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ABSTRACT

In e^+e^- annihilations at SPEAR we have searched for narrow neutral resonances in the $e\pi$ and $\mu\pi$ channels for masses between .5 GeV/c^2 and 1.5 GeV/c^2. No evidence for such states has been found. Under standard theoretical assumptions for production cross sections and decay branching ratios of heavy leptons a lower limit of 1.2 GeV/c^2 can be set on the mass.

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There has been considerable speculation about the existence of a massive neutral lepton, N, which would couple to the electron in a right-handed doublet as the neutrino does in the left-handed doublet. Since the decay $K^{\pm} \to Ne^{\pm}$ has not been observed, the mass of such a lepton if it exists must be greater than 0.5 GeV/c^2.

One of the main decay modes of such a lepton would be expected to be $e^{\mp}\pi^{\pm}$ with a predicted branching ratio[1] which falls from 80% at M_N = 0.5 GeV/c^2 to 10% at M_N = 2 GeV/c^2. (There could of course be a similar lepton decaying to $\mu^{\mp}\pi^{\pm}$ and in addition μ-e mixing. Therefore wherever ℓ is written in this paper μ or e is implied.)

A possible source of such leptons would be $e^+e^- \to \tau^+\tau^-$, τ representing a charged heavy lepton[2] with m_τ = 1.9 GeV/c^2. The subsequent decay $\tau = \nu_\tau$ eN could then occur. Since the primary decay of the second τ is expected to be into modes with a single charged particle, the signature for N would be a 4-prong event with at least 2 leptons and a clustering of events at a unique $\ell\pi$ mass.

The data which was used in the search was taken on the SLAC-LBL Magnetic Detector at SPEAR which has been described elsewhere.[3] An electron is identified by a shower in Pb-scintillation counters, the μ by penetration through 20 cm. of steel. Electrons and μ's below 0.6 GeV/c momentum could not be identified and were not used in the analysis. There is approximately a 15% chance of a hadron being misidentified as either an electron or a muon. The electron detectors cover 0.65 of the total solid angle, the muon detectors 0.45. The resolution for $\ell\pi$ pairs is 40 MeV FWHM at 1.0 GeV and is roughly proportional to the mass.

In the search 170,000 hadron events recorded at total center-of-mass energy > 5 GeV were used corresponding to an integrated luminosity of 2.3×10^{37} cm^{-2}. Selection was made on events with 3 or 4 observed prongs of which at least 2 had been identified as lepton candidates; 85% of the events had 4 prongs. The mass was calculated for all lepton-hadron mass combinations assuming the hadron to be a π. Corrections were made for the solid angle acceptance of the detector and the momentum acceptance for leptons. The data is shown in Fig. 1. Figure 2 shows the 90% confidence upper limit for the cross section as a function of the N mass at the average center-of-mass energy of 6.8 GeV.

The experimental upper limit can be compared with that expected if the N exists. It is assumed that τ pair production occurs at a level of one unit of R and hadron production at a level of 4 units of R in agreement with the best experimental knowledge. In addition the branching ratios $B_\tau \equiv \Gamma(\tau \to \nu_\tau \ell N)/\Gamma_\tau$ and $B_N \equiv \Gamma(N \to \ell\pi)/\Gamma_N$ are needed. These have been estimated theoretically.[1,4] The estimate of B_τ as a function of mass is essentially a calculation of the reduction in the available phase space for $\tau \to \nu_\tau eN$ as compared with the 5 competing channels $\tau \to \nu_\tau e\bar{\nu}$, $\nu_\tau \mu \bar{\nu}_\mu$ and $\nu_\tau u\bar{d}$ with 3 color degrees of freedom. That is $B_\tau = f/(5+f)$ where f is a factor less than 1 due to kinematics. Simiarly in the pertinent region of M_N around 1.3 GeV/c^2, $\Gamma_N = \Gamma(e^- e^+ \nu_e) + \Gamma(e^- \mu^+ \nu_\mu) + \Gamma(e^- u\bar{d})$. The $e\pi$ and $e\rho$ channels compete approximately equally for the 60% of the decay modes involving hadrons. Using $B_\tau B_N$ above the theoretically predicted rate is shown in Fig. 2.

Since the e's and μ's were identified separately, it was also possible to look at the four individual channels $\tau \to \nu_\tau Ne$ with $N \to e\pi$ or $\mu\pi$ and $\tau \to \nu_\tau N\mu$ with $N \to e\pi$ or $\mu\pi$. The background in the individual channels is of course lower than the combined background but so are the theoretical branching ratio curves. The mass limit which can be set is therefore approximately the same for the individual channels and the combined sample. No evidence is found in any of the reaction channels for an N.

It would be desirable to carry the search for a neutral heavy lepton to higher mass. Probably the most feasible reactions for such a search are $N\bar{N}$ and $N\bar{\nu}$ production in e^+e^- collisions. At PEP and PETRA energies these final states should have sizeable production cross sections[5] through weak coupling if the N exists.

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FIGURE CAPTIONS

Fig. 1. Number of events detected as a function of $\ell\pi$ mass.

Fig. 2. The solid curve gives the 90% confidence upper limit for an $\ell\pi$ mass peak. The dashed curve is the theoretical estimate based on expected τ and N branching ratios and τ pair production of one unit of R.

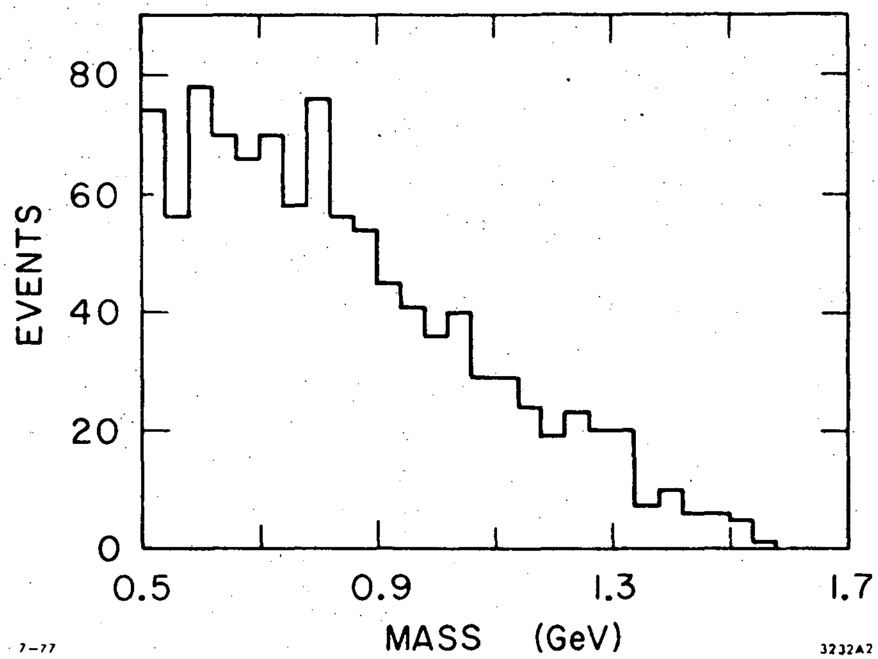
80
60
40
20
0
EVENTS
0.5
0.9
1.3
1.7
MASS (GeV)
7-77
3232A2

Fig. 1

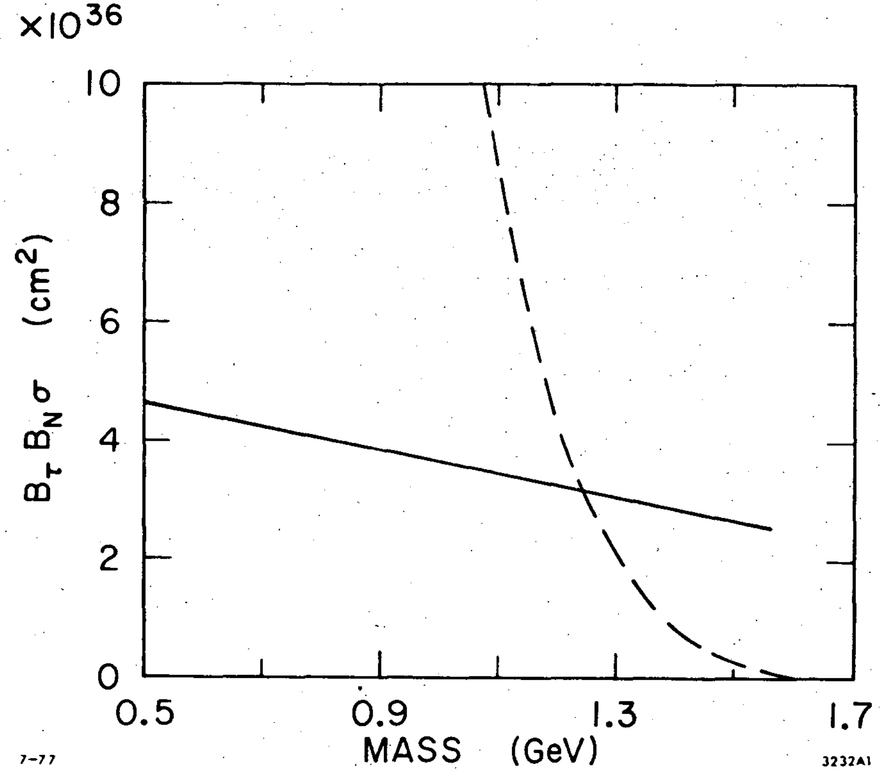
×10^36
10
8
6
4
2
0
$B_\tau B_N \sigma$ (cm²)
0.5
0.9
1.3
1.7
MASS (GeV)
7-77
3232A1

Fig. 2

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