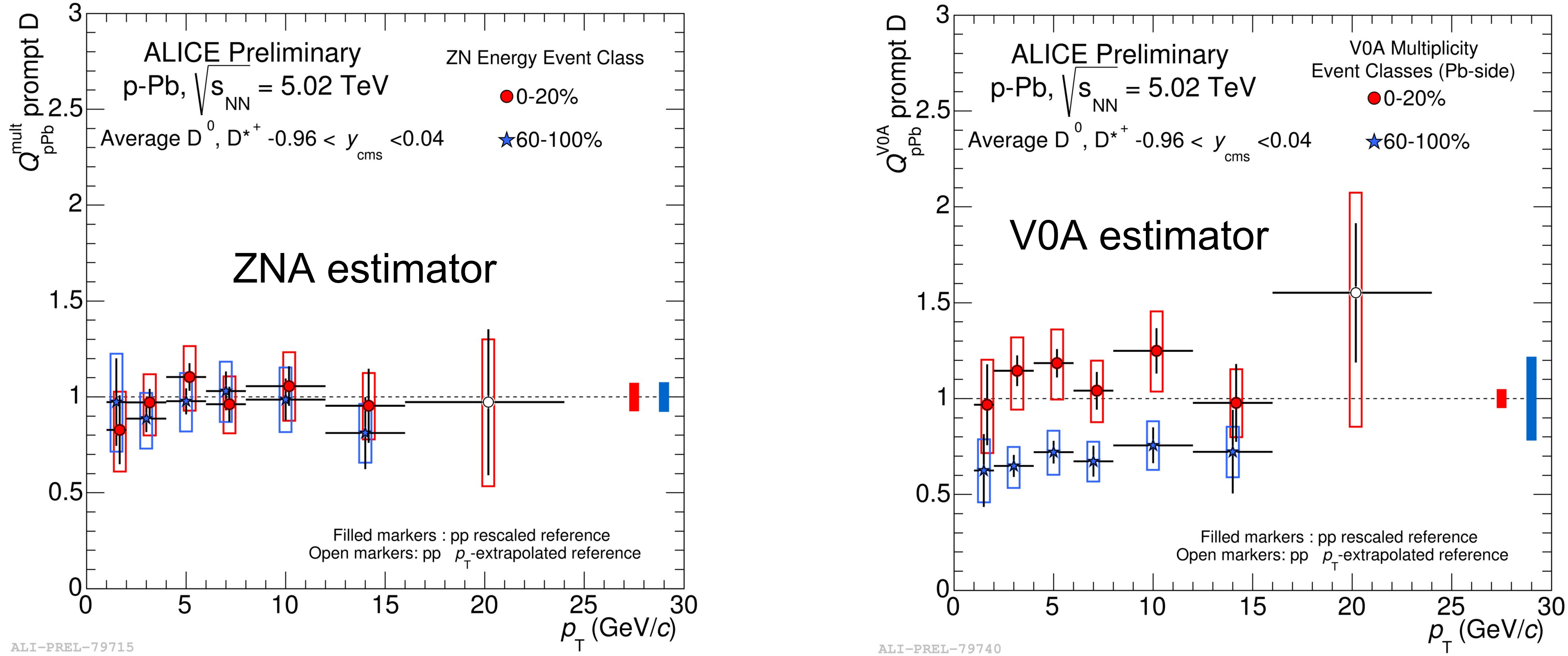


ALI-PREL-93073

Multiplicity dependence of D-meson production

Investigate scaling of charm production in p-Pb collisions w.r.t pp collisions

$$Q_{\mathrm{pPb}}^{\mathrm{V0A}}(p_{\mathrm{T}}) = \frac{\mathrm{d}N_{\mathrm{mult}}^{\mathrm{pPb}}/\mathrm{d}p_{\mathrm{T}}}{N_{\mathrm{coll}}^{\mathrm{Glauber}}\mathrm{d}N^{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}}$$



- Similar bias in <N_{coll}> determination as for charged hadrons
- With ZNA estimator (least bias estimator) no multiplicity dependent modification of D-meson production in p-Pb collisions w.r.t pp collisions

Talk by C. Terrevoli

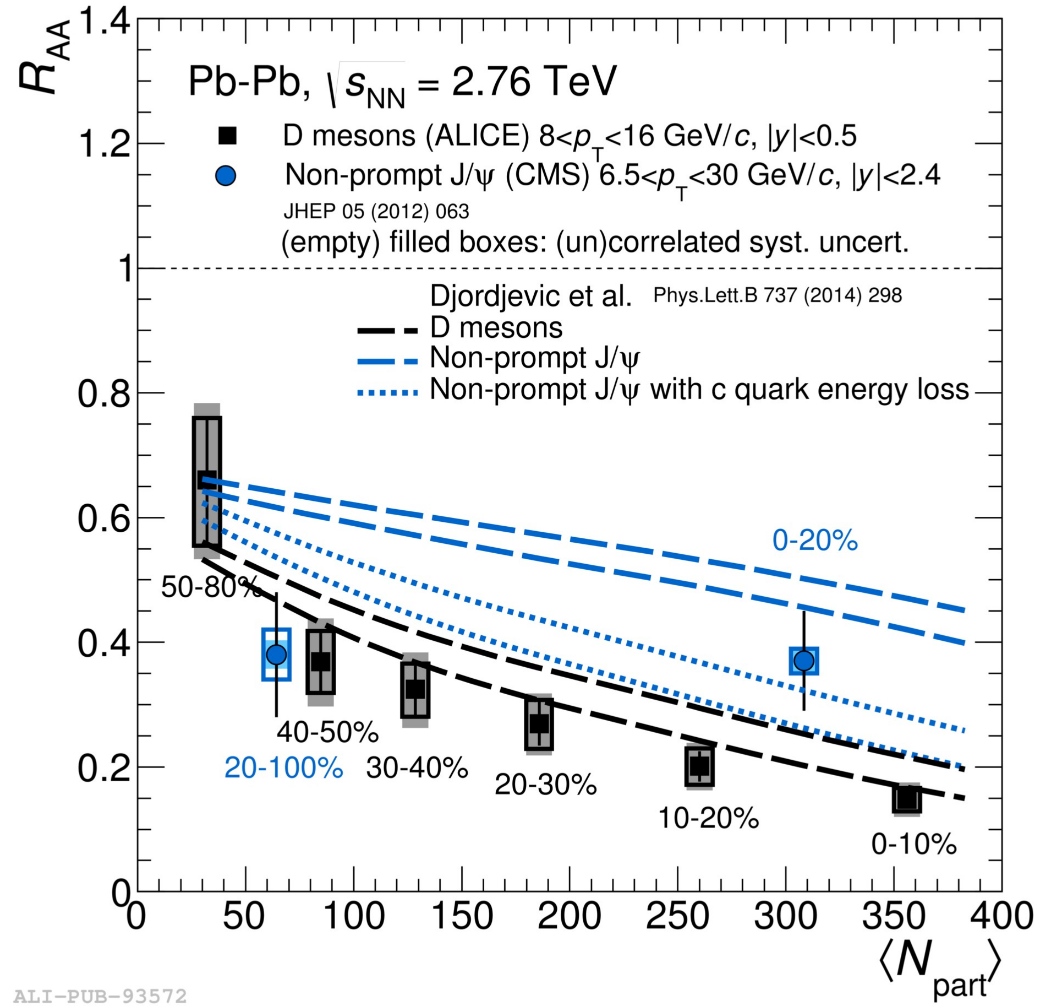
Mass dependence of parton energy loss

Talk by A. Festanti

R_{AA}(J/Ψ←B) > R_{AA}(D)

- Similar kinematic region: $\langle p_T^D \rangle \sim \langle p_T^B \rangle$
- Quark mass used in the model crucial to reproduce the data
  Djordjevic, PL B734(2014)286
- Similar pattern from other calculations
  TAMU elastic: arXiv:1401.3817 [nucl-th]
  MC@sHQ+EPOS2: Phys. Rec. C89 (2014) 014905
  BAMPS: J.Phys.G38 (2011) 124152
  WHDG: J.Phys.G38 (2011) 124114
  Vitev et al., Phys.Rev.C80 (2009) 054902

ALICE: arXiv: 1506.06604 [nucl-ex]
CMS Preliminary: CMS-PAS-HIN-12-014
See also CMS: JHEP 05 (2012) 063



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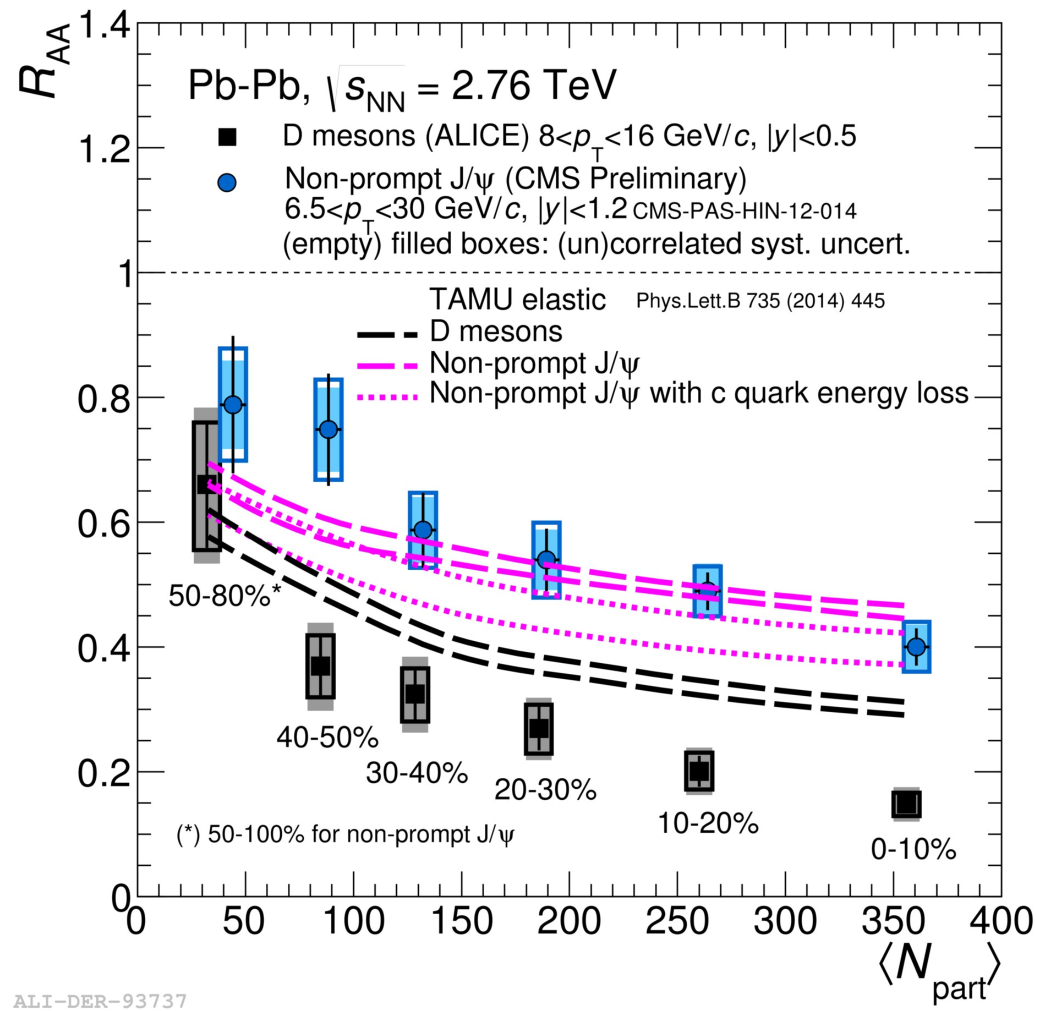

Mass dependence of parton energy loss

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ALICE

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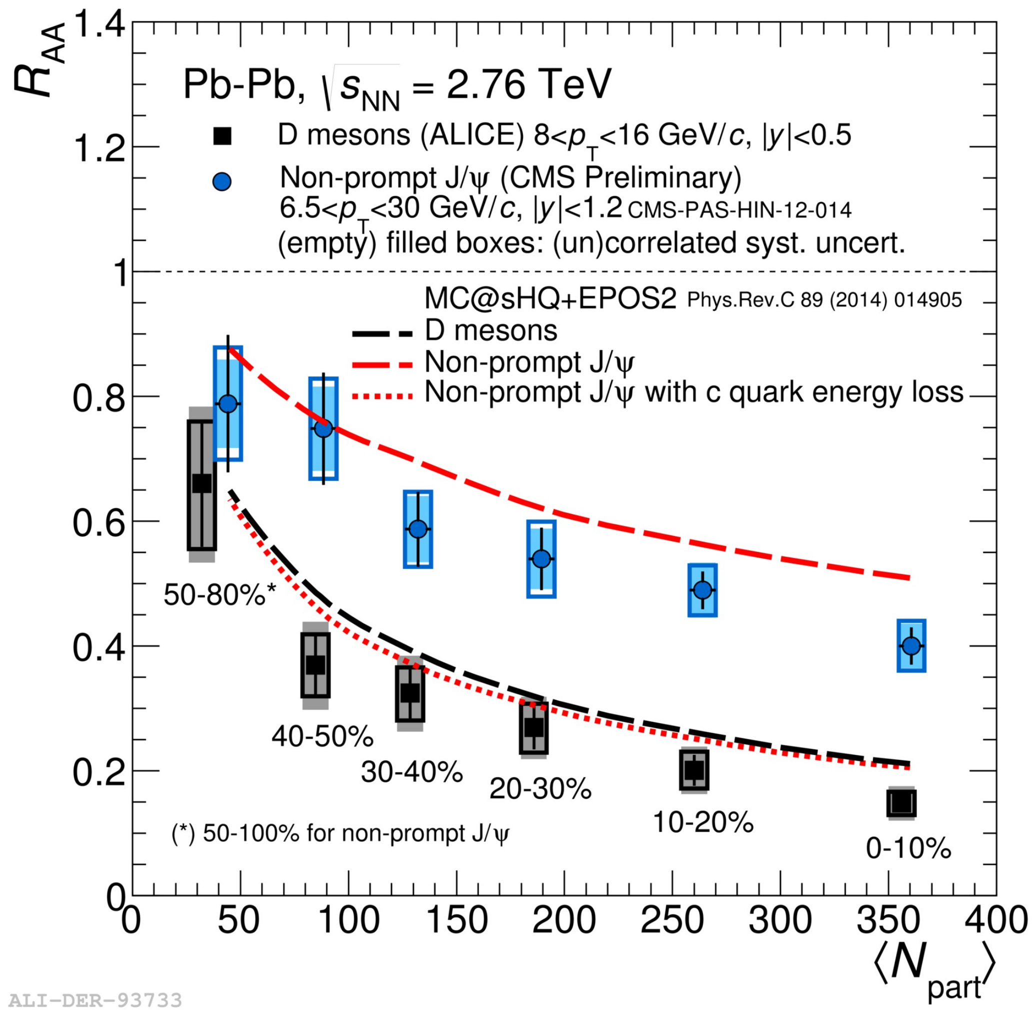

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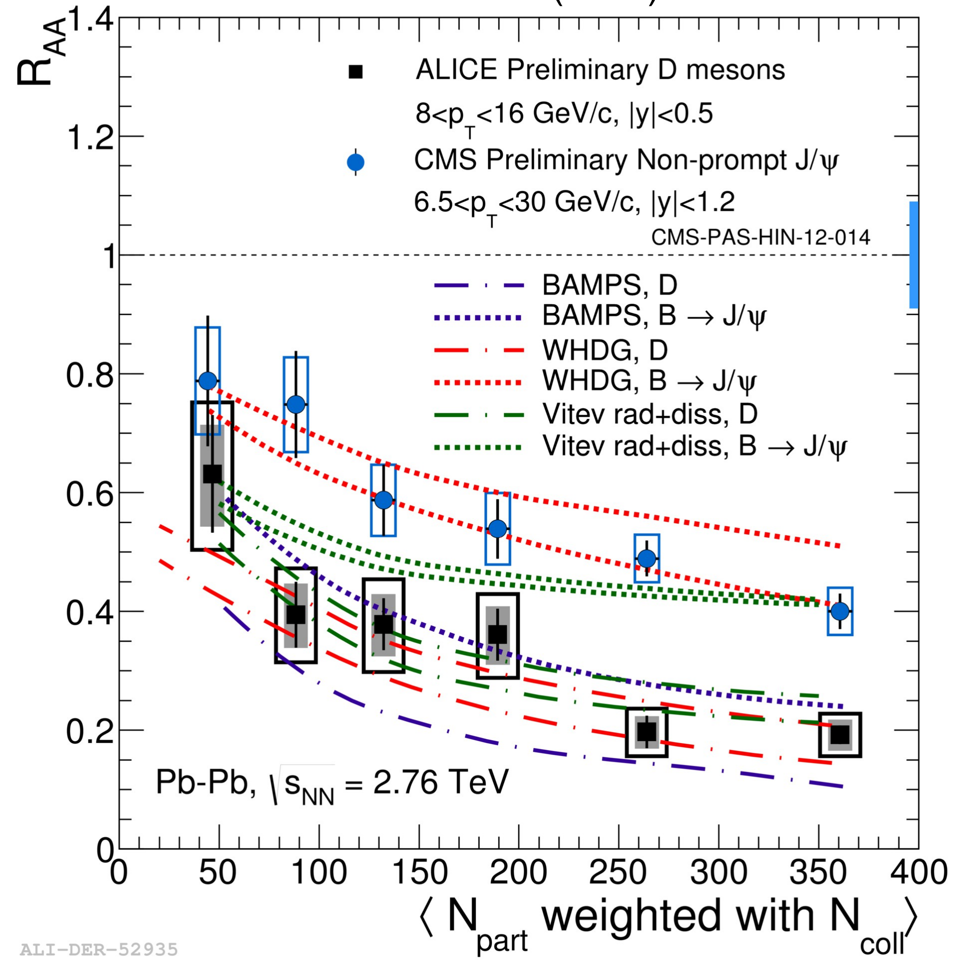
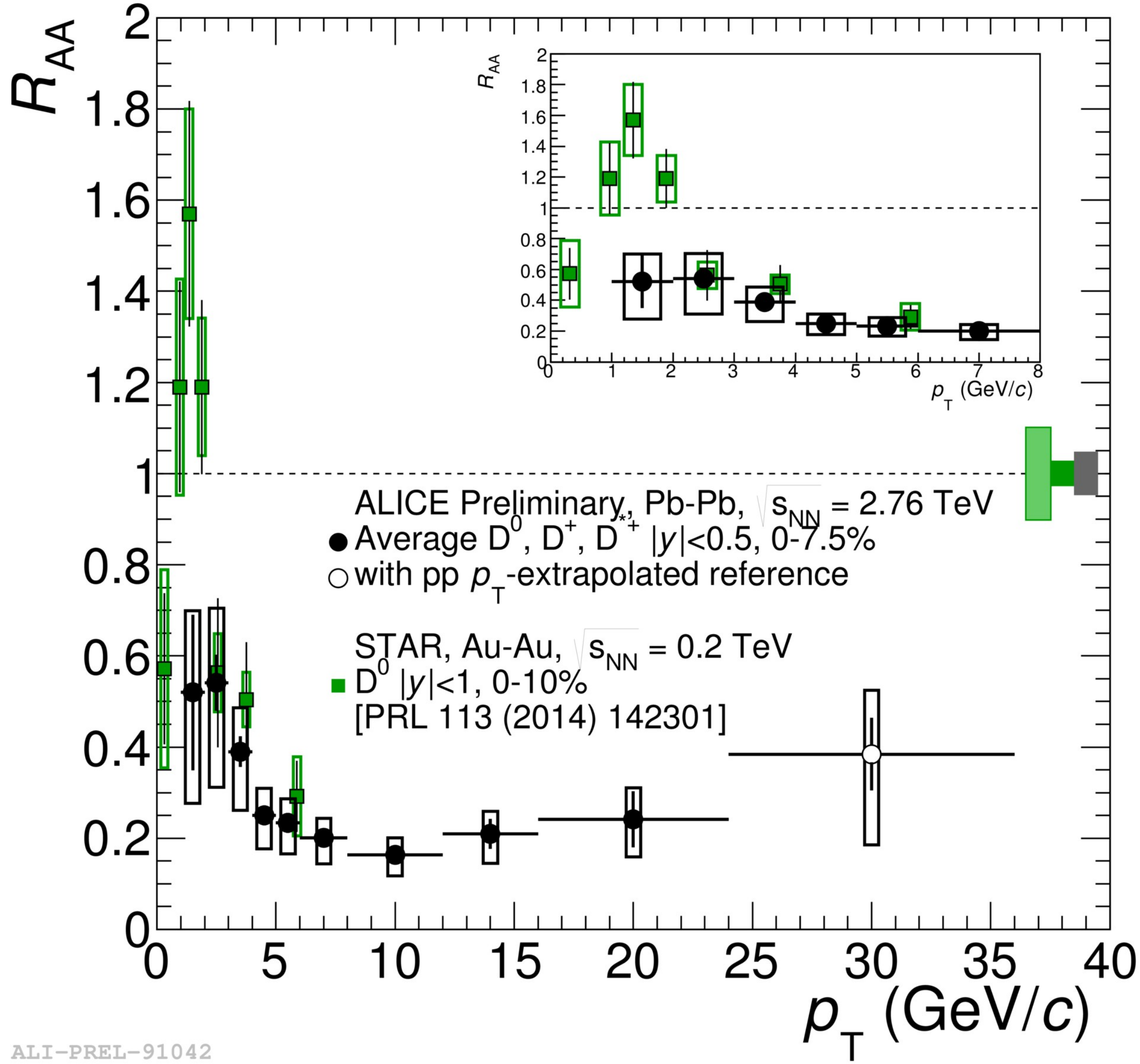
ALICE preliminary
See also ALICE: arXiv: 1506.06604 [nucl-ex]
CMS Preliminary: CMS-PAS-HIN-12-014
See also CMS: JHEP 05 (2012) 063



Modification factors of D mesons



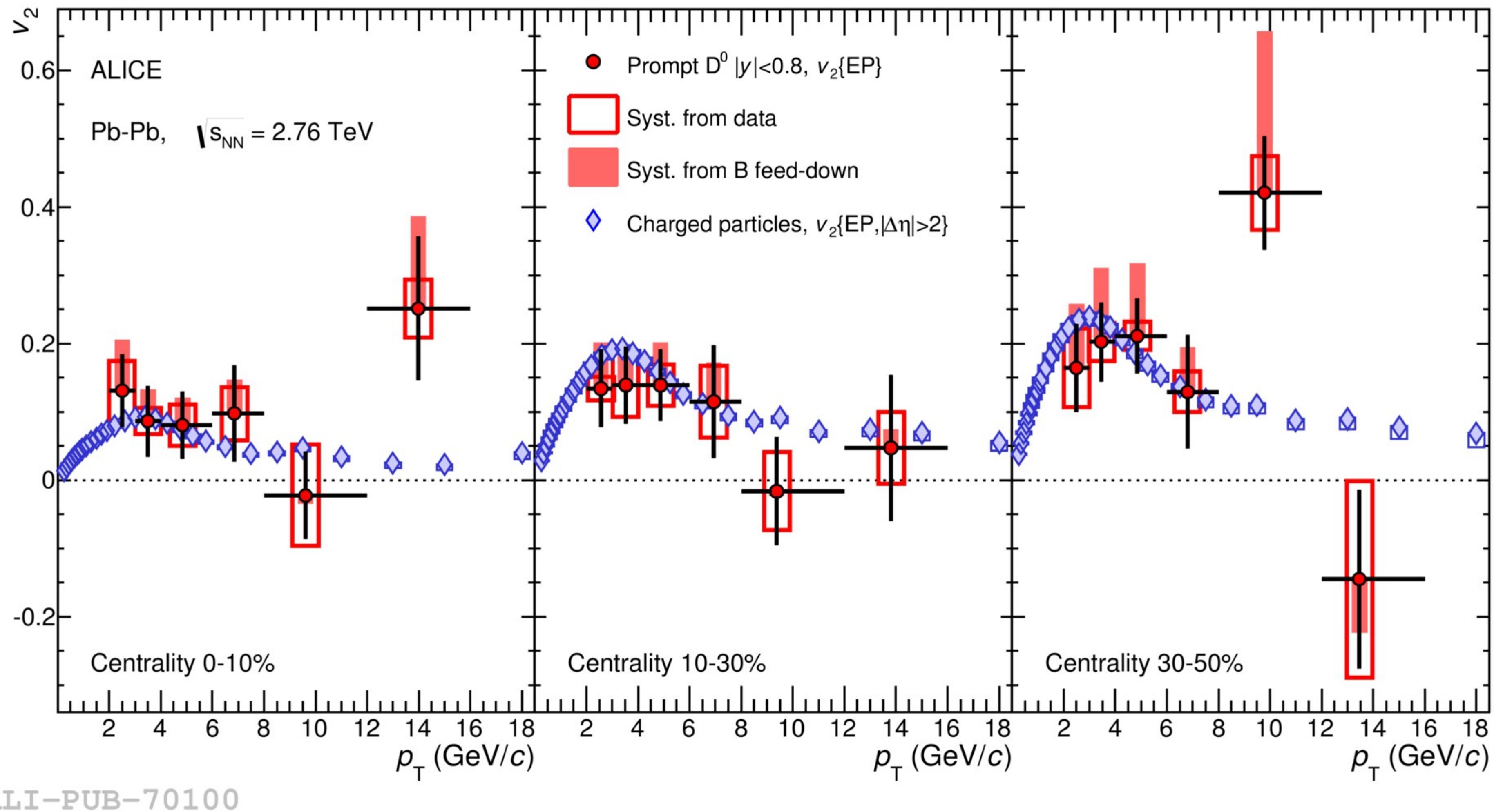
Talk by A. Festanti

- Strong suppression of high-p_T D mesons in central collisions
- Where does the energy loss end up ? Low-p_T measurement crucial

Heavy-flavor elliptic flow

Talk by A. Festanti

PRL 111 (2013) 102301
PRC 90 (2014) 034904

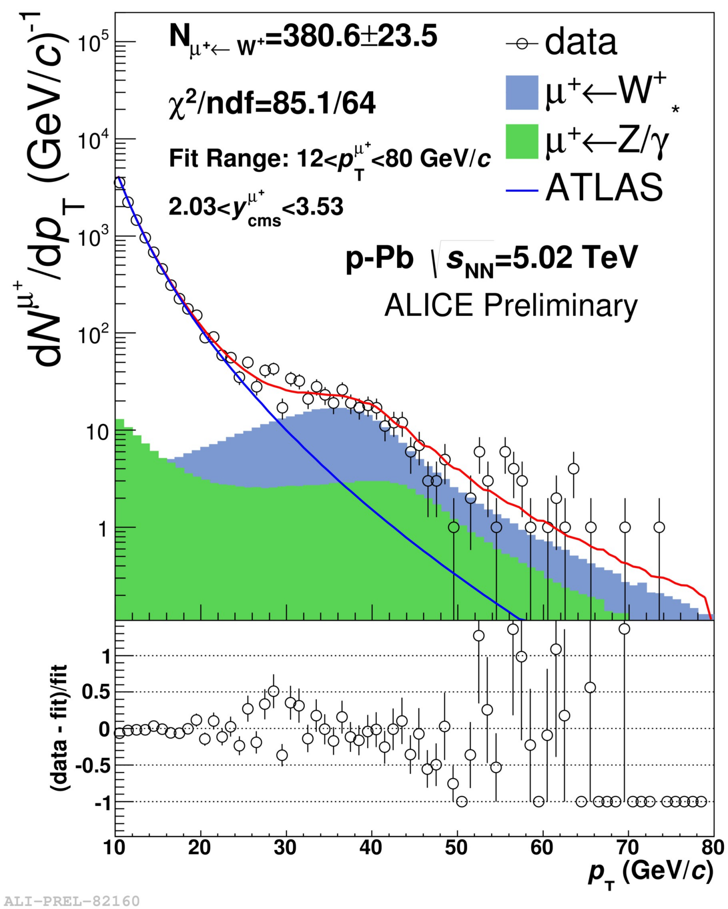


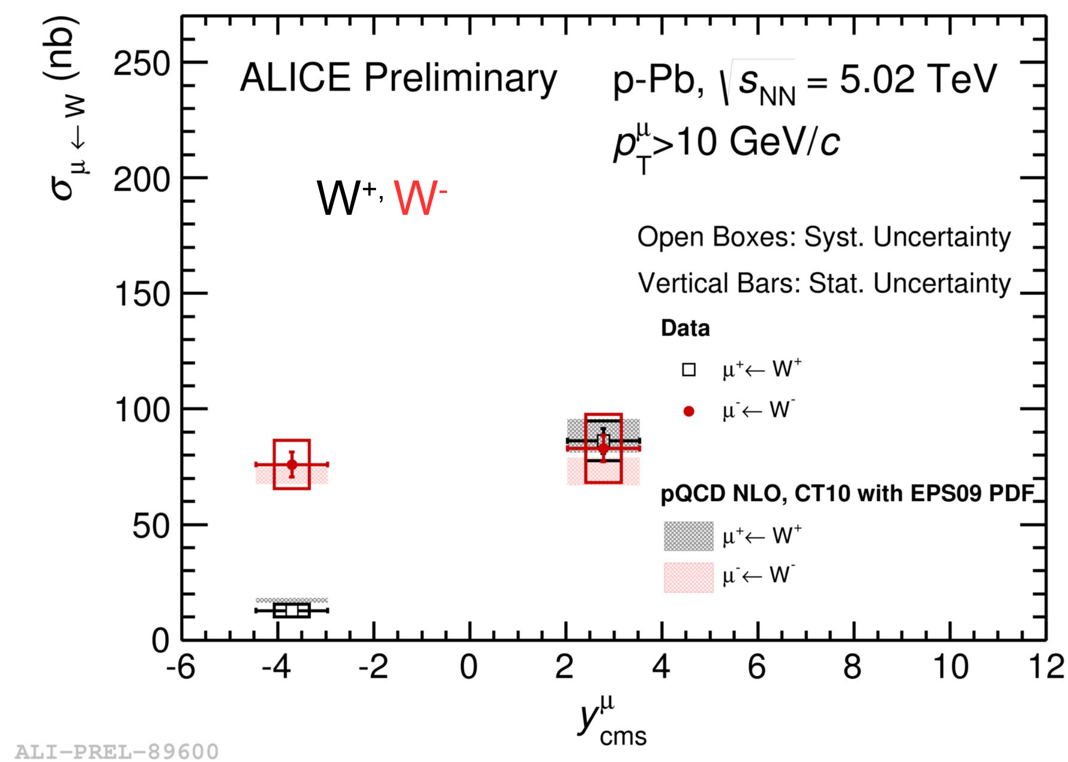
Talk by F. Bossu

W-boson productions

Electroweak probe produced in hard interactions
- Sensitive to modification of parton distributions inside the nucleus
- Test binary scaling of hard processes

Fit the single-muon p_T distribution → Measure production cross section at forward and backward rapidity

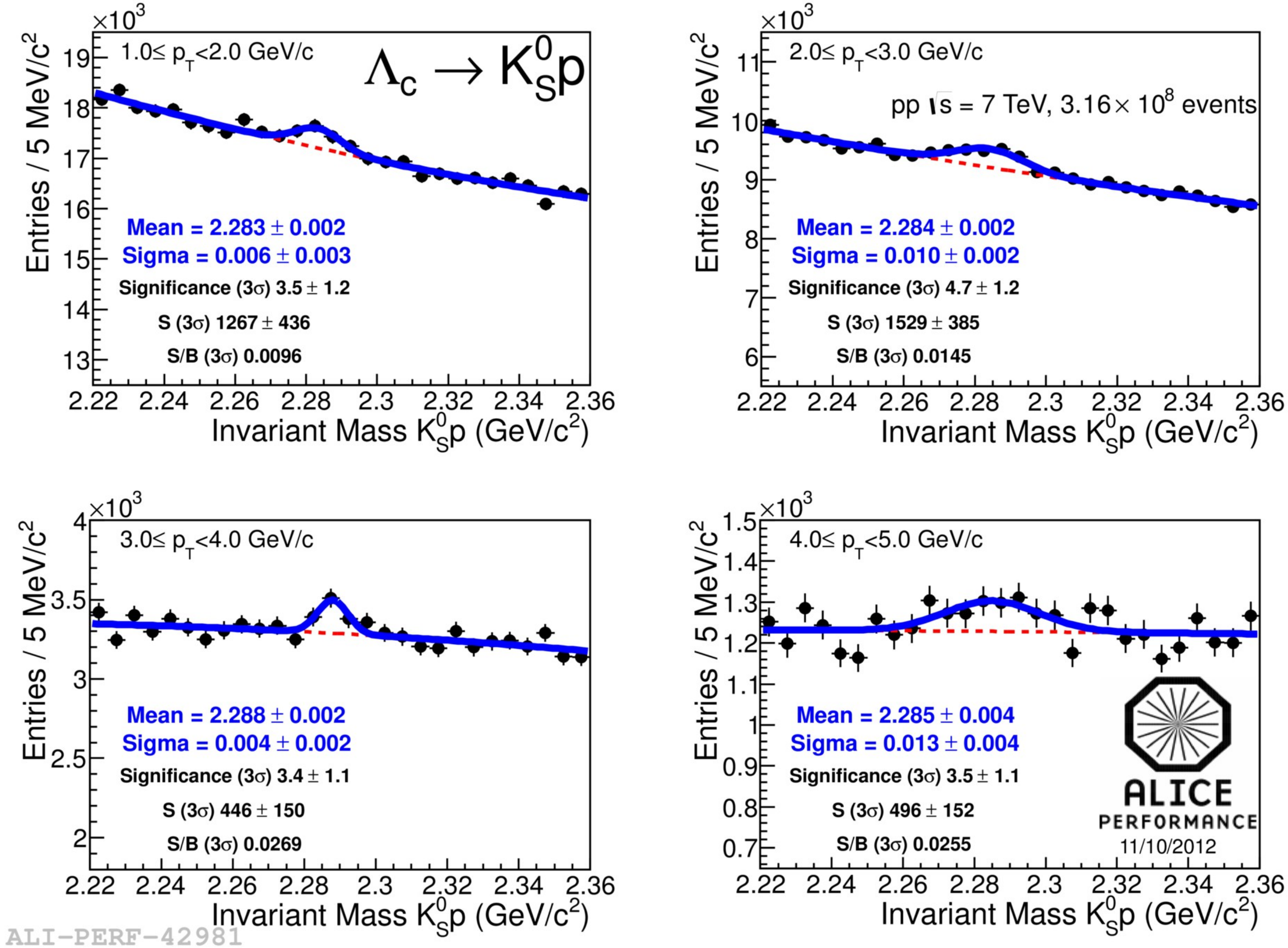




- Isospin effect visible at backward rapidity
- Results described by pQCD at NLO

JHEP 1103 (2011) 071

Λ_c measurements



Analyses in the following channels:

$\Lambda_c \rightarrow K_s^0 p$ and $\Lambda_c \rightarrow pK\pi$