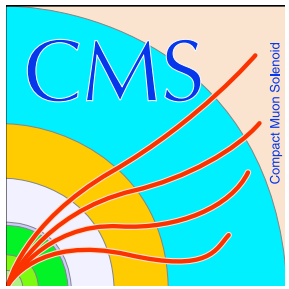
Measurement of the muon charge asymmetry in inclusive W production at $\sqrt{s}$= 7 TeV with CMS



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On behalf of the CMS collaboration

XXII International Workshop on
Deep-Inelastic Scattering and Related Subjects
Warsaw, April 30, 2014

UNIVERSITY of ROCHESTER

Outline & Reference

- Motivation and goal
- Measurement of $\mathcal{A}$ with CMS
- Results and implications

- Reference:
  - https://cds.cern.ch/record/1639605
  - http://arxiv.org/abs/arXiv:1312.6283
  - Submitted to PRD

Motivation and goal

- LHC – world's most energetic p-p collider
- Actual interactions proceed between partons
- Factorization of cross sections in pQCD

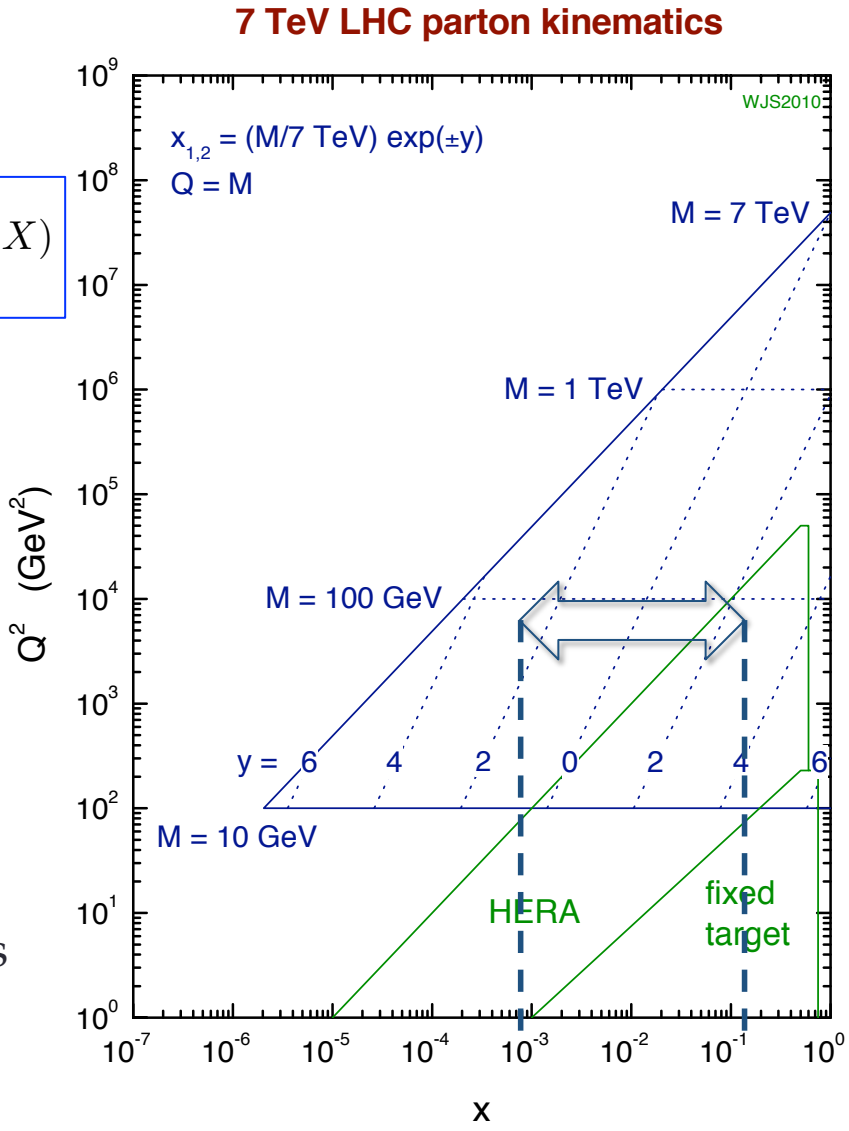
$$\sigma(pp \to X) = \sum_{a,b} \int \mathrm{d}x_a \mathrm{d}x_b f_{a/p}(x_a, Q^2) f_{b/p}(x_b, Q^2) \hat{\sigma}(ab \to X)$$

- Uncertainties in PDFs often dominate theoretical uncertainties of cross sections

- LHC explores new kinematic region

$$x_{1,2} = \frac{M_W}{\sqrt{s}} \mathrm{e}^{\pm y_W}$$

- Goal: use W→lν production to constrain PDFs
  - Large cross-section
  - Clean experimental signature



W charge asymmetry

- W charge asymmetry can probe PDFs directly →

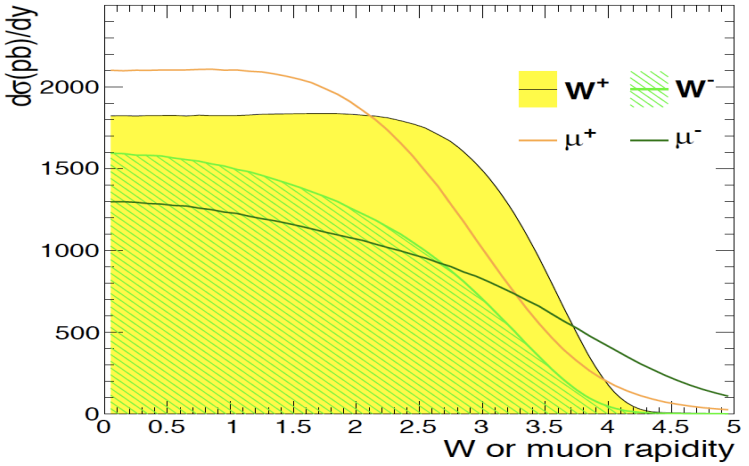
$$\mathcal{A}(y_W) = \frac{d\sigma(W^+)/dy_W - d\sigma(W^-)/dy_W}{d\sigma(W^+)/dy_W + d\sigma(W^-)/dy_W} \approx \frac{u-d}{u+d} \approx \frac{u_v - d_v}{u_v + d_v + 2\bar{q}}$$

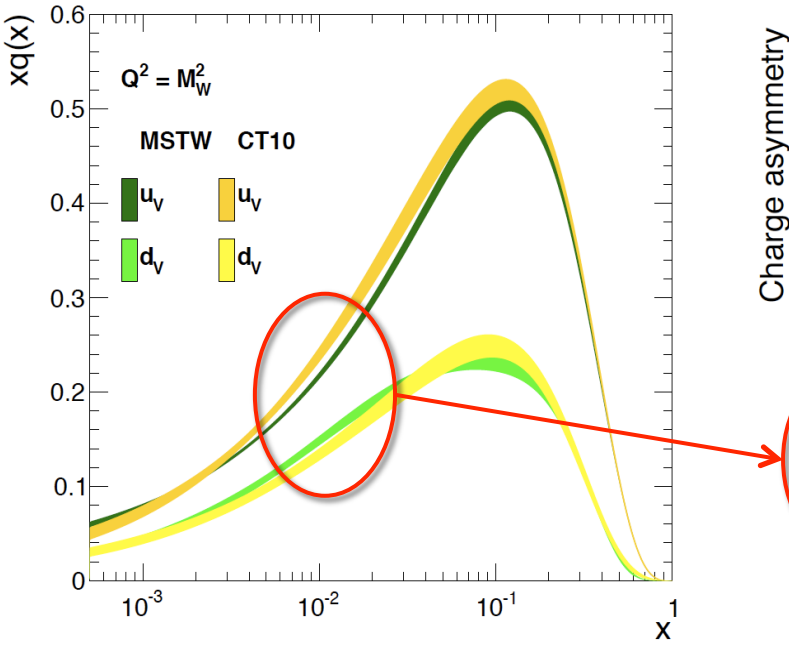
- But y_W cannot be measured

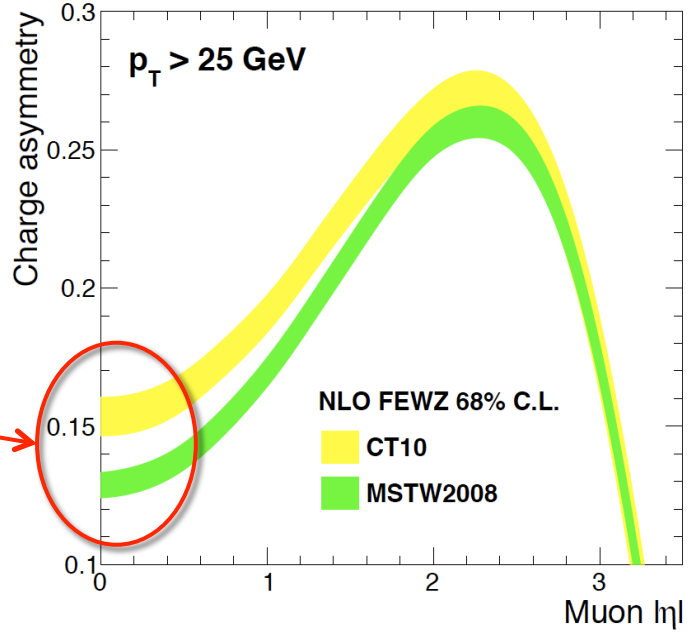
→ Measure $\mathcal{A}=\mathcal{A}(\eta_\mu)$, sensitive to PDFs

$$\mathcal{A}(\eta_\mu) = \frac{d\sigma(W^+)/d\eta_\mu - d\sigma(W^-)/d\eta_\mu}{d\sigma(W^+)/d\eta_\mu + d\sigma(W^-)/d\eta_\mu}$$

→ $\mathcal{A}(y_W)$ convoluted by anisotropic W decay







Overview of the measurement

- Measure muon charge asymmetry **in 11 $|\eta|$ bins**:

  [0.00, 0.20], [0.20, 0.40], [0.40, 0.60], [0.60,0.80],
  [0.80, 1.00], [1.00, 1.20], [1.20, 1.40], [1.40,1.60],
  [1.60, 1.85], [1.85, 2.10], [2.10, 2.40].

- Within **p_T>25 GeV** acceptance region for muon
  - Cross-check measurement **p_T>35 GeV**

- General approach:
  - Require =1 high p_T, good-quality, isolated muon to select $W\rightarrow\mu\nu$ candidates
  - Split selected sample in **11 $|\eta|$ × 2 Q** sets
  - In each $|\eta|$ bin,
    - Fit **MET$^+$** and **MET$^-$** simultaneously with signal and background templates to extract $W^{\pm}\rightarrow\mu^{\pm}\nu$ yields and $\mathcal{A}$
      - Template shapes from MC, + data-driven corrections
      - Normalizations from MC with theory xsec + corrections
    - Correct extracted $\mathcal{A}$ for difference between $\varepsilon^+(\eta)$ and $\varepsilon^-(\eta)$

Muon momentum correction

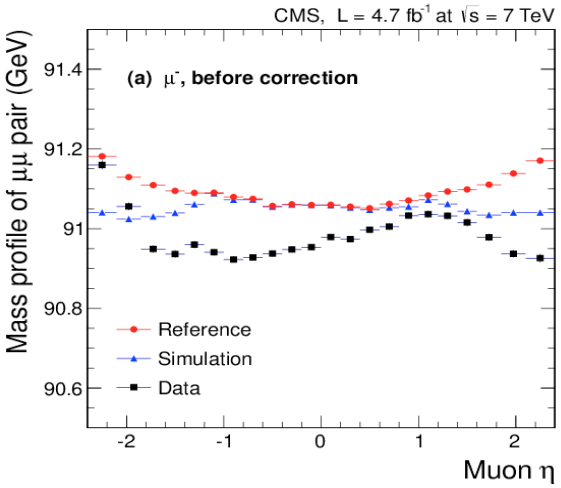
Accurate Q-dependent calibration of μ momentum important

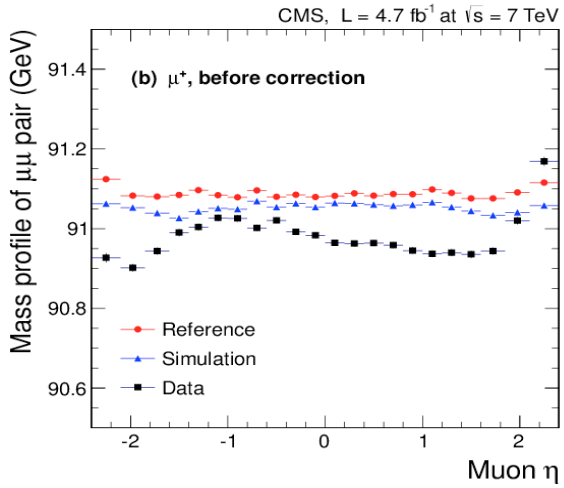
- largely from misalignment, partly from mis-modeling of magnetic field

- Defines acceptance region
- Affects MET shapes

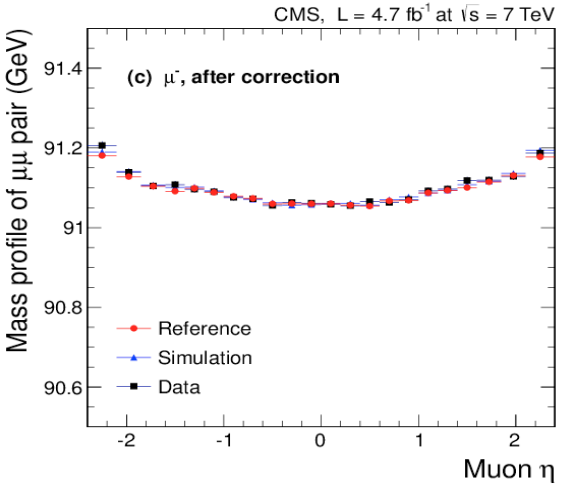
- Derived from Z→μμ events
  A. Bodek *et al*. *Euro. Phys. J.* C72, 2194 (2012)

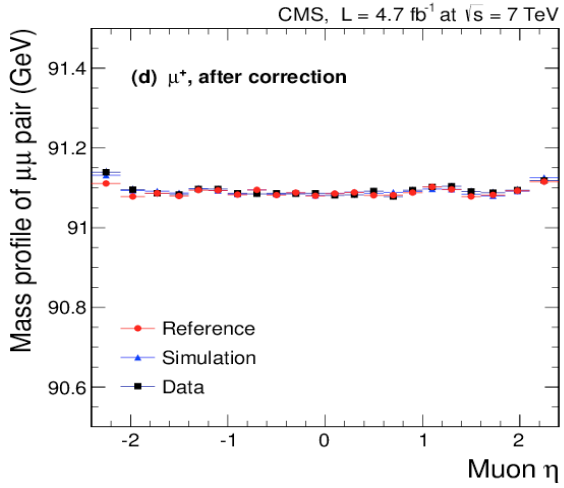
Before correction





After correction

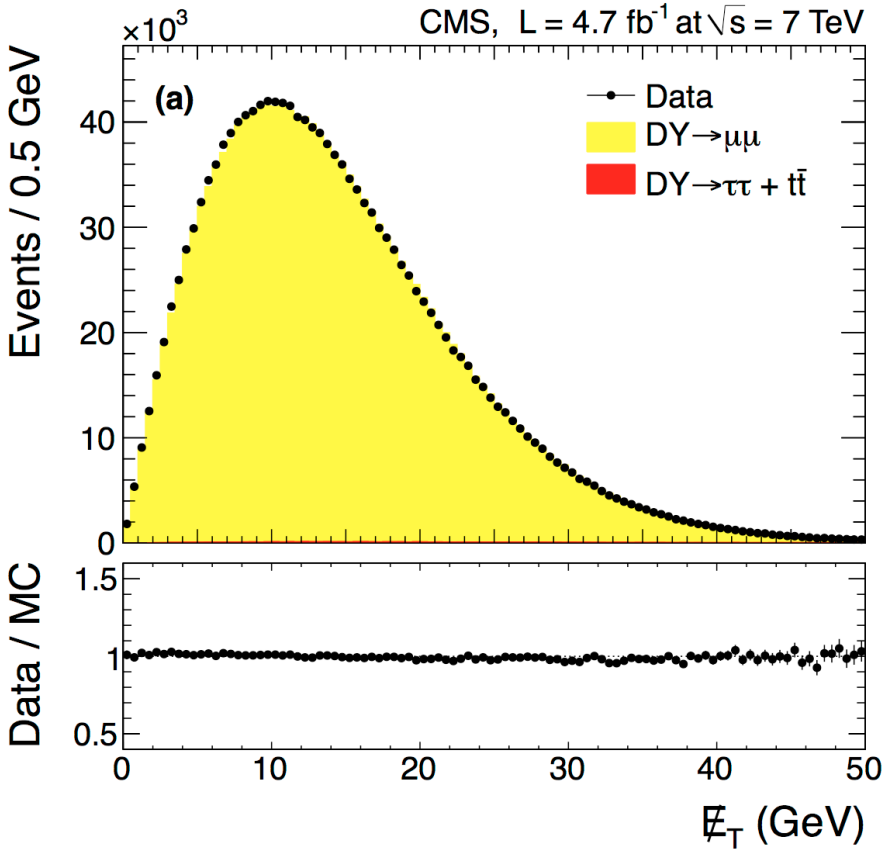


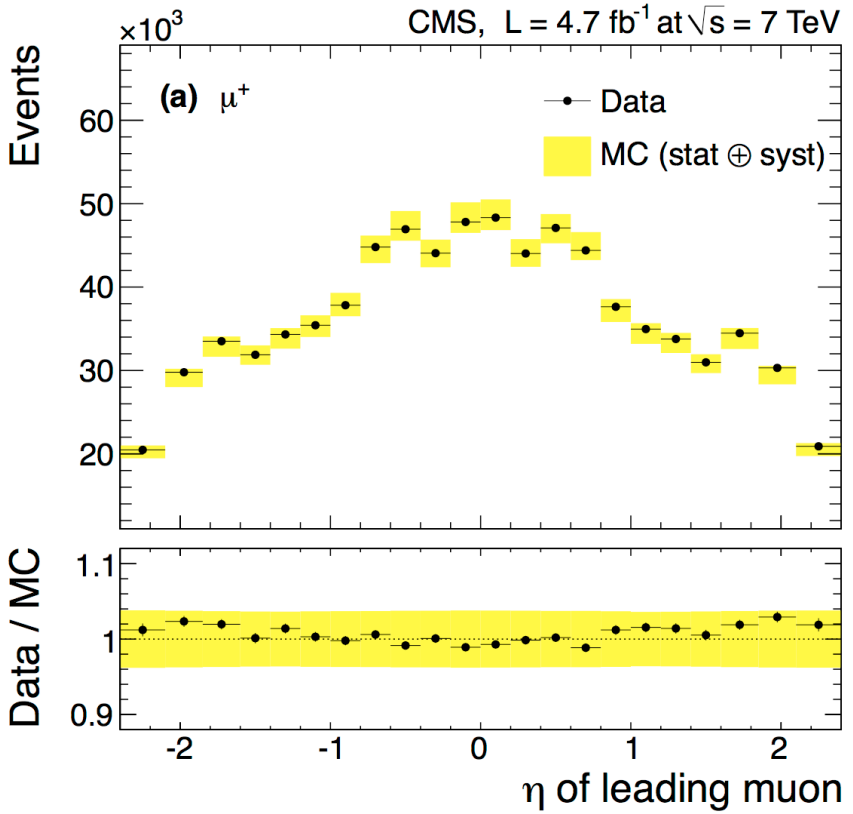


✓ After correction all biases are removed

MET shape and DY normalization

- DY background is first normalized to luminosity
- Correct with data/MC efficiency scale factors
- Additional k-factors applied that fix normalization in DY control region (full correction is taken as systematics)

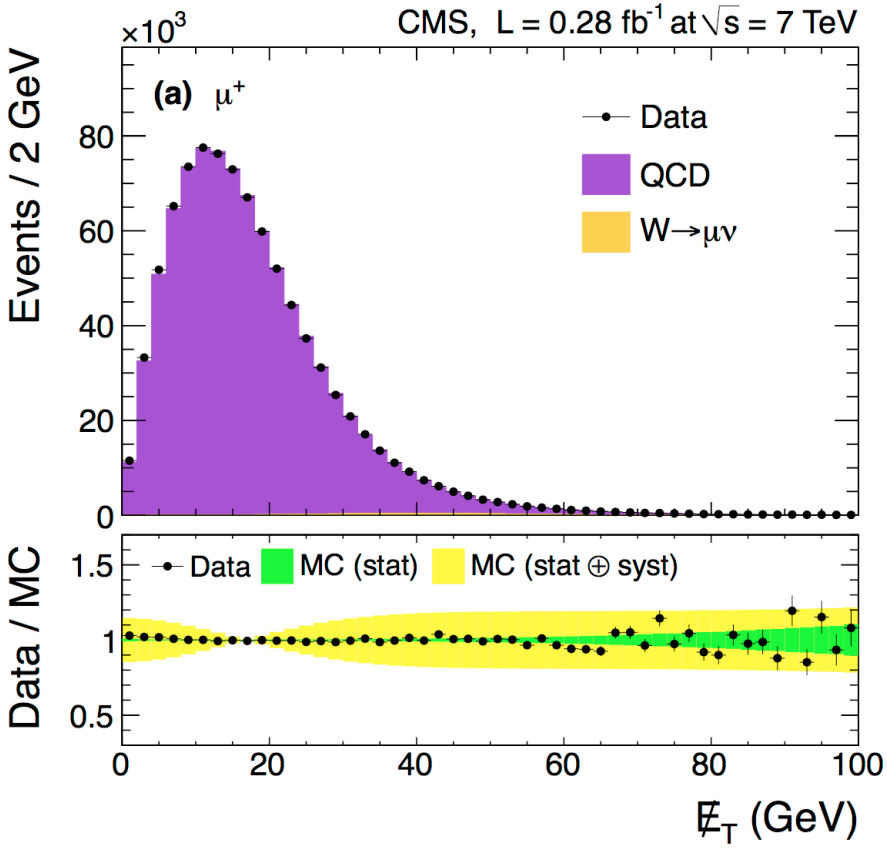


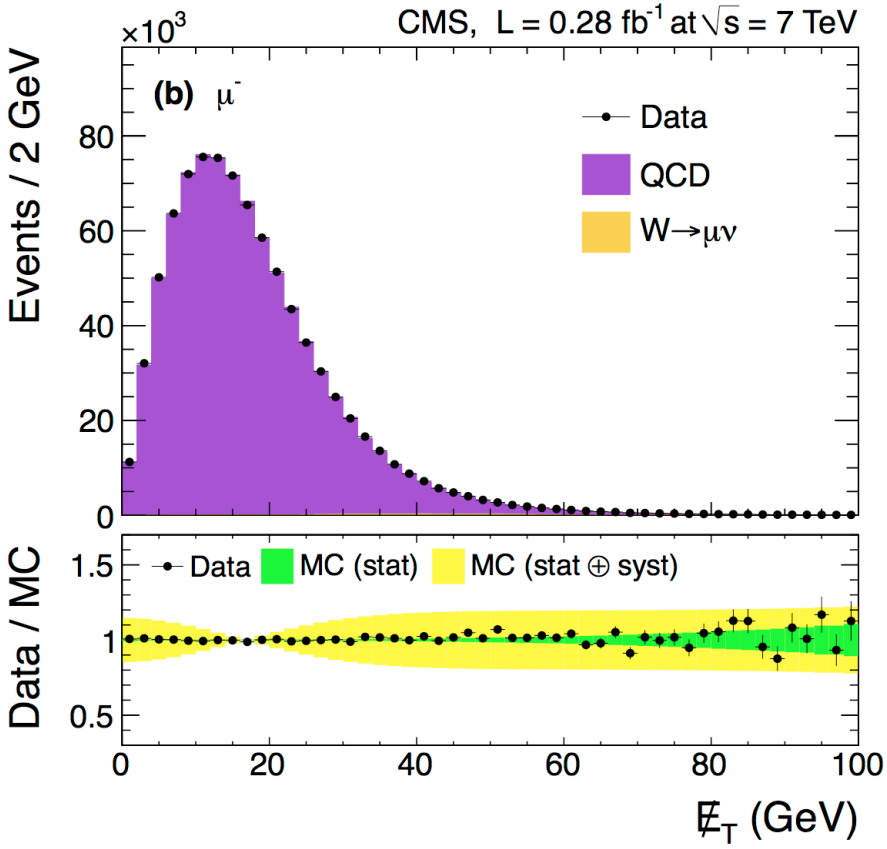


- MET is corrected for the muon Δp_T and MET-Φ modulation
- Additionally, MET in MC is corrected to match average hadronic recoil and its resolution to data values.

QCD Shape

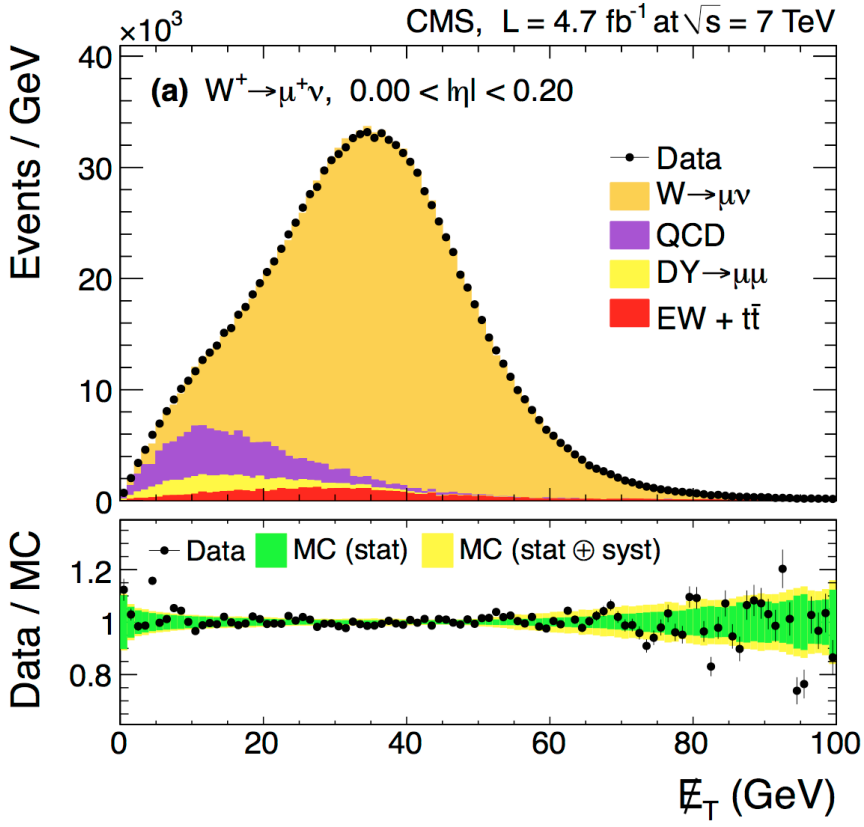
- QCD MET templates from MC, with all corrections applied
- Check how corrections work in QCD control region
  → selected by inverting offline and trigger isolation





- Full correction is taken as systematics (yellow band)

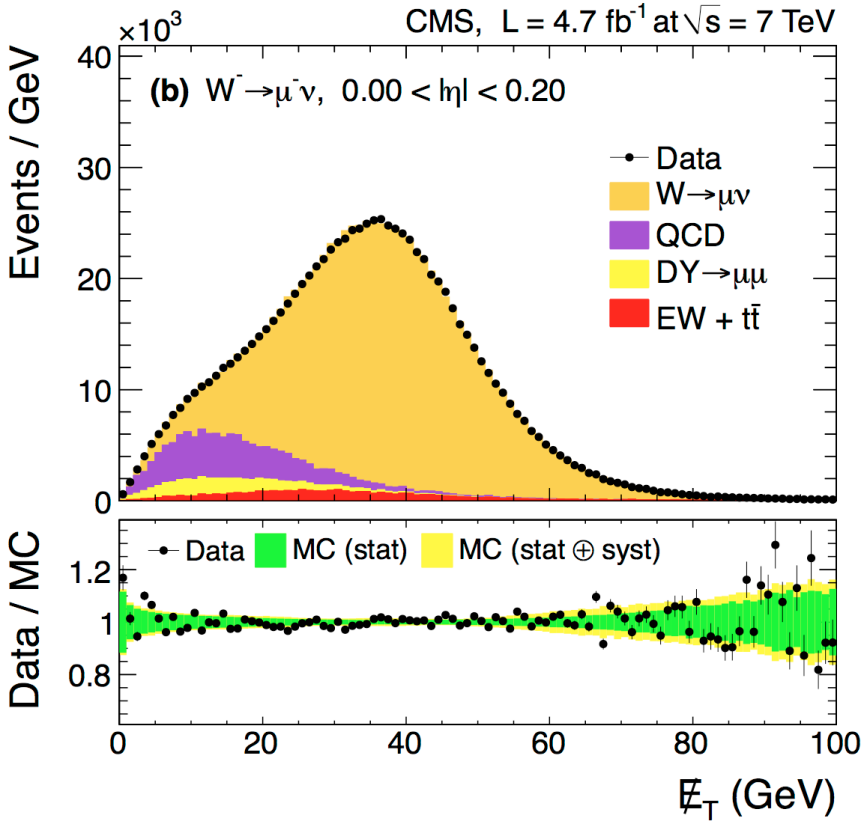
Signal extraction



- Template shapes from MC + corrections

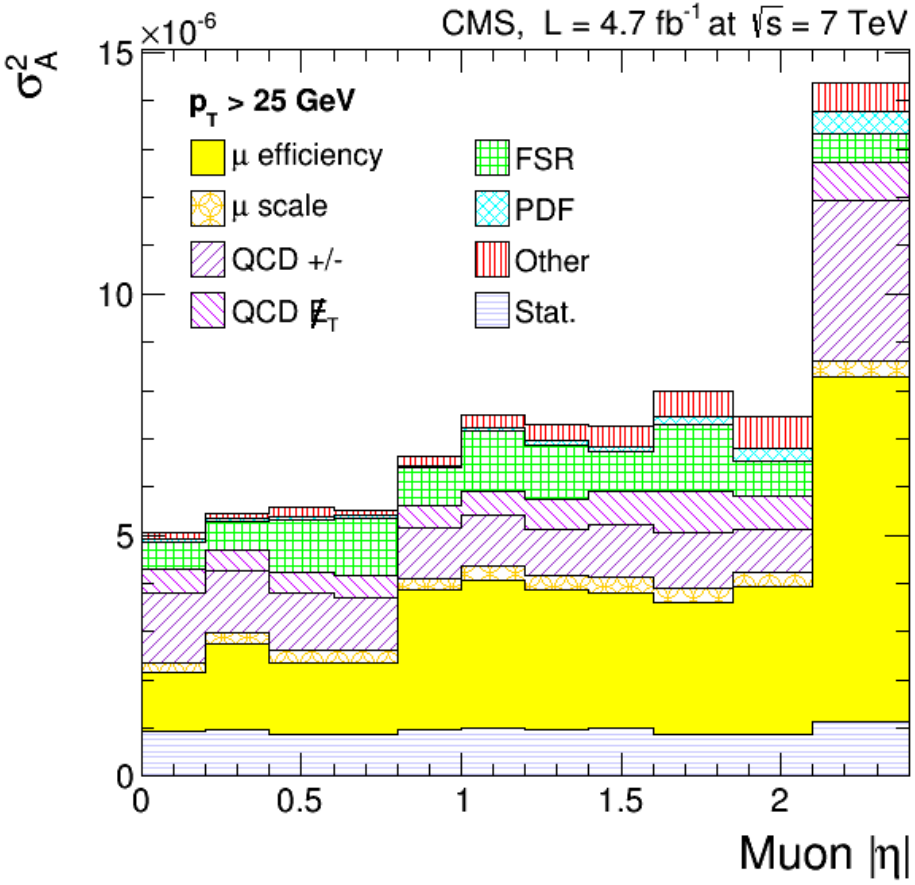
- Floating W^+ and W^- yields
- Floating QCD normalization with +/- fixed to control region value
- EW fixed to luminosity + corrections

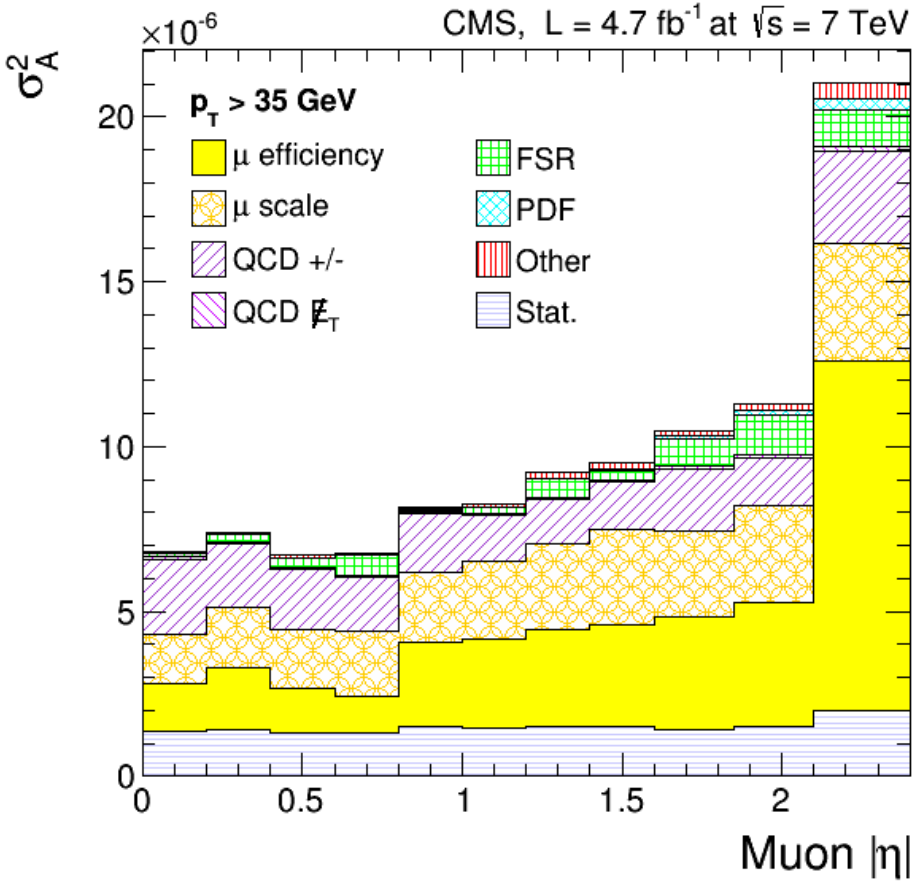
- After all selections about ~12.9M W^+ & 9.1M W^- candidates (~84% signal, ~8% EW, ~8% QCD)
- Signal is extracted with binned ML fit of MET in each $|\eta|$ bin for W^+ and W^- events simultaneously



Systematics

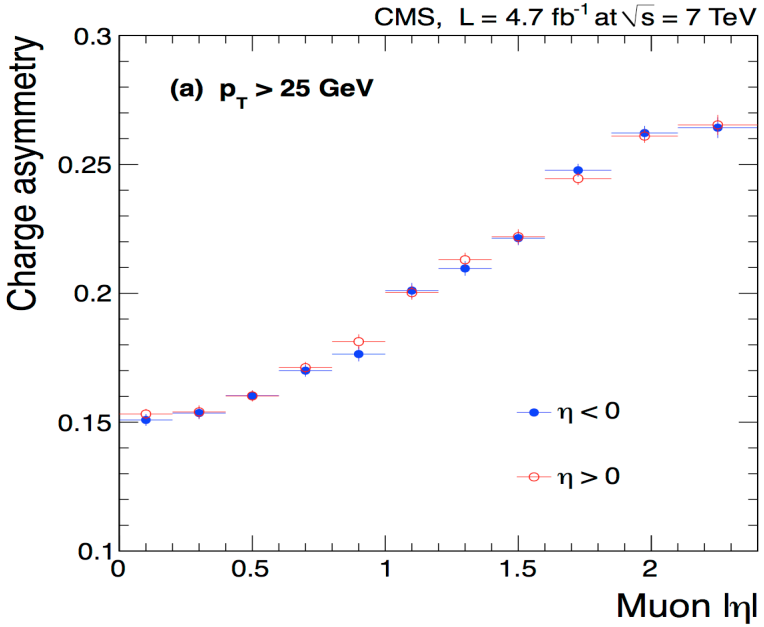
- **Dominant sources of systematics:**
  - $\varepsilon^+/\varepsilon^-$ ratio (limited by Z statistics)
  - QCD
  - Muon momentum for p_T>35 GeV

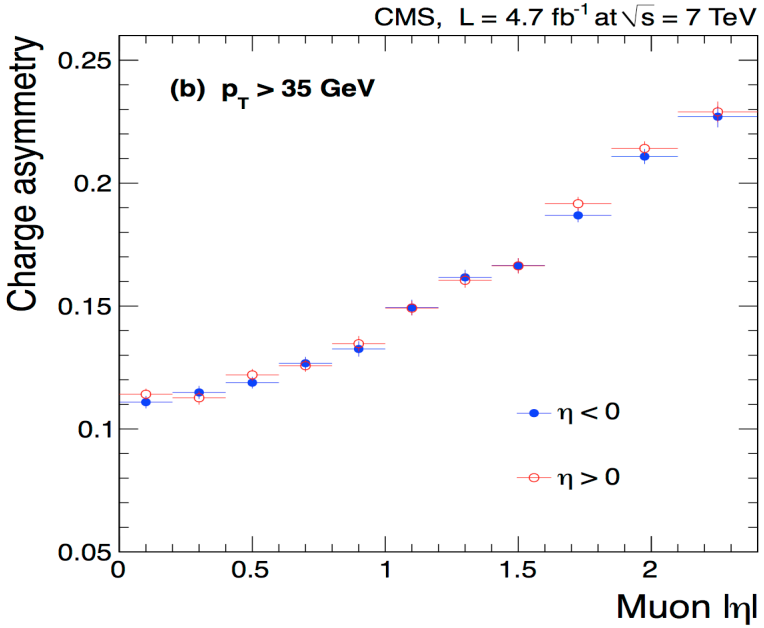




- **Maximum bin-to-bin correlations**
  - ~30% for p_T>25 GeV
  - ~10% for p_T>35 GeV

$\mathcal{A}(+\eta)$ vs $\mathcal{A}(-\eta)$ and comparison with $\mathcal{A}_e$

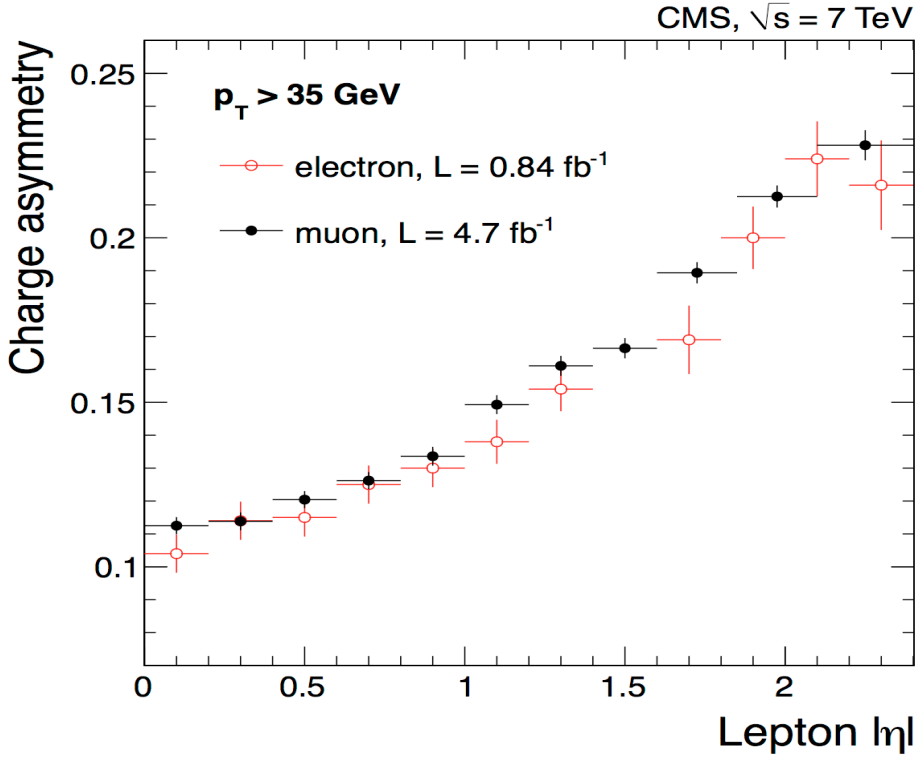




- Re-do analysis in 22 bins and check that

$$\mathcal{A}(+\eta) = \mathcal{A}(-\eta)$$

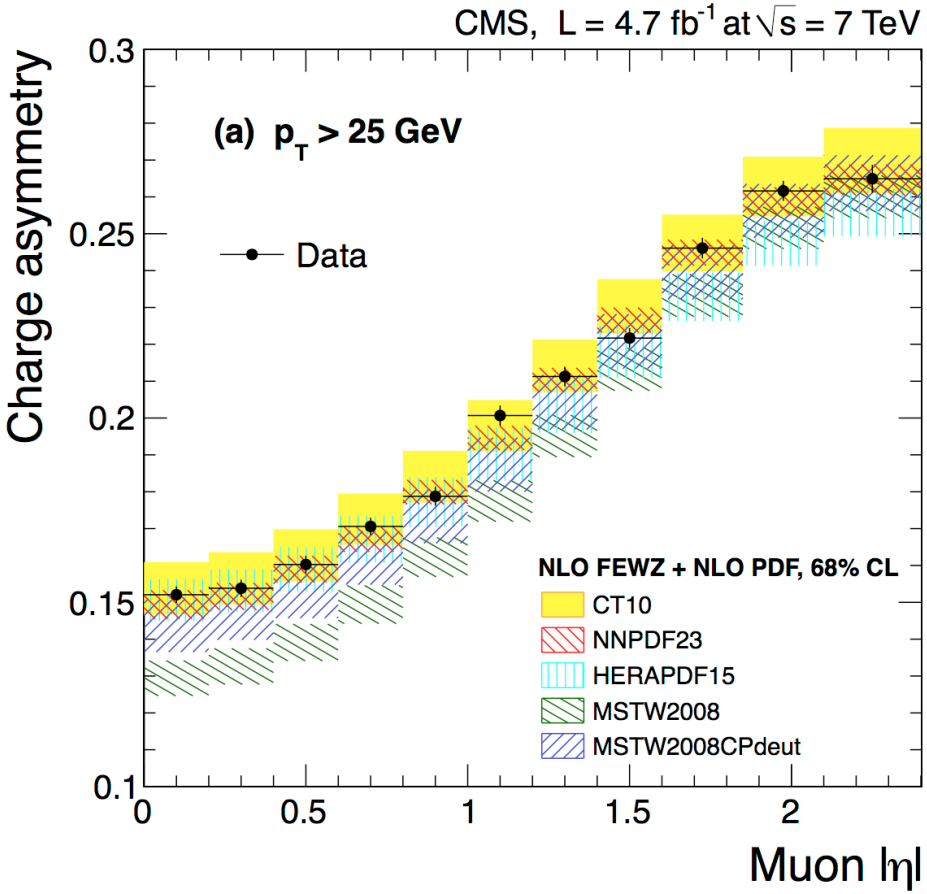
- Compare final result to previous measurement in electron channel
  → complementary input to PDF fits

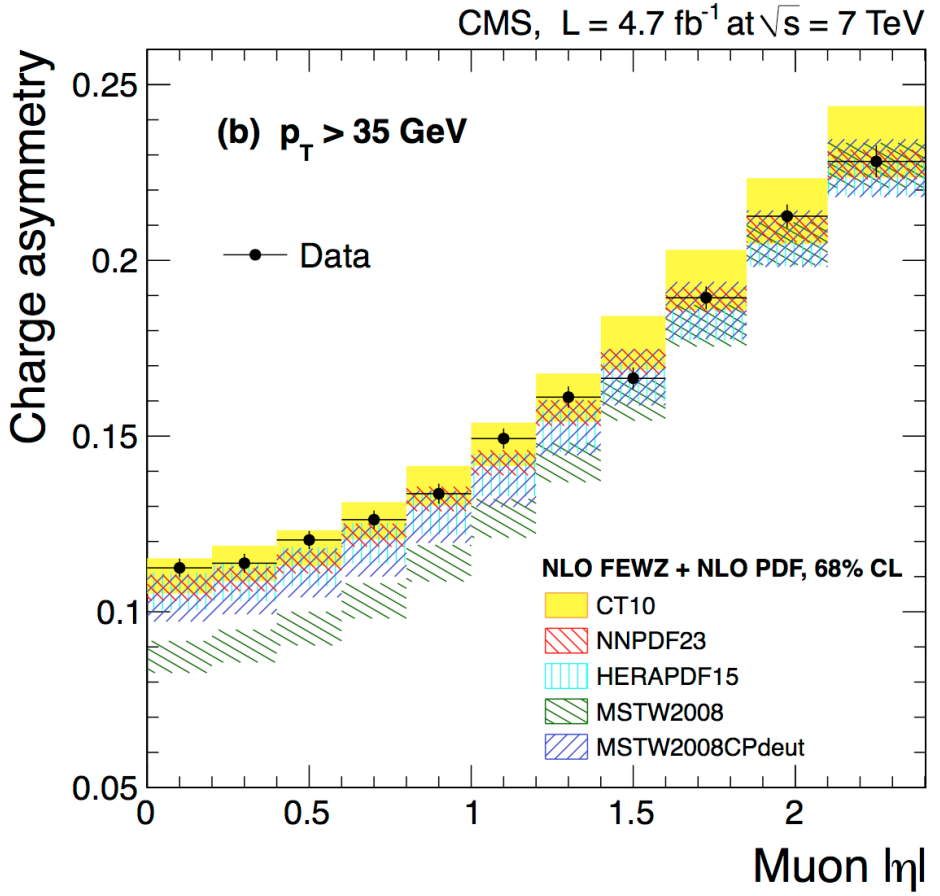


Comparison with theory

- Compare with NLO FEWZ predictions with 5 PDF models

- Good agreement with **CT10**, **NNPDF**, and **HERA**

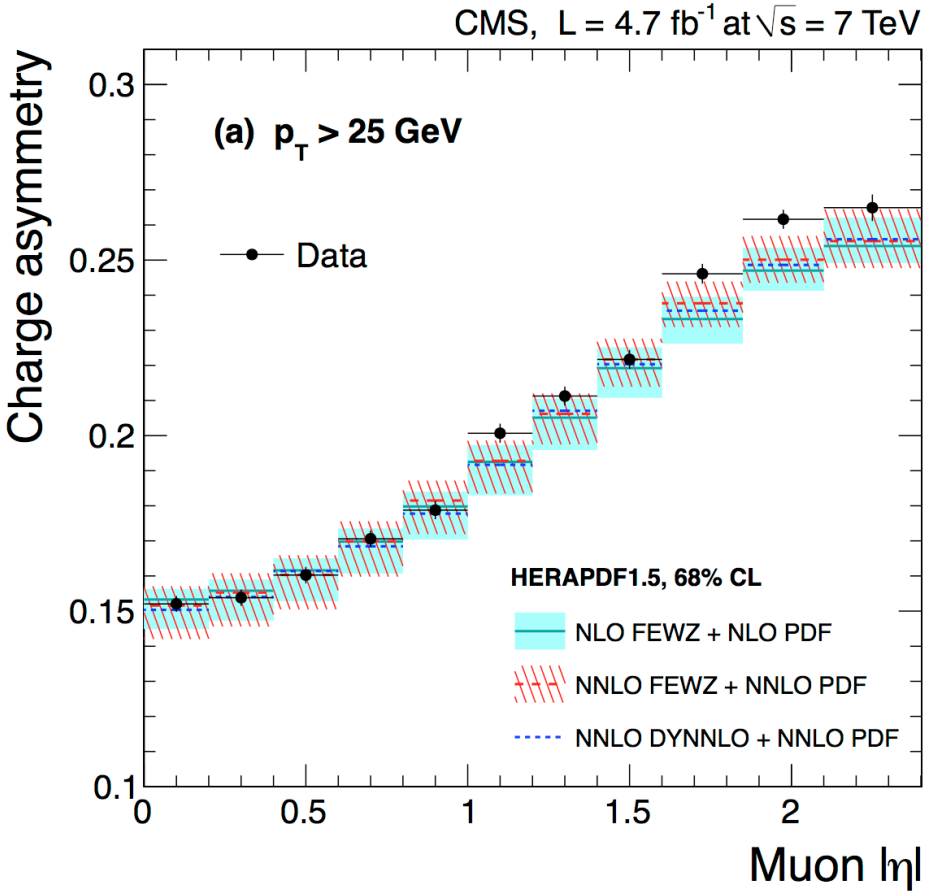


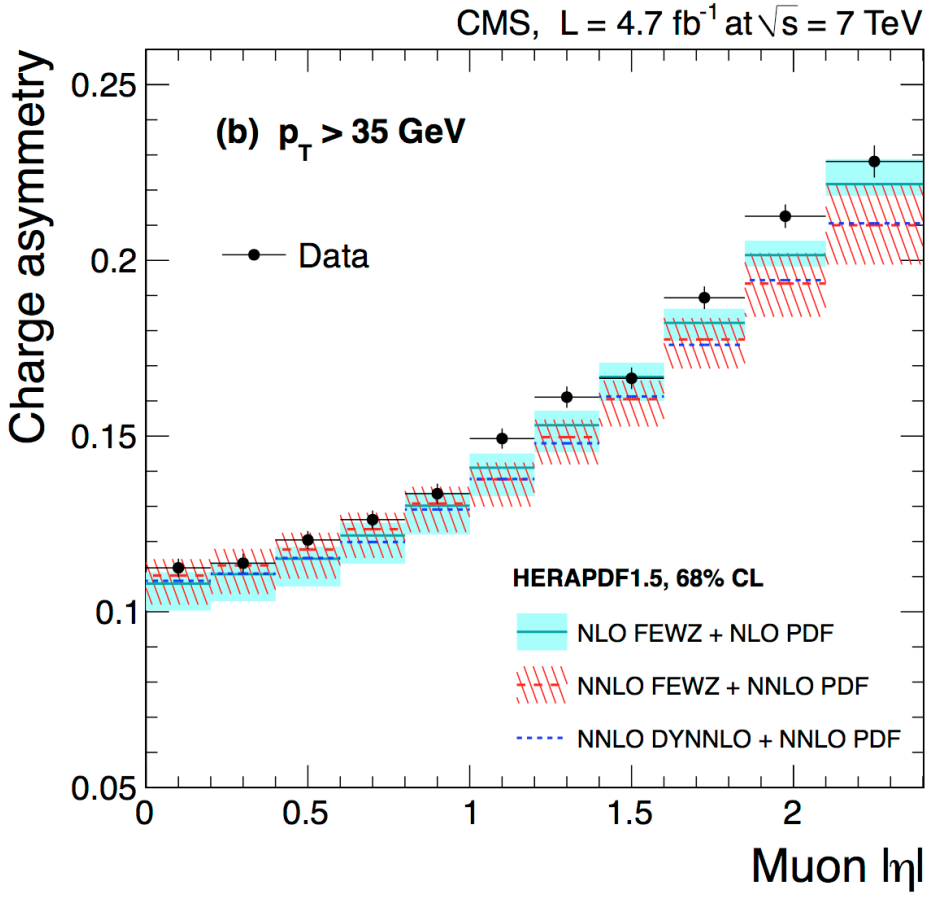


- Poor agreement with **MSTW2008**
  → was also noted with electron $\mathcal{A}$
- Significantly improved by flexible parameterization in **MSTW2008CPdeut**

NLO vs NNLO

- Compare **FEWZ** predictions with **HERA** at **NLO** *vs* **NNLO**
- Also cross-check with **DYNNLO** calculation

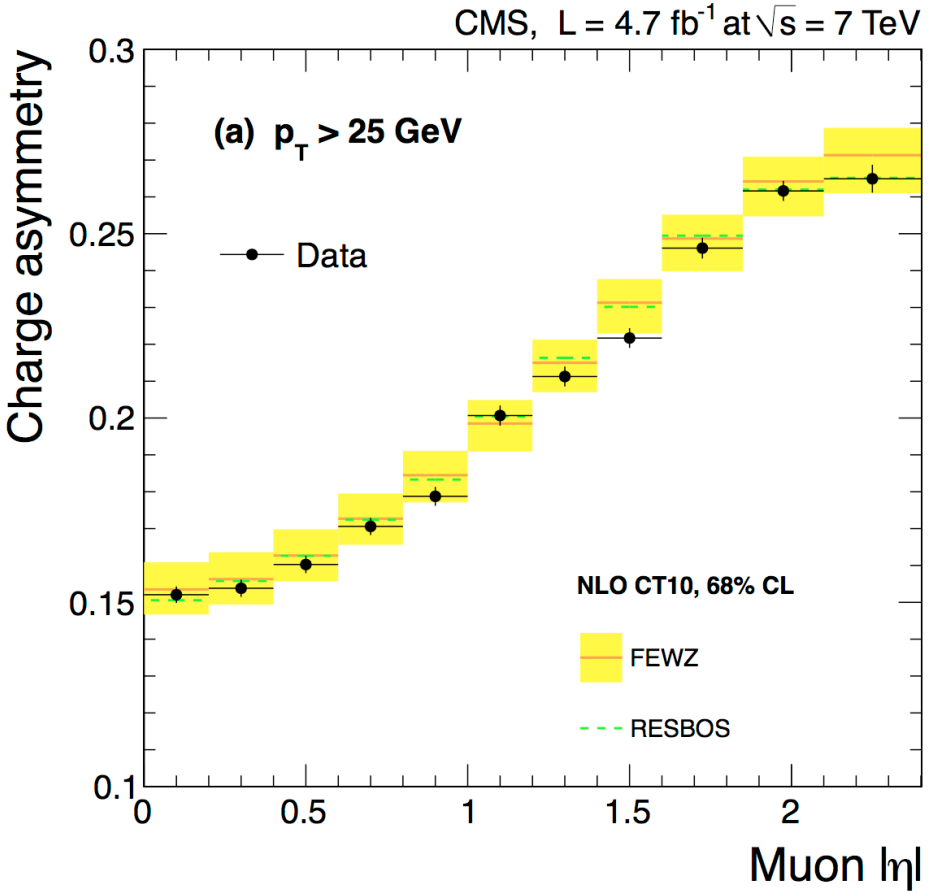


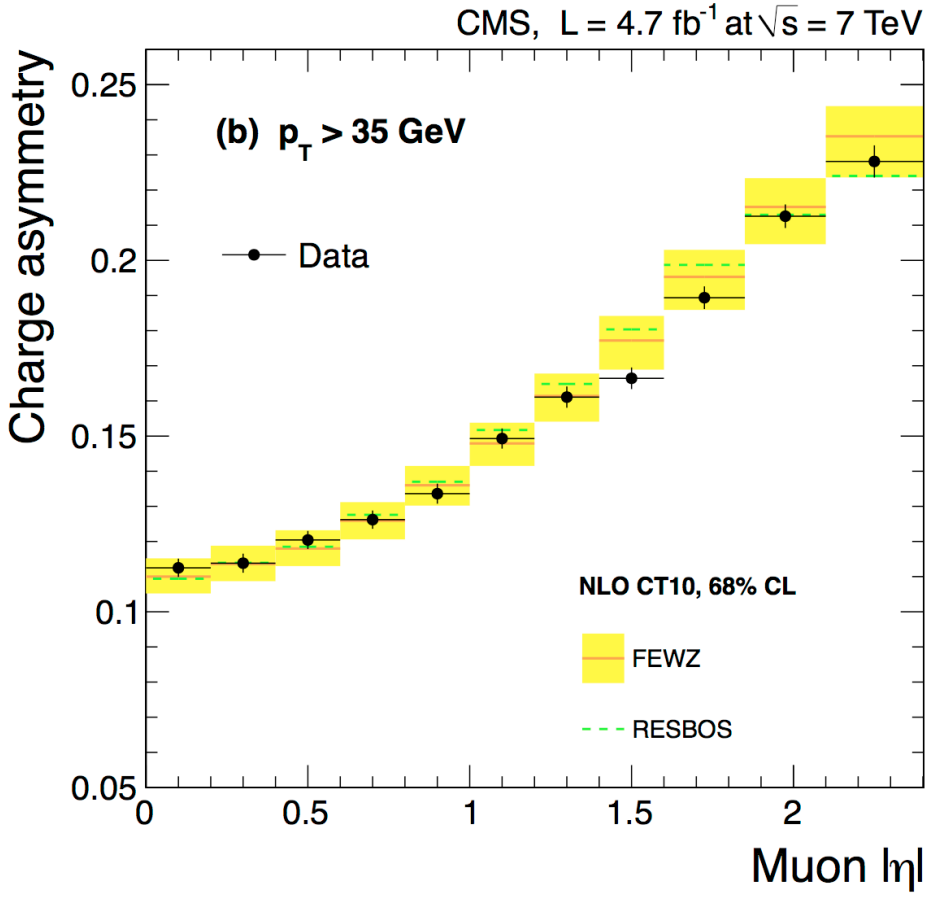


- For p_T>25 GeV no significant difference between NLO and NNLO
- For p_T>35 GeV difference becomes more significant at high η

FEWZ vs RESBOS

- Compare predictions with **CT10** by **FEWZ** *vs* **RESBOS** to see if $\mathcal{A}$ is sensitive to fixed-order *vs* re-summation calculations



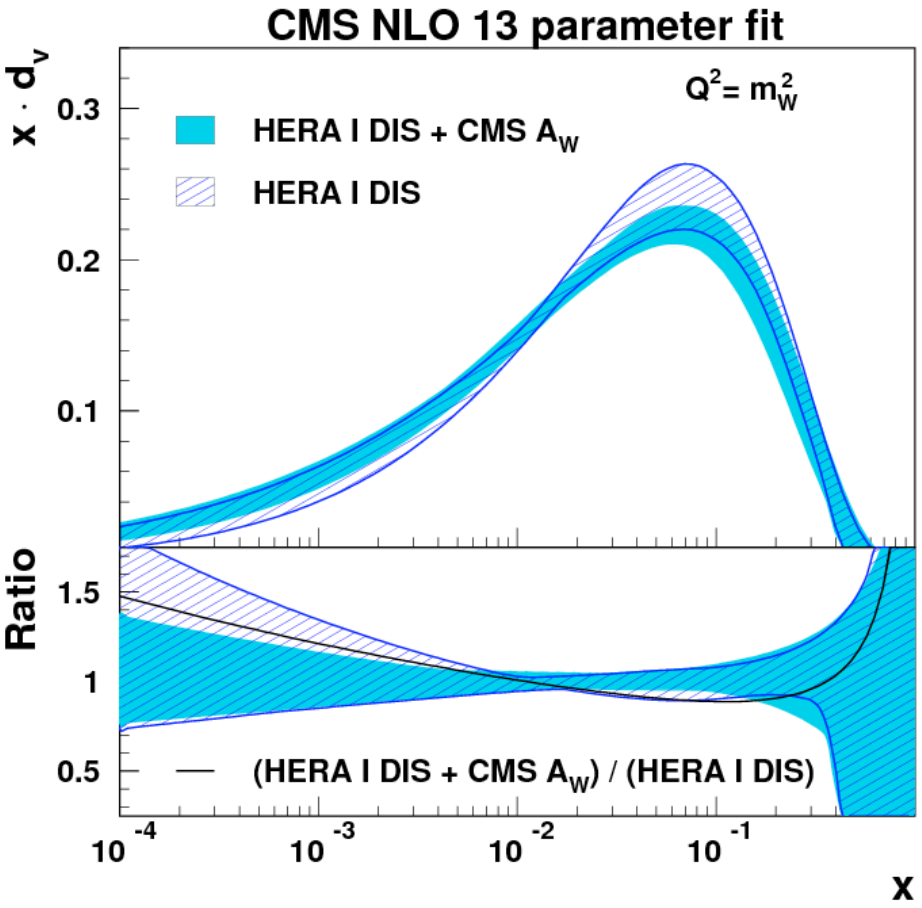


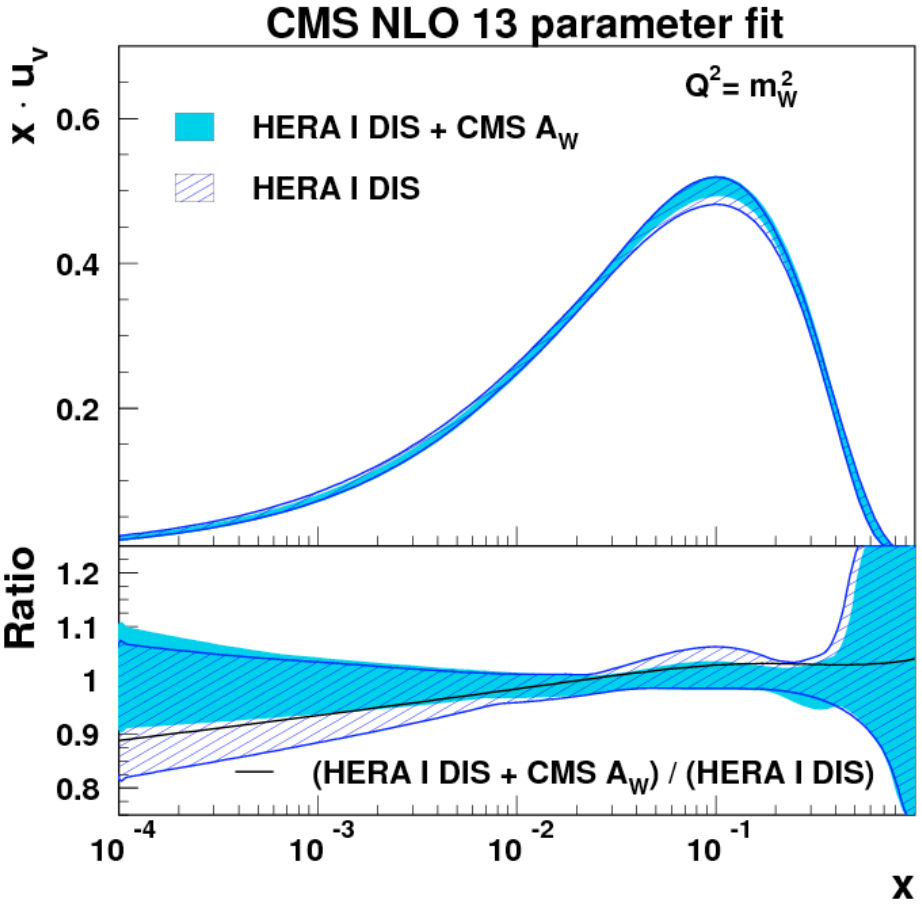
- No significant difference observed

Impact of $\mathcal{A}$ data on PDFs

- Look at the impact of including $\mathcal{A}$ result in **HERA** PDF fit

- $X^2/\mathrm{ndof} = 14/11$

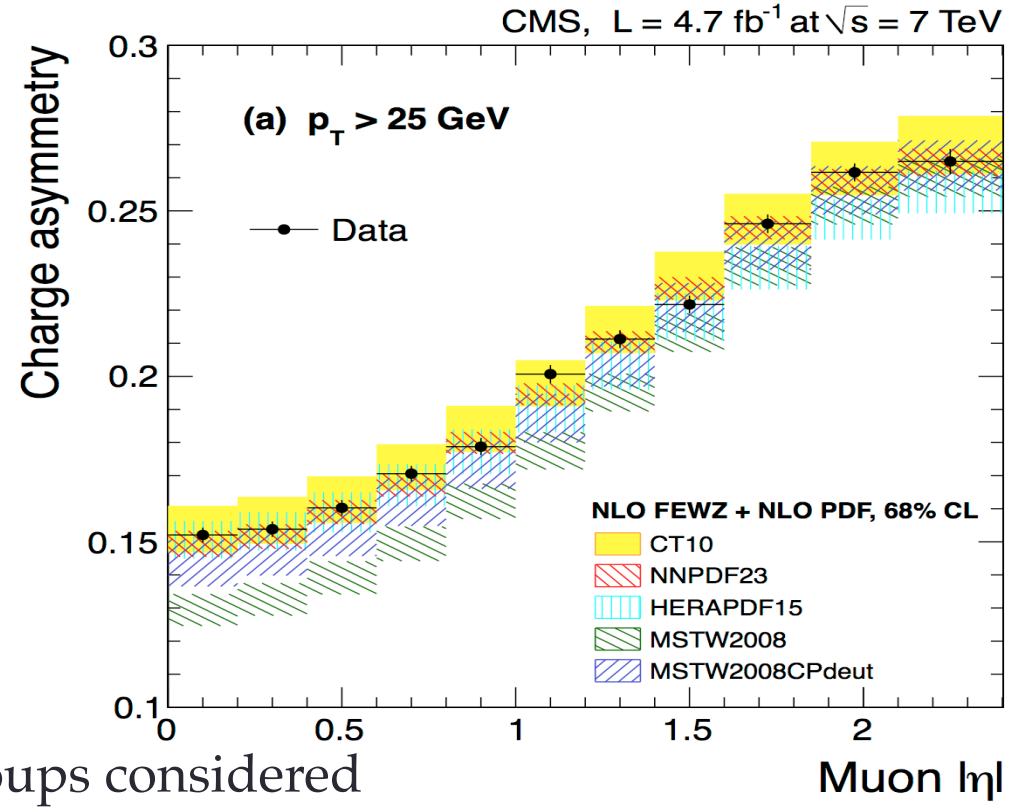




- Significant impact on valence $\mathbf{d}_v$ quark
- Some sensitivity to strange quark
  (→ more in Ringaile's talk)

Summary and Outlook

- Muon charge $\mathcal{A}$ measured with full 2011 7 TeV data (4.7 fb^{-1})
- Measurement precision
  $\delta\mathcal{A} \sim 0.2\%\text{-}0.4\%$
- Dominant systematics:
  - Efficiency ratio $\varepsilon+/\varepsilon-$
  - QCD
  - Muon scale (for p_T>35 GeV)
- Result is in good agreement with most recent PDF models of all groups considered



- Can make significant contribution to global QCD analysis
- Analysis of 8 TeV data ongoing:
  - Expect similar or better precision → can provide additional input
  - Preparatory step towards analysis of 13/14 TeV data
- More to come → https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP

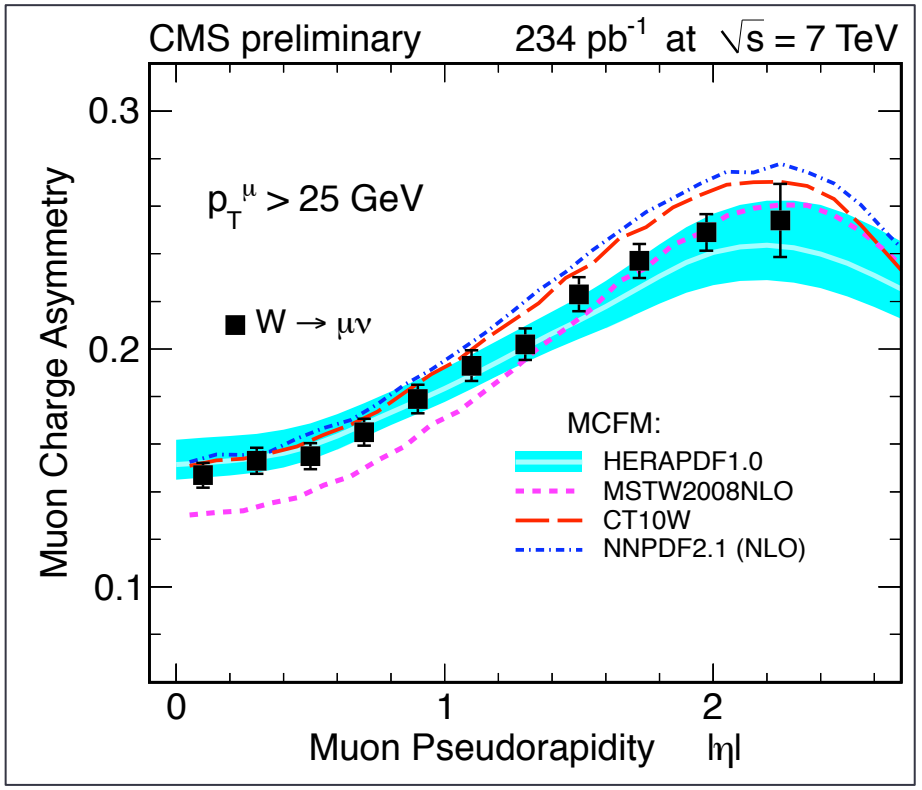
Thank you!

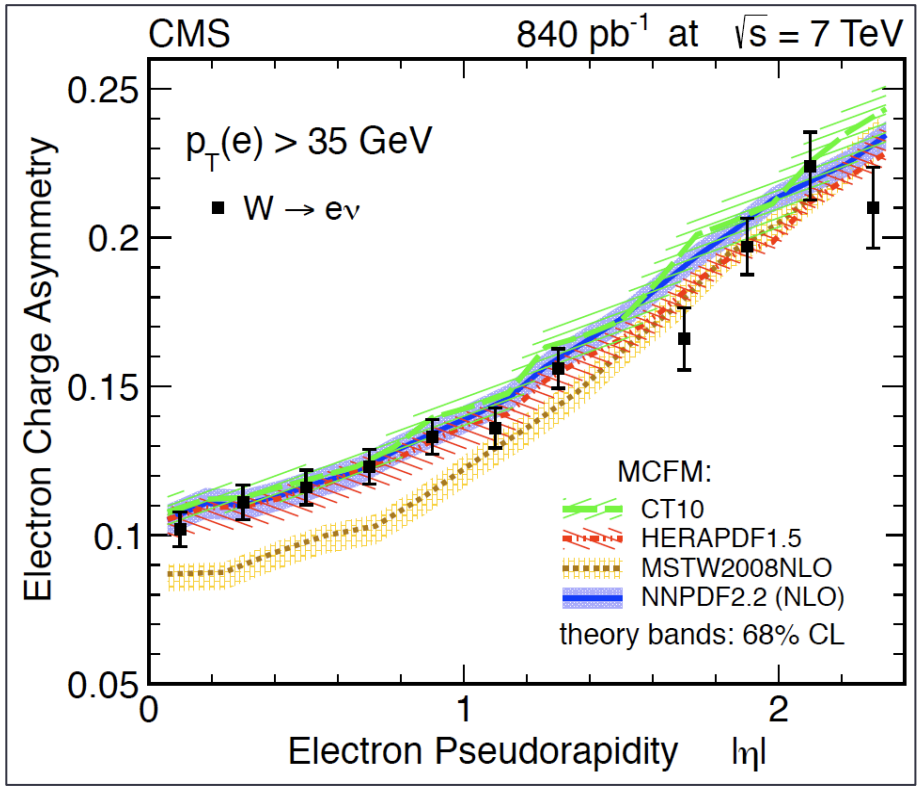
Backup

Latest CMS $\mathcal{A}$ measurements

- Preliminary muon charge asymmetry results:
  - First 234 pb^{-1} of 7 TeV data
  - **p_T>25 GeV**

- Published electron charge asymmetry results:
  - First 840 pb^{-1} of 7 TeV data
  - **p_T>35 GeV**





- Our measurement updates muon $\mathcal{A}$ results with full **4.7 fb^{-1}** dataset
  - **p_T>25 GeV** (main result) and **p_T>35 GeV** (cross-check)

Tevatron Asymmetry Measurements

- $\mathcal{A}(y_W)$ is sensitive to u/d ratio

$$\mathcal{A}(y_W) \approx \frac{d(x_2)/u(x_2) - d(x_1)/u(x_1)}{d(x_2)/u(x_2) + d(x_1)/u(x_1)}$$

- CDF used W mass constraint to unfold asymmetry as a function of W rapidity

$$x_{1,2} = \frac{M_W}{\sqrt{s}} e^{\pm y_W}$$

- Latest DØ muon charge asymmetry measured with 7.3 fb^{-1}