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Search for First and Second Generation Leptoquarks at DØ

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SEARCH FOR FIRST AND SECOND GENERATION LEPTOQUARKS AT DØ *

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ABSTRACT

A search for first and second generation leptoquarks has been done with the DØ detector at Fermilab's p$\bar{\text{p}}$ collider with $\sqrt{s} = 1.8$ TeV. 95% C.L. mass limits for first generation scalar leptoquarks have been recently published. The number for the total integrated luminosity used in the first generation leptoquark analysis has changed (via a change in the total inelastic cross section) since the publication. The new limits are 130 GeV/c^2 and 116 GeV/c^2 for a respective 100% and 50% decay branching ratio of the leptoquark to electron. The preliminary upper limit on the cross section from the search for second generation scalar leptoquarks has set limits on the mass of the second generation leptoquark of 97 GeV/c^2 for 100% branching to muons and 80 GeV/c^2 for 50% branching. In contrast with leptoquark detection thresholds at e$^+$e$^-$ and e-p machines, these limits are independent of the unknown coupling of the leptoquark to leptons and quarks.

1. Introduction

Leptoquarks are exotic particles with both color and lepton quantum numbers. They are bosons that appear as spin = 0 or spin = 1 particles in many SUSY, GUT and composite models.[1] The coupling constant of leptoquarks to leptons and quarks is an unknown parameter, λ, in the theory, but experimental constraints[2] require the coupling, $\lambda^2/4\pi$, to be on the order $0.1\alpha_{em}$ for masses of the leptoquark that can be probed with the current DØ data. Since leptoquarks have color, they can be produced via the strong interaction as leptoquark - anti-leptoquark pairs. For light leptoquarks ($\lesssim$ 1-100 TeV) the coupling of the leptoquark to fermions is required to be generational; for example, a first generation leptoquark may only couple to electrons, electron neutrinos, u and d quarks. This restriction is required to prevent leptoquarks from contributing to the violation of the limits on the branching ratio of rare decays such as $K^+ \rightarrow e^+\nu$. The expected signatures for light first generation leptoquark pairs are: two electrons plus at least two jets, one electron plus missing Et plus at least two jets, and missing Et plus two or more jets. The expected signatures for a second generation

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leptoquark pair are the same except the electrons are replaced by muons. The leptons, missing Et, and jets in leptoquark events are also expected to be well isolated from each other in general.

2. Analysis

A description of the DØ detector is given elsewhere.[3] Also, details of the first generation analysis can be found in a recent publication.[4] This report will cover the analysis for the second generation leptoquark search. Only those signatures which contain at least one muon are dealt with here.

The data used in this analysis were taken between September of 1992 and May of 1993 during the 1992-1993 Tevatron collider run. It represents 12.3 pb^{-1}. Two data sets were selected, one for the di-muon leptoquark signature and one for the single muon leptoquark signature. Both data sets were required to pass a trigger with a muon and jet requirement. The hardware portion of the trigger required a muon with Et greater than 3 GeV and $|\eta| < 2.4$, and one jet tower (0.2×0.2 radians in $\eta \times \phi$) with Et greater than 5 GeV. In the software portion of the trigger, one muon with Et greater than 8 GeV and one jet with Et greater than 15 GeV were required. The trigger cut left 751 events in the two muon sample and 2938 events in the single muon sample.

The event selection for the two muon leptoquark signature is given in table 1. The event selection for the single muon leptoquark signature is given in table 2. The muon quality cuts mentioned in both tables 1 and 2 are for rejecting cosmic muons and also combinatorics which are reconstructed out of stray hits in the muon chambers. The muon isolation cut mentioned in table 1 requires that there is no jet within 0.65 radians of the muon(s) in question. For the single muon selection no jet within 0.7 radians of the muon in question is allowed. The $\Delta\phi_{\mu\mu}$ cut in table 1 is for eliminating low mass di-muon events such as J/Ψ's. Here ϕ is the azimuthal angle. The last event after the jet Et cut in the two muon event sample is rejected by excluding events with back to back muons in ϕ. This cut rejects 75% of the Z background. The expected number of background for the cuts used in the two muon event selection was estimated to be about 0.9 events from Drell-Yan, $b\bar{b}$ production, and fake muons from punchthrough of pions in QCD events.

Table 1. The event selection for the two muon leptoquark signature

Selection cut	Number of events surviving cut
Trigger selection	751
Two muons with Pt > 25 GeV/c	206
Two muons: $\mid\eta\mid < 1.7$; one muon: $\mid\eta\mid < 1.0$	102
One muon passes muon quality cuts	49
Two muons pass muon isolation cut	18
$\Delta\phi_{\mu\mu} < 0.1$ rad	17
Two jets Et > 25 GeV	1
$\mid\pi - \Delta\phi_{\mu\mu}\mid > 0.2$ rad	0

The detector clean up cuts in the single muon analysis are used to eliminate those events that have badly measured jets or large amounts of electronic noise in the calorimeter which are more problematical in measuring missing Et. The back to back cut between the muon and the missing Et, $|\pi - \Delta\phi_{\mu,MEt}| > 0.2$ rad, in table 2 is designed to eliminate W associated events and also some events with badly measured muon momentum, since these events are expected to have the missing Et back to back in ϕ with the muon. The number of expected background events for the cuts given in table 2 was estimated to be about 1.1 events from $W \rightarrow \mu\nu$ plus jets, $b\bar{b}$ production, and fake muons from punchthrough.

Table 2. The event selection for the single muon leptoquark signature

Trigger selection	2938
Detector cleanup	1925
One muon Pt > 20 GeV/c	1660
One muon: $\mid \eta \mid < 1.0$	1232
One muon passes muon quality cuts	400
Missing Et > 25 GeV leaves	295
One muon passes isolation cut	92
$\mid \pi - \Delta\phi_{\mu,MEt} \mid > 0.2$ rad	59
Two jets Et > 25 GeV	18
Transverse mass for muon and missing Et > 95 GeV/c^2	0

With no observed events, the upper limit on the cross section was calculated as in equation 1.

$$\begin{aligned} \beta^2 \times \sigma^{\mu\mu} &= N_{\mu\mu}^{95\%\ CL} / (\epsilon_{\mu\mu} \cdot L) \\ 2\beta(1-\beta) \times \sigma^{\mu\nu} &= N_{\mu\nu}^{95\%\ CL} / (\epsilon_{\mu\nu} \cdot L) \end{aligned} \qquad (1)$$

Here β is the branching fraction for leptoquark decay to muon plus quark. The total efficiency for the two signatures is represented by $\epsilon_{\mu\mu}$ and $\epsilon_{\mu\nu}$. L is the integrated luminosity which was 12.3 pb^{-1} for this analysis. The kinematic efficiencies for detecting leptoquarks were determined from ISAJET[5] Monte Carlo processed with GEANT.[6] The muon detection efficiency was determined from a study of the data. And the trigger efficiency was determined from the data and a study of the leptoquark Monte Carlo processed with a simulation of the DØ trigger. The total preliminary efficiency for the two muon plus two jet leptoquark signature varied from 0.27% to 7.1% for masses ranging from 45 to 250 GeV/c^2. For the single muon plus missing Et plus two jet signature, the total efficiency varied from 0.1% to 4.56% for masses ranging from 45 to 200 GeV/c^2.

The number of expected events with no events seen was calculated according to the method by Cousins and Highland[7] using the total uncertainty on $\epsilon \cdot L$ given in table 3. These uncertainties are the total systematic and statistical uncertainties added in quadrature. The preliminary 95% CL limits on the number of expected events, $N_{\mu\mu}^{95\%\ CL}$ and $N_{\mu\nu}^{95\%\ CL}$, are also given for each mass in table 3 along with the upper limit on the measured cross section times the appropriate branching ratio factors.

Table 3. The preliminary total uncertainty (Err) from the second generation analysis and the 95% CL for the upper limit on the number of expect events and measured cross section

Mass (GeV/c^2)	45	75	100	150	200	250
$\mathrm{Err}_{\mu\mu}(\%)$	39.8	30.8	29.9	28.7	29.0	28.9
$\mathrm{Err}_{\mu\nu}(\%)$	24.3	19.7	19.3	19.9	20.0	-
$N_{\mu\mu}^{95\%\ CL}$	4.87	3.62	3.57	3.51	3.52	3.51
$N_{\mu\nu}^{95\%\ CL}$	3.32	3.19	3.18	3.2	3.22	-
$\beta^2 \times \sigma^{\mu\mu}$(pb)	149	14.8	8.34	4.62	4.28	4.02
$2\beta(1-\beta) \times \sigma^{\mu\nu}$(pb)	261	32.6	14.3	8.5	5.74	-

3. Results and Conclusion

Comparing the measured upper limit on the cross section with the theoretical cross section from ISAJET with Morfin and Tung leading order parton distribution functions, the DØ preliminary mass limit from the combined signal for 100% branching of leptoquark to muons was determined to be 97 GeV/c^2. For 50% branching, the mass limit was 80 GeV/c^2. The branching fraction vs. leptoquark mass excluded region is given in figure 1.

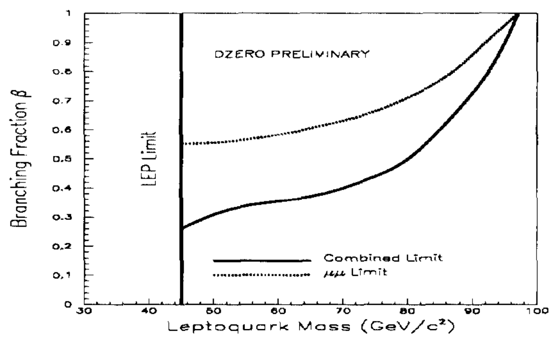

Fig. 1. The DØ preliminary 95% CL excluded region of branching fraction vs leptoquark mass

The DØ total integrated luminosity has changed since the publication of reference 4 due to an update of the total inelastic cross section (averaged new CDF and E710) used to calculate the luminosity. The new luminosity is 13.4 pb^{-1} for the first generation leptoquark search. The mass limits for first generation leptoquarks are now 130 GeV/c^2 for 100% branching of leptoquark to electron and 116 GeV/c^2 for 50% branching.

References

1. J.L. Hewett and S. Pakvasa, *Phys. Rev.* **D 37** (1988) 3165 and references therein.
2. J.L. Hewett and T.G. Rizzo, *Phys. Rev.* **D 36** (1987) 3367.
3. S. Abachi, *et al*, *Nucl. Instr. and Meth.* **A 338** (1994) 185.
4. S. Abachi, *et al*, *Phys. Rev. Lett.* **72** (1994) 965.
5. F.E. Paige and S. D. Protopopescu. BNL-37066, 1985, unpublished.

6. R. Brun and F. Carminati, CERN, Long Writeup W5013, July, 1993.
7. R.D. Cousins and V.L. Highland, *Nucl. Instr. and Meth.* **A 320** (1992) 331.