SUSY searches in Vector Boson Topology: Review and mu+VBF trigger performance with 2017 data with the CMS experiment

CMS collaboration

José David Ruiz-Ávarez
Universidad de Los Andes
jose.ruiz@cern.ch

Abstract

A review of results in SUSY searches in VBF topology with 8 TeV data collected by the CMS experiment is presented. A 13 TeV projection of these searches is performed with a report on the VBF+μ trigger performance using 2017 data collected.

Introduction

The Vector Boson Fusion (VBF) topology constitutes an interesting channel to search for electroweak physics. It is one of the main channels used for Higgs boson searches [2], but also for supersymmetry (SUSY) searches [3] and dark matter (DM) [3]. This topology is characterized by the presence of two jets with high η separation, located in opposite hemispheres of the detector $\eta(j_1) \times \eta(j_2) < 0$ and a high invariant mass.

However the VBF topology has smaller cross sections than leading production processes (normally 10^{-1}), the characteristics of the topology are very well suited to drastically decrease QCD background and also control other electroweak backgrounds. In this work we will concentrate on how this topology is used to look for physics beyond the standard model (SM) in the CMS experiment. Moreover, CMS SUSY searches, one with a DM interpretation, and future projections are discussed. We also report the current results for the VBF+μ trigger that has been implemented for these searches.

Searches at 8 TeV with CMS experiment

The VBF topology has been used for two SUSY searches analyzing CMS data recorded from proton-proton collisions at 8 TeV center of mass energy. In [2] leptonic signatures have been utilized to search for chargino-chargino or chargino-neutralino production in this topology. Further decays through sleptons and neutralinos are considered to arrive to di-lepton final states. Figure 1 shows the diagrams of the studied processes.

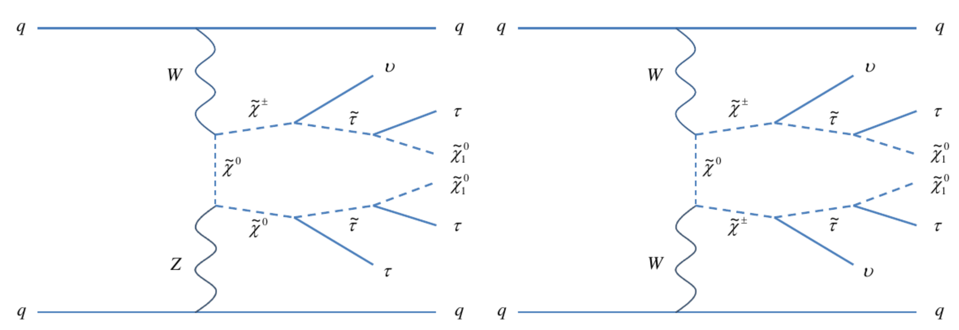

Figure 1: Diagrams for chargino-neutralino and chargino-chargino production in the VBF topology with the corresponding decay into sleptons and the LSP.

The channels considered are $\mu\mu jj$, $e\mu jj$, $\mu\tau_h jj$ and $\tau_h\tau_h jj$. The analysis relies in single or double lepton triggers which imposes a constraint to reach low p_T spectra. The selection requires a muon $p_T > 30$ GeV for all the channels with at least one muon and for the di-tau channel both taus are required to have $p_T > 45$ GeV. A criterion of $p_T^{miss} > 75(30)$ GeV is used for muon(di-tau) channels. In all channels events are required to have two jets with $\eta < 5$, $|\Delta\eta(jets)| > 4.2$ and $\eta_1\eta_2 < 0$, $m_{jj} > 250$ GeV. For the di-muon channel these two jets are required to have $p_T > 30$ GeV while for the rest of channels the criterion applied is $p_T > 50$ GeV. Signal events from monte-carlo simulation as well as the expected backgrounds compared to data events are displayed in Figure 2 (left) after the full selection has been applied. Figure 2 (right) shows the 95% CL limits on the signal production cross section after combining all channels.

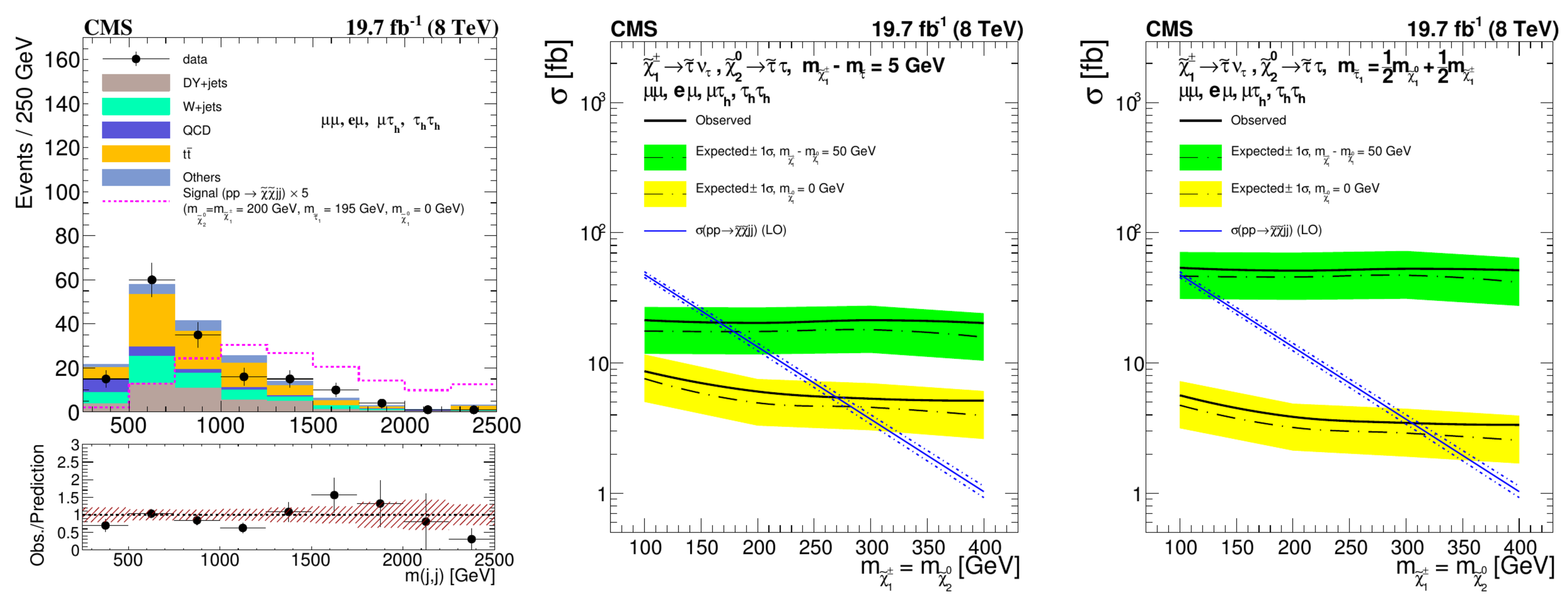

Figure 2: Dijet invariant mass combining all leptonic search channels with expected background and data events as well as expected signal yields (left) and limits on the signal production cross section from the combination of all leptonic channels at 95% CL. Some VBF criteria have been used to calculate the signal cross section: jet $p_T > 30$ GeV, $|\Delta\eta(jets)| > 4.2$ and $\eta_1\eta_2 < 0$. (right)

Another search [3] with no leptons was also performed at 8 TeV by the CMS experiment. This search is specially sensitive to the compressed spectra regime where the mass gap between the bottom squark and the LSP is small, which leads to b-quarks produced with low p_T that will fail the reconstruction leading to an invisible signature. Figure 3 shows the diagrams of such process.

For this search the selection criteria is: two jets with $p_T > 50$ GeV and $\eta < 5$, $|\Delta\eta(jets)| > 4.2$ and $\eta_1\eta_2 < 0$, $m_{jj} > 750$ GeV, leptons and b-tagged jets are vetoed, $p_T^{miss} > 250$ GeV and $|\Delta\phi(\vec{p}_T^{miss}, j_2)| > 0.5$. Figure 4 (left) shows the expected background events compared to data as well as the expected signal from sbottom production and effective field theory for DM production in VBF topology.

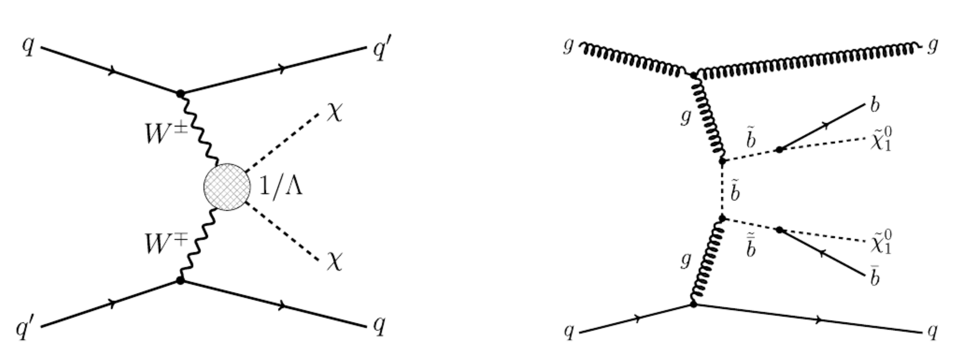

Figure 3: Diagrams for dark matter and bottom squark production in VBF topology.

Finally, from this search 95% CL limits can be set on the sbottom and DM production cross section. These limits are shown in Figure 4 (right). In the following section we will discuss the projected sensitivity of this analysis at 13 TeV.

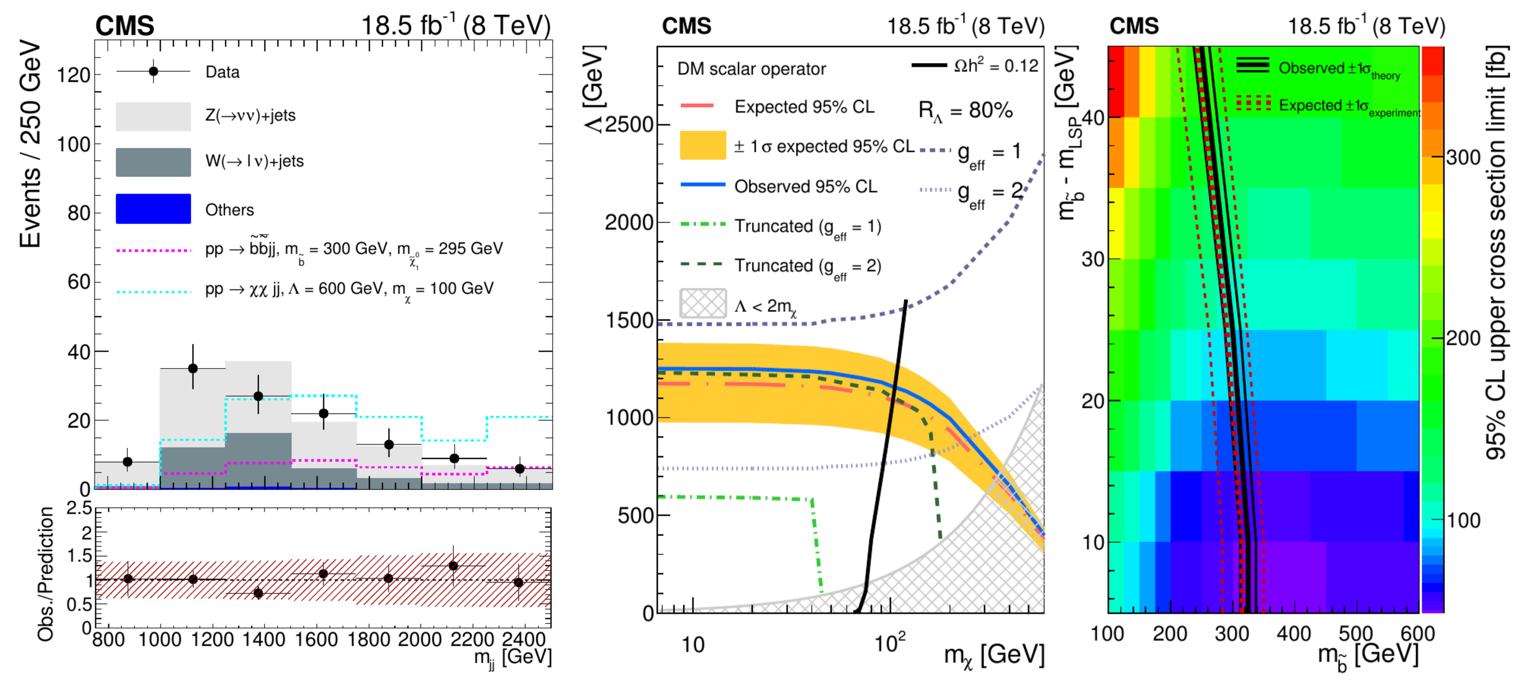

Figure 4: Dijet invariant mass with expected background and data events for no-leptons search with expected signal events from DM effective field theory and bottom squark (left) and limits on the production cross section for DM using effective field theory and in the sbottom mass - $m_{\tilde{b}} - m_{LSP}$ plane at 95 % CL.

Projections

Assuming the no-leptons criteria search have the same efficiencies at 13 TeV than at 8 TeV we can make a simple extrapolation of the cited results from 8 TeV to 13 TeV. The cross sections of the main backgrounds, Z+jets and W+jets will increase from 8 TeV to 13 TeV as the center of mass energy increase, around 1.6 times. However, as the initial state from the sbottom signal production comes from gluons, we expect a much higher (several times) increase in the cross section of the signal. Therefore, the same analysis would be able to reach higher sbottom masses at 13 TeV than at 8 TeV.

Also, another important input would be to consider lower missing energy and lower lepton p_T thresholds to assess very compressed mass spectra. For such type of search a special trigger has to be implemented in CMS in order to collect these events without biasing p_T^{miss}.

VBF+μ trigger performance with 2017 data

Typically the missing energy triggers push the thresholds to high value with $p_T^{miss} > 300$ GeV. Also single or di-lepton triggers enforce high p_T in the leptons in the online selection, normally greater than 30 GeV. In order to reach lower missing energy regimes and low p_T lepton regimes a trigger has been developed using VBF topology plus a low p_T muon. The VBF+μ trigger requires at online level two jets with $p_T > 40$ GeV, $|\Delta\eta_{jj}| > 3.5$, $m_{jj} > 750$ GeV, $p_T^{miss} > 60$ GeV and $H_T > 300$ GeV. VBF+μ trigger will allow to add in the VBF searches lower missing energy as well as lower lepton p_T regimes. Figure 5 shows the VBF+μ trigger efficiency measured with respect to single muon triggers as a function of p_T^{miss} and $\Delta\eta_{jj}$.

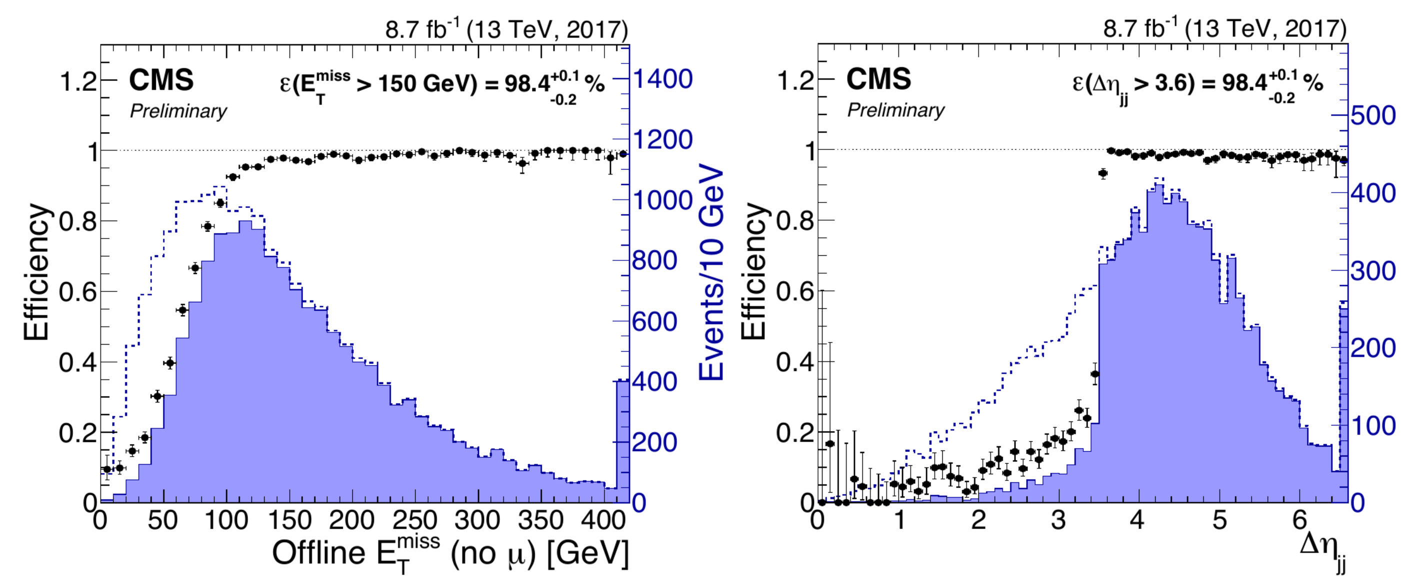

Figure 5: The denominator (dashed) is the number of events passing the single muon trigger (muon p_T >27 GeV online) which have at least one muon with $p_T > 30$ GeV and $|\eta| < 2.4$, and jets with the leading (sub-leading) $p_T > 120$ (50) GeV, $|\eta| < 5.0$, $\eta_{jet1}\eta_{jet2} < 0$, $\Delta\eta_{jj} > 3.6$, $M_{jj} > 1000$ GeV, $H_T(|\eta| < 5.0) > 450$ GeV, and $p_T^{miss} > 150$ GeV. Here, H_T is the scalar sum of the jet p_T greater than 30 GeV. The numerator (filled) is the number of events passing all selections above and the VBF+μ trigger. Efficiency (dots) = Numerator / Denominator, as a function of p_T^{miss} (left) and $\Delta\eta_{jj}$ (right).

Conclusions

- VBF topology constitutes a very interesting topology for searches to address special parameter space corners as compressed mass spectra.
- An enhanced sensitivity of these searches at 13 TeV compared to 8 TeV is expected.
- The new VBF+μ allows efficiently to lower down the p_T^{miss} and lepton p_T thresholds with regard to purely missing energy or leptonic triggers.

References

[1] Vardan Khachatryan et al. Searches for invisible decays of the Higgs boson in pp collisions at sqrt(s) = 7, 8, and 13 TeV. *JHEP*, 02:135, 2017.

[2] Vardan Khachatryan et al. Search for supersymmetry in the vector-boson fusion topology in proton-proton collisions at sqrt(s) = 8 TeV. *JHEP*, 11:189, 2015.

[3] Vardan Khachatryan et al. Search for Dark Matter and Supersymmetry with a Compressed Mass Spectrum in the Vector Boson Fusion Topology in Proton-Proton Collisions at sqrt(s) = 8TeV. *Phys. Rev. Lett.*, 118(2):021802, 2017.

Acknowledgements

J. D. Ruiz-Álvarez gratefully acknowledges the support of COLCIENCIAS, the Administrative Department of Science, Technology and Innovation of Colombia.