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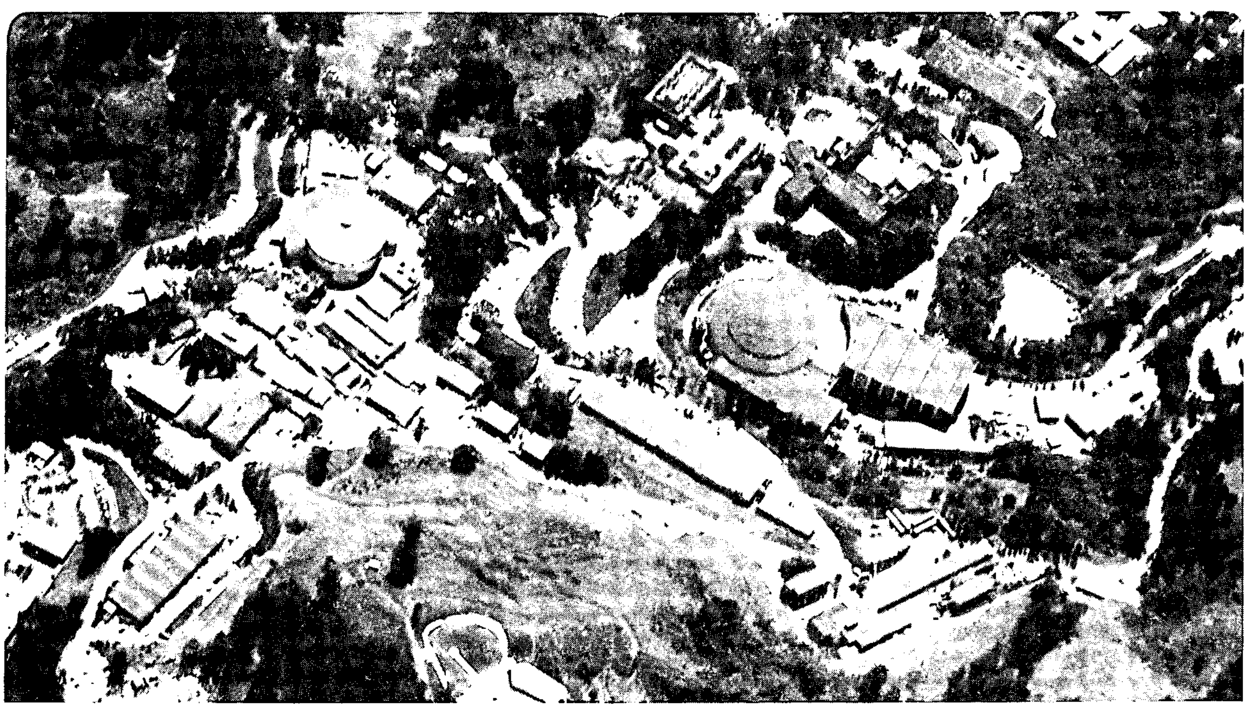

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HEAVY LEPTONS AT THE SSC *

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Abstract

We comment on heavy lepton searches at the SSC.

The cross-sections for the production of heavy leptons at the SSC are rather small. We shall discuss only a 4^{th} generation lepton doublet (L, ν_L) and will assume that the neutrino ν_L is stable. There are three relevant production mechanisms; a L^+L^- pair can be produced from $q\overline{q}$ annihilation via an intermediate photon or Z boson; a $L\nu_L$ pair can be produced from $q\overline{q}$ annihilation via an intermediate W boson;[1] and a L^+L^- pair can be produced from the annihilation of a pair of gluons with an intermediate quark loop[2] (see figure 1). The rates from these processes are shown in figure 2. From this figure, it is clear the rates are rather small and that, if ν_L is very light compared to L, the rate from the process with a $L\nu_L$ final state is dominant over most of the relevant mass region. We shall assume that $\nu_L = 0$ in what follows.

The signals and backgrounds for the $L\nu_L$ final state were discussed at the La Thuile study[3] where it was concluded that the signal was fairly easy to extract. This conclusion has been challenged by Barger *et al.*[4] who carried out an exhaustive study (including one for the final state L^+L^-). They claim that all of the signals are obscured by backgrounds. In order to understand the controversy, we have studied the signals and background for the $L\nu_L$ final state.

The heavy lepton will decay to $W\nu_L$. The leptonic decay of the W will produce an isolated lepton (l) and missing transverse momentum. This signal is completely obscured by the process $q\overline{q} \to l\nu$.[4] We must therefore consider the hadronic decays of the W. The background now arises from processes which can make a W at large transverse momenta. There are two dominant possibilities; the final state $Z + W$ followed by the decay $Z \to \nu\overline{\nu}$; and $Z + jets$ where the jet system has an invariant mass near the W and the Z decays to $\nu\overline{\nu}$. The former is smaller than the signal if L is lighter than 200 GeV or so, hence we will concentrate on the latter.

The lowest order QCD processes which can produce Z+"fake" W occur at order α_s^2 and include $gluon + gluon \to Z + q + \overline{q}$. The relevant partonic matrix elements are known[5] and

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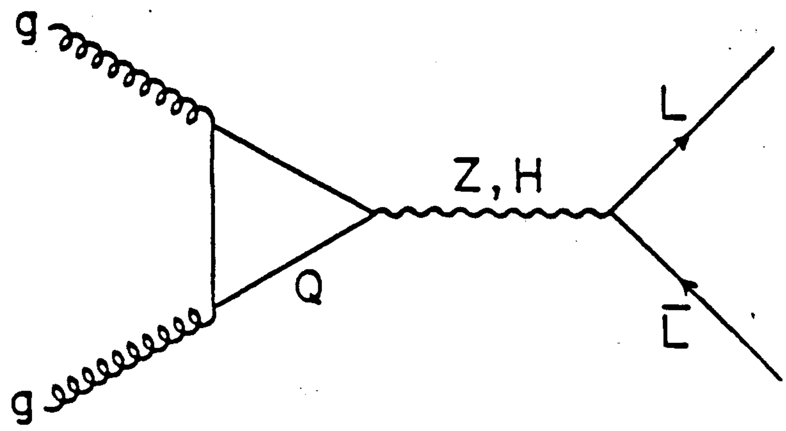

Figure 1: Diagram showing the parton model process $gg \to L^+L^-$.

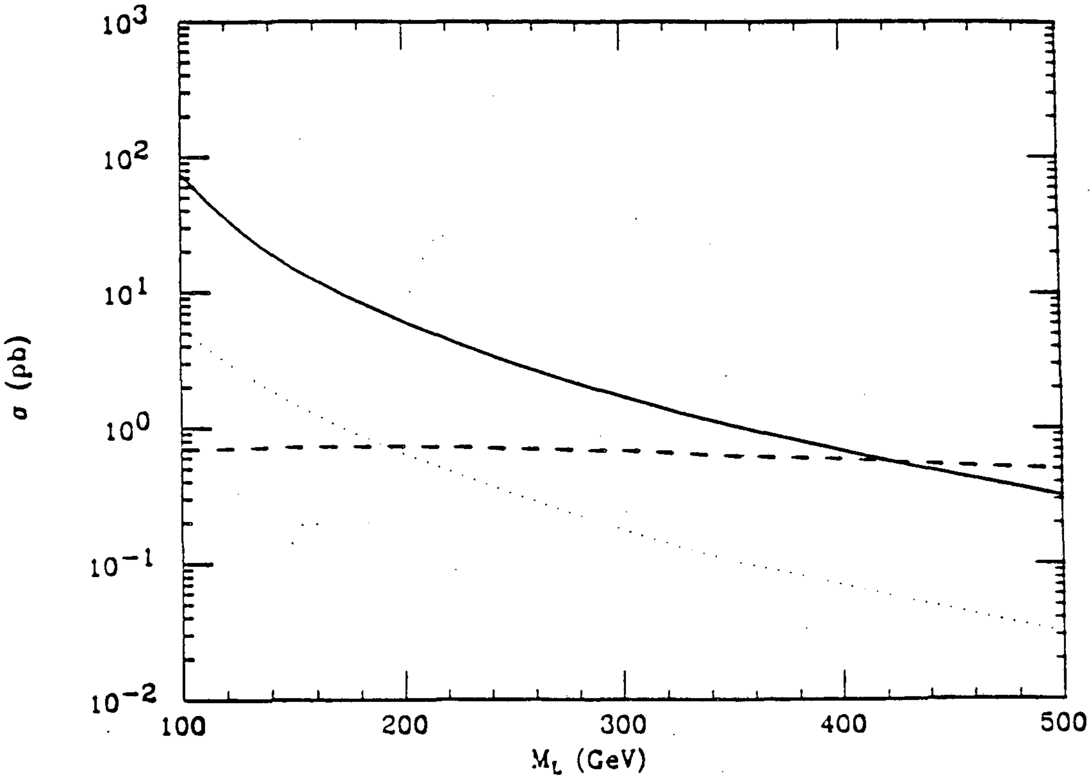

Figure 2: The cross section for heavy lepton production at the SSC as a function of the mass m_L of the charged lepton, for the three contributing partonic processes: $q\bar{q} \to L^+L^-$ (dotted line); $gg \to L^+L^-$ (dashed line); and $q\bar{q} \to L^\pm\nu$ (solid line);. The mass of the neutrino ν_L has been assumed to be zero. The gluon gluon rate[2] depends upon the Higgs mass, taken to be 100 GeV and upon the masses of the quarks in the fourth generation, taken to be m_L and $m_L + 250$ GeV for the charge 1/3 and 2/3 members of the doublet.[4]

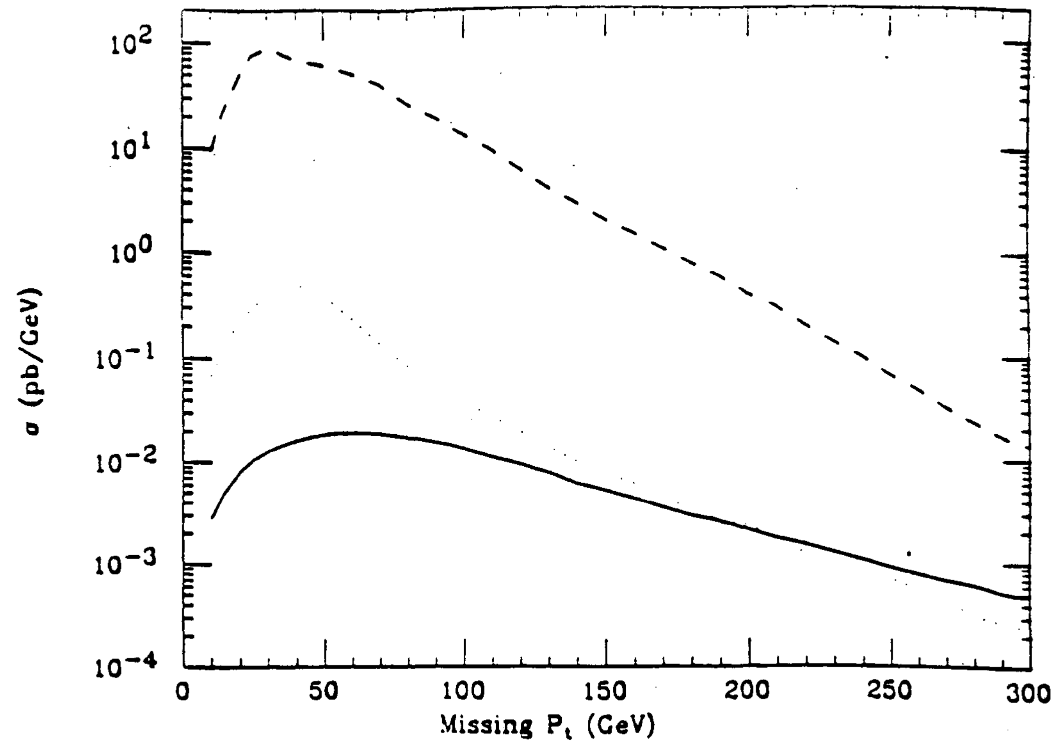

Figure 3: The missing transverse momentum distribution from the processes $pp \rightarrow L\nu_L + X \rightarrow W\nu\overline{\nu} + X$ and $pp \rightarrow Z + 2jets + X \rightarrow \nu\overline{\nu} + 2jet + X$. The sum of the absolute values of the transverse momenta of the two jets from W decay are required to be more than 20 GeV. The jets are required to satisfy $\Delta\eta^2 + \Delta\phi^2 > .5$ and have invariant mass $M_W \pm 10$ GeV. The dotted (solid) lines are for the $L^{\pm}\nu$ final state with $m_\nu = 0$ and $m_L = 100(200)$ GeV. The dashed line is from the final state $Z + 2jets$. Compare with figure 5b of reference 4.

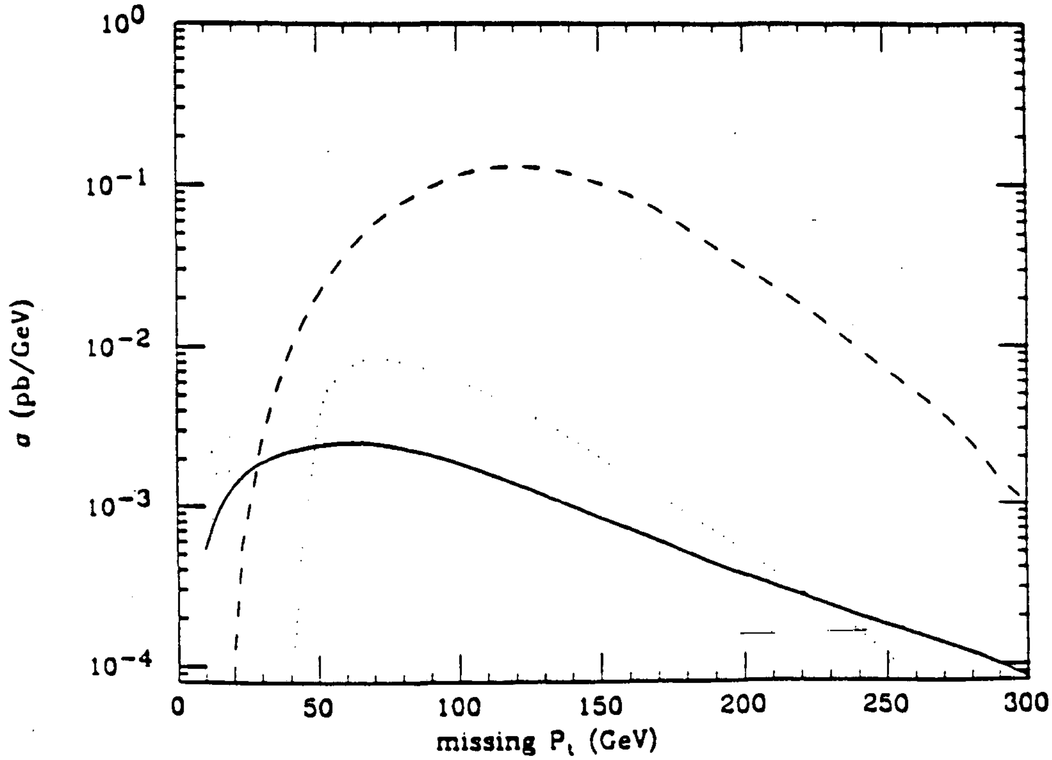

Figure 4: As figure 3 except each jet has transverse momentum of at least 50 GeV

are used in our calculation. The calculations of reference 4 used the order α_s processes of the type $q + \overline{q} \rightarrow Z + gluon$, and then produced a second jet by means of the leading log approximation[†]. This approximation is good when the invariant mass of the jet pair is much smaller than the partonic center of mass energy, so its accuracy in the region of interest where the two jets have an invariant mass of 80 GeV is not clear. The rates produced by our exact matrix elements are larger by approximately a factor of ten than those from the approximate form reported in reference 4.

Figure 3 shows the missing transverse momentum distribution in the signal and background. For the background we have required that the two final partons be separated by $\Delta\eta^2 + \Delta\phi^2 > .5$ and have invariant mass of $M_W \pm 10$ GeV. The signal to background ratio shown in this figure is worse than that of reference 4, since the $Z + jets$ rate is larger (see above) and reference 4 took a dijet mass of $M_W \pm 5$ GeV.

The momentum distributions of the jets from the real and "fake" W can be different so that techniques similar to those adopted in attempts to reject the $W + jets$ background to Higgs decay to WW may be useful.[8] In Figure 4 (5) we have made the additional requirement that the two jets each have transverse momentum greater than 50 (100) GeV. This cut reduces the background considerably. The number of events surviving these cuts is not great and it is unlikely that heavy leptons of mass more than 150 GeV will be observable. In addition the missing transverse momentum is not large so that detector hermeticity will be crucial.

In conclusion, detection of heavy leptons at the SSC seems to be very difficult, but perhaps not impossible. The feasibility depends critically upon the ability to identify events with W's decaying hadronically and missing transverse momentum.

Acknowledgment

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[†]This is the method used by the Monte-Carlo event generators PYTHIA[6] and ISAJET[7]

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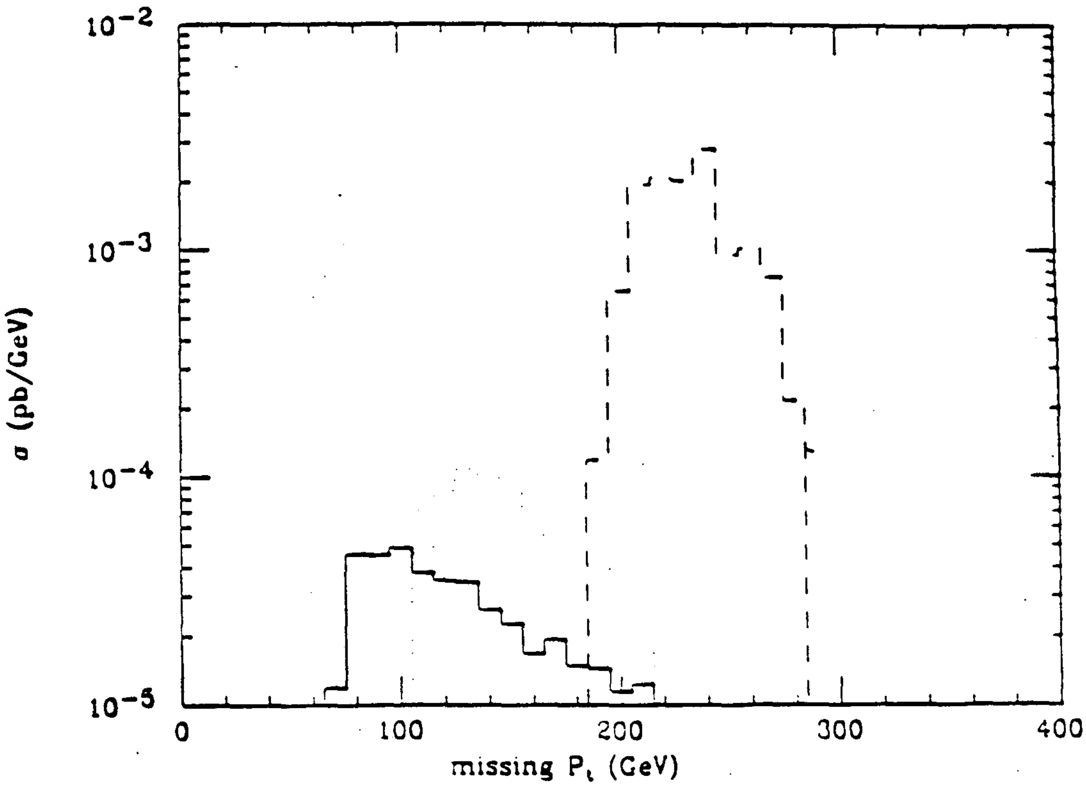

Figure 5: As figure 3 except each jet has transverse momentum of at least 100 GeV