AZIMUTHAL ANGULAR CORRELATIONS BETWEEN HEAVY FLAVOUR DECAY PARTICLES AND CHARGED HADRONS IN PP COLLISIONS IN ALICE

ALICE

Deepa Thomas
For the ALICE collaboration

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- Azimuthal angular correlation between heavy flavour electrons and charged hadrons in 2.76 TeV pp collisions
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  - Beauty and charm decay to electron cross-section
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- Conclusions

Motivation

HF Correlations:

❖ pp collisions:
- Disentangle charm and beauty
- Measurement of beauty to electron cross section from e-h correlation
- Provide test for pQCD calculations
- Use as a baseline measurement for Pb-Pb

❖ Pb-Pb collisions:
- Give insight into the energy loss mechanism of heavy quarks
- Study possible modification of jet fragmentation in QCD medium

❖ Correlations:
- Heavy flavour decay electron and charged hadrons
- D* mesons and charged hadrons

Heavy flavour decay electrons and charged hadron correlation in pp @ $\sqrt{s}$ = 2.76 TeV

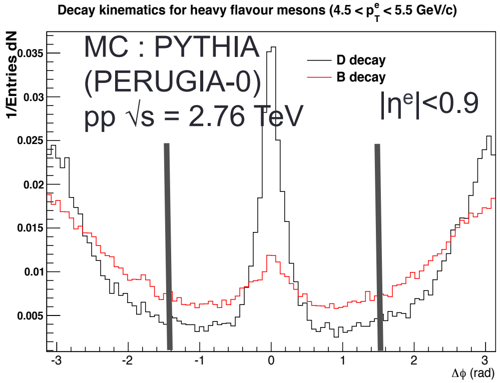
Motivation

- ALICE measurement of heavy flavour (D and B mesons) decay electron R_{AA} shows a suppression of ~0.4 → refer talk by Markus Fasel

- Understanding the energy loss of heavy quarks requires separation of electrons from D and B meson decays

- Azimuthal angular correlation between HF electrons and charged hadrons can be used to determine the relative contribution of B decays to HF electrons

- Exploit different decay kinematics of D and B mesons.
  - The width of near-side correlation distribution is larger for B meson compared to D meson



Decay kinematics of heavy flavour hadrons
- D decay,
- B decay

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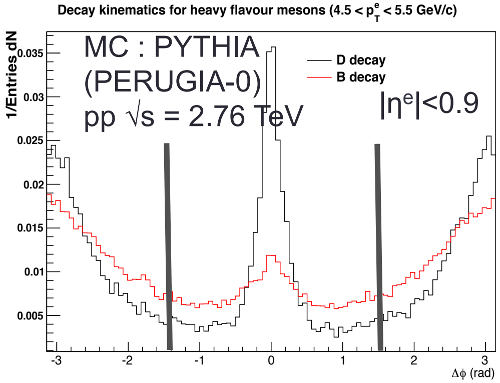
- Azimuthal angular correlation between HF electrons and charged hadrons can be used to determine the relative contribution of B decays to HF electrons
- Exploit different decay kinematics of D and B mesons.
  - The width of near-side correlation distribution is larger for B meson compared to D meson
- Relative beauty contribution extracted by fitting Monte Carlo (PYTHIA) templates (with detector simulation) to data
- STAR[1] and PHENIX[2] measurements with the same technique
- The cross sections of beauty-decay and charm-decay electrons can be computed separately
- Complementary analysis method to direct measurements using displaced vertices



Decay kinematics of heavy flavour hadrons
- D decay,
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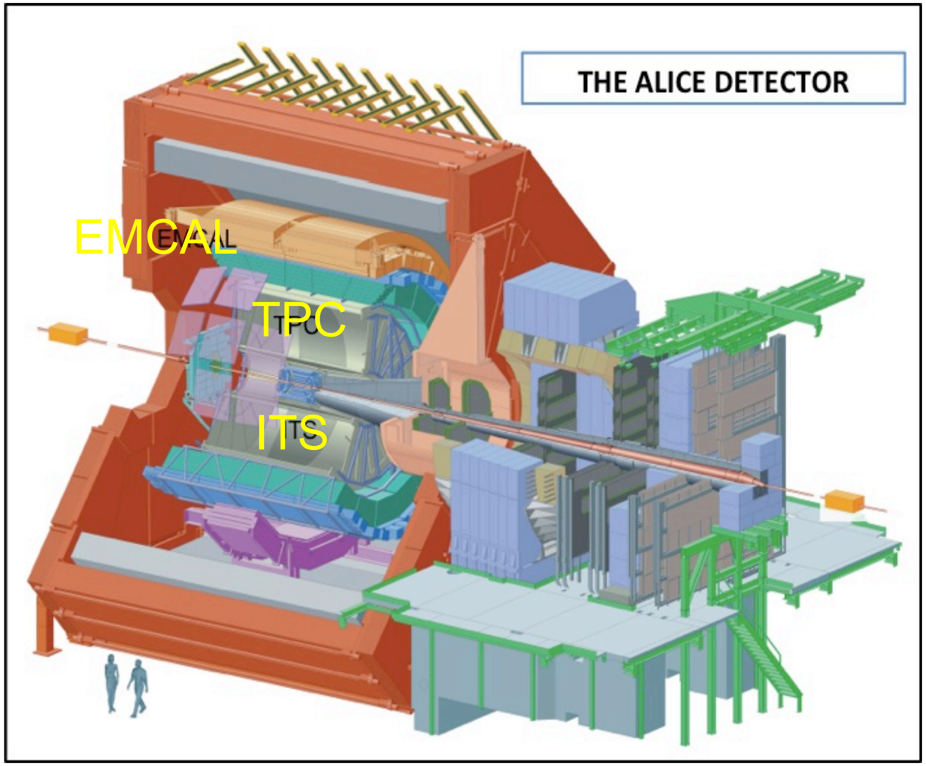
[1]STAR Collaboration, Phys. Rev. Lett. 105, 202301 (2010).
[2]PHENIX Collaboration, Phys. Rev. Lett. 103, 082002, (2009).

ALICE Detector



- Acceptance of central barrel tracking detectors : $|\eta| < 0.9$

- Detectors used for present analysis
  - Inner tracking system (ITS)
  - Time projection chamber (TPC)
  - Electromagnetic calorimeter (EMCAL)
    - $|\eta| < 0.7$
    - $80^0 < \phi < 180^0$

- EMCAL detector used to trigger events : Level 0 trigger (2x2 towers), cluster energy > 3 GeV

- Dataset:
  - pp at $\sqrt{s} = 2.76$ TeV
  - EMCal triggered events
  - Statistics : 6.2×10^5 events, Integrated luminosity = 14.8 nb^{-1}

Analysis Strategy

- Electron identification
  - TPC dE/dx and EMCAL E/p

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  - TPC d*E*/d*x* and EMCAL E/p
- Non-heavy flavour electron identification
  - Conversion and Dalitz decay
  - Invariant mass method

→ Heavy flavour electrons (HFE)

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- Azimuthal angular correlation between HFE and charged hadrons

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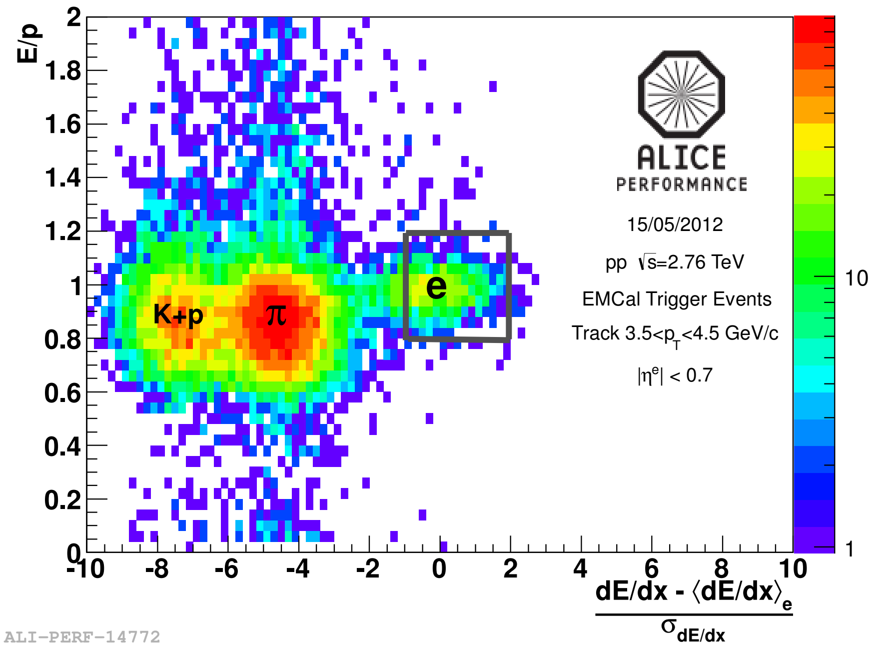
→ Heavy flavour electrons (HFE)

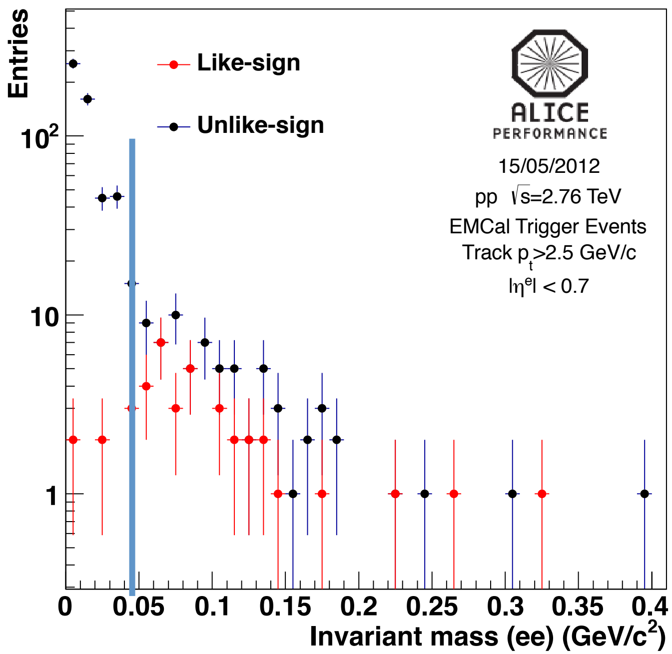
- Azimuthal angular correlation between HFE and charged hadrons
- Deconvolute c and b
  - Monte Carlo template
  - Fit data

Electron Identification

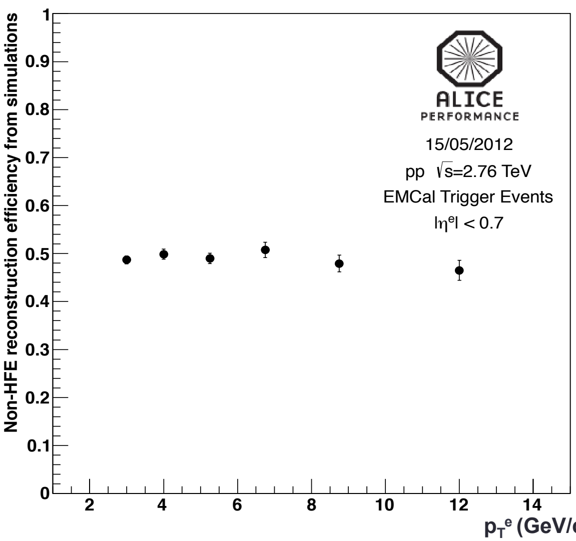


- Electron Identification
  - TPC : -1σ < TPC dE/dx < 3σ
  - EMCAL : $0.8 < E/p < 1.2$

Non heavy flavour electron Identification



- Non-heavy-flavour electron
  - Main sources : γ conversion, π^0 and η Dalitz decays
  - Identified using $e^+ e^-$ invariant mass method
- Invariant mass cut of 50 MeV/c^2 applied
- Efficiency (ε) for Non-heavy flavour electron identification
  - $N_{NHFe}^{reco} / N_{NHFe}$ ~ 50%



Azimuthal angular correlation of heavy flavour electrons and charged hadrons

$$N_e^{HF} = N_e^{Inclusive} - N_e^{reco-NonHF} - \left(\frac{1}{\epsilon} - 1\right) N_e^{reco-NonHF}$$

$\left(\frac{1}{\epsilon} - 1\right) N_e^{reco-NonHF}$ → Not reconstructed Non-HFE

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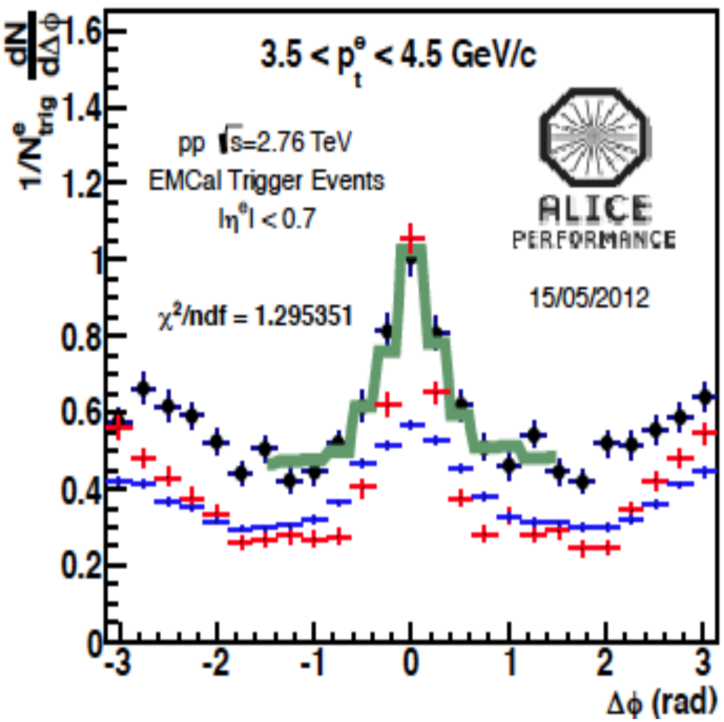
$$\Delta\phi^{HFE} = \Delta\phi^{InclusiveE} - \Delta\phi^{reco-NonHFE} - \left(\frac{1}{\epsilon} - 1\right) \Delta\phi^{reco-NonHFE}$$

Azimuthal angular correlation of heavy flavour electrons and charged hadrons



- Charged hadron selection
  - p_T > 0.3 GeV/c
  - $|\eta| < 0.9$, $0 < \phi < 360^0$

- Fit data with MC template for beauty and charm (PYTHIA + GEANT3)

- Fit function : $\Delta\phi_{data} = const + r_b \Delta\phi_B + (1-r_b)\Delta\phi_D$

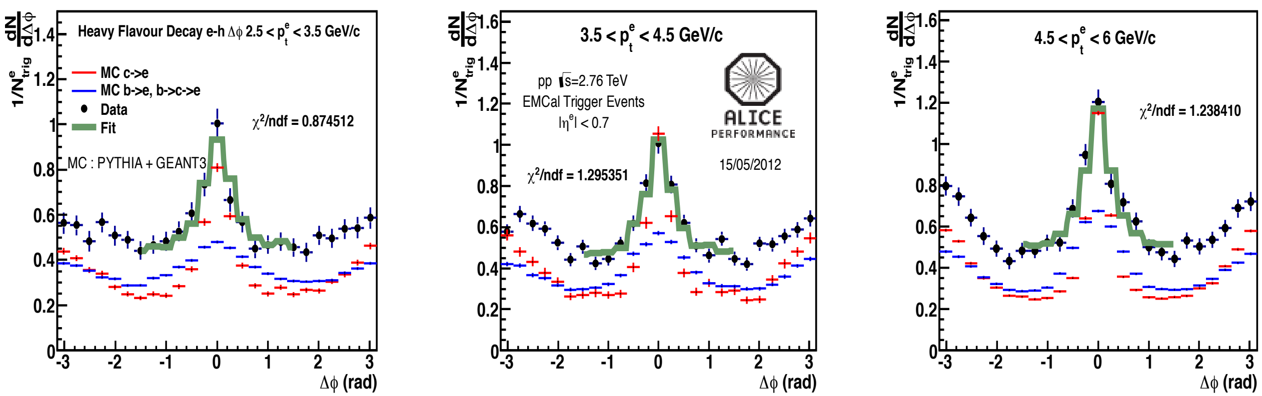
  where $\Delta\phi = dN^{hadrons} / d\Delta\phi$

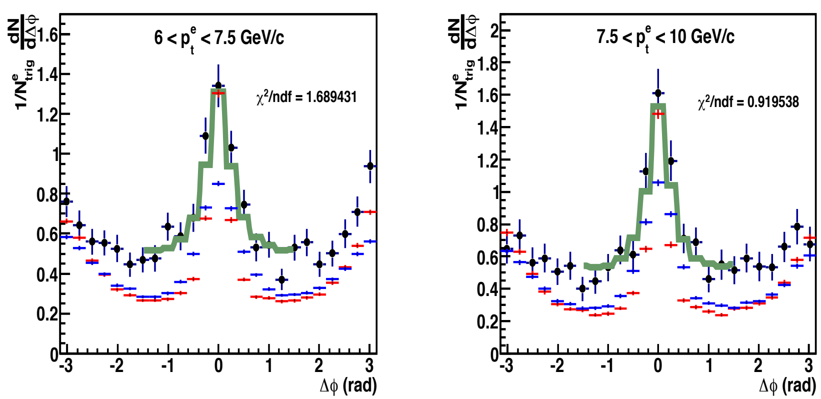
  $\Delta\phi = \phi^{elec} - \phi^{hadrons}$

  $r_b = N^B_e / (N^D_e + N^B_e)$

  const = uncorrelated background

Azimuthal angular correlation of heavy flavour electrons and charged hadrons





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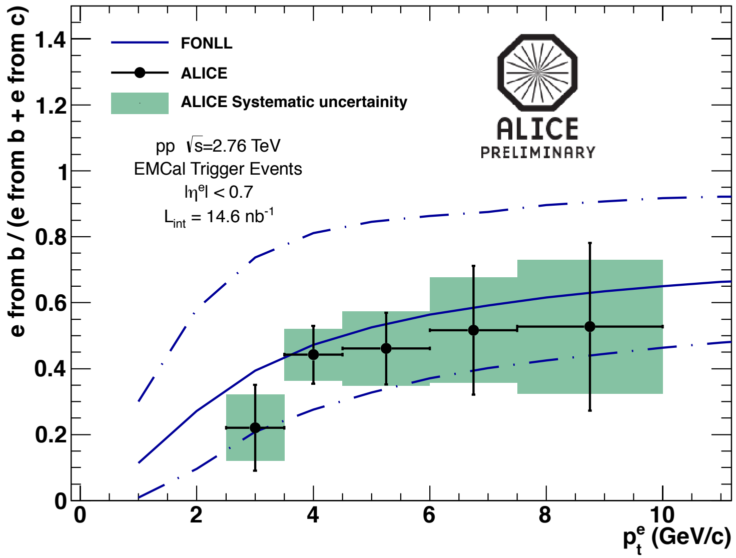
  where $r_b = N^B_e / (N^D_e + N^B_e)$
  const = uncorrelated background
- 5 bins covering $2.5 < p_T^e < 10$ GeV/c

Fraction of beauty decay electrons



- Main source of systematics:
  - Electron identification using TPC and EMCAL
  - Fit range : (-1,1) to (-2.5,2.5) radians
  - Non-HFE identification
    - invariant mass and d*E*/dx cut
- At ~ 5 GeV/c the beauty contribution has similar magnitude as charm

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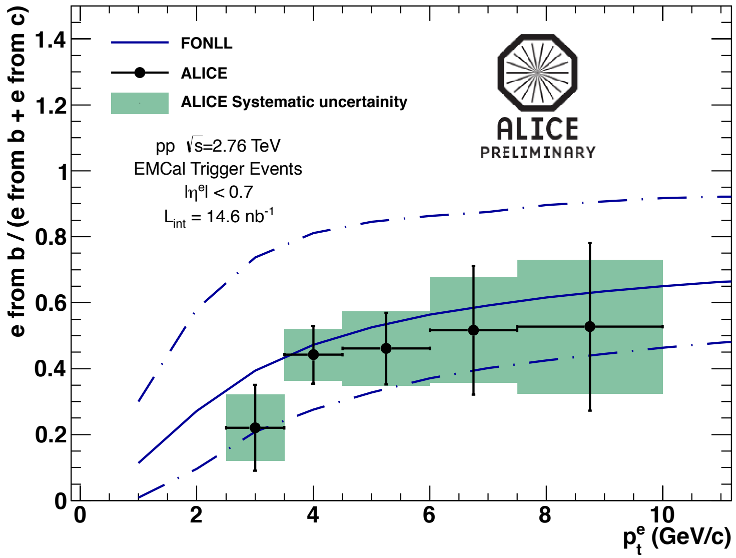

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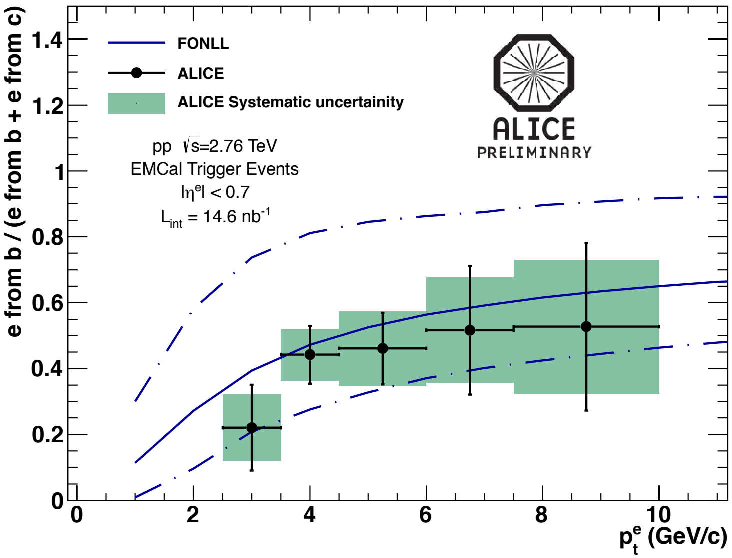

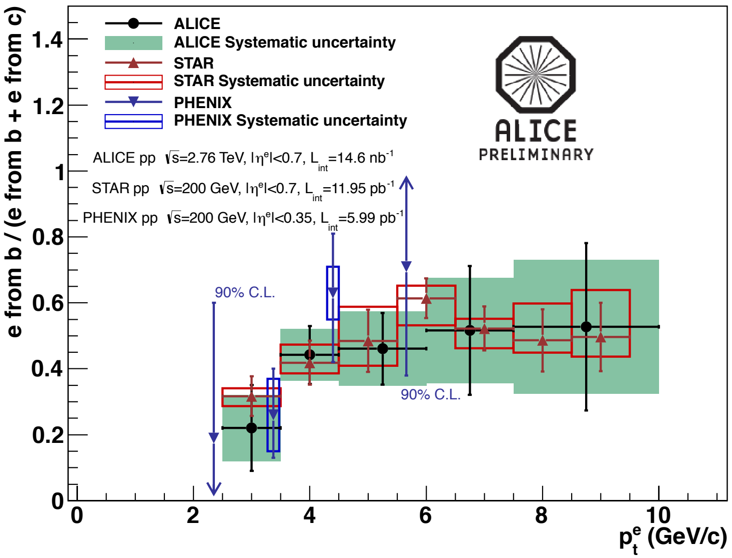

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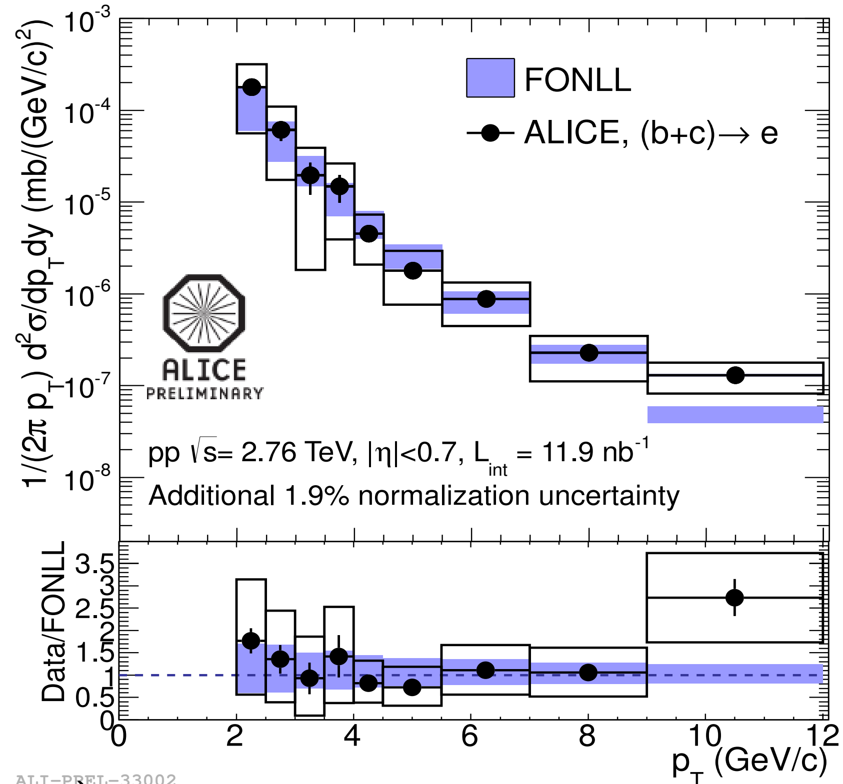
[2]PHENIX Collaboration, Phys. Rev. Lett. 103, 082002, (2009).
[3]M. Cacciari et al., JHEP 0103, 006 (2001) and private communication (2012).

Beauty and charm - decay electron cross-section at $\sqrt{s}$= 2.76 TeV

- Using HFE decay electron cross section and relative beauty contribution to the heavy flavour electron yield, the beauty and charm to electron cross section can be calculated



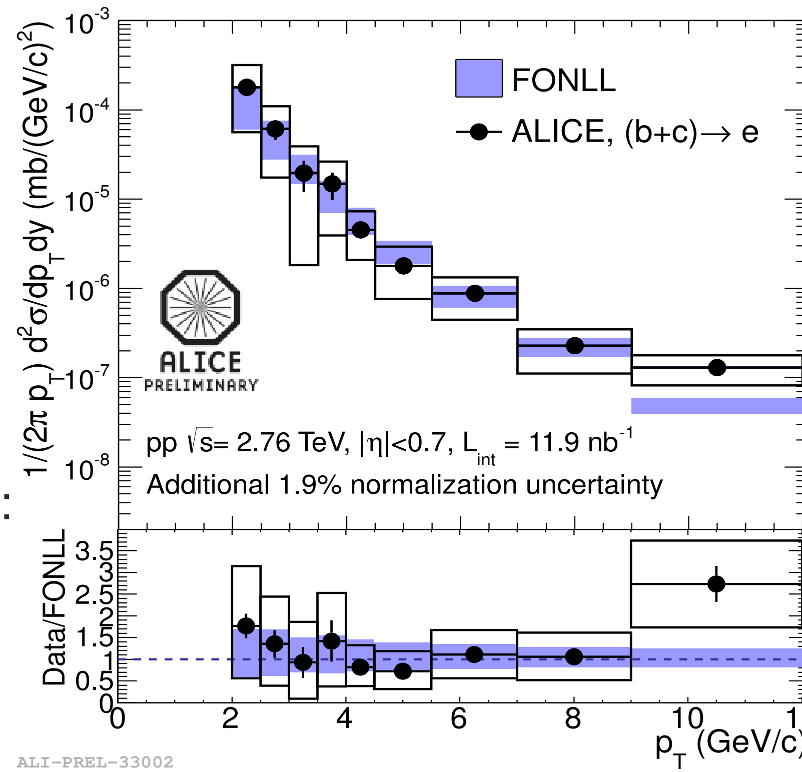
$$\left(\frac{d\sigma}{dp_T}\right)_{b\rightarrow e} = r_b \times \left(\frac{d\sigma}{dp_T}\right)_{b+c\rightarrow e}$$

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

Refer talk by Markus Fasel

HFE cross section at √s= 2.76 TeV

- Dataset :
  - pp at √ s = 2.76 TeV
  - EMCal triggered events
- Electron identication using TPC and EMCAL
- Corrections applied:
  - Tracking efficiency and unfolding
  - PID efficiency and purity
  - EMCAL trigger efficiency
- Non-HFE identified using cocktail method:
  - Use η/π cross section measurement as input
  - Cocktail with all known sources of background electrons
- Main Systematic sources:
  - Background cocktail
  - p_T unfolding
  - PID purity and efficiency
  - EMCAL trigger efficiency



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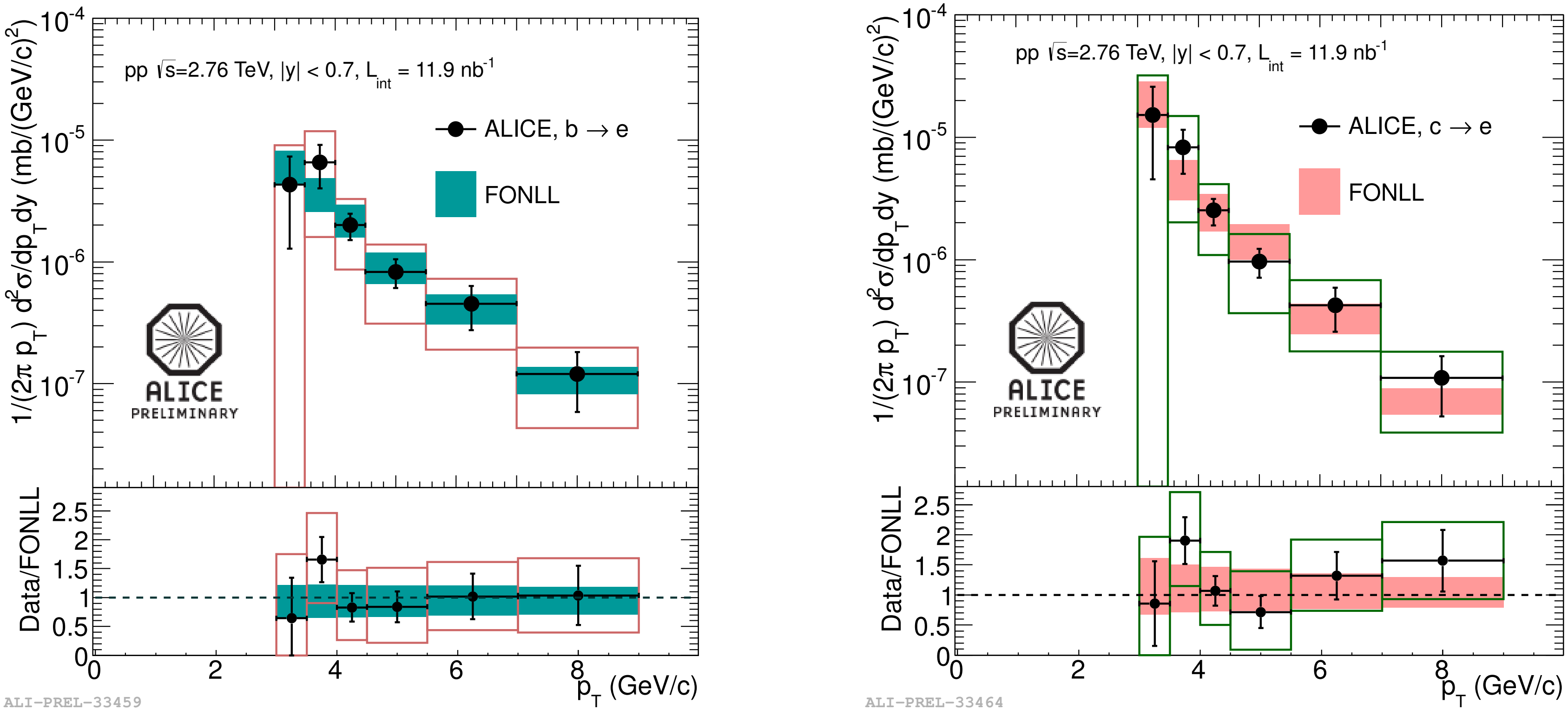
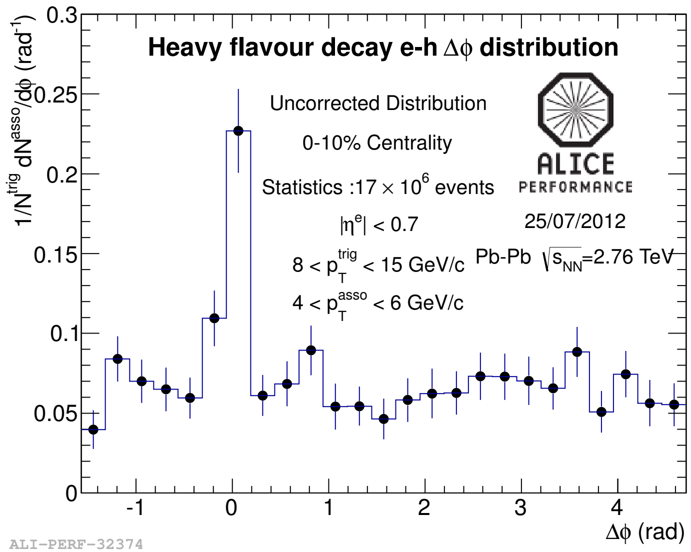
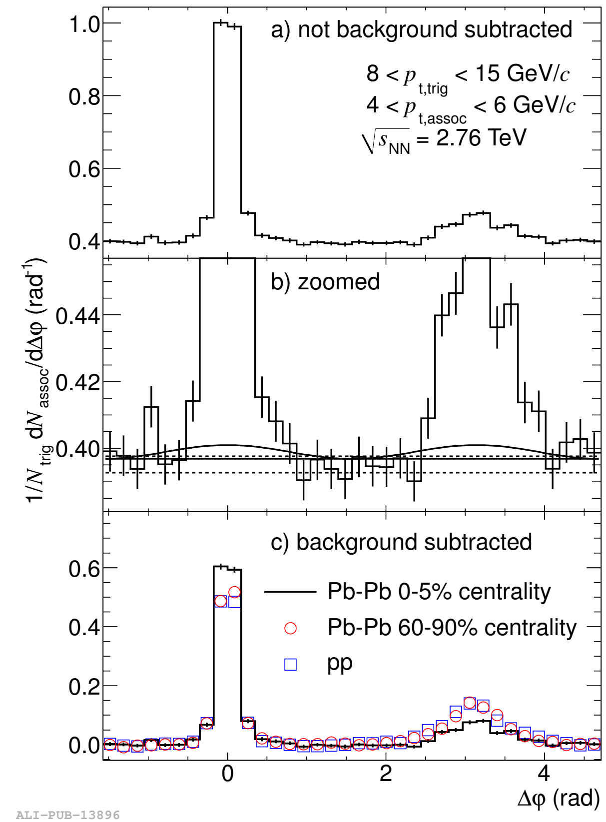


- r_b not measured in full p_T range
- Consistent with FONLL pQCD calculations

Outlook: Pb-Pb collisions

- Azimuthal angular correlation of heavy flavour decay electrons and charged hadrons in Pb-Pb collisions at 2.76 TeV
- Study the energy loss and modified fragmentation of heavy quarks in the QCD medium
- Uncorrected heavy flavour decay e-h $\Delta\phi$ distribution is shown
- Next:
  - Remove uncorrelated background and flow contribution
    → fully corrected HFE-h $\Delta\phi$ distribution
  - Comparison with dihadron $\Delta\phi$ distribution
  - I_{AA} (ratio of yields of Pb-Pb to pp collisions) measurement





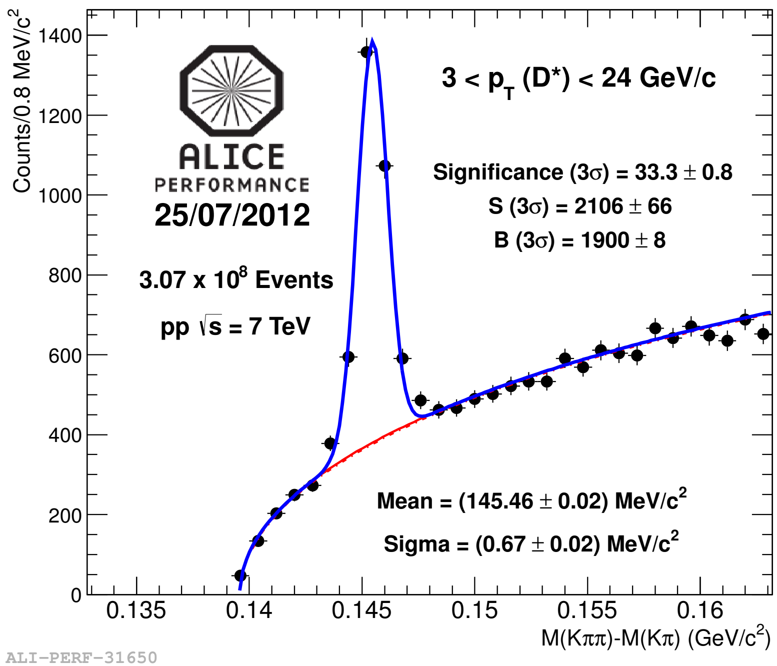
ALICE Collaboration, PRL 108,092301(2012)

D* meson and charged hadron correlations in pp @ $\sqrt{s}$ = 7 TeV

- Motivation:
  - Study energy loss and fragmentation mechanism of heavy quark in QCD medium
  - In pp collisions correlation measurement provides a baseline for Pb-Pb
- Analysis Strategy
  - D* reconstruction using invariant mass method
  - Azimuthal angular correlation between D* and charged hadrons
  - Identify background of $\Delta\phi$ distribution using side-bands
  - Detector effects

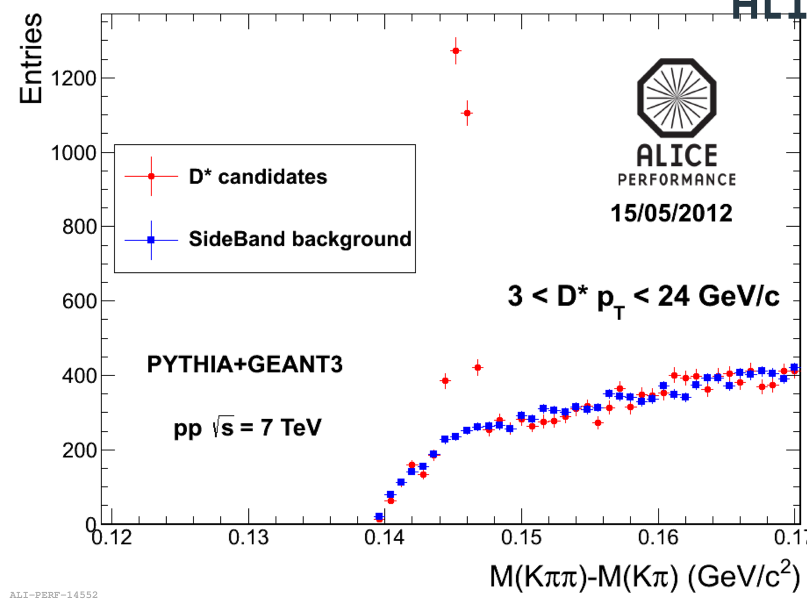
D* reconstruction

- $D^{*\pm}$ decay channel: $D^{*\pm} \rightarrow D^0 (K\pi)\pi^\pm$
- Reconstruction based on D^0 secondary vertex identification
- Combinatorial background reduced with topological selections and particle identification.
- Candidates - 3 σ around the peak in the mass difference M(Kππ) – M(Kπ)
- $D^{*\pm}$ mesons: ideal for open charm-hadron correlation studies because of the relatively high signal-to-background ratio



Background estimation and detector effects

- D* background
  - Estimated from D^0 sidebands
  - $4\sigma < |M(K\pi) - M(D^0)| < 10\sigma$
  - Fake D^0 with soft pion → reproduces background shape



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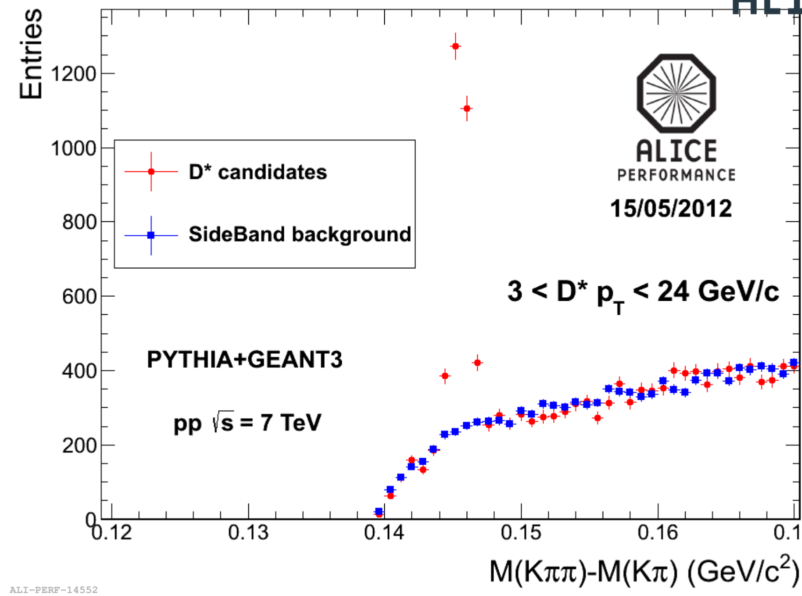
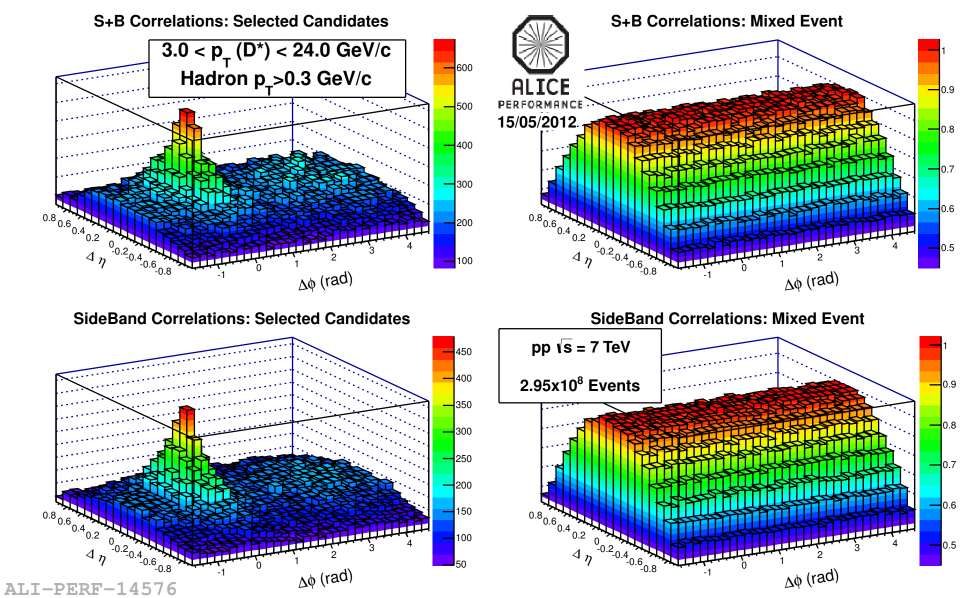
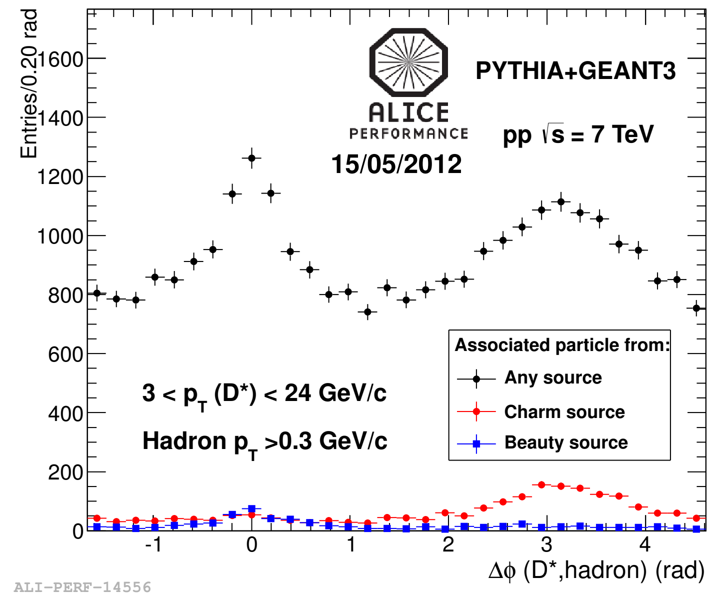




- Detector Effects
  - Mixed event technique
    - Events with similar multiplicity and Vtx_z position
  - In Δϕ, mixed events show a flat distribution within 2-3% w.r.t bin (Δϕ,Δη) = (0,0)

Analysis Results

- MonteCarlo
  - Charm contribution → away side
  - Beauty contribution → near side



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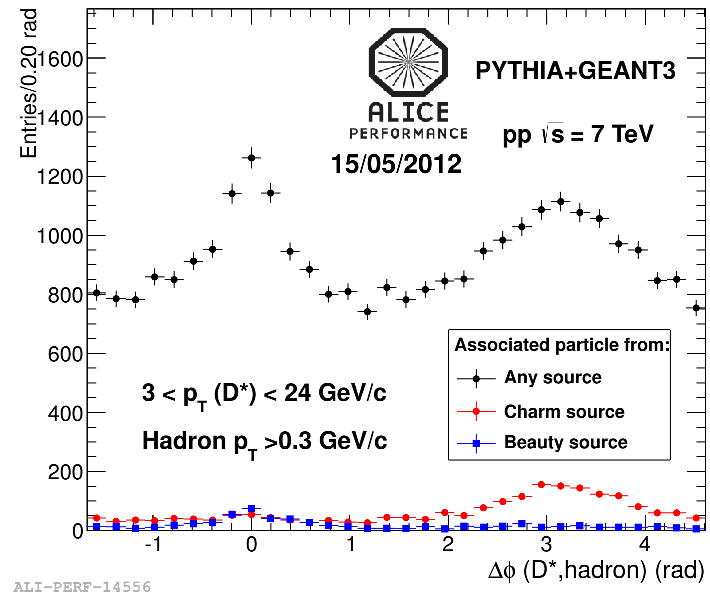
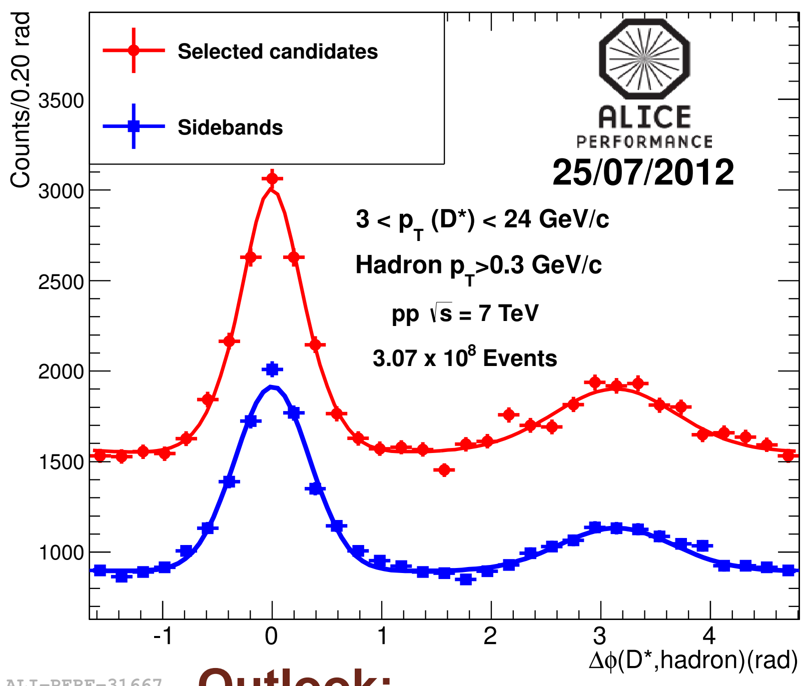




- Data
  - 7 TeV pp collisions
  - Similar shape for both distribution
  - Fitting Procedure
    - Fit background
    - Fix parameters from background function
    - Fit full distribution

Outlook:

- Extraction of correlation parameters in pp
- 2012 jet-triggered data sample → enhance the statistics to perform the study as a function of the D* p_T

Conclusions

- Relative beauty contribution to the heavy flavour decay electron yield is measured in pp collisions at 2.76 TeV in the p_T range between 2.5 and 10 GeV/c with the ALICE detector using an EMCAL trigger

- Relative beauty fraction measurement is well described by pQCD calculations at FONLL and comparable to previous measurements from RHIC at 200 GeV

- Beauty decay and charm decay electron cross sections is measured in pp collisions at 2.76 TeV in the p_T range between 3 and 9 GeV/c

- Study of azimuthal angular correlation between D* mesons and charged hadrons in pp collisions at 7 TeV ongoing → results promising

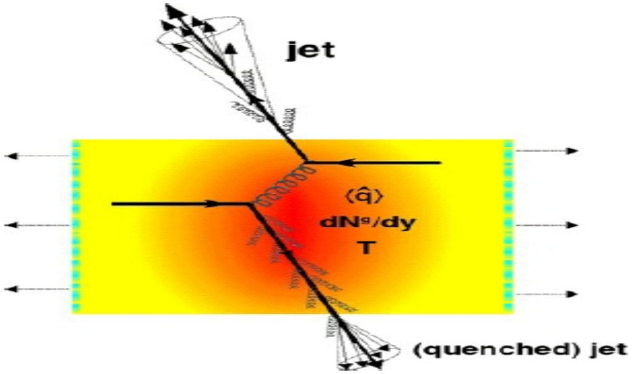
Back up

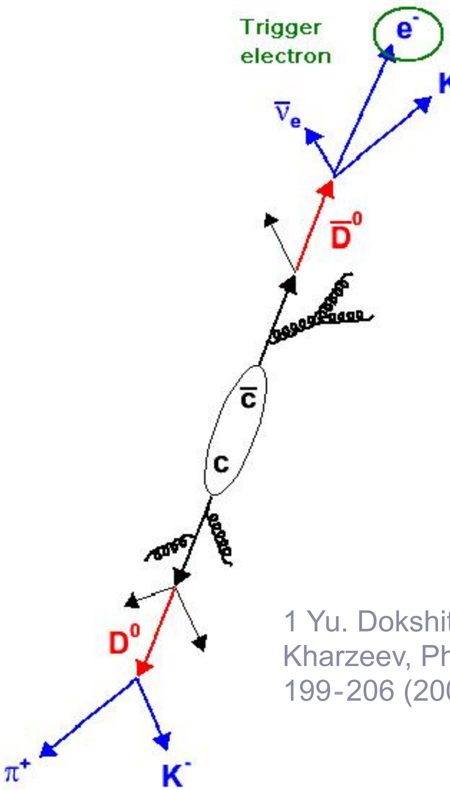
Motivation

- Heavy quarks are produced in hard scattering process in the early stage of collisions and traverse the medium, undergoing inelastic and elastic collisions

- Higher penetrating power.
  - Dead cone effect[1] – gluon radiation suppressed at $\theta < m_Q / E_Q$.
  - Smaller energy loss for heavy quarks

- Heavy quark production can be studied using hadronic and semi-leptonic decay channels of heavy flavour (HF) mesons





1 Yu. Dokshitzer and D.E. Kharzeev, Phys.Lett. B 519 199-206 (2001).

Background cocktail