Supersymmetry Searches at ATLAS and CMS
UK HEP Forum 2012
Friday 23rd November, 2012

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An Introduction

- Very many **Searches for Supersymmetry** completed by both the ATLAS and CMS collaborations in 2011 and 2012[1]
- It is a privilege to attempt to summarise these searches here...
- I will do my best to summarise it all, where possible showing the latest ones (i.e. SUSY and HCP, 7 TeV and 8 TeV) from both experiments
- See:
  `https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults` and
  `https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS`
  for a complete list and all the details!

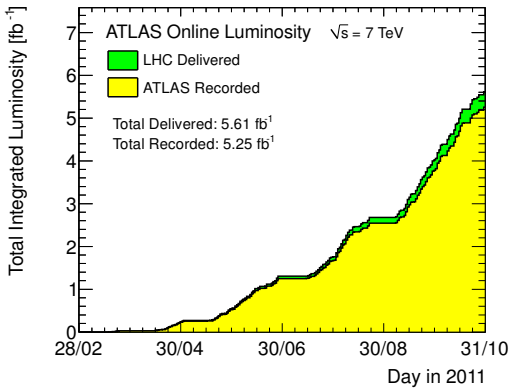
[1] And probably more to come before the year is over!

How many searches?

ATLAS SUSY Searches (2011 - 2012)

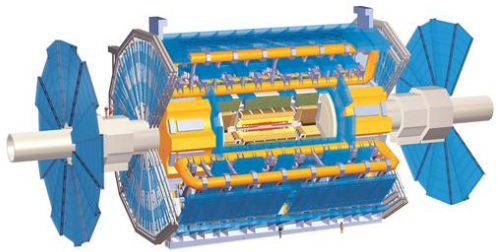
see: **https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults**

$\int \mathcal{L}$ **dt = 4.7 fb**$^{-1}$ at $\sqrt{s} = 7$ TeV

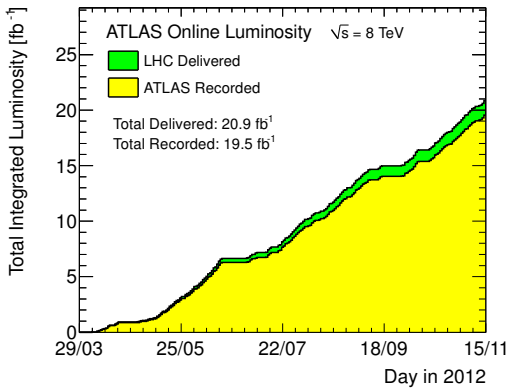


- 15 papers and 8 CONF notes with $\int \mathcal{L}$ dt = 1 - 2 fb^{-1}
- 20+ papers and 7 CONF notes with $\int \mathcal{L}$ dt = 4.7 fb^{-1}

+ 2010 35 pb^{-1} results



$\int \mathcal{L}$ **dt =** > 15 **fb**$^{-1}$ at $\sqrt{s} = 8$ TeV



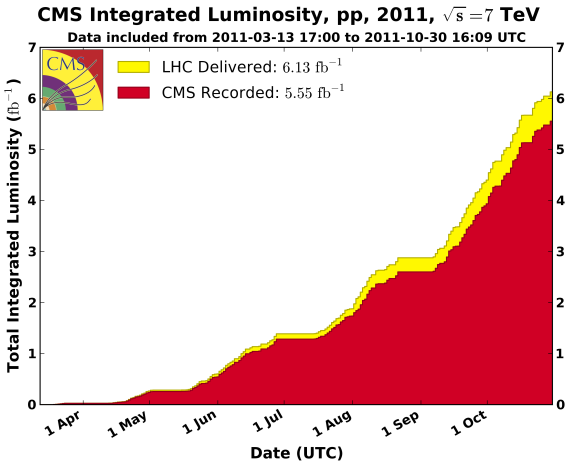
- 10 notes with $\int \mathcal{L}$ dt $6 - 13$ fb^{-1}

(6 new at HCP last week)

CMS SUSY Searches (2011- 2012)

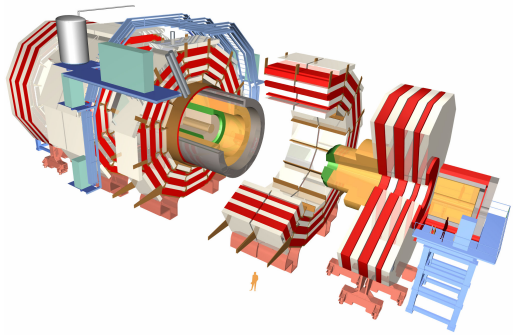
see: **https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS**

$\int \mathcal{L}$ **dt = 4.7 fb**$^{-1}$ at $\sqrt{s} = 7$ TeV

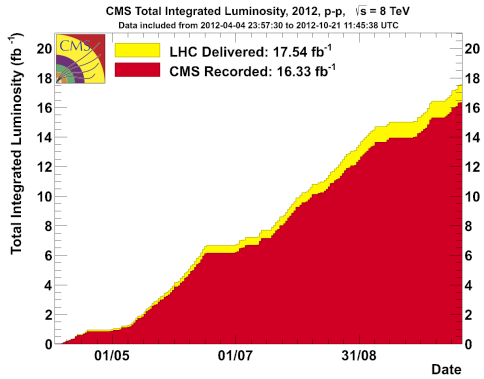


- 1 paper and 13 notes with $\int \mathcal{L}$ dt = 1 - 2 fb^{-1}
- 12 papers and 12 notes with $\int \mathcal{L}$ dt $\approx$ 5 fb^{-1}

+ 2010 35 pb^{-1} results



$\int \mathcal{L}$ **dt > 15 fb**$^{-1}$ at $\sqrt{s} = 8$ TeV



- 7 notes with $\int \mathcal{L}$ dt = 4-12 fb^{-1}

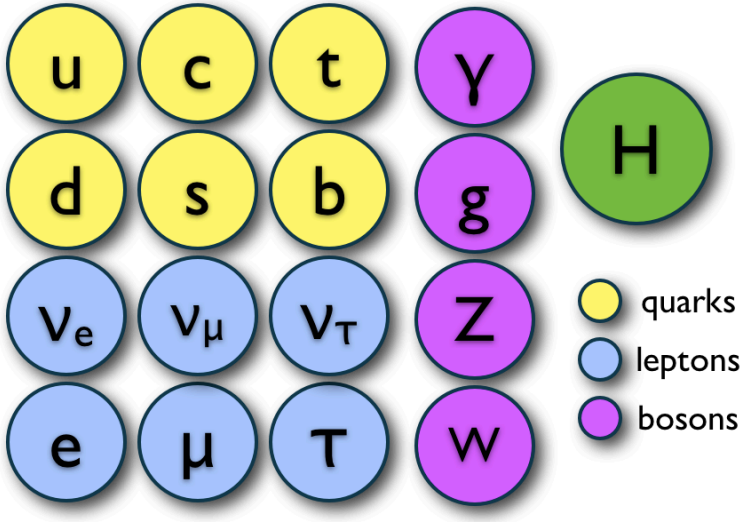
(4 new at HCP last week)

An Introduction

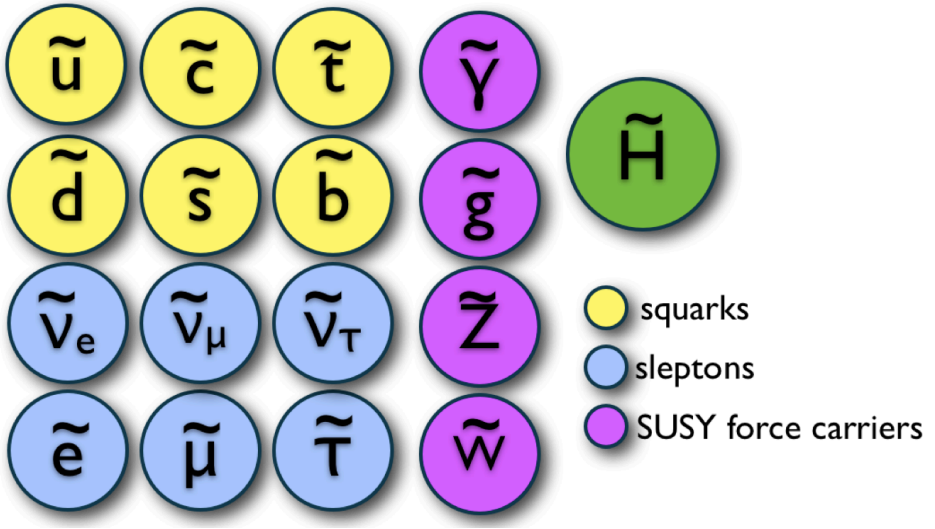
Supersymmetry (1)

- Weak scale SUSY is one of the most **extensively studied extensions to the Standard Model**
- Postulates superpartners for all the SM particles:
  SM fermions $\Leftrightarrow$ **SUSY bosons**
  SM bosons $\Leftrightarrow$ **SUSY fermions**

Standard Model:

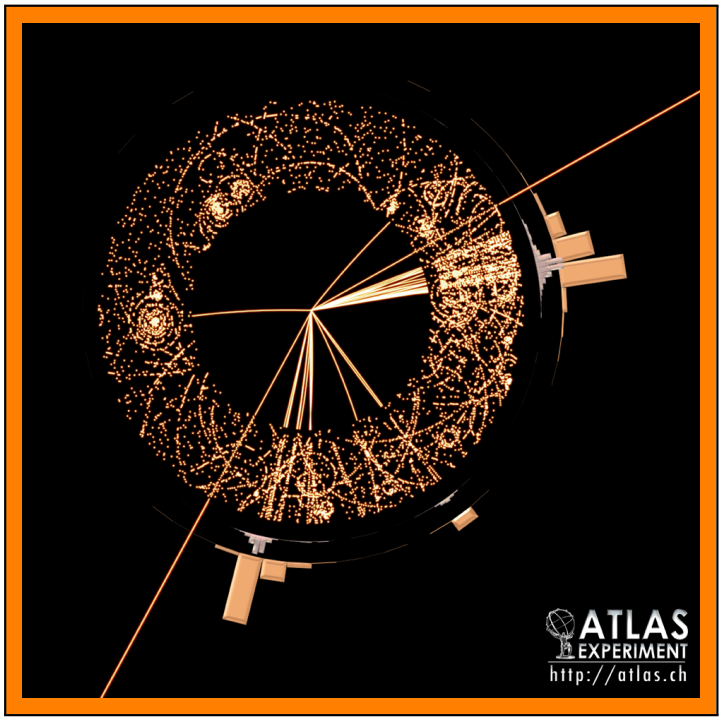


Supersymmetry:



Supersymmetry (2)

Supersymmetry is not just one model...



If $R-$parity is conserved
$R_p = (-1)^{(3B-3L+2s)}$, SM (SUSY) particles have $R_p = +1$ (-1)

- The lightest supersymmetry particle (LSP) is stable, it does not decay
- SUSY particles are produced in pairs

(but of course this need not be the case)

SUSY must be a broken symmetry
e.g. through a hidden sector with a messenger field

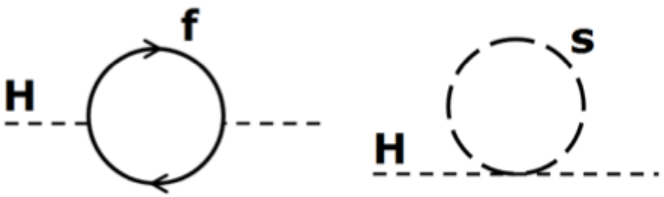
- **Supergravity** break SUSY via gravity
- **GMSB** break SUSY via new gauge interactions
- **AMSB** SUSY is broken by anomalies

Supersymmetry (3)

- We've perhaps been expecting SUSY for quite some time...
- But we've seen no sign of her... is the theory wrong? is she hiding?
- ... wide range of signatures, and many places to hide...

- **Key Motivations?**

  - Dark matter - WIMP fits with SUSY
  - Light Higgs - new physics is needed to stabilise mass



$$\Delta m_H^2 = \frac{|\lambda_f|^2}{16\pi^2}\left[-2\Lambda_{UV}^2 + 6m_f^2 \ln(\Lambda_{UV}/m_f) + \ldots\right]$$

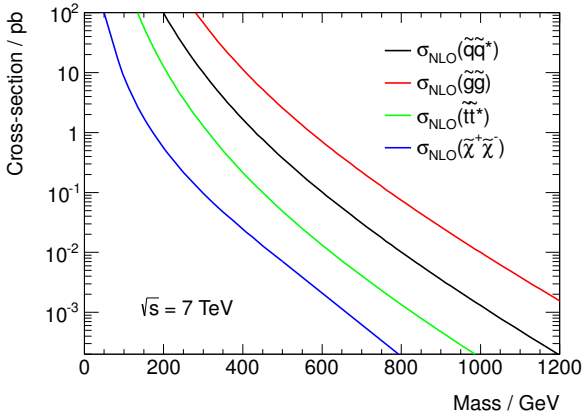
UV cut-off gives finite mass

$$\Delta m_H^2 = \frac{\lambda_s}{16\pi^2}\left[\Lambda_{UV}^2 - 2m_s^2 \ln(\Lambda_{UV}/m_s) + \ldots\right]$$

SUSY provides correct coupling and number of states for cancellations

Where to begin?

Plot by T. Khoo



"Strong Production"

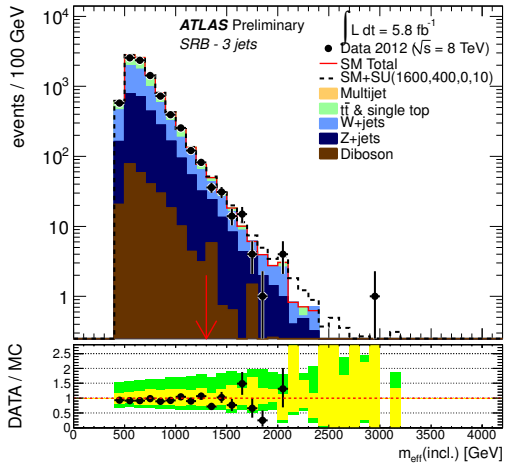
- Search for the most obvious thing (?)
- The LHC is a "QCD machine"...
- ... **1st and 2nd generation squarks ($\tilde{u}$, $\tilde{d}$, $\tilde{s}$, $\tilde{c}$) and gluinos will be produced dominantly**
- (unless the 3rd generation and electroweak sparticles are much lighter)
- If *R*-parity is conserved: neutral light LSP, sparticles produced in pairs
- **Look for the strong production and decay of squarks and gluinos** $\tilde{q}\tilde{q}$, $\tilde{q}\tilde{g}$, $\tilde{g}\tilde{g}$
  - $\tilde{q}$ and $\tilde{g}$ *cascade through lighter sparticles* to reach the LSP
  - $E_{\mathrm{T}}^{\mathrm{miss}}$ (from escaping LSPs) signature, expect jets
  - Any sleptons and gauginos produced in the cascades can give leptons, further-jets, *b*-jets etc

ATLAS 0-Lepton Search

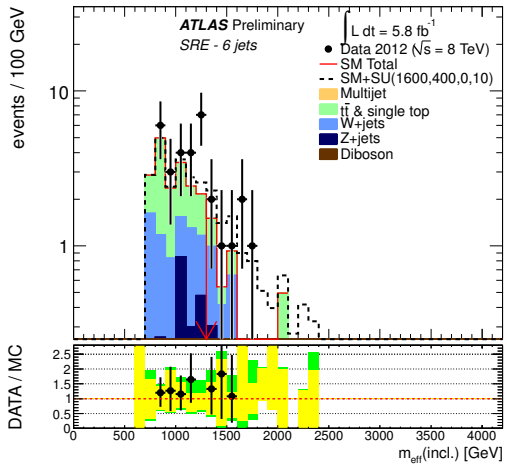
8 TeV 5.8 fb^{-1} ATLAS-CONF-2012-109

- Target $\tilde{g} \to q\bar{q}\tilde{\chi}_1^0$ and $\tilde{q} \to q\tilde{\chi}_1^0$ decays
- Following $\tilde{q}\tilde{q}$, $\tilde{q}\tilde{g}$, $\tilde{g}\tilde{g}$ production
- $\to$ expect different jet multiplicity depending on the process
- **Search in events with 2-6 jets $+E_{\mathrm{T}}^{\mathrm{miss}}$ at high m_{eff}**
  (m_{eff}: scalar sum of jet p_{T} and $E_{\mathrm{T}}^{\mathrm{miss}}$)

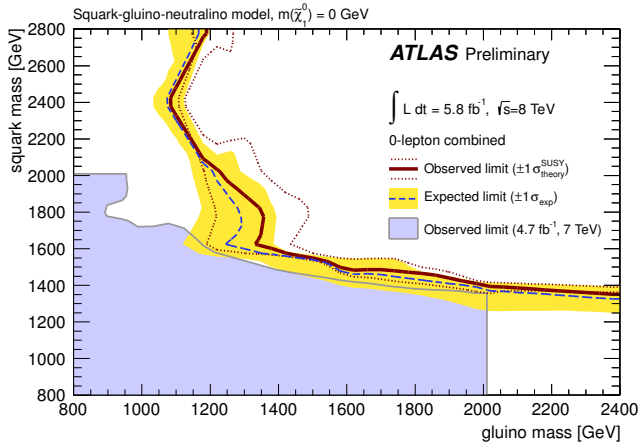
3-jet selection:



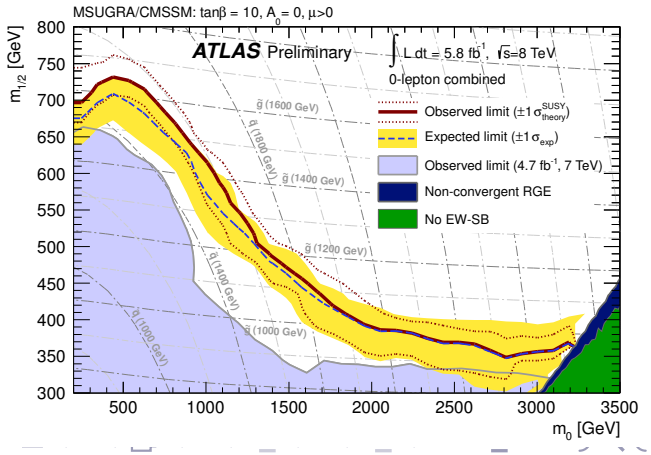
6-jet selection:



- squarks and gluinos with direct decays to the SM and LSP



- mSUGRA/CMSSM framework

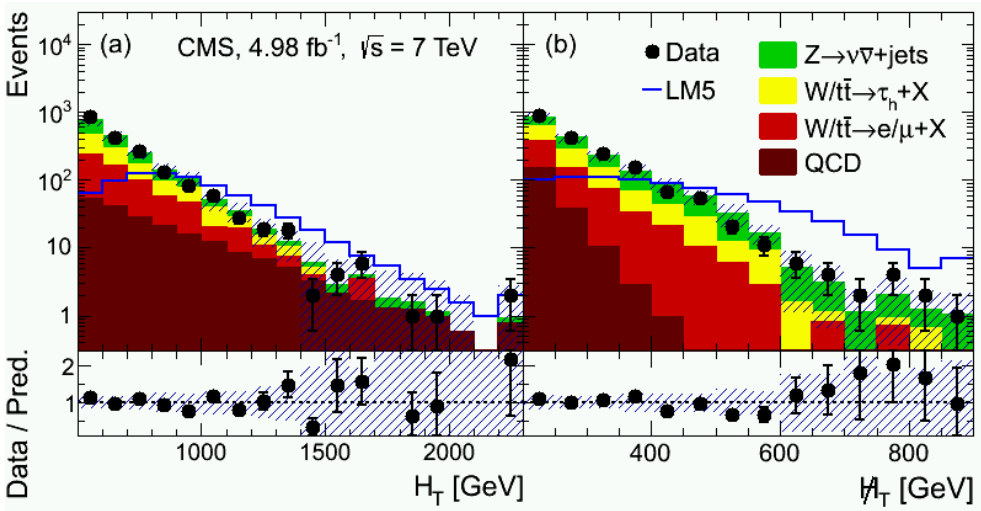


CMS 0-Lepton Search

7 TeV 4.98 fb^{-1} CMS-SUS-12-011, arXiv:1207.1898

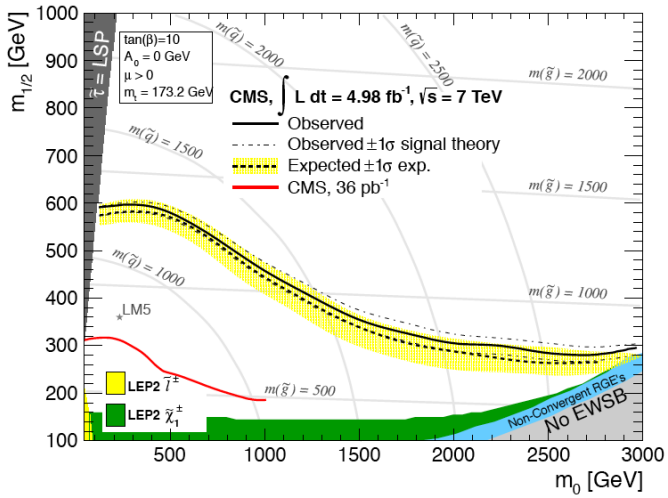
- **Search in events with ≥ 3 jets $+E_{\mathrm{T}}^{\mathrm{miss}}$ at high H_{T}**
  (H_{T}: scalar sum of jet p_{T})

H_{T} (left) and missing H_{T} (right)



Aside on the CMSSM?

- Often used as a benchmark
- Pick $\tan\beta = 10$, $A_0 = 0$, $\mu > 0$, scan m_0, $m_{1/2}$
- Only weak dependence on $\tan\beta$ up to ~ 40

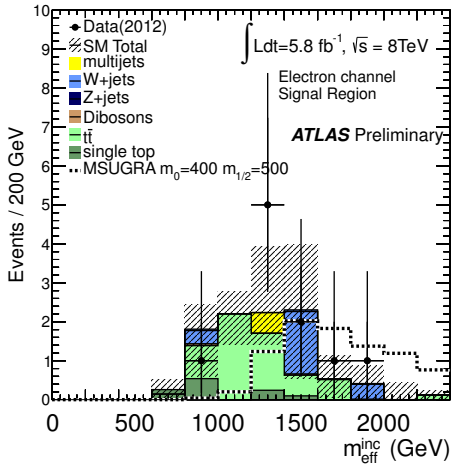


ATLAS 1 Lepton $\geq$ 4 jets

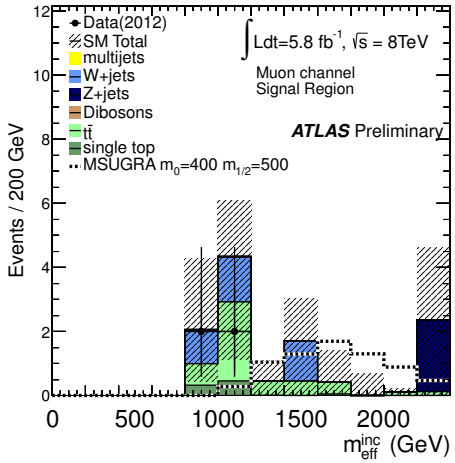
8 TeV 5.8 fb^{-1} ATLAS-CONF-2012-104

- Strongly interactive SUSY particles can decay into jets, the LSP **and leptons**
  e.g. $\tilde{q} \rightarrow q\tilde{\chi}_1^{\pm} \rightarrow qW^{\pm}\tilde{\chi}_1^0 \rightarrow qe^{\pm}\nu_e\tilde{\chi}_1^0$
- Consider **4 jet final states, and one isolated electron or muon**
- Veto on 2nd lepton to remove overlap with other searches
- Look at high $E_{\mathrm{T}}^{\mathrm{miss}}$, m_{eff}, m_{T} and $E_{\mathrm{T}}^{\mathrm{miss}}/m_{eff} > 0.2$

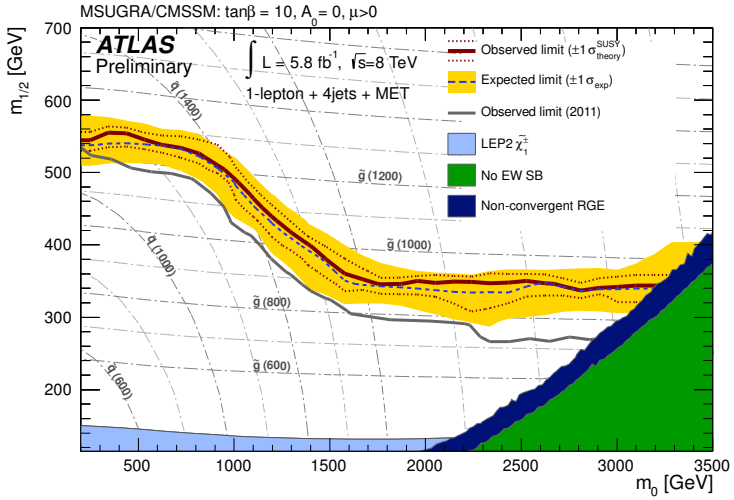
Electron channel:



Muon channel:



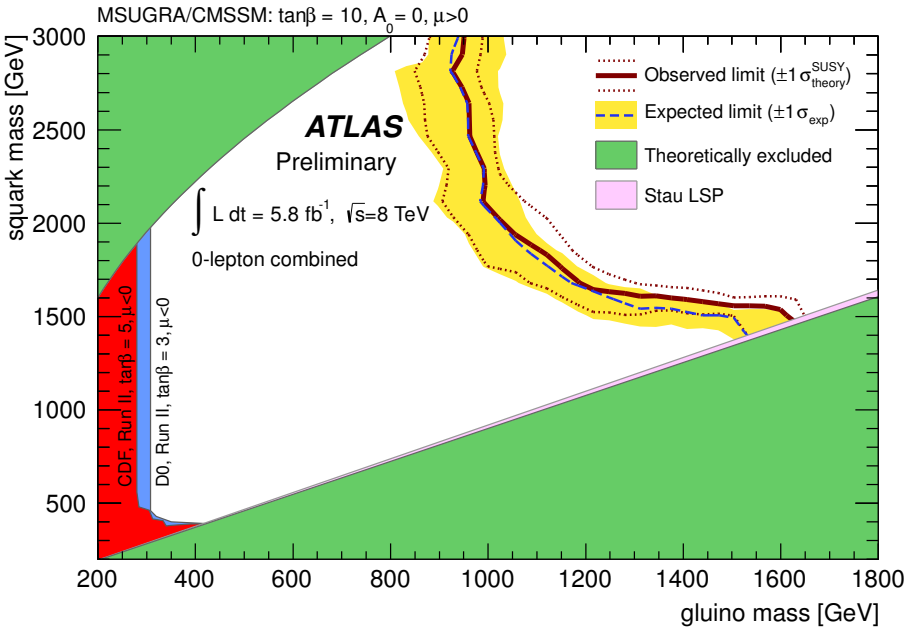
- mSUGRA/CMSSM framework



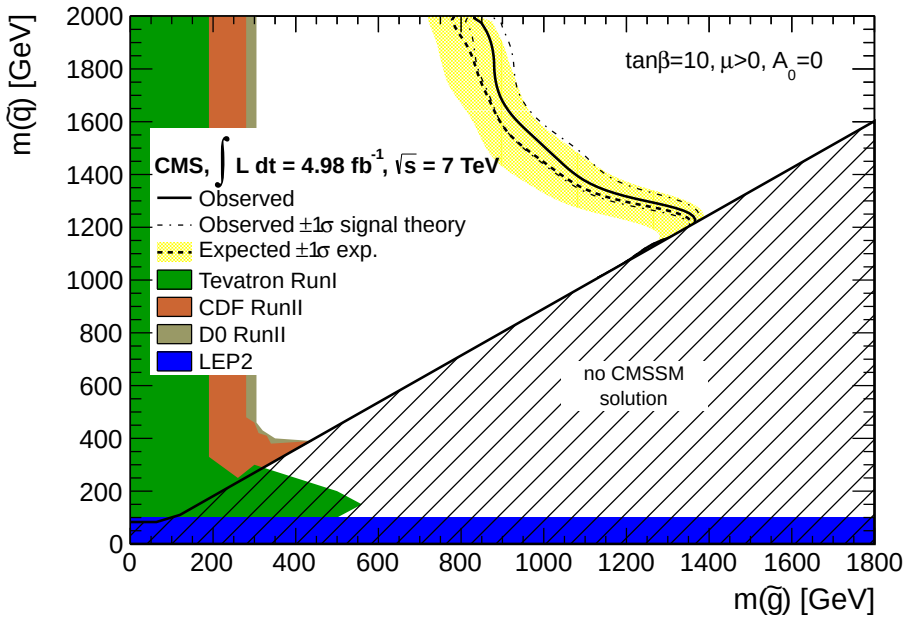
see also: CMS-SUS-11-011 OS-dilepton, ATLAS-CONF-2012-105 SS-dilepton searches

CMS and ATLAS searches have excluded light squarks and gluinos up to 1 TeV

ATLAS-CONF-2012-109



PRL 109, 171803



$m_{\tilde{q}} \gtrsim 1.4$ TeV, $m_{\tilde{g}} \gtrsim 900$ GeV OR $m_{\tilde{q}} - m_{\tilde{g}} \gtrsim 1.4$ TeV

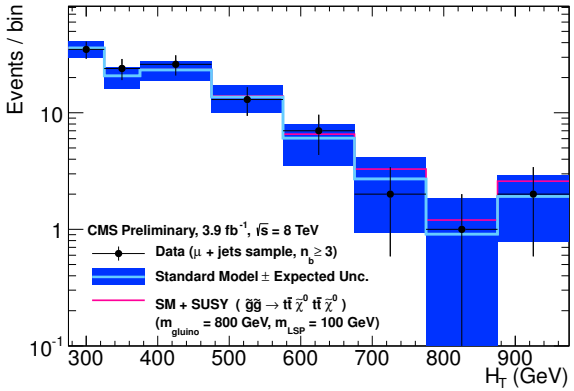
... but they are not *as* sensitive to the 3rd generation.

CMS 0-Lepton α_T search

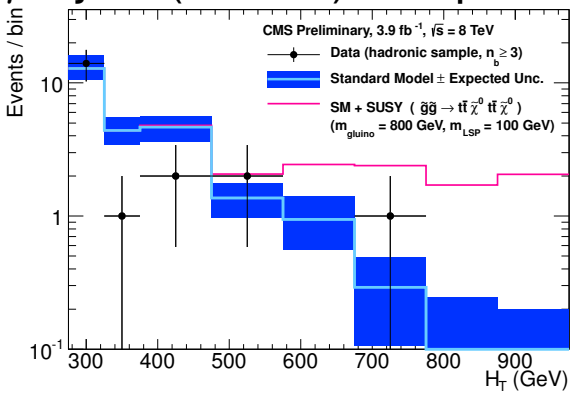
8 TeV 3.9 fb^{-1} CMS PAS SUS-12-016 **Updated to 11.7 fb^{-1} at HCP (CMS PAS SUS-12-028)**

- Again design for sensitivity to E_T^{miss} signatures in events with ≥ 2 jets
- But categorise by no. *b*-jets (0, 1, 2, ≥ 3)
  $\rightarrow$ **(1) improves sensitivity to third-generation squark signatures**
  $\rightarrow$ (2) whilst retaining sensitivity to massive coloured particle production processes ($\tilde{q}\tilde{q}$, $\tilde{q}\tilde{g}$, $\tilde{g}\tilde{g}$)
- α_T is used to remove QCD
- **Search in bins of H_T and no. *b*-jets**
  (H_T: scalar sum of jet p_T)

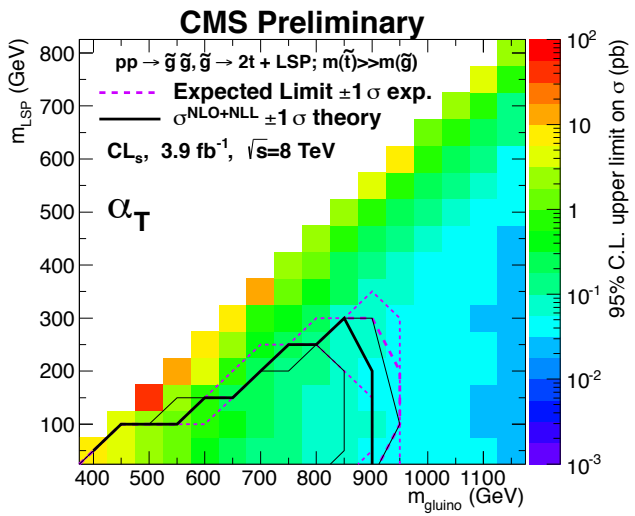
Hadronic sample:



μ+jets (control) sample:



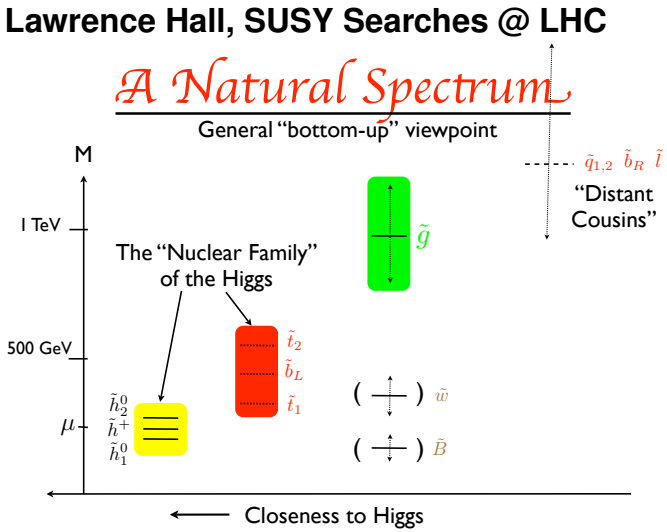
- Simplified model,
  $pp \rightarrow g\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0 t\bar{t}\tilde{\chi}_1^0$ [a]



[a] NB: $m(\tilde{t}) >> m(\tilde{g})$, stop off-shell

see: also ATLAS ATLAS-CONF-2012-103 $\geq 6 - 9$ jets 0 Lepton Search

Natural SUSY?



- Returning to:

$$\Delta m_H^2 = \frac{|\lambda_f|^2}{16\pi^2}\left[-2\Lambda_{UV}^2 + 6m_f^2 \ln(\Lambda_{UV}/m_f) + ...\right]$$

Dominant loop is from **t**: only the 3rd generation squarks need to be light

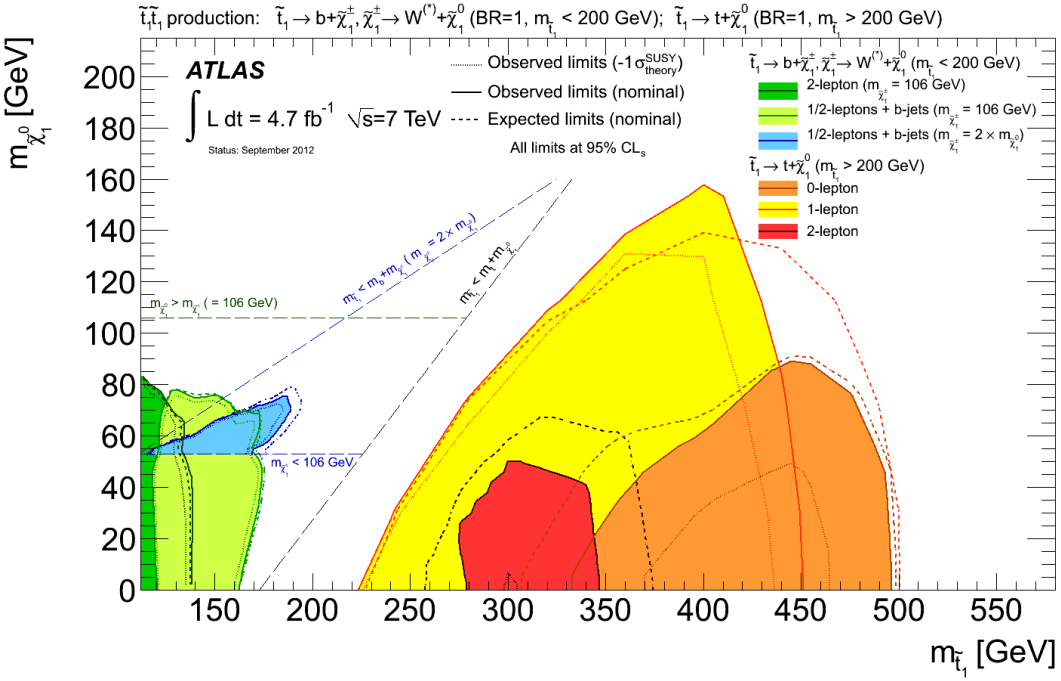
- 3rd generation cross-section smaller - existing limits don't rule this out.
- Generally speaking Jets $+E_{\mathrm{T}}^{\mathrm{miss}}$ searches probe $\tilde{u}$, $\tilde{d}$, $\tilde{c}$, $\tilde{s}$ **but not** $\tilde{t}$, $\tilde{b}$

Natural SUSY?

- **3rd Generation**
  - 3rd generation squarks can be relatively light (150-250 GeV), produced in pairs with high-cross section, or appear in gluino cascade decay (gluinos can't be too heavy).
    1. Direct Production: expect *b*s, *W*s, *t*s and $E_{\mathrm{T}}^{\mathrm{miss}}$
    2. Gluino mediated: all of the above - +jets
- **Gauginos**
  - Should be light
  - Signature expected: leptons, $E_{\mathrm{T}}^{\mathrm{miss}}$, no jets

ATLAS Direct Stop Searches

- Final results (at $\sqrt{s} = 7$ TeV, 5 fb^{-1}) summarised in the $\tilde{\chi}_1^0 - \tilde{t}_1$ plane below
  - $m(\tilde{t}) > m(t)$**:** hadronic or leptonic top decays with extra $E_{\mathrm{T}}^{\mathrm{miss}}$ ($\tilde{t}_1 \to t\tilde{\chi}_1^0 \to Wb\tilde{\chi}_1^0$)
  - $m(\tilde{t}) < m(t)$**:** top-like decay via chargino, lower p_{T} leptons ($\tilde{t} \to b\tilde{\chi}_1^{\pm} \to bW^{(*)}\tilde{\chi}_1^0$)



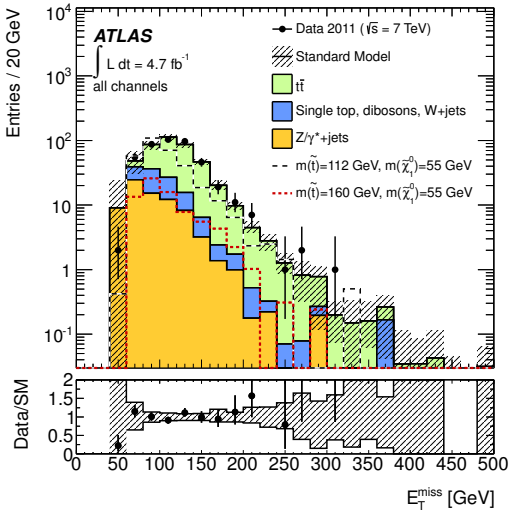
- arXiv: 1209.4186
- arXiv: 1209.2102
- arXiv: 1208.4305
- arXiv: 1208.2590
- arXiv: 1208.1447

Can ATLAS fill in the white spaces at 8 TeV?

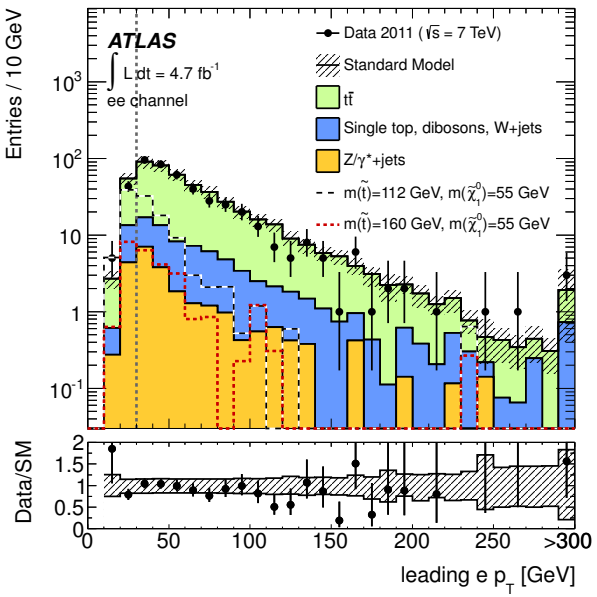
ATLAS Very Light Stop Search

7 TeV 4.7 fb^{-1} arXiv:1208.4305

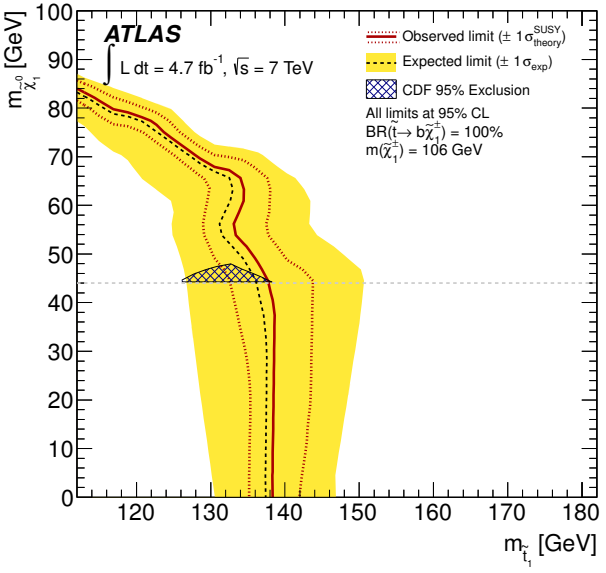
- Search for pair produced light scalar top quarks
- **2 lepton** final state
- High $E_{\mathrm{T}}^{\mathrm{miss}}$, at least one jet, low lepton p_{T}



Signal concentrated at low lepton p_{T}



Assume $\tilde{t} \to b\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_1^{\pm}$ decays via a virtual W boson
Assume $m(\tilde{\chi}_1^{\pm}) = 106$ GeV

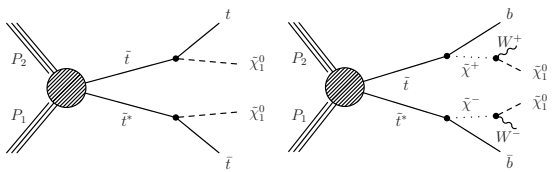


(corresponds to dark green patch on previous slide)

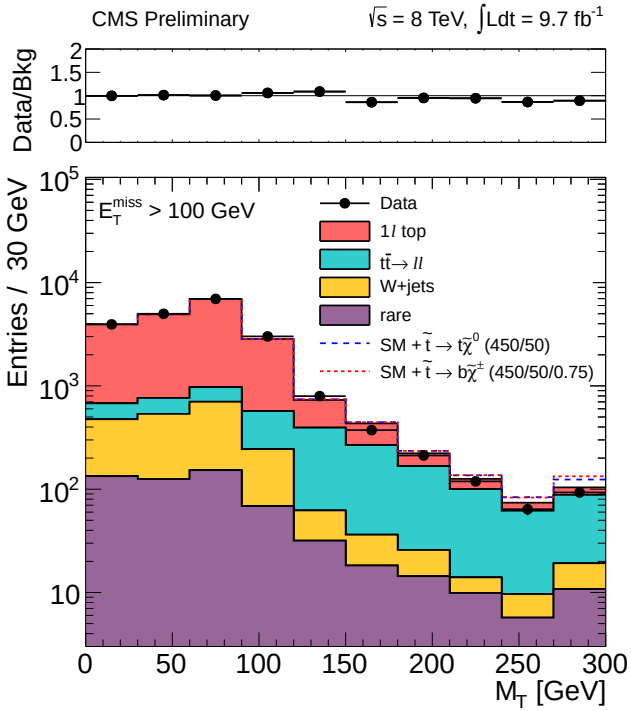
CMS Direct Stop Search

8 TeV 9.7 fb^{-1} CMS PAS SUS-12-023 New at HCP

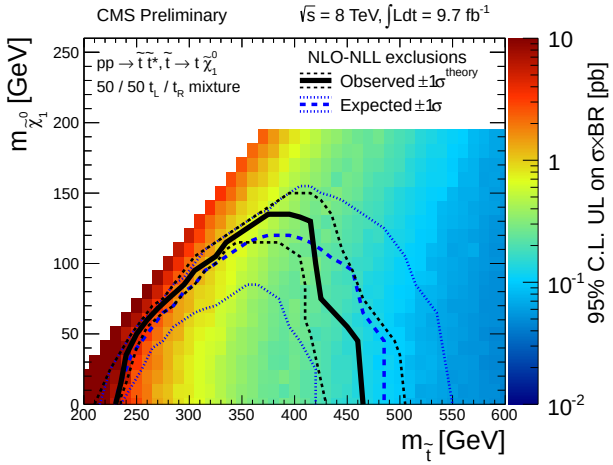
- Single isolated e or μ, jets and large $E_{\mathrm{T}}^{\mathrm{miss}}$
- Sensitivity to $\tilde{t} \to t\tilde{\chi}_1^0$, $\tilde{t} \to b\tilde{\chi}_1^{\pm} \to bW\tilde{\chi}_1^{\pm}$
- High p_{T} jets (incl. 2 b jets), $E_{\mathrm{T}}^{\mathrm{miss}}$ signature
- Search at high m_{T}



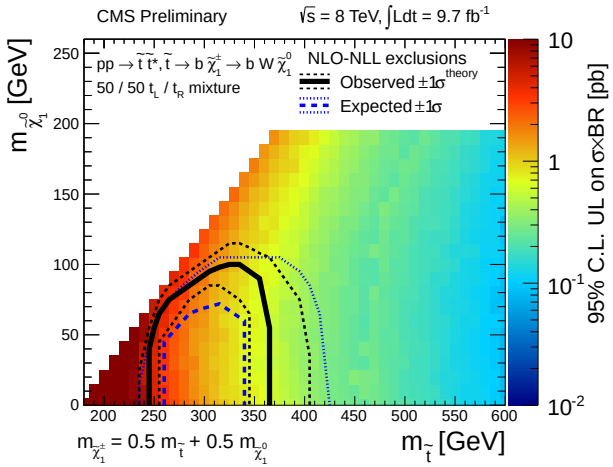
$M_{\mathrm{T}} > 150$ GeV corresponds to one signal region.



Stop to top



Stop to bottom



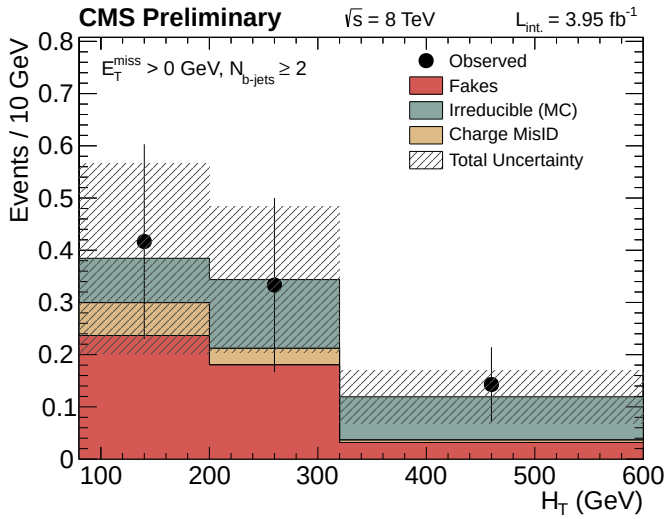
CMS SS-dilepton and ≥ 2 b-jets search

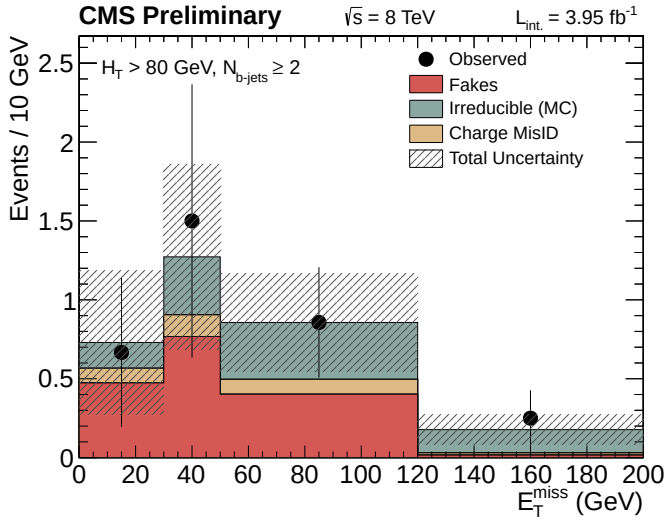
8 TeV 3.95 fb^{-1} CMS PAS SUS-12-017 Updated to 10.5 fb^{-1} at HCP (CMS PAS SUS-12-029)

Search in various bins of the H_T / E_T^{miss} plane
(13 events in total)

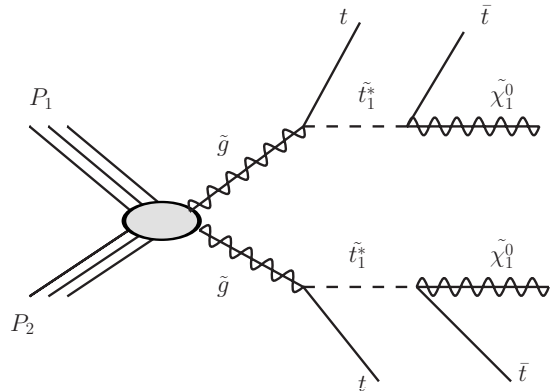
Backgrounds:

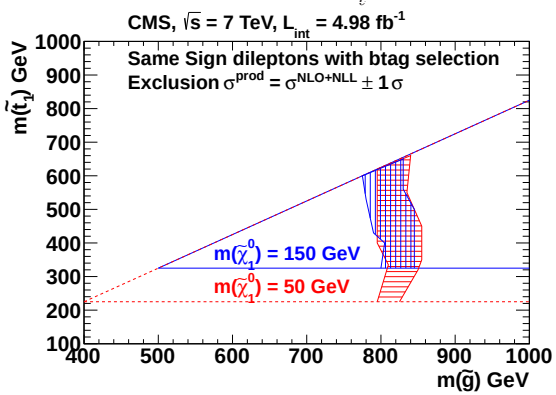
- fake leptons (from HF decays, mis-identified hadrons, muons from meson decay in flight, electrons from conversions)
- charge "flip", rare SM processes with 2 SS leptons and *b*-jets (e.g. $pp \to t\bar{t}W$)





Analysis is sensitive to both gluino mediated, and direct production, of 3rd generation squarks.

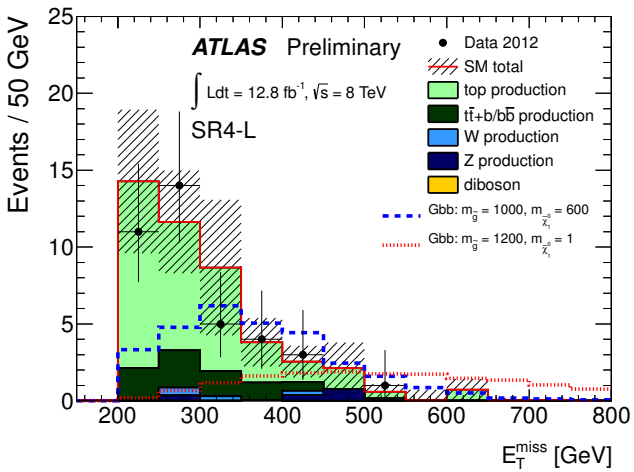




ATLAS 0 lepton $\geq$ 3 b-jets Search

8 TeV 13.0 fb^{-1} ATLAS-CONF-2012-145 New at HCP

- 4 or 6 jets, 3+ b-tagged
- $E_{\mathrm{T}}^{\mathrm{miss}} >$ 200 GeV
- Define multiple signal regions using different m_{eff} cuts



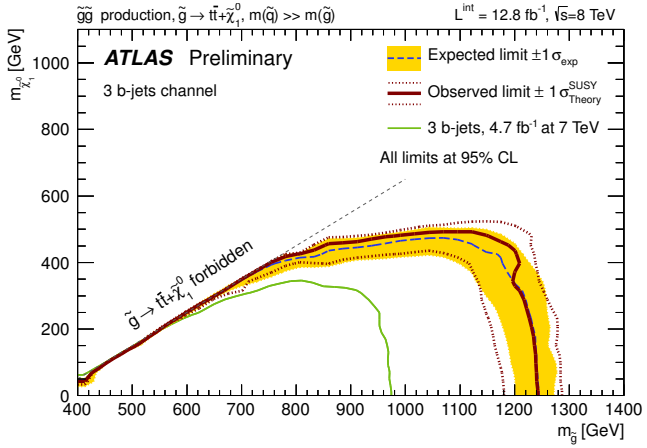
Backgrounds:

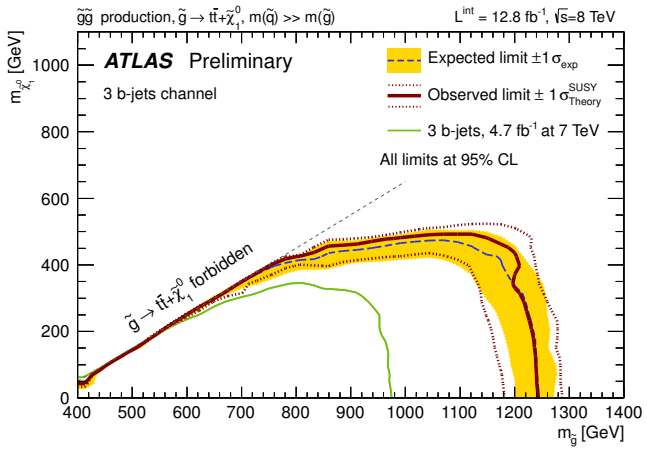
- Dominated by: $t\bar{t}$+jets
- Others: $t\bar{t} + b/b\bar{b}$, W, Z and diboson

Assume $pp \to \tilde{g}\tilde{g}$

$\tilde{g} \to b\tilde{b}\tilde{\chi}_1^0$ via off-shell sbottom

$\tilde{g} \to t\tilde{t}\tilde{\chi}_1^0$ via off-shell stop

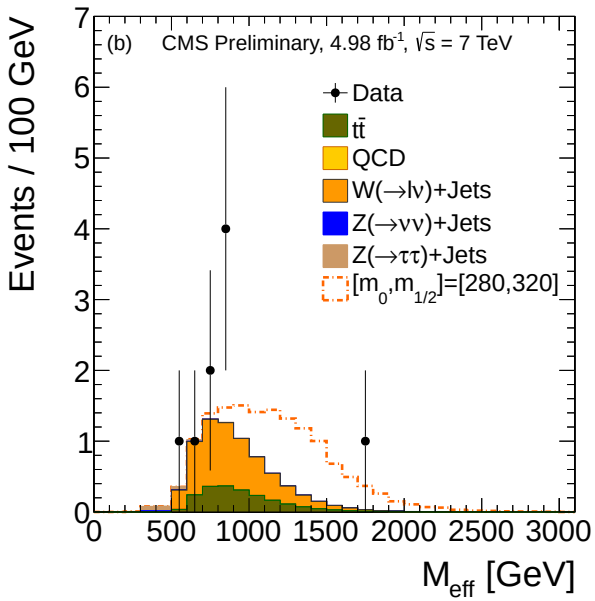


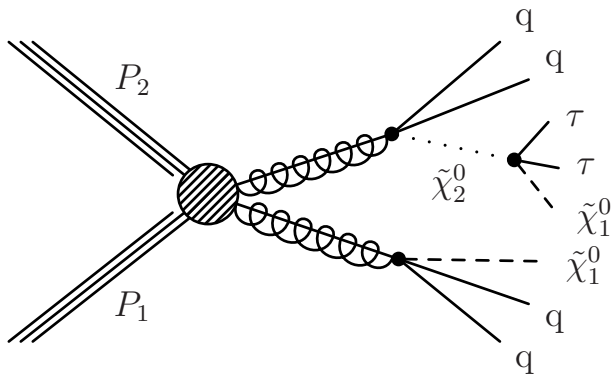


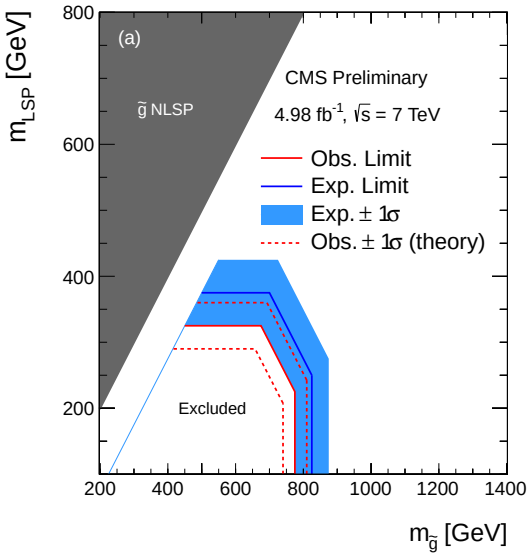
CMS search for τ-leptons in all hadronic events

7 TeV 4.98 fb^{-1} CMS PAS SUS-12-004

Not just searches for light stop/bottom.
Could also be **light** $\tilde{\tau} \rightarrow \tau$ production
with jets and $E_{\mathrm{T}}^{\mathrm{miss}}$







High luminosity brings sensitivity to electroweak production...

- If coloured SUSY particles are very massive while non-coloured SUSY particles are light, weak gauginos and sleptons may dominate SUSY production at the LHC.
- Limits on $\tilde{q}$ and $\tilde{g}$ masses pushed very high
- Naturalness favours gaugino masses $\sim$ 100 GeV

Search strategy? e.g.

Targeted Process	Signal Region
Two-lepton Final States	
$\tilde{\ell}^{\pm}\tilde{\ell}^{\mp} \rightarrow (\ell^{\mp}\tilde{\chi}_1^0) + (\ell^{\mp}\tilde{\chi}_1^0)$	SR-m_{T2}
$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp} \rightarrow (\ell^{\mp}\nu\tilde{\chi}_1^0) + (\ell^{\mp}\nu\tilde{\chi}_1^0)$	SR-m_{T2}, SR-OSjveto
$\tilde{\chi}_2^0\tilde{\chi}_i \rightarrow (\ell^{\mp}\ell^{\mp}\tilde{\chi}_1^0) + (q\bar{q}^{'}\tilde{\chi}_1^0)$	SR-2jets
Three-lepton Final States	
$\tilde{\chi}_2^0\tilde{\chi}_1^{\pm} \rightarrow (\ell^{\mp}\ell^{\mp}\tilde{\chi}_1^0) + (\ell^{\mp}\nu\tilde{\chi}_1^0)$	SR-OSjveto, SR-SSjveto

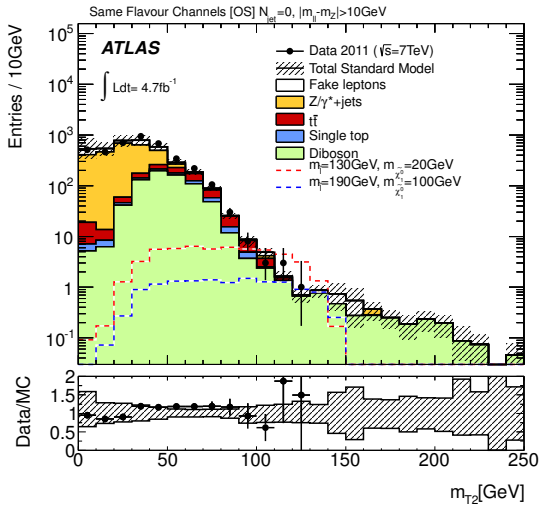
Table: Decay modes targeted by each SR in arXiv:1208.2884, $\tilde{\chi}_i$ denotes either a chargino or a neutralino. In decays producing three real leptons, one must be mis-reconstructed or fall outside the acceptance of the detector.

ATLAS direct slepton and gaugino production

7 TeV 4.7 fb^{-1} arXiv:1208.2884

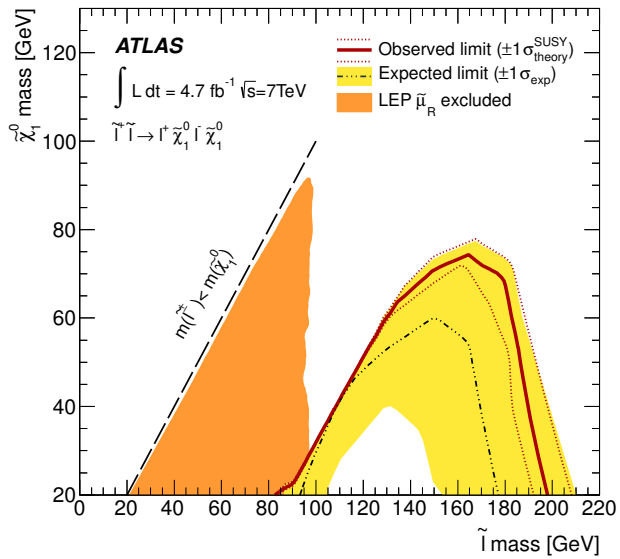
Search for $\tilde{l}^{\pm}\tilde{l}^{\mp}$ pair-production and $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$, $\tilde{\chi}_2^0\tilde{\chi}_1^{\pm}$

2 lepton final state

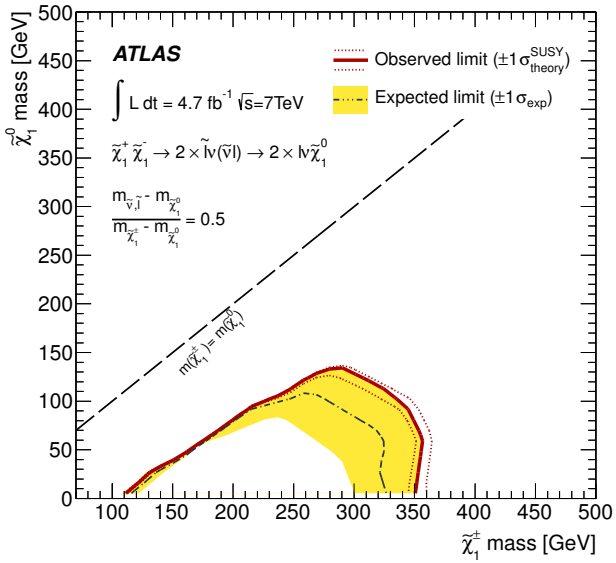


High-m_{T2} brings particular sensitivity to $\tilde{l}$ and $\tilde{\chi}_1^{\pm}$ pair production

Limits on direct $\tilde{l}$ production.



Sensitivity to weak production processes limited by the lower cross-section.

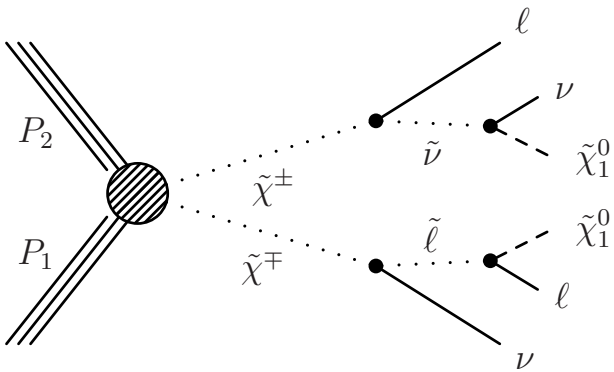


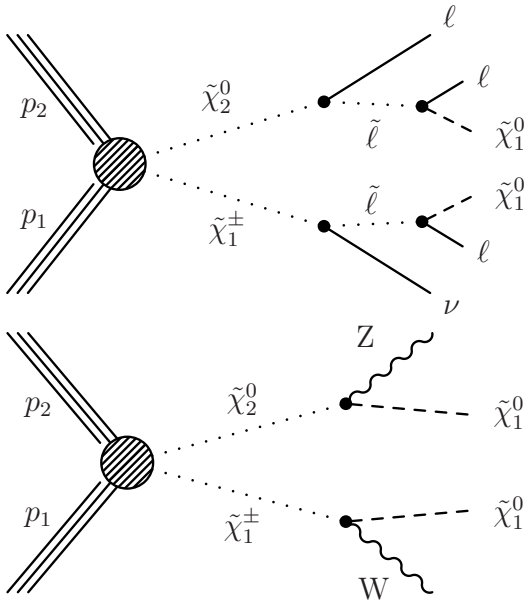
See: $\geq$ 3 leptons at ATLAS 7 TeV (arXiv:1208.3144), 3 leptons at ATLAS 8 TeV (ATLAS-CONF-2012-154)

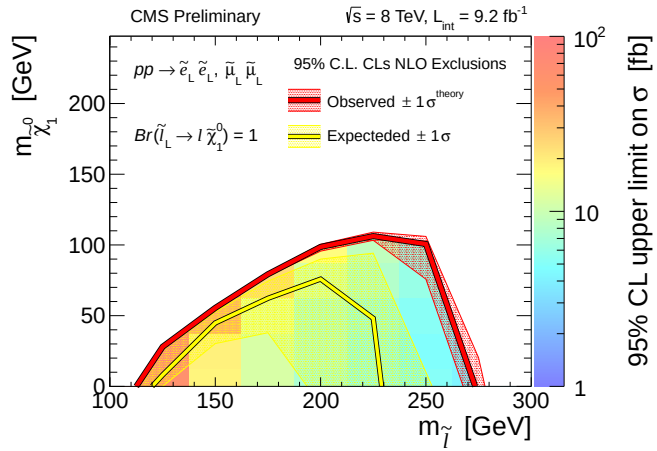
CMS direct slepton and gaugino production

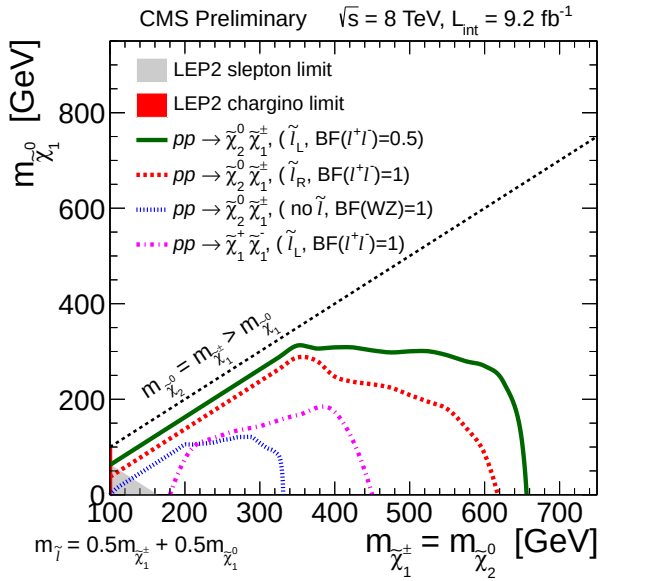
8 TeV 9.2 fb^{-1} CMS SUS-12-028 New at HCP

- 3 leptons, 4 leptons, two SS leptons, two OS-SF leptons...









RPV, Long-lived Particles?

If R-parity isn't conserved - ...

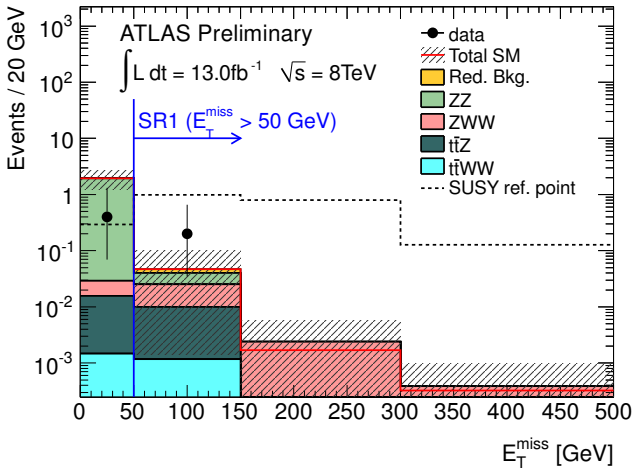
- lower $E_{\mathrm{T}}^{\mathrm{miss}}$
- SUSY particles decaying to SM particles
- possibilities for different final states

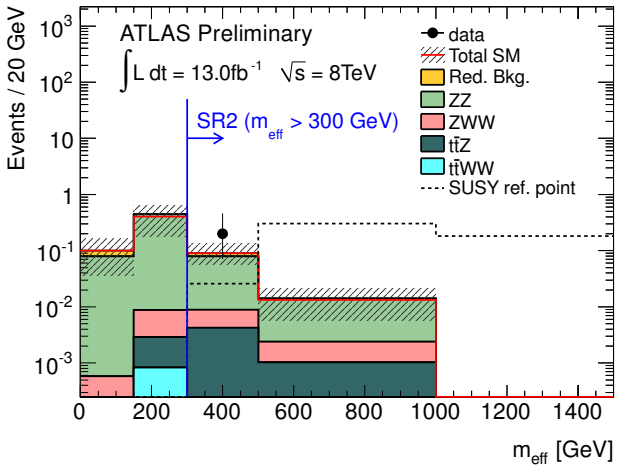
ATLAS 4 Lepton RPV Search

8 TeV 13.0 fb^{-1} ATLAS-CONF-2012-153 New at HCP

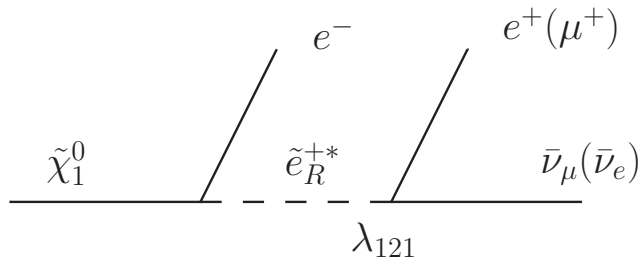
- **Search for RPV SUSY with four or more leptons (electrons or muons)**
  Non-zero λ_{121} coupling
- Irreducible (four real, isolated leptons) and reducible (at least one fake) background components
- *ZZ*, *WZ* and $t\bar{t}$ dominate in the SR

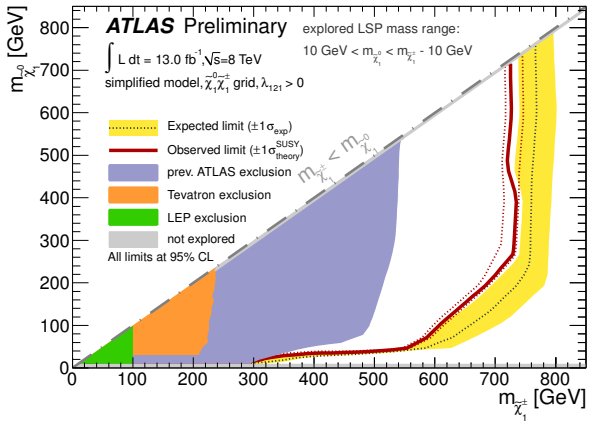
Moderate $E_{\mathrm{T}}^{\mathrm{miss}}$, high m_{eff}





Simplified model interpretation
Pair produce wino-like charginos ($\tilde{\chi}_1^{\pm} \rightarrow W\tilde{\chi}_1^0$)



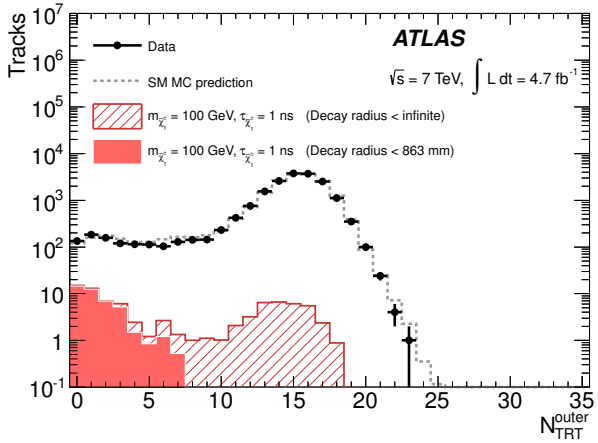


ATLAS Disappearing Track

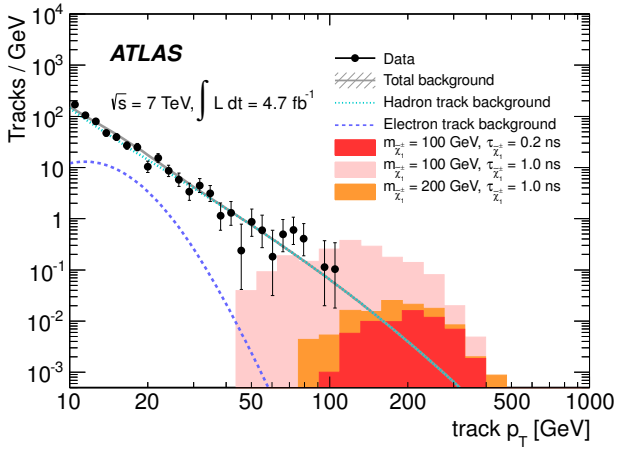
7 TeV 4.7 fb^{-1} arXiv:1210.2852

- **Direct chargino pair production in anomaly mediated SUSY breaking**
  Chargino lifetime long enough to be detected in the tracking detectors
- search for tracks with few associated hits in the outer region of the tracker
- analyse the p_T spectrum of such tracks

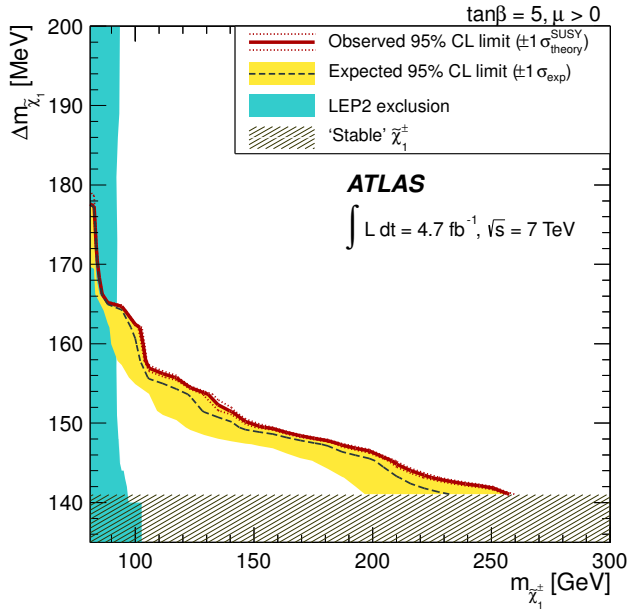
No. outer hits in TRT for data and signal:



p_T distribution of candidate tracks:



Limits in AMSB model parameter space

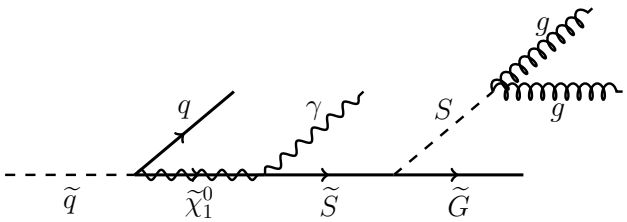


Others?

- If SUSY particle masses are close together, reduce the p_{T} in the final states
- Multiple jets, but little $E_{\mathrm{T}}^{\mathrm{miss}}$
- Compressed spectra, stealth SUSY...

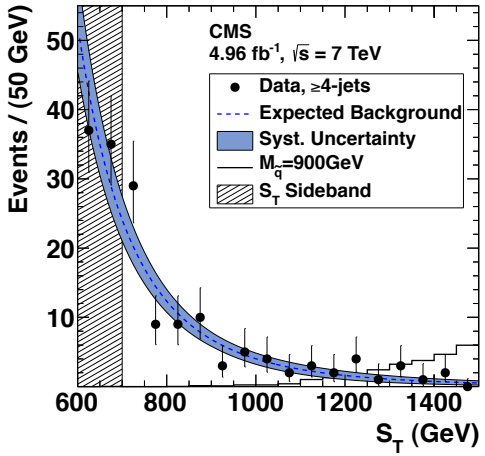
CMS Stealth SUSY

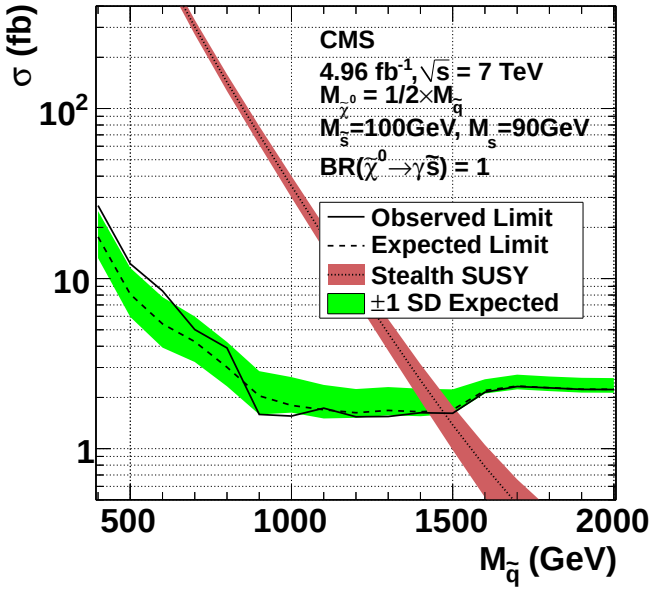
7 TeV 4.98 fb^{-1} arXiv:1210.2052



- Low $E_{\mathrm{T}}^{\mathrm{miss}}$, many energetic final-state objects
- Light "hidden sector" particles can mediate decays to many low p_{T} objects
- Very rich phenomenology

Search in events with $\gamma\gamma+ \leq 4$ jets, and large total energy
(no requirement on $E_{\mathrm{T}}^{\mathrm{miss}}$)





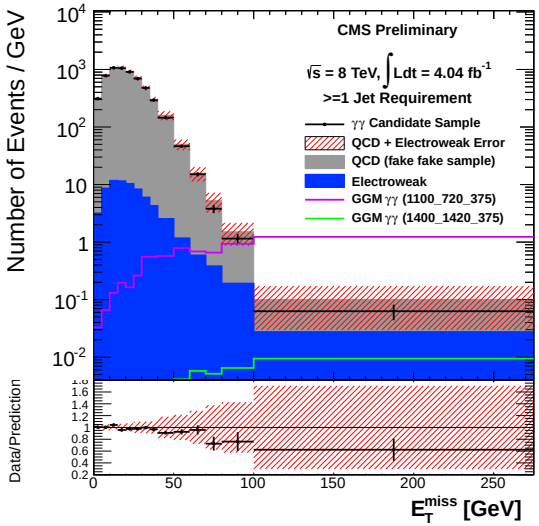
General Gauge Mediation

- The Gravitino $\tilde{G}$ is the LSP and very light
- The nature of the NLSP determines the main signature of the decay
  1. Stau $\rightarrow \tau + E_{\mathrm{T}}^{\mathrm{miss}}$
  2. Bino $\rightarrow \gamma + E_{\mathrm{T}}^{\mathrm{miss}}$
  3. Wino $\rightarrow W + E_{\mathrm{T}}^{\mathrm{miss}}$
  4. Higgsino $\rightarrow H/Z + E_{\mathrm{T}}^{\mathrm{miss}}$
- Gives lots of interesting things to look for: τs, γs....

CMS GGM $\gamma(\gamma) + \text{jet}(s) + E_{\text{T}}^{\text{miss}}$

8 TeV 4.04 fb^{-1} CMS PAS SUS-12-018

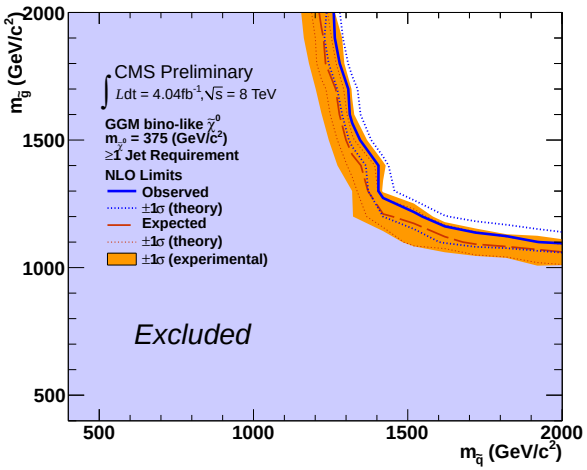
- Addresses a **General Gauge Mediation scenario**
- $\tilde{G}$ LSP, $\tilde{\chi}_1^0$ NLSP ($\tilde{\chi}_1^{\pm}$ co-NLSP possible)
- Looking for $\gamma\gamma + \text{jet} + E_{\text{T}}^{\text{miss}}$ or $\gamma + 2\text{jet} + E_{\text{T}}^{\text{miss}}$



Backgrounds:

- Mis-measurement of $E_{\text{T}}^{\text{miss}}$ in QCD processes, multijets with jets mimicking γ
- True $E_{\text{T}}^{\text{miss}}$ events with real or fake γ, and a W boson decaying to an e mis-identified as a γ.

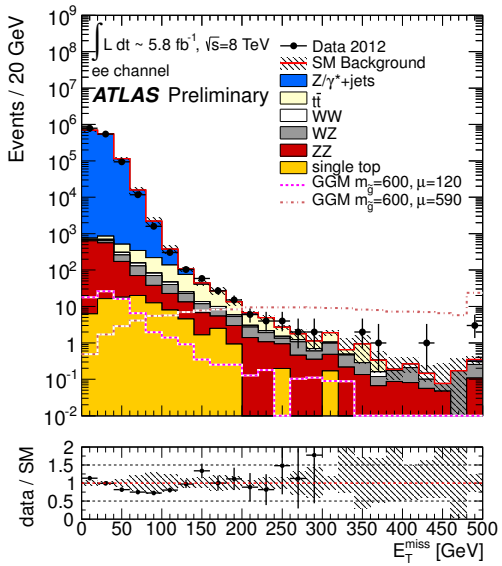
NLSP bino or wino-like
$\tilde{\chi}_1^0 \to \gamma\tilde{G}$
$\tilde{\chi}_1^0 \to Z\tilde{G}$
(with a wino-like NLSP, signal is suppressed by chargino decays without photons)

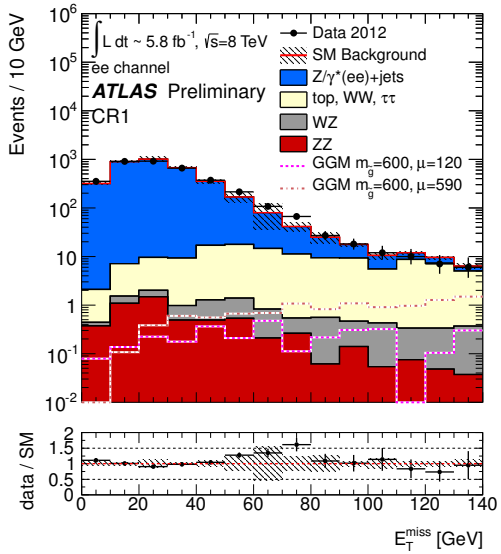


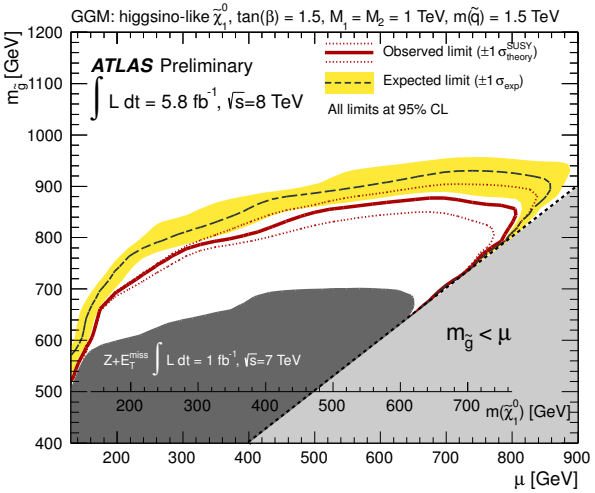
ATLAS Z+MET

8 TeV 5.8 fb^{-1} ATLAS-CONF-2012-152 **New at HCP**

- **General Gauge Mediation scenario**
- $\tilde{G}$ LSP, NLSP is a Higgsino-like neutralino
- $\tilde{\chi}_1^0 \to h\tilde{G}$ or $\tilde{\chi}_1^0 \to Z\tilde{G}$
- Search for events with at least one Z decay into OS ℓ pairs and $E_{\mathrm{T}}^{\mathrm{miss}}$

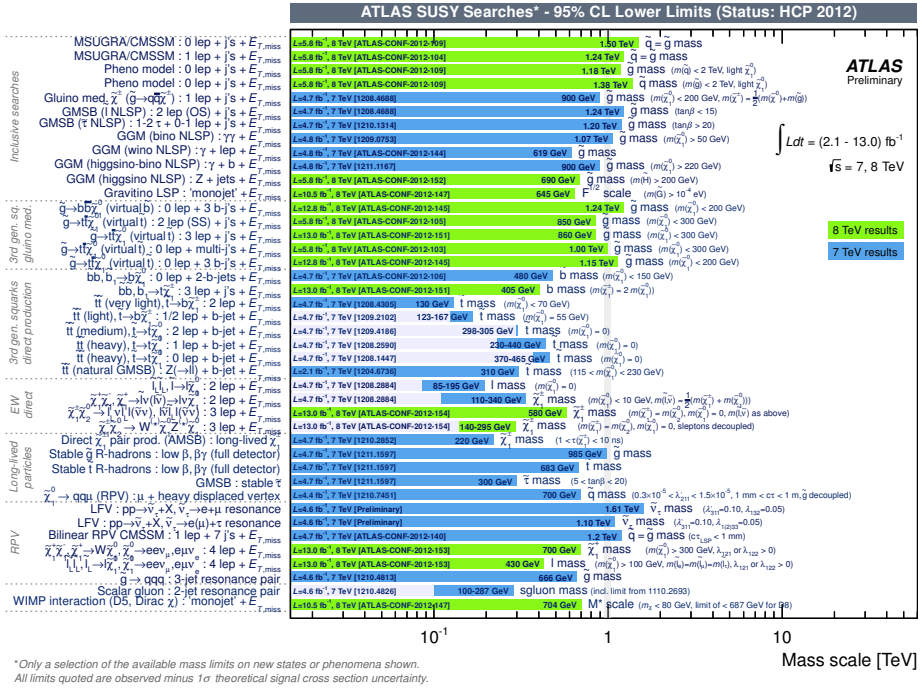






A Summary?

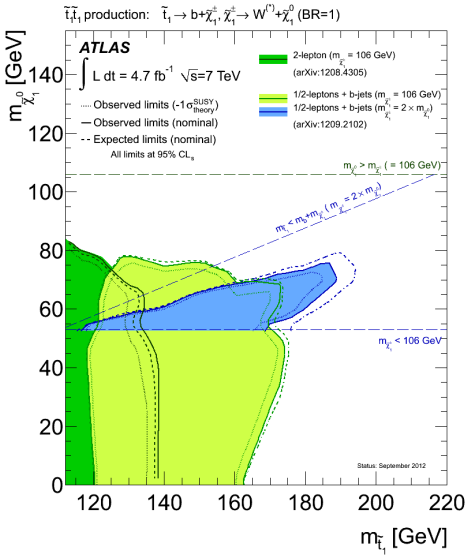
Summary Plots: ATLAS

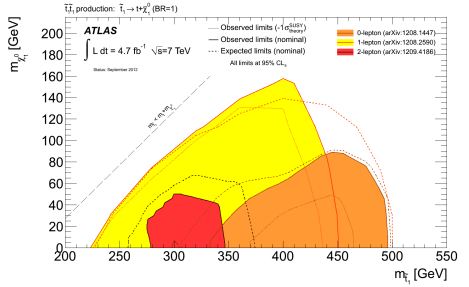


*Only a selection of the available mass limits on new states or phenomena shown.
All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Mass reach of ATLAS SUSY searches

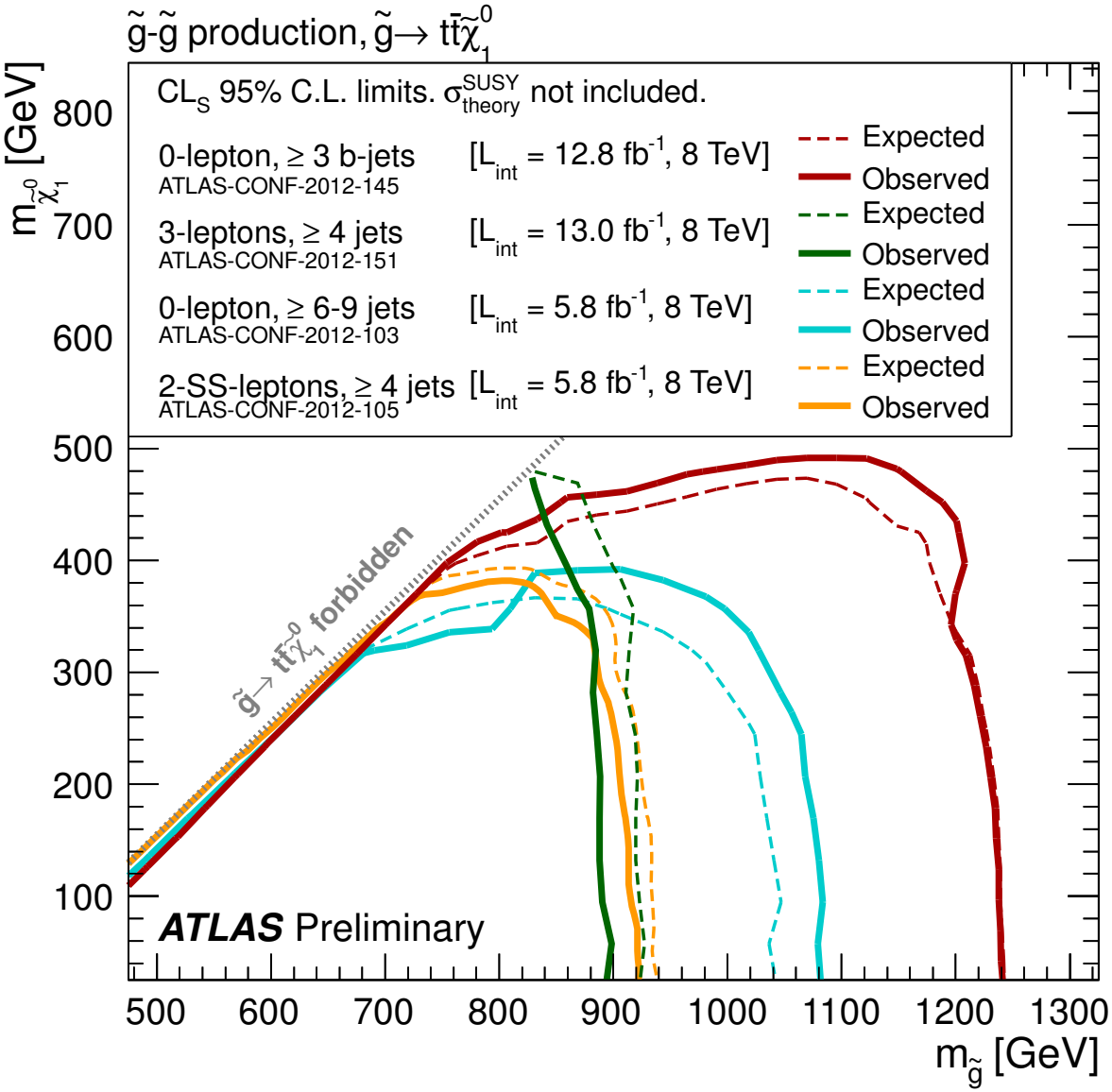
Updated for HCP



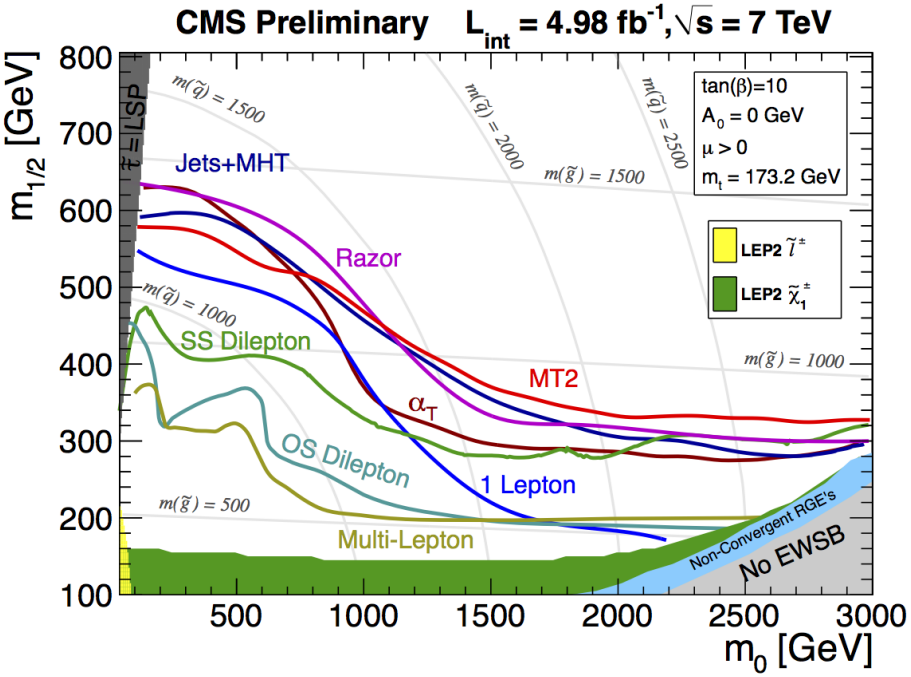


Summary of ATLAS dedicated searches for stop production

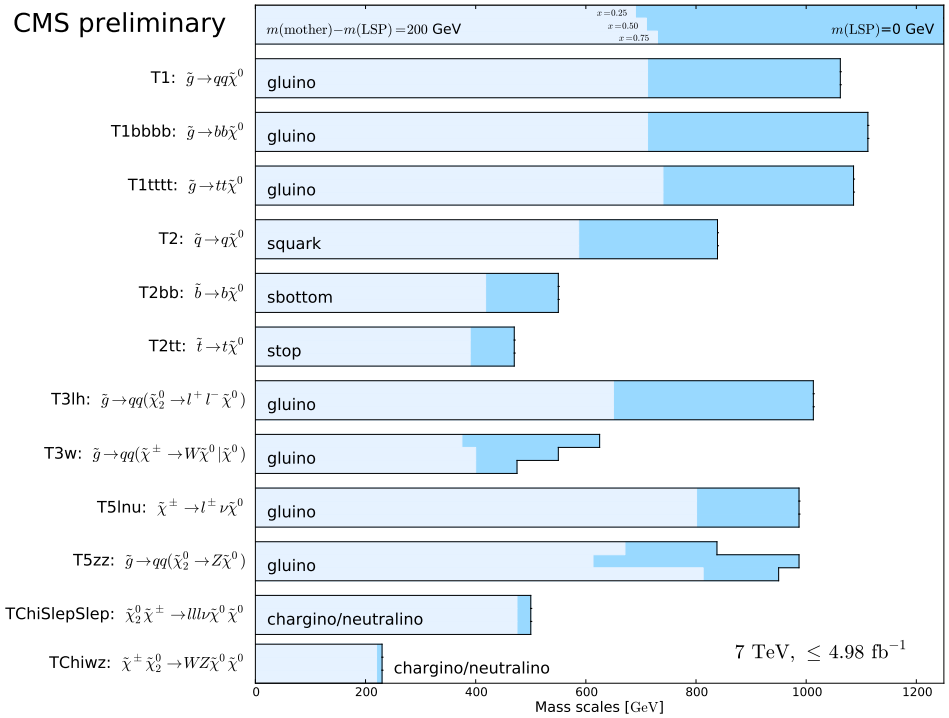
Summary Plots: ATLAS New at HCP



Summary Plots: CMS



Observed limits from several 2011 CMS SUSY searches plotted in the CMSSM (m0,m1/2) plane



Range of excluded mass scale in Simplified Model Spectra from several 2011 CMS SUSY searches: best analysis result per topology
see CMS SUS-11-016 for more detail

Conclusions

- ATLAS and CMS searches have **left little room for SUSY** in the reach of the existing data
- ATLAS and CMS have **set bounds at the TeV-scale on gluino and squark production**
- Reaching **sensitivity to sub-femtobarn cross-sections**
- 2011 and 2012 searches constrain squark and gluino masses uniformly in multiple model frameworks
- Plausible **"natural" scenarios are still not ruled out**: stop and/or RPV scenarios have few(er) constraints
- But **allowed phase space is certainly getting squeezed**
- **Higgs-like boson discovered, but at high end of (MSSM) preference**
- Need **heavy squarks, large stop mixing or beyond MSSM**
- This talk has illustrated a variety of results - covering all kinds of signatures
- Still no sign of SUSY... (but the full 2012 dataset is still to be analysed!)