DELPHI 97-112 CONF 94
28 July, 1997

Search for Single Leptoquark Production at $\sqrt{s}$ =161 GeV and $\sqrt{s}$ =172 GeV with the DELPHI Detector

Preliminary

F. Barão[1], M. Espirito Santo[1], P. Gonçalves[1], A. Onofre[1], R. Paiva[1], L. Peralta[1], and M. Pimenta[1]

DELPHI Collaboration

Abstract

A search for single leptoquark production has been performed based on data taken at LEPII by the DELPHI detector. The data analysed was accumulated at center-of-mass energies of 161 GeV and 172 GeV and correspond to an integral luminosity of 20 pb^{-1}. Both scalar and vector type leptoquarks were searched for. Preliminary limits with 95% confidence level were derived on the masses and couplings of the leptoquark states.

Paper submitted to the LP'97 Conference
Hamburg, July 28 - August 1st

[1]LIP-IST-FCUL, Av. Elias Garcia, 14, 1e, P-1000 Lisboa, Portugal

1 Introduction

Leptoquarks are coloured spin 0 or spin 1 particles which carry both baryon and lepton quantum numbers. These objects are predicted by a variety of extensions of the Standard Model (SM), from Grand Unified Theories [1] to Technicolor [2] and composite models [3]. These particles have electric charges of $\pm 5/3$, $\pm 4/3$, $\pm 2/3$ and $\pm 1/3$, and decay into a lepton and quark pair. The decay branching ratio for the charged mode (β) is either 1/2 or 1, for both scalar and vector leptoquarks, depending on the leptoquark quantum numbers. Only right- or left-handed leptoquarks were considered. They could be pair or singly produced at e^+e^- colliders.

Strong model independent constraints on the masses and couplings of such objects have been put by low energy experiments [4]. The search for the "utterly unavoidable" bounds [5] , showed that: (i) these objects should not couple to diquarks ; (ii) they should couple chiraly to either left or right handed quarks but not to both ; (iii) they should couple mainly diagonally. i.e., they couple to a single leptonic generation and to a single quark generation.

Similarly, in an R-parity violating scenario, single squark production ($\pm 1/3$, $\pm 2/3$) becomes possible. In this case β can be lower than 1 (for up-squarks) if R-parity allowed modes are present [6].

The present analysis covers the search for singly produced leptoquarks decaying through the charged mode at centre-of-mass energies of $\sqrt{s}$ = 161 GeV and $\sqrt{s}$ = 172 GeV. The statistics corresponds to an integrated luminosity of 9.7 pb^{-1} and 10.1 pb^{-1} at $\sqrt{s}$ =161 GeV and $\sqrt{s}$ =172 GeV, respectively. Since only single production is considered and leptoquarks should couple mainly diagonally only first generation leptoquarks are searched for.

The highest contribution to the total cross section used in this paper, comes from the resolved photon contribution [7], where the hadronic contents of a Weizacker-Williams photon radiating off from one of the initial electrons is taken into account. The corresponding diagram is shown in figure 1. The GRV parameterization [9] of the parton distribution is used. Since the photon has different u-quark and d-quark contents, the production of the corresponding leptoquarks will also be different. On the other hand, the production cross sections are similar for leptoquarks of charge q=-1/3 (-2/3) and q=-5/3 (-4/3) [8]. The approach used in [8] is independent of the leptoquark chirality and is almost insensitive to whether the leptoquark is scalar or vector.

The leptoquark signal was generated for different mass values using the PYTHIA generator [10] and the cross section value was taken from [8] for scalar and vector leptoquark production. Additional cross-checks were made using ERATO [11].

Bhabha events, $e^+e^- \rightarrow Z\gamma$, $e^+e^- \rightarrow WW$, $e^+e^- \rightarrow We\nu$, $e^+e^- \rightarrow ZZ$, and $e^+e^- \rightarrow Zee$ events were generated with PYTHIA [10]. In all four fermion channels, studies with the EXCALIBUR generator [12] were also performed. The two-photon ("$\gamma\gamma$") physics events were generated according to the TWOGAM [13] generator for quark channels.

The effects of the experimental resolution were studied by passing both the signal and the background Monte Carlo (MC) events through the full DELPHI simulation and reconstruction chain.

A detailed description of the DELPHI detector and its performance, of the triggering conditions and of the readout chain can be found in reference [14].

2 Event Selection

Charged decays of singly produced high mass leptoquarks would be characterised by a high transverse momentum jet recoiling against an electron. Some hadronic activity can be present in the forward region, originated from the remanent of the quasi real photon. The initial electron which scatters the quasi real photon was assumed to escape detection. Thus, final state topologies would be energetic monojet topologies with one well isolated energetic electron and eventually a low energy jet in the forward region of the detector.

The basis of the event selection follows the general criteria for the selection of *hadronic* events described in reference [16]. However in the present analysis the minimum charged multiplicity was lowered to six and events were forced both to one and two jets using the Durham jet algorithm [15].

Events were considered to have a monojet topology if the Durham resolution variable (y_{cut}) in the transition from two to one jet was lower than 0.09. Events were considered to have a two-jet topology if the resolution variable y_{cut} associated to the transition from three to two jets was lower than 0.03.

In a very loose identification, charged tracks were considered to be isolated energetic electrons if their momenta were higher than 10 GeV/c, if there were no associated hits in the muon chambers, and if in the double cone centered on each track with internal and external half-angles of 5° and 25° the charged energy and the neutral energy were less than 1 GeV and 2 GeV respectively. Inside the inner cone no other charged track was allowed.

To the obtained sample of events with one or two jets and one isolated electron, the following selection criteria were applied:

- the electron had to be between 30° and 150° in polar angle,
- the most energetic jet had to be between 30° and 150° in polar angle and to have an energy larger than 10 GeV,
- if two jets are present, the lowest energy jet had to be below 40° or above 140° in polar angle and to have an energy lower than 30 GeV,
- the angle between the lepton and the most energetic jet had to be larger than 90^0.

In order to reduce the contamination from semileptonic decays of WW pairs, an aditional cut was applied rejecting events with both the missing tranverse momentum and the momentum of the electron inside a window of ± 10 GeV around 40 GeV.

One and two events were found in the data at $\sqrt{s}$ =161 GeV and $\sqrt{s}$ =172 GeV, respectively. The expected SM background is 2.4 ± 0.5 at $\sqrt{s}$ =161 GeV and 1.8 ± 0.5 $\sqrt{s}$ =172 GeV.

3 Results

The jet-lepton invariant mass distribution, calculated using the lepton energy, is shown in figure 2, together with the MC expectation. The mass resolution at 100 GeV/c^2 is 12 GeV/c^2. In the case of two-jet topologies, the most energetic jet was considered. Within the low statistics there is a reasonable agreement between data and SM predictions. No significative accumulation is observed.

The efficiency was found to be between 30% and 56% for leptoquark masses in the range from 80 GeV/c^2 up to the kinematic limit for both $\sqrt{s}$ = 172 GeV and $\sqrt{s}$ = 161 GeV. The trigger efficiency is very close to 100%.

The 95% confidence level limit for the the single leptoquark production cross section as a function of the leptoquark mass is shown in figure 3 for both $\sqrt{s}$ = 172 GeV and $\sqrt{s}$ = 161 GeV.

This limit can be interpreted in terms of the leptoquark coupling parameter λ. Limits on λ as a function of the leptoquark mass are shown in figure 4 for both scalar and vector leptoquarks of different types and for the different charged decay branching ratios ($\beta = 1$ or $\beta = 0.5$).

The lower limits at 95% confidence level on the mass of a first generation leptoquark for a coupling parameter $\lambda = \sqrt{4\pi\alpha_{em}}$ are given in table 1, where different leptoquark types and branching ratios are considered [17].

	$\lvert Q\rvert$=1/3,5/3		$\lvert Q\rvert$=2/3,4/3	
	$\beta = 0.5$	$\beta = 1.0$	$\beta = 0.5$	$\beta = 1.0$
scalar	129	142	-	115
vector	-	152	114	131

Table 1: Lower limits (in GeV/c^2) at 95% confidence level on the the mass of a first generation leptoquark for coupling parameters $\lambda = \sqrt{4\pi\alpha_{em}}$.

Acknowledgements

We would like to thank M. Doncheski and C. Papadopoulos for the very useful discussions on the leptoquark production. We are greatly indebted to our technical collaborators and to the funding agencies for their support in building and operating the DELPHI detector. Very special thanks are due to the members of the CERN-SL Division for the excellent performance of the LEP collider.

References

[1] P. Langacker, Phys.Rep. **72**, 185 (1981).

[2] See for example S. Dimopoulos, Nucl. Phys. **B168**, 69 (1981).

[3] See for example B. Schremp and F. Schremp, Phys.Lett. **153B**, 101 (1985).

[4] S. Davidson et al., Z.Phys. **C61** 613 (1994).

[5] M. Leurer, Phys.Rev **D49** 333 (1994) and Phys.Rev **D50** 536 (1994).

[6] G. Altarelli et al., hep-ph/9703276.

[7] M. Doncheski and S. Godfrey, Phys. Rev. **D49** (1994) 6220.

[8] M. Doncheski and S. Godfrey, Phys. Lett. **B393** (1997) 355.

[9] M. Gluck et al., Phys.Rev. **D46** 1973 (1992) and Phys.Rev. **D45** 3986 (1992).

[10] T. Sjöstrand, Comp. Phys. Comm. **82** (1994) 74;
T. Sjöstrand, Pythia 5.7 and Jetset 7.4, CERN-TH/7112-93.

[11] C. Papadopoulos, hep-ph/9703372.

[12] F.A. Berends, R. Pittau, R. Kleiss, Comp. Phys. Comm **85** (1995) 437.

[13] S. Nova, A. Olchevski and T. Todorov, "TWOGAM, a Monte Carlo event generator for two photon physics", DELPHI Note 90-35 PROG 152.

[14] DELPHI coll., P.Aarnio et al., NIM **A303** (1991) 233;
DELPHI Coll., P. Abreu et al., Nucl. Instr. Methods **A378** (1996) 57.

[15] S. Catani et al., Phys. Lett. **B269** (1991) 432.

[16] DELPHI Coll., P. Abreu et al., Phys. Lett. **B393** (1997) 245.

[17] J.L. Hewett and T.G. Rizzo, hep-ph/9703337.

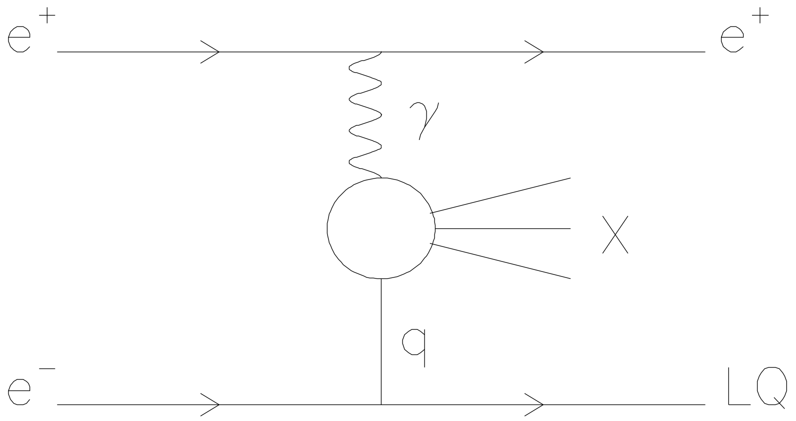

Figure 1: The resolved photon contribution for single leptoquark production in e^+e^- collisions.

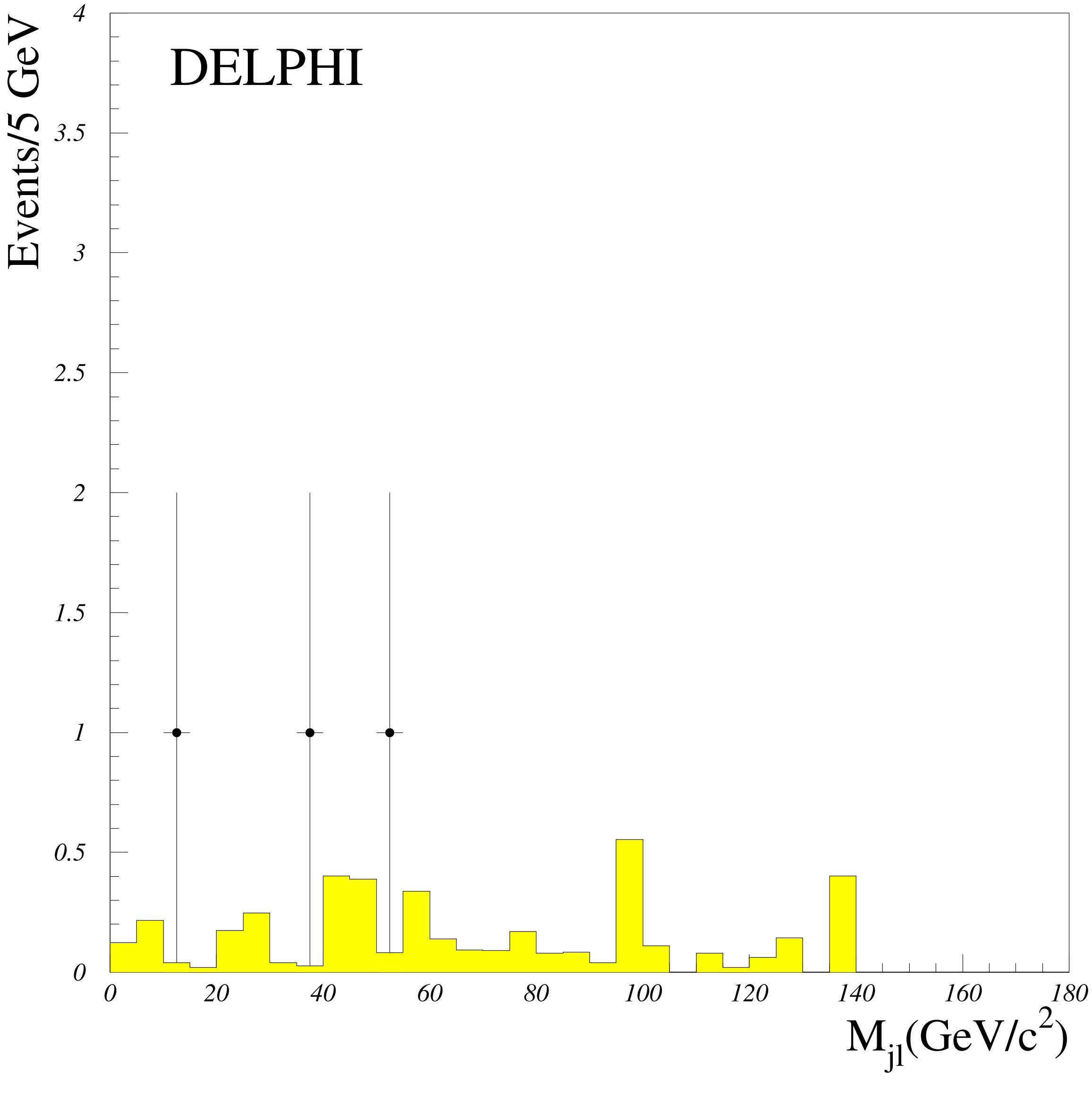

Figure 2: Invariant mass of the jet-lepton pair. The dots show the data and the shaded histogram shows the SM simulation.

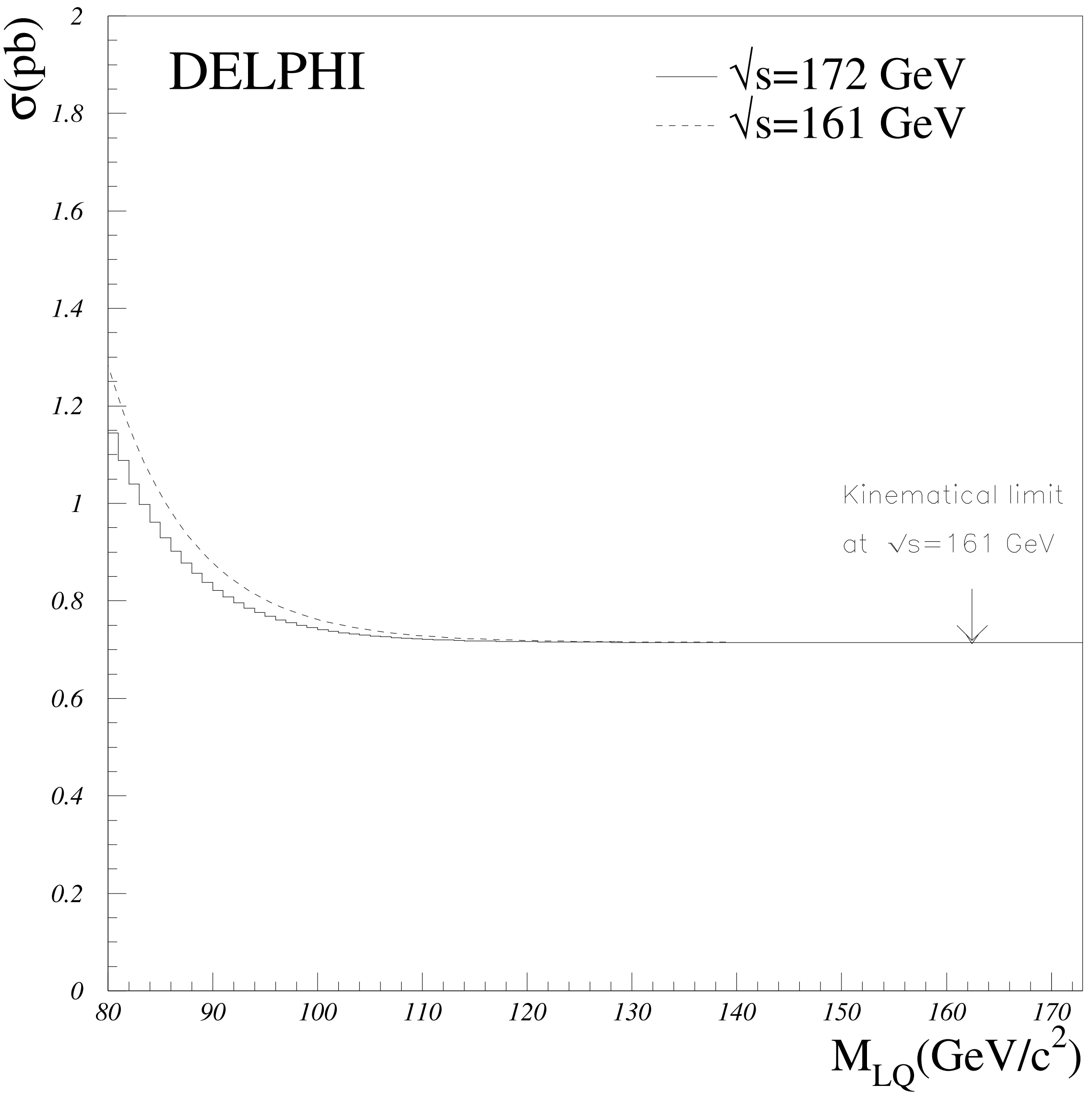

Figure 3: 95% confidence level limit for the single production cross section as a function of the leptoquark mass for center-of-mass energies of $\sqrt{s}$ =172 GeV and $\sqrt{s}$ =161 GeV.

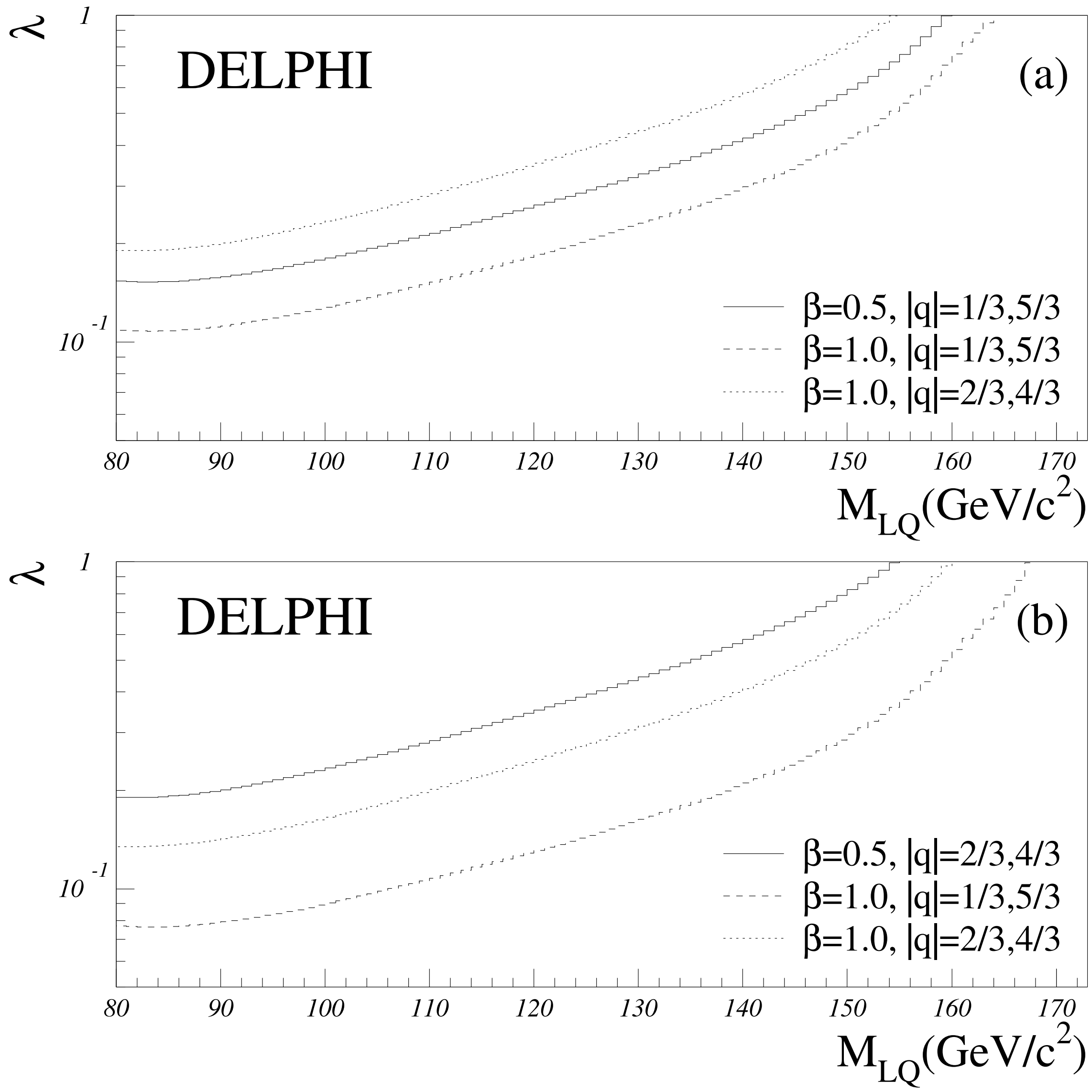

Figure 4: 95% confidence level limits on the coupling λ as a function of the leptoquark mass for scalar (a) and vector (b) leptoquarks.