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# THE ρ EXCHANGE ISOVECTOR PARITY VIOLATING POTENTIAL

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It is shown that the ρ exchange isovector parity violating potential is constrained by PCAC to be much weaker than the π exchange potential, and much weaker than recently proposed by Galić, Gubernia, Picek and Tadić. This potential does not therefore provide a mechanism for suppressing enhanced neutral current effects in the π exchange potential.

Recently Galić, Gubernia, Picek and Tadić (1978) have revived the concept of a $\rho$ exchange isovector parity violating potential between nucleons of the form

$$V_\rho^{(1)} = \lambda \frac{G\, m_p^2}{8\pi\sqrt{2}\, m_N} (\underset{\sim}{\sigma}_1 + \underset{\sim}{\sigma}_2) \cdot \left[\underset{\sim}{p}_{12}, \frac{e^{-m_\rho r}}{r}\right] T_{12}^{(-)} \qquad (1)$$

with

$$T_{12}^{(-)} = \tau_1^{(+)}\tau_2^{(-)} - \tau_1^{(-)}\tau_2^{(+)}. \qquad (2)$$

In the Weinberg Salam model of the weak interaction, Galić et al obtain

$$\lambda = \frac{1}{2} \frac{m_n^2 - m_p^2}{m_d^2 - m_u^2} g_A \alpha \qquad (3)$$

where

$$\alpha = \frac{1}{3\sqrt{2}} [\sin^2\theta_c (C_6' + \frac{16}{3} C_5') + (1 - 2\sin^2\theta_W)(C_6'' + \frac{16}{3} C_5'')$$
$$- \frac{2}{3} \sin^2\theta_W (C_6 + \frac{16}{3} C_5)] \qquad (4)$$

The parameters $C_i$ etc. are determined by Wilson expansion and renormalisation group methods. The potential (1) is derived from an effective Hamiltonian for the weak interaction

$$H_{eff} = \frac{G\alpha}{m_d^2 - m_u^2} \partial_\mu A_\mu^{(+)} \partial_\nu V_\nu^{(-)} + h.c. \qquad (5)$$

which follows from the renormalisation group technique and some quark field manipulations. Galić et al then obtained the potential (1) from the Hamiltonian (5) in the factorisation approximation

$$\langle n'p'|V|np\rangle = \frac{G\alpha}{m_d^2 - m_n^2} \{\langle p'|\partial_\mu A_\mu^{(+)}|n\rangle\langle n'|\partial_\nu V_\nu^{(-1)}|p\rangle$$
$$+ \langle p'|\partial_\nu V_\nu^{(+)}|n\rangle\langle n'|\partial_\mu A_\mu^{(-)}||p\rangle\}, \qquad (6)$$

which is illustrated in figure (1).

The result of Galić et al follows when one sets, using the normalisation conventions of Marshak, Riazuddin and Ryan (1968)

$$\langle p'|\partial_\mu A_\mu^{(+)}|n\rangle = \frac{i}{(2\pi)^3}\sqrt{\frac{m_n m_p}{E_n E_{p'}}}\,(m_n + m_p)\;\bar{u}_{p'}\gamma_5\tau^{(+)}u_n \tag{7}$$

However the result (7) ignores the induced pseudoscalar term $f_A$ in the axial current matrix element. Including it

$$(2\pi)^3\sqrt{\frac{E_n E_{p'}}{m_n m_p}}\,\langle p'|\partial_\mu A_\mu^{(+)}|n\rangle = i\{(m_n+m_p)g_A + f_A k^2\}\bar{u}_{p'}\gamma_5\tau^{(+)}u_n. \tag{8}$$

If in addition PCAC is used one finds (see e.g. Marshak, Riazuddin and Ryan (1968))

$$(m_n + m_p)\;g_A + f_A k^2 = \frac{\sqrt{2}g_{\pi NN}}{k^2+m_\pi^2}\,F_\pi m_\pi^2, \tag{9}$$

where the $\pi$ decay constant has been written as $F_\pi$.

$\rho$ dominance of the vector current form factor gives

$$(2\pi)^3\sqrt{\frac{m_n m_p}{E_{n'}E_p}}\,\langle n'|\partial_\nu V_\nu^{(-)}|p\rangle = i(m_n-m_p)\,\frac{m_p^2}{k^2+m_\rho^2}\,\bar{u}_{n'}\tau^{(-)}u_p. \tag{10}$$

Thus, taking PCAC into account we obtain the momentum space potential

$$\langle n'p'|V|np\rangle = G\alpha\,\frac{m_n-m_p}{m_d^2-m_u^2}\,\sqrt{2}\,g_{\pi NN}F_\pi m_\pi^2 m_\rho^2\,\frac{1}{k^2+m_\rho^2}\,\frac{1}{k^2+m_\pi^2}$$

$$\times\{\,\bar{u}_{n'}\tau^{(-)}u_p\bar{u}_{p'}\gamma_5\tau^{(+)}u_n + \bar{u}_{p'}\tau^{(+)}u_n\bar{u}_{n'}\gamma_5\tau^{(-)}u_p\} \tag{11}$$

Eqn (11) can be rewritten as a sum of $\rho$ and $\pi$ exchange potentials using

$$\frac{1}{k^2+m_\rho^2}\;\frac{1}{k^2+m_\pi^2} = \frac{1}{m_\rho^2-m_\pi^2}\left\{\frac{1}{k^2+m_\pi^2} - \frac{1}{k^2+m_\rho^2}\right\} \tag{12}$$

In the limit $m_\pi^2 \ll m_\rho^2$, figure (1) contributes a pion exchange potential with a strength equal to that given by Galić et al. However the $\rho$ exchange potential is reduced by a factor $m_\pi^2/m_\rho^2$ compared to that of eqn (1), (2) and (3), when one remembers the Goldberger-Trieman relation

$$(m_n + m_p)\ g_A = \sqrt{2}\ g_{\pi NN} F_\pi . \tag{13}$$

In terms of the weak $\pi$NN coupling constant $f_\pi$, given in this model by

$$f_\pi = G\alpha F_\pi m_\pi^2 \frac{m_n - m_p}{m_d^2 - m_n^2}, \tag{14}$$

as in Galić et al, we find an isovector $\rho$ exchange potential of the form (1), with $\lambda$ given by

$$\lambda = \frac{g_{\pi NN} f_\pi}{\sqrt{2}\ G\ m_\rho^2} \doteq 1.9 \frac{m_\pi^2}{m_\rho^2} \frac{f_\pi}{f_\pi^{(c)}} \tag{15}$$

introducing the usual normalisating factor $f_\pi^{(c)} = 4.5 \times 10^{-8} \approx \frac{1}{5} Gm_\pi^2$. This $\lambda$ is the same order as the $\lambda$ parameter obtained by McKellar and Pick (1973) from $SU6_W$ symmetry which allows the contribution of diagrams other than figure (1). The influence of this potential in heavy nuclei may be estimated from the work of Box et al (1975). For the photon asymmetry in $n + p \rightarrow d + \gamma$, the results of Lassey and McKellar (1976) can be extended to provide the contribution of the potential of eqn (1) (Lassey and McKellar (1979), McKellar (1978)).

I will call the $\pi$ exchange potential contribution to the photon asymmetry $A_\pi$ and the contribution of the potential of eqn (1) $A_\rho$. Then taking the Reid Soft Core potential as an example, for the value of $\lambda$ given by eqn (3)

$$A_\pi / A_\rho \doteq 1/2. \tag{16}$$

However when $\lambda$ is given by eqn (15)

$$A_\pi / A_\rho \doteq 10. \tag{17}$$

Thus when the induced pseudoscalar term in the matrix elements of the axial current is taken into account, and the PCAC constraints are used, the isovector $\rho$ exchange potential of eqn (1) is reduced to negligible strength.

## References

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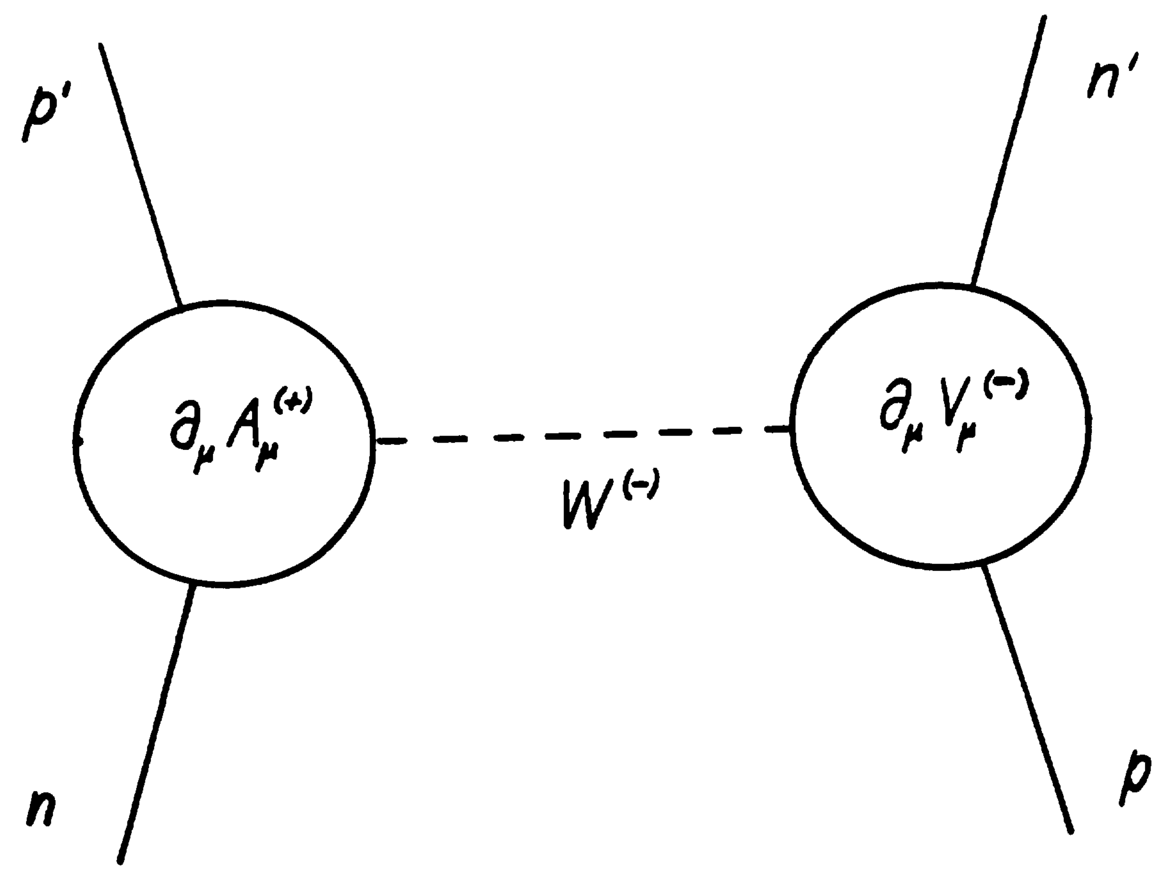
p'
n'
$\partial_\mu A_\mu^{(+)}$
$\partial_\mu V_\mu^{(-)}$
$W^{(-)}$
n
p