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RECENT RESULTS FROM NEUTRINO INTERACTIONS IN HEAVY NEON *

M. Kalelkar, C. Baltay, D. Caroumbalis, H. French, M. Hibbs, R. Hylton, and W. Orance
Columbia University, New York, N.Y. 10027

A.M. Cnops, P.L. Connolly, S.A. Kahn, H.G. Kirk, M.J. Murtagh, R.B. Palmer, N.P. Samios, and M. Tanaka
Brookhaven National Laboratory, Upton, N.Y. 11973

ABSTRACT

We report recent results from an analysis of 100,000 pictures of the Fermilab 15 ft bubble chamber filled with heavy neon and exposed to the double horn focused, wideband ν_μ beam. We have found 164 dilepton ($\mu^- e^+$) events with 33 vees, in good agreement with the GIM model of charm production. We have also observed the production of the charmed D^0 meson, followed by the decay $D^0 \rightarrow K^0\pi^+\pi^-$, at a rate of $(0.7 \pm 0.2)\%$ of all charged current events. From a subsample of our film, we have found four events of the purely leptonic neutrino-electron elastic scattering process.

INTRODUCTION

We present recent results from a study of ν_μ interactions in heavy neon. The experiment was carried out at Fermilab using the two-horn focused wideband muon neutrino beam and the 15 ft chamber filled with a heavy neon-hydrogen mixture (64 atomic % neon). A total of 150,000 pictures was taken with an average of 10^{13} 400 GeV protons per pulse on the neutrino target. The interaction length for hadrons is 125 cm, so that hadrons typically interact, while muons leave the chamber without interaction, and can thus be identified on the scan table. Electrons are easily identifiable through visible bremsstrahlung, since the radiation length is 40 cm.

DILEPTON PRODUCTION

We have previously published[1] results on dilepton production from the first 50,000 pictures of our exposure. We have now analyzed 100,000 pictures, corresponding to about 60,000 charged current neutrino interactions. In this sample, we have found 164 events with a μ^-, an e^+ and anything else. The e^+ is required to have two signatures and a momentum over 300 MeV/c. With these cuts, the background from asymmetric Dalitz

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pairs is a few percent. The μ^- is identified as the fastest negative leaving track. No momentum cut is made. From a comparison of interacting and non-interacting tracks of both signs, the background due to fake μ^- (hadron punchthrough) is determined to be about 10%. After correcting for these backgrounds, scan efficiency ($\sim$ 90%), and e^+ identification efficiency ($\sim$ 85%), we obtain a dilepton rate of

$$R = \frac{\nu_\mu + Ne \rightarrow \mu^- + e^+ + \ldots}{\nu_\mu + Ne \rightarrow \mu^- + \ldots} = (0.5 \pm 0.15)\% \quad .$$

This rate is calculated using half of our events for which we have an accurate normalization. Figure 1 shows the momentum distribution of the e^+ and μ^-, and also the total visible energy.

We have examined the 164 $\mu^- e^+$ events for associated $K_S \rightarrow \pi^+\pi^-$ and $\Lambda \rightarrow p\pi^-$ decays. We find 33 such vees (25 events with a single vee, 4 with a double vee), consisting of 20 unambiguous K^0's, 3 unambiguous Λ's, and 10 K/Λ ambiguities. From half of our events, this corresponds to a neutral strange particle rate of 0.6 $\pm$ 0.2 per dilepton event, in good agreement with the GIM model of charm production by neutrinos. From our 60,000 charged current events, we find that 6% have a visible vee. At that rate, we would expect 10 vees in 164 $\mu^- e^+$ events, whereas we actually see 33.

Figure 2 shows the $K^0 e^+$ effective mass from 19 $\mu^- e^+$ events with a single K^0. The data are not in good agreement with the distribution expected from the $K^0 e^+ \nu$ decay of a spin zero D^+ meson at 1868 MeV. However, the distribution is consistent with a calculation by Barger et al.[2] assuming a $K\pi e\nu$ decay.

OBSERVATION OF $D^0 \rightarrow K^0\pi^+\pi^-$

We have measured all events with vees in about 80,000 pictures, corresponding to 46,000 charged current events with a muon momentum over 2 GeV/c. We obtain good 2 or 3 constraint fits for 1815 $K_S \rightarrow \pi^+\pi^-$ and 1367 $\Lambda \rightarrow p\pi^-$. Correcting for branching ratios and detection efficiencies, this corresponds to a $(K^0 + \bar{K}^0)$ rate of (13.6 $\pm$ 1.5)% of all charged current events, and a $(\Lambda^0 + \Sigma^0)$ rate of (5.0 $\pm$ 0.5)%.

Figure 3 shows the $K_S\pi^+\pi^-$ mass distribution, indicating a peak in the mass region of the charmed D^0 meson seen at SPEAR.[3] The best fit to a polynomial background plus a Gaussian, shown by the curve, gives the following parameters:

$$M = 1850 \pm 15 \text{ MeV}, \quad \sigma = 20 \pm 8 \text{ MeV}$$

corresponding to 64 events above a background of 180, with a statistical significance of four standard deviations. The width is consistent with our experimental mass resolution of 20 MeV. No corresponding peak is apparent near the D mass in the events without a μ^-. This is consistent with the prediction of the GIM model that the charm changing neutral current interactions are absent. If the peak were due to K^* production, then one might expect it to be present in events both with and without a μ^-.

Correcting for branching ratios and detection efficiencies, we obtain a rate

$$\frac{\nu_\mu + Ne \to \mu^- + D^o + \ldots,\ D^o \to K^o\pi^+\pi^-}{\nu_\mu + Ne \to \mu^- + \ldots} = (0.7 \pm 0.2)\% \ .$$

Figure 4 shows the distribution in Z, the fraction of the hadronic energy carried by the D^o. We have used the visible hadronic energy for each event, correcting for our estimate of the energy lost due to missing neutrals or charged tracks that interact close to the vertex and therefore fail to reconstruct. The solid lines represent all of the events in the D^o region of the $K^o\pi^+\pi^-$ mass distribution, while the dashed lines give the contribution from the background under the D^o, obtained by using control regions above and below the D^o.

NEUTRINO-ELECTRON SCATTERING

From an analysis of half of our pictures, we have found four events of the purely leptonic neutral current process

$$\nu_\mu + e^- \to \nu_\mu + e^- \ .$$

The signature for this process is a single high energy e^- making a very small angle with the neutrino direction. The energies and angles of the four events are as follows:

E (GeV) :	31.5	34.6	9.0	8.9
θ (mrad) :	8 $\pm$ 2	4 $\pm$ 2	8 $\pm$ 5	4 $\pm$ 2

There are two backgrounds to this process. One comes from γ's originating outside the chamber and converting asymmetrically. By scanning for energetic forward γ's and measuring the probability for asymmetry, we find this background to be on the order of 1%. The other background comes from the reaction $\nu_e + n \to e^- + p$, where the proton is too slow to be visible. From the known cross section for this process, the ν_e flux in the beam, and the estimated q^2 distribution, we expect a background of about 10%.

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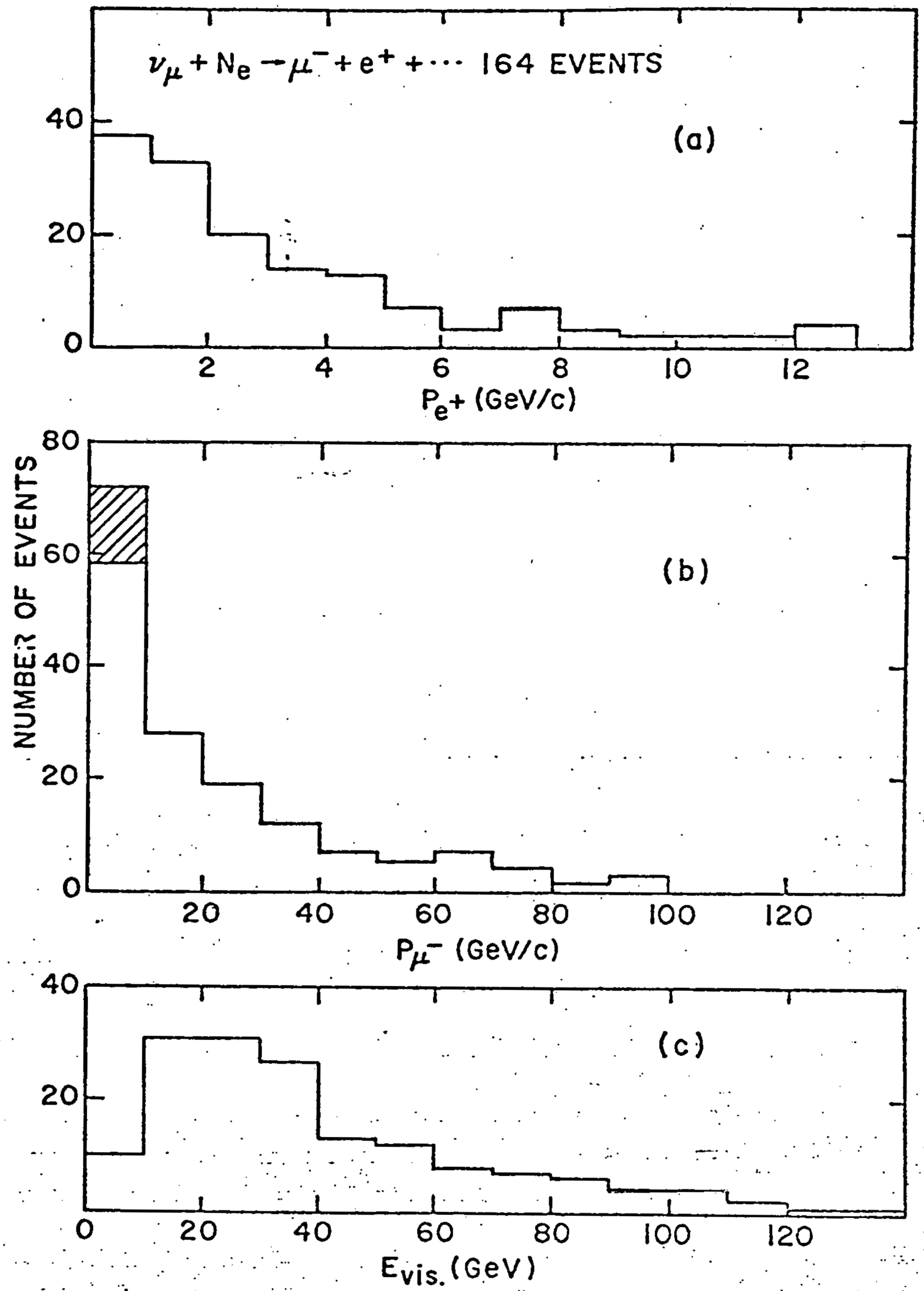

Fig. 1 Momentum of a) the e^+, and b) the μ^-, the dilepton sample. The shaded events are the background from hadron punchthrough. c) The total visible energy.

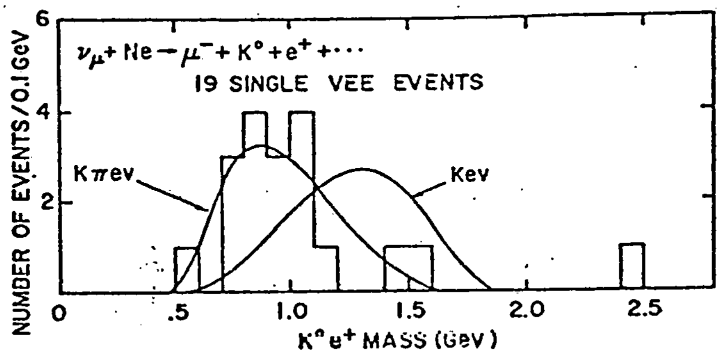

Fig. 2 K^O e^+ mass from dilepton sample.

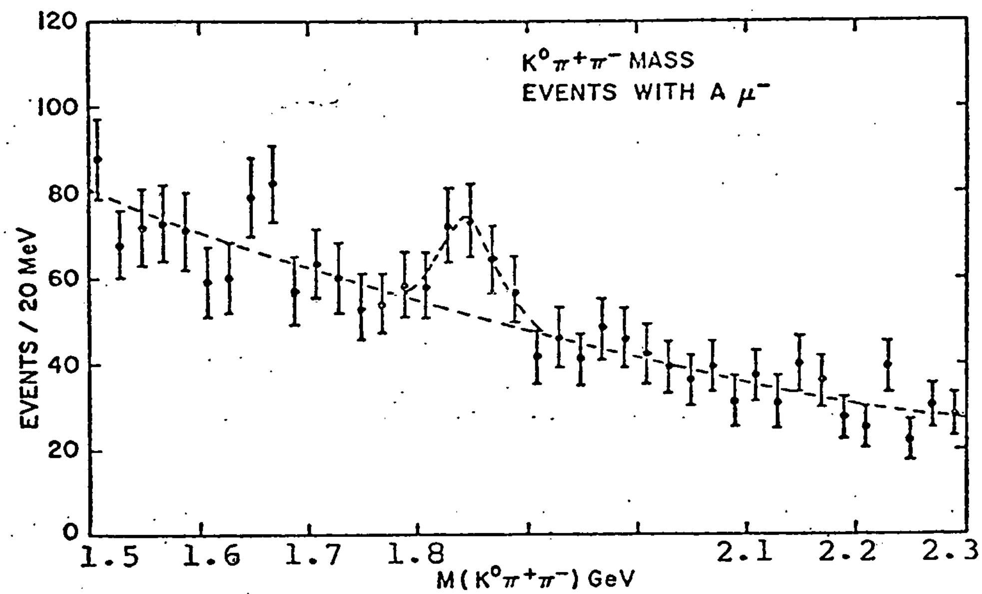

Fig. 3 $K^O\pi^+\pi^-$ mass from charged current events.

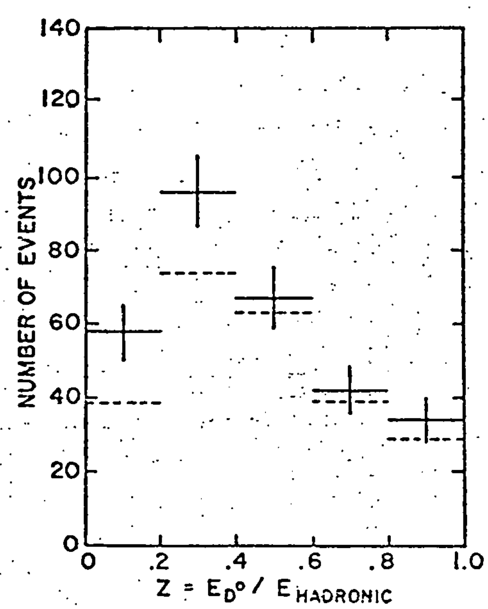

Fig. 4 Distribution of Z of the D^O.