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PARITY-NON-CONSERVING NUCLEAR FORCES

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Abstract : Theoretical and phenomenological approaches to parity-non-conserving nuclear forces are reviewed. Recent developments in the calculation of weak meson-nucleon coupling constants, whose knowledge is necessary to determine theoretically the parity-non-conserving nucleon-nucleon potential, are described. The consistency of different measurements of parity-non-conserving effects is discussed and the information they provide is compared to theoretical predictions.

1. INTRODUCTION

The study of nuclear parity-non-conserving (PNC) effects has been motivated for a long time in the hope it would provide some information on the weak interaction |1| to which they are usually ascribed. At present, the main goal of these studies has been achieved by neutrino and electron scattering experiments which have established the existence of the neutral current |2| as well as part of its properties |3|. Except for some experiments in atomic physics, all other experimental information is consistent with the Weinberg-Salam model of weak and electromagnetic interactions |4|.

There are several reasons for the failure of these studies in not achieving their original goal. These effects are small and difficult to measure and their theoretical interpretation in the case of complex nuclei, is restricted due to uncertainties in wave functions which have prevented us from making any definite statement. Furthermore, uncertainties in deriving the PNC NN potential, which is a necessary step in calculating these effects, have grown with time. In fact, this is a fundamental uncertainty, and the reason for studying now nuclear PNC effects is probably to gain some information on the different mechanisms which enter in the derivation of this potential from the weak interaction, which itself is supposed to be known from leptonic and semi-leptonic processes.

In the present review, we first describe recent progress in calculating various meson-nucleon weak coupling constants with particular attention to the πNN coupling constant, which governs the long range part of the PNC force, and to the use of the $SU(6)_w$ symmetry to treat simultaneously the πNN and VNN weak coupling constants. Then, after a presentation of recent measurements, we shall discuss the consistency of several PNC effects, assuming they are due to a PNC force, but without further hypothesis as to their origin. In the last part, we will compare the information available from these

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measurements on the PNC NN interaction to the one calculated from a potential dominated by the exchange of π, ρ and ω mesons. In the course of this review, only the Weinberg-Salam model of weak interactions in its SU(4) version will be considered.

2. THE THEORETICAL APPROACH TO PNC NUCLEAR FORCES

A. The PNC nuclear potential is usually assumed to arise from the exchange of low mass mesons : π, ρ and ω. Together with corrections due to 2π exchange, this potential should give a good representation of the PNC NN interaction for distances larger than about 0.8 fm. At shorter distances, significant corrections due to several mesons exchanges may occur. As indicated by the NN strong interaction, for which more information is available, such processes can be sizeable and therefore should not be forgotten, although they are unknown. The repulsive part of the Reid-soft-core potential |5| for instance is one order of magnitude larger than the one expected from an ω exchange. Although weaker, this feature is also evident from other better NN potentials which incorporate a theoretical calculation of the 2π exchange contribution |6|. As shown by Durso et al. |7|, this feature can be explained by the simultaneous exchange of π and ρ mesons. While it is difficult to extrapolate these results to the PNC interaction, the possible presence of similar corrections should be kept in mind when measurements are compared to theoretical predictions based on the dominance of π, ρ and ω exchange contributions.

In the following, we will concentrate on these π, ρ and ω exchange contributions which, as we will see, are not unambiguous. They are determined by the knowledge of both the PNC and PC meson-nucleon interactions, which we write as :

$$\mathcal{L}^{PC} = g_\omega \bar{N}(\gamma^\mu \varphi^\omega_\mu + \frac{\chi_S}{2M} \sigma^{\mu\nu} \partial_\nu \varphi^\omega_\mu) N$$
$$+ g_\rho \bar{N}\vec{\tau}.(\gamma^\mu \vec{\varphi}^\rho_\mu + \frac{\chi_V}{2M} \sigma^{\mu\nu}\partial_\nu \vec{\varphi}^\rho_\mu) N + i\, g_{\pi NN}\, \bar{N}\vec{\tau}.\vec{\varphi}^\pi \gamma_5 N \quad , \qquad (1)$$

$$\mathcal{L}^{PNC} = \frac{1}{\sqrt{2}} f_\pi \bar{N}(\vec{\tau}\times\vec{\varphi}^\pi)^z N + h_\rho^{1'} \bar{N}\, i\, \frac{\sigma^{\mu\nu}}{2M} \gamma_5 (\vec{\tau}\times\partial_\nu \vec{\varphi}^\rho_\mu)^z N$$
$$+ \bar{N}(h_\rho^0\, \vec{\tau}.\vec{\varphi}^\rho_\mu + h_\rho^1\, \varphi^{\rho z}_\mu + \frac{h_\rho^2}{2\sqrt{6}} (3\tau^z \varphi^{\rho z}_\mu - \vec{\tau}.\vec{\varphi}^\rho_\mu))\gamma^\mu \gamma_5 N$$
$$+ \bar{N}(h_\omega^0 + h_\omega^1 \tau^z)\varphi^\omega_\mu \gamma^\mu \gamma_5 N. \qquad (2)$$

Because the relative phases of weak and strong interactions is measurable, we need to be precise about the γ_5 matrix which is defined here as :

$$\gamma_5 = \begin{pmatrix} 0 & -1 \\ -1 & 0 \end{pmatrix}$$

The corresponding NN potential, which is the basic ingredient for calculations of PNC nuclear effects, can be written in the non-relativistic limit as :

$$
\begin{aligned}
V_{12}^{PNC} = {} & i\,\frac{1}{2}(\vec{\tau}_1 \times \vec{\tau}_2)^z(\vec{\sigma}_1+\vec{\sigma}_2)\left[\frac{\vec{p}}{M}\,,\ \frac{g_{\pi NN} f_\pi}{\sqrt{2}}\, f_\pi(r) - g_\rho h_\rho^{1'} f_\rho(r)\right] \\
& - g_\rho\left(h_\rho^0\ \vec{\tau}_1 \cdot \vec{\tau}_2 + \frac{1}{2}\, h_\rho^1(\tau_1^z+\tau_2^z) + \frac{1}{2}\,\frac{h_\rho^2}{\sqrt{6}}\,(3\tau_1^z\tau_2^z - \vec{\tau}_1 \cdot \vec{\tau}_2)\right) \\
& \times\left((\vec{\sigma}_1-\vec{\sigma}_2)\left\{\frac{\vec{p}}{M}\,, f_\rho(r)\right\} + i(1+\chi_V)(\vec{\sigma}_1 \times \vec{\sigma}_2)\left[\frac{\vec{p}}{M}\,,\ f_\rho(r)\right]\right) \\
& - g_\omega\left(h_\omega^0 + \frac{1}{2}\, h_\omega^1\ (\tau_1^z + \tau_2^z)\right) \\
& \times\left((\vec{\sigma}_1-\vec{\sigma}_2)\left\{\frac{\vec{p}}{M}\,, f_\omega(r)\right\} + i(1+\chi_S)(\vec{\sigma}_1 \times \vec{\sigma}_2)\left[\frac{\vec{p}}{M}\,, f_\omega(r)\right]\right) \\
& - (g_\omega h_\omega^1 - g_\rho h_\rho^1)\ \frac{1}{2}\ (\tau_1^z-\tau_2^z)(\vec{\sigma}_1+\vec{\sigma}_2)\left\{\frac{\vec{p}}{M}\,,\ f_{\rho,\omega}(r)\right\} \quad , \qquad (3)
\end{aligned}
$$

where

$$\vec{p} = \frac{1}{2}\ (\vec{p}_1-\vec{p}_2)\,,\quad f_\pi(r) = \frac{e^{-m_\pi r}}{4\pi\ r}\,,\quad f_\rho(r) = f_\omega(r) = \frac{e^{-m_\rho r}}{4\pi\ r}\ .$$

In the above expression of the potential, the g's represent the strong meson-nucleon coupling constants. They are assumed to be positive and are given the following values :

$$\frac{g_{\pi NN}^2}{4\pi} = 14.4 \quad , \qquad \frac{g_\rho^2}{4\pi} = \frac{1}{9}\,\frac{g_\omega^2}{4\pi} = 0.62 \quad .$$

The factors χ_V and χ_S, which describe the strong tensor couplings have often been given the values 3.7 and -0.12 which result from an identification with the anomalous isovector and isoscalar magnetic moments of the nucleon, but, at least for the first one, might be much larger |8|.

Among the different PNC meson-nucleon coupling constants which appear in exps. (2) and (3), the πNN coupling constant, f_π, has certainly received the most attention until now. On one hand, it determines the part of the PNC nuclear force which has the longest range. Because of this property, the corresponding contribution may be enhanced relatively to other contributions. While this is confirmed by calculations of PNC effects at very low energy, part of the advantage is lost at higher energies and in complex nuclei, due to the exchange character of this force. On the other hand, it is known that f_π depends only on the $\Delta I=1$ part of the weak interaction. Since its contribution from the charged current |9|, which contains the factor $\sin^2\theta_C \simeq 0.05$, is small, it essentially depends on the properties of the neutral current whose the contribution, which contains factors $\sin^2\theta_W \simeq 0.25$ and $(1-2\sin^2\theta_W) \simeq 0.5$, is not similarly suppressed.

The other coupling constants which appear in (3) are $h_\rho^{0,1,2}$, $h_\rho^{1'}$ and $h_\omega^{0,1}$, which govern the short range part of the potential. The indices represent the isospin components of the weak interaction to which they refer and the vector meson from which they originate. Except for $h_\rho^{1'}$, which corresponds to a tensor coupling, these coupling constants correspond to an axial vector coupling. They are sufficient to represent all the spin-isospin components of the force which are important at low energy, or equivalently, the transitions :

$^1S_0 - {}^3P_0$ (pp, nn, pn forces)

$^3S_1 - {}^1P_1$ (pn isoscalar force)

$^3S_1 - {}^3P_1$ (pn isovector force).

B. Before describing the recent developments in the calculation of PNC meson-nucleon coupling constants, we first review the methods which have been used extensively in this field. One of the methods employs a factorization approximation |10-13| which consists of identifying with a meson field any quark-antiquark pair appearing in the hamiltonian with the appropriate quantum numbers. This approach has been mainly applied to VNN coupling constants. It provides a theoretical determination of the magnitude as well as the sign (relative to the strong coupling constant) of PNC coupling constants. An other approach employs the strong interaction symmetries, mainly SU(3), and information available from non-leptonic hyperon decays |9,14|. It has been applied to estimate the πNN coupling constant, f_π, and, in contrast to the other approach, it provides neither a true theoretical determination of the magnitude nor information on the sign. An attempt to use the larger strong interaction symmetry, $SU(6)_W$, has been made to calculate the VNN coupling constants |15|. However the results contradicted those obtained with the factorization approximation. While the coupling constants obtained with the above methods have been extensively used in making predictions, it is clear that they have not been derived consistently and that some effort is necessary to reduce the present gap between these approaches.

Recent progress in this field arises partly from the necessity to overcome the rather arbitrary assumptions which have been made in the first estimates of the πNN coupling constant, f_π, in gauge models of weak and electromagnetic interactions |16,17|. Indeed, in these models, the neutral current is no longer of the V-A type and furthermore contain a SU(3) singlet part, which prevents us from making a definite prediction for f_π from our only information on hyperon decay amplitudes, as was the case with the first models of weak interactions. Present assumptions are now relying on an analysis of the strong interaction at the quark level and thus should provide a better estimate of f_π. The new interest for the calculation of f_π is also due to a better understanding of hyperon nonleptonic decays |18|. It seems that their magnitude, which for a long time has escaped any satisfying explanation, can be reproduced by taking into account strong interaction effects as well as those due to the breaking of the SU(4) symmetry. A precise determination of the relative weight of these effects, which have been shown to be coherent, is however lacking. The application of these methods to the calculation of f_π has allowed to identify a new contribution, the derivation of which has a strong similarity with the factorization approximation used until now for VNN coupling constants. Finally, part of the recent progress is due to a reexamination of the use of the $SU(6)_W$ symmetry. Until now, two parameters involved in this approach were undetermined and assumptions were necessary to make predictions for the VNN coupling constants. An analysis of the tensorial character of terms associated to these two parameters has shown that they were describing the factorization approximation results, thus providing more reliable predictions.

Before describing in more details recent works, we summarize the most important results. The sign of the πNN weak coupling constant, f_π, to which little attention has been given for a long time, is now predicted in any case and is positive in our notation. As we shall see in the fourth section, this is precisely what is required in explaining the sign of PNC effects measured in several complex nuclei. The magnitude is not so well determined. It depends on the size of strong interaction effects and on some details in estimating different matrix elements. An average expectation, which does not exclude values two times larger or smaller is :

$$f_\pi = +0.5 \times 10^{-6} \quad ,$$

which is about 12 times the conventional contribution of charged currents. It has been shown that $SU(6)_W$ results incorporate the results obtained for VNN coupling constants in the factorization approximation and that corrections to this approximation may be large enough to change the sign of some of them.

C. Since they provide a convenient framework to discuss past and recent contributions, we first give the expression of the PNC meson-nucleon coupling constants calculated with the $SU(6)_W$ symmetry for the Weinberg-Salam model of weak and electromagnetic interactions |19| :

$$f_\pi = \frac{1}{3\sqrt{2}} \left(\frac{4}{9}\,\tilde{a}\,\sin^2\theta_W F(K) - \frac{\tilde{b}}{3}\sin^2\theta_W E(K) + \tilde{c}\,C^1(K) \right) ,$$

$$\text{with}\quad C^1(K) = \sin^2\theta_C \left(\frac{K^{.48}+K^{-.24}}{2} \right) + (1-2\sin^2\theta_W)\left(\frac{K^{.48}-K^{-.24}}{2} \right)$$

$$- \frac{2}{3}\sin^2\theta_W\, G^1(K) \quad ,$$

$$h^0_\rho = \frac{25}{81}\tilde{a}\left(\left(\cos^2\theta_c + \frac{1-2\sin^2\theta_w}{2}\right)\left(\frac{3K^{.48}+2K^{-.24}}{5}\right) + \left(\frac{3-2\sin^2\theta_w}{5}\right)A^0_\rho(K)\right)$$
$$+ \frac{\tilde{b}}{3}\left(\left(\cos^2\theta_c + \frac{1-2\sin^2\theta_w}{2}\right)K^{.48} + (3-2\sin^2\theta_w)B^0_\rho(K)\right) - \frac{5}{9}\tilde{c}\,C^0(K),$$

with
$$C^0(K) = \left(\cos^2\theta_c + \frac{\sin^2\theta_c}{2} + \frac{1-2\sin^2\theta_w}{2}\right)\left(\frac{K^{.48}+K^{-.24}}{2}\right)$$
$$+ \left(\frac{3-2\sin^2\theta_w}{3}\right)A^0_\rho(K) + \sin^2\theta_w\,G^0(K)\,.,$$

$$\frac{h^2_\rho}{\sqrt{6}} = \frac{-40}{81}\tilde{a}\,(\cos^2\theta_c - (1-2\sin^2\theta_w))\,K^{-.24} \quad ,$$

$$h^1_\rho = -\frac{\tilde{a}}{27}\sin^2\theta_w\,A^1_\rho(K) + \frac{\tilde{b}}{27}\sin^2\theta_w\,E(K) - \frac{\tilde{c}}{6}C^1(K) \quad ,$$

$$h^0_\omega = \frac{\tilde{a}}{9}\left(\left(\cos^2\theta_c + \frac{1-2\sin^2\theta_w}{2}\right)(2K^{-.24}-K^{.48}) + (3-2\sin^2\theta_w)A^0_\omega(K)\right)$$
$$- \frac{\tilde{c}}{3}C^0(K) \quad ,$$

$$h^1_\omega = -\frac{35}{81}\tilde{a}\sin^2\theta_w\,A^1_\omega(K) - \frac{5}{18}\tilde{c}\,C^1(K) \quad . \qquad (4)$$

The different functions of K are given by :

$$F(K) = 1.07\,K^{.85} - .19\,K^{.43} - .09\,K^{-.13} + .25\,K^{-.35} \,,$$
$$E(K) = -.33\,K^{.85} + .0\,3\,K^{.43} + 1.62\,K^{-.13} - .31\,K^{-.35} \,,$$
$$G^1(K) = .45\,K^{.85} - .27\,K^{.43} - .34\,K^{-.13} + 1.16\,K^{-.35} \,,$$
$$G^0(K) = -.075\,K^{.85} - .066\,K^{.43} + .086\,K^{-.13} + .053\,K^{-.35} \,,$$
$$A^1_\rho(K) = -.48\,K^{.85} + .28\,K^{.43} - 2.13\,K^{-.13} + 3.28\,K^{-.35} \,,$$
$$A^1_\omega(K) = .04\,K^{.85} + .001\,K^{.43} + .60\,K^{-.13} + .36\,K^{-.35} \,,$$
$$A^0_\rho(K) = -.50\,K^{.48} - .60\,K^{-.24} + .29\,K^{.35} + .81\,K^{-.40} \,,$$
$$B^0_\rho(K) = -.167\,K^{.48} + .125\,K^{.35} + .042\,K^{-.40} \,,$$
$$A^0_\omega(K) = .17\,K^{.48} - .60\,K^{-.24} - .21\,K^{.35} + .64\,K^{-.40} \,.$$

In deriving the above expressions, the effects of the strong interactions, which manifest themselves by the presence of the factor K have been taken into account. SU(4) breaking corrections have not been included in the effective hamiltonian, but it has been assumed there were no charmed quark-antiquark pairs in nucleons and mesons in calculating matrix elements of this hamiltonian. Terms involving corrections of the 2d or higher order in gluon exchange have been neglected and Fierz transformations have been used to reduce the number of unknown quantities. Finally a non-relativistic approximation has been used in one unimportant case (term proportional to E(K)).

In the simplest quark model, the different quantities $\tilde{a}$, $\tilde{b}$ and $\tilde{c}$ appearing in (4) can be easily interpreted by looking at the tensorial properties of the corresponding terms in the hamiltonian. The quantity $\tilde{a}$ describes processes taken into account by the factorization approximation (fig. 1a). Its value is given by :

$$\tilde{a} = \frac{9}{10} \frac{G}{\sqrt{2}} \frac{m_\rho^2}{g_\rho} g_A = +1.9 \times 10^{-6} \quad . \tag{5a}$$

The quantity $\tilde{b}$ describes a process where the hamiltonian acts on two valence quarks of one of the initial or final nucleon (fig. 1b), whereas the quantity $\tilde{c}$, which takes into account SU(4) breaking effects, describes processes involving q $\bar{q}$ colored pairs in nucleons (fig. 1c). Numerical values of $\tilde{b}$ and $\tilde{c}$ can be obtained by applying

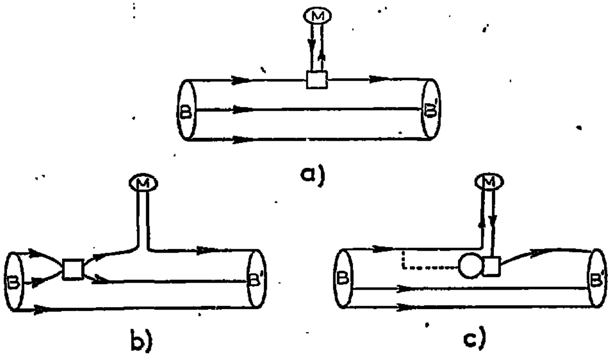

Fig. 1 Some examples of quark diagrams contributing to meson-nucleon weak coupling constants. The box represents the effective weak interaction.

the $SU(6)_W$ symmetry, as above, to nonleptonic hyperon decay amplitudes and determining the signs as in ref. |21| :

$$\tilde{b}\, K^{.48} = -4.0 \times 10^{-6} \quad , \tag{5b}$$

$$\tilde{c}\left(\frac{K^{.48}+K^{-.24}}{2}\right) = +3.2 \times 10^{-6} \quad . \tag{5c}$$

We now describe different estimates of the coupling constants. In doing so, we shall give more attention to the kind of contribution represented by the quantities $\tilde{a}$, $\tilde{b}$ and $\tilde{c}$ than to their values. Thus, they will be given their $SU(6)_W$ symmetry values as well as theoretical estimates incorporating for instance the effects of the breaking of the $SU(6)_W$ symmetry.

a. The first estimate of the πNN coupling constant, f_π, in the Weinberg-Salam model by Gari and Reid |16|, corrected as in ref. |17|, did not consider explicitly the effect of strong interactions (K=1) and neglected quantities which could not be related without further assumption to hyperon decay amplitudes ($\tilde{a}=\tilde{b}=0$). The total result was :

$$f_\pi = \frac{\tilde{c}}{3\sqrt{2}}\left(\sin^2\theta_C - \frac{2}{3}\sin^2\theta_W\right) = -0.09 \times 10^{-6} \quad .$$

In this calculation, neutral currents give a contribution which, for $\sin^2\theta_W=0.25$, is 3 times larger than the charged current contribution, but has a different sign.

Introducing a quark description of nucleons, Donoghue |20| considered the contribution of diagram 1b), the other contributions being neglected ($\tilde{a}=\tilde{c}=0$). Using information from hyperon decays, and assuming that the strong interaction effects are the same in both processes, f_π is found to be :

$$f_\pi \simeq 0.2 \times 10^{-6} \quad .$$

A much smaller value is however obtained when strong interaction effects are taken into account explicitly.

In ref. |21|, strong interaction effects are assumed to be taken into account in the wave functions. As in the previous work, the contribution of diagram 1b) is related to nonleptonic hyperon decay amplitudes, whereas contributions of diagram 1a) is neglected ($\tilde{a}=0$). In calculating contributions of diagram 1c), it is assumed that terms symmetrical in V and A currents and antisymmetrical in color indices have their contribution enhanced, which corresponds to pick up, in exp. (4) of f_π, $\tilde{c}$ contributions which have the dominant behavior when $K\to\infty$. The amplitude is then written as :

$$f_\pi = \frac{\sin^2\theta_W}{3|\cos\theta_C \sin\theta_C|}\left\{\begin{matrix} 2\sqrt{\frac{2}{3}}|\Lambda^0_-| \\ \sqrt{\frac{2}{3}}|\Xi^-_-| \\ \text{or } \frac{2}{3}|\Sigma^-_-| \end{matrix}\right\} + \sqrt{\frac{2}{3}}\left(\frac{\sin^2\theta_C + 1 - 2\sin^2\theta_W + \frac{\sin^2\theta_W}{3}}{|\cos\theta_C \sin\theta_C|}\right)(2|\Lambda^0_-| - |\Xi^-_-|) . \tag{6}$$

Depending on which hyperon decay amplitude is used and on various corrections, the following range of values is obtained :

$$+0.35 \times 10^{-6} < f_\pi < +0.6 \times 10^{-6} \quad .$$

The sign of f_π (relative to the strong interaction coupling constant), which was undetermined in previous calculations, is also predicted. Similar estimates retaining a part of the above contributions have been made. Weinberg |22| considered the contribution of terms proportional to $\sin^2\theta_C$ and $(1-2\sin^2\theta_W)$ in (6), leaving undetermined terms proportional to $\sin^2\theta_W$ whereas Konuma and Oka |23| retained only the contribution of diagram 1b) (first term in (6)).

In the most recent estimates, effects of strong interactions between quarks are taken into account explicitly and give rise to an effective hamiltonian. Körner et al. |24| calculated contribution of diagram 1b, they found negligeable, and of diagram 1a). SU(4) symmetry breaking effects are neglected. Their large result :

$$f_\pi = +0.8 \times 10^{-6} \quad ,$$

is due to a large value of the factor K=10, which characterizes strong interaction effects. Buccela et al. |25| also found a negligeable contribution for diagram 1b), whereas diagram 1a) is producing two kinds of contributions. One of them depends for its estimate on strong interaction effects and is found to be between 10 and 23 times the charged current contribution. The second one, which is smaller, but not negligeable, has the same sign. It depends on SU(4) symmetry breaking effects and can be related to nonleptonic hyperon decay amplitudes. The total result is in the range :

$$+0.6 \times 10^{-6} < f_\pi < +1.1 \times 10^{-6} \quad .$$

A very similar calculation has been done by Guberina et al. |26|. Their estimate is :

$$f_\pi = +0.3 \times 10^{-6} \quad ,$$

and is much smaller, due to a different estimate of the matrix element $<p|\bar{u}d|n>$ as well as strong interaction effects.

Two points are worth noting here. The last two calculations give formally the same result for the dominant contribution, despite different approaches : current algebra techniques in one case and factorization approximation in the other one. This is a rather welcome result as it allows us to unify methods which have been used in past years to calculate both the πNN and the VNN coupling constants. On the other hand, diagram 1c) does not contribute, which may contradict some of the other estimates |21,22| . In fact, apparent differences arise from the way strong interaction effects are shared between the hamiltonian and wave functions, and it can be shown that the expression of f_π derived by Buccela et al., who made a first order treatment of SU(4) symmetry breaking effects, is the same as the one derived using the $SU(6)_W$ symmetry (exp.(4)). Since it is consistent with the most recent approaches, this expression, together with values of $\tilde{a}$, $\tilde{b}$ and $\tilde{c}$ given in eqs.(5) can also provide an estimate. For K=7, we get :

$$f_\pi = +0.35 \times 10^{-6} \quad .$$

The difference with higher estimates is due to the use of the $SU(6)_W$ symmetry which implies a value of the sum of quark masses, m_u+m_d, of about 18 MeV (instead of 11 MeV) and a smaller value of the matrix element $\langle p|\bar{u}d|n\rangle$ ($\frac{3}{5}\, g_A \simeq .75$ instead of 1).

b. Most derivations of the ρNN and ωNN coupling constants have relied upon the factorization approximation |12,13| and the corresponding results can be obtained by picking up terms proportional to $\tilde{a}$ in eqs. (4). Assuming that the factor K, which characterizes strong interaction effects, varies in the range K=4 to K=7, we get :

$$h_\rho^0 = +(.89\ ,\ 1.05) \times 10^{-6} \quad ,$$
$$\frac{h_\rho^2}{\sqrt{6}} = (-.30\ ,\ -.27) \times 10^{-6} \quad ,$$
$$h_\rho^1 = (.014\ ,\ .032) \times 10^{-6} \quad ,$$
$$h_\omega^0 = (-.17\ ,\ -.36) \times 10^{-6} \quad ,$$
$$h_\omega^1 = \ -.18 \times 10^{-6} \quad .$$

There is presently no dynamical calculation of contributions of diagrams 1b) and 1c) similar to those which have been described above for the πNN coupling constant. We must therefore rely on the $SU(6)_W$ results |19| if we want to have some indication about them. Using the values of $\tilde{a}$, $\tilde{b}$ and $\tilde{c}$ given in (5), we get respectively for K=4 and K=7 :

$$h_\rho^0 = (-2.1\ ,\ -1.7) \times 10^{-6} \quad ,$$
$$\frac{h_\rho^2}{\sqrt{6}} = (-.30\ ,\ -.27) \times 10^{-6} \quad ,$$
$$h_\rho^1 = (-.04\ ,\ -.03) \times 10^{-6} \quad ,$$
$$h_\omega^0 = (-1.1\ ,\ -1.2) \times 10^{-6} \quad ,$$
$$h_\omega^1 = (-.27\ ,\ -.30) \times 10^{-6} \quad .$$

The most stricking features of these results are the change in sign for h_ρ^0 and the enhancement of h_ω^0. Since we are using data involving a pion to calculate processes involving a vector meson, the above results may be sensitive to $SU(6)_W$ symmetry breaking effects. Thus an explicit calculation in the MIT bag model |19| has shown that the actual value of $\tilde{b}$ to be used should be zero when the vector current-ρ field identity is assumed. While this is consistent with the result derived in the factorization approximation |11|, the fact that the strong tensor ρNN coupling constant, χ_V, may be different from the anomalous isovector nucleon magnetic moment shows that the above identity is not quite satisfied. In this case, $SU(6)_W$ results can indicate the direction in which the factorization approximation results should be corrected. The contributions due to quark-antiquark pairs in nucleons (diagram 1c), which are quite large, may also be sensitive to $SU(6)_W$ symmetry breaking effects : they are reduced by a factor $\frac{1}{2}$ when they are assumed to be a first order effect in gluon exchange.

3. ANALYSIS OF NUCLEAR PNC EFFECTS

PNC effects have now been observed in several nuclei. In some cases like ^{180}Hf, ^{181}Ta and ^{175}Lu, the observation has been confirmed by several groups, but in most other cases there is only one measurement. We consider these measurements and study their consistency for those cases where an expression of the effect has been calculated in terms of the parameters of some effective PNC NN interaction. Before going to this analysis, we first present results of recent experiments (results of older experiments can be found in ref. |27|).

A. Recent experimental studies of PNC effects deal with electromagnetic processes, as in most previous studies, but also with pure nuclear processes. Two different groups have observed in the reaction $n+{}^{117}Sn \to {}^{118}Sn+\gamma$ a large asymmetry of the emitted radiation with respect to the neutron polarization. Assuming that the angular distribution is written as :

$$W(\theta) = 1 + a \cos\theta \quad ,$$

where θ is the angle between the emitted radiation and the neutron polarization, they got :

$$a = (8.9 \pm 1.5)\times 10^{-4} \quad |28| \quad \text{and} \quad a = (4.4 \pm 0.6)\times 10^{-4} \quad |29| \; .$$

In nuclear fission, Danylian et al. |30| have measured a large asymmetry of the emitted light nuclei with respect to the neutron polarization in the three nuclei, ^{234}U, ^{236}U and ^{240}Pu, for which they got :

$$a(^{234}U) = (2.8 \pm 0.3)\times 10^{-4} \; , \; a(^{236}U) = (1.7 \pm 0.4)\times 10^{-4}$$

$$\text{and} \quad a(^{240}Pu) = -(4.8 \pm 0.8)\times 10^{-4} \quad .$$

A precise understanding of these effects is however lacking and therefore little can be learnt on PNC forces from them.

Among other processes in complex nuclei, attempts have been made to observe PNC effects in the following electromagnetic transitions :

$$^{18}F\ (0^- \xrightarrow{1.08\ MeV} 1^+) \quad : \quad P_\gamma \ ,$$

$$^{19}F\ (\tfrac{1}{2}^- \xrightarrow{110\ keV} \tfrac{1}{2}^+) \quad : \quad \delta_\gamma \ ,$$

$$^{21}Ne\ (\tfrac{1}{2}^- \xrightarrow{2.789\ MeV} \tfrac{3}{2}^+) \quad : \quad P_\gamma \ .$$

In the first process, Barnes et al. |31| have measured the circular polarization to be $P_\gamma=-(0.7\pm2.0)\times10^{-3}$, which is within usual expectations. In ^{19}F, the accuracy of the measurement of the asymmetry by Adelberger et al. |32| has been improved upon with the result : $\delta_\gamma=-(8.5\pm2.6)\times10^{-5}$. In the third process, the circular polarization P_γ has been measured by Snover et al. |33|. Despite a large error, the present value, $P_\gamma=-(9\pm51)\times10^{-4}$, is an order of magnitude smaller than expected on the basis of usual models and might be a strong constraint for theory if the process can be calculated reliably.

In contrast to most PNC effects, the above three have the advantage of essentially requiring the knowledge of one matrix element of the weak potential in each case, respectively $\langle 0^-,T=1,1.08MeV|V_W|0^+,T=0,1.04MeV\rangle$, $\langle \tfrac{1}{2}^-,110keV|V_W|\tfrac{1}{2}^+,g.s.\rangle$ and $\langle \tfrac{1}{2}^-,2.78MeV|V_W|\tfrac{1}{2}^+,2.796MeV\rangle$, which facilitates their theoretical interpretation. Thus the effect in ^{18}F depends on the $\Delta I=1$ part of the weak potential, whereas the effect in ^{19}F essentially depends on the strength of the p-nucleus PNC interaction since $\tfrac{1}{2}^-$ and $\tfrac{1}{2}^+$ states can be considered as proton-holes in ^{20}Ne. There is no similar result for ^{21}Ne, but if one assumes that $\tfrac{1}{2}^-$ and $\tfrac{1}{2}^+$ states are one nucleon hole in the A=22, T=1 core, then the contributions relative to the neutron and proton parts of the N-nucleus PNC interaction will be in the ratio 2:1, which is what we shall use in the following.

Cavaignac et al. |34| have measured the asymmetry of photons with respect to the neutron polarization in $n+p\rightarrow d+\gamma$. Their value is :

$$A_\gamma = (.6 \pm 2.1)\times10^{-7} \ ,$$

which is in agreement with usual expectations, but not accurate enough to provide some information on the weak πNN coupling constant to which this process is very sensitive.

Experiments in elementary processes which involve directly the NN weak interaction have also been performed. The measurement of the asymmetry in polarized pp scattering at 15 MeV |35| :

$$A_{pp}(15\ MeV) = -(1.7 \pm 0.8)\times10^{-7} \ ,$$

is rather larger than expected. This value is not inconsistent with the present upper limit of 5×10^{-7}, measured at 56 MeV |36| where the effect should be twice that at 15 MeV. Finally a measurement of the asymmetry in pd scattering at 15 MeV has also been reported |35|. Despite a large error, the measurement :

$$A_{pd}(15\ \mathrm{MeV}) = -(0.35 \pm 0.85)\times10^{-7} \quad ,$$

is not far from theory.

B. The difficulty in reproducing PNC effects from first principles has motivated several attempts |37-39| to find a parametrization for the PNC NN interaction to account for various measurements. Two different parametrizations have been used. One of them assumes that the weak potential is described by the exchange of π, ρ and ω mesons |37,39| and the corresponding weak coupling constants are parametrized. Although these coupling constants have an effective character -they depend for instance on the model used to describe the strong NN interaction- this approach does facilitate comparison with predictions for them. In the second approach |38|, PNC are described in terms of quantities which, in principle, are measurable, namely the NN scattering amplitudes at low energy. Because the parameters refer to the different NN amplitudes rather than to the exchange of particles, it is closer to measurements and so, facilitates their comparison. Furthermore, this approach provides quantities that any model of the weak and strong NN interaction should reproduce.

There are at present more measurements than necessary to determine the parameters of the different analysis, but not enough to alleviate the effects of experimental or theoretical uncertainties. Thus some parameters may depend on one measurement or also on details of some calculations which were done approximately to get an idea of the magnitude of the effects. While the parameters so obtained cannot be excluded, some of them, which we shall consider in the following, can be determined better than others.

The theoretical uncertainties which are relevant here and which, in contrast to those on the NN interaction, are not parametrized, arise mainly from calculations in complex nuclei. This observation suggests to consider PNC effects in those nuclei separately and to analyse them, as a first approximation, in terms of the strengths of the p-nucleus and n-nucleus PNC interactions, which are expected to take into account the main contributions |40|. These strengths, X_N^p and X_N^n , can be expressed in terms of the quantities f_π, $X_{pn}^{\pm}$, X_{pp} and X_{nn} which characterize the different contributions of the pn, pp and nn PNC forces to an effective interaction appropriate for calculations in complex nuclei |38| :

$$X_N^p = 5.5\ f_\pi + X_{pn}^{+} + X_{pp} \quad ,$$

$$X_N^n = -5.5\ f_\pi + X_{pn}^{-} + X_{nn} \quad . \qquad (7)$$

The expression of various PNC effects in terms of f_π, $X_{pn}^{\pm}$, X_{pn}^{0}, X_{pp} and X_{nn} can be found in table I whereas calculations which have lead to these expressions and a comparison with other calculations are described in refs. |38,40| Equivalent expressions, in terms for

Table I

Expression of PNC effects in terms of parameters of an effective potential |38a|.

Process	Observable	f_π	X_{pn}^{+}	X_{pn}^{-}	X_{pn}^{0}	X_{pp}	X_{nn}
${}^{16}O(2^-)\rightarrow{}^{12}C+\alpha$	$\pm\sqrt{\Gamma_\alpha}\,eV^{-1/2}$		2.8	2.8		2.8	2.8
${}^{18}F(0^-\rightarrow 1^+)$	P_γ	-8460	- 750	750		- 750	750
${}^{19}F(\frac{1}{2}^-\rightarrow\frac{1}{2}^+)$	δ_γ (or P_γ)	- 260	- 46			- 46	
${}^{21}Ne(\frac{1}{2}^-\rightarrow\frac{3}{2}^+)$	P_γ	40600	-7200	-14400		-7200	-14400
${}^{41}K(\frac{7}{2}^-\rightarrow\frac{3}{2}^+)$	P_γ	26	4.7			4.3	
${}^{175}Lu(\frac{9}{2}^-\rightarrow\frac{7}{2}^+)$	P_γ	89	16.8			11.5	
${}^{181}Ta(\frac{5}{2}^+\rightarrow\frac{7}{2}^+)$	P_γ	-8.1	-1.5			-1.0	
$n+p\rightarrow d+\gamma$	P_γ		.0127	.0127	.0461		
	α	-.107	-.005	.005			
$\vec{p}p\rightarrow pp$	A_{pp}(15MeV)					-.10	
$\vec{p}d\rightarrow dp$	A_{pd}(15MeV)	-.23	-.0195	-0.0001	-.0024	-.0146	

instance of zero energy PNC NN amplitudes, could be given, but they don't emphasize as clearly as the above ones the interdependance of different processes. The simplified expressions for complex nuclei in terms of X_N^p and X_N^n are given in table II. Since there are seven measurements, the two quantities X_N^p and X_N^n should be determined better than any of the quantities f_π, $X_{pn}^{\pm}$, X_{pp} and X_{nn} which enter in their definition. A least squares fit yields :

$$X_N^p = 3.34 \times 10^{-6} \quad , \qquad X_N^n = -0.66 \times 10^{-6} \quad . \tag{8}$$

Examination of table II shows that the discrepancy between the fitted value and the measurement rarely exceeds a factor 2, often used to characterize nuclear uncertainties. The largest discrepancy appears in ^{21}Ne. Since this effect results from a cancellation of contributions due to the p-nucleus and n-nucleus weak interactions, a slight modification of their strengths could give a better agreement. On the other hand, the calculation by Millener et al. |41| indicates that the ratio of contributions relative to the neutron

Table II

Expression of PNC effects in terms of the strengths of the nucleon-nucleus interaction.

Process	Observable	X_N^p	X_N^n	Fit(10^{-6})	Exp(10^{-6})
^{16}O	$\pm\sqrt{\Gamma_\alpha}\,eV^{-1/2}$	2.8	2.8	7.5	10 ± 1
^{18}F	P_γ	-750	750	-3000	-700 ± 2000
^{19}F	δ_γ	- 46		- 154	- 85 ± 26
^{21}Ne	P_γ	-7200	-14400	-14500	-900 ± 5100
^{41}K	P_γ	4.7		16.	20 ± 4
^{175}Lu	P_γ	16.8		56.	55 ± 5
^{181}Ta	P_γ	-1.5		-5.0	-5.2 ± 0.5

and proton parts of the N-nucleus weak interaction could be twice the one used here, which would also give a better agreement. Finally, the better agreement in ^{16}O, ^{41}K, ^{175}Lu and ^{181}Ta is partly due to the fitting procedure which favors processes measured more accurately, and one could certainly afford larger discrepancies for them to improve the fit to the rest of the nuclei in table II.

The determination of X_N^p and X_N^n from seven measurements should not be too sensitive to differences in the nuclear part of the calculations. The strength of the p-nucleus weak interaction, X_N^p, is severely constrained by measurements in ^{19}F, ^{41}K, ^{175}Lu and ^{181}Ta. In spite of differences in measurements or in calculations, this quantity is close to the one derived in ref. |38a| and thus, is probably the most reliable known component of PNC nuclear forces. The quantity X_N^n is constrained in part by the measurement in ^{21}Ne ; since the contribution of the n-nucleus weak interaction is favored in this process, its strength must be small and tend to cancel part of the contribution due to the p-nucleus weak interaction in order to explain the absence of a sizeable effect. While the above features of the calculation are strongly supported by the calculations of Millener et al. |41|, the evidence for them in the calculation of Brandenburg et al. |42| is rather weak. In fact this latter calculation shows such a large sensitivity to the nuclear model that no information could be obtained by studying this process. If ^{21}Ne is deleted in the fit, a small value of X_N^n is still found, but with a different sign. Thus the strength of the n-nucleus weak interaction given by (8) may not be as reliable as for the p-nucleus weak interaction.

Further information on PNC forces arise from elementary processes and, since the theoretical uncertainty apart from the one due to the weak and strong NN interaction is small here, it can be included directly in the analysis. The present measurement of the asymmetry at 15 MeV in pp scattering implies that the strength of the pp force, characterized here by X_{pp} for simplicity, is :

$$X_{pp} = (1.7 \pm 0.8)\times10^{-6} \quad . ,$$

This number indicates that the pp force contributes approximately half of the strength of the p-nucleus weak interaction, as it can be seen from (7) and (8). It also tells us that, in deriving expressions of PNC effects in terms of X_N^p and X_N^n, contributions of about 20% of the effect in ^{181}Ta and ^{175}Lu have been neglected.

The approximate expression of the asymmetry in pd scattering |43| :

$$A_{pd}(15\ \text{MeV}) = -0.020\ X_N^p \quad ,$$

together with the present upper limits on the measurement implies X_N^p to be between -2×10^{-6} and 6×10^{-6}, which is consistent with the value derived from complex nuclei. The present upper limit on the asymmetry in thermal radiative np capture indicates that the πNN coupling constant, f_π, assuming that the corresponding contribution dominates, is smaller than 2.6×10^{-6}. This upper bound is too large to tell, for instance, how much of the p-nucleus weak interaction is due to the long range π-exchange force. At present, the last available information is the circular polarization of the radiation emitted in the thermal np capture, $P_\gamma=-(1.3\pm0.45)\times10^{-6}$. The present measurement is not inconsistent with information extracted from other processes since it involves a combination of two components of the pn force (transitions $^1S_0-^3P_0$ and $^3S_1-^1P_1$) different from the one which contributes to the N-nucleus weak interaction. The size of the first combination is however much larger than for the second one.

4. COMPARISON WITH THEORY

In comparison with theory, we consider information provided by the strengths of the N-nucleus weak interaction, polarized pp scattering and the circular polarization, P_γ, in the radiative thermal np capture. Theoretical predictions are obtained by assuming that the weak NN potential is dominated by the exchange of π, ρ and ω mesons, which should be checked by appropriate experiments in the future, and by employing to describe the strong interaction the de Tourreil-Sprung potential |44|, which is close to what is expected if a quark description of nucleons is used. To calculate the different quantities which characterize the strengths of the effective NN interaction appropriate for complex nuclei, we have used their relationship to the zero-energy PNC scattering amplitudes |38|, although the choice we made to describe the NN strong interaction allows more refined predictions. We thus have :

$$X_{\binom{pp}{nn}} = M^2(\overline{v}^0 \pm \overline{v}^1 + \frac{\overline{v}^2}{\sqrt{6}}) \quad , \quad X^0_{pn} = M^2(\overline{u} - \overline{v}^0 + 2\frac{\overline{v}^2}{\sqrt{6}}) \quad ,$$

$$X^{\pm}_{pn} = \pm M^2\overline{w} + \frac{1}{2} M^2(\overline{u} + \overline{v}^0 - 2\frac{\overline{v}^2}{\sqrt{6}})$$

with

$$M^2\overline{v}^{0,1,2} = 4.8\ M\rho^{0,1,2} =$$

$$-0.049(g_\omega h^{0,1}_\omega + g_\rho h^{0,1,2}_\rho) - 0.057(g_\omega h^{0,1}_\omega(1+\chi_s)+g_\rho h^{0,1,2}_\rho(1+\chi_V))$$

$$M^2\overline{w} = 10.7\ MC^1 = -0.040\ (g_\omega h^1_\omega - g_\rho h^1_\rho) - 0.058 g_\rho h^{1'}_\rho$$

$$M^2\overline{u} = 10.7\ M\lambda_t = -0.077(g_\omega h^0_\omega - 3g_\rho h^0_\rho) + 0.042(g_\omega h^0_\omega(1+\chi_s) - 3g_\rho h^0_\rho(1+\chi_V))$$

If the ρNN and ωNN strong tensor couplings χ_V and χ_S are identified with the anormalous nucleon magnetic moments μ_V and μ_S, quantities X_{pp}, X_{nn}, $X^{\pm}_{pn}$, X^0_{pn} and $X^{p,n}_N$ can be written as :

$$X_{\binom{pp}{nn}} = -0.10 g_\omega(h^0_\omega \pm h^1_\omega) - 0.32 g_\rho(h^0_\rho \pm h^1_\rho + \frac{h^2_\rho}{\sqrt{6}})$$

$$X^0_{pn} = -0.05 g_\rho h^0_\rho + 0.06 g_\omega h^0_\omega - 0.64 g_\rho \frac{h^2_\rho}{\sqrt{6}}$$

$$X^{\pm}_{pn} = \mp 0.040(g_\omega h^1_\omega - g_\rho h^1_\rho) \mp 0.058\ g_\rho h^{1'}_\rho - 0.070 g_\omega h^0_\omega$$
$$- 0.34 g_\omega h^0_\omega + 0.32\ g_\rho \frac{h^2_\rho}{\sqrt{6}}$$

$$X^{\binom{p}{n}}_N = \pm(5.5 f_\pi - 0.14 g_\omega h^1_\omega - 0.28 g_\rho h^1_\rho - 0.06 g_\rho h^{1'}_\rho)$$
$$-(0.17 g_\omega h^0_\omega + 0.66 g_\rho h^0_\rho)$$

A value of X^n_N much smaller than X^p_N implies that isoscalar and isovector parts of the N-nucleus weak interaction have the same magnitude. This is what is expected in the Weinberg-Salam model of weak interactions, where isoscalar terms are of the order of G, whereas isovector terms, whose the contribution is somewhat enhanced by the long range of the π exchange force they can produce are of the order of G $\sin^2\theta_W$ or $G(1-2\sin^2\theta_W)$. The main problem is to know whether the relative sign is such that the strength of the n-nucleus weak interaction is suppressed. Assuming that the isovector part of this interaction, $\frac{1}{2}(X^p_N - X^n_N) = 1.5\times10^{-6}$, is dominated by the π exchange contribution would imply :

$$f_\pi = +0.3 \times 10^{-6} \quad .$$

This sign is expected in the Weinberg-Salam model, whereas the magnitude would favor the smallest estimates of this coupling constant.

The isoscalar part of the N-nucleus weak interaction, $\frac{1}{2}(X_N^p+X_N^n) = 1.5\times10^{-6}$, depends on ρNN and ωNN weak coupling constants in the following way :

$$\frac{1}{2}(X_N^p + X_N^n) = -0.17 g_\omega h_\omega^0 - 0.66 g_\rho h_\rho^0 \quad .$$

When these coupling constants are calculated in the factorization approximation, the magnitude of $\frac{1}{2}(X_N^p+X_N^n)$ is reproduced, but the sign is opposite to what is required. $SU(6)_W$ results, which take into account corrections to this approximation give the correct sign and a magnitude 2-3 times larger. The right magnitude would be obtained however if a model of the strong interaction more repulsive at short distances, as the Reid-soft-core potential, had been used, or more probably, if corrections to the factorization approximation have only part of their $SU(6)_W$ strength, as it is expected.

The comparison with theory for the strength of the pp force, characterized by the quantity X_{pp} derived from the measurement of the asymmetry in polarized pp scattering at 15 MeV ($X_{pp}=(1.7\pm0.8)\times10^{-6}$), is somewhat similar to the one for the isoscalar part of the N-nucleus weak interaction. This is not unexpected since, as we mentionned earlier, the pp force contributes a large part of the p-nucleus weak interaction. Coupling constants calculated in the factorization approximation lead to a value of X_{pp} which is too small in magnitude and, most important, has the opposite sign. When corrections to this approximation calculated by using the $SU(6)_W$ symmetry are included, the correct sign is obtained whereas the magnitude turns out to be two times too large. Again, more repulsion in the NN strong interaction at short distances, or $SU(6)_W$ symmetry breaking effects would provide the right magnitude.

The last constraining information is provided by the circular polarisation, P_γ, of photons emitted in the radiative thermal np capture. Predictions based on the coupling constants calculated in the factorization approximation are too small by two orders of magnitude, as is well known, and the discrepancy is not alleviated by including corrections to this approximation calculated with the $SU(6)_W$ symmetry. Thus, the result of the comparison with theory for this process is quite different from the one in complex nuclei or pp scattering where some agreement seems possible. A confirmation of the measurement of the polarization on one hand and of the Weinberg-Salam model from leptonic and semileptonic processes on the other hand would probably lead to a severe revision of our concepts about PNC NN forces. A possible issue would be the presence in the potential of further contributions, which, in contrast to those due to ρ and ω exchanges, would not be suppressed in this process. This may be an explanation for the large effects found in recent calculations |45|, which, however, should be confirmed.

5. CONCLUSION

In determining the theoretical PNC NN potential, most efforts have dealt with the PNC meson-nucleon coupling constants. Recent progress in this field arises from a better understanding of strong interaction effects in nonleptonic hyperon decays. If the most important contributions are probably incorporated now in the calculation of these coupling constants, a precise estimate is still lacking. Thus, the πNN coupling constant, f_π, which governs the long range part of the PNC NN force, varies between $.3\times10^{-6}$ and 1.1×10^{-6}. The isoscalar ρNN and ωNN coupling constants, which are the largest among the VNN coupling constants, vary respectively in the range $(.9\times10^{-6},-2.1\times10^{-6})$ and $(-.2\times10^{-6},-1.2\times10^{-6})$, depending on the validity of the $SU(6)_W$ symmetry to estimate corrections to the factorization approximation.

On the phenomenological side, PNC effects in several complex nuclei are reasonably well described from a N-nucleus PNC interaction dominated by the proton part, whereas the present measurement of the asymmetry in pp scattering indicates that half of the strength of this interaction arises from the pp force. It is interesting to note there is no evidence for a different origin of parity-non-conservation in electromagnetic and pure nuclear processes. Because the circular polarization, P_γ, in thermal np capture depends on a combination of components of the pn force which has a negligeable contribution in other processes, its present measurement is not inconsistent with information available from other processes.

The comparison with predictions for the different components of the weak force based on the π, ρ and ω exchanges shows that, apart the circular polarization in np capture, most PNC effects can be accommodated in the Weinberg-Salam model of weak interactions and are consistent with a set of coupling constants close to the average expectations from this model. This statement, which represents our present understanding of these effects, is far however from being definitive. Because in most cases there is only one measurement or a large theoretical uncertainty, no process is providing a firm information. Thus a new measurement, or a more reliable calculation may change the above picture in which, already, the circular polarization in np capture does not fit. In this respect, the measurement of the asymmetry in pp and pd scattering are probably most important. A confirmation of the sign and magnitude of the asymmetry in polarized pp scattering would indicate that corrections to the factorization approximation used to calculate the short range part of the PNC NN force are quite large and thus would give some support to those calculated using the $SU(6)_W$ symmetry. Apart the interest for itself, a better accuracy of the measurement of the asymmetry in polarized p-d scattering, which has been shown to depend on a combination of contributions of pn and pp weak forces close to the one measured in odd-proton nuclei, would also provide information on the reliability of calculations in complex nuclei.

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