Search for Supersymmetry with the Vector Boson Fusion tagging in pp collisions using CMS detector at the LHC

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Abstract

A search for Supersymmetry with Vector Boson Fusion (VBF) topology is performed using proton-proton collision data at 8 TeV collected with CMS detector at the LHC. The VBF processes offer a promising avenue at the LHC to study the non-colored sectors of supersymmetric extensions of the Standard Model where other searches have limited sensitivity. Final states consisting of at least two leptons, large missing transverse momentum, and two jets with a large pseudorapidity are expected in pair-production of charginos and neutralinos. The observed dijet invariant mass spectrum after the final selections is found to be consistent with the expected standard model predictions, hence the upper limits are set for the production of charginos and neutralinos with two associated jets, assuming the supersymmetric partner of the tau lepton to be the lightest slepton and the lightest slepton to be lighter than the charginos. The Run2 of LHC machine has allowed us to naturally extend this search to 13 TeV data where we utilize the methodology developed for 8 TeV search along with newly implemented VBF-Dijet Trigger. This is expected to improve the search sensitivity for compressed-mass SUSY spectra at high-luminosity.

Presented at DAE-HEP Symposium XXII DAE-BRNS High Energy Physics Symposium
Search for Supersymmetry in Vector Boson Fusion topology using proton-proton collision data at the LHC

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1 Introduction

With the outstanding performance of the LHC machine, Standard Model (SM) discovered its long-sought “Higgs” particle in July 2012, which proved to be the biggest success for the SM as well as for the CMS \cite{1} and ATLAS \cite{2} experiments at LHC. But some mysteries like: unification of forces, neutrino oscillations, matter-antimatter asymmetry and dark matter \textit{etc.} remains unexplained. In order to solve such mysteries, various extensions of the SM have been developed by the physicists. One of them is known as Supersymmetry (SUSY) \cite{3}-\cite{4} that associates every SM fermion with its “super-partner” boson and vice-versa. The SM and SUSY partners can be distinguished by a discrete quantum number called R-Parity. The R-parity conserving models involve a weakly interacting particle known as the Lightest Supersymmetric Particle (LSP) which gives rise
to transverse momentum imbalance ($E_{T}^{miss}$) in the detector and is considered to be a dark matter candidate. SUSY searches have set limits on masses of gluinos and 1st/2nd generation squarks of the order of 1.7 TeV while the limits on $\tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0}$ are relatively weaker in compressed-mass-spectra. In this paper, the search for electroweak SUSY in VBF topology is presented at $\sqrt{s} = 8$ TeV. Some prospects with Run2 data at $\sqrt{s} = 13$ TeV are also discussed.

2 Analysis Strategy

The VBF processes are characterized by the presence of two forward jets with large dijet invariant mass and large pseudorapidity gap in the opposite hemispheres of the detector. It provides a complementary tool to probe compressed-mass SUSY spectra and offers a unique handle for background suppression. Figure 1 (left) shows one of the representative Feynman diagram for pair-production of charginos and neutralinos in VBF processes where charginos/neutralinos decay to two $\tau$-leptons through $\tilde{\tau}_{s}$ (same-sign or opposite-sign) and LSP. The SUSY search with 8 TeV data was performed in the 8 final states (Opposite-Sign/Same-Sign), namely: $\mu\mu jj$, $e\mu jj$, $\mu\tau jj$ and $\tau_{h}\tau_{h}jj$. The central selections require the event to have two isolated leptons with $p_{T} > 30/45$ GeV ($\mu/\tau$), $|\eta| < 2.1$, $\Delta R(l_1, l_2) > 0.3$ and $E_{T}^{miss} > 75$ GeV ($> 30$ GeV only for $\tau_{h}\tau_{h}jj$). VBF selections requiring the presence of two VBF jets in opposite hemispheres ($\eta_1 * \eta_2 < 0$) with $p_{T} > 30/50$ GeV (Loose/Tight signal regions) and $|\eta| < 5.0$, reduces the background rate by a factor of $10^{-2} - 10^{-4}$. The b-jets are required to suppress $tt$ background. The selected events are required to have a dijet candidate with $m_{jj} > 250$ GeV. Control regions are defined by some modifications in the nominal selection cuts to measure VBF efficiency and $m_{jj}$ shapes from data in such a way that $m_{jj}$ distribution remains unbiased. The data was found to be consistent with SM predictions within uncertainty after combining all the final states as shown in Figure 1(right).

We are heading towards high luminosity of pp collision data at $\sqrt{s} = 13$ TeV, where focus is on single lepton final state namely: $\mu jj$, $e jj$ and $\tau jj$. This search includes new invisible VBF trigger to get large signal efficiency. Signal selection have been optimized for best signal significance and estimation of backgrounds using control regions is under progress to extend our reach substantially.

3 Results & Discussion

For the R-parity conserving MSSM models, results are simplified in four scenarios divided on the basis of masses of stau and LSP. The average mass assumption ($m_{\tilde{\tau}} = 0.5m_{\tilde{\chi}_{1}^{\pm}} + 0.5m_{\tilde{\chi}_{1}^{0}}$) with uncompressed mass spectra ($\tilde{\chi}_{1}^{0} = 0$) eliminates the possibility of $\tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0}$ with masses less than 300 GeV and masses upto 170 GeV for compressed mass spectra ($m_{\tilde{\chi}_{1}^{\pm}} - m_{\tilde{\chi}_{1}^{0}} = 50$ GeV) with $\tilde{\tau}$ mass closer to chargino mass i.e. $\Delta m(\tilde{\chi}_{1}^{\pm}, \tilde{\tau}) = 5$ GeV as shown in Figure 2.
Fig. 1. Left: [5] Chargino-Neutralino pair production by VBF processes, Right: [6] $m_{jj}$ distribution in the signal region obtained by combining all final states.

Fig. 2. Left: [6] Combined 95% CL upper limits on the cross section for scenario having $\tilde{\tau}$ closer to $m_{\tilde{\chi}_1^\pm}/m_{\tilde{\chi}_0^0}$ i.e. $\Delta m(\tilde{\chi}_1^\pm, \tilde{\tau}) = 5$ GeV for large mass gap scenarios where $m_{\tilde{\chi}_0^1} = 0$ GeV (yellow band) and the compressed mass scenario having a mass difference between chargino and LSP to be 50 GeV (green band), Right: [6] 95% CL on EWKino mass = 300 GeV for scenario having $m_\tau = 1/2 m_{\tilde{\chi}_1^\pm} + 1/2 m_{\tilde{\chi}_0^1}$.

References