Measurement of W/Z Boson Properties at the Tevatron

HEP 2013
Stockholm
18-24 July 2013

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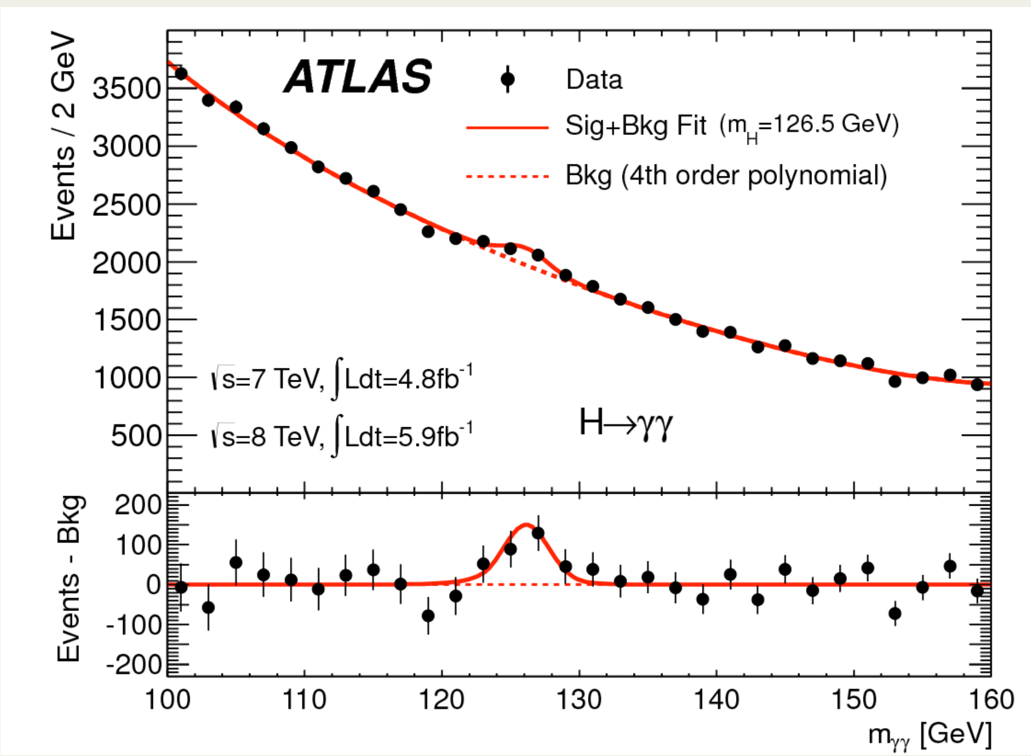
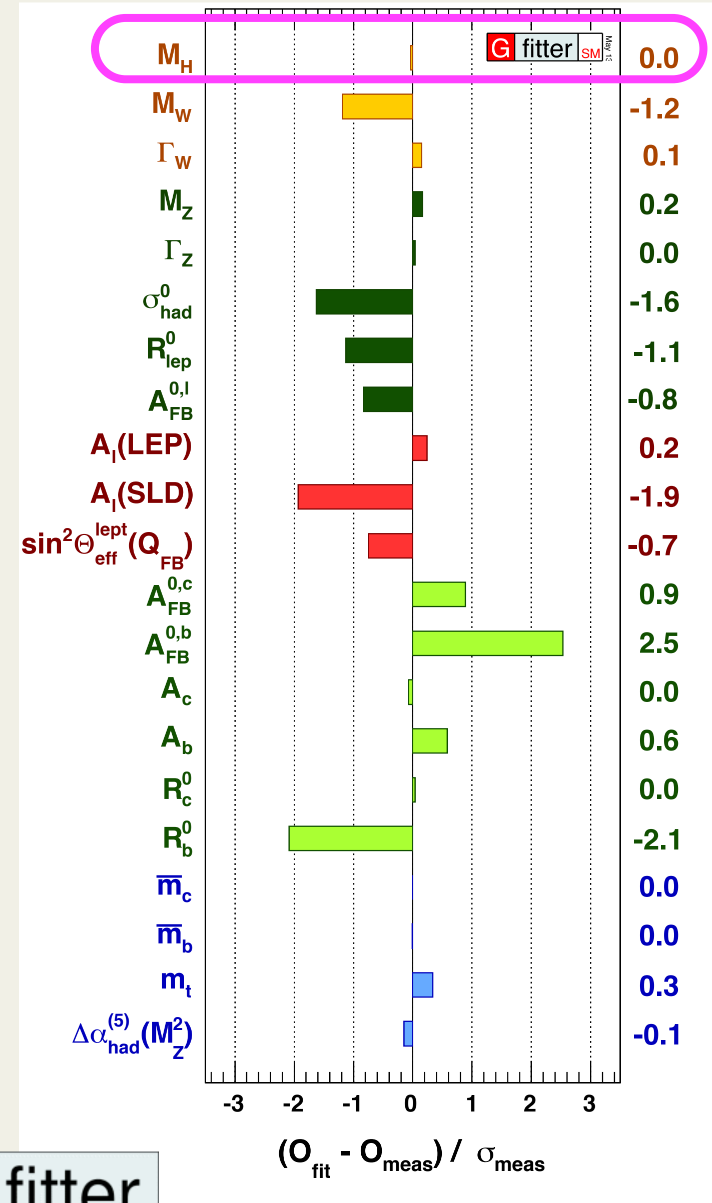
on behalf of the CDF and DØ Collaborations

Motivation

Higgs boson discovery allows us to test the self-consistency of the SM.

No significant deviation from SM expectations so far.





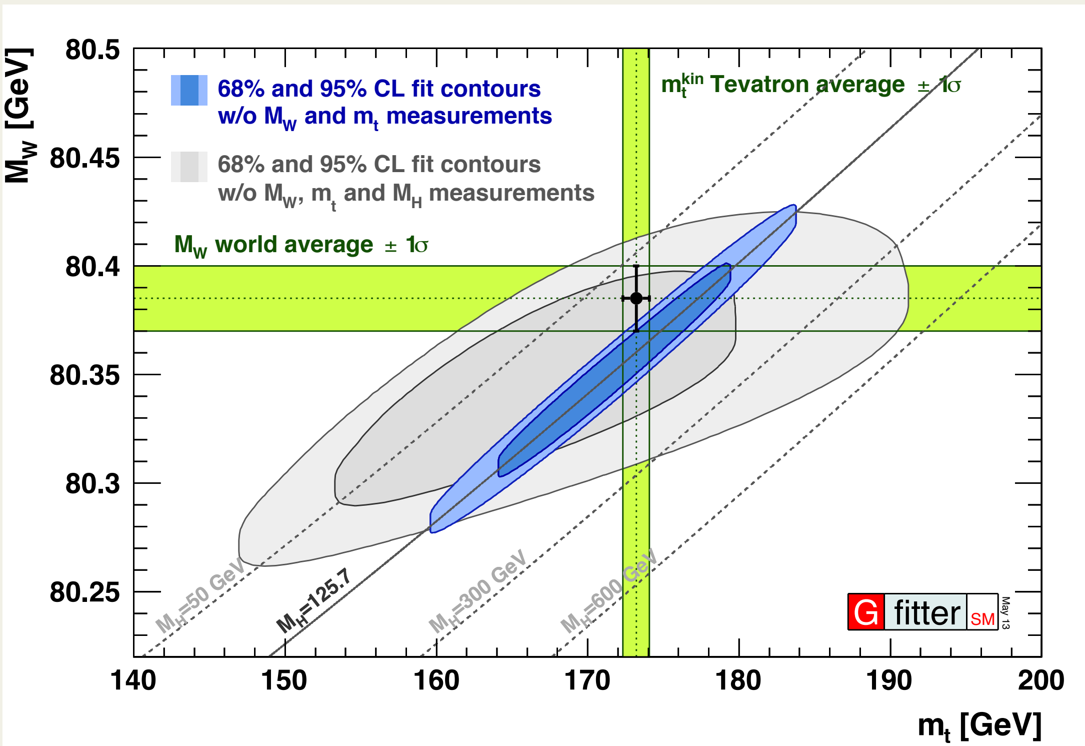
Motivation

Electroweak precision measurements limited by theoretical inputs:

- Parton Distribution Functions (PDFs)
  Constrained by W charge asymmetries
- W boson transverse momentum
  Constrained by Z boson p_T (or φ^*)

see talk by Tibor Kurca in this session.

Gfitter



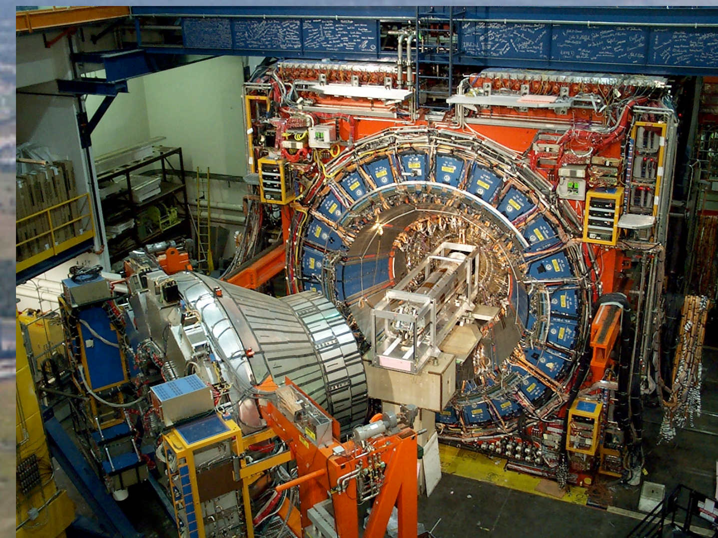
Example: M_W

	CDF (2.2 fb^{-1})	1919DØ (4.3 fb^{-1})
Experimental	10	18
PDFs	10	11
QED radiation	4	7
p_T(W) model	5	2
Statistics	12	13
Total uncertainty	19	26

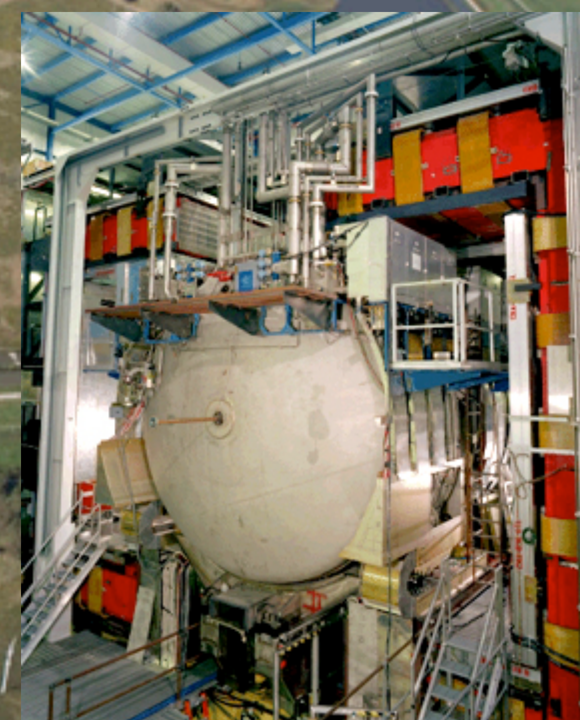
Predicted and measured M_W agree within 1.3σ

Highest energy proton-antiproton collider, with $\sqrt{s}$ = 1.96 TeV

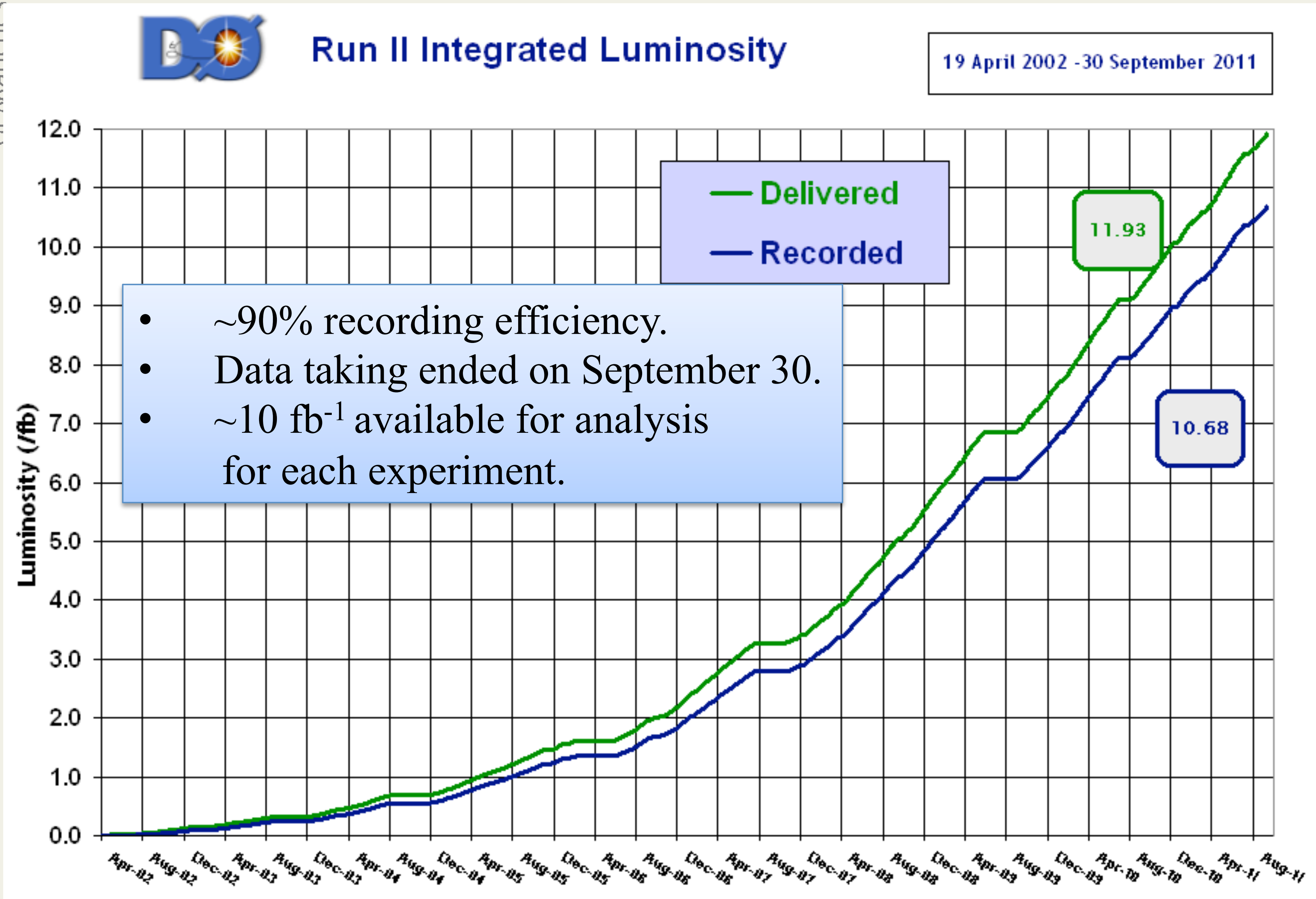
CDF



DØ

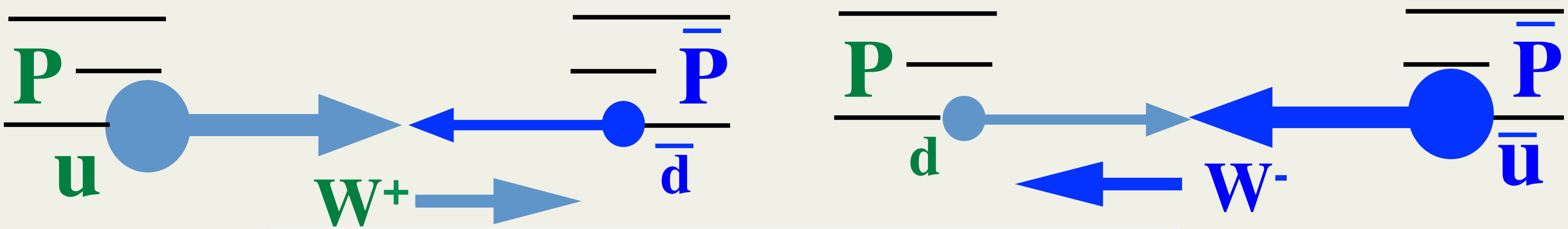


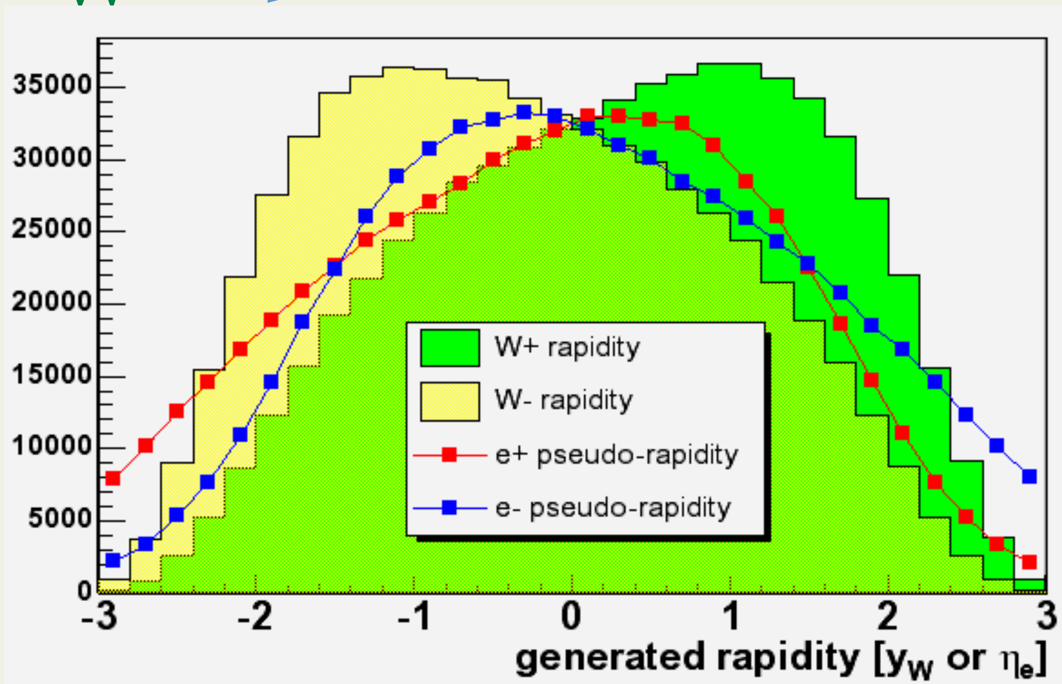
Integrated Luminosity



- ~90% recording efficiency.
- Data taking ended on September 30.
- ~10 fb^{-1} available for analysis for each experiment.

W Charge Asymmetry





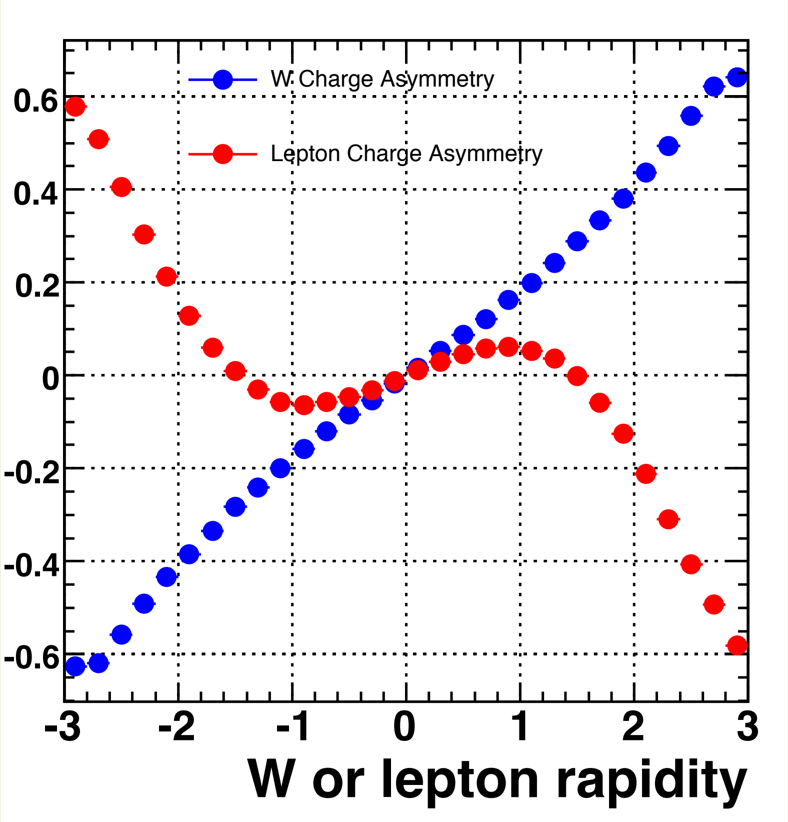
unique to Tevatron

- W Boson is mostly produced by valence quarks at Tevatron.
- u/anti-u quarks carry more momentum than d/anti-d quarks.
- W^+/W^- preferentially boosted in proton/anti-proton direction.

W Charge Asymmetry

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

- u(x) and d(x) are the PDFs of the valence u quark and d quark in the proton
- x_1 and x_2 are the momentum fractions in the proton and anti-proton.



- W boson rapidity cannot be reconstructed directly at a hadron collider.
- Use lepton charge from W boson decay as observable.

Lepton Charge Asymmetry

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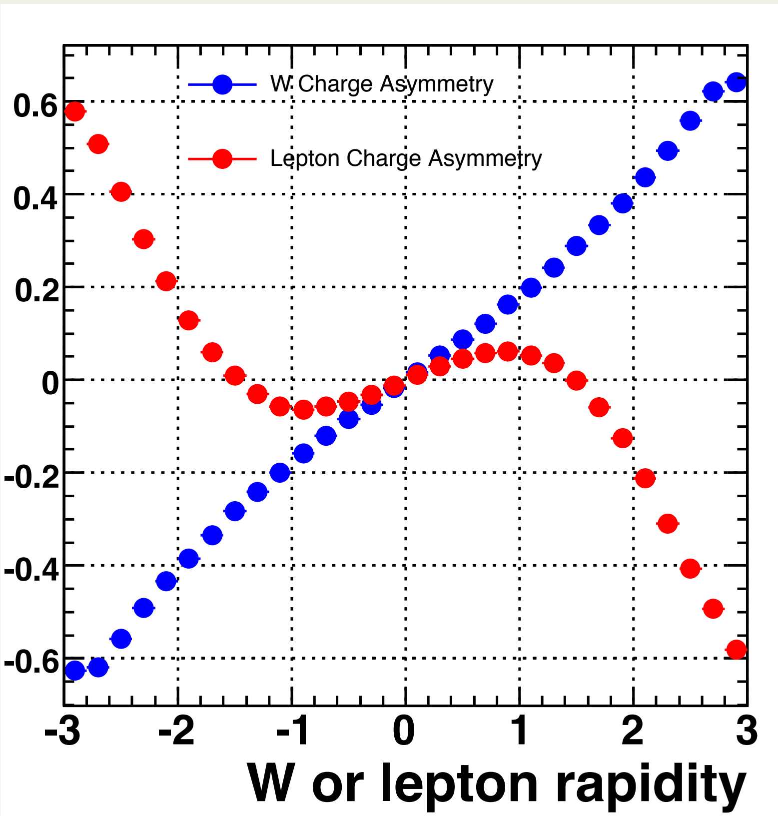
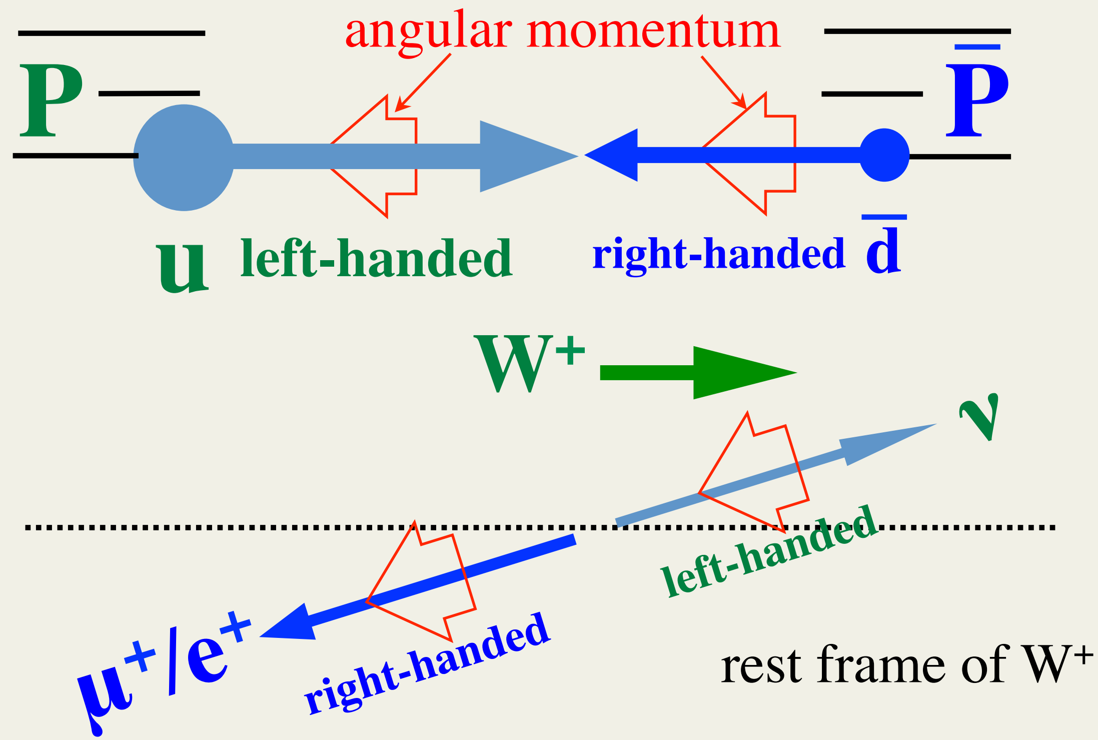
$$A(\eta_\mu) = \frac{\frac{d\sigma(\mu^+)}{d\eta_\mu} - \frac{d\sigma(\mu^-)}{d\eta_\mu}}{\frac{d\sigma(\mu^+)}{d\eta_\mu} + \frac{d\sigma(\mu^-)}{d\eta_\mu}}$$



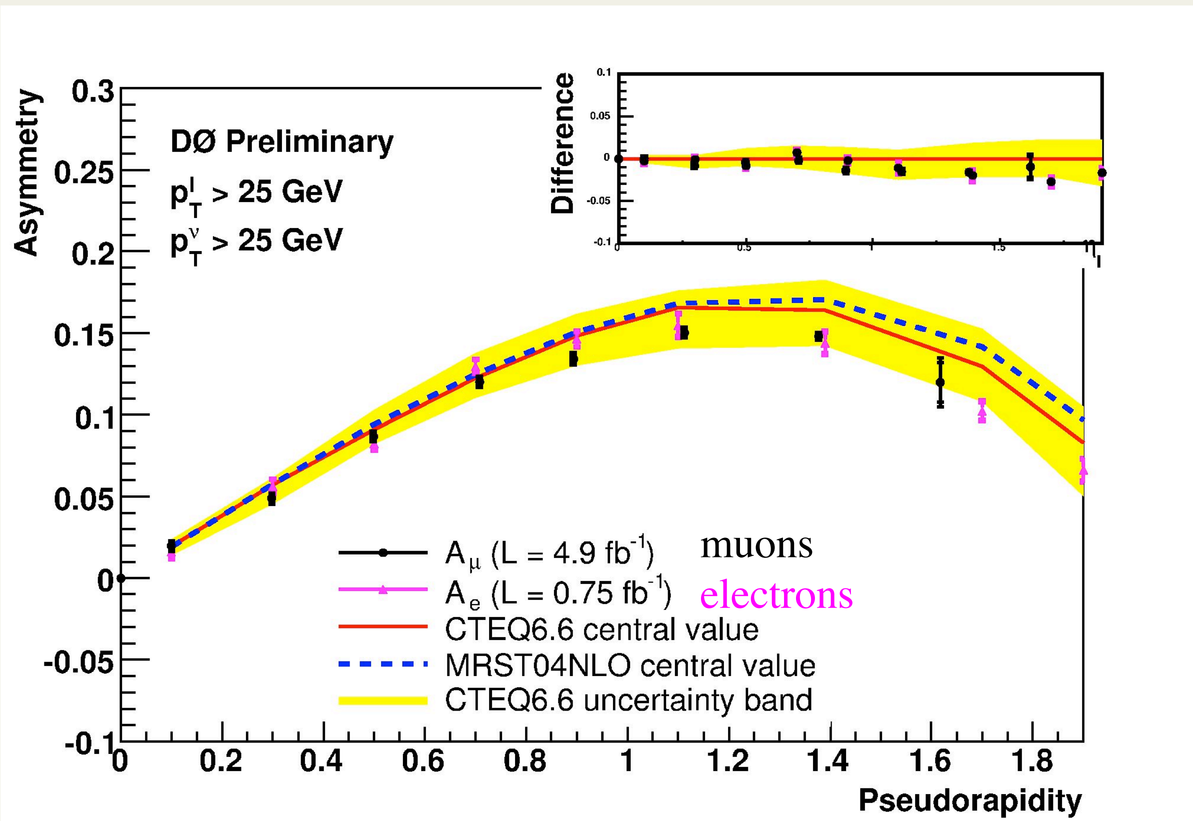


V-A nature of W boson decay will "invert" the observed asymmetry for leptons relative to W bosons.

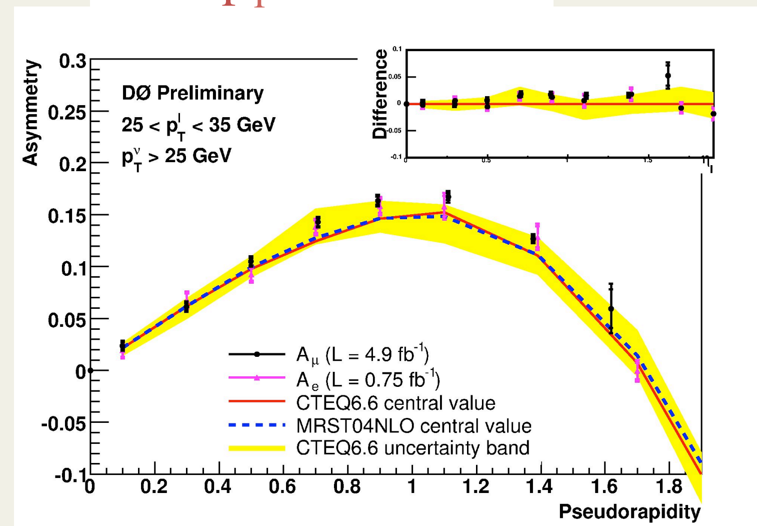
W Charge Asymmetry

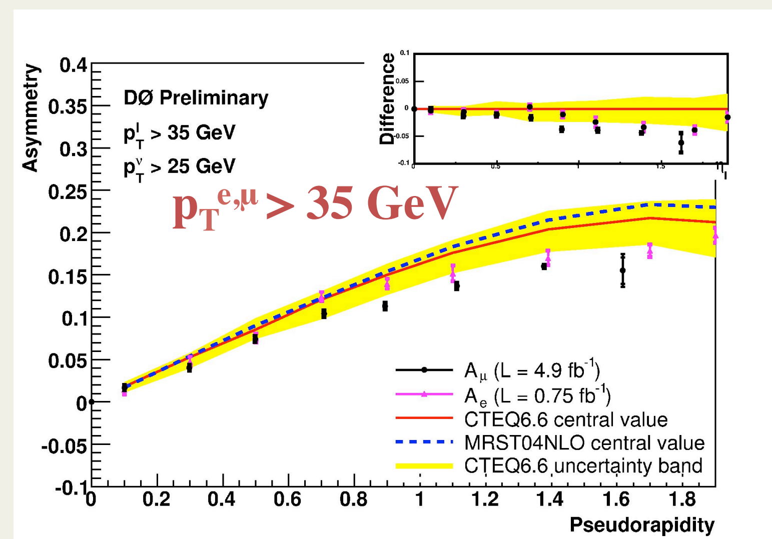
Experimental uncertainties smaller
than theoretical uncertainties from PDFs

Strong constraints on PDFs.



$20 < p_T^{e,\mu} < 35$ GeV

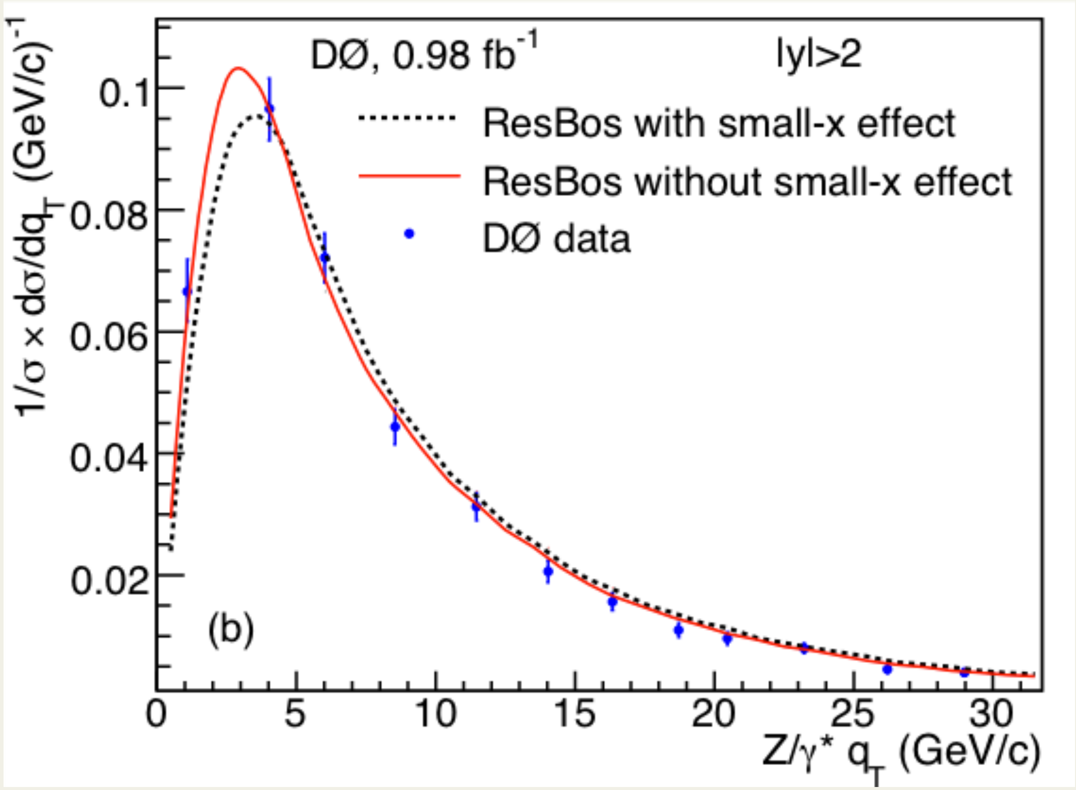




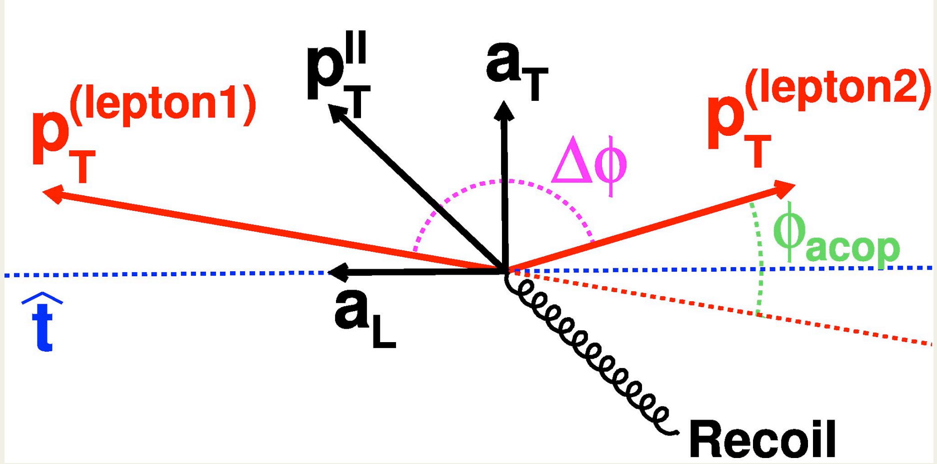
Muon and electron results consistent

Z Boson Kinematics

- Low $p_T(Z)$ region important for inclusive cross sections.
- Requires soft-gluon resummation
- Large effect due to small-x broadening (x<0.01)



Systematical uncertainty is dominant already at 1 fb^{-1} due to experimental resolution on $P_T(Z)$.



$$\Phi^* = \tan\left(\frac{\Phi_{\mathrm{acop}}}{2}\right)\sin\theta^*_\eta$$

$$\cos\theta^*_\eta = \tanh\left(\frac{\eta^- - \eta^+}{2}\right)$$

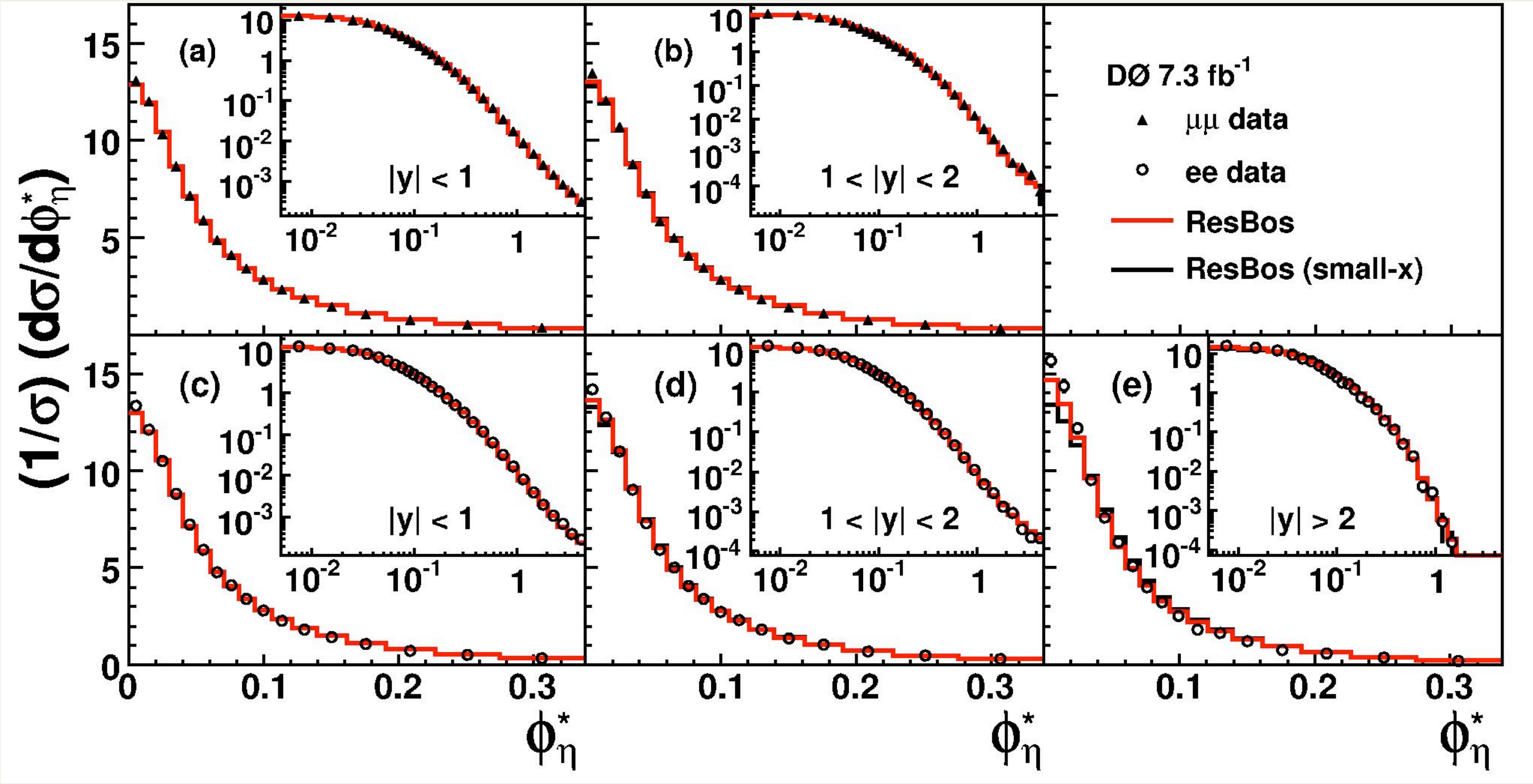
New variable ϕ^* :

- Determined only from angles (good resolution)
- Less correlated with lepton isolation than p_T

(1) M. Vesterinen, T.R. Wyatt, NIM A 602, 432 (2009)
(2) A. Banfi et all., , EPJ C 71, 1600 (2011).

Z Boson Kinematics

L=7.3 fb^{-1} 970k Z boson events (ee, μμ)



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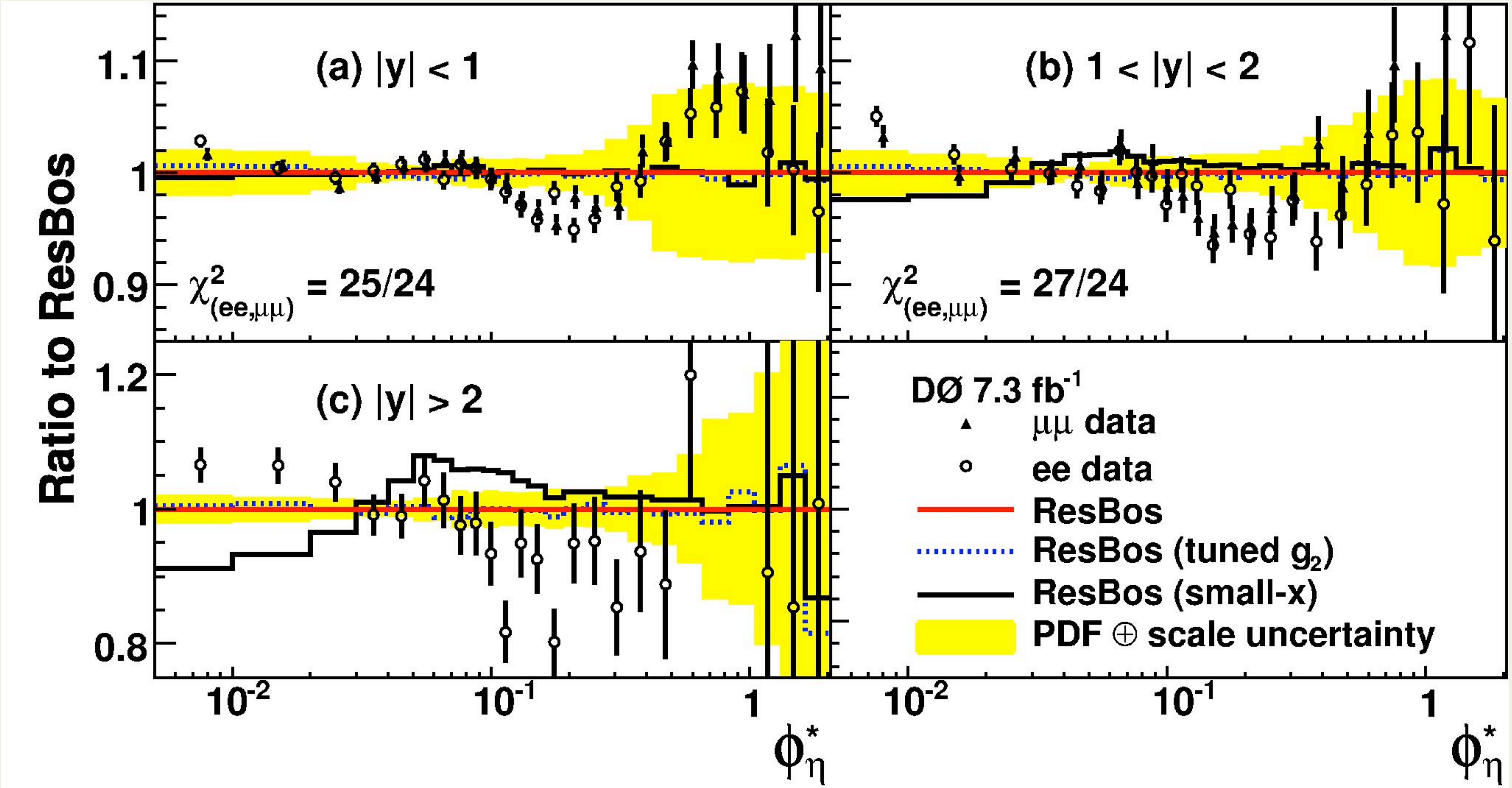
PRL 106, 122001 (2011)



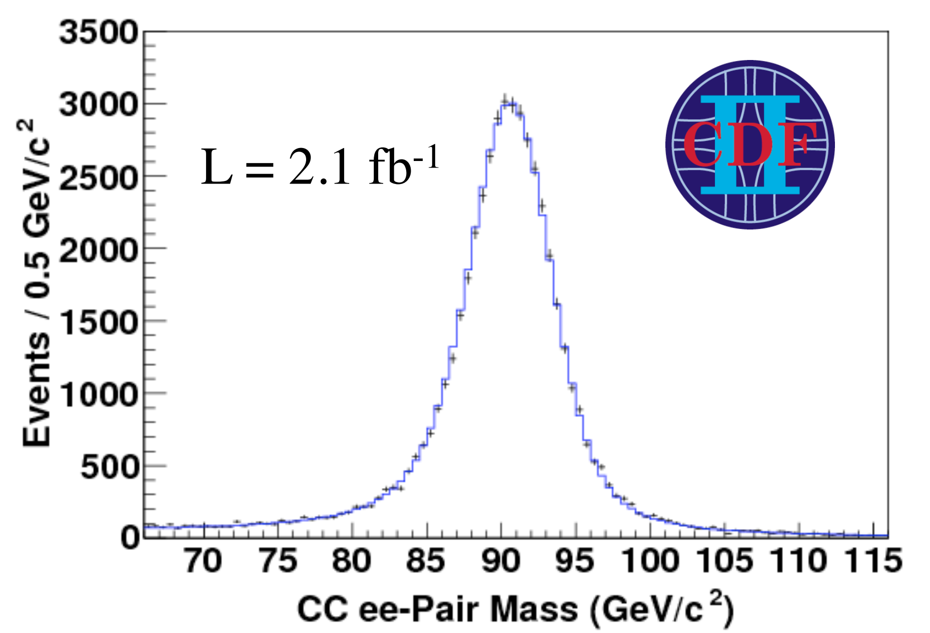
Significant deviations from model predictions observed at small ϕ^*

EW Mixing Angles

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

$A_4 \cos\vartheta$ is a parity-violating asymmetry term due to γ-Z and Z self-interference.

Measuring A_4 allows to extract $\sin^2\vartheta_W$ and $\sin^2\theta^{lep}_{eff}$



1. Central–Central (CC)
   - $E_T > 25$ (15) GeV for electron 1 (2)
   - $0.05 < |\eta_{det}| < 1.05$
2. Central–Plug (CP)
   - $E_T > 20$ GeV for both electrons
   - Central electron: $0.05 < |\eta_{det}| < 1.05$
   - Plug electron: $1.2 < |\eta_{det}| < 2.8$
3. Plug–Plug (PP)
   - $E_T > 25$ GeV for both electrons
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The University of Manchester

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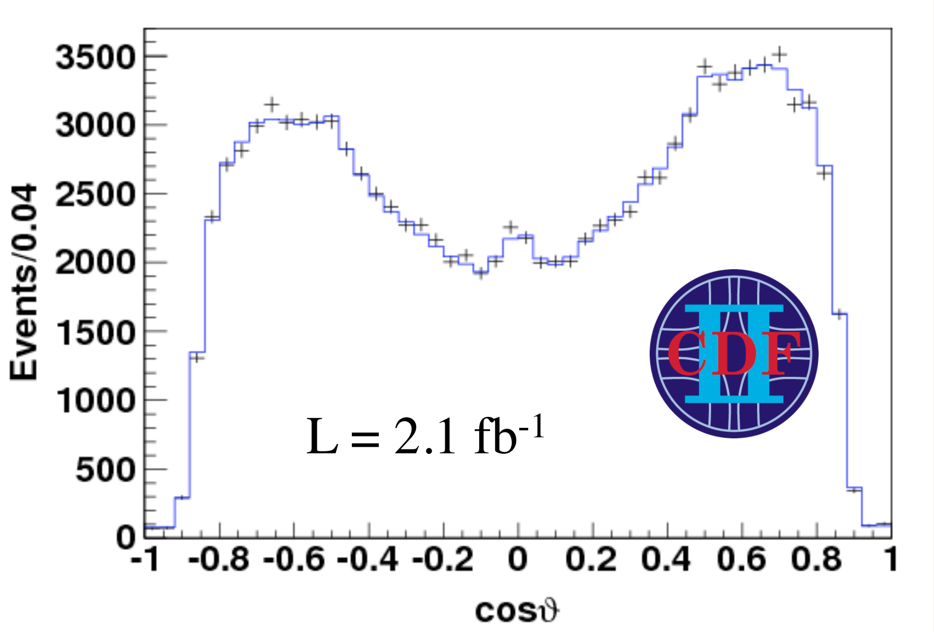

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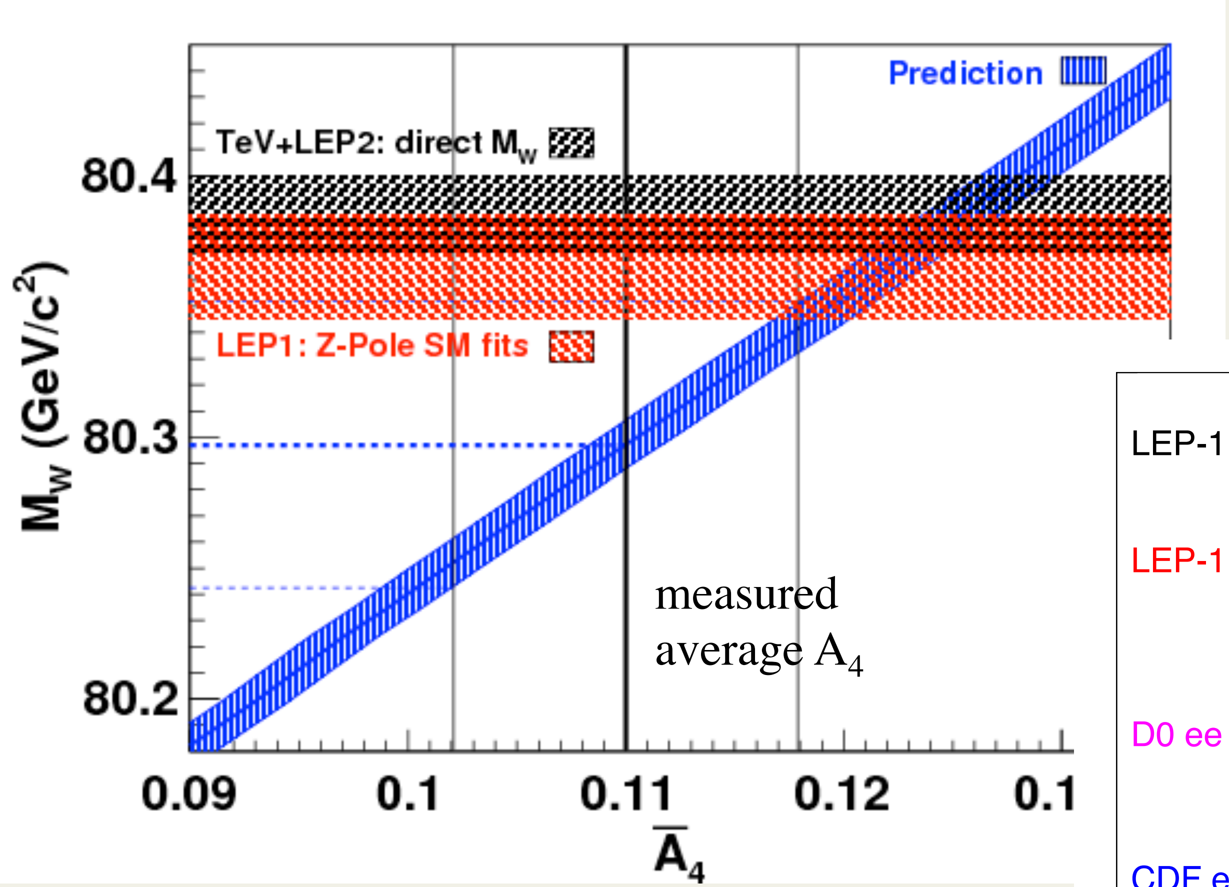
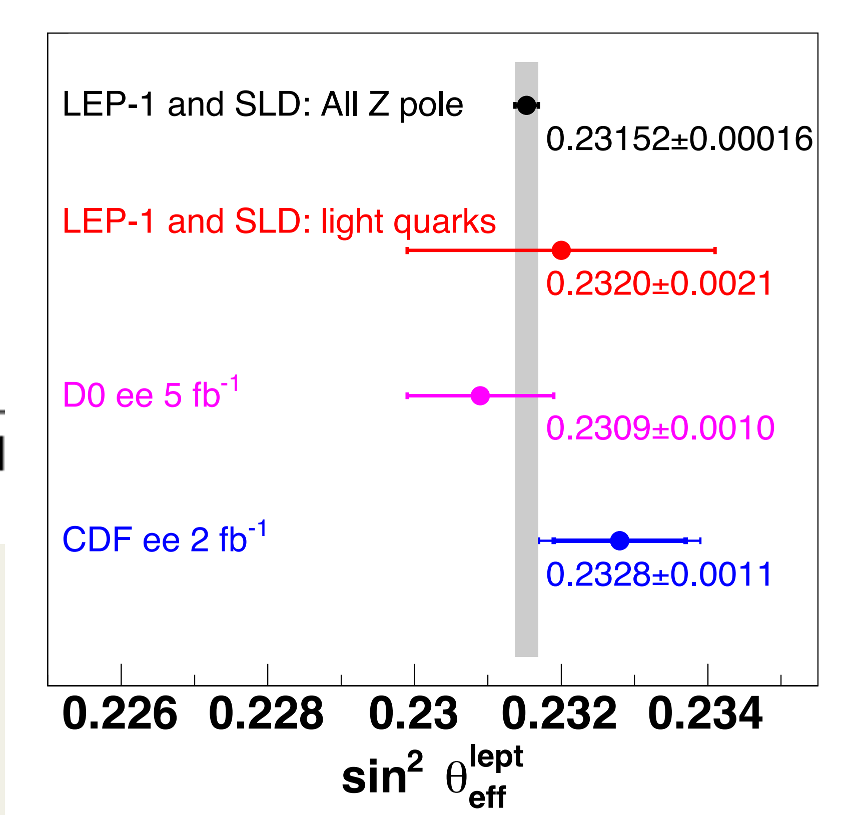
EW Mixing Angles

Indirect determination of M_W



CDF (2.1 fb^{-1}) A_4 measurement dominated by statistical uncertainty.

DØ (5 fb^{-1}) uses "traditional" Forward-Backward Asymmetry.



A_4 averaged over y, p_T, and M

$$A_4 = 0.1100 \pm 0.0079(\text{stat}) \pm 0.0004(\text{syst})$$

Summary

- The Higgs discovery allows us to perform EW precision tests of the self-consistency of the Standard Model.
- Some precision EW measurements start to be theoretically limited.
- W/Z properties measurements:
  - W charge asymmetry provides direct constraints on the valence quark PDFs – unique to Tevatron.
  - Z boson p_T (φ^*) measurements improve modeling of vector boson p_T – method pioneered by DØ.
  - Novel method to extract weak mixing angle from Z decays (CDF).
- Several publications using full data sets in the pipeline.