Search for Supersymmetry in jets + missing transverse momentum final states with the ATLAS detector

Bundesministerium für Bildung und Forschung

FSP 101 ATLAS

Michael Rammensee (Universität Freiburg)
on behalf of the **ATLAS collaboration**

UNI FREIBURG

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Introduction

• Dominant SUSY particle production at LHC:

squark-squark, squark-gluino, gluino-gluino

• Decay in cascades to Lightest Susy Particle (LSP)

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

• Assume ***R-Parity conservation*** → the LSP is stable and escapes detector unseen

→ final states with **jets** and **missing transverse momentum**

• Update of analysis of 2010 7TeV data (35 pb^{-1}), *ArXiV:1102.5290* (accepted by PLB)

• Results presented in this talk correspond to **165 pb^{-1}** recorded in 2011, *ATLAS-CONF-2011-086*

Analysis strategy

- Three inclusive signal regions with different jet multiplicities

- Veto events with one or more leptons with $p_T > 20$ GeV

- Event selection is based on

E_T^{miss} and m_{eff}

$$m_{\mathrm{eff}} \equiv \sum_{i=1}^{n} |\mathbf{p}_{\mathrm{T}}^{(i)}| + E_{\mathrm{T}}^{\mathrm{miss}}$$

scalar sum of E_t^{miss} and p_T of selected 2,3 or 4 jets

Signal Region	≥ 2 jets	≥ 3 jets	≥ 4 jets
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 130	> 130	> 130
Leading jet p_{T} [GeV]	> 130	> 130	> 130
Second jet p_{T} [GeV]	> 40	> 40	> 40
Third jet p_{T} [GeV]	–	> 40	> 40
Fourth jet p_{T} [GeV]	–	–	> 40
$\Delta\phi(\mathrm{jet}_i, E_{\mathrm{T}}^{\mathrm{miss}})_{\mathrm{min}}$ $(i = 1, 2, 3)$	> 0.4	> 0.4	> 0.4
$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}$	> 0.3	> 0.25	> 0.25
m_{eff} [GeV]	> 1000	> 1000	> 1000

Background estimation: Overview

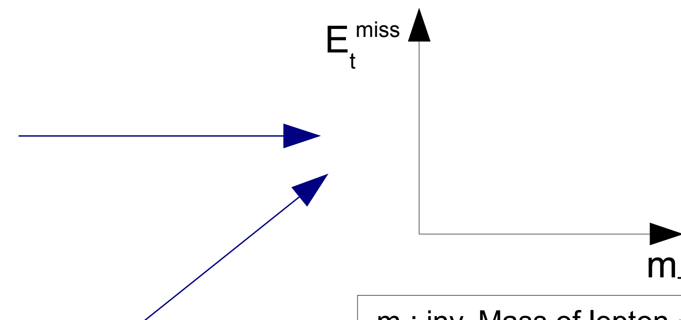
Dominant sources of background are:

Transfer function(TF): ratio of expected event counts between control and signal region for a given process

- **Z + jets:** irreducible $Z \rightarrow \nu\nu$ +jets,
  - fully data driven with γ +jets sample,
  - control measurements $Z \rightarrow ee$ and $Z \rightarrow$ mumu

- **W+jets :** $W \rightarrow \tau\nu$ and $W \rightarrow l\nu$ where l is not reconstructed control measurement via $W \rightarrow e\nu$ and $W \rightarrow \mu\nu$ defined in E_t^{miss}, m_T plane with veto on b-jets

- **Top :** Hadronic τ decays in $t\bar{t} \rightarrow b\bar{b}\tau\nu qq$ and single top control measurement defined in E_t^{miss}, m_T plane with b-jet requirement



m_T: inv. Mass of lepton + E_t^{miss} object

- **QCD multi jet:** mis-reconstruction leads to fake E_t^{miss}, neutrino production in heavy flavour decay
  - control region with inverted angular separation cuts,
  - fully data-driven TF by measuring detector response

All control regions and transfer functions are built into global likelihood function to get consistent estimates in all control regions as well as in the signal region

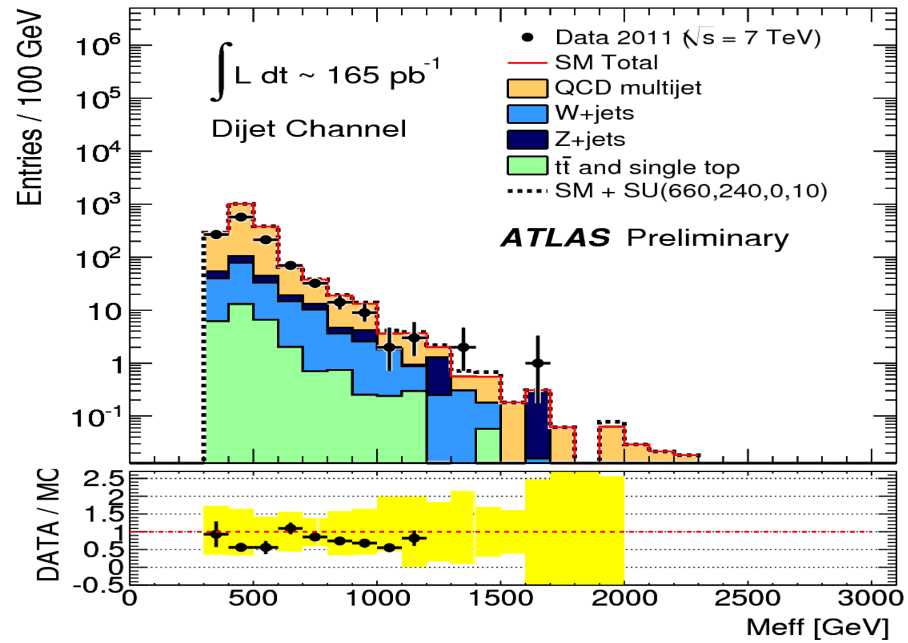
Background estimation: QCD multi jets

Targeted at

mis-measured jets or emission of neutrino in heavy flavor decay

Control region:
- Cut on angular separation between jets and E_T^{miss} inverted and tightened

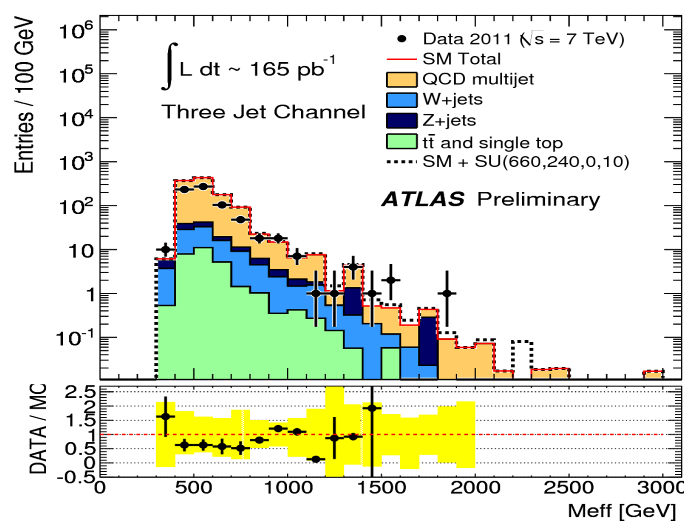
- Jets and E_T^{miss} point into **same direction**

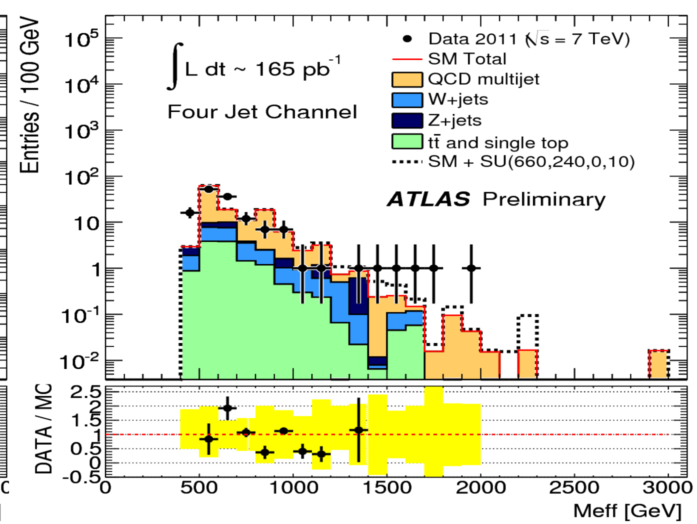


- TF from data, Extrapolate to signal region via jet smearing at low E_t^{miss}

- TF is ~ 0.05,~0.15 and ~0.35 for 2-jet,3-jet and 4jet SR

SUSY reference point:
CMSSM/MSUGRA
tanβ=10m,A_0=0
m0=660,m12=240





Background estimation: Z + jets

Irreducible $Z \rightarrow \nu\bar{\nu}$ + jets generates large E_T^{miss}

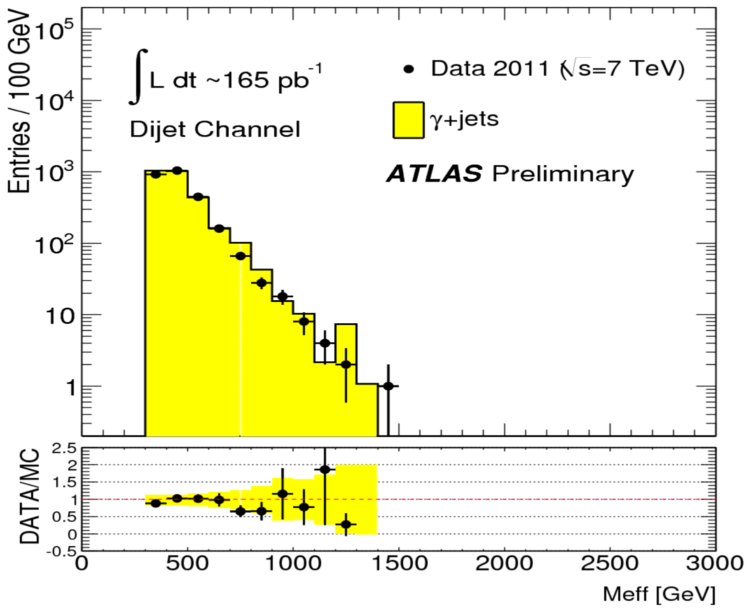
Fully data driven baseline method*:*

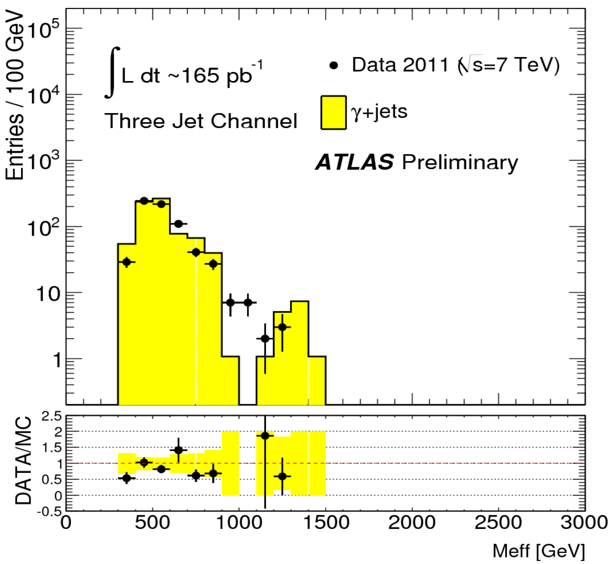
- Isolated photon + jets sample as control region
- At large p_T cross sections of γ,Z differ only by coupling constants to quarks

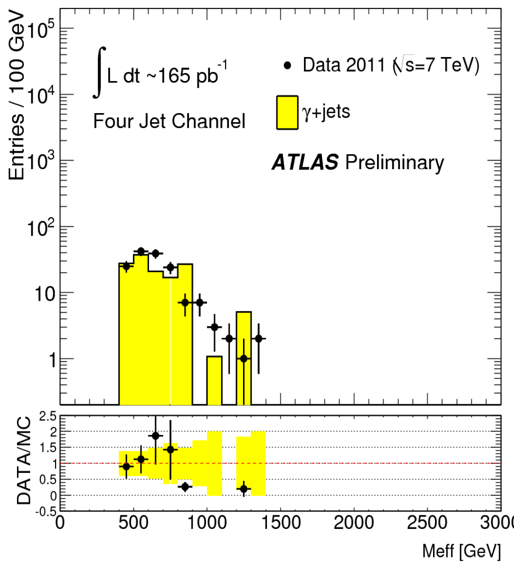
$$R_{Z/\gamma} = \frac{d\sigma(Z + \mathrm{jets})/dp_\mathrm{T}}{d\sigma(\gamma + \mathrm{jets})/dp_\mathrm{T}}$$

- Reconstructed momentum of photon is added to E_t^{miss}
- TF of order ~ 0.4 for all SR

Cross checks via Z->ee, Z->μμ and W+jets show consistency

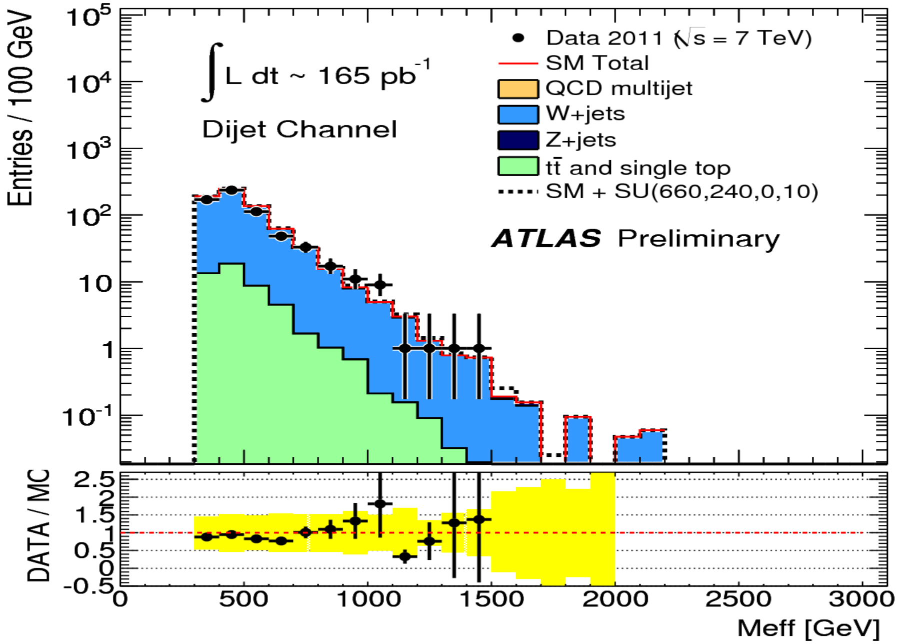






Background estimation: W + jets

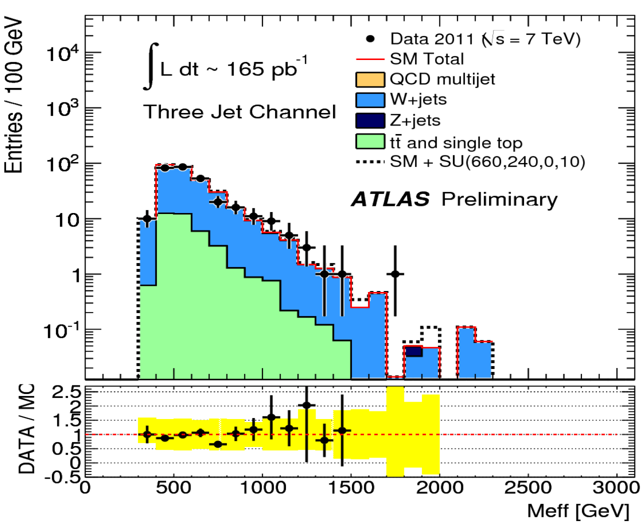
W → lν + jets with lepton measured as jet

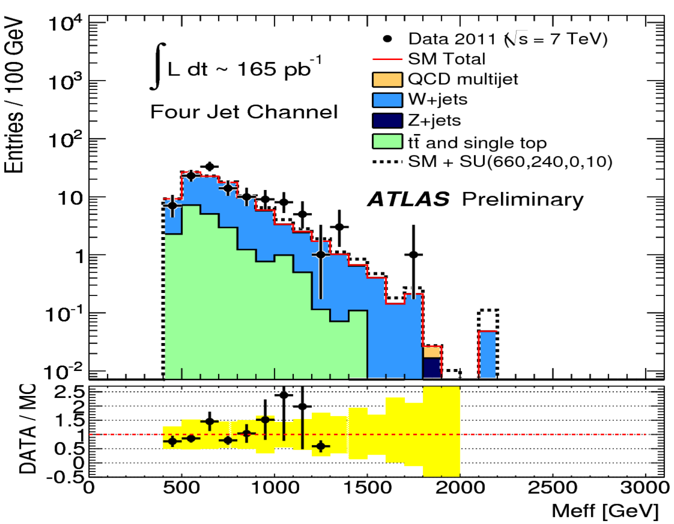


Control region:

- one lepton
- significant E_T^{miss}
- Transverse mass consistent with W
- Veto against b-jets

Lepton is replaced with jet
to estimate kinematic quantities

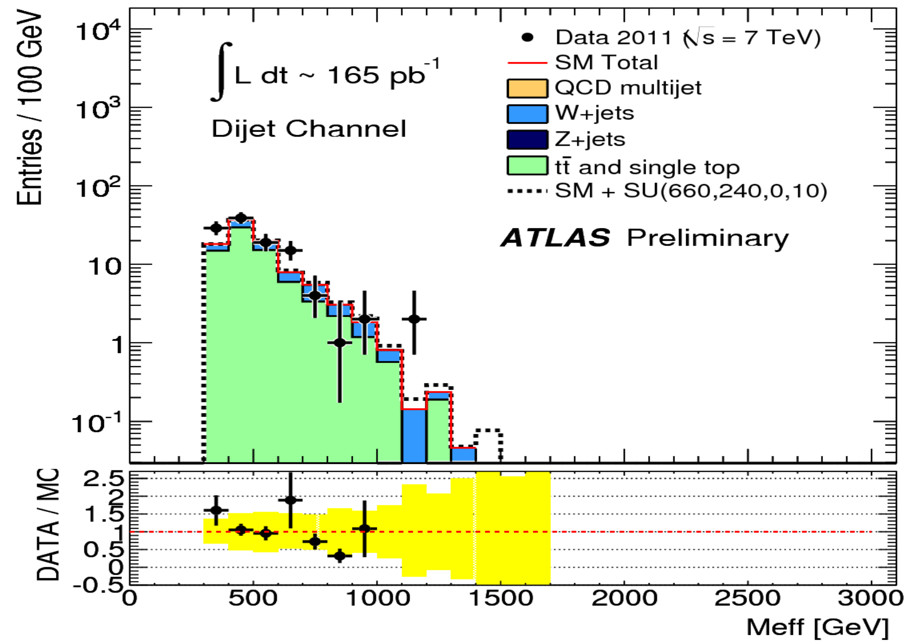




- Extrapolation(TF) to SR via MC ALPGEN,
- TF is ~ 0.1 for all SR

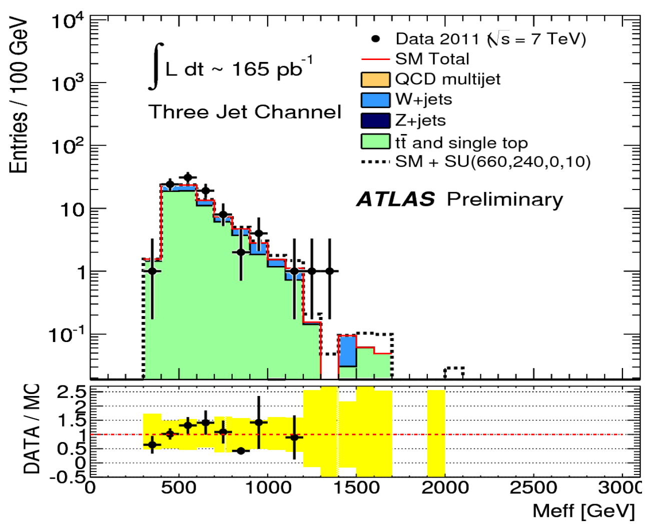
Background estimation: tt + jets

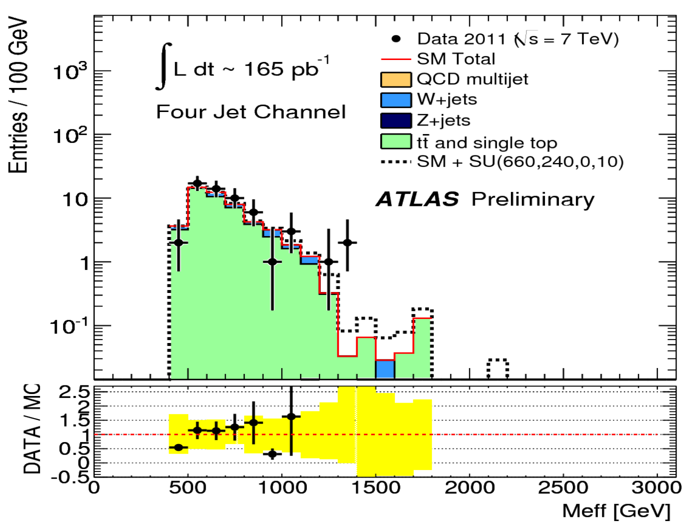
$t\bar{t}$ + jets and single top,
mainly hadronic τ decays in $t\bar{t} \rightarrow b\bar{b}\tau\nu qq$



Control region:

- one lepton
- significant E_T^{miss}
- Transverse mass consistent with W
- **b-jet requirement**





Extrapolation(TF) to SR
via MC MC@NLO,
TF is ~0.05 for all SR

Cross checks with tau embedding shows consistency

Background estimation: systematic uncertainties

Uncertainty due to pileup included into jet energy scale(JES) and jet energy resolution(JER) calibration via the difference of observed averaged number of collisions in 75 ns to 50 ns bunch spacings:

- uncertainty of 0.07 * p_T to JER for jets in forward region
- uncertainty of 0-7% on p_T to JES

Systematic uncertainties on *dominant* sources of background are (numbers refer to expected event count in signal region):

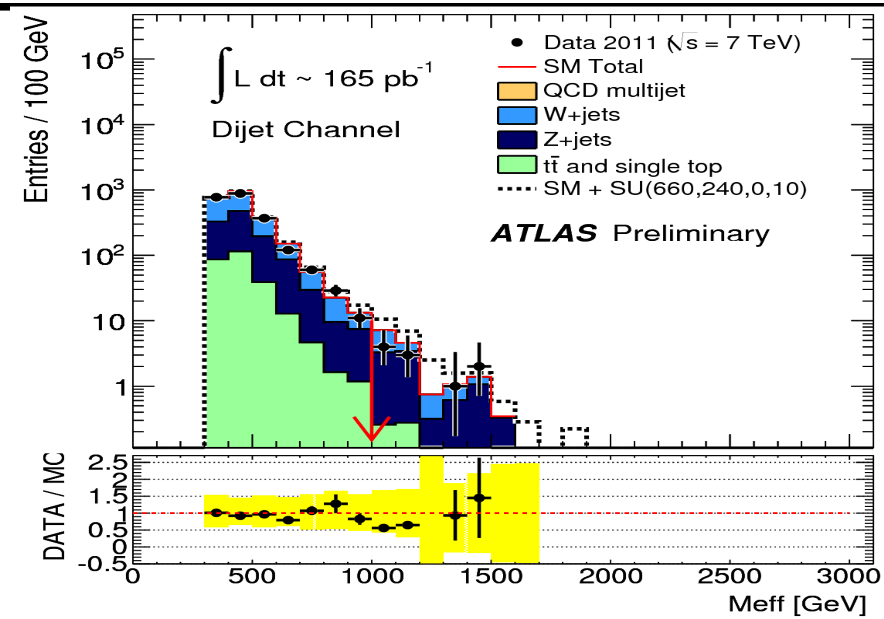
Luminosity 4.5%

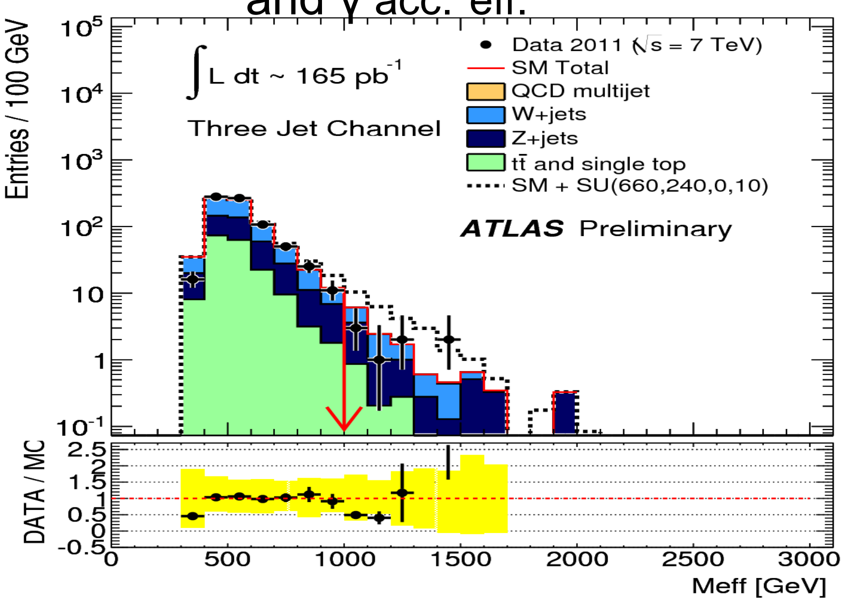
- **Z + jets:**
  - γ acc.*eff. ~15-20%
  - stat. Uncertainty ~ 25% (*4-jet sample only*)
- **W+jets :**
  - JES: ~ 10-20%
  - JER: ~ 10-20%
  - b-tagging: ~ 15-25%
  - MC modeling: ~15 %
- **Top :**
  - JES: ~ 50 %
  - MC modeling: ~ 40% (Alpgen vs. MC@NLO)
  - b-tagging: ~ 30%
- **QCD multi jet:**
  - Jet smearing: 20%-60%

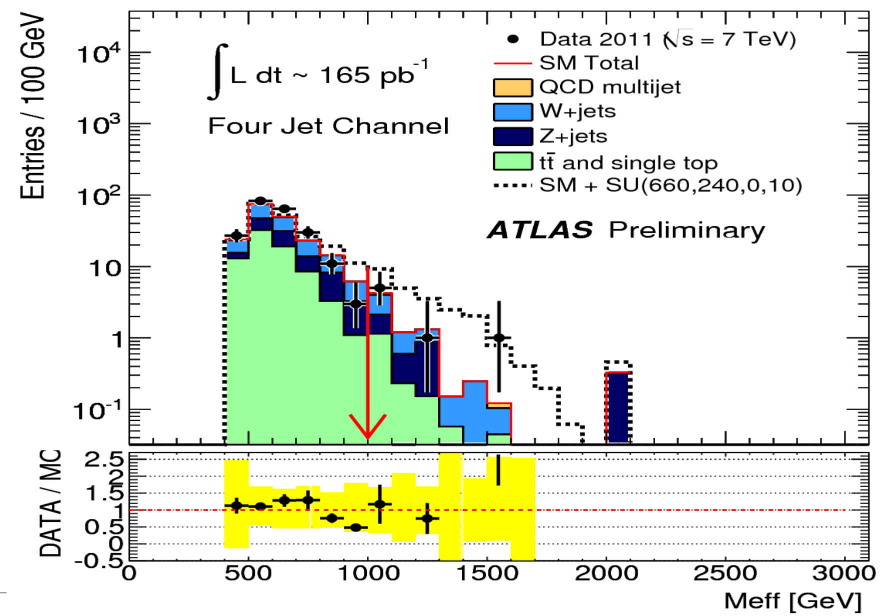
Results I

Process	Signal Region		
	≥ 2 jets	≥ 3 jets	≥ 4 jets
$Z \to (\nu\nu)$+jets	5.6 ± 2.1	4.4 ± 1.6	3.0 ± 1.3
$W \to (\ell\nu)$+jets	6.2 ± 1.8	4.5 ± 1.6	2.7 ± 1.3
$t\bar{t}$+ single top	0.2 ± 0.3	1.0 ± 0.9	1.4 ± 0.9
QCD jets	0.05 ± 0.04	0.21 ± 0.07	0.16 ± 0.11
Total	12.1 ± 2.8	10.1 ± 2.3	7.3 ± 1.7
Observed	10	8	7

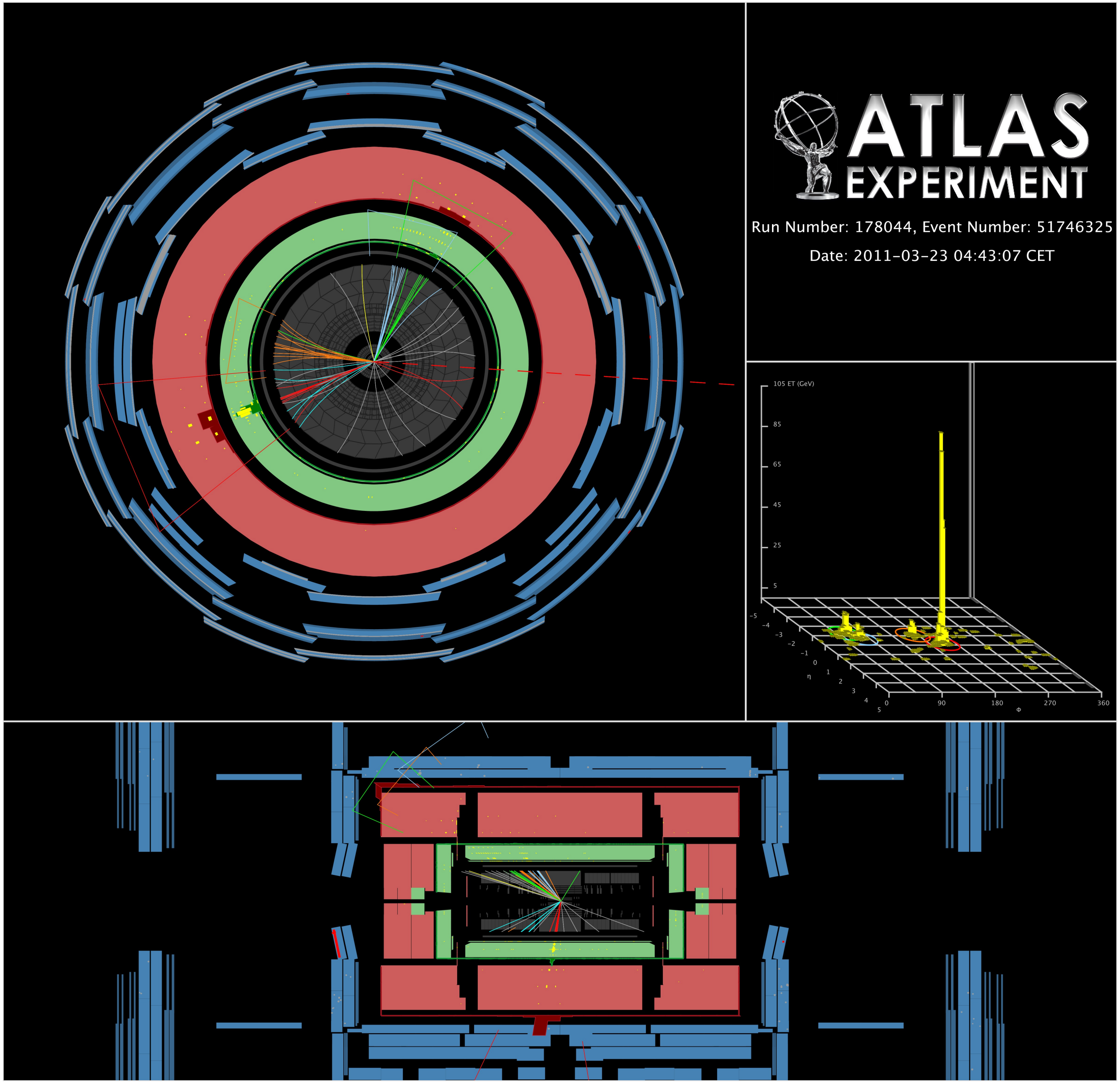
Uncertainty ~ 25%,
dominated by jet energy scale, jet energy resolution, and γ acc.*eff.







Event Display



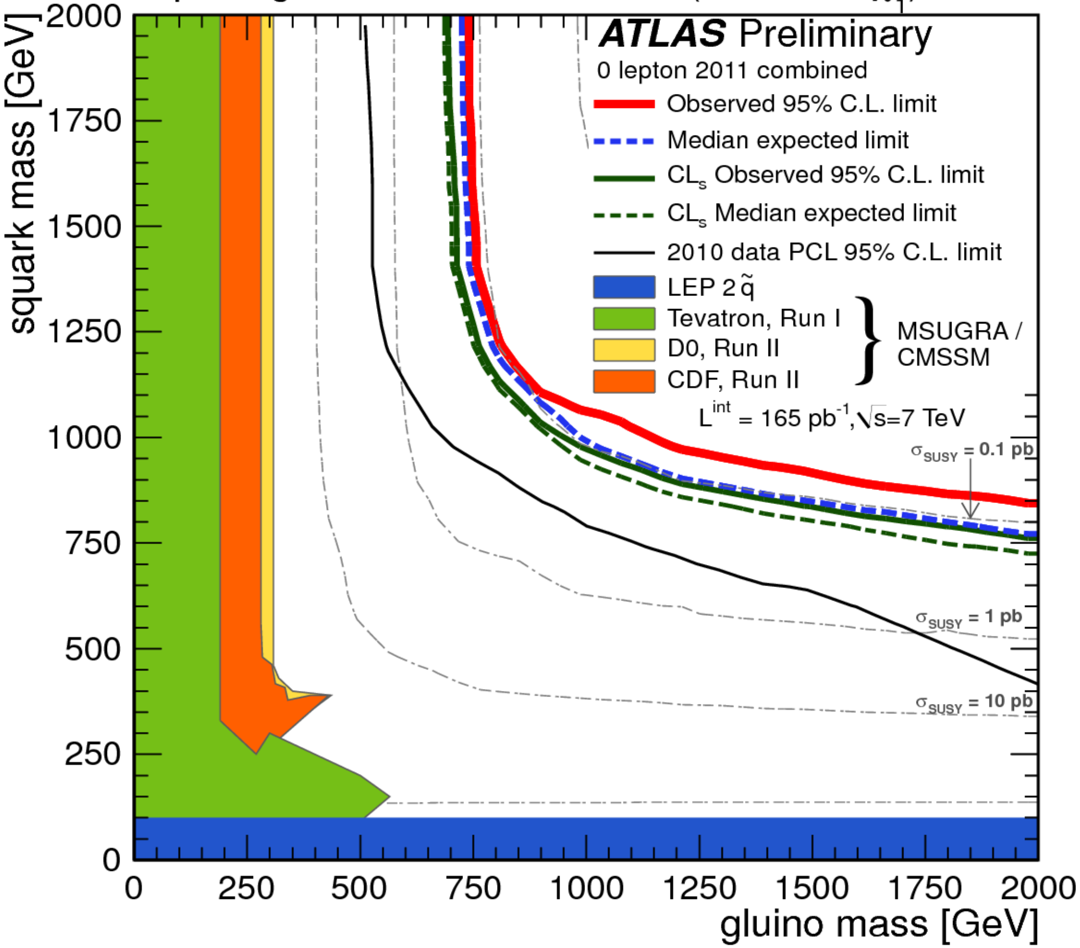
4jet event with largest $\mathbf{m}_{\mathbf{eff}}$

$\mathbf{m}_{\mathbf{eff}}$= 1548 GeV
$\mathbf{E}_{\mathbf{t}}^{\mathbf{miss}}$ = 547
Jet pT=636, 189, 96, 81 GeV

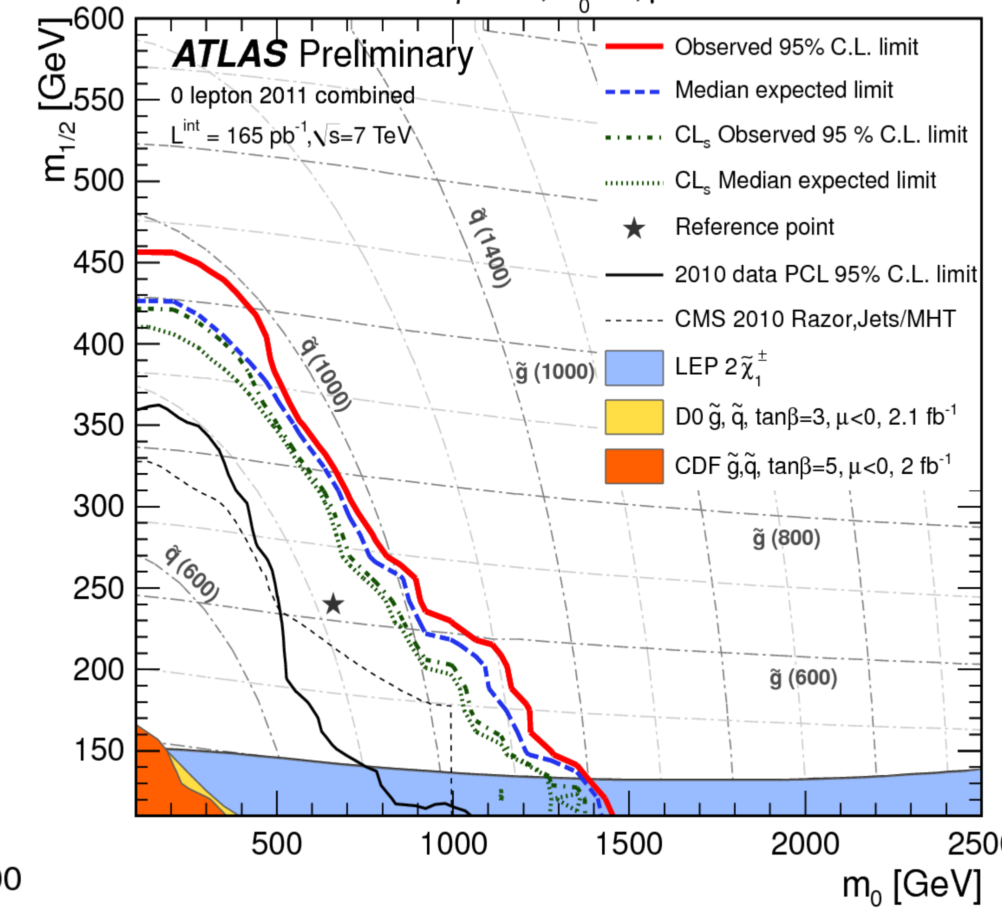
Results II

Profile log likelihood ratio test, chosen best *expected* signal region per model point

Squark-gluino-neutralino model (massless $\tilde{\chi}_1^0$)



MSUGRA/CMSSM: $\tan\beta = 10$, $A_0 = 0$, $\mu>0$



Exclude gluino masses < 725 GeV at 95% C.L.
If m(gluino)=m(squark) < 1025 GeV at 95% C.L. If m(gluino)=m(squark) < 950 GeV at 95% C.L.

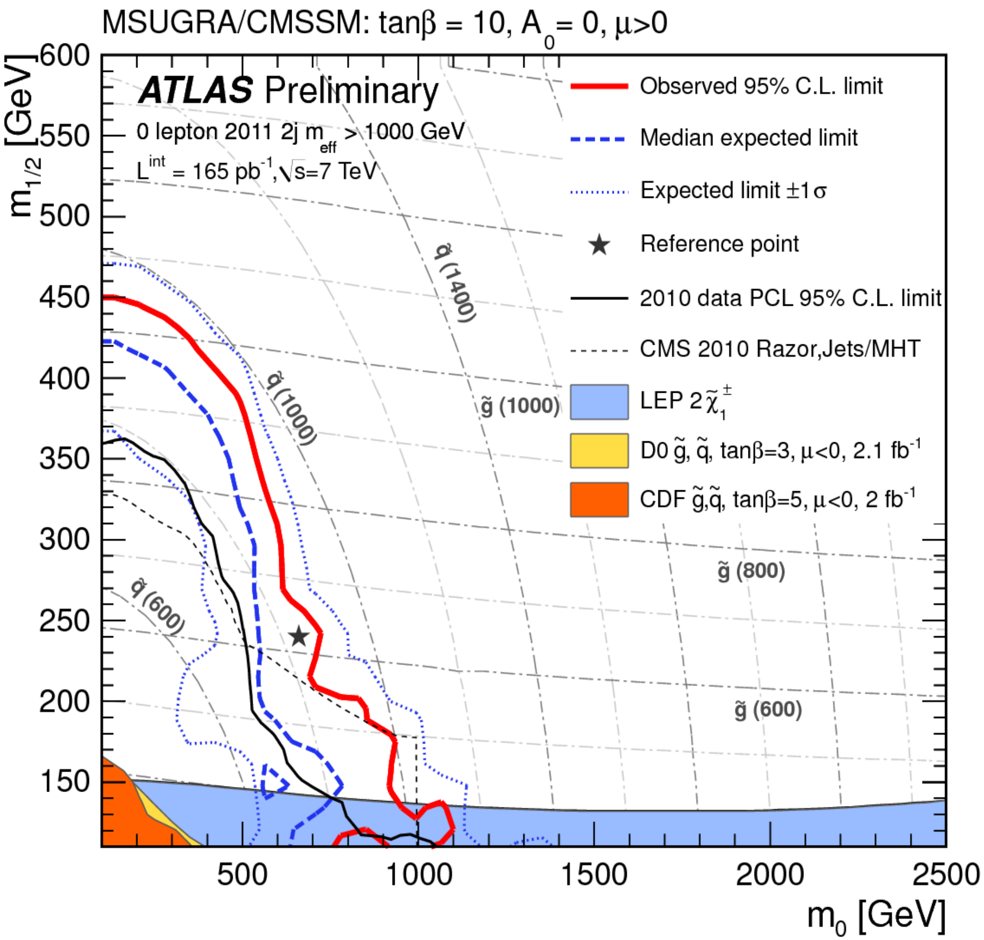
Results III and Summary

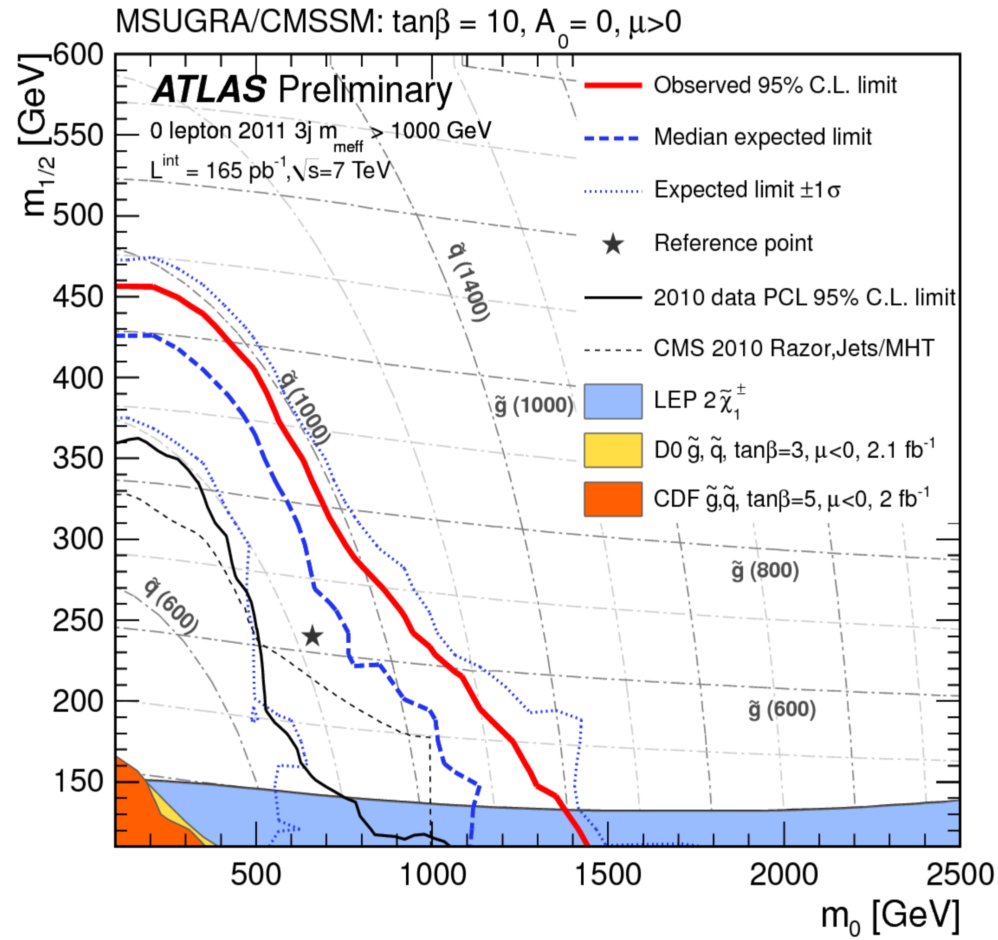
- Analysis of 165 pb^{-1} 7 TeV data recorded in 2011
- Inclusive jets + missing transverse momentum final states using different jet multiplicities (2-,3- and 4 jet)
- Dominating backgrounds are Z+ jets, W+jets, $t\bar{t}$, QCD multi jets and single top
- **No excess seen, observation agrees well with SM**
- Set limits @ 95 C.L in simplified models m(gluino) < 725 GeV
  in simplified models if m(gluino)=m(squark) < 1025 GeV
  in CMSSM if m(gluino)=m(squark) < 950 GeV

Exclude non - SM cross section *acceptance * efficiency at 95 % C.L.

SR (>= **2 jet**)	SR (>= **3 jet**)	SR (>= **4 jet**)
35 fb	**30 fb**	**35 fb**

BACKUP


MSUGRA/CMSSM: tanβ = 10, A0 = 0, μ>0
ATLAS Preliminary
0 lepton 2011 2j meff > 1000 GeV
Lint = 165 pb-1, √s=7 TeV
Observed 95% C.L. limit
Median expected limit
Expected limit ±1σ
Reference point
2010 data PCL 95% C.L. limit
CMS 2010 Razor,Jets/MHT
LEP 2 χ̃1±
D0 g̃, q̃, tanβ=3, μ<0, 2.1 fb-1
CDF g̃,q̃, tanβ=5, μ<0, 2 fb-1
q̃ (1400)
q̃ (1000)
q̃ (600)
g̃ (1000)
g̃ (800)
g̃ (600)
m1/2 [GeV]
m0 [GeV]
600
550
500
450
400
350
300
250
200
150
500
1000
1500
2000
2500


MSUGRA/CMSSM: tanβ = 10, A0 = 0, μ>0
ATLAS Preliminary
0 lepton 2011 3j meff > 1000 GeV
Lint = 165 pb-1, √s=7 TeV
Observed 95% C.L. limit
Median expected limit
Expected limit ±1σ
Reference point
2010 data PCL 95% C.L. limit
CMS 2010 Razor,Jets/MHT
LEP 2 χ̃1±
D0 g̃, q̃, tanβ=3, μ<0, 2.1 fb-1
CDF g̃,q̃, tanβ=5, μ<0, 2 fb-1
q̃ (1400)
q̃ (1000)
q̃ (600)
g̃ (1000)
g̃ (800)
g̃ (600)
m1/2 [GeV]
m0 [GeV]
600
550
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450
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350
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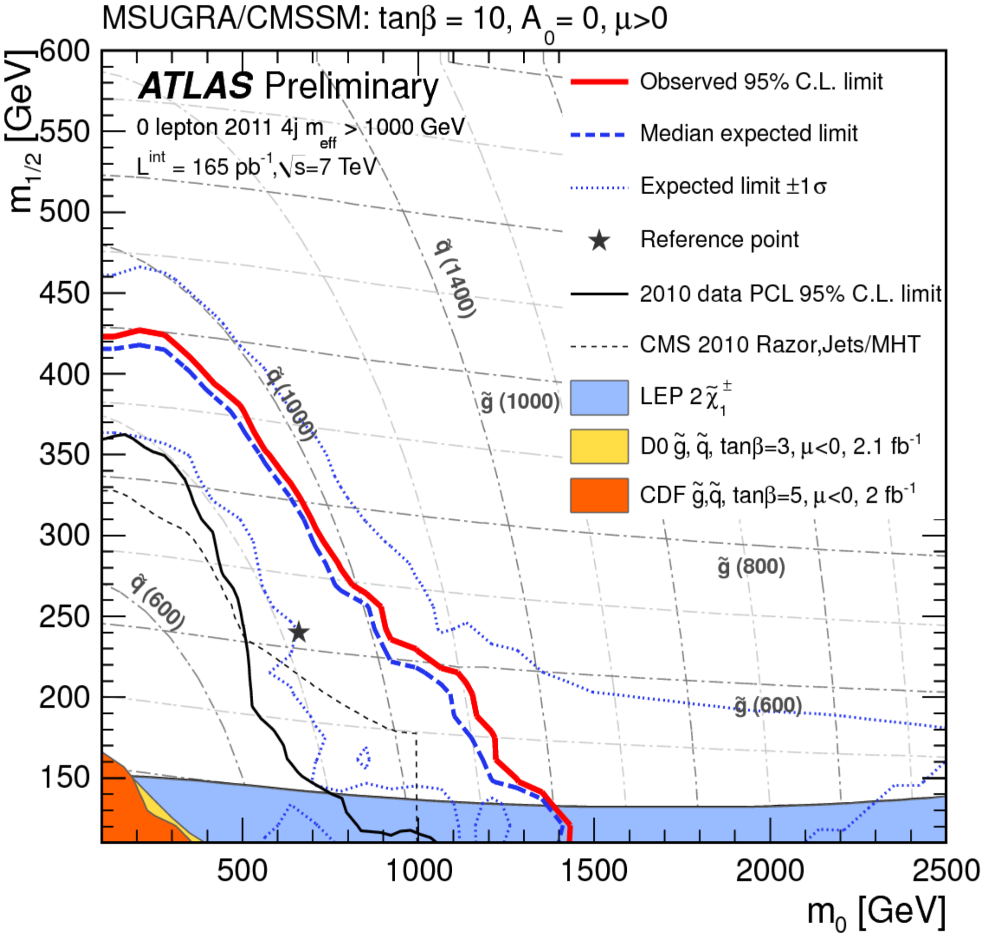
2500



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ATLAS Preliminary
0 lepton 2011 4j meff > 1000 GeV
Lint = 165 pb-1, √s=7 TeV
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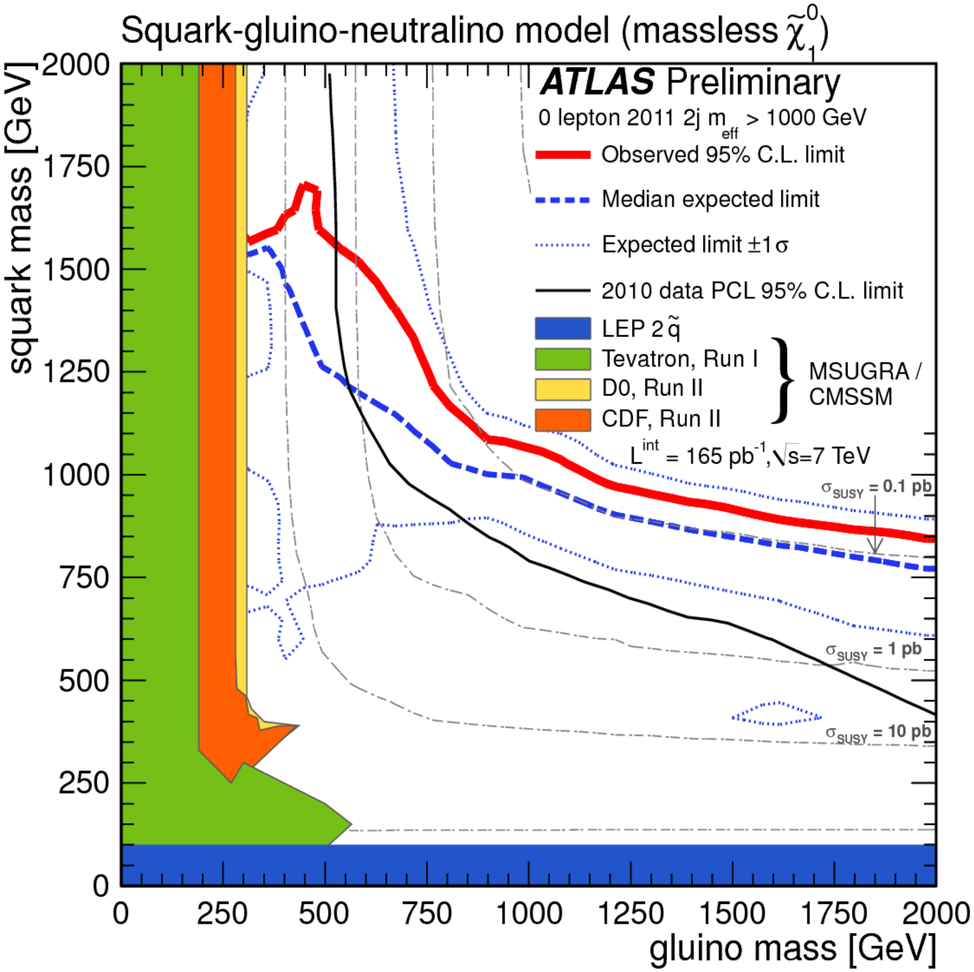
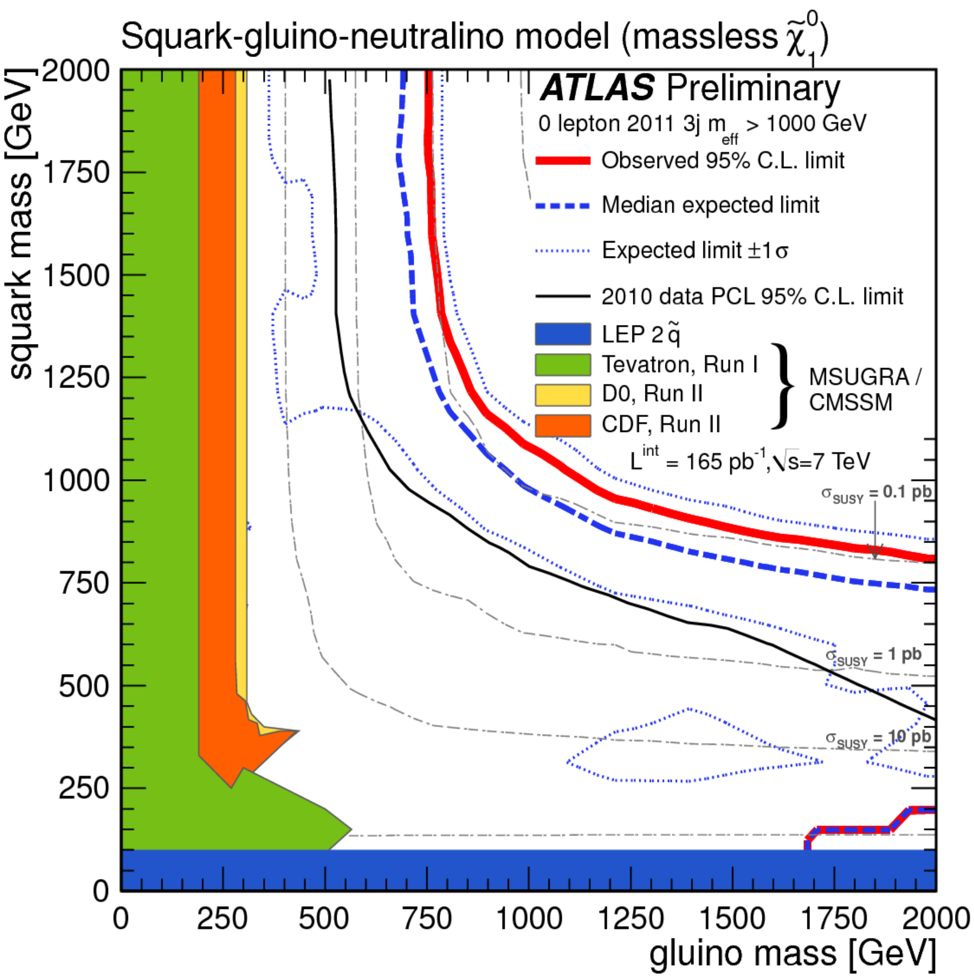
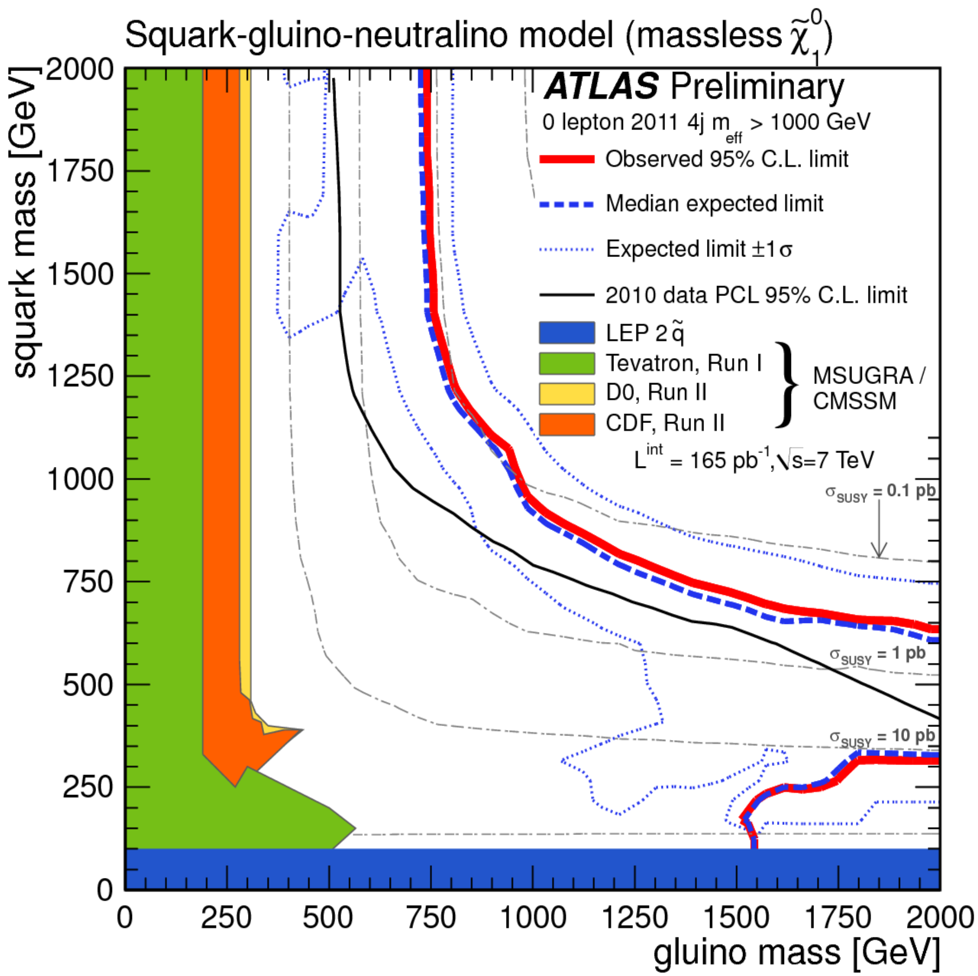
Median expected limit
Expected limit ±1σ
Reference point
2010 data PCL 95% C.L. limit
CMS 2010 Razor,Jets/MHT
LEP 2 χ̃1±
D0 g̃, q̃, tanβ=3, μ<0, 2.1 fb-1
CDF g̃,q̃, tanβ=5, μ<0, 2 fb-1
q̃ (1400)
q̃ (1000)
g̃ (1000)
g̃ (800)
g̃ (600)
q̃ (600)
m1/2 [GeV]
m0 [GeV]



Squark-gluino-neutralino model (massless χ̃10)
ATLAS Preliminary
0 lepton 2011 2j meff > 1000 GeV
Observed 95% C.L. limit
Median expected limit
Expected limit ±1σ
2010 data PCL 95% C.L. limit
LEP 2 q̃
Tevatron, Run I
D0, Run II
CDF, Run II
MSUGRA / CMSSM
Lint = 165 pb-1, √s=7 TeV
σSUSY = 0.1 pb
σSUSY = 1 pb
σSUSY = 10 pb
squark mass [GeV]
gluino mass [GeV]


Squark-gluino-neutralino model (massless $\tilde{\chi}_1^0$)
ATLAS Preliminary
0 lepton 2011 3j m_{eff} > 1000 GeV
Observed 95% C.L. limit
Median expected limit
Expected limit ±1σ
2010 data PCL 95% C.L. limit
LEP 2 $\tilde{q}$
Tevatron, Run I
D0, Run II
CDF, Run II
MSUGRA / CMSSM
L^{int} = 165 pb^{-1}, $\sqrt{s}$=7 TeV
σ_{SUSY} = 0.1 pb
σ_{SUSY} = 1 pb
σ_{SUSY} = 10 pb
squark mass [GeV]
gluino mass [GeV]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Tevatron, Run I
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L^{int} = 165 pb^{-1}, $\sqrt{s}$=7 TeV
σ_{SUSY} = 0.1 pb
σ_{SUSY} = 1 pb
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squark mass [GeV]
gluino mass [GeV]