

SUSY Searches in ATLAS

(3rd generation, Electroweak)

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(On behalf of the ATLAS collaboration)



Searches for 3rd generation SUSY particles

- ◎ The 3rd generation mass parameters are dependent on the mixing matrix of the q_L and q_R
- ◎ Larger mixing \implies Lighter sbottom (\tilde{b}) and stop (\tilde{t}) mass
 - ↳ Even though the common squarks are heavier, 3rd gen. should be accessible to the LHC
- ◎ Rich phenomenological aspects of \tilde{t} masses and mixing :
 - ▶ Light stop \implies EWBaryoGenesis and MSSM
 - ▶ little Higgs mass
 - ▶ BR($b \rightarrow s\gamma$), constraint on the charged higgs mass
- ◎ Favorable production scenarios at the LHC :

$$(I)_j \quad \tilde{g} \rightarrow b\tilde{b}_1 \rightarrow bb\tilde{\chi}_j^0 \quad (\rightarrow bbl^+l^-\tilde{\chi}_1^0),$$

$$(II)_j \quad \tilde{g} \rightarrow t\tilde{t}_1 \rightarrow tt\tilde{\chi}_j^0,$$

$$(III)_j \quad \tilde{g} \rightarrow t\tilde{t}_1 \rightarrow tb\tilde{\chi}_j^\pm,$$

$$(III)_{ij} \quad \tilde{g} \rightarrow b\tilde{b}_i \rightarrow bW\tilde{t}_1 \rightarrow bbW\tilde{\chi}_j^\pm,$$

$$(IV)_{ij} \quad \tilde{g} \rightarrow b\tilde{b}_i \rightarrow tb\tilde{\chi}_j^\pm.$$

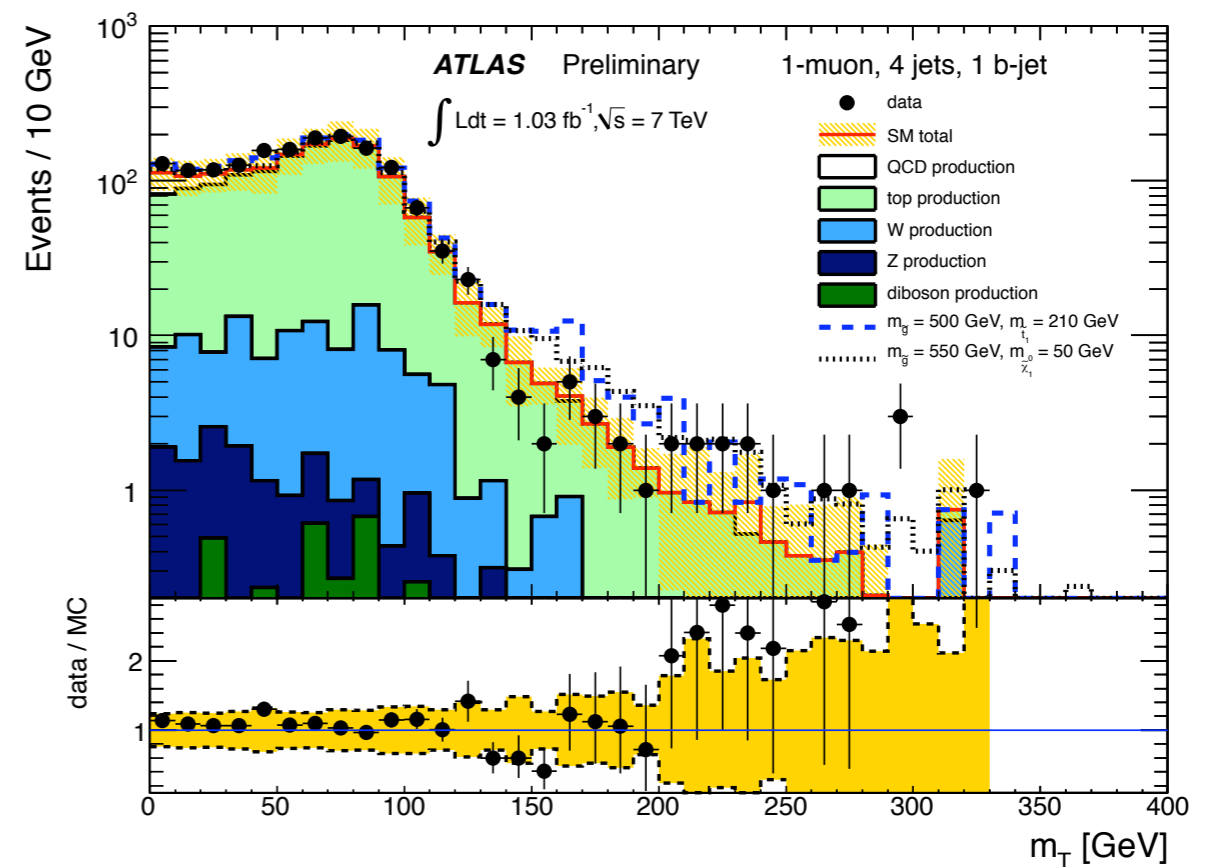
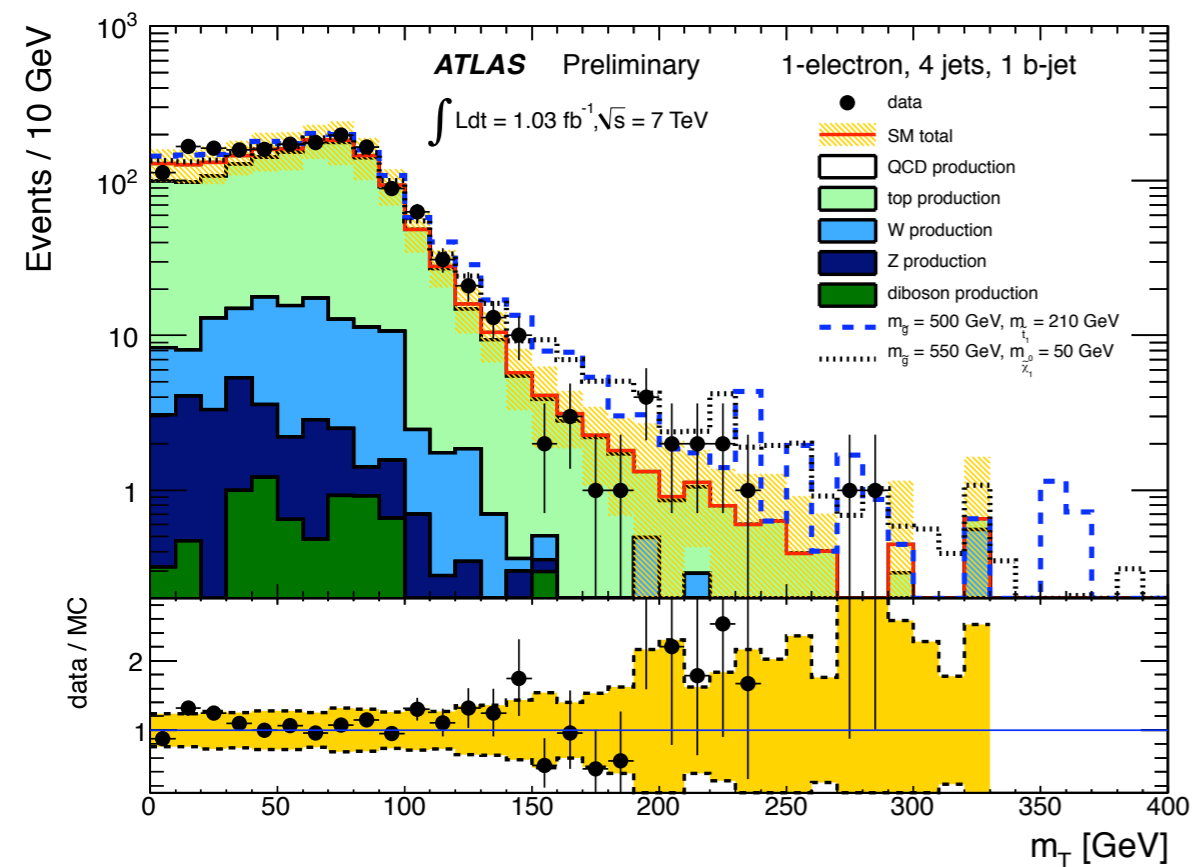
◎ **Look for a b -jet + Emiss (+ leptons) signature**

Single-lepton b -jet Signature (Signal Region)

$$\int L dt \sim 1 \text{ fb}^{-1}$$

Signal region selection criteria:

- Exactly one high p_T lepton; $p_T > 20 \text{ GeV}$
- Along with four high p_T jets; $p_T > 50 \text{ GeV}$
- At least one out of the four jets required to be a b -tagged jet
 - $E_{\text{tmiss}} > 50 \text{ GeV}$, Transverse mass; $m_T > 100 \text{ GeV}$
 - Effective mass (scalar sum of jet p_T and $E_{\text{tmiss}})$ $> 600 \text{ GeV}$



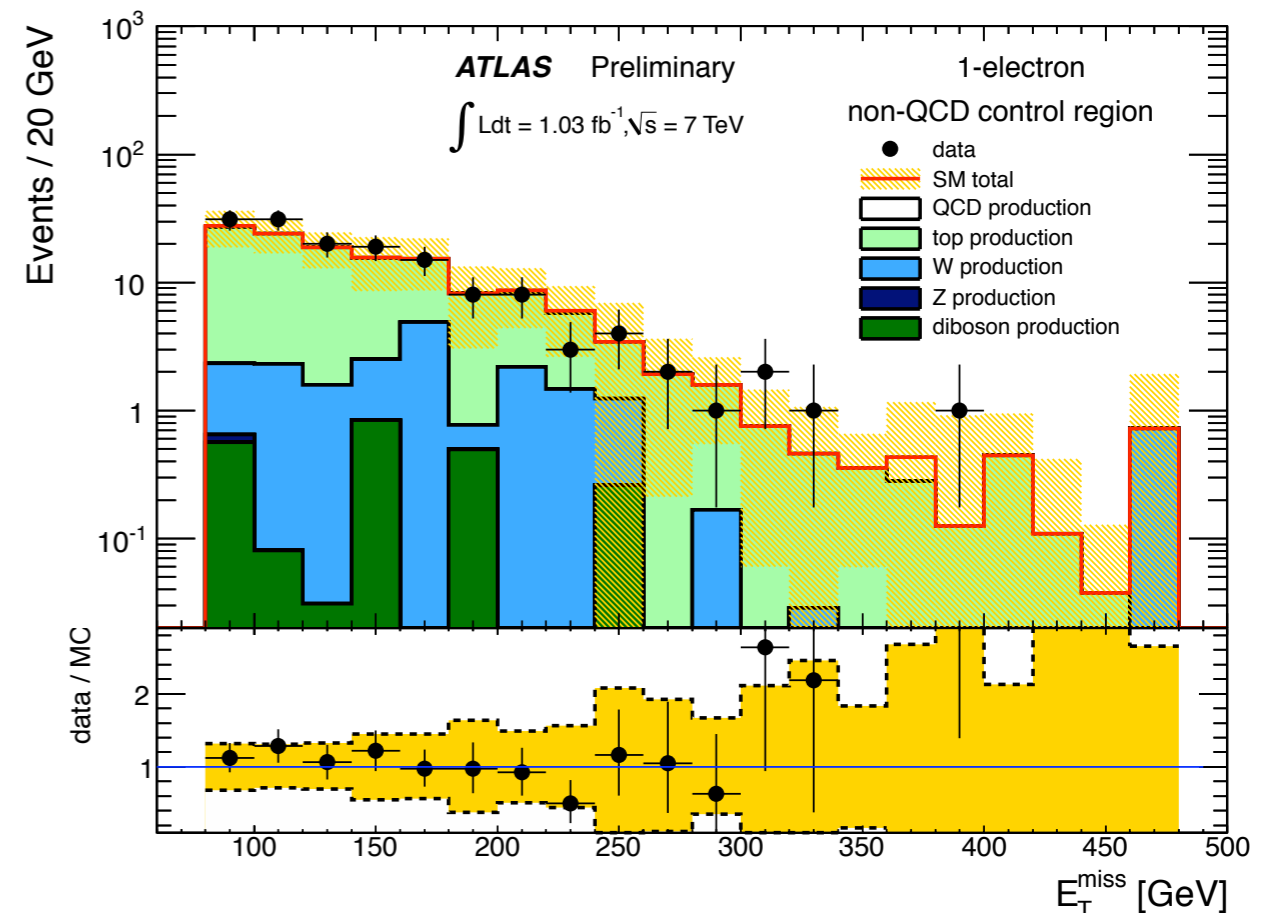
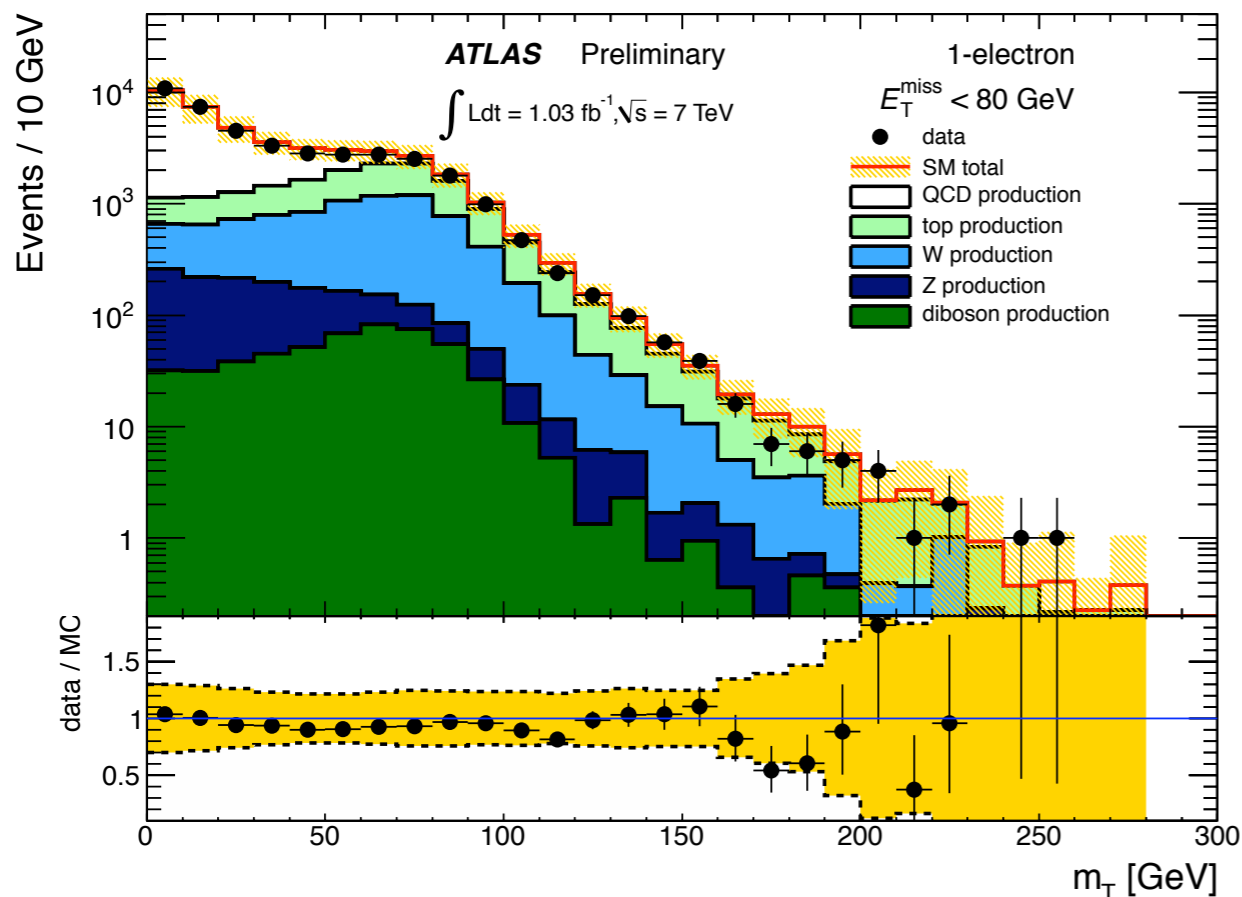
Single-lepton, b -jet Signature (Background Estimation)

QCD multijets:

- Suppressed by tighter event selection cuts
- Select events with a looser selection of leptons in a QCD multijet dominated region (ctrl sample)
- Calculate the pass/fail ratio by counting the leptons that satisfy the signal lepton selection

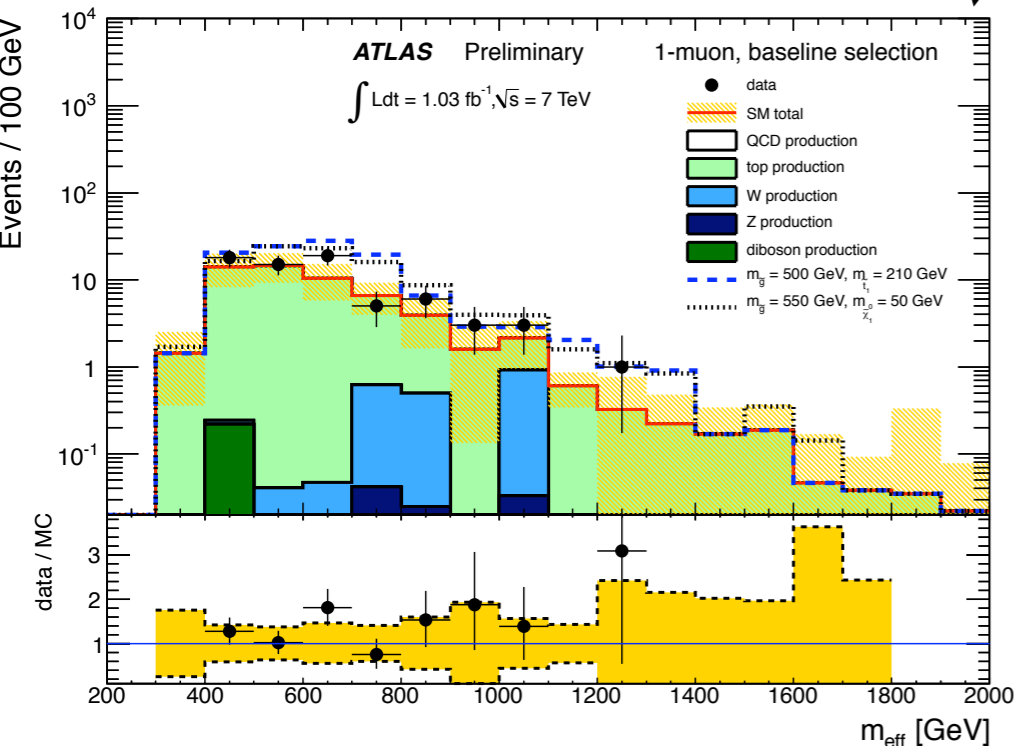
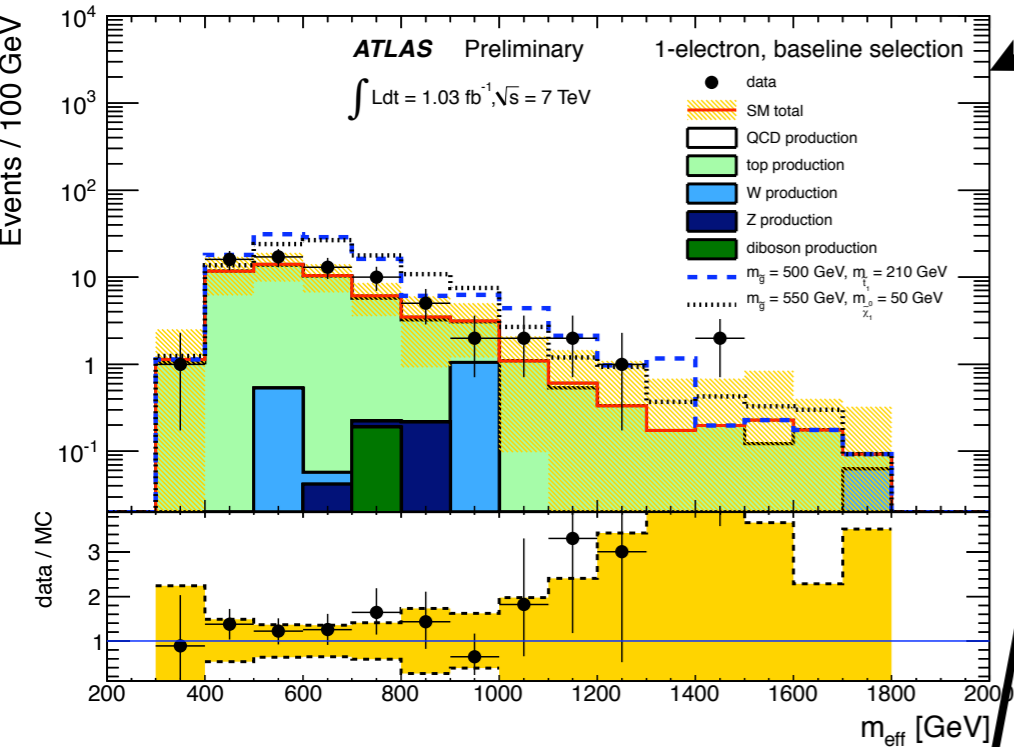
$t\bar{t}$ /W+jets:

- Use transverse mass to select the region dominated by leptons from a W decay



Single-lepton b -jet Signature (Events in the Signal Region)

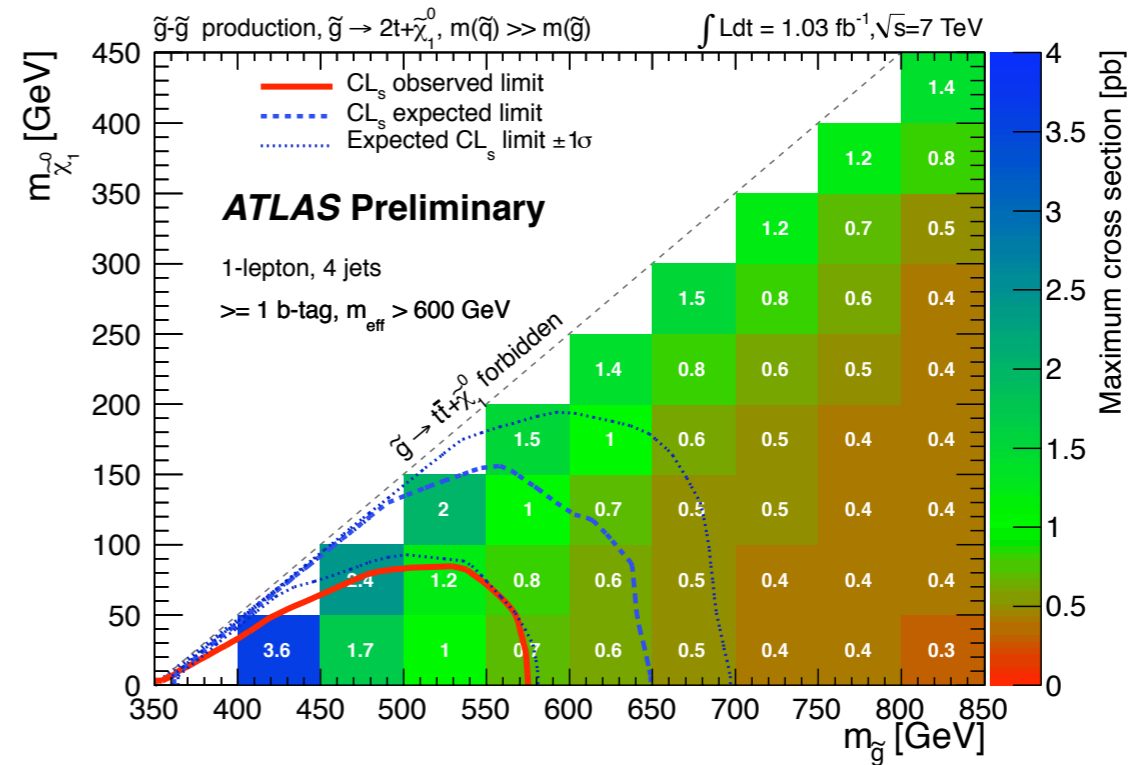
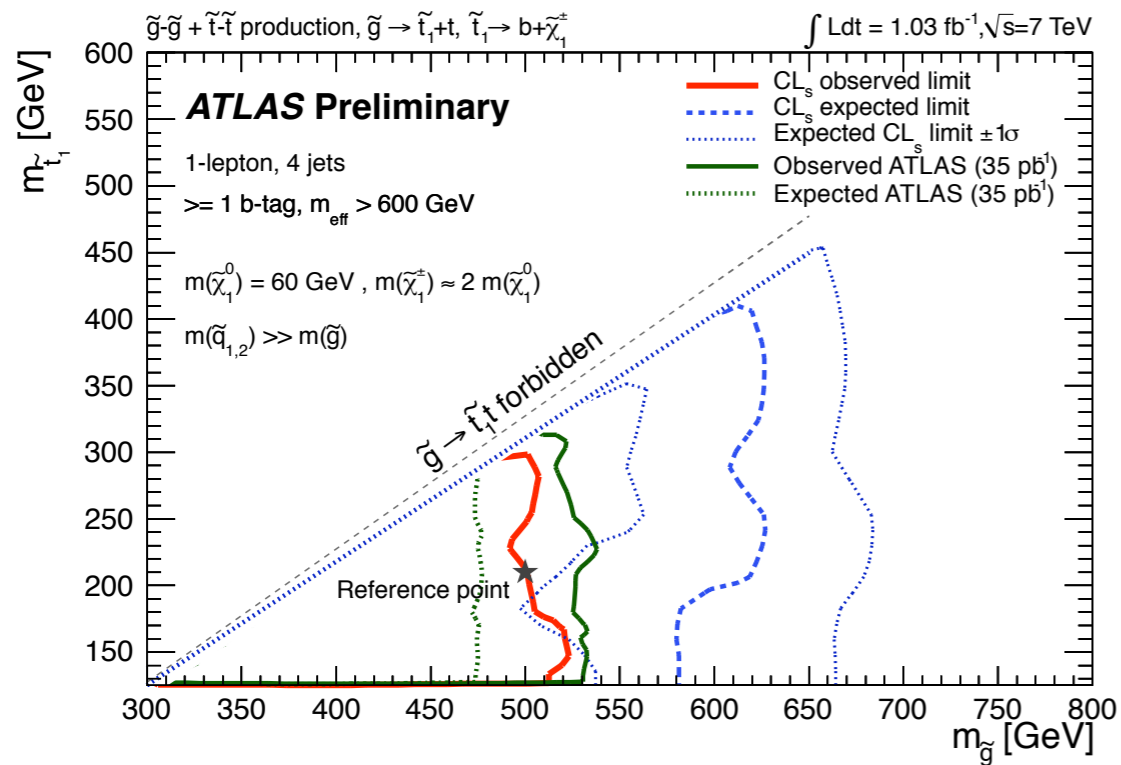
After :
 $E_{\text{miss}} > 50 \text{ GeV}$
 $m_T > 100 \text{ GeV}$



Cuts	≥ 4 jets	≥ 1 b jet	$E_T^{\text{miss}} > 80 \text{ GeV}$	$m_T > 100 \text{ GeV}$	$m_{\text{eff}} > 600 \text{ GeV}$
1 muon channel					
top	1670 ± 620	1290 ± 490	403 ± 169	54 ± 29	24 ± 13
W+jets	910 ± 370	100 ± 60	24 ± 17	2.0 ± 2.0	2.0 ± 1.9
Z+jets	150 ± 60	14 ± 10	0.7 ± 2.4	0.1 ± 0.3	0.1 ± 0.2
diboson	41 ± 17	2.9 ± 3.0	0.6 ± 0.8	0.2 ± 0.3	0
QCD (d-d)	250 ± 10	96 ± 43	5.1 ± 6.6	< 0.6	< 0.6
SM (MC)	3020 ± 910	1504 ± 515	433 ± 179	56 ± 30	26 ± 14
SM (d-d)					27.4 ± 5.2
data	3036	1640	497	70	37
1 electron channel					
top	1690 ± 620	1300 ± 480	406 ± 166	49 ± 24	23 ± 14
W+jets	940 ± 380	110 ± 70	31 ± 20	1.7 ± 1.4	1.1 ± 1.3
Z+jets	260 ± 100	25 ± 15	1.7 ± 1.0	0.3 ± 0.2	0.3 ± 0.2
diboson	46 ± 19	7.1 ± 3.4	3.4 ± 1.8	0.2 ± 0.2	0.2 ± 0.2
QCD (d-d)	620 ± 170	151 ± 78	4.6 ± 10.4	1.1 ± 1.8	0.9 ± 1.0
SM (MC)	3555 ± 960	1592 ± 522	447 ± 176	53 ± 25	26 ± 14
SM (d-d)					28.0 ± 8.4
data	3623	1721	492	71	37
Total					
top	3360 ± 1250	2590 ± 970	810 ± 337	103 ± 53	48 ± 27
W+jets	1850 ± 750	210 ± 130	55 ± 36	3.7 ± 3.1	3.1 ± 2.9
Z+jets	410 ± 170	39 ± 24	2.4 ± 3.1	0.4 ± 0.4	0.4 ± 0.3
diboson	87 ± 36	10 ± 6	4.0 ± 2.5	0.4 ± 0.4	0.2 ± 0.2
QCD (d-d)	870 ± 270	247 ± 121	9.7 ± 16.8	1.1 ± 2.3	0.9 ± 1.2
SM (MC)	6574 ± 1870	3096 ± 1042	881 ± 356	109 ± 55	52 ± 28
SM (d-d)					54.9 ± 13.6
data	6659	3361	989	141	74

Single-lepton b -jet Signature

(Signal Interpretation) ATLAS-CONF-2011-130



• Model Independent limits :

- 95% CL_{obs} upper limit on expected signal; 48 events
- 95% CL_{obs} upper limit on $\sigma \times B$ for a new signal; 46 fb

• Model dependent limits :

• pMSSM :

- For a gluino mediated/direct $\tilde{t} t$ pair production and with $B(\tilde{t} \rightarrow b \tilde{\chi}^\pm) = 1$, $m(\tilde{g})$ is excluded up to 520 GeV

• Simplified Model :

- In a gluino mediated decay to ‘tt+LSP’, $m(\tilde{g})$ is excluded up to 570 GeV

No-lepton b -jet Signature (Signal Region)

$$\int L dt \sim 0.83 \text{ fb}^{-1}$$

◎ Selection criteria :

- ▶ Require at least 3 high- p_T jets; $p_T > 130 \text{ GeV}, 50 \text{ GeV}, 50 \text{ GeV}$
- ▶ At least 1 b -tagged jet out of the 3 high- p_T jets
- ▶ Veto events that has an electron or a muon
- ▶ $E_{\text{miss}} > 130 \text{ GeV}, E_{\text{miss}}/M_{\text{eff}} > 0.25$
- ▶ Three high- p_T jets should have $\Delta\varphi(\text{jet}, E_{\text{miss}}) > 0.4$
(Reduces QCD multijet background significantly)
- ▶ Four signal regions
 - ▶ by the number of b -jets in the event and cut on M_{eff}

Signal Region-1
 ≥ 1 b -jet, $M_{\text{eff}} > 500 \text{ GeV}$

Signal Region-3
 ≥ 2 b -jet, $M_{\text{eff}} > 500 \text{ GeV}$

Signal Region-2
 ≥ 1 b -jet, $M_{\text{eff}} > 700 \text{ GeV}$

Signal Region-4
 ≥ 2 b -jet, $M_{\text{eff}} > 700 \text{ GeV}$

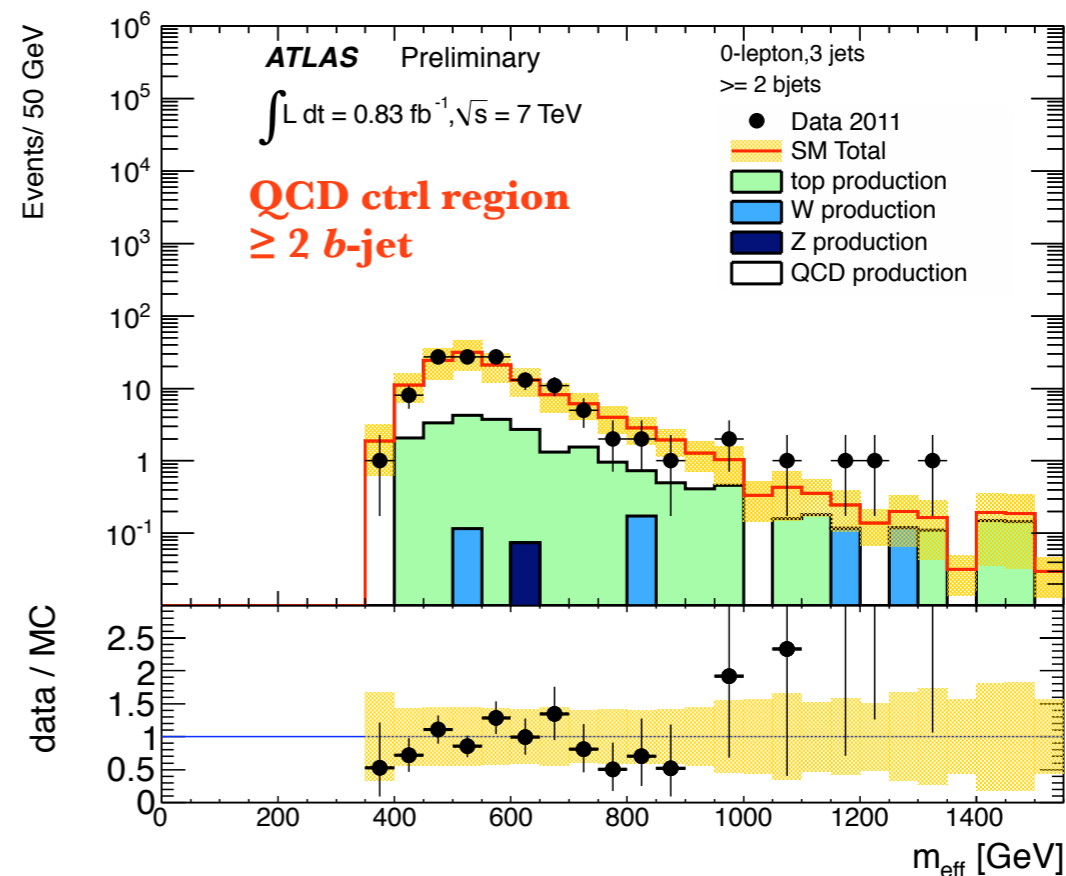
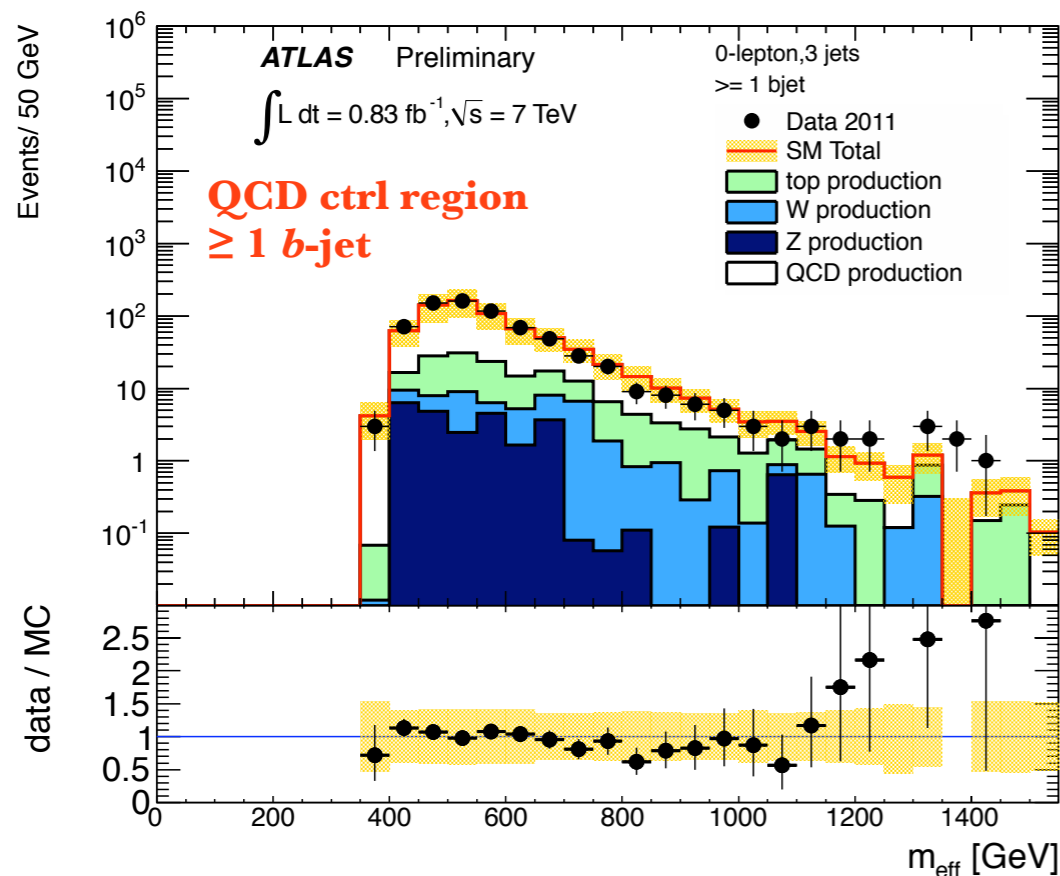
No-lepton b -jet Signature (Background Estimation)

QCD multijet:

- control region with $\Delta\varphi(\text{jet}, E_{\text{tmiss}}) < 0.4$
- Use jet-smearing technique \rightarrow extrapolate to large E_{tmiss}

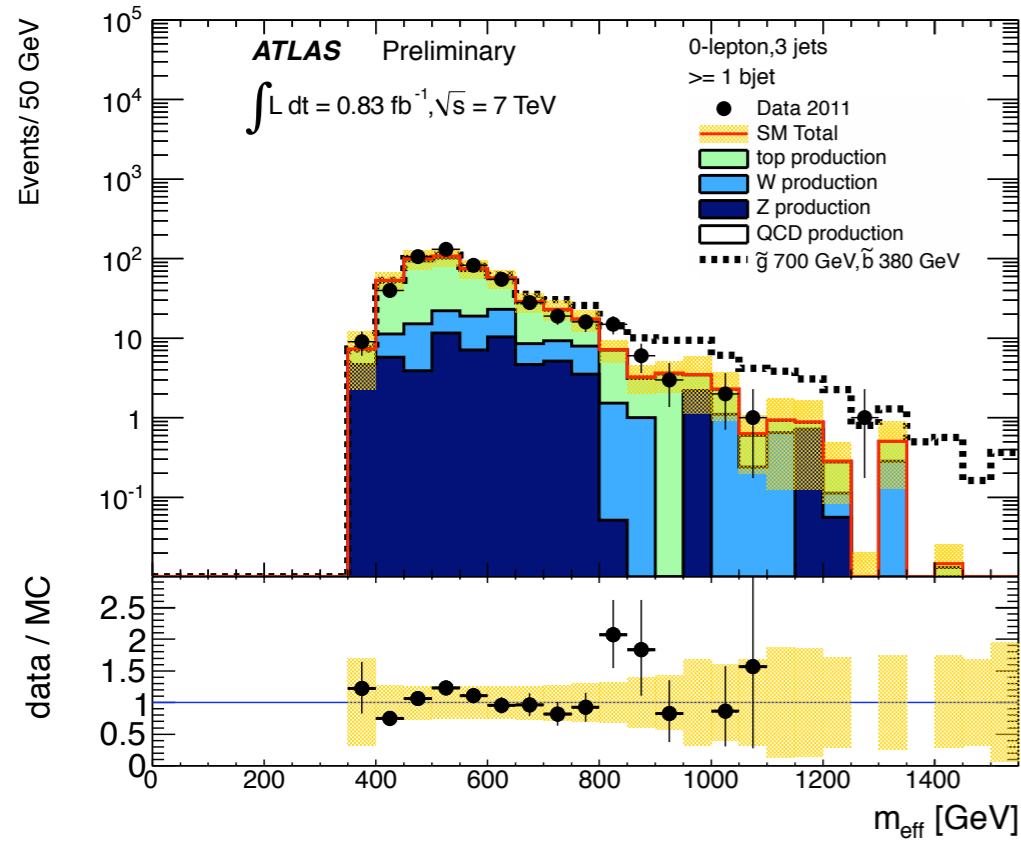
$t\bar{t}/W$ + jets:

- Use transverse mass (M_T ; lepton, E_{tmiss}) control region
- Extrapolate using Data, MC ratio



No-lepton b -jet Signature (Events in the signal regions)

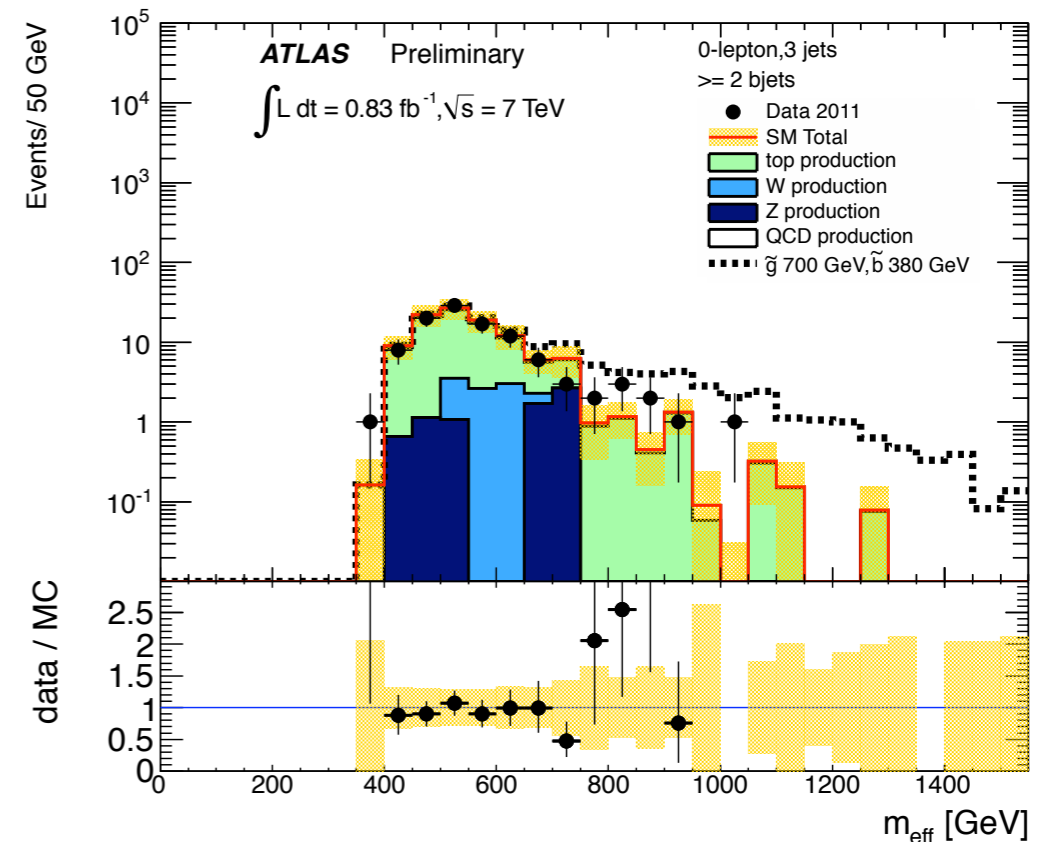
ATLAS-CONF-2011-098



Sig. Reg.	Data (0.83 fb^{-1})	Top	W/Z	QCD	Total
3JA (1 btag $m_{\text{eff}} > 500 \text{ GeV}$)	361	221^{+82}_{-68}	121 ± 61	15 ± 7	356^{+103}_{-92}
3JB (1 btag $m_{\text{eff}} > 700 \text{ GeV}$)	63	37^{+15}_{-12}	31 ± 19	1.9 ± 0.9	70^{+24}_{-22}
3JC (2 btag $m_{\text{eff}} > 500 \text{ GeV}$)	76	55^{+25}_{-22}	20 ± 12	3.6 ± 1.8	79^{+28}_{-25}
3JD (2 btag $m_{\text{eff}} > 700 \text{ GeV}$)	12	$7.8^{+3.5}_{-2.9}$	5 ± 4	0.5 ± 0.3	$13.0^{+5.6}_{-5.2}$

Model Independent Limit @ 0.83 fb^{-1}

Sig. Reg.	95% C.L. N events	95% C.L. σ_{eff} (pb)
	CL_s (PCL)	CL_s (PCL)
3JA (1 btag $m_{\text{eff}} > 500 \text{ GeV}$)	240 (206)	0.288 (0.247)
3JB (1 btag $m_{\text{eff}} > 700 \text{ GeV}$)	51 (40)	0.061 (0.048)
3JC (2 btag $m_{\text{eff}} > 500 \text{ GeV}$)	65 (53)	0.078 (0.064)
3JD (2 btag $m_{\text{eff}} > 700 \text{ GeV}$)	14 (11)	0.017 (0.014)



No-lepton b -jet Signature (Signal Interpretation)

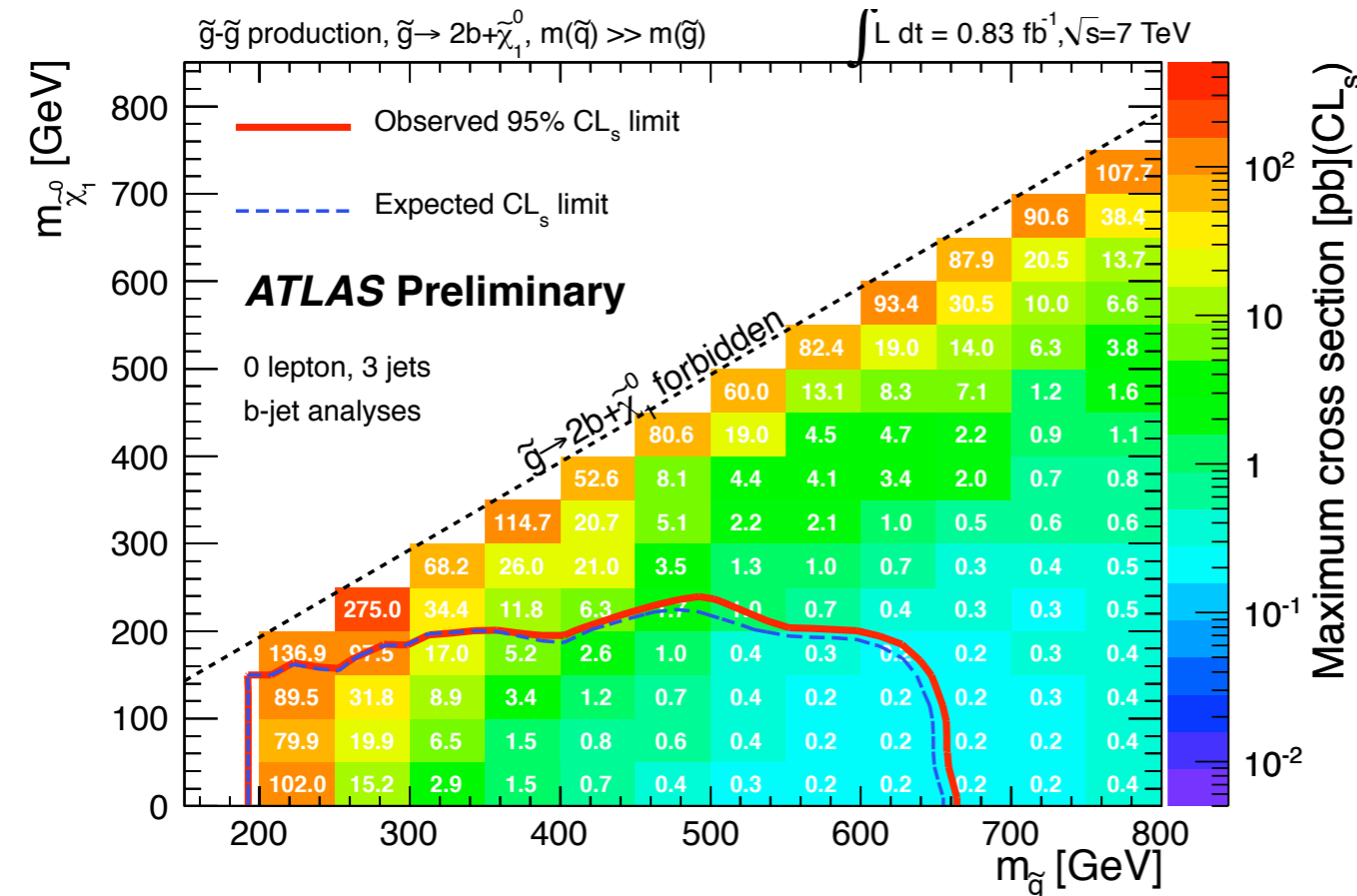
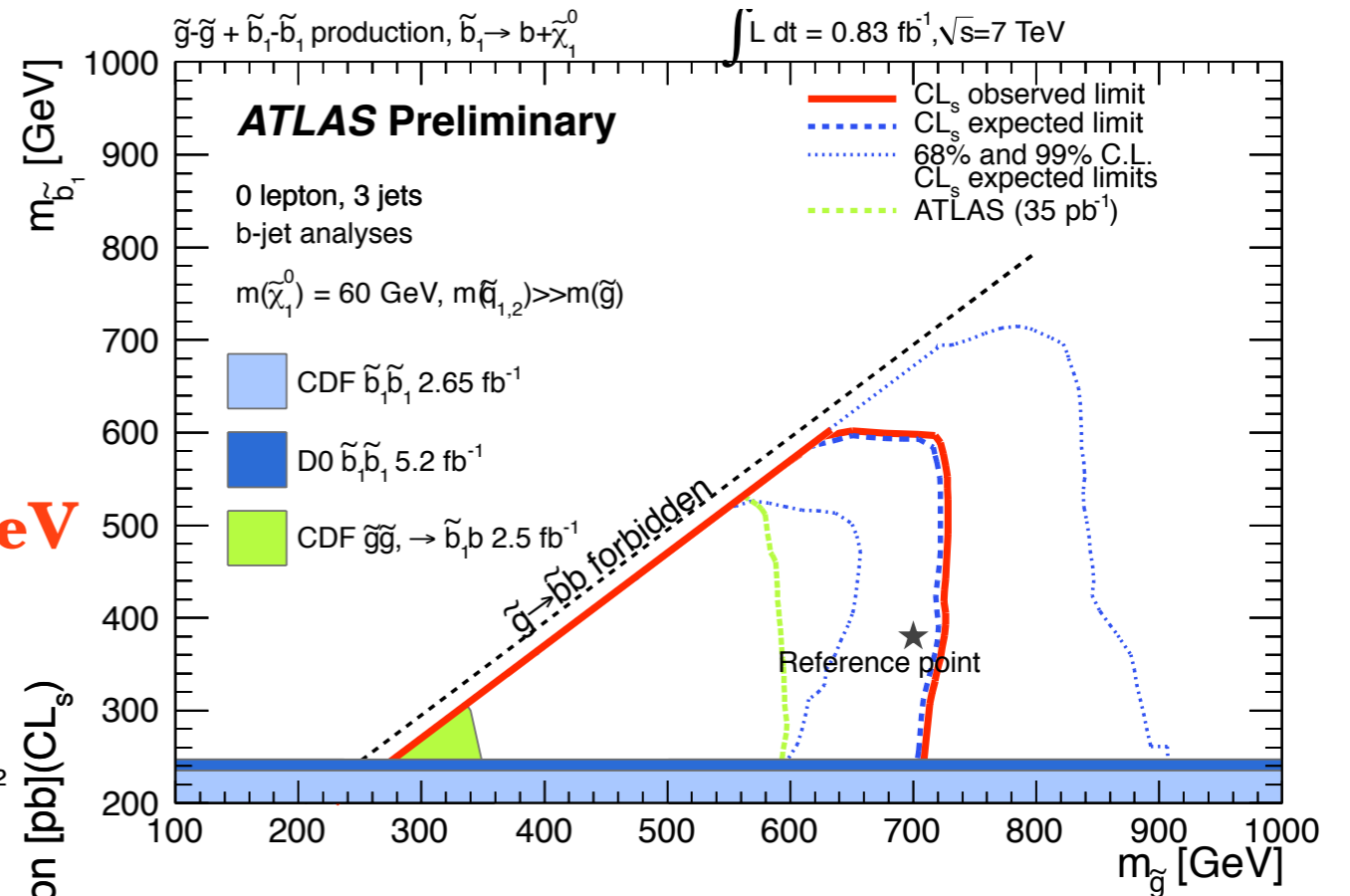
ATLAS-CONF-2011-098

pMSSM

- Gluino mediated $b\tilde{}$ ($b\chi_1$)
- Signal reg. with best expected limit is chosen

● Exclusion :

● $m(g\tilde{}) \sim 720 \text{ GeV}$; $m(b\tilde{}) \sim 600 \text{ GeV}$



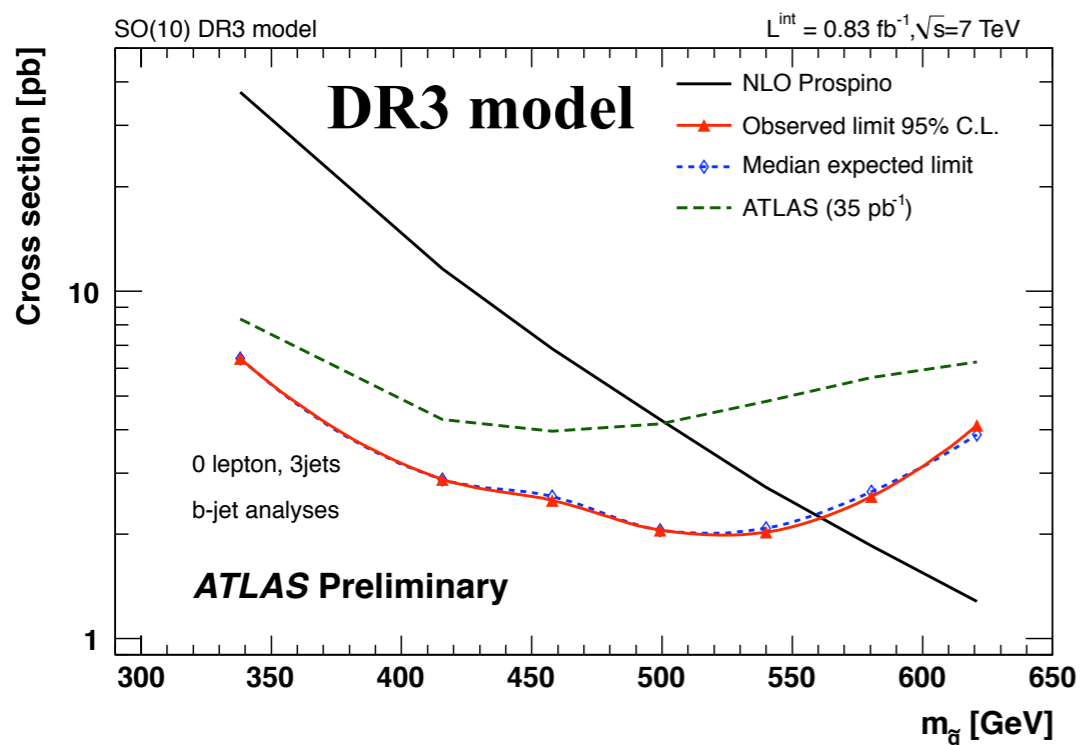
Simplified Model

- Gluino $\rightarrow bb\chi_1$
- Exclusion in the $m(g\tilde{})-m(\chi_1)$ plane:
 ● $m(g\tilde{}) \sim 660 \text{ GeV}$; $m(\chi_1) \sim [200-250] \text{ GeV}$

No-lepton b -jet Signature (Signal Interpretation)

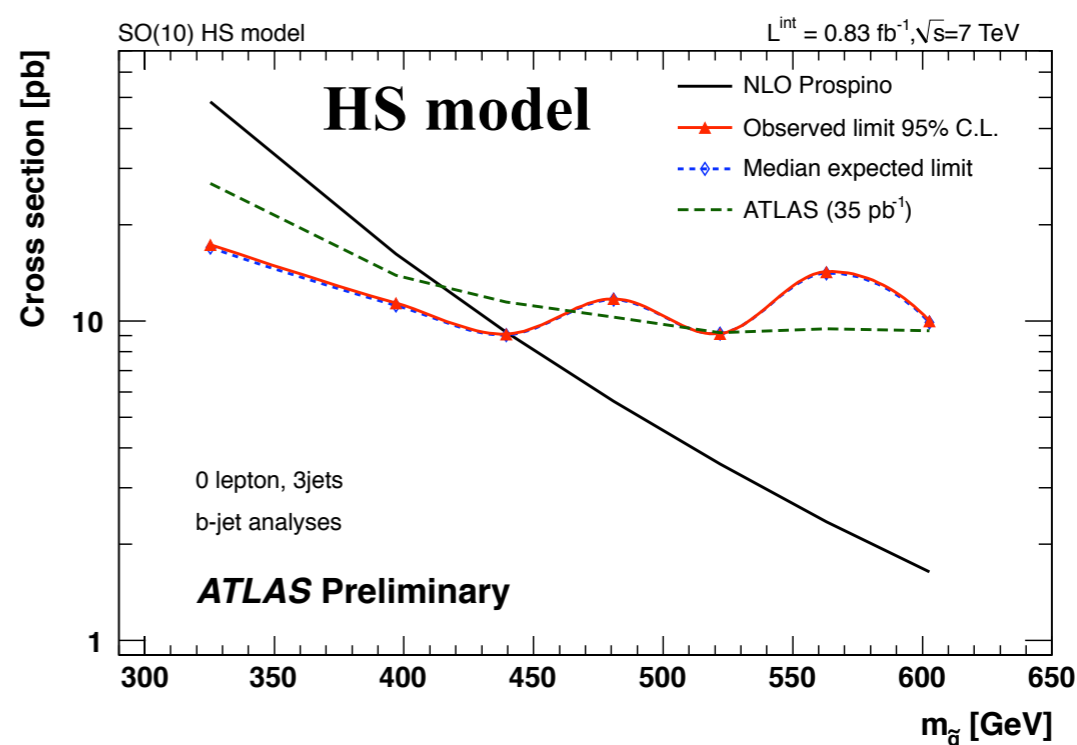
ATLAS-CONF-2011-098

- ⊙ GUT based gauge group model SO(10)
 - ⊙ 1st and 2nd gen. squarks ~ 10 TeV, 3rd gen $\sim [1-3]$ TeV
 - ⊙ Signal through low masses:
gluino (300-600) GeV, charginos (100-180) GeV, LSP (50-90) GeV
 - ⊙ Two signal models are considered: ([Baer, Kraml, Lessa, Sekmen, JHEP 1002 \(2010\) 055](#))
 - ‘D-term splitting’ and ‘Higgs splitting’ models



Exclusion :

• $m(g\tilde{)} \sim 570$ GeV



Exclusion :

• $m(g\tilde{)} \sim 450$ GeV

Dileptons, jets and Etmis

- Requires two isolated and high-pT leptons in the event
 - ▶ Complementary approach to other analyses (much smaller contribution from the SM background sources)
- Gives a handle to use the charge of the two leptons
- Three separate analysis are performed
- **Same-Sign dileptons :**
 - ▶ **Requires the charge of the two leptons to be same**
 - ▶ **Scarce production through SM processes, clean signature**
- Opposite-Sign dileptons :
 - Much higher rate for SUSY events that produces leptons from $\tilde{\chi}_2^0$ decay
- Flavor subtraction (exclusive OS-Same-Flavor leptons) :
 - ▶ Exclusively look into Same Flavor leptons with opposite charge
 - ▶ Exploit the fact that most of the dominant SM backgrounds are flavor symmetric

Dilepton Signature (Same-Sign analysis)

SM background source :

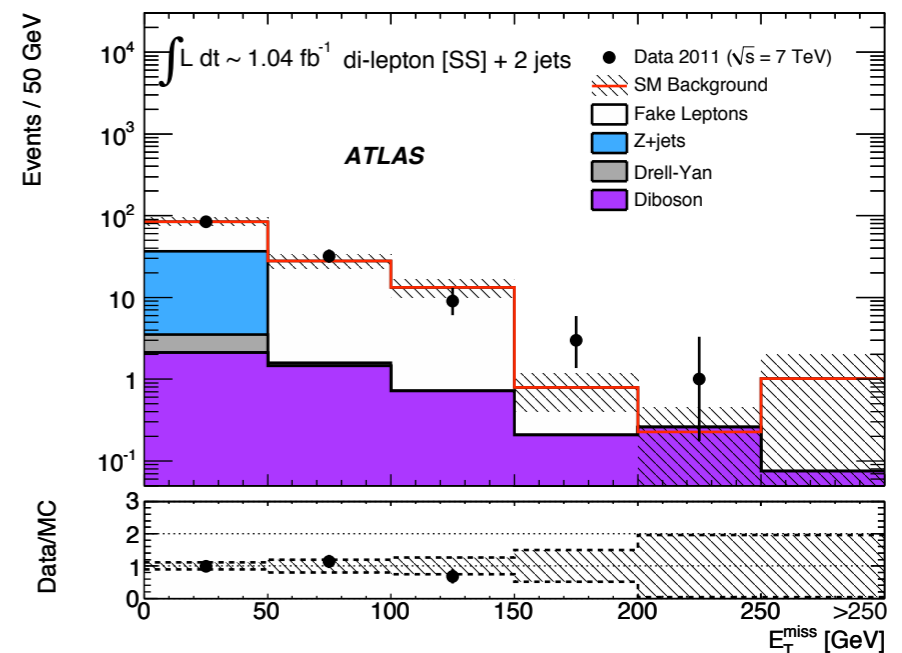
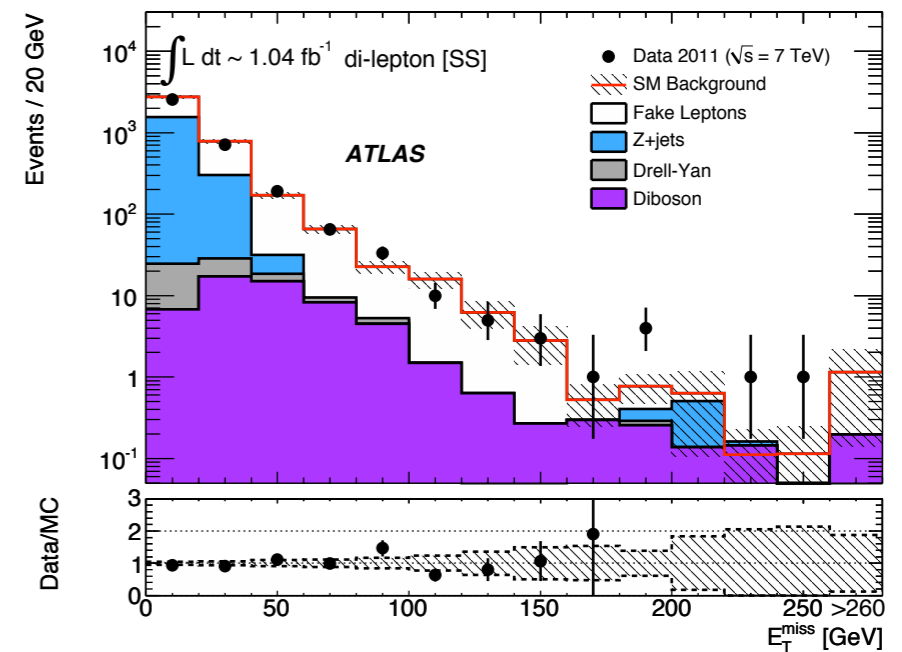
- Mostly an event contains at least one lepton from a fake source (e.g, heavy-flavor decay, jet fakes an electron)
- Z(ee) events contribute through charge flip

Fake-leptons (data-driven estimate) :

- Get the pass-fail ratio of a loose lepton to pass a tight(signal) lepton selection
- Estimates contribution from bb, QCD multijets, W+jets, tt(lvqq), single-top in the signal region

Charge flip :

- Use Z control region to get the charge flip rate from MC
- Closure test comparing data and MC numbers in the control region
- Estimates contribution from Z(ee), tt(lvlv) process into the signal region



SS Dileptons Signature (Signal Regions)

arXiv:1110.6189

[submitted to Phys. Lett. B]

◎ Selection criteria :

- ◎ Select 2 high- p_T leptons ; $p_T > 20$ GeV
- ◎ Signal region without any jets ; $E_{\text{miss}} > 100$ GeV
- ◎ Signal region with 2 jets ($p_T > 50$ GeV) ; $E_{\text{miss}} > 80$ GeV

Limit on the effective x-sec @ 1 fb^{-1}

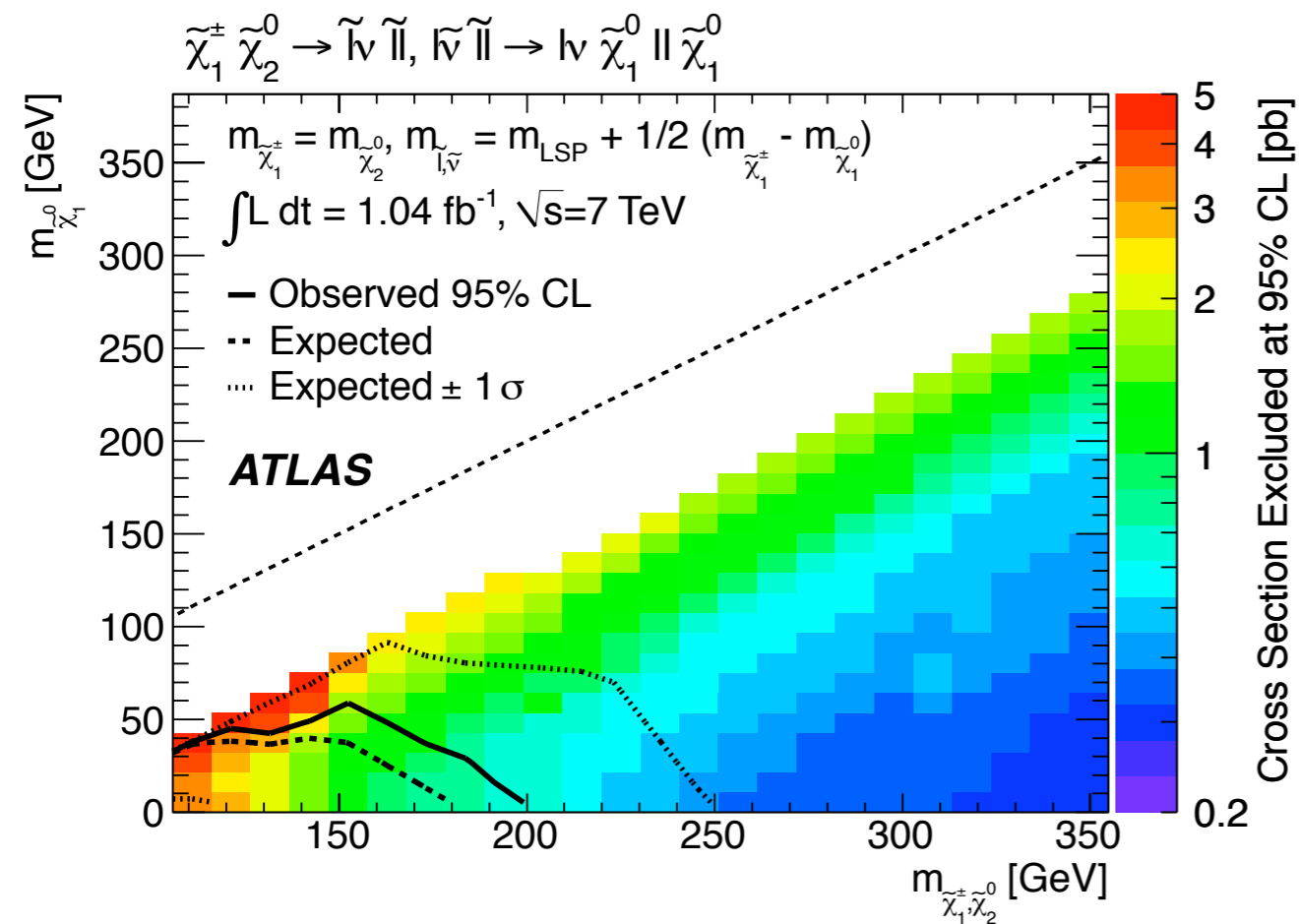
	Total SM BG @ 1 fb^{-1}	Observed Data events @ 1 fb^{-1}	95% CL Observed upper limit
Signal Region-1	32.6 ± 7.9	25	14.8 fb
Signal Region-2	24.9 ± 5.9	28	17.7 fb

SS Dileptons Signature (Signal Interpretation)

arXiv:1110.6189

[submitted to Phys. Lett. B]

- Interpretation in the simplified model of $(\chi^\pm\chi^0)$ production
- SS dilepton signature is sensitive to the lepton production through an intermediate and lighter slepton



Reference point :

- $m(\chi^\pm) = m(\chi^0) = 200 \text{ GeV}$
- $\sigma \sim 0.5 \text{ pb}$

● Cascade decays of $\chi^\pm\chi^0$ is dominated by intermediate sleptons

➔ **$m(\chi^\pm)$ is excluded up to 200 GeV**

SUMMARY

- ◎ ATLAS performed searches for 3rd generation squarks using signatures with a b -tagged jet with $\sim 1 \text{ fb}^{-1}$ data
 - ◎ Two complementary approaches
 - ▶ lepton + b -jet + E_{miss} ([ATLAS-CONF-2011-130](#)),
 - ▶ b -jet + E_{miss} ([ATLAS-CONF-2011-098](#))
 - ◎ No significant excess have seen over the SM expectation
 - ◎ $m(g\tilde{)}$ is excluded up to [500-700] GeV in Simplified model scenario
 - ◎ $m(b\tilde{)}$ is excluded up to 600 GeV in pMSSM scenario
 - ◎ $m(\chi\tilde{)}$ is excluded up to [200-250] GeV in Simplified model scenario
- ◎ Dilepton signature is getting sensitivity to the direct production of gauginos ([1st data results from LHC !](#)) @ 1 fb^{-1} ([arXiv:1110.6189](#))
 - ◎ Signal interpretation using simplified models
 - ◎ Decay to leptons dominated by intermediate sleptons,
 - ↳ $m(\chi_{\pm})$ is be excluded up to 200 GeV