Beyond the Standard Model
Highlights of Experimental Results from ATLAS & CMS

Frank Würthwein
UCSD
Many thanks to 22 Parallel Session Speakers from ATLAS & CMS…


• … for presenting 54 papers that came out in 2014, out of which 12 were presented for the first time at ICHEP.
Vast range of theoretical ideas

Hitoshi Murayama
Vast # of results to cover
even when considering only 8TeV results

**ATLAS**

- **Exotics:**
  - 10 pub + 29 conf. notes
  [https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults](https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults)

- **SUSY:**
  - 18 pub + 37 conf. notes
  [https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults](https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults)

- **BSM Higgs:**
  - 3 pub + 5 conf. notes
  [https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults](https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults)

**CMS**

- **Exotics:**
  - 10 pub + 18 PAS
  [https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO](https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO)

- **Beyond 2 Generations:**
  - 6 pub + 14 PAS
  [https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsB2G](https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsB2G)

- **SUSY:**
  - 12 pub + 21 PAS
  [https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS](https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS)

- **BSM Higgs:**
  - 6 pub + 4 PAS
  [https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIG](https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIG)
Vast # of results to cover
even when considering only 8TeV results

ATLAS

• Exotics:
  – 9 pub + 26 conf. notes
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Impossible to cover all !!!
Vast # of results to cover
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Impossible to cover all !!!

Instead, attempt to cover diversity of experimental signatures with a few examples.
Vast # of results to cover even when considering only 8TeV results

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Impossible to cover all !!!

• SUSY:
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• Beyond 2 Generations:
  - 12 pub + 19 PAS

Instead, attempt to cover diversity of experimental signatures with a few examples.

For each example shown in body of talk, the corresponding results from the other experiment are presented in the backup slides.
Outline

• Introduction

• Resonances
  - $2\rightarrow 1$
  - $2\rightarrow 2$
  - Simple, e.g. $ll,jj,...$
  - Complex, e.g. $tt,WZ,th,...$

• Dark Matter
  - Anti-social: $pp \rightarrow$ nothing
  - Semi-social: compressed spectra, ...
  - Social: DM at the end of cascades

• Long lived particles
Standard Model Backgrounds

Leptons, MET, Z, h, ... are excellent probes in search for BSM physics

1-lepton & MET cross section
~ $x10^6$ smaller than all hadronic

Higgs $x10^{10}$ smaller than all hadronic
Dilepton same-sign & MET
~ $x10^{12}$ smaller than all hadronic.
Standard Model Backgrounds

Cross sections decrease exponentially with jet pT and # of jets.

Define:

- $H_T = \sum p_T$ of jets above threshold
- $m_{eff} = H_T + \text{MET}$
- $S_T = m_{eff} + \sum p_T$ of leptons above threshold

$\sqrt{s} = 8 \text{ TeV}$

CMS Preliminary

Oct 2013

W & jets
Z & jets
Top & jets

Production Cross Section, $\sigma$ [pb]
Kinematic Endpoints

\[ \alpha_T = \frac{E_{\text{jet}}^2}{M_T} \]

Hadronic event clustered into 2 megajets

CMS, \( L_{\text{int}} = 11.7 \text{ fb}^{-1}, \sqrt{s} = 8 \text{ TeV} \)

\( 2 \leq n_{\text{jet}} \leq 3 \)

Simulation

1 \( \ell \), \( \geq 2 \) jets, MET \( > 50 \text{GeV} \)

Transverse mass for:

\( t \rightarrow Wb \rightarrow l\nu b \)

\( W \rightarrow \mu\nu, e\nu, \tau\nu \)

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Jet Substructure

\[ \Delta R_{qq}^{\text{min}} \approx \Delta \theta_{qq}^{\text{min}} \approx 2 \frac{M_V}{p_{T,V}} \]

For W, Z, h Bosons of \( M \sim 100 \text{GeV} \) and jet cones of \( \Delta R < 0.5 \) => cones start merging at \( p > \sim 200 \text{GeV} \)

**Background**

\( m_{\text{jet}} \sim m_q \sim 0 \)

**Signal**

\( m_{\text{jet}} \sim m_W \sim 80 \text{ GeV} \) + Dipolar structure

Jet Merging

\[ \Delta R \sim 0.2 \]
\[ \Delta R \sim 0.5 \]
Typical Search Strategy

- Define “low bkg” signal regions using the ingredients from previous slides.
- Extrapolate expected bkg yields from carefully chosen bkg rich samples.
  - Derive extrapolation factors from mix of data and simulation.
- Measure accuracy of extrapolation in independent control regions in data and simulation.

Brains (Strategy) + Brawn (Execution) => Success
Resonances

\[ \begin{align*}
2 &\rightarrow 1 \\
2 &\rightarrow 2
\end{align*} \]

Simple, e.g. \( \ell\ell, jj, \ldots \)

Complex, e.g. \( tt, WZ, th, \ldots \)

New in 2014

- ATLAS-CONF-2014-030
  - arXive: 1405.4123

- CMS-PAS-B2G-14-003
- CMS-PAS-B2G-14-002
- CMS-PAS-B2G-14-003
- CMS-PAS-EXO-12-030
- CMS-PAS-EXO-12-032
  - arXive: 1406.5171
  - arXive: 1405.3447
  - arXive: 1405.1994

15 new papers In 2014

New at ICHEP

- arXive: 1406.4456
- CMS-PAS-EXO-13-008
  - ATLAS-CONF-2014-039
  - ATLAS-CONF-2014-036

4 new papers at ICHEP
Dilepton Mass Spectrum

Highest mass event $\sim 1.9\text{TeV}$

$Z'$ ruled out up to $\sim 2.9\text{TeV}$

$\mu^+\mu^-$

$\mathcal{L} = \frac{g^2}{\Lambda^2}$ ...

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Singly produced Resonances

Fermion Pairs

Probing ~ 1 - 5 TeV scale masses across a very wide range of final states

<table>
<thead>
<tr>
<th>Final State</th>
<th>Highest mass event</th>
<th>Highest mass limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>ee</td>
<td>~1.8TeV</td>
<td>2.79TeV</td>
</tr>
<tr>
<td>mumu</td>
<td>~1.8TeV</td>
<td>2.53TeV</td>
</tr>
<tr>
<td>tautau</td>
<td>~0.7TeV</td>
<td>1.9TeV</td>
</tr>
<tr>
<td>dijet</td>
<td>~5.1TeV</td>
<td>5.1TeV</td>
</tr>
<tr>
<td>Inu</td>
<td>~2.4TeV</td>
<td>3.4TeV</td>
</tr>
<tr>
<td>bb</td>
<td>~4.1TeV</td>
<td>~1.2-1.5TeV</td>
</tr>
<tr>
<td>top b</td>
<td>~3.8TeV</td>
<td>2.05TeV</td>
</tr>
<tr>
<td>ttbar*</td>
<td>~3.5TeV</td>
<td>1.8TeV</td>
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Final states with bosons

*Analysis is using jet-substructure techniques

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<th>Final State</th>
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<tbody>
<tr>
<td>WZ(3Inu)</td>
<td>~1.1TeV</td>
<td>1.5TeV</td>
</tr>
<tr>
<td>VV(jjInu)</td>
<td>~3.3TeV</td>
<td>2.5TeV</td>
</tr>
<tr>
<td>Vq(jj)*</td>
<td>~3.7TeV</td>
<td>3.2TeV</td>
</tr>
<tr>
<td>VV(jj)*</td>
<td>~2.7TeV</td>
<td>1.7TeV</td>
</tr>
<tr>
<td>ZZ(lljj)</td>
<td>~1.7TeV</td>
<td>0.85TeV</td>
</tr>
<tr>
<td>hh(4b)</td>
<td>~1.3TeV</td>
<td>590-710GeV</td>
</tr>
<tr>
<td>Wt</td>
<td>~1.8TeV</td>
<td>1.8TeV</td>
</tr>
<tr>
<td>γjet</td>
<td>~3TeV</td>
<td>3.5TeV</td>
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</table>
Pair produced Resonances

Probing 0.5 – 1 TeV scale physics across a wide range of final states

ATLAS Exotics Searches* - 95% CL Exclusion
Status: ICHEP 2014

**Model** | **Final State** | **Highest mass event** | **Highest mass limit** |
--- | --- | --- | --- |
ADD $G_{ax} + g/q$ | $2x(top\ jet)$ | $\sim1.2\ TeV$ | $0.8\ TeV$ |
ADD non-resonant $E$ | $2xbZ(II)$ | $>1\ TeV$ | $0.7\ TeV$ |
ADD $g_{B} - 1\ E$ | $2x(jjj)$ | $\sim1.9\ TeV$ | $0.65\ TeV$ |
ADD $g_{B}$ | $2x(jjb)$ | $\sim1.7\ TeV$ | $0.835\ TeV$ |
ADD $2\ E$ | $2x(top\ tau)$ | $S_T \sim 0.8\ TeV$ | $0.55\ TeV$ |
ADD $2\ E$ | $2x(tau\ b)$ | $\sim0.85\ TeV$ | $0.74\ TeV$ |
ADD $2\ E$ | $2x(mu\ jet)$ | $\sim1.2\ TeV$ | $1.07\ TeV$ |

---

**Model** | **Final State** | **Highest mass event** | **Highest mass limit** |
--- | --- | --- | --- |
Scalar $L_{Q}\ 1$ | $2x(top\ jet)$ | $\sim1.2\ TeV$ | $0.8\ TeV$ |
Scalar $L_{Q}\ 1$ | $2xbZ(II)$ | $>1\ TeV$ | $0.7\ TeV$ |
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**Model** | **Final State** | **Highest mass event** | **Highest mass limit** |
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$Z\rightarrow\ tau\ tau$ | $2x(top\ jet)$ | $\sim1.2\ TeV$ | $0.8\ TeV$ |
$Z\rightarrow\ tau\ tau$ | $2xbZ(II)$ | $>1\ TeV$ | $0.7\ TeV$ |
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Beyond Resonances

• Many new physics scenarios include pair production of particles that decay to top, W, Z, and $h_{125}$ at model dependent rates.

$\Rightarrow$ 4W, 2W + 2Z, 2W + h + Z, …, 2Z, 2h, …

Best searched for when multiple final states are combined.
E.g. vector-like $T'$ pair production with $T'$ decaying to $h$ top, $Z$ top, or $W$ b

**ATLAS Z(II) + b search:**

ICHEP

**ATLAS Preliminary**

$\sqrt{s} = 8$ TeV

$\int L dt = 20.3$ fb$^{-1}$

$Zb/t + X$

Dilep. + Trilep. Combination

Best sensitivity only for ~ 100% 2Z 2top

**Search strategies for final states with multiple W, Z, h ideally combine multiple final state signatures.**

**Many channel combination:**

ICHEP

**ATLAS Preliminary**

$\int L dt = 14.3$ & 20.3 fb$^{-1}$

$\sqrt{s} = 8$ TeV

Summary results:

Same-Sign II

$ATLAS$-CONF-2013-051

$Ht+X,Wb+X$ comb.

$ATLAS$-CONF-2013-060

$Zb/t + X$

$ATLAS$-CONF-2014-036

Sensitivity broadly for all BR’s

$7/7/14$ **ATLAS-CONF-2014-036**

ICHEP 2014
Dark Matter

- Anti-social: pp $\rightarrow$ nothing
- Semi-social: compressed spectra, ...
- Social: DM at the end of cascades

New in 2014

- arXive: 1404.0051
- ATLAS-CONF-2014-014
- ATLAS-CONF-2014-006
- ATLAS-CONF-2014-001
- arXive: 1406.5375
- arXive: 1406.1122
- arXive: 1405.7875
- arXive: 1405.5086
- arXive: 1404.2500
- arXive: 1403.5294
- arXive: 1403.5222
- arXive: 1403.4853
- arXive: 1402.7029

- CMS-PAS-B2G-13-004
- CMS-PAS-B2G-12-022
- CMS-PAS-EXO-12-047
- CMS-PAS-SUS-13-020
- CMS-PAS-SUS-13-018
- CMS-PAS-SUS-13-022
- CMS-PAS-SUS-13-019
- CMS-PAS-SUS-13-009
- CMS-PAS-SUS-13-024
- arXive:1404.1344
- arXive: 1405.7570
- arXive: 1405.3886
- arXive: 1404.5801
- arXive: 1402.4770

New at ICHEP

- arXive: 1407.0608
- CMS-SUS-14-011
- CMS-SUS-14-002
- arXive: 1407.0583
- arXive: 1407.0603
- arXive: 1407.0600
- arXive: 1407.0350

34 new papers in 2014

7 new papers at ICHEP
Hunting anti-social DM

Large ISR boost of DM pair for MET to be visible.

ISR may be:
Jet(s), W, Z, photon

Large VBF boost of DM pair for MET to be visible.

Additional cuts on VBF Signature to suppress SM backgrounds.
Mono-X Searches

Jet recoil

W recoil

Z recoil

Hadronc W,Z

Dilepton Z

<table>
<thead>
<tr>
<th>Process</th>
<th>$E_T^{miss} &gt; 350$ GeV</th>
<th>$E_T^{miss} &gt; 500$ GeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z \rightarrow \nu\nu$</td>
<td>$402_{-34}^{+39}$</td>
<td>$54_{-10}^{+10}$</td>
</tr>
<tr>
<td>$W \rightarrow \ell\nu$, $Z \rightarrow \ell\ell\ell$</td>
<td>$210_{-20}^{+26}$</td>
<td>$22_{-4}^{+4}$</td>
</tr>
<tr>
<td>WW, WZ, ZZ</td>
<td>$57_{-11}^{+18}$</td>
<td>$9.1_{-1.3}^{+1.3}$</td>
</tr>
<tr>
<td>$tt, t\bar{t}$, single $t$</td>
<td>$39_{-4}^{+4}$</td>
<td>$3.7_{-1.4}^{+1.4}$</td>
</tr>
<tr>
<td>Total, single $t$</td>
<td>$707_{-38}^{+38}$</td>
<td>$89_{-12}^{+12}$</td>
</tr>
<tr>
<td>Data</td>
<td>705</td>
<td>89</td>
</tr>
</tbody>
</table>

SM bkg for $\sim$ MET $> 350$ GeV
jet : W/Z hadronic : Z(II)

10,000 : 1,000 : 1

Decreasing fraction of single boson bkg
Increasing fraction of di-boson bkg

2014

2014
Two diagrams with same initial and final state interfere.

If coupling is the same

\[ uu \rightarrow \chi^0 \chi^0 = dd \rightarrow \chi^0 \chi^0 \]

\[ \Rightarrow \] interference is destructive.

**Mono-W search is most sensitive to models where ratio of couplings = -1.**
Table 5: Theoretical dark-matter production cross section where generated photon transverse momentum is greater than 130 GeV and cut-off scale $L$ is 10 TeV. Observed (expected) 90% CL upper limits on the dark-matter production cross section $s$, 90% CL lower limits on the cut-off scale $L$ and the 90% CL upper limits on the $c$-nucleon cross section for the axial vector operator as a function of the dark-matter mass.

Figure 5: The 90% CL upper limits on the $c$-nucleon cross section as a function of $M_c$ for (a) spin-independent and (b) spin-dependent scattering. Also shown are the limits from selected experiments with published [32–41] results.

These limits, along with existing LO ADD limits from the Tevatron [42, 43] and LEP [44], are shown in Fig. 6 as a function of $M_D$, for $n=4$ and $n=6$ extra dimensions. These results extend significantly the limits on the ADD model in the single-photon channel beyond previous measurements, and set limits of $M_D > 2.30 – 2.00$ TeV for $n=3–6$ at 95% CL.

Limits on $f$ for branons are summarized in Table 7. For massless branons the brane tension $f$ is found to be greater than 412 GeV. These limits along with the existing limits from LEP, are shown in Fig. 7. Branon masses $M_B < 3.5$ TeV are excluded at 95% CL for low brane tension (20 GeV). These bounds are the most stringent to date on the possible existence of branons.
VBF to invisible

E.g. VBF higgs production with higgs to invisible

\[ M_{jj} > 1.1 \text{ TeV} \]
\[ \Delta \eta_{jj} > 4.2 \]
\[ \Delta \Phi_{jj} < 1 \]
\[ \text{MET} > 130 \text{ GeV} \]
\[ \text{lepton veto } p_T > 10 \text{GeV} \]
\[ \text{central jet veto } p_T > 30 \text{ GeV} \]

Expected 210\pm30 evts if BR\approx100%

\[ \Rightarrow \text{Would be clearly visible above bkg} \]

\[ \Rightarrow \text{Proof of principle for VBF to nothing search strategy!} \]
VBF vs Z Recoil

CMS performed search for H to invisible in both VBF and Z recoil topologies.

\[ B(h_{125} \to \text{inv.}) < 0.68 \ (0.81) \]

for VBF \((Z(\ell\ell))\)

Mass Reach for H to invisible with VBF far exceeds corresponding mass reach with Z(\(\ell\ell+bb\)) recoil.

**arXive:1404.1344**
Semi-social DM

What if DM is not completely alone?

DM will be missed by Mono-X searches if $\Delta m$ is not negligible.

$\Rightarrow$ Need Search Strategies that cover all possible $\Delta m$

(and all decay modes from 2$^{nd}$ lightest new particle to DM.)
E.g. stop to charm $X^0$

Mono jet analysis

As $\Delta m$ increases, mono-jet search becomes insensitive.

Charm Tag Analysis

Dedicated Search w. charm tags required to fill the gap

7/7/14

ICHEP 2014
Introduction

Supersymmetry (SUSY) is a theoretically favoured candidate for physics beyond the Standard Model (SM). It naturally solves the hierarchy problem and provides a possible candidate for dark matter in the universe. SUSY doubles the SM spectrum of particles by introducing a new supersymmetric (sparticle) for each particle in the SM. In particular, a new scalar field is associated with each left- and right-handed quark state, and two squark mass eigenstates $\tilde{q}_1$ and $\tilde{q}_2$ result from the mixing of the scalar fields. In some SUSY scenarios, a significant mass difference between eigenstates in the top squark (stop) sector can occur, leading to a rather light stop mass state. In addition, naturalness arguments suggest that the third generation sfermions should be light with masses below 1 TeV. In a generic minimal supersymmetric extension of the SM (MSSM) that assumes R-parity conservation, sparticles are produced in pairs and the lightest supersymmetric particle (LSP) is stable and identified as the lightest neutralino $\tilde{\chi}_0^1$. For a mass difference $\Delta m = m_{\tilde{t}} - m_{\tilde{\chi}_0^1} > m_t$, and depending on the SUSY parameters and mass hierarchy, the dominant decay channels are $\tilde{t} \rightarrow t + \tilde{\chi}_0^1$ or $\tilde{t} \rightarrow b + \tilde{\chi}_\pm^1$, where the latter involves the presence of charginos ($\tilde{\chi}_\pm^1$) which subsequently decay into the lightest neutralino via a $W^\ast$ emission. If the chargino is heavier than the stop and $m_W + m_b < \Delta m < m_t$, the dominant decay mode is expected to be the three-body $Wb\tilde{\chi}_0^1$ decay. Several searches on 2011 data have been carried out in these decay channels in 0 to 2 lepton final states and have been extended in 2012. In the scenario for which $\Delta m < m_W + m_b$, the dominant decay mode can be a stop decay to a charm quark and the LSP ($\tilde{t} \rightarrow c + \tilde{\chi}_0^1$), which proceeds via a loop decay (see Fig. 1). The corresponding final state is characterized by the presence of two jets from the hadronization of the charm quarks and missing transverse momentum (denoting its magnitude by $E_{T\text{miss}}$) from the two undetected LSPs. However, given the relatively small mass difference ($\Delta m$), both the transverse momenta of the two charm jets and $E_{T\text{miss}}$ are too low to extract this signal from the large multijet background. In this study, the event selection makes use of the presence of initial-state radiation (ISR) jets to identify signal events. Two different approaches are used to target the $\Delta m$ regions. For small $\Delta m$, the approach follows closely the "monojet" analysis of Ref. [17], where events with low jet multiplicity and large missing transverse momentum are selected. For moderate $\Delta m$, the charm jets receive a large enough boost to be detected. In addition to the requirements on the presence of ISR jets, charm tagging is required to fill the gap in the compressed spectra across a range of final states.

![Feynman diagram for the pair production of top squarks with subsequent decay to charm quarks and two LSP's.](image)

Mono jet analysis

Mono-X searches veto events with extra jets or lepton(s) above some $p_T$. Dedicated searches targeting compressed spectra are thus necessary across a range of final states.
On-shell $W$, top leads to DM \sim at rest in stop restframe

\[ \Rightarrow \text{No MET when } m_{\text{stop}} - m_{\text{DM}} \approx m_W \text{ or } m_{\text{top}} \]
“Closing the gaps”

At larger $m_{\text{DM}}$, ISR boost and increased luminosity will close the gap.

Near $m_{\text{DM}} \sim 0$ precision top measurements are needed.

(e.g. arXive: 1406.5375)
Social DM

What if DM is the lowest mass stable particle of a large family of new particles, several of which are accessible at LHC energies?

Searched for with Supersymmetry as “framework”

Natural SUSY Spectrum, e.g. Barbieri & Pappadopulo
arXive: 0906.4546
7/7/14

SUSY as “framework” for searches

Selecting 2-10 jets
w/w.o. leptons, photons, b-tags, jet substructure, MET, lifetime, …

Selecting 0-4 leptons, photons, w/w.o. b-tags, jets, Ws, Zs, hs, …

pT thresholds of objects selected go as low as 5GeV for leptons and 30GeV for jets.
SUSY as “framework”

Too many different final states have been explored to even list them all here.

Focus on only 3 results new @ ICHEP:
(many more in backup)

- Combination 0+1 lepton in 2top + MET
- Exploration of 4b to 4top + MET
- $h_{125} + \text{MET} + X$ via EWK production
CMS combined the published MVA 1-lepton analysis with a preliminary all hadronic Razor analysis.

(BR dependence in backup)

Increases stop mass reach by 75GeV @ $m_{DM} \sim 150$GeV
4 quarks + MET, from 4b to 4top

Inclusive Analysis using Razor variables

CMS, L = 19.3 fb⁻¹, √s = 8 TeV

pp → g g̃, 95% C.L. NLO+NLL exclusion

- 100% g̃ → b b̃ E°
- m̃ - m E° = 5 GeV
- 50% g̃ → t b̃ E°, 50% g̃ → b b̃ E°
- 100% g̃ → t b̃ E°
- 50% g̃ → t b̃ E°, 50% g̃ → t t̃ E°
- 100% g → t t̃ E°

Observed

Expected

Explore complete range of partial widths into 4b, 3b1t, 2b2t, 1b3t, 4t

As Q-value in decay shrinks due to mass of tops, sensitivity degrades.

\[ g \xrightarrow{} bb \]
\[ g \xrightarrow{} tt \]
\[ g \xrightarrow{} tb \]
\[ g \xrightarrow{} W^* \]
\[ g \xrightarrow{} \tilde{\chi}^\pm \]
\[ g \xrightarrow{} \tilde{\chi}^0 \]

5 GeV
Ewk production of new physics with $h_{125}$

CMS completed diboson + MET program: WW, WZ, ZZ, Wh, Zh, hh

Covered final states:
- Multileptons
  - $hZ$ with $Z(ll) + h(bb)$
  - $hh -> 4b$
  - $hh, hZ, hW$ with $h -> \gamma\gamma$
- ZZ with $Z(ll) + jj$
- WZ with 3 leptons
- ZZ with 4 leptons
- $W(\nu)Z(\nu)$ w. ss dileptons
- $WZ/ZZ$ with $Z(ll) + jj$
- Wh with 1-lepton $bb$
- Wh w. ss dileptons
- Wh w. multileptons
- WW w. os dileptons
Searches for unusual signatures with 8TeV data

**ATLAS:**
- Search for activity in empty bunch crossings -> long-lived R-hadrons (arXive: 1310.6584)
- Disappearing track -> compressed chargino-neutralino (arXive: 1310.3675)
- Displaced muon+jet -> RPV w. \( c \tau = 1 \text{mm to 1m} \)
- Long lived heavy particle using TOF & \( dE/dx \) -> long lived stau pair (ATLAS-CONF-2013-092)

**CMS:**
- Deficit in jet \( p_T \) distribution -> jet extinction (arXive: 1405.7653)
- Long lived dileptons
- Long lived dijets from common vertex
- Long lived heavy particle using TOF & \( dE/dx \) -> heavy and/or fractionally charged (CMS-EXO-12-037, CMS-B2G-12-024, CMS-EXO-12-038, arXive: 1305.0491, CMS-EXO-13-006)
Displaced Dilepton: e, μ

CMS-B2G-12-024

2014

- Pair production, leading to two pT > 25GeV, large d_0 leptons e, μ. No common vertex required.
- Define 3 mutually exclusive signal regions in |d_0| of the smaller of the two |d_0|.
- Interpret as colored pair production with 100% BR into lepton + X. No selection on X.

| Event Source       | 0.02 cm < |d_0| < 0.05 cm | 0.05 cm < |d_0| < 0.1 cm | |d_0| > 0.1 cm |
|--------------------|------------|------------|------------|
| other EWK          | 0.65 ± 0.13 ± 0.08 | (0.89 ± 0.53 ± 0.11) × 10⁻² | <(89 ± 53 ± 11) × 10⁻⁴ |
| top                | 0.767 ± 0.038 ± 0.061 | (1.25 ± 0.26 ± 0.10) × 10⁻² | (2.4 ± 1.3 ± 0.2) × 10⁻⁴ |
| Z→ττ               | 3.93 ± 0.42 ± 0.32 | (0.73 ± 0.73 ± 0.06) × 10⁻² | <(73 ± 73 ± 6) × 10⁻⁴ |
| QCD                | 12.7 ± 0.2 ± 3.8 | (98 ± 6 ± 30) × 10⁻² | (340 ± 110 ± 100) × 10⁻⁴ |
| Total expected background | 18.0 ± 0.5 ± 3.8 | 1.01 ± 0.06 ± 0.30 | 0.051 ± 0.015 ± 0.010 |
| Observation        | 19 | 0 | 0 |

<table>
<thead>
<tr>
<th>pp→t̄_t̄_±</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>M = 500 GeV, ⟨ct⟩ = 1 mm</td>
<td>30.1 ± 0.7 ± 1.1</td>
<td>6.54 ± 0.34 ± 0.24</td>
<td>1.34 ± 0.15 ± 0.05</td>
</tr>
<tr>
<td>M = 500 GeV, ⟨ct⟩ = 1 cm</td>
<td>35.3 ± 0.8 ± 1.3</td>
<td>30.3 ± 0.7 ± 1.1</td>
<td>51.3 ± 1.0 ± 1.9</td>
</tr>
<tr>
<td>M = 500 GeV, ⟨ct⟩ = 10 cm</td>
<td>4.73 ± 0.30 ± 0.17</td>
<td>5.57 ± 0.32 ± 0.20</td>
<td>26.27 ± 0.70 ± 0.93</td>
</tr>
</tbody>
</table>
Summary & Conclusions

• We looked all over the place ….
  – Singly produced resonances up to ~ 5 TeV
  – Pair produced new particles up to ~ 1.5 TeV
  – Vast diversity of signatures

• No new physics found anywhere we looked.
  – Devil’s in the details => many places left to hide!

• Let’s do it all over again next few years at higher energy and larger luminosity !!!
Additional Material

- Summary “bar plots” from all 5 BSM search groups across ATLAS & CMS
- SUSY Interpretation Summary plots
- Results from the respective “other” experiment not covered in main talk.
- Additional new Results from either experiment not mentioned at all in talk.
### ATLAS Exotics Searches* - 95% CL Exclusion

**Status:** ICHEP 2014

<table>
<thead>
<tr>
<th>Model</th>
<th>$t$, $\gamma$</th>
<th>Jets</th>
<th>$E_{\text{miss}}^T$</th>
<th>$\mathcal{L} dt$ [fb$^{-1}$]</th>
<th>Mass limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADD $G_{0X} + g/\gamma$</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.5</td>
<td>4.37 TeV</td>
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<tr>
<td>ADD non-resonant $t\ell$</td>
<td>$2e, \mu$</td>
<td>–</td>
<td>0.5</td>
<td>0.5</td>
<td>5.2 TeV</td>
</tr>
<tr>
<td>ADD QBBH $t \gamma$</td>
<td>$1 e, \mu$</td>
<td>–</td>
<td>0.5</td>
<td>0.5</td>
<td>5.2 TeV</td>
</tr>
<tr>
<td>ADD $t\ell$</td>
<td>–</td>
<td>0.5</td>
<td>–</td>
<td>0.5</td>
<td>5.8 TeV</td>
</tr>
<tr>
<td>ADD BH high $N_{\ell\ell}$</td>
<td>$2 \mu$ (SS)</td>
<td>2</td>
<td>–</td>
<td>2.03</td>
<td>5.7 TeV</td>
</tr>
<tr>
<td>ADD BH high $\Sigma p_{T}$</td>
<td>$\geq 1 e, \mu$</td>
<td>$\geq 2 j$</td>
<td>–</td>
<td>2.03</td>
<td>6.2 TeV</td>
</tr>
<tr>
<td>RS1 $G_{0X} + t\ell$</td>
<td>$2 e, \mu$</td>
<td>–</td>
<td>–</td>
<td>0.5</td>
<td>2.68 TeV</td>
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<tr>
<td>RS1 $G_{0X} + WW \rightarrow t\ell\ell$</td>
<td>$2 e, \mu$, $\gamma$, $\gamma$</td>
<td>–</td>
<td>–</td>
<td>0.5</td>
<td>1.23 TeV</td>
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<tr>
<td>Bulk RS $G_{0X} + ZZ \rightarrow t\ell\ell$</td>
<td>$2 e, \mu$, $\gamma$, $\gamma$</td>
<td>$2/j$</td>
<td>$1 J$</td>
<td>–</td>
<td>20.3</td>
</tr>
<tr>
<td>Bulk RS $G_{0X} + H\ell \rightarrow b\bar{b}bb$</td>
<td>$2 e, \mu$, $\gamma$, $\gamma$, $\gamma$</td>
<td>$2/j$</td>
<td>$1 J$</td>
<td>–</td>
<td>19.5</td>
</tr>
<tr>
<td>Bulk RS $G_{0X} + t\ell$</td>
<td>$1 e, \mu$, $\gamma$, $\gamma$</td>
<td>$\geq 1 b, \geq 1 j/2$, $\leq 1 j/2$</td>
<td>–</td>
<td>1.33</td>
<td>2.0 TeV</td>
</tr>
<tr>
<td>S$^1$/S$^2$ ED</td>
<td>$S^1$/S$^2$</td>
<td>$S^1$/S$^2$</td>
<td>–</td>
<td>5.0</td>
<td>4.71 TeV</td>
</tr>
<tr>
<td>UED</td>
<td>$2 \gamma$, $\gamma$, $\gamma$, $\gamma$</td>
<td>–</td>
<td>–</td>
<td>0.5</td>
<td>1.41 TeV</td>
</tr>
</tbody>
</table>

#### Extra dimensions

- **Gauge bosons**
  - SSM $Z'$ $\rightarrow t\ell$ | $2 e, \mu$, $\gamma$, $\gamma$ | – | – | 0.5 | 3.9 TeV |
  - SSM $Z''$ $\rightarrow \ell\ell$ | $2 e, \mu$, $\gamma$, $\gamma$ | – | – | 0.5 | 1.9 TeV |
  - EGM $W'$ $\rightarrow \ell\ell$ | $3 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | – | – | 0.5 | 3.25 TeV |
  - EGM $W''$ $\rightarrow \ell\ell$ | $2 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $2/j$ | $1 J$ | – | 20.3 |
  - LRSM $W'_R \rightarrow t\bar{b}$ | $1 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $2 b, O_{1, 1}$ | – | 14.3 | 2.8 TeV |
  - LRSM $W'_L \rightarrow t\bar{b}$ | $0 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $\geq 1 b, \geq 1 j$ | – | 20.3 | 1.77 TeV |

#### DM

- **DM EFT operator (Dirac)** | $0 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | – | – | 0.5 | 7.6 TeV |
- **DM EFT operator (Dirac)** | $0 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $1 J$, $L_{\leq 1}$ | $\geq 1 J$ | – | 10.5 |

#### LQ

- **Scalar LQ 1st gen** | $2 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | – | – | 0.5 | 660 GeV |
- **Scalar LQ 2nd gen** | $2 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $1 b$, $1 j$ | $\geq 1 j$ | – | 20.3 |
- **Scalar LQ 3rd gen** | $2 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $1 b$, $1 j$ | $\geq 1 j$ | – | 4.7 |

#### Heavy quarks

- **Vector-like quark $QQ + q\gamma$** | $1 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $2 b, \geq 2 j$ | – | 14.3 | 790 GeV |
- **Vector-like quark $TT + q\gamma$** | $1 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $2 b, \geq 2 j$ | – | 14.3 | 670 GeV |
- **Vector-like quark $TT + q\gamma$** | $1 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $2 b, \geq 2 j$ | – | 14.3 | 735 GeV |
- **Vector-like quark $BB + q\gamma$** | $1 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $2 b, \geq 2 j$ | – | 14.3 | 785 GeV |
- **Vector-like quark $BB + q\gamma$** | $1 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $2 b, \geq 2 j$ | – | 14.3 | 720 GeV |

#### Excited fermions

- **Excited quark $q' \rightarrow q\gamma$** | $1 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $2 b, \geq 2 j$ | – | 14.3 | 2.2 TeV |
- **Excited quark $q' \rightarrow q\gamma$** | $1 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $2 b, \geq 2 j$ | – | 14.3 | 2.2 TeV |
- **Excited quark $b' \rightarrow Wt$** | $1 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $2 b, \geq 2 j$ | – | 14.3 | 2.2 TeV |
- **Excited lepton $\ell' \rightarrow t\ell$** | $2 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $2 b, \geq 2 j$ | – | 14.3 | 2.2 TeV |

#### Other

- **LSTG $\pi \rightarrow W\gamma$** | $1 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $\gamma$, $\gamma$, $\gamma$ | – | 20.3 | 960 GeV |
- **LRSM Majorana other** | $2 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $\gamma$, $\gamma$, $\gamma$ | – | 20.3 | 1.5 TeV |
- **Type III Seesaw** | $2 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $\gamma$, $\gamma$, $\gamma$ | – | 20.3 | 245 GeV |
- **Multi-charged particles** | $2 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $\gamma$, $\gamma$, $\gamma$ | – | 20.3 | 409 GeV |
- **Magnetic monopoles** | $2 e, \mu$, $\gamma$, $\gamma$, $\gamma$ | $\gamma$, $\gamma$, $\gamma$ | – | 20.3 | 862 GeV |

#### Mass scale [TeV]

- $\sqrt{s} = 7$ TeV
- $\sqrt{s} = 8$ TeV
<table>
<thead>
<tr>
<th>Model</th>
<th>$\mu, \tau \gamma$ Jets</th>
<th>$E_{miss}^T$</th>
<th>$\mathcal{L} , dtt^{-1}$</th>
<th>Mass limit</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSUGRA/CMSSM</td>
<td>0</td>
<td>2-6 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>1.2 TeV</td>
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<tr>
<td>MSUGRA/CMSSM</td>
<td>1</td>
<td>$c, \mu$</td>
<td>3-6 jets</td>
<td>Yes</td>
<td>20.3</td>
</tr>
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<td>MSUGRA/CMSSM</td>
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<td>7-10 jets</td>
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<td>850 GeV</td>
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<td>$g\rightarrow q\bar{q}g^*\nu\nu$</td>
<td>0</td>
<td>2-6 jets</td>
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<td>20.3</td>
<td>1.33 TeV</td>
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<tr>
<td>$g\rightarrow q\bar{q}g^*\nu\nu$</td>
<td>1</td>
<td>$c, \mu$</td>
<td>3-6 jets</td>
<td>Yes</td>
<td>20.3</td>
</tr>
<tr>
<td>$g\rightarrow q\bar{q}g^*\nu\nu$, $g\rightarrow q\bar{q}qW^+W^-$</td>
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<td>0-3 jets</td>
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<tr>
<td>GMSB (N LSP)</td>
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<td>$e, \mu$</td>
<td>2-4 jets</td>
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<tr>
<td>Gravitino LSP</td>
<td>0</td>
<td>mono-jet</td>
<td>Yes</td>
<td>10.5</td>
<td>645 GeV</td>
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</tbody>
</table>

| ATLAS SUSY Searches* - 95% CL Lower Limits | |

**Status: ICHEP 2014**

**$\sqrt{s} = 7, 8$ TeV**

<table>
<thead>
<tr>
<th>Model</th>
<th>$\mu, \tau \gamma$ Jets</th>
<th>$E_{miss}^T$</th>
<th>$\mathcal{L} , dtt^{-1}$</th>
<th>Mass limit</th>
<th>Reference</th>
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<tbody>
<tr>
<td>Direct Searches</td>
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<td>0</td>
<td>2-3 h</td>
<td>Yes</td>
<td>20.3</td>
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<tr>
<td>Direct Searches</td>
<td>1, $c, \mu$</td>
<td>0</td>
<td>2-3 h</td>
<td>Yes</td>
<td>20.3</td>
</tr>
<tr>
<td>Direct Searches</td>
<td>0</td>
<td>2-4 h</td>
<td>Yes</td>
<td>20.3</td>
<td>1.0 TeV</td>
</tr>
<tr>
<td>EW direct</td>
<td>2</td>
<td>$c, \mu$</td>
<td>0</td>
<td>20.3</td>
<td>1.0 TeV</td>
</tr>
<tr>
<td>EW direct</td>
<td>1</td>
<td>$c, \mu$</td>
<td>0</td>
<td>20.3</td>
<td>1.0 TeV</td>
</tr>
<tr>
<td>EW direct</td>
<td>3</td>
<td>$c, \mu$</td>
<td>0</td>
<td>20.3</td>
<td>1.0 TeV</td>
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<td>2-5 jets</td>
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<td>1.0 TeV</td>
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<tr>
<td>Long-lived particles</td>
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<td>2-4 jets</td>
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<td>20.3</td>
<td>1.0 TeV</td>
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<tr>
<td>Long-lived particles</td>
<td>2</td>
<td>$c, \mu$</td>
<td>0</td>
<td>20.3</td>
<td>1.0 TeV</td>
</tr>
</tbody>
</table>

**Scalar gluon pair, $sgluon\rightarrow q\bar{q}$**

- 0 | 4 jets | No | 4.6 | 1.0 TeV |

**WIMP interaction (D5, Dirac $\chi$)**

- 2 | $c, \mu$ | 2 h | Yes | 14.3 | 1.0 TeV |

**Other**

- $\sqrt{s} = 7$ TeV
  - full data
  - partial data
- $\sqrt{s} = 8$ TeV
  - full data

**Mass scale [TeV]**

- 10^{-1} to 1
CMS Searches for New Physics Beyond Two Generations (B2G)

95% CL Exclusions (TeV)

- Excluded Mass (TeV)
  - 0
  - 0.2
  - 0.4
  - 0.6
  - 0.8
  - 1
  - 1.2
  - 1.4

**Vector-like T'**
- \( T'(5/3) \) (dilep, ss)
- \( T' \rightarrow tZ(\text{semilep+lep}) \)
- \( T' \rightarrow tH(\text{semilep+lep}) \)
- \( T' \rightarrow tW(\text{semilep+lep}) \)
- \( T' \rightarrow tH(H \rightarrow \gamma \gamma) \)
- \( T' \rightarrow tH(\text{hadronic}) \)
- \( T' \rightarrow tH(\text{hadronic}) \)
- \( B' \rightarrow bZ(\text{multilep}) \)
- \( B' \rightarrow bH(\text{multilep}) \)
- \( B' \rightarrow tW(\text{multilep}) \)
- \( B' \rightarrow tW(\text{ss-dilep}) \)
- \( B' \rightarrow bZ(\text{dilep}) \)
- \( B' \rightarrow bH(\text{semilep}) \)
- \( B' \rightarrow tW(\text{semilep}) \)
- \( B' \rightarrow tW(\text{had}) \)

**Vector-like B'**
- \( tH(\text{semilep+lep}) \)
- \( tZ(\text{semilep+lep}) \)
- \( T'(5/3)(\text{dilep, ss}) \)

**Dark matter**
- \( t\bar{t}+\text{MET, scalar (dilep)} \)
- \( t+\text{MET, vectorial (had)} \)
- \( t+\text{MET, scalar (had)} \)

**tt Resonances**
- \( g_{h\nu}(\text{combined}) \)
- \( Z(1.2\%)(\text{combined}) \)
- \( g_{h\nu}(\text{semilep}) \)
- \( Z(1.2\%)(\text{semilep}) \)
- \( g_{h\nu}(\text{all-had}) \)
- \( Z(1.2\%)(\text{all-had}) \)
- \( W(\text{lep}) \)
- \( t^*(\text{dilep}) \)
- \( t^*(\text{semilep}) \)
- \( cτ(\bar{t})=2cm (e+\mu) \)

**tb Resonances**
- \( Z'(1.2\%)(\text{combined}) \)
- \( Z'(1.2\%)(\text{semilep}) \)
- \( Z'(1.2\%)(\text{all-had}) \)

**Excited tops**
- \( Z'(1.2\%)(\text{combined}) \)
- \( Z'(1.2\%)(\text{semilep}) \)
- \( Z'(1.2\%)(\text{all-had}) \)

**Displaced tops**
- \( Z'(1.2\%)(\text{combined}) \)
- \( Z'(1.2\%)(\text{semilep}) \)
- \( Z'(1.2\%)(\text{all-had}) \)

**KK**
- \( g_{h\nu}(\text{combined}) \)
- \( Z(1.2\%)(\text{combined}) \)
- \( g_{h\nu}(\text{semilep}) \)
- \( Z(1.2\%)(\text{semilep}) \)
- \( g_{h\nu}(\text{all-had}) \)
- \( Z(1.2\%)(\text{all-had}) \)
- \( W(\text{lep}) \)
- \( t^*(\text{dilep}) \)
- \( t^*(\text{semilep}) \)
- \( cτ(\bar{t})=2cm (e+\mu) \)
Summary of CMS SUSY Results* in SMS framework

For decays with intermediate mass, $m_{\text{intermediate}} = x \cdot m_{\text{mother}} + (1-x) \cdot m_{\text{LSP}}$

*Observed limits, theory uncertainties not included
Only a selection of available mass limits
Probe "up to" the quoted mass limit

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SUSY Interpretation Summary plots
ATLAS Preliminary

MSUGRA/CMSSM: \( \tan(\beta) = 30, A_0 = -2m_0, \mu > 0 \)

\[ \int L \, dt = 20.1 - 20.7 \text{ fb}^{-1}, \sqrt{s} = 8 \text{ TeV} \]

95% CL limits. \( \sigma_{\text{SUSY theory}} \) not included.

- **Expected**
  - 0-lepton, 2-6 jets
  - 0-lepton, 7-10 jets
  - 0-1 lepton, 3 b-jets
  - 1-lepton + jets + MET
  - 1-2 taus + 0-1 lept. + jets + MET
  - 2SS/3 leptons, 0 - 3 b-jets

- **Observed**
  - 0-lepton, 2-6 jets
  - 0-lepton, 7-10 jets
  - 0-1 lepton, 3 b-jets
  - 1-lepton + jets + MET
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- **Status:** ICHEP 2014

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  - 2SS/3 leptons, 0 - 3 b-jets

---

**Status:** ICHEP 2014

**arXiv:** 1405.7875

**arXiv:** 1308.1841

**arXiv:** 1407.0600

**arXiv:** 1407.0603

**arXiv:** 1404.2500
**ATLAS & CMS Stop**

**ATLAS Preliminary**

- \( \tilde{t} \rightarrow t \tilde{\chi}^0 \)
- \( \tilde{t} \rightarrow t \tilde{\chi}^{0} / \tilde{t} \rightarrow W b \tilde{\chi}^{0} / \tilde{t} \rightarrow t \tilde{\chi}^{0} \)

Status: ICHEP 2014

**CMS Preliminary**

~\( \tilde{t} \tilde{t} \) production, ~\( \tilde{t} \rightarrow t \tilde{\chi}^0 / c \tilde{\chi}^0 \)

**Status:** ICHEP 2014

**Observed limits**

- \( L_{\text{int}} = 20 \text{ fb}^{-1} \) \( \sqrt{s} = 8 \text{ TeV} \)
- \( L_{\text{int}} = 4.7 \text{ fb}^{-1} \) \( \sqrt{s} = 7 \text{ TeV} \)

**Expected limits**

- \( L_{\text{int}} = 20 \text{ fb}^{-1} \) \( \sqrt{s} = 8 \text{ TeV} \)
- \( L_{\text{int}} = 4.7 \text{ fb}^{-1} \) \( \sqrt{s} = 7 \text{ TeV} \)

All limits at 95% CL

**Discussion**

- SUS-13-011 1-lep (MVA) 19.5 fb^{-1}
- SUS-14-011 0-lep + 1-lep + 2-lep (Razor) 19.3 fb^{-1}
- SUS-14-011 0-lep (Razor) + 1-lep (MVA) 19.3 fb^{-1}
- SUS-13-009 (monojet stop) 19.7 fb^{-1} (\( \tilde{t} \rightarrow c \tilde{\chi}^0 \))
- SUS-13-015 (hadronic stop) 19.4 fb^{-1}
ATLAS & CMS Ewkinos

**ATLAS Preliminary**

- $\tilde{\chi}_2^0 \to (H \tilde{\chi}_1^0 W^- Z)$
- $\tilde{\chi}_2^0 \to (\tilde{\tau}_1^\pm, BF(1^+) = 0.5)$
- $\tilde{\chi}_2^0 \to (\tilde{\tau}_1^0, BF(1^+) = 1)$
- $\tilde{\chi}_2^0 \to (\tilde{\tau}_2^0, BF(1^+) = 1)$

**CMS Preliminary**

- $\tilde{\chi}_2^0 \to (H \tilde{\chi}_1^0 W^- Z)$
- $\tilde{\chi}_2^0 \to (\tilde{\tau}_1^\pm, BF(1^+) = 0.5)$
- $\tilde{\chi}_2^0 \to (\tilde{\tau}_1^0, BF(1^+) = 1)$
- $\tilde{\chi}_2^0 \to (\tilde{\tau}_2^0, BF(1^+) = 1)$

All limits at 95% CL

**ATLAS - ICHEP 2014**

- $\sqrt{s} = 8$ TeV
- Status: ICHEP 2014
- Observed limits

**CMS - ICHEP 2014**

- $\sqrt{s} = 8$ TeV
- Status: ICHEP 2014
- Observed limits

**Expected limits: 20.3 fb$^{-1}$, $\sqrt{s} = 8$ TeV**

---

ATLAS-CONF-2013-093

arXiv:1402.7029

arXiv:1403.5294

arXiv:1407.0350

arXiv:1407.0350

arXiv:1403.5294

arXiv:1402.7029

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All limits at 95% CL

---

400 GeV

700 GeV

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ATLAS & CMS gluino to 2 top

\[ \tilde{g} \rightarrow t \tilde{\chi}_1^0 \]

**ICHEP 2014**

**ATLAS**

95% CL limits, \(\sigma_{\text{SUSY}}^{\text{SUSY}}\) not included.

- Expected 0-lepton, 7 - 10 jets
  \(L_{\text{int}} = 20.3 \text{ fb}^{-1}\)
- Observed

- Expected 0-1 lepton, \(\geq 3\) b-jets
  \(L_{\text{int}} = 20.1 \text{ fb}^{-1}\)
- Observed

- Expected 2SS/3 leptons, 0 - 2 b-jets
  \(L_{\text{int}} = 20.3 \text{ fb}^{-1}\)
- Observed

**CMS Preliminary**

\(\sqrt{s} = 8 \text{ TeV}\)

**ICHEP 2014**

\[ \tilde{g} \rightarrow t \tilde{\chi}_1^0 \]

\(\tilde{g} \rightarrow t \tilde{\chi}_1^0\) production, \(\tilde{g} \rightarrow t \tilde{\chi}_1^0\)

\(m(\tilde{g}) >> m(\tilde{t})\), \(\sqrt{s} = 8 \text{ TeV}\)
Other ATLAS SUSY Summaries

**ATLAS Preliminary**

Expected limits and observed limits for $t\bar{t}$ production, $t\bar{t} \rightarrow b\bar{b}X_{1}\rightarrow W^{++}X_{0}$, $m_{t}=300$ GeV. All limits at 95% CL.

**Status:** ICHEP 2014

- $L_{\text{int}} \sim 20$ fb$^{-1}$ $\sqrt{s}=8$ TeV

---

**Graphical Presentation**

- **Legend:**
  - Green line: $m_{\chi_{-}} > m_{\tau}$, $0-1L$, $1308.2631$, $1407.0583$
  - Blue line: $m_{\chi_{-}} > m_{\tau}$, $1-2L$, $1403.4853$
  - Yellow line: $m_{\chi_{-}} > m_{\tau}$, $1-2L$, $1208.4305$, $1209.2102$

- **Observed limits:**
  - $m_{\chi_{-}} = 5$ GeV

- **Expected limits:**
  - $m_{\chi_{-}} = 20$ GeV

- **LEP:**
  - Darker green line: $m_{\chi_{-}} = 150$ GeV
  - Lighter green line: $m_{\chi_{-}} = 106$ GeV

---

**Graphical Details**

- **Axes:**
  - $m_{\chi_{-}}$ vs. $m_{\chi_{1}}$
  - $m_{\tau}$ vs. $m_{\chi_{1}}$

- **Legend Entries:**
  - $m_{\chi_{-}} = 103.5$ GeV
  - $m_{\chi_{-}} = 150$ GeV

---

**Additional Information**

- **Status:** ICHEP 2014

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**References:**

- [1308.2631], [1407.0583], [1403.4853], [1208.4305], [1209.2102]
Other CMS SUSY Summaries

CMS

$\sqrt{s} = 8$ TeV, $\int \mathcal{L} dt = 19.5$ fb$^{-1}$

- Observed UL:
  - $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 175$ GeV, $\tilde{t}_1 \rightarrow \tilde{t}_2 \tilde{\chi}_1^0$

- Expected UL:
  - $\mathcal{B}(\tilde{t}_2 \rightarrow \tilde{t}_1 Z) = 100\%$
  - $\mathcal{B}(\tilde{t}_2 \rightarrow \tilde{t}_1 Z) = 50\%$
  - $\mathcal{B}(\tilde{t}_2 \rightarrow \tilde{t}_1 Z) = 0\%$

- $m_{\tilde{t}_2} < m_{\tilde{t}_1}$
- $m_{\tilde{t}_2} > m_{\tilde{t}_1} + m_H$
- $m_{\tilde{t}_1} \rightarrow \tilde{\chi}_1^0 H$ not allowed

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Branching Fraction Dependence of CMS stop limits

Allow for full range of 100% 2 top + MET -> 100% 2 b + MET

CMS Preliminary, L = 19.3 fb⁻¹, √s = 8 TeV

pp → ℓ⁺ℓ⁻ 95% C.L. NLO+NLL exclusion

- 100% ~t → bχ⁺
- 50% ~t → bχ⁺, 50% ~t → tχ⁺
- 100% ~t → tχ⁺
- 50%

Observed

Expected
Recent Results from the respective other experiment not covered in the talk
CMS Dilepton C.I. Search

limits on $\Lambda$ up to 18.3 TeV
Search strategies for final states with multiple W, Z, h ideally combine multiple final state signatures.
As $\Delta m$ increases, the charm quark $p_T$ increases, and efficiency decreases due to 3rd jet veto. => Sensitivity decreases with $\Delta m$
ATLAS ≥ 3 b-tags, 0,1 leptons

arXive: 1405.7875

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ATLAS Ewkinos

Di-tau + MET arXive: 1407.0350

Di-e/mu + MET arXive: 1403.5294

Trilepton + MET arXive: 1402.7029

Trilepton e/mu

Trilepton 2tau

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Few additional New Results not covered in the talk

Mono-Photons
Black Hole
CMS Preliminary
\( \sqrt{s} = 8 \text{ TeV}, L = 19.6 \text{ fb}^{-1} \)

### Events/GeV

<table>
<thead>
<tr>
<th>Category</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \gamma \text{jet}, W(\mu\nu), \gamma\gamma, Z(\ell\ell) )</td>
<td>( 1 \times 10^4 )</td>
</tr>
<tr>
<td>Beam Halo</td>
<td>( 1 \times 10^3 )</td>
</tr>
<tr>
<td>QCD</td>
<td>( 1 \times 10^2 )</td>
</tr>
<tr>
<td>( W \rightarrow \ell\nu )</td>
<td>( 1 \times 10^1 )</td>
</tr>
<tr>
<td>( W\gamma \rightarrow \ell\gamma )</td>
<td>( 1 \times 10^0 )</td>
</tr>
<tr>
<td>( Z\gamma \rightarrow \nu\nu\gamma )</td>
<td>( 1 \times 10^{-1} )</td>
</tr>
<tr>
<td>bkg.uncertainty</td>
<td>( 1 \times 10^{-2} )</td>
</tr>
<tr>
<td>SM+ADD((M_D = 2 \text{ TeV}, n=3))</td>
<td>( 1 \times 10^{-3} )</td>
</tr>
<tr>
<td>DATA</td>
<td>( 1 \times 10^{-4} )</td>
</tr>
</tbody>
</table>

### Data/MC

<table>
<thead>
<tr>
<th>Category</th>
<th>Data/MC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

### CMS Preliminary 2012
\( \sqrt{s} = 8 \text{ TeV}, L = 19.6 \text{ fb}^{-1} \)

- 95% CL Obs. Limit
- 95% CL Exp. Limit
- Exp. Limit + 95% CL
- Exp. Limit + 68% CL

### Figure 4: 95% and 90% upper limits on \( s \cdot A \) as a function of the cut on the photon \( p_T \)

- 95% Limits
- 90% Limits

### Table 4: Theoretical dark-matter production cross section

<table>
<thead>
<tr>
<th>Mass [GeV]</th>
<th>( \sigma ) [pb]</th>
<th>( \sigma \cdot A ) [fb]</th>
<th>( L ) [GeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.4666e-7</td>
<td>7.8(10.6)</td>
<td>750(694)</td>
</tr>
<tr>
<td>10</td>
<td>2.4614e-7</td>
<td>8.0(10.5)</td>
<td>745(696)</td>
</tr>
<tr>
<td>100</td>
<td>2.4437e-7</td>
<td>8.0(11.2)</td>
<td>742(684)</td>
</tr>
<tr>
<td>200</td>
<td>2.1687e-7</td>
<td>7.6(9.9)</td>
<td>729(684)</td>
</tr>
<tr>
<td>300</td>
<td>1.786e-7</td>
<td>6.9(9.4)</td>
<td>714(660)</td>
</tr>
<tr>
<td>500</td>
<td>1.0291e-7</td>
<td>5.2(7.8)</td>
<td>666(602)</td>
</tr>
<tr>
<td>1000</td>
<td>1.539e-8</td>
<td>4.9(7.2)</td>
<td>422(382)</td>
</tr>
</tbody>
</table>

90% CL upper limits are placed on the DM production cross sections, as a function of \( M_c \), assuming vector and axial-vector operators, summarized in Table 4 and Table 5. These are converted into the corresponding lower limits on the cutoff scale \( L \), also listed in Table 4 and Table 5.

The \( L \) values are then translated into upper limits on the \( c \)-nucleon cross sections, calculated within the effective theory framework. These are displayed in Fig. 5 as a function of \( M_c \). Superposed are the results from selected other experiments. Previously inaccessible \( c \) masses below \( \pi_c \approx 3.5 \text{ GeV} \) are excluded for a \( c \)-nucleon cross section greater than \( \pi_c \approx 0.03 \text{ fb} \) at 90% CL. For spin-dependent scattering, the upper limits surpass all previous constraints for the mass range of 1–100 GeV. The results presented are valid for mediator masses larger than...
Select events with at least one electron or muon w. $p_T > 50\text{GeV}$

Sum the $p_T$ of all electrons, muons, or jets with $p_T > 60\text{GeV}$; add MET, and plot the resulting $\Sigma p_T$ for events with leading electron (top) and muon (bottom).

arXive: 1405.4254
CMS Black Hole Search

Sum the pT of all photons, electrons, muons, or jets with pT > 50 GeV; add MET, and plot the resulting $S_T$ for different minimum number of such objects per event.

Shown here are the two extremes:
- inclusive $N \geq 2$ (top)
- $N \geq 10$ (bottom).

arXive: 1303.5338