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INTRODUCTION

We present recent results from a study of ν_μ interaction 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. Some previous publications from this experiment are given in Reference 1.

DILEPTON PRODUCTION

We have now analyzed 124,000 pictures, corresponding to about 75,000 charged current neutrino interactions. In this sample, we have found 204 events with a μ^-, and e^+ and anything else. The e^+ is required to have two signatures and a momentum over 300 MeV/c. With these events the background from asymmetric Dalitz 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 punch-through) is determined to be about 10%. After correcting for these backgrounds, scan efficiency (~90%), and e^+ identification efficiency (~85%), we obtain a dilepton rate of

$$R = \frac{\nu_\mu + Ne \rightarrow \mu^- + e^+ + \ldots}{\nu_\mu + Ne \rightarrow \mu^- + \ldots} = (0.5 \pm 0.15)\%. \qquad (1)$$

From the x distribution of these events we find that 37 ± 10% are from interactions with "sea" quarks, and the rest from valence quarks. The GIM model then predicts the total number of strange particles per dilepton event to be 1.37.

We find that in the 204 $\mu^- e^+$ events there are 43 V^o's: 29 K^o's and 14 Λ^o's. The V^o content is thus 0.21 ± .03. After correction for branching ratios this gives a neutral strange particle rate of 0.6 ± 0.1 per event. If we assume the number of charged strange particles is equal to the number of neutrals we obtain a total strange particle content of approximately 1.2, in good agreement with the value 1.37 obtained from the x distribution, the GIM theory and the assumption that all the $\mu^- e^+$ events come from charm production and decay. If the strange particle content of these events were the same as in other charged current events we would have expected 15 ± 4 visible V^o's where 43 were seen, of which 6.6 ± 2.6 visible Λ's would have been expected where 14 were seen. Thus, neither the total V^o content nor the Λ^o content alone can be explained without charm production or charm baryon production, respectively.

OBSERVATION OF $D^o \to K^o\pi^+\pi^-$

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 $K_S \to \pi^+\pi^-$ and 1367 $\Lambda \to p\pi^-$. Correcting for branching ratios and detection efficiencies, this corresponds to a $(K^o + \bar{K}^o)$ rate of $(13.6 \pm 1.5)\%$ of all charged current events, and a $(\Lambda^o + \bar{\Sigma}^o)$ rate of $(5.0 \pm 0.5)\%$.

Figure 1 shows the $K_S\pi^+\pi^-$ mass distribution, indicating a peak in the mass region of the charmed D^o meson seen at SPEAR.(2) 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 charging 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

$$\frac{\nu_\mu + Ne \to \mu^- + D^o + \ldots,\ D^o \to K^o\pi^+\pi^-}{\nu_\mu + Ne \to \mu^- + \ldots} = (0.7 \pm 0.2)\%. \qquad (2)$$

Comparing equation (1) with (2) we obtain

$$\frac{B(D^o \to e^+\nu \text{ etc.})}{B(D^o \to K^o\pi^+\pi^- \ )} \leq 0.84 \pm .38 \quad (3)$$

where the equality is reached if the D^+ production is negligible (we obtain $D^+/D^o = .5 \pm .4$). This may be compared with the result from SLAC/LBL:

$$\frac{B(D^o \to e^+\nu \text{ etc.})}{B(D^o \to K^o\pi^+\pi^-)} = \frac{(7.2 \pm 2.8)\%}{(4.0 \pm 1.3)\%} = 1.8 \pm 0.9 \quad (4)$$

assuming $B(D^o \to e^+\nu \text{ etc.}) = B(D^+ \to e^+\nu \text{ etc})$.

ν_e INTERACTIONS

We have observed 187 events containing an e^- and no μ, and 28 events with an e^+ and no μ. These events are consistent with the expected number of ν_e and $\bar{\nu}_e$ interactions and have the expected y distributions (see Figures 2 and 3). We obtain:

$$\frac{\sigma_T(\nu_e)}{\sigma_T(\nu_\mu)} = 0.87 \pm 0.3 \quad (5)$$

$$\frac{\sigma_T(\bar{\nu}_e)}{\sigma_T(\bar{\nu}_\mu)} = 1.2 \pm 0.4 \quad (6)$$

NEW PARTICLE PRODUCTION

We have not observed long lived particles decaying into $\mu^- e^+$ in 80,000 charged current events.[3] We also observe no evidence for a $\mu^- \pi^+$ enhancement[4] at $\sim$1.8 GeV in the effective mass distributions of 5000 charged current events (including 3000 with V^0's), with or without the cuts used in Reference 4. There is no excess of events with a single e^+ or e^- from which lower limits on the mass of heavy μ type leptons of 7.5 GeV for L^- and 9.0 GeV for L^+, and a limit on a $\mu^- \tau$ mixing of 2.5% are obtained.

$\nu_\mu e$ ELASTIC SCATTERING

We have scanned all our pictures for single unaccompanied e's or γ's and selected those whose directions were within 3^0 of the beam and whose energies were above 2 GeV. We require that they do not point (within 5^0) to another event nor are parallel to and near to a straight through track. e's are distinguished from γ's if there is observable curvature before any radiation is observed (7 events) or by the requirements that (1) the fastest measurable e^- be four times as energetic as the fastest e^+ and (2) the second fastest e^- be at least 1/10 as energetic as the fastest e^+ (4 events).

We find 11 e^-'s, 26 γ's and 4 e^+'s. The e^- events are plotted in Figure 4 against the angle θ and energy E, they all satisfy the requirement

$$E\,\theta^2 \leq 3 \text{ MeV}$$

which, with allowance for errors, all $\nu_\mu e$ elastic events must meet. Of the 26 γ's only 8 meet this requirement. From these we estimate the background of e^- events from misidentified γ's to be .08. The background from ν_e interactions is estimated to be 0.7 ± .7 events.

After correction for these backgrounds, scanning efficiency, the 2 GeV cut, identification efficiency, shower requirements and scanning rules we obtain

$$\frac{\sigma(\nu_\mu e \to \nu_\mu e)}{\sigma_T(\nu_\mu Ne \to \mu^- \text{ etc.})} = (1.36 \pm .54)\ 10^{-4}. \qquad (7)$$

Assuming [5] $\sigma_T(\nu_\mu Ne \to \mu^- \text{ etc.}) = (.67 \pm .06)\ 10^{-38}\ E_\nu\ \text{cm}^2$ per GeV per nucleon we obtain

$$\sigma(\nu_\mu e \to \nu_\mu e) = (1.8 \pm 0.8)\ 10^{-42}\ E_\nu\ \text{cm}^2 \text{ per GeV per electron.}$$

Assuming the Weinberg-Salam model (see Figure 5) this gives:

$$\sin^2\theta_w = 0.20^{+0.16}_{-0.08} \text{ or } 0.57\ ^{+.07}_{-.17}$$

the first of which is in good agreement with the values obtained by other neutrino interactions. The energy distribution of the 11 events is also in agreement with the Weinberg-Salam model expectation (see Figure 6).

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2. G. Goldhaber et al., Phys. Rev. Lett. 37, 255 (1976).

3. D.S. Baranov et al., Phys. Letters 70B, 269 (1977).

4. An enhancement in $\mu^-\pi^+$ in hydrogen and neon exposures was reported by the BEBC group at the Topical Conference on Neutrino Physics at Accelerators, Oxford, England. See Conference Proceedings, Rutherford Laboratory Report, 1978.

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FIGURE CAPTIONS

1. $K^{0}\pi^{+}\pi^{-}$ invariant mass distributions for (a) events with μ^{-} candidates and (b) without μ^{-} candidates.

2. y distribution for ν_e interactions. Broken line is the expectation from τ-meson decay.

3. y distribution for $\bar{\nu}_e$ interactions. Broken line is the expectation from τ-meson decay.

4. Electron angle vs. energy of the eleven observed single e^{-} events compared to the kinematics of the reaction $\nu_\mu e^{-} \rightarrow \nu_\mu e^{-}$.

5. Comparison of the prediction of the Weinberg-Salam model with the measured cross section for $\nu_\mu e^{-} \rightarrow \nu_\mu e^{-}$.

6. The electron energy of the eleven $\nu_\mu e^{-} \rightarrow \nu_\mu e^{-}$ events compared to the prediction of the Weinberg-Salam model with $\sin^2\theta_W = \frac{1}{4}$.

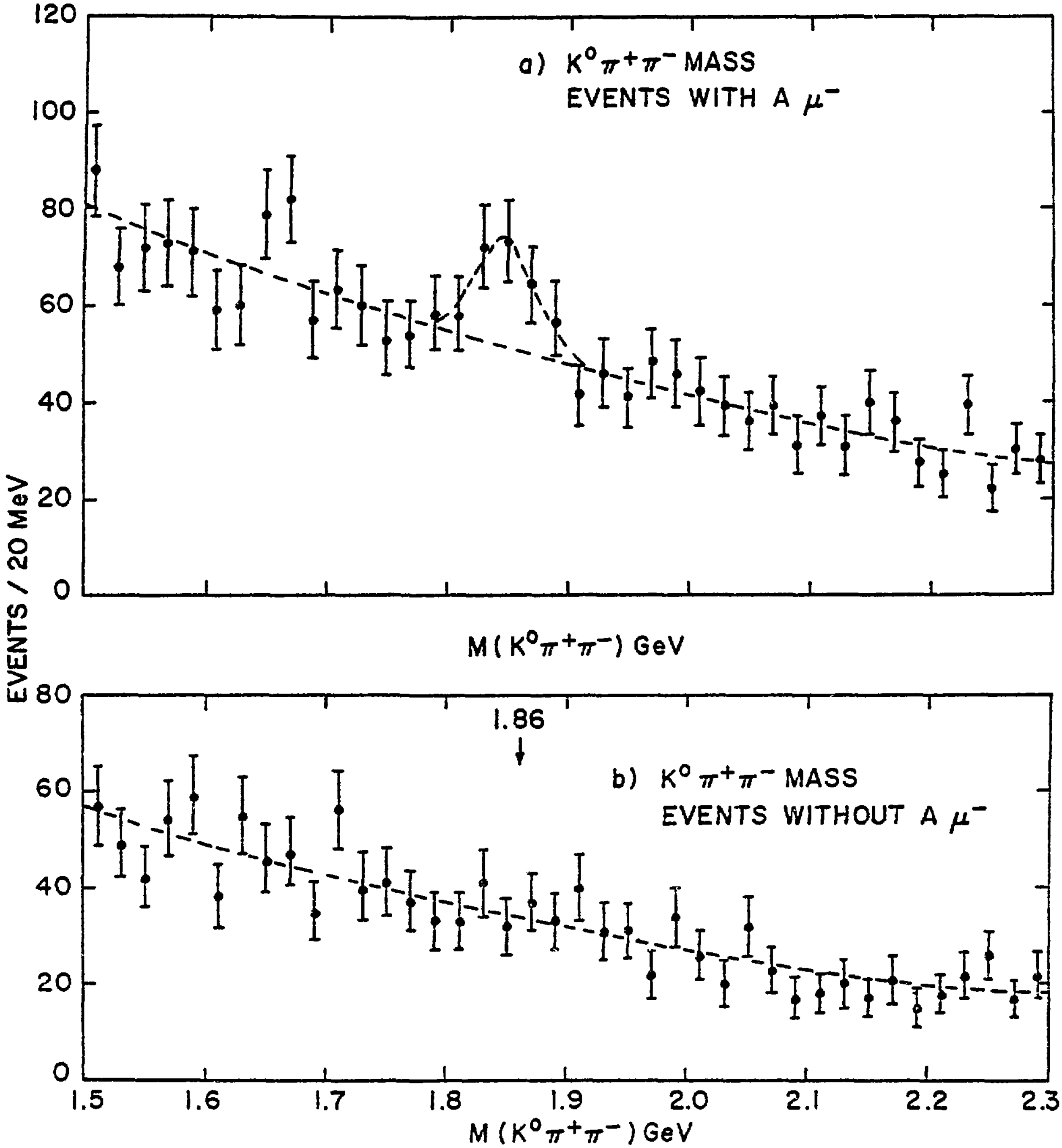
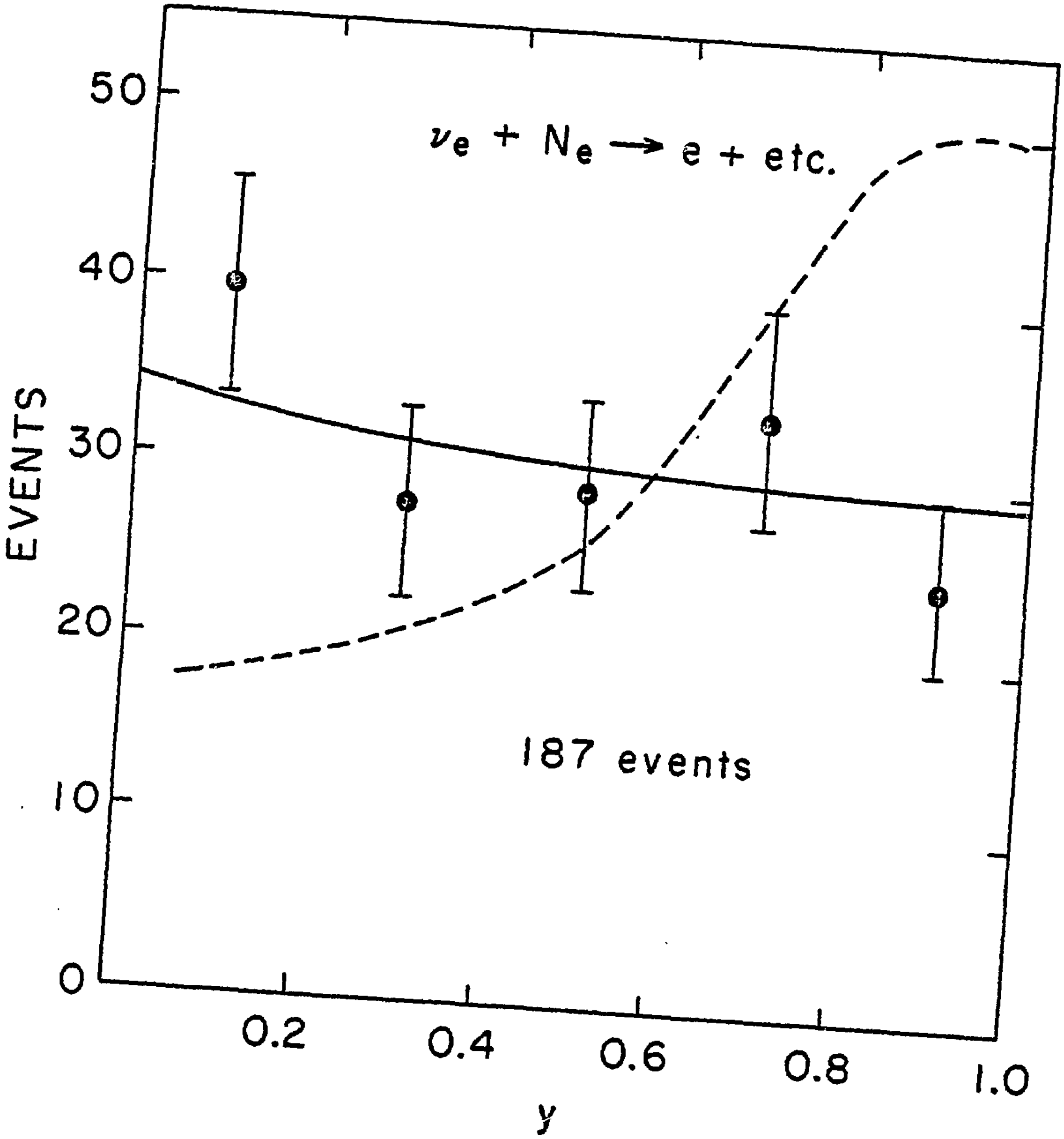

a) $K^0\pi^+\pi^-$ MASS
EVENTS WITH A μ^-
EVENTS / 20 MeV
M ($K^0\pi^+\pi^-$) GeV
1.86
b) $K^0\pi^+\pi^-$ MASS
EVENTS WITHOUT A μ^-
M ($K^0\pi^+\pi^-$) GeV

Figure 1.



50
40
30
20
10
0
EVENTS
$\nu_e + N_e \rightarrow e + etc.$
187 events
0.2
0.4
0.6
0.8
1.0
y

Figure 2.

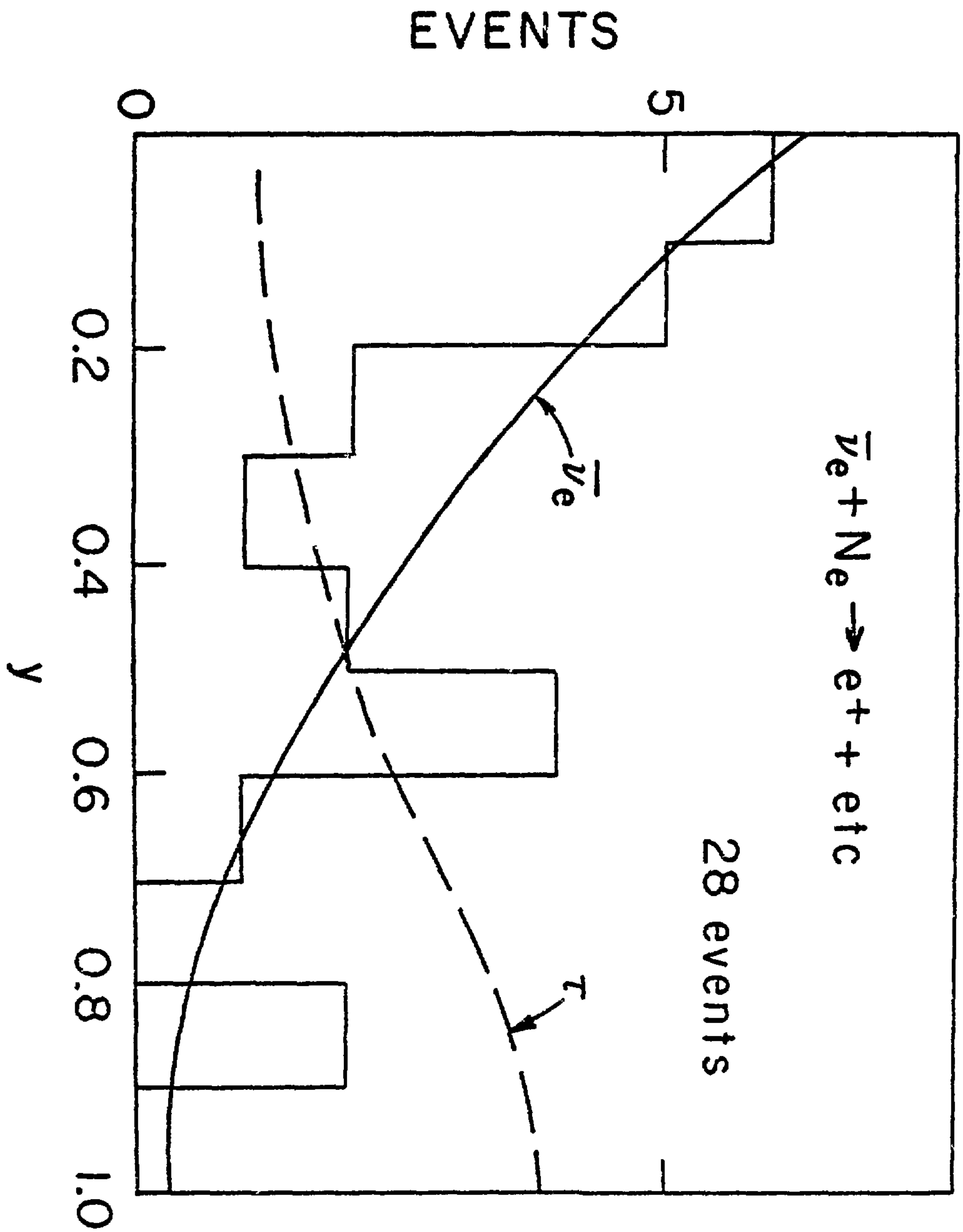
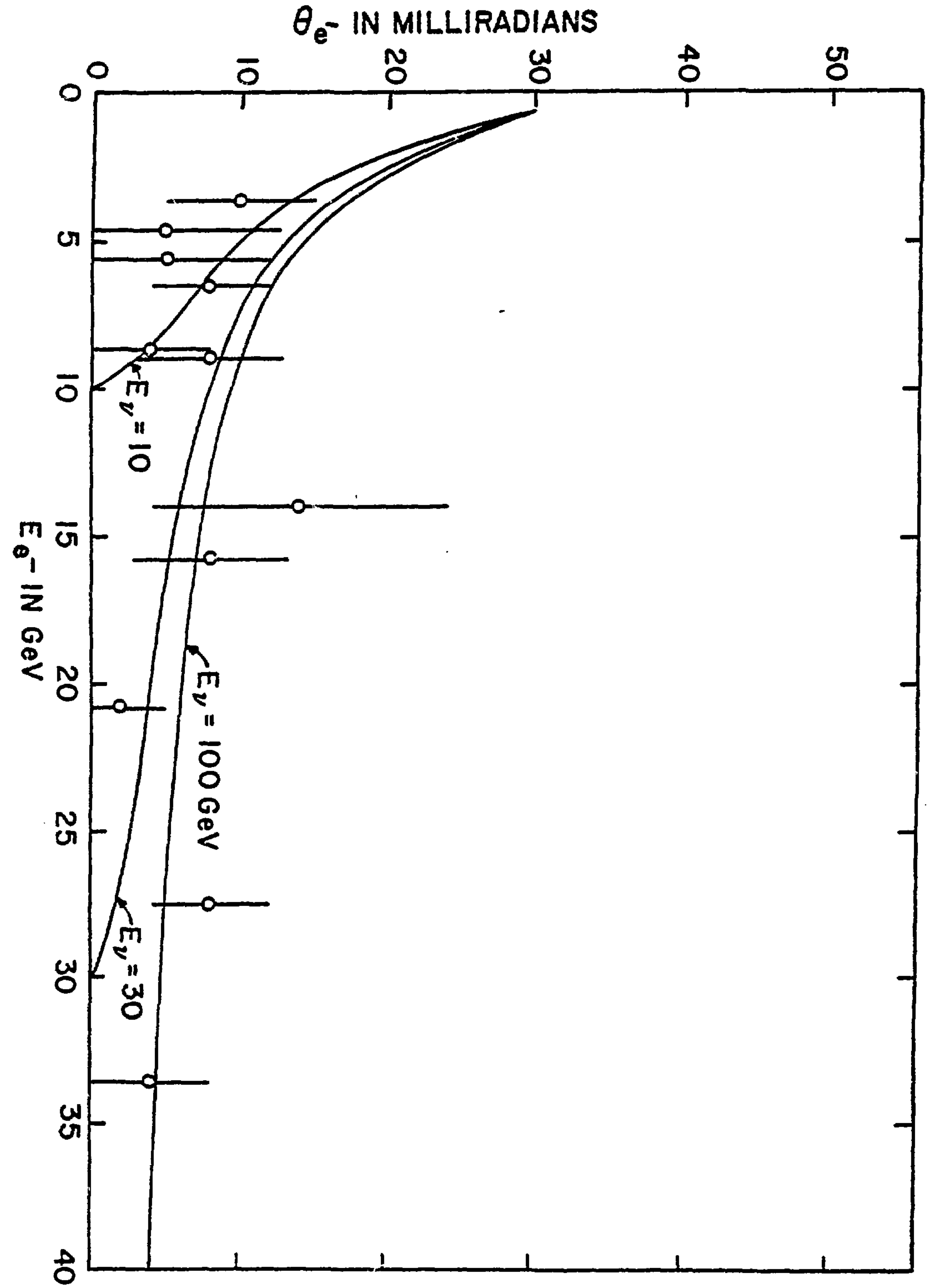

EVENTS
0
5
0.2
0.4
0.6
0.8
1.0
y
$\bar{\nu}_e + N_e \rightarrow e^+ + etc$
28 events
$\bar{\nu}_e$
τ

Figure 3.



θe- IN MILLIRADIANS
0
10
20
30
40
50
0
5
10
15
20
25
30
35
40
Ee- IN GeV
Eν = 10
Eν = 100 GeV
Eν = 30

Figure 4.

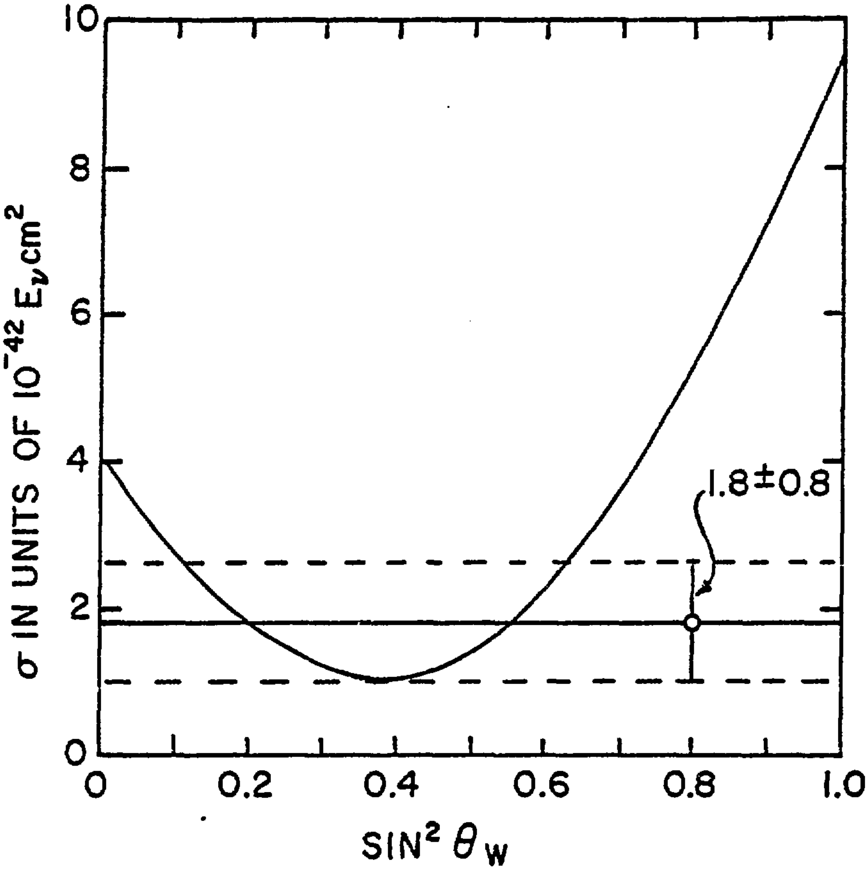


Figure 5.

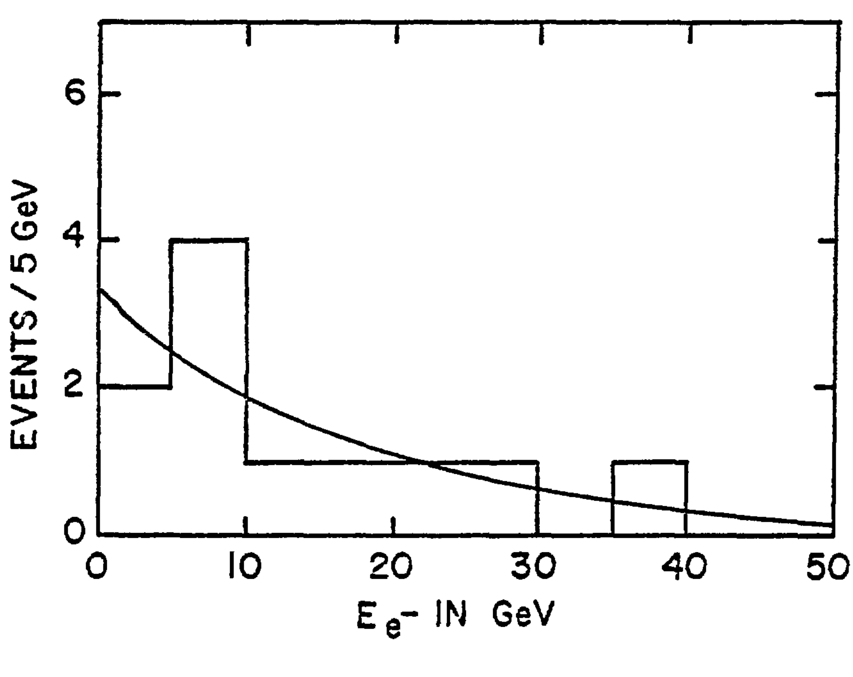


Figure 6.