Search for electroweak SUSY production at CMS

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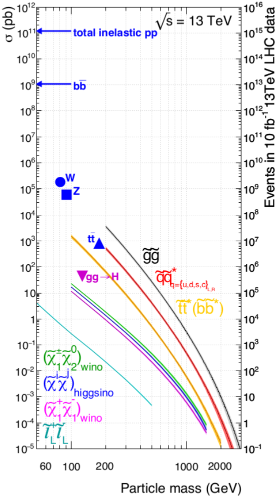
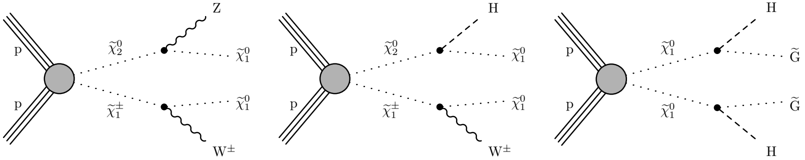
Motivations

- Natural way to look for SUSY at hadron colliders: Target strong SUSY production in purely hadronic final states and E_T^{miss}.
  $\rightarrow$ Limits set on squarks/gluinos typically $\geq$ 1 TeV.
- Searches presented here do the exact opposite: Target electroweak SUSY production with lepton(s) and E_T^{miss} .
  - Much weaker cross sections and therefore exclusion limits.
  - Naturalness typically constraints Higgsino masses more than gluino/squark.
  - In some cases, this searches allow to probe directly Higgs couplings to SUSY.

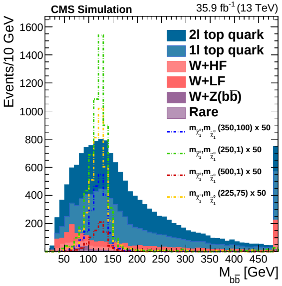


Content of the talk

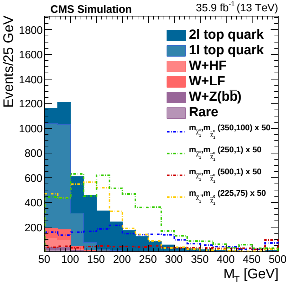
- Focus on CMS results targeting electroweakinos pair production
  $\rightarrow$ see I. Babounikau's talk for searches for direct slepton production at CMS.
- Rich phenomenology depending on mass spectrum, nature/stability of the LSP.
- Three final states reviewed (all with full 2016 dataset: 35.9 fb^{-1}, $\sqrt{s}$ =13 TeV)
  - **1 lepton +2 b-tagged jets + E_T^{miss}**
  - **2 opp. charge and same flavor leptons + jets + E_T^{miss}**
  - **Multi leptons + E_T^{miss}**
- **Combination of Electroweakino searches at CMS.**
  - All analyses above sensitive to $\tilde{\chi}_2^0\tilde{\chi}_1^{\pm} \rightarrow (\tilde{\chi}_1^0 Z/H)(\tilde{\chi}_1^0 W)$
  - Also includes:
    - soft opp. sign dilepton pair $+E_T^{\mathrm{miss}}$ ($\rightarrow$ see N. Rad's talk)
    - H($b\bar{b}$) H($b\bar{b}$) $+E_T^{\mathrm{miss}}$ ($\rightarrow$ see H. Kirschenmann's talk)
    - H($\gamma\gamma$)$+E_T^{\mathrm{miss}}$ ($\rightarrow$ see V. Hegde's talk)



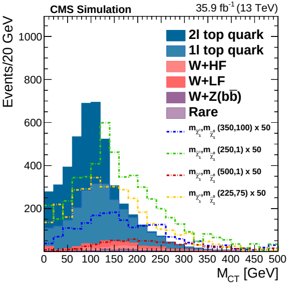
- Event selection:
  - =1 lepton (e/μ), $p_T > 30/25$ GeV and $|\eta| < 1.44/2.1$
  - =2 b-tagged jets with $p_T > 30$ GeV and $90 < M_{b\bar{b}} < 150$ GeV
  - $E_T^{\text{miss}} > 125$ GeV
  - Second lepton (incl. τ) veto.
  - $M_T = \sqrt{2 p_T^l E_T^{\text{miss}} (1 - \cos(\Delta\phi_l))} > 150$ GeV (endpoint at m_W for single leptonic W processes)
  - $M_{CT} = \sqrt{2 p_T^{b1} p_T^{b2} (1 + \cos(\Delta\phi_{bb}))} > 170$ GeV (endpoint at m_t for dileptonic $t\bar{t}$)



$M_{b\bar{b}}$



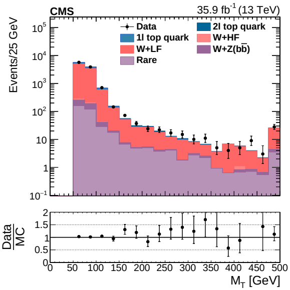
M_T



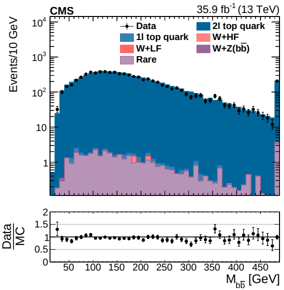
M_{CT}

1 lepton +2 b-tagged jets + E_T^{miss} CMS-SUS-16-043

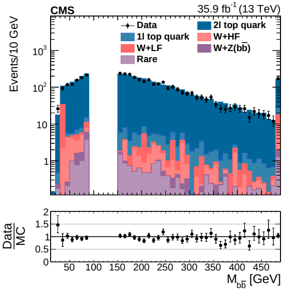
- Backgrounds:
  - Mostly dileptonic $t\bar{t}$, W+jets (splitted between light/heavy flavours).
  - From simulation.
  - Three sets of control regions (CR): 0 b-jets, =2l, $M_{b\bar{b}} \notin$ [90-150].
  - Shape of key variables validated in CR with relaxed M_T, M_{CT} ("preselection") conditions.
  - Systematic uncertainties assessed from CR with same M_T, M_{CT} conditions as SR.



0 b-jet CR

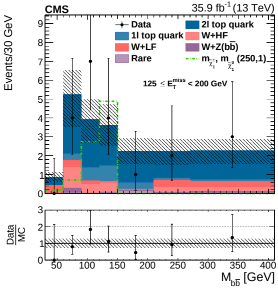


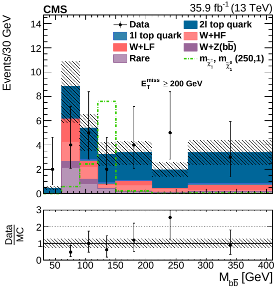
2 l CR

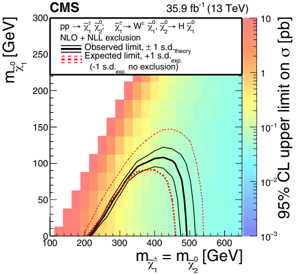


$M_{b\bar{b}} \notin$ [90-150] CR

- Results and interpretation:
  - Selected events splitted in two E_T^{miss} > bins: 125-200, >200 GeV.
  - Scan in the $m_{\tilde{\chi}^0_2/\tilde{\chi}^\pm_1}$ vs $m_{\tilde{\chi}^0_1}$ plane.
  - Exclusion limits in the range $200 < m_{\tilde{\chi}^0_2/\tilde{\chi}^\pm_1} < 500$ GeV.



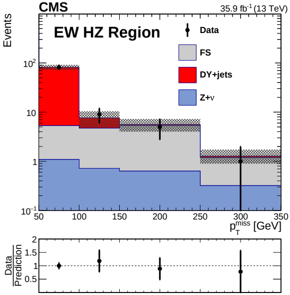




125< E_T^{miss} <200 GeV

E_T^{miss} >200 GeV

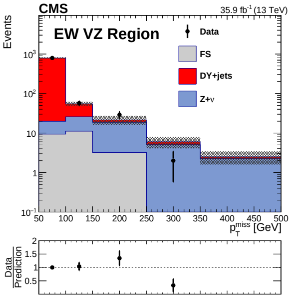
- Targets SUSY scenarios with onshell Z bosons and extra jets.
- Also target strong SUSY production
  →see L. Vesterbacka's talk
- Event selection:
  - 2 same flavor leptons (e/μ) with $p_T > 25$, 20 GeV
  - ≥ 2 jets with $p_T > 35$ GeV
  - $86 < M_{ll} < 96$ GeV
  - $E_T^{\text{miss}} > 100$ GeV
  - $M_{T2}(ll) > 80$ GeV (endpoint at M_W for WW, $t\bar{t}$).
  - various SR in bins of E_T^{miss}
- Two exclusive set of signal regions:
  - VZ: 0 b-tagged jets
  - HZ: 2 b-tagged jets

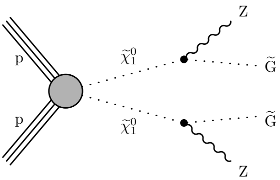


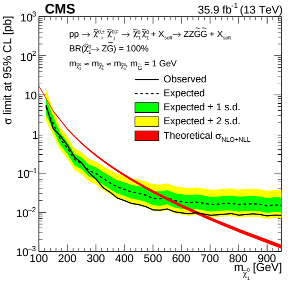
Electroweak-production on-Z ($86 < m_{\ell\ell} < 96$ GeV) signal regions					
Region	N_{jets}	$N_{\text{b-jets}}$	Dijet mass [GeV]	M_{T2} [GeV]	p_T^{miss} binning [GeV]
VZ	≥ 2	$=0$	$m_{jj} < 110$	$M_{T2}(\ell\ell) > 80$	100–150, 150–250, 250–350, >350
HZ	≥ 2	$=2$	$m_{bb} < 150$	$M_{T2}(\ell b \ell b) > 200$	100–150, 150–250, >250

2 opp. charge and same flavor leptons + jets + $E_T^{\rm miss}$ CMS SUS-16-034

- Main backgrounds:
  - flavor symmetric (FS) backgrounds ($t\bar{t}, WW, tW,\ldots$): data driven, from opp. flavor control regions.
  - Z+jets with instrumental $E_T^{\rm miss}$: data driven, templates from γ+jets.
  - ZZ: Monte Carlo validate in $WZ(3l\nu)$ enriched control region.
  - Z+jets normalized to data yields in the $E_T^{\rm miss}$ 50-100 control region.
- Interpretation:
  - Limits on $m_{\tilde{\chi}_2^0/\tilde{\chi}_1^\pm}$ up to 600 GeV.



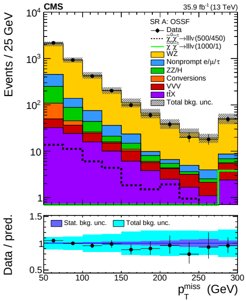


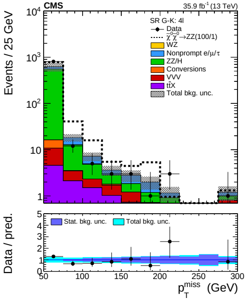


- Event selection
  - ≥ 3 l with $p_T \gtrsim 15/10/20$ GeV ($e/\mu/\tau_h$) or same sign (SS) $ee/\mu\mu/e\mu$ pair
  - At least one light l (e/μ) with $p_T \gtrsim 25$ GeV.
  - $E_T^{\text{miss}} > 50$ GeV.
  - $\lesssim 1$ jet with $p_T > 30$ GeV.
- Various event categories (A-K), depending on $e+\mu$ and τ multiplicity, presence of an opp. sign $ee/\mu\mu$ (OSSF) pair.

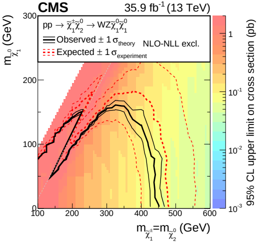
Category	SS	A	B	C	D	E	F	G-K
$N(e+\mu+\tau_h)$	2	3	3	3	3	3	3	≥ 4
$N(e+\mu)$	2	3	3	2	2	2	1	≥ 2
$N(\tau_h)$	0	0	0	1	1	1	2	$0,1,\geq 2$
(SS) $ee/\mu\mu/e\mu$ pair	1	0	1	0	0	1 SF	/	/
OSSF $ee/\mu\mu$ pair	0	1	0	1	0	0	/	$0,1,\geq 2$

- SR then defined in bins of various kinematic variables: E_T^{miss}, M_T, M_{ll}, M_{T2},...

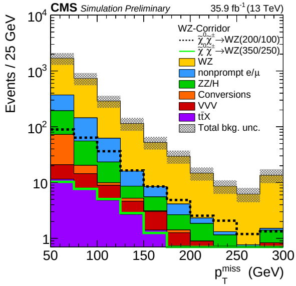




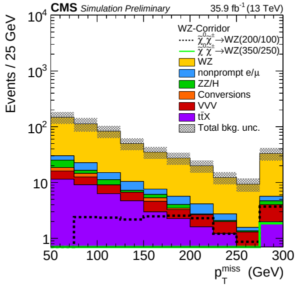
- Category A ($N(e+\mu)=3$, $N(\tau_h)=0$, 1 OSSF pair) by far the most sensitive to flavor democratic signals with uncompressed mass spectra.
- Sensitivity drop when: $m_{\tilde{\chi}^0_2/\tilde{\chi}^\pm_1}$-$m_{\tilde{\chi}^0_1} \approx M_Z$ ("WZ corridor")
- Additional binning in H_T (scalar p_T sum of jets with p_T>30 GeV) introduced in CMS-SUS-17-004 to target strong ISR.
- Found to improve discriminating power at high E_T^{miss}



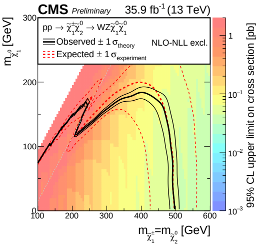
SUS-16-039



$H_T < 100$ GeV

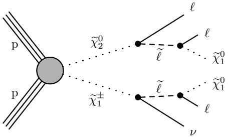


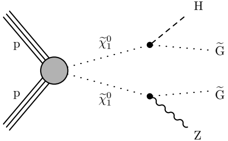
$H_T > 200$ GeV

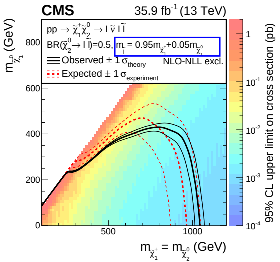


SUS-17-004

- Same Sign category to target **compressed mass spectra**
  - One lepton is soft and not reconstructed



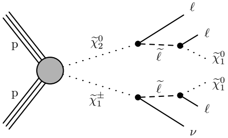


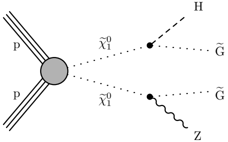


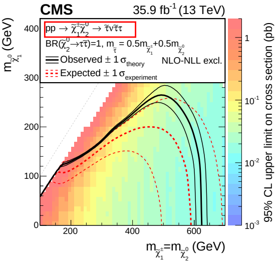
Model	Categories used
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production, flavor-democratic, $m_{\tilde{\ell}} = m_{\tilde{\chi}_1^0} + 0.5 \cdot (m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$	A
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production, flavor-democratic, $m_{\tilde{\ell}} = m_{\tilde{\chi}_1^0} + 0.05 \cdot (m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$	SS, A
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production, flavor-democratic, $m_{\tilde{\ell}} = m_{\tilde{\chi}_1^0} + 0.95 \cdot (m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$	SS, A
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production, τ-enriched, $m_{\tilde{\ell}} = m_{\tilde{\chi}_1^0} + 0.05 \cdot (m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$	A, C
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production, τ-enriched, $m_{\tilde{\ell}} = m_{\tilde{\chi}_1^0} + 0.5 \cdot (m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$	A, C
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production, τ-enriched, $m_{\tilde{\ell}} = m_{\tilde{\chi}_1^0} + 0.95 \cdot (m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$	A, C
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production, τ-dominated, $m_{\tilde{\tau}} = m_{\tilde{\chi}_1^0} + 0.5 \cdot (m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$	B–F
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production, heavy sleptons, $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to$ WZ	A
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production, heavy sleptons, $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to$ WH	SS, A–K
$\tilde{\chi}_1^0\tilde{\chi}_1^0$ production, $\tilde{\chi}_1^0\tilde{\chi}_1^0 \to$ ZZ$\tilde{G}\tilde{G}$	A–K
$\tilde{\chi}_1^0\tilde{\chi}_1^0$ production, $\tilde{\chi}_1^0\tilde{\chi}_1^0 \to$ HZ$\tilde{G}\tilde{G}$	A–K
$\tilde{\chi}_1^0\tilde{\chi}_1^0$ production, $\tilde{\chi}_1^0\tilde{\chi}_1^0 \to$ HH$\tilde{G}\tilde{G}$	A–K

Multi leptons + E_T^{miss} CMS-SUS-16-039/17-004

- Same Sign category to target **compressed mass spectra**
  - One lepton is soft and not reconstructed
- $N(\tau_h) = 1, 2$ categories designed to target signals with enhanced couplings to τ, e.g.:
  - $\tilde{\chi}_2^0 \tilde{\chi}_1^\pm$ production with $\tilde{l}_R$ mediated decays: τ favoured via higgsino component of $\tilde{\chi}_1^\pm$.
    τ **enriched** scenario.
  - Decoupled first and second generation of sleptons/sneutrinos.
    τ **dominated** scenario.
  - Allows one to also probe **final states with Higgs bosons**.







Model	Categories used
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production, flavor-democratic, $m_{\tilde{\ell}} = m_{\tilde{\chi}_1^0} + 0.5 \cdot (m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$	A
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production, flavor-democratic, $m_{\tilde{\ell}} = m_{\tilde{\chi}_1^0} + 0.05 \cdot (m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$	SS, A
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production, flavor-democratic, $m_{\tilde{\ell}} = m_{\tilde{\chi}_1^0} + 0.95 \cdot (m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$	SS, A
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production, τ-enriched, $m_{\tilde{\ell}} = m_{\tilde{\chi}_1^0} + 0.05 \cdot (m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$	A, C
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production, τ-enriched, $m_{\tilde{\ell}} = m_{\tilde{\chi}_1^0} + 0.5 \cdot (m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$	A, C
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production, τ-enriched, $m_{\tilde{\ell}} = m_{\tilde{\chi}_1^0} + 0.95 \cdot (m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$	A, C
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production, τ-dominated, $m_{\tilde{\tau}} = m_{\tilde{\chi}_1^0} + 0.5 \cdot (m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$	B–F
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production, heavy sleptons, $\tilde{\chi}_1^\pm\tilde{\chi}_2^0 \to$ WZ	A
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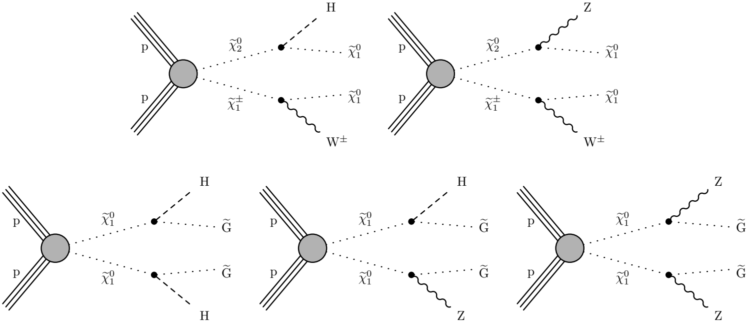
$\tilde{\chi}_1^0\tilde{\chi}_1^0$ production, $\tilde{\chi}_1^0\tilde{\chi}_1^0 \to$ ZZ$\tilde{G}\tilde{G}$	A–K
$\tilde{\chi}_1^0\tilde{\chi}_1^0$ production, $\tilde{\chi}_1^0\tilde{\chi}_1^0 \to$ HZ$\tilde{G}\tilde{G}$	A–K
$\tilde{\chi}_1^0\tilde{\chi}_1^0$ production, $\tilde{\chi}_1^0\tilde{\chi}_1^0 \to$ HH$\tilde{G}\tilde{G}$	A–K

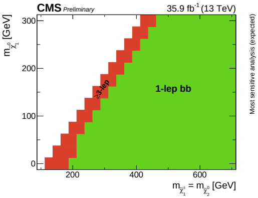
- Six analyses entering the combination.

	Signal topology				
Search	WZ	WH	ZZ	ZH	HH
1ℓ 2b		✓			
4b					✓
2ℓ on-Z	✓		✓	✓	
2ℓ soft	✓				
2ℓ SS, $\geq 3\ell$	✓	✓	✓	✓	✓
$\mathrm{H}(\gamma\gamma)$		✓		✓	✓

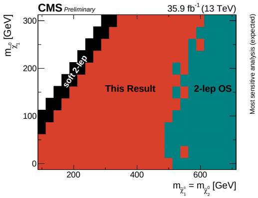
- Targeted models involve lightest neutralino or gravitino scenarios as LSP.



Most sensitive analysis

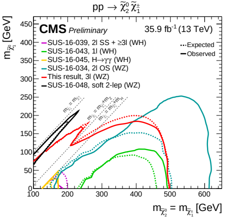


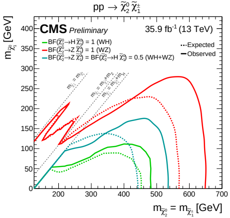
$\tilde{\chi}_2^0\tilde{\chi}_1^\pm \to (\tilde{\chi}_1^0 H)(\tilde{\chi}_1^0 W)$



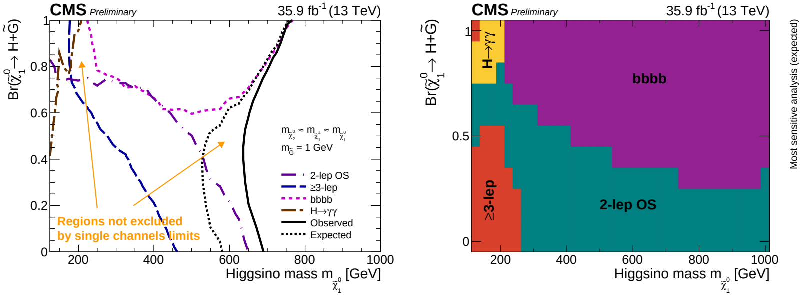
$\tilde{\chi}_2^0\tilde{\chi}_1^\pm \to (\tilde{\chi}_1^0 Z)(\tilde{\chi}_1^0 W)$

- Each of the presented searches drives the sensitivity for $\tilde{\chi}_2^0\tilde{\chi}_1^\pm \to (\tilde{\chi}_1^0 Z/H)(\tilde{\chi}_1^0 W)$ in some region of the mass spectrum or for a specific H/Z branching ratio.
- Excluded mass range extended by ≈ 50 GeV in a large fraction of the phase space.





- Combination also made for a GMSB scenario with $\tilde{\chi}_1^0\tilde{\chi}_1^0 \rightarrow (\tilde{G} + H/Z)(\tilde{G} + H/Z)$
- Limit parametrized vs $Br(\tilde{\chi}_1^0 \rightarrow \tilde{G} + H)$
- Combination significantly extends the limit and fills some holes.
- Higgsino masses below 600 GeV fully excluded in this model.



Conclusions

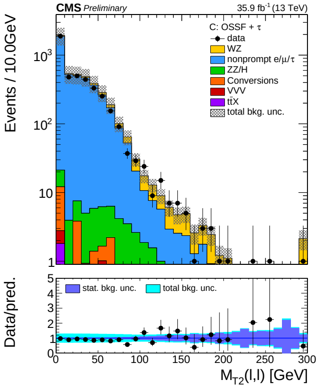
- Despite their low cross section, direct production of electroweakinos offers an alternative way to strong production for SUSY to reveal itself at the LHC.
- A broad variety of final states and phase space regions were considered by CMS.
- Recent results on the full 2016 dataset now surpass exclusion limits from Run 1 by a large margin.
- Complementarity between various analyses/final states allows us to significantly improve the exclusion range when combining.
- More results in the pipeline and full 2017 (and 2018 !) dataset still to be analyzed.

References:

- Search for electroweak production of charginos and neutralinos in the WH final state in proton-proton collisions at at$\sqrt{s} = 13$ TeV, CMS-PAS-SUS-16-043
- Search for new phenomena in final states with two opposite-charge, same-flavor leptons, jets, and missing transverse momentum in pp collisions at$\sqrt{s} = 13$ TeV, CMS-SUS-16-034
- Search for electroweak production of charginos and neutralinos in multilepton final states in proton-proton collisions at $\sqrt{s} = 13$ TeV, CMS-SUS-16-039
- Combined search for electroweak production of charginos and neutralinos in pp collisions at $\sqrt{s} = 13$ TeV CMS-PAS-SUS-17-004

M_{T2} definition

$$M_{\mathrm{T2}}^2 = \min_{\vec{p}_{\mathrm{T1}}^{\mathrm{miss}} + \vec{p}_{\mathrm{T2}}^{\mathrm{miss}} = \vec{p}_{\mathrm{T}}^{\mathrm{miss}}} \left[\max \left\{ M_{\mathrm{T}}^2(\vec{p}_{\mathrm{T}}^{\ell_1}, \vec{p}_{\mathrm{T1}}^{\mathrm{miss}}), M_{\mathrm{T}}^2(\vec{p}_{\mathrm{T}}^{\ell_2}, \vec{p}_{\mathrm{T2}}^{\mathrm{miss}}) \right\} \right]$$



SR C: $e^{\pm}e^{\mp}\ \tau_h\ /\mu^{\pm}\mu^{\mp}\ \tau_h$

- $WZ/W\gamma^*$ background
  - From simulation, normalized in control region with 3l, low M_T, moderate E_T^{miss} ($<$100 GeV).
  - M_T tails dominated by lepton mispairing in $eee/\mu\mu\mu$ channels, validated in $ee\mu/e\mu\mu$ channels.
  - Instrumental E_T^{miss} validated with $W+\gamma$ events.
- Fakes:
  - Jet misidentified as leptons or non prompt lepton from decays of heavy flavour hadrons.
  - Dominant for categories with $\geq 1\tau_h$.
  - Data driven (based on the jet fake rate measured in jet dominated sample).
- Conversions:
  - Z $\rightarrow$ 4l due to internal/external FSR conversion.
  - One of the lepton is lost
  - Verified in data CR with $|M_{3l} - M_Z| < 15$ GeV, $|M_{ll} - M_Z| > 15$ GeV.
- Charge mismeasurement
  - Relevant only for electrons.
  - Validated in data CR $M_{e^\pm e^\pm}$ in the Z peak region.

WZ corridor signal regions

- SRA: 3 light leptons (e/μ), with an OSSF pair.

<table>
<tr><th>$m_{\ell\ell}$ (GeV)</th><th>M_{T} (GeV)</th><th>$p_{\mathrm{T}}^{\mathrm{miss}}$ (GeV)</th><th>$H_{\mathrm{T}} < 100\,\mathrm{GeV}$</th><th>$100 < H_{\mathrm{T}} < 200\,\mathrm{GeV}$</th><th>$H_{\mathrm{T}} > 200\,\mathrm{GeV}$</th></tr>
<tr><td rowspan="11">$0 - 75$</td><td rowspan="4">$0 - 100$</td><td>$50 - 100$</td><td colspan="2">SR 01</td><td rowspan="4">SR 12</td></tr>
<tr><td>$100 - 150$</td><td colspan="2">SR 02</td></tr>
<tr><td>$150 - 200$</td><td colspan="2">SR 03</td></tr>
<tr><td>> 200</td><td colspan="2">SR 04</td></tr>
<tr><td rowspan="3">$100 - 160$</td><td>$50 - 100$</td><td colspan="2">SR 05</td><td rowspan="3">SR 13</td></tr>
<tr><td>$100 - 150$</td><td colspan="2">SR 06</td></tr>
<tr><td>> 150</td><td colspan="2">SR 07</td></tr>
<tr><td rowspan="4">> 160</td><td>$50 - 100$</td><td colspan="2">SR 08</td><td rowspan="4">SR 14</td></tr>
<tr><td>$100 - 150$</td><td colspan="2">SR 09</td></tr>
<tr><td>$150 - 200$</td><td colspan="2">SR 10</td></tr>
<tr><td>> 200</td><td colspan="2">SR 11</td></tr>
<tr><td rowspan="18">$75 - 105$</td><td rowspan="6">$0 - 100$</td><td>$50 - 100$</td><td>(WZ CR)</td><td>SR 27</td><td rowspan="2">SR 40</td></tr>
<tr><td>$100 - 150$</td><td>SR 15</td><td>SR 28</td></tr>
<tr><td>$150 - 200$</td><td>SR 16</td><td>SR 29</td><td rowspan="2">SR 41</td></tr>
<tr><td>$200 - 250$</td><td>SR 17</td><td>SR 30</td></tr>
<tr><td>$250 - 350$</td><td rowspan="2">SR 18</td><td rowspan="2">SR 31</td><td>SR 42</td></tr>
<tr><td>> 350</td><td>SR 43</td></tr>
<tr><td rowspan="6">$100 - 160$</td><td>$50 - 100$</td><td>SR 19</td><td>SR 32</td><td>SR 44</td></tr>
<tr><td>$100 - 150$</td><td>SR 20</td><td>SR 33</td><td>SR 45</td></tr>
<tr><td>$150 - 200$</td><td>SR 21</td><td>SR 34</td><td>SR 46</td></tr>
<tr><td>$200 - 250$</td><td rowspan="3">SR 22</td><td rowspan="3">SR 35</td><td>SR 47</td></tr>
<tr><td>$250 - 300$</td><td>SR 48</td></tr>
<tr><td>> 300</td><td>SR 49</td></tr>
<tr><td rowspan="6">> 160</td><td>$50 - 100$</td><td>SR 23</td><td>SR 36</td><td>SR 50</td></tr>
<tr><td>$100 - 150$</td><td>SR 24</td><td>SR 37</td><td>SR 51</td></tr>
<tr><td>$150 - 200$</td><td>SR 25</td><td>SR 38</td><td>SR 52</td></tr>
<tr><td>$200 - 250$</td><td rowspan="3">SR 26</td><td rowspan="3">SR 39</td><td>SR 53</td></tr>
<tr><td>$250 - 300$</td><td>SR 54</td></tr>
<tr><td>> 300</td><td>SR 55</td></tr>
<tr><td rowspan="3">> 105</td><td>$0 - 100$</td><td>> 50</td><td colspan="3">SR 56</td></tr>
<tr><td>$100 - 160$</td><td>> 50</td><td colspan="3">SR 57</td></tr>
<tr><td>> 160</td><td>> 50</td><td colspan="3">SR 58</td></tr>
</table>

Systematic uncertainties: effect on yields

Source	Typical values [%]
Integrated luminosity	2.5
Size of MC samples	2–60
Pileup	1–5
Renormalization and factorization scales	1–3
ISR modeling	1–5
b tagging efficiency	1–3
Lepton efficiency	2–5
Trigger efficiency	1–5
Jet energy scale	1–40
Fastsim E_T^{miss} resolution	1–50

1 lepton +2 b-jets + E_T^{miss}

Source of uncertainty	Uncertainty (%)
Integrated luminosity	2.5
Lepton reconstruction and isolation	5
Fast simulation lepton efficiency	4
b tag modeling	0–5
Trigger modeling	3
Jet energy scale	0–5
ISR modeling	0–2.5
Pileup	1–2
Fast simulation p_T^{miss} modeling	0–4
Renorm./fact. scales	1–3
Statistical uncertainty	1–15
Total uncertainty	9–18

2 OSSF e/μ + jets + E_T^{miss}