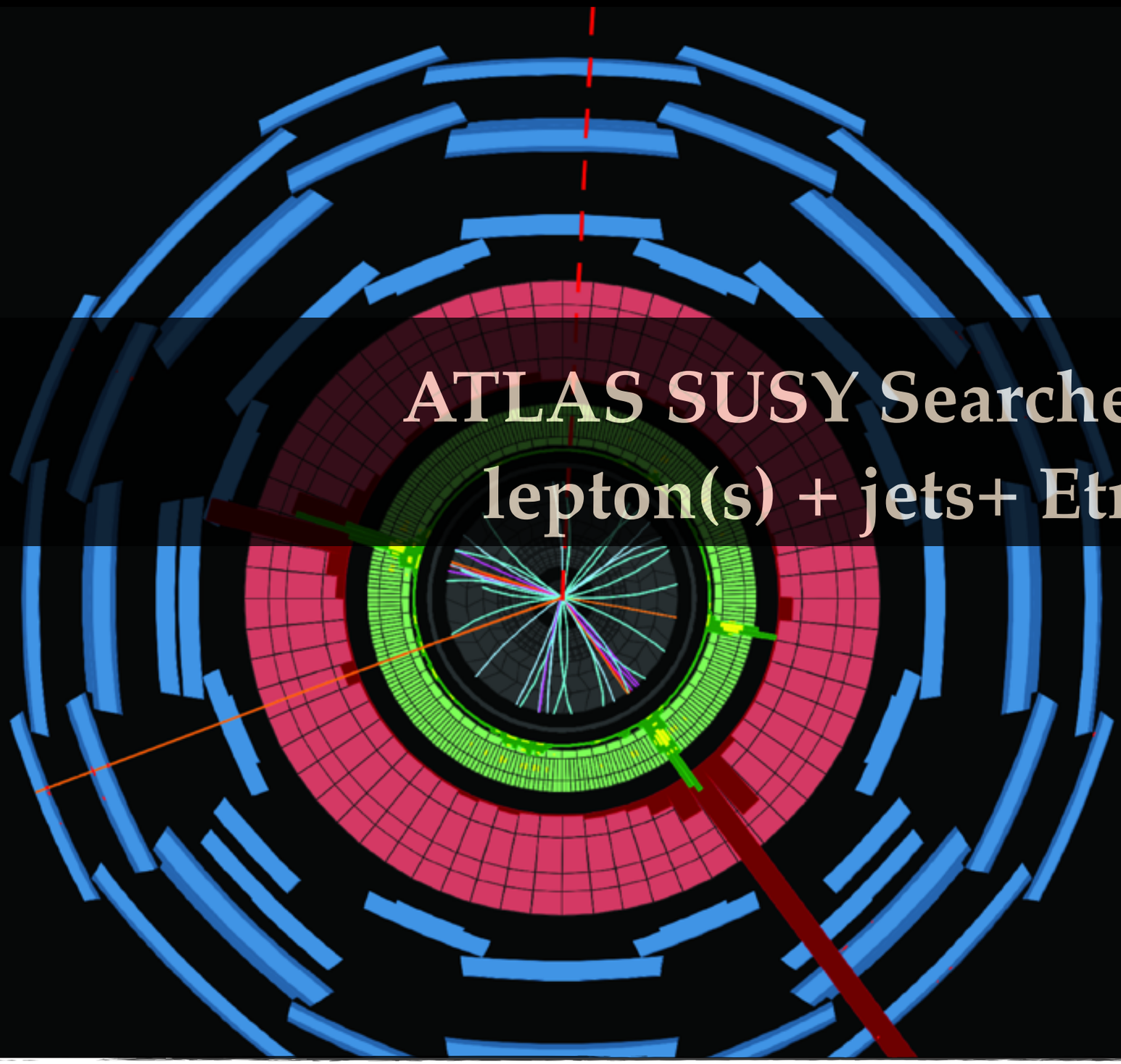
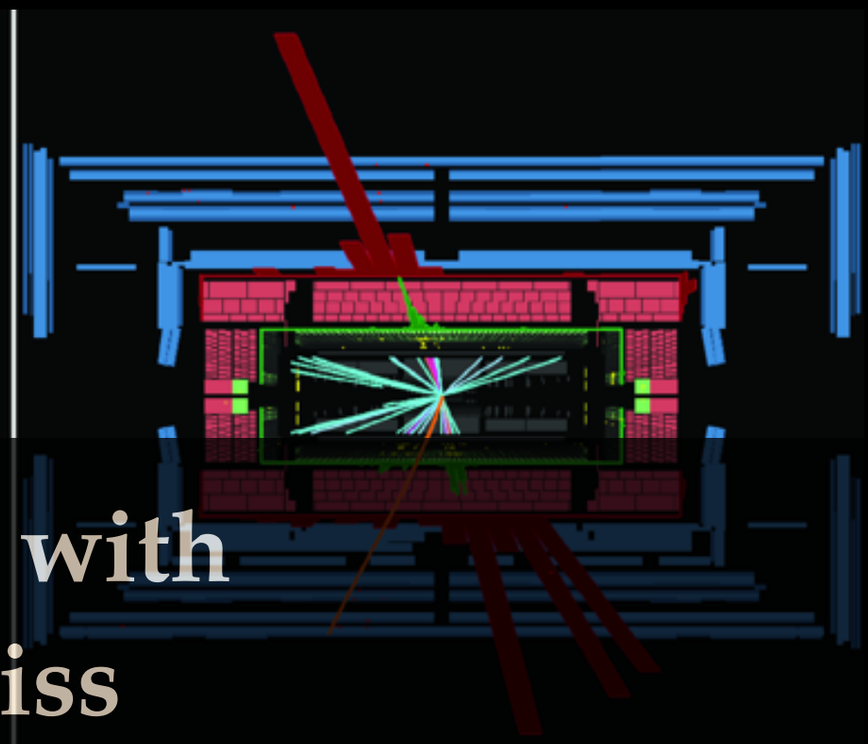




ATLAS SUSY Searches with lepton(s) + jets+ Etmiss

Run Number: 165815, Event Number: 12365502

Date: 2010-09-28 03:23:27 CEST

LPCC workshop: Status of Higgs and BSM searches at the LHC

Till Eifert (CERN)
on behalf of ATLAS

CERN, April 11-13, 2011

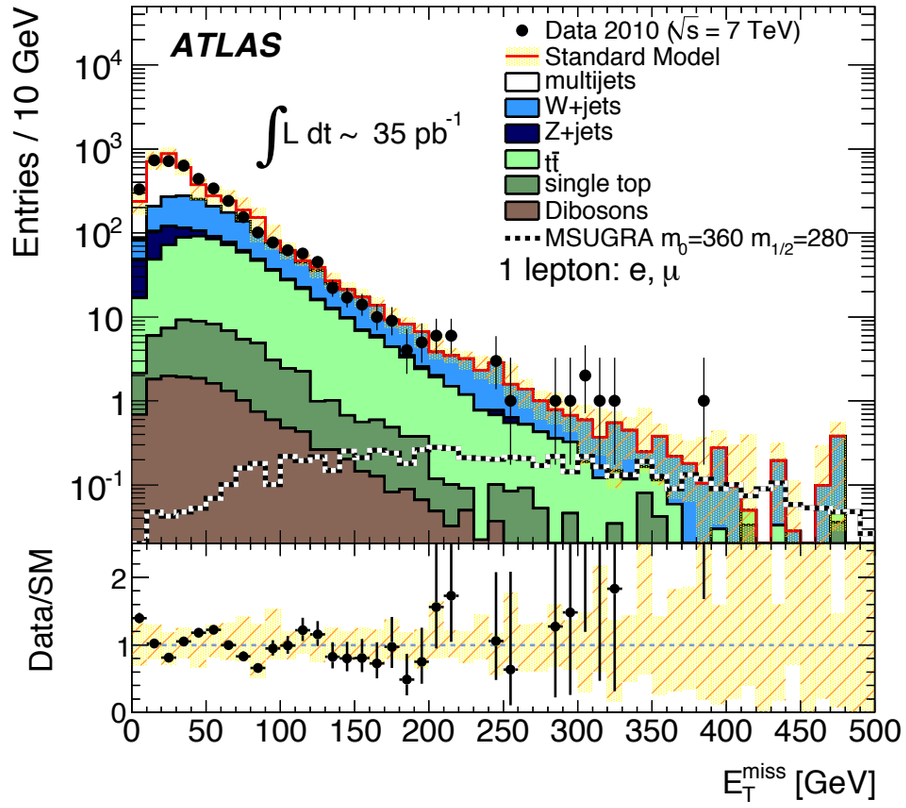
ATLAS SUSY searches assuming R-parity conservation

- 0-leptons + Jets + E_T^{miss}
  Submitted to PLB (25 Feb 2011), arxiv:1102.5290
- 1-leptons + Jets + E_T^{miss}
  PRL 106, 131802 (2011), arxiv:1102.2357
- 2-leptons + E_T^{miss}
  Submitted to EPJC letters (31 Mar 2011), arxiv:1103.6208, arxiv:1103.6214
- ≥3-leptons + Jets + E_T^{miss}
  ATLAS-CONF-2011-039
- 0-leptons + b-jets + E_T^{miss}
  Submitted to PLB (22 mar 2011), arxiv: 1103.4344
- ≥1-leptons + b-jets + E_T^{miss}
  Submitted to PLB (22 mar 2011), arxiv: 1103.4344

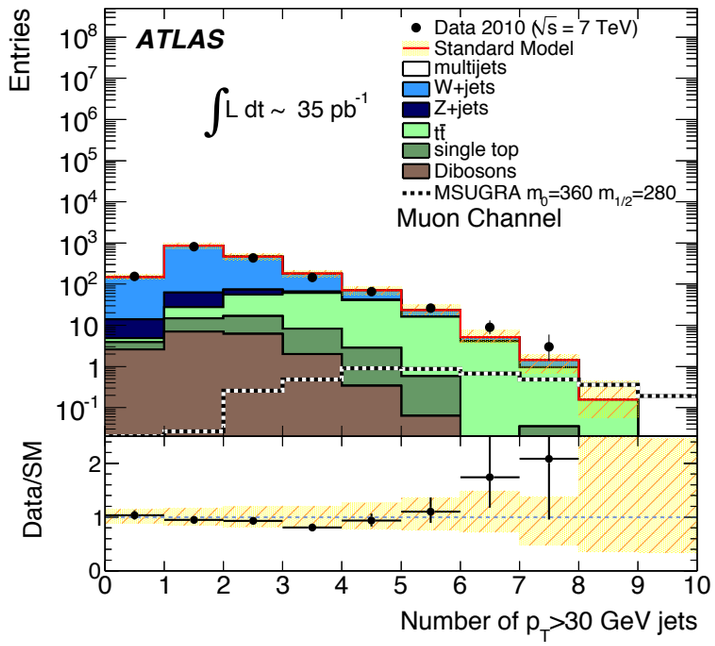
Odd-lepton numbers covered in this talk

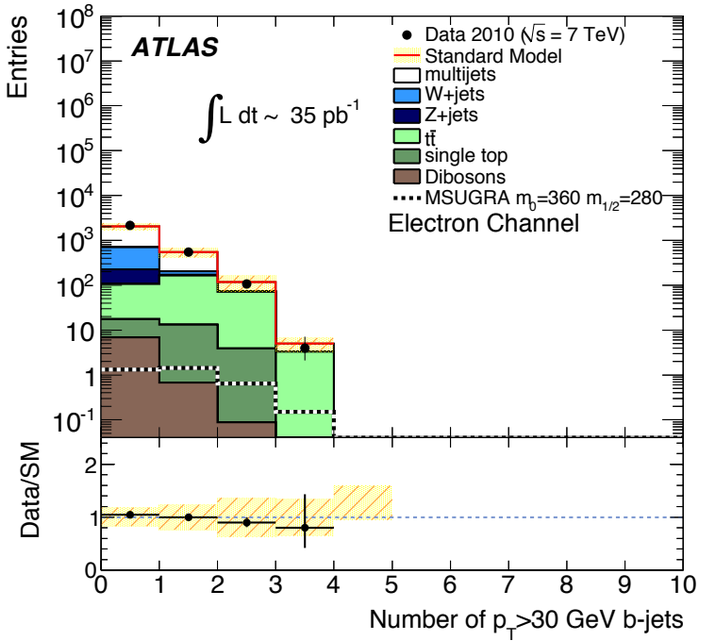
one lepton + jets + E_t^{miss}

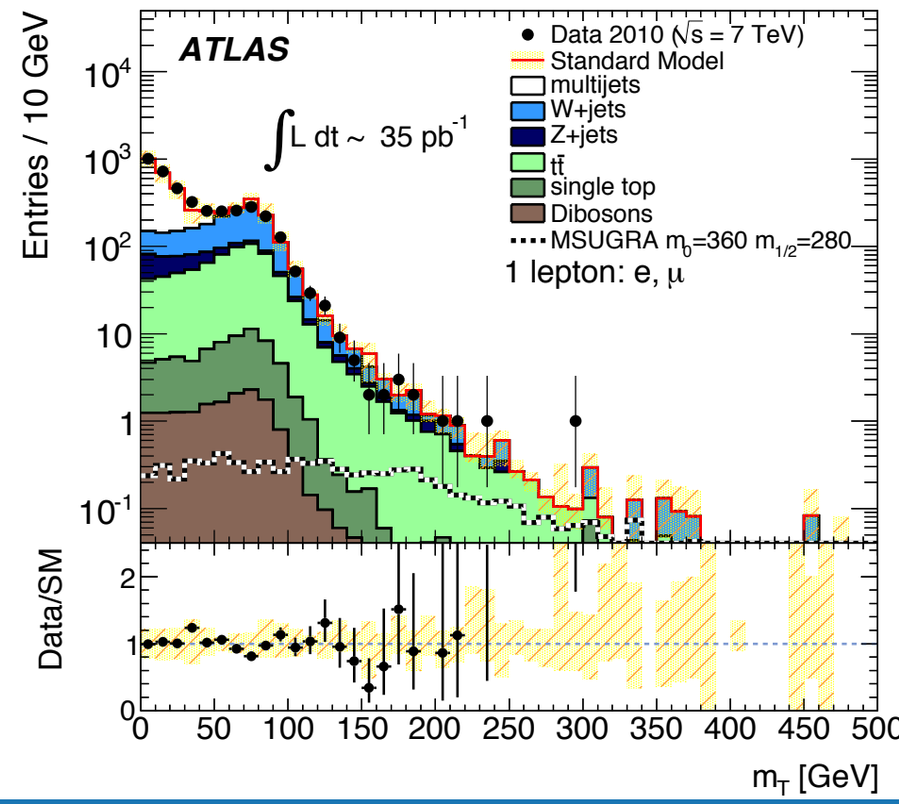
- First ATLAS SUSY publication
  PRL 106, 131802 (2011), arxiv:1102.2357
- Pre-selection
  Single el/mu triggers
  data & detector quality
  good primary vertex
- Kinematic selection :
  1-lepton (el/mu) with pT > 20 GeV
  ≥ 3-jets with pT > 60, 30, 30 GeV
- Data and simulation in good agreement



Plots: only QCD MC scaled to data, all other normalised by MC x-sec







l-lep Event selection : Signal Region

Simple counting-experiment in SR

➡ **Pre-selection**
as described before

➡ **Kinematic selection**
as described before

➡ **Signal-enhanced region (SR)**

1. $m_T > 100$ GeV
2. $E_T^{miss} > 0.25 \times m_{eff}$
3. $m_{eff} > 500$ GeV

Selection based on benchmark SUSY signal and SM bkg

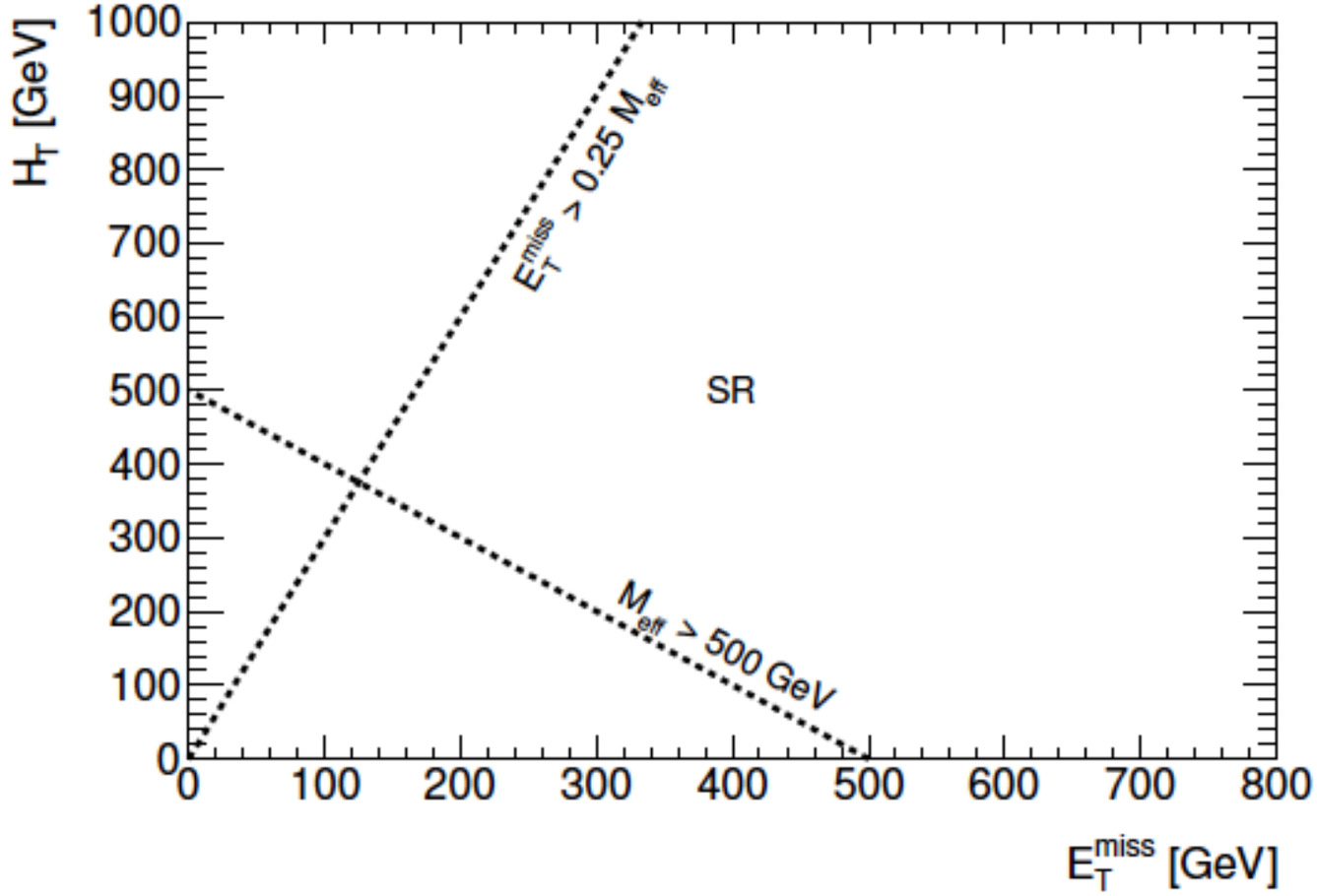
$$m_{\mathrm{T}} = \sqrt{2 \cdot p_T^{\ell} \cdot E_{\mathrm{T}}^{\mathrm{miss}} \cdot (1 - cos(\Delta\phi(\ell, E_{\mathrm{T}}^{\mathrm{miss}})))}$$

transverse scalar mass (HT):

$$H_T = p_T^{\ell} + \sum_{i=1}^{3} p_T^{jet_i}$$

“effective” mass (Meff):

$$m_{\mathrm{eff}} = H_T + E_{\mathrm{T}}^{\mathrm{miss}}$$



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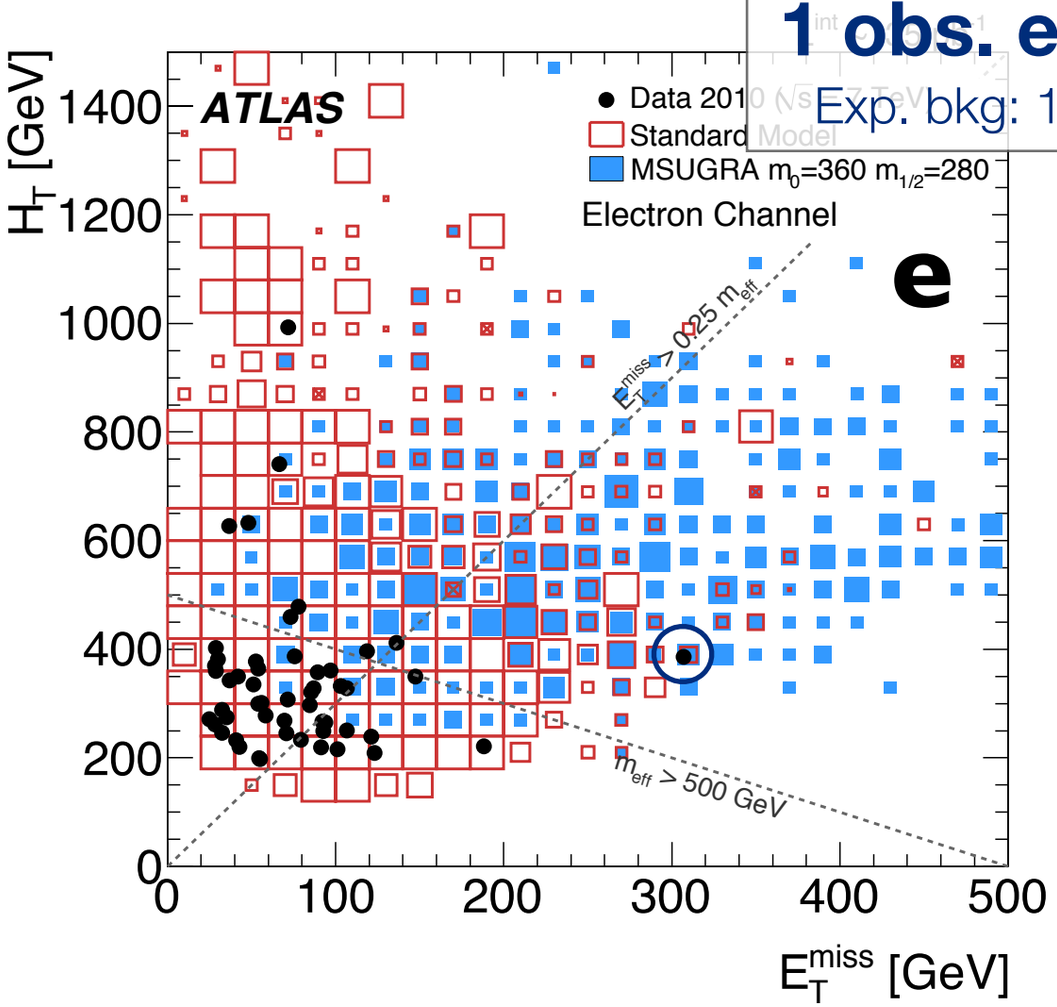
“effective” mass (Meff):

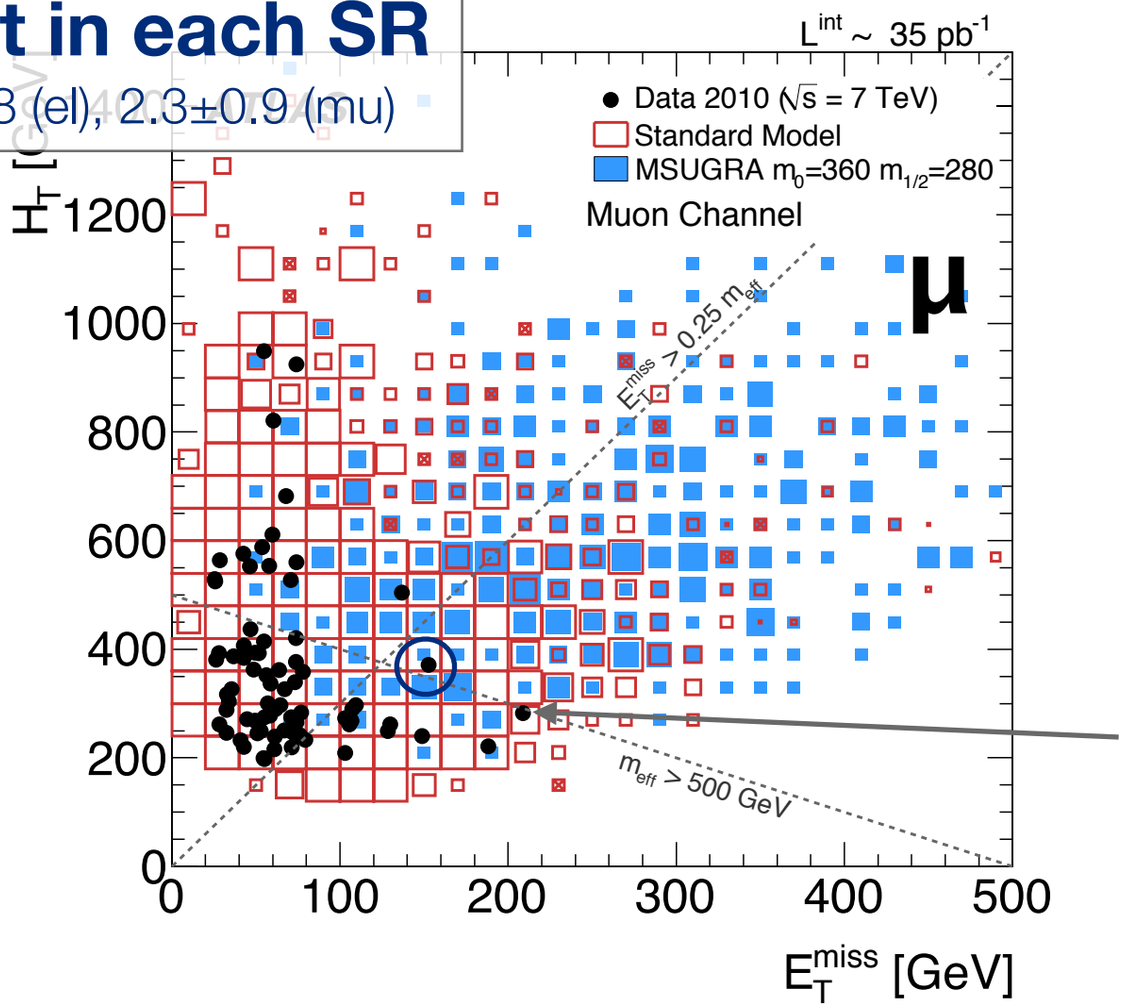
$$m_{\mathrm{eff}} = H_T + E_{\mathrm{T}}^{\mathrm{miss}}$$

Selection based on benchmark SUSY signal and SM bkg

1 obs. event in each SR

Exp. bkg: 1.8±0.8 (el), 2.3±0.9 (mu)





l-lep Event selection : Signal Region

Simple counting-experiment in SR

➡ **Pre-selection**
as described before

➡ **Kinematic selection**
as described before

➡ **Signal-enhanced region (SR)**

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3. $m_{eff} > 500$ GeV

Selection based on benchmark SUSY signal and SM bkg

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

transverse scalar mass (HT):

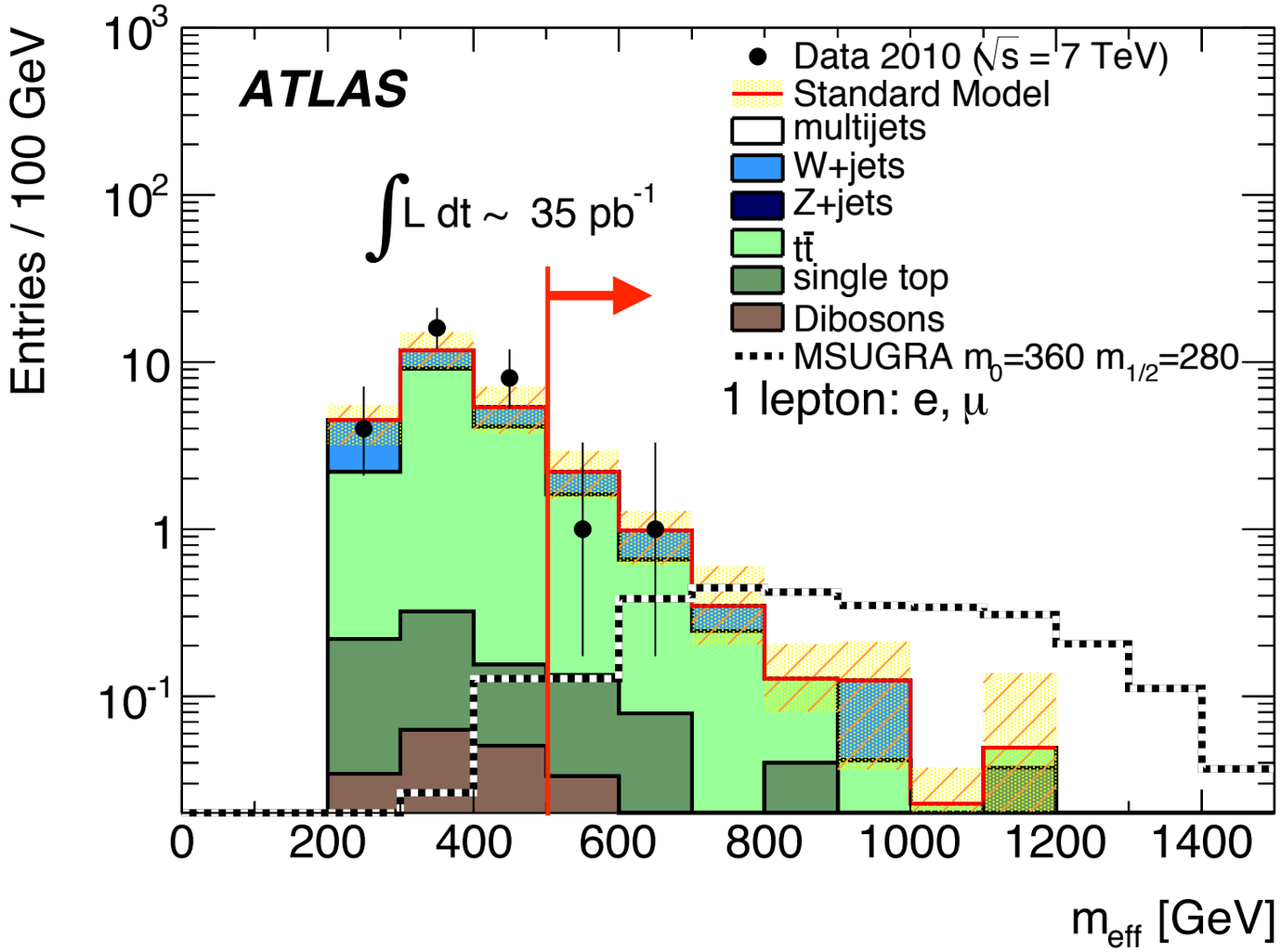
$$H_T = p_T^{\ell} + \sum_{i=1}^{3} p_T^{jet_i}$$

"effective" mass (Meff):

$$m_{eff} = H_T + E_T^{miss}$$

1 obs. event in each SR

Exp. bkg: 1.8±0.8 (el), 2.3±0.9 (mu)



l-lep Background Control Regions

Backgrounds are determined from data in control regions.

➡ **Pre-selection**
as described before

➡ **Kinematic selection**
as described before

➡ **W control region (WR)**

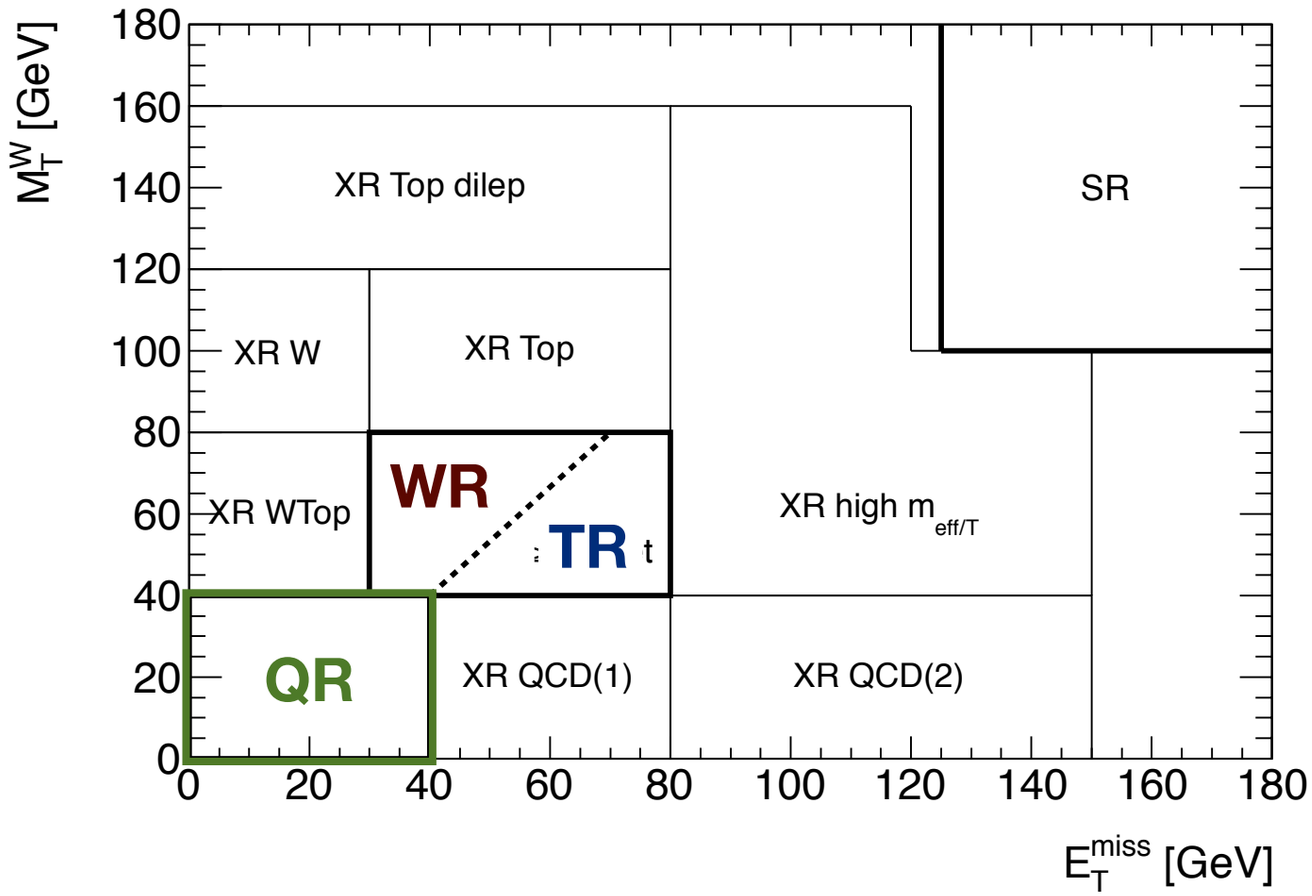
1. 40 GeV < m_T < 80 GeV
2. 30 GeV < E_T^{miss} < 80 GeV
3. None of 3 selected jets is b-tagged

➡ **Top control region (TR)**

1. 40 GeV < m_T < 80 GeV
2. 30 GeV < E_T^{miss} < 80 GeV
3. ≥1 of 3 selected jets is b-tagged

➡ **QCD control region (QR)**

1. m_T < 40 GeV
2. E_T^{miss} < 40 GeV



CRs with "XR" labels are used for validation (more later)

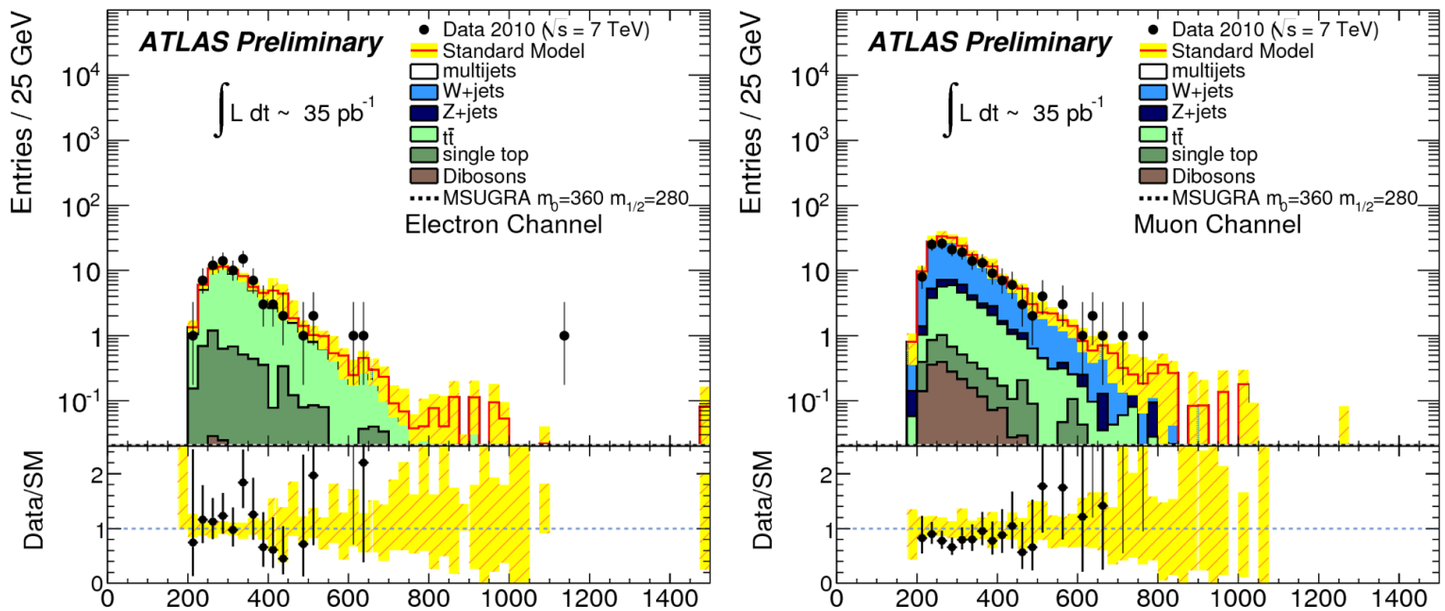
Simultaneous signal and background fit
with systematics treated as nuisance parameters
Top, V+jets bkg in SR: MC-based extrapolation of Data from WR,TR to SR
QCD contamination in WR,TR: MC-based extrapolation of Data from QR to WR,TR

l-lep Background Control Regions

effective mass (m_{eff}) distribution in **Top CR** (left) and **W CR** (right)

MC-based extrapolation to SR, uncertainties taken into account, incl. theory uncertainty, JES, JER

Extrapolation validated in several extra control regions (see next slide)



QCD in SR: estimated from data using "*matrix method*"

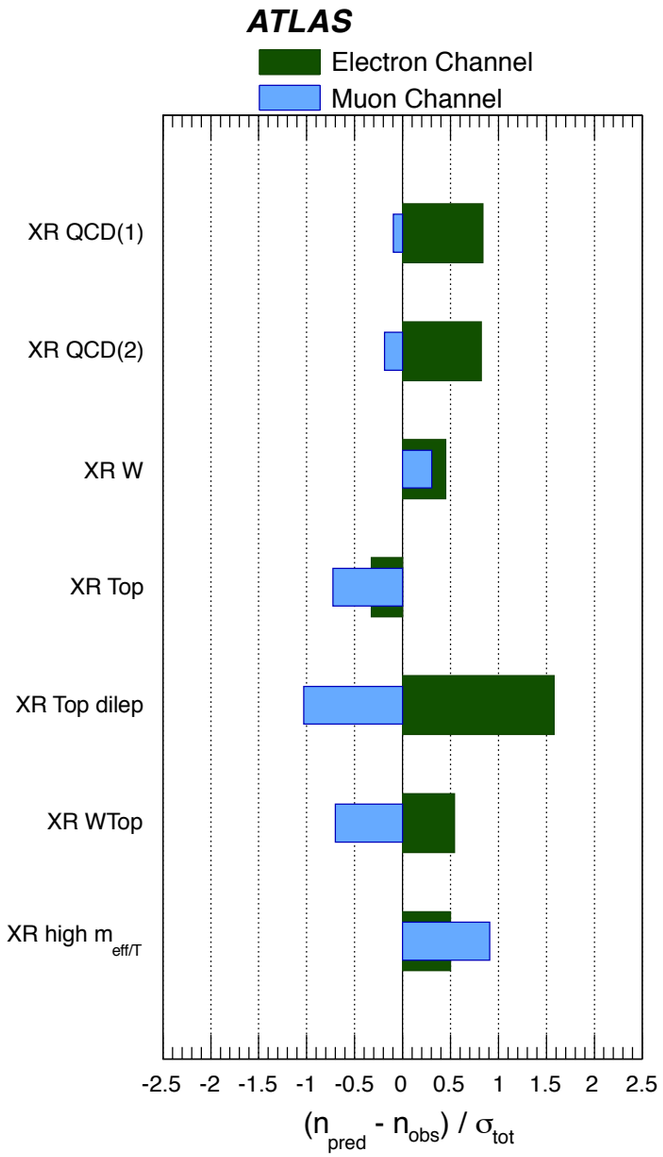
Use additional data sample with relaxed lepton identification criteria, where significantly more QCD jets fake a lepton.

QCD in SR, upper limits: **$0^{+0.3}$ (el), $0^{+0.5}$ (mu)**

Upper-limit dominated by uncertainty from low statistics in "loose" and "tight" SR data samples.

Results & Validation

Compare bkg extrapolated to other regions with data (also the meff cut and b-tagging were tested)



Data well described by bkg model

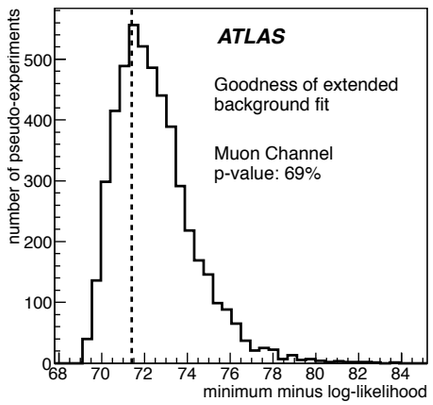
No excess is observed

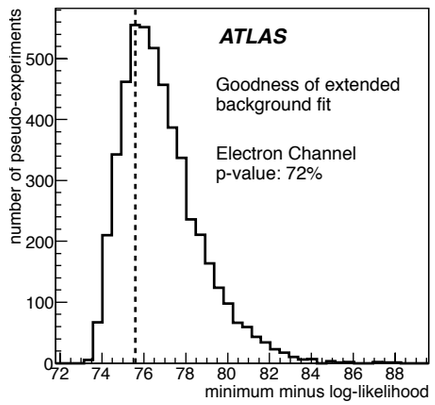
Electron channel	Signal region
Observed events	1
Fitted top events	1.34 ± 0.52 (1.29)
Fitted W/Z events	0.47 ± 0.40 (0.46)
Fitted QCD events	$0.0^{+0.3}_{-0.0}$
Fitted sum of background events	1.81 ± 0.75

Muon channel	Signal region
Observed events	1
Fitted top events	1.76 ± 0.67 (1.39)
Fitted W/Z events	0.49 ± 0.36 (0.71)
Fitted QCD events	$0.0^{+0.5}_{-0.0}$
Fitted sum of background events	2.25 ± 0.94

Numbers in brackets: nominal MC predictions: 1.75 (el), 2.1 (mu)

Over-constrain simultaneous bkg-fit by adding additional CRs --> **goodness-of-fit** found as expected for statistically compatible samples

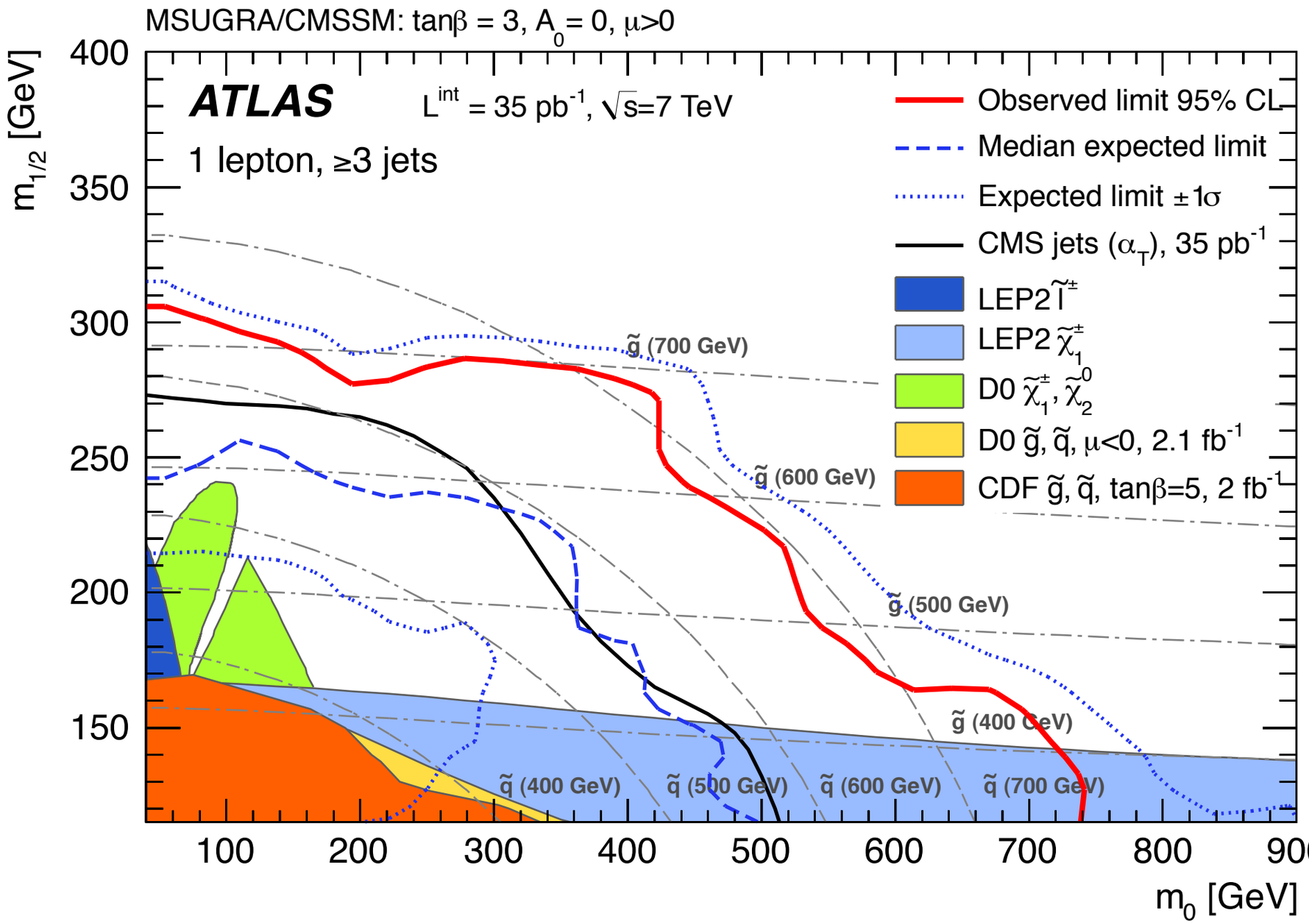




1-lep Interpretation : MSUGRA/CMSSM

One-sided limit based on observed CL_{s+b}

- MSUGRA/CMSSM used for comparison
- Future: explore more model-independent interpretations



Signal-model independent exclusion result :

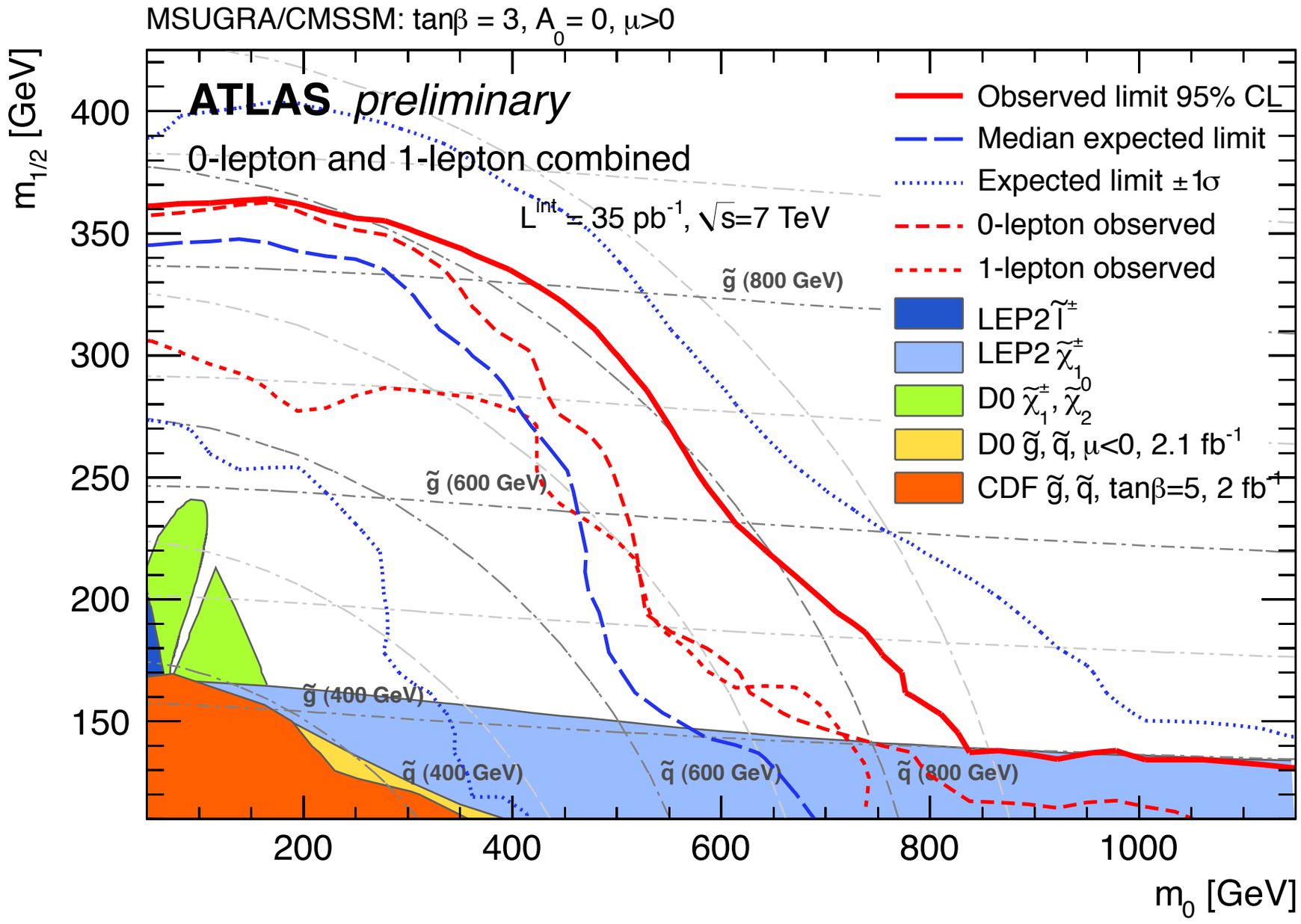
Upper limit on $\sigma_{eff} = \sigma \times \text{Acceptance} \times \varepsilon$

0.065 pb (el channel)

0.073 pb (mu channel)

Interpretation : MSUGRA/CMSSM

NEW: Combined exclusion of 0 and 1-lepton analyses



One-sided limit based on observed CL_{s+b}

$M_{gluino} = M_{squark} > 815$ GeV

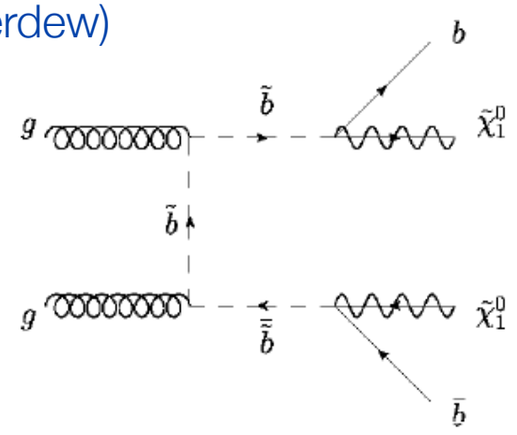
leptons + b-jets + E_t^{miss}

- 0, 1-lepton channels also studied for events with b-tag to enhance sensitivity to 3rd generation
  Submitted to PLB, arxiv:1103.4344
- 3rd generation (sbottom, stop) can be lighter than other squarks.
- Slightly modified selection criteria

0-lepton	1-lepton
Pre-selections cuts: Data Quality, Trigger requirements clean up for misidentified jets: electron fiduciality, ≥ 1 primary vertex with ≥ 5 tracks	
no-lepton ($p_T > 20$ GeV)	≥ 1 lepton ($p_T > 20$ GeV)
jet $p_T > 120, 30, 30$ GeV, $\|\eta\| < 2.5$	jet $p_T > 60, 30$ GeV, $\|\eta\| < 2.5$
$E_T^{miss} > 100$ GeV	$E_T^{miss} > 80$ GeV
$E_T^{miss}/M_{eff} > 0.2$	–
At least 1 b-tagged jet (SV0, $L/\sigma(L) > 5.72, p_T > 30$GeV, $\|\eta\| < 2.5$)	
minimum $\Delta\phi > 0.4$ rad	$M_T > 100$ GeV

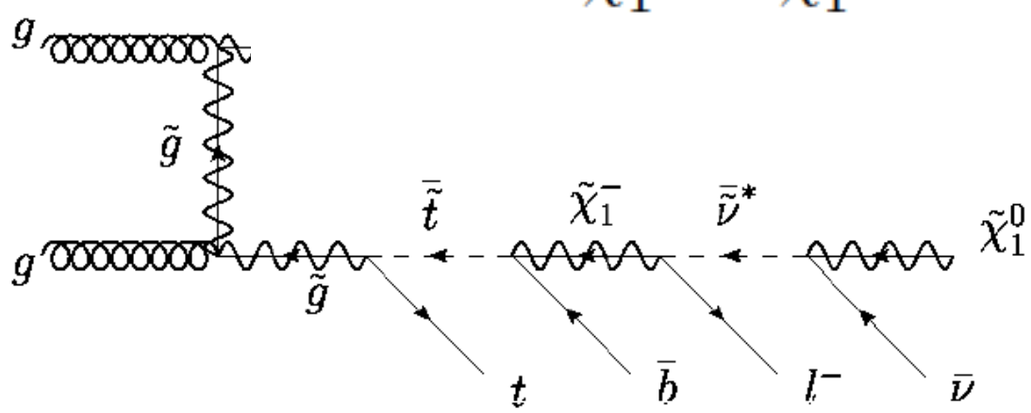
0-lepton + b-jets + E_t^{miss} :
Search for Sbottom is lightest squark scenarios (see talk from M. Flowerdew)

$$\tilde{g} \rightarrow \tilde{b}_1 b \qquad \tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$$



1-lepton + b-jets + E_t^{miss} :
Search for stop is lightest squark scenarios (this talk)

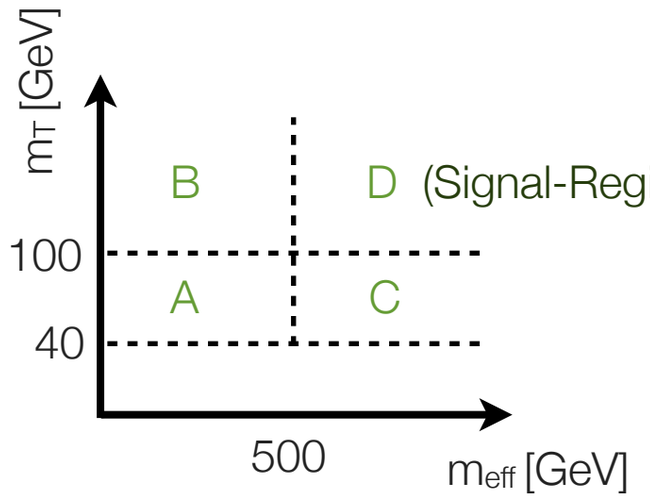
$$\tilde{g} \rightarrow \tilde{t}_1 t \qquad \tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm}$$
$$\tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^0 l^{\pm}\nu$$



Signal-Regions:
0-lepton : $m_{eff} > 600$ GeV
1-lepton : $m_{eff} > 500$ GeV

bjets

SM Backgrounds



$N_D = N_C / N_A \times N_B$

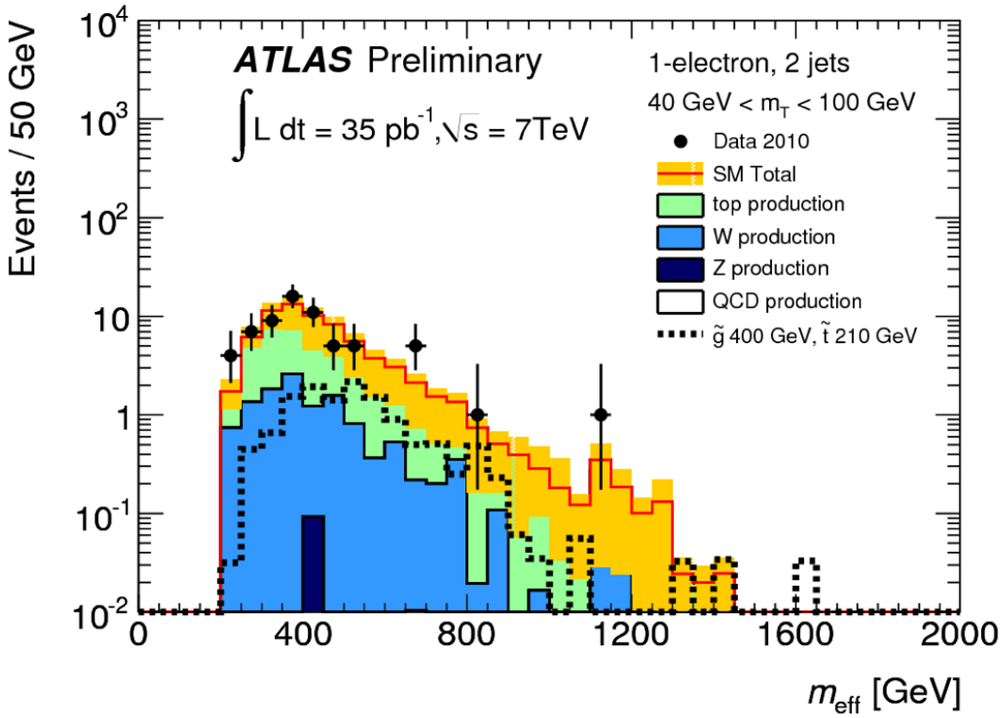
Region	Data	Monte Carlo
A: $40 < m_T < 100$ GeV and $m_{eff} < 500$ GeV	103	105.1 ± 1.5
B: $m_T > 100$ GeV and $m_{eff} < 500$ GeV	46	35.9 ± 0.5
C: $40 < m_T < 100$ GeV and $m_{eff} > 500$ GeV	33	40.1 ± 0.8
D: $m_T > 100$ GeV and $m_{eff} > 500$ GeV	9	13.5 ± 0.4
Estimation	14.7 ± 3.7	13.7 ± 0.4

Nominal MC expectation N_D = 13.5

QCD background :
Upper-limit in SR is set using data-driven technique (matrix-method): $\mathbf{0^{+0.4}}$

Non-QCD background :
ttbar, V+jets backgrounds are estimated from sidebands in m_T, m_{eff}.

- ➡ exploit low variable correlation
- ➡ good data-estimate MC agreement

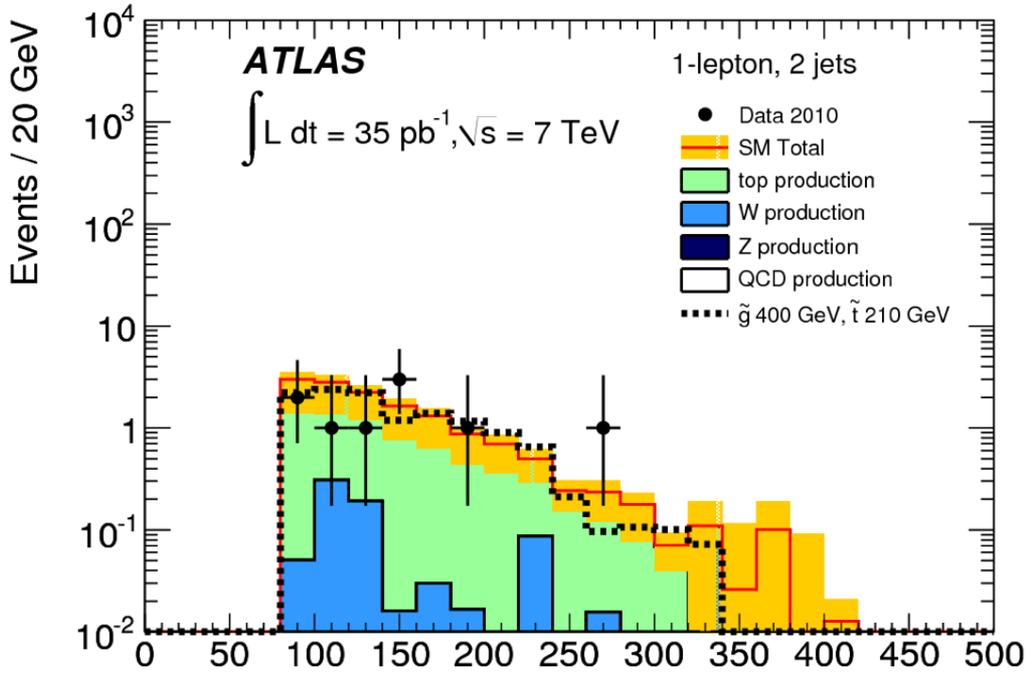


m_{eff} in sideband:
m_T = 40 - 100 GeV

Results

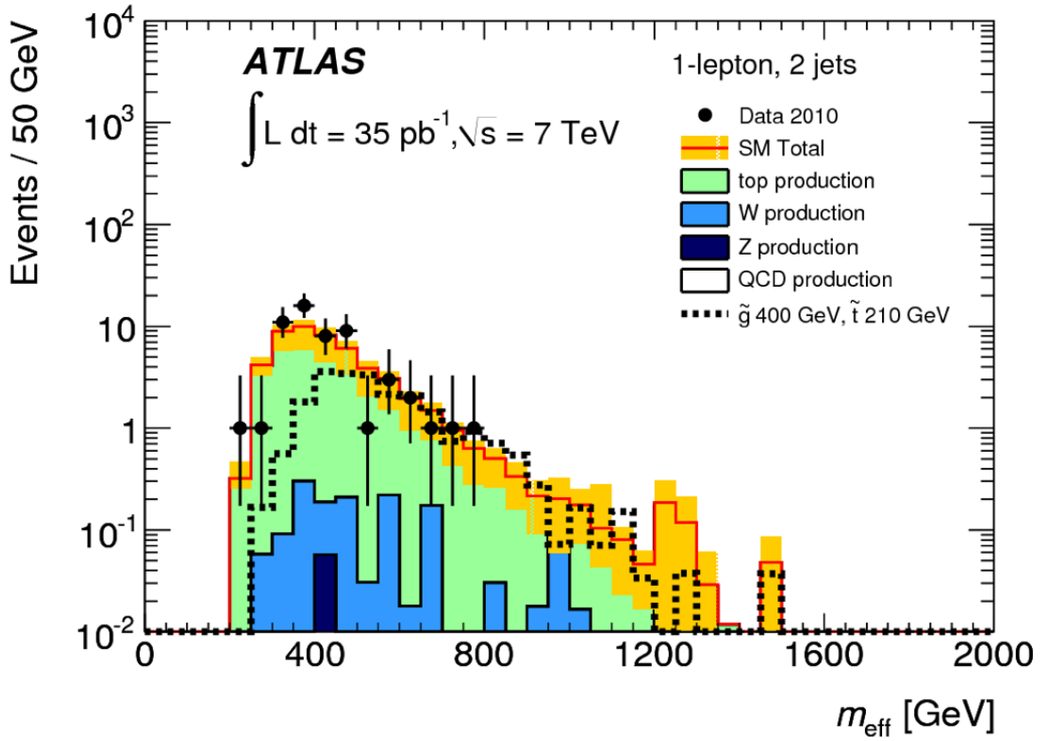
Data and SM predictions in SR agree within uncertainties.

	0-lepton	1-lepton Monte Carlo	1-lepton data-driven
$t\bar{t}$ and single top	12.2 ± 5.0	12.3 ± 4.0	14.7 ± 3.7
W and Z	6.0 ± 2.0	0.8 ± 0.4	-
QCD	1.4 ± 1.0	0.4 ± 0.4	$0^{+0.4}_{-0.0}$
Total SM	19.6 ± 6.9	13.5 ± 4.1	14.7 ± 3.7
Data	15	9	9



Set one-sided exclusion limits based on observed CL_{s+b}

Signal-model independent exclusion result :
Upper limit on $\sigma_{eff} = \sigma$ x Acceptance x ε
0.32 pb (1-lepton channel)



Interpretation : phenomenological MSSM

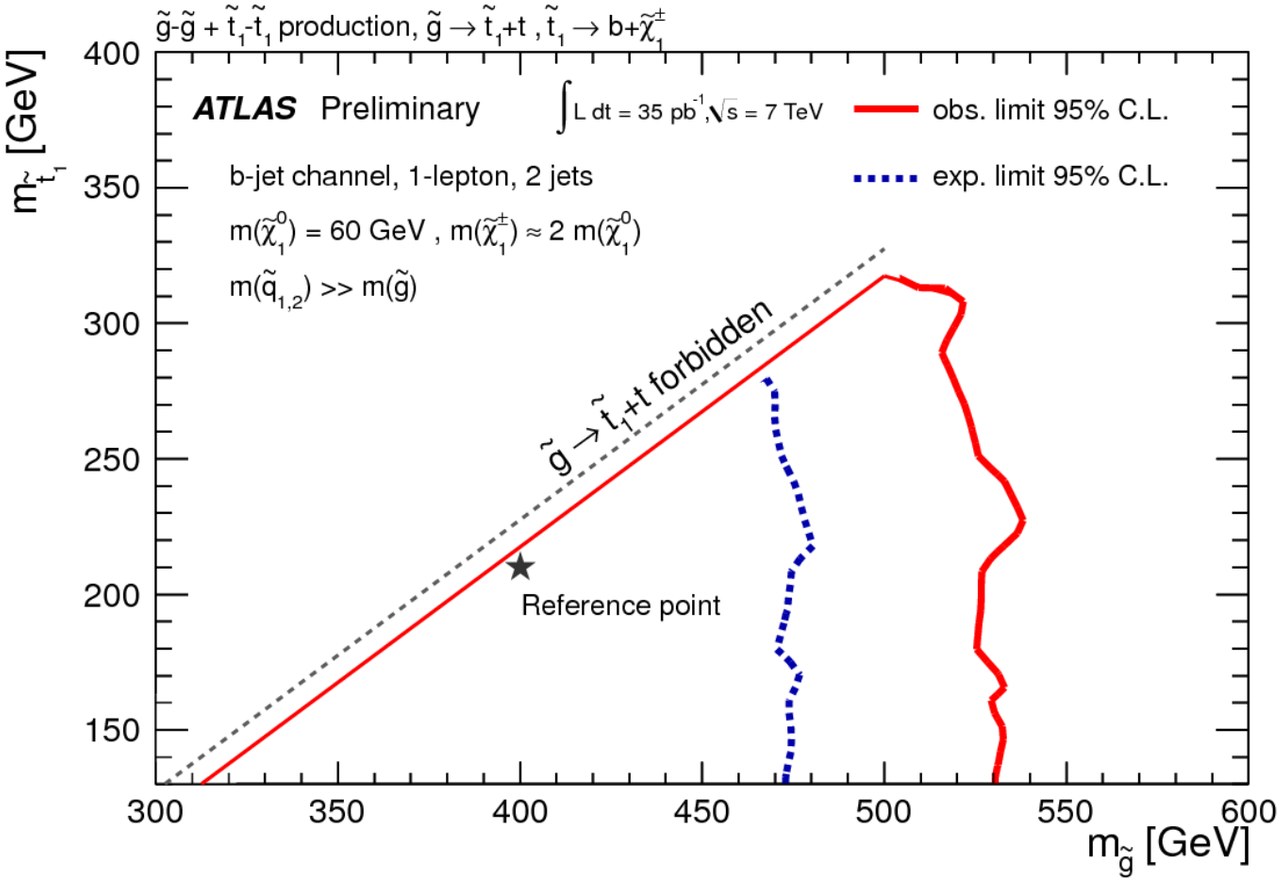
- Assume: stop is lightest squark, and produced in 100% of gluino decays (or directly produced).

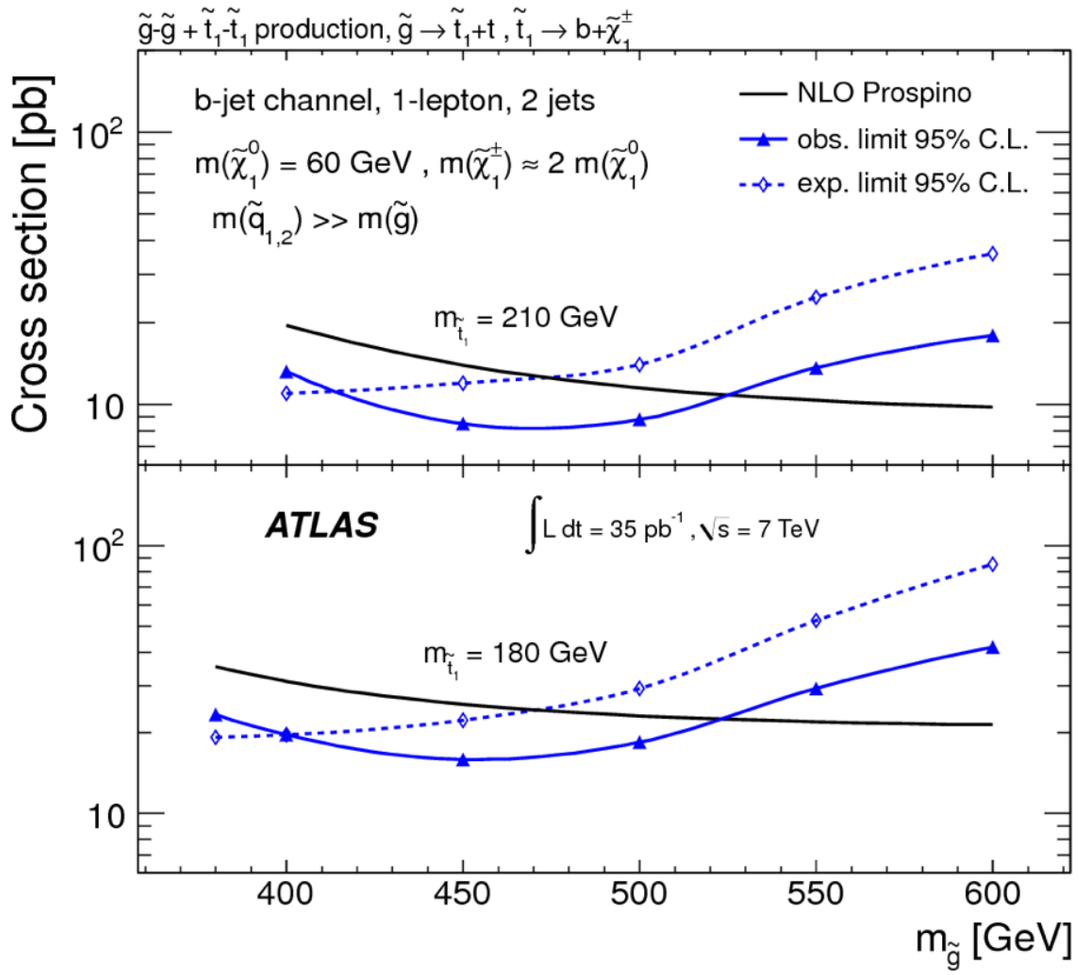
$$\tilde{g} \rightarrow \tilde{t}_1 t$$

- decays to $\chi^{\pm}$ (BR=100%)

$$\tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm}$$

- chargino emits W
  BR($\tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^0 l^{\pm} \nu$) = 11%
- $m(\chi^{\pm})$ = 120 GeV, $m(\chi^0)$=60 GeV

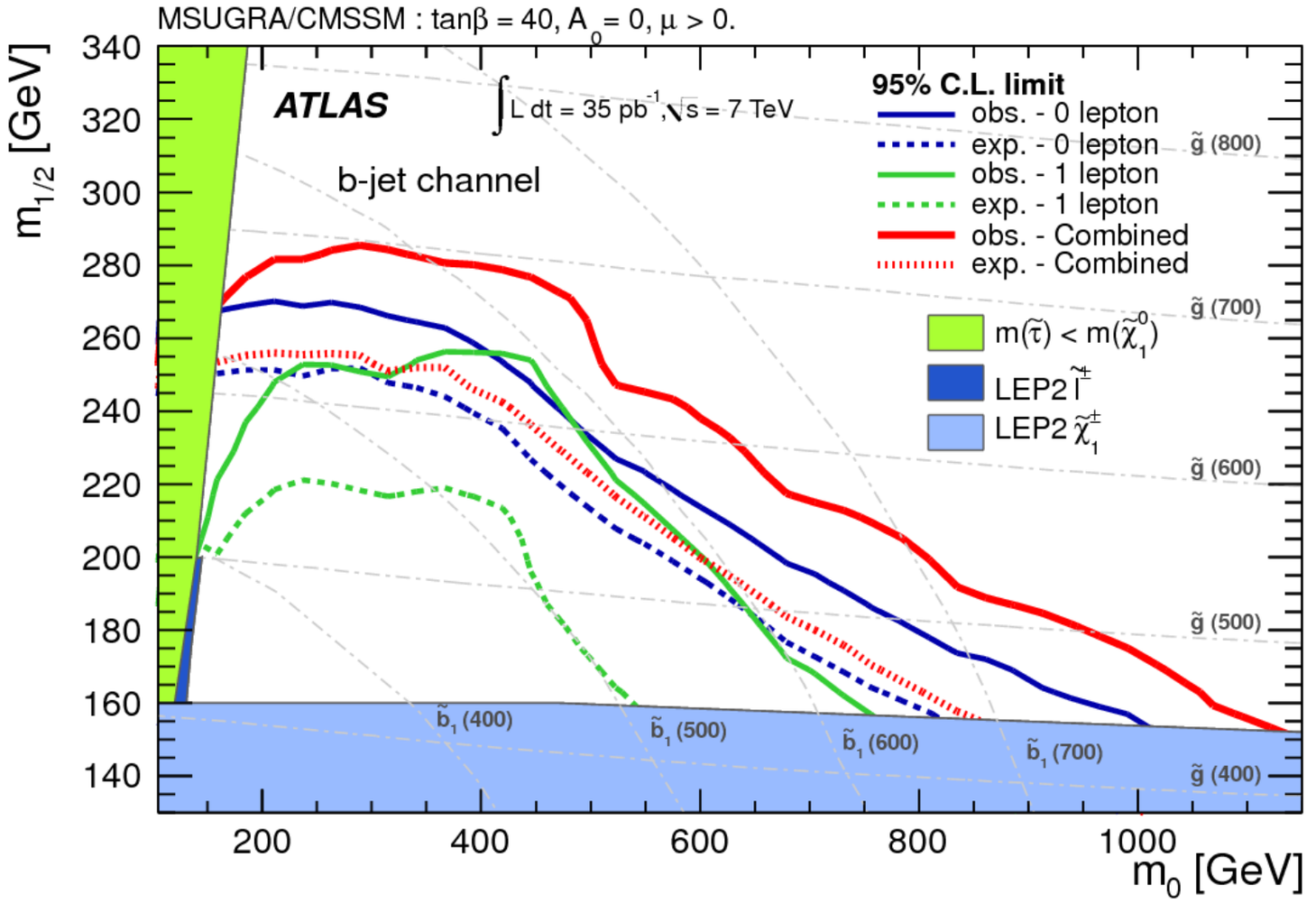




Exclusion of gluinos below 520 GeV for stops in the range 130 - 300 GeV

Interpretation : MSUGRA/CMSSM

- Interpretation within MSUGRA/ CMSSM
- Combination of 0 and 1-lepton channels with b-jets
- Here: large tan(β)=40 scenario, sbottom, stop lighter than in low tan(β) scenarios
- Greatest sensitivity from 0-lep channel



Exclusion of
gluinos below 500 GeV for the m_0 range 100 GeV - 1 TeV
stops, sbottoms below ~470, ~550 GeV respectively across the plane

If **A_0=0 => A_0=-500** :
sbottom and stop masses decrease by ~10% and ~30% respectively.
1-lepton sensitivity extends 0-lepton by ~20 GeV in $m_{1/2}$ for $m_0 < 600$ GeV

Multi-leptons + jets + E_t^{miss}

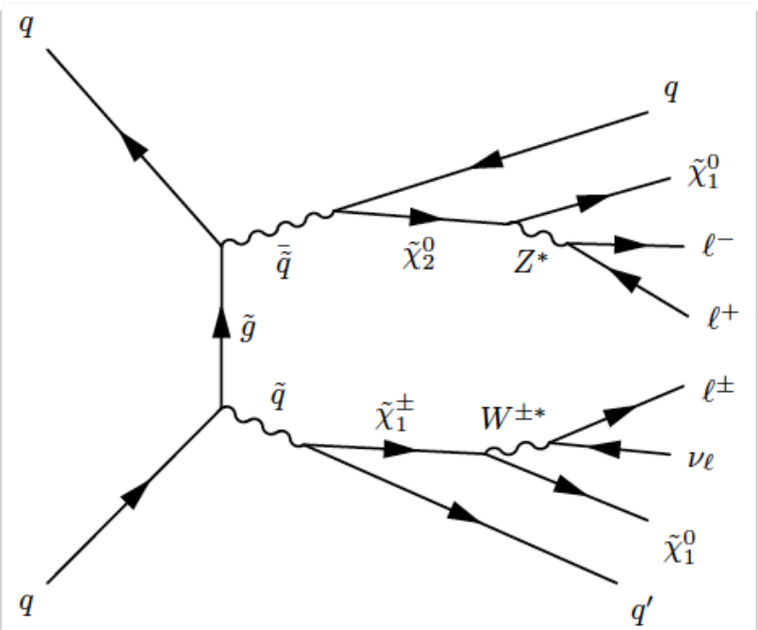
- Channel:

  ≥3 leptons (e,mu) + ≥2 jets + E_T^{miss}

  ATLAS-CONF-2011-039

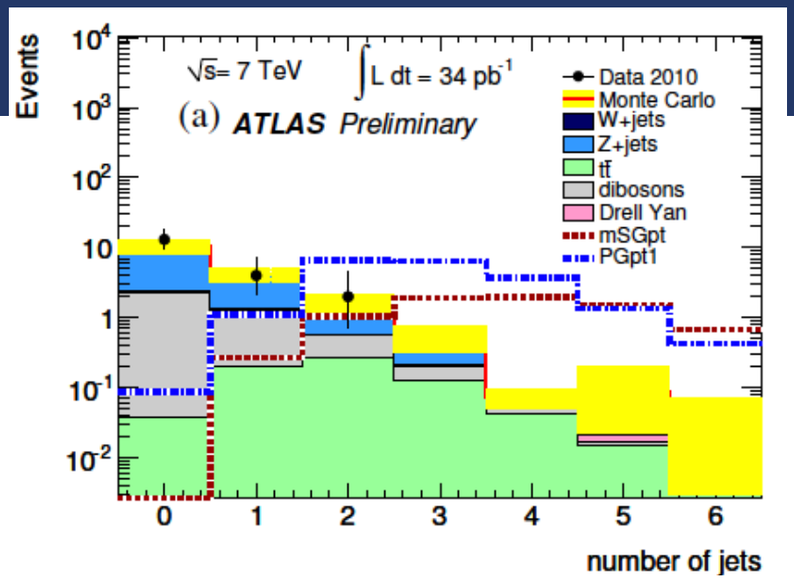
- multi-lepton final states from
  - $\chi^{\pm}$ and χ^0 (produced directly or as intermediate states in long decay chains), can decay leptonically via emission of gauge boson, or intermediate sleptons
  - third generati $\tilde{g} \rightarrow t\tilde{t} \rightarrow Wb\tilde{t}$, to W bosons, e.g.
- very little SM background

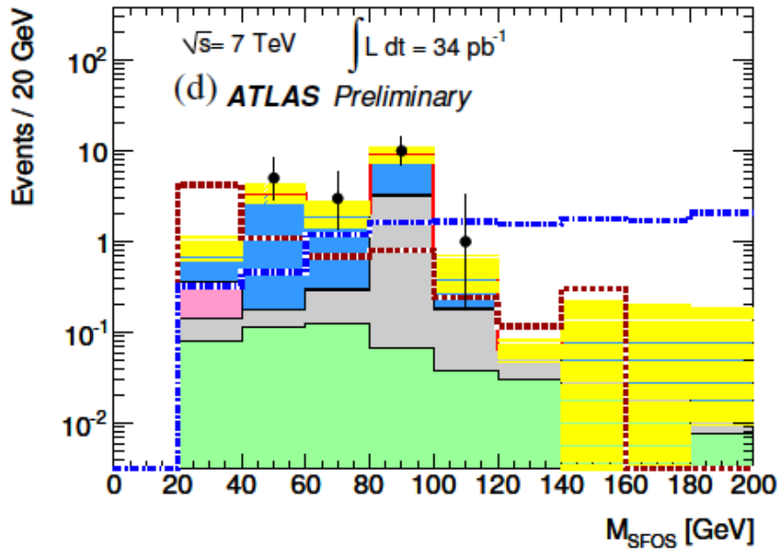
multi-lepton final state example

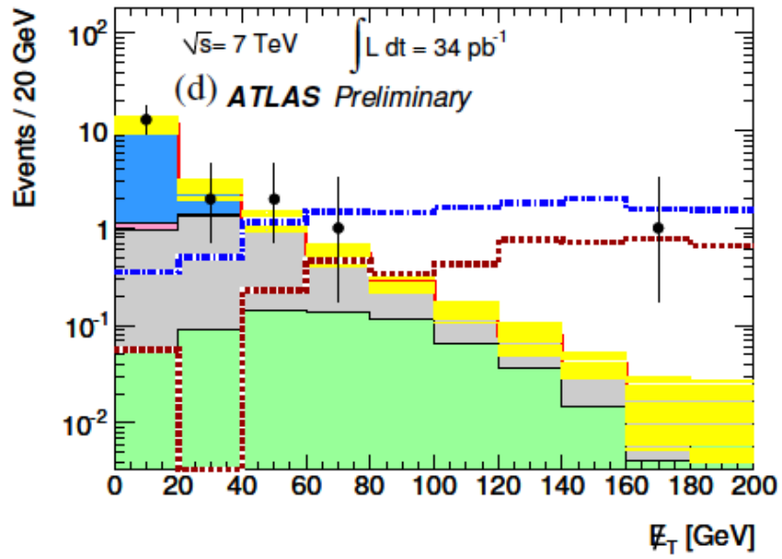


Results

- Event pre-selection
  ≥3 leptons (el/mu)
- Signal-selection
  ≥2 jets with pT > 50 GeV
  E_T^{miss} > 50 GeV
- Z boson veto:
  invariant mass of same-flavour opposite-sign (SFOS) lepton pairs is required to be at least 5 GeV off from Z mass
- DY veto:
  invariant mass of SFOS lepton pairs > 20 GeV







Using MC prediction for SM background

After ≥3 leptons pre-selection

Multilep. events	All	*eee*	*eeμ*	*eμμ*	*μμμ*
$t\bar{t}$	0.68±0.16	0.032±0.016	0.24±0.07	0.31±0.08	0.096±0.030
Z backgrounds	15.6±1.3	3.8±0.8	1.60±0.34	7.9±1.0	2.4±0.4
Other backgrounds	0.28±0.13	0.02±0.14	0.03±0.06	0.21±0.09	0.01±0.11
Total SM	16.6±1.3	3.8±0.8	1.9±0.4	8.4±1.0	2.5±0.4
Data	19	2	1	10	6

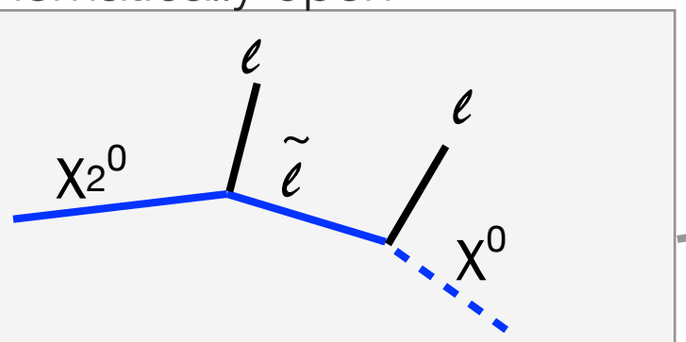
Interpretation : MSUGRA/CMSSM

0 observed events in SR

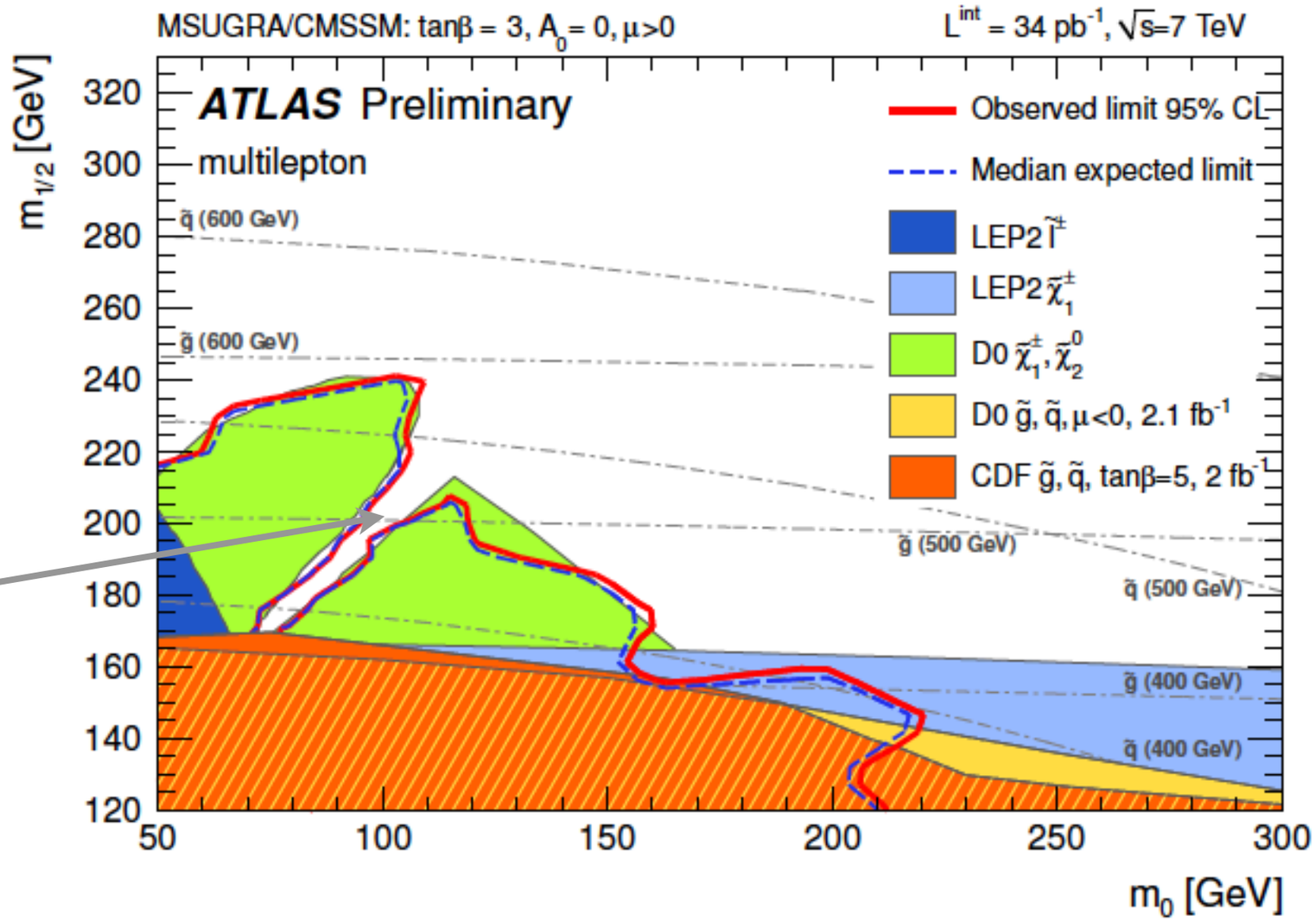
SM prediction:

$$0.109 \pm 0.023^{+0.036}_{-0.025}$$

kinematically open



$m_\ell \lesssim m_\chi$: very soft lepton



Signal-model independent exclusion result :

Upper limit on $\sigma_{eff} = \sigma$ x Acceptance x ε

62 fb

One-sided limit based on observed CL_{s+b}

Interpretation : Phenomenological MSSM

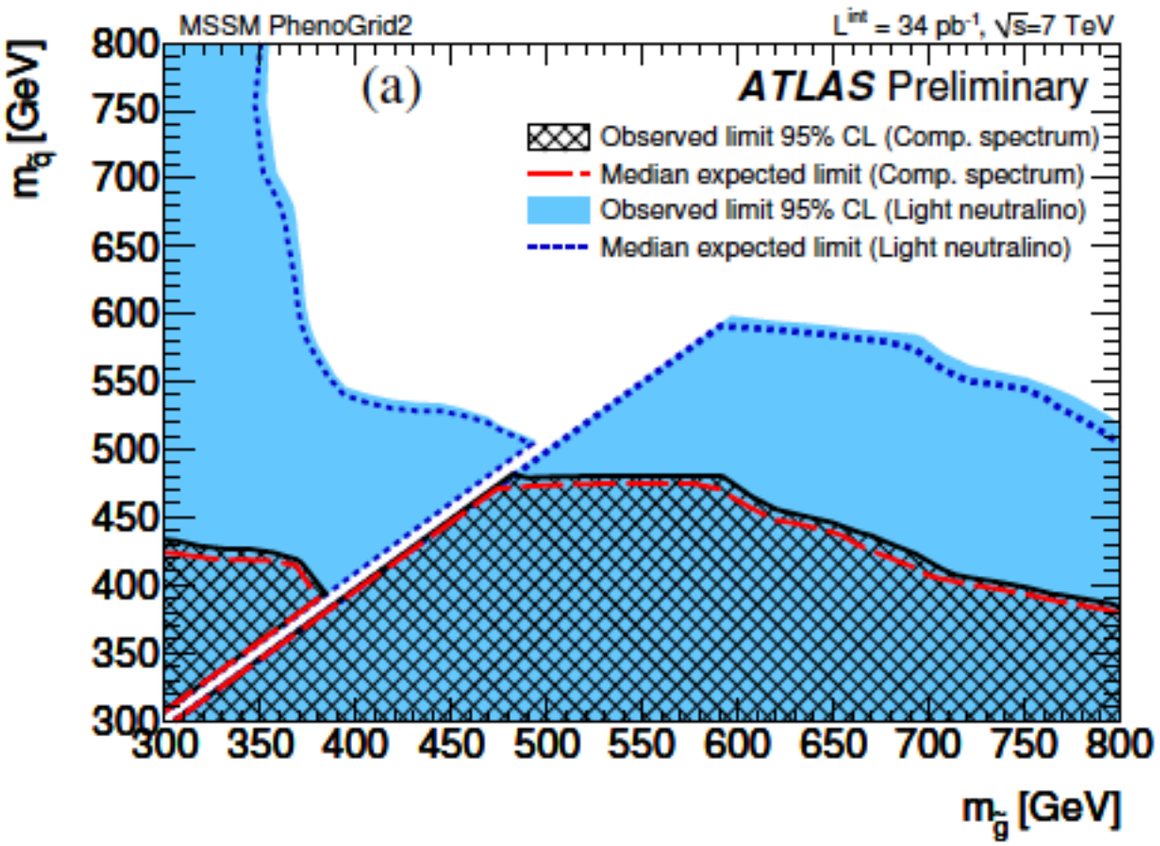
Phenomenological MSSM scenario:

- bino-like LSP, wino-like chi $\chi^{\pm}_1$ and χ^0_2
- decays w/ sleptons enhance leptons
- 3rd generation scalars at very high mass

"Compressed", "Light neutralino"

$m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^{\pm}_1)$	h-50	h-100
$m(\tilde{\ell})$	h-100	h/2
$m(\tilde{\chi}^0_1)$	h-150	100

h = min(gl, sq mass)



For m(squark) > m(gluino) :
BR(gluino->LSP) increases to ~90%

For m(gluino) = m(squark) + 10 GeV
Exclusion of
squarks below 480 (600) GeV in the "compressed" ("light neutralino") scenario

Interpretation : Phenomenological MSSM

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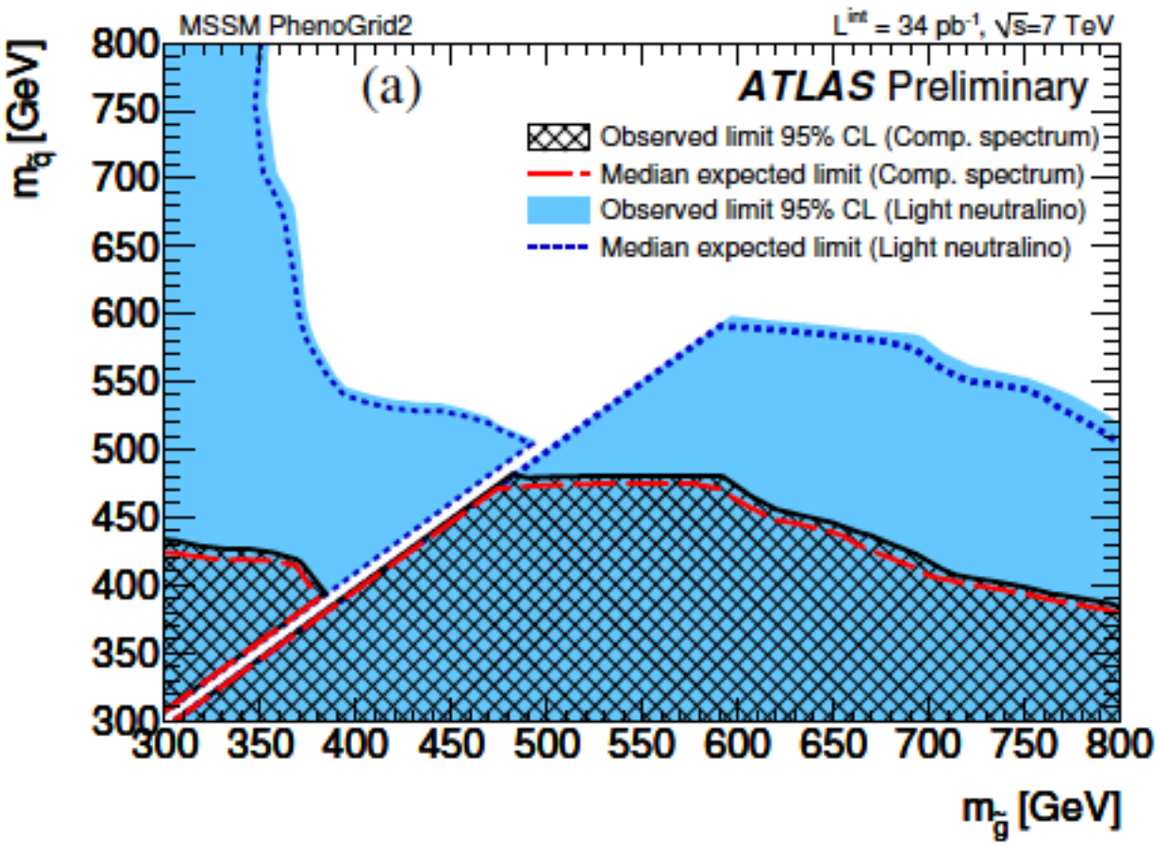
$m(\tilde{\chi}^0_1)$	h-150	100

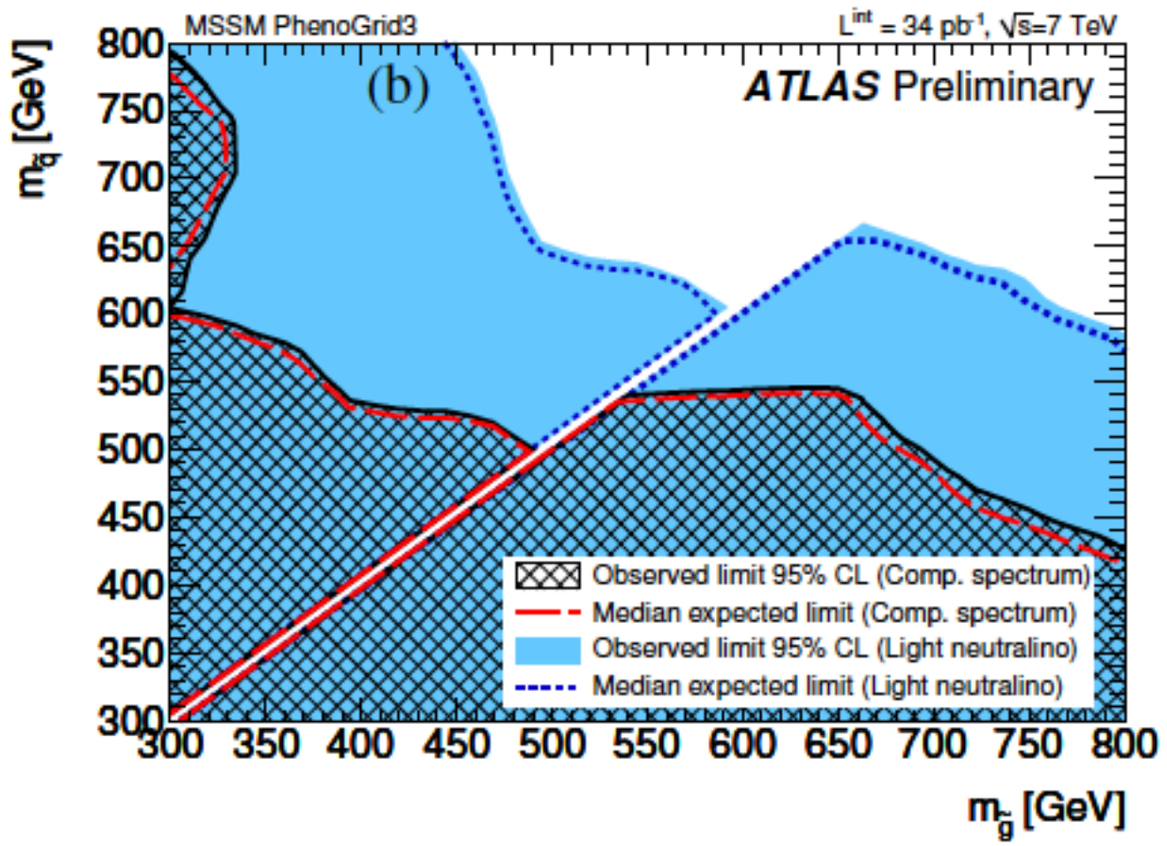
h = min(gl, sq mass)

Right plot

- right-handed sfermions pushed to high mass
- cross-section slightly reduced
- lepton fraction increased (right-handed squarks decay to bino-like LSP)

For m(gluino) = m(squark) + 10 GeV
Exclusion of
squarks below 540 (670) GeV in the "compressed" ("light neutralino") scenario





Summary

- LHC SUSY searches have begun
- Presented results from 2010 data in search channels

  1-leptons + Jets + E_T^{miss}

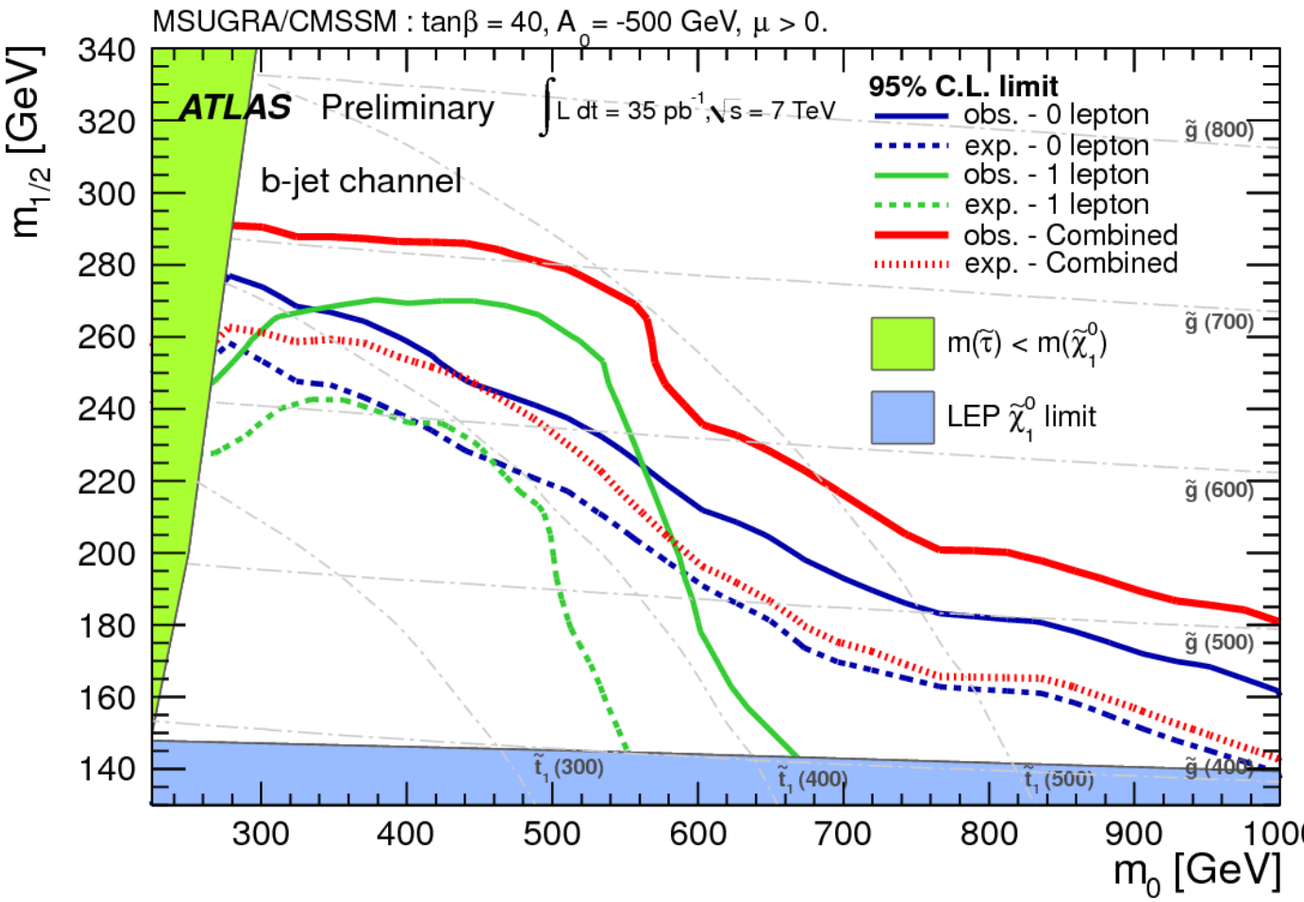
  ≥1-leptons + b-jets + E_T^{miss}

  ≥3-leptons + Jets + E_T^{miss}

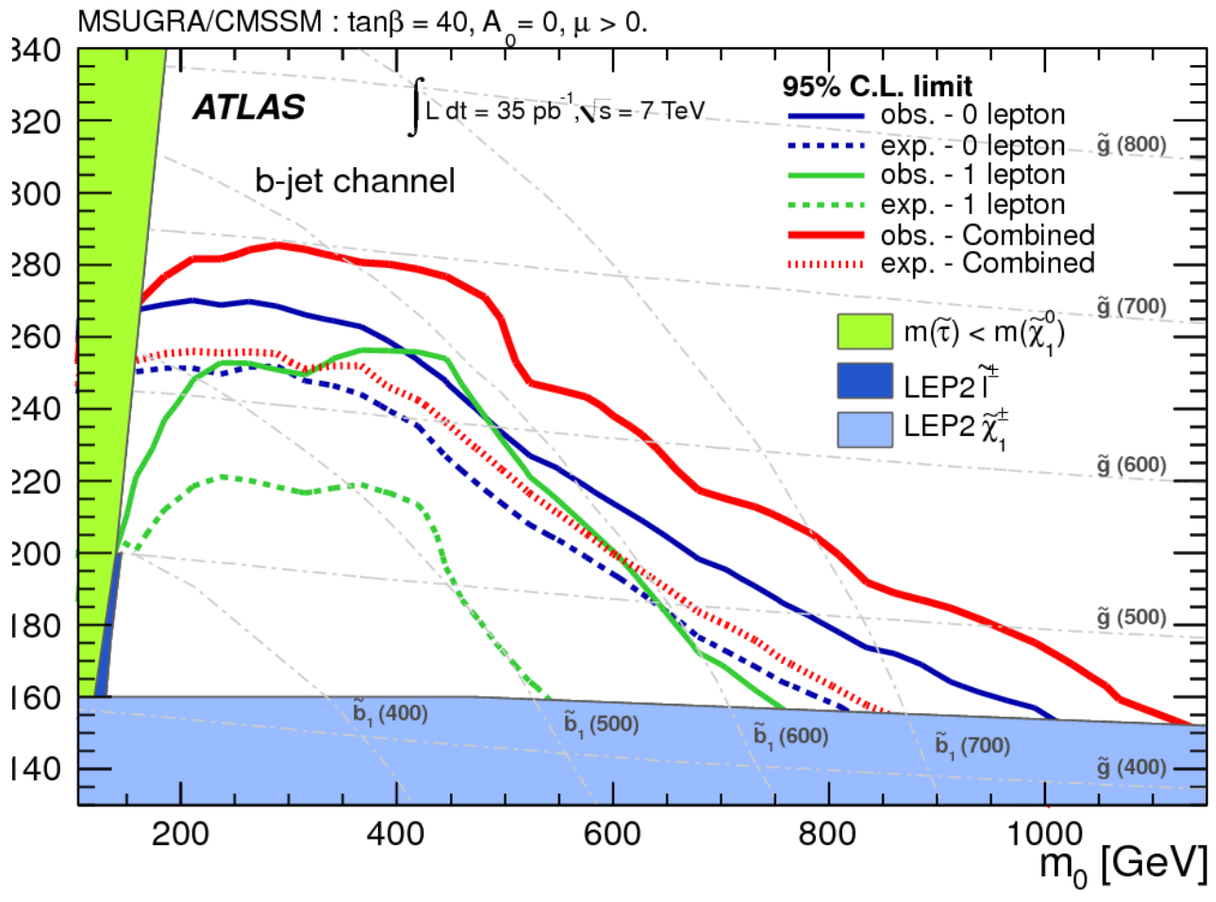
- Data agree with SM expectation within uncertainties
- No SUSY "just around the corner" of LEP/Tevatron limits
- Limits extend up to $M_{gluino} = M_{squark} > 815$ GeV (MSUGRA/CMSSM)

Backup Slides

bjets Interpretation : MSUGRA/CMSSM



A_0=-500



A_0=0

If **A_0=0 => A_0=-500** :
sbottom and stop masses decrease by ~10% and ~30% respectively.
1-lepton sensitivity extends 0-lepton by ~20 GeV in $m_{1/2}$ for $m_0 < 600$ GeV