сообщения
объединенного
института
ядерных
исследований
дубна

E2-83-922

V.M.Dubovik, S.V.Zenkin*

SELF-CONSISTENT CALCULATION OF THE WEAK CONSTANTS IN THE PARITY NONCONSERVING NUCLEAR FORCES.

PNC NN Potential. Experimental Consequences

* Institute of Nuclear Research of the USSR Acad. of Sciences, Moscow

1983

Using obtained in our previous papers [1,2] (hereafter I and II) constants h_M of parity nonconserving (PNC) MNN ($M = \pi, \rho, \omega$) couplings we shall consider experimental consequences of the standard model $SU(2)_L \times U(1) \times SU(3)_c$ for PNC effects in low-energy NN and nuclear processes. For this aim we shall need the results of calculations of PNC effects in terms of constants h_M.

A description of PNC effects in terms of PNC NN interactions has been started about twenty years ago (see reviews [3]), however, till now not all reactions are succeeded to be calculated on that (microscopic) level. So, for example, in terms of h_M for the present it is impossible to calculate PNC effects in those (n, γ) reactions that go through the compound states, although the first data have been obtained just in a reaction of this type (see, review [4]), and at present very large PNC effects in these reactions have been discovered.

The first microscopic calculations of the PNC effects have been performed for the reactions $np \to d\gamma$, $\gamma d \to np$ and $nd \to t\gamma$ [5]. At present the microscopic calculations of PNC effects are carried out for a more wide class of few-nucleon processes and processes involving intermediate and heavy nuclei.

In recent years the experimental study of PNC effects in pp-scattering and in the region of intermediate nuclei has achieved a certain progress, and, as a result, there appear possibilities for the constants h_M to be fixed experimentally. To detail such possibilities is one of our tasks. We do not here carry out new calculations of nuclear processes; we only unify the previous calculations and confine ourselves to comment on their merits and drawbacks.

The paper is organized as follows:
In sect.1 we briefly present main types of PNC effects in nucleon and nuclear processes and their expressions in terms of the constants h_M. In sect.2 it is shown that PNC NN interactions do not depend on signs of constants of strong NN interactions and the PNC OBE (one-boson exchange) potential is written. In sect.3 we discuss to what extent our results are consistent with available experimental data and present expected values for some yet unmeasured PNC effects which may be useful for obtaining further information on the constants h_M.

I. PARITY NONCONSERVATION EFFECTS AT LOW ENERGY

Recall first specific features of the formation of constants h_M, denoting the ways of their calculation and significance of different contributions. For convenience we collect in Table I the values of constants h_M obtained in I, II and widely used semiphenomenological "best values" of $h_M (h_M^{bv})$ from ref.[6].

a) The constants h_M are determined by the sum of contributions of two types (differing in the PNC mechanisms in MNN vertices): $h_M = h_M^F + h_M^{NF}$.

b) Factorizable (F) parts of h_M are calculated without the use of confinement models. $h_\pi^F \propto f_\pi m_\pi^2 (m_u + m_d)^{-1} (m_s - m_u)^{-1}$, or in a soft-pion approximation $\propto \langle 0|\bar{q}q|0\rangle f_\pi^{-1} (m_s - m_u)^{-1}$, $h_V^F (V = \rho, \omega)$ contain only experimentally established constants: $h_V^F \propto g_A f_\rho^{-1}$ or $(F + 3D) f_\rho^{-1}$. The F contributions dominate in h_π and completely determine h_ρ^2, h_ω^0, h_φ^1.

c) The nonfactorizable (NF) parts of h_M have been computed within the MIT bag model (MBM). h_π^{NF} is calculated in the MBM straightforwardly (in the soft-pion approximation) whereas h_V^{NF} are calculated on the basis of approximate SU(6) symmetry of matrix elements $\langle MB'|\mathcal{H}^{PNC}|B\rangle^{NF}$ (see II, sect.3). The most important are NF contributions in h_ρ^0; NF contributions in h_ρ^2, h_ω^0 and h_ω^1 equal zero.

d) Constants $h_M^{\Delta I = 1} (h_\pi, h_\rho^1, h_\omega^1)$ are almost completely determined by interactions of neutral currents, while in h_ρ^0, h_ρ^2, h_ω^0 contributions of charged currents dominate.

e) To color interactions ($SU(3)_c$ component of the standard model) the most sensitive are the following constants: $h_\pi (h_\pi/(h_\pi)_{a_s=0} \simeq 2.7)$, $h_\rho^0 (h_\rho^0/(h_\rho^0)_{a_s=0} \simeq 15)$, $h_\rho^1 (h_\rho^1/(h_\rho^1)_{a_s=0} \simeq -1.5)$, and $h_\omega^0 (h_\omega^0/(h_\omega^0)_{a_s=0} \simeq -1.8)$. The constant h_ω^1 at $a_s \to 0$ is practically unaltered.

In nucleon (nuclear) systems the PNC NN interactions determined by these constants lead to the appearance in the states formed by strong interactions of components with opposite parity. In the case of continuum this means that nonzero are P-odd amplitudes $A^{PNC} = A^j_{s\ell, s'\ell'}$, $\ell' = \ell + (2k+1)$, $k = 0, 1, \ldots$; for the nuclear levels this means that states with definite energy have the form $\Psi_i = \Psi_i^\pi + \sum_{j \neq i} F_{ij} \Psi_j^{-\pi}$, where F_{ij} is the matrix determining admixture to a level i with parity π of levels with opposite parity $(-\pi)$.

Table 1

The values of h_M, calculated in the standard model in I, II; (C.C) and (N.C) are contributions of charged and neutral currents to h_M; in brackets the values of h_M at $a_s = 0$ (i.e., without gluon corrections) are given. In the last column the "best values" of h_M[6] are cited

	$h_M(C.C.)\times 10^7$	$h_M(N.C.)\times 10^7$	$h_M \times 10^7$	$h_M^{b.v.}$ [6]
h_π	0.0	1.3	1.3 (0.48)	4.6
h_ρ^0	-6.2	-2.1	-8.3 (-0.55)	-11.4
h_ρ^1	0.00	0.39	0.39 (-0.26)	-0.19
h_ρ^2	-15.5	8.8	-6.7 (-11.1)	-9.5
h_ω^0	-2.9	-1.0	-3.9 (+2.2)	-1.9
h_ω^1	0.0	-2.2	-2.2 (-2.2)	-1.1

Observable PNC effects can be divided into two classes (see, e.g., ref.[4]):

I. P-odd correlations: asymmetry in the cross section of the scattering of longitudinally polarized nucleons on nonpolarized targets $A_L = (\sigma_{\lambda=+1} - \sigma_{\lambda=-1})/(\sigma_{\lambda=+1} + \sigma_{\lambda=-1})$ (λ is the helicity of nucleons); asymmetry of γ-quantum emission A_γ (or of other particles: $p, a, \ldots$) in the radiative capture of polarized neutrons (or (n, p), (n, a) reactions) and in electromagnetic transitions in polarized nuclei: $\sigma = \sigma_0 (1 + A_\gamma \vec{p}_n \cdot \vec{k}_\gamma)$; circular polarization of γ-quanta in the radiative capture of nonpolarized neutrons by nonpolarized targets and in electromagnetic transitions in nonpolarized nuclei $P_\gamma = (\sigma(P=+1) - \sigma(P=-1))/(\sigma(P=+1) + \sigma(P=-1))$, $\sigma(P)$ is the emission cross section of photons with circular polarization P; a neutron spin rotation at a coherent propagation of neutrons through matter (angle ϕ).

Effects of this class are consequences of the interference of regular transitions (i.e., transitions without involving weak interactions: $A^j_{s\ell, s'\ell'}$, $\ell' = \ell + 2k$; $\Psi_i^\pi \to \Psi_k^\pi$) with nonregular ones (i.e., with A^{PNC}; $\sum_{j\neq i} F_{ij}\Psi_j^{-\pi} \to \Psi_k^{\pi'}$) and consequently, they are PNC effects of $O(G)$*.

II. The second class incorporates the parity-forbidden nuclear α-decays and (α,γ)-reactions. These effects are completely determined by a nonregular part of decaying (capturing) states: $\Gamma_\alpha \propto |F_{ij}\Psi_j^{-\pi} \to \Psi_k^{\pi'}|^2$ and are effects of $O(G^2)$.

Among numerous experimental data in this field (see revews [9,10]) a theoretical analysis in terms of constant h_M can be performed only for the processes which are the most simple in dynamics and in structure of involving states. In this cases a convenient (as well as necessary in most cases) element of the calculation scheme is the PNC NN potential V^{PNC} determined by PNC π-, ρ-, ω-exchanges.

With the aid of V^{PNC} the amplitudes A^{PNC} are usually calculated in the distorted - wave Born approximation:

$$A^{PNC} \simeq \langle \psi^{(-)} | V^{PNC} | \psi^{(+)} \rangle , \qquad (1)$$

and nonregular parts of nuclear wave functions in the first order of perturbation theory

$$\sum_{j\neq i} F_{ij}\, \Psi_j^{-\pi} = \sum_{j\neq i} \frac{\langle \Psi_j^{-\pi} | V^{PNC} | \Psi_i^{\pi} \rangle}{E_i - E_j}\, \Psi_j^{-\pi} \;{**}. \qquad (2)$$

The quantities $Q = A_L, A_\gamma, P_\gamma, \phi, \sqrt{\Gamma_\alpha}$ are then represented by linear combinations of the constants h_M:

$$Q = \sum_{M,i} H^i_M h^i_M , \qquad (3)$$

where coefficients H^i_M are proportional to the matrix elements (1) and/or (2). The structure of Q(3) remains, of course, unaltered also in the calculations which do not apply the PNC potential as well as in those which involve nontrivial relativistic effects [11] (see also [12]). We shall not, however, consider such (nonpotential) effects, because, they, in any case, do not exceed uncertainties of potential calculations***

---

*This class of effects includes also asymmetry of the emission of fragments in the fission of polarized nuclei [7], however, the complexity of such processes does not yet allow us to extract from it information on weak NN interactions [8].

**Wave functions $\psi^{\pm}$ and $\Psi_k^{\pm\pi}$ are calculated as a rule with some realistic strong potential.

***This statement is illustrated in ref. [13] devoted to the analysis of such uncertainties for P_γ in the reaction $np \to d\gamma$ and in refs. [11,12] in which estimations have been made for contributions of relativistic effects to $P_\gamma(np \to d\gamma)$.

originating from inaccurate knowledge of the behaviour of strong wave functions of nucleon systems at short distances*. Here we carry out the analysis on the basis of an approximation usually used for PNC NN interactions, the PNC one boson exchange (OBE) potential.

2. PNC NN POTENTIAL

The vertices of the parity conserving (PC) (strong) MNN interactions, are given by the Hamiltonian

$$\mathcal{H}^{PC}_{MNN} = ig_\pi \bar{N}\gamma_5 \vec{\tau}\vec{\pi} N + g_\rho \bar{N}(\gamma^\mu \vec{\tau}\vec{\rho}_\mu + \frac{\chi_V}{2M_N}\sigma^{\mu\nu}\vec{\tau}\partial_\nu \vec{\rho}_\mu)N + \qquad (4)$$
$$+ g_\omega \bar{N}(\gamma^\mu \omega_\mu + \frac{\chi_S}{2M_N}\sigma^{\mu\nu}\partial_\nu \omega_\mu)N .$$

According to our aim (an analysis of consequences of the standard model) we take the values of constants g_M and $\chi_{V,S}$ following from general statements of the hadron theory (the standard model is known to be consistent with the latter) rather than from fits of phases of strong NN interactions with the help of strong OBE potentials [15,16] (certainly nonadequate, even because of the inclusion of fictitious particles). Dispersion relations for $\pi^{\pm}p$ scattering amplitudes give us: $|g_\pi| \simeq 13{,}4$ [17]; the constants g_ρ and g_ω, due to the universality of vector mesons and SU(3) symmetry of $\mathcal{H}^{PC}_{MNN}$, are represented in the form: $g_\rho = 1/2 \cdot f_\rho$, $g_\omega = 3/2 \cdot f_\rho$, $|f_\rho| \simeq 5.1$ [17], hence also $\chi_V = \mu_p - \mu_n - 1 \simeq 3.7$, $\chi_S = \mu_p + \mu_n - 1 \simeq -0.12$, where μ_N are the nucleon magnetic moments.

For the calculation of observable effects g_M are usually assumed to be positive (see, e.g., [6,18]). We shall show that this assumption is unessential and that the products $g_M h_M$ characterizing the PNC NN interactions do not depend on the sign of g_M.

$g_\pi h_\pi$: considering that $h^F_\pi \propto f_\pi$, $h^{NF}_\pi \propto f_\pi^{-1}$ (see sect.3 in I) and $g_\pi \simeq \sqrt{2} M_N g_A f_\pi^{-1}$ (the Goldberger-Treiman relation [19]) we find

$$g_\pi h^F_\pi \propto M_N g_A , \quad g_\pi h^{NF}_\pi \propto \frac{g_\pi^2}{M_N g_A} \qquad (5)$$

(see also [20,21]).

$g_V h_V$: since $h^F_V \propto f_\rho^{-1}$ (see sect.2 in II) and $h^{NF}_V \propto \pm f_\pi^{-1}$, where the sign in front of f_π^{-1} corresponds to the sign of the product $f_\pi f_\rho^{-1}$ (this follows immediately from the calculation h^{NF}_V see sect.3 in II), and $g_V \propto f_\rho$, we have

---

*These difficulties forced us to look for new ways of the description of the short distance PNC effects (see [14]).

$$g_V h_V^F \propto f_\rho^0, \quad g_V h_V^{NF} \propto \pm f_\rho f_\pi^{-1} = |f_\rho f_\pi^{-1}|. \tag{6}$$

Thus, the products $g_M h_M$ ($= g_M h_M^F + g_M h_M^{NF}$) and, consequently, the PNC NN interactions do not depend on the sign of g_M.

The PNC OBE potential is uniquely determined by the diagrams of π-, ρ- and ω-exchanges in the first approximation in $\vec{p}_N/M_N$. The derivation of V_{OBE}^{PNC} is considered in detail in refs. [22,23], here we present only its final form

$$V_{OBE}^{PNC} = V_\pi^{PNC} + V_V^{PNC}, \tag{7}$$

$$V_\pi^{PNC} = \frac{i}{2\sqrt{2}} g_\pi h_\pi (\vec{\tau}_1 \times \vec{\tau}_2)^3 (\vec{\sigma}_1 + \vec{\sigma}_2) [\frac{\vec{p}}{M_N}, f_\pi(r)], \tag{8}$$

$$V_V^{PNC} = -g_\rho (h_\rho^0 \vec{\tau}_1 \vec{\tau}_2 + h_\rho^1 \frac{\tau_1^3 + \tau_2^3}{2} + h_\rho^2 \frac{3\tau_1^3\tau_2^3 - \vec{\tau}_1\vec{\tau}_2}{2\sqrt{6}}) \times \tag{9}$$
$$\times ((\vec{\sigma}_1 - \vec{\sigma}_2)\{\frac{\vec{p}}{M_N}, f_V(r)\} + i(1+\chi_V)\vec{\sigma}_1 \times \vec{\sigma}_2 [\frac{\vec{p}}{M_N}, f_V(r)]) +$$
$$+ g_\rho h_\rho^1 \frac{\tau_1^3 - \tau_2^3}{2} (\vec{\sigma}_1 + \vec{\sigma}_2)\{\frac{\vec{p}}{M_N}, f_V(r)\} - g_\omega (h_\omega^0 + h_\omega^1 \frac{\tau_1^3 + \tau_2^3}{2}) \times$$
$$\times ((\vec{\sigma}_1 - \vec{\sigma}_2)\{\frac{\vec{p}}{M_N}, f_V(r)\} + i(1+\chi_S)\vec{\sigma}_1 \times \vec{\sigma}_2 [\frac{\vec{p}}{M_N}, f_V(r)]) -$$
$$- g_\omega h_\omega^1 \frac{\tau_1^3 - \tau_2^3}{2} (\vec{\sigma}_1 + \vec{\sigma}_2)\{\frac{\vec{p}}{M_N}, f_V(r)\}.$$

Here $\vec{p} = 1/2 \cdot (\vec{p}_1 - \vec{p}_2)$, $f_M(r) = e^{-m_M r}/4\pi r$ and we set $m_\rho = m_\omega = m_V$. The pion potential has the effective radius* $r_\pi \simeq 3$ fm and determines a long-range part of V_{OBE}^{PNC}. The potential originated from vector meson exchanges constitutes a short-range part of V_{OBE}^{PNC}, its effective radius $r_V \simeq 0.6$ fm.

Note here, that the question concerning the role of 2M-exchanges in PNC NN interactions is not yet answered satisfactorily. It is natural to expect that among exchanges of that type 2π-exchanges are dominating**.

The potential $V_{2\pi}^{PNC}$ was most thoroughly studied in ref. [25]. It has been shown there that the contributions from $V_{2\pi}^{PNC}$ may amount to about 30% of the contributions from V_{OBE}^{PNC} (the structure of the expression (3) is not changed when $V_{2\pi}^{PNC}$ is taken into account). However as is noted in ref. [26] (see also [6,27]) the

---

* The effective radius r_M of the Yukawa potential $V_M \propto \frac{e^{-m_M r}}{r}$ we determine as the value of r for which the function $\Phi(r, m_M)/\Phi(0, m_M)$, where $\Phi(r, m_M) = \int_r^\infty d^3x \frac{e^{-m_M|x|}}{|x|}$ becomes exponentially small, i.e., $\Phi(r_M, m_M)/\Phi(0, m_M) = e^{-1}$. Hence $r_M \simeq (e+1)/(e-1)\, m_M^{-1} \simeq 2.2\, m_M^{-1}$.

** In strong NN interactions 2π- and combined $\pi\rho$-exchanges play an important role [15,24].

inclusion of $V_{2\pi}^{PNC}$ together with V_{OBE}^{PNC} leads to the problem of double counting. Following refs. [6,18,26] we shall suppose that the matrix elements (1) and (2) of the potential V_{OBE}^{PNC} take effective account of the leading part of 2π-exchange contributions.

For the analysis of experimental consequences of our results we make use of parametrizations of quantities $Q = A_L, A_\gamma, P_\gamma, \phi, \sqrt{\Gamma_\alpha}$ (based on the potential (7)-(9)) listed in Table 2; the corresponding references are given in the last column of the Table.

3. EXPERIMENTAL CONSEQUENCES

The values of PNC effects for our values of h_M are presented in Table 3. From this Table we see that except of two cases ($A_L(\vec{p}\alpha)$ and $P_\gamma(^{21}Ne)$) to be discussed below the calculated values of the effects are consistent with experimental data. And what is more, this agreement is a consequence of a joint action of all the components of the standard model (charged and neutral currents and quark-gluon interactions). This is especially clear in examples $\Gamma_\alpha(^{16}O)$, $P_\gamma(^{19}F)$, $P_\gamma(^{41}K)$, $P_\gamma(^{175}Lu)$ and $P_\gamma(^{181}Ta)$ calculated values of which are doubled due to the neutral currents and increase by an order of magnitude due to quark-gluon interactions.

We shall proceed now to analyse the consequences from experiments for individual constants h_M. We start with h_V. These constants completely determine $A_L(\vec{p}p)$, $P_\gamma(np \to d\gamma)$, $A_L(\vec{\gamma}d \to np$; $\Delta E_\gamma \simeq 0 \div 0.01$ MeV) and $\Gamma_\alpha(^{16}O)$ (see Table 2). We may conclude from the agreement of calculated and experimental values of $A_L(\vec{p}p)$ and $\Gamma_\alpha(^{16}O)$ that the standard model (with our approximations, see I, II) provides a realistic value for the combinations $\sim h_\rho^0 + h_\omega^0$ and $\sim h_\rho^1 + 1/\sqrt{6} \cdot h_\rho^2 + h_\omega^1$. If we take into account the smallness of $h_\rho^1 (\sim 10^{-8})$ and stability of h_ω^1 (see p. c) and e)), the same conclusion follows for h_ρ^2. A separate determination of h_ρ^0 and h_ω^0 would be favoured by the measurement of $P_\gamma(np \to d\gamma)$ or asymmetry A_L in the inverse process $\vec{\gamma}d \to np$ at $\Delta E_\gamma \simeq 0 \div 0.01$ MeV (at the threshold $A_L(\vec{\gamma}d \to np) = P_\gamma(np \to d\gamma)$). It is to be noted, however, that the values of coefficients $H_\rho^0(np \to d\gamma)$ are highly sensitive to the behaviour of the NN wave functions near the core ($r \lesssim 0.5$ fm), and for different strong potentials they may differ even in sign (see Table 2), that, in turn, leads to discrepancies in estimations of $P_\gamma(np \to d\gamma)$ (or $A_L(\vec{\gamma}d \to np)$) up to a factor of ~ 10 (see Table 3). Therefore, in these processes PNC interactions may rather be considered as a tool for investigating strong NN interactions at short distances.

Table 2

Parametrizations of PNC effects (in the form Eq. (3))

Process	Q	H_π	H_ρ^0	H_ρ^1	H_ρ^2	H_ω^0	H_ω^1	ref.
$\vec{p}+p\to p+p$	A_L							
E_p = 15 MeV		0	0.081	0.081	0.033	0.076	0.076	/18/
45 MeV		0	0.14	0.14	0.058	0.13	0.13	
$\vec{n}+H_2\to\vec{n}+H_2$	$\varphi(rad/m)$	-1.20	0.38	-0.01	-0.35	0.39	0.03	/28/
$n+p\to d+\vec{\gamma}$	P_γ	0	-0.028	0	-0.022	0.0073	0	/18/
$\vec{n}+p\to d+\gamma$	A_γ	-0.11	0	-0.001	0	0	0.003	/18/
$\vec{\gamma}+d\to n+p$	A_L							/29/
$E_\gamma - E_B$ = 0–0.01 MeV		0	0.0041	0	-0.012	0.0055	0	
1 MeV		-0.014	0.0015	-0.0001	-0.0018	0.0015	0.0002	
10 MeV		-0.059	-0.0018	-0.0003	0.0017	-0.0017	0.0008	
30 MeV		-0.14	-0.003	-0.001	0.003	-0.003	0.002	
$\vec{p}+d\to p+d$	A_L							
E_p = 15 MeV		-0.23	0.029	0.010	0	0.020	0.017	/18/
$\vec{n}+d\to\vec{n}+d$	$\varphi(rad/m)$	3.0	0.13	0.01	0	0.06	-0.10	/28/

Table 2 (continued)

Process	Q	H_π	H_ρ^0	H_ρ^1	H_ρ^2	H_ω^0	H_ω^1	ref.
$n+d\to t+\vec{\gamma}$	P_γ	-1.79	0.12	0.02	-0.11	0.09	0.08	/30/
$\vec{p}+\alpha\to p+\alpha$	A_L							
E_p = 46 MeV		-0.46	0.27	0.09	0	0.12	0.12	/31/
$\vec{n}+{}^4He\to\vec{n}+{}^4He$	$\varphi(rad/m)$	-0.97	-0.32	0.11	0	-0.22	0.22	/32/
${}^{16}O(2^-)\to{}^{12}C+\alpha$	$\sqrt{\Gamma_\alpha}\,(eV^{1/2})$	0	-9.4	0	0	-7.2	0	/18/
${}^{18}F(0^-\to1^+)$	$\pm P_\gamma$	3740	0	-450	0	0	-450	/33/
${}^{19}F(\frac{1}{2}^-\to\frac{1}{2}^+)$	A_γ	-100	37	12	0	21	12	/33/
${}^{21}Ne(\frac{1}{2}^-\to\frac{3}{2}^+)$	$\pm P_\gamma$	-77500	-30000	9300	0	-16800	9300	/33/
${}^{41}K(\frac{7}{2}^-\to\frac{3}{2}^+)$	P_γ	26	-7.5	-3.0	0.1	-5.8	-4.7	/18/
${}^{175}Lu(\frac{9}{2}^-\to\frac{7}{2}^+)$	P_γ	89	-24	-7.5	1.7	-18	-14	/18/
${}^{181}Ta(\frac{5}{2}^+\to\frac{7}{2}^+)$	P_γ	-8.1	2.1	0.56	-0.17	1.6	1.2	/18/

Table 3

Calculated and experimental values of PNC effects. (C.C.) and (N.C.) are contributions of charged and neutral currents to the effects; in brackets the values of Q^{th} at $\alpha_s = 0$ are given. Refs. are given only for the recent (after 1980) experimental data, the others are cited from ref. /9/

Process	Q	$Q^{(C.C.)} + Q^{(N.C.)} = Q^{th}$	Q^{exp}
$\vec{p}p$	$A_L \times 10^7$		
E_p=15 MeV		-1.2 - 0.1 = -1.3 (-0.43)	-1.2 ± 0.6
45 MeV		-2.1 - 0.2 = -2.3 (-0.76)	-2.3 ± 0.8
$\vec{n}H_2$	$\varphi \times 10^7$ (rad/m)	2.0 - 5.9 = -3.9 (+3.9)	-
$np \to d\vec{\gamma}$	$P_\gamma \times 10^7$	0.49 - 0.14 = 0.35 (0.28)	< 5 /34/
$\vec{n}p \to d\gamma$	$A_\gamma \times 10^7$	0.00 - 0.15 = -0.15 (-0.054)	0.6 ± 2.1
$\vec{\gamma}d \to np$	$A_L \times 10^7$		
ΔE_γ = 0-0.01 MeV		0.145 - 0.120 = 0.025 (0.14)	-
1 MeV		-0.025	-
10 MeV		-0.068	-
30 MeV		-0.17	-
$\vec{p}d$	$A_L \times 10^8$		
E_p=15 MeV		-2.4 - 4.1 = -6.5 (-1.2)	-3.5 ± 8.5 /35/
$\vec{n}d$	$\varphi \times 10^7$ (rad/m)	-0.98 + 3.7 = 2.7 (1.6)	-
$nd \to t\vec{\gamma}$	$P_\gamma \times 10^7$	0.7 - 3.7 = -3.0 (0.44)	-
$\vec{p}\alpha$	$A_L \times 10^7$		
E_p= 46 MeV		-2.0 - 1.5 = -3.5 (-0.39)	0.94 ± 0.97 /31/
$\vec{n}\,{}^4He$	$\varphi \times 10^7$ (rad/m)	2.6 - 0.82 = 1.8 (-1.3)	-

Table 3 (continued)

Process	Q	$Q^{(C.C.)} + Q^{(N.C.)} = Q^{th}$	Q^{exp}
^{16}O	$\sqrt{\Gamma_\alpha} \times 10^5 (eV^{1/2})$	0.79 + 0.31 = 1.1 |-0.11|	1.0 ± 0.1
^{18}F	$P_\gamma \times 10^3$	± { 0.00 + 0.57 = 0.57 (0.29)	-1.0 ± 1.8 /36/
^{19}F	$A_\gamma \times 10^5$	-2.9 - 2.5 = -5.4 (-0.52)	-7.9 ± 1.9 /37/
^{21}Ne	$P_\gamma \times 10^3$	± { 23.5 - 3.7 = 19.8 (-8.1)	0.8 ± 1.4 /38/
^{41}K	$P_\gamma \times 10^5$	0.61 + 0.69 = 1.3 (0.13)	2.0 ± 0.4
^{175}Lu	$P_\gamma \times 10^5$	1.7 + 2.3 = 4.0 (0.28)	5.5 ± 0.5
^{181}Ta	$P_\gamma \times 10^6$	-1.5 - 2.0 = -3.5 (-0.22)	-5.2 ± 0.5

As to the disagreement of the experimental and calculated value of $A_L(\vec{p}\alpha)$*, note that the latter is obtained with the coefficients H_M calculated within the potential approximation for $p\alpha$ scattering (see ref. /31/). A final conclusion on relation of a theoretical and experimental values of $A_L(\vec{p}\alpha)$ requires more refine both theoretical and experimental treatments.

As for the constant h_π, the available experimental data are more scarce as compared to those on h_V.

Theoretically, for the determination of the constant h_π most attractive are $A_\gamma(\vec{n}p \to d\gamma)$, $A_L(\vec{\gamma}d \to np;\ \Delta E_\gamma \geq 30$ MeV) and $P_\gamma(^{18}F)$. h_π does almost completely determine the first two quantities and dominates in the third one ** (see Table 2). The existing experi-

* According to the parametrization presented in Table 2 for $A_L(\vec{p}\alpha)$ the constants h_V give a dominant contribution to this effect.

** Uncertainties in the calculation of the coefficients H_π in $A_\gamma(\vec{n}p \to d\gamma)$ and $A_L(\gamma d \to np)$ do not exceed the factor of ~1.5; $H_\pi(^{18}F)$ is recalculated practically in a model-independent way from the measured probability of β-transition $^{18}Ne(0^+,1) \to {}^{18}F(0^-,0)$ /39,33/

mental data on $A_\gamma(\vec{n}p \to d\gamma)$ and $P_\gamma(^{18}F)$ give for h_π only the upper bound $h_\pi < 10.2 \times 10^{-7}$ (90%c.l.)which is too high to allow any non-trivial conclusions. Effects that are essentially contributed, together with h_π, by the constants h_V may also be considered as sources of information on h_π provided that the h_V contributions are known with a sufficient accuracy. The most interesting effects here are $A_L(\vec{p}d)$, $\phi(\vec{n}d)$, $P_\gamma(nd \to t\gamma)$, $\phi(n\,^4He)$, and $P_\gamma(^{21}Ne)$. To $A_L(\vec{p}d)$ and $P_\gamma(nd \to t\gamma)$ the constants h_π and h_V give contributions of the same sign. Taking account of the given estimate of $A_L(\vec{p}d)$ (contributions of h_π and h_V are almost equal here) one may expect that an increase of the measurement accuracy of this effect ~3 times will allow one to distinguish the values $h_\pi \simeq 1.3 \times 10^{-7}$ and $h_\pi^{bv} \simeq 4.6 \times 10^{-7}$ $(A_L(\vec{p}d)|_{h_\pi^{bv}} \simeq 14.1 \times 10^{-8})$; in the reaction $nd \to t\gamma$ h_π determines more than $2/3 \cdot P_\gamma$.The contributions of h_π and h_V to $\phi(\vec{n}d)$, $\phi(\vec{n}\,^4He)$,and $P_\gamma(^{21}Ne)$ are opposite in sign, that leads to a higher sensitivity of this quantities to the value of h_π. When h_π changes from 1.3×10^{-7} to h_π^{bv} (by ~ 3.5 times), the $\phi(\vec{n}d)^{theor.}$ increases* by~4.7 times, and $\phi(\vec{n}\,^4He)$ even changes its sign.

The quantity $P_\gamma(^{21}Ne)$ represents an exceptional case. This is illustrated in Fig.1, where in terms of the parameters $h^1 = h_\pi - 0.12(h_\rho^1 + h_\omega^1)$ and $h^0 = h_\rho^0 + 0.56 h_\omega^0$ recent experimental and calculated results are shown for the group of intermediate nuclei (^{18}F, ^{19}F, ^{21}Ne). Regions III and III' in the figure correspond to the parametrizations of $P_\gamma(^{21}Ne)$ from refs.[33,40] and[41] (variant C(F)). (Table 2 contains only first of these parametrizations; the second one has the form: $\pm P_\gamma(^{21}Ne) = -122500\,h^1 - 9900\,h^0$). Both the calculations of $H_M(^{21}Ne)$ have been performed within the shell model and differ in the structure of model spaces and in the form of effective strong interactions. It is seen that advanced nuclear calculations of the coefficients $H_M(^{21}Ne)$ (or even of the ratio H_ρ^0/H_π) will allow us to get the most exact experimental value for h_π at present.

The quantities $P_\gamma(^{41}K)$, $P_\gamma(^{175}Lu)$and $P_\gamma(^{181}Ta)$although they are measured with high accuracy help little in a separate determination of h_M because of their parametrization are practically multiple. Besides, in heavy nuclei the renormalization due to medium effects may be essential for the constants f_π and g_A[42] entering into h_M. This may be a reason for same discrepancy between calculated and experimental results for these quantities.

It is seen that the determination of the constants h_M from the data on parity nonconservation in NN and nuclear processes

*At h_V fixed.

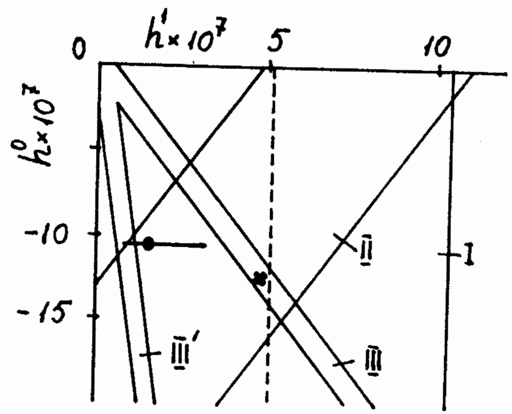

Fig.Restrictions on the combinations $h^1 = h_\pi - 0.12(h_\rho^1 + h_\omega^1)$ and $h^0 = h_\rho^0 + 0.56\,h_\omega^0$ following from the data on $P_\gamma(^{18}F)$ (region I),$A_\gamma(^{19}F)$ (region II), and $P_\gamma(^{21}Ne)$ (regions III, III') (90% c.l.). The regions I and II correspond to $H_M(^{18}F)$ and $H_M(^{19}F)$ from ref.[33]; region III to $H_M(^{21}Ne)$ from refs.[40,33], III' to $H_M(^{21}Ne)$ from ref.[41] version C(F). The black circle corresponds to our values of h_M (table 1); the segment, to the interval $0.6 \times 10^{-7} \lesssim h_\pi \lesssim 3.0 \times 10^{-7}$ (see Eq. (46) from I); the cross, to h_M^{bv}[6]. Dotted line denotes the upper limit for h^1, following from the data on $P_\gamma(^{18}F)$ if $H_\rho^0(^{18}F) < 0$.

is significantly complicated by uncertainties in the description of strong NN interactions at short distances and nuclear structure. Therefore, the study of PNC effects acquires still increasing interest (especially, with putting high-current accelerators in operation) in elementary processes: πN scattering[43,44], photo- and electroproduction of pions on nucleons[45], radiative capture of pions by protons[46]. Thus, the actually direct measurement of the constant h_π would be the measurement of asymmetry in the differential cross section at $\theta_0 = 163°$ of π^- charge-exchange on protons polarized along (+) and against (-) the pion momenta: $A_L(\pi^- p \to \pi^0 n) = (d\sigma^+ - d\sigma^-)/(d\sigma^+ + d\sigma^-)|_{\theta^0}$[44]. Using results of ref.[44] and $h_\pi = 1.3 \times 10^{-7}$ we find for A_L at T = 150 MeV (at the maximum absolute effect) the following value: $A_L(150\text{ MeV}) \simeq 0.6 \times 10^{-7}$.

We would like also to draw attention to the possibility of studying the PNC effects in $N\bar{N}$ systems. The PNC $N\bar{N}$ potential was obtained in terms of the constants h_M in ref.[23]. Because of a different spin-isospin structure of the potentials V_{NN}^{PNC} and $V_{N\bar{N}}^{PNC}$ the PNC effects observed in $N\bar{N}$ processes may be determined by combinations of h_M unusual for nucleon systems, e.g., in electromagnetic transitions in a bound $n\bar{p}(p\bar{n})$ system[47] $P_\gamma = \bar{H}_\rho^1 h_\rho^1 + \bar{H}_\omega^1 h_\omega^1$[23].

In the conclusion we note that at present the most keen problem in this field is still the problem of value of h_π. Being solved, it will allow us to get more exact comprehension of mechanisms responsible for the formation of PNC hadron-hadron interactions.

We are grateful to Yu.V.Gaponov, V.M.Lobashov, A.P.Serebrov, Yu.M.Tchuvilsky, N.A.Titov and L.A.Tosunyan for valuable discussion.

REFERENCES

1. Dubovik V.M., Zenkin S.V. JINR, E2-83-611, Dubna, 1983.
2. Dubovik V.M., Zenkin S.V. JINR, E2-83-615, Dubna, 1983.
3. Blin-Stoyle R.J. Fundamental Interactions and the Nucleus, N.A., 1973;
Gari M. Phys.Rep., 1973, C6, p. 317.
4. Abov Yu.G., Krupchitskii P.A. Usp.Fiz.Nauk, 1976, 118, p. 141.
5. Blin-Stoyle R.J., Feshbach H. Nucl.Phys., 1961, 27, p. 365; Partovi F. Ann.Phys., 1964, 27, p. 114; Danilov G.S. Phys. Lett., 1965, 18, p. 40.
6. Desplanques B., Donoghue J.F., Holstein B.R. Ann.Phys., 1980, 124, p. 449.
7. Danilyan G.V. Usp.Fiz.Nauk, 1980, 131, p. 329.
8. Sushkov O.P., Flambaum V.V. Usp.Fiz.Nauk, 1982, 136, p.3.
9. Robertson R.G.H. Proceedings of Neutrino '80; ed. E.Fiorini, N.Y.-L. 1982, p. 219.
10. Fiorini E. Nucl.Phys., 1982, A374, p. 577.
11. Kopeliovich V.B. Yadern. Fiz., 1982, 35, p. 716.
12. Friar J.L., McKellar B.H.J. Phys.Lett., 1983, 123B, p. 284.
13. Craver B.A. et al. Phys.Rev., 1976, D13, p. 1377.
14. Dubovik V.M., Kobushkin A.P. Report ITP-78-85, Kiev, 1978; Dubovik V.M., Obukhovsky I.T. Z.Phys. 1981, A299, p. 341; ibid., C10, p. 123; Simonov Yu.A. Preprint ITEP-31, Moscow, 1982.
15. Brown G.E., Jackson A.D. The Nucleon-Nucleon Interaction, N.Y., 1976.
16. Erkelenz K. Phys.Rev.,1974, 13C, p. 191.
17. Dumbrajs O. et al. Nucl.Phys., 1983, B216, p. 277.
18. Desplanques B. Nucl.Phys., 1980, A335, p. 147.
19. Goldberger M.C., Treiman S.B. Phys.Rev., 1958, 110, p. 1178.
20. Buccella F. et al. Nucl.Phys., 1979, B152, p. 461.
21. Desplanques B., Micheli J. Phys.Lett., 1977, 68B, p. 339.
22. Fischbach E., Tadic D. Phys.Rep., 1973, 6C, p. 123.
23. Dubovik V.M., Tosunyan L.A., Zenkin S.V. JINR, E2-80-671, Dubna, 1980.
24. Durso J.W. et al. Nucl.Phys., 1977, A278, p. 445.
25. Chemtob M., Desplanques B. Nucl.Phys., 1974, B78, p. 139.

26. Box M.A. et al. J.Phys., 1975, G1, p. 493.
27. Tadic D. Rep.Progr.Phys., 1980, 43, p. 67.
28. Serebrov A.P. Proceedings of the XIV Winter School of the L.I.Ya.F. for Nucl. and Elem.Part. Phys., USSR Acad.Sci., 1979, p. 28.
29. Oka T. Phys.Rev., 1983, D27, p. 523.
30. Moskalev A.N. Yadern.Fiz., 1969, 9, p. 163.
31. Jacquemart Ch. et al. Proceedings of the X International Conf. on Few Body Problem, Karlsruhe, 1983, p. 52.
32. Dmitriev V.F. et al. Phys.Lett., 1983, 125, p. 1.
33. Adelberger E.G. et al. Phys.Rev., 1983, C27, p. 2833.
34. Knyaz'kov V.A. et al. Pis'ma ZhETF, 1983, 38, p. 138.
35. Nagle D.E. et al. In: High Energy Physics with Polarized Beams and Targets (Argone, 1978), AIP Conf.Proc. N51 ed. by G.Tomas (AIP, N.Y., 1978), p. 224.
36. Ahrens et al. Nucl.Phys., 1982, A390, p. 486.
37. Elsener K. et al. Proceedings of the X International Conf. on Few Body Problem, Karlsruhe, 1983, p. 55.
38. Earle E.D. et al. Nucl.Phys., 1983, A396, p. 221.
39. Adelberger E.G. et al. Phys.Rev.Lett., 1981, 46, p. 695; Haxton W.C. Phys.Rev.Lett., 1981, 46, p. 698.
40. Haxton W.C., Gibson B.F., Henley E.M. Phys.Rev.Lett., 1980, 45, p. 1677.
41. Brown B.A., Richter W.A., Godwin N.S. Phys.Rev.Lett., 1980, 45, p. 1681.
42. Akhmedov E.Kh., Gaponov Yu.V. Yadern.Fiz., 1979, 30, p.1331.
43. McKellar B.H.J., Pick P. Nucl.Phys., 1970, B22, p. 625; Barroso A., Tadić D., Trampetić J. MPI-PAE/PTh 18/83, München 1983.
44. Gershtein S.S., Folomeshkin V.N., Khlopov M.Yu. Yadern.Fiz., 1974, 20, p. 737.
45. Rekalo M.P. KhFTI 78-9, 78-42, Kharkov, 1978; Woloshyn R.M. Can.J.Phys., 1979, 57, p. 805.
46. Hwang W.-Y., Henley E.M. Nucl.Phys., 1981, A356, p. 365.
47. Shapiro I.S. Phys.Rep., 1978, 35C, p. 129.

Received by Publishing Department
on December 30, 1983.

WILL YOU FILL BLANK SPACES IN YOUR LIBRARY?

You can receive by post the books listed below. Prices - in US $, including the packing and registered postage

D4-80-385	The Proceedings of the International School on Nuclear Structure. Alushta, 1980.	10.00
	Proceedings of the VII All-Union Conference on Charged Particle Accelerators. Dubna, 1980. 2 volumes.	25.00
D4-80-572	N.N.Kolesnikov et al. "The Energies and Half-Lives for the α - and β-Decays of Transfermium Elements"	10.00
D2-81-543	Proceedings of the VI International Conference on the Problems of Quantum Field Theory. Alushta, 1981	9.50
D10,11-81-622	Proceedings of the International Meeting on Problems of Mathematical Simulation in Nuclear Physics Researches. Dubna, 1980	9.00
D1,2-81-728	Proceedings of the VI International Seminar on High Energy Physics Problems. Dubna, 1981.	9.50
D17-81-758	Proceedings of the II International Symposium on Selected Problems in Statistical Mechanics. Dubna, 1981.	15.50
D1,2-82-27	Proceedings of the International Symposium on Polarization Phenomena in High Energy Physics. Dubna, 1981.	9.00
D2-82-568	Proceedings of the Meeting on Investigations in the Field of Relativistic Nuclear Physics. Dubna, 1982	7.50
D9-82-664	Proceedings of the Symposium on the Problems of Collective Methods of Acceleration. Dubna, 1982	9.20
D3,4-82-704	Proceedings of the IV International School on Neutron Physics. Dubna, 1982	12.00
D2,4-83-179	Proceedings of the XV International School on High-Energy Physics for Young Scientists. Dubna, 1982	10.00
	Proceedings of the VIII All-Union Conference on Charged Particle Accelerators. Protvino, 1982. 2 volumes.	25.00
D11-83-511	Proceedings of the Conference on Systems and Techniques of Analitical Computing and Their Applications in Theoretical Physics. Dubna,1982.	9.50
D7-83-644	Proceedings of the International School-Seminar on Heavy Ion Physics. Alushta, 1983.	11.30
D2,13-83-689	Proceedings of the Workshop on Radiation Problems and Gravitational Wave Detection. Dubna, 1983.	6.00

Orders for the above-mentioned books can be sent at the address:
Publishing Department, JINR
Head Post Office, P.O.Box 79 101000 Moscow, USSR

Дубовик В.М., Зенкин С.В.
E2-83-922
Самосогласованный расчет слабых констант в несохраняющих четность ядерных силах. НЧ NN потенциал. Экспериментальные следствия

Обсуждаются экспериментальные следствия, к которым приводят найденные нами в предыдущих работах /1,2/ на основе стандартной теории $SU(2)_L \times U(1) \times SU(3)_c$ константы несохраняющих четность πNN, ρNN и ωNN взаимодействий. Показано, что НЧ NN взаимодействия не зависят от знаков констант сильных πNN, ρNN и ωNN взаимодействий. Приведен НЧ NN OBEP, на основе которого проводится анализ эффектов НЧ. Констатируется согласие полученных значений $h_{\rho,\omega}$ с имеющимися низкоэнергетическими экспериментальными данными. Показано, что это согласие достигается в результате проявления всех компонент стандартной теории: заряженных и нейтральных токов и цветовых взаимодействий. Приведены ожидаемые величины ряда интересных для получения более определенной информации о h_M еще не измеренных эффектов.

Работа выполнена в Лаборатории теоретической физики ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна 1983

Dubovik V.M., Zenkin S.V.
E2-83-922
Self-Consistent Calculation of the Weak Constants in the Parity Nonconserving Nuclear Forces.PNC NN Potential. Experimental Consequences

We discuss experimental consequences which the constants of parity non-conserving (PNC) MNN ($M = \pi, \rho, \omega$) couplings h_M,calculated in our previous papers /1,2/ on the basis of the standard $SU(2)_L \times U(1) \times SU(3)_c$ theory, result in. It is argued that the PNC NN interactions do not depend on signs of strong MNN constants. For estimations of the PNC effects the results of description of nucleon and nuclear processes in the framework of PNC OBE potential are used. There is observed a rather good agreement, on the whole, of our values of h_M with available low-energy experimental data and it is demonstrated that the agreement is a consequence of a joint action of all the components of the standard model, i.e., charged and neutral current and QCD effects. Predictions for a number of processes (not measured for the present) valuable for more elaborate conclusions are provided.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna 1983