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PASCHOS-WOLFENSTEIN RELATION IN ELASTIC $\overset{(-)}{\nu}$ N-SCATTERING

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There is a formula applied to deep inelastic scattering of (anti)neutrino $(\overset{(-)}{\nu})$ by an isoscalar target (N) and called the Paschos-Wolfenstein relation [1] (PWR):

$$R_{-}^{DIS} = \frac{\sigma_{NC}^{DIS}(\nu N) - \sigma_{NC}^{DIS}(\bar{\nu}N)}{\sigma_{CC}^{DIS}(\nu N) - \sigma_{CC}^{DIS}(\bar{\nu}N)} = \frac{1}{2} - \sin^2\theta_w . \qquad (1)$$

Its right-hand side is calculated on the basis of the standard model (SM). An attractive feature of the PWR is a weak (about 2-3%) dependence on the type of nucleon structure functions. To derive the relation, the assumption of isospin invariance of valence quarks distribution, absence of threshold effects associated with production of charmed quarks were used.

The paper shows that a similar relation can be obtained for elastic $\overset{(-)}{\nu}N$-scattering as well.

We introduce the notation:

$$R_{-(p,n)}^{el} = \frac{\sigma^{NC}(\nu p,n) - \sigma^{NC}(\bar{\nu}p,n)}{\sigma^{CC}(\nu n) - \sigma^{CC}(\bar{\nu}p)} , \quad \tilde{R}_{-(p,n)}^{el} = \frac{\frac{d\sigma^{NC}}{dQ^2}(\nu p,n) - \frac{d\sigma^{NC}}{dQ^2}(\bar{\nu}p,n)}{\frac{d\sigma^{CC}}{dQ^2}(\nu n) - \frac{d\sigma^{CC}}{dQ^2}(\bar{\nu}p)} . \qquad (2)$$

A well-known expression for the cross sections of $\overset{(-)}{\nu}p$-, $\overset{(-)}{\nu}n$-scattering leads to the formula [2]:

$$\tilde{R}_{-(p,n)}^{el} = \frac{(F_{V(p,n)}^{NC} + F_{M(p,n)}^{NC})F_{A(p,n)}^{NC}}{\cos^2\theta_c\,(F_V^{CC} + F_M^{CC})F_A^{CC}} . \qquad (3)$$

The nucleon formfactors (NFF) $F_{V,M,A}^{NC,CC}$ determine the matrix element of the charged J_μ^{CC} and neutral J_μ^{NC} currents:

$$\langle N_2|J_\mu^i|N_1\rangle = \bar{u}_2(k_2)(F_V^i\gamma_\mu - \frac{\sigma_{\mu\nu}q^\nu}{2M}F_M^i + \gamma_\mu\gamma_5F_A^i)u_1(k_1). \qquad (4)$$

Here i = CC, NC; for i = CC: $N_1 = n$, $N_2 = p$; for i = NC: $N_1 = N_2 = p, n$.

We do not confine ourselves to the SM and consider the neutral current of the general form:

$$J_\mu^{NC} = \frac{\alpha}{2}(\bar{u}\gamma_\mu u - \bar{d}\gamma_\mu d) + \frac{\beta}{2}(\bar{u}\gamma_\mu\gamma_5 u - \bar{d}\gamma_\mu\gamma_5 d) + \frac{\gamma}{2}(\bar{u}\gamma_\mu u + \bar{d}\gamma_\mu d) + \frac{\delta}{2}(\bar{u}\gamma_\mu\gamma_5 u + \bar{d}\gamma_\mu\gamma_5 d). \qquad (5)$$

In the SM: $\alpha = 1 - 2\sin^2\theta_W$, $\beta = 1$, $\gamma = -(2/3)\sin^2\theta_W$, $\delta = 0$.

Relation between different NFF can be obtained on the basis of the CVC hypothesis and isospin summetry considerations[2]:

$$F^{CC}_{V,M} = F^p_{1,2} - F^n_{1,2}; \quad F^{NC}_{V,M(p,n)} = r_+ F^{p,n}_{1,2} - r_- F^{n,p}_{1,2}$$
$$F^{NC}_{A(p,n)} = \pm\frac{1}{2}\beta F^{CC}_A + (\delta + \epsilon)F^s_A; \quad r_\pm = \frac{1}{2}(\alpha \pm 3\gamma), \qquad (6)$$

where $F^{p,n}_{1,2}$ are electromagnetic NFF, F^s_A is the isoscalar axial-vector NFF. The correction ϵ is due to the contribution of heavy quakrs to the axial current. Its value obeys the perturbation theory[3-5]. When s,c,b,t quarks are taken into account, $\epsilon \approx 0.06$. The similar contribution to the vector current is small $O(\alpha_s^3) \lesssim 10^{-3}$, since in the lowest order it is determined by the 3-gluon exchange diagram.

Let us consider the isoscalar combination of cross sections $R^{el}_- = R^{el}_{-(p)} + R^{el}_{-(n)}$, $\tilde{R}^{el}_- = \tilde{R}^{el}_{-(p)} + \tilde{R}^{el}_{-(n)}$ within the framework of the SM. Substituting (6) into (3) we neglect the contribution of heavy quarks. As a result, we obtain a PWR for elastic $\overset{(-)}{\nu}$N-scattering:

$$\tilde{R}^{el} = \tilde{R}^{el} = \frac{1}{\cos^2\theta_W}\left(\frac{1}{2} - \sin^2\theta_W\right) \approx \frac{1}{2} - \sin^2\theta_W. \qquad (7)$$

The relation is valid within the SM and is a consequence of the isospin symmetry and CVC hypothesis.

To go beyond the SM and to take into account the contribution of heavy quarks, one needs additional assumptions.

Let us use the scale law for NFF:

$$(a):\ G_{Mp}/\mu_p \approx G_{Mn}/\mu_n; \qquad (b):\ F^s_A \approx \lambda F^{CC}_A, \qquad (8)$$

where $\mu_p = 2.79$, $\mu_n = -1.91$; $G_M = F_1 + F_2$.

Relation (8a) is well known. Now we explain (8b). This formula is valid in the region of small and moderate Q^2 from different points of view. In particular, coincidence of Q -dependences of F^{CC}_A and F^s_A follows from the hypothesis of A_1-meson dominance in the axial current. Preliminary estimations made in the approach based on local duality in QCD[6] also indicate that formula (8b) is a good approximation in the Q^2-region considered. The normalization constant is calculated on the basis of the non-relativistic quark SU_6 model: $\lambda = 0.3$.

Substituting (6), (8) to (3) we obtain relations:

$$R^{el}_{-(p,n)} = \tilde{R}^{el}_{-(p,n)} = \frac{(r_+\mu_{p,n} - r_-\mu_{n,p})}{2\cos^2\theta_c(\mu_p - \mu_n)}(2\lambda(\delta+\epsilon) \pm \beta) \qquad (9)$$

$$R^{el}_- = \tilde{R}^{el}_- = \frac{1}{2\cos^2\theta_c}\left[\alpha\beta + 6\gamma\lambda\delta\frac{\mu_p + \mu_n}{\mu_p - \mu_n}\right]. \qquad (10)$$

Like PWR (1), formulae (7), (9) and (10) can be used for extraction of the neutral current parameters, in particular $\sin^2\theta_W$, from the experimental data. In this case the model uncertainties related to NFF will not significantly affect the result.

Some corrections to formulae (7), (9), (10) occur as a result of inaccuracy in the initial assumptions. The most significant corrections to (9), (10) are caused by violation of the scale law (8), while the main correction (7) (in the SM) is determined by the contribution of heavy quarks. This correction is estimated on the basis of (10) and the known value $\epsilon = 0.06$. Roughly estimated in the region of moderate Q^2 ($\lesssim 30\ GeV^2$), the accuracy of relations (7), (9) and (10) is within several per cent.

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Бедняков В.А., Коваленко С.Г. E2-88-355
Соотношение Пашоса-Вольфенштейна
в упругом $\overset{(-)}{\nu}N$-рассеянии

Получено соотношение между сечениями упругого $\overset{(-)}{\nu}N$-рассеяния и параметрами нейтрального тока, слабо зависящее от нуклонной структуры. Результат находится в полной аналогии с известным соотноешнием Пашоса-Вольфенштейна для глубоконеупругого $\overset{(-)}{\nu}N$-рассеяния.

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Paschos-Wolfenstein Relation in Eleastic
$\overset{(-)}{\nu}N$-Scattering

A relation between the cross sections for elastic $\overset{(-)}{\nu}N$-scattering and the neutral current parameters is obtained. Its dependence on the nucleon structure is weak. The result is completely analogous to the known Paschos-Wolfenstein relation for deep inelastic $\overset{(-)}{\nu}N$-scattering.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

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