



ATLAS results on BSM searches with top quarks

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On behalf of the ATLAS Collaboration

Why Top?

- Theory
 - Top is heavy \Rightarrow special role in EWSB?
 - Need top partner to fix hierarchy problem
 - Tantalizing hints of NP in $t\bar{t}$ A_{FB} at Tevatron?
- Experiment
 - Experimental techniques well established to isolate and identify top quarks and b-jets
 - If there is top there also is bottom

Outline

- New top quark production mechanisms
 - $t\bar{t}$ resonances
 - SUSY 3rd generation
 - 4th generation and Vector-Like Quarks
 - Single top final states and other top searches
- I will not talk about New physics in top quark decay / properties
 - W polarization
 - FCNC
 - Spin correlations in $t\bar{t}$
 - ...

Find all results here:

<https://twiki.cern.ch/twiki/bin/view/AtlasPublic>

<http://cds.cern.ch/>

Close your eyes! Spoiler!

$t\bar{t}$ resonances:

RS with $g_{KK} / g_s = -0.20 : tt \rightarrow l+jets, m_{tt}$	$L=2.1 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-029]	1.03 TeV	KK gluon mass
RS with $BR(g_{KK} \rightarrow tt) = 0.925 : tt \rightarrow l+jets, m_{tt}$	$L=2.1 \text{ fb}^{-1}, 7 \text{ TeV}$ [Preliminary]	1.50 TeV	KK gluon mass

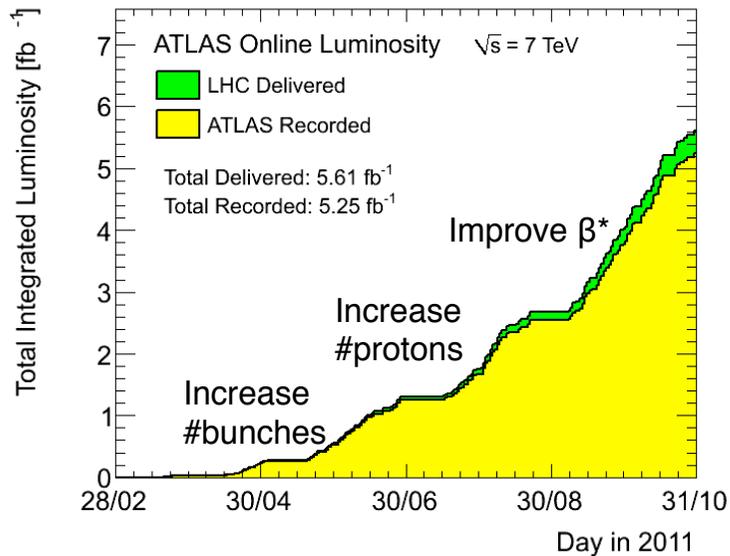
SUSY 3rd generation:

$\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_0^0$ (virtual b): 0 lep + 1/2 b-j's + $E_{T,miss}$	$L=2.1 \text{ fb}^{-1}, 7 \text{ TeV}$ [1203.6193]	900 GeV	\tilde{g} mass ($m_{\tilde{\chi}_1^0} < 300 \text{ GeV}$)
$\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_0^0$ (virtual b): 0 lep + 3 b-j's + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-058]	1.02 TeV	\tilde{g} mass ($m_{\tilde{\chi}_1^0} < 400 \text{ GeV}$)
$\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$ (real b): 0 lep + 3 b-j's + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-058]	1.00 TeV	\tilde{g} mass ($m_{\tilde{\chi}_1^0} = 60 \text{ GeV}$)
$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_0^0$ (virtual t): 1 lep + 1/2 b-j's + $E_{T,miss}$	$L=2.1 \text{ fb}^{-1}, 7 \text{ TeV}$ [1203.6193]	710 GeV	\tilde{g} mass ($m_{\tilde{\chi}_1^0} < 150 \text{ GeV}$)
$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_0^0$ (virtual t): 2 lep (SS) + j's + $E_{T,miss}$	$L=2.1 \text{ fb}^{-1}, 7 \text{ TeV}$ [1203.5763]	650 GeV	\tilde{g} mass ($m_{\tilde{\chi}_1^0} < 210 \text{ GeV}$)
$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_0^0$ (virtual t): 0 lep + multi-j's + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [1206.1760]	870 GeV	\tilde{g} mass ($m_{\tilde{\chi}_1^0} < 100 \text{ GeV}$)
$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_0^0$ (virtual t): 0 lep + 3 b-j's + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-058]	940 GeV	\tilde{g} mass ($m_{\tilde{\chi}_1^0} < 50 \text{ GeV}$)
$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ (real t): 0 lep + 3 b-j's + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-058]	820 GeV	\tilde{g} mass ($m_{\tilde{\chi}_1^0} = 60 \text{ GeV}$)
$bb, b_1 \rightarrow b\tilde{\chi}_1^0$: 0 lep + 2-b-jets + $E_{T,miss}$	$L=2.1 \text{ fb}^{-1}, 7 \text{ TeV}$ [1112.3832]	390 GeV	b mass ($m_{\tilde{\chi}_1^0} < 60 \text{ GeV}$)
$t\bar{t}$ (very light), $t \rightarrow b\tilde{\chi}_1^+$: 2 lep + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [CONF-2012-059]	135 GeV	t mass ($m_{\tilde{\chi}_1^0} = 45 \text{ GeV}$)
$t\bar{t}$ (light), $t \rightarrow b\tilde{\chi}_1^+$: 1/2 lep + b-jet + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [CONF-2012-070]	120-173 GeV	t mass ($m_{\tilde{\chi}_1^0} = 45 \text{ GeV}$)
$t\bar{t}$ (heavy), $t \rightarrow t\tilde{\chi}_0^0$: 0 lep + b-jet + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [CONF-2012-074]	380-465 GeV	t mass ($m_{\tilde{\chi}_1^0} = 0$)
$t\bar{t}$ (heavy), $t \rightarrow t\tilde{\chi}_0^0$: 1 lep + b-jet + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [CONF-2012-073]	230-440 GeV	t mass ($m_{\tilde{\chi}_1^0} = 0$)
$t\bar{t}$ (heavy), $t \rightarrow t\tilde{\chi}_0^0$: 2 lep + b-jet + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [CONF-2012-071]	298-305 GeV	t mass ($m_{\tilde{\chi}_1^0} = 0$)
$t\bar{t}$ (GMSB): $Z(\rightarrow ll) + b\text{-jet} + E_{T,miss}$	$L=2.1 \text{ fb}^{-1}, 7 \text{ TeV}$ [1204.6736]	310 GeV	t mass ($115 < m_{\tilde{\chi}_1^0} < 230 \text{ GeV}$)

4th generation, VLQ and others:

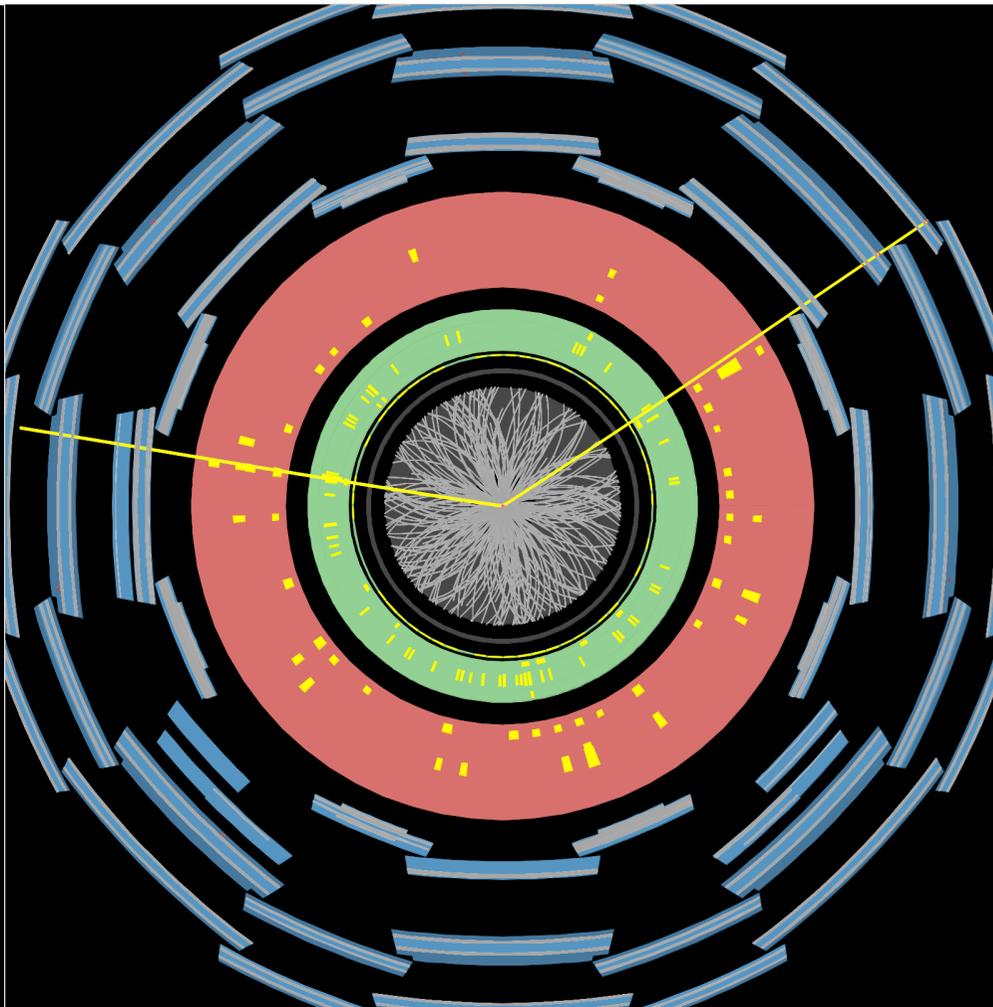
4 th generation: $Q Q_4 \rightarrow WqWq$	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1202.3389]	350 GeV	Q_4 mass
4 th generation: $u_4 \bar{u}_4 \rightarrow WbWb$	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1202.3076]	404 GeV	u_4 mass
4 th generation: $d_4 \bar{d}_4 \rightarrow WtWt$	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1202.6540]	480 GeV	d_4 mass
New quark b' : $b\bar{b}' \rightarrow Zb+X, m_{b'}$	$L=2.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1204.1265]	400 GeV	b' mass
$T\bar{T}$ top partner $\rightarrow tt + A_0 A_0$: 2-lep + jets + $E_{T,miss}$ (M_{T2})	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-071]	483 GeV	T mass ($m(A_0) < 100 \text{ GeV}$)
Vector-like quark: CC, m_{lvq}	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1112.5755]	900 GeV	Q mass (coupling $\kappa_{cQ} = v/m_Q$)
Vector-like quark: NC, m_{ln}	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1112.5755]	760 GeV	Q mass (coupling $\kappa_{nQ} = v/m_Q$)
uutt CI: SS dilepton + jets + $E_{T,miss}$	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1202.5520]	1.7 TeV	Λ

- Excellent performance of ATLAS and LHC in 2011



ATLAS

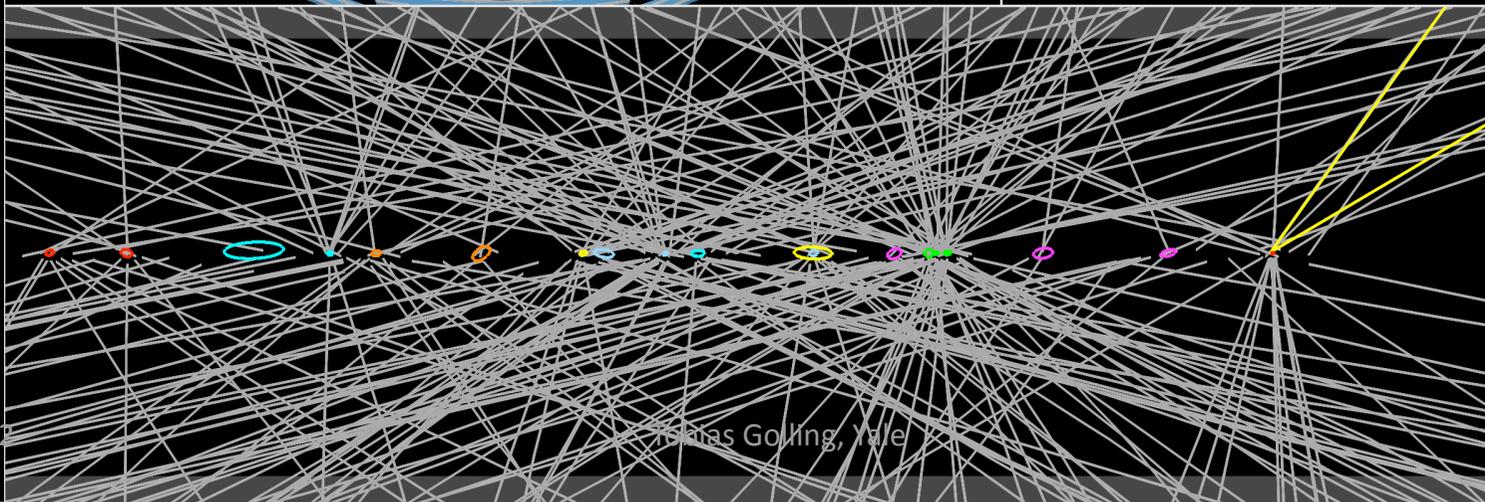
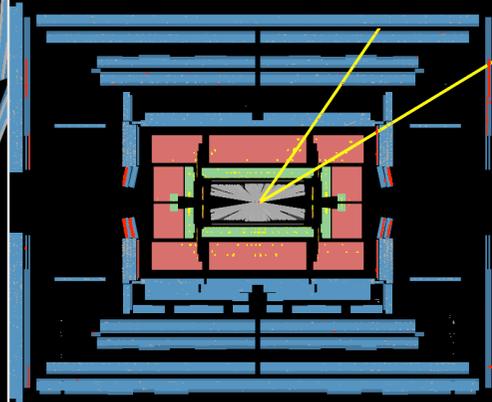
	2011 performance	Design performance
Colliding bunches	1331	2808
Energy	3.5 TeV x 3.5 TeV	7 TeV x 7 TeV
Bunch spacing	50 ns	25 ns
Luminosity	$3.6 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$	$10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
Pile-up interactions	~20	~25
Protons per bunch	1.45×10^{11}	1.15×10^{11}



Run Number: 189280, Event Number: 1705325

Date: 2011-09-14 02:47:14 CEST

$Z \rightarrow \mu\mu$ candidate with 20 reconstructed vertices

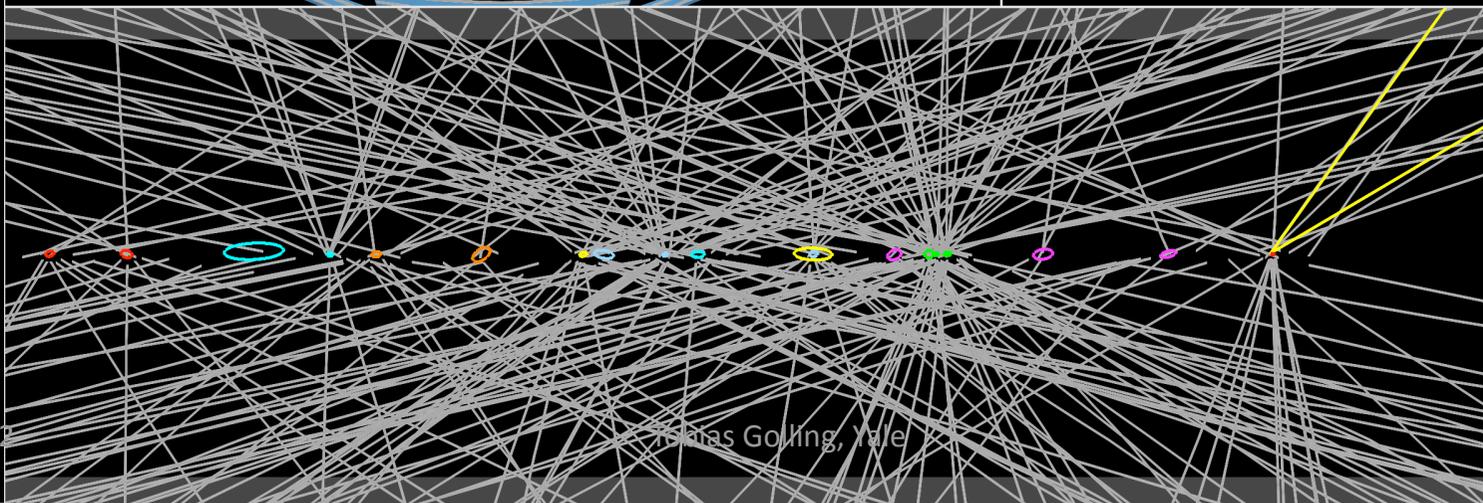
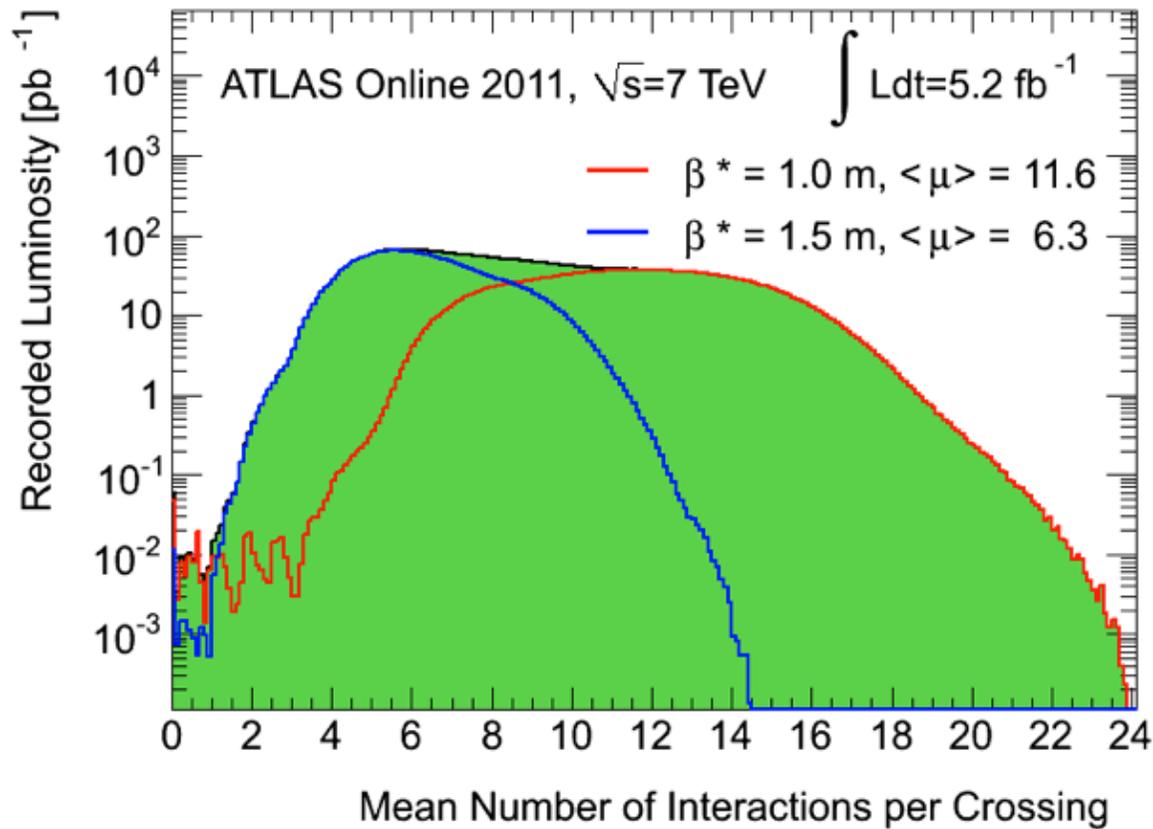
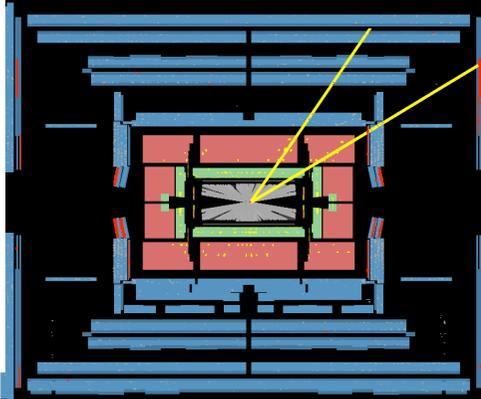




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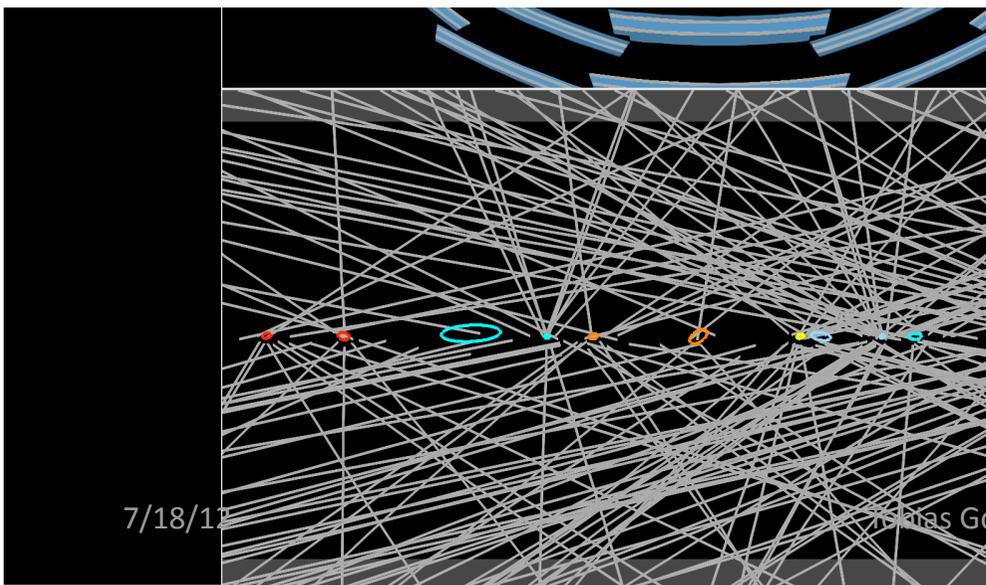
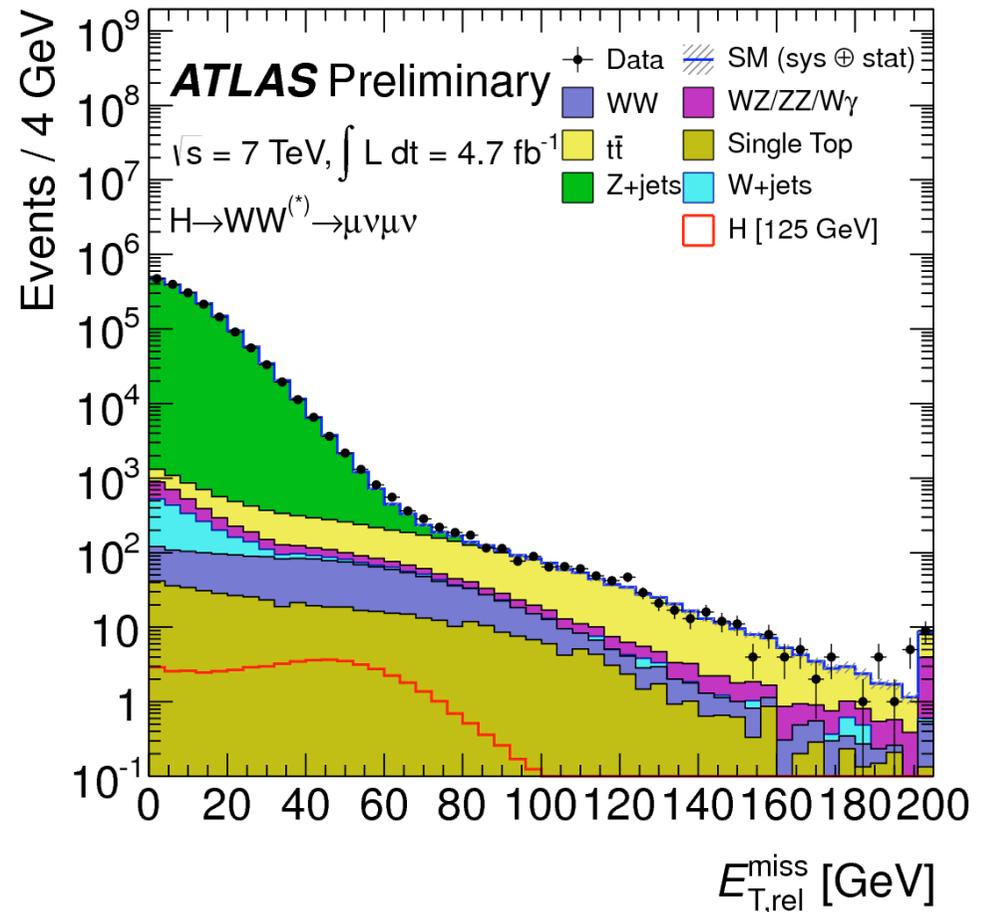
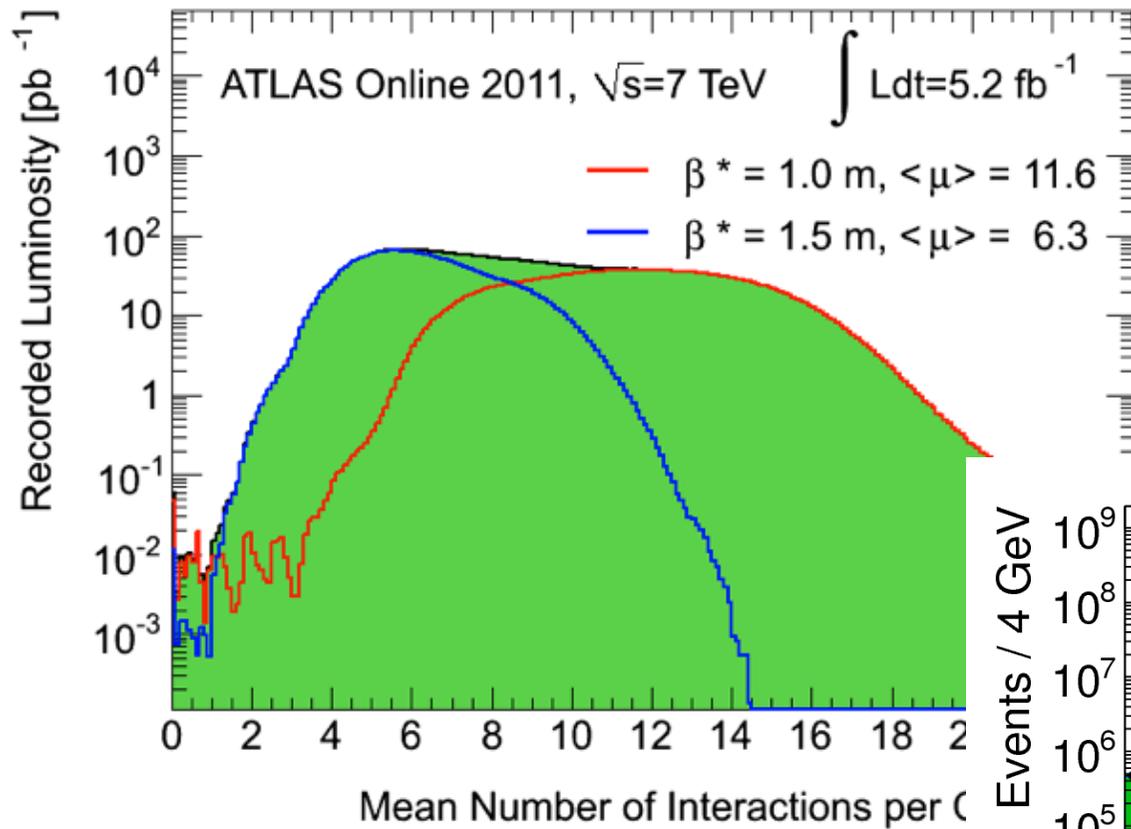




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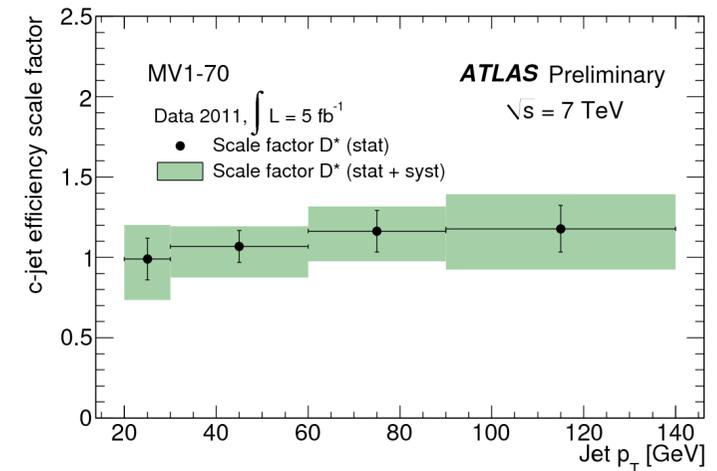
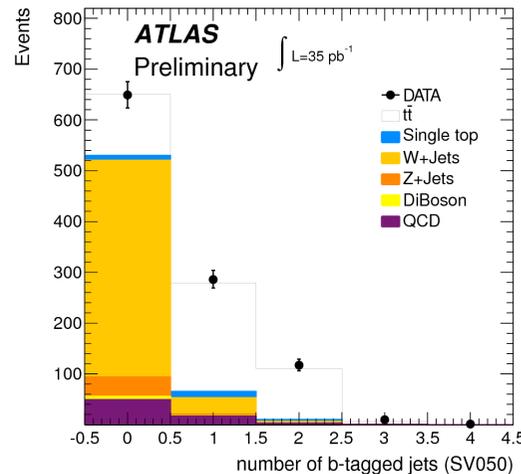
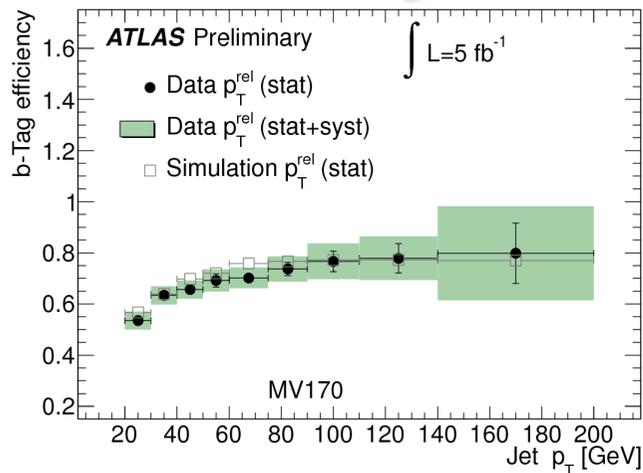
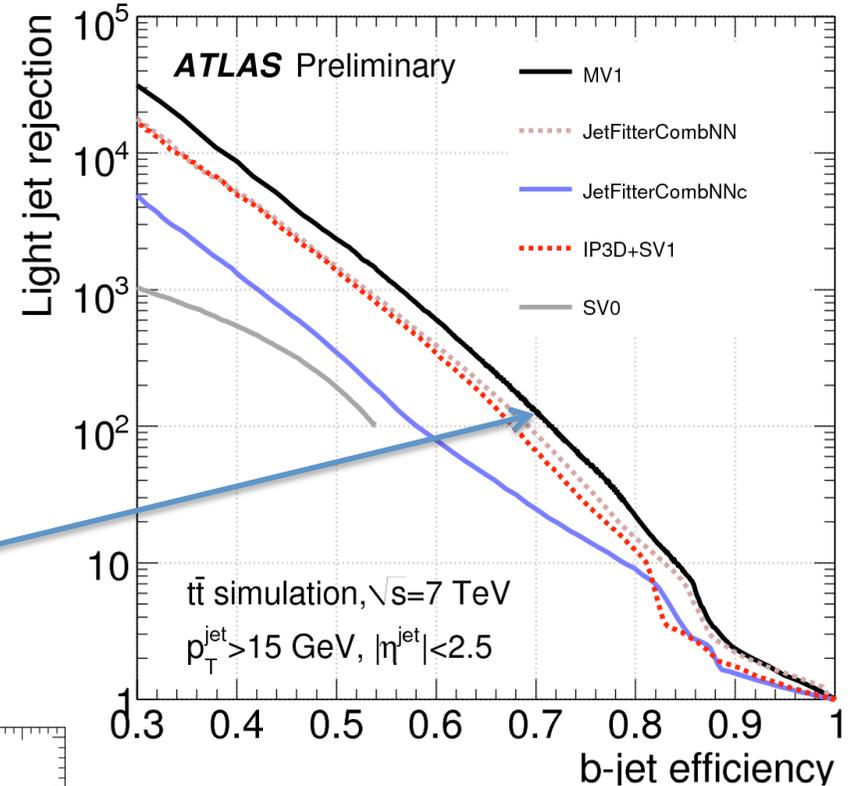
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Z → μμ candidate with 20 reconstructed vertices



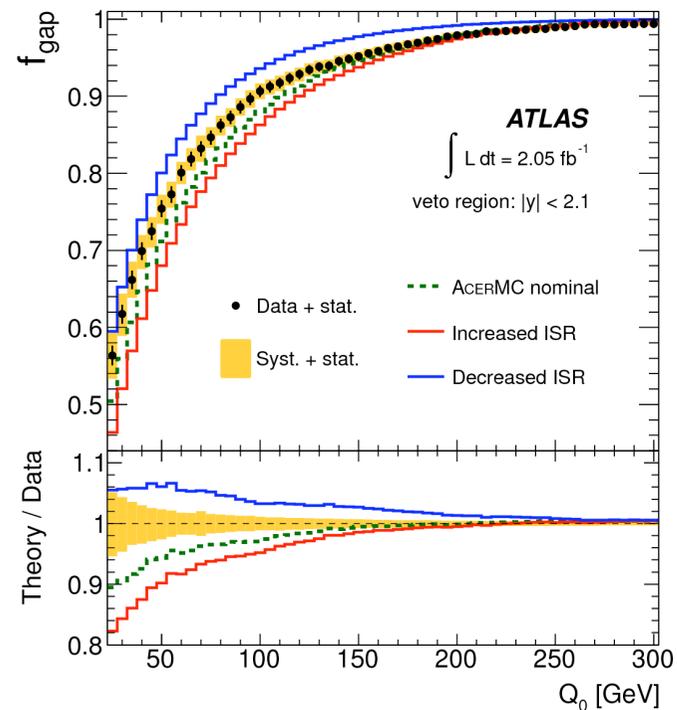
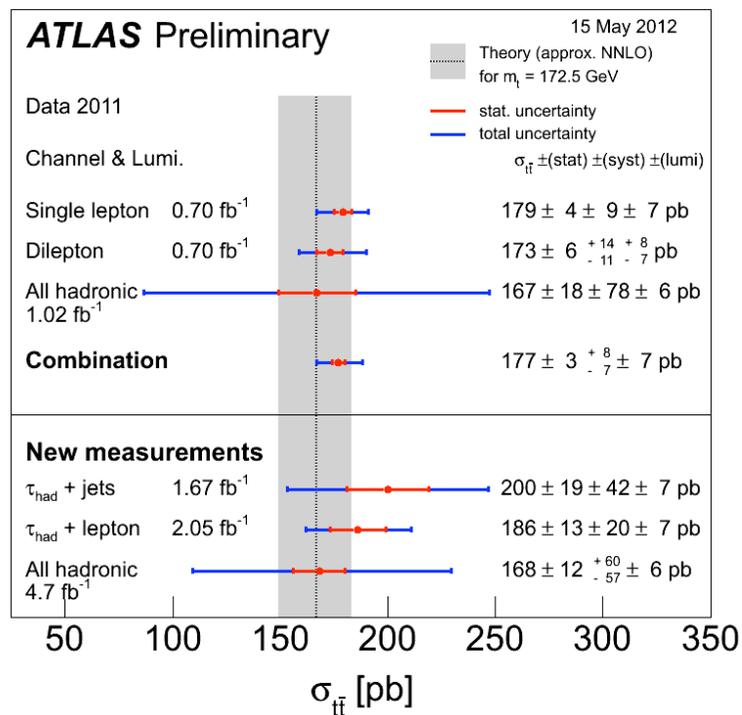
B-tagging at ATLAS

- Phenomenal b-tagging performance thanks to excellent Pixel detector performance
- B-tagging calibration with p_{Trel} , System8 [ATLAS-CONF-2012-043] and $t\bar{t}$ events [ATLAS-CONF-2011-089] (5%-19% uncertainty)
- Also first c-tagging calibration based on D^* events (12%-25% uncertainty) [ATLAS-CONF-2012-039]



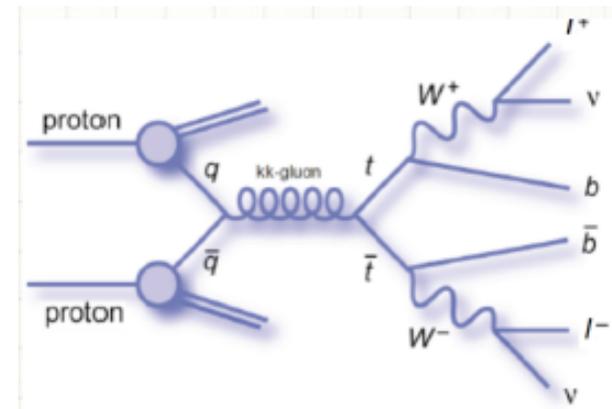
Top Quark Precision Physics Era

- $O(1M)$ $t\bar{t}$ produced at ATLAS in 2011 (~ 10 times Tevatron statistics)
- $t\bar{t}$ understanding important \rightarrow $t\bar{t}$ dominant background for many NP searches
 - $\sigma_{t\bar{t}}$ experimental precision 6% - approx. NNLO theory uncertainty $\sim 10\%$
 - Measurement of fraction of $t\bar{t}$ events with central jet veto reduces ISR/FSR modeling uncertainties by factor of ~ 2 [arXiv:1203.5015]



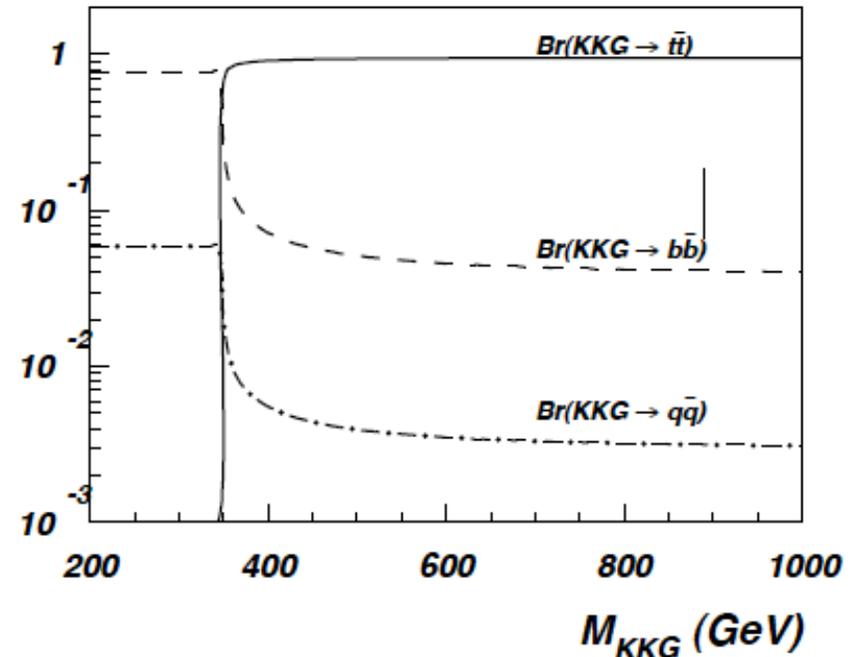
Resonance Searches in $t\bar{t}$

- Resonance searches have famous precedents in history
- Search strategy: look for bump in $m_{t\bar{t}}$ mass distribution
 - 3 different signatures depending on W boson decay from $t \rightarrow Wb$
- Experimental challenge
 - Understand detector effects (resolution, efficiency) at very high momentum
 - Almost no control samples for high- p_T leptons, W bosons, top quarks...
 - However, clean signal expected over SM tail



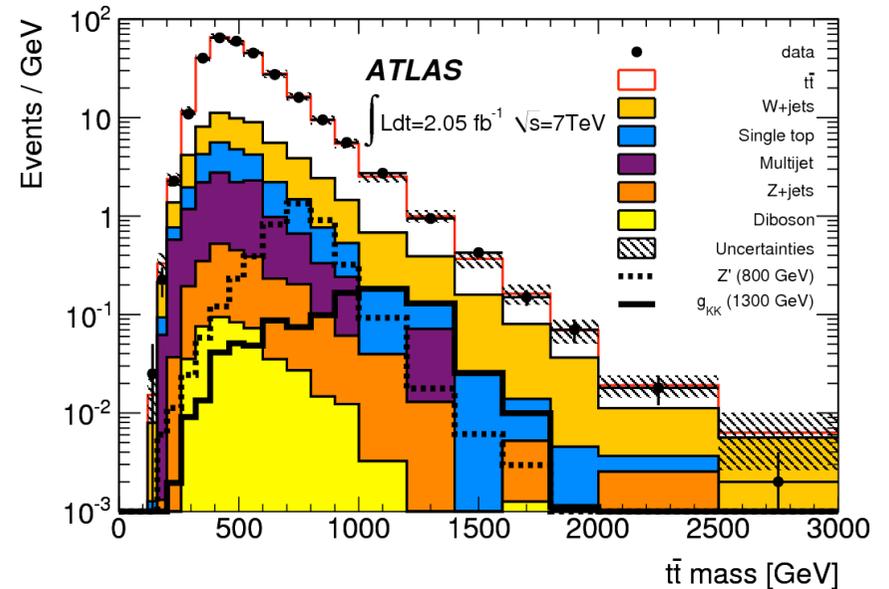
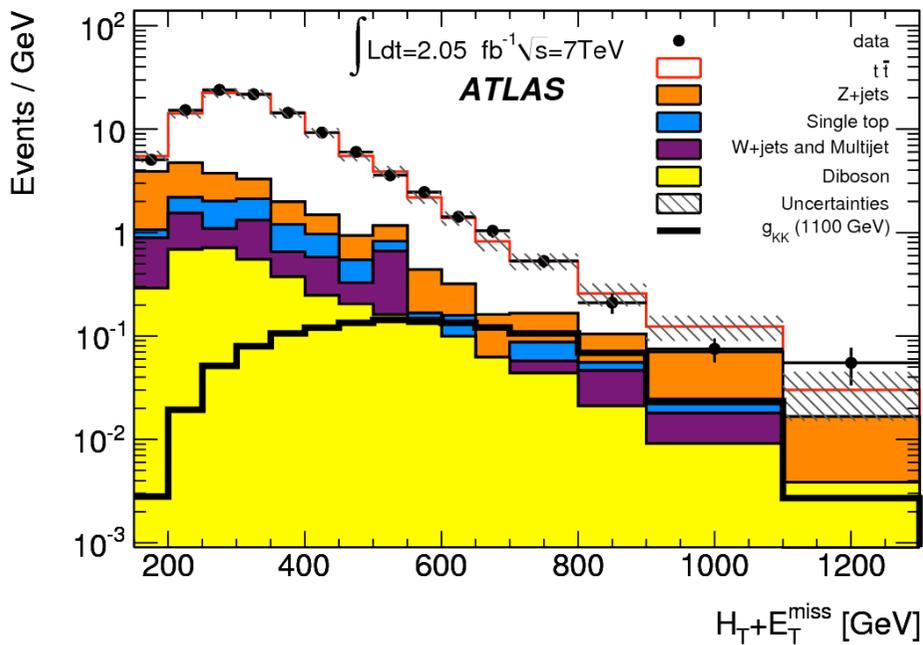
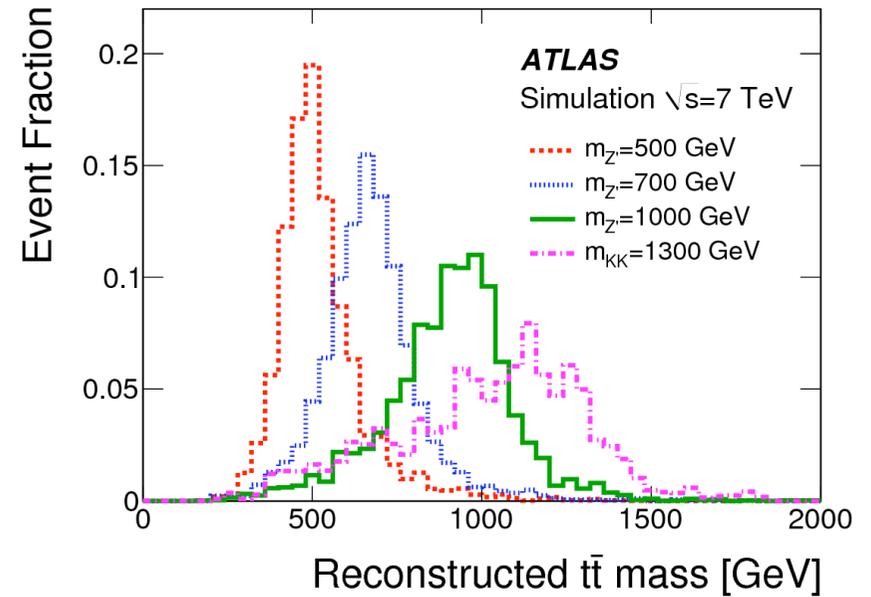
Resonance Searches in $t\bar{t}$

- Benchmark models:
 - Z' boson
 - Leptophobic topcolor model
 - Narrow: $\Gamma/m = 1.2\%$
 - Phys. Rev. D 49 (1994) 4454;
arXiv:hep-ph/9911288;
arXiv:1112.4928
 - Kaluza-Klein Gluon (KKG)
 - Colored resonance
 - Randall-Sundrum extra dimension models
 - $\Gamma/m = 10\text{-}15\%$
 - Phys. Rev. D 77 (2008) 015003;
Phys. Rev. D 76 (2007) 115016;
JHEP 09 (2007) 074

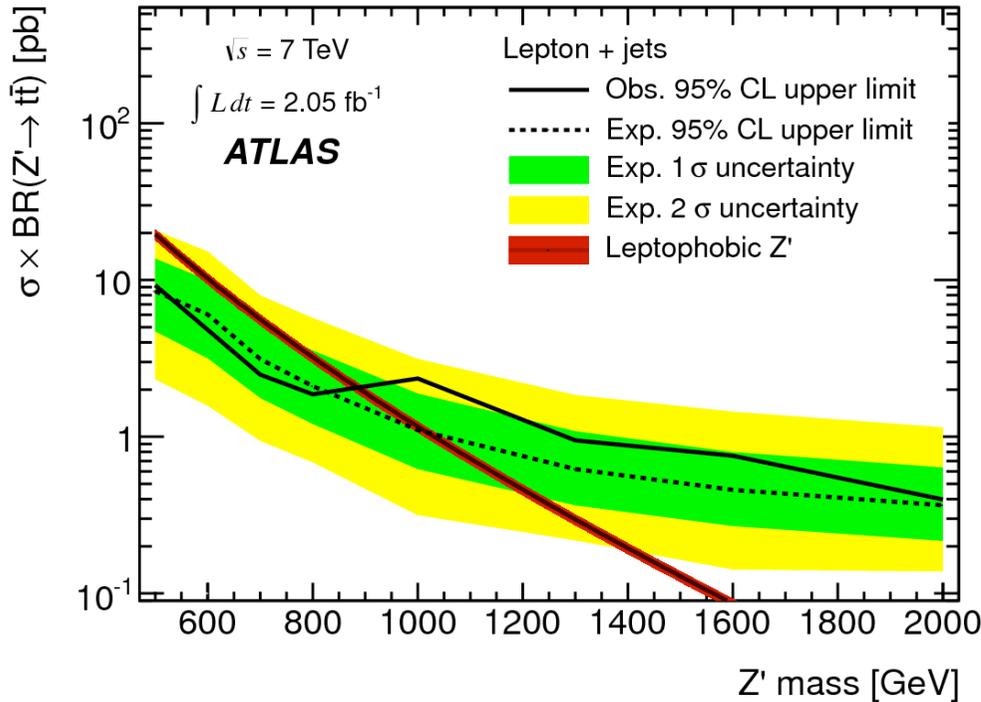


Search for $t\bar{t}$ Resonances

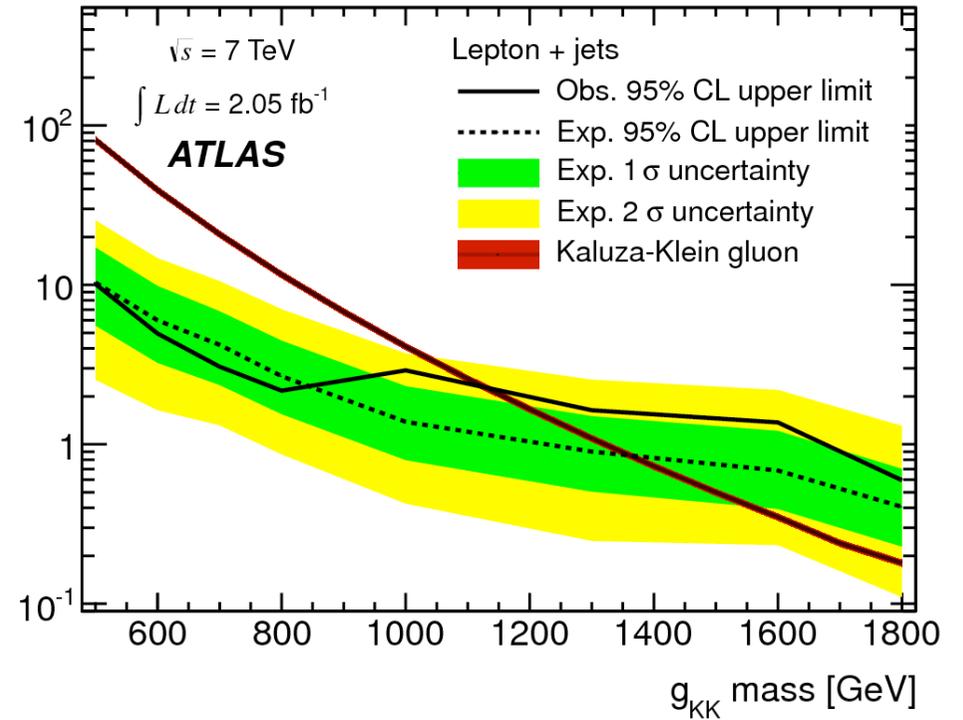
- L+jets discriminant: $m_{t\bar{t}}$ (ΔR_{\min} method, removes jets “far” from rest of activity)
- Dilepton discriminant: $H_T + E_T^{\text{miss}}$



Search for $t\bar{t}$ Resonances (l+jets)



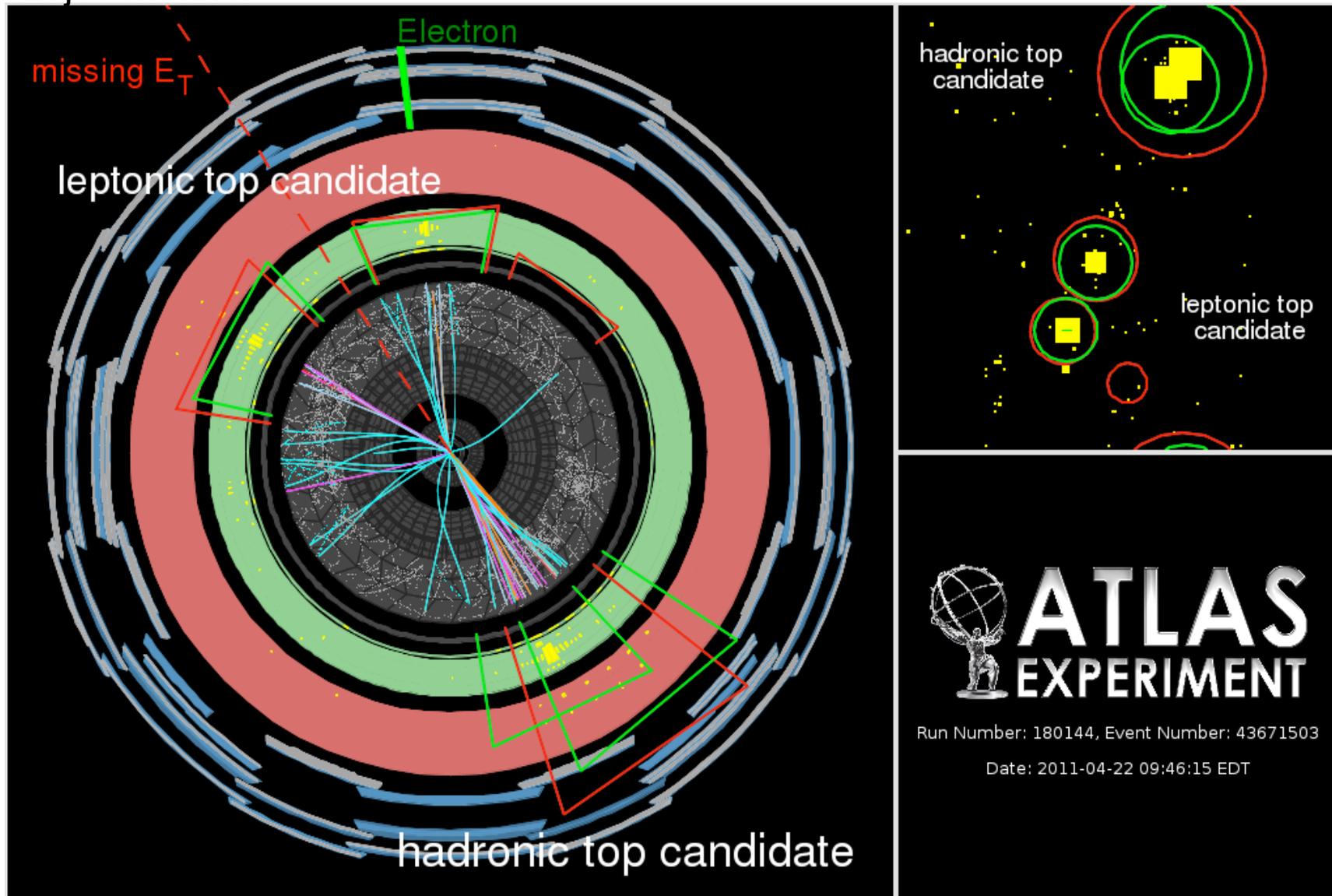
Leptophobic top-color:
 $0.5 \text{ TeV} < m(Z') < 0.88 \text{ TeV}$



RS model:
 $0.5 \text{ TeV} < m(g_{KK}) < 1.13 \text{ TeV}$

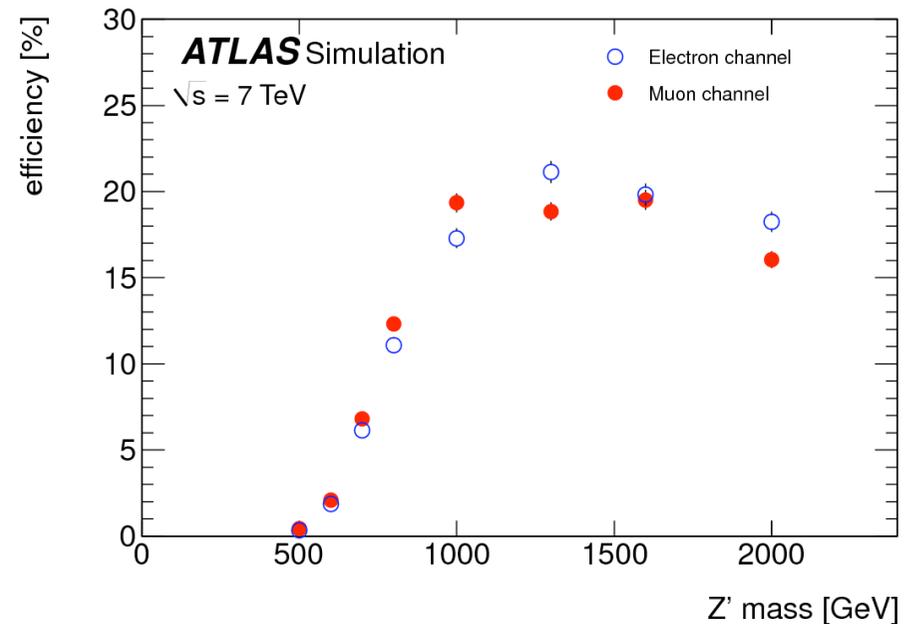
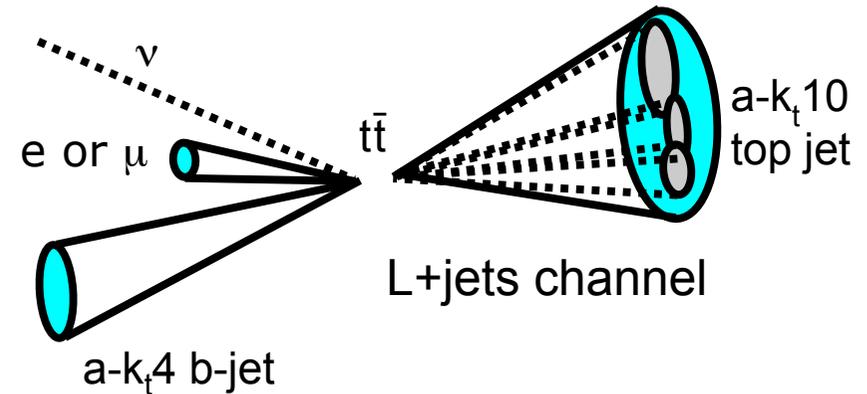
Search for $t\bar{t}$ Resonances (Boosted)

L+jet channel



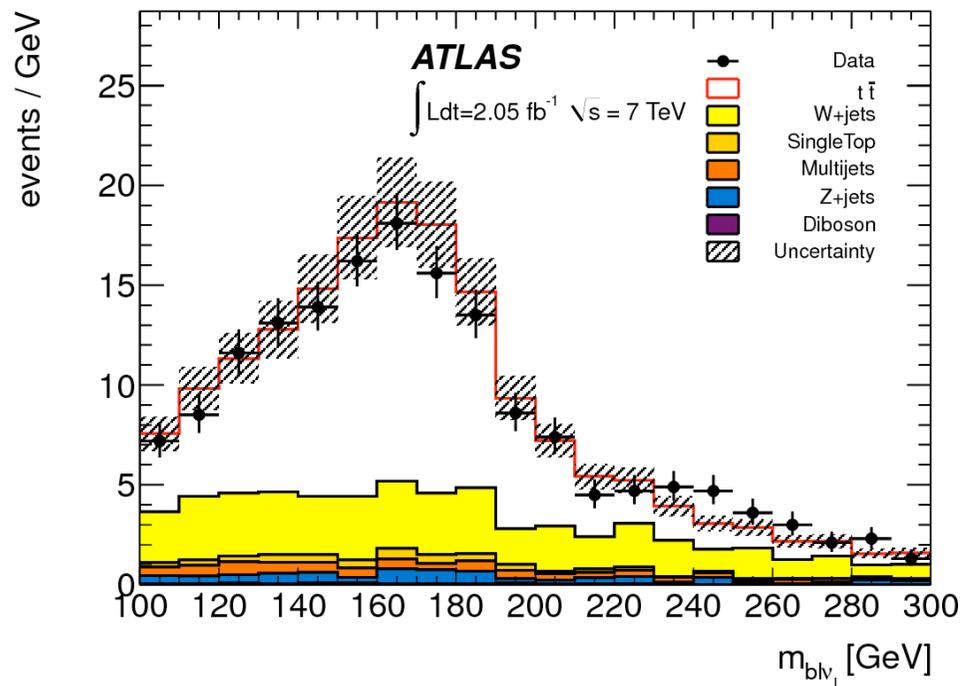
Object and Event Selection (Boosted)

- L+jets channel
- Same e and μ and trigger requirements as resolved analysis
- Leptonic top candidate
 - Take closest jet with $p_T > 30$ GeV with $0.4 < \Delta R(\text{lepton}, \text{jet}) < 1.5$
 - Use W mass hypothesis for neutrino p_z
- Hadronic top candidate
 - 1 anti-kT (R=1.0) fat jet
 - Large distance to jet from leptonic top: $\Delta R(\text{fat jet}, \text{leptonic top jet}) > 1.5$
 - $p_T > 250$ GeV, $m_j > 100$ GeV
 - Recluster (using FastJet) with kT-Algorithm and require last splitting scale $\sqrt{d_{12}} > 40$ GeV

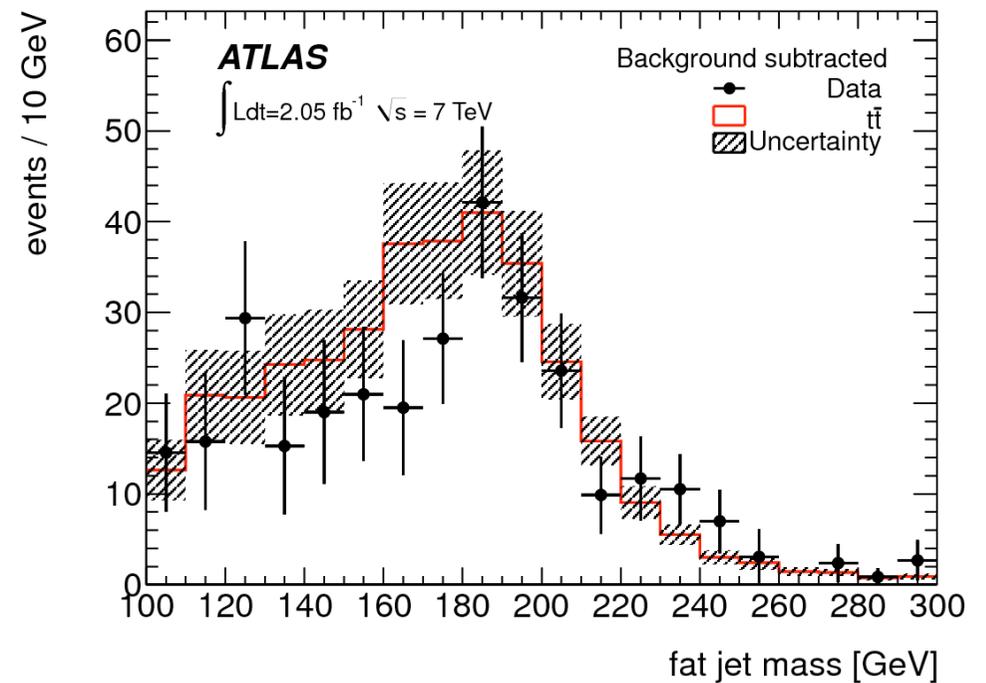


Search for $t\bar{t}$ Resonances (Boosted)

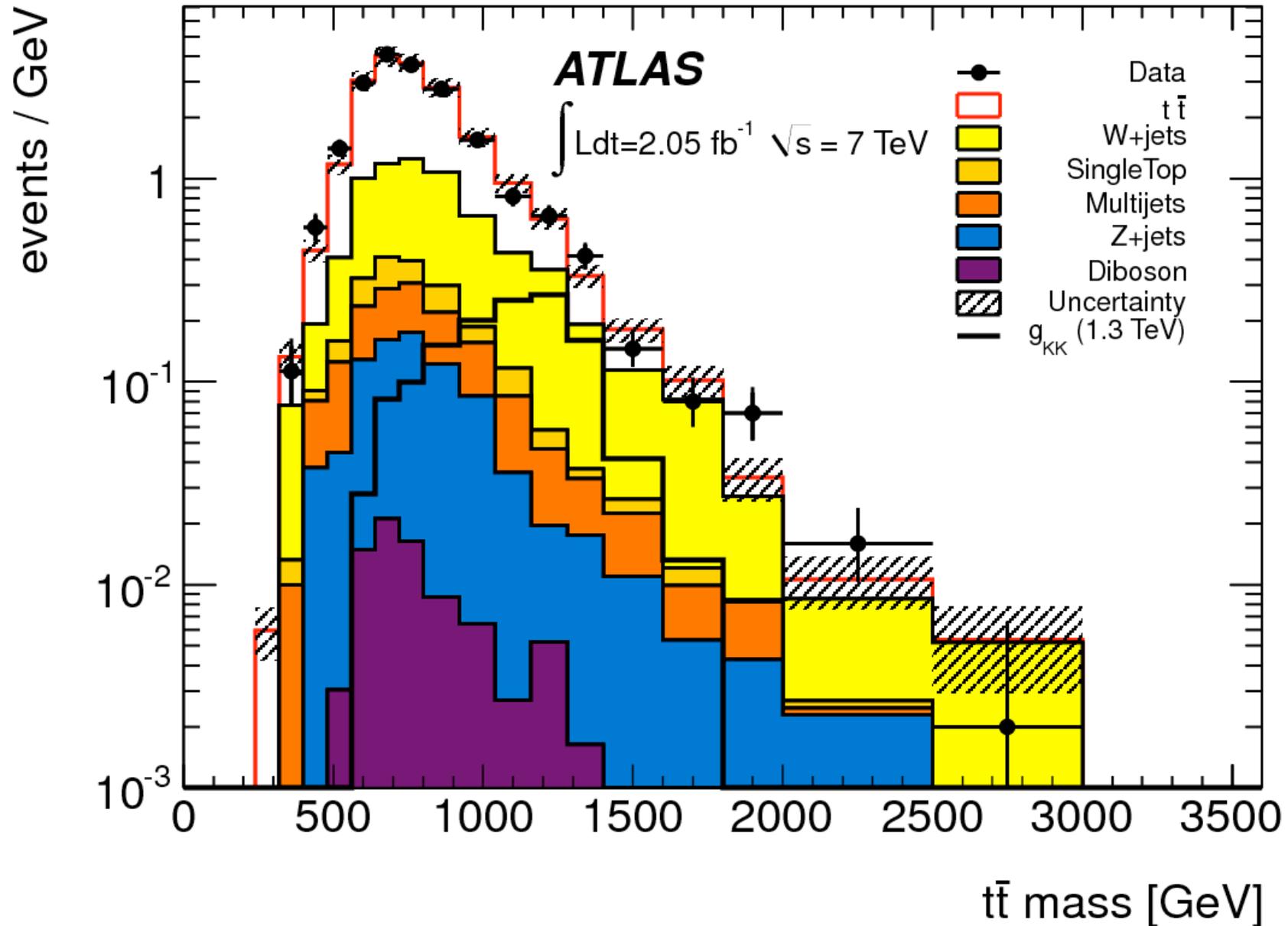
Leptonic top mass



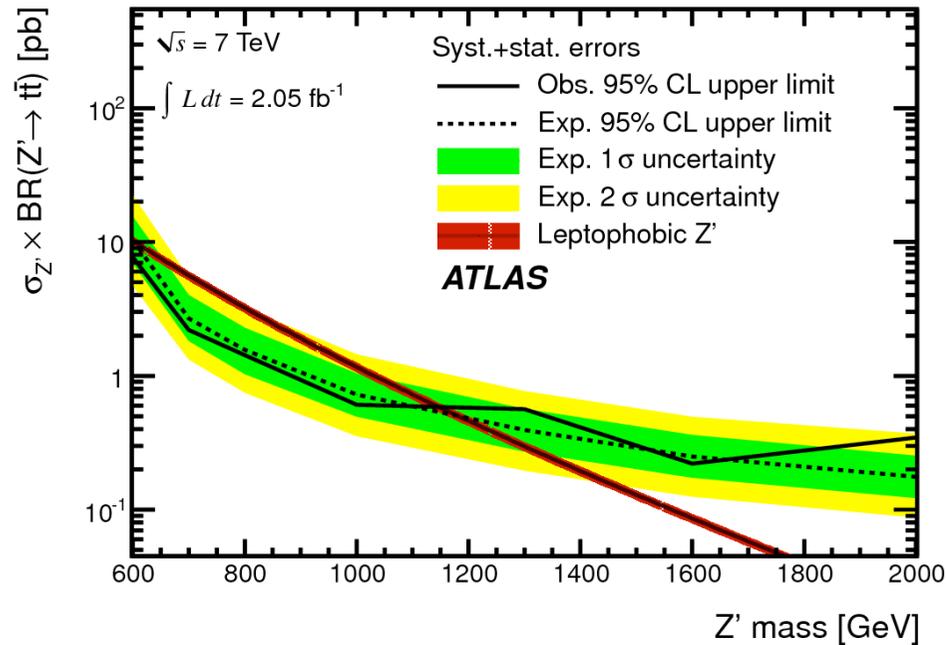
Hadronic top mass



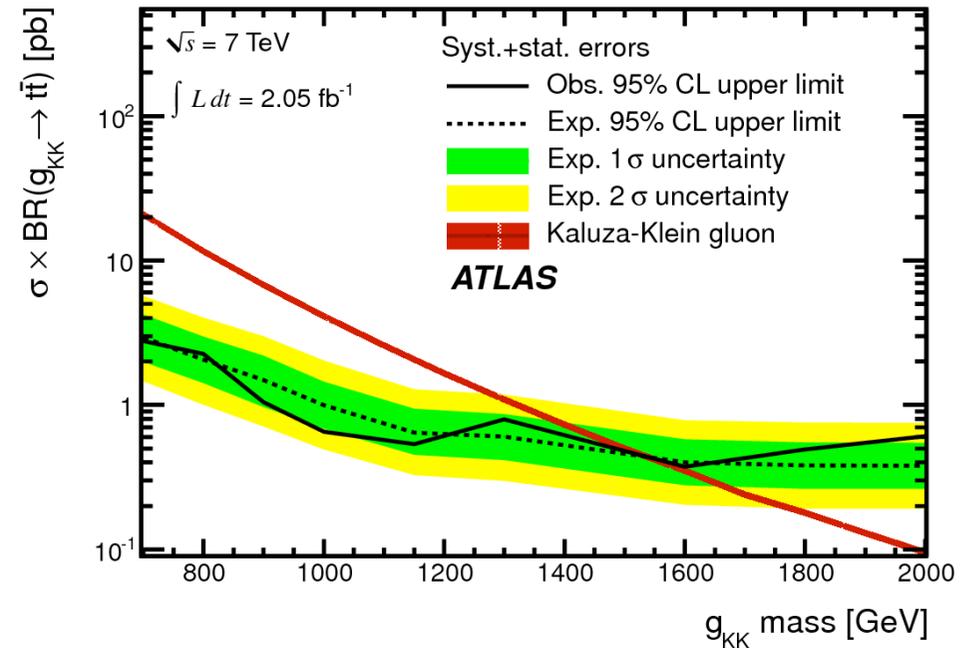
Search for $t\bar{t}$ Resonances (Boosted)



Search for $t\bar{t}$ Resonances (Boosted)



Leptophobic top-color:
 $0.6 \text{ TeV} < m(Z') < 1.15 \text{ TeV}$



RS model:
 $0.7 \text{ TeV} < m(g_{KK}) < 1.5 \text{ TeV}$

We have not seen SUSY yet

Is SUSY in trouble?

Compulsory Natural SUSY

1500 \overline{g}

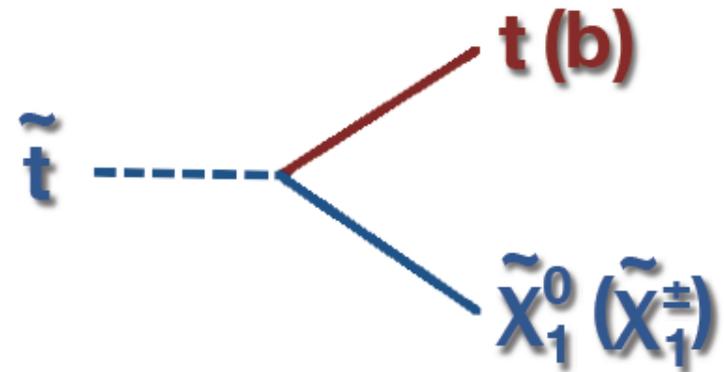
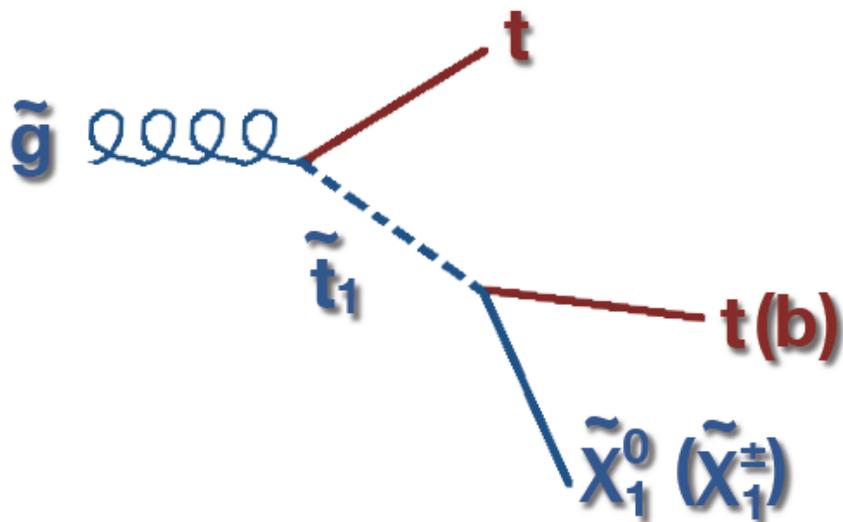
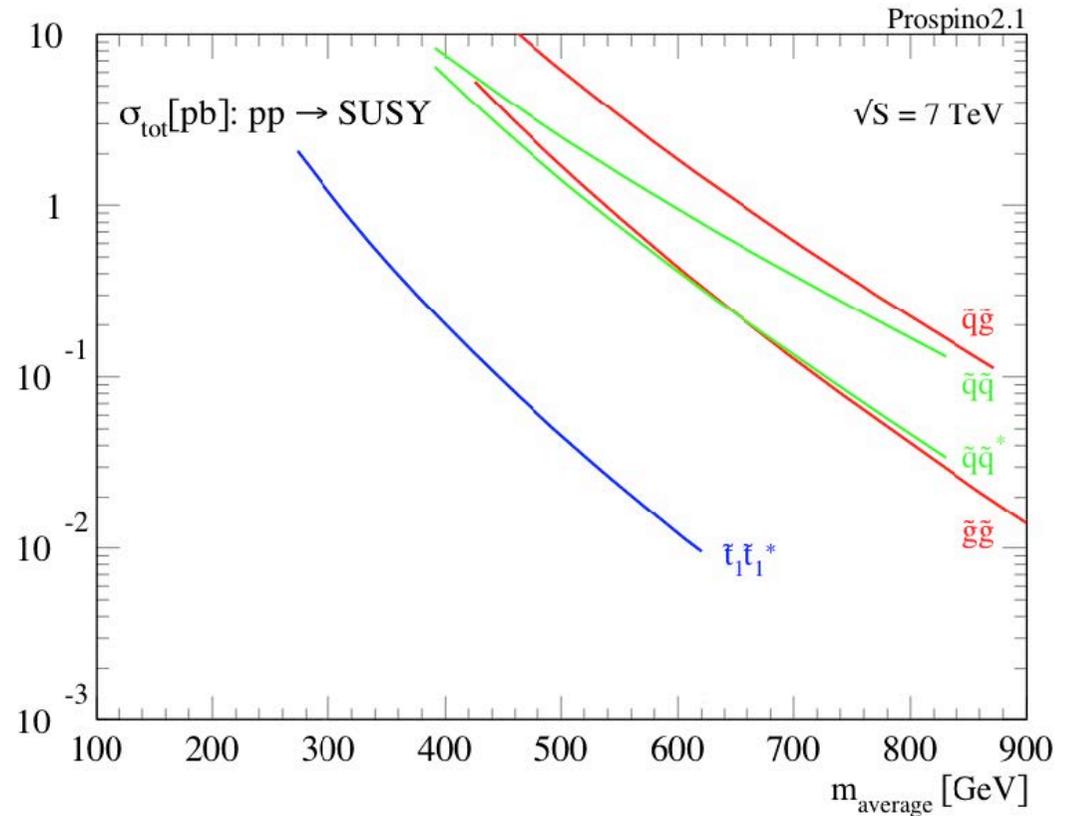
400 $\tilde{t}_{L,R}, \tilde{b}_L$

120 h

Unavoidable tunings: $\left(\frac{400}{m_{\tilde{t}}}\right)^2, \left(\frac{4m_{\tilde{t}}}{M_{\tilde{g}}}\right)^2$

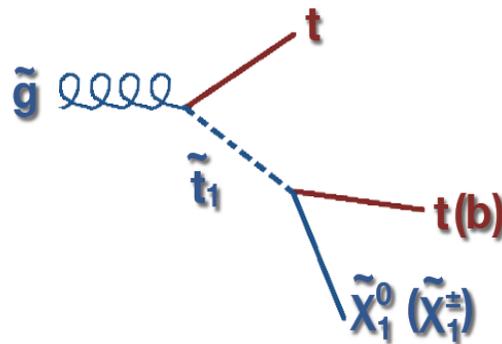
3rd Generation SUSY Searches

- Two ways to search for them
 - Gluino cascade decays
 - Direct pair production



Gluino Mediated Stop Production

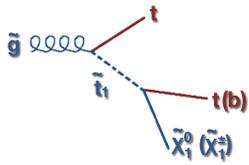
- Final state depending on W boson decay modes / #b-jets
 - 1 lepton + jets + E_T^{miss} (lepton trigger) [PRD 85 (2012) 112006, arXiv:1203.6193]
 - 2 same-sign leptons + jets + E_T^{miss} (lepton trigger) [PRL 108 (2012) 241802, arXiv:1203.5763]
 - Multijets + E_T^{miss} (jet triggers) [arXiv:1206.1760]
 - 3 b-jets [ATLAS-CONF-2012-058, <http://cdsweb.cern.ch/record/1453786>]
- We always assume pair production and 100% BR if not specified otherwise



Signatures

- 4 tops + E_T^{miss}
- 2 tops + 2 b's + E_T^{miss} + X

Glauino Mediated Stop – 1 Lepton Channel



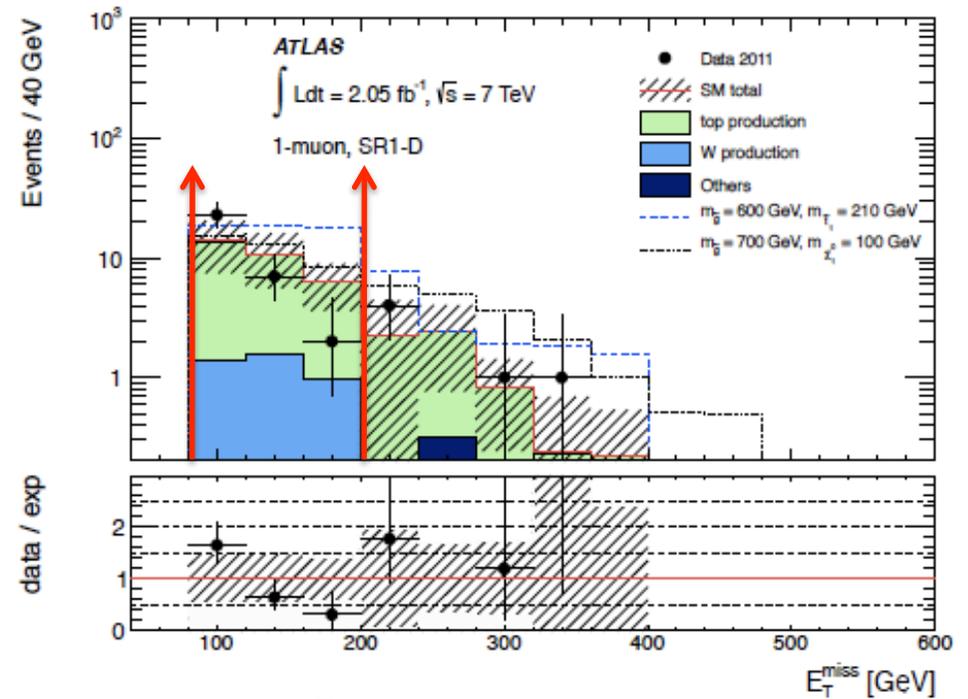
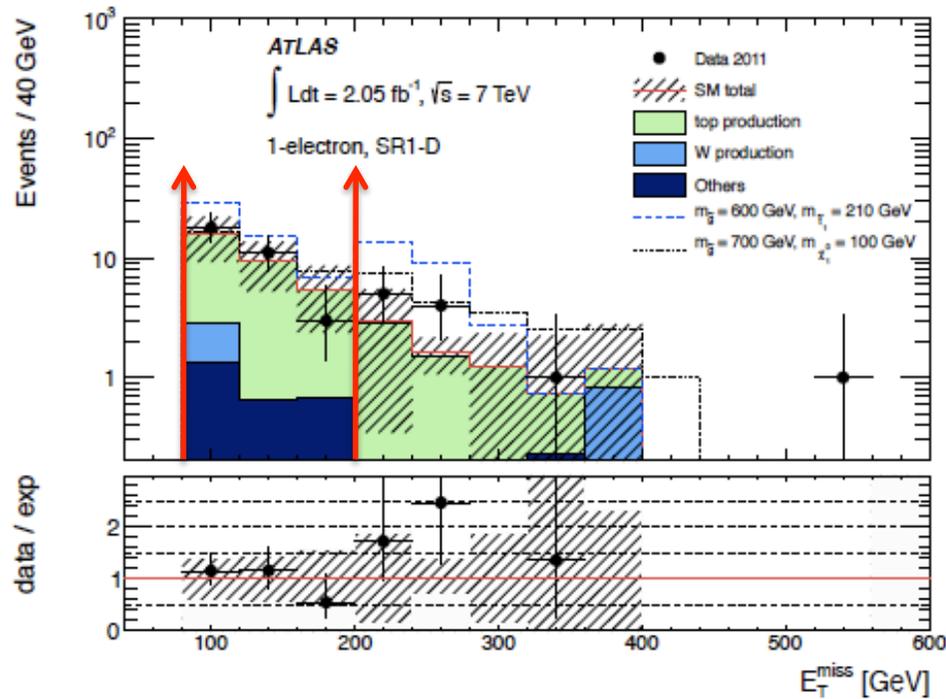
- Electron/muon $p_T > 25/20$ GeV
- ≥ 4 jets with $p_T > 50$ GeV (leading above 60 GeV)
- $m_T > 100$ GeV
- B-tagging: ≥ 1 jet b-tagged

Background estimated from data:

$$N_{SR} = \frac{N_{SR}^{MC}}{N_{CR}^{MC}} (N_{CR}^{obs} - N_{CR}^{res})$$

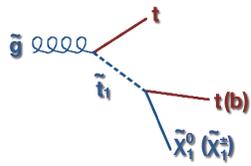
$$m_T = \sqrt{2p_T^l E_T^{miss} \cdot (1 - \cos \Delta\phi[l, E_T^{miss}])}$$

$$m_{eff} \equiv \Sigma |p_T^{jet}| + (\Sigma |p_T^{el/mu}|) + E_T^{miss} > 700 \text{ GeV}$$



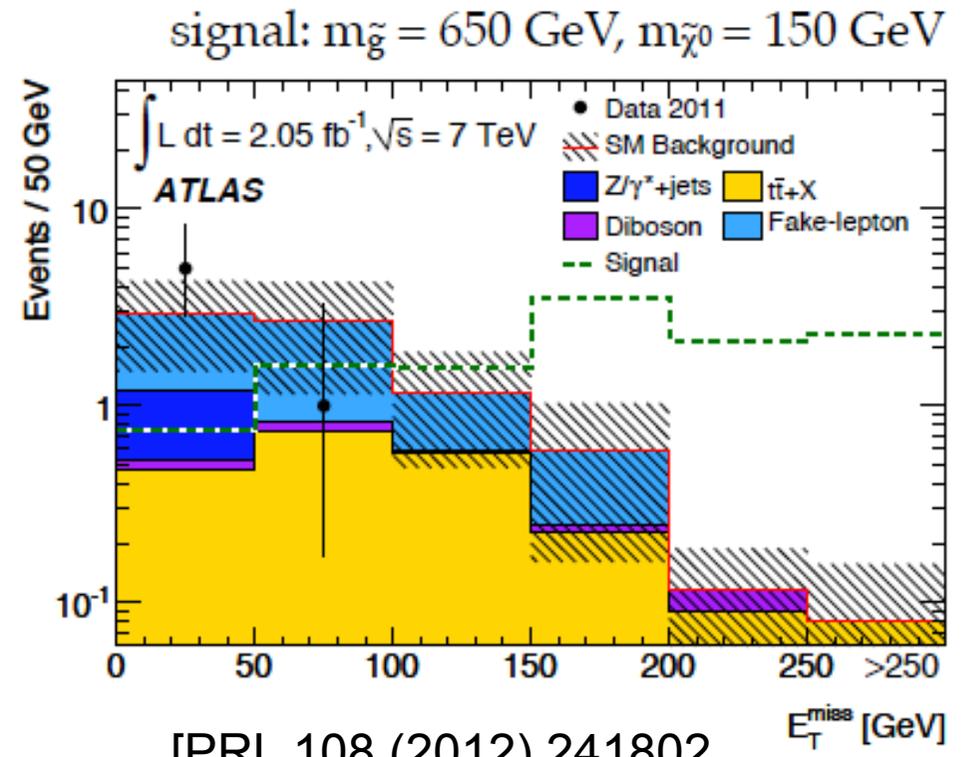
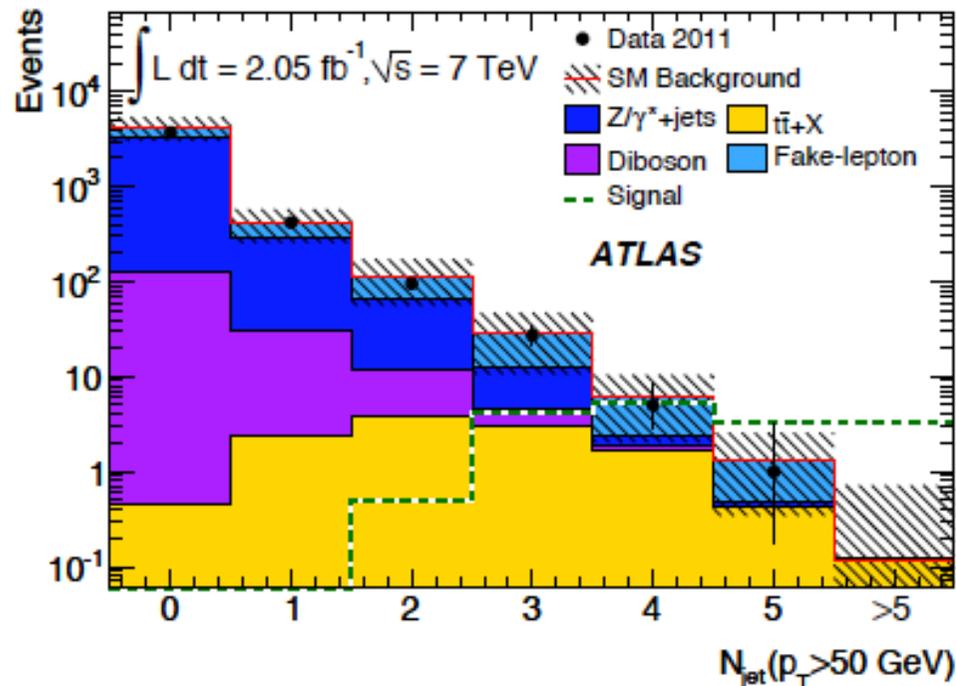
[PRD 85 (2012) 112006,
arXiv:1203.6193]

Glauino Mediated Stop – SS Lepton Channel



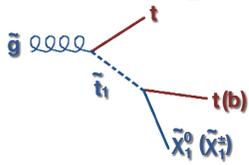
	SR1	SR2
$t\bar{t} + X$	0.37 ± 0.26	0.21 ± 0.16
Diboson	0.05 ± 0.02	0.02 ± 0.01
Fake-lepton	0.34 ± 0.20	< 0.17
Charge mis-ID	0.08 ± 0.01	0.039 ± 0.007
Total SM	0.84 ± 0.33	0.27 ± 0.24
Observed	0	0
σ_{vis}^{obs} [fb]	< 1.6	< 1.5
σ_{vis}^{exp} [fb]	$< 1.7^{+0.5}_{-0.1}$	$< 1.6^{+0.2}_{-0.1}$

- Electron/muon $p_T > 20/20$ GeV
- ≥ 4 jets with $p_T > 50$ GeV
- $E_T^{miss} > 150$ GeV
- $m_T > 100$ GeV (SR2)



[PRL 108 (2012) 241802,
arXiv:1203.5763]

Gluino Mediated Stop – 3 b-jets

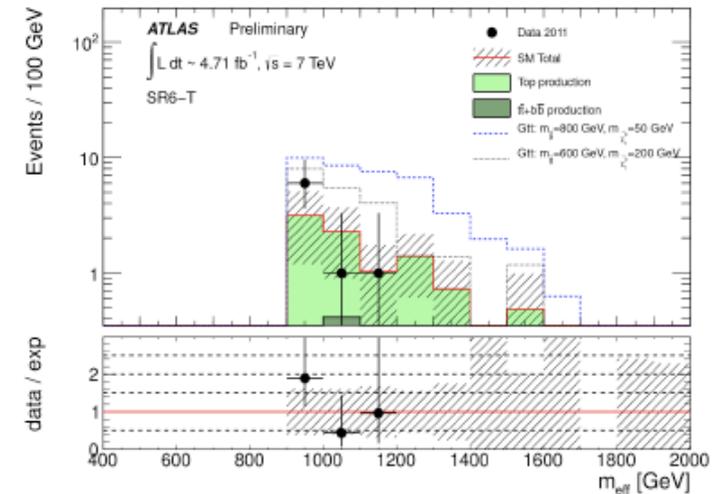
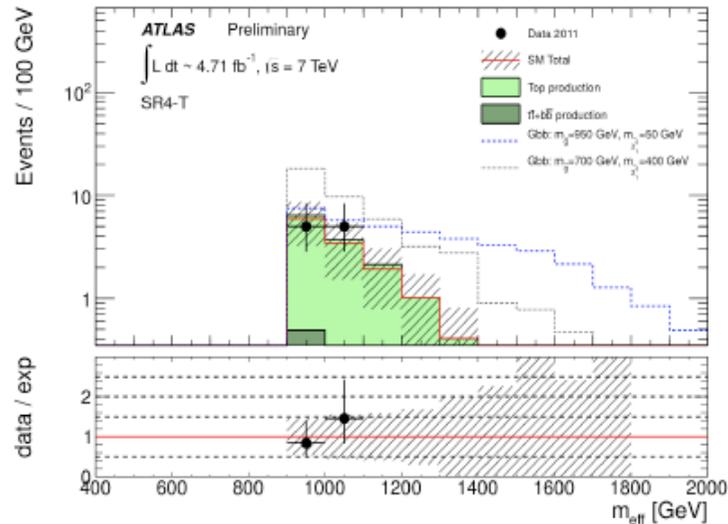
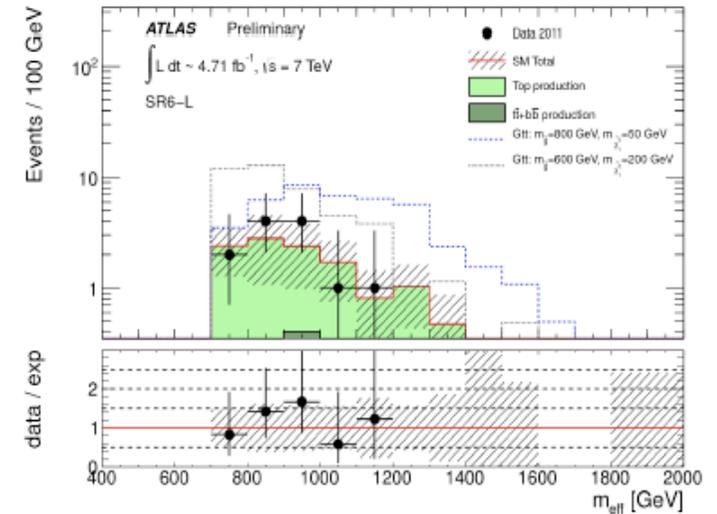


- SR's based on E_T^{miss} and m_{eff}

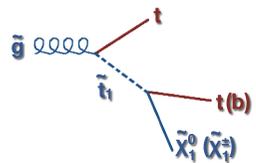
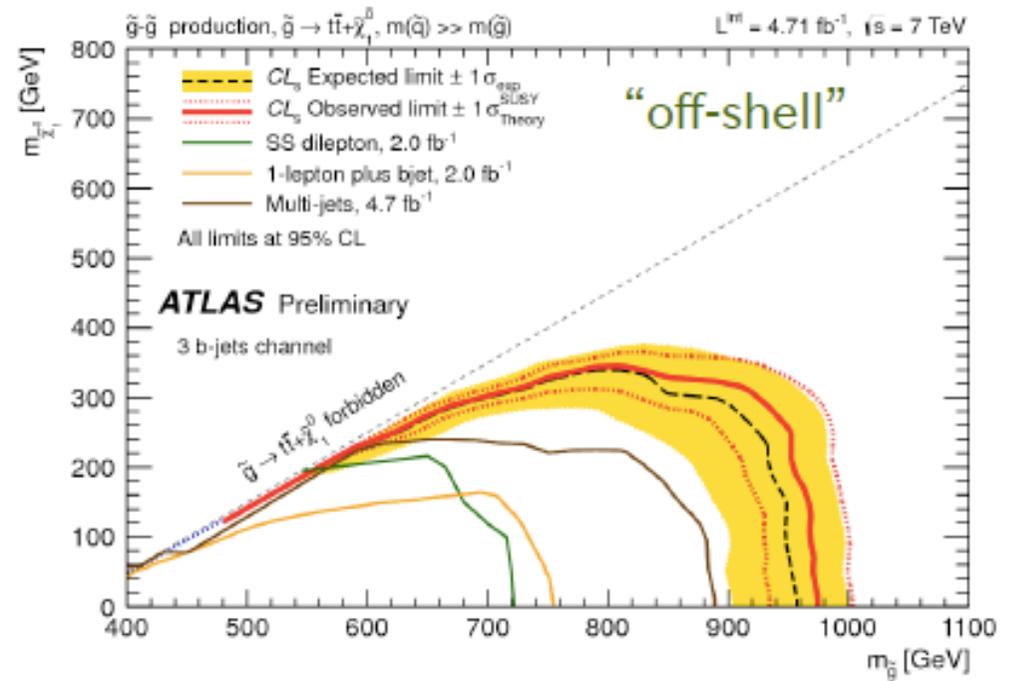
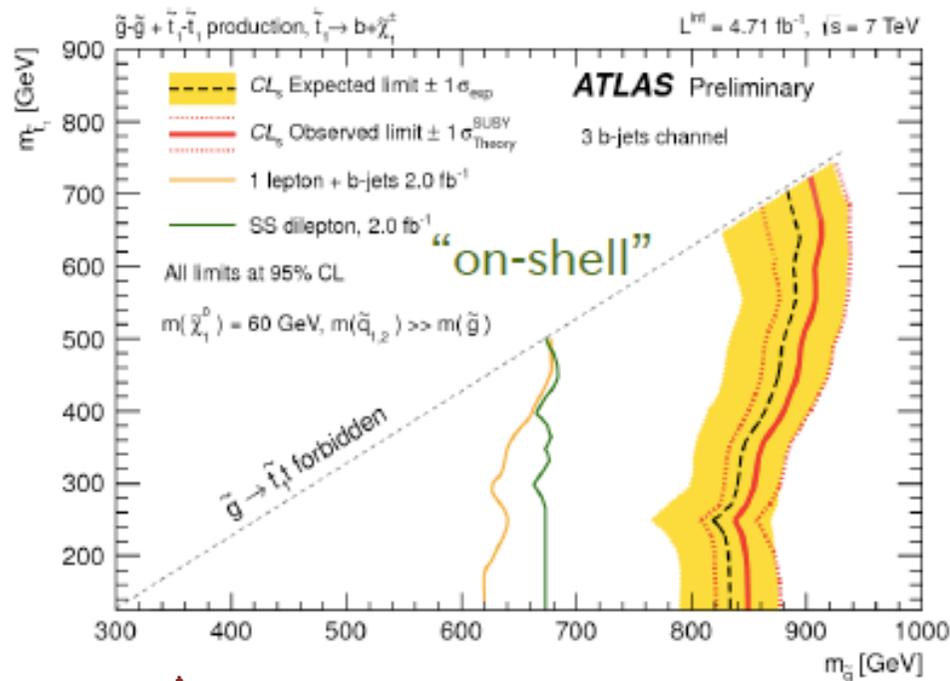
SR	$t\bar{t}$ +jets (MC)	others	SM	data
SR4-L	33.3 ± 7.9 (32.6 ± 15.4)	11.1 ± 4.9	44.4 ± 10.0	45
SR4-M	16.4 ± 4.1 (16.1 ± 8.4)	6.6 ± 2.9	23.0 ± 5.4	14
SR4-T	9.7 ± 2.1 (11.4 ± 5.4)	3.8 ± 1.6	13.3 ± 2.6	10
SR6-L	10.3 ± 3.3 (10.0 ± 6.2)	2.4 ± 1.4	12.7 ± 3.6	12
SR6-T	8.3 ± 2.4 (7.9 ± 5.3)	1.6 ± 1.1	9.9 ± 2.6	8

CR:

- 2 b-jets
- 1-lep



Glauino Mediated Stop – 3 b-jets

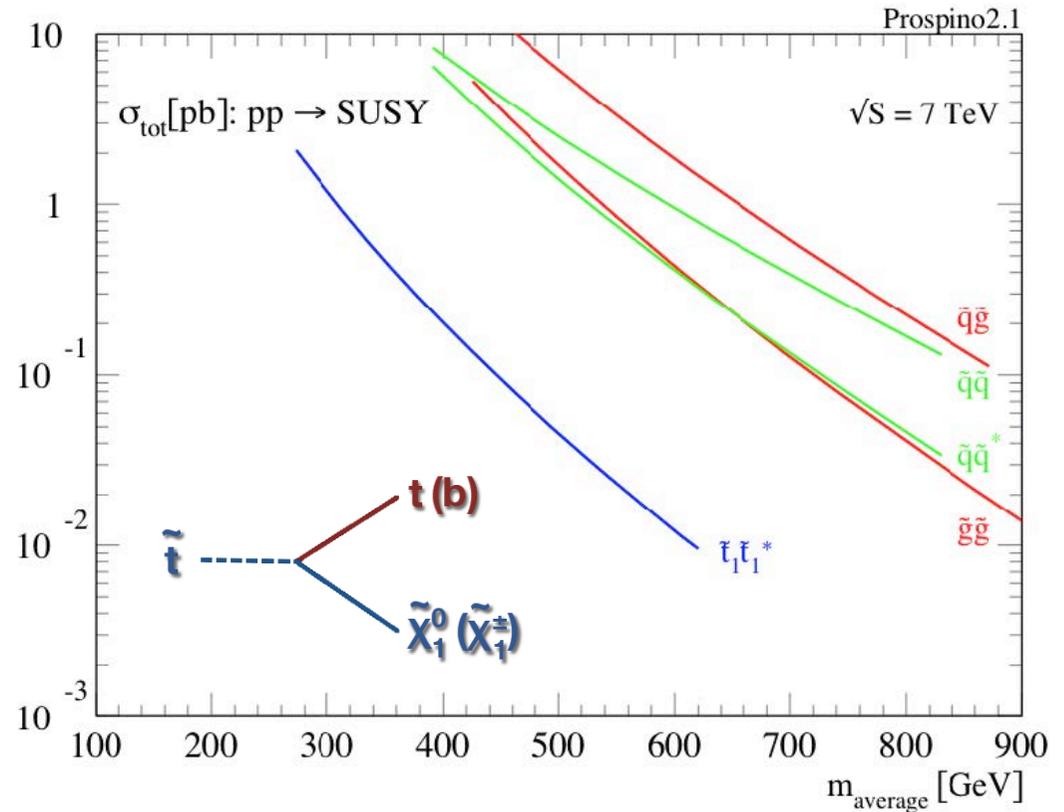
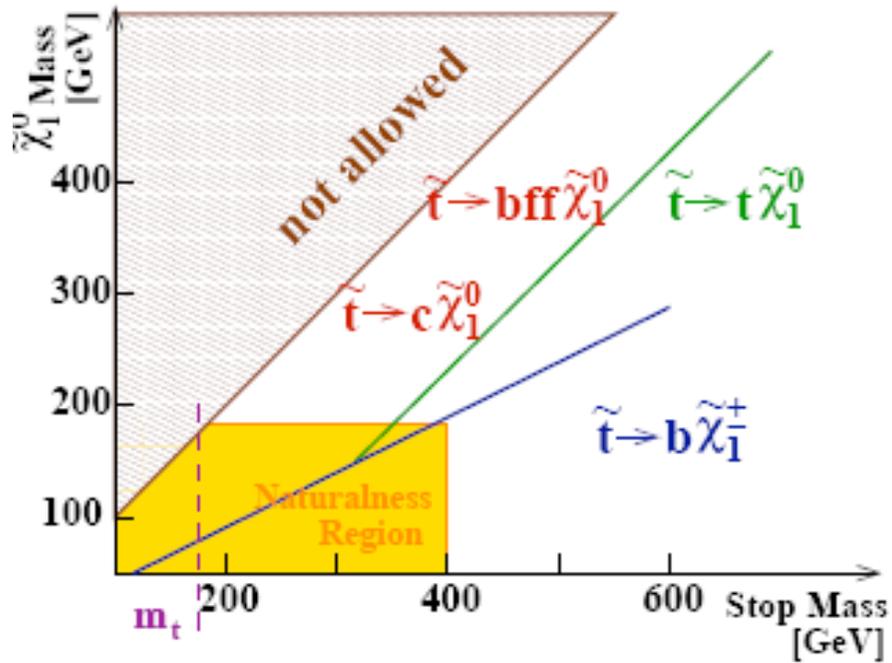


Summary:
 “On shell”: stop excluded up to 700 GeV for gluino below 900 GeV
 “Off shell”: gluino mass exclusion getting close to 1 TeV

Multi-jets [arXiv:1206.1760]:

- Electron/muon veto
- $\geq 6-9$ jets with $p_T > 55$ (80) GeV
- E_T^{miss} significance > 4

Direct Stop Pair Production



- Signature searches I will present
 - $t\bar{t} + E_T^{\text{miss}}$

Direct Stop Pair Production

The large number of topologies require a dedicated strategy to cover the maximum number of possibilities in a coherent way.

Challenge: large SM background and soft objects

2-lepton + jets (very light stop) (4.7 fb^{-1})
ATLAS-CONF-2012-059
<http://cdsweb.cern.ch/record/1453787>

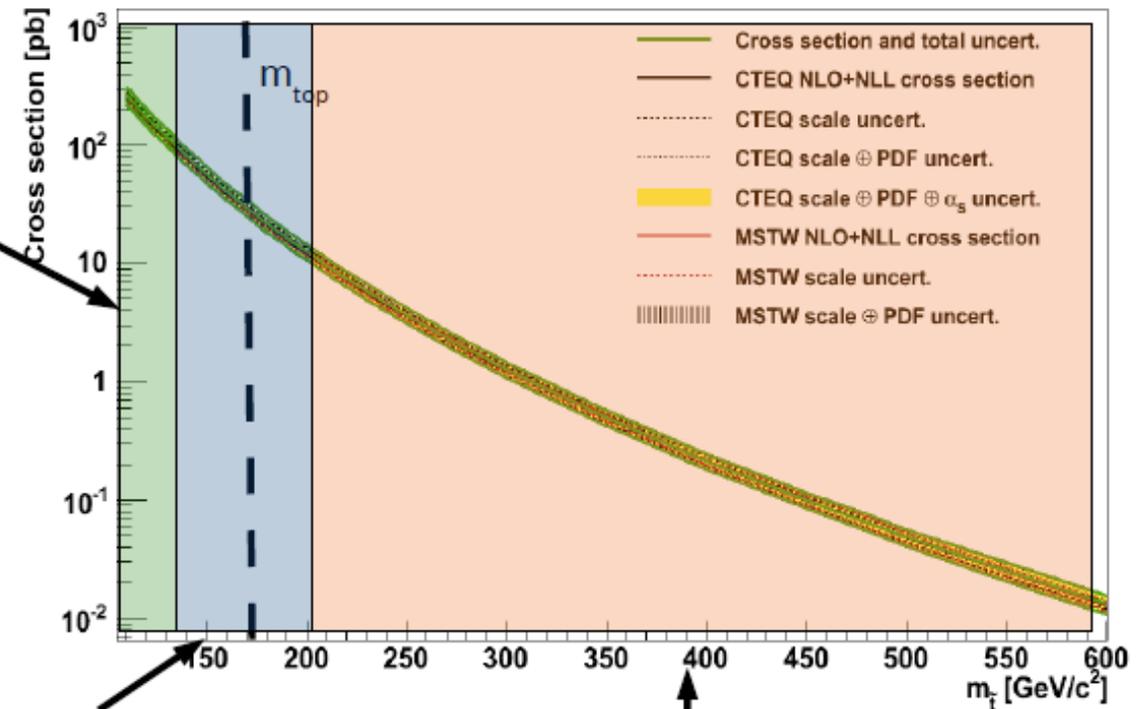
b-jets + 1-2 lep. (light stop) (4.7 fb^{-1})
ATLAS-CONF-2012-070
<http://cdsweb.cern.ch/record/1460267>

Challenge: signatures mimic $t\bar{t}$ decay

0-lepton + jets (heavy stop) (4.7 fb^{-1})
ATLAS-CONF-2012-074
<http://cdsweb.cern.ch/record/1460271>

2-leptons + jets (heavy stop) (4.7 fb^{-1})
ATLAS-CONF-2012-071
<http://cdsweb.cern.ch/record/1460268>

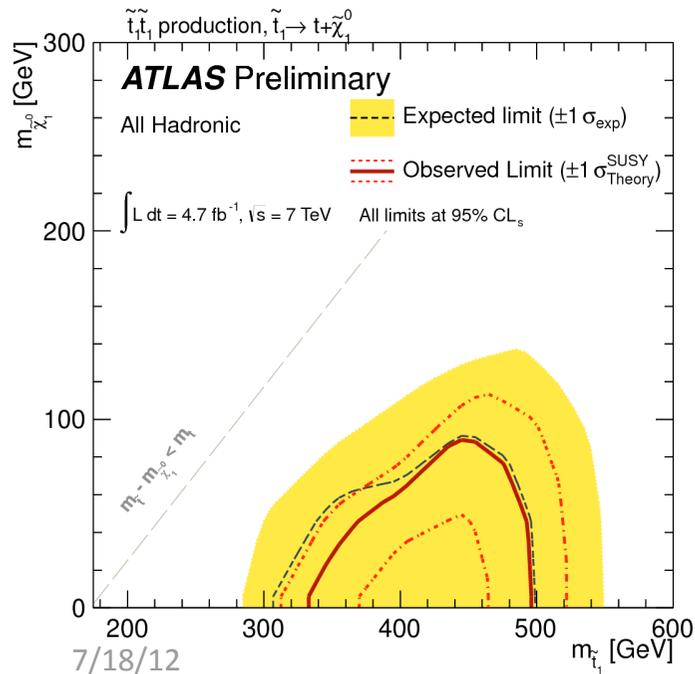
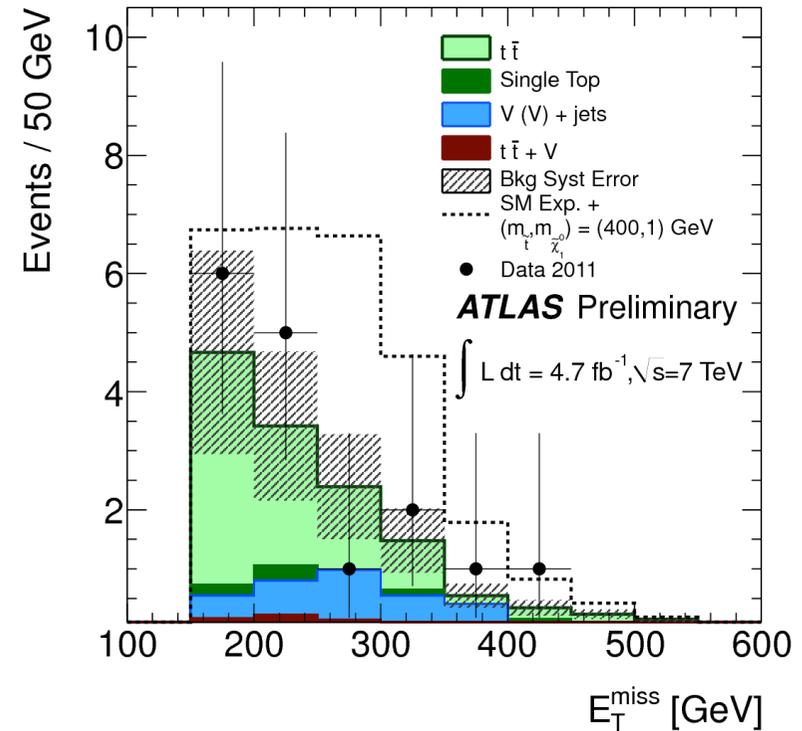
1-lepton + jets (heavy stop) (4.7 fb^{-1})
ATLAS-CONF-2012-073
<http://cdsweb.cern.ch/record/1460270>



Challenge: low cross sections

Direct Stop – 0-lepton Channel

	E_T^{miss}	SRA	SRB
		> 150 GeV	> 260 GeV
$t\bar{t}$		9.2 ± 2.7	2.3 ± 0.6
$t\bar{t} + W/Z$		0.8 ± 0.2	0.4 ± 0.1
Single top		0.7 ± 0.4	0.2 ± 0.3
Z+jets		1.3 ± 1.1 -1.0	0.9 ± 0.8 -0.7
W+jets		1.2 ± 1.4 -1.0	0.5 ± 0.4
Diboson		0.1 ± 0.2 -0.1	0.1 ± 0.2 -0.1
Multi-jets		0.2 ± 0.2	0.02 ± 0.02
Total SM		13.5 ± 3.7 -3.6	4.4 ± 1.7 -1.3
SUSY ($m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}$) = (400, 1) GeV		14.8 ± 4.0	8.9 ± 3.1
Data (observed)		16	4



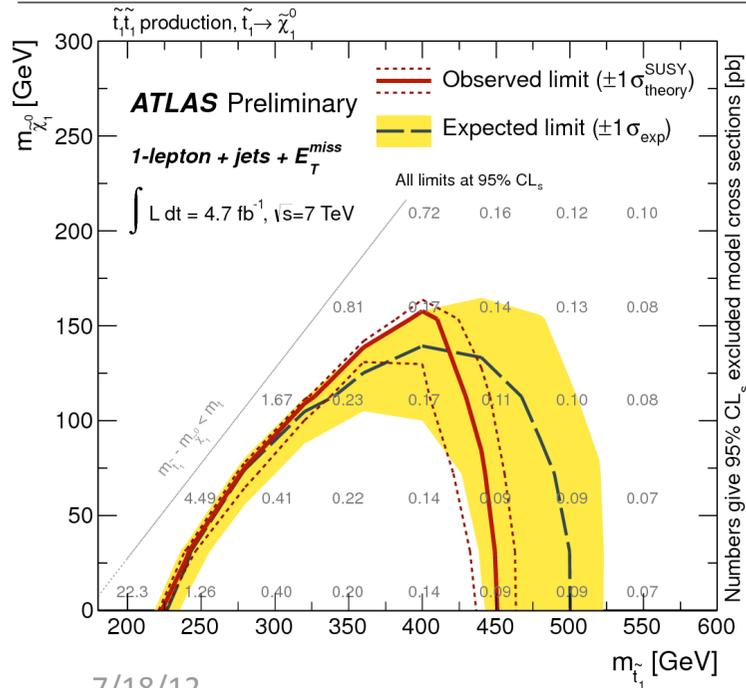
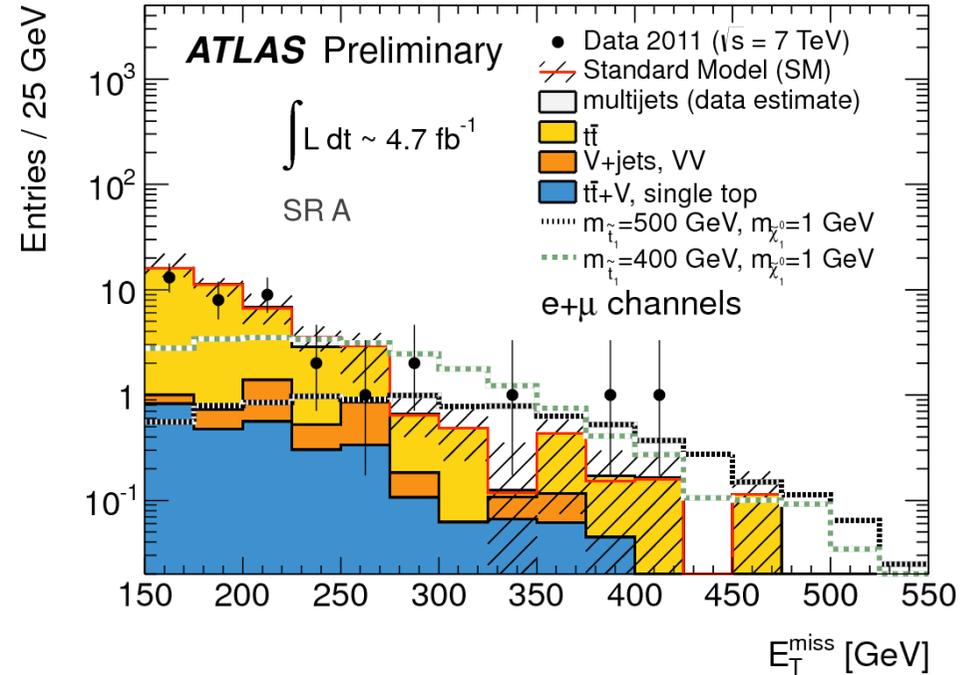
- ≥ 6 jets, ≥ 1 b-tag
- E_T^{miss} , E_T^{miss} angles, tracking vs calo, m_{jjj} (dRmin technique)
- Lepton veto, reduce taus with tracking info and m_T
- Dominant BG: $t\bar{t}$ (l+jets channel)
- Data-driven BG estimate

Direct Stop – 1-lepton Channel

Requirement	SR A	SR B	SR C	SR D	SR E
$E_T^{\text{miss}} [\text{GeV}] >$	150	150	150	225	275
$E_T^{\text{miss}} / \sqrt{H_T} [\text{GeV}^{1/2}] >$	7	9	11	11	11
$m_T [\text{GeV}] >$	120	120	120	130	140

Regions	SR A	SR B	SR C	SR D	SR E
$t\bar{t}$	36 ± 5	27 ± 4	11 ± 2	4.9 ± 1.3	1.3 ± 0.6
$t\bar{t} + V$, single top	2.9 ± 0.7	2.5 ± 0.6	1.6 ± 0.3	0.9 ± 0.3	0.4 ± 0.1
V +jets, VV	2.5 ± 1.3	1.7 ± 0.8	0.4 ± 0.1	0.3 ± 0.1	0.1 ± 0.1
Multijet	$0.4^{+0.4}_{-0.4}$	$0.3^{+0.3}_{-0.3}$	$0.3^{+0.3}_{-0.3}$	$0.3^{+0.3}_{-0.3}$	$0.0^{+0.3}_{-0.0}$
Total background	42 ± 6	31 ± 4	13 ± 2	6.4 ± 1.4	1.8 ± 0.7
Signal benchmark 1 (2)	25.6 (8.8)	23.0 (8.1)	17.5 (6.9)	13.5 (6.2)	7.1 (4.5)
Observed events	38	25	15	8	5

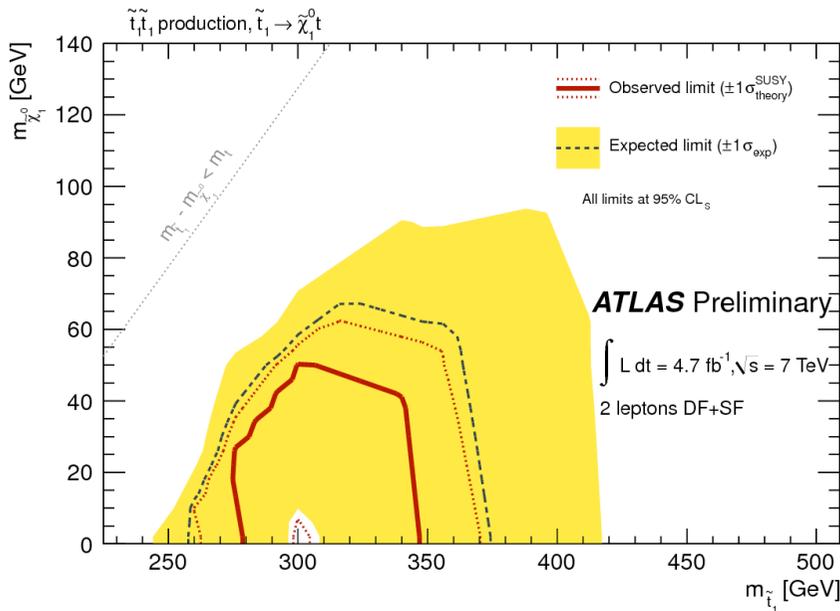
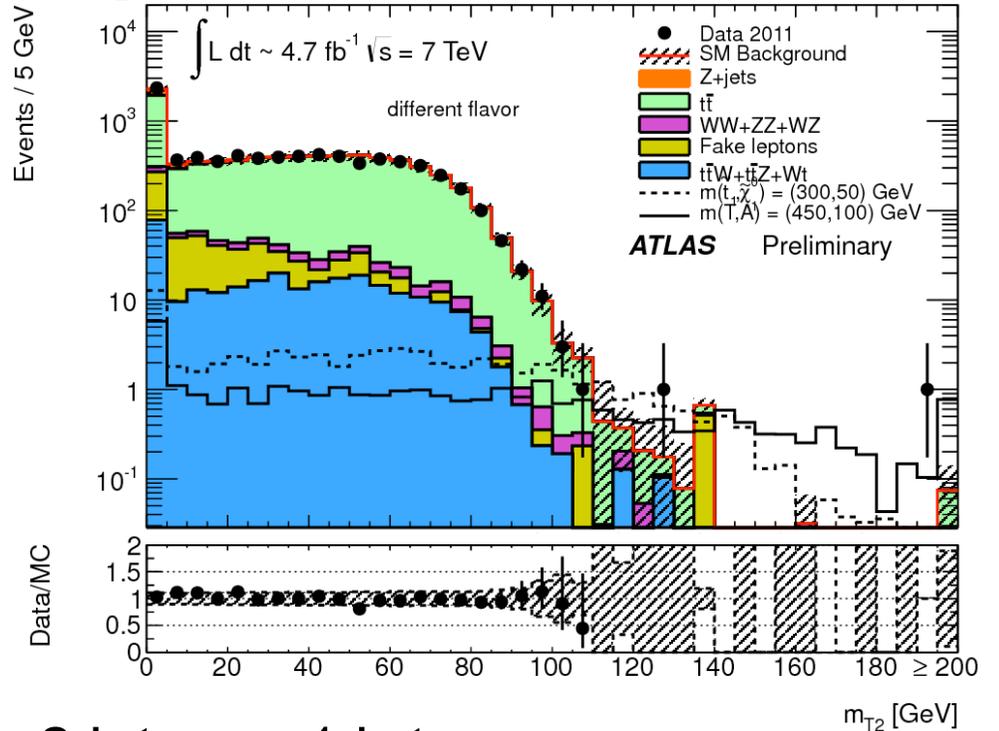
p_0 -values	0.5	0.5	0.32	0.24	0.015
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- ≥ 4 jets, ≥ 1 b-tag
- E_T^{miss} , m_T , m_{jij} (dRmin technique)
- Lepton veto
- Dominant BG: $t\bar{t}$ (dilepton channel)
- Data-driven BG estimate

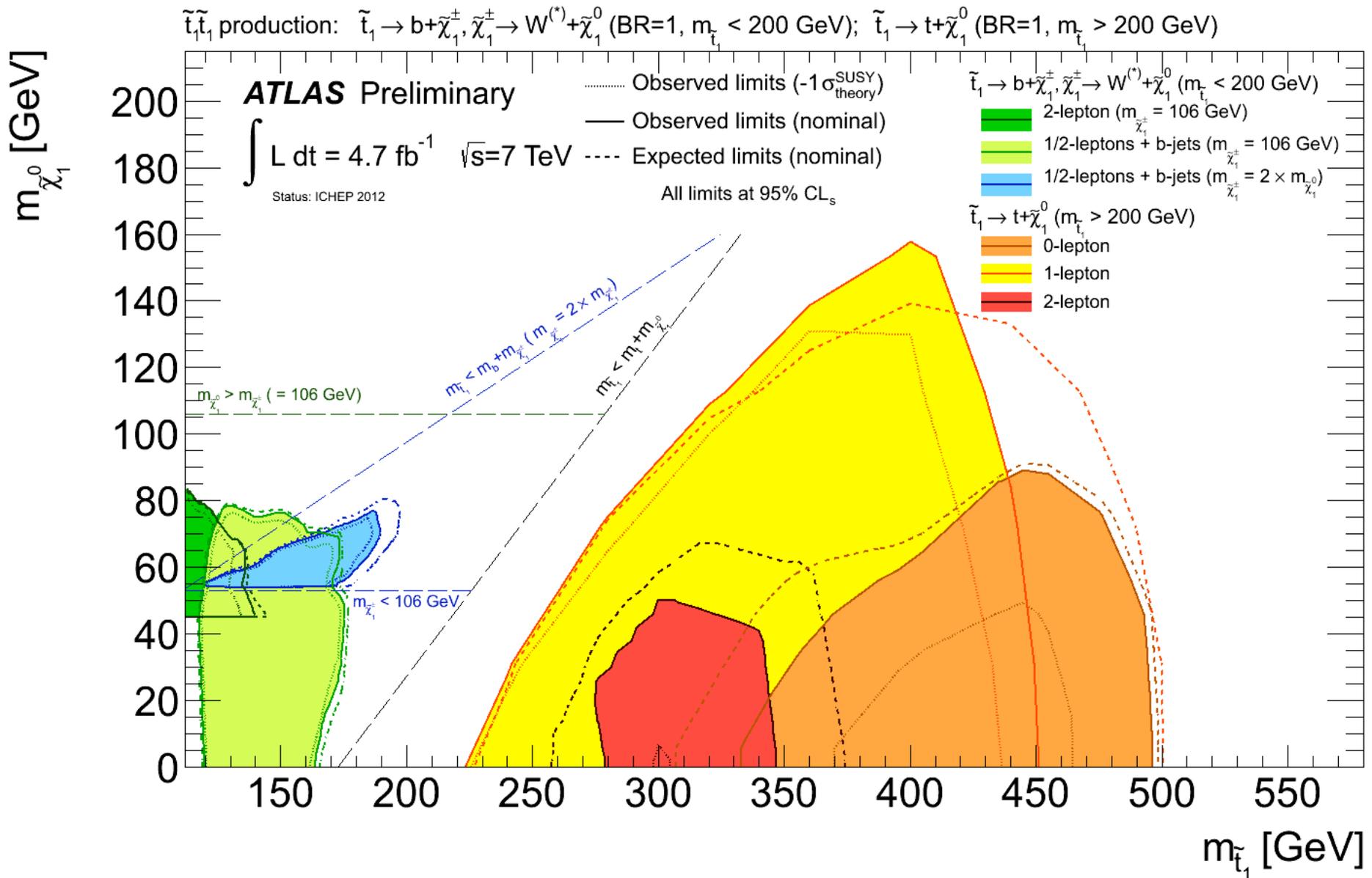
Direct Stop – 2-lepton Channel

	SF	DF
Z/ γ^* +jets (Z/ γ^* +jets scale factor)	1.2 \pm 0.5 (1.27)	- -
$t\bar{t}$ ($t\bar{t}$ scale factor)	0.23 \pm 0.23 (1.21)	0.4 \pm 0.3 (1.10)
$t\bar{t}W + t\bar{t}Z$	0.11 \pm 0.07	0.19 \pm 0.12
WW	0.01 ^{+0.02} _{-0.01}	0.19 \pm 0.18
WZ + ZZ	0.05 \pm 0.05	0.03 \pm 0.03
Wt	0.00 ^{+0.17} _{-0.00}	0.10 ^{+0.18} _{-0.10}
Fake leptons	0.00 ^{+0.14} _{-0.00}	0.00 ^{+0.09} _{-0.00}
Total SM	1.6 \pm 0.6	0.9 \pm 0.6
Signal, $m(\tilde{t}_1) = 300$ GeV, $m(\tilde{\chi}_1^0) = 50$ GeV	2.15	3.73
Signal, $m(T) = 450$ GeV, $m(A_0) = 100$ GeV	3.10	5.78
Observed	1	2
95% CL limit on σ_{vis}^{obs} [fb]	0.86	1.08
95% CL limit on σ_{vis}^{exp} [fb]	0.89	0.79



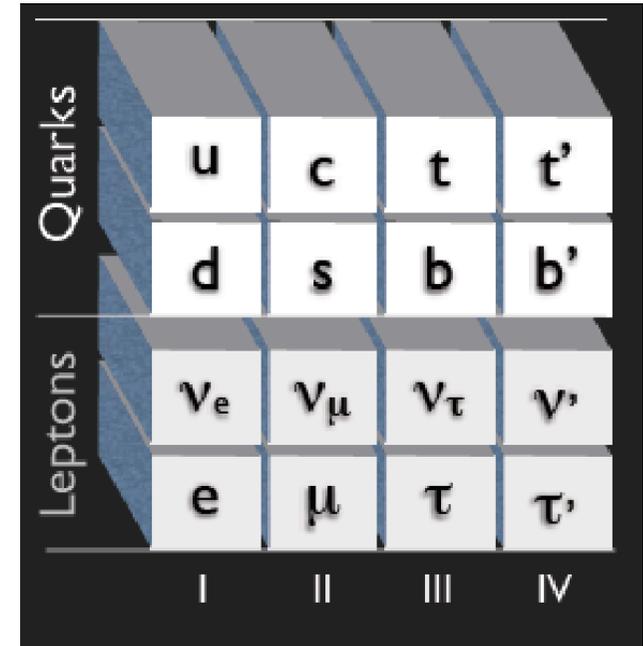
- ≥ 2 jets, ≥ 1 b-tag
- $m_{T2} > 120$ GeV
- Z mass veto
- Dominant BG: $t\bar{t}$, Z+jets
- Data-driven BG estimate

Direct Stop – Summary



4th Generation and Vector-Like Quarks

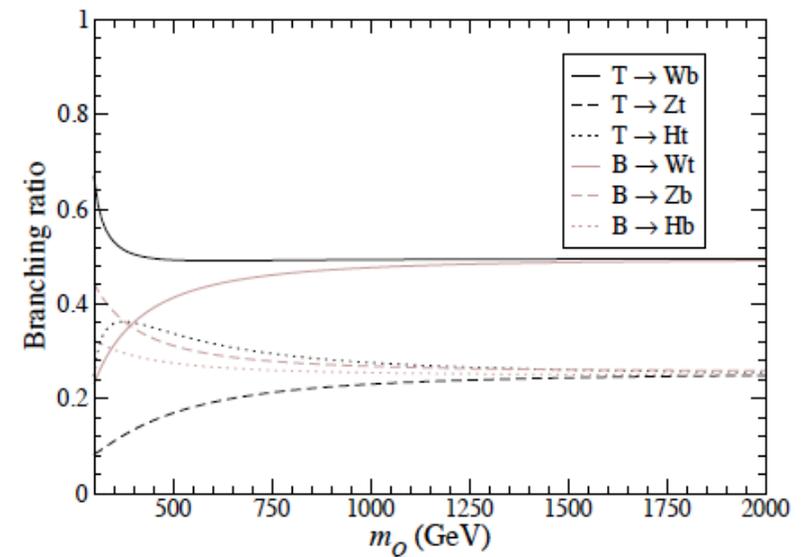
- Can explain
 - enough CP violation to explain matter-dominated universe
 - Higgs naturalness
 - Fermion mass hierarchy
 - Dark matter
- Sequential 4th generations in deep trouble with $m_H \sim 125$ GeV



Main channels:

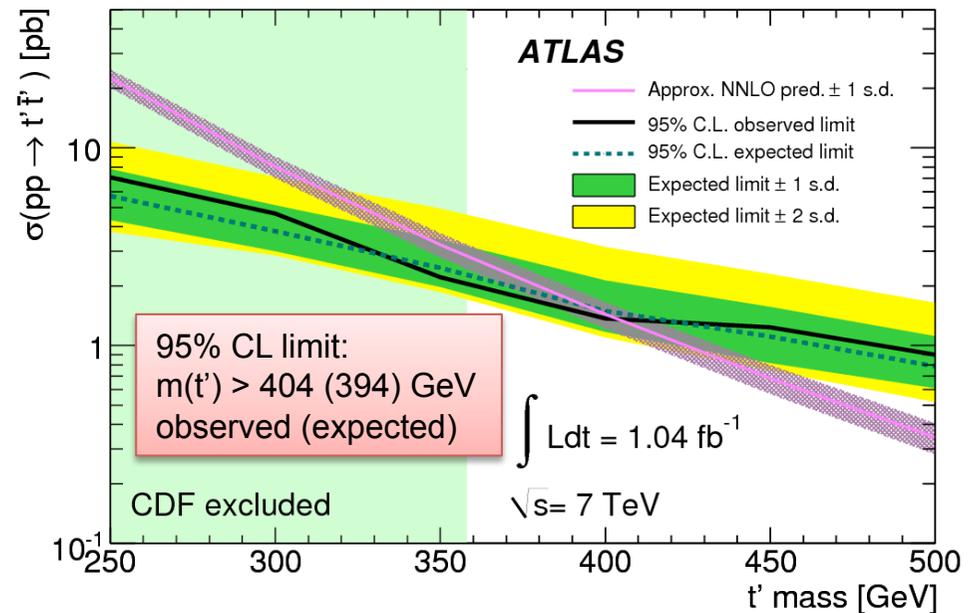
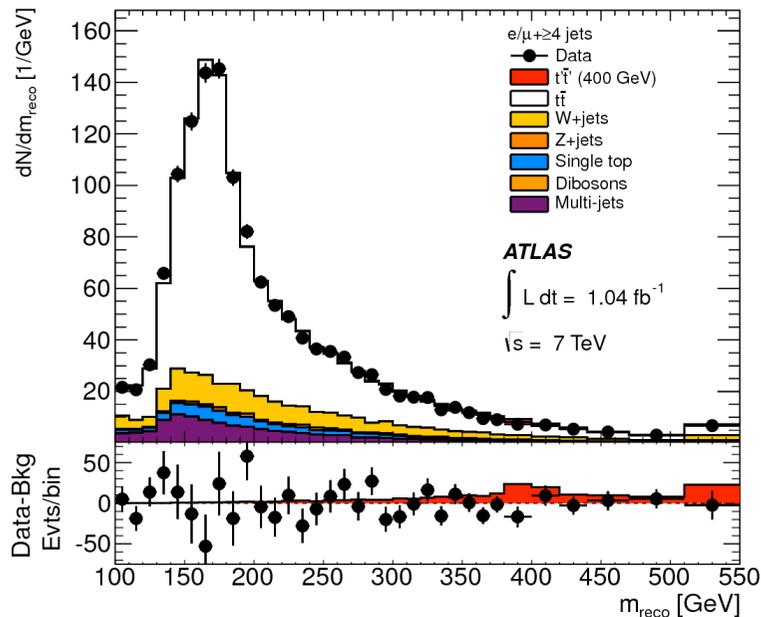
$$t'\bar{t}' \rightarrow WbW\bar{b}$$

$$b'\bar{b}' \rightarrow WtW\bar{t}$$



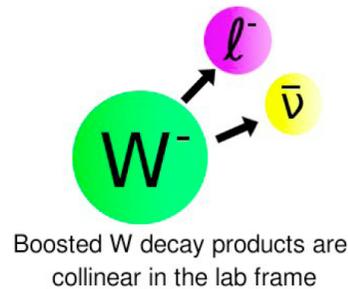
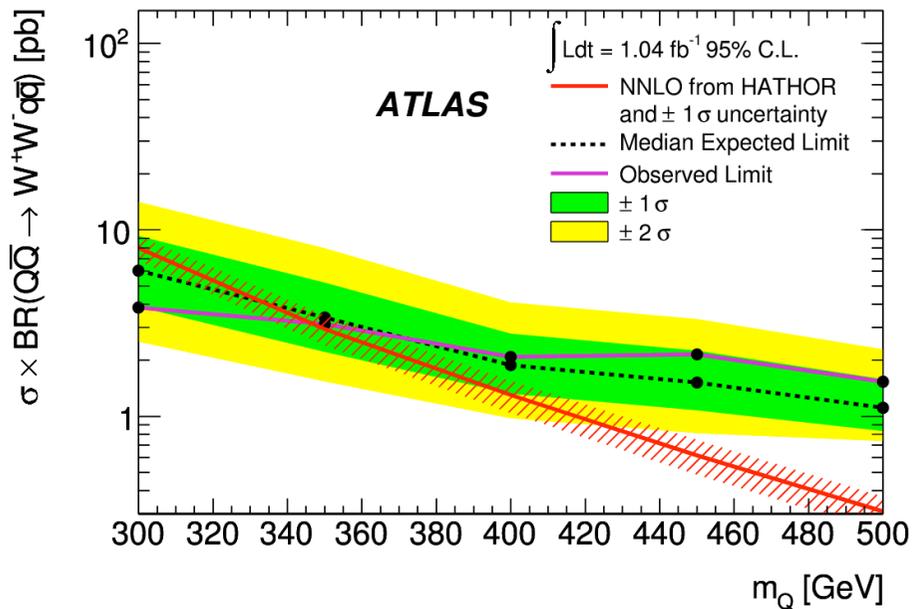
Search for Heavy Quarks in $t'\bar{t}' \rightarrow WbW\bar{b}$

- $t'\bar{t}' \rightarrow WbW\bar{b}$ (l+jets channel)
- Start from default $t\bar{t}$ selection using b-tagging and tighter cut on leading jet pT
- Discriminant: reconstructed top/t' mass (using a likelihood fit)
- 3-jet bin \rightarrow constrain W+heavy flavor
- 4-jet bin \rightarrow best S/B
- Use profiling carefully to reduce systematics

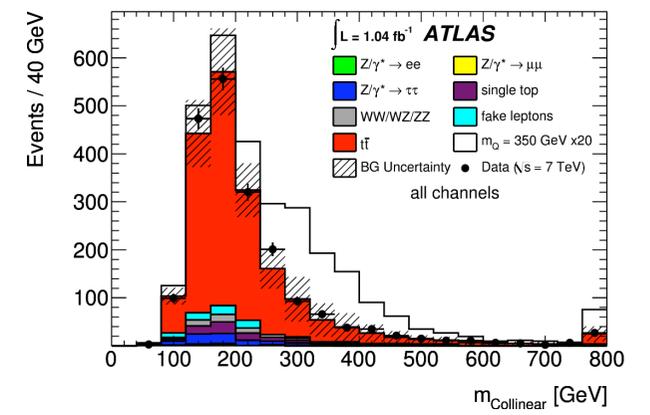
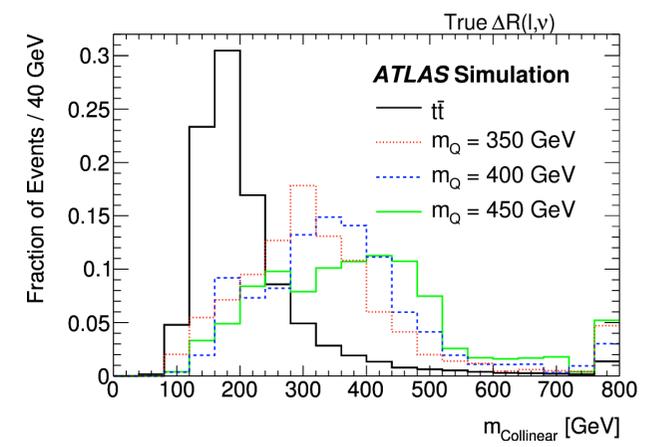
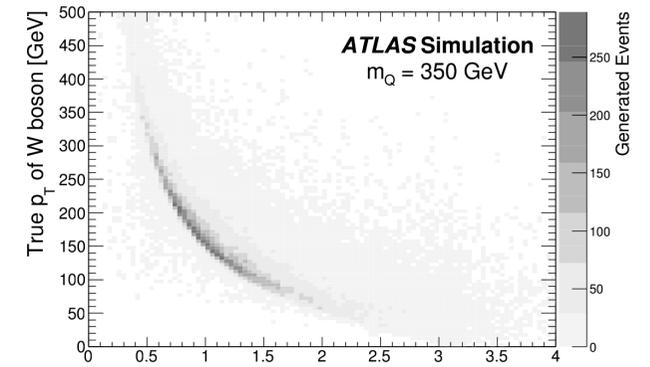


Search for Heavy Quarks in $Q\bar{Q} \rightarrow WqW\bar{q}$

- $Q\bar{Q} \rightarrow WqW\bar{q}$ (dilepton channel)
 - more general decay to q , no b -tagging
- Start from default $t\bar{t}$ selection
- Discriminant: collinear mass



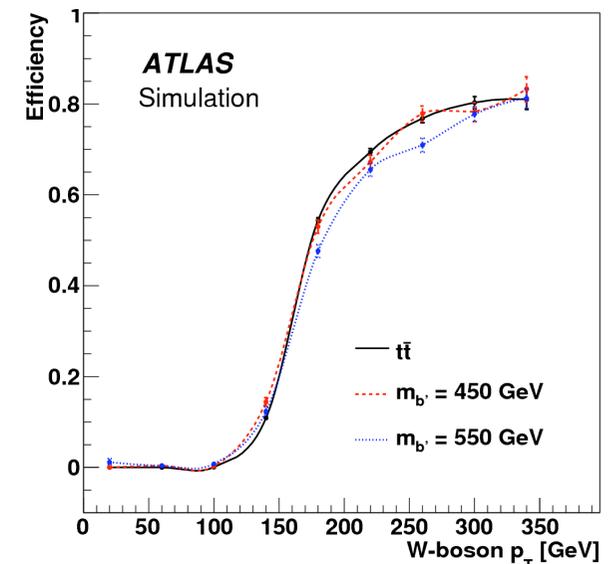
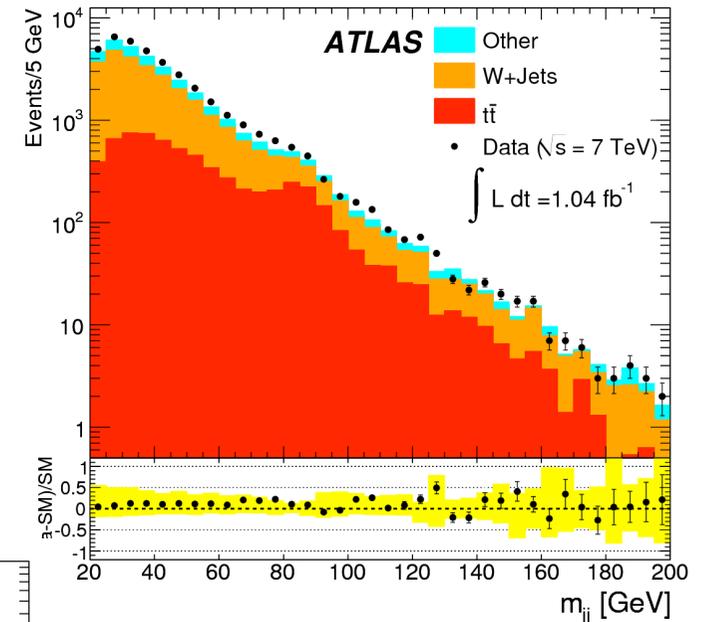
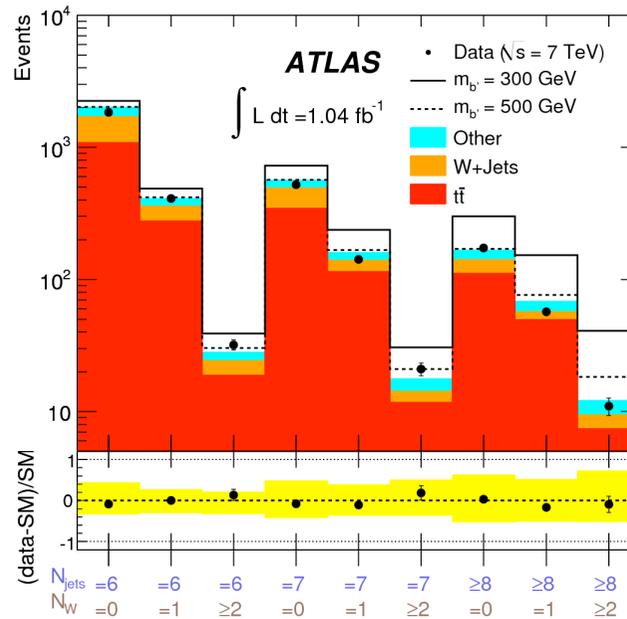
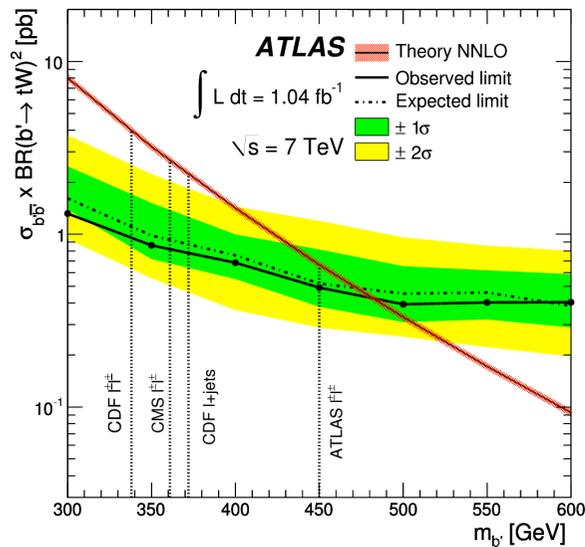
95% CL limit:
 $m(Q) > 350$ (335) GeV
 observed (expected)



Search for Heavy Quarks in $b'\bar{b}' \rightarrow WtW\bar{t}$

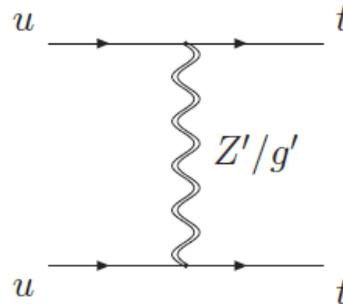
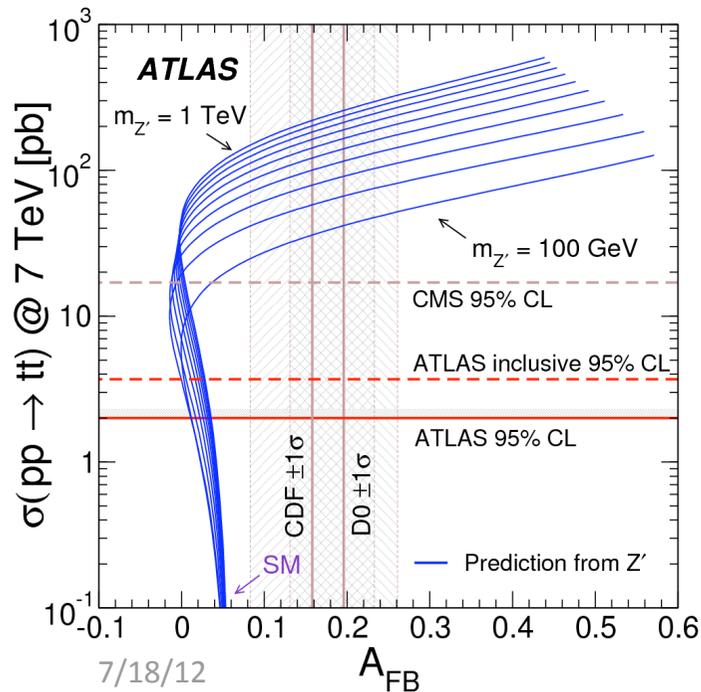
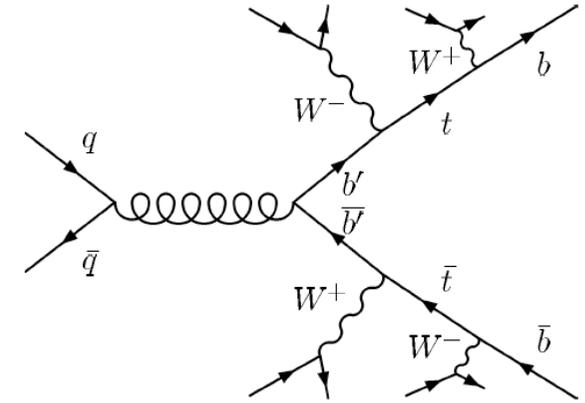
- $b'\bar{b}' \rightarrow WtW\bar{t}$ (1 lepton + jets channel)
 - Lepton, E_T^{miss} , jets, semi-boosted $W \rightarrow q\bar{q}'$
- Start from default $t\bar{t}$ selection
 - Look at higher jet multiplicity (no b-tagging)
- Discriminant: number of jets and number of semi-boosted $W \rightarrow q\bar{q}'$ (cut on m_{jj} if $\Delta R(j,j) < 1.0$)

95% CL limit:
 $m(b') > 480$ (468) GeV
 observed (expected)

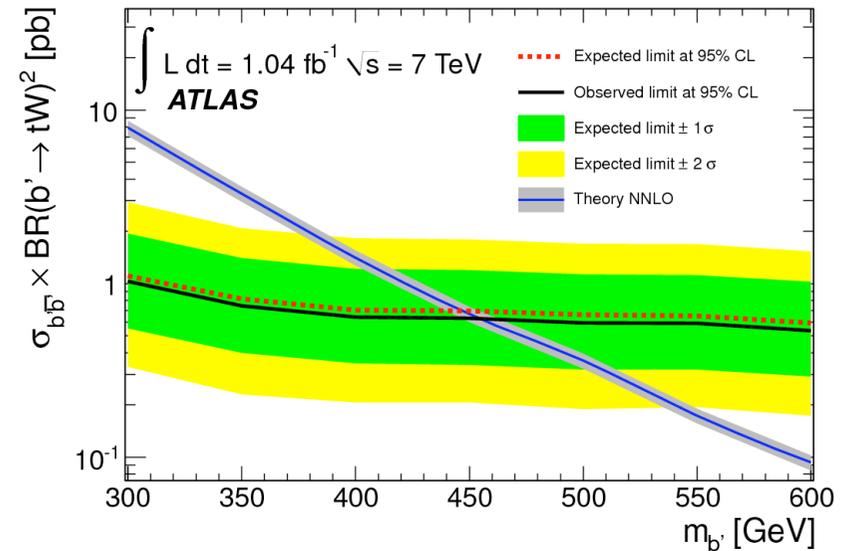


Search for Heavy Quarks and SS Top

- SS top and $b'\bar{b}' \rightarrow WtW\bar{t}$
 - Two SS leptons + 2 jets + $H_T + E_T^{\text{miss}}$
- $b'\bar{b}' \rightarrow WtW\bar{t}$ BR to SS leptons is 8/81 (4 times smaller than l+jets channel) but better S/B
- Select positively charged leptons for SS top signal
- Backgrounds
 - Irreducible diboson background
 - Fakes, determined using matrix method
 - Charge flip, determined using Z events

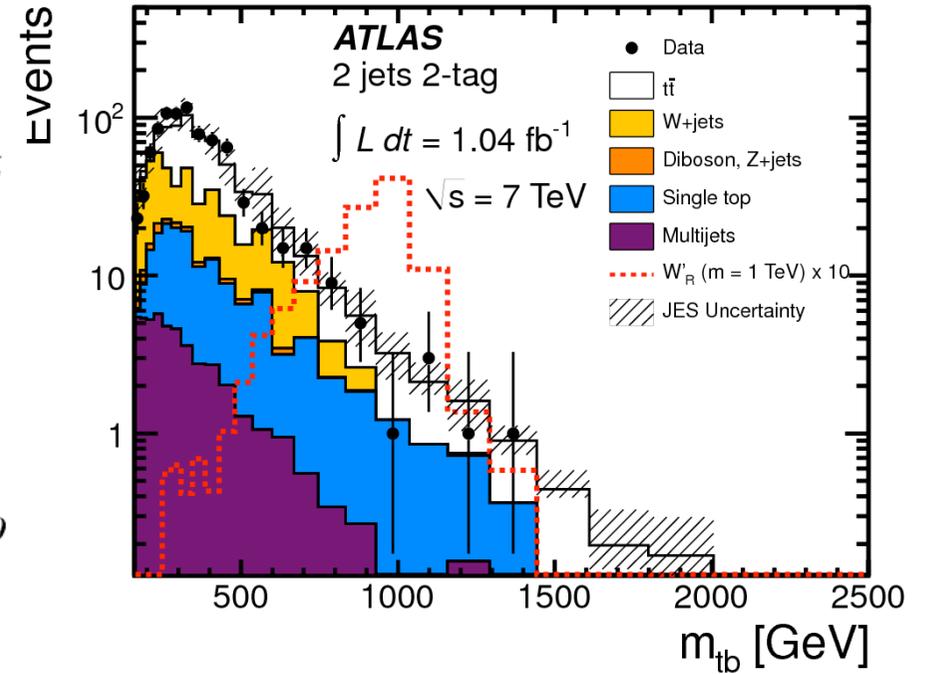
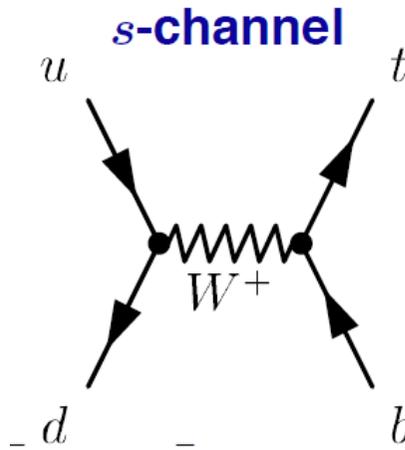
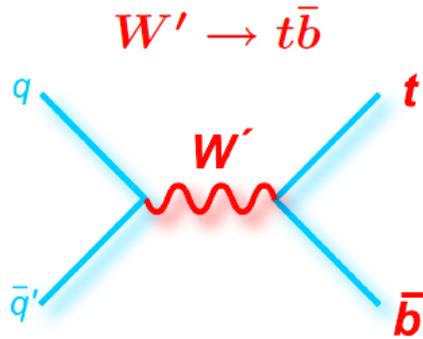


Relation between A_{FB} (Tevatron) and tt cross section (LHC) for a given coupling and mass of Z'



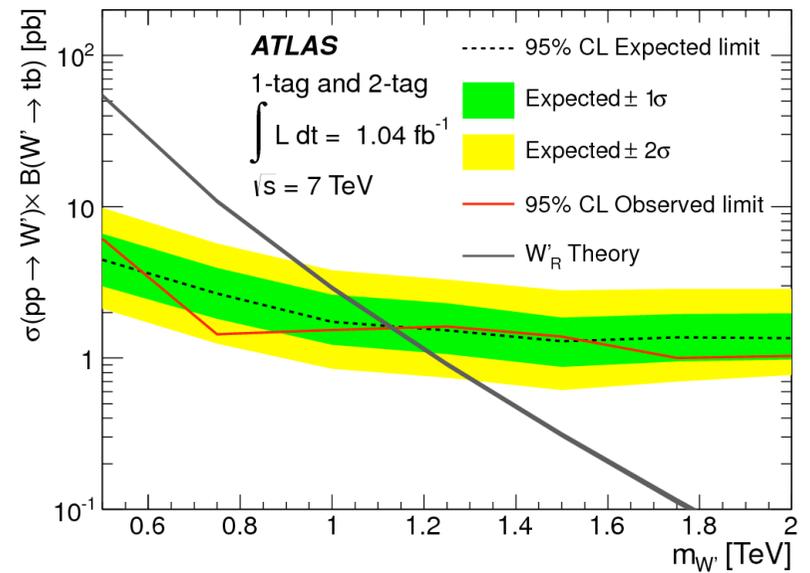
95% CL limit:
 $m(b') > 450$ GeV

Search for $W' \rightarrow tb$



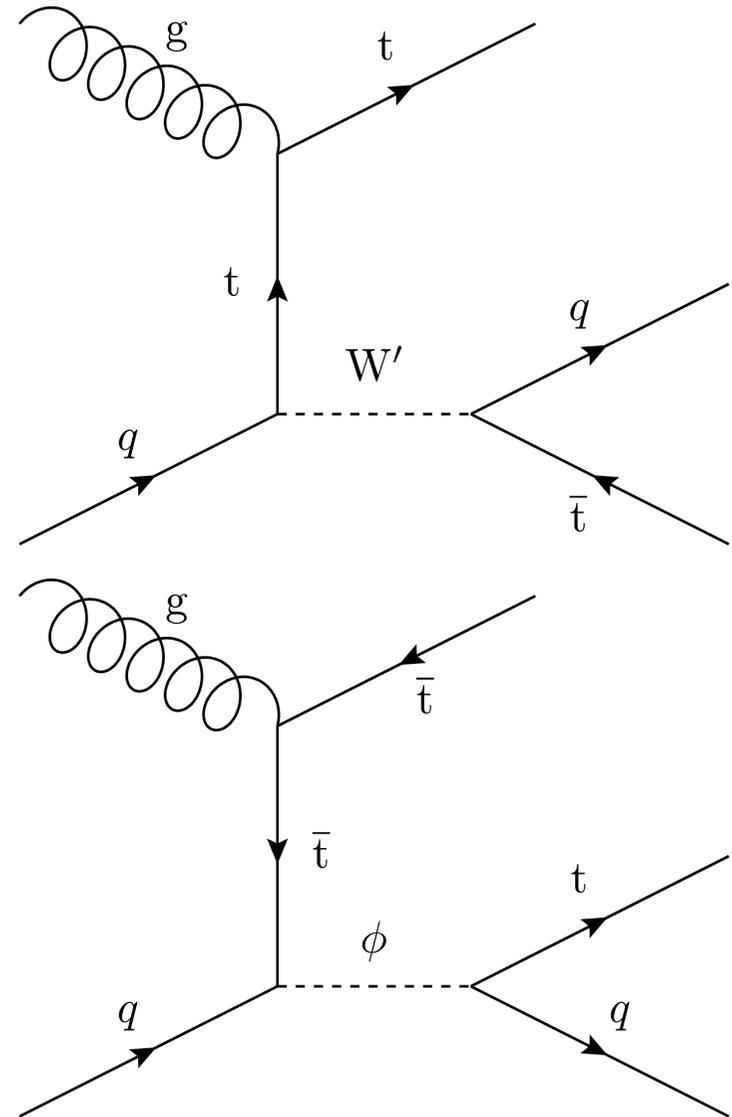
- NP searches in single-top final states
- Based on single top s -channel analysis
- Discriminant: m_{tb}

95% CL limit:
 $m(W'_R) > 1.13 \text{ TeV}$



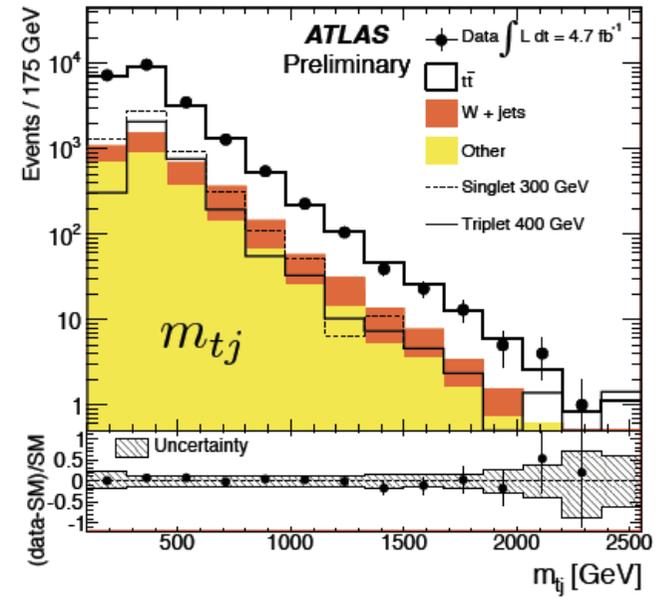
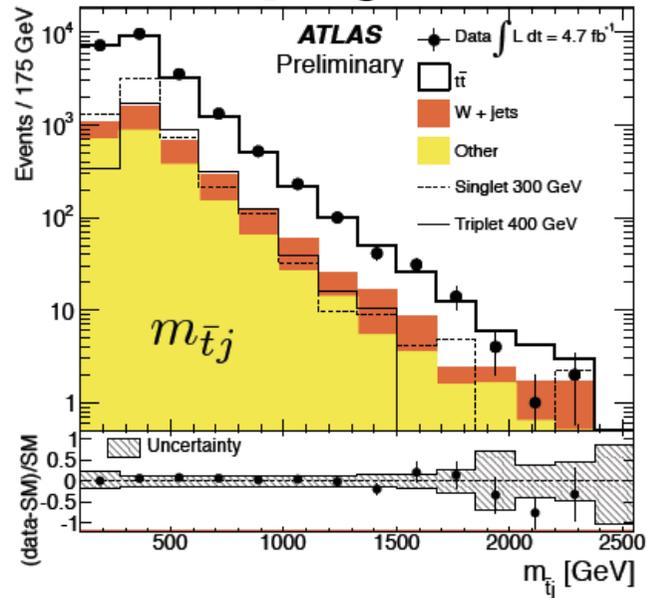
Search for Top-jet Resonances

- Motivation: $t\bar{t}$ forward-backward asymmetry @Tevatron [arXiv:1101.0034, arXiv:1107.4995]
- Possible explanation: Top-flavor violating processes
- Look for a new heavy resonance produced in association with a top-quark
- Two types of X resonances considered
 - color singlet $W' \rightarrow m(\bar{t}+\text{jet})$ resonance
 - di-quark color triplet $\rightarrow m(t+\text{jet})$ resonance
- Resonance occurs in the $m(t+\text{jet})$ or $m(\bar{t}+\text{jet})$ channel, but not in both

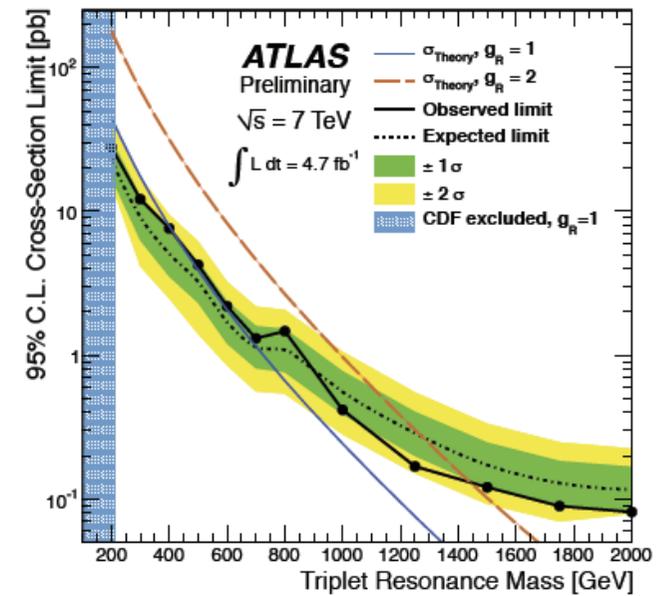
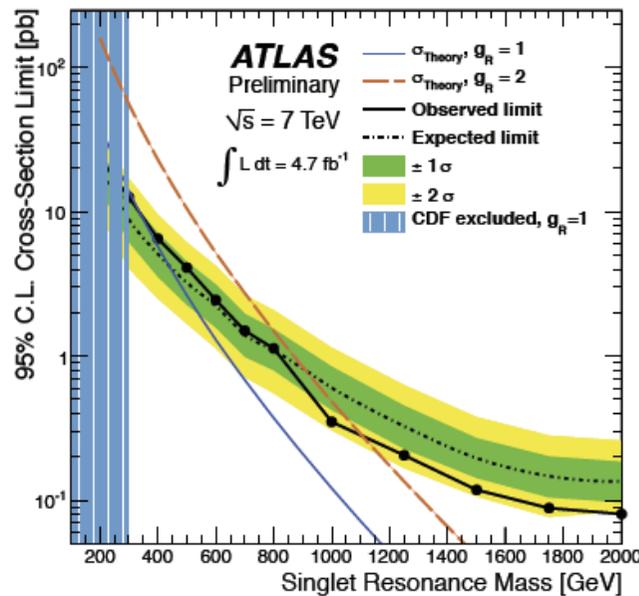


Search for Top-jet Resonances

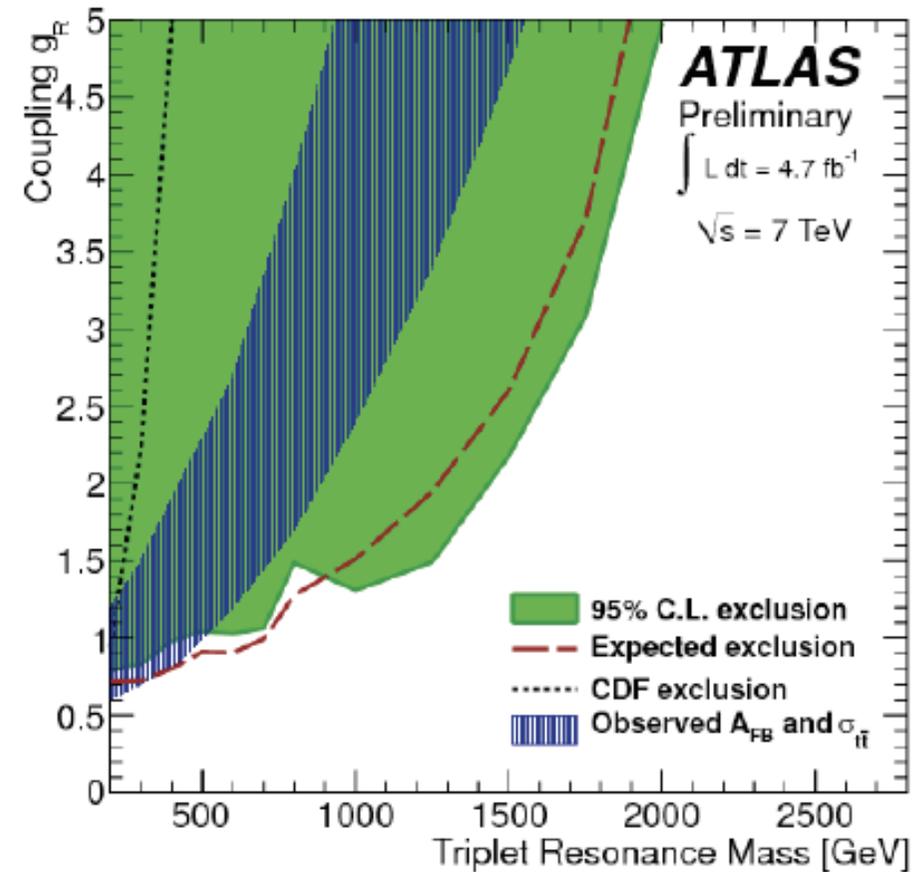
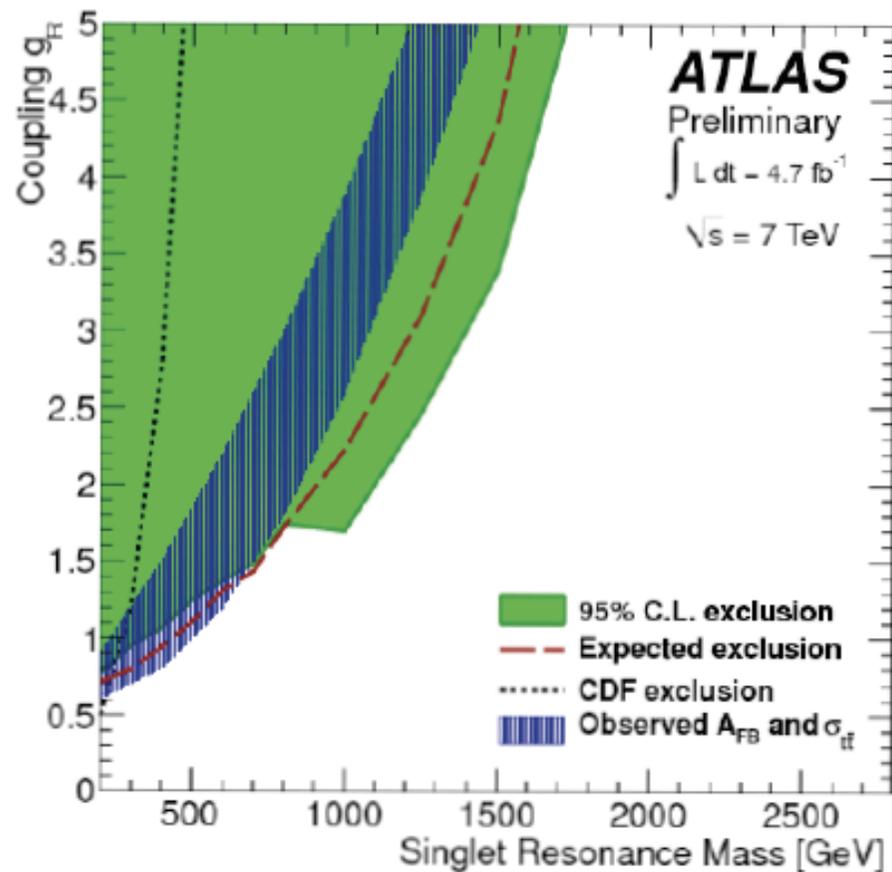
Assume unit coupling here



Observed (expected):
 $m_W < 350$ (450) GeV
 at 95% C.L. (singlet)
 $m_{\text{di-quark}} < 430$ (700) GeV
 at 95% C.L. (triplet)



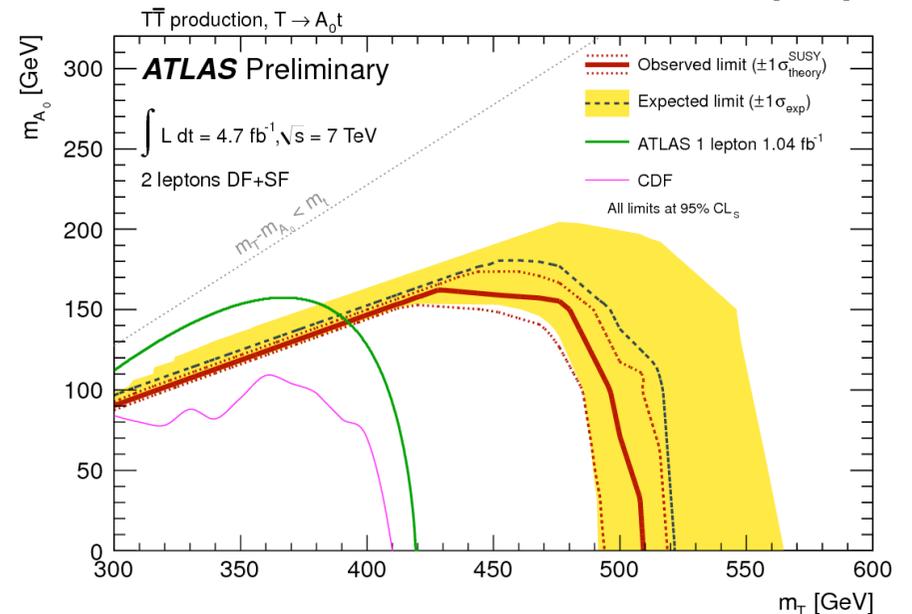
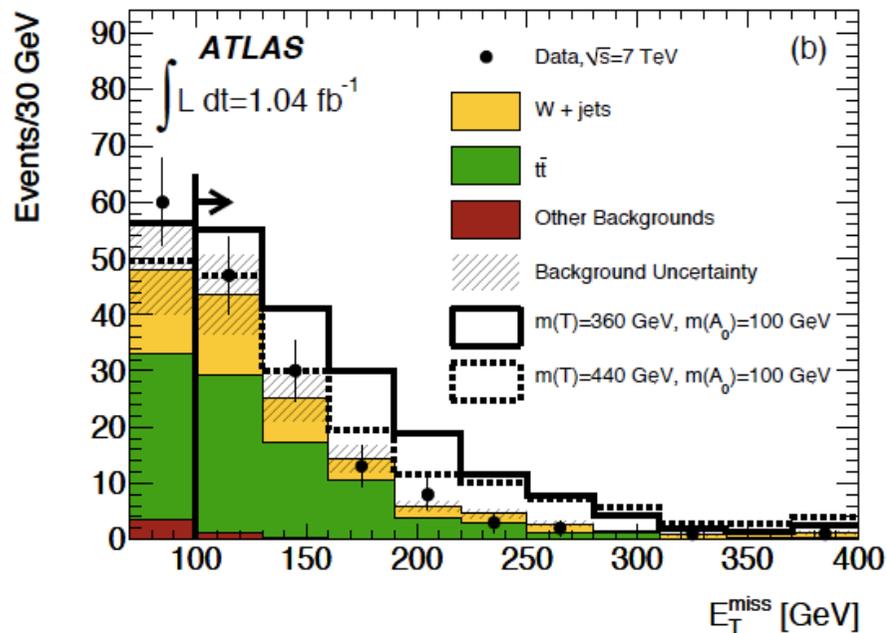
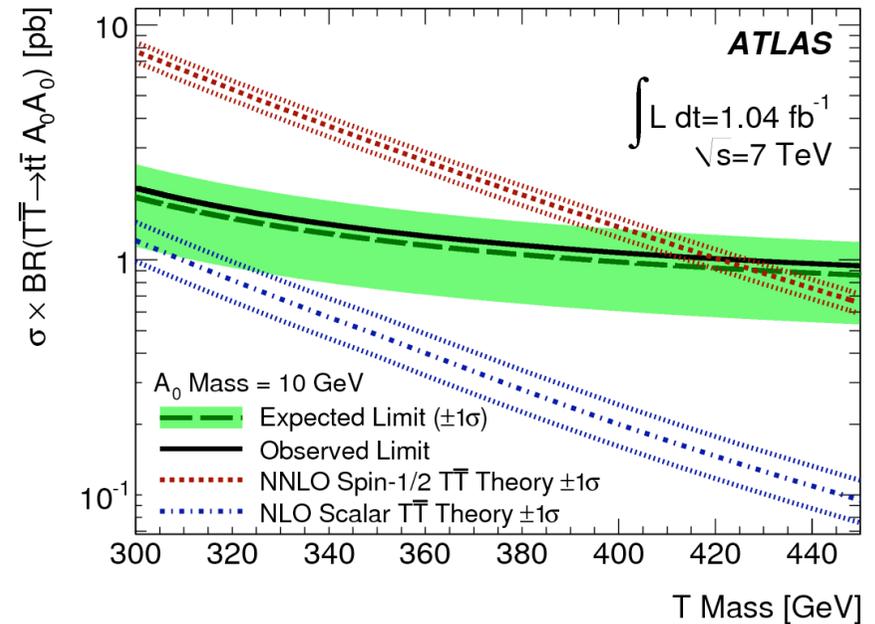
Search for Top-jet Resonances



- Set limits vs right-handed coupling to tq

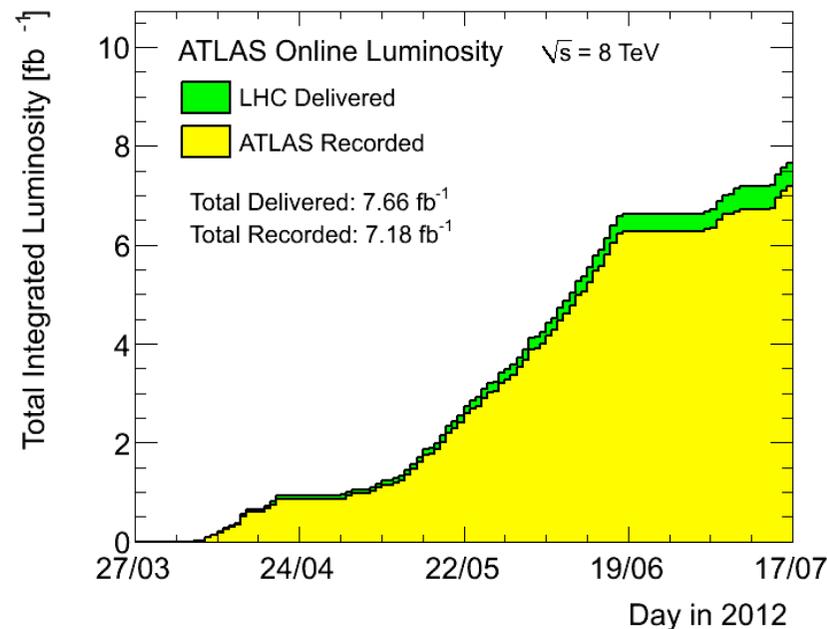
Other Top Partners

- Little Higgs models with T-parity conservation
- Search in tails of E_T^{miss} and m_T in $l+jets$ channel
- [Phys. Rev. Lett. 108, 041805 (2012)
arXiv:1109.4725]
- Reinterpretation of stop search (2-lepton)



Summary

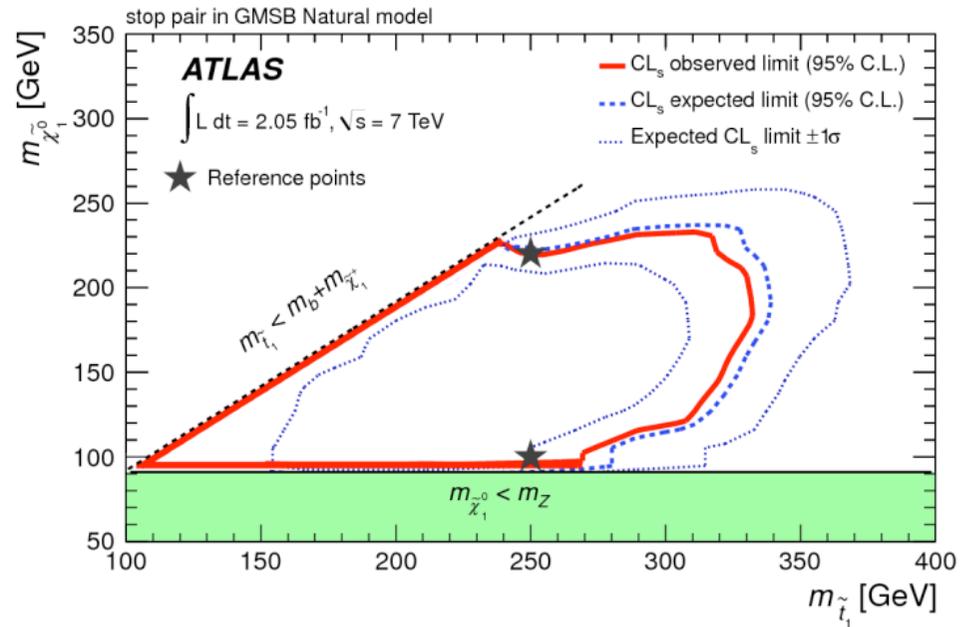
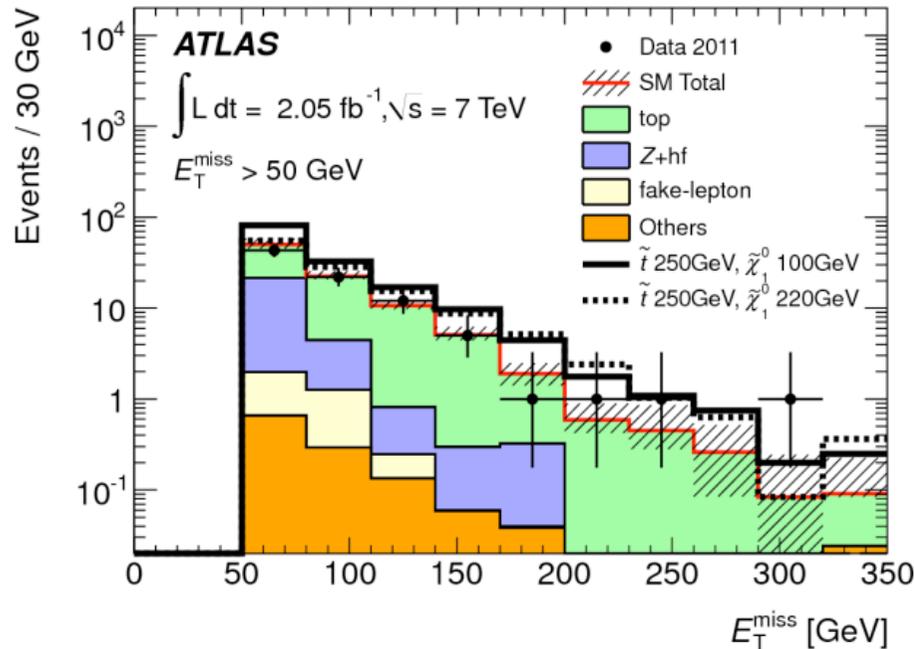
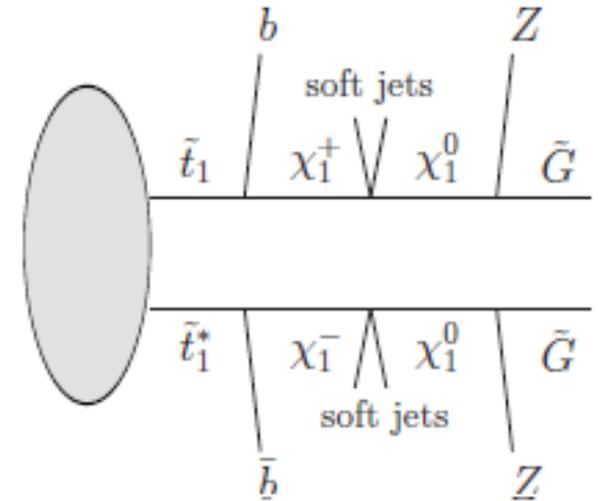
- LHC and ATLAS performing very well
- Large ATLAS physics program – top plays an important role
- No hints of New Phenomena – YET
- Many new results in pipeline – stay tuned



Backup

Direct Stop Pair Production in GMSB

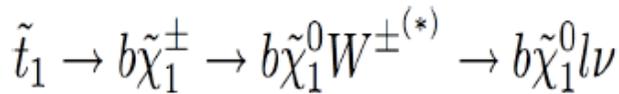
- GMSB scenario with gravitino LSP ($m < 1$ keV) and neutralino NLSP (higgsino-like considered)
- Analysis signature: $Z \rightarrow ll + b\text{-jet} + \text{jets} + E_T^{\text{miss}}$



Very Light Stop – 2 Leptons

Explore very light stop masses.

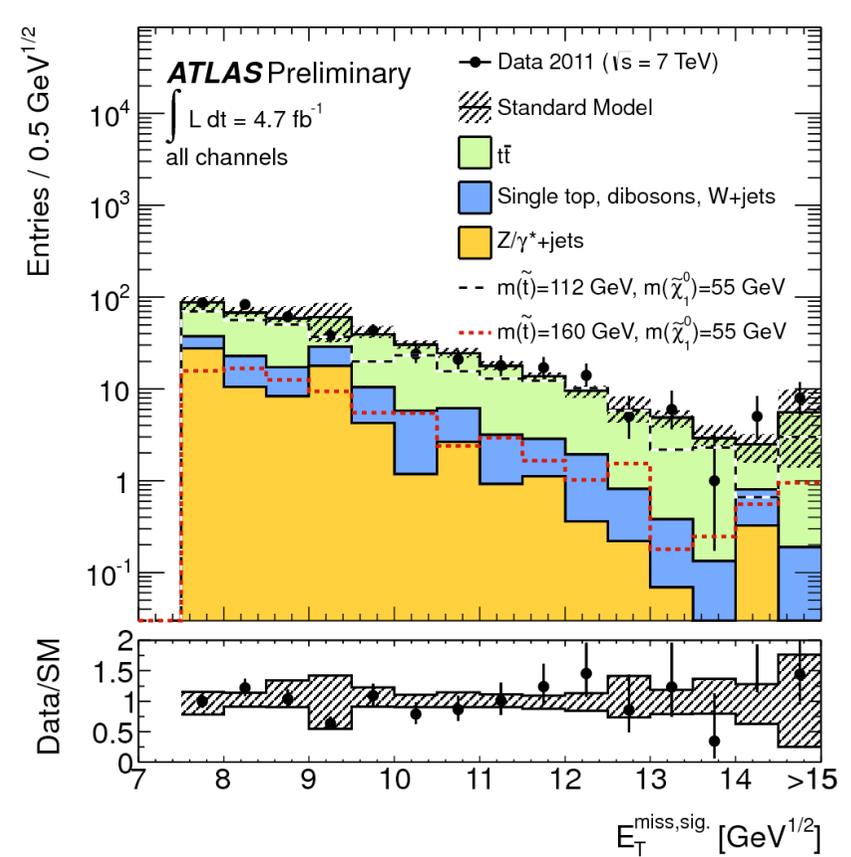
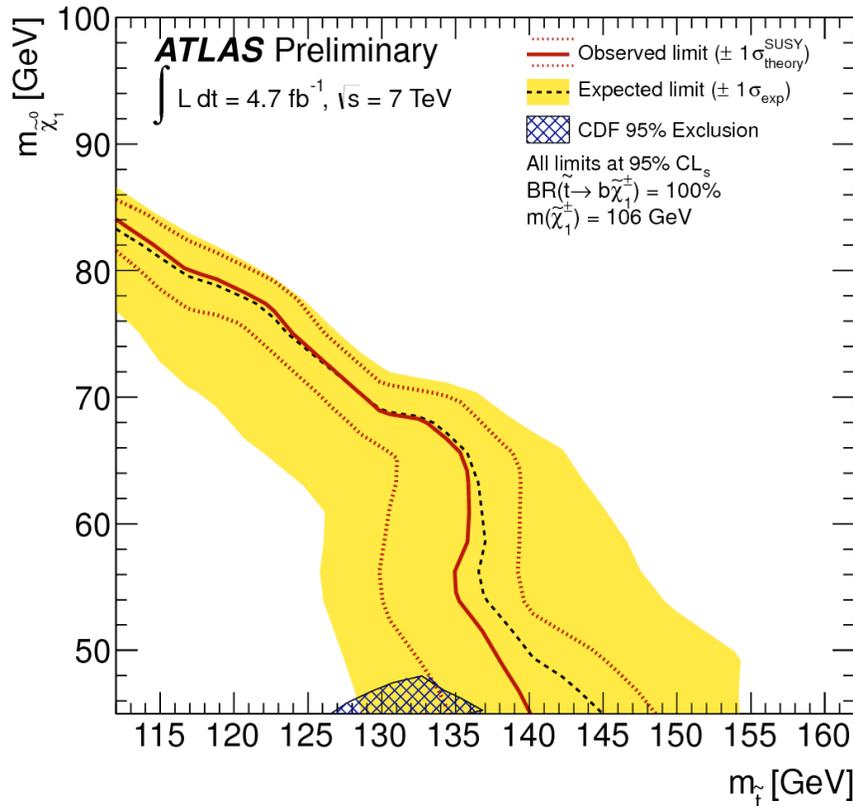
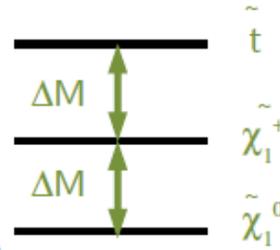
Assume:



100% ↑ 100%

Fixed at 106 GeV (just above LEP limits)

~26%
(no hadr taus)



[ATLAS-CONF-2012-059
<http://cdsweb.cern.ch/record/1453787>]

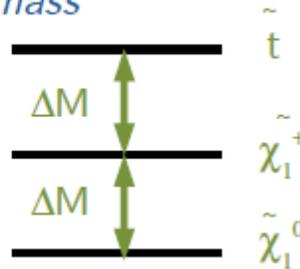
Light Stop – 1/2 Leptons

Explore stop masses below and around the top mass

Assume:

$$\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm \rightarrow b\tilde{\chi}_1^0 W^{\pm(*)} \rightarrow b\tilde{\chi}_1^0 l\nu$$

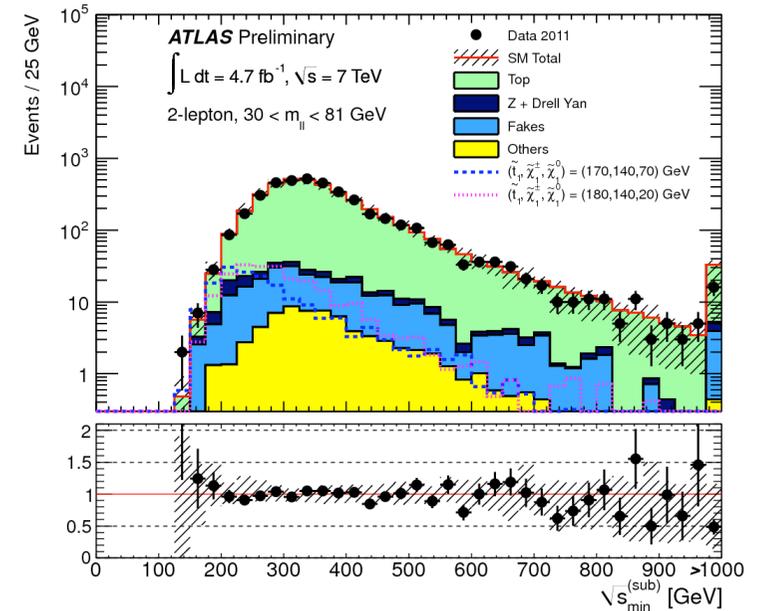
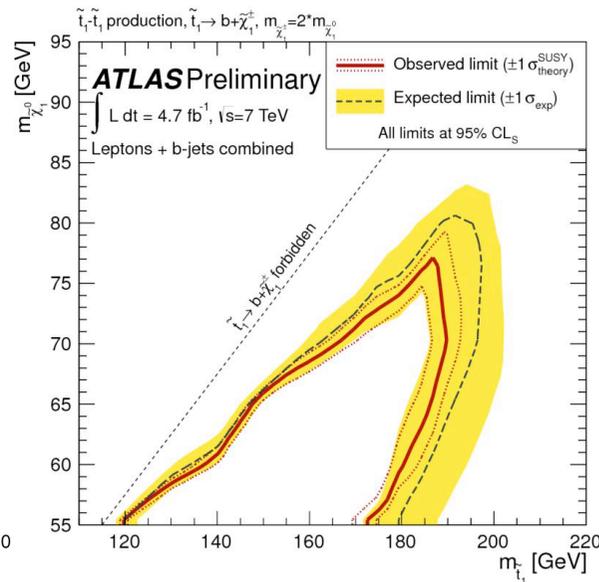
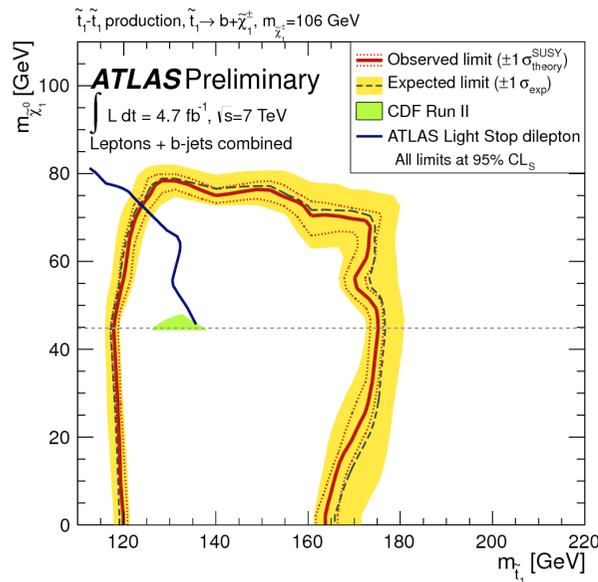
100% 100% ~26%
(no hadr taus)



→ Determines the b-jet p_T

→ Determines the lepton p_T

Discriminant: global minimum mass compatible with the hard-scattering (built from Mandelstam variables)



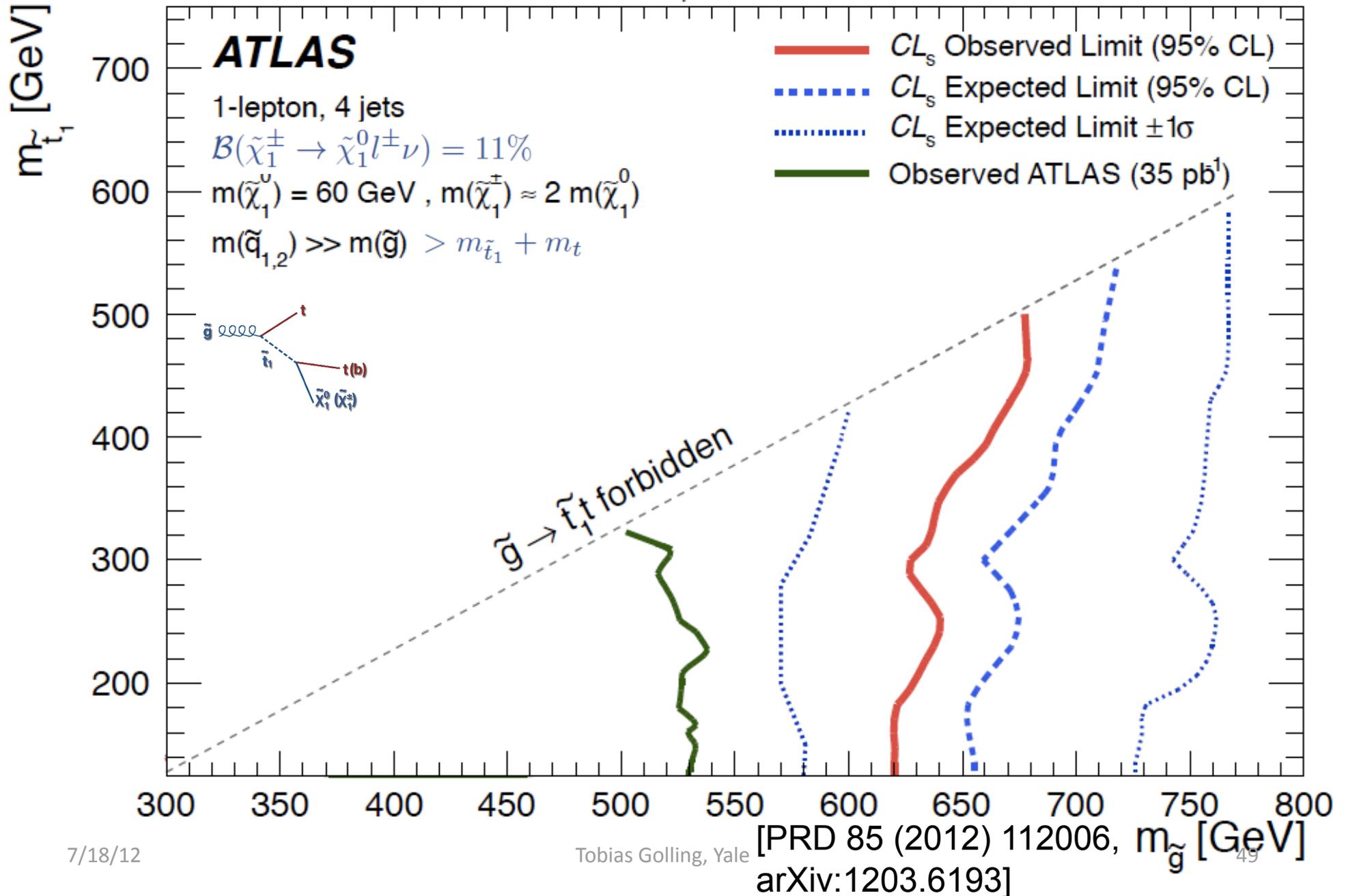
[ATLAS-CONF-2012-070

<http://cdsweb.cern.ch/record/1460267>]

Glino Mediated Stop – 1 Lepton Channel

$\tilde{g}-\tilde{g} + \tilde{t}_1-\tilde{t}_1$ production, $\tilde{g} \rightarrow \tilde{t}_1+t$, $\tilde{t}_1 \rightarrow b+\tilde{\chi}_1^\pm$

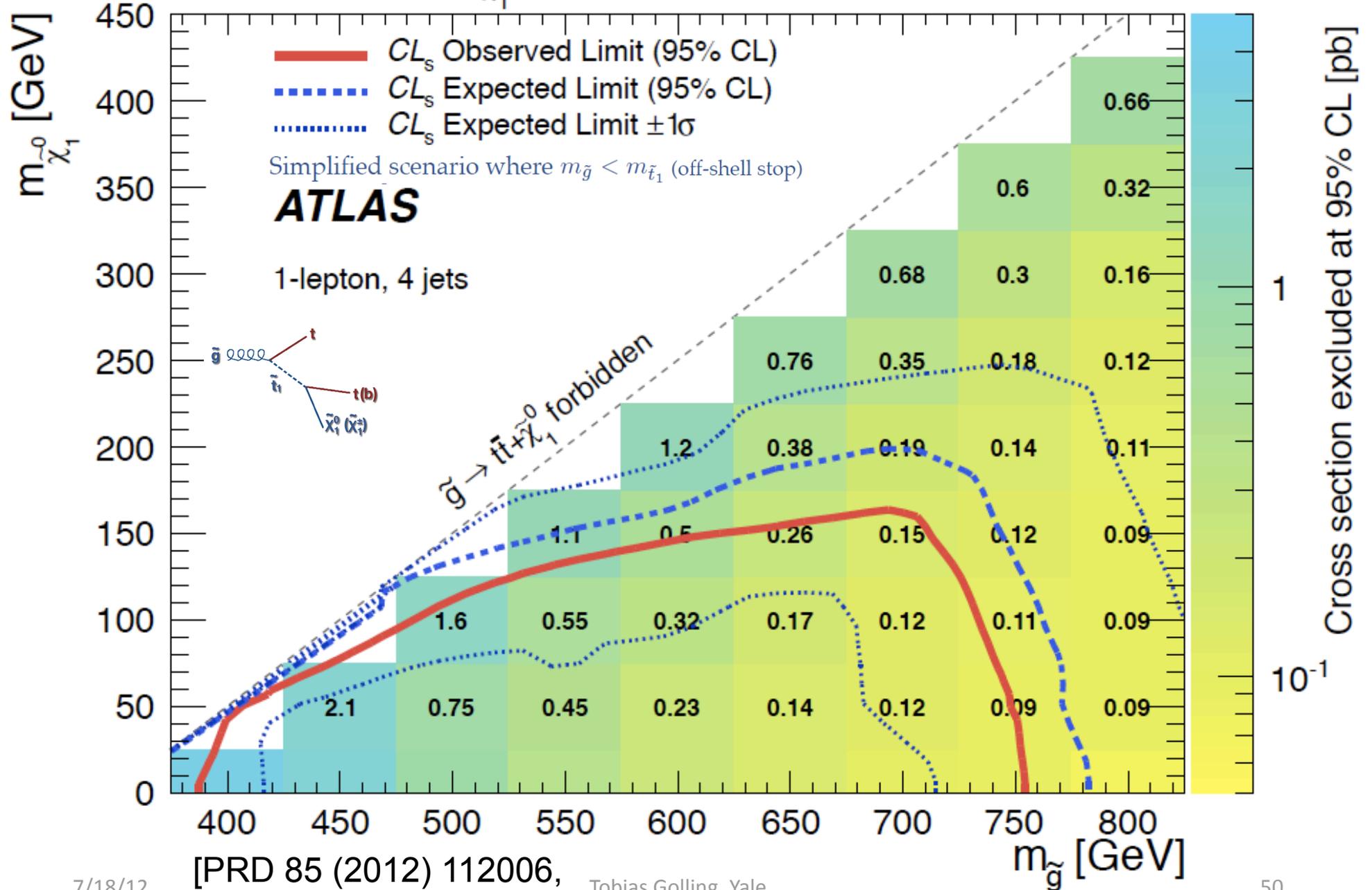
$L^{\text{int}} = 2.05 \text{ fb}^{-1}, \sqrt{s} = 7 \text{ TeV}$



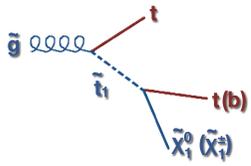
Glino Mediated Stop – 1 Lepton Channel

$\tilde{g}\text{-}\tilde{g}$ production, $\tilde{g} \rightarrow t\bar{t} + \tilde{\chi}_1^0$, $m(\tilde{q}) \gg m(\tilde{g})$

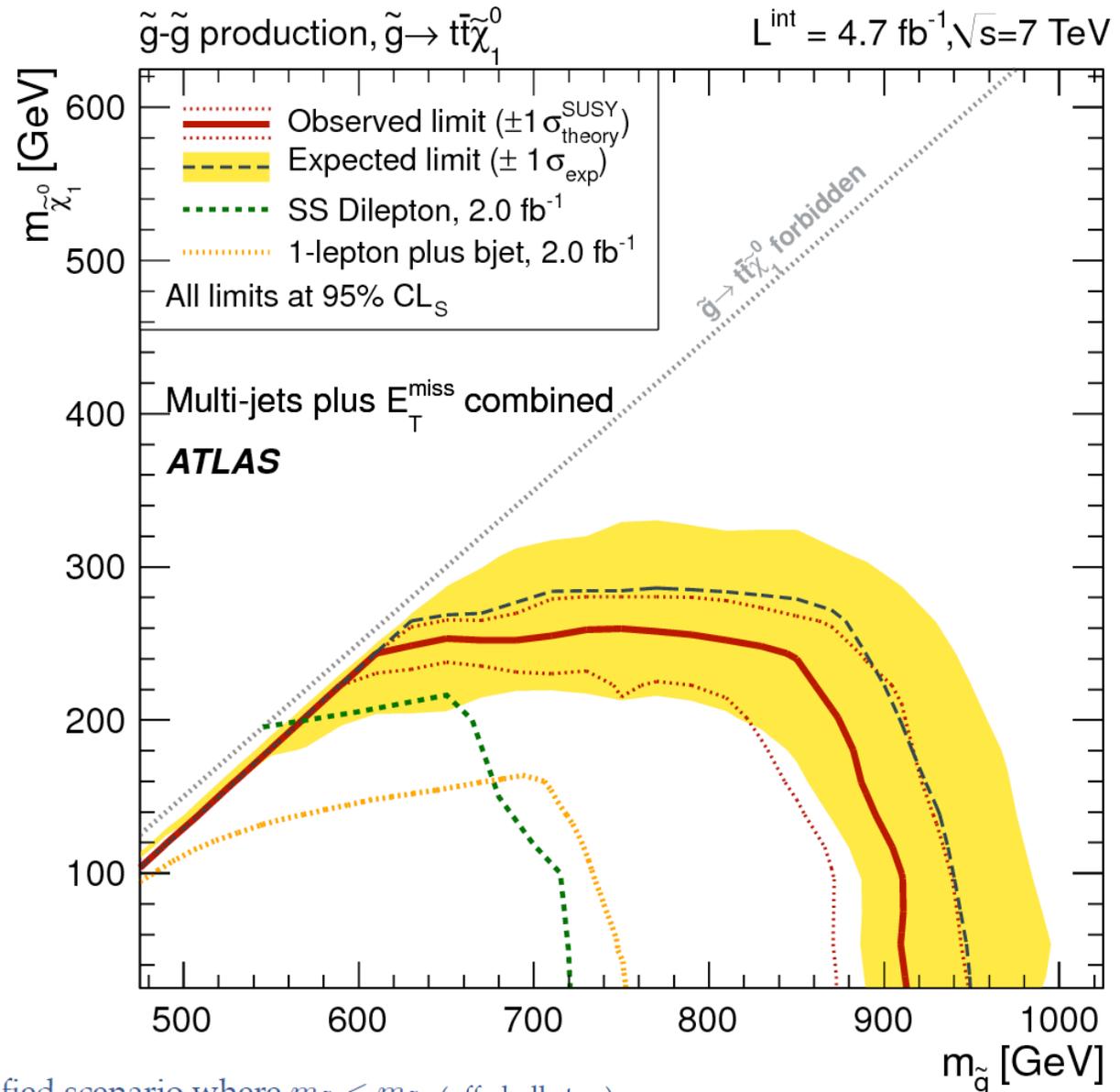
$L^{\text{int}} = 2.05 \text{ fb}^{-1}, \sqrt{s} = 7 \text{ TeV}$



Glauino Mediated Stop – Multijets Channel

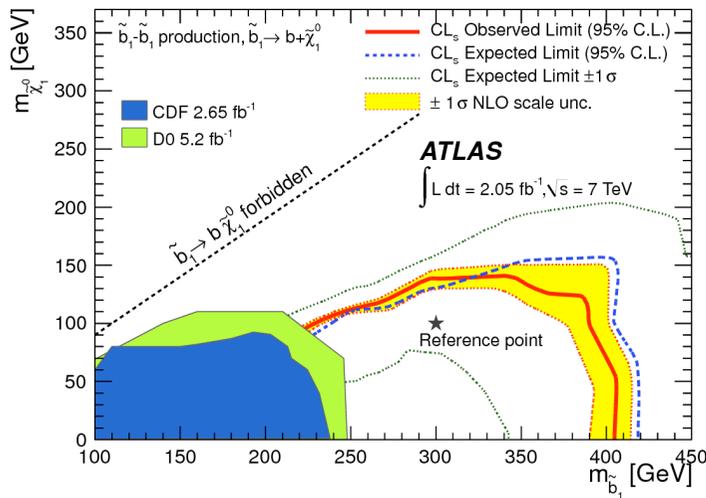


- Electron/muon veto
- $\geq 6-9$ jets with $p_T > 55$ (80) GeV
- E_T^{miss} significance > 4

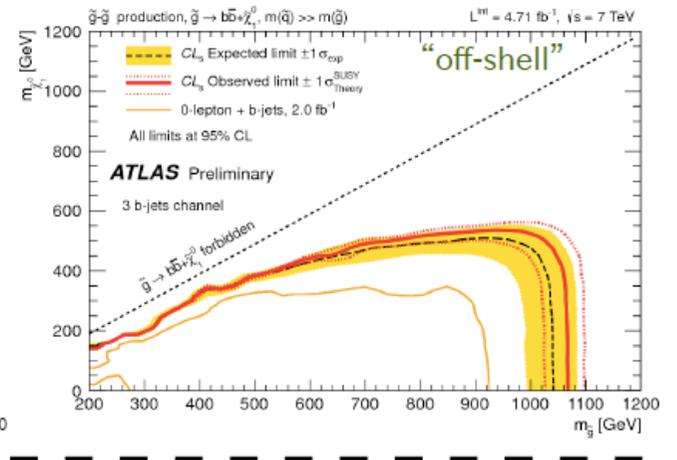
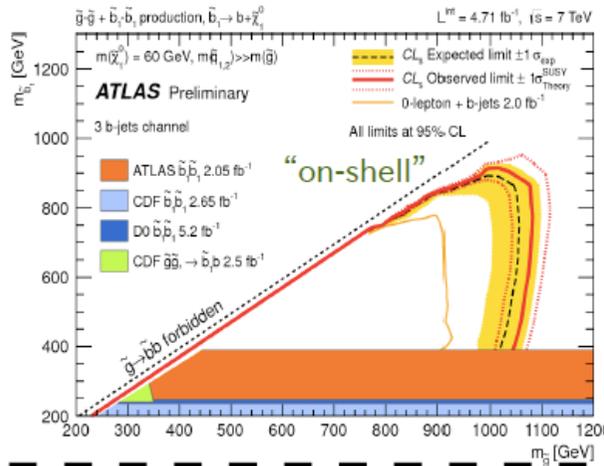


Simplified scenario where $m_{\tilde{g}} < m_{\tilde{t}_1}$ (off-shell stop)

Sbottom SUSY Searches



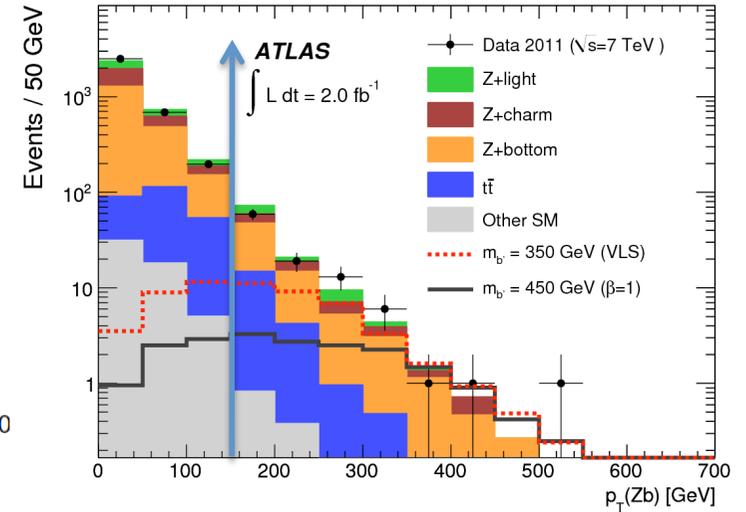
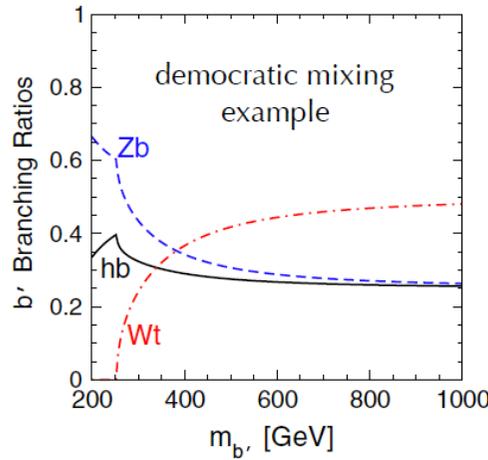
[PRL 108 (2012) 181802
(arXiv:1112.3832 [hep-ex])]



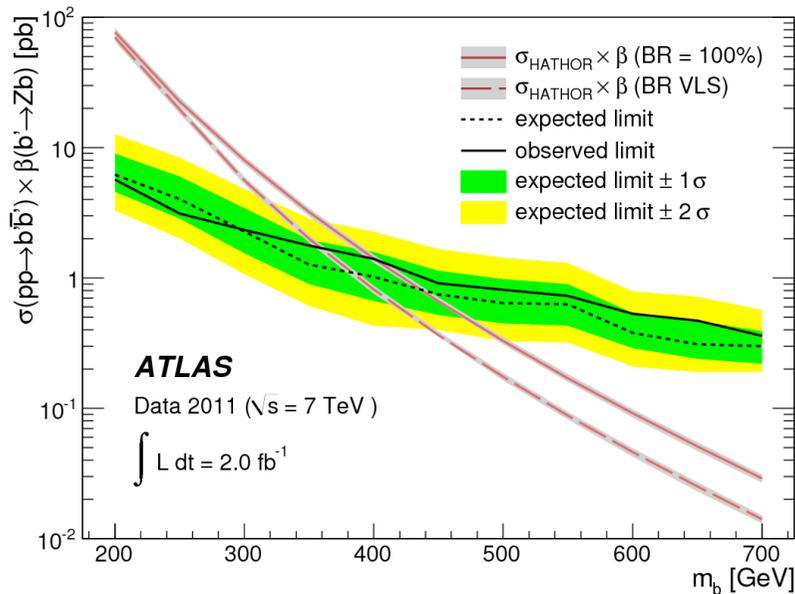
[ATLAS-CONF-2012-058
<http://cdsweb.cern.ch/record/1453786>]

Search for Heavy Quarks in $b'\bar{b}' \rightarrow Zb+X$

- $b'\bar{b}' \rightarrow Zb+X$
- Select Z and b-jet
 - $p_T(Zb) > 150$ GeV
 - Set limit based on $m(Zb)$



VLS = vector-like singlet



95% CL limit:
 $m(b') > 358$ GeV
(VLS)

