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W-Charge Asymmetry at CDF, Tests of Structure Functions

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W-CHARGE ASYMMETRY AT CDF, TESTS OF STRUCTURE FUNCTIONS

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Abstract

The charge asymmetry of W-bosons produced in $p\bar{p}$ collisions has been measured using 19,039 $W \to e\nu$ and $W \to \mu\nu$ decays recorded by the CDF detector during the 1992-93 Tevatron collider run. The asymmetry is sensitive to the slope of the proton's d/u quark distribution ratio down to $x < 0.01$ at $Q^2 \approx M_W^2$, where nonperturbative QCD effects are minimal. Of recent parton distribution functions, those of Martin, Roberts and Stirling are favored over those of the CTEQ collaboration. This difference is seen even though both sets agree, at the level of the nuclear shadowing corrections, with the recent NMC measurements of $F_2^{\mu n}/F_2^{\mu p}$.

1. Introduction

W^+ (W^-) bosons are produced in $p\bar{p}$ collisions primarily by the annihilation of u (d) quarks from the p with $\bar{d}$ ($\bar{u}$) quarks from the $\bar{p}$. Since the u quark tends to carry a larger fraction of the proton's momentum than the d quark, the W^+ (W^-) tends to be boosted in the p ($\bar{p}$) direction. The resulting charge asymmetry in the production of W's as a function of rapidity is related to the slope of the $d(x)/u(x)$ quark distribution ratio at low x ($0.007 < x < 0.24$) and $Q^2 \approx M_W^2$ [1]. This measurement complements the F_2^n/F_2^p measured via deep inelastic scattering (DIS).

In this communication, the W charge asymmetry analysis from the 1992-93 data is presented. Relative to the 1988-89 data analysis [2], there is a seven fold increase in statistics from detector improvements and a luminosity of $\sim 20pb^{-1}$.

2. Charged lepton asymmetry in W Decays

The W-bosons are identified by their $W \to e\nu$ and $W \to \mu\nu$ decays. At the Tevatron ($\sqrt{s} = 1.8$ TeV), the longitudinal momentum of the neutrino cannot be reconstructed. Since the $W^\pm$ rapidity is indeterminate, the charge asymmetry of the decay leptons is measured:

$$A(\eta) = \frac{d\sigma(l^+)/d\eta - d\sigma(l^-)/d\eta}{d\sigma(l^+)/d\eta + d\sigma(l^-)/d\eta} \qquad (1)$$

where $d\sigma(l^\pm)/d\eta$ is the cross section for $W^\pm$ decay leptons as a function of lepton pseudorapidity, η [3]. (Positive η is along the proton beam direction.) Since $A(\eta)$ is a ratio, normalisation uncertainties in both the theory and the data tend to cancel, and the analysis becomes simpler.

The asymmetry analysis [4] of the 1992-93 data has 19,039 $W \to e, \mu\nu$ events. These are obtained by selecting isolated, identified, and well-tracked e's and μ's with transverse energy $E_T > 25\ GeV$. The missing transverse energy of the event in the calorimeter and muon system must be $\not{E}_T > 25\ GeV$. To suppress QCD background, events with a jet whose $E_T > 20\ GeV$ are rejected. As the acceptance and efficiencies for detecting l^+ and l^- are found to be equal, $A(\eta)$ reduces to the difference in the number of l^+ and l^- over the sum. Since CP invariance gives $A(+\eta) = -A(-\eta)$, data at $-\eta$

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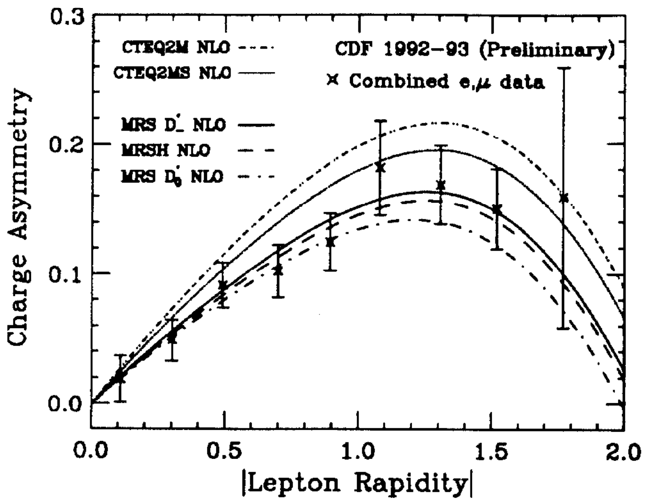

Figure 1. The measured charge asymmetry and predictions from recent PDF's. The data are fully corrected for trigger efficiencies and backgrounds. Systematic errors are included.

	$0.2 < \|\eta\| < 1.7$			$\overline{A}$
PDF Set	χ^2 (7 *dof*)	Prob.	$\Delta\overline{A}$	Prob.
CTEQ 2M	24.	< 0.01	4.6	< 0.01
CTEQ 2MS	11.	0.15	2.9	< 0.01
MRS H	1.8	0.97	-0.1	0.96
MRS D'_-	1.9	0.97	0.5	0.61
MRS D'_0	3.6	0.83	-0.9	0.35

Table 1. χ^2 comparisons of the predicted NLO asymmetries for the most recent MRS and CTEQ distributions. The comparison of the weighted means $(\overline{A})$ is sensitive to systematic shifts, and indicates the MRS H distributions fit the asymmetry data best.

is combined with that at $+\eta$ to increase the statistics in η bins and to further reduce the effect of small undetected differences in the efficiencies for l^+ and l^-. Systematic errors are negligible relative to statistical errors and corrections to the raw measurement are small (5% or less). Hence, the asymmetry measurement is robust. Figure 1 shows the asymmetry measurement.

3. Comparisons with Predictions

Predictions of $A(\eta)$ are from calculations of $d\sigma(l^\pm)/d\eta$ which use next to leading order (NLO) QCD partonic cross sections [5], NLO parton distribution functions (PDF), and the well-known, purely leptonic V-A decay of the W. Experimental cuts and detector effects [4] are also included in the calculations. Figure 1 also shows the asymmetries predicted by the most recent PDF's from Martin, Roberts and Stirling (MRS) [6] and the CTEQ [7] collaboration. Both groups have access to recent DIS results from the CCFR [8] neutrino data, NMC [9] muon data, and HERA [10, 11] *ep* collider data. CTEQ2M and MRSH are post HERA PDF's. To quantify the data's discriminating power to the various predictions, Table 1 shows the goodness of fit χ^2 over seven η bins ($0.2 < |\eta| < 1.7$) and the χ^2 test of the error weighted mean difference ($\Delta\overline{A}$) of the seven data points against calculations.

The DIS $F_2^{\mu n}/F_2^{\mu p}$ and $p\overline{p}$ W charge asymmetry ($A(\eta)$) measurements provide complementary information on the proton structure. $A(\eta)$ is sensitive to the slope of the $d(x)/u(x)$ ratio [1, 12] in the x range $0.007 - 0.27$, whereas the $F_2^{\mu n}/F_2^{\mu p}$ is sensitive to the magnitude of this ratio. $F_2^{\mu n}/F_2^{\mu p}$ is more sensitive to the $\overline{u}$ and $\overline{d}$ sea distributions than $A(\eta)$. Both the MRS and CTEQ NLO predictions on $F_2^{\mu n}/F_2^{\mu p}$ agree (at the level of the 100% uncertainty in the deuteron shadowing corrections [13, 14]), with the recent NMC [9] measurement. What is different is that PDF's which predict the largest difference between the d/u ratio at small x relative to moderate x, also predict the largest W charge asymmetries. Thus, the fact that the charge asymmetry discriminates between PDF's which fit the NMC $F_2^{\mu n}/F_2^{\mu p}$ measurements demonstrates that its sensitivity to the d/u ratio (and not to $\overline{u}$ or $\overline{d}$) at very low x is better than that of the muon scattering experiments. In addition to having very low systematics, the asymmetry data does not have the deuteron shadowing uncertainties, nor is it sensitive to any low Q^2 higher twist corrections.

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