2013 PASCOS

19th International Symposium on Particles, Strings and Cosmology

Inclusive searches for squarks and gluinos with the ATLAS detector

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on behalf of the ATLAS collaboration

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名古屋大学
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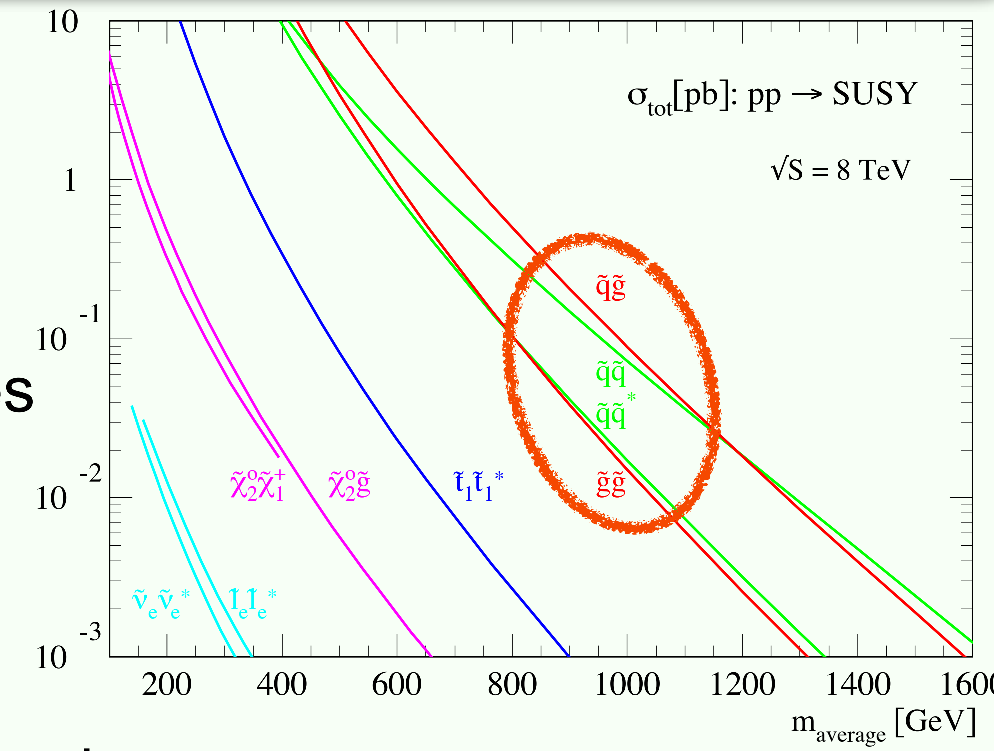
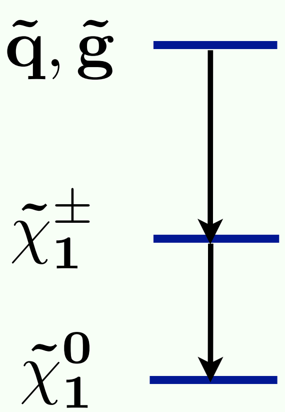
Outline

- Introduction - inclusive searches for squarks and gluinos
- Search channels:
  - 0-lepton multi-jet searches
  - 1-lepton searches + jet + E_T^{miss} searches
  - 2-leptons “razor” searches
  - Tau searches
  - 2 same-sign leptons / photon searches
- Results and interpretations in SUSY models
- Summary

Introduction

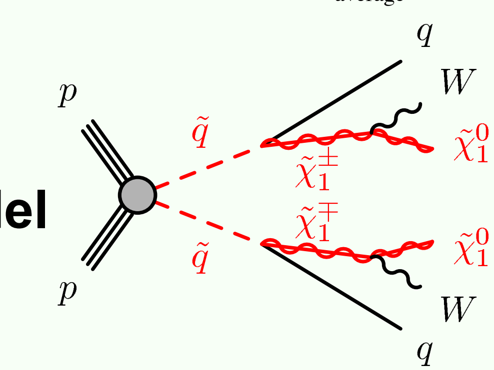
- **Strong production of gluinos and 1st & 2nd generation squarks**
  - Relatively large cross-sections
- **R-parity conserving SUSY => LSP stable**
  - Missing transverse energy ($\mathbf{E_T^{miss}}$) based signatures
  - For RPV and split-SUSY scenarios see Jorge Armando's talk



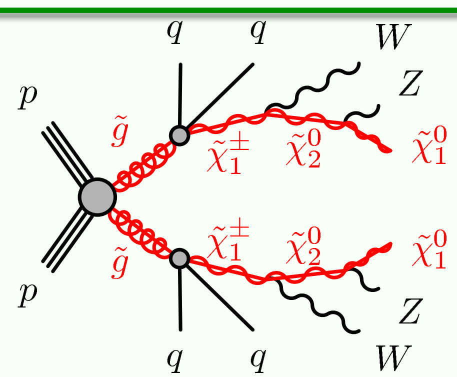


- **SUSY simplified models** used in many cases for optimisation/interpretation
  - Specific decay chain with 100% Br is assumed
  - Free parameters are sparticle masses
  - 3rd generation squarks often decoupled

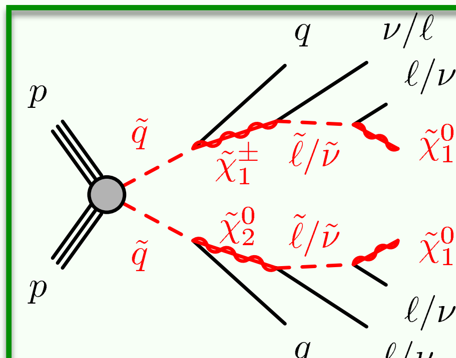
"1-step" simplified model



- **Analyses are optimised for various:**
  - Δm between the states ==> softer/harder decay products
  - Steps in the decay chain ==> smaller/larger final particles multiplicity



- Jet rich signatures
- 0 lepton + multi-jet searches



- Lepton rich signatures
- 1,2 lepton searches

- All the analyses use **full ATLAS 2012 √s=8 TeV dataset with L=20.3 fb^{-1}**

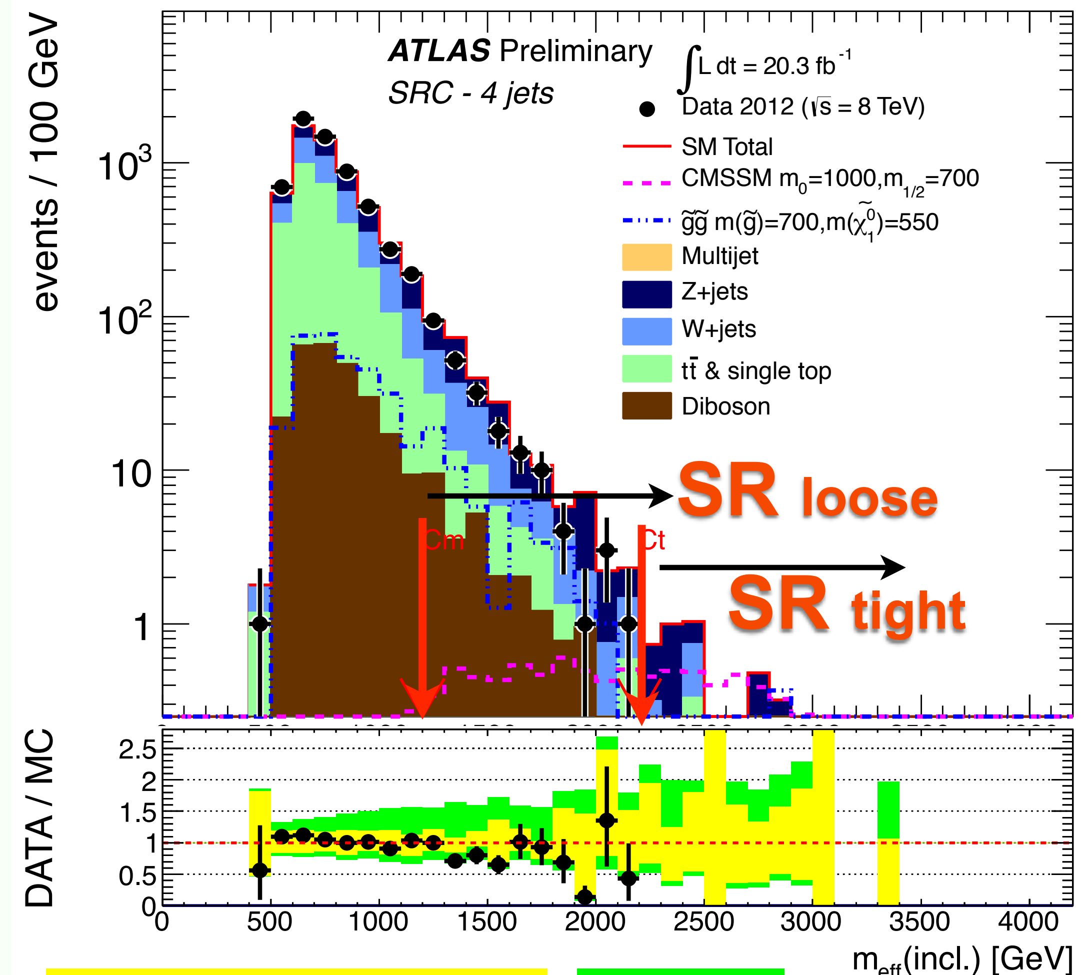
0-lepton + 2-6 jets

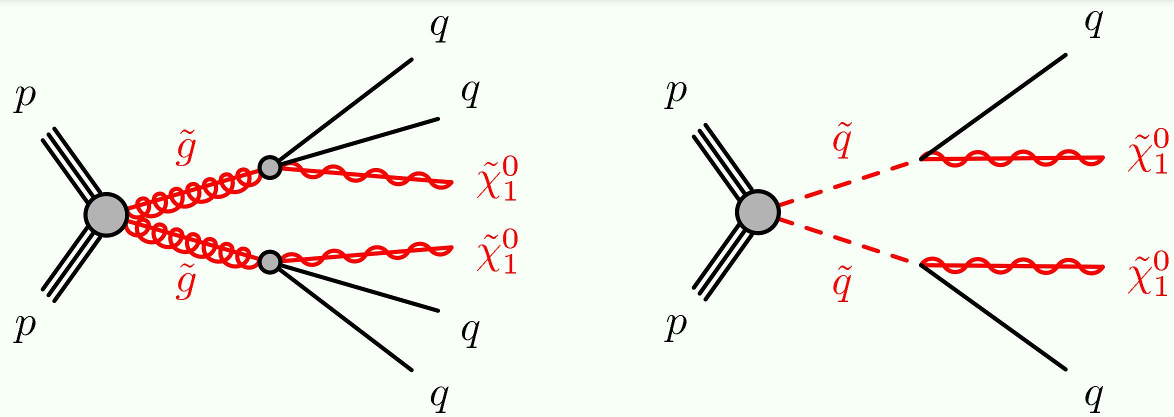
ATLAS-CONF-2013-047

Signal regions

- No leptons and moderate number of jets (2-6) with p_T^{jets}>{130,60} GeV
- Discriminating variables:
  - $\mathbf{E_T^{miss}} > 160\ \mathrm{GeV}$
  - $\mathbf{m_{eff}} = \mathbf{E_T^{miss}} + \sum_i \mathbf{p_{T,i}^{jet}}$

➡ **high mass scale of SUSY events**





- SRs with looser/tighter cuts on m_{eff} and $\mathbf{E_T^{miss}}/\mathbf{m_{eff}}$ for each jet multiplicity

Requirement	Channel									
	A (2-jets)		B (3-jets)		C (4-jets)		D (5-jets)	E (6-jets)		
	L	M	M	T	M	T	–	L	M	T
$E_T^{miss}/m_eff(Nj) >$	0.2	–[a]	0.3	0.4	0.25	0.25	0.2	0.15	0.2	0.25
m_eff(incl.) [GeV] >	1000	1600	1800	2200	1200	2200	1600	1000	1200	1500

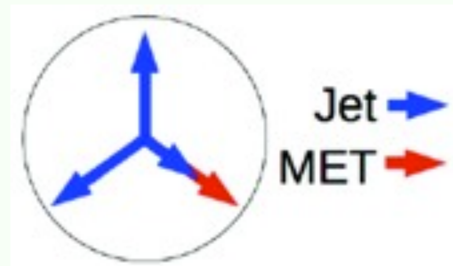
(a) For SR A-medium the cut on $E_T^{miss}/m_eff(Nj)$ is replaced by a requirement $E_T^{miss}/\sqrt{H_T} > 15\ \mathrm{GeV}^{1/2}$.

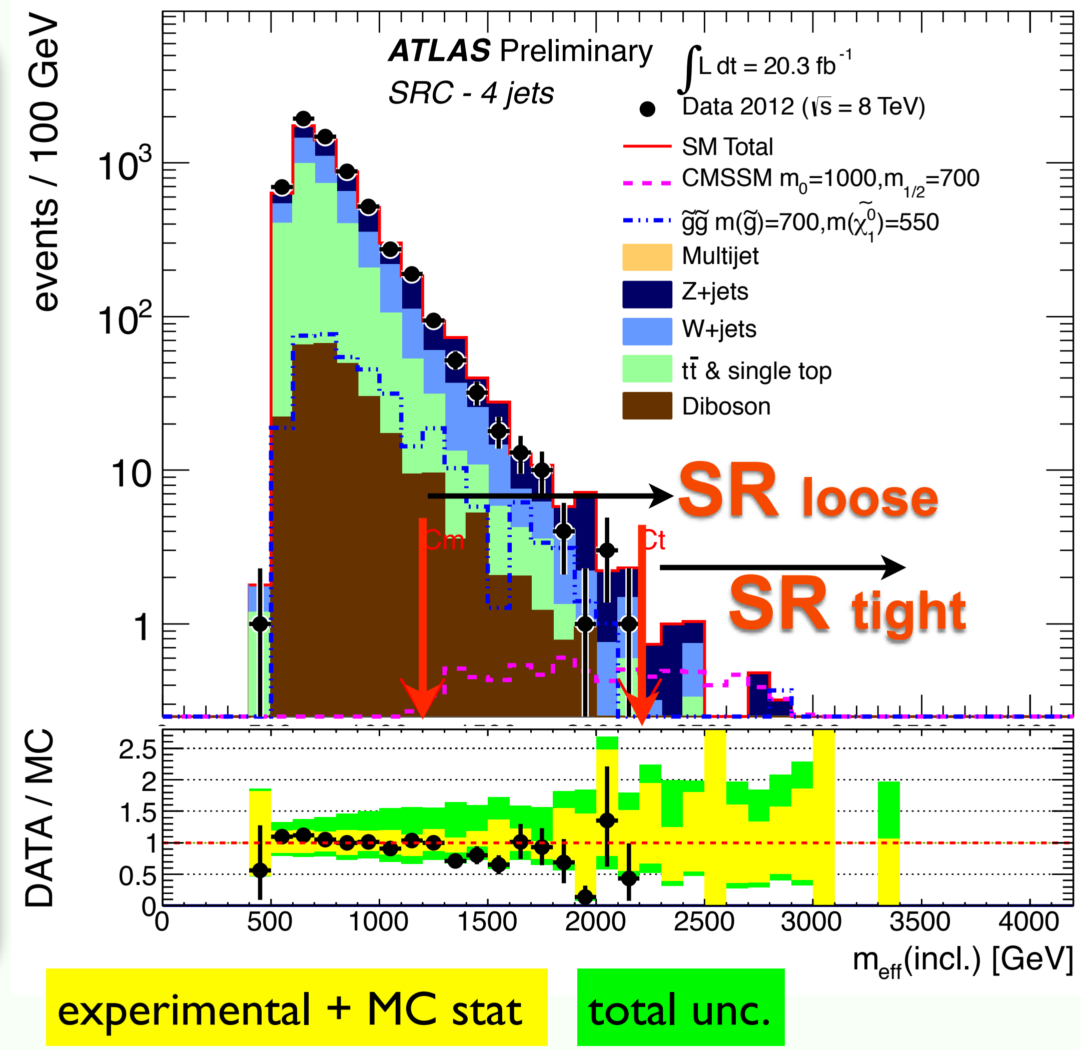
0-lepton + 2-6 jets

ATLAS-CONF-2013-047

Backgrounds

- Dominant: **Z($\rightarrow \nu\nu$)+jets**, **W+jets** & **tt-bar/single top** (hadronic tau dominated)
- **Multi-jet background**
  - Mis-reconstructed jet energy can produce large (fake) $\mathbf{E_T^{miss}}$
  - Significantly suppressed by $\Delta\phi(\mathbf{jet}, \mathbf{E_T^{miss}})_{\mathbf{min}}$ & $\mathbf{E_T^{miss}}/\mathbf{m_{eff}}$ cuts
  - The mis-reconstructed $\mathbf{E_T^{miss}}$ tail is estimated fully from the data





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0-lepton + 2-6 jets

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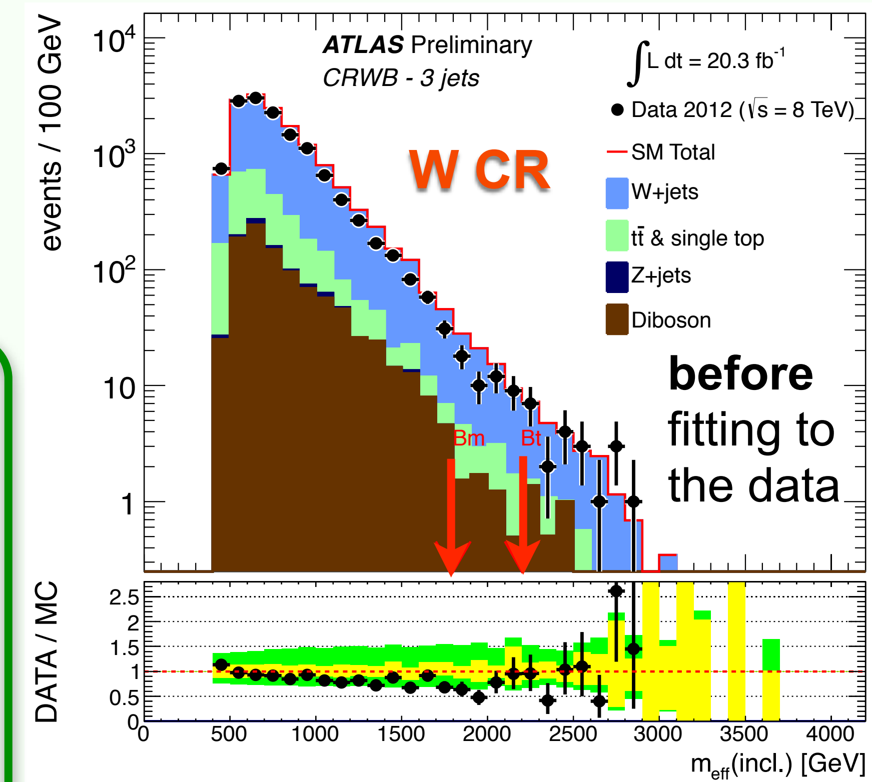
Backgrounds - method

- **Z($\rightarrow \nu\nu$)+jets**, **W+jets** & **tt-bar** (hadronic tau dominated) are normalised to the data in the **combined fit**

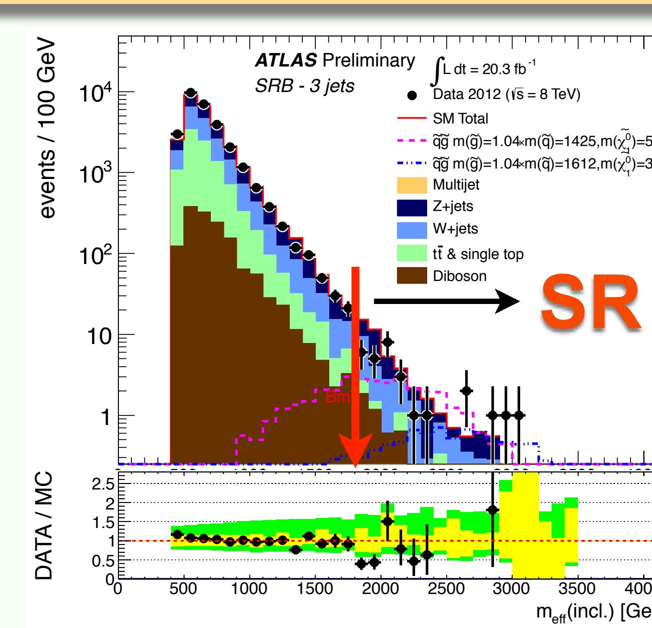


experimental + MC stat

total unc.

- **Fit based on profile likelihood** (used in all analyses presented)
- MC samples normalised simultaneously to the data in their control regions (CRs)
  - Orthogonal to SRs
  - **Z+jets** CR: isolated photon
  - **W+jets** / **tt-bar** CR: lepton + no b-jets / ≥1 b-tagged jet
- **Rely on MC shape** to extrapolate the prediction to the SR
- Systematic uncertainties included as nuisance parameters

$$N_{SR,est.data} = N_{CR,obs.data} \times \frac{N_{SR,MC}}{N_{CR,MC}}$$



No significant deviation from SM expectation

- Model-independent limits on the visible BSM cross-section are set
- σ(vis) = σ(BSM) x [kinematic acceptance] x [exp efficiency]

≥ 4 J, tight	N_{exp}	N_{obs}	$\langle A\epsilon\sigma\rangle^{95\%}_{obs}$ [fb]
	1.6±1.4	0	0.12

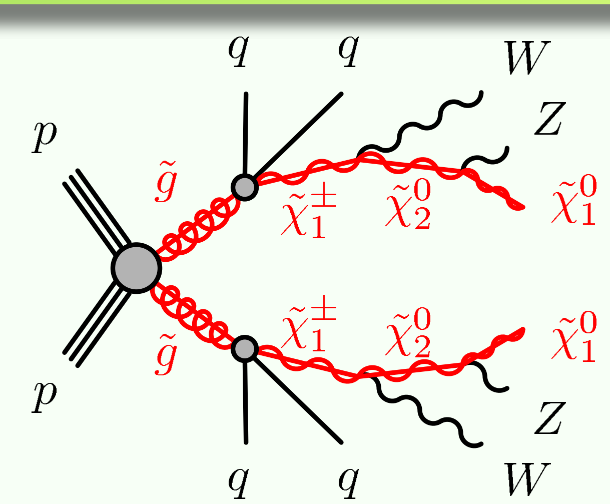
All the umbers are in the backup, here showing only best-limit SR

0-lepton + 7-10 jets

arXiv:1308.1841

Signal regions

- Large number of jets (7-10)
  - **Cascade decays**
  - May include stops in the decay chains
  - Large number of SRs separated into 2 “streams”



	Multi-jet + flavour stream															Multi-jet + M_J^{Σ} stream		
Identifier	8j50			9j50			≥10j50	7j80			≥8j80			≥8j50	≥9j50	≥10j50
Jet $\|\eta\|$	< 2.0							< 2.0						< 2.8		
Jet p_T	> 50 GeV							> 80 GeV						> 50 GeV		
Jet count	$= 8$			$= 9$			≥ 10	$= 7$			≥ 8			≥ 8	≥ 9	≥ 10
b-jets ($p_T > 40\,GeV, \|\eta\| < 2.5$)	0	1	≥ 2	0	1	≥ 2	—	0	1	≥ 2	0	1	≥ 2	—		
M_J^{Σ} [GeV]	—							—						> 340 and > 420 for each case		
$E_T^{miss}/\sqrt{H_T}$	$> 4\,\mathrm{GeV}^{1/2}$							$> 4\,\mathrm{GeV}^{1/2}$						$> 4\,\mathrm{GeV}^{1/2}$		

- **Flavour stream**: separated by the **number of b-tagged jets**
  - Targetting also decay chains like: $\tilde{g} \to \bar{t} + \tilde{t} \to \bar{t} + t + \tilde{\chi}_1^0$ → *See the talk by Alexandra Tudorache for the interpretation*
- Missing E_T significance: $E_T^{miss}/\sqrt{H_T}$
  - Suppressing multi-jet background

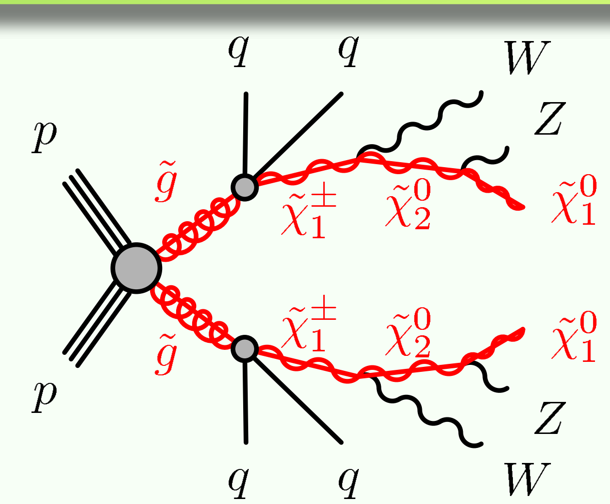
$$H_T = \sum_i p_{T,i}^{jet}, \quad p_T^{jet} > 40\,\mathrm{GeV}, \ |\eta| < 2.8$$

0-lepton + 7-10 jets

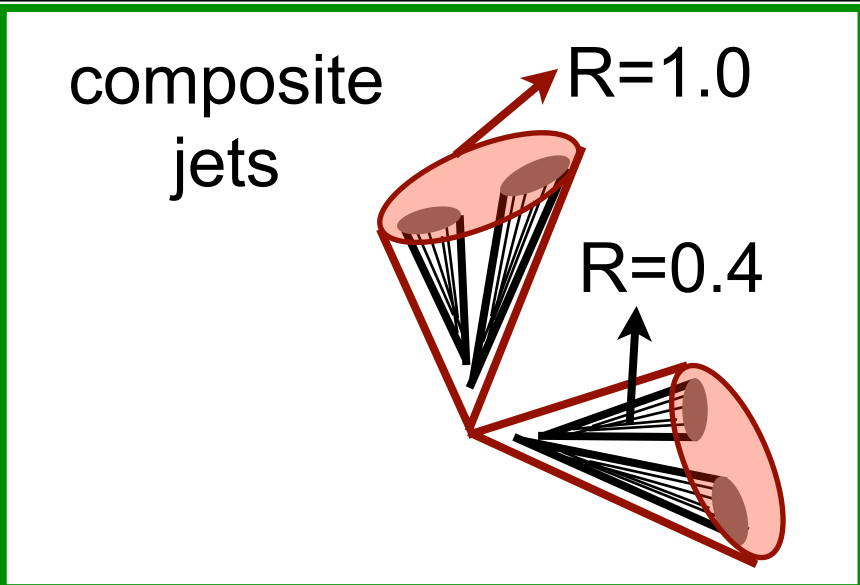
arXiv:1308.1841

Signal regions

- Large number of jets (7-10)
  - **Cascade decays**
  - May include stops in the decay chains
  - Large number of SRs separated into 2 “streams”



					Multi-jet + M_J^Σ stream		
Identifier	8j5…		≥8j80		≥8j50	≥9j50	≥10j50
Jet $\|\eta\|$					< 2.8		
Jet p_T			…eV		> 50 GeV		
Jet count	$= 8$…		≥ 8		≥ 8	≥ 9	≥ 10
b-jets ($p_T > 40\,GeV, \|\eta\| < 2.5$)	0	1 …	1	≥ 2	—		
M_J^Σ [GeV]	—		—		> 340 and > 420 for each case		
$E_T^{miss}/\sqrt{H_T}$	$> 4\,\mathrm{GeV}^{1/2}$		$> 4\,\mathrm{GeV}^{1/2}$		$> 4\,\mathrm{GeV}^{1/2}$		



- **Fat-jet stream**: constructing **composite jets**
  - Collect all p_T>20 GeV jets with cone radius R=0.4
  - Use them as an input to a 2nd iteration of the anti-k_t jet algorithm with R=1.0
  - Sum the masses of the composite jets:

$$\mathbf{M_J^\Sigma = \sum_j m_j^{R=1.0,\, p_T > 100GeV}}$$

0-lepton + 7-10 jets

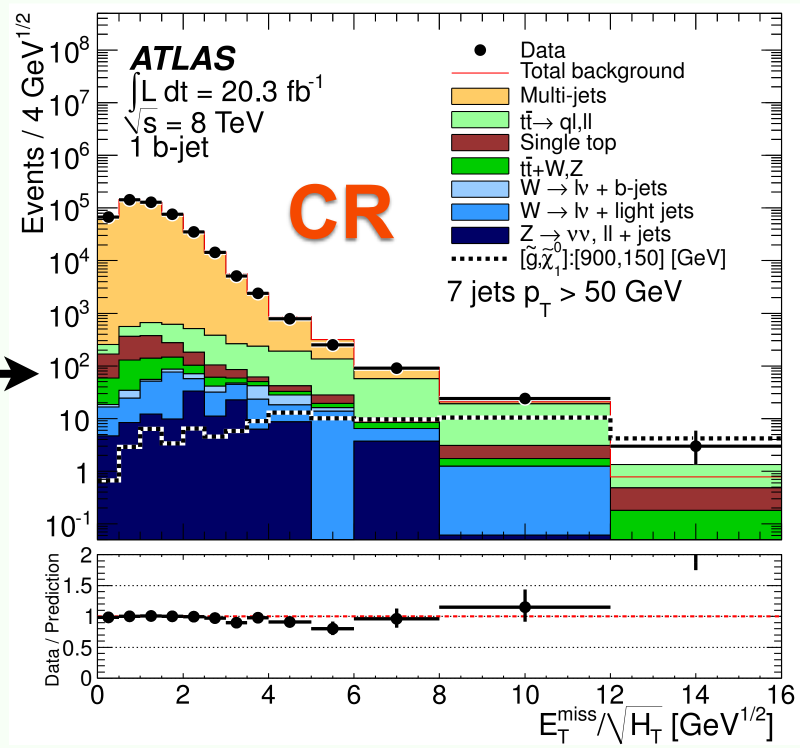
arXiv:1308.1841

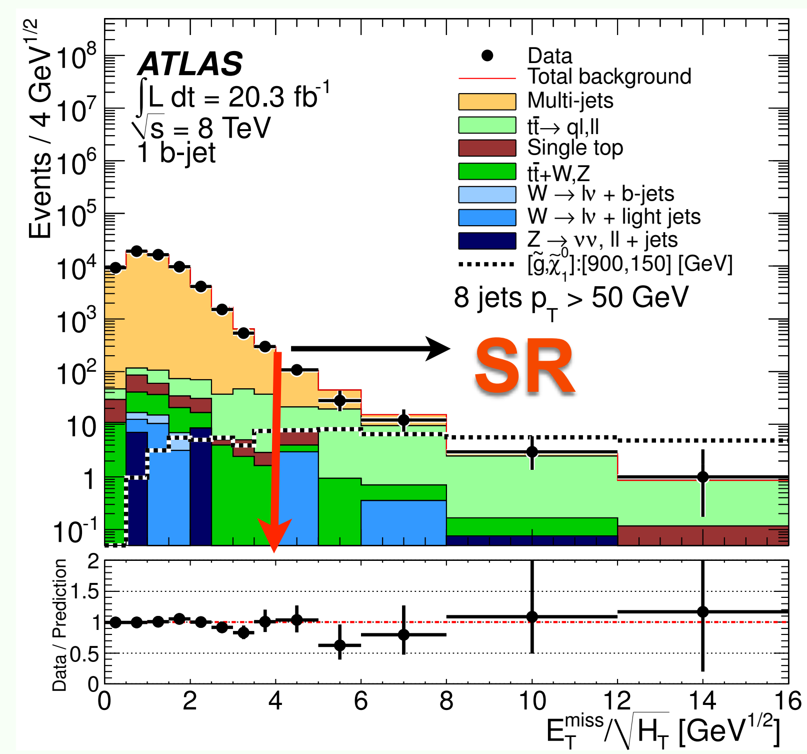
Backgrounds

- Dominant: **Multi-jets** (includes QCD, hadronic decays of $t\bar{t}$,W & Z)
  - **Data driven**
    - $E_T^{miss}/\sqrt{H_T}$ shape (E_T^{miss} resolution) is ~invariant in every number-of-jets bin
    - Extract the shape template in the lower jet multiplicity region where there is no contamination from non-SM physics

= 6 jets: **make a shape-template of $E_T^{miss}/\sqrt{H_T}$** → = 7 jets: **CR - validate the template** → >= 8 jets: **use it in the signal region**

- Control region (with 1 b-jet) - good agreement





0-lepton + 7-10 jets

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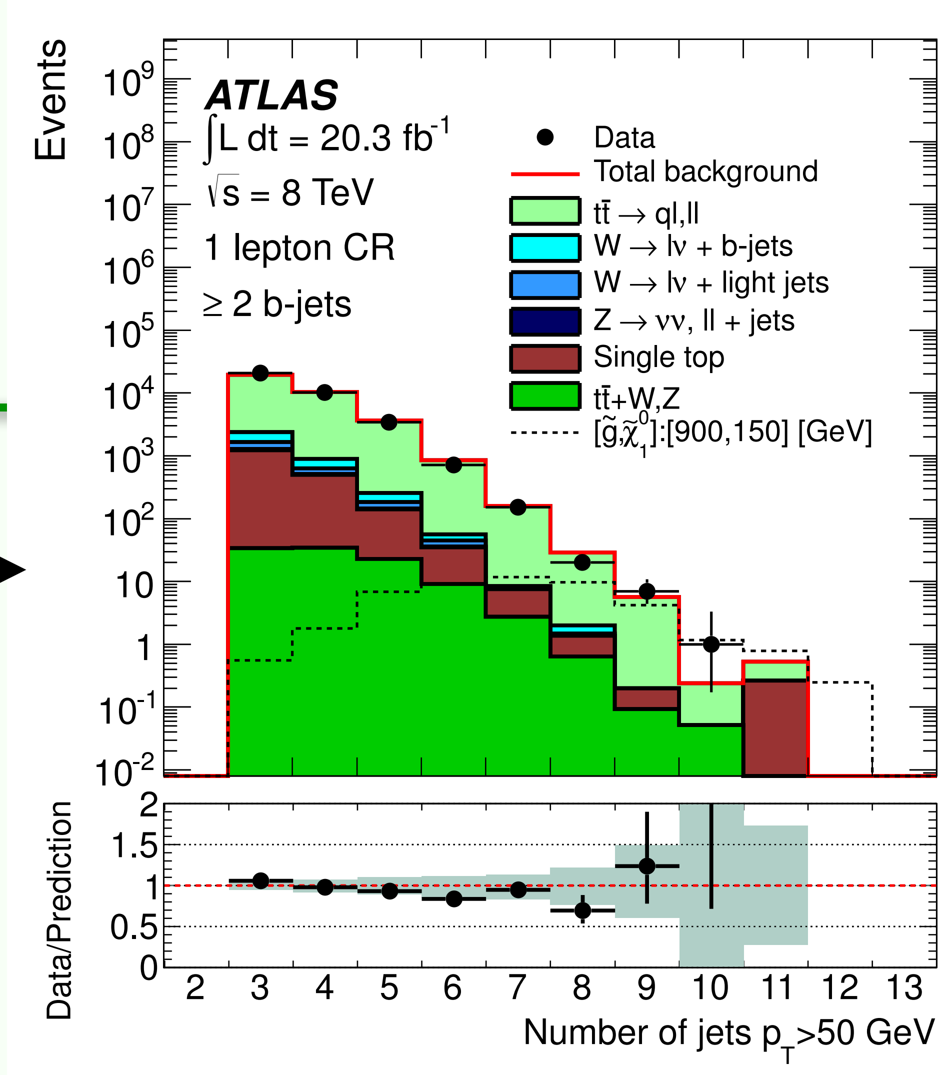
- Dominant: **Multi-jets** (includes QCD, hadronic decays of $t\bar{t}$,W & Z)
  - **Data driven**
    - $E_T^{miss}/\sqrt{H_T}$ shape (E_T^{miss} resolution) is ~invariant in every number-of-jets bin
    - Extract the shape template in the lower jet multiplicity region where there is no contamination form non-SM physics
- **Leptonic backgrounds**
  - Leptonic decays of $t\bar{t}$ & **W** (hadronic tau dominated)
- **MC normalised to the data** in the combined fit
  - Control regions: require one lepton

- Control region with >=2 b-jets (**before** fitting to the data) →



No significant deviation from SM expectation

- Set limits on σ(vis) = σ(BSM) x acceptance x efficiency

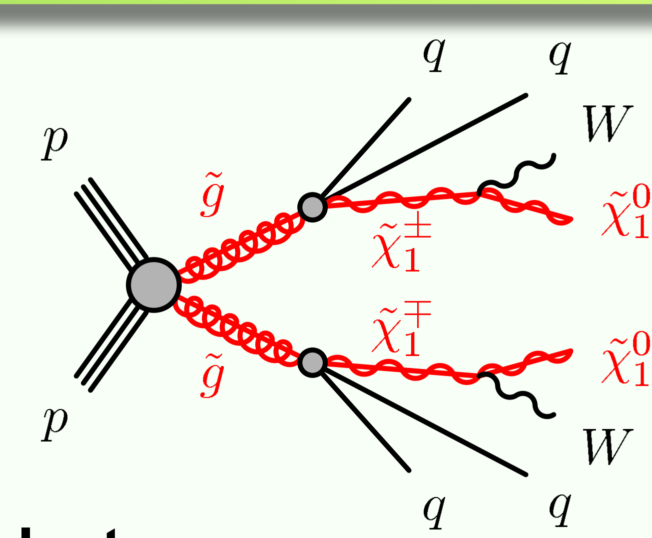
≥ 8 J, = 1b-J	N_{exp}	N_{obs}	$\langle A\epsilon\sigma\rangle^{95\%}_{obs}$ [fb]
	1.5±0.9	1	0.17

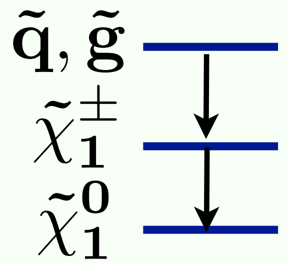
1-lepton + 3-6 jets

ATLAS-CONF-2013-062

Signal regions

- Target: 1- and 2-step gluino/squark decays
- Divided into “soft” and “hard” lepton channels

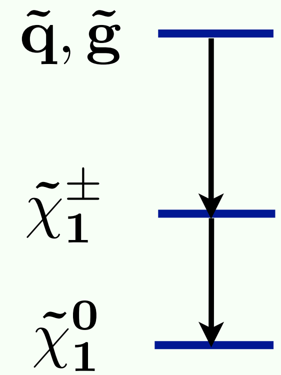




soft leptons, jets

- 6(10)<p_T(μ,e)<25 GeV

Leading hard jet is initial state radiation jet: p_T>180 GeV



harder jets & leptons from sparticle decays

- p_T(μ,e)>25 GeV

p_T^{jets}>{80,40} GeV

	soft single-lepton	
	3-jet	**5-jet**
E_T^{miss} [GeV]	>400	>300
m_T [GeV]	> 100	
$E_T^{miss}/m_{\rm eff}^{\rm incl}$	> 0.3	

	inclusive (binned) hard single-lepton		
	3-jet	**5-jet**	**6-jet**
E_T^{miss} [GeV]	>500 (300)	>300	>350 (250)
m_T [GeV]	> 150	> 200 (150)	> 150
$E_T^{miss}/m_{\rm eff}^{\rm excl}$	> 0.3	–	–
$m_{\rm eff}^{\rm incl}$ [GeV]	> 1400 (800)		> 600

- Discriminating variables:
  - $\mathbf{E_T^{miss}}$, transverse mass (m_T), effective mass (m_{eff}), $\mathbf{E_T^{miss}/m_{eff}}$

$$\mathbf{m_T} = \sqrt{\mathbf{2E_T^{miss}p_T^{lep}} \cdot \left(\mathbf{1} - \cos\left(\mathbf{\Delta}\phi(\vec{p}_{\mathbf{T}}^{\mathbf{miss}}, \vec{p}_{\mathbf{T}}^{\mathbf{lep}})\right)\right)}$$

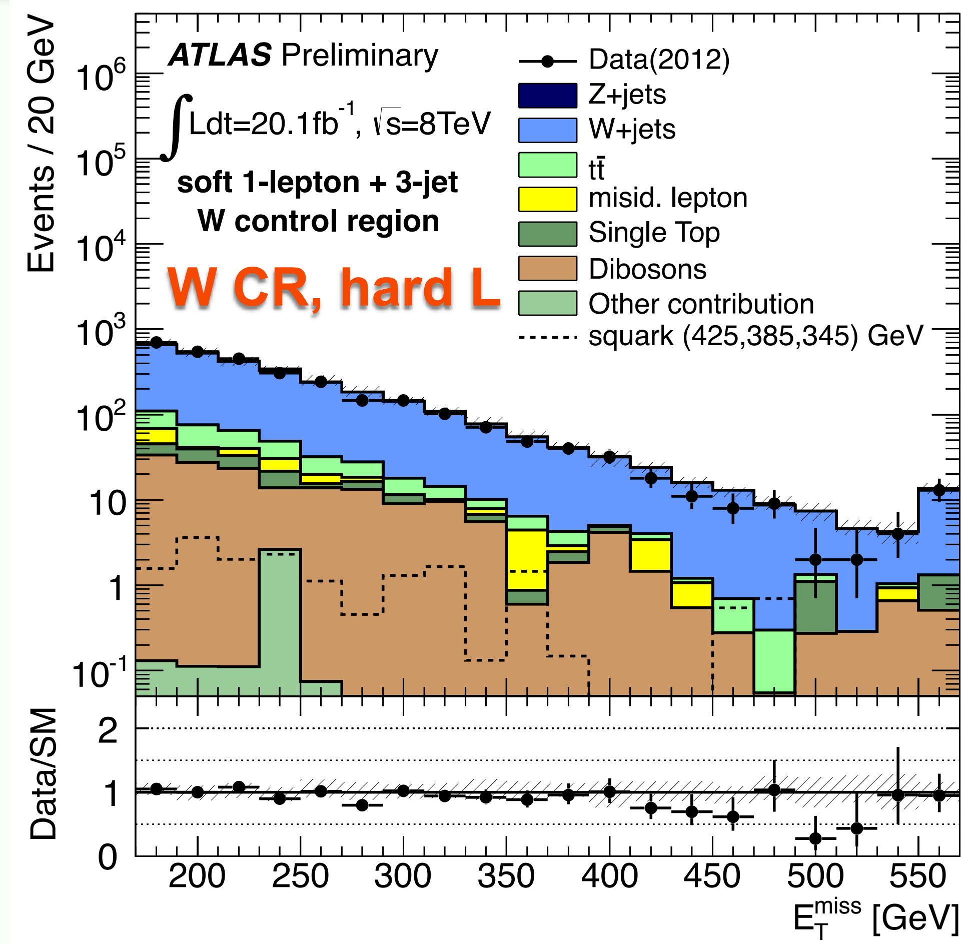
$$\mathbf{m_{eff}} = \mathbf{E_T^{miss}} + \mathbf{p_T^{\ell}} + \sum_{\mathbf{i}} \mathbf{p_{T,i}^{jet}}$$

1-lepton + 3-6 jets

ATLAS-CONF-2013-062

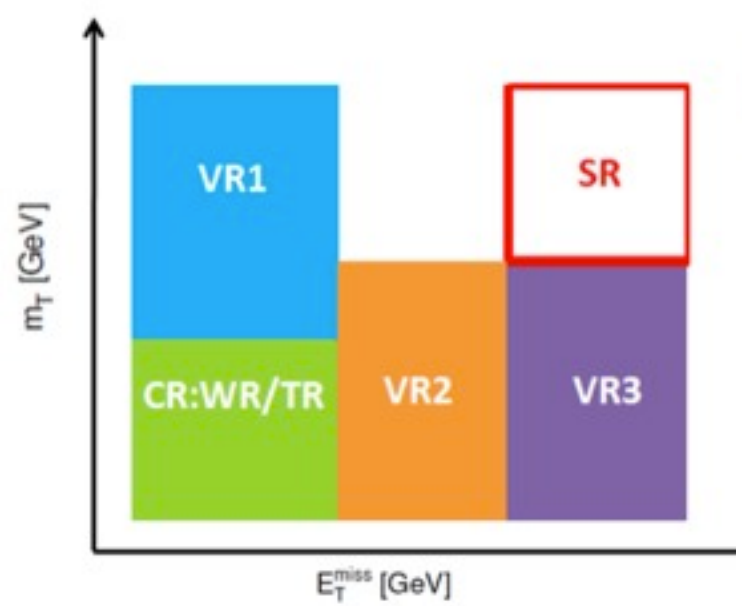
Backgrounds

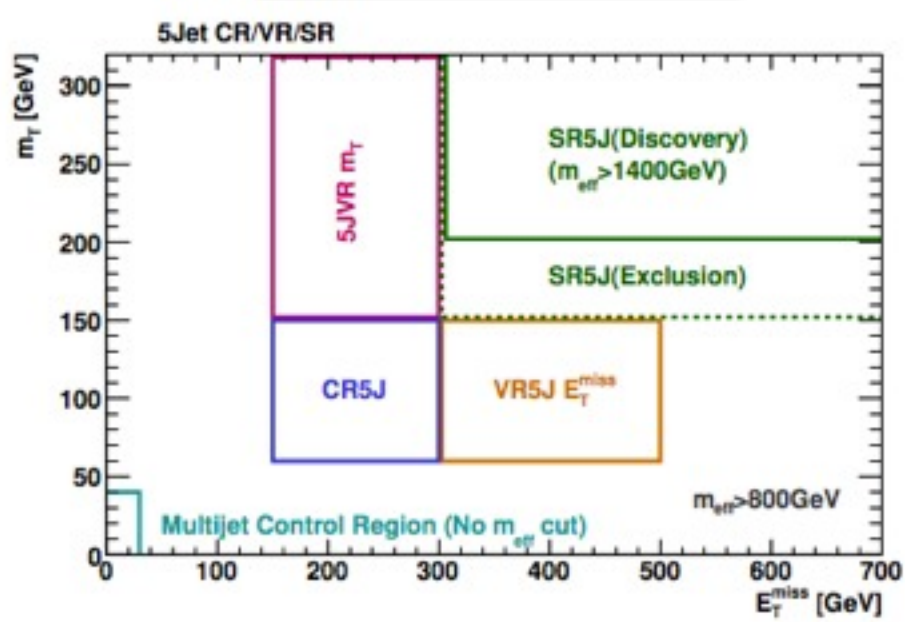
- Dominant: **W+jets** & **tt-bar** (leptonic decays)
  - **Normalised to the data** in the simultaneous fit
    - require no b-jets for **W** CR and at least 1 b-jet for **tt-bar** CR
    - the result checked in validation regions (VR) - good agreement between prediction and observation (mostly within 1 sigma error)

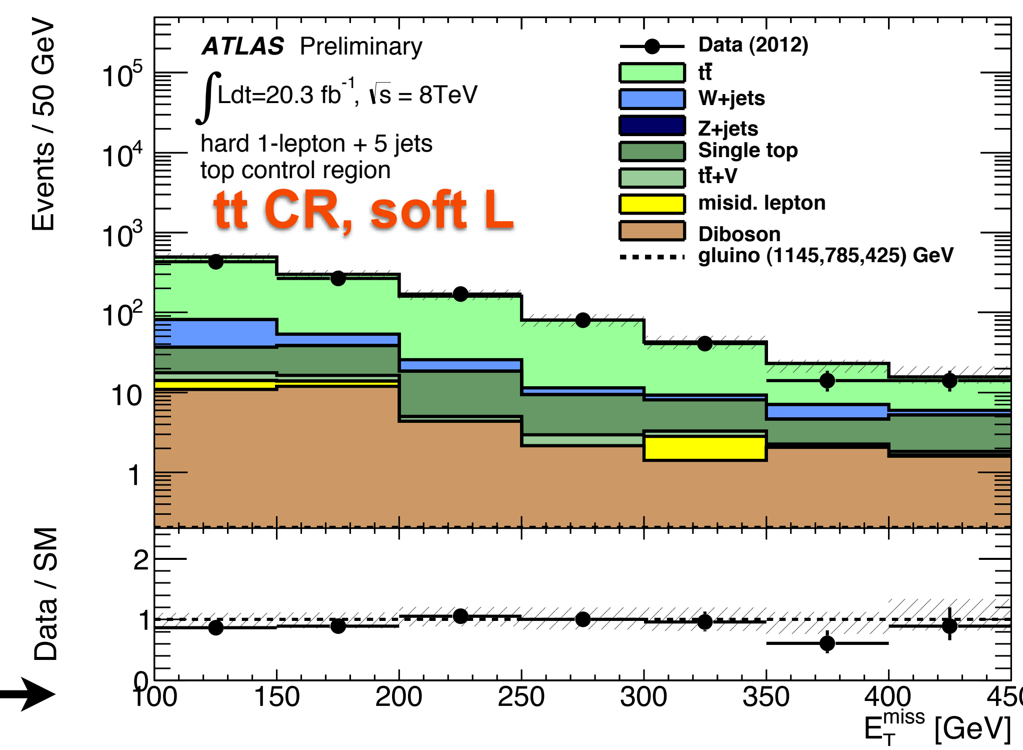


soft L channel

hard L channel







Control regions (after fitting to the data) →

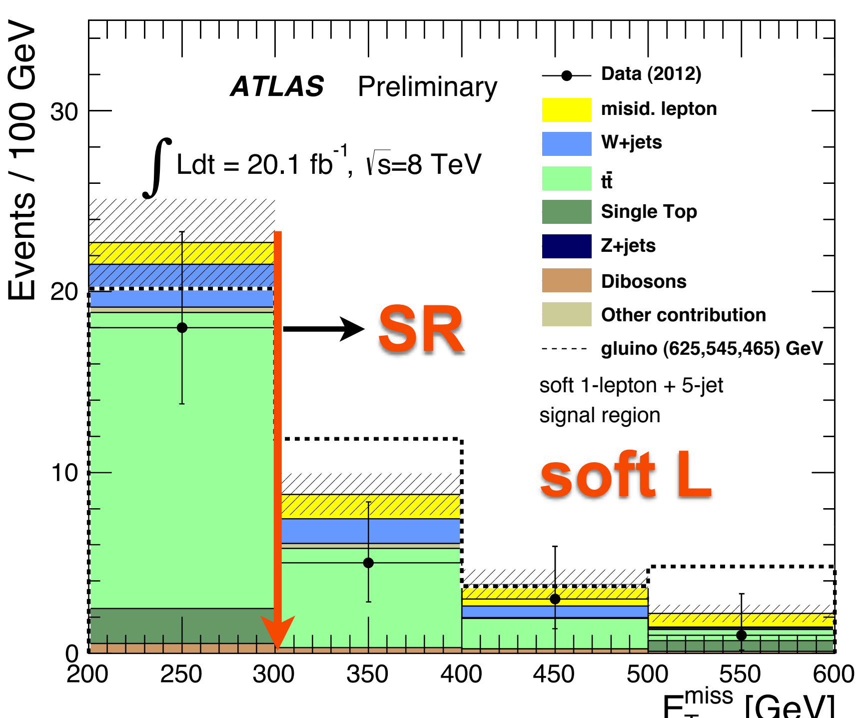
1-lepton + 3-6 jets

ATLAS-CONF-2013-062

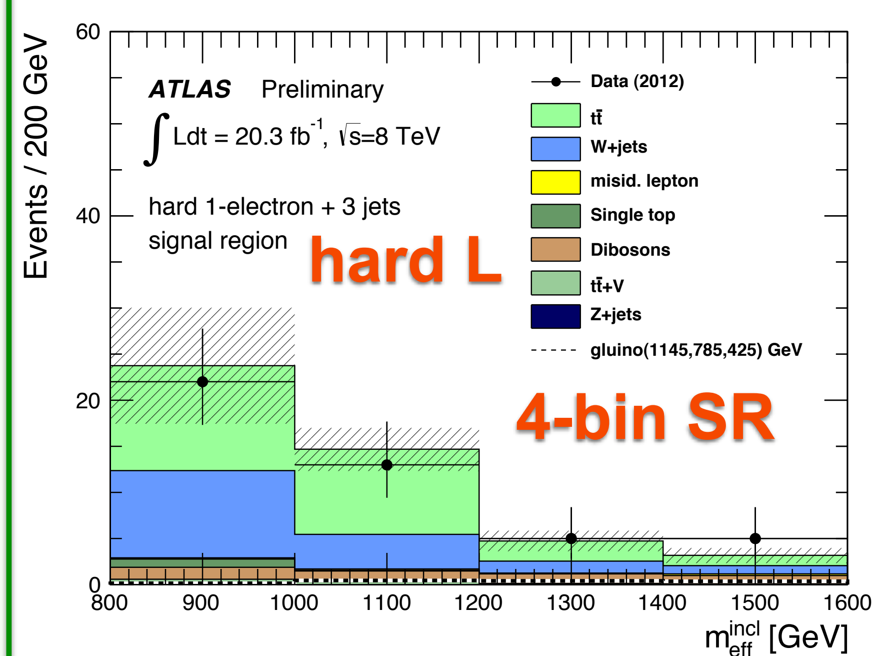
Backgrounds

- **Misidentified lepton background**
  - Jets misidentified as leptons or leptons from c- & b-hadron decays ($Z \to \nu\nu$ dominant)
  - Suppressed by requiring the lepton to be well isolated
- Estimated in a **fully data-driven** way
  - Fake lepton rate measured in the di-jet data sample by inverting the isolation requirement

No significant deviation from SM expectation



- **Soft L** - 1 bin, no shape-fit



- **Inclusive SRs**
  - Optimised for discovery and placing the model-independent limits
  - Tighter E_T^{miss}, m_T, M_{eff} cuts
  - Place more stringent limits on σ(vis)

	N_{exp}	N_{obs}	$\langle A\epsilon\sigma\rangle^{95\%}_{obs}$ [fb]
≥ 6 J, μ SR	7.4±1.7	7	0.15

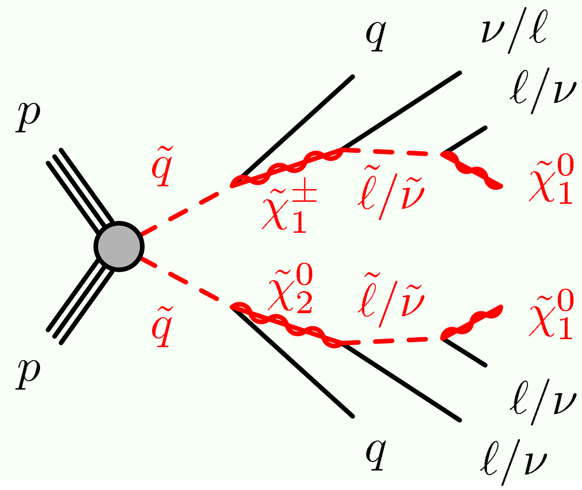
- **Binned SRs** (in M_{eff} or E_T^{miss})
  - Exploit signal shape-info when placing limits in specific models
  - Orthogonal in N_{jet} requirement

2-leptons

ATLAS-CONF-2013-089

Signal regions

- 2 leptons (p_T^{lep}>{14,8} GeV) and jets (p_T^{jet}>50 GeV)
- Discriminating variable: **“razor”**
  - **Group all visible final state objects into two mega-jets**
  - Each represents the decay products of a single sparticle

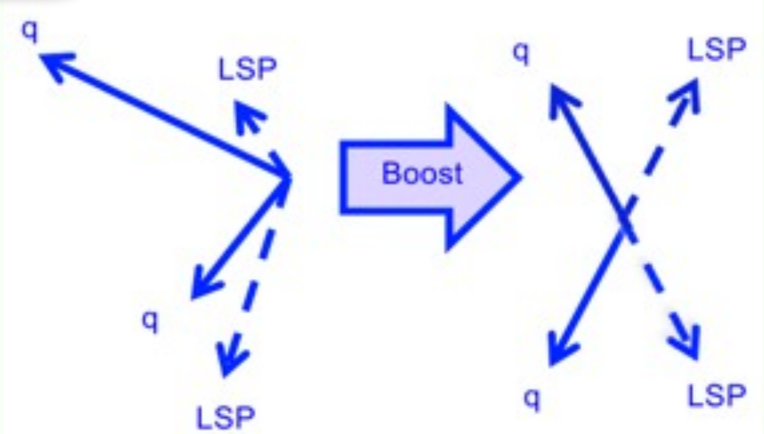


- Longitudinal info: mass scale of the event

$$M'_R = \sqrt{(j_{1,E} + j_{2,E})^2 - (j_{1,L} + j_{2,L})^2}$$

- Transverse info

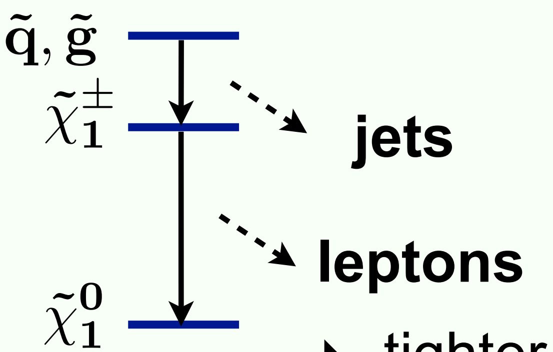
$$M_T^R = \sqrt{\frac{|\vec{E}_T^{miss}|(|\vec{j}_{1,T}| + |\vec{j}_{2,T}|) - \vec{E}_T^{miss} \cdot (\vec{j}_{1,T} + \vec{j}_{2,T})}{2}}$$



- The “razor variable” $R = \frac{M_T^R}{M'_R}$

- **Close to 0 for SM events**
- **Approximately uniform for SUSY events**

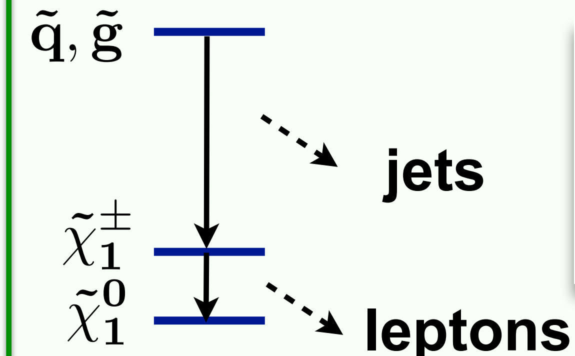
Larger $\tilde{\chi}^\pm$- LSP splitting



- $N_{jets} \leq 2$
- R > 0.5
- M_R > 400 GeV

- tighter discovery SR with M_R>600 GeV

Smaller $\tilde{\chi}^\pm$- LSP splittings



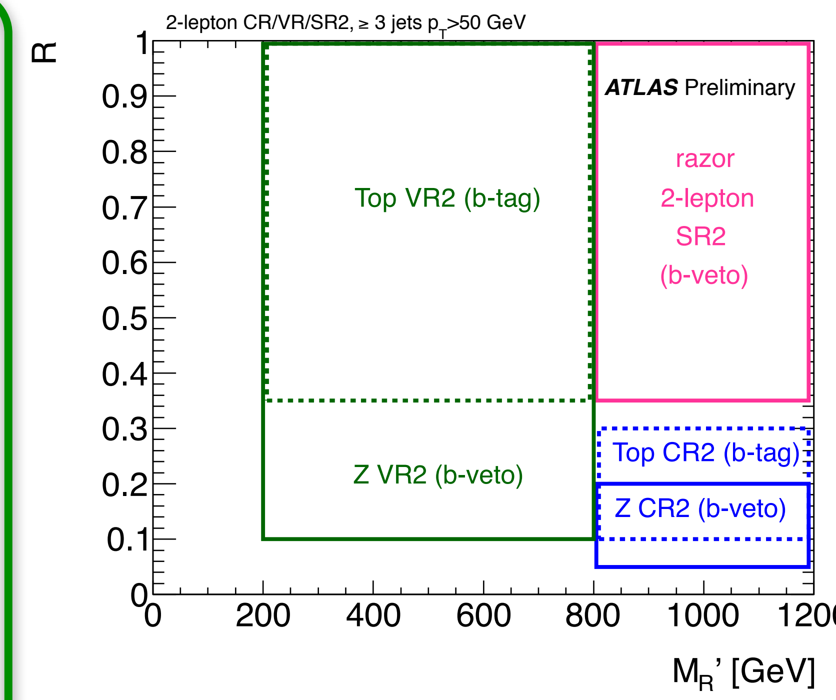
- $N_{jets} \geq 3$
- R > 0.35
- M_R > 800 GeV

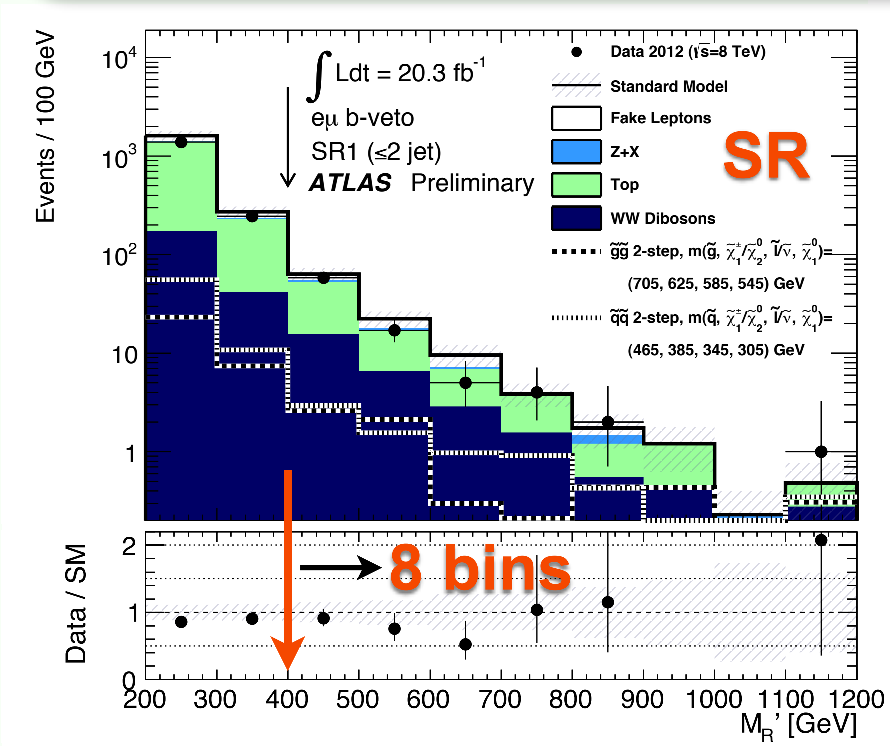
2-leptons

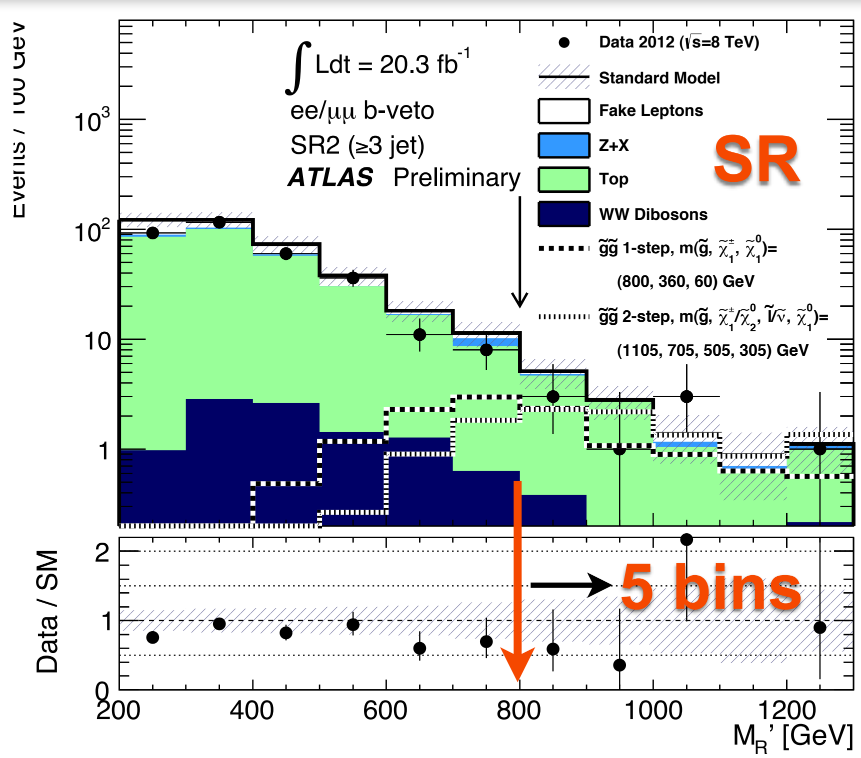
ATLAS-CONF-2013-089

Backgrounds

- **Top** (tt-bar, single top, tt+EW) & **Z+X** (Z/γ+jets, WZ, ZZ)
  - Z-mass window is vetoed
  - **Normalised to the data** in the simultaneous fit
  - require no b-jets for **Z** CR and at least 1 b-jet for **top** CR
- **Misidentified (fake) leptons** (from W+jets and semilep. tt)
  - **Data-driven** (same method as in 1L analysis)
- **WW** - using only MC estimate







- SRs are **binned in M_R**
  - shape discriminant between the signal and the background
- **For model-independent limits only 1 bin is used**
  - 2 tighter discovery regions included to provide more stringent limits on larger Δm splitting models

No significant deviation from SM expectation

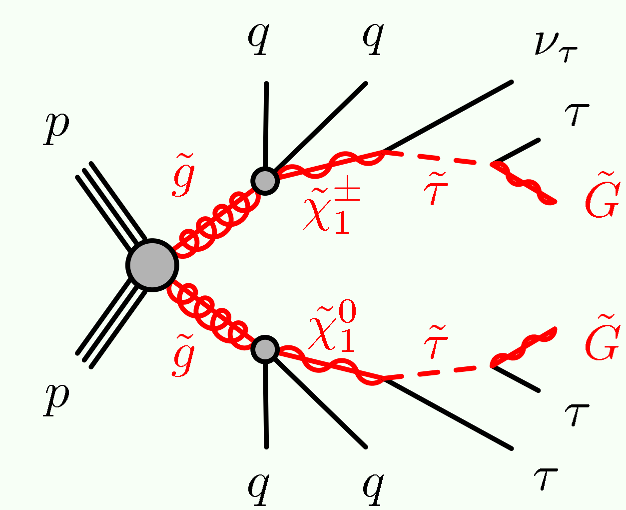
≥ 3 J,	N_{exp}	N_{obs}	$\langle A\epsilon\sigma\rangle^{95\%}_{obs}$ [fb]
ee/μμ SR	10.3±2.6	7	0.3

Tau + jets + E_T^{miss}

ATLAS-CONF-2013-026

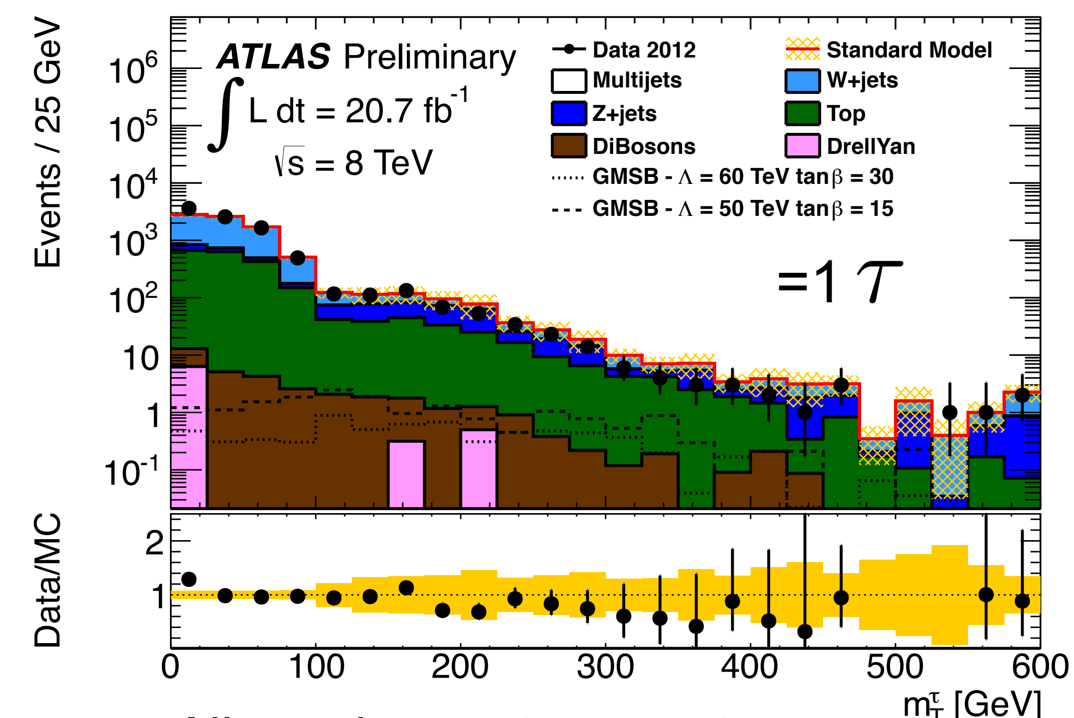
Signal regions

- Gauge-mediated SUSY breaking models
  - $\tilde{\tau}$ NLSP decaying to gravitino LSP & τ
  - SRs with ≥1 τ , ≥2 jets & E_T^{miss}



Backgrounds

- Dominant: **W/Z+jets** + **tt-bar** production
  - True tau / jets misId for a tau
  - MC is scaled to the data
    - m_T<80 GeV for true τ
    - 80<m_T<130 GeV for fake τ
- **Multi-jet background**: data-driven



*All requirements except on m_T & H_T, **after** data-driven correct.*

	1τ SR	2τ GMSB SR	2τ nGM SR
Pre-selection	$p_T^{jet1} > 130$ GeV, $p_T^{jet2} > 30$ GeV, $E_T^{miss} > 150$ GeV		
Taus	$N_\tau^{medium} = 1$, $p_T^\tau > 30$ GeV	$N_\tau^{loose} \geq 2$, $p_T^\tau > 20$ GeV	
Light leptons	$N_\ell = 0$		
QCD rejection	$\Delta(\phi_{jet_{1,2}-\mathbf{p}_T^{miss}}) > 0.3$ rad, $E_T^{miss}/m_{eff} > 0.3$	$\Delta(\phi_{jet_{1,2}-\mathbf{p}_T^{miss}}) > 0.3$ rad	
Signal cuts	$m_T^\tau > 140$ GeV, $H_T > 800$ GeV	$m_T^{\tau_1} + m_T^{\tau_2} \geq 150$ GeV, $H_T > 900$ GeV	$m_T^{\tau_1} + m_T^{\tau_2} \geq 250$ GeV, $H_T > 600$ GeV, $N_{jet} \geq 4$

No significant deviation from SM expectation →

≥ 2 τ N_{exp}	N_{obs}	$\langle A\epsilon\sigma\rangle_{obs}^{95\%}$ [fb]
3.5±1.1±1.9	1	0.24

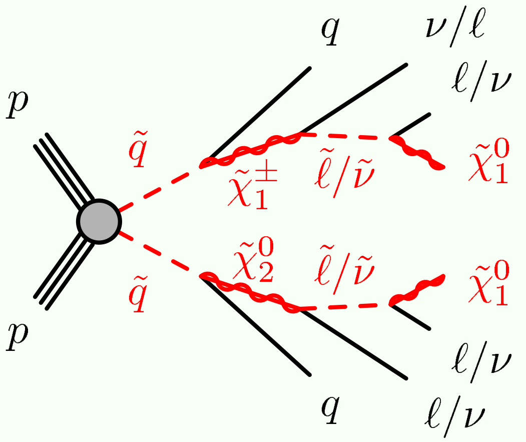
Other searches

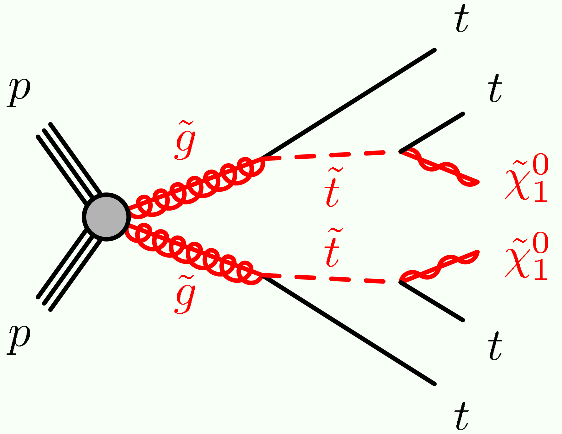
Same-sign leptons

ATLAS-CONF-2013-007

- Decay chains with top-quark production and/or decays through sleptons produce final states with same-sign (SS) leptons
  - Interesting because of small SM background
  - SRs with 2 SS leptons, $\mathbf{E_T^{miss}}$, jets and 0, ≥1 or ≥3 b-jets

See the talk by Alexandra Tudorache



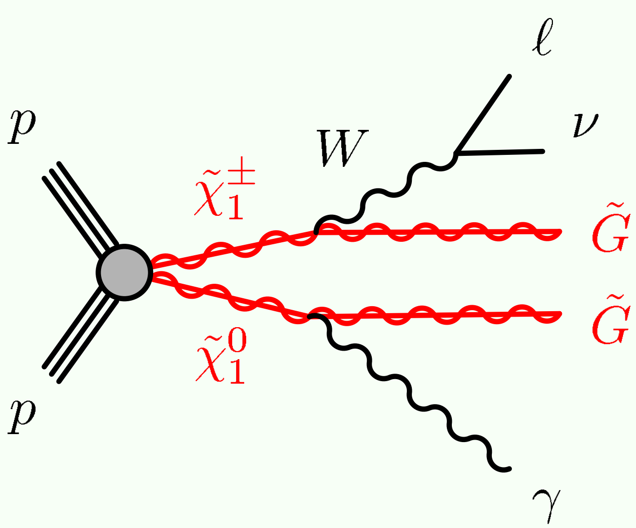


Photon final states

ATLAS-CONF-2012-144

- Gauge-mediated SUSY breaking models
  - Gravitino is the LSP
- Wino NLSP decaying to gravitino & photon
  - SR with ≥1 γ, ≥1 lepton & $\mathbf{E_T^{miss}}$
  - (L=4.8 fb^{-1} & √**s=**7 TeV)

See backup for details

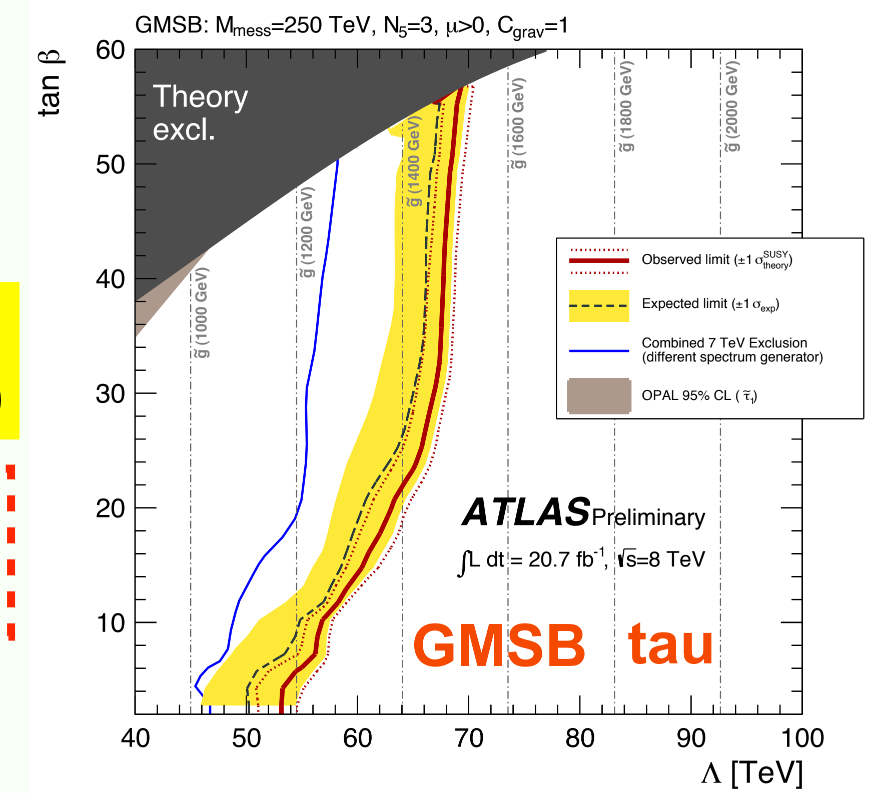


Interpretations

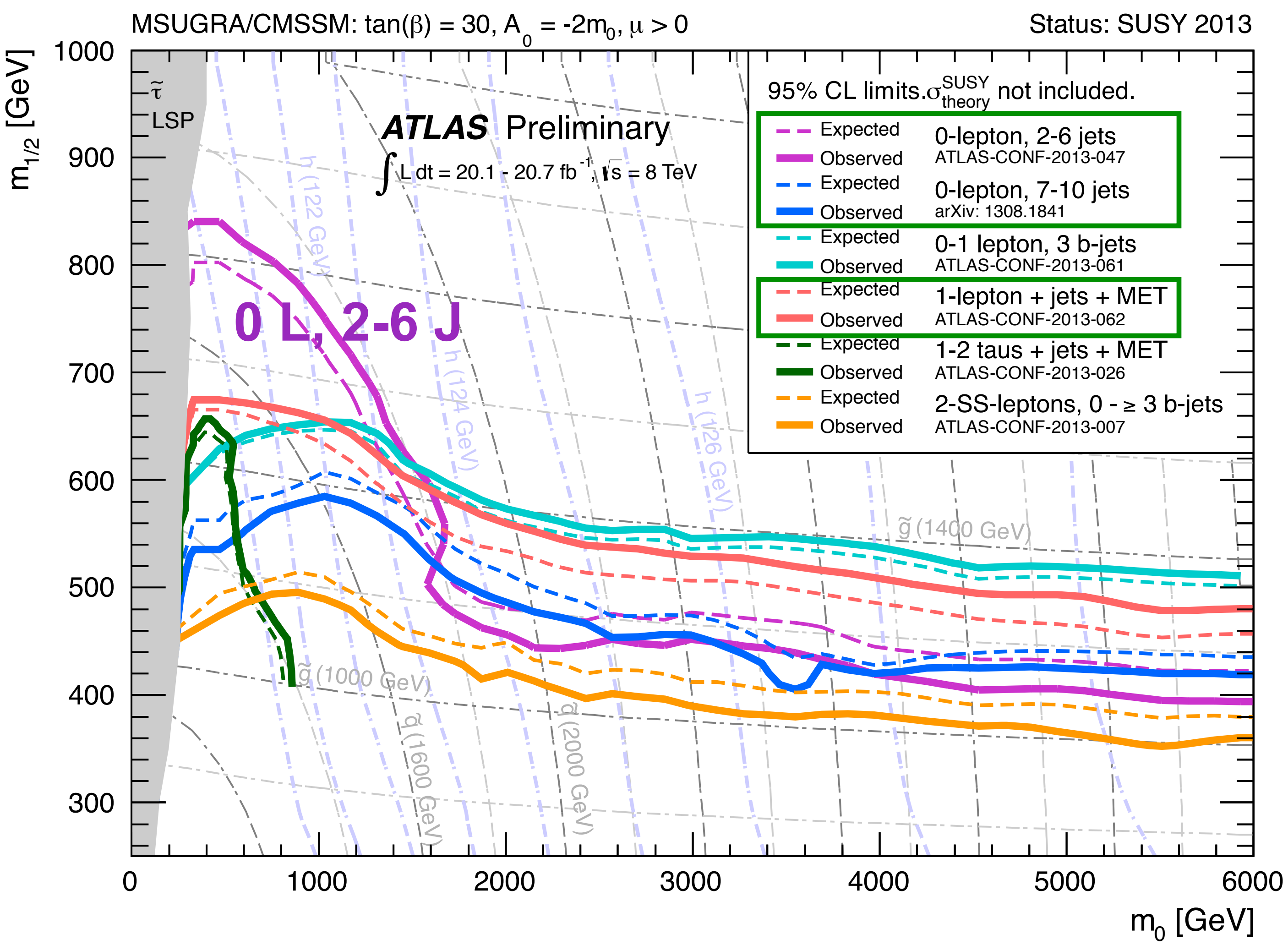
- Exclusion limits calculated using CLs method
- Possible signal contamination in the CRs taken into account

The yellow band includes ±σ of all experimental uncertainties (syst+stat)

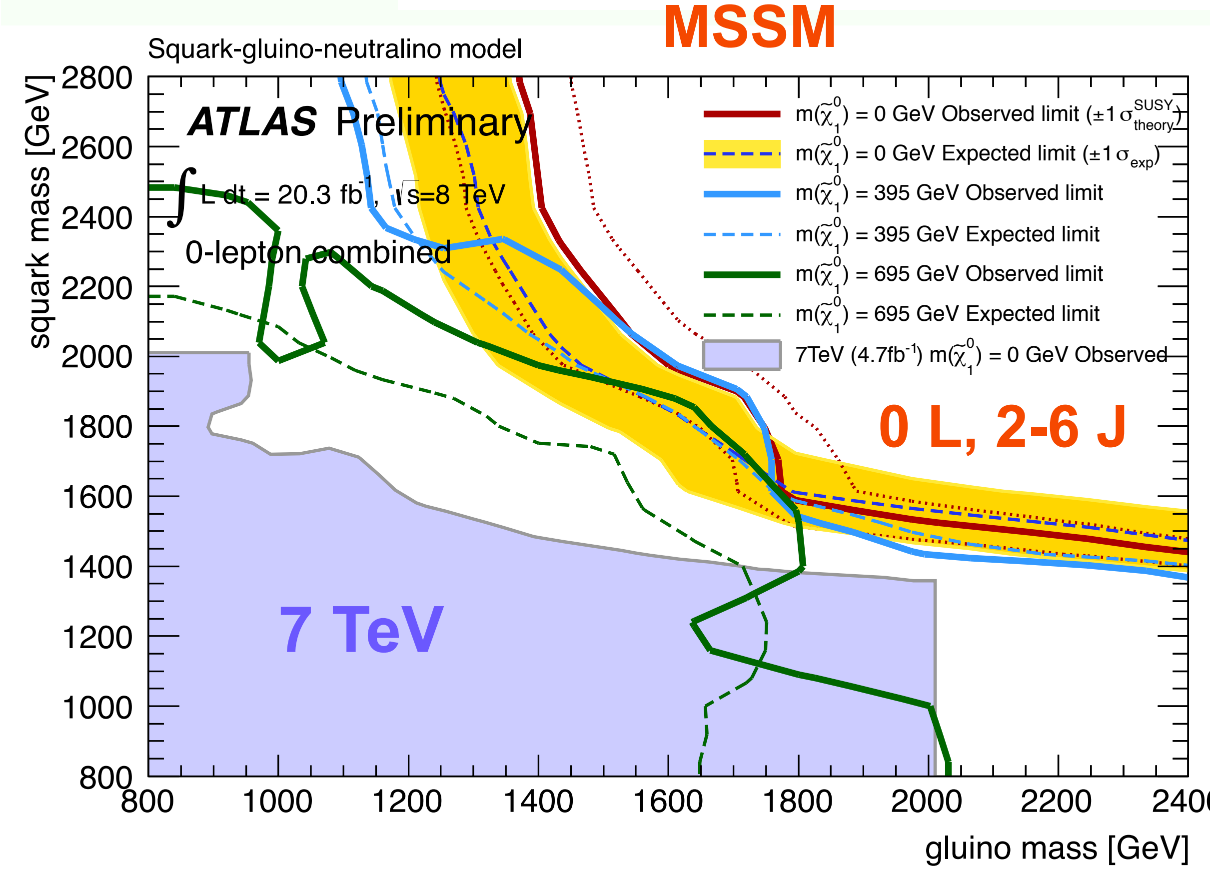
Dotted red: changing signal production cross section by ±σ



MSUGRA/CMSSM

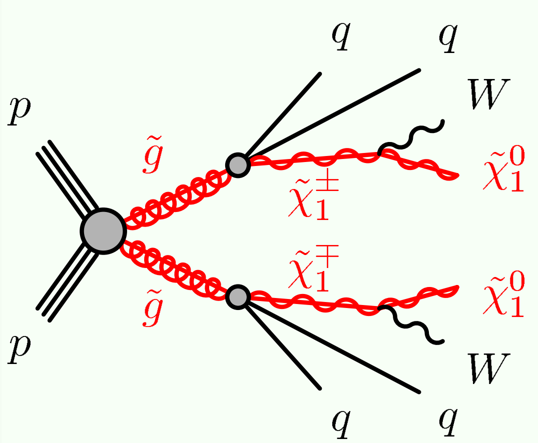


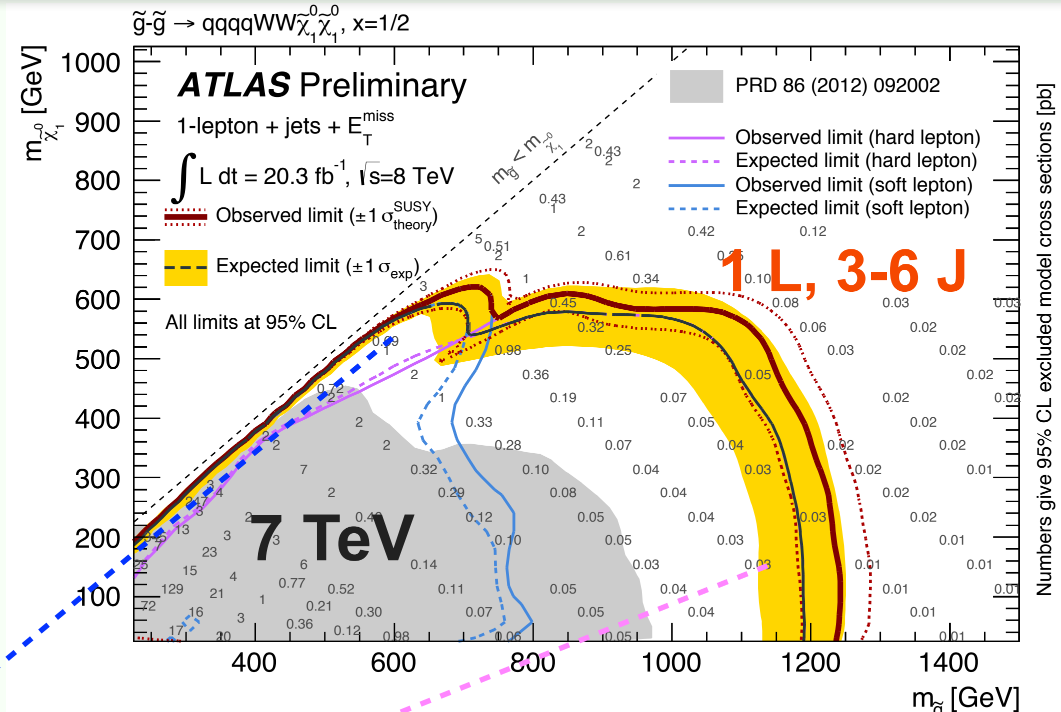
MSSM

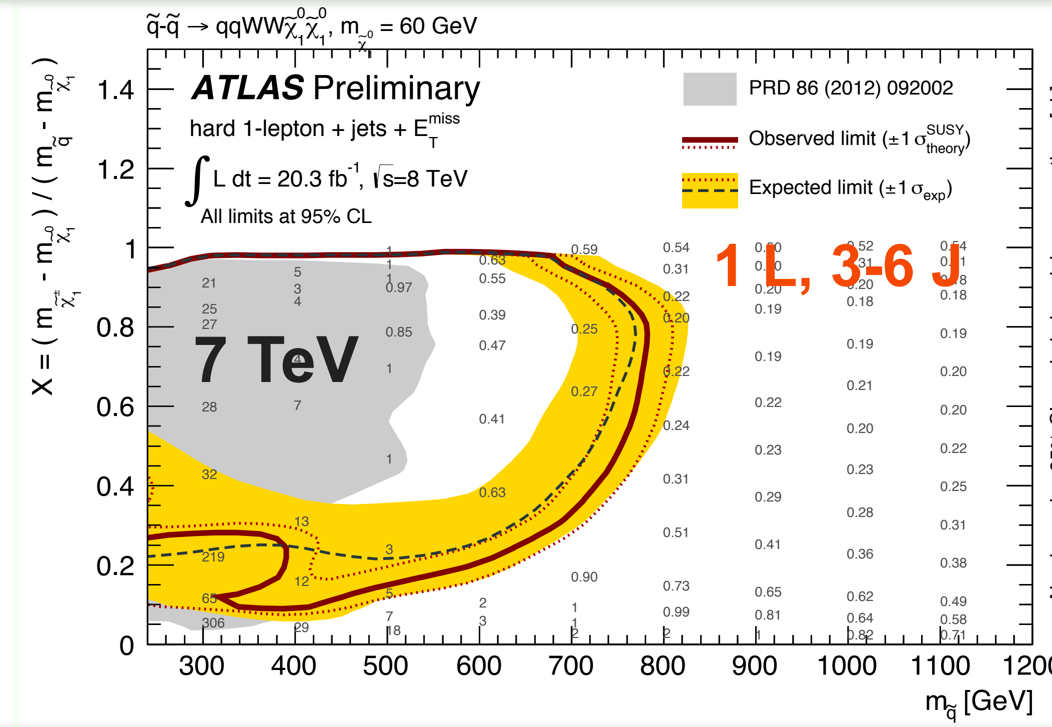


Interpretations

1-step simplified models







➡ **soft lepton** analysis covers the region close to the diagonal (compressed spectrum)

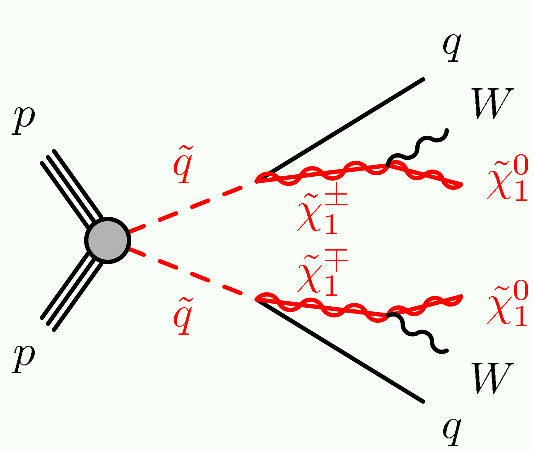
➡ **hard lepton** analysis excludes gluinos up to 1.2 TeV

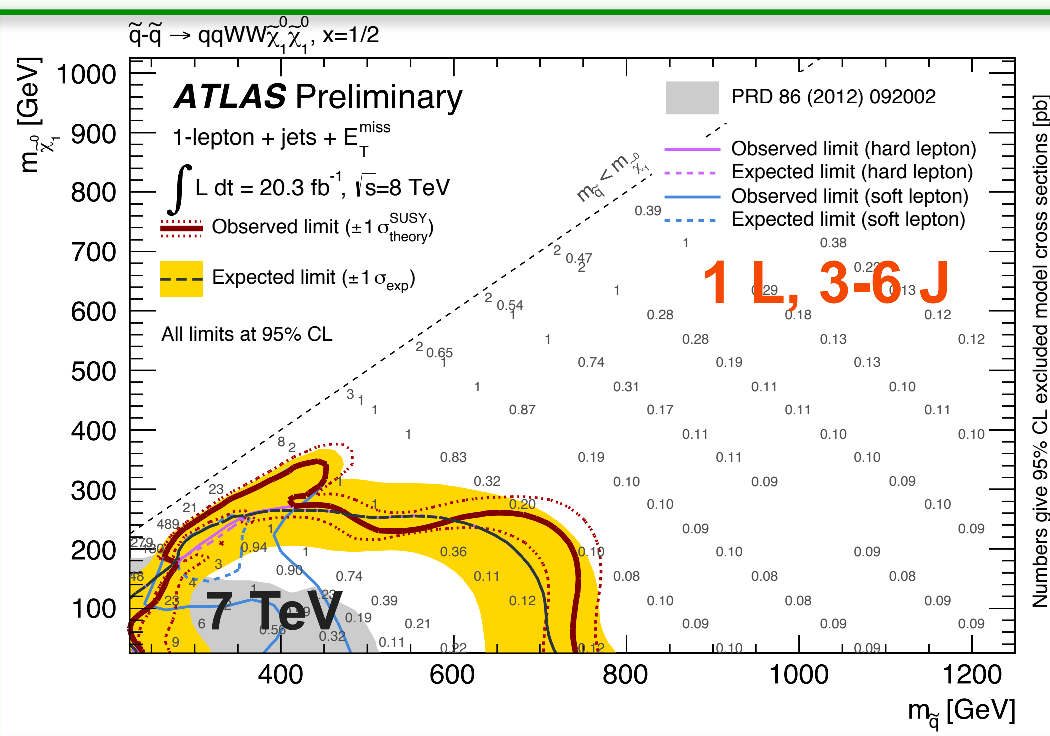
➡ LSP mass fixed

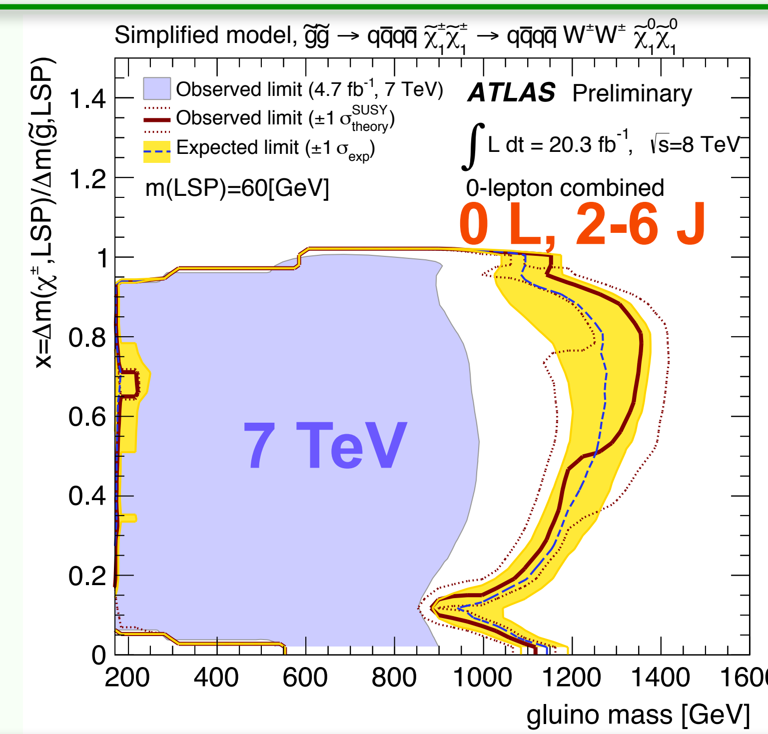
➡ parametrisation in terms of

$$x = (m_{\tilde{\chi}_1^{\pm}} - m_{\tilde{\chi}_1^0})/(m_{\tilde{g}(\tilde{q})} - m_{\tilde{\chi}_1^0})$$

1-step simplified models

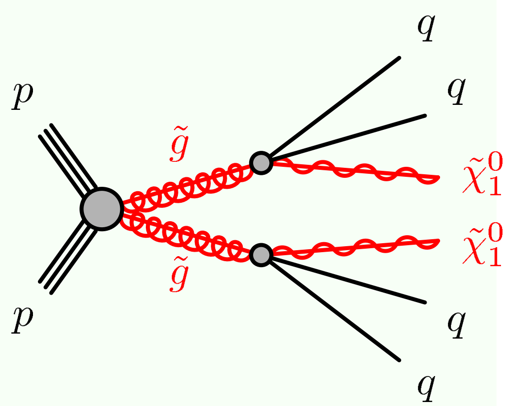




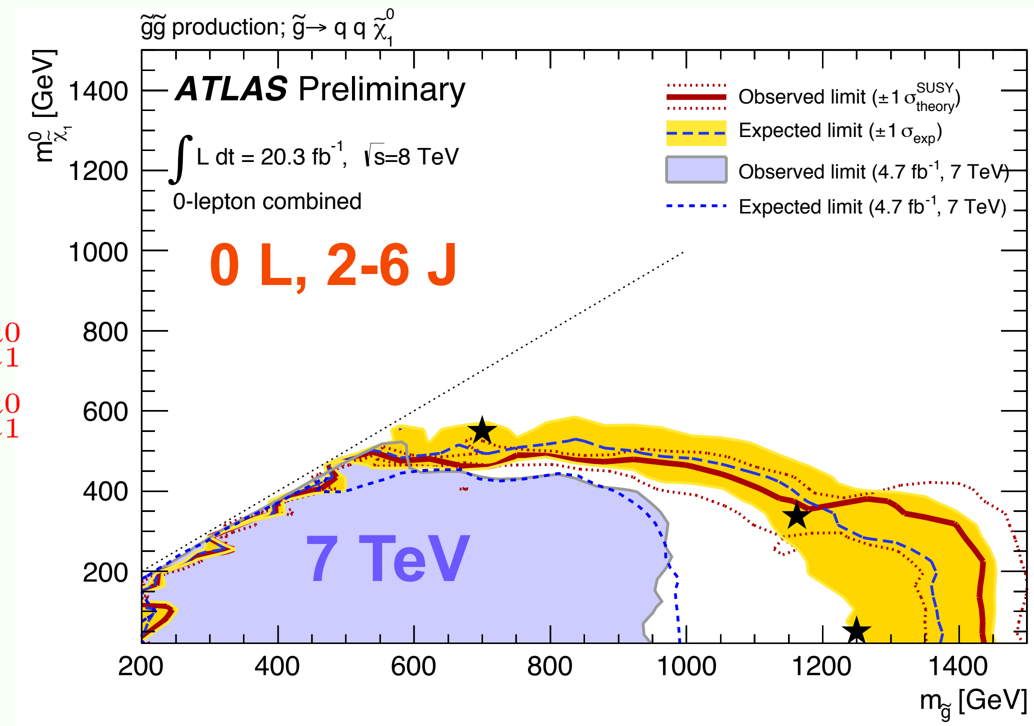


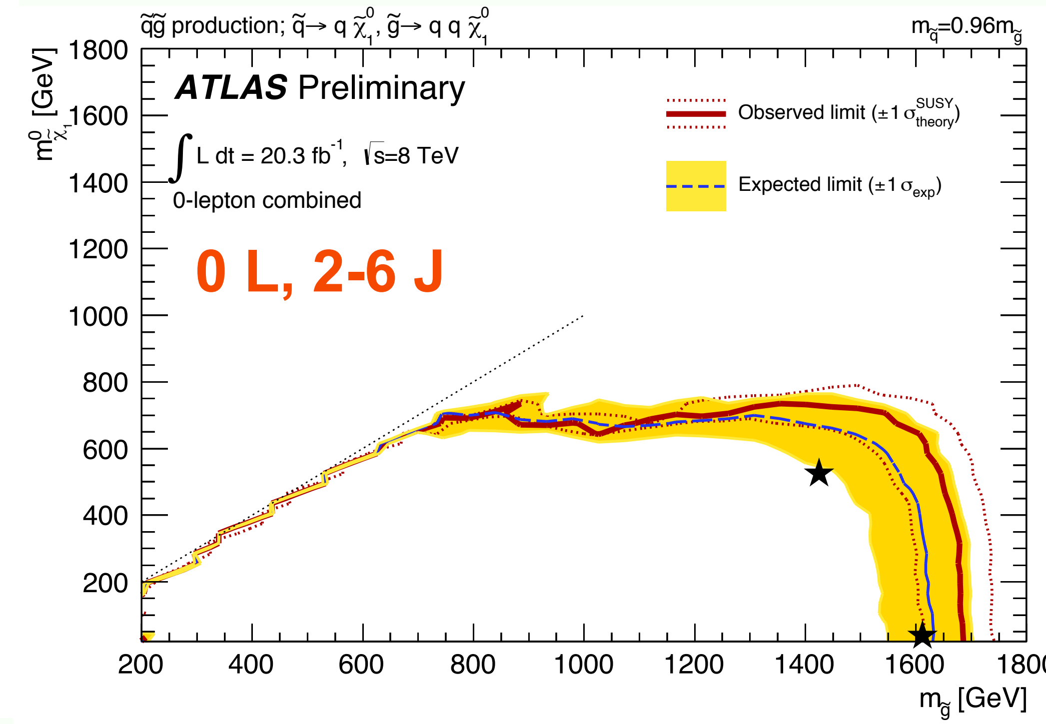
Interpretations

0-step simplified models

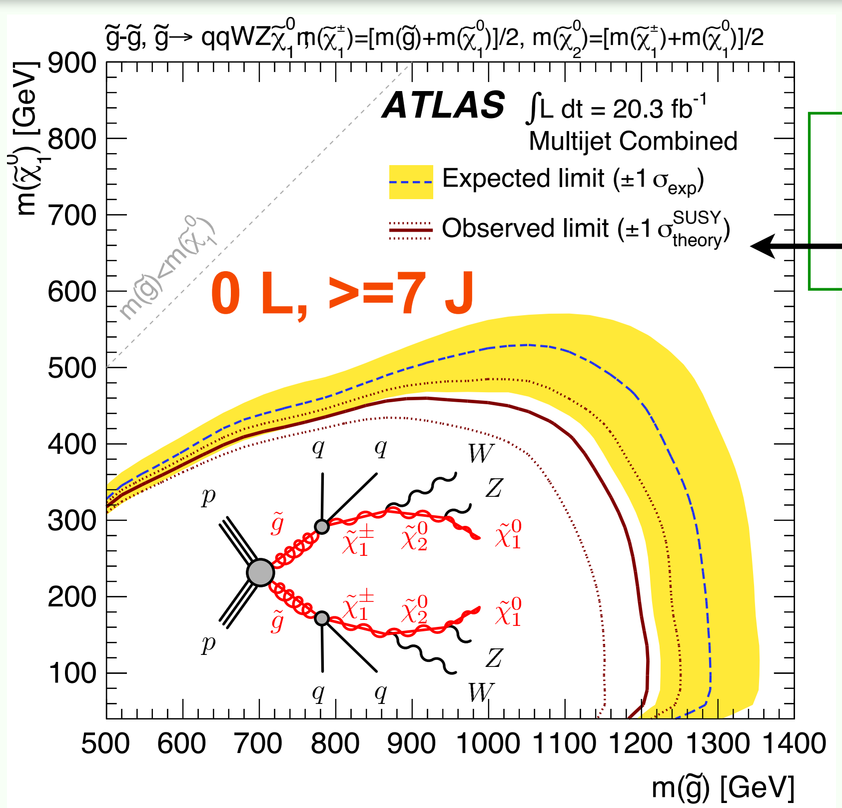


➡ 0-lepton, 2-6 jets analysis





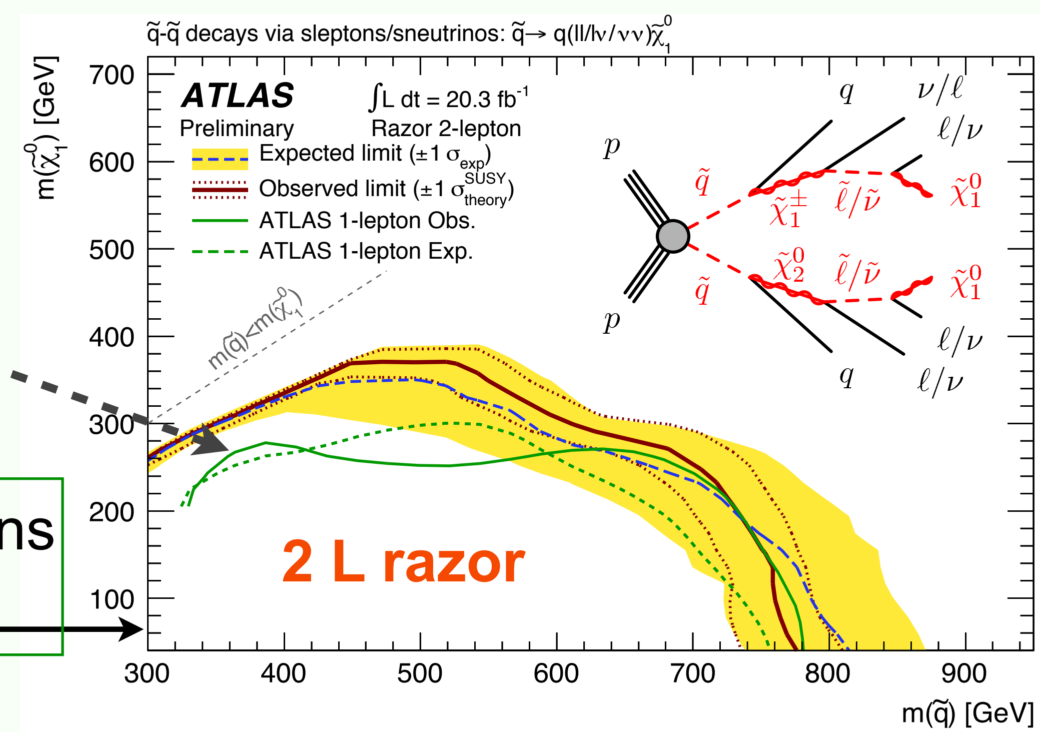
2-step simplified models



Cascade decays
➡ multi-jet analysis

1L, 3-6 J

Lepton rich decay chains
➡ 2L analysis



Summary

- Some very powerful ATLAS searches for strongly produced squarks and gluinos are presented
- No significant excess above the SM expectation has been observed
- Model-independent upper limits are placed on the visible BSM cross-section
  - as low as 0.15 fb, depending on the channel/analysis
  - all the details can be found *ATLAS public* results page
- Large portions of parameter space excluded in various models
  - Gluino masses up to 1.3 TeV
  - Squark masses up to 740 GeV

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: SUSY 2013

ATLAS Preliminary

$\int \mathcal{L}\, dt = (4.6 - 22.9)\ \text{fb}^{-1}$ $\sqrt{s} = 7, 8$ TeV

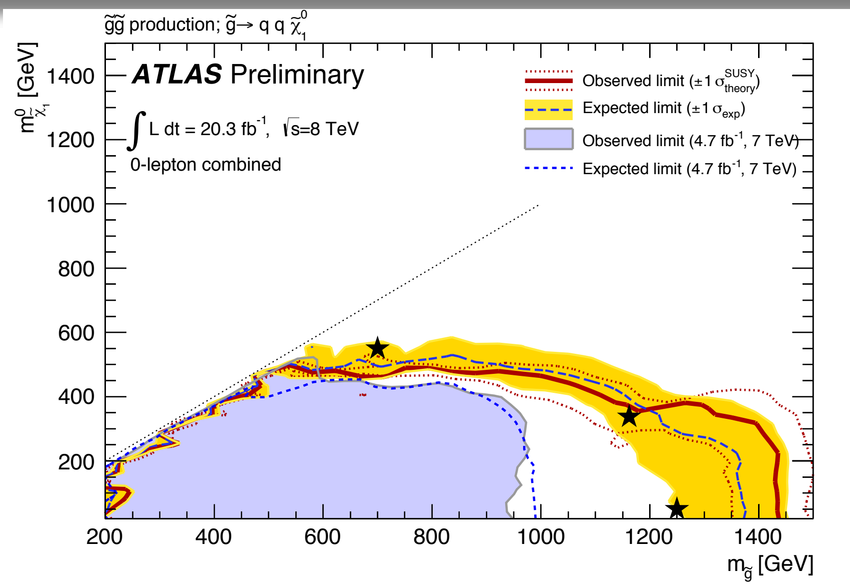
Inclusive Searches

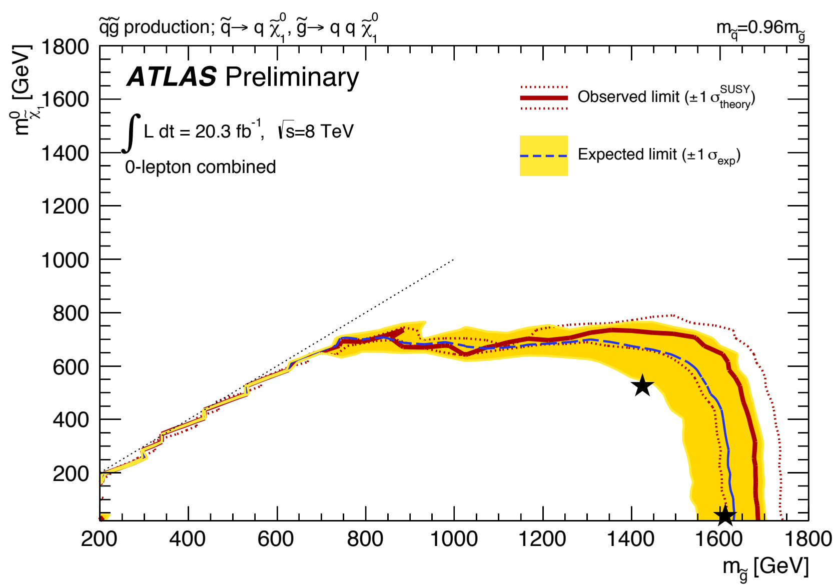
Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt [fb^{-1}]$	Mass limit		Reference
MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
MSUGRA/CMSSM	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	any $m(\tilde{q})$	1308.1841
$\tilde{q}\tilde{q}, \tilde{q}\rightarrow q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 740 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
$\tilde{g}\tilde{g}, \tilde{g}\rightarrow q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
$\tilde{g}\tilde{g}, \tilde{g}\rightarrow qq\tilde{\chi}_1^{\pm}\rightarrow qqW^{\pm}\tilde{\chi}_1^0$	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.18 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}^{\pm})=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	ATLAS-CONF-2013-062
$\tilde{g}\tilde{g}, \tilde{g}\rightarrow qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e, μ	0-3 jets	-	20.3	$\tilde{g}$ 1.12 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-089
GMSB ($\tilde{\ell}$ NLSP)	2 e, μ	2-4 jets	Yes	4.7	$\tilde{g}$ 1.24 TeV	$\tan\beta$<15	1208.4688
GMSB ($\tilde{\ell}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$ 1.4 TeV	$\tan\beta$ >18	ATLAS-CONF-2013-026
GGM (bino NLSP)	2 γ	-	Yes	4.8	$\tilde{g}$ 1.07 TeV	$m(\tilde{\chi}_1^0)$>50 GeV	1209.0753
GGM (wino NLSP)	1 $e, \mu + \gamma$	-	Yes	4.8	$\tilde{g}$ 619 GeV	$m(\tilde{\chi}_1^0)$>50 GeV	ATLAS-CONF-2012-144
GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$ 900 GeV	$m(\tilde{\chi}_1^0)$>220 GeV	1211.1167
GGM (higgsino NLSP)	2 e, μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$ 690 GeV	$m(\tilde{H})$>200 GeV	ATLAS-CONF-2012-152
Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale 645 GeV	$m(\tilde{g})>10^{-4}$ eV	ATLAS-CONF-2012-147

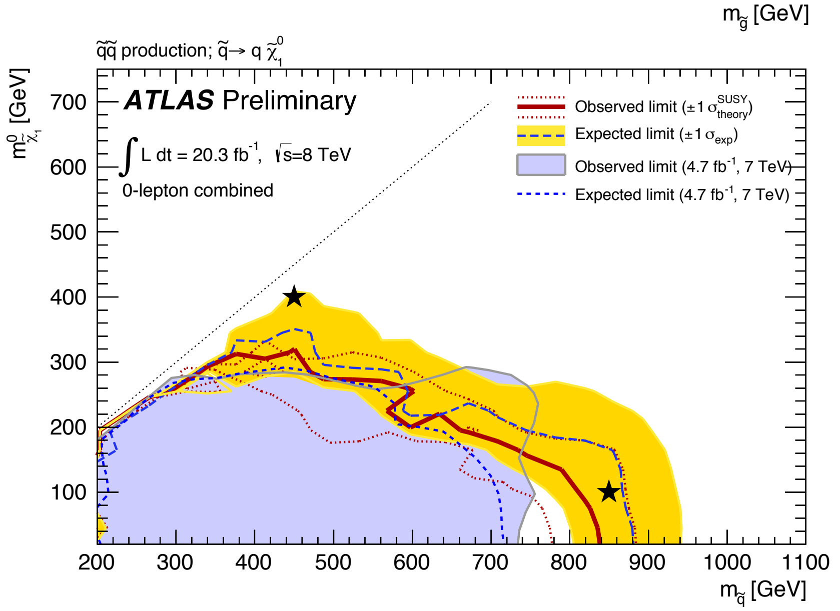
Backup slides

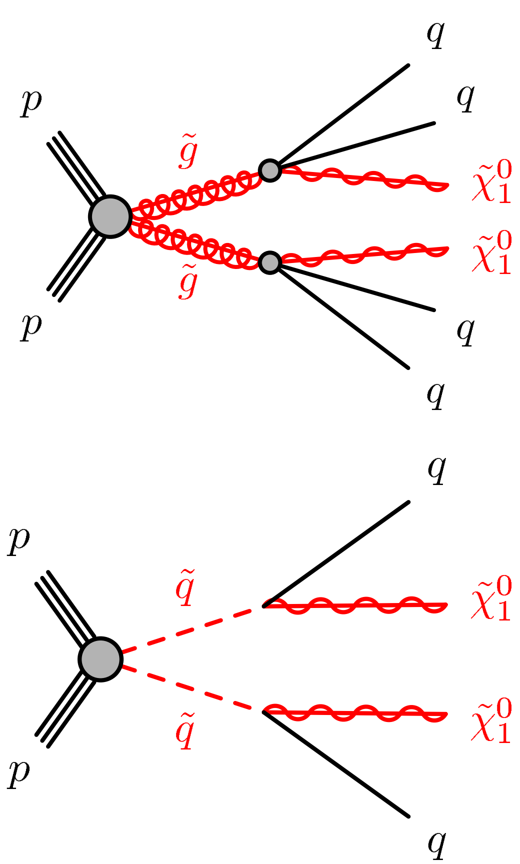
Additional info

0-lepton + 2-6 jets

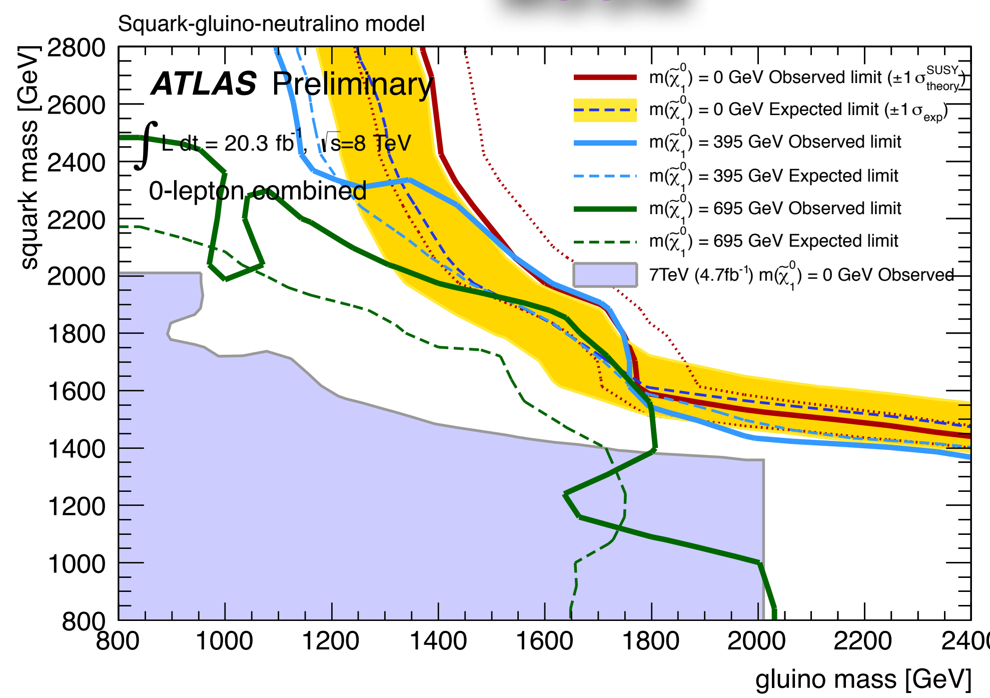


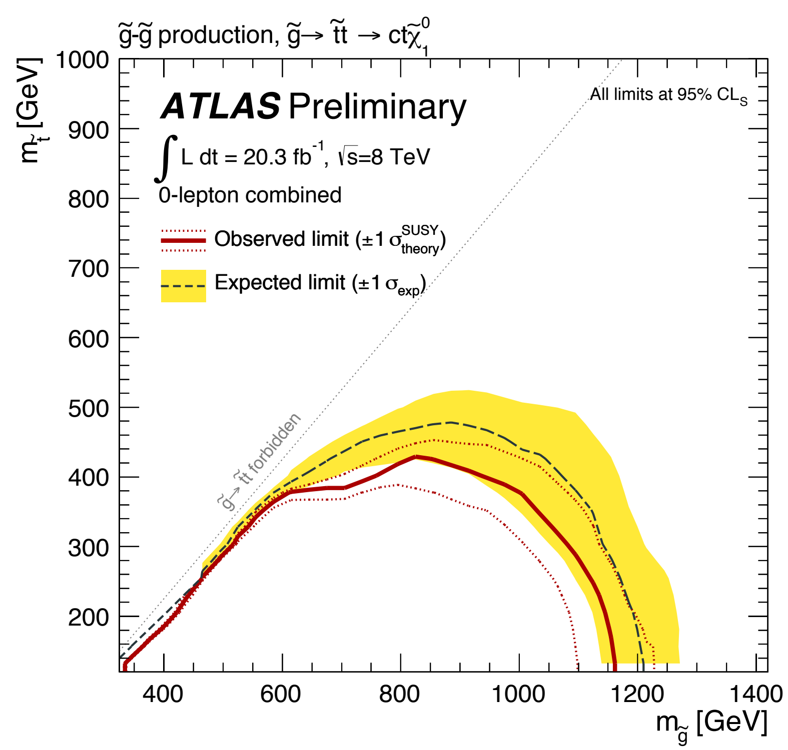




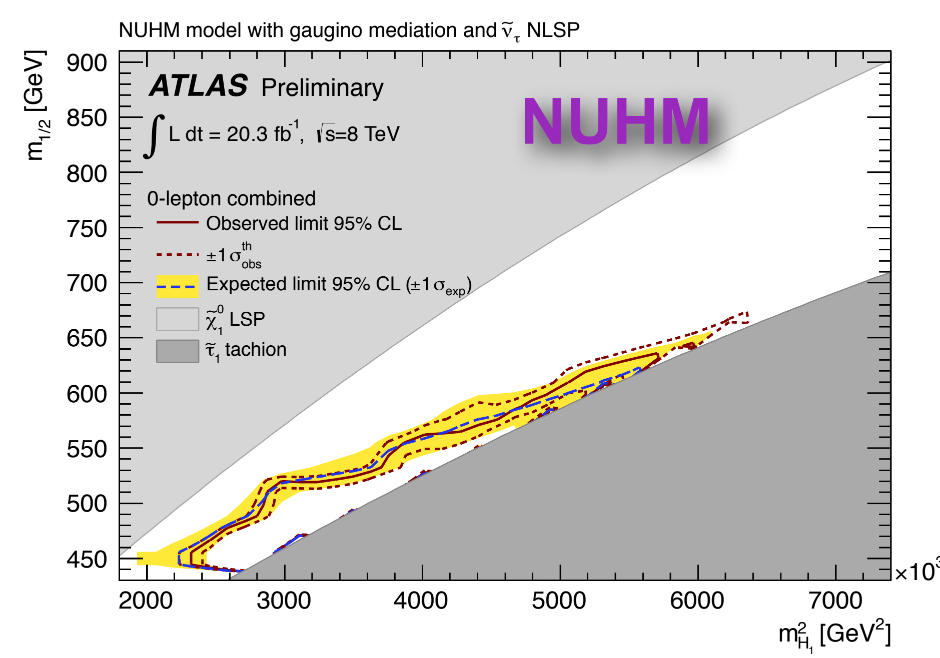


MSSM

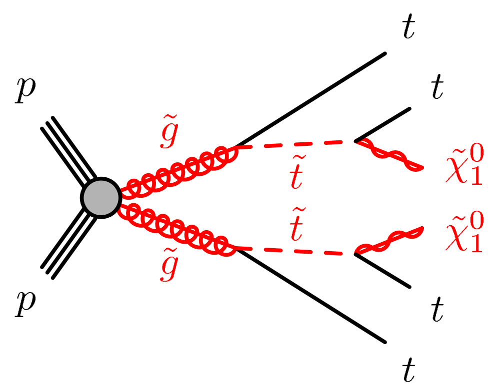


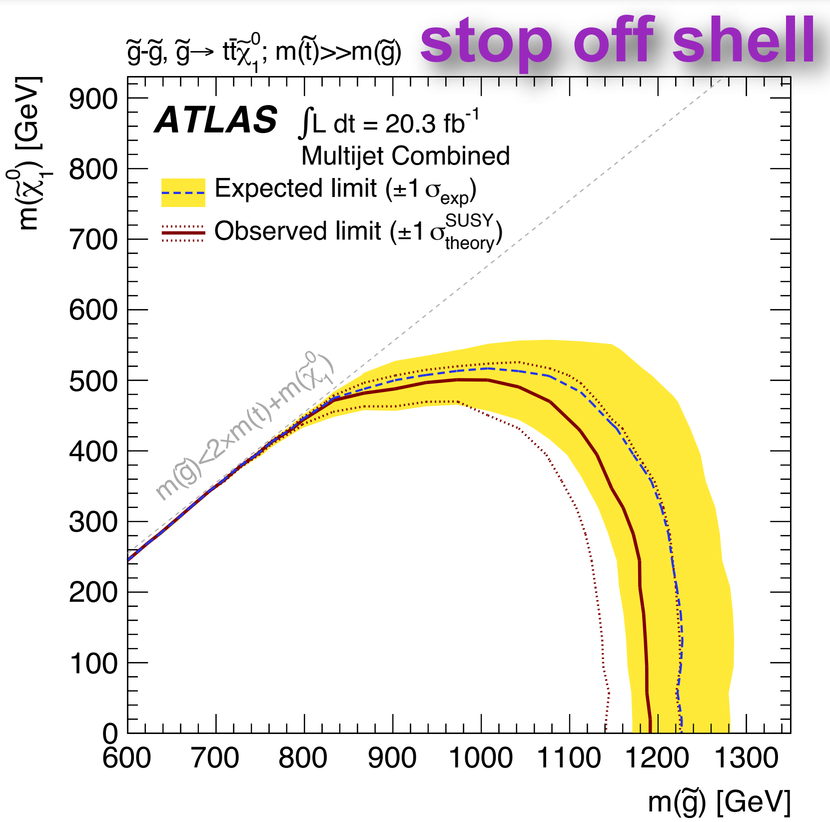


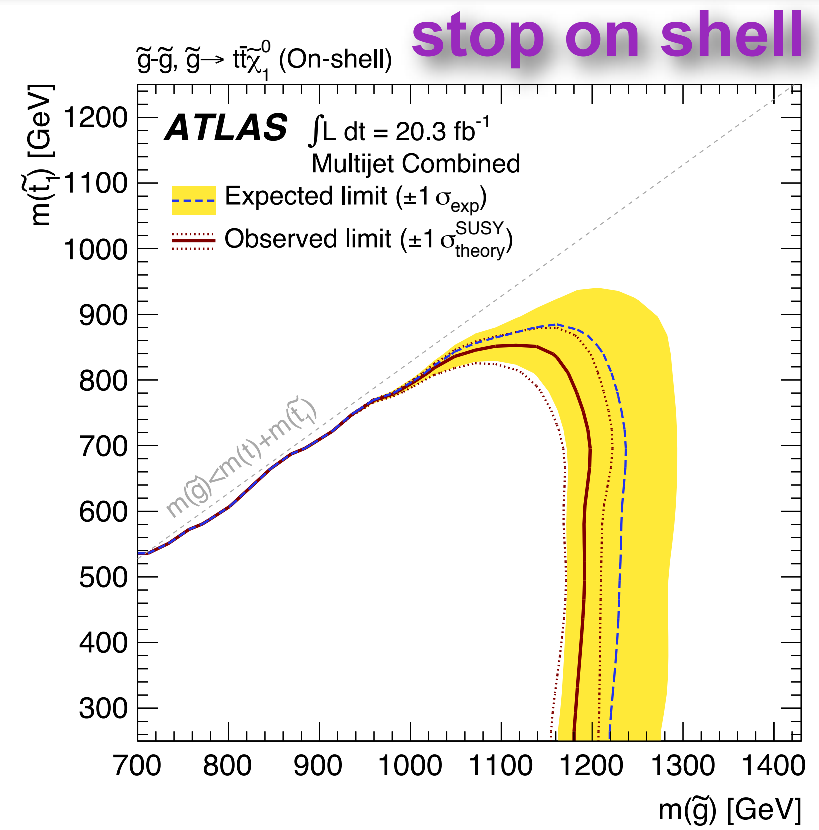
NUHM

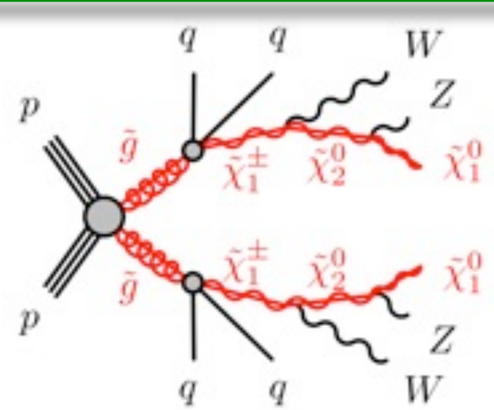


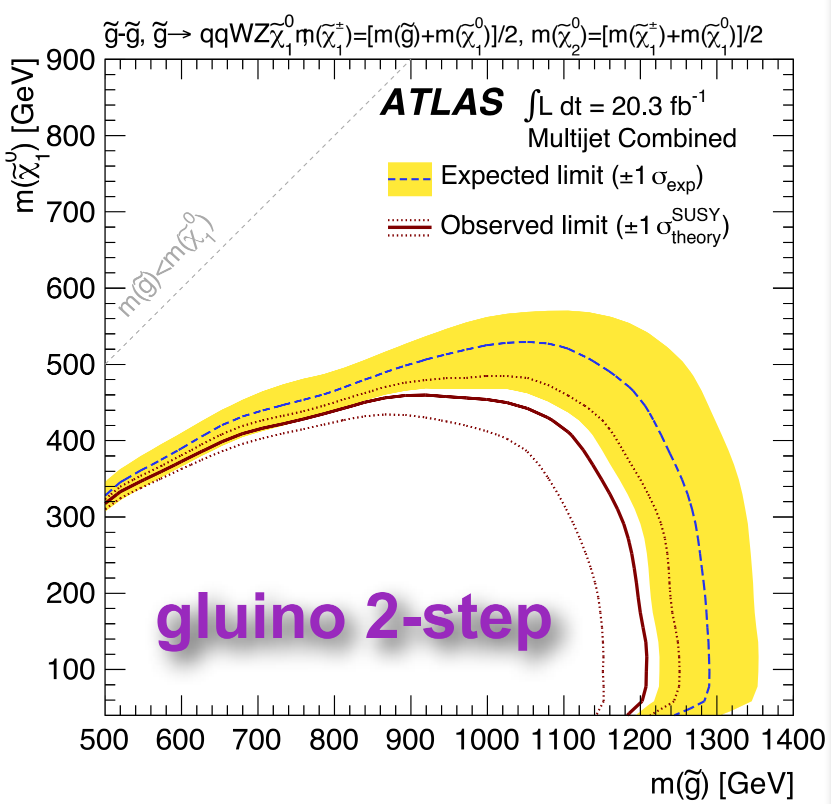
0-lepton + 7-10 jets



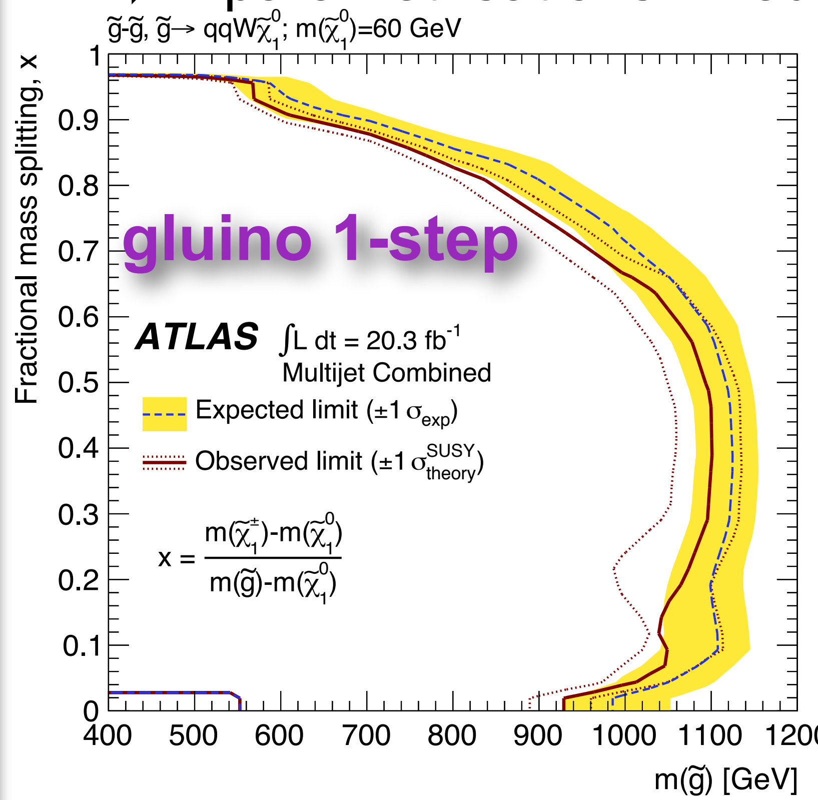


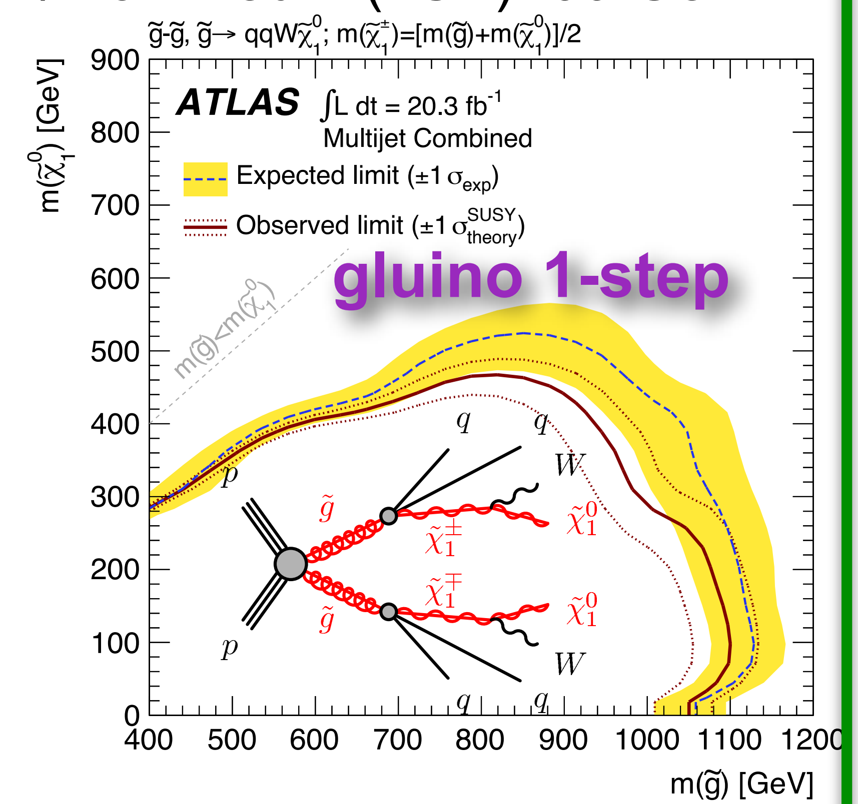




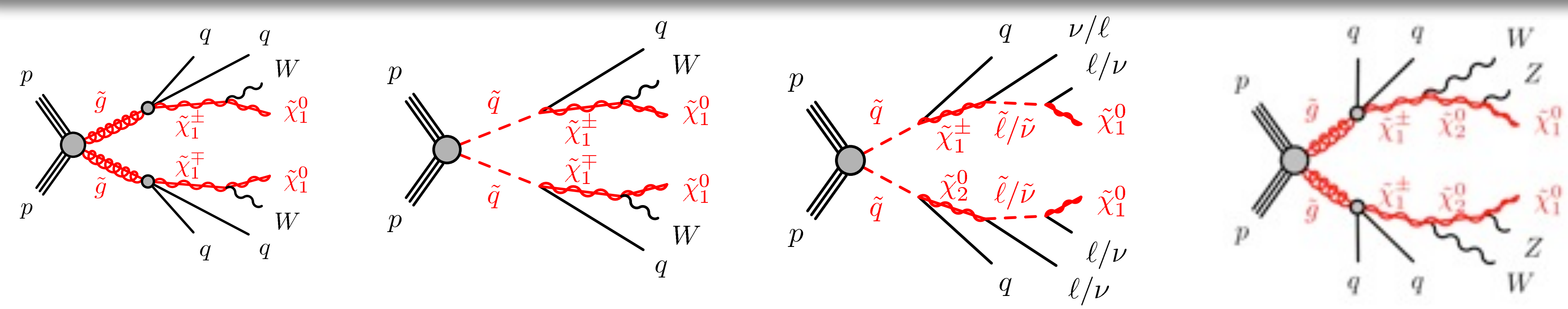


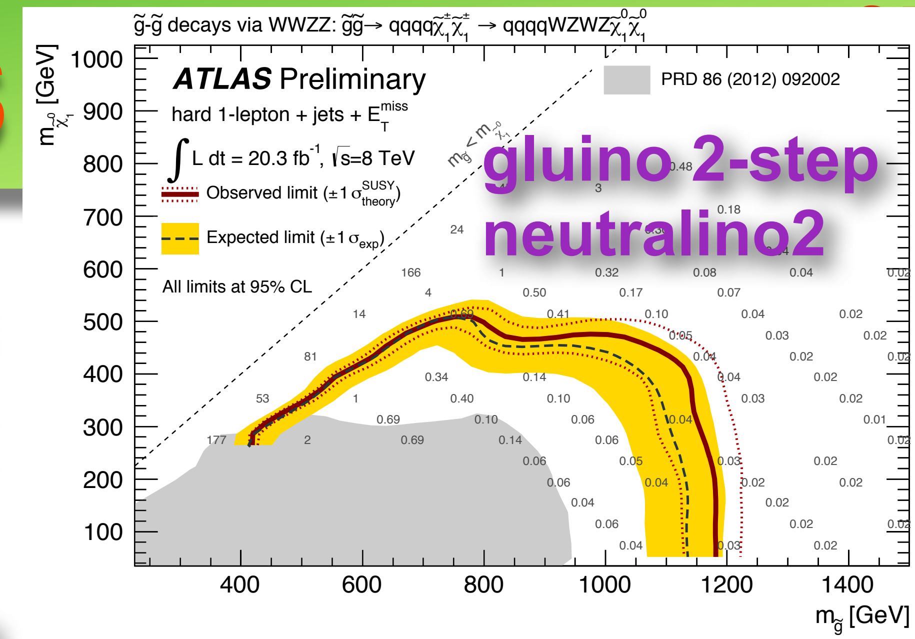
▸ 2 parametrisations: fixed x=1/2 or fixed m(LSP)=60 GeV

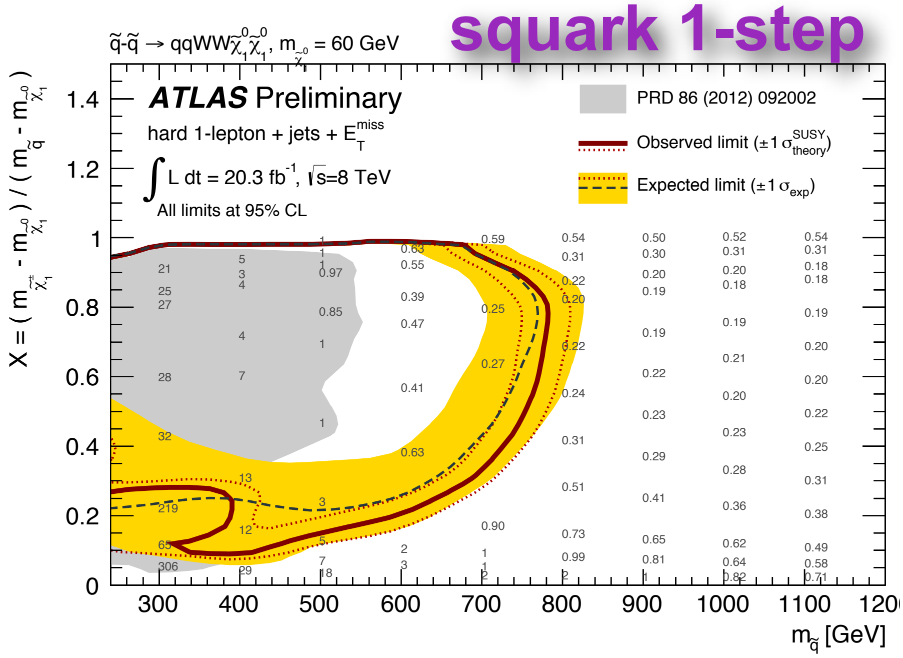


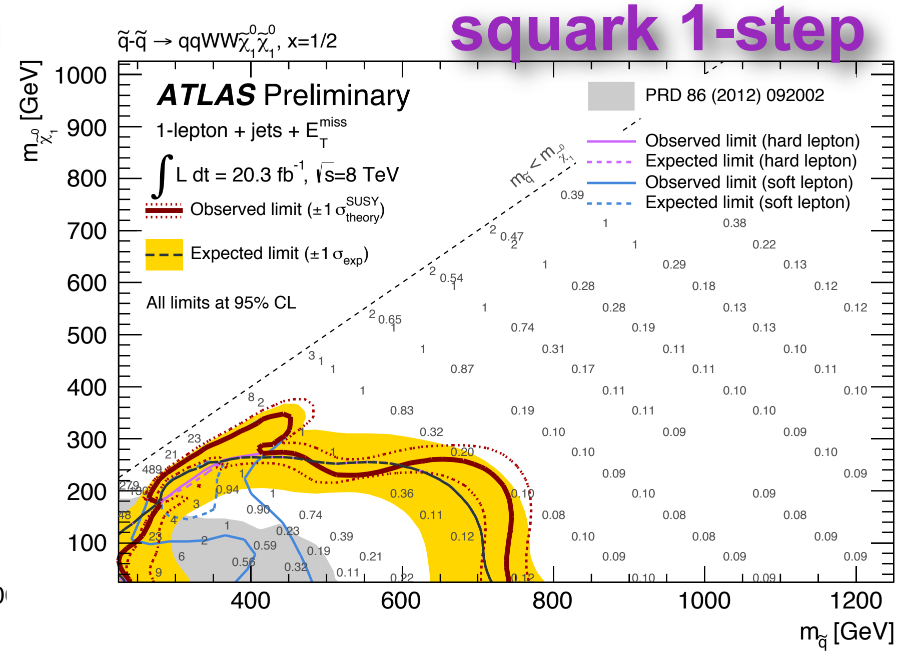


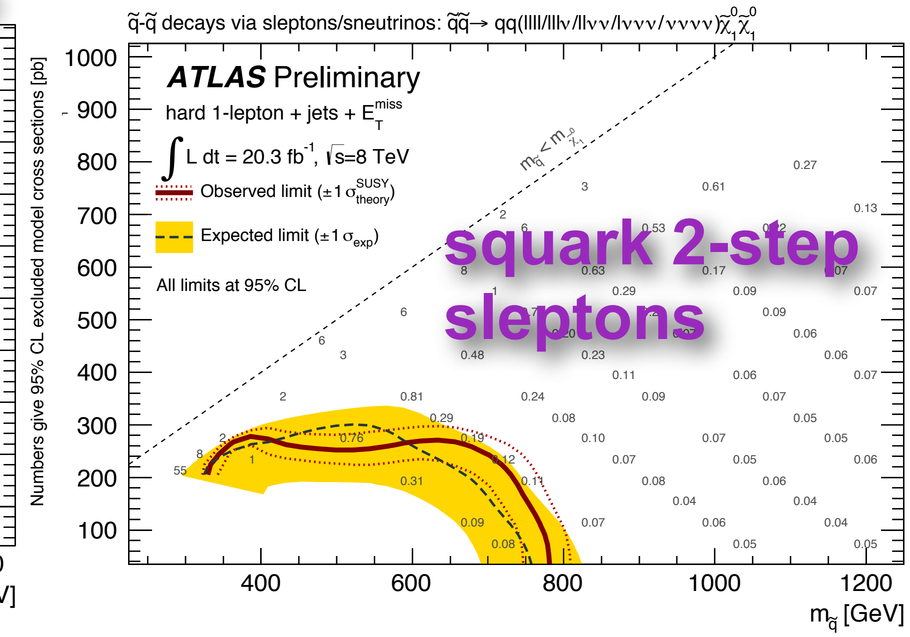
1-lepton + 3-6 jets

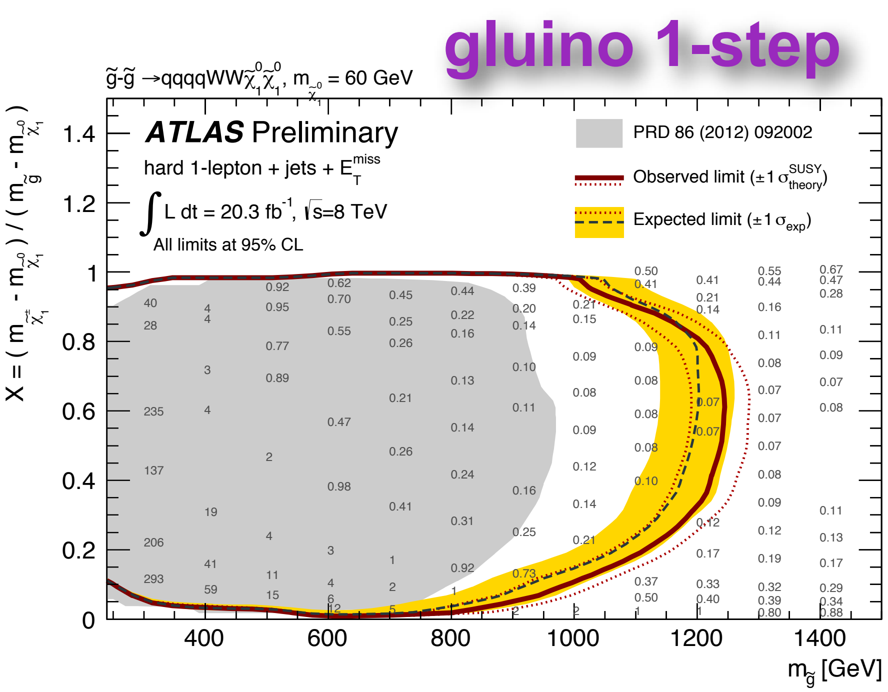


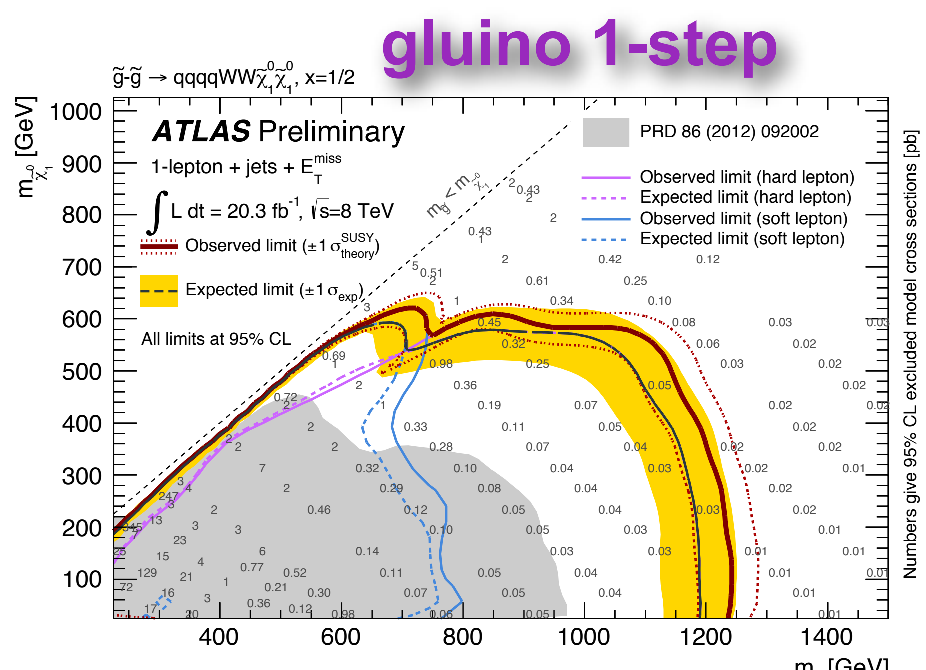


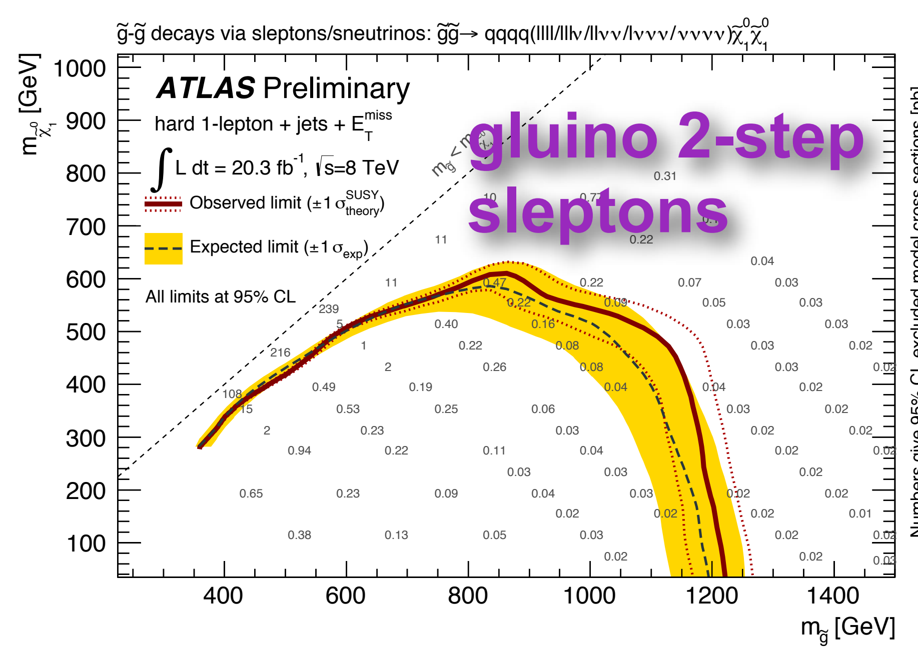




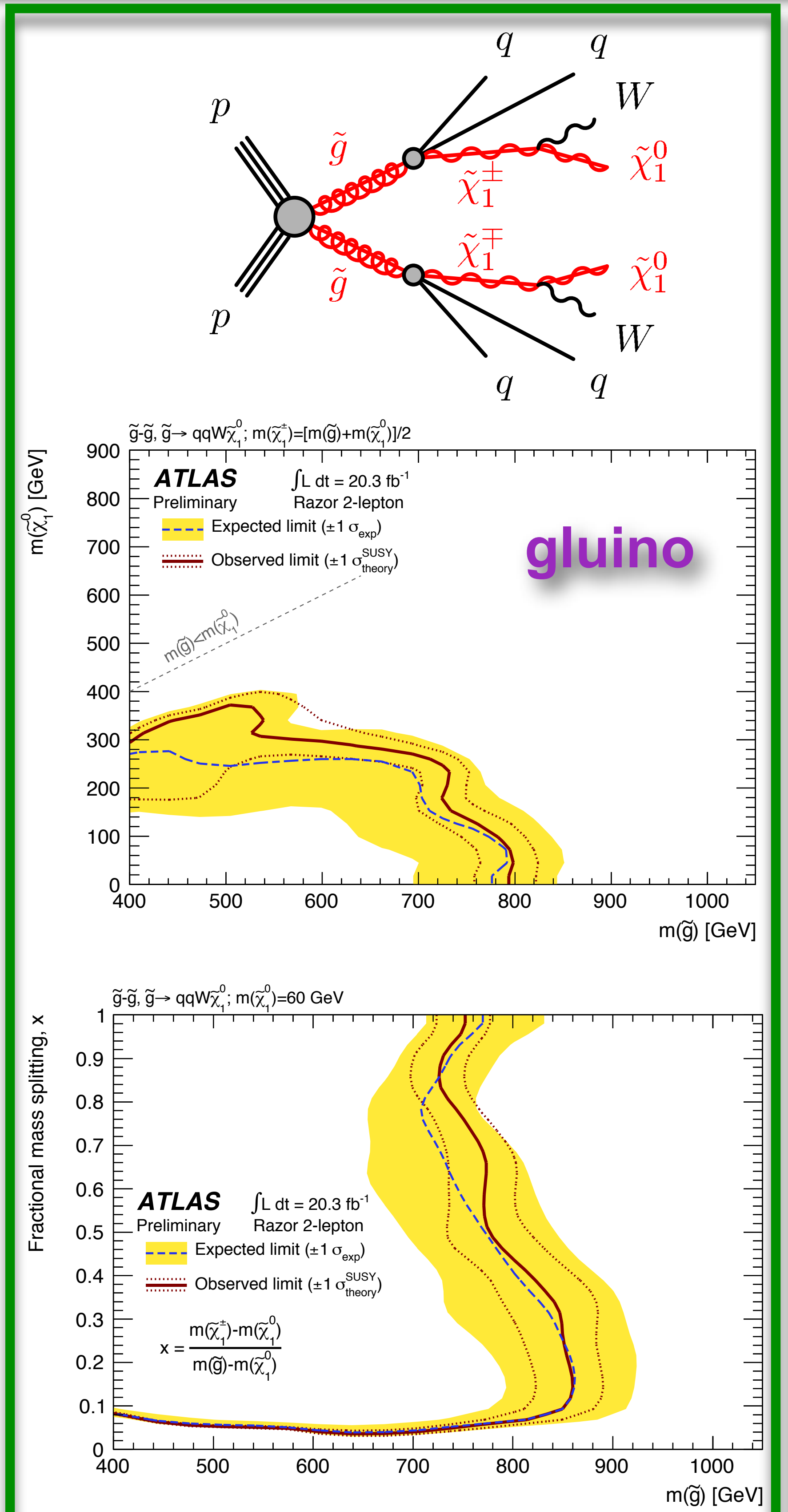




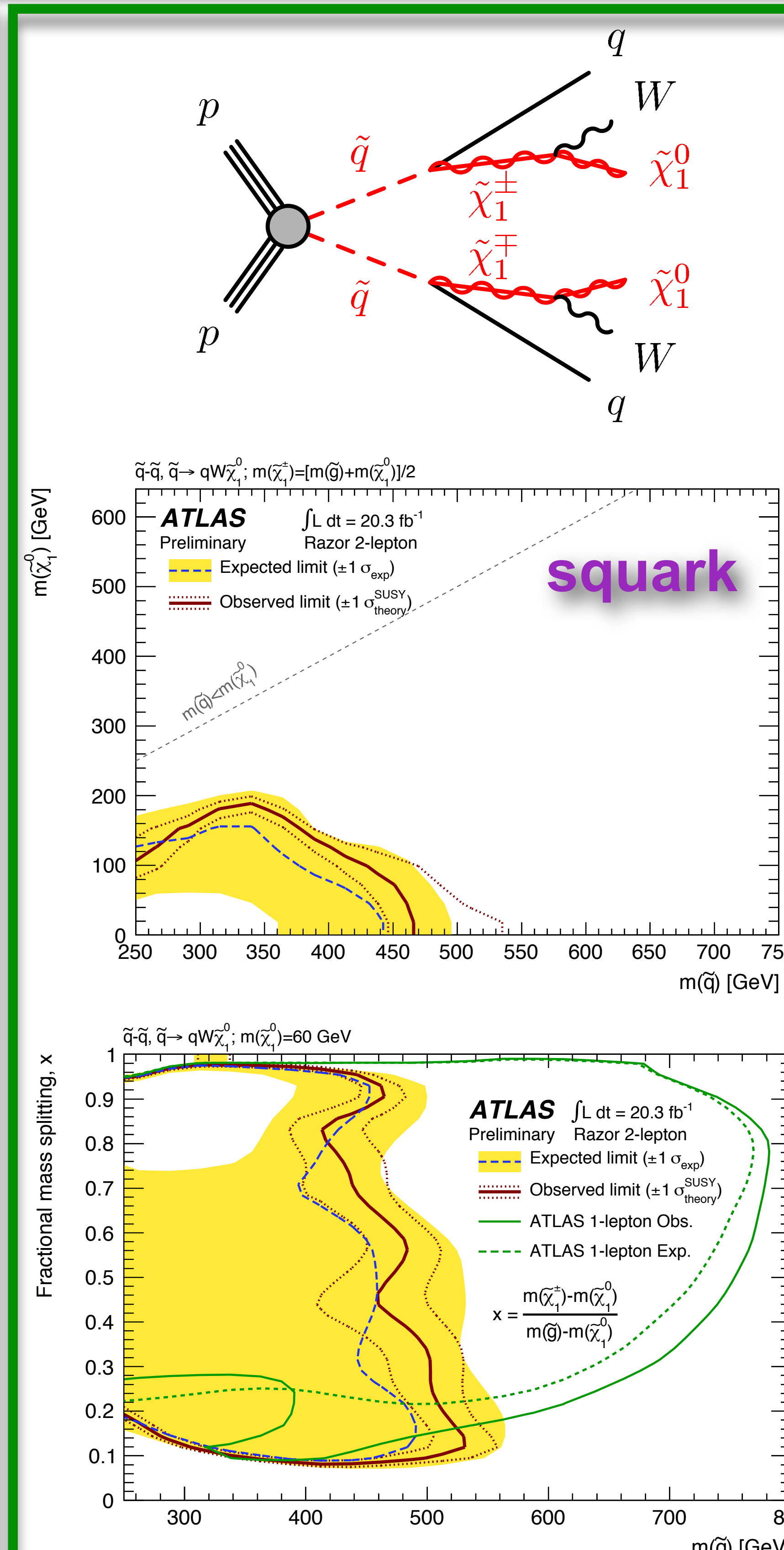




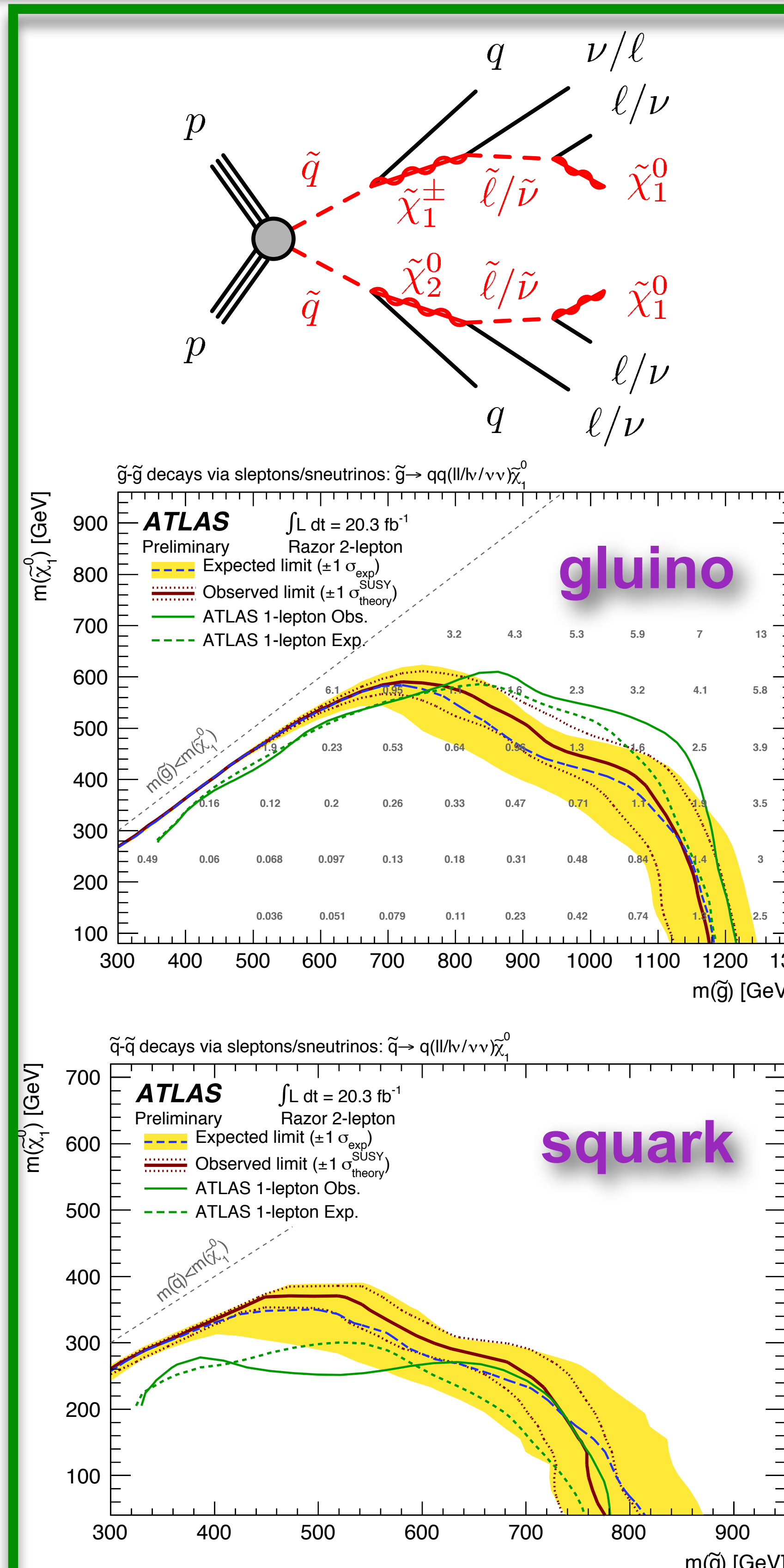
2 leptons



gluino
g̃-g̃, g̃→ qqWχ̃⁰₁; m(χ̃±₁)=[m(g̃)+m(χ̃⁰₁)]/2
ATLAS Preliminary
∫L dt = 20.3 fb⁻¹
Razor 2-lepton
Expected limit (±1 σexp)
Observed limit (±1 σSUSYtheory)
m(g̃)<m(χ̃⁰₁)
m(χ̃⁰₁) [GeV]
m(g̃) [GeV]
g̃-g̃, g̃→ qqWχ̃⁰₁; m(χ̃⁰₁)=60 GeV
Fractional mass splitting, x
x = [m(χ̃±₁)-m(χ̃⁰₁)] / [m(g̃)-m(χ̃⁰₁)]



squark
q̃-q̃, q̃→ qWχ̃⁰₁; m(χ̃±₁)=[m(q̃)+m(χ̃⁰₁)]/2
ATLAS Preliminary
∫L dt = 20.3 fb⁻¹
Razor 2-lepton
Expected limit (±1 σexp)
Observed limit (±1 σSUSYtheory)
m(q̃)<m(χ̃⁰₁)
m(χ̃⁰₁) [GeV]
m(q̃) [GeV]
q̃-q̃, q̃→ qWχ̃⁰₁; m(χ̃⁰₁)=60 GeV
ATLAS 1-lepton Obs.
ATLAS 1-lepton Exp.
Fractional mass splitting, x
x = [m(χ̃±₁)-m(χ̃⁰₁)] / [m(q̃)-m(χ̃⁰₁)]



gluino
g̃-g̃ decays via sleptons/sneutrinos: g̃→ qq(ll/lν/νν)χ̃⁰₁
ATLAS Preliminary
∫L dt = 20.3 fb⁻¹
Razor 2-lepton
Expected limit (±1 σexp)
Observed limit (±1 σSUSYtheory)
ATLAS 1-lepton Obs.
ATLAS 1-lepton Exp.
m(g̃)<m(χ̃⁰₁)
m(χ̃⁰₁) [GeV]
m(g̃) [GeV]
squark
q̃-q̃ decays via sleptons/sneutrinos: q̃→ q(ll/lν/νν)χ̃⁰₁
m(q̃)<m(χ̃⁰₁)
m(q̃) [GeV]

0-lepton + 2-6 jets

- Complete selection
- Trigger:
  - p_T^{jet}>80 GeV
  - $\mathbf{E_T^{miss}}$ > 100 GeV

Requirement	Channel									
	A (2-jets)		B (3-jets)		C (4-jets)		D (5-jets)	E (6-jets)		
	L	M	M	T	M	T	–	L	M	T
E_T^{miss}[GeV] >	160									
$p_T(j_1)$ [GeV] >	130									
$p_T(j_2)$ [GeV] >	60									
$p_T(j_3)$ [GeV] >	–		60		60		60	60		
$p_T(j_4)$ [GeV] >	–		–		60		60	60		
$p_T(j_5)$ [GeV] >	–		–		–		60	60		
$p_T(j_6)$ [GeV] >	–		–		–		–	60		
$\Delta\phi(\text{jet}_i, \mathbf{E}_T^{miss})_{min}$ >	0.4 (i = {1, 2, (3 if $p_T(j_3)$ > 40 GeV)})				0.4 (i = {1, 2, 3}), 0.2 (p_T > 40 GeV jets)					
$E_T^{miss}/m_{eff}(Nj)$ >	0.2	–[a]	0.3	0.4	0.25	0.25	0.2	0.15	0.2	0.25
m_{eff}(incl.) [GeV] >	1000	1600	1800	2200	1200	2200	1600	1000	1200	1500

(a) For SR A-medium the cut on $E_T^{miss}/m_{eff}(Nj)$ is replaced by a requirement $E_T^{miss}/\sqrt{H_T}$ > 15 GeV$^{1/2}$.

CR	SR background	CR process	CR selection
CRY	$Z(\to \nu\nu)$+jets	γ+jets	Isolated photon **pT>130**
CRQ	multi-jets	multi-jets	Reversed $\Delta\phi(\text{jet}, \mathbf{E}_T^{miss})_{min}$ and $E_T^{miss}/m_{eff}(Nj)$ requirements[a]
CRW	$W(\to \ell\nu)$+jets	$W(\to \ell\nu)$+jets	30 GeV < $m_T(\ell, E_T^{miss})$ < 100 GeV, b-veto
CRT	$t\bar{t}$ and single-t	$t\bar{t} \to bbqq'\ell\nu$	30 GeV < $m_T(\ell, E_T^{miss})$ < 100 GeV, b-tag **pT>25**

(a) For SR A-medium the selection requirement placed on $E_T^{miss}/\sqrt{H_T}$ is reversed.

- remove $\Delta\phi(\text{jet}, \mathbf{E}_T^{miss})_{min}$ or $E_T^{miss}/m_{eff}(Nj)$ ($E_T^{miss}/\sqrt{H_T}$ in SR A-medium) & loosen M_{eff} to get more stat in the CR

0-lepton + 2-6 jets

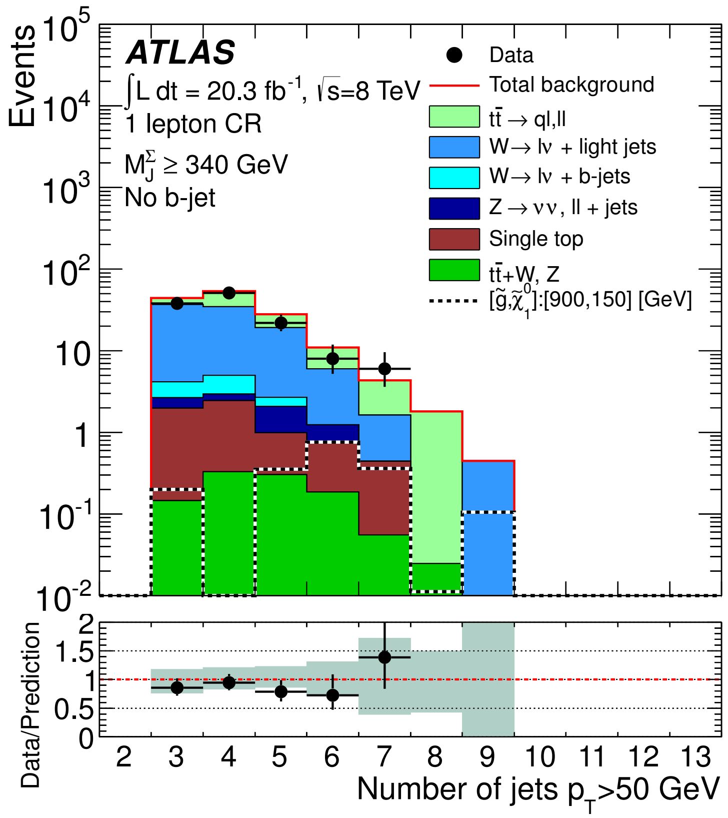
- Number of expected-observed events in the signal regions & model-independent limits
- The best upper limit on σ(vis) is set in the C-tight signal region: 0.12 fb

Signal Region	A-loose	A-medium	B-medium	B-tight	C-medium	C-tight	D	E-loose	E-medium	E-tight
	MC expected events						MC expected events			
Diboson	428.6	15.0	4.3	0.0	25.5	0.0	2.0	5.5	1.7	0.0
Z/γ^*+jets	2044.4	83.1	20.6	2.3	119.4	2.6	8.5	19.6	6.3	1.9
W+jets	2109.0	58.8	16.4	2.1	88.7	1.0	4.8	23.1	5.2	0.8
$t\bar{t}$(+EW) + single top	785.9	8.2	2.0	0.3	45.9	0.3	5.0	67.3	16.8	1.5
	Fitted background events						Fitted background events			
Diboson	430 ± 190	15 ± 7	4.3 ± 2.0	–	26 ± 11	–	2.0 ± 2.0	5.5 ± 2.1	1.7 ± 0.8	–
Z/γ^*+jets	1870 ± 320	57 ± 11	16 ± 5	0.2 ± 0.5	80 ± 29	$0.0^{+0.6}_{-0.0}$	3.8 ± 2.5	12 ± 7	2.9 ± 2.6	0.4 ± 0.6
W+jets	1540 ± 260	42 ± 11	10 ± 4	1.6 ± 1.2	55 ± 18	0.7 ± 0.9	3.3 ± 2.5	18 ± 7	4.9 ± 2.7	0.7 ± 0.5
$t\bar{t}$(+EW) + single top	870 ± 180	7.8 ± 2.8	2.2 ± 2.0	0.6 ± 0.7	50 ± 11	0.9 ± 0.9	5.8 ± 2.1	76 ± 19	20 ± 6	1.7 ± 1.4
Multi-jets	33 ± 33	–	0.1 ± 0.1	–	–	–	–	1.0 ± 1.0	–	–
Total bkg	4700 ± 500	122 ± 18	33 ± 7	2.4 ± 1.4	210 ± 40	1.6 ± 1.4	15 ± 5	113 ± 21	30 ± 8	2.9 ± 1.8
Observed	5333	135	29	4	228	0	18	166	41	5
$\langle\epsilon\sigma\rangle^{95}_{\rm obs}$[fb]	66.07	2.52	0.73	0.33	4.00	0.12	0.77	4.55	1.41	0.41
$S^{95}_{\rm obs}$	1341.2	51.3	14.9	6.7	81.2	2.4	15.5	92.4	28.6	8.3
$S^{95}_{\rm exp}$	$1135.0^{+332.7}_{-291.5}$	$42.7^{+15.5}_{-11.4}$	$17.0^{+6.6}_{-4.6}$	$5.8^{+2.9}_{-1.8}$	$72.9^{+23.6}_{-18.0}$	$3.3^{+2.1}_{-1.2}$	$13.6^{+5.1}_{-3.5}$	$57.3^{+20.0}_{-14.4}$	$21.4^{+7.6}_{-5.8}$	$6.5^{+3.0}_{-1.9}$
p_0 (Z_n)	0.45 (0.1)	0.27 (0.6)	0.50 (0.0)	0.34 (0.4)	0.34 (0.4)	0.50 (0.0)	0.32 (0.5)	0.03 (1.9)	0.14 (1.1)	0.22 (0.8)

0-lepton + 7-10 jets

Paper

- Multi-jet triggers:
  - at least 5 jets with E_T^{jet}>55 GeV
  - at least 6 jets with E_T^{jet}>45 GeV
- W & tt-bar (1-lepton) control regions
  ➡ the lepton is recast as a jet so it contributes to H_T and to the jet multiplicity
  ➡ W: no b-jets; tt-bar: ≥ 1 b-jets
- Single top, tt-bar+EW estimated using only MC
- As not enough events remain at high jet multiplicity, $\mathbf{Z} \to \nu\nu$ estimation taken from MC



- Multi-jet bkg:

$$N^{\text{multi-jet}}_{\text{predicted}} = \left(N^{A,\,n^{\text{jet}}=9}_{\text{data}} - N^{A,\,n^{\text{jet}}=9}_{\text{leptonic MC}}\right) \times \left(\frac{N^{B,\,n^{\text{jet}}=6}_{\text{data}} - N^{B,\,n^{\text{jet}}=6}_{\text{leptonic MC}}}{N^{A,\,n^{\text{jet}}=6}_{\text{data}} - N^{A,\,n^{\text{jet}}=6}_{\text{leptonic MC}}}\right)$$

Single-lepton validation region	
Lepton p_T	> 25 GeV
Lepton multiplicity	Exactly one, $\ell \in \{e, \mu\}$
E_T^{miss}	> 30 GeV
$E_T^{miss}/\sqrt{H_T}$	$> 2.0\ \text{GeV}^{1/2}$
m_T	< 120 GeV
Jet p_T	As for signal regions (table 1)
Jet multiplicity	
b-jet multiplicity	
M_J^Σ	
Control region (additional criteria)	
Jet multiplicity	Unit increment if $p_T^\ell > p_T^{min}$
$E_T^{miss}/\sqrt{H_T\ (+p_T^\ell)}$	$> 4.0\ \text{GeV}^{1/2}$

Two-lepton validation region	
Lepton p_T	> 25 GeV
Lepton multiplicity	Exactly two, ee or $\mu\mu$
$m_{\ell\ell}$	80 GeV to 100 GeV
Jet p_T	As for signal regions (table 1)
Jet multiplicity	
b-jet multiplicity	
M_J^Σ	
Control region (additional criteria)	
$\lvert\mathbf{p}_T^{miss} + \mathbf{p}_T^{\ell_1} + \mathbf{p}_T^{\ell_2}\rvert/\sqrt{H_T}$	$> 4.0\ \text{GeV}^{1/2}$

0-lepton + 7-10 jets

Paper

Signal region	8j50			9j50			10j50
b-jets	0	1	≥ 2	0	1	≥ 2	—
Observed events	40	44	44	5	8	7	3
Total events after fit	35 ± 4	40 ± 10	50 ± 10	3.3 ± 0.7	6.1 ± 1.7	8.0 ± 2.7	1.37 ± 0.35
Fitted $t\bar{t}$	2.7 ± 0.9	11.8 ± 3.0	23.0 ± 5.0	0.36 ± 0.18	1.5 ± 0.5	3.2 ± 1.1	$0.06^{+0.09}_{-0.06}$
Fitted W+jets	$2.0^{+2.6}_{-2.0}$	$0.62^{+0.81}_{-0.62}$	$0.20^{+0.28}_{-0.20}$	–	$0.24^{+0.65}_{-0.24}$	–	–
Fitted others	$2.9^{+1.8}_{-1.8}$	$1.7^{+1.5}_{-1.2}$	$2.8^{+2.3}_{-2.0}$	0.03 ± 0.03	0.38 ± 0.25	$0.40^{+0.60}_{-0.24}$	0.08 ± 0.08
Total events before fit	36	48	59	3.4	6.6	8.9	1.39
$t\bar{t}$ before fit	3.5	15	30	0.41	1.8	4	0.08
W+jets before fit	2.9	1.0	0.29	–	0.40	–	–
Others before fit	2.4	1.8	2.8	0.03	0.34	0.4	0.08
Multi-jets	27 ± 3	30 ± 10	26 ± 10	3.0 ± 0.6	4.0 ± 1.4	4.4 ± 2.2	1.23 ± 0.32
$N^{95\%}_{\mathrm{BSM}}$ (exp)	16	23	26	5	7	8	4
$N^{95\%}_{\mathrm{BSM}}$ (obs)	20	23	22	7	9	7	6
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (exp) [fb]	0.8	1.2	1.3	0.26	0.36	0.40	0.19
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (obs) [fb]	0.97	1.1	1.1	0.34	0.43	0.37	0.29
p_0	0.24	0.5	0.7	0.21	0.28	0.6	0.13
Significance (σ)	0.7	−0.02	−0.6	0.8	0.6	−0.28	1.14

Signal region	7j80			8j80		
b-jets	0	1	≥ 2	0	1	≥ 2
Observed events	12	17	13	2	1	3
Total events after fit	11.0 ± 2.2	17 ± 6	25 ± 10	0.9 ± 0.6	1.5 ± 0.9	3.3 ± 2.2
Fitted $t\bar{t}$	$0.00^{+0.26}_{-0.00}$	5.0 ± 4.0	12 ± 9	$0.10^{+0.14}_{-0.10}$	$0.32^{+0.67}_{-0.32}$	$1.5^{+1.9}_{-1.5}$
Fitted W+jets	$0.07^{+0.38}_{-0.07}$	$0.29^{+0.37}_{-0.29}$	–	–	–	–
Fitted others	$1.9^{+1.1}_{-0.9}$	$0.71^{+0.31}_{-0.25}$	$2.6^{+1.7}_{-1.1}$	0.02 ± 0.02	0.02 ± 0.02	$0.32^{+0.36}_{-0.21}$
Total events before fit	11.7	16	23	0.8	1.8	3.3
$t\bar{t}$ before fit	0.34	4	10	0.08	0.6	1.5
W+jets before fit	0.46	0.29	–	–	–	–
Others before fit	1.8	0.89	3.0	0.02	0.02	0.35
Multi-jets	9.1 ± 1.6	11 ± 4	10 ± 4	0.75 ± 0.56	1.2 ± 0.5	1.4 ± 1.0
$N^{95\%}_{\mathrm{BSM}}$ (exp)	10	17	14	4	4	6
$N^{95\%}_{\mathrm{BSM}}$ (obs)	10	16	12	5	3.5	6
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (exp) [fb]	0.5	0.8	0.7	0.18	0.18	0.31
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (obs) [fb]	0.5	0.8	0.6	0.24	0.17	0.31
p_0	0.5	0.6	0.8	0.19	0.6	0.5
Significance (σ)	0.05	−0.14	−1.0	0.9	−0.28	−0.06

Table 5: As for table 4 but for the six signal regions for which $p_{\mathrm{T}}^{\min} = 80$ GeV.

Signal region	8j50	
M_J^{Σ} [GeV]	340	420
Observed events	69	37
Total events after fit	75 ± 19	45 ± 14
Fitted $t\bar{t}$	17 ± 11	16 ± 13
Fitted W+jets	$0.8^{+1.3}_{-0.8}$	$0.4^{+0.7}_{-0.4}$
Fitted others	$5.2^{+4.0}_{-2.5}$	$2.8^{+2.9}_{-1.6}$
Total events before fit	85	44
$t\bar{t}$ before fit	27	14
W+jets before fit	0.8	0.4
Others before fit	5	2.8
Multi-jets	52 ± 15	27 ± 7
$N^{95\%}_{\mathrm{BSM}}$ (exp)	40	23
$N^{95\%}_{\mathrm{BSM}}$ (obs)	35	20
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (exp) [fb]	1.9	1.1
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (obs) [fb]	1.7	1.0
p_0	0.60	0.7
Significance (σ)	−0.27	−0.6

Signal region	9j50		10j50	
M_J^{Σ} [GeV]	340	420	340	420
Observed events	13	9	1	1
Total events	17 ± 7	11 ± 5	$3.2^{+3.7}_{-3.2}$	2.2 ± 2.0
$t\bar{t}$	5 ± 4	$3.4^{+3.6}_{-3.4}$	$0.8^{+0.8}_{-0.8}$	$0.6^{+0.9}_{-0.6}$
W+jets	–	–	–	–
Others	$0.58^{+0.54}_{-0.33}$	$0.39^{+0.32}_{-0.30}$	0.12 ± 0.12	0.06 ± 0.06
Multi-jets	12 ± 4	7.0 ± 2.3	$2.3^{+3.6}_{-2.3}$	$1.6^{+1.8}_{-1.6}$
$N^{95\%}_{\mathrm{BSM}}$ (exp)	13	11	5	5
$N^{95\%}_{\mathrm{BSM}}$ (obs)	11	10	4	4
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (exp) [fb]	0.7	0.5	0.23	0.23
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (obs) [fb]	0.5	0.5	0.2	0.2
p_0	0.7	0.6	0.8	0.7
Significance (σ)	−0.6	−0.34	−0.8	−0.6

- Flavour-stream has typically stronger expected exclusion limits for signal points
- $\mathbf{M_J^{\Sigma}}$ stream competitive in models with large number of final states and boosted topologies

1-lepton + 3-6 jets

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Signal channel	$\langle\epsilon\sigma\rangle^{95}_{obs}$ [fb]	S^{95}_{obs}	S^{95}_{exp}	CL_B	$p(s=0)$
soft single-lepton one b-jet channels					
low-mass	0.43 (0.42)	8.8 (8.6)	$6.9^{+3.0}_{-2.0}$ $(6.9^{+3.4}_{-2.1})$	0.76 (0.71)	0.26 (0.27)
high-mass	0.39 (0.38)	7.9 (7.7)	$6.3^{+1.9}_{-1.1}$ $(5.9^{+3.0}_{-1.9})$	0.79 (0.75)	0.21 (0.22)
soft single-lepton two b-jet channels					
low-mass	0.66 (0.62)	13.4 (12.7)	$13.2^{+5.9}_{-4.1}$ $(13.1^{+5.6}_{-3.8})$	0.52 (0.46)	0.50 (0.50)
high-mass	0.26 (0.24)	5.3 (4.9)	$5.3^{+2.4}_{-1.4}$ $(5.5^{+2.8}_{-1.8})$	0.50 (0.40)	0.50 (0.50)
soft single-lepton channels					
3-jet	0.40 (0.39)	8.1 (8.1)	$7.3^{+2.7}_{-1.8}$ $(6.8^{+3.3}_{-2.1})$	0.67 (0.66)	0.36 (0.31)
5-jet	0.35 (0.33)	7.1 (6.8)	$10.0^{+3.6}_{-3.0}$ $(9.8^{+4.2}_{-2.9})$	0.15 (0.15)	0.50 (0.50)
soft dimuon channel	0.57 (0.54)	11.5 (11.1)	$5.9^{+2.1}_{-1.0}$ $(6.5^{+3.1}_{-1.9})$	0.98 (0.92)	0.01 (0.02)
binned hard single-lepton channels					
3-jet (electron)	0.97 (0.98)	19.8 (19.9)	$20.2^{+8.3}_{-4.8}$ $(20.7^{+7.9}_{-5.6})$	0.47 (0.45)	0.50 (0.50)
3-jet (muon)	0.57 (0.52)	11.6 (10.6)	$15.6^{+5.8}_{-3.8}$ $(15.8^{+6.5}_{-4.4})$	0.13 (0.12)	0.50 (0.50)
5-jet (electron)	0.63 (0.60)	12.7 (12.1)	$12.6^{+3.2}_{-2.7}$ $(12.2^{+4.5}_{-3.2})$	0.50 (0.49)	0.50 (0.50)
5-jet (muon)	0.38 (0.36)	7.7 (7.2)	$7.6^{+2.8}_{-2.4}$ $(7.3^{+3.4}_{-2.2})$	0.53 (0.49)	0.50 (0.50)
6-jet (electron)	0.33 (0.34)	6.6 (6.8)	$7.8^{+3.1}_{-2.4}$ $(7.7^{+3.6}_{-2.4})$	0.32 (0.37)	0.50 (0.50)
6-jet (muon)	0.35 (0.35)	7.1 (7.1)	$7.1^{+3.4}_{-1.4}$ $(7.4^{+3.5}_{-2.3})$	0.50 (0.46)	0.50 (0.50)
inclusive hard single-lepton channels					
3-jet (electron)	0.30 (0.28)	6.0 (5.7)	$5.7^{+2.2}_{-1.5}$ $(5.6^{+2.9}_{-1.8})$	0.56 (0.51)	0.48 (0.48)
3-jet (muon)	0.38 (0.37)	7.7 (7.5)	$5.1^{+2.0}_{-1.5}$ $(5.1^{+2.7}_{-1.7})$	0.89 (0.82)	0.13 (0.13)
5-jet (electron)	0.30 (0.29)	6.0 (5.9)	$5.4^{+2.3}_{-1.5}$ $(5.5^{+2.9}_{-1.7})$	0.60 (0.56)	0.43 (0.43)
5-jet (muon)	0.22 (0.21)	4.6 (4.2)	$4.7^{+1.9}_{-1.2}$ $(4.7^{+2.5}_{-1.6})$	0.44 (0.41)	0.50 (0.50)
6-jet (electron)	0.23 (0.22)	4.6 (4.4)	$4.4^{+1.9}_{-0.8}$ $(4.4^{+2.5}_{-1.5})$	0.56 (0.49)	0.50 (0.50)
6-jet (muon)	0.15 (0.12)	3.0 (2.5)	$4.1^{+1.3}_{-1.1}$ $(3.8^{+2.3}_{-1.3})$	0.13 (0.16)	0.50 (0.50)

- **Inclusive SRs**
  - Optimised for discovery and placing the model-independent limits
  - Place more stringent limits on σ(vis)

2-leptons

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	b-jets	Z-veto	N_{Jets}	Jet p_{T}	R Range	M'_R Range [GeV]	M'_R bins
Signal Regions							
$ee/\mu\mu$ SR 1	No	Yes	≤ 2	> 50	$R > 0.5$	$400 < M'_R$	8
$e\mu$ SR 1	No	No	≤ 2	> 50	$R > 0.5$	$400 < M'_R$	8
$ee/\mu\mu$ SR 2	No	Yes	≥ 3	> 50	$R > 0.35$	$800 < M'_R$	5
$e\mu$ SR 2	No	No	≥ 3	> 50	$R > 0.35$	$800 < M'_R$	5
Discovery Regions							
$ee/\mu\mu$ DR	No	Yes	≤ 2	> 50	$R > 0.5$	$600 < M'_R$	1
$e\mu$ DR	No	No	≤ 2	> 50	$R > 0.5$	$600 < M'_R$	1
Control Regions							
$ee/\mu\mu$ Z CR 1	No	Yes	≤ 2	> 50	$0.15 < R < 0.3$	$400 < M'_R < 1200$	8
$ee/\mu\mu$ Z CR 2	No	Yes	≥ 3	> 50	$0.05 < R < 0.2$	$800 < M'_R < 1600$	4
$ee/\mu\mu$ Top CR 1	Yes	Yes	≤ 2	> 50	$0.2 < R < 0.4$	$400 < M'_R < 1200$	8
$e\mu$ Top CR 1	Yes	No	≤ 2	> 50	$0.2 < R < 0.4$	$400 < M'_R < 1200$	8
$ee/\mu\mu$ Top CR 2	Yes	Yes	≥ 3	> 50	$0.1 < R < 0.3$	$800 < M'_R < 1600$	4
$e\mu$ Top CR 2	Yes	No	≥ 3	> 50	$0.1 < R < 0.3$	$800 < M'_R < 1600$	4
Validation Regions							
$ee/\mu\mu$ Z VR 1	No	Yes	≤ 2	> 50	$0.25 < R < 1$	$200 < M'_R < 400$	4
$ee/\mu\mu$ Z VR 2	No	Yes	≥ 3	> 50	$0.1 < R < 1$	$200 < M'_R < 800$	6
$ee/\mu\mu$ Top VR 1	Yes	Yes	≤ 2	> 50	$0.5 < R < 1$	$200 < M'_R < 400$	4
$e\mu$ Top VR 1	Yes	No	≤ 2	> 50	$0.5 < R < 1$	$200 < M'_R < 400$	4
$ee/\mu\mu$ Top VR 2	Yes	Yes	≥ 3	> 50	$0.35 < R < 1$	$200 < M'_R < 800$	6
$e\mu$ Top VR 2	Yes	No	≥ 3	> 50	$0.35 < R < 1$	$200 < M'_R < 800$	6

2-leptons

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- SR1 limits significantly lower than SR2 because they include low-mass, high stat bins to enhance the sensitivity for small mass splitting SUSY

channel	$ee/\mu\mu$ SR1	$e\mu$ SR1	$ee/\mu\mu$ SR2	$e\mu$ SR2	OS $ee/\mu\mu$ SR1	OS $e\mu$ SR1	OS $ee/\mu\mu$ SR2	OS $e\mu$ SR2
Observed events	102	87	8	8	91	81	7	8
Fitted bkg events	117 ± 16	103 ± 15	11.0 ± 2.8	10.1 ± 2.7	112 ± 16	92 ± 13	10.3 ± 2.6	9.8 ± 2.7
Fitted DibosonWW events	32 ± 8	28 ± 7	0.9 ± 0.3	0.44 ± 0.15	31 ± 8	28 ± 7	0.89 ± 0.25	0.45 ± 0.14
Fitted ZX events	6.8 ± 1.5	3.6 ± 0.3	0.57 ± 0.14	0.22 ± 0.06	5.1 ± 1.1	1.90 ± 0.15	0.44 ± 0.10	0.10 ± 0.03
Fitted Top events	66 ± 11	55 ± 10	8.9 ± 2.4	8.6 ± 2.4	64 ± 11	53 ± 10	8.6 ± 2.4	8.4 ± 2.3
Fitted reducible bkg. events	13 ± 7	16 ± 8	$0.7^{+1.0}_{-0.7}$	$0.8^{+1.1}_{-0.8}$	11 ± 6	8.9 ± 5	$0.4^{+0.7}_{-0.4}$	$0.8^{+1.1}_{-0.8}$
MC exp. SM events	115	101	12.8	10.4	109	90	11.9	10.1
MC exp. DibosonWW events	29	26	0.8	0.50	29	26	0.84	0.45
MC exp. ZX events	8.2	3.5	0.70	0.19	6.3	1.84	0.54	0.10
MC exp. Top events	65	56	10.6	8.9	62	54	10.2	8.7
Exp. reducible bkg events	13	16	0.7	0.8	11	8.9	0.4	0.8
95 % C.L. upper limit on N_{BSM}	$28\ (35^{\uparrow 48}_{\downarrow 25})$	$24\ (31^{\uparrow 43}_{\downarrow 23})$	$6.7\ (8.5^{\uparrow 12.4}_{\downarrow 6.0})$	$7.1\ (8.4^{\uparrow 12.2}_{\downarrow 5.9})$	$24\ (33^{\uparrow 45}_{\downarrow 24})$	$25\ (30^{\uparrow 41}_{\downarrow 22})$	$6.1\ (8.2^{\uparrow 11.9}_{\downarrow 5.7})$	$7.3\ (8.3^{\uparrow 12.1}_{\downarrow 5.8})$
95 % C.L. upper limit on σ_{BSM} [fb]	$1.4\ (1.7^{\uparrow 2.3}_{\downarrow 1.2})$	$1.2\ (1.5^{\uparrow 2.1}_{\downarrow 1.1})$	$0.33\ (0.42^{\uparrow 0.61}_{\downarrow 0.29})$	$0.35\ (0.41^{\uparrow 0.60}_{\downarrow 0.29})$	$1.2\ (1.6^{\uparrow 2.2}_{\downarrow 1.2})$	$1.2\ (1.5^{\uparrow 2.0}_{\downarrow 1.0})$	$0.30\ (0.40^{\uparrow 0.59}_{\downarrow 0.28})$	$0.36\ (0.41^{\uparrow 0.59}_{\downarrow 0.29})$
p_0-value (Gauss. σ)	0.76 (−0.70)	0.80 (−0.86)	0.77 (−0.75)	0.69 (−0.49)	0.86 (−1.1)	0.73 (−0.60)	0.81 (−0.88)	0.66 (−0.42)

- Discovery regions (DR) provide more stringent limits on larger Δm models

channel	$ee/\mu\mu$ DR	$e\mu$ DR	OS $ee/\mu\mu$ DR	OS e/μ DR
Observed events	17	12	17	10
Fitted bkg events	17.3 ± 2.6	17.8 ± 3.2	16.3 ± 2.5	15.6 ± 2.8
Fitted DibosonWW events	5.9 ± 1.3	5.8 ± 1.5	5.9 ± 1.3	5.8 ± 1.5
Fitted ZX events	1.52 ± 0.30	0.76 ± 0.11	1.17 ± 0.21	0.20 ± 0.03
Fitted Top events	7.7 ± 1.5	7.6 ± 1.7	7.4 ± 1.5	7.3 ± 1.6
Fitted reducible bkg. events	1.2 ± 1.2	2.6 ± 1.7	$0.9^{+1.0}_{-0.9}$	1.3 ± 1.2
MC exp. SM events	17.6	17.3	16.4	15.2
MC exp. DibosonWW events	5.6	5.4	5.6	5.3
MC exp. ZX events	1.83	0.78	1.41	0.22
MC exp. Top events	8.0	7.6	7.6	7.3
Exp. reducible bkg events	1.2	2.6	0.9	1.3
95 % C.L. upper limit on N_{BSM}	$11.0\ (10.4^{\uparrow 15.1}_{\downarrow 7.3})$	$7.6\ (10.4^{\uparrow 15.0}_{\downarrow 7.3})$	$11.6\ (10.2^{\uparrow 14.8}_{\downarrow 7.1})$	$6.8\ (9.6^{\uparrow 13.9}_{\downarrow 6.7})$
95 % C.L. upper limit on σ_{BSM} [fb]	$0.54\ (0.51^{\uparrow 0.74}_{\downarrow 0.36})$	$0.37\ (0.51^{\uparrow 0.74}_{\downarrow 0.36})$	$0.57\ (0.50^{\uparrow 0.73}_{\downarrow 0.35})$	$0.33\ (0.47^{\uparrow 0.68}_{\downarrow 0.33})$
p_0-value (Gauss. σ)	0.44 (0.16)	0.84 (−0.98)	0.36 (0.36)	0.85 (−1.1)

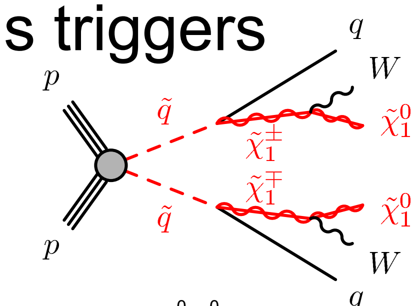
2 same-sign leptons

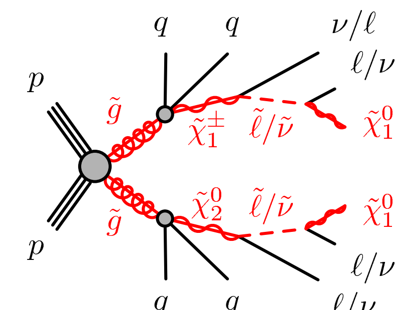
ATLAS-CONF-2013-007

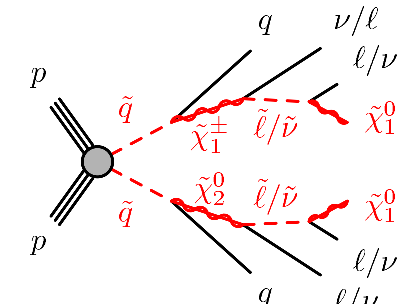
- p_T^{lep}>20 GeV
- p_T^{jet}>50 GeV
- $p_T^{b\text{-}jet}$>20 GeV

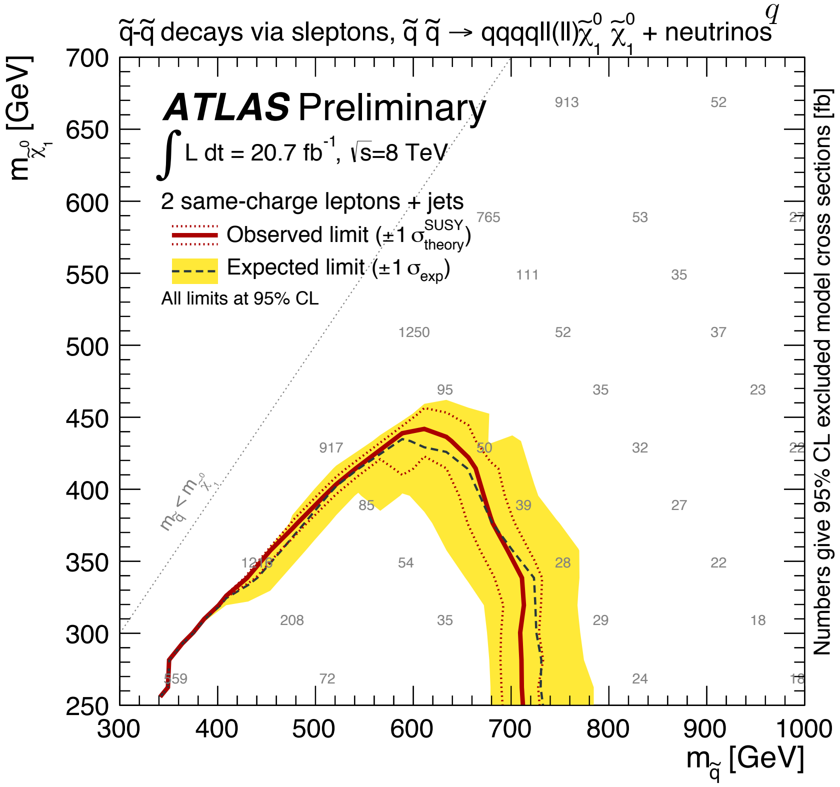
- Triggers:
  - For E_T^{miss}>150 GeV SRs E_T^{miss} trigger is used
  - Otherwise single- and di-leptons triggers

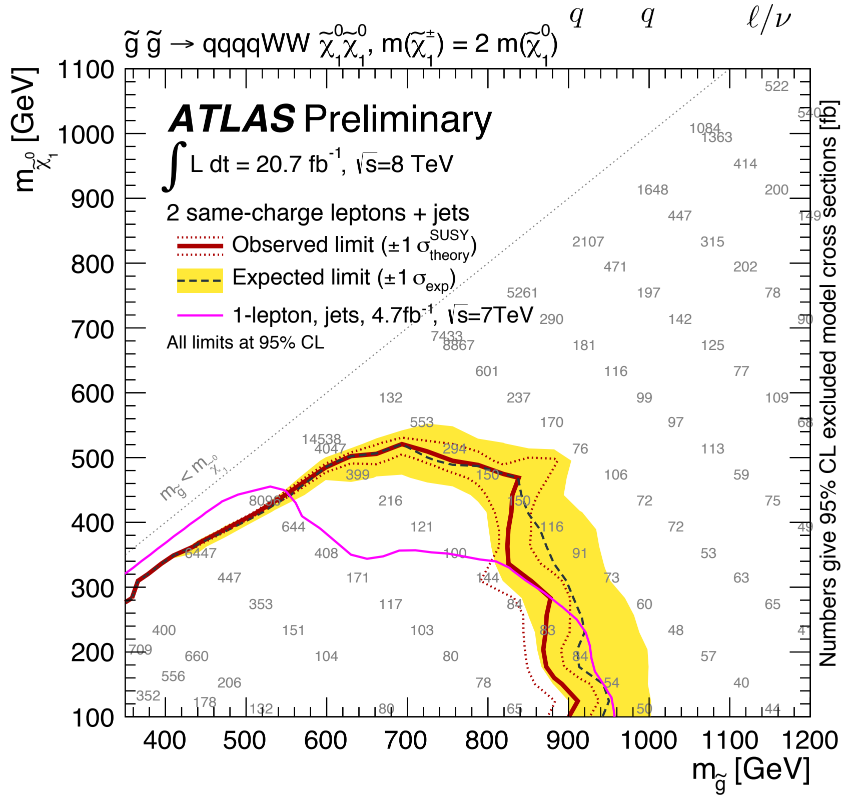
Signal region	$N_{b\text{-jets}}$	Signal cuts (discovery case)	Signal cuts (exclusion case)
SR0b	0	$N_{jets} \geq 3$, E_T^{miss}> 150 GeV m_T> 100 GeV, m_{eff}>400 GeV	$N_{jets} \geq 3$, E_T^{miss}> 150 GeV, m_T> 100 GeV, binned shape fit in m_{eff} for m_{eff} >300 GeV
SR1b	≥1	$N_{jets} \geq 3$, E_T^{miss}> 150 GeV m_T>100 GeV, m_{eff}>700 GeV	$N_{jets} \geq 3$, E_T^{miss}> 150 GeV, m_T>100 GeV, binned shape fit in m_{eff} for m_{eff}>300 GeV
SR3b	≥3	$N_{jets} \geq 4$ -	$N_{jets} \geq 5$, E_T^{miss}< 150 GeV or m_T< 100 GeV

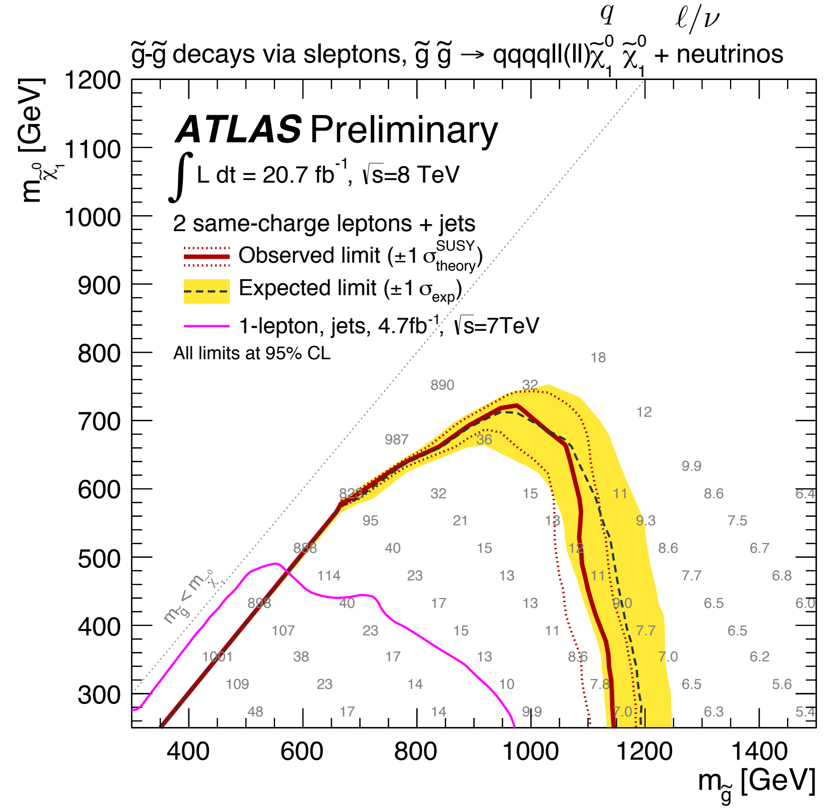










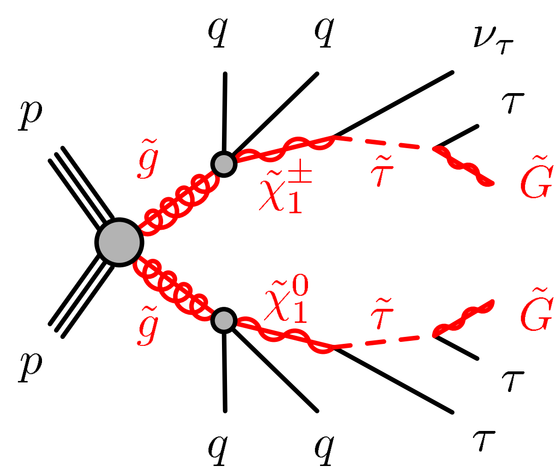


Tau + jets + E_T^{miss}

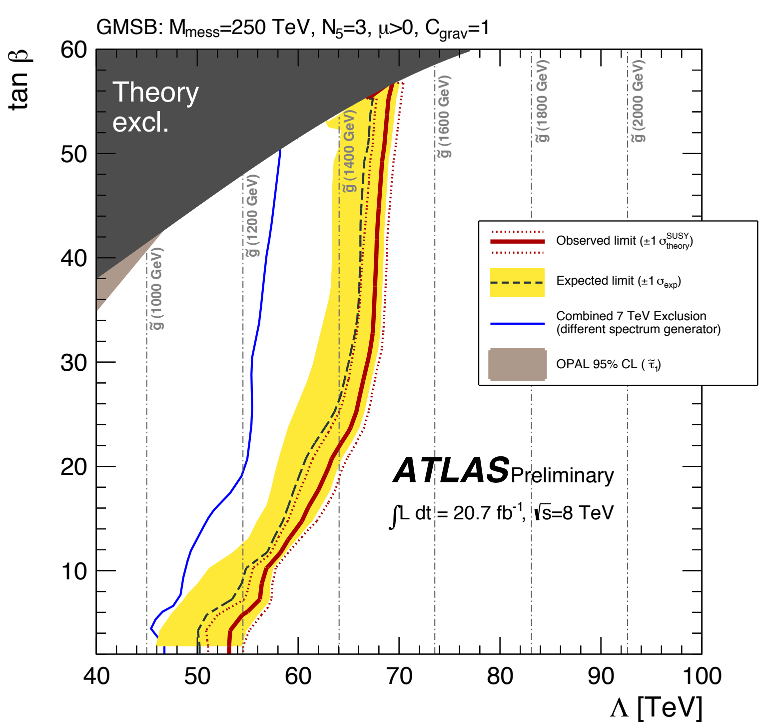
ATLAS-CONF-2013-026

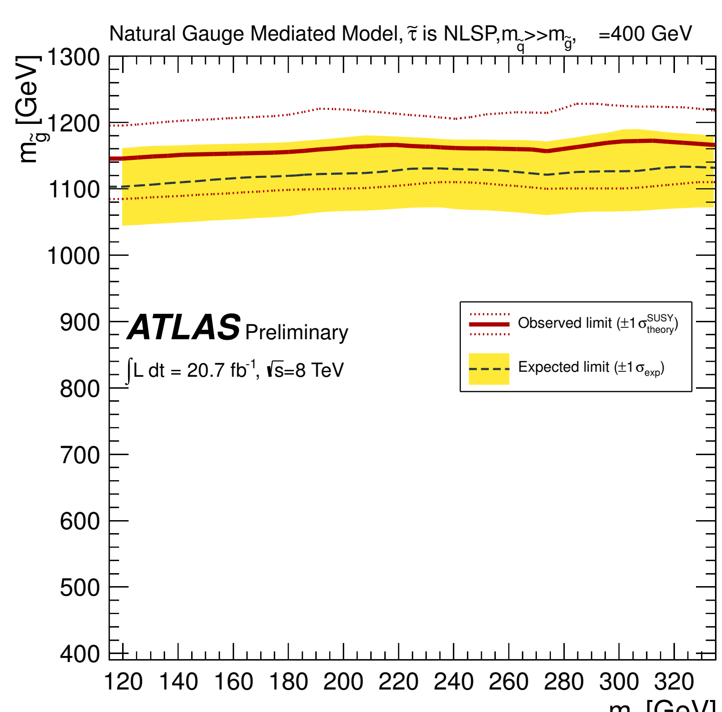
- Gauge-mediated SUSY breaking models
  - $\tilde{\tau}$ NLSP decaying to gravitino LSP & τ
- SRs with ≥1 τ , ≥2 jets & E_T^{miss}
- Dominant bkg: **W/Z+jets** + **tt-bar** production
  - True tau / jets misId for a tau
  - MC is scaled to the data
    - m_T<80 GeV for true τ
    - 80<m_T<130 GeV for fake τ
- Multi-jet bkg => data-driven

	1τ SR	2τ GMSB SR	2τ nGM SR
Pre-selection	$p_T^{jet1} > 130$ GeV, $p_T^{jet2} > 30$ GeV, $E_T^{miss} > 150$ GeV		
Taus	$N_\tau^{medium} = 1$, $p_T^\tau > 30$ GeV	$N_\tau^{loose} \geq 2$, $p_T^\tau > 20$ GeV	
Light leptons	$N_\ell = 0$		
QCD rejection	$\Delta(\phi_{jet_{1,2}-p_T^{miss}}) > 0.3$ rad, $E_T^{miss}/m_{eff} > 0.3$	$\Delta(\phi_{jet_{1,2}-p_T^{miss}}) > 0.3$ rad	
Signal cuts	$m_T^\tau > 140$ GeV, $H_T > 800$ GeV	$m_T^{\tau_1} + m_T^{\tau_2} \geq 150$ GeV, $H_T > 900$ GeV	$m_T^{\tau_1} + m_T^{\tau_2} \geq 250$ GeV, $H_T > 600$ GeV, $N_{jet} \geq 4$

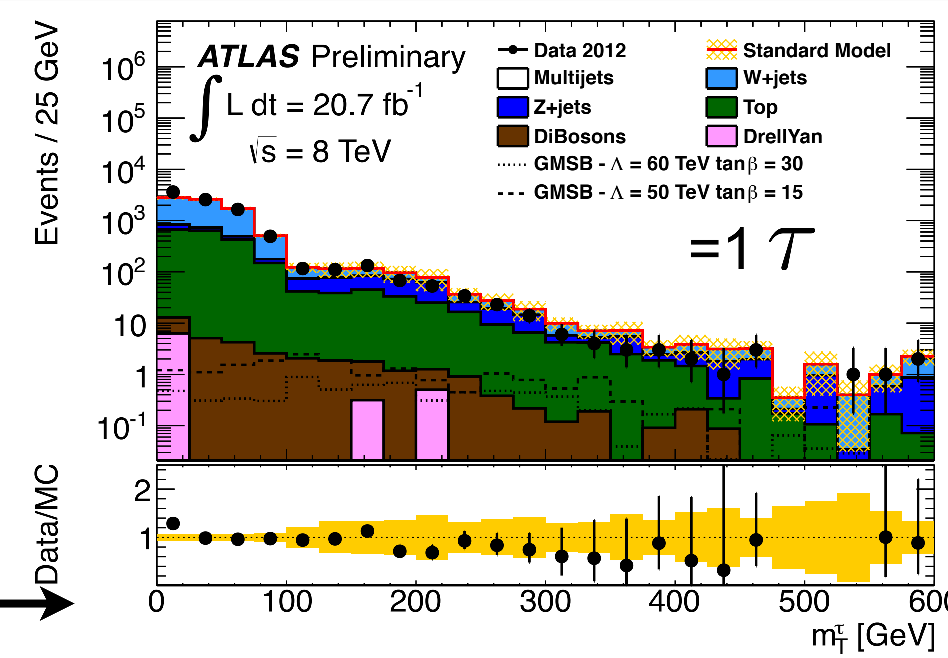


–	1τ	2τ GMSB region	2τ nGM region
Multi-jet	0.03±0.01	0.14 ± 0.04	0.04 ± 0.02
W + jets	1.9 ± 0.5 ± 0.7	3.8 ± 1.1 ± 0.9	0.3 ± 0.2 ± 0.4
Z + jets	2.1 ± 1.2 ± 1.7	0.3 ± 0.3 ± 0.5	0.02 ± 0.02 ± 0.01
top	0.7 ± 0.6 ± 0.3	2.4 ± 0.7 ± 1.4	3.1 ± 1.0 ± 1.7
di-boson	0.1±0.1 ± 0.1	0.6 ± 0.2 ± 0.2	0.02 ± 0.02 ± 0.02
Total background	4.9±1.5 ±1.3	7.2 ± 1.3 ± 1.6	3.5 ± 1.1 ± 1.9
Data	3	5	1
Signal MC Events			
GMSB5030	9 ± 2	36 ± 2	–
nGM 210-1020	–	–	10 ± 1
mSUGRA 400-650	6 ± 1	–	–
Obs (exp) limit on signal events	8.3 ($9.0^{+2.7}_{-2.2}$)	8.7 ($9.6^{+5.2}_{-2.4}$)	5.0 ($6.3^{+3.7}_{-0.6}$)
Obs limit on Cross Section (fb)	0.40	0.42	0.24





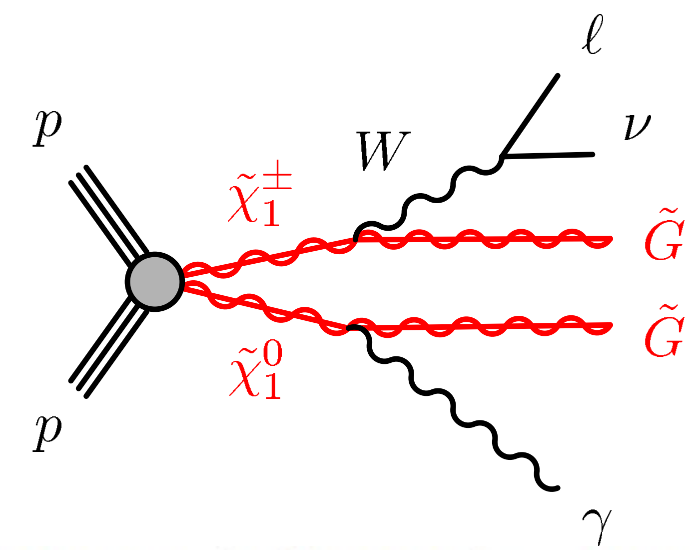
All requirements except on m_T & H_T, after data-driven correct. →



Photon+lepton+E_T^{miss}

ATLAS-CONF-2012-144

- Gauge-mediated SUSY breaking models
  - Wino NLSP decaying to gravitino LSP & photon
- SR with **≥1 γ** (p_T>85/100), **≥1 lepton** (p_T>25) & $\mathbf{E_T^{miss}}$
- L=4.8 fb^{-1} & √s=7 TeV
- lepton/γ triggers



- Dominant bkg: **W+ γ**, **tt+ γ**, tt+charge-flip => MC only
- **Jet misId as γ or lep**: W+jets, tt+jets, γ+jets, Z+jets
  - data-driven (matrix method)
- Z+X, single top, dibosons => MC only

Signal or Control Region	E_T^{miss} [GeV] low	E_T^{miss} [GeV] high	m_T [GeV] low	m_T [GeV] high
SR	100	—	100	—
WCR	35	80	35	90
HMET	80	—	35	90
HMT	35	80	90	—

- **Upper limit on σ(vis): 2.7 fb (el) & 1.8 fb (mu)**