ment is contradictory to the conjecture that f^0 may belong to the Pomeranchuk-Regge trajectory, since the Pomeranchuk trajectory necessarily is the unitary singlet [8]. If we take f^0 as the $T = Y = 0$ member of the octuplet, we do not find an enhancement in any V_8P_8 system, since the $T = Y = 0$ member of the 8_A representation of V_8P_8 is composed of only $K^*\bar{K}$ and $\bar{K}^*K$.

Applying the Gell-Mann Okubo formula, we find that the last member ($\tilde{K}$) with $T = \frac{1}{2}$ and $|Y| = 1$ should be situated around 1270 MeV. No evidence has been reported for it yet. The branching ratio of this not yet discovered meson is simply calculated to be $\Gamma(\tilde{K} \to K\eta)/\Gamma(\tilde{K} \to K\pi) = 0.016$. Since

$$\Gamma(\tilde{K} \to K\pi)/\Gamma(R \to \pi\eta) = 2.2, \qquad (6)$$

we can expect an appreciable amount of enhancement in the $K\pi$ effective mass plot around 1270 MeV, as well as in the $K^*\pi$ and ρK plots.

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TRANSVERSE MUON POLARIZATION IN NEUTRINO INDUCED INTERACTIONS AS A TEST FOR TIME REVERSAL VIOLATION

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The experiments of Christenson et al. [1] interpreted as a violation of CP invariance have opened the question as to whether there may be indeed other weak interaction processes which violate CP invariance. If the CPT theorem [2] is assumed then a violation of CP invariance implies the corresponding violation of time reversal invariance. Experiments [3] studying the β decay of polarized neutrons already performed indicate that only a small violation of time-reversal invariance is permitted in the allowed β transitions. However, should there be time-reversal violations in terms which vanish for small momentum transfers then there exists no $\Delta S = 0$ experiments which explicitly test for possible violations.

In this note we investigate processes of the type (for definiteness we restrict ourselves to incident neutrinos).

$$\nu + \text{nucleus} \to \mu^- + \text{all final states} \qquad (1)$$

and the elastic process

$$\nu + n \to \mu^- + p \qquad (2)$$

which are especially well suited for the study of weak interactions at appreciable momentum transfers. In particular we examine the possibility of studying the produced muon transverse (i.e., perpendicular to the plane containing neutrino and muon momenta) polarization as a means of detecting a possible violation of time-reversal invariance.

We first show that if time reversal is a valid symmetry operation, that the transverse muon polarization vanishes for an arbitrary neutrino induced nuclear process like (1), provided one averages over all strongly interacting particles in the final state and uses an unpolarized target. Thus, a non-zero value for the transverse muon polarization indicates violation of time reversal invariance.

Subsequently an estimate of what the numerical value of such a transverse polarization might be, is given by following the suggestion of Cabibbo [4] who speculates that the time-reversal violation is due to a 90° phase between first and second class currents [5].

Consider now reactions (1), described by an S matrix which to lowest order in weak interactions, all orders in strong interactions and neglecting electromagnetism, is of the form

$$S = 1 + \mathrm{i} j_\alpha O_\alpha + \mathrm{i} j_\alpha^\dagger O_\alpha'^\dagger + \mathrm{i}\, T\,. \qquad (3)$$

Of course, $j_\alpha O_\alpha$ and T have non-zero matrix elements only between states of equal energy momentum. j_α is the usual lepton current $j_\alpha = \overline{\psi_\mu}\gamma^\alpha(1+\gamma^5)\psi_\nu$. The operator O_α carries the initial nucleus to the system of final strongly interacting particles and includes all possible interactions among the final strongly interacting particles. O_α' analogously for antineutrino processes. The operator $1+\mathrm{i}T$ is the S matrix for strongly interacting particles in the absence of weak interactions. Thus T is zero between states where one state has leptons different from those present in the other states. The reverse holds for $j_\alpha O_\alpha$ and $j_\alpha^\dagger O_\alpha'^\dagger$.

The cross section for process (1) where only the outgoing muon is observed is proportional to

$$|M|^2 = \sum_{I,F} \langle\mu|j_\alpha|\nu\rangle\langle\nu|j_\beta^\dagger|\mu\rangle\langle F|O_\alpha|I\rangle\langle I|O_\beta^\dagger|F\rangle$$

$$\equiv L_{\alpha\beta}N_{\alpha\beta}\,. \qquad (4)$$

Averaging over initial and summing over final states is indicated. $L_{\alpha\beta}$ refers only to leptons and $N_{\alpha\beta}$ to the system of strongly interacting particles. The quantity $L_{\alpha\beta}$ is given by [6]

$$L_{\alpha\beta} = q_\alpha q_\beta' + q_\alpha' q_\beta - \delta_{\alpha\beta}(qq') + \epsilon_{\chi\alpha\kappa\beta}q_\lambda' q_\kappa \qquad (5)$$

$$- m\{q_\alpha w_\beta + w_\alpha q_\beta - \delta_{\alpha\beta}(qw) + \epsilon_{\lambda\alpha\kappa\beta}w_\lambda q_\kappa\}$$

q, q' are neutrino and muon four momenta respectively, m is the muon mass and w is a unit spacelike vector along the direction of the muon polarization. As a consequence of Lorentz invariance and hermiticity the most general form for the tensor $N_{\alpha\beta}$ is

$$N_{\alpha\beta} = \sum_{I,F} \langle I|O_\beta^\dagger|F\rangle\langle F|O_\alpha|I\rangle$$

$$= A_1\delta_{\alpha\beta} + A_2 p_\alpha p_\beta + A_3 Q_\alpha Q_\beta + A_4(p_\alpha Q_\beta + Q_\alpha p_\beta)$$

$$+ A_5\epsilon_{\alpha\beta\sigma\tau}p_\sigma Q_\tau + \mathrm{i}A_6(p_\alpha Q_\beta - Q_\alpha p_\beta) \quad (6)$$

p is the four momentum of the initial nucleus, $Q = q' - q$ is the four momentum transfer. The six real scalar quantities $A_{1\ldots6}$ are functions of the only possible invariants Q^2, p^2 and (pQ).

Unitarity of the S matrix as well as time-reversal invariance has been shown [7] to give

$$\langle F,\mu|S|I,\nu\rangle = \langle I',\nu'|S|F',\mu'\rangle \qquad (7)$$

where I',ν' and F',μ' are the time reversal initial and final states respectively, for instance, F' is F with all three moments and spins reversed, and outgoing states changed into ingoing states. Thus instead of (4) we have the time reversed cross section proportional to

$$|M'|^2 = \sum_{I',F'} \langle\nu'|j_\beta^\dagger|\mu'\rangle\langle\mu'|j_\alpha|\nu'\rangle$$

$$\times\langle I'|O_\beta'^\dagger|F'\rangle\langle F'|O_\alpha'|I'\rangle$$

which should equal $|M|^2$ if time reversal invariance holds. The time reversed form $L'_{\alpha\beta}$ of $L_{\alpha\beta}$ may be obtained from the explicitly given form (5) by the rule $\mu \to \mu'$, $\nu \to \nu'$. On the other hand the expression for $N_{\alpha\beta}$ (6) is more complicated since O_α' is not equal to O_α.

We now note that the unitarity condition $S^\dagger S = 1$ leads in lowest order in weak interactions to

$$O_\alpha = O_\alpha' + \mathrm{i}\,T^\dagger O_\alpha + \mathrm{i}\,O_\alpha' T \qquad (8)$$

and, independently

$$\mathrm{i}(T - T^\dagger) = -T^\dagger T \qquad (9)$$

Furthermore, since the initial nucleus is stable against strong interactions we have

$$T|I'\rangle = T|I\rangle = 0 \qquad (10)$$

Using (8) and (10) we have

$$\sum_{F'}\langle I'|O_\beta'^\dagger|F'\rangle\langle F'|O_\alpha'|I'\rangle$$

$$= \sum_{F'}\langle I'|O_\beta^\dagger(1+\mathrm{i}T)|F'\rangle\langle F'|(1-\mathrm{i}T^\dagger)O_\alpha|I'\rangle \qquad (11)$$

Inserting a complete set of states between $O_\beta^\dagger$ and $(1+\mathrm{i}T)$ as well as between $(1-\mathrm{i}T)$ and O_α yields with the help of (9) the desired result

$$\sum_{F'}\langle I'|O_\beta'^\dagger|F'\rangle\langle F'|O_\alpha'|I'\rangle$$

$$= \sum_F\langle I'|O_\beta^\dagger|F\rangle\langle F|O_\alpha|I'\rangle$$

Table 1

E_ν in MeV, θ in degrees, average polarization in %. θ is the angle between muon and neutrino momentum in the lab. system. E_ν = neutrino-energy in the lab. system.

θ \ E_ν	B = 3.71					B = 6				
	500	750	1000	1500	2000	500	750	1000	1500	2000
0	0	0	0	0	0	0	0	0	0	0
10	- 1.3	- 0.8	- 0.1	1.4	3	- 2	- 1.2	- 0.2	2	4
20	- 0.3	2.4	5.2	10	14	- 0.5	3.5	7.1	13	16
30	3	8.2	13	19	23	4.4	11	16.5	23	27
40	7	14	19	26	30	10	19	25	32	35
50	11	18	23	30	33	16	25	31	37	41
60	14	21	26	31	34	20	29	35	41	44
70	16	22	26	31	34	23	32	37	42	45
80	16.5	22	26	30	32	24	32	37	42	45
90	16.5	21	25	28	30	25	32	36	40	43
100	16	20	23	25	27	24	30	34	37.5	40
110	14.5	18	20	22	24	22	28	31	34	36
120	13	16	17.5	19	20	20	25	27	30	31
130	11	13.5	15	16	17	17	21	23	25	26.5
140	9	11	12	13	13.5	14	17	19	20.5	21.5
150	7	8.2	9	10	10	11	13	14	15.5	16
160	4.5	5.5	6	6.5	7	7.4	9	9.5	10.5	11
170	2.3	2.7	3	3.2	3.4	3.7	4.5	5	5	5.5

we see that in $N'_{\alpha\beta}$ we have the same operator taken between the state $|I'\rangle$ whereas for $N_{\alpha\beta}$ with respect to $|I\rangle$. Therefore, $N'_{\alpha\beta}$ is derived from $N_{\alpha\beta}$ with three momenta reversed, thus $A'_i = A_i$.

Applying the result to the term

$$i\epsilon_{\lambda\alpha\kappa\beta}w_\lambda q_\kappa(p_\kappa Q_\beta - Q_\alpha p_\beta) = 2M_I(w\cdot q\times q')_{\text{lab}}$$

M_I being the mass of the initial state, yields immediately that this term goes to the negative of itself under the rule $\nu \to \nu', \mu \to \mu', I \to I'$ (i.e., $q \to -q$, $q' \to -q', w \to -w$) and hence must vanish if time reversal holds. All other terms are invariant under the transformation and do not occasion any perpendicular polarization of the muon.

If time reversal invariance is violated then A_6 may be non-vanishing and would give rise to a transverse polarization $P_\perp$ of amount

$$P_\perp = 2mM_I(q\times q')A_6/|M|^2 \quad .$$

The transverse polarization can be determined by the up-down asymmetry of the decay electron with respect to the q, q' plane.

In order to give some estimate of the possible order of magnitude of such a transverse polarization we follow the suggestion of Cabibbo [4] that the second class currents could be 90° out of phase with the first class currents and thus constitute an explicit example of time reversal violation. Consider the elastic process (2). Taking for the first class current the usual one [8] we have for the matrix element of the heavy current (ref. 9)

$$J_\alpha = F(Q^2)(\bar{u}_p\{\gamma^\alpha - \frac{\mu}{2M}\sigma_{\alpha\lambda}Q_\lambda + A\frac{Q_\alpha}{m} + \lambda\gamma^\alpha\gamma^5 + \frac{iB}{2M}\sigma_{\alpha\lambda}\gamma^5 Q_\lambda + i\frac{l}{m}Q_\alpha\gamma^5\}u_n)$$

The terms with A and B constitute the second class current. Squaring this we obtain for the coefficients $A_1 - A_6$ as in (6):

$$A_1 = 4\lambda^2(pQ + 2M^2) + 2Q^2(1+\mu)^2$$

$$A_2 = 8(1+\lambda^2) + 2(B^2+\mu^2)Q^2M^{-2}$$

$$A_3 = 4A^2(pQ + 2M^2)m^{-2} + (B^2+\mu^2)(pQ)M^{-2} - 4\mu - 2\mu^2 - 8\lambda bMm^{-1} + 4b^2(pQ)m^{-2}$$

$$A_4 = -4(1+\lambda^2) - 2(B^2+\mu^2)(pQ)M^{-2}$$

$$A_5 = -8\lambda(1+\mu)$$

$$A_6 = -2(Bb - A\mu)Q^2M^{-1}m^{-1} + 8AMm^{-1} - 4B\lambda$$

where M is the nucleon mass.

From μ capture we may obtain an upper limit [10] for the scalar coefficient A. The result is that A must be smaller than 0.2, thus giving rise to negligible effects. The transverse polarization for two choices for B and several neutrino energies and muon neutrino angles in the lab. system are given in the table. We see that for a large domain of energy and angle the polarization can be considerable.

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CROSS SECTION FOR THE CHARGE EXCHANGE REACTION $\pi^+ + n \rightarrow p + \pi^0$ AT 6 GeV/c PION MOMENTUM

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Recently [1] we published a study of two-prong stars from interactions of 6 GeV/c π^+ mesons in deuterium. The analysis was based on 388 events of the type $\pi^+ + d \rightarrow p + p +$ neutrals, observed in the 81-cm Saclay bubble chamber at the CERN proton synchrotron. Protons were identified by ionisation up to a momentum of 1.3 GeV/c.

The frequency distribution of the events as function of the square of the missing (neutral) masses displays two clear accumulations, certainly not due to phase space (fig. 1, see also ref. 1). One is at the very beginning of the spectrum, the second one is centered at about 1.55 GeV^2. The latter has been discussed in detail in ref. 1 and was interpreted as mainly due to f^0 production with the f^0 decaying into neutral pions. In the present letter we want to comment on the first peak and derive from it an estimate for the cross section of the charge exchange process

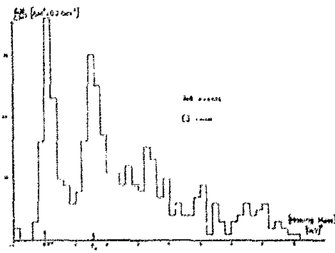

Fig. 1. Frequency distribution of missing masses for the two prong events.

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