NONSTANDARD BOSON IN DEEP INELASTIC $L^{\pm}$-N SCATTERING

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Different polarization asymmetries in deep inelastic scattering of charged leptons on nucleons as possible tests for nonstandard weak neutral Z'-boson are discussed.

The standard model (SM) of electroweak interactions of elementary particles that was created by Weinberg and Salam [1] (WS) and which is based on gauge group $SU_L(2)\times U_Y(1)$ successfully describes a series of experiments made in various laboratories over the world. Despite the successful application of WS theory, it is unsatisfactory in many respects. It is unclear why the generations of leptons and quarks repeat, their number is not substantiated, the mechanism of particle-mass generation is unknown, and there is no theoretical validation of its spectrum. The exictence of the scalar Higgs boson has yet to be proven. The spacetime structure of weak interactions does not follow from any internal requirements of the theory - it was introduced phenomenologically in accodance with experimental data. Some SM parameters are known to an insufficent accuracy.

The further verification of the SM and the searches of the more general theory erasing the fenomenological character of this model are the necessity.

Among considerable advances that have recently been made in the realms of high-energy physics, the development of superstring theory [2] is of particular importance. The superstring model of elementary particles that is based on $E_8\times E_8'$ gouge symmetry is considered as a real candidate for the rale of the consistent unified theory of all fundamental interactions, including gravity. Upon compactification, ten-dimensional group $E_8\times E_8'$ of the superstring model leads to the fourdimensional N=1 supersymmetric theory with the gauge group E_6. An interesting implication of this model is that it predicts the existense of new exotic fermions and, at least, one additional neutral Z' boson of mass less than 1 TeV.

In the past few years, considerable attention has been given to searches for effects associated with the additional vector boson [3-10]. In particular general expressions for various characteristics of the processes $e^-e^+ \to f\bar{f}$, $e^-e^+ \to \tilde{f}\bar{\tilde{f}}$, $e^-e^{\pm} \to e^-e^{\pm}$, $e^-e^+ \to q\bar{q}g$, $e^-e^+ \to BX$, $e^-e^+ \to \gamma X$, $ab \to l\bar{l}X$ have been obtained and the detailed analysis of these characteristics has been performed in the SM and in the E_6 superstring model [5-10].

In this paper, the effects, due to the additional vector boson, are considered in the deep inelastic scattering (DIS) of charged leptons on nucleons

$$l^{\mp} + N \to (\gamma, Z_1, Z_2) \to l^{\mp} + X, \qquad (l = e, \mu), \tag{1}$$

where Z_1 and Z_2 are the gauge bosons, X is the final hadron system.

The matrix element of (1) can be written in the form:

$$M^{\mp} = e^2\sum_i D_i\bar{u}(k_2, \lambda_2)\gamma_\mu(\pm g_v^i + \gamma_5 g_A^i)\bar{u}(k_1; \lambda_1)\cdot H_\mu^i, \tag{2}$$

where summation is performed over all gauge bosons $i=\gamma, Z_1, Z_2$; $k_1(\lambda_1)$ and $k_2(\lambda_2)$ are the momenta (helicities) of the initial and final leptons; $D_i=(q^2+M_i^2)^{-1}$; $q=k_1-k_2$; M_i - the mass of the i - th boson (For the photon M_γ=0); g^i_v and g^i_A are the vector and axial vector couplings of a lepton to the i - boson; $H_\mu^i = \langle X(p_x)|J_\mu^i|N(p; h)\rangle$ is the hadron current that describes the transition $i+N\to X$; P and h are the 4-momenta and helicity of the nucleon N.

In the general case of longitudinally polarized leptons and nucleon the cross section is given by the expression:

$$d\sigma^{\mp} = \frac{\alpha^2}{|pk_1|}\cdot\frac{d\vec{k}_2}{2\varepsilon_2}\sum_i\sum_k D_iD_k L_{\mu\nu}^{ik}\bar{H}_{\mu\nu}^{ik} \tag{3}$$

Here $L_{\mu\nu}^{ik}$ and $H_{\mu\nu}^{ik}$ are the lepton and hadron tensors. The tensor $L_{\mu\nu}^{ik}$ can easily be calculated on the basis of the matrix element (2).For longitudinally polarized leptons the tensor $L_{\mu\nu}^{ik}$ is given by

$$L_{\mu\nu}^{ik} = \left[C_{ik}\left(1 + \lambda_1\lambda_2\right) \mp d_{ik}\left(\lambda_2 + \lambda_1\right)\right]\left(k_{1\mu}k_{2\nu} + k_{1\nu}k_{2\mu} - k_1k_2\delta_{\mu\nu}\right) + \\ + \left[\pm d_{ik}\left(1 + \lambda_1\lambda_2\right) - C_{ik}\left(\lambda_2 + \lambda_1\right)\right] \times \varepsilon_{\mu\nu\rho\sigma}k_{1\rho}k_{2\sigma} \quad (4)$$

Here and everywhere below the summation indexes run over the possible vector γ, Z_1, Z_2 bosons. The following notations are introduced:

$$C_{ik} = g_V^i g_V^k + g_A^i g_A^k,\ d_{ik} = g_V^i g_A^k + g_A^i g_V^k \quad (5)$$

The bar over the hadronic tensor denotes summation over the polarizations undetected hadrons and integration over their momenta:

$$\overline{H}_{\mu\nu}(p;\ q;\ h) = (2\pi)^4 \sum_{Spin} \langle X(p_x)|J_\mu^i|N(p;\ h)\rangle\langle X(p_x)|J_\nu^k|N(p;\ h)\rangle^* \delta(p - q - p_x)d\Phi_x \quad (6)$$

Here $d\Phi_x$ is the phase space of the hadron system X.

Let us construct the general expression for the hadronic tensor $\overline{H}_{\mu\nu}(p;\ q;\ h)$. It follows from (6) that this tensor has the form

$$\overline{H}_{\mu\nu}^{ik}(p;\ q;\ h) = W_{\mu\nu}^{ik}(p;\ q) + hG_{\mu\nu}^{ik}(p;\ q) \quad (7)$$

By using the vectors p and q, we can obviously construct the tensor

$$W_{\mu\nu}^{ik}(p;\ q) = \delta_{\mu\nu}W_1^{ik} + \frac{p_\mu p_\nu}{M^2} W_2^{ik} + \varepsilon_{\mu\nu\rho\sigma} \frac{p_\rho q_\sigma}{2M^2} W_3^{ik} + \cdots, \quad (8)$$

where W_n^{ik} $(n = 1 - 3)$ are real-valued hadron structure functions that depend on the invariant variables q^2 and pq.

In (8) we omitted terms that are proportional to q_μ and q_ν, since these terms contracted with the leptonic tensor that does not contribute to the cross section (when the lepton mass is disregarded, the tensor $L_{\mu\nu}^{ik}$ is conserved: ($L_{\mu\nu}^{ik} q_\mu = L_{\mu\nu}^{ik} q_\nu = 0$).

The hadron polarization tensor $G_{\mu\nu}^{ik}$ is obtained from (8) by means of the substitutions $W_n^{ik} \to G_n^{ik}$ The structure functions W_1^{ik}, W_2^{ik} and G_3^{ik} do not violate parity,the functions W_3^{ik}, G_1^{ik} and G_2^{ik} lead to P-violation.

The expression for the differential cross section of DIS of longitudinally polarized leptons (antileptons) on longitudinally polarized nucleons can be written in the form

$$\frac{d\sigma^\mp(\lambda_1,\ \lambda_2,\ h)}{dxdy} = \pi\alpha^2 s\left\{\left(1 + \lambda_1\lambda_2\right)\left[W_1^\mp(x,\ y) + hG_1^\mp(x,\ y)\right] - \left(\lambda_1 + \lambda_2\right)\left[W_2^\mp(x,\ y) + hG_2^\mp(x,\ y)\right]\right\} \quad (9)$$

where

$$W_1^\mp(x,\ y) = \sum_i\sum_k D_iD_k\left\{C_{ik}\left[2Mxy^2W_1^{ik} + 2(1 - y)\nu W_2^{ik}\right] \pm d_{ik}y(2 - y)x\nu W_3^{ik}\right\},$$

$$W_2^\mp(x,\ y) = \sum_i\sum_k D_iD_k\left\{C_{ik}y(2 - y)x\nu W_3^{ik} \pm d_{ik}\left[2Mxy^2W_1^{ik} + 2(1 - y)\nu W_2^{ik}\right]\right\}, \quad (10)$$

$$G_1^\mp(x,\ y) = \sum_i\sum_k D_iD_k\left\{C_{ik}\left[2Mxy^2G_1^{ik} + 2(1 - y)\nu G_2^{ik}\right] \pm d_{ik}y(2 - y)x\nu G_3^{ik}\right\},$$

$$G_2^\mp(x,\ y) = \sum_i\sum_k D_iD_k\left\{C_{ik}y(2 - y)x\nu G_3^{ik} \pm d_{ik}\left[2y^2MxG_1^{ik} + 2(1 - y)\nu G_2^{ik}\right]\right\}; \quad (11)$$

M is the nucleon mass; $s=-(p+k_1)^2$; $\nu=-(pq)/M$; $x=-q^2/2(pq)$ and $y=(pq)/(pk_1)$ are the dimensionless scaling variables.

The following electroweak asymmetries can be determined from (9);

(I) the polarization asymmetry

$$A^{\mp} = -\frac{1}{\lambda_1}\frac{\sigma^{\mp}(\lambda_1) - \sigma^{\mp}(-\lambda_1)}{\sigma^{\mp}(\lambda_1) + \sigma^{\mp}(-\lambda_2)} = \frac{W_2^{\mp}(x, y)}{W_1^{\mp}(x, y)}; \tag{12}$$

(II) the charge asymmetry

$$\begin{aligned} C^{\mp}(\lambda_1) &= \left[\sigma^{\mp}(\lambda_1) - \sigma^{\pm}(\lambda_1)\right] / \left[\sigma^{\mp}(\lambda_1) + \sigma^{\pm}(\lambda_1)\right] = \\ &= \pm \frac{\sum_i \sum_k D_i D_k d_{ik}\left[y(2-y)xvW_3^{ik} - \lambda_1\left(2Mxy^2 W_1^{ik} + 2(1-y)vW_2^{ik}\right)\right]}{\sum_i \sum_k D_i D_k C_{ik}\left[2Mxy^2 W_1^{ik} + 2(1-y)vW_2^{ik} - \lambda_1 y(2-y)xvW_3^{ik}\right]}; \end{aligned} \tag{13}$$

(III) the charge-polarization asymmetry

$$\begin{aligned} B^{\mp}(\lambda_1) &= \left[\sigma^{\mp}(\lambda_1) - \sigma^{\pm}(-\lambda_1)\right] / \left[\sigma^{\mp}(\lambda_1) + \sigma^{\pm}(-\lambda_1)\right] = \\ &= \pm \frac{\sum_i \sum_k D_i D_k \left(d_{ik} - \lambda_1 C_{ik}\right) y(2-y)xW_3^{ik}}{\sum_i \sum_k D_i D_k \left(C_{ik} - \lambda_1 d_{ik}\right)\left[2Mxy^2 W_1^{ik} + 2(1-y)vW_2^{ik}\right]} \end{aligned} \tag{14}$$

(IV) the right-left asymmetry

$$A_{RL}^{\mp} = \frac{\sigma^{\mp}(h = 1) - \sigma^{\mp}(h = -1)}{\sigma^{\mp}(.\ h = 1) + \sigma^{\mp}(h = -1)} = G_1^{\mp}(x, y) / W_1^{\mp}(x, y) \tag{15}$$

(V) the degree of longitudinal polarization of the lepton

$$P^{\mp} = \frac{\sigma^{\mp}(\lambda_2 = 1) - \sigma^{\mp}(\lambda_2 = -1)}{\sigma^{\mp}(\lambda_2 = 1) + \sigma^{\pm}(\lambda_2 = -1)} = -W_2^{\mp}(x, y) / W_1^{\mp}(x, y); \tag{16}$$

(VI) the spin correlation lepton-nucleon

$$C_{1N}^{\mp} = \frac{\sigma^{\mp}(\lambda_1, h) - \sigma^{\mp}(-\lambda_1, h) + \sigma^{\mp}(-\lambda_1, -h) - \sigma^{\mp}(\lambda_1, -h)}{\sigma^{\mp}(\lambda_1, h) + \sigma^{\mp}(-\lambda_1, h) + \sigma^{\mp}(-\lambda_1, -h) + \sigma^{\mp}(\lambda_1, -h)} = -\lambda_1 h \frac{G_2^{\mp}(x, y)}{W_1^{\mp}(x, y)}. \tag{17}$$

From (12)- (17) it follows that the relations between the asymmetries

$$\begin{aligned} A^{-}|_{y=0} &= -A^{+}|_{y=0} = \sum_i \sum_k D_i D_k d_{ik} W_2^{ik} \Big/ \sum_i \sum_k D_i D_k C_{ik} W_2^{ik}, \\ C^{\mp}(\lambda_1)|_{y=0} &= -\lambda_1 A^{\mp}|_{y=0}, \\ B^{\mp}(\lambda_1)|_{y=0} &= 0, \\ A_{RL}^{\mp}|_{y=0} &= \sum_i \sum_k D_i D_k C_{ik} G_2^{ik} \Big/ \sum_i \sum_k D_i D_k C_{ik} W_2^{ik}, \\ P^{\mp}|_{y=0} &= -A^{\mp}|_{y=0}, \\ C_{1N}^{\mp}|_{y=0} &= \mp \lambda_1 h \sum_i \sum_k D_i D_k d_{ik} G_2^{ik} \Big/ \sum_i \sum_k D_i D_k C_{ik} W_2^{ik}. \end{aligned} \tag{18}$$

To estimate numerically the effective cross section for process (1) and the electroweak asymmetries (12)-(17), we must calculate the hadron structure functions W_n^{ik} and G_n^{ik} ($n=1,2,3$) in some specific model. We find that the structure function in the quark-parton model are as follows:

$$MW_1^{ik} = \frac{vW_2^{ik}}{2x} = \sum_q \left(V_q^i V_q^k + A_q^i A_q^k\right)\left[f_q(x) + f_{\bar q}(x)\right],$$
$$vW_3^{ik} = 2\sum_q \left(V_q^i A_q^k + A_q^i V_q^k\right)\left[f_q(x) - f_{\bar q}(x)\right],$$
$$MG_1^{ik} = \frac{vG_2^{ik}}{2x} = \sum \left(V_q^i A_q^k + A_q^i V_q^k\right)\left[\Delta f_q(x) - \Delta f_{\bar q}(x)\right],$$
$$vG_3^{ik} = 2\sum_q \left(V_q^i V_q^k + A_q^i A_q^k\right)\left[\Delta f_q(x) + \Delta f_{\bar q}(x)\right], \qquad (19)$$

where

$\Delta f_q(x) = f_q^+(x) - f_q^-(x)$; $f_q(x) = f_q^+(x) + f_q^-(x)$;

$f_q^+(x)\left(f_{\bar q}^+(x)\right)$ and $f_q^-(x)\left(f_{\bar q}^-(x)\right)$ are the distribution functions of quarks (antiquarks) with spin parallel and antiparalell to the nucleon spin, respectively; V_q^i and A_q^i are the vector and axialvector coupling constant of the quarks.

Computer analysis of the electroweak asymmetries (12)-(17) will be given elsewhere.

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QEYRİ ELASTİKİ $L^{\pm}$ -N SƏPİLMƏSİNDƏ STANDARD OLMAYAN BOZON

Standard olmayan əlavə neytral bozonun xassələrini öyrənmək məqsədilə $L^{\pm}$ -N qeyri elastiki səpilməsində elektrozəif asimmetriyalar (polyarizasiya asimmetriyası, yük asimmetriyası, leptonun uzununa polyarizasiya dərəcəsi və s.) üçün ifadələr alınmışdır.

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НЕСТАНДАРТНЫЙ БОЗОН В ГЛУБОКО-НЕУПРУГОМ $L^{\pm}$ -N РАССЕЯНИИ

С целью получения информации о свойствах нестандартного нейтрального бозона получены выражения для электрослабых асимметрий (поляризационной асимметрии, зарядовой асимметрии зарядово-поляризационной асимметрии и т.д) в глубоко-неупругом $L^{\pm}$ -N рассеянии.

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