Searches for the Third Generation: SUSY with b-jets in ATLAS

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UNIVERSITY OF LIVERPOOL

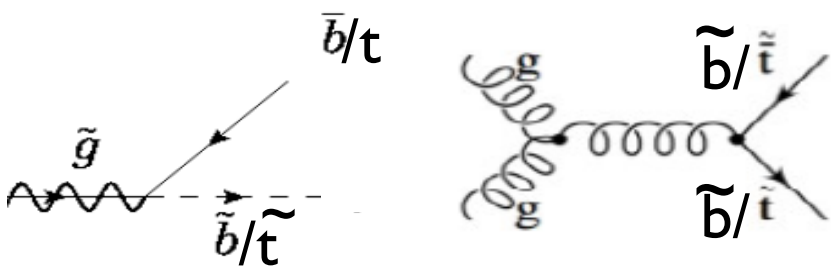
ATLAS

Science & Technology Facilities Council

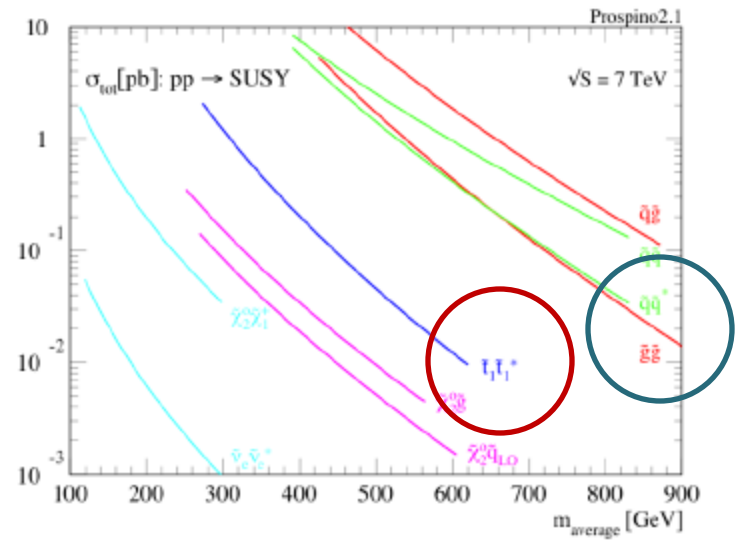
Third generation squarks

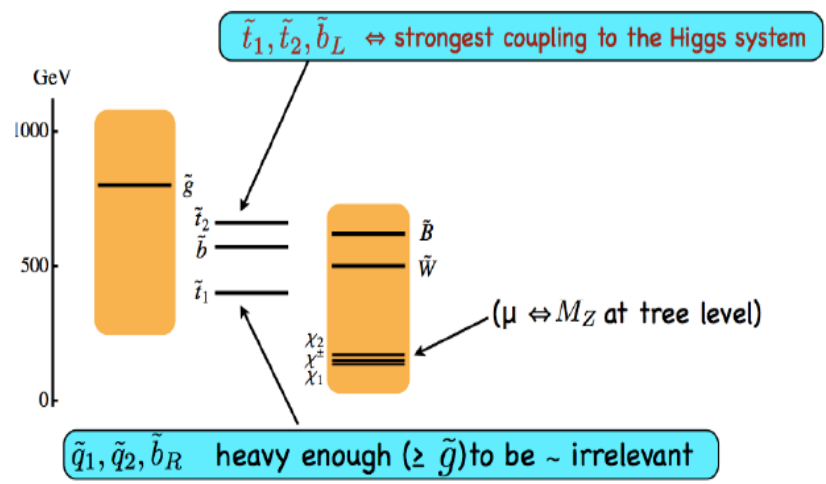
Third generation squarks might be lighter than 1st, 2nd generation → possibly high production cross sections:

- **gluino-mediated** or **direct pair** production: if m(gluino) not too high, and m(gl) > m(~b)+m(b) or m(~t)+m(t), gl-gl dominate



- Phenomenology depends on the SUSY particle mass hierarchy
- Final states with several **b-jets** are expected





Outline

In this talk:

Searches for gluino-mediated production of third generation squarks in R-parity conserving SUSY scenarios:

- in jets+MET (lepton veto) final states, (1 or 2 *b-jet*) for sbottom search using 0.83 fb^{-1} of data
  - ATLAS Collaboration, ATLAS-CONF-2011-098 (2011).
- in jets+MET+1-lepton final states, (1 *b-jet*) for stop search using 1.03 fb^{-1} of data
  - ATLAS Collaboration, ATLAS-CONF-2011-130 (2011).

→ update of analysis at 2010, integrated luminosity of 35 pb^{-1}.

- ATLAS Collaboration, "Search for supersymmetry in *ppcollisions at sqrt(s)=7 TeV in final states with missing transverse momentum and b-jets", Physics Letters B Volume 701, Issue 4, July 2011, p.398-416*

Object identifications

Common tools and requirements for 'good events' are used

Primary vertex
- At least 1 good vertex with $N_{tracks}>4$

Jets
- anti-k_T, R=0.4
- $p_T > 20$ GeV, $|\eta|$ up to 2.8
- Reject events compatible with noise or cosmics

B-Jets
- $p_T > 50$ GeV
- Secondary vertex-based tagger with 50% b-tagging efficiency for MET+jets channel
- secondary vertex / impact parameter combined tagger with 60% b-tagging efficiency for 1-lepton tagger

Electrons
- $p_T > 20$ GeV, $|\eta|<2.47$
- If $\Delta R(jet,e)<0.2$, remove jet
- If $0.2<\Delta R(jet,e)<0.4$, veto electron

Muons
- $p_T > 20$ GeV (10 GeV for veto), $|\eta|<2.4$
- combined/extrapolated info from ID and Muon spectrometer
- Sum p_T of tracks <1.8 GeV in $\Delta R<0.2$
- if $\Delta R(jet,\mu)<0.4$, veto muon

Missing E_T
- Calculated from the vector sum of reconstructed jets with $p_T>20$ GeV, $|\eta|<4.5$, leptons and calorimeter clusters not belonging to reconstructed objects

Discriminating variables

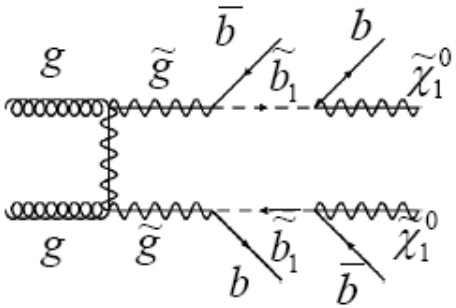
- ***m_{eff}***: scalar sum of the Etmiss and up to
  - 3 leading jet pT (*0-lepton*)
  - 4 leading jet pT and identified lepton pT (*1-lepton*)

$$H_T = \sum_{i=1}^{3(4)} p_T^{jet_i} (+p_T^l) \qquad m_{eff} = H_T + E_T^{Miss}$$

- ***m_T***: missing transverse mass calculated from the lepton and missing transverse energy (*1-lepton*)

$$m_{\mathrm{T}} = \sqrt{2(p_{\mathrm{T}}^{\mathrm{lepton}} E_{\mathrm{T}}^{\mathrm{miss}} - \vec{p}_{\mathrm{T}}^{\mathrm{lepton}} \cdot \vec{E}_{\mathrm{T}}^{\mathrm{miss}})}$$

Search in jets+MET (+b-jets)



Target → gluino-mediated ~b production

- At least 4 b-jets expected (+MET)

Event selection:

- Lepton-veto with p_T>20 GeV(*e*), 10 GeV(μ)
- Jet p_T>130,50,50 GeV
- MET>130 GeV

Trigger-driven selections

- **$\Delta\varphi_{min}$**, minimum Δφ between any of 3 leading jets and MET, >0.4 rad
- **MET/m_{eff}**>0.25

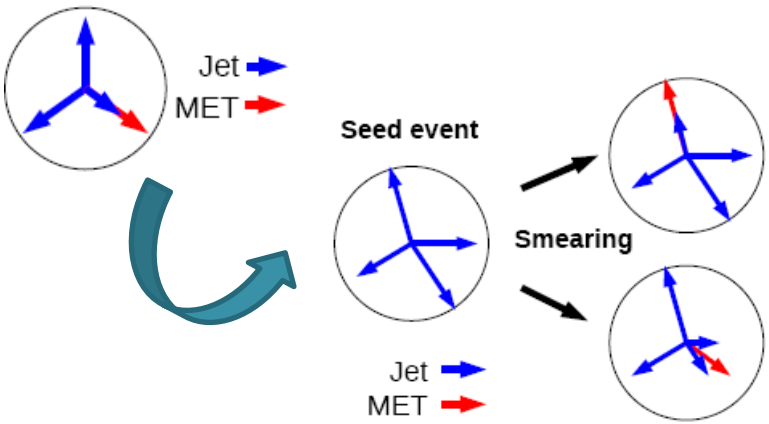
QCD-multijet background rejection

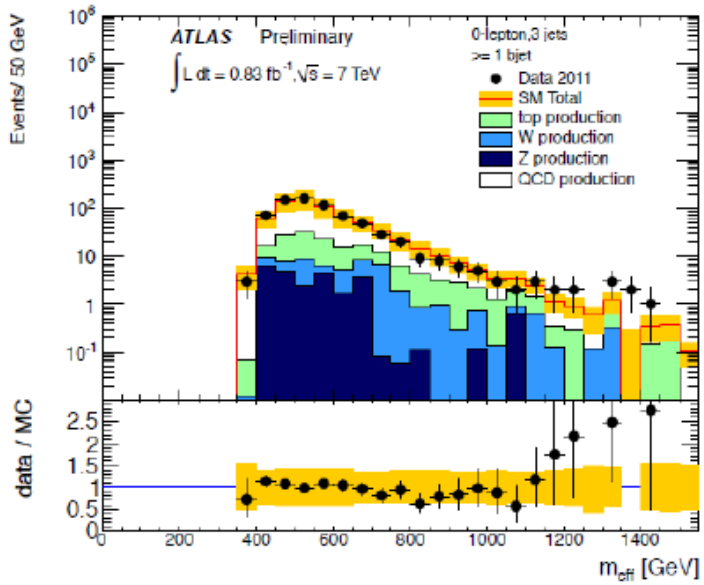
- Define **4-signal regions**
  - 3JA (>=1 *b-jet*, m_{eff}> 500 GeV)
  - 3JB (>=1 *b-jet*, m_{eff}> 700 GeV)
  - 3JC (>=2 *b-jets*, m_{eff}> 500 GeV)
  - 3JD (>=2 *b-jets*, m_{eff}> 700 GeV)

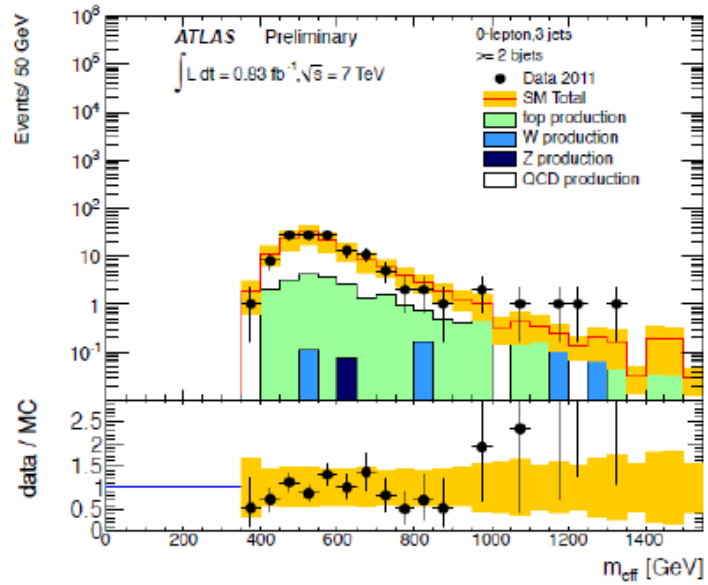
designed to enhance sensitivity in different scenarios:
- low/high DM(g-b)
- low/high DM(g-LSP)

QCD-multijet background

- Smear p_T of jets in data events with no MET to create sample of pseudo-events with large fake MET ***(Jet Smearing Method)***
- Normalize pseudo-events to data in QCD-enriched control-region (reversal of $\Delta\phi_{min}$ cut).







Validated by checking Meff distributions for SM bkg and data in QCD CR

→ 4-5% of total background depending on SR

Non-QCD background estimates

- Dominated by **top pair production**
- MC-driven estimate:
  - ttbar, single top: use MC@NLO+HERWIG
  - W,Z+jets (light/HF): ALPGEN+HERWIG
- **1-lepton control region:**

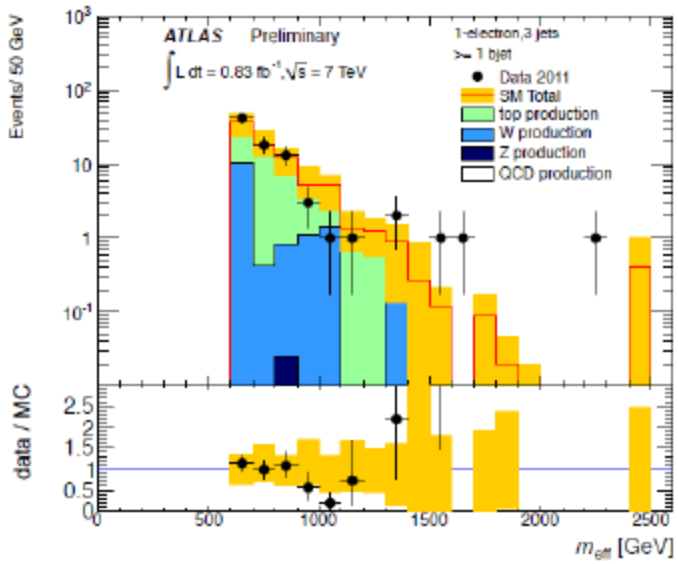
$$N^{SR0L,t\bar{t}} = (N^{CR1}_{data} - N^{CR1,non-t\bar{t}}_{MC})\frac{N^{SR0L,t\bar{t}}_{MC}}{N^{CR1,t\bar{t}}_{MC}}$$

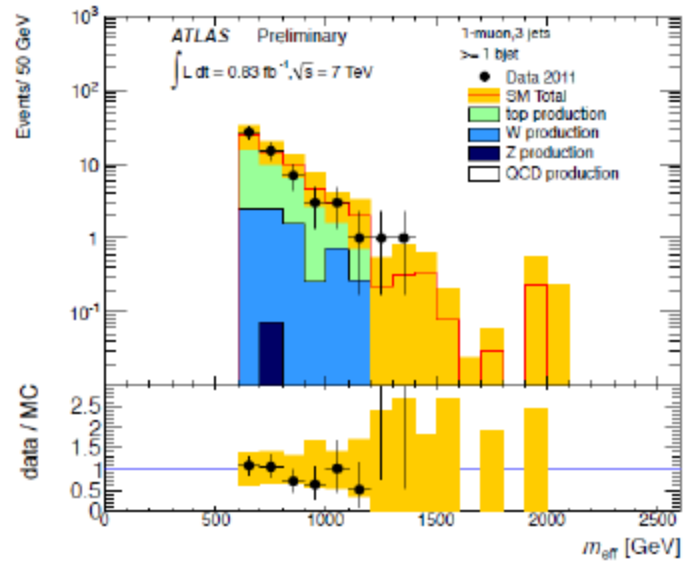
Transfer Factor

validated in control regions

- lepton p_T > 20 GeV
- jet p_T>130,50,50GeV
- 40 GeV < m_T < 100 GeV
- m_{eff} > 600 GeV
- 1 *b*-jet or 2 *b*-jet

l-ele





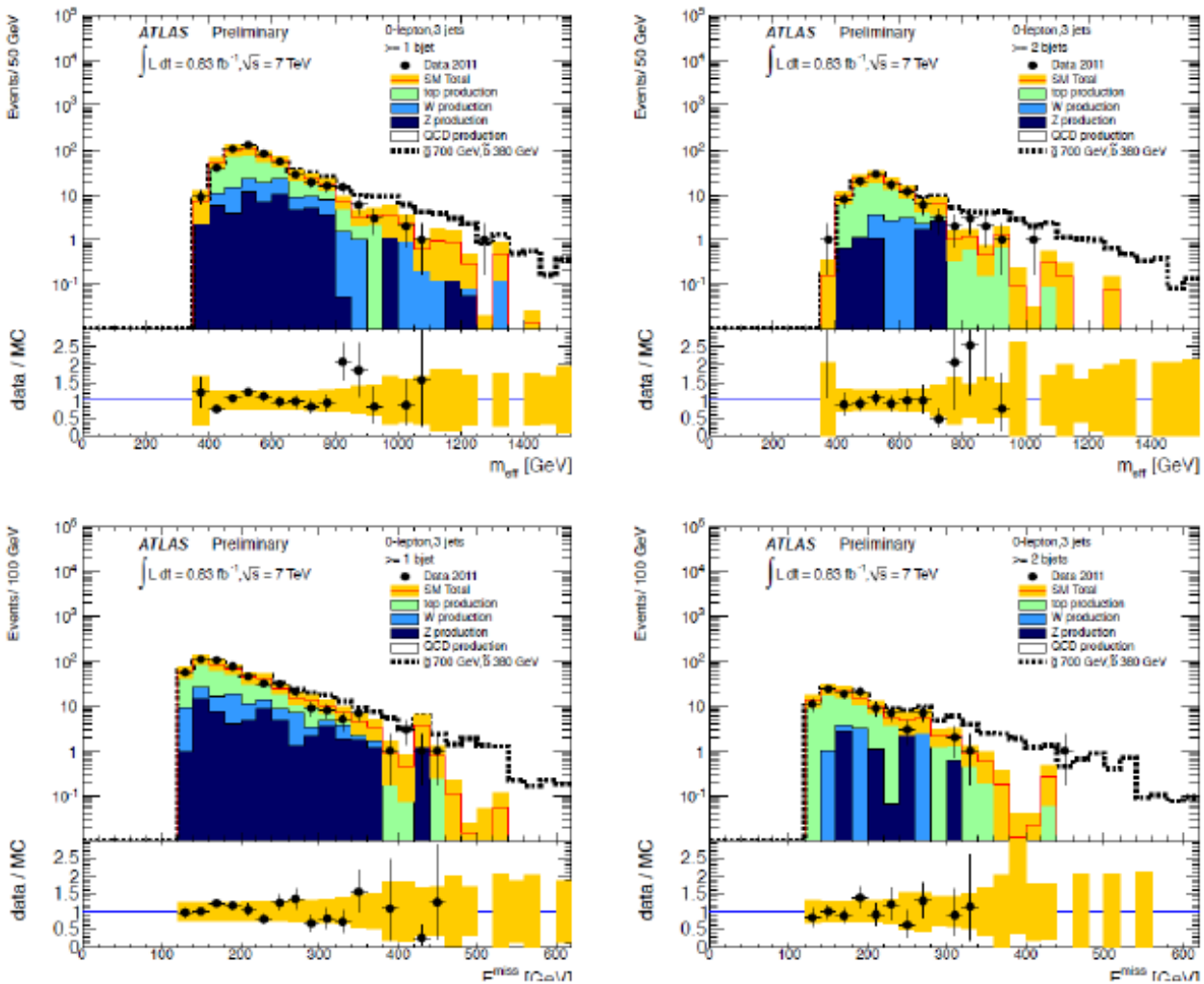
l-muon

Results (I)

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

- **Good agreement between data and SM expectations** within uncertainties
- Systematic uncertainties dominated by:
  - Jet energy scale and resolution
  - B-tagging (especially for 2-btags case)
  - Theoretical uncertainties
    - **Top pair** cross section, ISR/FSR variation, generator dependence, Parton shower and fragmentation models
    - **W/Z+jets:** uncertainties on N jets ($\sqrt{N}\times 24\%$ and HF rescale
    - **SUSY signals**: renormalization/factorization scale (20-30%), PDF(10-20%)

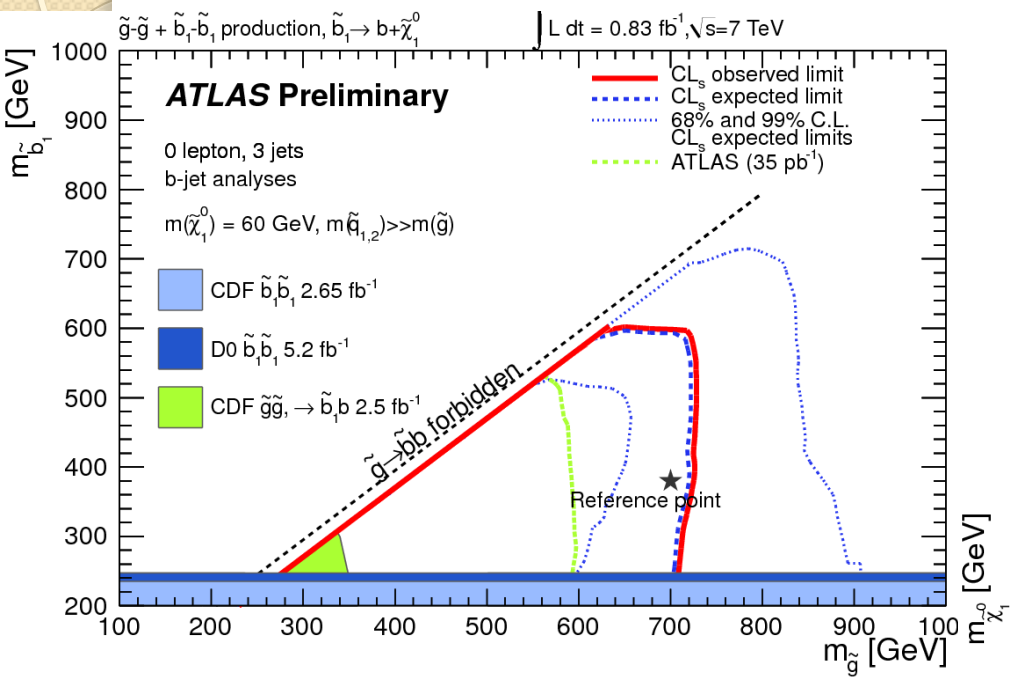
Results (II)



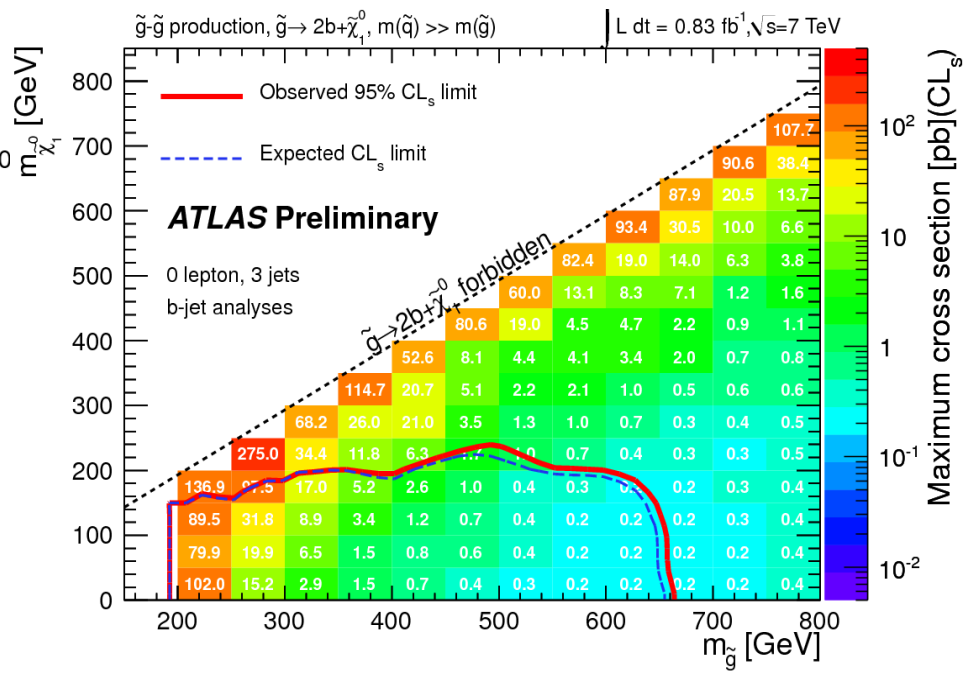
- Results translated as model-independent exclusion limits
  - in N events and σ

95% C.L. N events CL_s (PCL)		95% C.L. σ_{eff}(pb) CL_s (PCL)
3JA	240 (206)	0.288 (0.247)
3JB	51 (40)	0.061 (0.048)
3JC	65 (53)	0.078 (0.064)
3JD	14 (11)	0.017 (0.014)

Interpretation of the results (I)



- Two phenomenological interpretations
  - Gluino-sbottom decays on-shell or off-shell, sbottom in b+LSP in both cases
- **m(gl)>720(660) GeV** excluded depending on gluino – sbottom - neutralino mass hierarchy



Upper cross section limits also provided in case of simplified models

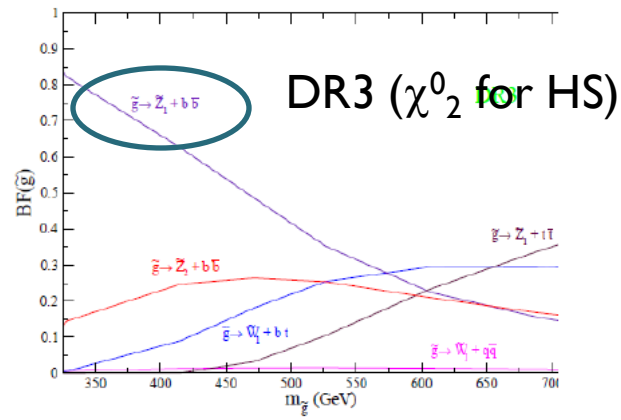
Interpretation of the results (II)

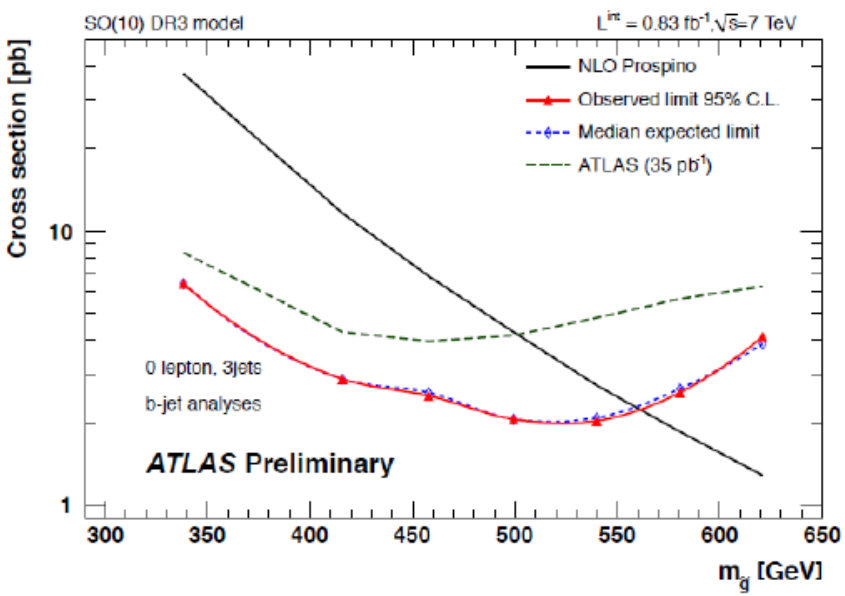
- Interpretation in GUT based on the gauge group SO(10), D-term splitting model, DR3 and Higgs splitting model, HS

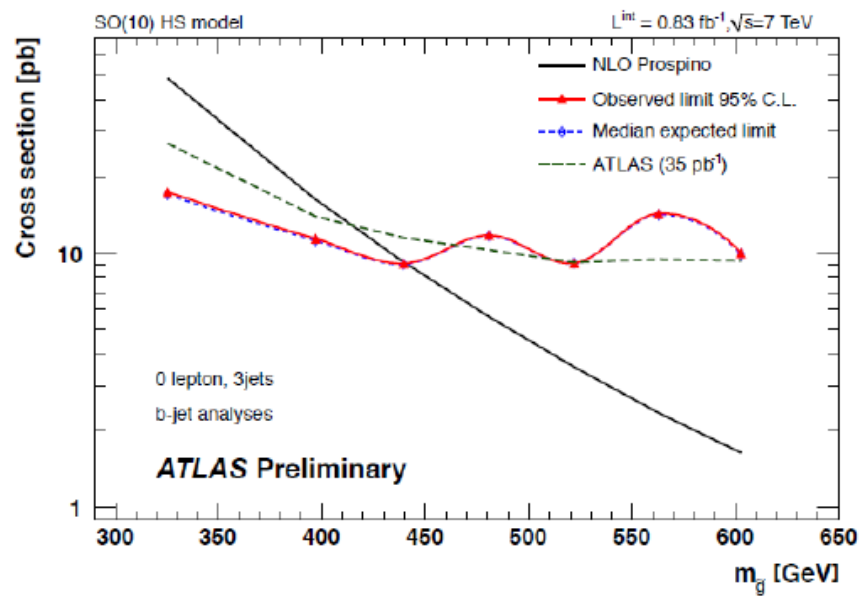
  (H. Baer, S. Kraml, A. Lessa, S. Sekmen, JHEP 1002 (2010) 055)

  - In these models, squarks (~10 TeV) much heavier than gluino.
  - Third generation squarks (~1 TeV), gluino 3-body decay to *bb+LSP/NLSP is enhanced.*

Theoretical BR





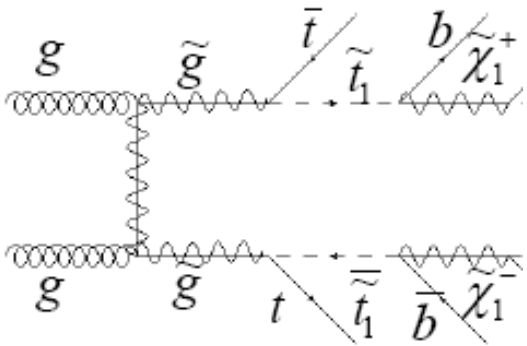


Search in jets+MET+1-lepton (b-jets)

Target → gluino-mediated ~t production

- At least 2 tops and b-jets expected, or 4 tops

$$\tilde{t}_1 \rightarrow b + \tilde{\chi}_1^{\pm} \quad \text{or} \quad \tilde{t}_1 \rightarrow t + \tilde{\chi}_1^{0}$$



Event selection:

- Exactly one lepton (electron or muon):
  - Electron: p_T>25 GeV, track isolation
  - Muon : p_T>20 GeV, track isolation

  } Trigger-driven selections
- 4 Jets with p_T>50 GeV
- MET > 80 GeV
- At least 1 b-jet

Signal region:

m_T>100 GeV and m_{eff}>600 GeV

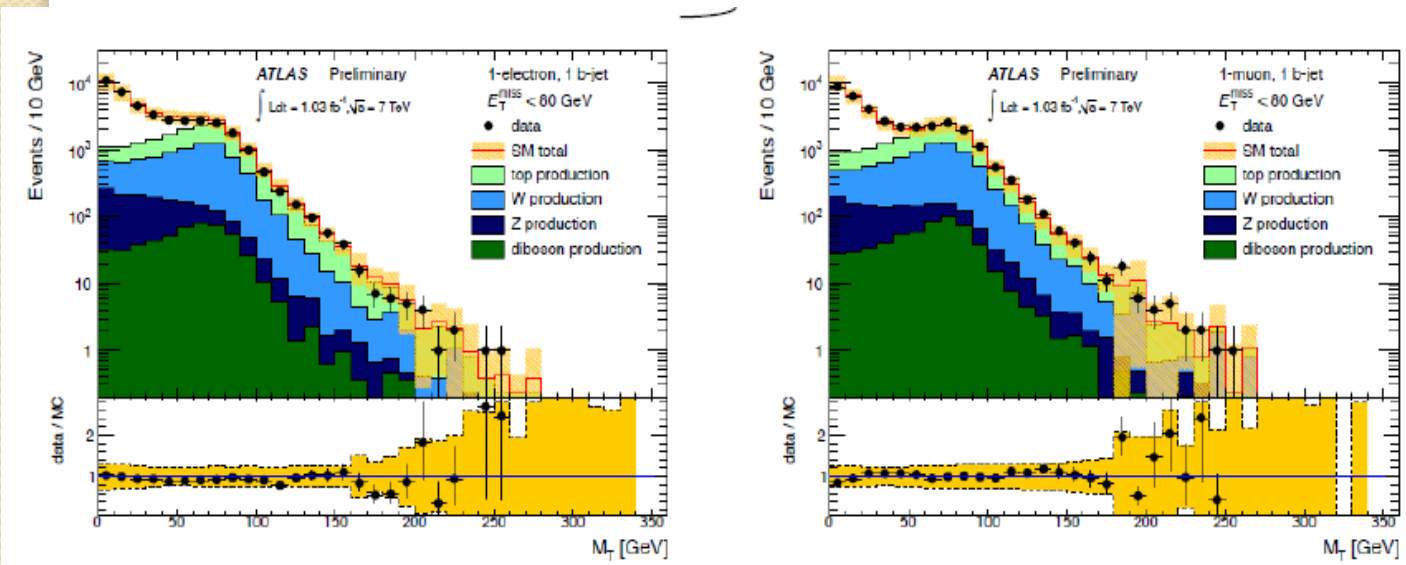
QCD-multijet background

- QCD multi-jet data-driven estimation
  - So-called Matrix Method : decompose "*loose*" and "*tight*" selected leptons into real (EW) and fake (QCD).

$$N^{\text{loose}} = N^{\text{loose}}_{\text{real}} + N^{\text{loose}}_{\text{fake}}$$

$$N^{\text{tight}} = \varepsilon_{\text{real}} N^{\text{loose}}_{\text{real}} + \varepsilon_{\text{fake}} N^{\text{tight}}_{\text{fake}}$$

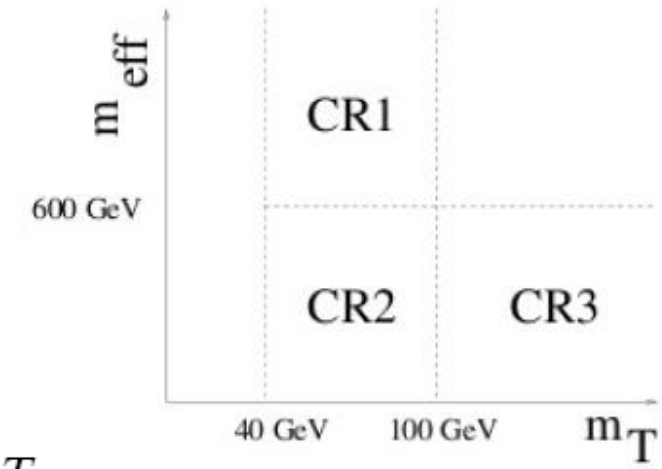
$$N^{\text{tight}}_{\text{fake}} = \frac{\varepsilon_{\text{real}}}{\varepsilon_{\text{real}} - \varepsilon_{\text{fake}}} (\varepsilon_{\text{real}} N^{\text{loose}} + N^{\text{tight}})$$



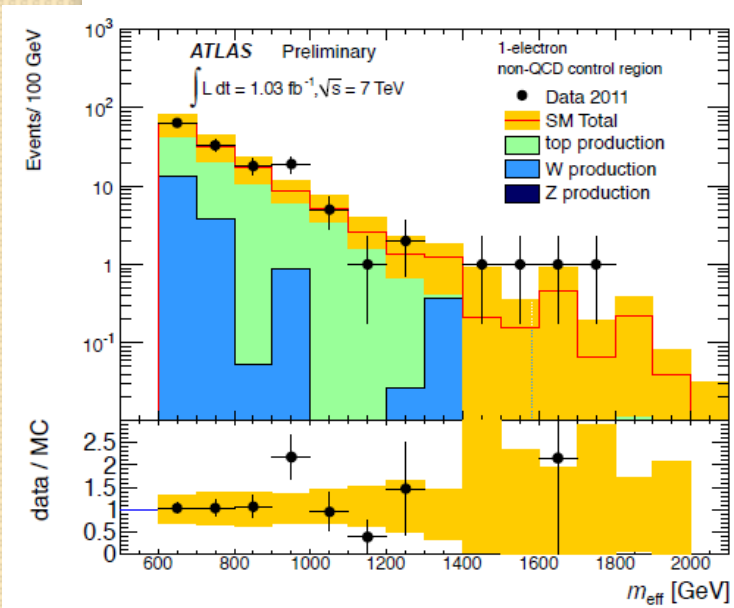
m_T distributions for QCD control region

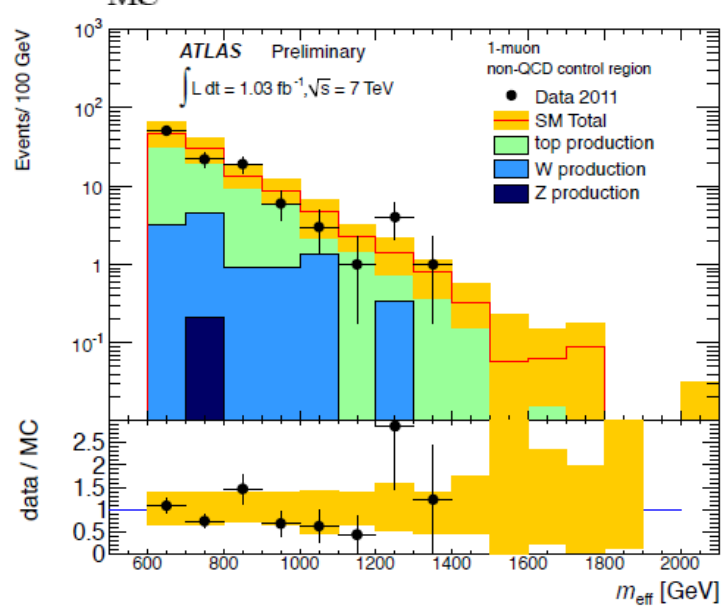
Non-QCD background

- ttbar and single top estimated using a semi-data-driven estimation
- Define m_T vs m_{eff} plane
  - Obtain Transfer Factor (T) in control region (CR) defined by 40 GeV < m_T< 100 GeV and m_{eff}> 600 GeV.



$$N_{\text{data}}^{\text{SR}} = N_{\text{data}}^{\text{CR}} \frac{N_{\text{MC}}^{\text{SR}}}{N_{\text{MC}}^{\text{CR}}} = N_{\text{data}}^{\text{CR}} T_{\text{MC}}$$





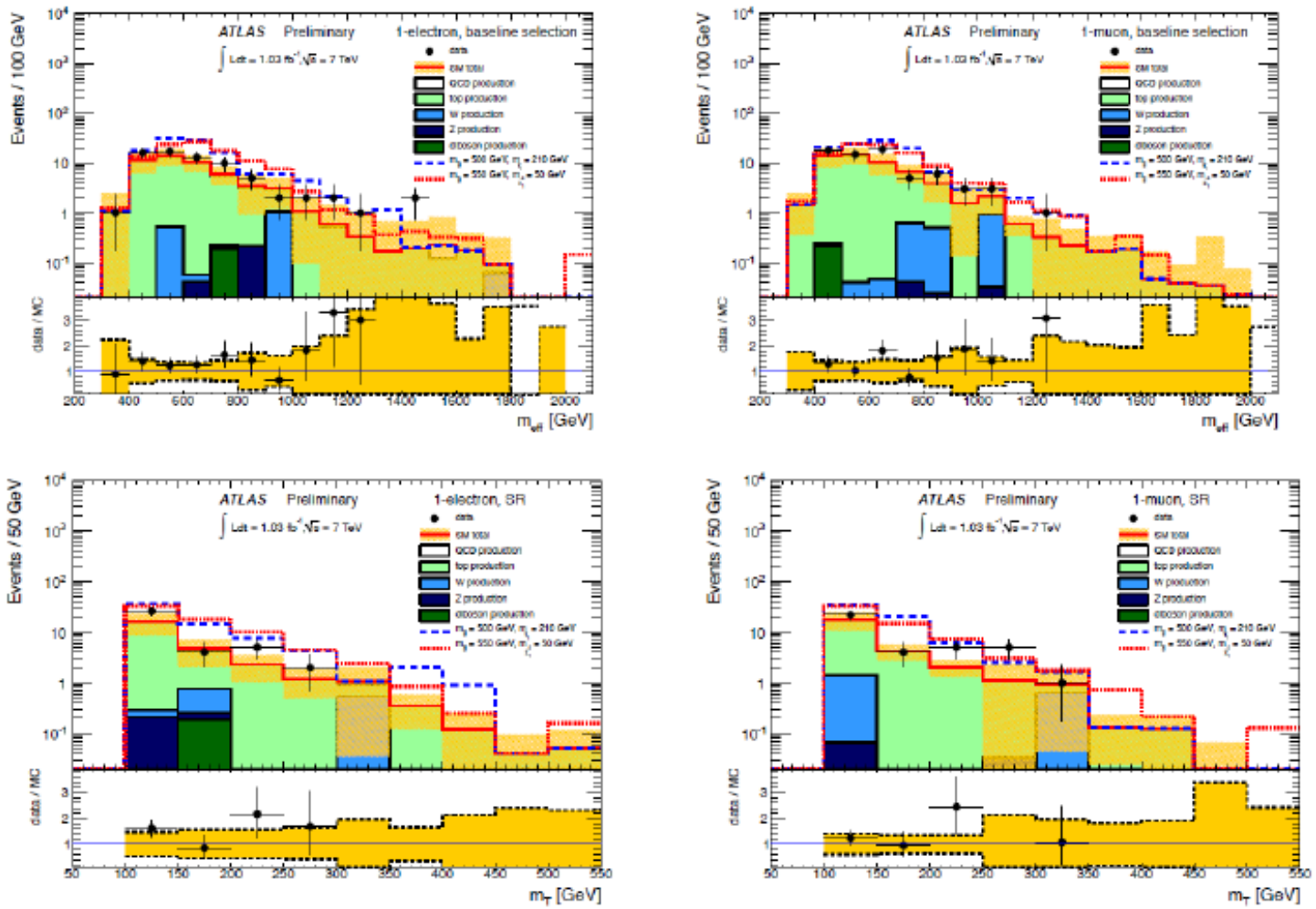
Good agreement in other CR verified as further cross check

Results (I)

Cuts	≥ 4 jets	≥ 1 b jet	$E_T^{miss} > 80$ GeV	$m_T > 100$ GeV	$m_{eff} > 600$ GeV
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

- Systematic uncertainties dominated by:
  - Jet energy scale and resolution and b-tagging
  - Theoretical uncertainties (partially reduced by semi-data driven method)
  - **SUSY signals**: renormalization/factorization scale (20-30%), PDF(10-20%)

Results (II)



Model independent upper cross section limits:

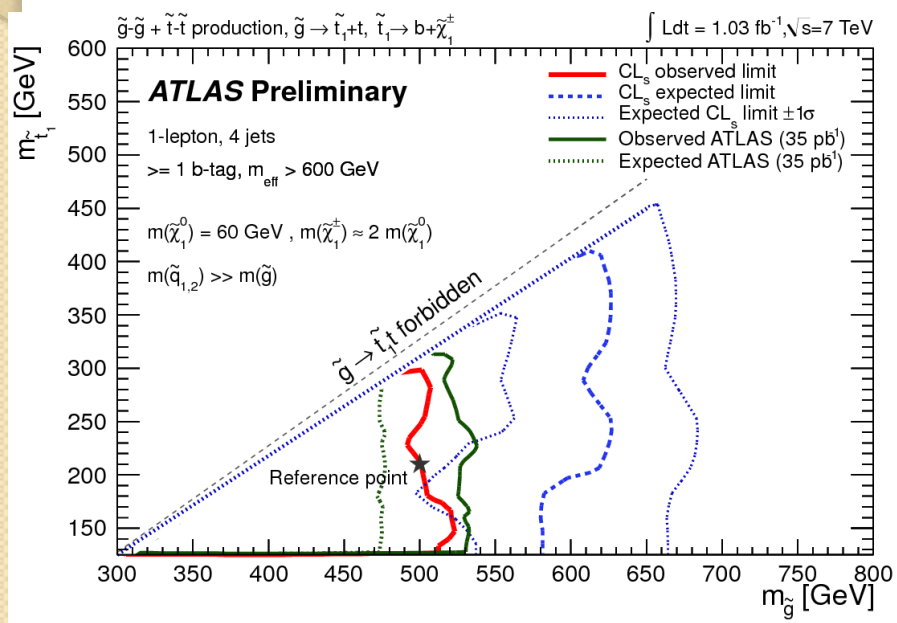
Exp: 31 fb
Obs: 46 fb

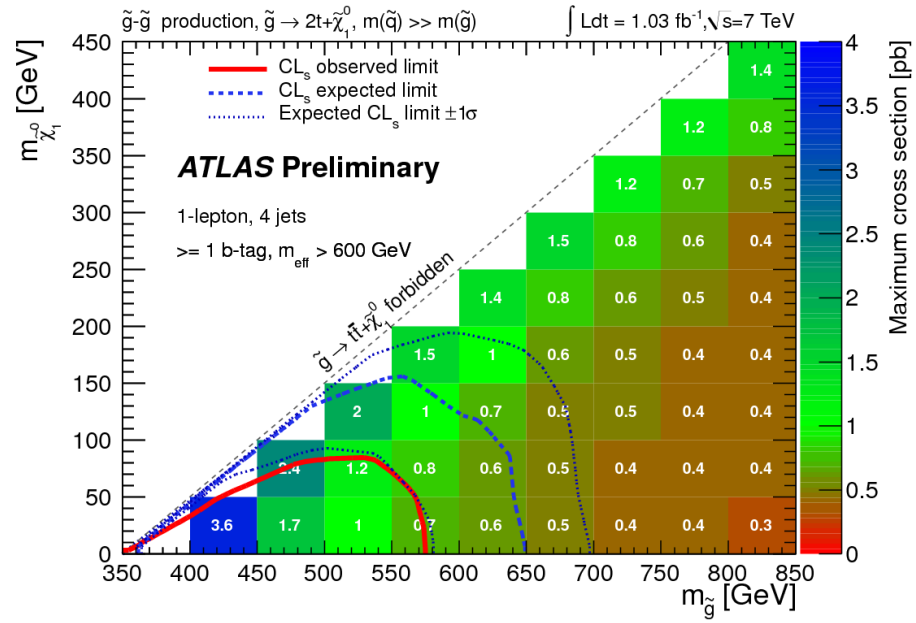
Interpretation of the results

- Two phenomenological interpretations depending on mass hierarchy and stop decay mode

$\tilde{t}_1 \to b + \tilde{\chi}_1^{\pm}$

$\tilde{t}_1 \to t + \tilde{\chi}_1^{0}$





gluino-stop plane: m(~g)>m(~t1).
Lightest neutralino mass → 60 GeV,
m(chargino) ~ 2 * m(neut)

gluino masses below 520 GeV is excluded @ 95% CL.

gluino masses below 570 GeV (and up to LSP mass 40 GeV) excluded @ 95% CL.

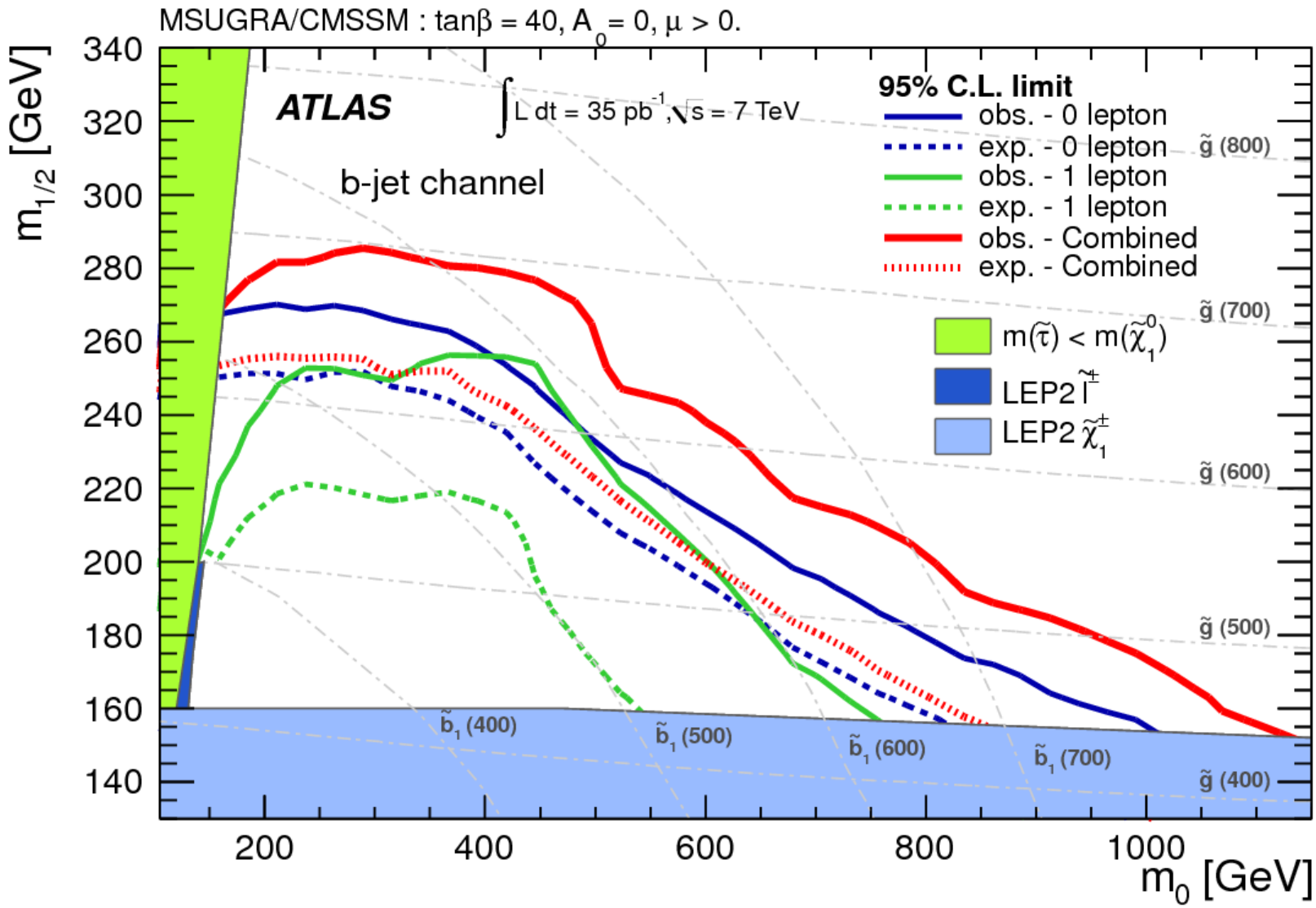
Conclusions

- Updates on the search for supersymmetry in final states with missing transverse momentum, *b-jet and 0/1-lepton are presented.*
  - In the *pp collision of 7 TeV at LHC with the ATLAS detector, integrated luminosity of 0.83 fb-1/1.03 fb-1*
- The results are used to set limits on the models of gluino-sbottom or gluino-stop cascade decay.
  - In sbottom case, gluino masses below 720 GeV are excluded at 95% CL.
  - In stop case, gluino masses below 570 GeV for LSP masses below 40GeV are excluded at 95% CL.

- Updates with 2 / 5 fb-1 in preparation
- Analyses targeting direct sbottom/stop pair production will follow soon → stay tuned for more results !

Back-up

mSUGRA interpretation (35 pb^{-1})



mSUGRA interpretation (35 pb^{-1})