Search for supersymmetry with a compressed mass spectrum in the vector boson fusion topology with 1-lepton and 0-lepton final states

Brenda Fabela-Enriquez (Vanderbilt University) on behalf of the CMS collaboration

brenda.fabela.enriquez@cern.ch

CMS-SUS-17-007
[arXiv:1905.13059]

Introduction

- Lightest neutralino (LSP) $\tilde{\chi}_1^0$ in SUSY models with $R-$parity conservation $\Rightarrow$ canonical dark matter candidate.
- Null results on diverse SUSY searches: SUSY particles too heavy or low sensitivity in compressed mass spectrum scenarios (small $\Delta m = m(\tilde{\chi}_1^{\pm}) - m(\tilde{\chi}_1^0)$).
- Events boosted by an initial state radiation (ISR) jet or via **electroweak vector boson fusion (VBF)** provide **enhanced sensitivity** to detect chargino-neutralino ($\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$) production for small Δm.

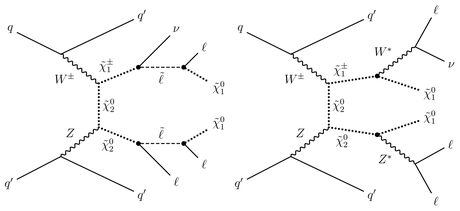

Fig. 1: Feynman diagrams of $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ pair production through VBF, followed by their decays to leptons and the LSP via a light slepton or a W^*/Z^*.

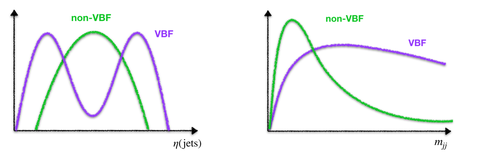

Fig. 2: Schematic comparison of the jet η and dijet invariant mass m_{jj} distributions for VBF- vs. non-VBF-like processes.

Analysis strategy and event selection

- In VBF, SUSY particles are produced in association with 2 high-p_T jets oppositely-directed, close to the beam region.
- Low-p_{T} decay products from $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production for small $\Delta m \Rightarrow$ leptons can get lost during reconstruction $\rightarrow$ **categories: 0ℓ and 1ℓ + $p_{\mathrm{T}}^{\mathrm{miss}}$ + VBF jets**.

Selection criteria (all channels)

- $p_{\mathrm{T}}^{\mathrm{miss}} > 250$ GeV,
- $\geq$ 2 jets, $p_{\mathrm{T}}(j) > 60$ GeV, $|\eta(j)| < 5.0$, (only 0ℓjj: $|\Delta\phi_{\mathrm{min}}(p_{\mathrm{T}}^{\mathrm{miss}}, j)| > 0.5$),
- zero b-tagged jets, $p_{\mathrm{T}} > 30$ GeV, $|\eta| < 2.4$, $\Delta R(\mathrm{b-jet}, \ell) > 0.3$.

VBF selections

- $\geq$ 1 dijet pair (j_1, j_2), $\eta(j_1) \times \eta(j_2) < 0$, $\Delta\eta(j_1, j_2) > 3.8$, $m(jj) > 1$ TeV.

- Data analysis of pp collisions at $\sqrt{s} = 13$ TeV collected in 2016 with CMS detector and int. lumi. $\mathcal{L}_{int} = 35.9$ fb^{-1}.

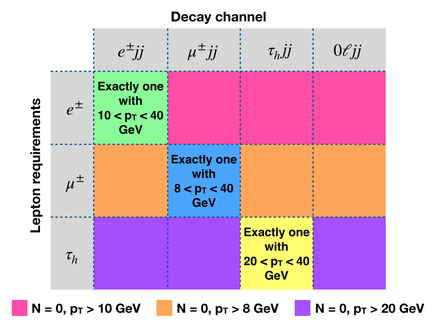

Fig. 3: Lepton requirements for each decay channel considered.

Background estimation

1ℓjj channels

- **Main backgrounds**: $t\bar{t}$, W+jets, Z+jets, QCD (single-τ_h).
- $N_{\mathrm{BG}}^{\mathrm{Expected}} = N_{\mathrm{BG}}^{\mathrm{MC}}(\mathrm{SR\ cuts}) \cdot SF_{\mathrm{inv.\ VBF\ cuts}}^{\mathrm{CR1}} \cdot SF_{\mathrm{VBF\ cuts}}^{\mathrm{CR2}}$.
- $SF_{\mathrm{inv.\ VBF\ cuts}}^{\mathrm{CR1}} = \frac{N^{\mathrm{CR1}}(\mathrm{Data}) - N^{\mathrm{CR1}}(\mathrm{other\ BGs})}{N^{\mathrm{CR1}}(\mathrm{BG\ studied})}$;
- $SF_{\mathrm{VBF\ cuts}}^{\mathrm{CR2}} = \frac{N^{\mathrm{CR2}}(\mathrm{Data}) - N^{\mathrm{CR2}}(\mathrm{other\ BGs})}{N^{\mathrm{CR1}}(\mathrm{BG\ studied}) \cdot SF_{\mathrm{inv.\ VBF\ cuts}}^{\mathrm{CR1}}}$.

0ℓjj channel

- **Main backgrounds**: $Z \rightarrow \nu\nu$+jets and $W \rightarrow \ell\nu$+jets (estimated from simulation using $\mu \rightarrow \nu$ emulation), QCD.

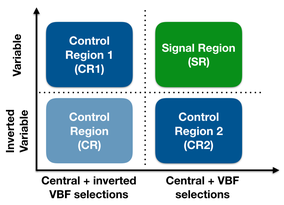

Fig. 4: Control region (CR) definition for the 1ℓjj channels.

Background	Variable	Inverted VBF selections		VBF selections	
		CR1	CR3	CR2	SR
$t\bar{t}$	$N_{\mathrm{b-jet}}$	=1	-	=1	=0
W+jets	$Z \rightarrow \mu\mu$ cuts	fail	pass	pass	fail
QCD (ABCD method)	Tight iso.	pass	fail	fail	pass
	Loose iso.	-	pass	pass	-

Tab. 1: Description of the CRs for the 1ℓjj channels.

Background	CR1 (Basic)	CR2 (+ basic)	CR3 (+ basic + $p_{\mathrm{T}}^{\mathrm{miss}}$)
$Z \rightarrow \nu\nu$+jets	$N_\mu \geq 2$, 60< $m(\mu,\mu)$ <120 GeV	$p_{\mathrm{T}}^{\mathrm{miss}} + \sum_i^{N_\mu} p_{\mathrm{T}} > 250$ GeV	VBF selections
$W \rightarrow \mu\nu$+jets	$N_\mu = 1$, 50< $m_{\mathrm{T}}(\mu, p_{\mathrm{T}}^{\mathrm{miss}})$ <100 GeV		
QCD	SR selections but $\lvert\Delta\phi_{\mathrm{min}}(p_{\mathrm{T}}^{\mathrm{miss}}, j)\rvert < 0.5$		

Tab. 2: Description of the CRs for the 0ℓjj channel. For Z+jets and W+jets, muons with $p_{\mathrm{T}}(\mu) > 30$ GeV, $|\eta\mu| < 2.5$, tight ID and $I < 0.25$ are selected.

Results and interpretation

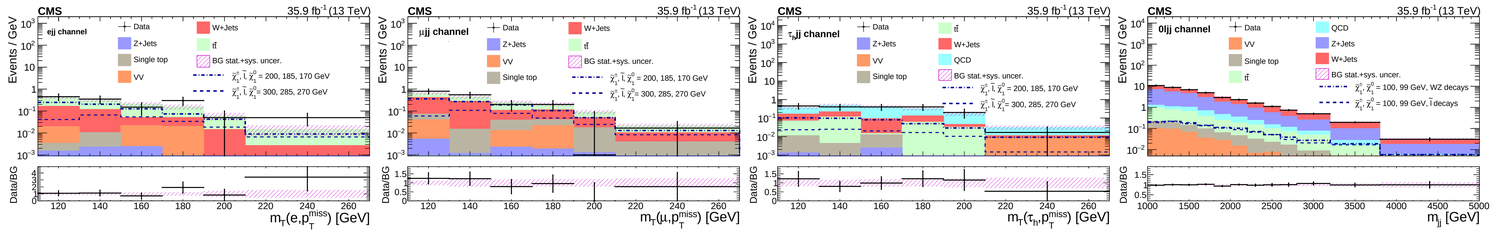

Fig. 5: Observed m_{T} and m_{jj} distributions for the 1ℓjj and 0ℓjj signal regions. Expected signal distributions are overlaid.

No significant excess is observed above the SM prediction in any of the search regions.

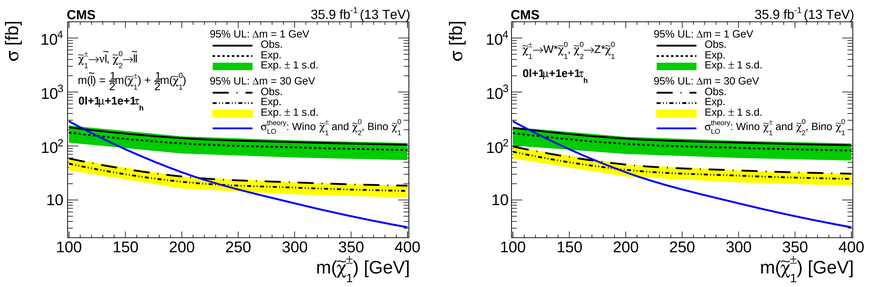

Fig. 6: (Left) Expected and observed 95% confidence level (CL) upper limit (UL) on the signal cross section assuming that the $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ decay via light sleptons (top) and virtual W^*/Z^* bosons (bottom).

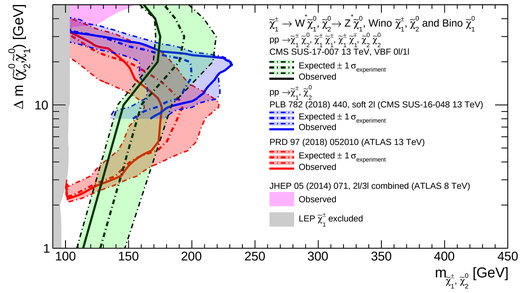

Fig. 7: Exclusion limits for chargino and neutralino searches at the LHC and LEP as a function of Δm and $m(\tilde{\chi}_1^{\pm}) = m(\tilde{\chi}_2^0)$.

Most stringent limits to date on $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production decaying to leptons in compressed mass spectrum scenarios for $1 \leq \Delta m < 3$ GeV and $25 \leq \Delta m < 50$ GeV.