INCLUSIVE SEARCHES FOR SQUARKS AND GLUINOS AT ATLAS

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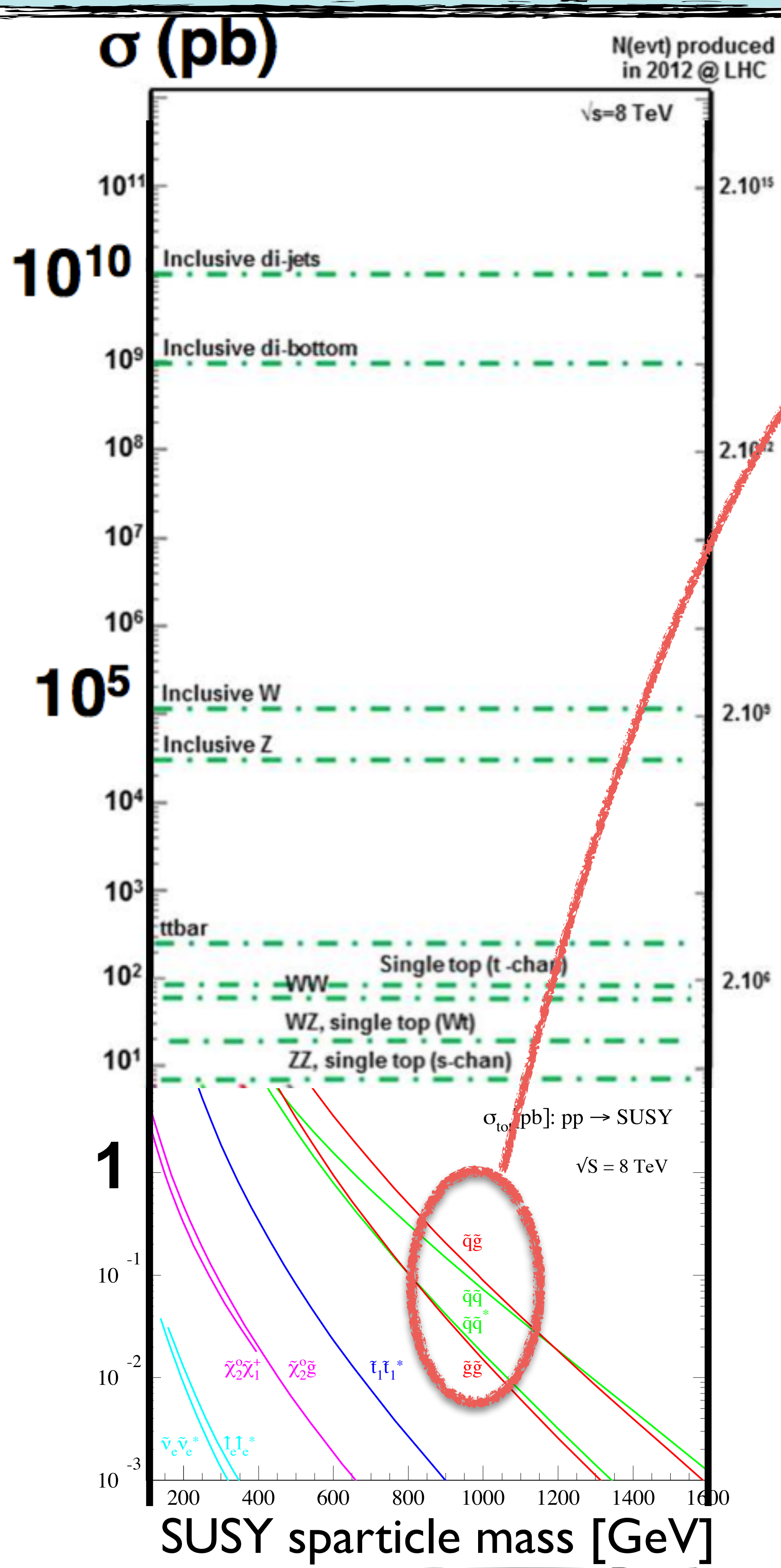
SUSY @ LHC

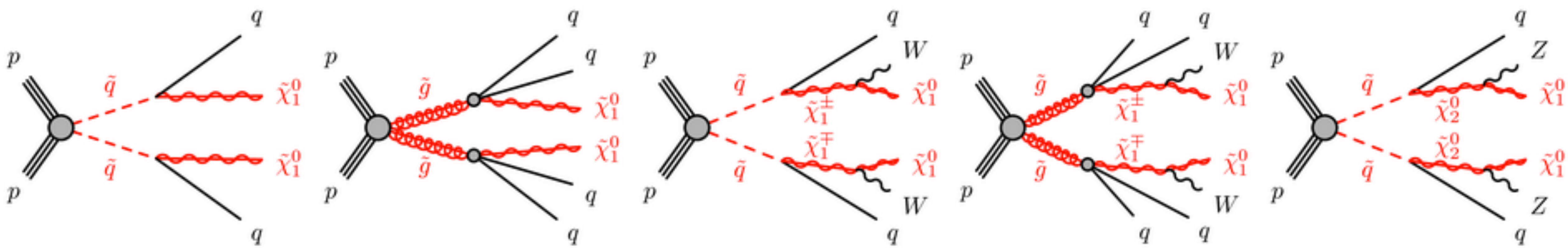


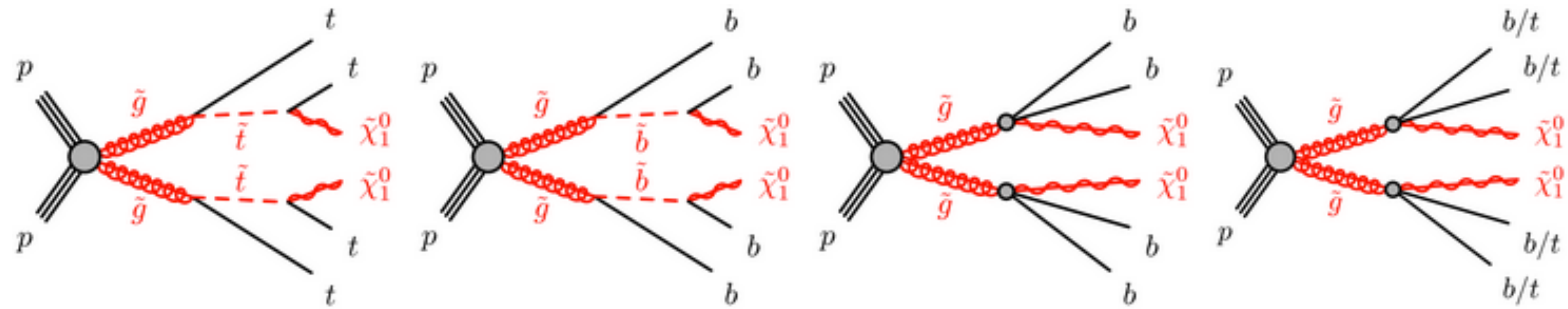
- Strong production: gluino pair, squark pair, gluino with associated squark
- Many possible decays => multiple search strategies:
  - Interpretation of these in both specific susy-breaking scenarios:
    - mSUGRA (minimal Supergravity)
    - NUHM (Non-Universal Higgs masses)
    - GMSB (Gauge Mediated Symmetry breaking)
    - GGM (General Gauge Mediation)
  - And generic scenarios:
    - Simplified Models
    - phenomenological MSSM

What is important?

- Powerful discriminating variables
- Well-understood simulation
- Background under control
- Interpret results in multiple scenarios

INCLUSIVE SEARCHES AT ATLAS





and more…

IN THIS TALK:

0 lepton, 2-6 jets, EtMiss *NEW*	arXiv: 1405.7875 (submitted to JHEP)
0 lepton, 7-10 jets, EtMiss	arXiv:1308.1841 (JHEP 10 (2013) 130)
0-1 lepton, 3 b-jets, EtMiss	ATLAS-CONF-2013-061
1-2 lepton, 3-6 jets, EtMiss	ATLAS-CONF-2013-062
2 SS leptons / 3 leptons	arXiv:1404.2500 (accepted by JHEP)
taus, jets, EtMiss	ATLAS-CONF-2013-026
diphoton, EtMiss	ATLAS-CONF-2014-001
multijets (RPV)	ATLAS-CONF-2013-091

SEARCH FOR SUSY: STRATEGY

SM BACKGROUND ESTIMATION - CONTROL REGIONS
(ttbar/t, W/Z+jets, Multi-jets, Diboson)

↔

MAIN BACKGROUNDS:
(determination methods)

- (semi)data-driven using control regions kinematically close to signal regions
  - transfer factors (minimize systematics)
- fully data-driven:
  - jet smearing method
  - matrix method
  - templates

↓

Check bkg estimate in validation regions (closer to signal regions then control regions)

↓

Look for the excess in signal regions

→

Interpretation:
Set model dependent / independent limits

NO LEPTON + 2-6 JETS + ETMISS

Target: Large number of RPC models containing final states with jets and missing energy originating from the decays of $\tilde{q}$ and $\tilde{g}$.

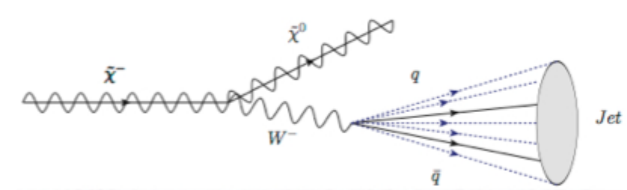
- $Z(\rightarrow\nu\nu)$+jets bkg estimated using a sample of γ+jets events using a data-driven normalisation procedure.

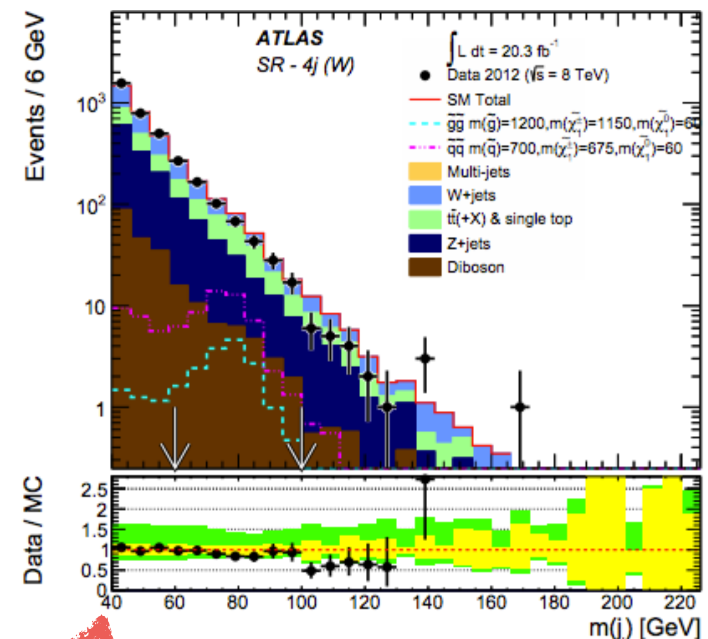
- Multi-jets bkg estimated using data-driven technique (normalized using reversed EtMiss/m_{eff} or EtMiss/$\sqrt{HT}$ cuts)

- Inclusive signal regions defined for increased jet multiplicity (2-6 jets) and with loose, medium and tight selections on m_{eff}(incl), EtMiss/m_{eff} or EtMiss/$\sqrt{HT}$

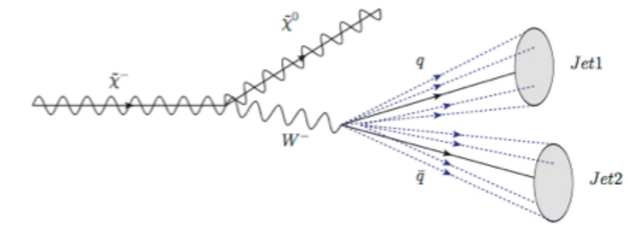
- Two dedicated SRs (2jW and 4jW) place additional requirements on the invariant masses of candidate W bosons decaying to hadrons => designed to improve sensitivity to models predicting $\tilde{q}/\tilde{g}$ decays to W (via $\tilde{\chi}^{\pm}$), in case where $\tilde{\chi}^{\pm}$ is nearly degenerate in mass with $\tilde{q}/\tilde{g}$.

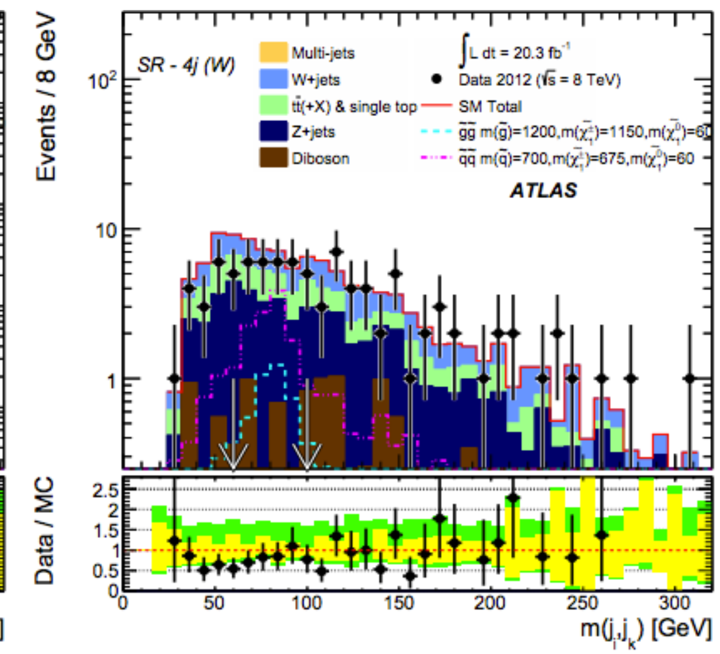
Unresolved



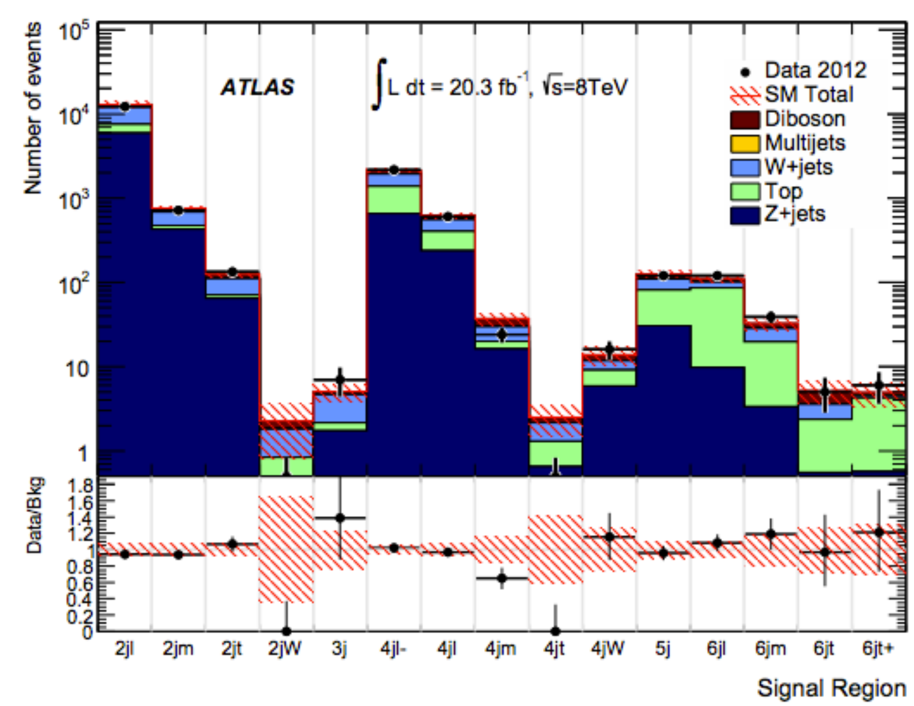


Resolved

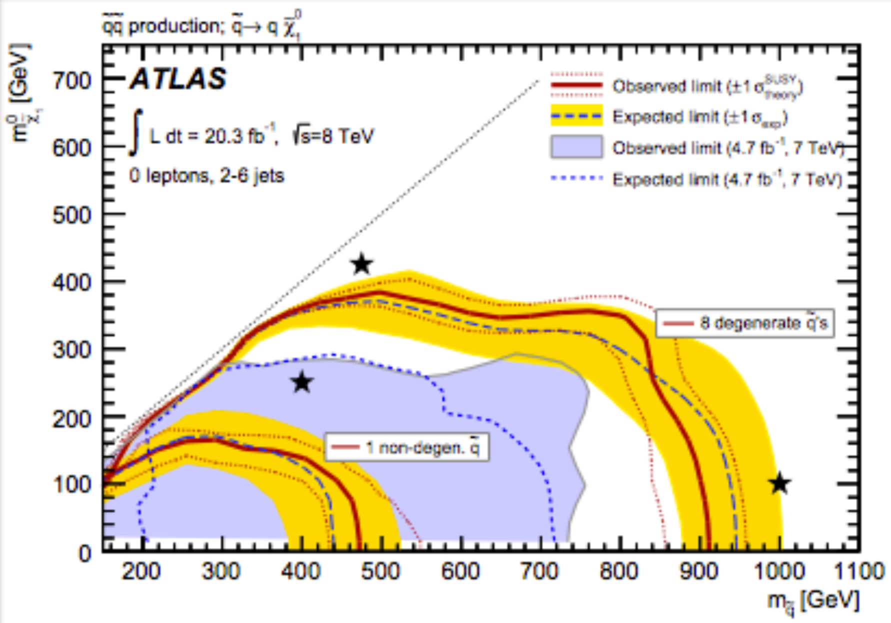


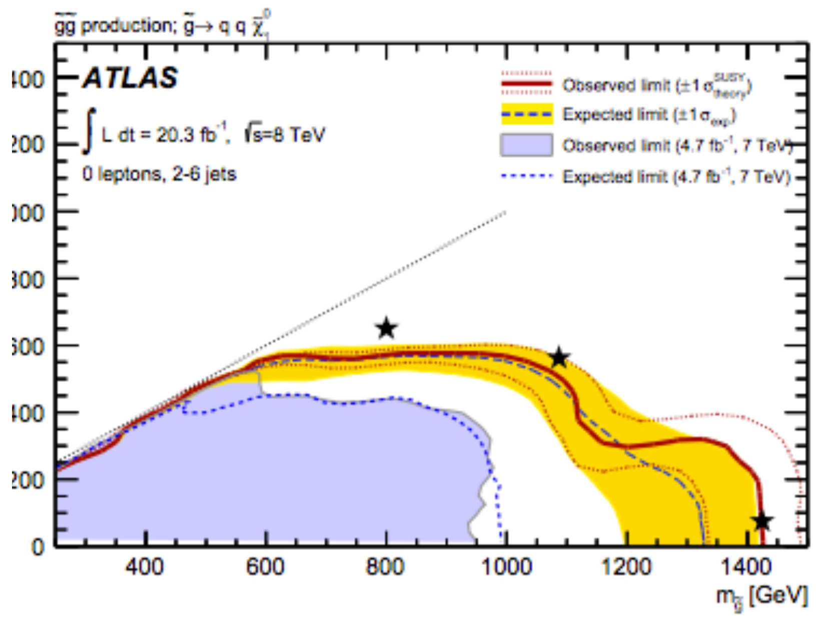


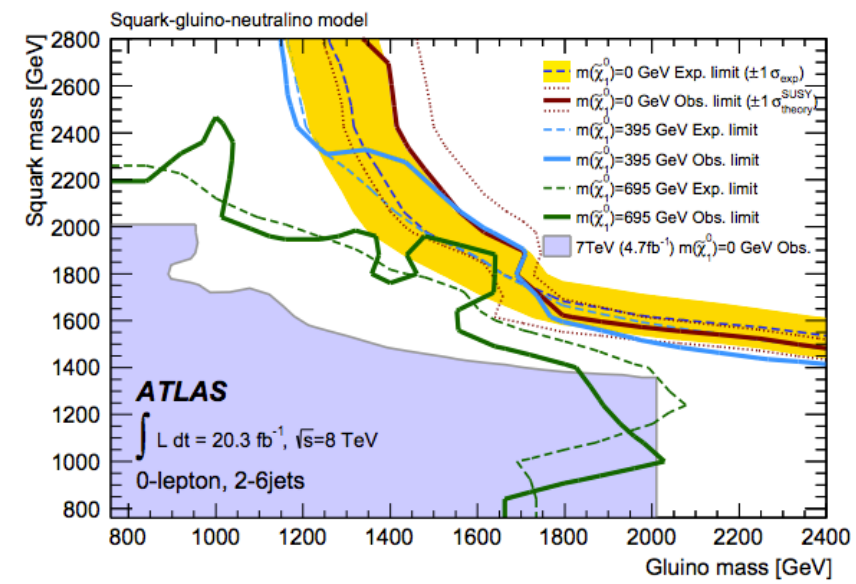
observed and expected event yields as a function of signal region

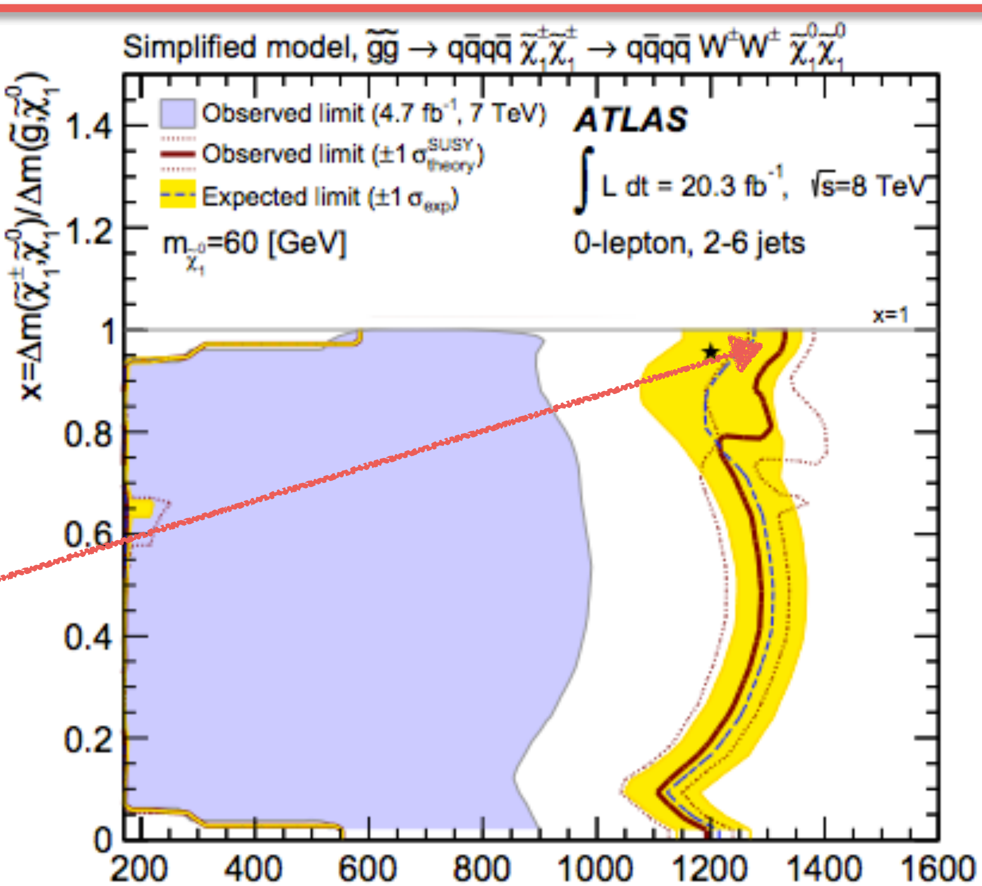


NO LEPTON + 2-6 JETS + ETMISS

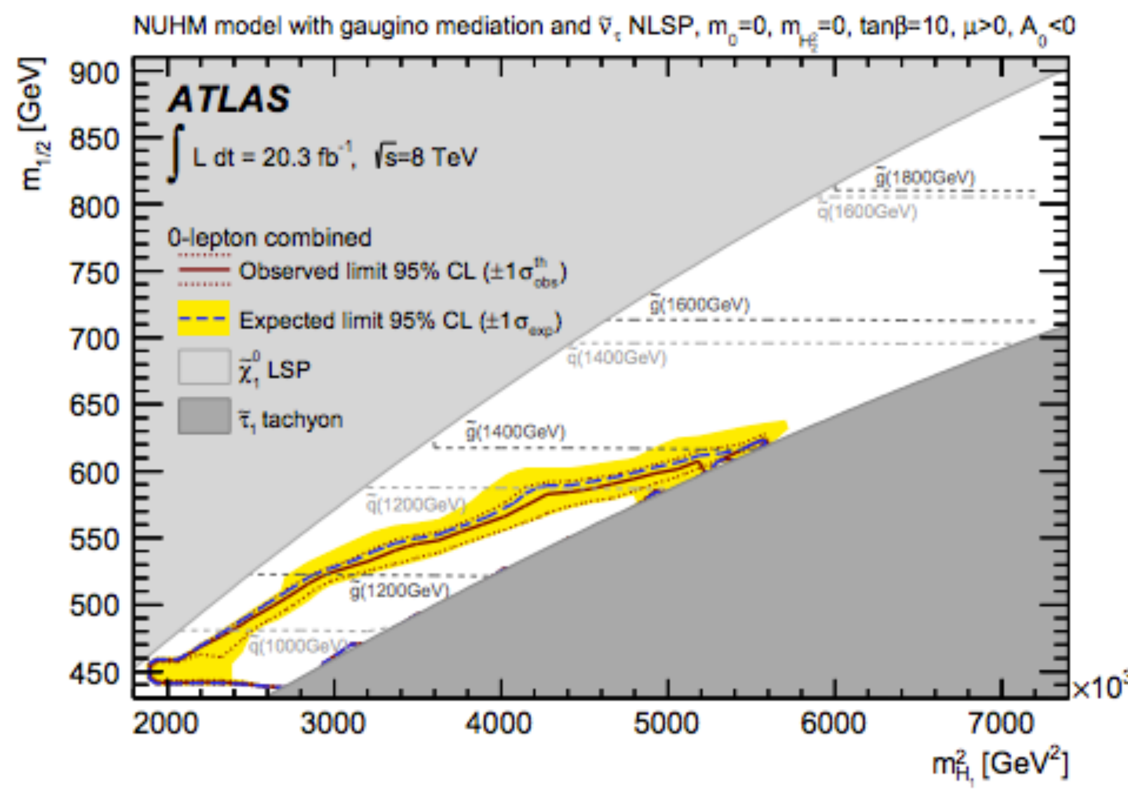








2jW region



Lower limit of 1650 GeV for equal mass light-flavour squarks and gluinos is found for phenoMSSM models with a massless LSP
Squark masses below 850 GeV (440 GeV) are excluded, assuming mass degenerate (single light-flavour) squarks.
Gluino masses below 1330 GeV are excluded in a simplified model with only gluinos and the lightest neutralino for a light LSP.

Target: High jet multiplicity scenarios from long decay chains ($\tilde{g}\to\tilde{t}t$, $\tilde{g}\to\tilde{q}$ (via $\tilde{\chi}^{\pm}$ or $\tilde{\chi}^{\pm}$ and $\tilde{\chi}^{0}{}_{2}$), $\tilde{g}\to\tilde{t}t$(RPV))

Template method used to estimate background from mismeasured MET

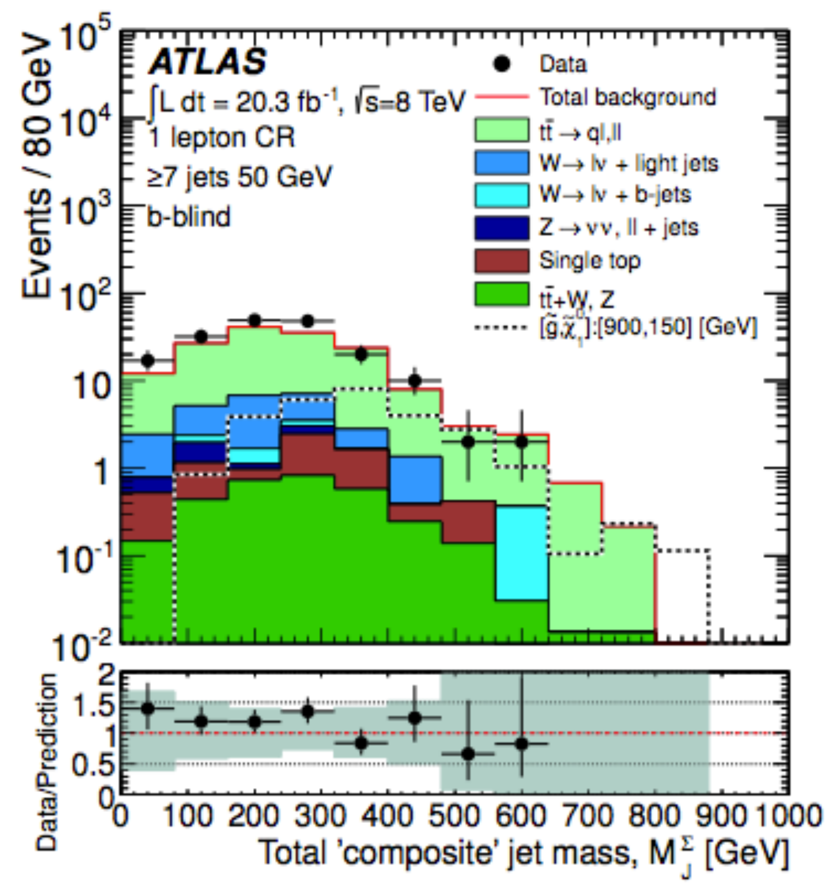
2 streams of selection criteria:

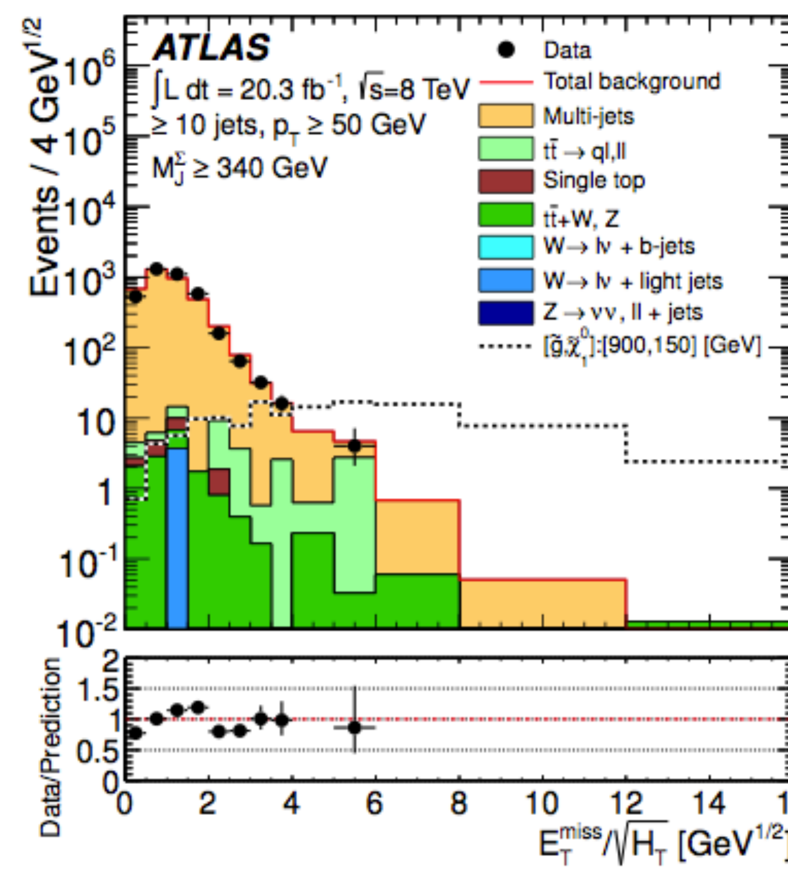
- #jets + flavour (0,1,>=2 b-jets)
- #jets + composite jets' mass

Composite (fat) jets are formed from reclustered anti-kt R=0.4 jets to R=1.0 jets. Mass of those jets used to isolate signal:

$$M_J^{\Sigma} = \Sigma m_j^{R=1.0}$$

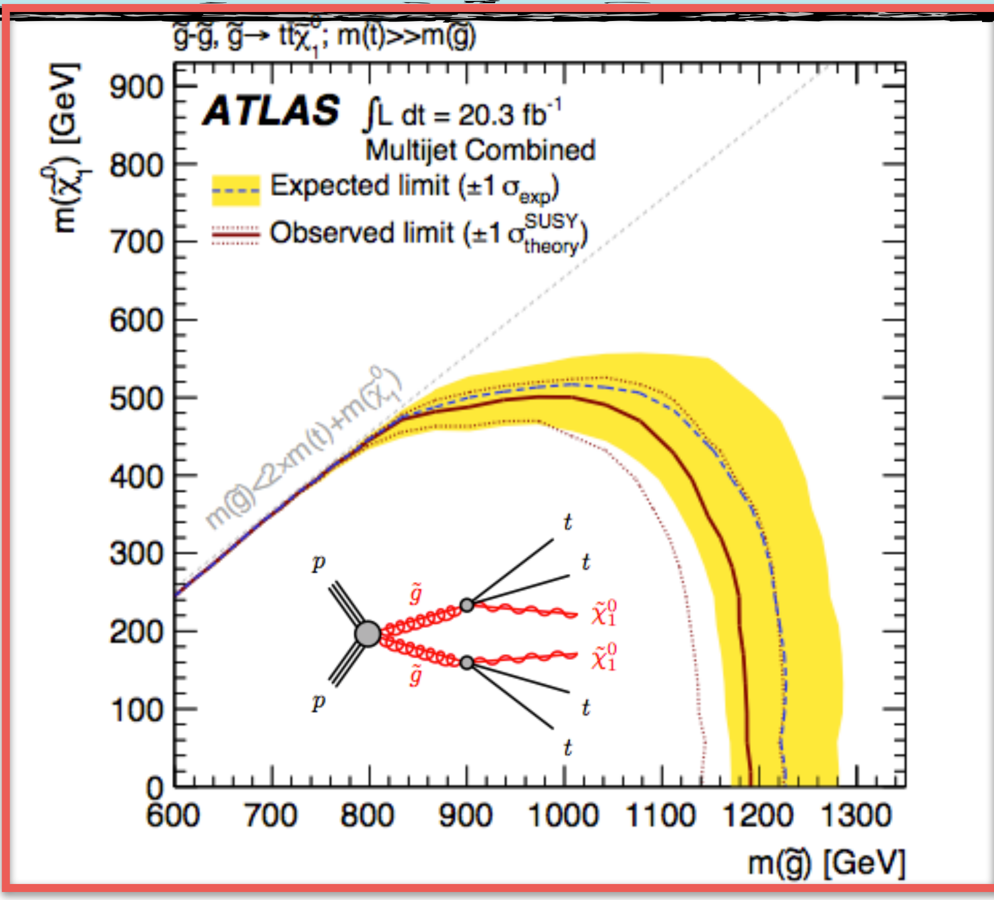
1-lepton control region

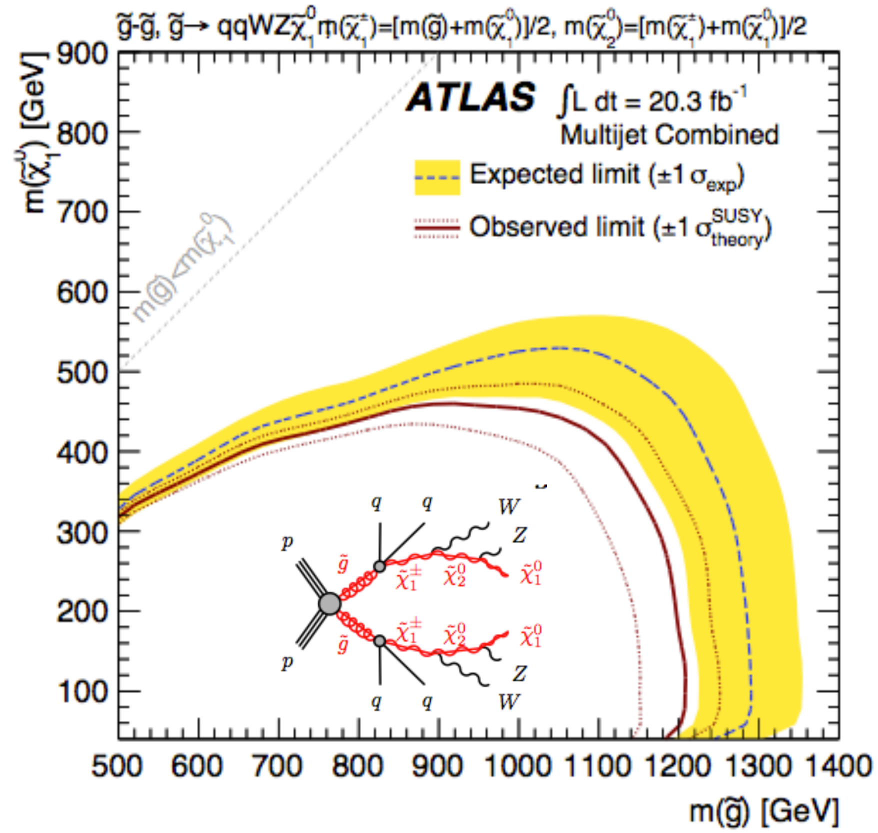


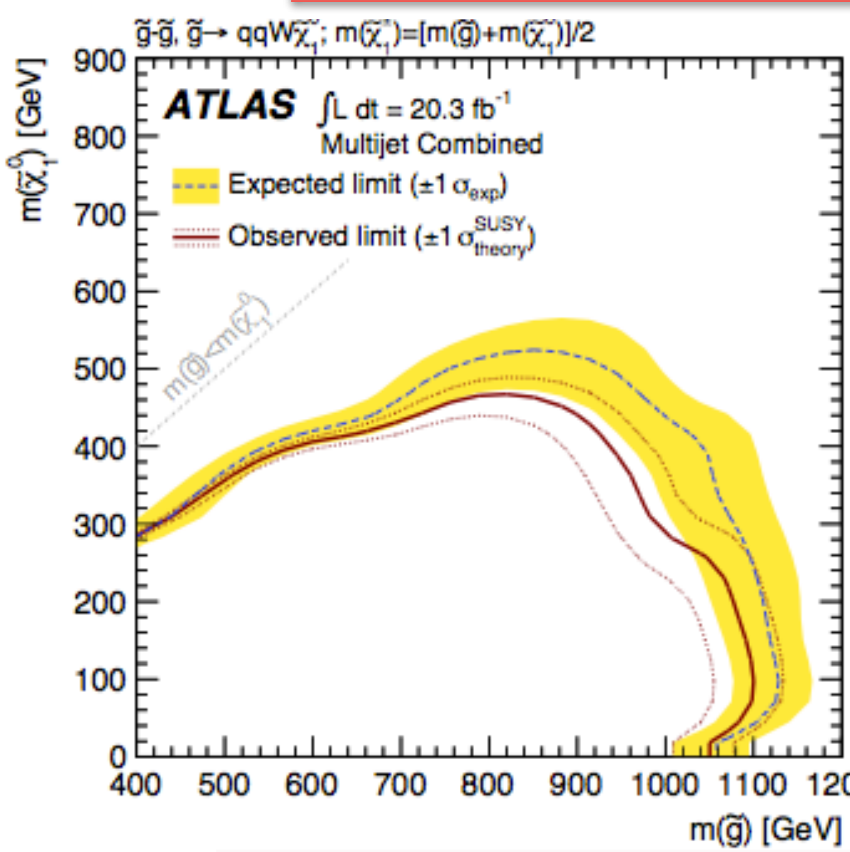


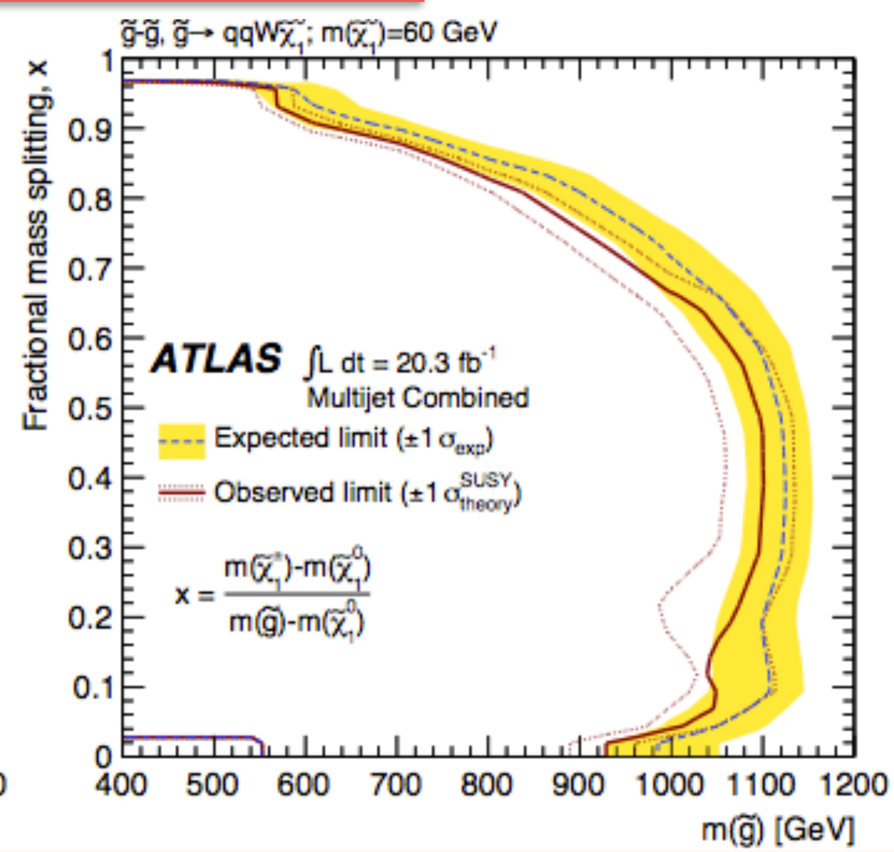
	Multi-jet + flavour stream					Multi-jet + M_J^{Σ} stream		
Identifier	8j50	9j50	≥ 10j50	7j80	≥ 8j80	≥ 8j50	≥ 9j50	≥ 10j50
M_J^{Σ} [GeV]	—			—		> 340 and > 420 for each case		
$E_T^{miss}/\sqrt{H_T}$	> 4 GeV$^{1/2}$			> 4 GeV$^{1/2}$		> 4 GeV$^{1/2}$		

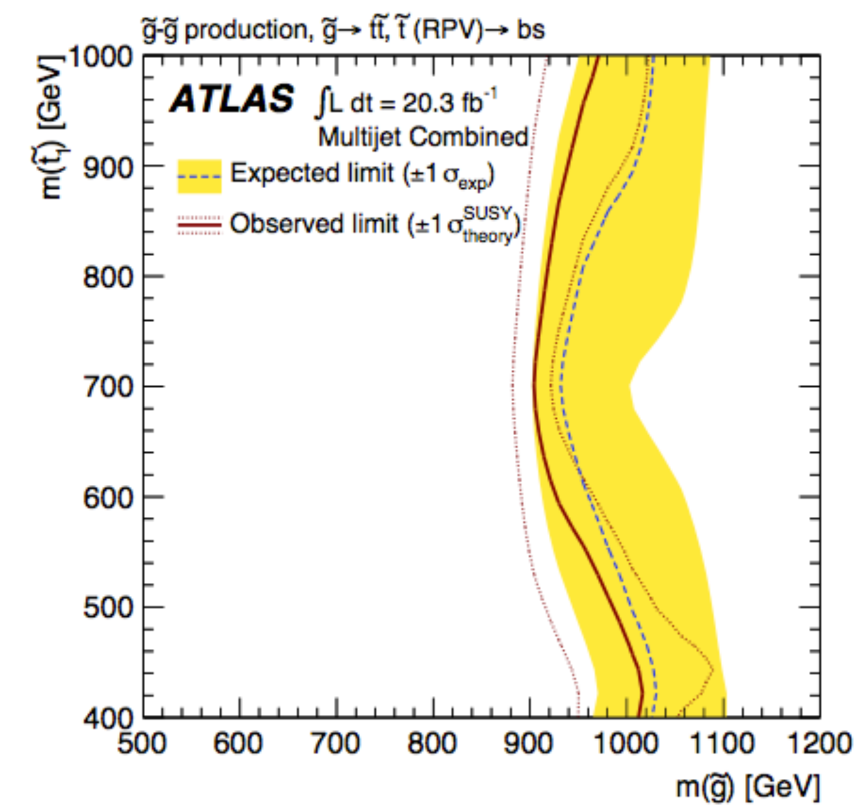
NO LEPTON + 7-10 JETS + ETMISS











g̃→t̃t model: Gluino masses smaller than 1.1 TeV are excluded for neutralino masses below 350 GeV

0/1 LEPTON + 3B-JETS + ETMISS

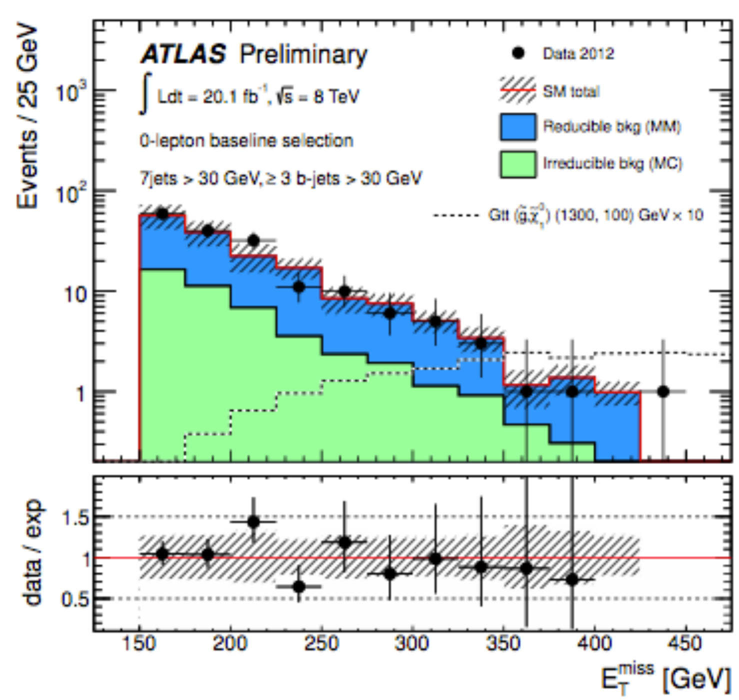
Target: various SUSY models where top or bottom quarks are produced in gluino decay chains
- Reducible bkg: *ttbar* events in association with additional non-*b* jets, ttbar+W/Z, single top, W/Z+heavy flavour jets; irreducible bkg: ttbar+b/bbar, ttbar+Z/h(Z/h→bb)
  - -Reducible bkg sources estimated simultaneously using the matrix method (MM) based on number of b-tagged and non b-tagged jets including efficiencies and mistag rates.
  - -MC used for irreducible bkg

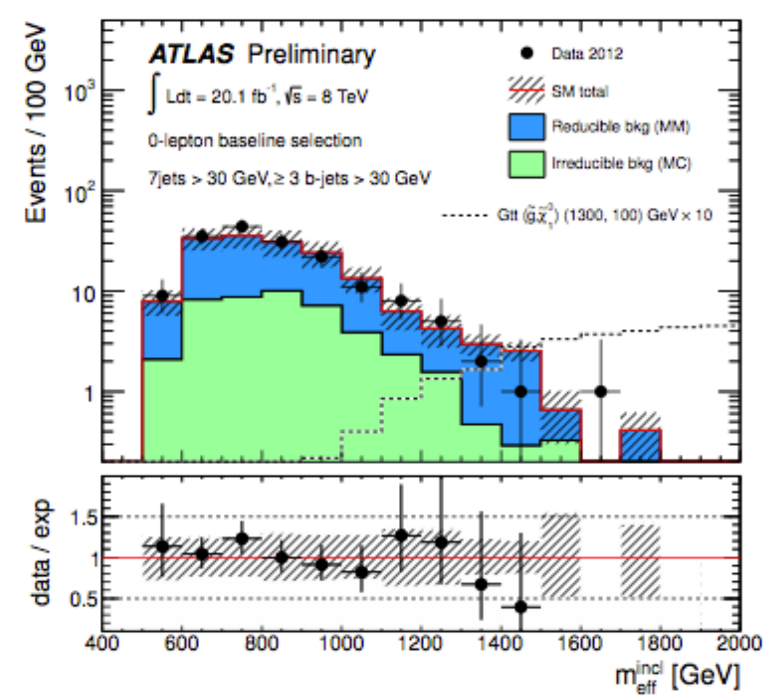
baseline selection: baseline lepton veto, $p_T^{j_1} > 90$ GeV, $E_{\mathrm{T}}^{\mathrm{miss}} > 150$ GeV, ≥ 4 jets with $p_T > 30$ GeV, $\Delta\phi_{\mathrm{min}}^{4j} > 0.5$, $E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}^{4j} > 0.2$, ≥ 3 b-jets with $p_T > 30$ GeV

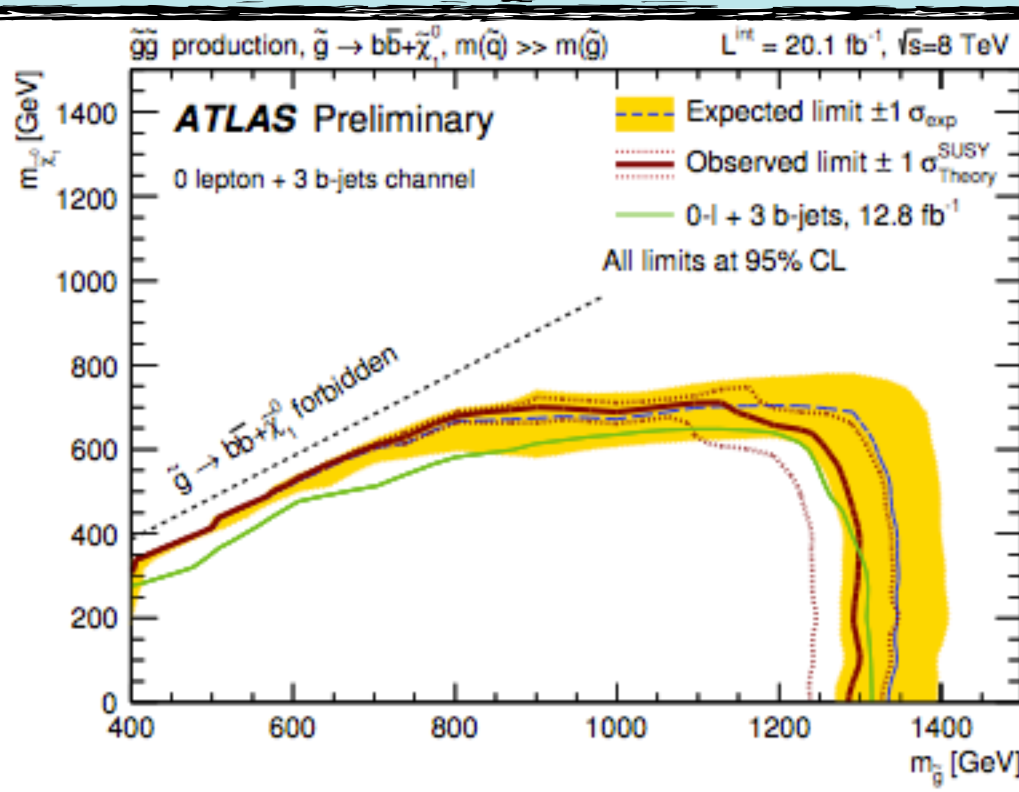
SR-0l-4j-A	≥ 4	> 30	> 200	$m_{\mathrm{eff}}^{4j} > 1000$	SR-0l-7j-A	≥ 7	> 30	> 200	$m_{\mathrm{eff}}^{\mathrm{incl}} > 1000$
SR-0l-4j-B	≥ 4	> 50	> 350	$m_{\mathrm{eff}}^{4j} > 1100$	SR-0l-7j-B	≥ 7	> 30	> 350	$m_{\mathrm{eff}}^{\mathrm{incl}} > 1000$
SR-0l-4j-C	≥ 4	> 50	> 250	$m_{\mathrm{eff}}^{4j} > 1300$	SR-0l-7j-C	≥ 7	> 30	> 250	$m_{\mathrm{eff}}^{\mathrm{incl}} > 1500$

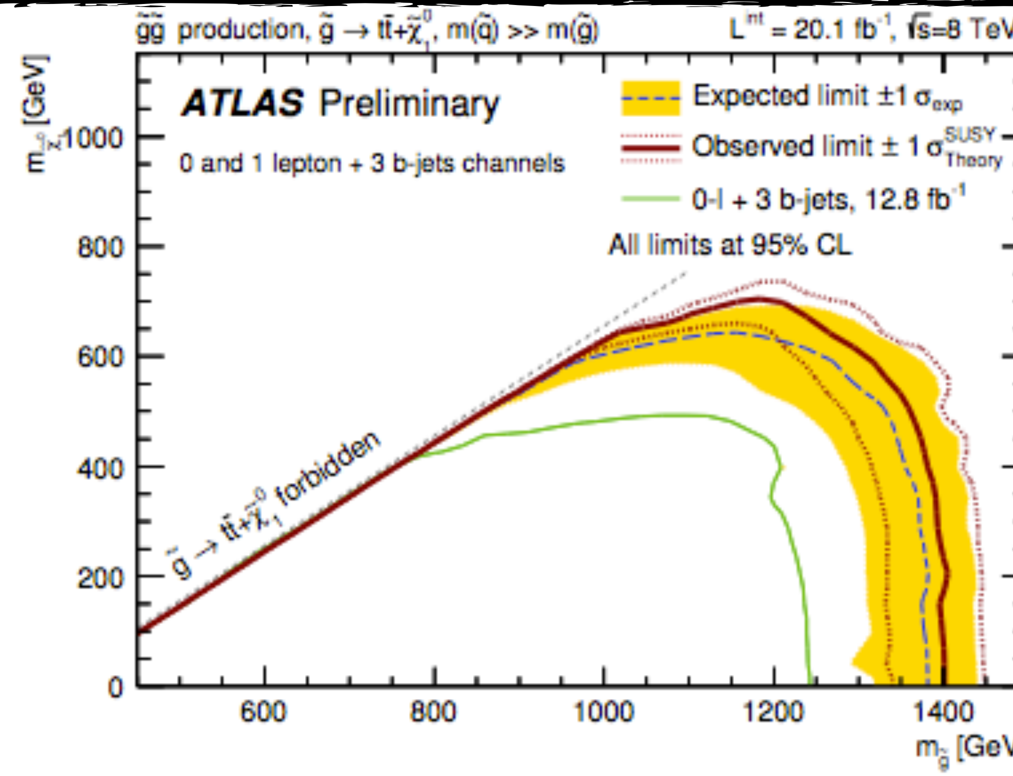
baseline selection: $\geqslant 1$ signal lepton (e,μ), $p_T^{j_1} > 90$ GeV, $E_{\mathrm{T}}^{\mathrm{miss}} > 150$ GeV, ≥ 4 jets with $p_T > 30$ GeV, ≥ 3 b-jets with $p_T > 30$ GeV

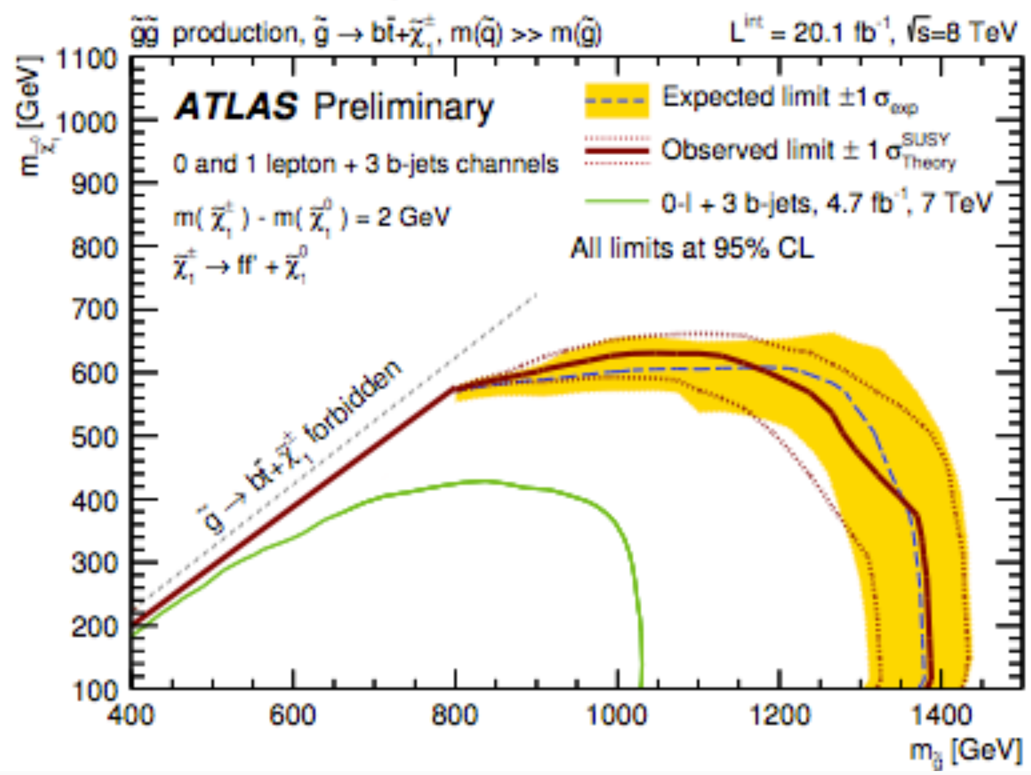
SR-1l-6j-A	≥ 6	> 175	> 140	> 700	> 5
SR-1l-6j-B	≥ 6	> 225	> 140	> 800	> 5
SR-1l-6j-C	≥ 6	> 275	> 160	> 900	> 5











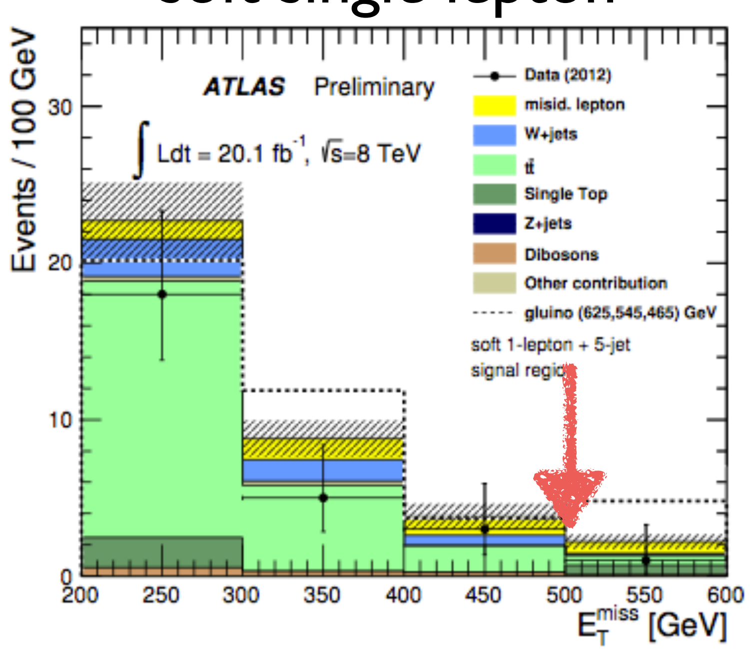
- $\tilde{g} \rightarrow \tilde{t}t$ model: gluino masses below 1340 GeV are excluded for m(LSP)< 400 GeV while neutralino masses below 620 GeV are excluded for $m_{(gluino)}$= 1000 GeV
- $\tilde{g} \rightarrow \tilde{t}b$ model, gluino masses below 1300 GeV are excluded for m(LSP)< 300 GeV while neutralino masses below 580 GeV are excluded for m(gluino)= 1100 GeV.

1-2 LEPTON + 3-6 JETS + ETMISS

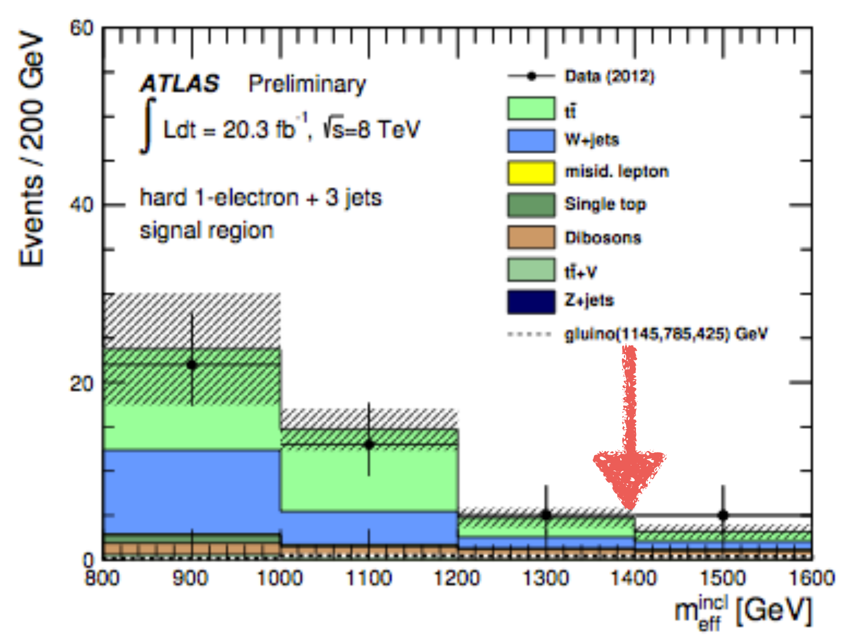
Target: pair production of gluinos or squarks (assuming degenerate first and second generation squarks) considering three different simplified models: the "one-step" models, "two-step" models with sleptons and "two-step" models without sleptons.
- Signal regions defined to target both soft and hard leptons
- Fake leptons from matrix method

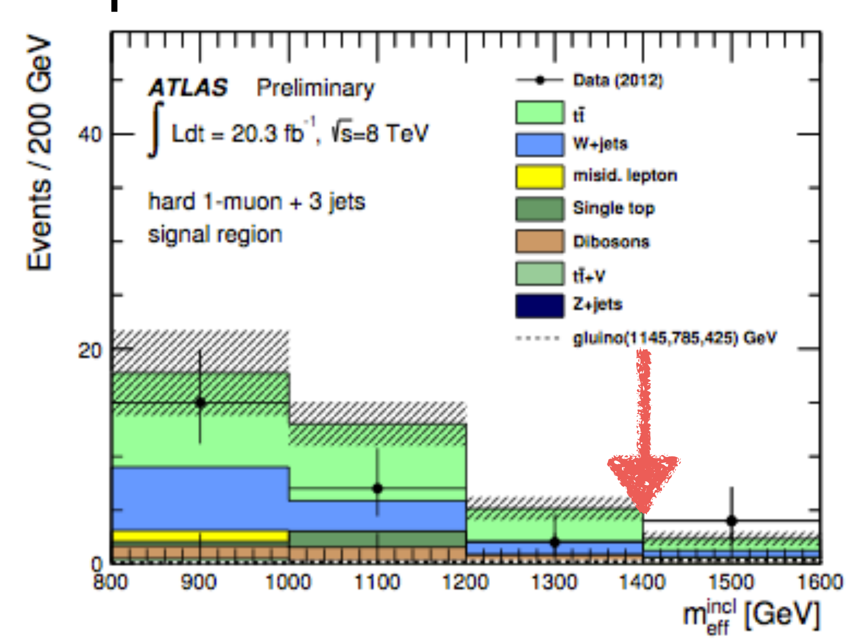
- ***SOFT SINGLE LEPTON** (optimized for compressed spectra)*
    - one electron or muon 10(6)GeV<pT<25 GeV
      3 jets (EtMiss>400 GeV) OR 5 jets (EtMiss>300 GeV)
- ***HARD SINGLE LEPTON***
    - one electron or muon pT>25 GeV
      3 jets (EtMiss>500 GeV) OR 5 jets (EtMiss>300 GeV) OR 6 jets (EtMiss>350 GeV)

soft single lepton

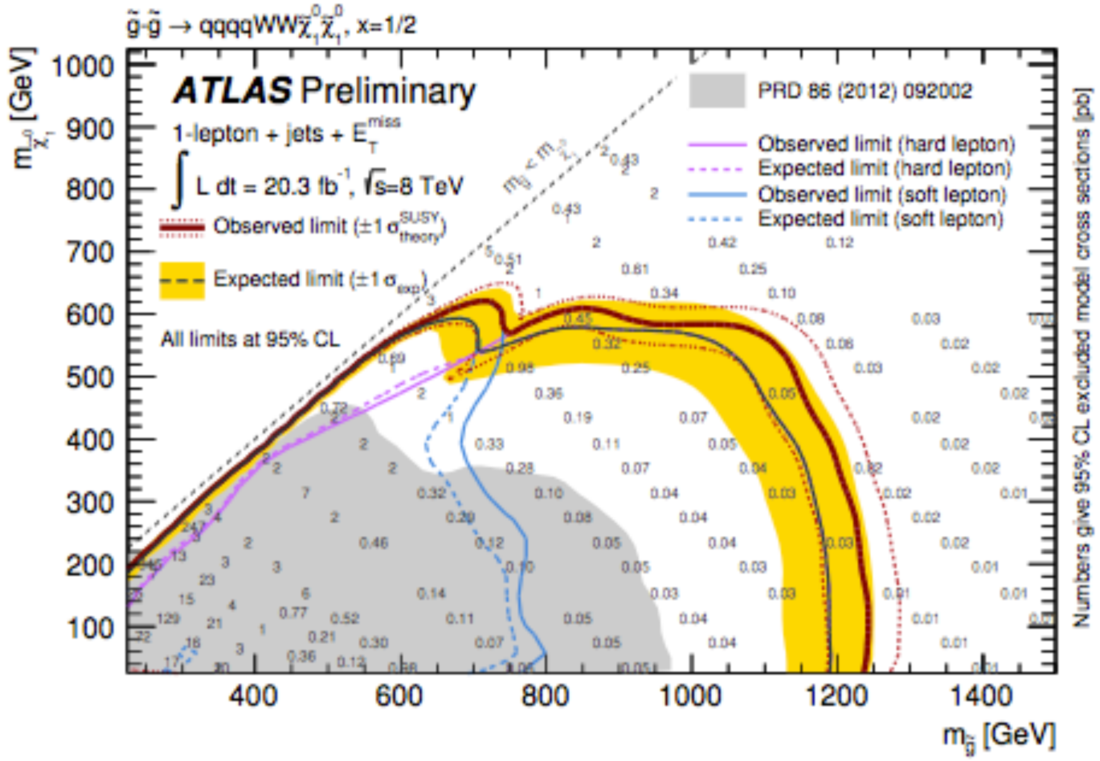


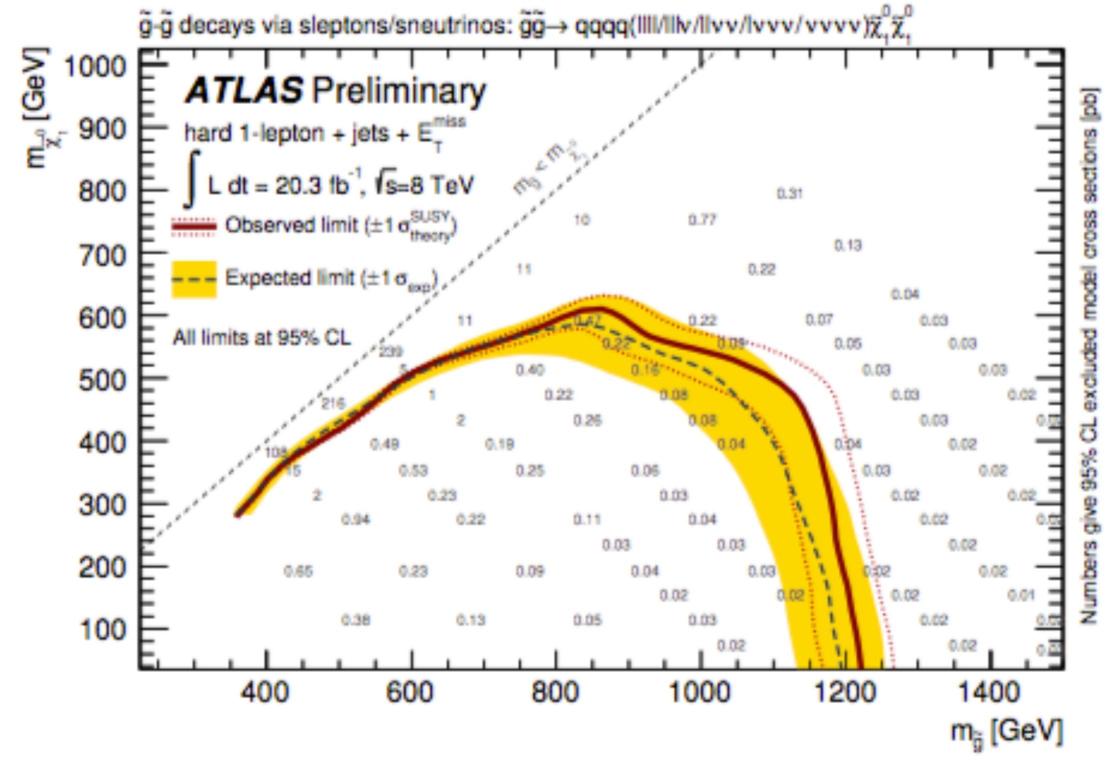
hard single lepton

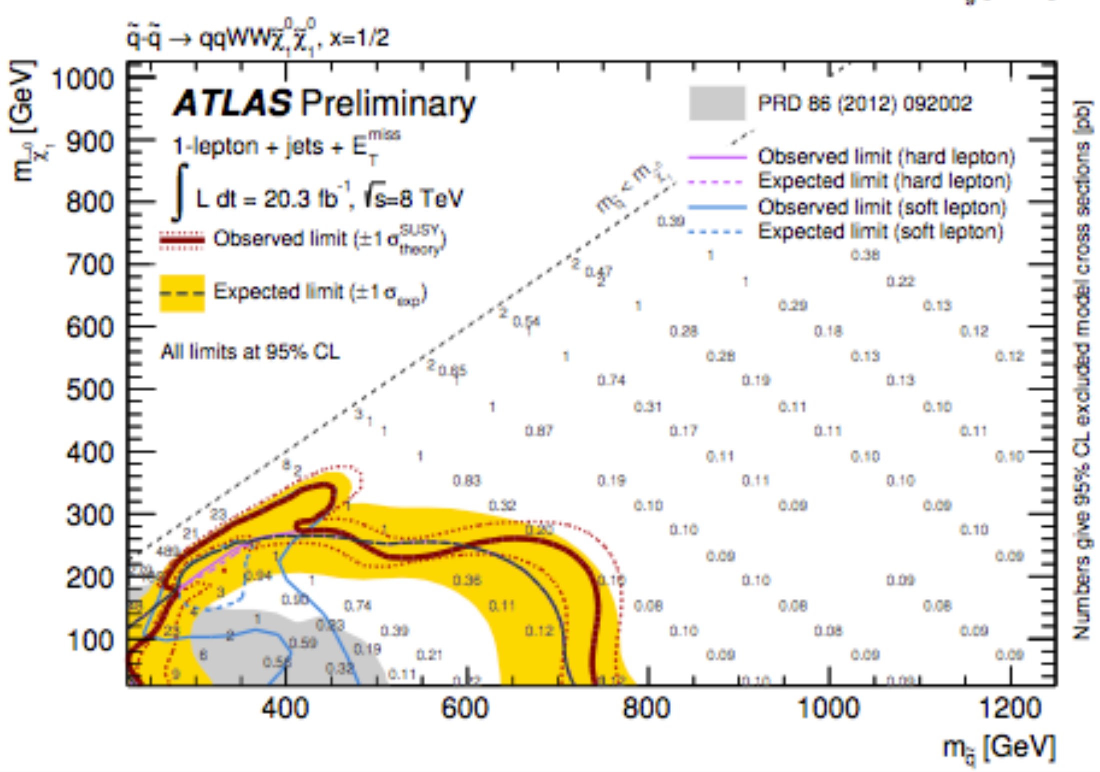


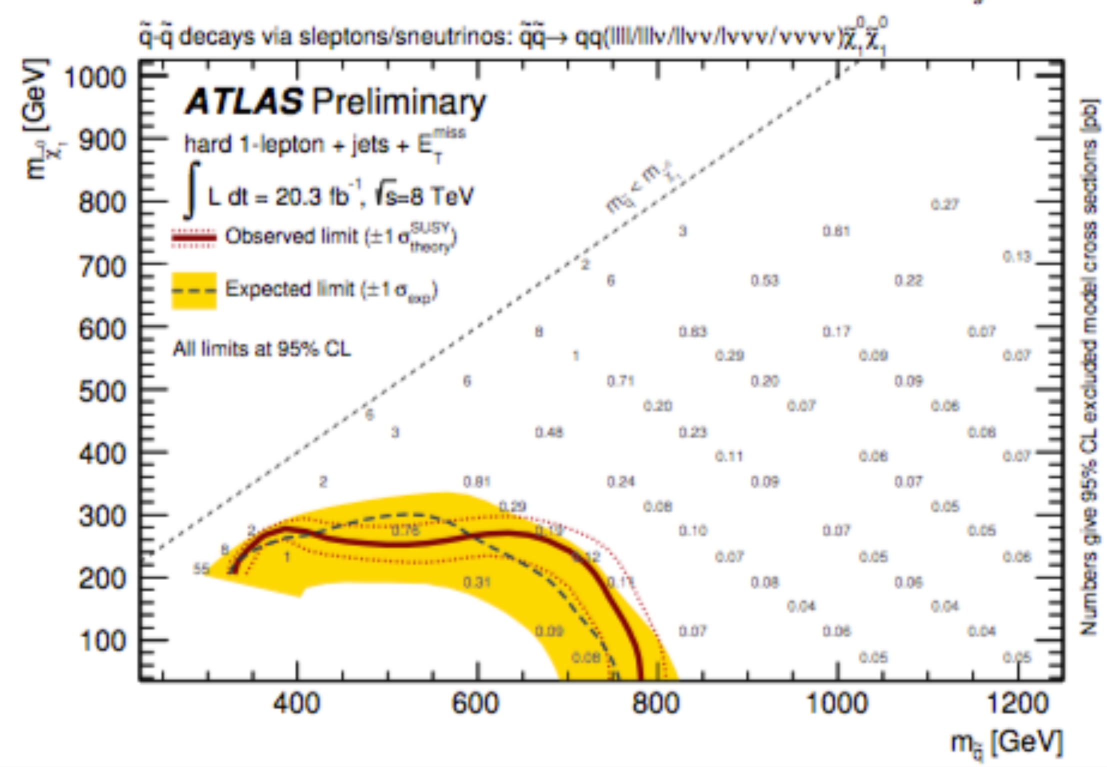


1-2 LEPTON + 3-6 JETS + ETMISS









Gluino mass up to 1.1-1.2 TeV excluded in the one-step and two-step gluino simplified models.
First and second generation squark masses up to 700-750 GeV are also excluded in the one-step and two-step squark simplified models.

2 SAME SIGN LEPTONS OR 3 LEPTONS

Target: g̃g̃ / q̃q̃ / g̃q̃ pairs production leading to same-sign or 3-lepton signatures when decaying to any final state that includes leptons;

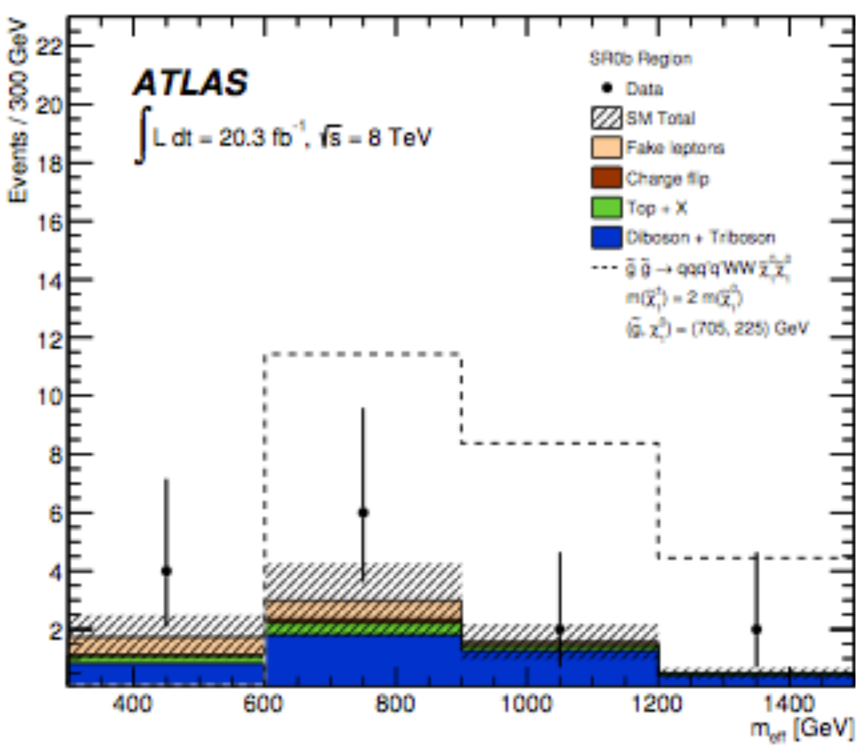
- Scenarios with small mass differences between SUSY particles (compressed scenarios) or in RPV scenarios.

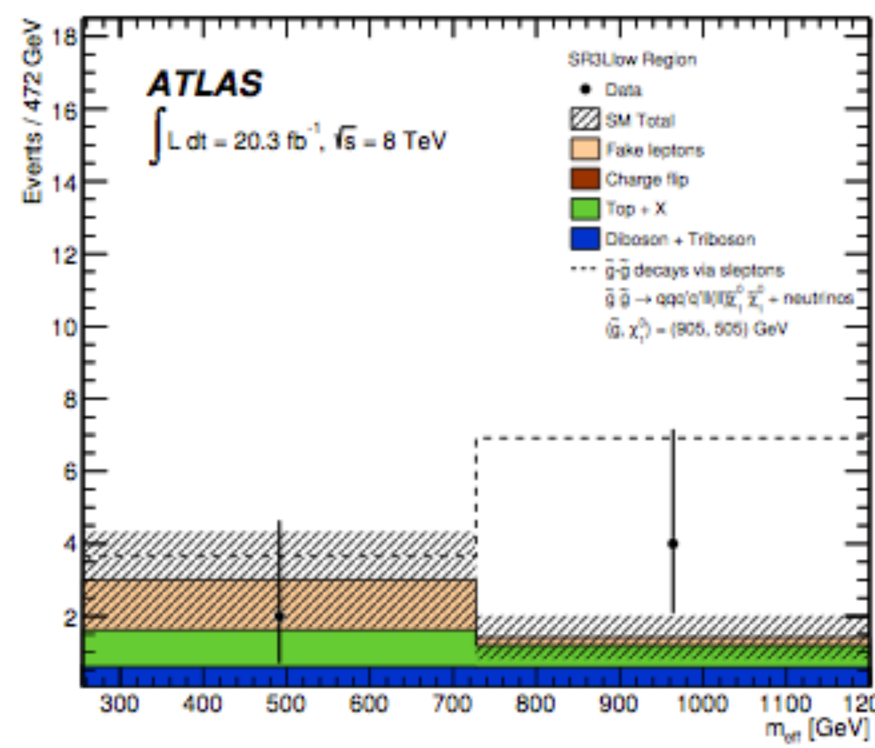
- very low background for same-sign lepton modes

- 3L signal regions increase sensitivity to longer cascades

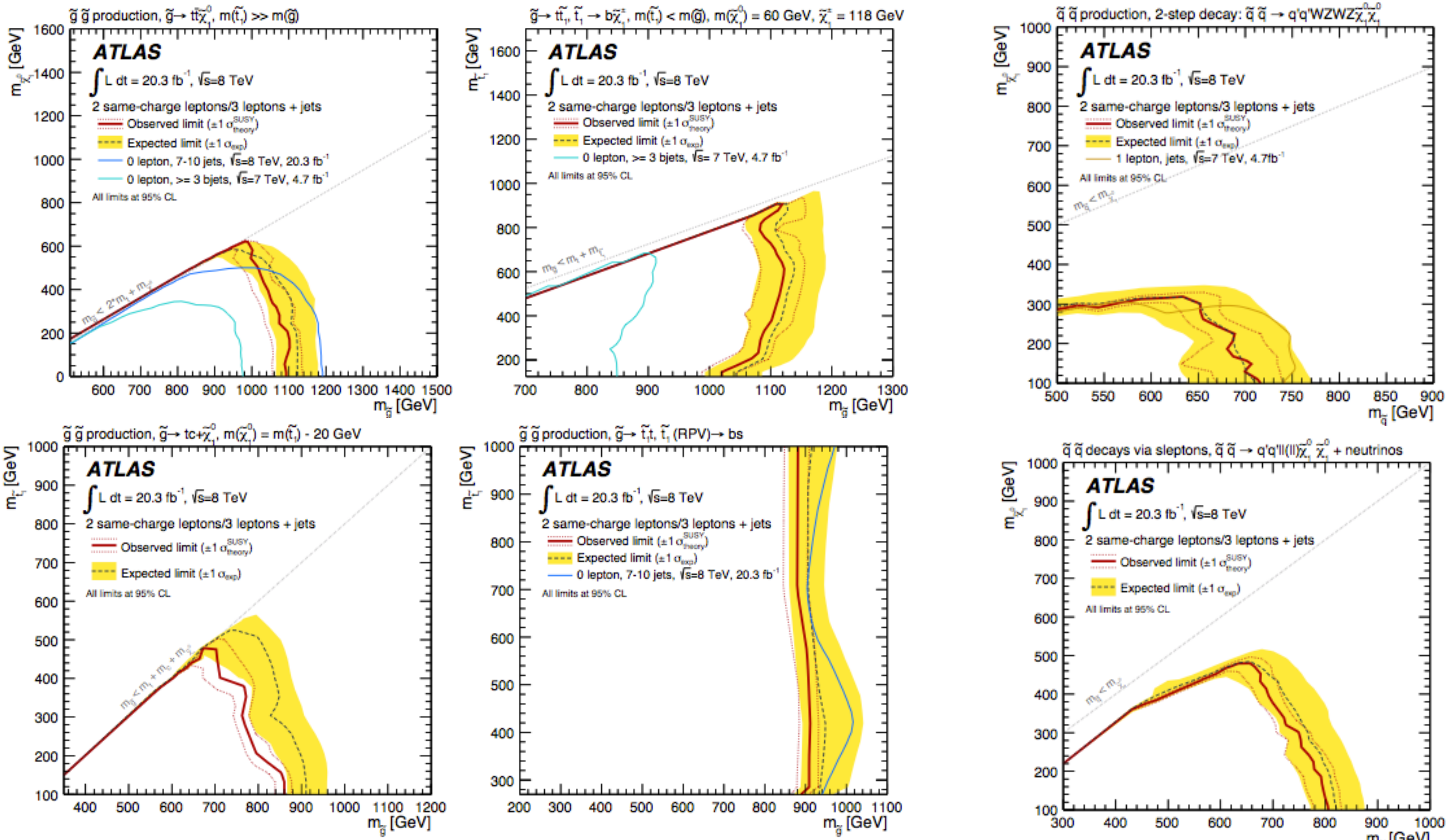
- Data-driven estimation of charge-flip and fake lepton bkg.

SR	Leptons	$N_{b-\text{jets}}$	Other variables	Additional requirement on m_{eff}
SR3b	SS or 3L	≥3	$N_{\text{jets}} \geq 5$	m_{eff}>350 GeV
SR0b	SS	= 0	$N_{\text{jets}} \geq 3$, $E_{\text{T}}^{\text{miss}}$> 150 GeV, m_{T}> 100 GeV	m_{eff}>400 GeV
SR1b	SS	≥1	$N_{\text{jets}} \geq 3$, $E_{\text{T}}^{\text{miss}}$> 150 GeV, m_{T}>100 GeV, SR3b veto	m_{eff}>700 GeV
SR3Llow	3L	-	$N_{\text{jets}} \geq 4$, $50 < E_{\text{T}}^{\text{miss}} < 150$ GeV, Z boson veto, SR3b veto	m_{eff}>400 GeV
SR3Lhigh	3L	-	$N_{\text{jets}} \geq 4$, $E_{\text{T}}^{\text{miss}}$> 150 GeV, SR3b veto	m_{eff}>400 GeV





2 SAME SIGN LEPTONS / 3 LEPTONS

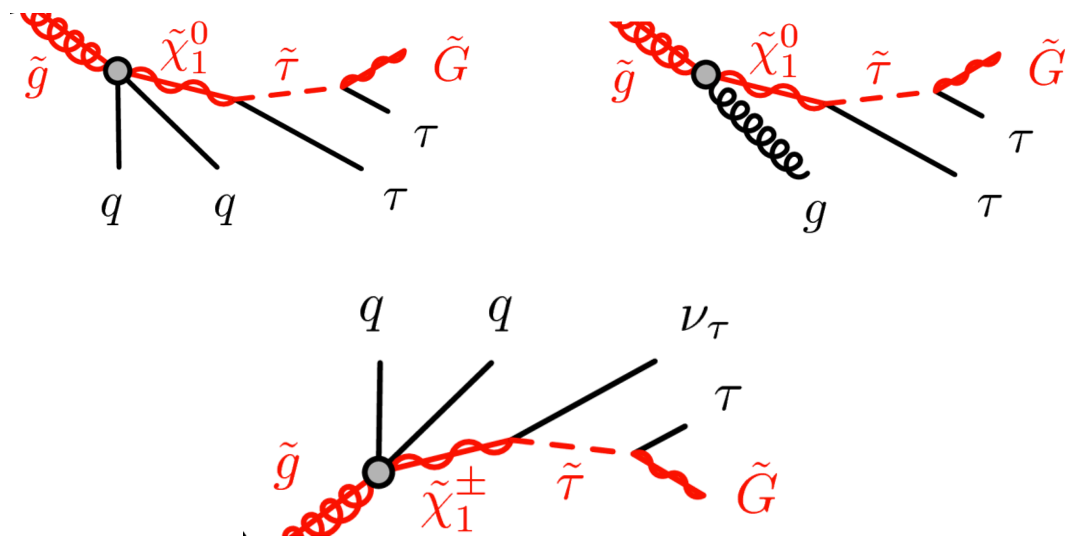


Gluino-mediated top squark scenarios, favoured by naturalness arguments, are excluded for m(gl) < [600–1000] GeV

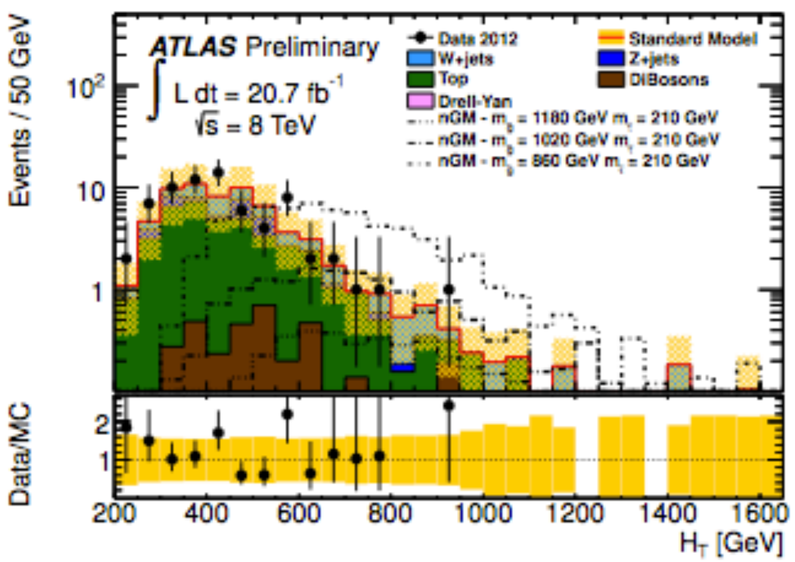
TAUS + JETS + ETMISS

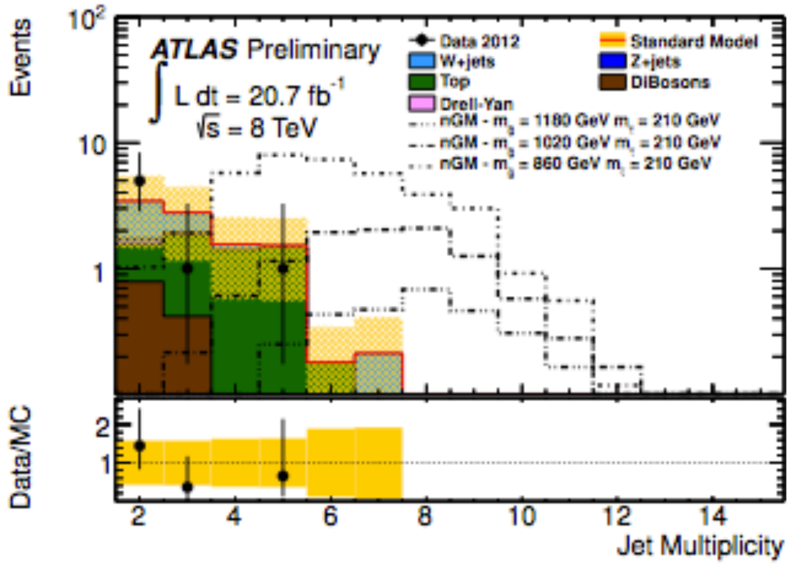
Target: GMSB, nGM (tuned version of GGM to avoid fine tuning in Higgs sector) models

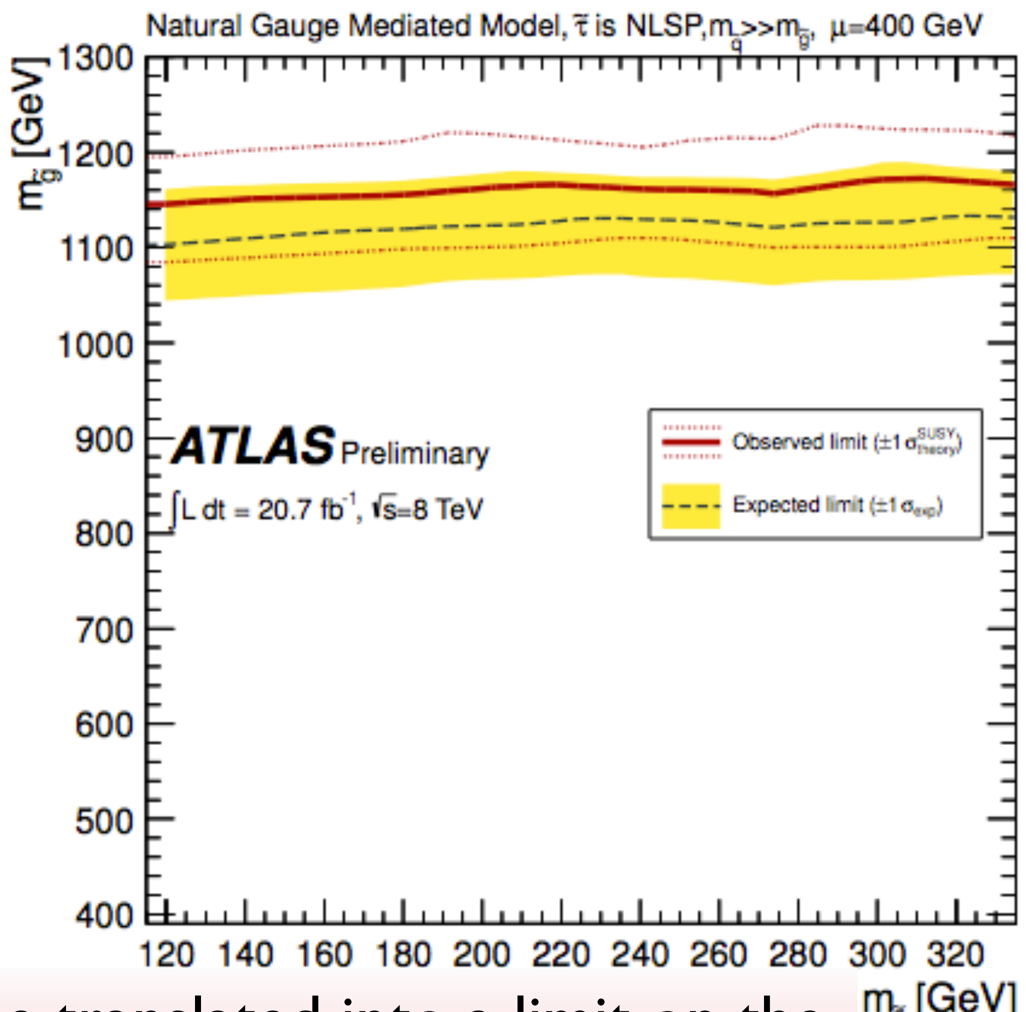
- Signal regions with either 1 tau or at least 2 tau leptons
- Fake tau contribution estimated with data-driven method (ABCD)



	1τ SR	2τ GMSB SR	2τ nGM SR
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 $N_{jet} \geq 4$







The result of the 2τ analysis in an optimised signal region can be translated into a limit on the gluino mass of 1140 GeV, independent of the $\tilde{\tau}$ mass, provided the $\tilde{\tau}$ is the NLSP

DIPHOTON + ETMISS

	SP1	SP2
$\Delta\phi_{\gamma}^{\min} >$	0.5	0.0
$\Delta\phi_{\text{jet}}^{\min} >$	0.5	0.5
$M_{\text{eff}} > (H_T >)$ (GeV)	1500	1800
$E_T^{\text{miss}} >$ (GeV)	250	150

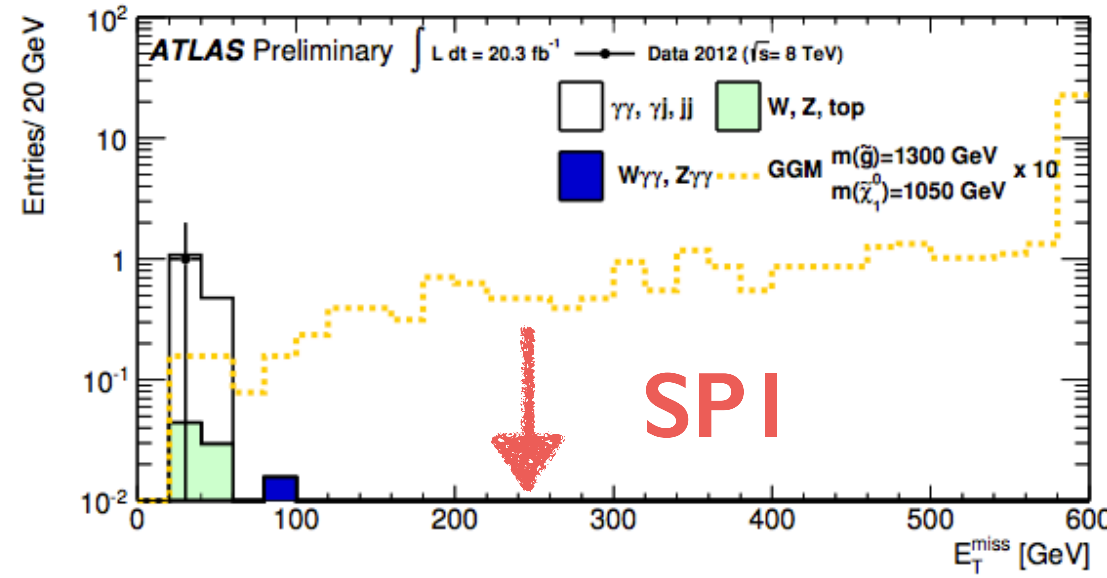
Target: GGM models ($\tilde{\chi}^0_1$ decay to photon and gravitino)

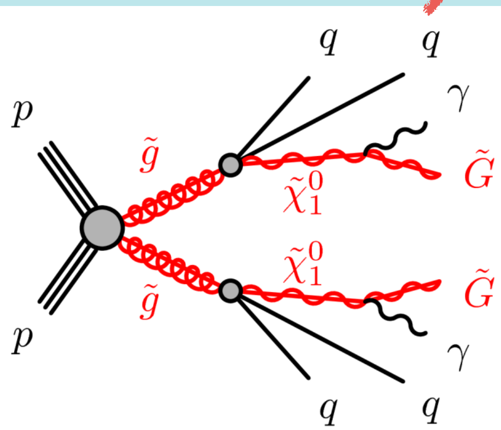
- All backgrounds except $Z \rightarrow \nu\nu + \gamma\gamma$ estimated from data.

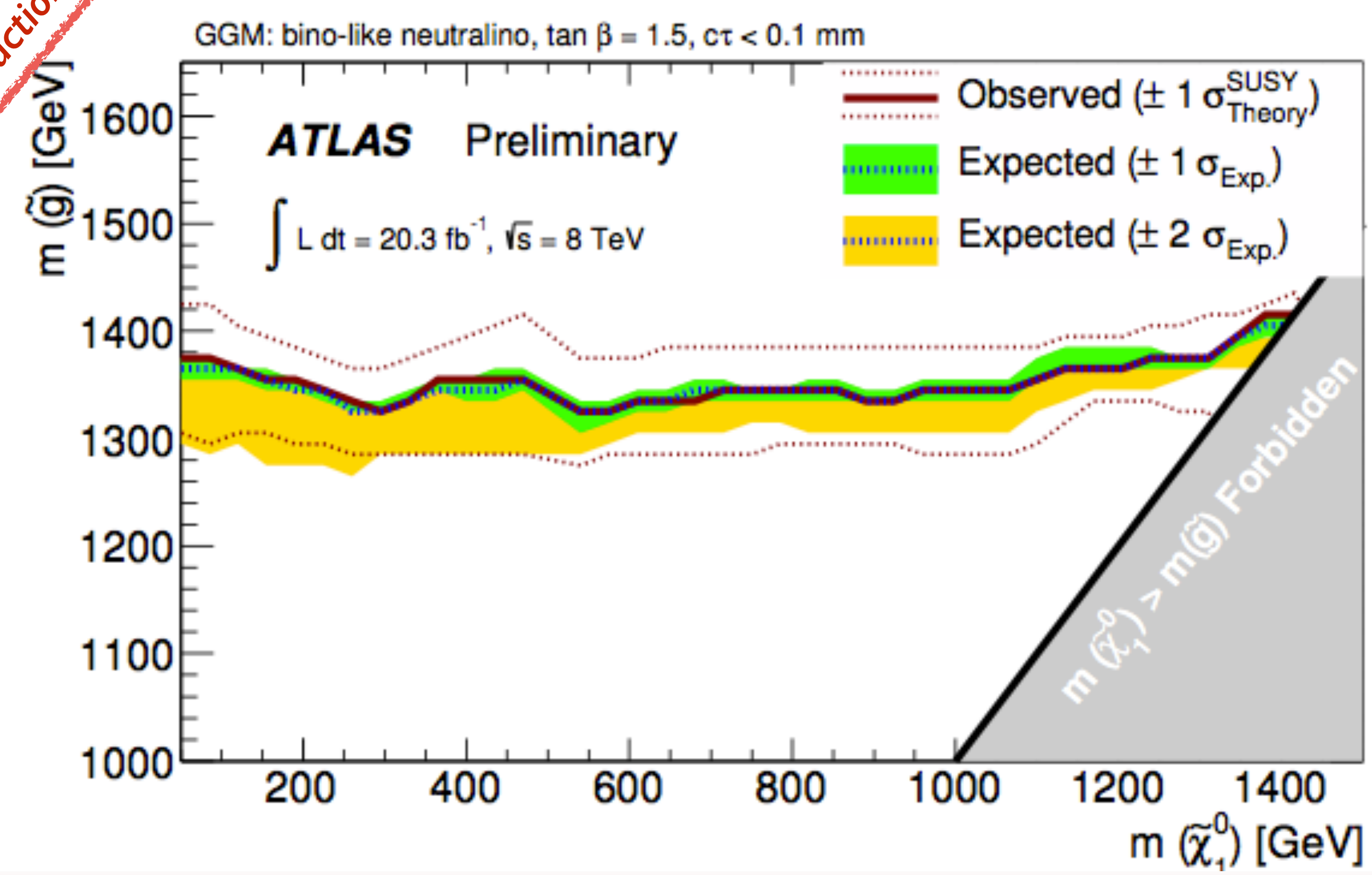
- Bkgs largely jets/electrons faking photons

- Here focus on strong production signal regions

strong production signal regions







Under the GGM hypothesis, lower limits on the gluino masses of 1280 GeV are set for bino masses above 50 GeV.

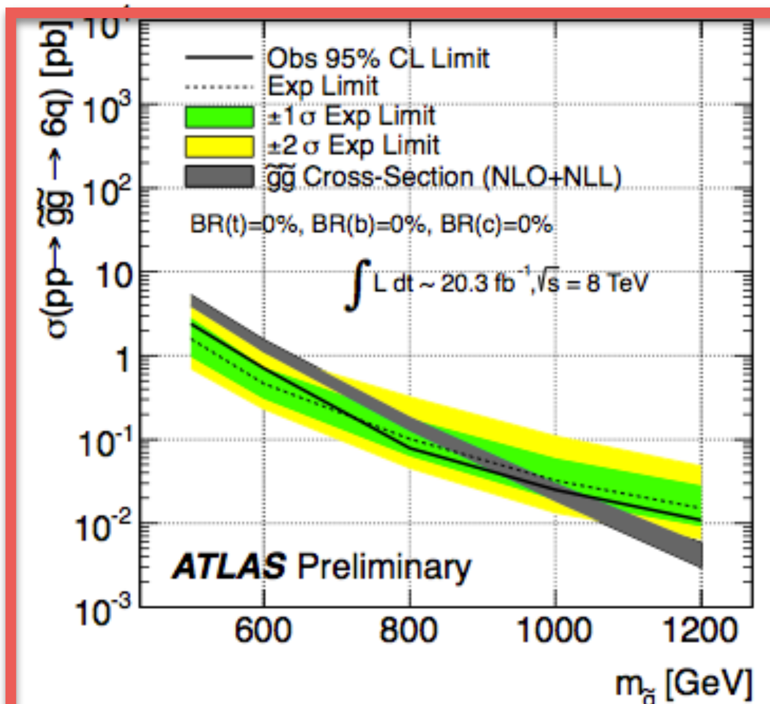
MULTIJETS (RPV)

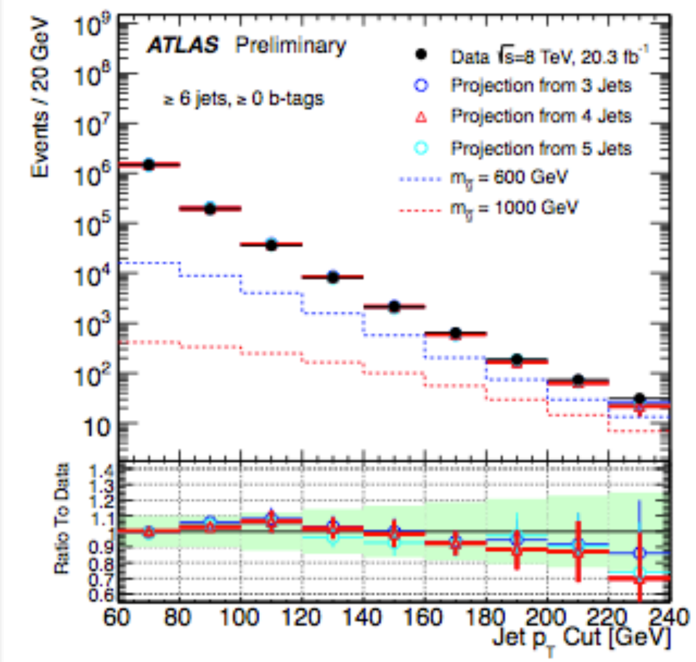
Target: Gluino production through all possible *R*-parity violating branching fractions of gluino decays to various quark flavours (6-quark final states)

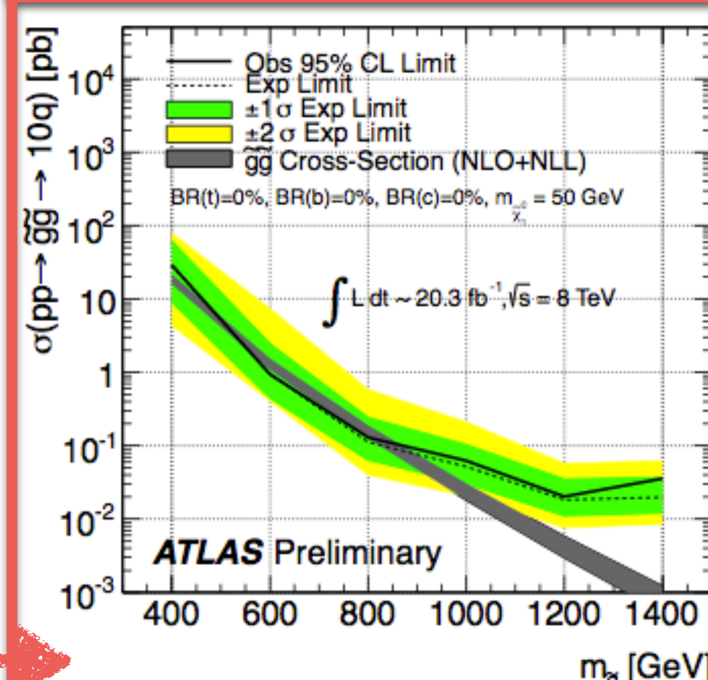
- Limits are also set for decay modes through an intermediary neutralino, which leads to 10-quark final states

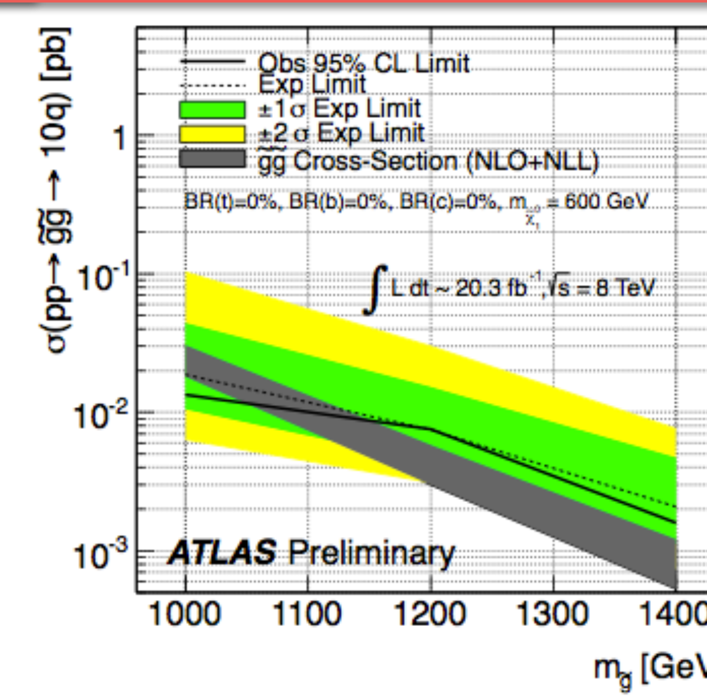
- A single systematic uncertainty on the background yield is determined by comparing the background prediction to the data in a wide variety of control regions

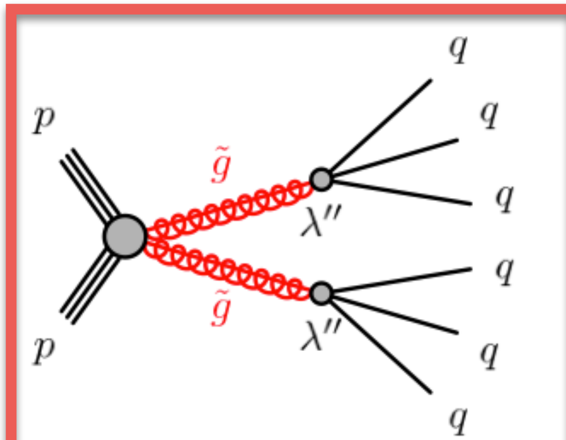
Example: extrapolation of data events from the low-jet multiplicity (3J, 4J, 5J) control regions to >=6 jets signal regions



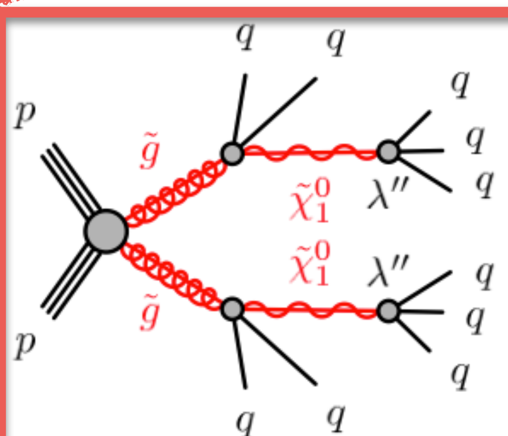








6-quark model



10-quark model

SUMMARY

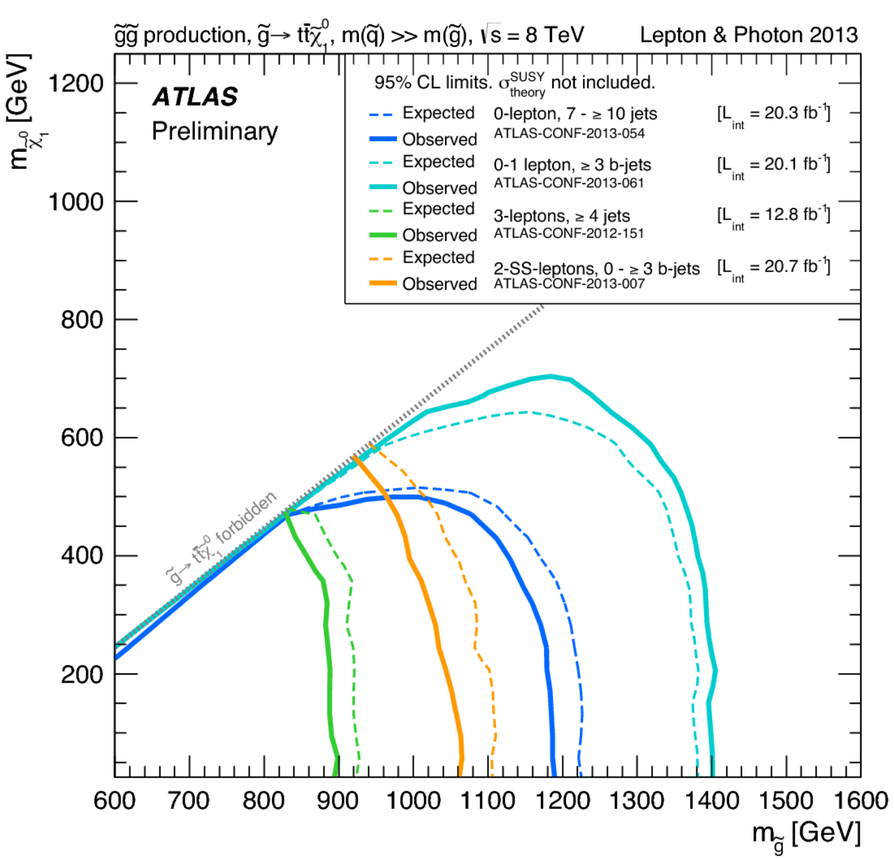
ATLAS SUSY Searches* - 95% CL Lower Limits

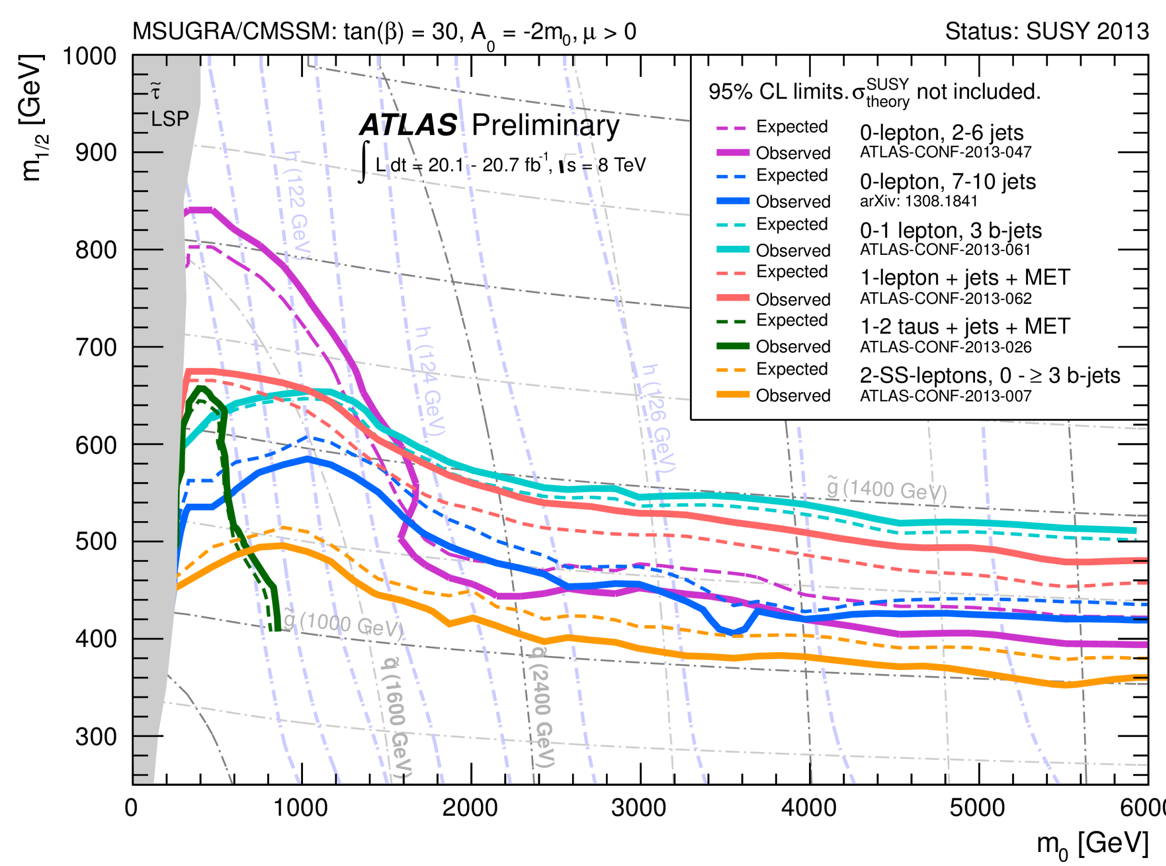
Status: Moriond 2014

ATLAS Preliminary

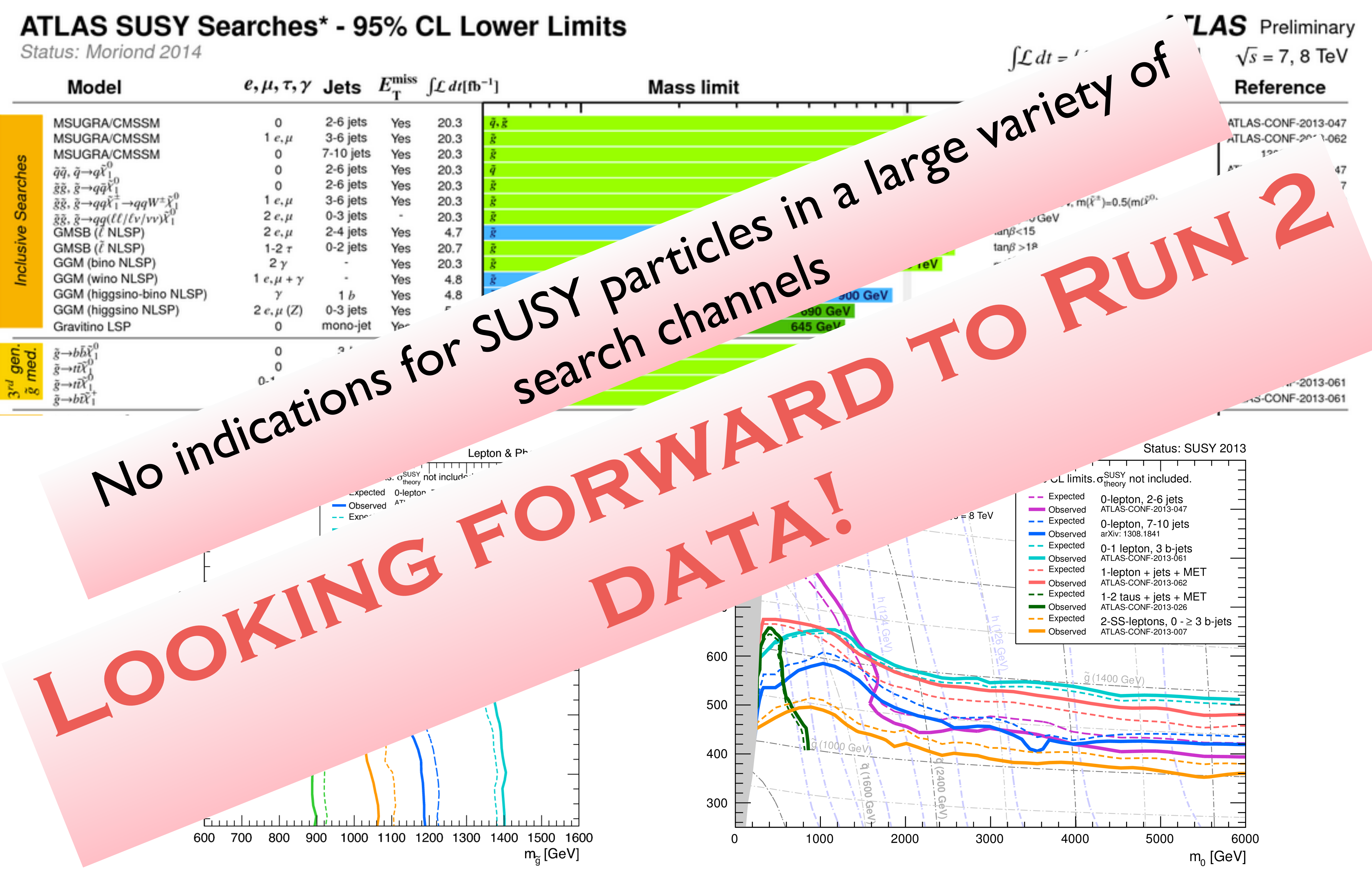
$\int \mathcal{L}\, dt = (4.6 - 22.9)$ fb^{-1} $\sqrt{s} = 7, 8$ TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt [fb^{-1}]$	Mass limit		Reference
Inclusive Searches	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
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 740 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	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
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	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	20.3	$\tilde{g}$ 1.28 TeV	$m(\tilde{\chi}_1^0)$>50 GeV	ATLAS-CONF-2014-001
	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
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$ 1.2 TeV	$m(\tilde{\chi}_1^0)$<600 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	$m(\tilde{\chi}_1^0)$ <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$ 1.34 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	ATLAS-CONF-2013-061





SUMMARY



No indications for SUSY particles in a large variety of search channels

LOOKING FORWARD TO RUN 2 DATA!