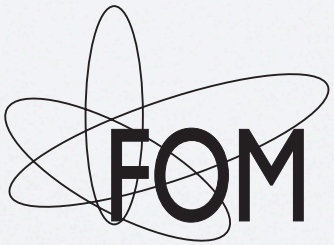
Open heavy flavour measurements in pp and Pb-Pb collisions with ALICE at the LHC

Sarah LaPointe
for the ALICE collaboration
Utrecht University



OUTLINE

Motivation

Measuring heavy flavours in ALICE

Open heavy flavour (HF) in pp and Pb-Pb collisions
- Production cross section in pp
- Nuclear modification factor
- Elliptic flow

Conclusions/outlook

MOTIVATION FOR HF MEASUREMENTS

Production

- Heavy flavour (HF) quarks (charm and bottom) are primarily produced in the initial hard scatterings of the collision
- They experience the full evolution of the system, making them excellent probes

ALICE baseline for charm/bottom

	Pb-Pb (5%) 2.76 TeV	pp 7 TeV	pp 14 TeV
σ_{NN}^{qq} (mb)	2.1/0.075	6.91/0.23	11.2/0.45
N^{qq} /event	56/2	0.1/0.003	0.16/0.006

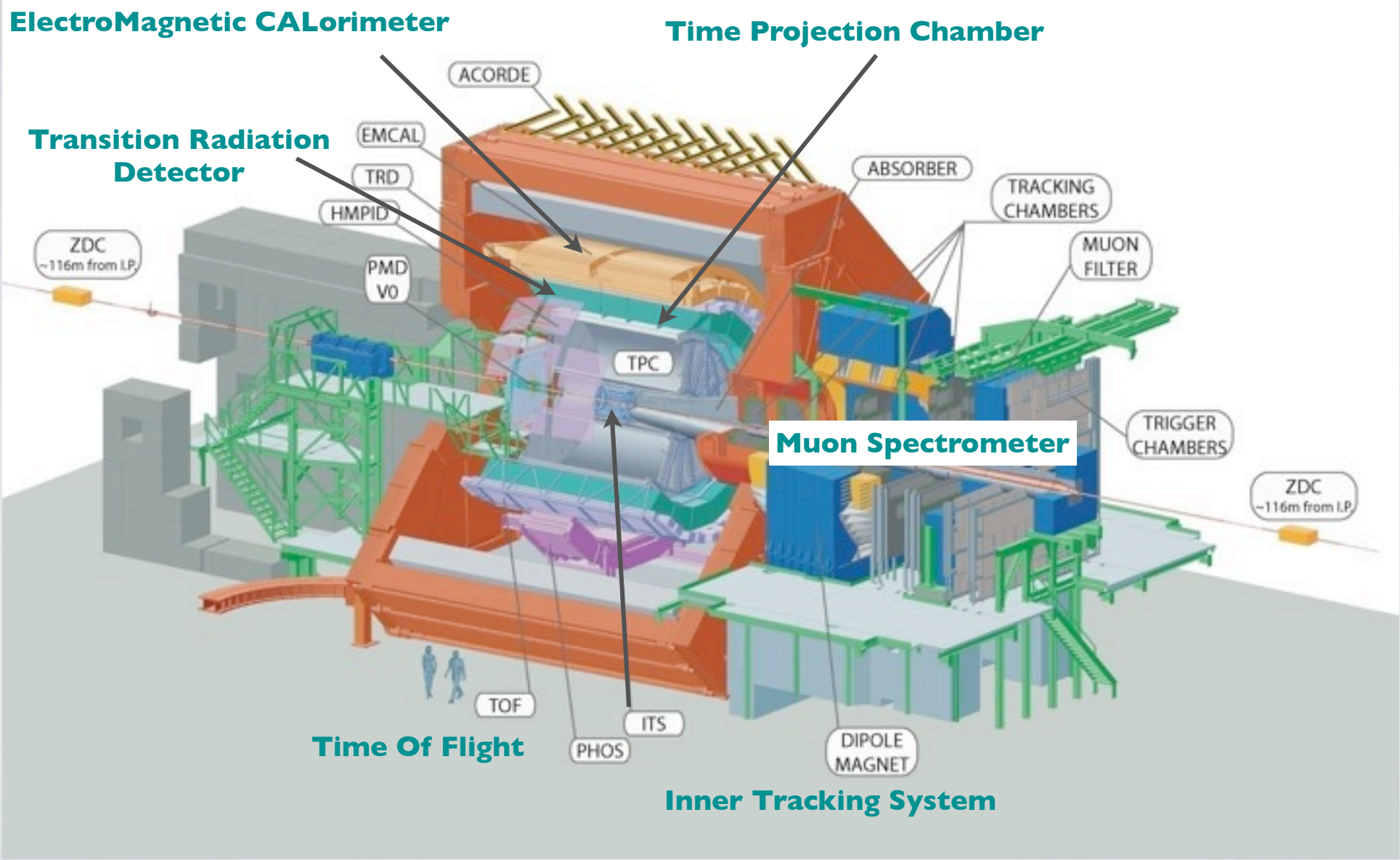
MNR code: Mangano, Nason, Ridolfi, NPB373 (1992) 295. EKS98, EPS08: Eskola et al., EPJC9 (1999) 61; JHEP07 (2008) 102

Probing the QCD matter

- In-medium partonic energy loss - Both mass (dead cone effect) and color charge dependent → $\Delta E_g > \Delta E_{u,d,s} > \Delta E_c > \Delta E_b$ Phys. Lett. B 519 (2001) 199
- Collectivity - in-medium transport properties. Probe the thermalization of the system

Energy loss is studied primarily via R_{AA} and collectivity via flow (v_2)

THE ALICE DETECTOR



HEAVY FLAVOUR PROGRAM

Mid rapidity ($|\eta| < 0.9$)

D mesons (D^0, D^+, D^*, D_s) via hadronic decays
- Select on displaced vertices using TPC and ITS
- Particle ID using TPC and TOF
- Invariant mass analysis

Single electrons from semi-leptonic D and B decays
- e ID using TRD, EMCal, TPC, and ToF
- Background estimated from MC cocktail or e^+e^- M_{inv} method
- Displaced electrons using ITS (B tagging)

Forward rapidity ($2.5 < \eta < 4$)

Single muons from semi-leptonic D and B decays
- Muon spectrometer
- Background primary π, K decays. In pp estimated using MC, in Pb-Pb extrapolated from measured π, K at mid rapidity

pp OVERVIEW

- Charm and beauty production cross sections, along with a comparison to FONLL and GM-VFNS(D mesons)

- Additional charm hadron measurements

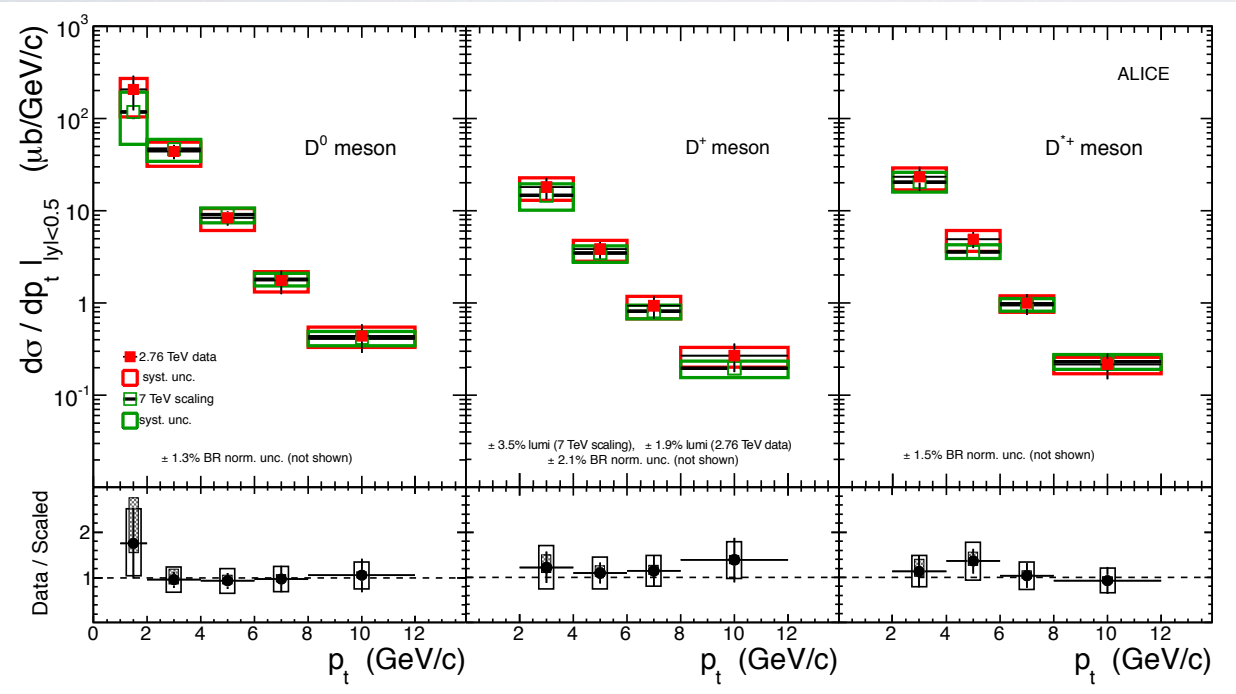
- Beauty with electrons
  - Impact parameter analysis
  - Electron-hadron azimuthal correlations

pp data sets:
$\sqrt{s}$ = 2.76 TeV (2011)
7 TeV (2010)

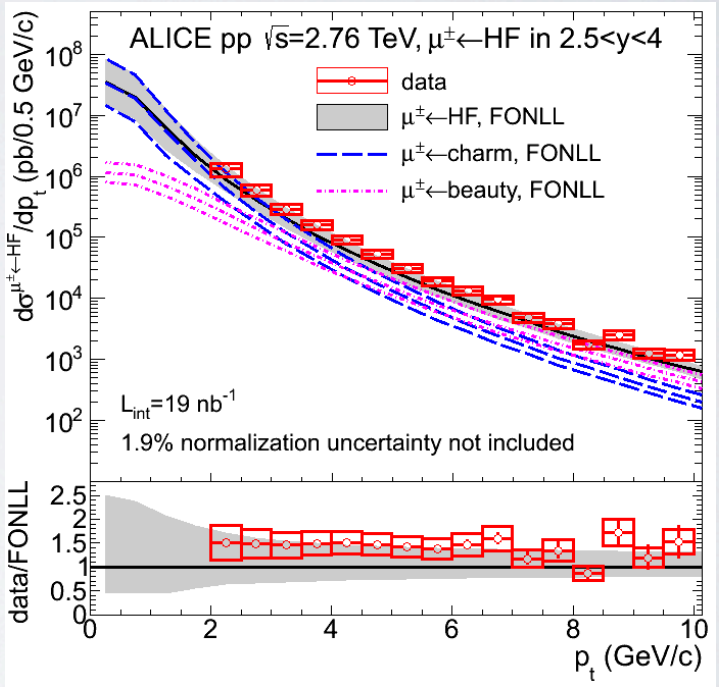
pp AT 2.76 TeV, D MESONS AND MUONS

Small data sample ($L_{int}(D)=1.35nb^{-1}$, $L_{int}(\mu)=19nb^{-1}$)

- Reference for PbPb collisions at 2.76 TeV
- Measured differential cross section for D mesons and HF muons



arXiv:1205.4007

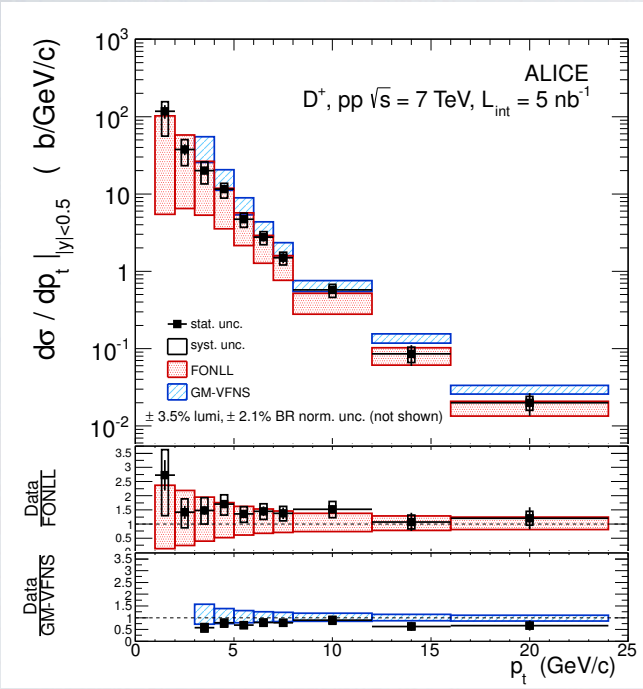


arXiv:1205.6443

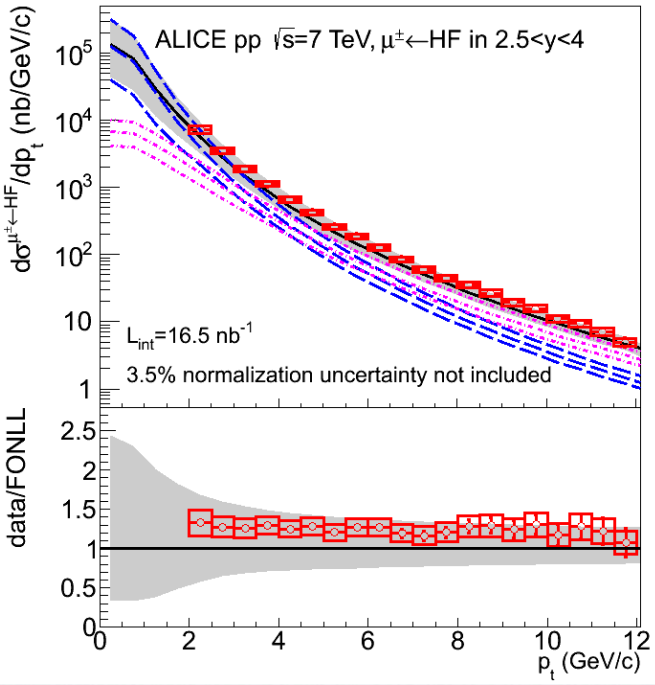
- The HF muon cross section is well described by FONLL predictions

pp AT 7 TeV, D MESONS, MUONS, ELECTRONS

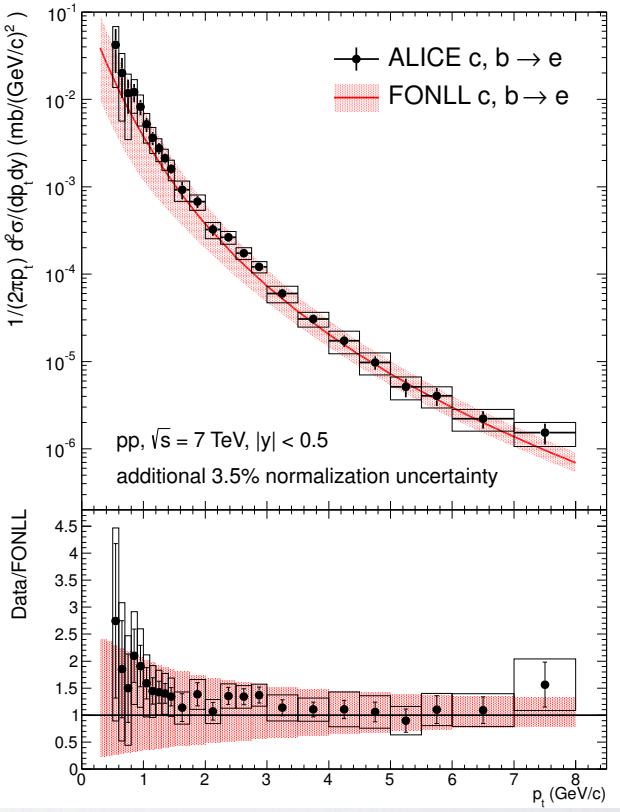
Heavy flavour spectra



JHEP01 (2012) 128



PLB 708 (2012) 265



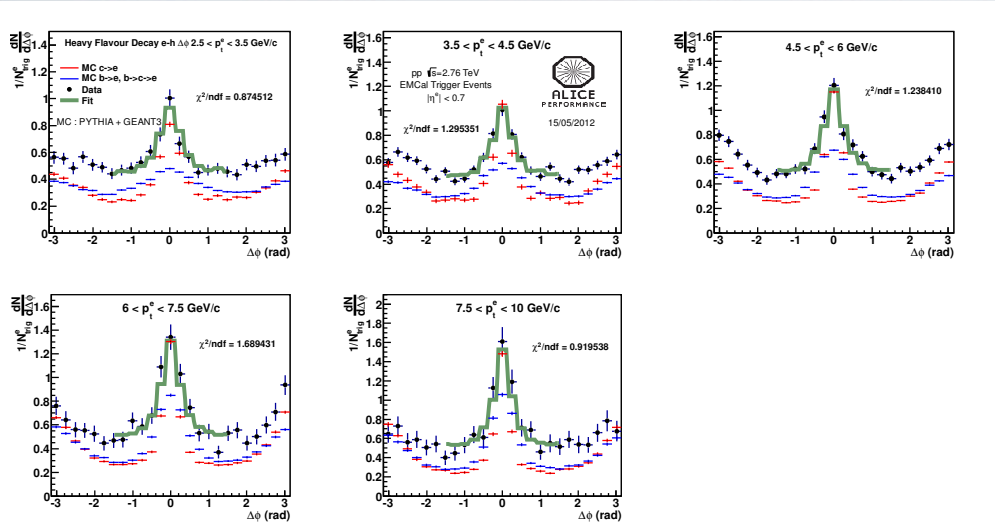
arXiv:1205:5423

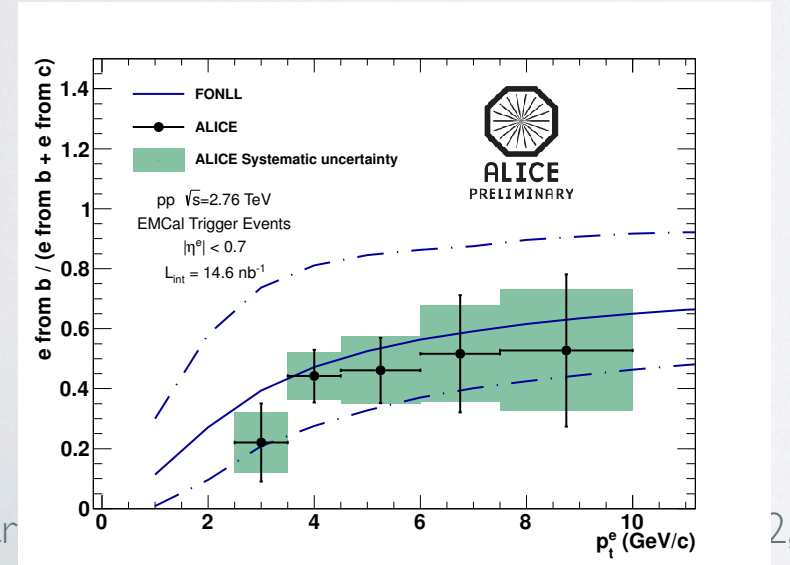
- Measured production cross section of D mesons, muons and electrons
- pQCD predictions (FONLL, GM-VFNS) describe the data well

BEAUTY WITH ELECTRONS

Electron-hadron correlations

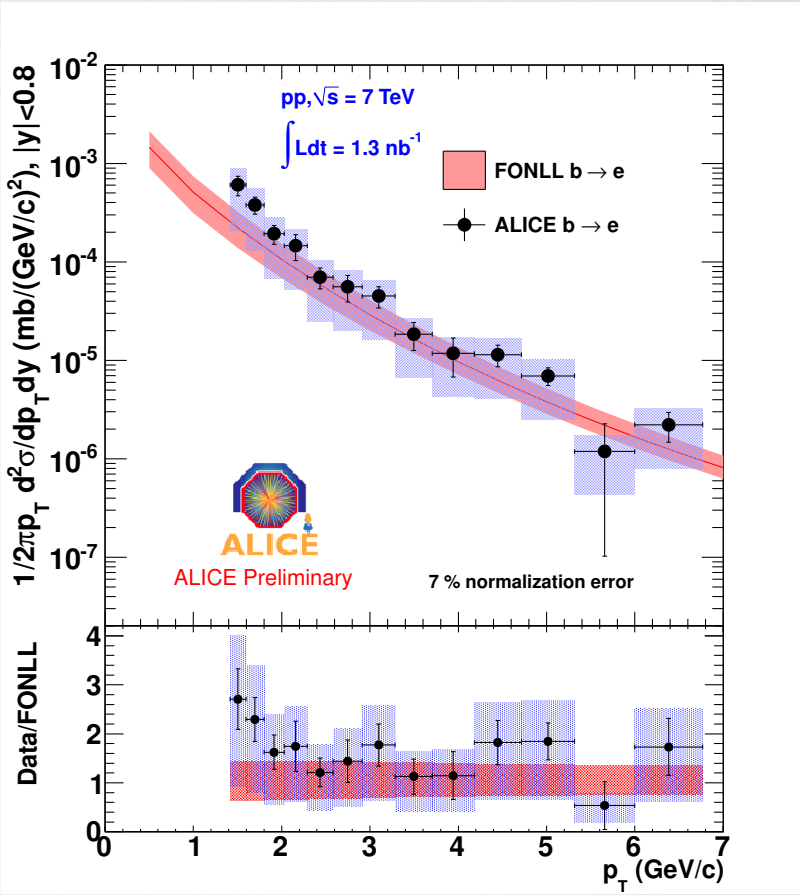
- extract relative B contribution to HF e yield
- pp at 2.76 TeV



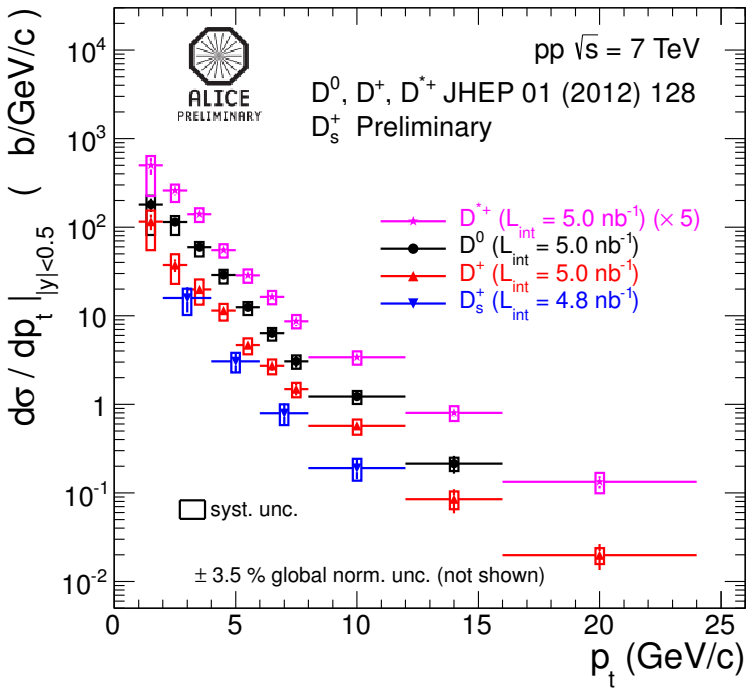


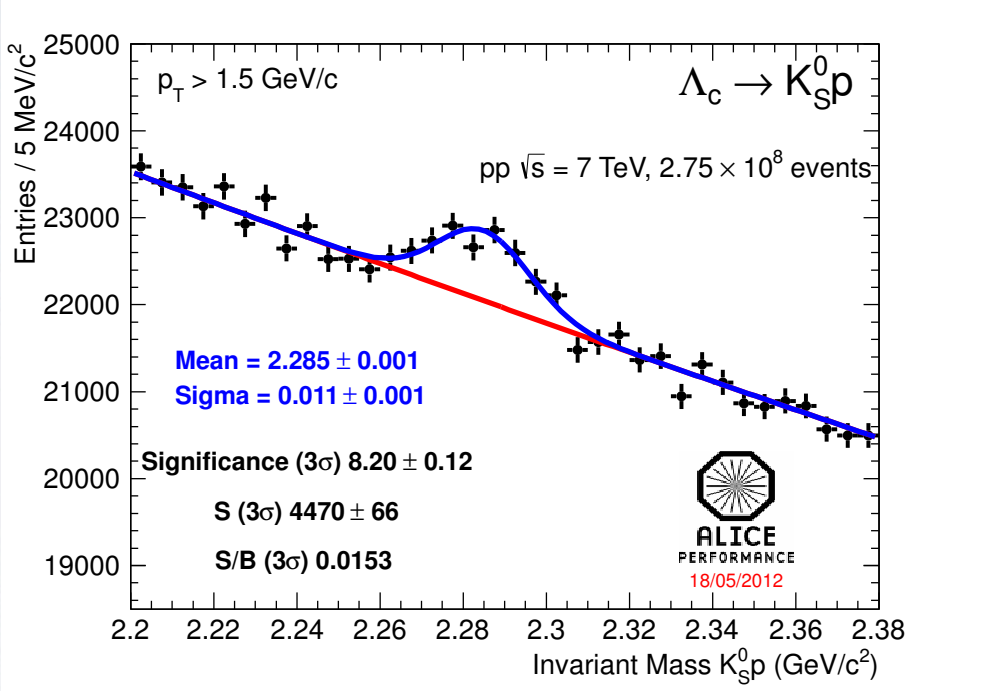
Impact parameter analysis

- exploit relatively long lifetime of B
- pp at 7 TeV



ADDITIONAL HF MEASUREMENTS





$D_s \rightarrow KK\pi$

$\Lambda_c \rightarrow K^0_s\, p$

* For the Λ_c analysis is statistics-limited and corrections are ongoing

PbPb OVERVIEW

- **Nuclear modification factor**

$$R_{AA} = \frac{1}{\langle N_{coll} \rangle} \frac{yield\ in\ AA}{yield\ in\ pp} = \frac{1}{\langle T_{AA} \rangle} \frac{dN_{AA}/dp_T}{d\sigma_{pp}/dp_T}$$

* N_{coll} depends on the centrality of the collision. Estimated using the Glauber model

- Single electrons at mid rapidity
- Single muons at forward rapidity
- D mesons at mid rapidity

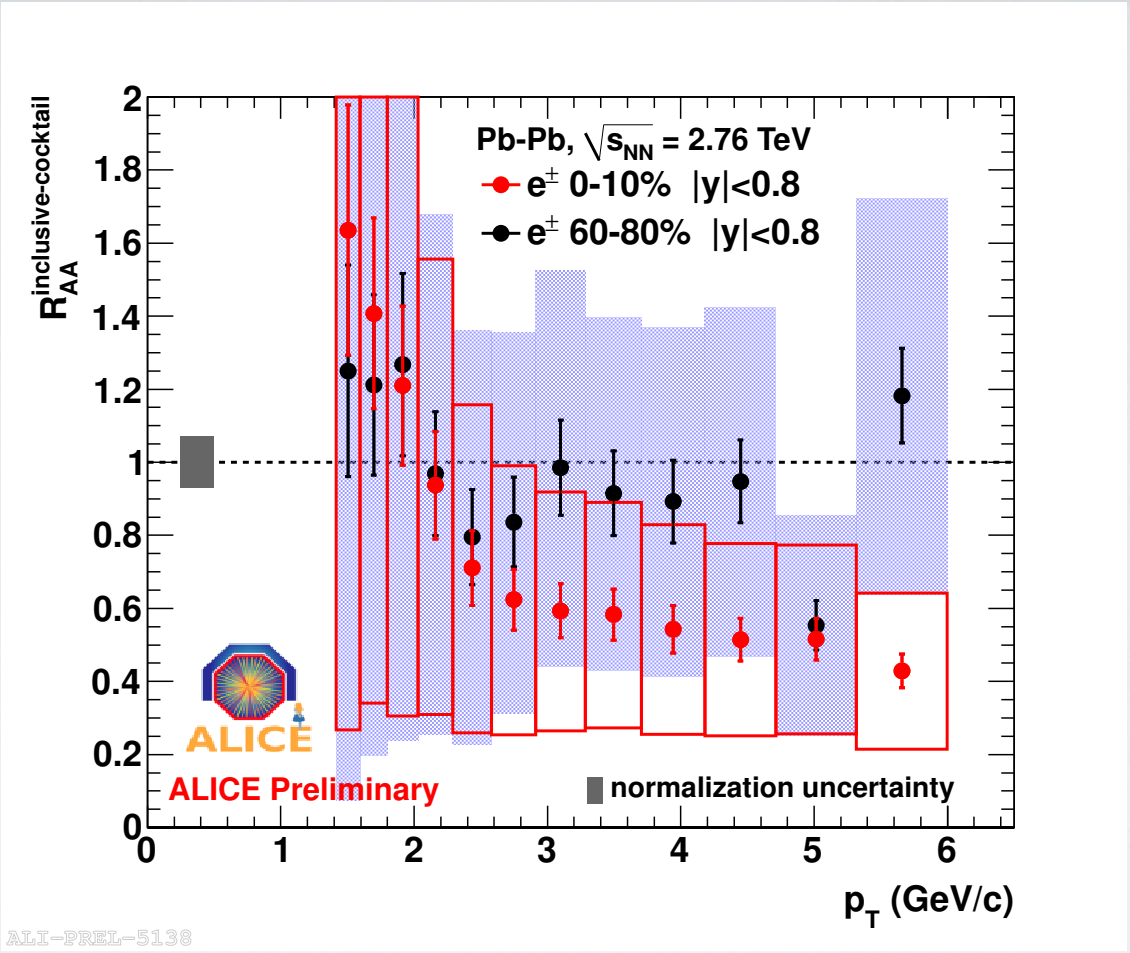
PbPb data sets:
$\sqrt{s}$ = 2.76 TeV (2010,2011)
minimum bias, central, EMCal, and muon triggers

- **Elliptic flow**- provides a measure of the strength of the collectivity
  - D Mesons

$$E\frac{d^3N}{dp^3} = \frac{1}{2\pi}\frac{d^2n}{p_T dp_T dy}(1 + 2\sum_{n=1}^{\infty} \nu_n \cos[n(\phi - \Psi_{RP})])$$

$$\nu_2 = < \cos(2[\phi - \Psi_{RP}]) >$$

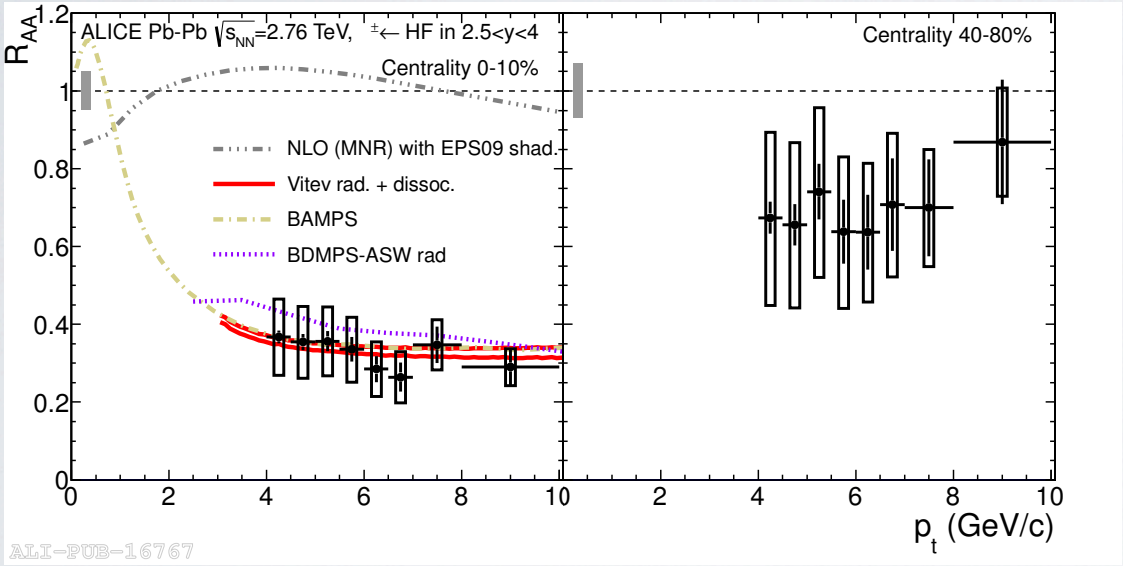
SINGLE ELECTRON R_{AA}

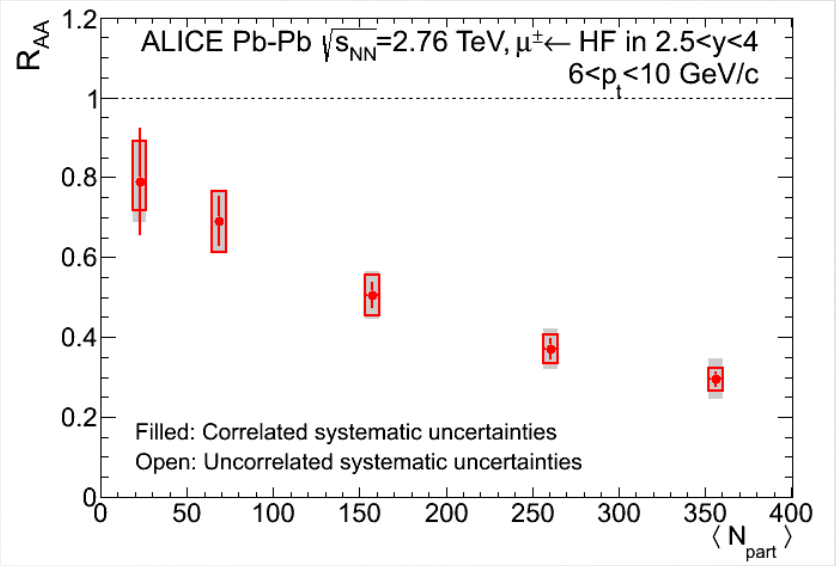


- Close to unity in peripheral collisions
- 0.5 for p_t > 3 GeV/c in central collisions
- Large uncertainties (systematics error ~35%, dominated by PID)

SINGLE MUON R_{AA}

- Single muons from HF decays and primary π, K (background)
- Background: in pp estimated using MC, in Pb-Pb extrapolated from measured π, K at mid rapidity
- p_t > 4 GeV/c to limit systematics from background subtraction

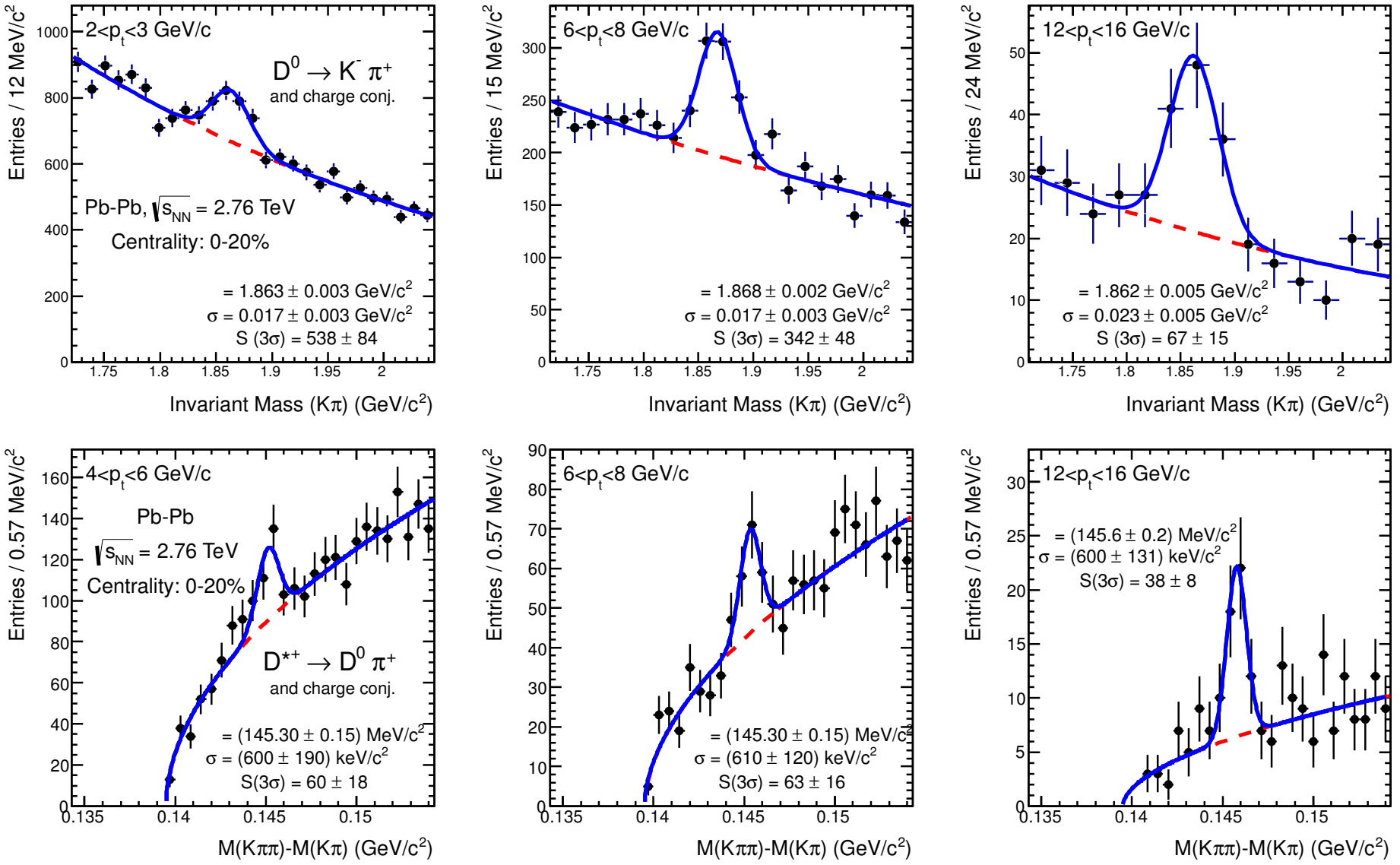




arXiv:1205.6443

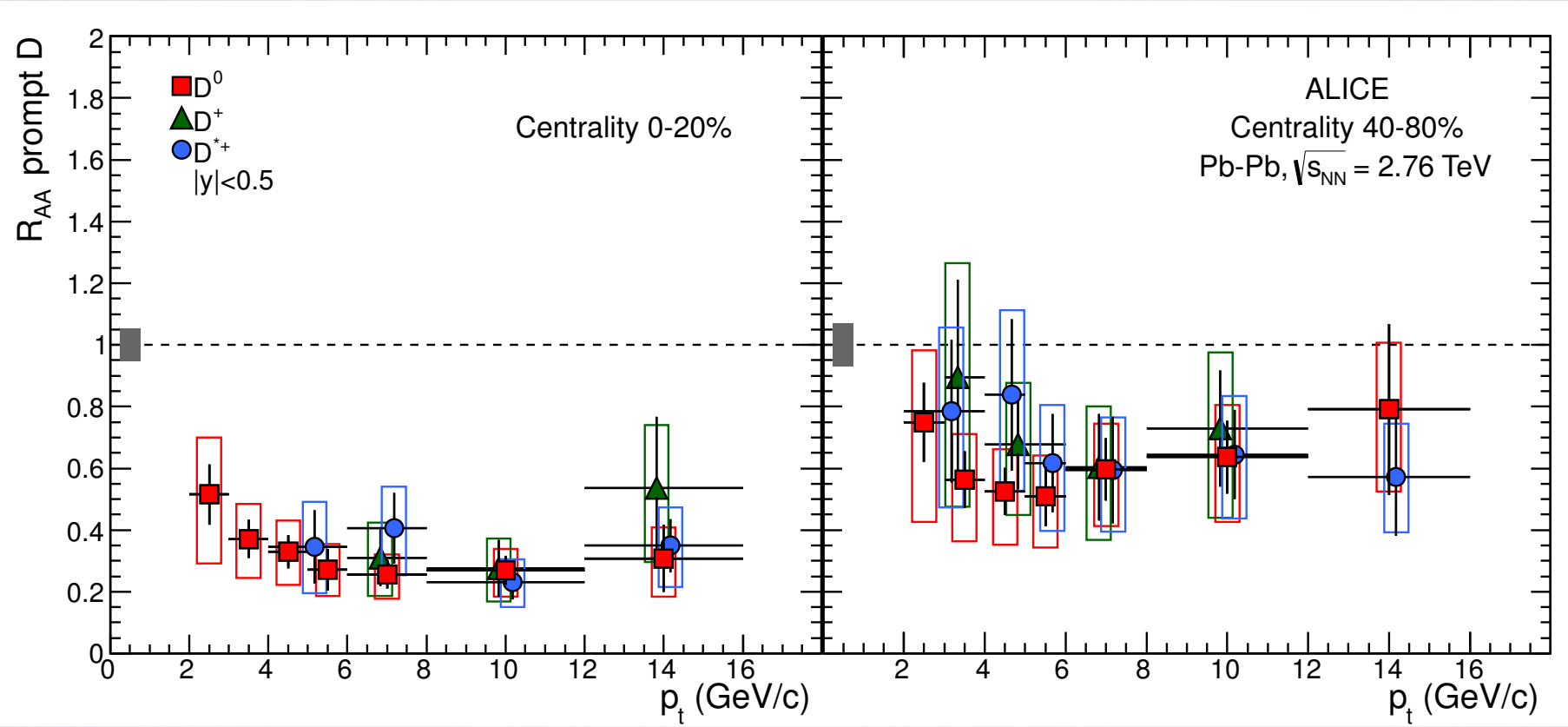
- In central collisions a strong suppression is observed
- No significant dependence on p_t in the measured p_t region

D MESONS IN PbPb



arXiv:1203.2160

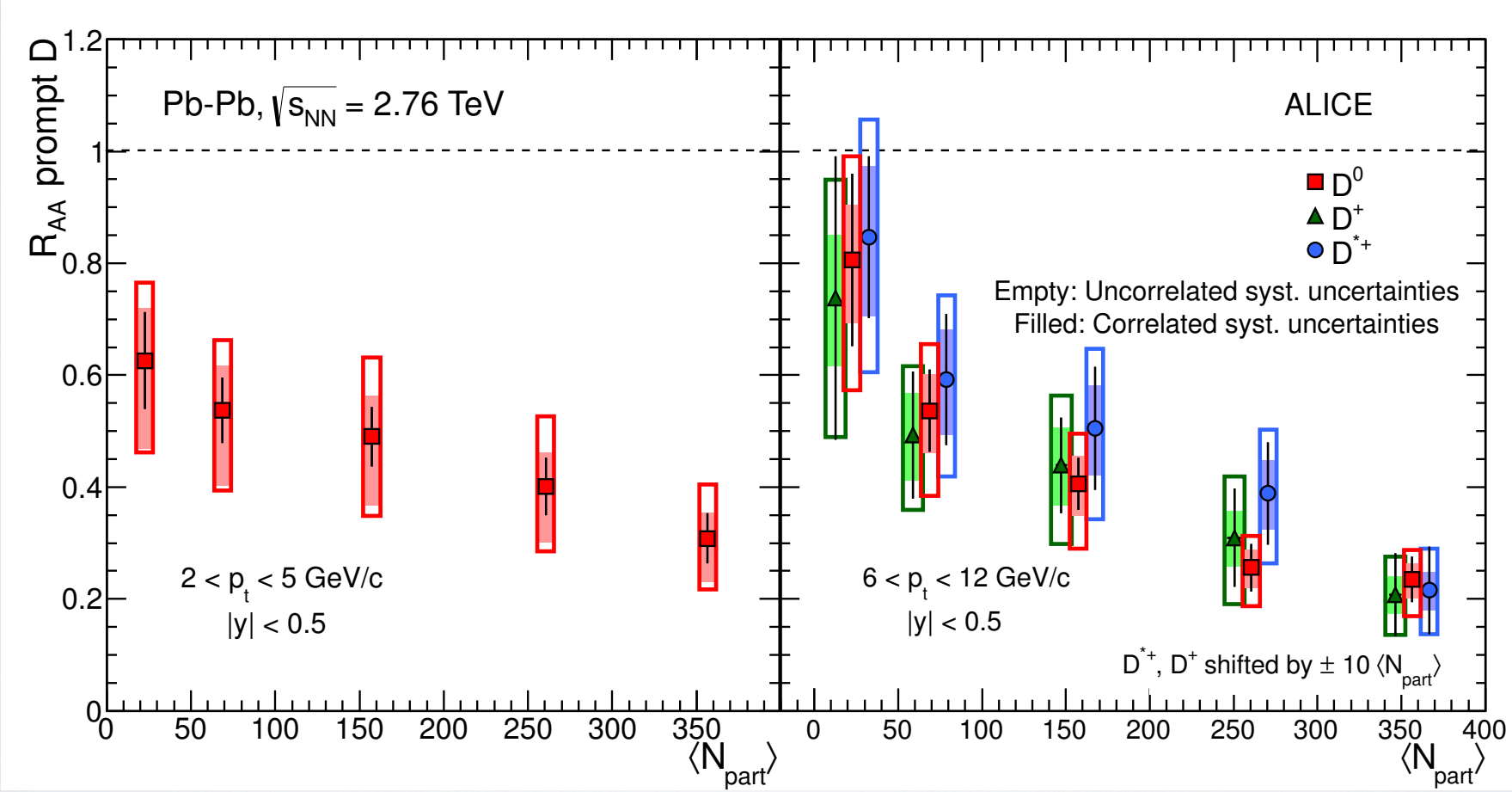
D MESON R_{AA}



arXiv:1203.2160

- Measured D^0, D^+, and D^* R_{AA} agree
- In central collisions, a strong suppression is observed

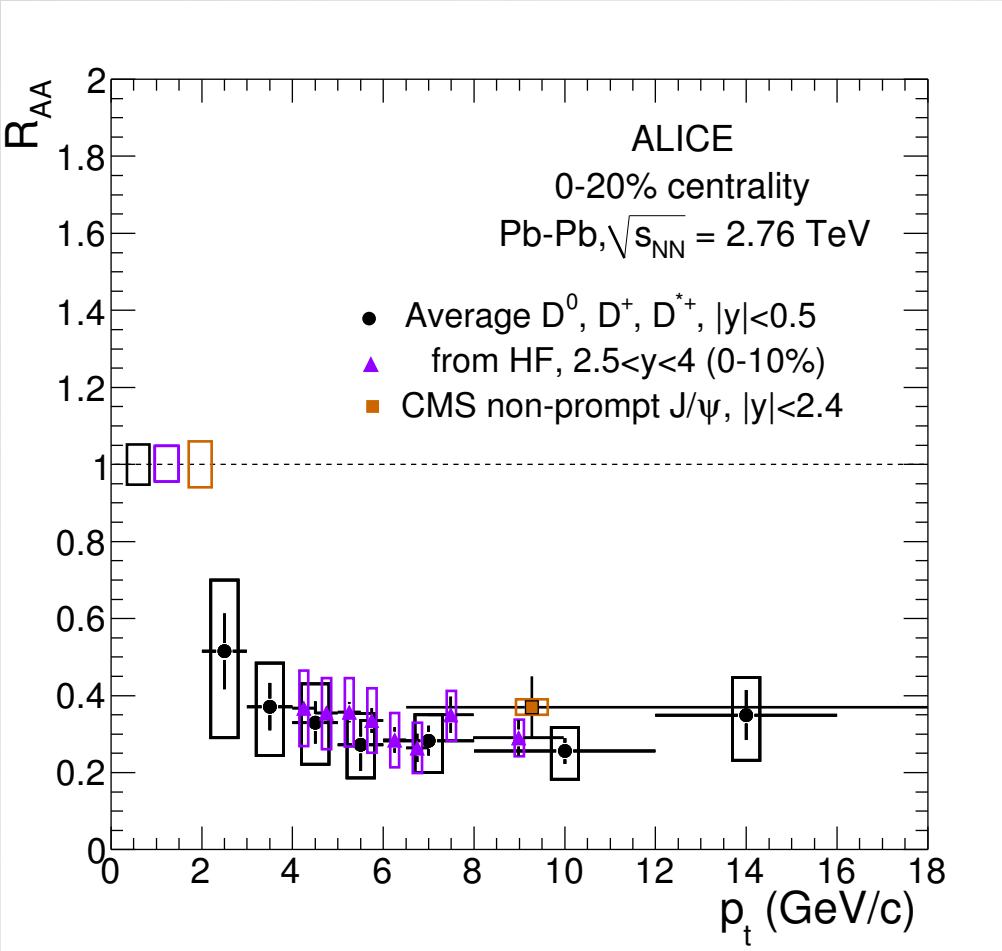
D MESON R_{AA}



arXiv:1203.2160

Suppression increases with increasing centrality

COMPARISON OF R_{AA}

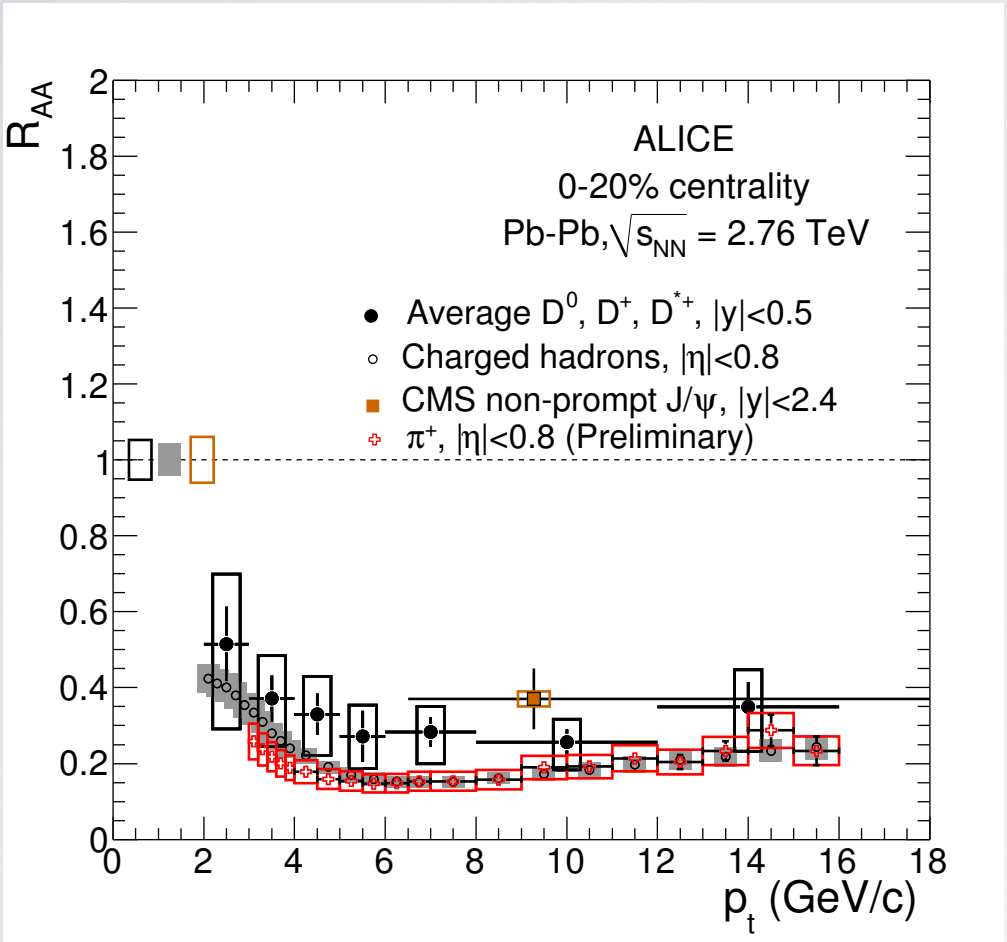


- D mesons
- HF(c+b) muons arXiv:1205.6443
- B→J/ψ (CMS) arXiv:1201.5069

- No observable difference of charm and beauty suppression
- Dead cone effect - radiative energy loss suppressed with increasing mass.
- Currently no mass effect observed

! Different rapidity range and decay kinematics

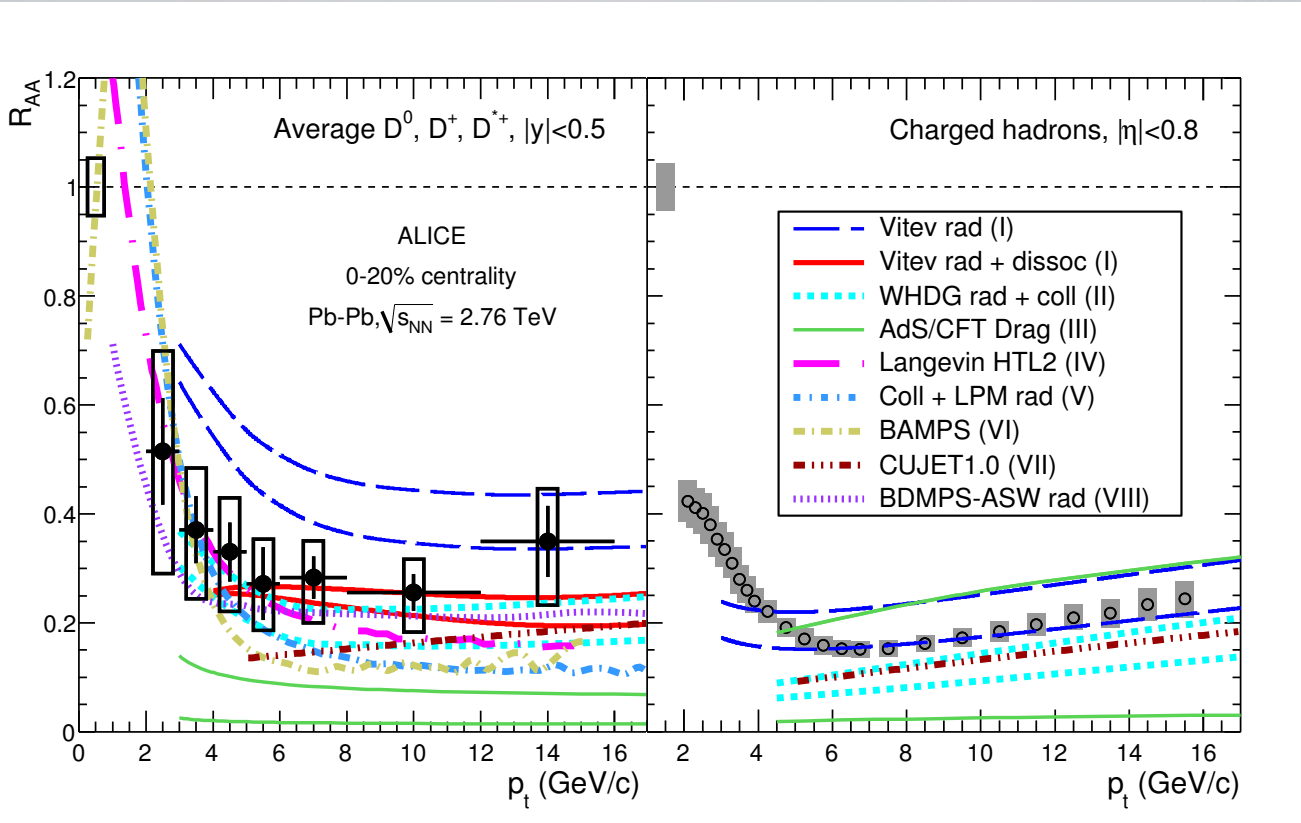
COMPARISON OF R_{AA}



- D mesons
- Charged hadrons arXiv:1012.1004
- pions
- B→J/ψ (CMS)

- No observable difference of charm and beauty suppression
- Dead cone effect - radiative energy loss suppressed with increasing mass.
- Currently no mass effect observed
- Suppression comparable
- Slight indication of hierarchy
- color charge effect?

MODEL COMPARISON



- Model predictions describe both charged hadrons and D mesons well

I. Radiative + D meson in-medium dissociation (tuned to LHC jet data)

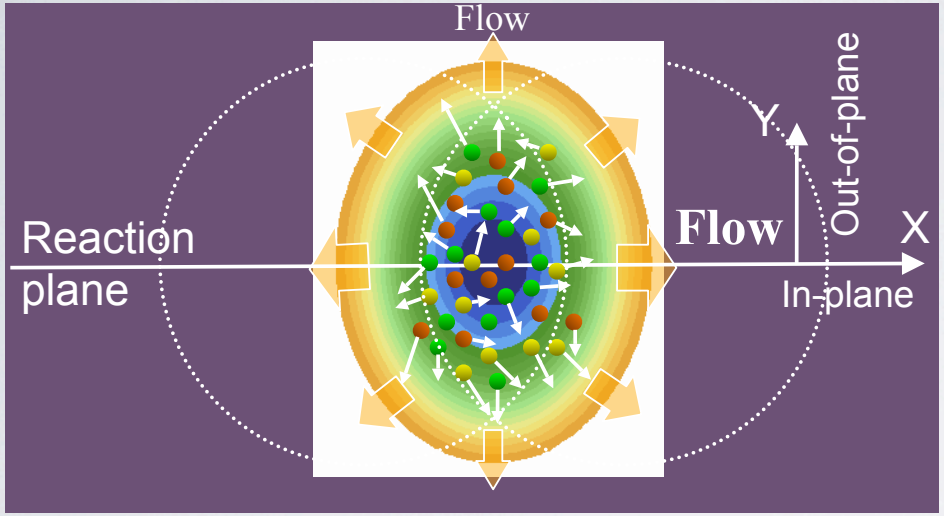
II. Radiative + collisional energy loss (tuned to RHIC data)

VII. Radiative + collisional energy loss (tuned to RHIC data)

* The model based on AdS/CFT drag coefficients significantly underestimates the charm R_{AA} and have limited predictive power for the charged hadron R_{AA}.

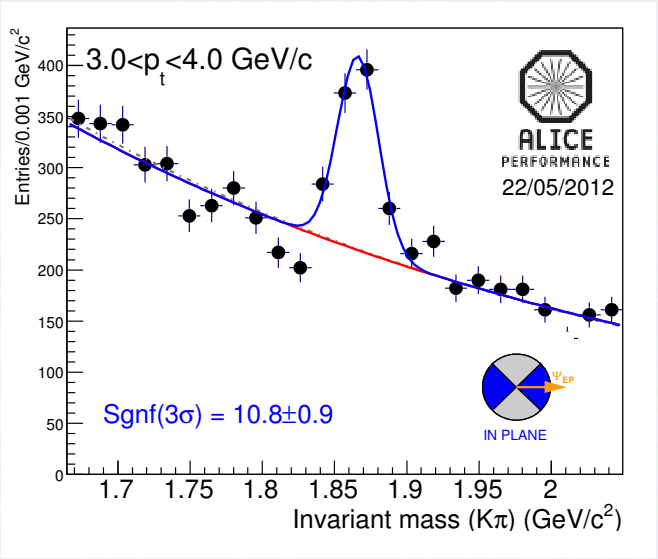
ELLIPTIC FLOW OF D MESONS

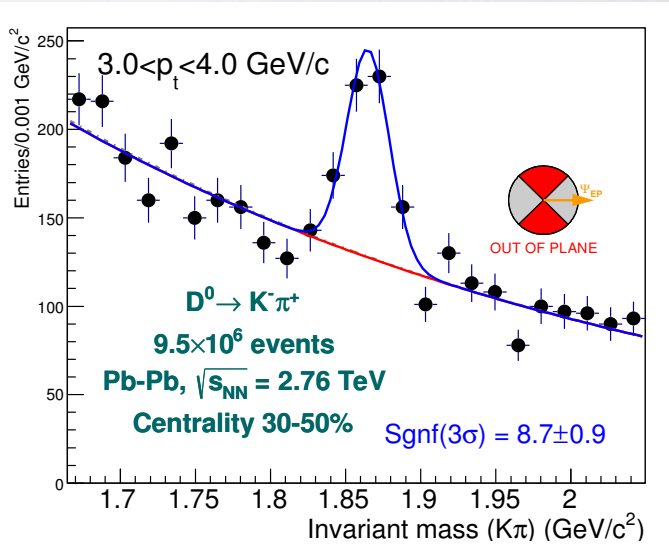
Momentum space azimuthal anisotropy - ELLIPTIC FLOW



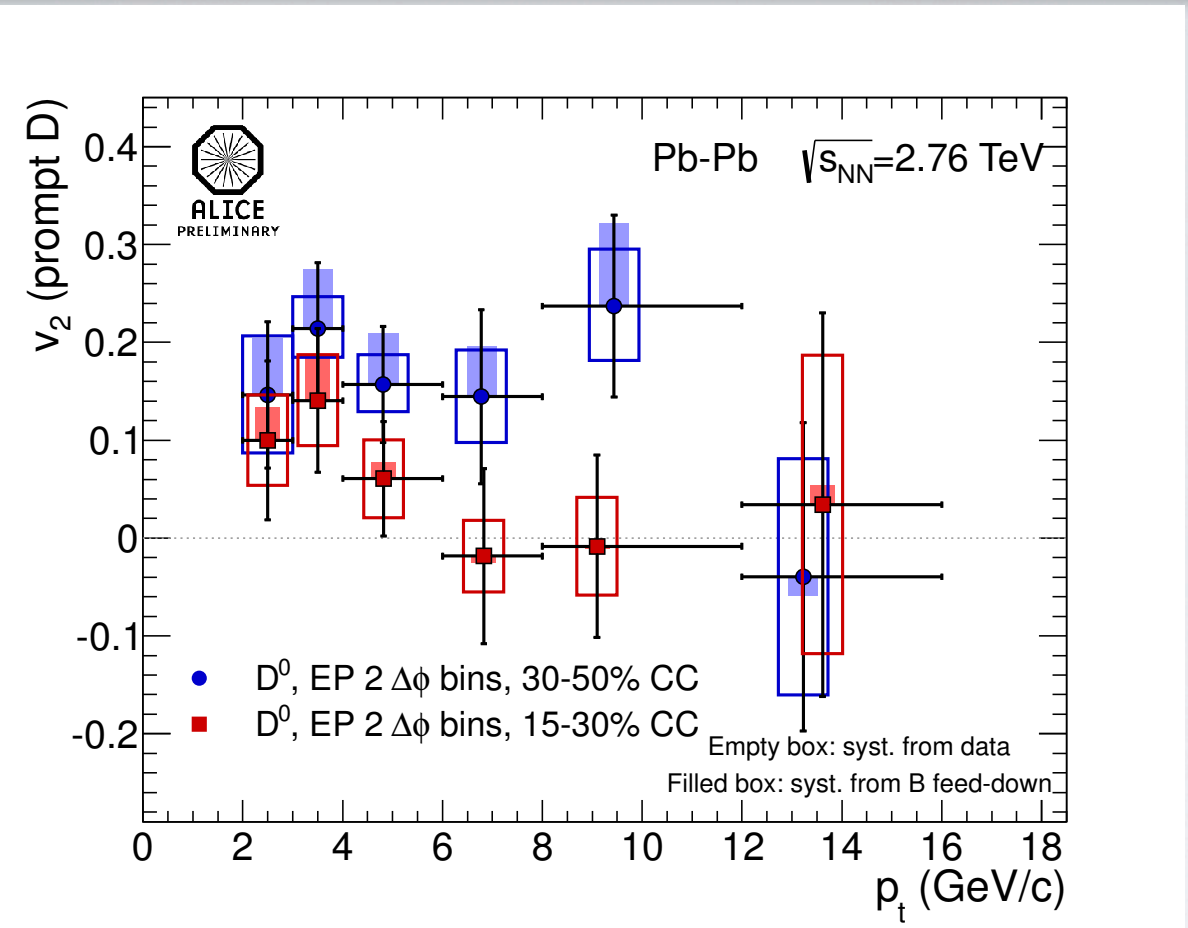
- Using measured D^0 and D^+
- Event plane using TPC tracks
- Signals measured in-plane and out-of-plane
- FONLL is used to correct for B feeddown

$$\nu_2 = \frac{\pi}{4}\frac{N_{in} - N_{out}}{N_{in} + N_{out}}$$



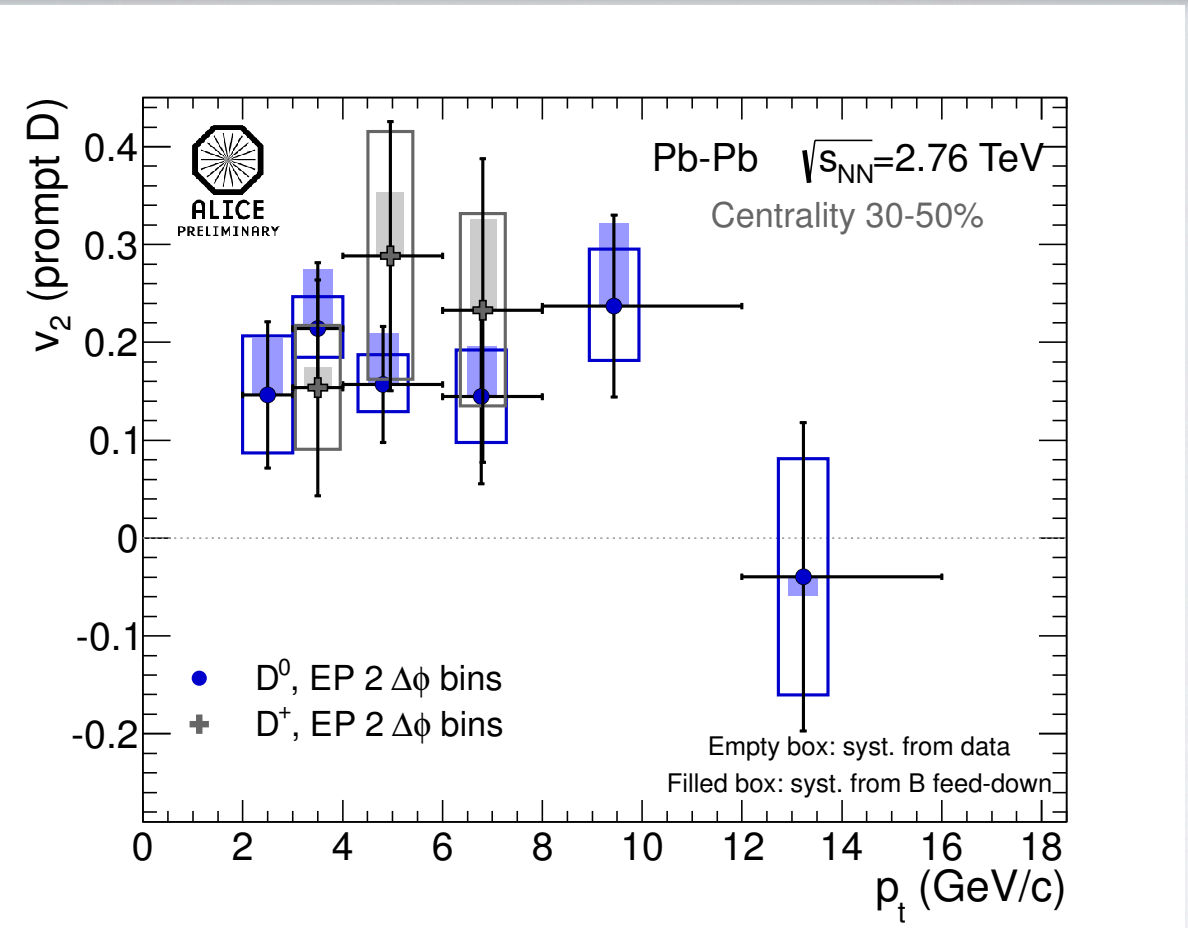


ELLIPTIC FLOW OF D MESONS



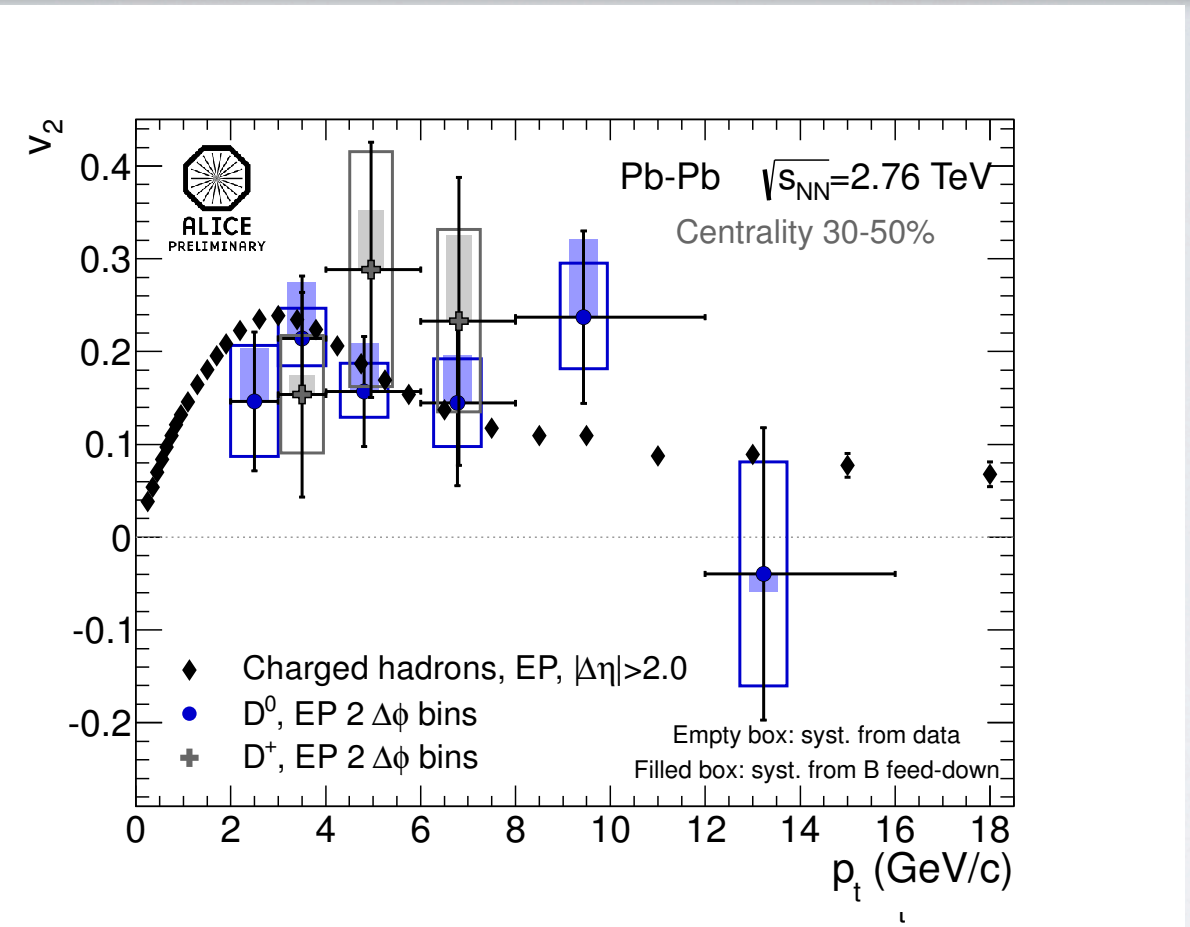
- Non-zero v_2 in semi-central collisions
- Decrease in v_2 with increased centrality

ELLIPTIC FLOW OF D MESONS



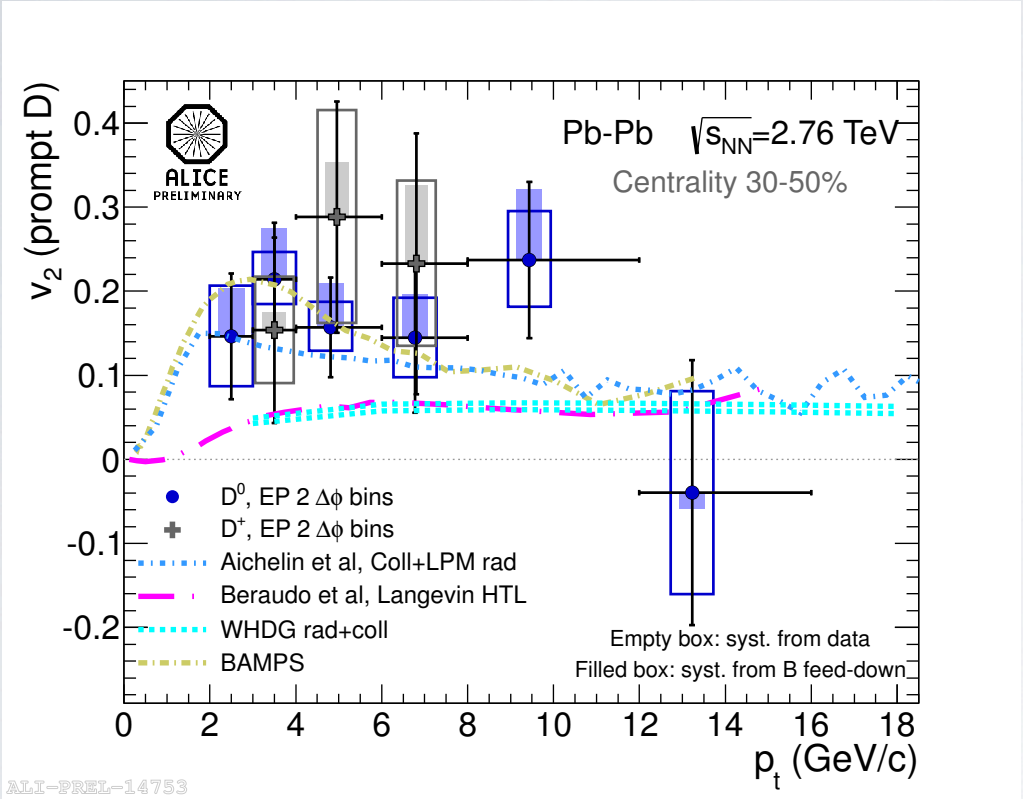
- Non-zero v_2 in peripheral collisions
- D+ comparable for centrality 30-50%

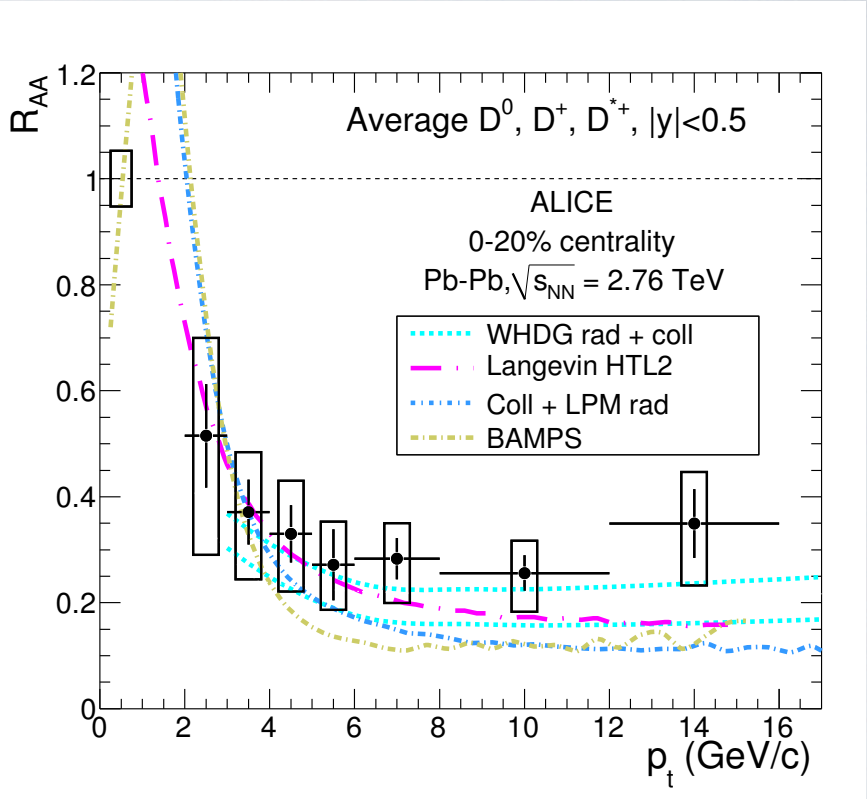
ELLIPTIC FLOW OF D MESONS



- Non-zero v_2 in peripheral collisions
- D+ comparable in 30-50%
- D mesons comparable to charged hadrons

COMPARISON TO MODELS





Partonic transport models (BAMPS and Aichelin et al) describe the D v_2, but underestimate R_{AA}. Difficult for models to describe both observables.

SUMMARY

Open heavy flavours at ALICE measured via hadronic and semileptonic decay channels

Nuclear modification factor:

- Measured for several channels, each showing strong suppression in central collisions
- Moves toward unity in peripheral collisions
- Hint that $R_{AA}(\pi) < R_{AA}(D)$

  *more data and pPb collisions needed for a more conclusive statement

Elliptic flow:

- Indication of non-zero v_2
- Comparable with charged hadron v_2

Outlook:

- Separate charm and beauty contribution in the semielectronic channel
- Increase p_t reach and decrease uncertainties
- Elliptic flow of electrons and muons from HF decays