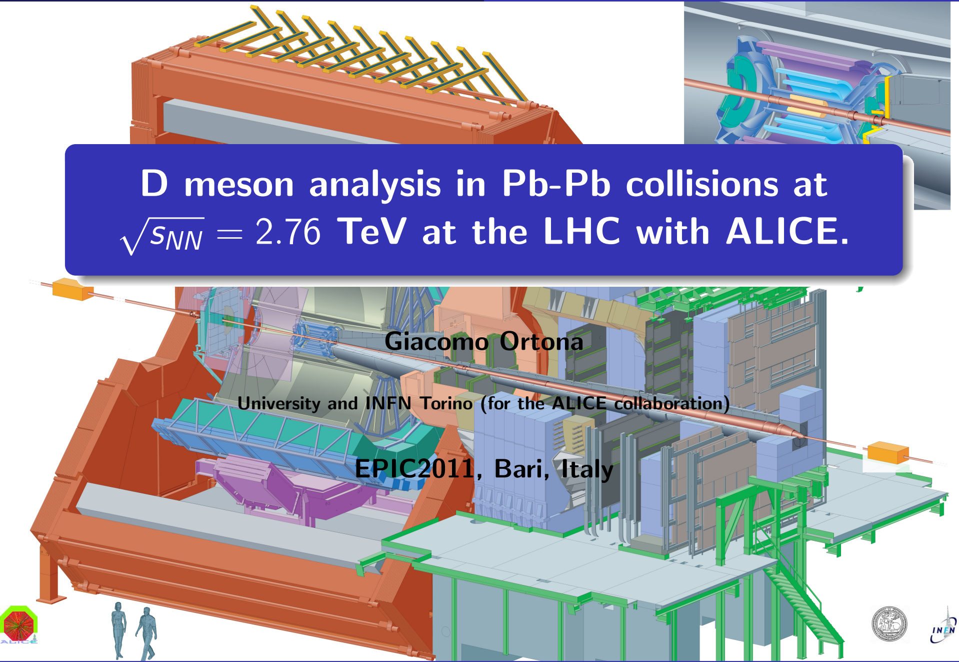


D meson analysis in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV at the LHC with ALICE.

Giacomo Ortona

University and INFN Torino (for the ALICE collaboration)

EPIC2011, Bari, Italy

Outline

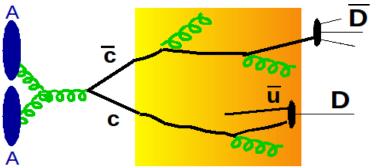
Motivations (I)

- p-p collisions
  - measurement of HF production $\Rightarrow$ test of pQCD calculations
  - reference for A-A studies
- A-A
  - study of the medium produced in A-A collisions (QGP)
    - HQ production
    - Energy loss
    - Flow
- p-A
  - Disentangle initial and final state effects

Forward rapidity and low p_t charm study allows to probe extremely small x-region ($\sim 10^{-4}$).

Motivations (II)

charm is a good probe of the medium formed in heavy-ion collisions



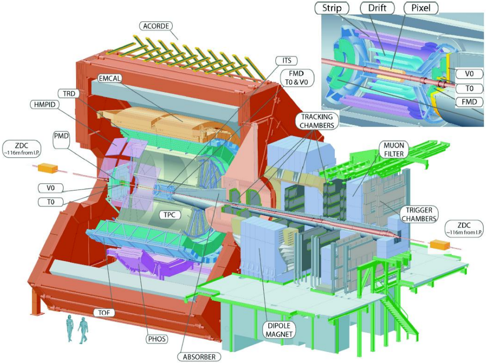
- Produced at the very beginning of the collision
- follow the evolution of the "fireball"
- Interacts strongly with the medium (energy loss, in-medium hadronization...)

Main observables

- Energy Loss: $R_{AA}(p_t) = \frac{1}{<T_{AA}>} \frac{dN_{AA}/dp_t}{d\sigma_{pp}/dp_t}$.
  - quark have smaller color charge of gluons, expectation: $R^{\pi}_{AA} < R^{D}_{AA}$
  - Dead cone effect is mass dependent, expectation: $R^{D}_{AA} < R^{B}_{AA}$
- Flow
  - Strongly related to thermalization and medium properties

ALICE Detector

- Central barrel: ($|\eta| < 0.9$, B=0.5 T)
- Muon Arm: $-4 < \eta < -2.5$
- ALICE coverage extends to very low p_t



Open charm to hadrons:

fully reconstructed hadronic decay topologies

- Vertexing (ITS), tracking (ITS, TPC)
- PID (TOF, TPC)

Datasets:

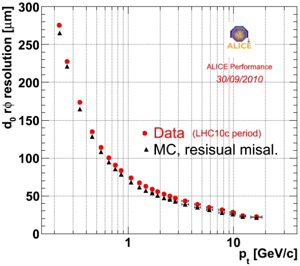
- pp 7 TeV, 100-180$\times 10^6$ events, April to August 2010
- pp 2.76 TeV, 65$\times 10^6$ events, March 2011
- PbPb 2.76 TeV, 17$\times 10^6$ events, November 2010

Heavy flavour at ALICE

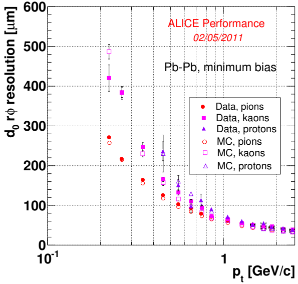
ALICE has very good performance in HF study:

- Excellent vertexing and tracking
- electrons and muons channels are both studied in different rapidity regions
  - See talks by M. Fasel (next) and N. Bastid (tomorrow)
- very good track impact parameter resolution (minimum distance between track and primary vertex) for the tracking in the central barrel
- PID is performed with several techniques ($\frac{dE}{dx}$, TOF, TRD)

Track impact parameter resolution in the rϕ plane



pp



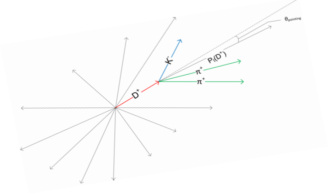
PbPb

D to hadrons analysis strategy

D meson (to hadrons) analysis strategy based on invariant mass analysis of fully reconstructed decay topologies displaced from the interaction vertex

Golden channel topologies are:

Meson	Decay channel	$c\tau$	BR
D^0	$D^0 \to K^-\pi^+$	$\sim 120\mu m$	$\sim 3.8\%$
D^0	$D^0 \to K\pi\pi\pi$	$\sim 120\mu m$	$\sim 7.45\%$
D^+	$D^+ \to K^-\pi^+\pi^+$	$\sim 310\mu m$	$\sim 9.2\%$
D_s^+	$D_s^+ \to K^+K^-\pi^+$	$\sim 150\mu m$	$\sim 5.2\%$
D^{*+}	$D^{*+} \to D^0\pi^+$		$\sim 67.7\%$
Λ_c	$\Lambda_c \to pK^-\pi^+$	$\sim 60\mu m$	$\sim 5.0\%$

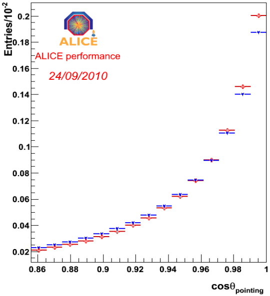


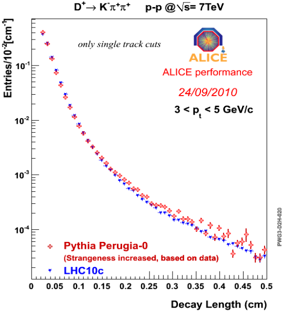
Thanks to ALICE very good vertexing resolution it is possible to reconstruct and analyze D meson through their hadronic decay channels

Analysis Strategy

- Build pairs(D^0) / triplets(D^+) / quadruplets of tracks with the correct sign combination passing single tracks selection cuts
- Calculate the tracks vertex; apply topological cuts (Pointing of the reconstructed D meson to the primary vertex of the event, large impact parameter, large distance between the vertex of the event and the vertex of the tracks)
- Apply PID to tag decay products
- Estimation of feed down from Beauty based on FONLL and MC selection efficiencies; Efficiency and acceptance corrections

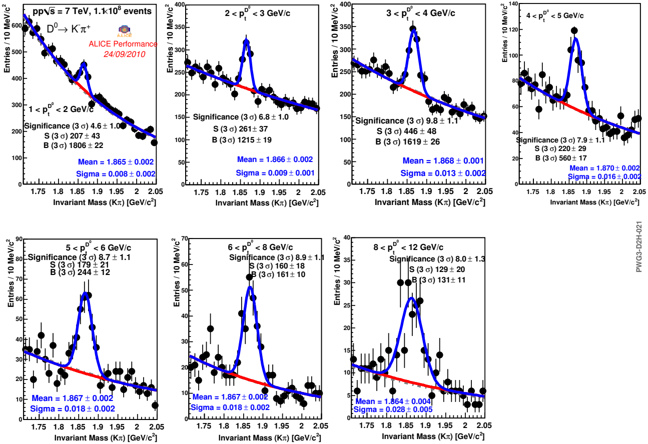
Then: $$\frac{d\sigma^D(p_t)}{dp_t}\Big|_{|y|<0.5} = \frac{1}{2}\frac{1}{\Delta y(p_t)}\frac{1}{BR} f_c(p_t) \frac{1}{\epsilon_c} \frac{N^D_{raw}(p_t)|_{y<\Delta y(p_t)}}{\Delta p_t} \frac{\sigma^{mb}}{N^{mb}}$$





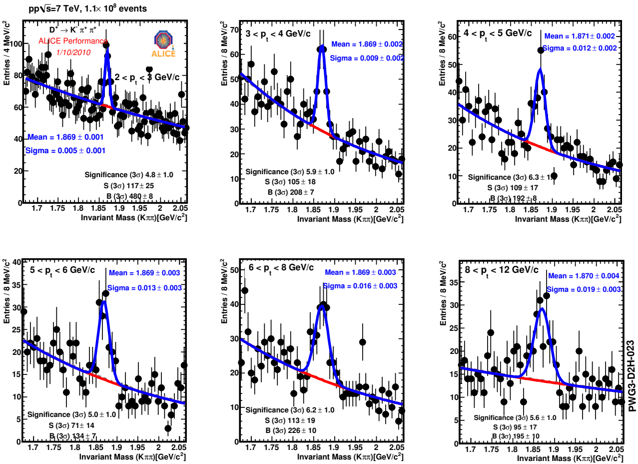
Raw Yields

$D^0 \to K^- \pi^+$



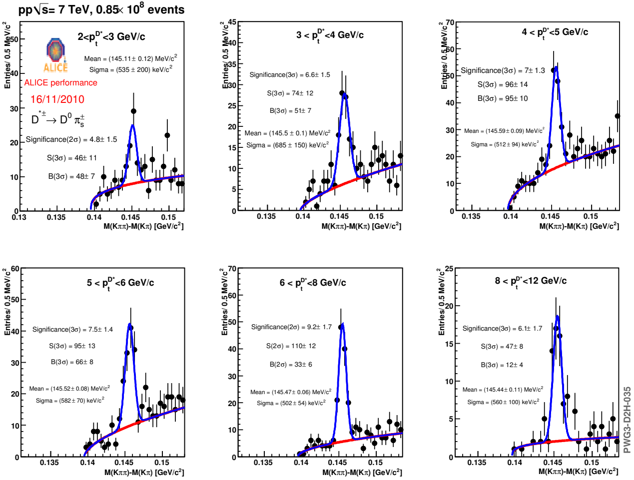
Raw Yields

$$D^+ \rightarrow K^-\pi^+\pi^+$$

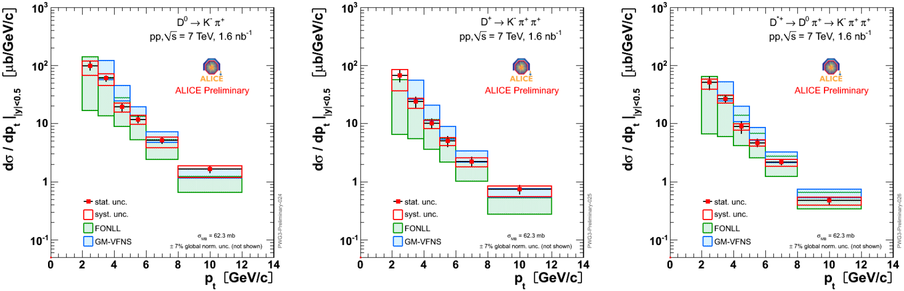


Raw Yields

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



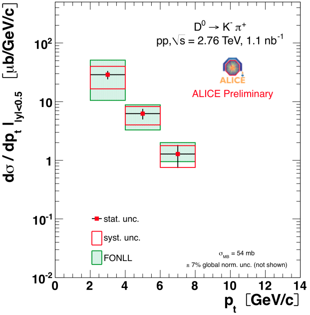
Cross section 7 TeV

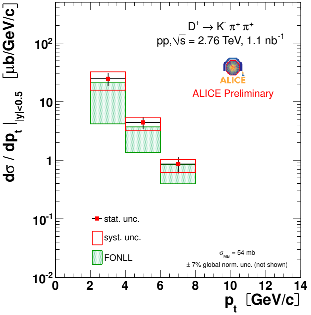


- $2 < p_t < 12$GeV/c with $1.6 nb^{-1}$ (∼20% of 2010 statistics); data rescaled to $|y| < 0.5$
- Feed down: B→D
  - Main method: use σ^{DfromB} from FONLL as input to estimate $f_c(p_t)$
  - Second method: FONLL input is the ratio of prompt to total D meson cross section
  - Envelope of the error bands from the two as a systematic error

FONLL: Cacciari et al., in preparation; GM-VFNS: Kniehl et al., in preparation

Cross section 2.76 TeV





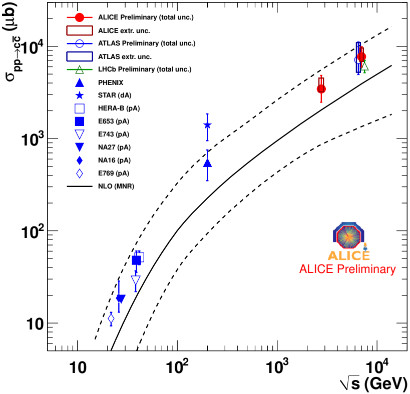
- $2 < p_t < 8\text{GeV}/c$
- $1.1 nb^{-1}$ (3 days of data taking!)
- data taken in $|y| < 0.8$, rescaled to $|y| < 0.5$
- pQCD predictions compatible with our data

FONLL: Cacciari et al., in preparation; GM-VFNS: Kniehl et al., in preparation

Total charm cross section

Combining the cross sections of the different mesons:

$$\sigma_{c\bar{c}}(ALICE, 2.76\,TeV) = 3.45 \pm 0.41(\text{stat})^{+0.72}_{-0.84}(\text{syst}) \pm 0.17(\text{lum})^{+1.09}_{-0.24}(\text{extr})\text{mb}$$
$$\sigma_{c\bar{c}}(ALICE, 7\,TeV) = 7.73 \pm 0.54(\text{stat})^{+0.74}_{-1.48}(\text{syst}) \pm 0.44(\text{lum})^{+1.90}_{-0.87}(\text{extr})\text{mb}$$

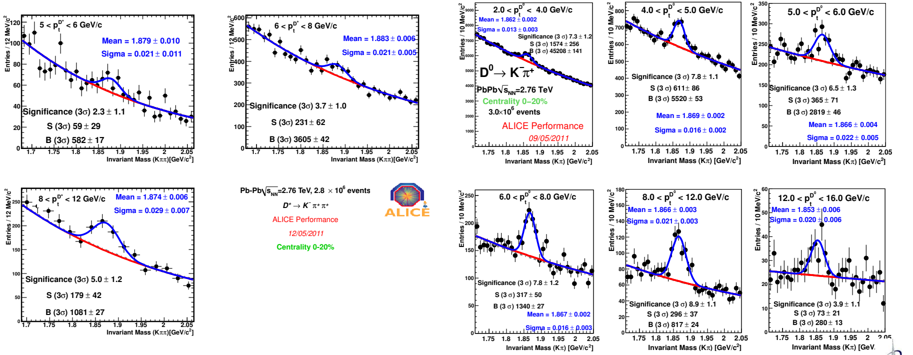


- Extrapolation from $p_t > 2$ GeV/c down to $p_t \sim 0$ and to full y using FONLL, fragmentation ratios from PDG
- Comparison with NLO is consistent within 3 orders of magnitude
- Good agreement between ALICE, ATLAS and LHCb results

Outline

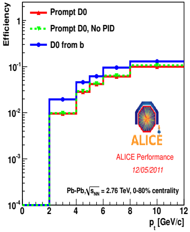
Candidates selection in PbPb

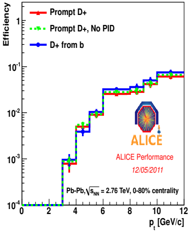
- The analysis strategy is similar in PbPb and pp
- Huge combinatorial background is the main difference
- Centrality selection: Glauber model from large-η V0 scintillatores amplitudes



PbPb, $\sqrt{s_{NN}} = 2.76$ TeV, central (0-20%) collisions, 2.8(D^+)/3(D^0) million events

Efficiency and feed-down



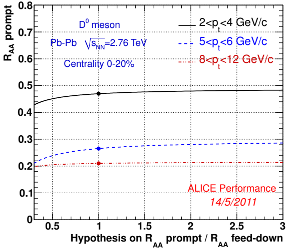


Efficiency reconstruction ranges from 1 to 10% (but it's larger for D from B)
PID efficiency close to 1
Efficiencies are evaluated from MC simulations

- Detector status and performance described to few % by the MC
- No centrality dependence

Feed-down

- Feed down from B-decays are 10-15% after selection cuts.
- Assumption on their energy loss is needed. Our choice: $\frac{1}{3} < \frac{R_{AA}^{D}}{R_{AA}^{B}} < 3$
- Maximum uncertainty: $\sim 15\%$

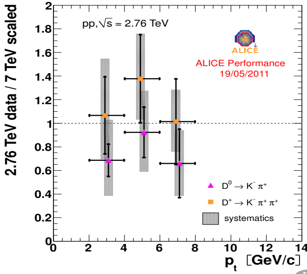


Reference scaling

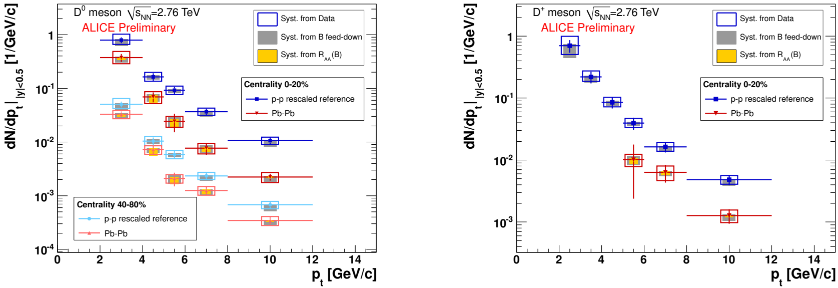
The statistics we have from the 2.76 TeV run is not enough to have a reference for the D meson R_{AA}.

We have rescaled the $\sigma_{pp}(p_t; 7\,TeV)$ to the value at 2.76 TeV using FONLL, with full theoretical uncertainty

- Relative scaling uncertainty goes from 25% ($p_t = 2$ GeV/c) to 10% ($p_t = 10$ GeV/c)
- Assumptions: pQCD scales; quark masses does not depend on the energy
- Rescaled 7 TeV data are compatible with measured 2.76 TeV data both for D^+ and D^0

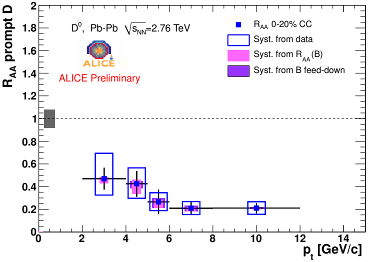


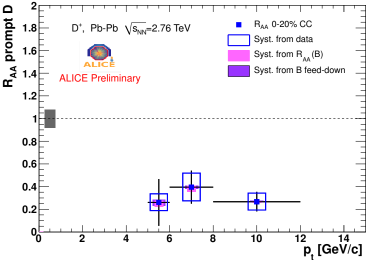
D mesons distributions



- Strong suppression observed in central (0-20%) PbPb collisions with respect to the scaled pp reference
- Significant suppression also seen between semiperipheral (40-80%) PbPb collisions and the scaled pp reference

Nuclear modification factors of D^0 and D^+ in 0-20%

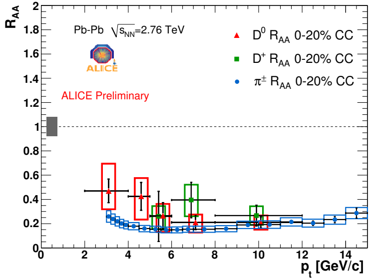




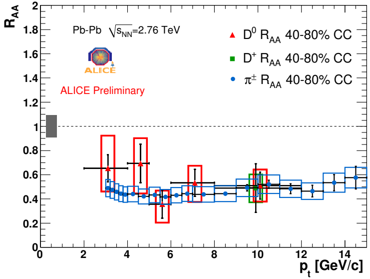
Suppression for charm is a factor 4-5 Above 5 GeV/c

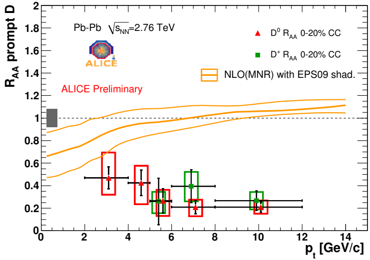
Charmed and light hadrons

Central (0-20%)



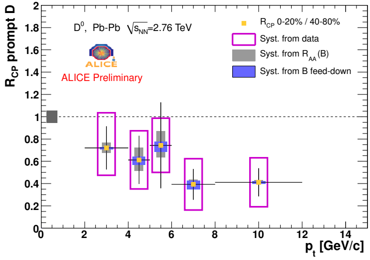
Peripheral (40-80%)

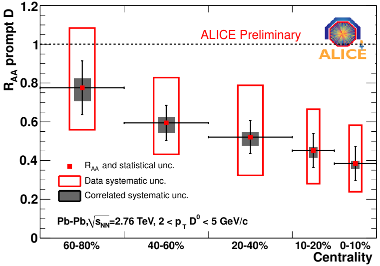




- Suppression for charm is compatible to the one of pions for $p_t > 5$ GeV/c
- Slightly less below ⇒ Possible hint for $R^D_{AA} > R^{\pi}_{AA}$ (color charge effect)?
- No shadowing is expected in this p_t range, hot medium effect

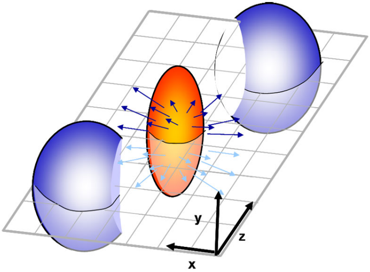
Central vs peripheral





- Suppression clearly seen in R_{cp}
- factor 2-3 above 5 GeV/c
- Clear centrality dependance → medium effect

Charm flow analysis



At midrapidity dominant contribution to the azimuthal distribution of the particles are even armonics

$$\frac{1}{N}\frac{dN}{d\Delta\phi} = 1 + 2v_2\cos(2\Delta\phi) + \ldots$$

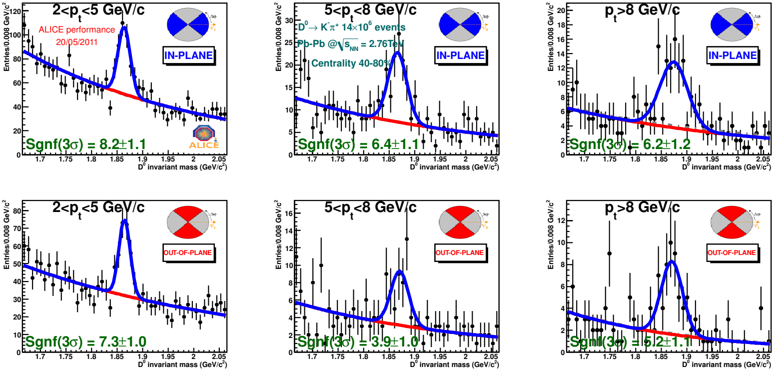
$$\Delta\phi = \phi_{particle} - \Phi_{Eventplane}$$

HF elliptic flow v_2 is strongly related to the degree of thermalization of the medium

We are planning to measure v_2 with 2 different methods:

- Measure the invariant mass distributions in bins of $\Delta\phi$ and p_t and extract the v_2 from azimuthal asymmetries
- Use Scalar products from well $|\eta|$ separate subevents

D^0 Distributions in azimuthal bins - 40-80% centrality class



- Statistics is a real challenge for this analysis
- Only D^0 is clearly visible from the current set of data
- v_2 estimation is ongoing
- Looking forward for a clear signal from 2011 PbPb run!

Conclusions and outlook

pp collisions

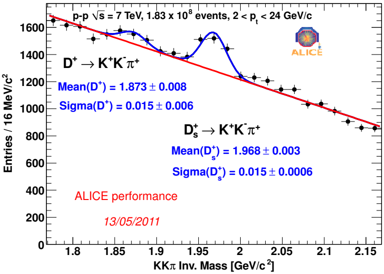
- The production cross section of charm has been measured at 2 different system energies
- Our data are well described by pQCD predictions for $2 < p_t < 12$ GeV

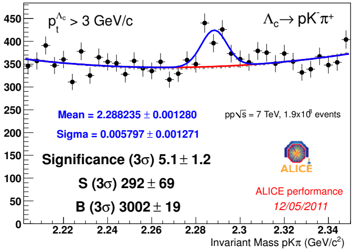
PbPb collisions

- Strong suppression observed in central PbPb collisions, vanishing towards peripheral
- Suppression is visible in a p_t range with very small initial state effects
- First challenging analysis of D meson flow is ongoing

BACKUP

Rare channels D_s^+ and Λ_c

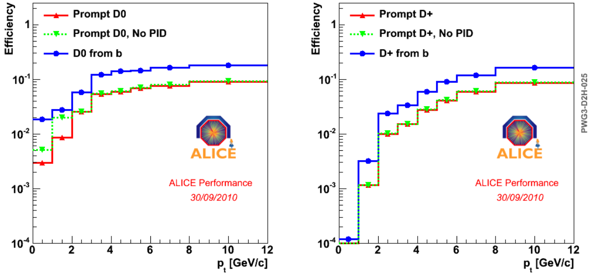




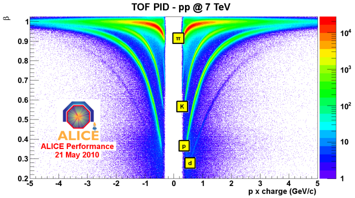
Extracting the Cross Section

Corrections are needed in order to be able to calculate the cross section:

1. Correction for the efficiency
   - from 1% to 10% increasing with p_t
   - factor 2 larger for mesons coming from B decay
2. Correction for feed down from B
   - $\sim$ 20%
   - Done using FONLL predictions for now, will be done based on data when we have more statistics



PID

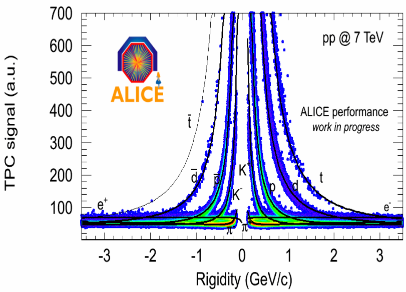


TOF

Particle identification based on mass hypothesis compatibility with the measured time TOF - T0.

TPC

Particle identified if its energy loss is compatible with Bethe-Block prediction.



K ID in TPC and TOF is powerful in rejecting background at low p_t.