Measurement of heavy-flavour correlations in pp and p-Pb collisions with ALICE

By: Jitendra Kumar (IIT Bombay, India)
of behalf of the ALICE Collaboration

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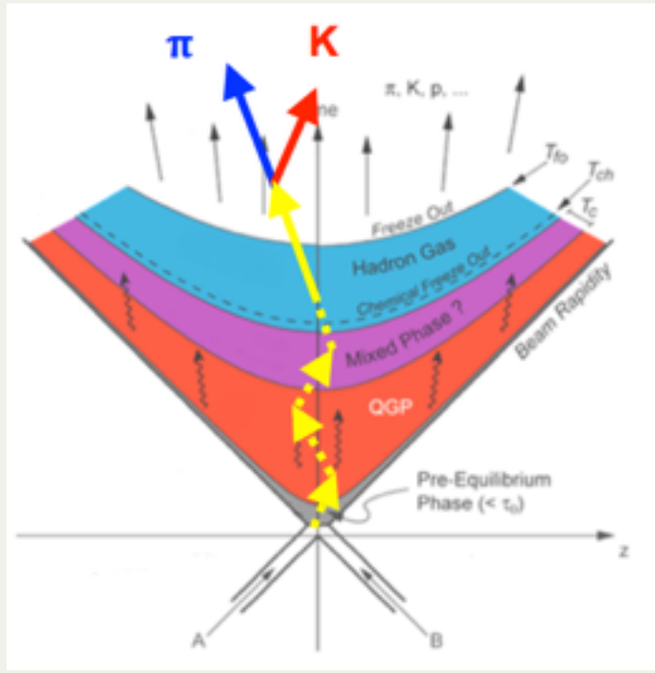
Outline

- Physics motivations
- ALICE detector
- Analysis method
- D meson- charged particle angular correlations in pp and p-Pb collisions
- Summary and outlook (including Pb-Pb)

Physics Motivation



Open heavy flavour in heavy-ion collisions:

☑ Heavy quarks produced in the initial stage of the collision (production time 0.05-0.15 fm/c) → powerful probes for studying the properties of **QGP**.

☑ We can investigate the properties of the dense matter by studying its influence on open heavy-flavour production.

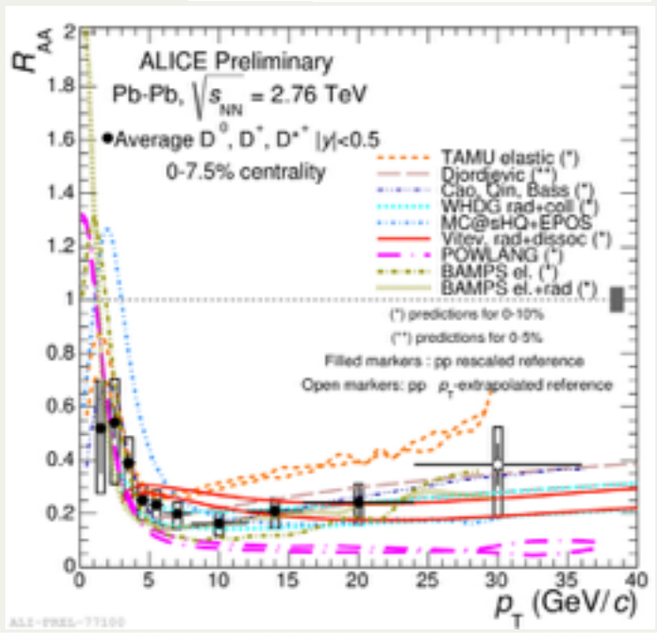
ALICE observed

A significant modification of the momentum distribution of D mesons in Pb-Pb compared to pp collisions.

→ **heavy quark in-medium energy loss**

(JHEP 09 (2012) 112)

$$R_{AA}(p_T) = \frac{dN_{AA}/dp_T}{\langle T_{AA}\rangle d\sigma_{pp}/dp_T}$$

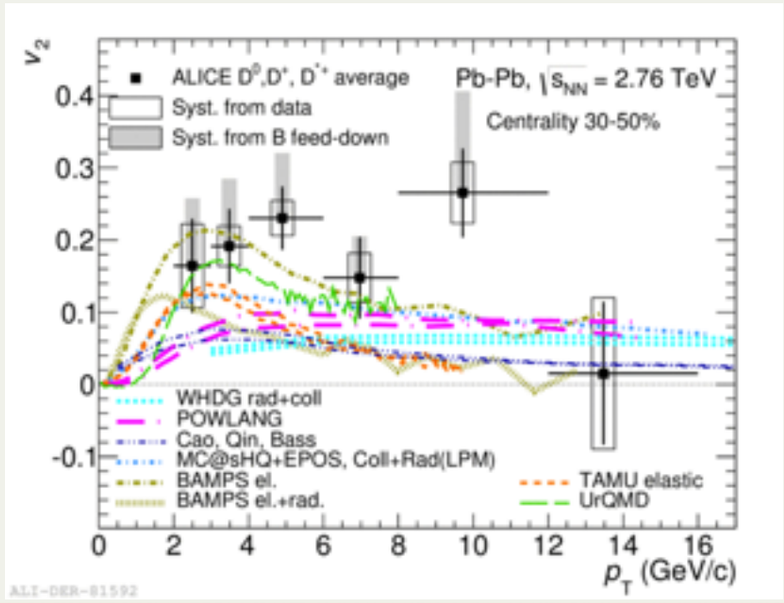


Non-zero D-meson v_2 in $2 < p_T < 6$ GeV/c

→ **suggests that charm takes part in the collective expansion of the medium**

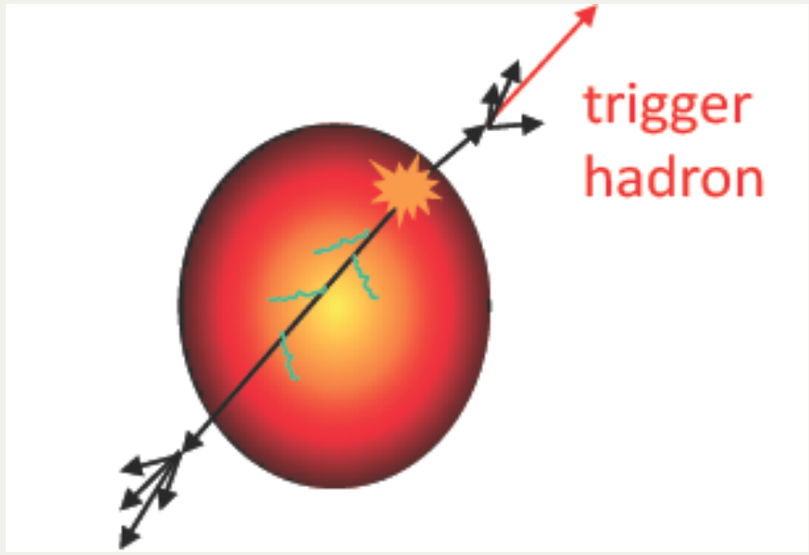
$$\frac{dN}{d\varphi} = \frac{N_0}{2\pi}\left(1 + 2v_1\cos(\varphi - \Psi_1) + 2v_2\cos[2(\varphi - \Psi_2)] + \ldots\right)$$

Phys. Rev Lett. 111, 102301 (2013), arXiv:1405.2001



Physics Motivation

Azimuthal correlations of high-p_T trigger hadrons with other hadrons produced in heavy-ion collisions are sensitive to:



➡ in medium partonic energy loss:

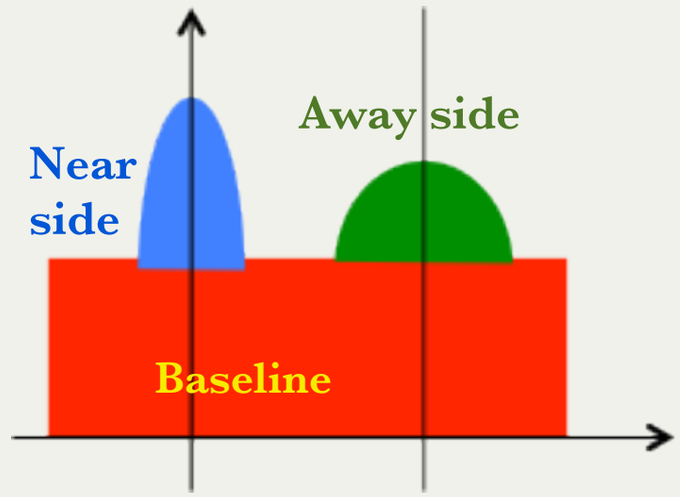
- path-length dependence of energy loss
  - surface bias (due to high-p_T selection for trigger particle)
  - away-side suppression.

➡ possible modification of jet formation (modified parton shower and fragmentation)

- modification of near and away side associated yields and correlation peak widths.

Main observable: $I_{AA} = Y_{PbPb} / Y_{pp}$

where Y_{PbPb} and Y_{pp} are the yield in Pb-Pb and pp collisions.



Physics Motivation

azimuthal correlations with HF

Di-hadron (i.e. light flavour) correlations with ALICE

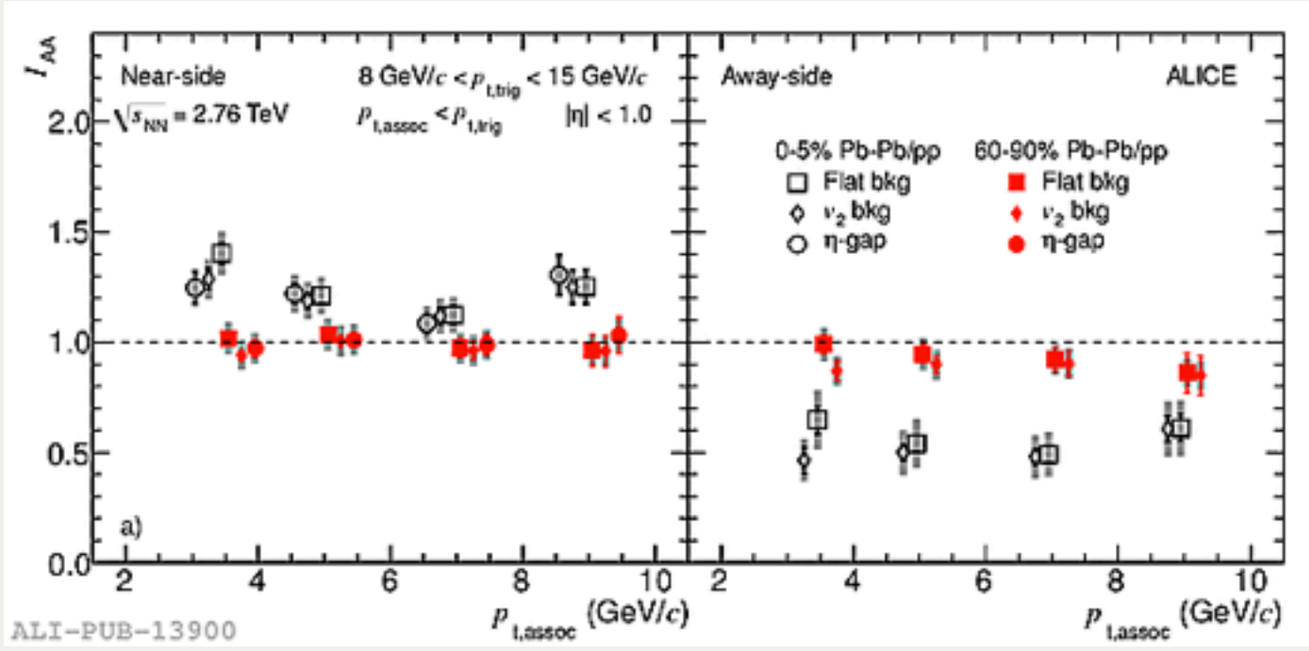
Comparing central Pb-Pb to pp collisions

Near side: 20% enhancement

Away side: 50% suppression

Phys. Rev. Lett. 108, 092301 (2012)

*no such effect in 60-90% peripheral Pb-Pb collisions



Possibility of similar effect in the heavy-flavour correlations ? IAA for heavy-flavours ?

Azimuthal correlations with HF: Due to their large masses, heavy quarks (charm and beauty) are predominantly produced via hard scatterings in the initial phase of the collision.

➡ They experience the full evolution of the system, losing energy while interacting with the medium.

➡ Energy loss predicted to be different for gluons, light quarks and heavy quarks.

- Dead cone effect.
- Casimir factor.

$$\Delta E_g > \Delta E_{(u,d,s)} > \Delta E_c > \Delta E_b$$ Dokshitzer & Kharzeev, PLB 519(2001)199)

➡ Harder fragmentation relative to light quarks and gluons: experimentally accessible meson kinematics closer to parton kinematics.

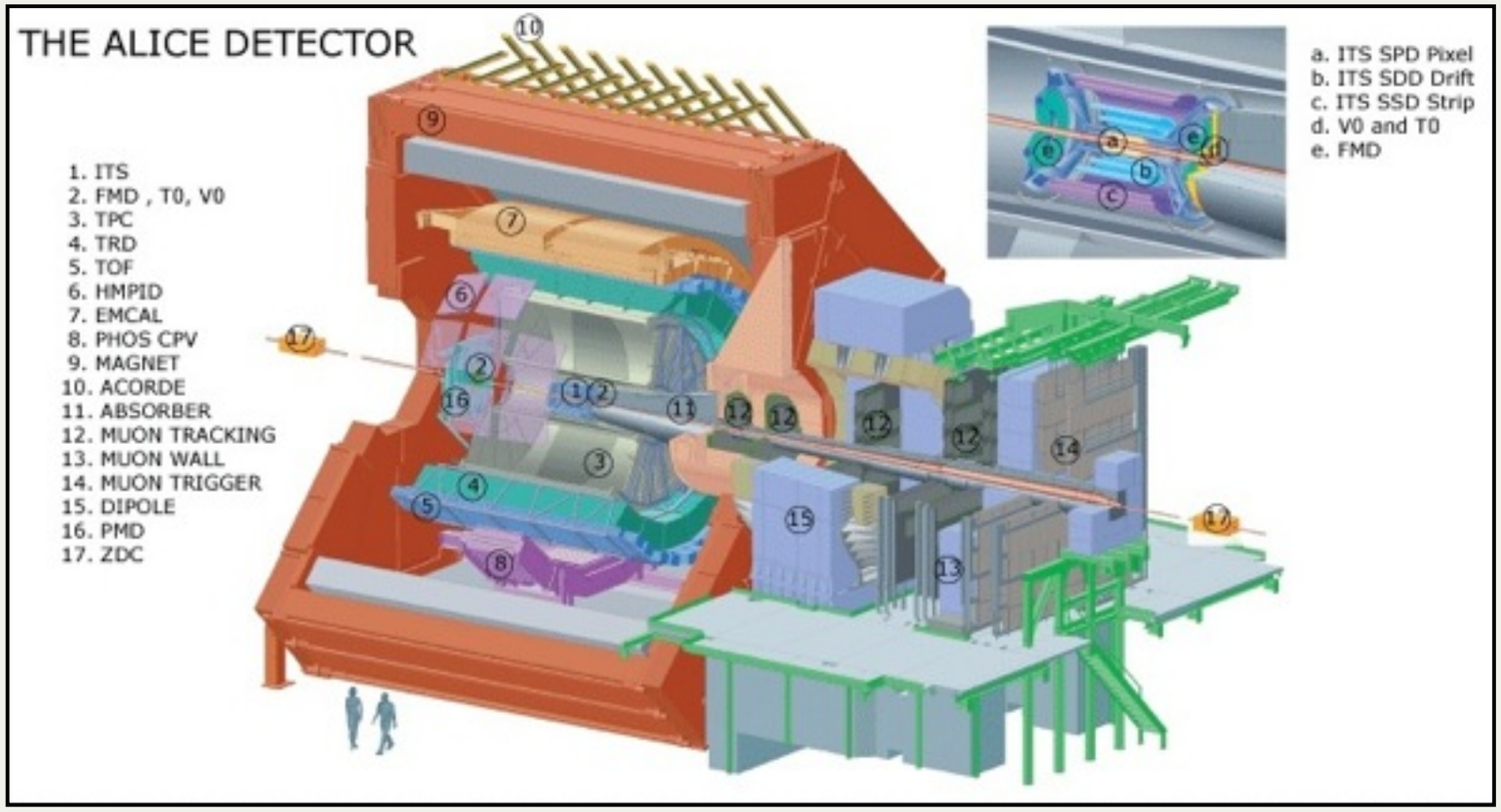
pp collision:
- ✓ reference for p-Pb and Pb-Pb collisions.
- ✓ information on different charm production mechanisms

ALICE Detector

ALICE (A Large Ion Collider Experiment) is specifically optimized for the study of heavy-ion collisions at the LHC.

Detectors used in this analysis:

- ➡ Inner Tracking System (ITS)
- ➡ Time Projection Chamber (TPC)
- ➡ Time Of Flight (TOF)



Heavy flavour detection with ALICE

Tracking: the Inner Tracking System (ITS) and the Time Projection Chamber (TPC) embedded in a magnetic field of 0.5 T, allow track reconstruction in the pseudorapidity range $-0.9 < \eta < 0.9$.

☞ **down to low p_T** ☞ **excellent resolution on track momentum and impact parameter**

Particle identification: Particle identification with TPC and TOF via the measurement of the specific energy loss dE/dx and of the time of flight ☞ **separate pions and kaons up to 1.5(2) GeV/c in pp(p-Pb) collisions**

DATA Samples

pp, $\sqrt{s} = 7$ TeV, 3.1 x10^8 minimum-bias triggers (2010 sample)

p-Pb, $\sqrt{s_{NN}} = 5.02$ TeV, 1.0 x10^8 minimum-bias triggers (2013 sample)

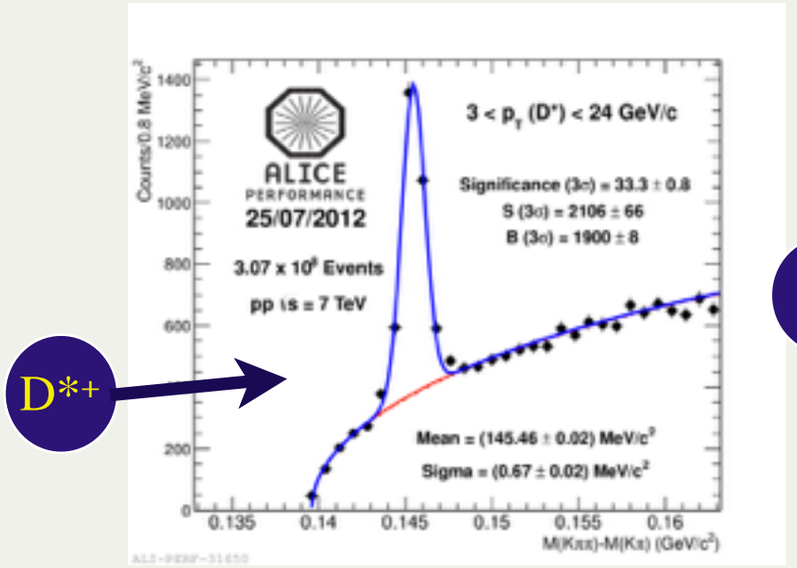
Analysis Method

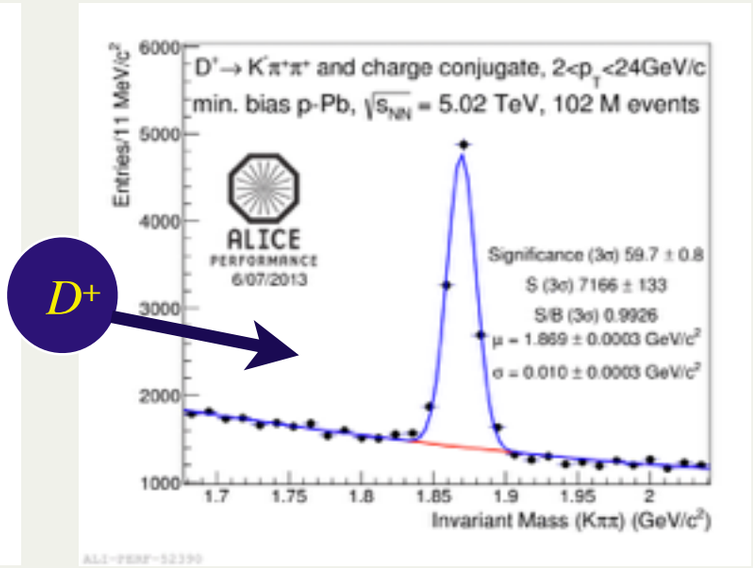
1. D meson signal extraction

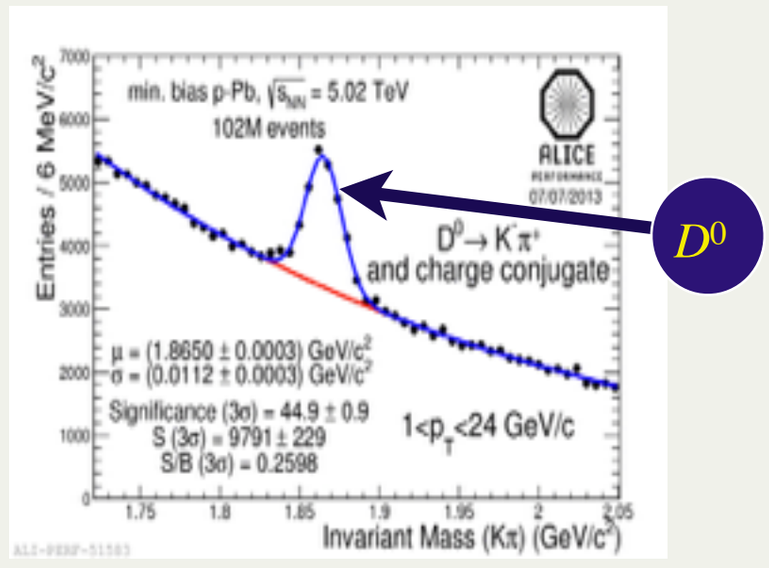
D meson signal extraction

- ➡ Invariant mass analysis of *D*-meson candidates.
- ➡ Displaced vertices selected via topological cuts
- ➡ PID on decay products

Decay Channel	Branching Ratio
$D^+ \rightarrow K^- \pi^+ \pi^+$	9.13 ± 0.19%
$D^0 \rightarrow K^- \pi^+$	3.88 ± 0.05%
$D^{*+} \rightarrow D^0 \pi^+ \rightarrow K^- \pi^+ \pi^+$	2.62 ± 0.10%







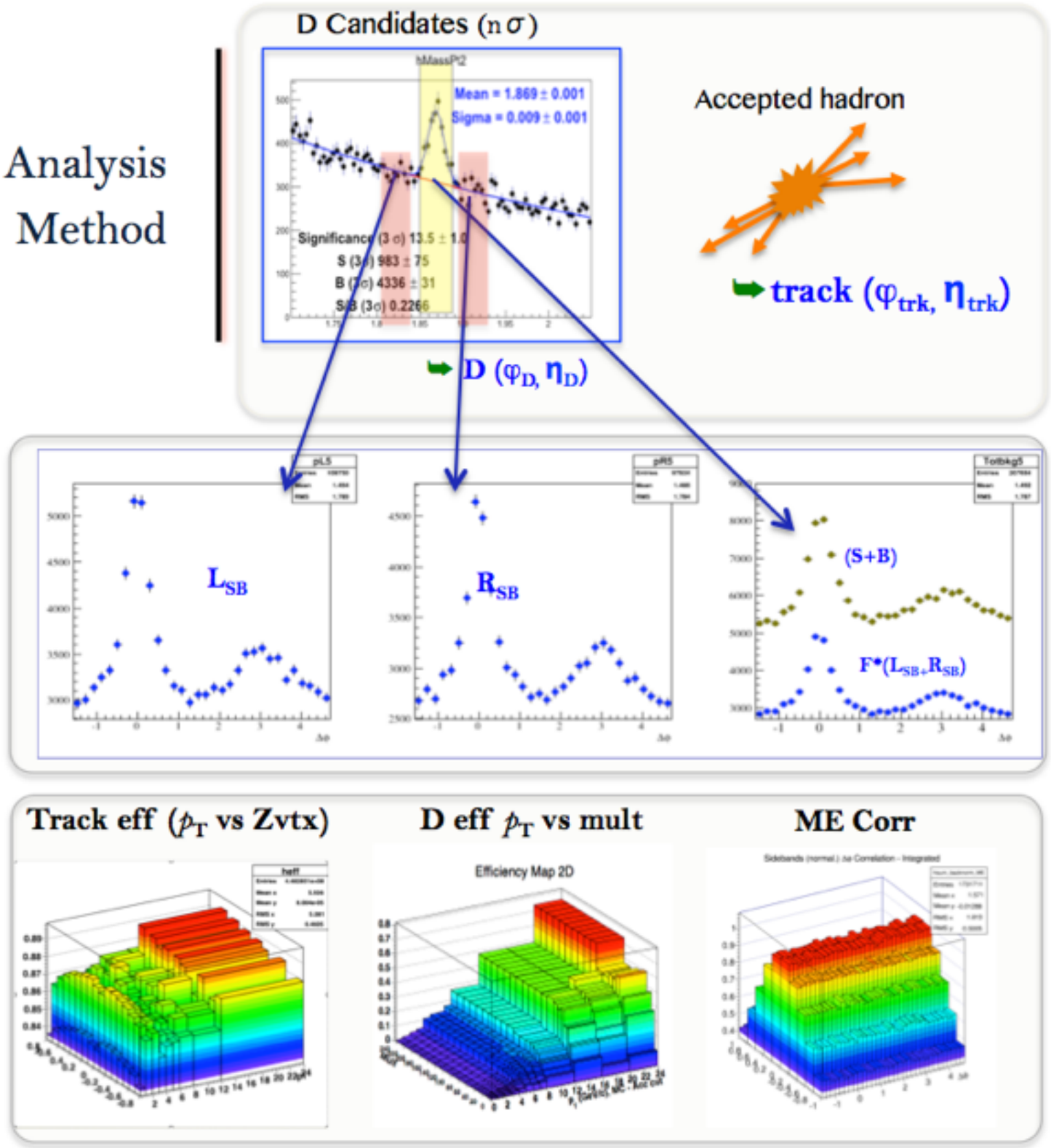
☞ Challenge with HF

- ☑ Large statistics needed
- ☑ High combinatorial background (in the reconstruction of D-meson hadronic decays)
  - * tight selection applied (low D-meson selection efficiency)
  - * need to subtract correlations of background
- ☑ Contamination due to D from B decays

Analysis Method

2. Azimuthal correlations

Analysis Method



Each selected *D*-meson is correlated with charged tracks produced in the collision (excluding the *D*-meson daughter particles)

1. Raw Correlations

⇨ $(\Delta\varphi, \Delta\eta)$

2. Background subtraction from side bands

Obtain D–hadron correlations in
S1. $\pm 2\sigma$ region (S+B)
S2. $-(8\sigma - 4\sigma)$ Left side band (B)
S3. $+(4\sigma - 8\sigma)$ Right side band (B)
S4. Add bkg from Left + Right with scaling.
$WB_L + WB_R \sim B_0(\pm 2\sigma)$
S5. Subtract S4 from S1.

3. Corrections

Detector acceptance and inhomogeneities via Mixed Events
D-meson reconstruction and selection efficiency
Associated track reconstruction efficiency
Subtraction of feed-down from B decays

4. Systematic errors evaluation

Results from pp collision at 7 TeV

D-meson p_T range
low(3-5) mid(5-8) high(8-16) GeV/*c*

Associated particle p_T
> 0.3, 0.5, 1.0 GeV/*c*

↳ **Correlations are measured for D^0, D^{+*}, D^+**
↳ **In different p_T intervals of D: low(3-5), mid(5-8), high(8-16) GeV/*c***
↳ **With different thresholds on associated particle p_T > 0.3, 0.5, 1.0 GeV/*c***

Results from pp collisions at 7 TeV

Data analysis

Case of D^+

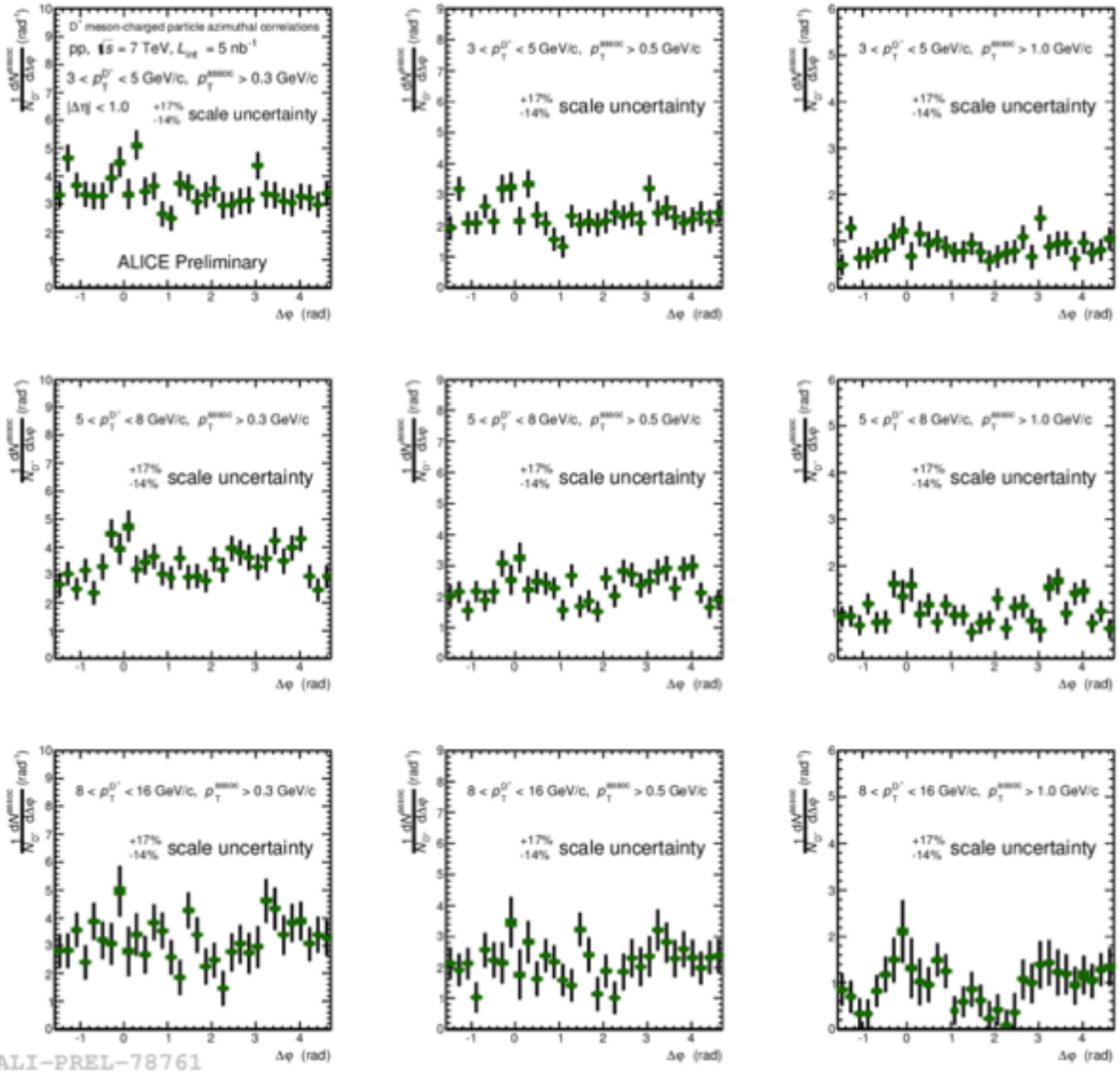
low (D^+) p_T

mid (D^+) p_T

high (D^+) p_T

Associated particle p_T threshold

> 0.3 GeV/c | **> 0.5 GeV/c** | **> 1.0 GeV/c**

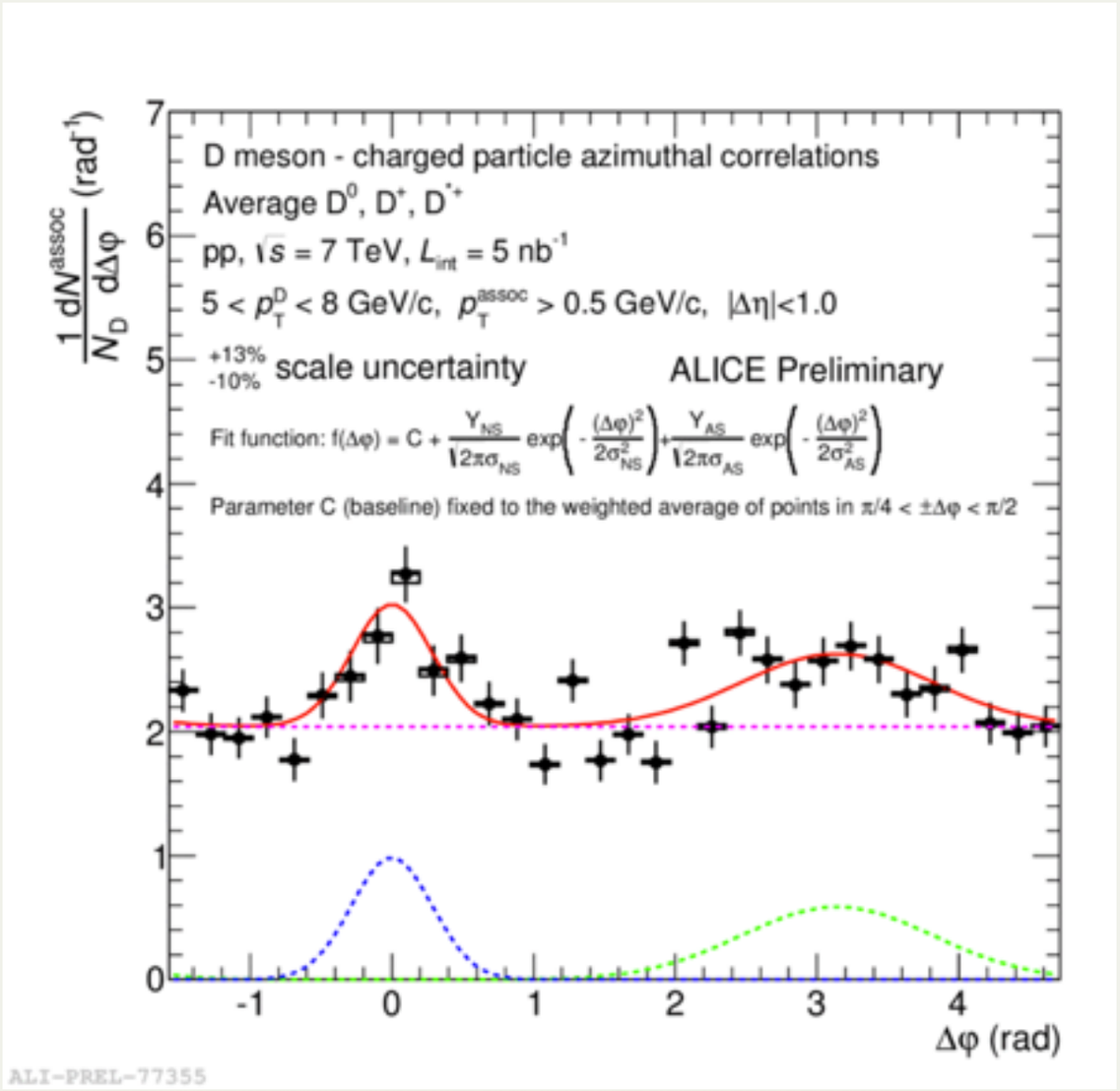


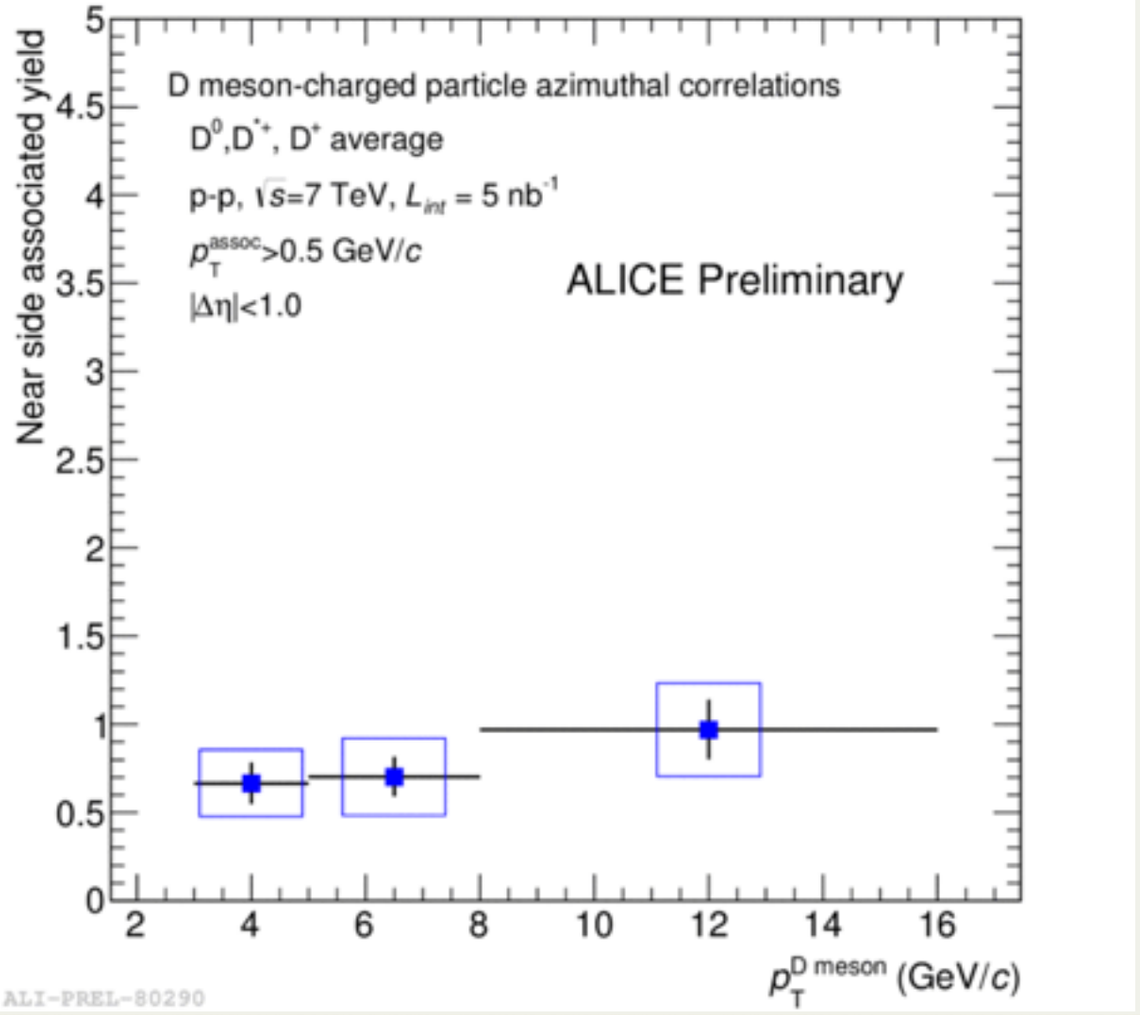
Results from pp collisions at 7 TeV

Data analysis

- Average of the D^0, D^{+*}, D^+ mesons
- (left plot) D-meson p_T 5-8 GeV/c and hadron p_T > 0.5 GeV/c
- (right plot) Near side associated yield vs. D-meson p_T (low, mid, high) with hadron p_T > 0.5 GeV/c

* Near side associated yield is taken from the fit to the correlation distribution at $\Delta\varphi = 0$

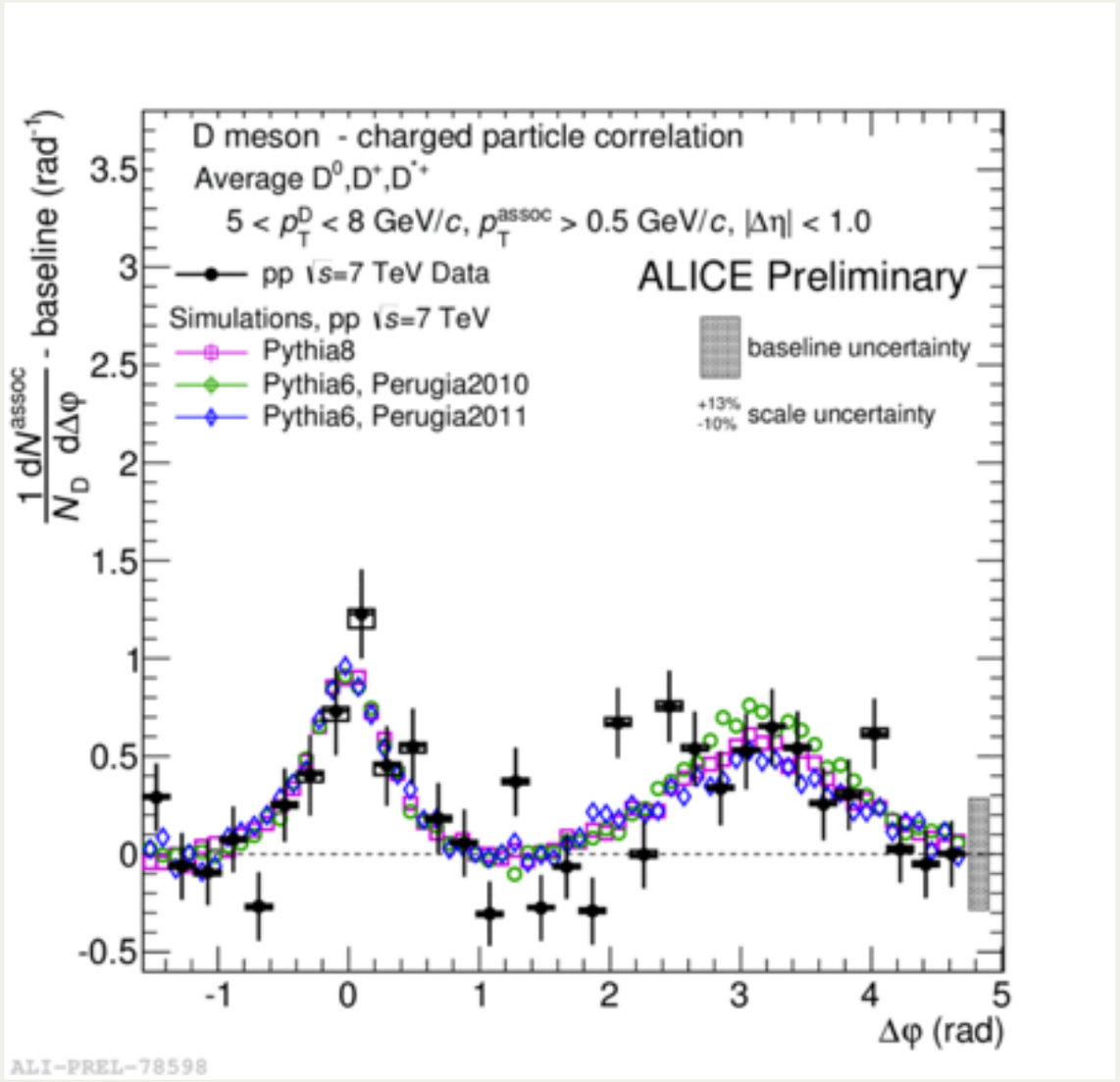


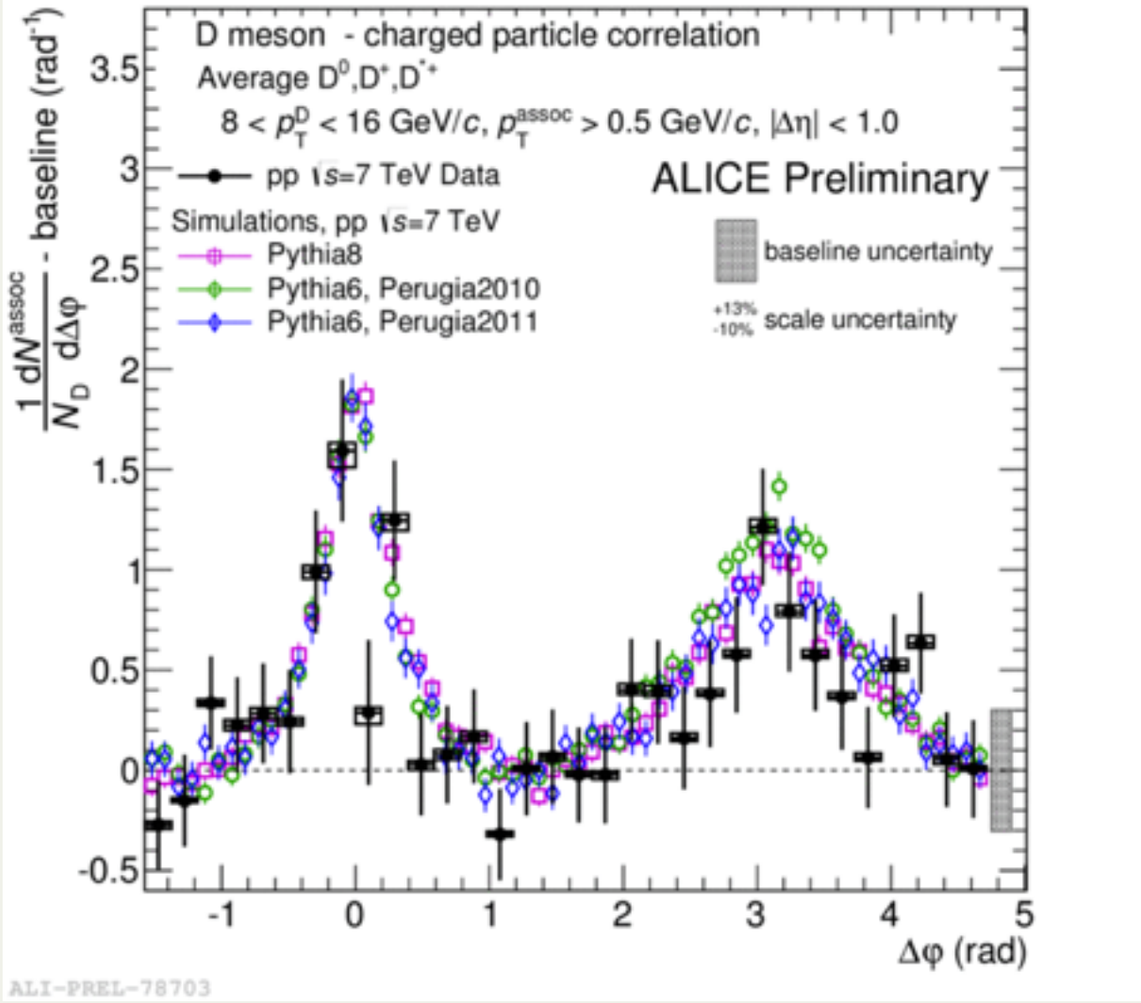


Results from pp collisions at 7 TeV

Data vs. Pythia

- Average of the D^0, D^{+*}, D^+ mesons
- **(left plot)** D-meson p_T 5-8 GeV/c and hadron p_T > 0.5 GeV/c
- **(right plot)** D-meson p_T 8-16 GeV/c and hadron p_T > 0.5 GeV/c





Data are described within uncertainties by different PYTHIA tunes

Results

Results from collision p-Pb at 5.02 TeV

D-meson p_T range
mid(5-8) high(8-16) GeV/*c*

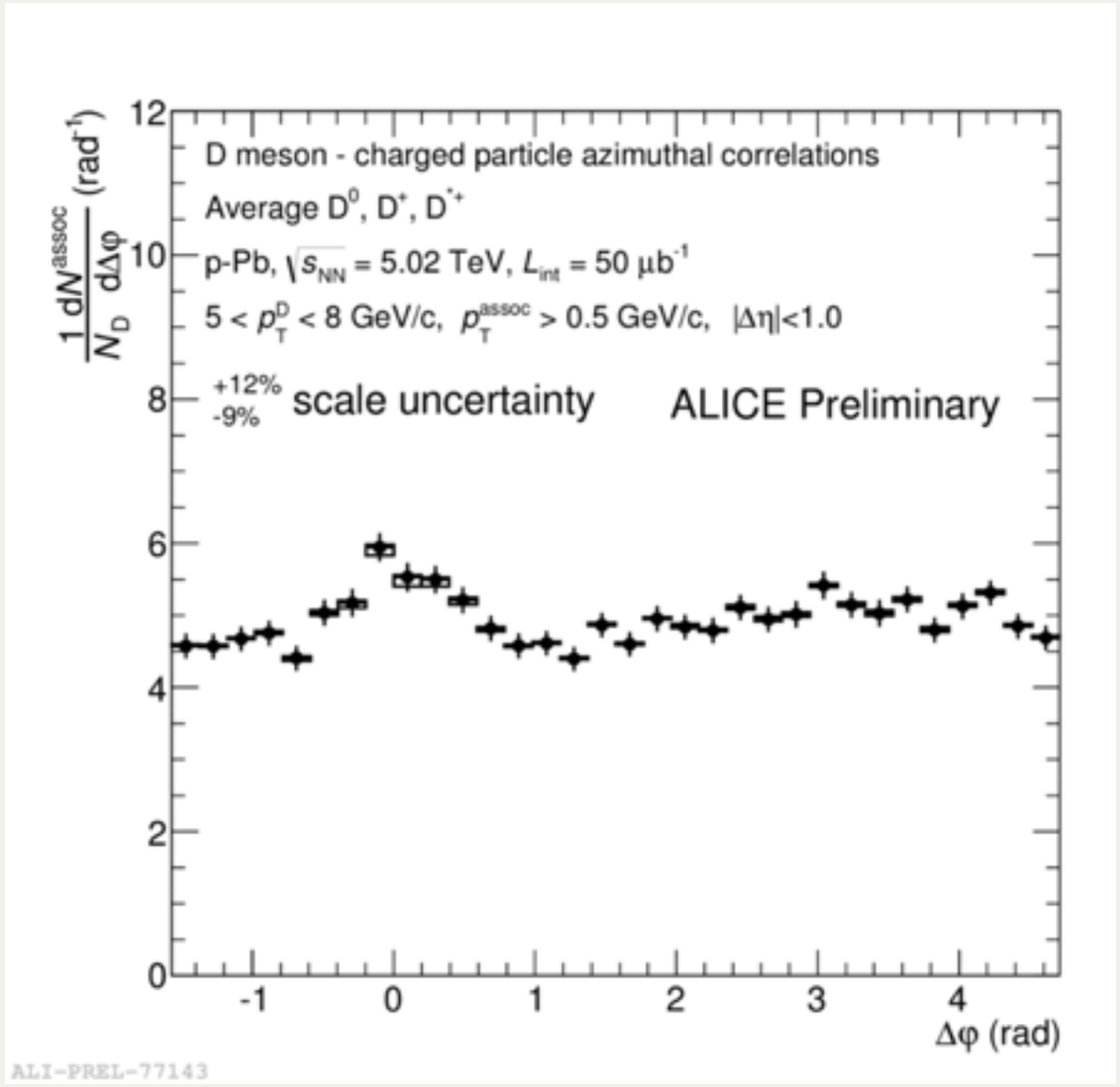
Associated particle p_T
> 0.3, **0.5, 1.0** GeV/*c*

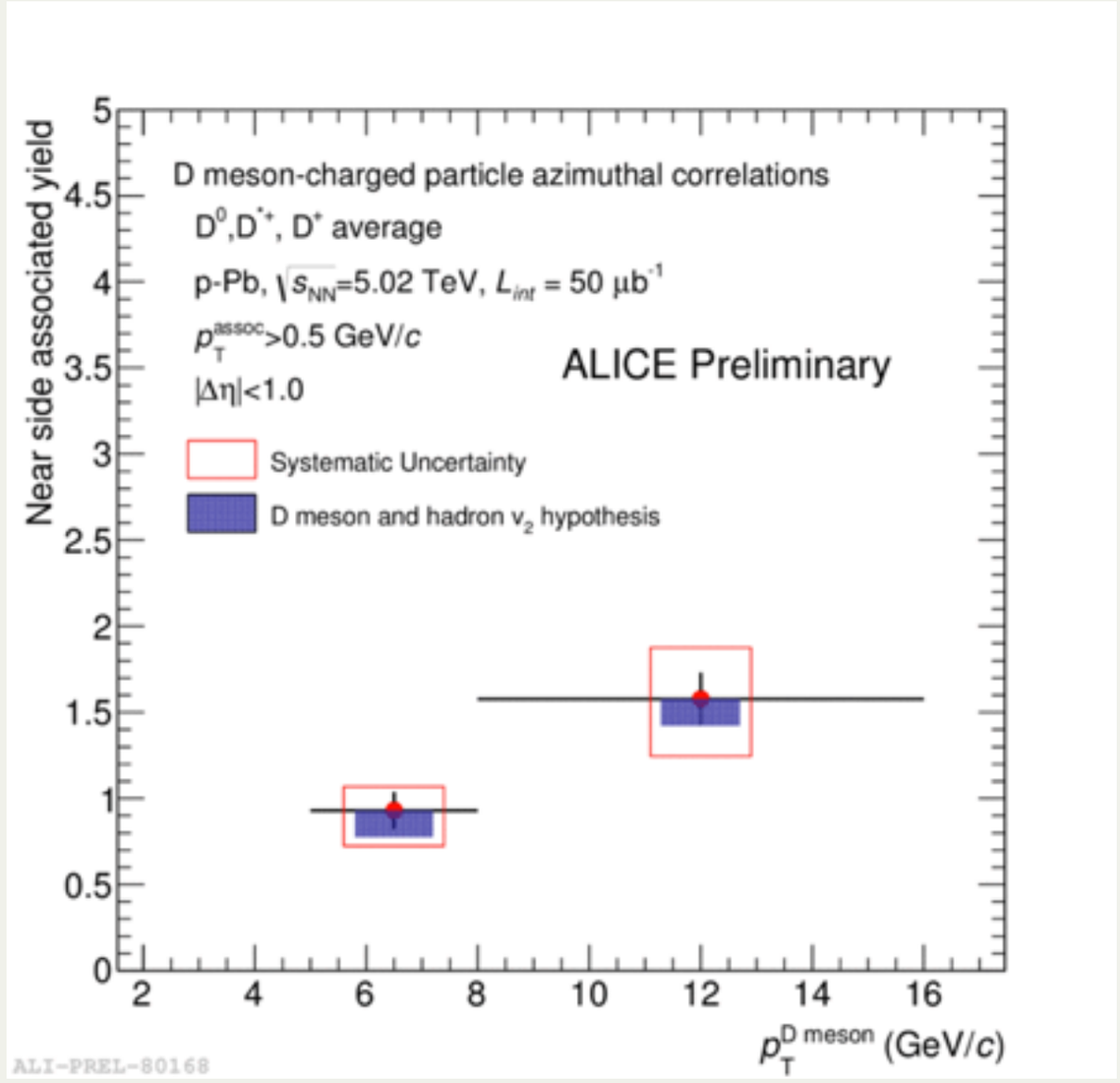
Results from p-Pb at 5.02 TeV

Data analysis

- Average of the D^0, D^{+*}, D^+ mesons
- (left plot) D-meson p_T 5-8 GeV/c and hadron p_T > 0.5 GeV/c
- (right plot) Near side associated yield vs. D-meson p_T (mid, high) with hadron p_T > 0.5 GeV/c

* Near side associated yield is taken from the fit to the correlation distribution at $\Delta\varphi = 0$



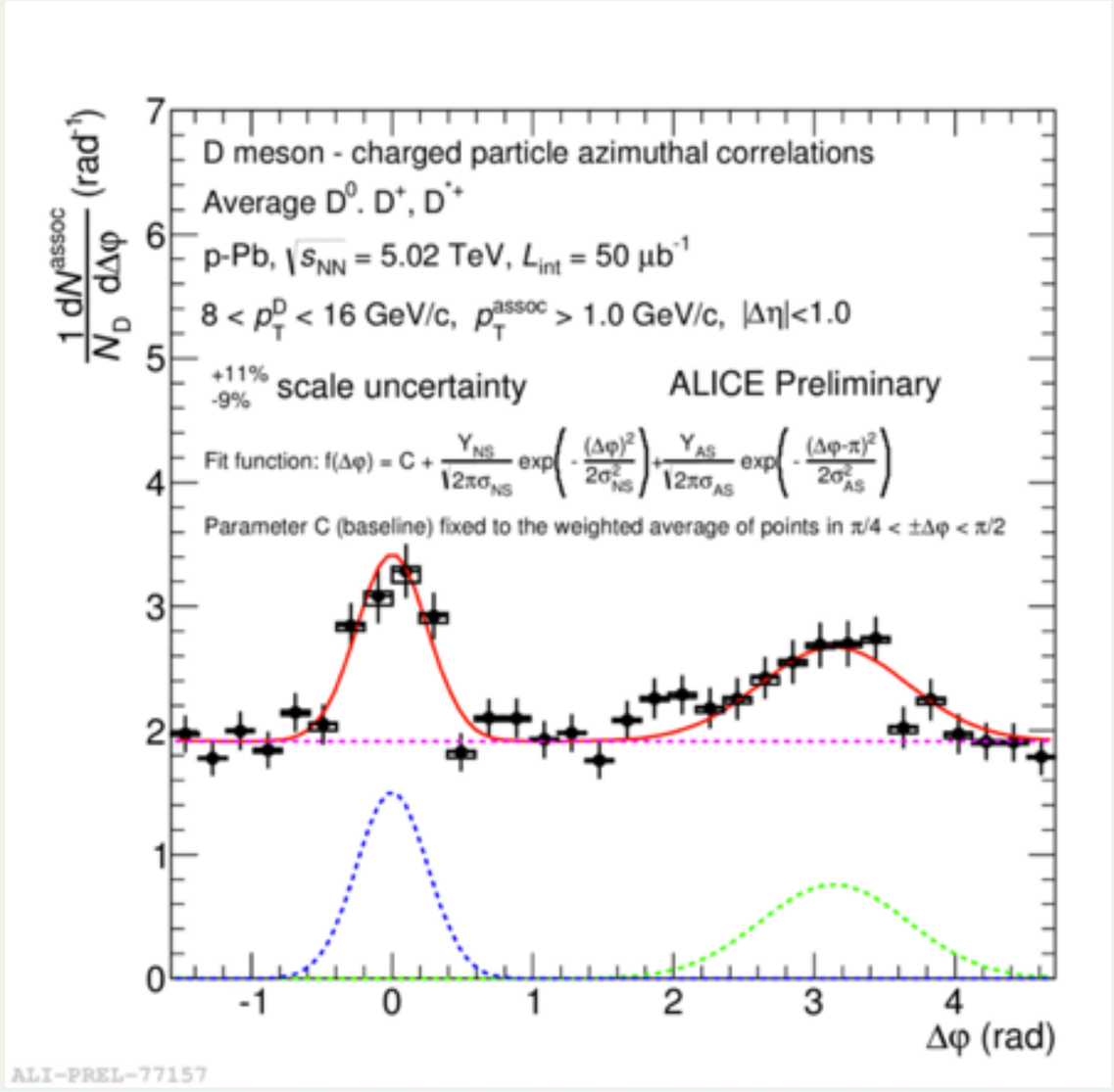


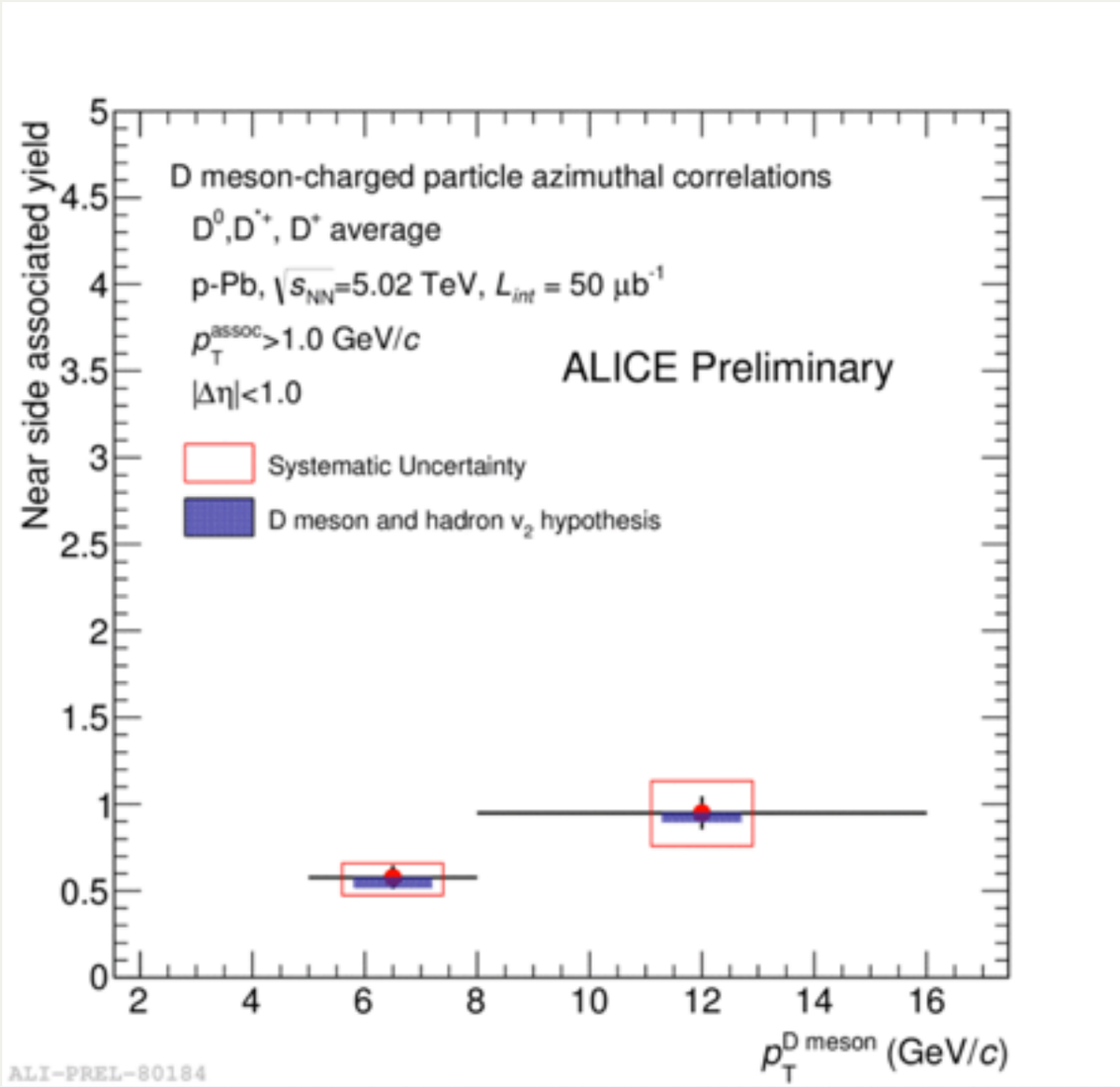
Results from p-Pb at 5.02 TeV

Data analysis

- Average of the D^0, D^{+*}, D^+ mesons
- (left plot) D-meson p_T 8-16 GeV/c and hadron p_T > 1.0 GeV/c (with fit)
- (right plot) Near side associated yield vs. D-meson p_T (mid, high) with hadron p_T > 1.0 GeV/c

* Near side associated yield is taken from the fit to the correlation distribution at $\Delta\varphi = 0$





Comparison of pp and p-Pb

D-meson p_T range
high(8-16) GeV/*c*

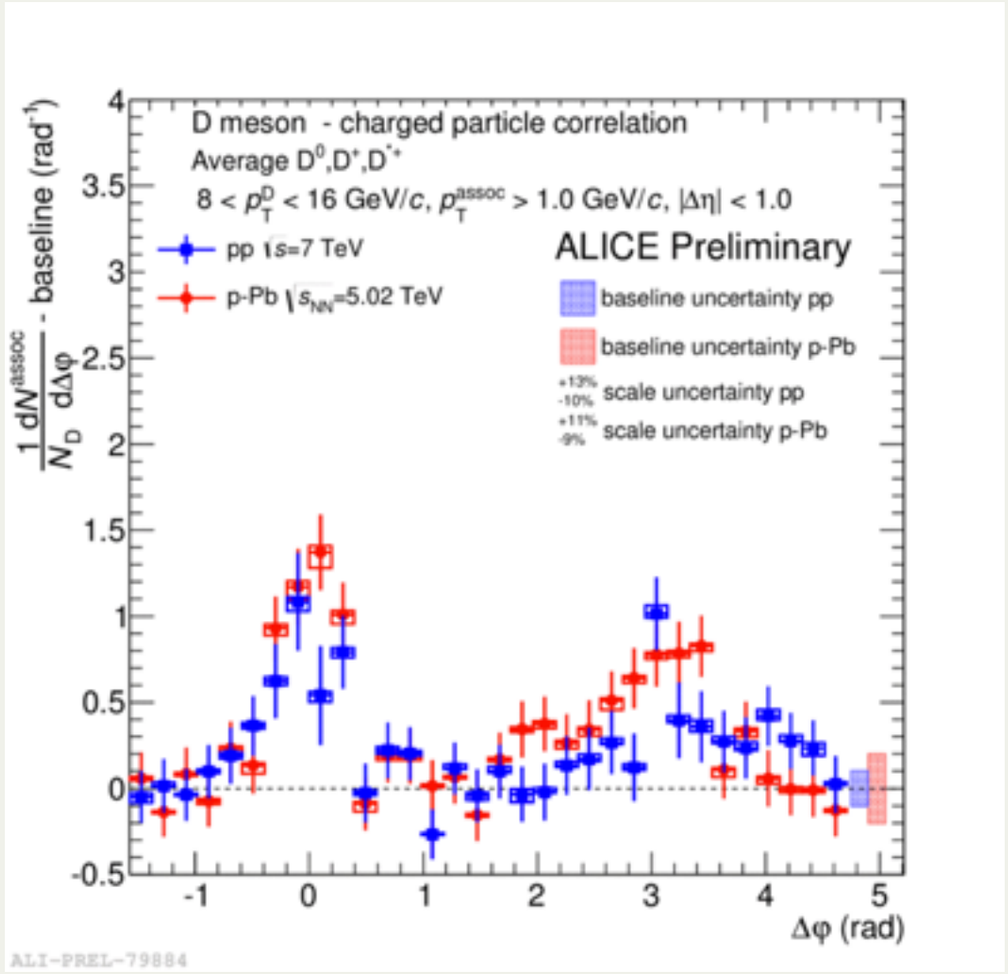
Associated particle p_T
> 1.0 GeV/*c*

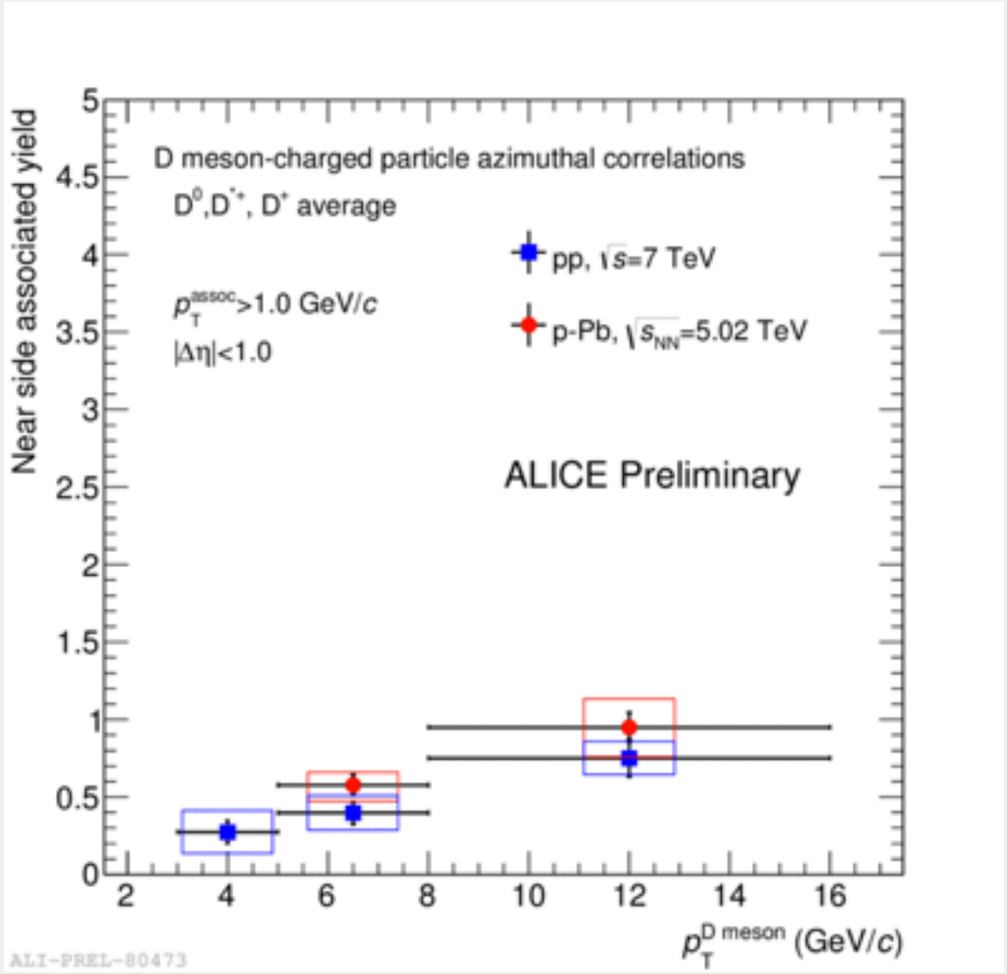
Results

Data analysis

- Average of the D^0, D^{+*}, D^+ mesons
- **(left plot)** D-meson p_T 8-16 GeV/c and hadron p_T > 1.0 GeV/c
- **(right plot)** Near side associated yield vs. D-meson p_T (low, **mid, high**) with hadron p_T > 1.0 GeV/c

* **Near side associated yield** is taken from the fit to the correlation distribution at $\Delta\varphi = 0$





Compatibility within uncertainties between pp at $\sqrt{s}$ = 7 TeV and p-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV correlation distributions after baseline subtraction.

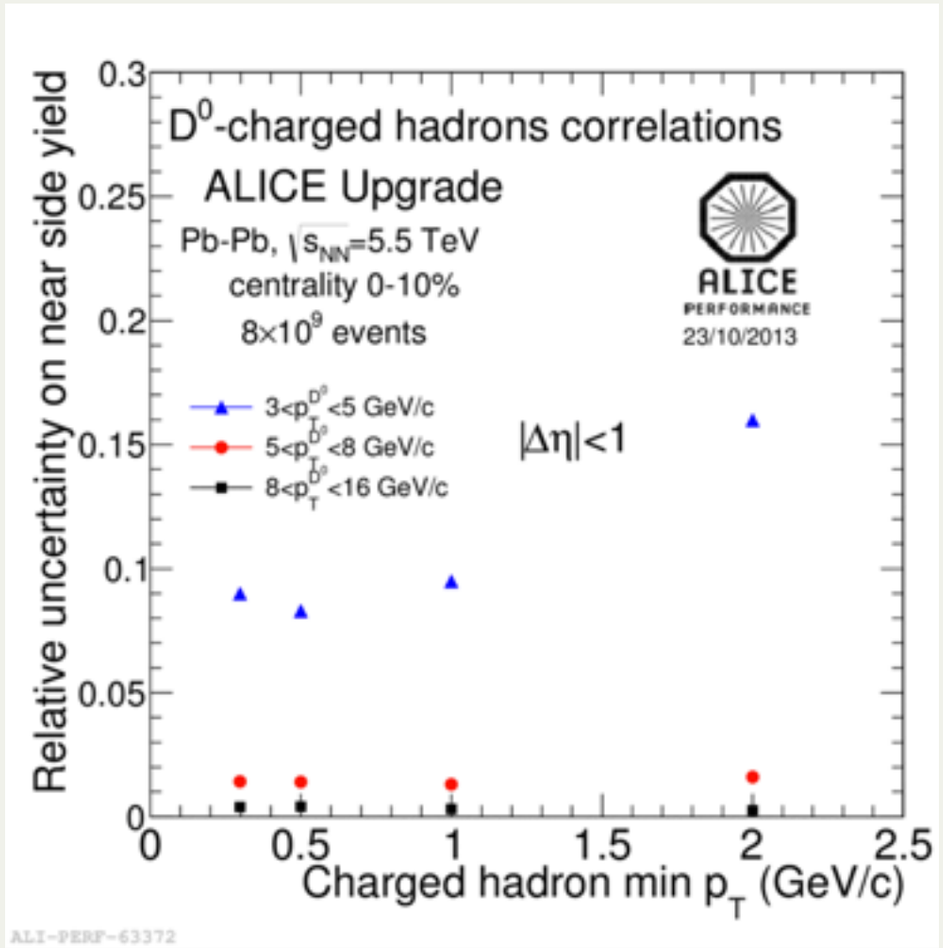
Perspectives with ALICE upgrades

Upgraded ITS will provide better spatial resolution

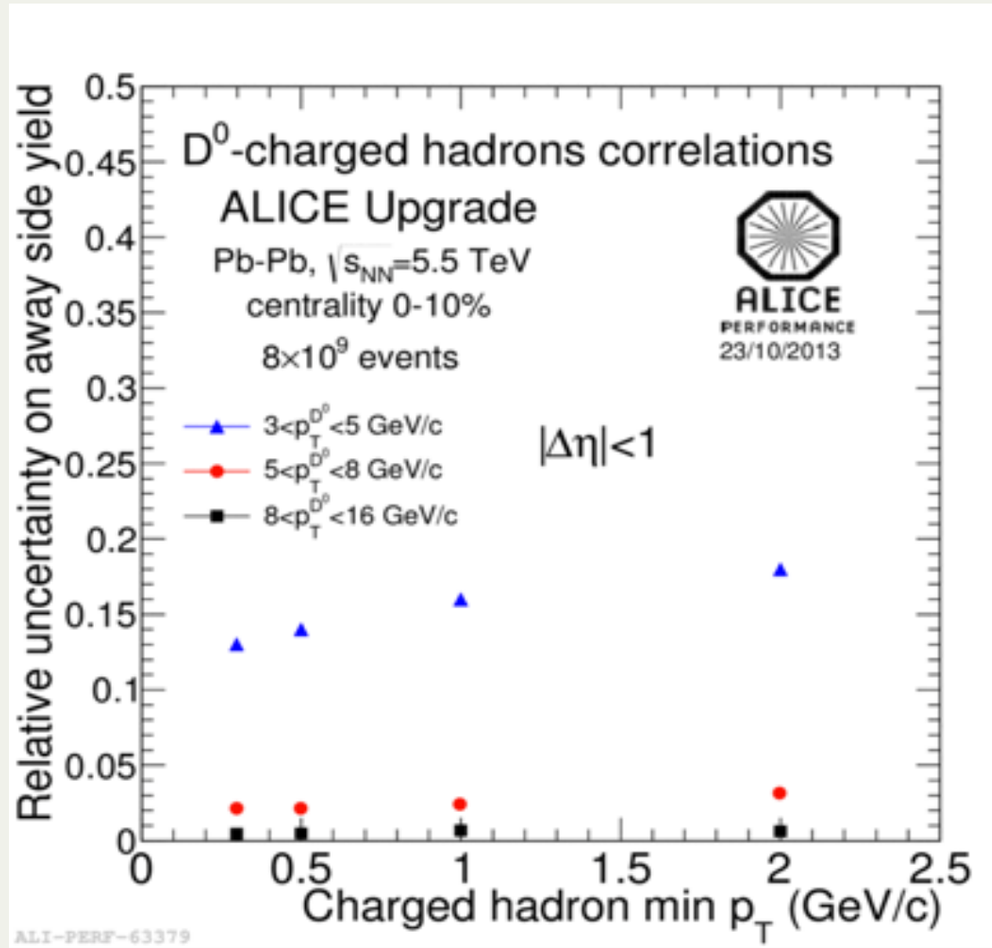
Higher integrated luminosity: $L_{int(Pb\text{-}Pb)} = 10\ nb^{-1}$

From continuous readout of min. bias interactions at 50 kHz

* **Near side yield**



* **Away side yield**



Measurements will benefit a lot from increased statistics from the ALICE-ITS upgrades (will arrive in 2018)

* **Pb-Pb data this time..**

Summary

First measurement of the angular correlations between D mesons and charged hadrons in pp and p-Pb collisions is presented.

Results in pp collisions at $\sqrt{s}$ = 7 TeV are compatible with predictions from different PYTHIA tunes

Results from p-Pb collisions are compatible with pp collisions after baseline subtraction.

Such measurements will benefit a lot from increased statistics in Run II and from the ALICE upgrades.

Thank you