linearity is good to 1 part in 2000. This is the calibration which was used in the investigation on B^{12} and N^{12}, and we found that the end point of B^{12} is in agreement with the value from the reaction data[14] within the experimental uncertainty of 0.3% of the end point of the Kurie plot.

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REMARKS CONCERNING THE RECENT HIGH-ENERGY NEUTRINO EXPERIMENT*

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A recent experiment by Danby *et al.*[1] showed that if the reactions

$$\nu_e + n \to p + e^- \tag{1}$$

and

$$\bar{\nu}_e + p \to n + e^+ \tag{2}$$

have cross sections comparable to those of

$$\nu_\mu + n \to p + \mu^- \tag{3}$$

and

$$\bar{\nu}_\mu + p \to n + \mu^+ \tag{4}$$

at the observed momentum range, then ν_e is, most likely, different from ν_μ. Nevertheless, it could be argued that the form factors for the heavy-particle currents in the $e^\pm$-producing reactions might be very different from that in the $\mu^\pm$-producing reactions at momentum transfers greater than, say 200 MeV. If this were the case, the observed absence of Reactions (1) and (2) would not imply the existence of two neutrinos unless an absolute theoretical lower limit could be established for the rates of the $e^\pm$-producing reactions without a relative comparison with that of the $\mu^\pm$-producing reactions. The purpose of our first remark is to point out that such a limit can indeed be set, provided one assumes the conserved vector-current hypothesis proposed by Feynman and Gell-Mann[2] to be correct for Reactions (1) and (2). Recently, striking confirmation of this hypothesis has been obtained by Wu, Lee, and Mo for the case of β decays of N^{12} and B^{12}.[3]

Let $d\sigma(1)$ and $d\sigma(2)$ be, respectively, the differential cross sections for Reaction (1) and Reaction (2); let $d\sigma$ be their arithmetic mean:

$$d\sigma = \tfrac{1}{2}[d\sigma(1) + d\sigma(2)]. \tag{5}$$

In terms of the form factors[4] g_V, f_V, and g_A, the cross section $d\sigma$ can be written as a sum of two positive terms

$$d\sigma = d\sigma_V + d\sigma_A, \tag{6}$$

where ($\hbar = c = 1$),

$$d\sigma_V = (4\pi)^{-1}(dq^2)\{[(2m_n k_\nu)^{-1}q^2]^2 g_V{}^2 + [2 - (2m_n k_\nu{}^2)^{-1}(m_n + 2k_\nu)q^2][(2m_n f_V - g_V)^2 + q^2 f_V{}^2]\}, \tag{7}$$

$$d\sigma_A = (4\pi)^{-1}(dq^2)g_A^2\{(2k_\nu^2)^{-1}q^2+1$$
$$+[1-(2m_nk_\nu)^{-1}q^2]^2\}. \quad (8)$$

q^2 is the square of the 4-momentum transfer, k_ν is the energy of the neutrino (or antineutrino) in the laboratory system, and m_n is the mass of the nucleon. It is important to notice that there is no interference term between the vector form factors and the axial-vector form factors in the expression for $d\sigma$. Therefore, we obtain the inequality

$$d\sigma \geq d\sigma_V. \quad (9)$$

Assuming that the conserved vector-current hypothesis is correct for β decay, the form factors g_V and f_V for Reactions (1) and (2) can be obtained from the known isotopic vector parts of the charge and magnetic form factors F_Q and F_M of the nucleon.[5] We have (in the absence of an intermediate boson)

$$g_V = G_V[F_Q + (\mu_p - \mu_n)F_M]$$

and

$$f_V = G_V(2m_n)^{-1}(\mu_p - \mu_n)F_M, \quad (10)$$

where G_V is the Fermi coupling constant ($G_V \cong 10^{-5}m_n^{-2}$), and $\mu_p \cong 1.79$ and $\mu_n \cong -1.90$ are, respectively, the anomalous magnetic moment of p and that of n in units of the nuclear Bohr magneton. In Fig. 1, σ_V is plotted by using

$$F_Q = F_M = (1+\tfrac{1}{12}q^2a^2)^{-2}, \quad (11)$$

where $a = 0.8\times10^{-13}$ cm, and $\sigma_V = \int d\sigma_V$.

In the experiment by Danby et al., there are about equal numbers of neutrinos and antineutrinos. By using this lower limit of the cross section and the known flux, we conclude that if $\nu_e = \nu_\mu$, then a total number N_e of $e^\pm$ should be observed during the experiment by Danby et al., where

$$N_e > 12. \quad (12)$$

This number is subject to an error of ±30% due to poor knowledge of the flux. At any rate, this is in disagreement with the experimental result. This lower limit is independent of any symmetry assumption between $e^\pm$ and $\mu^\pm$.

Our second remark concerns the consequences of the possible existence of an intermediate boson, $W^\pm$. If Reactions (1)-(4) are actually second-order processes mediated by the exchange of such a boson of mass m_W, then (10) should be changed

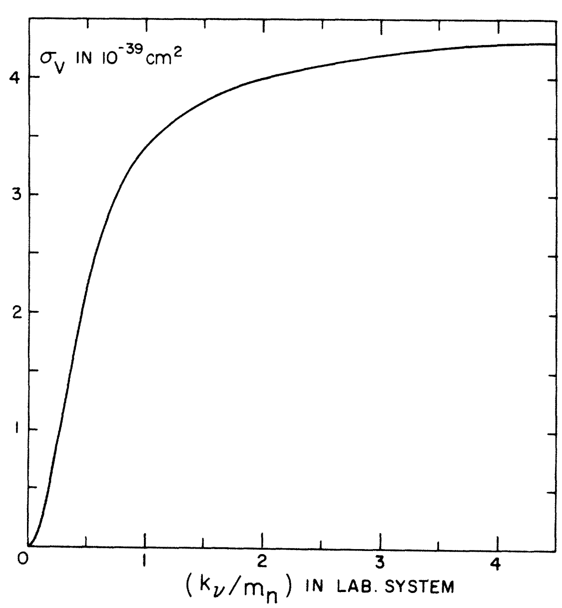

FIG. 1. A lower limit of $\frac{1}{2}[\sigma(\nu_e+n\to p+e^-)+\sigma(\bar{\nu}_e+p\to n+e^+)]$.

Table I. Number of $\mu^\pm$ that should be expected in the experiment by Danby et al. for various values of m_W and b. The actual observed number of events = 29. Note that these numbers are only valid to ±30% in the actual experiment because of lack of knowledge of the neutrino flux. They are listed to the above accuracy only to indicate the sensitivity of this method of determining b.

m_W	b (10^{-13} cm)	Expected number of events
500	0	20.0
500	0.1	19.8
500	0.2	19.1
500	0.4	17.4
500	0.8	13.9
500	1.6	9.1
750	0	31.0
750	0.1	30.6
750	0.2	29.2
750	0.4	25.4
750	0.8	19.1
750	1.6	12.9
1250	0	45.2
1250	0.1	44.5
1250	0.2	42.0
1250	0.4	35.1
1250	0.8	24.7
1250	1.6	16.7

into

$$g_V = G_V[F_Q + (\mu_p - \mu_n)F_M][1 + m_W^{-2}q^2]^{-1}$$

and

$$f_V = G_V(2m_n)^{-1}(\mu_p - \mu_n)F_M[1 + m_W^{-2}q^2]^{-1}. \quad (13)$$

In such a case, the heavy-particle current that interacts with $W^{\pm}$ must be responsible for both Reactions (1) and (2), and Reactions (3) and (4). Therefore, if $\nu_e = \nu_\mu$, and if $W^{\pm}$ exists, the total number N_μ of $\mu^{\pm}$ produced must be the same as N_e (neglecting the mass difference between e and μ). This does not agree with the observed result.

Furthermore, information concerning g_A can now be obtained by using (6), (11), and (13). As an ad hoc assumption, we may take g_A to be of the form

$$g_A = -G_A[1 + \tfrac{1}{12}q^2b^2]^{-2}[1 + m_W^{-2}q^2]^{-1}, \quad (14)$$

where $G_A \cong -1.25\,G_V$. Then, for example, we may calculate how many events would have been expected in the Brookhaven experiment for various choices of m_W and b. The results of this calculation are shown in Table I. The results are not to be taken as any more than an indication of the sensitivity of the procedure, inasmuch as the neutrino flux in the experiment is not known to better than 30%.

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STRUCTURE IN THE PION-PROTON TOTAL CROSS SECTION BETWEEN 2 AND 3 BeV†

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The total cross sections for $\pi^{\pm}$ on protons in the energy range from 1.5 to 6 BeV have been measured in a transmission experiment at the AGS. Many measurements have been made in the past at pion kinetic energies below 1.5 BeV,[1-3] and recently data in the energy range 5-20 BeV have become available.[4,5] However, in the intermediate range, the total cross section has been determined only at widely spaced points,[3,6,7] particularly in the case of $\pi^- - p$. It is the purpose of this Letter to report new data in this range, taken in smaller energy steps and with a statistical accuracy of about 1%. These results indicate two statistically significant and previously unreported pion-nucleon resonances, one in each of the two isotopic spin states.

The secondary beam was taken at an angle of -15° to the internal proton beam of the AGS. The particles, after collimation and magnetic analysis, were defined by 2-in. diameter scintillation counters S_1 and S_2. The pions were identified by means of a differential gas Cherenkov counter[8] taken in coincidence with S_1 and S_2 to form a pion telescope. Any pions interacting in the walls or gas of the Cherenkov counter were swept away by a second bending magnet. The flux in the telescope varied from 2×10^3 per pulse at the lowest momenta to 3×10^2 per pulse at 6 BeV, for an internal circulating beam of 3×10^{11} protons per pulse. The accepted beam, whose absolute momentum was known to $\pm 1\frac{1}{2}$% and had a spread of $4\frac{1}{2}$% full width at half-height, was then incident upon a 48-in. long liquid hydrogen target, 6 in. in diameter, and with 0.007-in. Mylar walls. The pions which passed through the target were detected in four scintillation counters S_{3-6}, the outputs from which were separately placed in coincidence with the telescope and scaled.