FERMILAB PROPOSAL No. 320

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PROPOSAL TO MEASURE NEUTRAL CURRENT CROSS-SECTIONS AND ASSOCIATED INELASTIC DISTRIBUTIONS IN THE NARROW-BAND BEAM

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Abstract

We propose to continue the neutral current investigations begun in Experiment 262 with measurements of inelasticity distributions and cross-sections.

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Abstract

We propose to continue the neutral current investigations begun in Experiment 262 with measurements of inelasticity distributions and cross-sections.

Legal Notice

This proposal was prepared as an intention to engage in certain research contingent upon the presence of the stated phenomenon. At this time, neither these experimenters, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, that the phenomenon actually exists.

Introduction

The most common theoretical assumption in the neutral current game provides that the weak and electromagnetic currents form an SU(2) X U(1) group[1]. With the added assumption of hadronic scaling, this gives specific and definite predictions[2] for the differential distributions in terms of the nucleon structure functions. For illustration, we make here the simplifying assumption that such scaling processes are dominated by the "valence" quarks, as preliminary evidence[3] indicates is the case for charged currents. In terms of the scaling parameters (x,y), the charged current cross-sections are given by:

$$\frac{d\sigma^{\nu}(c)}{dy} = \sigma_c Q \qquad \frac{d\sigma^{\bar{\nu}}(c)}{dy} = \sigma_c Q(1-y)^2 \qquad (1)$$

with:

$$Q = \int(u(x) + d(x))dx \qquad \sigma_C = G_C{}^2 s/2\pi$$

and:

G_C = Fermi constant.

For the neutral currents the cross-sections would be:

$$\frac{d\sigma^{\nu}(N)}{dy} = \sigma_N Q\{r+s(1-y)^2\} \qquad \frac{d\sigma^{\nu}(N)}{dy} = \sigma_N Q\{r(1-y)^2+s\} \tag{2}$$

where:

$$r = \tfrac{1}{2} - \sin^2\theta_W + 5/9\ \sin^4\theta_W$$
$$s = 5/9\ \sin^4\theta_W$$

in terms of the Weinberg angle, θ_W. Also,

$$\sigma_N = G_N{}^2 s/2\pi$$

where G_N is an effective neutral current coupling.

The assumption of SU(2) X U(1) for the currents predicts, therefore, that the forms of the differential cross-sections are predictable by a single parameter, θ_W. Further the ratio of the total cross-sections would be specified by the same parameter:

$$\sigma^{\nu}(N) = \sigma_N Q(r+s/3) \qquad \sigma^{\nu}(N) = \sigma_N Q(r/3+s) \tag{3}$$

The Weinberg model[1] makes the further assumption that the relative couplings of the neutral and charged currents are related by the spontaneous breaking of the gauge invariance of the group. That is, in our notation,

$$\sigma_N = \sigma_C.$$

Clearly, then, both the y-distribution and the overall normalization of the neutral current rate are of the greatest experimental import. It should be noted that the y-distributions and total interaction rates are correlated in an important experimental way as well. No experiment measures these cross-sections without some bias on the energy of the final state hadrons. Typically, low energy hadron states (small y) are more difficult to detect and separate from backgrounds. The observed data must be extrapolated to the lower hadron energies where detection efficiency becomes poor. This extrapolation is best done in beams with predominantly high energy neutrinos and with experimentally determined y-distributions.

EXPERIMENTAL APPROACH

The advantages of the narrow band beam for the investigation of neutral currents have been described previously[4]. The most important of these advantages are (1) the predominantly high energy neutrinos, and (2) the well-defined peaks in total neutrino energy. These allow a definitive determination of the existence or non-existence of neutral currents. If the beam consisted only of kaon-type neutrinos, a determination of the y-distribution and total interaction rates would follow trivially from the hadron energy measurement ($y = E_h/E\nu$). This measurement would work, under typical conditions ($E_\nu \simeq 100$ GeV, $E_h \gtrsim 6$ GeV) for $y \gtrsim .06$.

Figure 1 shows a calculated energy spectrum of interacting neutrinos for the narrow band beam tuned to a mean momentum $P_0 = 140$ GeV, and steered at $\theta_s = 0$ mrad relative to the axis of the neutrino target. The existence of the two peaks produces an ambiguity precisely in the region most sensitive to the $(1-y)^2$ term in equations (2); i.e., the region at low y.

Figure 2 shows the effect of steering the hadron beam at a finite angle, θ_S, relative to the axis of the neutrino detector. The relative fraction of kaon induced events rises by a factor of 10 for $\theta_S = 1.75$ mrad relative to $\theta_S = 0$. At the same time, the peak energy of the pion neutrinos is reduced considerably while that of the kaon neutrinos is changed only slightly. These effects are due to the larger transverse momentum available to the neutrino from K-decay.

The small number of low energy neutrinos in the "steered" beam allow the y-distribution to be measured directly over the upper range of y from the kaon neutrinos. At lower observed hadron energies, the small contamination from pion neutrino interactions can be corrected by the known pion flux and the knowledge of the form of the y-distribution at larger y as measured from the kaon neutrinos. The subtraction can be tested directly by applying the same procedure to data taken with $\theta_S = 0$, where the pion neutrinos predominate (see Figure 1).

In short, the technique involves the introduction of an additional parameter, the relative number of kaon and pion neutrinos. In the narrow band beam, we believe that the inelasticity distribution for the kaon neutrinos will be measured down to small y.

REQUIREMENTS

We estimate, based on rates from Experiment 262, that we will need about 3×10^{18} protons to measure the absolute neutral current rate and inelasticity distributions for both neutrinos and anti-neutrinos. We propose that this experiment begin in September, 1974 with a fast-spill run of 10^{18} protons, and the major emphasis on neutrinos. For this run, it is essential that appropriate steering be available for the last beam dipole.

We consider this proposal contingent upon the observation of neutral currents in E262. If the result of that experiment states that neutral currents are not visible (i.e., substantially smaller than the Gargamelle result), this proposal should be considered withdrawn by all parties.

CS/emk

References

1. S. Weinberg, Phys. Rev. D5, 1412 (1971).

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   L.M. Sehgal, Aachen preprint (June, 1973).
   E.A. Paschos and L. Wolfenstein, PR D7 (91) 1973.

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FIGURE 1

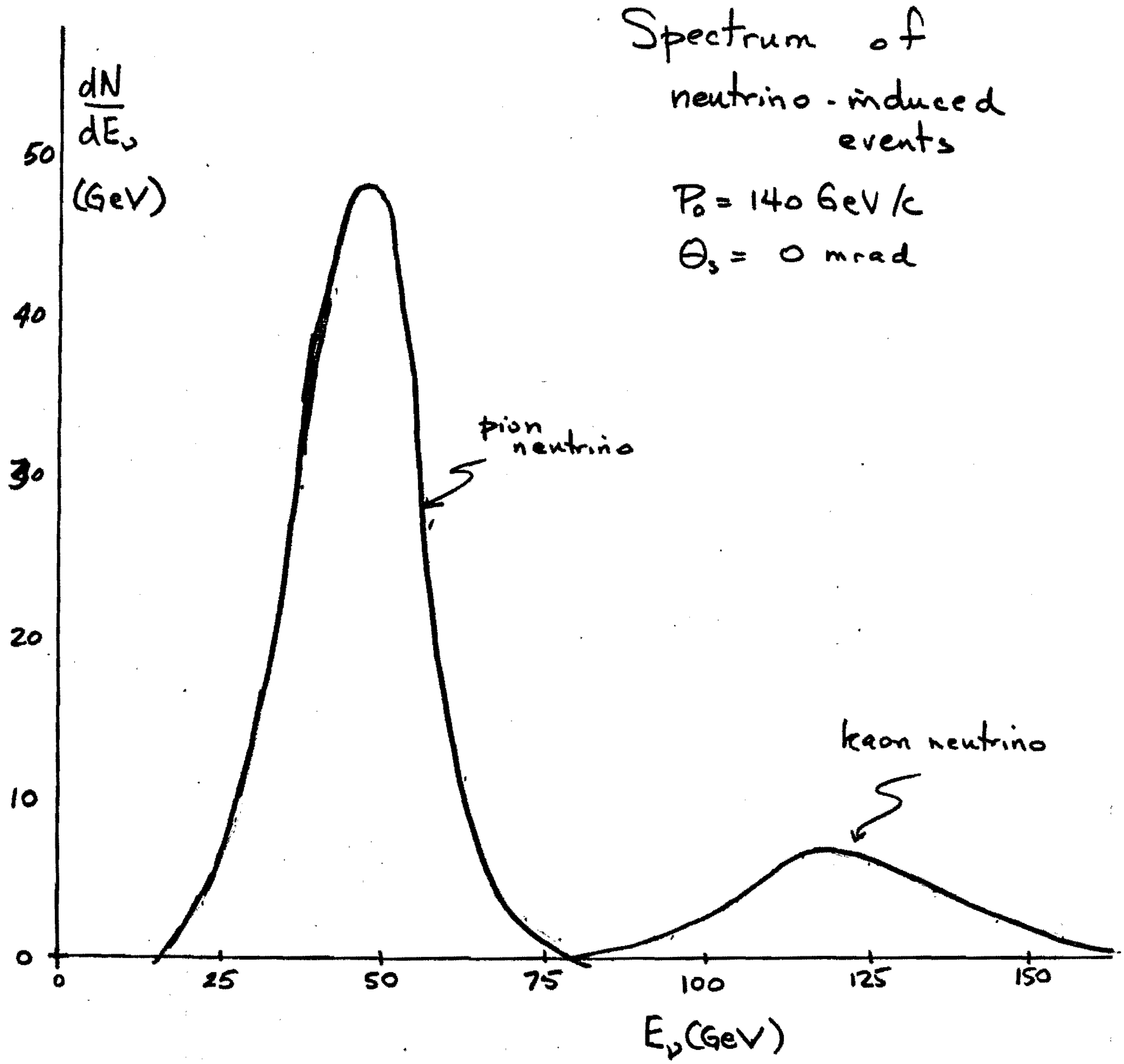

FIGURE 1

FIGURE 2

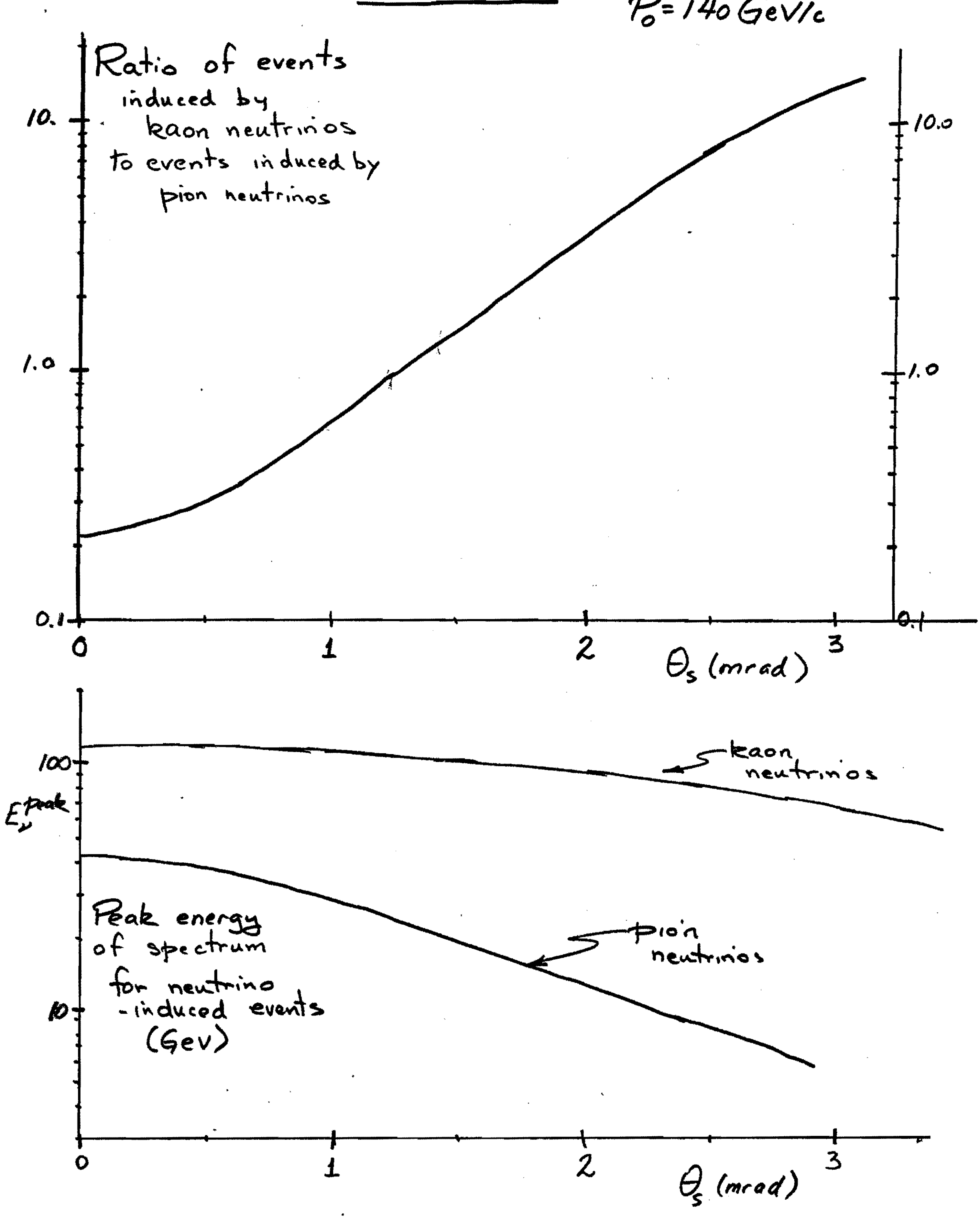

FIGURE 2