Early Estimates of the Impact of W/Z pPb and PbPb LHC Data on nCTEQ15 PDFs

Eric Godat

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Outline

- Introduction to nCTEQ

- W/Z Production at LHC

- Estimating Impact on nCTEQ15 PDFs

- Outlook

Introduction to nCTEQ

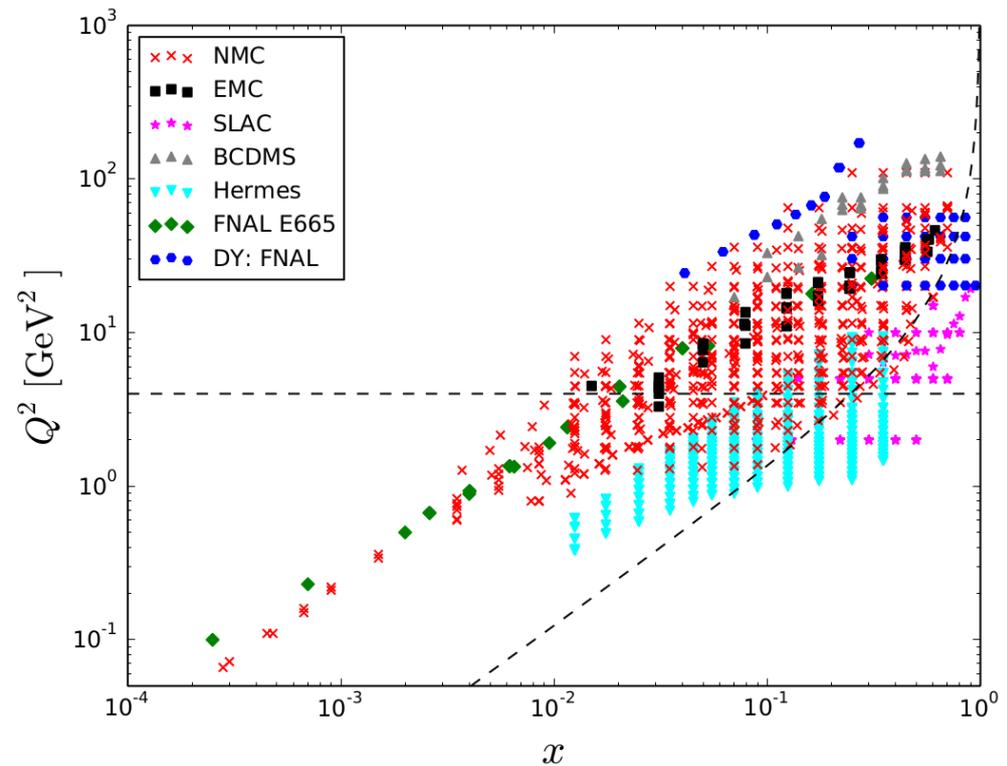# nCTEQ PDFs

Global fit to experimental data

- Deep Inelastic Scattering

- Drell-Yan

- Pion Production Data

  NO LHC data

740 nuclear data points after kinematic cuts

Error analysis with Hessian Method

- 16 Eigenvalues

nCTEQ PDFs

Formalism:

- ## Generalized A-Parameterization

  - $$xf_i^{p/A}(x, Q^2) = c_0 x^{c_1}(1-x)^{c_2} e^{c_3 x}(1 + e^{c_4 x})^{c_5}$$

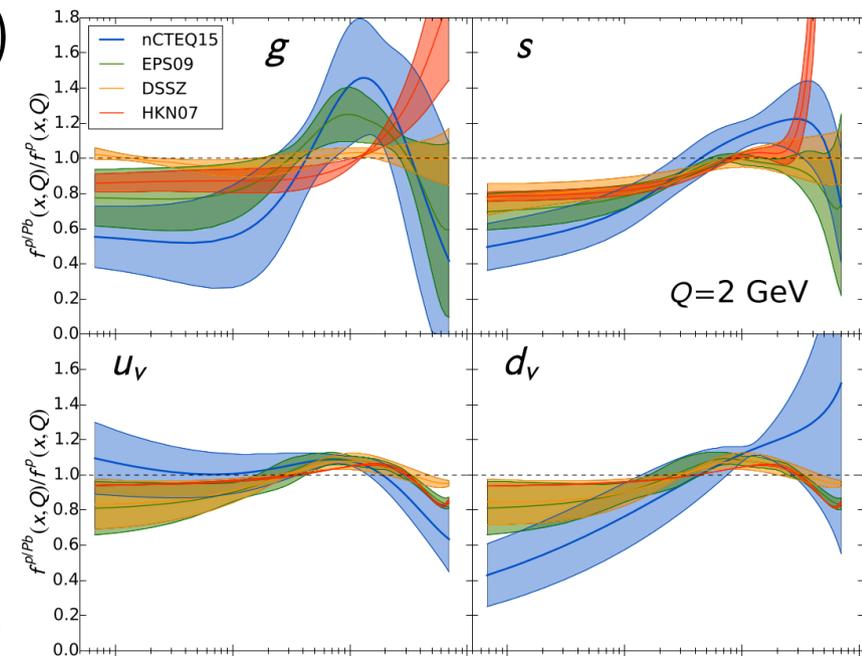 - $$c_k \rightarrow c_{k,0} + c_{k,1}(1 - A^{-c_{k,2}})$$

    No multiplicative nuclear correction

- ## More parameters than proton fits

    ~ 3 times as many so we make
    assumptions

- ## Fewer data points

    e.g 740 nuclear points for nCTEQ15 vs
    2947 protons points for CT14[1]

[1]Ref: Dulat et Al. arXiv:1506.07443

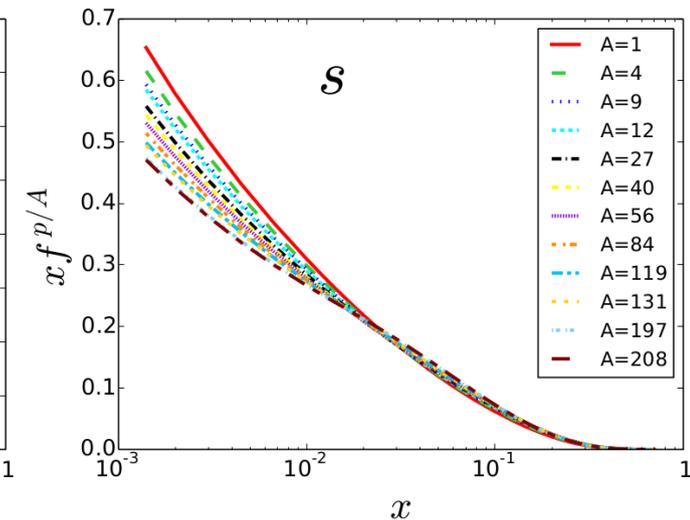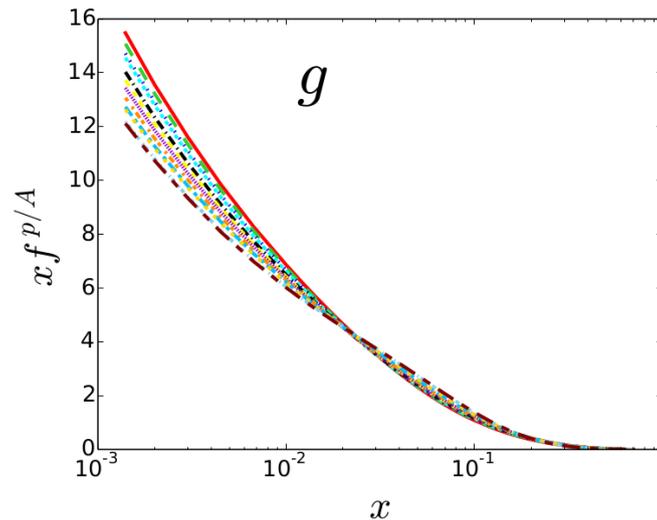Eric Godat - SMU

nCTEQ PDFs

Nuclei with DIS data included in nCTEQ15

$$f^N = \frac{Z}{A} f^{p/N} + \frac{A-Z}{A} f^{n/N}$$

Assume isospin symmetry

Currently at NLO

Parameterization allows for construction of any nuclei

W/Z Production at LHC

LHC Data for nCTEQ

$$\sqrt{s_{pp}} = 7\ TeV \to \sqrt{s_{PbPb}} = 2.76\ TeV$$

$$\sqrt{s_{pp}} = 8\ TeV \to \sqrt{s_{pPb}} = 5.02\ TeV$$
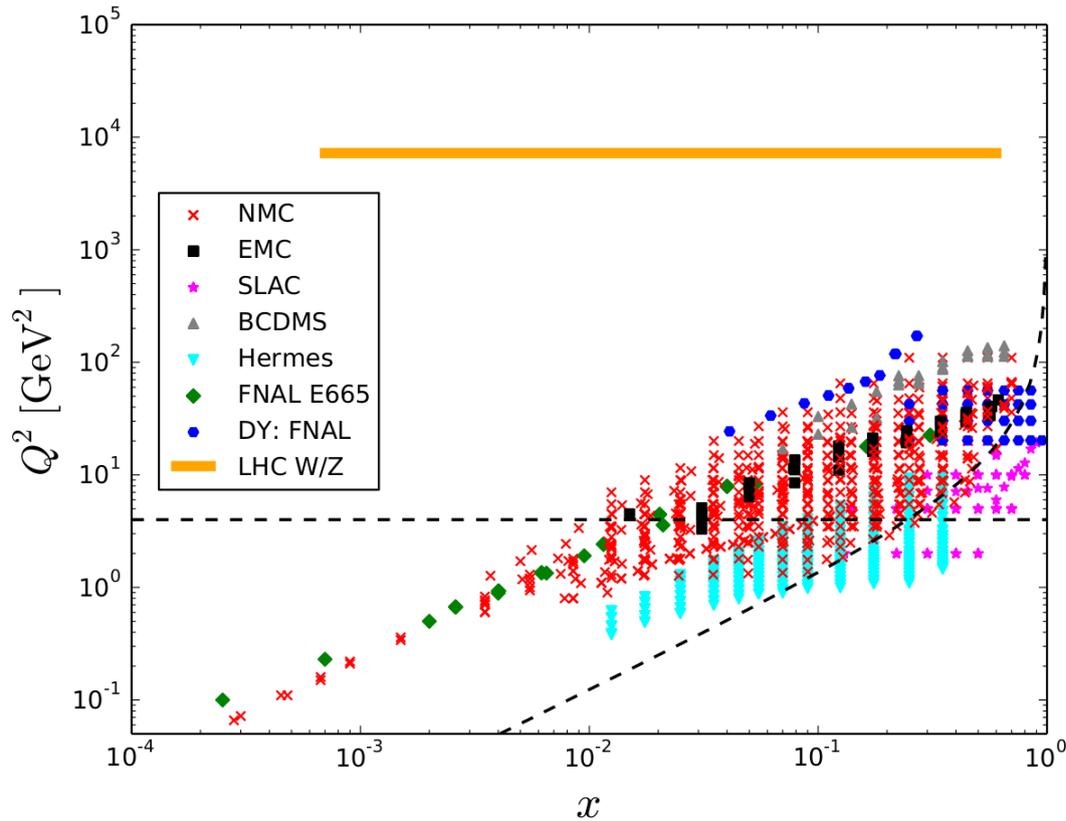
pPb and PbPb collisions

- LHCb: $\sigma(Z \to \ell^+ \ell^-)$

- ALICE: $\sigma(W^\pm \to \ell^\pm \nu)$

- ATLAS: $d\sigma(W^\pm \to \ell^\pm \nu)/dy$
  $d\sigma(Z \to \ell^+ \ell^-)/dy$
  A_ℓ

- CMS: $d\sigma(W^\pm \to \ell^\pm \nu)/dy$
  $d\sigma(Z \to \ell^+ \ell^-)/dy$
  A_ℓ
  A_{FB}

nCTEQ PDFs at the LHC

Smaller x range corresponds to larger rapidities

x_2 covered by LHC W/Z Data

x_2 Covered by Existing DIS Data
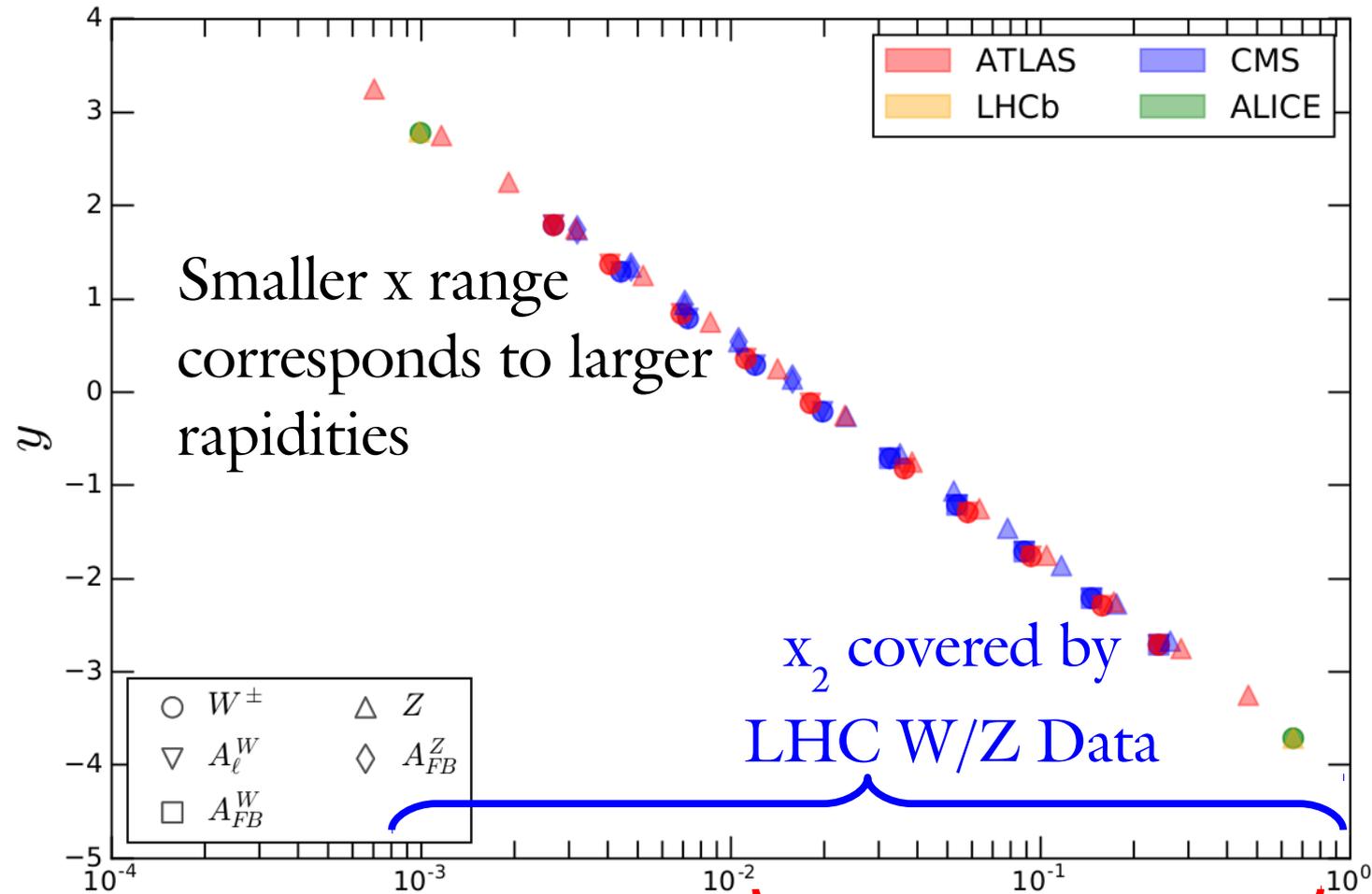
x_2 is the Lead PDF

W/Z Production

CMS PbPb Z

ATLAS PbPb Z

All predictions shown at NLO
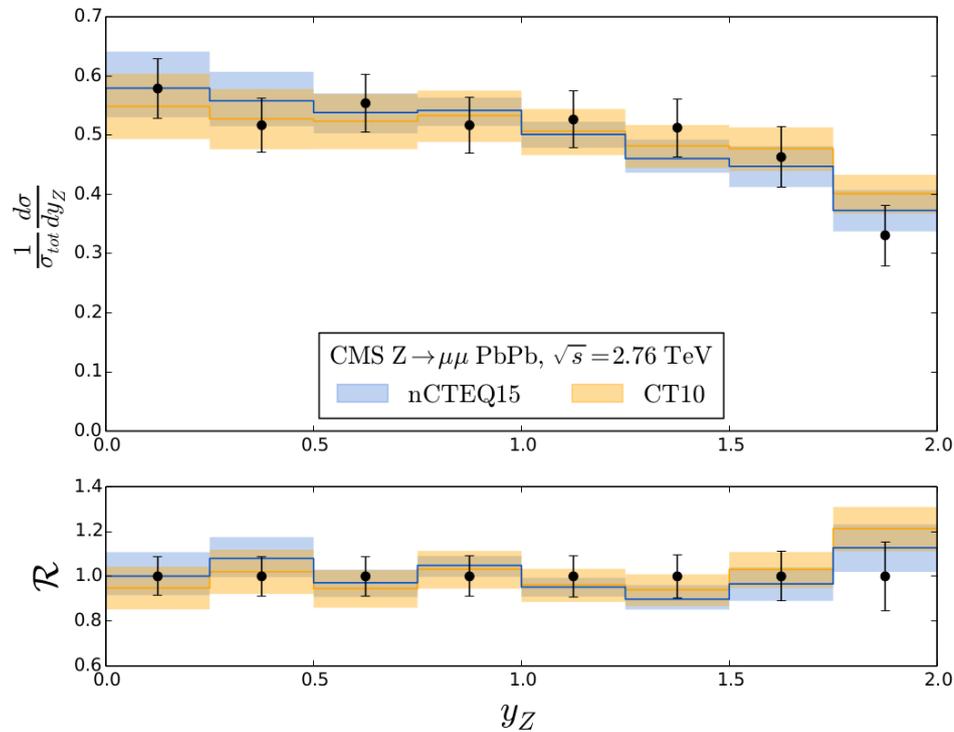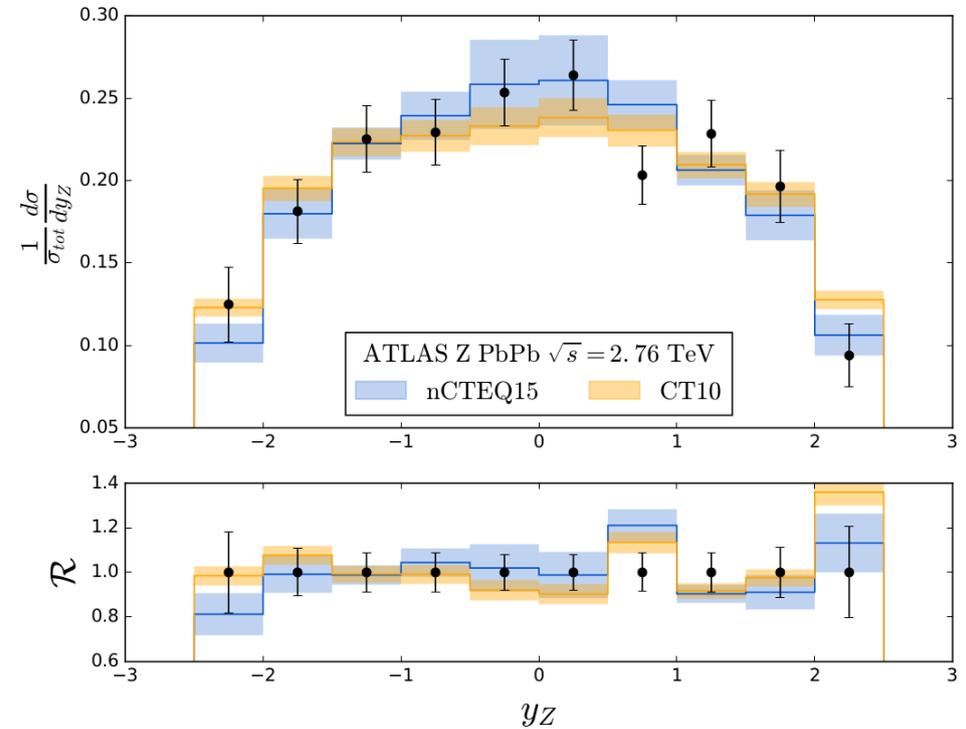
Done in modified FEWZ software which allows for pp, pPb, and PbPb collisions

CT10 nucleus constructed using CT10 free protons

W/Z Production
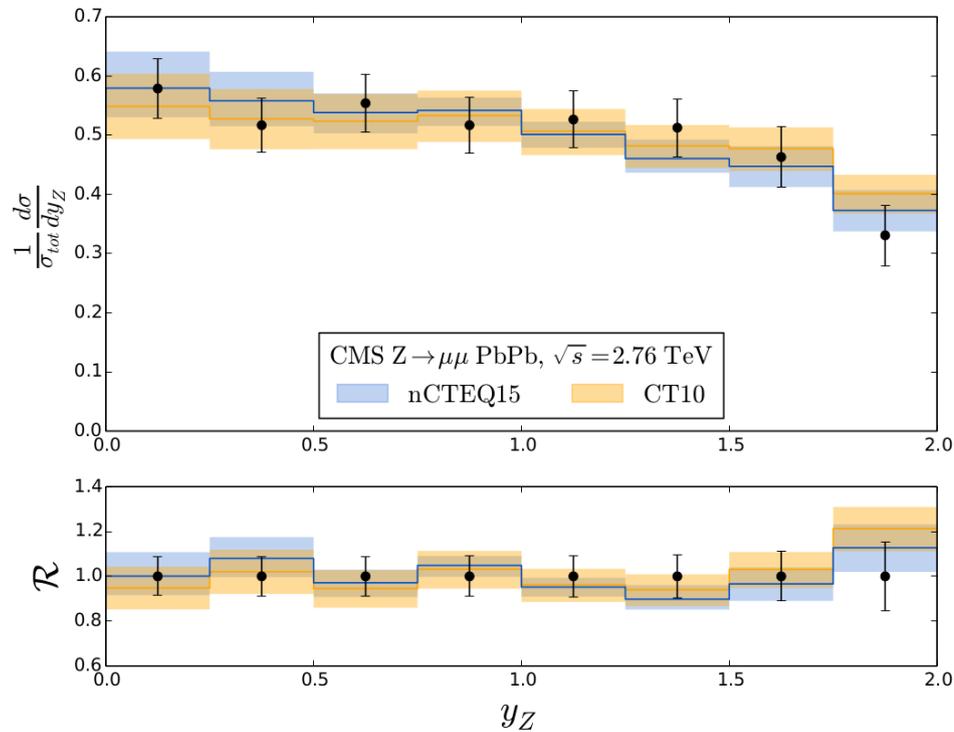
CMS PbPb Z

ATLAS PbPb Z

Good agreement between data and both sets

Not sensitive to nuclear corrections

W/Z Production
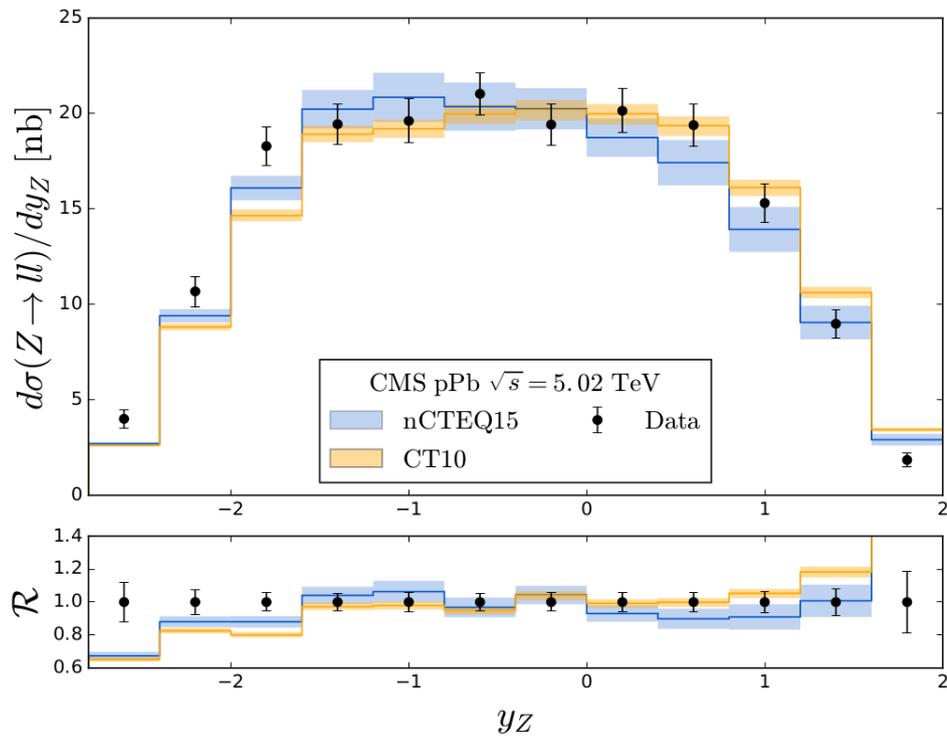
CMS pPb Z

ATLAS pPb Z

W/Z Production

CMS pPb Z
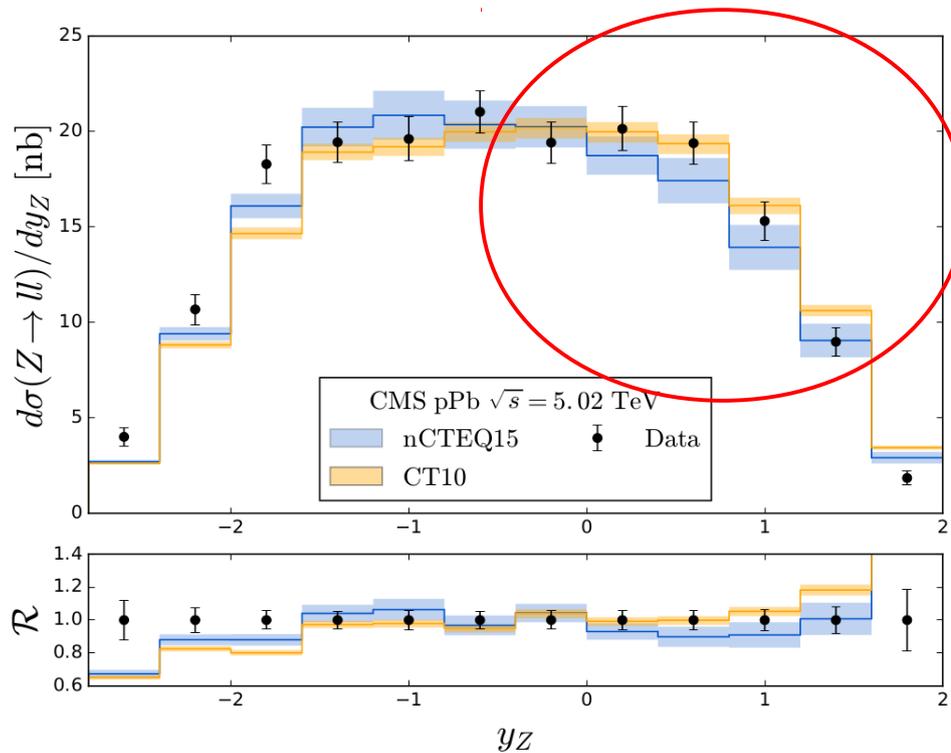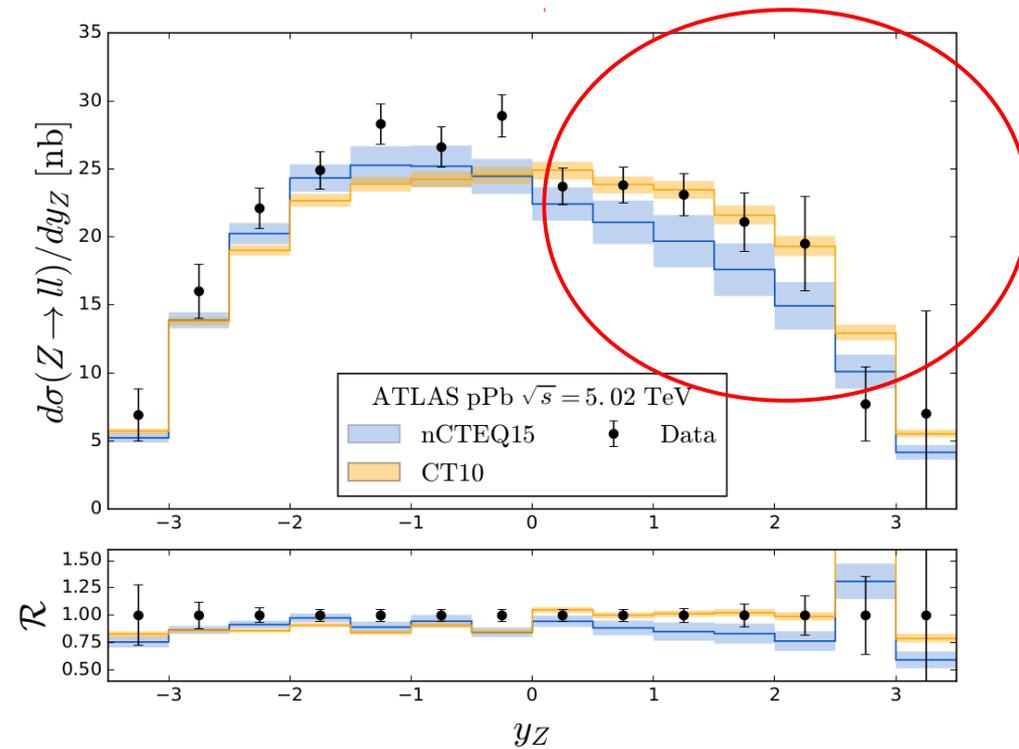
ATLAS pPb Z

Slight deviance between data and CT10 from nCTEQ15

Good agreement for negative rapidities, the region we have data to constrain the PDF

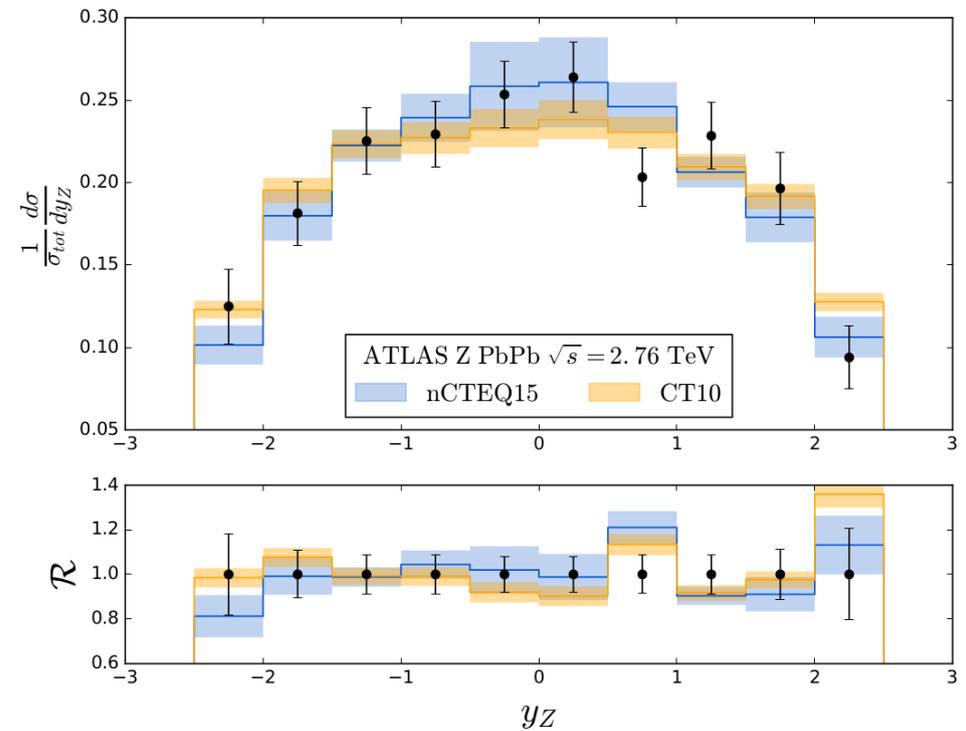# W/Z Production
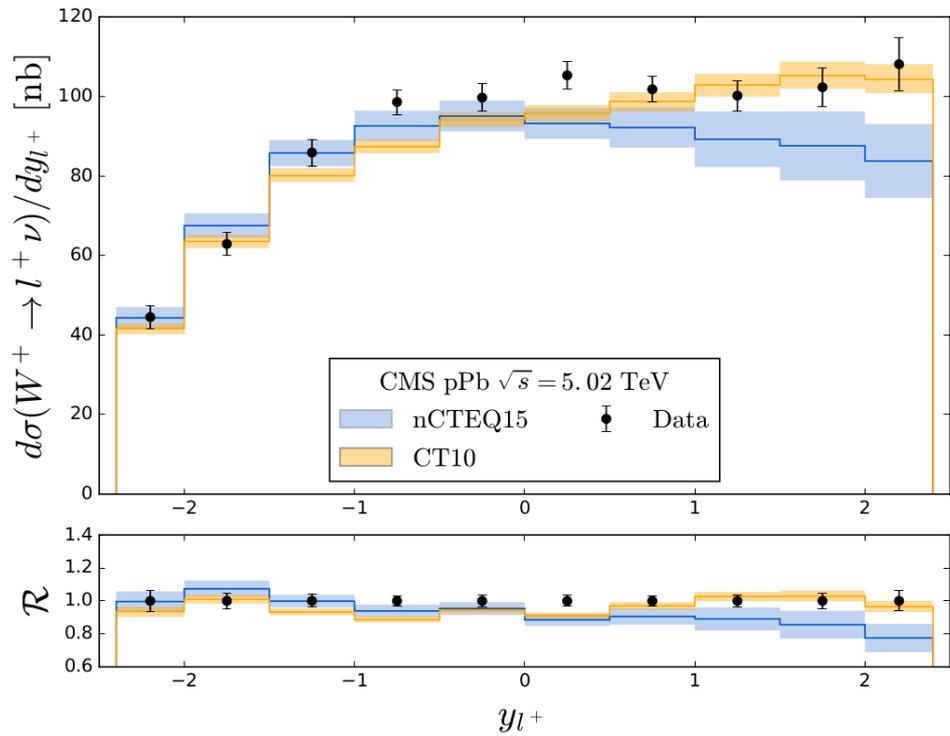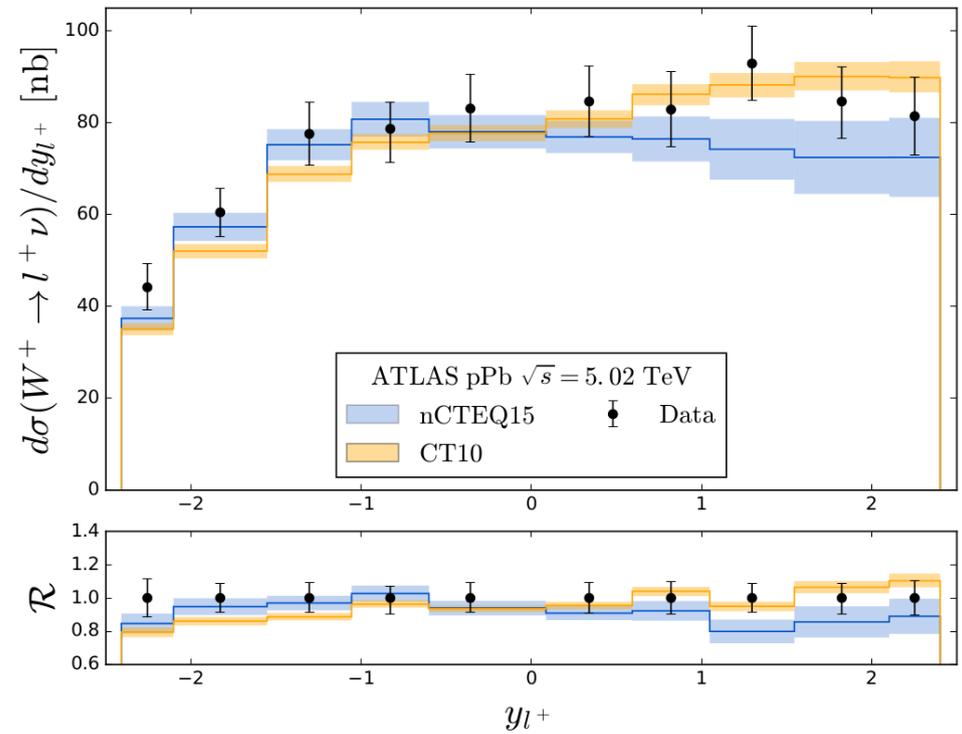
CMS pPb W⁺

ATLAS pPb W⁺

W/Z Production

CMS pPb W⁺
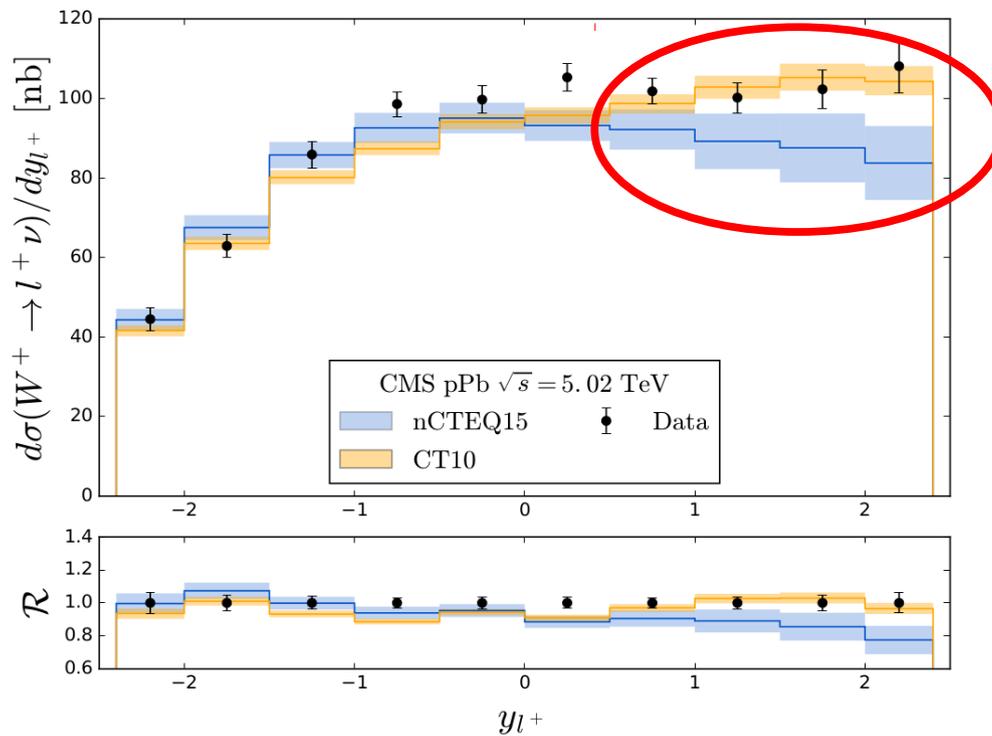
ATLAS pPb W⁺
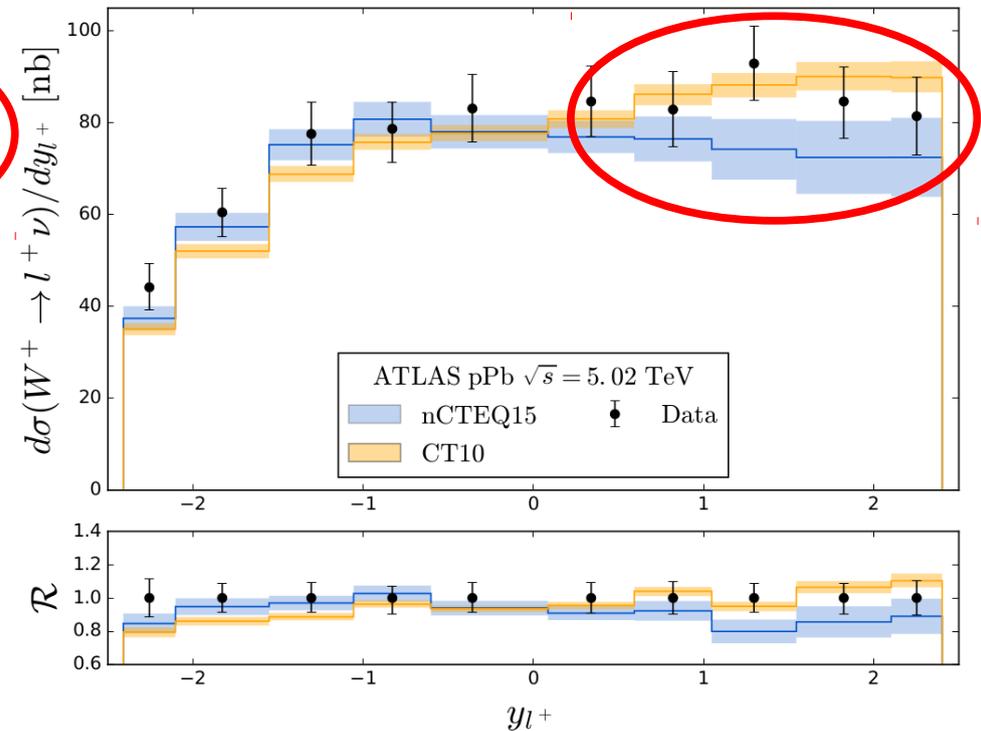
Definite separation between data and CT10 from nCTEQ15

Indicates this data could be useful in constraining PDFs in this region

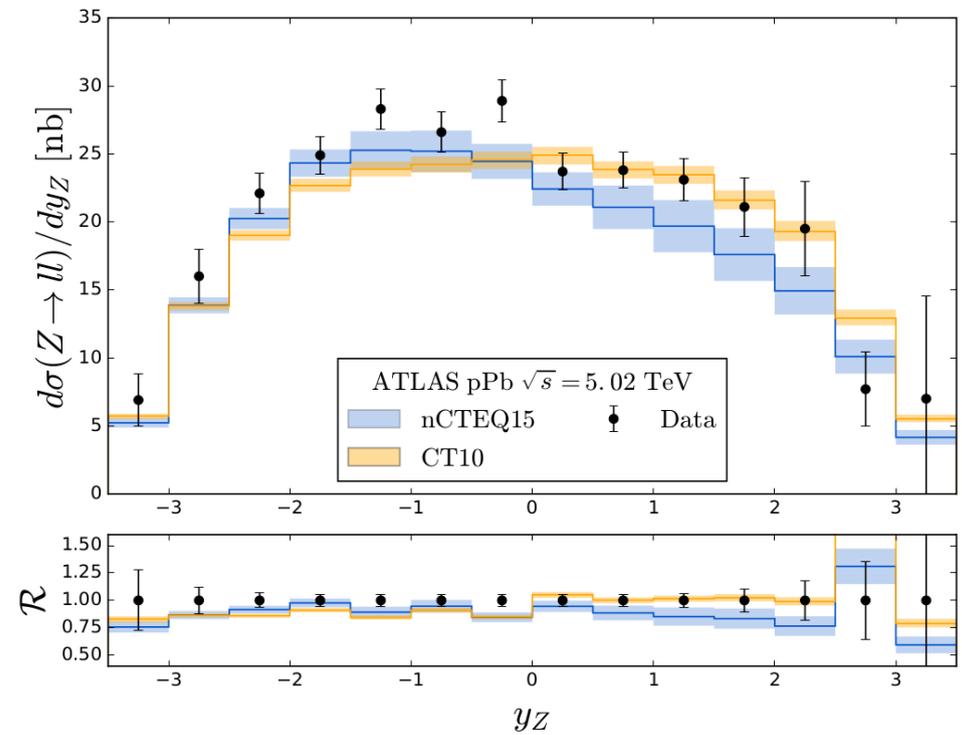# Estimating Impact on nCTEQ15 PDFs

Reweighting

Reweighting study[1] performed to analyze the potential impact of LHC pPb W/Z data on nCTEQ15 PDFs

- Study suggested data had significant pull to warrant inclusion in full fit

$Q = 10$ GeV, Nrep = 10000
- - - before rew.
— after rew.

Reweighted PDF shifts slightly
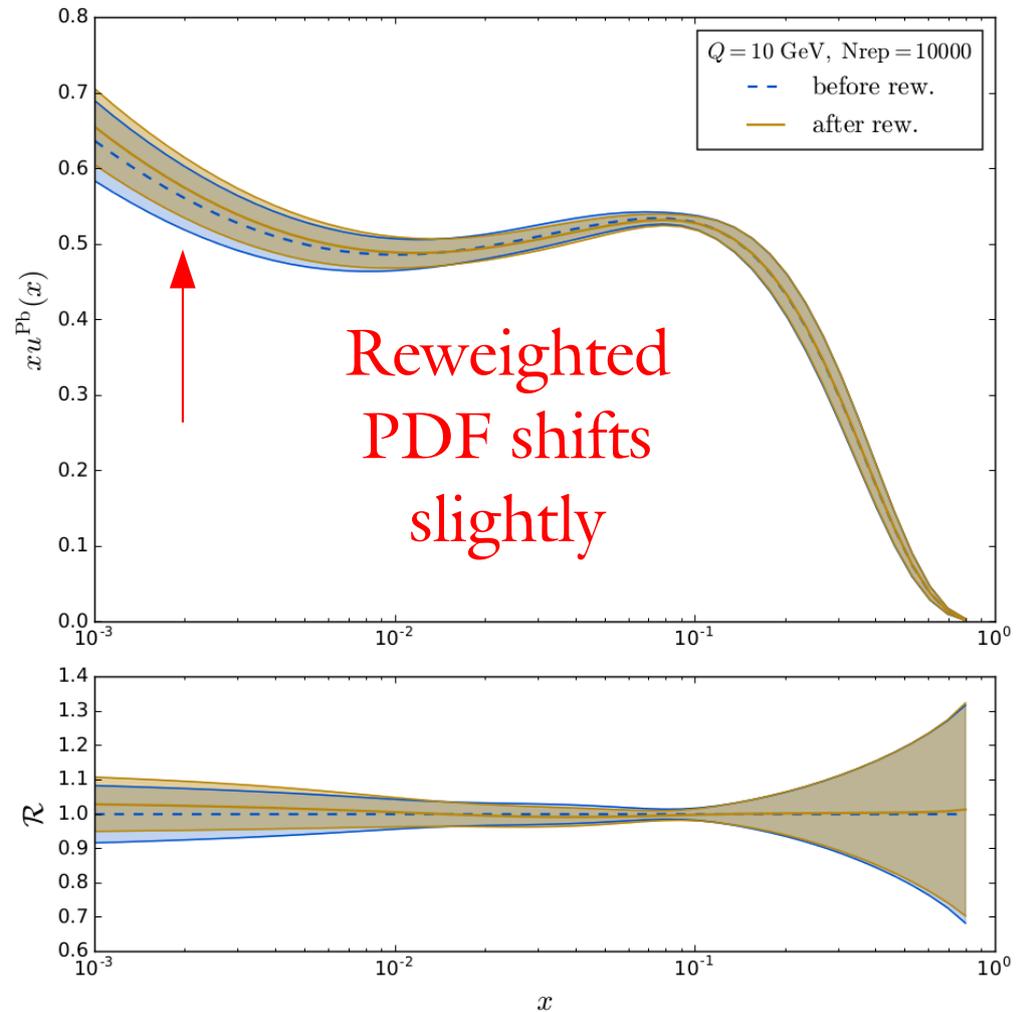
Reweighting

Results indicated parameterization is inflexible

- Extrapolation in x_2 region corresponding to positive rapidity
  - Previously lacked data in this range
- Strange quark parameter could be opened
  - Currently fixed to up and down quarks

Observable slightly shifts towards data
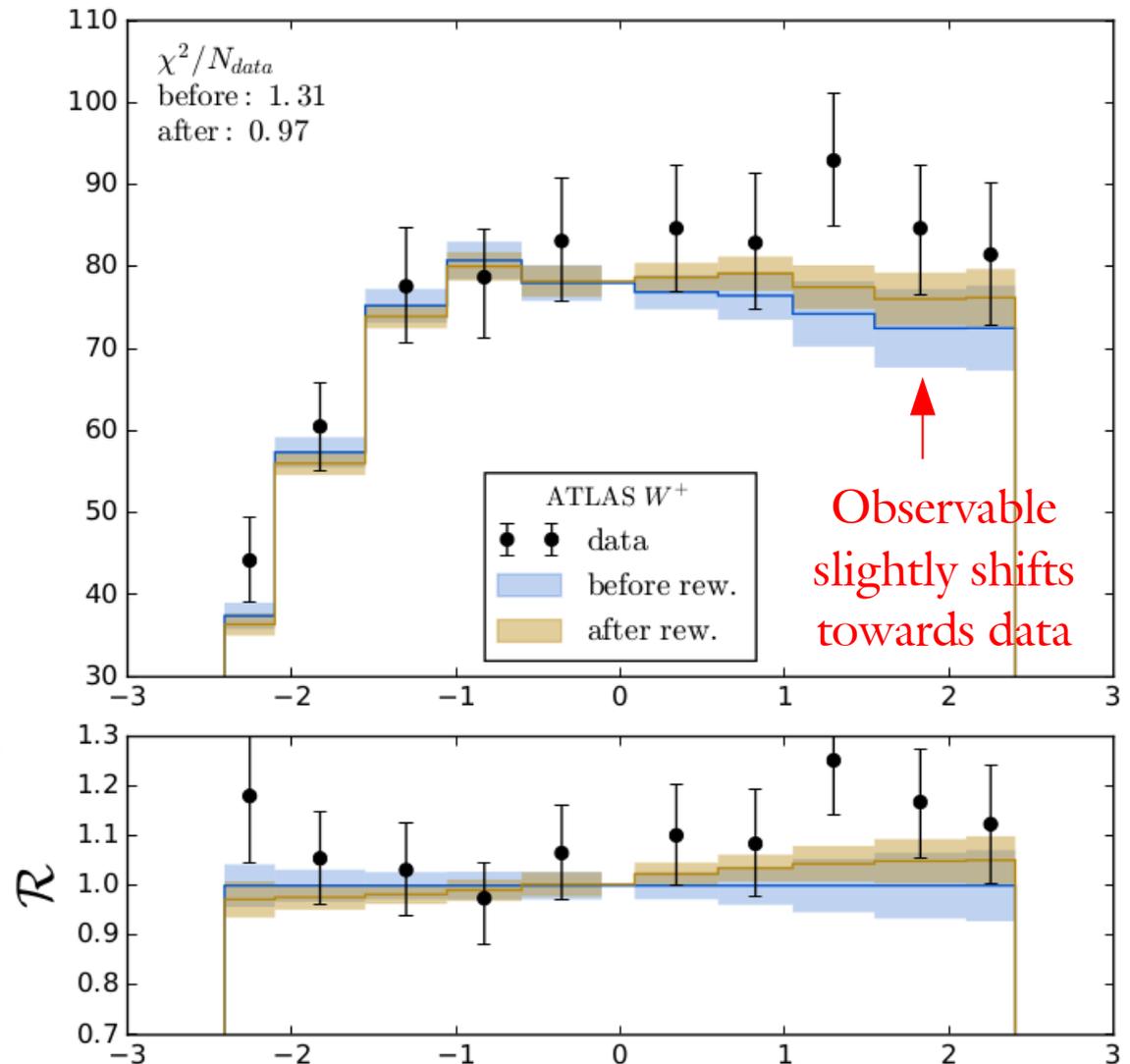
Outlook

Outlook

- Currently working on including LHC W/Z pPb data in new fit of nCTEQ15 PDFs

  - Utilizing:
    - APPLGrid
    - pAFEWZ
    - MCFM

- Free up parameterization

  - Strange quark (preliminary study)

Thank you to:
A. Kusina
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D.B. Clark
T. Jezo
I. Schienbein
K. Kovarik
J.Y. Yu

Additional Slides

nCTEQ PDFs at the LHC

x₂ is the
Lead PDF

Reweighting Formalism

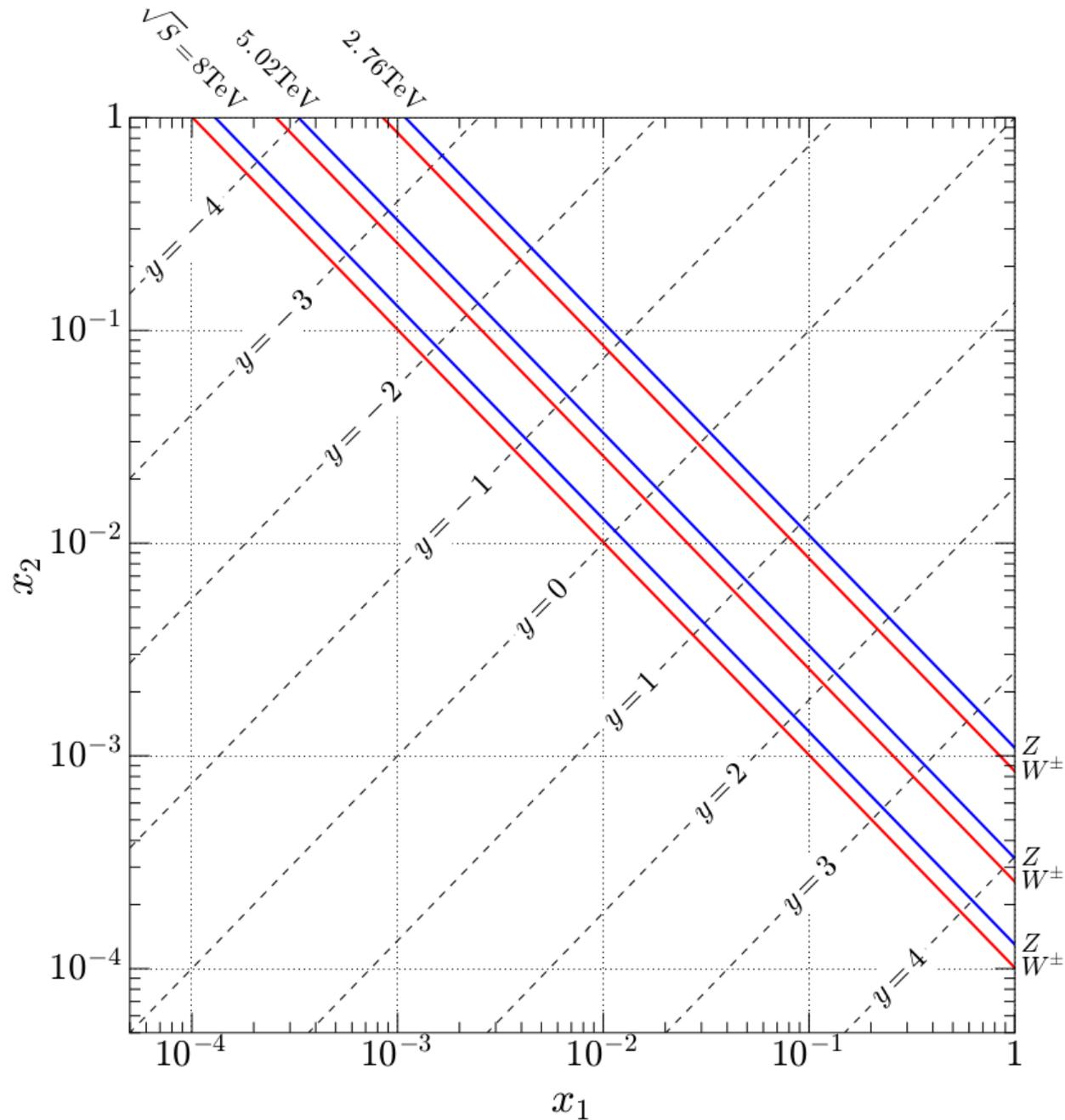## Bayesian Reweighting Technique

- Generate Replica: $f_k(x) = f_0 + \sum_i \frac{1}{2}(f_i^+ - f_i^-)R_{ik}$

- Calculate Giele-Keller weights: $w_k = \dfrac{e^{\frac{-1}{2}\chi_k^2}}{\frac{1}{N_{rep}}\sum_i e^{\frac{-1}{2}\chi_i^2}}$

- Estimate weighted average and standard deviation:

$$< O > = \frac{1}{N_{rep}}\sum_k w_k O(f_k)$$

$$\delta < O > = \sqrt{\frac{1}{N_{rep}}\sum_k w_k (O(f_k) - < O >)^2}$$

LHC Data vs Current Data Cuts

$$W = \frac{Q^2(1-x)}{x} + m_p^2 > 3.5 GeV$$

NMC
EMC
SLAC
BCDMS
Hermes
FNAL E665
DY: FNAL
LHC W/Z

Nonpertubative nuclear corrections at high x

$Q^2 > 2$ GeV

Ensure DIS Range

Higher Twist effects at low Q^2