Squark & gluino searches in leptonic channels with CMS

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Strong SUSY after LHC Run1

Interpretation within simplified models:

> Gluinos excluded in various searches > 1400 (700) GeV for light (heavy) neutralinos

> Squarks excluded above 900 (700) GeV for light (heavy) neutralinos

CMS Preliminary

\[ \tilde{g} \rightarrow t \bar{t} \tilde{\chi}^0_1 \]
Strong SUSY at the LHC with \( \sqrt{s} = 13 \) TeV

- Strong SUSY profits largely from increased \( \sqrt{s} \)
- Gluino with largest absolute xsec and also largest gain wrt 8TeV for excluded \( m_{\text{gluino}} \)
- In this talk: gluino/squark searches at CMS using 2015 data at \( \sqrt{s} = 13 \) TeV
- See Eric’s talk for 3rd gen SUSY in the afternoon

\[ \sigma_{\text{NLO+NLL}} \]

\[ [\text{pb}] \]

\[ 13 \text{ TeV} \]

\[ 8 \text{ TeV} \]

\[ m_x [\text{GeV}] \]

\[ 400 \]

\[ 600 \]

\[ 800 \]

\[ 1000 \]

\[ 1200 \]

\[ 1400 \]

\[ 1600 \]

\[ 1800 \]

\[ \times 10 \]

\[ \times 30 \]

\[ \text{Xsec source} \]
Leptons in gluino production:

- $W$ from top quarks
- $W/Z$ from charginos

Leptonic channels:

- $=1\ell$ — high BR, inclusive
- $\geq2\ell$ — moderate BR, low SM
- $\geq3\ell$ — low BR and ~no SM

Simplified Model: $T1tttt$

$T5qqqqVV, V = W/Z$

(various EWKino mass splittings)
Leptonic gluino searches at CMS

- Leptons in gluino production:
  - W from top quarks
  - W/Z from charginos

- Leptonic channels:
  - $1\ell$ — high BR, inclusive
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*All-hadronic searches — see [Talk by Tai](#) from Tuesday

> SUS-15-004 (Razor*)
> SUS-15-006 ($\Delta\phi$)
> SUS-15-007 ($M_J$)
> SUS-16-011 (Soft)
> SUS-15-008 (SS)
> SUS-15-011 (OS)
> SUS-16-003 ($\geq 3\ell$)
Targets T5qqqqWW & T1tttt with single isolated e/µ p_T > 25 GeV

Preselection:
> L_T = MET + p_T (lepton) > 250 GeV
> n_jets ≥ 5 (p_T > 30 GeV)
> H_T = ∑ p_T (jets) > 500 GeV

Signal discrimination
> ΔΦ(W,ℓ) — azimuthal angle between lepton and reconstructed W(MET+ℓ)

b-jet multiplicity (CSVM)

Data/Pred. 0.5 1 1.5 2 2.5 3 3.5 < Events / 0.1 >

n_b = 0

n_b ≥ 1
Multi-bin search with ABCD-like background prediction based on $\Delta \phi$ & $n_{\text{jets}}$

- Exclusive search bins in $H_T$, $L_T$, $n_j$, $n_b$
- Total regions: 13 (30) for $n_{\text{btags}} = 0$ ($\geq 1$)

Data-driven background estimation
- High-to-low $\Delta \phi$ transfer factors from low $n_j$ data sidebands ($R_{CS}$)
- Residual corrections between $n_j$ bands from MC
- QCD contribution estimated from fake-enriched control sample

$\rightarrow$ good agreement with observation
Targets T1tttt with single isolated e/μ p_T > 20 GeV

Preselection:
> n_{jets} \geq 6 (p_T > 30 \text{ GeV}), \ n_b \geq 1
> H_T = \sum p_T (jets) > 500 \text{ GeV}
> \text{MET} > 200 \text{ GeV}

Signal discrimination
> m_T: from MET and lepton
> M_J: sum of large-R(1.2) jet masses

tt+jets background dominates \rightarrow\suppressedby M_J cut
Multi-bin search with ABCD-like background prediction

> Exclusive search bins in MET, $n_j$ and $n_b$
> Total regions: 10

Data-driven background prediction
> $m_T$ and $M_J$ not correlated
> Low-to-high $m_T$ transfer factors
> Residual corrections between $M_J$ regions from MC
> Prediction from fit in each bin

$\rightarrow$ agrees with observation
**Preselection:**

- No second lepton/isolated track
- \( H_T = \Sigma p_T \) (jets) > 200 GeV
- \( \text{MET} > 200 \) GeV
- \( |\text{MET} - H_T| < 0.5 \) MET
- \( n_{\text{jets}} \geq 1 \)
- \( m_T > 20 \) GeV

**Search bins in** \( H_T, \text{MET}, m_T, n_{\text{jets}}, n_{\text{btags}} \)

**Background estimation in categories:**

- \( 1\ell \) — from hard muon, low MET CR
- \( 2\ell \) — from \( 2\ell \) control region
- Fakes from fake-enriched sample

\( \rightarrow \) agrees with observation

**More details in** [Giovanni’s talk](#)
Targets various scenarios with two same-sign e/µ

Preselection:
> SS e/µ with $p_T > 15/10$ GeV
> Any $m_{e\mu} > 12$ GeV and outside Z
> $n_{jets} \geq 2$ ($p_T > 40$ GeV)
> $H_T = \sum p_T$ (jets) > 500 GeV
> MET > 50 GeV

Background estimation in categories:
> Nonprompt from loose leptons in data
> Same-sign 2\ell SM processes from MC
> Charge misidentified from OS data
—> agrees with observation

Signal discrimination:
> $\min(m_T)$ of two leptons

Search categories based on $p_T$ of leptons and binned in $m_T$, $H_T$, MET, $n_{jets}$, $n_{btags}$
SUS-16-003 (multileptons)

Targets T1tttt & T5qqqqVV with multileptons

Preselection:
> 3 e/μ with p_T > 20/15/10 GeV
> OS SF m_ℓℓ > 12 GeV
> n_jets ≥ 2 (p_T > 30 GeV)
> H_T = \Sigma p_T (jets) > 60 GeV
> MET > 50 GeV

Search categories:
> m_ℓℓ on/off-Z peak
> binned in H_T, MET, n_b

Background estimation in categories:
> Nonprompt from loose leptons in data
> Dibosons from normalised MC
> Rare SM processes from MC
→ agrees with observation

Data/pred
Limit summary: T1tttt

- 1ℓ analyses most sensitive and comparable to full hadronic
- Significant extension beyond 8TeV results

Compressed region well covered by 1ℓ-Δφ and SS analyses due to low MET cut

Light neutralino region pushed by 1ℓ searches with high n_jets
Limit summary: T5qqqqVV

- 1\ell analyses most sensitive and comparable to full hadronic
- Significant extension beyond 8TeV results
- Two mass splittings probed

pp $\rightarrow \tilde{g}\tilde{g}$, $\tilde{g} \rightarrow q\bar{q}V\tilde{\chi}^0_1$ Moriond 2016

CMS Preliminary

- $V = W$: SUS-15-006, 1-lep ($\Delta\phi$), 2.3 fb$^{-1}$ (13 TeV)
- $V = W$: SUS-15-008, 2-lep (SS), 2.2 fb$^{-1}$ (13 TeV)
- $V = W/Z$: SUS-16-003, 3-lep, 2.3 fb$^{-1}$ (13 TeV)

$m_{\tilde{\chi}_1^0} = 0.5(m_{\tilde{g}} + m_{\chi_1}$)

CMS Preliminary

pp $\rightarrow \tilde{g}\tilde{g}, \tilde{g} \rightarrow q\bar{q}V\tilde{\chi}^0_1$

2.3 fb$^{-1}$ (13 TeV)

CMS-PAS-SUS-16-011
Preselection:
> OS same-flavour e/µ with $p_T > 20$ GeV
> $n_{jets} \geq 2$ ($p_T > 35$ GeV)
> MET > 100 GeV

Background estimation in categories:
> flavour-symmetric from OF control region
> Drell-Yan-like from data MET templates

$\rightarrow$ no excess found at 13TeV!

Search categories for edge/on-Z binned in:
> MET, $H_T$, $n_{jets}$, $n_{btags}$ and $m_{\ell\ell}$
> including ATLAS-like SR (with 8TeV excess)
Summary

- Gluino sensitivity strongly enhanced with 13 TeV
  - At least 30 times larger x-sec wrt 8 TeV
  - SM backgrounds increase < 4x
- Leptonic channels complement hadronic searches performed by CMS
  - less background, good acceptance
  - high discovery & measurement sensitivity
- No deviations from expectations in 2015 data
  - → strong limits on simplified SUSY models surpassing 8 TeV results significantly
  - → CMS ready for SUSY searches in 2016 data!
BACKUP
> With/without b-tag analyses allow two interpretations

**CMS Preliminary** 2.3 fb⁻¹ (13 TeV)

**T1tttt**

- Observed ± 1σ_{theory}
- Expected ± 1σ_{experiment}

pp → g g~, g g→ t t χ⁻₁
NLO+NLL exclusion

**T5qqqqWW**

- Observed ± 1σ_{theory}
- Expected ± 1σ_{experiment}

pp → g g~, g g→ q q' W⁺ χ⁺₁
NLO+NLL exclusion

m₀ [GeV] = 0.5(m₉ + mₐ)
Also interpreted with intermediate stop of top mass 175 GeV

**CMS**

NLO+NLL exclusion

pp → ĝ ĝ, ĝ → t ĭ \tilde{χ}_0^0

**Observed ± 1 \sigma_{\text{theory}}**

**Expected ± 1 \sigma_{\text{experiment}}**

\begin{align*}
\text{T1tttt} & \quad m_\tilde{g} \text{ [GeV]} \\
\text{T5tttt}, m_{\text{stop}} = 175\text{GeV} & \quad m_\tilde{g} \text{ [GeV]}
\end{align*}
SUS-16-003 (multileptons)

CMS Preliminary 2.3 fb⁻¹ (13 TeV)

pp → gb, ĝ → tbb̄, NLO+NLL exclusion

Observed ± 1 σ_{theory}

Expected ± 1 σ_{experiment}

95% C.L. upper limit on cross section [pb]

m_{χ}\, [GeV]

m_{b}\, [GeV]

m_{g}\, [GeV]
SUS-15-011 (opposite-sign 2ℓ)

ATLAS-like SR

CMS 8TeV excess SR

2.3 fb⁻¹ (13 TeV)

Data
E_{miss} templates
FS background
Other SM

Σ p_{T(lep)} + H_{T} > 600 GeV
Δφ(E_{miss}, jet) > 0.4
N_{miss} ≥ 2

2.2 fb⁻¹ (13 TeV)

Central signal region
Data
Total backgrounds
Drell-Yan
Total unc.
Scaled 8 TeV signal fit:
Σ_m = 300 GeV hypothesis
Σ_m = 500 GeV hypothesis
Σ_m = 700 GeV hypothesis

CMS-PAS-SUS-15-011

CMS
2.3 fb⁻¹ (13 TeV)

pp → g̅g → ℓ⁺ℓ⁻, Z → Z_{2b} → Z_{1b} + Z_{1b}, m_{b} = 1 GeV

NLO+NLL exclusion
Expected limit, ± 1σ_{exp.}
Observed limit, ± 1σ_{theory}
95% CL upper limit on σ [pb]

2.3 fb⁻¹ (13 TeV)

pp → g̅g → ℓ⁺ℓ⁻, Z → Z_{2b} → Z_{1b} + Z_{1b}, m_{b} = 100 GeV

m_{b} = 0.5(m_{Z1} + m_{Z2}) NLO+NLL exclusion
Expected limit, ± 1σ_{exp.}
Observed limit, ± 1σ_{theory}
95% CL upper limit on σ [pb]