Top quark phenomena in association with new vector bosons

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In this work, we study collider phenomenology of pair produced new heavy vector bosons further decaying into top quark pair and quartic top, top pair plus bottom pair production in proton-proton collisions at CERN LHC with 13 TeV center of mass energy in the presence of new color octet vector boson. The complete simulation chain analysis from parton to the detector level is done for the pair production, As for the four quark production through pair of the new heavy vector particles is done at the matrix level. In doing so we have preparatory work . The extension of SM is implemented by Mathematica—FeynRule package. Calculations are done by MadGraph5 /+ Phythia6, Delphes / simulation program and results are analysed in ROOT CERN. In conclusion, we compared Standard model extension results with the SM.

I. INTRODUCTION

The Standard Model (SM) of paricle physics has been very successful in explaining particle physics phenomena. Still there are questions that are not adequately addressed in the SM. These include baryon antibaryon asymmetry, neutrino oscillations and in some extent the scale of electroweak symmetry breaking. Currently the only experiments that may shed light on these questions are the LHC up to 14 TeV center of mass energy. One of the leading hypothesis on the baryon asymmetry of the universe is the electroweak baryogenesis. The requirement of this frame work is that the electroweak phase transition from symmetric state to spontaneously broken one should be strongly first order and to do so one must have:

$$\frac{\phi_c}{T_c} \gtrsim \varnothing(1), \qquad (1)$$

where ϕ_c is the vacuum expectation value of the Higgs field at the critical temperature T_c of the thermal bath. Unfortunately, it does not work in the SM where it implies the Higgs mass to be 70 GeV which is in a direct conflict with the measured value by ATLAS and CMS collaborations at the LHC [1]. Therefore new particles which modify the Higgs potential through quantum corrections or new shape for the Higgs potential are needed. Colored particles within the reach of the LHC experiments are one such possiblility (See for example [2]). In doing so, Higgs pair production can be modified substantially. In the present talk we present our work on the decay of pair new heavy vector bosons with color quantum numbers. The decay channels we examine are the pair produced heavy vector bosons dominantly decay into third generation quarks. The analysis of such events are quite complicated and in the current work we present (i) the cross–section of the new vector boson pair production, (ii) identification of one them by their decay products, (iii) four quark event simulation all at the 13 TeV center of mass energy of the LHC. In the final part we present prelimenary results of the four quark singals at the detector level for the case of two top and two bottom quarks.

II. PAIR OF NEW VECTOR BOSONS

A. Analysis

Madgraph5 [4] is a matrix element generator that simulates high energy proton-proton collision at the CERN-LHC. To have a Madgraph implementable model file we use Feynrule software. Feynrule [3] is a Mathematica package in which user provdes the Lagrangian of the model under the cosideration. If it is properly implemented the feynrule package generates all the necessary Feynman rules for the model (such as the SM and its extension) in the UFO format that is ready to be used in the Madgraph5 model environment. In order to simulate the full process in Madgraph5, we use Pythia6-hadron showering [5] and Delphes detector simulation tools [6], which are integrated with Madgraph5 environment.
The steps pf our computation are given as follows:

First step: Matrix level
Matrix elements of our events are calculated using the MadGraph5. The invariant mass distribution of matrix level top pair production at the LHC is shown Figure(1).

Second step: Parton level
Using the results of matrix element, hadron showering is done by Pythia. The Pythia provides

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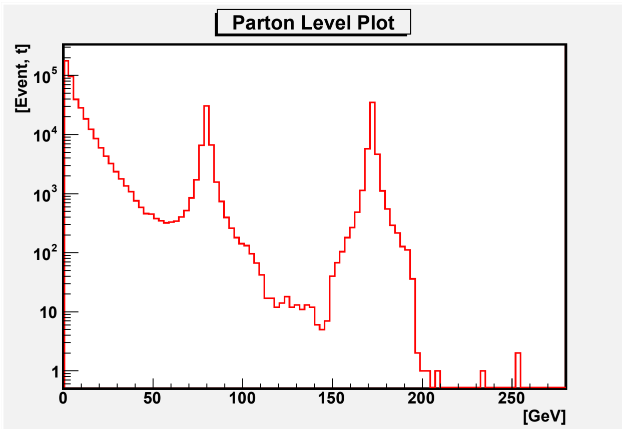

Fig. 1: result of matrix level

the results in the CERN root file format.

Third step: Detector level
To seperate our events from the SM background we use suitable kinematic cuts. Finally, the latest results are processed by ROOT-CERN data analyser program.

B. Top quark pair production

To identify top quark pair production in our extended SM we identify the SM background as follows. First we identify top quark by its decay products via W–boson and b–quark jets. For this, one has to adequately recostruct W boson decays either to two light jet or lepton and missing energy. In the present work we choose the former one. The identification of W candidate is done by pair of jets that have invariant mass close to W boson masses. To identify the top candidate, we select events with the combined invariant mass with b jet (3-invariant mass of jets) near top quark mass range. The final step we use invariant mass of the top quark pair or top bottom pair to reconstruct new vector boson candidate.

C. New vector boson production

In this section, we consider the top quark pair production coming from the decay of color octet vector boson. The cross section result of the top quark pair is $\sigma = 518.3 \pm 0.45 pb$ in the extended SM. Here the result is presented for color octet vector particle with mass $M_V = 700$ GeV. The calculated cross section result of top quark pair production from color octet vector particle is $\sigma = 1,4 \pm 0.45 pb$. These results are shown, respectively, in Figure2.

Figure 3 shows the invariant mass of the top quark pair production for Parton and detector levels.

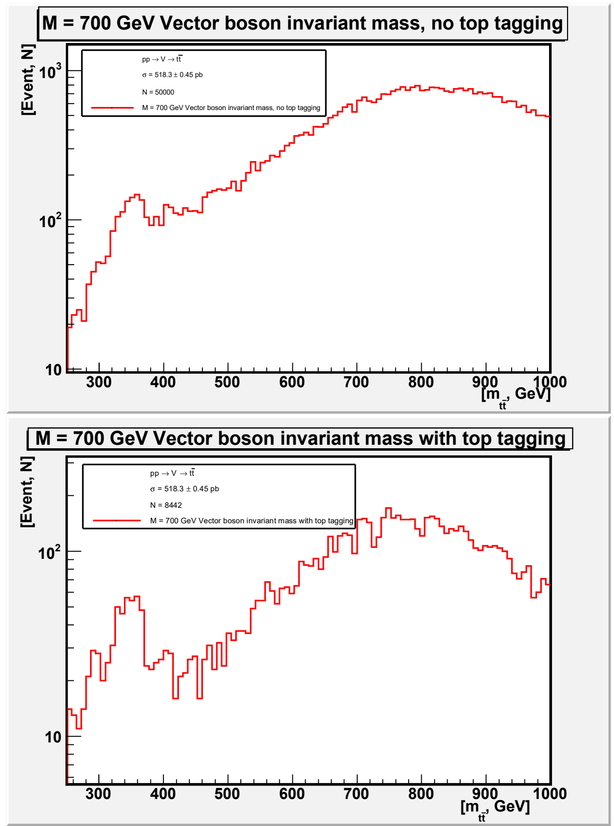

Fig. 2: Top quark pair production in extended the SM without top tagging and with top tagging.

We have done mass scan for the new vector boson and the results are shown as the cross–section versus the vector boson mass. The results for charged particle production cross-section and its decay to top and bottom quarks are shown in Figure 4. The neutral case is shown in Figure 5.

III. CONCLUSIONS

In the current talk, we have presented our study on the production of new vector boson pairs at the LHC and their decay to the third generation quarks. As an example we have chosen the results from the four top quak case. The cross section of $pp \to V \to t\bar{t}$ was $\sigma = 1,4 \pm 0.45$ pb in the extended SM compared to the SM value $\sigma = 517.3 \pm 0.45$ pb. With these results we are now in a position to complete full detector simulations.

Acknowledgments

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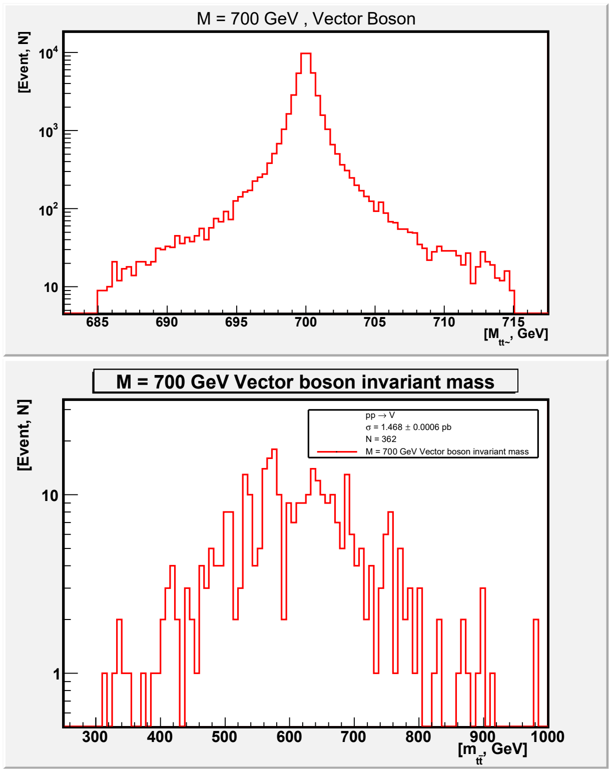

Fig. 3: Results of parton and detector levels.

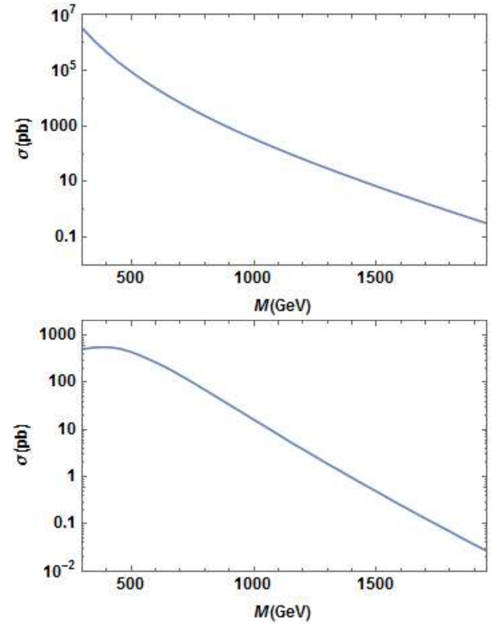

Fig. 4: Production Cross-section and decay to t, b quarks at the matrix level for charged vector boson

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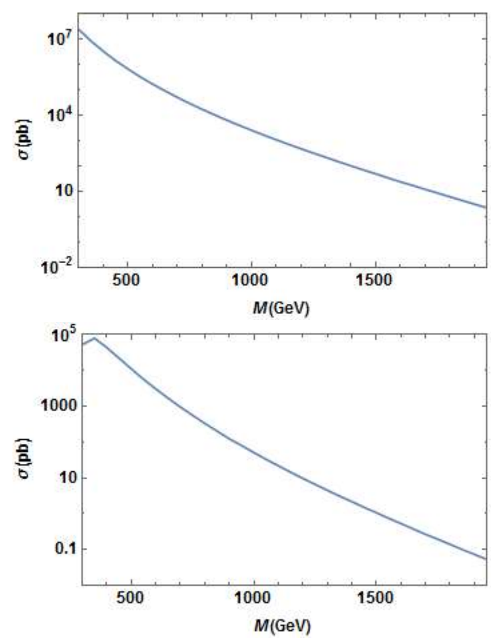

Fig. 5: Production Cross-section and decay to t, $\bar{t}$ quarks at the matrix level for neutral heavy boson.