Heavy-flavour production in small systems with ALICE

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Outline

- Physics motivations
- The ALICE experiment

Results
- Heavy-flavour cross section in pp and p-Pb collisions
  - Down to $p_T=0$  
  New on arXiv:1605.07569
- Multiplicity dependence of heavy-flavour production in pp and p-Pb collisions  
  New on arXiv:1602.07240
- Azimuthal correlations of D mesons with charged particles in pp and p-Pb collisions  
  New on arXiv:1605.06963

Conclusions
Heavy quarks are produced in initial high-$Q^2$ scattering processes.

Production calculable with pQCD.

Heavy-flavour (HF) results described by pQCD at LHC energies.

$pP$ system is the reference for $p$-$Pb$ and $Pb$-$Pb$ collisions.

$p$-$Pb$ collisions provide the control experiment to study Cold Nuclear Matter (CNM) effects.

More differential measurements provide more insight into heavy-flavour (HF) production mechanisms in small systems.
HF production in pp collisions at LHC

- Several hard partonic interactions can occur
- In events with multi-parton interactions (MPIs) higher charged-particle multiplicity expected

In addition:
- Role of the collision geometry
- Final-state effects
- Collectivity at high multiplicities?

→ Effects of MPIs and geometry/final-state/collectivity on the heavy-flavour sector in pp collisions?
→ Can we assess charm fragmentation and jet properties?

More differential HF observables:
- Multiplicity dependence of HF production in pp collisions
- Angular correlations of D mesons with charged particles in pp collisions

Bartalini, Fano, arXiv:1003.4220
Frankfurt, Strikman, Weiss, PRD 83 (2011) 054012
Azarkin, Dremin, Strikman, PLB 735 (2014) 244
Ferreiro, Pajares, PRC 86 (2012) 034903
Werner et al., PRC 83 (2011) 044915
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Additional effects in p-Pb collisions

In presence of a nucleus (p-Pb collisions):

• Multiple nucleon-nucleon collisions
• Nuclear PDFs, saturation effects
• Initial-state $k_T$ broadening
• Initial/final-state energy loss

→ Collective-like effects observed for light quarks. Same mechanisms (CGC/hydro) for light and heavy flavours?

→ Do CNM effects influence HF production depending on collision geometry and/or multiplicity density?

→ Can we assess possible effects of charm fragmentation/jet properties in the presence of the nucleus?

More differential HF observables also in p-Pb collisions

Multiplicity dependence
Angular correlations
**TPC** → tracking, PID via dE/dx, |η|<0.9

**ZDC** (112.5 from interaction point) → centrality

**TOF** → PID w/ Time Of Flight, |η|<0.9

**ITS** → vertexing, tracking, |η|<0.9

**V0** → trigger and multiplicity

**Forward Muon Spectrometer**
**ITS** → vertexing, tracking, $|\eta|<0.9$

**TPC** → tracking, PID via $dE/dx$, $|\eta|<0.9$

**TOF** → PID w/ Time Of Flight, $|\eta|<0.9$

**ZDC** (112.5 from interaction point) → centrality

**V0** → trigger and multiplicity

**SPD**

**pp collisions at $\sqrt{s}=7$ TeV**

$\sim 3 \times 10^8$ events collected in 2010

Min. Bias trigger: V0 and SPD

**p-Pb collisions at $\sqrt{s_{NN}}=5.02$ TeV**

$\sim 10^8$ events collected in 2013

Min. Bias trigger: V0

$E_p=4$ TeV, $E_{pd}=(208)\times 1.58$ TeV, $\sqrt{s_{NN}}=5.02$ TeV

$\Delta y_{\text{cms}}=0.465$ (in proton direction)
Heavy flavours with ALICE

Full reconstruction of D-meson hadronic decays (prompt D mesons)

\[
\begin{align*}
D^0 & \rightarrow K^-\pi^+ \\
D^+ & \rightarrow K^-\pi^+\pi^+ \\
D^{*+} & \rightarrow D^0\pi^+ \\
D_s^+ & \rightarrow \phi\pi^+ \rightarrow K^-K^+\pi^+
\end{align*}
\]

Invariant mass analysis based on displaced secondary vertices, selected with topological cuts and PID

Correction for beauty feed-down (based on FONLL) to extract results for prompt D mesons

Semi-leptonic decays (charm, beauty)

- Electrons: mid-rapidity
- Muons: forward rapidity

Electrons: background (\(\pi^0\) and \(\eta\), Dalitz decays, photon conversions) subtracted with Invariant mass method (e+e-) and cocktail

Muons: background (\(\pi, K \rightarrow \mu\)) subtracted with MC (pp) and data-tuned MC cocktail (p-Pb, Pb-Pb)

Displaced electrons, \(J/\psi\) (from B decays)

Separation of prompt and non-prompt \(J/\psi\) using the pseudo-proper decay length

Beauty-decay electrons: Exploit displaced track impact parameter
Cross sections in pp and p-Pb collisions
Heavy-flavour cross sections in pp collisions

Cross sections described by FONLL, GM-VFNS, $k_T$ factorization pQCD calculations
Low $p_T$ semi-leptonic cross section in good agreement with ATLAS at high $p_T$
D⁰ cross section in pp collisions - down to \( p_T = 0 \)

arXiv:1605.07569

\[ 0 < p_T(D^0) < 1 \text{ GeV}/c \]

No secondary vertex reconstruction

Combinatorial background subtraction via:

- event mixing, like sign, track rotation, side-band fit
D⁰ cross section in pp collisions - down to pₜ=0

Good agreement with the measurement at higher pₜ based on secondary vertex topology

arXiv:1605.07569

pp collisions at √s = 7 TeV:

dσ_{pp,7 TeV}^{\text{prompt D⁰}}/dy = 518 ± 43 (stat.) ± 57 (syst.) ± 18 (lumi.) ± 7 (BR) µb

→ updated total charm cross section with reduced uncertainty
**D⁰ cross section in p-Pb collisions - down to p_T=0**

Measurement of inclusive (no B feed-down subtraction) and prompt D⁰ meson cross section

**p-Pb collisions at \( \sqrt{s_{NN}} = 5.02 \) TeV:**

\[
\frac{d\sigma^{\text{prompt}D^0}_{p-Pb,5.02\text{TeV}}}{dy} = 79.0 \pm 7.3 \text{ (stat.)} \pm 7.1 \text{ (syst.)} \pm 2.9 \text{ (lumi.)} \pm 1.0 \text{ (BR)} \text{ mb}
\]
Nuclear modification factor in p-Pb collisions

\[ R_{pPb} = \frac{(d\sigma/dp_T)_{pPb}}{A \times (d\sigma/dp_T)_{pp}} \]

Results shown as a function of \( p_T \) and \( y \)
Data described within uncertainties by models with:

- initial-state effects
- final-state effects due to the presence of hot nuclear medium (high-\(p_T\) suppression, radial flow bump at intermediate \(p_T\))

Data disfavour suppression larger than 15% at high \(p_T\)

\[ R_{ppb}^{D^0, p_T=0} (p_T > 0, -0.96 < y_{cms} < 0.04) = 0.89 \pm 0.11 \text{(stat.)}^{+0.13}_{-0.18} \text{(syst.)} \]
HF $R_{pPb}$ at different rapidities

\[ R_{pPb} = \frac{(d\sigma/dp_T)_{pPb}}{A \times (d\sigma/dp_T)_{pp}} \]

-4.46 < $y_{CMS}$ < -2.96
10^{-2} < x < 5 \cdot 10^{-2}
c, b \rightarrow \mu

c, b \rightarrow e
2.03 < $y_{CMS}$ < 3.53
10^{-5} < x < 8 \cdot 10^{-5}
c, b \rightarrow \mu

Different $x$ regimes explored in different rapidity ranges with HF probes
→shadowing/saturation relevant at low $p_T$ at the LHC

Data described within uncertainties by the models with CNM effects
Multiplicity dependence of HF production in pp and p-Pb collisions
**Centrality/multiplicity estimators in pp and p-Pb collisions**

- **Centrality estimators in p-Pb collisions**
  - CL1 (clusters in outer SPD layer)
  - V0A (Pb-going) amplitude
  - ZNA (Pb-going): \(<N_{part}\) in ZN energy class from scaling the min. bias value assuming scaling with multiplicity at mid-rapidity.

- **Multiplicity estimators in pp and p-Pb collisions**
  - Number of track segments (or tracklets) of the SPD
  - Sum of amplitudes in the V0 scintillator arrays (V0A only for p-Pb)
D-meson production in different p-Pb centrality classes

With ZN estimator: free from biases due to event selection (multiplicity fluctuations/jet-veto).

**No multiplicity dependent modification** of D-meson production relative to pp collisions within uncertainties. **Consistent with binary collision scaling of the yield in pp collisions.**

\[ Q_{pPb}^{\text{mult}}(p_T) = \frac{dN_{pPb}^{\text{mult}}/dp_T}{N_{\text{coll}}^{\text{mult}}dN_{pp}/dp_T} \]
Increase of D-meson yields with charged-particle multiplicity at mid rapidity:

- slightly faster-than-linear increase at large multiplicities,
- independent of $p_T$ within uncertainties.
**Per-event yields vs. $N_{\text{ch}}$ in p-Pb collisions**

- Introducing an $\eta$ gap -

**Nearly linear increase with multiplicity at backward rapidity** (Pb-going direction).

Results consistent within uncertainties when an $\eta$ gap is introduced between the regions where the D mesons and the multiplicity are measured.
Per-event yields vs. $N_{ch}$ in pp collisions

Increase of D-meson yields with charged-particle multiplicity at mid rapidity:

- faster-than-linear increase at large multiplicities
- independent of $p_T$ within uncertainties
Per-event yields vs. $N_{ch}$ in pp collisions

- Introducing an $\eta$ gap -

Qualitatively similar increasing trend of D-meson yields when an $\eta$ gap is introduced between the regions where the D mesons and the multiplicity are measured.
**Comparison of pp and p-Pb results**

**Multiplicity at mid-rapidity:** similar trend for in pp and p-Pb collisions

**Multiplicity at large (backward) rapidities:**

- measured in different η ranges in pp and p-Pb collisions
- faster increase of D-meson yields in pp than in p-Pb collisions

**Possible effects due to MPI in high-multiplicity pp collisions**

**p-Pb:** multiple (and softer) nucleon-nucleon collisions also contribute

*arXiv:1602.07240*
Per-event yields: comparison with models in pp collisions

**Percolation:**
- interactions driven by the *exchange of colour sources* (strings ~ MPI scenario)

**EPOS 3 (event generator):**
- Flux-tube initial conditions
- Hydrodynamical evolution

**PYTHIA 8:**
- SoftQCD process selection
- including colour reconnection
- MPI

Results qualitative described by models including MPIs

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Comparison with models in p-Pb collisions

EPOS 3 with initial conditions and hydrodynamic evolution

- faster-than-linear increase of D-meson yields with multiplicity at mid rapidity
- approximately linear trend with multiplicity at backward rapidity (reduced influence of hydro on charged-particle production at backward rapidity)


arXiv:1602.07240
Azimuthal correlations of $D$ mesons with charged particles in pp and p-Pb collisions
D meson-charged particle azimuthal correlations

**D-meson trigger $p_T$**

- **3-5 GeV/c**
- **5-8 GeV/c**
- **8-16 GeV/c**

**Average $D^0, D^+, D^+$ ALICE**

- $3 < p_T < 5$ GeV/c, $p_T^{assoc} > 0.3$ GeV/c
- $|y^{meas}| < 0.5, |\eta| < 1$
- pp, $\sqrt{s} = 7$ TeV

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

- **PYTHIA6, Perugia 0**
- **PYTHIA6, Perugia 2010**
- **PYTHIA6, Perugia 2011**

Baseline-subtraction uncertainty

- $\pm 0.1\%$ scale uncertainty

**In pp collisions:**

- Address charm fragmentation
- Reference for comparison with Pb-Pb and p-Pb collisions

Compatible within uncertainties with expectations from different MC generators and tunes (PYTHIA6, PYTHIA8, POWHEG+PYTHIA) after baseline subtraction

**Near side:**

- $D$ meson trigger

**Away side:**

- Associate hadron

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Comparison to p-Pb collisions

**D-meson trigger** $p_T$:

- **5-8 GeV/c**
  - Average $D^0, D^+, D^+$
  - ALICE
  - $pp$, $\sqrt{s} = 7$ TeV, $|y_{D^{0}}| < 0.5$
  - p-Pb, $\sqrt{s_{NN}} = 5.02$ TeV, $-0.96 < y_{D^{0}} < 0.04$
  - $5 < p_T^D < 8$ GeV/c, $p_T^{assoc} > 0.3$ GeV/c
  - $|\Delta\eta| < 1$
  - $\pm 13\%$ scale uncertainty (pp)
  - $\pm 10\%$ scale uncertainty (p-Pb)

- **8-16 GeV/c**
  - $8 < p_T^D < 16$ GeV/c, $p_T^{assoc} > 0.3$ GeV/c
  - Baseline-subtraction uncertainty (pp)
  - Baseline-subtraction uncertainty (p-Pb)

**Near side:** D-meson trigger

**Away side** associate hadron

In p-Pb collisions:

- Are heavy-flavour jet properties affected by nuclear effects due to the Pb nucleus?

Compatibility within uncertainties between pp collisions at $\sqrt{s} = 7$ TeV and p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV after baseline subtraction
Near-side yields and widths in p-Pb collisions

Near-side yield

Near-side width

Near-side yields and widths compatible in data and simulations within uncertainties
Conclusions

Cross sections in pp collisions for D mesons and leptons from heavy-flavour decays described by pQCD, down to \( p_T=0 \) (D\( ^0 \))

- heavy flavours as test for pQCD at LHC energies

\( R_{ppb} \) compatible with unity within uncertainties, down to \( p_T=0 \) (D\( ^0 \))

- described by different models of initial-/final-state effects,
- no centrality dependence

Relative D-meson yields increase with charged-particle multiplicity in pp and p-Pb collisions

- Models including multiple-parton interactions reproduce pp results.
- In p-Pb collisions, also contributions from multiple nucleon-nucleon collisions

D-charged particle correlations in pp and p-Pb collisions:

- Near-side structure in good agreement with Monte Carlo generators

Outlook: larger data samples in Run 2, higher \( \sqrt{s} \), higher multiplicities: access to physics-rich program down to \( p_T=0 \), angular correlations in high-multiplicity events
Extra slides
(Some) measured effects on the hard scale

In pp collisions:
- **NA27** (pp collisions at $\sqrt{s} = 28$ GeV): NA27 Coll. Z.Phys.C41:191
  Events with charm have larger charged particle multiplicity
  Studies on jets and underlying event are better agreement with models including MPI
- **LHCb** (pp collisions at $\sqrt{s} = 7$ TeV): J. High Energy Phys., 06 (2012) 141
  Double charm production agrees better with models including double parton scattering
  Approximately linear increase of J/$\psi$ yield as a function of multiplicity

And in pA collisions:
- **PHENIX** (d+Au at 200 GeV)
  CNM effects observed from e-$\mu$ correlations
- **ALICE** (p-Pb collisions at 5 TeV)
  Collective effects for high-$p_T$ muons in high-multiplicity events via $\mu$-h correlations

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Data-driven feed-down subtraction

\[ D^0 \rightarrow K\pi^+ \quad 3 < p_T < 4 \text{ GeV/c} \]

\[ f_{\text{prompt}} = 0.87 \pm 0.05 \]

\[ p_{\text{Pb}}, \sqrt{s_{\text{NN}}} = 5.02 \text{ TeV} \]

ALICE

\[ D^0 \rightarrow K\pi^+ \]

Entries vs. Impact parameter (µm)

\[ 0 \leq \rho < 500 \mu m \]

Entries vs. \( \rho_T \) (GeV/c)

\[ f_{\text{prompt}} \]

Entries vs. Impact parameter (µm)

\[ 5 < \rho_T < 6 \text{ GeV/c} \]

Entries vs. \( \rho_T \) (GeV/c)

\[ f_{\text{prompt}} = 0.89 \pm 0.05 \]

Entries vs. Impact parameter (µm)

\[ 6 < \rho_T < 8 \text{ GeV/c} \]

Entries vs. \( \rho_T \) (GeV/c)

\[ f_{\text{prompt}} = 0.92 \pm 0.05 \]

Entries vs. Impact parameter (µm)

\[ 0 \leq \rho < 500 \mu m \]

Entries vs. \( \rho_T \) (GeV/c)

\[ f_{\text{prompt}} \]

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Entries vs. Impact parameter (µm)

\[ 6 < \rho_T < 8 \text{ GeV/c} \]

Entries vs. \( \rho_T \) (GeV/c)

\[ f_{\text{prompt}} = 0.92 \pm 0.05 \]
Low-$p_T$ $D^0$

arXiv:1605.07569

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

$\sqrt{s}_{NN} = 5.02$ TeV

Prompt $D^0$
- with vertexing
- w/o vertexing

$\pm 3.5\%$ lumi, $\pm 1.3\%$ BR uncertainty not shown

ALICE, $pp$, $|y|<0.5$

ALICE = 5.02 TeV

ALICE, $p-Pb$

$\pm 3.5\%$ lumi, $\pm 1.3\%$ BR uncertainty not shown

ALICE = 5.02 TeV

Data

FONLL

GM-VFNS

$LO_k_f$ fact

FONLL
Centrality estimation in p-Pb collisions

**CL1** (clusters in outer SPD layer): $<N_{\text{coll}}>$ from Glauber fit to cluster distribution

**V0A:** $<N_{\text{coll}}>$ from Glauber fit to V0A amplitude

**ZNA:** $<N_{\text{part}}>$ in ZN energy class from scaling the min. bias value assuming scaling with multiplicity at mid-rapidity.

**Q_{pPb} in p-Pb collisions**

\[
Q_{pPb}^{\text{mult}}(p_T) = \frac{dN_{\text{mult}}^{pPb}/dp_T}{N_{\text{coll}}^\text{dNNPp/dp_T}}
\]

**Average D^0, D^+, D^{**} Q_{pPb}** shows:
- ordering from low to high multiplicity when evaluated with CL1 (bias on multiplicity fluctuation/jets)
- a residual bias when computed using the V0A estimator (a rapidity gap)
- that is reduced when using ZN one.

With ZN estimator: **no multiplicity dependent modification** of D meson production relative to pp collisions within uncertainties.

**Consistent with binary collision scaling of the yield in pp collisions.**
Average D meson $Q_{pPb}$ shows a similar trend as a function of centrality with the three estimators at low and high $p_T$.

At high $p_T$, the trend is similar to that of charged hadrons (expected to scale with $N_{coll}$ only at high $p_T$).
Multiplicity estimation

Multiplicity estimators:

- number of track segments (or tracklets) of the **Silicon Pixel Detector** (2 innermost layers of the *Inner Tracking System*).

- sum of amplitudes in the **V0** scintillator arrays

SPD layers of radii of 3.9 cm (1 cm from beam vacuum tube) and 7.6 cm. Formed by $9.8 \times 10^6$ pixels of size $50(r\phi) \times 425(z) \ \mu m^2$, with intrinsic spatial resolution of $12(r\phi) \times 100(z) \ \mu m^2$.

V0 scintillator arrays at $-3.7 < \eta < -1.7$ and $2.8 < \eta < 5.1$

- $N_{\text{tracklets}} \propto dN_{\text{ch}} / d\eta$

- $\langle dN_{\text{ch}} / d\eta \rangle = 6.01 \pm 0.01 \text{(stat.)} +0.20^{+0.12}_{-0.12} \text{(syst.)}$ for $|\eta| < 1.0$ in pp collisions at 7 TeV

Open-charm production vs multiplicity

D-meson yield in multiplicity intervals (pp and p-Pb)

Multiplicity estimator: N tracklets = n. track segments reconstructed in SPD ($|\eta|<1$)

$$\frac{d^2N^D}{dyd\eta_T} = \frac{\frac{Y^{\text{mult}}}{\epsilon^{\text{mult}} \times N_{\text{event}}^{\text{mult}}}}{\frac{Y^{\text{tot}}}{\epsilon^{\text{tot}} \times N_{\text{event}}^{\text{tot}} / \epsilon_{\text{trigger}}}}$$

D yield/event integrated in multiplicity, corrected for reconstruction and trigger efficiencies

Example: D$^+$ meson

pp $\sqrt{s}=7$ TeV
Comparison of open vs hidden heavy flavours

- Heavy-flavour yields increase with charged-particle multiplicity at mid rapidity;
  - similar trend in pp collisions,
  - in p-Pb collisions, D mesons increase faster than J/ψ.

In particular for J/ψ yields measured at forward rapidity (p-going direction).

Note: J/ψ yields measured in the p-going direction probe low-\(x\) gluons.

Error bars: statistical uncertainty.
Vertical size of boxes: systematic uncertainties but feed-down.
Bottom panels lines: relative feed-down systematic uncertainties.
Not shown: systematic uncertainty on \((dN/d\eta)/\langle dN/d\eta \rangle\). and normalisation.
Comparison of open and hidden heavy flavours in pp collisions

- Similar increase of open charm, open beauty and charmonia yields as a function of charged-particle multiplicity at mid rapidity.
- Caveats: different rapidity and $p_T$ interval of the measurements.
- Likely related to heavy-flavour production processes, and not significantly influenced by hadronisation.


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Quarkonia vs. multiplicity

- Increase of J/ψ yields as a function of multiplicity at mid rapidity.
- Similar increase of J/ψ yields measured at central and forward rapidity.
- The fraction of non-prompt J/ψ in the inclusive yields shows no multiplicity dependence with multiplicity within uncertainties.

Error bars: statistical uncertainty.

Horizontal size of boxes: systematic uncertainty on $(dN/d\eta)/\langle dN/d\eta \rangle$.
Vertical size of boxes: systematic uncertainties but feed-down.
Not shown: normalisation systematic uncertainty.


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**Quarkonia in pp and p-Pb collisions**

- **Multiplicity at mid rapidity:**
  - similar trend for J/ψ yields measured in pp and p-Pb collisions at backward rapidity (Pb-going direction),
  - deviation of J/ψ yields measured at forward rapidity (p-going direction).

Note: J/ψ yields measured in the p-going direction probe low-x gluons.
**J/ψ in pp collisions vs. percolation model**

- **Percolation:**
  - interactions driven by the **exchange of colour sources** (strings ~ MPI scenario);
  - the strings **have a finite spatial extension and can interact**,
    - at high density the coherence leads to a reduction of their number, i.e. a reduction of charged-particle multiplicity,
    - heavy-flavours are less affected due to the smaller transverse size of hard sources;
  - **faster-than-linear increase of J/ψ yield with multiplicity**

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Non-prompt J/ψ in pp collisions vs. models

- **PYTHIA 8:**
  - SoftQCD process selection,
  - including colour reconnection,
  - as well as MPI,
  - and diffractive processes

✿ nearly linear trend of B-hadron yield with multiplicity.
More details on PYTHIA 8

- Calculation: SoftQCD process selection, including colour reconnection and diffractive processes.

- Contributions of:
  - **first hard process** ∝ hardest process
    - weak dependence on multiplicity (slight increase at low multiplicities followed by a saturation)
  - **MPI** ∝ subsequent hard process
    - increasing trend vs. multiplicity
  - **gluon splitting from hard process**
    - increasing trend vs. multiplicity
  - **initial and final-state radiation**
    - increasing trend vs. multiplicity

Comparison to p-Pb collisions

D-meson trigger $p_T$:

- Near side:
  - Heavy-flavour jet properties affected by nuclear effects due to the Pb nucleus?

- Away side:
  - Associate hadron

In p-Pb collisions:

- Are heavy-flavour jet properties affected by nuclear effects due to the Pb nucleus?

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

arXiv:1605.06963
Correlations in pp and p-Pb collisions

Average $D^0$, $D^+$, $D^+$ ALICE

- pp, $\sqrt{s} = 7$ TeV, $|y_{\text{cms}}^p| < 0.5$
- p-Pb, $\sqrt{s_{\text{NN}}} = 5.02$ TeV, $-0.96 < y_{\text{cms}}^D < 0.04$

$|\Delta\eta| < 1$

- $3 < p_T^D < 5$ GeV/c
- $p_T^{\text{assoc}} > 0.3$ GeV/c

Scale uncertainty (pp) $\pm 13\%$

- $5 < p_T^D < 8$ GeV/c
- $p_T^{\text{assoc}} > 0.3$ GeV/c

Scale uncertainty (p-Pb) $\pm 14\%$

- $8 < p_T^D < 16$ GeV/c
- $p_T^{\text{assoc}} > 0.3$ GeV/c

Scale uncertainty (p-Pb) $\pm 14\%$

$|\Delta\phi| < 1$

- $3 < p_T^D < 5$ GeV/c
- $0.3 < p_T^{\text{assoc}} < 1$ GeV/c

Scale uncertainty (pp) $\pm 13\%$

- $5 < p_T^D < 8$ GeV/c
- $0.3 < p_T^{\text{assoc}} < 1$ GeV/c

Scale uncertainty (p-Pb) $\pm 10\%$

- $8 < p_T^D < 16$ GeV/c
- $0.3 < p_T^{\text{assoc}} < 1$ GeV/c

Scale uncertainty (p-Pb) $\pm 10\%$
Near-side yields and widths in pp and p-Pb collisions

0.3 < $p^\text{assoc}_T$ < 1 GeV/c, $|\Delta \eta| < 1$
- pp, $\sqrt{s} = 7$ TeV, $|y^D_{\text{cms}}| < 0.5$
- p-Pb, $\sqrt{s_{\text{NN}}} = 5.02$ TeV, -0.96 < $y^D_{\text{cms}}$ < 0.04

<7% variation expected from different energy and rapidity (Pythia, Perugia 2011)
Near-side yields and widths in pp collisions

(arXiv:1605.06963)

Graphs showing associated yield, $\sigma_{\text{NS}}$, baseline, and $D$ meson $p_T$ distributions for different conditions and simulations.