Estimates of the effects of parity violation in quasi-nuclear systems

V. M. Dubovik and L. A. Tosunyan
Joint Institute for Nuclear Research

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Parity violation (PV) in a quasi-nuclear system is dramatically different from that in a nucleus. Quantitatively, the relevant effects may increase by several orders of magnitude.

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Dalkarov *et al.*[1] and Shapiro[2] have predicted the existence of a quasinuclear system (QS): the existence of $\bar{N}N$ that are bound by nuclear forces. Such a system is not as loosely bound as a deuteron, since, in terms of the OVE potential, the attraction in it is provided by an ω meson; $r_{\bar{N}N} \lesssim 1$ F. That fact, together with the other properties of the system, give rise to curious parity violating (PV) effects in the γ transitions in the QS. Note that the QS is instantly annihilated if its quarks and antiquarks fluctuate in a small volume $r \sim r_A \approx 1/2\, M_N \approx 0.1$-$0.2$ F. As a result, the potential contribution[3,4] to PV in a QS presumably should exceed the quark-nuclear contribution,[5] in contrast with the situation in a deuteron ($np \rightarrow d\gamma$ reaction[6]).

We estimate the degree of circular polarization P_γ for the transitions in Fig. 1, by using the equation

$$P_\gamma = \frac{2 < E1 > < \widetilde{M1} >}{< E1 >^2 + < M1 >^2} \approx 2 \frac{< \widetilde{M1} >}{< E1 >}, \qquad (1)$$

where

$$< \widetilde{M1} > = \frac{< 2 \mid \bar{V} \mid 1 >}{E_1 - E_2} < M1 > .$$

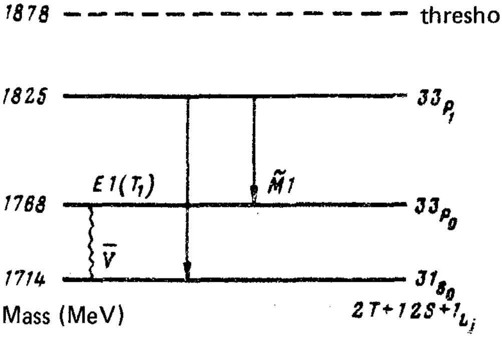

Fig. 1

Here $\langle E1\rangle$ and $\langle\widetilde{M}1\rangle$ are the amplitudes of the regular and irregular transitions and V is the parity-violating potential of weak interaction in the $\overline{N}N$ system (it significantly changes the spin-isospin structure as a result of transition from NN to $\overline{N}N$; its general form will be represented in a future paper).

The $\mathbf{E}_1$ operators, in which the toroidal moment $\mathbf{T}_1$ is taken into account,[7,8] $\mathbf{M}_1$, and part of the $\overline{V}$ potential, which is allowed by the selection rules, have the following form:

$$\mathbf{E}_1 = \frac{\partial}{\partial t}\mathbf{Q}_1 + \omega^2\mathbf{T}_1 = \sum_{i=1,2}\left\{-\frac{e_i}{M_i}\mathbf{p}_i + \omega^2\left(\frac{e_i}{10M_i}r_i^2\mathbf{p}_i\right) - \frac{\mu_c}{2}\left[\mathbf{r}_i x\left(\mu_i\vec{\sigma}_i + \frac{2}{5}g_i\mathbf{l}_i\right)\right]\right\} \tag{2}$$

$$\mathbf{M}_1 = \mu_o\sum_{i=1,2}(\mu_i\vec{\sigma}_i + g_i\mathbf{l}_i), \tag{3}$$

$$\overline{V} = \vec{V}_v(r) = -\frac{Gg_A m^2}{8\sqrt{2}M_N}\left[(\vec{\sigma}_1 - \vec{\sigma}_2)\{\mathbf{p}_1 - \mathbf{p}_2, f(mr)\}(c\zeta - 3c')\right.$$
$$\left. + i(\vec{\sigma}_1 \times \vec{\sigma}_2)[\mathbf{p}_1 - \mathbf{p}_2, f(mr)](\overline{\mu}_v c\zeta - 3\overline{\mu}_s c')\frac{\tau_3^1 + \tau_3^2}{2}\right., \tag{4}$$

$$v_o = \rho, \omega; \quad m_\rho = m_\omega \equiv m, \quad \mu_o = \frac{e}{2M_N}; \quad \overline{\mu}_v = 4{,}7; \quad \overline{\mu}_s = 0{,}12; \quad \zeta = 0{,}4 \text{ (Ref. 4)}$$

where $\mathbf{r}_i$ is the coordinate, $\mathbf{p}_i$ is the momentum, M_i is the mass, e_i is the charge, μ_i is the spin magnetic moment, and g_i is the orbital magnetic moment of the ith particle.

In calculating the PV effects, we have observed the following peculiarities of the $\overline{N}N$ system: 1) The contribution of the toroidal part is substantial in the $\mathbf{E}_1$ operator; however, the $\mathbf{E}_1$ transition in the γ-ray transitions in Fig. 1 is entirely attributable to the spin part of the T_1 operator because of the selection rules. 2) $P_\gamma = 0$ for the γ-ray transitions between the states $\overline{N}N(T_3 = 0) = 1/\sqrt{2}\ (\overline{p}p \pm \overline{n}n)$. 3) The numerical values of P_γ for the γ-ray transitions in Fig. 1 are:

$$P_\gamma = \pm(9{,}27\zeta c - 7{,}55c') = \begin{cases} \pm 0{,}8\ \ 10^{-6} & c = c' = -0{,}20 \text{ (Ref. 4)} \\ \pm 0{,}5\ \ 10^{-6} & c = c' = -0{,}13 \text{ (Ref. 4)} \\ \pm 1{,}2\ \ 10^{-6} & c = -0{,}084;\ c' = -0{,}20 \text{ (Ref. 9)} \end{cases} \tag{5}$$
$$E_\gamma = 111 \text{ MeV}$$

Here the plus(+) sign corresponds to the $\overline{n}p$ system and the minus (-) sign to the $\overline{p}n$ system.

Summary: i) P_γ for the transitions in a QS exceed the calculated values of P_γ in the $np \to d\gamma$ reaction by a factor of $\sim 10^2$; ii) since P_γ for $\overline{N}N$ are determined by small constants c and c', there exists, in principle, a unique opportunity to measure them; iii) since P_γ occurs only in the transitions of the $\overline{p}n$ (or $\overline{n}p$) system, the target for $\overline{p}$ must be a nuclear target [if the transition $A(\overline{p}p) \to B(\overline{n}p) + \pi^-$ is suppressed];

iv) since the PV effect is statistically suppressed because of the competition between the annihilation channel $Y = \Gamma_\gamma/\Gamma_A \sim 10^{-2}$ and the small probability of the transition $W[A(\bar{p}p) \rightarrow B$ (upper level) $+ \gamma(\pi)] \sim 10^{-2}$, it should be thoroughly investigated in the reactions $\bar{p}p \rightarrow \bar{p}p$, $\bar{N}N \rightarrow$ into π mesons, and others.

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[1] O. D. Dalkarov, V. B. Mandelzweig, and I. S. Shapiro, Nucl. Phys. **B21**, 88 (1970).

[2] I. S. Shapiro, Phys. Rep. **35C**, 122 (1978).

[3] E. Fishbach and D. Tadic, Phys. Rep. **6C**, 123 (1973).

[4] V. M. Dubovik, V. S. Zamiralov, and S. V. Zenkin, J. I. N. R. E2-12381, Dubna, 1979; J. I. N. R. E2-80-502, Dubna, 1980.

[5] V. M. Dubovik and A. P. Kobushkin, ITP-78-85E, Kiev, 1978; V. M. Dubovik and I. T. Obukhovsky, J. I. N. R. PZ-80-501; E2-80-554; E2-80-555, Dubna, 1980.

[6] V. M. Lobashov *et al.*, Nucl. Phys. A197, 241 (1972).

[7] V. M. Dubovik and A. A. Cheshkov, Fiz. Elem. Chastitis At. Yadra **5**, 791 (1974) [Sov. J. Part. Nucl. **5**, 318 (1974)]; V. M. Dubovik, J. I. N. R. Comm. E2-9262, Dubna, 1975.

[8] V. M. Dubovik, R. A. Eramzhyan, and I. A. Tosunyan, J. I. N. R. Comm. E4-9979, Dubna, 1976.

[9] B. Desplanques, J. F. Donoghue, and B. Holstein, Ann. Phys. (N.Y.) **124**, 449 (1980).

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