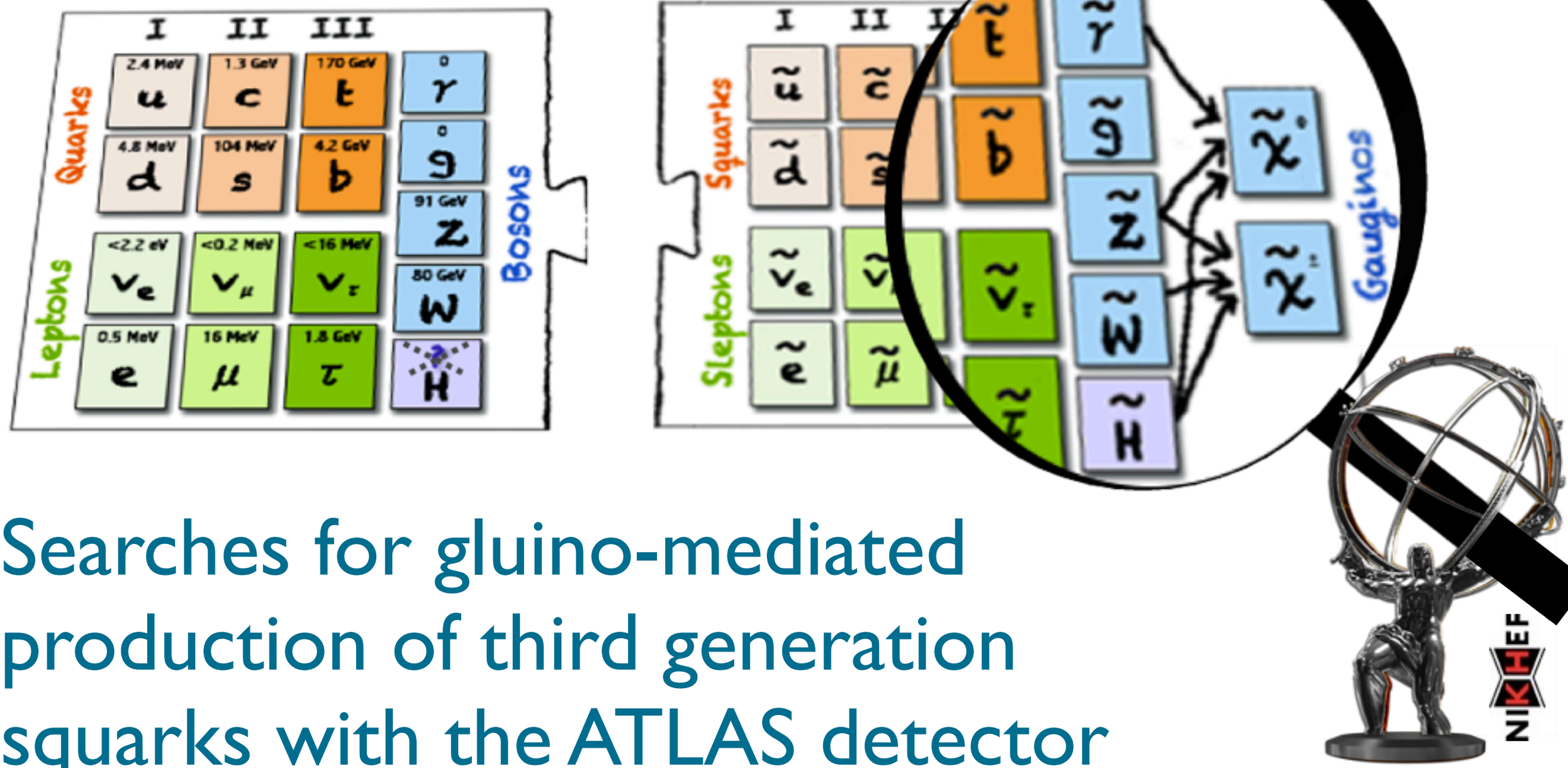


Searches for gluino-mediated production of third generation squarks with the ATLAS detector

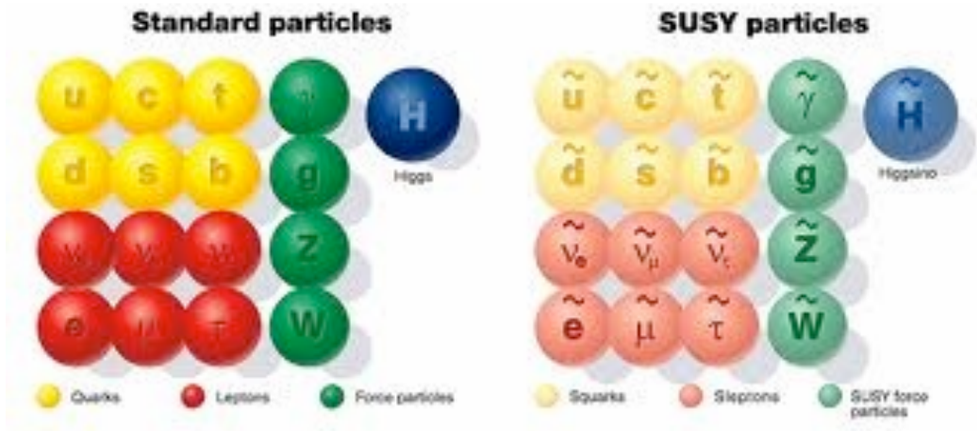
Carolina Deluca (Nikhef)
on behalf of the ATLAS Collaboration

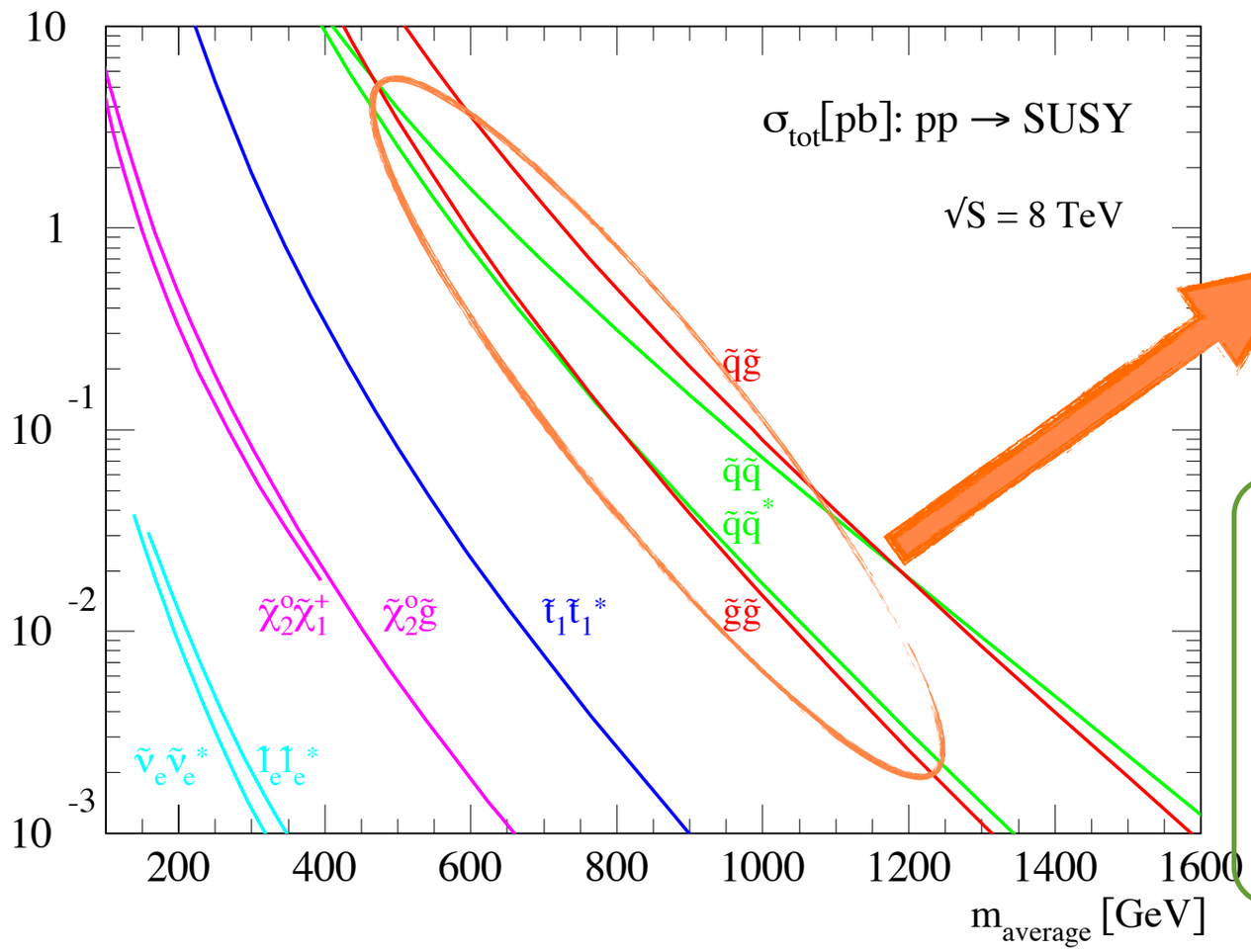
XXI. International Workshop on Deep-Inelastic Scattering and Related Subjects
Marseille, 22-26 April 2013

Introduction & motivation

* Most elegant *TeV-scale* theory to solve Hierarchy problem, natural mechanism for EW symmetry breaking, neutralino as LSP is an ideal dark matter candidate

* *Light 3rd generation within current LHC reach* favored by *naturalness* arguments

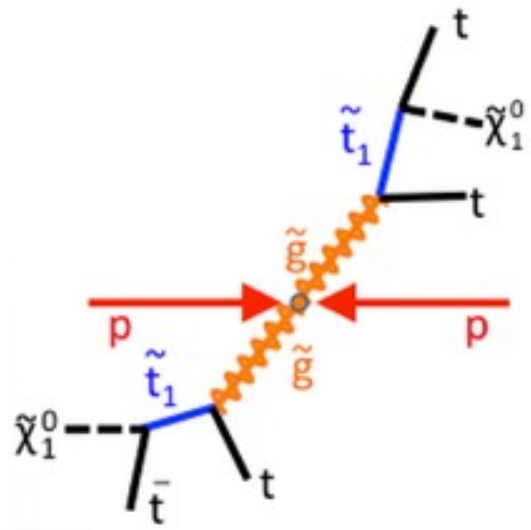




strong production

* Large cross-sections

* Expect final states with many jets, bjets and leptons



Most recent ATLAS results

* Same-sign leptons+jets, 21 fb^{-1}, ATLAS-CONF-2013-007

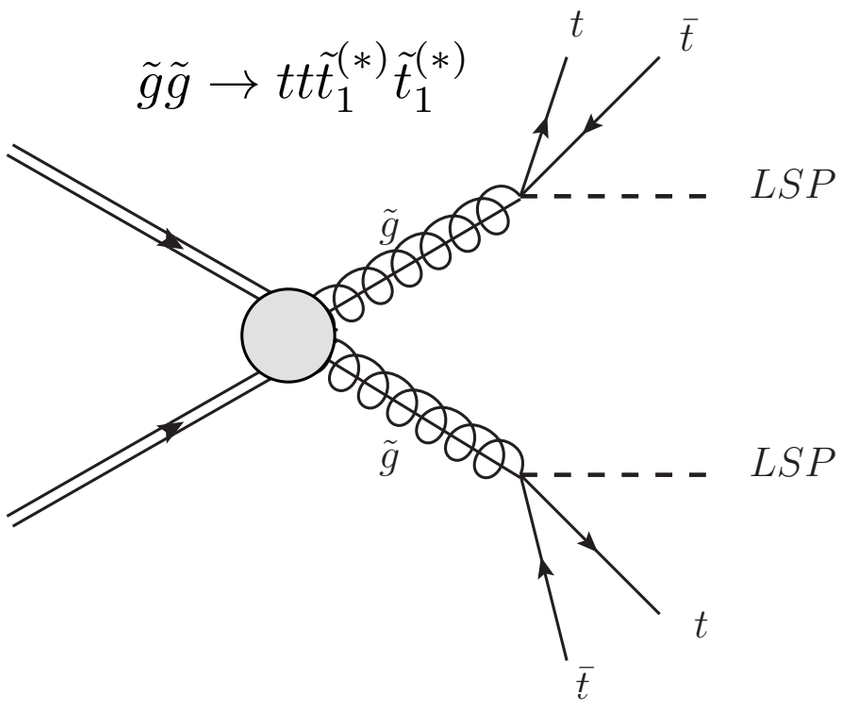
* 0L+3 b-jets, 13 fb^{-1}, ATLAS-CONF-2012-145

* 3L+jets+MET, 13 fb-1, ATLAS-CONF-2012-151

Targeted 3rd generation models

Simplified models - BR 100%, interpreted as boundaries on masses of involved particles

SS+jets aim only at final states with tops
0L+3bjets analysis is sensitive to all scenarios (but no interpretations for all ..... yet!)



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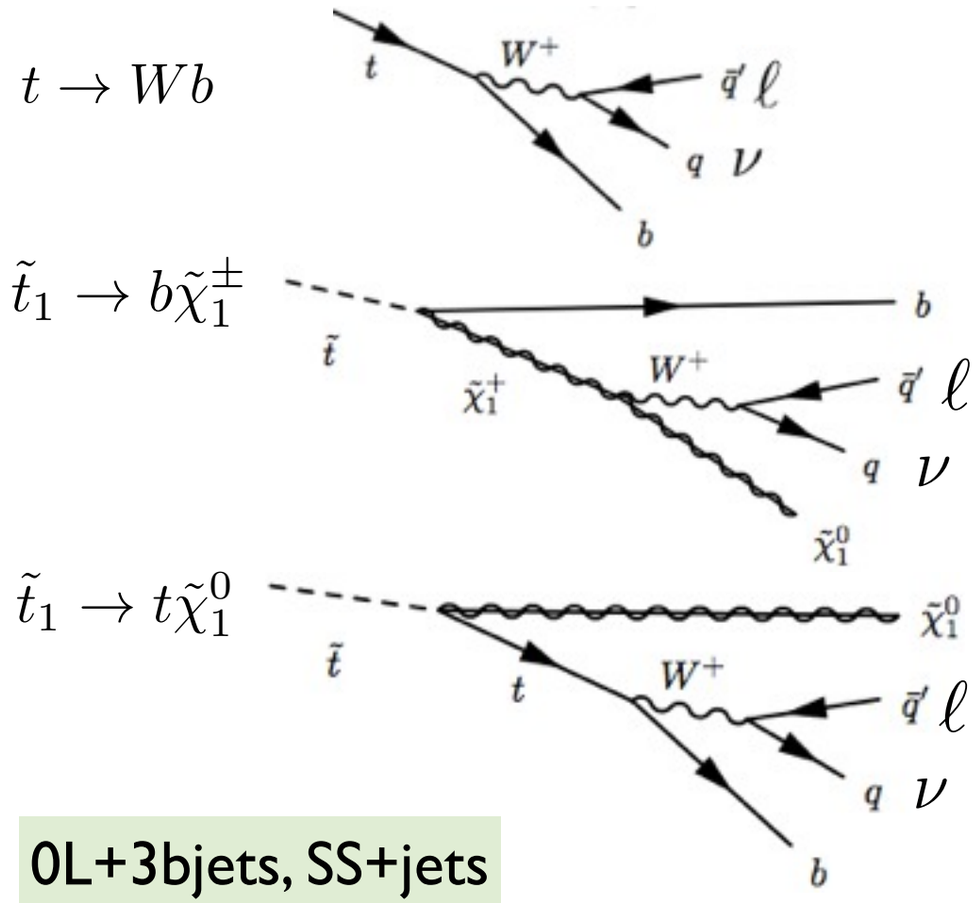


SS + jets :
2 leptons + 4 b-jets + 8 jets + Etmiss

0L + 3 b-jets :
4 b-jets + 12 jets + Etmiss

$\tilde{g}\tilde{g} \to tt\tilde{t}_1^*\tilde{t}_1^*\ (\tilde{t}_1\ off\ shell\ and\ \tilde{t}_1 \to t\tilde{\chi}_1^0)$ 0L+3bjets, SS+jets

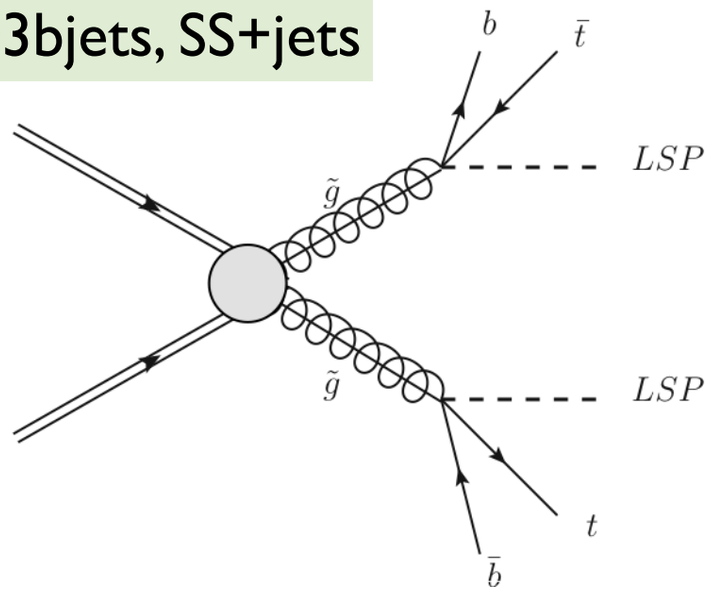
$\tilde{g}\tilde{g} \to tt\tilde{t}_1\tilde{t}_1\ (\tilde{t}_1\ on\ shell, \tilde{t}_1 \to t\tilde{\chi}_1^0\ and\ m_{\tilde{\chi}_1^0} = 60\ GeV)$ SS+jets

$\tilde{g}\tilde{g} \to tt\tilde{t}_1\tilde{t}_1\ (\tilde{t}_1\ on\ shell, \tilde{t}_1 \to b\tilde{\chi}_1^{\pm}\ , m_{\tilde{\chi}_1^0} = 60\ GeV\ and\ m_{\tilde{\chi}_1^{\pm}} = 120\ GeV)$ SS+jets

Targeted 3rd generation models

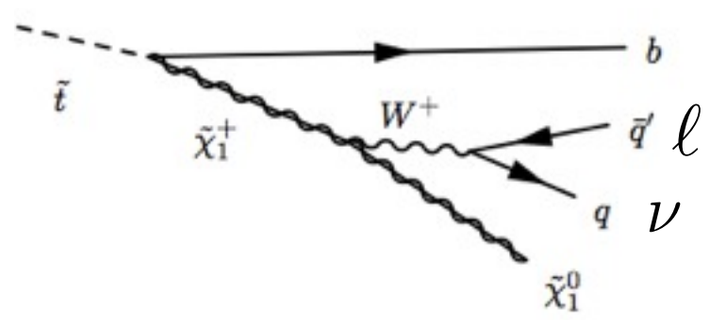
Simplified models - BR 100%, interpreted as boundaries on masses of involved particles

0L+3bjets, SS+jets



$\tilde{g}\tilde{g} \rightarrow tb\tilde{t}_1\tilde{b}_1$
$(\tilde{t}_1, \tilde{b}_1\ off\ shell, degenerate\ m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_1^\pm})$

$\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$



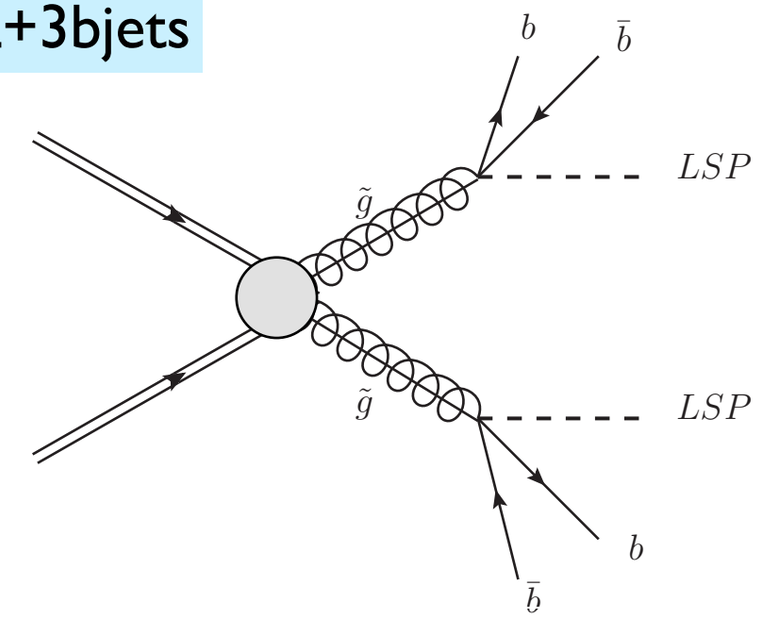
+

$\tilde{b}_1 \rightarrow t\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \rightarrow W^*\tilde{\chi}_1^0, t \rightarrow Wb$

SS + jets :
2 leptons + 4 b-jets + jets + Etmiss

0L + 3 b-jets :
4 b-jets + jets + Etmiss

0L+3bjets



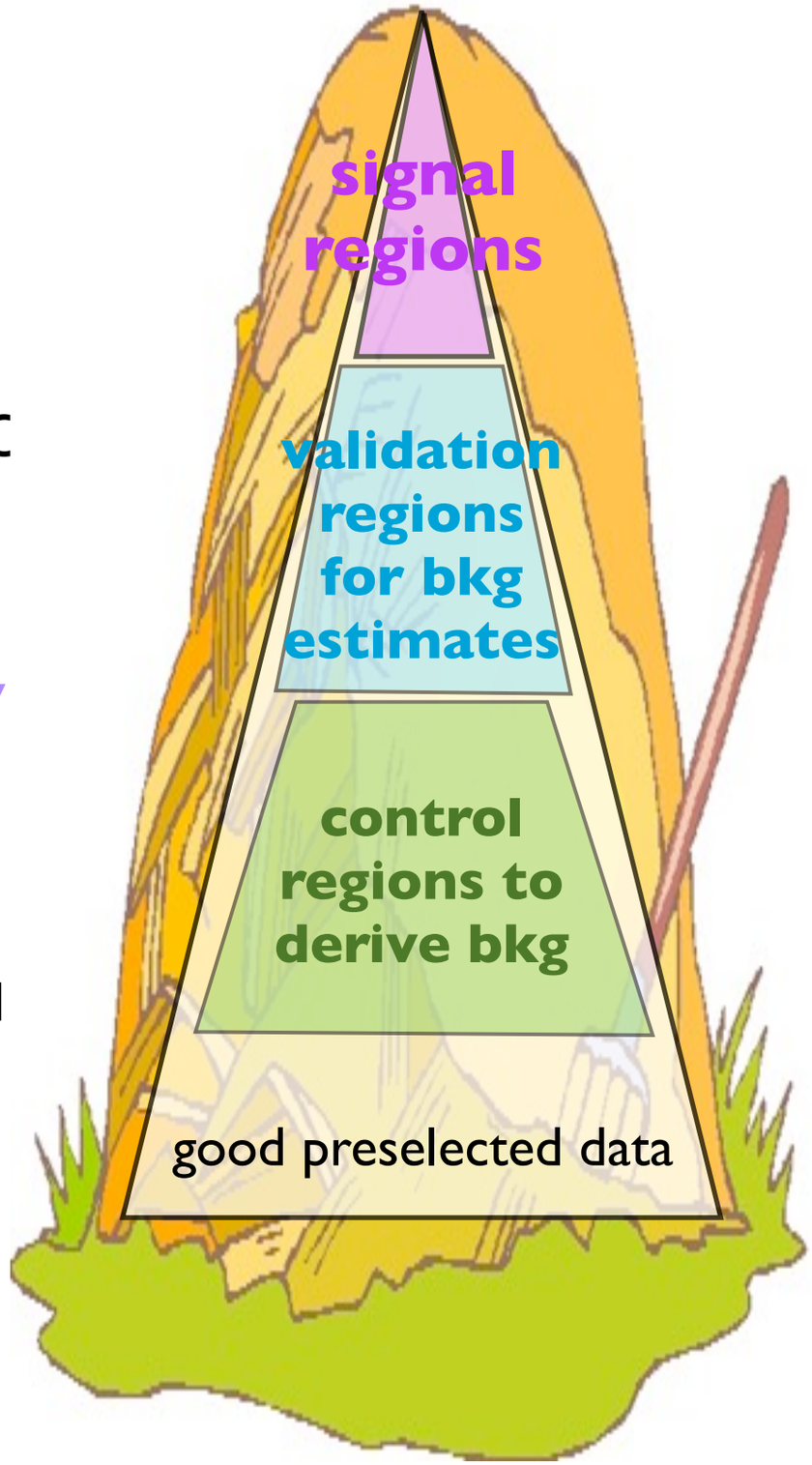
+ $\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$

$\tilde{g}\tilde{g} \rightarrow bb\tilde{b}_1^*\tilde{b}_1^*\ (\tilde{b}_1\ off\ shell)$

0L + 3 b-jets : 4 b-jets + Etmiss

General analysis approach

* All analyses performed in *trigger plateau* and with *good data quality*
* MC samples used to optimize event selections, data is kept blinded in the signal regions until analysis is mature
* SUSY signals acceptance and efficiency simulated with MC
* Backgrounds
  - *Reducible:* due to fake or mis-identified objects, usually fully data-driven approach
  - *Irreducible:* usually estimated with semi data-driven 'transfer-factor (TF)' approach (shape from MC and normalization in signal regions using background dedicated control regions), if minor, purely MC
    - TFs ⇒ systematic uncertainties (partially) cancel-out
* '*Open the box*' - if excess
  if not, then *interpret results for different models*

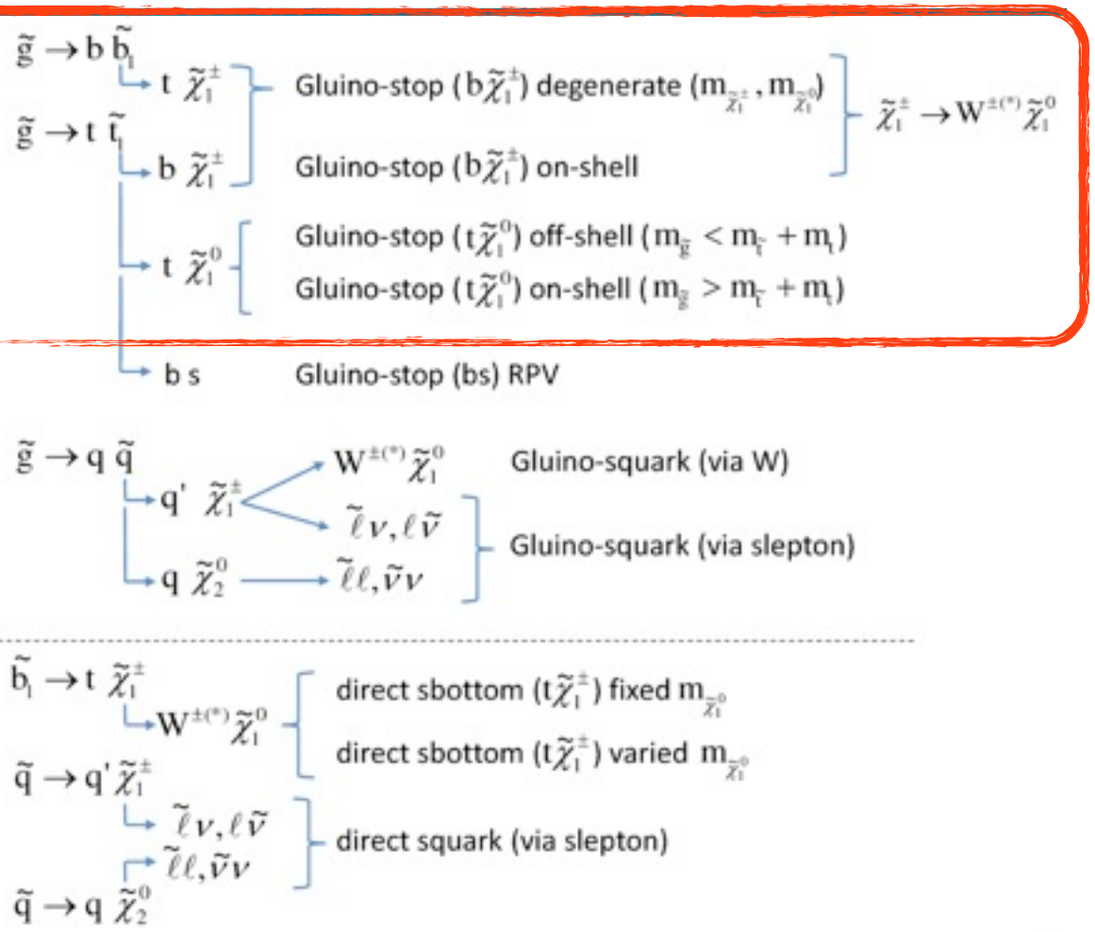


SS + jets : event selections

21 fb^{-1}

ATLAS-CONF-2013-007

* ***Basic event selection:***
  2 same-sign (SS) leptons + jets + MET
  - **SS ⇒ small backgrounds**
  - **Large lepton multiplicity expected from top quark decays** in 3rd generation squarks production



* Dedicated signal regions for exclusion and discovery cases, and aiming at different models and SUSY particles mass hierarchy

b-jets, large MET and Meff for large mass splitting regions

small MET, m_T for compressed regions

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

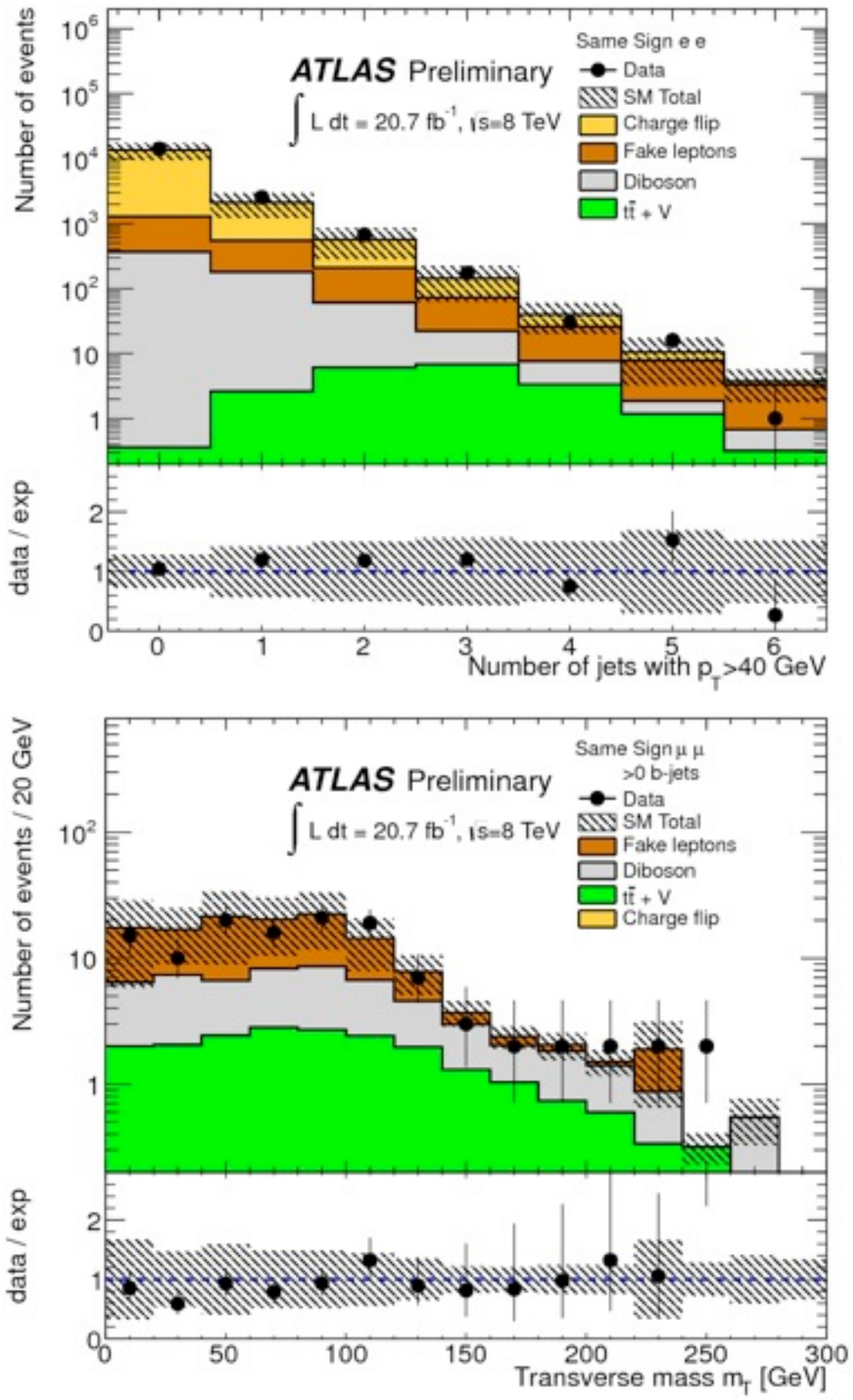
$$M_{eff} = p_T^{lep1} + p_T^{lep2} + E_T^{miss} + \sum p_T^{jets} \qquad m_T = \sqrt{2E_T^{miss} p_T^{lep}(1 - cos\Delta\phi(lep, E_T^{miss}))}$$

SS + jets : backgrounds

21 fb^{-1}

ATLAS-CONF-2013-007

* 3 types of background:
  - Irreducible (tt+Z/W, ZZ+jets, WZ+jets): estimated with MC
  - Charge mis-measurement (e-channel - breemstrahlung + asymmetric conversion, dileptonic tt): Data-driven with OS → SS probability in data from Z events
  - Fakes (tt) : Data-driven with a Matrix Method
* Backgrounds checked in validation regions for all same-sign channels (ee + eμ + μμ) separately
* Good agreement found
* Systematic uncertainties:
  - jet energy scales and resolution, lepton energy scales and resolution, b-tag, pileup and theoretical uncertainties on MC backgrounds



SS + jets : results

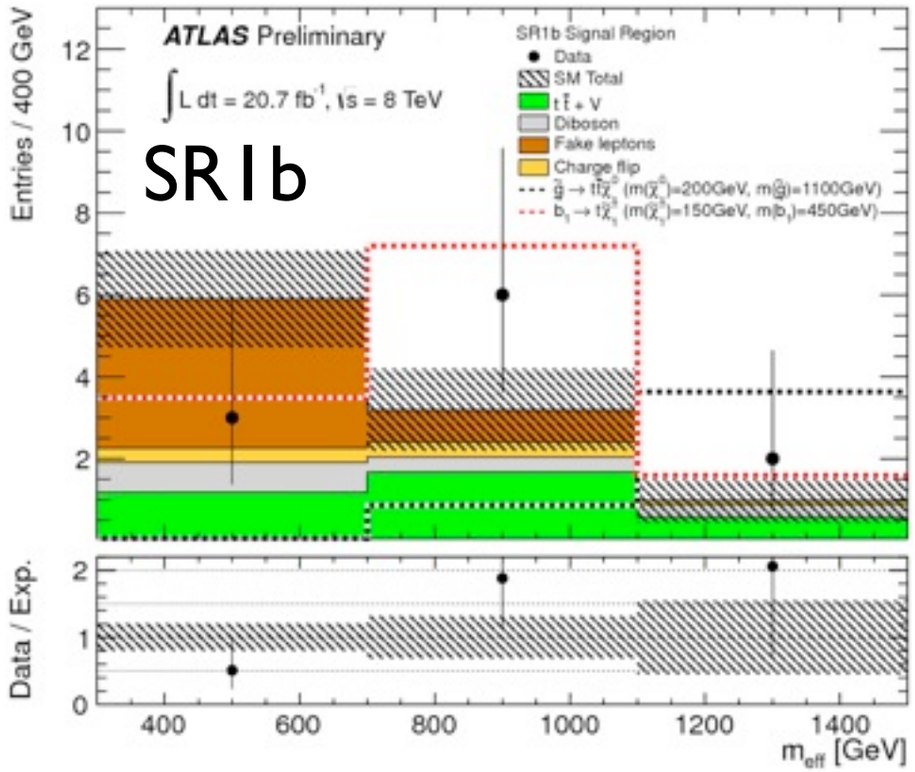
21 fb^{-1}

ATLAS-CONF-2013-007

* No excess observed in the signal regions ⇒ Exclusion limits

A) Discovery case	SR0b	SR1b	SR3b
Observed events	5	8	4
Expected background events	7.5 ± 3.3	3.7 ± 1.6	3.1 ± 1.6
Expected $t\bar{t} + V$ events	0.5 ± 0.4	2.2 ± 1.0	1.7 ± 0.8
Expected diboson events	3.4 ± 1.0	0.7 ± 0.4	0.1 ± 0.1
Expected fake lepton events	3.4 ± 3.1	$0.3^{+1.1}_{-0.3}$	$0.9^{+1.4}_{-0.9}$
Expected charge mis-measurement events	0.1 ± 0.1	0.5 ± 0.2	0.4 ± 0.1
p_0	0.50	0.11	0.36

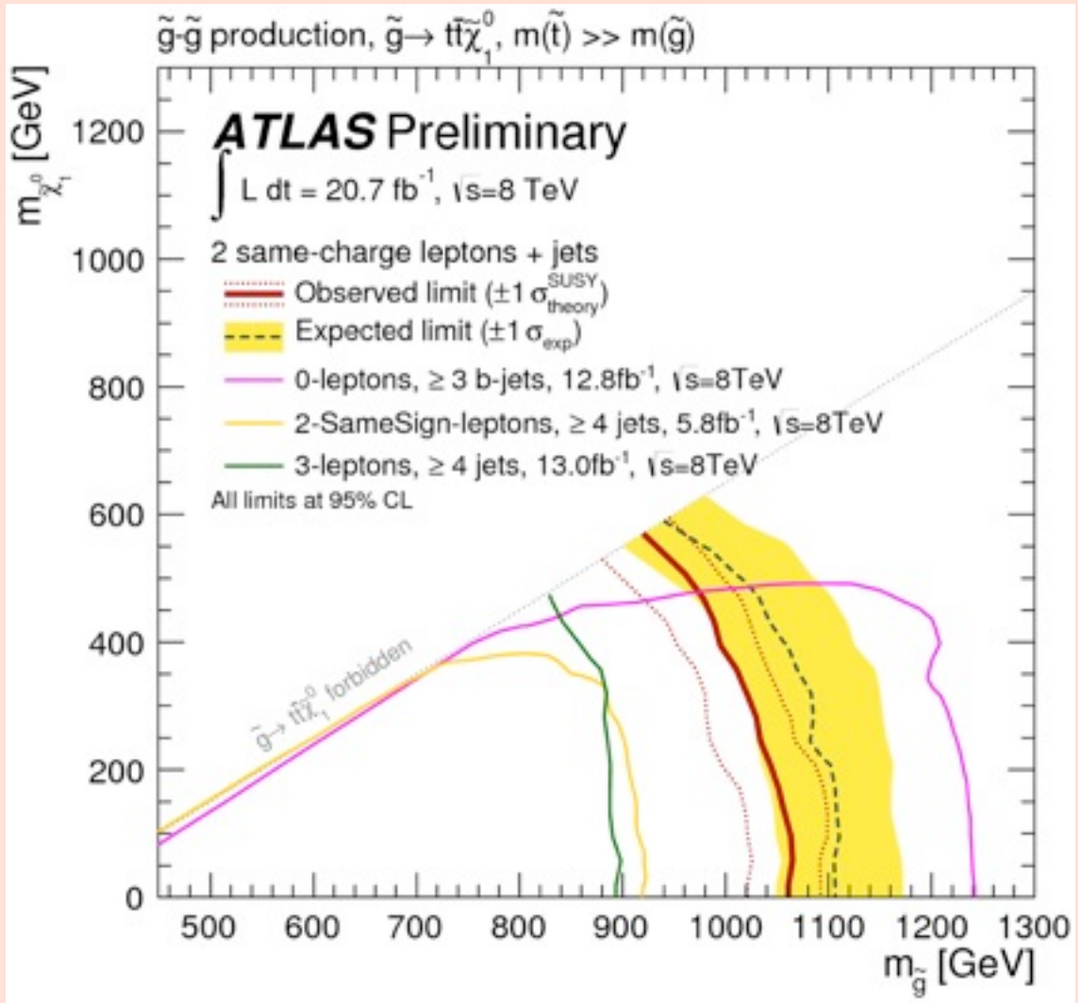
B) Exclusion case	SR0b	SR1b	SR3b
Observed events	5	11	1
Expected background events	7.5 ± 3.2	10.1 ± 3.9	1.8 ± 1.3
Expected $t\bar{t} + V$ events	0.5 ± 0.4	3.4 ± 1.5	0.6 ± 0.4
Expected diboson events	3.4 ± 1.1	1.4 ± 0.7	< 0.1
Expected fake lepton events	3.4 ± 2.9	4.4 ± 3.1	1.0 ± 1.1
Expected charge mis-measurement events	0.2 ± 0.1	0.8 ± 0.3	0.1 ± 0.1
p_0	0.5	0.39	0.5



SS + jets : interpretations

21 fb^{-1}

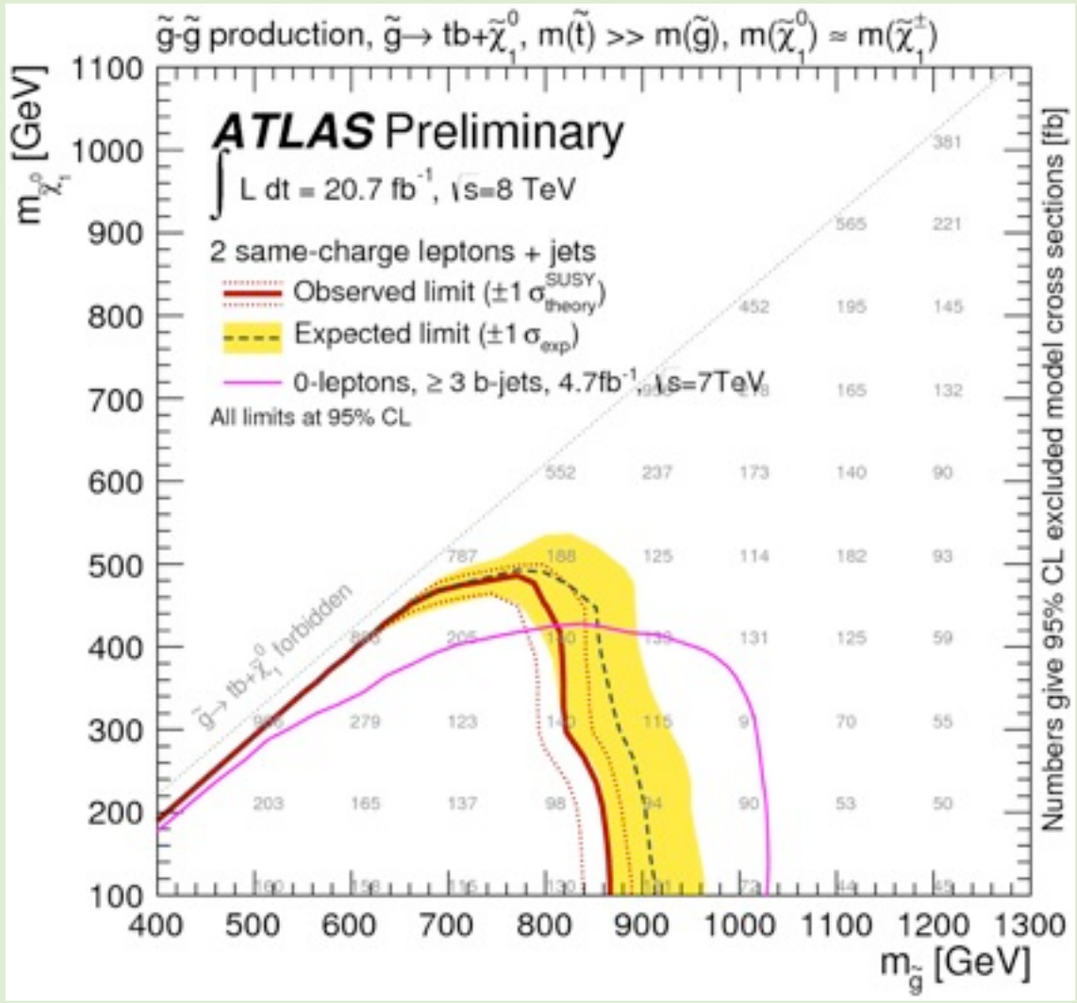
ATLAS-CONF-2013-007



$\tilde{g}\tilde{g} \to tt\tilde{t}_1^*\tilde{t}_1^* \; (\tilde{t}_1 \; off \; shell \; and \; \tilde{t}_1 \to t\tilde{\chi}_1^0)$

Increased reach in low mass splitting regions compared to 0L channels

Exclude m_{LSP}~600 GeV up to m_g~1 TeV



$\tilde{g}\tilde{g} \to tb\tilde{t}_1\tilde{b}_1$
$(\tilde{t}_1, \tilde{b}_1 \; off \; shell, degenerate \; m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_1^\pm})$

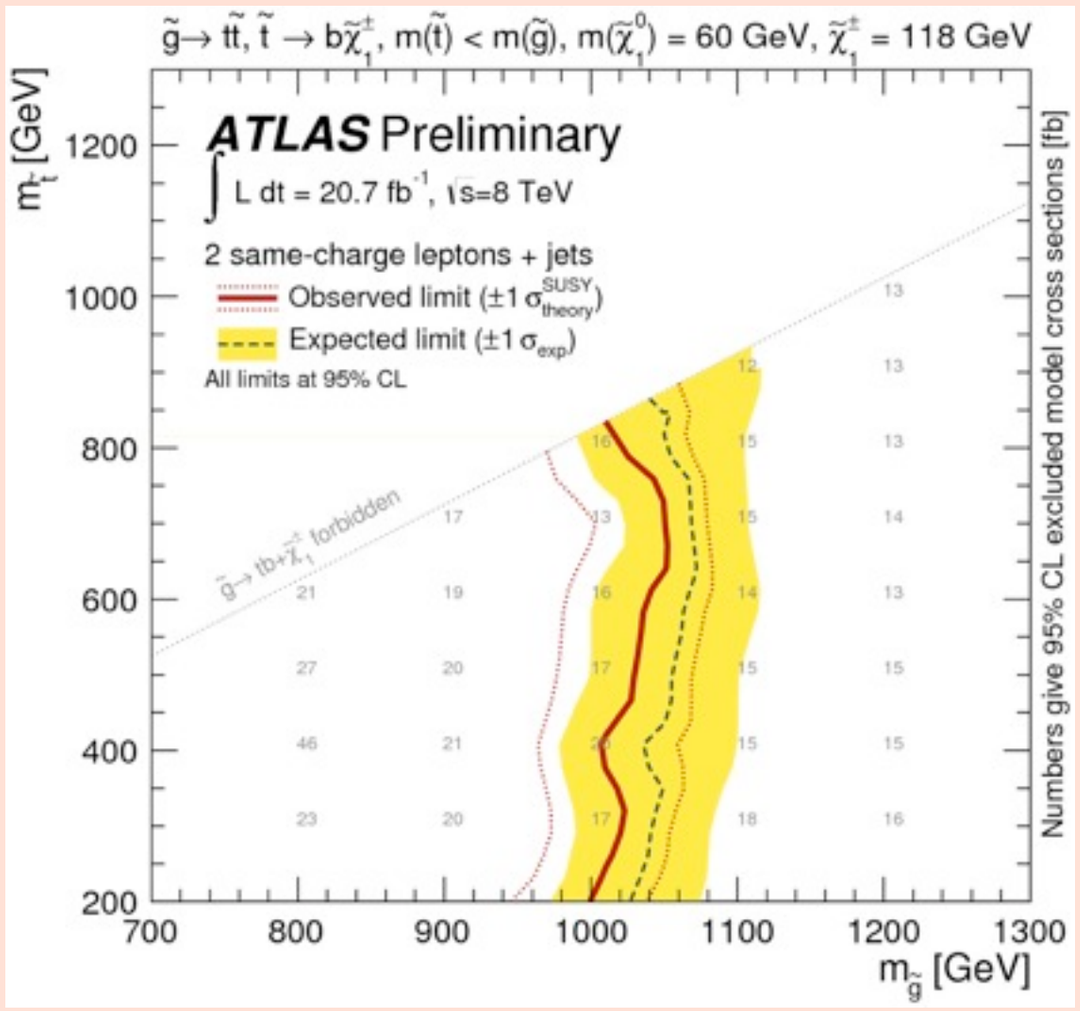
Increased reach in low mass splitting regions compared to 0L channels

Exclude m_{LSP}~500 GeV up to m_g~0.8 TeV

SS + jets : interpretations

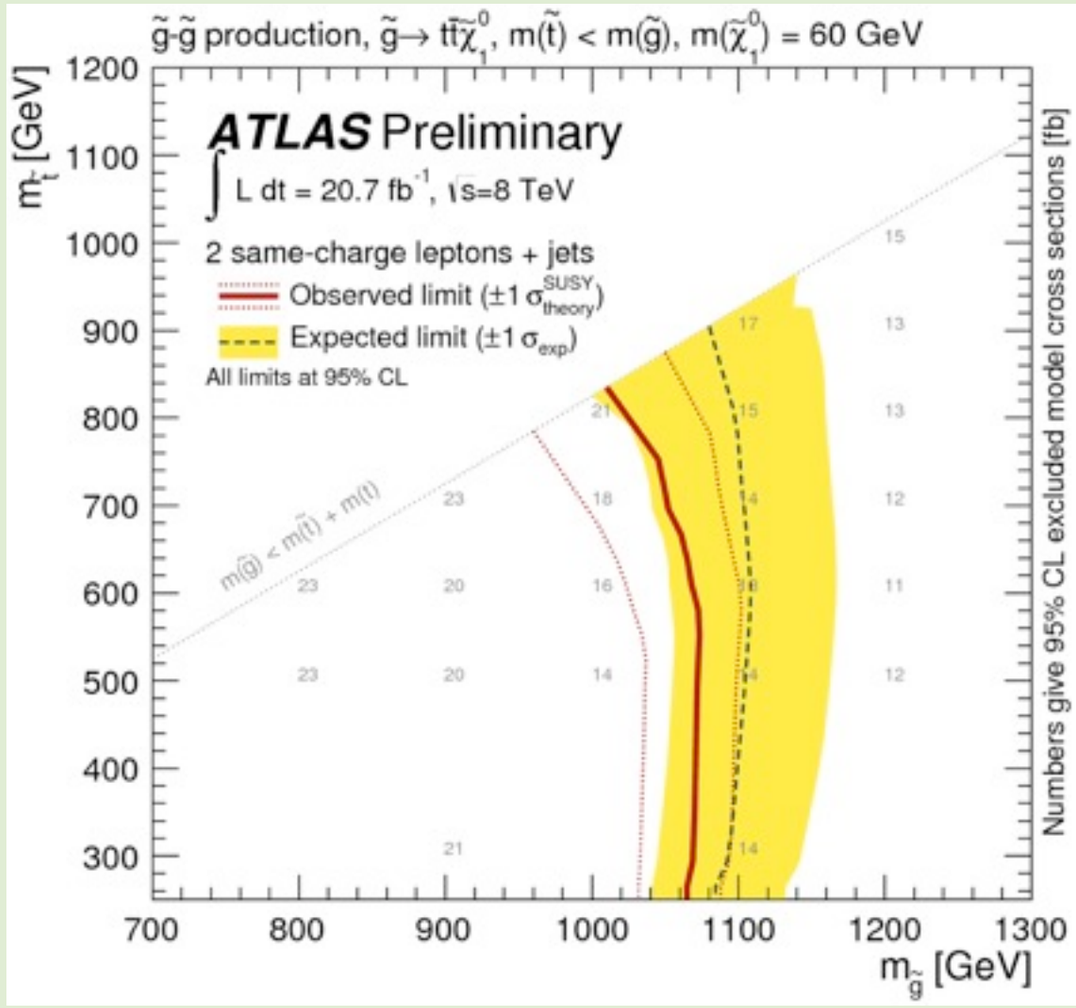
21 fb^{-1}

ATLAS-CONF-2013-007



$\tilde{g}\tilde{g} \to tt\tilde{t}_1\tilde{t}_1$
$(\tilde{t}_1\ on\ shell, \tilde{t}_1 \to b\tilde{\chi}_1^{\pm},$
$m_{\tilde{\chi}_1^{\pm}} = 120\ GeV\ and\ m_{\tilde{\chi}_1^0} = 60\ GeV)$

Exclude m_{t1}~800 GeV up to m_g~1 TeV



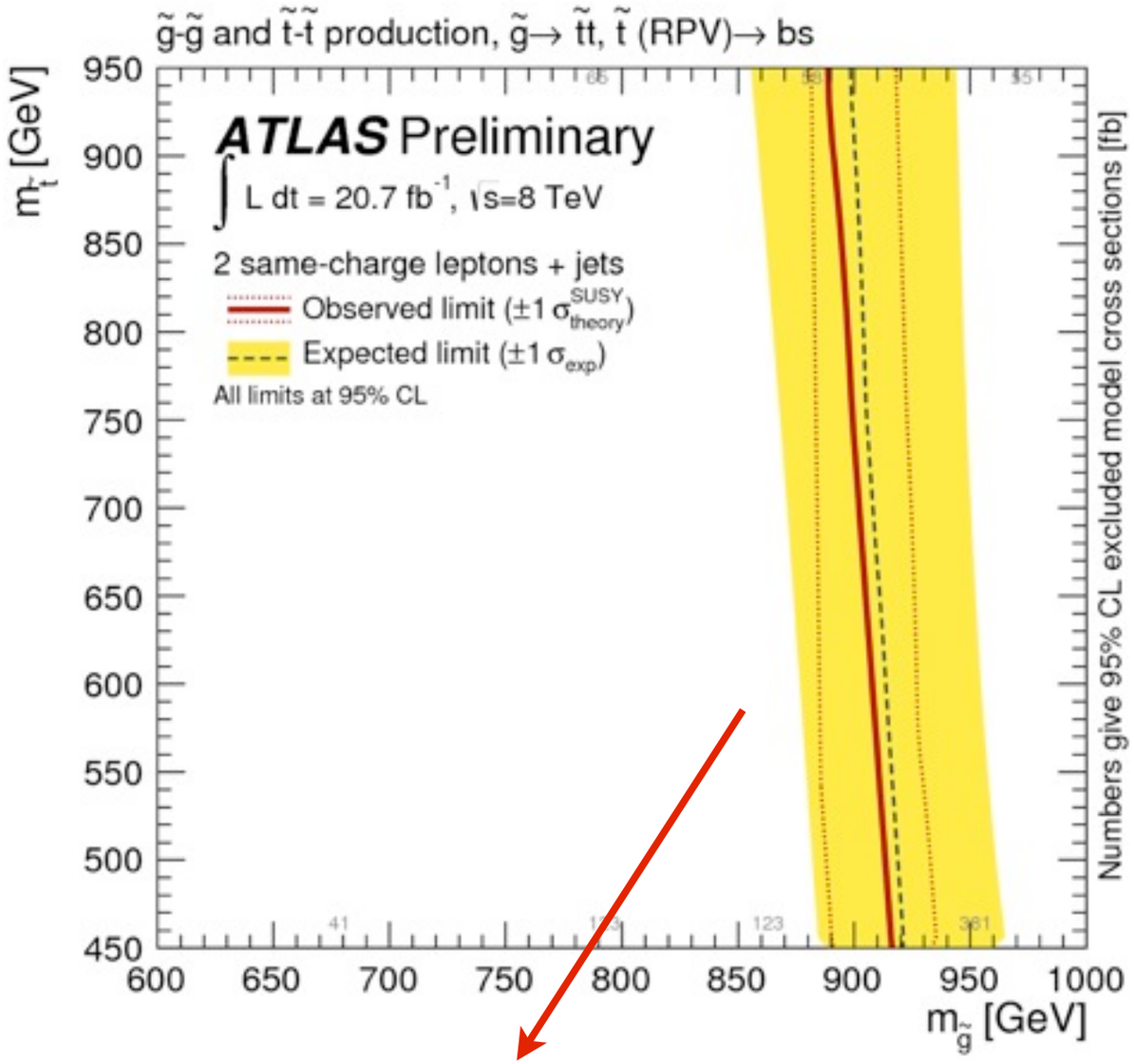
$\tilde{g}\tilde{g} \to tt\tilde{t}_1\tilde{t}_1\ (\tilde{t}_1\ on\ shell, \tilde{t}_1 \to t\tilde{\chi}_1^0\ and\ m_{\tilde{\chi}_1^0} = 60\ GeV)$

Exclude m_{t1}~800 GeV up to m_g~1 TeV

SS + jets : interpretations

21 fb^{-1}

ATLAS-CONF-2013-007



leptons come from top quarks, limits ~independent of stop mass

Gluino-stop (bs) RPV model

$$\tilde{g}\tilde{g} \rightarrow tt\tilde{t}\tilde{t}$$
$$\tilde{t} \rightarrow bs, \lambda''_{123} = 1$$

Final state: 2 tops + 2 b-jets + 2 LF-jets + moderate MET

Excluded up to $m_{\tilde{g}}$~0.9 TeV

0L + 3 b-jets : event selections

13 fb^{-1}

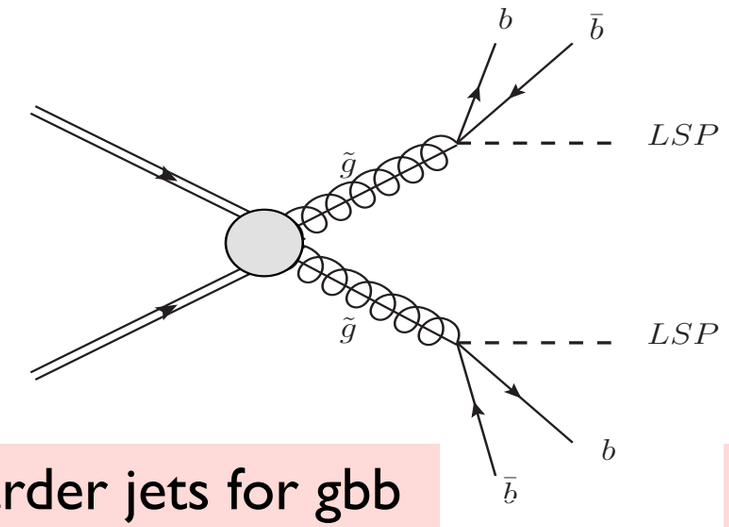
ATLAS-CONF-2012-145

* gtt model with 0 leptons: 4 b-jets + 12 jets + large MET
* gbb model: 4 b-jets + large MET
* **At least 3 b-jets and large jet multiplicities ⇒ small backgrounds**
* Dedicated signal regions for each model and different kinematic regions

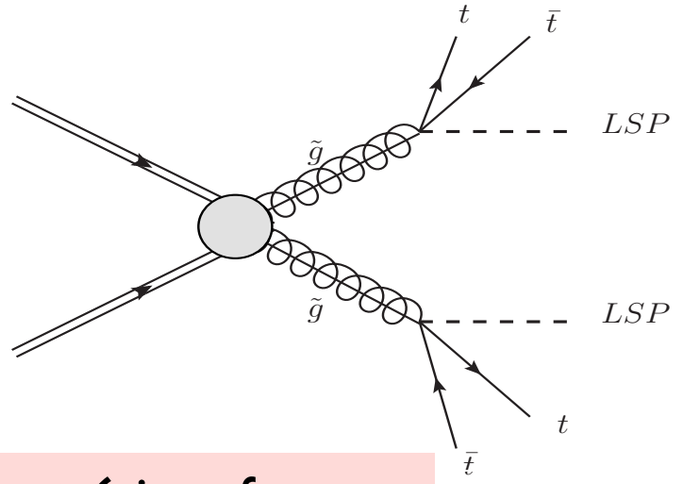
Loose/Medium/Tight Signal Regions binning in Meff (with 4 or all jets) provide sensitivity in regions with different mass splitting

$$m_{eff}^{4j} = \sum_{4j} p_T^{jets}$$

$$m_{eff} = \sum_{all\ jets} p_T^{jets}$$



4 harder jets for gbb



at least 6 jets for gtt

Common criteria: lepton veto, $p_T^{j_1} > 90$ GeV, $E_T^{miss} > 200$ GeV, ≥ 3 b-jets, $E_T^{miss}/m_{eff}^{4j} > 0.2$, $\Delta\phi_{min}^{4j} > 0.4$

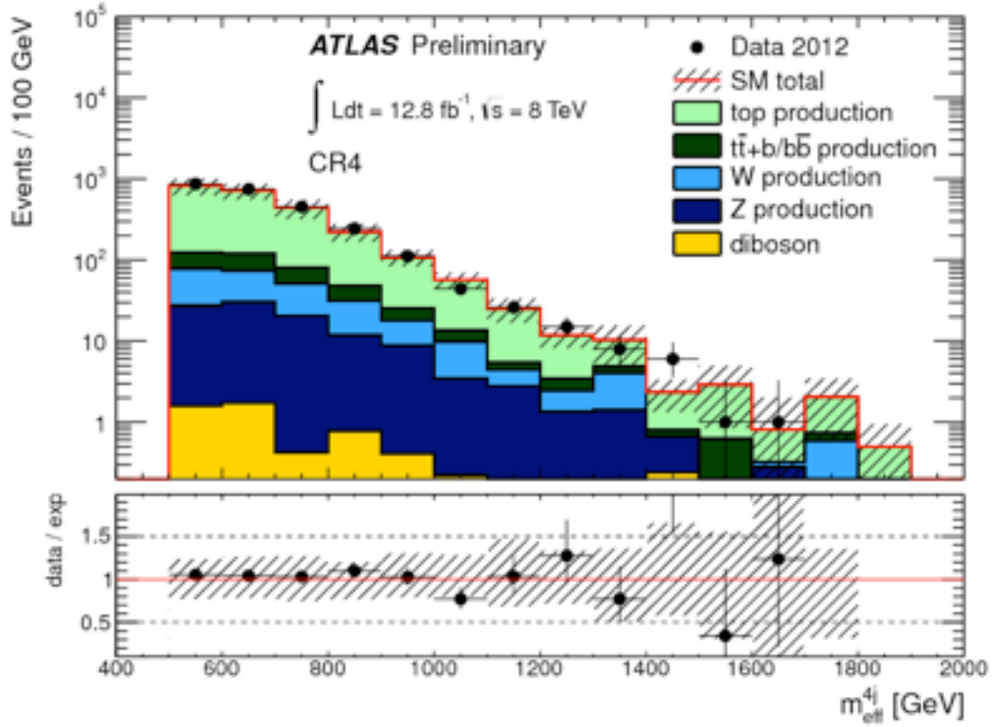
SR	N_J ($p_T > 50$ GeV)	p_T b-jets	m_{eff}
SR4-L/M/T	≥ 4 jets	> 50 GeV	$m_{eff}^{4j} > 900/1100/1300$ GeV
SR6-L/M/T	≥ 6 jets	> 30 GeV	$m_{eff}^{incl} > 1100/1300/1500$ GeV

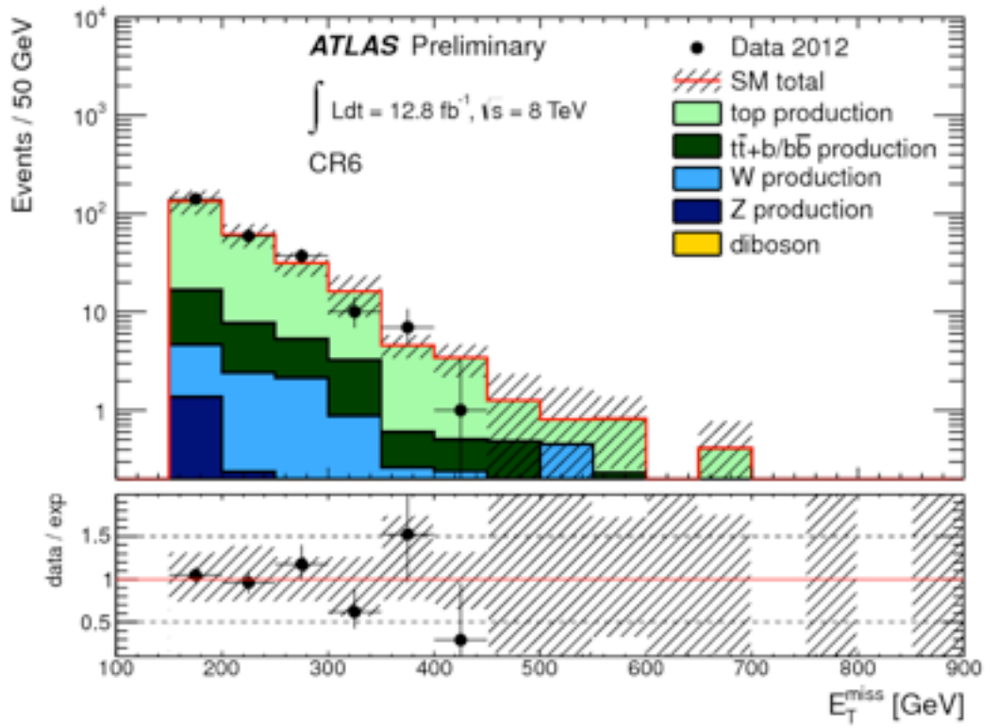
0L + 3 b-jets : backgrounds

13 fb^{-1}

ATLAS-CONF-2012-145

* 3 types of background:
  - Main reducible component (tt+LF jets): shape from MC, normalization from data in control regions with a likelihood fit
  - Irreducible (tt+b/bb): MC
  - Minor reducible (W/Z+jets, dibosons): MC
* Control regions for tt+LF defined with 2 b-jets events, relaxed Meff cuts and same jet requirements as in corresponding signal regions
* Excellent agreement between data and MC





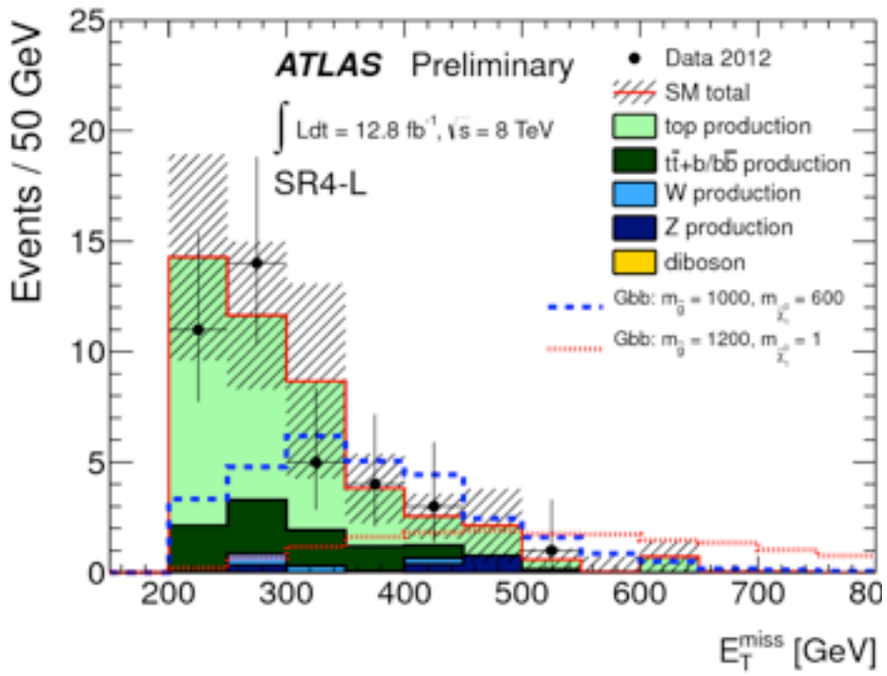
Common criteria: lepton veto, $p_T^{j_1} > 90$ GeV, $E_T^{miss} > 150$ GeV, = 2 b-jets, $E_T^{miss}/m_{eff}^{4j} > 0.2$, $\Delta\phi_{min}^{4j} > 0.4$

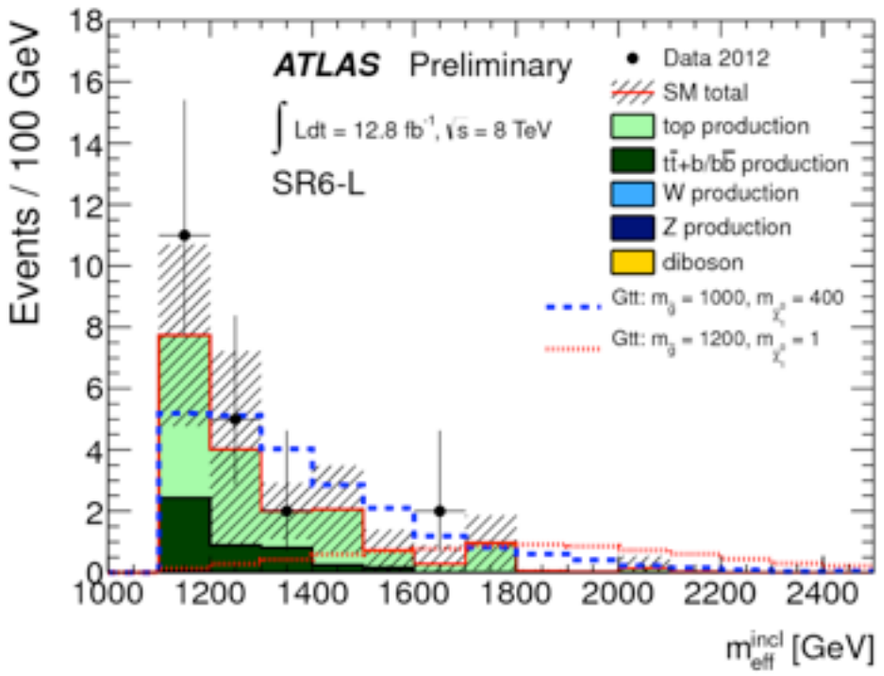
CR	N_J ($p_T > 50$ GeV)	p_T b-jets	m_{eff}	corresponding SR
CR4	≥ 4 jets	> 50 GeV	$m_{eff}^{4j} > 500$ GeV	SR4-L, SR4-M, SR4-T
CR6	≥ 6 jets	> 30 GeV	$m_{eff}^{incl} > 600$ GeV	SR6-L, SR6-M, SR6-T

0L + 3 b-jets : results

13 fb^{-1}

ATLAS-CONF-2012-145





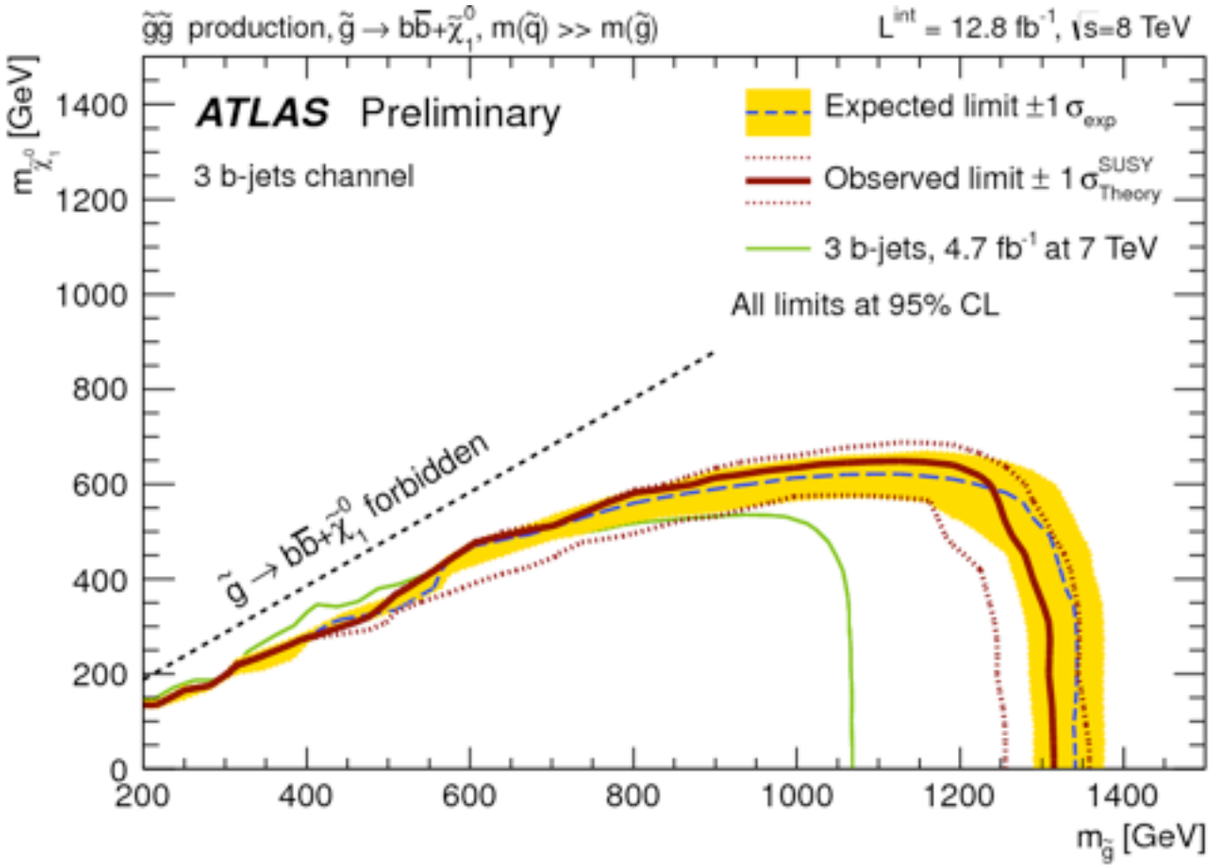
channel	SR4-L	SR4-M	SR4-T
Observed events	38	8	4
Total background events	46 ± 10	10.7 ± 2.9	2.9 ± 1.0
(MC prediction)	(44 ± 17)	(10.3 ± 4.6)	(2.7 ± 1.3)
channel	SR6-L	SR6-M	SR6-T
Observed events	20	4	2
Total background events	18 ± 6	6.3 ± 2.4	2.2 ± 1.3
(MC prediction)	(18 ± 9)	(6.3 ± 3.4)	(2.2 ± 1.8)

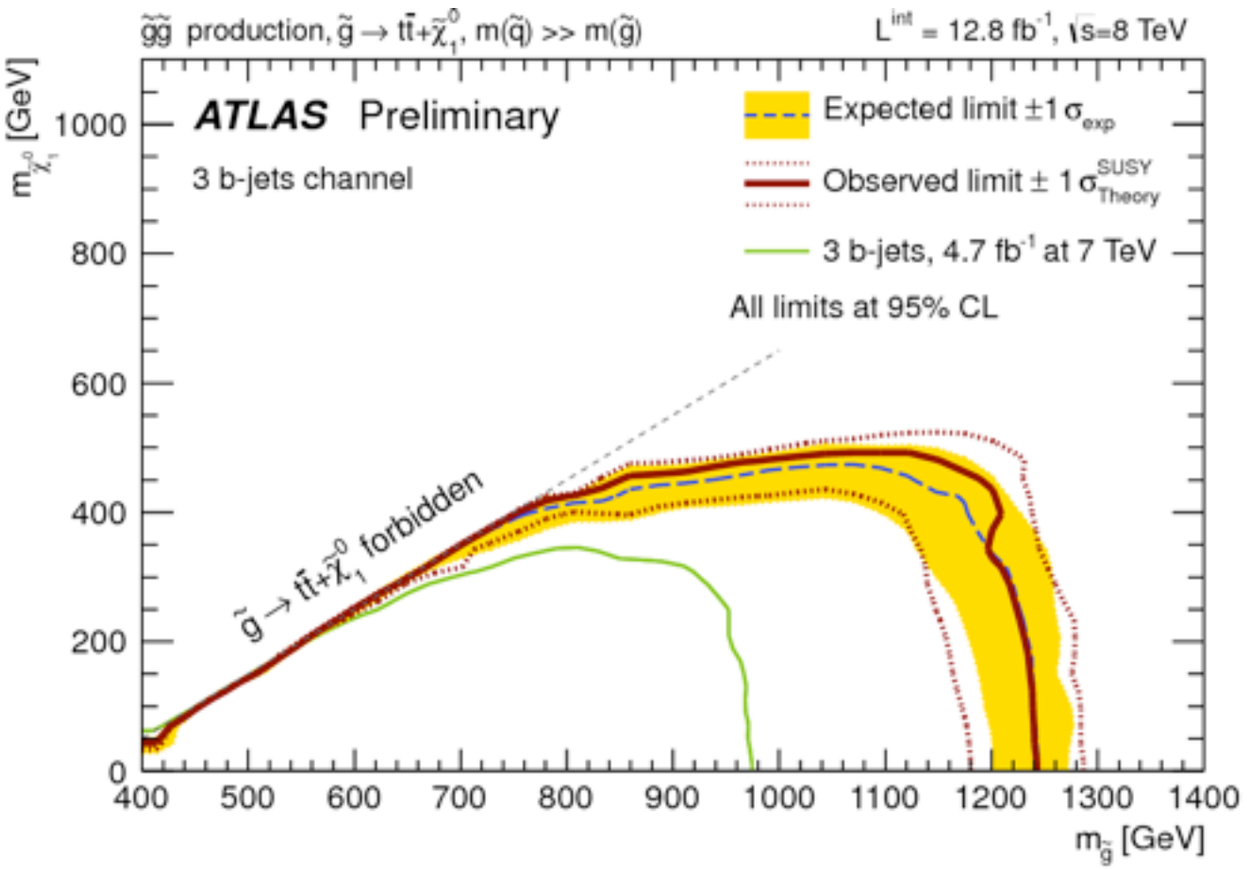
excellent agreement in SRs too ....

0L + 3 b-jets : interpretations

13 fb^{-1}

ATLAS-CONF-2012-145





$\tilde{g}\tilde{g} \to bb\tilde{b}_1^*\tilde{b}_1^* \; (\tilde{b}_1 \; off \; shell)$

Big gain from 7 → 8 TeV and increased luminosity

Exclude m_{LSP}~600 GeV up to m_g~1.2 TeV

$\tilde{g}\tilde{g} \to tt\tilde{t}_1^*\tilde{t}_1^* \; (\tilde{t}_1 \; off \; shell \; and \; \tilde{t}_1 \to t\tilde{\chi}_1^0)$

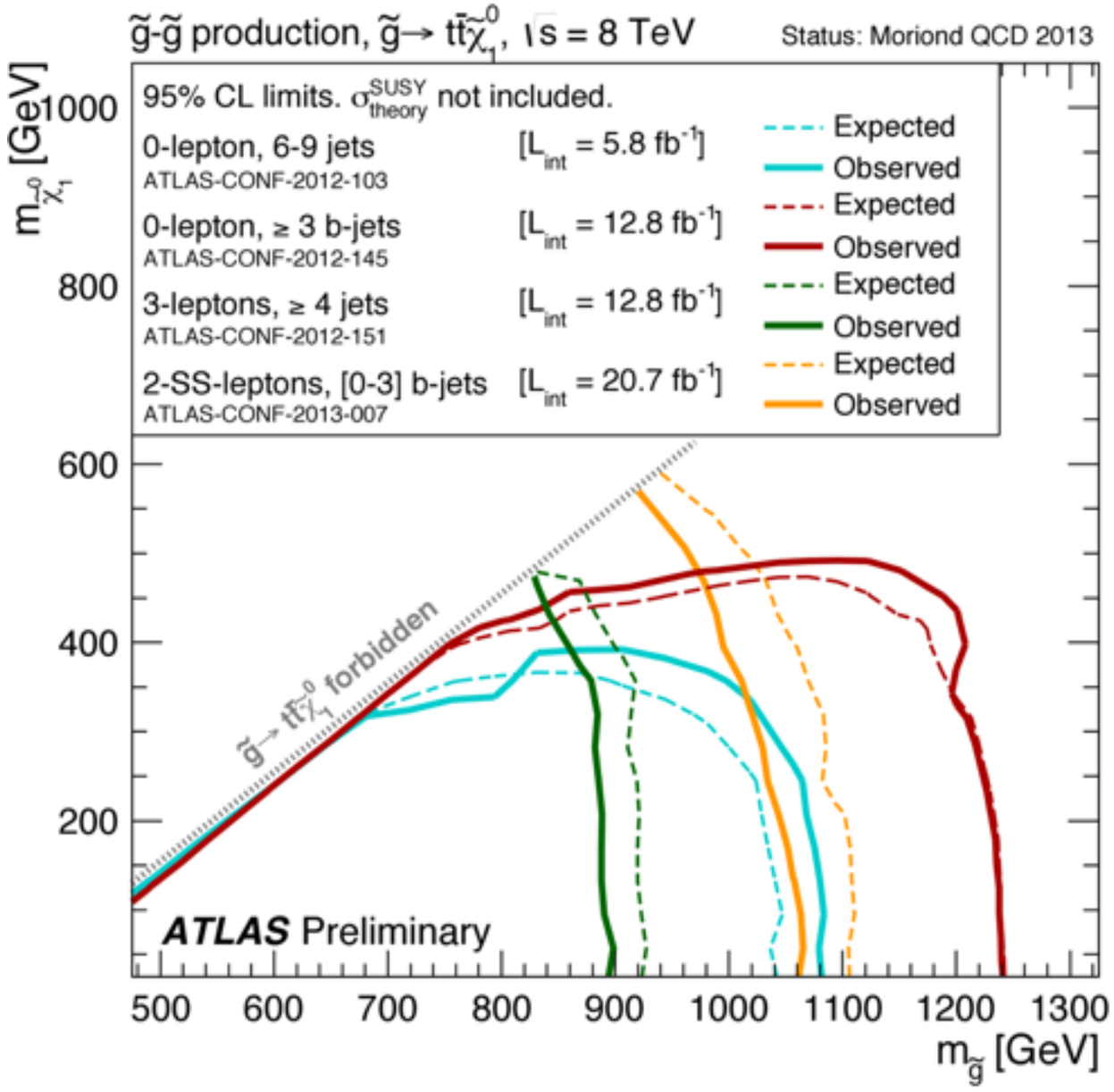
Increased reach in high mass splitting regions compared to SS+jets analysis

Exclude m_{LSP}~500 GeV up to m_g~1.1 TeV

Summary and conclusions

* Broad program in ATLAS to attack 3rd generation SUSY particles
* Excluded gluino masses up to 1 TeV and beyond for several simplified models
* LSPs excluded up to 600-800 GeV depending on the scenario/analysis
* Significant work going on to extend current searches .....

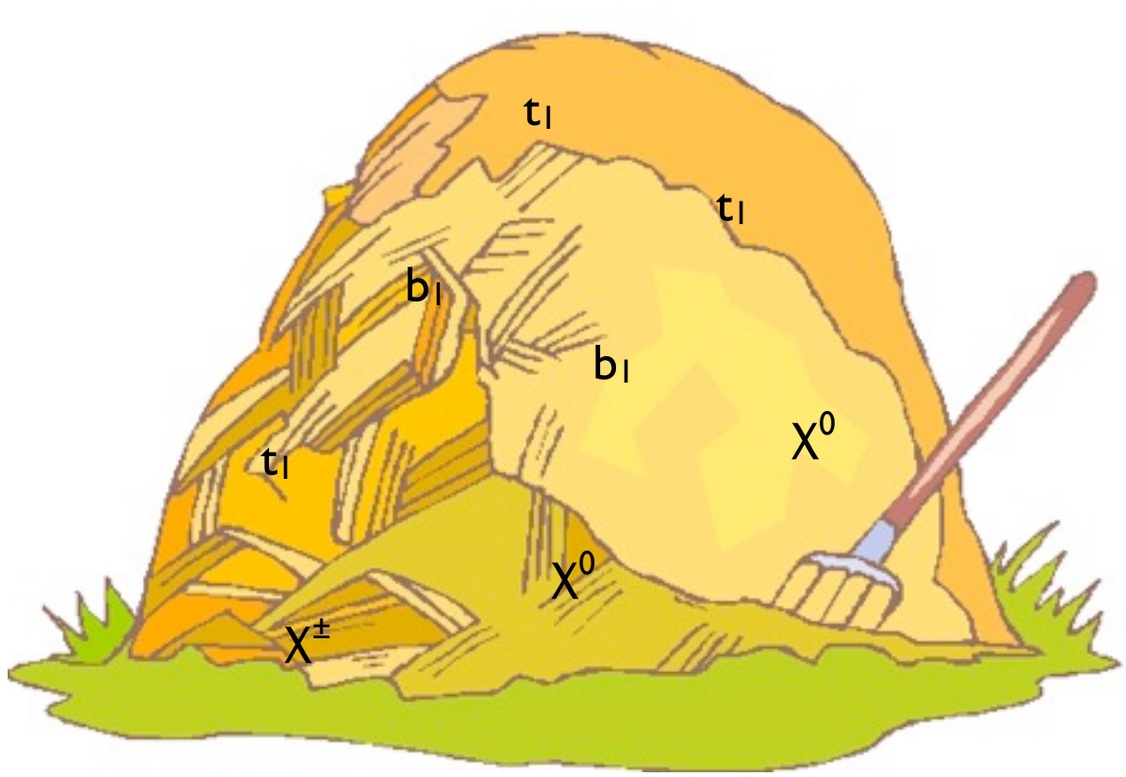
stay tuned !



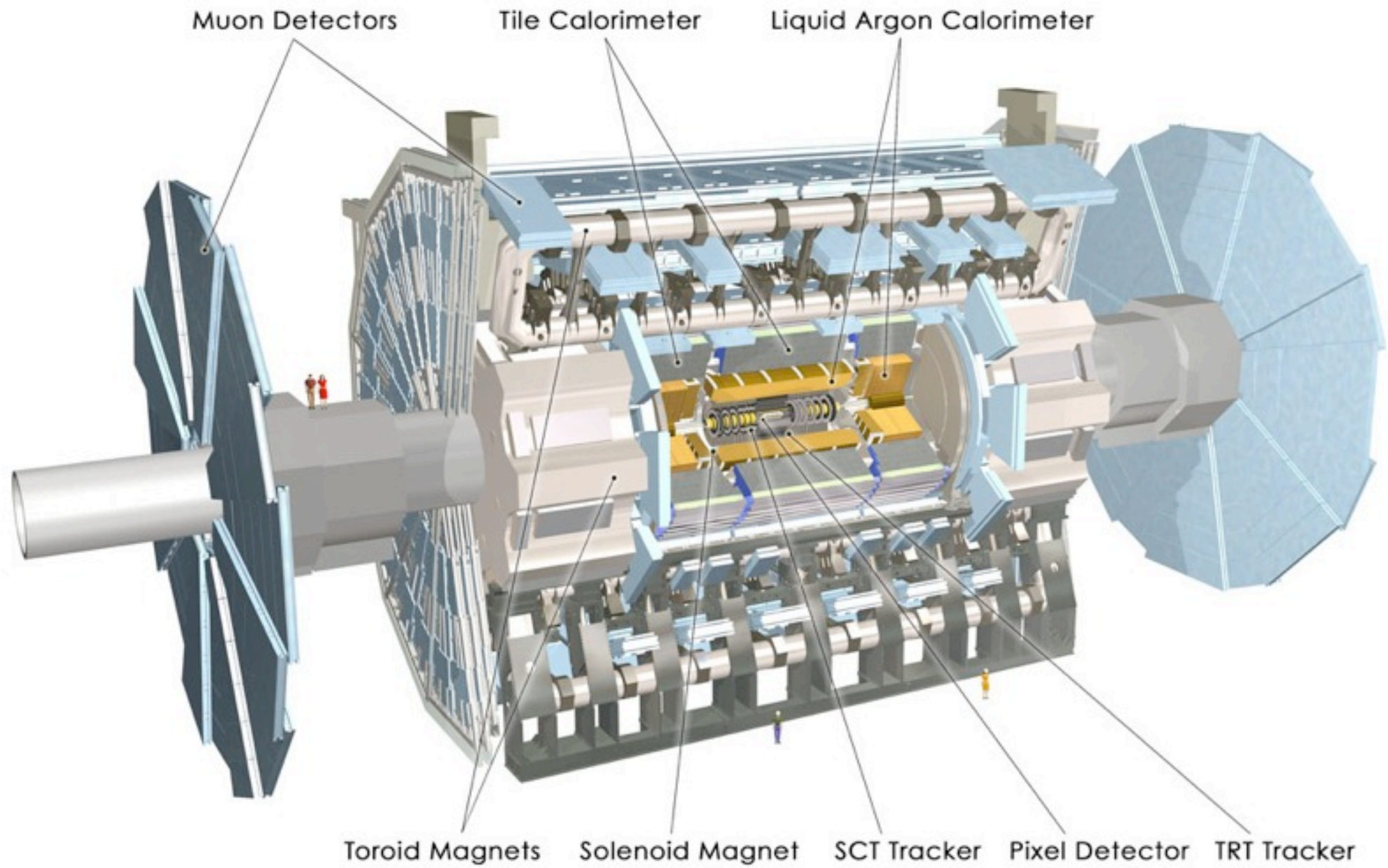
More SUSY results

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

Backup slides



ATLAS detector

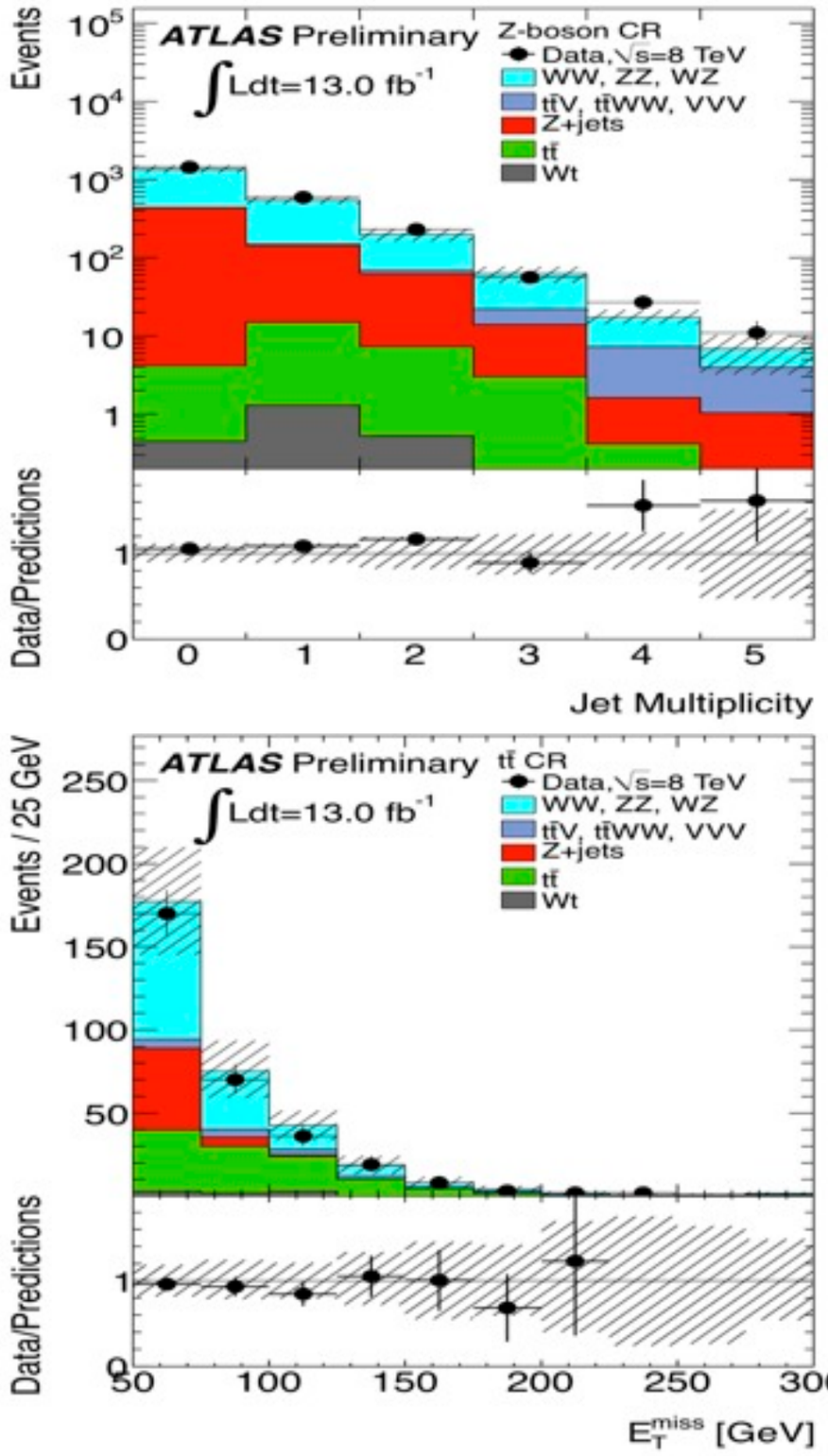


3L + jets + MET

13 fb^{-1}

ATLAS-CONF-2012-151

* 3rd generation with tops in the final state
* Main backgrounds:
  - processes with two real leptons and a fake lepton (Z+jets, tt+jets) - Estimated from MC with corrections from fake rates measured in data separately for electron and muon events
  - irreducible (WZ, WW) from MC
* Three control regions: Z, low MET and tt
* Good agreement between data and MC



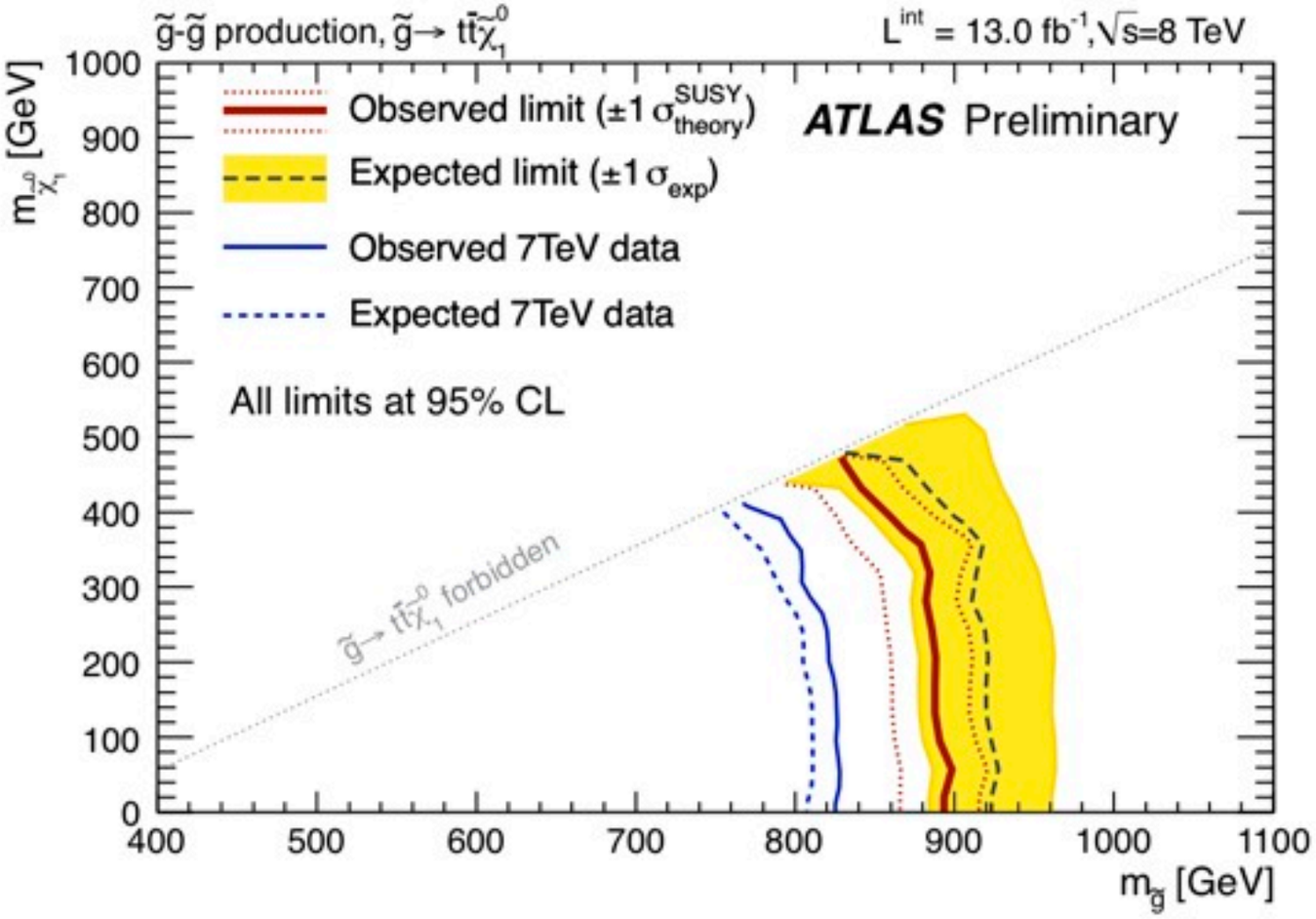
	Z-boson CR	low-E_T^{miss} CR	$t\bar{t}$ CR
Z+jets and $Z+b\bar{b}$+jets	630^{+200}_{-160} (520)	460^{+200}_{-60} (520)	56^{+26}_{-27} (54)
$t\bar{t}$	28^{+8}_{-7} (17)	45^{+16}_{-14} (28)	103^{+31}_{-24} (64)
Wt	1±1 (1)	5^{+3}_{-2} (3)	8^{+4}_{-3} (5)
WW, WZ, and ZZ	1500±120 (1500)	452±35 (452)	145±17 (145)
$t\bar{t}+V$, $t\bar{t}+WW$, and VVV	31±12 (31)	7±4 (7)	18±9 (18)
Total SM	2190^{+240}_{-200} (2070)	970^{+210}_{-80} (1010)	330^{+51}_{-57} (287)
Data	2358	959	310

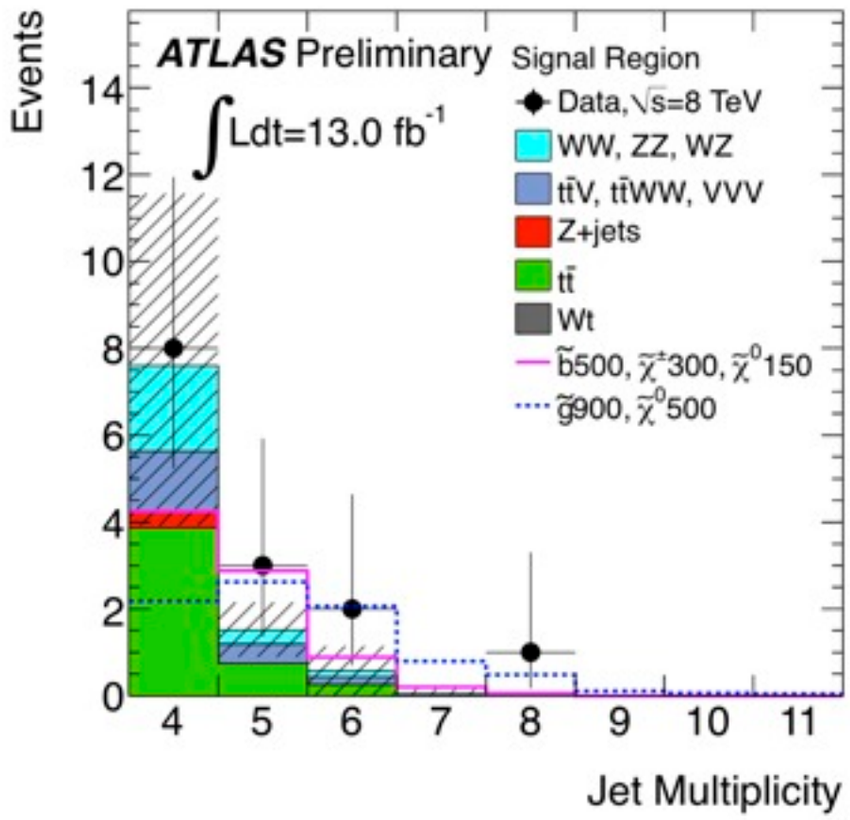
3L + jets + MET

13 fb^{-1}

ATLAS-CONF-2012-151

	3μ	$1e2SS\mu$	$1e2OS\mu$	$2SSe1\mu$	$2OSe1\mu$	$3e$	3ℓ
Z+jets and $Z+b\bar{b}$+jets	-	-	-	-	-	$0.4^{+0.4}_{-0.4}$	$0.4^{+0.4}_{-0.4}$
$t\bar{t}$ and Wt	0.7±0.8	0.5±0.5	$1.5^{+0.9}_{-0.8}$	$0.9^{+1.0}_{-0.9}$	$1.0^{+0.9}_{-0.8}$	$0.2^{+0.4}_{-0.2}$	$4.9^{+2.6}_{-2.0}$
WW, WZ, and ZZ	$0.7^{+0.4}_{-0.3}$	-	$0.8^{+0.3}_{-0.5}$	-	$0.3^{+0.3}_{-0.2}$	0.6±0.6	$2.4^{+1.3}_{-1.2}$
$t\bar{t}$+W and $t\bar{t}$+Z, and VVV	0.3±0.2	0.2 ±0.2	0.6±0.5	0.3±0.2	0.4±0.3	0.2±0.1	2.0±1.0
Total SM	1.8±1.0	0.8±0.5	2.9±1.2	$1.2^{+1.2}_{-1.0}$	$1.7^{+1.1}_{-1.0}$	$1.4^{+0.9}_{-0.8}$	$9.7^{+3.8}_{-3.4}$
Signal1	$1.3^{+0.4}_{-0.5}$	$1.2^{+0.3}_{-0.4}$	$2.2^{+0.6}_{-0.7}$	$1.2^{+0.3}_{-0.4}$	$2.2^{+0.6}_{-0.8}$	$0.7^{+0.2}_{-0.3}$	$8.9^{+2.2}_{-3.0}$
Signal2	0.9±0.3	$1.2^{+0.3}_{-0.4}$	$2.0^{+0.5}_{-0.6}$	$1.4^{+0.4}_{-0.5}$	2.0±0.6	$0.8^{+0.3}_{-0.3}$	$8.3^{+1.9}_{-2.3}$
Data	1	2	3	1	4	3	14





* Data and SM bkg within one sigma
* Exclude gluinos up to 0.9 TeV and LSPs up to 400 GeV for gtt off-shell model