Search for Supersymmetry with a Compressed Mass Spectrum in VBF topology with 1 and 0-lepton final states in pp collisions at sqrt(s) = 13 TeV with CMS

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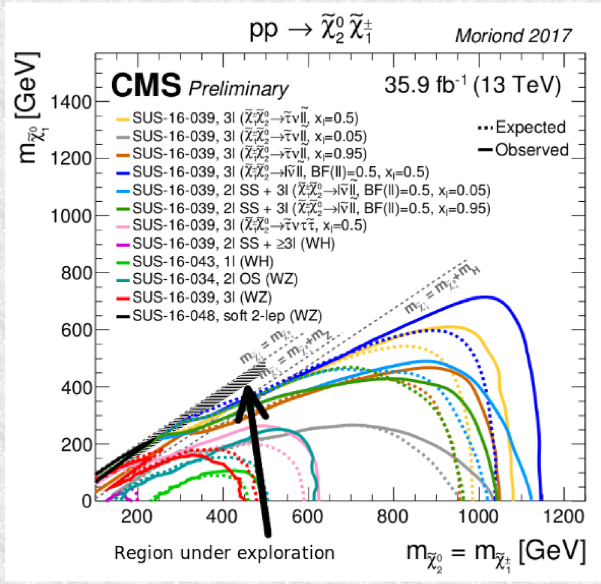
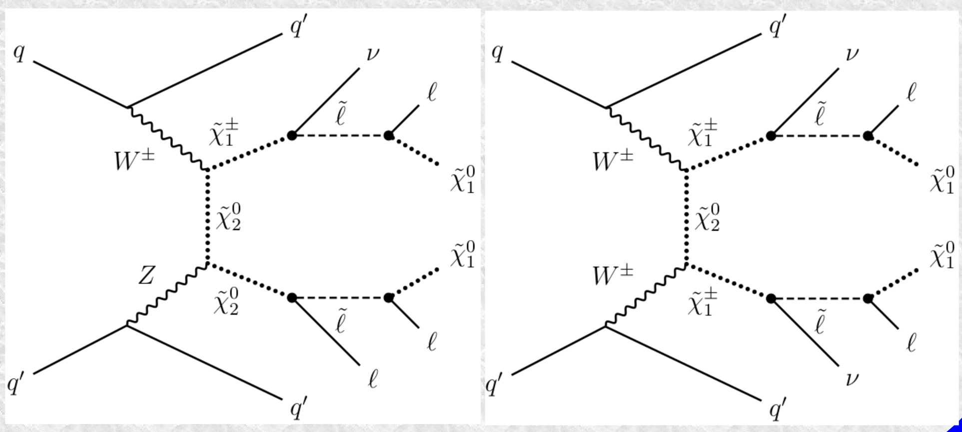
Motivation

- First focus of SUSY searches is on colored sectors due to its large cross-section.
- Gluinos/1st & 2nd generation squarks are excluded upto 2 TeV and too heavy to be produced at LHC.
- Limits on charginos/neutralinos are relatively weaker in compressed mass sepctra and is a window for New Physics.
- VBF topology provides a complementary tool to look for compressed mass spectra.
- Suppress background by a large factor of the order of 10^3.



- Experimental Signatures of VBF processes are:
  a) Two highly energetic jets with large pseudorapidity gap, located in opposite hemispheres of the detector and with a large dijet reconstructed mass.
  b) Two leptons in final state and large MET but we are focusing on 1 or 0 soft-lepton channels since it's difficult to reconstruct multiple leptons in compress mass spectra (Large acceptence/ sensitivity than Dilepton channels) .



Analysis Strategy

- Search is performed with 13 TeV data corresponding to an integrated luminosity of 35.87 fb^{-1} in the following final states.

1 or 0 lepton + 2 Jets + MET (Final state)

4 Final states

1.) μ+jj
2.) e+jj
3.) τ_h+jj
4.) 0l+jj

Central Selections for 1-lepton

Lepton Flavor & p_T		e± Channel	μ± Channel	τ± Channel
	e±	Selected with pt 10-40 GeV	Vetoed with pt > 10 GeV	Vetoed with pt > 10 GeV
	μ±	Vetoed with pt > 8 GeV	Selected with pt 8-40 GeV	Vetoed with pt > 8 GeV
	τ±	Vetoed with pt > 20 GeV	Vetoed with pt > 20 GeV	Selected with pt 20-40 GeV

- $m_T(l, p^{miss}_T)$ > 110 GeV for each channel in final state only.
- P^{miss}_T > 250 GeV to remove QCD multijet BG.
- No b-jet with p_T > 30 GeV, |η| < 2.4 with CSVv2Medium WP.

SR m_T bins : [110-130], [130-150], [150-170], [170-190], [190-210], [210-∞].

VBF Selections

- $N_{jets} \geq 2$ with p^{jet}_T > 60 GeV, |η| < 2.4
- Atleast one pair of jets (j_1, j_2) with M_{jj} > 1 TeV, $|\Delta\eta (j_1, j_2)| > 3.8$, $\eta(j_1) \times \eta(j_2) < 0$

Background Estimation Strategy

- Trigger used for this analysis : **HLT_PFMETNoMu120_PFMHTNoMu120_IDTight**
- Main backgrounds : $t\bar{t}$ → major BG for ejj and μjj (57-64%).
  QCD → major BG for τjj and 0-lepton .
  W+Jets → third highest BG .

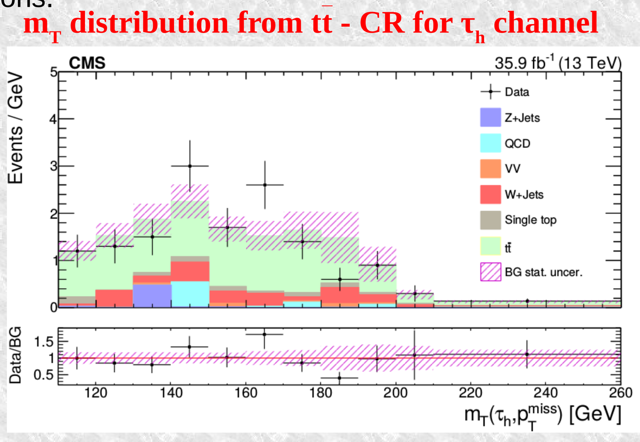
- Create BG enriched Control Regions (CR) by applying selections orthogonal to Signal Region (SR).
- CRs are used to measure the efficiencies of VBF and Central selections, determine the correction factors to account for these efficiencies and to derive the shape of m_T and m_{jj} BG distribution in SR.
- Backgrounds in SR are estimated by using the following equation:

$$N^{\rm pred}_{\rm BG} = N^{\rm MC}_{\rm BG}\, SF^{\rm CR1}_{\rm BG}({\rm central})\, SF^{\rm CR2}_{\rm BG}({\rm VBF})$$

Predicted BG yield in the SR; Rate predicted by simulation for SR; Data-to-simluation Correction factor for Central selections.; Data-to-simluation Correction factor for efficiency of VBF selections.

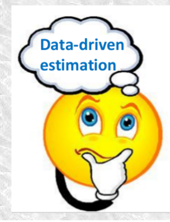
- $t\bar{t}$ m_T shapes in the SR are taken directly from simulations.
- For W+Jets BG, there is good agreement on the shapes for the electron and muon channels.
- But in τ_h channel QCD has larger contamination, and is difficult to obtain CR enriched in W+jets so we are using the average of corrections factors from ejj and μjj. This is justified since there is no difference in the modelling of W → l + ν.

m_T distribution from tt - CR for τ_h channel



QCD Background Estimation for τ_h and 0-lepton channel

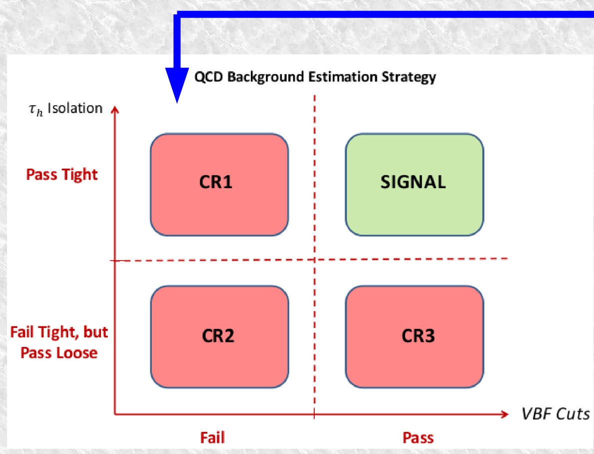
- Main discrimination variable for QCD BG: VBF channels, τ_h isolation and min seperation between p^{miss}_T and any jet $|\Delta\varphi_{min}(p^{miss}_T, j)|$.
- CRs are obtained by inverting these variables.

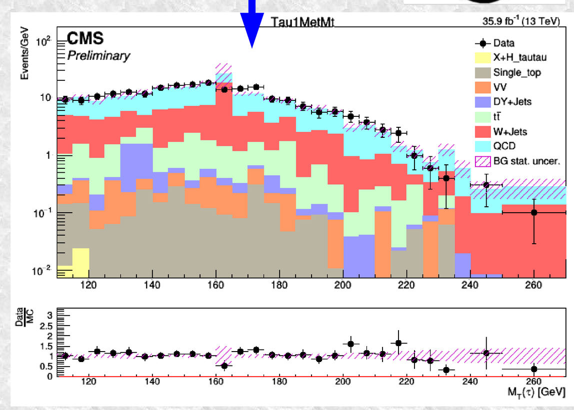


- **Estimation of QCD in SR:**

$$N^{SR}_{\rm QCD} = N^{\rm CR1}_{\rm QCD} \cdot \frac{N^{\rm CR3}_{\rm QCD}}{N^{\rm CR2}_{\rm QCD}}$$

Pass-To-Fail correction factor (TF_{VBF})

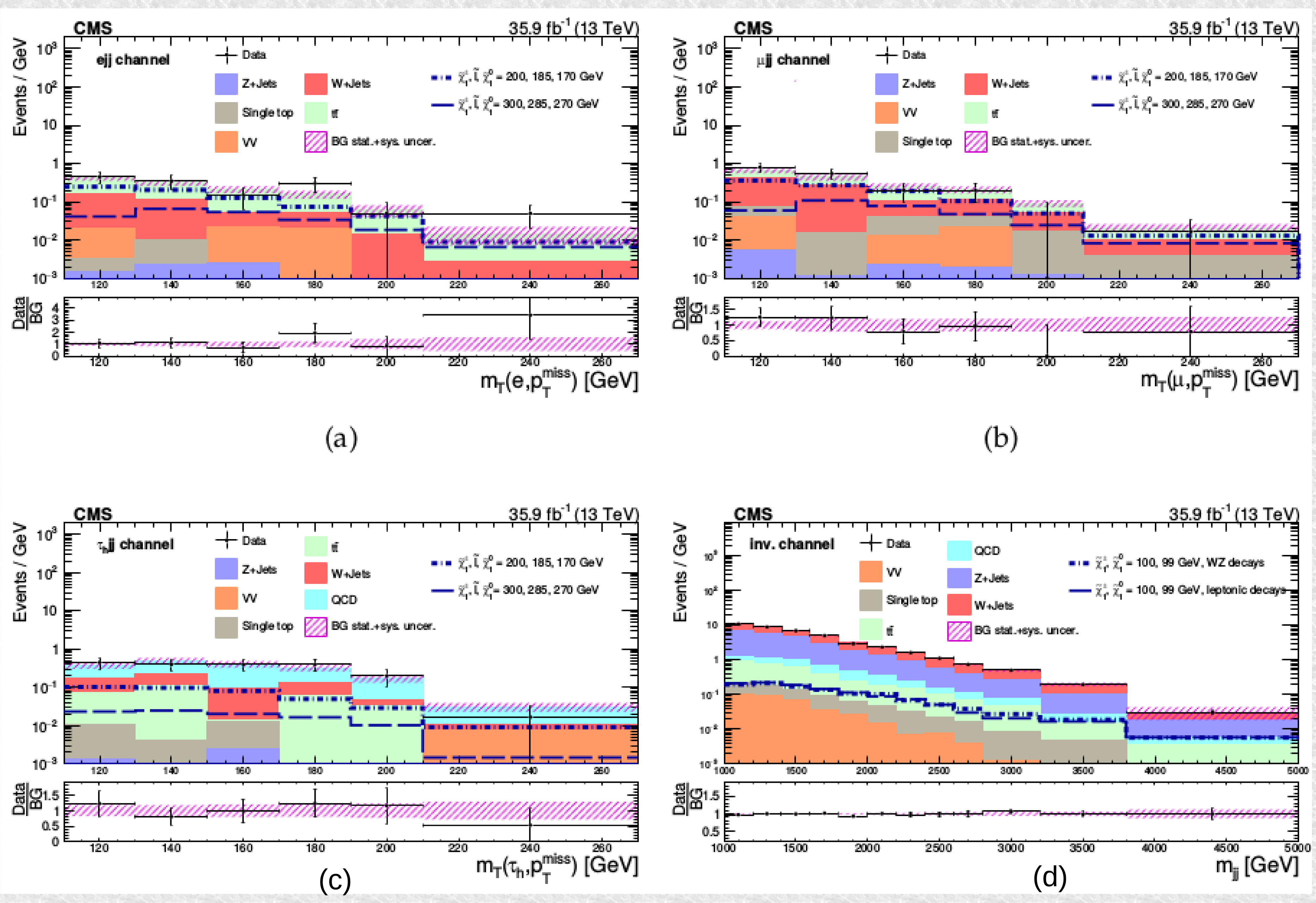




- For 0ljj channel, QCD is estimated by using the number of events passing the analysis selection except the $|\Delta\varphi_{min}(p^{miss}_T, j)|$ cut.
- The m_{jj} distribution of the non-QCD background is subtracted from the m_{jj} data distribution, and the resultant QCD multijet m_{jj} distribution from data is scaled by the efficiency to inefficiency ratio of the $|\Delta\varphi_{min}(p^{miss}_T, j)|$ requirement, $TF_{\Delta\varphi}$.
- Transfer factor obtained is: 0.06 ± 0.01.

Results

- The background yields and shapes are determined using data-driven methods for the major backgrounds, and based on simulation for the smaller backgrounds.
- Bin size in the below plots are chosen to maximize the signal significance of the analysis.



(a) (b) (c) (d)

- The observed m_T distribution in SR compared with the SM background yields:
  a) e+jj b) μ + jj c) τ_h + jj
- d) m_{jj} distributions in the 0 lep + jj channel in SR.

Conclusion

- **No excess of events above the SM prediction in any of the final state considered.**

Number of observed events and corresponding background predictions for all the search channels. The uncertainties include the statistical and systematic effects.

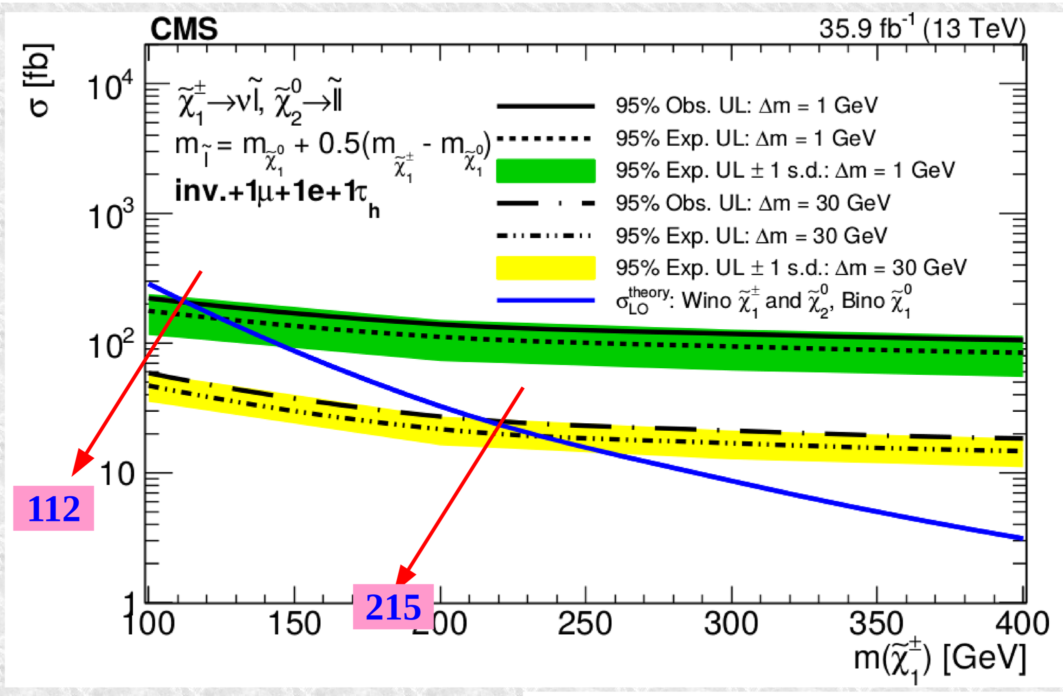
Process	μjj	ejj	$\tau_h jj$	0ℓjj
DY+jets	$0.2 \pm 6.8 \times 10^{-2}$	$0.1 \pm 4.0 \times 10^{-2}$	$0.1 \pm 3.8 \times 10^{-2}$	3714 ± 760
W+jets	13.3 ± 3.0	6.1 ± 1.4	7.0 ± 1.7	2999 ± 620
VV	1.7 ± 0.7	1.5 ± 0.6	0.9 ± 0.9	77 ± 18
$t\bar{t}$	13.1 ± 3.8	10.9 ± 4.1	5.1 ± 2.7	577 ± 128
Single top	2.2 ± 0.9	0.2 ± 0.1	0.6 ± 0.3	104 ± 10
QCD	$0^{+0.2}_{-0}$	$0^{+1.2}_{-0}$	23.1 ± 5.0	546 ± 69
Total BG	30.5 ± 5.0	18.8 ± 4.6	36.8 ± 6.0	8017 ± 992
Data	36	29	38	8408
$\frac{Data-BG}{\sqrt{\delta^2_{BG}+BG}}$	+0.74	+1.61	+0.14	+0.39

No Excess Found

Exclusion limits for 2016 data at luminosity of 35.9 fb^{-1}

For $\Delta m = m(\tilde{\chi}_1^{\pm}) - m(\tilde{\chi}_1^0)$ = 30 GeV, $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ masses are excluded upto 215 GeV

For $\Delta m = m(\tilde{\chi}_1^{\pm}) - m(\tilde{\chi}_1^0)$ = 1 GeV, $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ masses are excluded upto 112 GeV



Reference: arXiv:1905.13059v1

29th International Symposium on Lepton Photon Interactions at High Energies, 5-10 Aug 2019, University of Toronto, Toronto (Canada)