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MEASUREMENT OF THE W BOSON MASS

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We present a preliminary measurement of the W boson mass using data collected by the DØ experiment at the Fermilab Tevatron during the 1994/95 collider run 1b. We use $W \to e\nu$ decays to extract the W mass from the observed spectrum of transverse mass of the electron ($|\eta| < 1.2$) and the inferred neutrino. We use $Z^0 \to ee$ decays to constrain our model of the detector response. We measure $m_W/m_Z = 0.8815 \pm 0.0011(stat) \pm 0.0014(syst)$ and $m_W = 80.38 \pm 0.07(W\ stat) \pm 0.08(Z\ stat) \pm 0.13(syst)$ GeV. Combining this result with our previous measurement from the 1992/93 data [1], we obtain $m_W = 80.37 \pm 0.15$ GeV (errors combined in quadrature).

1 Introduction

The parameters of the electroweak sector of the Standard Model[2] can be taken to be the fine structure constant α_{em}, the Fermi constant G_F, and the mass of the Z^0 boson m_Z, all measured to a precision better than 0.01%. Radiative corrections due to loop diagrams then relate the mass of the W boson m_W and the weak mixing angle θ_W, through these three parameters, the heavy fermion masses, and the Higgs boson mass. Within the Standard Model, a direct measurement of m_W thus constrains the allowed region for the top quark and Higgs masses. In conjunction with a measurement of the top quark mass, it constrains the Higgs mass. Alternatively, a precise measurement of the W mass in combination with measurements of $\sin^2\theta_W$ provides a test of the Standard Model.

2 Data Samples

The DØ detector is described elsewhere [3]. Electrons are identified using the longitudinal and transverse shower shape measurements of clusters in the Uranium-liquid argon calorimeter and matching tracks in the central and forward drift chamber tracking detectors. Electron candidates from $W \to e\nu$ and $Z^0 \to ee$ decays are required to be isolated. The transverse momentum of the neutrino in $W \to e\nu$ decays is inferred by imposing transverse momentum balance.

The electron (two electrons) with highest transverse momentum (p_T) in the event is (are) associated with the W (Z^0) decay. The following kinematic and

[d]Representing the Fermilab DØ Collaboration.

acceptance cuts are made on the W and Z^0 candidate events: $p_T(e) > 25$ GeV, $p_T(\nu) > 25$ GeV and hadronic recoil $p_T(rec) < 30$ GeV (for W only), electron pseudorapidity $|\eta| < 1.2$ (central) or $1.5 < |\eta| < 2.5$ (forward). The final 1994/95 data sample, corresponding to an integrated luminosity of 76 pb^{-1}, consists of 32856 $W \to e\nu$ candidates with central electrons, 1562 $Z^0 \to ee$ candidates with both electrons central, and 1548 $Z^0 \to ee$ candidates with one central and one forward electron.

3 Analysis Technique

Analogous to the invariant mass, we define the transverse mass of the W using the transverse momenta of the decay products only,

$$m_T = \sqrt{2p_T(e)p_T(\nu)\left(1 - \cos\left(\phi(e) - \phi(\nu)\right)\right)}. \tag{1}$$

The transverse mass distribution of $W \to e\nu$ decays has a characteristic Jacobian shape with a mass scale which is set by the W mass. The distribution observed in the data is fitted with templates generated by a Monte Carlo simulation of the W production, decay, detector response and backgrounds. The same procedure is used to extract the W mass from the electron and neutrino p_T spectra as cross-checks, and the Z^0 mass from the ee invariant mass spectrum for calorimeter energy scale calibration purposes.

A fast Monte Carlo simulation is used to generate large numbers of events to obtain statistically precise templates to compare with the data. The W double differential cross section with respect to transverse momentum and rapidity is obtained from the calculation of Ladinsky and Yuan [4]. The mass dependence is parametrized as a relativistic Breit-Wigner line shape, skewed by an exponential parton luminosity factor. The MRSA parton distributions [5] are used for these calculations. The W helicity is chosen according to the probabilities of the various parent quark configurations. Radiative decays ($W \to e\nu\gamma$ and $Z^0 \to ee\gamma$) are generated according to the calculation of Berends and Kleiss [6], and the detector response to radiative decays is simulated. The $W \to \tau\nu \to e\nu\bar{\nu}\nu$ are topologically indistinguishable from $W \to e\nu$ decays, and are included in the W decay model.

The calorimeter energy response to electrons is constrained using test beam data, and calibrated using measurements of the response to π^0 and J/ψ decays, and the Z^0 mass measurement which is calibrated against the value measured at LEP [7]. The calorimeter response to the hard recoil is measured using the $Z^0 \to ee$ decays, in which the p_T of the Z^0 can be measured using the electrons and the recoil separately, and compared. The underlying event is modelled using measurements of minimum bias events. The electron energy and angular resolutions, energy biases due to overlap between electron and recoil, trigger and offline identification efficiencies are measured and incorporated in the detector simulation. The shape and the normalization of backgrounds to the W from QCD and $Z^0 \to ee$ sources are measured and included in the resolution functions. The QCD and Z^0 backgrounds are estimated to be $(1.5 \pm 0.3)\%$ and $(0.55 \pm 0.05)\%$ respectively.

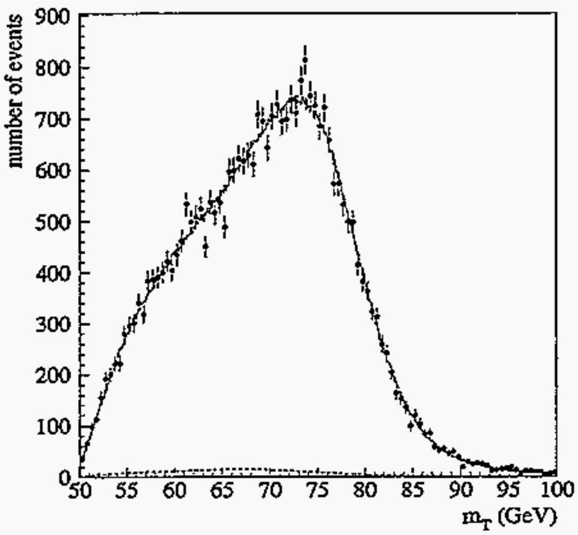

Figure 1: The transverse mass distribution for the Run1b W sample. The points indicate the data, the solid line the simulated m_T lineshape for the maximum likelihood fit, and the dashed line the background contribution.

4 Results

A maximum likelihood fit to the W transverse mass spectrum in the range $60 < m_T < 90$ GeV (figure 1) yields the result $m_W = 80.38 \pm 0.068$ (stat) GeV. We have checked that the result is insensitive to the fitting window. The energy scale uncertainty due to the statistical error in the Z^0 mass measurement is 74 MeV. All other systematic uncertainties combined in quadrature give an uncertainty of 130 MeV. These include uncertainties in calorimeter linearity, electron energy resolution, calibration of the central tracker, hadronic recoil and resolution, lepton removal, efficiencies, backgrounds, W production and decay modelling, and modelling of the detector at high luminosities. The results are preliminary and the systematic uncertainty is expected to reduce as the analysis progresses.

5 Conclusion

A preliminary measurement of the W boson mass from the transverse mass spectrum of central $W \to e\nu$ decays from the DØ 1994/95 (Run 1b) data is presented. The preliminary result is $m_W = 80.38 \pm 0.07(W\ stat) \pm 0.08(Z\ stat) \pm 0.13(syst)$ GeV (total uncertainty is 170 MeV), in good agreement with previous measurements. Combining this result with our previous measurement from the 1992/93 data [1], we obtain $m_W = 80.37 \pm 0.15$ GeV (errors combined in quadrature).

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