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LEPTOQUARK SEARCHES AT THE TEVATRON

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We report on the most recent searches by CDF and DØ for scalar leptoquarks in Run 2 Tevatron $p\bar{p}$ collisions at $\sqrt{s} = 1960$ GeV/c^2. Both CDF and DØ use approximately 200 pb^{-1} data. No scalar leptoquark signal is observed and new limits on first and second generation leptoquark masses are set.

1 Introduction

Leptoquarks are hypothetical color-triplet particles carrying both baryon and lepton quantum numbers and are predicted by many extensions of the Standard Model as new bosons coupling to a lepton-quark pair [1]. Their masses are not predicted. They can be scalar (spin 0) or vector (spin 1) particles and at high-energy hadron colliders they would be produced directly in pairs, mainly through gluon fusion or quark-antiquark annihilation [2].

The gluon-leptoquark interactions are determined by non-Abelian $SU(3)_c$ gauge-symmetry of scalar QCD, making theoretical calculation of the pair-production cross-section independent of the lepton-quark coupling, λ_{lq} [1]. Thus for scalar leptoquarks the production cross-section can be calculated as a function of leptoquark mass only. The couplings of vector leptoquarks to the gauge sector are predicted up to model dependent anomalous couplings. The searches reported in this paper are only for scalar leptoquarks.

In most models, leptoquarks are expected to couple only to fermions of the same generation because of experimental constraints such as non-observation of flavor changing neutral currents (FCNC) or helicity suppressed decays. Scalar leptoquarks can decay either into a lepton and a quark or a neutrino and quark, where β is the branching ratio of leptoquark decays into a charged lepton-quark pair. The final state decay products of pair-produced leptoquarks for $\beta = 1, 0.5, 0$, are $\ell^{\pm}\ell^{\mp}q\bar{q}$, $\ell^{\pm}\nu q\bar{q}$ and $\nu\bar{\nu}q\bar{q}$ respectively.

The production cross-section for pair produced scalar leptoquarks has been calculated up to NLO [1] and is essentially model independent. The decay angular distribution of scalar leptoquarks is isotropic. The production cross-section for pair produced vector leptoquarks and squarks are model dependent and are larger than the scalar leptoquark cross-section. In the past, searches have been done at the Tevatron for the Yang-Mills type coupling and the Minimal Vector type coupling. Table 1 shows a summary of the scalar and vector leptoquark mass limits from Run I and Run II.

Channel	$\mathcal{L}$, pb^{-1}	M, GeV/c^2	Comments
First Generation			
$eeqq$	110	213	CDF Collaboration [5]
$eeqq$	115	225	combined result, DØ Collaboration [6]
$eeqq$	123	225	DØ Collaboration [7]
$e\nu qq$	115	204	combined result, DØ Collaboration [6]
$\nu\nu qq$	85.2	98	DØ Collaboration [8]
Second Generation			
$\mu\mu qq$	202	110	CDF Collaboration [9]
$\mu\mu qq$	94	200	combined result, DØ [10]
$\mu\nu qq$	94	160	DØ Collaboration [11]
$\mu\nu qq$	94	180	combined result, DØ Collaboration [10]
$\nu\nu cc$	88	123	CDF Collaboration [12]
Third Generation			
$\tau\tau bb$	60,20,92	94	DØ Collaboration [13]
$\tau\tau bb$	110	99	CDF Collaboration [14]
$\nu\nu bb$	88	148	CDF Collaboration [12]

Table 1. Published results of scalar leptoquark searches from the Run 1 Tevatron. $\mathcal{L}$ is the integrated luminosity and M is the leptoquark mass below which scalar leptoquarks have been excluded at the 95% C.L. The $\tau\tau bb$ channel was analyzed by DØ using three sets of data collected using different triggers.

2 First Generation Limits

DØ has performed a search for first generation scalar leptoquarks in the $eeqq$ and $e\nu qq$ channels using 175 pb^{-1}of data. Due to the large mass of the leptoquark, its experimental signal is characterized by large transverse energies from the electrons and jets. In the $e\nu qq$ channel, the presence of a neutrino in an event is indicated by large missing transverse energy $\not\!\!E_T$. In the $eeqq$ final state, the events are selected by requiring two electromagnetic (EM) clusters each with transverse energy $E_T(e) > 25$ GeV/c^{2}and two jets each with $E_T(jet) > 20$ GeV/c^2. At least one EM cluster is required to be matched to a track. Events in which the dielectron invariant mass falls in the Z boson mass window $80 < M_{ee}/\text{GeV/c}^2 < 102$ are rejected. The scalar sum of the energies from the two electrons and two jets are required to be greater than 450 GeV/c^2. This last selection discriminates the leptoquark signal from QCD multi-jet, Z/γ^* Drell-Yan, and $t\bar{t}$ processes. For the $e\nu qq$ channel, the events are selected by requiring one track matched EM cluster with $E_T(e) > 35$ GeV/c^2, $\not\!\!E_T > 30$ GeV/c^2, and two jets each with $E_T(jet) > 25$ GeV/c^2. Each jet is required to have an azimuthal angle with respect to the $\not\!\!E_T$ greater than 8 degrees. The scalar sum of the jets, electron and $\not\!\!E_T$ are required to be greater than 330 GeV/c^{2}to suppress W + jets and $t\bar{t}$ backgrounds. The W + jets background is further suppressed by removing events in which the transverse invariant mass of the $\not\!\!E_T$ and electron is less than 130 GeV/c^2. After applying the selection requirements to the data, DØ expects 0.4 ± 0.1 Standard Model background events in the $eeqq$ channel and observes 0. Because no excess of events is observed, a leptoquark mass limit at 95% C.L. is set at $M > 238$ GeV/c^2. In the $e\nu qq$ channel, DØ expects 4.7 ± 0.9 SM background events and observes 2 and sets a mass limit at $M > 194$ GeV/c^2.

CDF searches for first generation scalar leptoquarks in the $eeqq$, $e\nu qq$ channels using 203 pb^{-1}, and 72 pb^{-1}, respectively. CDF's events selection requirements in the $eeqq$ channel are in general similar to the DØ selection. However, CDF does not use a scalar sum cut but instead places a 2-dimensional cut in the phase space defined by the sum of the electron p_T and the sum of the jet p_T. After selection, 4 events are observed which is consistent with an expected background of $6.2^{+3.2}_{-2.5}$ SM events. An upper mass limit is set at the 95% C.L. at $M > 230$ GeV/c^2. For the $e\nu qq$ channel, CDF also uses a $\not\!\!E_T$ significance cut defined by $\not\!\!E_T/\sqrt{\sum E_T}$ which discriminates the leptoquark signal from W + jets and $t\bar{t}$ processes. CDF expects 1.7 ± 1.5 SM background events and observes 2 and sets a mass limit at the 95% C.L. at 166 GeV/c^2. An analysis updating the data sample for this channel is currently underway.

CDF also searches for scalar leptoquark pair production in the $\nu\bar{\nu}q\bar{q}$ channel. This channel is the most challenging because of the large amounts of background. The events are selected by requiring two or three high-E_T jets and large $\not\!\!E_T$. QCD multi-jet events faking large $\not\!\!E_T$ from energy mismeasurement are suppressed by requiring that the jets are not aligned with the $\not\!\!E_T$. Events in which a charged lepton are present are rejected in order to suppress W/Z + jets and $t\bar{t}$ backgrounds. An estimated 118 ± 14 SM background events are expected in the signal region and 124 events are observed in the data. CDF sets an upper limit on the leptoquark cross section and excludes scalar leptoquarks at the 95% C.L. having a mass in the range between 78 and 117 GeV/c^2. DØ performed a search in this channel in Run 1 and set a 95% C.L. mass limit at $M > 98$ GeV/c^2[3].

3 Second Generation Limits

CDF searches for second generation scalar leptoquarks in the $\mu\mu qq$ channel using 198 pb^{-1}of data. The event selection and analysis closely follows the one carried out for the $eeqq$ channel. The events are selected by requiring two isolated muons each with $p_T > 25$ GeV/c^2, and two isolated tight(loose) jets having $E_T > 30(15)$ GeV/c^2. Backgrounds from J/Ψ, Υ and the Z boson are suppressed by rejecting events in which the invariant dimuon mass is below 15 GeV/c^{2}or in the range $76 < M_{\mu\mu}/\text{GeV/c}^2 < 110$. The Z/γ^* Drell-Yan and $t\bar{t}$ background events are discriminated by making cuts in the phase space defined by the scalar sum of muon transverse energy and the scalar sum of the leading jet transverse energies. The expected SM background events in the channel is 3.2 ± 1.2 and 2 events are observed. A lower mass limit at the 95% C.L. is set at 241 GeV/c^2. DØ searches for second generation scalar leptoquarks in the same channel using 104 pb^{-1}and sets a mass limit at the 95% C.L. at $M > 186$ GeV/c^2.

Both CDF and DØ are carrying out analyses which look for second generation scalar leptoquarks in the $\mu\nu qq$ channel. In Run 1, DØ combined the results of searches in the $\mu\mu qq$, $\mu\nu qq$ and $\nu\nu qq$ channels [4] and set a 95% C.L. lower mass limit for the $\beta = 1(\beta = 0.5)$ at $M > 200(180)$ GeV/c^2.

4 Summary

CDF and DØ have carried out searches for first and second generation pair produced scalar leptoquarks in $p\bar{p}$ collisions at $\sqrt{s} = 1960$ GeV/c^2. No new physics has been discovered in the Run 2 data and new mass limits have been derived which are better than or comparable to the limits obtained using Run 1 data. The Run 2 analyses are being updated with new data and searches in the $\mu\nu qq$ channel are under way.

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