Heavy flavour measurements in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV with the ALICE experiment

D. Stocco for the ALICE Collaboration

Subatech

Ecole des Mines, CNRS-IN2P3, Université de Nantes
Nantes, France

ALICE

International Europhysics Conference on High Energy Physics
Grenoble, Rhône-Alpes France July 21-27 2011

European Physical Society
HEP 2011

Outline

1. Introduction
   - Motivations
   - ALICE layout
2. Analysis
   - D $\rightarrow$ hadrons (mid-rapidity)
   - B, D $\rightarrow$ electrons (mid-rapidity)
   - B, D $\rightarrow$ muons (forward-rapidity)
3. Results: nuclear modification factors
   - Prompt D mesons
   - Single electrons from B, D decay
   - Single muons from B, D decay
4. Summary

- Charm and beauty: hard probes of the hot and dense matter formed in heavy-ion collisions:
  - produced at the beginning of the collision (large Q^2)
  - experience the evolution of the "fireball" (large $c\tau$)
  - interact strongly with the medium (parton energy-loss)

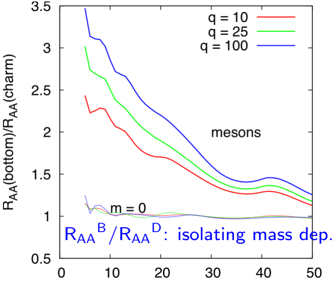
- QCD models describing collisional and radiative energy-loss in the medium depend on:
  - medium density and size
  - color charge (Casimir factor)
  - parton mass (dead-cone effect*)

$$\left.\right\} \quad \Delta E_g > \Delta E_{q/c} > \Delta E_b \qquad \mathrm{R_{AA}}^{h} < \mathrm{R_{AA}}^{D} < \mathrm{R_{AA}}^{B}$$

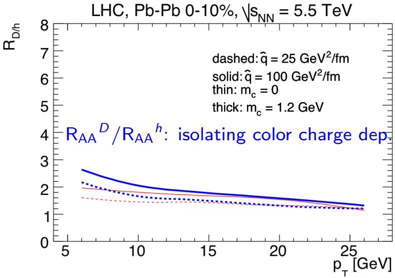
$$\mathrm{R_{AA}}(p_t) = \frac{1}{\langle T_{AA}\rangle}\frac{\mathrm{d}N_{AA}/\mathrm{d}p_t}{\mathrm{d}\sigma_{pp}/\mathrm{d}p_t}$$

* Dokshitzer and Kharzeev, Phys.Lett.B **519** (2001) 199

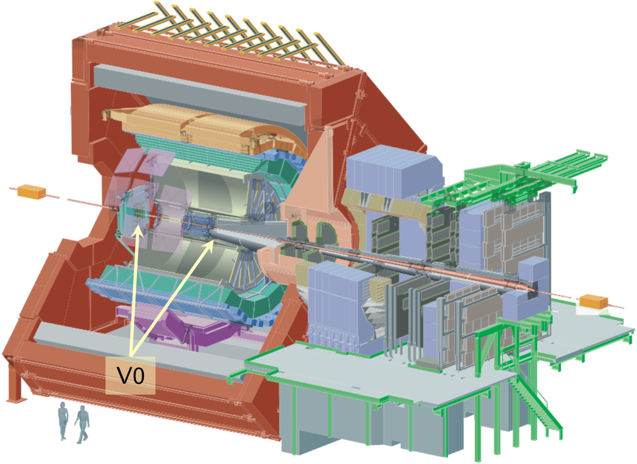
- New ratios available at the LHC:



N.Armesto et al., J.Phys.G **35** (2008) 054001



A. Dainese, Eur.Phys.J.C **49** (2007) 135

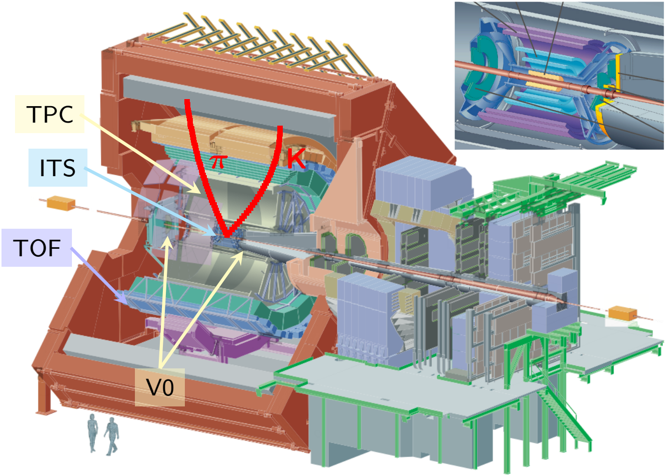


- Centrality selection based on a geometrical Glauber model fit of the V0 scintillators amplitude

ALICE layout

$|\eta| < 0.9$
$B = 0.5$ T

D^0	$\rightarrow$	$K\pi$
D^+	$\rightarrow$	$K\pi\pi$
D_s	$\rightarrow$	$KK\pi$
D^*	$\rightarrow$	$D^0\pi$
D^0	$\rightarrow$	$K\pi\pi\pi$



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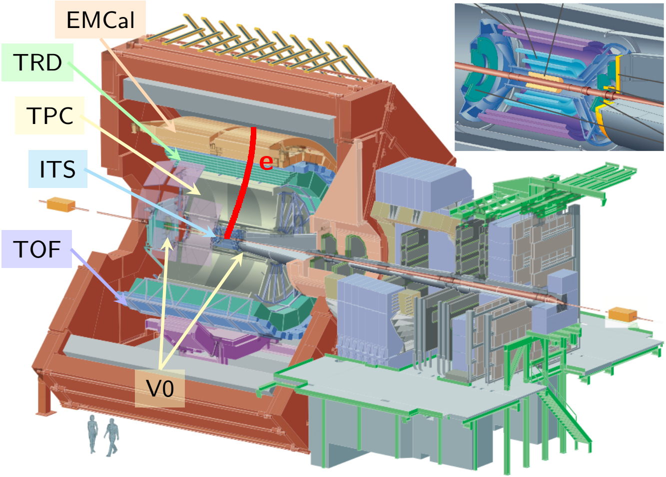
B, D	$\rightarrow$	$e + X$



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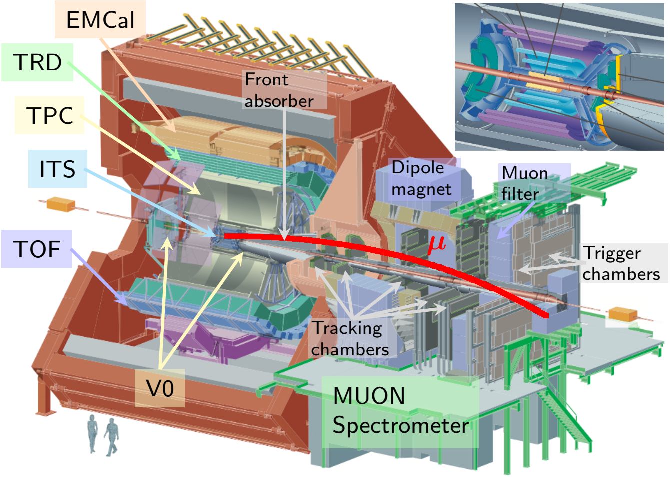
$-4 < \eta < -2.5$

B, D	$\rightarrow$	$\mu + X$



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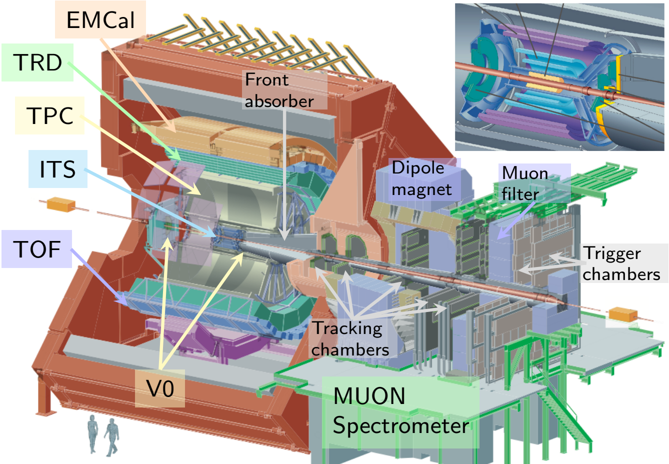

- Centrality selection based on a geometrical Glauber model fit of the V0 scintillators amplitude

- Minimum-Bias (MB) triggers from the coincidence of V0 & SPD (Silicon Pixel Detector)
- Muon triggers ($p_t^\mu \gtrsim 0.5$ GeV/c) in pp

Analyzed data

	pp @ 7 TeV	pp @ 2.76 TeV	PbPb @ 2.76 TeV
N_{MB}	100-180 M	65 M	17M

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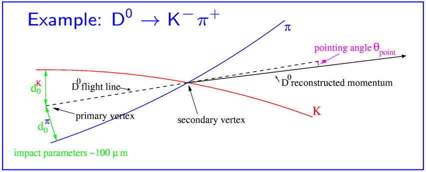
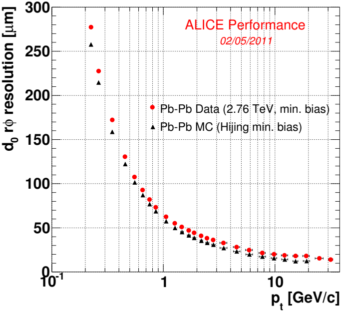
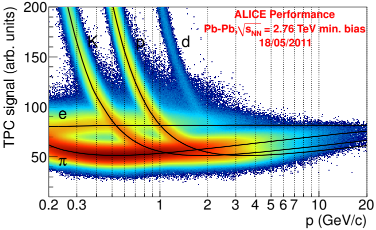


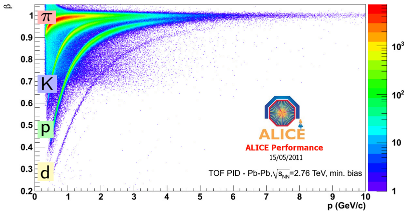


- Main selection: displaced-vertex topology (for $D^0 \to K^- \pi^+$ large impact parameters of opposite-sign pairs & good pointing of reconstructed D to primary vertex)
- Kaon ID in TPC+TOF to reduce background at low p_t

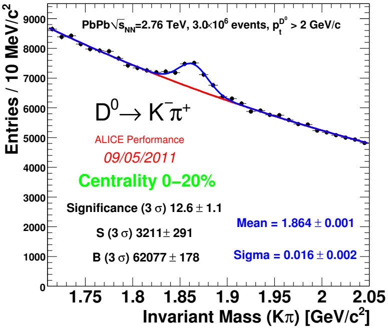
TPC: p/K separation for $p \lesssim 1.1$ GeV/c

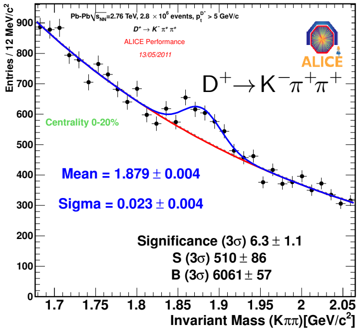


TOF: π/K separation for $p \lesssim 1.5$ GeV/c



D meson analysis



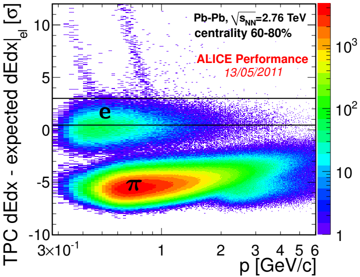


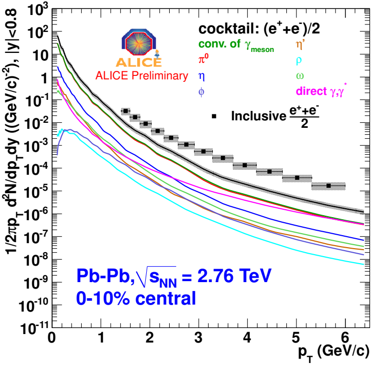
In ∼ 3M central collisions (0-20%)

- D^0: 5 bins in $2 < p_t < 12$ GeV/c
- D^+: 3 bins in $5 < p_t < 12$ GeV/c

Electron identification:

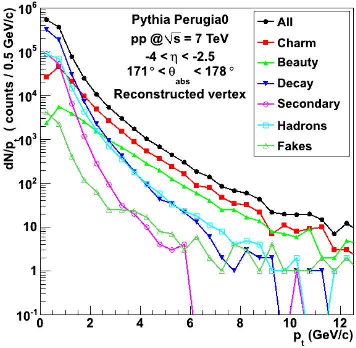
- TOF: reject kaons ($p_t \lesssim 1.5$ GeV/c) and protons ($p_t \lesssim 3$ GeV/c)
- TPC dE/dx: asymmetric cut around the electron Bethe-Bloch line
- TRD (pp only): reject pions ($p_t \lesssim 10$ GeV/c) via TR + energy deposit

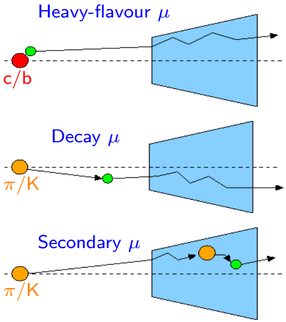




Background subtraction:

1. Cocktail of background electrons:
   - Dalitz decays using as inputs the measured distributions of
     - π^0 (pp collisions)
     - $\pi^\pm$ (PbPb collisions)
   - heavier mesons by m_t scaling
   - prompt γ from pQCD
2. Heavy-flavour electrons = data - background cocktail





- Remove hadrons and low-p_t secondary μ $\Rightarrow$ matching tracks with tracklets in the trigger chambers
- Remove decay μ $\Rightarrow$ MC normalized to data
- Correct for acceptance/efficiency
- Estimate the cross-section

In PbPb:

- No decay μ subtraction but restrict data to high-p_t region where bkg. contribution is small

Fraction of decay muons
(hijing, no quenching)

Centrality	$p_t \geq 4$ GeV/c	$p_t \geq 6$ GeV/c
0-10%	0.15 ± 0.02	0.09 ± 0.03
20-40%	0.11 ± 0.02	0.05 ± 0.02
40-80%	0.06 ± 0.02	0.02 ± 0.02

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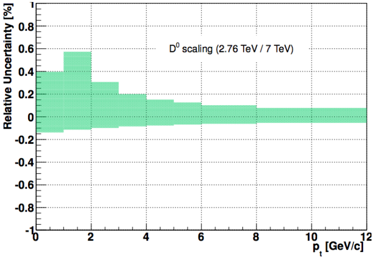
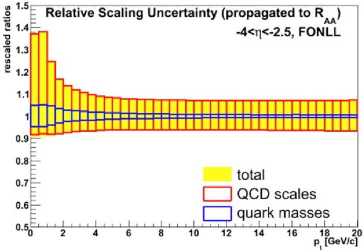
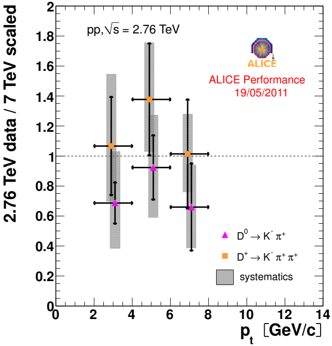
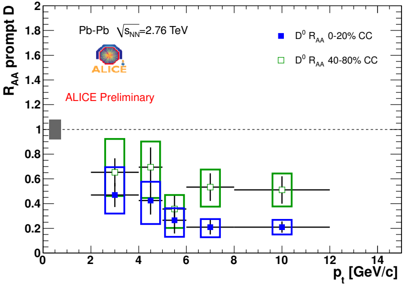




- Proton-proton data at $\sqrt{s} = 7$ TeV scaled to $\sqrt{s} = 2.76$ TeV with FONLL
  - full theoretical uncertainty used
  - assume no dependence of quark mass and scales with $\sqrt{s}$
- Relative scaling uncertainty: 25% $\rightarrow$ 10% in p_t 2 $\rightarrow$ 10 GeV/c
- Cross-check with 3-days pp data at $\sqrt{s} = 2.76$ TeV

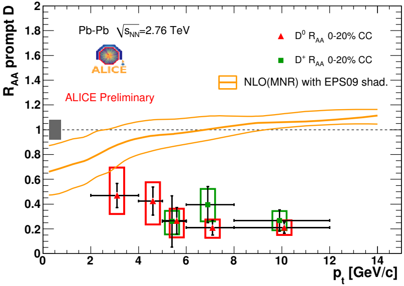


Heavy flavours results in pp collisions: talk by **Y. C. Pachmayer**

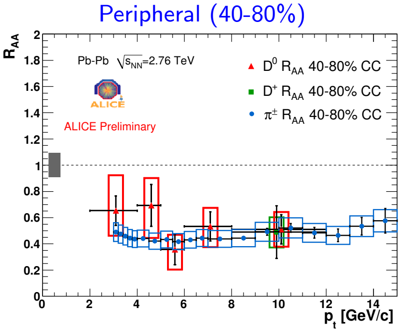


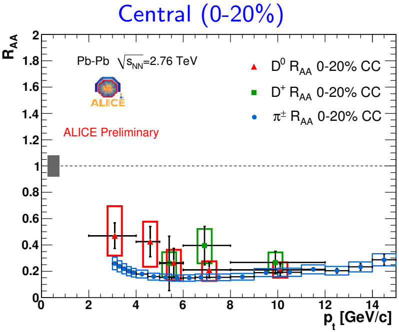
- Strong suppression observed in central collisions (0-20%)
- Significant suppression also in semi-peripheral collisions (40-80%)

- Large suppression factor for $p_t \gtrsim 5$ GeV/c
- Little contribution from initial state effects expected

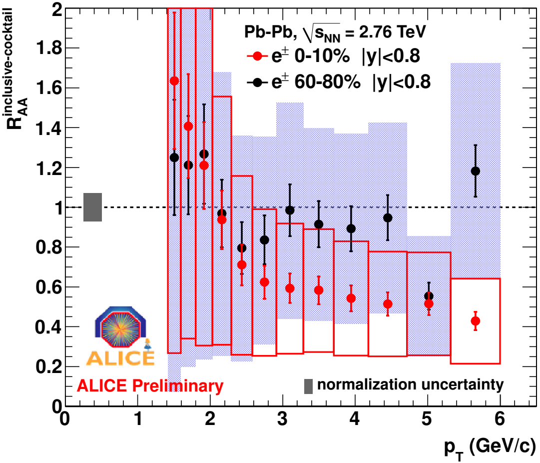


The suppression is a hot medium effect!



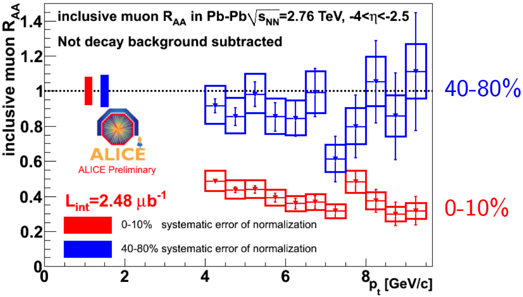


- Charm suppression compatible with pions R_{AA} (slightly higher for $p_t \lesssim 4-5$ GeV/c)

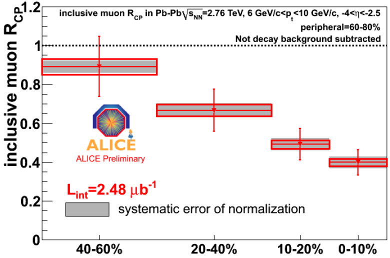


- Large systematic uncertainties at low-p_t (also in pp collisions)
- Heavy-flavour decay dominant for $p_t \gtrsim 3-4$ GeV/c
- Suppression in most central collision (factor $1.5-4$)

- Suppression factor of ~ 3 for $p_t > 6$ GeV/c $\Rightarrow$ region dominated by beauty according to FONLL
- Small p_t dependence



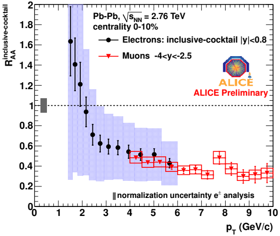
$$R_{CP}(p_t) = \frac{[\langle 1/T_{AA}\rangle \times dN/dp_t]_{central}}{[\langle 1/T_{AA}\rangle \times dN/dp_t]_{peripheral}}$$



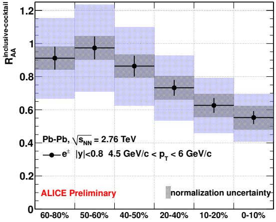
- Suppression increases with centrality

Data comparison

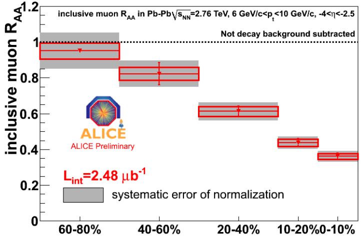
Electrons + Muons



Electrons



Muons



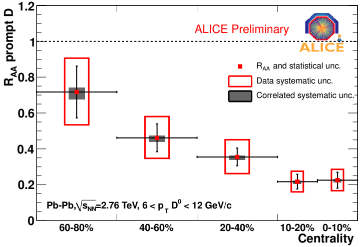
Forward muons vs. mid-rapidity electrons:

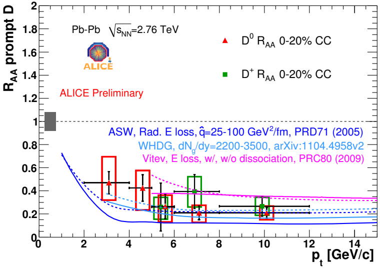
- Consistent within errors

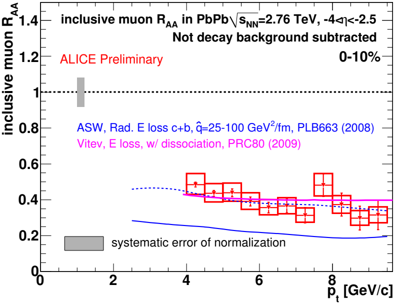
D^0 mesons vs muons:

- Consistent centrality dependence
- Higher R_{AA} for muons ⇒ beauty contribution?

D^0 mesons







CAVEAT: Most of the theoretical predictions are for PbPb @ 5.5 TeV: qualitative comparison only

- Radiative energy loss for $\hat{q} = 25$ GeV/fm^3 in qualitative agreement with both D mesons and muons R_{AA}
- Light-cone wave function approach with dissociation in agreement with muon but a bit high for D mesons

Conclusions

- The nuclear modification factors for heavy flavour in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV have been measured in ALICE:
  - in the hadronic channel at mid-rapidity
  - in the semi-leptonic channel at mid and forward rapidities

- Strong suppression measured in R_{AA} and R_{CP} variables:
  - increasing with centrality (down to 0.2 for D mesons)
  - persisting in a p_t region where initial state effects are expected to be small

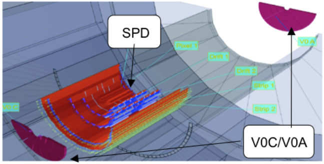
Outlooks:

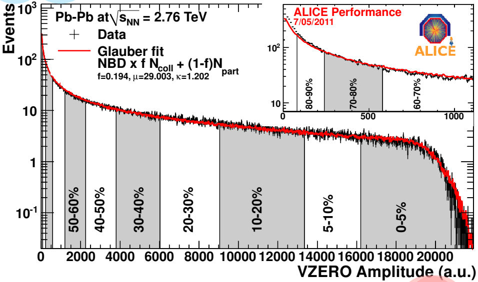
- Study of heavy flavour's flow (measuring event plane)
- Extract beauty contribution

Outline

5. Backup slides

- Minimum-bias triggers from the coincidence of SPD & V0A & V0C





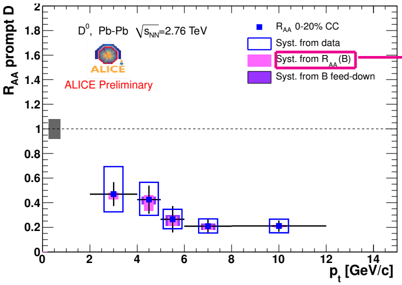
- Centrality selection based on a geometrical Glauber model fit of the V0 amplitude

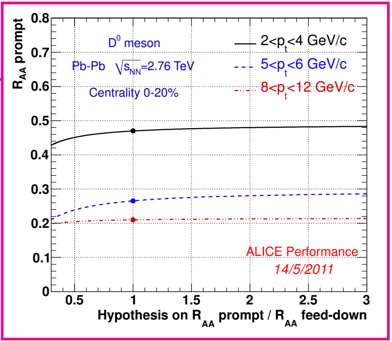
D mesons analysis: feed down subtraction

- Prompt D yields obtained after subtracting secondary D mesons from B decay
- Rely on FONLL predictions (as in pp)
- Additional hypothesis on B mesons R_{AA} required

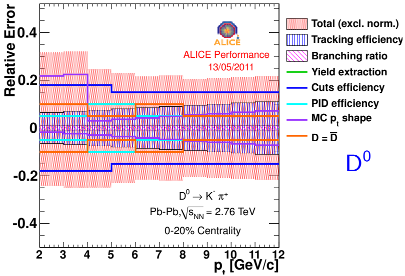
$$\frac{dN^{\text{uncorrected}}_{D\leftarrow B}}{dp_t} = \epsilon^{MC}_{D\leftarrow B} \times \underbrace{\frac{d\sigma^{\text{theory}}}{dp_t} \times T_{AA} \times {R_{AA}}^{D\leftarrow B}}_{\frac{dN^{\text{theory}}_{D\leftarrow B}}{dp_t}}$$

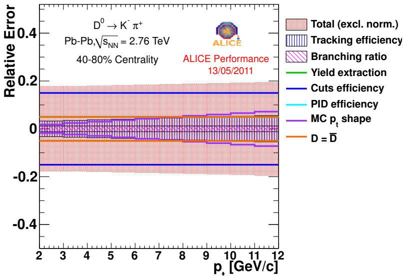
- Choice for systematic computation on ${R_{AA}}^{D}$: $1/3 < {R_{AA}}^{D}/{R_{AA}}^{B} < 3$

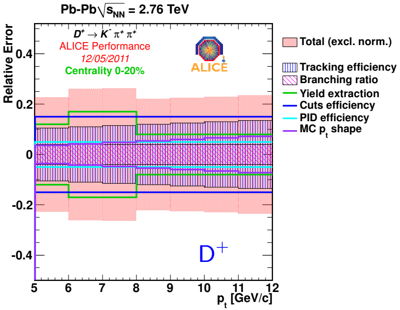




D mesons analysis: systematics



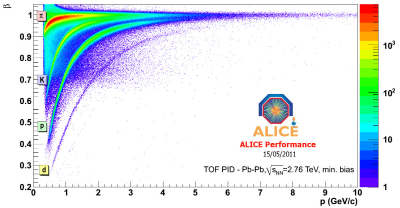


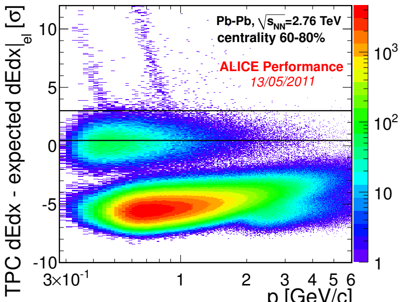


Heavy-flavour electron analysis: PID (I)

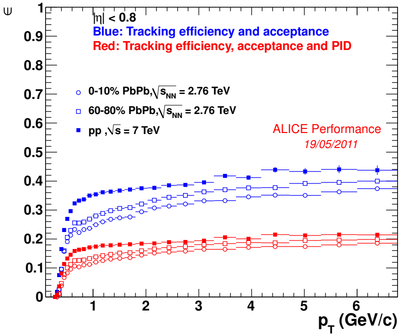
Electron identification:

- TOF: reject kaons ($p_t \lesssim 1.5$ GeV/c) and protons ($p_t \lesssim 3$ GeV/c)
- TPC dE/dx: asymmetric cut around the electron Bethe-Bloch line



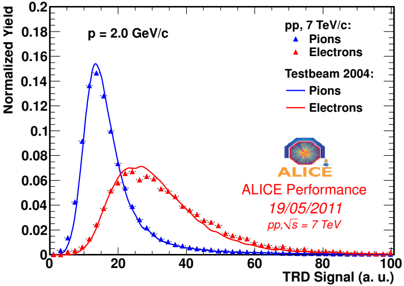


TPC + TOF (3σ electron compatibility cut)

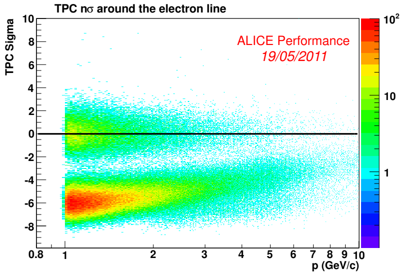


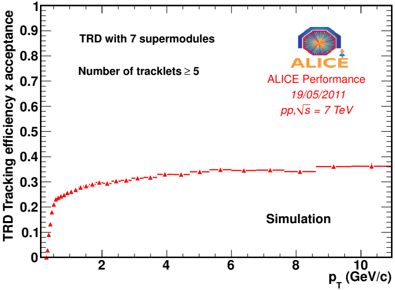
Electron identification with TRD (in pp):

- Energy deposit + transition radiation
- Electron likelihood cut fixed at 80% electron efficiency



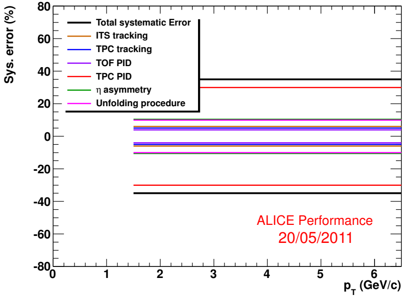
- Strong π suppression when combining TOF+TRD+TPC cuts:



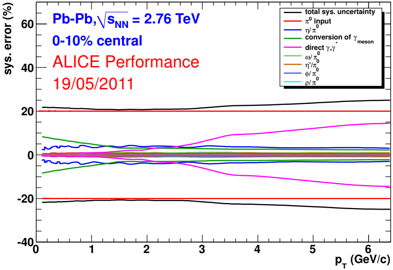


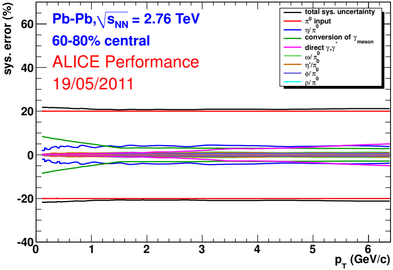
Heavy-flavour electron analysis: systematics

Data

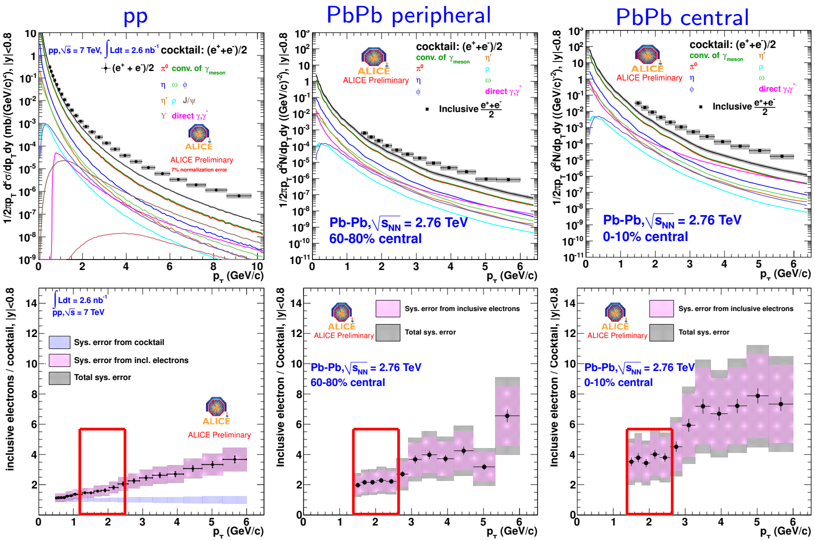


Cocktail





Inclusive electrons



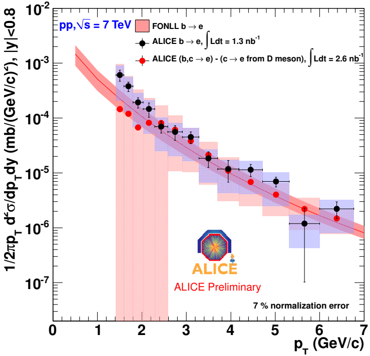
- Hint for an electron excess at low p_t
- Increase with centrality

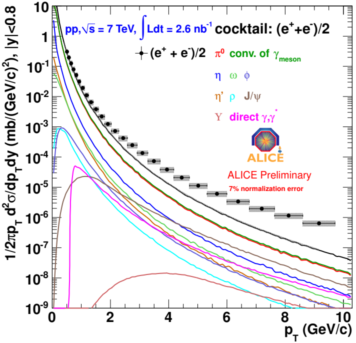
Thermal photons?

Heavy-flavour electron analysis in pp collisions: background subtraction

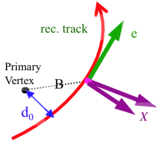
Two ways of extracting heavy flavour contribution:

1. Subtract "background" electrons from cocktail:
   - input from measured distributions of
     - π^0 (pp collisions)
     - $\pi^{\pm}$ (PbPb collisions)
   - Dalitz decays based on π inputs
   - heavier mesons by m_t scaling
   - prompt γ from pQCD





2. Isolate beauty decay by the large impact parameter of the electron (beauty $c\tau \sim 500\ \mu\mathrm{m}$)

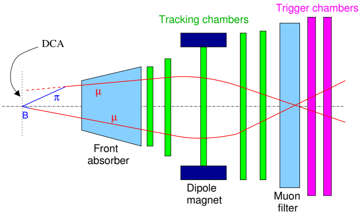


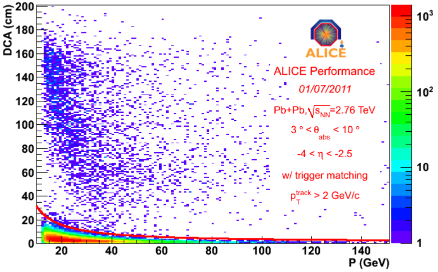
Data sample:

- Minimum-bias events

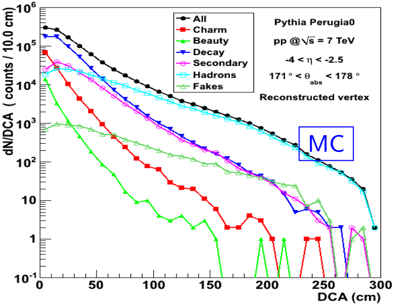
Track selection:

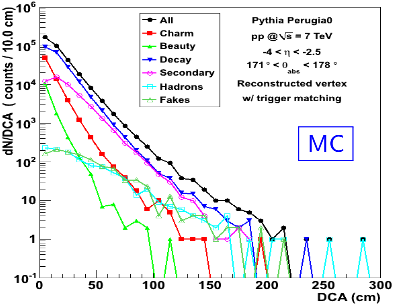
- Acceptance cut: $-4 < \eta < -2.5$
- Cut on the angle of the track at the exit point of the front absorber ($171^\circ < \theta_{abs} < 178^\circ$).
- Rejection of beam-gas background events.
- Reject events with no reconstructed vertex in the two pixel layers
- Matching tracks with trigger (see next slide)
- Remove fake tracks and improve beam-gas rejection: cut on $p \times DCA$ variable:

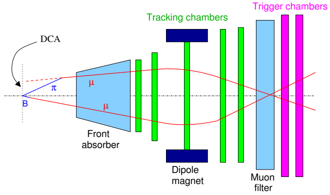


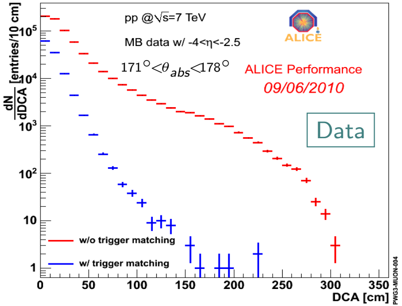


Heavy-flavour muons analysis: trigger selection



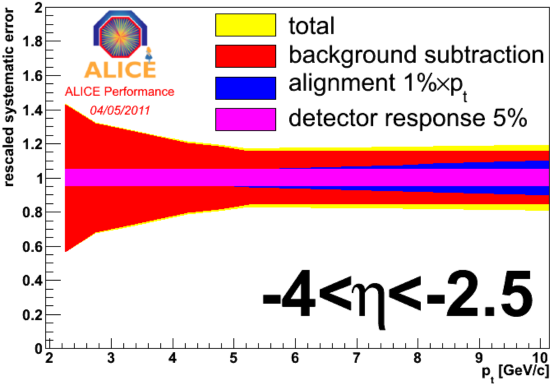






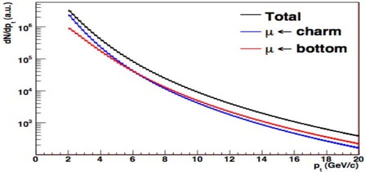
- Hadrons rejected by requiring the matching of tracks with trigger

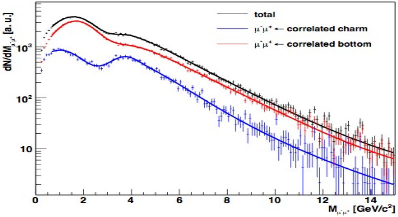
- Systematics in pp collisions at 7 TeV:
  - background subtraction: ∼20%
  - alignment: 1% × p_t
  - detector response: 5%
  - Minimum-Bias pp cross section from van der Meer scan: 7% (not shown)



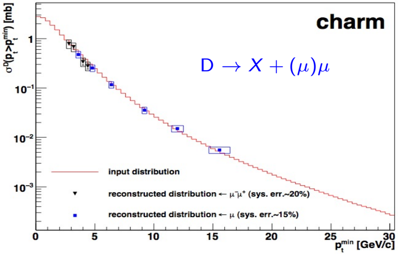
Heavy-flavour muons: disentangle charm and beauty

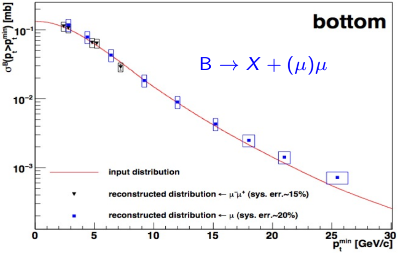
MC study





- CAVEAT: assuming perfect combinatorial bkg. subtraction.
- Statistical and systematic errors in 1 month of pp collisions @ 14 TeV, assuming $\mathcal{L} = 10^{30}$.





- Systematic error (taking into account combinatorial bkg. subtraction): $\sim$ 20% for B and $\sim$ 20% for D

L.Manceau *et al.*, ALICE-INT-2010-004