Universiteit Utrecht

ALICE

Azimuthal angular correlations of D mesons and charged particles in pp at 7 TeV and p-Pb at 5.02 TeV with the ALICE detector at the LHC

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for the ALICE collaboration

5th International Conference on New Frontiers in Physics 2016

Outline

Outline

Why heavy flavours ?

in pp collisions

- Test for pQCD calculations for the production cross-sections.
- Reference for p-Pb and Pb-Pb measurements.

in p-Pb collisions

- Control experiment for the Pb-Pb measurements.
- Studies of cold nuclear matter effects.

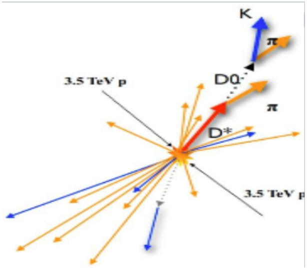
in Pb-Pb

- Studies on the interaction of heavy quarks with the medium.
- Study the transport properties in the hot and dense medium.

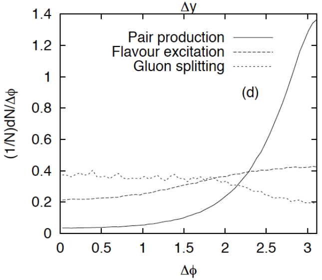
Why D-hadron correlations studies are interesting ?

Why Correlations ?

- Flavour conservation in QCD (charm quarks are produced in pairs) => Jet formation due to the fragmentation of charm quark.
- Correlation distributions are sensitive to the fragmentation and production mechanisms of charm quarks in pp collisions.
- Angular correlations are investigated also in p-Pb collisions for possible modifications due to the presence of cold nuclear matter.



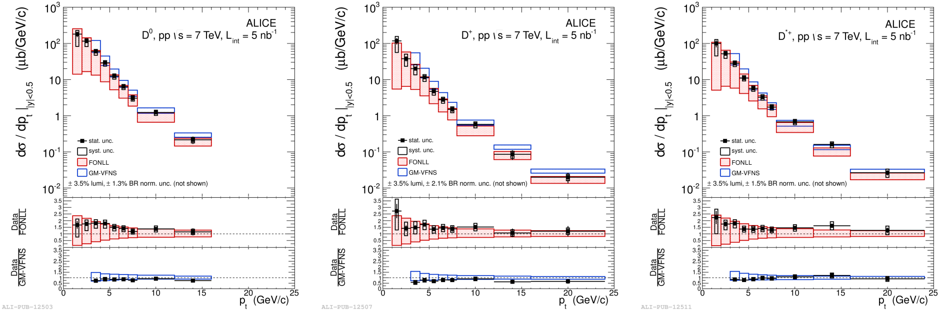
Eur.Phys.J.C17 :137-161,2000



Why D-hadron correlations studies are interesting ?

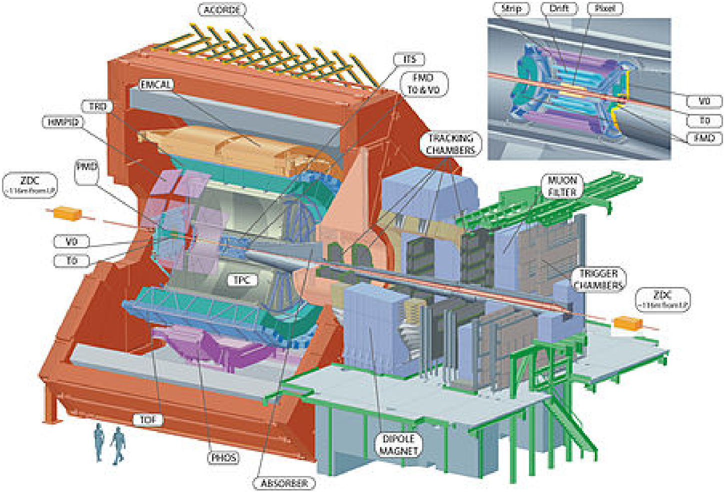
Why D mesons ?

- $D^0 = c\bar{u}$, $D^+ = c\bar{d}$, $D^{*+} = c\bar{d}$ ($m_c \approx 1.5$ GeV/c^2).
- $Q^2 > 4m_c^2 \Rightarrow \alpha_s < 1 \Rightarrow$ pQCD calculation applicable
- D^0, D^+ and D^{*+} cross-section at $\sqrt{s} = 7$ TeV, $|y| < 0.5$.
- Large p_T coverage [1,24] GeV/c and well described by the pQCD predictions **ALICE, JHEP 1201 (2012) 128**.



Outline

ALICE detector



Central barrel

Pseudorapidity $|\eta| < 0.9$

Muon spectrometer

Pseudorapidity $-4.0 < \eta < -2.5$

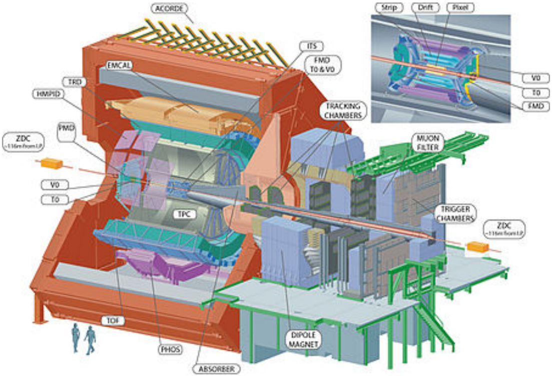
ALICE detector

Central barrel

ITS
Inner Tracking System
vertexing, tracking and
Particle Identification.

TPC
Time Projection Chamber
Tracking and Particle
Identification.

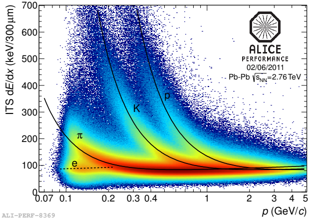
TOF
Time-Of-Flight
Tracking and Particle
Identification.



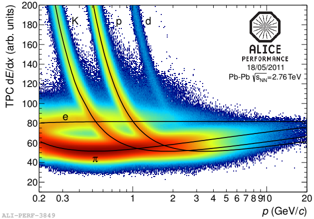
pp@7TeV 300 M minimum bias events
Integrated luminosity 5 nb^{-1}
p-Pb@5.02TeV 100 M minimum bias events
Integrated luminosity 50 nb^{-1}

ALICE detector : PID using ITS, TPC and TOF

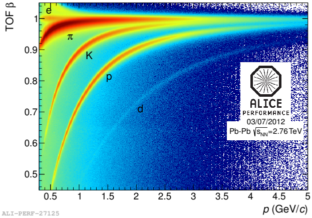
PID ITS



PID TPC



PID TOF



More about PID in

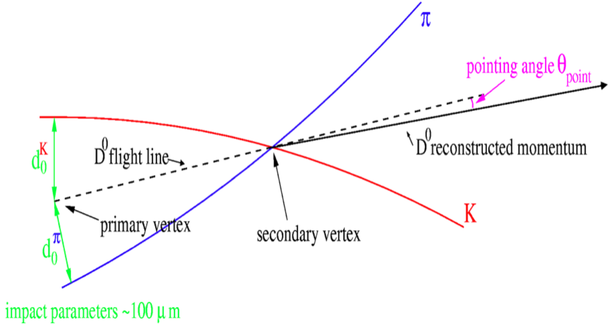
Eur. Phys. J. Plus 131 (2016) 168

Outline

Analysis strategy : Steps

- **D meson (trigger) reconstruction - invariant mass spectra**.
- **Associated tracks selection**.
- Single-event (SE) and mixed-event (ME) distributions.
- Corrected single events for signal and background.
- Projection on $\Delta\varphi$ for signal and background.
- Normalise the $\Delta\varphi$-distributions to the number of triggers (D mesons).
- Remove secondary tracks.
- Remove the B feed-down contribution.

Analysis strategy - D-meson reconstruction



Topological cuts
about 14 parameters :
p_T (K,π) [GeV/c]
min d_0 (K,π) [cm]
min $d_0 \times d_0$ [cm^2]
cos(θ_{Point}), ...

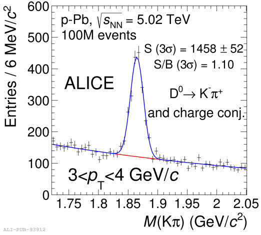
- Optimised to maximize the significance ($\frac{S}{\sqrt{S+B}}$) / Reduce the background / Keep the selection efficiency large enough.
- Selection cuts complemented by the particle identification (PID).

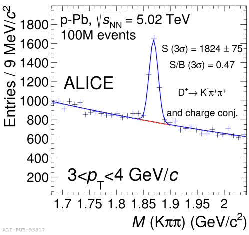
Analysis strategy : D-meson reconstruction

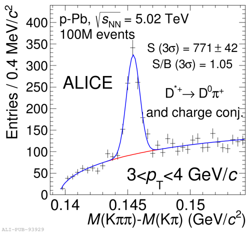
Selection criteria required for D-meson candidate daughters :

- $|\eta| < 0.8$, $\chi^2/NDF < 2$,
- $p_T > 0.3$ GeV/c ($p_T > 0.1$ GeV/c for D^{*+}),
- 70 (at least) out of 159 space points in the TPC,
- 2 (at least) out of 6 hits in the ITS.

PRL 113 (2014) 232301





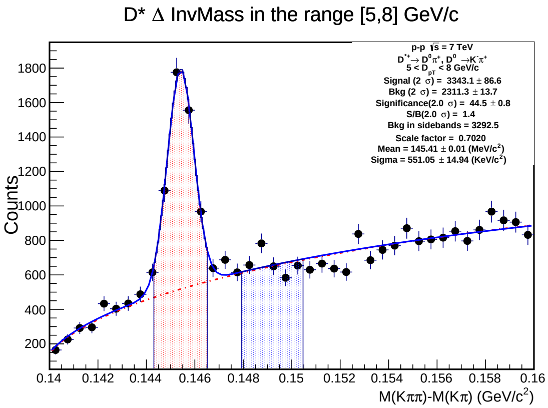


$D^0 \to K^-\pi^+$
BR $\approx (3.88 \pm 0.05)\%$

$D^+ \to K^-\pi^+\pi^+$
BR $\approx (9.13 \pm 0.19)\%$

$D^{*+} \to D^0\pi^+$
BR $\approx (67.7 \pm 0.5)\%$

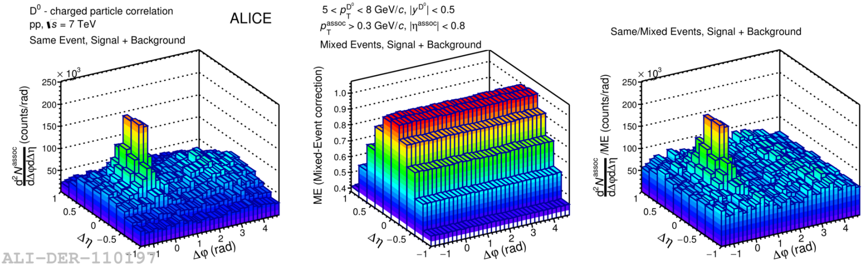
Invariant mass spectra



- Peak => Signal region [mean-2σ,mean+2σ]
- SB => Sideband region [mean+4σ,mean+8σ]
- M => Invariant mass spectra
- $Scale_{factor} = \frac{\int_{Peak} Background(M)}{\int_{SB} Background(M)}$

Analysis strategy :Single events(SE) and mixed events(ME)

$$\Delta\varphi = \varphi^{assoc} - \varphi^{trigg}, \Delta\eta = \eta^{assoc} - \eta^{trigg}$$

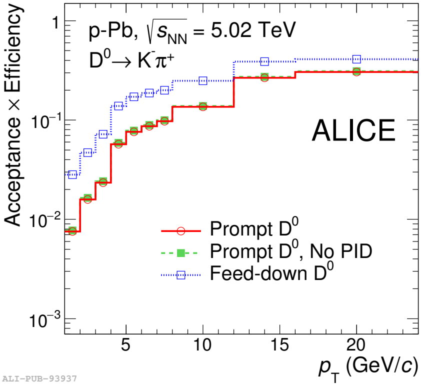


$$\frac{dN^{corr}(\Delta\varphi,\Delta\eta)}{d\Delta\varphi\Delta\eta} = \frac{\frac{dN^{SE}(\Delta\varphi,\Delta\eta)}{d\Delta\varphi\Delta\eta}}{\frac{dN^{ME}(\Delta\varphi,\Delta\eta)}{d\Delta\varphi\Delta\eta} / \frac{dN^{ME}(0,0)}{d\Delta\varphi\Delta\eta}}$$

$$C_{inclusive}(\Delta\varphi) = Signal(\Delta\varphi) - Scale_{factor} \times Background(\Delta\varphi)$$

Analysis strategy : Correction for the efficiency

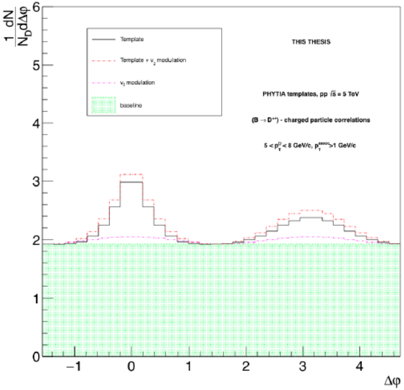
arXiv :1605.07569



- **Efficiency correction for D mesons**
  A Monte Carlo (MC) sample is used (enhanced production).
  The efficiency map is obtained.
  Invariant mass spectra, SE and ME are weighted by the inverse of the efficiency.

- **Efficiency correction for associated tracks**
  A Monte Carlo (MC) Sample is used (minimum bias production)
  The efficiency map is obtained.
  SE and ME are weighted by the inverse of the efficiency.

Analysis strategy : B feed-down subtraction



Subtraction of the contribution of D meson from B using a MC PYTHIA template. Prompt D fraction (f_{prompt}) is computed using FONLL.

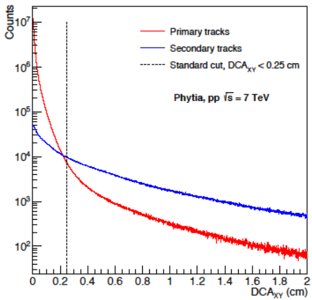
S.Bjelogrlic, PhD thesis, 2016.

$$\widetilde{C}_{promptD}(\Delta\varphi) = \frac{1}{f_{prompt}}\left(\tilde{C}_{inclusive}(\Delta\varphi) - (1 - f_{prompt})\,\tilde{C}^{MCtempl}_{feed-down}(\Delta\varphi)\right)$$

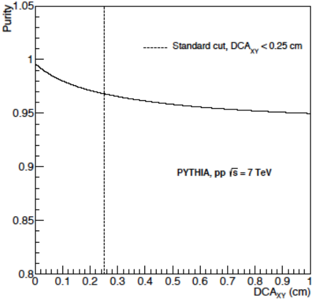
$$f_{prompt} = \left(1 + \frac{(Acc \times \epsilon)_{feeddownD^{*+}}}{(Acc \times \epsilon)_{promptD^{*+}}} \frac{\frac{d\sigma}{dp_T}^{feeddownD^{*+}}\Big|_{|y|<0.5}}{\frac{d\sigma}{dp_T}^{promptD^{*+}}\Big|_{|y|<0.5}}\right)$$

Analysis strategy : Correction for the purity

Distribution of the tracks.



Distribution of the purity.



S.Bjelogrlic, PhD thesis, 2016.

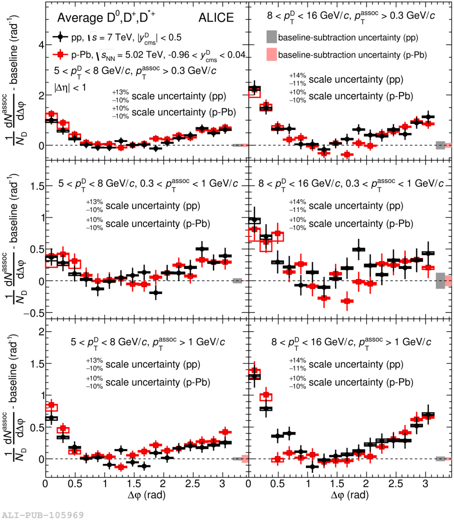
$$Purity = \frac{\int_0^{DCA_{XY}^{cut}} f_{prim}(DCA_{XY}) dDCA_{XY}}{\int_0^{DCA_{XY}^{cut}} f_{prim}(DCA_{XY}) + f_{sec}(DCA_{XY}) dDCA_{XY}}$$

$$C_{promptD}(\Delta\varphi) = purity \times \widetilde{C}_{promptD}(\Delta\varphi)$$

Outline

Correlations in pp and p-Pb - baseline subtracted

$5 < p_T < 8$ GeV/c $8 < p_T < 16$ GeV/c

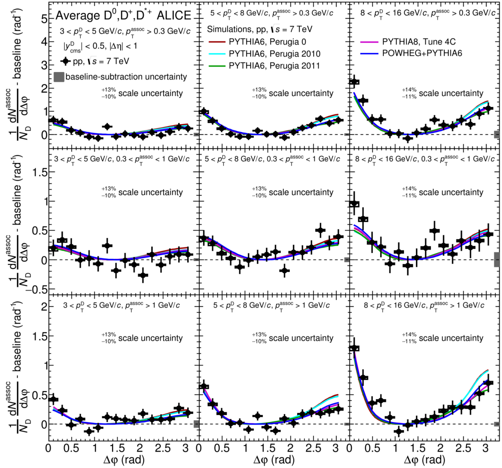


arXiv :1605.06963v1

- The results from pp and p-Pb are compatible within uncertainties.
- No significant cold nuclear matter effect affecting the distribution.

Correlations : Data vs theoretical predictions

$3 < p_T < 5$ GeV/c | $5 < p_T < 8$ GeV/c | $8 < p_T < 16$ GeV/c



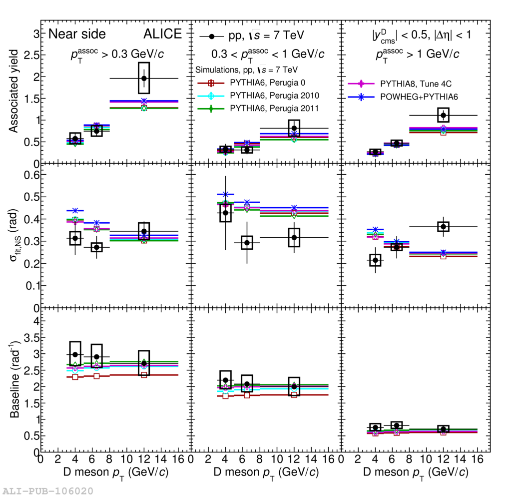
ALI-PUB-106084

arXiv :1605.06963v1

- No significant difference between different event generators.
- Measurements and Monte Carlo simulations are in agreement within uncertainties.

Associated yield, NS sigma and baseline for D mesons in pp

$p_T^{assoc} > 0.3$ GeV/c | $0.3 < p_T^{assoc} < 1$ GeV/c | $p_T^{assoc} > 1$ GeV/c



arXiv :1605.06963v1

Measurements vs MC simulations

- The measured associated yield and the width of near-side peak are in agreement with the predicted ones from simulations within uncertainties.
- The measured baseline is well reproduced by the simulations.

Outline

Conclusions and outlook

- D mesons - charged particles correlations were measured in pp collisions at 7 TeV and p-Pb collisions at 5.02 TeV.
- Correlation distributions in pp and p-Pb are similar i.e. there is no significant cold nuclear matter effects.
- The obtained results were compared with those obtained using different Monte Carlo generators which are in agreement with each other within uncertainties.
- Improved results are expected with the high statistics in Run2 and with the upgrade of the LHC Run3 and the upgraded ALICE ITS.

Thank you for your attention

Questions ?

Comments !

Backup slides

Analysis strategy : Associated tracks reconstruction

Selection criteria for the associated track :

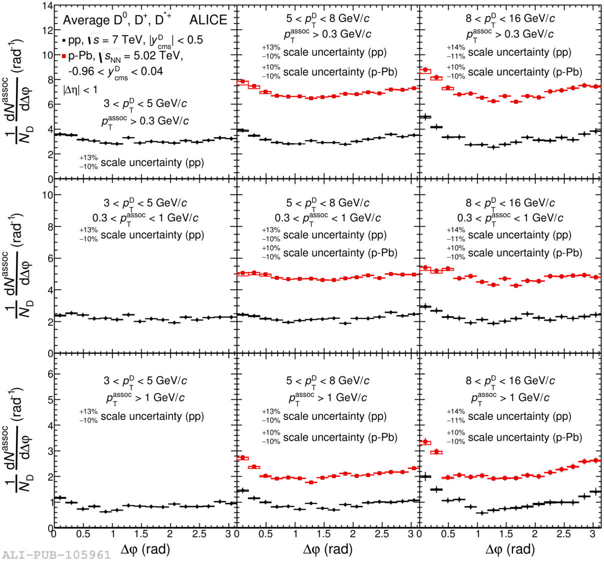
- ITS Refit : **Yes**
- TPC Refit : **Yes**

- Min number of ITS clusters : **3**
- Min number of TPC clusters : **70**

- pt min : **0.3** [GeV/c]
- pt max : **100** [GeV/c]

- $|\eta| < \mathbf{0.8}$

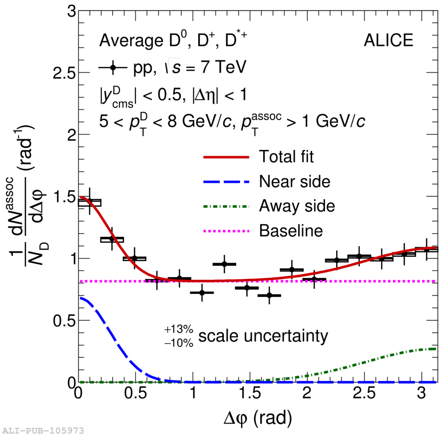
Correlations : D meson average in pp and p-Pb for different p_T ranges

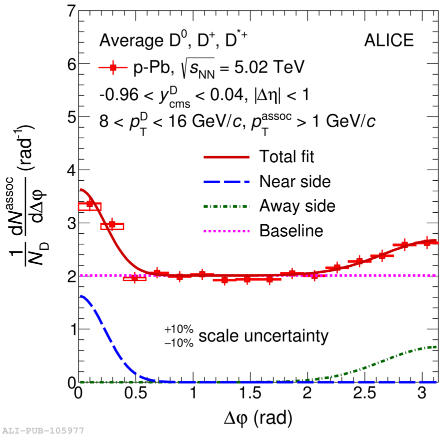


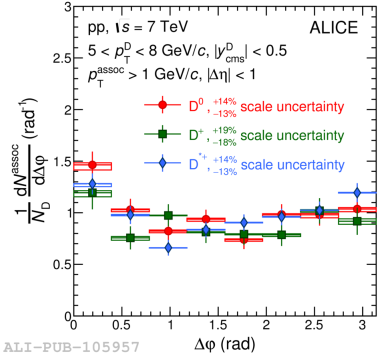
Correlations : Systematic uncertainties

System D-meson species	pp D^0, D^{*+}, D^+	p–Pb D^0, D^{*+} (D^+)
Signal, background normalization	$\pm 10\%$	$\pm 10\%$
Background $\Delta\varphi$ distribution	$\pm 5\%$	$\pm 5\%$ ($\pm 10\%$)
Associated-track reconstruction efficiency	$+10\%, -5\%$	$\pm 4\%$
Primary-particle purity	$\pm 5\%$	$\pm 3.5\%$
D-meson efficiency	$\pm 5\%$	$\pm 5\%$ ($\pm 10\%$)
Feed-down subtraction	up to 8%, $\Delta\varphi$ dependent	up to 8%, $\Delta\varphi$ dependent
MC closure test	-2% (near side)	-2% (near side), $\pm 2\%$

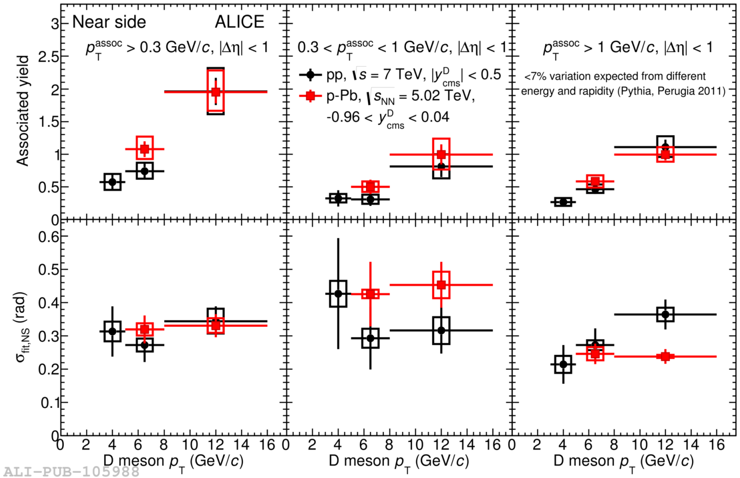
3 D mesons correlations in pp@7TeV and p-Pb@5.02TeV



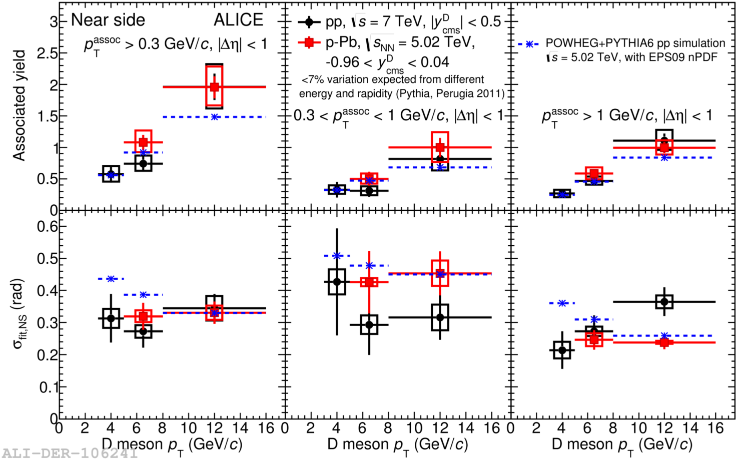



pp, √s = 7 TeV
ALICE
5 < p_T^D < 8 GeV/c, |y_cms^D| < 0.5
p_T^assoc > 1 GeV/c, |Δη| < 1
D0, +14% −13% scale uncertainty
D+, +19% −18% scale uncertainty
D*+, +14% −13% scale uncertainty
1/N_D dN^assoc/dΔφ (rad^-1)
Δφ (rad)
ALI-PUB-105957
p-Pb, √s_NN = 5.02 TeV
ALICE
8 < p_T^D < 16 GeV/c, -0.96 < y_cms^D < 0.04
p_T^assoc > 1 GeV/c, |Δη| < 1
D0, +14% −13% scale uncertainty
D+, +19% −18% scale uncertainty
D*+, +14% −13% scale uncertainty
1/N_D dN^assoc/dΔφ (rad^-1)
Δφ (rad)

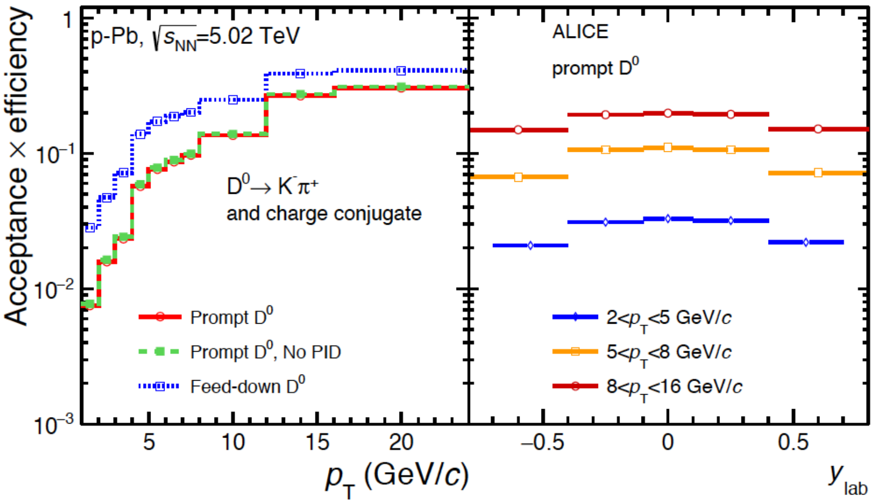
Associated yield, NS sigma : pp vs p-Pb



Associated yield and NS peak width for D mesons in p-Pb



Efficiency x Acceptance map for D^0 f(p_T,y_{lab})



Prompt D^0 cross-section - ratios between data and theoretical predictions

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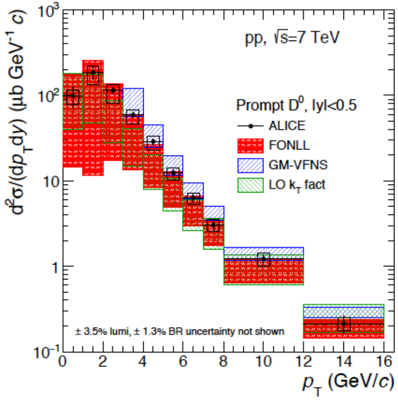
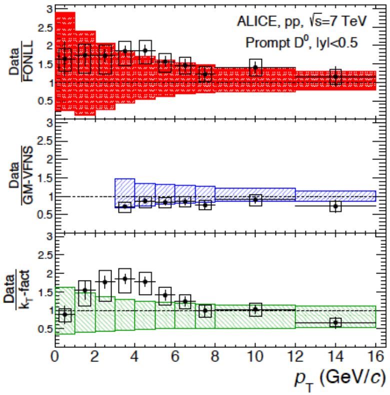
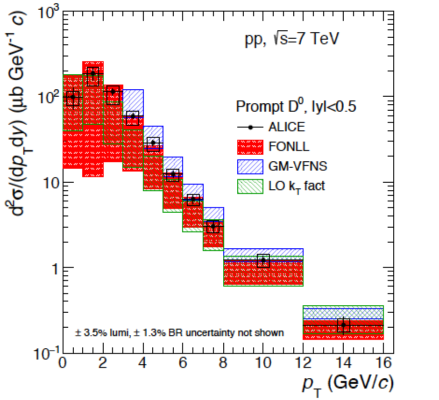




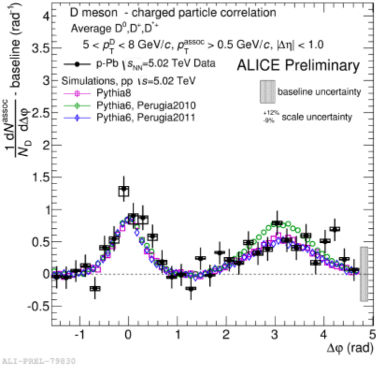
Prompt D^0 cross-section

Prompt D^0 cross-section

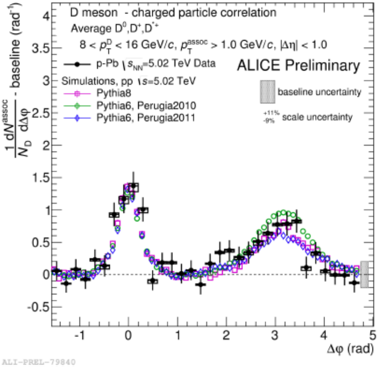


PYTHA vs p-Pb @ 5.02 TeV Data

[5 - 8] GeV/c



[8 - 16] GeV/c



Equations used for the fit of the invariant mass spectra

- For D^{*+}
  $Signal(\Delta M) = Y_D \frac{1}{\sqrt{2\pi}\sigma} e^{\frac{(\Delta M-\mu)^2}{2\sigma^2}}$
  $Background(\Delta M) = a\sqrt{\Delta M - m_\pi} \times e^{b(\Delta M - m_\pi)}$

- For D^0 and D^+
  $Signal(M) = Y_D \frac{1}{\sqrt{2\pi}\sigma} e^{\frac{(M-\mu)^2}{2\sigma^2}}$
  $Background(M) = a \times e^{b(M - m_\pi)}$