Search for electroweak SUSY production at CMS

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Introduction and Motivation
Introduction and Motivation

Subject of this talk:

[very] Low cross sections

Clear Signatures

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SUSYCrossSections

arXiv:1206.2892
Bibliography

- **CMS-SUS-13-006**: Search for electroweak production of charginos, neutralinos, and sleptons using *leptonic final states* in pp collisions at 8 TeV

- **CMS-SUS-13-017**: Search for electroweak production of charginos and neutralinos in final states with *a Higgs boson* in pp collisions at 8 TeV

- **CMS-SUS-13-022**: Search for electroweak production of higgsinos in channels with *two Higgs bosons decaying to b quarks* in pp collisions at 8 TeV
Chargino–Neutralino production
Chargino-Neutralino decay modes

Chargino Mass = Neutralino Mass
Slepton mass = LSP Mass + K( Chargino Mass – LSP Mass)
Signature : 3 Leptons (2 SS Leptons) + MET

Leptonic decay of Z
Leptonic and Hadronic decays of W

Leptonic decay of W
Higgs decay :
  • bb, W(lnu)W(jj), WW/tautau/ZZ

1Lepton, SS Leptons, > 2 leptons
**Chargino-Neutralino**

**3Leptons + MET**

- **Selection**
  - Exactly 3 leptons, up to one hadronic tau
  - MET > 50 GeV (Suppress Z+Jets)
  - b-veto (Suppress ttbar)
  - Classify events based on lepton flavours, \( M(\ell\ell) \), Transverse mass, MET

- **Main Backgrounds**
  - WZ : MC (with data-driven MET correction)
  - \( tt\bar{t} \) + fake : data-driven fake rate method

Lepton Flavour Categories

- 3\( \ell \), OSSF Pair
- 3\( \ell \), No OSSF Pair
- SS 2\( \ell \) + one hadronic tau
- OS 2\( \ell \) + one hadronic tau
Chargino-Neutralino

3Leptons + MET: Limits

Data consistent with BKG over range of kinematic regions and lepton categories:

- "flavor-democratic" (3ℓ) light (\tilde{\ell}_L, \tilde{\nu}_L)
- "tau-enriched" (2ℓ+τ) light \tilde{\ell}_R, small tan β
- "tau-dominated" (3τ) light \tilde{\ell}_R, high tan β

\[
m_\ell = \frac{1}{2} \left( m_{\tilde{\chi}_1^\pm} + m_{\tilde{\chi}_1^0} \right)
\]
Chargino-Neutralino

**SS Dilepton + MET**

Event Selection:
- Exactly two high Pt SS e/mu leptons
- 2 Signal Regions:
  - $120 < \text{MET} < 200$, At most 2 jets, No b-jets
  - MET > 200 GeV

**Diagram:**
- $\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$
- $\ell, \nu_\ell$
- $\tilde{\ell}_R$
- $\tilde{\chi}_1^0$
- $\tilde{\tau}$
- Lost \ell
- compressed $\rightarrow$ low $p_T$ leptons

- $p_T > 200$ GeV
- $E_T^{miss}$ vs. $E_T^{miss}$
- $SS$ 2l Recovery

**Graph:**
- CMS Preliminary
- $\sqrt{s} = 8$ TeV, $L_{int} = 19.5$ fb$^{-1}$
- 95% C.L. CLs NLO Exclusions
- Observed $3/0SS \pm 1\sigma$ theory
- Expected $3/0SS \pm 1\sigma$ experiment
- Observed $3/0SS$ only
- Observed $SS$ only

**Legend:**
- $pp \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_2^0$
- $\tilde{\chi}_1^\pm \rightarrow \ell \nu_\ell$
- $\tilde{\chi}_2^0 \rightarrow \ell \ell$, $\mu\mu$, $\tau\tau$
- $Br(\tilde{\chi}_2^0 \rightarrow \ell \ell) = 1$

**Cross section:**
- 95% C.L. upper limit on cross section (fb)
Chargino-Neutralino

Z+W+MET

- **Event Selection**
  - $Z \rightarrow ll$ candidate
  - MET $> 80$ GeV
  - 2Jets with M$_{jj} \sim W/Z$ mass
  - b-veto (to suppress ttbar)

- **Backgrounds**
  - Z+Jets: Fake MET is modeled using photon+jets events
  - ttbar: estimated using e/mu control sample

- No excess is observed
Chargino-Neutralino

\[ Z+W+\text{MET} : \text{Limits} \]

- Results based on \( Z(\ell\ell)W(jj) \) and \( 3\ell \) searches
  - Complementarity: improvement from combination
Chargino-Neutralino

$H + W + \text{MET}$
Chargino-Neutralino

$H + W + \text{MET}$

$\sigma(pp \rightarrow \tilde{\chi}_1^\pm \chi_2^0) \times \text{BF} [\text{pb}]$

- **total**
- **$W(\ell\nu)H(b\bar{b})$**

$8$ TeV NLO

$m_{\chi_1^\pm} = m_{\chi_2^0}$ [GeV]
Chargino-Neutralino

$H + W + \text{MET}$

$\sigma(pp \rightarrow \chi_1^\pm \chi_2^0) \times BF [pb]$ vs $m_{\chi_1^\pm} = m_{\chi_2^0} [GeV]$ for $8 \text{ TeV NLO}$

- $1\ell$
- $SS \ 2\ell$

Events in 20 fb$^{-1}$
Chargino-Neutralino

$H + W + \text{MET}$

$\sigma(p\bar{p} \to \tilde{\chi}_1^\pm \tilde{\chi}_2^0) \times \text{BF}$ [pb]

- total
- $W(\ell\nu)H(b\bar{b})$
- $W(\ell\nu)H(WW)$
- $W(\ell\nu)H(\tau\tau)$
- $W(\ell\nu)H(ZZ)$

8 TeV NLO

$m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}$ [GeV]

- 1\ell
- SS 2\ell
- \geq 3\ell

exclusive:
combine to improve sensitivity

reinterpretation of SUS-13-002
inclusive multilepton SUSY search
Chargino-Neutralino

$H + W + \text{MET}$

1 lepton + $bb$

- Selection
  - Exactly on high pt lepton
  - Exactly 2 jets, both b-tagged
  - Cuts on MET and MT

- Backgrounds from MC

- Search for a peak in $M_{bb}$
  - No evidence for a peak is found
Chargino-Neutralino

H+W+MET

SS Dileptons + Jets + MET

- Selection
  - Exactly two SS e/mu
  - 2/3 jets, b-veto
  - Moderate MET

- Data-driven fake lepton estimate

- Prompt SS 2l bkg from MC

- Search for a bump in $M_{\ell\ell j}$
  - No evidence for a peak is found
Chargino-Neutralino

H+W+MET

- 1lepton : best at large chargino mass
  - SS 2l and >2l contributes at low chargino mass
- Combined 3 channels:
  probe up to chargino mass $\sim 200$ GeV
Chargino-Neutralino

SUMMARY

observed $\text{CL}_S$ limits (95% CL)
- $pp \rightarrow \tilde{\chi}_2^0 \tilde{\chi}_1^\pm$, ($\tilde{t}_L$, BF(l$^+$$l^-$)=0.5)
- $pp \rightarrow \tilde{\chi}_2^0 \tilde{\chi}_1^\pm$, ($\tilde{t}_R$, BF(l$^+$$l^-$)=1)
- $pp \rightarrow \tilde{\chi}_2^0 \tilde{\chi}_1^\pm$, (no $\tilde{t}$, BF(WZ)=1)
- $pp \rightarrow \tilde{\chi}_2^0 \tilde{\chi}_1^\pm$, (no $\tilde{t}$, BF(WH)=1)
- $pp \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_1^-$, ($\tilde{t}_L$, BF(l$^+$$l^-$)=1)

$\sqrt{s} = 8 \text{ TeV, } L_{\text{int}} = 19.5 \text{ fb}^{-1}$

$m_\gamma = 0.5m_{\tilde{\chi}_1^\pm} + 0.5m_{\tilde{\chi}_2^0}$

CMS Preliminary

$m_{\tilde{\chi}_1^0} = m_{\tilde{\chi}_2^0} > m_{\tilde{\chi}_1^\pm}$
Chargino-Chargino & Slepton-SLepton
Chargino-Chargino & Slepton-SLepton

Signature: 2 OS leptons + MET
Chargino-Chargino & Slepton-SLepton Selection

- Event Selection
  - 2 high Pt OS e/mu leptons with Z-veto
  - b-veto, moderate MET cut
- $M_{\text{CT}}$: Kinematic Reconstruction
  - Separate WW backgrounds
  - Fitted using data driven templates and MC
  - Data agrees well with prediction
Chargino-Chargino & Slepton-SLepton

Results

Use $e^+\mu^+$ and $e\mu$ lepton pairs

Use $e^+\mu^+$ lepton pairs only

$\ell$

$P_2$

$P_1$

$\tilde{\chi}^0_1$

$\tilde{\nu}$

$\nu$

$\tilde{\ell}$

$\tilde{\chi}^\pm$

$\tilde{\chi}^\mp$

CMS Preliminary

$L_{\text{int}} = 19.5$ fb$^{-1}$, $\sqrt{s} = 8$ TeV

95% C.L. CLs NLO Exclusions

Observed $\pm 1\sigma_{\text{theory}}$

Expected $\pm 1\sigma_{\text{experiment}}$

$m_{\tilde{\chi}^0_1}$ (GeV)

$m_{\tilde{\chi}^\pm_1}$ (GeV)

Probed up to $m_{\tilde{\chi}^\pm_1} \sim 550$ GeV

$m_{\tilde{\chi}^0_1}$ (GeV)

$B r(\tilde{\ell}_L \rightarrow \ell \tilde{\chi}^0_1) = 1$

95% C.L. upper limit on cross section (fb)

Probed up to $m_{\tilde{\chi}^0_1} \sim 280$ GeV

$m_{\tilde{\ell}}$ (GeV)

$m_{\tilde{\chi}^0_1}$ (GeV)

$m_{\tilde{\chi}^0_1} > m_{\tilde{\ell}}$

$m_{\tilde{\chi}^0_1} > m_{\tilde{\chi}^0_1} + 0.5m_{\tilde{\chi}^0_1}$ ($t = e, \mu, \tau$)

$m_{\tilde{\chi}^0_1}$ (GeV)

95% C.L. upper limit on cross section (fb)
Neutralino–Neutralino
Neutralino-Neutralino decay modes

- R-parity-conserving gauge-mediated SUSY-breaking (GMSB) models are considered
  - Gravitino is a nearly massless LSP
- $X^0_{1,2}$ and $X^\pm_0$ are approximately mass-degenerate
- $X^0_2 / X^\pm_0 \rightarrow X^0_1 + \text{low pt standard model particle}$

- 4 leptons
- 3 leptons
- 2 leptons + 2 jets

- 4 b-jets: ✓
- Higgs decays to gauge bosons ( photon, W, Z): under study
Neutralino-Neutralino

**Z+Z+MET**

- **Event Selection**
  - 4 leptons (up to one hadronic tau)
  - Classify events by #OSSF pairs, #hadronic taus, MET

- **Main Background**
  - ZZ : estimated from MC, with data-driven MET corrections

- **Results**
  - No sign of new physics
Neutralino-Neutralino

Z+Z+MET (Results)

- Results based on $Z(\ell\ell)V(jj), 3\ell+4\ell$, and combination
  - Combination of complementary channels $\rightarrow$ exclude $\mu$ 110-330 GeV
Neutralino-Neutralino

**H+H+MET (4b)**

- **Event Selection**
  - 4/5 Jets, at least 3 b's
  - Moderate MET cut
  - Cut on Dphi of MET and Jets to eliminate QCD and ttbar

- **HH Reconstruction**
  - $|\Delta m_{jj}| \equiv |m_{jj,1} - m_{jj,2}|$ is minimized
  - $|\Delta m_{jj}| < 20 \text{GeV}$
  - $100 < \langle m_{jj} \rangle < 140 \text{ GeV}$
Neutralino-Neutralino
H+H+MET (4b)

• Background estimation
  - $\langle m_{jj} \rangle$ and $|\Delta m_{jj}|$ are used to define signal and background regions
  - #Signal and background for different #b's are illustrated
  - #background can be estimated using an ABCD method

• Results
  - Binning vs. MET
  - No sign of new physics is observed
Neutralino-Neutralino

$H+H+\mathrm{MET}$ (4b)

- For higgsino masses between $\sim 270$ and 350 GeV, the expected cross section upper limits reach the level of the expected production cross section.
- Because of a slight excess in the observed number of events compared to the estimated background, we are unable to exclude the signal model for any value of higgsino mass.
Summary and Conclusion

- A wide range of searches for electroweak SUSY production is performed with full 8 TeV dataset
- Different decay scenarios are considered:
  - 1,2,3,4 leptons
  - 2leptons + 2jets
  - 4b
- The results are interpreted in various simplified models spectra
- No sign of new physics is observed