Searches for SUSY and BSM Higgs with ATLAS in Run II

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Outline

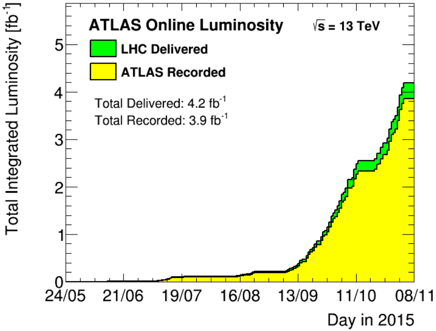
1. Introduction

2. Supersymmetry searches
   - 1ℓ + jets + $E_{\mathrm{T}}^{\mathrm{miss}}$
   - 0ℓ + 4-6 jets $+E_{\mathrm{T}}^{\mathrm{miss}}$
   - 0ℓ + 7-10 jets + $E_{\mathrm{T}}^{\mathrm{miss}}$
   - $Z(\ell\ell)$ + jets + $E_{\mathrm{T}}^{\mathrm{miss}}$
   - 2 b-jets + $E_{\mathrm{T}}^{\mathrm{miss}}$
   - 3-4 b-jets + $E_{\mathrm{T}}^{\mathrm{miss}}$
   - 2ℓ same-sign/3ℓ + $E_{\mathrm{T}}^{\mathrm{miss}}$

3. Beyond-SM Higgs searches
   - $H/A \to \tau\tau(+b)$
   - High-mass $\gamma\gamma$ resonance

4. Summary & conclusions

2015 ATLAS pp data set



$$\sqrt{s} = 13\ \mathrm{TeV}, \int \mathcal{L}\ dt = 3.2\ \mathrm{fb}^{-1}$$

Still more ATLAS BSM results in talks by L. Bryngemark, D. Strom, D. Lopez, and A. Cortes!

A brief introduction to supersymmetry

What is SUSY?

- Generalization of SM: symmetry between forces and matter particles
- Introduces sfermions and gauginos $\Rightarrow$ doubles particle content wrt SM

SUSY is attractive

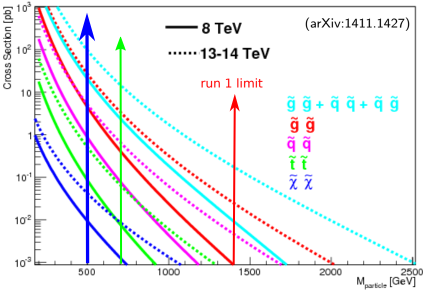
- Can explain Dark Matter
- Alleviates hierarchy problem
- Allows for gauge coupling unification

but. . .

- Over 100 free parameters $\Rightarrow$ wide range of possible exp. signatures

So, SUSY is theoretically appealing, phenomenologically rich, and therefore experimentally challenging

- Extended Higgs sector: $h, H, A, H^{\pm}$



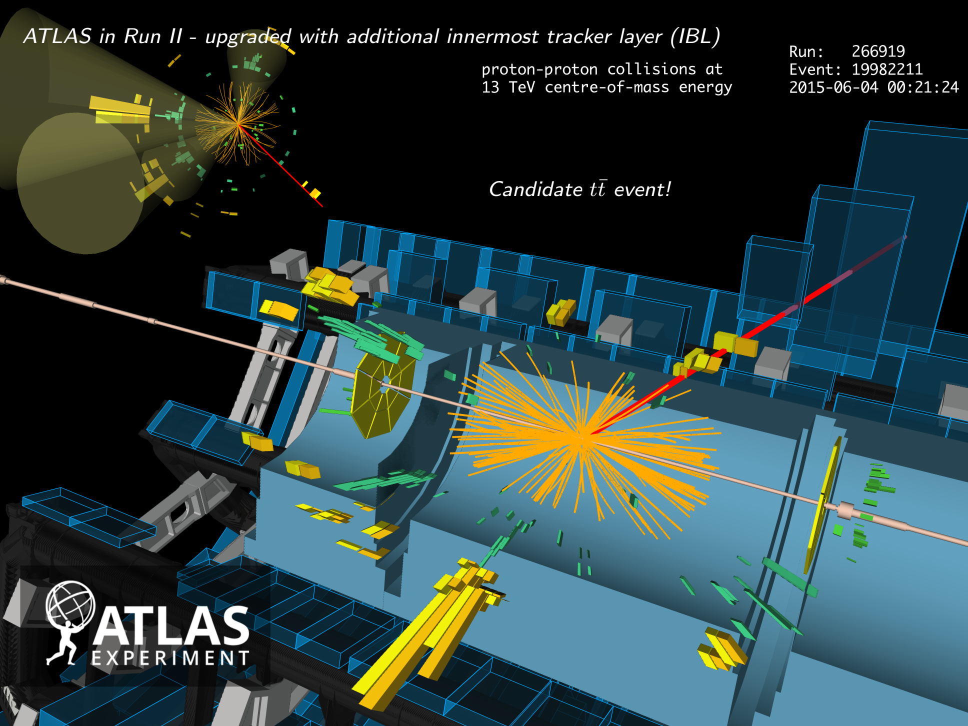
$8\text{ TeV} \rightarrow 13\text{ TeV} \Rightarrow \sigma(\text{SUSY})$ grows:

- $\sigma(\tilde{g}\tilde{g}) \times 30$ for $m_{\tilde{g}} = 1.4\text{ TeV}$
- $\sigma(\tilde{t}\tilde{t}) \times 8$ for $m_{\tilde{t}} = 700\text{ GeV}$
- $\sigma(\chi\chi) \times 4$ for $m_{\chi} = 500\text{ GeV}$

In contrast: $\sigma(t\bar{t}) \times 3.3 \Rightarrow S/B$ boost

Early Run II priorities:

- Target strong production of $\tilde{g}$ and $\tilde{q}$
- Optimize for discovery, simple and robust analyses (cut & count),



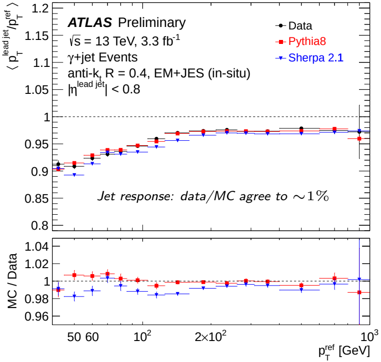
ATLAS in Run II - upgraded with additional innermost tracker layer (IBL)

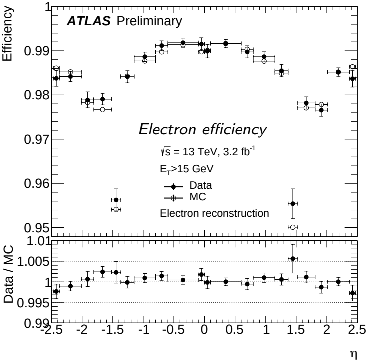
proton-proton collisions at
13 TeV centre-of-mass energy

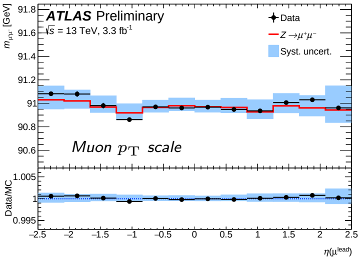
Run: 266919
Event: 19982211
2015-06-04 00:21:24

Candidate $t\bar{t}$ event!

Detector performance understood quickly with 13 TeV data





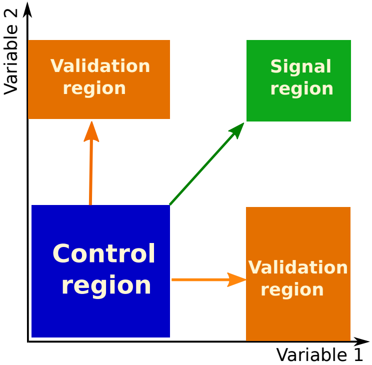


Also key for these results:

- flavor tagging
- $E_{\mathrm{T}}^{\mathrm{miss}}$ - strong discrimination power due to escaping DM particles!
- Variables describing event topology and kinematics

General strategy for Run II: typical workflow

- Signal region: optimized for S/B
- Uses variables describing event topology and kinematics
- Can't rely on perfect modeling in MC out to tails in distributions



For main irreducible BGs ($t\bar{t}, V$+jets):

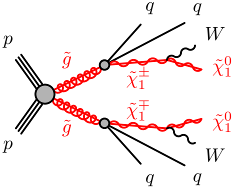
- Define
  1. Control regions (CRs) $\Rightarrow$ MC normalization factors
  2. Test extrapolation using validation regions (VRs)
  3. Predict yields in blinded signal regions (SRs)
- Considerations:
  - Extrapolate along reliably modeled variables
  - Uncertainties: trade-off between stat and syst.

Reducible backgrounds measured in data, for example:

- "Fake" $E_{\mathrm{T}}^{\mathrm{miss}}$, ℓ
- Charge mis-identification for ℓ

1ℓ + jets + $E_{\mathrm{T}}^{\mathrm{miss}}$ search

Target: final states with significant $E_{\mathrm{T}}^{\mathrm{miss}}$, jets and exactly one isolated e/μ



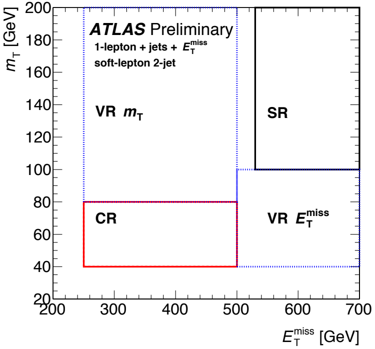
Background estimation: $t\bar{t}$ and W+jets dominate ⇒ normalize MC in CRs

Ex: soft-lepton 2-jet

- Regions split by requirements on $E_{\mathrm{T}}^{\mathrm{miss}}$ and m_{T}
- $t\bar{t}$ CR: ≥ 1 b-jet
- W+jets CR: no b-jets

Design of SRs:

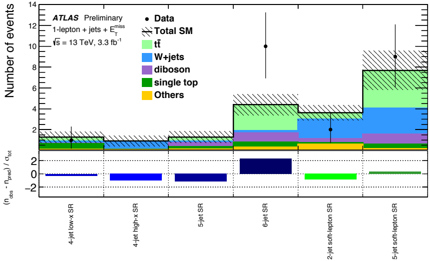
- 4 hard-lepton SRs (large $m_{\tilde{\chi}_1^{\pm}} - m_{\tilde{\chi}_1^0}$)
- 2 soft-lepton (compressed spectra)
- Further subdivided using $n_{\mathrm{jets}}, E_{\mathrm{T}}^{\mathrm{miss}}, m_{\mathrm{T}}, m_{\mathrm{eff}}^{\mathrm{incl}}$



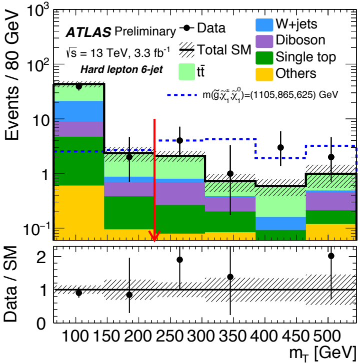
1ℓ + jets + $E_{\mathrm{T}}^{\mathrm{miss}}$: results

ATLAS-CONF-2015-076

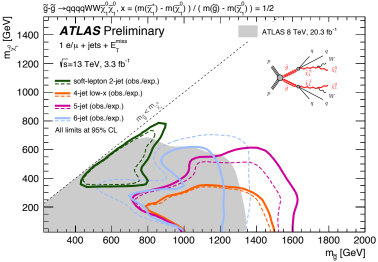
- SR yields agree with bg-only hypo:



- Largest deviation: 2σ excess in hard-lepton 6-jet SR:
  - e: exp: 1.9 ± 0.6, obs: 2
  - μ: exp: 2.5 ± 0.8, obs: 8



- Exclusion curves in $m_{\tilde{g}}$-$m_{\chi_1^0}$ plane ⇒
- Run-I contour in gray, improved limits now exclude up to $m_{\tilde{g}} = 1.6$ TeV

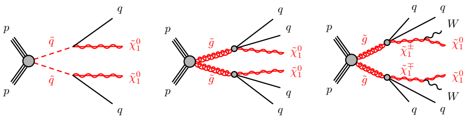


(Throughout: only showing example interpretations - more available!)

$0\ell +$ 4-6 jets $+E_{\mathrm{T}}^{\mathrm{miss}}$ search

ATLAS-CONF-2015-062

Target: $\tilde{g}$ and $\tilde{q}$ prod. with hadronic final states



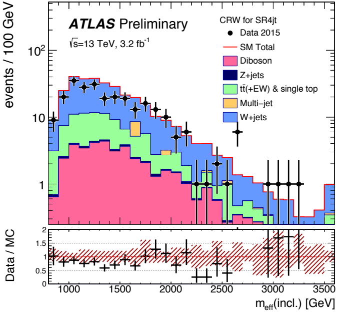
SR design:

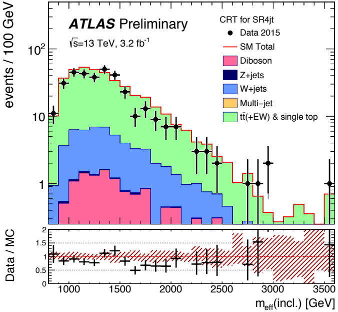
- 2, 4, 5, 6 jets (no ℓ!)
- Subdivided in effective mass

$$m_{\mathrm{eff}} = \sum_{\mathrm{jets}} p_{\mathrm{T}} + E_{\mathrm{T}}^{\mathrm{miss}}$$

Backgrounds:

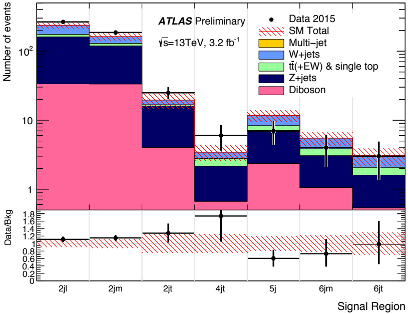
- W+jets: CR for $W \to \ell\nu$ (b-jet veto) ↗
- Top: CR with 1ℓ & ≥ 1 b-jet →
- $Z(\nu\nu)$+jets: estimated from γ+jets
- Diboson from MC
- Selection efficiently rejects multijet bg, residual estimated from CR with small $\Delta\phi_{\min}(E_{\mathrm{T}}^{\mathrm{miss}}, j)$





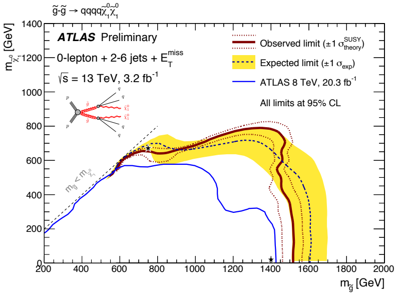
0ℓ + 4-6 jets $+E_{\mathrm{T}}^{\mathrm{miss}}$: results

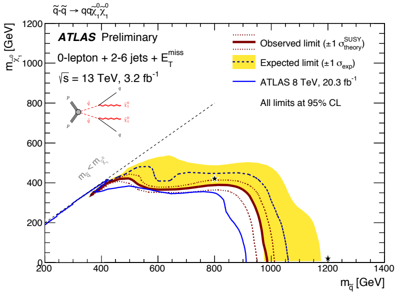
ATLAS-CONF-2015-062



Results

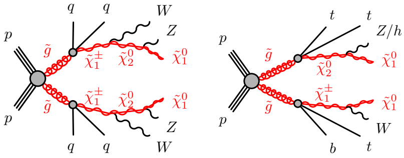
- Data agrees with bg estimate, no significant excess observed
- New limits derived:
    - ↙ New exclusions in $m_{\tilde{g}}$-$m_{\chi_1^0}$ plane
    - ↓ Slightly improved limits in $m_{\tilde{q}}$-$m_{\chi_1^0}$





0ℓ + 7-10 jets + $E_{\mathrm{T}}^{\mathrm{miss}}$ search

⇒ arXiv:1602.06194



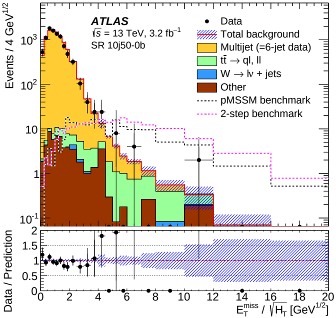
SRs for $\tilde{g}\tilde{g}$ with complex decays:

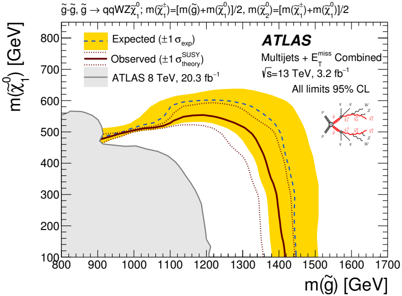
- 7, 8, 9, 10 jets
- Looser $E_{\mathrm{T}}^{\mathrm{miss}}$ requirements
- Up to 2 b-jets

Background estimation:

- Multijet: $E_{\mathrm{T}}^{\mathrm{miss}}$ significance, $E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}}$, is ∼indep. of n_{jets}, extract templates from 5j and 6j CRs
- Top and W+jets from MC

No significant excess ⇒
Limits up to $m_{\tilde{g}} \sim 1.4$ TeV

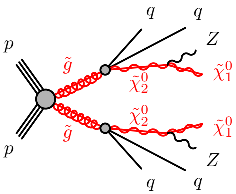




$Z(\ell\ell)$ + jets + $E_{\mathrm{T}}^{\mathrm{miss}}$ search

ATLAS-CONF-2015-082

Target: $\tilde{g}\tilde{g}$ or $\tilde{q}\tilde{q}$ with $Z \to \ell\ell$ in decay



Background estimation:

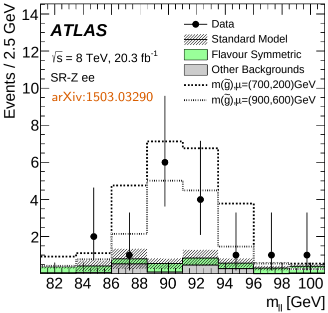
- $t\bar{t}$, WW, Wt: flavor-symmetric (1:1:2 ratio for ee:$\mu\mu$:$e\mu$), estimated from $e\mu$ data:

$$N_{ee/\mu\mu}^{\text{bg est.}} = \frac{1}{2} N_{e\mu}^{\text{CR}} \times k_{ee/\mu\mu}$$

- WZ, ZZ, $t\bar{t}V$ from MC, checked in VR
- Z+jets: estimated from γ+jets events in data

Excess in 8 TeV Run I search:

- ee: 3σ, $\mu\mu$: 1.7σ

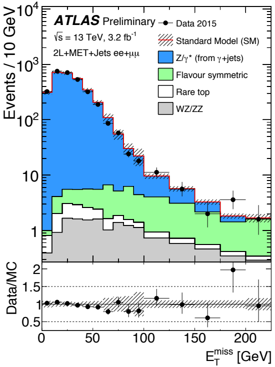


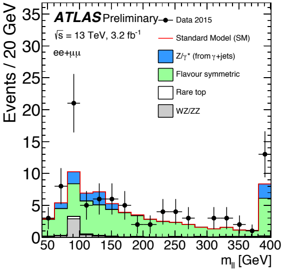
Reproduce Run I SR:

- SFOS $ee/\mu\mu$ with $81\ \text{GeV} < m_{\ell\ell} < 101\ \text{GeV}$
- 2 jets with $\Delta\phi_{\min}(E_{\mathrm{T}}^{\mathrm{miss}}, j) > 0.4$
- $E_{\mathrm{T}}^{\mathrm{miss}} > 225\ \text{GeV}$, $H_{\mathrm{T}} > 600\ \text{GeV}$

$Z(\ell\ell)$ + jets + $E_{\mathrm{T}}^{\mathrm{miss}}$: results

ATLAS-CONF-2015-082

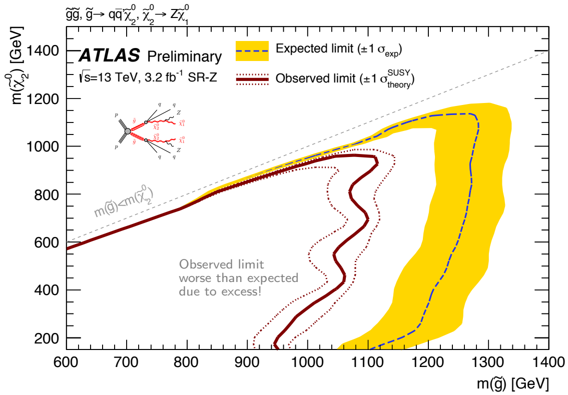




Final event yield for 2015 data:

- Expected: 10.3 ± 2.3
- Observed: 21 (10 ee, 11 $\mu\mu$)

  $\Rightarrow$ 2.2σ excess



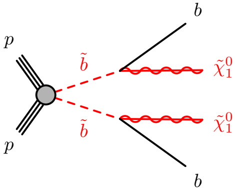
Observed limit
worse than expected
due to excess!

CMS observes 12 with $12^{+4.0}_{-2.8}$ expected (CMS-PAS-SUS-15-011)

2 b-jets + $E_{\mathrm{T}}^{\mathrm{miss}}$ search

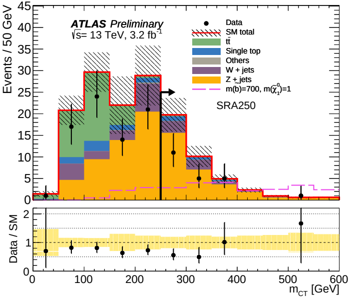
ATLAS-CONF-2015-066

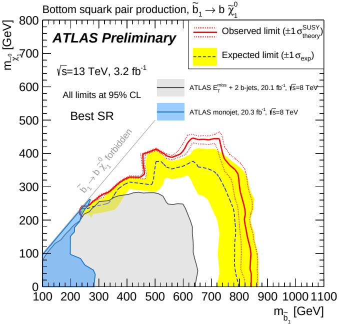
Targets direct $\tilde{b}$ pair-production



- 4 SRs for
  - low $m_{\tilde{\chi}_1^0}$ (subdivided in m_{CT})
  - more compressed SUSY spectra
- BG from $W/Z/t\bar{t}$ estimated from CRs with 1-2 ℓ

No significant excess ⇒ $m_{\tilde{b}} < 850$ GeV excluded

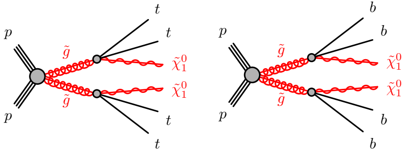




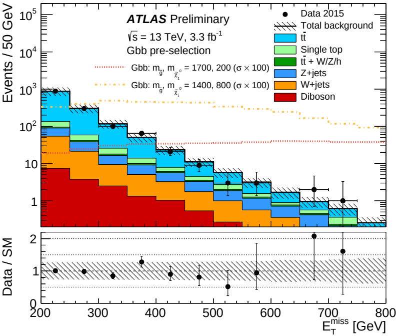
3-4 b-jets + $E_{\mathrm{T}}^{\mathrm{miss}}$ search

ATLAS-CONF-2015-067

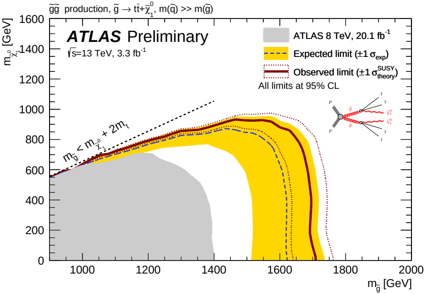
Target: $\tilde{g}\tilde{g}$ with 3rd gen. decays



- SR design:
  - 0ℓ (b) and 1ℓ (t)
  - Subdivided in $E_{\mathrm{T}}^{\mathrm{miss}}$, n_{jets}, b-jets
- Backgrounds
  - Dominated by $t\bar{t}$, estimated in lower-$E_{\mathrm{T}}^{\mathrm{miss}}$ CRs
  - Other BGs from MC



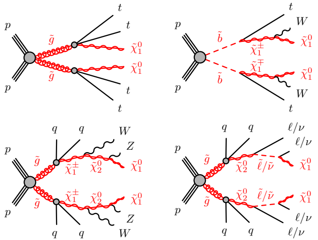
No significant excess ⇒
Limits up to $m_{\tilde{g}} \sim 1.7$ TeV



2ℓ same-sign$/3\ell + E_{\mathrm{T}}^{\mathrm{miss}}$ search

arXiv:1602.09058

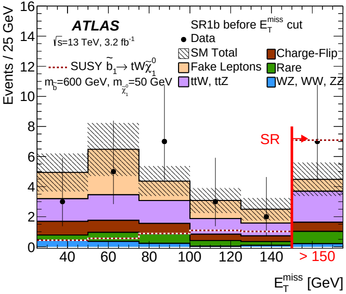
Target: $\tilde{g}/\tilde{q}$ prod. w/ $W \to \ell\nu$ decays

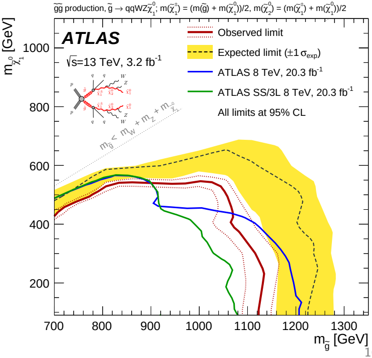


- SR design: 0, 1 and 3 b-jets

Signal region	$N_{\mathrm{lept}}^{\mathrm{signal}}$	$N_{b-\mathrm{jets}}^{20}$	N_{jets}^{50}	$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	m_{eff} [GeV]
SR0b3j	≥ 3	$=0$	≥ 3	>200	>550
SR0b5j	≥ 2	$=0$	≥ 5	>125	>650
SR1b	≥ 2	≥ 1	≥ 4	>150	>550
SR3b	≥ 2	≥ 3	-	>125	>650

- Backgrounds
  - Charge mis-id measured in $Z \to \ell\ell$
  - Fake leptons from id-based matrix method
  - Other processes from MC





$H/A \to \tau\tau(+b)$ search

ATLAS-CONF-2015-061

Target: additional neutral Higgs bosons A and H in MSSM from gg fusion & b-associated production $\Rightarrow$

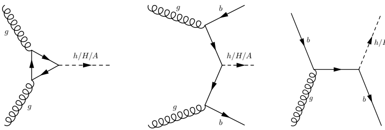
τ_{lep}-τ_{had}

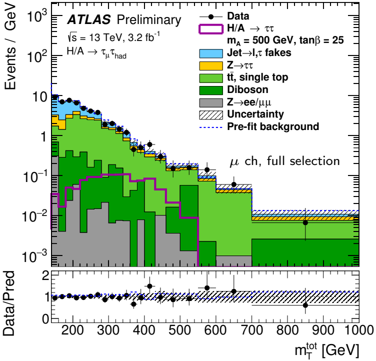
- Jets (W, QCD) faking e/μ, τ estimated from fake-factors in CRs
- Z, top from MC

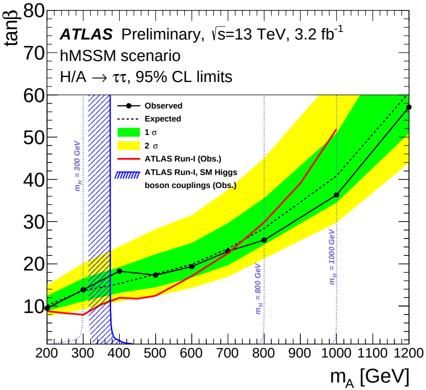
τ_{had}-τ_{had}

- Dominant BG QCD, estimated from fake-factor method

Can dominate at large $\tan\beta$







Improved upper $\tan\beta$ limit for $m_A > 700$ GeV

High-mass $\gamma\gamma$ resonance search

ATLAS-CONF-2015-081

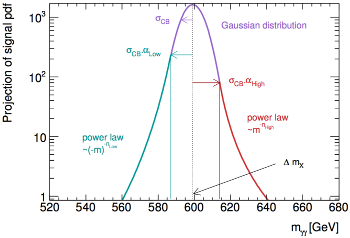
- $\gamma\gamma$ key channel for discovering and measuring the 125 GeV Higgs
- Refined but simple analysis, selection, optimized for scalar

Selection

- Two 'tight' photons
- Relative E_T cuts:
  $E_\mathrm{T}^{\gamma 1}/m_{\gamma\gamma} > 0.4$
  $E_\mathrm{T}^{\gamma 2}/m_{\gamma\gamma} > 0.3$
- Isolation: E_T-dependent, calo- and track-based

Signal model: double-sided Crystal Ball function, two width hypotheses:

- Narrow-Width Approx. (NWA)
- Large Width (LW), $\leq 25\%$ of $m_{\gamma\gamma}$



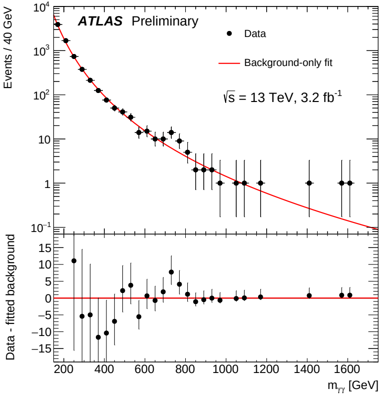
Search looks for bump in $m_{\gamma\gamma}$, SM bg from fit of smooth function to data:

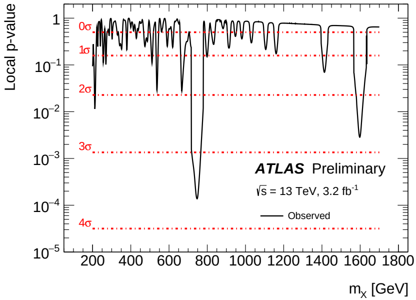
$$f_{(k)}(x; b, \{a_k\}) = (1 - x^{1/3})^b x^{\sum_{j=0}^{k} a_j (\log\ x)^j}, \text{ where } x = m_{\gamma\gamma}/\sqrt{s}$$

Background fit tested for several k-values, $k = 0$ performs sufficiently.
$S + B$ fit for $m_{\gamma\gamma} > 150$ GeV.

High-mass $\gamma\gamma$ resonance: results

ATLAS-CONF-2015-081





- Under NWA: local excess of 3.6σ, minimal p_0 at $m_{\gamma\gamma} \approx 750$ GeV
- $[200, 2000]$ GeV considered $\Rightarrow$ compensate for *look-elsewhere effect* $\Rightarrow$ global significance 2.0σ

(PER pulled 1.5σ in NWA fit)

LW hypothesis:

- Best-fit width of 45 GeV ($\sim 6\%$)
- Increased local significance: 3.9σ
- LEE-adjustment (mass range & width up to 10%) $\Rightarrow$ global significance of 2.3σ

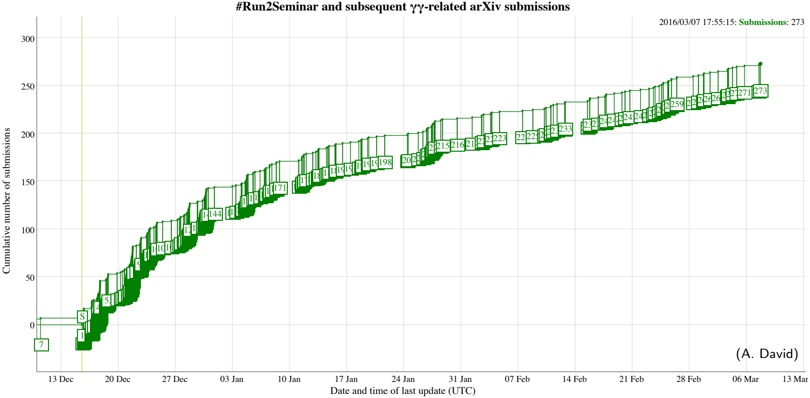
Summary & conclusions

- Several searches for SUSY and additional Higgs bosons have already been performed by ATLAS using the 3.2 fb^{-1} of data from 2015
- More results presented tonight & tomorrow (Lene, David, David, Arely) - keep an eye on the ATLAS winter conference results page for updates
- For most searches the observations in the data agree well with the expectations from background processes. Two intriguing excesses seen:
  - Z + jets + $E_{\mathrm{T}}^{\mathrm{miss}}$: 2.2σ (in ATLAS also in Run I, not in CMS)
  - High-mass $\gamma\gamma$: $\sim 2\sigma$ around $m_{\gamma\gamma} = 750$ GeV

The 25 fb^{-1} the LHC plans to deliver during 2016 will reveal the nature of the observed excesses - the data taking starts soon!

Back-up material

Interest in the $\gamma\gamma$ results on the arXiv since December



Number of arXiv papers related to December's preliminary high-mass $\gamma\gamma$ results. Probably more on interpretations in Marco Nardecchia's talk tomorrow.

There's even a paper predicting the shape of this curve:

> *"...fits to the current data predict that the total number of papers on the topic will not exceed 310 papers by the June 1. 2016"*

High-mass $\gamma\gamma$ resonance search: more details

Signal selection eff:

- Overall signal efficiency:
  - 30-40% for ggF
  - 30-45% for VBF
  - 25-35% for $t\bar{t}H$
- In fiducial volume: 55-70%

Signal modeling:

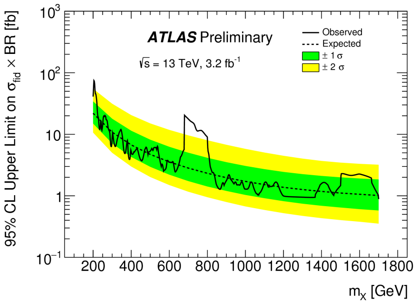
- Optimized for narrow Higgs-like resonances with $m > 200$ GeV
- Prod. via ggF, VBF, WH/ZH, $t\bar{t}H$

Background estimation:

- Parameterized by smooth function, free parameters adjusts it to the data
- Possibility of needing more degrees of freedom considered and evaluated with F-test $\Rightarrow k > 0$ not needed

Fit & significance:

- Unbinned ML fit of $m_{\gamma\gamma}$ distribution
- Local p-value for bg-only hypo from asymptotic approximation
- LEE based on number of 2σ crossings in $[200, 2000]$ GeV



Compatibility with 8 TeV data: within 2.2σ (1.4σ) for NWA (LW)

High-mass $\gamma\gamma$ resonance search: main uncertainties

Source	Uncertainty
Background modeling $^{\circ\bullet}$	
Spurious signal	$2-10^{-3}$ events, mass-dependent
Background fit	$\leq 50\%-\leq 20\%$ of the total signal yield uncertainty, mass- and signal-dependent
Signal modeling $^{\circ\bullet}$	
Photon energy resolution	$^{+[55-110]\%}_{-[20-40]\%}$, mass-dependent
Signal yield $^{\bullet}$	
Luminosity	±5%
Trigger	±0.63%
C_X *factors* $^{\bullet}$	
Photon identification	±(3–2)%, mass-dependent
Photon isolation	±(4.1–1)%, mass-dependent
Production process	±3.1%

Table 1: Summary of the systematic uncertainties in the signal-plus-background likelihood fit when considering the NWA signal model. The $\circ$ symbol denotes categories of uncertainties that affect the local p-value for the background-only hypothesis, while the $\bullet$ symbol denotes uncertainties that impact the limit on $\sigma_{\text{fiducial}} \times \text{BR}(X \to \gamma\gamma)$.

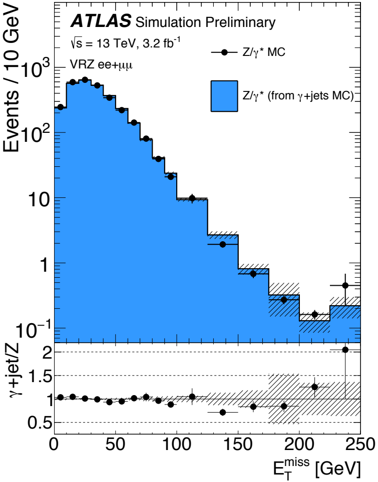
$Z(\ell\ell)$ + jets + $E_{\mathrm{T}}^{\mathrm{miss}}$: additional details

Background estimation:

- Flavor-symmetric: $t\bar{t}$, WW, Wt
  $\Rightarrow$ measured in $e\mu$ data
  Total: 60% $(70\%, 20\%, 8\%)$
- $Z/\gamma*$+jets: gives $E_{\mathrm{T}}^{\mathrm{miss}}$ due to mismeasurements (or ν in jet fragmentation) $\Rightarrow$ small but peaked at $m_{\ell\ell} \sim m_Z$
- Diboson: $\sim 30\%$ (from MC)

$Z/\gamma*$+jets details:

- Exploit that Z+jets and γ+jets have similar topologies, Z and γ both well-measured, hadronic recoil
- Use (lepton-free) γ+jets sample with SRZ-like kinematics (no $E_{\mathrm{T}}^{\mathrm{miss}}$ cut)
- Apply p_{T} reweighting, smearing (μ channel only), recalculate $E_{\mathrm{T}}^{\mathrm{miss}}$
- Normalize $E_{\mathrm{T}}^{\mathrm{miss}}$ in Z CR



MC closure test

$Z(\ell\ell)$ + jets + $E_{\mathrm{T}}^{\mathrm{miss}}$: additional details about SR, VRs, CRs

Region	$E_{\mathbf{T}}^{\mathbf{miss}}$ **[GeV]**	$H_{\mathbf{T}}$ **[GeV]**	$n_{\mathbf{jets}}$	$m_{\ell\ell}$ **[GeV]**	**SF/DF**	$\Delta\phi(\mathbf{jet}_{12}, \boldsymbol{p}_{\mathrm{T}}^{\mathrm{miss}})$	$m_{\mathrm{T}}(\ell_3, E_{\mathrm{T}}^{\mathrm{miss}})$ [GeV]	$n_{\text{b-jets}}$
Signal regions								
SRZ	> 225	> 600	≥ 2	$81 < m_{\ell\ell} < 101$	SF	> 0.4	-	-
Control regions								
Z normalisation	< 60	> 600	≥ 2	$81 < m_{\ell\ell} < 101$	SF	> 0.4	-	-
CR-FS	> 225	> 600	≥ 2	$61 < m_{\ell\ell} < 121$	DF	> 0.4	-	-
CRT	> 225	> 600	≥ 2	$m_{\ell\ell} \notin [81, 101]$	SF	> 0.4	-	-
Validation regions								
VRZ	< 225	> 600	≥ 2	$81 < m_{\ell\ell} < 101$	SF	> 0.4	-	-
VRT	100–200	> 600	≥ 2	$m_{\ell\ell} \notin [81, 101]$	SF	> 0.4	-	-
VRS	100–200	> 600	≥ 2	$81 < m_{\ell\ell} < 101$	SF	> 0.4	-	-
VR-FS	100–200	> 600	≥ 2	$61 < m_{\ell\ell} < 121$	DF	> 0.4	-	-
VR-WZ	100–200	-	-	-	3ℓ	-	< 100	0
VR-ZZ	< 100	-	-	-	4ℓ	-	-	0
VR-3L	60–100	> 200	≥ 2	$81 < m_{\ell\ell} < 101$	3ℓ	> 0.4	-	-

Preparing for La Thuile

How to *not* do it

Variable definitions

- Missing transverse momentum (or energy):

$$E_{\mathrm{T}}^{\mathrm{miss}} = \sqrt{(E_x^{\mathrm{miss}})^2 + (E_y^{\mathrm{miss}})^2}$$

  where $E_{x(y)}^{\mathrm{miss}} = -\sum E_{x(y)}$ summed over all calibrated e, γ, μ, τ, jets...

- Scalar transverse-energy sum:

$$H_{\mathrm{T}} = \sum_{\mathrm{jets},\ell} p_{\mathrm{T}}$$

- Effective mass:

$$m_{\mathrm{eff}}^{(\mathrm{incl})} = \sum_{\mathrm{jets},\ell} p_{\mathrm{T}} + E_{\mathrm{T}}^{\mathrm{miss}}$$

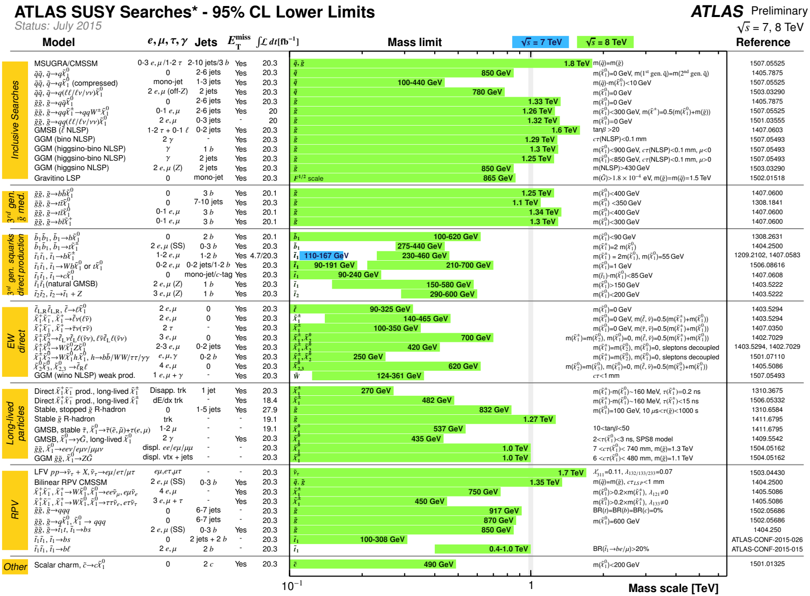
- Transverse mass (1ℓ):

$$m_{\mathrm{T}} = \sqrt{2 p_{\mathrm{T}}^{\ell} E_{\mathrm{T}}^{\mathrm{miss}} (1 - \cos[\Delta\phi(\vec{\ell}, E_{\mathrm{T}}^{\mathrm{miss}})])}$$

- Contransverse mass (measures the masses of pair-prod. semi-invisibly decaying heavy particles, e.g. $\tilde{b} \to b\chi^0$):

$$m_{\mathrm{CT}}^2(\upsilon_1, \upsilon_2) = [E_{\mathrm{T}}(\upsilon_1) + E_{\mathrm{T}}(\upsilon_2)]^2 - [\boldsymbol{p}_{\mathrm{T}}(\upsilon_1) - \boldsymbol{p}_{\mathrm{T}}(\upsilon_2)]^2$$

Run I SUSY results



ATLAS SUSY Searches* - 95% CL Lower Limits

Status: July 2015

ATLAS Preliminary

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

$\sqrt{s}$ = 7 TeV

$\sqrt{s}$ = 8 TeV

	Model	e,μ,τ,γ	Jets	E_T^{miss}	$\int\mathcal{L}\,dt[\mathrm{fb}^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0-3 e,μ/1-2 τ	2-10 jets/3 b	Yes	20.3	$\tilde{q},\tilde{g}$ 1.8 TeV	m($\tilde{q}$)=m($\tilde{g}$)	1507.05525
	$\tilde{q}\tilde{q}, \tilde{q}\rightarrow q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 850 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)	1405.7875
	$\tilde{q}\tilde{q}, \tilde{q}\rightarrow q\tilde{\chi}_1^0$ (compressed)	mono-jet	1-3 jets	Yes	20.3	$\tilde{q}$ 100-440 GeV	m($\tilde{q}$)-m($\tilde{\chi}_1^0$)<10 GeV	1507.05525
	$\tilde{q}\tilde{q}, \tilde{q}\rightarrow q(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ (off-Z)	2 jets	Yes	20.3	$\tilde{q}$ 780 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1503.03290
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.33 TeV	m($\tilde{\chi}_1^0$)=0 GeV	1405.7875
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow qq\tilde{\chi}_1^{\pm}\rightarrow qqW^{\pm}\tilde{\chi}_1^0$	0-1 e,μ	2-6 jets	Yes	20	$\tilde{g}$ 1.26 TeV	m($\tilde{\chi}_1^0$)<300 GeV, m($\tilde{\chi}^{\pm}$)=0.5(m($\tilde{\chi}_1^0$)+m($\tilde{g}$))	1507.05525
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ	0-3 jets	-	20	$\tilde{g}$ 1.32 TeV	m($\tilde{\chi}_1^0$)=0 GeV	1501.03555
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	20.3	$\tilde{g}$ 1.6 TeV	tanβ >20	1407.0603
	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$ 1.29 TeV	$c\tau$(NLSP)<0.1 mm	1507.05493
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	20.3	$\tilde{g}$ 1.3 TeV	m($\tilde{\chi}_1^0$)<900 GeV, $c\tau$(NLSP)<0.1 mm, μ<0	1507.05493
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	20.3	$\tilde{g}$ 1.25 TeV	m($\tilde{\chi}_1^0$)<850 GeV, $c\tau$(NLSP)<0.1 mm, μ>0	1507.05493
	GGM (higgsino NLSP)	2 e,μ (Z)	2 jets	Yes	20.3	$\tilde{g}$ 850 GeV	m(NLSP)>430 GeV	1503.03290
	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2}$ scale 865 GeV	m($\tilde{G}$)>1.8×10^{-4} eV, m($\tilde{g}$)=m($\tilde{q}$)=1.5 TeV	1502.01518
3rd gen. $\tilde{g}$ med.	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$ 1.25 TeV	m($\tilde{\chi}_1^0$)<400 GeV	1407.0600
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	m($\tilde{\chi}_1^0$) <350 GeV	1308.1841
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.34 TeV	m($\tilde{\chi}_1^0$)<400 GeV	1407.0600
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.3 TeV	m($\tilde{\chi}_1^0$)<300 GeV	1407.0600
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\rightarrow b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$ 100-620 GeV	m($\tilde{\chi}_1^0$)<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\rightarrow t\tilde{\chi}_1^{\pm}$	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{b}_1$ 275-440 GeV	m($\tilde{\chi}_1^{\pm}$)=2 m($\tilde{\chi}_1^0$)	1404.2500
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow b\tilde{\chi}_1^{\pm}$	1-2 e,μ	1-2 b	Yes	4.7/20.3	$\tilde{t}_1$ 110-167 GeV 230-460 GeV	m($\tilde{\chi}_1^{\pm}$) = 2m($\tilde{\chi}_1^0$), m($\tilde{\chi}_1^0$)=55 GeV	1209.2102, 1407.0583
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow Wb\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$	0-2 e,μ	0-2 jets/1-2 b	Yes	20.3	$\tilde{t}_1$ 90-191 GeV 210-700 GeV	m($\tilde{\chi}_1^0$)=1 GeV	1506.08616
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$ 90-240 GeV	m($\tilde{t}_1$)-m($\tilde{\chi}_1^0$)<85 GeV	1407.0608
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$ 150-580 GeV	m($\tilde{\chi}_1^0$)>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\rightarrow\tilde{t}_1 + Z$	3 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_2$ 290-600 GeV	m($\tilde{\chi}_1^0$)<200 GeV	1403.5222
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\rightarrow\ell\tilde{\chi}_1^0$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$ 90-325 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\rightarrow\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 140-465 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\ell},\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^{\pm}$)+m($\tilde{\chi}_1^0$))	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\rightarrow\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 100-350 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\tau},\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^{\pm}$)+m($\tilde{\chi}_1^0$))	1407.0350
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\rightarrow\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$ 700 GeV	m($\tilde{\chi}_1^{\pm}$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell},\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^{\pm}$)+m($\tilde{\chi}_1^0$))	1402.7029
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\rightarrow W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	2-3 e,μ	0-2 jets	Yes	20.3	$\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$ 420 GeV	m($\tilde{\chi}_1^{\pm}$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\rightarrow W\tilde{\chi}_1^0 h\tilde{\chi}_1^0, h\rightarrow b\bar{b}/WW/\tau\tau/\gamma\gamma$	e,μ,γ	0-2 b	Yes	20.3	$\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$ 250 GeV	m($\tilde{\chi}_1^{\pm}$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	1501.07110
	$\tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_{2,3}^0\rightarrow\tilde{\ell}_R\ell$	4 e,μ	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$ 620 GeV	m($\tilde{\chi}_2^0$)=m($\tilde{\chi}_3^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell},\tilde{\nu}$)=0.5(m($\tilde{\chi}_2^0$)+m($\tilde{\chi}_1^0$))	1405.5086
	GGM (wino NLSP) weak prod.	1 $e,\mu + \gamma$	-	Yes	20.3	$\tilde{W}$ 124-361 GeV	$c\tau$<1 mm	1507.05493
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 270 GeV	m($\tilde{\chi}_1^{\pm}$)-m($\tilde{\chi}_1^0$)~160 MeV, τ($\tilde{\chi}_1^{\pm}$)=0.2 ns	1310.3675
	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	dE/dx trk	-	Yes	18.4	$\tilde{\chi}_1^{\pm}$ 482 GeV	m($\tilde{\chi}_1^{\pm}$)-m($\tilde{\chi}_1^0$)~160 MeV, τ($\tilde{\chi}_1^{\pm}$)<15 ns	1506.05332
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$ 832 GeV	m($\tilde{\chi}_1^0$)=100 GeV, 10 μs<τ($\tilde{g}$)<1000 s	1310.6584
	Stable $\tilde{g}$ R-hadron	trk	-	-	19.1	$\tilde{g}$ 1.27 TeV		1411.6795
	GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0\rightarrow\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	19.1	$\tilde{\chi}_1^0$ 537 GeV	10<tanβ<50	1411.6795
	GMSB, $\tilde{\chi}_1^0\rightarrow\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	20.3	$\tilde{\chi}_1^0$ 435 GeV	2<τ($\tilde{\chi}_1^0$)<3 ns, SPS8 model	1409.5542
	$\tilde{g}\tilde{g}, \tilde{\chi}_1^0\rightarrow ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde{\chi}_1^0$ 1.0 TeV	7 <$c\tau$($\tilde{\chi}_1^0$)< 740 mm, m($\tilde{g}$)=1.3 TeV	1504.05162
	GGM $\tilde{g}\tilde{g}, \tilde{\chi}_1^0\rightarrow Z\tilde{G}$	displ. vtx + jets	-	-	20.3	$\tilde{\chi}_1^0$ 1.0 TeV	6 <$c\tau$($\tilde{\chi}_1^0$)< 480 mm, m($\tilde{g}$)=1.1 TeV	1504.05162
RPV	LFV $pp\rightarrow\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\rightarrow e\mu/e\tau/\mu\tau$	$e\mu,e\tau,\mu\tau$	-	-	20.3	$\tilde{\nu}_\tau$ 1.7 TeV	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07	1503.04430
	Bilinear RPV CMSSM	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{q},\tilde{g}$ 1.35 TeV	m($\tilde{q}$)=m($\tilde{g}$), $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0\rightarrow ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 750 GeV	m($\tilde{\chi}_1^0$)>0.2×m($\tilde{\chi}_1^{\pm}$), $\lambda_{121}\neq0$	1405.5086
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0\rightarrow\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e,\mu + \tau$	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 450 GeV	m($\tilde{\chi}_1^0$)>0.2×m($\tilde{\chi}_1^{\pm}$), $\lambda_{133}\neq0$	1405.5086
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 917 GeV	BR(t)=BR(b)=BR(c)=0%	1502.05686
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow q\tilde{\chi}_1^0, \tilde{\chi}_1^0\rightarrow qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 870 GeV	m($\tilde{\chi}_1^0$)=600 GeV	1502.05686
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{t}_1 t, \tilde{t}_1\rightarrow bs$	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{g}$ 850 GeV		1404.250
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow bs$	0	2 jets + 2 b	-	20.3	$\tilde{t}_1$ 100-308 GeV		ATLAS-CONF-2015-026
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow b\ell$	2 e,μ	2 b	-	20.3	$\tilde{t}_1$ 0.4-1.0 TeV	BR($\tilde{t}_1\rightarrow be/\mu$)>20%	ATLAS-CONF-2015-015
Other	Scalar charm, $\tilde{c}\rightarrow c\tilde{\chi}_1^0$	0	2 c	Yes	20.3	$\tilde{c}$ 490 GeV	m($\tilde{\chi}_1^0$)<200 GeV	1501.01325

*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.