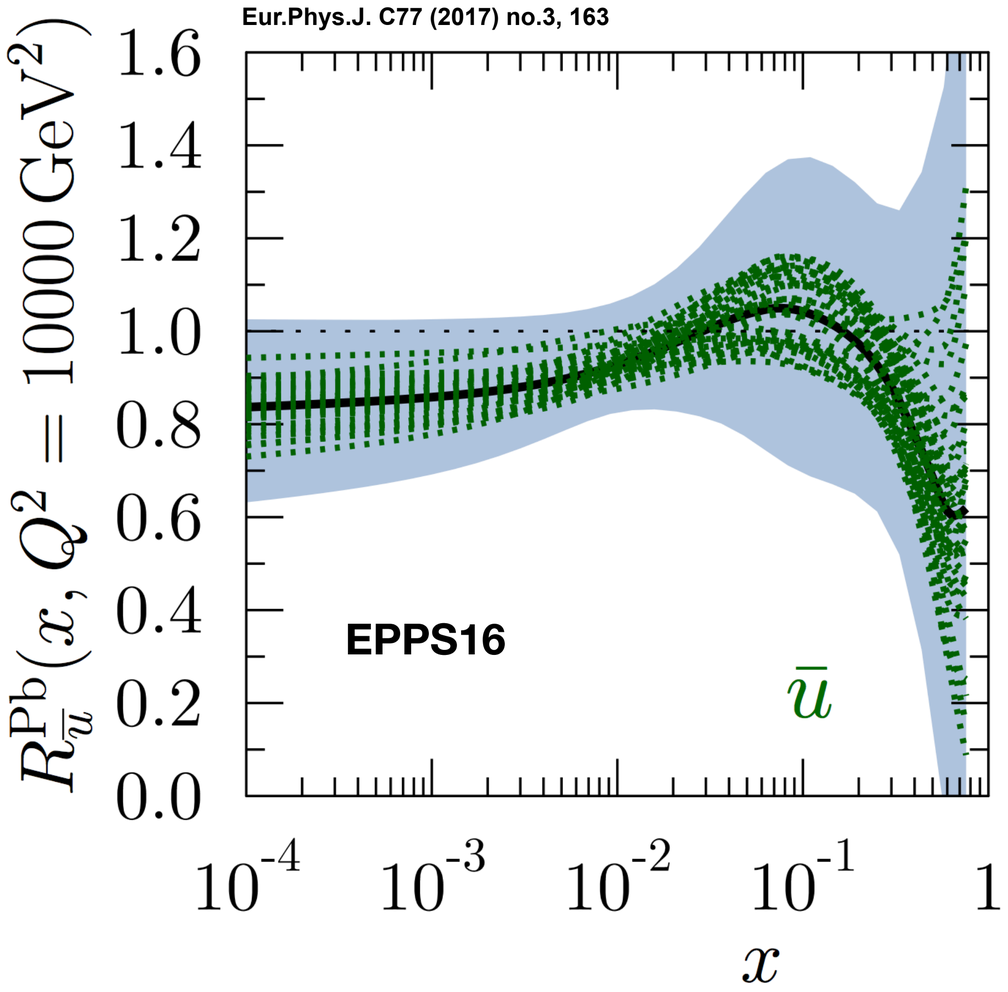
Measurements of electroweak boson production in p-Pb and Pb-Pb collisions at $\sqrt{s_{NN}}$ 5.02 TeV with ALICE

Mohamad Tarhini
For the ALICE collaboration

- In nuclei, parton distribution functions (PDFs) are modified (**nPDFs**)
- Lack of experimental datasets to constrain nPDFs ➜ **large uncertainties**



Introduction

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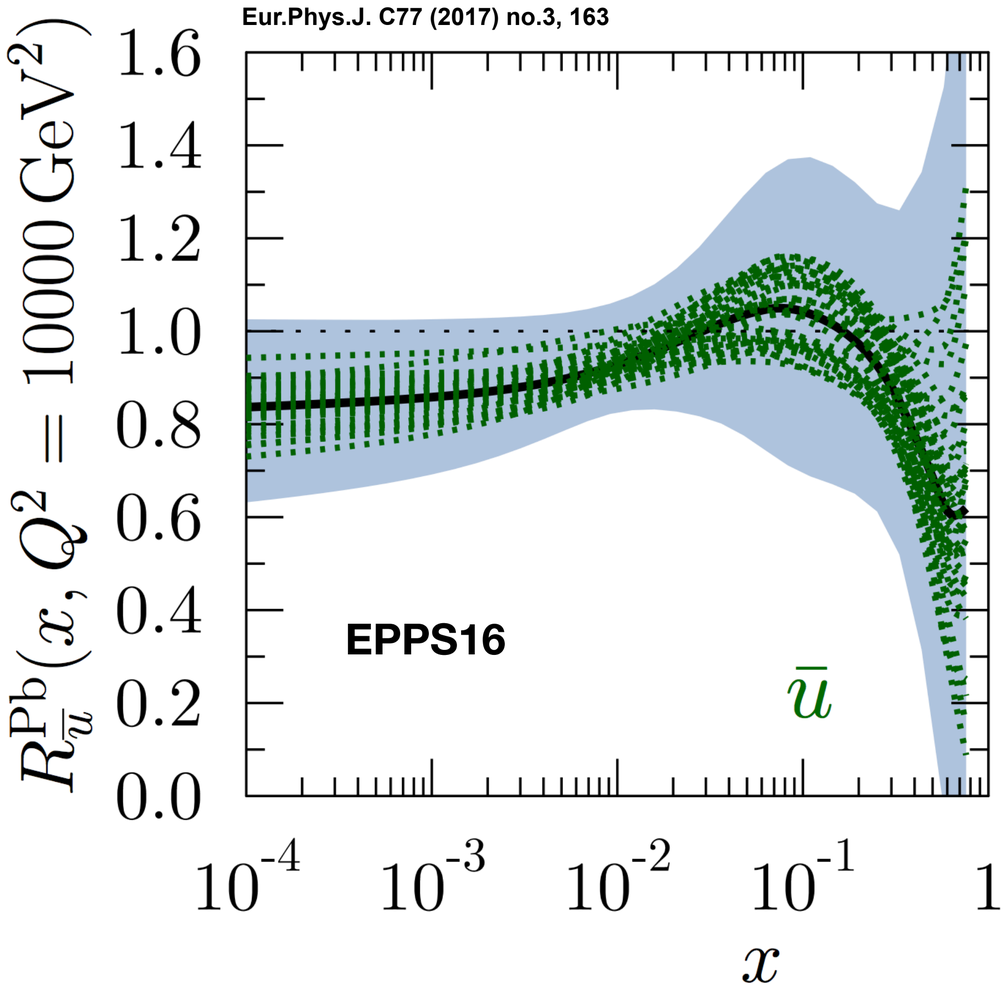
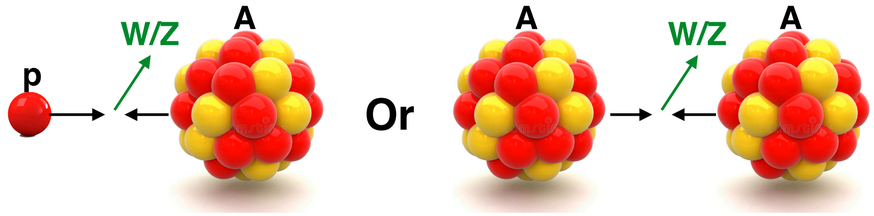


- **W/Z** boson production in heavy-ion collisions:



- Not affected by the presence of the strongly-interacting medium
- The PDF modification is the major Cold Nuclear Matter (CNM) effect

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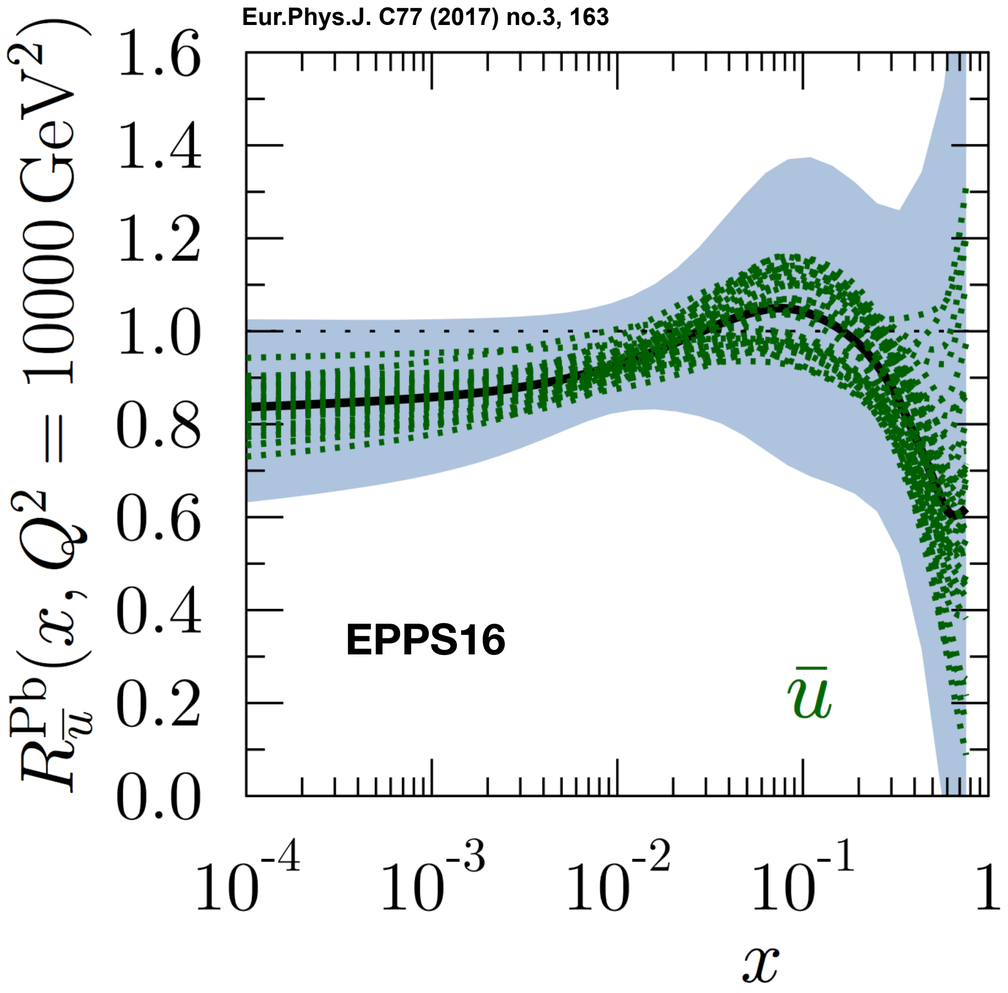
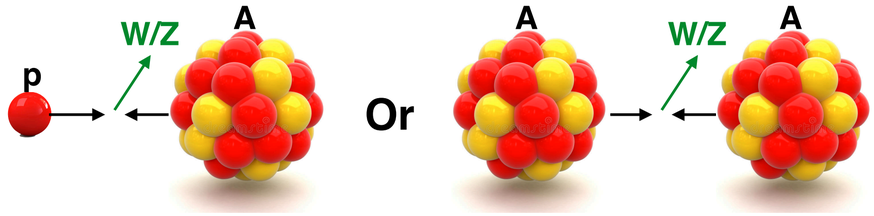


- **W/Z** boson production in heavy-ion collisions:



- Not affected by the presence of the strongly-interacting medium
- The PDF modification is the major Cold Nuclear Matter (CNM) effect

➡ **W/Z** bosons measurement in heavy-ion collisions can constrain nPDFs at large Q^2

W/Z boson production at the LHC

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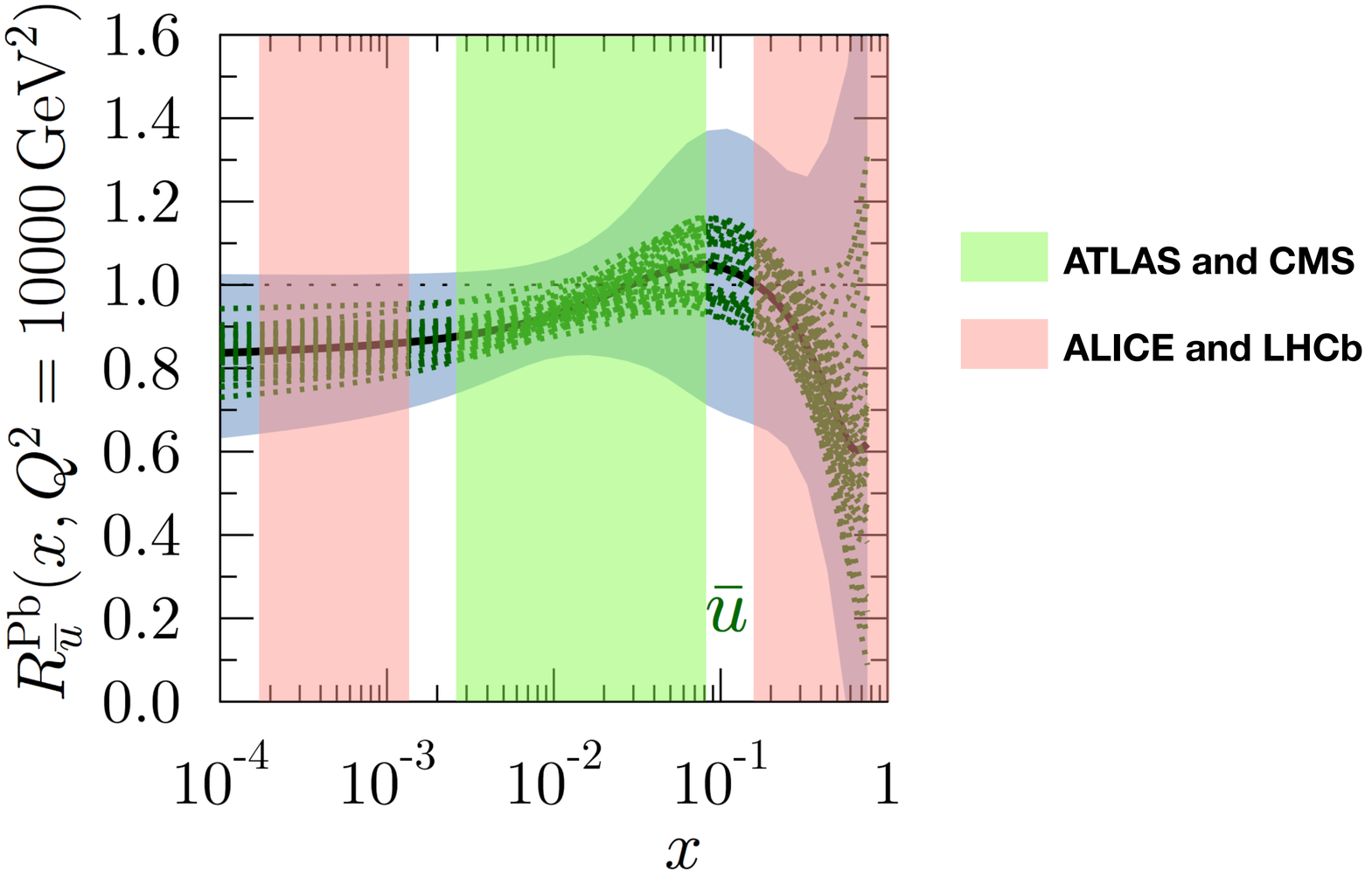
- The LHC experiments are complementary in the phase-space coverage



- ALICE can (**in p-Pb and Pb-Pb collisions**) access the large-*x* region where nPDFs are least constrained

ALICE detector and data samples

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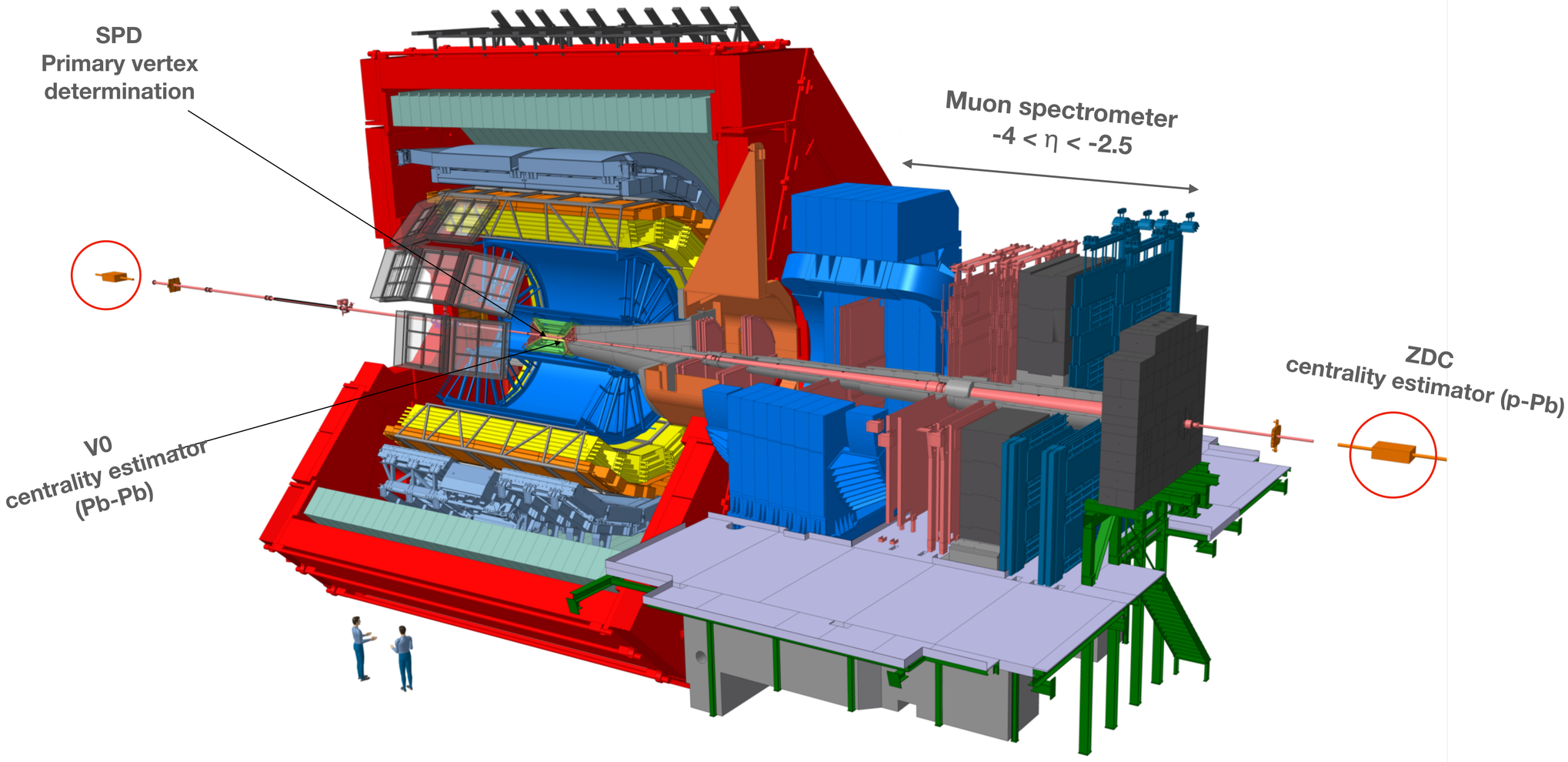
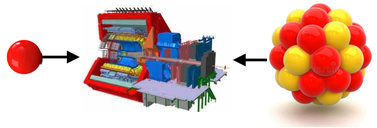
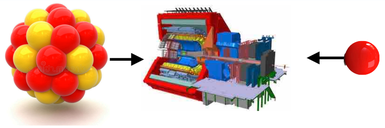
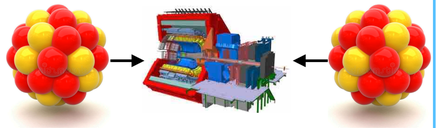




p-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV
(p-going)
$2.03 < y_{cms} < 3.53$
L_{int} ~ 5.1 nb^{-1}



p-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV
(Pb-going)
$-4.46 < y_{cms} < -2.96$
L_{int} ~ 5.8 nb^{-1}



Pb-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV
$2.5 < y < 4$
L_{int} ~ 225 μb^{-1}

Signal extraction

Z-boson measurement in ALICE

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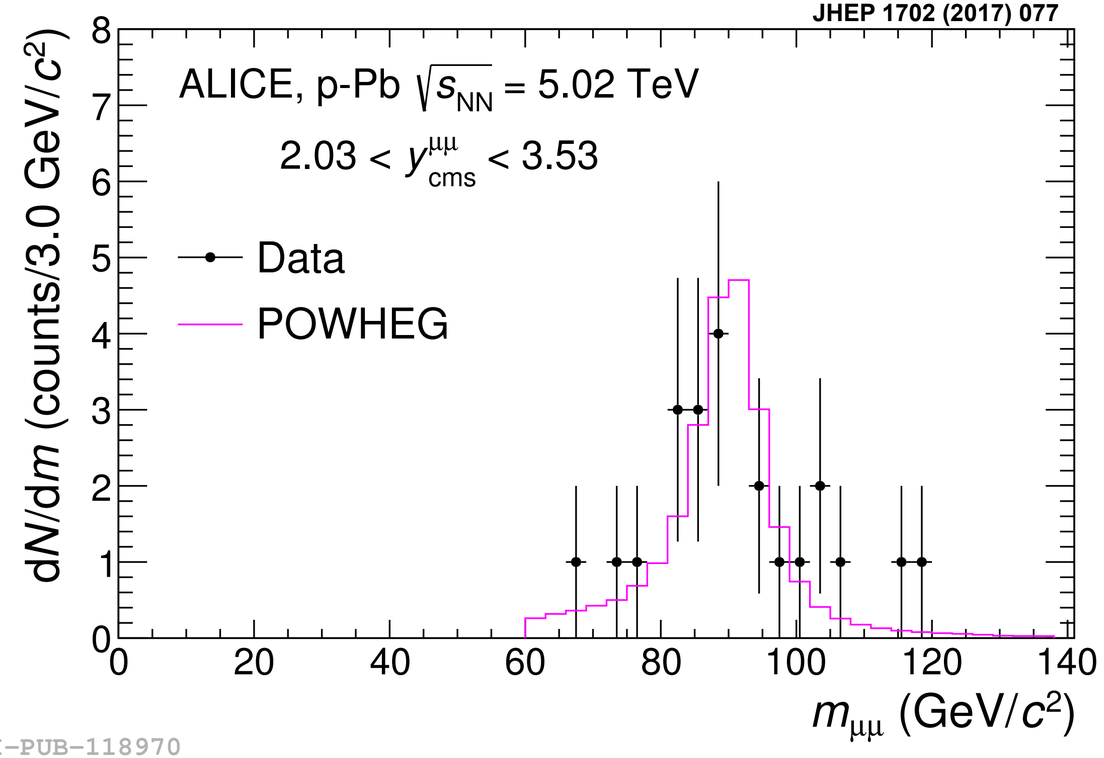
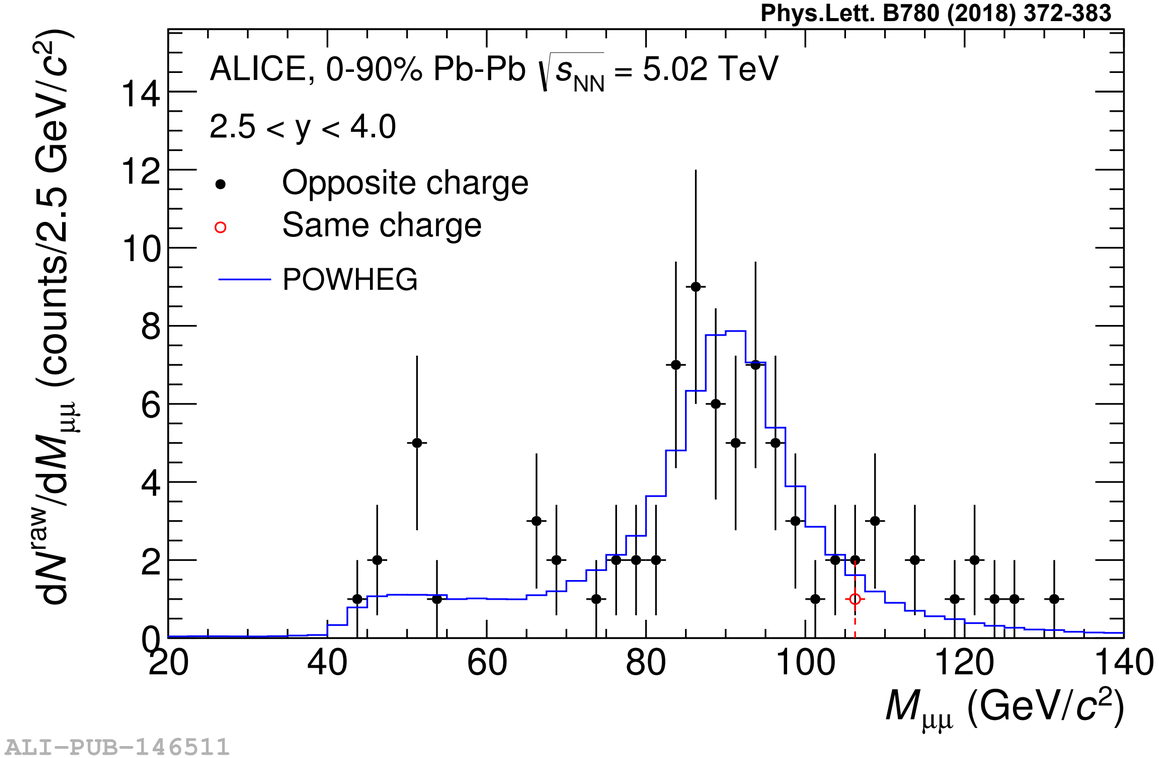
- The Z-boson signal is extracted by counting $\mu^+\mu^-$ candidates with $60 < M_{\mu\mu} < 120$ GeV/c^2, and $p_T > 20$ GeV/c for each muon
- Contribution from other physics background sources ($b\bar{b}$, $c\bar{c}$, $t\bar{t}$, $Z \rightarrow \tau\tau \rightarrow \mu\mu$) estimated w.r.t $[Z \rightarrow \mu\mu]$ using PYTHIA and POWHEG simulations (< 1%)





- Combinatorial background accounted for by looking at the same-charge dimuon distribution
- The raw yield is corrected by the detector acceptance-times-efficiency obtained via MC simulations (+ embedding in Pb-Pb collisions)

W-boson measurement in ALICE

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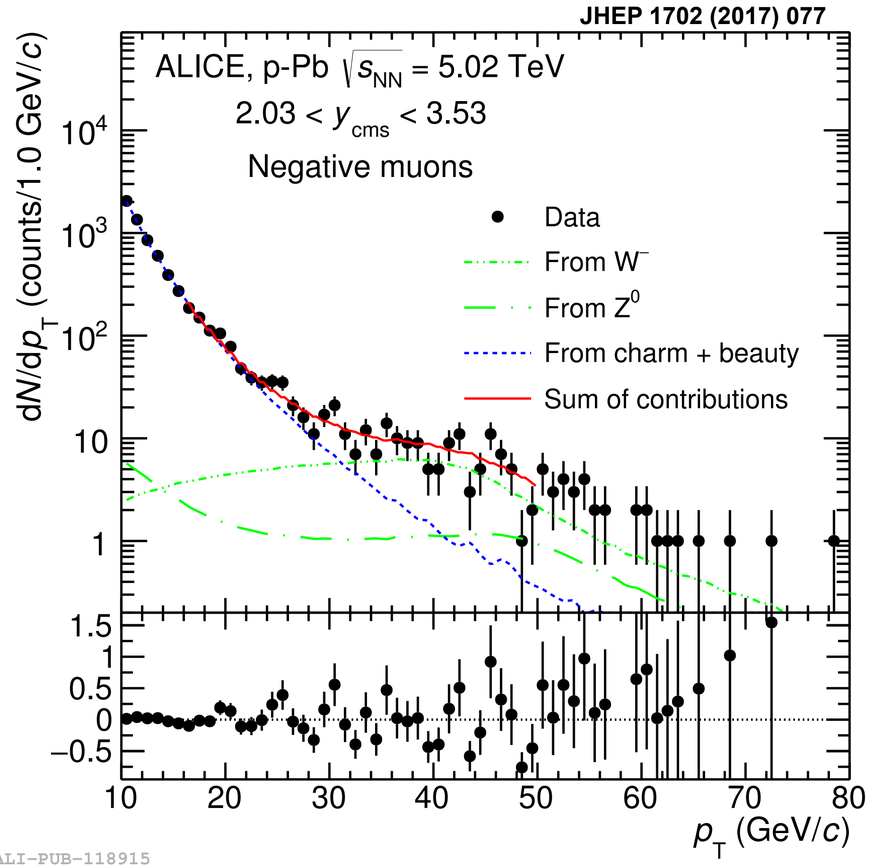
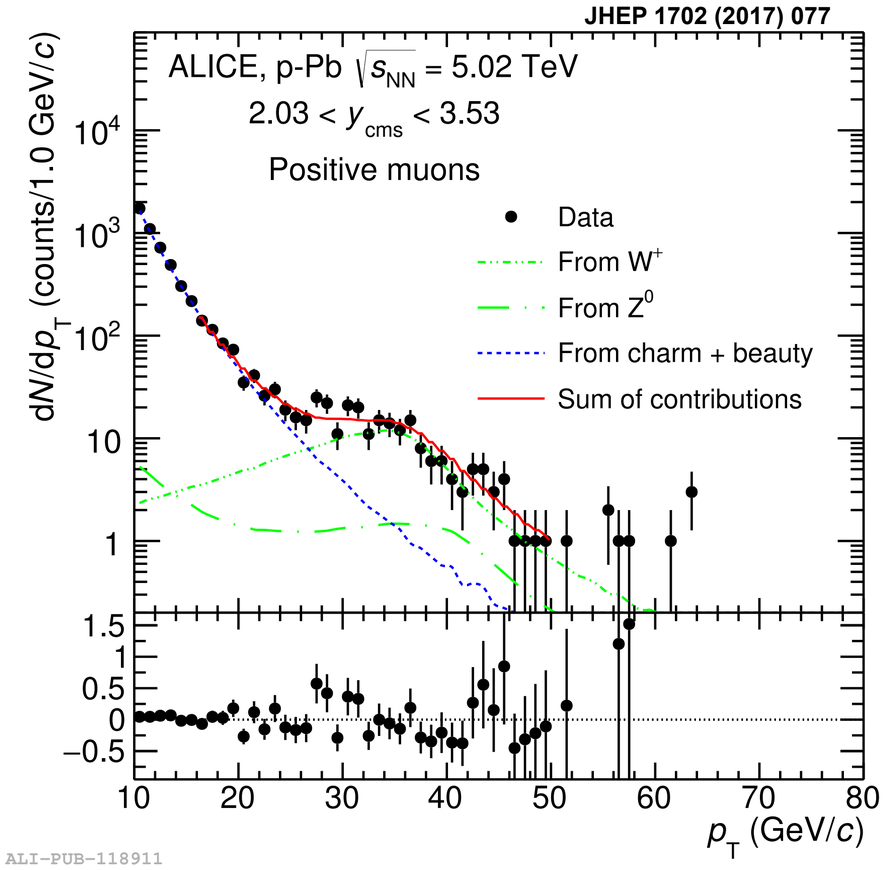
- The signal is extracted using a MC template fit of the single muon distribution ($p_T > 10$ GeV/c)
- Taking into account contributions of muons from heavy-flavour and Drell-Yan decays





- The raw yield is corrected by the acceptance-times-efficiency of the detector

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

Z-boson production in p-Pb collisions

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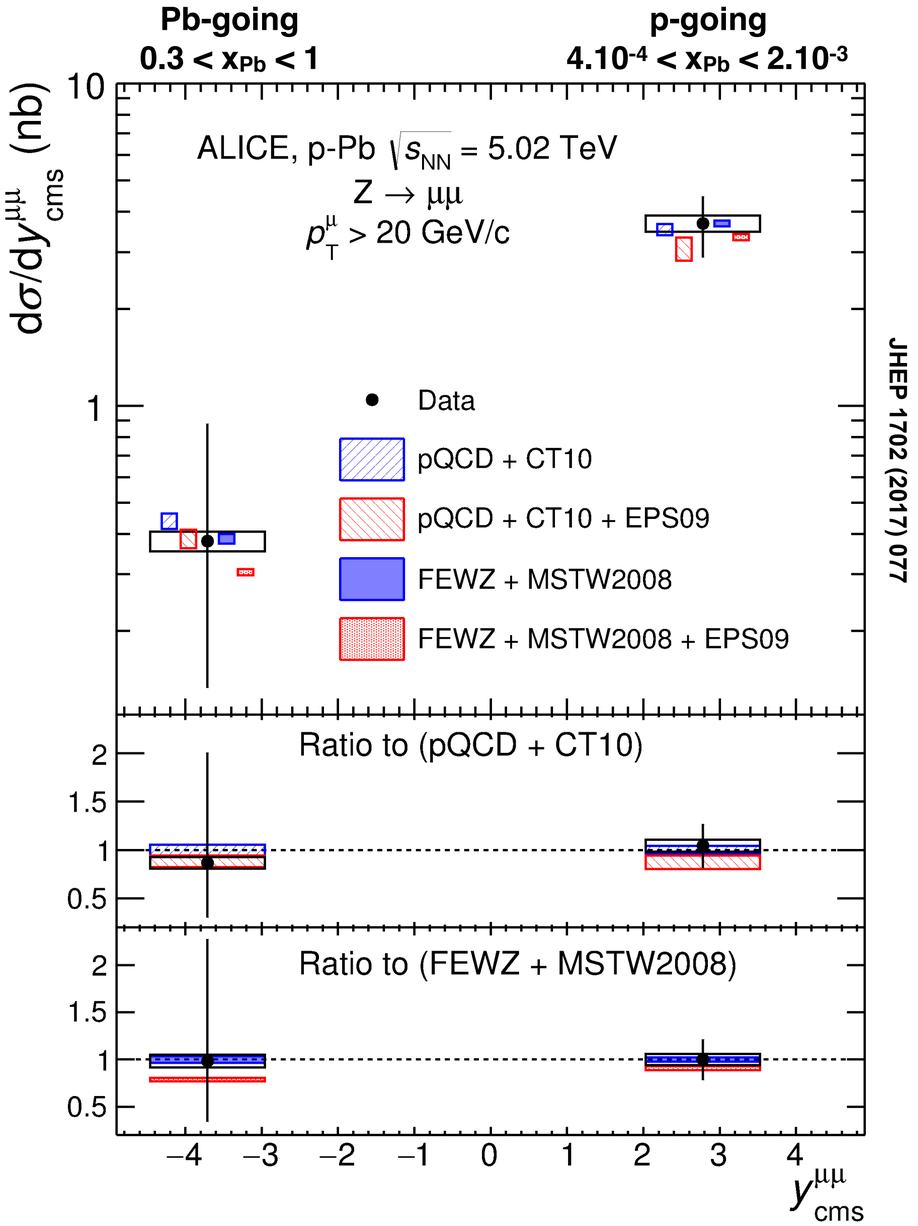
- **First Z-boson measurement in ALICE**

- Cross section compared to:
  - pQCD calculations (NLO) [using CT10 NLO as PDF]
  - FEWZ calculations (NNLO) [using MSTW2008NNLO as PDF]

- Results in agreement with calculations **with** and **without** including nPDFs (EPS09)

➡ The measurement is compatible with the different calculations. More precision is needed to constrain nPDFs



W-boson production in p-Pb collisions

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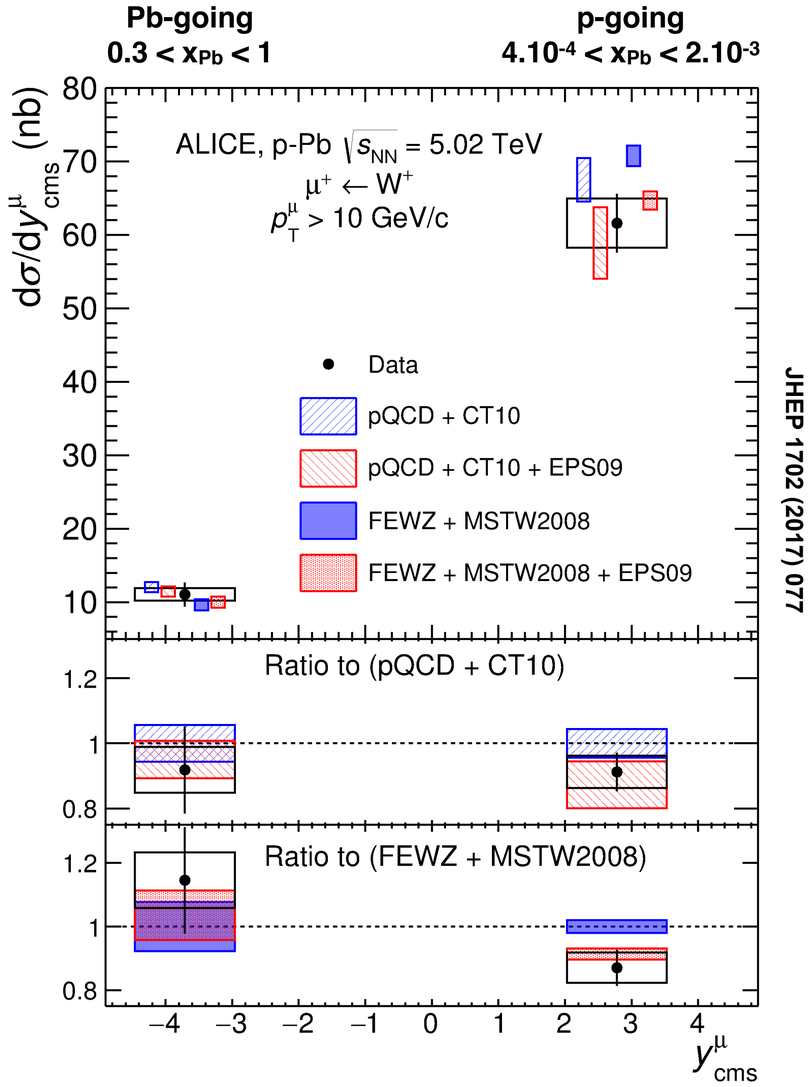

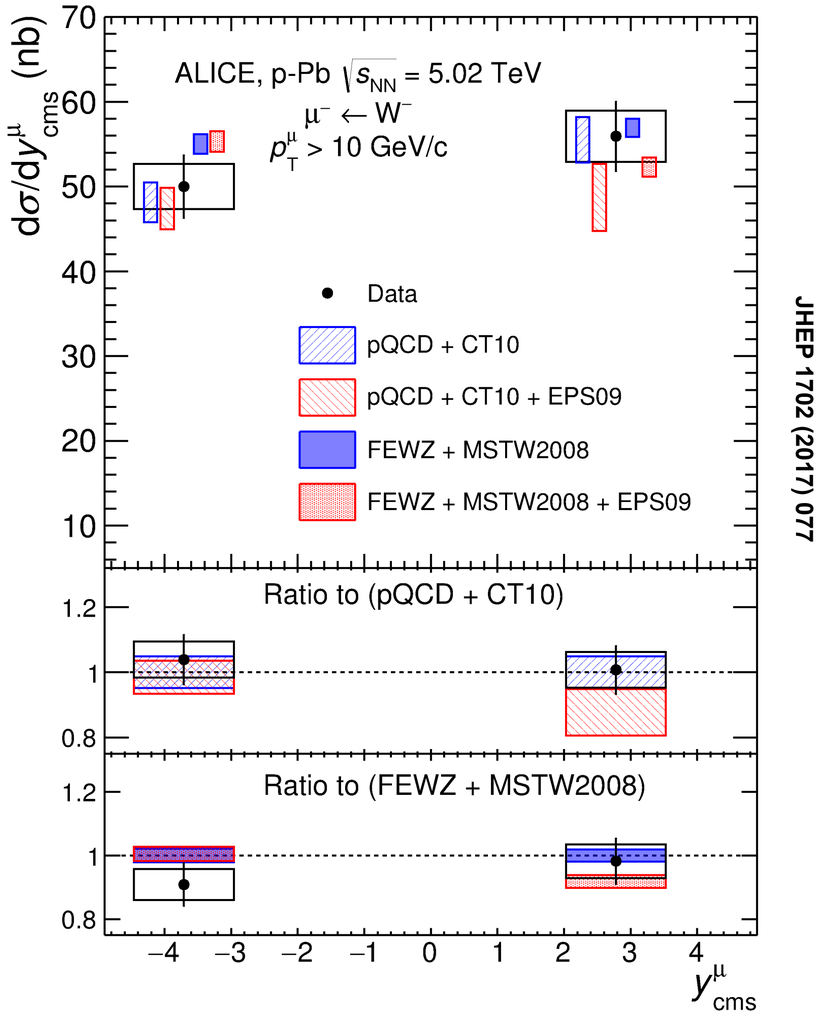

- Calculations with and without nPDF can reproduce the results
- As for the Z-boson results, more precision is needed to constrain nPDFs

W-boson production in p-Pb collisions

as a function of centrality

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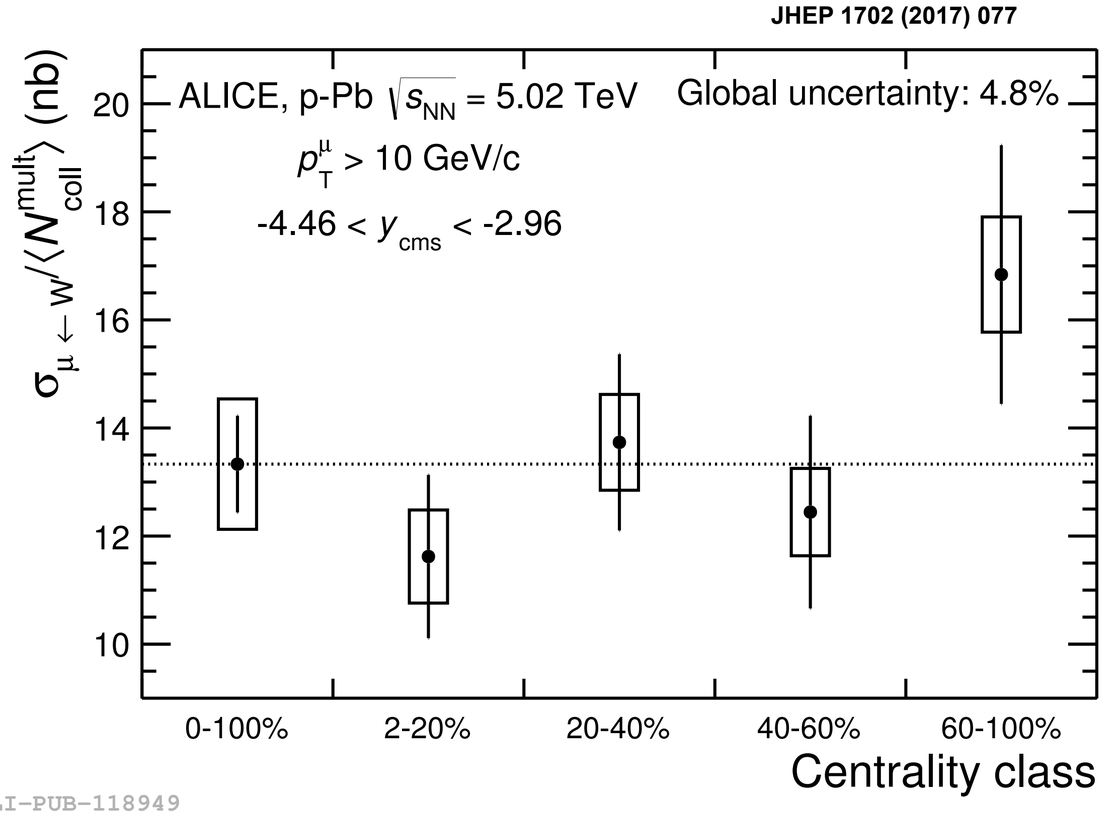
- For the centrality dependence, the contributions from W^+ and W^- are added



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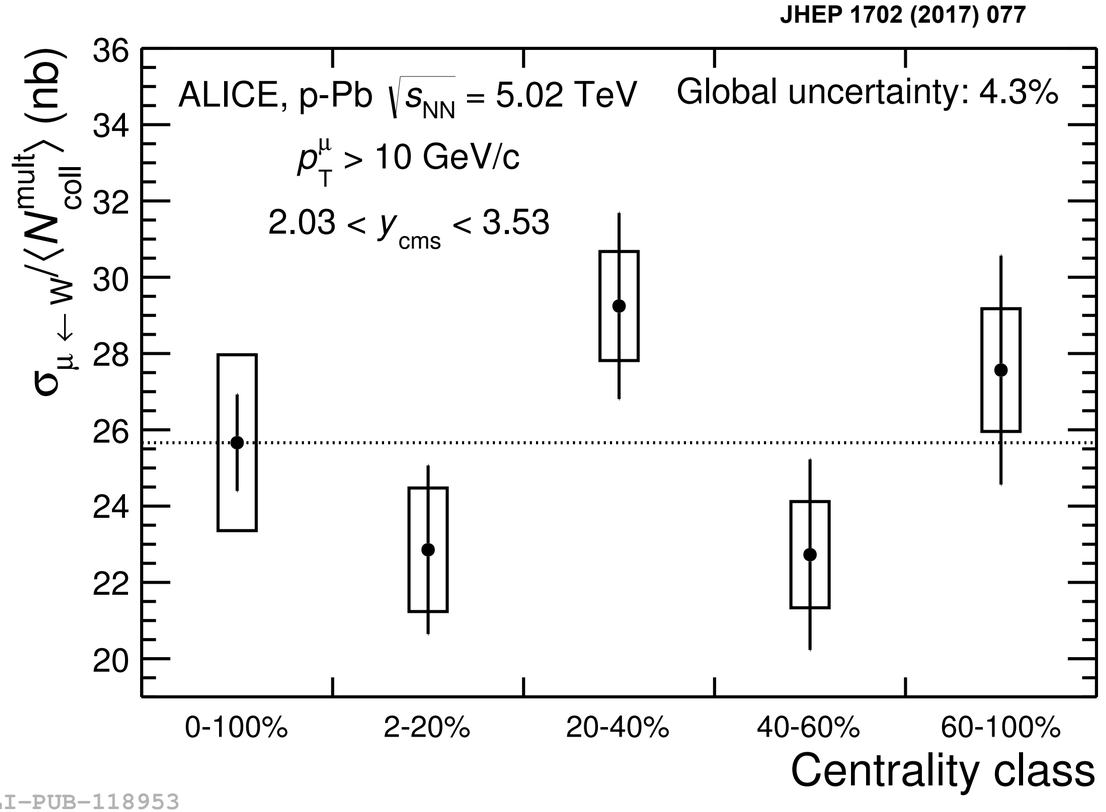

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- Within uncertainties, the centrality dependence of the W-boson production is compatible with a constant

Results: Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV

(Phys. Lett. B780 (2018) 372-383)

Z-boson production in Pb-Pb collisions I

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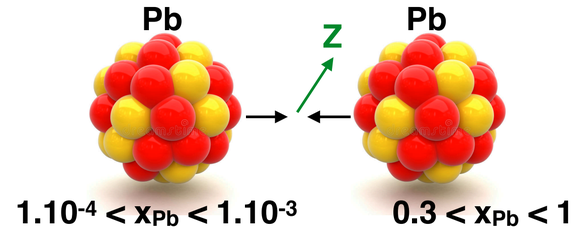
- Larger data sample than in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV



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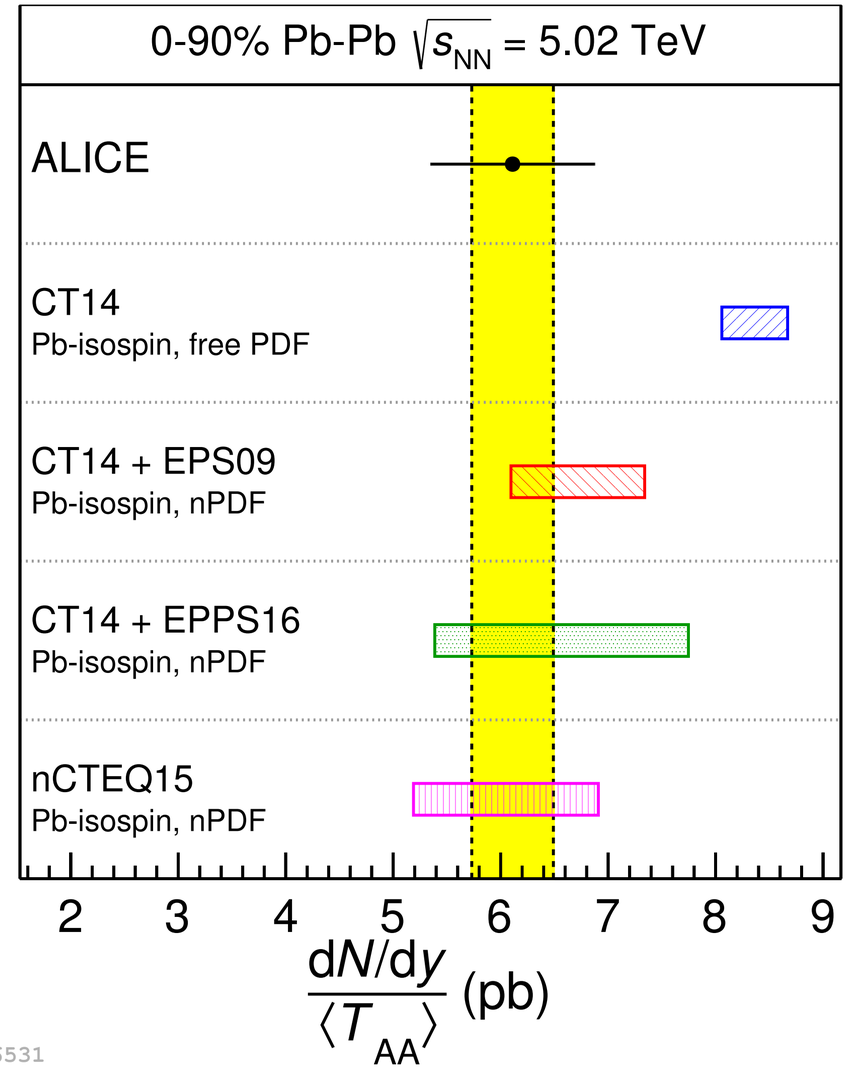

Systematic uncertainty

- Within uncertainties, the result is in agreement with the calculation using three different nPDFs

Z-boson production in Pb-Pb collisions I

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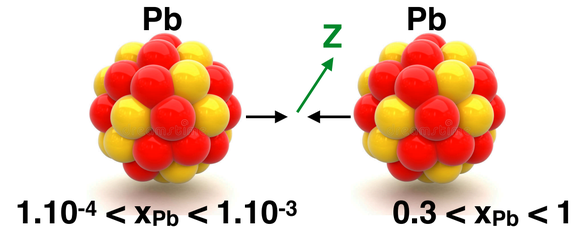
- Larger data sample than in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV



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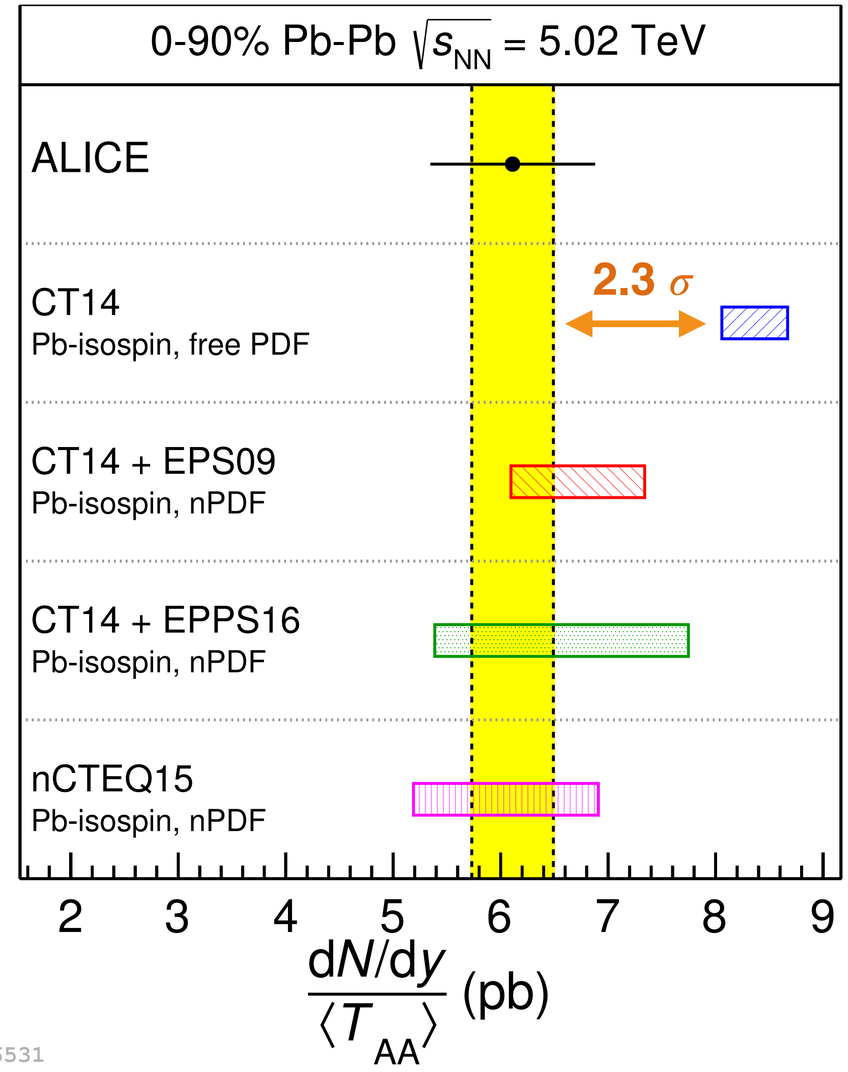

Systematic uncertainty

- Within uncertainties, the result is in agreement with the calculation using three different nPDFs
- 2.3 σ separation between the results and the calculations without including nPDF

Z-boson production in Pb-Pb collisions I

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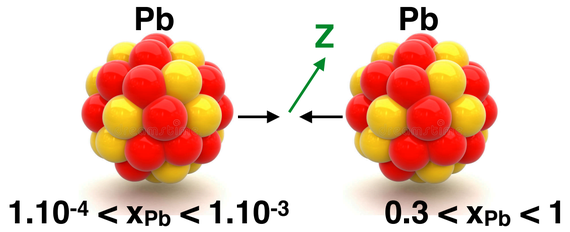
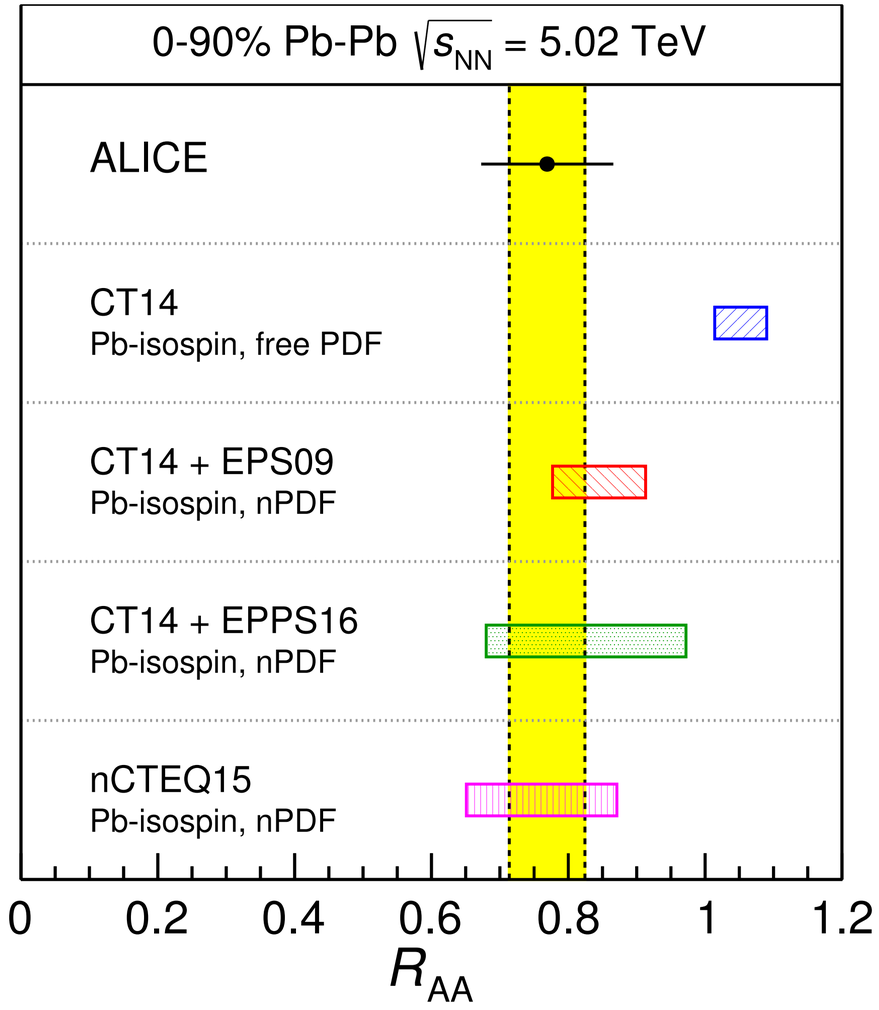
- Larger data sample than in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV



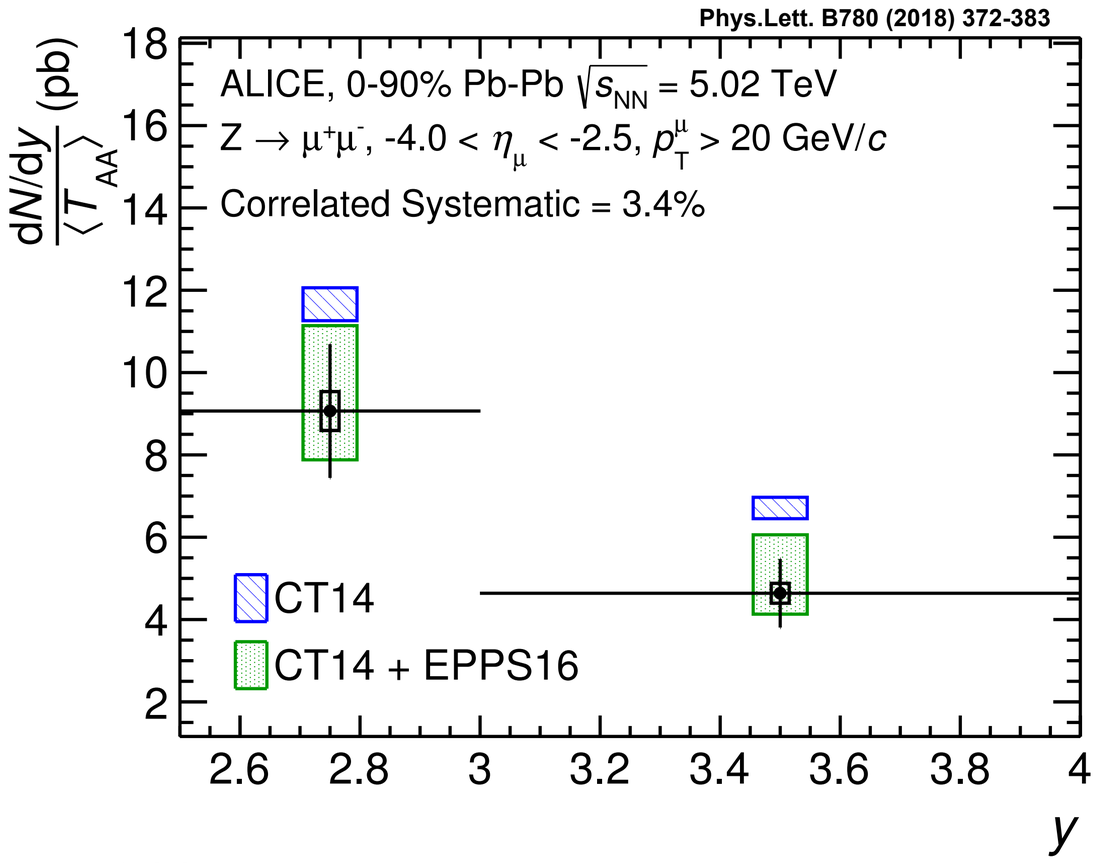


Systematic uncertainty

- Within uncertainties, the result is in agreement with the calculation using three different nPDFs
- 2.3 σ separation between the results and the calculations without including nPDF
- The R_{AA} is evaluated, dividing the normalised yield by CT14 pp cross section (σ_{pp} = 11.92 ± 0.43 pb)

Z-boson production in Pb-Pb collisions II

- The PDFs modification depends on the rapidity



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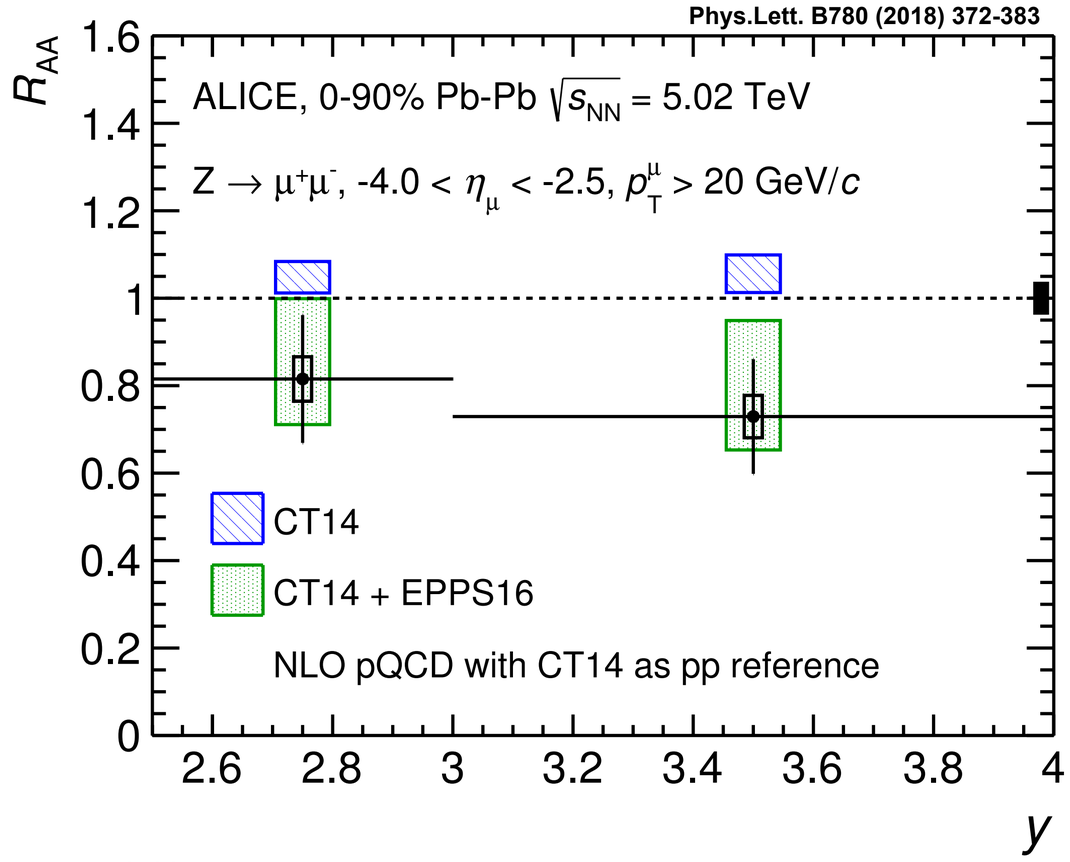

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- The results are in a better agreement with the calculation that includes PDFs modification

Z-boson production in Pb-Pb collisions III

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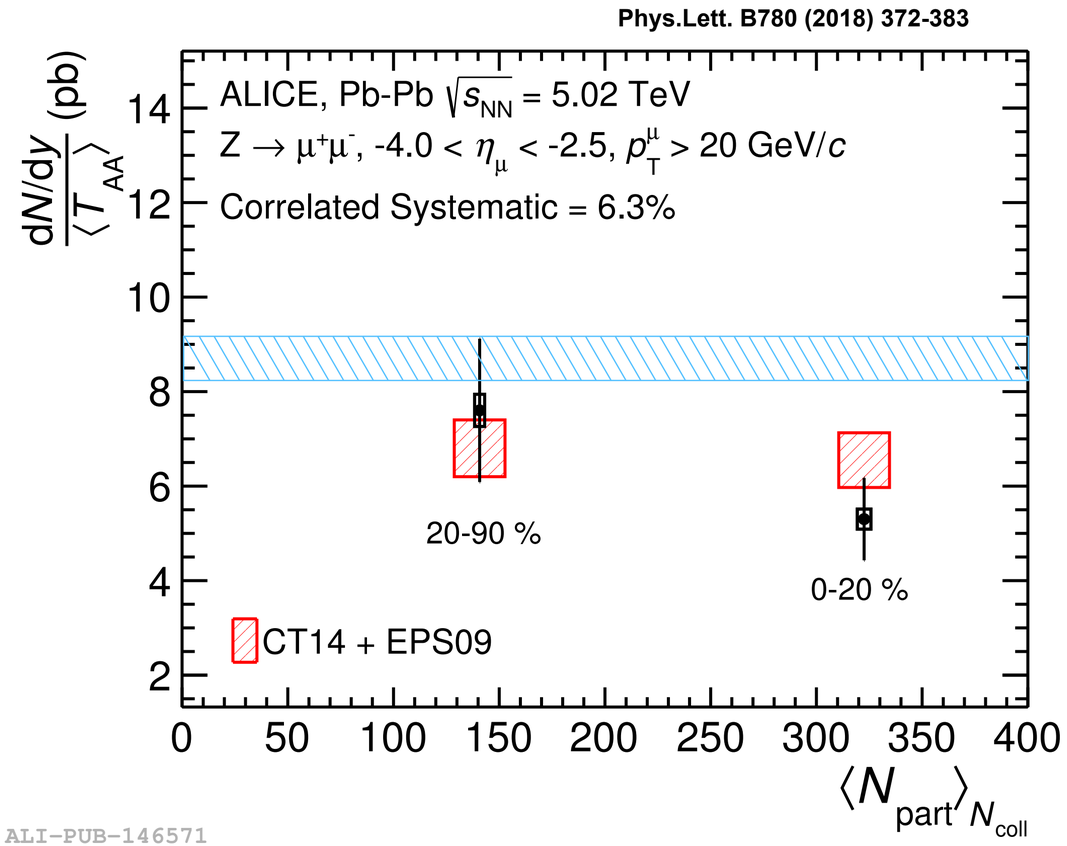
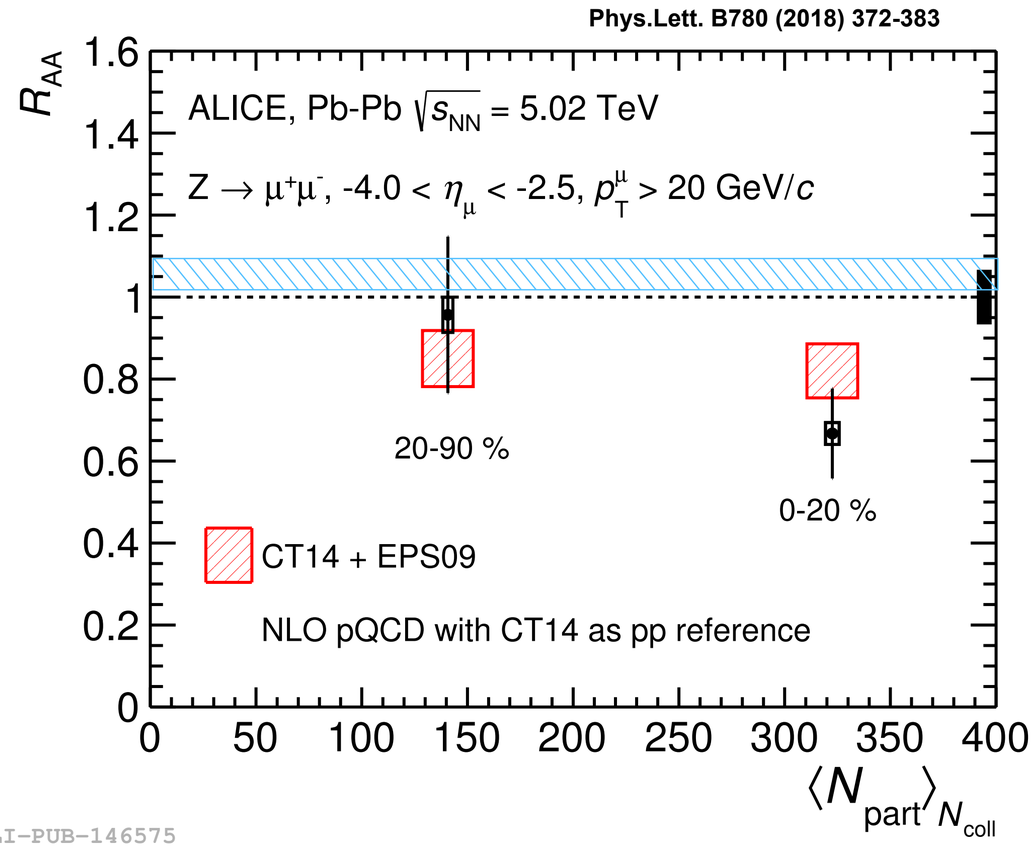
- The nPDF is expected to slightly depend on the centrality





- **Free PDFs prediction** overestimates the measurement by ~3 σ for 0-20% centrality
- The results are in agreement within uncertainties with calculations based on EPS09

Conclusions and perspectives

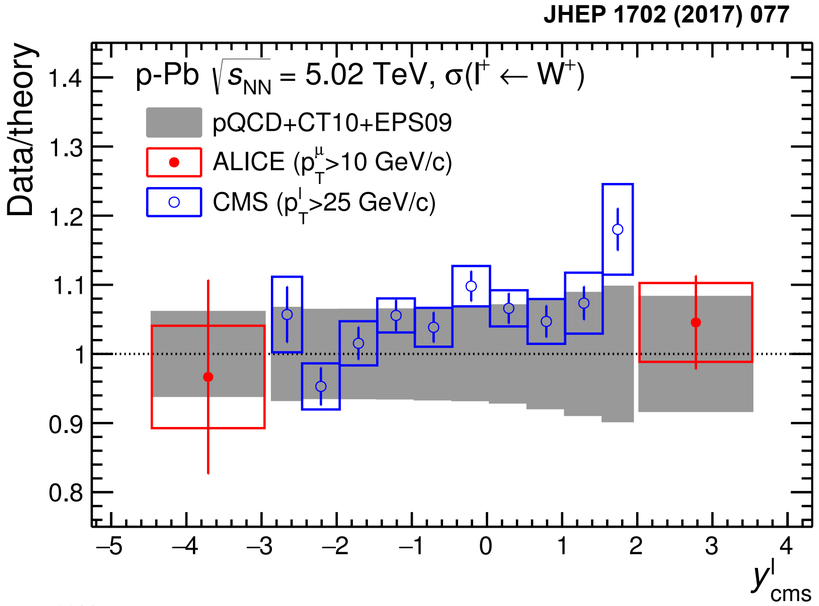
- **W/Z-boson production in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV**
  - Results can be described by theoretical calculations within uncertainties
  - Precision is not enough to conclude on the nPDFs
  - Analysis of the $\sqrt{s_{NN}}$ = 8.16 TeV data sample is ongoing: 4 (12) x more statistics expected in the p-going (Pb-going) direction
- **Z-boson production in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV**
  - Calculations with free PDFs overestimate the measurement by 2.3 σ (3 σ for the 20% most central collisions)
  - Larger Pb-Pb data sample is expected later in 2018
- **Analysis is ongoing to measure the W-boson production in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV**
- **Results can be included in nPDF global fits**

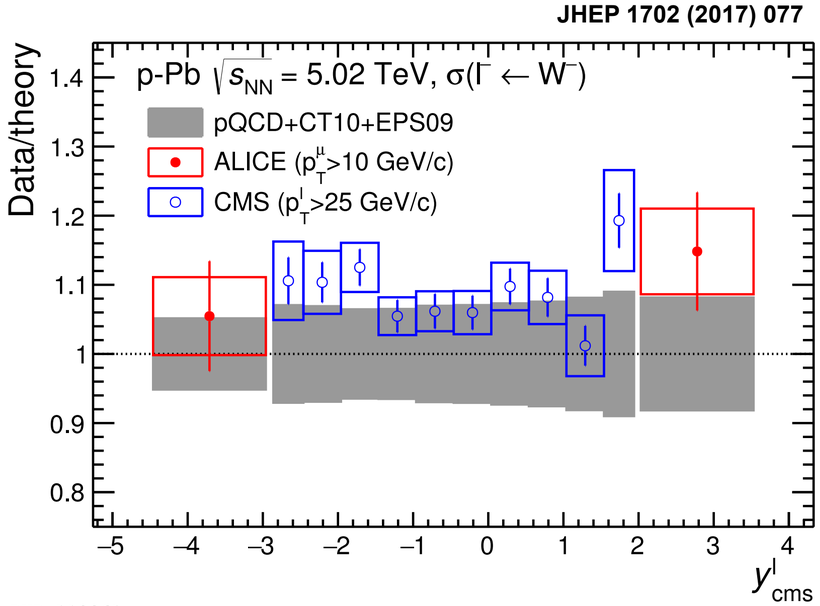
Extra slides

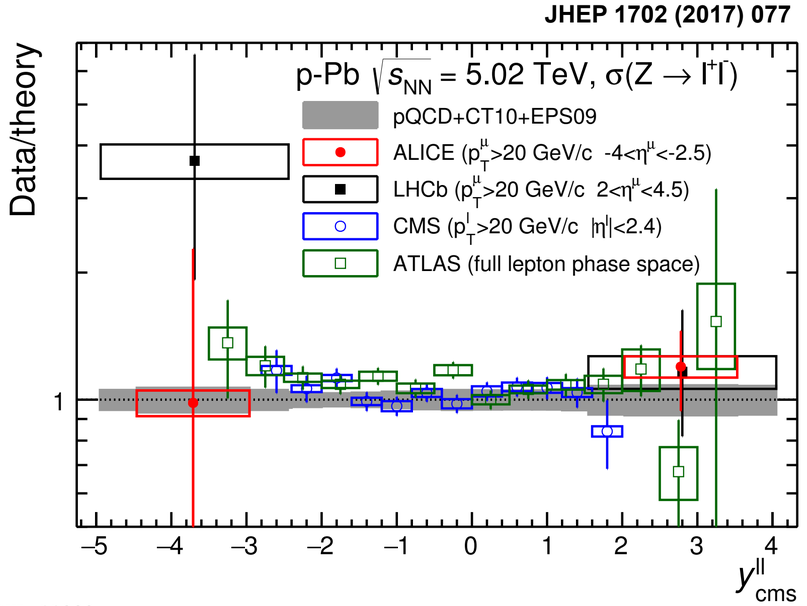
W/Z-boson production in p-Pb collisions

comparison to other LHC results

- Results not directly comparable (different kinematic cuts) ➜ compare the ratio data over the corresponding pQCD predictions



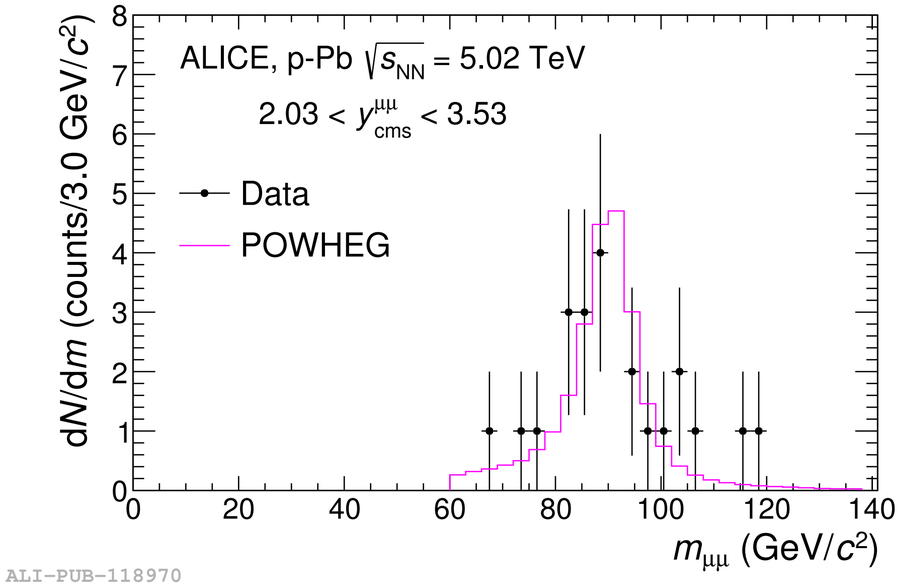




- Calculations including EPS09 PDFs modification can describe data within uncertainties over the full rapidity interval

Dimuon invariant mass distributions

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



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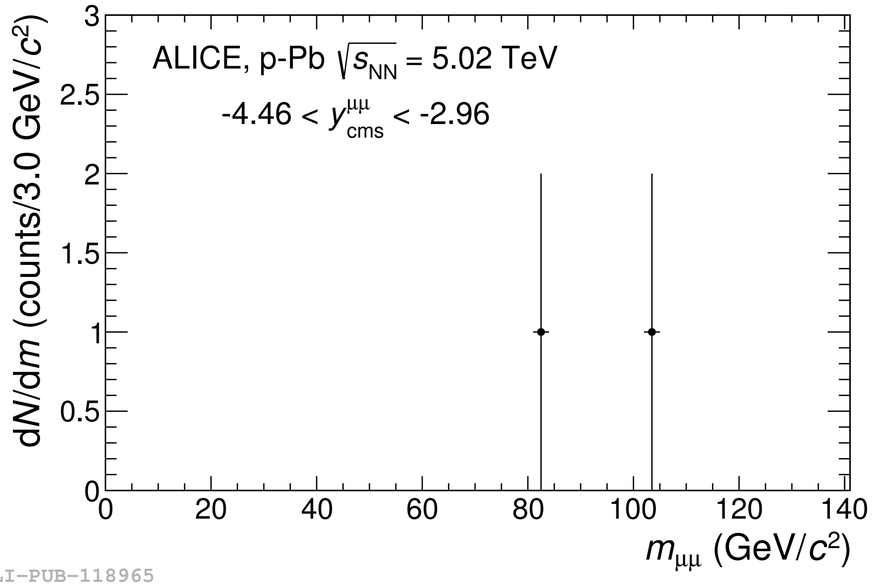

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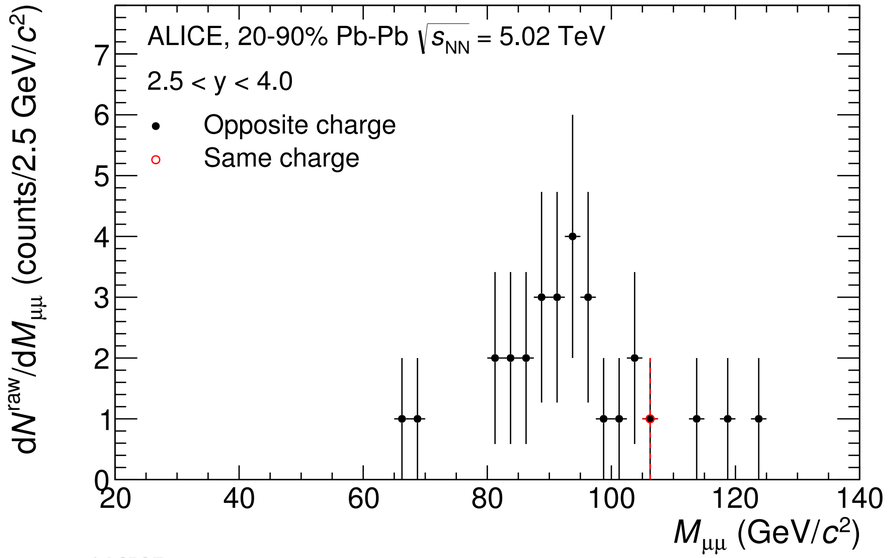
Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV



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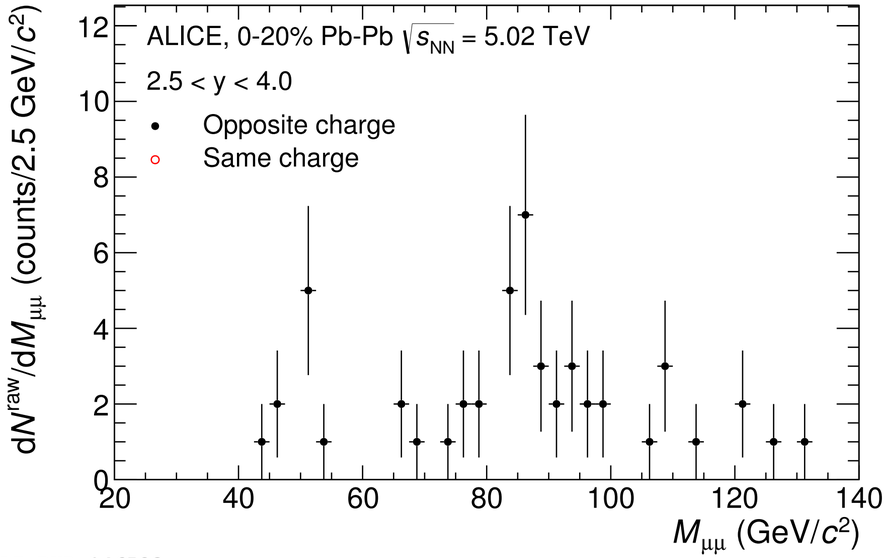

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nPDF sets

nPDF set	EPPS16	EPS09	DSSZ12	nCTEQ15
Order	NLO	NLO	NLO	NLO
Flavour separation	Full	none	none	partial
Baseline PDFs	CT14	CTEQ6	MSTW2008	
# Free parameters	20	15	25	17
# data points	1811	929	1579	708
	Included experimental data			
Neutral current DIS				
DY lepton in pA				
RHIC pions in d-Au				
neutrino nucleus DIS				
LHC p-Pb jets				
LHC p-Pb W,Z				