Probing new particles in proton-proton collisions with CMS Detector at the LHC

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Introduction

The Large Hadron Collider (LHC) is the world's biggest and most powerful particle accelerator aimed to study the fundamental particles and their interactions. Although the underlying physics of fundamental particles is well explained by the Standard Model (SM) [1] and supported by experimental testing over the time, yet it is considered to be an effective theory up to some scale. SM has some serious shortcomings such as it fails to explain matter-antimatter asymmetry, Dark matter, the hierarchy problem, unification of fundamental forces, etc. To address these shortcomings, new theories/extensions of SM have evolved. One such popular beyond SM theory is called Super-Symmetry (SUSY). However, this theory requires the existence of a new set of particles called super-partners of SM particles, none of which has been found experimentally so far. The experimental confirmation of these new SUSY particles will provide solution to the hierarchy problem, unification of three fundamental forces and the dark matter candidate. Therefore, investigation of such particles at the TeV energy scale is a quite natural step. The hadron colliders are well suited to the task of exploring the new energy domains such as the region of 1 TeV constituent center-of-mass energy provided the proton energy and the luminosity are high enough. At the LHC, two counter-rotating high energy proton beams are made to cross and interact each other at four interaction points where different detectors are placed to record the collision events for the subsequent physics study. The Compact Muon Solenoid (CMS) detector [2] is placed at one of the interaction points and aims for the precision measurements of SM predictions as well as for the study of the new sectors of Beyond SM (BSM) physics. The work presented in this proceeding, is based on the search for SUSY particles using proton-proton collision data at center-of-mass energy of 13 TeV recorded by the CMS detector at LHC.

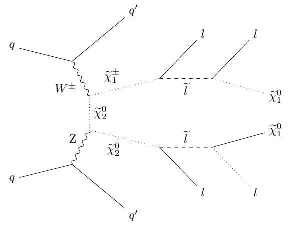

FIG. 1: Feynman diagram for VBF production of $\widetilde{\chi}_{\rm i}^{\pm}/\widetilde{\chi}_{\rm j}^{0}$ with subsequent decays through sleptons.

Analysis Details

The common strategy is to search for charginos ($\widetilde{\chi}_{\rm i}^{\pm}$) and neutralinos ($\widetilde{\chi}_{\rm j}^{0}$) (SUSY particles) through the vector boson fusion (VBF) [3] processes involving virtual W and Z bosons ($\rm W^*/Z^*$) *i.e.* $\rm qq \rightarrow q'q'W^*/Z^* \rightarrow \widetilde{\chi}_i^{\pm}\widetilde{\chi}_j^0$, with their subsequent decay, resulting in final states having one or more charged leptons (electrons, muons and hadronically decaying taus), missing transverse momentum ($\rm p_T^{miss}$) and two VBF jets. Fig. 1 shows the Feynman diagrams for VBF production of $\widetilde{\chi}_{\rm i}^{\pm}/\widetilde{\chi}_{\rm j}^{0}$ with subsequent decays through sleptons.

The first step is to select the events based on the final state signatures of the signal pro-

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cess. The signal event selections are divided into two parts: central selections and VBF selections. The central selections are composed of lepton selection, identification and missing transverse energy (MET) requirement. VBF selections involve requirements on the VBF jets. The SM processes (W+jets, $t\bar{t}$, QCD, DY+jets, etc.) that can mimic the signatures of signal process are known as background processes. The main contribution to the total background comes from W+jets, $t\bar{t}$ and QCD depending on the leptonic final state under consideration. The estimation of these dominant background processes are done using data-driven methods whereas the subdominant processes are estimated directly based on the Monte-Carlo (MC) simulation.

Background estimation strategy

The general methodology for the estimation of background processes in the signal region (SR) is similar for all the search channels and is based on both simulation and data as mentioned earlier. Background-enriched control regions (CRs) are constructed by applying selections orthogonal to those for the SR. These CRs are then used to measure the scale factors (SFs) that are subsequently applied to the MC yields to correct for any mismodeling. The idea is that these CRs should have a high purity of the background under consideration and a negligible contribution from signal. CR1 is used for the evaluation of correction factor for the central selections whereas CR2 is used for the VBF selections. CR2 has to be orthogonal to both CR1 and SR. To achieve this, we choose a "variable" that enriches the background process, but at the same time, the inverted requirement on that variable allows us to arrive at the SR. The transverse mass ($\mathrm{m_T}$) distribution for the $t\bar{t}$ enriched CR1 for muon channel with year 2016 data is shown in Fig. 2.

The following equation is used to estimate the surviving background yield in the SR:

$$\mathrm{N_{BG}^{Data}} = \mathrm{N_{BG}^{MC}(SR)\ .\ SF^{CR1}\ .\ SF^{CR2}}$$

where $\mathrm{N_{BG}^{MC}(SR)}$ is the predicted background yield in MC simulation after applying SR selections, $\mathrm{SF^{CR1}}$ and $\mathrm{SF^{CR2}}$ are the correction factors for the central selections (obtained from CR1) and VBF selections (obtained from CR2), respectively.

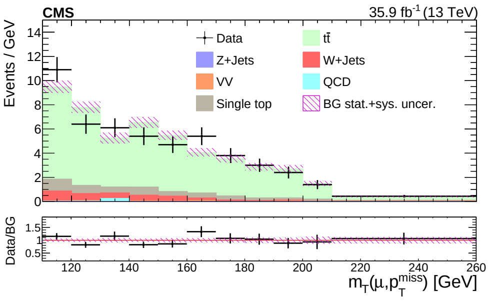

FIG. 2: The m_T distribution for the $t\bar{t}$ enriched CR1 for muon channel (year 2016 data) [4].

Results and Discussions

The search performed in the final states involving one lepton, MET and two VBF jets with 35.86 fb^{-1} of data collected by the CMS detector in year 2016 didn't reveal any excess of events over the expected SM background yield. Based on it, an exclusion limit (95% CL) of 212 GeV was set on the mass of $\widetilde{\chi}_{\mathrm{i}}^{\pm}/\widetilde{\chi}_{\mathrm{j}}^{0}$. The present search being performed with full LHC Run2 pp collision data at $\sqrt{\mathrm{s}} = 13$ TeV with an integrated luminosity of 137 fb^{-1} is expected to extend our reach significantly.

References

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