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FERMILAB-CONF-78-157-E

RATIO OF CHARGED CURRENT CROSS SECTIONS OF PION AND KAON NEUTRINOS NEAR 80 GeV

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ABSTRACT

The ratio of σ/E for 86 GeV kaon neutrinos relative to σ/E for 68 GeV pion neutrinos has been directly measured to be 1.04 ± 0.14.

Two samples of neutrinos near 80 GeV were directly compared in an experiment[1] performed at Fermilab. The data were taken using the CalTech-Fermilab detector exposed to neutrino beams provided by the old narrow band (dichromatic) train. A momentum selected beam of secondary particles of 250 GeV yields 68 GeV pion neutrinos (and 200 GeV kaon neutrinos) for the first sample. A tune to 80 GeV secondaries yields a beam of 80 GeV kaon neutrinos for the second sample (as well as 30 GeV pion neutrinos). Flux monitoring of the secondary hadrons and muons allows for a direct comparison of the cross sections (σ) of pion and kaon neutrino charged current interactions near 80 GeV.

Since the mean energies ($\bar{E}$) of the two samples were not matched as well as originally intended, we report a measurement of the ratio R of σ/E for kaon and pion neutrinos. Since σ/E is proportional to the number of events (N), and inversely to the energy, acceptance (A) and flux (F), this ratio is

*Operated by Universities Research Association, Inc., under contract with the U.S.Department of Energy.

†Operated by Associated Universities, Inc., under contract with the U.S.Department of Energy.

$$R = \frac{N_K \cdot A_\pi \cdot \bar{E}_\pi \cdot F_\pi}{N_\pi \cdot A_K \cdot \bar{E}_K \cdot F_K} \qquad (1)$$

where π, K refer to pion and kaon neutrinos (ν_π ν_K) respectively.

The number of events $N_\pi(N_K)$ were obtained from the total energy distribution for the muon and hadron triggers below (above) 130 (60) GeV for the momentum setting of the train to 250 (80) GeV respectively. The cuts at 130 (60) GeV were obtained from the cross-over point of the pion and kaon event peaks as determined by a Monte Carlo simulation of the train, the detector, and the physics for the two trigger types. The calculated Monte Carlo spectra compare very well with the observed distributions of events versus neutrino energy. The event numbers observed below (above) the specified cut must be corrected for the tail of the other species of neutrino events (dichromatic beam) falling below (above) the cut and for the "wideband background". The flux is calculated for the momentum selected secondaries in the decay space. Some pion and kaon decays occur on the train before the momentum selection is complete and give rise to this "wideband background". Special data runs with the momentum slit "closed" yield a sample of events (per unit beam on target) which are used to make an empirical subtraction of this background. This subtraction is generally small except for the 80 GeV kaon neutrino sample where it accounts for about 25 percent of the events. The observed raw numbers of events 544 above 60 GeV in the 80 GeV data and 538 below 130 GeV in the 250 GeV runs, thus yield

$$N_{\nu_K} = 388 \pm 33 \text{ and } N_{\nu_\pi} = 515 \pm 25,$$

for the sum of muon and hadron triggers together.

For these conditions the Monte Carlo simulation mentioned above give the corresponding acceptances for the samples of events, corrected for scanning and triggering efficiencies (each about 97 percent)

$$A_{\nu_K} = 0.60 \pm 0.03 \text{ and } A_{\nu_\pi} = 0.80 \pm 0.02.$$

The errors include the statistical uncertanties in the Monte Carlo as well as variations in the modeling of the physics, (such as differing parameterizations of the scaling violations in $F_2[x]$). The larger acceptance for the pion neutrinos is accounted for by the fact that almost all the hadron triggers from ν_π are accepted for the less than 130 GeV cut, whereas only about one-third of them are accepted in the greater than 60 GeV cut case. This is due to an incomplete measurement of the energy of the event for hadron

triggers (the muon is not measured, since it misses the magnet for these events).

The Monte Carlo simulation also gives the average energy of the neutrino flux spectrum. The 80 GeV data were collected in three different settings of the train due to technical difficulties. Averaging over these conditions in the appropriate way gives

$$\bar{E}_{\nu_K} = 86 \pm 2 \text{ GeV and } \bar{E}_{\nu_\pi} = 68 \pm 1.5 \text{ GeV}.$$

The neutrino fluxes were calculated from the measured hadron and muon fluxes and from the measured particle fractions. The particle fractions were measured during special low intensity differential Cherenkov runs prior to the neutrino data taking. The hadron fluxes were measured by summing the integrated signals from two gated ion chambers located in the decay drift space. The muon fluxes were determined from a movable array of eight five-fold coincidence telescopes which counted the muons downstream of the secondary hadron dump. The integrated muon flux was estimated from the profiles of the muon intensity as measured by the scans of the muon distributions in positions (x, y) and angle ($\dot{x}$, $\dot{y}$). The three monitors determine the neutrino fluxes to be the same to ≤7 percent on average. The average fluxes of neutrinos incident on the chosen fiducial volume of the CalTech-Fermilab detector were measured to be

$$F_{\nu_K} = (4.65 \pm 0.4) \times 10^{11} \ \nu_K\text{'s for the 80 GeV data and}$$

$$F_{\nu_\pi} = (6.1 \pm 0.3) \times 10^{11} \ \nu_\pi\text{'s for 250 GeV.}$$

Substituting the four pairs of N_i, A_i, $\bar{E}_i$ and F_i given above into (1), we find[2]

$$R = \frac{\begin{pmatrix}388\\ \pm 33\end{pmatrix}\begin{pmatrix}.80\\ \pm .02\end{pmatrix}\begin{pmatrix}68\\ \pm 1.5\end{pmatrix}\begin{pmatrix}6.1\\ \pm .3\end{pmatrix}\times 10^{11}}{\begin{pmatrix}515\\ \pm 25\end{pmatrix}\begin{pmatrix}.60\\ \pm .03\end{pmatrix}\begin{pmatrix}86\\ \pm 2\end{pmatrix}\begin{pmatrix}4.65\\ \pm .4\end{pmatrix}\times 10^{11}}$$

or

$$R\left(\frac{(\sigma/E)\nu_K}{(\sigma/E)\nu_\pi}\right) = 1.04 \pm 0.14 \qquad (2)$$

If in addition, we supply the effective number of "nucleons" in the detector-target per cm^2 we obtain

$$\left.\frac{\sigma}{E}\right|_{\nu_K} = (0.67 \pm 0.09) \times 10^{-38} \ cm^2/GeV \qquad (3)$$

at 86 GeV. This value compares favorably with σ/E data from the recently published CITFR[3] and BEBC[4] experiments, which are consistent with an average value of 0.61×10^{-38} cm^2/GeV.

ACKNOWLEDGEMENTS

Many thanks go to all those who were helpful and instrumental in the execution of the experiment, especially our CITFR colleagues, the Neutrino Laboratory, Fermilab, and our home institutions.

REFERENCES

[1] Fermilab experiment E-254.

[2] The value of 1.08 ± 0.15 reported verbally was based on a determination of the neutrino fluxes only from the two ion chambers, ala CITFR (see Ref. 3).

[3] B.C.Barish et al, Phys. Rev. Letts, 39, 1595 (1977).

[4] P.C.Bosetti et al, Phys. Letts, 70B, 273 (1977).