Electroweak Bosons production in Heavy-Ion Collisions with ALICE

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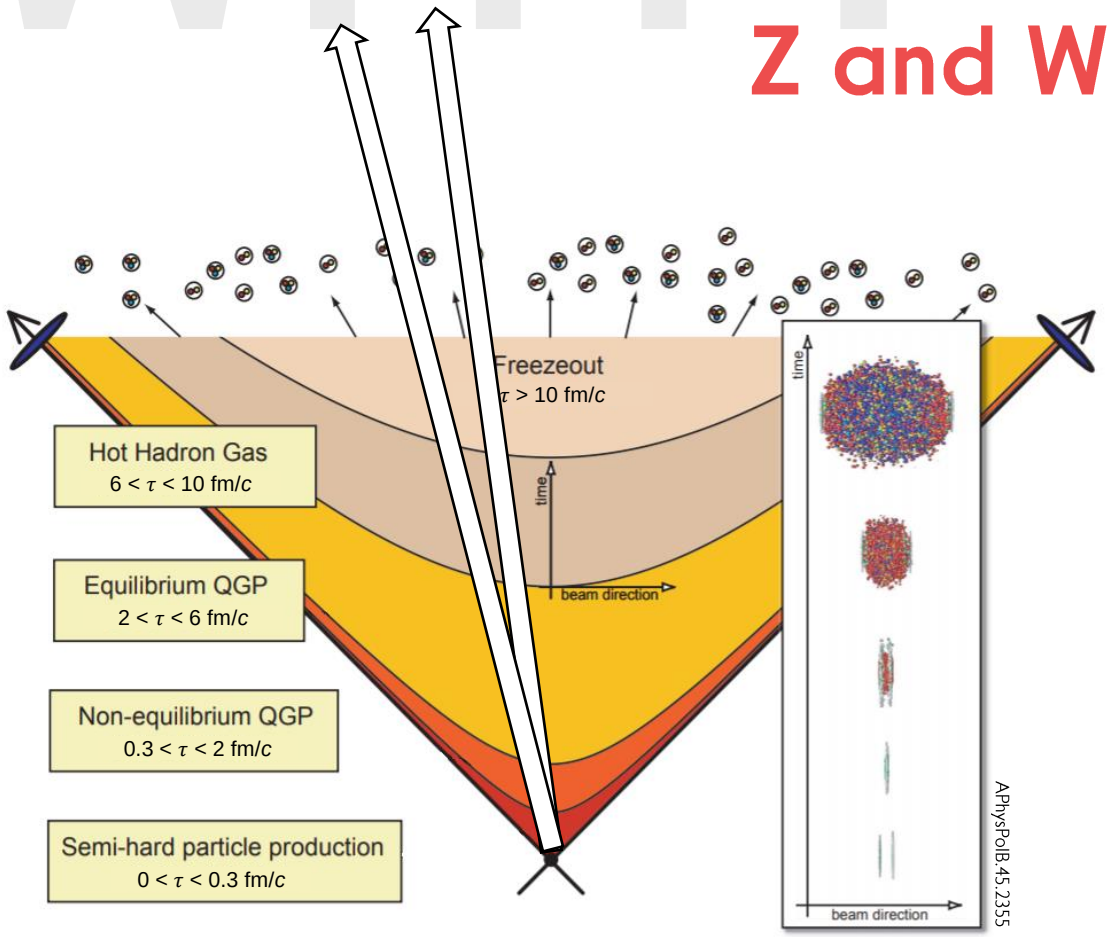
WHY?

Z and W bosons



- ✓ Well described by pQCD and EW theory
- ✓ Produced during initial stages of the collision
- ✓ Insensitive to the presence of strongly interacting medium / quark-gluon plasma

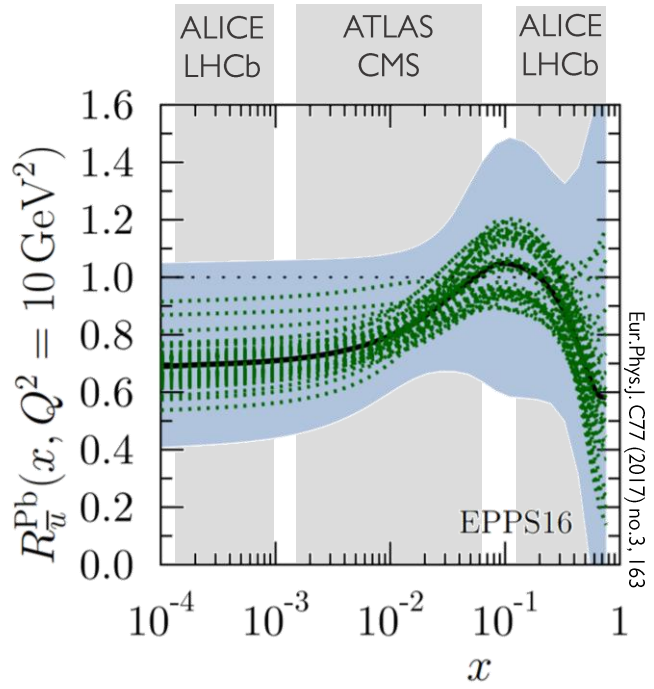
Clean probes of the nuclear modification to the Parton Distribution Functions

EW bosons production. Hard process, quark-antiquark annihilation.
At leading order:

$$\sigma_{AB} \propto \sum_q \frac{4\pi e_q^2 \alpha^2}{9s} f_q^A(x_1, Q^2)\, f_{\bar{q}}^B(x_2, Q^2)$$

Nuclear PDF (nPDF). $f_q^{\boldsymbol{A}}(x, Q^2) \neq \boldsymbol{A}\, f_q(x, Q^2)$

Goal Help constraining the nPDFs by adding data for their global fits



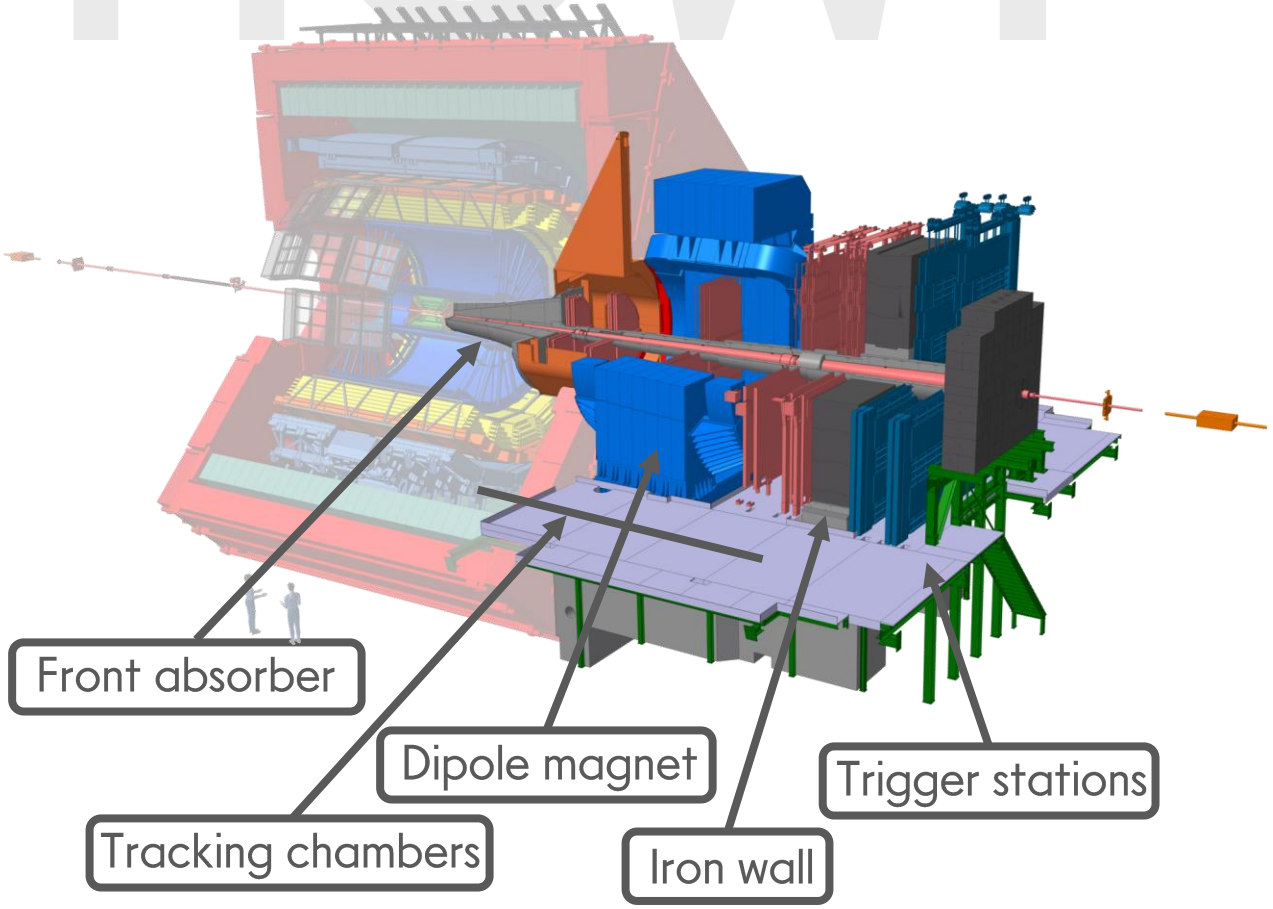
	EPS09 nlo	nCTEQ15 nlo	EPPS16 nlo
Flavour separation		Valence quarks	Valence + sea
Free parameters	15	35	52
Data points	929	708	1811
DIS in l+A	✔	✔	✔
Drell-Yan in p+A	✔	✔	✔
RHIC pions d+Au	✔	✔	✔
ν-nucleus DIS			✔
Drell-Yan in π+A		23 data points (ATLAS, CMS)	✔
LHC p–Pb dijets			✔
LHC p–Pb W and Z			✔

PoS (HardProbes2018) 014

+ Other groups working on nPDFs (NNPDF)

HOW?

Z and W reconstructed in their **muonic decay** channels



Rapidity coverage. $2.5 < y < 4$ in the laboratory frame

Shifted in the cms by $\Delta y = \pm 0.46$ when proton and lead nucleus collide

Probing regions at low $(10^{-4} - 10^{-3})$ and high $(10^{-1} - 1)$ Bjorken-x, where the nPDFs are less constrained

Z signal extraction

Opposite-sign muon pairs in the fiducial region:

$$2.5 < |\eta_\mu| < 4$$

$$p_{\mathrm{T},\mu} > 20\ \mathrm{GeV}/c$$

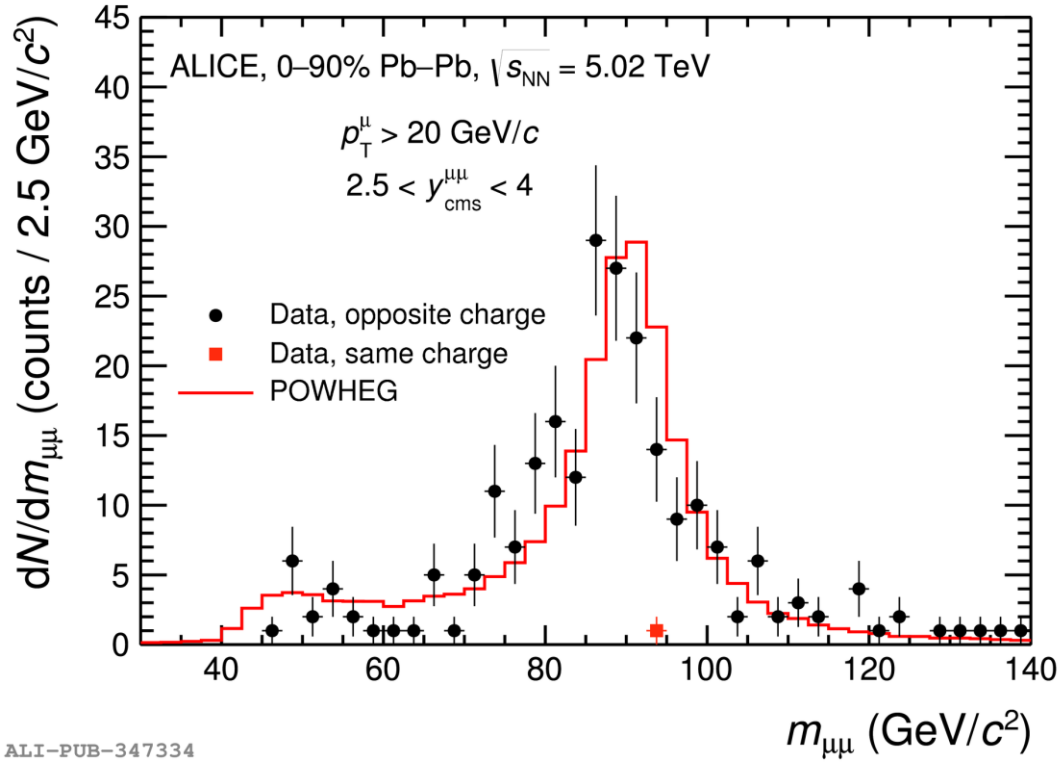
$$60 < m_{\mu\mu} < 120\ \mathrm{GeV}/c^2$$

Background from heavy-flavor, top quark and $Z \to \tau\tau \to \mu\mu$: lower than ~1.5%

Combinatorial background (almost) negligible

→ signal extracted by bin counting ←

Raw yield corrected for efficiency (POWHEG + Pythia, + embedding in Pb–Pb)



POWHEG: JHEP 07(2008)060

W signal extraction

→ signal extracted by fitting single muon p_{T} distribution ←

$$f(p_{\mathrm{T}}) = N_{HF}\, f_{HF}(p_{\mathrm{T}}) + N_{\mu\leftarrow W}\left[f_{\mu\leftarrow W}(p_{\mathrm{T}}) + R\, f_{\mu\leftarrow Z}(p_{\mathrm{T}})\right]$$

Fitted parameters

MC templates (FONLL, POWHEG)

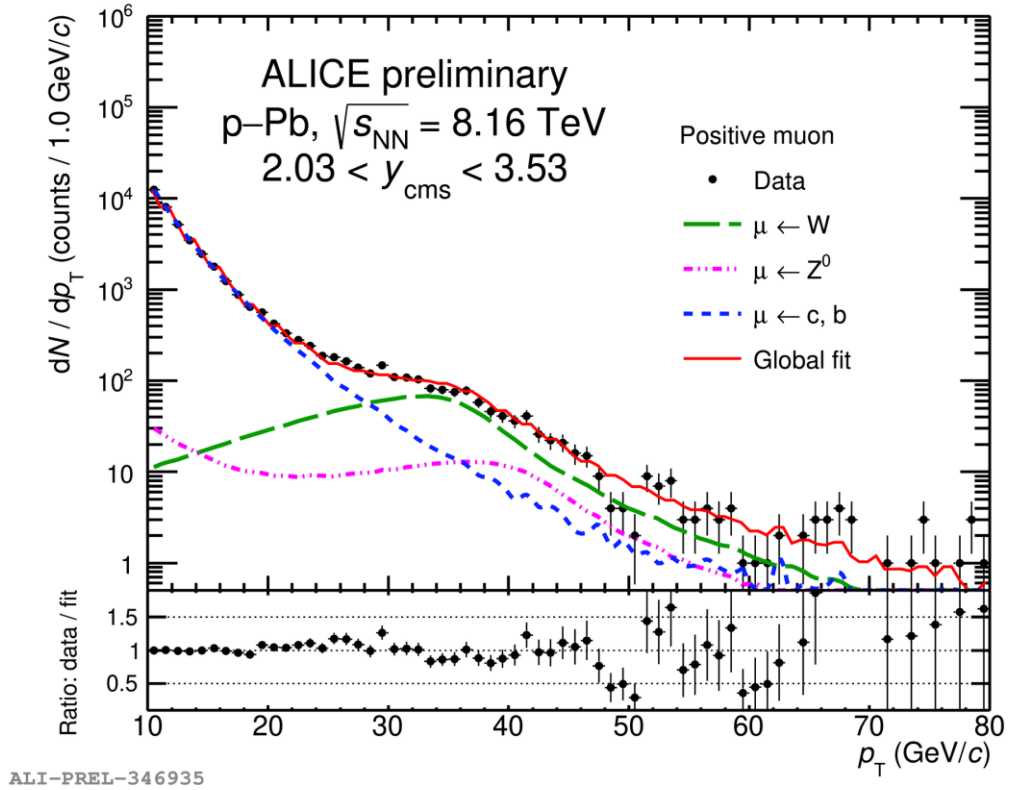
Fixed, from POWHEG

Fiducial region:

$2.5 < |\eta_{\mu}| < 4$

$p_{\mathrm{T},\mu} > 10\ \mathrm{GeV}/c$

Raw yield corrected for efficiency (POWHEG + Pythia, + embedding in Pb–Pb)

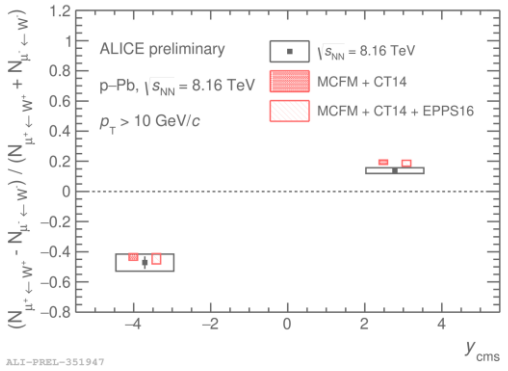


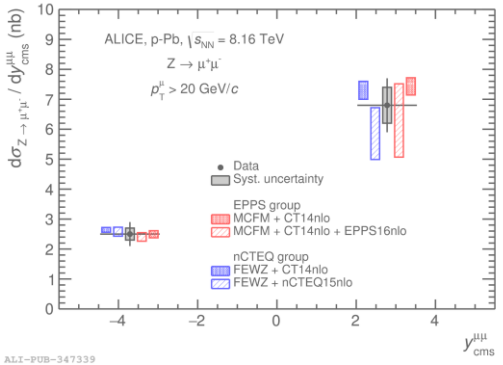
FONLL: JHEP 10 (2012) 137 POWHEG: JHEP 07(2008)060

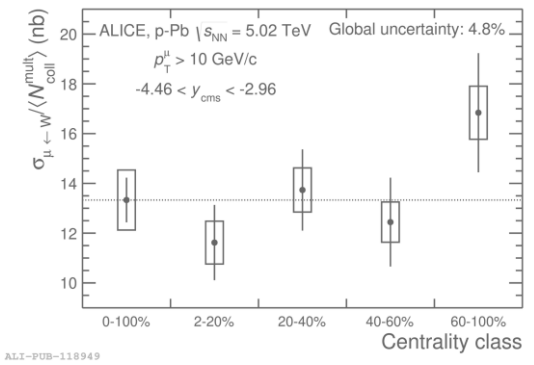
LHC Run2, ALICE measurements

System , $\sqrt{s_{NN}}$ luminosity	Z bsoson	W boson
Pb–Pb, 5.02 TeV ~ 750 μb^{-1}	Phys.Lett.B 780 (2018) 372 * arXiv:2005.11126[nucl-ex] NEW	NEW *
p–Pb, 5.02 TeV ~ 10.8 nb^{-1}	JHEP 02 (2017) 077	JHEP 02 (2017) 077
p–Pb, 8.16 TeV ~ 21.2 nb^{-1}	NEW arXiv:2005.11126[nucl-ex]	NEW

* Not full statistics ($L_{\mathrm{int}} \sim 225$ μb^{-1})



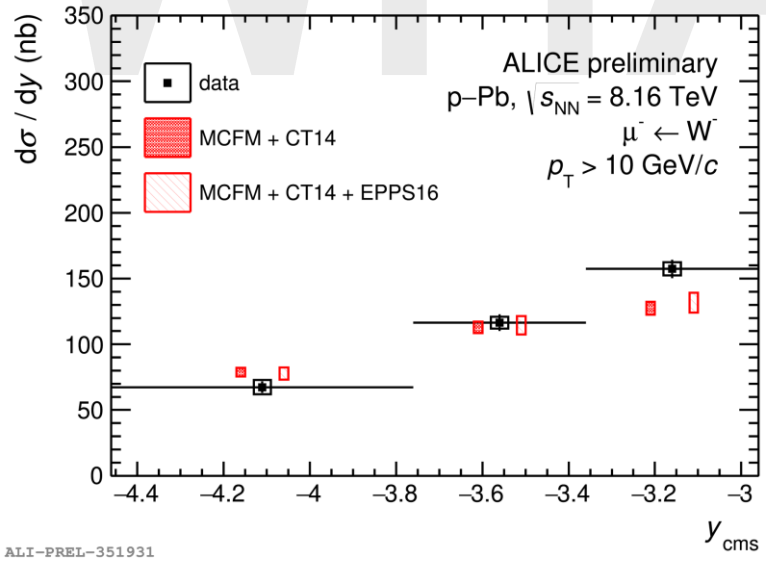


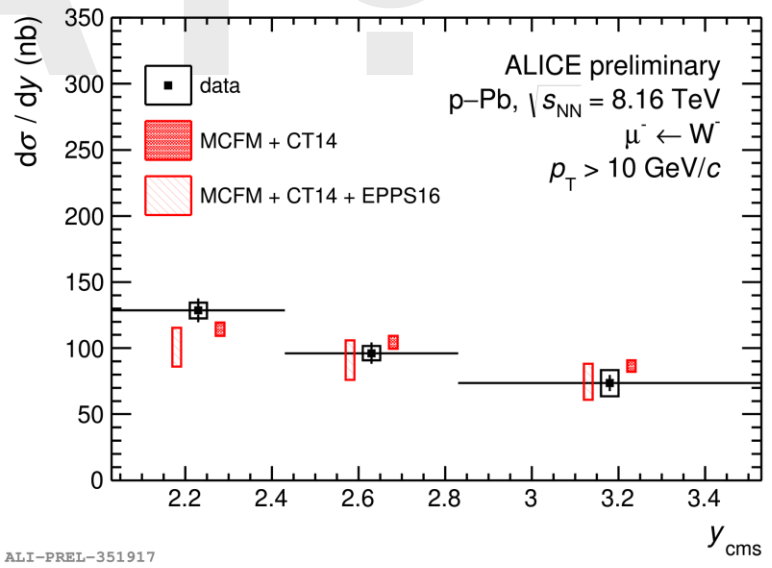


Differential results for production yield, cross sections, nuclear modification factor, lepton charge asymmetry...

W± in p–Pb at 8.16 TeV

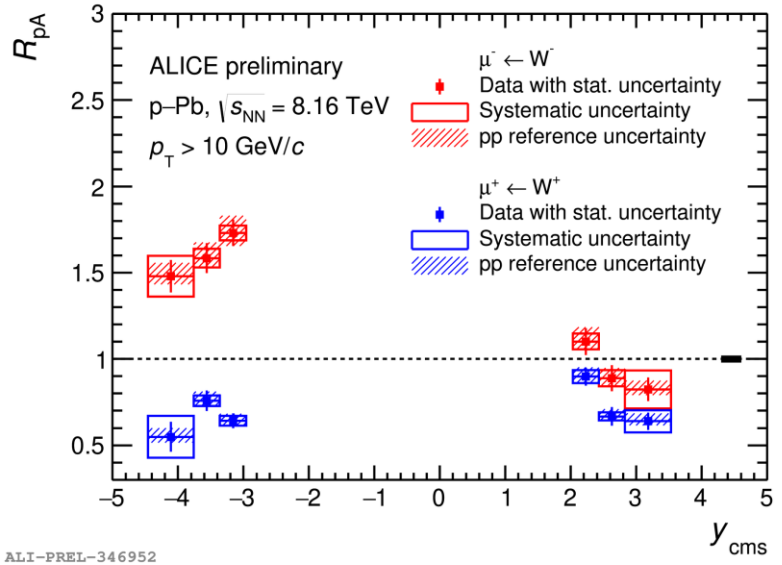
First measurement of W at 8 TeV at large rapidities





$$R_{\mathrm{pA}} = \frac{1}{208}\,\frac{\sigma_{\mathrm{pA}}}{\sigma_{\mathrm{pp}}}$$

σ_{pp} from POWHEG with CT10nlo PDF



Comparison with pQCD calculations with (CT14+EPPS16) and without (CT14) nuclear modification

↓

Tension especially with free PDF predictions (up to 2.8 σ)

CT14: Phys. Rev. D 93 (2016) 033006 EPPS16: EPJC (2017) 77:163

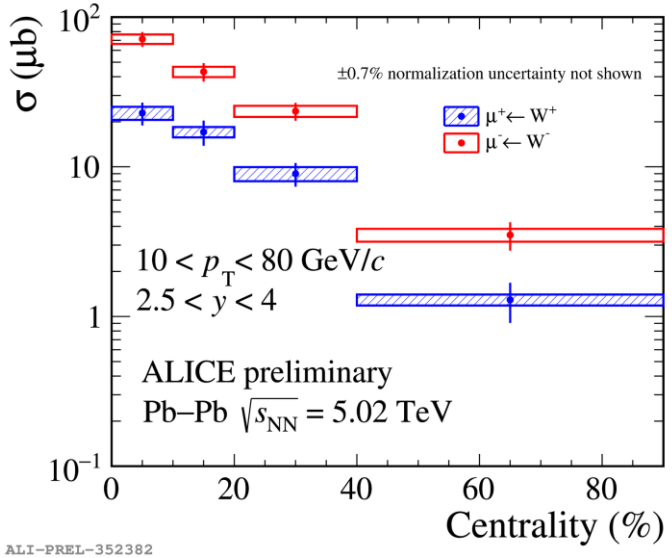
Pb–Pb collisions

$$\text{Normalized yield} = \frac{N_{\mathrm{Z/W}}}{\langle T_{\mathrm{AA}} \rangle \, N_{\mathrm{evt}}} \qquad R_{\mathrm{AA}} = \frac{N_{\mathrm{Z/W}}}{\langle T_{\mathrm{AA}} \rangle \, N_{\mathrm{evt}} \, \sigma_{\mathrm{pp}}}$$

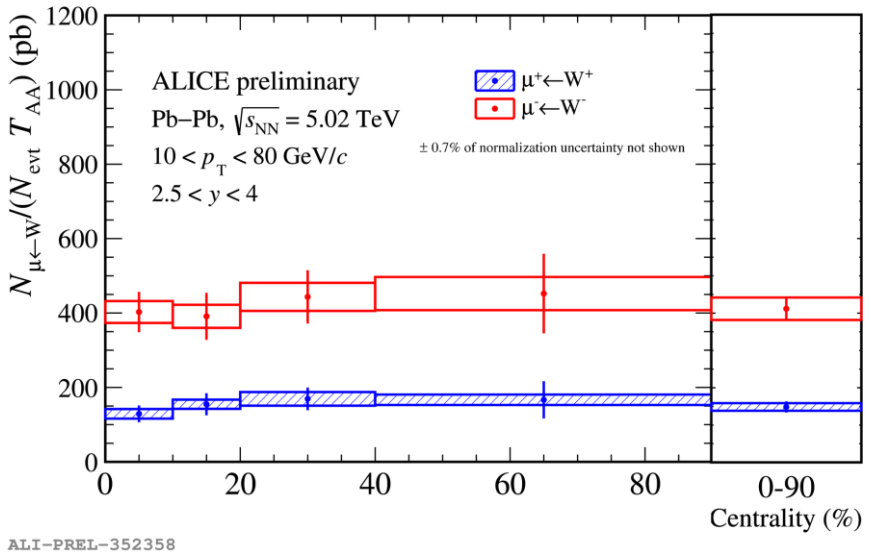
σ_{pp} from pQCD calculations

W± in Pb–Pb at 5.02 TeV

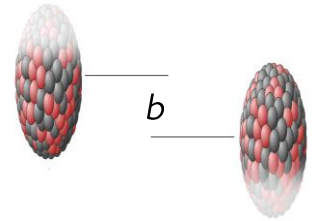
First measurement of W in Pb–Pb at large rapidities



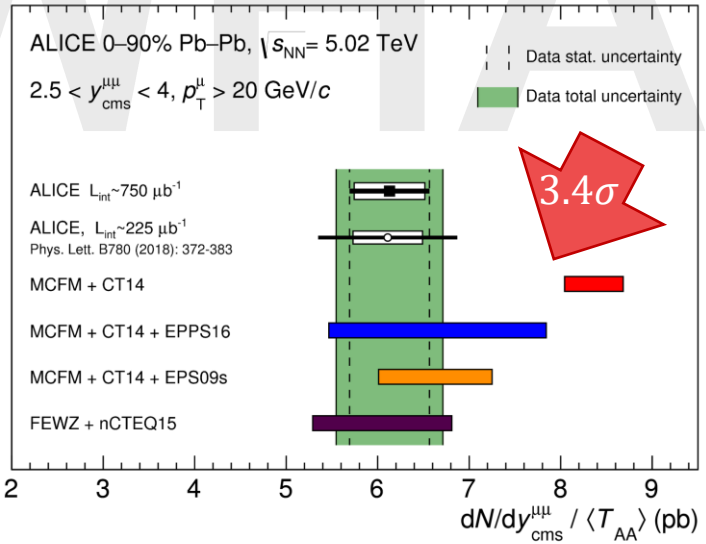
Isospin differentiates W^+ and W^- production



Expected scaling of the yield with the nuclear overlap function T_{AA}



Z in Pb–Pb at 5.02 TeV

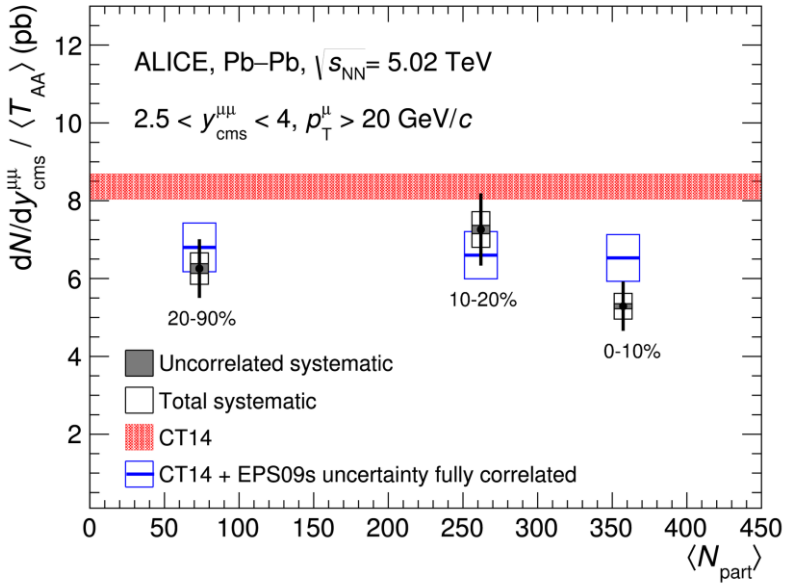


free PDF

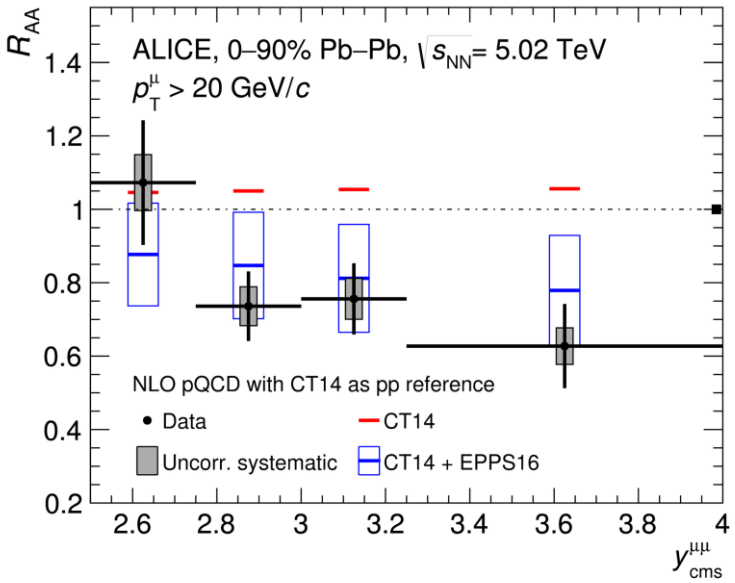
nuclear PDF

Strongest evidence of nuclear modifications with gauge bosons measured with ALICE

ALI-PUB-347344



ALI-PUB-347359



ALI-PUB-347354

Larger deviation from free PDFs for the most central events and the largest rapidities

The measurements at large rapidities provide data in a kinematic region where the nPDFs are less constrained.

The results are better described by calculations including nuclear modification of the PDFs. Large significance of nuclear modification has been measured in Pb–Pb collisions.

Sizable amount of new data points providing extra inputs for nPDFs global fits