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DØ

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ABSTRACT

A search has been made using the data from the first run of the DØ detector at the Fermilab Tevatron for pair production of scalar leptoquarks, each decaying into electron plus quark (visible in the detector as electron plus jet). From a data sample representing 841 nb^{-1}, a limit of 74 GeV at 95% confidence level can be set on the mass of the first generation scalar leptoquark, for a particular calculation of the production cross section and a 100% branching fraction into electron plus quark.

1. Introduction

Exotic particles called leptoquarks appear in many of the theoretical models proposed to go beyond the Standard Model. A leptoquark carries both lepton quantum numbers and quark quantum numbers (fractional charge, baryon number, and color). They would exist as elementary objects in unified theories with large gauge groups, for example E(6) theories,[1] and as composite objects in composite and technicolor models.[2] They are scalar particles in most models. At HERA, which is one obvious place to search for leptoquarks, the production cross section depends on the unknown coupling of the leptoquark to ordinary quarks and leptons. However, since the leptoquarks carry color, they could be pair-produced in strong interactions at hadron colliders, *independently* of their unknown Yukawa coupling, and their charged lepton decays would produce a distinctive signal (a peak in the lepton-jet invariant mass spectrum). Their decays to neutrinos result in events with high missing transverse energy, which may also be identifiable above background in collider detectors. One constraint imposed by agreement with low-energy phenomena is that the different leptoquark generations do not mix, so that one expects, for example, pair-production of leptoquarks decaying only to electrons or ν_e's. We report here a search at $\sqrt{s} = 1.8$ TeV, using the DØ detector at the Fermilab Tevatron, for pair production of scalar leptoquarks, each decaying into electron plus jet.

2. The DØ Detector

The detector,[3] newly commissioned in the current run of the Fermilab Tevatron, is well-suited for identifying electrons and jets and for measuring the transverse energy of an event. It comprises 3 major subsystems: central tracking detectors (with no central magnetic field), hermetic uranium-liquid argon calorimeters, and a muon spectrometer. The muon subsystem is not used in this analysis.

The central tracking system is used to distinguish electrons from photons. It has 4 parts: a vertex chamber, a central drift chamber, a forward drift chamber, and a transition radiation detector. The TRD is not used in this preliminary analysis; tracks found in the other detectors indicate charged particles.

The readout for the three uranium-liquid argon calorimeters is segmented longitudinally and horizontally to provide a good measure of electromagnetic shower shape, so electrons can be distinguished from jets. Resolution for electrons and photons is approximately $\frac{15\%}{\sqrt{E}}$, and for hadrons is approximately $\frac{50\%}{\sqrt{E}}$. Other details of the calorimetry, including electron identification, are reported elsewhere.[4]

3. Leptoquark Analysis

The data used in this analysis were collected in September and October of this year (1992), after a 4 month commissioning period for the detector. The integrated luminosity was 841 nb^{-1}, representing less than 10% of the total expected for this collider run. The data were from that subset of triggers chosen to be analyzed immediately for topical physics results. The triggers of interest for this analysis required either multiple jet towers, or 2 electromagnetic clusters of large transverse energy. The offline sample was selected to have at least 2 EM clusters (those with 90% of the cluster energy in the EM calorimeter section) with $\geq$ 20 GeV E_t, and at least 2 other jets with $\geq$ 20 GeV E_t. Cuts were then applied to define good leptoquark candidates, as follows:

1. The EM energy was computed within 2 cones, of radius 0.4 and 0.2 in η-ϕ space, respectively. Each EM cluster was required to have $E(0.4) - E(0.2) < (15\% \times E(0.2))$.

2. There was required to be exactly one central detector track in the road projected from an EM shower center to the vertex. The road had a width in ϕ of 0.1 radians, and in θ of the angle from the shower center to the vertex $\pm$ the error in the vertex (but not less than 0.1 radians).

3. The distance of closest approach of the track to the EM shower center was required to be less than 10 cm.

4. The energy in the electromagnetic layers was required, for each jet, to be greater than 20% of the total jet energy.

5. Events with the invariant mass of the two electrons consistent with the Z^0 mass ($70 < m_{ee} < 110$ GeV) were rejected.

The first three cuts, applied to each EM cluster, defined a good, isolated electron and reduced the sample from 226 to 3 events. Cut 4 removed 2 events, in each of which one of the jets found was actually due to a noisy channel in the hadronic calorimeter. Cut 5 was used to reject the background from the production of a $Z^0 \rightarrow e^+e^-$, with 2 associated jets. This cut removed the one remaining event; it is consistent with the Z^0 + 2 jet hypothesis, having $m_{ee} = 82$ GeV. A Monte Carlo calculation had predicted 0.3 events of this type for this luminosity.

Other backgrounds which might be expected (Drell-Yan production of 2 electrons away from the Z resonance plus 2 jets; heavy quark decays to electrons) were calculated to be negligible in this sample.

With no events remaining after the 5 cuts, we can set a lower limit on the leptoquark mass. We use the KMRS-B0 structure functions in the ISAJET calculation of the production cross section for squark pairs, with the gluino mass raised to a very large value to suppress irrelevant diagrams. The efficiency for detection of a leptoquark decaying to electron plus jet was calculated from a full simulation of the detector and triggers. For an 80 GeV leptoquark, for example, it was calculated to be 9.7%, from the product of a 72% trigger efficiency and a 14% reconstruction efficiency. A substantial part of the inefficiency in reconstruction comes from the requirement of 4 objects in the event, each with $E_t \geq 20$ GeV, produced from two particles with mass 80 GeV each.

4. Conclusion

We estimate the errors on the luminosity to be 15%, on the cross section to be 20% (by varying the structure function choice), and on the efficiency calculation to be 20%. Note that this analysis is preliminary and will certainly be improved with time and more data. The limit on the leptoquark mass is calculated to be 74 GeV at a confidence level of 95%.[5] This limit is comparable to limits set from SPS collider data and LEP data;[6,7] but, of course, well below the limit CDF has quoted from its previous run of 4 pb^{-1}.[8] We look forward to the acquisition of significantly more data in the remainder of this collider run. We also plan to investigate the other allowed decay mode of the first generation leptoquark (ν_e+ jet), and the signals from a second generation leptoquark (μ+ jet, ν_μ+ jet).

5. References

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