Heavy-flavour production in pp collisions and correlations in pp and p-Pb collisions with ALICE at the LHC

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Berkeley 2016

Istituto Nazionale di Fisica Nucleare

ALICE

Strangeness in Quark Matter 2016, UC Berkeley, 27/6 - 1/7/2016

OUTLINE OF THE TALK

- Physics motivations
- ALICE detector and open heavy-flavour reconstruction
- Results
  - Open heavy-flavour cross sections in pp collisions
    → **New ALICE paper**, arXiv:1605.07569
  - Heavy-flavour production versus multiplicity in pp collisions
  - Azimuthal correlations of D mesons and charged particles in pp and p-Pb collisions
    → **New ALICE paper**, arXiv:1605.06963
- Conclusions

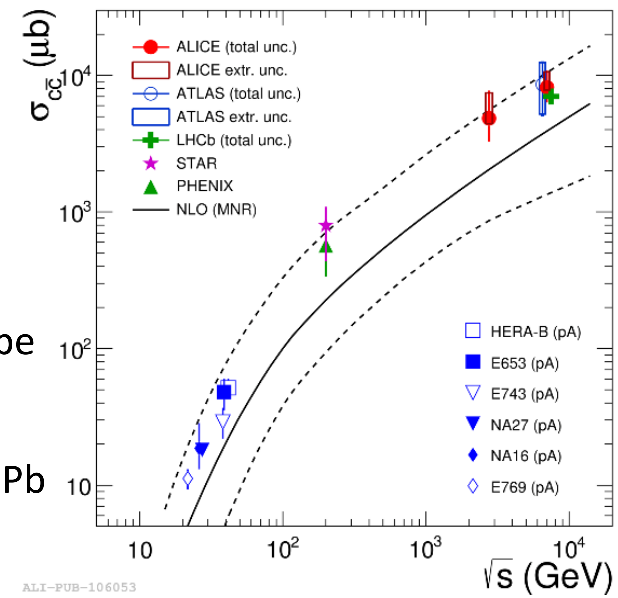
HEAVY-FLAVOUR PRODUCTION STUDIES IN pp COLLISIONS

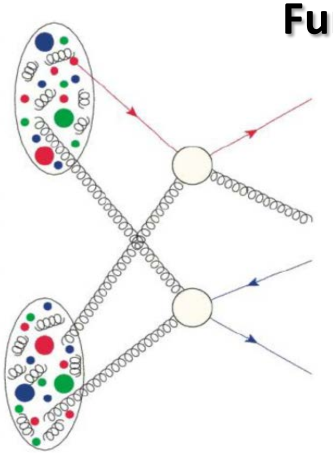
ALICE

arXiv: 1605.07569

Heavy-flavour (charm and beauty) quarks are produced in hard parton scattering processes with large Q^2:

- Production cross sections can be calculated via perturbative QCD ($\alpha_s << 1$):
    - Test and constrain pQCD calculations
- Heavy-quark production at the LHC energies allows us to probe Parton Distribution Functions at very low values of Bjorken-x
- Measurements in pp act as reference for measurements in p-Pb and Pb-Pb collisions, where heavy quarks can probe QGP properties





Further insight can be obtained through more differential studies…

→ Heavy-flavour production as a function of event multiplicity

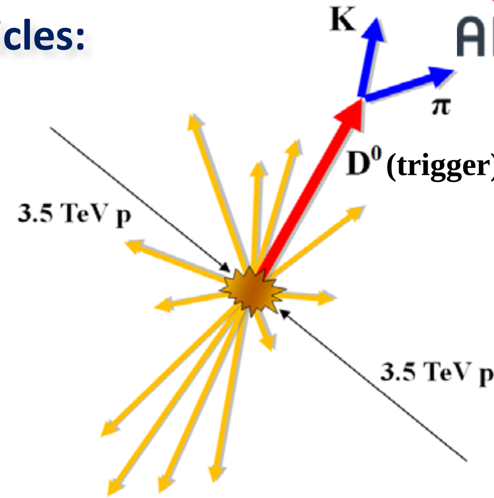
- Investigate interplay between hard and soft processes of particle production
- Study the possible role of multi-parton interactions (MPI) in the heavy-flavour sector

See talks by C. Terrevoli (HQ production I) and J. Wagner (this session)

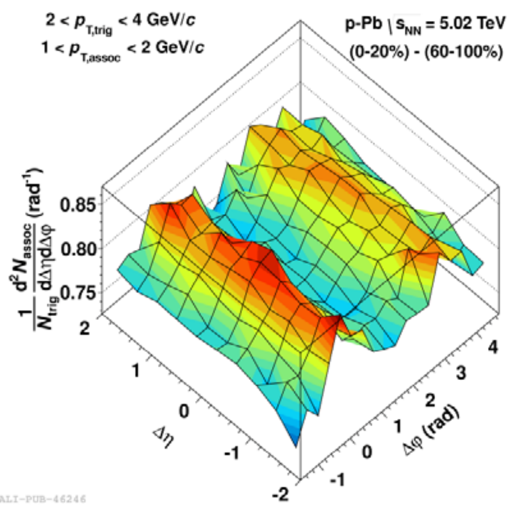
HEAVY-FLAVOUR CORRELATION STUDIES

→ **Angular correlations of heavy-flavour particles with charged particles:**

- **In pp collisions**:
  - Investigate heavy-flavour quark fragmentation properties
  - Sensitive to the relative contribution of different LO and NLO heavy-quark production processes
    → Norrbin and Sjöstrand, Eur. Phys. J. C17 (2000) 137
  - Extract relative fraction of electrons from charm and beauty decays via correlations between heavy-flavour hadron decay electrons and charged particles → ALICE, PLB 738 (2014) 97-108
  - Reference for p-Pb and Pb-Pb results



- **In p-Pb collisions**:
  - Investigate possible modifications of angular correlations which could derive from initial-state effects (e.g. CGC) or possible final-state effects (e.g. hydrodynamics)
  - Are there long-range ridge-like structures (double ridge) also in the heavy-flavour sector?



ALICE, PLB 709 (2013) 29
di-hadron angular correlations in p-Pb collisions

ALICE DETECTOR

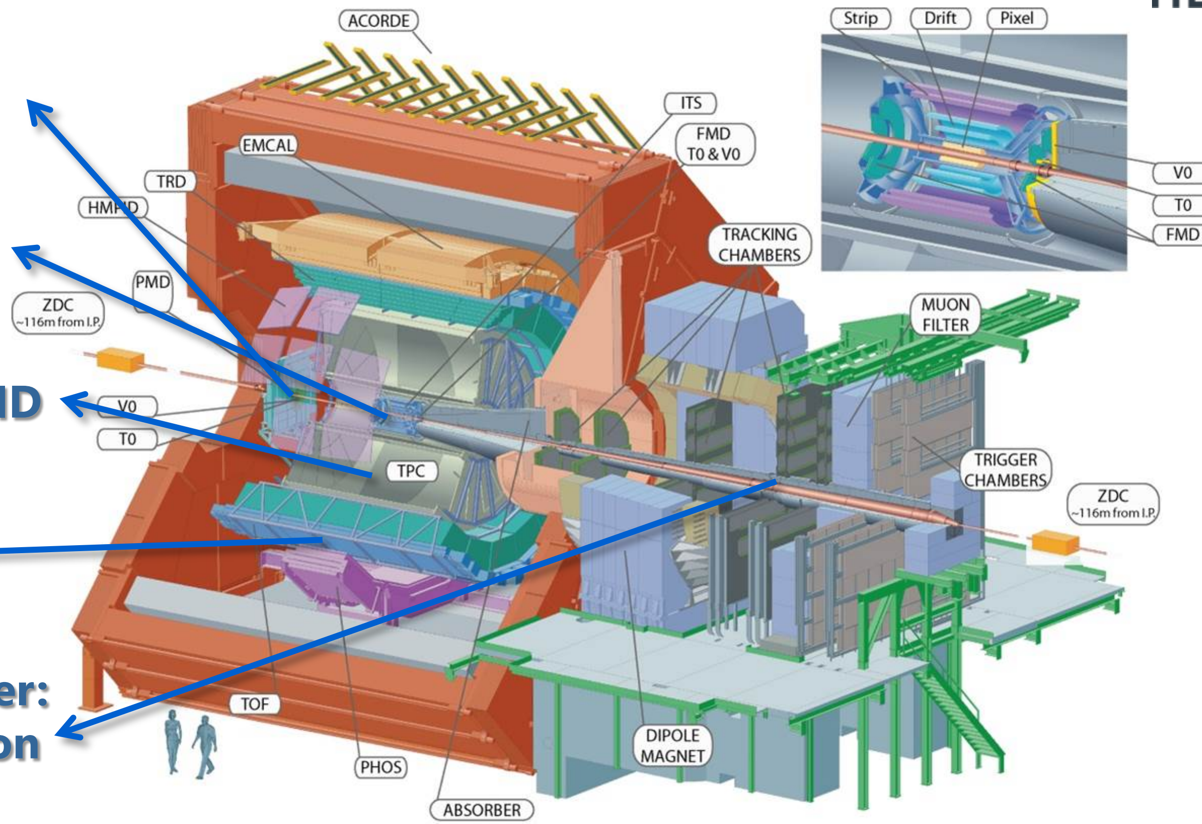
V0: trigger + multiplicity estimation

ITS: tracking + vertexing

TPC: tracking + p/K/π/e PID

TOF: p/K/π/e PID

Forward muon spectrometer: μ triggers + μ reconstruction



Data samples:

- **pp**: $L_{int} \approx 5\ nb^{-1}$ at $\sqrt{s}$ = 7 TeV, minimum-bias events (from 2010)
- **p-Pb**: $L_{int} \approx 50\ \mu b^{-1}$ at $\sqrt{s_{NN}}$ = 5.02 TeV, minimum-bias events (from 2013)

OPEN HEAVY-FLAVOUR RECONSTRUCTION

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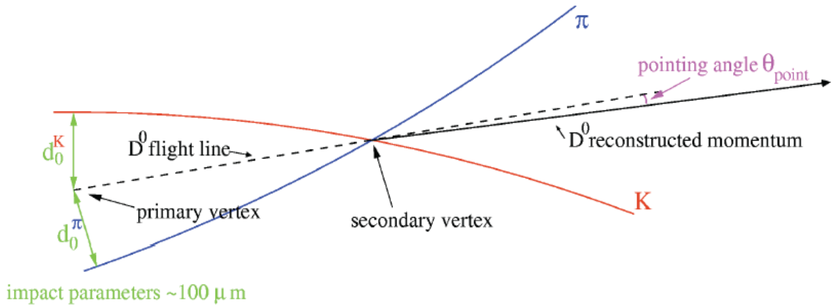
D mesons (from full reconstruction of hadronic decay channels)



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

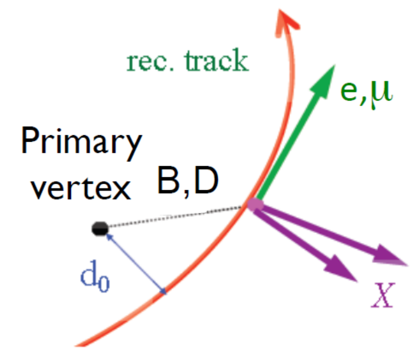
$D^+ \to K^- \pi^+ \pi^+$ (BR = 9.13± 0.19%)

$D^{*+} \to D^0 \pi^+$ (BR = 67.7 ± 0.05%)

$D_s^+ \to \phi \pi^+ \to K^+ K^- \pi^+$ (BR = 2.28 ± 0.12%)

- D-meson candidates reconstructed from pairs/triplets of displaced tracks and selected with topological cuts and PID
- K, π identification using TPC+TOF PID
- Removal of beauty feed-down contribution (via FONLL calculations) to extract results for prompt D mesons

Heavy-flavour decay electrons and muons (from hadron semileptonic decays)



B → e + X	B → μ + X
D → e + X	D → μ + X

- Electron identification using TPC+TOF PID
- Non-heavy-flavour electrons (from π^0, η Dalitz decays, photon conversions) removed with invariant mass method (e^+e^-) and/or background cocktail
- Muons: background (π, K decays) subtracted with MC (pp) or data-tuned MC cocktail (p-Pb, Pb-Pb)

Heavy-flavour production cross sections in pp collisions at $\sqrt{s}$ = 7 TeV

HEAVY-FLAVOUR CROSS SECTIONS IN pp COLLISIONS

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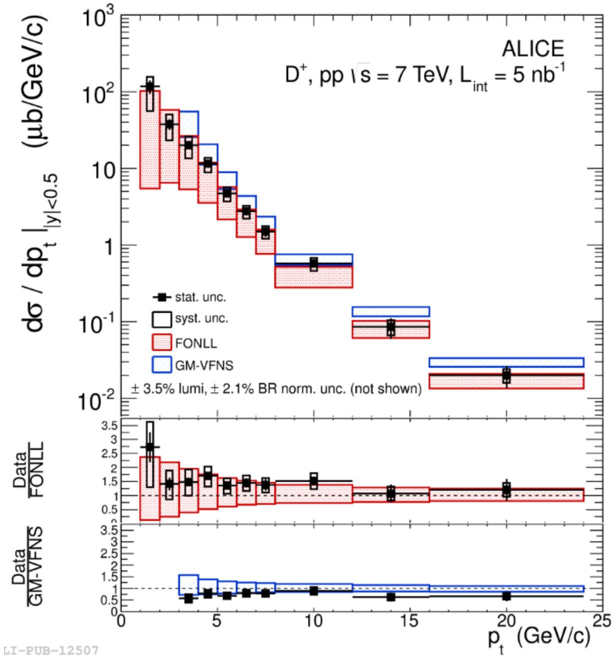
Prompt D^0,D^+,D^{*+},D_s^+ mesons

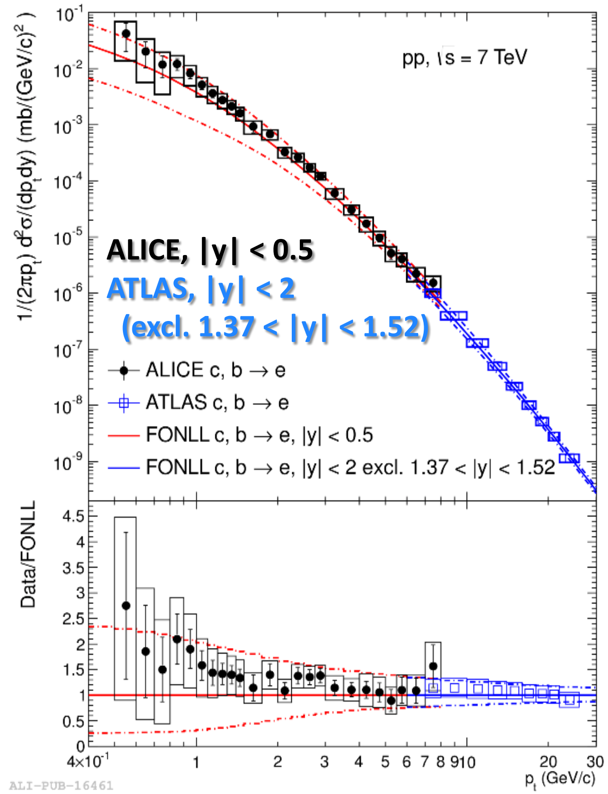


ALICE, JHEP 1201 (2012) 128

FONLL: JHEP0407 (2004) 033,
JHEP, 1210 (2012) 137

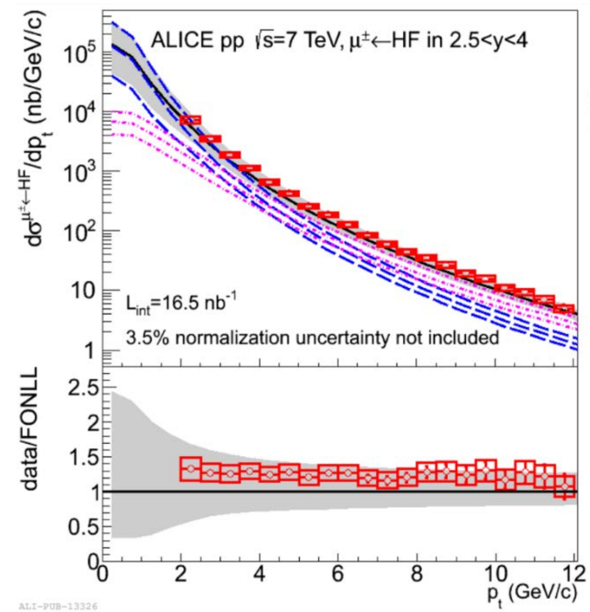
GM-VFNS: Eur.Phys.J., C72 (2012) 2082

HF-decay electrons



ALICE, Phys. Rev. D86 (2012) 112007
ATLAS, PLB 707 (2012) 438

HF-decay muons



ALICE, PLB 708 (2012) 265

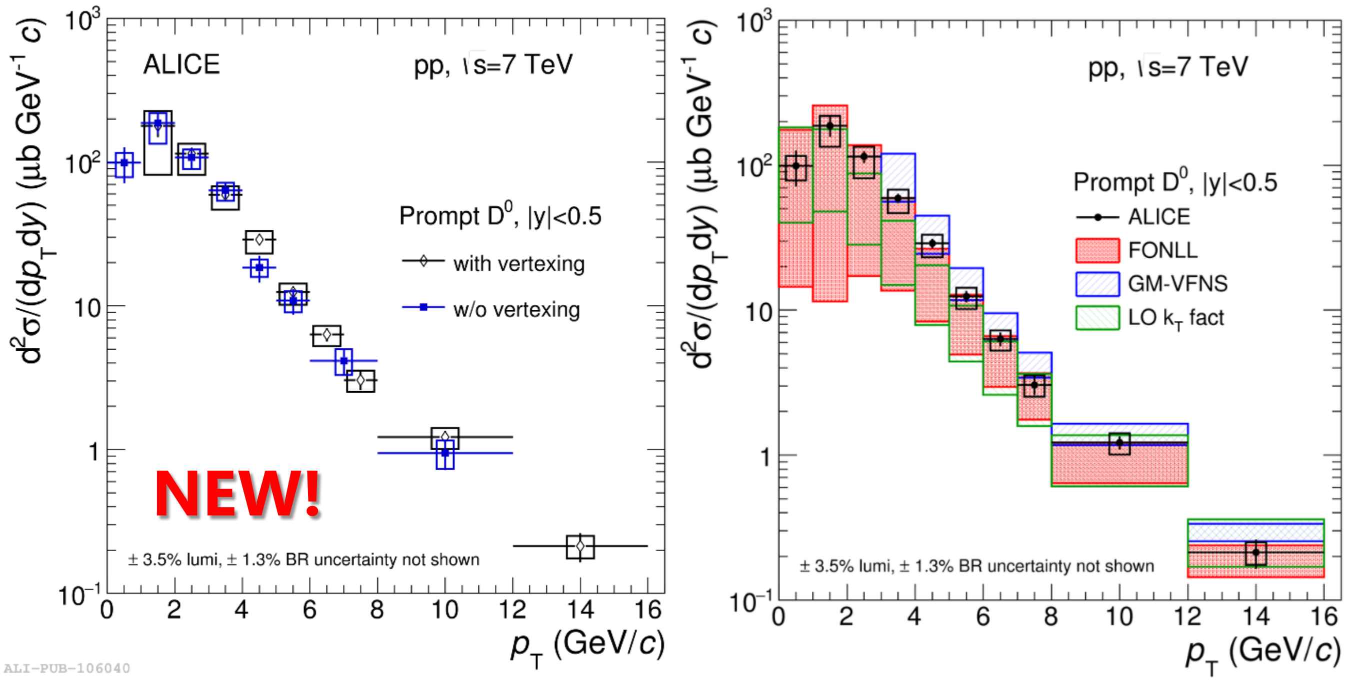
- Cross sections at $\sqrt{s}$ = 7 TeV compatible within uncertainties with expectations from FONLL and GM-VFNS pQCD calculations
- Results available also for pp collisions at $\sqrt{s}$ = 2.76 TeV → ALICE, JHEP 1207 (2012) 191; ALICE, Phys. Rev. D91 (2015) 012001; ALICE, Phys. Rev. Lett. 109 (2012) 112301

D^0 CROSS SECTION IN pp COLLISIONS DOWN TO p_T=0

ALICE

Analysis technique without secondary vertex reconstruction and topological selection

- Background subtraction via event mixing, like-sign distribution, track rotation or fit of sidebands



arXiv: 1605.07569

FONLL: JHEP0407 (2004) 033, JHEP, 1210 (2012) 137

GM-VFNS: Eur.Phys.J., C72 (2012) 2082

LO k_T fact: Phys.Rev., D87 (2013) 094022

Results from same technique available also for p-Pb collisions

See C. Terrevoli's talk, this session

- Results compatible with measurements based on topological selections and pQCD calculations
- Measurement extended down to p_T = 0, better performance also for 1 < p_T < 2 GeV/c
- Reduced uncertainty on total charm production cross section:

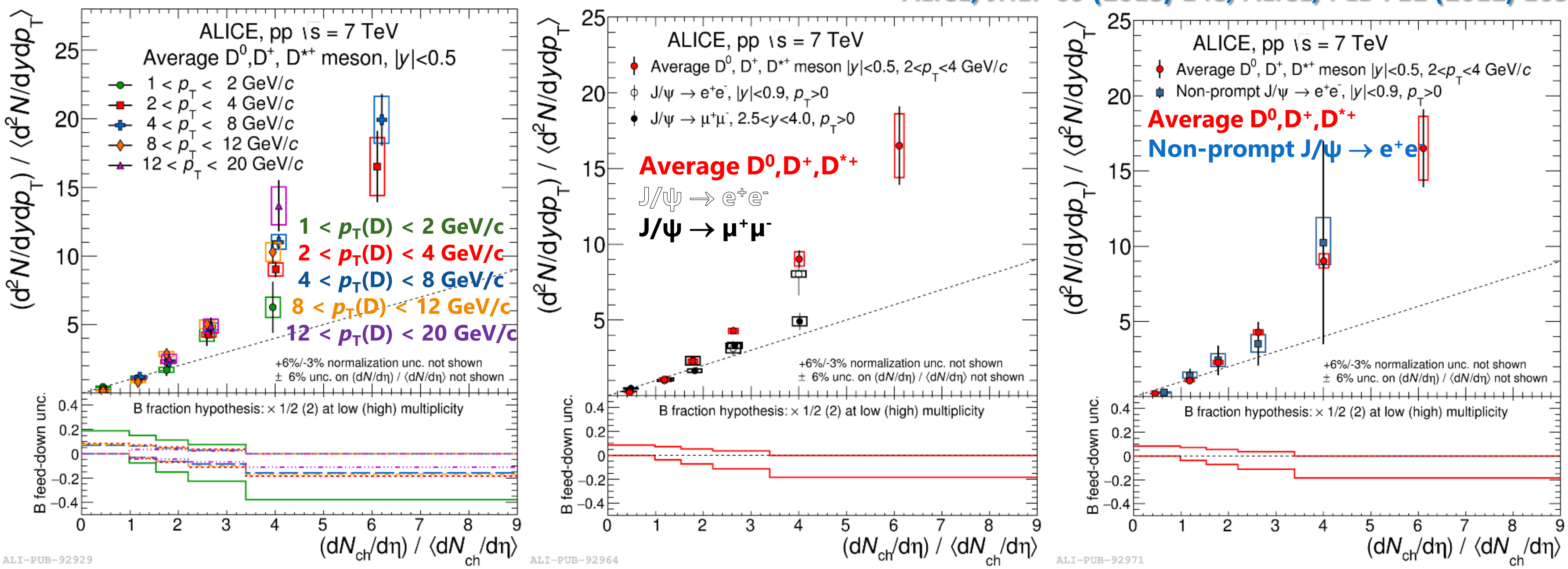
$$\sigma_{c\bar{c}}^{tot}(7\text{TeV}) = 7.96 \pm 0.65\,(\text{stat.})\,^{+0.87}_{-1.57}\,(\text{syst.})\,^{+2.34}_{-0.35}(\text{extr.}) \pm 0.28\,(\text{lumi.}) \pm 0.10\,(\text{BR}) \pm 0.03\,(\text{FF})\ \text{mb}$$

D-meson production vs multiplicity in pp collisions

Self-normalized D-meson yields (with respect to the multiplicity-integrated yields):

$$\frac{d^2N^D/dydp_T}{\langle d^2N^D/dydp_T \rangle} = \frac{Y^{mult}/(\varepsilon^{mult} \times N^{mult}_{event})}{Y^{tot}/(\varepsilon^{tot} \times N^{tot}_{event})/\varepsilon^{trigger}}$$

ALICE, JHEP 09 (2015) 148; ALICE, PLB 712 (2012) 165

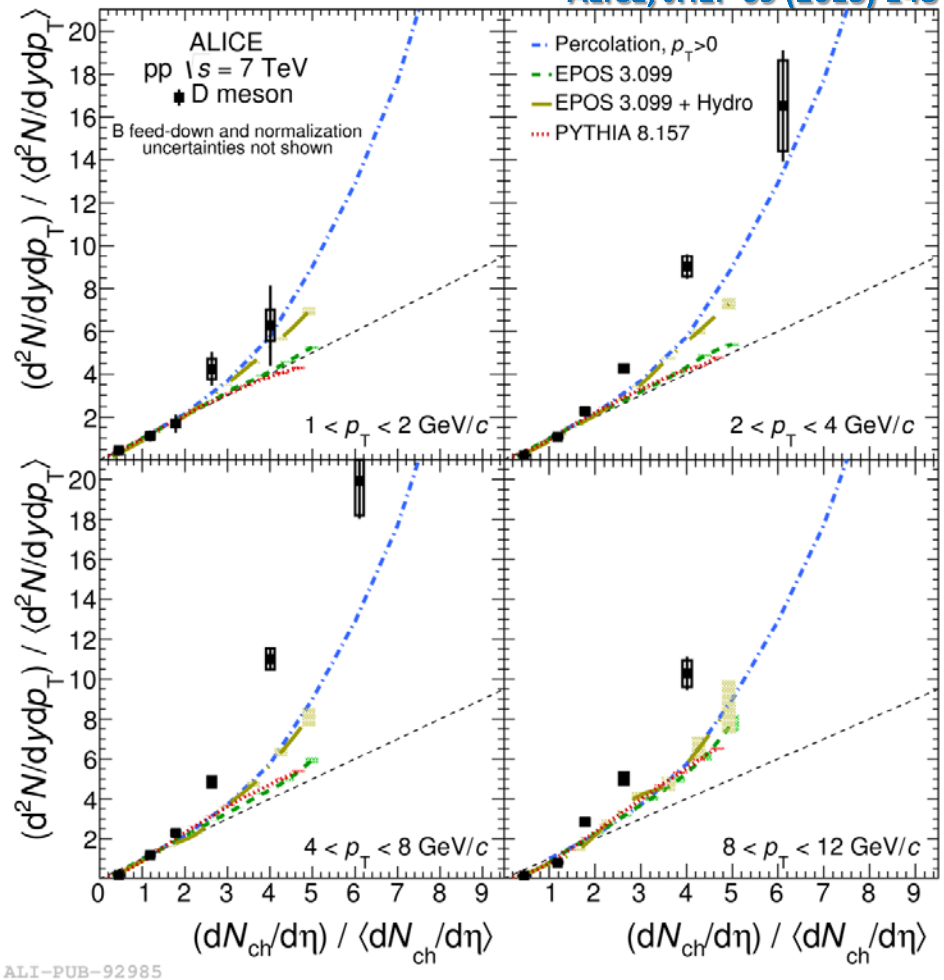


- Faster-than-linear increasing trend of the yields independent of D-meson p_T within uncertainties
- Consistent increase for open charm, hidden charm (at central and forward rapidity) and beauty
  - Behaviour related to HQ production process rather than to hadronization mechanism

ALICE

Comparison of self-normalized yields with models

ALICE, JHEP 09 (2015) 148



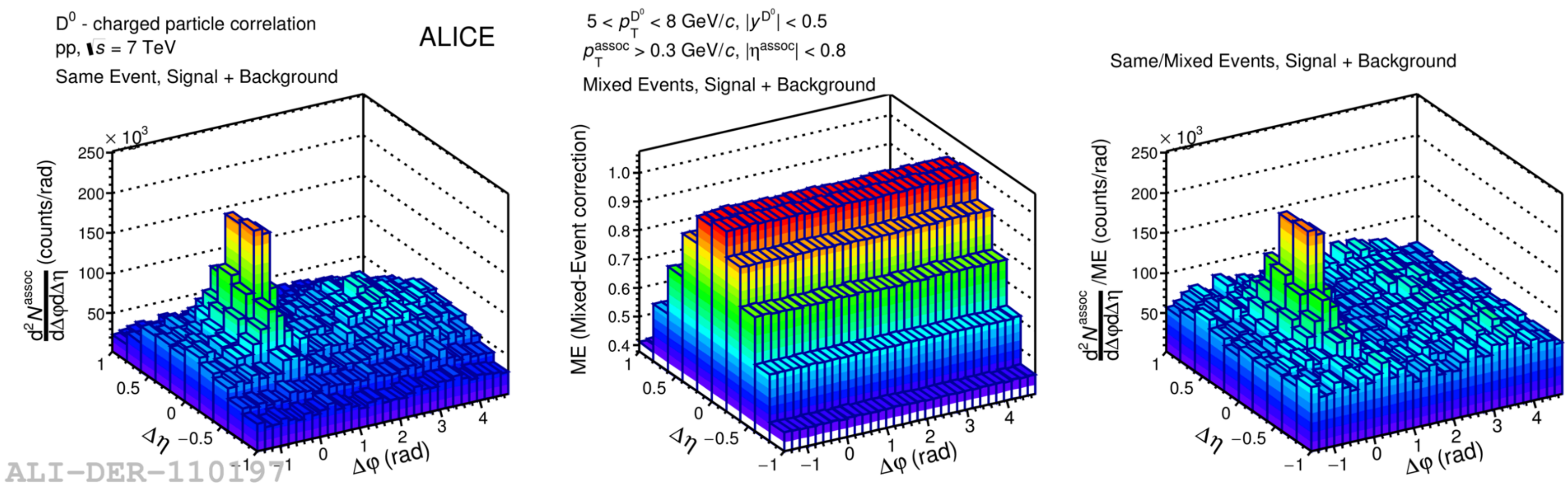
Ferreiro et al., PRC 86 (2012) 034903; Werner et al., PRC 89 (2014) 064903; Sjostrand et al., Comput.Phys.Commun. 178 (2008) 852

- **Percolation model**:
  - Sources of particle production: elementary strings
  - Reflects a MPI scenario
  - Predicts a faster-than-linear increase
- **EPOS (w/ or w/o Hydro)**:
  - Gribov/Regge multi-scattering formalism + saturation scale to mimic non-linear effects
  - Number of MPI related to multiplicity
  - Hydrodynamic evolution can be applied to the collision, predicting a faster-than-linear increase
- **PYTHIA 8**:
  - Soft-QCD tune
  - Includes MPI, color reconnection, initial-state and final-state radiations
- **Data qualitatively described by models including MPI**

Azimuthal correlations of D mesons and charged particles in pp and p–Pb collisions

Azimuthal correlations of D mesons and charged particles in pp and p-Pb collisions

- (Δφ,Δη) correlation of selected D mesons ("trigger particles") with the other charged tracks reconstructed in the event ("associated particles")
- Correction for detector inhomogeneities and limited acceptance via event-mixing technique



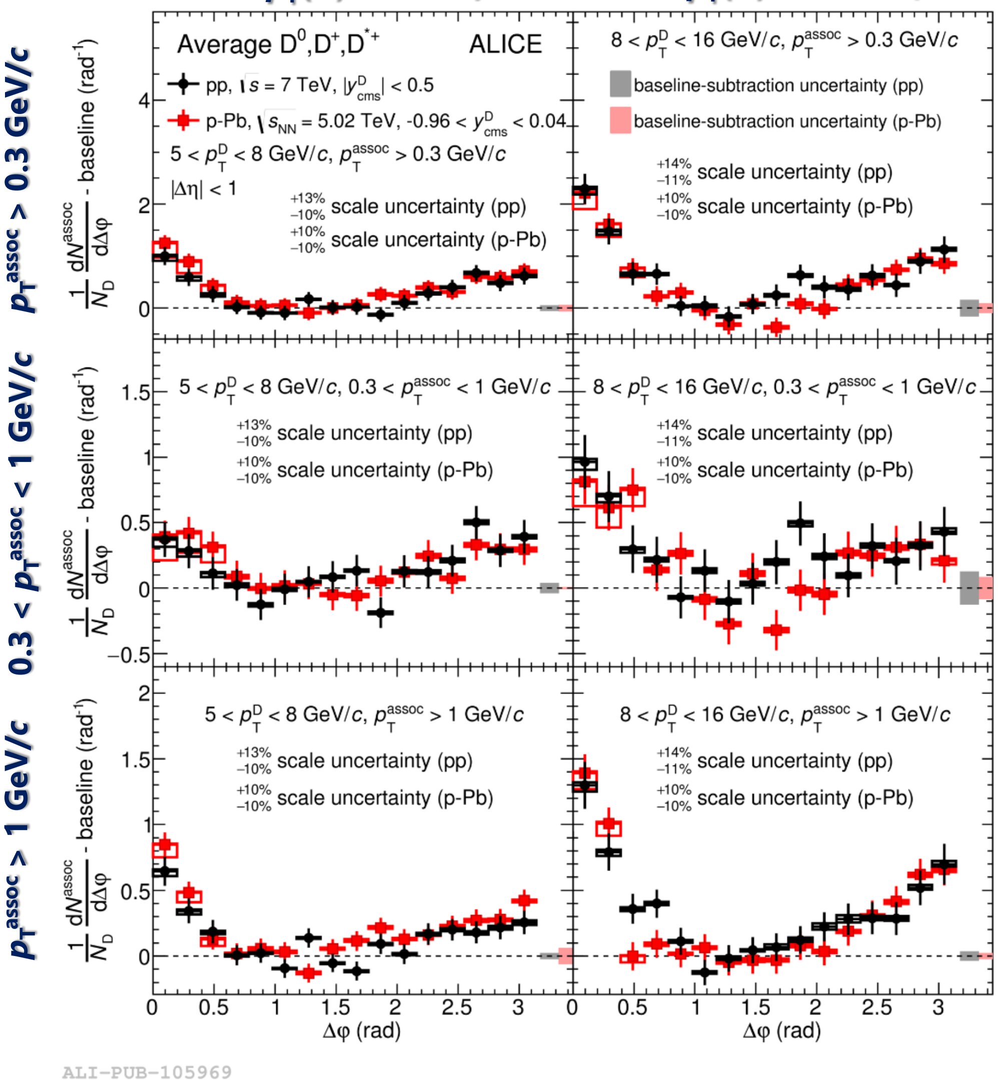
Same events **Mixed events** **Same/Mixed events**

- Contribution from background D mesons removed via sideband subtraction
- Efficiency correction for reconstruction and selection of trigger and associated particles
- Subtraction of contamination by strange hadron decays and conversions in the detector material
- Subtraction of D from B "feed-down" contribution based on FONLL calculations and PYTHIA Monte Carlo simulations

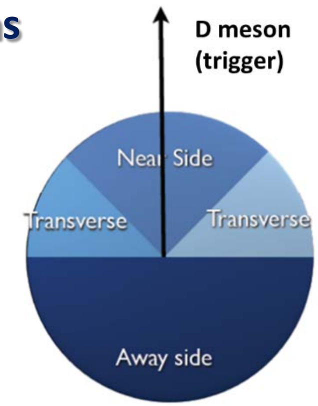
AZIMUTHAL CORRELATIONS OF D MESONS AND CHARGED PARTICLES IN pp AND p-Pb COLLISIONS

Comparison of azimuthal correlation distributions in pp and p-Pb collisions

$5 < p_T(D) < 8$ GeV/c | $8 < p_T(D) < 16$ GeV/c



NEW!

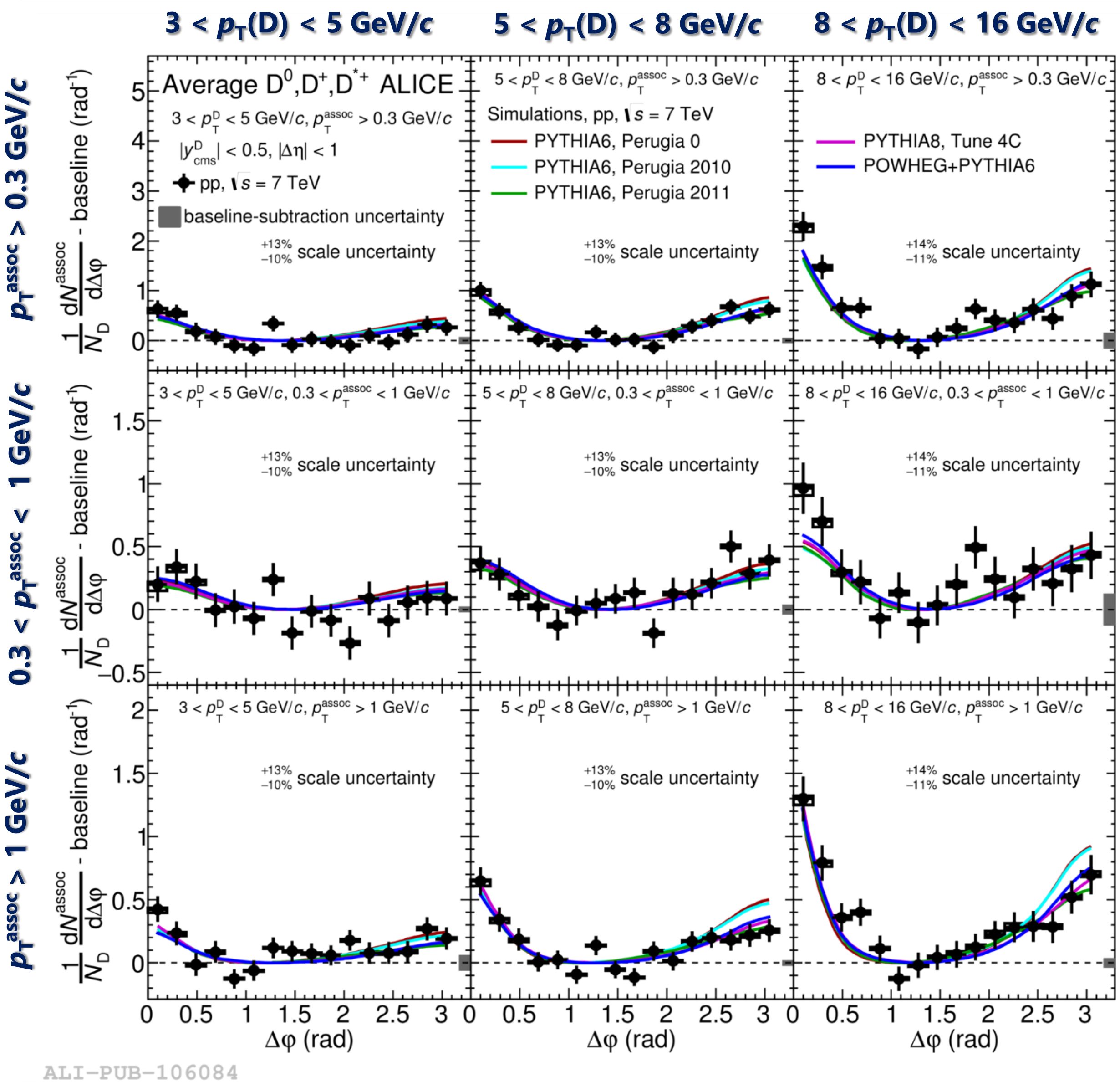


pp, $\sqrt{s}$ = 7 TeV
p-Pb, $\sqrt{s_{NN}}$ = 5.02 TeV

- Azimuthal correlation distributions fitted with a double Gaussian + constant baseline
- Results are shown after the subtraction of the baseline, largely composed of uncorrelated pairs
- pp and p-Pb baseline-subtracted correlation distributions are consistent within uncertainties

arXiv:1605.06963

AZIMUTHAL CORRELATIONS OF D MESONS AND CHARGED PARTICLES IN pp COLLISIONS



NEW!

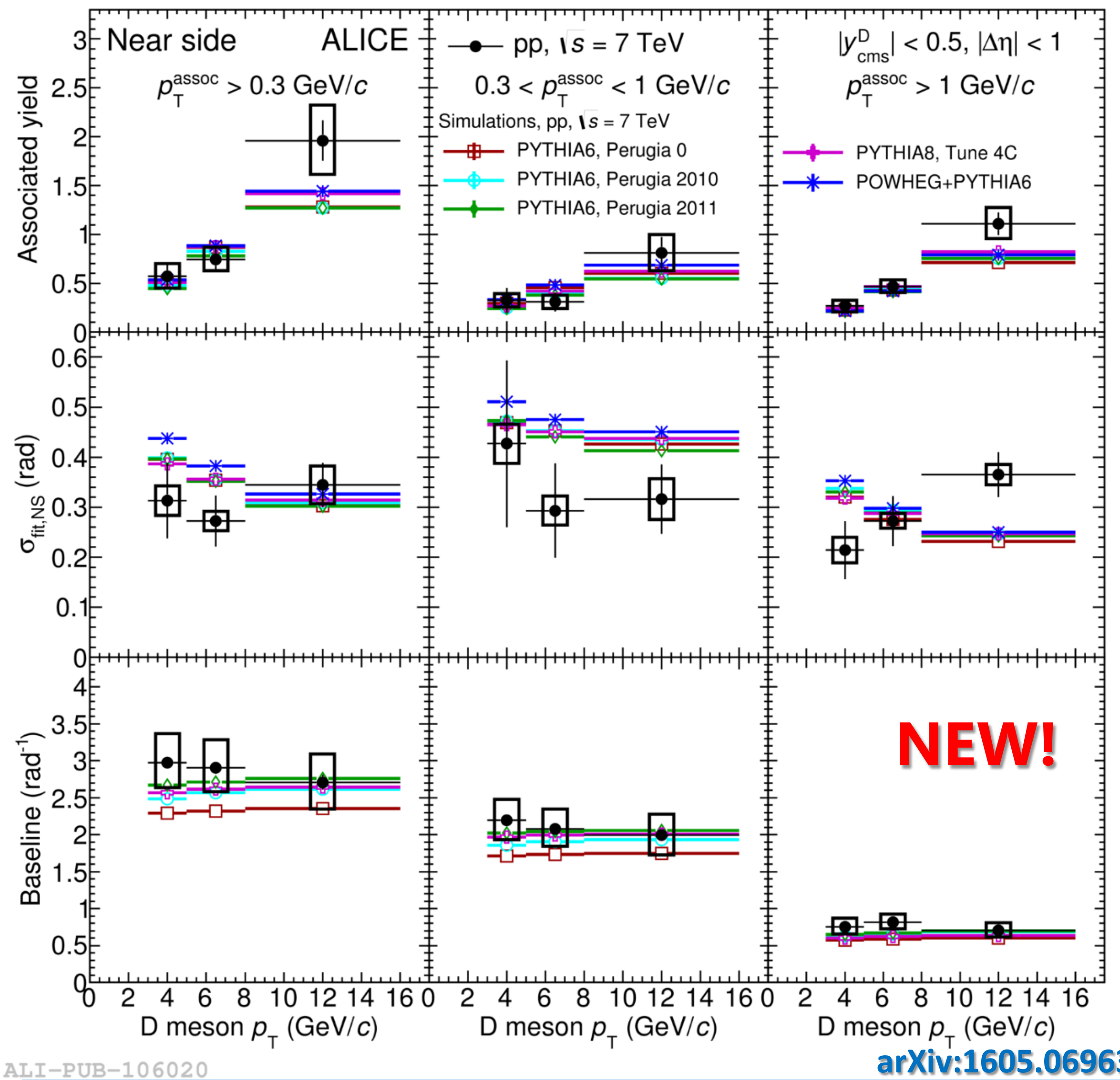
pp, $\sqrt{s}$ = 7 TeV

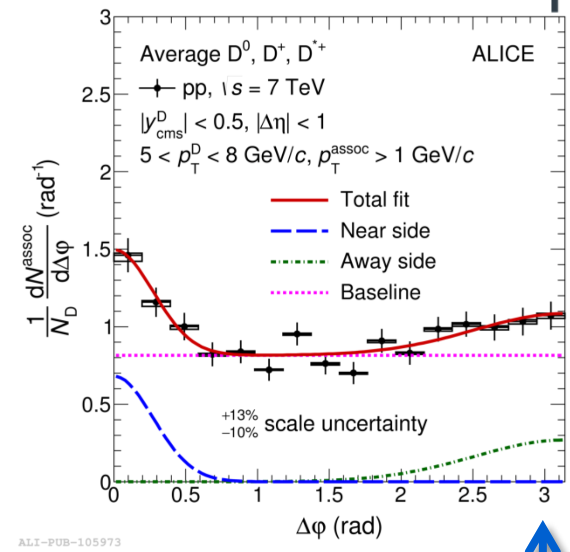
- Correlation distributions in pp collisions after baseline subtraction are well described by expectations from PYTHIA6 (with different Perugia tunes), PYTHIA8 and POWHEG+PYTHIA generators in all kinematic ranges

arXiv:1605.06963

Azimuthal correlations of D mesons and charged particles in pp collisions

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





arXiv:1605.06963

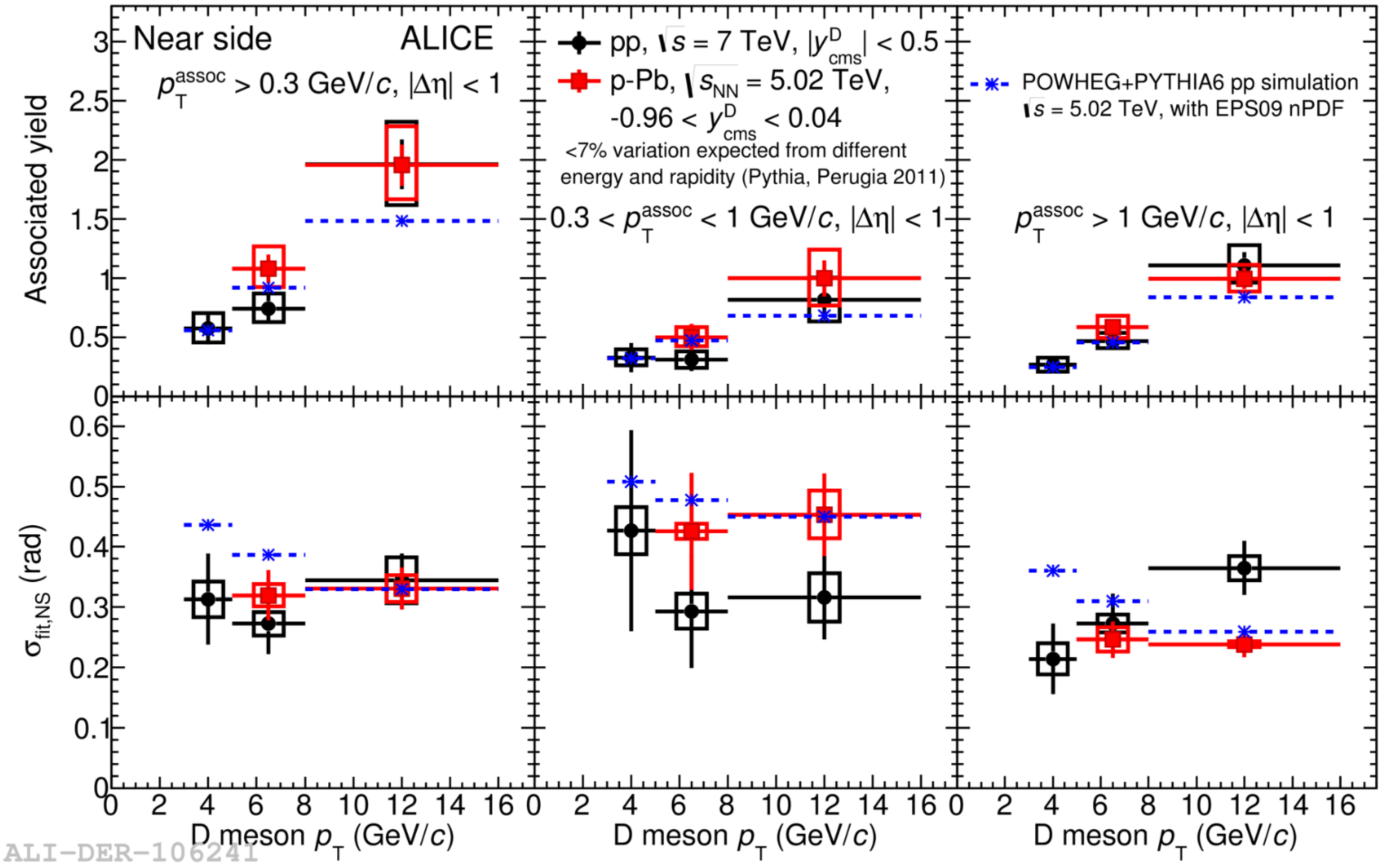
- Quantitative observables extracted from the fit:
  - Near-side yield
  - Near-side width
  - Baseline value
- Agreement between data and Monte Carlo expectations within uncertainties for all the observables

AZIMUTHAL CORRELATIONS OF D MESONS AND CHARGED PARTICLES IN pp AND p-Pb COLLISIONS

ALICE

Comparison of near-side yield and width in pp and p-Pb collisions

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



NEW!

pp, √s = 7 TeV
p-Pb, $\sqrt{s_{NN}}$ = 5.02 TeV

arXiv:1605.06963

- Near-side peak properties compatible between the two collision systems
  - ➤ No signs of modifications due to initial-state or final-state effects are observed within uncertainties

CONCLUSIONS

Open heavy-flavour production in pp collisions

- Wide spectrum of heavy-flavour production results in pp collisions at different energies ($\sqrt{s}$ = 2.76, 7 TeV) from ALICE
  - At $\sqrt{s}$ = 7 TeV D^0 measurements available down to $p_T = 0$
- p_T-differential cross section measurements well described by pQCD predictions
- Faster-than-linear increase of heavy-flavour hadron yields with event multiplicity, with no p_T dependence
  - Yield increase well described by models including MPI, suggesting that they play a significant role for heavy-flavour production

Azimuthal correlations of D mesons and charged particles in pp and p-Pb collisions

- Correlation distributions, and near-side yields and widths compatible between pp and p-Pb collisions
- Near-side peak properties are described by the Monte Carlo generators within the uncertainties

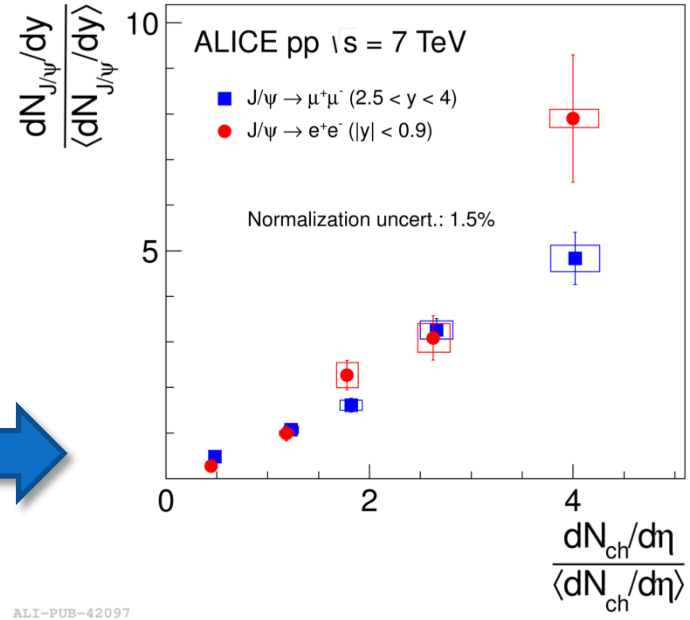
Stay tuned for the upcoming results in pp collisions at $\sqrt{s}$ = 13 TeV!

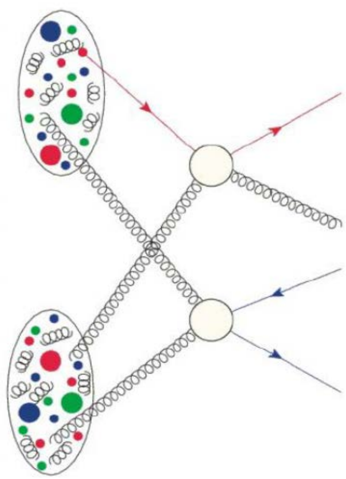
BACKUP SLIDES

HEAVY-FLAVOUR MULTIPLICITY STUDIES

What has been observed so far:

- **NA27** (pp, $\sqrt{s}$ = 28 GeV): events with charm production have larger charged-particle multiplicity
  → NA27, Z. Phys C41 (1988) 191
- **LHCb**: double charm production is better described by models including double parton scattering
  → LHCb, JHEP 06 (2012) 141
- **ALICE**: increase of inclusive J/ψ yield as a function of event multiplicity with approximately linear trend
  → ALICE, PLB 712 (2012) 165





What we can learn:

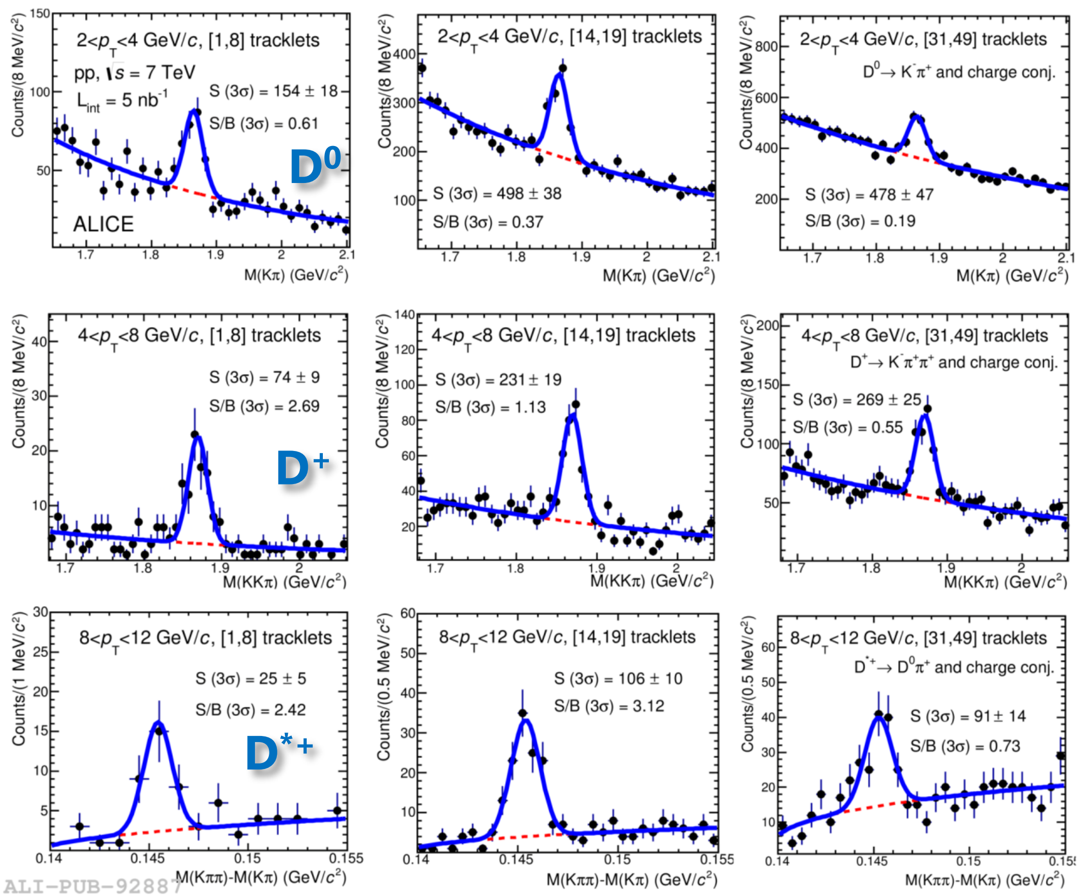
- Study the interplay between hard and soft processes of particle production
- Investigate the possible role of multi parton interactions (MPI) in the heavy-flavour sector

D MESON VS MULTIPLICITY – RAW YIELDS AND CORRECTIONS

ALICE

Self-normalized D-meson yields (with respect to the multiplicity-integrated yield):

$$\frac{d^2N^D/dydp_T}{\langle d^2N^D/dydp_T\rangle} = \frac{Y^{mult}/(\varepsilon^{mult} \times N^{mult}_{event})}{Y^{tot}/(\varepsilon^{tot} \times N^{tot}_{event})/\varepsilon^{trigger}}$$



<u>Multiplicity estimator</u>:

Number of tracklets (i.e. track segments in the two innermost ITS layers) for |η| < 1

- Proportional to dN_{ch}/dη

<u>Contribution of D from B</u>:

- Assumed independent of multiplicity

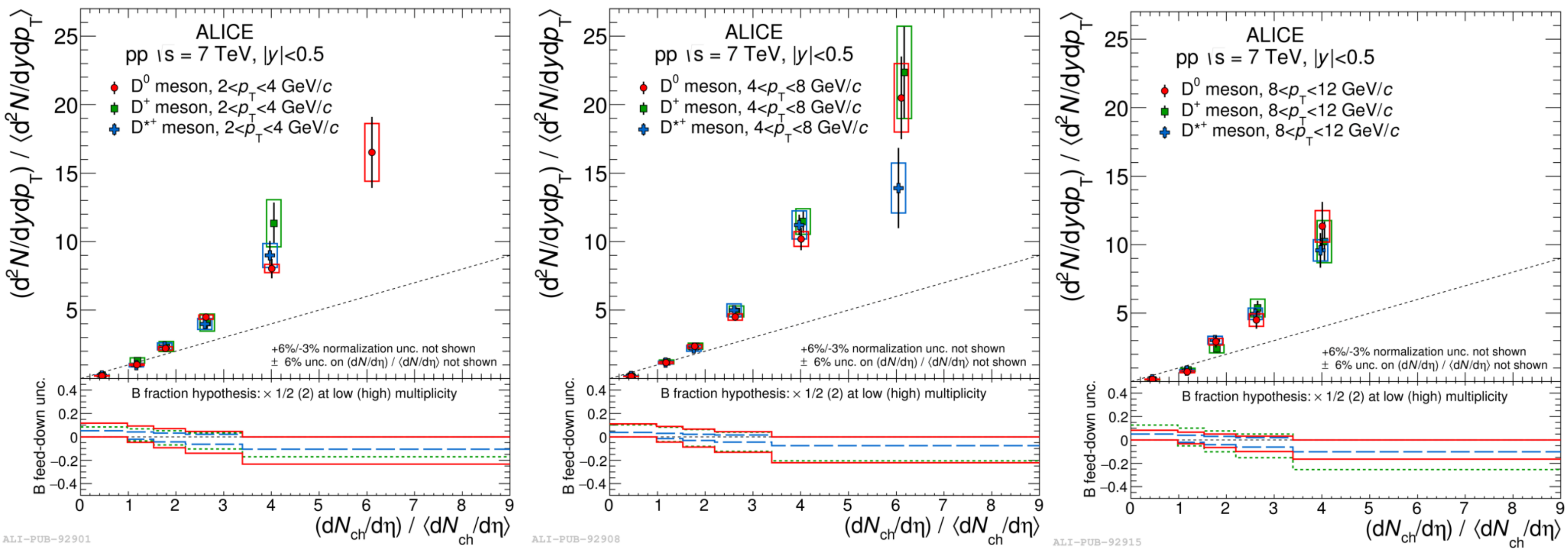
Invariant mass spectra of D^0 (top), D$^+$ (middle) and D^{*+} (bottom) candidates for three multiplicity ranges

ALICE, JHEP 09 (2015) 148

D MESON VS MULTIPLICITY - RESULTS

Self-normalized D^0, D^+, D^*-meson yields

ALICE, JHEP 09 (2015) 148



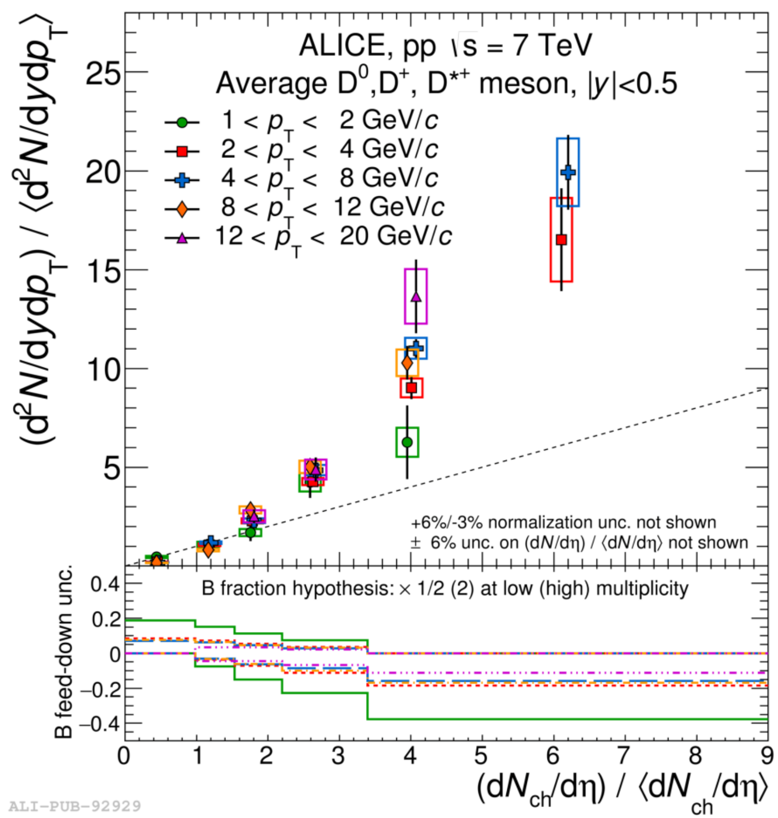
$2 < p_T(D) < 4$ GeV/c **$4 < p_T(D) < 8$ GeV/c** **$8 < p_T(D) < 12$ GeV/c**

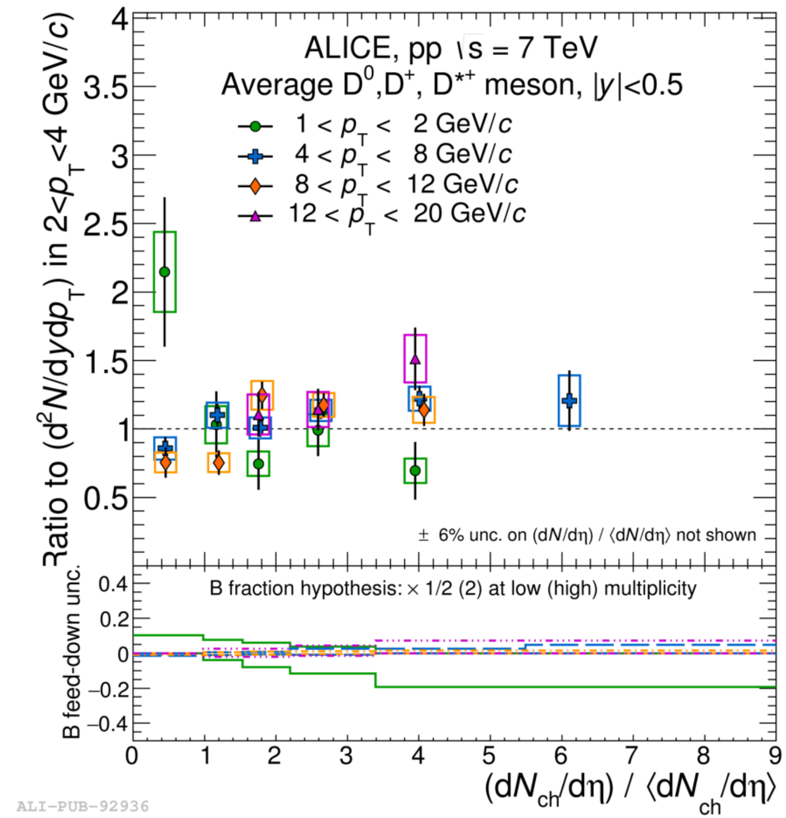
- Uncertainty by varying the D from B contribution with event multiplicity
- Faster-than-linear increase of self-normalized yields with event multiplicity
- Agreement within uncertainties of D^0, D^+, D^* results

D MESON VS MULTIPLICITY - RESULTS

Average of self-normalized D-meson yields: p_T dependence

ALICE, JHEP 09 (2015) 148

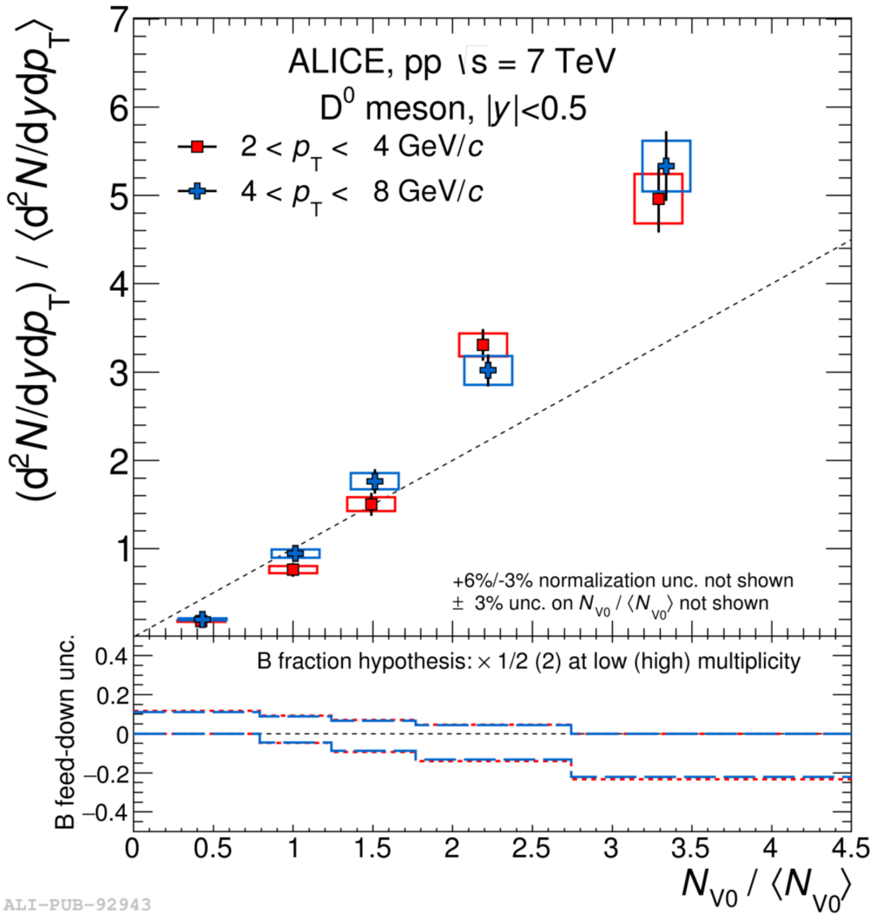




- Increasing trend of D-meson yields independent of D-meson p_T within uncertainties

D-MESON VS MULTIPLICITY – η-GAP

Average of self-normalized D-meson yields
Evaluation of event multiplicity at large rapidity

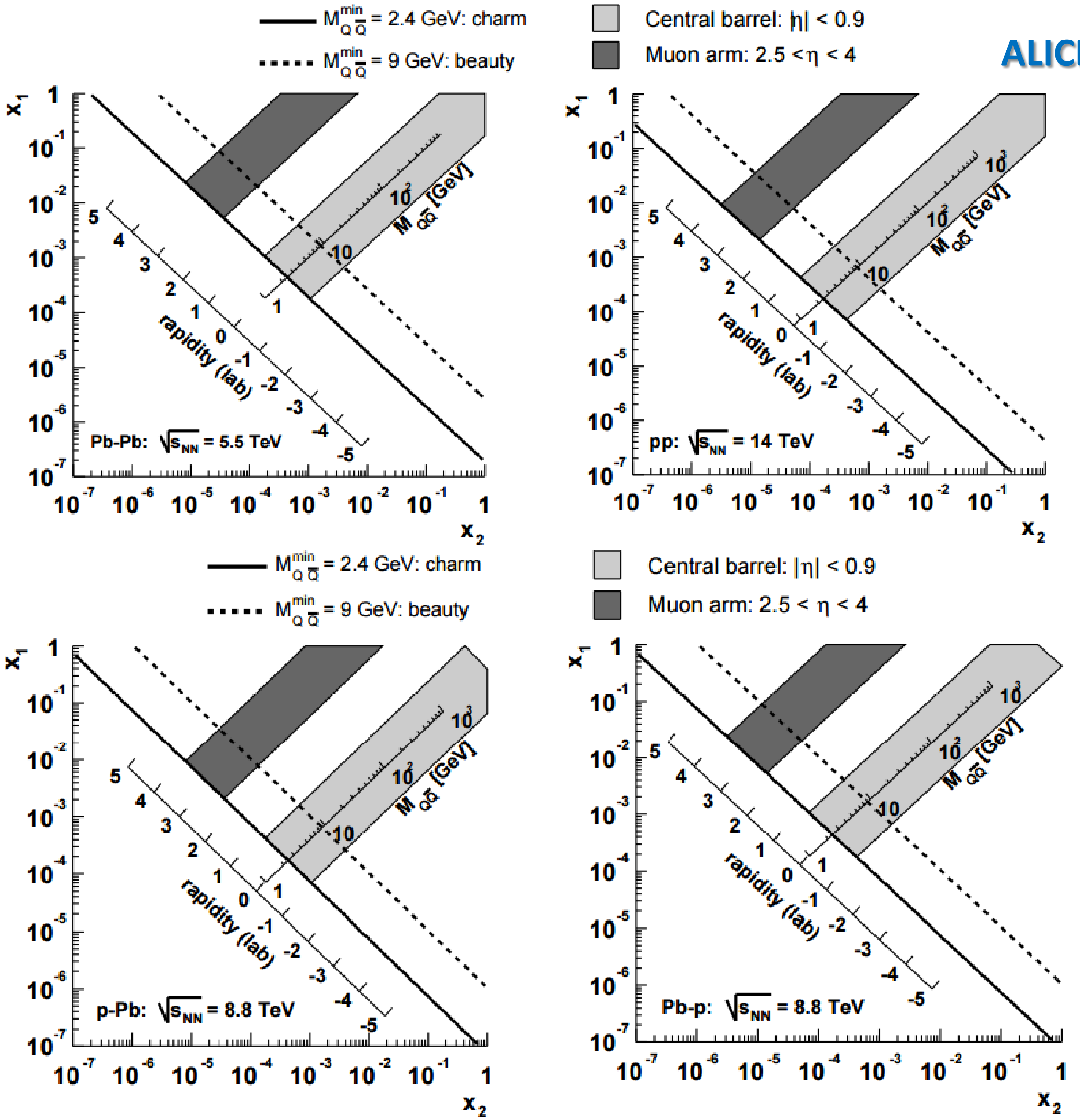


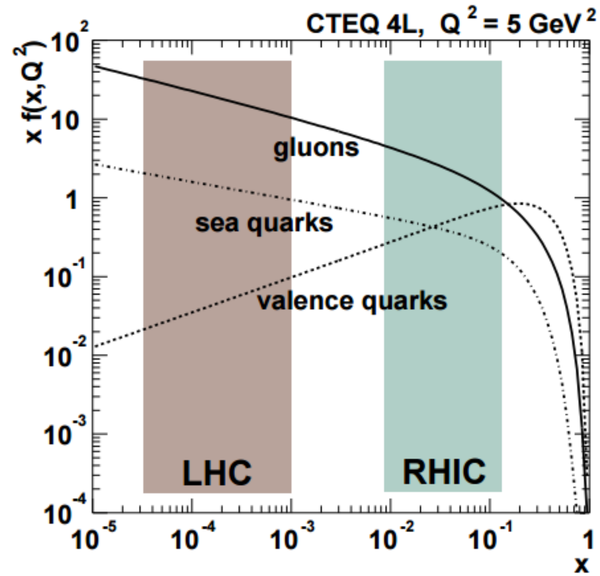
ALICE, JHEP 09 (2015) 148

- Amount of charge collected by V0 detectors used to estimate the event multiplicity
- η-gap introduced to remove possible auto-correlation biases in multiplicity estimation
- Trend of yield with event multiplicity compatible with what observed using the SPD tracklets for multiplicity estimation

Bjorken x regions at the LHC and PDF

ALICE, J. Phys. G, 32 (2010) 1295

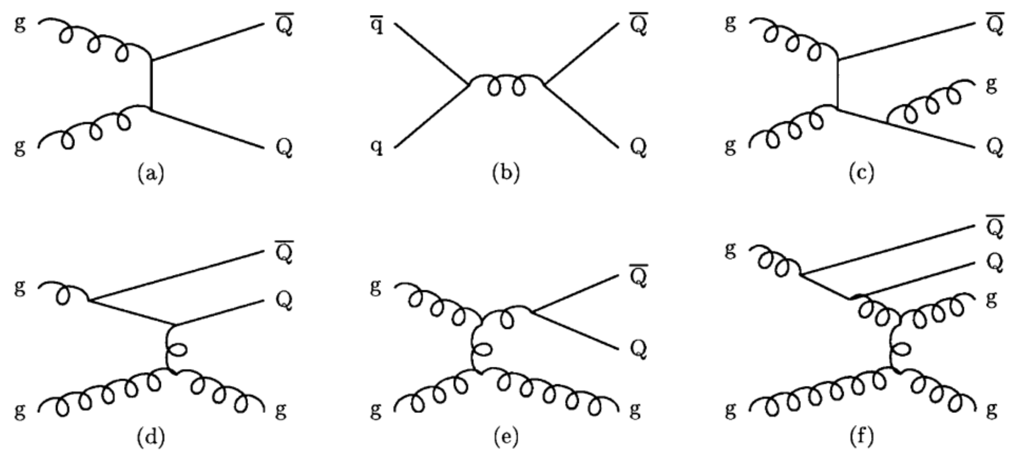




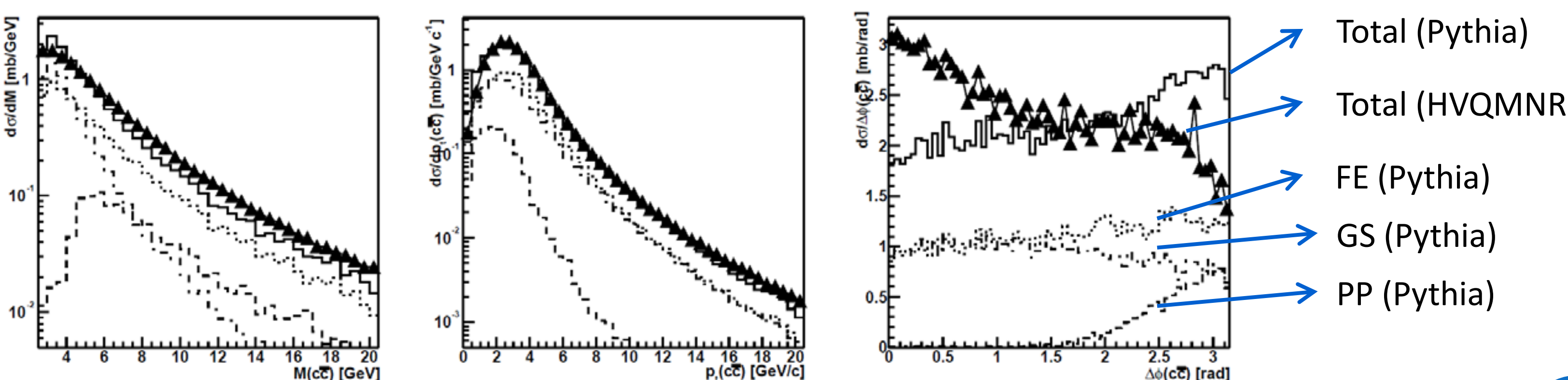
Parton Distribution Functions in CTEQ 4L parametrization, for Q^2 = 5 GeV^2

Charm azimuthal correlations

- Can we disentangle the charm production mechanisms?
  - Pair production (a, b)
  - Flavour excitation (d)
  - Gluon splitting (e)

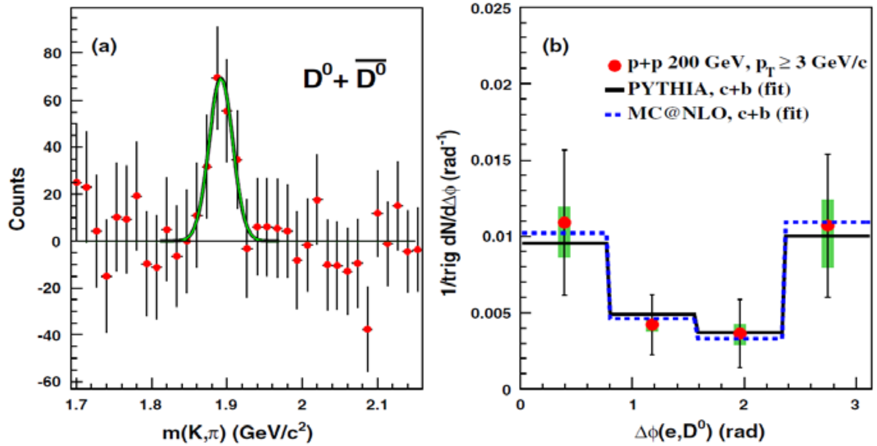


Sjostrand et al., Comput.Phys.Commun. 135 (2001) 238



Previous results on HF correlations

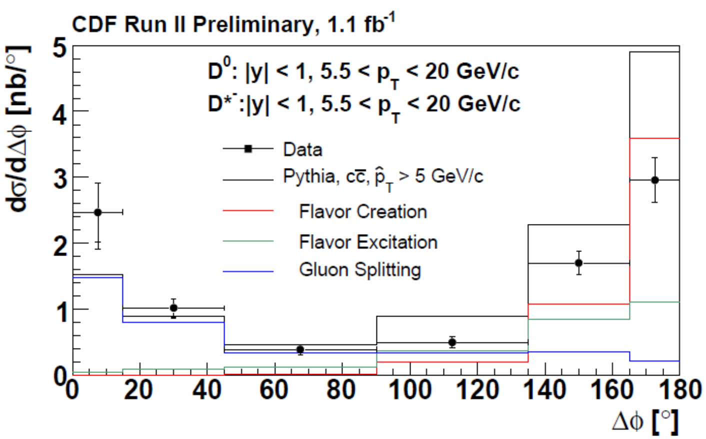
- STAR measurements for D^0-HFe correlations in pp collisions at 200 GeV, compared with PYTHIA simulation and MC@NLO theoretical predictions

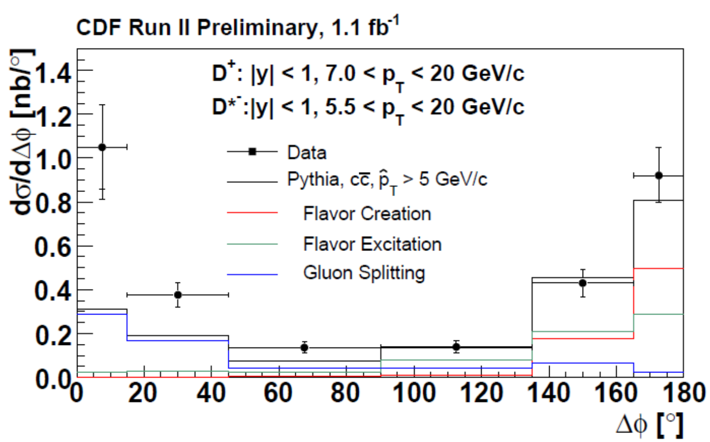


STAR, PRL 105 (2010) 202301

- CDF measurements for D^0-D^{*+} and D^+-D^{*+} correlations
  - Comparison to PYTHIA, with different production mechanism breakdown
  - PYTHIA overestimates LO (b2b) and underestimates NLO contribution (collinear production)

CDF, Nucl.Phys.Proc.Suppl. 170 (2007) 243–247

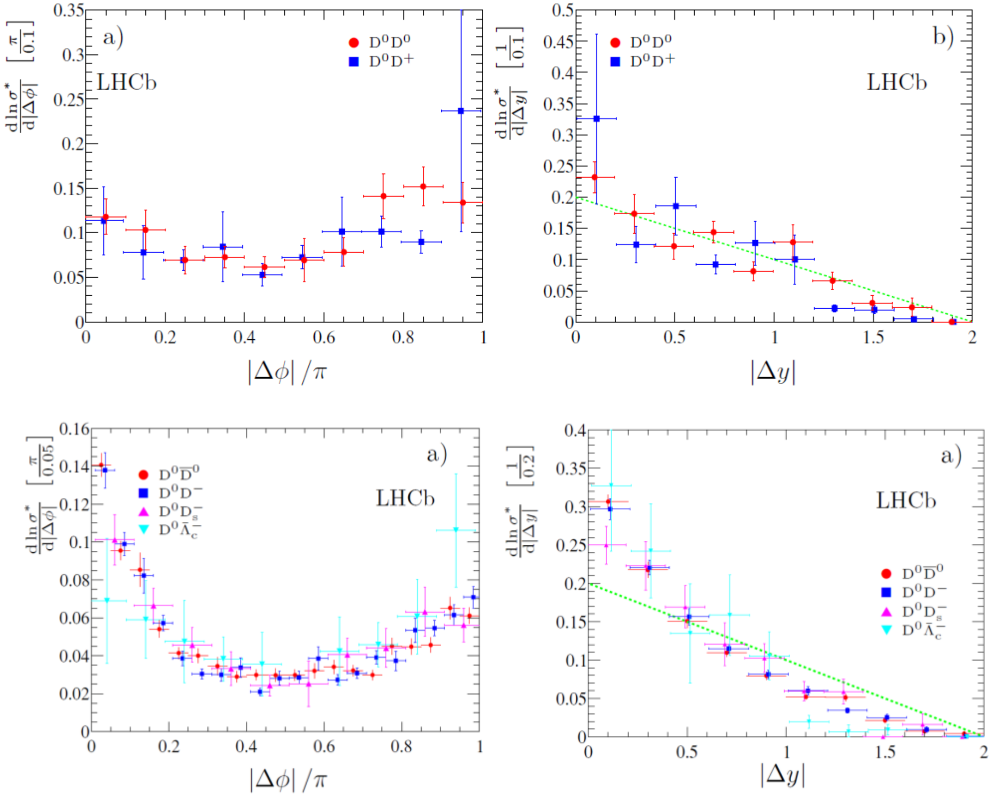




Previous results on HF correlations

Selection of LHCb measurements for DD (top row) and DDbar (bottom row) angular correlations in pp collisions at 7 TeV:

- DD are uncorrelated (independently produced)
- DDbar are mostly produced in the same hard scattering
    - ✓ NS and AS peaks are clearly visible

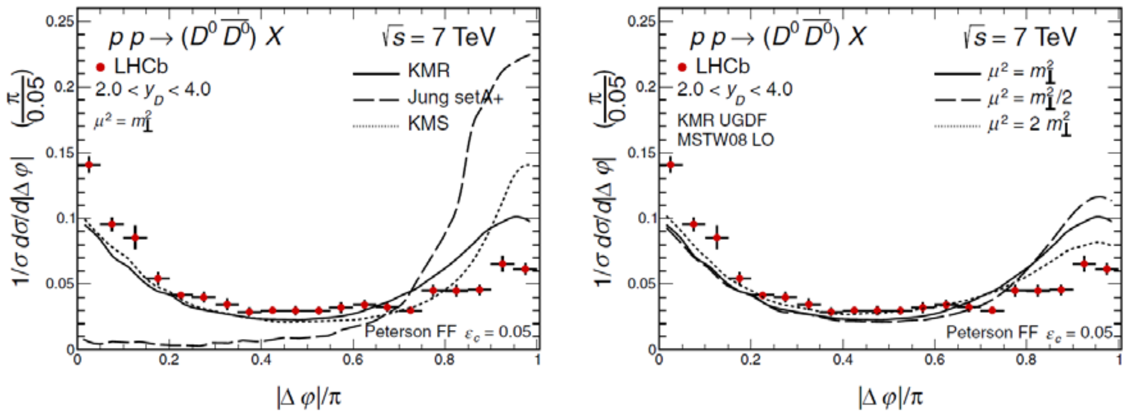


LHCb, JHEP 06 (2012) 141

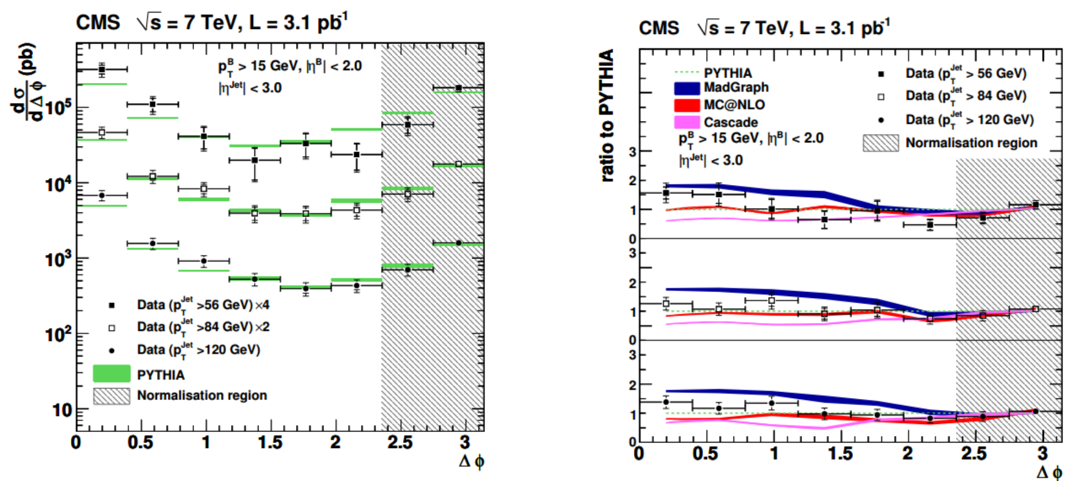
Previous results on HF correlations

- LHCb measurements for D^0-D^0bar correlations compared with calculations from k_T-factorization approach, in pp collisions at 7 TeV

LHCb, JHEP 06 (2012) 141



- CMS measurements for B-Bbar production cross section as a function of $\Delta\varphi$, compared with predictions, in pp collisions at 7 TeV

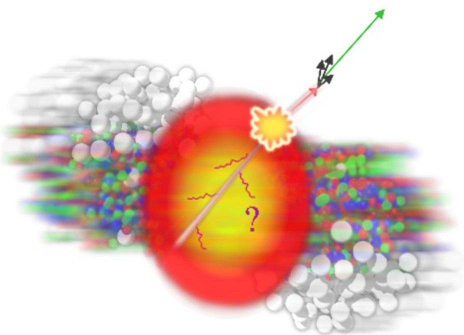


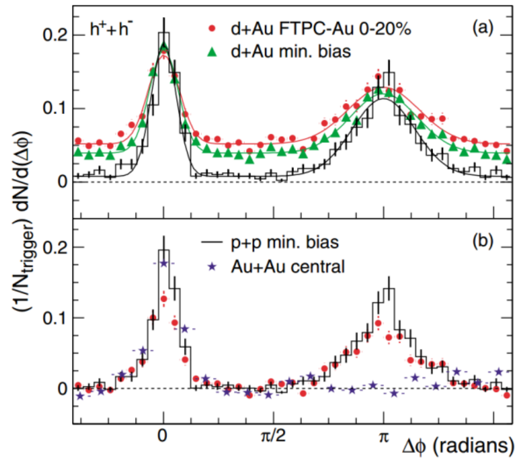
CMS, JHEP 136 (2011) 1103

COMPARISON: CHARGED PARTICLE SUPPRESSION AT RHIC AND LHC

- I_{AA} definition: $$I_{AA}(p_{T,\mathrm{trig}};p_{T,\mathrm{assoc}}) = \frac{Y^{AA}(p_{T,\mathrm{trig}};p_{T,\mathrm{assoc}})}{Y^{pp}(p_{T,\mathrm{trig}};p_{T,\mathrm{assoc}})}$$

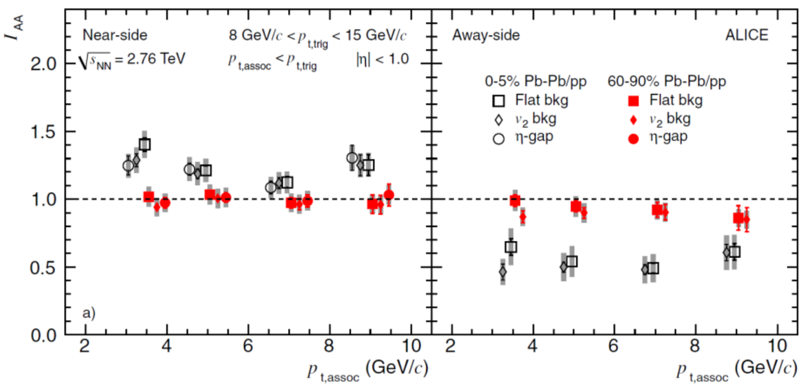
- From STAR measurements, heavy suppression of away side for h-h correlations in Au-Au central collisions (not in d-Au)





STAR, PRL 97 (2006) 162301

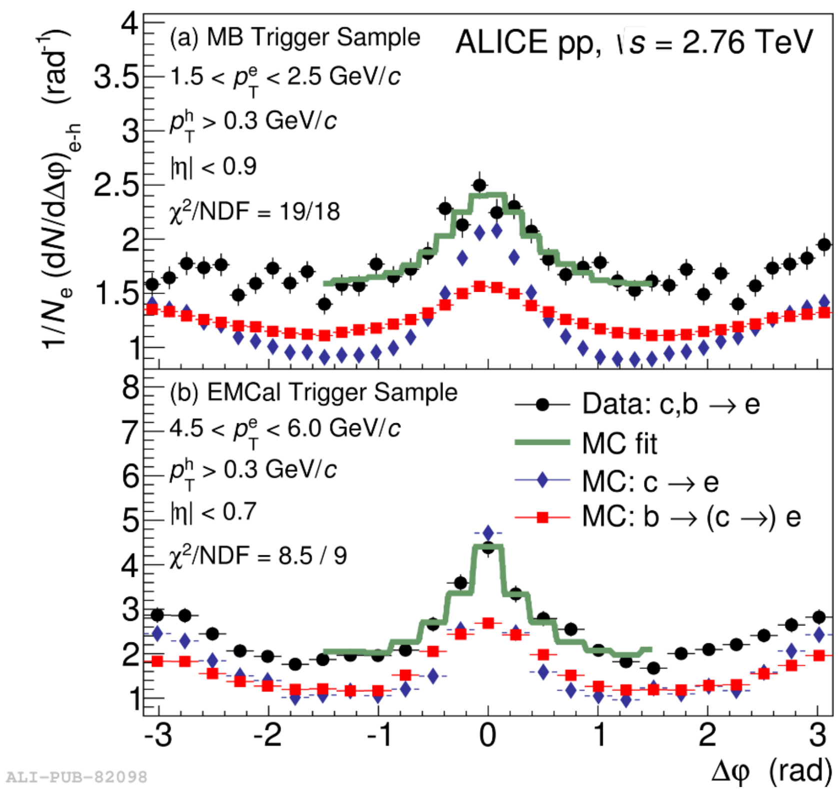
ALICE, PRL 108 (2012) 092301



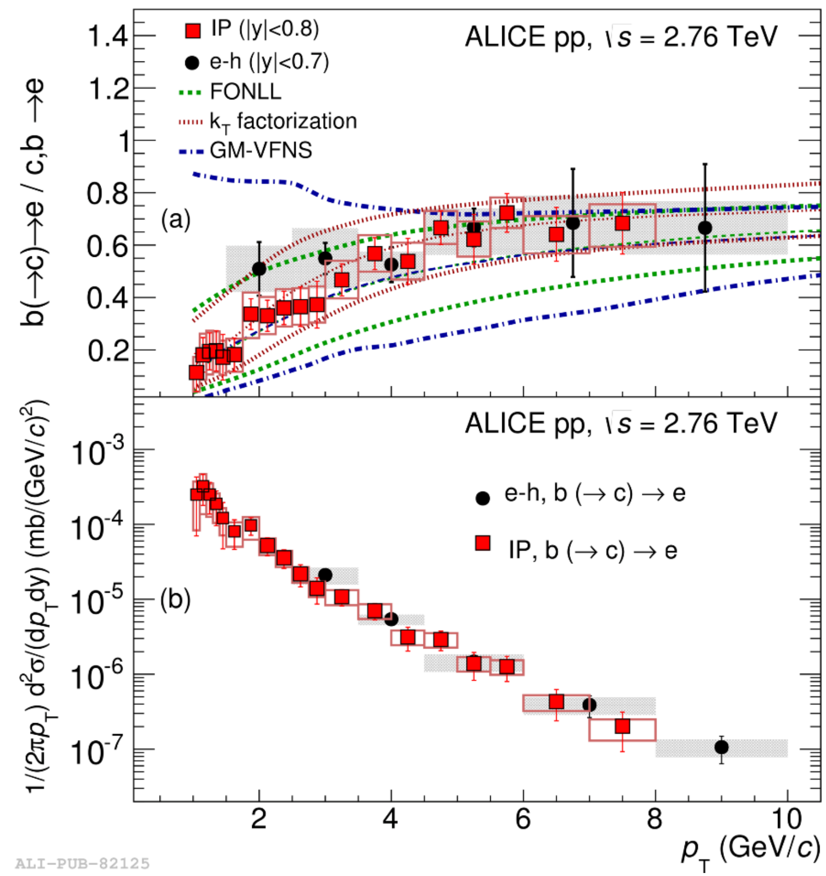
- ALICE I_{AA} for h-h correlations:
  - 20% enhancement of near side peak in Pb-Pb collisions, no away side effects
  - Strong away side suppression in central Pb-Pb, but by a lower factor w.r.t. RHIC

ELECTRON-HADRON CORRELATIONS IN pp COLLISIONS

- Separate beauty and charm contributions to heavy-flavour decay electrons
  - Electrons from beauty show a flatter correlation distribution than electrons from charm



ALICE, PLB 738 (2014) 97



$$\Delta\varphi = c + r_B \cdot \Delta\varphi^{B}_{Templ} + (1 - r_B)\Delta\varphi^{C}_{templ}$$

r_B = beauty fraction

Ratio b→(c)→e/c,b→e compatible with FONLL prediction

MINIMUM-BIAS TRIGGER AND INTEGRATED LUMINOSITY

- “**Minimum bias**”, based on interaction trigger (for pp 2010 data):
  - **SPD** or **VOA** or **VOC**
    - At least one charged particle in 8 rapidity units
    - About 86.4% of inelastic cross section **ALICE, PLB 712 (2012) 165**
  - Read-out by all ALICE

- Integrated luminosity evaluated using as a reference the minimum-bias trigger cross section:

$$L_{int} = N_{MB} / \sigma_{MB}$$

- σ_{MB} (**62.3** ± 0.4(stat) ± 4.3(syst) mb) evaluated through a Van der Meer scan.

Details on corrections, All-in-one

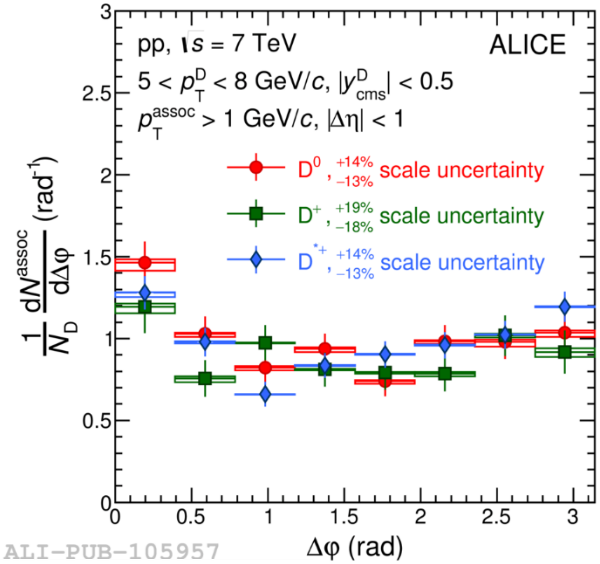
- D-meson and associated track efficiency correction:
  - Accounts for associated track reconstruction efficiency and for p_T dependence of D-meson reconstruction and selection efficiency
  - Each (D, charged particle) pair is weighted by the inverse of the **D meson reconstruction efficiency** and of the **associated track reconstruction efficiency**
  - D-meson p_T and event multiplicity dependencies considered for D-meson efficiency; track p_T, η and *z* position of primary vertex dependencies considered for track efficiency
- Feed-down D contribution subtraction:
  - A template of angular correlation distribution of D mesons from beauty hadrons decays (from PYTHIA) is subtracted from the data distributions
  - Different PYTHIA parameter «tunes» exploited for the templates, after matching their baselines to the data level, to obtain a systematic uncertainty on the correction
- Removal of contamination from secondary tracks:
  - Tracks from strange-hadron decays or produced in interactions of particles with the detector material
  - The contribution of secondary track particles, evaluated via Monte Carlo studies, is flat in Δφ and is removed by multipliying the data correlation distributions by the the fraction of primary particles in the track sample

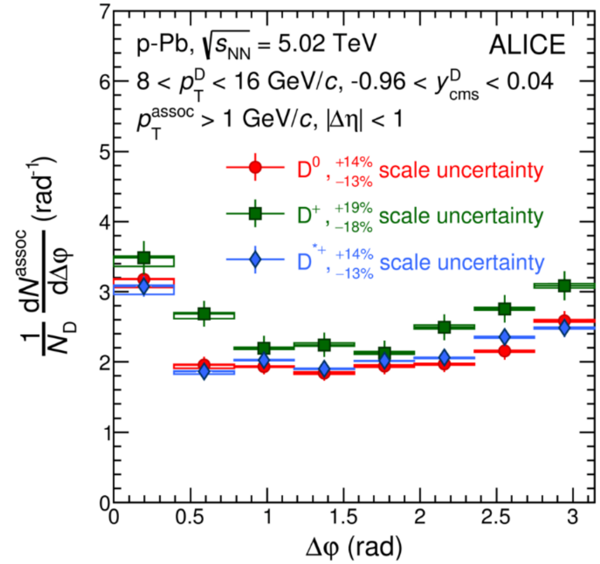
SYSTEMATIC UNCERTAINTIES LIST

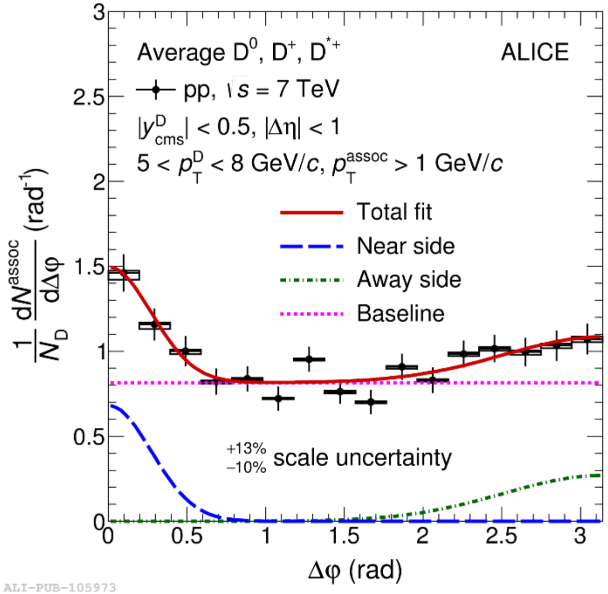
- **D yield extraction**: change fit parameters (rebin spectra, modify fit range/fit functions, bin counting) - Affects both normalization to N of triggers and background subtraction.
- **Background subtraction:** vary the invariant mass regions from which we take the background correlation shape.
- **Fit of correlation plot**: use different fit functions: (e.g. 2 gauss+pedestal+periodicity condition, pedestal as minimum of the correlation histo, …)
- **Beauty feed-down**: use a range of f_{PROMPT} values, and use templates from different generators like POWHEG.
- **Correction for contamination from secondary**: estimate the contribution from MC and its $\Delta\varphi$ shape. Some studies on DCA cut already started (in backup slides).
- **Soft pion removal for D^0 correlations**: estimate efficiency and purity of the invariant mass cut from MC and evaluate the effect of the cut on the near side yields on data → Negligible!
- **Associate tracking efficiency**: use different track selections.
- **D meson reconstruction and selection efficiency**: extracted from varying the cuts for D meson selection.

D MESON-CHARGED PARTICLE CORRELATION DISTRIBUTIONS

Comparison of D^0, D^+, D^{*+} distributions

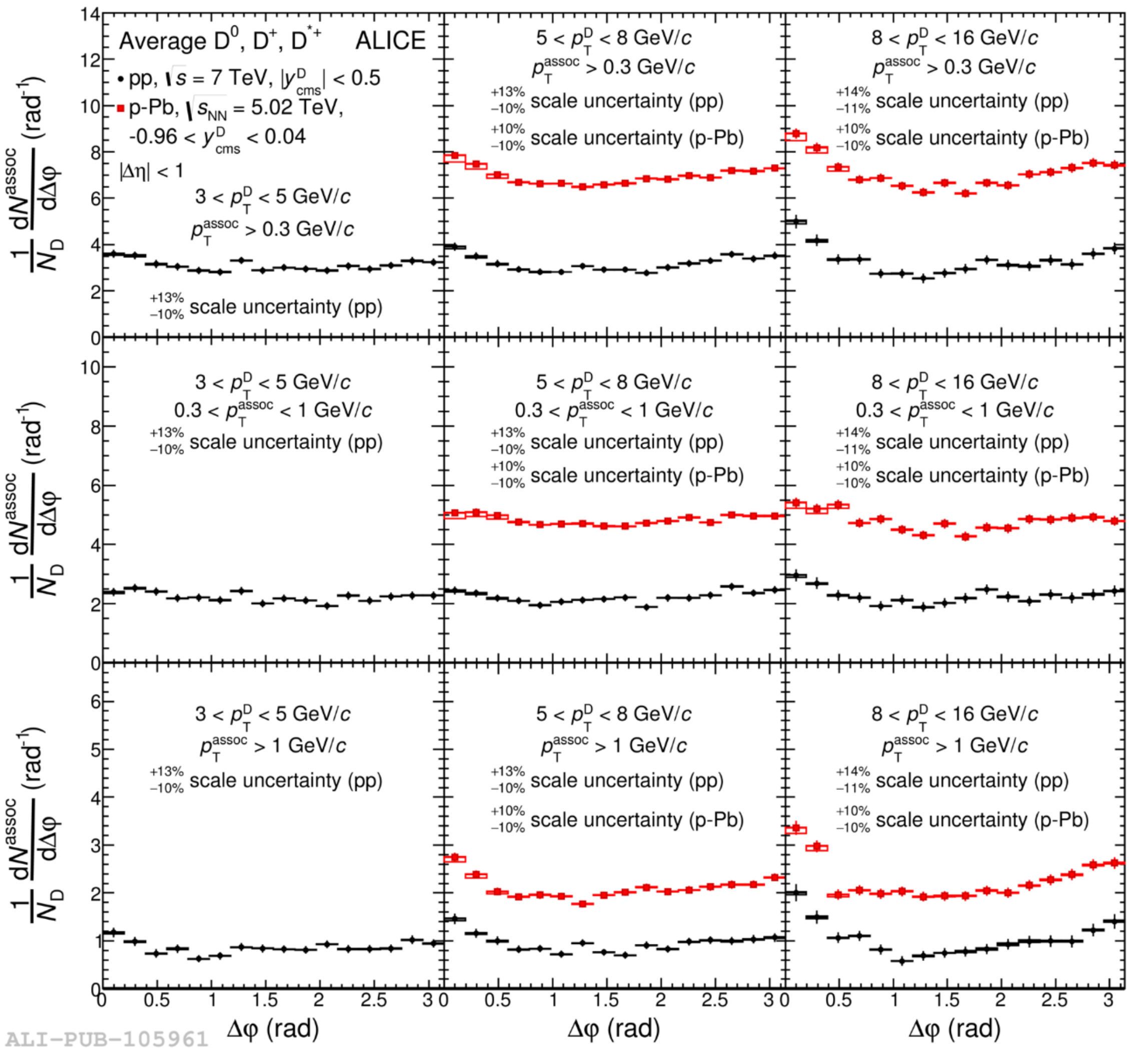






Example of fit to correlation distributions

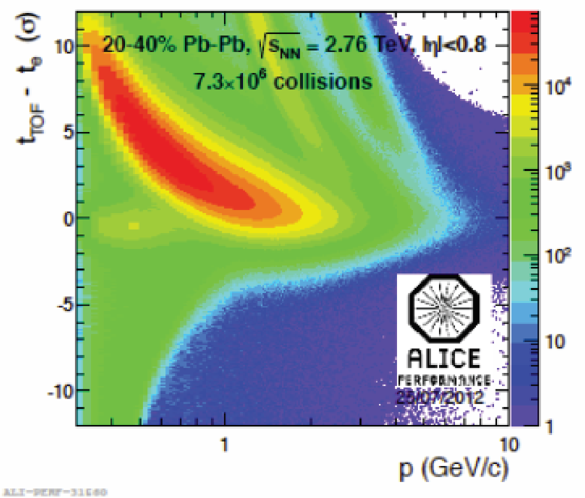
D MESON-CHARGED PARTICLE CORRELATION DISTRIBUTIONS



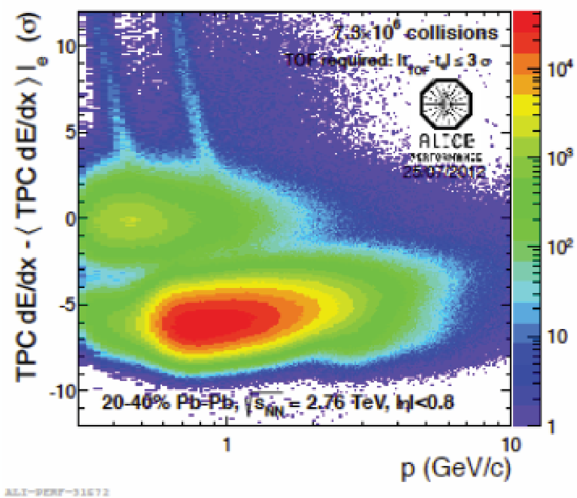
Correlation distribution in pp and p-Pb collisions before baseline subtraction

ELECTRON PID IN ALICE

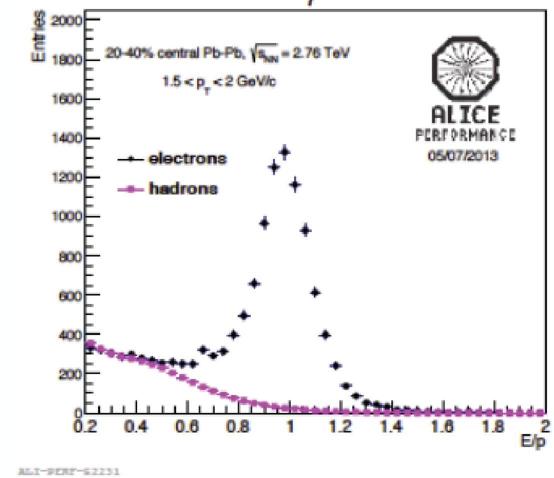
TOF: *3σ band around electron hypothesis*

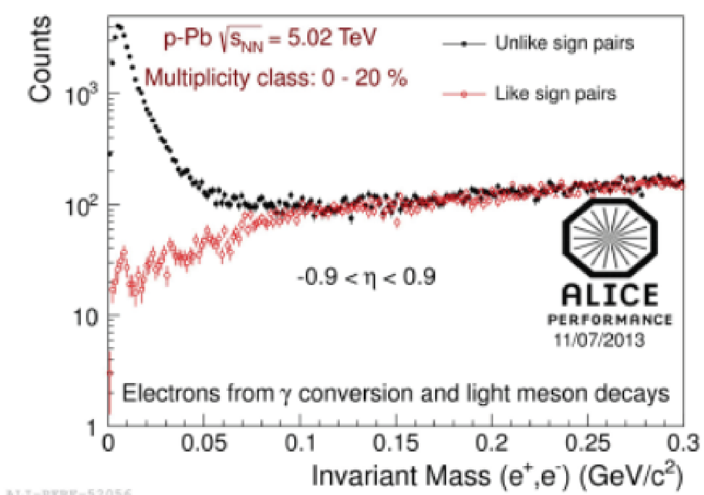


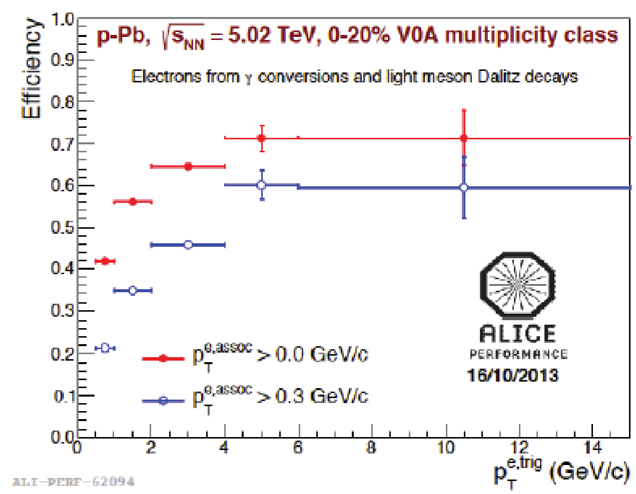
TPC: *0-3σ of <dE/dx>e band*



EMCAL: *0.8 < E/p < 1.2*







D-meson yields – Multiplicity ranges

$N_{\text{tracklets}}$	$(\mathrm{d}N_{\text{ch}}/\mathrm{d}\eta)^j$	$(\mathrm{d}N_{\text{ch}}/\mathrm{d}\eta)^j/\langle \mathrm{d}N_{\text{ch}}/\mathrm{d}\eta \rangle$	$N_{\text{events}}^{\text{D}^0}/10^6$	$N_{\text{events}}^{\text{J}/\psi}/10^6$
$[1,8]$	2.7	$0.45^{+0.03}_{-0.03}$	155.1	–
$[4,8]$	3.8	$0.63^{+0.04}_{-0.04}$	–	89.0
$[9,13]$	7.1	$1.18^{+0.07}_{-0.07}$	46.2	50.5
$[14,19]$	10.7	$1.78^{+0.10}_{-0.11}$	32.0	35.5
$[20,30]$	15.8	$2.63^{+0.15}_{-0.17}$	24.7	28.0
$[31,49]$	24.1	$4.01^{+0.23}_{-0.25}$	7.9	9.5
$[50,80]$	36.7	$6.11^{+0.35}_{-0.39}$	1.7	–

High-multiplicity trigger for this range (threshold on number of SPD tracklets)

$$\langle \mathrm{d}N_{\text{ch}}/\mathrm{d}\eta \rangle = 6.01 \pm 0.01(\text{stat.})^{+0.20}_{-0.12}(\text{syst.}) \text{ in } |\eta| < 1$$

D-meson yields – Systematic uncertainties

- **Raw yield extraction**
  - Different approaches for fitting and extracting the yields
  - Background fit function
  - 3-15% depending on pT, multiplicity, species
- **Primary vertex determination**
  - With/without D-meson decay tracks
  - Negligible effect
- **Selection and PID efficiency**
  - Same selection used in all multiplicity intervals
  - Negligible residual effect due to multiplicity dependence of efficiency
- **Fraction of prompt D mesons in the raw yield**
  - Assumed to be the same in all multiplicity bins (cancels out in the ratio)
  - Uncertainty by varying the D←B contribution by a factor 1/2 (2) at low(high) multiplicity