Possibilities for charged Higgs bosons at the LHC in a
SU(3)$_L$⊗U(1)$_N$ Model

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Abstract

We have studied the branching ratios of doubly charged Higgs bosons at the LHC using a version of the SU(3)$_L$⊗U(1)$_N$ electroweak model. At the end of this work we have made a very simple plotting comparing the total cross section of this model using Drell-Yan, gluon-gluon fusion and Left-right symmetric model.
Doubly charged scalar particles arise in many scenarios extending the weak interactions beyond the Standard Model (SM) as the left-right symmetric model (LR) and Higgs triplet models. In the LR Model electroweak theory such a particle is a member of a triplet Higgs representation which plays a crucial part in the model. The gauge symmetry of the LR Model is broken to the SM symmetry due to a non-vanishing expectation value in the vacuum of the neutral component of the triplet right-handed Higgs. The Left-Right Model predicts two kinds of doubly charged particles with different interactions.

| TABLE I: The approximate values of the masses (in GeV) used in the present work. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| f | mE | mM | mT | mH01 | mH01 | mH02 | mH02 | mH03 | mH03 | mH± | mH± | mV | mU | mZ' |
| ≈ 0 | 194 | 1138 | 2600 | 874 | 1322 | 2600 | 0 | 426 | 1315 | 603 | 601 | 2220 |
| -99.63 | 194 | 1138 | 2600 | 874 | 1322 | 2600 | 520 | 218 | 1295 | 603 | 601 | 2220 |

The so called 3-3-1 Models are another interesting class of electroweak models that also predict such particles. It is able to solve the fermion family’s replication problem through a simple relation between the colors number and the anomaly cancellation mechanism. In a similar fashion as occurs in LR Model, the seesaw mechanism can be incorporated in some versions of the 3-3-1 Models.

Since the 3-3-1 Models are good candidates to physics beyond the SM, it is interesting to evaluate if the future accelerators will produce events in sufficient numbers to detected some of the 3-3-1 Higgs bosons. In particular, there is an increasing interest in the phenomenology associated with doubly charged Higgs bosons. Here we are interested in one of such version of the 3-3-1 Models for which the scalar fields come only in triplet representation of the SU(3) gauge group.

It predicts four neutral \((H_1^0, H_2^0, H_3^0, h0)\), four single charged \((H_1^\pm, H_2^\pm)\) and two doubly charged \((H^{\pm\pm})\) Higgs bosons. In the gauge sector, beyond the standard gauge fields, the model predict also the extra neutral \(Z'\) and the charged \(V^\pm\) and \(U^{\pm\pm}\) bosons. The fermionic sector is enlarged by the heavy leptons \(E^\pm, M^\pm\) and \(T^\pm\) and the quarks \(J_1, J_2, J_3\).

The main mechanism for the production of Higgs particles in \(pp\) collisions occurs in association with the bosons \(\gamma, Z, Z', H_1^0\) and \(H_2^0\) through the mechanism of Drell-Yan and with the \(H_0^0, H_2^0\) and \(H_3^0\) by gluon-gluon fusion. In all calculations in this work we are considering that the charged fermionic mixing matrices are diagonals. We first evaluate the
TABLE II: Branching ratio for the $H_0^3$ decays with $m_{H_0^3} = 2600$ GeV. Here $BR_{XY}^0$ stands for $BR(H_0^3 \rightarrow XY)$.

| $f$ (GeV) | $BR_{H_0^1H_0^0}^0$ | $BR_{H_1^0H_1^-}^0$ | $BR_{H_0^1H_2^-}^0$ | $BR_{H_2^0H_1^-}^0$ | $BR_{E^+E^-}^0$ | $BR_{M^+M^-}^0$ |
|-----------|------------------|------------------|------------------|------------------|----------------|----------------|
| ≈ 0       | $3.35 \times 10^{-5}$ | $2 \times 10^{-8}$ | No               | 0.9999          | $2 \times 10^{-7}$ | $2 \times 10^{-6}$ |
| -99.63    | 3.14             | 4                | $4 \times 10^{-7}$ | 0.9999          | $2 \times 10^{-7}$ | $2 \times 10^{-6}$ |

FIG. 1: Total cross section for the process $pp \rightarrow H^--H^{++}$ as a function of $m_{H^{\pm\pm}}$ for $f = 0$ GeV at $\sqrt{s} = 14$ TeV for Drell-Yan (dotted line) and Gluon-Gluon fusion (dot-dashed line).

differential cross section for the Drell-Yan, that is, the process $pp \rightarrow H^{++}H^{--}$ which takes place through the exchange of refereed bosons in the s-channel.

We have considered two possibilities: $f \simeq 0$ and $f = -99.63$ GeV, where $f$ is the strenght of the trilinear coupling of the Higgs potential. The masses of the exotic bosons Table II are in accordance with the estimates of the CDF and D0 experiments, which probes their masses in the 500 GeV – 800 GeV range.
TABLE III: Branching ratios for $H^{\pm\pm}$ decays with $m_{H^{\pm\pm}} = 1309$ GeV. $BR_{XY}^{\pm\pm}$ stands for $BR_{XY}^{\pm\pm} = 10^3 \times BR(H^{\pm\pm} \rightarrow XY)$.

| $f$ (GeV) | $BR_{J_3}^{\pm\pm}$ | $BR_{E^{-}}^{\pm\pm}$ | $BR_{M^{-}}^{\pm\pm}$ | $BR_{E^{+}}^{\pm\pm}$ | $BR_{M^{+}}^{\pm\pm}$ | $BR_{U^{\pm\pm}}^{\pm\pm}$ |
|----------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| $\approx 0$ | 0.001 | 0.08 | 0.005 | 3 | 6 | 29 |
| -99.63 | 2 | 0.001 | 0.004 | 0.4 | 4 | 2 |

| $f$ (GeV) | $BR_{W^{\pm}}^{\pm\pm}$ | $BR_{V^{\pm}}^{\pm\pm}$ | $BR_{H^{\pm}}^{\pm\pm}$ | $BR_{H^{-}}^{\pm\pm}$ | $BR_{h^{0}}^{\pm\pm}$ | $BR_{U^{\pm\pm}}^{\pm\pm}$ | $BR_{Z^{\pm\pm}}^{\pm\pm}$ | $BR_{H^{-}}^{\pm\pm}$ |
|----------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| $\approx 0$ | No | 19 | No | No | 444 | 2 | |
| -99.63 | 0.09 | 13 | 329 | 6 | 146 | 0.5 | |

FIG. 2: Total cross section for the process $pp \rightarrow H^{-}H^{++}$ as a function of $m_{H^{\pm\pm}}$ for $f = 0$ GeV at $\sqrt{s} = 14$ TeV for Drell-Yan (dotted line) and Gluon-Gluon fusion (dot-dashed line) and Left-Right symmetric model (solid line).

We calculate the doubly charged Higgs pair production by computing the contributions due the Drell-Yan and quark loop processes. We present, in Fig. 1, the cross section for the process $pp \rightarrow H^{-}H^{++}$ at the LHC energies (14 TeV) computed from the Drell-Yan mechanism and from the gluon-gluon. One can observe that the cross section corresponding to the Drell-Yan mechanism is four orders of magnitude larger than the quark loop contribution.
Next we have computed the branching ratios for the $H_3^0$ decay with $m_{H_3^0} = 2600$ GeV (Table II). The branching ratios for $H_{±±}$ decay with $m_{H_{±±}} = 1309$ GeV are presented in Table III. Finally the Fig. 2 show the comparison of our results with those obtained from the Left-Right symmetric model [7]. As a result we show that the Drell-Yan mechanism contribute much more than the gluon-gluon fusion to the total cross section production.

The analysis of these yields show that, although a large number of doubly charged Higgs can be produced by the Drell Yang mechanism, the decays of these particles into ordinary fermions do not lead to a good signature for its detection even for LHC energies. We can observe that the window for the free parameters is small, because of the constraints imposed on the model.

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