Searches for SUSY with jets + X + MET at the LHC

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on behalf of the ATLAS and CMS Collaborations

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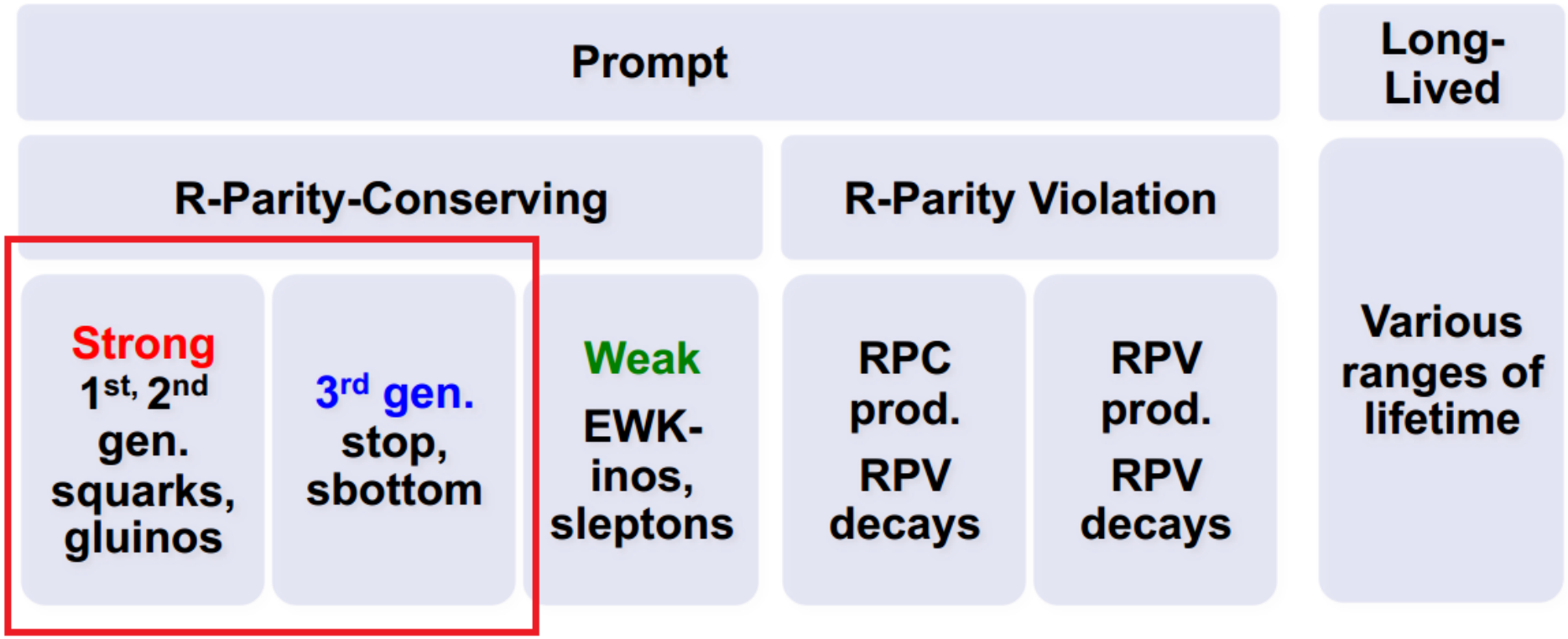
Search strategy

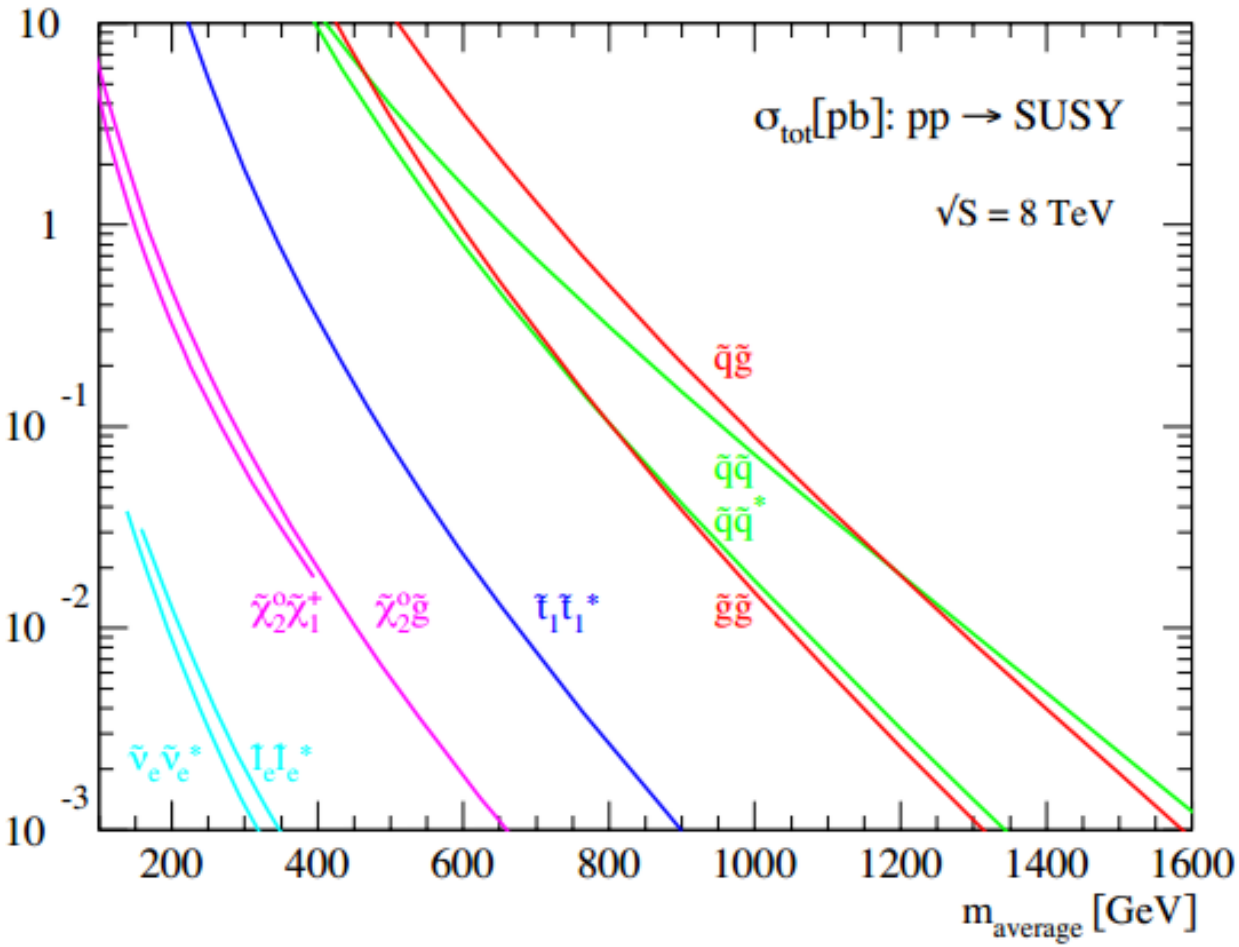


$$R = (-1)^{(L+3B+2J)}, \text{ where } \begin{cases} \text{L = leptonic number} \\ \text{B = baryonic number} \\ \text{J = spin} \end{cases}$$

Final states with jets + $E_{\mathrm{T}}^{\mathrm{miss}}$ (+ leptons) $\Rightarrow$ R-parity conserving models

- $\{\tilde{q}\tilde{q}, \tilde{g}\tilde{g}, \tilde{q}\tilde{g}\}$
- $\tilde{\chi}_1^0$ is the LSP $\Rightarrow E_{\mathrm{T}}^{\mathrm{miss}}$

Production of SUSY particles at the LHC



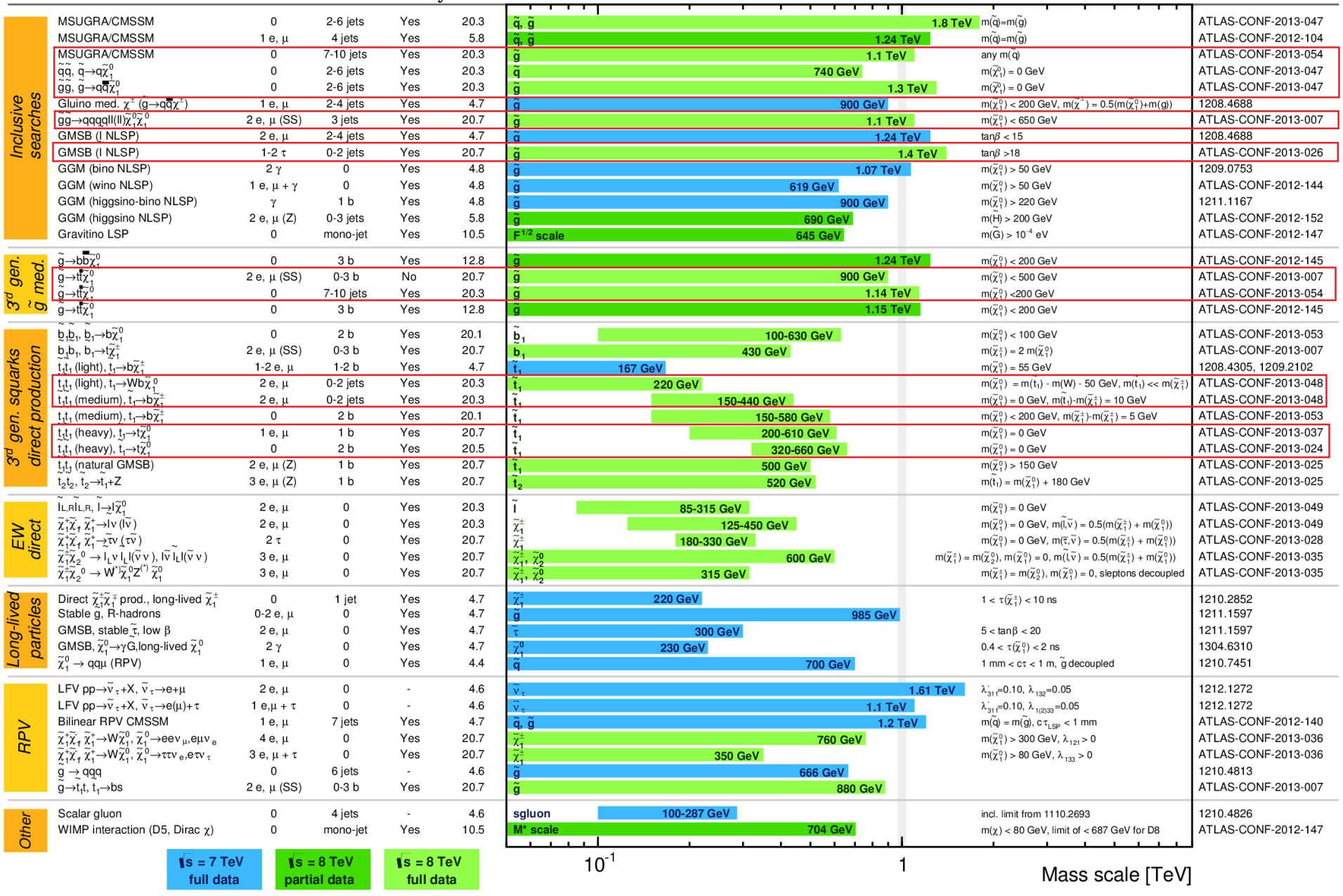
- The production cross-section at the LHC for 8 TeV versus the mass of the different types of SUSY particles

ATLAS SUSY Searches* - 95% CL Lower Limits

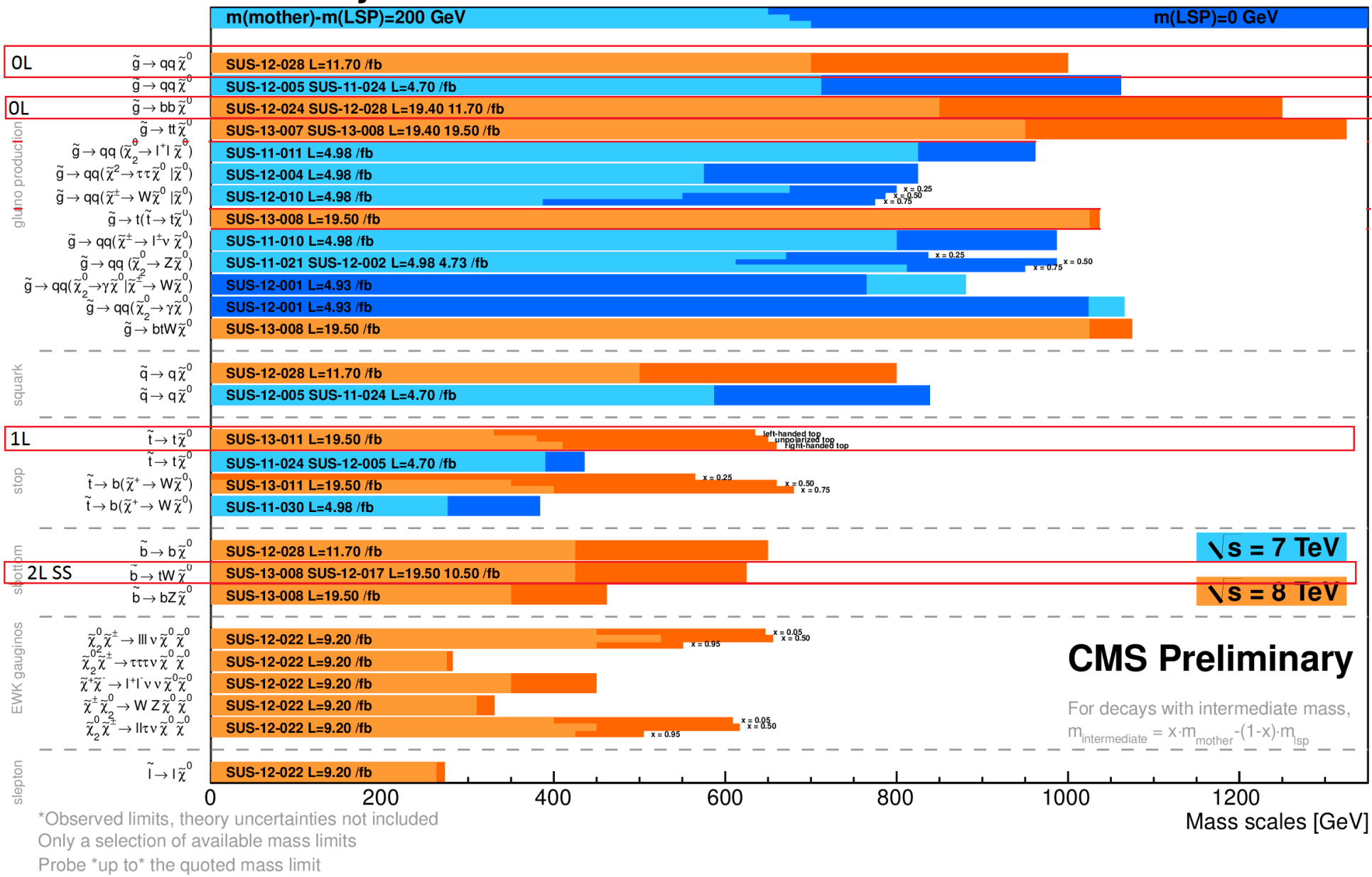
Status: LHCP 2013

ATLAS Preliminary

$\int Ldt$ = (4.4 - 20.7) fb^{-1} $\sqrt{s}$ = 7, 8 TeV



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



- CMS-PAS-SUS-018: single and di-photon+jets+MET GMSB analysis

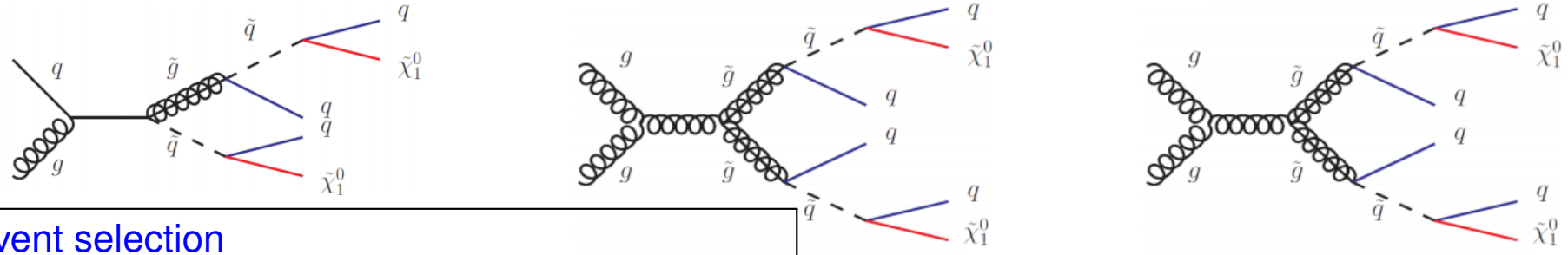
Strong production of 1st generation squarks and gluinos

- ▷ 0 lepton, jets, MET
- ▷ 2 same-sign leptons, jets, MET

ATLAS 0-lepton, jets, MET

ATLAS-CONF-2013-047

Targeting models where squarks and gluinos can be produced in pairs and can decay through $\tilde{q} \to q\tilde{\chi}_1^0$ and $\tilde{g} \to q\bar{q}\tilde{\chi}_1^0$; $\tilde{\chi}_1^0$ is the LSP $\Rightarrow E_{\mathrm{T}}^{\mathrm{miss}}$



Event selection

reject events with hight pT leptons (e or μ)
MET > 160 GeV
pT(jet1) > 130 GeV
pT(jet2) > 60 GeV

- discriminant signal / SM backgrounds
  $m_{\mathrm{eff}}(\mathrm{incl})$
- multijet background
  $E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}(Nj)$
  $m_{\mathrm{eff}}(Nj)$
  $\Delta\phi(\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}, \mathrm{jet}_i)_{\mathrm{min}}$

$m_{\mathrm{eff}}(\mathrm{incl}) = E_{\mathrm{T}}^{\mathrm{miss}} + \sum p_{\mathrm{T}}^{\mathrm{jet,\ pT > 40\ GeV}}$
$m_{\mathrm{eff}}(Nj)$ computed with N leading jets
$\Rightarrow$ 5 inclusive channels with at least 2-6 jets and different requirements on $E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}$ and $m_{\mathrm{eff}}^{\mathrm{inc}}$

Backgrounds

- Z($\to \nu\bar{\nu}$)+jets $\Rightarrow$ large $E_{\mathrm{T}}^{\mathrm{miss}}$
- W+jets

$$\begin{cases} W \to \tau + \nu \\ W \to e(\mu) + \nu \text{ with no reco } e \text{ or } \mu \end{cases}$$

- $t\bar{t}$ semileptonic decays
  $t\bar{t} \to b\bar{b}\tau\nu qq'$ with τ decaying to hadrons
- single top
- multiple jets $\Rightarrow$ data-driven

CMS 0-lepton, jets, α_T

CMS-SUS-12-028

Selection criteria (signal region)

- veto events with high pT leptons (e or μ)
- veto events with hight pT photons to ensure an all-jet final-state
- jets: pt>50 GeV; the 2 highest Et jets > 100 GeV
- $\mathbf{H_T} = \sum \mathrm{p}_\mathrm{T}^{jet} > 275$ GeV
- Multijet background
  $\alpha_T > 0.55$
  (reject multijet events without significant MET, or with MET mismeasurement, while retaining good sensitivity to new physics)
- signal region divided into bins in H_T
- events are further cathegorised according to the:
  jet multiplicity: 2-3 jets or >=4 jets
  b-jet multiplicity: 0,1,2,3 or >=4

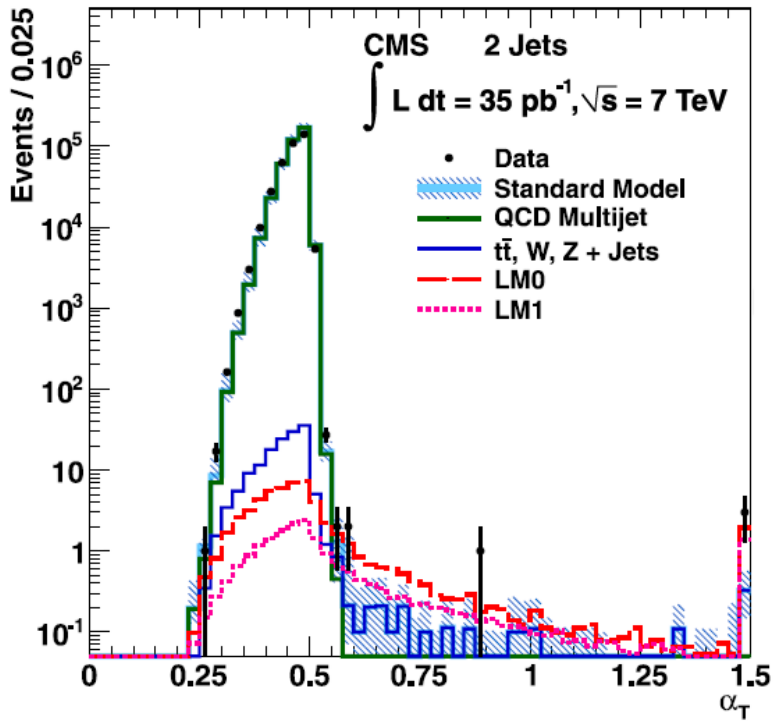
Dijet events: $\alpha_T = \sum \frac{E_T^{j2}}{M_T}$

$M_T = \sqrt{(\sum E_T^{j_i})^2 - (\sum p_x^{j_i})^2 - (\sum p_y^{j_i})^2}$

Backgrounds

- W+jets, Z+jets
- semileptonic $t\bar{t}$
- multijet

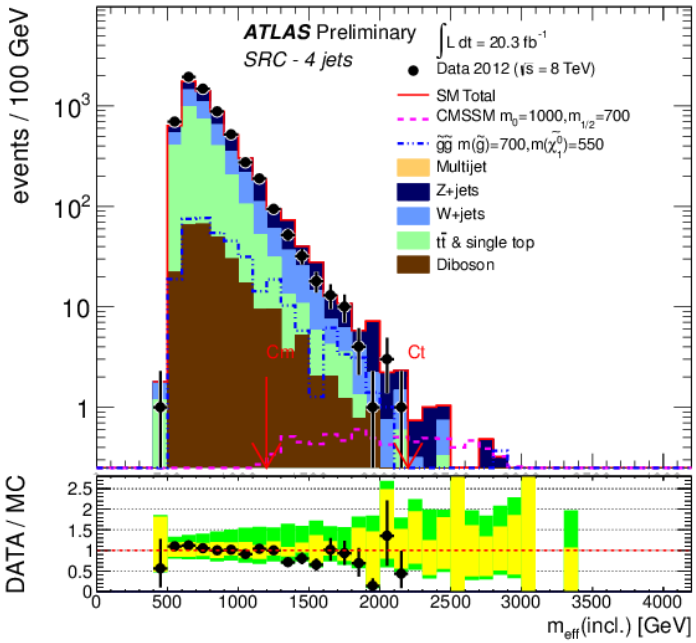
Phys. Lett. B 698 (2011) (CMS SUSY 0L)



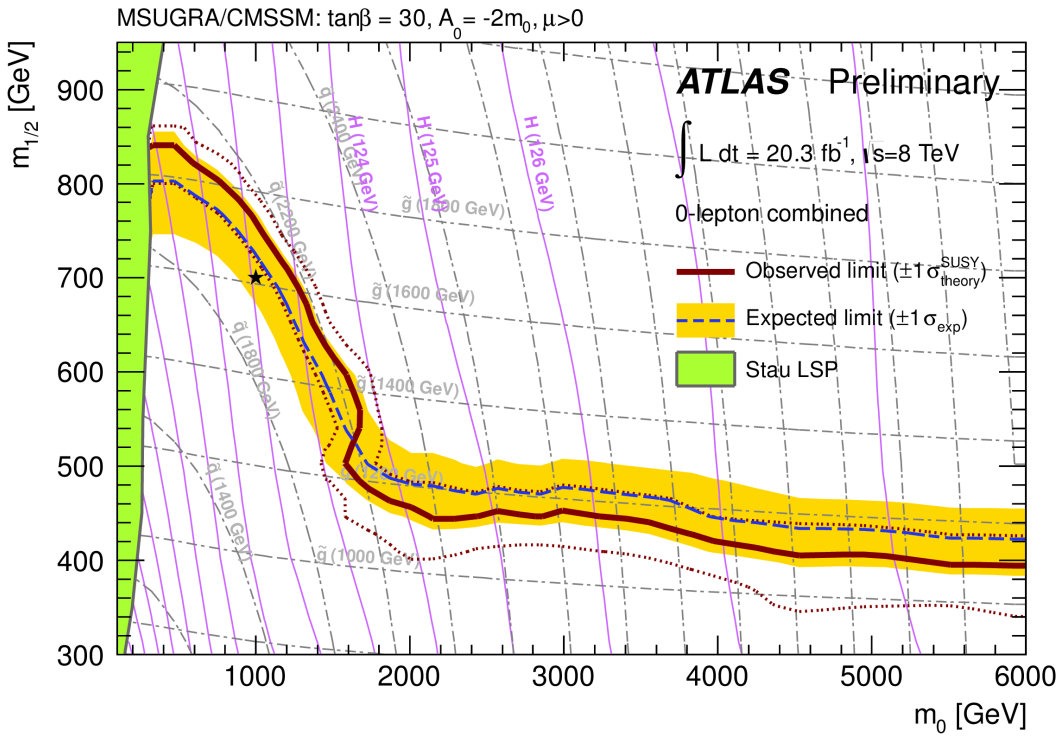
0-lepton, jets: Results

ATLAS-CONF-2013-047

$m_{\text{eff}}^{\text{incl}}$ before the final cut



Signal region	Expected	Observed
A-loose	4700 ± 500	5333
A-medium	122 ± 18	135
B-medium	33 ± 7	29
B-tight	2.4 ± 1.4	4
C-medium	210 ± 40	228
C-tight	1.6 ± 1.4	0
D	15 ± 5	18
E-loose	113 ± 21	166
E-medium	30 ± 8	41
E-tight	2.9 ± 1.8	5

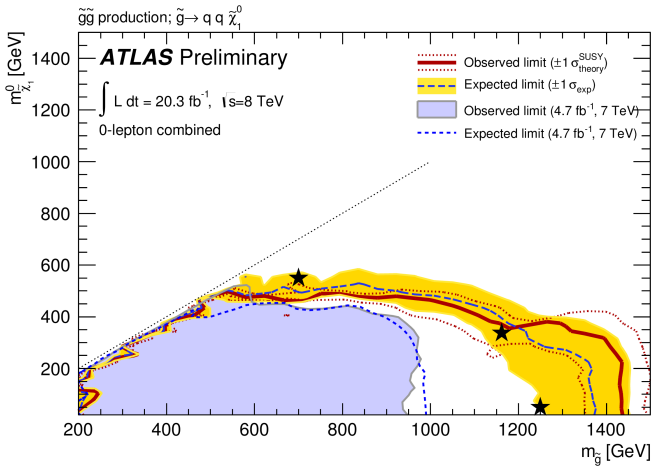


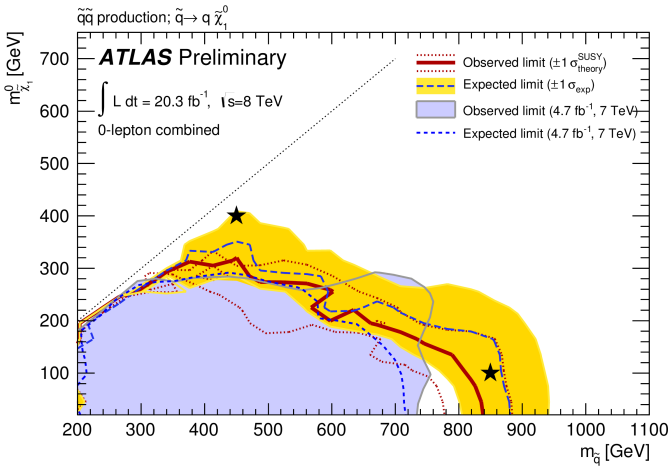
MSUGRA/CMSSM model with $\tan\beta = 30$, $A_0 = -2\,m_0$ and $\mu > 0$

- values of $m_{1/2} < 340$ GeV are excluded at the 95% confidence level for $m_0 < 7$ TeV

- Good agreement between the number of events observed in the data and the number of events from MC sources

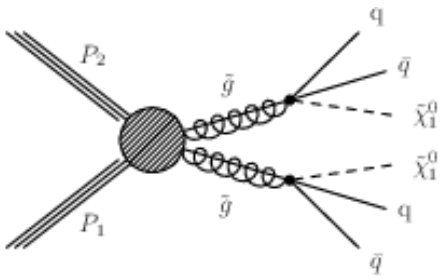
0-lepton, jets: Results

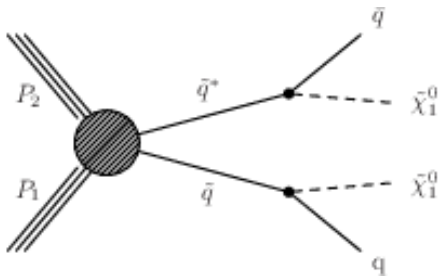


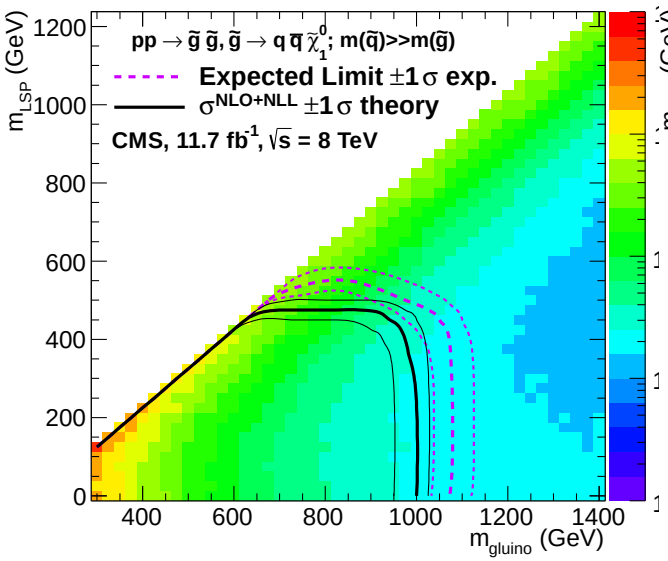


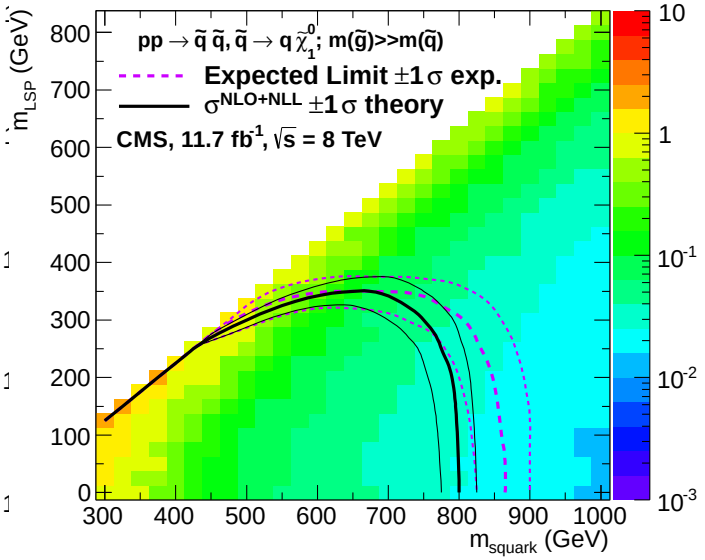
ATLAS-CONF-2013-047

- gluino masses below 1350 GeV are excluded
- squark masses below 780 GeV are excluded









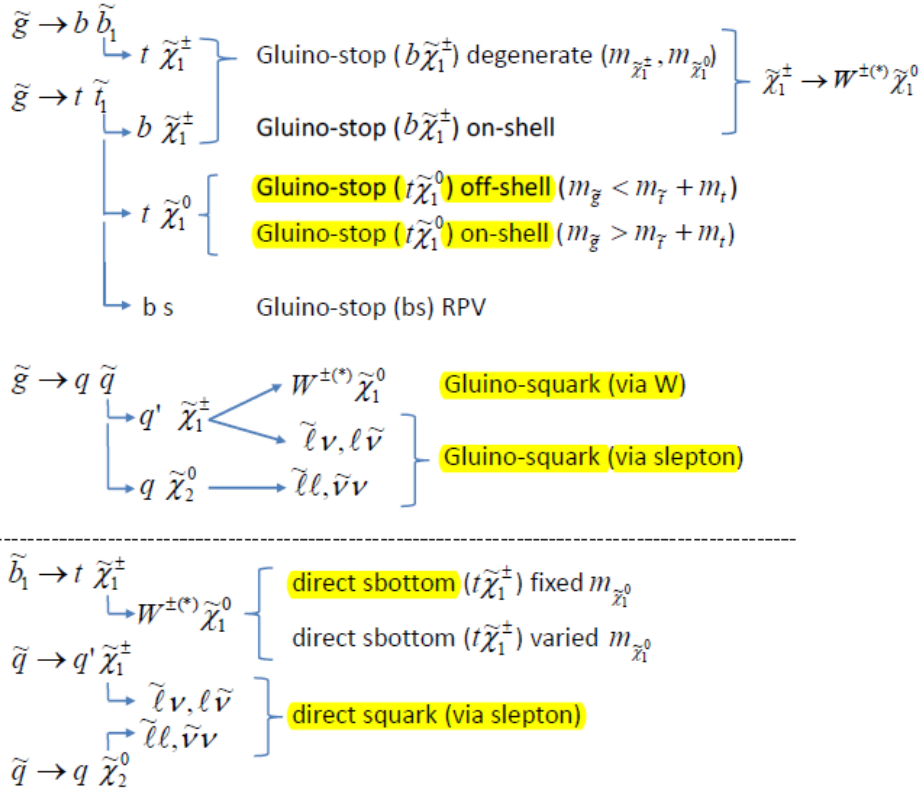
CMS-SUS-12-028

- gluino masses below 1 TeV are excluded
- squarks masses below 775 GeV are excluded

Two same-sign leptons

ATLAS-CONF-2013-007

- Search for same-sign lepton pairs (ee, $e\mu$, $\mu\mu$) in final states with MET, b-jets, multiple jets
- same-sign leptons: gluino-mediated top squark production $\rightarrow$ 4 top quarks in final states for $t\bar{t}$ semileptonic decay
- generic analysis that targets many different models with strong pair production: $pp \rightarrow \tilde{g}\tilde{g}, \tilde{q}\bar{\tilde{q}}, \tilde{b}\bar{\tilde{b}}$



Baseline selection

- same-sign leading leptons

Signal regions

SR0b	SR1b	SR2b
(direct squark)	(majority of models)	
b-jet veto	$\geq$ 1 b-jet	$\geq$ 3 b-jets
>=3 jets	>= 3 jets	>= 4 jets

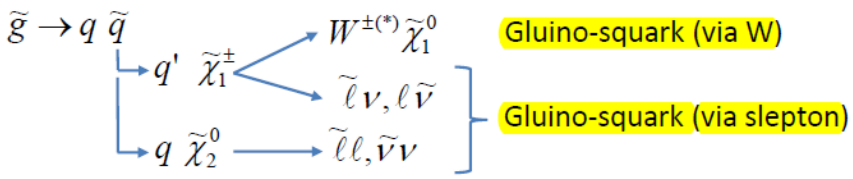
- $E_{\mathrm{T}}^{\mathrm{miss}}$
- $m_{\mathrm{eff}} = p_{\mathrm{T}}^{l1} + p_{\mathrm{T}}^{l2} + \sum p_{\mathrm{T}}^{jet} + E_{\mathrm{T}}^{\mathrm{miss}}$
- $m_{\mathrm{T}} = \sqrt{p_{\mathrm{T}}^{l1}\, E_{\mathrm{T}}^{\mathrm{miss}} (1 - \cos[\Delta\Phi(l, E_{\mathrm{T}}^{\mathrm{miss}})])}$

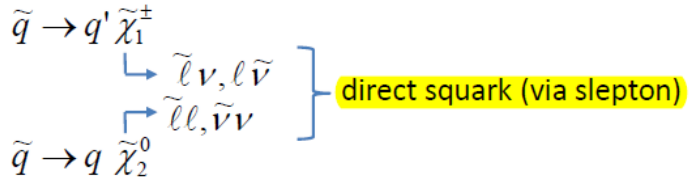
Backgrounds

- very low backgrounds
- W/Z decaying leptonically + $t\bar{t}$ where at least one top decays leptonically
- diboson background + jets
- charge mismeasurement: OS leptons $\Rightarrow$misidentified charge due to the radion of a hard photon followed by asymmetric conversion
- fake leptons

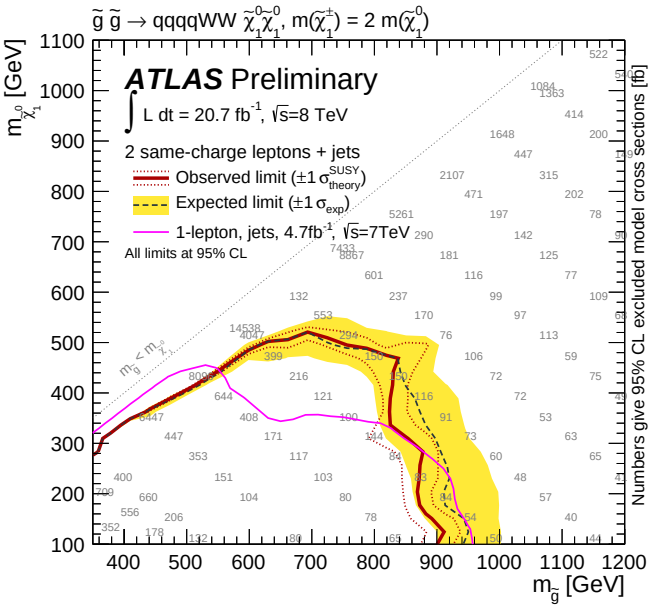
Two same-sign leptons

ATLAS-CONF-2013-007

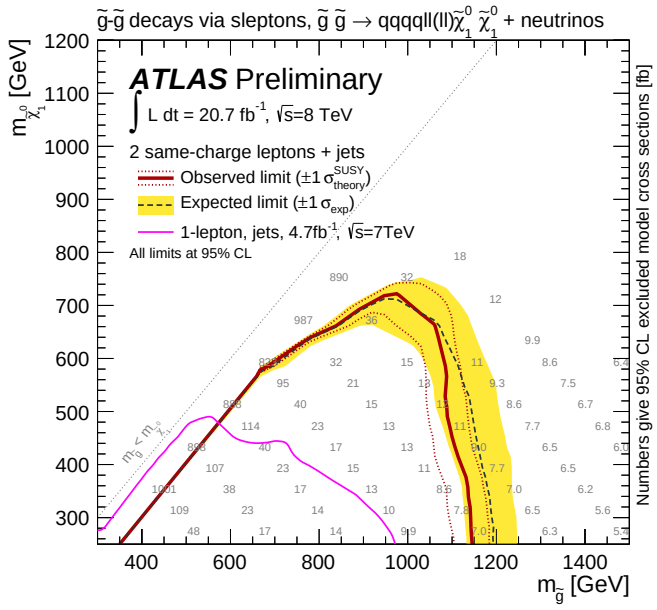




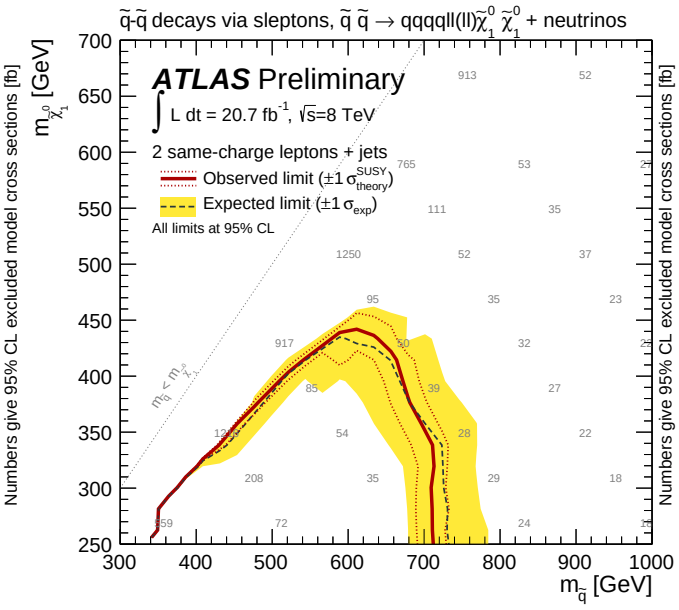
Gluino-squark (via W)



Gluino-squark (via slepton)



Direct-squark (via slepton)



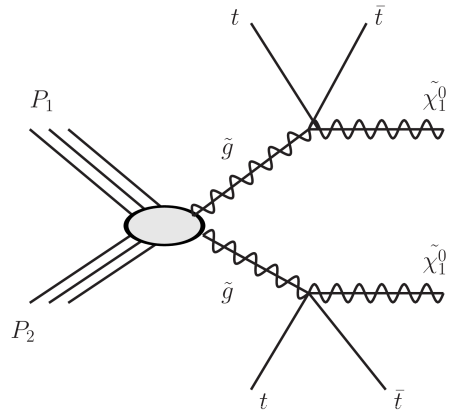
Gluino-mediated production of 3rd generation squarks

- ▷ 0-lepton, jets, MET
- ▷ 2 same-sign leptons, jets, MET

ATLAS 0-lepton, multijets, b-jets, MET

▷ targeting models where $\tilde{g} \to \tilde{t} + \bar{t} \to t + \bar{t} + \tilde{\chi}_1^0$
▷ final states: large number of jets + MET + no leptons

ATLAS-CONF-2013-054



Event selection

- ▷ veto events with high pT electrons or muons
- ▷ large jet multiplicity: from >=7 to >= 10

Multi-jet + flavour stream

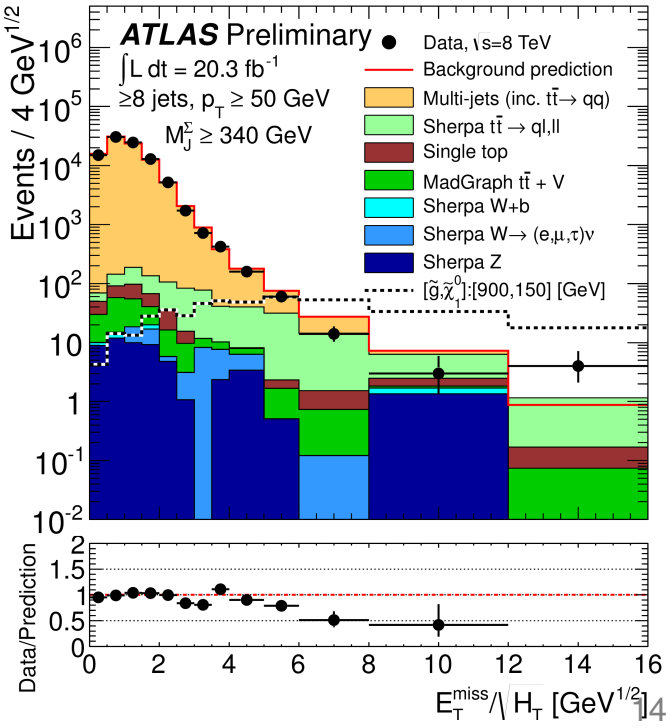
- ▷ **b-jet multiplicity** (=0, =1, >=2)

Multi-jet + M_J^{Σ} stream

- ▷ $\mathbf{M_J^{\Sigma}}$

Final cut on $E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{\mathrm{H_T}} > 4\ \mathrm{GeV}^{1/2}$
$\mathrm{H_T} = \sum p_{\mathrm{T}}^{\mathrm{jet,\ pT > 40\ GeV}}$
$\mathrm{M_J^{\Sigma}} = \sum_j m_j^{R=1.0}$ (composites jets)

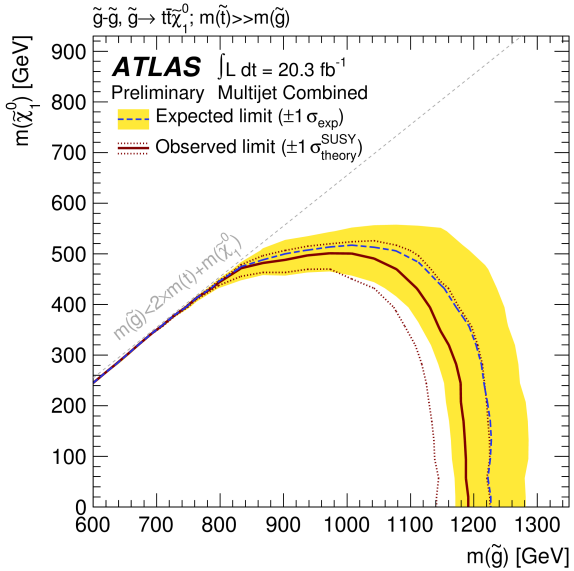
multijet + $\mathrm{M_J^{\Sigma}}$ >=8 jets SR

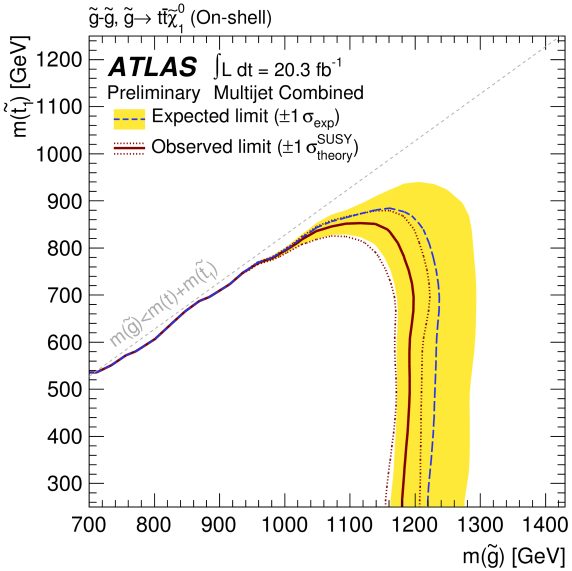


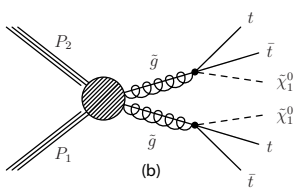
Backgrounds

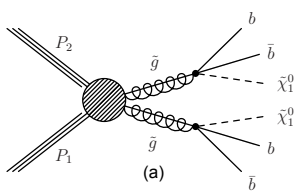
- multijets : fully hadronic decays of $t\bar{t}$ and hadronic decay of W and Z bosons + jets
- semi and fully leptonic decays of $t\bar{t}$
- leptonically decaying W or Z + jets

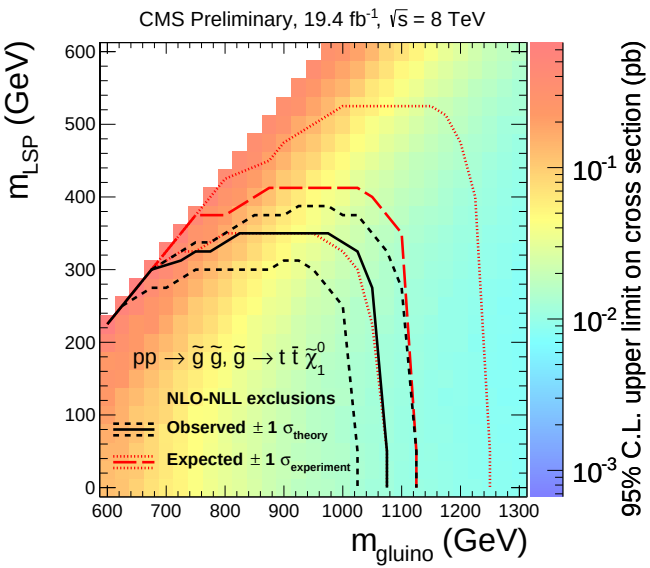
0-lepton, multijets, b-jets, MET

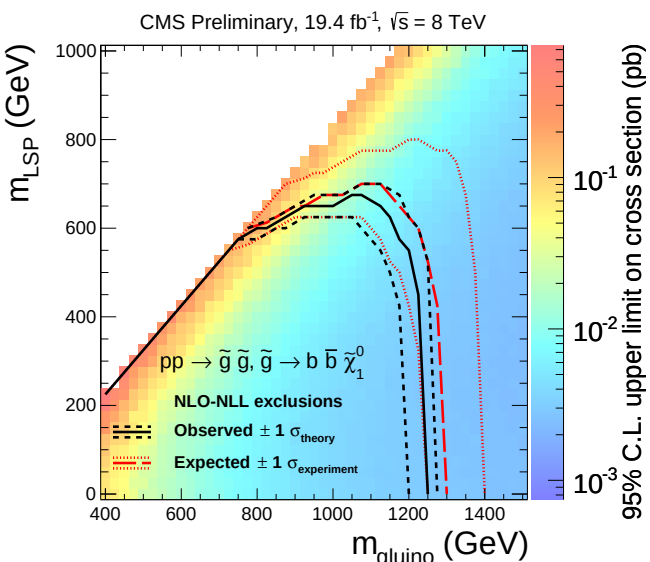












ATLAS-CONF-2013-054

- ▷ **Gluino-stop (off-shell)**

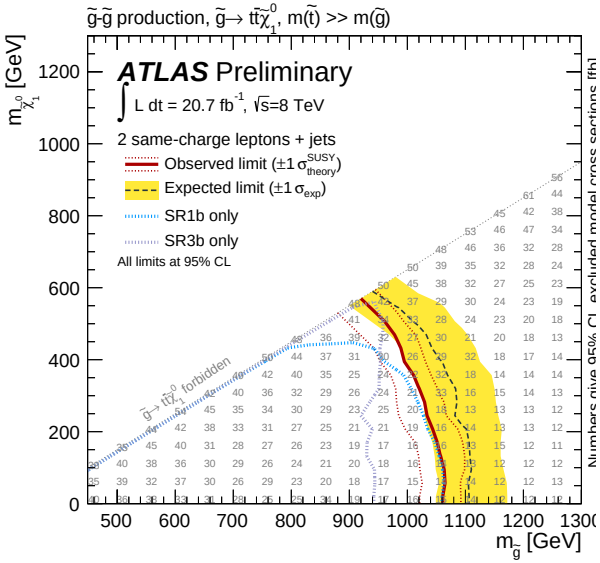
  $\tilde{g}\to t+\bar{t}+\tilde{\chi}_1^0$ with unit probability via an off-shell $\tilde{t}$

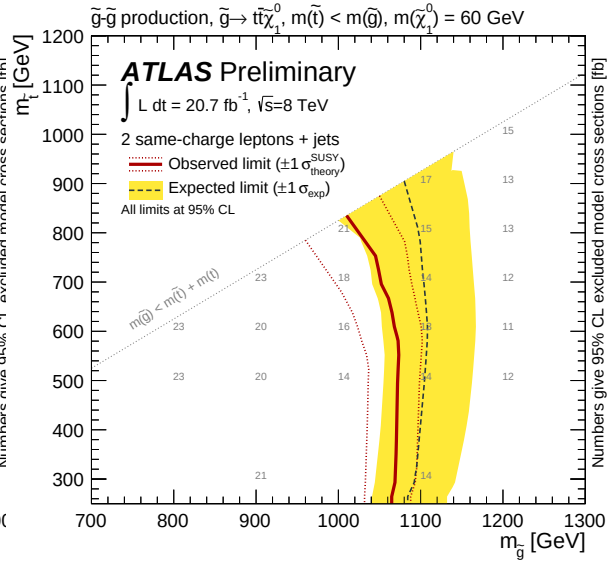
  - $m(\tilde{g})\leq 1.1$ TeV excluded for $m(\tilde{\chi}_1^0)\leq 350$ GeV
- ▷ **Gluino-stop (on-shell)** with fixed $m(\tilde{\chi}_1^0)=60$ GeV
  - $m(\tilde{g})\leq 1.1$ TeV are excluded for $m(\tilde{t})\leq 750$ GeV

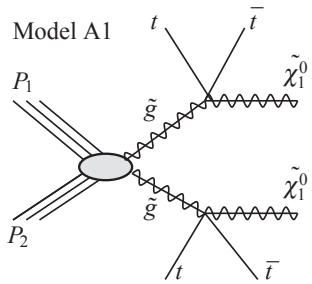
CMS-SUS-12-024

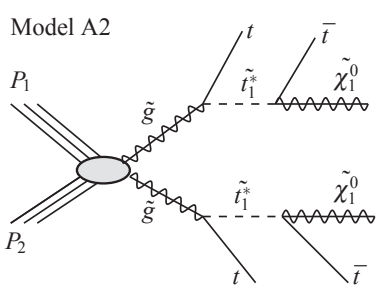
- ▷ **T1tttt scenario**
  - $m(\tilde{g})\leq 1000$ GeV excluded for LSP masses ≤ 250 GeV
- ▷ **T1bbbb scenario**
  - $m(\tilde{g})\leq 1150$ GeV excluded for LSP masses ≤ 250 GeV

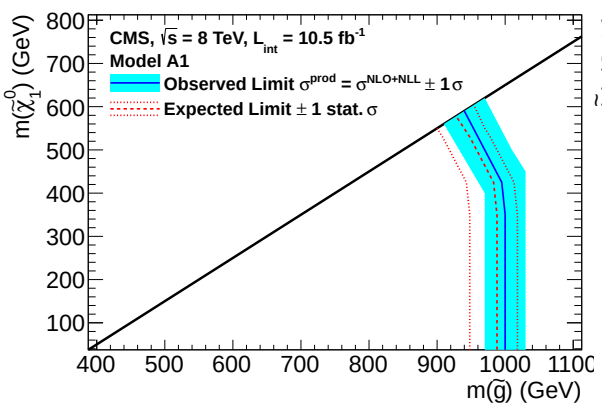
Two same-sign leptons

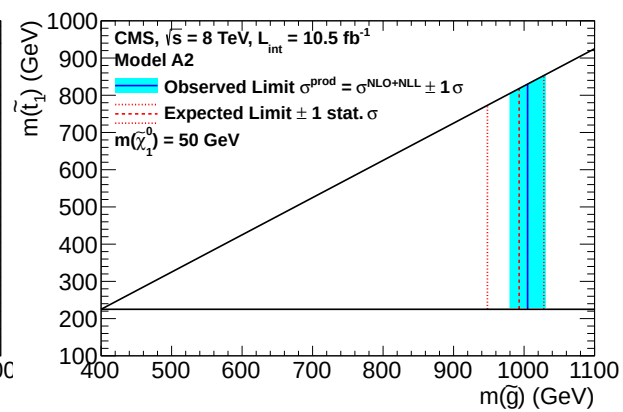












ATLAS-CONF-2013-007

- **Gluino-stop off-shell**

  gluinos are excluded up to masses of 900-1020 GeV for LSP masses below 550 GeV

- **Gluino-stop on-shell**

  gluinos are excluded up to masses of about 1 TeV for stop masses below 750 GeV

CMS-PAS-SUS-12-017
Event selection

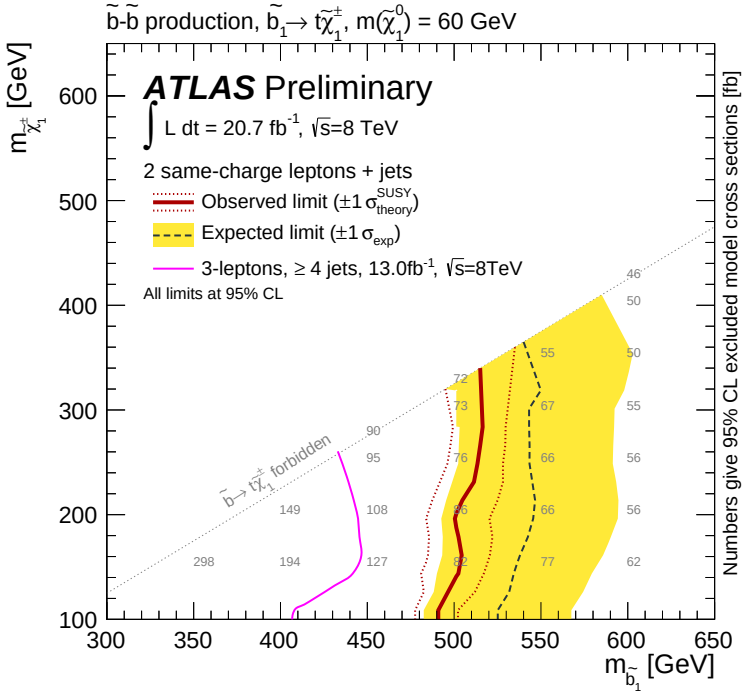
- 2 SS leptons with $m_{ll} > 8$ GeV
- >=2 b-tagged jets
- reject events with third lepton pT>10 GeV

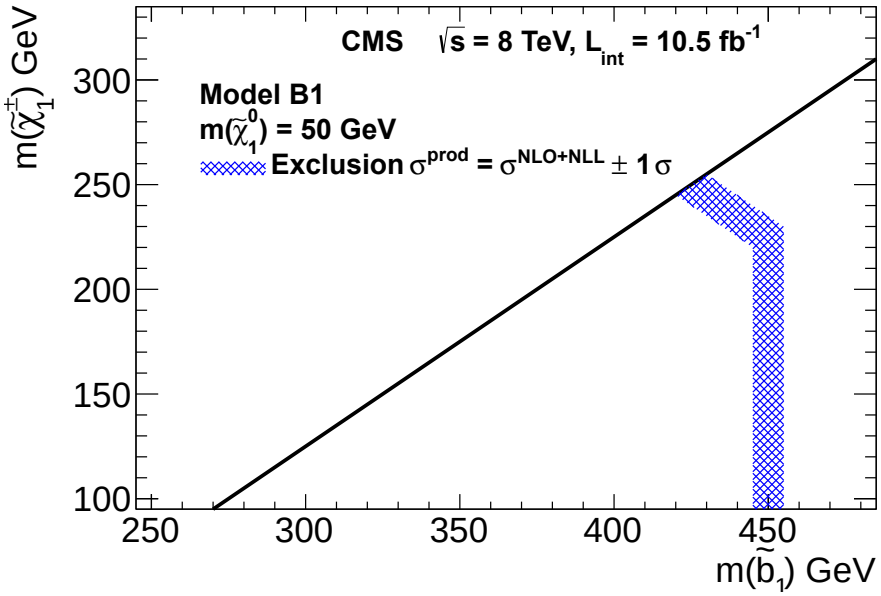
  gluinos are excluded up to 1 TeV

Direct production of 3rd generation squarks

- ▷ 2 same-sign leptons
- ▷ 0 lepton, direct stop search
- ▷ 1 lepton, direct stop search
- ▷ 2 lepton, direct stop search

Two same-sign leptons

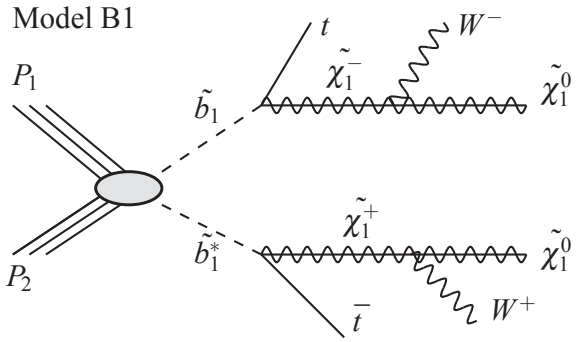




ATLAS-CONF-2013-007

direct sbottom, $m(\tilde{\chi}_1^0) = 60$ GeV

- ▷ only direct production of sbottom quarks is relevant
- ▷ limit of sbottom mass at 470-480 GeV for chargino masses below 280 GeV



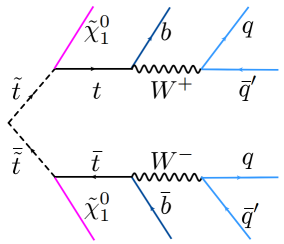
CMS-PAS-SUS-12-017

direct sbottom, $m(\tilde{\chi}_1^0) = 50$ GeV

- ▷ limit on the sbottom mass at 450 GeV

Direct stop searches

0L



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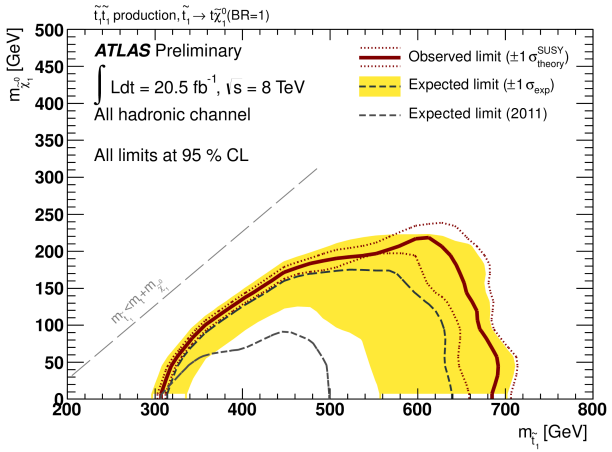
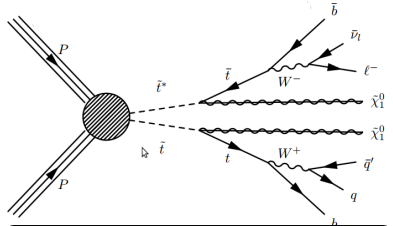
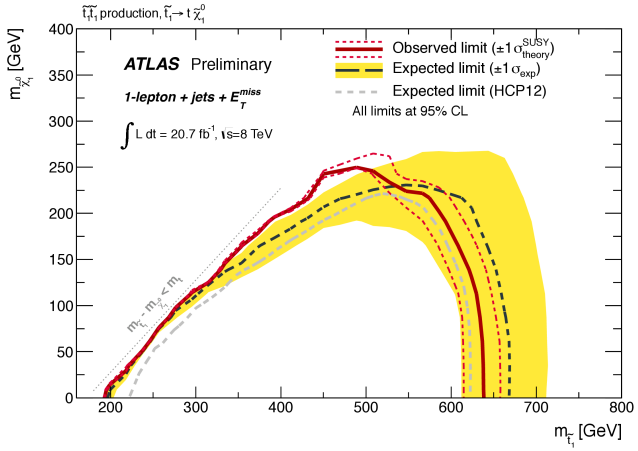


- search in the all-hadronic $t\bar{t}$ decay
- top squarks with masses between 320 and 660 GeV excluded for a nearly massless LSP

1L



ATLAS-CONF-2013-037

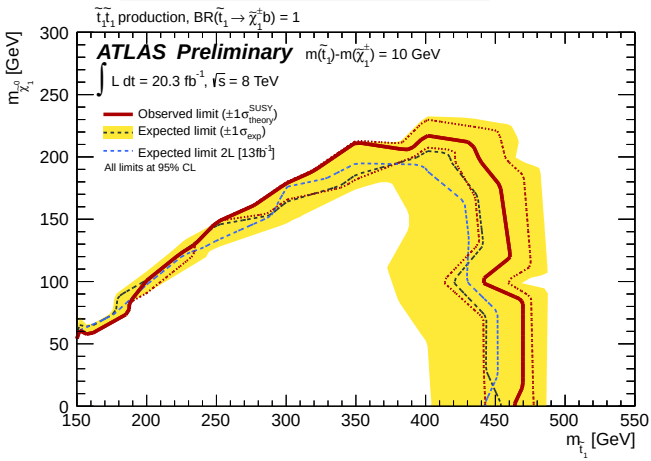


- final state with $t\bar{t}$
- top squark masses between 200 and 610 GeV are excluded at 95% CL for massless LSP

2L

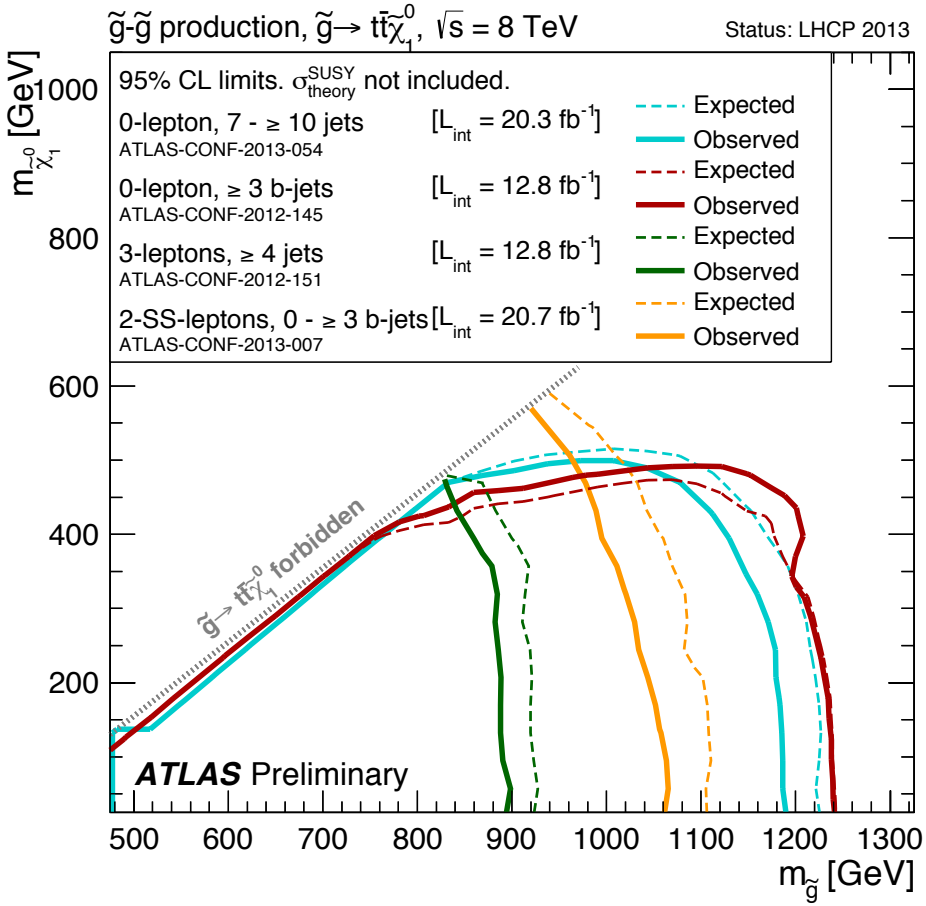
- $\tilde{t}_1 \rightarrow \tilde{\chi}_1^{\pm} b \rightarrow \tilde{\chi}_1^0 W^{(*)} b$
- final states with 2 $W^{(*)}$, 2 b-quarks, 2 $\tilde{\chi}_1^0$

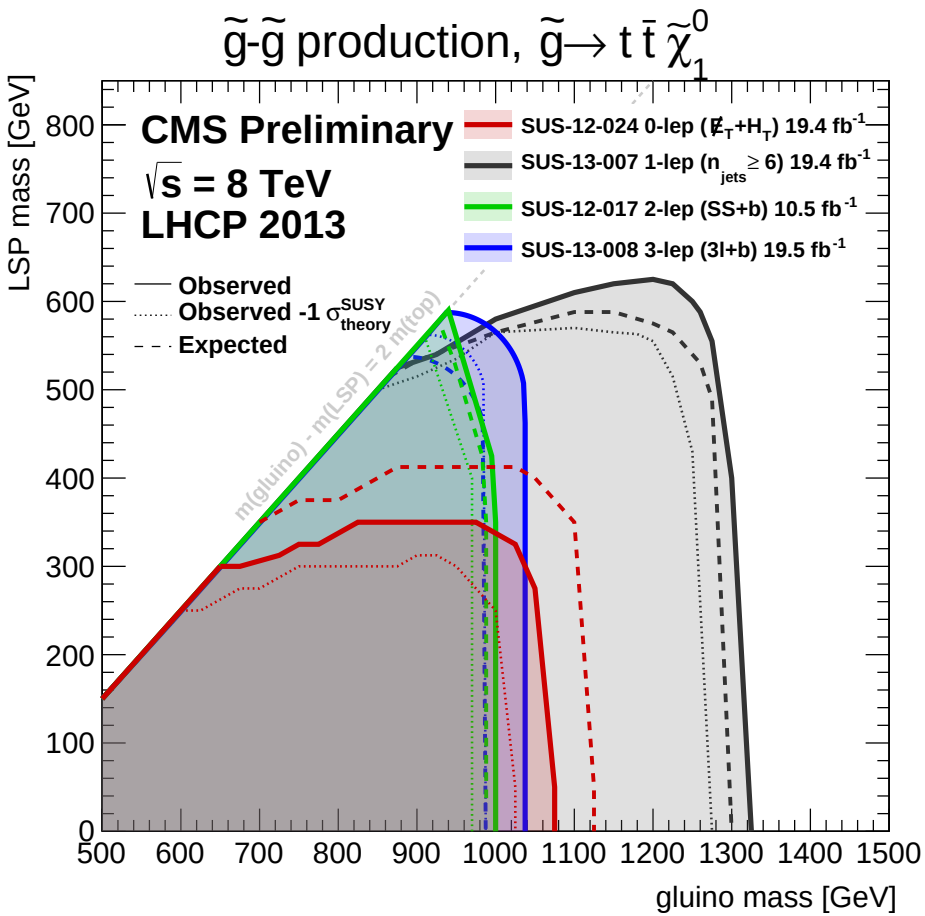
ATLAS-CONF-2013-048



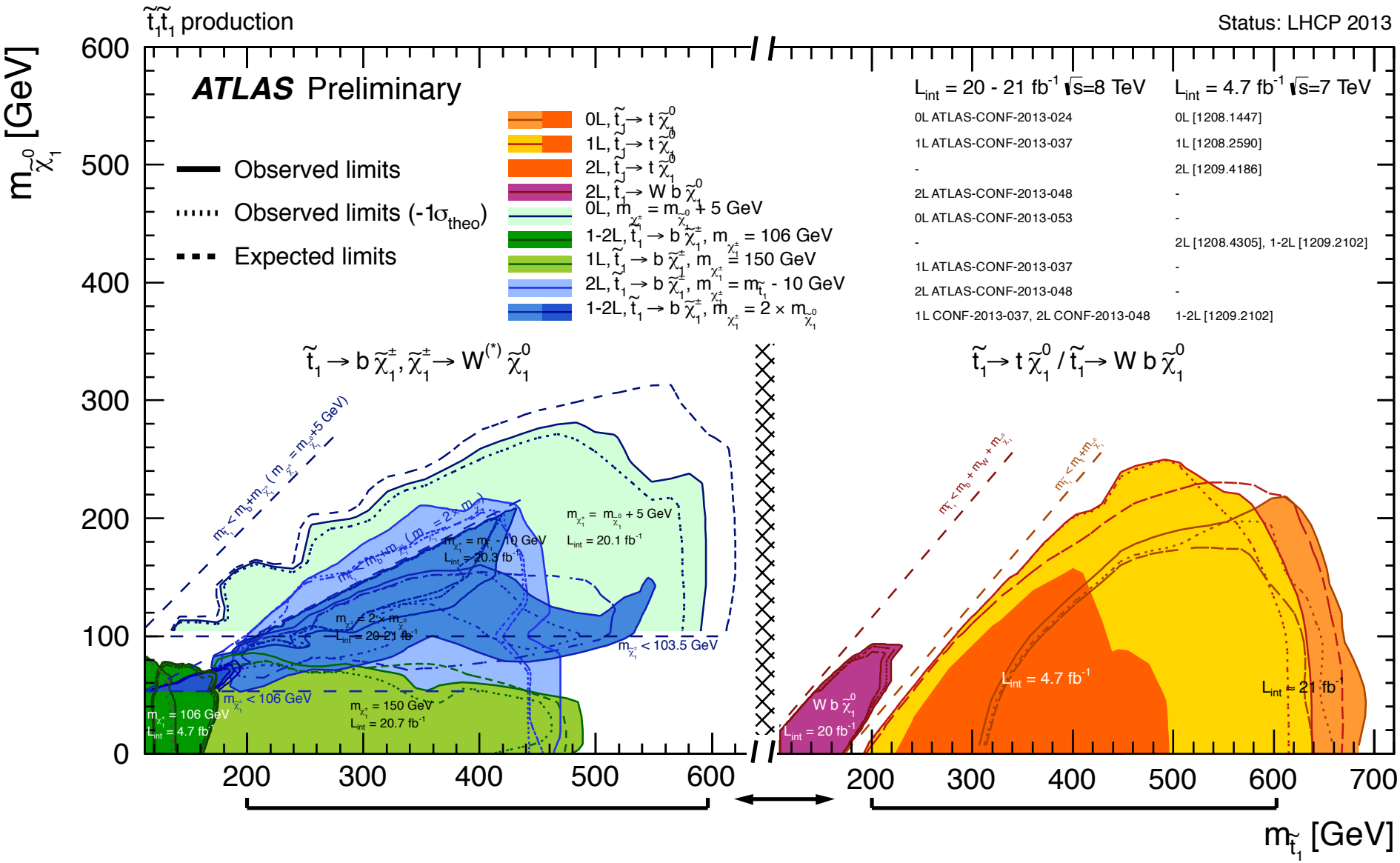
- fixed $m(\tilde{t}_1) - m(\tilde{\chi}_1^{\pm}) = 10$ GeV and assuming BR($\tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm}$)=100%
- stop quark mass excluded between 150 GeV and 442 GeV

Summary plots





Summary plots



Conclusions

The latest SUSY searches from ATLAS and CMS with jets, missing transverse energy and other objects (leptons, photons) are presented.

- no evidence on SUSY with the 2012 dataset, analyses have placed limits on SUSY cross-section and constrained model parameters
- most analyses have moved to the complete 2012 dataset
- data analysis is still continuing, more to come!

All supersymmetry results can be found here:

ATLAS: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults
CMS: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

List of notes presented

- ATLAS-CONF-2013-047 "Search for squarks and gluinos with the ATLAS detector in final states with jets and missing transverse momentum and 20.3 fb-1 of $\sqrt{s}$ = 8 TeV proton-proton collision data"
- ATLAS-CONF-2013-054 "Search for new phenomena using final states with large jet multiplicities and missing transverse momentum with ATLAS in 20 fb-1 of $\sqrt{s}$ = 8 TeV proton-proton collisions"
- ATLAS-CONF-2013-007 "Search for strongly produced supersymmetric particles in final states with two same-sign leptons and jets with the ATLAS detector using 21 fb-1 of proton-proton collisions at $\sqrt{s}$ = 8 TeV"
- ATLAS-CONF-2013-026 "Search for Supersymmetry in Events with Large Missing Transverse Momentum, Jets, and at Least One Tau Lepton in 21 fb-1 of $\sqrt{s}$ = 8 TeV Proton-Proton Collision Data with the ATLAS Detector"
- ATLAS-CONF-2013-024 "Search for direct production of the top squark in the all-hadronic $t\bar{t} + E_{\mathrm{T}}^{\mathrm{miss}}$ final state in 21 fb^{-1} of p-p collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector"
- ATLAS-CONF-2013-037 "Search for direct top squark pair production in final states with one isolated lepton, jets, and missing transverse momentum in $\sqrt{s}$ = 8 TeV pp collisions using 21 fb^{-1} of ATLAS data"
- ATLAS-CONF-2013-048 "Search for direct top squark pair production in final states with one isolated lepton, jets, and missing transverse momentum in $\sqrt{s}$ = 8 TeV pp collisions using 21 fb^{-1} of ATLAS data"

List of notes presented

- CMS-PAS-SUS-12-028 "Search for supersymmetry in hadronic final states with missing transverse energy using the variables α_{T} and b-quark multiplicity in pp collisions at $\sqrt{s}$ = 8 TeV"
- CMS-PAS-SUS-12-017 "Search for new physics in events with same-sign dileptons and b-tagged jets in pp collisions at $\sqrt{s}$ = 8 TeV"
- CMS-PAS-SUS-12-018 "Search for supersymmetry in events with photons and missing energy"
- CMS-PAS-SUS-13-011 "Search for top-squark pair production in the single lepton final state in pp collisions at $\sqrt{s}$ = 8 TeV"

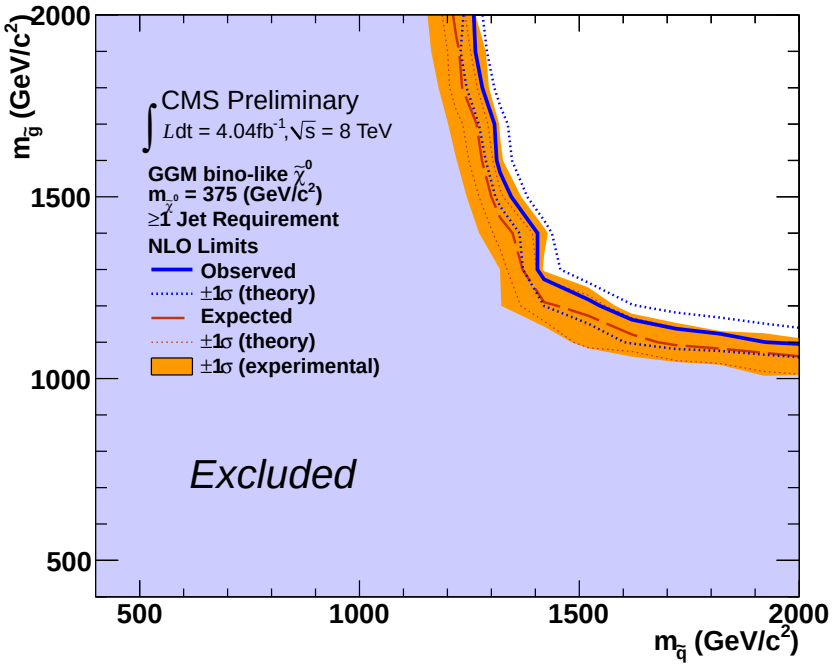
Gauge-mediated Susy Breaking

1 or 2 photons, jets, MET
1 or >=2 taus, jets, MET

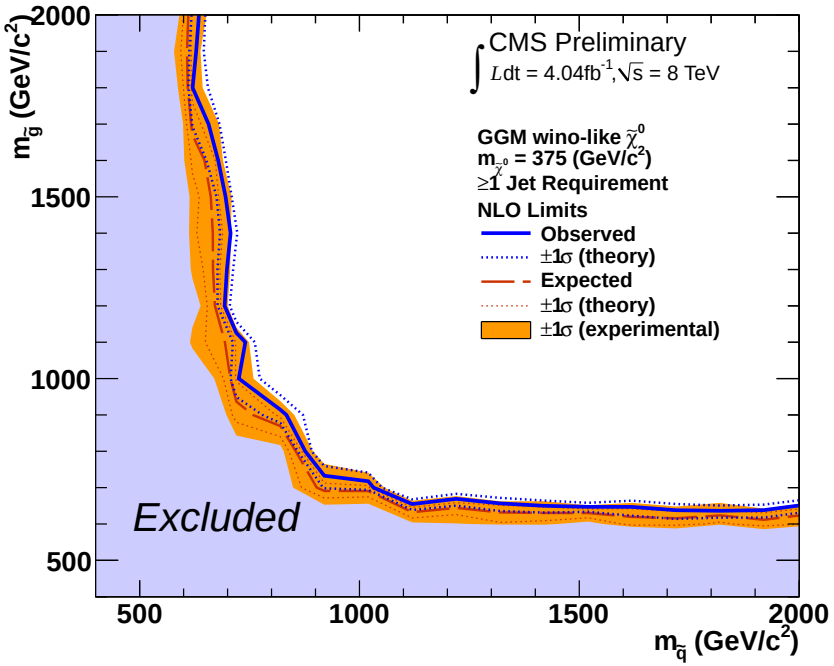
Di-photon analysis

CMS-PAS-SUS-12-018

- search for evidence of GGM SUSY production in di-photon events using MET spectrum spectrum beyond 100 GeV
- no evidence of SUSY GGM production



- bino-like neutralino

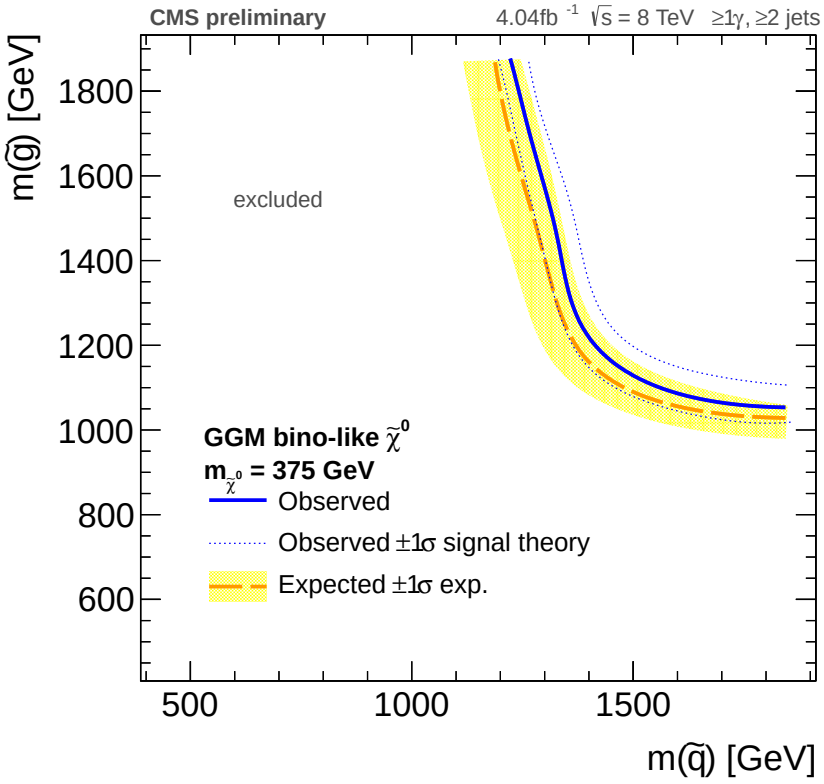


- wino-like neutralino

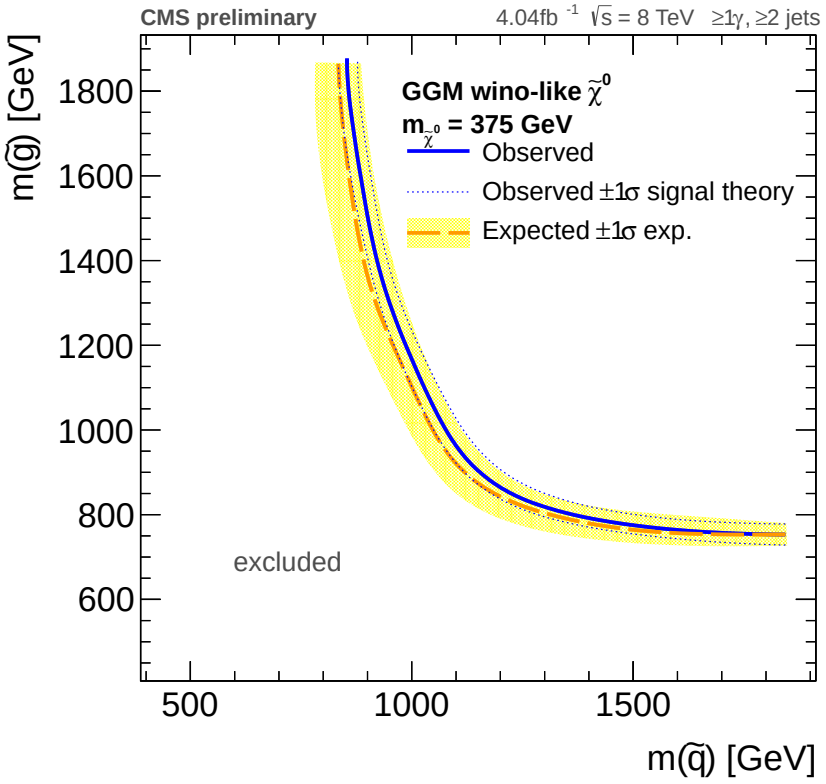
Single photon analysis

CMS-PAS-SUS-12-018

- search for evidence of GGM SUSY production in di-photon events using MET spectrum spectrum beyond 100 GeV
- no evidence of SUSY GGM production



- bine-like neutralino



- wino-like neutralino

1 or >=2 taus, jets and MET

ATLAS-CONF-2013-026

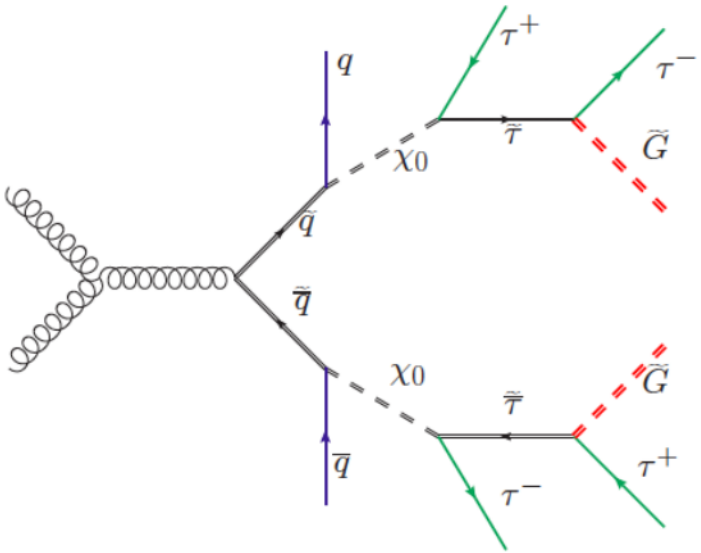
events
with taus produced in the neutralino decay

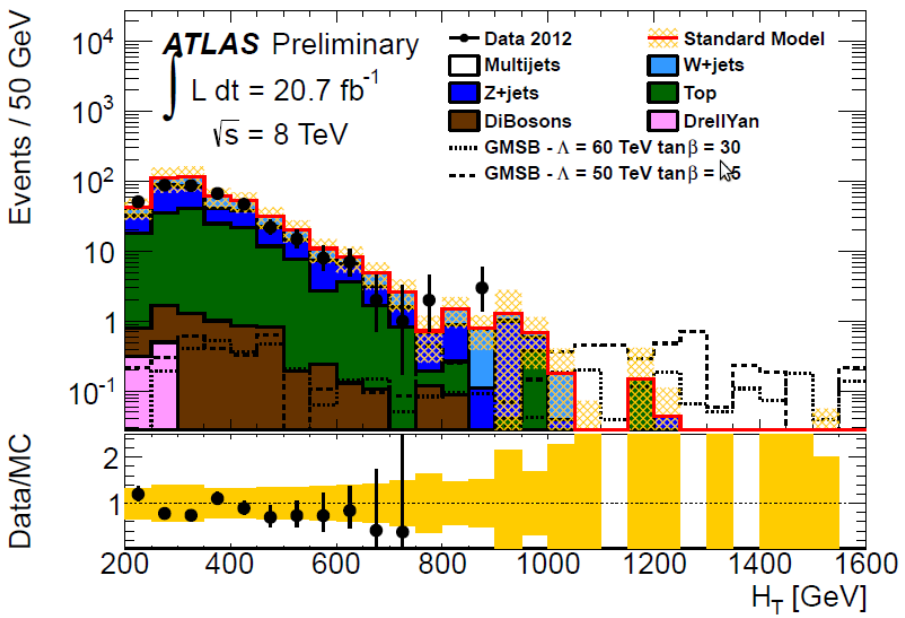
pre-selection

- 0 additional leptons (e, μ)
- p_T^{jet1} > 130 GeV, p_T^{jet2} > 30 GeV
- MET > 150 GeV
- == 1 medium tau with p_T > 30 GeV
  >= 2 loose taus with p_T > 20 GeV
- $\Delta\phi$(jets, MET) and $E_{\text{T}}^{\text{miss}}/m_{\text{eff}}$ cuts

backgrounds

- Z and W + jets, top production
- multijet production estimated from data

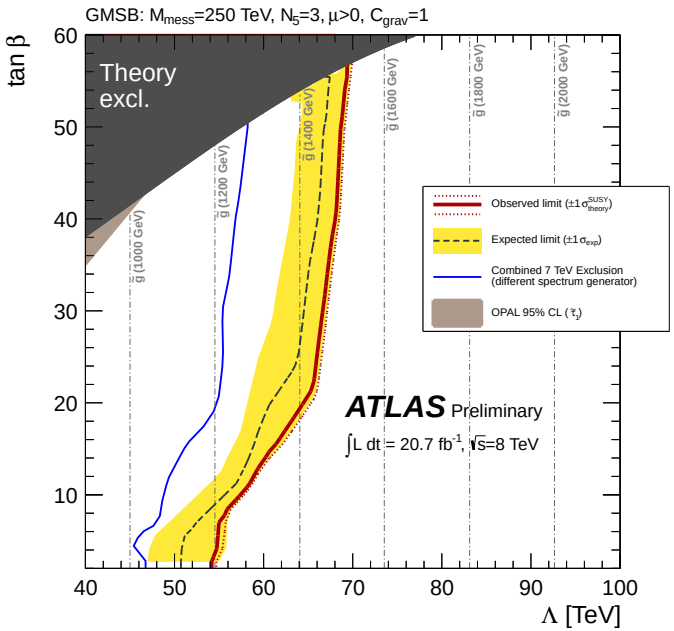


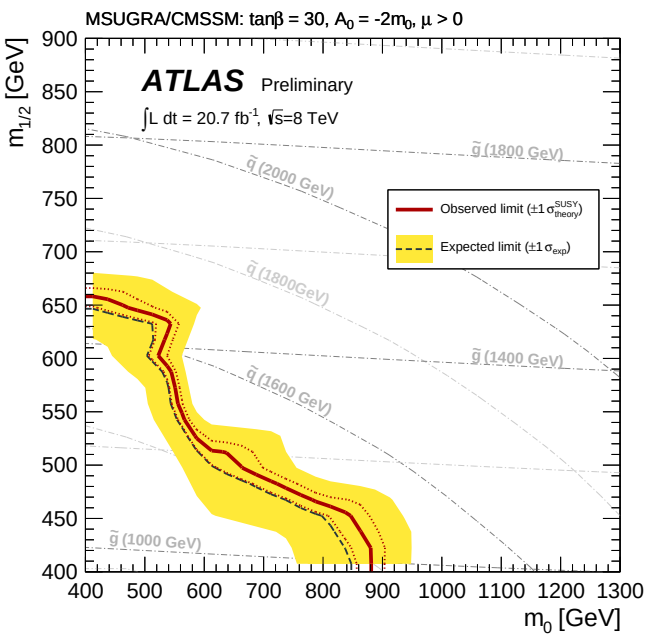


Signal region	1 tau	2 tau GMSB	2 tau nGM
M_T^τ $(M_T^{\tau 1} + M_T^{\tau 2})$	140 GeV	150 GeV	250 GeV
H_T	800 GeV	900 GeV	600 GeV

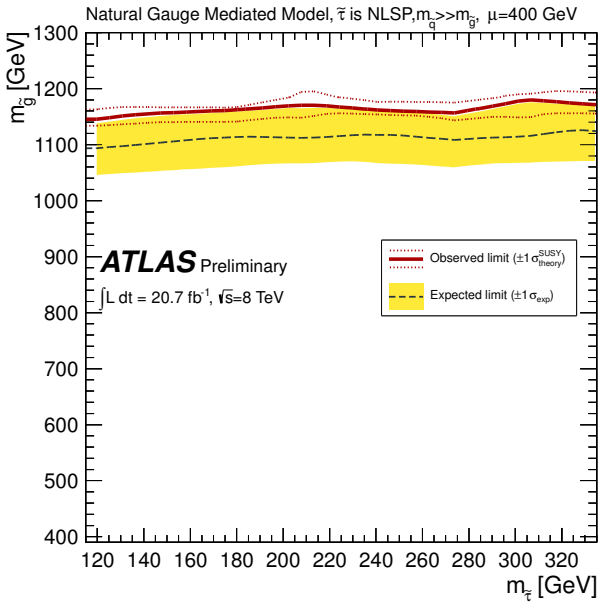
Results

ATLAS-CONF-2013-026





	Expected	Observed
1 τ	$4.9 \pm 1.5 \pm 1.3$	3
2 τ GMSB	$7.2 \pm 1.3 \pm 1.6$	5
2 τ nGM	$3.5 \pm 1.1 \pm 1.9$	1



no excess above the SM backgroud is observed

GMSB model: limit on the SUSY breaking scale Λ of 54 TeV, independent of $\tan\beta$

mSUGRA/CMSSM: result of the 1τ analysis

nGM: the result of the 2τ analysis can be translated into a limit on the gluino mass of 1140 GeV independent of $\tilde{\tau}$ mass