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E2-87-800

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ON POSSIBLE MANIFESTATIONS OF THE SUPERSTRING Z'-BOSON IN NEUTRAL CURRENTS

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1987

The theory of the ten-dimensional heteroitic $E_8' \times E_8$ superstring [1] is now regarded as the basis for unification of all fundamental interactions including gravitation. Compactification of excessive dimensions onto the six-dimensional Calabi-Yau manifold is considered to lead to an effective 4-dimensional theory which correctly describes dynamics of elementary particles at energies below Planck mass scale $M_P \approx \approx 10^{19}$ GeV.

The present understanding of the compactification does not yet allow unambiguously obtaining the 4-dimensional theory corresponding to the given 10-dimensional one. This has stimulated the efforts to find out which of the known possibilities is in the best agreement with the established experimental and cosmological facts. Despite the existing arbitrariness, the superstring predictions display some generality. This is first of all a specific pattern of the gauge symmetry breaking in the 4-dimensional theory. A typical feature is that in most realistic cases at low energy close to $\sim 10^2$ GeV the unbroken gauge group is larger than standard group by at least one additional U'(1)-factor [2]. This means that in the theory there is an extra light Z'-boson with the mass of the order of hundreds of GeV. Its contribution must manifest itself to some extent in all interactions involving a usual Z-boson. So the experimental data must deviate from predictions of the standard model (SM). Nothing of the kind is observed yet, and SM is in good agreement with all available data [3]. However, discovering a contribution of the extra Z'-boson in more precise experiments would be a good argument in favour of the superstring theory. This possibility is now widely discussed [4-7]. We see some encouraging facts: on the one hand, there is some theoretical estimation of the upper limit for the mass of the Z'-boson $M_{Z'} \lesssim 320$ GeV [6] (though it is not a rigorous result), on the other hand, accelerators of the new generation, including UNK, can provide so much experimental statistics that one could reach this limit.

In this paper we considers, manifestations of the superstring Z'-boson in deep inelastic (anti)neutrino-nucleon scattering. Special attention is paid to what follows as a consequence of the Z'-boson mass being limited to $M_{Z'} \lesssim 320$ GeV.

Here we consider the case with the E_6 - intermediate gauge group which remains unbroken after compactification.

EFFECTIVE LAGRANGIAN OF ν ($\bar{\nu}$)N-INTERACTIONS

The Lagrangian of neutral currents in the theory with the extra Z'-boson has the form[7]:

$$\mathcal{L}_{NC} = eA_\mu J^\mu_{em} + gZ_\mu J^\mu_Z + g' Z'_\mu J^\mu_{Z'}, \qquad (1)$$

where J^μ_{em} and $J^\mu_Z = J^\mu_3 - wQ^\mu$ are the electromagnetic and usual electroweak currents of SM. $J^\mu_{Z'} = 2\bar{f}_i \gamma^\mu Q_i f_i$ is the current of the Z'-boson, Q_i are the U'(1) charges of the fermion fields belonging to the 27-plet of the group E_6. The coupling constants are determined by the relations

$$g = \frac{e}{\sqrt{w(1-w)}}, \quad g' = \frac{e}{\sqrt{1-w}}, \qquad (2)$$

where $w = \sin^2\theta_W$.

From now on we shall ignore the Z-Z'-mixing, which is small according to the experimental estimations[4,5].

On the basis of (1) one can obtain the effective low-energy Lagrangian of the νN neutral current scattering (see Ref.[8]):

$$\mathcal{L}_{eff} = -\frac{G_F}{\sqrt{2}} \bar{\nu}_L \gamma^\mu \nu_L J^H_\mu, \qquad (3)$$

where the hadron current has the form:

$$J^H_\mu = \sum_i q'_i \bar{q}_i \gamma_\mu q_i, \qquad (4)$$

here summation is taken with respect to all types of quarks and their right and left chiral states. The chiral constants[8] q'_i we shall write as a sum[7]:

$$\begin{aligned} u'_{L,R} &= u_{L,R} + \Delta u_{L,R}, \quad & c'_{L,R} &= u'_{L,R}, \\ d'_{L,R} &= d_{L,R} + \Delta d_{L,R}, \quad & s'_{L,R} &= d'_{L,R}, \end{aligned} \qquad (5)$$

where $u_{L,R}$ and $d_{L,R}$ are completely defined within SM[8]:

$$u_L = \frac{1}{2} - \frac{2}{3}w, \quad u_R = -\frac{2}{3}w, \quad d_L = -\frac{1}{2} + \frac{1}{3}w, \quad d_R = \frac{1}{3}w. \qquad (6)$$

$\Delta u_{L,R}$ and $\Delta d_{L,R}$ are due to the contribution of the extra superstring Z'-boson[7]:

$$\Delta u_L = -w\gamma, \quad \Delta u_R = w\gamma, \quad \Delta d_L = -w\gamma, \quad \Delta d_R = -\frac{1}{2}w\gamma, \qquad (7)$$

where $\gamma = \frac{1}{9}(M_Z/M_{Z'})^2$ and M_Z is the mass of the usual Z-boson.

The cross sections of νN neutral current scattering have the form[8]:

$$\begin{aligned} \sigma(x,y|\nu i) \equiv \frac{d^2\sigma^{\nu i}_{NC}}{dxdy} = \sigma_0 \{ & (u_L^2 + u_R^2(1-y)^2)(xu^i(x,Q^2) + \\ & + xc^i(x,Q^2)) + (d_L^2 + d_R^2(1-y)^2)(xd^i(x,Q^2) + xs^i(x,Q^2)) + \\ & + (u_R^2 + u_L^2(1-y)^2)(x\bar{u}^i(x,Q^2) + x\bar{c}^i(x,Q^2)) + \\ & + (d_R^2 + d_L^2(1-y)^2)(x\bar{d}^i(x,Q^2) + x\bar{s}^i(x,Q^2))\}. \end{aligned} \qquad (8)$$

$\sigma(|\bar{\nu}i) \to \sigma(|\nu i)$ if $L \leftrightarrow R$; $q^i(x,Q^2)$ are the parton distribution functions in the proton (i = p), neutron (i = n).

Deviations from SM predictions are determined by difference between the chiral constants $u_{L,R}$, $d_{L,R}$, and $u'_{L,R}$, $d'_{L,R}$.

Let us now consider the character of the deviations for some experimental quantities calculated with contribution of Z'-boson.

ANALYSIS OF DEVIATIONS FROM THE STANDARD MODEL

1. Deviation from SM for (Anti)Neutrino-Nucleon Scattering

Assuming scaling and SU(4) symmetry of distribution functions, we obtain for relative differences:

$$\begin{aligned} n(\nu) &= \frac{\sigma'(\nu n) - \sigma(\nu n)}{\sigma(\nu n)} = \frac{\Delta U + 2\Delta D + \xi\Delta\Sigma}{U + 2D + \xi\Sigma}, \\ p(\nu) &= \frac{\sigma'(\nu p) - \sigma(\nu p)}{\sigma(\nu p)} = \frac{\Delta D + 2\Delta U + \xi\Delta\Sigma}{D + 2U + \xi\Sigma}, \end{aligned} \qquad (9)$$

$$n(\bar\nu) = \frac{\sigma'(\bar\nu n) - \sigma(\bar\nu n)}{\sigma(\bar\nu n)} = \frac{\Delta\bar U + 2\Delta\bar D + \xi\Delta\Sigma}{\bar U + 2\bar D + \xi\Sigma}, \tag{9}$$

$$p(\bar\nu) = \frac{\sigma'(\bar\nu p) - \sigma(\bar\nu p)}{\sigma(\bar\nu p)} = \frac{\Delta\bar D + 2\Delta\bar U + \xi\Delta\Sigma}{\bar D + 2\bar U + \xi\Sigma}.$$

Here we introduce the following notation:

$$D = d_L^2 + \omega d_R^2,\quad U = u_L^2 + \omega u_R^2,\quad \bar D = d_R^2 + \omega d_L^2,\quad \bar U = u_R^2 + \omega u_L^2, \tag{10}$$

$$\Sigma = u_L^2 + u_R^2 + d_L^2 + d_R^2 .$$

$$\Delta D = D' - D,\ \Delta U = U' - U,\ \Delta\Sigma = \Sigma' - \Sigma,\ \Delta\bar D = \bar D' - \bar D,\ \Delta\bar U = \bar U' - \bar U . \tag{11}$$

$$\xi = 2\,\frac{\int x\,\Sigma\,\bar q(x)\,dx}{\int x(q(x) - \bar q(x))\,dx}$$

is the sea-to-valence quark total momentum ratio in the proton.

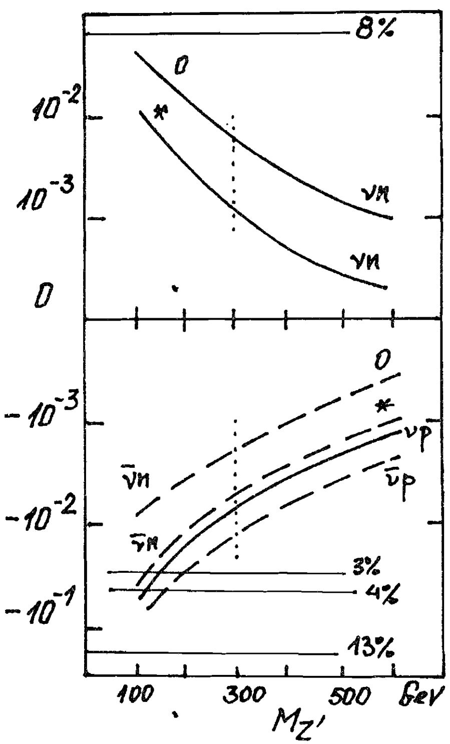

Fig. 1

In this case $\omega = 1/3$. The primed quantities are calculated with the contribution of the Z'-boson by formulae (10), (11) and (5)-(7). One can find the explicit form of expressions (10) and (11) in the Appendix.

Let us consider the dependence of ratios (9) on $M_{Z'}$ (the mass of the Z'-boson). This dependence is plotted in Fig. 1. The solid curves are for neutrino scattering, the dashed curves are for antineutrino scattering. The curves marked by "0" ("*") correspond to $\xi = 0 (=2/3)$ /9/. Since these curves coincide for the proton, only one curve is shown ($\xi = 2/3$). The horizontal straight lines show the accuracies achieved in determination of cross sections by now: 8% for νp -scattering, 13% for $\bar\nu p$ -scattering; 3% for neutrino scattering on the isoscalar target, 4% for antineutrino scattering on the isoscalar target.

In the case of the isoscalar target $\nu N(I=0) \to \nu X$ the given curves allow an easy estimation of the deviation from SM by the formula:

$$\frac{\sigma' - \sigma}{\sigma} = \frac{p + nR}{1 + R} \approx \frac{p + n}{2}, \tag{12}$$

since $R = \dfrac{\sigma_{NC}(\nu n)}{\sigma_{NC}(\nu p)} \simeq 1$.

When $M_{Z'} = 300$ GeV, the Z'-boson manifests itself at the level +0.3% for νn-scattering and -0.5% for νp-scattering. So, according to (12), there are no experimental manifestations of the Z'-boson in the reaction $\nu N(I=0) \to \nu X$: the positive deviation on the neutron compensates the negative deviation on the proton. For $\bar\nu n$- and $\bar\nu p$-scattering the deviation from SM has the same sign and is equal to $-(0.8\div1.0\%)$. Thus the same deviation occurs at $\bar\nu N(I=0)$ - scattering as well.

A 10-20 fold increase in statistics will allow achieving such an experimental accuracy that a contribution of the Z'-boson with the mass $M_{Z'} \approx 300$ GeV can be observed. It seems to be possible in experiments at accelerators of the new generation, including UNK. To do the same with a non-isoscalar target would require a much greater increase in the statistics (almost by two orders of magnitude).

Let us consider the deviation from SM in various kinematic regions of (anti)neutrino-nucleon scattering.

The region $X > 0.3$. Practically, there is no contribution of sea quarks to the cross section, i.e. $\xi = 0$ in (9). Integrating differential cross sections (8) over the variable y, we obtain the following X-dependence of the quantities introducted earlier:

$$n_1(\nu) = \frac{\sigma'(x|\nu n) - \sigma(x|\nu n)}{\sigma(x|\nu n)} = \frac{\eta(x)\,\Delta U + \Delta D}{\eta(x)\,U + D},$$

$$p_1(\nu) = \frac{\sigma'(x|\nu p) - \sigma(x|\nu p)}{\sigma(x|\nu p)} = \frac{\Delta U + \eta(x)\,\Delta D}{U + \eta(x)\,D}, \tag{13}$$

$$n_1(\bar\nu) = \frac{\sigma'(x|\bar\nu n) - \sigma(x|\bar\nu n)}{\sigma(x|\bar\nu n)} = \frac{\eta(x)\,\Delta\bar U + \Delta\bar D}{\eta(x)\bar U + \bar D},$$

$$p_1(\bar\nu) = \frac{\sigma'(x\,|\,\bar\nu p) - \sigma(x\,|\,\bar\nu p)}{\sigma(x\,|\,\bar\nu p)} = \frac{\Delta\bar U + \eta(x)\,\Delta\bar D}{U + \eta(x)\bar D}\,.$$

Here $\eta(x) = \dfrac{d_v^p(x)}{u_v^p(x)} \approx \dfrac{1-x}{2}$ takes into account the difference in distribution of d- and u-quarks in the proton. Other parameters were determined earlier (see (10), (11)).

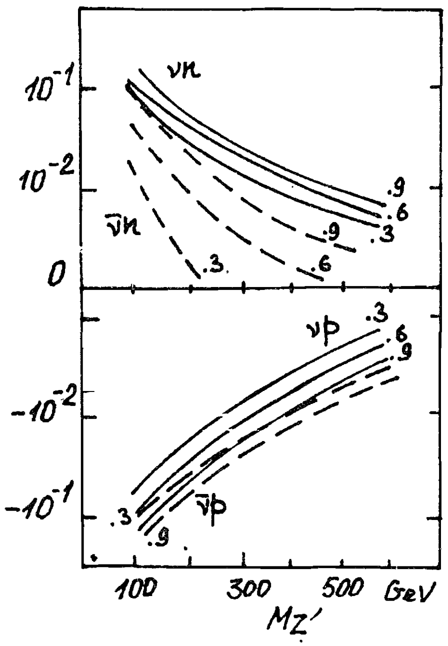

Fig. 2

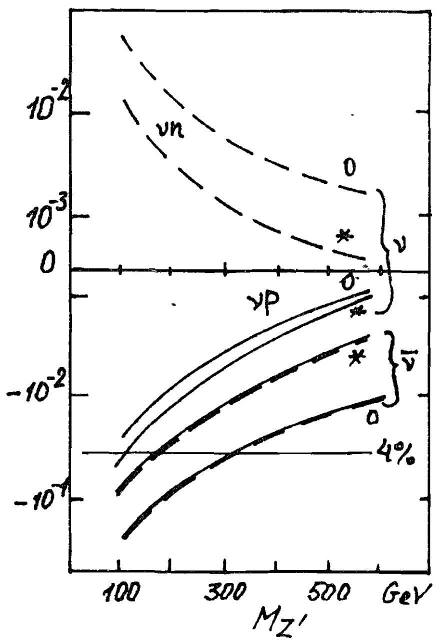

Fig. 3

The results of calculations by formulae (13) for various values of X are shown in Fig. 2. At $M_{Z'} \approx 300$ GeV the deviation from SM for scattering on the proton has a negative sign and does not exceed 0.8% in this kinematic region ($X > 0.3$). For the scattering on the neutron it is positive and is not more than 0.8÷1.1% for the neutrino and less than 0.7% for the antineutrino. Thus, the given kinematic region provides no new possibilities for detection of the deviations under consideration.

The region $y > 2/3$. Practically, there are no right-(left-) hand currents in $\nu(\bar\nu)$-scattering, since the contributions of u_R, d_R(u_L, d_L) are suppressed.

Integrating cross sections (8), we obtain the deviation from SM due to the Z'-boson in the form of (9), but this is for $\omega = 0$. The relevant plots are shown in Fig. 3.

The solid curves are for the proton target, the dashed curves are for the neutron one. The braces unite the curves corresponding to scattering on the neutrino or antineutrino. "0" ("*") correspond to $\xi = 0$ or (2/3). In this kinematic region ($y > 2/3$) the deviation from SM is about +0.4%, −0.6%, −0.3÷÷0.1% for νn-, νp- and $\nu N(I=0)$-scattering if $M_{Z'} \approx 300$ GeV. In the antineutrino beam the deviation is negative for all targets and equals approximately 1.5÷4.0%. For an isoscalar target a deviation like this is at the level of present accuracies of measurements of total cross sections (4% - level is shown in the figure by the horizontal straight line). However, not more than 1/5 of all events get into the kinematic region $y > 2/3$. Therefore, at $y > 2/3$ the accuracy in determination of cross sections is 2-3 times worse than the one presently achieved for total cross sections. But even in this case a 3-4-fold increase in accuracy of measurement will allow achieving the upper mass limit of the Z'-boson 300 GeV in antineutrino scattering on the isoscalar target at $y > 2/3$.

The region of large X ($X > 0.6$). Owing to the breakdown of isotopic symmetry of quark distributions /10/ ($d/u \to 0$) expressions (13) get the form:

$$\begin{aligned}
n_3(\nu) &= \frac{\sigma'(x\,|\,\nu n) - \sigma(x\,|\,\nu n)}{\sigma(x\,|\,\nu n)} = 4w\gamma\,\frac{1 - \frac{7}{9}w + \frac{13}{12}w\gamma}{1 - \frac{4}{3}w + \frac{16}{27}w^2}\,,\\
p_3(\nu) &= \frac{\sigma'(x\,|\,\nu p) - \sigma(x\,|\,\nu p)}{\sigma(x\,|\,\nu p)} = -4w\gamma\,\frac{1 - \frac{8}{9}w - \frac{4}{3}w\gamma}{1 - \frac{8}{3}w + \frac{64}{27}w^2}\,,\\
n_3(\bar\nu) &= \frac{\sigma'(x\,|\,\bar\nu n) - \sigma(x\,|\,\bar\nu n)}{\sigma(x\,|\,\bar\nu n)} = 4w\gamma\,\frac{1 - \frac{5}{3}w + \frac{7}{4}w\gamma}{1 - \frac{4}{3}w + \frac{48}{27}w^2}\,,\\
p_3(\bar\nu) &= \frac{\sigma'(x\,|\,\bar\nu p) - \sigma(x\,|\,\bar\nu p)}{\sigma(x\,|\,\bar\nu p)} = -4w\gamma\,\frac{1 + \frac{8}{3}w - 4w\gamma}{1 - \frac{8}{3}w + \frac{48}{9}w^2}\,,
\end{aligned} \tag{14}$$

where $\gamma = \dfrac{1}{9}\,\dfrac{M_Z^2}{M_{Z'}^2}$, and $w = \sin^2\theta_W$.

Fig.4 shows the $M_{Z'}$ dependence of deviation (14). This deviation does not exceed +1.6% at 300 GeV.

The region $x,y > 0.6$. In this region $\xi = 0$, $d/u = 0$, $(1-y)^2 \to 0$. Deviations from SM get a simple form:

$$n_4(\nu) = \frac{\sigma'(x,y|\nu n) - \sigma(x,y|\nu n)}{\sigma(x,y|\nu n)} = 4w\gamma \frac{1 - \frac{2}{3}w + w\gamma}{1 - \frac{4}{3}w + \frac{4}{9}w^2},$$

$$p_4(\nu) = \frac{\sigma'(x,y|\nu p) - \sigma(x,y|\nu p')}{\sigma(x,y|\nu p)} = -4w\gamma \frac{1 - \frac{4}{3}w - w\gamma}{1 - \frac{8}{3}w + \frac{16}{9}w^2}, \qquad (15)$$

$$n_4(\bar\nu) = \frac{\sigma'(x,y|\bar\nu n) - \sigma(x,y|\bar\nu n)}{\sigma(x,y|\nu n)} = -3\gamma(1 - \frac{3}{4}\gamma),$$

$$p_4(\bar\nu) = \frac{\sigma'(x,y|\bar\nu p) - \sigma(x,y|\bar\nu p)}{\sigma(x,y|\bar\nu p)} = -3\gamma(1 - \frac{3}{4}\gamma).$$

Fig. 5 shows the $M_{Z'}$ dependence of these deviations.

The solid curves are for the proton target, the dashed curves are for neutron target. The horizontal straight lines correspond to the experimental accuracies.

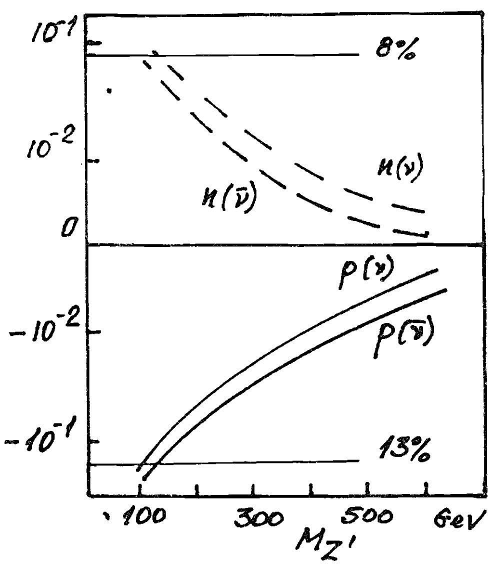

Fig. 4

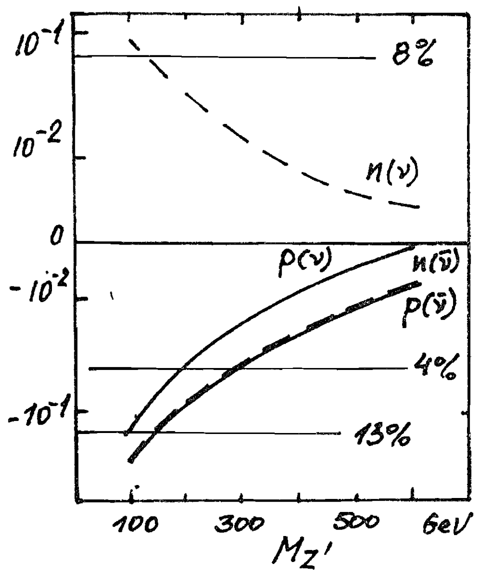

Fig. 5

If $M_{Z'} \approx 300$ GeV, the deviation from SM achieves 4% for antineutrino interactions. For the isoscalar target this deviation is already at the accuracy level of measurement of total cross sections (4%). However, statistics in the region where the above quantities are defined is almost two orders worse than in the whole kinematic region. So one has to increase statistics by two orders to achieve the necessary accuracy.

2. Deviations from SM in Ratios of Cross Sections $R_\nu^{n/p}$ and $R_{\bar\nu}^{n/p}$

By definition [8]

$$R_\nu^{n/p} = \frac{\sigma(\nu n \to \nu X)}{\sigma(\nu p \to \nu X)}, \quad R_{\bar\nu}^{n/p} = \frac{\sigma(\bar\nu n \to \bar\nu X)}{\sigma(\bar\nu p \to \bar\nu X)}. \qquad (16)$$

At high energies we obtain from (8):

$$R_\nu^{n/p} = \frac{d_L^2(2+\xi) + d_R^2(\frac{2}{3}+\xi) + u_L^2(1+\xi) + u_R^2(\frac{1}{3}+\xi)}{d_L^2(1+\xi) + d_R^2(\frac{1}{3}+\xi) + u_L^2(2+\xi) + u_R^2(\frac{2}{3}+\xi)}. \qquad (17)$$

The formula for $R_{\bar\nu}^{n/p}$ is obtained from (17) by substituting $L \leftrightarrow R$.

To estimate the deviation of the above ratios from SM predictions, we consider the quantities:

$$\delta R_\nu^{n/p} = \frac{R_\nu'^{n/p} - R_\nu^{n/p}}{R_\nu^{n/p}}, \quad \delta R_{\bar\nu}^{n/p} = \frac{R_{\bar\nu}'^{n/p} - R_{\bar\nu}^{n/p}}{R_{\bar\nu}^{n/p}}, \qquad (18)$$

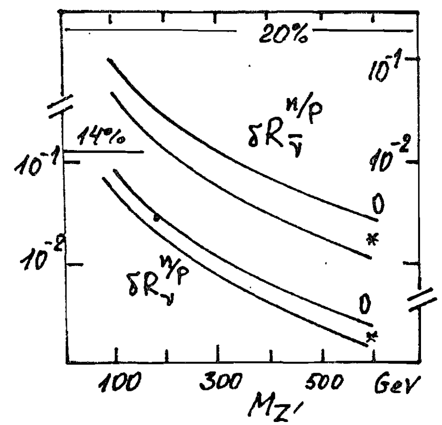

Fig. 6

where $R_\nu'^{n/p}$ and $R_{\bar\nu}'^{n/p}$ are calculated with the contribution of the Z'-boson.

Fig. 6 shows deviations (18) as a function of $M_{Z'}$. The curves marked with "0" ("*") correspond to $\xi = 0$ ($\xi = 2/3$). These deviations are positive both for neutrino and antineutrino, and do not exceed 1% at the value $M_{Z'} \approx 300$ GeV. The horizontal straight lines show the experimental errors which are 14% and 20% for the neutrino and the antineutrino, respectively.

3. Deviations from SM in Relations of the Paschos-Wolfenstein Type

Let us consider the ratios of differences like

$$\Delta_i = \frac{\sigma^{\nu i}_{NC} - \sigma^{\bar{\nu} i}_{NC}}{\sigma^{\nu i}_{CC} - \sigma^{\bar{\nu} i}_{CC}}, \qquad (19)$$

where i = p for the proton, i = n for the neutron, and i = 0 for the isoscalar target. At high energies we have

$$\Delta_n = u_L^2 - u_R^2 + \beta(d_L^2 - d_R^2),$$
$$\Delta_p = (u_L^2 - u_R^2)\beta + d_L^2 - d_R^2, \qquad (20)$$

where $\beta = \frac{\int x u_\nu^p(x)\,dx}{\int x d_\nu^p(x)\,dx} = 2$ in the case of SU(2) symmetry of distribution functions, and $\beta = 2.5$ if SU(2) symmetry is broken [10].

The relative deviation from SM owing to the Z'-boson is written for these differences as:

$$\delta_p = \frac{\Delta'_p - \Delta_p}{\Delta_p} = -w\gamma \frac{\beta - 1 + \frac{8\beta - 1}{3} w - \frac{3}{4} w\gamma}{\frac{1+\beta}{4} - \frac{2\beta + 1}{3} w},$$

$$\delta_n = \frac{\Delta'_n - \Delta_n}{\Delta_n} = w\gamma \frac{\beta - 1 + \frac{8 - \beta}{3} w + \frac{3}{4} w\gamma\beta}{\frac{1+\beta}{4} - \frac{2+\beta}{3} w}, \qquad (21)$$

$$\delta_0 = \frac{\Delta'_0 - \Delta_0}{\Delta_0} = w\gamma \frac{\frac{3}{4} w\gamma + \frac{7}{3} w}{\frac{1}{2} - w}.$$

The primed quantities are calculated with the contribution of the Z'-boson. Fig. 7 shows the curves for $\beta = 2$ and 2.5. The solid curves are for the proton target, the dashed ones are for the neutron targets (they coincide with one another). If $M_{Z'} \approx 300$ GeV, the maximum deviation does not exceed 1%. The deviation is about 1/w times smaller for δ_0. However, the experimental errors for differences (19) at the isoscalar target are not less than 10%. Therefore, the search for deviation from SM in relations (19) is hopeless.

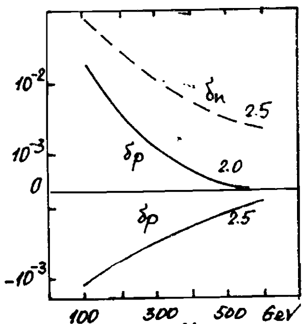

Fig. 7

4. The Ratios of Differences

$$\Delta = \frac{\sigma^{\nu n}_{NC} - \sigma^{\nu p}_{NC}}{\sigma^{\nu n}_{CC} - \sigma^{\nu p}_{CC}}, \quad \bar{\Delta} = \frac{\sigma^{\bar{\nu} n}_{NC} - \sigma^{\bar{\nu} p}_{NC}}{\sigma^{\bar{\nu} n}_{CC} - \sigma^{\bar{\nu} p}_{CC}} \qquad (22)$$

are of great interest in searching for deviations from SM due to the Z'-boson. We obtain from (8):

$$\Delta = d_L^2 - u_L^2 + \frac{1}{3}(d_R^2 - u_R^2), \quad \bar{\Delta} = d_R^2 - u_R^2 + \frac{1}{3}(d_L^2 - u_L^2). \qquad (23)$$

Then the searched for relative deviations from SM get the form:

$$\delta_\nu = \frac{\Delta' - \Delta}{\Delta} = \gamma \frac{6 - 5w - \frac{3}{4} w\gamma}{1 - \frac{4}{3} w},$$

$$\delta_{\bar{\nu}} = \frac{\bar{\Delta}' - \bar{\Delta}}{\bar{\Delta}} = \gamma \frac{6 + 3w - \frac{27}{4} w\gamma}{1 - 4w}. \qquad (24)$$

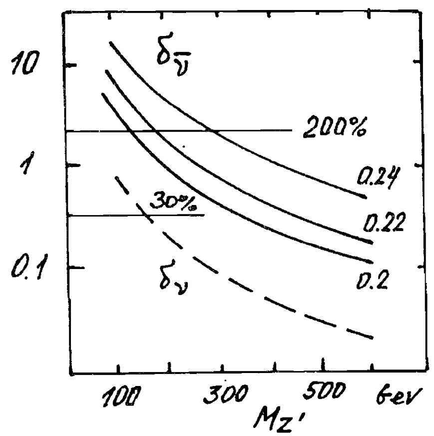

Fig. 8

Figure 8 shows the curves δ_ν and $\delta_{\bar{\nu}}$ for different values of $w = \sin^2\theta_W$. For δ_ν (the dashed curves) there is practically no dependence on w, and the ratio is 8% for $M_{Z'} \approx 300$ GeV.

The experimental ratio Δ was measured by the collaboration [11] with an error 80%. But the accuracy of measurements in this experiment is 4(3) times worse than the best accuracy achieved at $\nu(\bar{\nu})$-beams (see the Table) in other experiments [12].

So we have regarded 30% as the rough estimation of the accuracy which can be achieved in measurements of Δ at available experimental set-ups. This value is shown by the horizontal straight line in the figure. Thus the 3-4-fold increase in the accuracy of measurement of Δ will probably allow the experiment to get closer to the theoretically expected upper limit of the Z'-boson mass $M_{Z'} \approx 320$ GeV.

For the antineutrino beam the deviation from SM greatly depends on the $w = \sin^2\theta_W$ (because the denominator $\delta_{\bar\nu}$ is equal to $1-4w$ and close to 0), and at $M_{Z'} \approx 300$ GeV it is 40%, 70% and 200% for $w = 0.2$, 0.22 and 0.24, respectively.

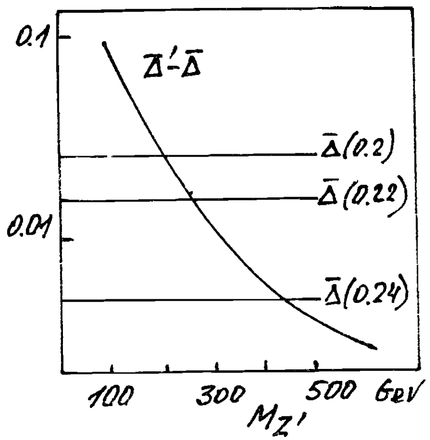

Fig. 9

Figure 9 allows comparing the absolute values of differences $\bar\Delta$ for three values of w (0.2, 0.22 and 0.24), with the value of $\bar\Delta' - \bar\Delta$ which depends on the Z' contribution. For example, if $M = 260$ GeV and $w = 0.22$, the contribution of the Z'-boson equals the $\bar\Delta$ calculated on the basis of SM alone. Thus the experimental value of this differences $(\bar\Delta')$ has to be approximately two times larger than SM prediction $(\bar\Delta)$.

The ratio $\bar\Delta$ was experimentally estimated to an accuracy of 450% in Ref. [11]. One can expect, however, that more accurate measurements of $\bar\Delta$ (at the level of 200% [12], see the horizontal straight line in Fig. 8) are already attainable. A 3-4-fold increase of these accuracies at new accelerators will allow achieving the mass $M_{Z'} \approx 300$ GeV. In this case it would be necessary, perhaps, to measure the cross sections $\sigma_{NC}^{\bar\nu p}$, $\sigma_{NC}^{\bar\nu n}$ with an accuracy not lower than 2%.

5. There are practically no nuclear effects of the target. Let us take the differences Δ^{AB} at different nuclei A and B:

$$\Delta^{AB} = \sigma_{NC}^{\nu A} - \sigma_{NC}^{\nu B} = (\alpha - \beta)\Delta,$$

where Δ are calculated by formulae (22), and $\alpha = N_A/A$, $\beta = N_B/B$, where $N_{A(B)}$ is the number of neutrons in the nucleus A(B).

Then, if $\alpha \neq \beta$,

$$(\Delta'^{AB} - \Delta^{AB})/\Delta^{AB} = (\Delta' - \Delta)/\Delta.$$

So, in order to study δ_ν and $\delta_{\bar\nu}$, pure proton and neutron targets are not necessary, investigation of scattering on nuclei with different isospins is quite enough.

DISCUSSION

Results of our consideration are listed in the Table. Let us discuss some of them.

The present experimental accuracies (the best one is 2-3% for the isoscalar target in neutrino interactions, see the Table) do not allow observing the manifestations of the additional superstring Z'-boson in neutral current νN-interactions. Generally, deviations from SM are considerably smaller than the accuracies of measurement of the corresponding quantities (see the Table). However, the available theoretical estimations of the upper limit for the mass $M_{Z'} \approx 320$ GeV [6] make the search for these manifestations into the task of current importance. The accelerators of the new generation, including the UNK, will allow an almost 3-5-fold increase in measurement accuracies due to larger statistics. As is shown, it can ensure achieving the above-mentioned upper limit for the mass of the Z'-boson.

To search for manifestations of the Z'-boson, it would be better, to our opinion, to analyse the quantity $R_{\bar\nu} = \sigma_{NC}^{\bar\nu n,p}/\sigma_{CC}^{\bar\nu n,p}$, ratios of differences $\Delta = (\sigma^n - \sigma^p)_{NC}^{\nu}/(\sigma^n - \sigma^p)_{CC}$ and $\Delta = (\sigma^n - \sigma^p)_{NC}^{\bar\nu}/(\sigma^n - \sigma^p)_{CC}^{\bar\nu}$. An increase in accuracy of determination of these quantities to 1%, 10% and 70%, respectively, will allow achieving the upper limit $M_{Z'} \approx 320$ GeV.

The tentative rough estimations (see the Table) show that deviations of the data from SM for the relations $R_{\bar\nu}$, Δ and $\bar\Delta$, though they are considerably smaller than measurement errors, qualitatively agree with predictions of the superstring phenomenology. This, however, can only be regarded as a trend with some hopes to find manifestations of the superstring Z'-boson in relations Δ, $\bar\Delta$ and $R_{\bar\nu}$.

According to the tentative calculation [19], the use of the IHEP-JINR Neutrino Detector at energies and intensities of the UNK will lead to a 10-20-fold increase in statistics as compared with the level achieved in the world today. Consequently, if will be possible to increase the accuracy of

Table

Symbol	Ref.	$\bar{x}_{exp}$	$\Delta x_{exp}/\bar{x}_{exp}$	$(\bar{x}_{exp}-x_{SM})/x_{SM}$	$(x_{SS}-x_{SM})/x_{SM}$ 200 GeV	300 GeV	400 GeV
R_ν	/I2/	0.300	0.023	-0.029	-0.006	-0.003	0.00I5
	/II/	0.328	0.082	0.065			
$R_{\bar{\nu}}$	/I2/	0.357	0.042	-0.03	-0.02	-0.0I	-0.005
	/II/	0.353	0.I2I	0.04			
R_ν^p	/I4/	0.47	0.08	0.02	-0.0I	-0.005	-0.003
	/I5/	0.49	0.I2	0.07			
$R_{\bar{\nu}}^p$	/I6/	0.36	0.I7	0.0	-0.03	-0.0I	-0.006
$R_\nu^{n/p}$	/I7/	I.22	0.3	0.I2	0.02	0.008	0.004
	/I5/	I.0I	0.I5	-0.07			
$R_{\bar{\nu}}^{n/p}$	/I8/	I.06	0.2I	0.I3	0.0I5	0.007	0.004
δ_ν	/II/	0.06	0.8 (0.3)	0.09	0.I9	0.09	0.05
$\delta_{\bar{\nu}}$	/II/	0.02	4.5 (2.0)	0.25	I.5	0.7	0.4

measurements by a factor of 3-4. This increase in the accuracy, as is shown above, can be sufficient for observation of manifestations of the extra Z'-boson in neutral currents. So the search for these manifestations is a task of current importance and it can be solved at UNK with the Neutrino Detector.

The authors thank Bunyatov S.A. and Isaev P.S. for stimulating interests in this work, Osipov A.A. and Ivanov Yu.P. for helpful discussions.

APPENDIX

Below is the explicit form of formulae (10) and (11):

$$D = \frac{1}{4} - \frac{1}{3}w + \frac{4}{27}w^2, \quad U = \frac{1}{4} - \frac{2}{3}w + \frac{16}{27}w^2,$$

$$\bar{D} = \frac{1}{12} - \frac{1}{9}w + \frac{4}{27}w^2, \quad \bar{U} = \frac{1}{12} - \frac{2}{9}w + \frac{16}{27}w^2,$$

$$\Sigma = \frac{1}{2} - w + \frac{10}{9}w^2.$$

$$\Delta\Sigma = \frac{13}{4}w^2\gamma^2 - w\gamma,$$

$$\Delta D = \frac{13}{12}w^2\gamma^2 + w\gamma(1 - \frac{7}{9}w),$$

$$\Delta U = \frac{4}{3}w^2\gamma^2 - w\gamma(1 - \frac{8}{9}w),$$

$$\Delta\bar{D} = \frac{7}{12}w^2\gamma^2 + w\gamma(\frac{1}{3} - \frac{5}{9}w),$$

$$\Delta\bar{U} = \frac{4}{3}w^2\gamma^2 - w\gamma(\frac{1}{3} + \frac{8}{9}w).$$

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Received by Publishing Department
on November 11, 1987.

Бедняков В.А., Коваленко С.Г., Новожилов В.Ю. E2-87-800
О возможных проявлениях суперструнного Z'-бозона в нейтральных токах

Изучен вклад дополнительного суперструнного Z'-бозона в некоторые величины, измеряемые в рассеянии нейтральных токов. Проанализирован характер возникающих отклонений от предсказаний стандартной модели. На основе известных теоретических ограничений на массу Z'-бозона аргументирована возможность наблюдения этих отклонений на ускорителях нового поколения, включая УНК.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна 1987

Bednyakov V.A., Kovalenko S.G., Novozhilov V.Yu. E2-87-800
On Possible Manifestations of the Superstring Z'-Boson in Neutral Currents

Contribution of the additional superstring Z'-boson to the neutral current scattering is analysed. We consider some Z'-induced deviations from the standard model predictions. On the ground of the well known theoretical constraints on the mass of Z'-boson we show that these deviations can be observed at accelerators of new generation including UNK.

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

Communication of the Joint Institute for Nuclear Research. Dubna 1987