

# The LHCb p–Pb programme

Michael Winn  
on behalf of the LHCb Collaboration

Laboratoire de l'Accélérateur Linéaire, Orsay

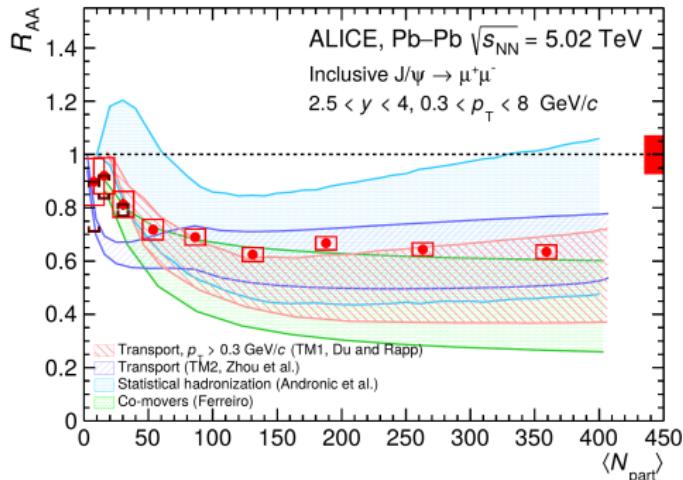


QGP France, 11.10.2016

# Outline

1. p–Pb collisions at the LHC
2. p–Pb results
3. Outlook and Conclusions

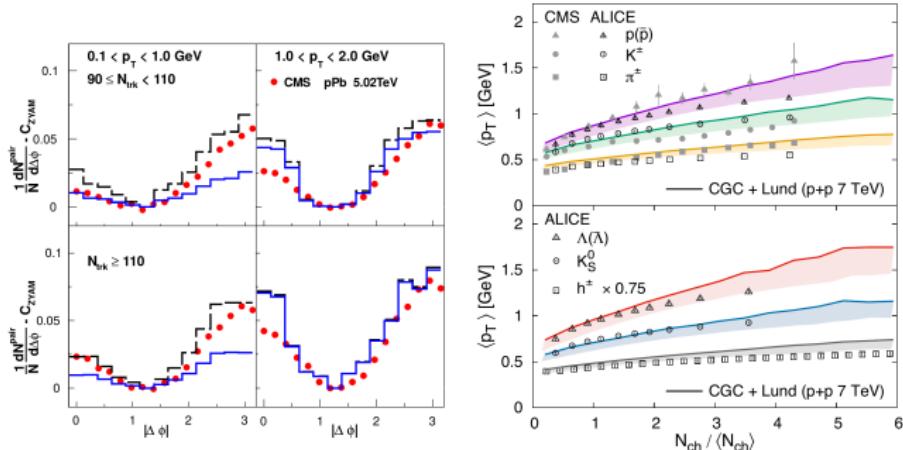
# The physics case of p–Pb collisions at the LHC



- ▶ Main goal at the LHC: measure QGP properties in A–A collisions
- ▶ Model precision in A–A collisions strongly limited by non-QGP effects for many observables

parton flux at low  $x$  and best factorisation framework, energy loss phenomena

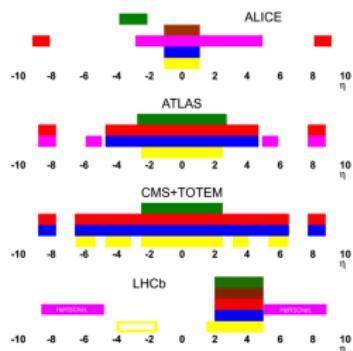
# The physics case of p–Pb collisions at the LHC



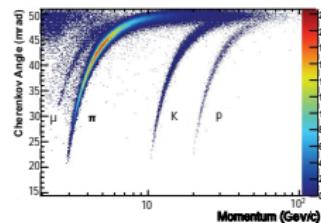
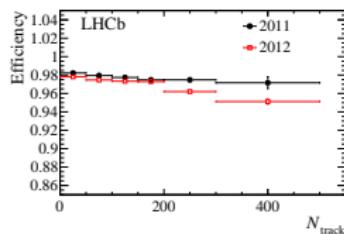
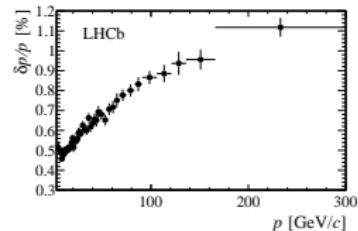
LHS: 2012 Bozek vs. first CMS data [Phys.Lett. B718 \(2013\) 1557-1561](#), RHS: CGC+Lund hadronisation in pp [arXiv:1607.02496](#).

- ▶ Observation of 'collective' effects in high-multiplicity p–Pb collisions:
  - applicability of hydrodynamics
  - role of long-range correlations from density enhanced diagrams
  - role of hadronisation models
- ▶ No common understanding yet

# LHCb: a fast multi-purpose forward detector



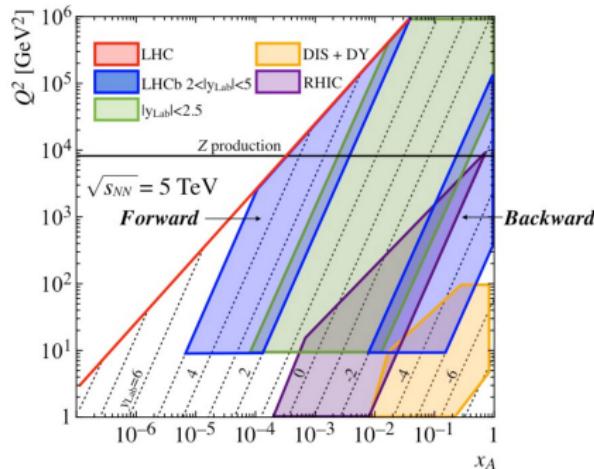
hadron PID  
muon system  
lumi counters  
HCAL  
ECAL  
tracking



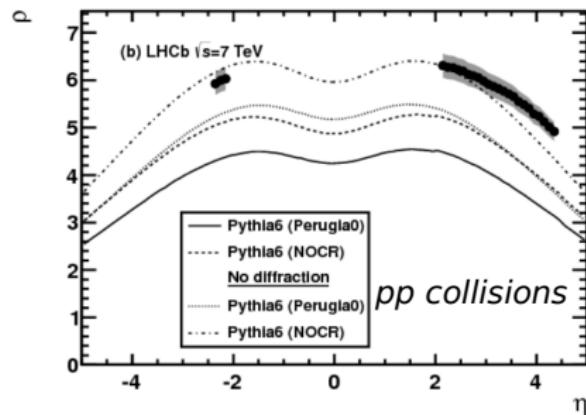
Int. J. Mod. Phys. A 30 1530022.

- ▶ momentum resolution below 1% and hadron ID in large momentum range
- ▶ topological ID of charm and beauty hadrons down to 0  $p_T$
- ▶ hardware trigger inspecting all bunch crossing at 40 MHz in pp
- ▶ 1 MHz input software trigger system,  $\approx 10$  kHz to tape in pp

# The LHCb detector: its p–Pb physics case



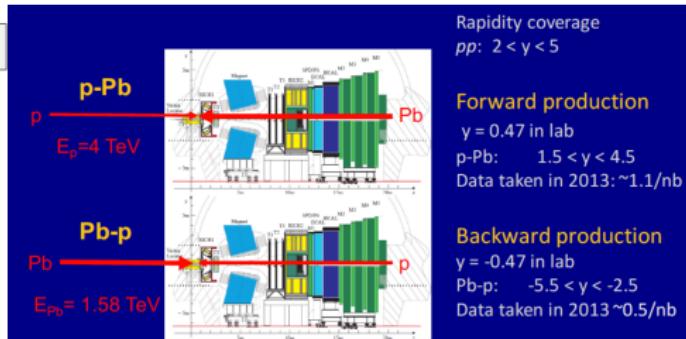
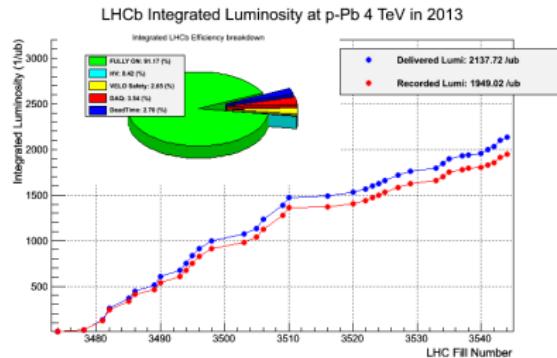
RHS: [Eur. Phys. J. C 72 \(2012\) 1947](#).



Unique kinematics at the edge of the midrapidity plateau  
PID and topological identification profiting from longitudinal boost

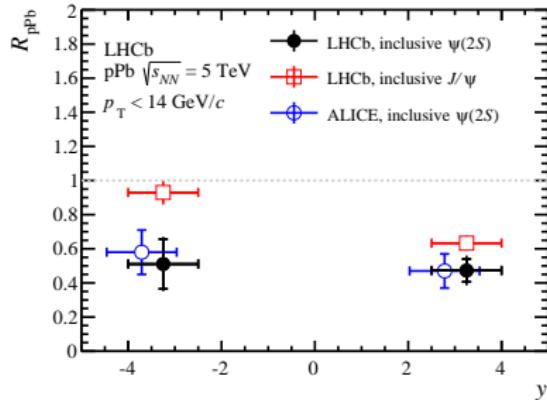
- Your observable of choice with this beautiful detector!

# LHCb p-Pb programme: 2013 run



- ▶ first data taking with Pb beams for LHCb
- ▶ smooth detector operation
- ▶  $1.1 \text{ nb}^{-1}$  at forward and  $0.5 \text{ nb}^{-1}$  backward rapidity collected at  $\sqrt{s_{\text{NN}}} = 5 \text{ TeV}$

# LHCb p-Pb programme: charmonium

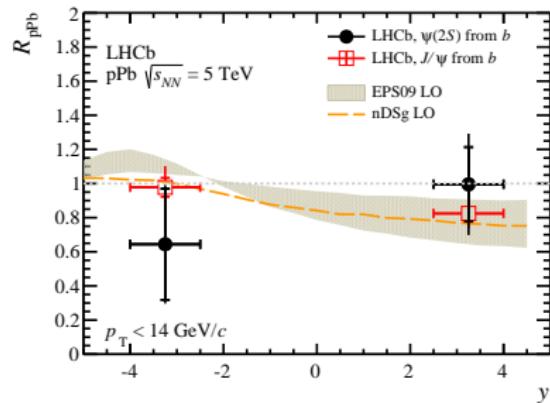


$J/\psi$ : [JHEP 02 \(2014\) 072](#);  $\psi(2S)$ : [JHEP 1603 \(2016\) 133](#).

Charmonium results with  $\approx 10\%(20\%)$  at backward (forward) of luminosity of ALICE muon arm:

- ▶ similar precision for inclusive measurement thanks to better resolution
- ▶ separation prompt and B-feeddown down to 0  $p_T$ : unique at the LHC

# LHCb p-Pb programme: non-prompt charmonium results

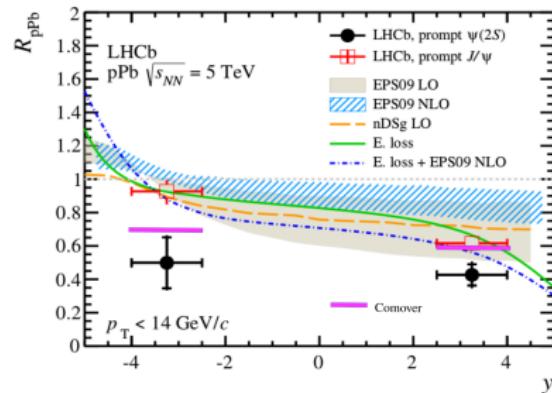


[JHEP 02 \(2014\) 072](#), [JHEP 1603 \(2016\) 133](#).

Capability to separate prompt and non-prompt component down to 0  $p_T$ : constraints on low- $p_T$  B production

- ▶ result compatible with modifications expected from nuclear PDFs
- ▶ no discrimination between parameterisation due to statistical limitations

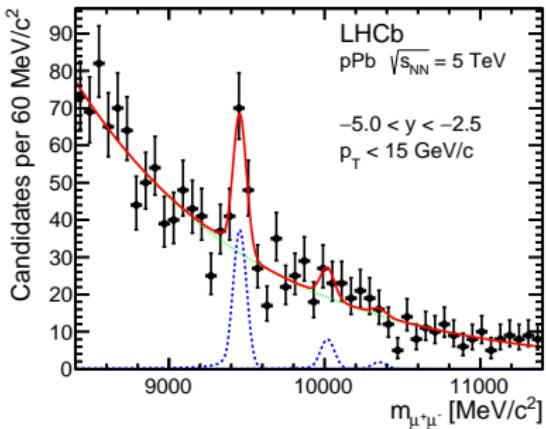
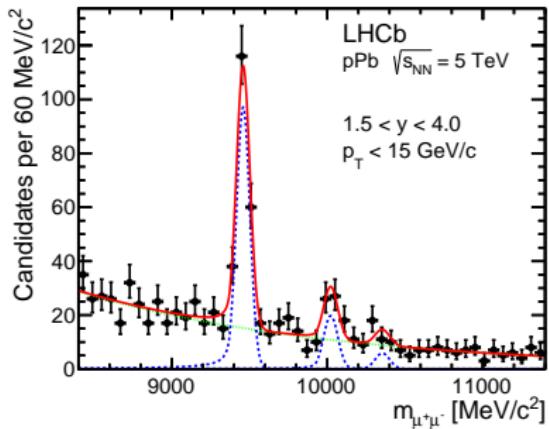
# LHCb p-Pb programme: prompt charmonium results



[JHEP 02 \(2014\) 072](#), [JHEP 1603 \(2016\) 133](#).

- ▶ result compatible with modifications expected from nuclear PDFs, coherent energy loss model, recent CGC calculations
- ▶ additional suppression for  $\psi(2S)$  not explained by nuclear PDFs nor by coherent energy loss
- ▶ comover model shows observed additional suppression
- ▶ data also described with HRG+QGP ansatz by Du & Rapp [Nucl.Phys. A 943 \(2015\)](#)

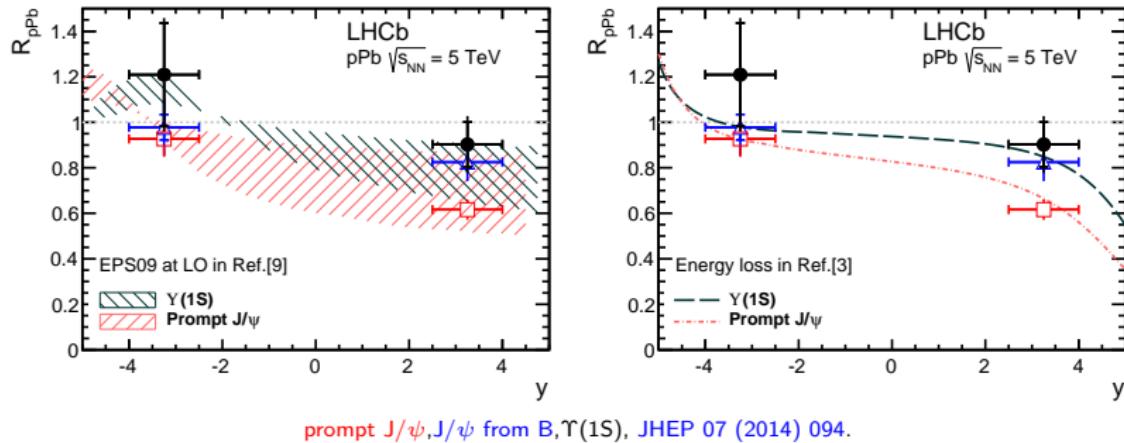
# LHCb p-Pb programme: $\Upsilon$ results



JHEP 07 (2014) 094.

- ▶ clear separation of  $\Upsilon$  states
- ▶ statistical limitations

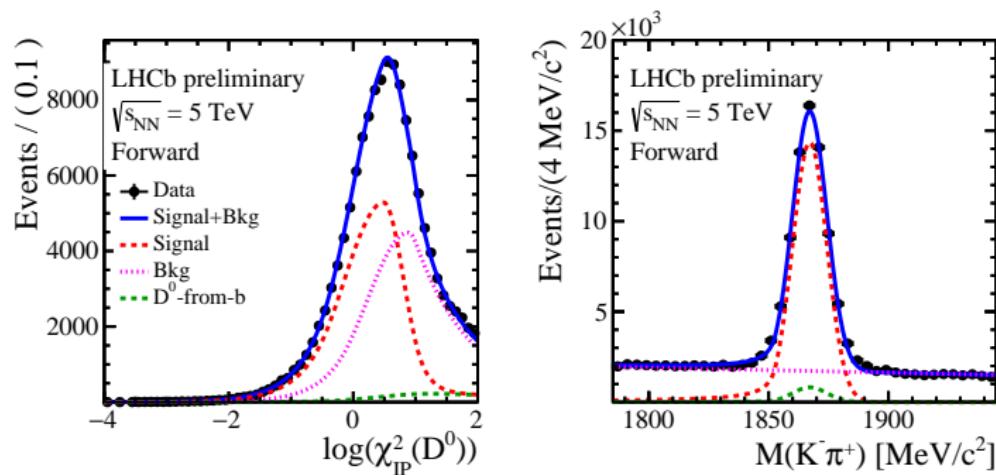
# LHCb p-Pb programme: $\Upsilon$ results



prompt  $J/\psi, J/\psi$  from  $B, \Upsilon(1S)$ , JHEP 07 (2014) 094.

- ▶ results compatible with modifications expected from nuclear PDFs and from coherent energy loss model
- ▶ within uncertainties compatible modification of open and hidden beauty

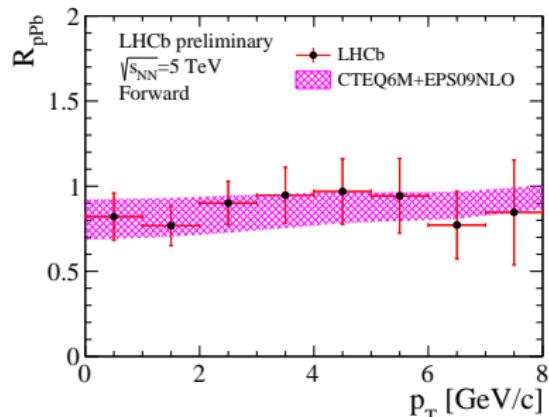
# LHCb p-Pb programme: $D^0$ analysis



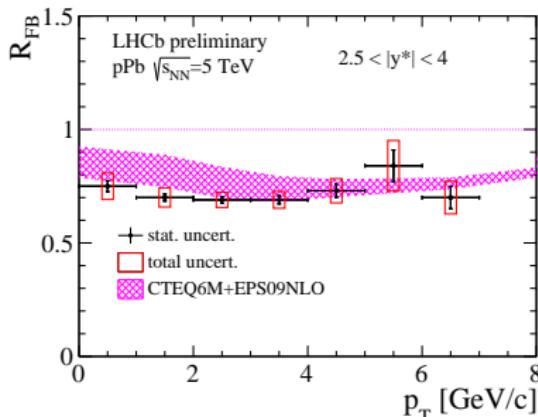
$D^0$  meson ( $p_T < 8 \text{ GeV}/c$ ) with  $\approx 10\%$  of available statistics at  $\sqrt{s_{\text{NN}}} = 5.02 \text{ TeV}$  [LHCb-CONF-2016-003!](#)

- ▶ unique measurement at the LHC: open charm down to 0  $p_T$  with high precision
- ▶ large statistics sample available
- ▶ separation of B feed-down from prompt production by impact parameter of D-meson

# LHCb p-Pb programme: $D^0$ results



LHCb-CONF-2016-003.



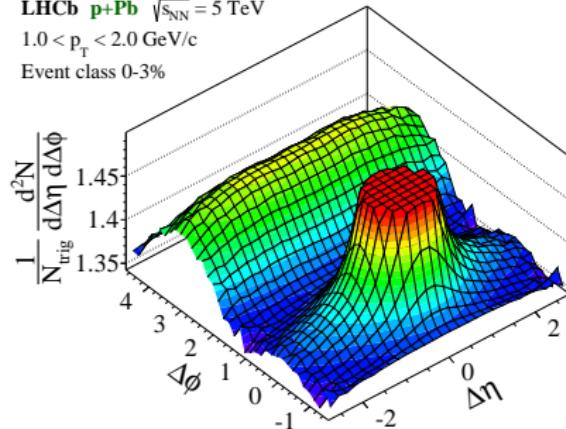
- ▶ observed nuclear modification compatible with EPS09 parametrisation
- ▶ forward-backward ratio more precise than theory thanks to cancellation of uncertainties
- ▶ stay tuned for full statistics result with pp reference from data!

# LHCb p-Pb programme: Di-hadron correlations

LHCb **p+Pb**  $\sqrt{s_{NN}} = 5 \text{ TeV}$

$1.0 < p_T < 2.0 \text{ GeV}/c$

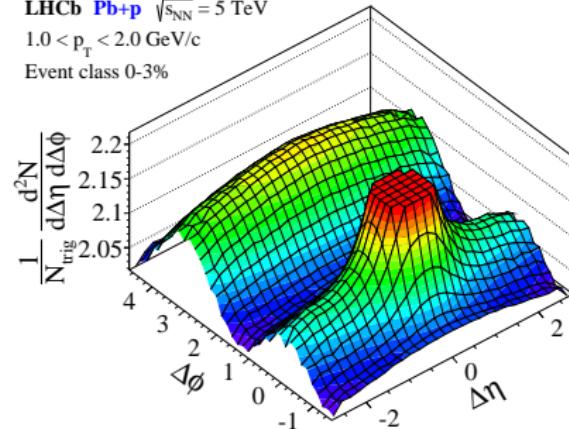
Event class 0-3%



LHCb **Pb+p**  $\sqrt{s_{NN}} = 5 \text{ TeV}$

$1.0 < p_T < 2.0 \text{ GeV}/c$

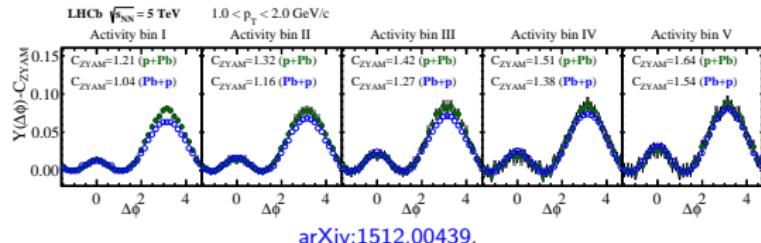
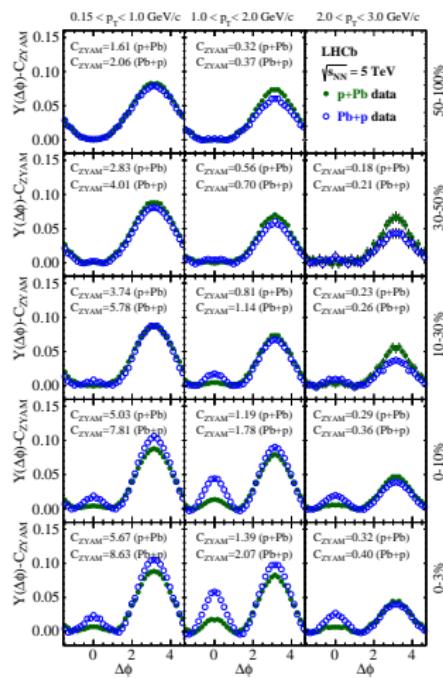
Event class 0-3%



[arXiv:1512.00439](https://arxiv.org/abs/1512.00439).

- ▶ unique forward acceptance with full tracking
- ▶ qualitative agreement with mid-rapidity findings by ALICE, ATLAS and CMS in high multiplicity events
- ▶ significant difference between lead and proton fragmentation side, when comparing same fraction of events based on multiplicity in experimental acceptance  $2.0 < \eta < 4.9$

# LHCb p-Pb programme: Di-hadron correlations



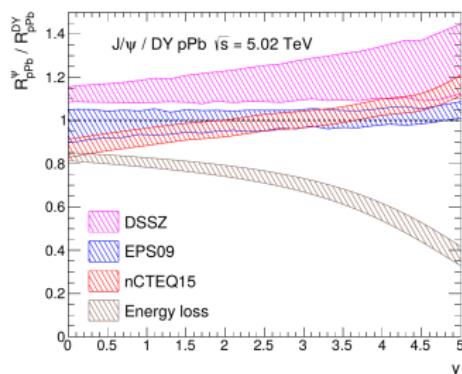
- ▶ increase of near-side correlation towards larger multiplicities and lower  $p_T$  after pedestal subtraction
- ▶ results at forward and backward rapidity at same estimated overall multiplicity: similar results of correlation strength after pedestal subtraction
- ▶ looking forward to phenomenological models

# LHCb p-Pb programme: 2016 run

request  $10 \text{ nb}^{-1}$  per beam direction at 8 TeV:

Hadron PID and precision tracking/vertexing down to low- $p_T$  with nearly 2013 CMS/ATLAS statistics, e.g.:

- ▶  $\psi(2S)$  results with  $J/\psi$  2013 precision
- ▶ W,Z and Drell-Yan at lower masses:  
theoretical clean constraints for nuclear PDFs/saturation  
down to low  $x$



understand dominant nuclear  
modification of quarkonium in  
p-A collisions

Fig. taken from [arXiv:1512.01794 \[hep-ph\]](https://arxiv.org/abs/1512.01794).

# Conclusions

- ▶ unique potential in many sectors in p–Pb collisions at forward rapidity, where data are scarce and precious
- ▶ first measurements in p–A collisions with high impact
- ▶ fascinating opportunities with large data samples both at 5 and at 8 TeV centre-of-mass energy