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NEW RESULTS FROM DELCO†

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ABSTRACT

New results from the DELCO experiment at SPEAR are presented. New data and reanalysis give conclusive evidence for the τ heavy lepton with mass 1.777 + .005 − .009 GeV/c^2. Preliminary branching ratios for the τ are discussed, along with analysis of the electron momentum spectrum, favoring V-A. A preliminary look at D beta decay at ψ"(3770) in terms of K and K*(890) is also discussed.

INTRODUCTION

DELCO[1] is an east pit experiment at SPEAR designed to study production of new particles tagged by direct electrons from weak decays. In practice we study charm[2] and the heavy lepton.[3] The physicists are a collaboration from Stanford, UCLA, Stony Brook, and U.C. Irvine.[4] I will describe the detector and briefly review old results presented last summer before describing our new results, which are of course, preliminary.

THE DETECTOR

The detector is shown in Fig. 1. The interaction region is in a small volume of magnetic field (3.5kG). The beam passes through the poles of the magnet, and the return yoke is extended far up and down to avoid interfering with the detectors. Six cylinders of low mass wire proportional chambers with radii from 10-30 cm surround the vacuum pipe. Cathode strips aid in z reconstruction. Scintillation counters on the pole tips increase the solid angle for charge particle detection. The MWPC are surrounded by a segmented atmospheric ethane Cerenkov counter of one meter radiator. Two bounce optics focuses the Cerenkov light on five inch phototubes. Each of the sextents follows with two planes of XY magnetostrictive wire spark chambers and lead scintillator sandwich shower counters. The inner scintillator strips are timed at both ends. Over the summer the eight inch lead walls followed by spark chambers and scintillation counters were added to give muon identification over 20% of 4π. We do not have results to report yet on identified muons.

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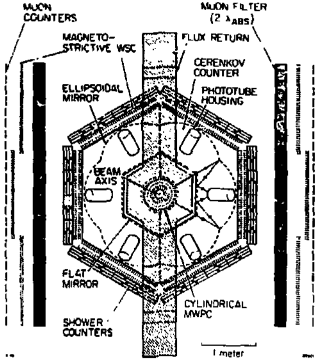

Fig. 1. The DELCO Apparatus

Our basic trigger requires two out of three layers in a shower counter in at least two sextants including at least one timed layer, as well as one or more tracks in the inner two layers of MWPC. There are neutral triggers which are currently being studied.

The detector gives some charged particle detection over 90% of 4π, and electron identification (hadron rejection $<5\times10^{-4}$) and momentum measured (σ of $\delta p/p$ is 8% x p (GeV)) over about 60% of 4π.

OLD RESULTS

Quoted results from DELCO[1] include measurement of

$$R \equiv \left(\frac{\sigma\ e^+e^- \to \text{hadrons}}{\sigma\ e^+e^- \to \mu^+\mu^-}\right)$$

in the charm threshold region with description of the $\psi''(3770)$, the similar rate for multiprong events with an electron showing the charm resonance structure and, by comparison of the ψ'', giving a D beta decay branching ratio of 11 ± 2%. A smooth excitation function for two prong events where one is identified as an electron and the other not (eX) was contrasted with the multiprong electron events as evidence for the τ.

NEW RESULTS

New data points have been added to a reanalysis of eX events. Clean two prong events where both prongs could be identified electrons are selected in a physicist scan of reconstructed events. Any number of photons is allowed. The electron is required to have momentum greater than 200 MeV/c and the non electron greater than 300 MeV/c. These cuts are explained by the Cerenkov efficiency determined by studying electron pairs, shown in Fig. 2. The relative azimuthal angle must be less than 160°. Apparent eeγ topology events (15) are removed. A sample of 660 events results. To further eliminate electrons which have not been Cerenkov tagged, the X prong is required to have a shower counter pulse height less than 3.3 times minimum ionizing. This leaves 540 events with an estimated background of 15 events, which is consistant with the rate of candidates seen at the ψ(3095) and E_{CM} of 3.5 GeV. Two photon processes are estimated by comparing like sign events to opposite sign candidates, about 2%.

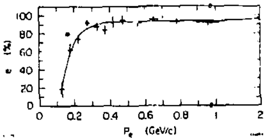

Fig. 2. Cerenkov efficiency. The data points are from analysis of electron pairs. The curve is a Monte Carlo calculation

The first conclusion we reach is that any remaining doubts about the existence of the τ are dispelled. Not only is the excitation completely inconsistent with the charm associated structure, but also events are found at several energies below charm threshold: E_{CM}=3.72 and 3.625 GeV/c and the ψ'. Candidates below charm threshold were reported previously.[6] The eX spectrum is shown in Fig. 3 for all candidates and events without photons. The distributions are fit to a background plus heavy lepton. The point at the ψ" is estimated to contain 30% background from charm and is eliminated from the fit. Charm background at other points is estimated to be less than our statistical error. The fits yield a heavy lepton mass and twice the branching ratio to electrons times the branching ratio to X. The results are summarized in Table I.[7] To interpret the branching ratio information we are required to use a model due to Gilman and Miller[8] yielding a branching ratio to electrons of 16±1% and a branching ratio to multiprongs of 32±3%, where the error is statistical only.

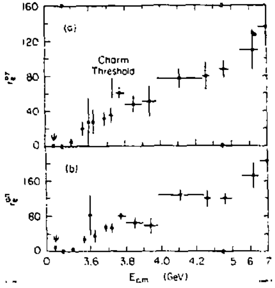

Fig. 3. Rate of eX production normalized to the muon pair rate for (a) events with no photons (b) all events. ($r=R_{eX}\times10^{-3}$)

TABLE I

Sample	No. photons	All Events
Mass (GeV)	$1.777 + .005 - .009$	$1.780 + .003 - .006$
$2b_e\ b_x$	$.118 \pm .008$	$.170 \pm .010$
χ^2/NDF	9.9/11	19.2/11

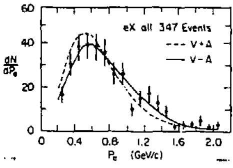

Fig. 4. Electron momentum spectrum from eX events, all energies. The curves are detailed Monte Carlo generated fits.

Next we study the electron momentum distribution. In complete analogy to muon decay, the momentum spectrum yields information about the helicity of the τ neutrino and thus the V-A or V+A characteristic of the decay. For maximum electron momentum the neutrinos are parallel and the combination is allowed for V-A and forbidden for V+A. We analyze the momentum distribution in terms of Michel parameter and also study the average of electron momentum divided by the beam energy, predicted to be .35 for V-A and .30 for V+A. The momentum distribution is shown in Fig. 4. The fits are summarized in Table II. Average scaled electron momentum is plotted in Fig. 5. We conclude that if V+A is not ruled out, it is at least very unlikely (<1% probability).

TABLE II

ρ	χ^2/NDF
0 V+A	38/18
.75 V-A	17.6/18
$.73 \pm .15$	17.5/17

The effect of a finite neutrino mass is also to give lower electron momentum.[8] Fits to the momentum distribution give a 90% confidence level upper limit to the τ neutrino mass of 250 MeV/c^2.

Next we study the branching ratio of τ into multiprongs. Two methods are used. First we investigate multiprong electron events in the charm depleted regions at E_{CM} of 3.72, 3.85 and 4.25 GeV. To eliminate residual charm background we require the electron momentum to be greater than one third the beam momentum. This gives 78 multiprongs compared to 29 eX events. After correction for relative detection efficiency the ratio is $2.1 \pm .4$, giving a multiprong branching ratio, assuming b_e, of $34 \pm 6\%$. We can also use the fact that charm events do not give stiff electrons. As we cut progressively higher on the electron momentum the ratio of multiprongs to eX events

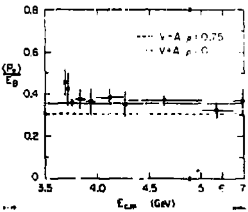

Fig. 5. Average scaled electron momentum

should become constant. This distribution is shown in Fig.6. The ratio is 1.8 ± .3 gives multiprong branching ratio of 35 ± 6%. This high multiprong branching ratio implies a 40% background from the τ in multiprong electrons at the ψ"!

Assuming we now reasonably understand the background from τ at the ψ" we can now investigate the electron spectrum at the ψ". The distribution is shown in Fig. 7, fit to a combination of D → Keν and D → K*(890) eν after removing soft pair background and the τ contribution. In this preliminary analysis we find comparable contributions from K and K*.

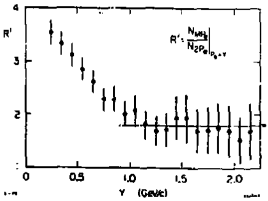

Fig. 6. Ratio of multiprong electrons to eX events versus minimum required electron momentum.

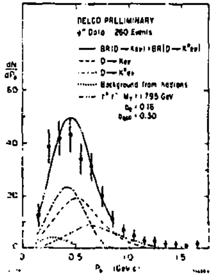

Fig. 7 Electron momentum distribution for multiprong electron events at the ψ".

SPECULATION

Data taking continues and may include new points for the eX analysis. A reasonable point requires about a week of data. Further and more detailed analysis of the τ including muon information, and analysis of charm is continuing. Probably not all developments can be forseen.

FOOTNOTES

1. The Direct Electron Counter experiment is supported in part by grants from the Department of Energy and the National Science Foundation.
2. S.L. Glashow, Illiopoulos and Maiani, Phys.Rev. D 2, 1285 (1970). G. Goldhaber et al., Phys. Rev. Letters 37, 1255 (1976).
3. M.L. Perl, et al., Phys. Rev. Letters 35, 1489 (1975).
4. DELCO Physicists include W. Bacino, R. Burns, P. Condon, P.Cowell, A. Diamant-Berger, T. Ferguson, A.Hall, J. Hauptman, G. Irwin, J. Kirkby, J. Kirz, J. Liu, F. Merritt, L. Nodulman, W. Slater, M. Schwartz, H. Ticho, and S. Wojcicki.
5. W. Bacino et al., Phys. Rev. Letters, 40, 671 (1978), J. Kirkby, SLAC-PUB-2040, 1977 International Symposium on Lepton and Photon Interactions at High Energies, Hamburg, Germany, August 25-31, 1977.
6. R. Brandelik et al., Phys. Letters, 37B, 109 (1978).
7. Heavy lepton mass results have been updated to include 9 events at E_{CM}=3.57, giving $1.75 < m_T < 1.785$ GeV/c^2.
8. F. Gilman and D.H. Miller, Phys. Rev. to be published, SLAC-PUB 2046 (1977).
9. The algorithm for including finite neutrino mass in our calculations was provided by Yung-Su Tsai.