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APPLICATION OF NEW TECHNIQUE FOR IDENTIFYING EXOTIC EVENTS WITH LOW VISIBLE ENERGY IN e^+e^- ANNIHILATION AT 29 GEV *

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ABSTRACT

Using a new technique based on photon tagging, we have searched for a fourth-generation charged lepton associated with a heavy neutral partner of nearly equal mass. Preliminary limits on allowed lepton masses are presented.

Exotic processes in e^+e^- annihilation that are characterized by large missing energy because of escaping massive particles can be difficult to distinguish from backgrounds due to two-photon processes. We find, however, that requiring the production of an energetic, isolated photon at large angles relative to the e^+e^- beams, reduces considerably the two-photon contamination.[1] Dominated by t-channel processes, this background is suppressed much more by a radiative tag than are annihilation processes. Recent searches[2–4] for a fourth-generation lepton doublet where the charged lepton is heavier than the neutral lepton have excluded mass values accessible at PEP energy(29 GeV), except in a narrow range where the charged lepton's mass is only a few hundred MeV/c^2 heavier than the neutral partner's. In this region, detected decay product energies are low enough that techniques based on electron and muon identification are inadequate to extract a heavy lepton signal. We have applied the radiative tag technique to explore this region, using 104 pb^{-1} of e^+e^- collision data taken at a c.m. energy of 29 GeV. A detailed description of the Mark II/PEP5 detector can be found in ref. 5.

The characteristics of close-mass leptons have been studied with a Monte Carlo program[3] that simulates production and decay of heavy leptons, including electroweak effects in production and spin-spin correlations in decays. The program uses Lund[6] algorithms to simulate some hadronic decay modes and to generate initial state radiation.[7] Small corrections for final state radiation[7] are included in weights assigned to generated events.

Heavy lepton candidate events must contain two well-measured, oppositely-

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charged particles and one or more photons detected in the calorimeter. To ensure accurate simulation of trigger and tracking efficiency and to suppress radiative Bhabha and tau pair backgrounds, stringent fiducial and momentum requirements are placed on the reconstructed charged tracks. The most severe requirements are that both tracks point more than 45° away from the e^+e^- beams and that their momenta be less than 4 GeV/c. The tagging photon must have a reconstructed energy of at least 1 GeV and must point more than 45° away both from the nearest charged track and from the beam direction. Any two photons consistent with a π^0 or an η decay are excluded from tagging consideration.

We also apply cuts based on the overall event topology. The opening angle between the two charged particles at the interaction point must be between 20° and 160°. In the plane transverse to the beam, the opening angle must be between 100 mrad and π - 20 mrad. A momentum vector is calculated from the sum of the photon and charged particle momenta. The direction of that vector must lie more than 45° away from the beam direction, and its azimuth angle must not point toward gaps in the calorimeter acceptance. A transverse momentum vector of the event is formed from the vector sum of transverse components of the tagging photon, the two charged particles and any remaining photons detected in the barrel calorimeter. The magnitude of this transverse momentum must be at least 1 GeV/c. In addition, events with large energy deposition in the forward calorimeters are discarded. An unusual background is the coincidence of a calorimeter shower induced by an incident cosmic ray and the two-photon process, $e^+e^- \rightarrow e^+e^-e^+e^-$. Various algorithms are used to veto such coincidences, based on excess energy deposition near the tagging photon and on alignment of drift chamber or muon tube hits with the tagging photon. After all selection criteria, 13 heavy lepton candidate events remain in the data.

We have considered backgrounds from various processes, but those found to be non-negligible are from radiative tau pair production, from two-photon production of tau pairs and charged rho pairs, and from radiative hadronic events containing undetected neutrons. The radiative tau pair background has been simulated with the heavy lepton Monte Carlo program, which predicts 9.2±0.6±0.6 events where the first error is statistical and the second systematic. The two-photon backgrounds are simulated with a Monte Carlo program that uses the double equivalent photon approximation.[8] We expect 2.3±0.6 and 0.3±0.2 events from the two-photon produced tau and rho pairs, respectively, where the errors are purely statistical. Because of present uncertainties in the accuracy of the Monte Carlo, both in generating particles and in the simulation of the SAT system, we do not yet claim to understand the systematic error. The background from hadronic events is estimated from a sample of 110,000 events generated with the Lund Monte Carlo(version 5.2)[6] program. From this sample, we expect 2.1±0.9 events in the data, where the error is statistical. Again, we do not feel confident assigning a systematic error to this background estimate. Therefore, in setting conservative limits on heavy lepton production, we use only the radiative tau pair background estimate.

From 86 Monte Carlo lepton samples with various charged and neutral mass values, we determine regions in the $M_L - M_{\nu_L}$ vs M_L plane that can be excluded with 90% and 99% confidence. These are shown in fig. 1. It is difficult in this analysis to exclude mass differences below 200 MeV/c^2 because of dependence on a charged particle trigger. At very low mass differences, the total decay width of the charged lepton becomes quite small. Therefore, the distance the particle travels before decaying can be substantial, leading to daughter particle trajectories with large impact parameters, for which our trigger efficiency is poor. Considerable improvement in exploring the very low mass difference region could be attained with a trigger sensitive to low energy photons.

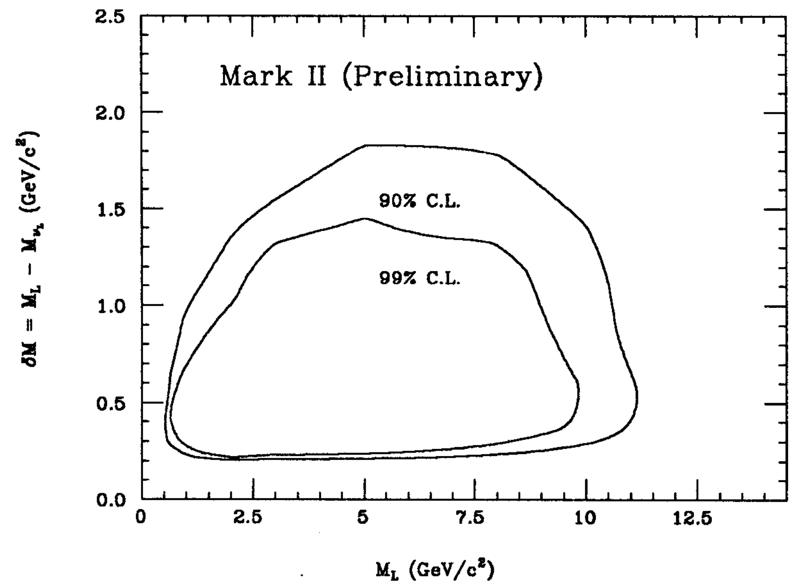

Figure 1. Shown within the contours are regions excluded with 90% and 99% confidence by the radiative tagging technique.

In conclusion, we have used a new radiative-tagging technique to search for a nearly mass-degenerate heavy lepton doublet. We find no evidence for the existence of such leptons and place preliminary 90% and 99% confidence level limits on allowed values of charged and neutral lepton masses.

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