W ASYMMETRY AT THE TEVATRON: INTERPRETATION

April 11, 2011

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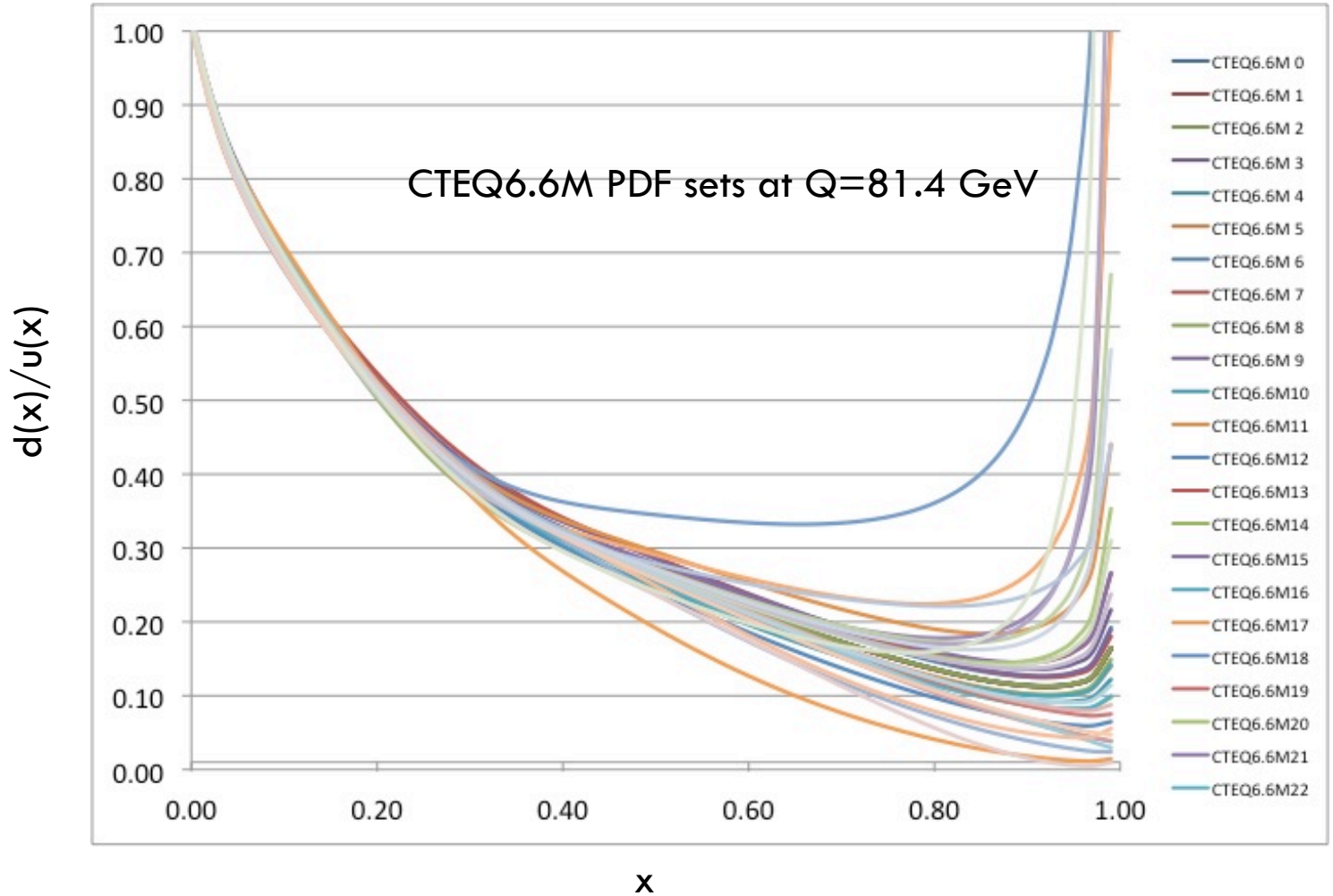
April 6, 2011

What do we know about d(x)/u(x)?

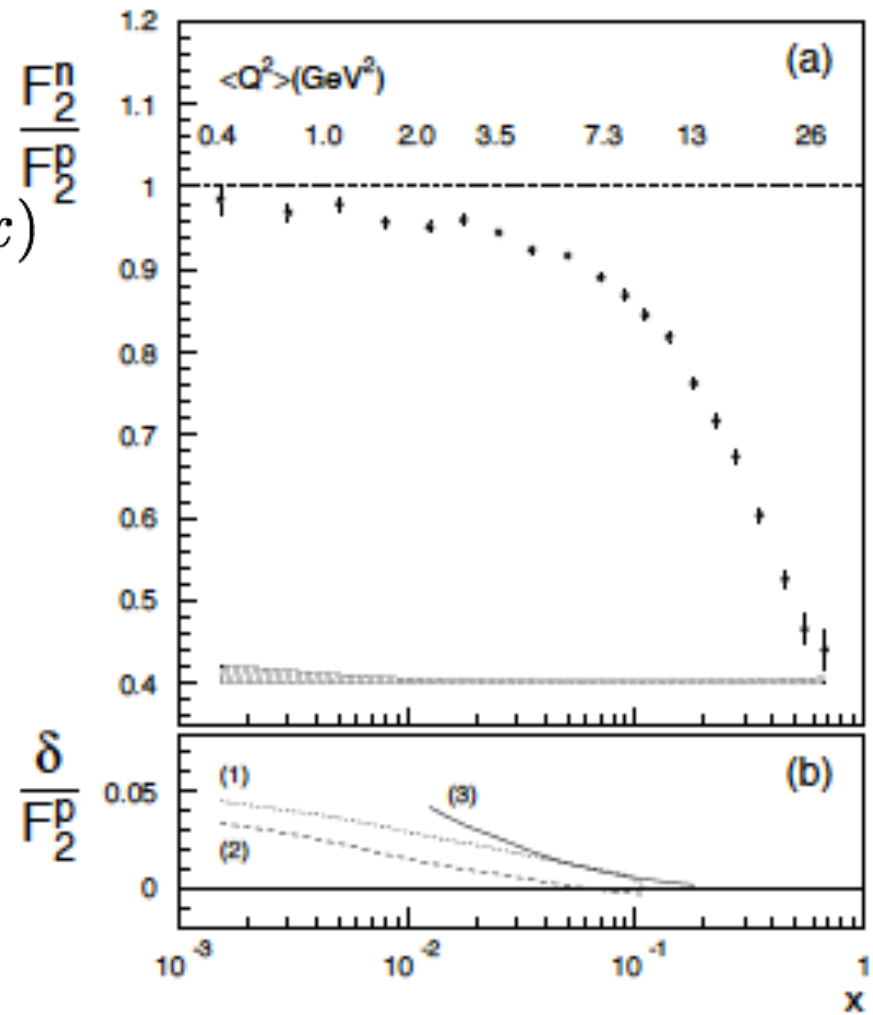


Main input to PDF's is D/H in DIS

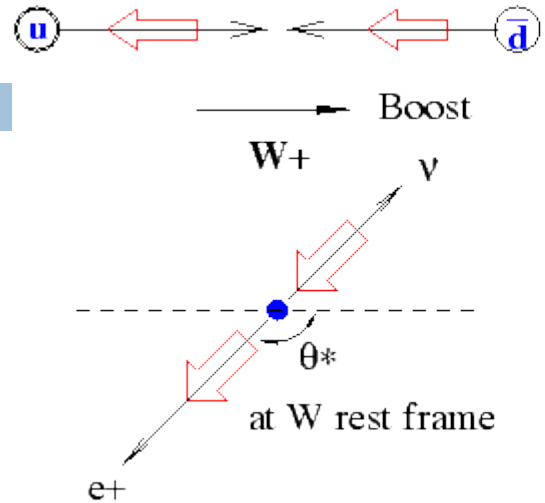
$$F_2^n(x) \simeq 2F_2^D - F_2^p(x) + \delta_{nucl}(x)$$

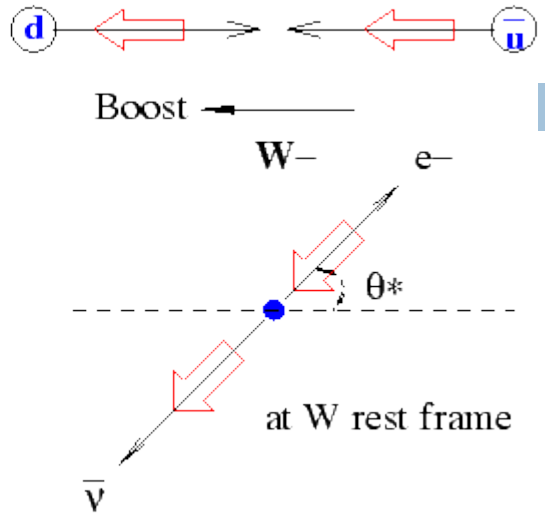
$$F_2^n/F_2^p \simeq \frac{1 + 4d(x)/u(x)}{4 + d(x)/u(x)}$$

- NMC, Arneodo et al, Nucl.Phys.B483,(1997)

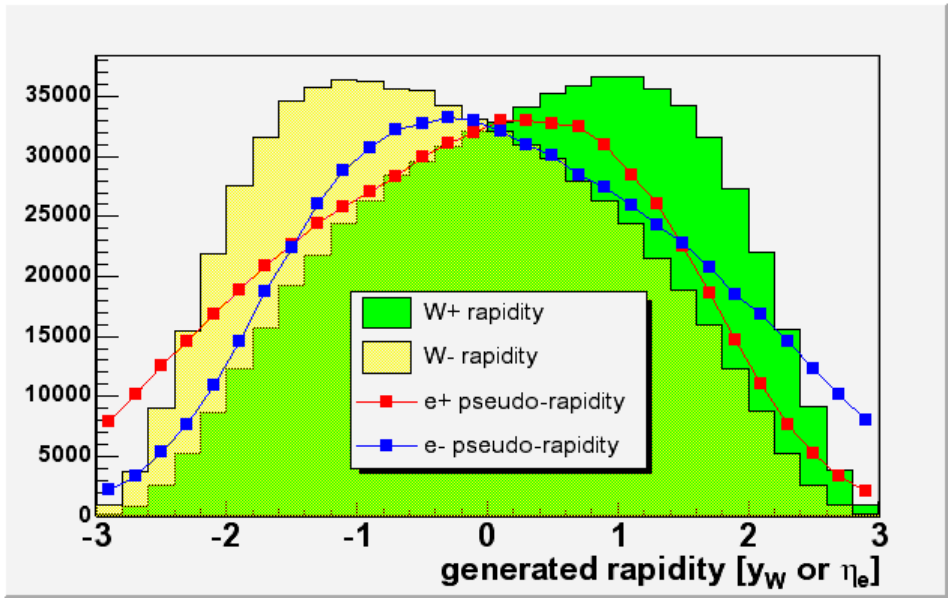


W asymmetry in p-pbar collisions





- If u quarks carry more momentum than d quarks, the W^+ will head in the proton direction preferentially.
- Unfortunately, the V-A interaction means that the charged lepton from W decay heads backwards in the W frame



W Asymmetry in p-pbar collisions

$$A(y_W) = \frac{\frac{d\sigma(W^+)}{dy_W} - \frac{d\sigma(W^-)}{dy_W}}{\frac{d\sigma(W^+)}{dy_W} + \frac{d\sigma(W^-)}{dy_W}} \simeq \frac{u(x_1)/d(x_1) - u(x_2)/d(x_2)}{u(x_1)/d(x_1) + u(x_2)/d(x_2)}$$

- Where $u(x)$ and $d(x)$ are the u and d quark parton distribution functions in the proton and
- x_1 and x_2 are the momentum fractions in the proton and anti-proton.

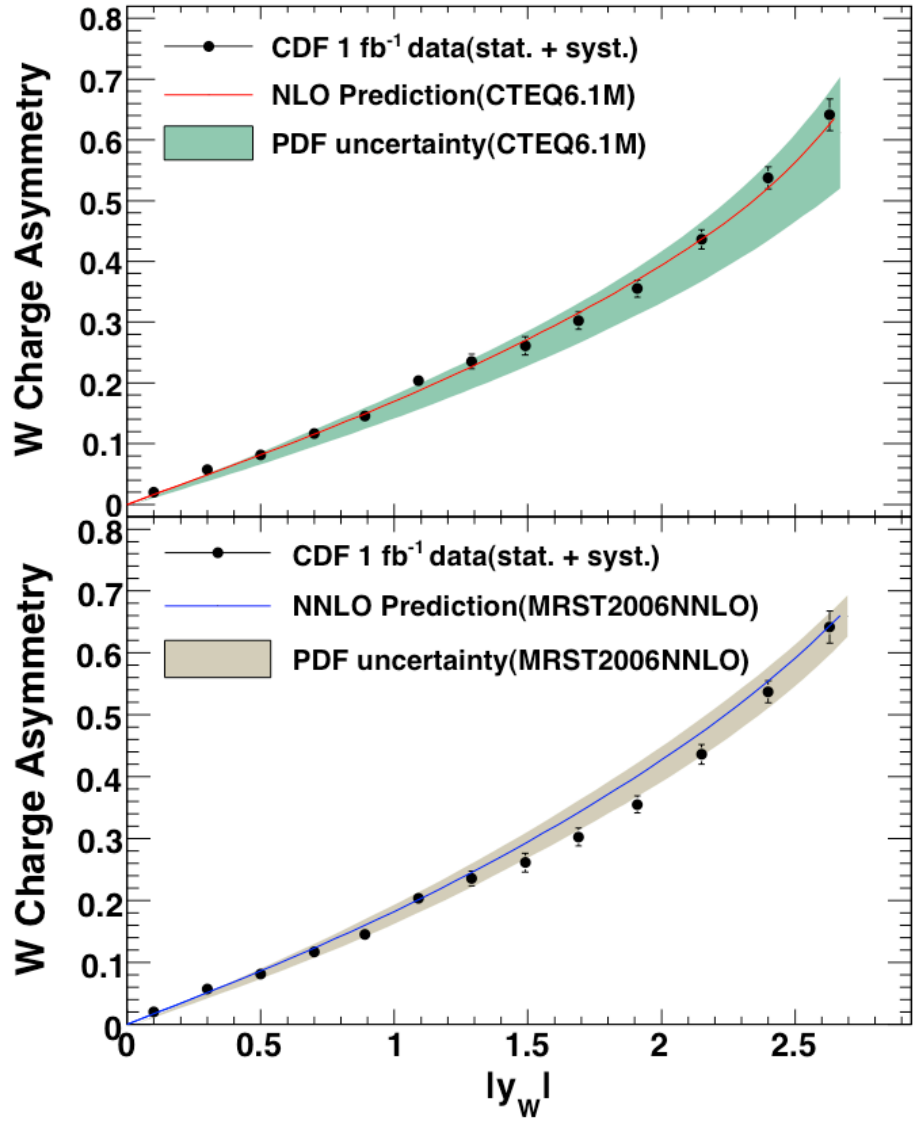
Phys. Rev. Lett. 102, 181801 (2009).

CDF Result (1 fb^{-1})

Direct measure of the W asymmetry by estimating the neutrino kinematics with a mass constraint

Compare to CTEQ6.1M (NLO) and MRST2006 (NNLO) PDFs and their uncertainties

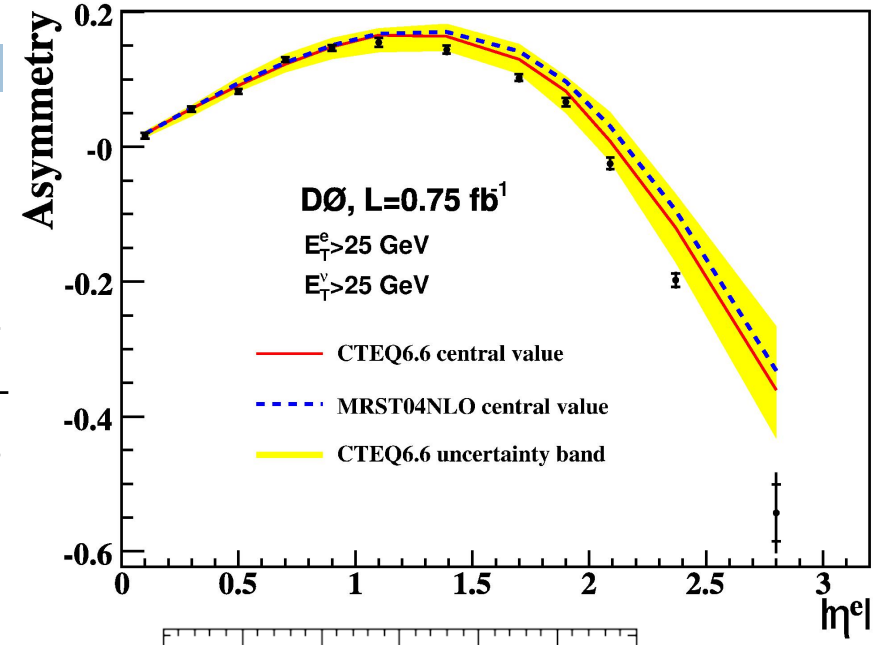
Experimental precision is *much* better than the theoretical error band!



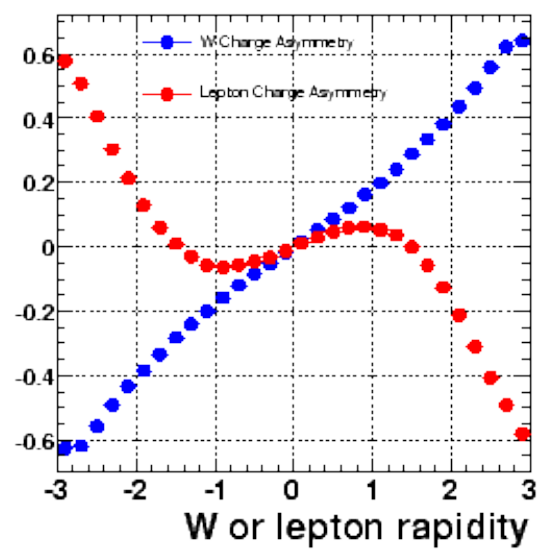
Traditional Lepton method

- Lepton Asymmetry

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



- Experimentally very well defined
- Theory comparison depends on good knowledge of helicity structure and modeling of PT, rapidity distributions.



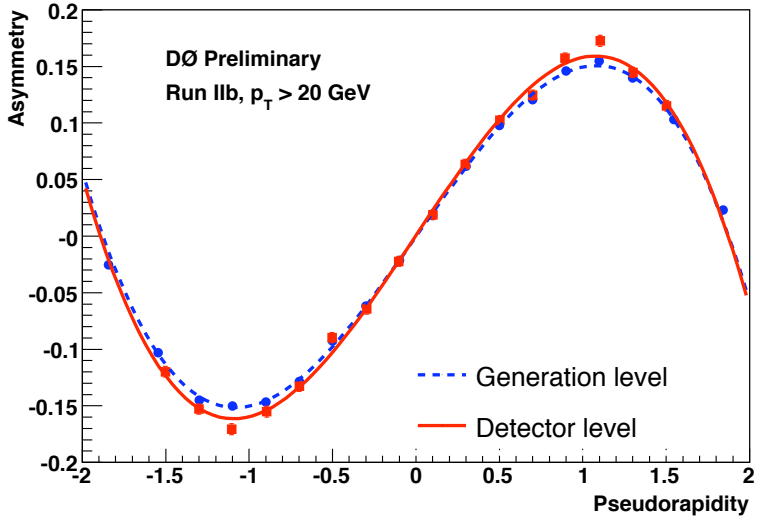
D0 muon charge asymmetry

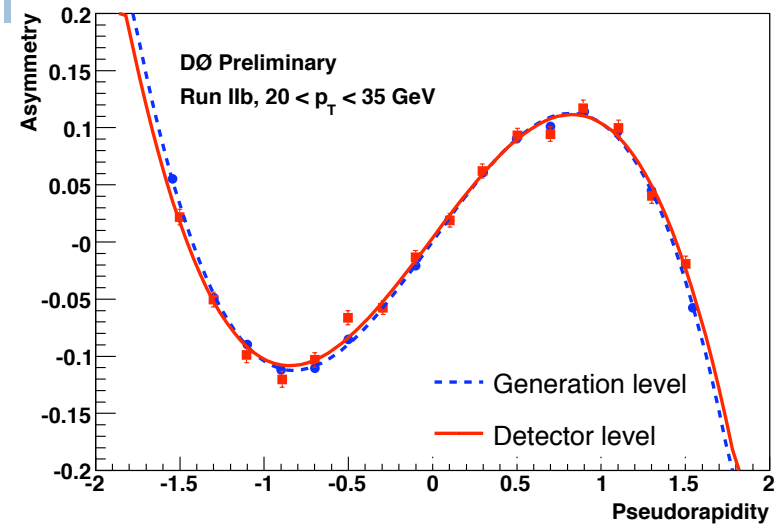
$\mathcal{L}$ = 4.9 fb^{-1}, 2.3 M reconstructed W decays!

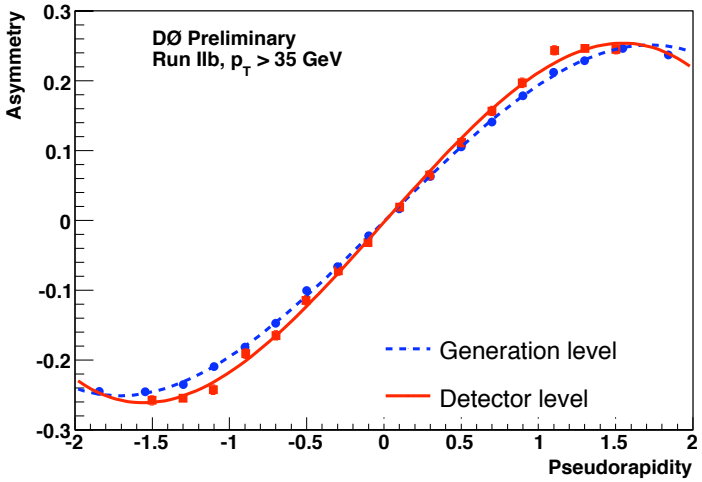
Previous Publications from TeV Run II

- ☐ D0: Measurement of the Muon Charge Asymmetry from W Boson Decays, Phys. Rev. D77, 011106 (2008), 0.3 fb^{-1}
- ☐ D0: Measurement of the Electron Charge Asymmetry, Phys. Rev. Lett 101, 211801 (2008), 0.7 fb^{-1}
- ☐ CDF: W boson charge asymmetry vs W rapidity, Phys. Rev. Lett. 102, 181801 (2009), 1 fb^{-1}
- ☐ CDF: lepton charge asymmetry, Phys. Rev. D71, 051104, 0.17 fb^{-1}

Muon Asymmetry measurement 2.3 M W decays!



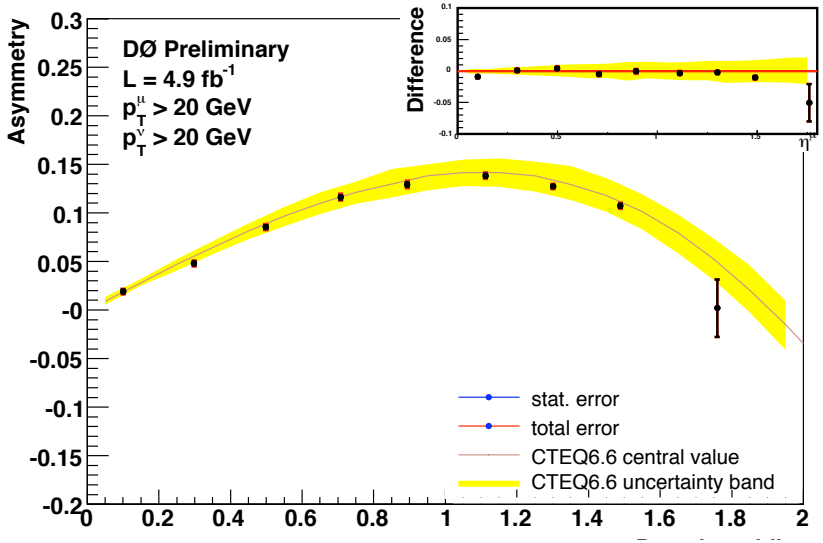


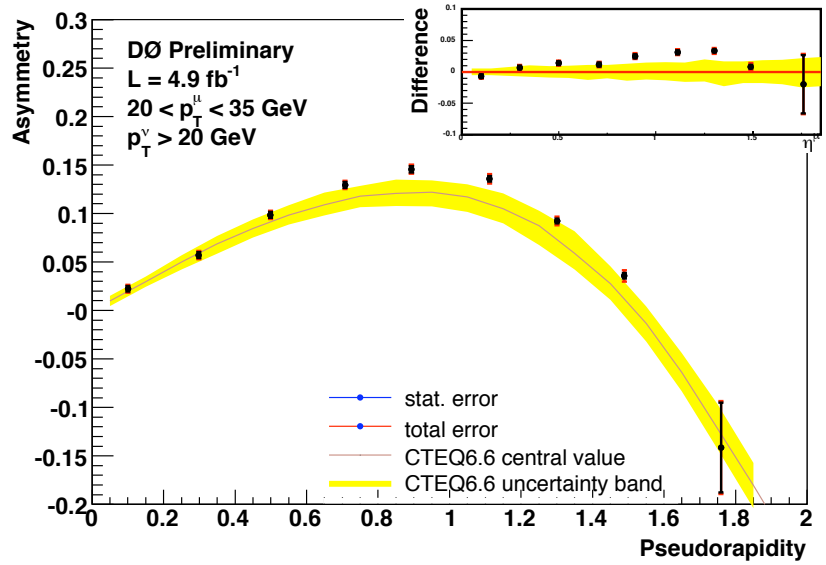


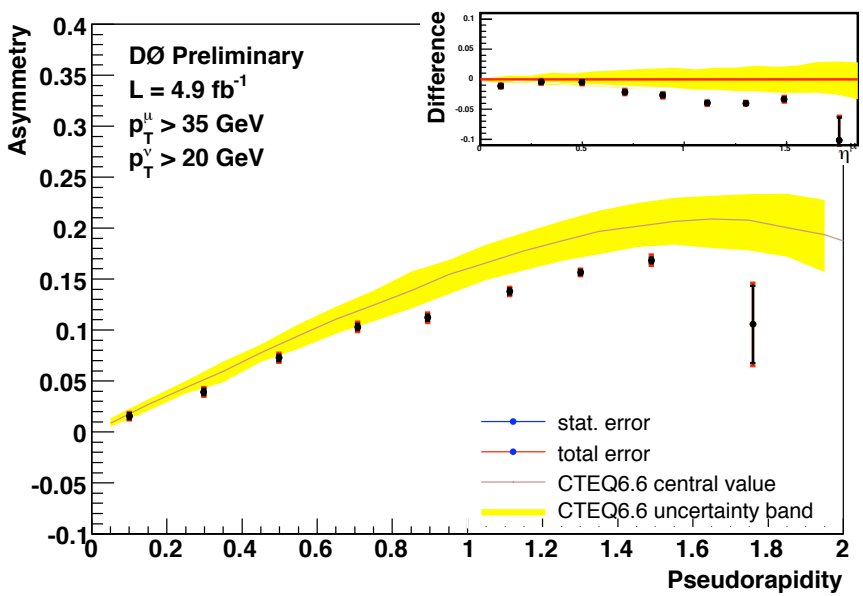
Momentum smearing can cause events to migrate between PT bins
Rapidity smearing is negligible.

Raw asymmetries are corrected for charge misid, backgrounds and for momentum smearing to get the lepton asymmetry.

Results compared to RESBOS+CTEQ6.6M





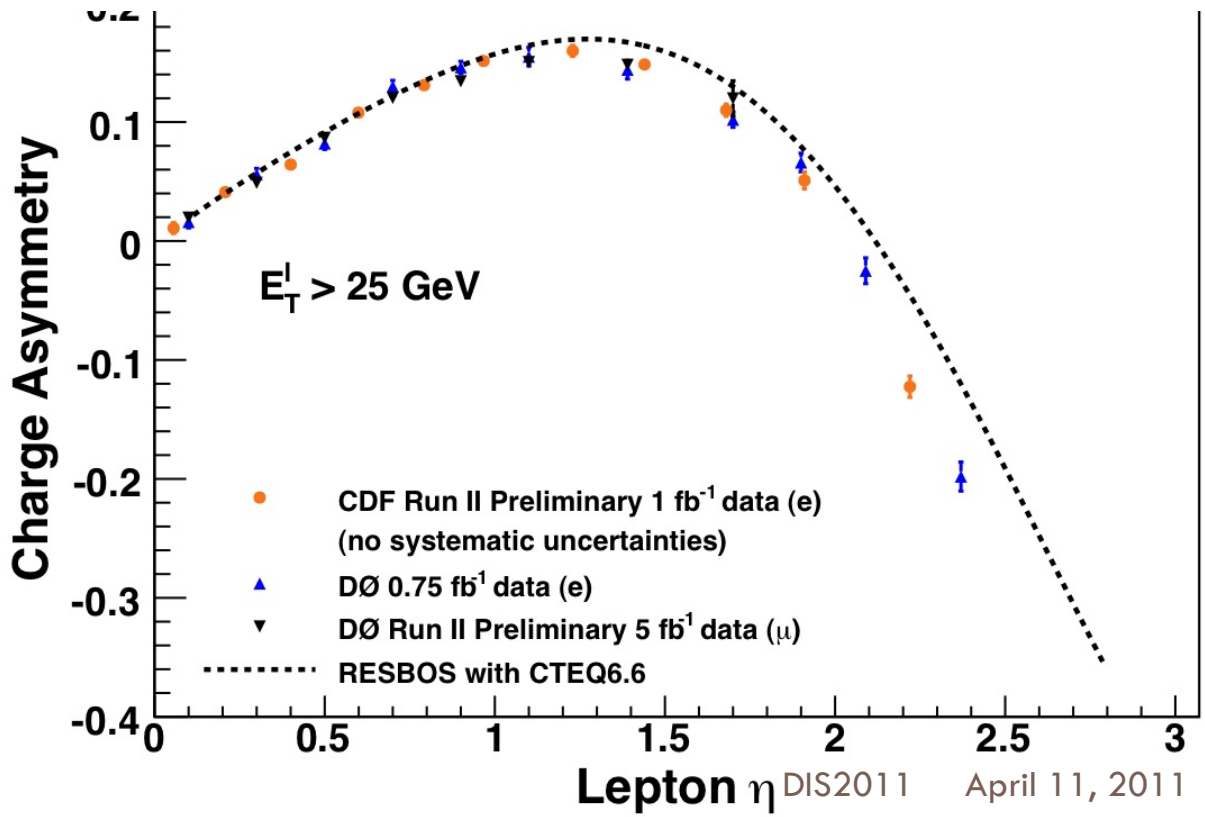


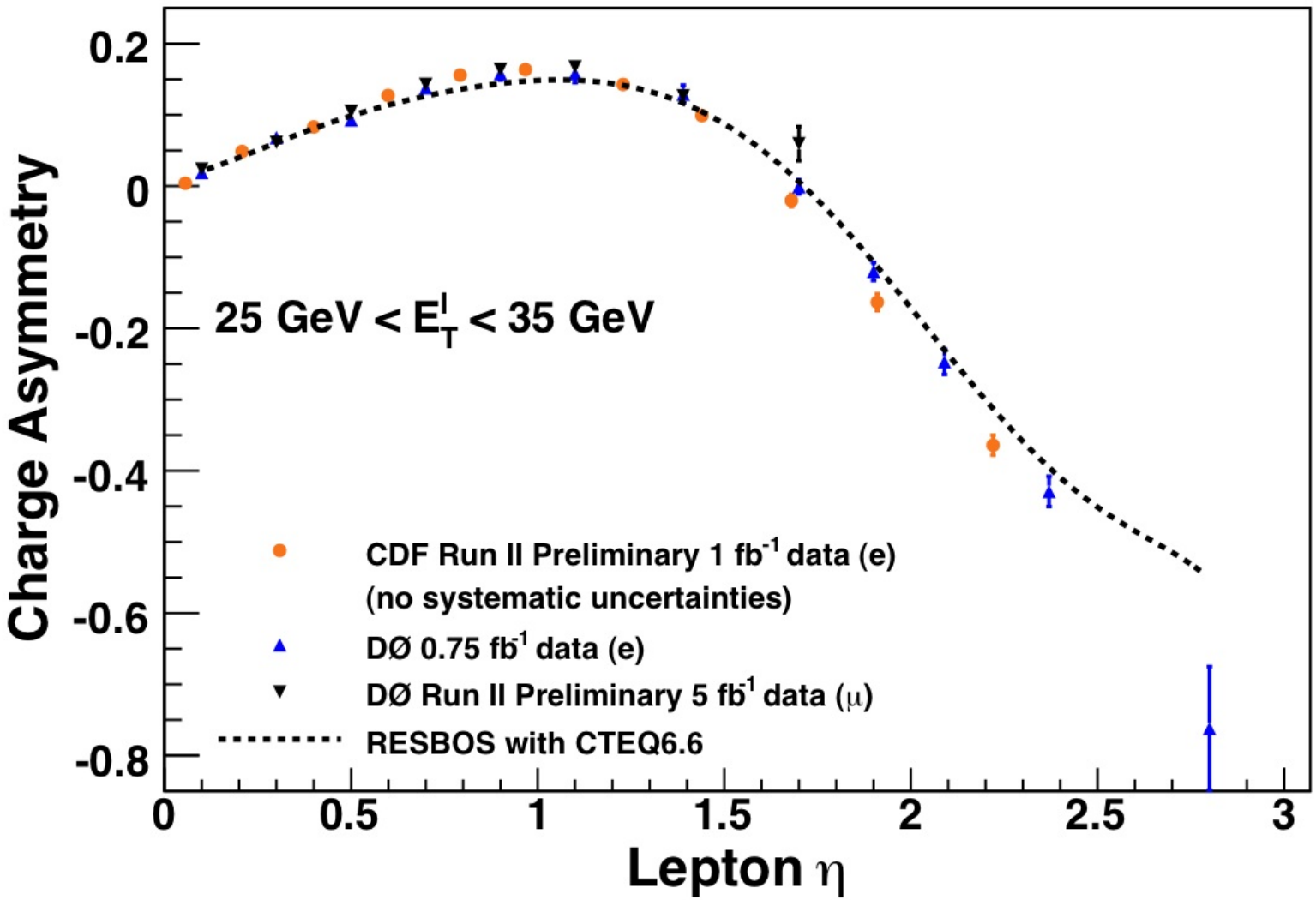
3 muon PT bins, PT(ν) > 20 GeV

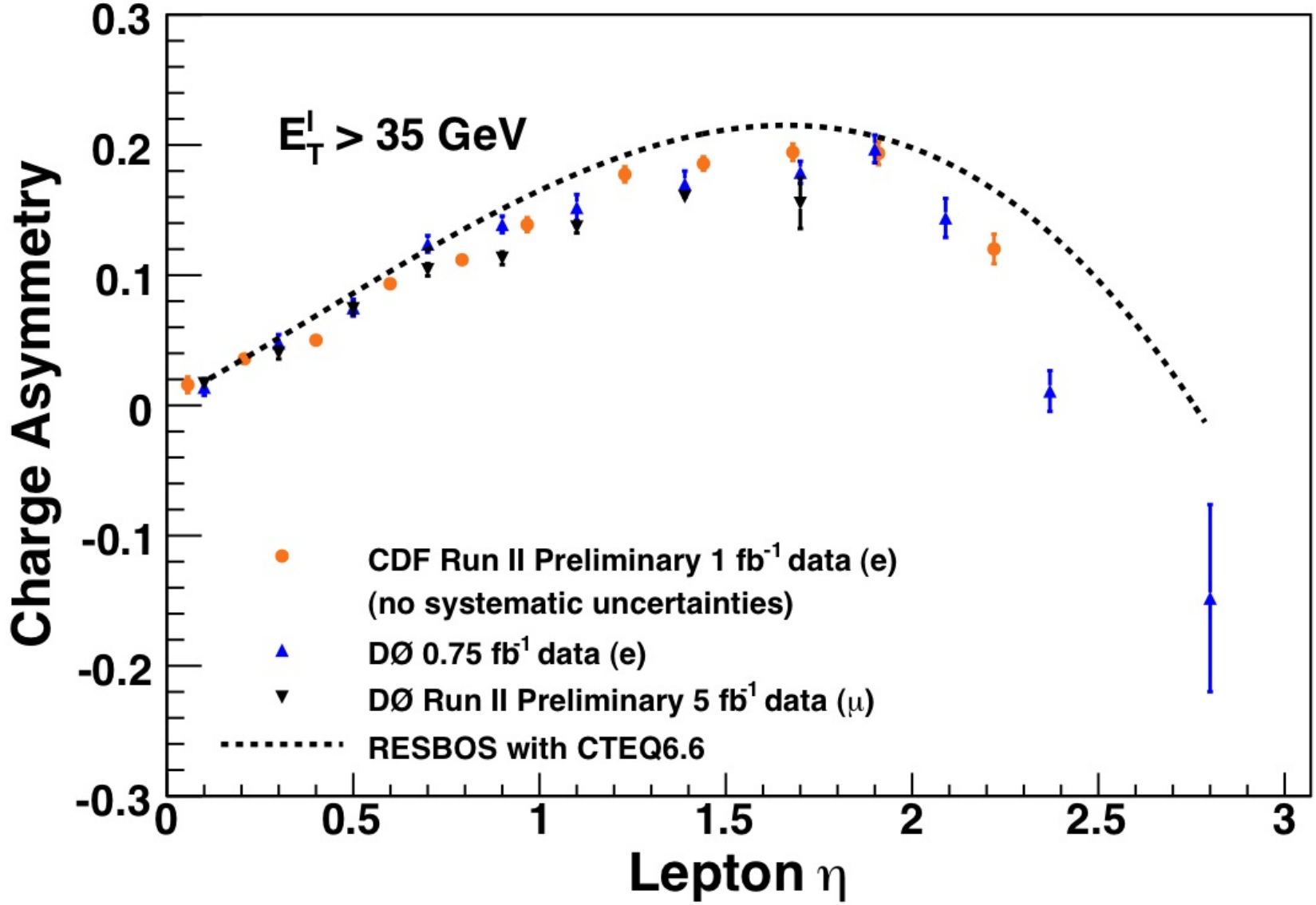
Upper Left – PT(μ) > 20 GeV
Upper Right 20 GeV < PT(μ) < 35 GeV
Lower Left PT(μ) > 35 GeV

Are CDF and D0 Consistent?

- CDF have measured the electron asymmetry from the same data sample as their W asymmetry. Compare with D0 muon and electron data – with a higher cut of 25 GeV on both ν and l



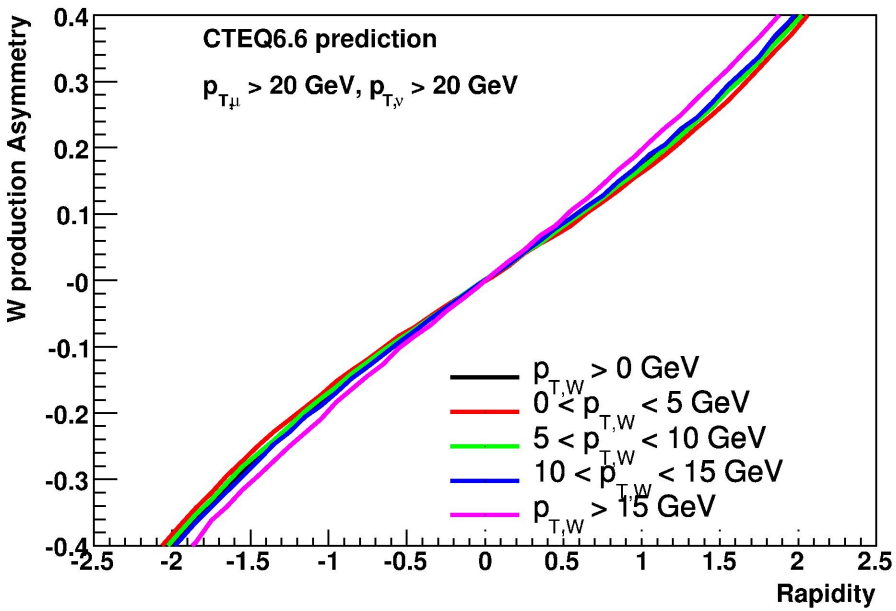

Charge Asymmetry
0.2
0
-0.2
-0.4
-0.6
-0.8
25 GeV < E_T^l < 35 GeV
CDF Run II Preliminary 1 fb^{-1} data (e)
(no systematic uncertainties)
DØ 0.75 fb^{-1} data (e)
DØ Run II Preliminary 5 fb^{-1} data (μ)
RESBOS with CTEQ6.6
0
0.5
1
1.5
2
2.5
3
Lepton η

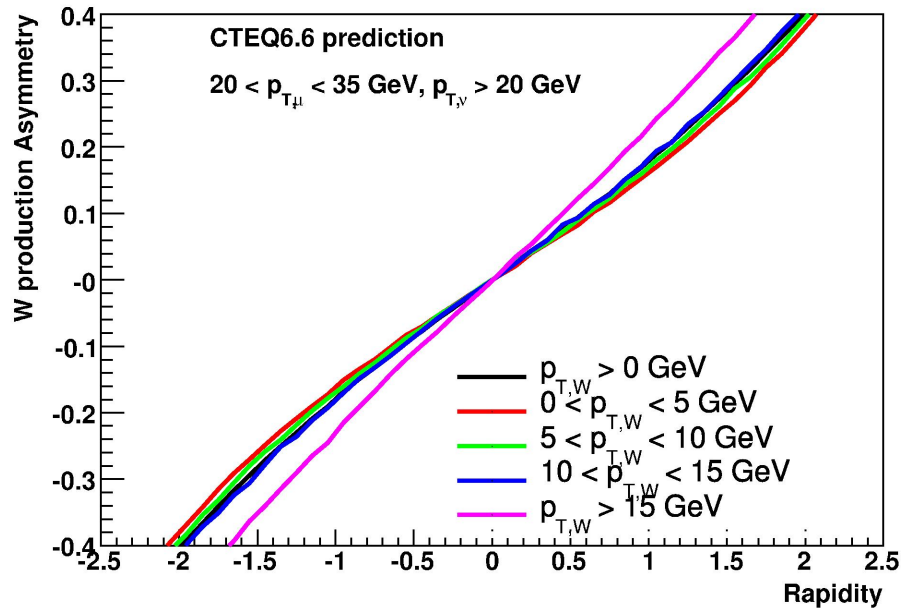

E_T^l > 35 GeV
Charge Asymmetry
Lepton η
CDF Run II Preliminary 1 fb^{-1} data (e)
(no systematic uncertainties)
DØ 0.75 fb^{-1} data (e)
DØ Run II Preliminary 5 fb^{-1} data (μ)
RESBOS with CTEQ6.6
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
0
0.5
1
1.5
2
2.5
3

What is going on?

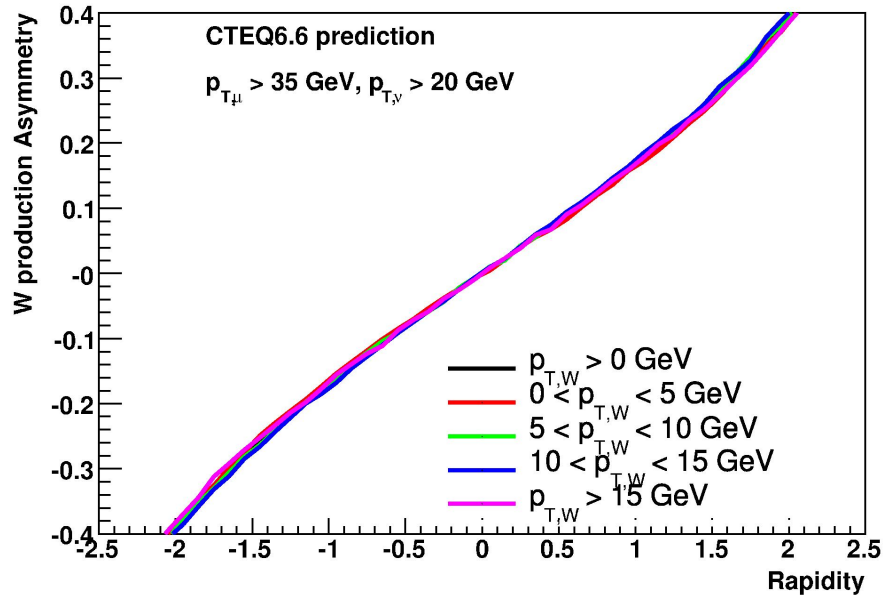
- CDF W asymmetry agrees pretty well with theoretical predictions
- D0 and CDF lepton asymmetries agree better if data are not segregated into pt bins.

- Is it the data or some aspect of the theoretical predictions we use?

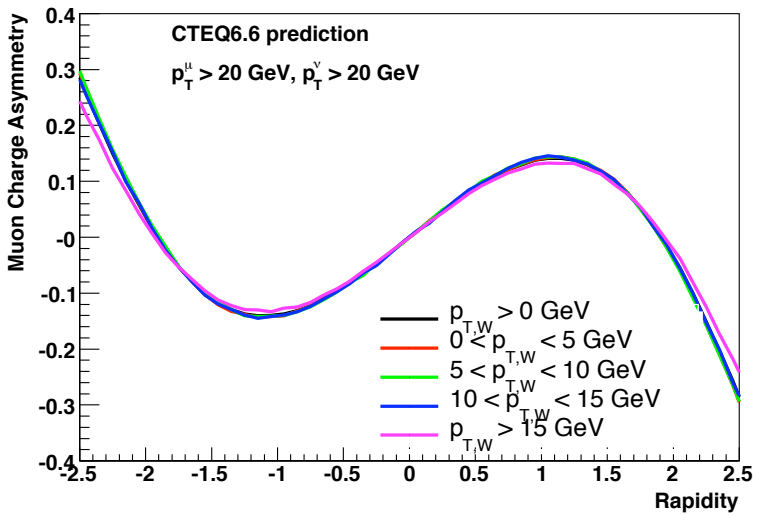


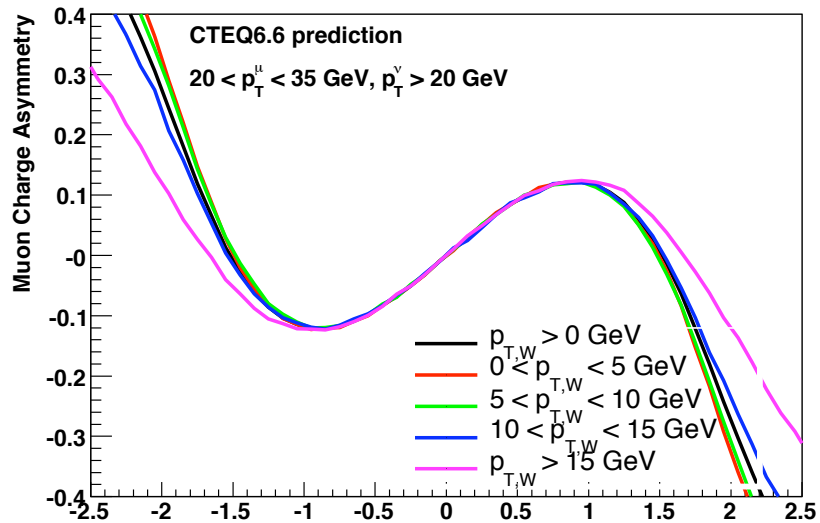


- Dependence of W asymmetry on W kinematics.
- RESBOS + CTEQ6.6

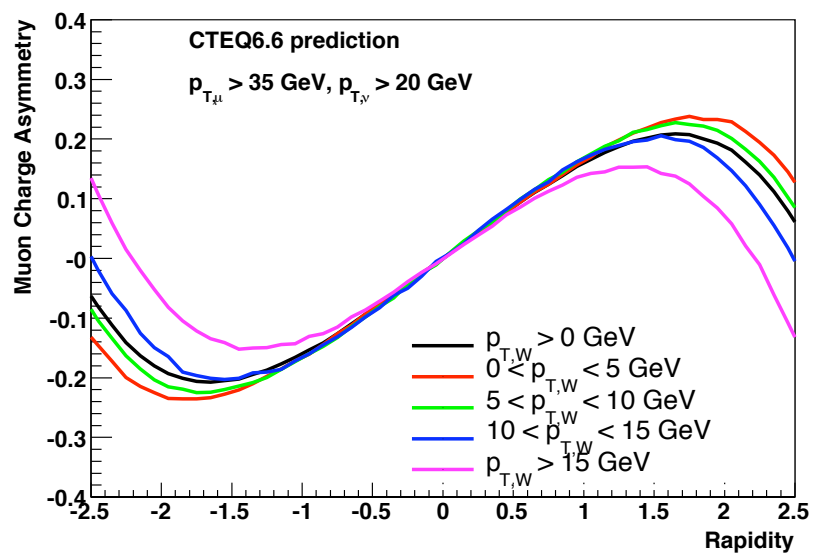


Muon asymmetry predictions CTEQ6.6M with RESBOS





Note that lepton pt cut introduces correlation between A and pt of the boson.



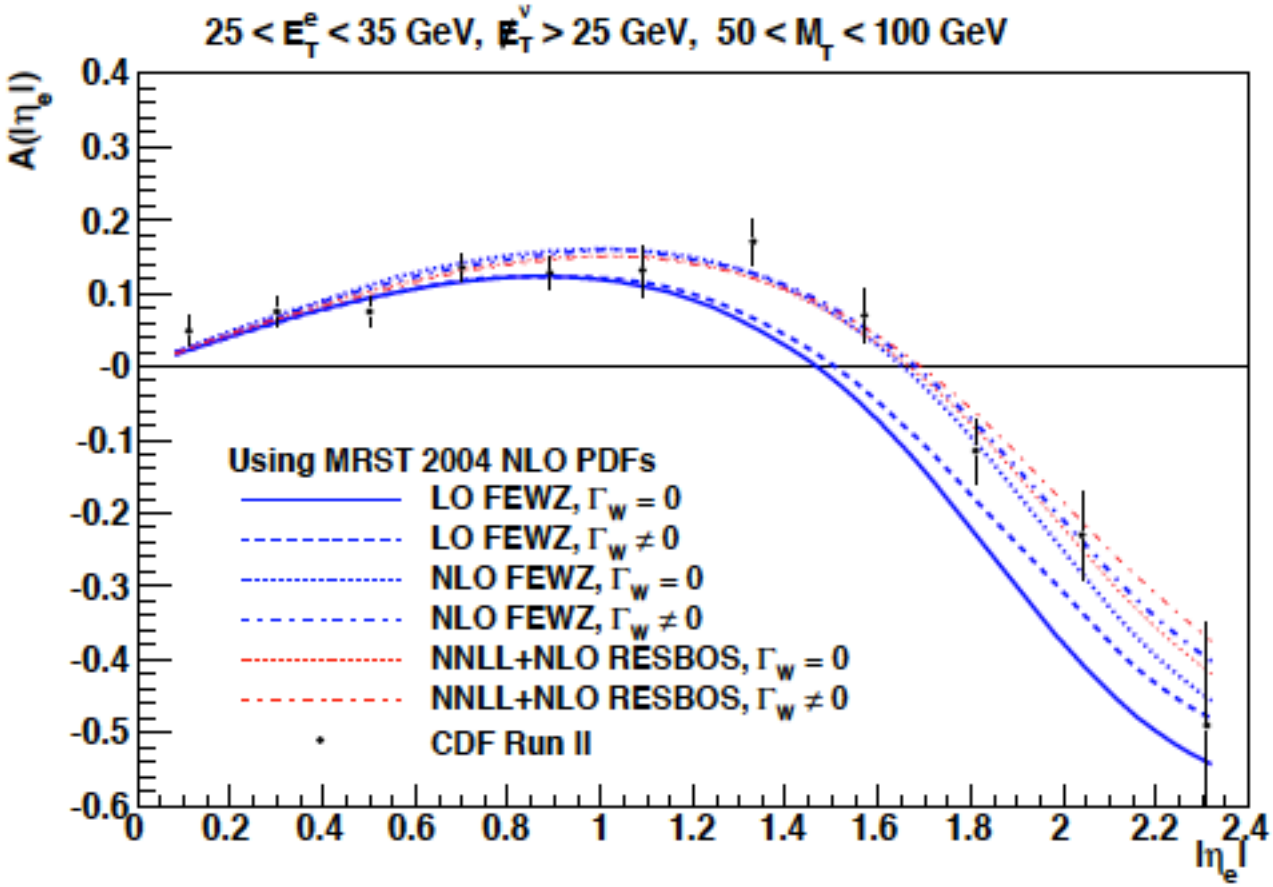
Tentative conclusions

- The CDF W asymmetry agrees well with theoretical predictions.
- D0 and CDF lepton asymmetries disagree with theoretical predictions for binned lepton pt, but seem to agree with each other!

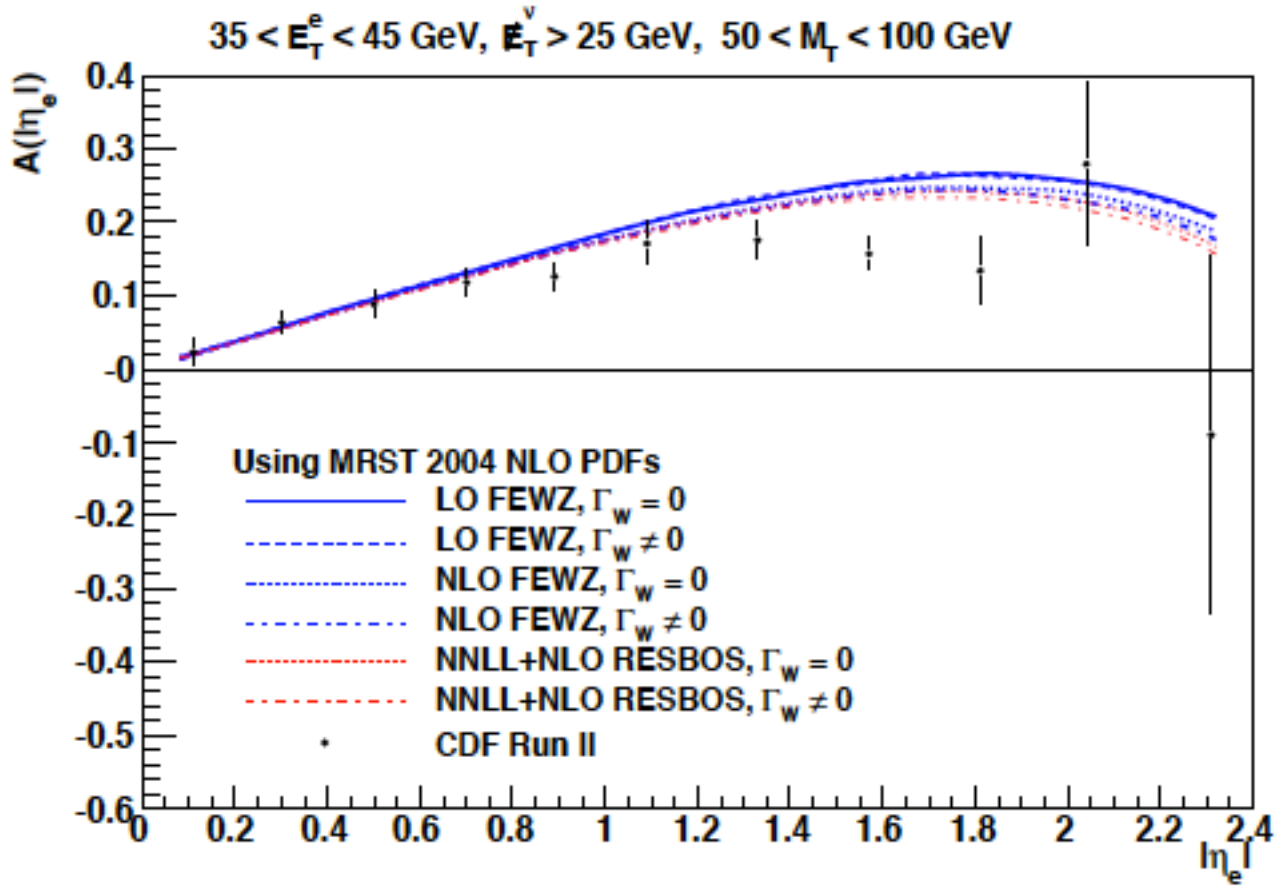
New realization

- Modeling of the lepton asymmetry probably requires a good understanding of the W PT distributions
- Even if our data and curves are perfect anyone fitting our data may use different models.
- Need to encourage use of least sensitive observable – either a very inclusive lepton asymmetry or the W asymmetry itself

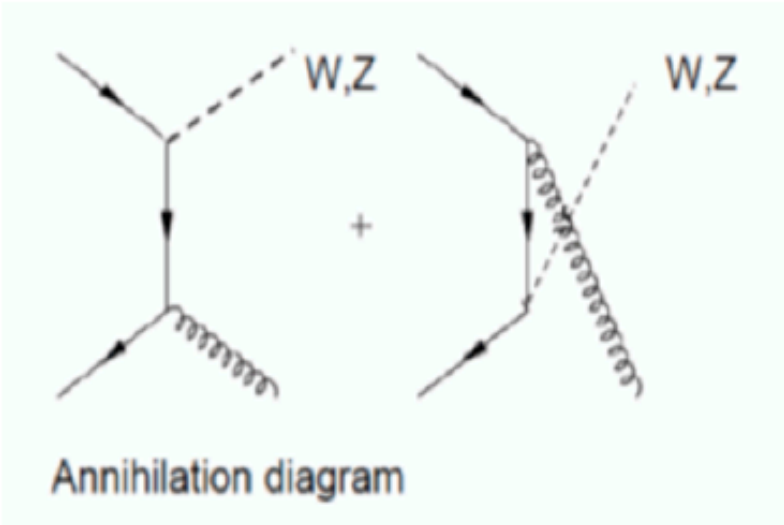
MSTW study 2009

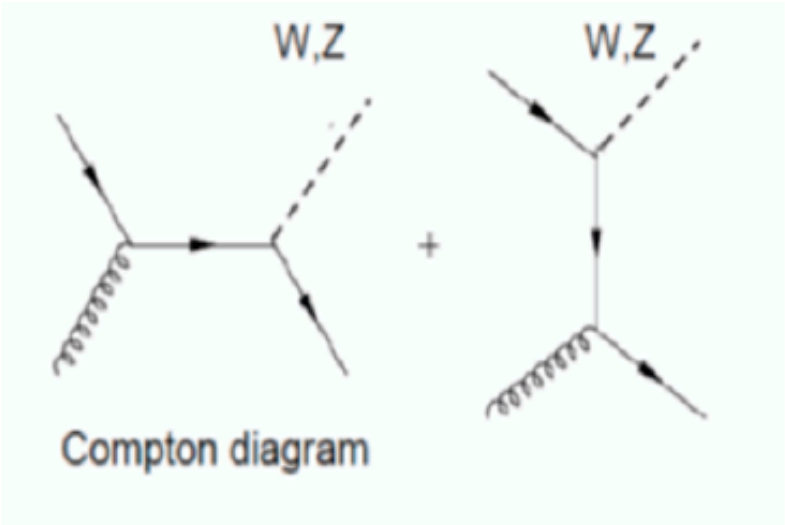


More MSTW 2009



CDF helicity measurement



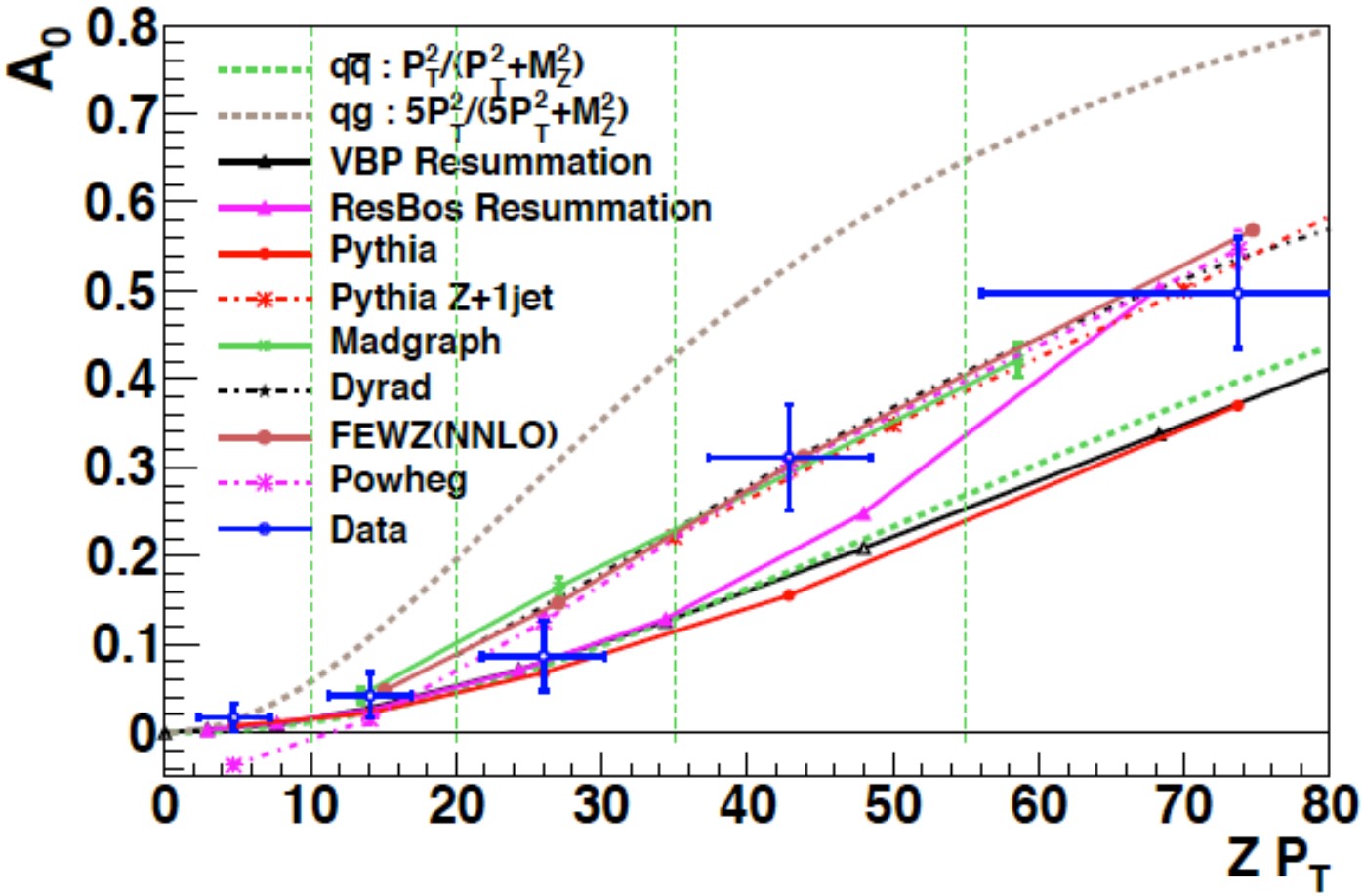


http://www-cdf.fnal.gov/physics/ewk/2010/Z_angle/angular_public_web/main.html

Now submitted to PRL, arxiv 1103.5699

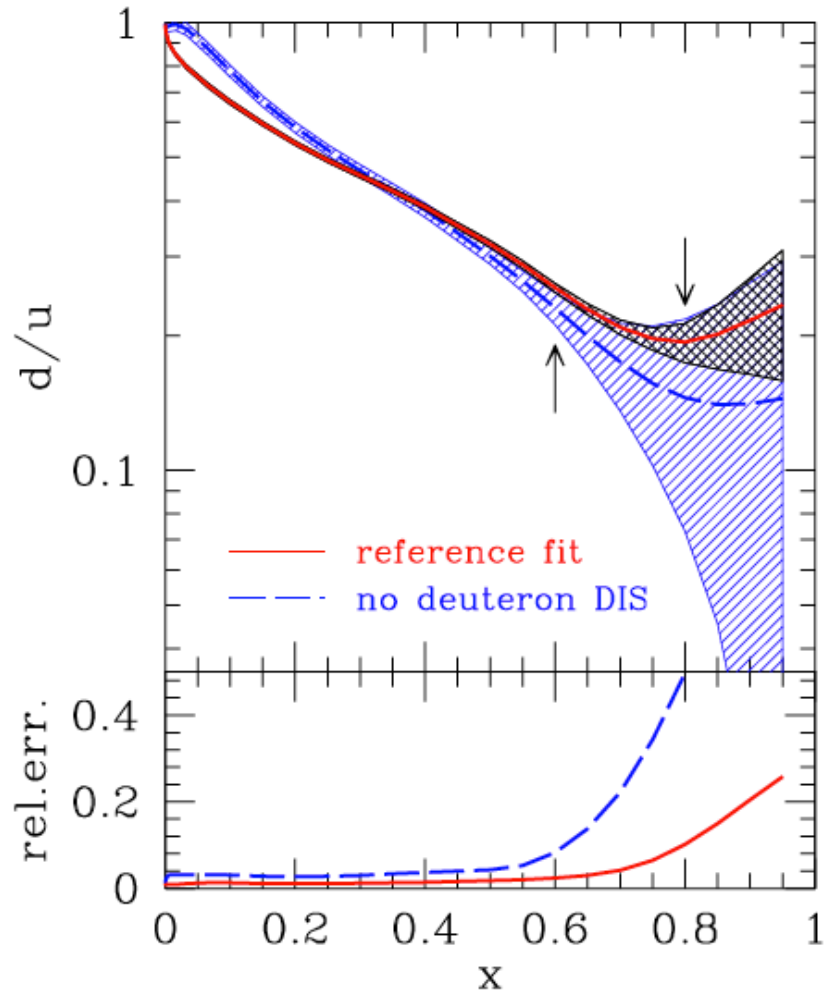
Talk by Arie Bodek in QCD and Hadronic Final States on Thursday afternoon

$$\frac{d\sigma}{d\cos\theta} \propto (1+\cos^2\theta) + \frac{1}{2}A_0(1-3\cos^2\theta) + A_4\cos\theta$$



Conclusion

- When you get to the few percent level, the lepton asymmetries are sensitive to W kinematics.
- Theory and experiment need to have the same assumptions or they can't be compared precisely.
- How do we proceed?
  - Publish only most inclusive measurement?
  - Publish in bins of W pt and rapidity?
  - Publish our inclusive W pt and rapidity distributions when we publish the asymmetry?
  - Adopt the CDF method?

This is not just for collider physicists

- Recent work by JLab/ Hampton/Florida St./FNAL
  - arXiv:1102.3686 [hep-ph], Owens talk here.
- Fit the PDF inputs with and without the D data.
- Significant differences (but larger errors)
- Is D0 a nuclear physics experiment?