Exploring the Higgs Bosons in the compact 341 model

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Introduction

Neutrinos oscillations phenomenon reveals that the neutrinos have masses in contrast to what the Standard Model has expected, this outstanding question with many other unexplained problems have motivated the theoretical physicists to build models beyond the Standard Model.

The Standard Model can be extended in several different ways [1], by adding new fermions fields, by augmenting the scalar sector to more than Higgs field and by enlarging the local gauge group.

Among many BSM models, we are interested in the second extension of the SM, models based on the gauge group $SU(3)_C \otimes SU(4)_L \otimes U(1)_X$ (the 341 models just for short). Those models predicted the existence of new particles: exotic leptons, new gauge, and scalar bosons.

In our work, we focus on the study of the various decay modes of the neutral scalar bosons h_1, h_2 and h_3 in the context of the so-called the compact 341 model and confront our theoretical results with the experimental data reported by ATLAS and CMS in order to check the viability of this model and to know how much the compact 341 model survives to the LHC tests in the next coming run.

We discuss some phenomenology in order to understand more on the properties of the heavy scalars and to check if the compact 341 model could have a good contribution to increasing the signal of the double Higgs production at the LHC.

OBJECTIVES

The goal of this work is to test the validity of the compact 341 model using the signal strength and the calculation of the branching ratio for the heavy scalars bosons h_2 and h_3 in different channels in the frame work $SU(3)_C \otimes SU(4)_L \otimes U(1)_X$.

The compact 341 model

The electric charge operator in the comapct 341 model is:

$$Q = T_3 + \beta T_8 + \gamma T_{15} + X \quad (1)$$

In our case, $\beta = -\frac{1}{\sqrt{3}}$ and $\gamma = -\frac{4}{\sqrt{6}}$.
The fermions content of this model is:

$$f_{aL}\begin{pmatrix} \nu_a \\ l_a \\ \nu_a^c \\ l_a^c \end{pmatrix}, Q_{1L}\begin{pmatrix} u_1 \\ d_1 \\ U_1 \\ J_1 \end{pmatrix}, Q_{iL}\begin{pmatrix} d_i \\ u_i \\ D_i \\ J_i \end{pmatrix}$$

Where a=1,2,3 and i=2,3. One of the quark families should be arranged in a different representation to the other two families while all leptons are in the same representation.

About Right-handed quarks, they transform as singlets under $SU(4)_L \otimes U(1)_X$.

The most general scalar potential in the compact 341 model is given:

$$\begin{aligned} V(\eta,\rho,\chi) &= \mu_\eta^2 \eta^\dagger \eta + \mu_\rho^2 \rho^\dagger \rho + \mu_\chi^2 \chi^\dagger \chi + \lambda_1 (\eta^\dagger \eta)^2 \\ &+ \lambda_2 (\rho^\dagger \rho)^2 + \lambda_3 (\chi^\dagger \chi)^2 + \lambda_4 (\eta^\dagger \eta)(\rho^\dagger \rho) \\ &+ \lambda_5 (\eta^\dagger \eta)(\chi^\dagger \chi) + \lambda_6 (\rho^\dagger \rho)(\chi^\dagger \chi) + \lambda_7 \\ &(\rho^\dagger \eta)(\eta^\dagger \rho) + \lambda_8 (\chi^\dagger \eta)(\eta^\dagger \chi) + \lambda_9 (\rho^\dagger \chi) \\ &(\chi^\dagger \rho), \end{aligned} \quad (2)$$

Where $\mu^2_{\mu\rho\chi}$ are the mass dimension parameters, λ_S are dimensionless coupling constants, η, ρ and χ are the scalar fields.

Theoritical constraints

The scalar potential couplings $\lambda_{1..9}$ have constrained by the following conditions:
1- The unitarity,
2- Stability of the potential,
3- No ghost.

The signal strength and the branching ratio

To get the deviation of the compact 341 model from the SM, the signal strength for the lightest neutral scalar boson h_1 has calculted from the following expression:

$$\mu_{xy} = \frac{BR_{341}}{BR_{SM}} = \frac{\Gamma_{SM}(h \longrightarrow all)\Gamma_{341}(h_1 \longrightarrow xy)}{\Gamma_{341}(h_1 \longrightarrow all)\Gamma_{SM}(h \longrightarrow xy)}. \quad (3)$$

for each individual channels $b\bar{b}$,ll,$\gamma\gamma$, ZZ and WW as it presented in the figure 1. Notice that the predictions of the compact 341 model are fairly good and compatible with the run2 experimental data. This is a confirmation and a proof of the viability of the 341 BSM model.

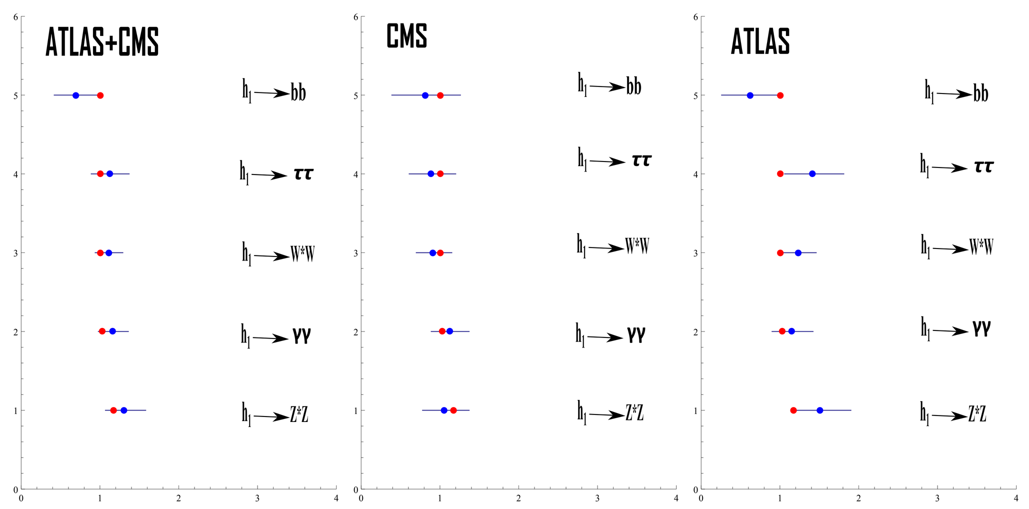

Figure 1: Signal Strengths for various decay modes compared to the ATLAS, CMS and ATLAS+CMS data

We have calculated the Branching ratio for the other heavy neutral scalar h_2 and h_3.

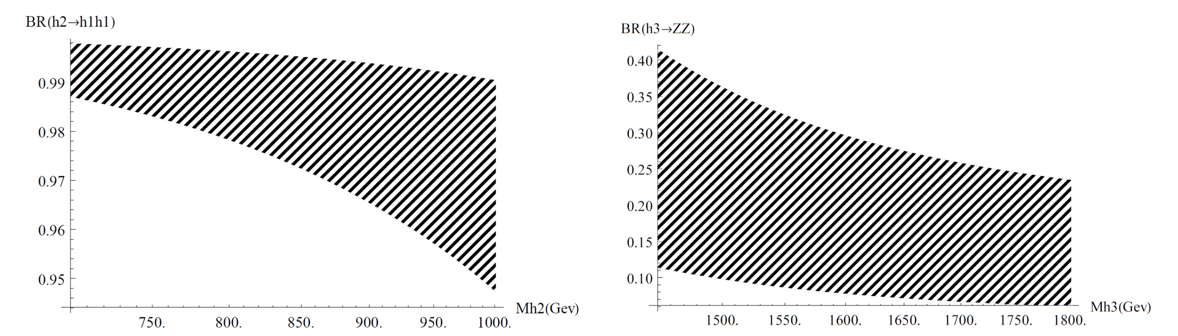

Figure 2: The dominat branching ratio for h_2 and h_3

In fact, we have obtained a confidence band due to the variations of the couplings λ_i's within the allowed parameter space region after imposing the noghost, perturbative unitarity and stability conditions.

For the heavy Higgs h_2, the dominant decay mode is $h_2 \longrightarrow h_1 h_1$ where it's branching ratio is about 0.98 and it is a decreasing function of m_{h_2}. This could be a good signal for the 341 model regarding the double Higgs production process at the LHC.

Double Higgs pair production

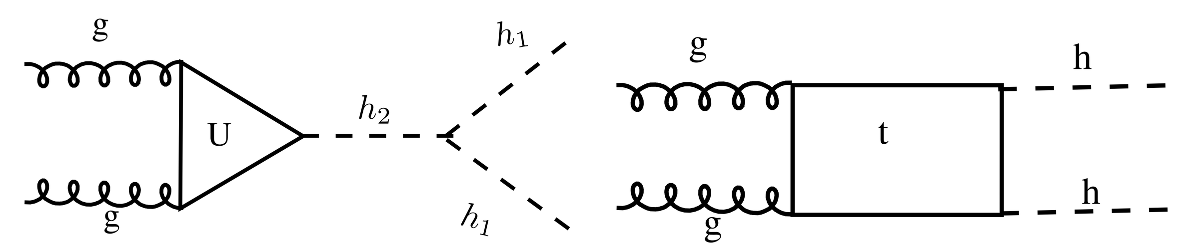

Figure 3: Double higgs pair production diagram

The search for the double Higgs boson production is the main work in the future work at the LHC. This production has already been searched at the LHC in both Run 1, Run 2 but without signals.

The existence of the heavy neutral scalars h_2 and h_3 in our model and the fact that h_2 prefers to decay into a pair of Higgs like-bosons h_1, that makes h_2 the most probable neutral particle which can act the role of the resonant in the double Higgs production process. the contributions of the compact 341 model in this production maybe leads to enhance the signal excess at the LHC and increase the probability to detect the Higgs pair productions in the next run.

Figure 3 represents Trilinear Feynam diagrams of the Higgs pair productions $pp \longrightarrow h_2 \longrightarrow h_1 h_1$ in the compact 341 model.

References

1- A. G. Dias, P. R. D. Pinheirob, C. A. de S. Pires, P. S. Rodrigues da Silva,[arXiv:1309.6644v2].
2- W. Caetano, C. A. de S. Pires, and P. S. Rodrigues da Silva,[arXiv:1305.7246v2].

Future Research

The 341 models predicted the existence of new heavy neutral gauge bosons Z′ and Z″, The non-universal coupling of those gauge bosons with fermions leading to the appearance of the flavor changing neutral current. In our future direction, We will discuss the FCNC in the fermion sectors, Furthermore, bounds on some of the flavor changing parameters are derived using the recent experimental data.

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