D meson nuclear modification factors in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV, measured with ALICE detector

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on behalf of the ALICE Collaboration

QUARK MATTER
ANNECY 2011

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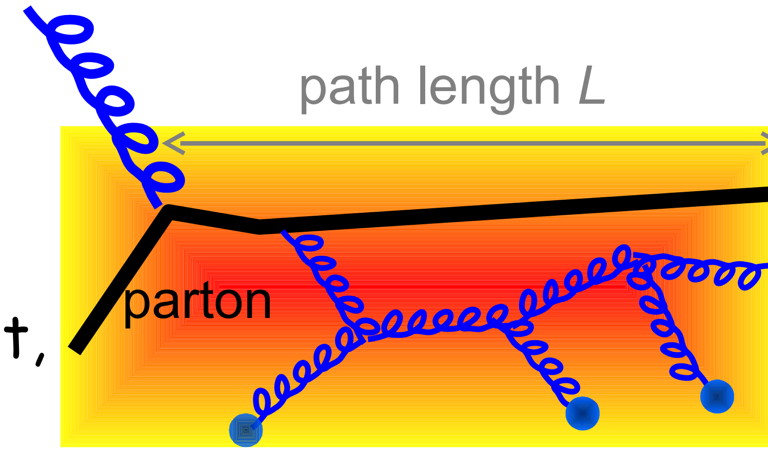
  - Signal extraction for D^0 and D^+ in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV
- D^0 and D^+ R_{AA} as a function of p_t (2-12 GeV/c) and collision centrality

Heavy quarks in heavy ion collisions



- Heavy quarks are produced at the beginning of the collisions (high Q^2)
- Pass through the medium and interact with it, loosing energy

→ Test QCD models describing in-medium partonic energy loss
  - color charge (Casimir factor)
  - parton mass (Dead cone effect)
  - medium density and size

$$\Delta E_g > \Delta E_{u,d,s} > \Delta E_c > \Delta E_b$$

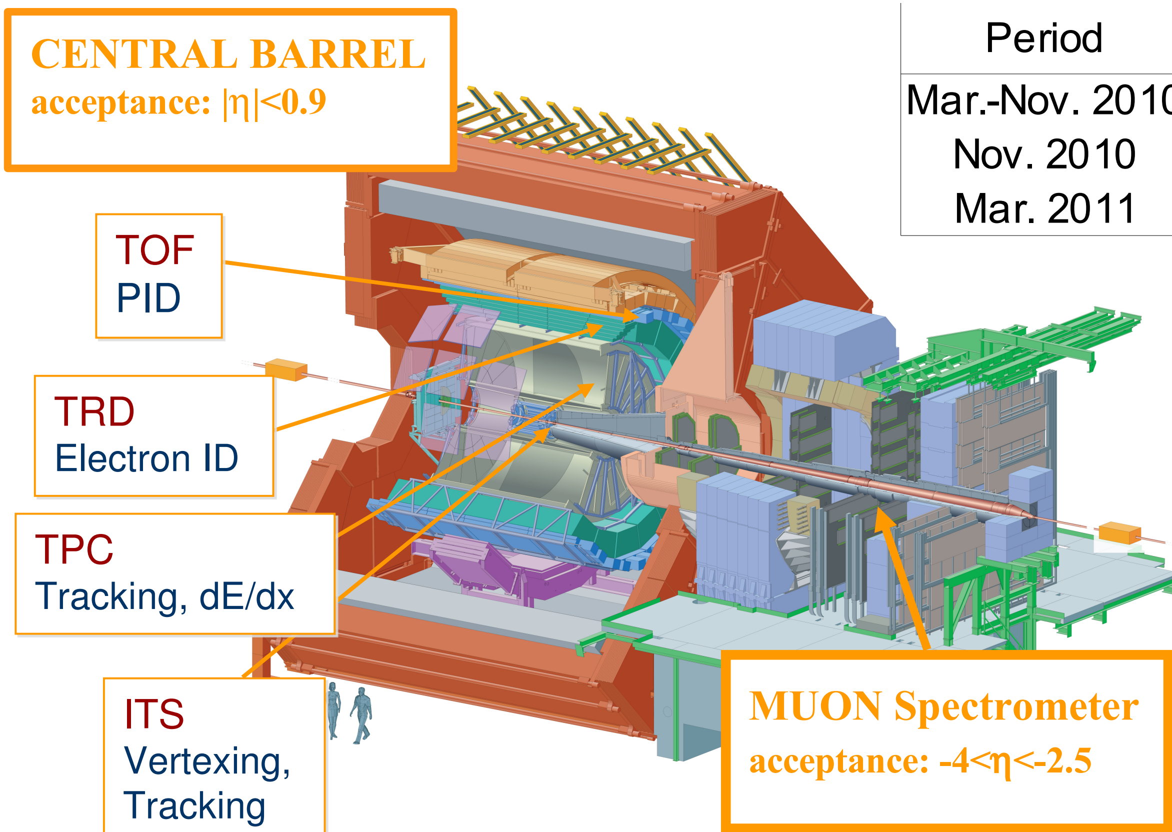
→ Compare light partons/heavy flavour observables ⇒ $R_{AA}^{\pi} < R_{AA}^{D,B}$

→ Probe medium properties

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

Need to separate D and B $R_{AA}^{\pi} < R_{AA}^{D} < R_{AA}^{B}$

The ALICE detector and data samples



Period	System	$\sqrt{s_{NN}}$ (TeV)	Stat. anal.(ev.)
Mar.-Nov. 2010	pp	7	$\sim 1.0 \times 10^8$
Nov. 2010	Pb-Pb	2.76	$\sim 1.7 \times 10^7$
Mar. 2011	pp	2.76	$\sim 6.5 \times 10^7$

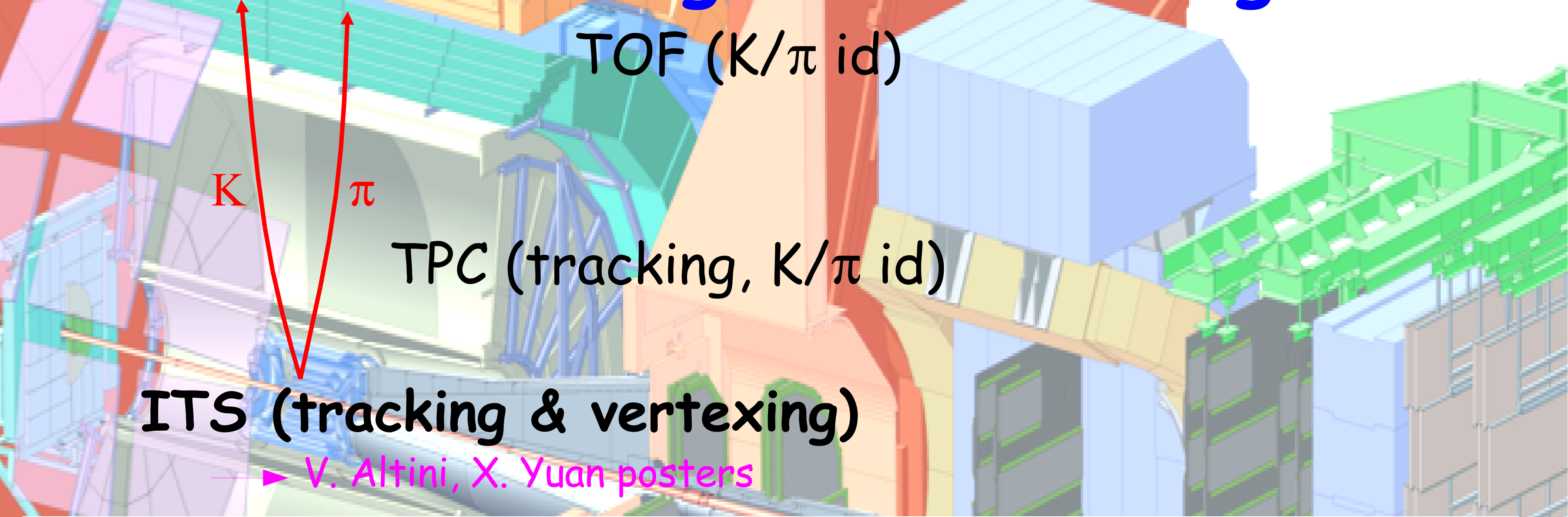
Minimum Bias Trigger based on pixels and V0 scintillator hodoscopes

Centrality selection based on a geometrical-Glauber model fit of the V0 amplitude (correlated with forward track multiplicity)

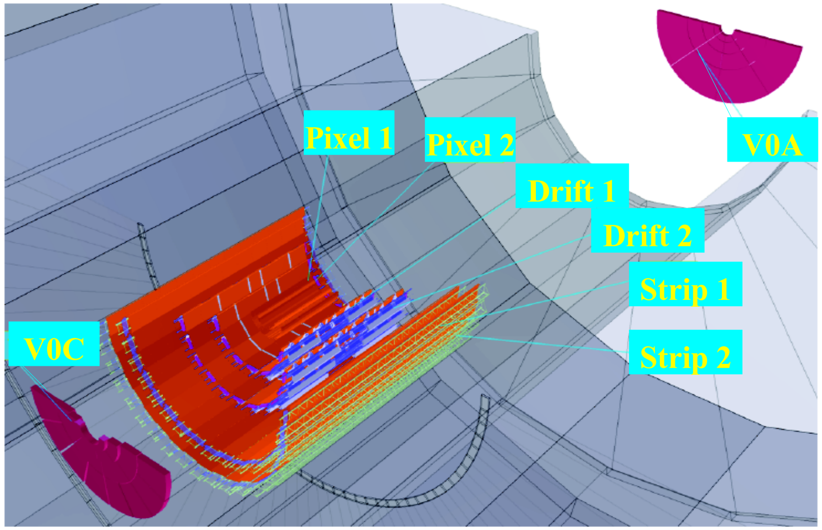
→ see J. Schukraft talk on 23rd May

→ see A. Toia talk on 24th May

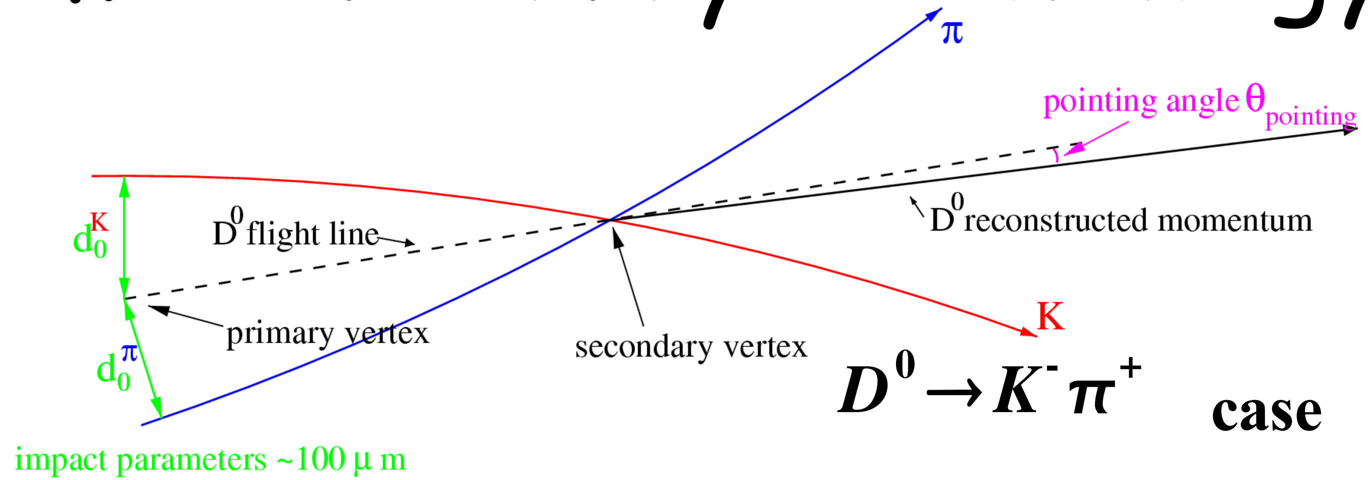
$D^0 \to K^- \pi^+$ and $D^+ \to K^- \pi^+ \pi^+$: a challenge for tracking and vertexing



- 6 layer of silicon detectors
  - 2 pixels, 2 drift, 2 strips
- 2198 modules with intrinsic precision at the level of tens of micron
- detector aligned with cosmics (see 2010 JINST 5 P03003) and pp: crucial for results that will be shown



D mesons: analysis strategy



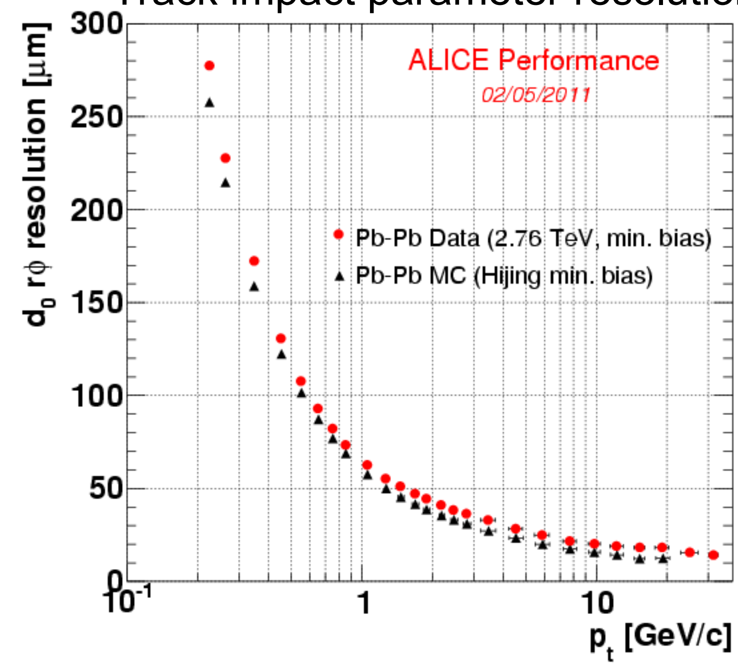
Main selection strategy (common to pp and PbPb):

Displaced secondary vertices topology (-> ITS)

- (e.g. $D^0 \to K^- \pi^+$) : pair of opposite charge tracks with large impact parameters
- good pointing of reconstructed D momentum to the primary vertex

PID selection (TOF+TPC) to reduce background (mainly via K identification)

Track impact parameter resolution

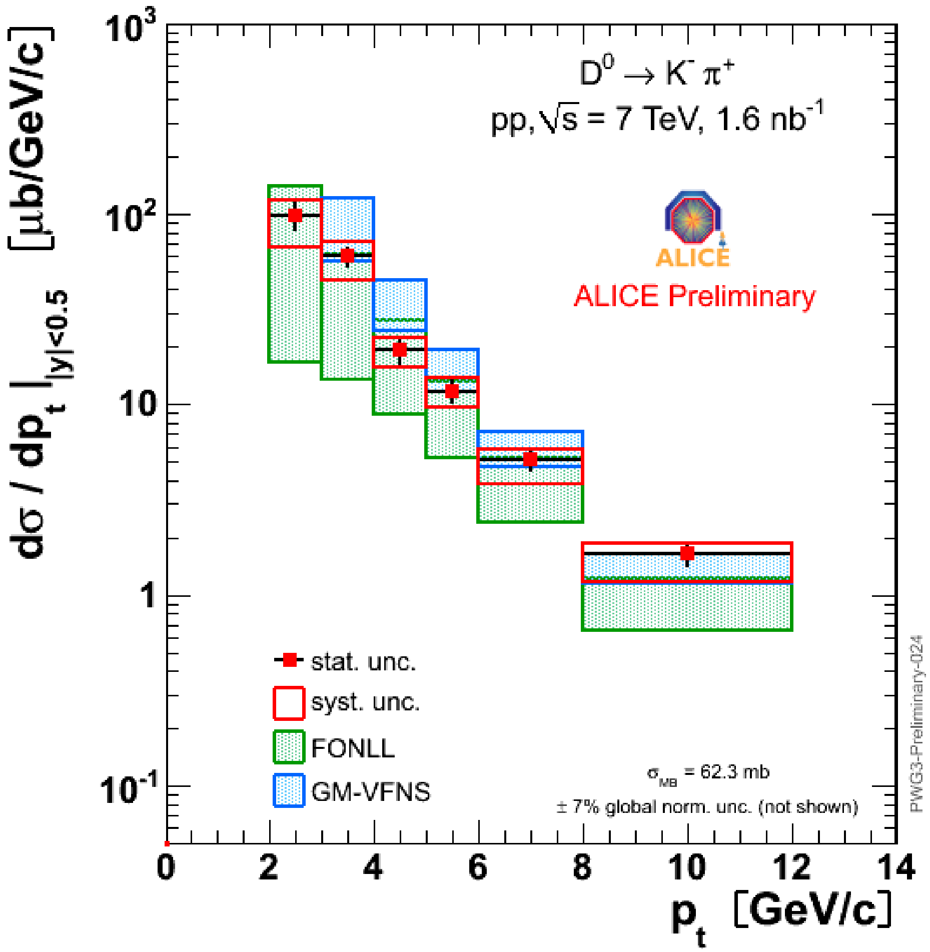


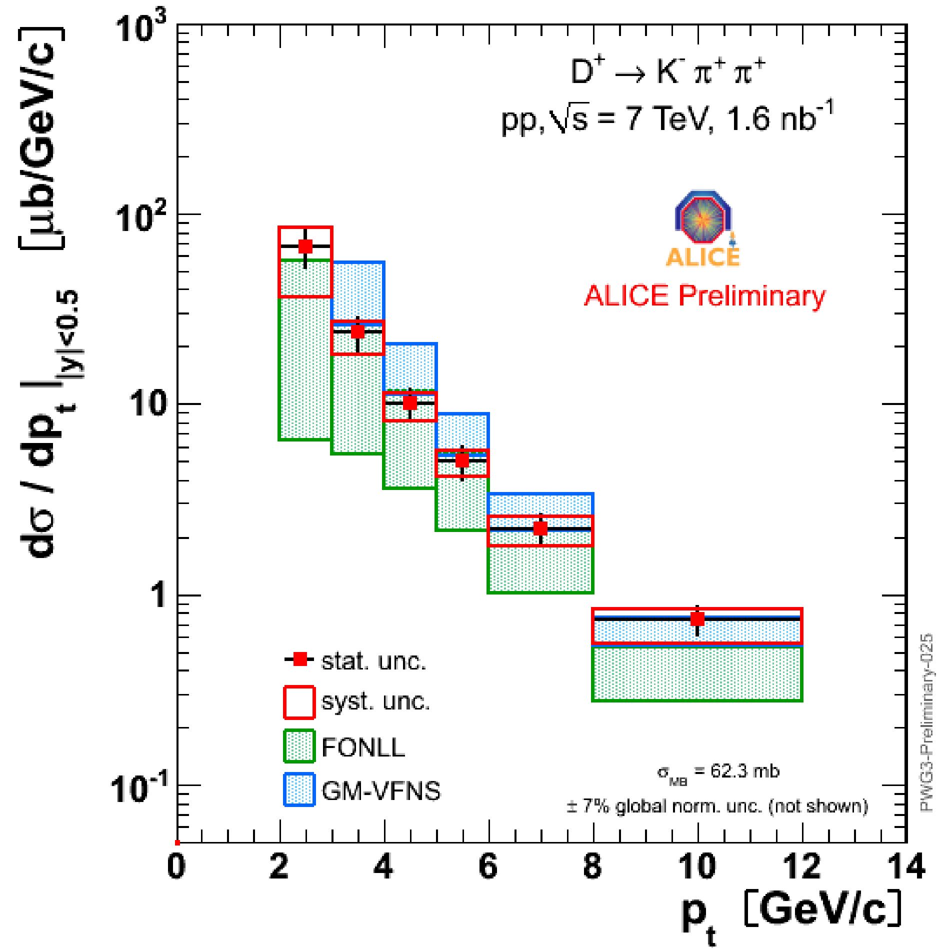
→ **Invariant mass analysis**

Ingredients from pp analyses

D^0 and D^+ cross-section in pp at 7 TeV in |y|<0.5

→ posters by R. Bala, C. Bianchin, A. Grelli



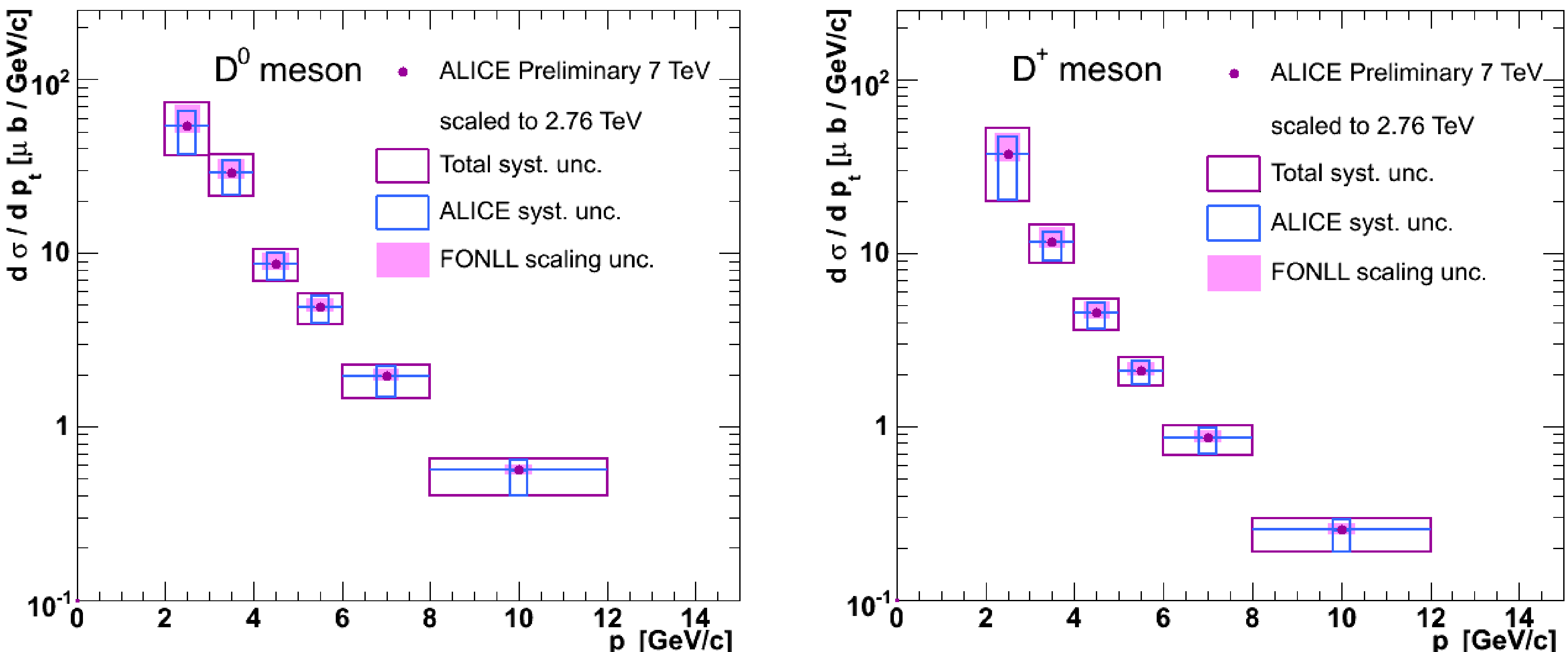


Data well described by pQCD predictions

Scaling from 7 to 2.76 TeV

→ poster by Z. Conesa del Valle

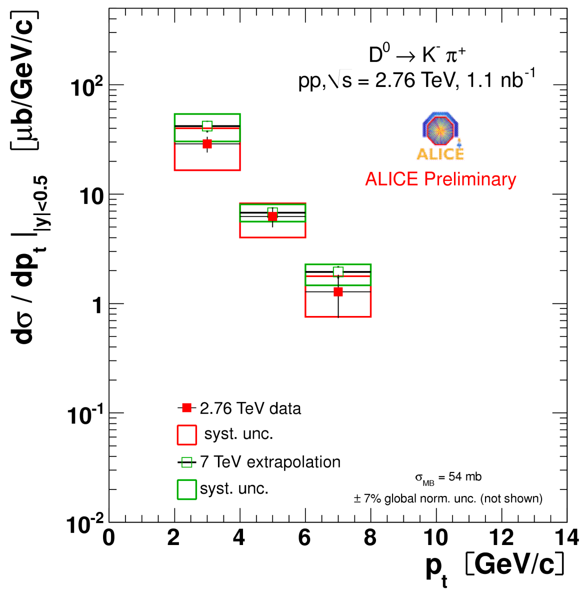
Ratio of FONLL predictions for D production at 2.76 and at 7 TeV used to scale ALICE measurement at 7 TeV down to 2.76 TeV



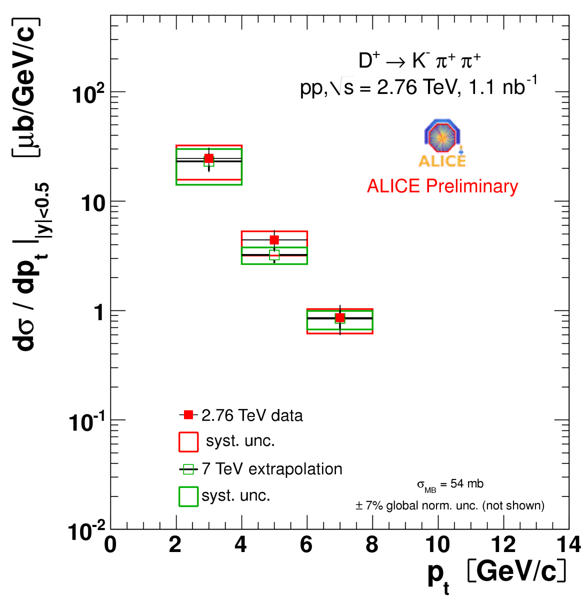
scaling uncertainty: from ~20% (low p_t) to 5% (high p_t)

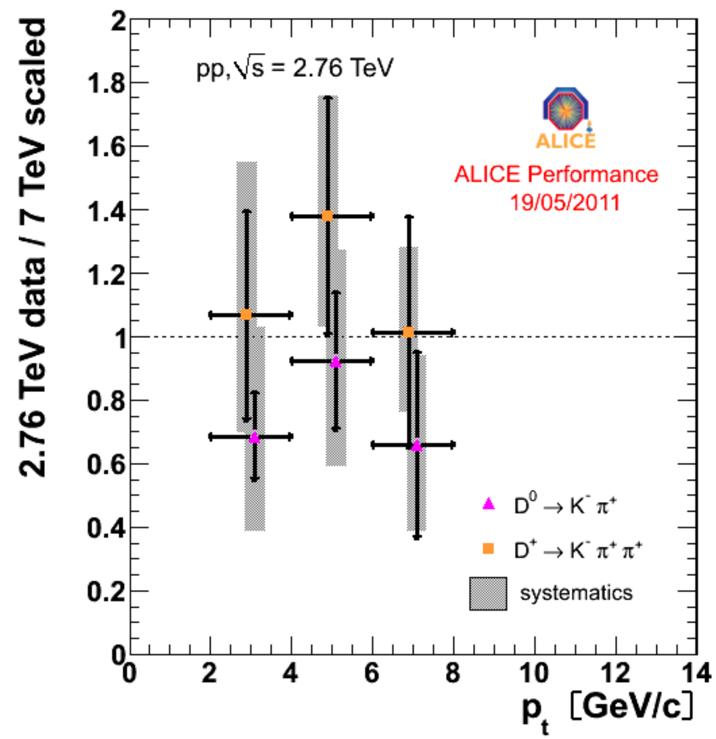
Scaling from 7 to 2.76 TeV Vs data

→ poster by Z. Conesa del Valle



Measured D^0 and D^+ cross section for pp collisions at $\sqrt{s}$=2.76 TeV compatible with scaling of 7 TeV data

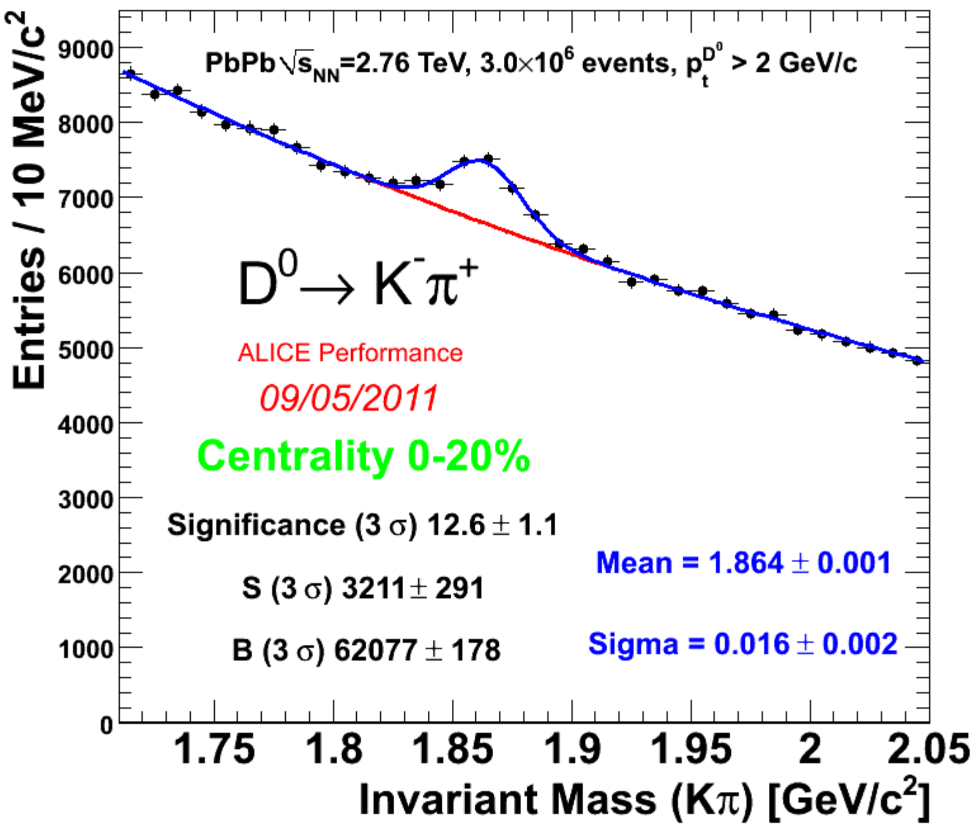


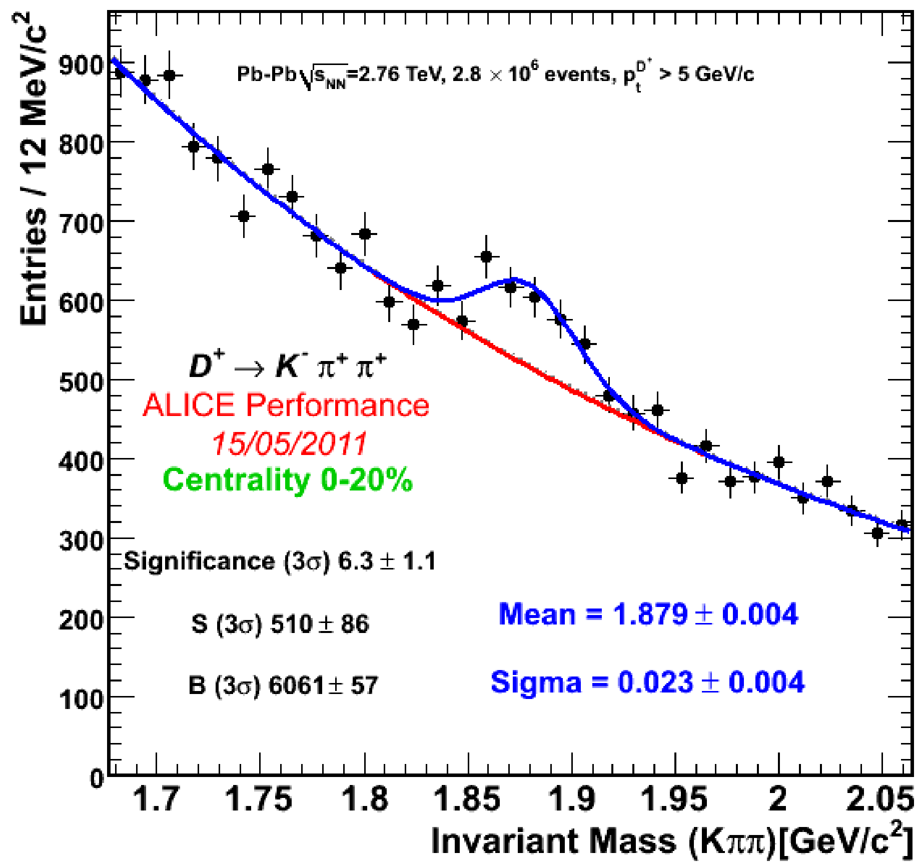


Pb-Pb results

D^0 and D^+ signals in Pb-Pb

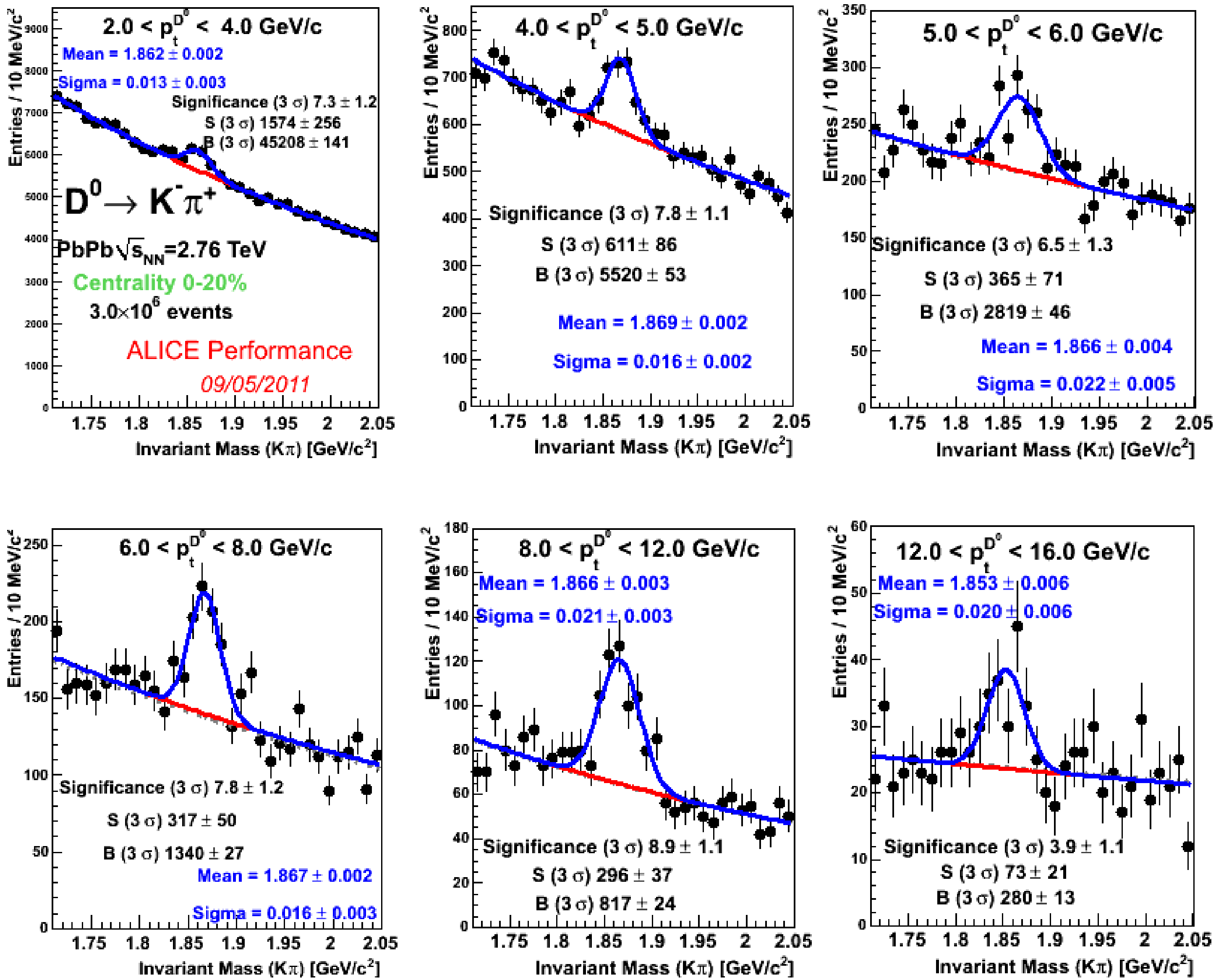
~3×10^6 Pb-Pb events at $\sqrt{s_{NN}}$=2.76 TeV in 0-20% centrality range





Down to p_t = 2 GeV/c, with significance >12

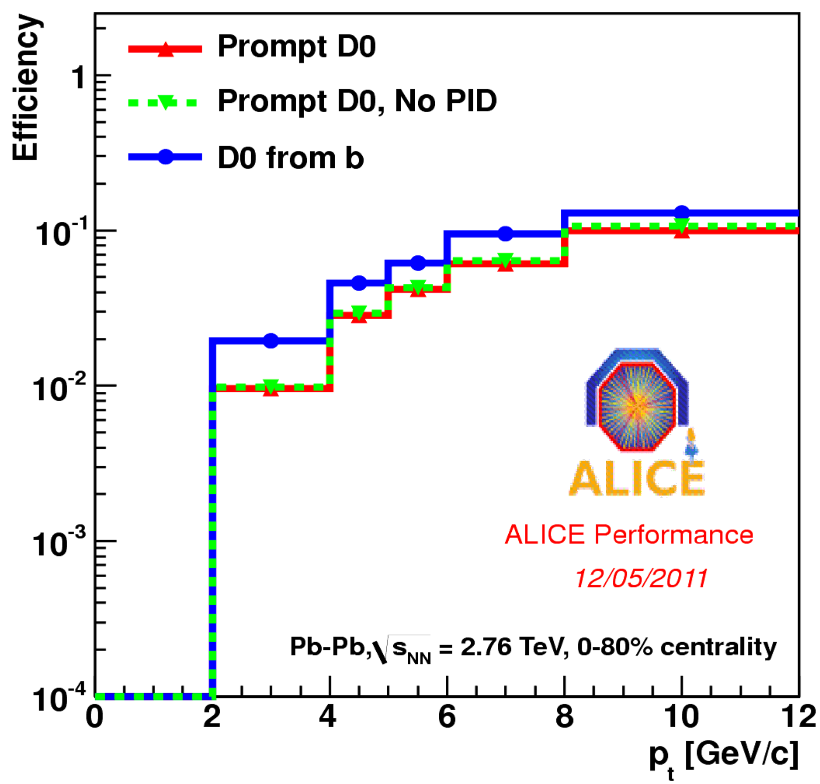
D^0 signals in Pb-Pb, in p_t bins



Acceptance and efficiency corrections

From MC simulation:

- HIJING + Pythia (D meson enriched)
- full description of detector status "run-by-run"
- Tracking efficiency in Si tracker measured from data

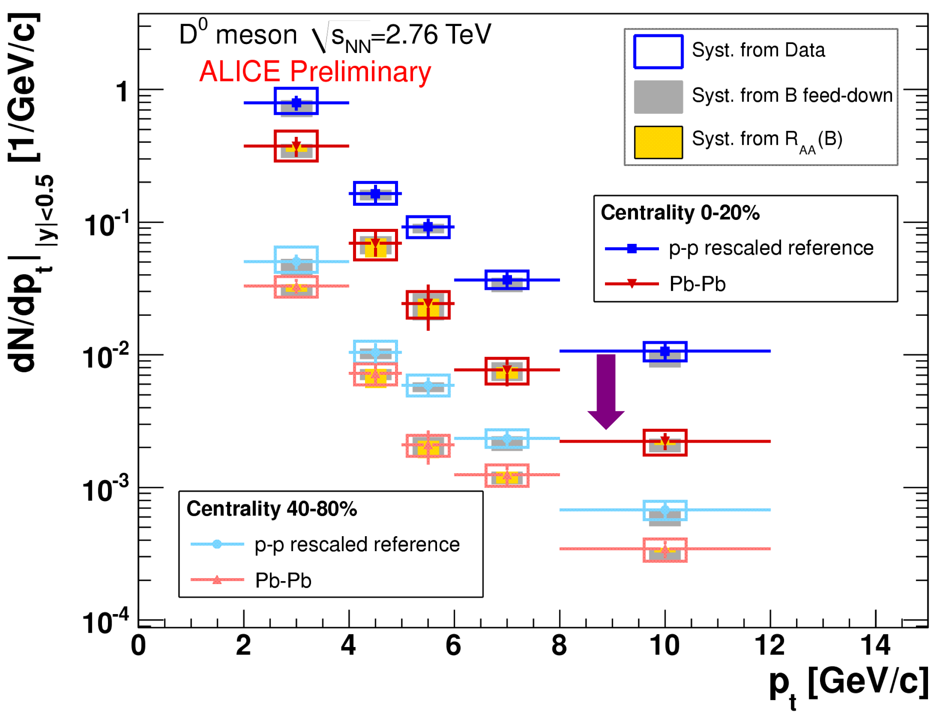


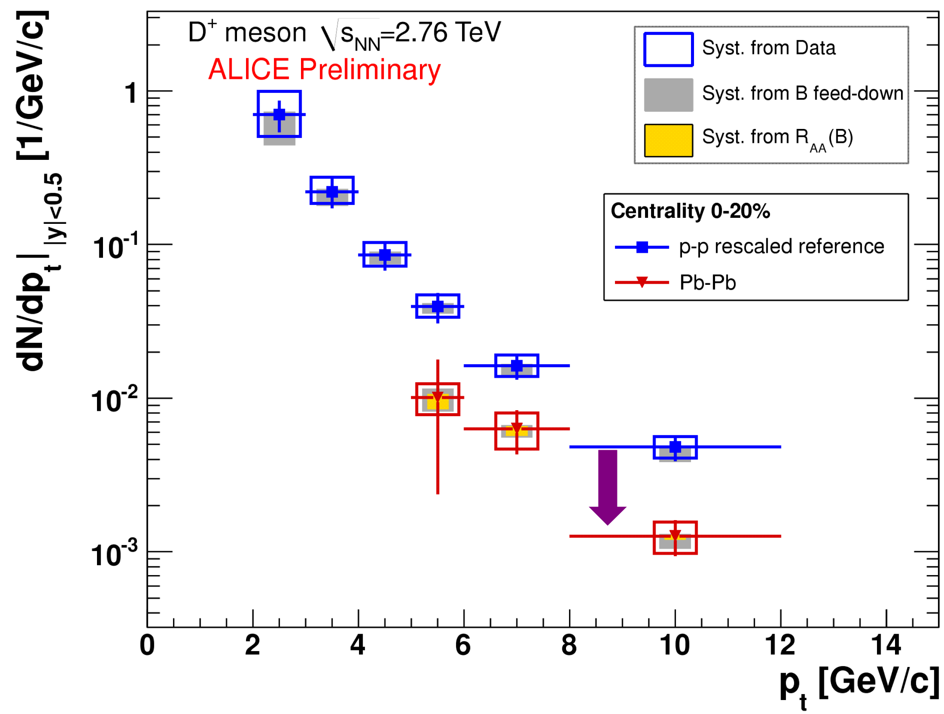
Detailed analysis of possible sources of systematic errors from MC corrections:

- <6% fraction of D meson with K/π tracks with a wrong cluster attached ("fake" tracks) after cut selection
- D meson p_t shape varied in MC
- data analysis repeated W/ and W/O PID, for particle and antiparticle alone, with different set of cuts

D^0 and D^+ spectra

→ posters by D. Caffarri G. Ortona



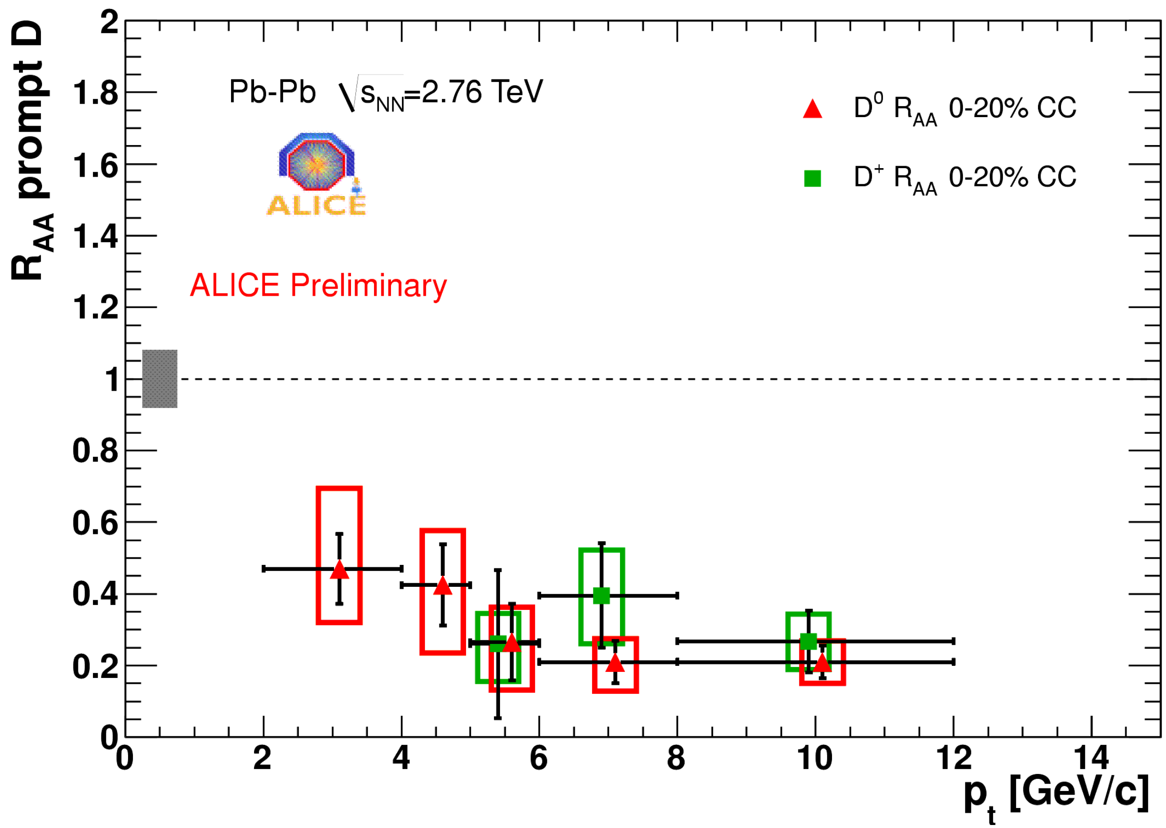


- **pp points**: cross-section at 7 TeV scaled to 2.76 TeV with FONLL and, multiplied by T_{AA} from Glauber model

Large suppression observed for open charm in Pb-Pb collisions!

D^0 and D^+ suppressed by factor 4-5!

→ posters by D. Caffarri, G. Ortona



$$R^D_{AA}(p_t) = \frac{dN^D_{AA}/dp_t}{\langle T_{AA}\rangle \times d\sigma^D_{pp}/dp_t}$$

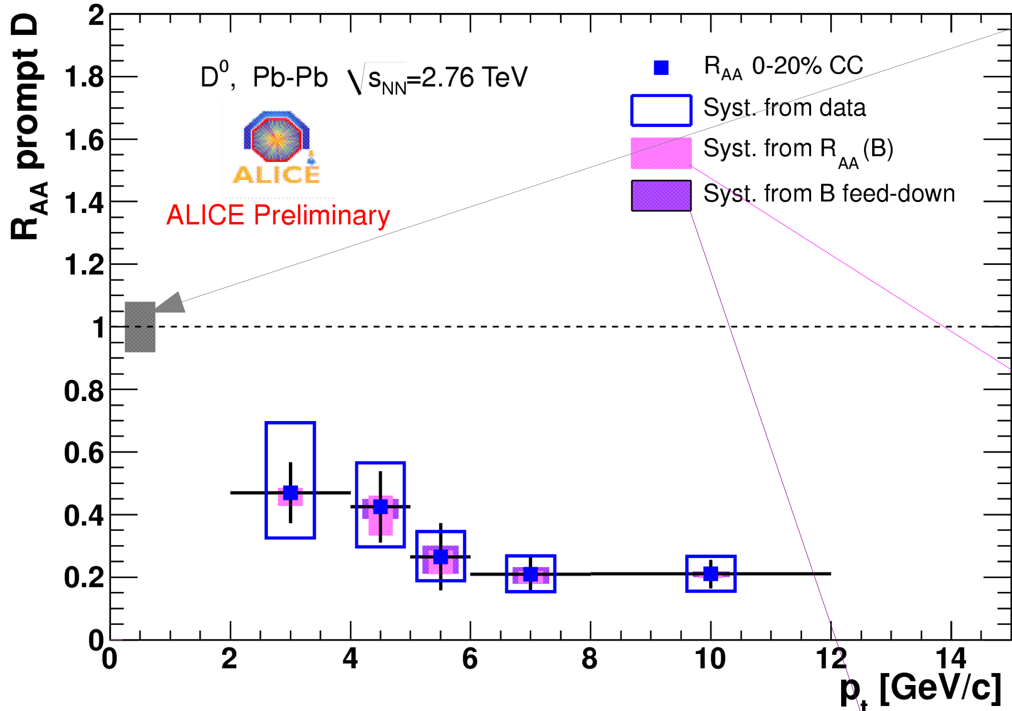
Glauber model

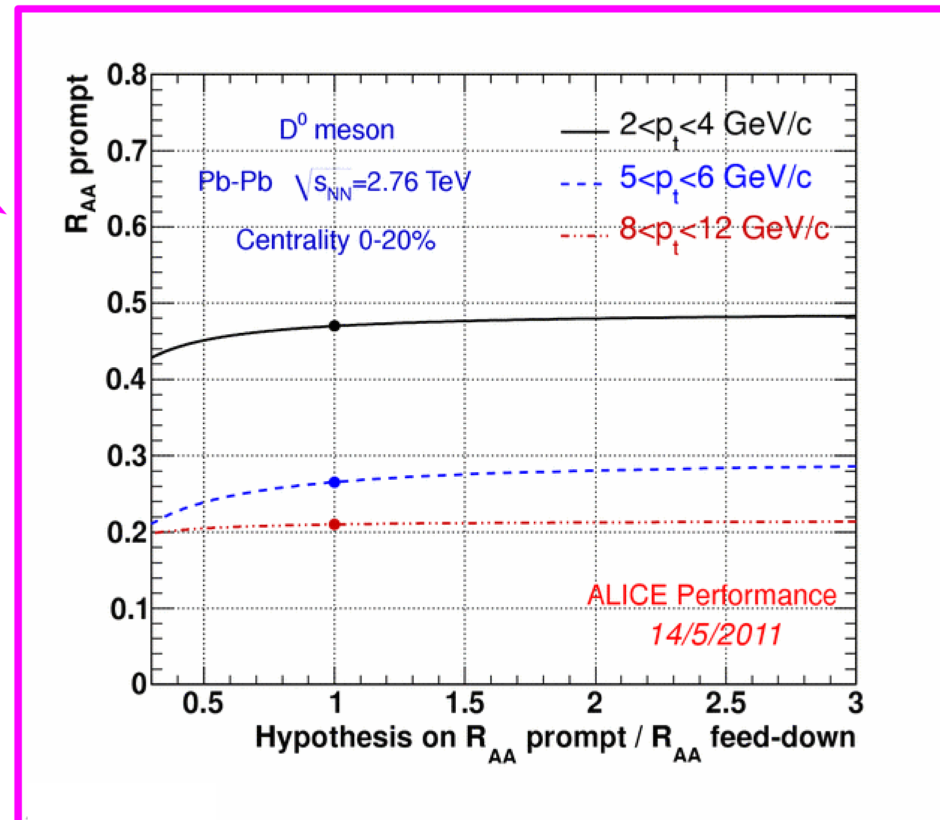
Large suppression observed for open charm in Pb-Pb collisions!

- factor ~ 4-5 for p_t>5 GeV/c
- smaller at lower p_t

$R_{AA}(D^0)$ results in central (0-20%) events

~8% normalization uncertainty (from σ(pp min. bias) at 7 TeV and T_{AA})



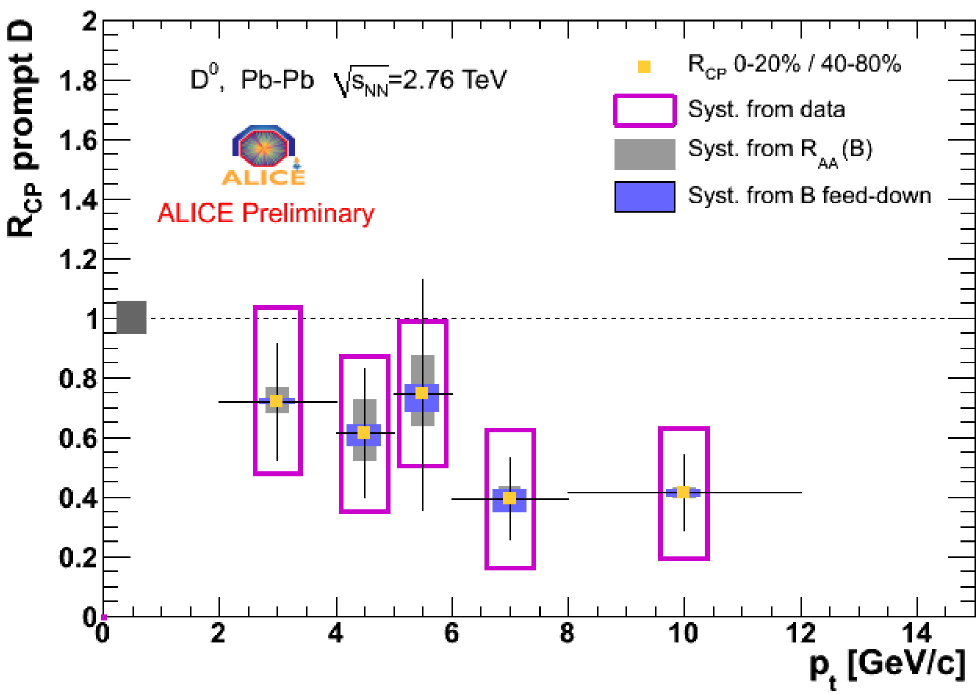


Blu Markers: $R_{AA}(D)/R_{AA}(B) = 1$

Syst. from feed-down correction via FONLL, partially cancels in the ratio

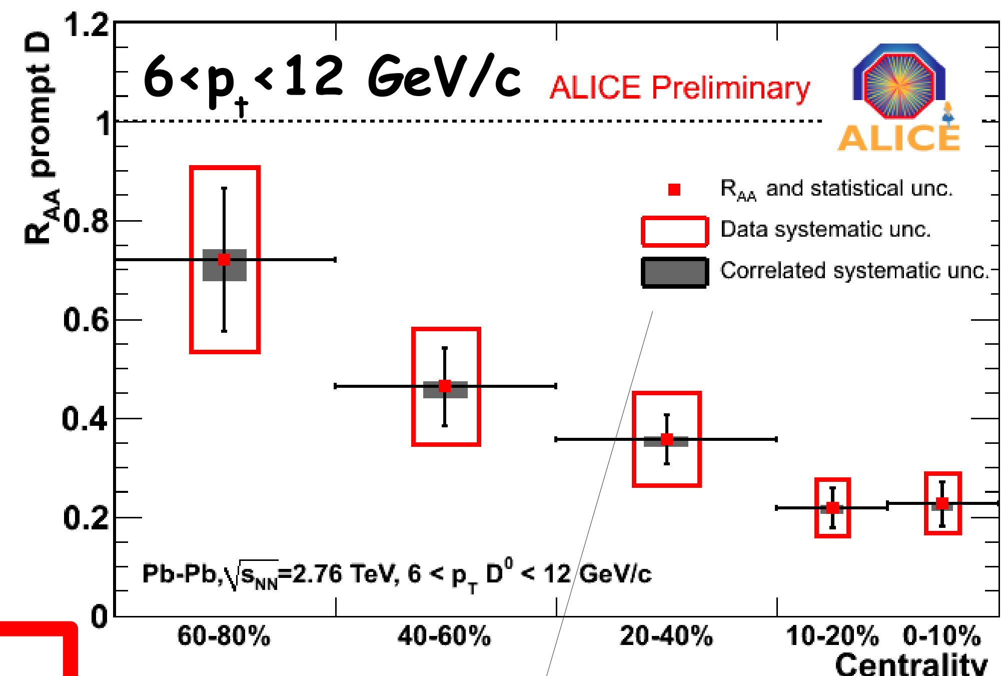
R_{CP} and dependence on the centrality

→ poster by D. Caffarri



D^0 R_{CP} (0-20%/ 40-80%)

D^0 R_{AA} VS centrality

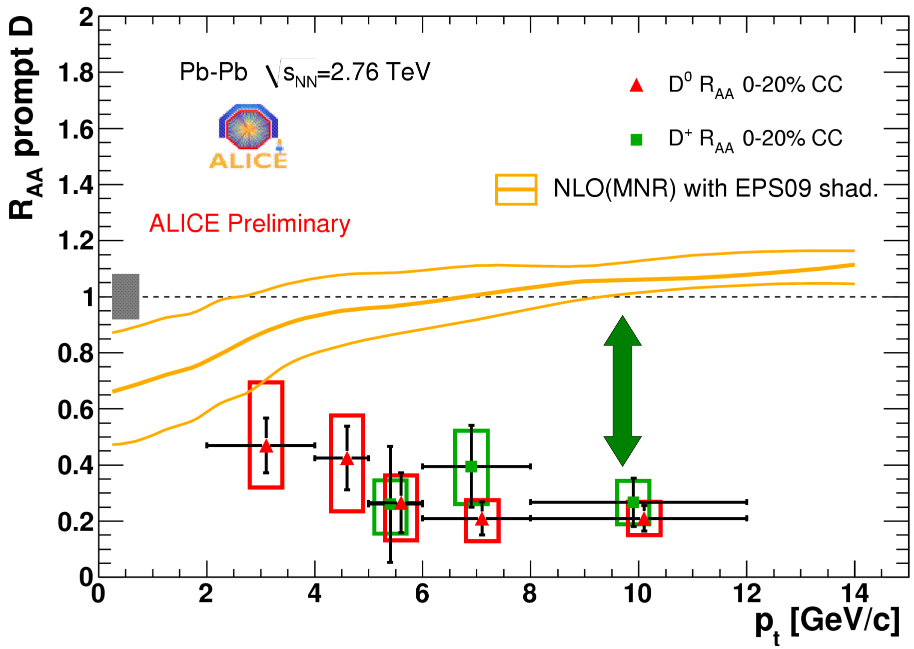


Normalization, feed-down, R_{AA}(B)

Relevant dependence from the centrality:

~0.7 in peripherals -> ~0.2 in central

Comparison with charged particles and with shadowing prediction



Comparison to **shadowing** predictions

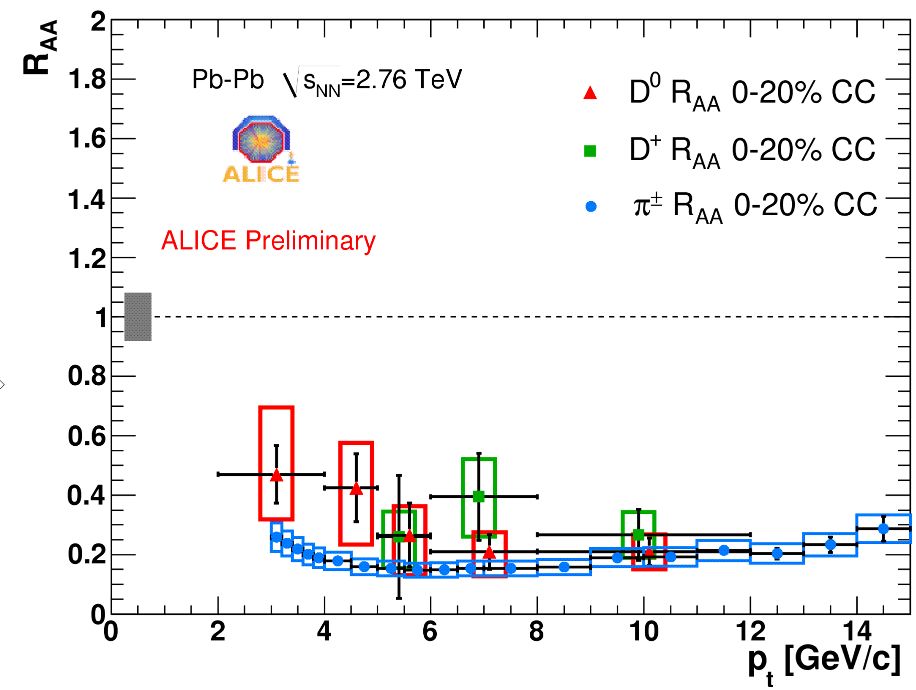
R_{AA}(D) <-Medium effect

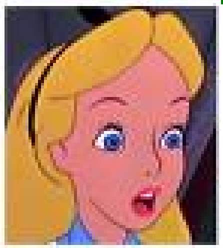
Comparison with **charged pions R_{AA}**

Compatible within errors

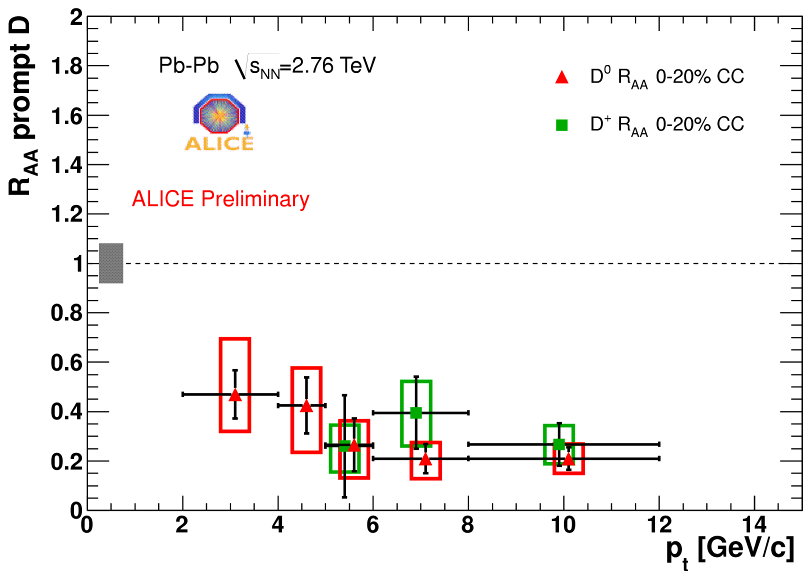
Very close at high p_t

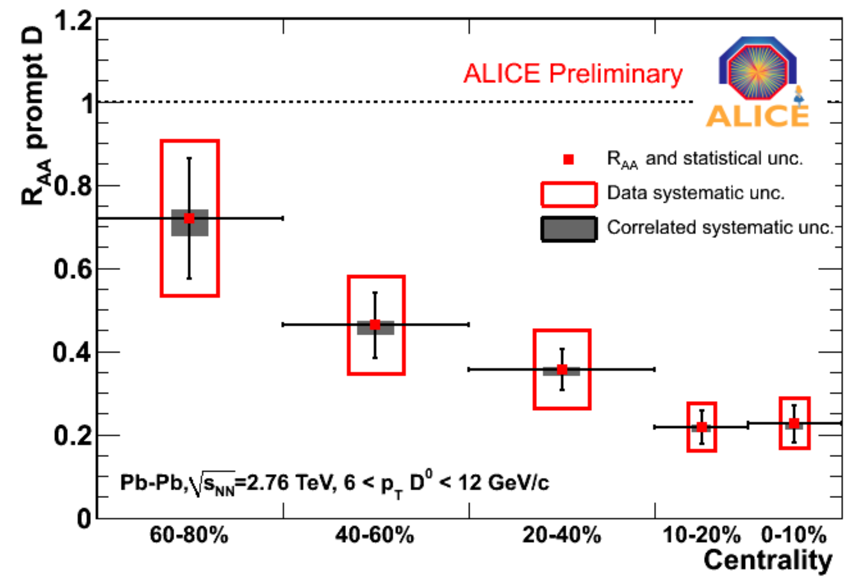
Hints of $R_{AA}^{D} > R_{AA}^{\pi}$ at low p_t





Summary





D meson R_{AA} measured:

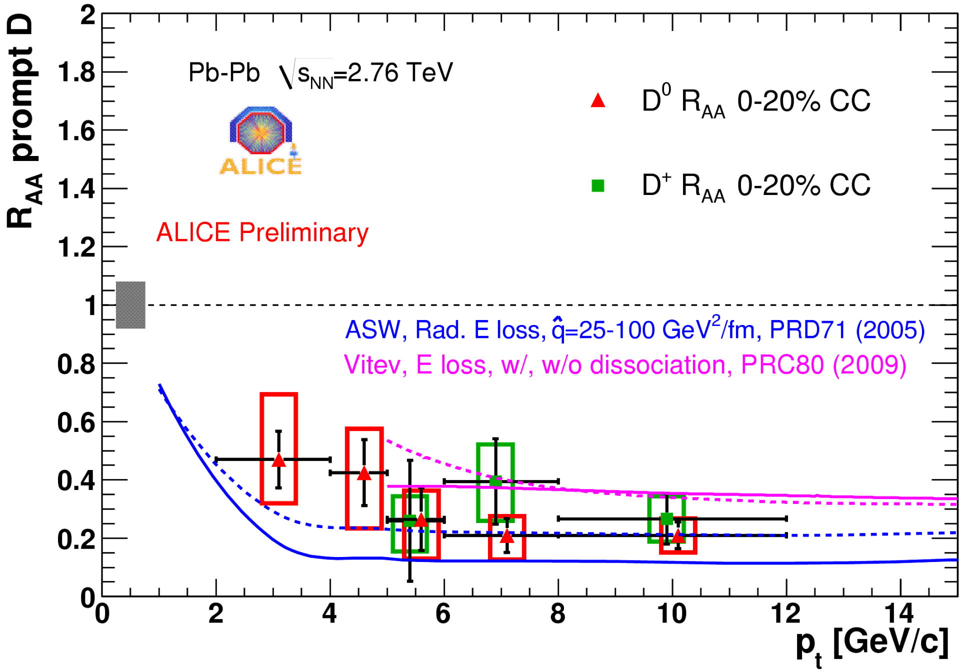
- suppression by a factor 4-5 in central events
- R_{AA} decreases with p_t (up to 12 GeV/c) in 0-20% central events
- medium effect
- at high pt D R_{AA} compatible within errors with charged tracks R_{AA}

Posters related to this talk

- R. Bala: "$D^+ \rightarrow K^- \pi^+ \pi^+$ Production in pp collisions at LHC with the ALICE detector"
- C. Bianchin: "D^0 meson production in pp collisions at the LHC with ALICE and prospects for charm flow measurements in Pb-Pb collisions"
- A. Grelli: "D meson production cross section in pp collisions at s = √7 TeV measured with the ALICE detector at LHC"
- Z. Conesa del Valle: "D mesons reference spectra at 2.76 TeV"
- D. Caffarri: "Charm R_{AA} in Pb-Pb collisions at LHC via $D^0 \rightarrow K^- \pi^+$ reconstruction in ALICE"
- R. Grajcarek: "Preparation for open charm elliptic flow measurement via D-meson decay to hadrons with ALICE"
- G. Ortona: "D^+ analysis in Pb-Pb collisions at $\sqrt{s}$ = 2.76 TeV at the LHC with ALICE"
- Y. Xian Bao: "ALICE vertexing performance and charm reconstruction"

Extra

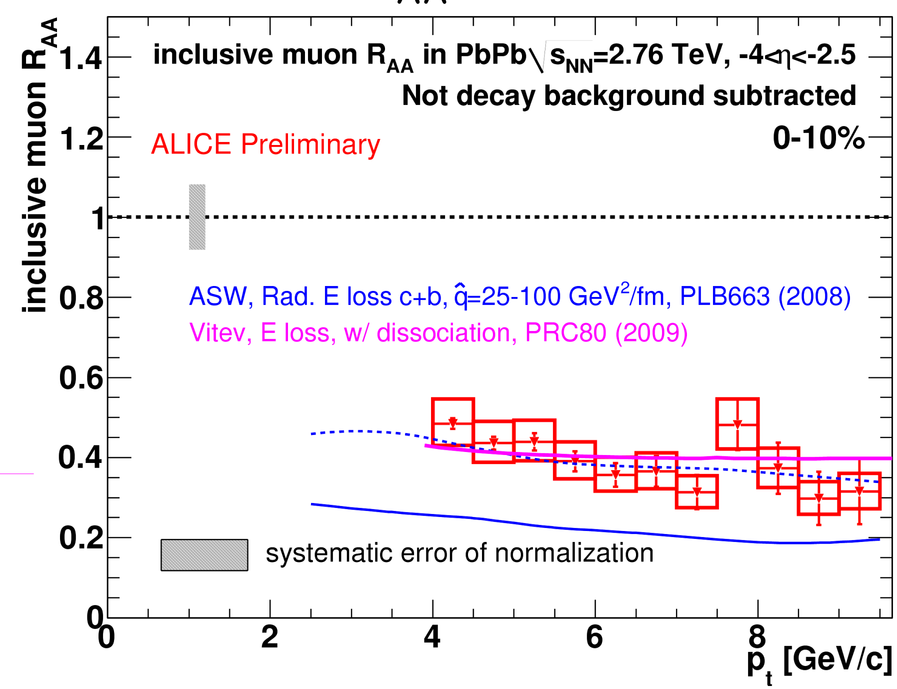
Consistency check



D meson R_{AA} in |y|<0.5

Comparison of D meson R_{AA} with and single-μ at forward rapidity with analogous calculation

single μ R_{AA} at -4<η<-2.5



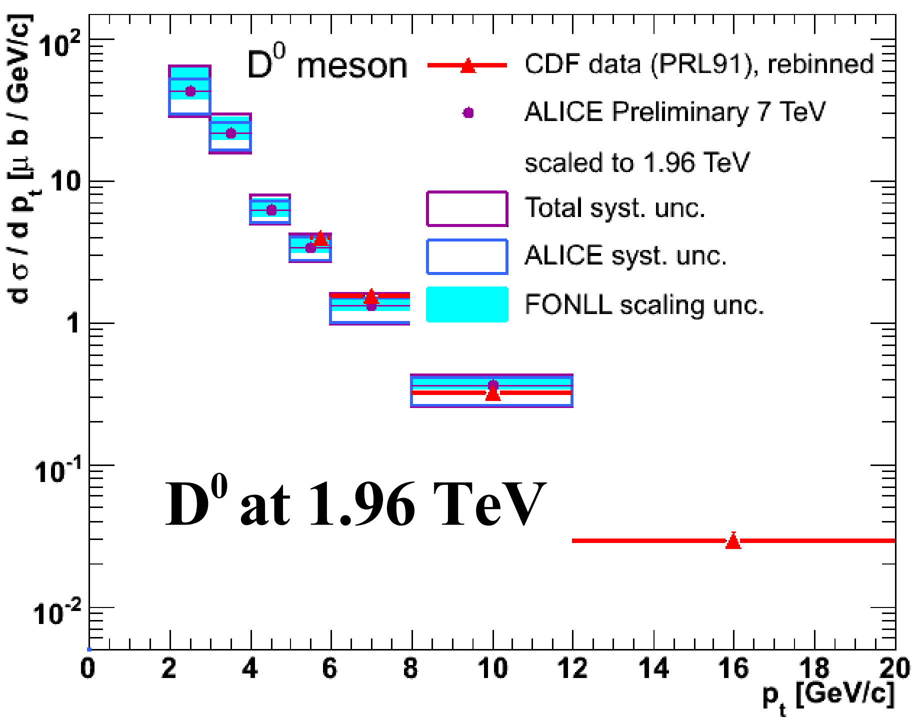
see X. Zhang talk on 23rd May

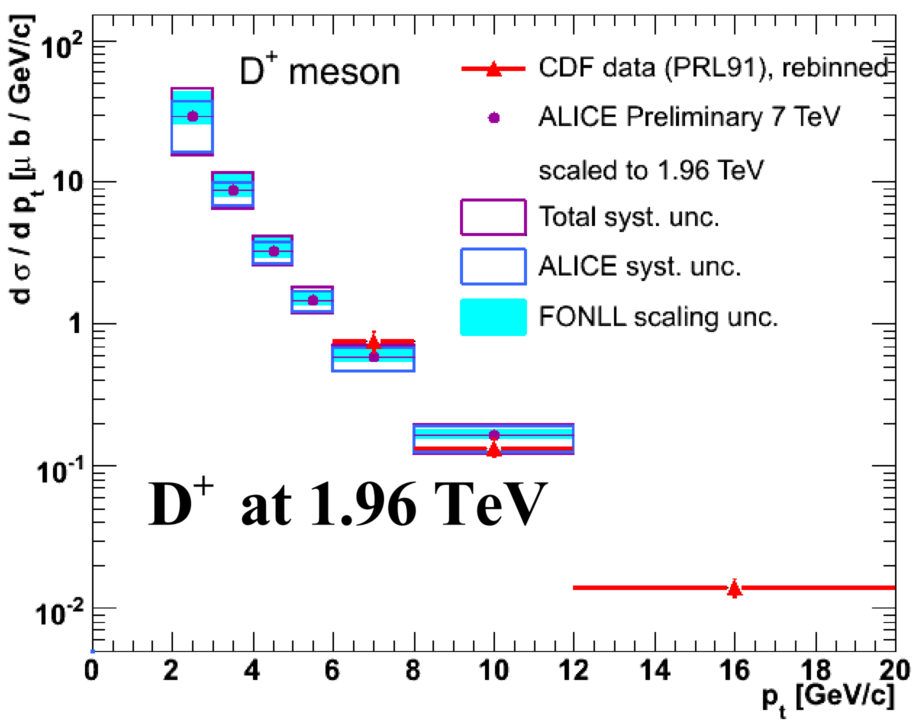
Scaling to CDF energy: more than a check of consistency

→ poster by Z. Conesa del Valle

Ratio of FONLL predictions for D production at 1.96 and at 7 TeV used to scale ALICE measurement at 7 TeV down to CDF energy

-> comparison of ALICE and CDF measurements





Feed down subtraction in PbPb

- Subtraction of secondary D from B needed to compute charm R_{AA} (prompt D)

→ Rely on FONLL predictions as done for the preliminary cross-section measured in pp collisions at 7 and 2.76 TeV

→ In PbPb an hypothesis on B mesons R_{AA} must be done

measured raw yield per central event

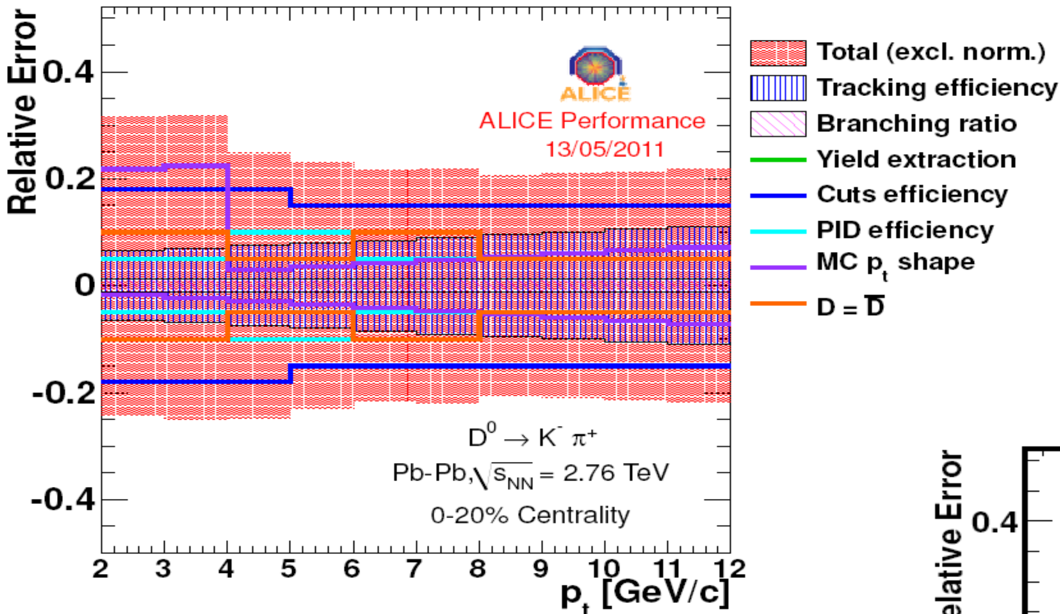
$$N^{\text{measured}}_{\text{prompt D+ D from B}}$$

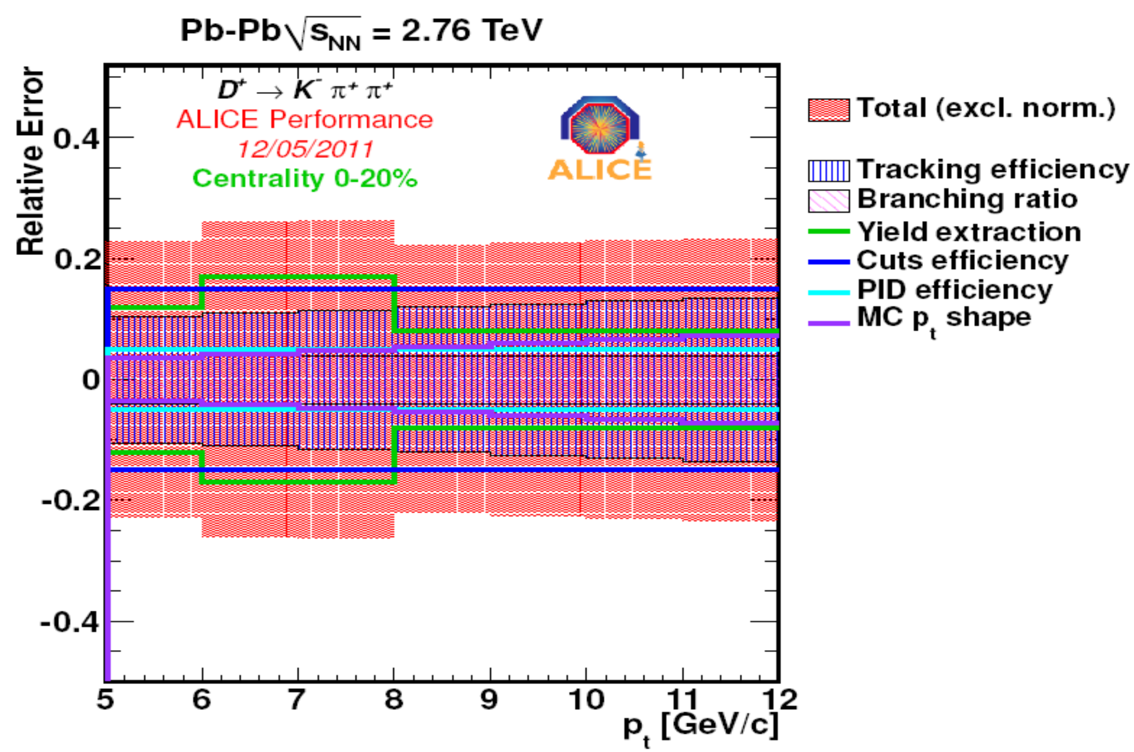
this is what we subtract

$$N^{\text{theory, uncorrected}}_{\text{D from B}} = \Delta p_t \times \epsilon_{\text{D from B}} \times \frac{dN^{\text{theory}}_{\text{D from B}}}{dp_t}$$

$$\frac{dN^{\text{theory}}_{\text{D from B}}}{dp_t} = R^{\text{D from B}}_{AA} \times T_{AA} \times \frac{d\sigma^{\text{pp,theory}}_{\text{D from B}}}{dp_t}$$

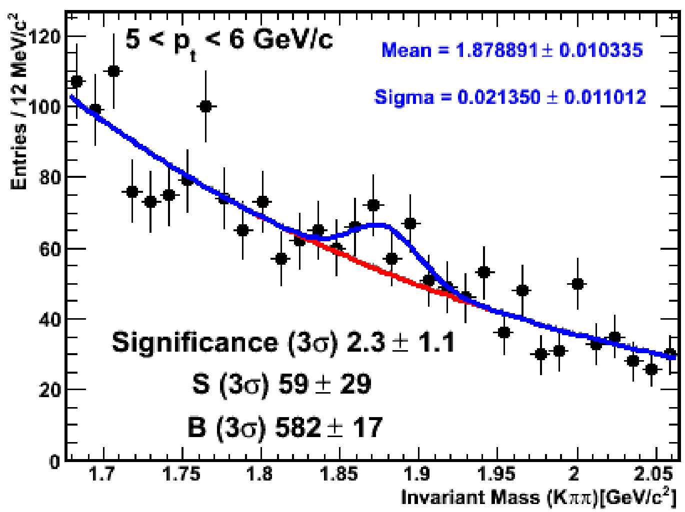
Systematics on PbPb analysis

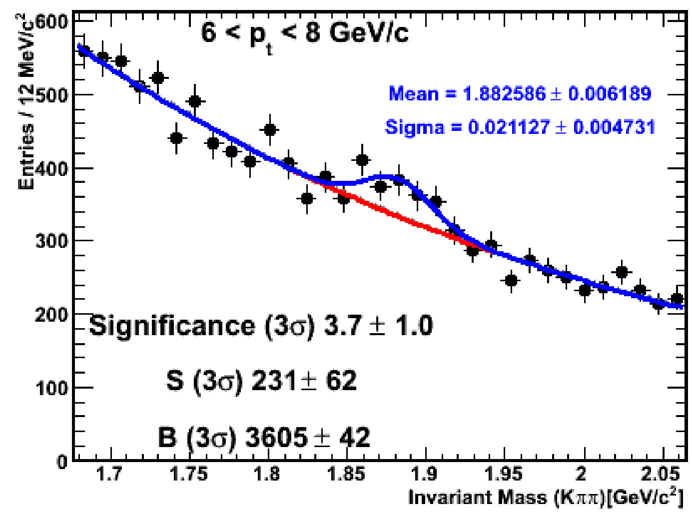


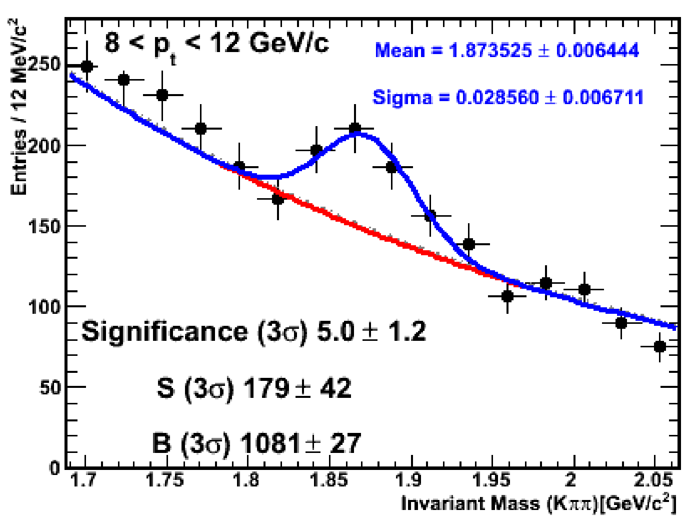


For R_{AA}: systematics from pp and PbPb summed in quadrature (all but BR and Feed-Down)

D^+ signal extraction in PbPb





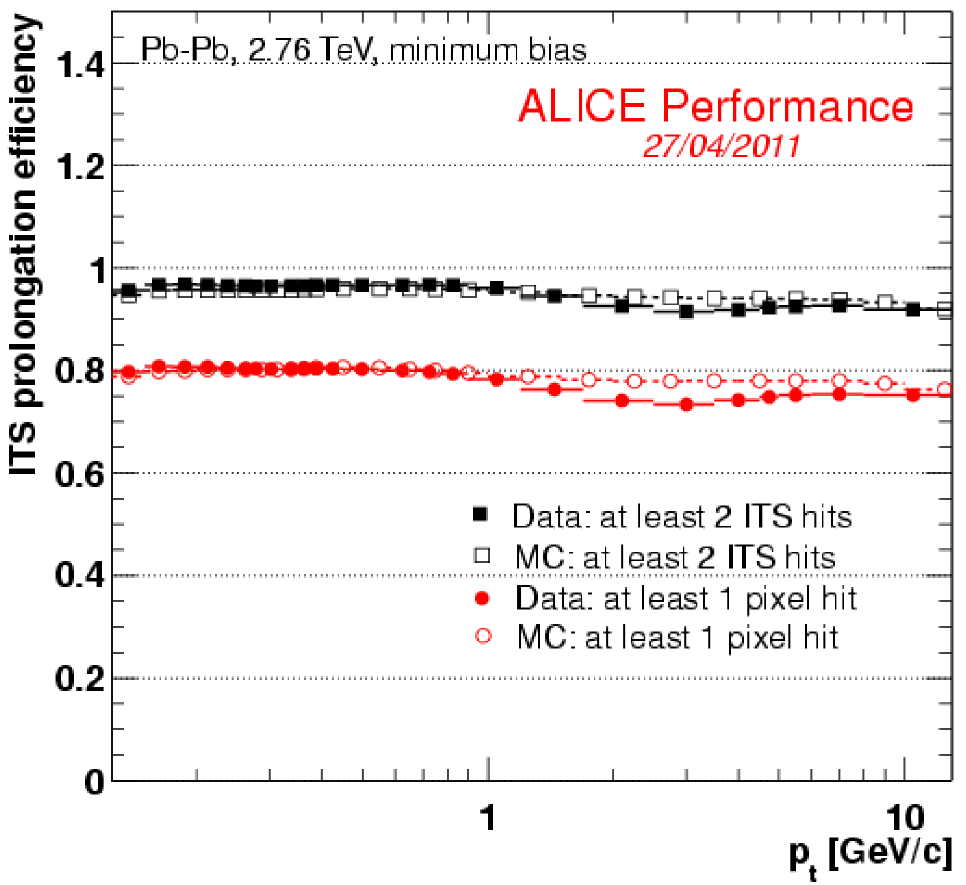


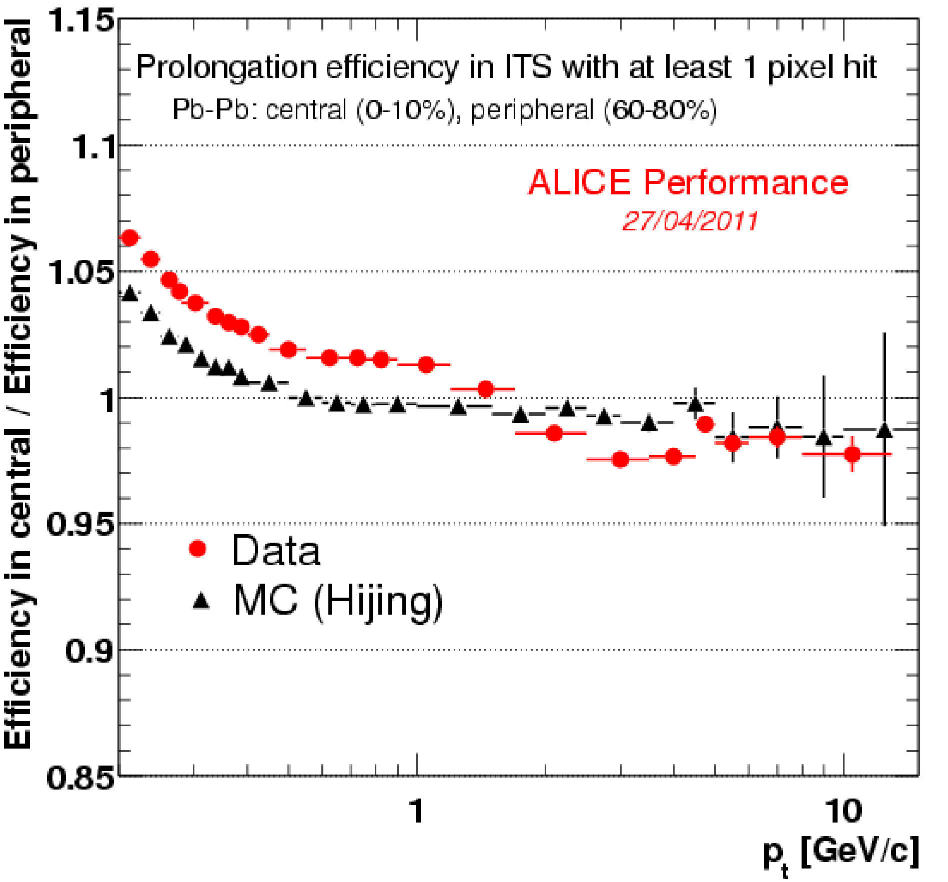
Pb-Pb $\sqrt{s}$=2.76 TeV, 2.8 × 10^6 events
Centrality 0-20%
$D^+ \to K^- \pi^+ \pi^+$

ALICE Performance

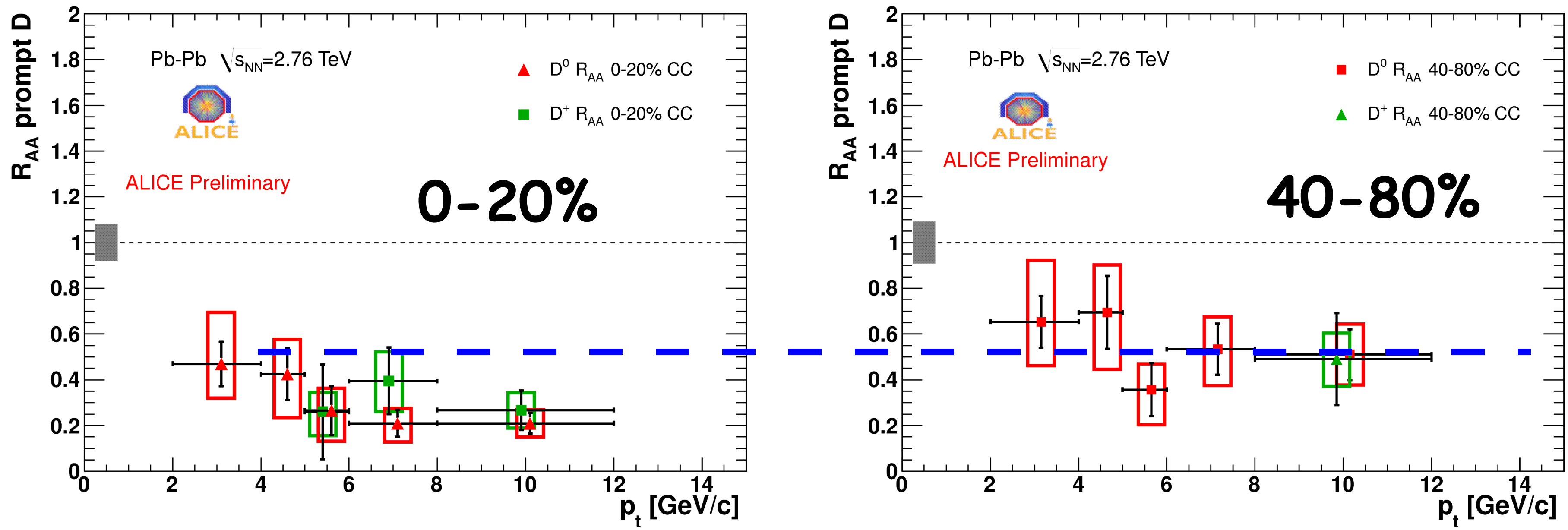
11/05/2011

TPC-to-ITS tracking efficiency



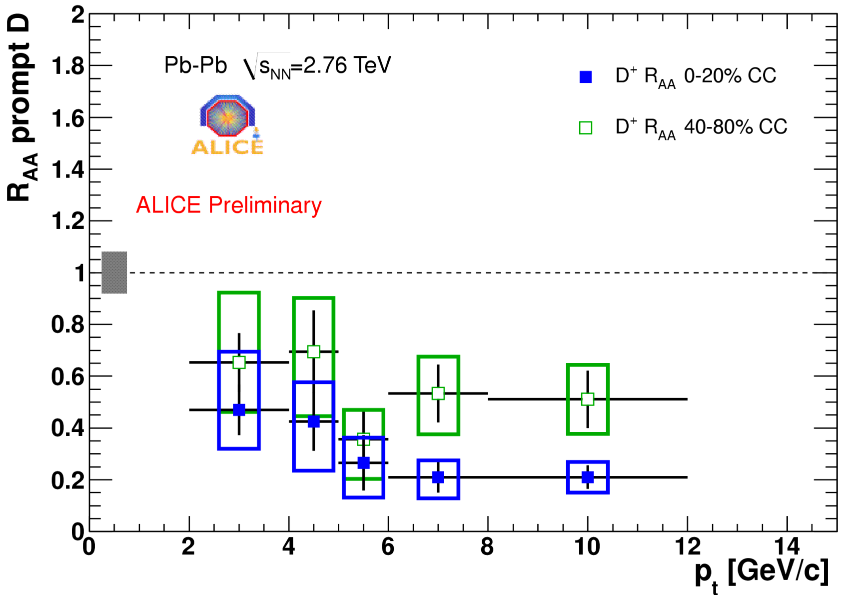


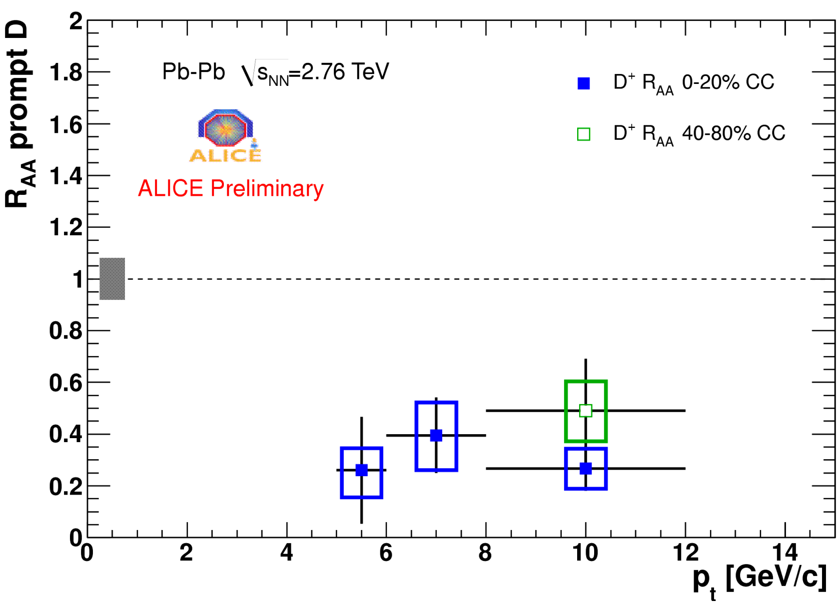
D^0 and D^+ R_{AA} in 40-80%

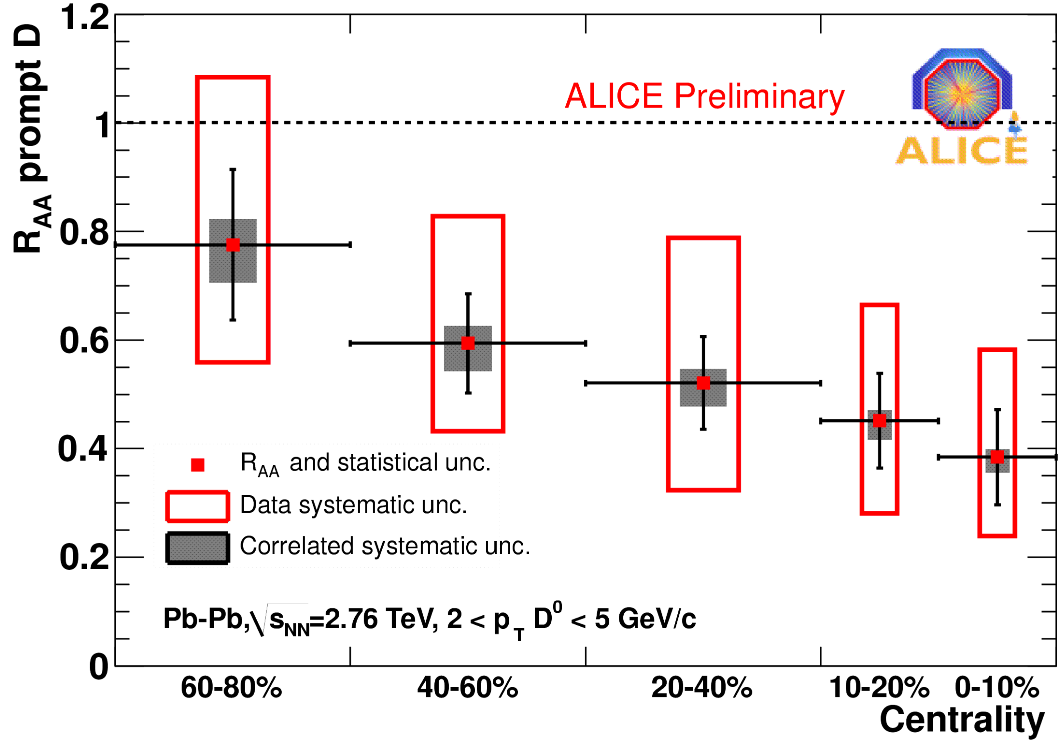


D mesons R_{AA} higher in peripheral collisions

D^0 and D^+ in central and peripherals

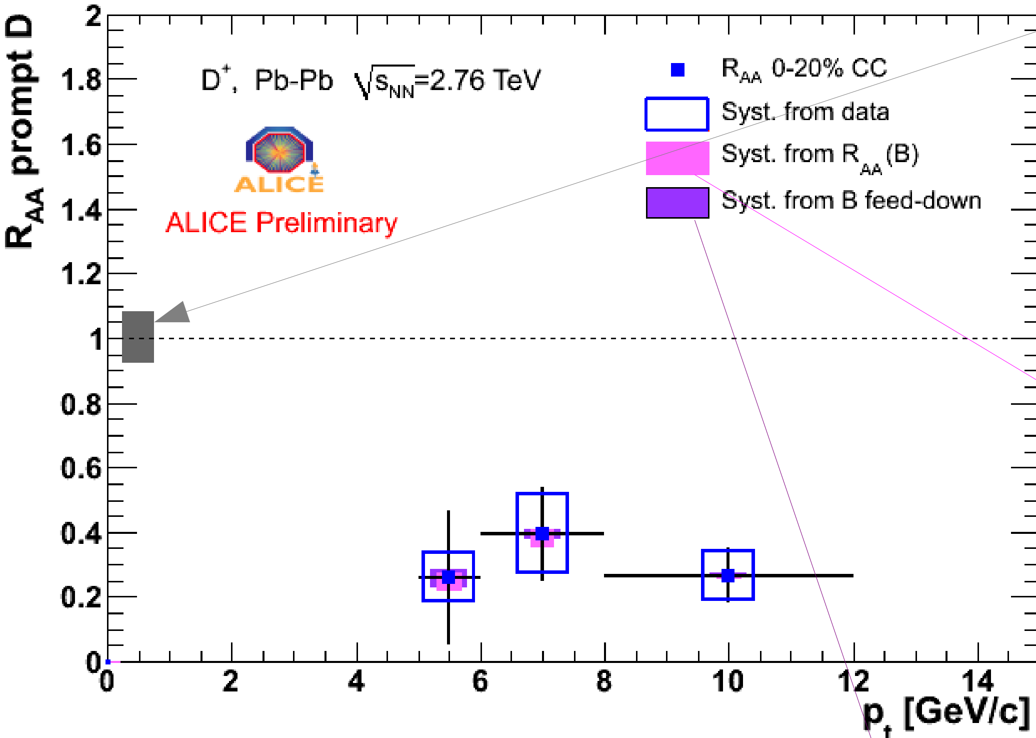




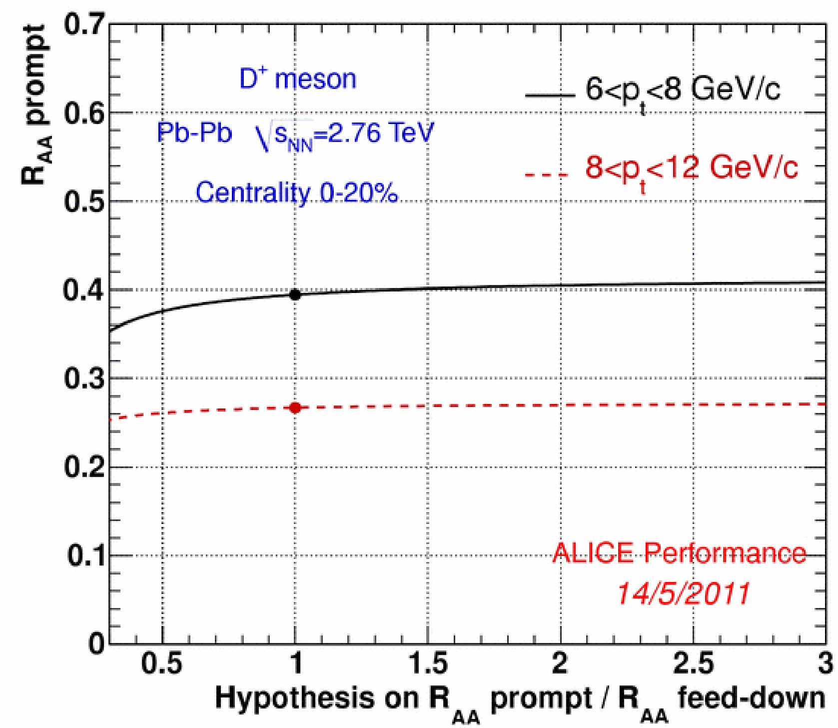


Centrality trend observed also at low p_t

$R_{AA}(D^+)$ results in central (0-20%) events



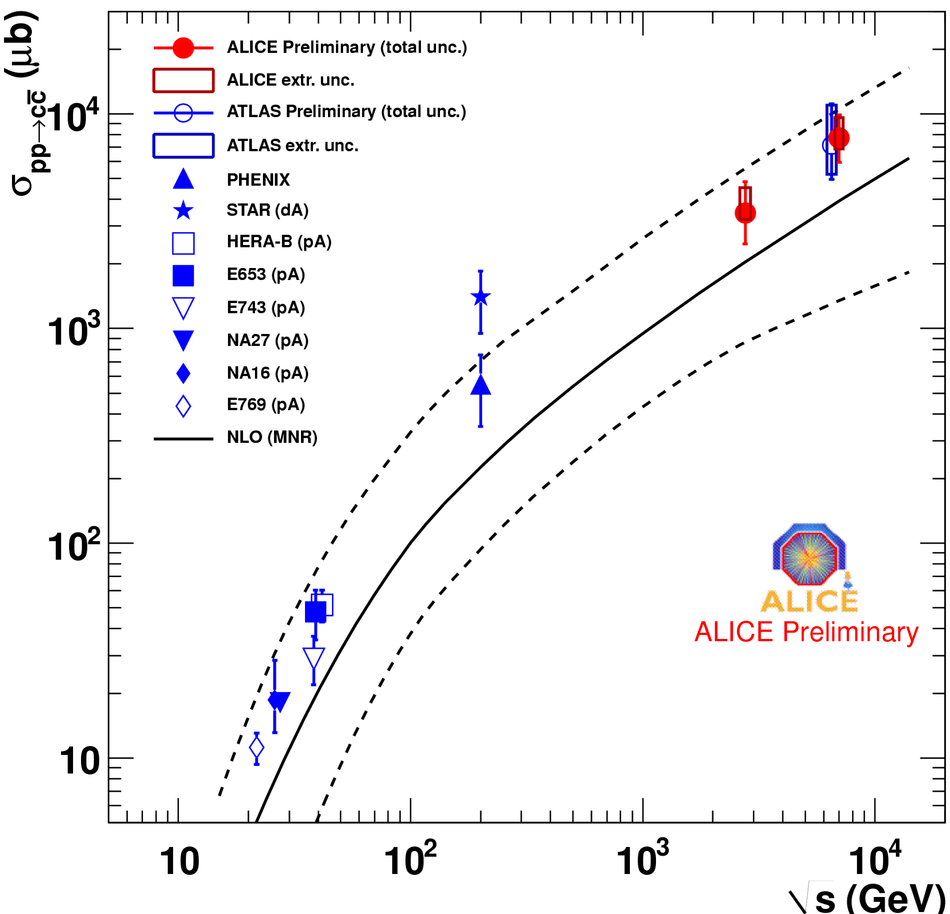
~8% normalization uncertainty (from σ(pp min. bias) at 7 TeV and T_{AA})



Blu Markers: $R_{AA}(D)/R_{AA}(B) = 1$

Syst. from feed-down correction via FONLL, partially cancels in the ratio

Total charm production in pp collisions



- ALICE measurements in |y|<0.5
  - $2<p_t<12$ GeV/c (at 7 TeV)
  - $2<p_t<8$ GeV/c (at 2.76 TeV)
- FONLL predictions used to extrapolate to the full p_t and y ranges
- D^0 and D^+ contributions summed

at 2.76 TeV: $\sigma^{tot}_{c\bar{c}}(\mathrm{ALICE}) = 3.45 \pm 0.41(\mathrm{stat.})^{+0.72}_{-0.84}(\mathrm{syst}) \pm 0.17(\mathrm{lum.})^{+1.09}_{-0.24}(\mathrm{extr.})\,\mathrm{mb}$

at 7 TeV:

$\sigma^{tot}_{c\bar{c}}(\mathrm{ALICE}) = 7.73 \pm 0.54(\mathrm{stat.})^{+0.74}_{-1.38}(\mathrm{syst}) \pm 0.44(\mathrm{lum.})^{+1.90}_{-0.87}(\mathrm{extr.})\,\mathrm{mb}$

$\sigma^{tot}_{c\bar{c}}(\mathrm{ATLAS}) = 7.13 \pm 0.28(\mathrm{stat.})^{+0.90}_{-0.66}(\mathrm{syst}) \pm 0.78(\mathrm{lum.})^{+3.82}_{-1.90}(\mathrm{extr.})\,\mathrm{mb}$

Scaling to 2.76 TeV

1) Rebin FONLL predictions for $\sigma(2.76)$ & $\sigma(7)$ (for different sets of μ_F,μ_R, m_c parameters) to match the binning used for ALICE measurement at 7 TeV

2) Estimate the FONLL ratio $\sigma(2.76)/\sigma(7)$
   - take as the central value the ratio of the central predictions
   - take as its uncertainty the envelope of the results for all the scales and values

3) Multiply the ALICE 7 TeV measurement by $\sigma(2.76)/\sigma(7)$

4) Propagate the uncertainties:
   - on the FONLL ratio
   - on the 7 TeV measurement

Towards R_{AA} calculation

PbPb raw yield

Prompt D fraction

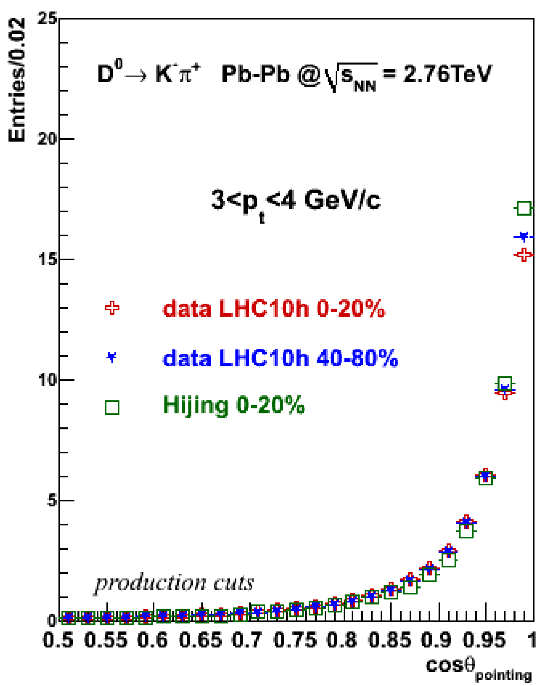
Efficiency

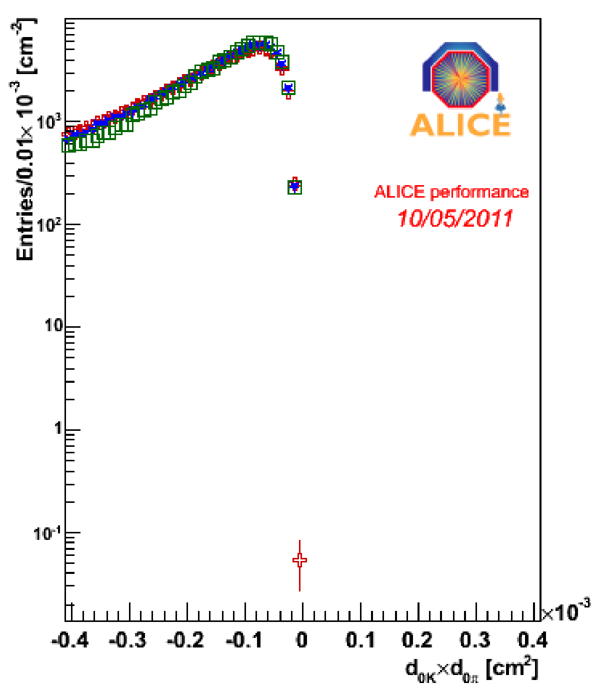
$$R_{AA}(D^0) = \frac{\dfrac{dN^{D^0\to K\pi,\,PbPb}_{\text{corrected}}}{dp_t}}{\langle T_{AA}\rangle \times \dfrac{d\sigma^{D^0}_{pp}}{dp_t}(\sqrt{s}=2.76\,\text{TeV})} = \frac{\left(\dfrac{0.5\times S^{\text{raw}}/(\Delta p_t)\times fc}{\varepsilon N^{\text{cent}}_{\text{ev}}}\right)}{\langle T_{AA}\rangle \times d\dfrac{\sigma^{D^0}_{pp}}{dp_t}(\sqrt{s}=2.76\,\text{TeV})}$$

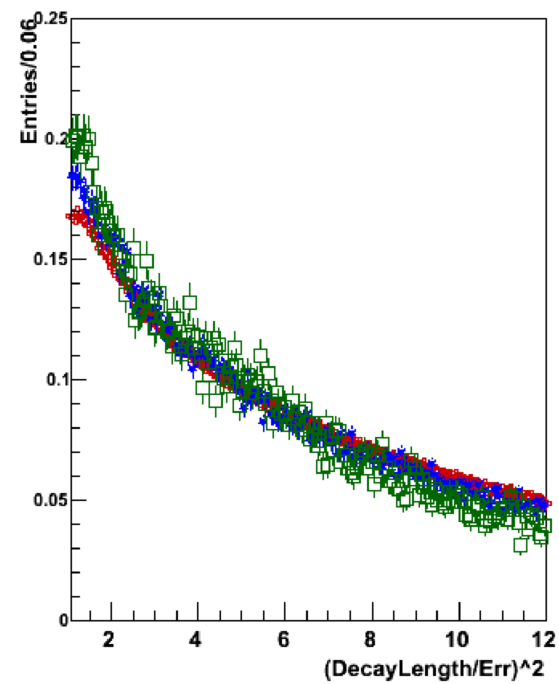
(same for D^+)

Cut variable distributions in data and MC and in different centralities

$d_0^K \times d_0^\pi$ and $\cos\theta_{point}$, normalized decay length distribution in data (0-20%, 40-80%) and MC (0-20%) events (background!)

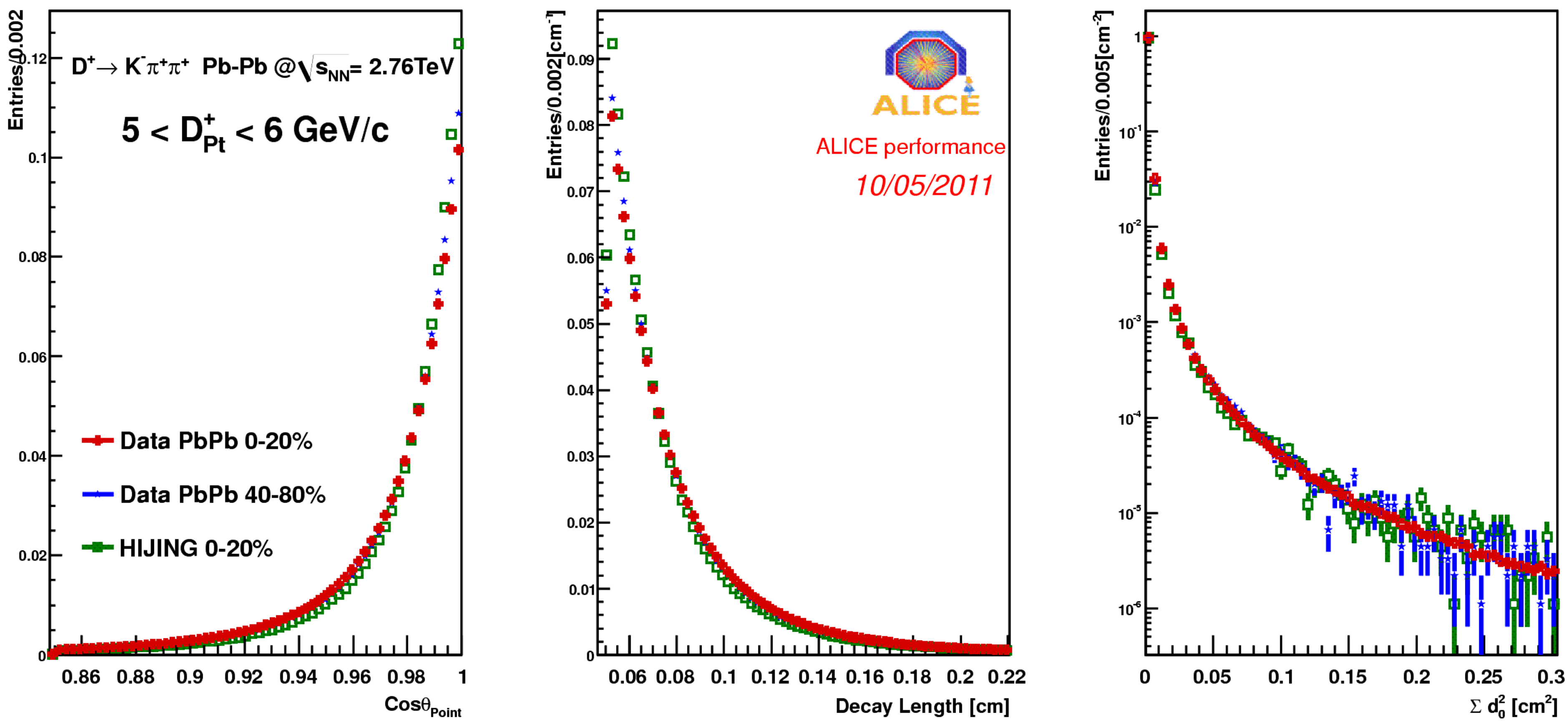




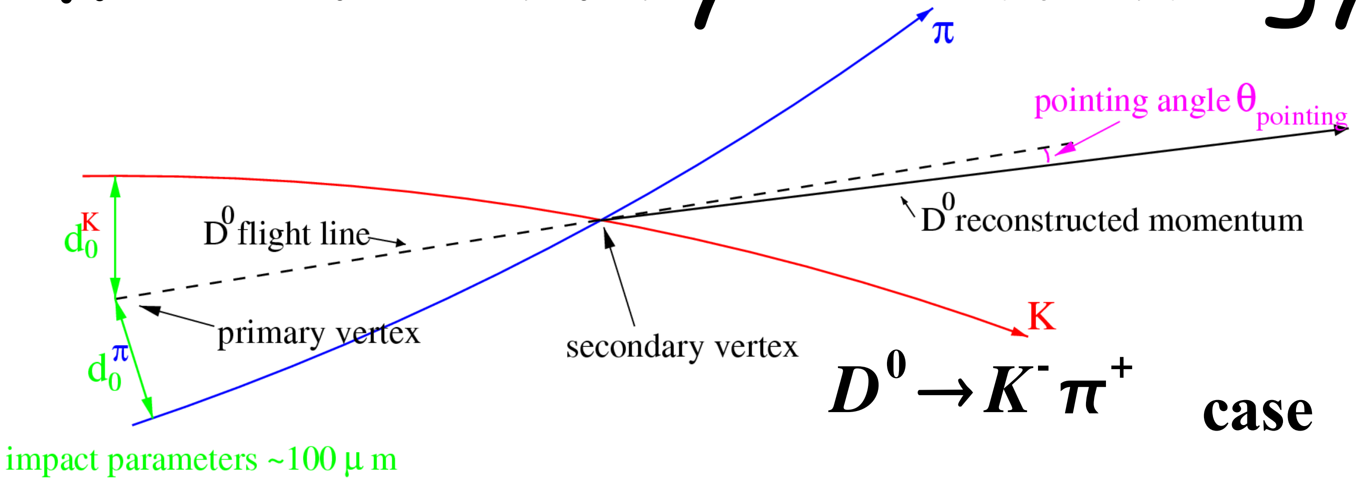


Cut variable distributions in data and MC and in different centralities

$\cos\theta_{point}$, $\cos\theta_{point}^{XY}$, decay length distribution in data and MC (40-80%) (background!)



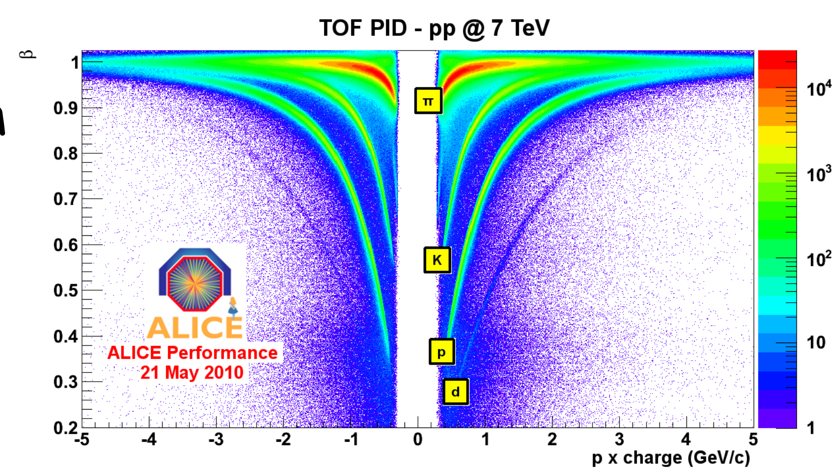
D mesons: analysis strategy



Main selection strategy (common to pp and PbPb):

Displaced secondary vertices topology (-> ITS)

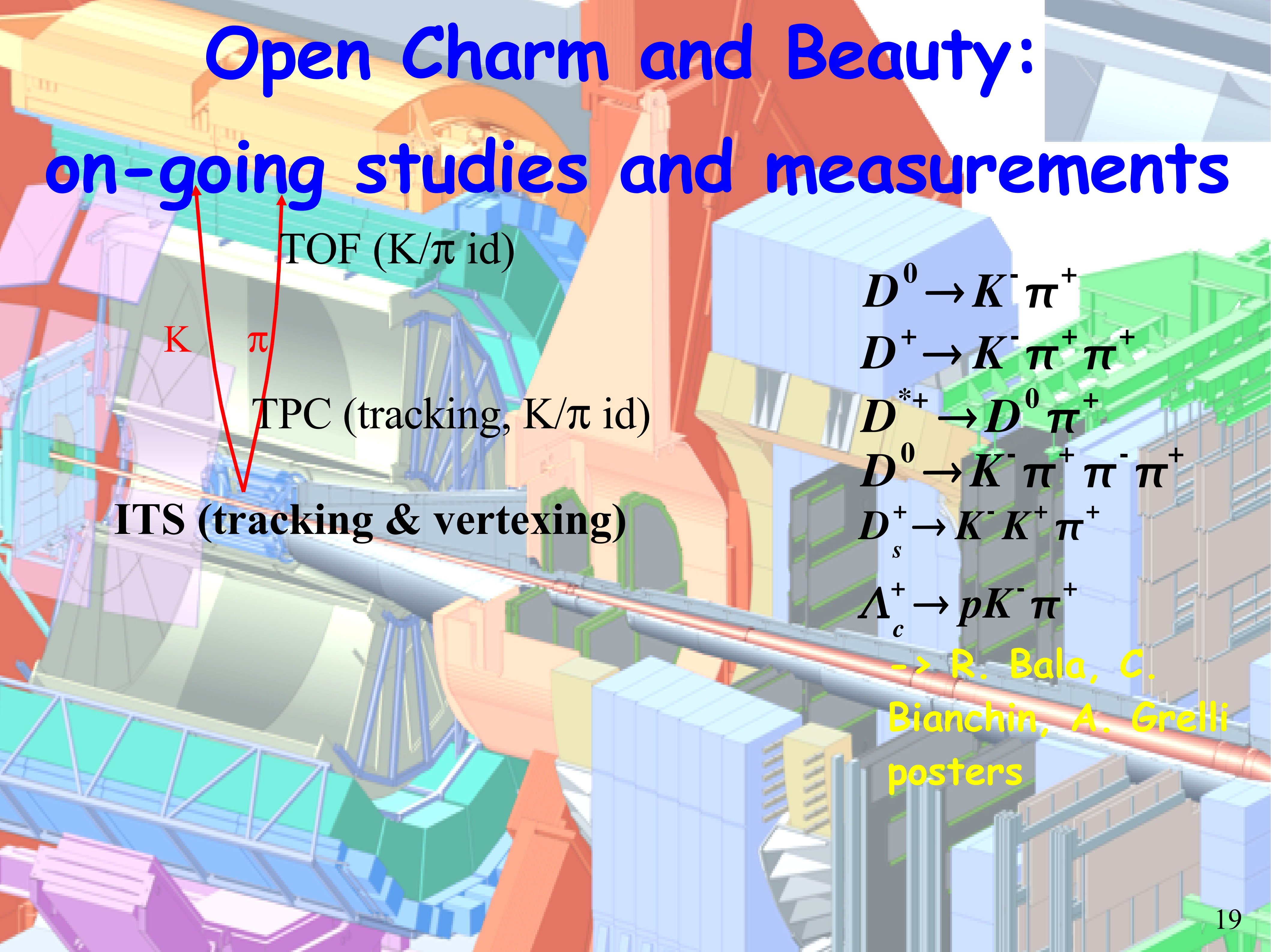
- (e.g. $D^0 \to K^- \pi^+$) : pair of opposite charge tracks with large impact parameters
- good pointing of reconstructed D momentum to the primary vertex



PID selection (TOF+TPC) to reduce background (mainly via K identification)

→ **Invariant mass analysis**

Open Charm and Beauty: on-going studies and measurements



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

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

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

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

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

$\Lambda_c^+ \rightarrow p K^- \pi^+$

-> R. Bala, C. Bianchin, A. Grelli posters