

# Search for SUSY in the jets plus missing transverse energy channel with zero and one lepton in ATLAS

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Bundesministerium  
für Bildung  
und Forschung



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# Introduction

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- Dominant SUSY production channels at LHC:  
*squark/squark, gluino/gluino, squark/gluino*
- Will decay in cascades to jets and charginos/neutralinos
- If R-parity is conserved:  
Lightest SUSY particle (LSP) is stable and escapes detection
- A typical SUSY signature: Jets (+ leptons) + missing energy
- Results presented with 2010 7TeV data:  $35\text{pb}^{-1}$
- Focusing on two recently performed ATLAS SUSY searches

## 0-lepton search:

squark / gluino decaying to

$$\tilde{q} \rightarrow q\tilde{\chi}_1^0 \quad \tilde{g} \rightarrow qq\tilde{\chi}_1^0$$

## 1-lepton search:

In decay chains with charginos

$\tilde{q}_L \rightarrow q\tilde{\chi}^\pm$ ,  $\tilde{g} \rightarrow q\bar{q}'\tilde{\chi}^\pm$  chargino decays to the LSP can produce high momentum leptons

# 0-Lepton Channel

arXiv:1102.5290 [hep-ex] (submitted to PLB)

- Veto events with one or more electrons or muons with  $p_T > 10 \text{ GeV}$  (exclusive wrt. 1-lepton channel)
- Define 4 inclusive signal regions to obtain improved coverage of the  $m_{\text{squark}} - m_{\text{gluino}}$  plane

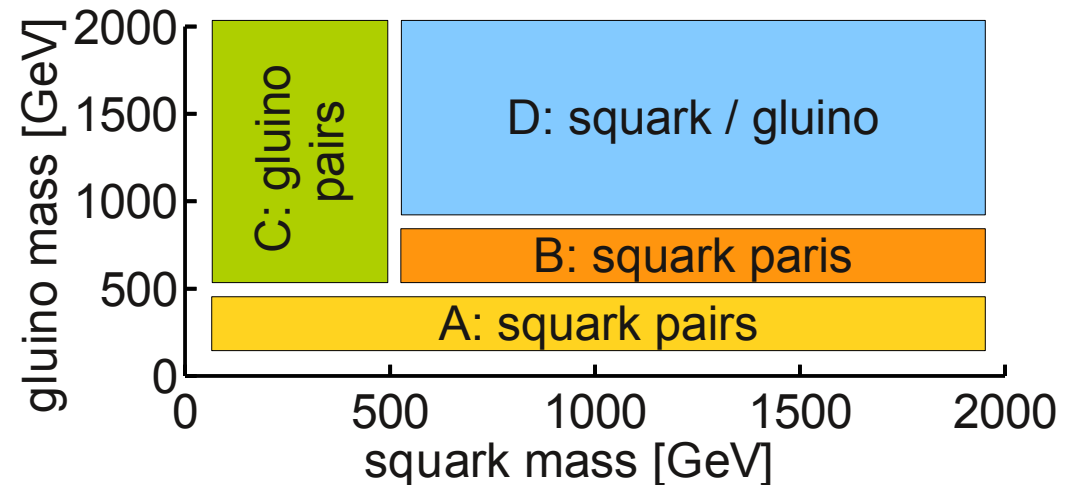
## Signal regions:

		A	B	C	D
Pre-selection	Number of required jets	$\geq 2$	$\geq 2$	$\geq 3$	$\geq 3$
	Leading jet $p_T$ [GeV]	$> 120$	$> 120$	$> 120$	$> 120$
	Other jet(s) $p_T$ [GeV]	$> 40$	$> 40$	$> 40$	$> 40$
	$E_T^{\text{miss}}$ [GeV]	$> 100$	$> 100$	$> 100$	$> 100$
Final selection	$\Delta\phi(\text{jet}, \vec{P}_T^{\text{miss}})_{\text{min}}$	$> 0.4$	$> 0.4$	$> 0.4$	$> 0.4$
	$E_T^{\text{miss}} / m_{\text{eff}}$	$> 0.3$	–	$> 0.25$	$> 0.25$
	$m_{\text{eff}}$ [GeV]	$> 500$	–	$> 500$	$> 1000$
	$m_{T2}$ [GeV]	–	$> 300$	–	–

$m_{\text{eff}}$ : scalar sum of  $E_T^{\text{miss}}$  and  $p_T$  of selected 2 or 3 jets

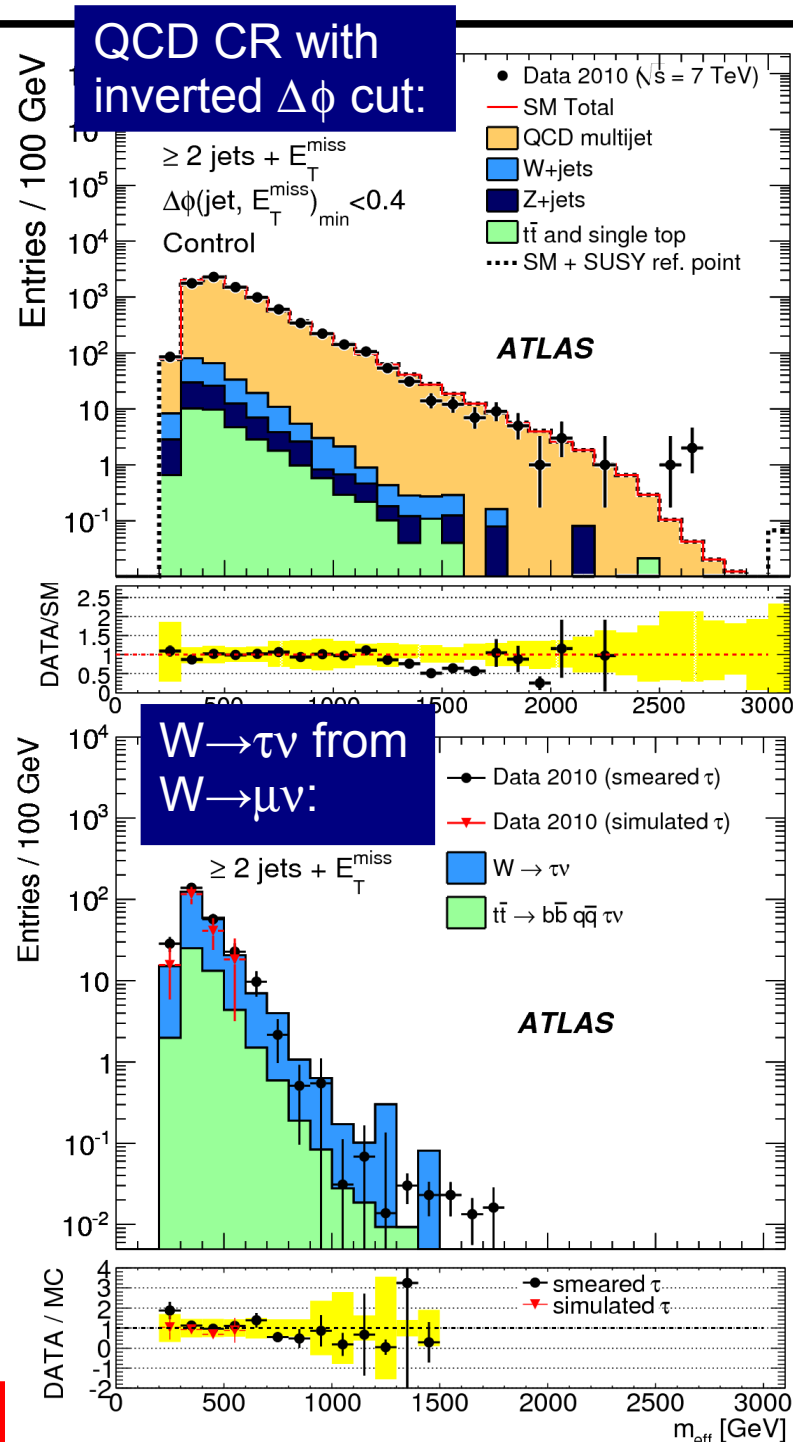
$m_{T2}$ : maximal lower bound on the mass of a pair produced particle which decays into one of the pre-selected jets and a massless undetected particle

## Expected coverage of signal regions:



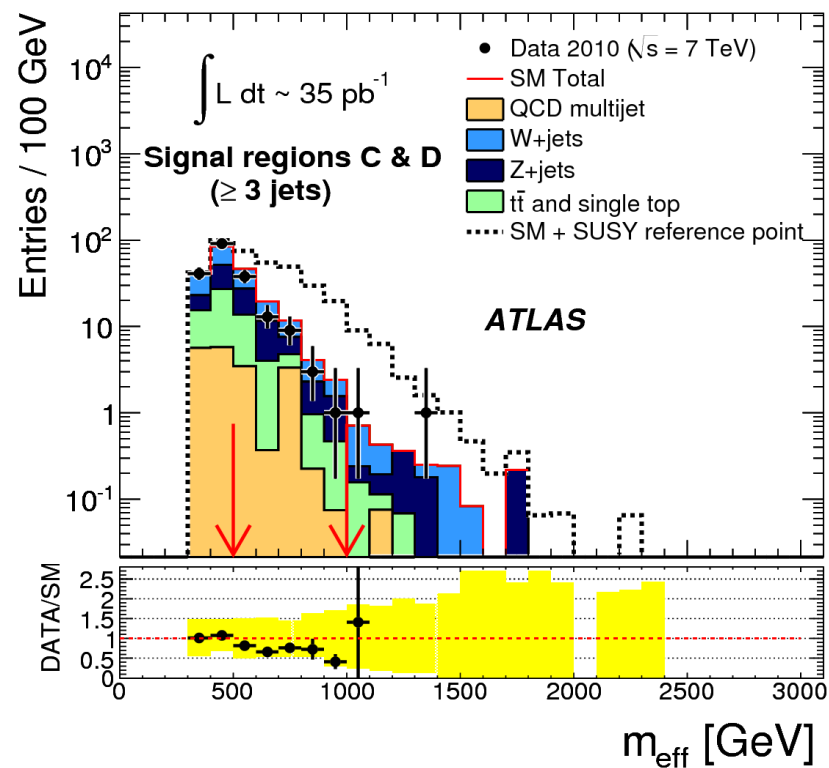
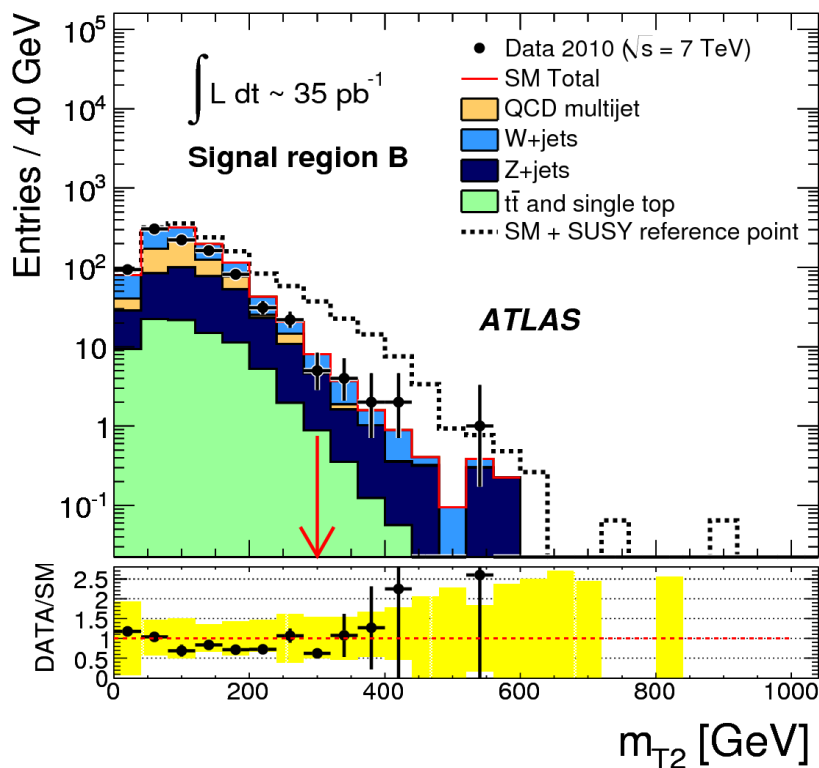
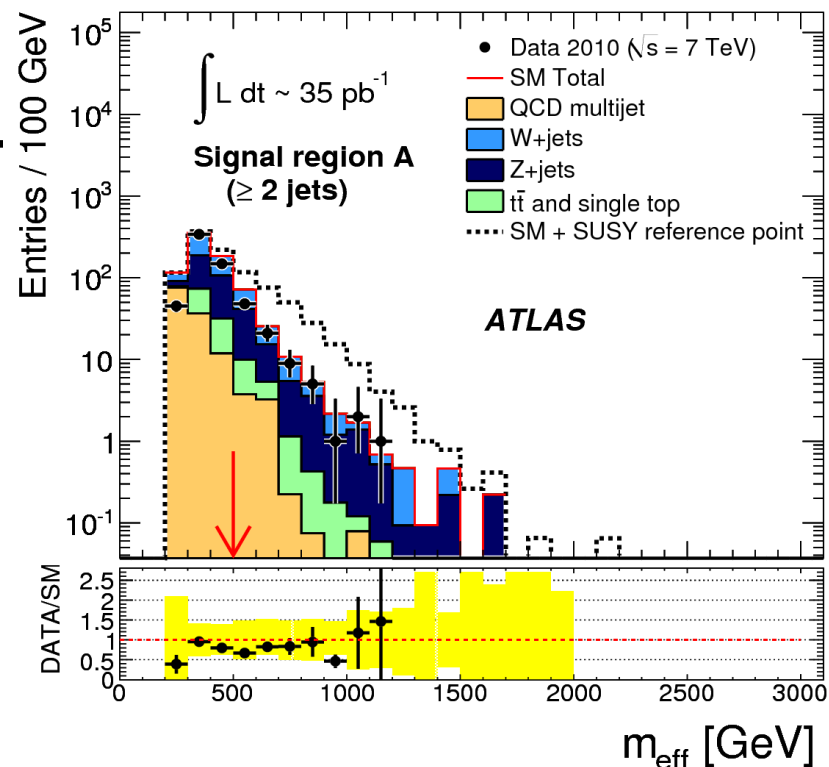
# 0-Lepton Channel: Background Estimation

- Backgrounds checked in several control regions (CR):
  - ◻ **Z+jets:** irreducible  $Z \rightarrow \nu\nu$ , control measurements with  $Z \rightarrow ee$ ,  $Z \rightarrow \mu\mu$ ,  $W \rightarrow e\nu$ ,  $W \rightarrow \mu\nu$
  - ◻ **W+jets:** dominated by  $W \rightarrow \tau\nu$  control measurements with  $W \rightarrow e\nu$ ,  $W \rightarrow \mu\nu$  and data via tau embedding
  - ◻ **QCD multi-jets:** control region with inverted  $\Delta\phi$  or  $E_T^{\text{miss}}/m_{\text{eff}}$  cuts, fully data-driven by measuring detector response
  - ◻ **Top-pairs:** minor background
- Found good agreement of MC with data for W/Z+jets and top pairs  $\rightarrow$  using MC for background prediction in signal region
- QCD MC rescaled to data in CR
- Uncertainties in signal region estimated from control measurements



# 0-Lepton Channel

- Distributions in the signal region
- SUSY reference point:  
 mSUGRA with  $m_0=200\text{GeV}$ ,  
 $m_{1/2}=190\text{GeV}$ ,  $A_0=0$ ,  $\tan\beta=3$ ,  $\mu>0$



# 0-Lepton Channel: Results

arXiv:1102.5290 [hep-ex] (submitted to PLB)

- Background model found to be in good agreement with data in all signal regions
- Main systematics:  
jet energy scale/resolution (7%), luminosity (11%), MC modeling, lepton eff., extrapolation CR→SR, MC statistics

Excludes non-SM cross-section \* acceptance \* efficiency at 95% CL:

Signal region A: 1.3 pb  
Signal region B: 0.35 pb  
Signal region C: 1.1 pb  
Signal region D: 0.11 pb

# events in signal region:

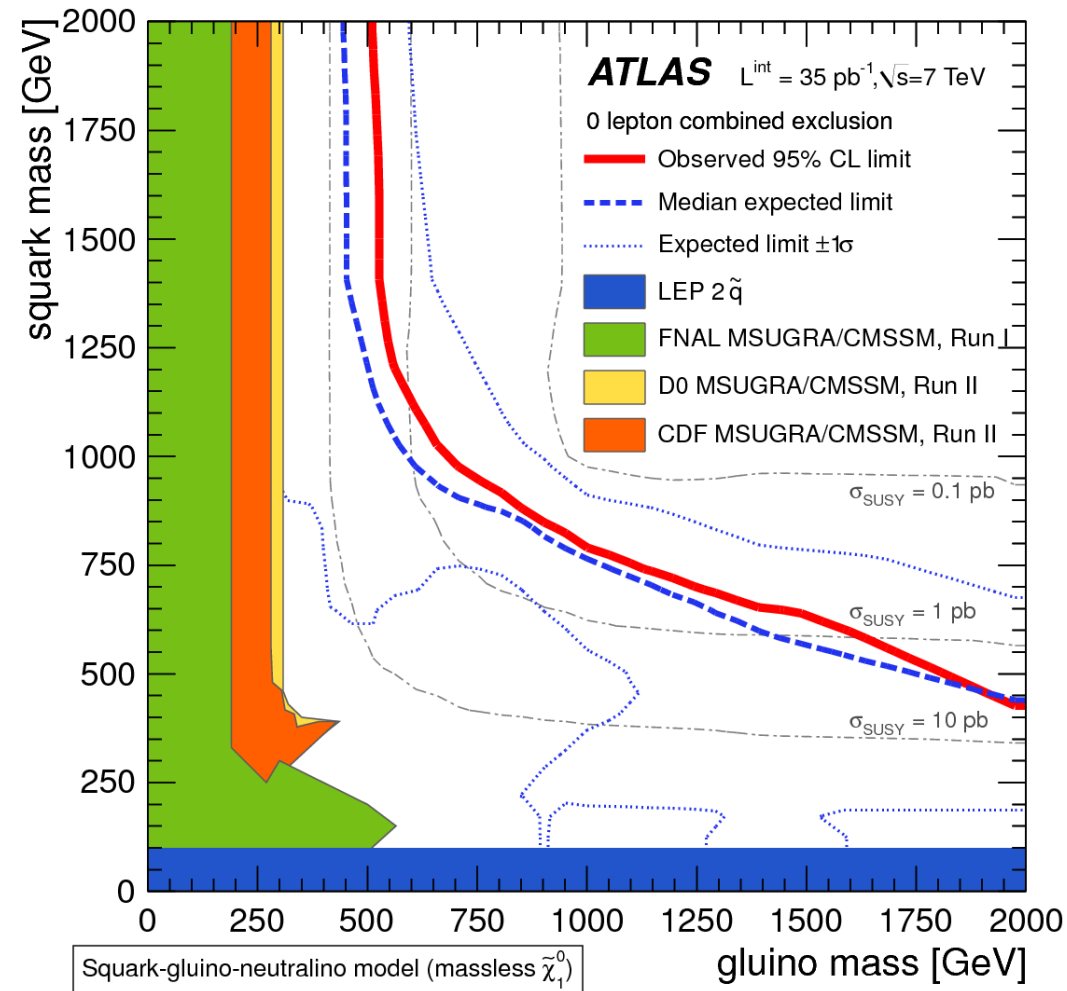
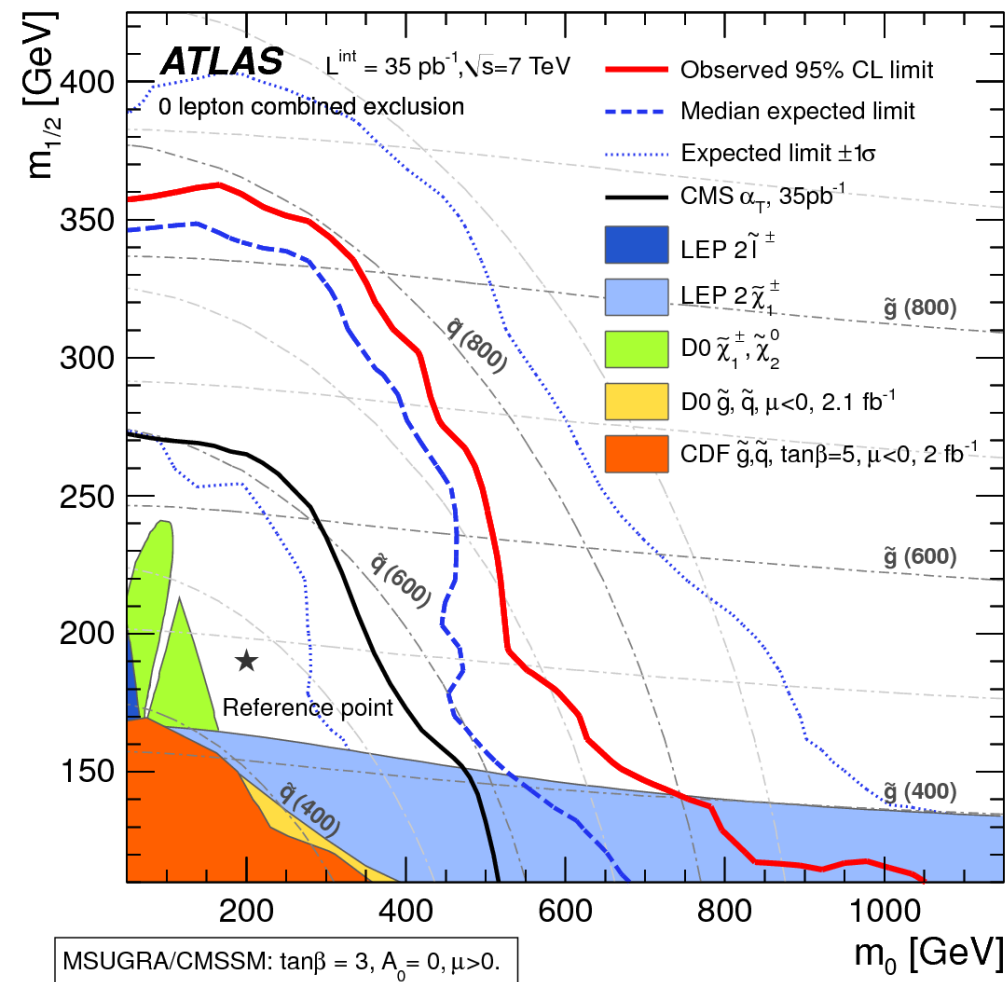
	Signal region A	Signal region B	Signal region C	Signal region D
QCD	$7^{+8}_{-7}[\text{u+j}]$	$0.6^{+0.7}_{-0.6}[\text{u+j}]$	$9^{+10}_{-9}[\text{u+j}]$	$0.2^{+0.4}_{-0.2}[\text{u+j}]$
W+jets	$50 \pm 11[\text{u}]^{+14}_{-10}[\text{j}] \pm 5[\mathcal{L}]$	$4.4 \pm 3.2[\text{u}]^{+1.5}_{-0.8}[\text{j}] \pm 0.5[\mathcal{L}]$	$35 \pm 9[\text{u}]^{+10}_{-8}[\text{j}] \pm 4[\mathcal{L}]$	$1.1 \pm 0.7[\text{u}]^{+0.2}_{-0.3}[\text{j}] \pm 0.1[\mathcal{L}]$
Z+jets	$52 \pm 21[\text{u}]^{+15}_{-11}[\text{j}] \pm 6[\mathcal{L}]$	$4.1 \pm 2.9[\text{u}]^{+2.1}_{-0.8}[\text{j}] \pm 0.5[\mathcal{L}]$	$27 \pm 12[\text{u}]^{+10}_{-6}[\text{j}] \pm 3[\mathcal{L}]$	$0.8 \pm 0.7[\text{u}]^{+0.6}_{-0.0}[\text{j}] \pm 0.1[\mathcal{L}]$
$t\bar{t}$ and $t$	$10 \pm 0[\text{u}]^{+3}_{-2}[\text{j}] \pm 1[\mathcal{L}]$	$0.9 \pm 0.1[\text{u}]^{+0.4}_{-0.3}[\text{j}] \pm 0.1[\mathcal{L}]$	$17 \pm 1[\text{u}]^{+6}_{-4}[\text{j}] \pm 2[\mathcal{L}]$	$0.3 \pm 0.1[\text{u}]^{+0.2}_{-0.1}[\text{j}] \pm 0.0[\mathcal{L}]$
Total SM	$118 \pm 25[\text{u}]^{+32}_{-23}[\text{j}] \pm 12[\mathcal{L}]$	$10.0 \pm 4.3[\text{u}]^{+4.0}_{-1.9}[\text{j}] \pm 1.0[\mathcal{L}]$	$88 \pm 18[\text{u}]^{+26}_{-18}[\text{j}] \pm 9[\mathcal{L}]$	$2.5 \pm 1.0[\text{u}]^{+1.0}_{-0.4}[\text{j}] \pm 0.2[\mathcal{L}]$
Data	87	11	66	2

[u]: uncorrelated errors like MC/CR statistics + jet energy resolution + lepton efficiencies  
[j]: jet energy scale [L]: luminosity

# 0-Lepton Channel: Results

arXiv:1102.5290 [hep-ex] (submitted to PLB)

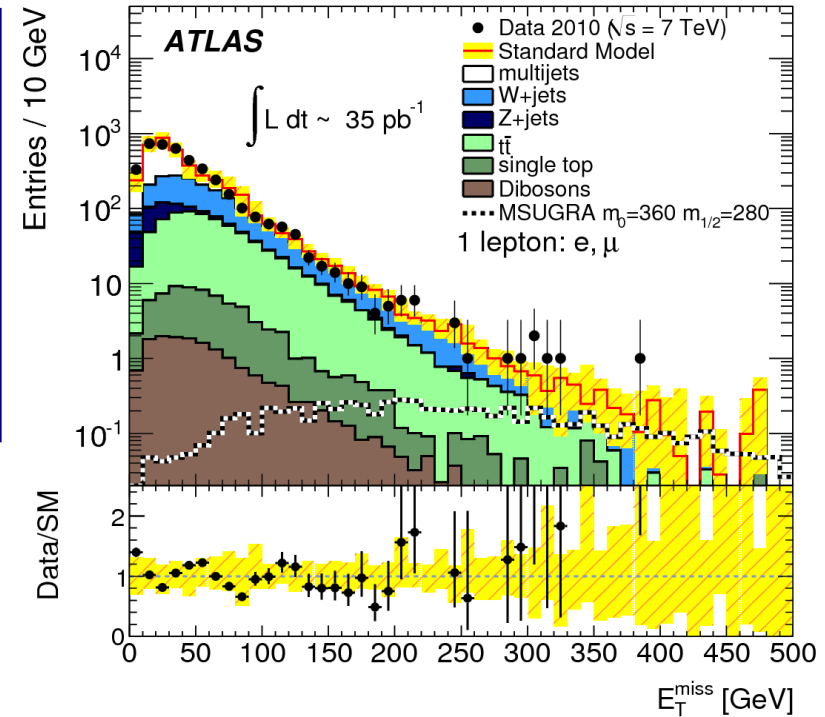
- Profile likelihood ratio test and toy experiments to obtain 95% CL exclusion limits
- Choose signal region with highest expected sensitivity



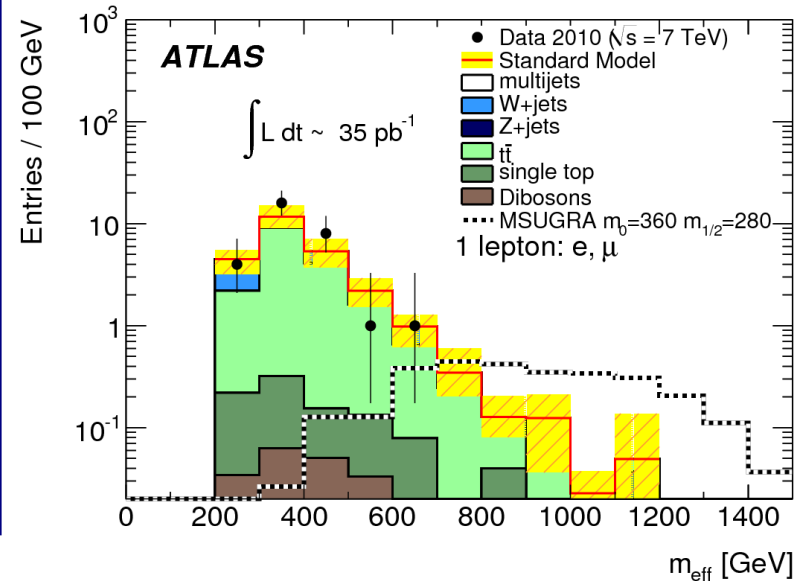
# 1-Lepton Channel

- Select event with:
  - ◻ 1 electron or muon with  $p_T > 20 \text{ GeV}$
  - ◻ 3 jets with  $p_T > 60/30/30 \text{ GeV}$
  - ◻  $\Delta\phi(\text{jet}, E_T^{\text{miss}}) > 0.2$   
(to reduce fake  $E_T^{\text{miss}}$  from jets)
  - ◻ Transverse mass of lepton and  $E_T^{\text{miss}}$ :  
 $m_T > 100 \text{ GeV}$   
(to suppress W+jets background)
  - ◻ Missing transverse energy:  
 $E_T^{\text{miss}} > 125 \text{ GeV}$  and  $E_T^{\text{miss}} > 0.25 * m_{\text{eff}}$
- Signal selection:
  - ◻ Effective mass (scalar sum of lepton/jets/ $E_T^{\text{miss}}$ ):  $M_{\text{eff}} > 500 \text{ GeV}$

**$E_T^{\text{miss}}$  after lepton/jet selection**



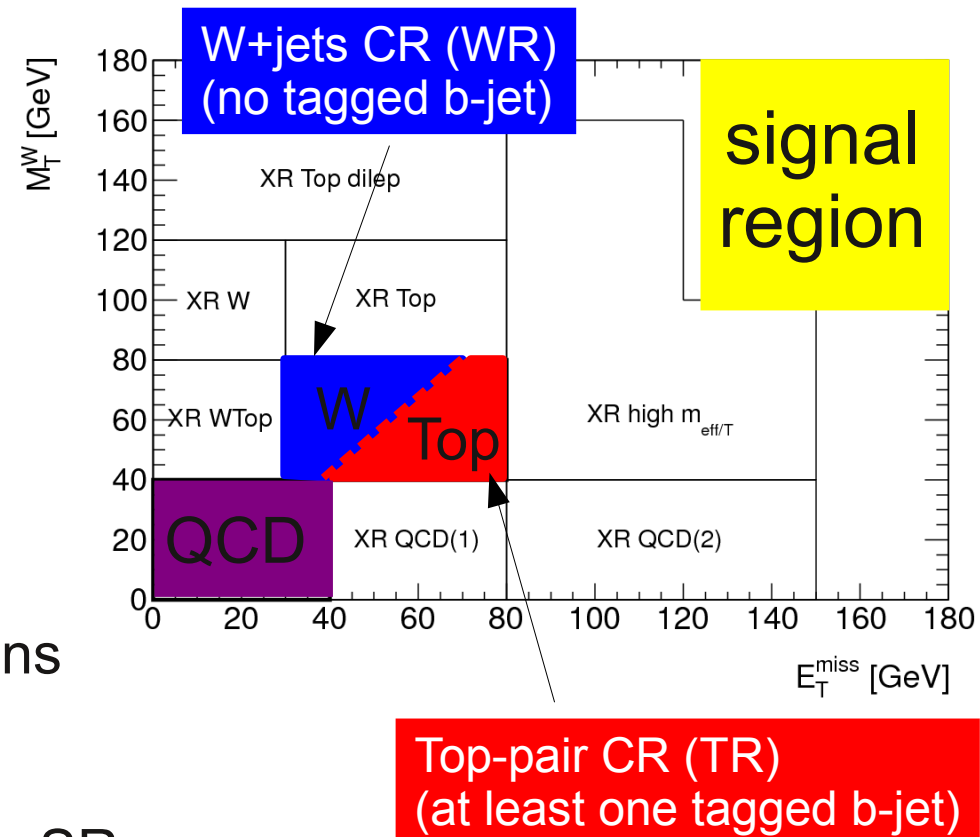
**$m_{\text{eff}}$  after final selection without  $m_{\text{eff}}$  requirement**





# 1-Lepton Channel: Background Estimation

- Main backgrounds:
  - **Top-pair production**  
(decaying both di- and semi-leptonically)
  - **W+jets**
  - **QCD multi-jets**  
(with fake lepton)
- Fit MC to number of data events in background-dominated control-regions to predict events in signal region (SR)
- Relies on simulation for extrapolation to SR
- QCD CR used only to predict QCD in other CRs
- QCD estimate in signal region fully data-driven
- Several cross checks performed with alternative CRs



# 1-Lepton Channel: QCD Background

- Data-driven matrix method to set upper limit on QCD events in SR
- Relies on loose control samples with relaxed lepton isolation criteria

non-QCD events
QCD events

# events in signal region  $\rightarrow N_{tight}^{obs} = N_{tight}^{real} + N_{tight}^{fake}$

$$N_{loose\ not\ tight}^{obs} = \left(1/\epsilon^{real} - 1\right) N_{tight}^{real} + \left(1/\epsilon^{fake} - 1\right) N_{tight}^{fake}$$

$= N_{tight}^{real} / N_{loose}^{real}$

$= N_{tight}^{fake} / N_{loose}^{fake}$

- QCD events in the signal region:

$$N_{tight}^{fake} = \frac{N_{loose\ not\ tight}^{obs} - \left(1/\epsilon^{real} - 1\right) N_{tight}^{obs}}{1/\epsilon^{fake} - 1/\epsilon^{real}}$$

- $\epsilon^{real} \sim 0.9-1.0$ : estimated from MC  $\epsilon^{fake} \sim 0.2-0.3$ : data in QCD CR

# 1-Lepton Channel: Results

Phys. Rev. Lett. 106, 131802 (2011)

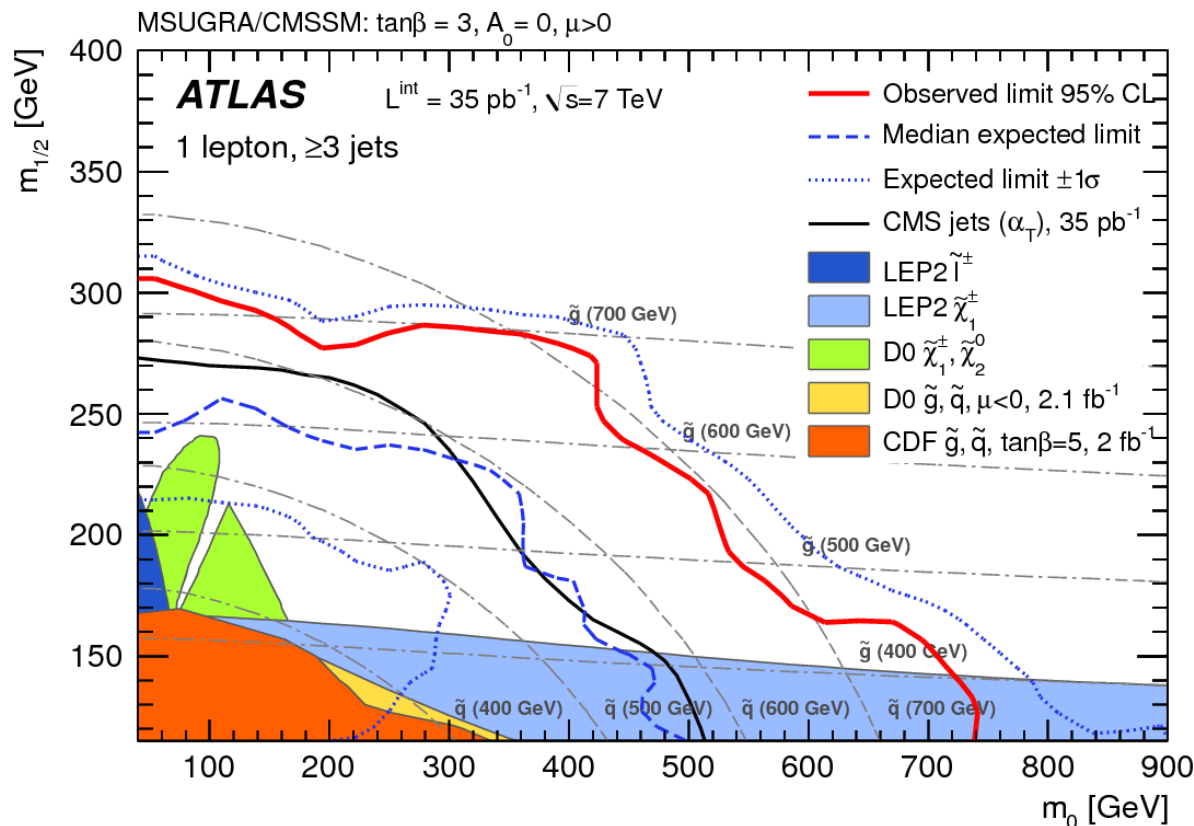
- Main systematics: MC modeling, jet energy scale, b-tagging, luminosity, signal model
- Profile likelihood ratio test and toy experiments to obtain 95% CL exclusion limits

Excludes non-SM cross-section \* acceptance \* efficiency at 95% CL:

Electron channel: 0.065 pb  
 Muon channel: 0.073 pb

# Events in signal region:

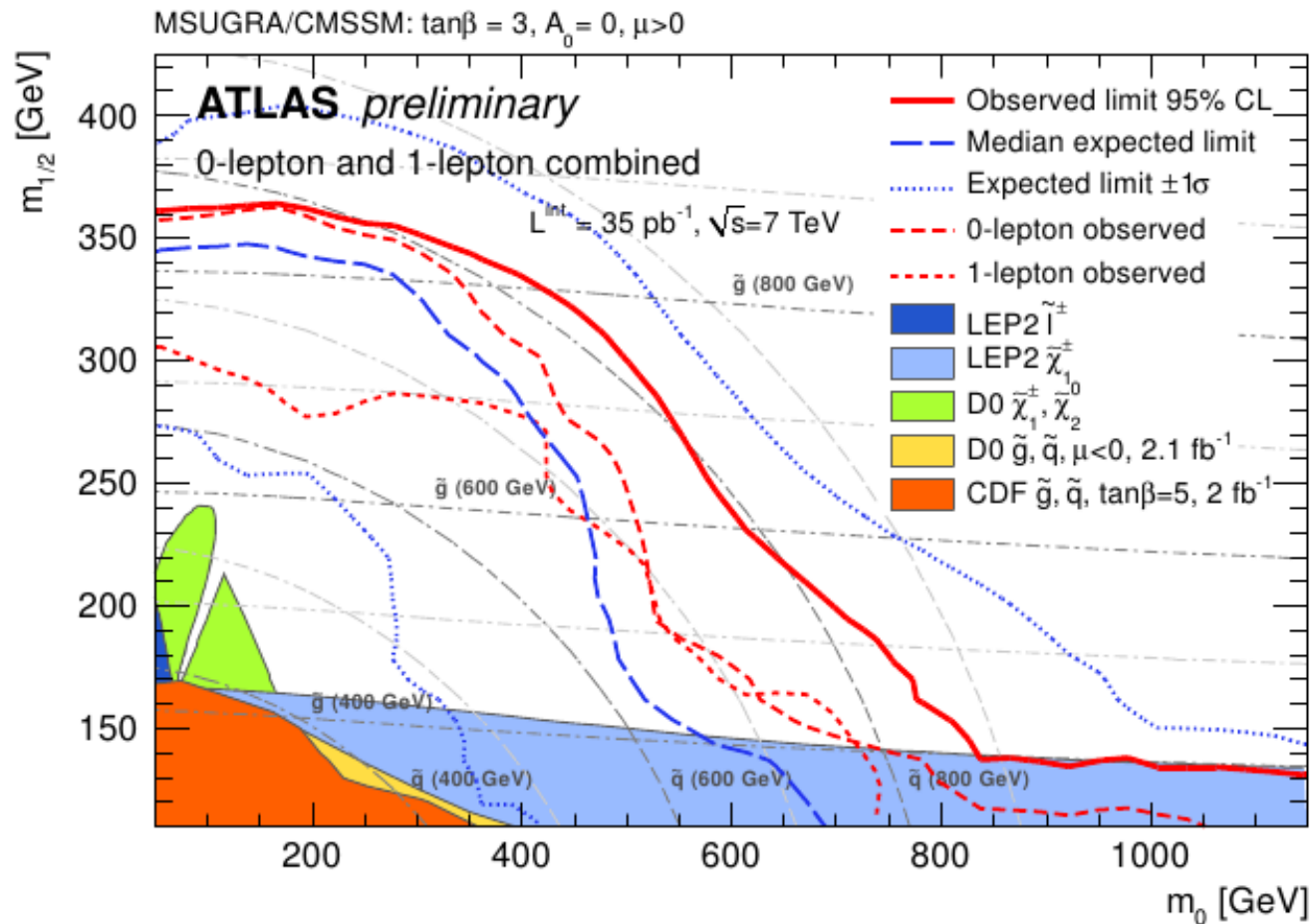
	Data	Fitted top	Fitted W/Z	Fitted QCD	Sum BG
Electron channel	1	1.34±0.52 (1.29)	0.47±0.40 (0.46)	<0.3	1.81±0.75
Muon channel	1	1.76±0.67 (1.39)	0.49±0.36 (0.71)	<0.5	2.25±0.94



# Combined Results

ATLAS-CONF-2011-064

- Combined 95% CL exclusion limits of 0-lepton and 1-lepton search
- Obtained from combined profile likelihood ratio test and toy experiments



- Combined limit in mSUGRA:  $m_{\text{squark}} = m_{\text{gluino}} > 815 \text{ GeV}$  (95% CL)

# Summary

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- Presented first results of ATLAS SUSY searches in the channel with 0 or 1 leptons, jets and missing transverse energy

- 0-lepton channel:

Excludes non-SM cross-section \* acceptance \* efficiency at 95% CL:

Signal region A: 1.3 pb

Signal region C: 1.1 pb

Signal region B: 0.35 pb

Signal region D: 0.11 pb

- 1-lepton channel:

Excludes non-SM cross-section \* acceptance \* efficiency at 95% CL:

Electron channel: 0.065 pb

Muon channel: 0.073 pb

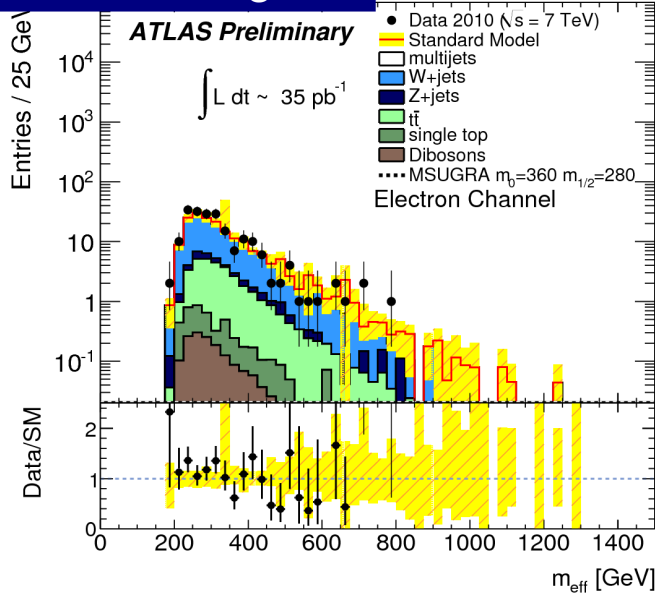
- Combined limit in mSUGRA:  $m_{\text{squark}} = m_{\text{gluino}} > 815 \text{ GeV}$  (95% CL)

– Backup –

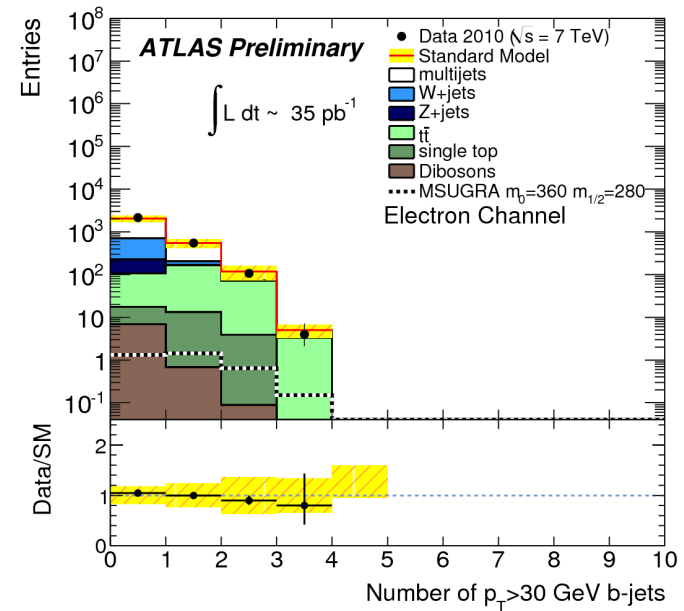
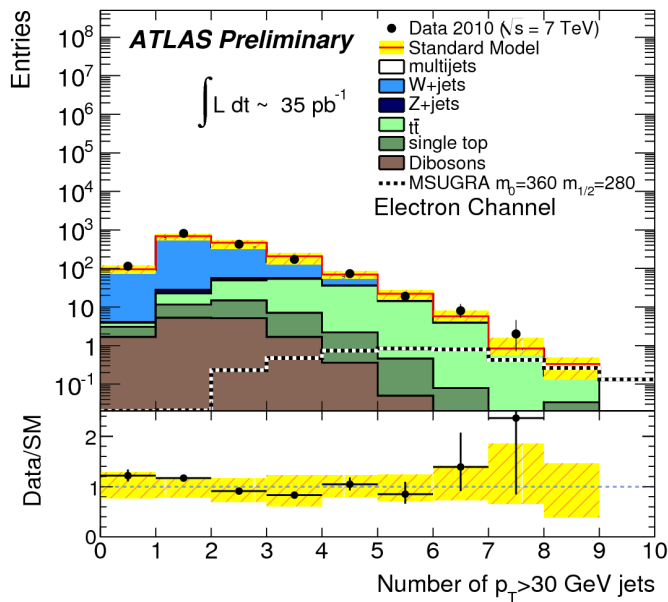
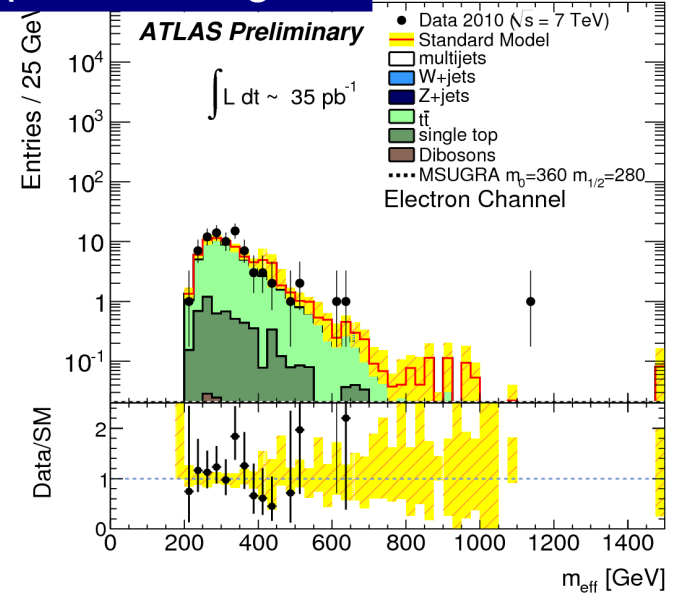
# 1-Lepton Channel: Control Regions

- Validation of W and Top background estimation in control regions:

W+jets control region:



Top control region:

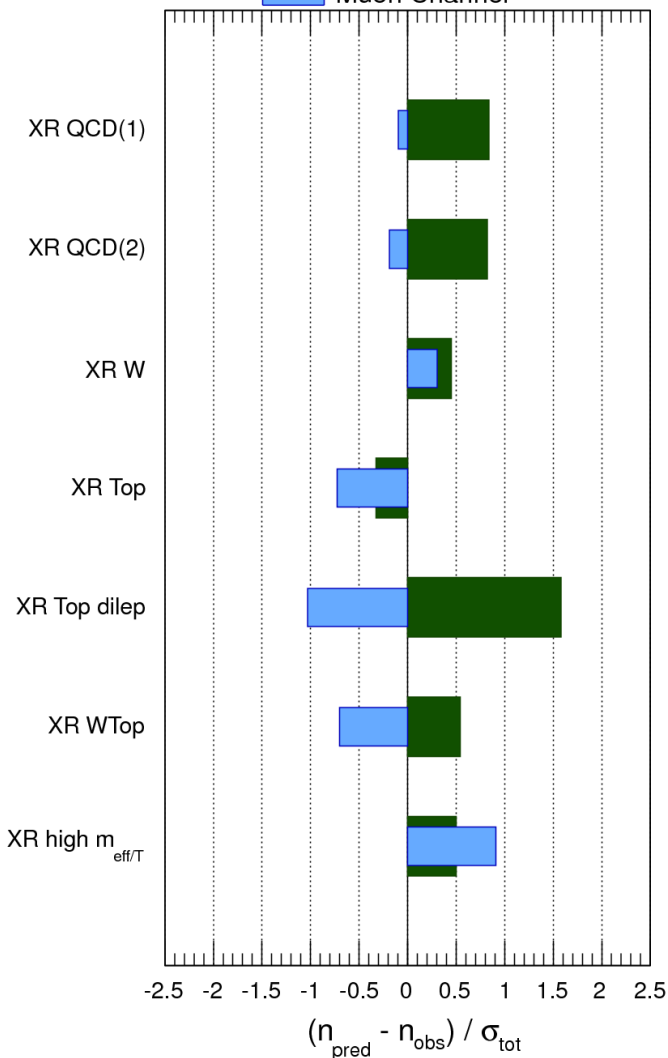


# 1-Lepton Channel: Fit Validation

- Background validated by predicting event yields in additional control regions with likelihood fit does not include XR

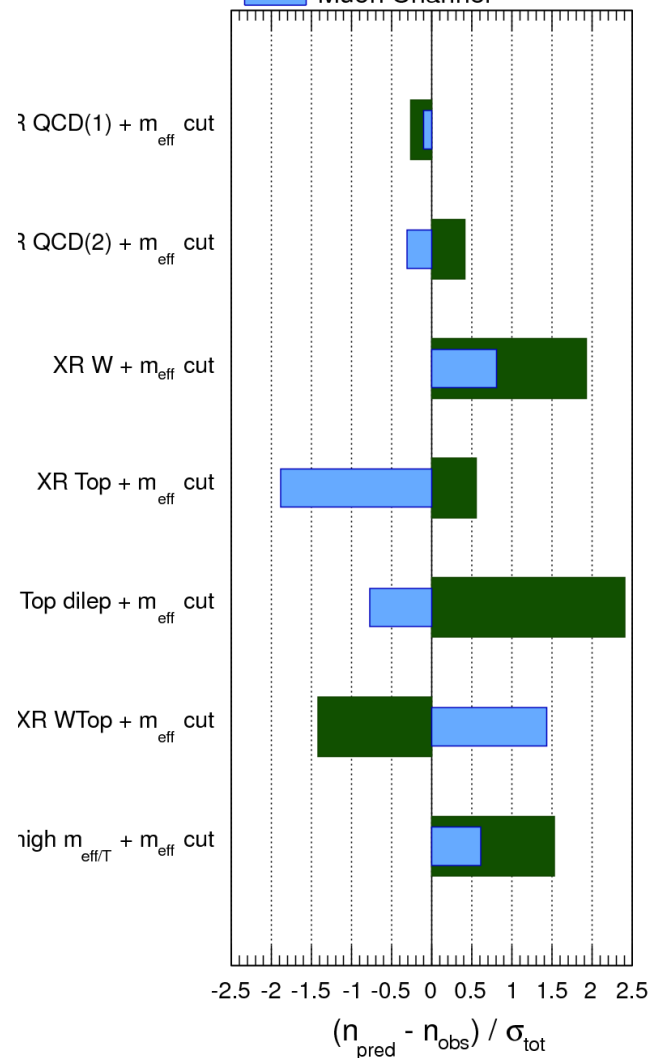
*ATLAS Preliminary*

■ Electron Channel  
■ Muon Channel



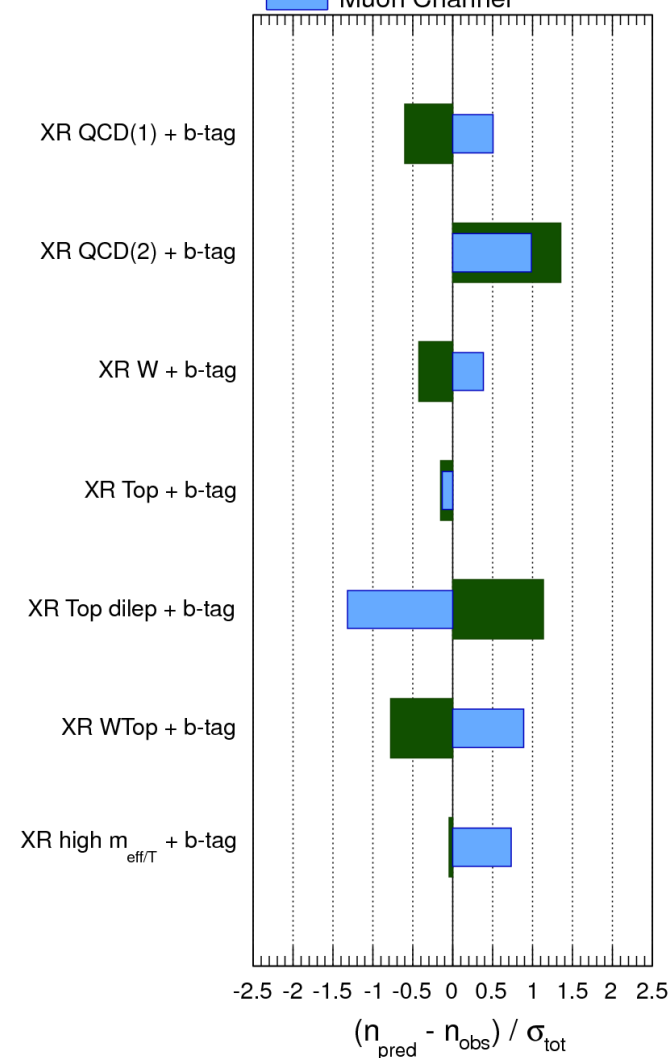
*ATLAS Preliminary*

■ Electron Channel  
■ Muon Channel



*ATLAS Preliminary*

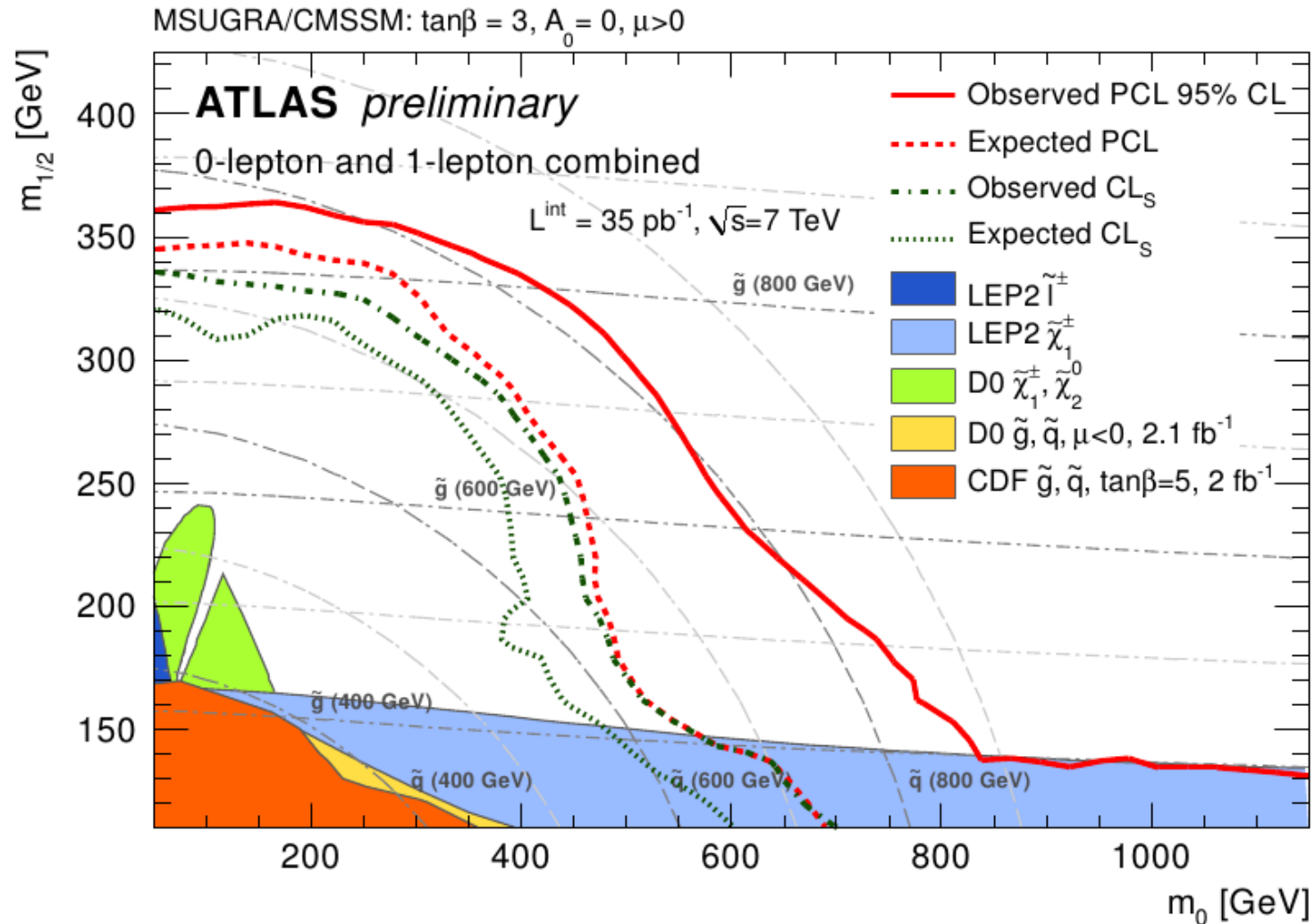
■ Electron Channel  
■ Muon Channel





# Combined Results

- Alternative approach for limit calculation:



# Outlook

- Additional data recorded in 2011 (04.05.2011): **268pb<sup>-1</sup>**

