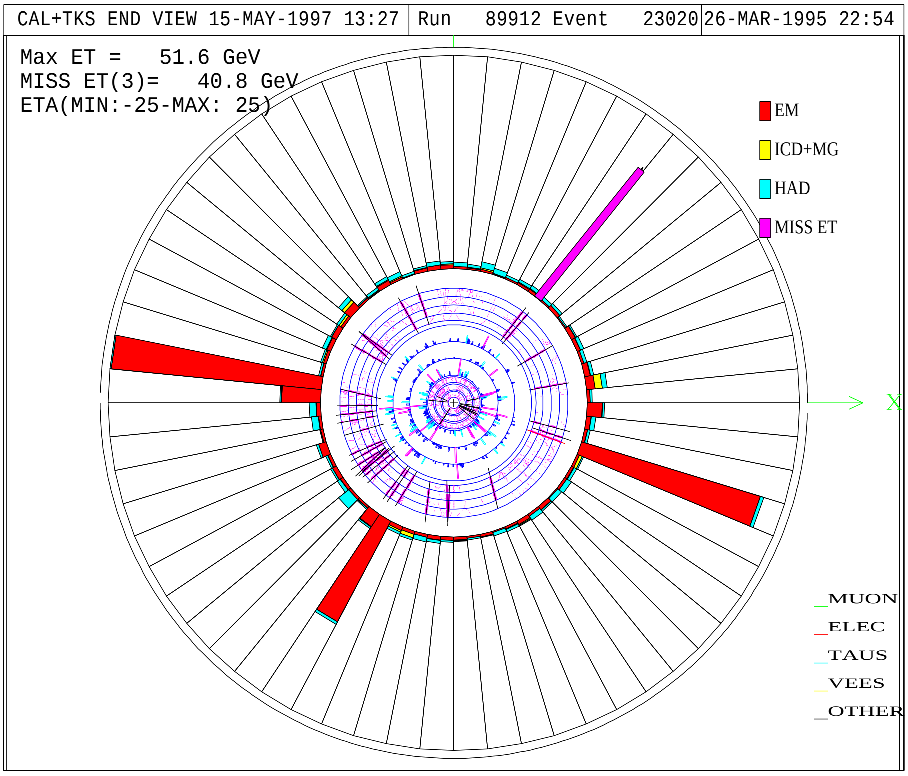
New Results from DØ :
1999 Summer Conferences

The DØ Collaboration



Abstract

This report contains a brief summary of the results submitted to the 1999 Summer Conferences by the DØ experiment.

1 Introduction

This document summarizes the results from papers presented by the DØ Experiment at the biennial European Physical Society conference in Tampere, Finland in July 1999, and at the International Symposium on Lepton and Photon Physics at Stanford, U.S.A. in August 1999 along with some additional results submitted for publication in the past year. Most results from DØ can be found on the World Wide Web at `http://www-d0.fnal.gov/public/d0_physics_v2.html`.

2 QCD Results

2.1 Energy dependence of Inclusive Jet Production

Previous measurements made in central regions of rapidity have been extended to a rapidity of 1.5. Next-to-leading order QCD calculations continue to provide a good description of these data. In addition, a measurement [1] of the inclusive jets cross section at 630 GeV has been completed. Data were taken at 1800 GeV under experimental conditions comparable to those at 630 GeV and permit an incisive comparison. We scale the jet transverse momentum by the collision energy and construct the ratio of invariant dimensionless cross sections as motivated by the quark parton model. This ratio indicates about 10-15% discrepancy with respect to expectations of next-to-leading order QCD.

2.2 Triple Differential Cross Section

By measuring two jets in the final state, we have extracted [2] a differential cross section as a function of transverse energy of the leading jet and the pseudorapidities of the two leading jets. The measurement is sensitive to different ranges of parton distribution functions. Next-to-leading order calculations based on the MRSTU set from the Durham-RAL group, and on CTEQ4M from the CTEQ group, provide better descriptions than other choices.

2.3 Dijet Cross Section and BFKL

Using data at both 1800 GeV and 630 GeV we are able to construct a ratio of cross sections in which the jets, with relatively low transverse energy are separated by substantial intervals in rapidity. It has been argued that such a measurement should be sensitive to the terms of the *BFKL* expansion of the QCD calculation. In particular the BFKL intercept could, in principle, be extracted. A preliminary result was presented at the EPS conference which suggests that the ratio of cross sections is higher than that anticipated by *DGLAP* QCD calculations and may be better described using BFKL techniques.

2.4 Hard Diffractive Jet Production

Diffractive processes account for a substantial fraction of the total $\overline{p}p$ cross section and are usually associated with soft processes. Recently, the process in which two hard jets produced in an event that contains one or more diffractively excited systems have been studied [3].

The measurements define a region of rapidity with no observed particles as a rapidity gap and use that as an indication of exchange of a colorless object, such as a pomeron. In events with characteristics of single diffraction signalled by one forward gap, and with two hard jets, the dependence of the fraction of such jets on both transverse energy, collision energy and other characteristics, is used to deduce that the exchanged pomeron has a hard component similar to that of valence quark distributions in the nucleon.

Events with two forward rapidity gaps, and a pair of high E_T jets in the central region between the two gaps correspond to the configuration expected from double pomeron exchange with the jets originating from a pomeron-pomeron vertex. The E_T distribution is similar to that seen in standard jet events.

2.5 Substructure of Jets and Parton Characteristics

Since parton jets were originally observed in electron-positron collisions considerable effort has been expended in attempting to distinguish the species of partons by their jet characteristics. In proton-antiproton collisions progress has been rather slow. DØ has examined [4] the internal structure of jets using the "k_T" algorithm which is an adaptation of the "Jade" or "Durham" algorithms, used in e^+e^- physics. Using measured parton distribution functions, and data from both 630 GeV and 1800 GeV, we have compared the internal multiplicity of jets, purely as a function of Bjorken x. Because this comparison involves different linear combinations of parton species at the two energies, the measurement can be translated into a comparison of quark and gluon jets. The result indicates a higher sub-jet multiplicity in gluon jets, much as expected qualitatively from the dependence on color charge.

2.6 Angular Distributions in W-boson

In the quark parton model, W production without transverse momentum, the angular distribution of the decay lepton is dominated by the $V-A$ structure of the couplings between leptons and the W boson. In the presence of transverse momentum generated by higher order QCD interactions, the angular distribution is modified. DØ has measured [5] the angular distribution of electrons from W-boson decay as a function of the W-boson transverse momentum. The data favor next-to-leading order QCD over the $V-A$ prediction without QCD effects.

2.7 Transverse Momentum Distributions for Inclusive W- and Z-Boson Production

A measurement of the transverse momentum spectrum of gauge bosons provides a check of QCD both at high p_T, where the perturbative expansions are expected to work well, and at low p_T where soft-gluon resummation techniques are expected to provide important corrections. The W-boson data have high statistics, and therefore can yield a stronger test at high p_T. At low p_T, the higher precision of the Z-boson data are more relevant. DØ has measured [6, 7] both. For the case of the Z-boson data, fully corrected cross sections have been obtained, and the need for inclusion of resummation is clearly evident. The parameter

g_2 is determined very precisely to be $g_2 = 0.59 \pm 0.06$. Again, the agreement between QCD and data is quite good.

2.8 Color Coherence Studies with W bosons

Using W bosons we have made further studies [8] of the emission patterns of energy in proton-antiproton collisions. These studies are sensitive to QCD radiation and to collective effects such as the coherent radiation from different partons. From the pattern of jet emission relative to the direction of a W-boson, there is clear evidence for the expected quantum interference.

3 Electroweak Physics

During the first run of DØ , over 50,000 W bosons and several thousand Z bosons were observed through their decay into electrons. Improvements in the measurement of several characteristics of the W boson, and its couplings to the other electroweak bosons continue, to be made. These constitute important components of the attempts to seek the breakdown of the standard electroweak model of particle interations.

3.1 Width of the W-Boson

The products of absolute cross sections and branching ratios into leptons have been measured [9] for both W- and Z-bosons. The high statistics and well-controlled systematics make this one of the highest precision tests of QCD at the Collider. By taking the ratio of the two processes, several systematic errors, in particular that from the determination of the luminosity, cancel. Combining our results with our previous measurements that used both electrons and muons we obtain 10.54 ± 0.24 for the ratio of cross sections multiplied by branching fractions. This has been used to determine the total decay width of the W, $\Gamma_W = 2.107 \pm 0.0054$ GeV. The upper limit on width of the W-boson into unknown channels is 132 MeV at 95% CL.

Using data at 630 GeV, we have also determined the W cross section at that energy. The precision is about 10% and agrees with the measurements made at the S$p\overline{p}$S by the UA1 and UA2 experiments.

3.2 Mass of the W-Boson

DØ has obtained a new result for the mass of the W of $M_W = 80.691 \pm 0.227$ GeV based on measurements using the end calorimeter [10]. Combining this and previous measurements using central calorimeters leads to a final DØ measurement of $M_W = 80.482 \pm 0.091$ GeV. Some of the reduction in the uncertainty comes from the use of the increased rapidity range afforded by the use of both forward and central calorimeters. This accuracy establishes the need for electroweak loop corrections to the W-boson mass at the level of five standard deviations. The result has recently been submitted for publication [11].

3.3 Anomalous Couplings of the W-Boson

DØ continues to produce consolidated determinations [12] of limits on anomalous gauge couplings among the three electroweak vector bosons, the photon, the Z and the W. Such couplings are accessed through diboson production processes. Our latest publication describes in detail the determination of limits on the WWZ and $WW\gamma$ couplings. Although no significant departure is observed, a beautiful candidate $WZ \rightarrow e\nu\ ee$ event has been found, despite a signal expectation of about a tenth of an event, and is displayed on the cover of this document.

4 Results for Bottom and Top Quark Physics

The results for top physics are now based on the full 1992-96 data sample of approximately 120 pb^{-1}. In most cases the results are final. During 1998-9, the CDF and DØ collaborations combined all their measurements to produce a Tevatron-averaged mass value of 174.3 ± 5.1 GeV. The procedure and result have been fully documented in Fermilab-TM-2084. Several interesting analyses are still being pursued, but, because of low statistics, are aimed more at the thorough understanding of issues that will become crucial during the next data taking period.

4.1 b-quark Physics

The work on measurements of the b-quark cross section has led to two papers [13], that were submitted for publication during the past year. One paper described results on $b\bar{b}$ correlations and updated the cross section measurement, the other covered b quark production measurements at large rapidity.

4.2 Advanced Analysis Techniques in Top Physics

Over the course of the past few years, advanced multivariate analyses have come to fruition at DØ . We describe [14] here just two new applications of neural net analyses in top physics.

The first example involves the approach being employed to search for single top production. This process has a cross section about 50% of that for top-antitop pair production. However, the signal is far less distinctive and we have attempted to design variables for the neural net analysis that emphasize the unique kinematic singularities, based on an analysis of the Feynman diagrams relevant to both signal and backgrounds. In the second example, a neural net analysis is used to measure the $e\mu$ dilepton signal of top-antitop production. This was measured previously using a more traditional approach to the analysis, but another $e\mu$ event was found using the new technique.

In both these cases, significant improvements have been achieved in discrimination of signal relative to background.

4.3 Spin correlations in $t\bar{t}$ production

During the course of this year we have performed an analysis [15] to search for the correlations between the spin orientations of the top-quark and its anti-partner. In contrast to the situation with lighter quarks, the short lifetime of the top quark implies that it should decay before the correlations generated at production are destroyed by hadronization. For this analysis, we use $t\bar{t}$ dilepton events and, although the results indicate the expected correlation, the statistics are too limited to yield a definitive result at this stage.

5 Results on New Phenomena

At the highest energy collider in the world, it is imperative to search for *unexpected* phenomena, and during this past year we have extended our searches in several directions.

5.1 High-Mass Lepton-Pairs

The production of vector bosons proceeds primarily through the fusion of a quark and an antiquark in the colliding proton and antiproton. This process is well described by QCD. DØ presented measurements [16] that extend the mass of the dilepton system to 600 GeV. If, at some higher scale, leptons and quarks were to be composite, the effects could be detected at present mass scales through effective contact terms in the lagrangian, which would give contributions to the cross sections and alter angular distributions. The good description of the electron-positron pair data by QCD permits limits to be placed on compositeness models, which use mutual constituents for the quarks and leptons, with a scale of up to 6 TeV at 95% confidence. The specific limits depend on the details assumed for the space-time character of the interaction of the sub-constituents.

5.2 High-Mass Photon-Pairs

Certain models of electroweak symmetry breaking contain a Higgs particle that decays with standard model strength, but only to bosons. For such a Higgs, often called the bosonic Higgs, at low mass, only the two photon decay channel is available. We have therefore searched [17] for associated production of such 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 exclude a bosonic Higgs with a mass of less than 78.5 GeV at 95% confidence level.

5.3 High-Mass Parton-Pairs

We have measured [18] the dijet mass spectrum up to masses of nearly one TeV, and once again find good quantitative agreement with the Next-to-Leading Order QCD predictions. By taking the ratio of the dijet mass distributions in two regions of pseudorapidity, systematic uncertainties are reduced, thereby enhancing the sensitivity to quark compositeness. This is an extension of the technique described in the above section on lepton pairs. This measurement excludes compositeness scales of quark substructure below 2.4 TeV at the 95% confidence level.

A model that can lead to deviations from QCD at high transverse jet energies adds a second color SU(3) multiplet of gluon-like objects (colorons), but no additional quarks, to the standard model. Colorons lead to modifications of jet angular distributions, similar to those expected from contact terms associated with substructure of partons. Our published dijet angular distributions [18] are very well described by Next-to-Leading-Order QCD. DØ has translated that agreement into a mass limit on possible colorons. At a 95% confidence level, masses less than $759 \times \cot\theta$ GeV are excluded, where $\cot\theta$ is the relative coupling of the two multiplets.

5.4 Leptoquarks

Leptoquarks containing both lepton and quark flavor quantum numbers arise in a variety of compositeness and extended technicolor models. Limits from flavor changing neutral currents confine the models to the cases where any given leptoquark decays to leptons and quarks of the same generation. First generation leptoquarks were a popular explanation for the high mass events observed in HERA experiments. These were systematically sought in electron final states but not found. They are now conclusively excluded as a source for the HERA excess.

The search for second and third generation leptoquarks has continued. DØ has presented two recent results [19, 20], which exclude second generation scalar leptoquarks if the masses are less than about 200 GeV, and vector leptoquarks of the same species are excluded at somewhat higher mass values.

5.5 Searches for Supersymmetric Particle

Searches for supersymmetric partners of the quarks, gluons and gauge bosons have been conducted in frameworks of several models, including gauge-mediated and gravity-mediated SUSY, and R-parity violating models. The results provide limits in multidimensional parameter space. Conventionally, the limits are often quoted for the particular condition where the squark and gluino masses are equal.

5.5.1 Dilepton Signatures of SUSY

A pair of leptons and missing energy is a signature favored in many models, in particular the popular minimal low-energy super-gravity(mSUGRA) models. DØ has performed [21] a search in these channels, using a technique based on an approach in which a very large number of models (parameter sets) and different experimental criteria are examined simultaneously. This compute-intensive approach extends previous preliminary results from the experiment and for low values of the SUSY parameter $\tan\beta$, the limits on SUSY searches are extended beyond those set previously by the LEP experiments.

5.5.2 The Sbottom Quark

In order to retain simplicity, the masses of the squarks of all three generations are often assumed to be degenerate. However, the large masses of the third generation of quarks, the bottom and the top, suggest that the Yukawa couplings might lead to large splittings between the mass eigenstates of the respective partner squarks. We therefore specifically sought the super partner of the top quark. Now, using the same data and analysis as for a third generation leptoquark search [22], we have also looked for [23] the superpartner of the bottom quark, the sbottom.

The search assumes the decay of the sbottom quark produces a bottom quark and the lightest supersymmetric particle (LSP). The former would decay semi-muonically, and the latter would add to the missing energy. Limits on the production cross section are obtained as a function of the mass of the sbottom quark and of the LSP. In turn, this excludes masses of the sbottom quark up to 115 GeV for LSP masses up to about 20 GeV. For lower sbottom masses, the excluded LSP mass range is larger.

5.5.3 R-Parity Violating SUSY

Although much of the phenomenology of SUSY production is carried through assuming conservation of R parity, in fact, this is an assumption not imposed by any demands of data or theory. Searches without such assumptions tend to be more difficult. DØ has searched [24] for final states with two electrons and four jets. For the case in which their masses are equal, the lower limit on gluino and squark masses is 277 GeV.

5.5.4 The Supersymmetric Charged Higgs Particle

In the standard model, the Higgs field can be accomodated by a single Higgs particle. In supersymmetric models a somewhat more complicated situation exists. There must be at least two complex Higgs-doublet fields. The particle spectrum is then much richer and includes a charged Higgs. If light enough, one could expect that decays of the top quark into a charged Higgs and a b quark might compete with the more usual charged W boson and b quark. The agreement between the measured rate and that expected for the latter mode has been used [25] by DØ to set limits on the mass of the charged Higgs-boson for a range of values of $\tan\beta$, which controls the relative vacuum expectation values of the two Higgs fields in the models.

6 Conclusions

The DØ Experiment has presented a large number of new and interesting measurements at the summer conferences of 1999. Top and bottom physics, results from studies of QCD, electroweak parameters and searches for new phenomena continue. Especially important are the new measurement of the electroweak parameters, the W mass, and, through the ratio of W and Z production cross sections, the W-boson width.

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