Heavy-Flavour Correlation Measurements in pp and Pb-Pb Collisions with ALICE

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for the ALICE collaboration

5th International workshop on heavy quark production in heavy-ion collisions

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Outline

- Motivation for heavy-flavour correlation measurements
- The ALICE detector
- Azimuthal angular correlation measurements
  - HF electron-hadron in 2.76 TeV pp collisions
    - Relative beauty fraction
    - Beauty to electron cross section
    - Outlook in Pb-Pb collisions
  - D^{*+} mesons -hadron in 7 TeV pp collisions
    - First studies - Comparison of MC and data
  - Conclusions/Outlook

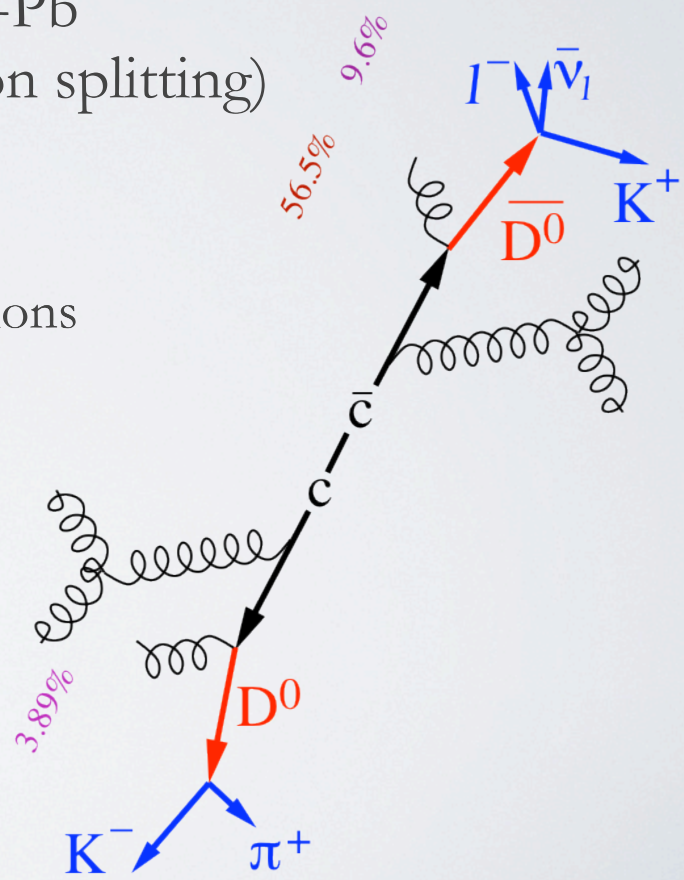
Why HF correlation studies?

pp collisions

Disentangle charm and beauty within HF single electrons
→ Measure beauty to HF decay electrons cross section
Important tests of pQCD predictions
All correlation measurements baseline for Pb-Pb
Production mechanism (pair production, gluon splitting)

Pb-Pb collisions

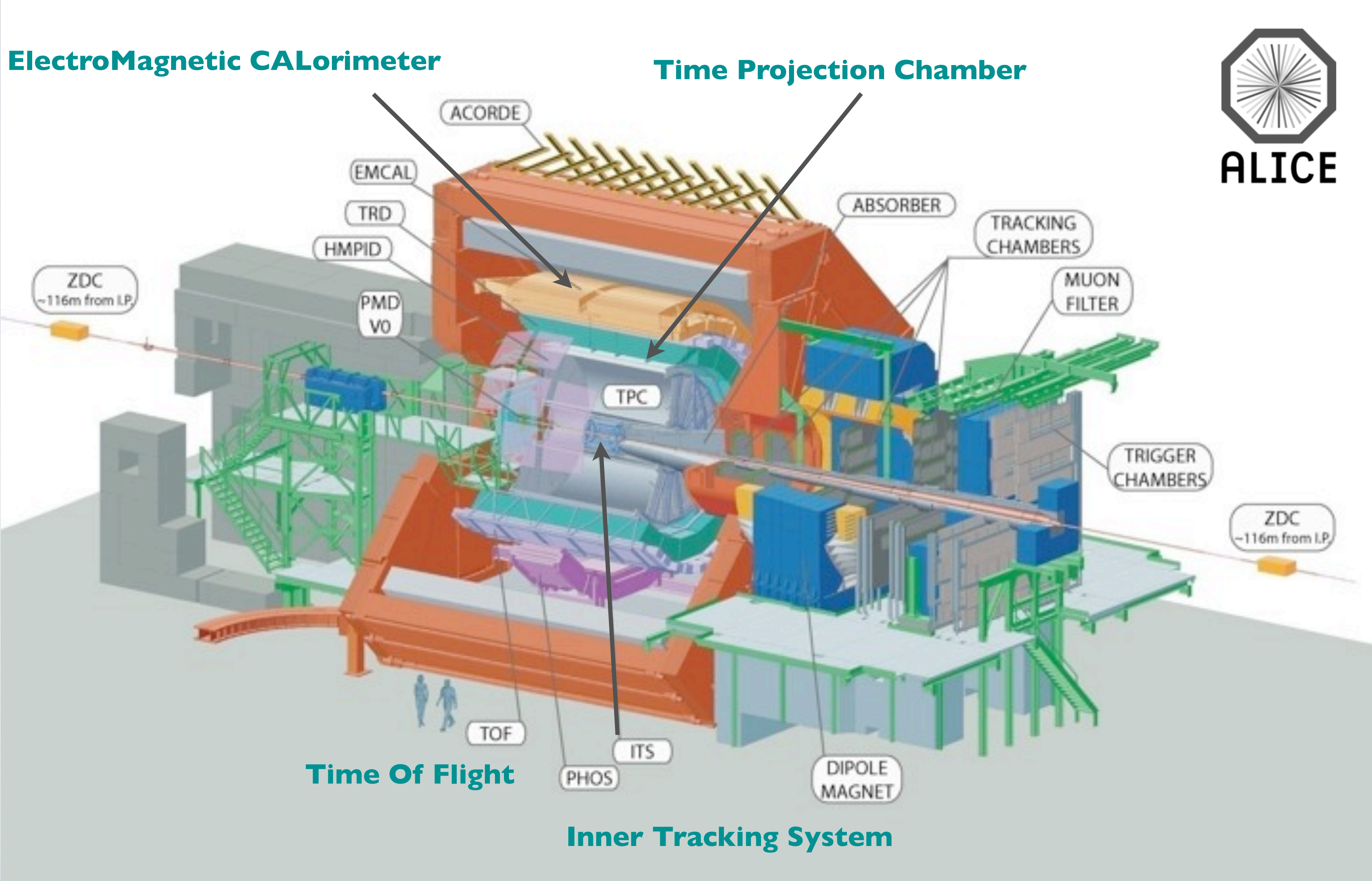
Measure I_{AA} -ratio of yields of Pb-Pb to pp collisions
- Away side- Energy loss via I_{AA}
- Near side- Fragmentation via I_{AA}



Correlation measurements in ALICE

- HF electron- hadron
- D meson- hadron
- HF electron- D meson

ALICE Detector



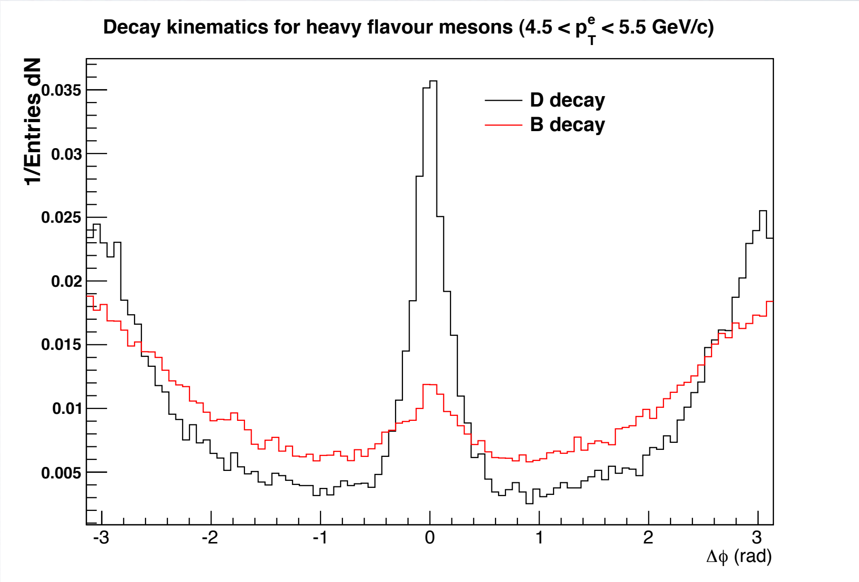
e-h correlations

e-h Correlation Motivation

ALICE measurement of D meson R_{AA} shows a maximum suppression factor of 5 at p_T of 7 GeV/c (talk by A. Grelli)

ALICE measurement of HF decay electron and muon R_{AA} reach a suppression factor 3-4 (talk by T. Rascanu and P. Pillot, respectively)

- pp $\Delta\phi$ correlation between HF electrons and hadrons used to determine the relative contribution of B decays to HF electrons
- Exploit different decay kinematics of D and B mesons, where the width of near-side correlation distribution is wider for B meson compared to D meson
- Relative beauty contribution extracted by fitting MC (PYTHIA) templates (with detector simulation) to data.



STAR measurement using the same technique
Phys. Rev. Lett. 105, 202301 (2010)
PHENIX using a correlation in M_{inv}
Phys. Rev. Lett. 103, 082002, (2009).

e-h Correlation Motivation

ALICE

Using relative beauty fraction and inclusive cross section of HF-decay electrons, the cross sections of beauty and charm decay electrons can be computed separately.

- Alternative analysis method to direct measurements using displaced vertices (talk by T. Aronsson and arXiv:1208.1902)

- In Pb-Pb collisions, azimuthal angular correlations between heavy flavour electron and charged hadrons can be used to study energy loss and possible fragmentation modification in the QCD medium

e-h Correlation Analysis Strategy

ALICE

- Electron identification
  - TPC dE/dx and EMCal E/p
- Non-HF electron identification
  - Conversions and π^0 and η Dalitz decays
  - Invariant mass method

Heavy flavor electrons (HFE)

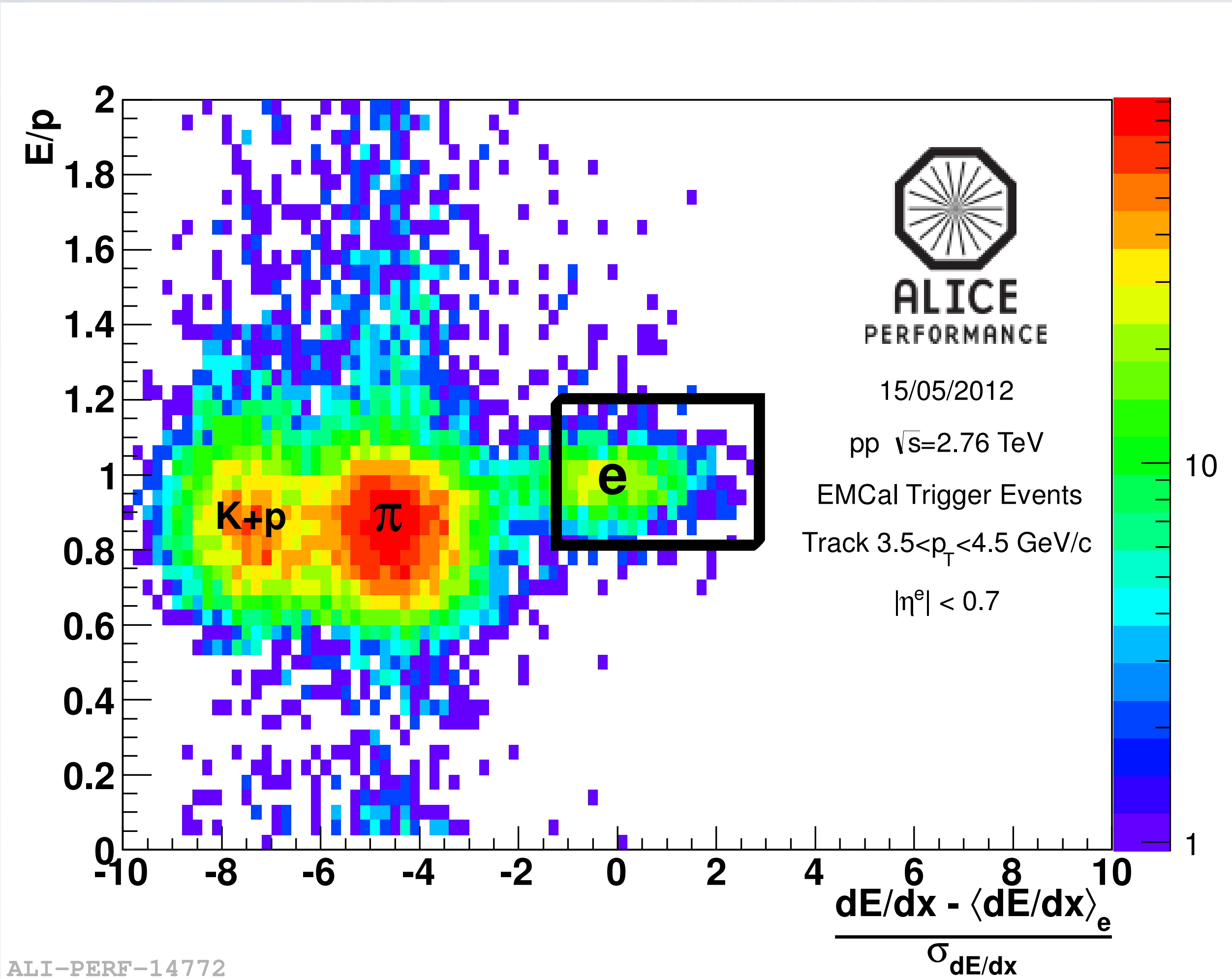
- Azimuthal angular correlation between HFE and hadrons
- Distinguish charm and beauty contribution
  - Monte Carlo templates
  - Fit to the data

Dataset:

- pp at $\sqrt{s}$ = 2.76 TeV
- EMCal triggered events
- Statistics : 620k events,

Integrated luminosity = 14.8 nb^{-1}

Electron identification



EMCal acceptance

- $|\eta| < 0.7$
- $80 < \phi < 180$

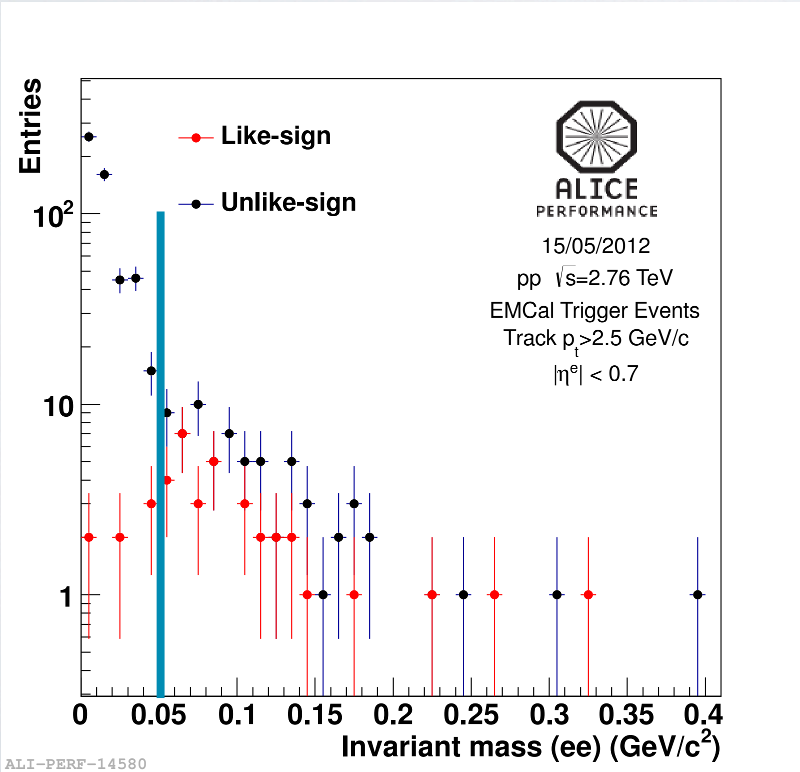
TPC : $-1 < N\sigma < 3$

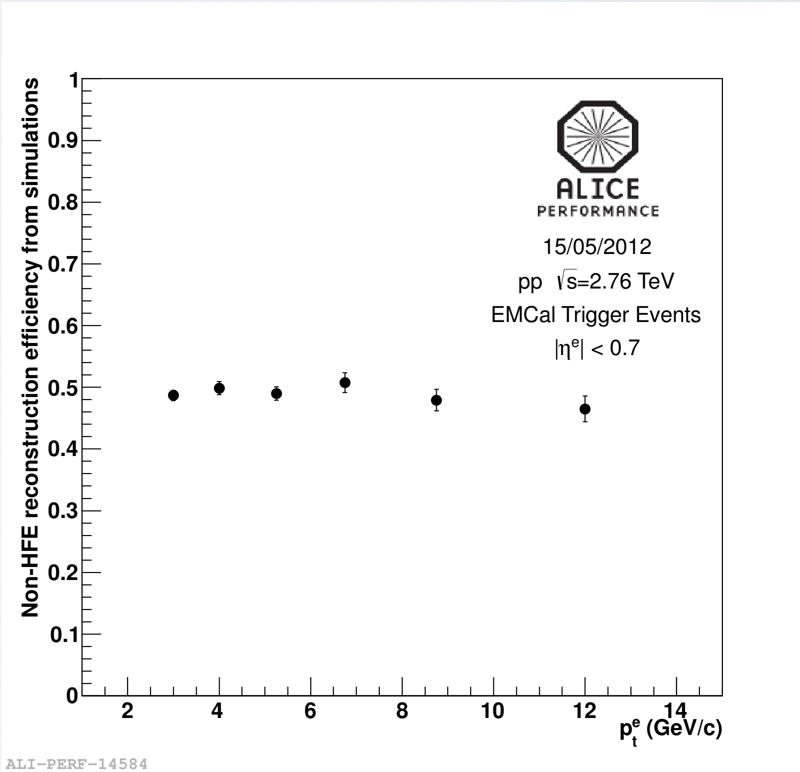
EMCal : $0.8 < E/p < 1.2$

Non-HF electron identification

- Non-heavy flavour electrons
  - Primary background sources: γ conversion, π^0 and η Dalitz decays
  - Identify background using e^+e^- invariant mass

- Tag non-HF with $M_{ee} < 50$ MeV/c^2
- Non-HF reconstruction efficiency ~ 50%





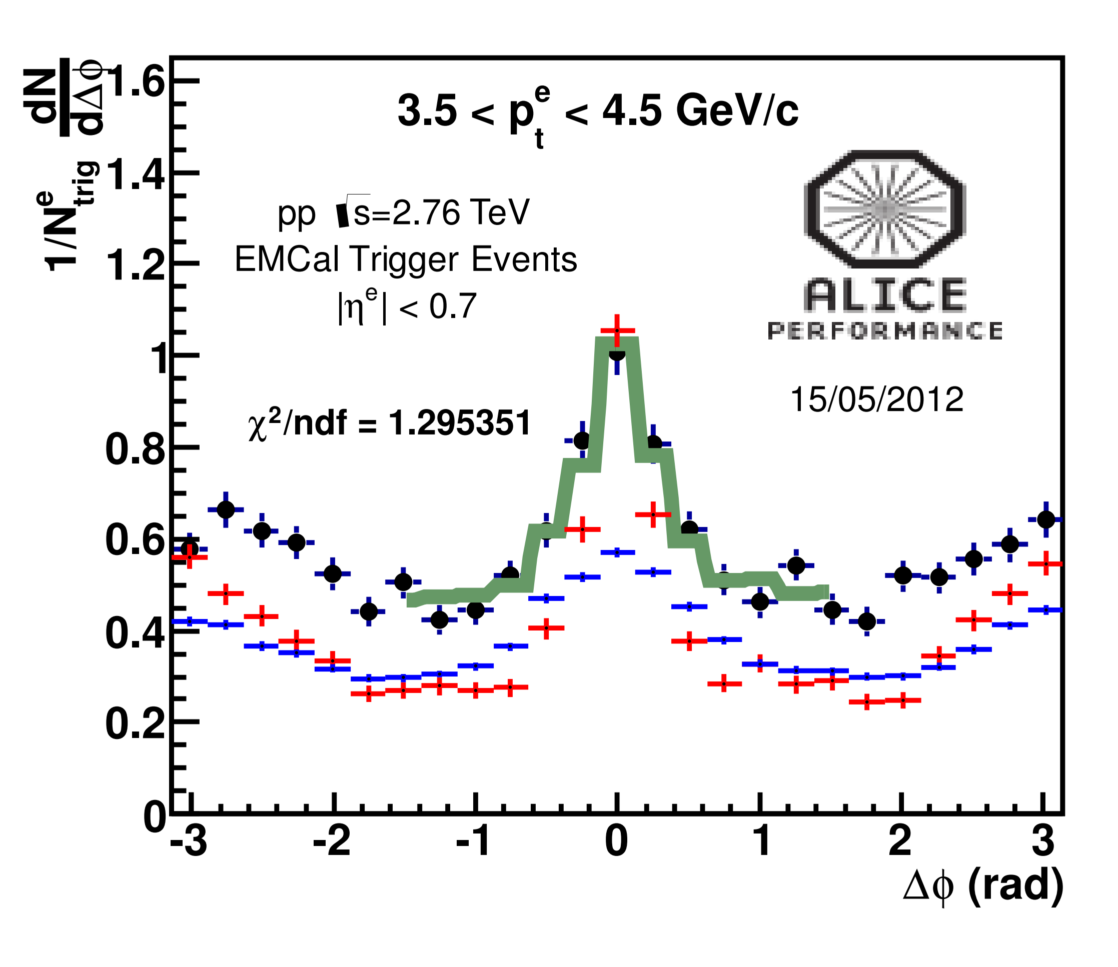
Azimuthal angular e-h correlations

$$N_e^{HF} = N_e^{inclusive} - N_e^{reco.\ nonHF} - \left(\frac{1}{\epsilon} - 1\right) N_e^{reco.\ nonHF}$$

$$where \left(\frac{1}{\epsilon} - 1\right) N_e^{reco.\ nonHF} \longrightarrow$$ **Not reconstructed non-HF**

$$\Delta\phi = \Delta\phi^{inclusive} - \Delta\phi^{reco.\ nonHF} - \left(\frac{1}{\epsilon} - 1\right) \Delta\phi^{reco.\ nonHF}$$

Azimuthal angular e-h correlations

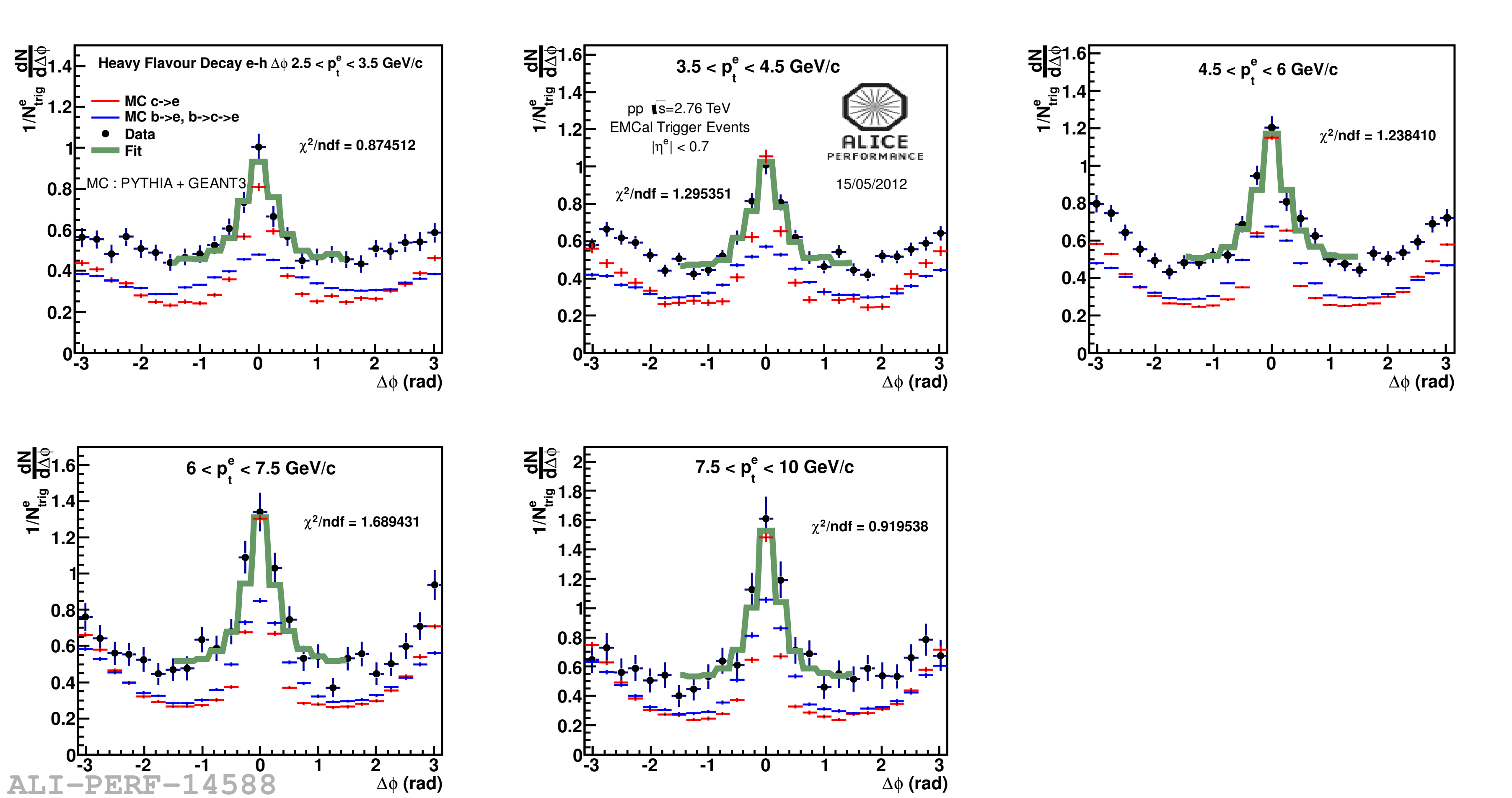


Charged hadron selection

- $p_T > 0.3$ GeV/c
- $|\eta| < 0.9$
- $0 < \varphi < 360$

- Fit data with MC template for beauty and charm (PYTHIA + GEANT3)
- Fit function : $\Delta\varphi_{data} = \text{const.} + r_b \, \Delta\varphi_B + (1 - r_b) \, \Delta\varphi_D$
  where $r_b = Ne_B / (Ne_D + Ne_B)$
  const. = uncorrelated background.

Azimuthal angular e-h correlations



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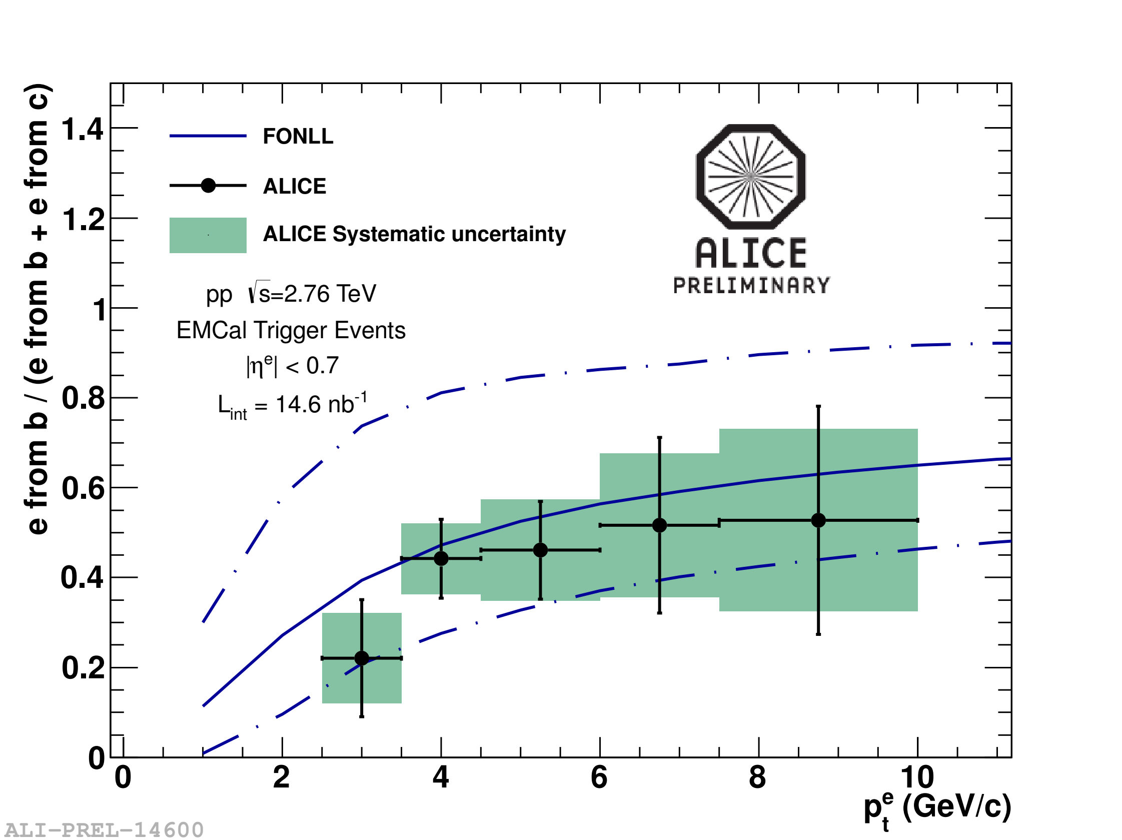
Fraction of beauty decay electrons



Main source of systematics:

- eID using TPC and EMCal
- Fit range: (-1,1) to (-2.5,2.5) rad.
- Non-HFE identification
  - inv. mass and dE/dx cut

At 5 GeV/c the beauty contribution is comparable to charm.

Consistent with FONLL pQCD calculations

M. Cacciari et al., JHEP 0103, 006 (2001) and private communication (2012)

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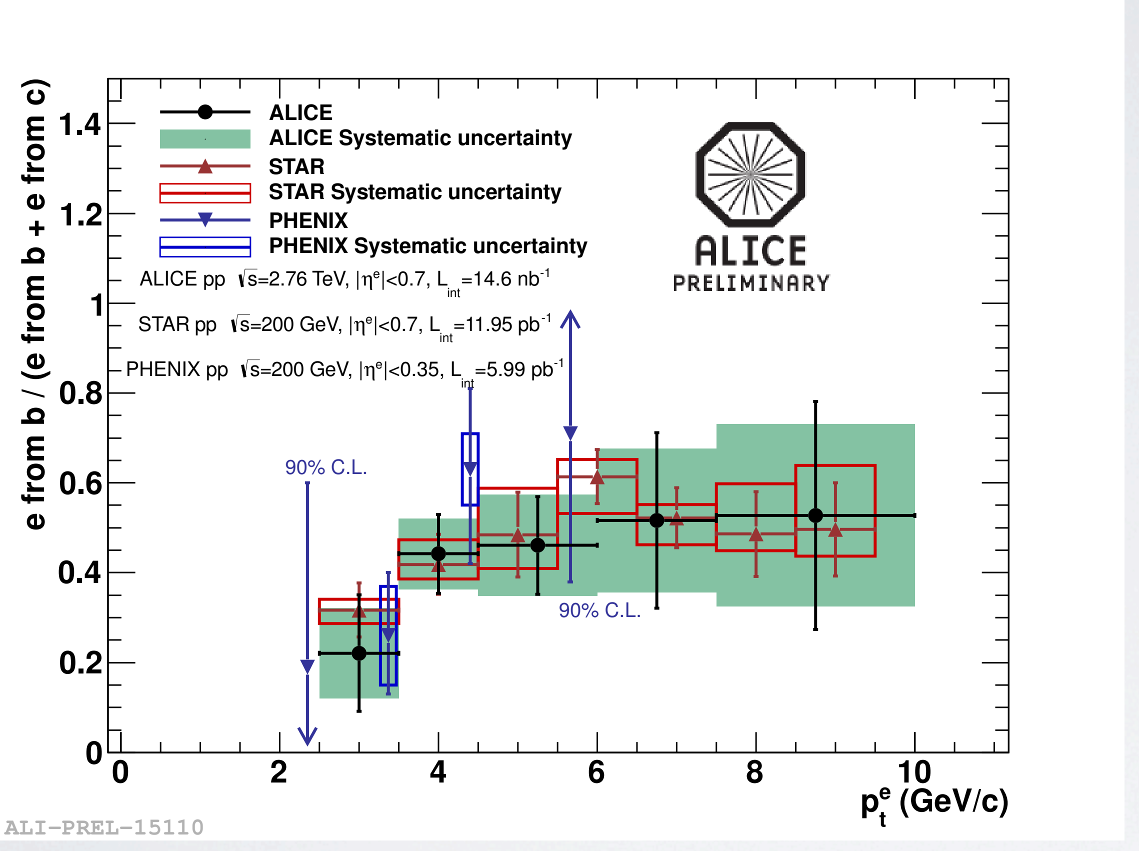

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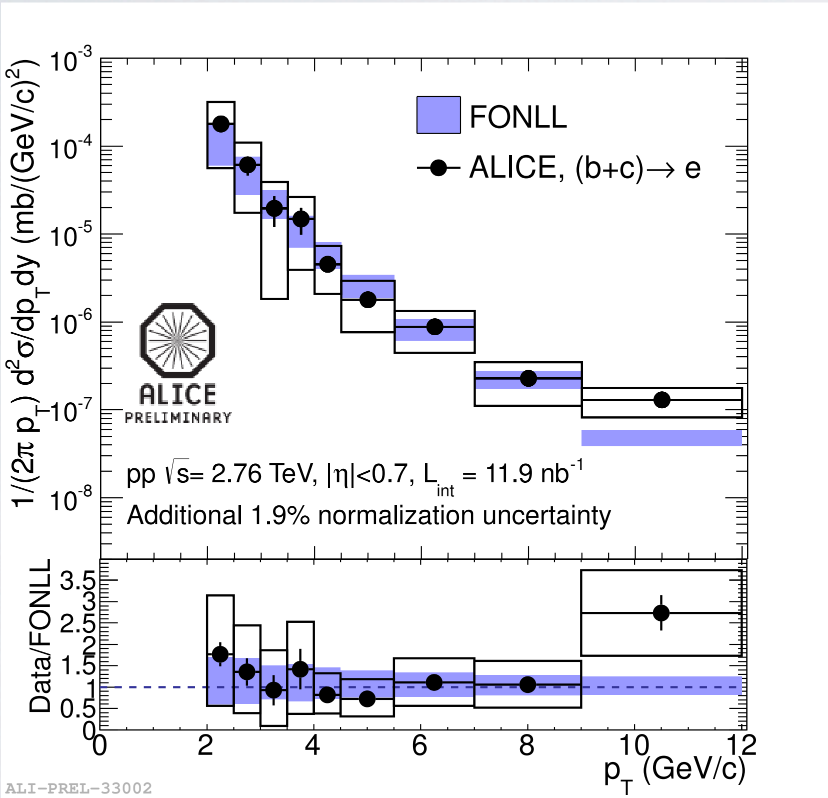
Consistent with RHIC measurements

Phys. Rev. Lett. 105, 202301 (2010)

Phys. Rev. Lett. 103, 082002, (2009).

Beauty and charm decay cross sections

- HFE decay electron cross section
- Relative beauty fraction to the HFE yield (r_b)
- Beauty and charm to electron cross section can be calculated.



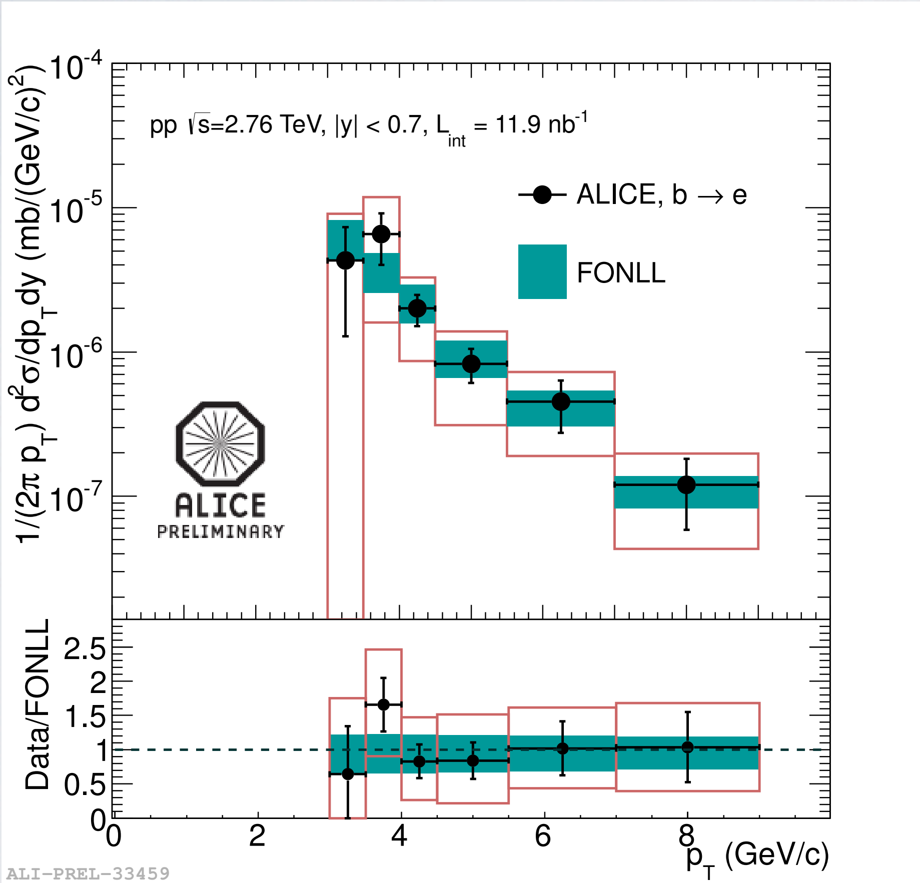
<u>Dataset :</u>
pp at √s=2.76 TeV
EMCal triggered events

Electron ID using TPC and EMCAL

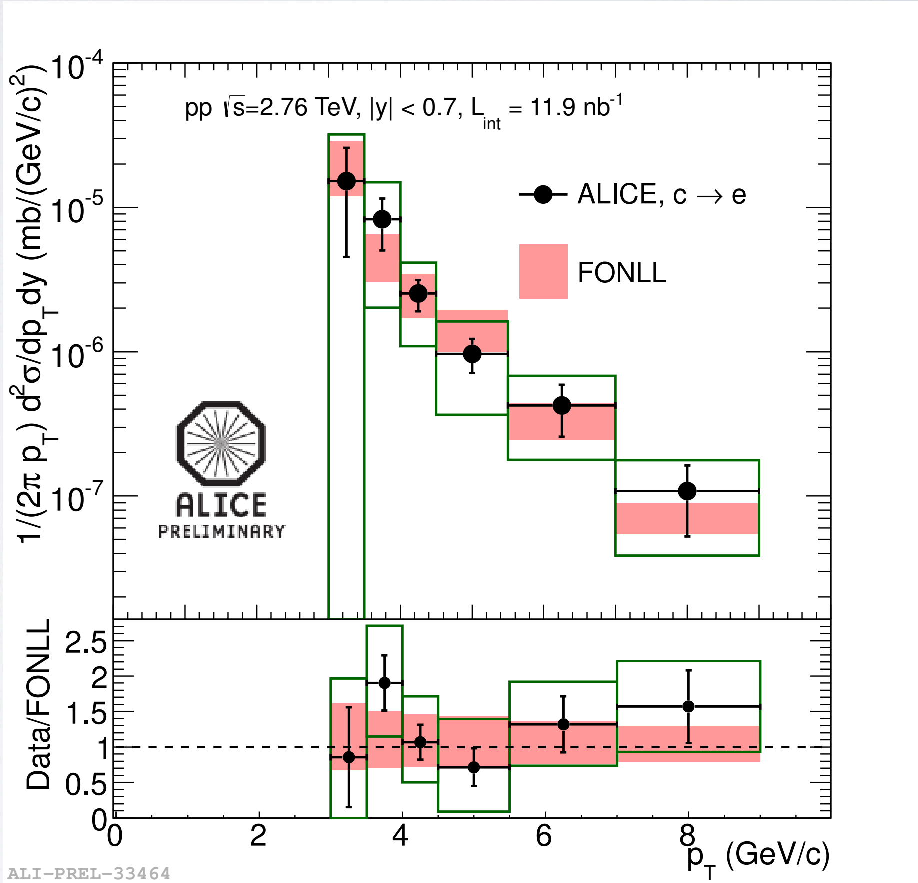
$$\left(\frac{d\sigma}{dp_T}\right)_{b\to e} = r_b \left(\frac{d\sigma}{dp_T}\right)_{b+c\to e} \qquad \left(\frac{d\sigma}{dp_T}\right)_{c\to e} = \left(\frac{d\sigma}{dp_T}\right)_{b+c\to e} - \left(\frac{d\sigma}{dp_T}\right)_{b\to e}$$

Beauty and charm decay cross sections

$b \rightarrow e$



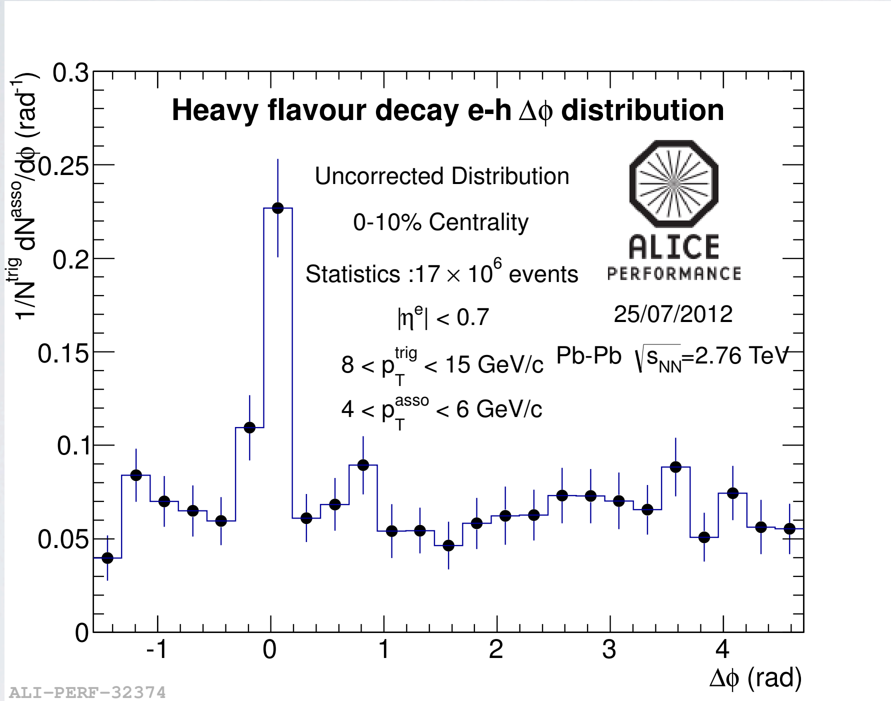
$c \rightarrow e$

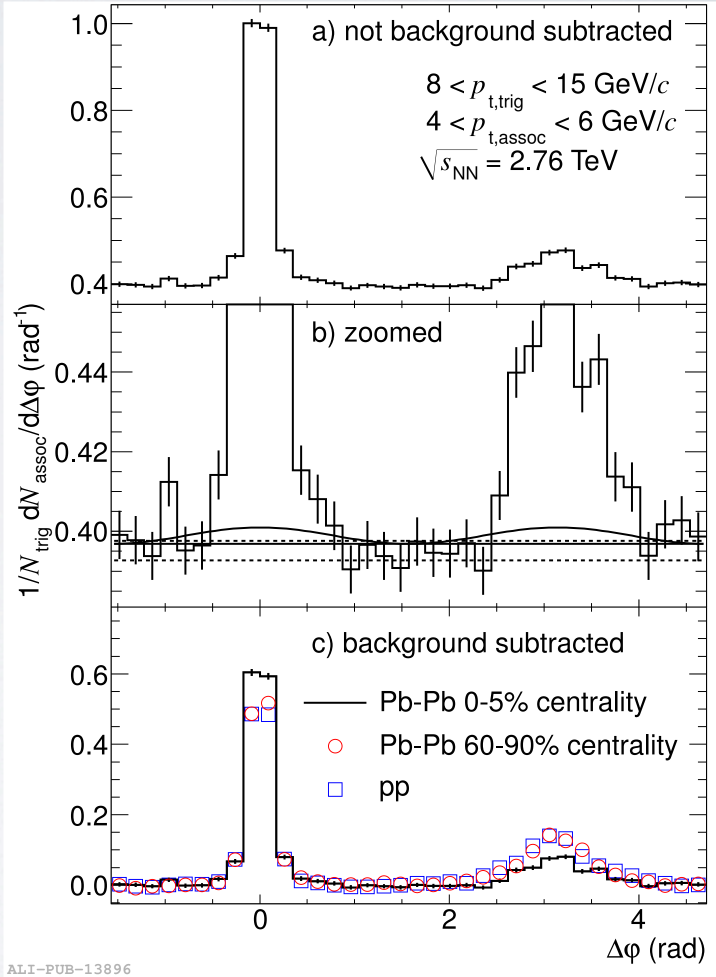


- r_b not measured in full p_T range
- Consistent with FONLL pQCD calculations

Outlook e-h correlations in Pb-Pb

- Uncorrected heavy flavour decay e-h Δϕ distribution is shown
- Comparison to di-hadron measurement from ALICE





ALICE Collaboration, PRL 108,092301(2012)

Next steps:

1. Remove uncorrelated background and flow contribution to obtain fully corrected HFE-h Δϕ distribution
2. Comparison with di-hadron Δϕ distribution I_{AA} measurement

D^*-h correlations

D*-h Correlation Analysis

Similar motivation

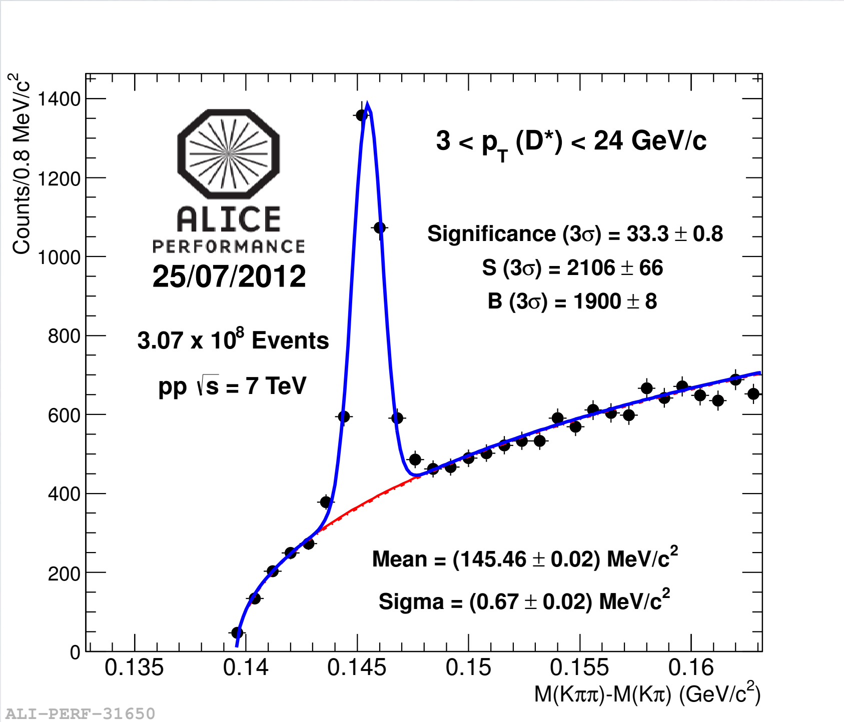
energy loss and fragmentation mechanisms of heavy quarks

pp provides the baseline for Pb-Pb collisions

Strategy

- D^{*+} reconstruction
  - Invariant mass method
- Azimuthal angular correlation between D^{*+} and hadrons
- Identify background of $\Delta\phi$ distribution using invariant mass side-bands
- Correct for detector effects with event mixing

D*+ reconstruction



Decay channel: $D^{*} \rightarrow D^{0}(K\pi)\pi$

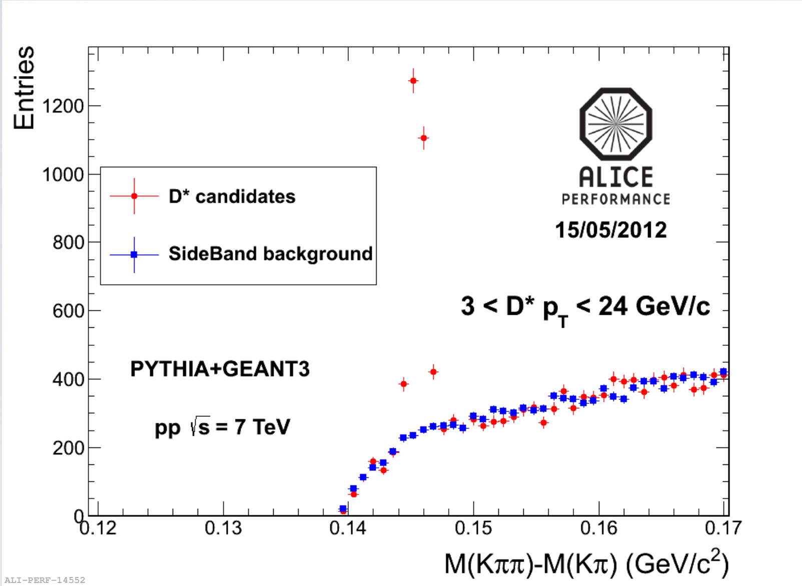
Reconstruction: D^{0} decay vertex identification (topological info)

Combinatorial background: topological cut criteria and PID (3σ TOF & 2σ TPC)

Candidates: 3σ around the peak in the mass difference M(Kππ) - M(Kπ)

D^{*} mesons are ideal for D-hadron correlation studies because of the relatively high signal-to-background ratio

Background Estimation & Detector Effects

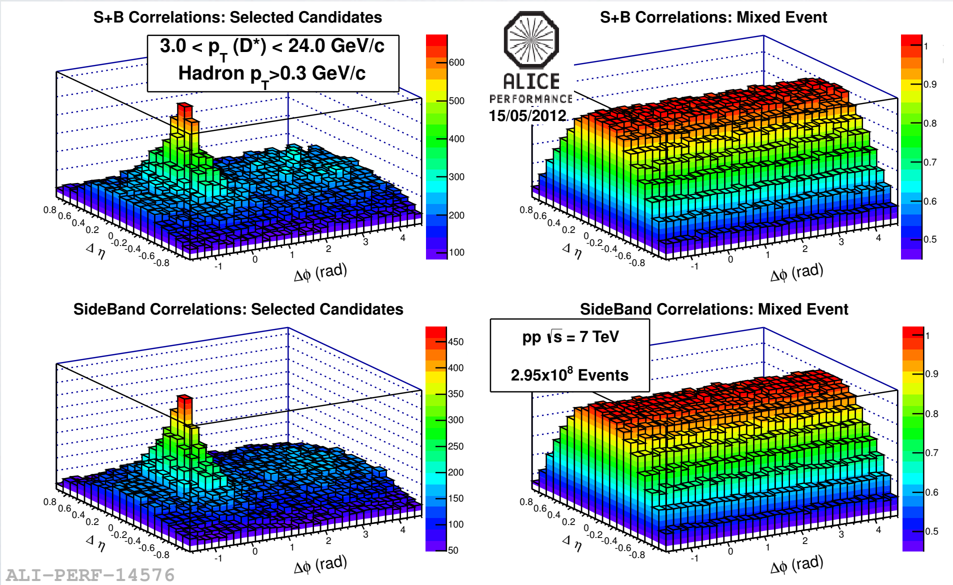


Background

Estimated from D^0 Minv side bands

$4\sigma < |M(K\pi)\text{-}M(D^0)| < 10\sigma$

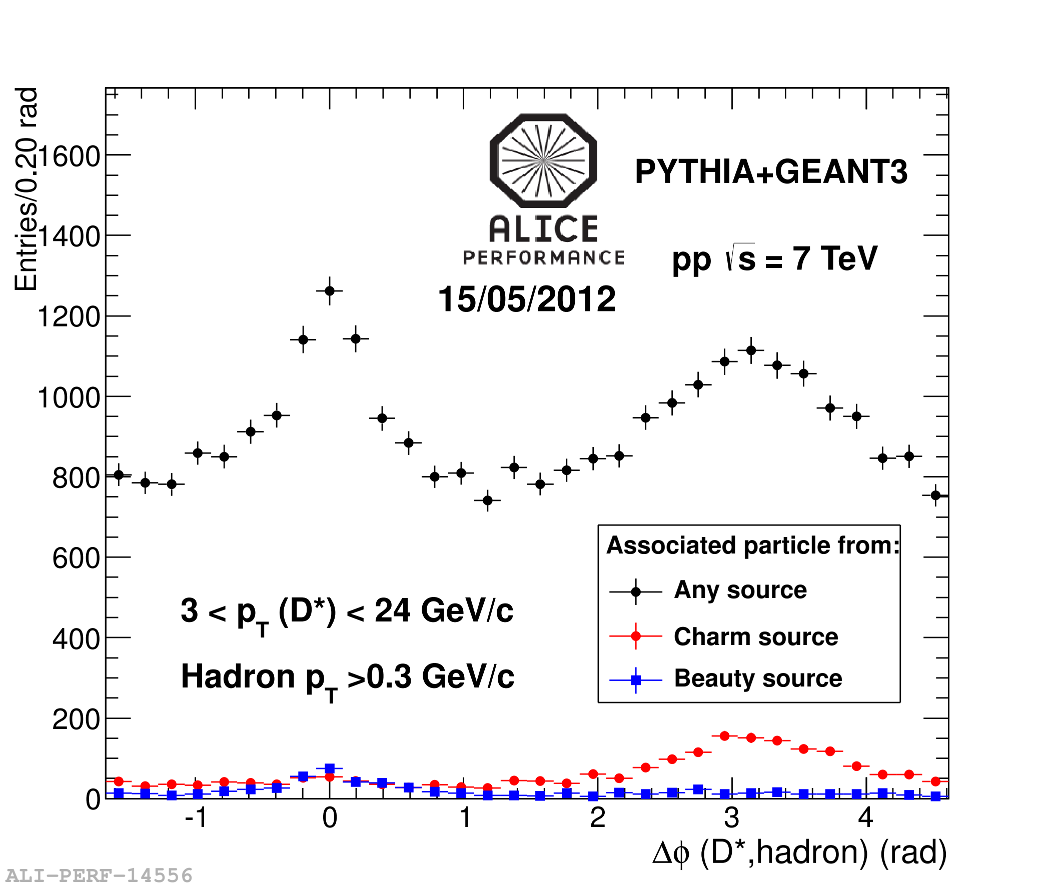
Background reproduced well by associating fake D^0 to π



Detector Effects

Event mixing technique
- Mixing events with similar multiplicity and primary vertex z
- In $\Delta\phi$, mixed events show a flat distribution within 2-3%, w.r.t peak at (0,0)

D*-h correlation results - MC



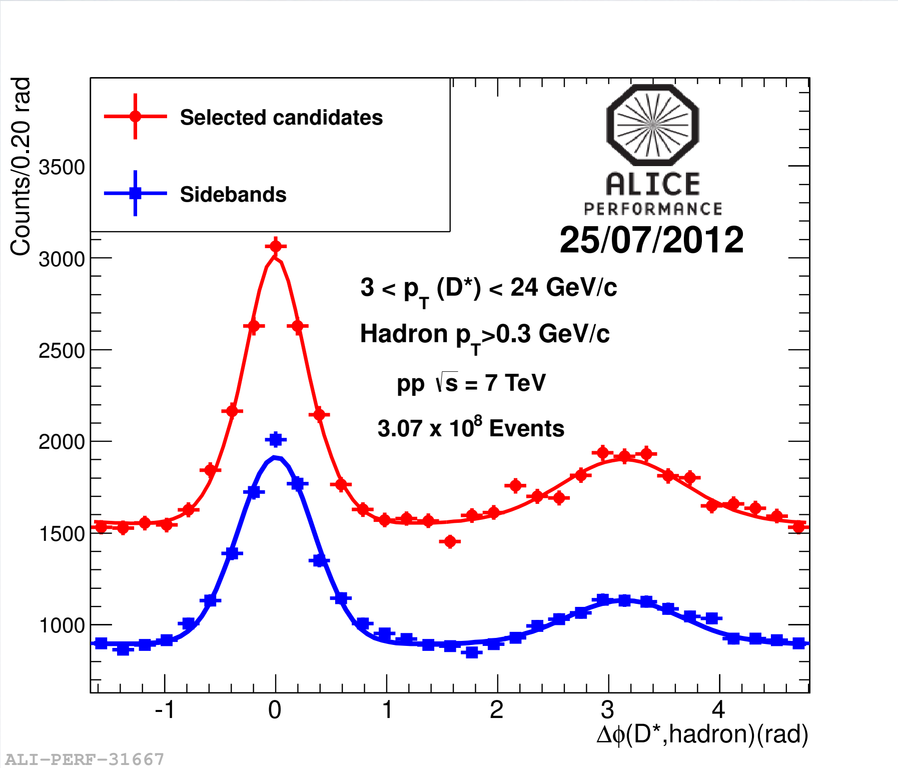
Associated hadrons

From charm - mostly on the away side

From beauty - mostly on the near side

D*-h correlation results - Data

pp collisions at 7 TeV



Correlation signal visible for both selected candidates and background (sideband)

Fitting procedure:
1. Fit the background
2. Fix the parameters of the background function
3. Fit the overall distribution

extract parameters of the signal

Prospects

pp: 2012 jet-triggered data sample should enhance the statistics. Study as a function of the D^{*+} p_T.

Conclusions

e-h

- ☐ Relative beauty fraction to the HF decay electron yield is measured in pp collisions at 2.76 TeV in p_{T} 2.5-10 GeV/c with the ALICE detector using an EMCAL trigger
- ☐ Relative beauty fraction is well described by FONLL calculations and comparable to previous RHIC results at 0.2 TeV
- ☐ Beauty and charm decay electron cross section is measured in pp collisions at 2.76 TeV in the p_{T} = 3-9 GeV/c range.

D*-h

- ☐ D*-hadron correlations analysis is well advanced - extraction of the parameters of the correlation in pp is ongoing

Target for all HF correlation measurements in Pb-Pb:
Modification of near-side and away-side peak (I_{AA}) compared to pp

Backup

HF program in ALICE

ALICE

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 EMCal ,TRD, TPC, and TOF
- Background estimated from MC cocktail or e^+e^- M_{inv} method
- Displaced electrons using ITS (B tagging)

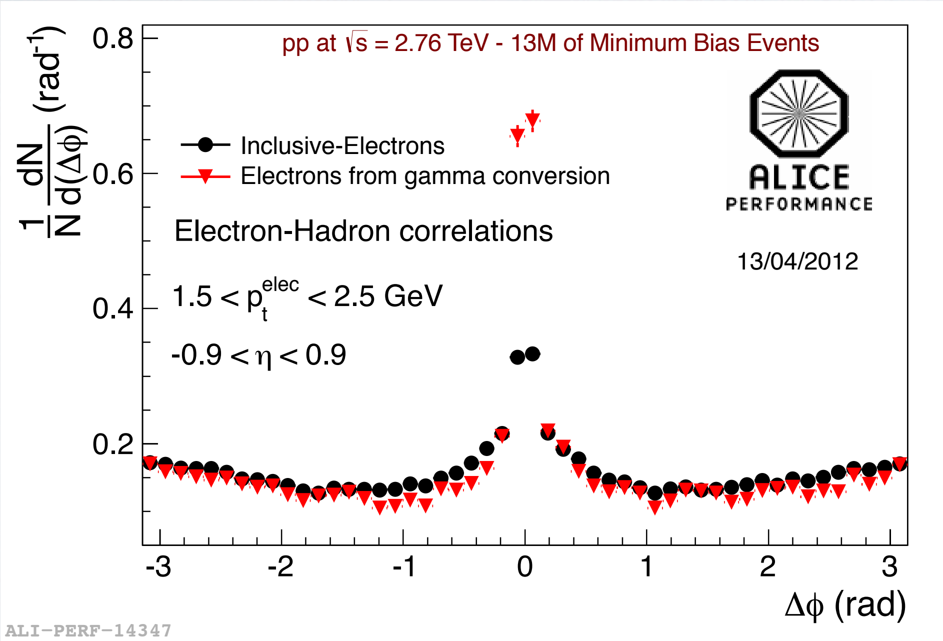
Forward rapidity ($2.5 < \eta < 4$)

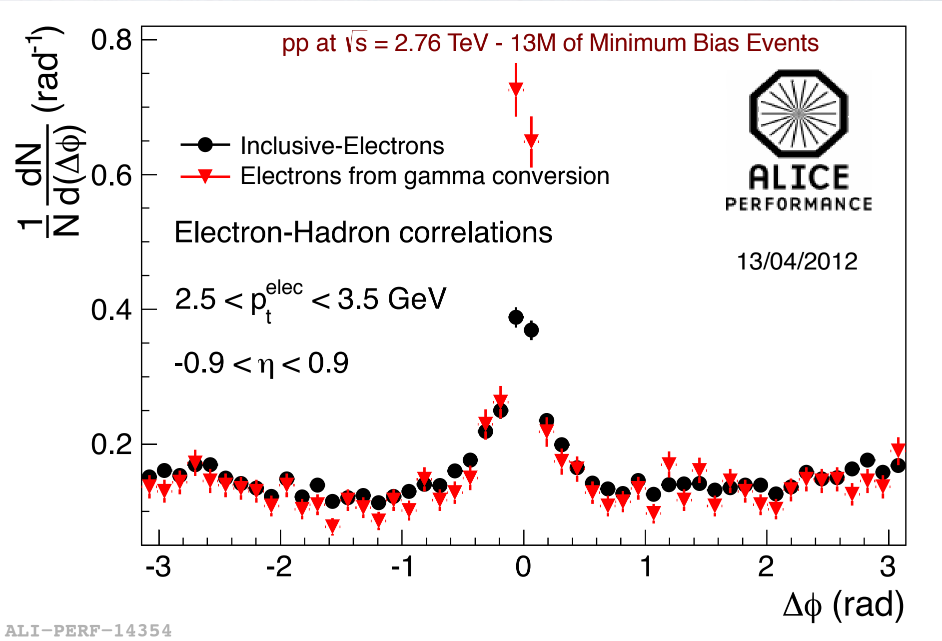
Single muons from semi-leptonic D and B decays
- Muon spectrometer
- Background primary π, K decays. In pp estimated using MC, in Pb-Pb extrapolated from measured π, K at mid rapidity

Outlook e-h correlations

Analysis using electrons identified with TPC+TOF

- MB events
- Lower p_T reach
- Systematic checks ongoing





Beauty and charm decay Xsection at 2.76 TeV

Dataset :
pp at √s=2.76 TeV
EMCal triggered events

Electron ID using TPC and EMCAL

Corrections applied:
Tracking efficiency and unfolding
PID efficiency and purity
High tower trigger efficiency

- Non-HFE identified using cocktail method.
  - Use η/π cross section measurement as input
  - Background cocktail generated contain significant sources of background electrons
- Main Systematic sources:
  - Background cocktail
  - p_T unfolding
  - PID purity and efficiency
  - HT trigger efficiency