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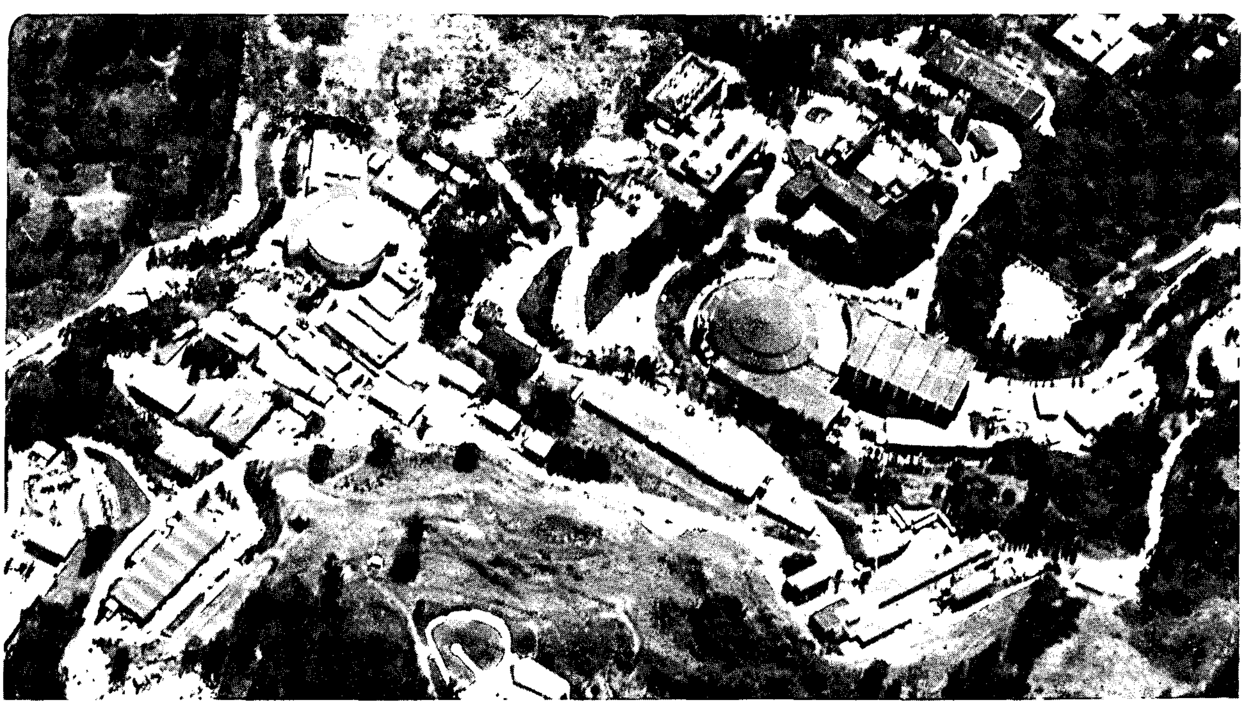

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PRODUCTION OF NEW CHARGED LEPTONS DECAYING INTO MASSIVE NEUTRINOS*

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ABSTRACT

A recent paper from Perl pointed out that existing limits from e^+e^- annihilation data for a fourth generation charged lepton, L^+, were not valid if the mass splitting between the lepton and its associated neutral lepton were small. The purpose of this paper is twofold: to urge experimentalists at hadron colliders to examine limits for charged leptons without assuming $m(L^0) = 0$, and to provide the necessary formulae for the widths and matrix elements. The formulae presented here assume couplings with arbitrary vector and axial-vector pieces, and are thus applicable to the production and decay of other fermions such as right-handed leptons and supersymmetric fermions. We present some sample cross-sections for $W^+ \to L^+L^0$ applicable to the $Sp\bar{p}S$ collider.

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The currently reported limits for a fourth generation charged lepton, L^+, with an associated neutral heavy lepton (L^0) are:

$$m_{L^+} > 22.5\ GeV \qquad e^+e^- \quad annihilation^1$$

$$m_{L^+} > 41.0\ GeV \qquad p\overline{p} \quad collisions^2$$

if L^0 is massless. However, Perl[3] has recently argued that the e^+e^- limits are not valid if the mass splitting $m_{L^+} - m_{L^0}$ is between 0.2 and 3.5 GeV. Under this condition, the very large missing energy which results makes it difficult to observe charged leptons as light as 2-4 GeV. Further study will undoubtedly reduce the allowed region.

In general, if m_{L^0} is not negligible, one would expect L^0 to be unstable and decay rather quickly due to mixing with the lighter generations[4]. However, recently one theoretical model[5] has been proposed in which the L^0 is massive and yet is absolutely stable. (Such a particle could be a candidate for the dark matter of the universe). Thus, it is important for experimentalists to allow for a stable massive L^0 when determining what limits experimental results can place on a new heavy lepton generation. (Actually, it is only necessary to require that L^0 live long enough to escape the detector.) The current limit (for massless L^0) at hadron colliders was obtained by assuming that $W^+ \to L^+L^0$ occurs at the same rate as $W^+ \to e^+\nu$ except for phase space corrections. The L^+ was taken to have the standard decay, $L^+ \to \bar{L}^0 q\overline{q}$. As stated above, it was assumed that both L^0 and $\bar{L}^0$ leave the detector undetected. The observed event would, therefore, have substantial missing energy and one jet (occasionally two jets). To set their lepton limit, the UA1 Collaboration used an analysis similar to their original monojet analysis. They apply an additional cut $E_T^{jet} < 40\ GeV$, but for the process $W^+ \to L^+ L^0$ ($L^+ \to \bar{L^0} q\bar{q}$) this is at most a 7% effect.

In order to analyze the case where $m_{L^0} \neq 0$, we shall present formulas for the width $\Gamma(L^+ \to \bar{L^0} q\bar{q})$ and the squared matrix element for $u\bar{d} \to W^+ \to L^+ L^0 \to \bar{L^0} L^0 q\bar{q}$. In presenting the matrix element for the $2 \to 4$ process, we automatically include all spin correlations between the production and decay. For the case of a fourth generation sequential lepton, the $W^+ L^- L^0$ vertex is $V - A$. We will allow for arbitrary combinations of V and A couplings at the vertices, so that the formalism can also be applied to the production and decay of right-handed leptons and supersymmetric fermions (neutralinos and charginos). This also allows our formulae to be used for processes involving Z exchange.

For the width $\Gamma(L^+ \to \bar{L^0} q\bar{q})$, we use the labels of Fig. 1. The required vertices are:

$$W^+ L^- L^0 : \qquad \frac{g}{\sqrt{2}} \gamma^\mu \left[G_L \left(\frac{1 - \gamma_5}{2} \right) + G_R \left(\frac{1 + \gamma_5}{2} \right) \right] \tag{1a}$$

$$W^+ q\bar{q}' : \qquad \frac{g}{\sqrt{2}} \gamma^\mu \left[g_L \left(\frac{1 - \gamma_5}{2} \right) + g_R \left(\frac{1 + \gamma_5}{2} \right) \right] \tag{1b}$$

Eq. 1 is also applicable for Z-exchange (for W-exchange, $g_L = 1$ and $g_R = 0$). Defining

$$s_1 = (k_1 + k_2)^2 \quad s_2 = (k_2 + k_3)^2 \quad s_3 = (k_1 + k_3)^2 \tag{2}$$

we have $s_3 = m_{L^+}^2 + m_{L^0}^2 - s_1 - s_2$ since we will always take the quark mass to be zero. Then,

$$|\mathcal{M}|^2_{\rm ave} = \frac{\frac{3}{2}g^4}{(s_2 - m_W^2)^2 + \Gamma_W^2 m_W^2}$$
$$[(G_L^2 g_L^2 + G_R^2 g_R^2)(m_{L^+}^2 - s_1)(s_1 - m_{L^0}^2)$$
$$+(G_L^2 g_R^2 + G_R^2 g_L^2)(m_{L^+}^2 - s_3)(s_3 - m_{L^0}^2)$$
$$-2G_L G_R (g_L^2 + g_R^2) m_{L^+} m_{L^0} s_2] \qquad (3)$$

including the spin-average factor of 1/2 and a color factor of 3.

Performing the integration over phase space, we find the following total rate:

$$\Gamma(L^+ \to \bar{L^0} q\bar{q}) = \frac{3G_F^2 m_{L^+}^5}{16\pi^3}(g_L^2 + g_R^2)$$
$$\Bigg\{(G_L^2 + G_R^2)\left[\frac{(x-1)}{6z^3}(x^2z^2 - 2xz^2 + z^2 + 3xz + 3z - 6)\right.$$
$$\left. + \frac{(1 - z - zx)\log x}{2z^4} + (x^2z^2 + z^2 - 2xz - 2z + 1)\frac{J}{2z^4}\right]$$
$$- 2G_L G_R x^{\frac{1}{2}}\left[\frac{(1+x)\log x - 4(1-x)}{2z^2} - \frac{1}{z^3}\log x\right.$$
$$\left. - (1 - z - xz + \lambda)\frac{J}{2z^3}\right]\Bigg\} \qquad (4)$$

where

$$J = \lambda^{-\frac{1}{2}} \log\left(\frac{1 + x + 2xz - z - zx^2 + (1-x)\lambda^{\frac{1}{2}}}{1 + x + 2xz - z - zx^2 - (1-x)\lambda^{\frac{1}{2}}}\right) \qquad (5)$$

$$\lambda \equiv [(1 - z - zx)^2 - 4xz^2] \qquad (6)$$

$$x \equiv \frac{m_{L^0}^2}{m_{L^+}^2} \qquad \textit{and} \qquad z \equiv \frac{m_{L^+}^2}{m_W^2} \qquad (7)$$

We can obtain the standard result for $m_{L^0} = 0$ by letting $x \to 0$:

$$\Gamma(L^+ \to \bar{L}^0 q\bar{q}) = \frac{3G_F^2 m_{L^+}^5}{16\pi^3}(g_L^2 + g_R^2)(G_L^2 + G_R^2) \times \left[\frac{6 - 3z + z^2}{6z^3} + \frac{(1-z)\log(1-z)}{z^4}\right] \quad (8)$$

Another useful limit is the one for $m_W \gg m_{L^+}, m_{L^0}$ (*i.e.* $z \to 0$ with x fixed):

$$\Gamma(L^+ \to \bar{L}^0 q\bar{q}) = \frac{3G_F^2 m_{L^+}^5}{16\pi^3}(g_L^2 + g_R^2) \times \Big[\tfrac{1}{12}(G_L^2 + G_R^2)((1-x^2)(1-8x+x^2) - 12x^2\log x) - \tfrac{1}{3}G_L G_R x^{\frac{1}{2}}((1-x)(1+10x+x^2) + 6x(1+x)\log x)\Big] \quad (9)$$

Turning now to the calculation of the full matrix element, we use the labeling of Fig. 2. We give results for the case where the $W^+L^-L^0$ vertex is either $V-A$ or $V+A$. Formulae for the general case are given in an Appendix.

First, the results for the $2 \to 2$ process $u\bar{d} \to L^+L^0$ are:

$$|\mathcal{M}|^2_{\text{ave}} = \frac{(\frac{1}{12})4g^4 Q\cdot p_1\, q_1\cdot p_2}{(s - m_W^2)^2 + \Gamma_W^2 m_W^2} \qquad for \quad V-A \qquad (10a)$$

$$|\mathcal{M}|^2_{\text{ave}} = \frac{(\frac{1}{12})4g^4 Q\cdot p_2\, q_1\cdot p_1}{(s - m_W^2)^2 + \Gamma_W^2 m_W^2} \qquad for \quad V+A \qquad (10b)$$

where the factor $(\frac{1}{12})$ includes the color average $(\frac{1}{9})$, the spin average $(\frac{1}{4})$ and the color factor (3). The partonic center-of-mass energy is denoted by $s = (p_1 + p_2)^2$.

Second, the full $2 \to 4$ matrix element squared for $u\bar{d} \to L^+L^0$ with $L^+ \to \bar{L}^0 q\bar{q}$ (in the narrow-width approximation) for the case of $V-A$ is[6]:

$$|\mathcal{M}|^2 = \frac{3(\frac{1}{12})16g^8(q_2\cdot q_4)q_1\cdot p_2(Q\cdot q_3\, p_1\cdot Q - \frac{1}{2}Q^2 p_1\cdot q_3)}{[(s-m_W^2)^2+\Gamma_W^2 m_W^2][(q_3+q_4)^2-m_W^2]^2}\frac{\pi}{\Gamma_L m_{L^+}}\delta(Q^2-m_{L^+}^2) \quad (11)$$

where we have included the factor of $(\frac{1}{12})$ described above and a color factor of (3) from the L^+ decay. The expression for the $V+A$ case is the same as Eq. 11 with the interchange $p_1 \leftrightarrow p_2$. The corresponding formulae for W^- exchange are exactly the same as those given in Eqs. 10-11, as long as one charge-conjugates all particles in Fig. 2, while leaving the momenta labels unchanged. Since one cannot determine the charge of the W in the actual experiment when the final decay products are quarks, we shall sum both W^+ and W^- contributions when presenting numerical results.

With these formulae, one can now proceed to determine cross-sections for the production of charged leptons with associated massive neutral leptons. We have performed a theorist's version of this calculation in order to give the reader an approximate idea of the limits possible from current hadron colliders (the $Sp\bar{p}S$ and Tevatron). We urge experimentalists to use the formulae here to do the complete determination of the limits.

Our procedure was to use the partonic event simulator described in Ref. 7. We are able to simulate many of the UA1 cuts, triggers and resolutions at the partonic level. Our jets consist of partons which have been coalesced by an algorithm which is very similar to that of UA1. We do not hadronize our partons, and therefore cannot simulate any cuts which depend on multiplicity, jet shapes, etc. Many UA1 cuts are designed to eliminate backgrounds which, of course, we do not generate. As a check that our results are approximately correct, we have reproduced Table 2 of Ref. 2 which shows the predicted event rates after cuts for $W \rightarrow L^+L^0$, $L^+ \rightarrow \bar{L}^0 q\bar{q}$. We agree with this table within 10-20%.

Our rough estimates of curves of constant cross-section for given masses of L^+ and L^0 is shown in Fig. 3, for the case of $V-A$ coupling. The solid curve corresponds to 0.013 nanobarns which is the level at which UA1 claimed to exclude heavy leptons[2]. The dashed (dash-dotted) curve indicates 1/2 (1/4) of the cross-section of the solid curve. We see that one cannot exclude the region where $m_{L^0} \gtrsim 0.4 m_{L^+}$ with the UA1 $p\bar{p}$ data. To understand why such a result emerges, consider the type of event which occurs when the mass of L^0 is a substantial fraction of the L^+ mass. Then by energy-momentum conservation, the jets which come from $L^+ \rightarrow \bar{L}^0 q\bar{q}$ will carry only a small amount of transverse momentum. On the other hand, the L^0's tend to be going in opposite directions, and the resulting missing transverse energy for such events is small. Note that although the actual (scalar) missing energy is large, detectors at hadron colliders can only measure the vector sum of missing energy in the transverse plane, which is small in this case. Hence, if m_{L^0} is a substantial fraction of m_{L^+}, too few events pass the E_T^{jet} and E_T^{miss} cuts and triggers, so that this scenario cannot be excluded. We again emphasize that a full analysis is needed to set firm limits.

In summary, the widths and matrix elements reported here allow for the determination of mass limits for charged leptons which are coupled to massive neutral leptons via the W boson. We show the approximate cross-sections at $\sqrt{s} = 630\ GeV$ where the events have been subjected to a set of UA1 inspired cuts, and urge experimentalists at hadron colliders to perform a full analysis.

We acknowledge helpful conversations with Martin Perl and Stuart Raby.

APPENDIX: General Formulae for $u\bar{d} \to L^0 \bar{L}^0 q\bar{q}'$ with Arbitrary V and A couplings.

The formalism presented in this paper can be used in more general situations. For example, consider the case of supersymmetric fermion pair production in W and Z decay. One may have:

$$u\bar{d} \to W^+ \to \tilde{\chi}^+ \tilde{\chi}_1^0 \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 q\bar{q}' \tag{A.1}$$

or

$$q\bar{q} \to Z^0 \to \tilde{\chi}_1^0 \tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 q'\bar{q}' \tag{A.2}$$

where the $\tilde{\chi}_1^0$ is the lightest supersymmetric particle and escapes the detector. The $W^+\tilde{\chi}^-\tilde{\chi}_1^0$ and $Z^0\tilde{\chi}_1^0, \tilde{\chi}_2^0$ are in general mixtures of V and A couplings; general formulae can be found in Appendix C of ref. 8. One major difference in these processes is that the decaying neutralino ($\tilde{\chi}_2^0$) or chargino ($\tilde{\chi}^+$) can decay via scalar-quark exchange as well as by vector-boson exchange. Thus, our formalism is not immediately applicable without further generalization. However, if the scalar quarks are heavy (say $M_{\tilde{q}} \gtrsim 150$ GeV), then the vector-boson exchange contributions are dominant and the formulae presented below are applicable.

We present the results for arbitrary V and A couplings. However, we will continue to follow the notation of Fig. 2. The $W^+L^-L^0$ vertex and the final $W^+q\bar{q}$ vertex are given in Eq. 1. In addition we also allow the initial $\bar{u}dW^+$ vertex to have an arbitrary mixture of V and A:

$$\bar{u}dW^+ : \quad \frac{g}{\sqrt{2}}\gamma^\mu \left[f_L \left(\frac{1-\gamma_5}{2} \right) + f_R \left(\frac{1+\gamma_5}{2} \right) \right] \tag{A.3}$$

The averaged matrix element squared for $u\bar{d} \to L^+ L^0$ is then given by:

$$|\mathcal{M}|^2_{ave} = \frac{(\frac{1}{12})4g^4}{(s-m_W^2)^2 + \Gamma_W^2 m_W^2} \quad [(f_L^2 G_L^2 + f_R^2 G_R^2) p_1{\cdot}Q \; p_2{\cdot}q_1$$
$$+ (f_L^2 G_R^2 + f_R^2 G_L^2) p_1{\cdot}q_1 \; p_2{\cdot}Q$$
$$+ \tfrac{1}{2} G_L G_R (f_L^2 + f_R^2) s m_{L^+} m_{L^0}] \qquad (A.4)$$

where $s = 2p_1{\cdot}p_2$ (we set all quark masses to zero).

The full $2 \to 4$ spin-averaged matrix element squared for $u\bar{d} \to L^+ L^0$ with $L^+ \to \bar{L}^0 q\bar{q}$ (in the narrow-width approximation) is:

$$|\mathcal{M}|^2_{ave} = \frac{8g^8}{[(s-m_W^2)^2 + \Gamma_W m_W^2][(q_3+q_4)^2 - m_W^2]^2} \frac{\pi}{\Gamma_L m_{L^+}} \delta(Q^2 - m_{L^+}^2)$$
$$\times \{(f_L^2 + f_R^2)(g_L^2 + g_R^2)[(G_L^4 + G_R^4)T_1$$
$$+ m_{L^0} m_{L^+} G_L G_R (G_L^2 + G_R^2) T_2$$
$$+ 2G_L^2 G_R^2 [M_{L^+}^2 T_3 - m_{L^0}^2 (Q^2 + m_{L^+}^2) p_1{\cdot}p_2 \; q_3{\cdot}q_4]]$$
$$+ (f_L^2 + f_R^2)(g_L^2 - g_R^2)[(G_L^4 - G_R^4)T_4 + G_L G_R (G_L^2 - G_R^2) m_{L^0} m_{L^+} T_5]$$
$$+ (f_L^2 - f_R^2)(g_L^2 + g_R^2)[(G_L^4 - G_R^4)T_6 + G_L G_R (G_L^2 - G_R^2) m_{L^0} m_{L^+} T_7]$$
$$+ (f_L^2 - f_R^2)(g_L^2 - g_R^2)[(G_L^4 + G_R^4)T_8 - 2m_{L^+}^2 m_{L^0}^2 G_L^2 G_R^2 T_9$$
$$+ 2m_{L^+}^2 G_L^2 G_R^2 T_{10} - 2m_{L^0}^2 G_L^2 G_R^2 T_{11}$$
$$+ G_L G_R (G_L^2 + G_R^2) m_{L^0} m_{L^+} T_{12}]\} \qquad (A.5)$$

where

$$T_1 = 2(p_1{\cdot}Q \; p_2{\cdot}q_1 + p_1{\cdot}q_1 \; p_2{\cdot}Q)(Q{\cdot}q_3 \; q_2{\cdot}q_4 + Q{\cdot}q_4 \; q_2{\cdot}q_3)$$
$$- Q^2 \; q_2{\cdot}q_3 (p_1{\cdot}q_1 \; p_2{\cdot}q_4 + p_1{\cdot}q_4 \; p_2{\cdot}q_1)$$

$$- Q^2\, q_2{\cdot}q_4(p_1{\cdot}q_1\, p_2{\cdot}q_3 + p_1{\cdot}q_3\, p_2{\cdot}q_1) \tag{A.6}$$

$$T_2 = 2p_1{\cdot}p_2(Q{\cdot}q_3\, q_2{\cdot}q_4 + Q{\cdot}q_4\, q_2{\cdot}q_3)$$

$$- 2q_3{\cdot}q_4(Q{\cdot}p_1\, q_1{\cdot}p_2 + Q{\cdot}p_2\, q_1{\cdot}p_1) \tag{A.7}$$

$$T_3 = q_2{\cdot}q_4(p_1{\cdot}q_1\, p_2{\cdot}q_3 + p_1{\cdot}q_3\, p_2{\cdot}q_1)$$

$$+ q_2{\cdot}q_3(p_1{\cdot}q_1\, p_2{\cdot}q_4 + p_1{\cdot}q_4\, p_2{\cdot}q_1) \tag{A.8}$$

$$T_4 = 2(p_1{\cdot}Q\, p_2{\cdot}q_1 + p_1{\cdot}q_1\, p_2{\cdot}Q)(Q{\cdot}q_3\, q_2{\cdot}q_4 - Q{\cdot}q_4\, q_2{\cdot}q_3)$$

$$- Q^2\, q_2{\cdot}q_4(p_1{\cdot}q_1\, p_2{\cdot}q_3 + p_1{\cdot}q_3\, p_2{\cdot}q_1)$$

$$+ Q^2\, q_2{\cdot}q_3(p_1{\cdot}q_1\, p_2{\cdot}q_4 + p_1{\cdot}q_4\, p_2{\cdot}q_1) \tag{A.9}$$

$$T_5 = 2Q{\cdot}q_4(p_1{\cdot}q_1\, p_2{\cdot}q_3 + p_1{\cdot}q_3\, p_2{\cdot}q_1)$$

$$- 2Q{\cdot}q_3(p_1{\cdot}q_1\, p_2{\cdot}q_4 + p_1{\cdot}q_4\, p_2{\cdot}q_1)$$

$$+ p_1{\cdot}p_2(Q{\cdot}q_3\, q_2{\cdot}q_4 - Q{\cdot}q_4\, q_2{\cdot}q_3) \tag{A.10}$$

$$T_6 = 2(q_4{\cdot}Q\, q_2{\cdot}q_3 + q_3{\cdot}Q\, q_2{\cdot}q_4)(p_2{\cdot}q_1\, p_1{\cdot}Q - p_2{\cdot}Q\, p_1{\cdot}q_1)$$

$$- Q^2 q_2{\cdot}q_3(p_2{\cdot}q_1\, p_1{\cdot}q_4 - p_2{\cdot}q_4\, p_1{\cdot}q_1)$$

$$- Q^2\, q_2{\cdot}q_4(p_2{\cdot}q_1\, p_1{\cdot}q_3 - p_2{\cdot}q_3\, p_1{\cdot}q_1) \tag{A.11}$$

$$T_7 = 2q_2{\cdot}q_4(p_1{\cdot}Q\, p_2{\cdot}q_3 - p_1{\cdot}q_3\, p_2{\cdot}Q)$$

$$+ 2q_2{\cdot}q_3(p_1{\cdot}Q\, p_2{\cdot}q_4 - p_1{\cdot}q_4\, p_2{\cdot}Q)$$

$$+ 2q_3{\cdot}q_4(p_2{\cdot}Q\, p_1{\cdot}q_1 - p_1{\cdot}Q\, p_2{\cdot}q_1) \tag{A.12}$$

$$T_8 = 2(p_1{\cdot}Q\, p_2{\cdot}q_1 - p_2{\cdot}Q\, p_1{\cdot}q_1)(Q{\cdot}q_3\, q_2{\cdot}q_4 - Q{\cdot}q_4\, q_2{\cdot}q_3)$$

$$- Q^2\, q_2{\cdot}q_4(p_1{\cdot}q_3\, p_2{\cdot}q_1 - p_1{\cdot}q_1\, p_2{\cdot}q_3)$$

$$+ Q^2\, q_2{\cdot}q_3(p_1{\cdot}q_4\, p_2{\cdot}q_1 - p_1{\cdot}q_1\, p_2{\cdot}q_4) \tag{A.13}$$

$$T_9 = p_1{\cdot}q_4\, p_2{\cdot}q_3 - p_1{\cdot}q_3\, p_2{\cdot}q_4 \tag{A.14}$$

$$T_{10} = q_2{\cdot}q_4(p_1{\cdot}q_1\, p_2{\cdot}q_3 - p_1{\cdot}q_3\, p_2{\cdot}q_1)$$

$$+ q_2{\cdot}q_3(p_1{\cdot}q_4\, p_2{\cdot}q_1 - p_1{\cdot}q_1\, p_2{\cdot}q_4 \qquad (A.15)$$

$$T_{11} = 2Q{\cdot}q_4(Q{\cdot}p_1\, p_2{\cdot}q_3 - Q{\cdot}p_2\, p_1{\cdot}q_3)$$

$$+ 2Q{\cdot}q_3(Q{\cdot}p_2\, p_1{\cdot}q_4 - Q{\cdot}p_1\, p_2{\cdot}q_4)$$

$$+ Q^2(p_1{\cdot}q_3\, p_2{\cdot}q_4 - p_1{\cdot}q_4\, p_2{\cdot}q_3) \qquad (A.16)$$

$$T_{12} = 2Q{\cdot}q_3(p_1{\cdot}q_1\, p_2{\cdot}q_4 - p_1{\cdot}q_4\, p_2{\cdot}q_1)$$

$$+ 2Q{\cdot}q_4(p_1{\cdot}q_3\, p_2{\cdot}q_1 - p_1{\cdot}q_1\, p_2{\cdot}q_3)$$

$$+ 2q_2{\cdot}q_3(p_1{\cdot}q_4\, p_2{\cdot}Q - p_2{\cdot}q_4\, p_1{\cdot}Q)$$

$$+ 2q_2{\cdot}q_4(p_2{\cdot}q_3\, p_1{\cdot}Q - p_1{\cdot}q_3\, p_2{\cdot}Q) \qquad (A.17)$$

All the formulae above correspond to W^+ exchange. For W^- exchange, all the equations above apply as written if one charge-conjugates all particles in Fig. 2 while leaving momentum labels unchanged. We have checked that Eq. A.5 reduces to the results given in Ref. 6 when the appropriate $V \pm A$ limit is taken.

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Figure Captions

1. Diagram of L^+ decay into $\bar{L}^0 q\bar{q}$.

2. Diagram from $p\overline{p}$ collisions of $u + \overline{d}$ annihilations into a W boson which decays into L^+L^0. The L^+ in turn decays into $\bar{L}^0 q\bar{q}$.

3. Curves of constant cross section for massive charged and neutral leptons which have $V-A$ couplings with W bosons. It is assumed that L^0 is stable enough to leave the detector. These results include a rough modeling of the UA1 cuts and triggers. The solid curve indicates an approximate cross-section of 0.013 nb. The dashed (dash-dotted) curves represent 0.5 (0.25) of the cross-section of the solid curve.

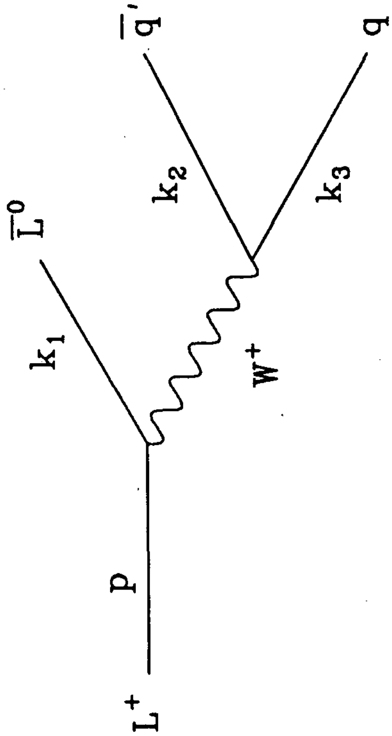

Fig. 1

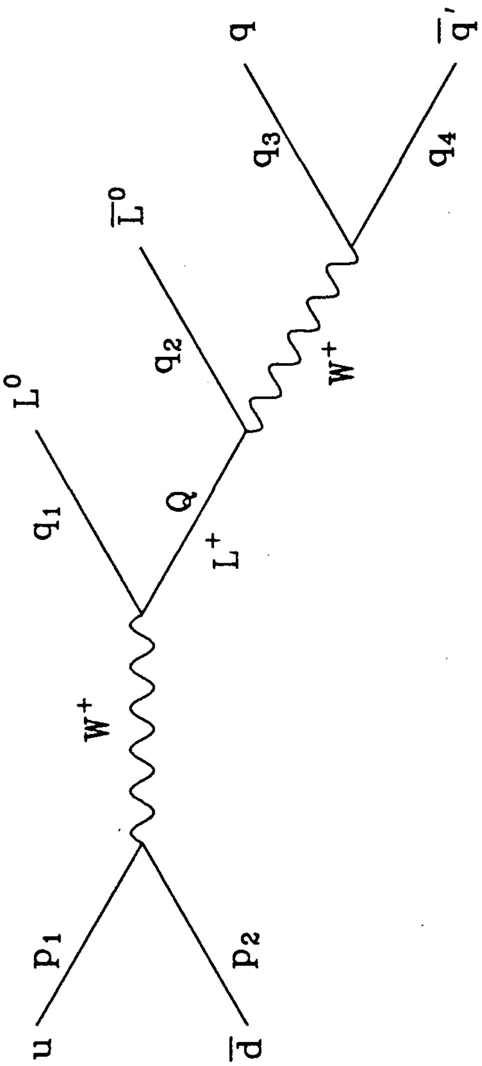

Fig. 2

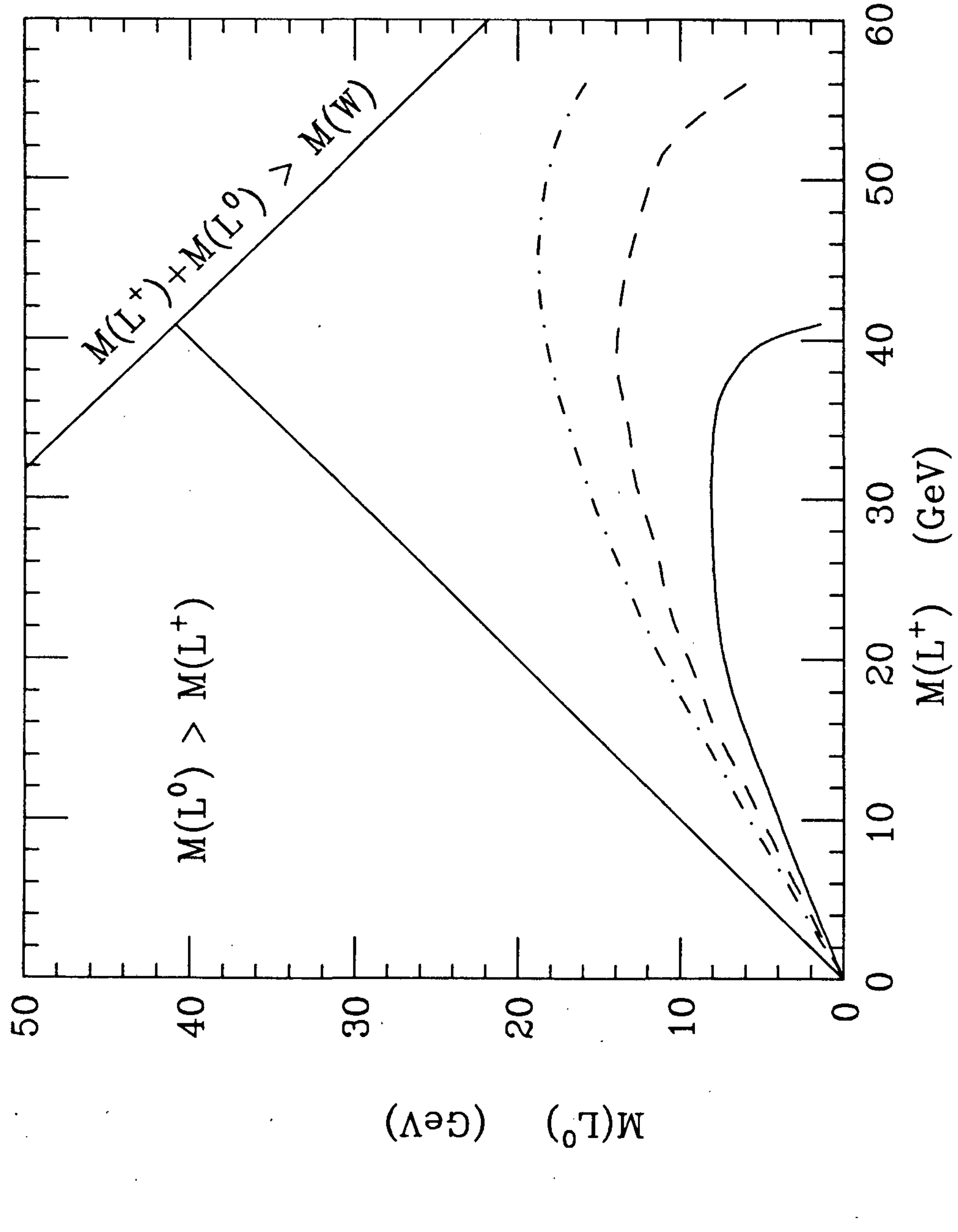

Fig. 3

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