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A new determination of the parity violating pion-nucleon coupling constant

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Parity violations (P.V.) in nuclear physics have recently received considerable interest both experimentally[1] and theoretically[2]. A basic quantity is the parity-violating pion-nucleon coupling constant F_π ; by using P.C.A.C. and Current Algebra one can write

$$F_\pi \equiv i \langle p\pi^- \mid H_{PV} \mid n\rangle \sim 2/f_\pi \langle p \mid H_{PC} \mid p\rangle \tag{1}$$

where H_{PV} and H_{PC} are the parity violating and parity conserving weak, $\Delta S=0$, non leptonic hamiltonians. In the following we shall describe a new determination of F_π and its phenomenological consequences; a systematic study can be found elsewhere[2]. H_{PC} can be written as follows:

$$H_{PC} = \sqrt{2}\ G \sin^2\theta_c (C_+O_+ + C_-O_-) + \sqrt{2}\ G\ ((1-2\sin^2\theta_W)(C_-O_- - C_+O_+) - \sin^2\theta_W/3\sum_1^4 C_\alpha O_\alpha) \tag{2}$$

where $C_\pm$, C_α are QCD coefficients (choosing as the onset of the scaling $\mu \simeq 0.8$ GeV and $\Lambda_{QCD} = 0.1$ GeV, one has $C_+ = 0.77$, $C_- = 1.67$, $C_\alpha = (1.08, -0.01, -0.01, -0.27)$) and θ_c, θ_W are the Cabibbo and Weinberg angles respectively. The local operators $O_\pm$, O_1, O_4 are given by (due to the smallness of C_2 and C_3, O_2 and O_3 play no role):

$$\begin{aligned} O_\pm &= 1/8\ (\{(\{\ \bar{u}\gamma_\mu s\ \bar{s}\gamma^\mu u \pm \bar{u}\gamma_\mu u\ \bar{s}\gamma^\mu s\ \} - u\to d\ ) - s\to c\ \} + \gamma_\mu \to \gamma_\mu\gamma_5) \\ O_1 &= 1/2\ (\ \bar{u}\gamma_\mu u - \bar{d}\gamma_\mu d)\ \bar{q}\gamma^\mu q \\ O_4 &= 1/2\ (\ \bar{u}\gamma_\mu\gamma_5\lambda^\alpha u - \bar{d}\gamma_\mu\gamma_5\lambda^\alpha d\ )\ \bar{q}\gamma^\mu\gamma_5\lambda^\alpha q \end{aligned} \tag{3}$$

where $\bar{q}\,\Gamma q \equiv \sum_q \bar{q}\Gamma q$ and λ^α are colour matrices.

In previous calculations of F_π[3] emphasis has been given to the so-called factorized terms which are proportional to the matrix elements of scalar densities between nucleons; for istance, by making a Fierz transformation of the O_4 operator, it is easy to show that one obtains the following contribution:

$$F_\pi^{fact} = 2\sqrt{2}/3\ G \sin^2\theta_W\ C_4\ 8/9\ f_\pi\ m_\pi^2\ /(m_u + m_d)\ (d + f) \simeq -1.19\ 10^{-7} \tag{4}$$

where $f_\pi = 0.95\ m_\pi$, $m_u + m_d = 12$ MeV; $d=-0.4$, $f= 1.3$ are the d and f which supply SU(3) mass splittings in the baryon octet. As for the contributions from the other operators $O_\pm$, O_1 , our method consists in writing dispersion relations for their invariant amplitudes. We consider the contribution of the low-lying poles: the $1/2^+$ baryon octet, the $3/2^+$ decuplet and the $3/2^-$ octet as well as the continuum integral, parametrized à la Regge. In Table I we give our calculated different contributions to F_π ; their sum is

$$F_\pi = (\ 2.1 - 5.5)\cdot 10^{-7} \tag{5}$$

Table I. Different contributions to $F_\pi \cdot 10^7$.

factorized contribution	$1/2^+$	$3/2^+$	$3/2^-$	continuum
-1.19	-0.98	+0.41	-0.12	3.96 - 7.36

The main difference between our result in eq. (5) and previous findings[3)] is in the sign of F_π that turns out to be opposite ($F_\pi \equiv -f_\pi^{DDH}$). Nevertheless we find that a positive and small value of F_π : $F_\pi \simeq + 2\cdot 10^{-7}$ is compatible with experimental results of P.V. in the systems ^{18}F, ^{19}F, ^{21}Ne, $p\alpha$ elastic scattering at 46 MeV, low energy pp elastic scattering, provided that the tensorial coupling constant[3)] $h_\rho^{1'}$ is large: $h_\rho^{1'} \simeq -150\cdot 10^{-7}$. In Table II we give experimental results, fitted values and theoretical expressions for different systems. Even though we are not able to extend our calculation of F_π to the ρ and ω P.V. exchanges, we may say that large values of $h_\rho^{1'}$ and h_ρ^2, as used in Table II, are not surprising, as only these two couplings are not constrained by Ward identities and approximate Vector Meson Dominance (VMD) to be small[5)] (exact VMD would give $h_\rho^o = h_\omega^o = h_\rho^1 = h_\omega^1 = 0$).

Table II. Comparison between experimental results (circular polarization P_γ, asymmetries A_γ and A) and theoretical expressions for P.V. in different systems. Data and nuclear matrix elements are from Refs. 1) and 4). Fitted values are for $\bar{h}_\rho^o \simeq h_\rho^o + 0.6\, h_\omega^o \simeq h_\rho^o + h_\omega^o \simeq -10$; $\bar{h}_\rho^1 \simeq h_\rho^1 + 1.7\cdot h_\omega^1 \simeq h_\rho^1 + h_\omega^1 \simeq -15$; $h_\rho^{1'} \simeq -150$; $h_\rho^2 \simeq -30$; $\bar{F}_\pi = F_\pi + 0.11\bar{h}_\rho^1 + 0.024\, h_\rho^{1'} \simeq -3.25$. Units are 10^{-7}.

System	Measured value	Fitted value	Theoretical expression
pp	$A = -2.50 \pm 0.75$	-2.6	$0.07(h_\rho^o + h_\omega^o + h_\rho^1 + h_\omega^1 + h_\rho^2/\sqrt{6})$
$p\alpha$	$A = -3.34 \pm 0.93$	-2.5	$0.34\, \bar{F}_\pi + 0.14\, \bar{h}_\rho^o$
^{18}F	$P_\gamma = (-4.2 \pm 7)10^3$	$\pm 14.5\cdot 10^3$	$\pm 4450\, \bar{F}_\pi$
^{19}F	$A_\gamma = -740 \pm 190$	-620	$90\, \bar{F}_\pi + 33\, \bar{h}_\rho^o$
^{21}Ne	$P_\gamma = (8 \pm 14)10^3$	$\pm 21\cdot 10^3$	$\pm(28350\, \bar{F}_\pi - 11340\, \bar{h}_\rho^o)$

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