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Searches for New Particles at DØ

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SEARCHES FOR NEW PARTICLES AT DØ

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REPRESENTING THE DØ COLLABORATION

We report the results of searches at the Tevatron for first and second generation leptoquarks and for new charged gauge bosons. The data were collected with the DØ detector from $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV. No evidence for the existence of these particles is seen and mass limits are set. We report new preliminary results of a search for a heavy neutral gauge boson in the process $Z' \rightarrow e\bar{e}$, from an integrated luminosity of 105 pb^{-1} . We exclude the existence of a Z' of mass less than $670 \text{ GeV}/c^2$, assuming a Z' with the same coupling strengths to quarks and leptons as the standard model Z boson.

1 Searches for leptoquarks

Leptoquark bosons which couple to a lepton and a quark are predicted by a number of extensions to the standard model.¹ Leptoquarks are expected to couple to a single generation of leptons and quarks and are assumed to be produced in pairs in $p\bar{p}$ collisions. The leptoquark may decay to $l^\pm q$ or νq . We have searched for the signatures $l^+ l^- jj$ and $l^\pm \nu jj$ in both the electron and muon channels using the DØ detector.² The data sets represent 14 pb^{-1} and 12 pb^{-1} respectively. We exclude a first generation leptoquark with mass less than 130 (116) GeV/c^2 for $\beta = 1.0$ (0.5), where β is the branching fraction of leptoquarks to $l^\pm q$.³ We exclude the existence of a second generation leptoquark of mass less than 111 (89) GeV/c^2 for $\beta = 1.0$ (0.5).⁴ CDF has reported first and second generation leptoquark searches using a larger data sample and a third generation search at this conference.⁵ All limits referred to in this paper are at the 95% CL.

2 Searches for new gauge bosons

2.1 Introduction

Additional heavy neutral gauge bosons, generically called Z' , and heavy charged gauge bosons, W' , are predicted by numerous extensions to the standard model. One of the earliest of these extensions is the left-right model, the addition of a right-handed gauge group to the electroweak sector giving $SU(2)_R \times SU(2)_L \times U(1)$.⁶ There are three new gauge bosons which arise in the left-right

model, two charged bosons with right-handed couplings, W_R^\pm , and a neutral Z' . There are many superstring-derived unified models that contain additional $U(1)$ symmetry groups, possibly leading to detectable additional neutral gauge bosons.⁷

Reported searches for W' (Z') typically set a limit on the W' (Z') mass based on a particular model. A reference model W' (Z') with the same coupling strengths to quarks and leptons as the standard model W (Z) boson and with decay to W and Z bosons suppressed is traditionally used for this purpose. All mass limits in this paper refer to a W' (Z') of this type. Many specific models are expected to have smaller cross sections than this model, so the mass limit for a specific new boson can be substantially less.⁸

The W' (Z') width $\Gamma_{W'(Z')}$ is assumed to scale with the W' (Z') mass, $\Gamma_{W'(Z')} = (m_{W'(Z')}/m_{W(Z)})\Gamma_{W(Z)}$. This scaling is what would be expected for a reference model W' (Z'). The scaling is modified as the decay channel to top quarks becomes available.

2.2 Searches for new charged gauge bosons

Both DØ and CDF have reported searches for $W' \rightarrow e\nu$, assuming that the neutrino does not interact in the detector and that $m_\nu \ll m_{W'}$. These searches use the missing E_T from the neutrino and the electron p_T to construct a transverse mass, then look in the transverse mass spectrum for signs of a W' . The DØ limit from 14 pb⁻¹ is $m_{W'} > 610$ GeV/c².⁹ The CDF limit from 20 pb⁻¹ is $m_{W'} > 652$ GeV/c².¹⁰ DØ has also reported a search specific for W_R in the channel $W_R \rightarrow e\nu_R$.¹¹ The right-handed neutrino ν_R is a new particle and is likely to be massive and unstable. The method of search does not rely on missing transverse energy but looks in the inclusive electron p_T spectrum for the Jacobian peak expected from W_R . This method is applicable to any W' decaying to an electron and a neutrino and in the limit $m_\nu \ll m_{W'}$, the mass limit obtained from 75 pb⁻¹ of data is $m_{W'} > 720$ GeV/c².

The event sample consists of high quality, central electrons with $p_T > 55$ GeV/c. Aside from electrons from possible W' decays, this sample includes electrons from W and Z /Drell-Yan and apparent electrons arising from QCD processes in which jets are misidentified as isolated electrons. The amount of these three processes in the data is determined by a simultaneous fit of the data to electron p_T and transverse mass spectra for these processes determined from simulation and from data, assuming no W' . The spectra obtained from this fit are compared to the data in Fig. 1. The limit on W' production is obtained by constructing probability distributions for the inclusion of W' production in the electron p_T spectrum for a range of m_{W_R} - m_{ν_R} combinations. The limits

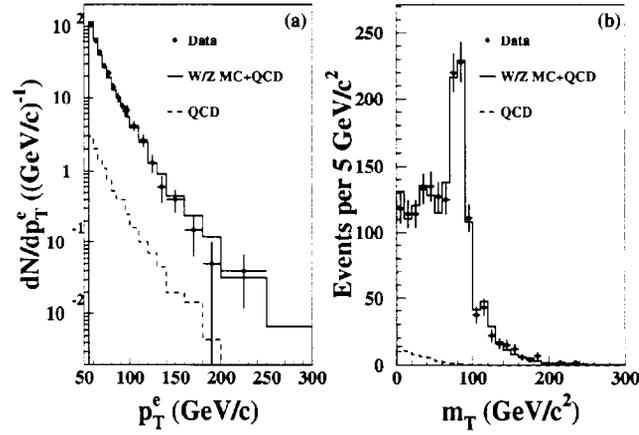


Figure 1: (a) Electron transverse momentum and (b) transverse mass distributions of the inclusive high p_T electron sample.

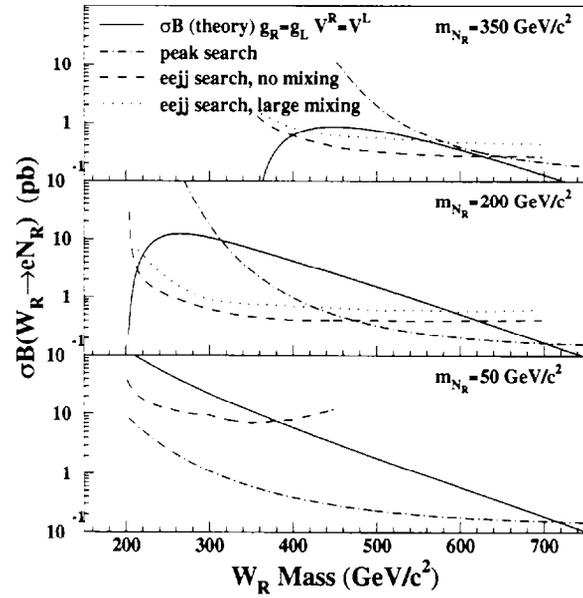


Figure 2: 95% CL upper limit on σ_B as a function of the W_R mass. Limits are shown for three values of the neutrino N_R mass.

Table 1: Background estimates and event yields for the eej and $eejj$ samples.

process	eej	$eejj$
Z, γ^*	12.84 ± 2.31	1.26 ± 0.34
$t\bar{t}$	0.61 ± 0.35	0.42 ± 0.16
WW	0.13 ± 0.02	0.01 ± 0.68
QCD	9.90 ± 4.01	1.38 ± 0.68
total	23.84 ± 4.64	3.08 ± 0.78
observed	23	2

obtained for three neutrino masses are shown in Fig. 2 (peak search).

If the right-handed neutrino is sufficiently massive, the decay products may be searched for explicitly. The decay proceeds $\nu_R \rightarrow W_R^* e$, $W_R^* \rightarrow q\bar{q}'$, assuming that the other generations of right-handed neutrinos are at least as massive. If the W_R mixes with the W , the decay will also proceed $\nu_R \rightarrow W e$ and the branching fraction to $q\bar{q}'$ will be reduced by the leptonic decay of the W . A data sample is selected with two electrons and two jets with $E_T > 25$ GeV. The dielectron invariant mass range in the vicinity of the Z pole is removed. Table 1 shows the number of observed events and the estimated background in the sample. A two electron one jet sample is also exhibited to demonstrate that the background is understood. There is no observed signal. The limits obtained from this search are also shown in Fig. 2. The limits from both searches are shown in Fig. 3 as excluded regions in the $m_{W_R}-m_{\nu_R}$ plane.

2.3 Searches for new neutral gauge bosons

DØ has previously reported a search for $Z' \rightarrow ee$, setting a limit $m_{Z'} > 490$ GeV/ c^2 from 15 pb $^{-1}$ of data.¹² CDF has reported searches for $Z' \rightarrow ee$ and $Z' \rightarrow \mu\mu$ and the combined limits from these searches at this conference.⁵ DØ reports new preliminary results from a search for $Z' \rightarrow ee$ in 90 pb $^{-1}$ of additional data.

A data sample of dielectron events is selected requiring one electron with $E_T > 30$ GeV and one electron with $E_T > 25$ GeV. The electron identification requirements are relaxed to assure high acceptance. Electrons near module boundaries in the central calorimeter are removed. At least one electron energy cluster must be in the central calorimeter. At least one of the electron energy clusters must have a matching track in the tracking system. There are 5707 events in the data sample. In the absence of Z' , the sample consists of Z

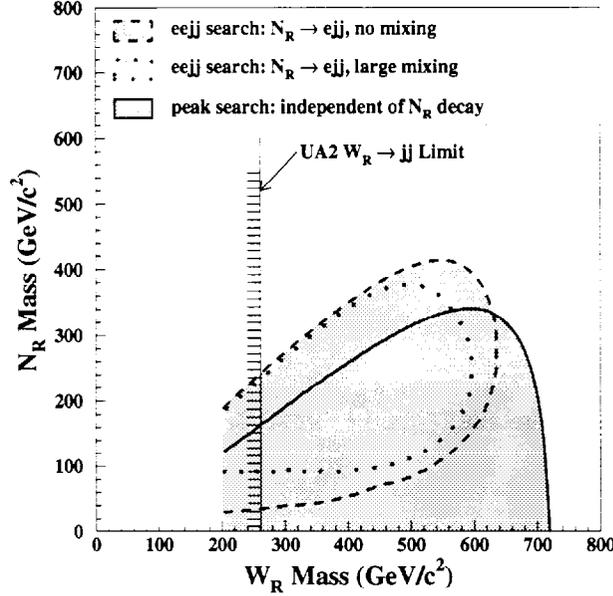


Figure 3: Excluded regions of W_R mass at the 95% CL assuming a reference model W_R .

and Drell-Yan production and includes a background of approximately 3% from QCD processes in which jets are misidentified as isolated electrons. The dielectron invariant mass spectrum is shown in Fig. 4. For $m_{ee} > 300 \text{ GeV}/c^2$ we expect 5.8 events from Z continuum and Drell-Yan production; six events are observed. Above $500 \text{ GeV}/c^2$ we expect 0.3 events; one event is observed.

A limit is obtained on Z' production expressed as the ratio $\sigma B(Z' \rightarrow ee)/\sigma B(Z \rightarrow ee)$. The relative acceptance for Z' to Z production is determined from Monte Carlo simulation.¹³ The event selection efficiency for Z' and Z are taken to be substantially the same. The production limit is obtained for a range of Z' masses by constructing probability distributions for Z' production based on the events observed in $m_{Z'} \pm 4\Gamma_{Z'}$. Uncertainty of 10% in translating events to a cross section ratio is included in this distribution. The likelihood that the observed events could be Z /Drell-Yan or QCD background is not included in the calculation. The region above the limit curve in Fig. 5 is excluded. From the intersection of the limit and theory curves, we exclude the existence of a Z' from the process $Z' \rightarrow ee$ for $m_{Z'} < 660 \text{ GeV}/c^2$. This limit may be combined with the limit obtained previously from 15 pb^{-1} of data. From a combined data set of 105 pb^{-1} , we exclude the existence of a Z' boson

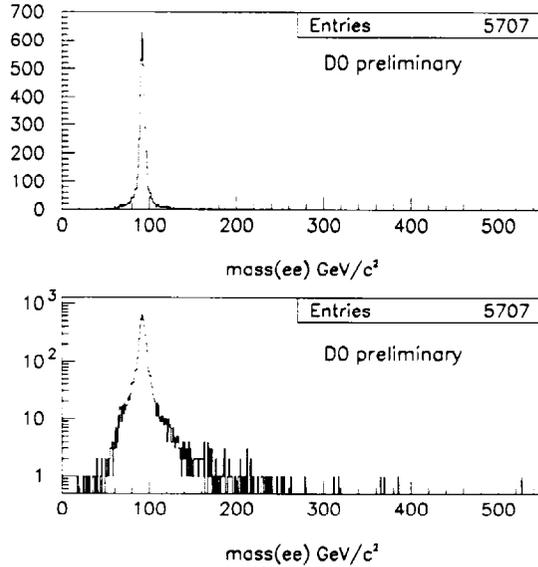


Figure 4: The dielectron invariant mass spectrum from 90 pb⁻¹.

for $m_{Z'} < 670 \text{ GeV}/c^2$.

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References

1. J. Pati and A. Salam, *Phys. Rev. D* **10**, 275 (1974); H. Georgi and S. Glashow, *Phys. Rev. Lett.* **32**, 438 (1974); E. Eichten *et al.*, *Phys. Rev. D* **34**, 1547 (1986); J.L. Hewett and T.G. Rizzo, *Phys. Rep.* **183**, 193 (1989).
2. DØ Collaboration, S. Abachi *et al.*, *Nucl. Instrum. Methods A* **338**, 185 (1994).
3. DØ Collaboration, S. Abachi *et al.*, *Phys. Rev. Lett.* **72**, 965 (1994).

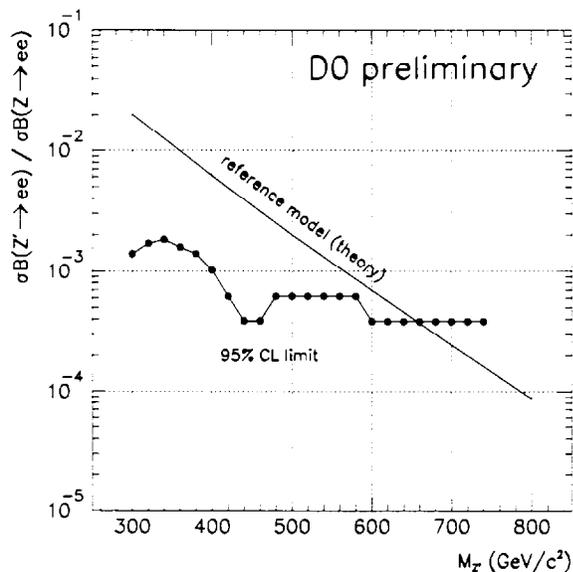


Figure 5: 95% CL upper limit as a function m_Z . The expected theoretical value using standard model Z couplings is also shown.

4. DØ Collaboration, S. Abachi *et al.*, *Phys. Rev. Lett.* **75**, 3618 (1995).
5. H. Wenzel for the CDF Collaboration, these proceedings.
6. For a general survey and original references see R.N. Mohapatra, *Unification and Supersymmetry*, (Springer-Verlag, New York, 1992).
7. M. Cvetič and P. Langacker, U. of Penn. Rep., UPR-0690-T (1996).
8. J.L. Hewett and T.G. Rizzo, U. of Wisconsin Rep., MAD-PH-645 (1991).
9. DØ Collaboration, S. Abachi *et al.*, *Phys. Lett. B* **358**, 405 (1995).
10. CDF Collaboration, F. Abe *et al.*, *Phys. Rev. Lett.* **74**, 2900 (1995).
11. DØ Collaboration, S. Abachi *et al.*, *Phys. Rev. Lett.* **76**, 3271 (1996).
12. DØ Collaboration, S. Abachi *et al.*, accepted for publication, *Phys. Lett. B*, FERMILAB-PUB-96/187-E.
13. PYTHIA Monte Carlo with MRSD-' pdf's. T. Sjöstrand, *Computer Physics Commun.* **82**, 74 (1994); A.D. Martin, R.G. Roberts and W.J. Stirling, *Phys. Lett. B* **306**, 145 (1993); *Erratum Phys. Lett. B* **309**, 492 (1993).