причем $V_m^{(2)}(t \to \infty) = 2\sqrt{-h_1/B_2}$, что совпадает с (5). Это соответствие говорит о единой физической природе возмущений. Решение (6) представляет собой уединенную волну возмущения. В этом случае пространственно-временной портрет линии роста имеет морфологические свойства (рис. 2), структурно отличающиеся от свойств точечного возмущения.

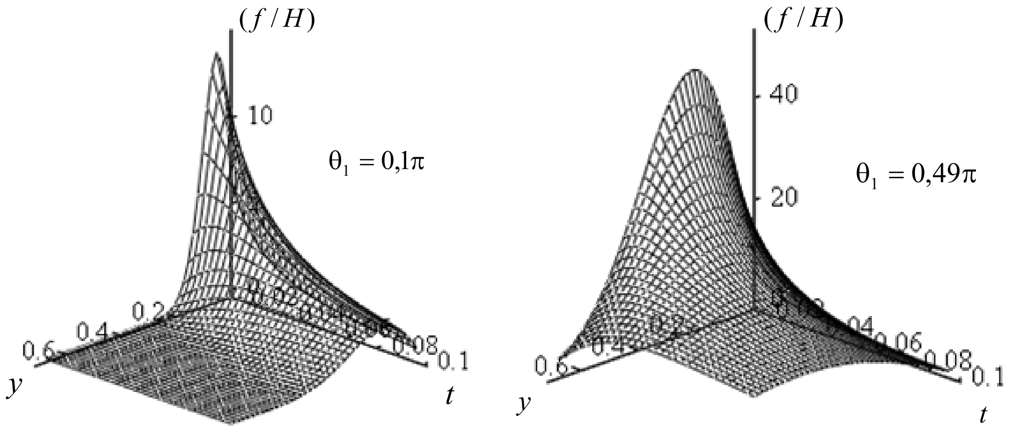

Рис. 2. Уединенная волна (6): нестационарные свойства возмущения

Дано аналитическое описание возбужденного состояния стационарного контура свободного дендрита на конечном удалении от его вершины. Построены два варианта точечного возмущения линии роста: монотонный (экспоненциальный по координате) и немонотонный (имеющий вид уединенной волны).

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UDC 539.12

NEW HEAVY GAUGE BOSONS DECAYING TO PAIR OF ELECTROWEAK BOSONS AT LHC AND HL-LHC WITH ATLAS

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The expected ATLAS Run 3 data set with time-integrated luminosity of 300 fb^{-1} and HL-LHC option of the LHC with L = 3000 fb^{-1} in the diboson channels in semileptonic final states are used to probe a simple benchmark model with an extended gauge sector, proposed by Altarelli et al. This model accommodates new charged W' and neutral Z' vector bosons with modified trilinear Standard Model gauge couplings, decaying into electroweak gauge boson pairs WZ *or WW, where W/Z decay semileptonically. We present upper limits on the mixing parameters, $W-W'$ and $Z-Z'$, by using the expected Run 3 data and HL-LHC options of the LHC.*

Keywords: gauge Z' and W' bosons, ATLAS experiment, Large Hadron Collider (LHC).

The High Luminosity LHC (HL-LHC) upgrade will eventually collect an integrated luminosity of 3 ab^{-1} of data in pp collisions at a centre-of-mass energy of 14 TeV, which should maximise the LHC potential to uncover new phenomena [1]. One of the main aims of the physics programme at the Large Hadron Collider (LHC) is to search for new phenomena that become visible in high-energy proton-proton collisions. A possible signature of such new phenomena would be the production of a heavy resonance with its subsequent decay into a final state consisting of a pair of fermions or vector bosons. Many new physics scenarios beyond the Standard Model (SM) predict such a signal. Possible candidates are charged and neutral heavy gauge bosons. In the simplest models these particles are considered copies of the SM W and Z bosons and are commonly referred to as W' and Z' bosons [2]. In the Sequential Standard Model (SSM) [3] the W'_{SSM} and Z'_{SSM} bosons have couplings to fermions that are identical to those of the SM W and Z bosons, but for which the trilinear couplings $W'WZ$ and $Z'WW$ are absent. The SSM has been used as a reference for experimental W' and Z' boson searches for decades, the results can be reinterpreted in the context of other models of new physics, and it is useful for comparing the sensitivity of different experiments.

At the LHC, such heavy W' and Z' bosons could be observed through their single production as *s*-channel resonances with subsequent leptonic decays

$$pp \to W'X \to l\nu X \tag{1}$$

and

$$pp \to Z'X \to l^+l^-X \tag{2}$$

respectively, where in what follows, $l = e, \mu$ unless otherwise stated. The production of W' and Z' bosons at hadron colliders is expected to be dominated by the process $q\bar{q}'/q\bar{q} \to W'/Z'$. Leptonic final states provide a low-background and efficient experimental signature that results in excellent sensitivity to new phenomena at the LHC.

Heavy resonances that can decay to gauge boson pairs are predicted in many scenarios of new physics, including extended gauge models (EGM) [3], models of warped extra dimensions [4], technicolour models [5] associated with the existence of technirho and other technimesons, more generic composite Higgs models, and the heavy vector-triplet (HVT) model, which generalises a large number of models that predict spin-1 charged (W') and neutral (Z') resonances etc. Searches for exotic heavy particles that decay into WZ or WW pairs are complementary to searches in the leptonic channels $l\nu$ and l^+l^- of the processes (1) and (2). Moreover, there are models in which new gauge boson couplings to SM fermions are suppressed, giving rise to a fermiophobic W' and Z' with an enhanced coupling to electroweak gauge bosons. It is therefore important to search for W' and Z' bosons also in the WZ and WW final states.

Cross section and numerical analysis. Here, we will consider a new physics (NP) model where Z' interacts with light quarks and charged gauge bosons via their mixing with the SM Z assuming that the Z' couplings exhibit the same Lorentz structure as those of the SM. In particular, in the present analysis we will focus on a gauge boson of the SSM and EGM Here, we will consider a new physics (NP) model where Z' interacts with light quarks and charged gauge bosons via their mixing with the SM Z assuming that the Z' couplings exhibit the same Lorentz structure as those of the SM. In particular, in the present analysis we will focus on a gauge boson of the EGM. In the simple reference model described in [3], the couplings of the Z' boson to fermions (quarks, leptons) and W bosons are a direct transcription of the corresponding standard-model couplings. Note that such a Z' boson is not expected in the context of gauge theories unless it has additional couplings to exotic fermions. However, it serves as a useful reference case when comparing constraints from various sources.

In many extended gauge models, while the couplings to fermions are not much different from those of the SM, the $Z'WW$ coupling is substantially suppressed with respect to that of the SM. In fact, in an extended gauge model the standard-model trilinear gauge boson coupling strength, $g_{WWZ}(=\cot\theta_W)$, is replaced by $g_{WWZ} \to \xi_{Z-Z'}\, g_{WWZ}$, where $\xi_{Z-Z'} = C(M_W / M'_Z)^2$ is the mixing factor and C the coupling strength scaling factor. One should note that most Z' search results report mass limits along the $\xi_{Z-Z'} = (M_W / M'_Z)^2$ line ($C = 1$ is referred to as “reference model”) EGM and we have also done so for comparison.

The number of signal events for a narrow Z' resonance state can be written as follows

$$N^{Z'} = L\varepsilon A_{ww}\sigma(pp \to Z')BR(Z' \to W^+W^-). \quad (3)$$

In the calculation of the total width $\Gamma_{Z'}$ we included the following channels: $Z' \to f\bar{f}, W^+W^-$, and ZH [10], where H is the SM Higgs boson and f are the SM fermions $f = l, \nu, q$. The total width $\Gamma_{Z'}$ of the Z' boson can be written as follows:

$$\Gamma_{Z'} = \sum_f \Gamma_{Z'}^{ff} + \Gamma_{Z'}^{WW} + \Gamma_{Z'}^{ZH} \quad (4)$$

The expression for the partial width of the $Z' \to W^+W^-$ decay channel can be written as [3]:

$$\Gamma_{Z'}^{WW} = \frac{\alpha}{48}\cot^2\theta_W M_{Z'}\left(\frac{M_{Z'}}{M_W}\right)^4\left(1-4\frac{M_W^2}{M_{Z'}^2}\right)^{3/2} \times \left[1+20\left(\frac{M_W}{M_{Z'}}\right)^2+12\left(\frac{M_W}{M_{Z'}}\right)^4\right]\xi_{Z-Z'}^2. \quad (5)$$

Here, we utilize the expected measurement of diboson processes provided by ATLAS for time-integrated luminosity of 300 fb^{-1} (Run 3) and 3000 fb^{-1} (HL-LHC). As mentioned above, ATLAS analyzed the WZ production (6) through the seileptonic final states.

Fig. 1 shows the expected 95% C. L. upper limits on the production cross section times the branching fraction for a s a function of $Z'(W')$ mass [8], $M_{Z'}$ $(M_{Z'})$. We found that the minimum observed exclusion limit on $\xi_{W-W'}$ as small $\cong 1.7\cdot 10^{-4}(9.3\cdot 10^{-5})$ for 300 (3000) fb^{-1}.

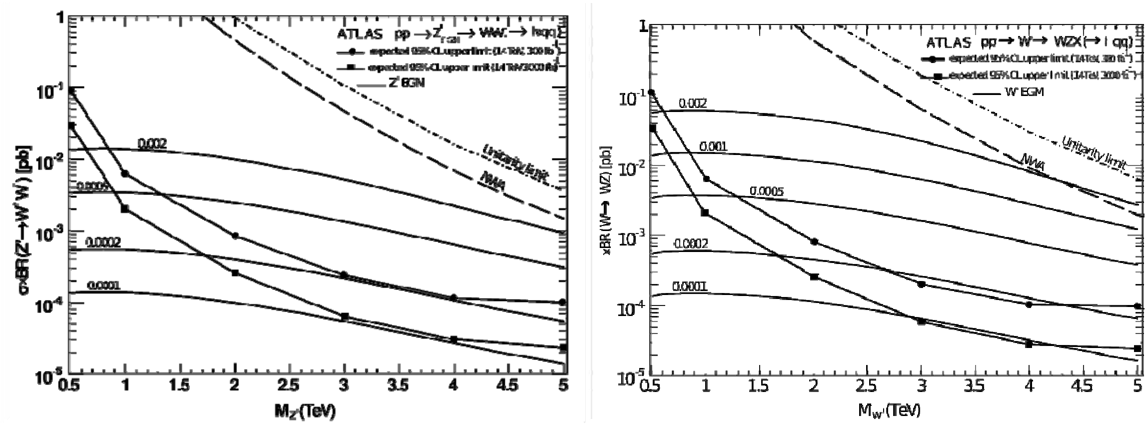

Fig. 1. Expected 95% C. L. upper limits on the production cross section times the branching fraction for $Z' \to W^+W^-$ $(W' \to WZ)$ as a function of $Z'(W')$ mass, $Z'_{EGM}(M_{W'})$. Theoretical production cross sections $\sigma\, BR(Z'_{EGM} \to W^+W^-)$ $(\sigma\, BR(W'_{EGM} \to WZ)$ for Z'_{EGM} (W'_{EGM}) are calculated from PYHTHIA 8.2, and given by thin solid curves. Labels attached to the curves for the W'_{EGM} cross section correspond to the considered mixing factor $\xi_{Z-Z'}$ $(\xi_{W-W'})$

If a new $W'(Z')$ bosons exist in the mass range $3 \sim 5$ TeV, its discovery is possible at the LHC in the Drell – Yan channels, (1) and (2). Moreover, the detection of the $Z' \to WW(W' \to WZ)$ mode is eminently possible and would presents an analysis of $Z - Z'(W - W')$ mixing in the process of $WW(WZ)$ pair production. The present analysis is based on the expected pp collision data at a center-of-mass energy at the LHC with integrated luminosities of 300 fb^{-1} and 3000 fb^{-1}.We show that the expected constraints on the mixing parameters, $\xi_{Z-Z'}$ and $\xi_{W-W'}$, achieved from the analysis of data to be collected in Run 3 as well as at the next option of hadron collider HL-LHC, can be substantially improved with respect to those obtained from the LHC Run 1 and Run 2 at 13 TeV [1–5].

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