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Estimation of parameters in parity-violating nuclear force using single-Z-boson factorisation relations

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Abstract. Using suitable factorisation relations and factorisation dependent neutral-current parameters of Hung and Sakurai, the neutral current contributions to the parity violating parameters in nuclear force are estimated. Using Cabbibo rotation and Fierz transformation, the charge current contribution is added. It is found that three out of four parity violating parameters can be calculated with respect to their signs and magnitudes. The range of values of the other parameter appears to be small.

Keywords. Factorisation relations; parity violating nuclear force.

1. Introduction

Although parity violation in the electron-hadron and neutrino-hadron sectors has been well understood by the standard model (Weinberg 1967; Salam 1968), there exist glaring discrepancies between experimental data and model-calculations, (Dutta *et al* 1977, Donoghue and Holstein 1980, 1981; Box *et al* 1976, Galic *et al* 1976) in the case of parity violation in nucleon-nucleon interactions. Apart from the existing controversies regarding the signs and magnitudes of parity violating inter-nucleon potentials, the experimental value of the circular polarisation of photons in the thermal neutron capture of the process $n + p - d + \gamma$ appears to be two orders of magnitude higher than the theoretical calculations using several models, including the standard one. In view of this, a drastic modification of our insight into either the weak interaction models or nuclear forces has also been called for (Galic *et al* 1976). But before going in for such drastic modifications, an estimation of parity violating parameters in nuclear forces is essential without taking recourse to any particular gauge model. In this note, without entering into the part of calculation involving complications of non-leptonic and nuclear physics, we estimate values of parameters contributing to the parity-violating nuclear force using suitable factorisation relations and factorisation-dependent numerical computations of neutral current parameters in other sectors recently obtained by Hung and Sakurai (1979). We then add charged current contributions using Cabbibo rotation and Fierz transformation.

2. Factorisation relations and numerical estimation of neutral current parameters

We use the definitions of neutral current parameters and notations as adopted by Parida and Rajasekaran (1979) and Hung and Sakurai (1979). Parida and Rajasekaran (1979) have derived factorisation relations including the parity-violating-neutral-current parameters in the hadron-hadron sector. Throughout this note we will assume $\mu - e$ universality, use quack model and the single-Z-boson factorisation relations. In this sense our analysis is not a model-independent one. At first we note that using the factorisation relations (14a)–(14j) of Parida and Rajasekaran (1979) the experimentally determined value of the asymmetry parameter h_{AA} (Heuer 1980) and the factorisation dependent numerical values of the relevant parameters of Hung and Sakurai (1979) result in a very poor determination of the parameter h_{VA} and consequently also of ξ, η, ζ and ρ with large errors. (Hazra and Parida 1981).

To obtain an improved estimation of the parameters we rewrite the factorisation relations (Parida and Rajasekaran 1979) in a suitably modified form eliminating the parameter h_{VA},

$$\frac{\tilde{\alpha}}{\gamma} = \frac{\alpha}{\gamma} \quad \text{(1a)} \qquad \frac{\tilde{\beta}}{\tilde{\delta}} = \frac{\beta}{\delta} \quad \text{(1b)}$$

$$g_v/g_A = \frac{\alpha\tilde{\beta}}{\tilde{\alpha}\beta} \quad \text{(1c)} \qquad \xi = \tilde{\alpha}\beta/g_A \quad \text{(1d)}$$

$$\eta = \tilde{\gamma}\delta/g_A \quad \text{(1e)} \qquad \xi = \tilde{\alpha}\delta/g_A \quad \text{(1f)}$$

$$\rho = \tilde{\gamma}\beta/g_A. \quad \text{(1g)}$$

It may be remarked that these seven relations can be obtained using the procedure of Parida and Rajasekaran (1979) and considering the four phenomenological effective Lagrangians in the neutrino-hadron, neutrino-electron, electron-hadron and hadron-hadron sectors. Using the following factorisation-dependent numerical estimation of the parameters (Hung and Sakurai 1979)

$$\tilde{\alpha} = 0{\cdot}72 \pm 0{\cdot}25, \quad \text{(2a)} \qquad \tilde{\gamma} = 0{\cdot}38 \pm 0{\cdot}28, \quad \text{(2b)}$$

$$\beta = 0{\cdot}92 \pm 0{\cdot}14, \quad \text{(2c)} \qquad \delta = 0{\cdot}06 \pm 0{\cdot}14, \quad \text{(2d)}$$

$$g_A = -(0{\cdot}56 \pm 0{\cdot}14), \quad \text{(2e)}$$

in (1d) – (1g) we obtain

$$\xi = 1{\cdot}18 \pm 0{\cdot}53, \quad \text{(3a)} \qquad \eta = -(0{\cdot}04 \pm 0{\cdot}09), \quad \text{(3b)}$$

$$\zeta = 0{\cdot}077 \pm 0{\cdot}183, \quad \text{(3c)} \qquad \rho = -(0{\cdot}624 \pm 0{\cdot}490). \quad \text{(3d)}$$

The errors in (3a)–(3d) have been estimated using the standard procedure (Melissinos 1969) and making the approximation that the errors in (2a)–(2e) are uncorrelated statistical errors. Although the estimation of errors may not be the best possible, other refinements over this approximation may not be called for in view of large errors in (3a)–(3d). Even though the errors are rather large the signs and magnitudes of the two parameters ξ and ρ are clearly determined. Although no such determination has been possible for η and ζ, only their ranges of variation are known from this estimation.

These factorisation dependent values of the parameters may be compared with the predictions of the standard model (Weinberg 1967; Salam 1968) with $\sin^2\theta_\omega = 0{\cdot}23$,

$$\xi = 2 - 4\sin^2\theta_\omega = 1{\cdot}08, \quad \eta = 0,$$

$$\zeta = 0, \quad \rho = -\frac{4}{3}\sin^2\theta_\omega = 0{\cdot}306. \tag{4}$$

Taking into account the error corridors in (3a)–(3d), these values are consistent with factorisation-dependent estimation.

3. Inclusion of charged current contributions

Neglecting contributions due to strange quarks and using cabbibo rotation and Fierz transformation, the charged current contribution to the effective Lagrangian can be added to the neutral current contribution resulting in the following modifications (Parida and Rajasekaran 1979)

$$\xi_{\text{tot}} = \xi - 2\cos^2\theta_c,$$

$$\eta_{\text{tot}} = \eta + 2\cos^2\theta_c, \tag{5}$$

while keeping ζ and ρ unchanged. Using (3a)–(3d), (5) and $\theta_c = 0{\cdot}22$ we have

$$\xi_{\text{tot}} = -(0{\cdot}723 \pm 0{\cdot}53), \quad \eta_{\text{tot}} = 1{\cdot}863 \pm 0{\cdot}09,$$

$$\zeta_{\text{tot}} = \zeta = 0{\cdot}077 \pm 0{\cdot}184, \quad \rho_{\text{tot}} = \rho = -(0{\cdot}624 \pm 0{\cdot}490). \tag{6}$$

Thus, adding charged current contribution results in the determination of three out of four parity violating parameters, with respect to their signs and magnitudes. The range of the remaining one parameter appears to be small.

4. Summary and conclusion

Using a suitably modified form of factorisation relations of Parida and Rajasekaran (1979) and the factorisation-dependent numerical estimation of the neutral-current parameters in other sectors (Hung and Sakurai 1979) we find that two out of the four parity-violating parameters in nuclear force are determined with respect to their signs and magnitudes, although with rather large errors. Addition of charged current contributions results in the determination of three out of the four parameters. The range of the remaining one parameter is found to be small. These numerical estimations may be treated as complementary to those of Hung and Sakurai (1979) where parity violation in nucleon-nucleon interaction was not considered. But such determinations are not quite model-independent as they are based upon quark model, μ-e universality and factorisation hypothesis. The parameters ξ and η contribute to the $\Delta I = 0$, 2 transitions at the πNN and VNN vertices, where V stands for a vector meson, and ζ and ρ contribute to $\Delta I = 1$ transitions. We plan to carry out the computations of signs and magnitudes of the parity violating potentials in nucleon-nucleon interaction in a future paper using the numerical estimations presented here.

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