Direct Measurement of the W Production Charge Asymmetry in $p\bar{p}$ Collisions at $\sqrt{s} = 1.96\,\text{TeV}$

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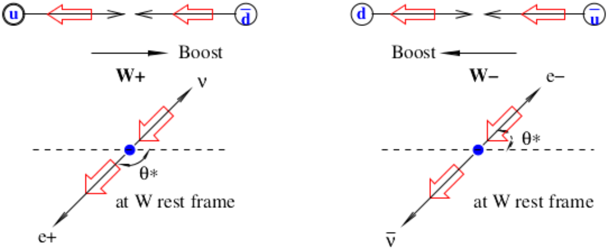
Charge asymmetry in $W^{\pm}$*production*

- Tevatron, $p\bar{p}$ at $\sqrt{s} = 1.96$ TeV
- Dominant production: $u\bar{d} \to W^+$, $\bar{u}d \to W^-$



$$A(y_W) = \frac{d\sigma^+/dy_W - d\sigma^-/dy_W}{d\sigma^+/dy_W + d\sigma^-/dy_W}$$

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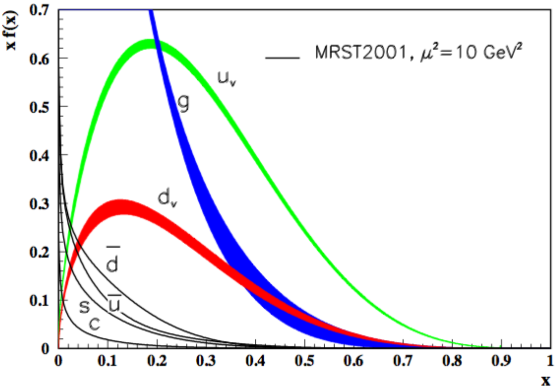


u quark carries higher fraction of proton momentum than d quark!

Motivation

- Constraining the proton PDFs ⇒ reduce total error on W mass
- Probing for physics beyond SM

Previous approach

- $W \to l\nu_l$
- W charge asymmetry measured as function of η_l ($l = e, \mu$)
- Lepton charge asymmetry ⇒ convolution of V–A asymmetry from W decays and W production asymmetry
- *Problem? Convolution weakens at high $|\eta|$!*

New approach

Direct measurement of $|y_W|$

- $W \to e\nu_e$
- Measure asymmetry via $|y_W|$ instead of lepton $|\eta|$
- Use lepton E_T and neutrino $\not{E}_T$
- Data from CDF II, $\int L\,dt = 1 fb^{-1}$
- Region of acceptance $|y_W| < 3.0$
- Ability to improve proton PDF determinations for $0.002 \lesssim x \lesssim 0.8$

Reconstruction of $|y_W|$

$$y_W = ln\frac{E + p_z}{E - p_z}$$

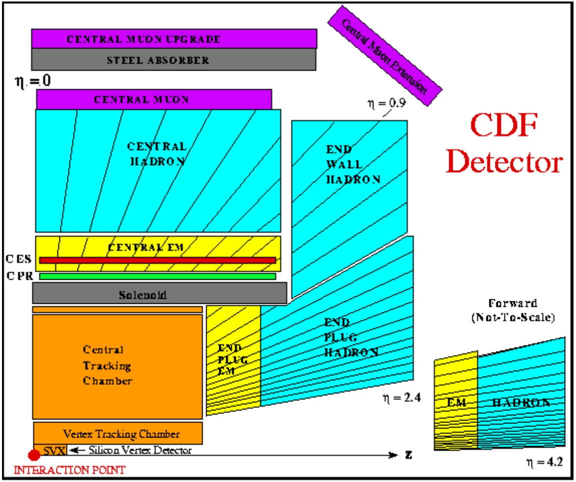
Problem: Can't measure p_z^ν

- Constrain W mass: $M_W^2 = (E_l + E_\nu)^2 + (\vec{p}_l + \vec{p}_\nu)^2$
- $\Rightarrow$ Determine p_z^ν of neutrino $\Rightarrow$ two solutions
- Weighting factor $w_{1,2}^{\pm}$ distinguishes directionality of neutrino momentum using V–A decay distribution
- Weak dependence of $w_{1,2}^{\pm}$ on y_W $\Rightarrow$ iterative calculation

Event selection

Two types of events:

Central electrons: $|\eta| < 1.1$ Forward electrons: $1.2 < |\eta| < 3.5$



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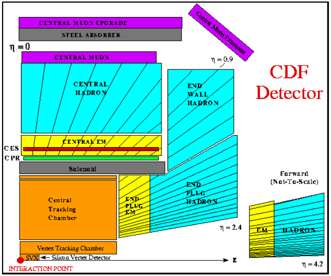


- Central e: EM cluster $E_T > 25\,\text{GeV}$, $\text{Iso}(0.4) < 4.0\,\text{GeV}$
- Forward e: EM cluster $E_T > 20\,\text{GeV}$, $\frac{E(HAD)}{E(EM)} < 0.05$
- Missing energy (neutrino) $\not{E}_T > 25\,\text{GeV}$
- 537 857 events – central e, 176 941 events – forward e

Background processes

- $W \to \tau\nu_\tau$ contribution, where τ decays to e and neutrinos $\Rightarrow$ included in the overall signal
- $Z \to e^+e^-$, one e not reconstructed, mimics ν
- $Z \to \tau^+\tau^-$
- QCD background

Process	Central [%]	Forward [%]
$Z \to e^+e^-$	0.59 ± 0.02	0.54 ± 0.03
$Z \to \tau^+\tau^-$	0.10 ± 0.01	0.10 ± 0.01
QCD bckgr.	1.21 ± 0.21	0.67 ± 0.18

Table 1: Considered background fractions

Uncertainties and corrections

- Charge misidentification rate: dependent on η, measured using $Z \to ee$ events (both identified with same sign)
- EM calorimeter energy scale and resolution simulation tuned to reproduce $Z \to e^+e^-$ mass peak
- Simulation of calorimeter deposition and its dependence on η
- Consideration of kinematic and geometrical acceptance of events
- Trigger efficiencies for electrons dependent on η and E_T

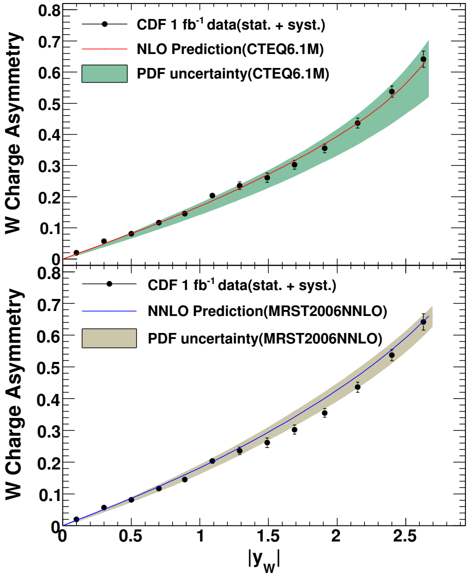
Source	Central [%]	Forward [%]
Charge misID rate	0.18 ± 0.05	17.26 ± 2.02
EM energy scale uncertainty	± 0.05	± 0.3
EM resolution uncertainty	± 0.07	± 0.8
Transverse recoil uncertainty	$\pm$ 0.3	$\pm$ 1.4
Trigger efficiencies	96.1 ± 1.0	92.5 ± 0.3

Table 2: Corrections of various types

Uncertainties and corrections

- PDF uncertainties:
  - MRST2006NNLO
  - CTEQ6.1M
- Correction of bin centers for $|y_W|$ adjusted to fixed W mass ($80.403\,\mathrm{GeV}/c^2$)
- Combination of $A(y_W)$ and $-A(-y_W)$ bins (due to CP invariance) valid due to small correlation (< 0.05)

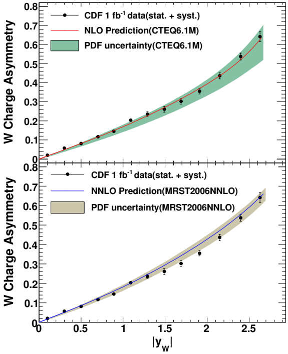
Results



The measured W production charge asymmetry and predictions from (a) NLO CTEQ6.1 and (b) NNLO MRST2006, with their associated PDF uncertainties.

Conclusion

- First direct measurement of y_W using $1\,fb^{-1}$ data
- Total uncertainties smaller than PDF uncertainties $\Rightarrow$ measurement more sensitive to the ratio of d/u momentum distributions in proton at high x than previous approach
- Results expected to improve precision of global PDF fits



Weighting factor for solutions of longitudinal momentum of neutrino

$$w^{\pm}_{1,2} = \frac{P_{\pm}(\cos\theta^{*}_{1,2}, y_{1,2}, p_T^W)\sigma^{\pm}(y_{1,2})}{P_{\pm}(\cos\theta^{*}_{1}, y_{1}, p_T^W)\sigma^{\pm}(y_{1}) + P_{\pm}(\cos\theta^{*}_{2}, y_{2}, p_T^W)\sigma^{\pm}(y_{2})},$$

where

$$P_{\pm}(cos\theta^{*}, y_W, p_T^W) = (1 \mp cos\theta^{*})^2 + Q(y_W, p_T^W)(1 \pm cos\theta^{*})^2.$$

- $\sigma^{\pm}(y_{1,2})$ calculated using NNLO QCD calculation using MRST 2006 NNLO PDFs
- Factor $Q(y_W, p_T^W)$ determined by quark vs antiquark composition of proton using MC@NLO generator