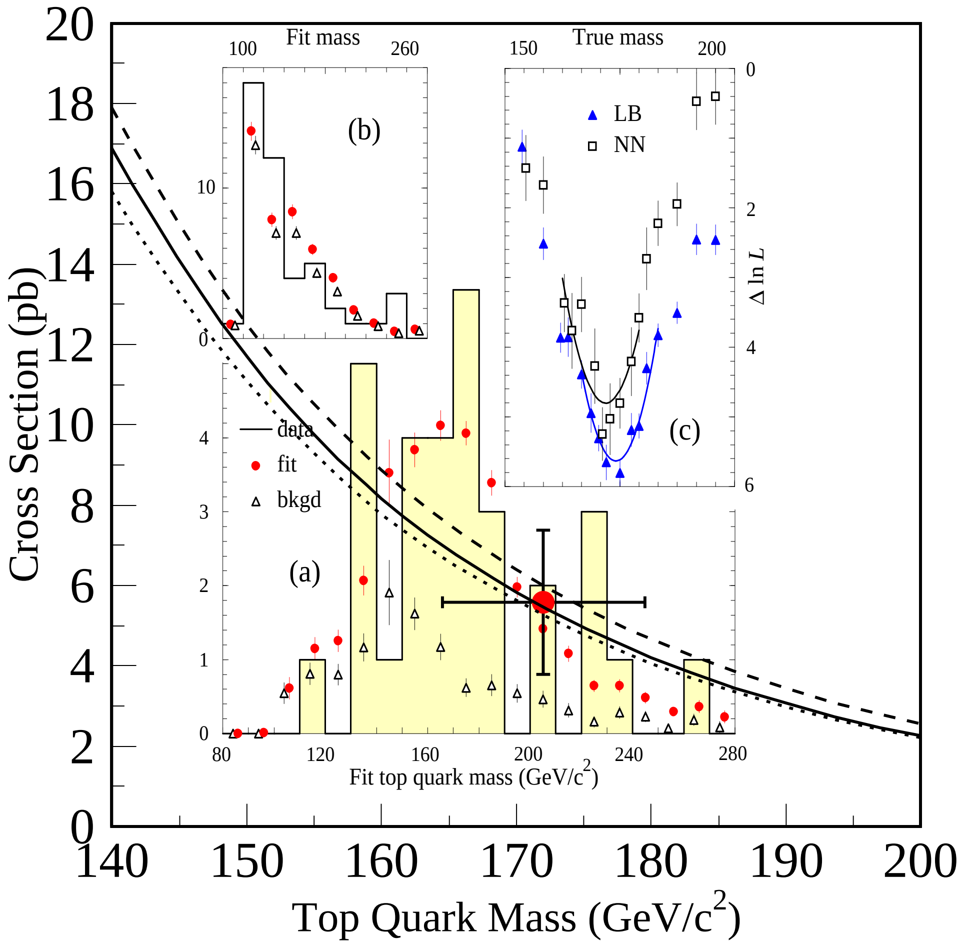
New Results from DØ : 1997 Summer Conferences

The DØ Collaboration



Abstract

This paper contains a brief summary of the physics results presented at the 1997 Summer Conferences by the DØ experiment at the Tevatron $\overline{p}p$ collider.

1 Introduction

This document is a brief summary of the salient results from papers presented by the DØ Experiment at the two major summer conferences, the Lepton Photon Conference at Hamburg and the European Physical Society meeting in Jerusalem. Results from DØ can also be obtained on the World Wide Web at $http://www-d0.fnal.gov/public/d0\_physics\_v2.html$.

2 Top Quark Physics Results

The top physics results are now based on the full 1992-96 data sample of approximately 120 pb^{-1}: the actual value varies from channel to channel as a result of differences in operation of the triggers and the detector.

2.1 Top Mass

The top quark mass has been determined from both the lepton-plus-jets sample and from the di-lepton sample. The combined result is 172.0 ± 7.5 GeV.

2.1.1 Top Quark Mass from Lepton-Plus-Jets Sample

Lepton-plus-jets events may be used to determine the apparent top quark mass using a two-constraint fit to each event. A likelihood fit is made to the resultant distribution taking into account backgrounds. Two different methods, each of which uses a measure of the likelihood that an event be top as compared to background, are used. The results[1] are consistent and are combined. The dominant systematic error is that associated with the determination of the jet energy scale which is checked using samples of Z-plus-jets events. The resultant top mass is $173.3 \pm 5.6(stat) \pm 6.2(syst)$ GeV.

2.1.2 Top Quark Mass from Di-lepton Sample

The dilepton decays of the top quark contain an extra neutrino compared to the lepton-plus-jets decays. This means that with an assumed top mass, the events have zero constraints. Extra constraints must be introduced which permit a given event to favor different top masses. Two methods have been used and entirely consistent results[1] obtained. The results from each have been combined. The numbers of events are small so the statistical error is relatively large. On the other hand the systematic error obtained is such that a significant cross-check of the lepton plus-jets determination is achieved and indeed a perceptible improvement in the overall error on the top mass results. From the dilepton measurement alone we obtain $168.4 \pm 12.3(stat) \pm 3.6(syst)$ GeV.

2.2 Top Production Cross Section

A total of 39 candidate events in the lepton-plus-jets and dilepton channels, with an estimated background of 13.7 ± 2.2 events is used to determine[3] a cross-section for $t\bar{t}$ production of 5.5 ± 1.8 pb. Top may also be observed in the channel in which both W bosons decay to light quarks and result in an all-jet final state. Using this channel, we measure the cross section to be 7.9 ± 3.1(stat) ± 1.7(syst) pb.

3 Electroweak Physics

During the first run of DØ over fifty thousand W bosons decaying through the electron channel were produced. In addition several thousand Z bosons were observed. This large sample has permitted some rather sensitive tests and standard model precision measurements of electroweak physics.

3.1 Diboson Production, Trilinear Couplings

A broad program of investigation of the couplings between the three electroweak bosons, the photon, the Z and the W, has been conducted[4]. Four processes have been examined. They are expected to be strongly dependent on the center of mass energy so the high energy of the Tevatron is an advantage.

$W\gamma$ production is sensitive to the $WW\gamma$ coupling. The final states measured include both the muon and electron decays of the W boson. A search for W boson pair production with the W decaying leptonically is also sensitive to this same coupling as well as to the WWZ coupling. The final state containing WW and WZ pairs could be observed when a W boson decays to lepton and neutrino and the partner W or Z boson decays hadronically. These measurements have been analyzed coherently and the combined limits on anomalous contributions to the vertex functions are very stringent. The precision is sufficient to establish that the couplings between photon and W boson are those of the SU(2)×U(1) electroweak model rather than just the U(1) of electromagnetism.

$Z\gamma$ production has been measured using three leptonic decays of the Z boson ($e\overline{e}, \mu\overline{\mu}, \nu\overline{\nu}$). The charged lepton modes are in principle the more accessible experimentally. However the neutrino mode has less physics background and is remarkably sensitive. This mode gives the single most sensitive set of limits to date on the $ZZ\gamma$ and $Z\gamma\gamma$ couplings.

In general, these measurements have established the SU(2)×U(1) nature of the couplings and are the strongest limits on contributions from beyond the standard model.

3.2 W Boson Properties

Several characteristics of the W boson and its production have been measured[5].

3.2.1 W Production

The measurements of the W cross-section from the Run Ib sample, with 89 pb^{-1} contain about 60k electron decays and the Z sample, nearly 6k decays. The ratio between the W and Z cross sections times branching ratio is 10.32 ± 0.43.

3.2.2 W Width

The ratio between the production cross sections for W and Z is sensitive to several standard model parameters. It may be cast as either a determination of the ratio between total and leptonic widths or of the total W decay width(Γ_W) assuming the standard model for the leptonic rate. We determine a preliminary value of $\Gamma_W = 2.159 \pm 0.092$ GeV.

3.2.3 Universality

By studying the decays of the W to the τ lepton, we can compare the couplings of the W to the electron and τ. The result obtained for the ratio of the couplings is $g_\tau^W / g_e^W = 1.004 \pm 0.019(stat) \pm 0.026(syst)$. This is the best test so far of the universality between $W - e$ and $W - \tau$ couplings at high energy.

3.2.4 W Mass

In the Spring 1997 we presented an update of the W mass determination from fits of the transverse mass and electron p_T distributions. The two are sensitive to different aspects of the measurement and so provide an excellent cross check. The value obtained from the 1994-95 sample is $M_W = 80.45 \pm 0.070(stat) \pm 0.065(scale) \pm 0.070(syst)$ GeV. When combined with the earlier 1992-93 measurement from DØ we obtain $M_W = 80.42 \pm 0.11$ GeV. This is the most precise number to date from a single experiment. While quoted as preliminary, these numbers have survived further cross checks and are currently being submitted for publication with changes at the 10 MeV level.

3.3 Transverse Momentum and Jets with W and Z Bosons

The large sample of intermediate vector bosons has also been used to study QCD. The p_T distributions[6] of the W and Z bosons are described by QCD calculations in the high and low p_T regions with a matching between them. The phenomenological parameter, g_2, which mainly affects the low p_T region has been determined to be $g_2 = 0.59 \pm 0.10(stat) \pm 0.05(sys) \pm 0.04(pdf)$.

The fraction of W events containing a jet is also sensitive to several aspects of the QCD description of the process. The current preliminary result[7], in which theory underestimates the observed $W + 1$ jet rate, is not well described by the QCD calculation. This is an unexpected result.

4 QCD Results

4.1 b-Quark Production Cross Section

The b production cross section at 630 GeV center of mass energy has been measured. The ratio[8] between the measured cross section and the theory is 2.1 ± 0.2. The ratio between the cross-sections at the two energies is well described by the Next-to-Leading Order QCD calculation.

4.2 Photon and Diphoton Production, and $\mathbf{k}_T$ Effects

The different distributions[9] of single and diphoton production are tests of different aspects of the QCD calculations. In order to describe the single photon data an *ad hoc* intrinsic parton transverse momentum needs to be added. The diphoton p_T measurements appear to be well described by a calculation which includes soft gluon resummation in much the same way as the calculation of the W and Z p_T spectra.

4.3 Dijet Angular Distributions and Quark Compositeness

The angular distribution of dijet production can be thought of as a search for scattering between hypothetical constituents of the quarks and gluons. In fact the data[10] demonstrate remarkable agreement with the expectations of QCD, and can be used to set limits on compositeness which vary slightly, depending on the details of the theoretial prescription, but exceed 2 TeV.

4.4 The Dijet Mass Spectrum

We have measured[11] the dijet mass spectrum up to masses of nearly one TeV and find good agreement with the Next-to-Leading Order QCD predictions within the approximately 30-50 % variations in the predictions permitted by the calculations, the parton distribution functions, and the choice of scale.

4.5 Color-Singlet Exchange

Color singlet exchange is characterised by regions of rapidity in which no particles are found, rapidity gaps. At 1800 GeV these gaps occur in slightly less than 1% of those events with two moderate p_T jets. At 630 GeV we find[12] a similar signal but stronger by a factor 2.6 ± 0.6, which is indicative of the pomeron (the singlet exchange) being quark-like.

4.6 Diffractive Rapidity Gap Events

By using rapidity gaps at relatively high η as an indicator of diffractive events, diffractively produced dijets have been observed at both 1800 GeV and at 630 GeV. Triggering on two forward jets, gaps are observed at high η in the opposite direction in $0.67 \pm 0.05\%$ of the events at 1800 GeV. Similarly a signal is present for the topology with two central jets and a rapidity gap at high η on either side. This is the topology expected for double pomeron exchange.

4.7 Azimuthal Decorrelation of Jets

When two and only two jets are produced in the final state, one expects that the two jets will be azimuthally back to back. If there are other jets or radiation in the event then a decorrelation is expected. There are different predictions for the extent of this decorrelation depending on the description used for the radiation. The data are well described by the

Herwig Monte Carlo but the current implementation of the BFKL expectations lies below the data.

4.8 Color Coherence

The interference between radiation from the different partons participating in high energy interactions can be further investigated by looking at event topologies more complex than those with just two jets. In a three jet study[15] a radiation pattern well characterised by Monte Carlo predictions incorporating the *angular ordering* approximation and Next-to-Leading Order QCD calculations, is observed.

Similarly[16], in events with a W boson and a jet, the flow of non-clustered energy in the event is observed to be enhanced in the event plane as compared to the transverse plane, again, as expected from color coherence effects.

4.9 The k_T Jet-Finding Algorithm

Most of the jet studies at hadron colliders have been conducted using a simple cone algorithm to define the jets. A more sophisticated approach, more consonant with the desires of the active theoreticians, and similar to that used in lepton collisions, has recently been initiated[17]. This has been used to determine an average jet mass and also to try and see if there is jet substructure visible as expected in the QCD evolution of a parton shower.

5 New Phenomena Results

At the highest energy collider in the world, searches for *unexpected* phenomena are imperative.

5.1 $ZX \to \nu\overline{\nu} + b\overline{b}$

In the standard model and most of its extensions, Higgs bosons are assumed to be the source of the observed masses of the Z and W bosons. These could be produced in association with a Z boson at the Tevatron collider. We searched for such a signal in which the Z decays to neutrinos, producing large missing momentum, and the Higgs decays to b quarks. Upper limits on the cross section of 84 pb at a mass of 90 GeV falling to 37 pb at a mass of 180 GeV are obtained[18].

5.2 Charged Higgs

A light charged Higgs boson could contribute to the decay modes of the top quark. We have searched for such decays and find none. The limits are sensitive to charged Higgs masses up to 168 GeV. We obtain 0.96(0.26)< $tan\beta$ <35(96) for a Higgs mass of 50(168) GeV using $\sigma_{t\bar{t}} = 5.53$ pb and $m_t = 175$ GeV.

5.3 High Mass Photon Pairs

In some models, there can exist a Higgs which decays predominantly to bosons. For such a Higgs at low mass only the two photon channel is available. We have therefore searched for associated production of a Higgs and a W or Z boson with the W/Z decaying to two hadronic jets. No signal is found and cross section limits are obtained[19]. We exclude a bosonic Higgs with a mass less than 81 GeV at 95% confidence level.

5.4 Squarks and Gluinos

Squarks and gluinos are partners of the quarks and gluons in a supersymmetric description of the world. Being strongly interacting, they would be easily produced, mass permitting, at a hadron collider. Looking for multi-jet events with missing transverse energy gives lower limits[20] on their masses of 260 GeV for equal squark and gluino mass.

5.5 Gaugino Production in Light Gravitino Models

There are several supersymmetric models, especially those with light gravitinos, which lead to a pair of photons and missing transverse energy in the final state. These result as the light neutral gauginos decay to photons and the gravitino which is not detected. Within such models we obtain[21] lower limits on the mass of the lightest chargino of 150 GeV and of the lightest neutralino of 75 GeV.

5.6 New Particles Decaying to Two-Jets

An extension[22] of the analysis of dijet masses is used to search for possible new states. Limits are placed on the cross section which correspond to lower limits on the mass of an excited quark of 725 GeV.

5.7 Heavy Neutral Gauge Bosons

In the same way as the now well known Z boson decays to an electron-positron pair, so also might a putative boson of higher mass. Assuming a coupling equal to that of the Z boson we put a lower limit[23] of 670 GeV on the mass of a possible Z' boson.

5.8 Leptoquarks

It is widely believed that quarks and leptons will eventually be understood to be different states of some unified representation. In that case one expects states which decay into leptons and quarks. Recent experimental hints in high Q^2 deep inelastic production at HERA have enhanced interest in these models. There are DØ results[24] on searches for all generations, but most incisively so far for the first generation (electron-type) leptoquarks. A lower mass limit of 225 GeV for the case of exclusive decay to electrons plus quarks is obtained. For the case when the leptoquark decays 50% of the time to electron and quark and 50% of the time to neutrino plus quark, the 95% confidence level lower limit on the mass is 204 GeV.

6 Conclusions

The DØ Experiment has presented a large number of incisive measurements at the summer conferences of 1997. Particularly telling are the mass measurement of the top quark, the measurement of the mass of the W boson which is currently the world's best single measurement and the study of leptoquarks decaying into leptons and quarks where the current limits rule out a leptoquark interpretation of the HERA data of 1996.

References

[1] B. Abbott et al., DØ Collaboration, Direct Measurement of the Top Quark Mass, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany,FERMILAB-Pub-97/059-E, hep-ex/9703008.

[2] B. Abbott et al., DØ Collaboration, Measurement of the Top Quark Mass Using Dilepton Events,Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Pub-97/172-E.

[3] B. Abbott et al., DØ Collaboration, Measurement of the Top Quark Pair Production Cross Section in $p\overline{p}$ Collisions. Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Pub-97/109-E.

[4] B. Abbott et al., DØ Collaboration, Measurements of Trilinear Gauge Boson Couplings, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/365-E.

[5] B. Abbott et al., DØ Collaboration, DØ Results on W Boson Properties, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/354-E.

[6] B. Abbott et al., DØ Collaboration, Transverse Momentum Distributions of W and Z Bosons Produced in $p\overline{p}$ Collisions at 1.8 TeV, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/355-E.

[7] B. Abbott et al., DØ Collaboration, A Measurement of the Ratio of Production Cross Sections for $W + 1Jet$ to $W + 0Jets$ and Comparisons to QCD, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/369-E.

[8] B. Abbott et al., DØ Collaboration, Determination of the b-Quark Production Cross Section in $p\overline{p}$ Collisions at 630 GeV, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/366-E.

[9] B. Abbott et al., DØ Collaboration, Photon and Diphoton Production, and k_T Effects, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/370-E.

[10] B. Abbott et al., DØ Collaboration, Measurement of Dijet Angular Distributions and Search for Quark Compositeness, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Pub-97/237-E, hep-ex/9707016.

[11] B. Abbott et al., DØ Collaboration, The Dijet Mass Spectrum at DØ , Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/360-E.

[12] B. Abbott et al., DØ Collaboration, Probing Color-Singlet Exchange at DØ , Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/250-E.

[13] B. Abbott et al., DØ Collaboration, Rapidity Gaps in Jet Events at DØ , Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/251-E.

[14] B. Abbott et al., DØ Collaboration, The Azimuthal Decorrelation of Jets Widely Separated in Rapidity, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/371-E.

[15] B. Abbott et al., DØ Collaboration, Color Coherent Radiation in Multijet Events from $p\overline{p}$ Collisions at 1.8 TeV, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Pub-97/201-E, hep-ex/9706012.

[16] B. Abbott et al., DØ Collaboration, Color Coherence in $W + Jet$ Events, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/372-E.

[17] B. Abbott et al., DØ Collaboration, QCD Results Using the k_T Jet-Finding Algorithm in $p\overline{p}$ Collisions at 1800 GeV, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/149-E.

[18] B. Abbott et al., DØ Collaboration, Search for $ZX \to \nu\overline{\nu} + b\overline{b}$Events in the DØ Detector, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/358-E.

[19] B. Abbott et al., DØ Collaboration, Search for High Mass Photon Pairs in $p\overline{p}\to$ diphoton+dijet Events at 1.8 TeV, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/325-E, http://fnalpubs.fnal.gov/archive/1997/conf/Conf-97-325-E.html

[20] B. Abbott et al., DØ Collaboration, Search for Squarks and Gluinos with the DZERO Detector, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/357-E.

[21] B. Abbott et al., DØ Collaboration, Search for Chargino and Neutralino Production in Gauge-Mediated Supersymmetry Breaking Models, Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Pub-97/273-E, hep-ex/9708005.

[22] B. Abbott et al., DØ Collaboration, Search for New Particles Decaying to Two-Jets with the DØ Detector,Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/356-E.

[23] B. Abbott et al., DØ Collaboration, Search for Heavy Neutral Gauge Bosons at DØ , Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/367-E.

[24] B. Abbott et al., DØ Collaboration, Search for Leptoquarks at DØ , Submitted to the XVIII International Symposium on Lepton Photon Interactions, July 28 - August 1, 1997, Hamburg, Germany, FERMILAB-Conf-97/359-E; "Search for Scalar Leptoquark Pairs Decaying to Electrons and Jets in $p\overline{p}$ Collisions." , Fermilab-Pub-97/252-E, hep-ex/9707033.