The Muon Charge Asymmetry Measurement in Inclusive pp→W production at √s=8 TeV

CMS-SMP-14-022

Hasan Ogul University of Iowa

DPF 2015

August 6th , 2015

Outline

Introduction

Analysis Details

Results and Implication

- Reference:

7 TeV paper:(Published)
Phys. Rev. D 90, 032004 – Published 13 August 2014

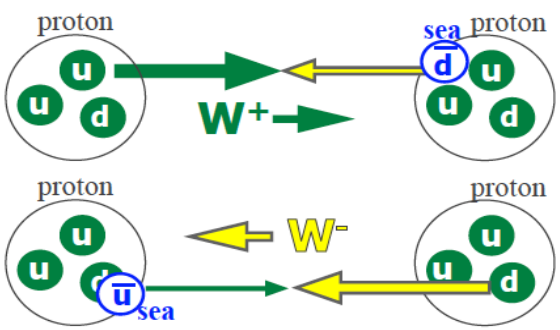
8 TeV Analysis: aiming for paper
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP14022

Introduction

- In pp collisions, primary mechanism of W production:

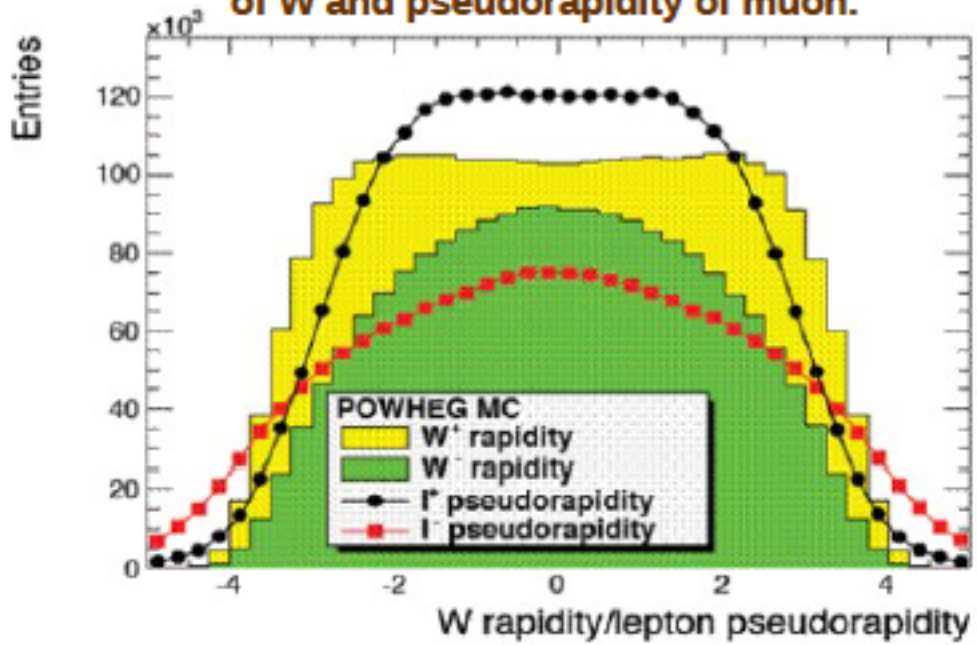
$u\bar{d} \rightarrow W^+$

$d\bar{u} \rightarrow W^-$



- $N(u_V) > N(d_V)$
  $\Rightarrow$ Total $N(W+) > N(W-)$

W^+ and W^- production rate as a function of rapidity of W and pseudorapidity of muon.



- Measurement of W charge asymmetry in bins of rapidity of boson can provide new insight into u/d ratio and sea quark densities in ranges of Bjorken parameter x probed by pp collisions at √s = 8 TeV.

$$x_{1,2} = \frac{m_W}{\sqrt{s}} \cdot e^{\pm y}$$

Lepton Charge Asymmetry:

$$A(\eta) = \frac{\frac{d\sigma}{d\eta}(pp \rightarrow W^+) - \frac{d\sigma}{d\eta}(pp \rightarrow W^-)}{\frac{d\sigma}{d\eta}(pp \rightarrow W^+) + \frac{d\sigma}{d\eta}(pp \rightarrow W^-)}$$

Muon Selection

- $W \to \mu\nu$ candidate events are characterized by a high p_T muon and MET due to the neutrino.
- Trigger: single isolated muon trigger, p_T >24 GeV, |η|<2.4
- Muon identified by hits in silicon tracker and muon detector, global track fitting chi-squared, |dxy|, isolation…
- Sort muons by p_T and the leading one is taken as the W(μν) candidate. Require the leading muon p_T >25 GeV, |η|<2.4 and to trigger the event .
- Reject events with another muon with p_T >15 GeV.

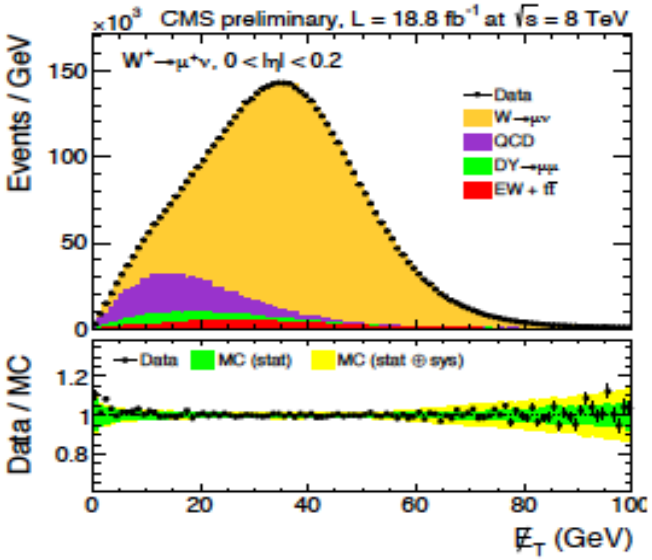
Overview of the analysis

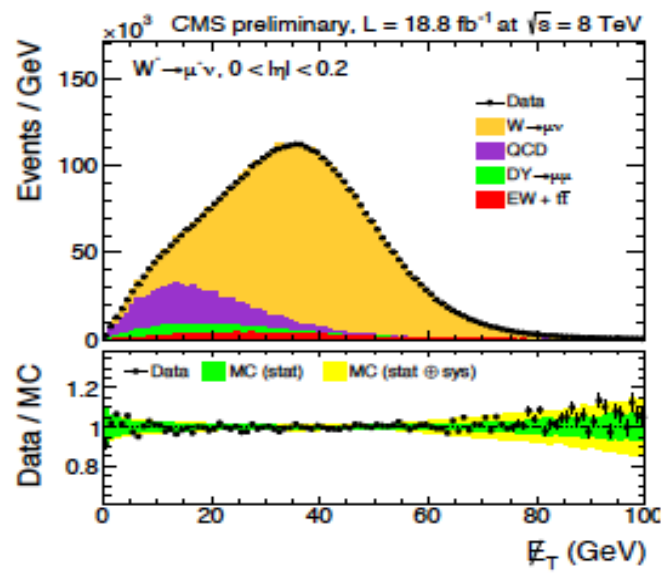
- After the selection of events, Asymmetry is measured in bins of muon pseudorapidity

[0,0.2],[0.2,0.4],[0.4,0.6],[0.6,0.8],[0.8,1.0],[1.0,1.2],[1.2,1.4],[1.4,1.6],[1.6,1.85],[1.85,2.1],[2.1,2.4]

- In each |η| bin, MET templates from MC samples are fitted to the MET distribution in data for Signal & Background extraction.

- Met fits are performed simultaneously for W+ and W- candidate events.





Backgrounds

- A total of **61 million** $W^+ \to \mu^+\nu$ and **45 million** $W^- \to \mu^-\nu$ candidate events are selected.

Two dominant processes contributing to the total backgrounds:

1. Multijet **(QCD)** events with high p_T muons.(~10%)
2. **Electro-weak** and **ttbar** events (~8%)

The contribution from single-top and diboson events are negligible.

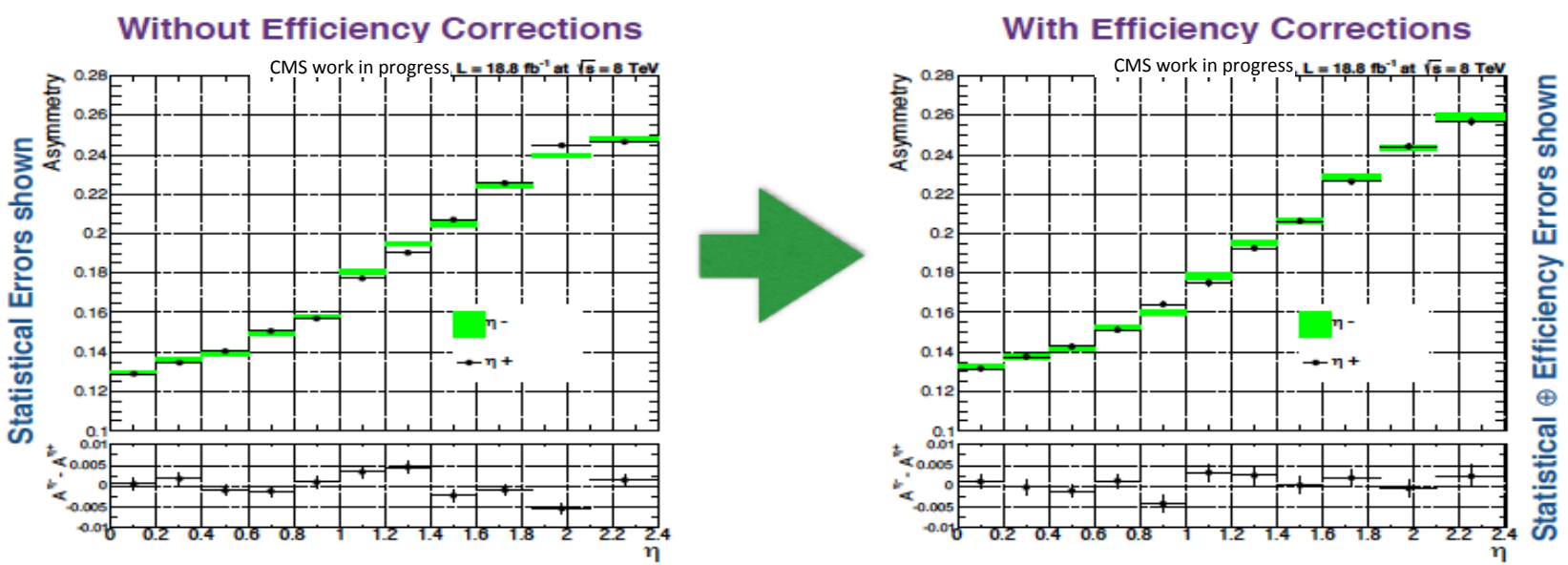
Raw Charge Asymmetry and Asymmetry

- Raw asymmetry is calculated from the number of W+ and W- signal events ,which are obtained from the fits.

$$A_{raw} = \frac{N^{W+} - N^{W-}}{N^{W+} + N^{W-}} \qquad \text{(Eq. 1)}$$

- **Correct for efficiency difference between μ +/μ -**

$$A_{true} = A_{raw} - \frac{1-(A_{raw})^2}{2}\left(\frac{\epsilon^+}{\epsilon^-} - 1\right) \qquad \text{(Eq. 2)}$$



Efficiency correction improves the agreement between + and – eta sides

Systematic Uncertainties

- **Consider sources that affect**
  - MET Shapes
  - Yield
  - Background Normalization
  - Araw → Atrue correction

- For several systematic sources we smear their corresponding parameters 400 time (redo every step in the analysis)

- At the end we take the RMS of result asymmetry distribution in each |η| bin as systematic source

Systematic Uncertainties

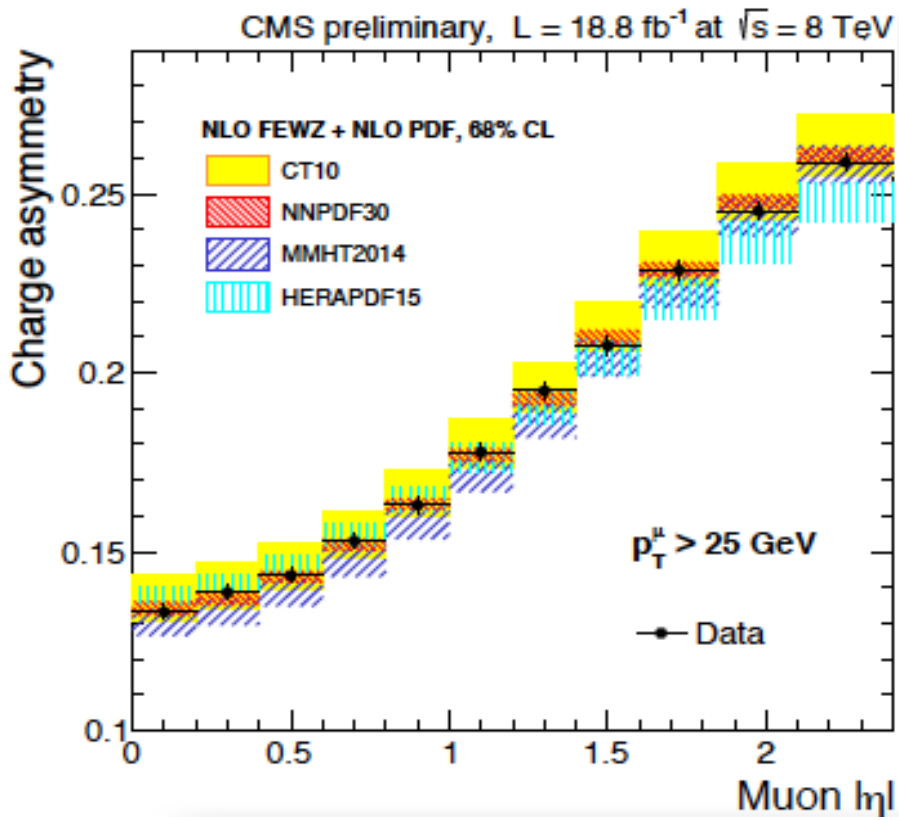
Table 2: Systematic uncertainties in $\mathcal{A}$ for each $|\eta|$ bin. The statistical uncertainty in each $|\eta|$ bin is also shown for comparison. A detailed description of each systematic uncertainty is given in the text. The values are expressed as percentages (as are the measured asymmetries).

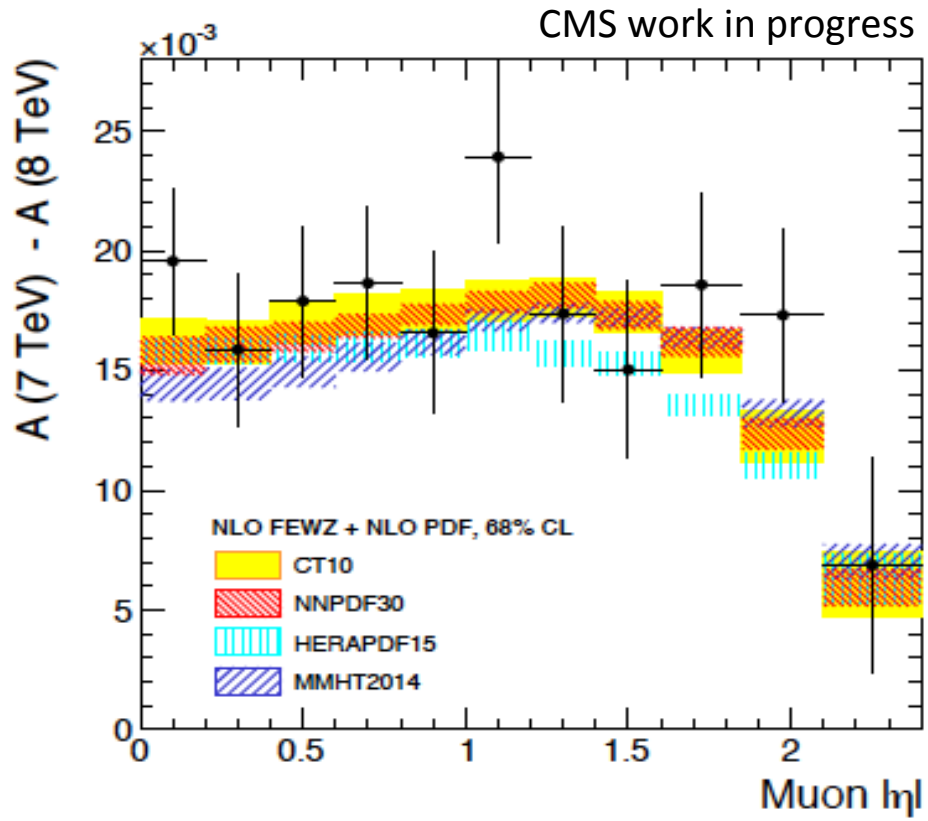
$\|\eta\|$ bin	0.0–0.2	0.2–0.4	0.4–0.6	0.6–0.8	0.8–1.0	1.0–1.2	1.2–1.4	1.4–1.6	1.6–1.85	1.85–2.1	2.1–2.4
Stat. Unc.	0.062	0.063	0.061	0.061	0.063	0.065	0.068	0.069	0.065	0.062	0.072
Efficiency	0.058	0.071	0.057	0.058	0.082	0.091	0.092	0.085	0.085	0.082	0.134
Muon scale	0.028	0.028	0.027	0.027	0.030	0.030	0.029	0.034	0.034	0.032	0.028
QCD $+/-$	0.151	0.150	0.152	0.152	0.152	0.155	0.165	0.176	0.172	0.138	0.102
QCD shape	0.022	0.032	0.031	0.029	0.039	0.043	0.054	0.060	0.071	0.055	0.040
EW+$t\bar{t}$ bkg.	0.027	0.027	0.027	0.028	0.027	0.028	0.029	0.031	0.035	0.042	0.052
$\not{E}_T$ shape	0.033	0.042	0.039	0.043	0.055	0.059	0.060	0.084	0.086	0.085	0.067
FSR	0.081	0.105	0.086	0.093	0.082	0.100	0.100	0.093	0.100	0.089	0.067
PDF	0.025	0.024	0.022	0.021	0.018	0.022	0.032	0.037	0.049	0.059	0.081
Total Sys. Unc.	0.191	0.208	0.195	0.200	0.207	0.223	0.234	0.247	0.253	0.224	0.221
Total Unc.	0.201	0.217	0.205	0.209	0.217	0.232	0.244	0.256	0.261	0.233	0.233

Dominant systematics are QCD, FSR and Efficiency.

Results

- **Measured asymmetry compared to predictions from different PDF sets**





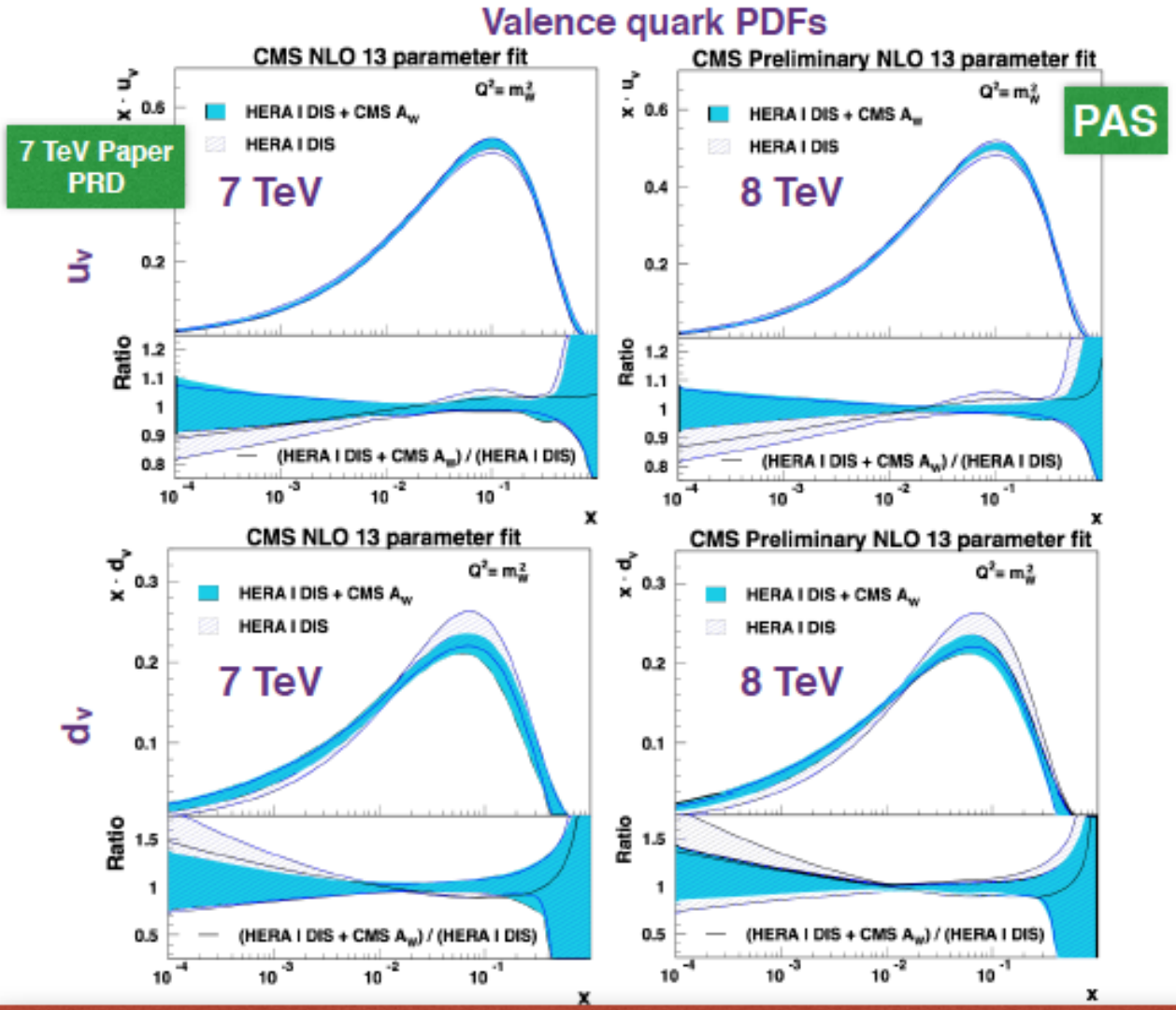
Measurement compatible with predictions within their uncertainties.

- **The results can be used to further constrain PDFs**

❑ The experimental uncertainties are smaller than the current PDF uncertainties in the present QCD calculations.

Implication of Charge asymmetry

- **HERA + W Asymmetry (7 TeV) vs HERA + W Asymmetry (8 TeV)**



An update work with NNLO is in progress

Similar change of PDF shape. More improved constraints using 8 TeV measurement.

Summary

- W boson muon charge asymmetry measurement at 8 TeV has been performed, it is available to public:

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP14022

- Improves the description of PDF.

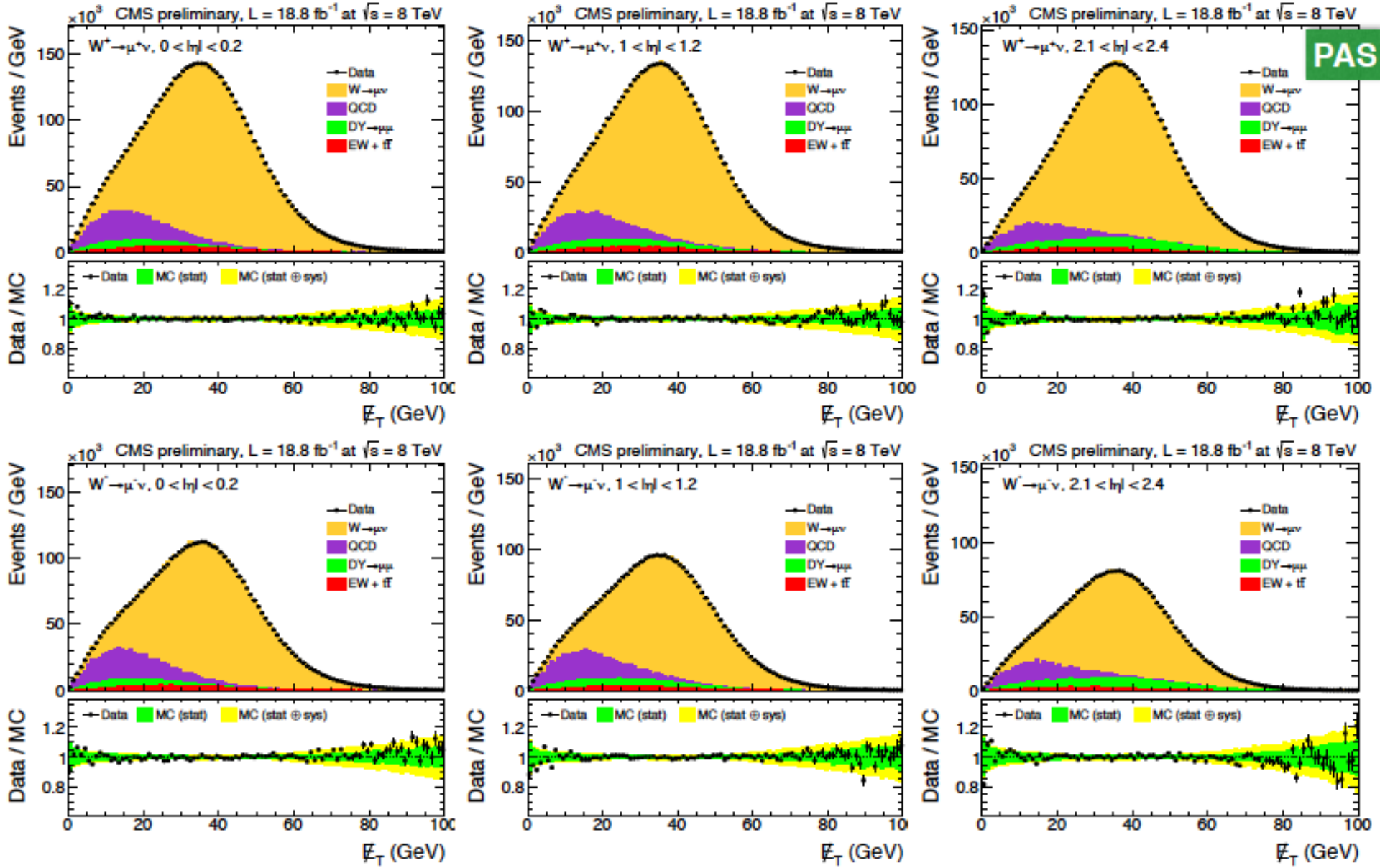
- Aiming for paper.

Work in progress

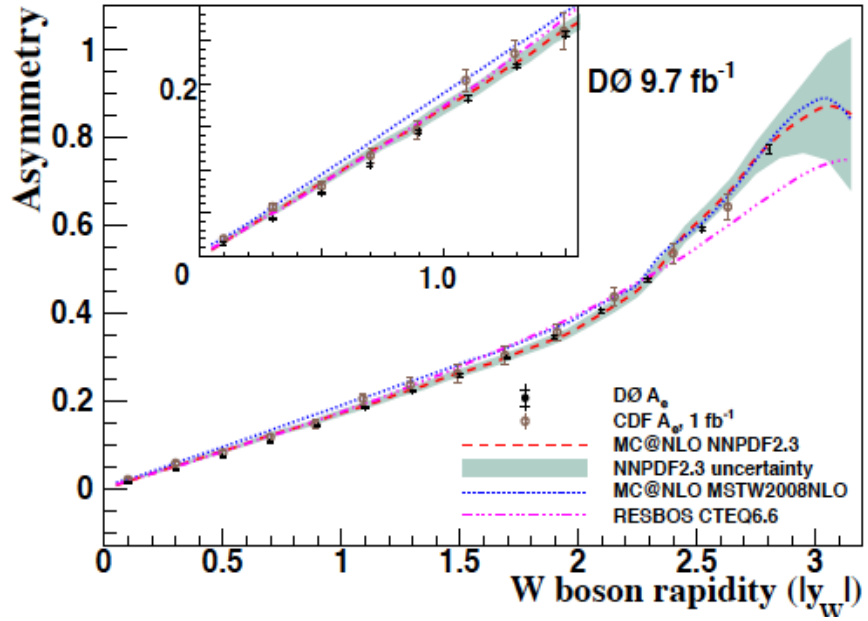
- QCD analysis at NNLO order is being performed.
- Decided to expand the paper with differential cross section.
- Redo QCD analysis with differential cross section results.

Thank You!

Met Fits


CMS preliminary, L = 18.8 fb^{-1} at $\sqrt{s}$ = 8 TeV
$W^+ \to \mu^+\nu$, $0 < |\eta| < 0.2$
$W^+ \to \mu^+\nu$, $1 < |\eta| < 1.2$
$W^+ \to \mu^+\nu$, $2.1 < |\eta| < 2.4$
$W^- \to \mu^-\nu$, $0 < |\eta| < 0.2$
$W^- \to \mu^-\nu$, $1 < |\eta| < 1.2$
$W^- \to \mu^-\nu$, $2.1 < |\eta| < 2.4$
Data
$W \to \mu\nu$
QCD
$DY \to \mu\mu$
EW + $t\bar{t}$
Events / GeV
Data / MC
MC (stat)
MC (stat ⊕ sys)
$\not{E}_T$ (GeV)
PAS

Introduction and Motivation: latest Results



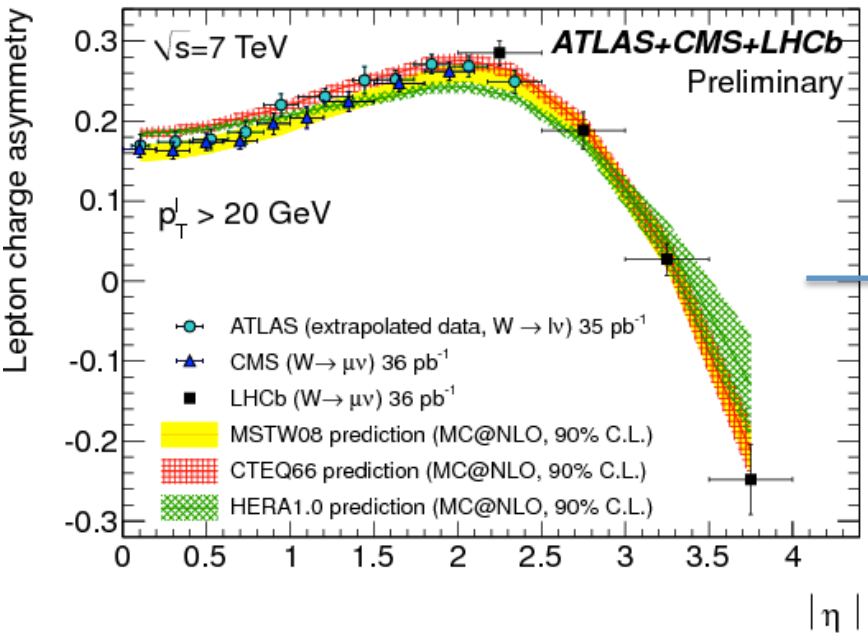
CDF result 1 fb-1

Phys. Rev. Lett. 102, 181801 (2009)

D0 result 9.7 fb-1

arXiv:1312.2895v3 [hep-ex], 22 Apr. 2014.

Conclusion:
the total uncertainties are smaller than the uncertainties coming from PDFs.



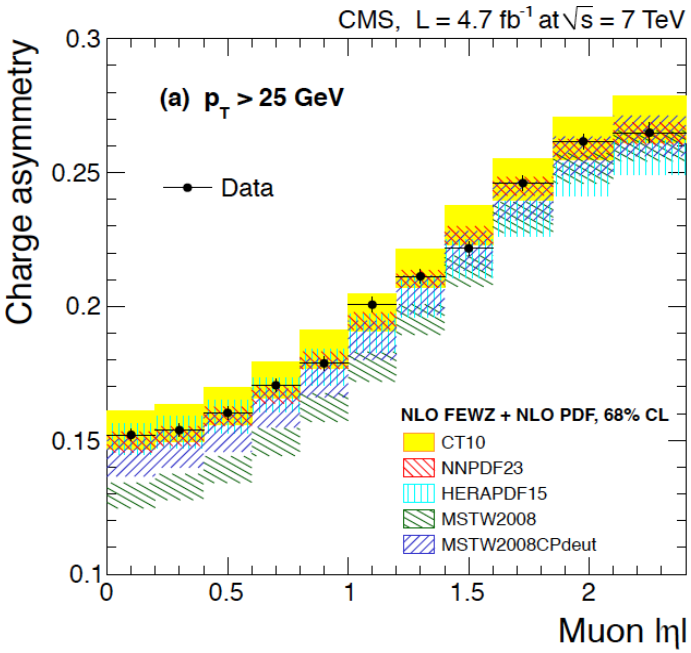
ATLAS-CONF-2011-129
LHCb-CONF-2011-039
CMS-EWK-10-006 (arXiv:1103.3407)

arXiv:1111.2840 [hep-ex], 2011

Update the CMS muon measurement with Full 2011 CMS data!

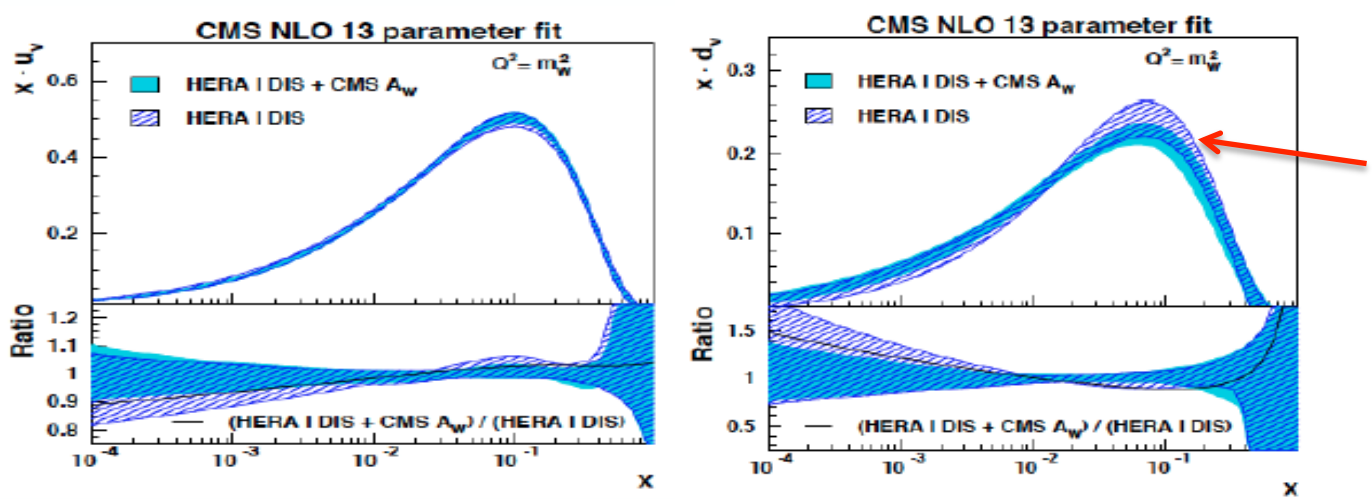
Next Page

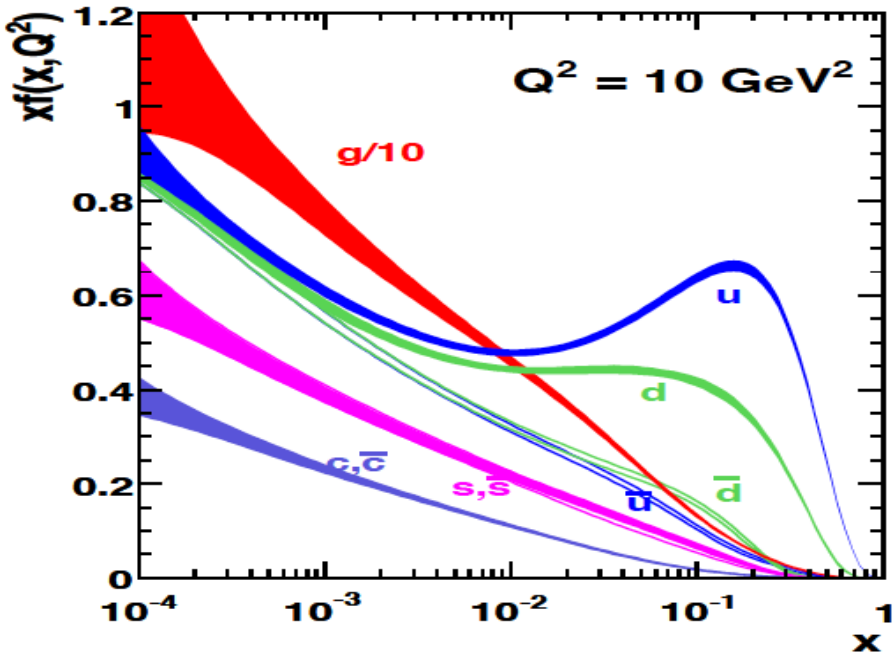
Introduction and Motivation: 7TeV CMS Measurement

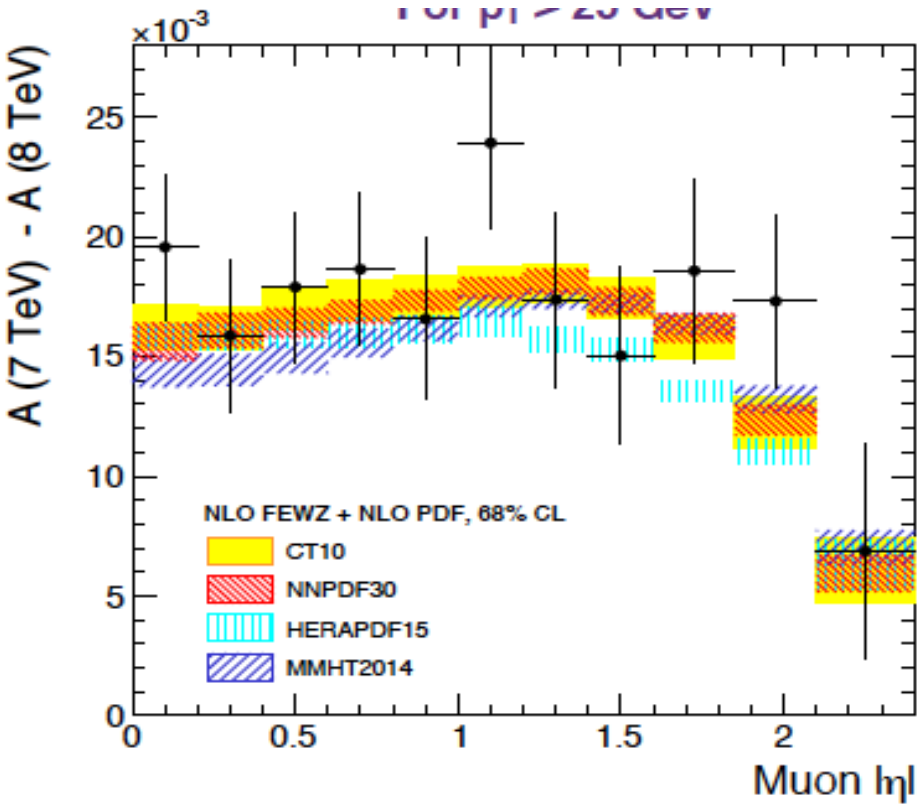


- Most Precise measurement of W lepton C. Asymmetry.
- The experimental uncertainties are smaller than the current PDF uncertainties in the present QCD calculations.
- Changes the PDF shape, improves constraints on the valance distributions.

Phys. Rev. D 90, 032004, 13 August 2014.

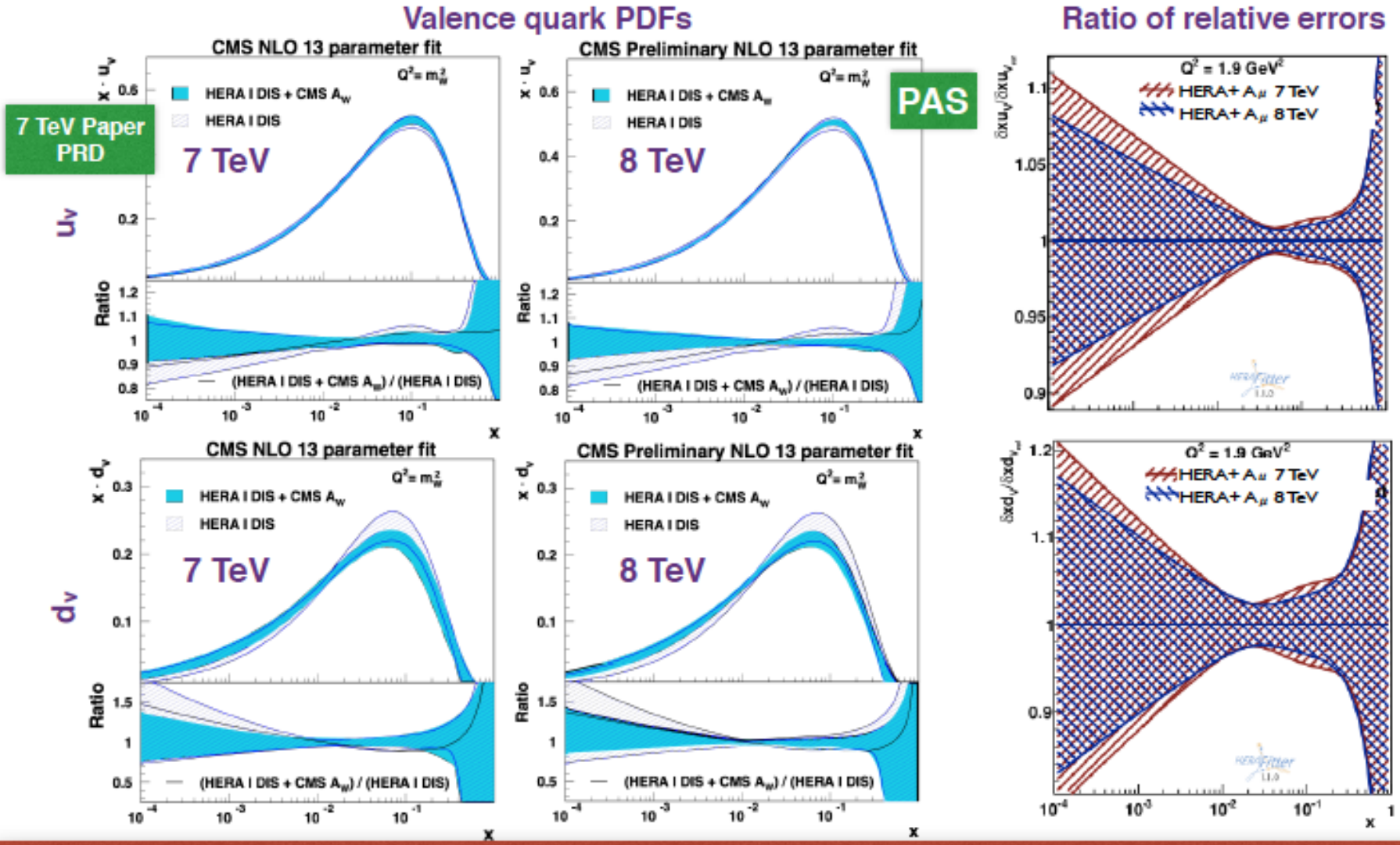



xf(x,Q²)
Q² = 10 GeV²
g/10
u
d
ū
d̄
c,c̄
s,s̄
x


A (7 TeV) - A (8 TeV)
×10⁻³
NLO FEWZ + NLO PDF, 68% CL
CT10
NNPDF30
HERAPDF15
MMHT2014
Muon |η|

Results

- **HERA + W Asymmetry (7 TeV) vs HERA + W Asymmetry (8 TeV)**



Similar change of PDF shape. More improved constraints using 8 TeV measurement.