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дубна

E2-88-157

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SUPERSTRING Z'-BOSON AT UNK ENERGIES

Submitted to "Ядерная физика"

1988

INTRODUCTION

Investigations of superstrings [1] are expected to lead to a unified theory of all fundamental interactions. From the point of view of physical consequences one now prefers the model of the 10-dimensional heteroitic superstring with the gauge group $E_8 \times E_8'$ [2]. One of the most advanced schemes of compactification onto the Calabi-Yau manifold at energies below the Planck masses $M_p \sim 10^{19}$ GeV yields an effective 4-dimensional N = 1 supersymmetrical theory with the gauge group E_6 [3]. A large number of new exotic fermions and an extra Z′-boson of mass below 1 TeV are predicted. It is still not clear whether the exotic fermions can be ligth enough [4,5]. So the experiments in the search for the Z′-boson at accelerators of the new generation (SSC, LHC, UNK) seem better substantiated, though one considers the possibility of observing exotic E_6 fermions.

The following simple arguments [5] for existence of this particle in the E_6-model are in place here. Let us consider the maximal subgroup

$$E_6 \supset SU_{3C} \times SU_{3L} \times SU_{3R}, \qquad (1)$$

assuming such an imbedding of the standard group $SU_{3C} \times SU_{2L} \times SU_{1Y}$ that $SU_{2L} \subset SU_{3L}$.

In the superstring-inspired E_6-model the breaking of the gauge group at the compactification scale M_c ($M_c \lesssim M_p \sim 10^{19}$ GeV) is due to the flux breaking mechanism [3]. This mechanism has the same effect as the Higgs mechanism with the Higgs fields in the abjoint representation of the group E_6, i.e. in its 78-plet. Remember that each generation of fermions is part of the fundamental 27-dimensional representation. For the above maximal subgroup (1) there is a decomposition

$$78 = (8,1,1) + (1,8,1) + (1,1,8) + (3^*,3,3) + (3,3^*,3^*) \qquad (2)$$

$$27 = (3^*,1,3^*) + (3,3,1) + (1,3^*,3). \qquad (3)$$

The first set of parentheses in (3) contains antiquarks, the second one - quarks, and the third one - leptons.

The Higgs fields preserving SU_{3C} can be present in $(1,8,1)+(1,1,8)$. It is known that if the group SU_3 is broken by the Higgs fields from its octet representation, the subgroup SU_2 can remain only with the U_1-factor. Thus, SU_{3L} can be broken to $SU_{2L}\times U_{1L}$. The charge Y_L corresponding to U_{1L} cannot be identified with the weak hypercharge Y. It follows from the relation

$$Q^{em} = I_{3L} + Y/2$$

and decomposition of the 27-plet (3) that in this case SU_{3L}-singlet antiquarks would not carry the electric charge Q^{em} and the leptons would have a fractional charge. Consequently, one of the preserved quantities corresponding to SU_{3R} must make a contribution to the weak hypercharge Y. In other words, at least one subgroup $U_{1R}\subset SU_{3R}$ must survive the breaking. So a group appears in the superstring-inspired E_6-model, it is wider than the standard one at least by one U_1'-factor

$$E_6 \to SU_{3C}\times SU_{2L}\times U_{1Y}\times U_1'. \qquad (4)$$

This is just the indication of existence of an additional Z'-boson associated with U_1'.

In a general case the E_6-symmetry may be broken in superstring models only to the rank 5 and rank 6 subgroups depending on the topology of the compact manifold /3/. Other possibilities are regarded as non-realistic /6/.

Below we shall consider a model with an intermediate gauge group of rank 5, since its predictions are more definite.

Note that there can be direct and indirect experimental manifestations of the Z'-boson. Produced in high-energy collisions, Z' can be directly observed in colliding beams of SSC ($\sqrt{S}$ = 40 TeV), LHC ($\sqrt{S}$ = 16.5 TeV), UNK ($\sqrt{S}$ = 6 TeV). The study of indirect manifestations of the Z'-boson has good prospects in fixed target experiments at UNK ($\sqrt{S}$ = 75 GeV). In some cases these manifestations are practically independent of the energy and the possibility of observing them is determined by the accuracy of measurements. According to tentative estimations /7/, the necessary statistics can be provided by the planned neutrino experiments at UNK /8/. Higher neutrino beam energies, as compared with the present level, result in larger statistics owing to the linear growth of total cross sections for neutrino interactions ($\sigma \sim \sigma_0 E_\nu$).

In this paper we study the contribution of the Z'-boson to neutral currents taking into account the $Z^0 - Z'$ mixing. We have found quantities composed of deep inelastic $\nu(\bar\nu)N$ scattering cross sections which are most sensitive to the Z' contribution. These quantities analysed, we discuss some possibilities of indirect observation of this particle in neutrino experiments at UNK.

1. MASS MATRIX AND Z' INTARCTIONS WITH FERMIONS

Properties of the Z'-boson can be considered on the same basis within the models with the intermediate group of both the 5th and 6th rank:

$$SU_{3C}\times SU_{2L}\times U_{1Y}\times U_1' \qquad \text{rank} = 5, \qquad (5)$$

$$SU_{3C}\times SU_{2L}\times U_{1Y}\times U_{1\chi}\times U_{1\psi} \quad \text{rank} = 6. \qquad (6)$$

Imbedding in E_6 is determined by a sequence of subgroups:

$$E_6 \supset SO_{10}\times U_{1\psi} \supset SU_5 \times U_{1\chi}\times U_{1\psi}, \qquad (7)$$

when

$$SU_5 \supset SU_{3C}\times SU_{2L}\times U_{1Y}. \qquad (8)$$

Generators of U_1' have the form

$$Q' = \sqrt{\tfrac{3}{8}}\,Q_\chi - \sqrt{\tfrac{5}{8}}\,Q_\psi \qquad (9)$$

Q_χ and Q_ψ are the generators of $U_{1\chi}$ and $U_{1\psi}$. Q' is associated with the Z'-boson in the model with the group of rank 5.

In the version with the group of rank 6 there is also one light boson. This is the additional $Z(\theta)$-boson coupled with the superposition of the generators:

$$\tilde{Q}(\theta_{E_6}) = Q_\psi \cos\theta_{E_6} + Q_\chi \sin\theta_{E_6}. \qquad (10)$$

Values of the charges Q_χ, Q_ψ, Q' for the fields from the E_6 27-plet are listed in the Table. The angle θ_{E_6} parametrises the E_6-symmetry breaking scheme. Evidently, (9) is a particular case of (10) at θ_{E_6} =142.24°, i.e. $Q' = \tilde{Q}(142.24°)$. It is this case that we shall consider. The narrowing of the parametric arbitrariness allows more specific estimations of the contribution of the Z'-boson.

The initial Lagrangian of interactions with neutral currents has the form:

Table. Quantum numbers of the E_6 27-plet

SO_{10}	SU_5	left-handed field	Su_{3C}	I_{3L}	Q^{em}	$2\sqrt{15}\cdot Q'$	$2\sqrt{10}\cdot Q_\chi$	$\sqrt{24}\cdot Q_\psi$
16	5*	d^c	3*	0	1/3	1	3	1
		e^-	1	-1/2	-1	1	3	1
		ν_e	1	1/2	0	1	3	1
	10	e^{-c}	1	0	1	-2	-1	1
		d	3	-1/2	-1/3	-2	-1	1
		u	3	1/2	2/3	-2	-1	1
		u^c	3*	0	-2/3	-2	-1	1
	1	N^c	1	0	0	-5	-5	1
10	5*	h^c	3*	0	1/3	1	-2	-2
		E^-	1	-1/2	-1	1	-2	-2
		ν_E	1	1/2	0	1	-2	-2
	5	h	3	0	-1/3	4	2	-2
		E^{-c}	1	1/2	1	4	2	-2
		N_E^c	1	-1/2	0	4	2	-2
1	1	n	1	0	0	-5	0	4

$$-\mathcal{L}_{NC}= eA^\mu J_\mu^{em} + gZ^\mu J_\mu^{Z} + g'Z'^\mu J_\mu^{Z'} . \qquad (11)$$

Here J_μ^{em} is the usual electromagnetic current, J_Z and $J_{Z'}$ are the currents interacting with Z- and Z'-bosons, respectively,

$$J_\mu^Z=\sum_i \bar\psi_i \gamma_\mu (I_{3L}- Q^{em} x_W)\psi_i \equiv \sum_i Q_i \bar\psi_i \gamma_\mu \psi_i \qquad (12)$$

$$J_\mu^{Z'}=\sum_i Q'_i \bar\psi_i \gamma_\mu \psi_i , \qquad (13)$$

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

Let us specify the coupling constants g and g' by the formulae[9]:

$$g = \frac{e}{\sqrt{x_W(1-x_W)}} , \quad g'=\sqrt{\frac{5}{3}}\,\frac{e}{\sqrt{1-x_W}} . \qquad (14)$$

Then the normalization of the charge Q' chosen ensures equality of these constants at the scale of unification of M_C into the E_6 group. Ignoring a slight difference in the renormalisation-group evolution of g and g', we shall use expessions (14) for energies $\sim M_W$ as well.

In a general case the mass matrix in the basis of $Z^\circ - Z'$ is non-diagonal:

$$M^2= \begin{pmatrix} M^2_{Z_0} & \delta M^2 \\ \delta M^2 & M^2_{Z'} \end{pmatrix} \qquad (15)$$

It leads to the mixing of the Z'-boson with the standard Z_0-boson. Diagonalisation of matrix (15) results in the states $Z_{1,2}$ with a definite mass:

$$\begin{pmatrix} Z_1 \\ Z_2 \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} Z_0 \\ Z' \end{pmatrix} \qquad (16)$$

The masses and the mixing angle are expressed through the initial parameters:

$$M_1^2 = M^2_{Z_0} - \frac{(\delta M^2)^2}{M^2_{Z'} - M^2_{Z_0}} , \quad M_2^2 = M^2_{Z'} + \frac{(\delta M^2)^2}{M^2_{Z'} - M^2_{Z_0}} \qquad (17)$$

$$\tan^2\theta = (M^2_{Z_0} - M_1^2)/(M_2^2 - M^2_{Z_0}) . \qquad (18)$$

In the models with SU_{2L}-doublet and singlet Higgs fields the following relation occurs:

$$M^2_{Z_0} = \frac{M_W^2}{1-x_W}, \qquad (19)$$

i.e. for $x_W = 0.229\pm0.05$ we have $M_{Z_0} = 92.1\pm0.7$ GeV. In the superstring-inspired E_6-model with the intermediate gauge group of rank 5 there are two doublet $(H, \bar{H})$ and one singlet (N) Higgs fields. In this case

$$\delta M^2 = \sqrt{x_W}\,\frac{4v^2 - \bar{v}^2}{3(v^2 + \bar{v}^2)},$$

$$M^2_{Z'} = M^2_{Z_0}\,\frac{16v^2 + \bar{v}^2 + 25x^2}{9(v^2 + \bar{v}^2)}, \qquad (20)$$

where $\langle H^0\rangle \equiv \langle \tilde{N}^c_E\rangle = v$, $\langle \bar{H}^0\rangle \equiv \langle \tilde{\nu}_E\rangle = \bar{v}$, $\langle N\rangle \equiv \langle \tilde{n}\rangle = x$. This structure of the Higgs sector leads to a restriction for the mixing angle [10]:

$$-\frac{8}{3}\,\frac{\sqrt{x_W}}{(M^2_{Z'}/M^2_{Z_0} - 1)} < \tan 2\theta < \frac{2}{3}\,\frac{\sqrt{x_W}}{(M^2_{Z'}/M^2_{Z_0} - 1)}. \qquad (21)$$

In the popular "no-scale" version of the model [11] $\theta > 0$. With allowance for mixing, the Lagrangian (11) has the form:

$$-\mathcal{L}_{NC} = eA^\mu J^{em}_\mu + gZ^\mu_1(J^Z_\mu \cos\theta + \frac{g'}{g} J^{Z'}_\mu \sin\theta)$$
$$+ g' Z^\mu_2(J^{Z'}_\mu \cos\theta - \frac{g}{g'} J^Z_\mu \sin\theta). \qquad (22)$$

Hence we obtain the low-energy effective Lagrangian of νN-neutral current interactions [12]

$$\mathcal{L}^{eff}_{NC} = \frac{G_F}{\sqrt{2}}(\bar{\nu}_L \gamma^\mu \nu_L)\sum_i \epsilon'_i \bar{f}_i \gamma_\mu f_i. \qquad (23)$$

Dependence on the mixing angle θ and the masses M_1 and M_2 of intermediate bosons is concentrated in chiral constants:

$$\epsilon'_i = \frac{M^2_{Z_0}}{M^2_1}(\cos\theta - \frac{g'}{g}\frac{\sin\theta}{3})(Q_i\cos\theta + Q'_i\frac{g'}{g}\sin\theta) +$$
$$+ \frac{M^2_{Z_0}}{M^2_2}(\sin\theta + \frac{g'}{g}\frac{\cos\theta}{3})(Q_i\sin\theta + Q'_i\frac{g'}{g}\cos\theta), \qquad (24)$$

where Q_i and Q'_i are defined in (12) and (13).

In the standard model (SM) the chiral constants have a simple form

$$\epsilon_i = Q_i. \qquad (25)$$

A cross section for deep inelastic scattering is the following linear combination [12]

$$\sigma^\nu_{NC} = \frac{2G^2_F ME}{\pi}\sum_i |\epsilon'_i|^2 C_i. \qquad (26)$$

The coefficients C_i are determined by the hadron target structure and do not depend on the type of the intermediate boson.

2. DEVIATIONS FROM THE STANDARD MODEL DUE TO THE SUPERSTRING Z′-BOSON

To investigate these deviations, we shall analyse the quantities of the type

$$\delta = \frac{A'(Z, Z') - A(Z)}{A(Z)}. \qquad (27)$$

$A'(Z, Z')$ and $A(Z)$ are the observable quantities calculated with and without the Z' contribution. It is important that the value of δ weakly depends on the hadron target structure.

1. Let us consider deviations in the ratio of cross sections $R = \sigma^{NC}/\sigma^{CC}$.

At high energies the total cross sections for deep inelastic $\nu(\bar{\nu})$N scattering have the form:

$$\sigma(\nu h \to \nu X) = C\{\epsilon'^2_L(u)U^h_L + \epsilon'^2_L(d)D^h_L + \epsilon'^2_R(u)U^h_R + \epsilon'^2_R(d)D^h_R\},$$
$$\sigma(\bar{\nu} h \to \bar{\nu} X) = C\{\epsilon'^2_L(u)U^h_R + \epsilon'^2_L(d)D^h_R + \epsilon'^2_R(u)U^h_L + \epsilon'^2_R(d)D^h_L\}, \qquad (28)$$

where $C = \frac{2}{\pi}G^2_F MED^p_v h$, h is the number of nucleons in the target h, $D^p_v = \int x\,dx\,d^p_v(x, Q^2)$ is the total momentum of valence d-quarks in a proton;

$$U_L = \eta - \beta\eta + \beta + (1 + \omega)(\xi + \zeta),$$
$$U_R = \omega(\eta - \beta\eta + \beta) + (1 + \omega)(\xi + \zeta),$$
$$D_L = 1 - \beta + \beta\eta + 2(1 + \omega)\xi, \qquad (29)$$
$$D_R = \omega(1 - \beta + \beta\eta) + 2(1 + \omega)\xi,$$

$\beta = n/h$, n is the number of neutrons in the target h, $\beta = (0, 1/2, 1)$ for proton, isoscalar, neutron, $\eta = \int x dx\, u_v^p(x)/D_v^p$, in our case $\eta = 2$ (isotopically symmetric distribution functions),

$\xi = \int x dx s(x)/D_v^p = 0.25$ /13/,

$\zeta = \int x dx c(x)/D_v^p = 0.125$,

$\omega = 1/3$ is the kinematic factor.

The multiplicative factor C taken out of the brackets in (28) is insignificant, since it is removed when one calculates the quantity

$$\delta_{\nu,\bar\nu} = \frac{R'_{\nu,\bar\nu} - R_{\nu,\bar\nu}}{R_{\nu,\bar\nu}} = \frac{\sigma'_{\nu,\bar\nu} - \sigma_{\nu,\bar\nu}}{\sigma_{\nu,\bar\nu}} . \qquad (30)$$

Figs.1 (2) show the dependence of $\delta_\nu (\delta_{\bar\nu})$ on the mass of the Z'-boson M_2 for different mixing angles. The curves have typical features:

a) They all intersect at the same point for $M_1 = M_2$. It follows from (24). There is no dependence on the mixing angle if $M_1 = M_2$;

b) At zero mixing angles $|\delta_{\nu,\bar\nu}|$ decreases, at non-zero ones it increases with the mass M_2. In fact, if $\theta = 0$,

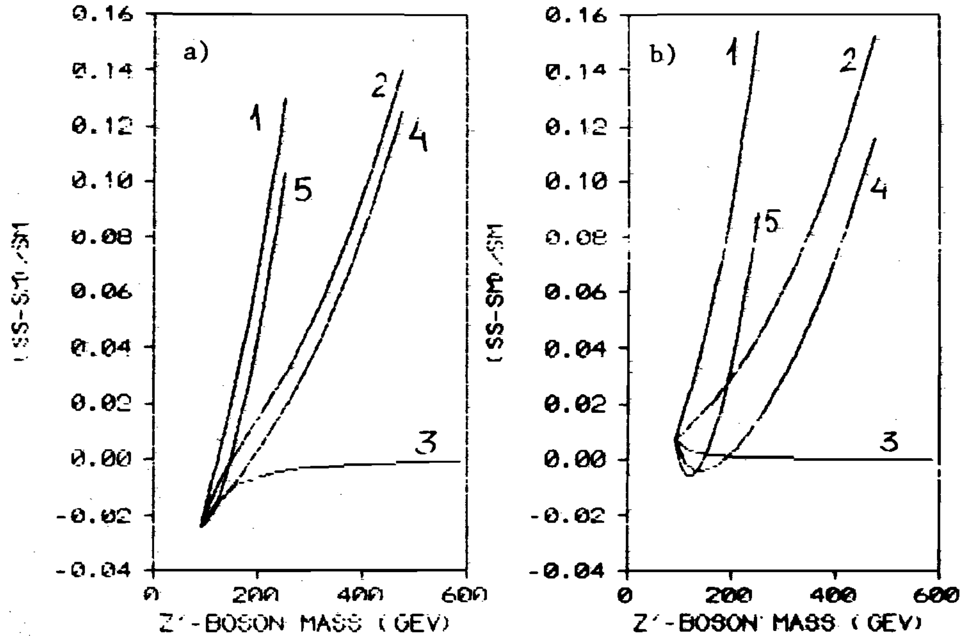
$$\epsilon'_i = \epsilon_i - Q'_i \frac{\sin^2 Q_W}{3} \frac{M_0^2}{M_2^2} \qquad (31)$$

tends to the ϵ_i (standard model) with growing M_2. At fixed non-zero θ the second term in (24) proportional to M_2^{-2} rapidly decreases while M_2 increases, and the first term proportional to M_1^{-2} increases, since M_1 decreases because of relation (18).

A disagreement between ϵ'_i and ϵ_i leads to considerable deviations of $R'_{\nu,\bar\nu}$ from $R_{\nu,\bar\nu}$;

c) According to (18), the value of the Z_0-boson mass $M_1 = 91.5 \pm 1.2 \pm 1.7$ GeV /14/ known from the experiment imposes a constraint

$$M_2^2 \leq \frac{M_W^2}{(1 - x_W)\sin^2\theta} - \mathrm{ctan}^2\theta\, M^2_{min} , \qquad (32)$$



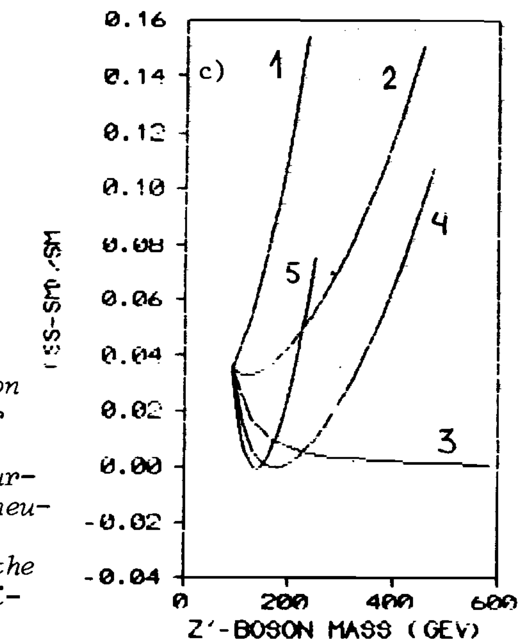
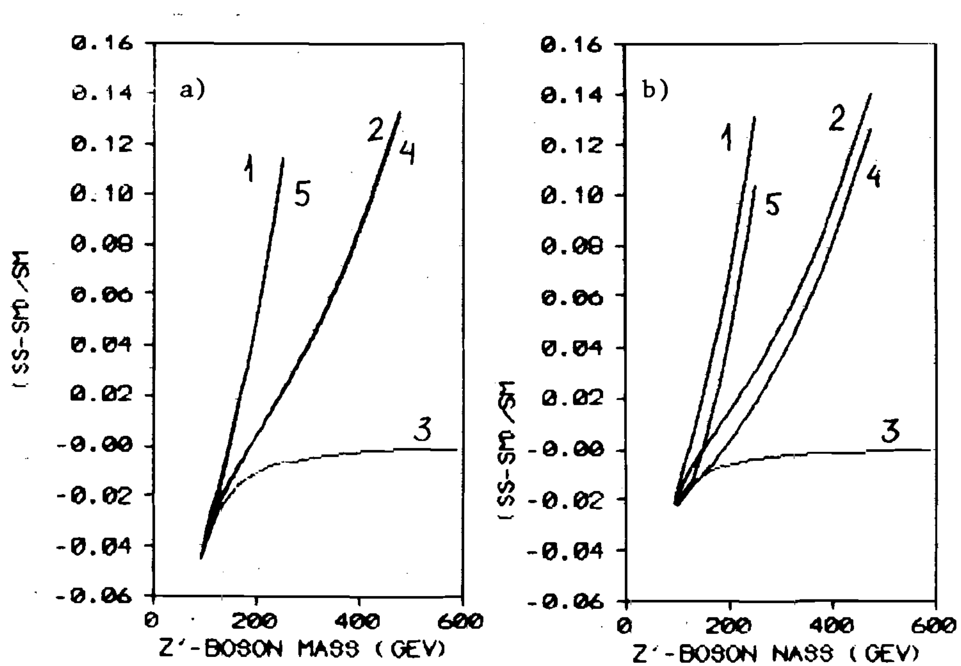


Fig.1. Deviation from the standard model as a function of the Z'-boson mass M_2 for the mixing angles -0.1; -0.05; 0; 0.05; 0.1 rad (curves 1-5 respectively); a) neutrino-proton scattering, b) neutrino scattering on the isoscalar target, c) neutrino-neutron scattering.



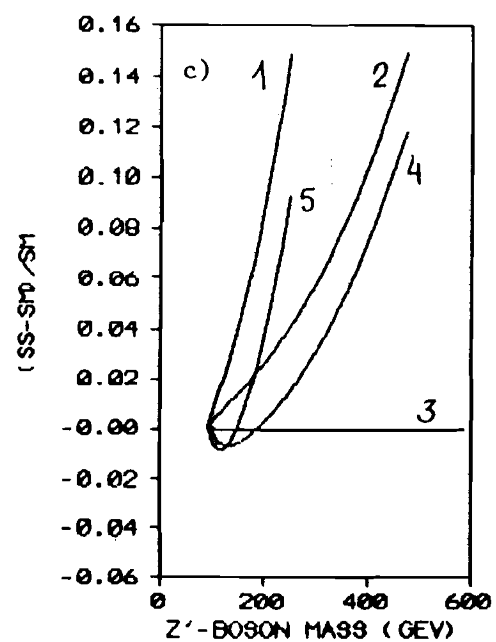


Fig. 2. Deviation from the standard model as a function of the Z'-boson mass M_2 for the mixing angles -0.1; -0.05; 0; 0.05; 0.1 rad (curves 1-5 respectively); a) antineutrino-proton scattering, b) antineutrino scattering on the isoscalar target, c) antineutrino-neutron scattering.

where $M_{min} \cong 90$ GeV. Therefore at increasing $|\theta|$ the curves are cut off at smaller M_2. Besides, very large values of $|\delta_{\nu,\bar{\nu}}|$ ($\delta_{\nu,\bar{\nu}} \geq 10\%$) are excluded owing to the experimental accuracy achieved.

The present region of allowable mixing angles and masses of the additional Z'-boson (θ and M_2) is shown in Figs.3 (4) by contour 1 /15/. Curves 2 and 3 show the narrowing of this region when $R_\nu(R_{\bar{\nu}})$ is measured on the isoscalar target with an accuracy 1% and 0.5%. It is the accuracy that one plans to achieve in neutrino experiments at the UNK.

As is seen, the same accuracy of measurements in the antineutrino beam will probably allow more rigid constraints on the region of M_2 and θ.

2. Let us consider deviations from SM in the Paschos-Wolfenstein relation

$$r^h = \frac{\sigma(\nu h \to \nu X) - \sigma(\bar{\nu} h \to \bar{\nu} X)}{\sigma(\nu h \to \mu X) - \sigma(\bar{\nu} h \to \mu X)} . \qquad (33)$$

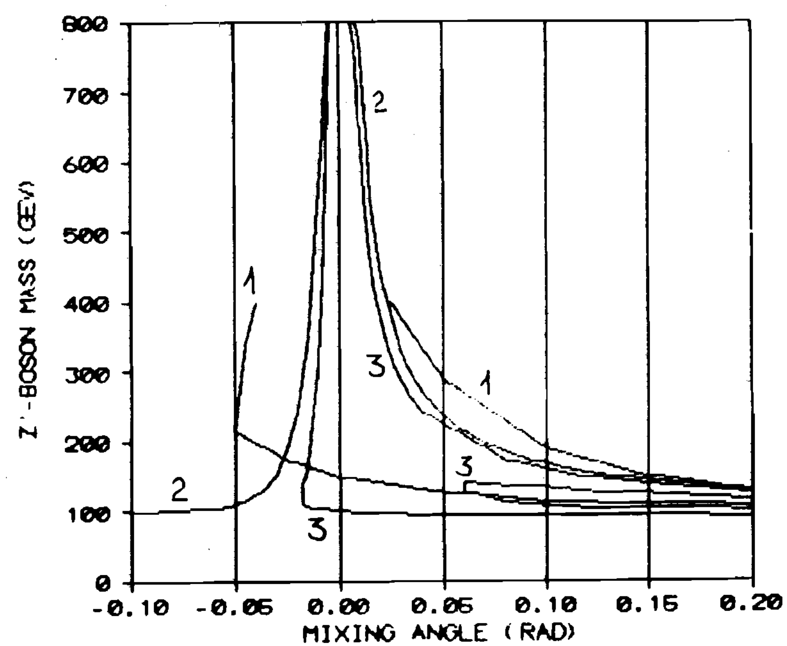


Fig. 3. Constraints on the mixing angle θ and the mass M_2 of the Z'-boson from neutral currents. 1 - contour from Ref. /15/; 2,3 - contours corresponding to the measurement of R_ν on the isoscalar target with an accuracy 1%, 0.5%.

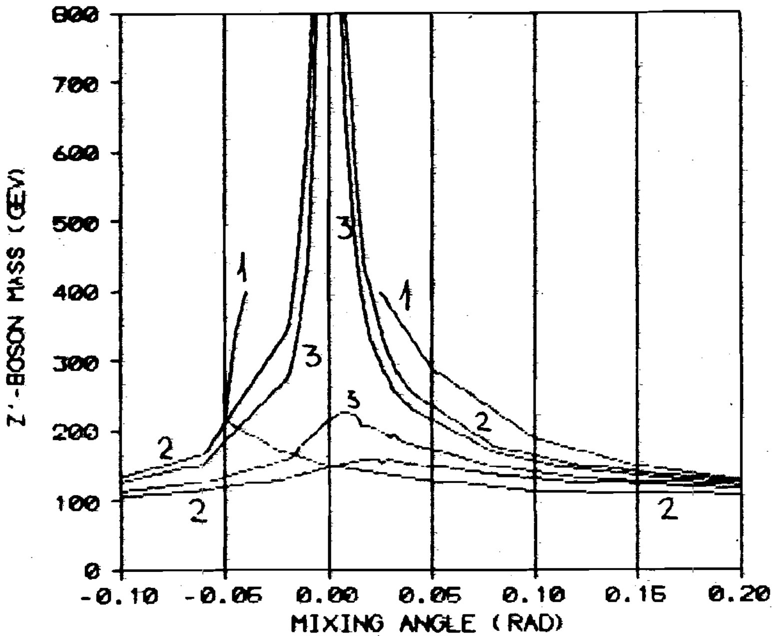


Fig.4. Constraints on the mixing angle θ and the Z'-boson mass M_2 from neutral currents. 1 - contour from Ref. [15]*; 2-3 - contours corresponding to the measurement of $R_{\bar{\nu}}$ on the isoscalar target with an accuracy 1%, 0.5%.*

In the usual parton model there is a relation

$$r^h = \frac{C}{\sigma^{\nu}_{CC} - \sigma^{\bar{\nu}}_{CC}} \{[\epsilon'^2_L(u) - \epsilon'^2_L(d)]U^h + [\epsilon'^2_R(u) - \epsilon'^2_R(d)]D^h\}, \qquad (34)$$

where

$$U^h = (1-\omega)(\eta - \beta\eta + \beta),$$

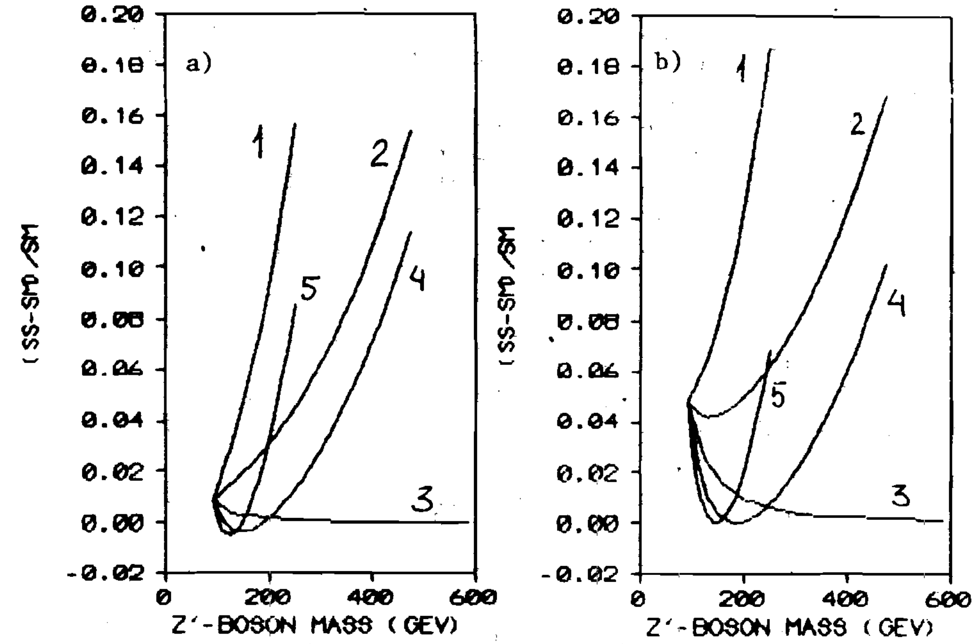
$$D^h = (1-\omega)(1 - \beta + \beta\eta)$$

and other quantities are defined earlier.

Deviation from SM

$$\delta^h = \frac{r'^h - r^h}{r^h}$$

is plotted in Fig.5 as a function of the Z'-boson mass for different mixing angles and targets.



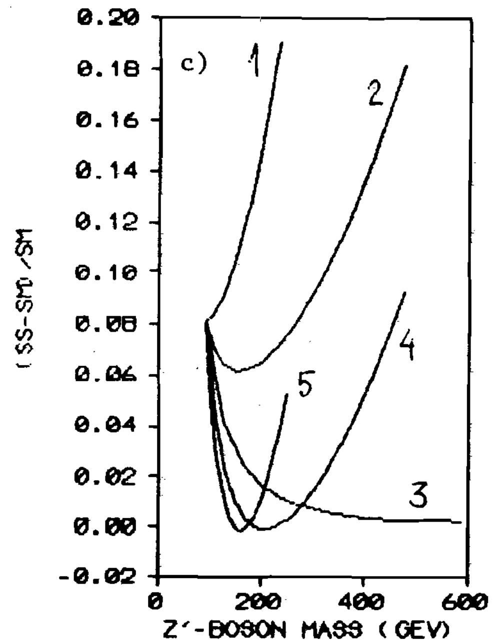


Fig.5. Deviation from the standard model in the Paschos-Wolfenstein relations as a function of the Z'-boson mass M_2 for the mixing angles -0.1; -0.05; 0; 0.05; 0.1 rad (curves 1-5 respectively); a) on the proton target, b) on the isoscalar target, c) on the neutron target.

Peculiarities in the behaviour of the curves (coincidences at $M_1 = M_2$, increase with M_2 at non-zero θ and decrease at $\theta = 0$, cut off graphs when M_2 and θ increase) have the same reasons as in the case of $R_{\nu,\bar\nu}$.

The accuracy achieved in measurements of r^h is not high (about 10-20%); only the region of large negative mixing angles is excluded. More details can be found in Fig.6. Besides contour 1, one can see curves 2 and 3 corresponding to the measurement of r on the isoscalar target with an accuracy 3% and 1.5%.

The measurement of r on the isoscalar target with the above accuracy will evidently allow one to exclude almost the whole of the region of negative mixing angles $\theta \lesssim -0.02$.

3. Let us consider deviations from SM in the ratios of cross sections

$$R_\nu^{n/p} = \frac{\sigma(\nu n \to \nu X)}{\sigma(\nu p \to \nu X)}, \quad R_{\bar\nu}^{n/p} = \frac{\sigma(\bar\nu n \to \bar\nu X)}{\sigma(\bar\nu p \to \bar\nu X)}. \tag{35}$$

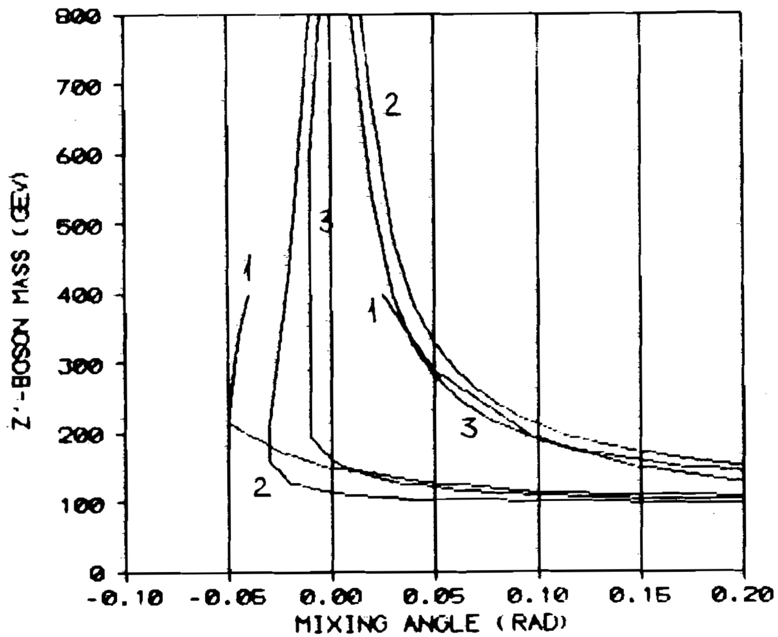


Fig.6. Constraints on the mixing angle θ and the Z'-boson mass M_2 from the analysis of the Paschos-Wolfenstein relation. 1 - contour from Ref. /15/, 2,3 - contours corresponding to measurements of r on the isoscalar target with an accuracy 3%, 0.5%.

The quantity we are interested in

$$\delta_{\nu,\bar\nu} = \frac{R'^{n/p}_{\nu,\bar\nu} - R^{n/p}_{\nu,\bar\nu}}{R^{n/p}_{\nu,\bar\nu}}$$

is calculated by means of formulae (28)-(29) for the proton and the neutron.

Figs.7 and 8 show the dependence of δ_ν, $\delta_{\bar\nu}$ on the Z'-boson mass for different mixing angles. The curves do not go beyond the presently achieved experimental accuracy in determination of $R^{n/p}_{\nu,\bar\nu}$ (about 10%). At all θ they decrease as M_2 increases, at positive θ they increase in absolute values.

In figs.9 and 10 the curves corresponding to measurement of $R^{n/p}_{\nu,\bar\nu}$ with an accuracy 3% and 1.5% are numbered 2 and 3.

Thus, measurement of $R^{n/p}_{\nu,\bar\nu}$ with an accuracy 3% does not impose more constraints on the region of allowable values of the parameters.

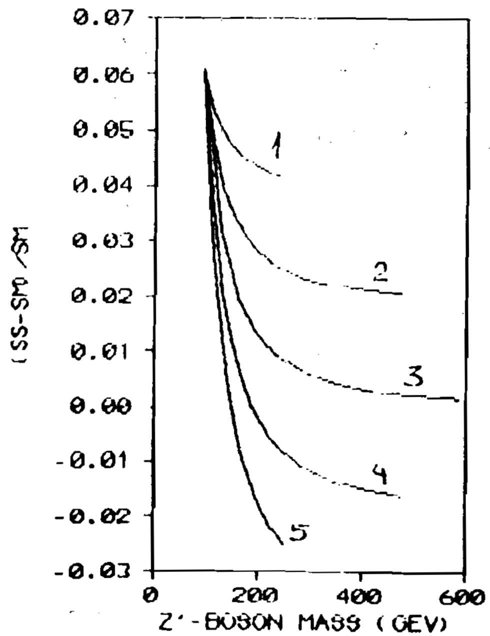


Fig.7. Deviation from the standard model in $R_\nu^{n/p}$ as a function of the Z'-boson mass M_2 for mixing angles -0.1; -0.05; 0; 0.05; 0.1 rad (curves 1-5 respectively).

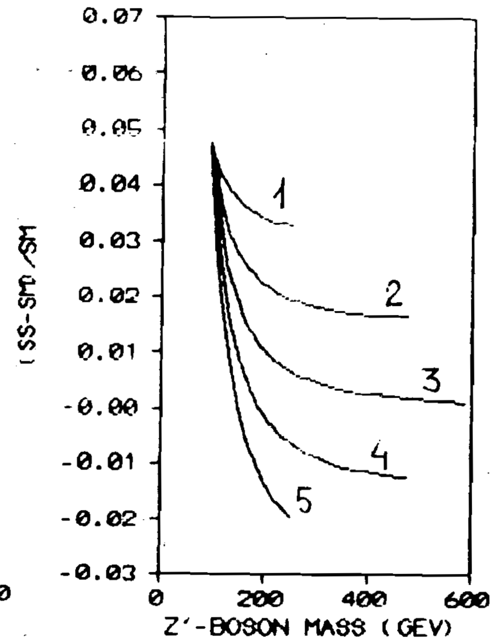


Fig.8. Deviation from the standard model in $R_{\bar\nu}^{n/p}$ as a function of the Z'-boson mass M_2 for mixing angles -0.1; -0.05; 0; 0.05; 0.1 rad (curves 1-5 respectively).

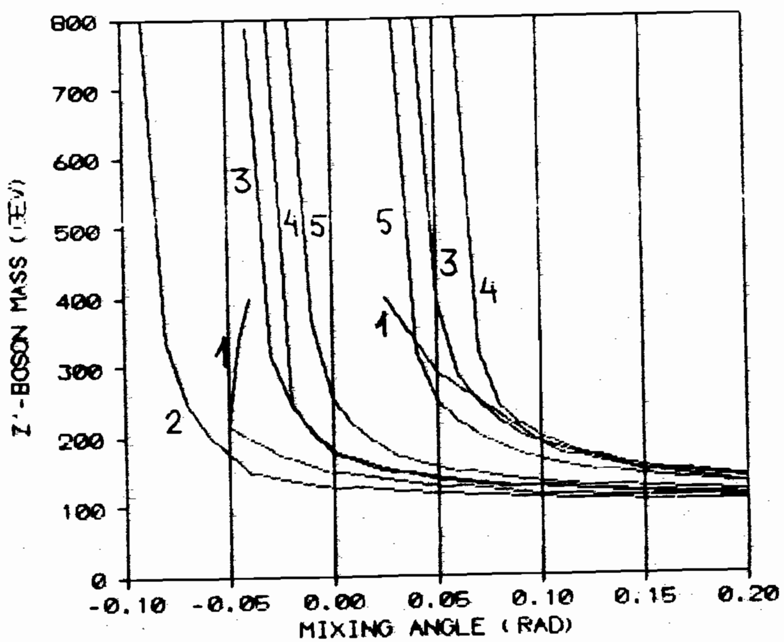


Fig.9. Constraints on the mixing angle θ and the Z′-boson mass M_2 from measurements of $R_\nu^{n/p}$ and Δ_ν. 1 – contour from Ref. [15], *2,3 – contours corresponding to the measurement of $R_\nu^{n/p}$ with an accuracy 3% and 1.5%, 4,5 – contours corresponding to the measurement of Δ_ν with an accuracy 20% and 10%.*

4. The relative differences

$$\Delta_\nu = \frac{\sigma(\nu n \to \nu X) - \sigma(\nu p \to \nu X)}{\sigma(\nu n \to \mu X) - \sigma(\nu p \to \mu X)},$$

$$\Delta_{\bar\nu} = \frac{\sigma(\bar\nu n \to \bar\nu X) - \sigma(\bar\nu p \to \bar\nu X)}{\sigma(\bar\nu n \to \mu X) - \sigma(\bar\nu p \to \mu X)} \qquad (36)$$

are of great interest for the search for deviations from SM because of the additional Z′-boson.

In the parton model we have

$$\Delta_\nu = \epsilon_L'^2(u) - \epsilon_L'^2(d) + \omega[\epsilon_R'^2(u) - \epsilon_R'^2(d)], \qquad (37)$$

$$\Delta_{\bar\nu} = \epsilon_R'^2(u) - \epsilon_R'^2(d) + \omega[\epsilon_L'^2(u) - \epsilon_L'^2(d)].$$

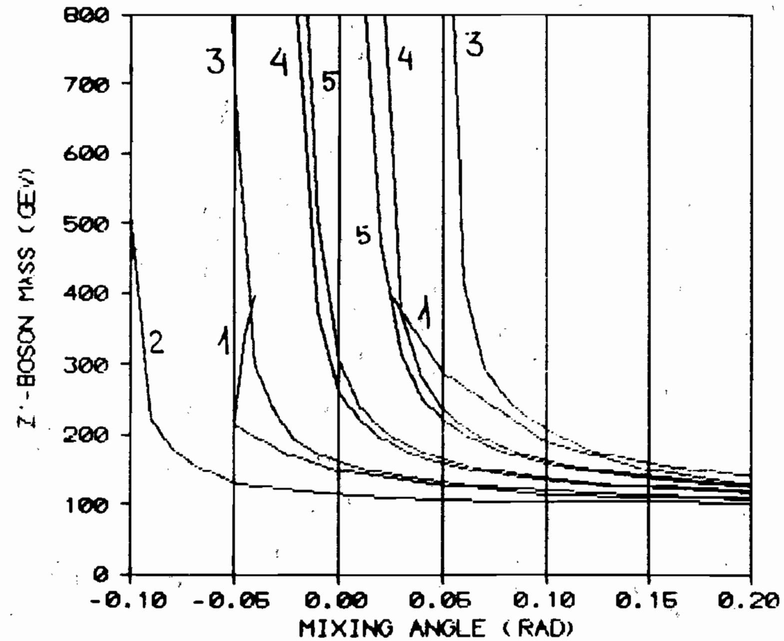


Fig.10. Constraints on the mixing angle θ and the Z′-boson mass M_2 from measurements of $R_{\bar\nu}^{n/p}$ and $\Delta_{\bar\nu}$. 1 – contour from Ref. [15], *2,3 – contours corresponding to the measurement of $R_{\bar\nu}^{n/p}$ with an accuracy 3%, 1.5%, 4,5 – contours corresponding to the measurement of $\Delta_{\bar\nu}$ with an accuracy 80%, 60%.*

We shall calculate a relative deviation from SM by the formula

$$\delta_{\nu,\bar\nu} = \frac{\Delta'_{\nu,\bar\nu} - \Delta_{\nu,\bar\nu}}{\Delta_{\nu,\bar\nu}}.$$

Figs.11 and 12 show the dependence of $\delta_{\nu,\bar\nu}$ on M_2 at different mixing angles. Deviations from SM are large: up to 80% for Δ_ν and 600% for $\Delta_{\bar\nu}$ at the experimentally achieved accuracies 80% for Δ_ν and 400% for $\Delta_{\bar\nu}$ [16].

This large relative error of $\Delta_{\bar\nu}$ is simply explained by the fact that $\Delta_{\bar\nu}$ is close to zero in SM:

$\Delta_{\bar\nu} = 1 - 4\sin^2\theta_W$

(e.g. $\Delta_\nu \approx 0$ at $\sin^2\theta_W = 0.22 \pm 0.05$).

In other words, a 600% error means that the contribution of the Z′-boson to $\Delta_{\bar\nu}$ is 7 times larger than that of the conventional Z-boson. So to study $\Delta_{\bar\nu}$ virtually means to study a practically pure contribution of the Z′-boson.

The authors are thankful to S.A.Bunyatov, Yu.P.Ivanov, P.S.Isaev for the stimulating discussion and valuable comments on the paper.

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Received by Publishing Department
on March 4, 1988.

Бедняков В.А., Коваленко С.Г. E2-88-157
Суперструнный Z′-бозон при энергиях УНК

В работе изучен вклад Z′-бозона в нейтральные токи. Учтено Z-Z′ смешивание. Найдены такие величины, составленные из сечений глубоконеупругого /анти/ нейтрино-нуклонного рассеяния, которые наиболее чувствительны к вкладу Z′-бозона. Рассматривается возможность косвенного наблюдения этой экзотической частицы в нейтринных экспериментах на УНК.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1988

Bednyakov V.A., Kovalenko S.G. E2-88-157
Superstring Z′-Boson at UNK Energies

The contribution of the extra Z′-boson to neutral currents has been studied. Z - Z′ mixing has been taken into account. The quantities most sensitive to the Z′-boson contribution are found; they are composed of cross sections for deep inelastic (anti) neutrino-nucleon scattering. Possibility of indirectly observing this exotic particle in UNK neutrino experiments is considered.

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

Preprint of the Joint Institute for Nuclear Research. Dubna 1988