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PREDICTION OF EXISTENCE OF NEUTRAL BOSON WITH SPIN 2 IN MASS RANGE FROM ZERO TO 160.77 GEV

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Abstract
The questions connected with the possibility of the existence of new neutral bosons with the spins 0, 2 and 3 in the mass range from zero to $160.77\,GeV$ are discussed. We investigate the decay of an arbitrary neutral boson into a pair of W-bosons in a magnetic field. The possible existence of the new neutral bosons with the spins 0, 2, 3 and with the charge conjugation $C=+1$ in the mass range from zero to $160.77\,GeV$ is predicted. The analyses show that the existence of the neutral boson with the spin 2 in the mass range from zero to $160.77\,GeV$ is more promising and realistic.

Keywords: Higgs boson, W-boson in a magnetic field, spin 2 particle, spin 3 particle, parity, charge conjugation, neutral boson with the mass $126\ GeV$
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1. INTRODUCTION

Recently the ATLAS and CMS Collaborations reported on the discovery of a new neutral boson (NB) at a mass around $126\ GeV$ [1, 2] with properties compatible with the Standard Model Higgs boson [3-8] that is described with $J^{PC}=0^{++}$ where P is the parity, C is the charge conjugation, J is the spin. Plenty of background phenomena were observed in the pp-collisions in the LHC experiments. From this point of view it is difficult to distinguish the signals from the background phenomena in pp-collisions. Therefore the production of new particles in the pp-collisions in the energy (mass) range $0<m\le 2m_W$ ($m_W \cong 80.385\,GeV$ [9] is the W-boson mass) is not excluded in the future improved LHC experiments. Here we investigate the possibility of the existence of the NBs with the spins 0, 2 and higher than 2 in the mass range $0<m\le 2m_W$. The following natural questions arise. Is the existence of any other NBs with the spin 0 except the $126\ GeV$ NB in the mass

range $0 < m \leq 2m_W$ possible? How is realistic and promising the existence of the NB with the spin 2 and higher than 2 in the mass range $0 < m \leq 2m_W$? Search for the answers to these questions determines the motivation for the presented investigation. We investigate the decay of an arbitrary NB (we call it a neutral Y-boson) including the NB observed at the LHC into a W^-W^+-pair in a magnetic field (MF) provided that our arbitrary NB also decays into the two photons. The main purpose of this work is to predict the existence of new NBs in the mass range $0 < m \leq 2m_W$ and to determine their spins.

2. BASIC IDEA IN THIS WORK

To consider the energy spectrum of a $W^\mp$-boson in an external uniform MF [10-14] in the $\hbar = c = 1$ system of units we will use the formula [10, 11]

$$E^2 = p_{\mp z}^2 + (2n_\mp + 1 - 2q_\mp s_{\mp z})eB + m_W^2, \tag{1}$$

where $B = |\vec{B}|$ is the strength of a MF whose intensity vector $\vec{B}$ is directed along the Oz-axis, $p_{\mp z}$ and $s_{\mp z}$ are the third component of the momentum and the third component of the spin of a $W^\mp$-boson, respectively, $n_\mp = 0,1,2,...$ enumerates the Landau energy levels, $q_+ = +1$ ($q_- = -1$) is the sign of the electric charge of a W^+ (W^-)-boson. The formula

$$E^2 = p_z^2 + (2n+1)e|\vec{B}| - 2e\vec{B}\cdot\vec{s} + m_W^2, \tag{2}$$

presented in [12-14] is applicable only for the positively charged W-boson, where $\vec{s}$ is the spin vector of a W^+-boson. Therefore we use the formula (1) for the investigation of the energy spectrum of a $W^\mp$-boson in an external uniform MF. A $W^\mp$-boson has three polarization states: $|W^\mp(s_\mp = 1,\, s_{\mp z} = +1)\rangle = |1,+1\rangle$, $|W^\mp(s_\mp = 1,\, s_{\mp z} = 0)\rangle = |1,0\rangle$, $|W^\mp(s_\mp = 1,\, s_{\mp z} = -1)\rangle = |1,-1\rangle$, where $s_\mp$ is the spin of a $W^\mp$-boson. Hereafter we will consider the case $n_\mp = 0,\ p_{\mp z} = 0$. Let us consider the case $q_\mp s_{\mp z} = +1$ in the formula (1). The case $n_\mp = 0,\ p_{\mp z} = 0$ and $q_\mp s_{\mp z} = +1$ corresponds to the ground Landau level of the $W^+(W^-)$-boson. When the $W^+(W^-)$-boson spin is oriented along (against) the MF direction, i.e. when $s_{+z} = +1$ ($s_{-z} = -1$), the $W^\mp$-boson energy satisfies the inequality $E = \sqrt{m_W^2 - eB} \leq m_W$ for an arbitrary B taken from the range $0 \leq B < B_{0W}$ where $B_{0W} = m_W^2/e$.

The NB at a mass around 126 GeV observed at the LHC is produced in the pp-collisions via the one of the following main reaction channels: the gluon-gluon fusion channel, the vector boson fusion channel, the Higgs-strahlung channel and the channel of the associated production with a $t\bar{t}$ quark-antiquark pair [15-19]. We assume that the production of the other new NBs via the above indicated channels is not excluded in the pp-collisions in the future improved LHC experiments or in other planned collider experiments. The possible new NBs can decay via the one of the main decay channels: $Y \to \gamma\gamma$, $Y \to ZZ^*$, $Y \to WW^*$, $Y \to \tau^-\tau^+$, $Y \to b\bar{b}$ like the NB at a mass around 126 GeV.

Let us consider the decay of an arbitrary NB into the W^-W^+-boson pair. For instance, the NB at a mass around 126 GeV observed at the ATLAS and CMS experiments decays via the $H \to WW^* \to l\nu l\nu$ channel [20]. One of these $W^\mp$-bosons is on-shell, the other one (W^*) is off-shell. According to the energy conservation law the decay of this NB into the on-shell W^-W^+-boson pair is impossible. Therefore, this NB decays into one on-shell W-boson and one off-shell W^*-boson. However, if we place this NB or any other neutral Y-boson with the mass $m \le 2m_W$ in a uniform MF, the MF will affect on the W^+- and W^--bosons that are the products of the decay $Y \to W^-W^+$. If we consider the decaying neutral Y-boson in the rest frame and take into account the relation $E = \sqrt{m_W^2 - eB} \le m_W$ for the W^+ (W^-)-boson with $s_{+z} = +1$ ($s_{-z} = -1$) in the energy conservation law $m = E_Y = E_{W^-} + E_{W^+}$, we can see that in a sufficiently strong MF with the strength B_Y the equality $m = 2\sqrt{m_W^2 - eB_Y}$ is satisfied and even the decay of any NB with the mass $m \le 2m_W$ including the NB with the mass around 126 GeV into the two on-shell $W^\mp$-bosons becomes, in principle, energetically possible. So, as a result of the decay reaction $Y \to W^-W^+$ in a MF we have the final diboson system Y' that consists of the on-shell W^-- and W^+-bosons situating in a MF.

3. POLARIZATION STATES OF W-BOSON PAIR SYSTEM

We denote an arbitrary polarization state of the system Y' as $|S_{Y'}, S_{Y'z}\rangle$ where $S_{Y'} = S_{W^-W^+}$ is the total spin of the system Y' and $S_{Y'z}$ is the third component of the total spin vector $\vec{S}_{Y'} = \vec{S}_{W^-W^+}$. The quantum states of the system Y' can have the spin equal to 0, 1, 2. Using the three possible polarization states of $W^\mp$-bosons, the addition rule of spins and the Clebsch-Gordan coefficients [9, 21] we obtain nine polarization states $|S_{Y'}, S_{Y'z}\rangle$ of the system Y': $|2,+2\rangle$, $|2,+1\rangle$, $|2,0\rangle$, $|2,-1\rangle$, $|2,-2\rangle$, $|1,+1\rangle$, $|1,0\rangle$, $|1,-1\rangle$, $|0,0\rangle$. The total angular momentum vector $\vec{J}$ of the W^-W^+-system is determined with the total spin vector $\vec{S}_{W^-W^+}$ of the W^-W^+-system and the orbital angular momentum vector $\vec{L}_{W^-W^+}$ of the relative motion performed by the W^-- and W^+-bosons on the plane perpendicular to the MF intensity vector which is oriented along the Oz-axis. In case of the longitudinal polarization the spin of the on-shell W^- (W^+)-boson in a MF changes its direction in time because of its performing the cyclotron motion in a MF on the plane perpendicular to the MF intensity vector. It means that the total angular momentum is not conserved in a MF in case of the longitudinal polarization. It should be also noted that in case of the longitudinal polarization of the spin of the $W^\mp$-boson we have $s_{\mp z} = 0$ and from the formula (1) we derive $E = \sqrt{m_W^2 + eB} \geq m_W$ for an arbitrary B taken from the range $0 \leq B < B_{0W}$. In this case we obtain the relation $m = 2\sqrt{m_W^2 + eB_Y} \geq 2m_W$ for the mass of the decaying neutral Y-boson. The last relation contradicts to the condition $0 < m \leq 2m_W$ that we investigate. So, in the energy range $0 < m \leq 2m_W$ there is no sense to investigate the case of the longitudinal polarization of the spin of the on-shell W^- (W^+)-boson in a MF. However, in case of the transverse polarization the spin vector $\vec{S}_{W^-W^+}$ in a MF is strictly oriented along or against the MF (Oz -axis) direction. So, in case of the transverse polarization the relations $\left|\vec{J}\right| = J = const$ and $\left|J_z\right| = const$ can be written for the total angular momentum J and its projection J_z. Therefore here we investigate the case of the transverse polarization of the spins of the on-shell $W^\mp$-bosons in a MF. In this case the polarization states $\left|W^\pm(s_\pm = 1,\, s_{\pm z} = +1)\right\rangle = \left|1, +1\right\rangle$ and $\left|W^\pm(s_\pm = 1,\, s_{\pm z} = -1)\right\rangle = \left|1, -1\right\rangle$ only contributes to the transverse polarization of the system Y' that has five different polarization states: $\left|2, +2\right\rangle = \left|1, +1; 1, +1\right\rangle$, $\left|2, 0\right\rangle = \left(1/\sqrt{6}\right)\left(\left|1, +1; 1, -1\right\rangle + \left|1, -1; 1, +1\right\rangle\right)$, $\left|2, -2\right\rangle = \left|1, -1; 1, -1\right\rangle$, $\left|1, 0\right\rangle = \left(1/\sqrt{2}\right)\left(\left|1, +1; 1, -1\right\rangle - \left|1, -1; 1, +1\right\rangle\right)$, $\left|0, 0\right\rangle = \frac{1}{\sqrt{3}}\left(\left|1, +1; 1, -1\right\rangle + \left|1, -1; 1, +1\right\rangle\right)$. The states $\left|2,\, 0\right\rangle$, $\left|1,\, 0\right\rangle$ and $\left|0,\, 0\right\rangle$ are formed from $W^-(s_- = 1, s_{-z} = +1)$ and $W^+(s_+ = 1, s_{+z} = -1)$ or from $W^-(s_- = 1, s_{-z} = -1)$ and $W^+(s_+ = 1, s_{+z} = +1)$ as a result of the transition reactions $Y \to Y'(S_{Y'} = 2,\, S_{Y'z} = 0)$, $Y \to Y'(S_{Y'} = 1,\, S_{Y'z} = 0)$, $Y \to Y'(S_{Y'} = 0,\, S_{Y'z} = 0)$, respectively. According to the energy conservation law the energy of the final W^+W^--system $E_{W^-W^+}$ is to be in the range $0 < E_{W^-W^+} \leq 2m_W$ and $E_{W^-W^+}$ can not be more than $2m_W$. The polarization states $\left|W^+(s_+ = 1,\, s_{+z} = +1)\right\rangle = \left|1, +1\right\rangle$ and $\left|W^-(s_- = 1,\, s_{-z} = -1)\right\rangle = \left|1, -1\right\rangle$ only satisfy the condition $0 < E_{W^-W^+} \le 2m_W$. Therefore we assume that the $W^{\mp}$-bosons are produced on the ground Landau level and we consider the contributions from the polarization states $\left|W^+(s_+ = 1,\, s_{+z} = +1)\right\rangle = \left|1, +1\right\rangle$ and $\left|W^-(s_- = 1,\, s_{-z} = -1)\right\rangle = \left|1, -1\right\rangle$. The energy conservation law is as $m = m_Y = 2\sqrt{m_W^2 - eB_Y}$ for the transition reactions $Y \to Y'(S_{Y'} = 2,\, S_{Y'_z} = 0)$, $Y \to Y'(S_{Y'} = 1,\, S_{Y'_z} = 0)$, $Y \to Y'(S_{Y'} = 0,\, S_{Y'_z} = 0)$ when $W^-(s_- = 1, s_{-z} = -1)$ and $W^+(s_+ = 1, s_{+z} = +1)$ are produced on the ground Landau level. Since we consider a NB in the rest frame, its mass can not be zero: $m \ne 0$. Taking into account the condition $m \ne 0$ we obtain from the formula $m = m_Y = 2\sqrt{m_W^2 - eB_Y}$ that $B_H \ne B_{0W}$ and $B_H < B_{0W}$. So, the mass of the NB at a mass around $125\, GeV$ satisfies the condition $0 < m \le 2m_W$ ($0 < m \le 160.77\ GeV$) for an arbitrary B_Y taken from the range $0 \le B_Y < B_{0W}$.

4. QUANTUM CHARACTERISTICS OF W^-W^+-PAIR AND SPIN OF Y-BOSON

Introducing the intrinsic parity $P_{W^-}\left(P_{W^+}\right)$ for the $W^-\left(W^+\right)$-boson, the orbital quantum number $L_{W^-W^+}$ and the total spin $S_{W^-W^+}$ for the W^-W^+-system we can determine the charge conjugation $C_{W^-W^+}$, the parity $P_{W^-W^+}$ and the total angular momentum J for the W^-W^+-system by the following formulas, respectively:

$$C_{W^-W^+} = (-1)^{L_{W^-W^+} + S_{W^-W^+}}, \tag{3}$$

$$P_{W^-W^+} = (-1)^{L_{W^-W^+}} P_{W^-} P_{W^+} = (-1)^{L_{W^-W^+}}, \tag{4}$$

$$J = L_{W^-W^+} + S_{W^-W^+},\ L_{W^-W^+} + S_{W^-W^+} - 1, \ldots, \left|L_{W^-W^+} - S_{W^-W^+}\right|. \tag{5}$$

We accept that the initial NB can also decay into the two photons. Therefore its spin J can not be 1 according to the Landau-Yang theorem [22, 23] and the charge conjugation C of the initial decaying neutral Y-boson is $C = C_Y = 1$. The decay $Y \to W^-W^+$ is a weak process and C is not conserved in this process. It means that if the charge conjugation of the initial neutral Y-boson is $C_Y = 1$ before the reaction $Y \to W^-W^+$, the charge conjugation $C_{W^-W^+}$ might be $+1$ or -1 after the reaction, or it might also go to a state that is not a $C_{W^-W^+}$ eigenstate. Here we assume that $C_{W^-W^+}$ is either $+1$ or -1 after the reaction. We also assume that $P_{W^-W^+}$ is either $+1$ or -1 after the reaction. The following combinations of $C_{W^-W^+}$ and $P_{W^-W^+}$ for the W^-W^+-system are possible:

case A: $C_{W^-W^+} = +1, \quad P_{W^-W^+} = +1,$ (6)

case B: $C_{W^-W^+} = +1, \quad P_{W^-W^+} = -1,$ (7)

case C: $C_{W^-W^+} = -1, \quad P_{W^-W^+} = +1,$ (8)

case D: $C_{W^-W^+} = -1, \quad P_{W^-W^+} = -1.$ (9)

Case A: If $S_{W^-W^+} = 1$, the condition (6) is not satisfied. When $S_{W^-W^+} = 0$ and $S_{W^-W^+} = 2$, the minimal value for $L_{W^-W^+}$ is $L_{W^-W^+} = 0$. In this case we obtain $J = 0,2$ for the decaying NB. So, if $C_{W^-W^+} = +1, \quad P_{W^-W^+} = +1$, the NBs with the spins $J = 0$ and $J = 2$ can exist in the range $0 < m \le 2m_W$. The particle with $J = 0$ in the range $0 < m \le 2m_W$ corresponds to the Higgs boson at a mass around $126\,GeV$ discovered in 2012 at the LHC [1, 2]. The calculations and analyses also show that if $C_{W^-W^+} = +1, \quad P_{W^-W^+} = +1$, the existence of the NBs with $J = 2$ is allowed in the range $0 < m \le 2m_W$.

Case B: If $S_{W^-W^+} = 0$ and $S_{W^-W^+} = 2$, the condition (7) is not satisfied. When $S_{W^-W^+} = 1$, the minimal value for $L_{W^-W^+}$ is $L_{W^-W^+} = 1$. In this case we obtain $J = 0,2$ for the decaying NB. It means that if $C_{W^-W^+} = +1, \quad P_{W^-W^+} = -1$, the decaying NBs with the spins $J = 0$ and $J = 2$ can exist in the mass range $0 < m \le 2m_W$.

Case C: If $S_{W^-W^+} = 0$ and $S_{W^-W^+} = 2$, the condition (8) is not satisfied. When $S_{W^-W^+} = 1$, the minimal value for $L_{W^-W^+}$ is $L_{W^-W^+} = 2$ ($L_{W^-W^+} = 0$ is not allowed according to the Landau-Yang theorem) and we obtain $J = 2,3$ for the decaying NB. So, if $C_{W^-W^+} = -1, \quad P_{W^-W^+} = +1$, the NBs with the spins $J = 2$ and $J = 3$ can exist in the range $0 < m \le 2m_W$.

Case D: If $S_{W^-W^+} = 1$, the condition (9) is not satisfied. When $S_{W^-W^+} = 0$, the minimal value for $L_{W^-W^+}$ is $L_{W^-W^+} = 3$ ($L_{W^-W^+} = 1$ is not allowed according to the Landau-Yang theorem) and we obtain $J = 3$ for the decaying NB. When $S_{W^-W^+} = 2$, the minimal value for $L_{W^-W^+}$ is $L_{W^-W^+} = 1$ and we obtain $J = 2,3$ for the decaying NBs. So, if $C_{W^-W^+} = -1, \quad P_{W^-W^+} = -1$, the NBs with $J = 2$ and $J = 3$ can exist in the range $0 < m \le 2m_W$.

5. DISCUSSION OF THE RESULTS

We have obtained that the NBs with the following spins can exist in the mass range $0 < m \le 2m_W$ and they can decay into the on-shell $W^-(s_- = 1, s_{-z} = -1)$ - and $W^+(s_+ = 1, s_{+z} = +1)$ -bosons in a MF:

case A: if $C_{W^-W^+} = +1$ and $P_{W^-W^+} = +1$, $J = 0,2$ $(S_{W^-W^+} = 0,2;\ L_{W^-W^+} = 0)$, (10)

case B: if $C_{W^-W^+} = +1$ and $P_{W^-W^+} = -1$, $J = 0,2$ $(S_{W^-W^+} = 1;\ L_{W^-W^+} = 1)$, (11)

case C: if $C_{W^-W^+} = -1$ and $P_{W^-W^+} = +1$, $J = 2,3$ $(S_{W^-W^+} = 1;\ L_{W^-W^+} = 2)$, (12)

case D: if $C_{W^-W^+} = -1$ and $P_{W^-W^+} = -1$, $J = 2$ $(S_{W^-W^+} = 2;\ L_{W^-W^+} = 1)$ and

$J = 3$ $(S_{W^-W^+} = 0;\ L_{W^-W^+} = 3; S_{W^-W^+} = 2; L_{W^-W^+} = 1)$. (13)

We have obtained $J = 0, 2$ for the spin of the neutral Y-boson if $C_{W^-W^+} = +1$ and $J = 2, 3$ for the spin of the neutral Y-boson if $C_{W^-W^+} = -1$. One NB with the spin $J = 0$ has already been observed in the mass range $0 < m \le 2m_W$ by the ATLAS and CMS Collaborations [1, 2]. However the existence of the other NB with the spin $J = 0$ and with the other mass is not excluded in the mass range $0 < m \le 2m_W$. The analysis of the above considered cases A, B, C and D show that the existence of the NB with the spin $J = 2$ is allowed in all possible cases A, B, C and D. When W^-W^+-pair are produced on the ground Landau level, the orbital quantum number $L_{W^-W^+}$ should be minimal. $L_{W^-W^+}$ is minimal only in the case A. So, the case A is more suitable for the particle with the spin $J = 2$. The mass of the NB with the spin $J = 2$ is in the range $0 < m \le 2m_W$. If we use J^{PC} assignment, for the NB with the spin $J = 2$ we have two possible cases: 2^{++} (a tensor boson) and 2^{-+}(a pseudo tensor boson). The existence of the particle with the spin 3 in the mass range $0 < m \le 2m_W$ is not excluded, if $C_{W^-W^+} = -1$. The existence of the particle with the spin $J \ge 2$ would indicate that the world we live has additional dimensions besides known four ones [24, 25].

The MF strength required for the decay of an arbitrary neutral Y-boson with the mass in the range $0 < m \le 2m_W$ into the on-shell $W^-(s_- = 1, s_{-z} = -1)$ - and $W^+(s_+ = 1, s_{+z} = +1)$ - bosons is calculated by the formula $B_Y = B_{0W}\left[1 - (m/2m_W)^2\right]$. If we take into account the mass range $0 < m \le 2m_W$ in the presented formula, the corresponding range for the MF strength will be given by the inequality $B_{0W} > B_Y \ge 0$ where $B_Y = 0$ corresponds to $m = 2m_W$. The last means that no MF is required for the decay of the NB with the mass $m = 2m_W$ into the on shell W^- -and W^+-bosons. Let us perform the simple numerical estimations for the strength of the MF required for the decay of an arbitrary massive neutral Y-boson with the mass less than $2m_W$ into the on-shell $W^-(s_- = 1, s_{-z} = -1)$ - and $W^+(s_+ = 1, s_{+z} = +1)$ -bosons in a MF. When $m \cong 126\,GeV$ (the NB discovered at the LHC), the required MF strength is $\sim 10^{23}\,G$

(or in Teslas it is $\sim 10^{19}\,T$). If $m \cong 159\,GeV$, the required MF strength is $\sim 10^{22}\,G$ (or $\sim 10^{18}\,T$). The strongest (pulsed) MF ever obtained in a laboratory is $28\,MG$ (or $2.8\times 10^{3}\,T$) [26] that is much less than $\sim 10^{22}\,G$ (or $\sim 10^{18}\,T$). The maximum strength of the produced strong MF in noncentral heavy-ion collisions in the direction perpendicular to the reaction plane is estimated to be $\sim 10^{17}\,G(\sim 10^{13}\,T)$ at the RHIC and $\sim 10^{18}\,G(\sim 10^{14}\,T)$ at the LHC [27-33]. In lead-lead collisions at the LHC, the strength of the generated MF may reach $\sim 10^{20}\,G(\sim 10^{16}\,T)$ [28, 29]. We hope that in the future collider experiments, when the strength of the produced strong MF reaches the magnitude $\sim 10^{22\div 23}\,G$, the decay of the NBs with the spins $J = 0, 2$ into the on shell W^- -and W^+ -bosons can be observed experimentally. In the absence of a MF the NB with the mass less than $2m_W$ and with the spin 2 can decay into the one on-shell W-boson and one off-shell W-boson like in case of the decay of the NB with the mass $126\,GeV$ discovered at the LHC experiments.

6. CONCLUSIONS

We have investigated the decay of an arbitrary NB into a W^-W^+-pair in a uniform MF provided that this arbitrary NB also decays into the two photons. We have obtained that the neutral particles with the spins $J = 0,\, 2,\, 3$ and with the charge conjugation $C = +1$ can exist in the mass range $0 < m \le 2m_W$ ($0 < m \le 160.77\; GeV$). The neutral Y-bosons with the spins $J = 0,\, 2$ in the mass range $0 < m \le 160.77\; GeV$ is allowed if $C_{W^-W^+} = +1$. The neutral Y-bosons with the spins $J = 2,\, 3$ in the mass range $0 < m \le 160.77\; GeV$ is allowed if $C_{W^-W^+} = -1$. The analyses of the obtained results enable us to come to the conclusion that the existence of the NB with the spin $J = 2$ and the charge conjugation $C = +1$ in the mass range $0 < m \le 160.77\; GeV$ is allowed in all possible cases. Therefore its existence is more promising and realistic. We hope that the possible existence of the indicated NBs with the spins $J = 0,\, 2,\, 3$ and the charge conjugation $C = +1$, especially, the existence of the new NB with the spin $J = 2$ in the mass range $0 < m \le 160.77\; GeV$ will attract the experimental physicists' attention in future collider experiments.

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REFERENCES

1. G. Aad *et al*. (ATLAS Collaboration), Phys. Lett. B **716**, 1 (2012).
2. S. Chatrchyan *et al*. (CMS Collaboration), Phys. Lett. B **716**, 30 (2012).
3. F. Englert and R. Brout, Phys. Rev. Lett. **13,** 321 (1964).
4. P. W. Higgs, Phys. Lett. **12**, 132 (1964).

5 P. W. Higgs, Phys. Rev. Lett. **13**, 508 (1964).

6. G. S. Guralnik, C. R. Hagen and T. W. B. Kibble, Phys. Rev. Lett. **13**, 585 (1964).
7. P. W. Higgs, Phys. Rev. **145**, 1156 (1966).
8. T. W. B. Kibble, Phys. Rev. **155**, 1554 (1967).
9. J. Beringer *et al*., Particle Data Group, PR D **86**, 010001 (2012).
10. T. Goldman, W. Tsai, and A. Yildiz, Phys. Rev. D **8**, 1926 (1972).
11. A. Salam, J. Strathdee, Nucl. Phys. B **90**, 203 (1975).
12. V. V. Skalozub, Yad. Fiz. **37**, 474 (1983).
13. V. V. Skalozub, Yad. Fiz. 4**3**, 1045 (1986) [Sov. J. Nucl. Phys, **43**, 665 (1986)].
14. D. Grasso, H. R. Rubinstein, Phys. Rept. **348**, 163 (2001).
15. A. Djouadi, Phys. Rept. **457**, 1 (2008), arXiv: 0503172 [hep-ph], 2005.
16. A. Djouadi, Pramana **79**, 513 (2012), arXiv:1203.4199 [hep-ph], 2012.
17. Science, **338**, 1558 (2012).
18. S. Dittmaier et al.,(LHC Higgs Cross Section Working Group), arXiv:1101.0593[hep-ph], 2011.
19. V. Rubakov, Uspekhi fizicheskikh nauk, **182 (10)**, 1017 (2012).
20. ATLAS Collaboration. ATLAS-CONF-2012-098; ATLAS-COM-CONF-2012-138.
21. G. Källén, *Elementary Particle Physics* (Addison-Wesley, Reading, MA, 1964).
22. L. D. Landau, Dokl. Akad. Nauk USSR **60**, 207 (1948).
23. C. N. Yang, Phys. Rev. **77**, 242 (1950).
24. N. Arkani-Hamed, S. Dimopoulos and G. R. Dvali, Phys. Lett. B **429**, 263 (1998).
25. N. Arkani-Hamed, S. Dimopoulos and G.R. Dvali, Phys. Rev. D **59**, 086004(1999).
26. B. A. Boyko et al., in 12th IEEE Intern. Pulsed Power Conf., Monterey, Calif., USA, 1999, Digest of Technical Papers (Eds C. Stallings, H. Kirbie) (New York: IEEE, 1999).
27. V. Skokov, A. Y. Illarionov, V. Toneev, Int. J. Mod. Phys. A **24**, 5925 (2009).
28. W. -T. Deng and X. -G. Huang, Phys. Rev. C **85**, 044907 (2012).
29. A. Bzdak and V. Skokov, Phys. Lett. B **710**, 171 (2012).
30. D. E. Kharzeev, L. D. McLerran and H. J. Warringa, Nucl. Phys. A **803**, 227 (2008).
31. M. N. Chernodub, Phys. Rev. D **82**, 085011 (2010).
32. M. N. Chernodub, Phys. Rev. Lett. **106**, 142003 (2011).
33. M. N. Chernodub, Lect. Notes Phys. **871**, 143 (2013).