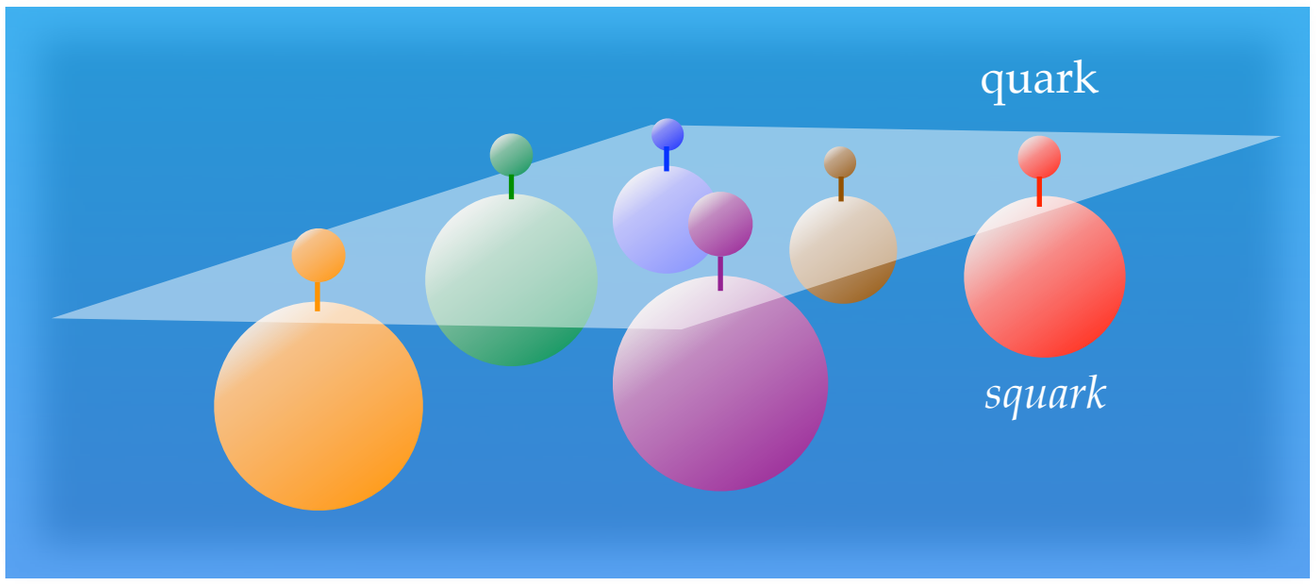
Searches for 3rd generation squark production at ATLAS

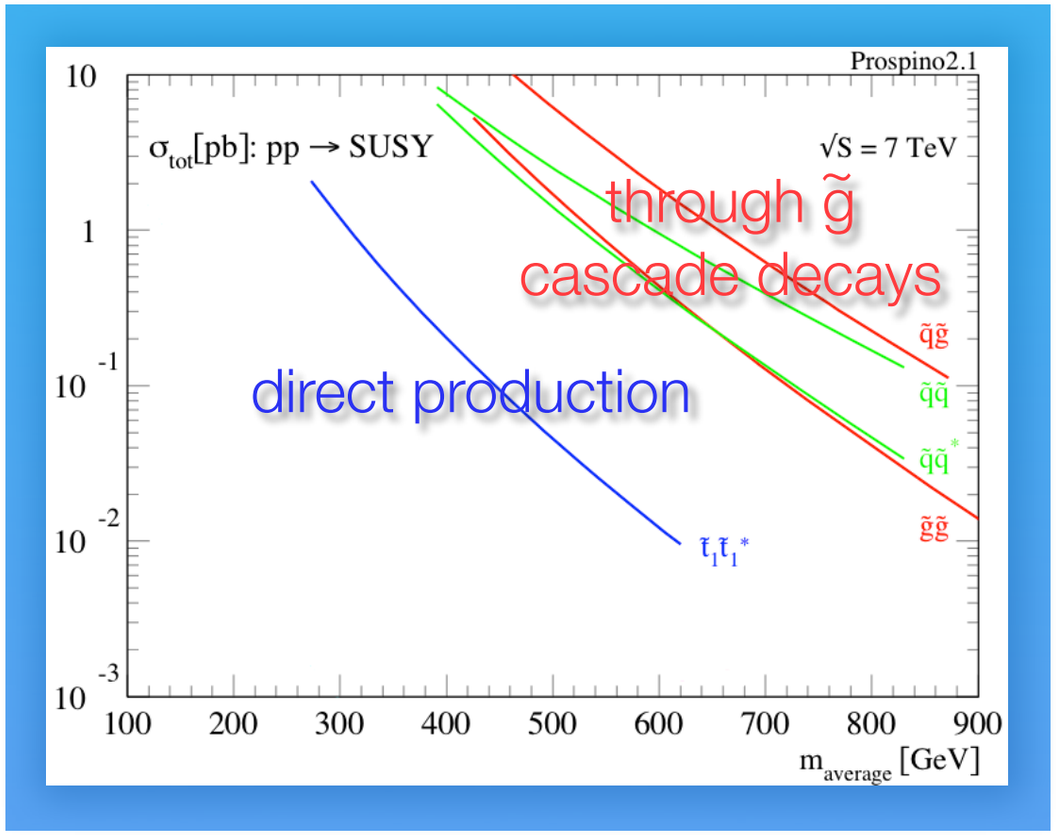


Stephanie Majewski,

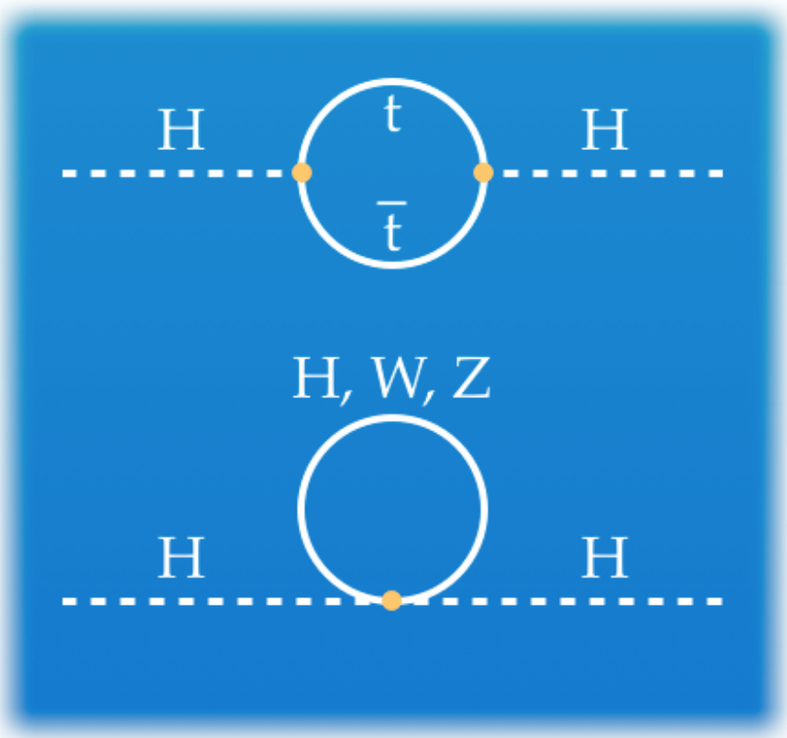
BROOKHAVEN NATIONAL LABORATORY

on behalf of the ATLAS Collaboration

3rd Generation SUSY Searches

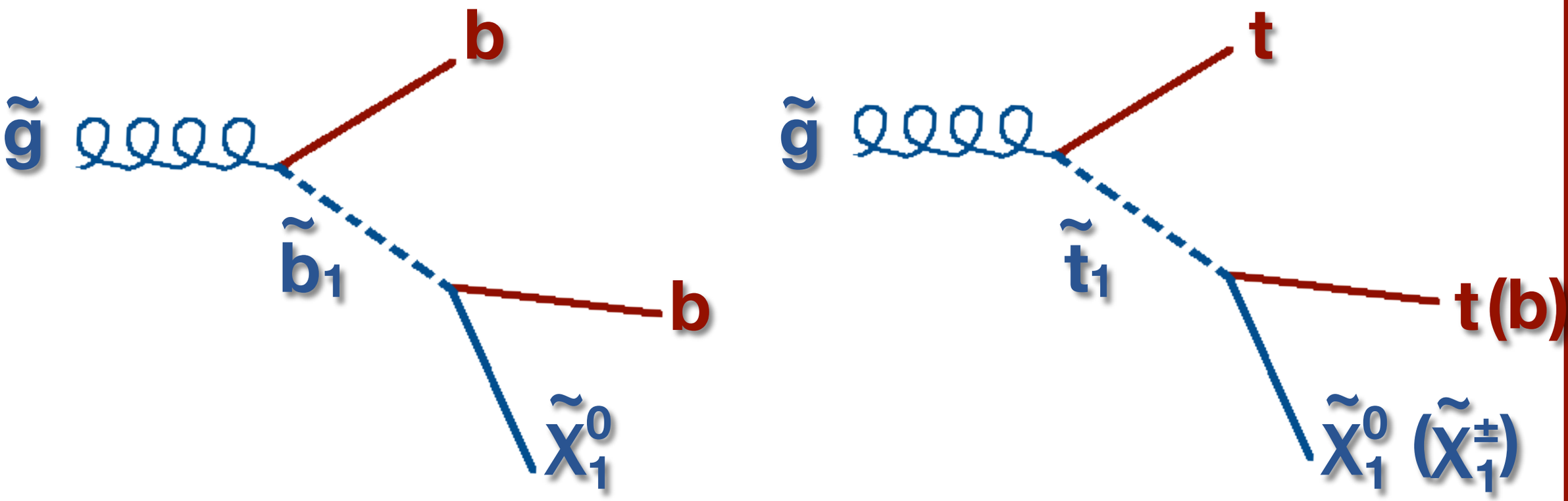


- An important motivation for SUSY: **"naturalness"**
  => stabilize the Higgs mass without massive fine tuning
- 3rd generation squarks **($\tilde{t}$, $\tilde{b}$)** could be *light*

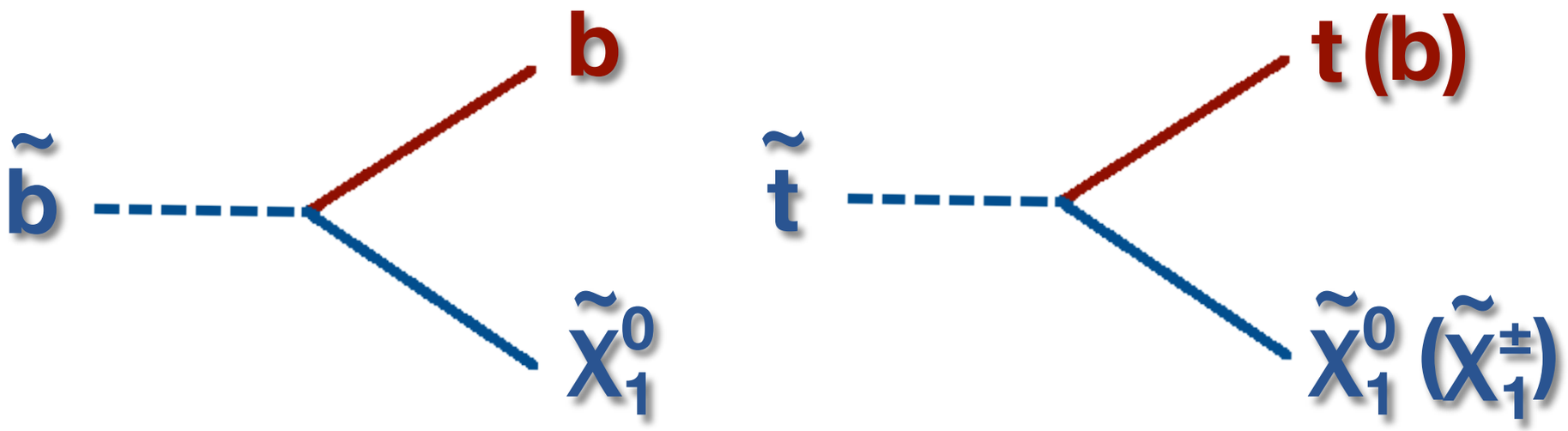


- 2 ways to search for them:
  - gluino cascade decays
  - direct pair production

through gluino decays



direct production

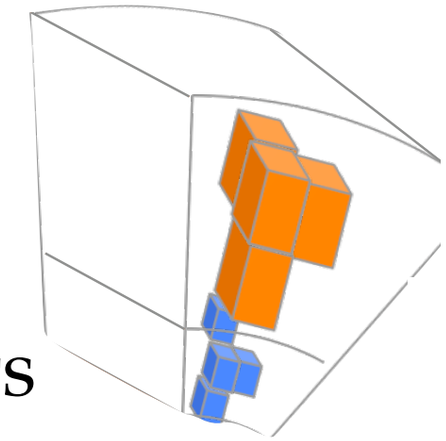


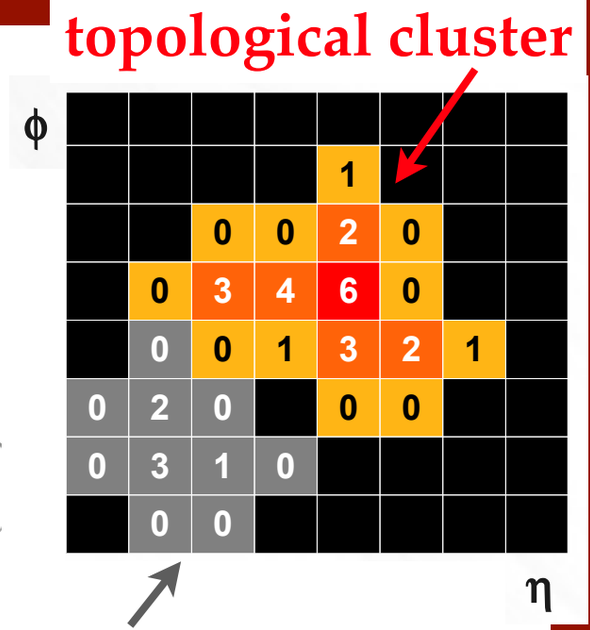
General Features of ATLAS SUSY Analyses

- Electrons & muons are well-reconstructed and <u>isolated</u> wrt surrounding tracks (within $\Delta R \leq 0.2$)
- Electrons within $0.2 \leq \Delta R \leq 0.4$ of jets and muons within $\Delta R \leq 0.4$ of jets are considered jets
- E_T^{miss}: negative vector sum of all objects (jets, electrons, muons, and "soft" energy deposits)
- A few more details about jet reconstruction...
  ➡ **important systematic uncertainties**

Jet Reconstruction

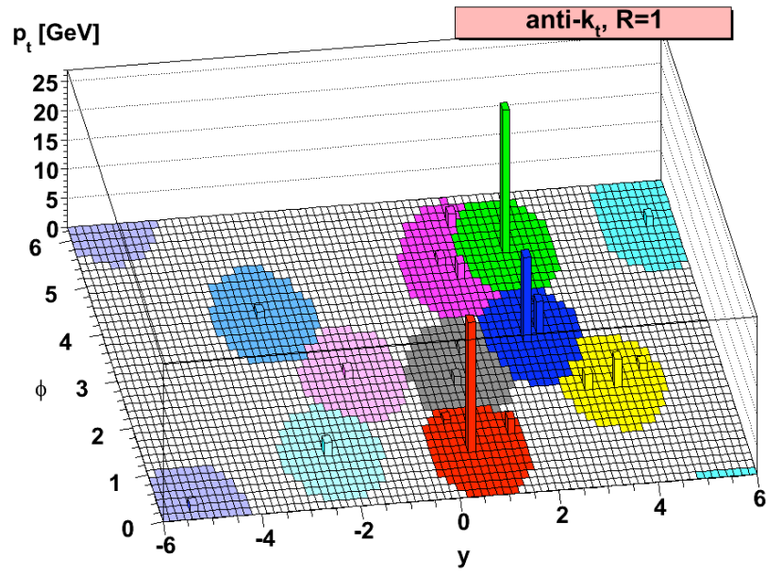
- **Constituents:** Topological Clusters
  - Seeded from cells with $|E_{cell}| > 4\sigma_{noise}$ in the calorimeters





  - 3-dimensional; excellent noise suppression

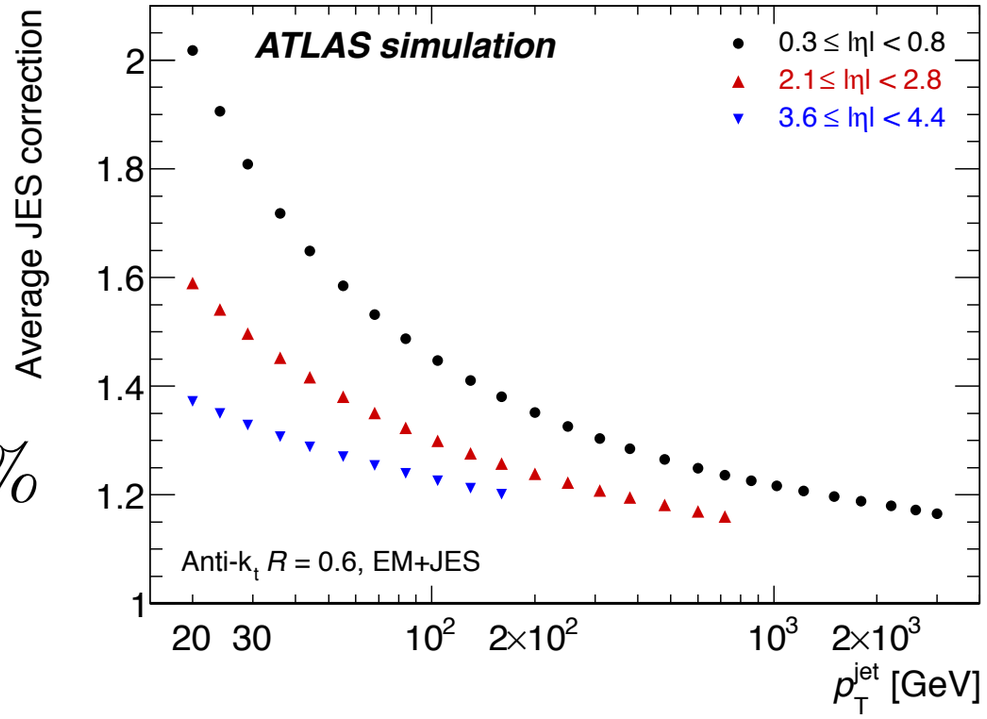
- **Jet definition**:
  - anti-k_T sequential combination algorithm (IR, collinear safe)
  - corrected for "pileup" (multiple interactions / beam crossing)



arXiv:0802.1189 [hep-ex]

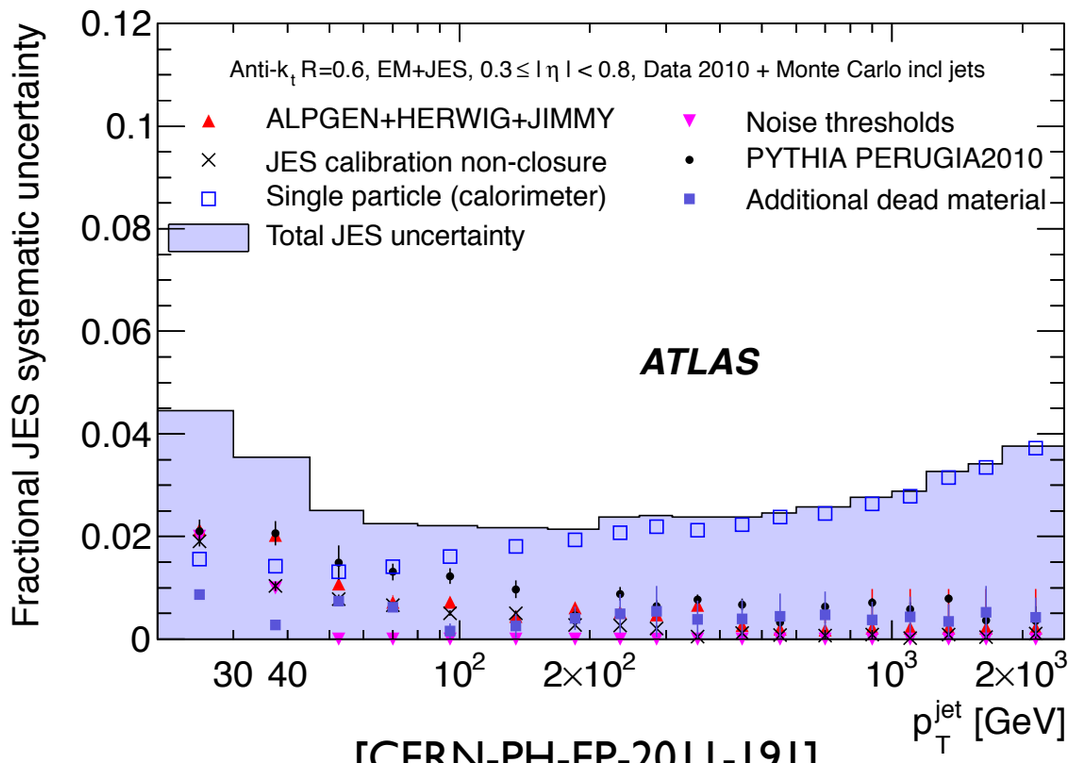
Jet Calibration

- Jet p_T corrected on average from electromagnetic to hadronic scale in (p_T, η)
  - Overall correction to jet p_T is ~50% for central jets with p_T ~ 100 GeV



- Systematic uncertainties due to jet energy scale < 2.5% for central jets with 60 < p_T < 800 GeV

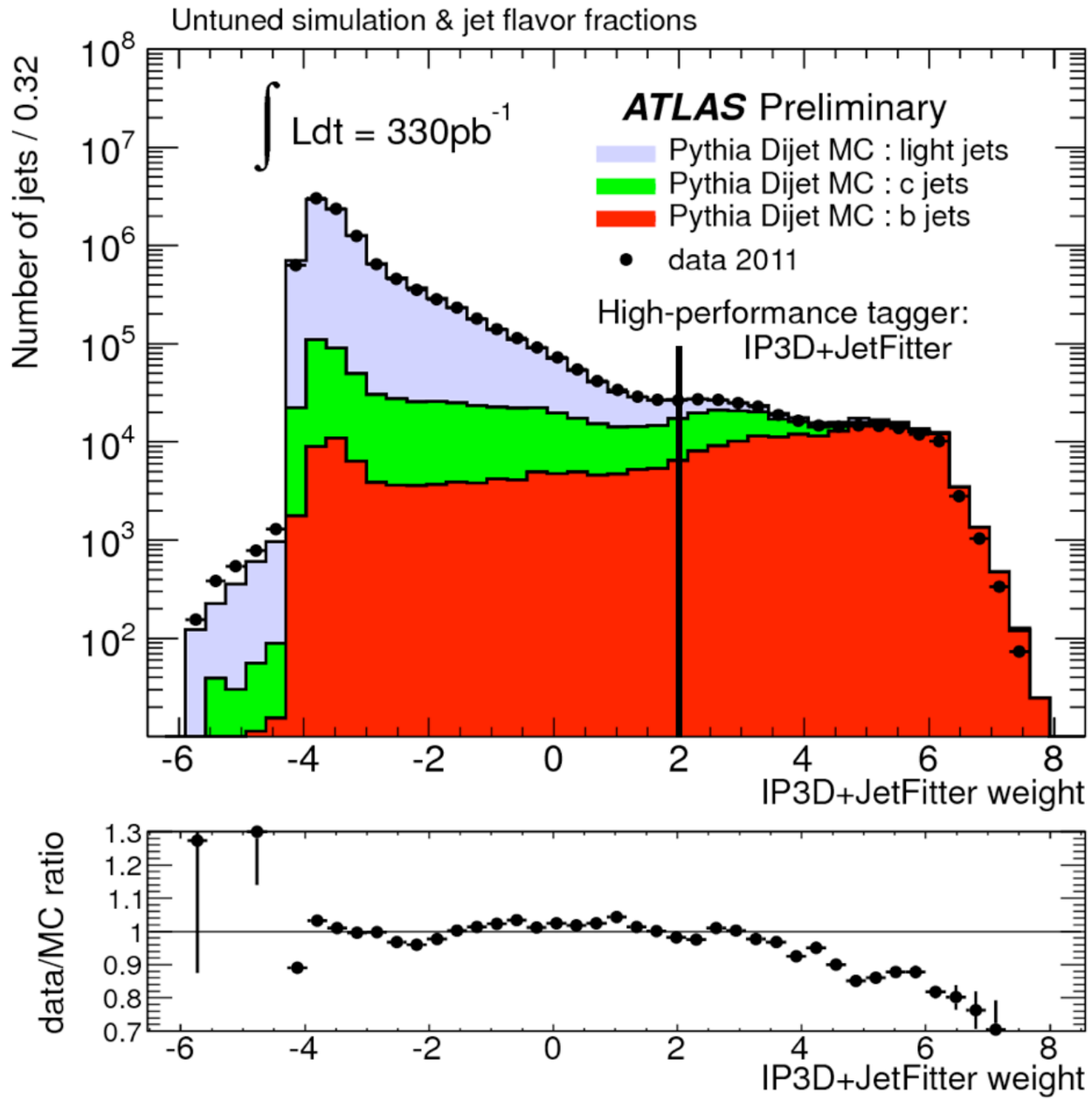
➡ small uncertainty extremely important for SUSY searches with many jets in the final state



[CERN-PH-EP-2011-191], submitted to EPJC

Jet Flavor Tagging

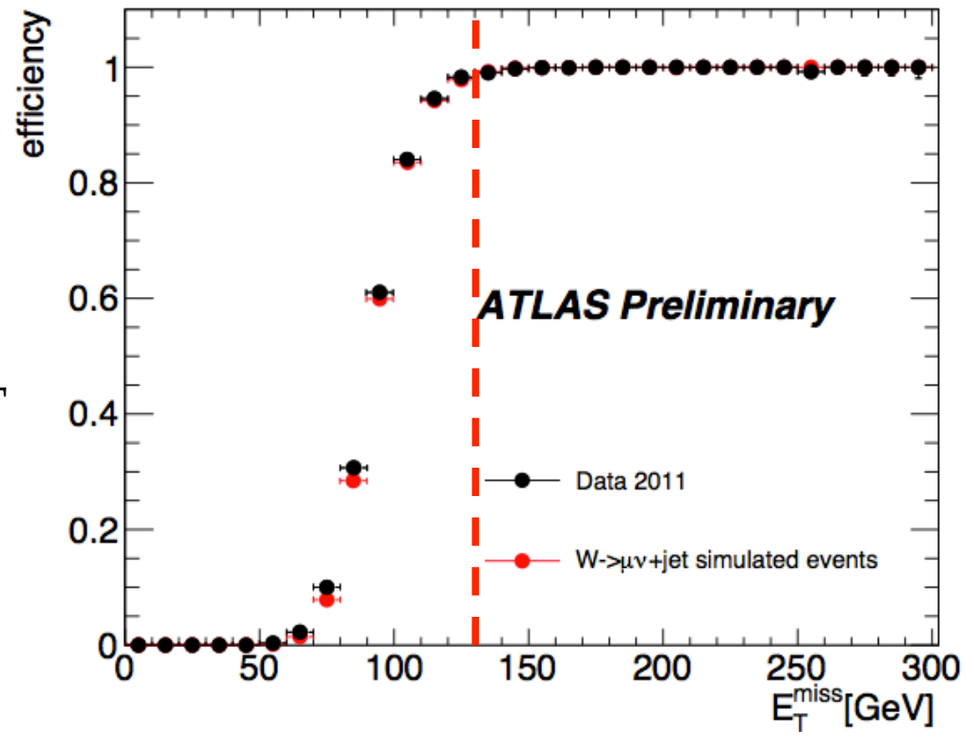
- well-measured tracks w / $p_T > 1$ GeV considered [400 MeV for secondary vertices]
- uses 3-D tracking impact parameters and vertices of c- and b-hadrons inside jet
- 60% efficiency in ttbar, < 1% mistag rate for light flavor / gluon jets



ATLAS-CONF-2011-102

Triggers

- 1 high p_T jet + E_T^{miss}:
  fully efficient at jet $p_T > 130$ GeV,
  $E_T^{miss} > 130$ GeV



- multijet triggers: allow lower jet p_T thresholds for analyses with many jets, e.g. 6 jets > 55 GeV

- single lepton triggers: constant efficiency for electrons w/ $p_T > 25$ GeV, muons /w $p_T > 20$ GeV
  [during higher pileup conditions, a muon+jet trigger is used, where the muon > 20 GeV and one jet > 60 GeV]

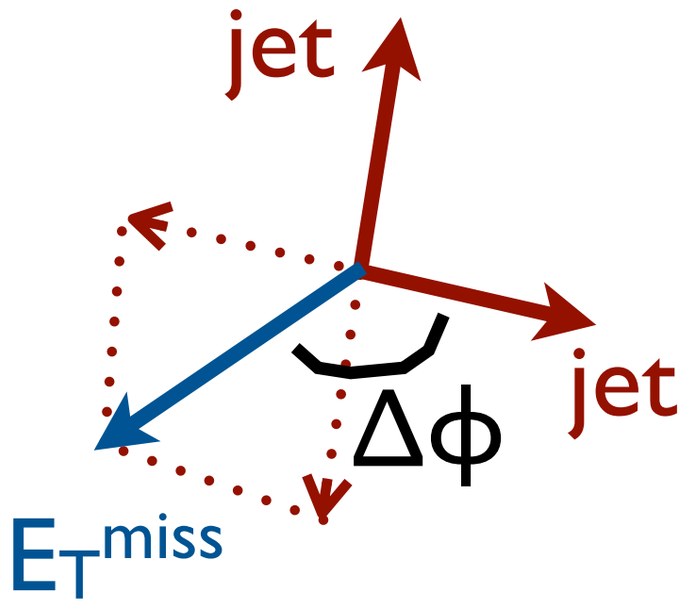
- di-lepton triggers (*ee, eμ*): *e* $p_T > 15$ GeV, *μ* $p_T > 8$ GeV

Event-level Variables

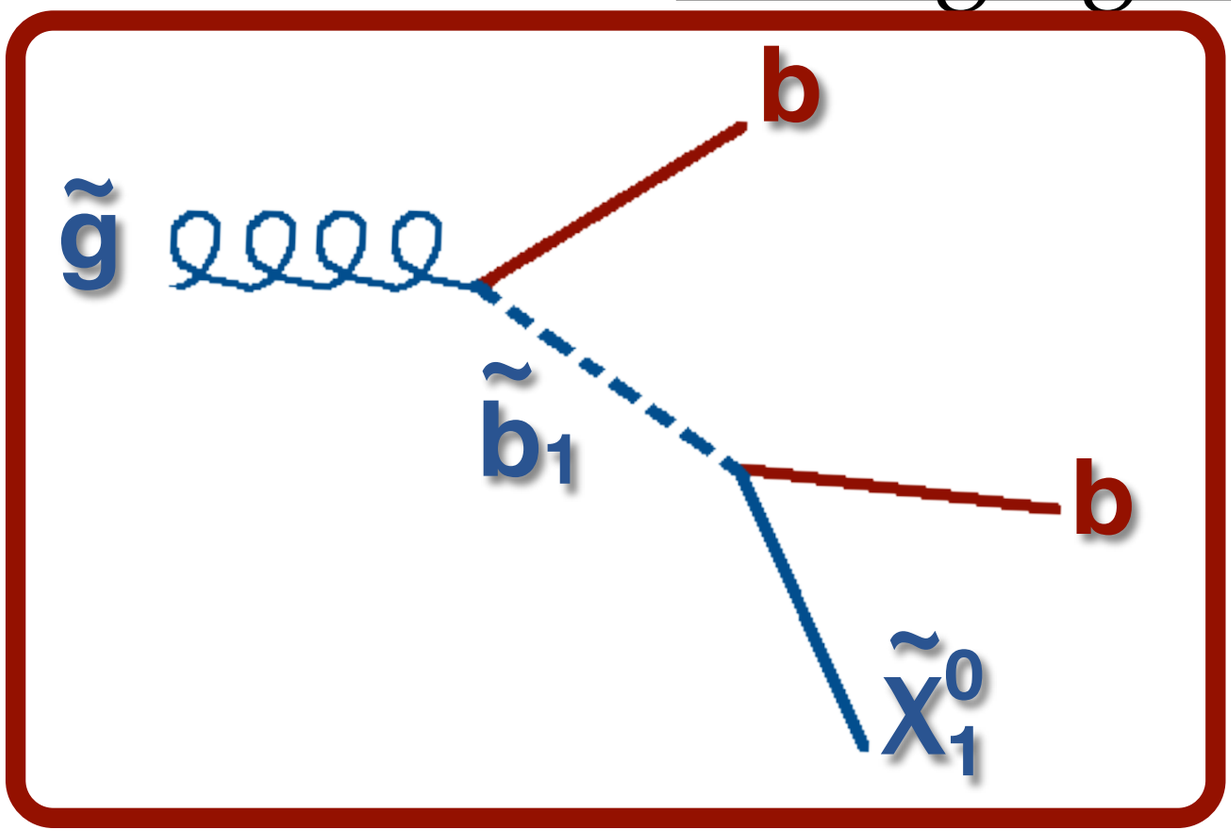
Signal Regions:

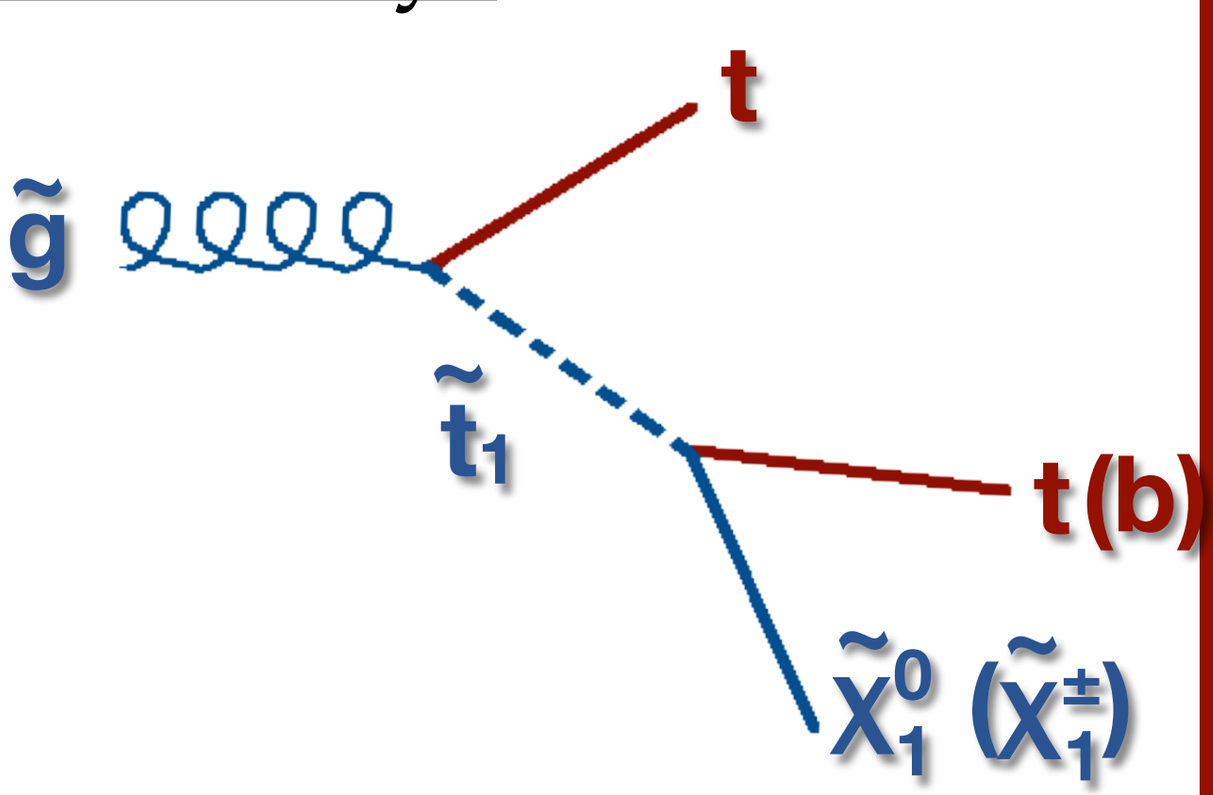
- E_T^{miss}
- $m_{eff} \equiv \Sigma | p_T^{jet} | + (\Sigma | p_T^{el/mu} |) + E_T^{miss}$ ("effective mass")
- E_T^{miss} / m_{eff}
- $m_T = \sqrt{2 p_T^l E_T^{miss} \cdot (1 - \cos \Delta\phi[l, E_T^{miss}])}$

$\Delta\varphi(jet, E_T^{miss}) > 0.4$ rejects QCD bkg

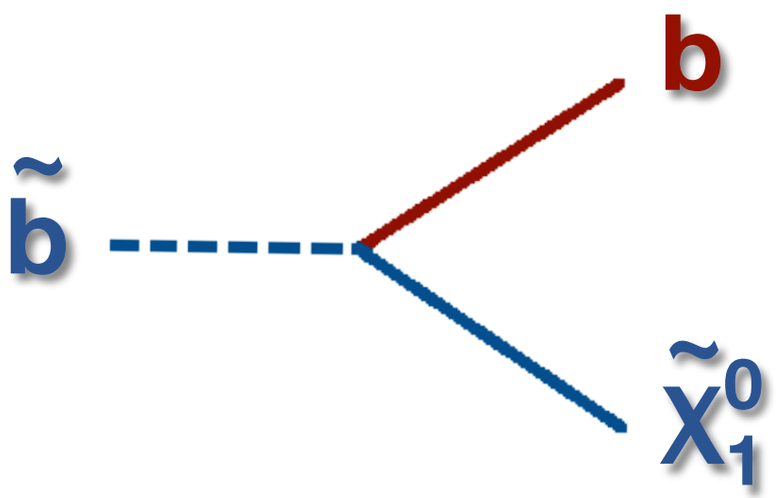


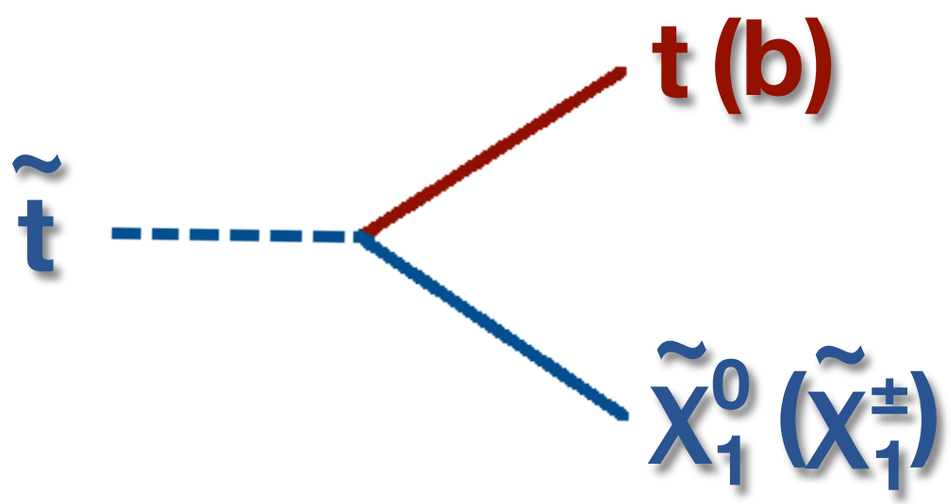
through gluino decays





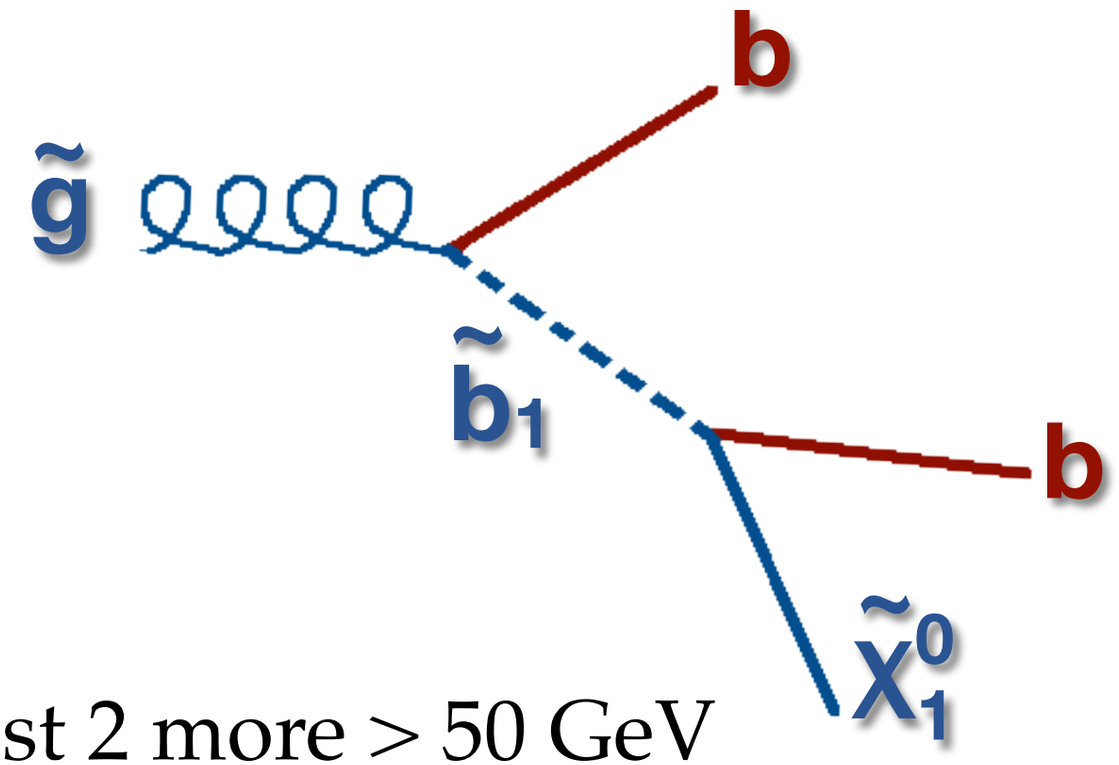
direct production





Gluino Mediated Sbottom

- **Analysis signature:**
  b-tagged jets + E_T^{miss}
- **Trigger:**
  1 high p_T jet + E_T^{miss}
- **Selection:**
  first jet > 130 GeV; at least 2 more > 50 GeV
  E_T^{miss} > 130 GeV
  1-2 jets must be *b*-tagged
  veto electrons & muons
  E_T^{miss} / m_{eff} > 0.25



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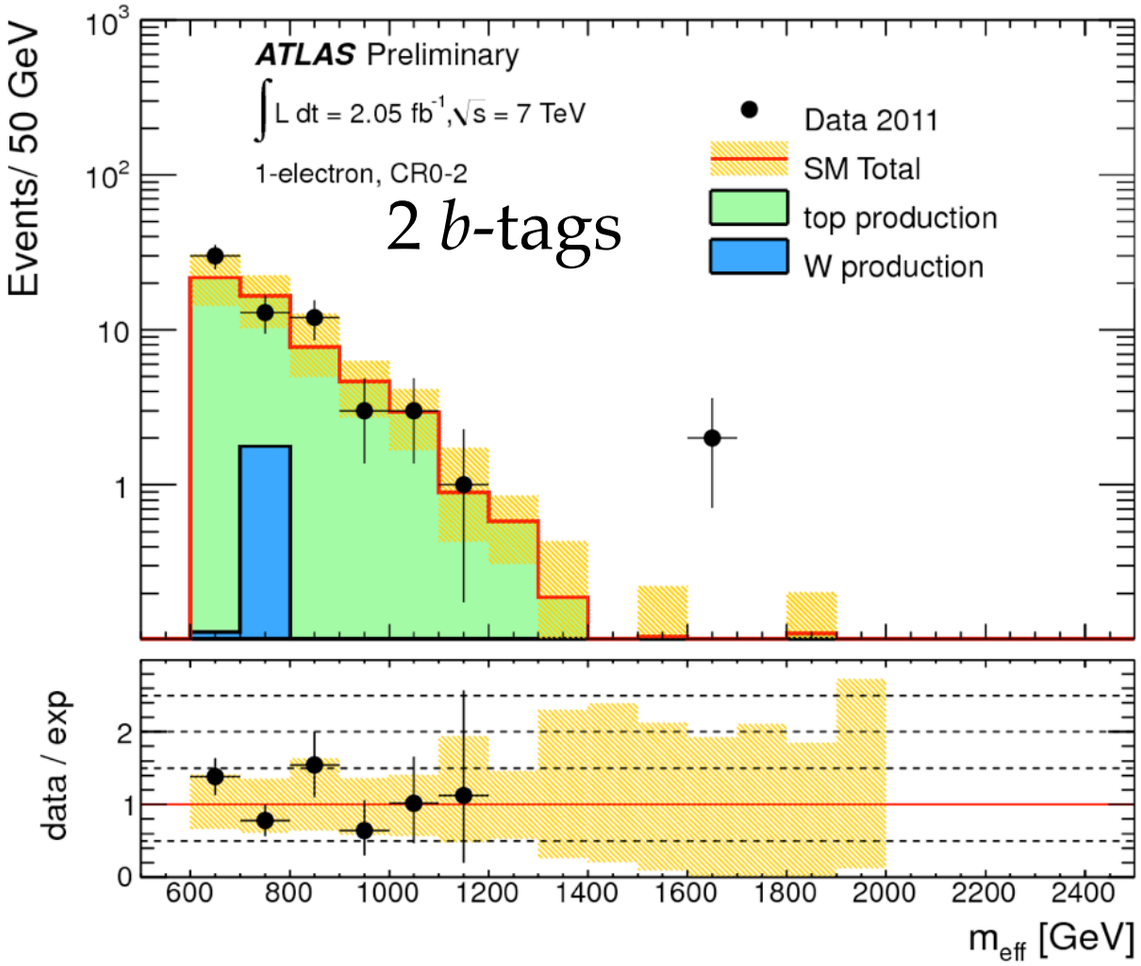
Gluino Mediated Sbottom

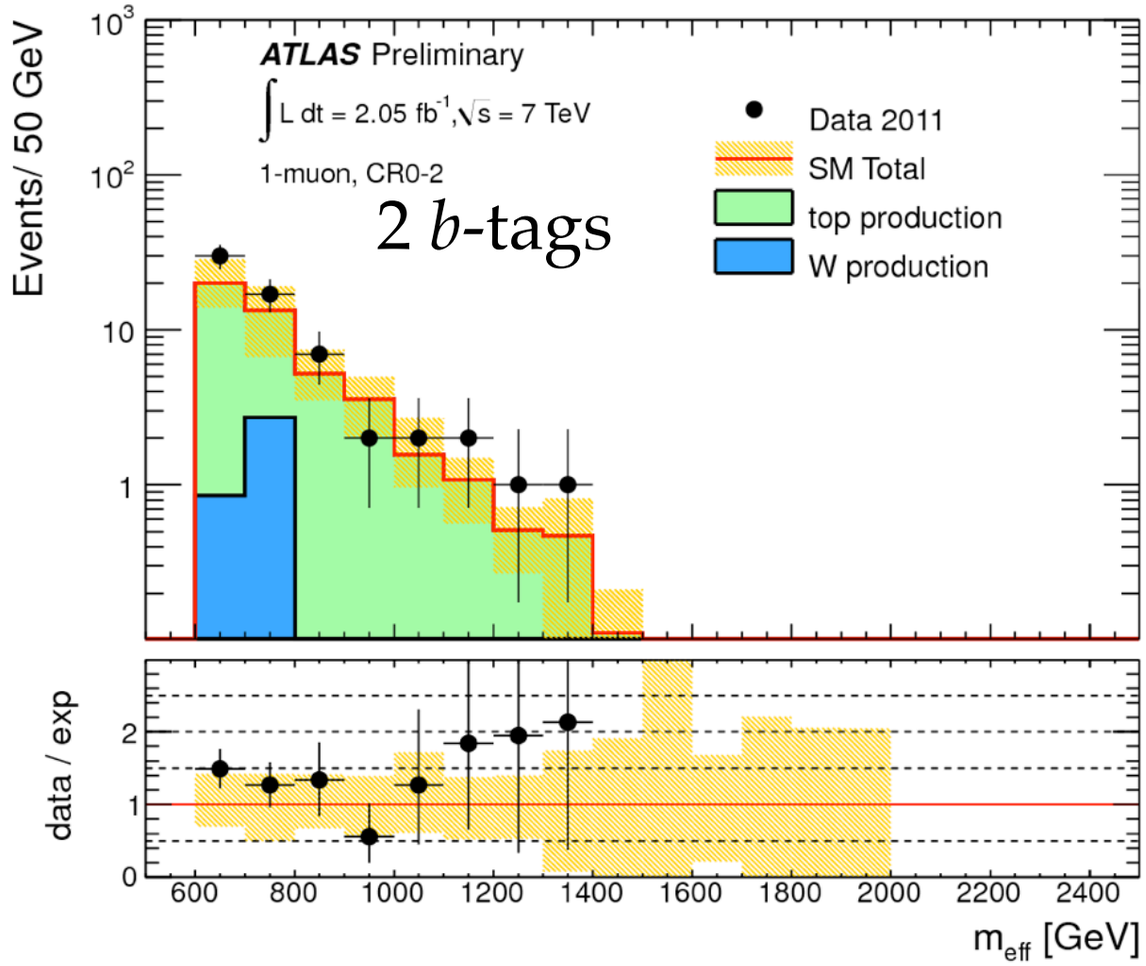
top background estimation:

1 lepton, $m_{eff} > 600$ GeV

$40 < m_T < 100$ GeV

uncertainties: 15-35%, dominated by theory





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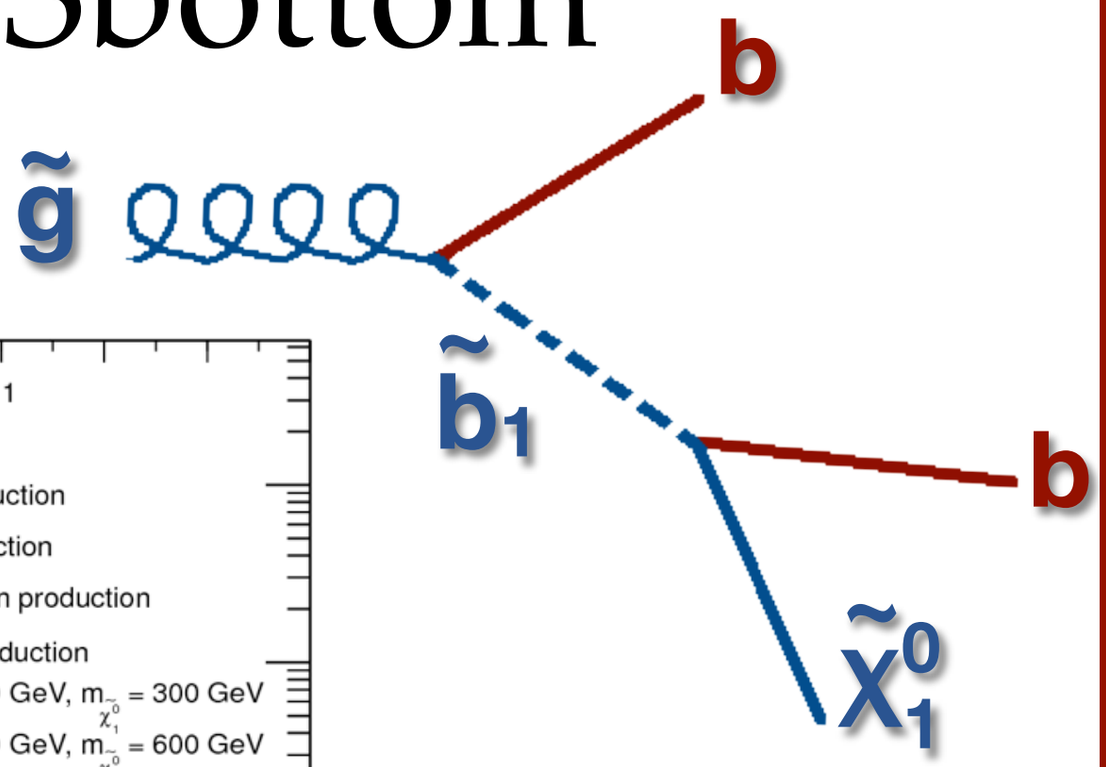
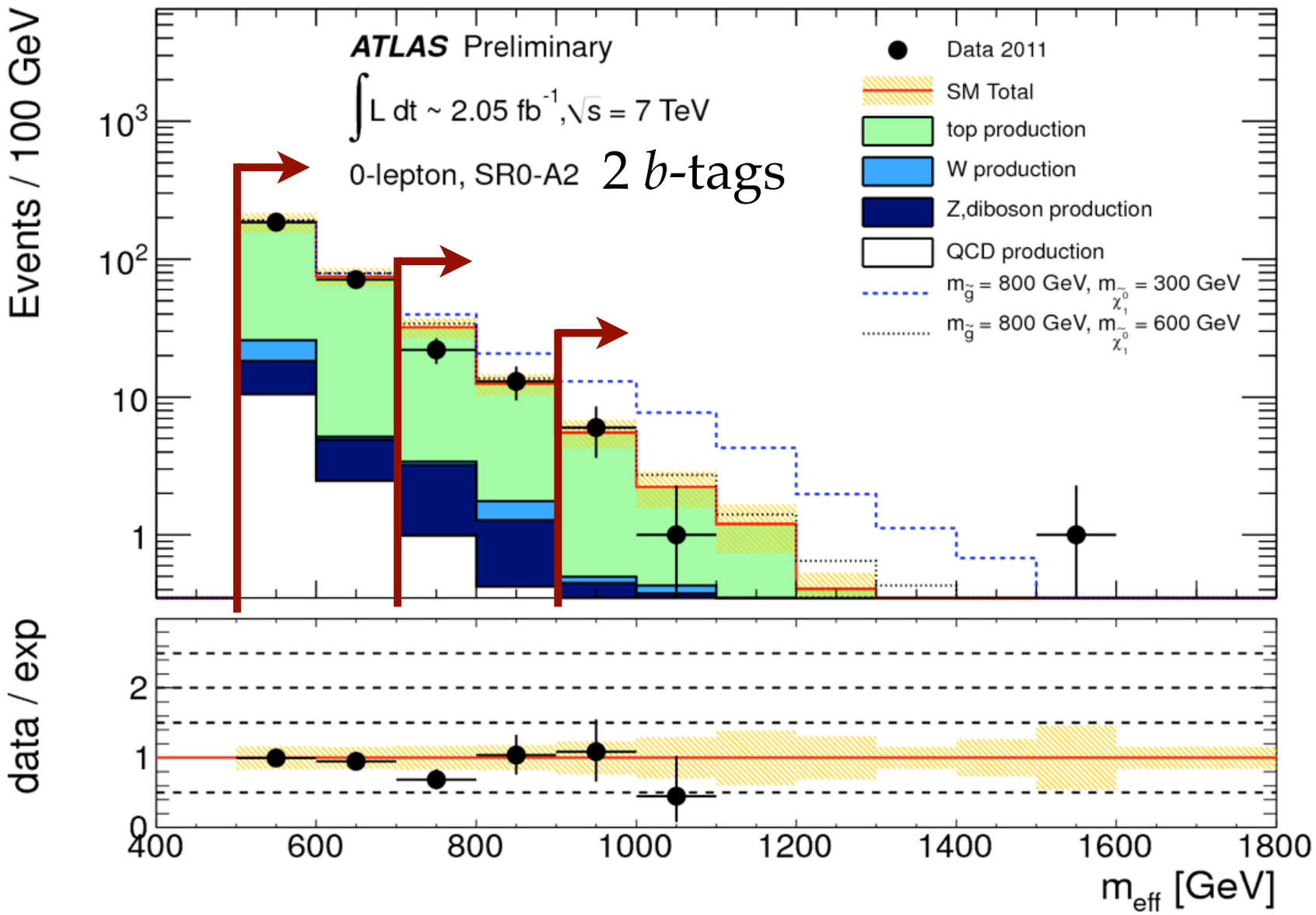
Gluino Mediated Sbottom





Signal Region	Expected Bkg	Data
$m_{eff} > 500$ GeV	316 ± 72	299
$m_{eff} > 700$ GeV	54 ± 11	43
$m_{eff} > 900$ GeV	9.8 ± 3.2	8

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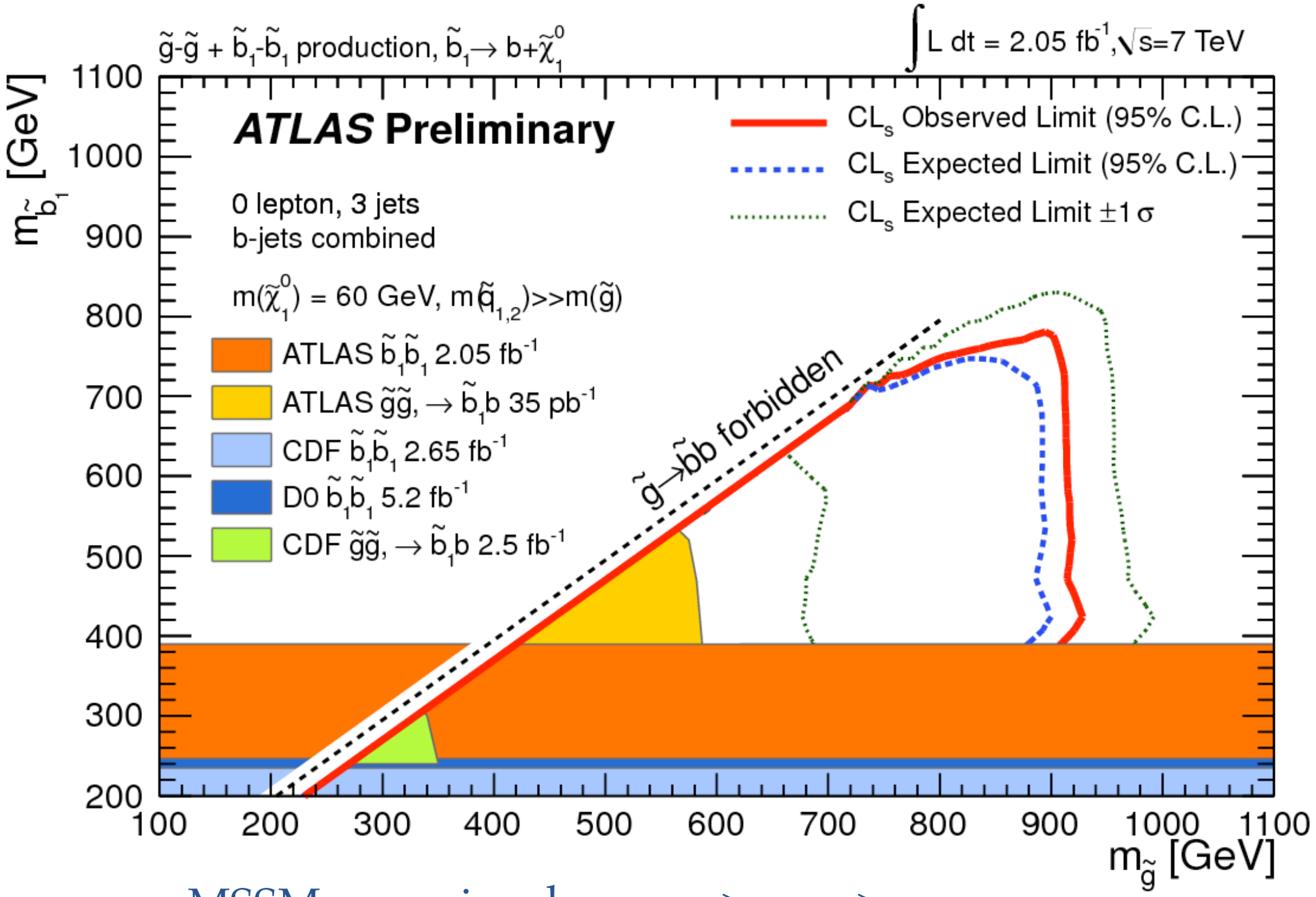

MSSM scenario where $m_{\tilde{g}} > m_{\tilde{b}_1} > m_{\tilde{\chi}_1^0}$

$\mathcal{B}(\tilde{g} \rightarrow \tilde{b}_1 b) = 100\%$ (other squarks heavy)

$\mathcal{B}(\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0) = 100\%$

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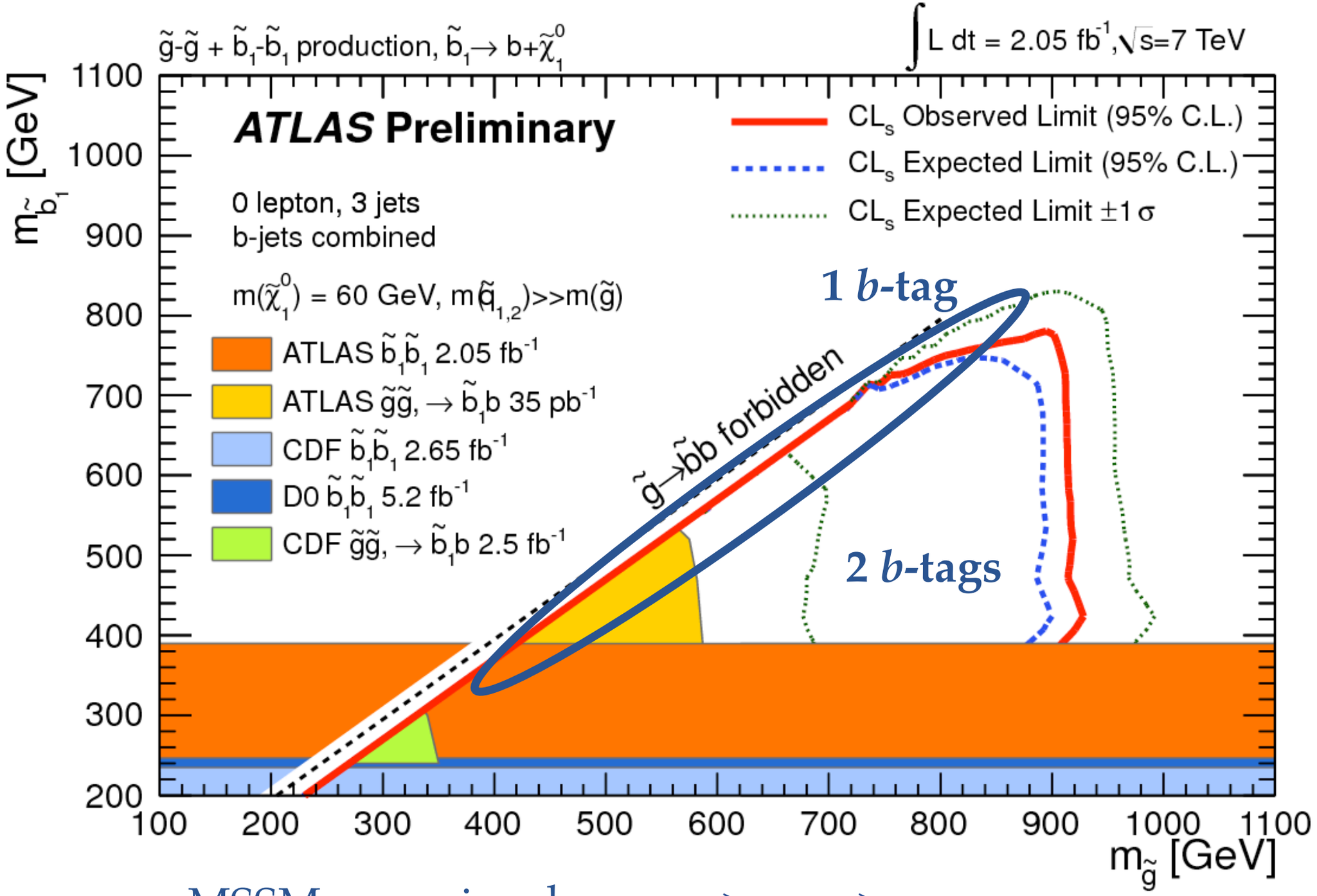
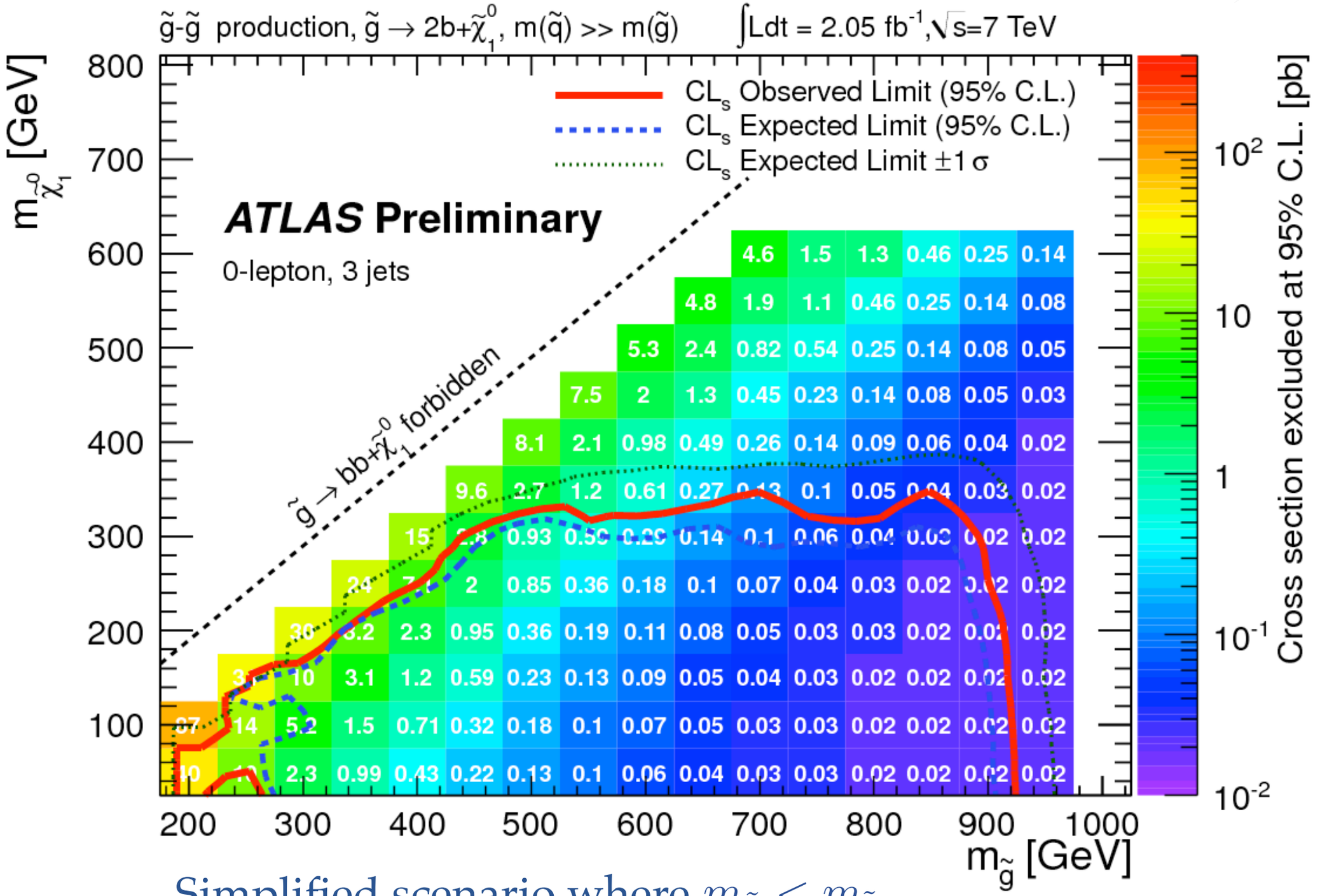


MSSM scenario where $m_{\tilde{g}} > m_{\tilde{b}_1} > m_{\tilde{\chi}_1^0}$

$\mathcal{B}(\tilde{g} \rightarrow \tilde{b}_1 b) = 100\%$ (other squarks heavy)

$\mathcal{B}(\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0) = 100\%$

ATLAS-CONF-2012-003



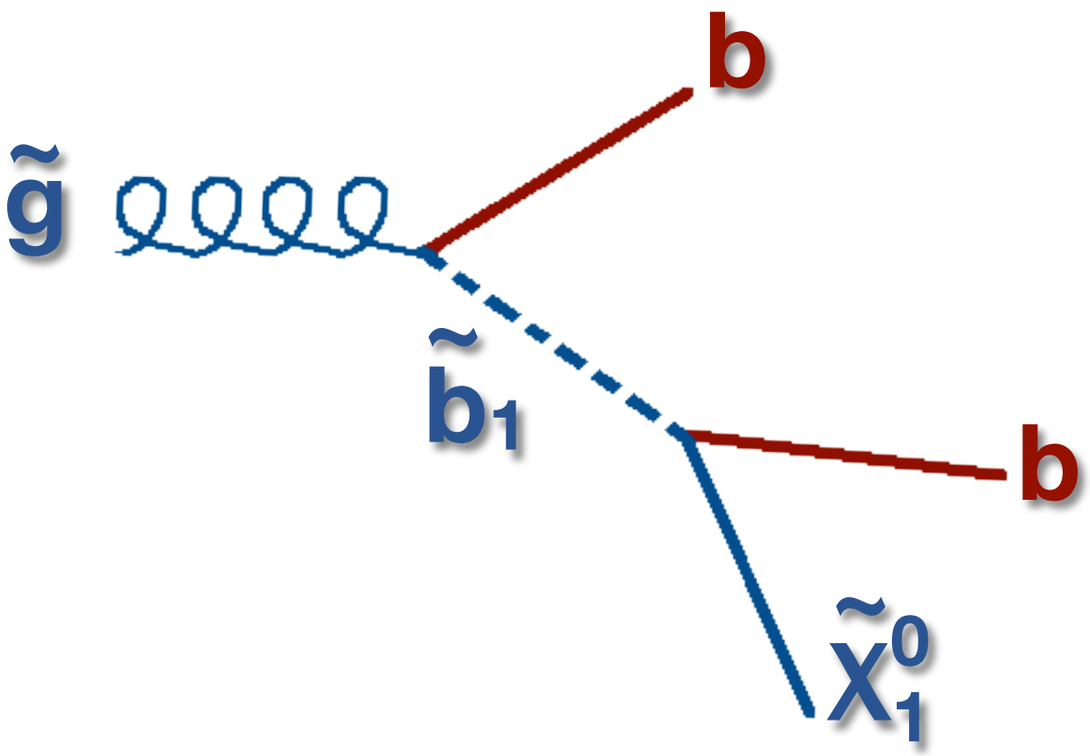
Simplified scenario where $m_{\tilde{g}} < m_{\tilde{b}_1}$

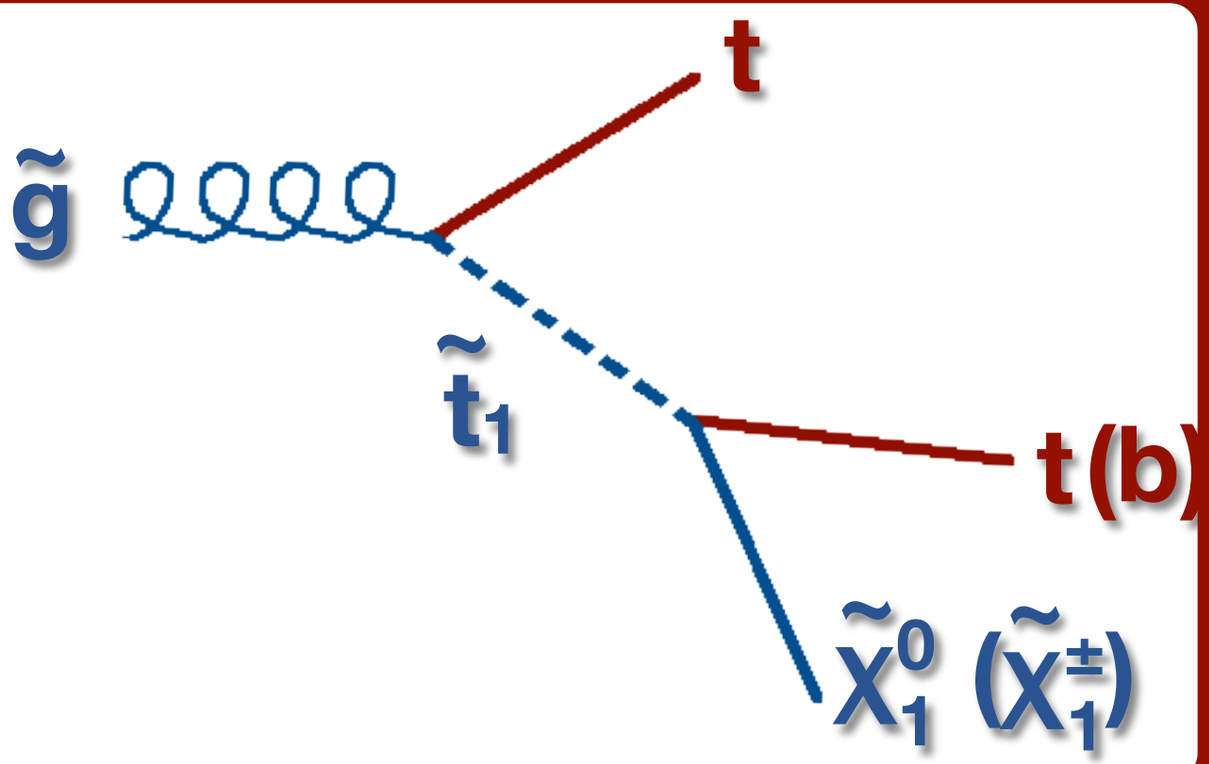
$\mathcal{B}(\tilde{g} \to b\bar{b}\tilde{\chi}_1^0) = 100\%$ (other squarks heavy)

(off-shell sbottom)

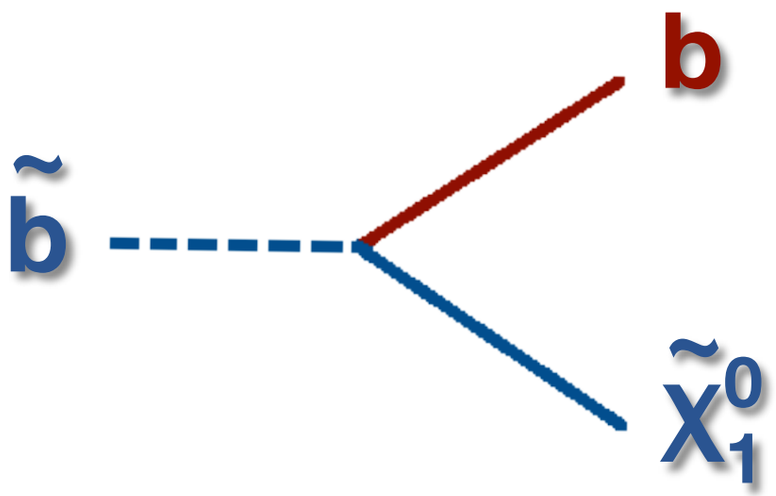
ATLAS-CONF-2012-003

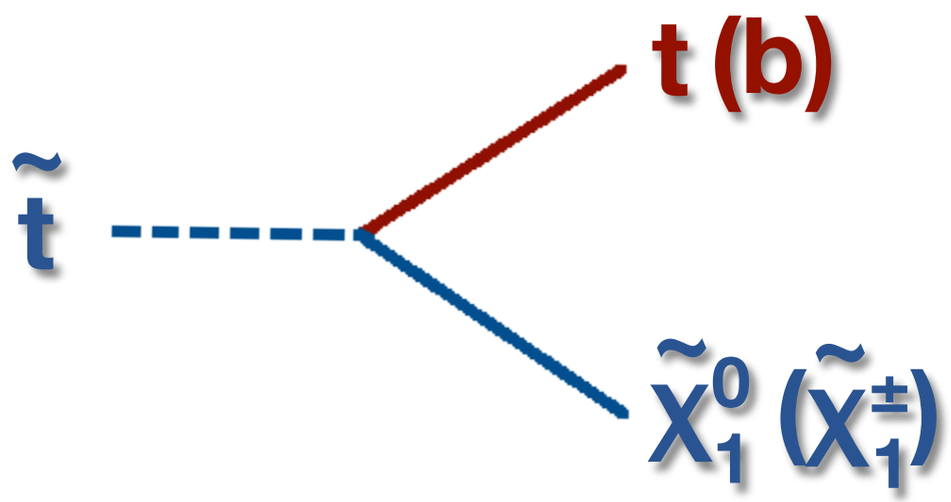
through gluino decays





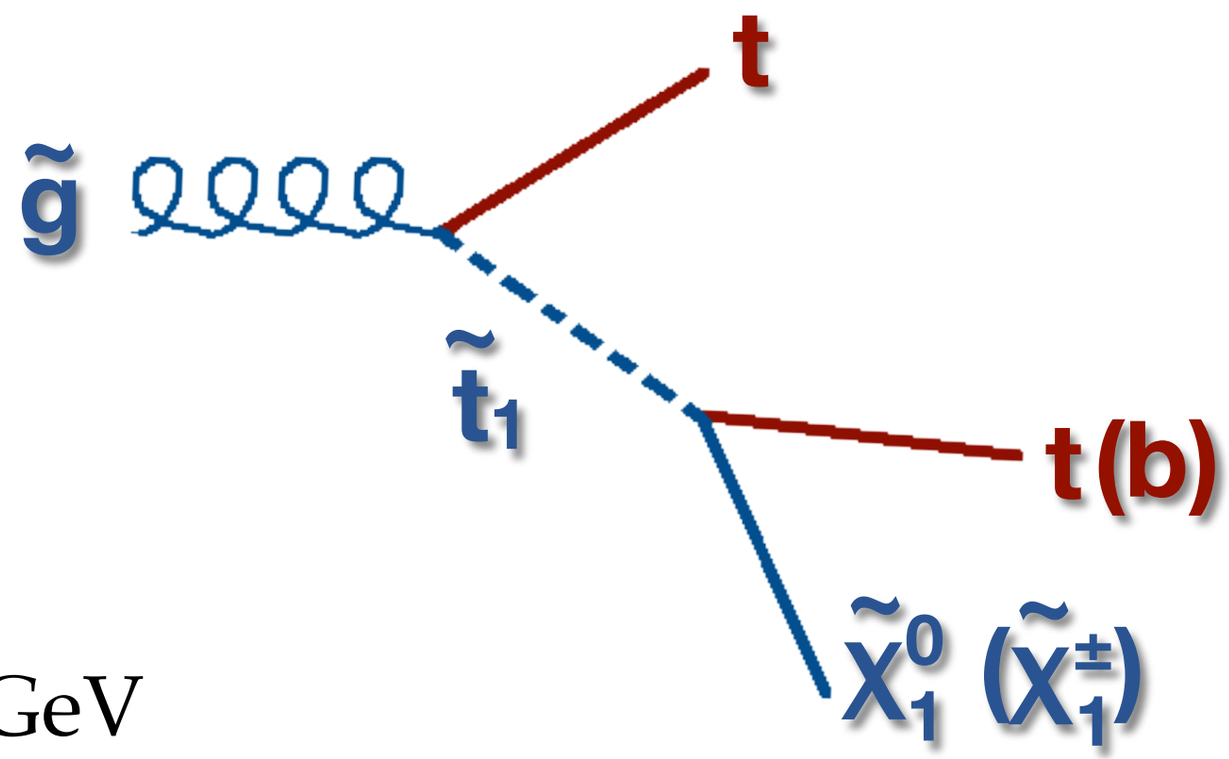
direct production





Gluino Mediated Stop

- **Analysis signature:**
  1 lepton + jets + E_T^{miss}
- **Trigger:**
  electron / muon + jet
- **Selection:**
  electron (muon) > 25 (20) GeV
  first jet > 60 GeV, at least 3 more > 50 GeV
  ≥ 1 jets must be *b*-tagged
  E_T^{miss} > 80 GeV
  m_T > 100 GeV



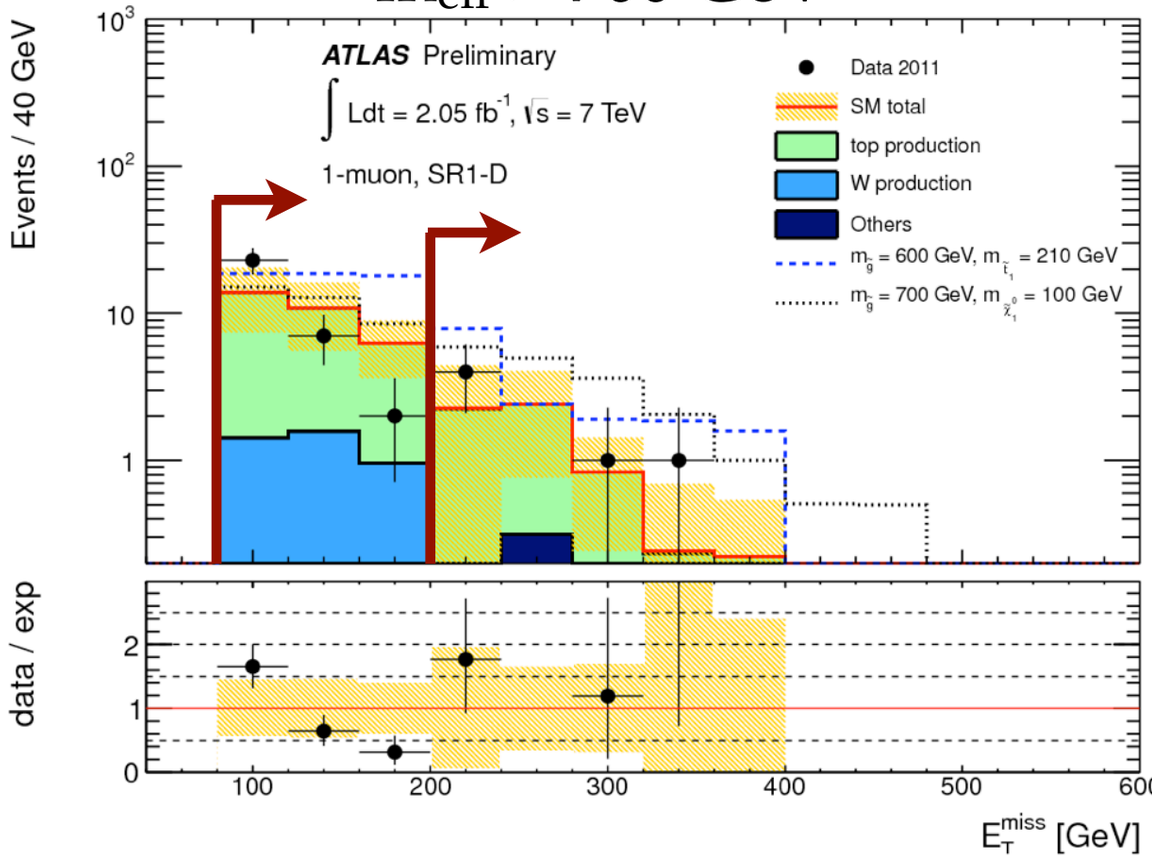
ATLAS-CONF-2012-003

Gluino Mediated Stop

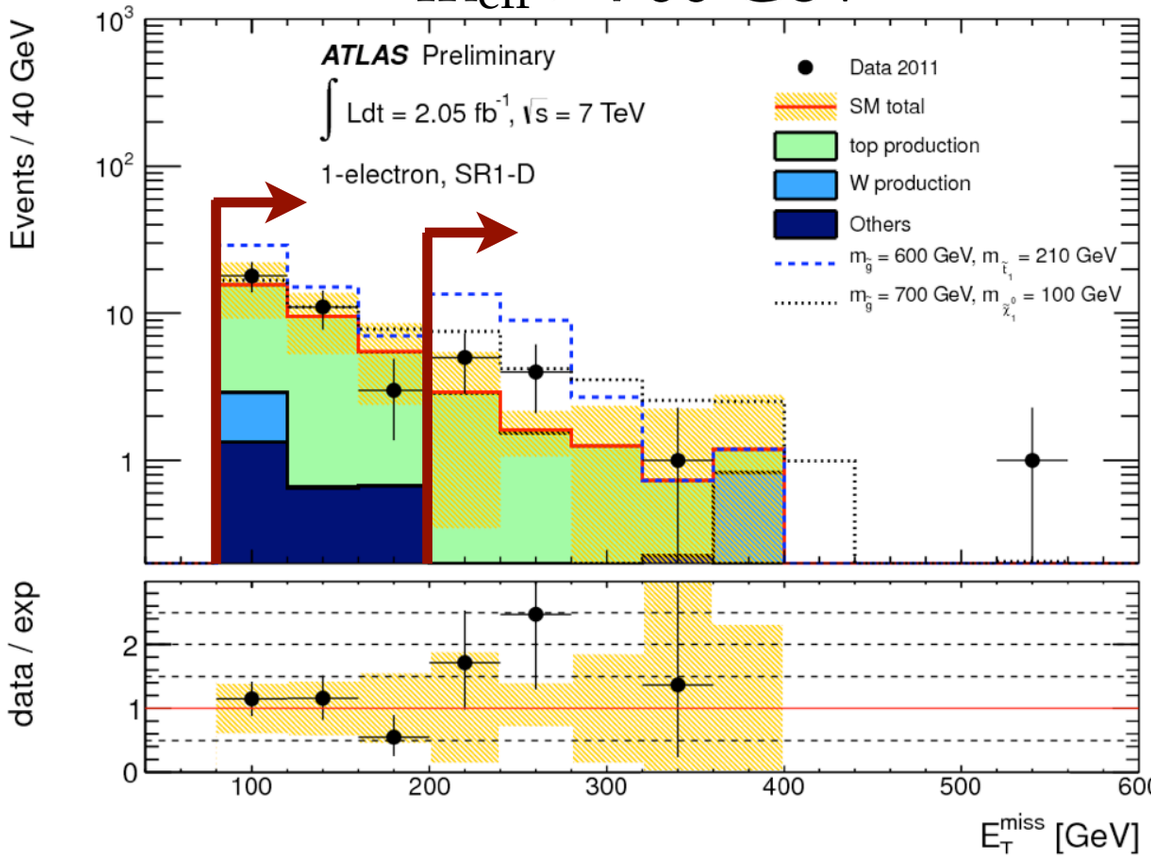
	Signal Region	Expected Bkg	Data
electron	$E_T^{miss} > 80$ GeV	39 ± 12	43
muon	$E_T^{miss} > 80$ GeV	38 ± 14	38
electron	$E_T^{miss} > 200$ GeV	8.1 ± 3.4	11
muon	$E_T^{miss} > 200$ GeV	6.3 ± 4.2	6

1 lepton + jets + E_T^{miss}

$m_{eff} > 700$ GeV



$m_{eff} > 700$ GeV



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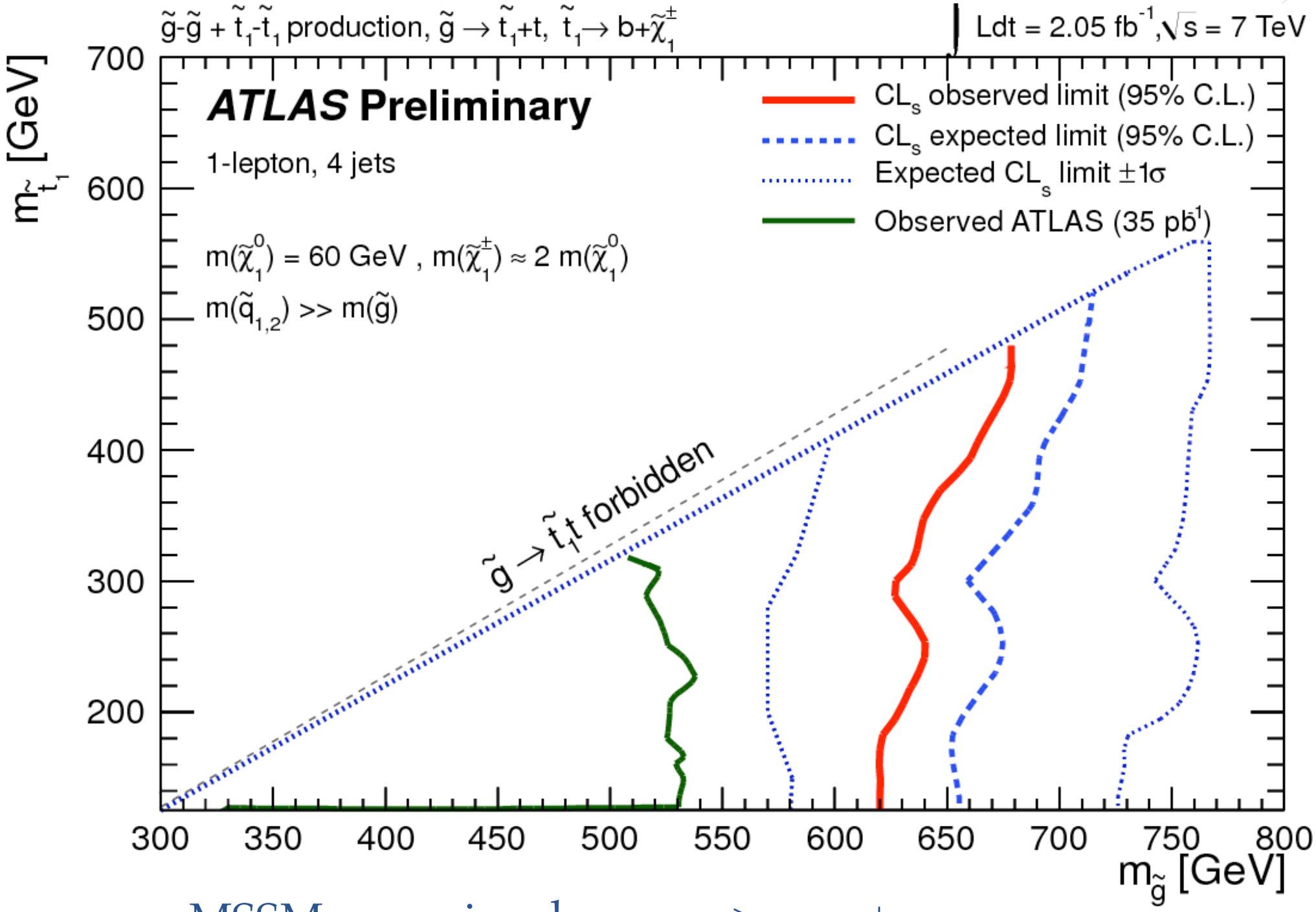

MSSM scenario where $m_{\tilde{g}} > m_{\tilde{t}_1} + m_t$

$\mathcal{B}(\tilde{g} \rightarrow \tilde{t}_1 t) = 100\%$

$\mathcal{B}(\tilde{t}_1 \rightarrow b\tilde{\chi}_1^0) = 100\%$

$\mathcal{B}(\tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^0 l^{\pm} \nu) = 11\%$

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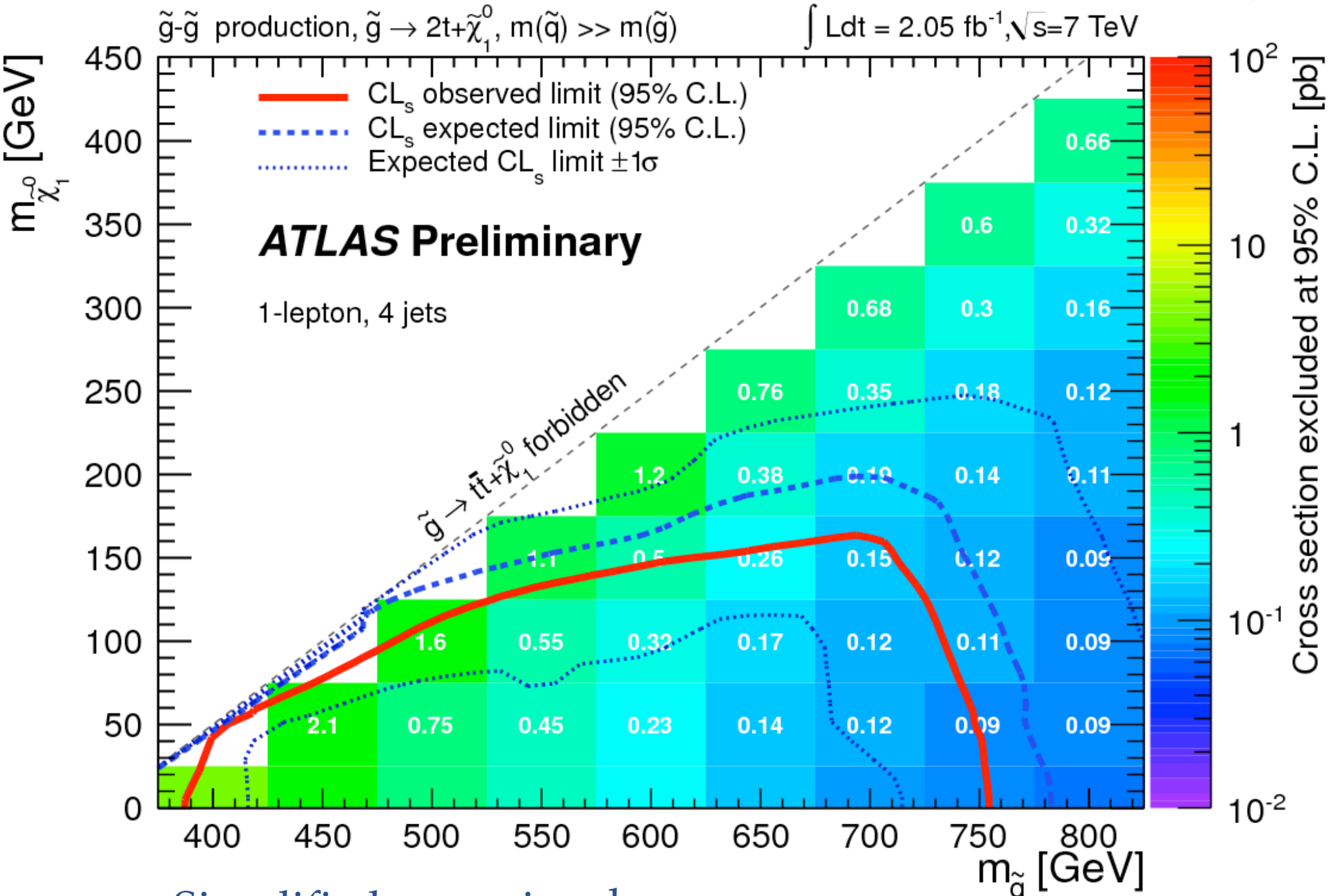


Simplified scenario where $m_{\tilde{g}} < m_{\tilde{t}_1}$

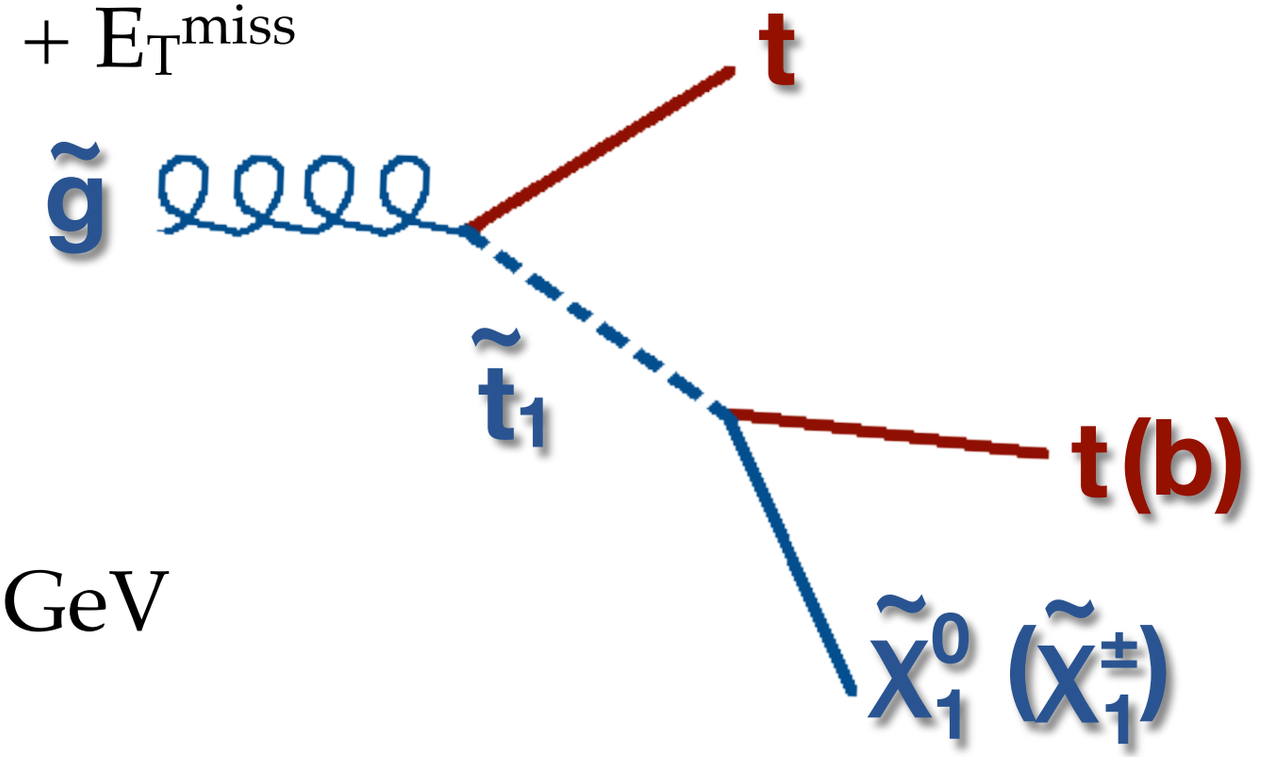
$\mathcal{B}(\tilde{g} \to t\bar{t}\tilde{\chi}_1^0) = 100\%$ (other squarks heavy)

(off-shell stop)

ATLAS-CONF-2012-003

Gluino Mediated Stop

- **Analysis signature:**
  2 same-sign leptons + jets + E_T^{miss}
- **Trigger:**
  single / di-lepton
- **Selection:**
  electron (muon) > 20 (20) GeV
  at least 4 jets > 50 GeV
  E_T^{miss} > 150 GeV
  (m_T > 100 GeV)



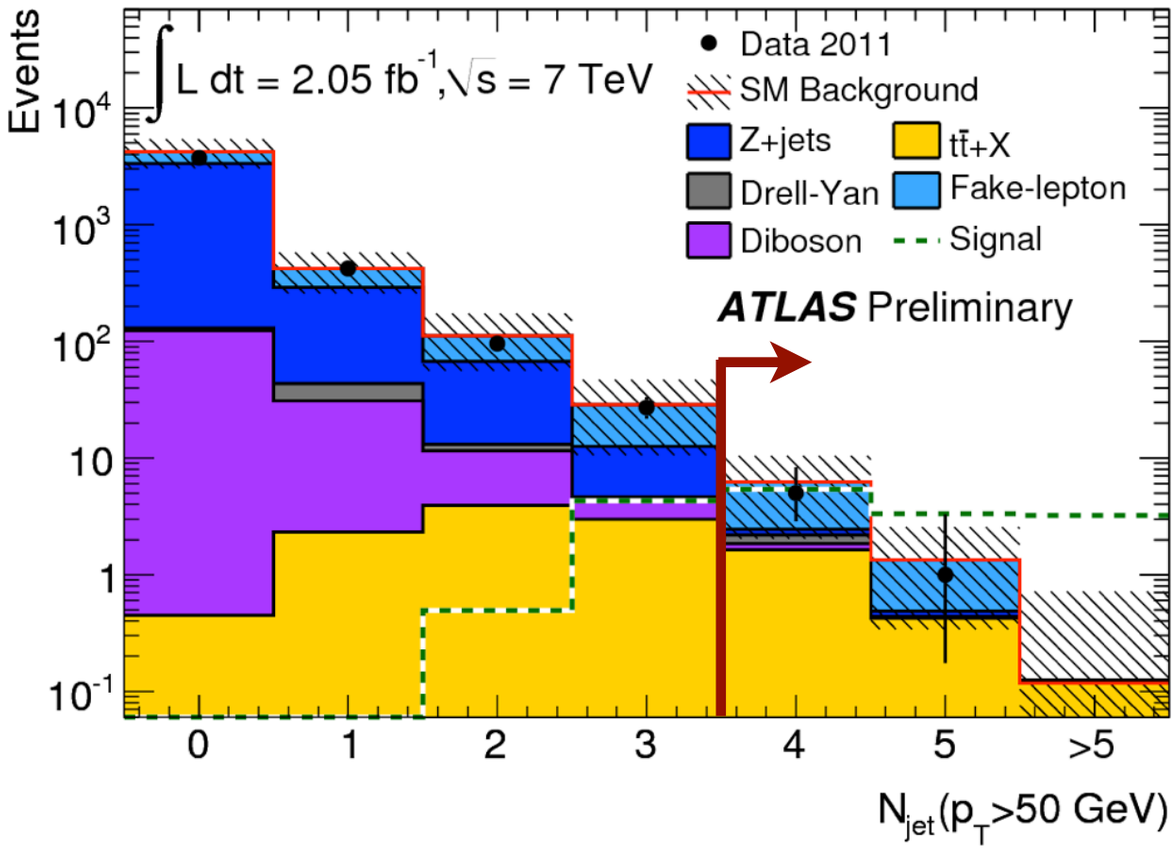
ATLAS-CONF-2012-004

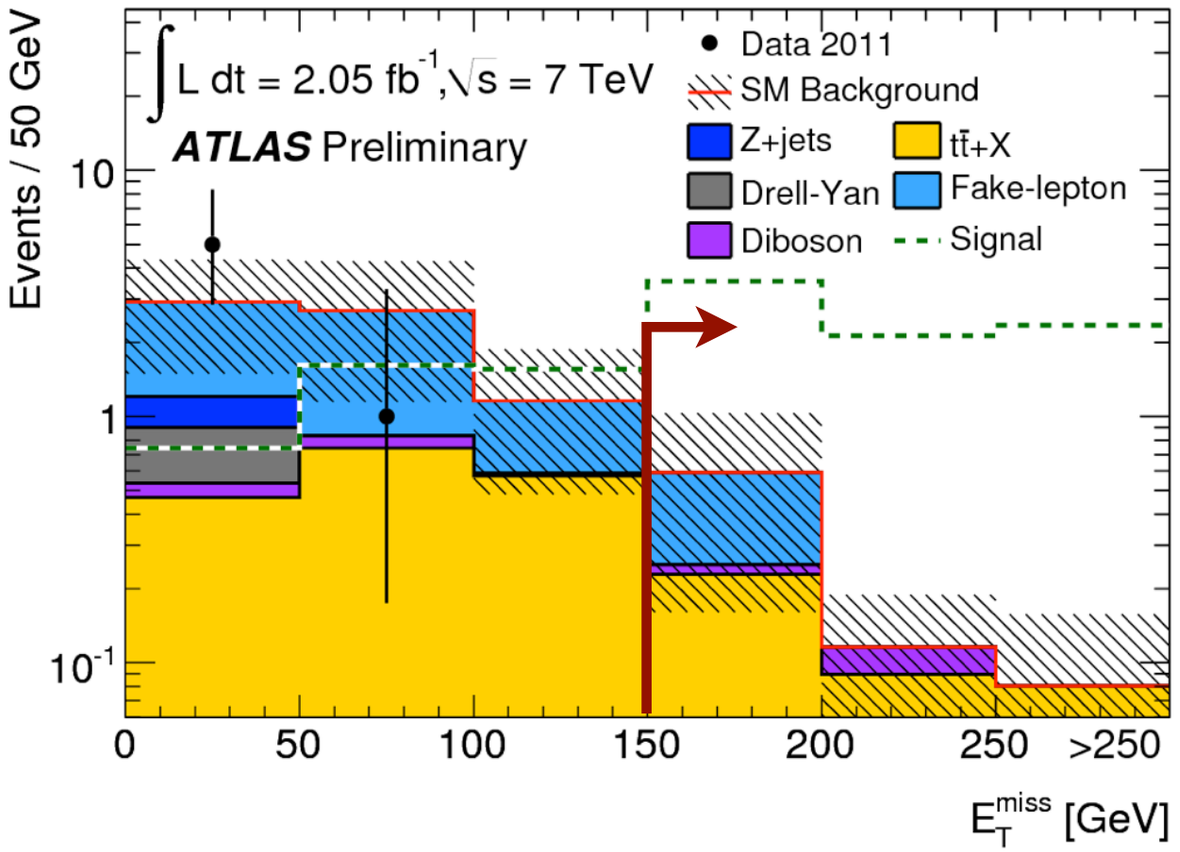
Gluino Mediated Stop

	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}	<1.6 fb	<1.5 fb

2 same-sign leptons + jets + E_T^{miss}

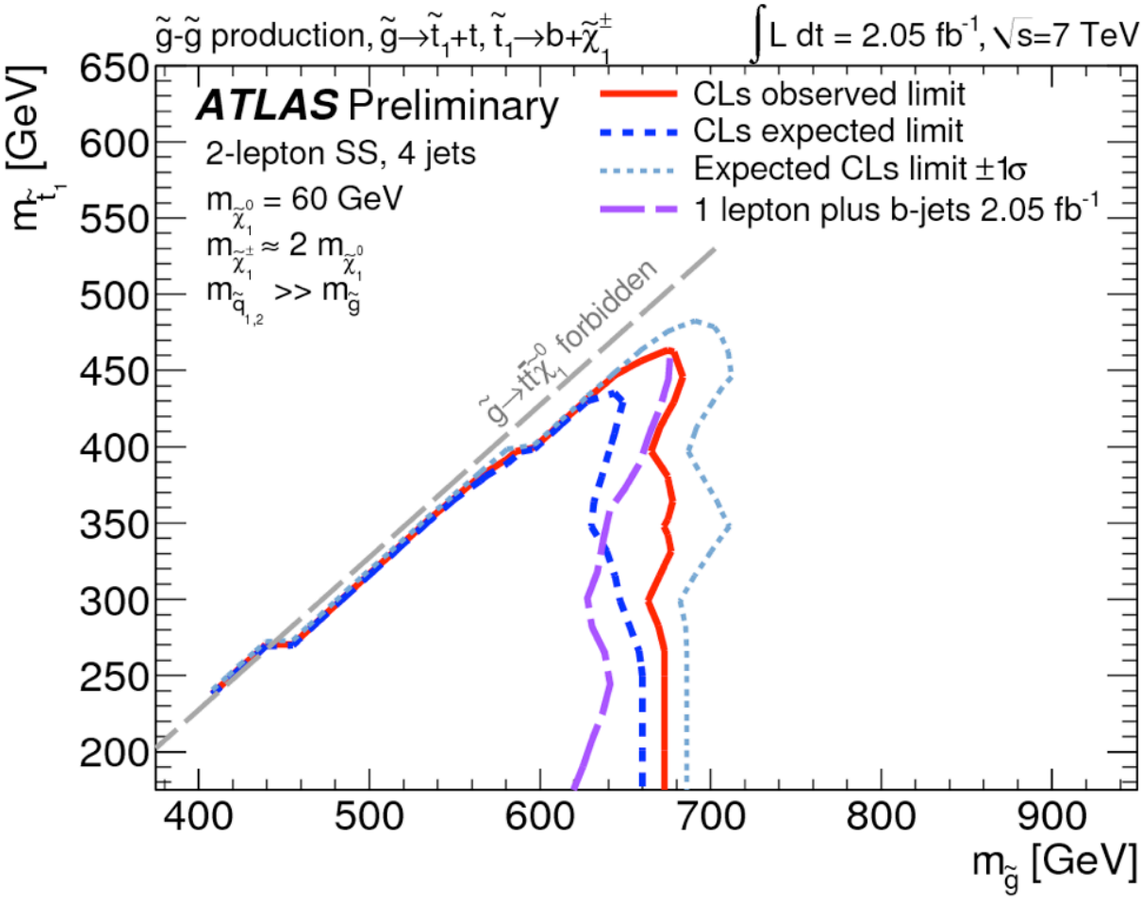
signal: $m_{\tilde{g}} = 650$ GeV, $m_{\tilde{\chi}^0} = 150$ GeV

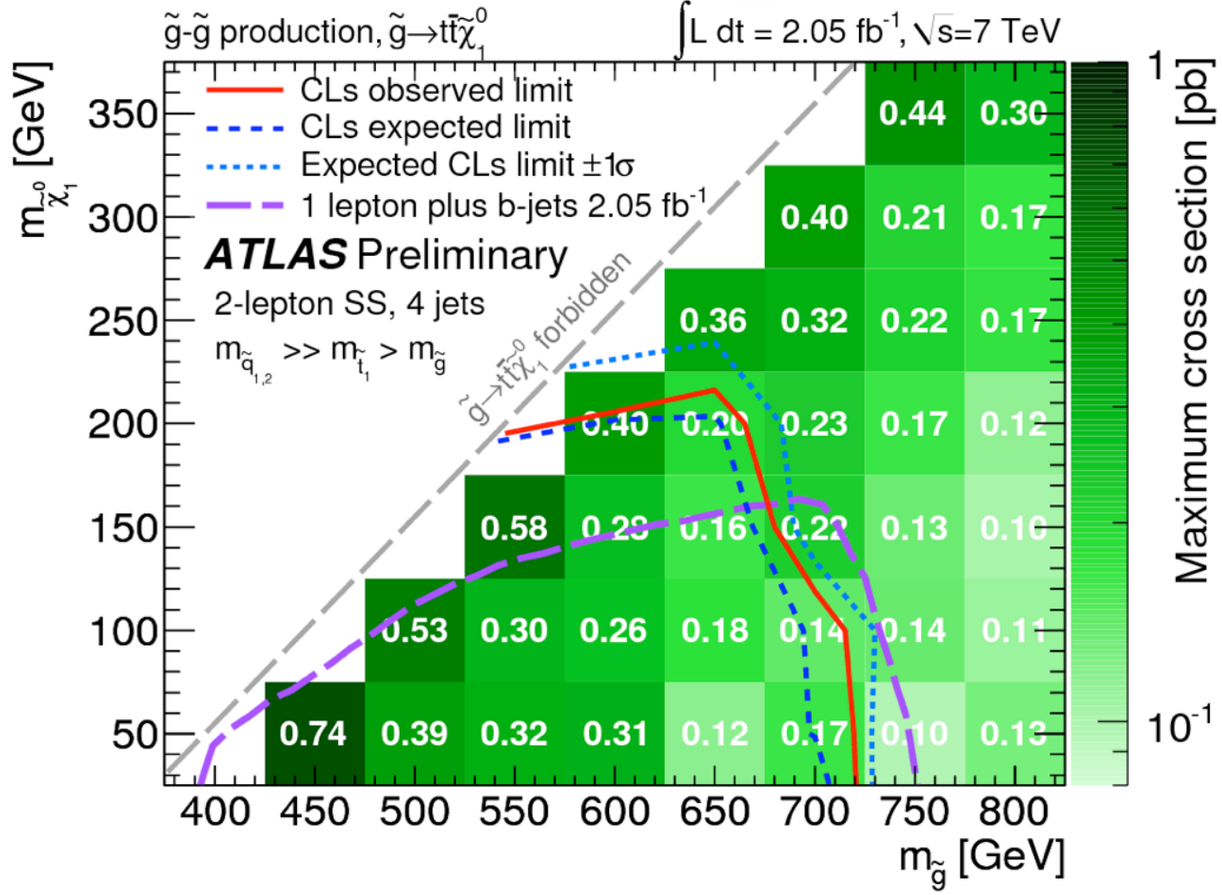




ATLAS-CONF-2012-004

Gluino Mediated Stop





Simplified scenario where $m_{\tilde{g}} < m_{\tilde{t}_1}$

$\mathcal{B}(\tilde{g} \to t\bar{t}\tilde{\chi}_1^0) = 100\%$

(off-shell stop; other squarks heavy)

MSSM scenario where $m_{\tilde{g}} > m_{\tilde{t}_1} + m_t$

$\mathcal{B}(\tilde{g} \to \tilde{t}_1 t) = 100\%$

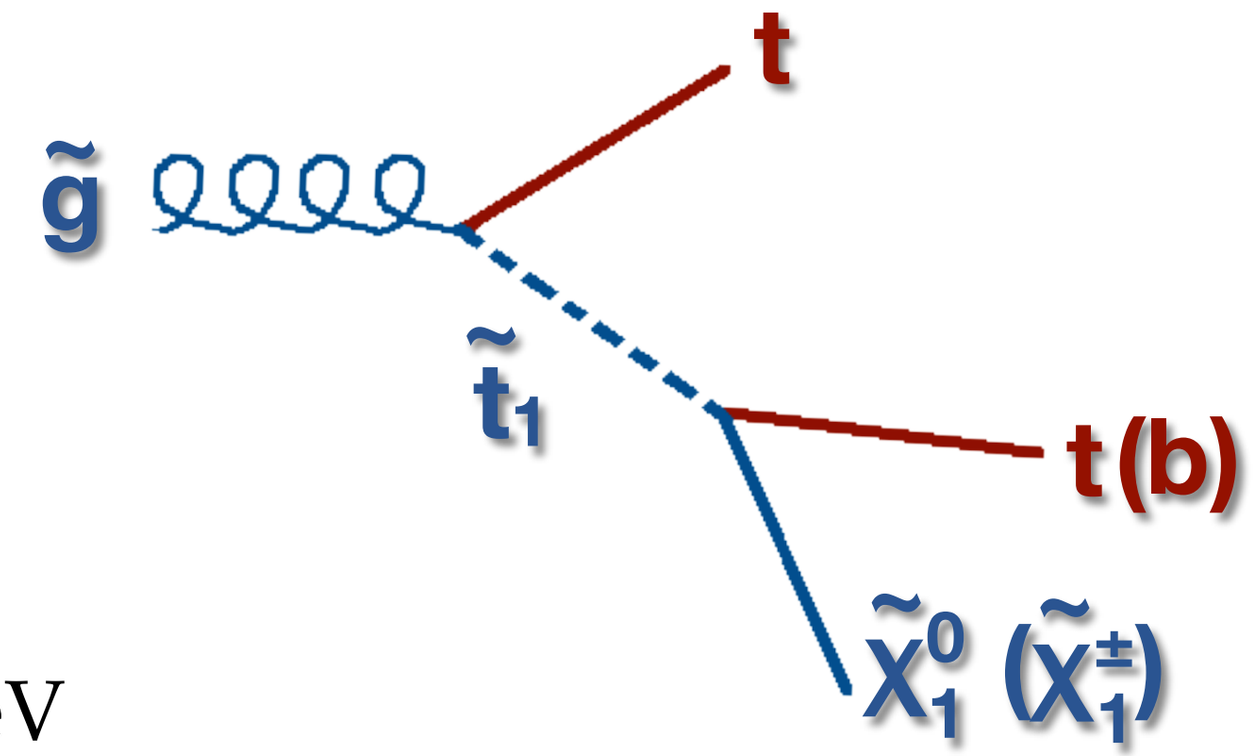
$\mathcal{B}(\tilde{t}_1 \to b\tilde{\chi}_1^0) = 100\%$

$\mathcal{B}(\tilde{\chi}_1^{\pm} \to \tilde{\chi}_1^0 l^{\pm}\nu) = 11\%$

ATLAS-CONF-2012-004

Gluino Mediated Stop

- **Analysis signature:**
  multijets + E_T^{miss}
- **Trigger:**
  various multijet triggers
- **Selection:**
  electron/muon veto
  at least N jets > 55 (80) GeV
  E_T^{miss} / $\sqrt{H_T}$ > 4 GeV$^{1/2}$



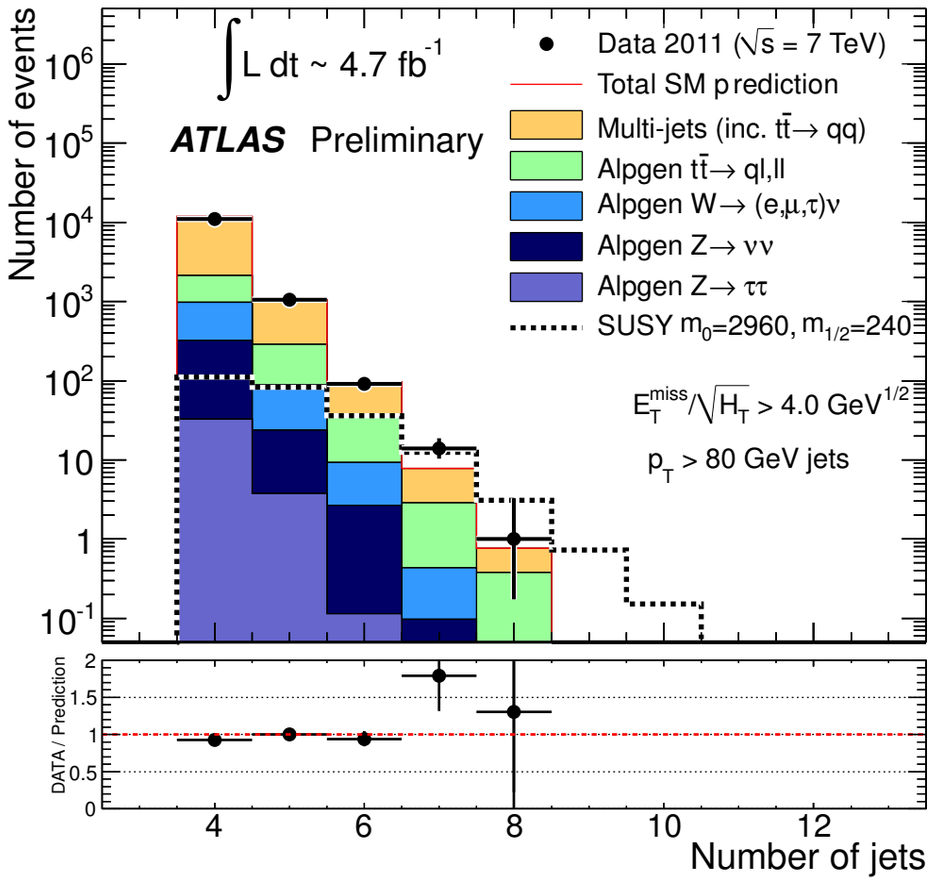
new result! based on 4.7 fb^{-1}

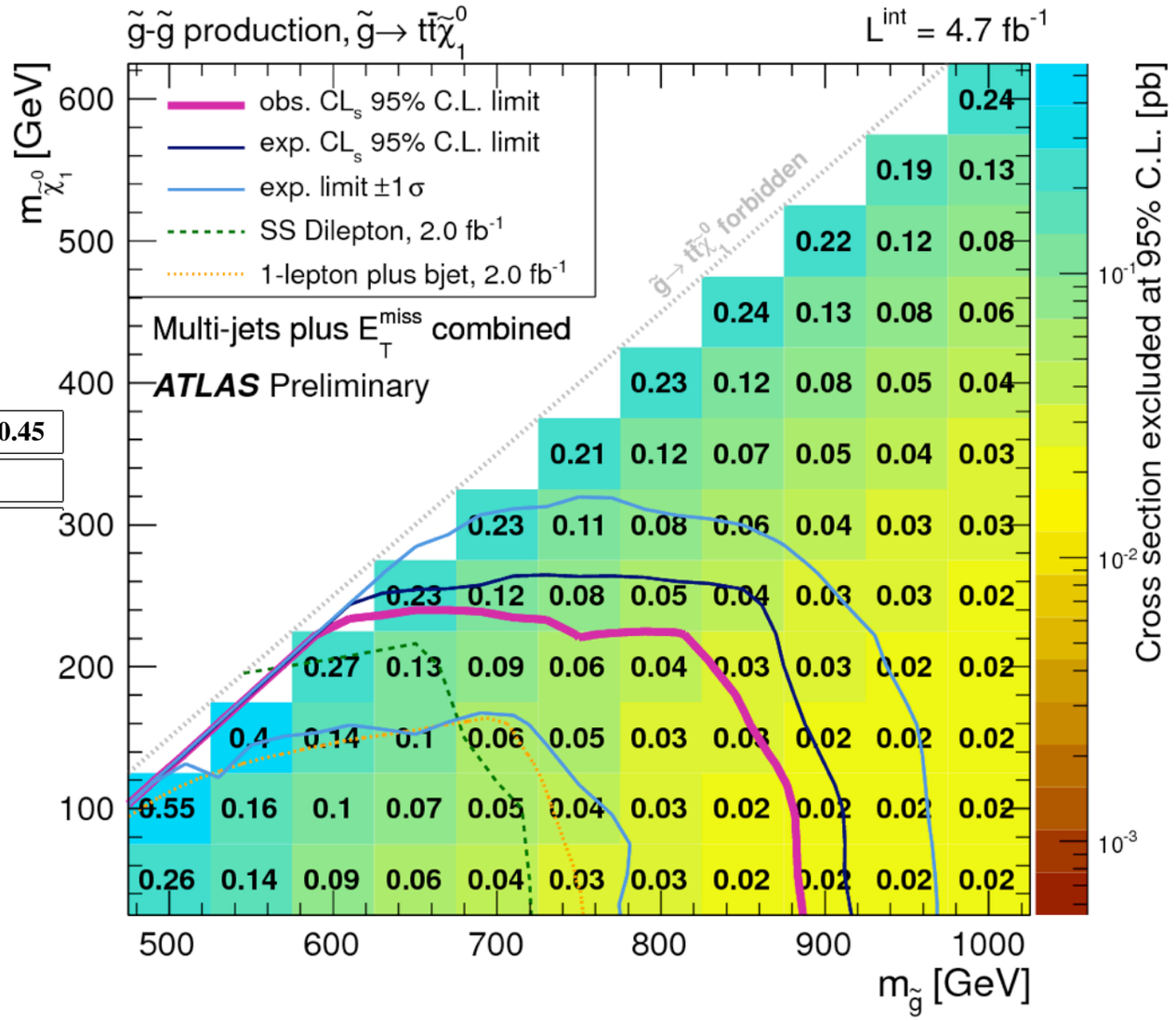
ATLAS-CONF-2012-037

Gluino Mediated Stop

Signal region	7j55	8j55	9j55	6j80	7j80	8j80
Isolated leptons (e, μ)	=0					
Jet p_T	> 55 GeV			> 80 GeV		
Jet $\|\eta\|$	< 2.8					
Number of jets	≥ 7	≥ 8	≥ 9	≥ 6	≥ 7	≥ 8
$E_{\mathrm{T}}^{\mathrm{miss}} / \sqrt{H_T}$	> 4 GeV$^{1/2}$					

Total Standard Model	**167±34**	**17±7**	**1.9±0.8**	**107±21**	**8.6±2.5**	**0.80±0.45**
Data	**154**	**22**	**3**	**106**	**15**	**1**





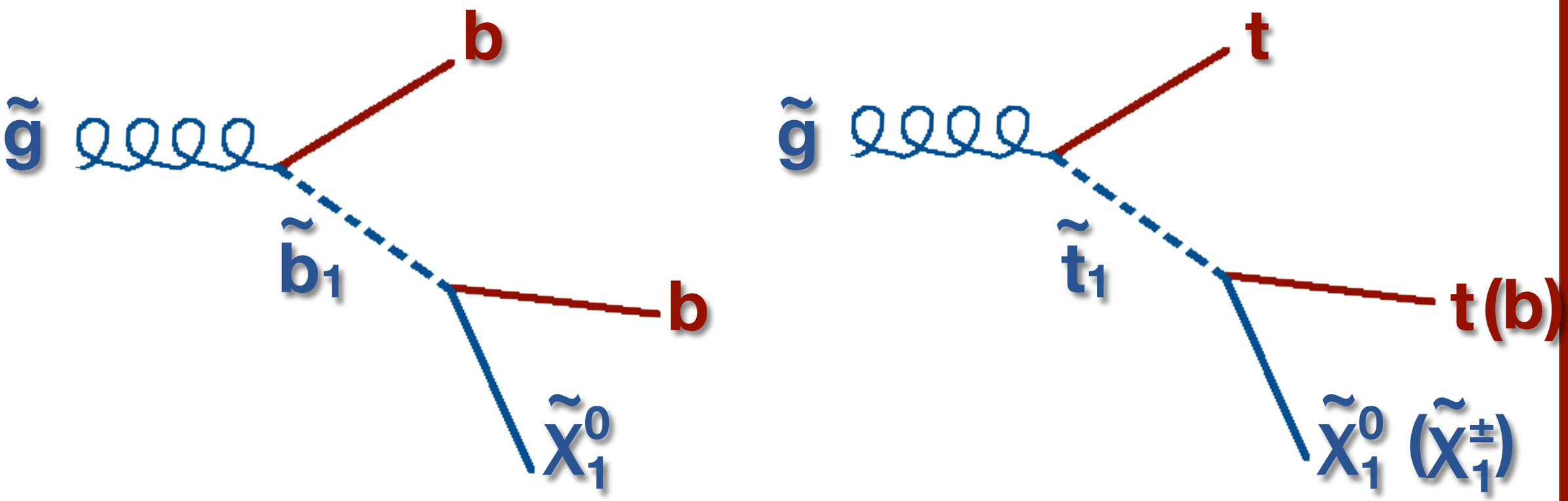
Simplified scenario where $m_{\tilde{g}} < m_{\tilde{t}_1}$

$\mathcal{B}(\tilde{g} \to t\bar{t}\tilde{\chi}_1^0) = 100\%$

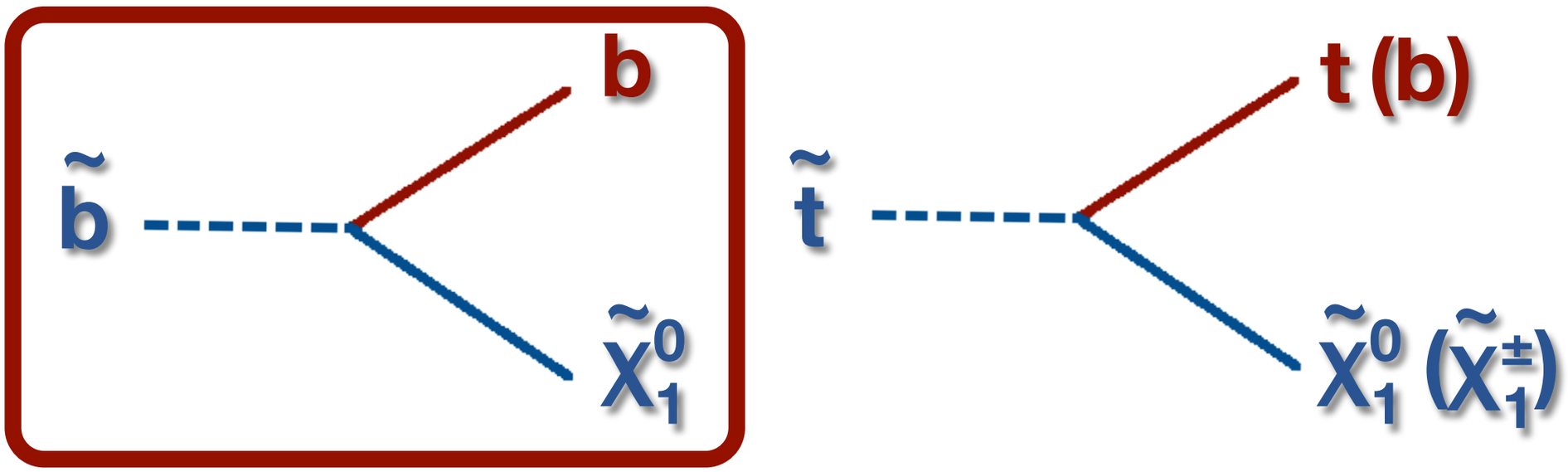
(off-shell stop; other squarks heavy)

ATLAS-CONF-2012-037

through gluino decays



direct production

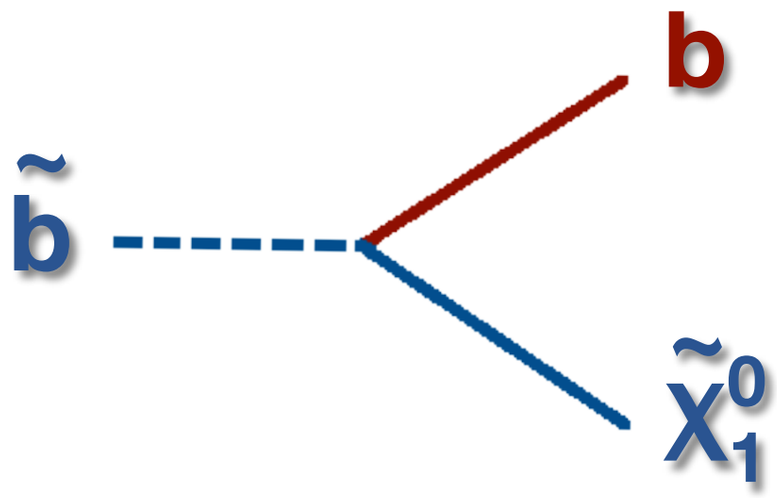


Direct Sbottom

- **Analysis signature:**
  2 *b*-tagged jets + E_T^{miss}

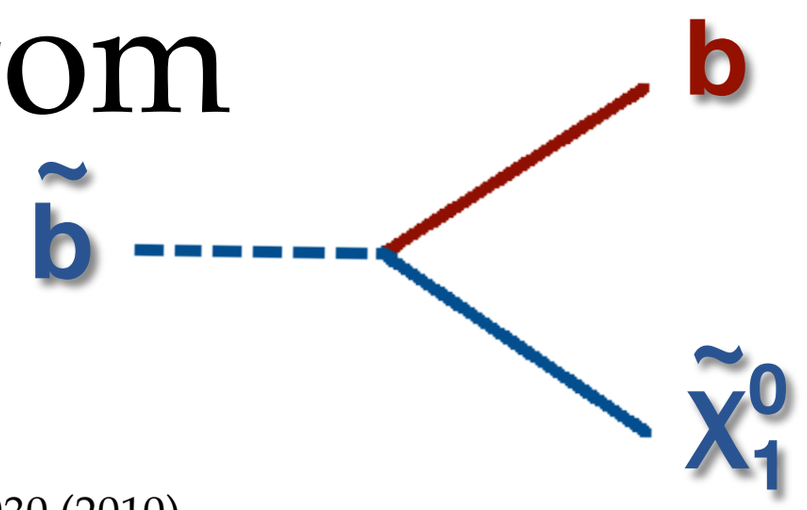
- **Trigger:**
  1 high p_T jet + E_T^{miss}

- **Selection:**
  first jet > 130 GeV; second jet > 50 GeV
  E_T^{miss} > 130 GeV
  2 jets must be *b*-tagged
  veto electrons & muons
  E_T^{miss} / m_{eff} > 0.25



arXiv 1112.3832, submitted to PRL

Direct Sbottom



"contransverse mass": JHEP **03**, 030 (2010)

$$m_{\mathrm{CT}} = \sqrt{\left[E_T(b_1) + E_T(b_2)\right]^2 - \left[p_T(b_1) - p_T(b_2)\right]^2}$$

<u>endpoint</u>: 135 GeV (ttbar), $\frac{m_{\tilde{b}}^2 - m_{\tilde{\chi}_1^0}^2}{m_{\tilde{b}}}$ ($\tilde{b}$)

- useful for pair production
- depends on energy, momentum of visible particles
- boost-corrected variable robust against initial state radiation

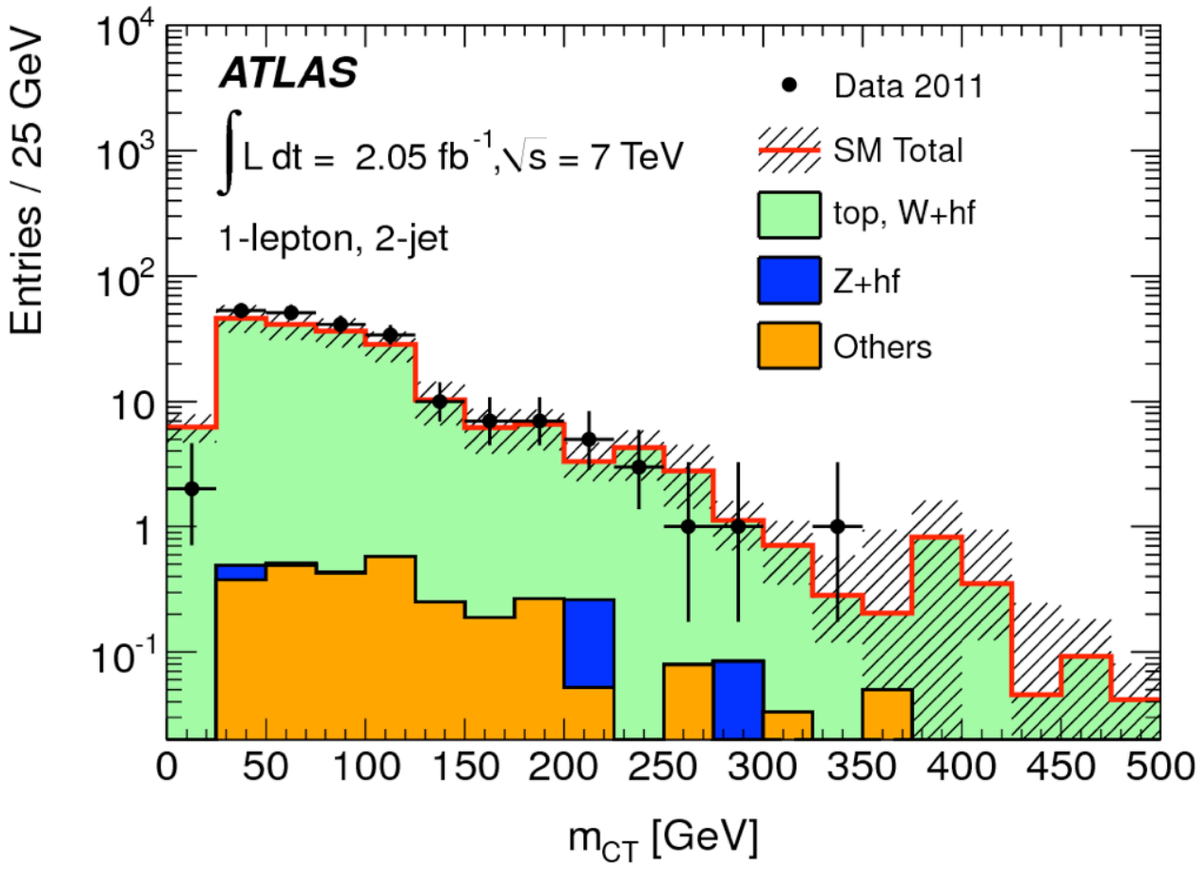
Direct Sbottom

top bkg:

1 lepton, 2 *b*-jets

$40 < m_T < 100$ GeV

~10-15% uncertainties

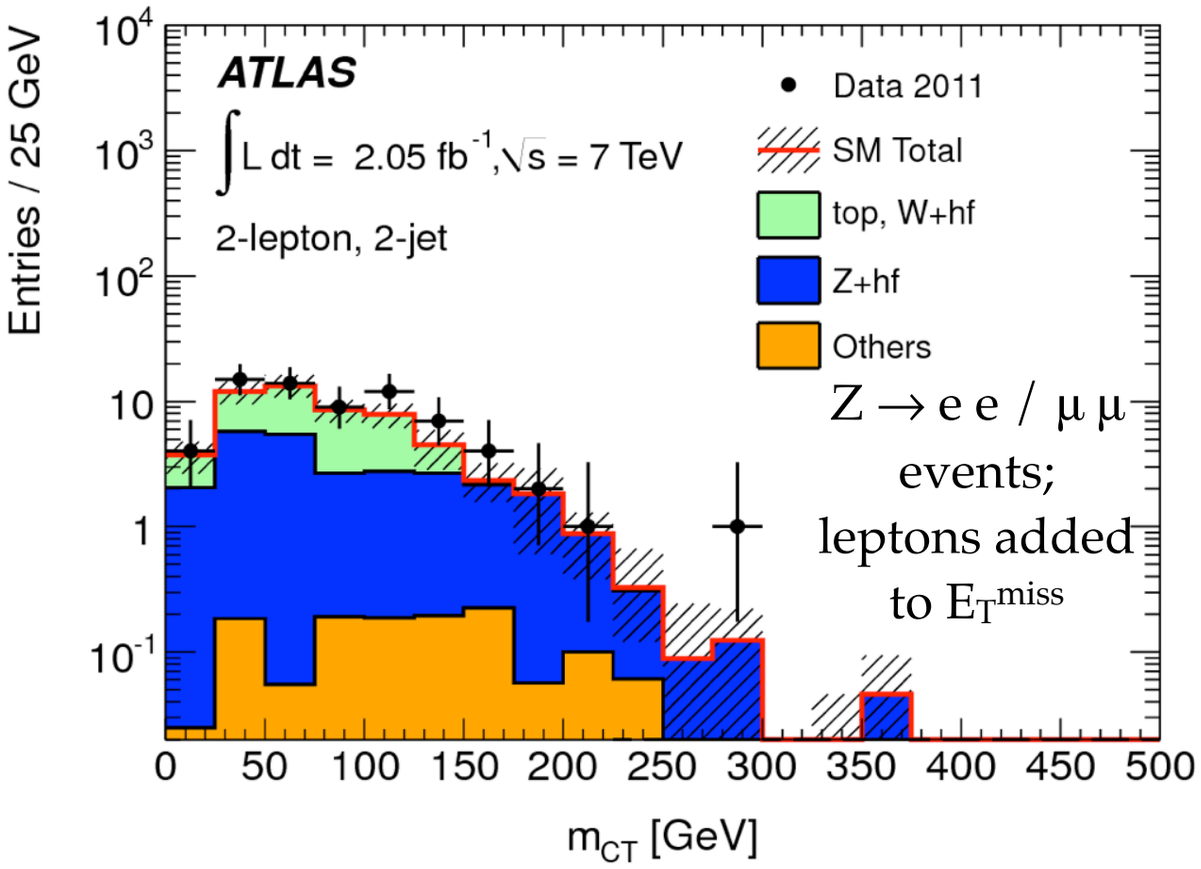


Z + heavy flavor bkg:

2 leptons, 2 *b*-jets

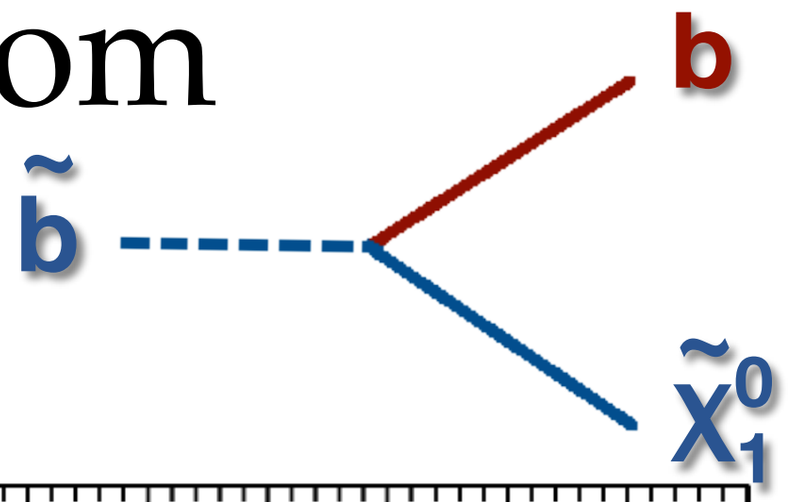
$81 < m_{ll} < 101$ GeV

< 5% uncertainty

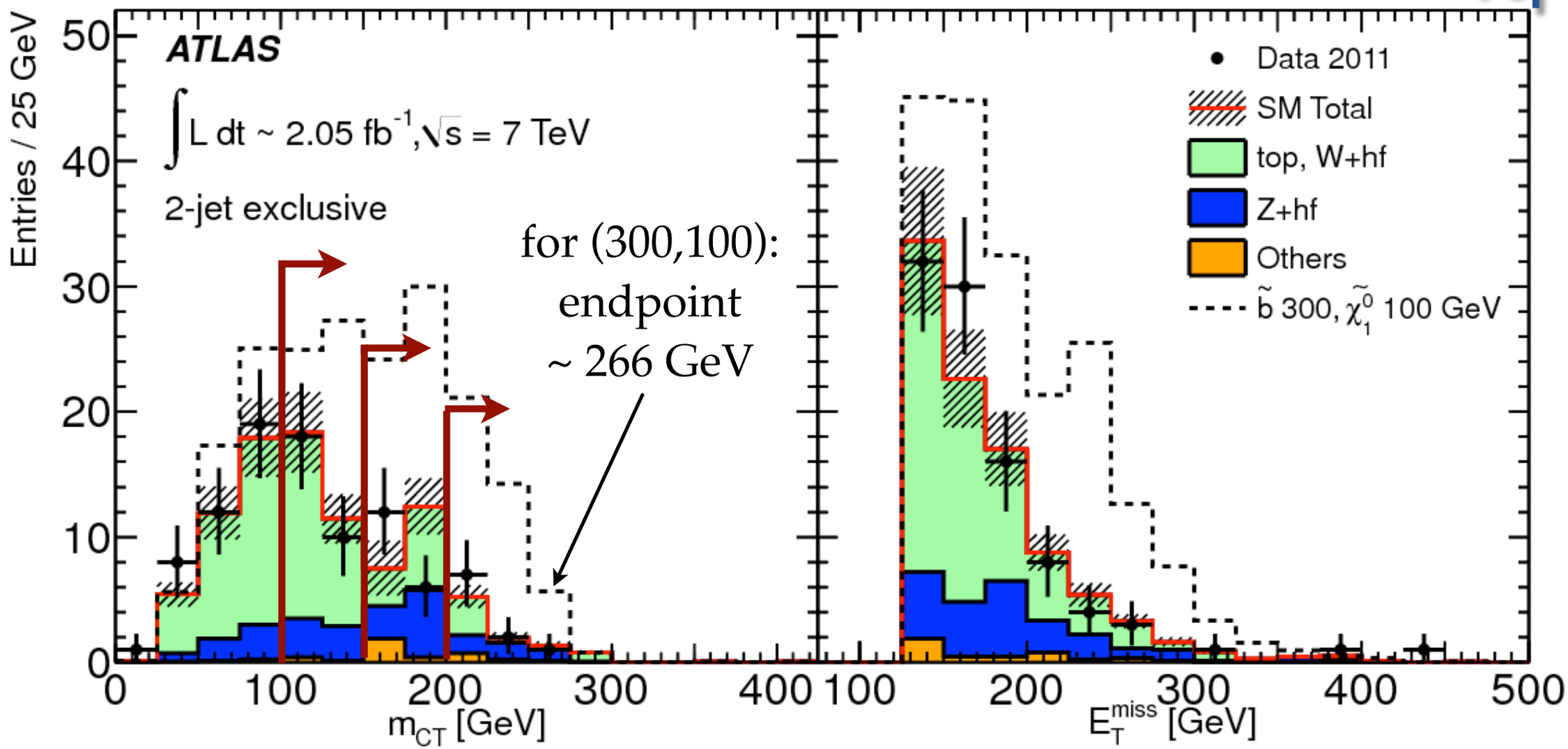


arXiv 1112.3832, submitted to PRL

Direct Sbottom

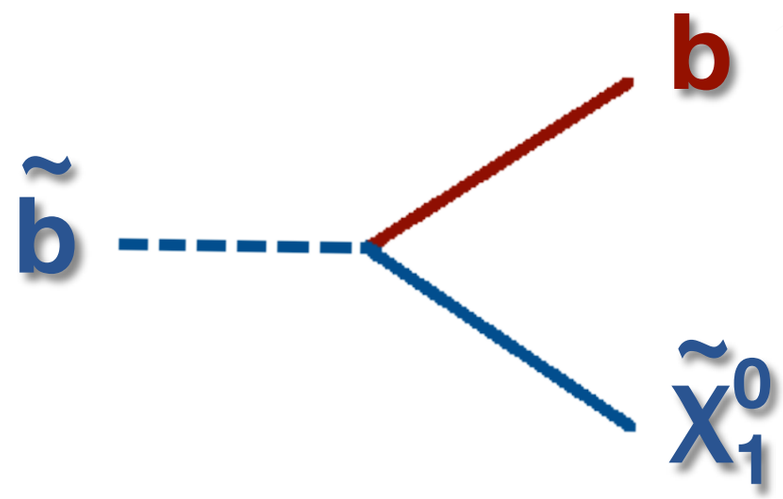


contransverse mass

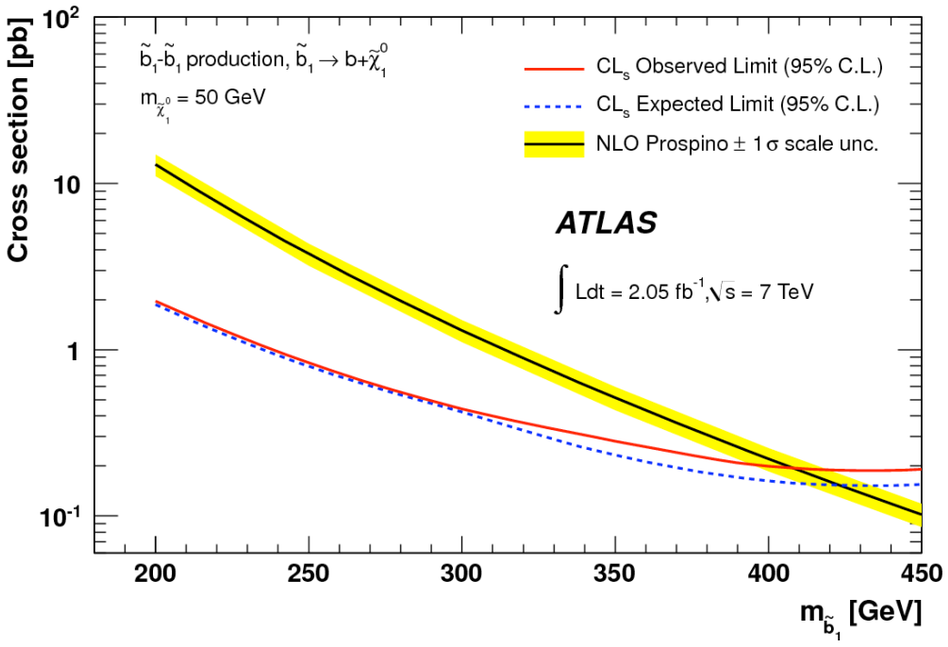


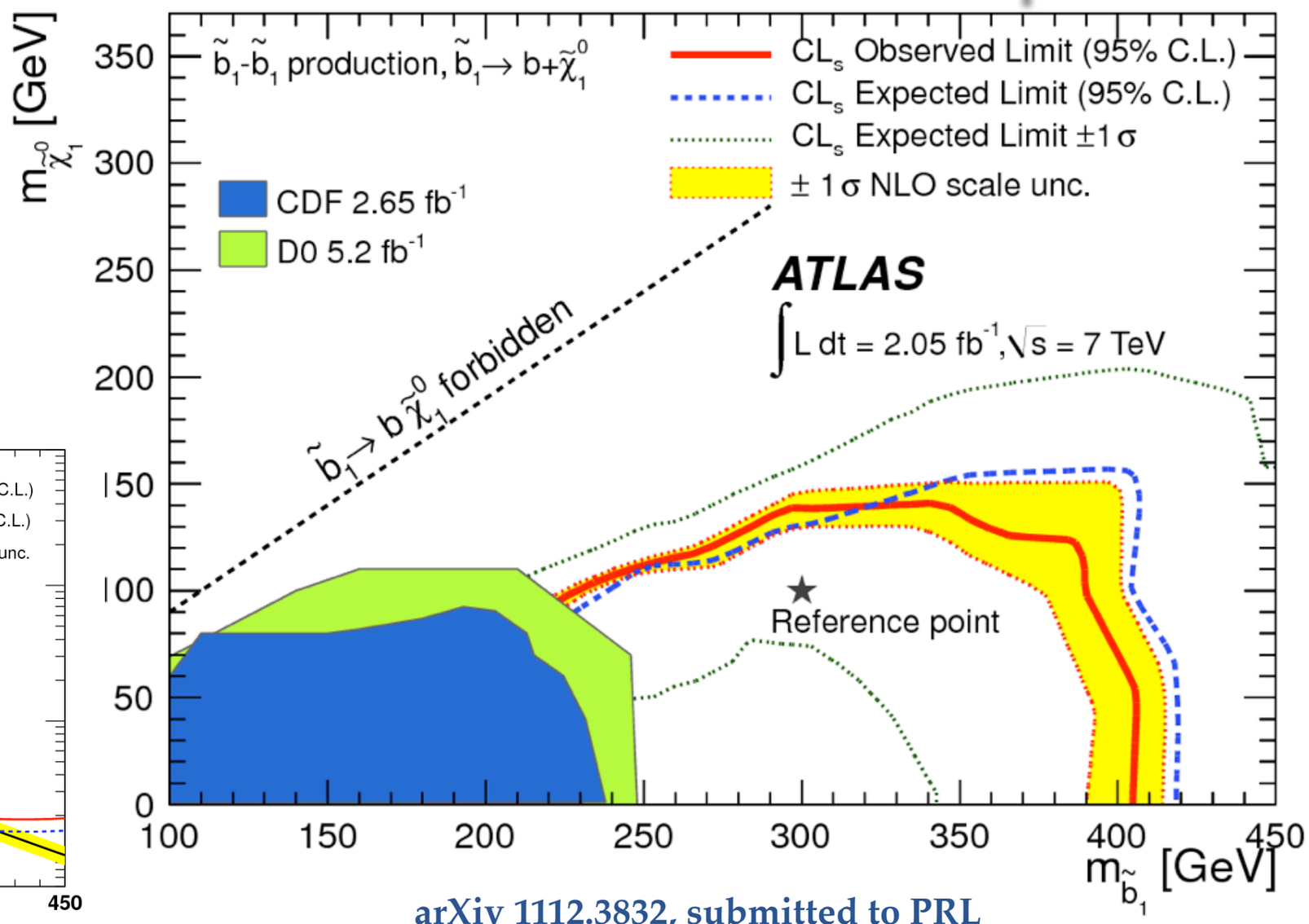
arXiv 1112.3832, submitted to PRL

Direct Sbottom

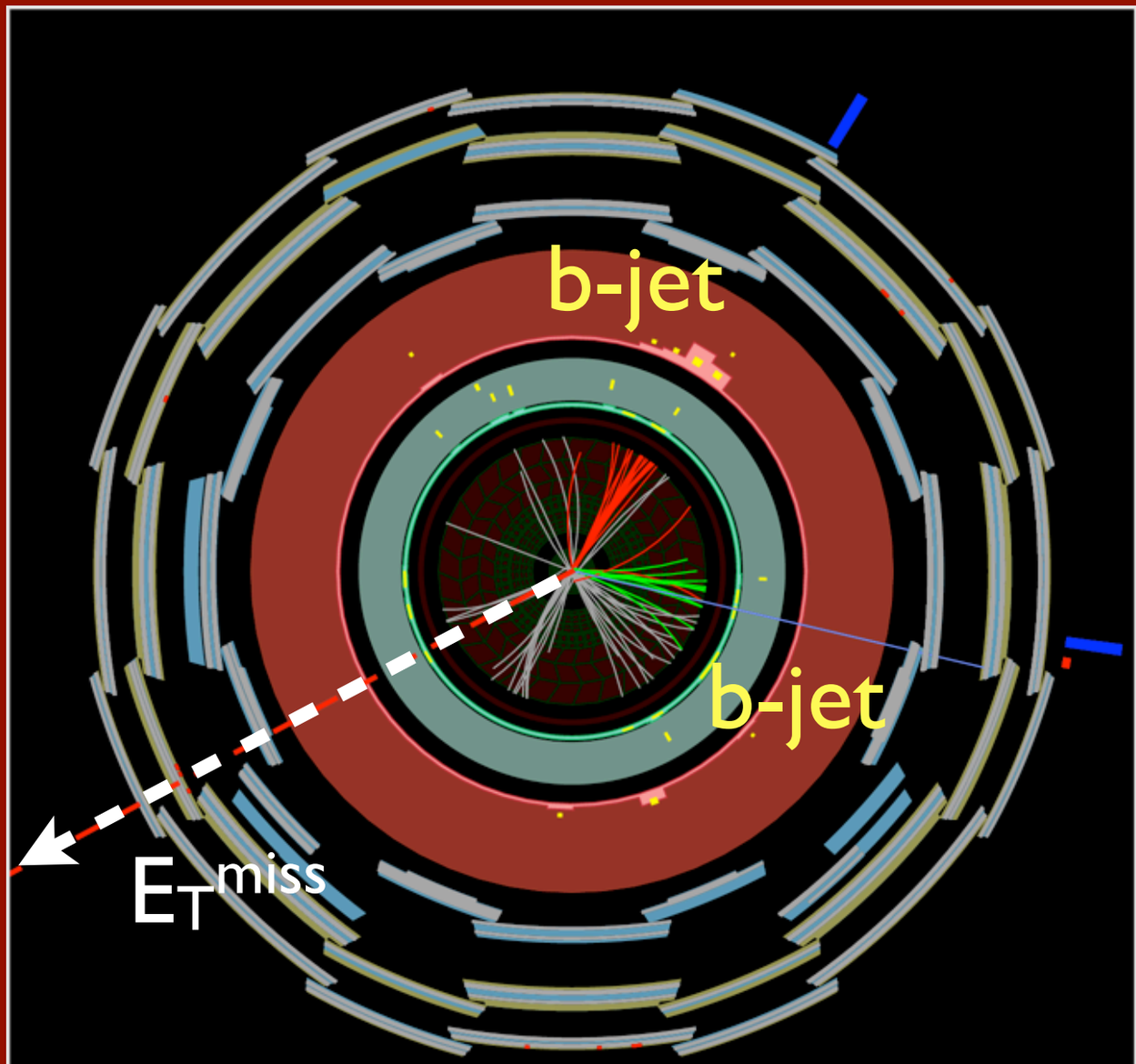


Signal Region	Expected Bkg	Data
$m_{CT} > 0$ GeV	94 ± 16	96
$m_{CT} > 100$ GeV	62 ± 13	56
$m_{CT} > 150$ GeV	27 ± 8	28
$m_{CT} > 200$ GeV	8.1 ± 3.5	10





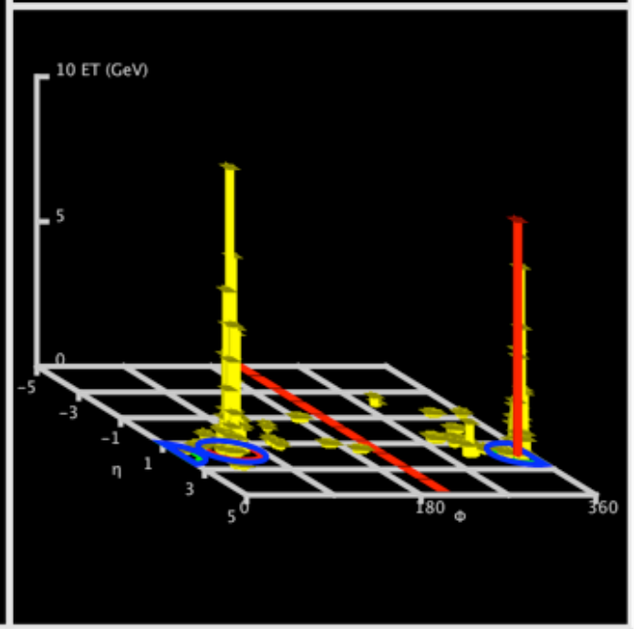
arXiv 1112.3832, submitted to PRL

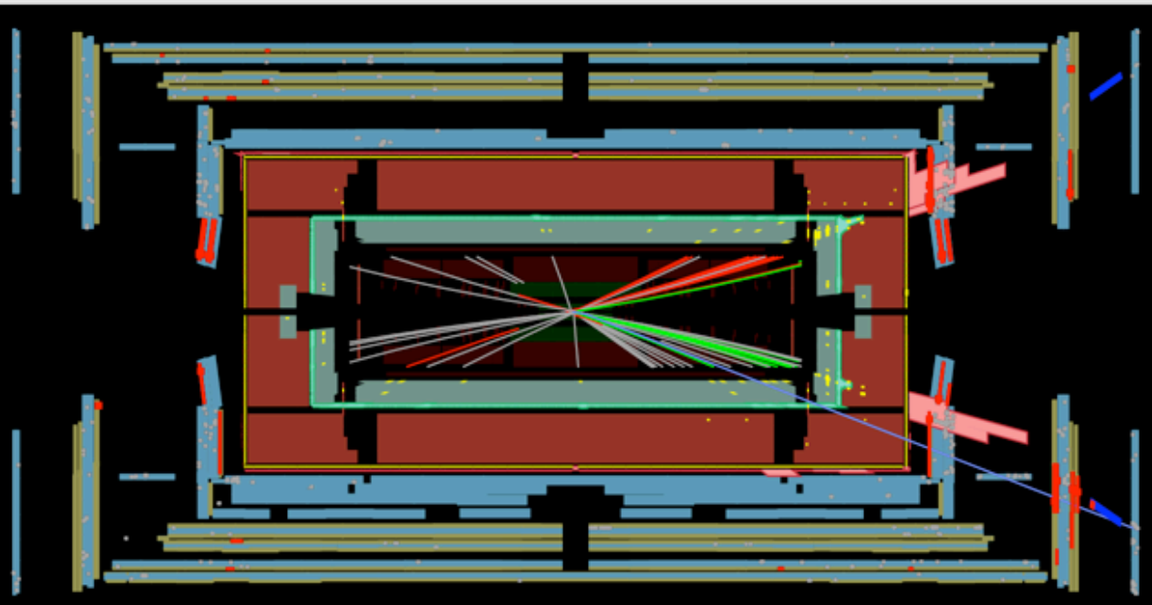


ATLAS EXPERIMENT

Run Number: 182787, Event Number: 13824019

Date: 2011-05-29 11:51:09 CEST

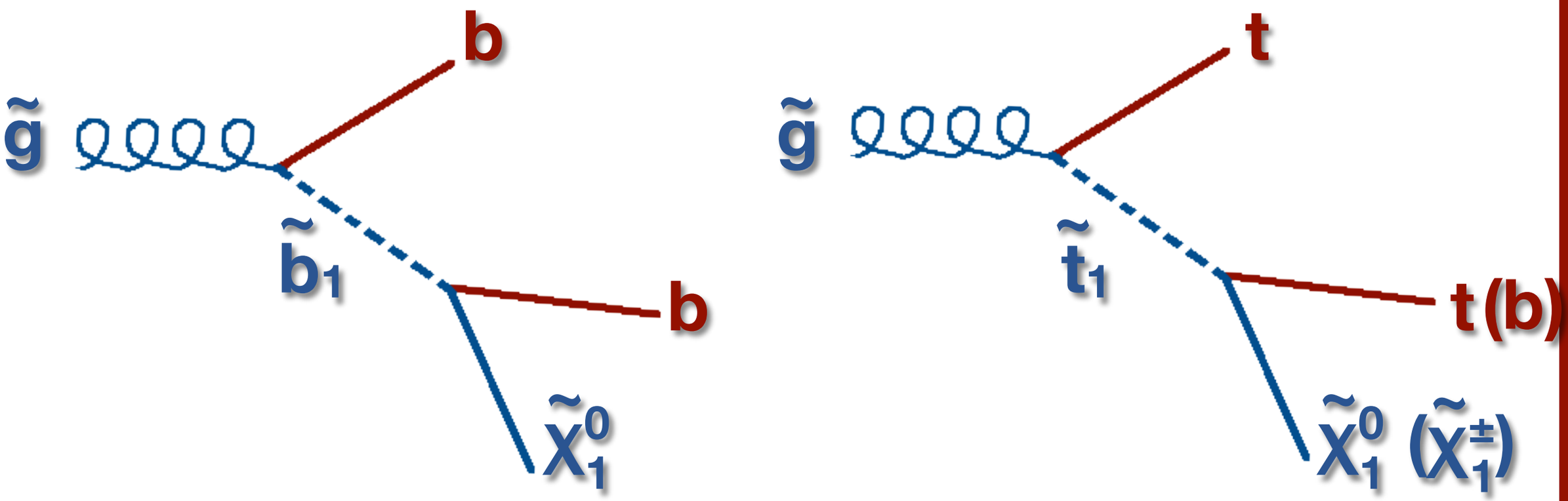




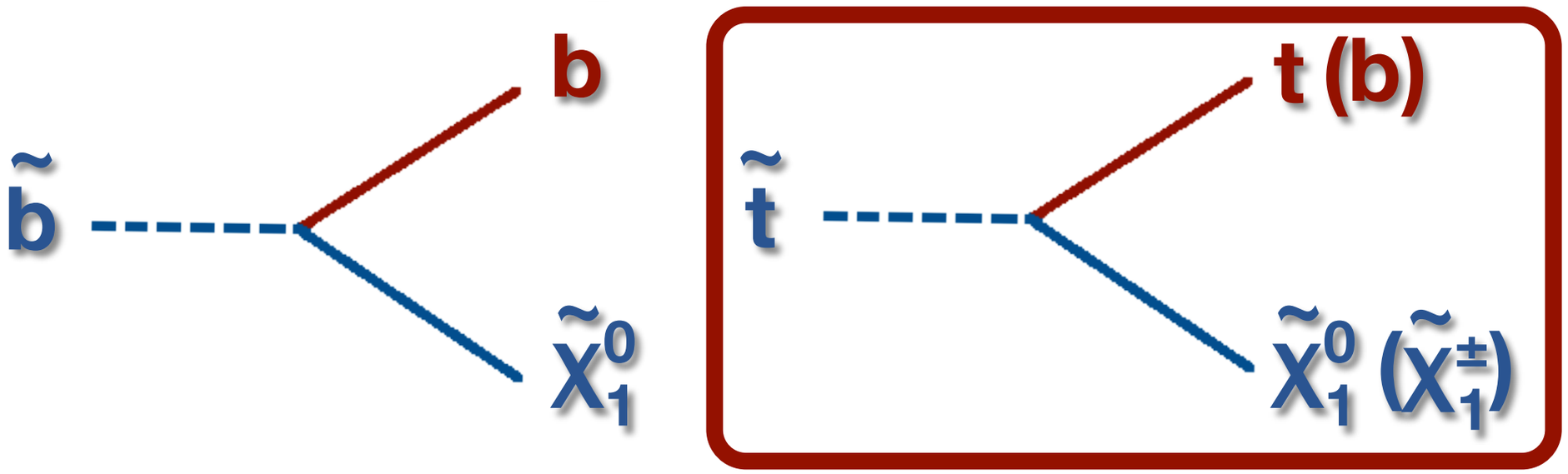
E_T^{miss}: 205 GeV

b-jet p_Ts: 152 GeV, 96 GeV

through gluino decays



direct production

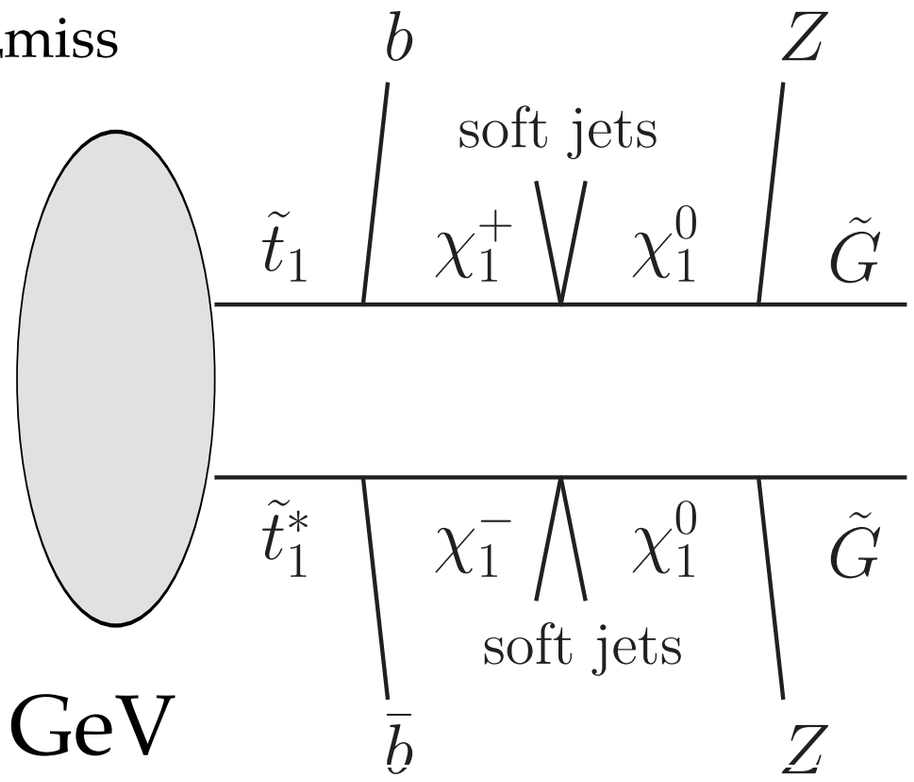


Direct Stop

- GMSB scenario with gravitino LSP ($m_{\tilde{G}} < 1$ keV), neutralino NLSP [Higgsino-like $\tilde{\chi}_1^0$ considered here]

M. Asano, et al., JHEP 1012:019,2010

- **Analysis signature:**
  2 same-flavor leptons + jets + E_T^{miss}



- **Trigger:**
  electron / muon + jet

- **Selection:**
  $86 < m_{ll} < 96$ GeV
  first jet > 60 GeV, one more > 50 GeV
  1 b-tagged jet
  $E_T^{miss} > 50$ (80) GeV

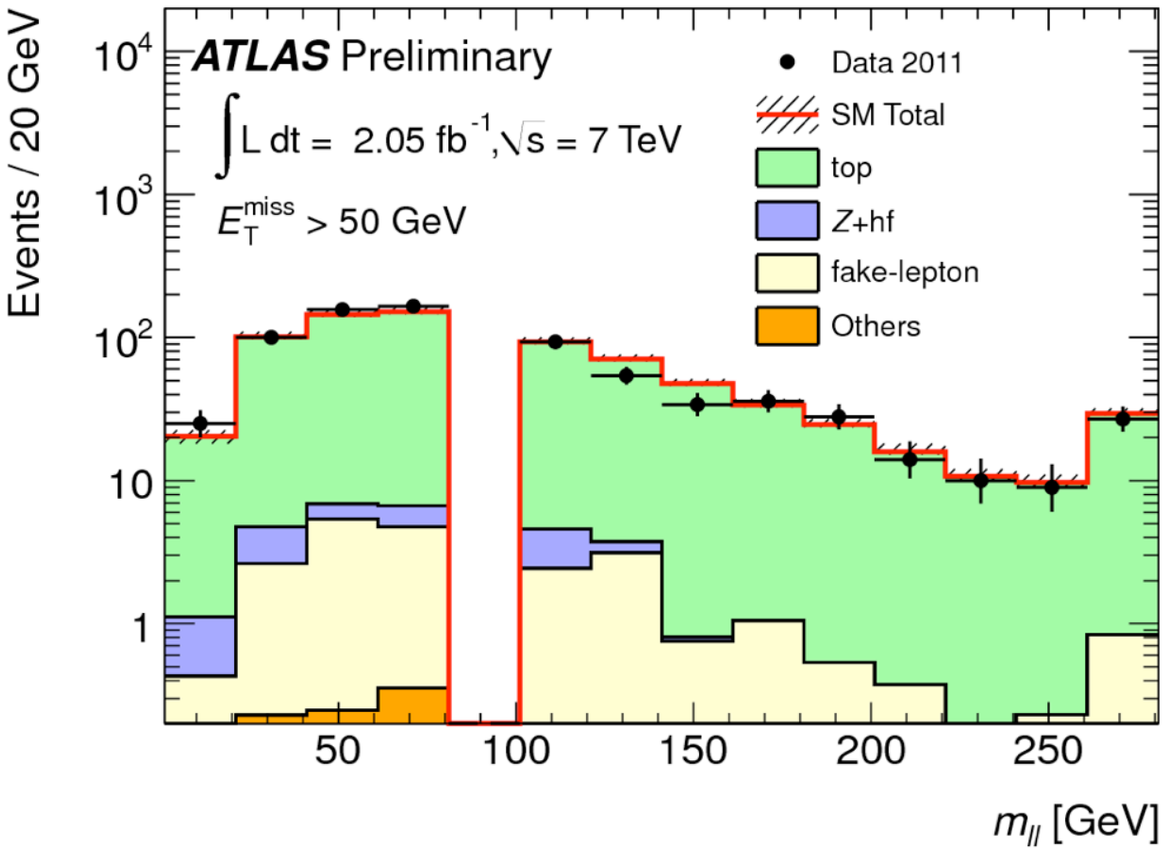
ATLAS-CONF-2012-036

Direct Stop

top bkg:

ee + $\mu\mu$, Z veto

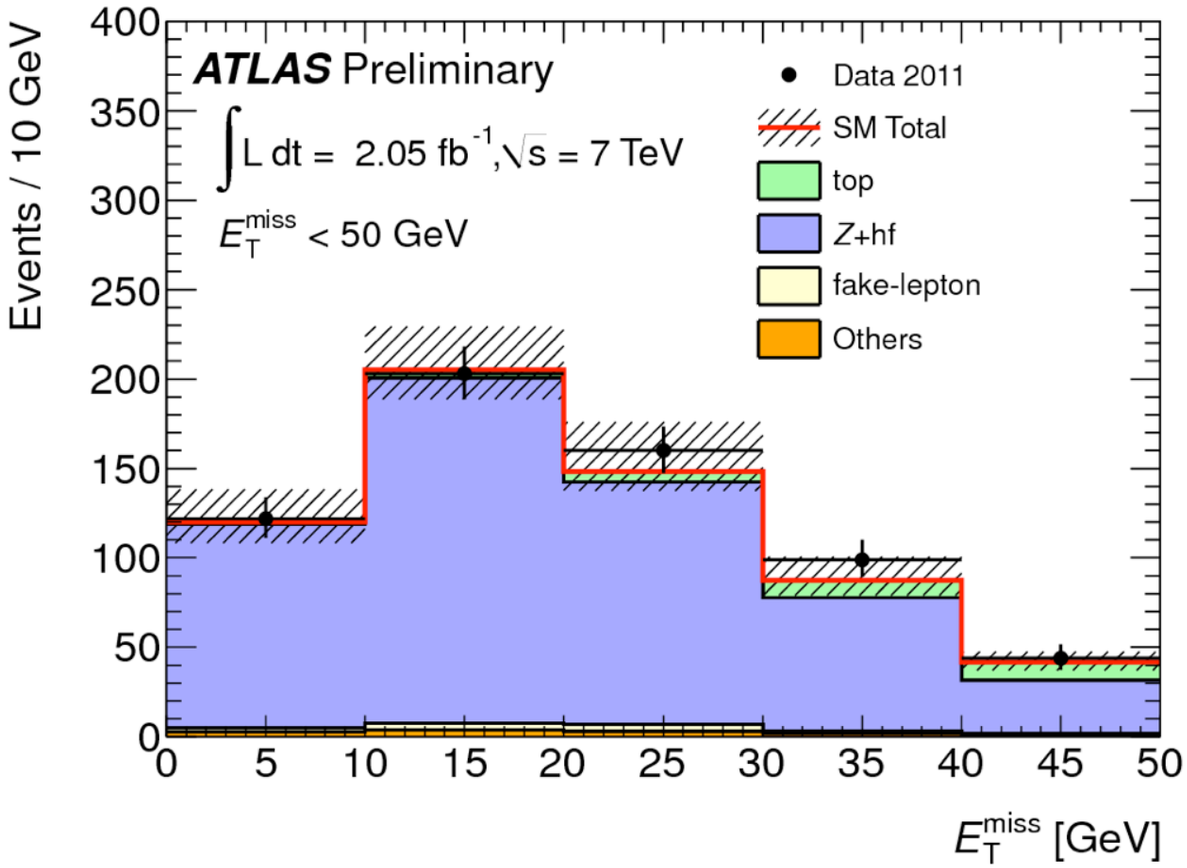
~11-13% uncertainties



Z + heavy flavor bkg:

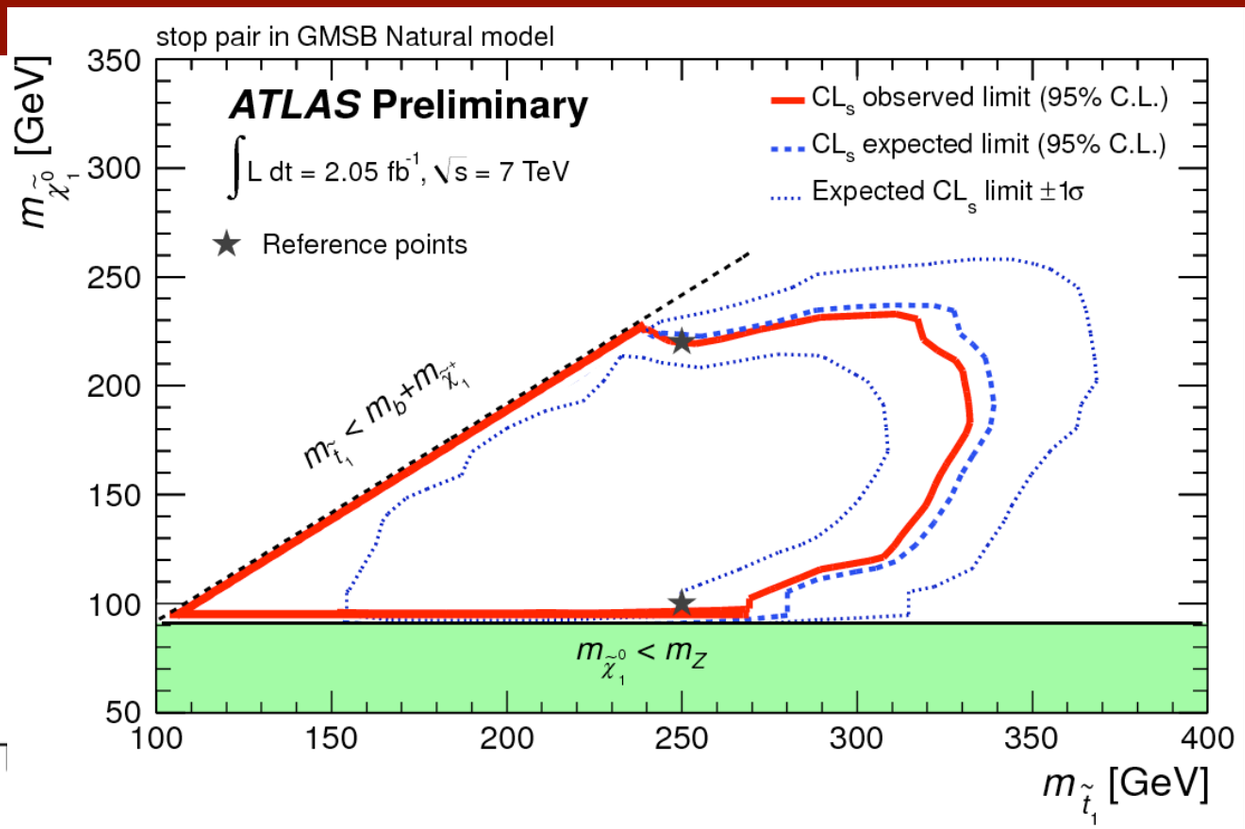
ee + $\mu\mu$, $E_T^{miss} < 50$ GeV

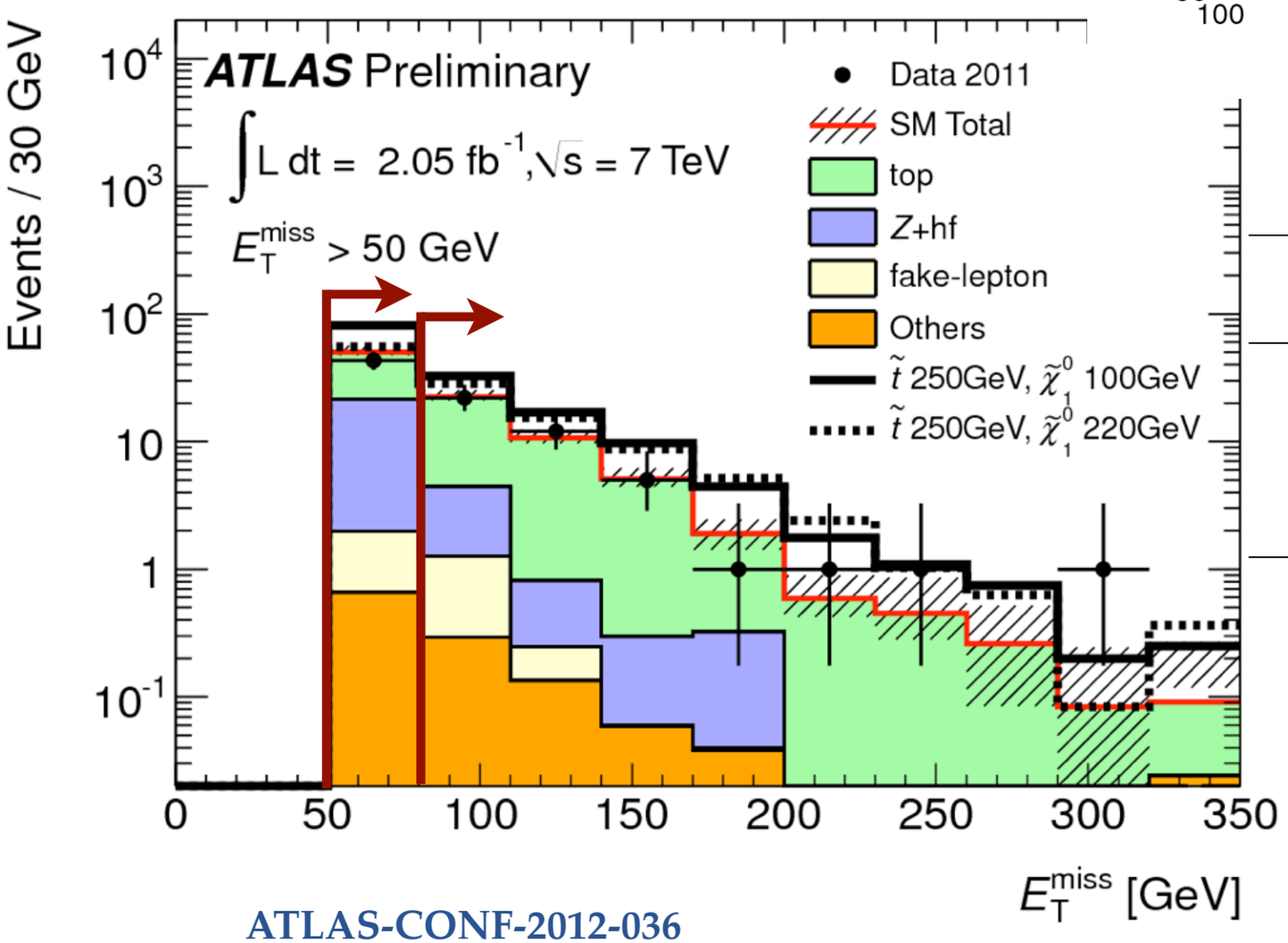
(55% uncertainty on xsec)



ATLAS-CONF-2012-036

Direct Stop

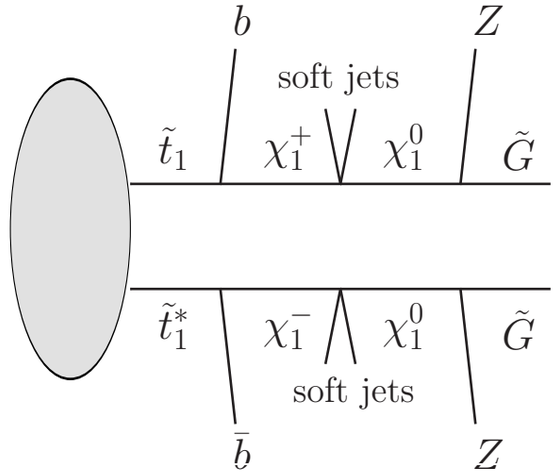




ATLAS-CONF-2012-036

$ee + \mu\mu$

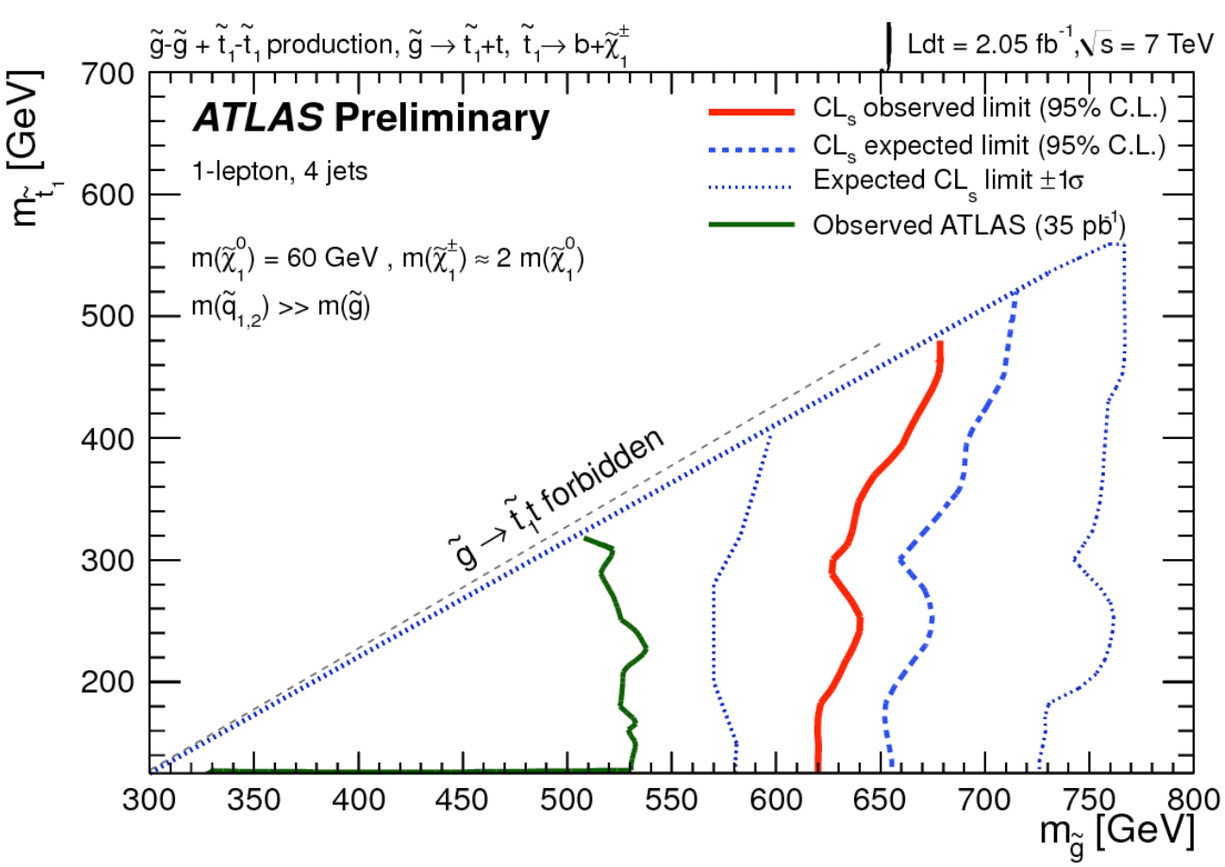
	$E_T^{miss} > 50$ GeV	> 80 GeV
Data (2.05 fb^{-1})	86	43
SM	92 ± 19	40.7 ± 6.0
top	64.3 ± 7.7	34.8 ± 5.0
Z+hf	24 ± 16	4.2 ± 3.2
fake lepton	2.4 ± 0.9	1.1 ± 0.6
Others	1.2 ± 1.2	0.6 ± 0.6

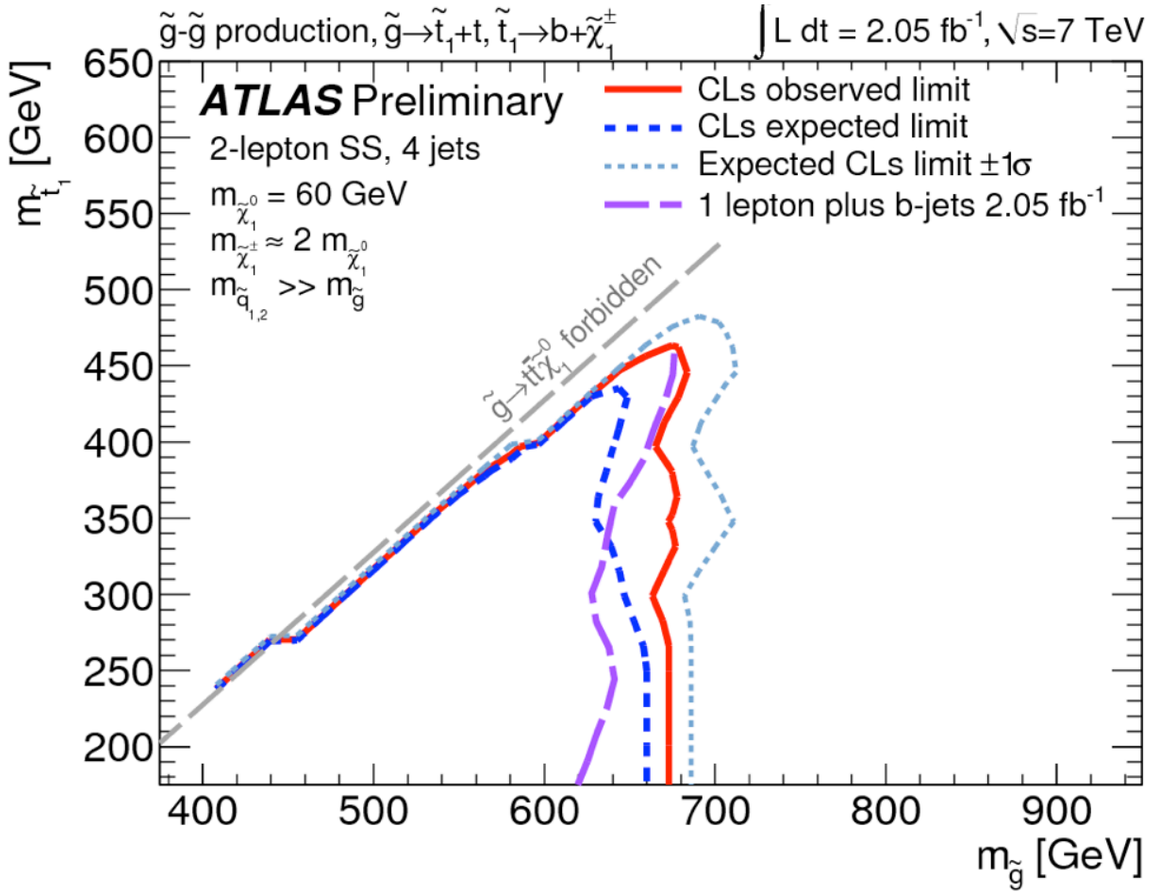


Summary

- Broad program of 3rd generation squark searches underway on ATLAS
  - **Gluino-mediated sbottom:** *b*-jets + E_T^{miss}
  - **Gluino-mediated stop:** 1 lepton + 4 jets + E_T^{miss}, same-sign dilepton + E_T^{miss}, multijets + E_T^{miss}
  - **Direct sbottom:** 2 *b*-jets + E_T^{miss} (m_{CT})
  - **Direct stop (GMSB):** 2 leptons + jets + E_T^{miss}
- No significant excesses; limits set on stop and sbottom masses ($m_{\tilde{b}} > 800$ GeV for $m_{\tilde{g}} < 920$ GeV [MSSM], $m_{\tilde{t}} > 450$ GeV for $m_{\tilde{g}} < 650$ GeV [MSSM])
- Still analyzing 5 fb^{-1} @ 7 TeV and looking forward to 8 TeV data in 2012!

Gluino Mediated Stop





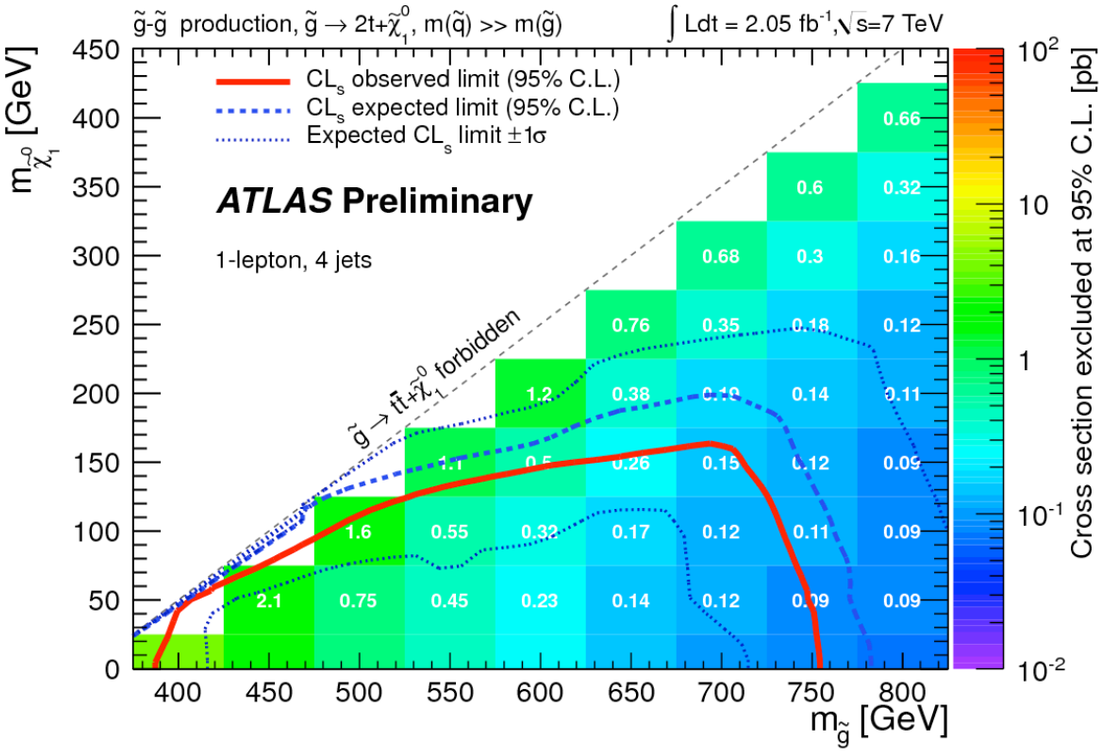
MSSM scenario where $m_{\tilde{g}} > m_{\tilde{t}_1} + m_t$

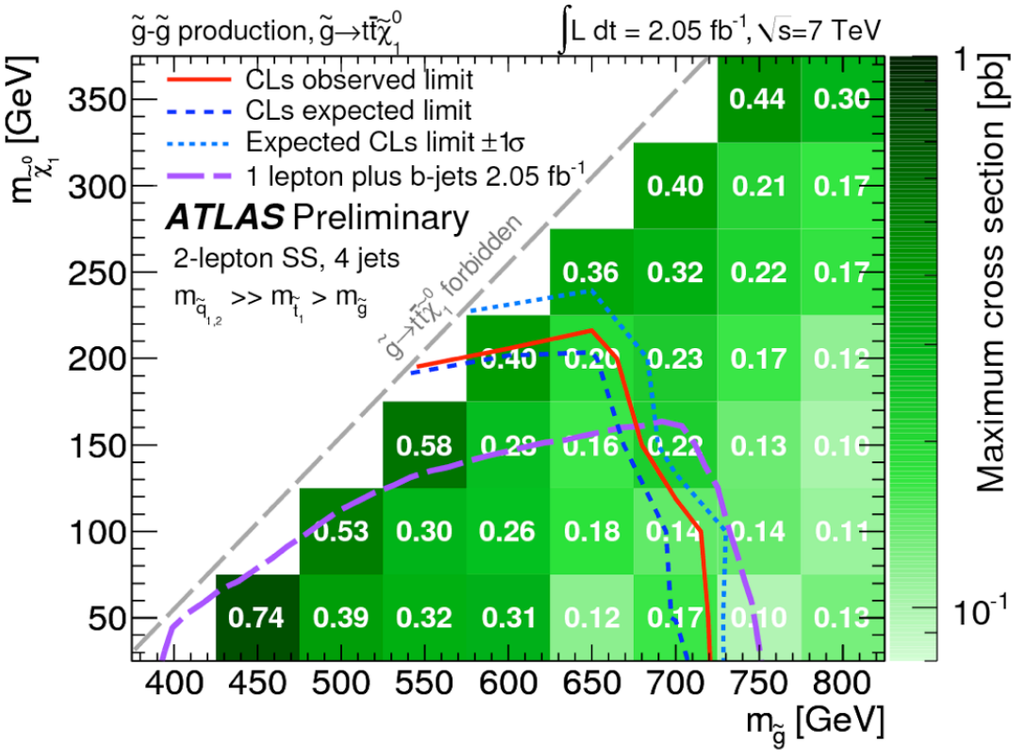
$\mathcal{B}(\tilde{g} \to \tilde{t}_1 t) = 100\%$

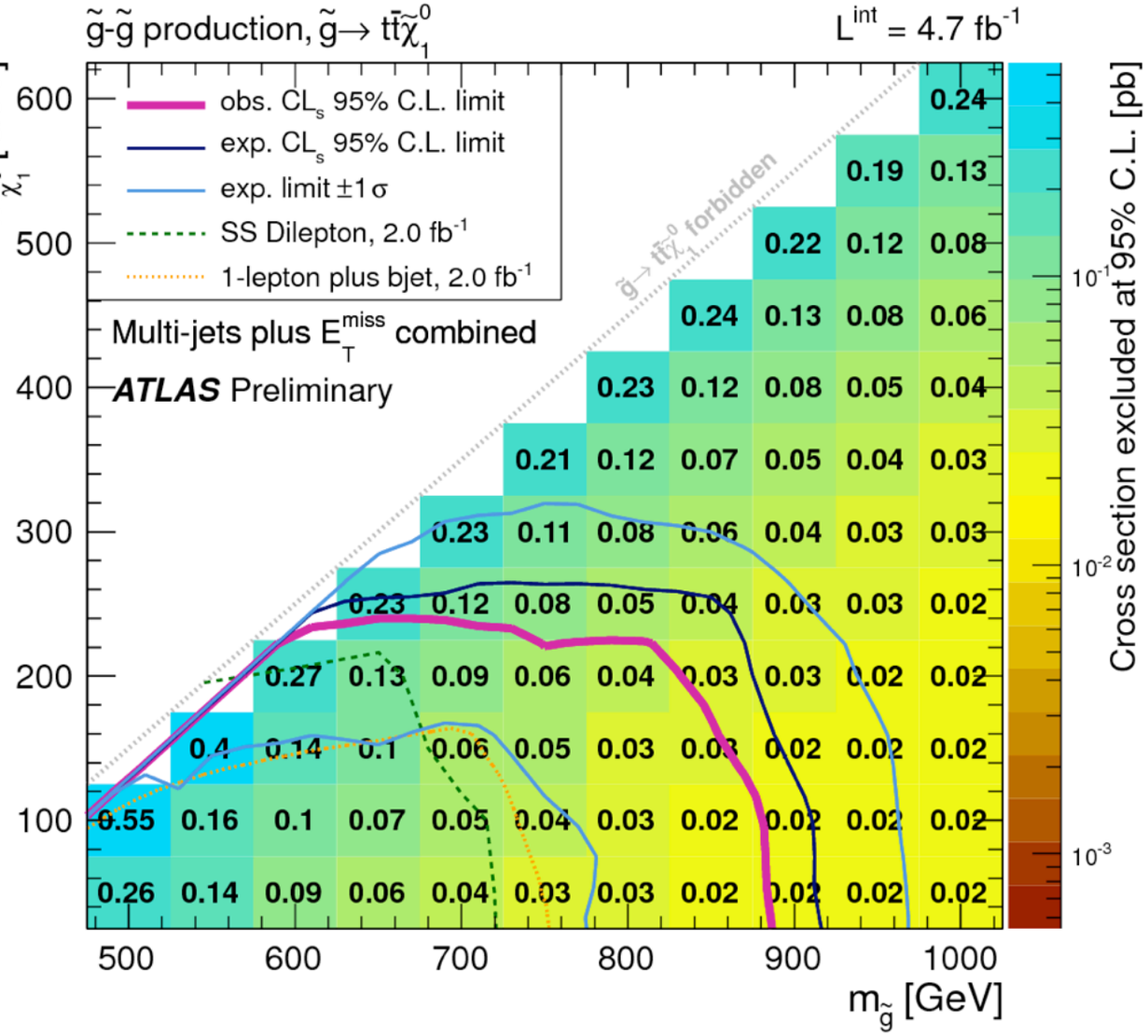
$\mathcal{B}(\tilde{t}_1 \to b\tilde{\chi}_1^0) = 100\%$

$\mathcal{B}(\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0 l^\pm \nu) = 11\%$

Gluino Mediated Stop







Simplified scenario where $m_{\tilde{g}} < m_{\tilde{t}_1}$
$\mathcal{B}(\tilde{g} \to t\bar{t}\tilde{\chi}_1^0) = 100\%$
(off-shell stop, other squarks heavy)

Systematic Uncertainties

- Top production uncertainties:
  - comparisons of MC@NLO, Alpgen, PowHeg
  - different showering (PowHeg+Pythia/Herwig)
  - ISR/FSR variations (AcerMC)
- W/Z production uncertainties:
  - Alpgen, vary relative cross-sections of #parton sub-samples
  - W/Z+bb cross-section ~70%

Additional details:

Gluino Mediated Sbottom

b-tagged jets + E_T^{miss}

ATLAS-CONF-2012-003

Pre-selection	Control region name	Selection
one lepton, three jets $p_T(j1) > 130$ GeV, $p_T(j2, j3) > 50$ GeV, $E_T^{miss} > 130$ GeV, 40 GeV $< m_T <$ 100 GeV, $m_{eff} > 600$ GeV	CR0-1 CR0-2	one b-tag two b-tag

$$N_{SR} = \frac{N_{SR}^{MC}}{N_{CR}^{MC}} N_{CR}^{obs} = T_f N_{CR}^{obs}$$

SR	Top	W/Z	QCD/ di-boson	Total	Data
SR0-A1	705 ± 110 (725)	248 ± 150	53 ± 21	1000 ± 180	1112
SR0-B1	119 ± 26 (122)	67 ± 42	7.3 ± 4.7	190 ± 50	197
SR0-C1	22 ± 9 (22)	16 ± 11	1.5 ± 1	39 ± 14	34
SR0-A2	272 ± 70 (212)	22.5 ± 15	21 ± 12	316 ± 72	299
SR0-B2	47 ± 11 (37)	4.5 ± 3	2.8 ± 1.7	54 ± 11	43
SR0-C2	8.5 ± 3 (6.6)	0.8 ± 1	0.5 ± 0.4	9.8 ± 3.2	8

all systematics included

SR	95% C.L. upper limit	
	N events obs. (exp.)	σ_{vis}(fb) obs. (exp.)
SR0-A1	578 (516)	282 (251)
SR0-B1	133 (133)	65 (65)
SR0-C1	31.6 (34.6)	15.4 (16.9)
SR0-A2	124 (134)	61 (66)
SR0-B2	29.6 (31.0)	14.4 (15.0)
SR0-C2	8.9 (10.3)	4.3 (5.0)

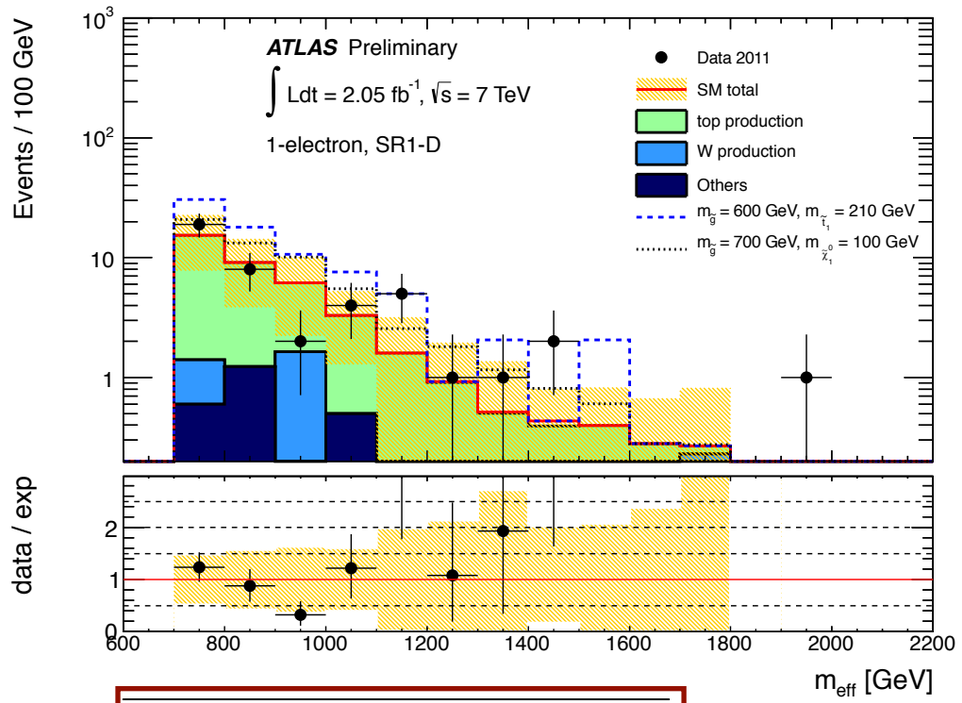
Additional details:

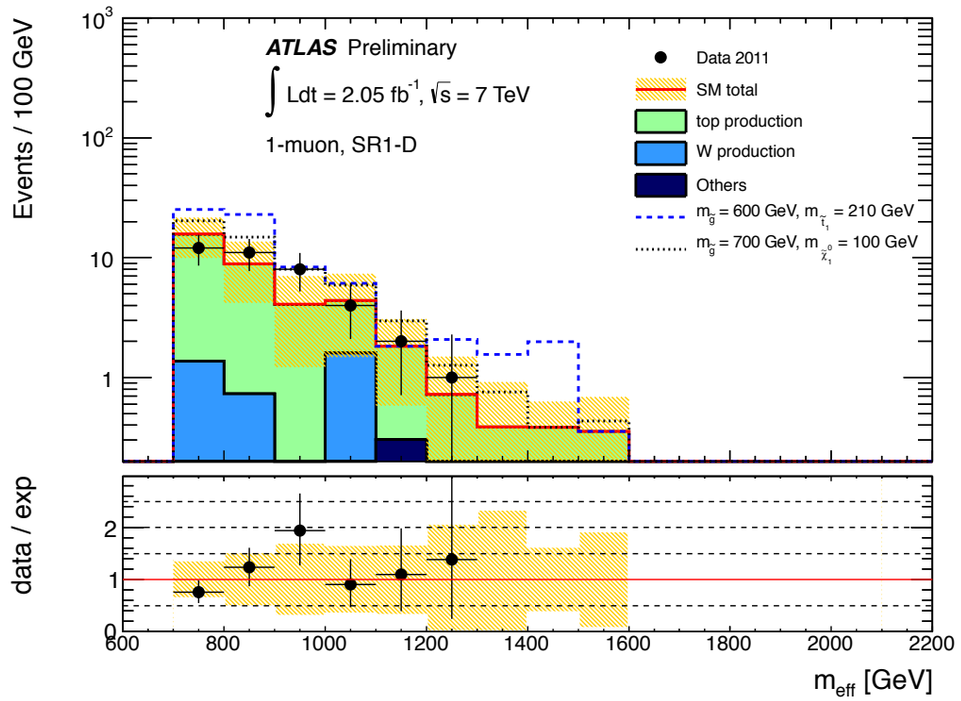
Gluino Mediated Stop

1 lepton + jets + E_T^{miss}

ATLAS-CONF-2012-003

Pre-selection	Control region name	Selection
one lepton, four jets $p_T(j1) > 60$ GeV, $p_T(j2, j3, j4) > 50$ GeV, $E_T^{miss} > 80$ GeV, 40 GeV $< m_T <$ 100 GeV, $m_{eff} > 500$ GeV	CR1	one b-tag





SR	95% C.L. upper limit	
	N events	σ_{vis}(fb)
	obs. (exp.)	obs. (exp.)
SR1-D	45.5 (42.1)	22.2 (20.5)
SR1-E	17.5 (15.3)	8.5 (7.5)

one control region

Additional details:

Gluino Mediated Stop

2 same-sign leptons + jets + E_T^{miss}

- Background Estimation techniques (1)
  - "fake lepton": (10-80% uncertainty [lepton p_T])

    P(loose-real to pass tight selection): $Z \to l\,l$ sample

    P(loose-fake to pass tight selection): multijet CR (2 SS leptons, low E_T^{miss})

- Relate the number of observed events with combination of tight (T) and loose (L) leptons with the number of events with combinations of real (R) and fake (F) leptons

$$\begin{bmatrix} N_{TT} \\ N_{TL} \\ N_{LT} \\ N_{LL} \end{bmatrix} = \begin{bmatrix} rr & rf & fr & ff \\ r(1-r) & r(1-f) & f(1-r) & f(1-f) \\ (1-r)r & (1-r)f & (1-f)r & (1-f)f \\ (1-r)(1-r) & (1-r)(1-f) & (1-f)(1-r) & (1-f)(1-f) \end{bmatrix} \begin{bmatrix} N_{RR} \\ N_{RF} \\ N_{FR} \\ N_{FF} \end{bmatrix}$$

ATLAS-CONF-2012-004

Additional details:

Gluino Mediated Stop

2 same-sign leptons + jets + E_T^{miss}

- Background Estimation techniques (2)
  - theory uncertainty on tt + X: (~75% uncertainty)

    bkg estimate taken from MC

    55% from fact./renorm. scale variations, 25% from PDF, 50% on k-factor

  - charge mis-ID: (5-13% uncertainty)

    bkg estimate using semi data-driven technique (in di-lepton ttbar)

    source: hard brems

    [e.g., e^- (hard) $\rightarrow \gamma$ (hard) e^- (soft) $\rightarrow e^+$ (hard) e^- (soft) e^- (soft)]

ATLAS-CONF-2012-004

Additional details:

Gluino Mediated Stop

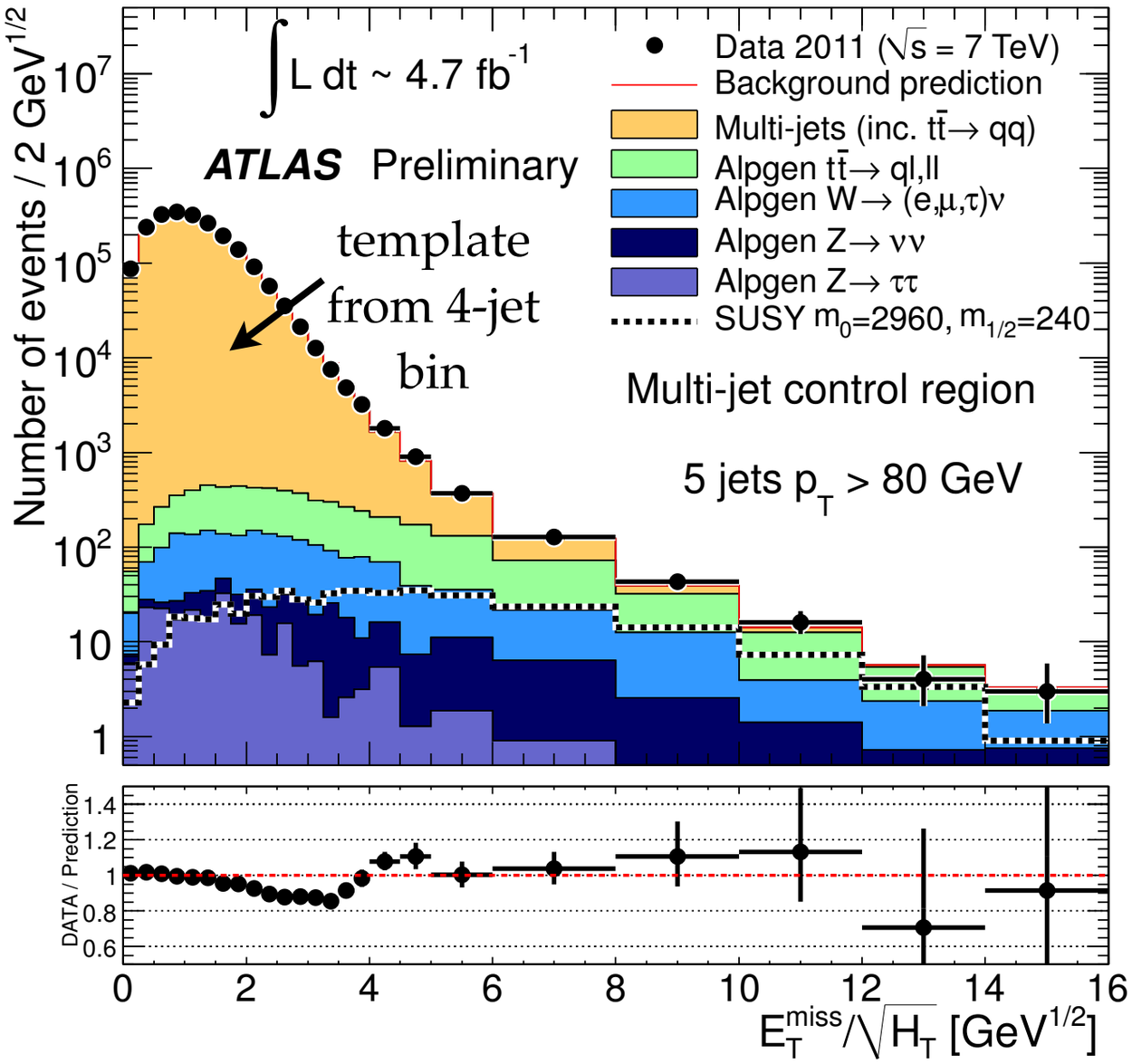
multijets + E_T^{miss}

Signal region	**7j55**	**8j55**	**9j55**	**6j80**	**7j80**	**8j80**
Multi-jets	91±20	10±3	1.2±0.4	67±12	5.4±1.7	0.42±0.16
$t\bar{t} \to q\ell, \ell\ell$	55±18	5.7±6.0	0.70±0.72	24±13	2.8±1.8	0.38±0.40
W + jets	18±11	0.81±0.72	0+0.13	13±10	0.34±0.21	0+0.06
Z + jets	2.7±1.6	0.05±0.19	0+0.12	2.7±2.9	0.10±0.17	0+0.13
Total Standard Model	**167±34**	**17±7**	**1.9±0.8**	**107±21**	**8.6±2.5**	**0.80±0.45**
Data	**154**	**22**	**3**	**106**	**15**	**1**
$N^{95\%}_{\mathrm{BSM,max}}$ (exp)	72	16	4.5	46	8.4	3.5
$N^{95\%}_{\mathrm{BSM,max}}$ (obs)	64	20	5.7	46	15	3.8
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (exp) [fb]	15	3.4	0.96	9.8	1.8	0.74
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (obs) [fb]	14	4.2	1.2	9.8	3.2	0.81
p_{SM}	0.64	0.27	0.28	0.52	0.07	0.43

ATLAS-CONF-2012-037

Gluino Mediated Stop

multijets + E_T^{miss}

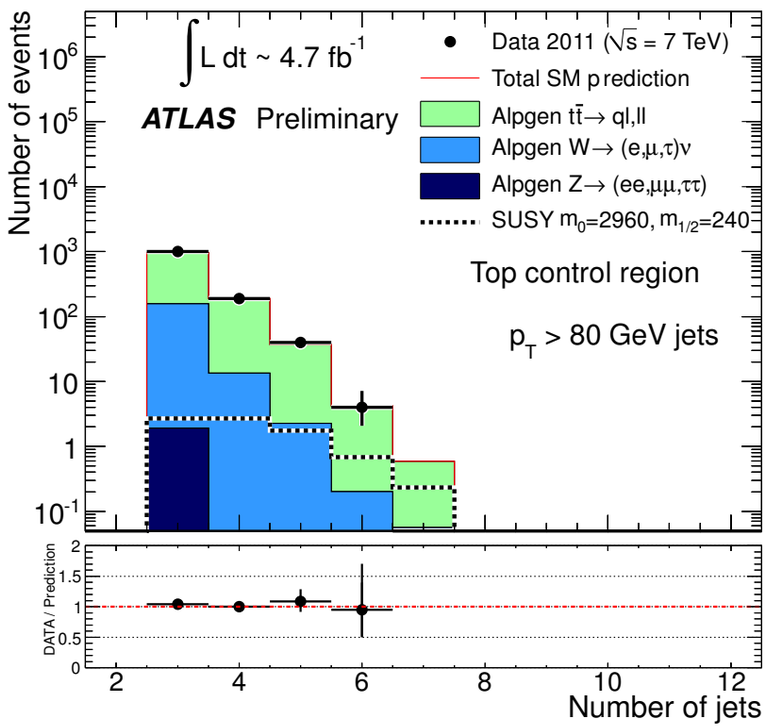


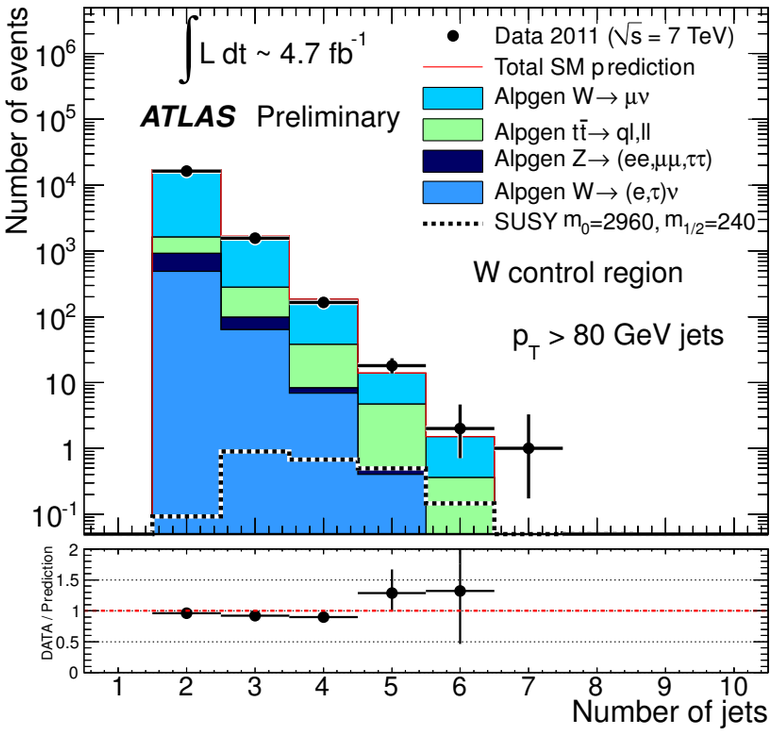
- Multijet Background Estimate:
  - E_T^{miss} / $\sqrt{H_T}$ ~invariant with respect to jet multiplicity
  - extrapolation from lower to higher jet multiplicity bins

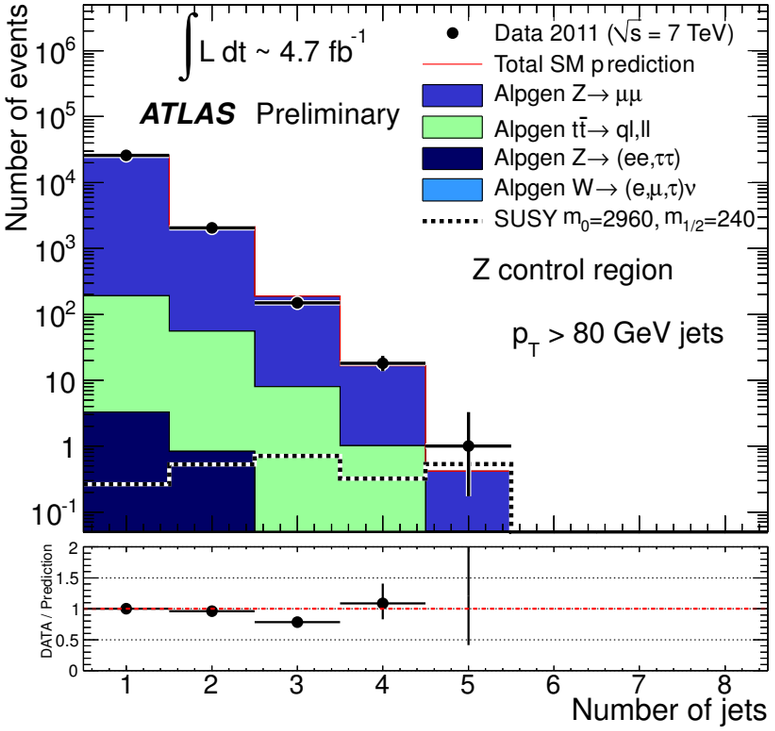
Additional details:

Gluino Mediated Stop

multijets + E_T^{miss}







	$t\bar{t}$ + jets	W + jets	Z + jets
Muon kinematics	$p_T > 20$ GeV, $\|\eta\| < 2.4$		
Muon multiplicity	= 1		= 2
Electron multiplicity	= 0		
b-tag jets	≥ 1	= 0	—
m_T or $m_{\mu\mu}$	50 GeV $< m_T <$ 100 GeV		80 GeV $< m_{\mu\mu} <$ 100 GeV
VR → CR transform	$\mu \rightarrow$ jet		$\mu \rightarrow \nu$

Direct Sbottom

m_{CT}

- Signal Efficiencies: 1–6% (200–500 GeV $\tilde{b}$), 6→2% as Δm decreases

m_{CT} GeV	top, W+hf TF (MC)	Z+hf TF (MC)	Others MC+DD	Total SM	Data
0	67 ± 10 (60 ± 25)	23 ± 8 (16 ± 9)	3.6 ± 1.5	94 ± 16 (80 ± 35)	96
100	36 ± 10 (34 ± 16)	23 ± 9 (12 ± 7)	3.1 ± 1.6	62 ± 13 (49 ± 25)	56
150	12 ± 5 (13 ± 8)	12 ± 6 (8.3 ± 4.7)	2.7 ± 0.9	27 ± 8 (24 ± 13)	28
200	3.2 ± 1.6 (4.1 ± 3.4)	3.9 ± 3.2 (2.8 ± 1.5)	1.0 ± 0.9	8.1 ± 3.5 (8.0 ± 4.9)	10

arXiv 1112.3832, submitted to PRL

Additional details:

Direct Stop (GMSB)

$$m_{\tilde{q}_3} = m_{\tilde{u}_3} = -A_t/2; \quad \tan\beta = 10,$$

$$\mathcal{B}\left(\tilde{\chi}_1^0 \to Z\tilde{G}\right) = 1 - 0.65\,[m_{\tilde{\chi}_1^0} : 100 - 350\,\mathrm{GeV}]$$

characteristic scale of messenger fields ~ 10 TeV,
fine tuning < 10 %

- Signal Efficiencies:
  0.01–2% (100–400 GeV $\tilde{t}$),
  2→0.5% as Δm decreases ($\tilde{t}$ = 400 GeV)

	SR1	SR2
ee channel		
Data (2.05 fb^{-1})	39	20
SM	36.2±8.5	14.1±3.0
top	23.8±4.8	11.9±2.8
Z+hf	9.4±7.0	0.9±0.8
fake lepton	2.4±0.9	1.1±0.6
Others	0.5 ± 0.5	0.2 ± 0.2
$\mu\mu$ channel		
Data (2.05 fb^{-1})	47	23
SM	55 ± 12	26.6±5.1
top	40.4 ± 6.2	22.9 ± 4.3
Z+hf	14.2±9.9	3.3±2.6
fake lepton	0.00±0.08	0.00±0.07
Others	0.7 ± 0.7	0.3 ± 0.3
ee+$\mu\mu$		
Data (2.05 fb^{-1})	86	43
SM	92±19	40.7 ± 6.0
top	64.3±7.7	34.8 ± 5.0
Z+hf	24±16	4.2±3.2
fake lepton	2.4 ± 0.9	1.1 ± 0.6
Others	1.2 ± 1.2	0.6 ± 0.6
95% C.L. upper limits: observed (expected)		
events (2.05 fb^{-1})	37.2 (40.6)	19.8 (17.8)
visible σ [fb]	18.2 (19.8)	9.7 (8.7)

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