Searches for supersymmetry in final states with photons in CMS

Pheno 2018

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One possible scenario: Gauge-mediated supersymmetry breaking

Gauge-mediated SUSY breaking

- virtually massless (stable) $\tilde{G}$ as LSP
- $\tilde{\chi}_1^0$ as NLSP
- NLSP is Bino-like: high probability for $\tilde{\chi}_1^0 \to \tilde{G} + \gamma$
Photon final states in Supersymmetry

**One possible scenario:** Gauge-mediated supersymmetry breaking

- **Gauge-mediated SUSY breaking**
  - virtually massless (stable) $\tilde{G}$ as LSP
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  - NLSP is Bino-like: high probability for $\tilde{\chi}_1^0 \rightarrow \tilde{G} + \gamma$

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**Public results with photons at 13 TeV**

<table>
<thead>
<tr>
<th>CADI-label</th>
<th>Signature</th>
<th>Journal</th>
<th>Data set</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUS-16-012</td>
<td>$H \rightarrow \gamma\gamma$ + Razor</td>
<td>PAS</td>
<td>2015</td>
</tr>
<tr>
<td>SUS-16-023</td>
<td>$\gamma + S_T^\gamma$</td>
<td>PAS</td>
<td>2015</td>
</tr>
</tbody>
</table>
| **SUS-16-047** | $\gamma + H_T^\gamma$         | JHEP 12 (2017) 142           | 2016     | (1)
Focus on strong production, high-$p_T$ jets

Event Selection

- $\geq 1 \gamma$, $p_{\gamma T} > 100 \text{GeV}$, $|\eta| < 1$.4
- $p_{\text{miss}} T > 350 \text{GeV}$
- $H_{\gamma T} > 700 \text{GeV}$
- $|\Delta \phi(p_{\text{miss}} T, \gamma)| > 0.3$

$H_{\gamma T} = p_{\gamma T} + \sum \text{jets} p_T$
Focus on strong production, high-$p_T$ jets

Event Selection

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- $H_T^{\gamma} > 700$ GeV
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$$H_T^{\gamma} = p_T^{\gamma} + \sum_{\text{jets}} p_T$$
$\gamma + \text{jets}$

- multijet events are similar, $\sigma_E(\gamma) \ll \sigma_E(\text{jet})$
- Select multijet events with $p_T^{\text{miss}} < 100$ GeV
- Rescale $p_T^{\text{miss}}$ of multijet events so their spectrum matches with $\gamma + \text{jet}$ spectrum ($\chi^2$ fit)
- Scale factor 0.9 (0.84) for high (low) $H_T^\gamma$
- Systematic uncertainty from deviation from unity
**SUS-16-047 ($\gamma + H_T^\gamma$): Backgrounds**

### $\gamma$+jets
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### $e \rightarrow \gamma$
- Tag-and-probe method
- $f_{e \rightarrow \gamma} = 2.7\%$
- 30 % systematic uncertainty

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**Marius Teroerde (RWTH Aachen)**

Searches for SUSY with photons (CMS)

7.-9. May 2018
**γ+jets**

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**e → γ**

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- $f_{e\rightarrow\gamma} = 2.7\%$
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**γW, γZ, γt\bar{t}**

- Estimated from simulation
SUS-16-047 ($\gamma + H_T^\gamma$): Backgrounds

$\gamma$+jets

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- $f_{e \rightarrow \gamma} = 2.7\%$
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$\gamma W, \gamma Z, \gamma t\bar{t}$

- Estimated from simulation

Probe full prediction in two exclusive validation regions:

- $1.4 < |\eta_\gamma| < 2.4$
- $100 < p_T^{\text{miss}} < 350$ GeV
• Deviations in medium $p_T^{miss}$ bins
• Not compatible with new physics models
• 1.9 and 2.7 $\sigma$ significance
• Considered fluctuations, set limits

Limits:
• T6gg: up to $m_{\tilde{q}} > 1650$ GeV
- Deviations in medium $p_T^{miss}$ bins
- Not compatible with new physics models
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Limits:
- T6gg: up to $m_{\tilde{q}} > 1650$ GeV
- T6Wg: up to $m_{\tilde{q}} > 1550$ GeV
• Deviations in medium $p_T^{miss}$ bins
• Not compatible with new physics models
• 1.9 and 2.7 $\sigma$ significance
• Considered fluctuations, set limits

Limits:
• T6gg: up to $m_{\tilde{q}} > 1650$ GeV
• T6Wg: up to $m_{\tilde{q}} > 1550$ GeV
• T5gg: up to $m_{\tilde{G}} > 2000$ GeV
Deviations in medium $p_T^{\text{miss}}$ bins
- Not compatible with new physics models
- 1.9 and 2.7 $\sigma$ significance
- Considered fluctuations, set limits

Limits:
- T6gg: up to $m_{\tilde{q}} > 1650$ GeV
- T6Wg: up to $m_{\tilde{q}} > 1550$ GeV
- T5gg: up to $m_{\tilde{g}} > 2000$ GeV
- T5Wg: up to $m_{\tilde{g}} > 1900$ GeV
Very inclusive search, no requirement on leptons, jets, $H_T$

Also sensitive for strong production (as for previous analysis) in compressed scenarios
Very inclusive search, no requirement on leptons, jets, $H_T$

Also sensitive for strong production (as for previous analysis) in compressed scenarios

**Event selection**

- $\geq 1\gamma$, $p_T^{\gamma} > 180$ GeV
- $\Delta R(\gamma, \text{nearest jet}) > 0.5$
- If $p_T^{\text{jet}} > 100$ GeV: $\Delta\phi(\text{jet}, p_T^{\text{miss}}) > 0.3$

**Control region**

$p_T^{\text{miss}} > 100$ GeV, $M_T(\gamma, p_T^{\text{miss}}) > 100$ GeV

Veto SR

$$S_T^{\gamma} = \sum_{\gamma_i} p_{T,i} + p_T^{\text{miss}}$$

**Signal regions**

- $p_T^{\text{miss}} > 300$ GeV
- $M_T(\gamma, p_T^{\text{miss}}) > 300$ GeV
- $S_T^{\gamma} > 600$ GeV

Counting experiment in 4 bins of $S_T^{\gamma}$

**Validation region**

Signal region, but $S_T^{\gamma} < 600$ GeV
Simultaneous fit of MC to data in control region
- $\chi^2$ fit on template variable $\Delta \phi(p_T^{\text{miss}}, \text{nearest jet or } \gamma)$
- Other backgrounds and total scale fixed
- Additional uncertainties on shape
SUS-16-046 ($\gamma + S_T^\gamma$): Backgrounds

$\gamma$+jets and $V\gamma$

- Simultaneous fit of MC to data in control region
- $\chi^2$ fit on template variable $\Delta\phi(p_T^{\text{miss}}, $ nearest jet or $\gamma$)
- Other backgrounds and total scale fixed
- Additional uncertainties on shape

$e \rightarrow \gamma$

- tag-and-probe method
- $f_{e \rightarrow \gamma} = 2.7\%$
- 50% uncertainty

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Searches for SUSY with photons (CMS)

7.-9. May 2018
SUS-16-046 ($\gamma + S_T^\gamma$): Backgrounds

$\gamma + \text{jets and } V\gamma$

- Simultaneous fit of MC to data in control region
- $\chi^2$ fit on template variable $\Delta \phi(p_T^{\text{miss}}, \text{nearest jet or } \gamma)$
- Other backgrounds and total scale fixed
- Additional uncertainties on shape

- tag-and-probe method
- $f_{e \rightarrow \gamma} = 2.7\%$
- $50\%$ uncertainty

$t\bar{t}\gamma$

- Simulation without further scaling
SUS-16-046 (\(\gamma + S_T^\gamma\)): Results and Interpretation

Events/bin

- Data
- \(V(\gamma)\)
- \(\gamma +\)jets
- \(t\bar{t}(\gamma)\)
- \(e^{\pm}\gamma\)
- Diboson
- TChiWg
- T5Wg
- syst

\[\sigma (13\ TeV) = -135.9\ fb\]

CMS

\[\gamma_T^S\]

600 800 1000 1200 1400 1600

95\% CL upper limit / cross section (pb)

pp \(\rightarrow \tilde{\chi}_i^{\pm}\tilde{\chi}_j^{\pm},\)

\[\tilde{\chi}_i^{0}\rightarrow \tilde{\chi}_j^{0} \text{+soft, } \tilde{\chi}_i^{0} \rightarrow \gamma (H,Z)\tilde{G}\]

CMS

\[\sigma_{\text{tot}} - \sigma_{\text{syst}}\]

95\% expected

Cross section

Theory uncert.

Observed limit

Expected limit

68\% expected

1\(\pm\)\(\chi\)\sim 1\(\pm\)\(\chi\)\sim 1\(\pm\)\(\chi\)\sim

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Searches for SUSY with photons (CMS)

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SUS-16-046 ($\gamma + S_T$): Results and Interpretation

Limits on more models (General gauge mediation + strong production)
Summary and outlook

- Presented two searches for SUSY in final states with photons
- Signals motivated by gauge mediated SUSY breaking
- $\gamma + H_T^\gamma$: Focus on strong production
- $\gamma + S_T^\gamma$: Inclusive search, sensitive also to EWK production

What’s next?

- Search for SUSY in $\ell\gamma$ final states with 2016 data set approved
- Search for SUSY in $\gamma\gamma$ final states with 2016 data set seeking approval for summer conferences
- Combination of SUSY photon searches for different GMSB models expected for summer conferences
Photon CR: Photon candidate has pixel seeds
Sample dominated by $Z \rightarrow ee$ events
For higher $p_T^{miss}$ values, dominated by $W$ production
Uncertainty accounts for differences in misreconstruction at high $p_T^{miss}$ and $H_T^\gamma$ values
$\gamma + H_T^\gamma$: Validation

$$35.9 \text{ fb}^{-1} (13 \text{ TeV})$$

**CMS**

$H_T^\gamma < 2 \text{ TeV}, \text{EE, } |\Delta \phi| > 0.3$

- Data
- Nongenuine $p_T^{\text{miss}}$
- $\gamma W$
- $\gamma t\bar{t}$
- $\gamma Z$
- $e\rightarrow \gamma$
- $T5Wg \ 1600 \ 100$
- $T6gg \ 1750 \ 1650$
- Total uncertainty

**Validation**

$\text{Bkg. frac.} = \frac{\text{Data}}{\text{Pred.}}$

$\text{Data/Pred.}$

$0 \ 0.5 \ 1 \ 1.5$

$\text{Normaliz}^{}$

$0 \ 200 \ 400 \ 600 \ 800 \ p_T^{\text{miss}} \ (\text{GeV})$

$\text{Events / GeV}$

$10^2 \ 10^3 \ 10^4$

$\text{Normalization}$

$\text{Data/Pred.}$

$0 \ 0.5 \ 1 \ 1.5$

$\text{Total uncertainty}$

$\text{Data/Pred.}$

$0 \ 200 \ 400 \ 600 \ 800 \ p_T^{\text{miss}} \ (\text{GeV})$

$\text{Events / GeV}$

$10^{-1} \ 10^{-2} \ 10^{-3}$

$\text{Validation}$

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$\text{Data/Pred.}$

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$0 \ 200 \ 400 \ 600 \ 800 \ p_T^{\text{miss}} \ (\text{GeV})$

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$\text{Data/Pred.}$

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$\text{Total uncertainty}$

$\text{Data/Pred.}$
### Systematic uncertainties

<table>
<thead>
<tr>
<th>Source</th>
<th>Relative uncertainty (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nongenuine ( p_T^{\text{miss}} )</td>
<td>14–250</td>
</tr>
<tr>
<td>( e \rightarrow \gamma )</td>
<td>30</td>
</tr>
<tr>
<td>Integrated luminosity</td>
<td>2.5</td>
</tr>
<tr>
<td>Photon scale factors</td>
<td>2</td>
</tr>
<tr>
<td>Trigger</td>
<td>4</td>
</tr>
<tr>
<td>PDFs</td>
<td>5–10</td>
</tr>
<tr>
<td>Renormalization/factorization scales</td>
<td>16–27</td>
</tr>
<tr>
<td>Jet energy scale and resolution</td>
<td>2–20</td>
</tr>
<tr>
<td>Pileup</td>
<td>0.2–6</td>
</tr>
<tr>
<td>ISR</td>
<td>0–10</td>
</tr>
<tr>
<td>Fast simulation ( p_T^{\text{miss}} ) modelling</td>
<td>0.5–6</td>
</tr>
</tbody>
</table>

Table 2. Systematic uncertainties for background determined from control samples in data (first two rows) and simulation (all other rows). If two values are given, the first one is for simulated SM backgrounds, while the latter is for simulated signal. The PDF and scale uncertainties for the signal simulation affect the shape only, as the uncertainty in the rate is already considered in the overall cross section uncertainty \([35]\).
## $\gamma + H_T^\gamma$: Results

<table>
<thead>
<tr>
<th>$H_T^\gamma$ (GeV)</th>
<th>$p_T^{\text{miss}}$ (GeV)</th>
<th>&lt;2000</th>
<th>&gt;600</th>
<th>&gt;2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(350, 450)</td>
<td>(450, 600)</td>
<td>&gt;600</td>
<td>(350, 450)</td>
</tr>
<tr>
<td>Nongenuine $p_T^{\text{miss}}$</td>
<td>9.6 ± 11.1 9.6</td>
<td>2.2 ± 5.5 2.2</td>
<td>&lt; 0.1</td>
<td>2.83 ± 2.51</td>
</tr>
<tr>
<td>$\gamma W$</td>
<td>51.3 ± 9.7</td>
<td>29.1 ± 5.5 11.6 ± 2.5</td>
<td>1.58 ± 0.58</td>
<td>0.70 ± 0.37</td>
</tr>
<tr>
<td>$\gamma t\bar{t}$</td>
<td>17.1 ± 5.4</td>
<td>5.6 ± 2.6 1.9 ± 0.4</td>
<td>0.97 ± 0.38</td>
<td>0.45 ± 0.29</td>
</tr>
<tr>
<td>$\gamma Z$</td>
<td>11.5 ± 2.4</td>
<td>9.7 ± 1.8 7.1 ± 1.4</td>
<td>0.12 ± 0.07</td>
<td>0.25 ± 0.11</td>
</tr>
<tr>
<td>$e \rightarrow \gamma$</td>
<td>15.1 ± 4.6</td>
<td>6.3 ± 1.9 1.4 ± 0.5</td>
<td>0.21 ± 0.10</td>
<td>0.13 ± 0.07</td>
</tr>
<tr>
<td>Total bkg.</td>
<td>104.6 ± 16.5</td>
<td>53.0 ± 8.6 22.0 ± 3.0</td>
<td>5.72 ± 2.60</td>
<td>2.84 ± 0.89</td>
</tr>
<tr>
<td>Data</td>
<td>103</td>
<td>82</td>
<td>21</td>
<td>6</td>
</tr>
<tr>
<td>T5Wg 1600 100</td>
<td>0.4 ± 0.1</td>
<td>0.8 ± 0.1 0.7 ± 0.1</td>
<td>3.66 ± 0.40</td>
<td>3.09 ± 0.40</td>
</tr>
<tr>
<td>T6gg 1750 1650</td>
<td>0.5 ± 0.1</td>
<td>0.8 ± 0.1 4.9 ± 0.4</td>
<td>0.31 ± 0.04</td>
<td>0.46 ± 0.07</td>
</tr>
</tbody>
</table>

**Table 1.** Observed data compared to the background prediction and the expected signal yields for two signal scenarios. The expectations are given for the T5Wg signal scenario with a gluino mass of 1600 GeV and a gaugino mass of 100 GeV and the T6gg signal scenario with a squark mass of 1750 GeV and a neutralino mass of 1650 GeV. The quadratic sum of statistical and systematical uncertainties is given. Only experimental uncertainties for the signal model are stated.
left: control region, right: validation region
Scale factors:
\( V\gamma < 1 \) because of electroweak corrections for high \( \gamma - p_T \)
\( \gamma + \text{jets} > 1 \) because no k-factor applied and QCD corrections
Signal contamination: Light gauginos because similarity to \( V\gamma \)
Similar to other analysis, study also nonresonant background in $e\mu$
Dependency in $\eta_\gamma$, $p_T^\gamma$ and other variables leads to uncertainty.
\( \gamma + S^\gamma_T \): Systematic uncertainties

**Table 2**
Systematic uncertainties in the background prediction in percent.

<table>
<thead>
<tr>
<th>Source</th>
<th>V((\gamma))</th>
<th>(\gamma + \text{jets})</th>
<th>e (\rightarrow) (\gamma)</th>
<th>tt((\gamma))</th>
<th>Diboson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fit uncert. of statistical origin</td>
<td>6.9</td>
<td>3.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Scale uncertainty in shape</td>
<td>3.8–9.0</td>
<td>2.8–7.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PDF uncertainty in shape</td>
<td>1.6–3.8</td>
<td>1.9–8.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>JES uncertainty in shape</td>
<td>5.0–5.9</td>
<td>0.9–32</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tag-and-probe fit</td>
<td>-</td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cross section, PDF, scales</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Integrated luminosity</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Photon eff. scale factor</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Trigger efficiency</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.4</td>
<td>0.4</td>
</tr>
</tbody>
</table>

**Table 3**
Systematic uncertainties in the signal predictions in percent.

<table>
<thead>
<tr>
<th>Source</th>
<th>Signal scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EWK</td>
</tr>
<tr>
<td>Statistical MC precision per signal region</td>
<td>1–28</td>
</tr>
<tr>
<td>Fast simulation uncertainty in p_{T}^{miss}</td>
<td>&lt;0.1–5</td>
</tr>
<tr>
<td>Scale uncertainty in shape</td>
<td>&lt;0.1–1.8</td>
</tr>
<tr>
<td>Integrated luminosity</td>
<td>2.5</td>
</tr>
<tr>
<td>Trigger efficiency</td>
<td>0.4</td>
</tr>
<tr>
<td>Photon scale factor</td>
<td>2.0</td>
</tr>
<tr>
<td>Pileup</td>
<td>&lt;0.1–0.4</td>
</tr>
<tr>
<td>ISR reweighting</td>
<td>0.6–3.0</td>
</tr>
</tbody>
</table>
### Table 4
Background and data yields, as well as the statistical and systematic uncertainties for the separate signal region bins. For the total background uncertainty the uncertainties of the individual background components are summed quadratically.

**$S_T^\gamma$: 600–800 GeV**

<table>
<thead>
<tr>
<th>Component</th>
<th>Yield</th>
<th>$\sigma_{\text{stat}}$</th>
<th>$\sigma_{\text{syst}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V(\gamma)$</td>
<td>213</td>
<td>4.4</td>
<td>21.3</td>
</tr>
<tr>
<td>$\gamma + \text{jets}$</td>
<td>5</td>
<td>1.1</td>
<td>0.5</td>
</tr>
<tr>
<td>$t\bar{t}(\gamma)$</td>
<td>13</td>
<td>5.7</td>
<td>3.9</td>
</tr>
<tr>
<td>$e \to \gamma$</td>
<td>29</td>
<td>0.9</td>
<td>14.2</td>
</tr>
<tr>
<td>Diboson</td>
<td>7</td>
<td>2.8</td>
<td>2.1</td>
</tr>
<tr>
<td><strong>Total Data</strong></td>
<td><strong>267</strong></td>
<td><strong>7.9</strong></td>
<td><strong>26.0</strong></td>
</tr>
</tbody>
</table>

**$S_T^\gamma$: 800–1000 GeV**

<table>
<thead>
<tr>
<th>Component</th>
<th>Yield</th>
<th>$\sigma_{\text{stat}}$</th>
<th>$\sigma_{\text{syst}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V(\gamma)$</td>
<td>76.8</td>
<td>1.9</td>
<td>8.1</td>
</tr>
<tr>
<td>$\gamma + \text{jets}$</td>
<td>4.4</td>
<td>1.2</td>
<td>0.4</td>
</tr>
<tr>
<td>$t\bar{t}(\gamma)$</td>
<td>8.0</td>
<td>3.8</td>
<td>2.4</td>
</tr>
<tr>
<td>$e \to \gamma$</td>
<td>9.2</td>
<td>0.5</td>
<td>4.6</td>
</tr>
<tr>
<td>Diboson</td>
<td>1.9</td>
<td>1.7</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>Total Data</strong></td>
<td><strong>100.2</strong></td>
<td><strong>4.7</strong></td>
<td><strong>9.7</strong></td>
</tr>
</tbody>
</table>

**$S_T^\gamma$: 1000–1300 GeV**

<table>
<thead>
<tr>
<th>Component</th>
<th>Yield</th>
<th>$\sigma_{\text{stat}}$</th>
<th>$\sigma_{\text{syst}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V(\gamma)$</td>
<td>35.0</td>
<td>1.3</td>
<td>3.9</td>
</tr>
<tr>
<td>$\gamma + \text{jets}$</td>
<td>4.2</td>
<td>1.3</td>
<td>0.4</td>
</tr>
<tr>
<td>$t\bar{t}(\gamma)$</td>
<td>3.5</td>
<td>0.9</td>
<td>1.1</td>
</tr>
<tr>
<td>$e \to \gamma$</td>
<td>4.7</td>
<td>0.4</td>
<td>2.3</td>
</tr>
<tr>
<td>Diboson</td>
<td>5.4</td>
<td>3.0</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Total Data</strong></td>
<td><strong>52.8</strong></td>
<td><strong>3.6</strong></td>
<td><strong>5.0</strong></td>
</tr>
</tbody>
</table>

**$S_T^\gamma$: >1300 GeV**

<table>
<thead>
<tr>
<th>Component</th>
<th>Yield</th>
<th>$\sigma_{\text{stat}}$</th>
<th>$\sigma_{\text{syst}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V(\gamma)$</td>
<td>12.6</td>
<td>0.7</td>
<td>1.6</td>
</tr>
<tr>
<td>$\gamma + \text{jets}$</td>
<td>1.1</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>$t\bar{t}(\gamma)$</td>
<td>0.7</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>$e \to \gamma$</td>
<td>1.5</td>
<td>0.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Diboson</td>
<td>1.7</td>
<td>1.7</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Total Data</strong></td>
<td><strong>17.6</strong></td>
<td><strong>2.0</strong></td>
<td><strong>1.9</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Component</th>
<th>Yield</th>
<th>$\sigma_{\text{stat}}$</th>
<th>$\sigma_{\text{syst}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diboson</td>
<td>5.4</td>
<td>3.0</td>
<td>1.6</td>
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<tr>
<td><strong>Total Data</strong></td>
<td><strong>65</strong></td>
<td><strong>3.6</strong></td>
<td><strong>5.0</strong></td>
</tr>
</tbody>
</table>
$\gamma + S_T$: GGM

CMS

GGM electroweak production

- Observed ± theory uncertainty
- Expected ± experimental uncertainty

95% CL upper limit on cross section (fb)

$35.9 \text{ fb}^{-1} (13 \text{ TeV})$

$\tilde{m}_W$ (GeV)

$\tilde{m}_{\tilde{B}}$ (GeV)

Marius Teroerde (RWTH Aachen)  
Searches for SUSY with photons (CMS)
\[ \gamma + S_T: T6gg/T6Wg \]

**CMS**

35.9 fb\(^{-1}\) (13 TeV)

\[ \text{Observed} \pm \text{theory uncertainty} \]

\[ \text{Expected} \pm \text{experimental uncertainty} \]

- NLO-NLL exclusion

- \[ \text{BR}(\tilde{q} \to q\tilde{\chi}_1^\pm) = 0.5 \]

- Observed experimental uncertainty

- Expected theoretical uncertainty

\[ \text{95\% CL upper limit on cross section (fb)} \]
\( \gamma + S^\gamma_T: T5gg/T5Wg \)

- **CMS**
  - Observed \pm theory uncertainty
  - Expected \pm experimental uncertainty

### Exclusion Limits

<table>
<thead>
<tr>
<th>Mass (GeV)</th>
<th>Observed Limit (fb)</th>
<th>Expected Limit (fb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1400</td>
<td></td>
<td></td>
</tr>
<tr>
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<tr>
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</tr>
<tr>
<td>2400</td>
<td></td>
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</tr>
</tbody>
</table>

- **BR(\tilde{g} \rightarrow q\tilde{\chi}_{0,1}^{-}) = 0.5**

- **Theory and Experimental Uncertainties**
- **95% CL Upper Limit on Cross Section**

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Marius Teroerde (RWTH Aachen)  
Searches for SUSY with photons (CMS)  
7.-9. May 2018  
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