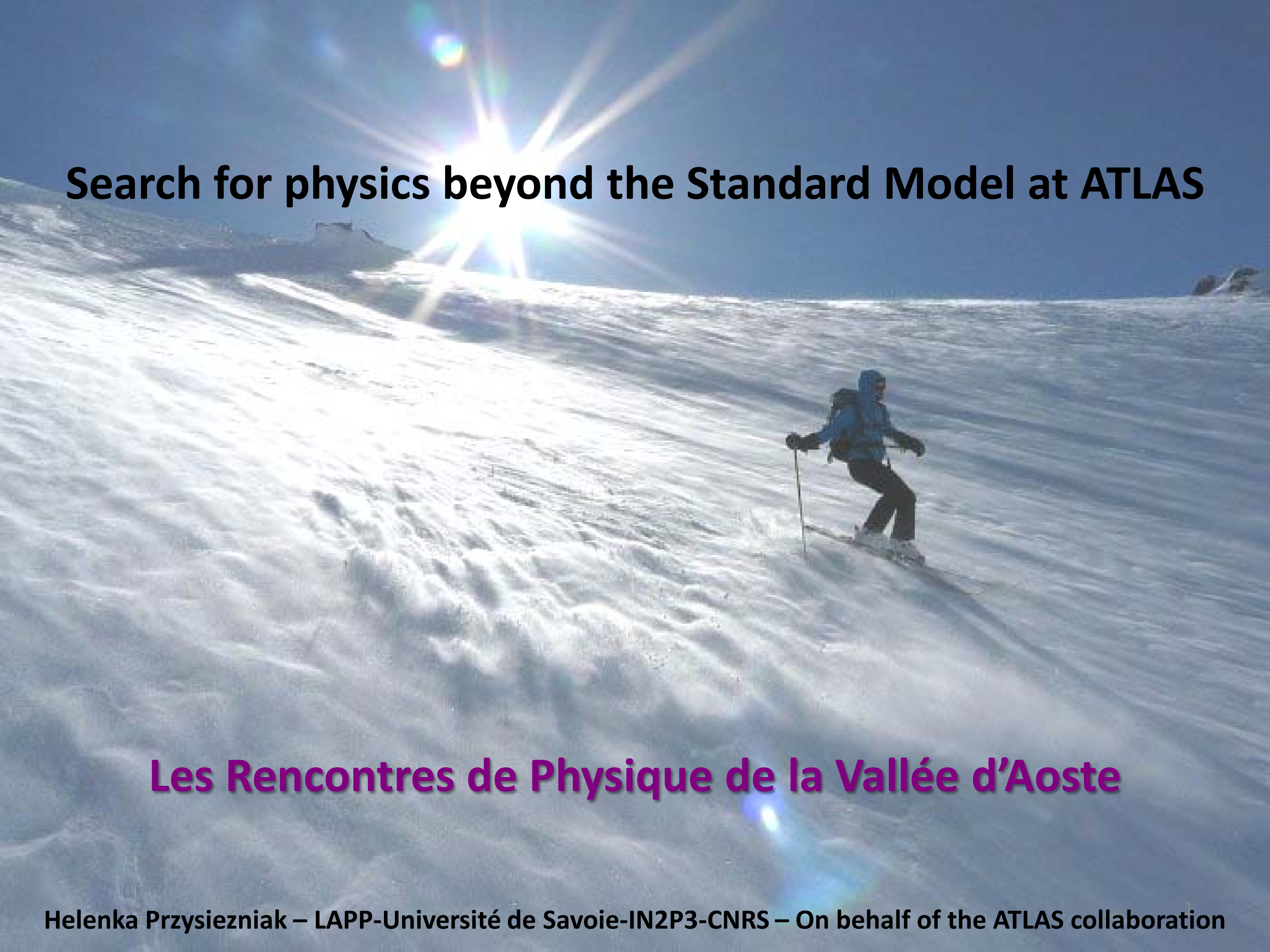


Search for physics beyond the Standard Model at ATLAS

Les Rencontres de Physique de la Vallée d'Aoste

Helenka Przysiezniak – LAPP-Université de Savoie-IN2P3-CNRS – On behalf of the ATLAS collaboration

Wassup?

What's up in searches – SUSY and Exotics – at the LHC

LHC-ATLAS

2010-11	$\sqrt{s}$ = 7 TeV	4.7 fb-1
2012	$\sqrt{s}$ = 8 TeV	21 fb-1

Although a new boson has been discovered at the LHC
"it" can't explain "everything" e.g.

- Hierarchy issues $M_{weak} \rightarrow M_{planck}$?
- Dark matter/energy
- Gauge Coupling Unification

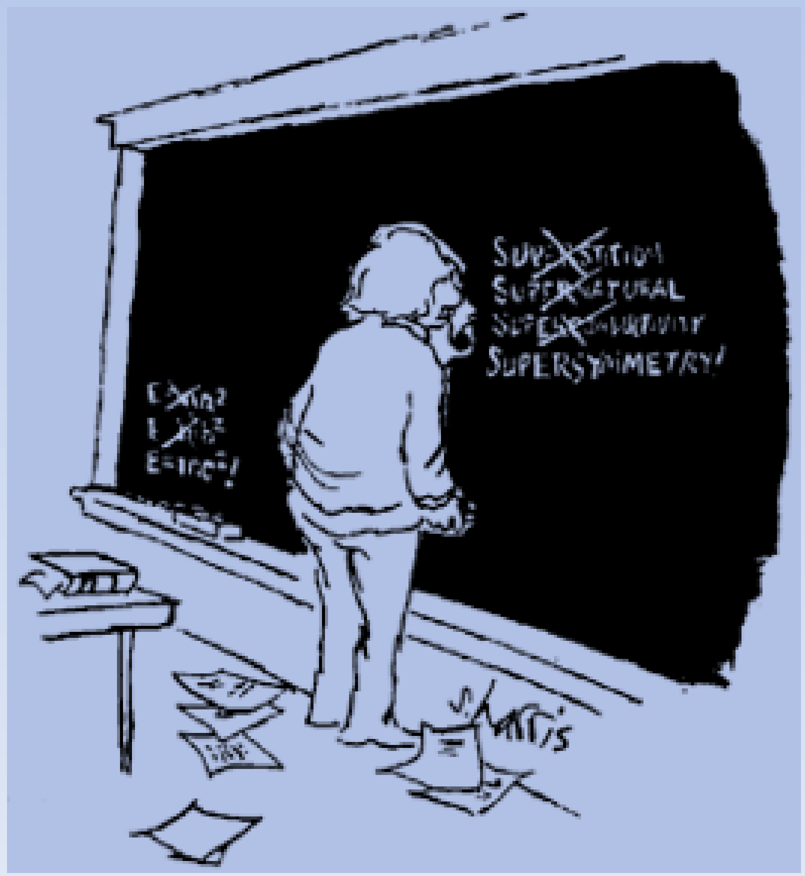
etc.

Exotics and SUSY searches excluding more and more phase space.

Signature and model based searches
Sometimes cross-over with SM/Exotics/SUSY/Top/Higgs searches

SU$_{\text{per}}$SY$_{\text{mmetry}}$

@ √s=8TeV
unless otherwise mentioned
all exclusions @ 95% C.L.



Broken

We know SUSY must be broken (or absent)

Absinth

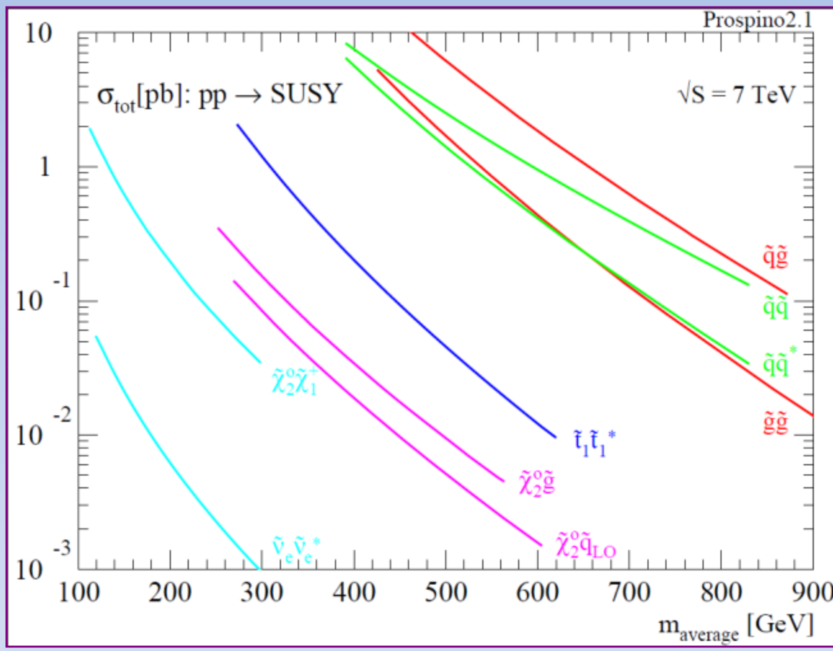
The analyses shown here consider

MSSM

→ gravity mediated MSUGRA or gauge mediated GMSB breaking

→ R-parity conserving

→ Prompt particles



Production of

(in order of decreasing cross sections) :

- **squarks/gluinos**
- **3rd gen. stop/sbottom**
- **gauginos/sleptons**

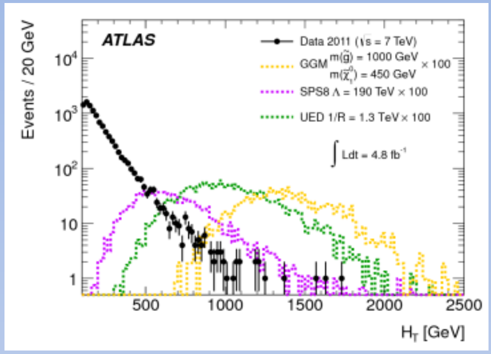
If m~125 GeV boson is MSSM Higgs then in a "Natural spectrum"
Light stop-sbottom and charginos should be fairly light (<~ 500 GeV)
m(gluinos) <~1500 GeV [arxiv 1302.2146v1, 1110.6670]

→ Hence emphasize search for

→ gluino mediated and direct production of stops or sbottoms

→ direct production of charginos and neutralinos (see Stewart Martin-Haugh's talk)

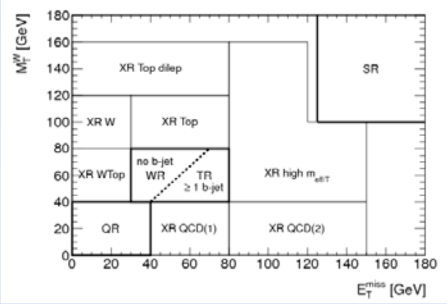
Searching for SUSY and Exotics (non SUSY) – Experimental issues



Signal and background separation ; exploit :

- o High-mass/high-MET/Signal-Background mass gap
- o More than one signal region
- o Jet, lepton multiplicities; high ET photons
- o Variables : MET , M_{eff} , m_{CT} , etc.

Background estimation



- o Using **control regions (CRs)** in data or MC
  and apply to **signal region (SR)** using transfer factors
- o Reducible backgrounds directly from data :
  fake leptons/b-jets, charge flip, etc.
- o Irreducible backgrounds using MC
- o Fitting functional form to data (resonances)

Mains systematics

- o Theoretical uncertainties : scale, PDFs, parton showering
- o JES/JER, Lepton/Photon id, b-tagging, luminosity, MC statistics, etc.
- o Background extrapolations

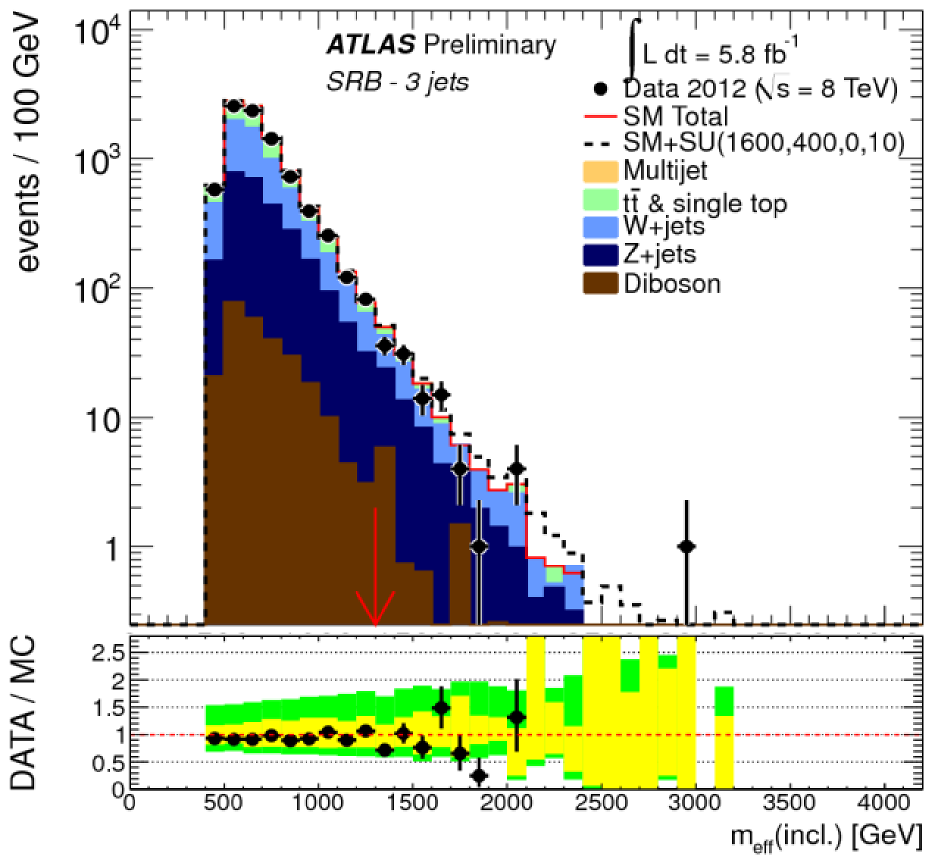
Limit setting : 95% Confidence Level (C.L.)

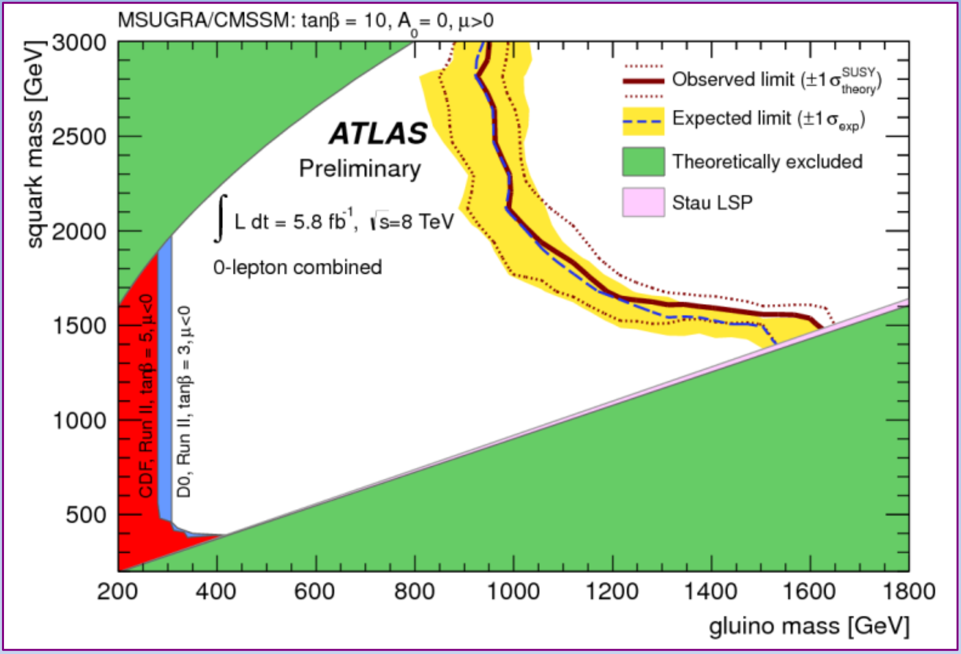
N.B. The following are a selection of recent SUSY and Exotics (non SUSY) analyses performed and clearly NOT A SUMMARY OF ALL ANALYSES !!!
Many upcoming updates.

Inclusive searches : (lepton+) jets + MET

Signal : jets + MET
15 signal regions (SRs)
4 control regions (CRs)/SR for background estimation
Backgrounds
W/Z+jets backgrounds, top → from CR ; Diboson → MC

Variables e.g. $M_{eff}=\sum p_T^{jets} + E_t miss\ (+p_T^{lepton})$

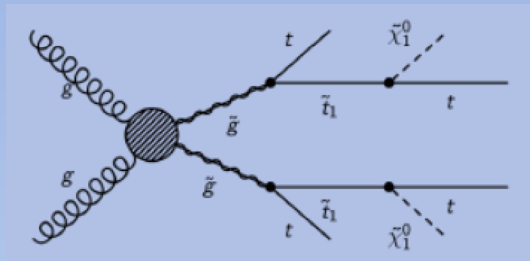




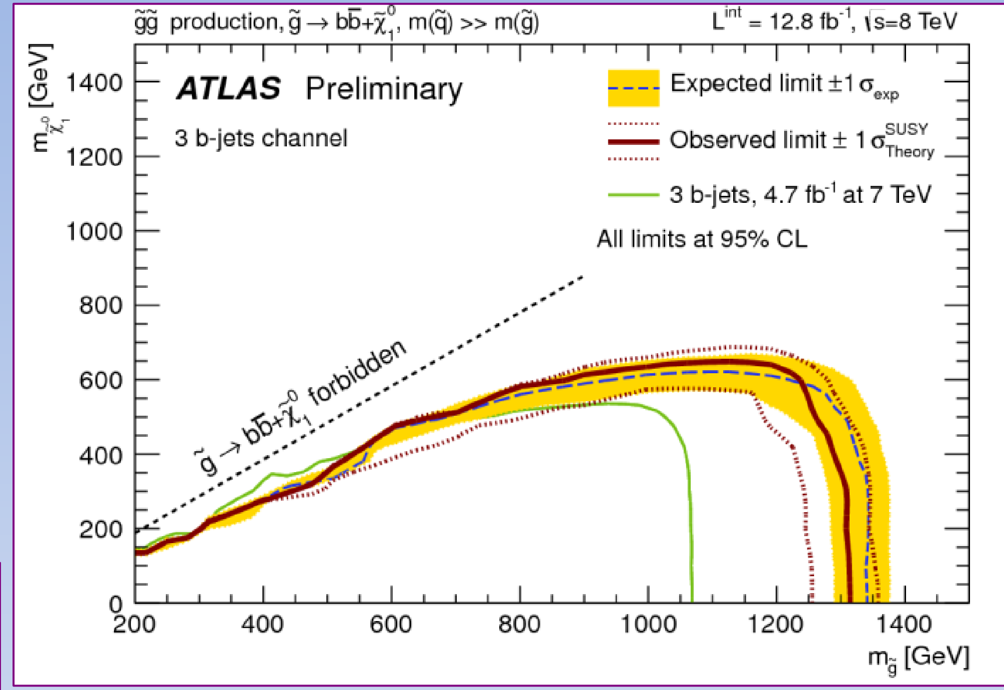
MSUGRA/CMSSM tanβ=10, A_0=0 and μ>0
Exclude @95% C.L.
m(squark)=m(gluino) < 1500 GeV
m(gluino)< ~900 GeV at high m_0
from lepton+jets+MET
Also interpretations in various "process-driven" <<simplified models>>

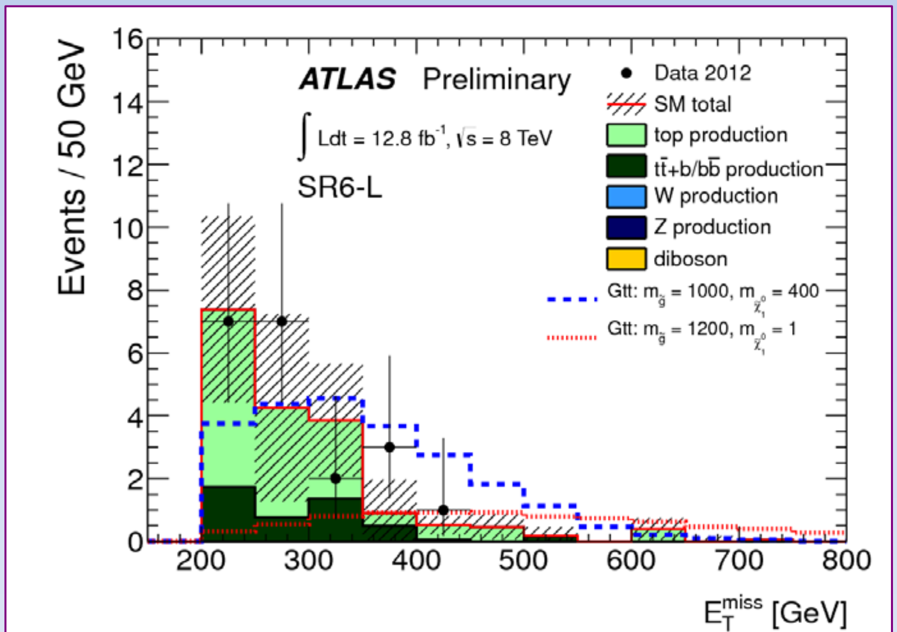
ATLAS-CONF-2012-109 (103; 104)

Gluino pair production : 3 b-jets + MET



Gluino pair production
gluino→ sbottom$_1$+b (Gbb) or stop$_1$+ t (Gtt)
18 signal regions
Main backgrounds
Top → from MC ; ttbar + jets : from data CR
Variables e.g. MET, Meff





Exclude – for BR(gluino→bbar χ_1^0)=100%
[for BR(gluino→ttbar χ_1^0)=100%)]

for m χ_1^0 < 200 GeV
m(gluino) < 1240 [1150] GeV

for m(gluino)=1100 GeV
mχ_1^0 < 570 [440] GeV

ATLAS-CONF-2012-145

General gauge mediation : photon + b-jets + MET

$\sqrt{s}$= 7 TeV

LSP = light gravitino

NSLP=neutralino

bino/wino/higgsino-like neutralino $\rightarrow \gamma$/Z/h + gravitino

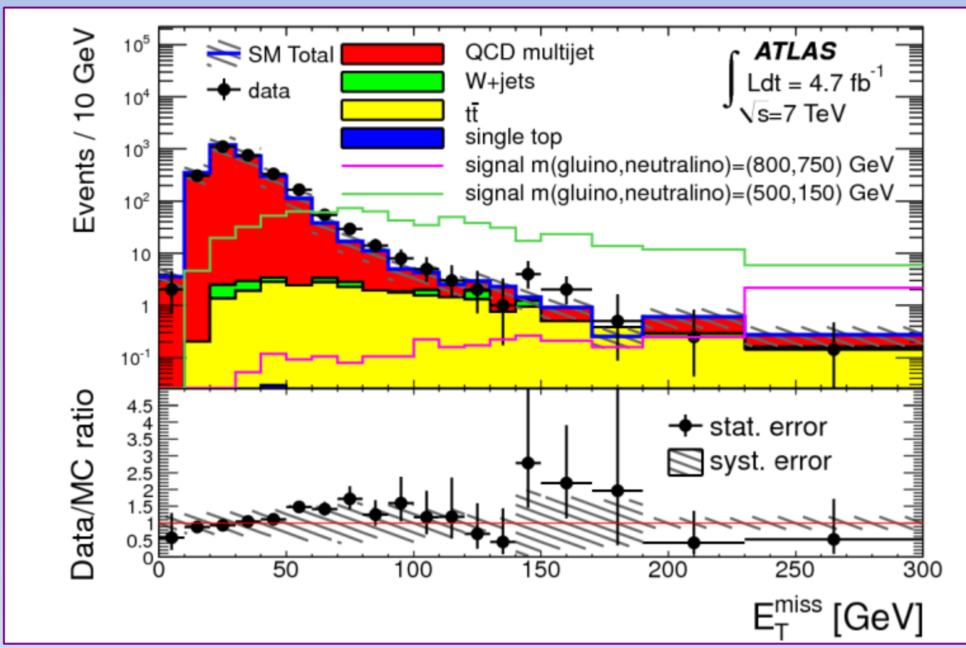
Signal

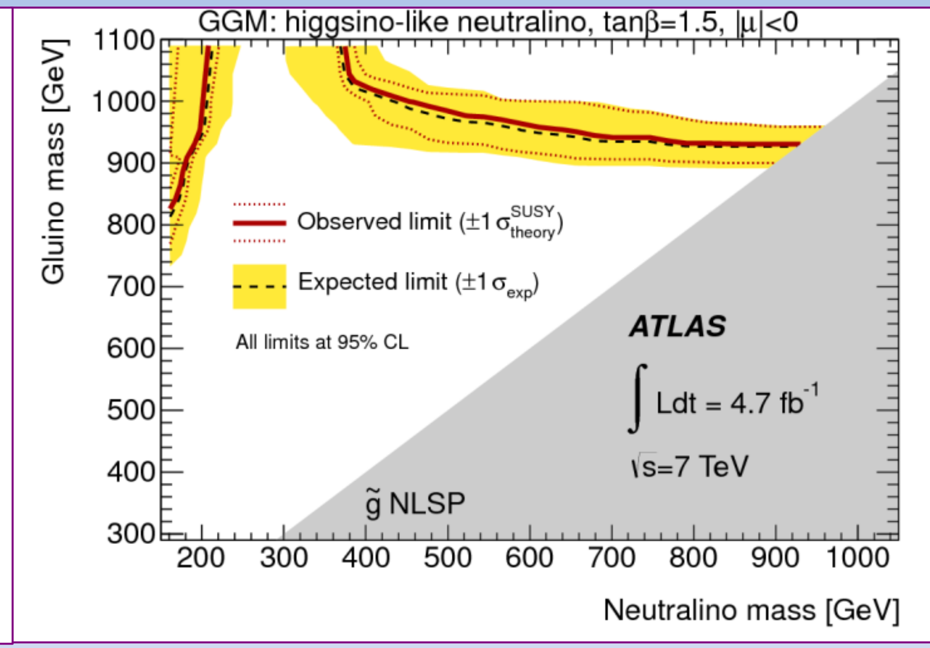
higgsino-like neutralino $\rightarrow \gamma$/h/Z

Backgrounds

QCD multijet, W+jets, top $\rightarrow$ from data

Variables e.g. MET





Exclude – for $m_{neutralino}$ > 220 GeV

m(gluino) < 900 GeV and m(squark) < 1020 GeV

arXiv:1211.1167

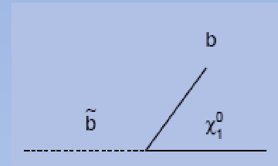
Direct sbottom production : two b-jets + MET

4 signal regions

Background

Top, W/Z+heavy flavour hadrons → data CR

Other backgrounds (except multijet) → MC

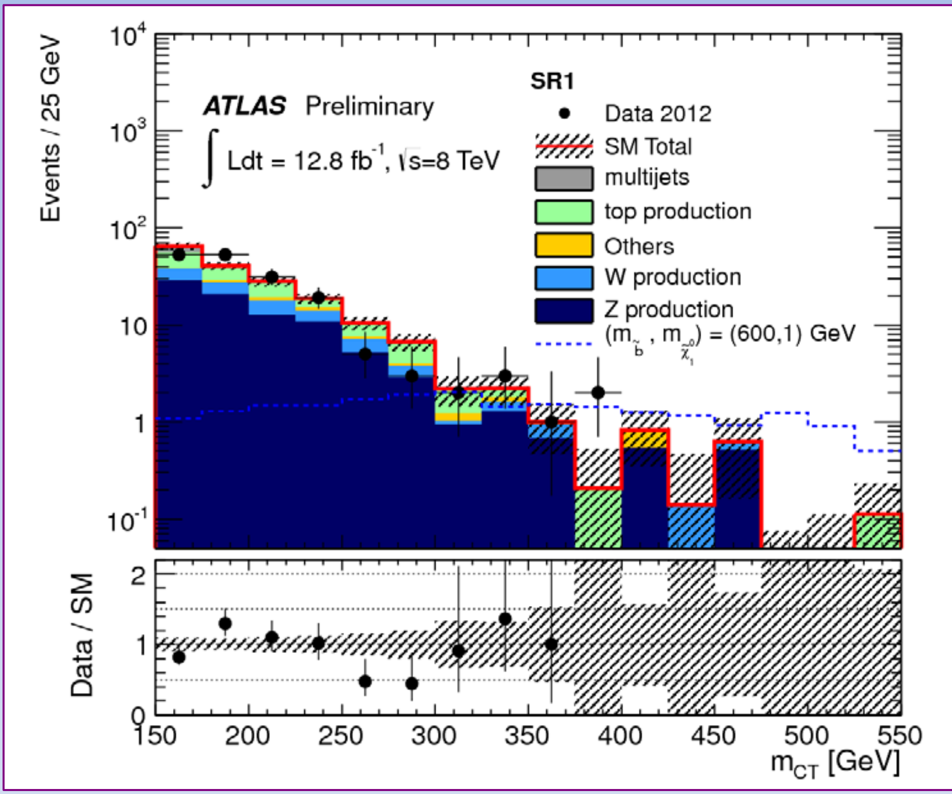


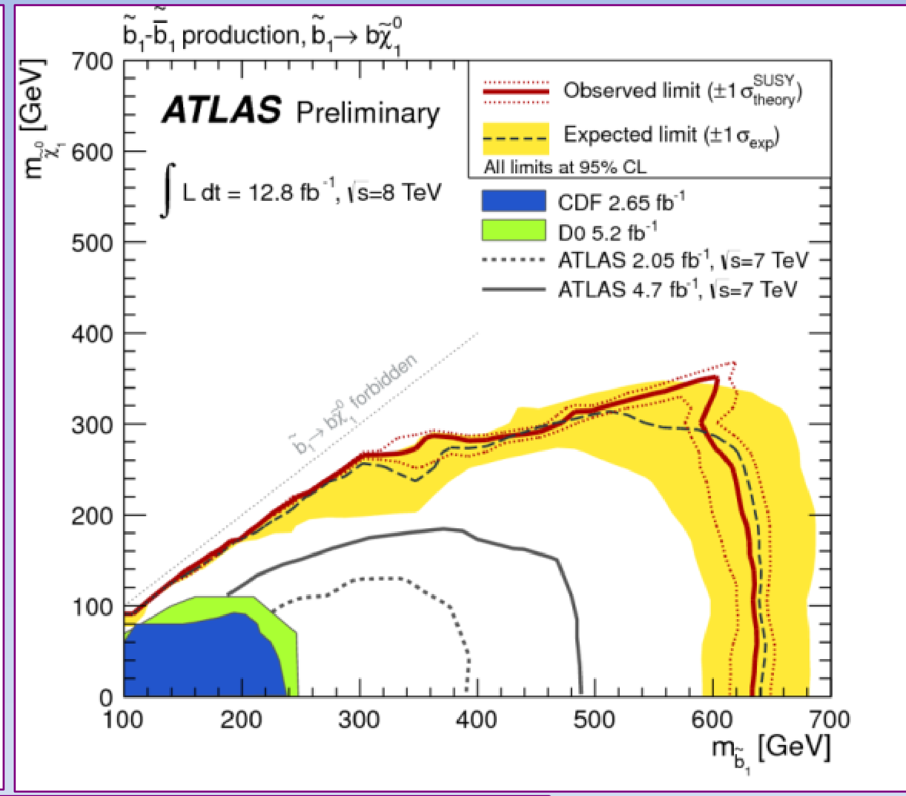
Variables e.g.

Contransverse mass

$$m_{CT}^2 = [E_T(\nu_1) + E_T(\nu_2)]^2 - [\vec{p}_T(\nu_1) - \vec{p}_T(\nu_2)]^2$$

where νi = visible particle i





Exclude – if BR(sbottom$_1$→b χ_1^0)=100%

m(sbottom$_1$) < 620 GeV for mχ_1^0 < 150 GeV

mχ_1^0 < 320 GeV for m(sbottom$_1$) ~550 GeV

($m_{sbottom1}$- m χ_1^0) > 40 GeV for m(sbottom1) < 300 GeV

ATLAS-CONF-2012-165

Direct medium/heavy stop production : two b-jets + MET

Reinterpretation of previous analysis

stop1→b χ_1^+ with $\chi_1^+ \rightarrow W^{(*)}\chi_1^0$

Exclude

– assuming $(m_{chargino}-m\chi_1^0)$=5 GeV

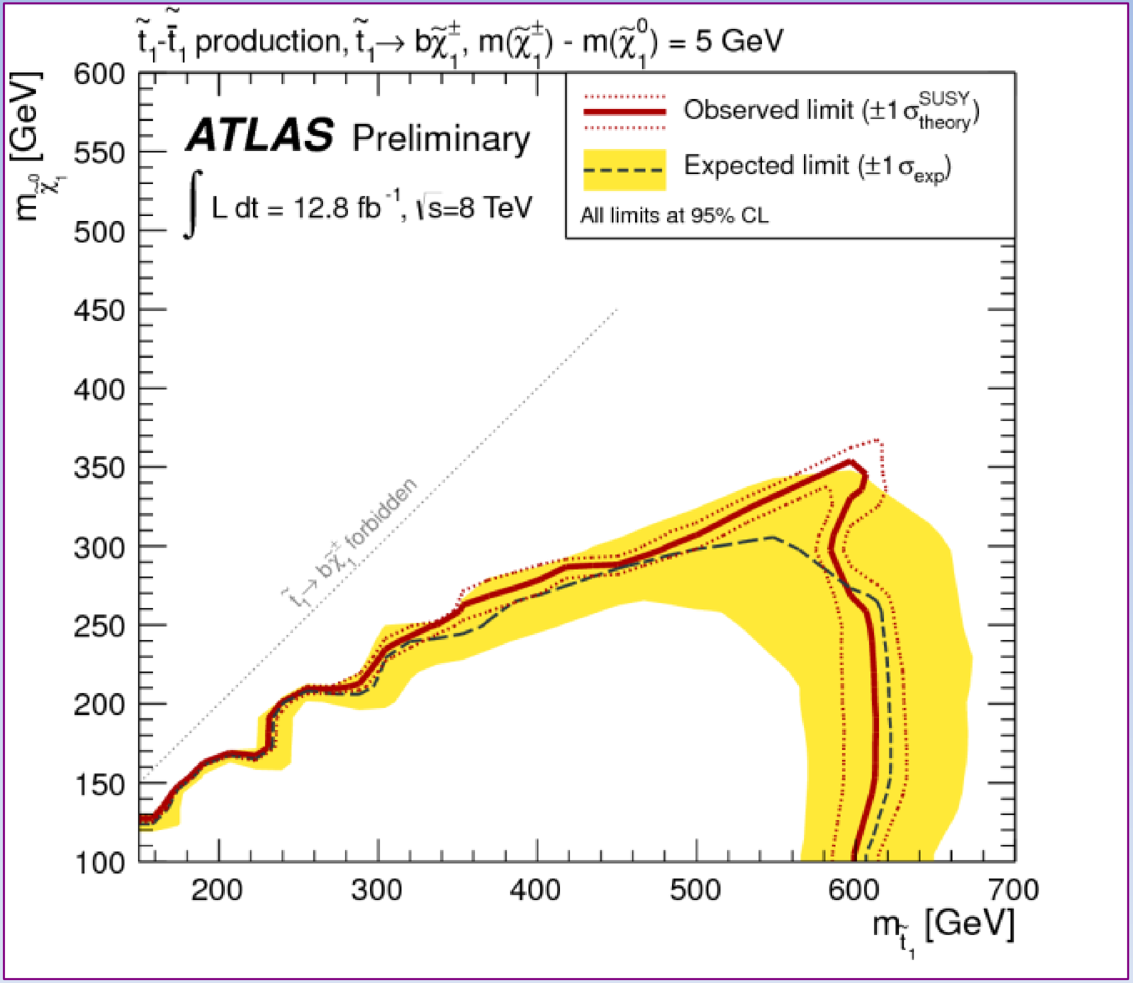
m(stop1) < 580 GeV

for $m\chi_1^0 \simeq$ 100 GeV

$m\chi_1^0$ < 300 GeV

for m(stop1)≃ 500 GeV

If $(m_{chargino}-m\chi_1^0)$=20 GeV limits weaken by up to 100 GeV



ATLAS-CONF-2013-001

Direct stop exclusion limits summary

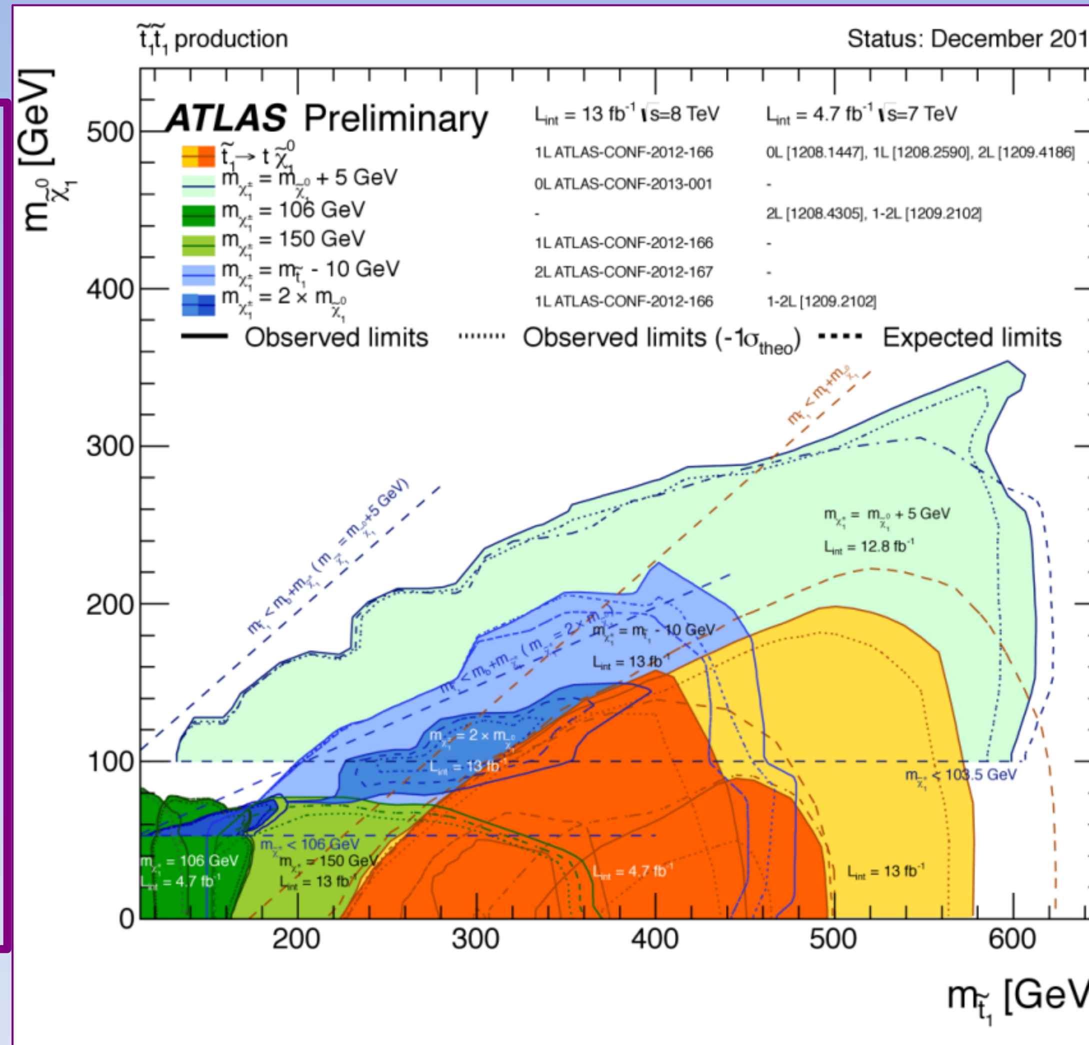
BR(stop1 → b + $\chi^{\pm}_1$;
$\chi^{\pm}_1$ → $W^{(*)}$+ χ^0_1)=100%
(green and blue) :

0L : m($\chi^{\pm}_1$) = 106 GeV (dark green) @7TeV
1L : m($\chi^{\pm}_1$) = 150 GeV (light green)

1-2L : m($\chi^{\pm}_1$) =2m(χ^0_1) (dark blue)
2L : m($stop_1$) – m($\chi^{\pm}_1$) = 10 GeV (light blue)
0L : m($\chi^{\pm}_1$) – m(χ^0_1) = 5 GeV (light turquoise)

BR(stop1 → t + χ^0_1)=100%
(orange) :

0-1-2L : 4,7 fb-1 @ 7TeV (dark orange)
1L : 13 fb-1 @ 8 TeV (light orange)



arxiv1208.1447 ; 1208.2590 ; 1209.4186 ;
ATLAS-CONF-2012-166 ; 1208.4305 ; 1209.2102 ;
ATLAS-CONF-2012-167 ; ATLAS-CONF-2013-001

Other SUSY options if nothing is seen

Compressed spectrum

ATLAS studies $\rightarrow$ squark/gluino limits collapse for small mass gaps

Long lived particles

See 1211.1597

R-parity violation

See recent arXiv:1212.1272

Beyond the MSSM

Stealth SUSY, scalar gluons, NMSSM ?

Exotics

@ √s=8TeV
unless otherwise mentioned
all exclusions @ 95% C.L.

Theoretical issues

Same theoretical issues as for SUSY…
…However different possible origins

- o **Extra dimensions**
- o **Compositeness**
- o **4^{th} generation particles**
- o **Strong symmetry breaking**
- o **New gauge bosons**
- o **etc.**

Final states

→

- o **Leptons+jets**
- o **Leptonic**
- o **Jet(s)**

Leptons + jets final state – Resonant ZZ with ZZ $\rightarrow$ llqq

The model

Small extra dimensions Randall-Sundrum-2 (RS2)

- $M_{planck} \rightarrow M_{weak}$
- Exponentially warped fifth dimension

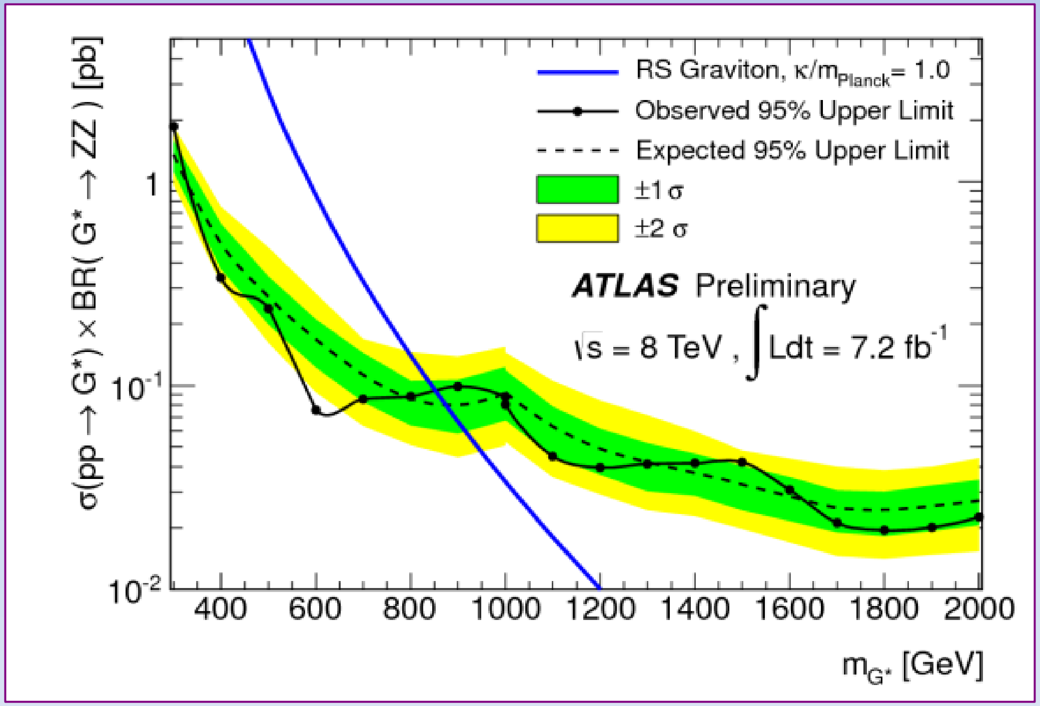
$$ds^2 = e^{-2krc|y|}\eta_{\mu\nu}\, dx_\mu\, dx_\nu - r^2_c\, dy^2$$

where k=curvature, of order of Planck scale

r_c compactification radius

- $k/M_{Pl} \approx 0.01\text{-}1.0$

$\rightarrow$ **Heavy excited graviton J=2 in the bulk**

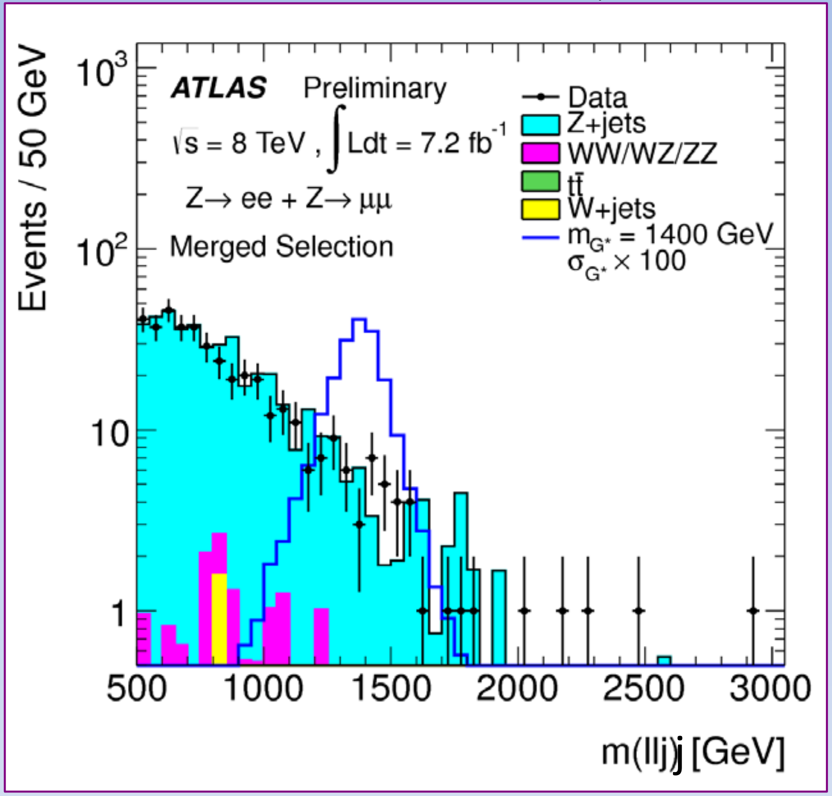


2 signal regions – 2 channels (ee, $\mu\mu$)

N.B. Resolved (low mass) and merged jets (high mass) from Z

Background : Fitting functional form to data

Variables : m(jjll), low and high $pT_{dilepton}$



Exclude – for $k/M_{planck\text{-}reduced}$= 1.0

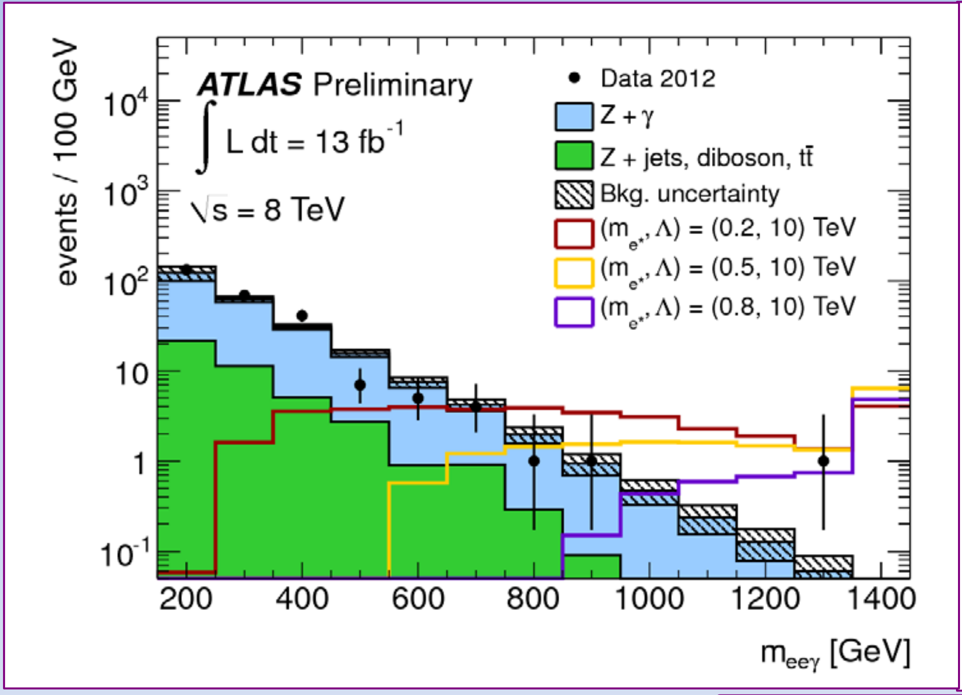
m(Graviton) < 850 GeV

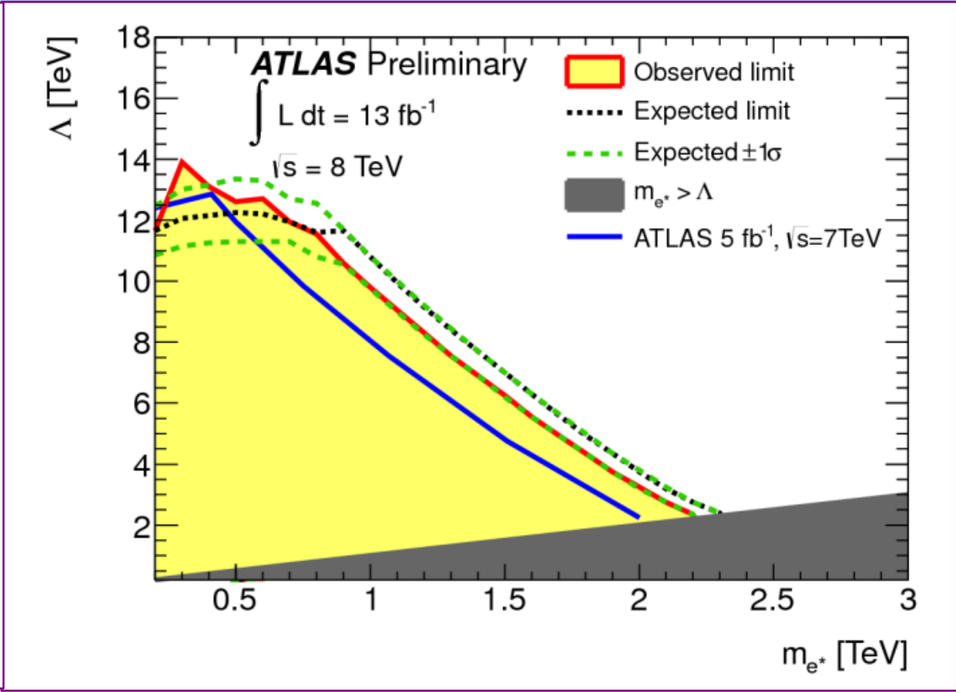
ATLAS-CONF-2012-150

Leptonic final states – Excited electrons and muons ℓ* → ℓγ

The model
Contact Interaction
Compositeness
Λ = compositeness scale
where m(ℓ*) ≤ Λ
qqbar → ℓ*ℓbar ; σ(ℓ+*ℓ-*) too low

Signal ℓ+ℓ-γ - eeγ, μμγ
Isolated leptons (e,μ) with pT cut ; isolated photon
m(ℓℓ) > 110 GeV
Background → from MC scaled to data
DY + ISR/FSR γ/jets
ttbar and diboson → small





Exclude – for Λ = m(ℓ*)
m(ℓ*) < 2.2 TeV

ATLAS-CONF-2012-146

Leptonic final states – High mass dilepton searches

The models

o Sequential Standard Model Z'

Same couplings to fermions as SM Z

o Grand Unification model

with broken E6 gauge group

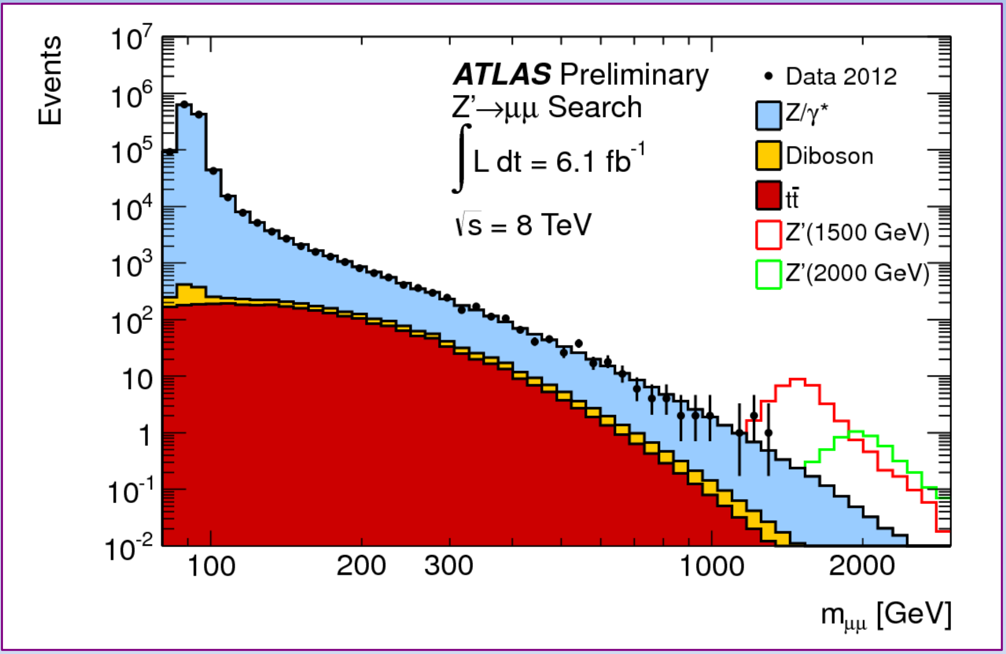
Signal – ee, $\mu\mu$

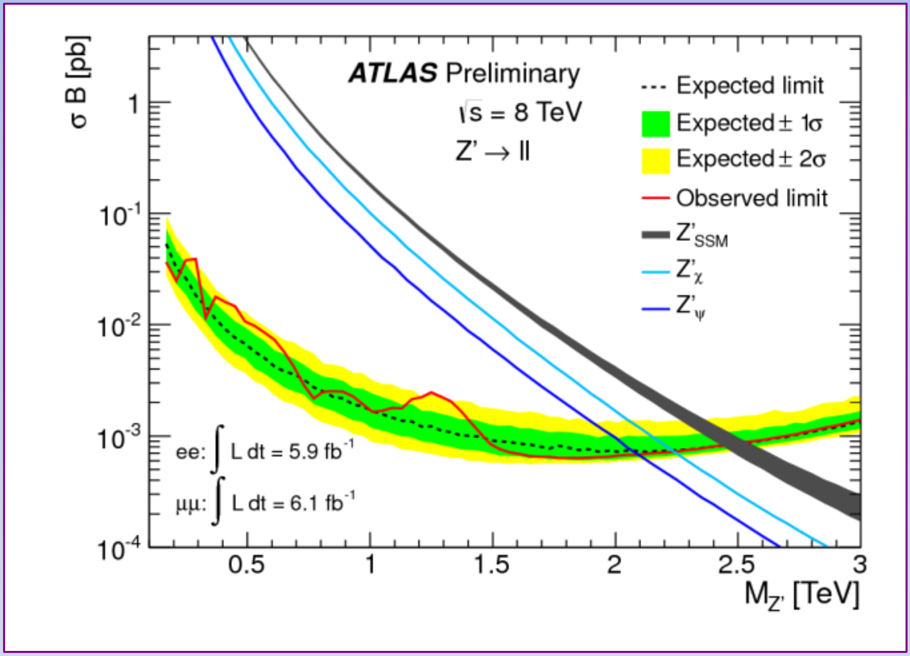
Background

DY Z/γ^*, Diboson, ttbar

→ from MC normalized w.r.t each other in Z peak region

Dijets (mostly ee) → from data in low mass region





Exclude – for combined (ee, $\mu\mu$) channels

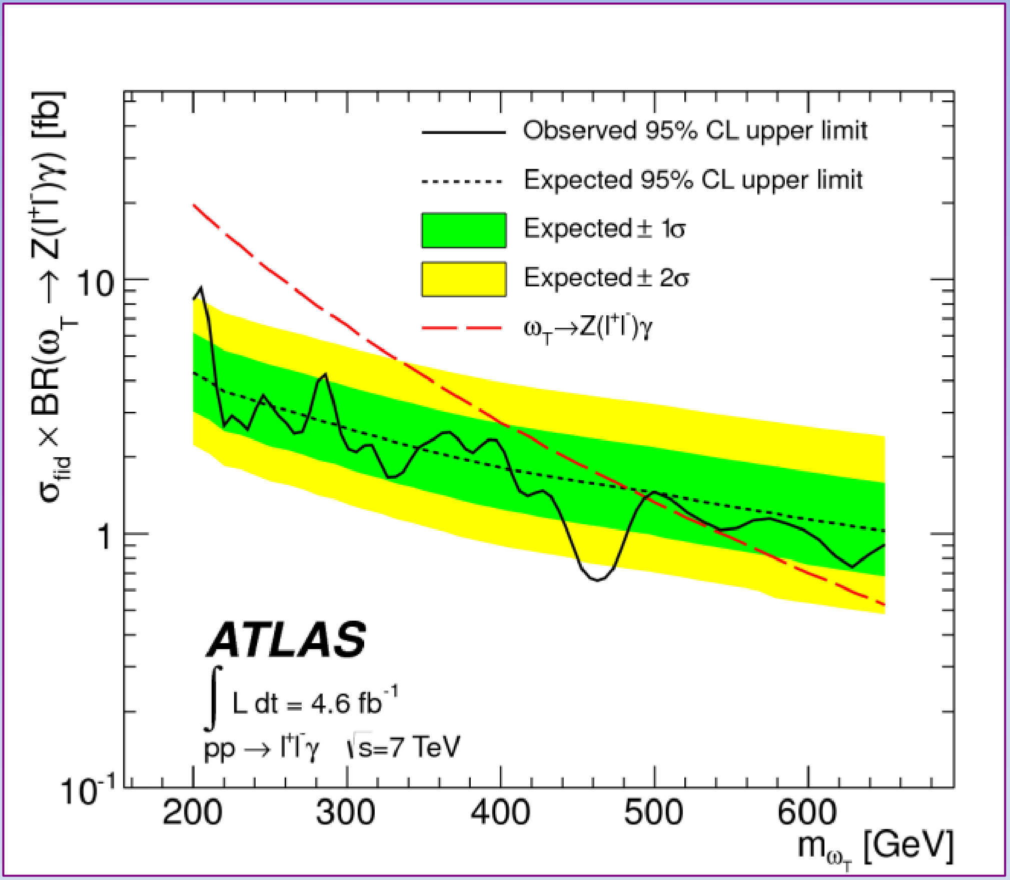
mZ' (SSM) < 2.49 (2.39, 2.19) TeV

mZ' (E6 models) < 2.09 – 2.24 TeV

ATLAS-CONF-2012-129

Leptonic final states – Wgamma and Zgamma Production

m(Wγ) and m(Zγ)→ limits on TC



The models

o Anomalous Triple Gauge Couplings
→ Already covered in Konstantinos Bachas' talk

o Low Scale Techni-Colour (LSTC) resonances

Signal – (ℓℓ,ℓν,νν) + γ
Background
Z/W/γ+jets , multijets → from data
Others → from MC
Variables : m(ℓℓ), mT, MET
LSTC: Fit to invariant mass distribution of Wγ and Zγ

Exclude
m(ωT) < 494 GeV in Zγ mode
m(aT) < 703 GeV in Wγ mode
No deviations from SM WWγ, ZZγ and Zγγ triple-gauge-boson couplings (λ_γ $\Delta\kappa_\gamma$ h_3^V h_4^V)

arXiv:1302.1283

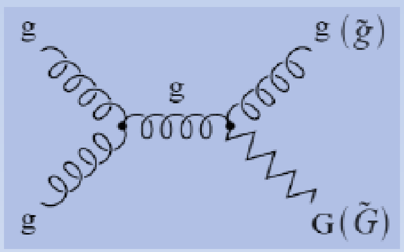
Jet final state – Monojet + MET → Both SUSY and Exotics search (1)

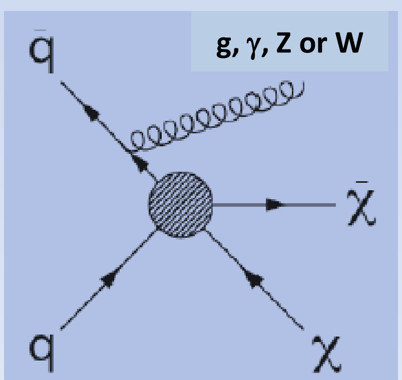
The models

o Large Extra Dimensions e.g. ADD $M_{Pl}^2 \sim M_D^{2+n} R^n$
MD=fundamental Planck scale in 4+n dimensions
R=compactification radius
n = number of XtraDs

o WIMPs : Dirac fermions
Non-renormalizable effective theory
with vertex operators e.g. D5, D9, D11
Effective cutoff mass scale
(suppression scale) M*

o GMSB
$m_{Gravitino} \propto$ (SUSY breaking scale F)/ M_{Pl}

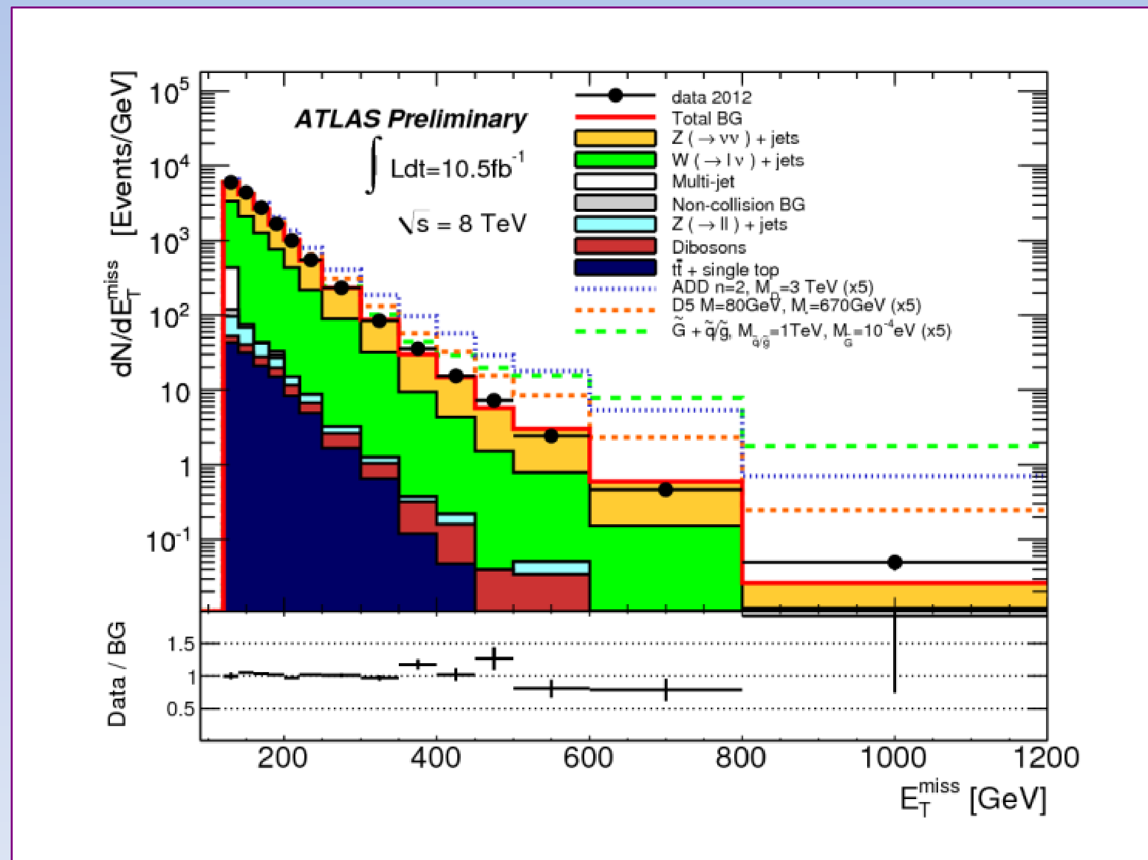




4 signal regions

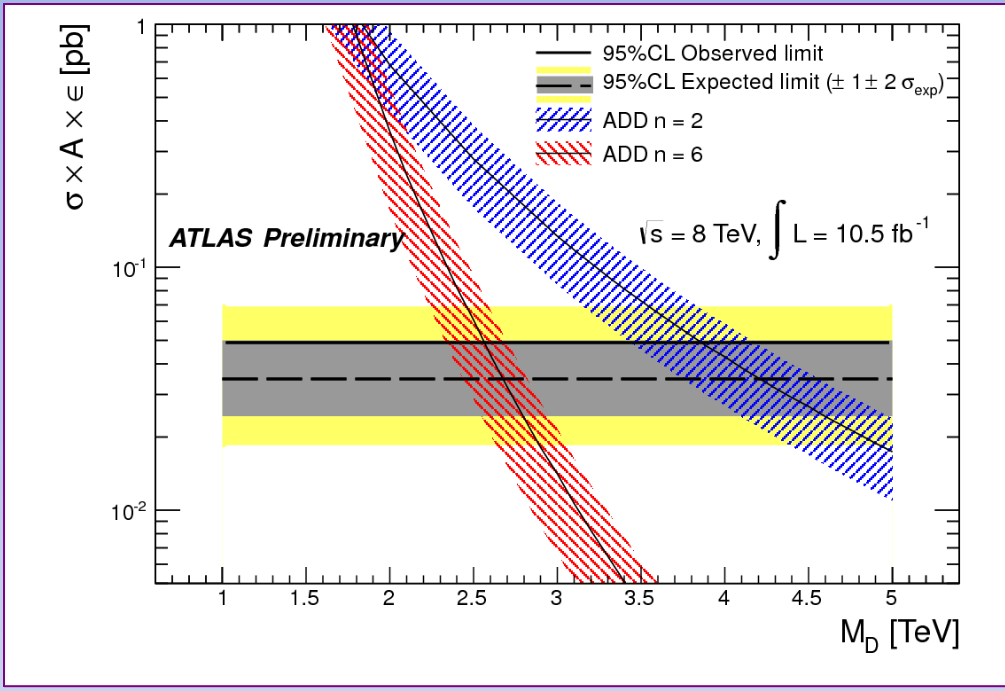
Background

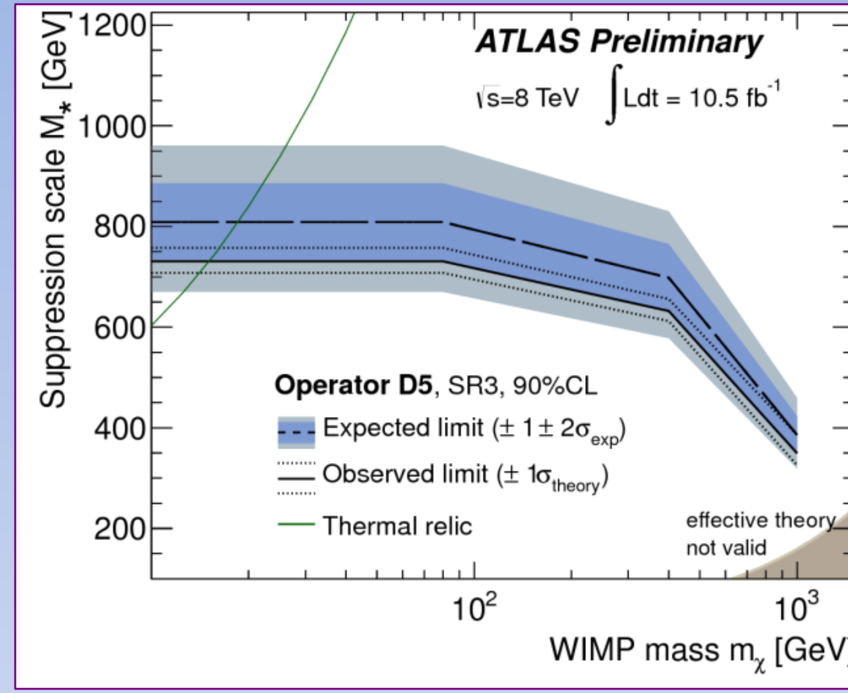
Z(→νν)/W (→lν)+jets :
from MC normalized to data CRs
Other (except multijet) : from MC



ATLAS-CONF-2012-147

Jet final state – Monojet + MET → Both SUSY and Exotics search (2)





Exclude :

o ADD fundamental Planck scale in 4+n dimensions

$M_D <$ 4.37 (2.53) TeV **for n = 2 (6) (NLO)**

o WIMP suppression scale (effective cut-off mass scale) @ 90% CL

M*< 704, 608, 336 GeV

for $m_{WIMP} \leq$80, =400, =1000 GeV with the D5 contact operator

o GMSB m(Gravitino) < $3 \cdot 10^{-4}$ eV – $3 \cdot 10^{-5}$ eV **depending on m(squark) and m(gluino)**

ATLAS-CONF-2012-147

Conclusion and outlook

"C'mon, c'mon — it's either one or the other."

- Individual searches are sensitive to different complementary regions of the SUSY/Exotics parameter space

- 2011 – gradually coming in 2012 – data results are truly amazing and together disconcerting for the "Searches clan"

- What if there isn't anything more than the 125 Gev boson –SM Higgs ? – to discover at the LHC? Would this really be *The Nightmare Scenario ?*

- On the other hand, other particles e.g. light stop/sbottom/gauginos could be just around the corner !!

- 13-14 TeV high luminosity upgrade very promising

Backup slides

Recent searches results – more to come in upcoming conferences

@ 8TeV
New Phenomena in the Dijet Mass Distribution @8TeV ATLAS-CONF-2012-148

0 lepton + 2 b-jets + Etmiss [Medium / heavy stop] ATLAS-CONF-2013-001
2 leptons + Etmiss [Medium stop] ATLAS-CONF-2012-167
1 lepton + >=4 jets (>=1 b-jet) + Etmiss [Medium / heavy stop] ATLAS-CONF-2012-166

@ 7 TeV
WH production with a light Higgs boson decaying to prompt electron-jets 1302.4393
Single b*-quark production 1301.1583
Long-lived, multi-charged particles 1301.5272

0-2 leptons + 0-1 b-jets multichannel (razor) 1212.6149
Heavy resonance to eμ, eτ, μτ [RPV-LFV] 1212.1272
Long-lived particles [R-hadrons, slepton] 1211.1597

ATLAS

A Toroidal LHC Apparatus

Calorimetry $|\eta| < 4.9$

EMBC, EMEC accordion LAr + Pb $|\eta|<3.2$

Tile Hadronic Fe + scintillator $|\eta|<1.7$

HEC Hadr end cap Cu+Lar $1.5<|\eta|<3.2$

FCAL Forward calo Cu+W+Lar $3.1<|\eta|<4.9$

Muon spectrometer $|\eta| < 2.7$

High precision tracking

MDT Monitored Drift Tubes

CSC Cathode Strip Chambers

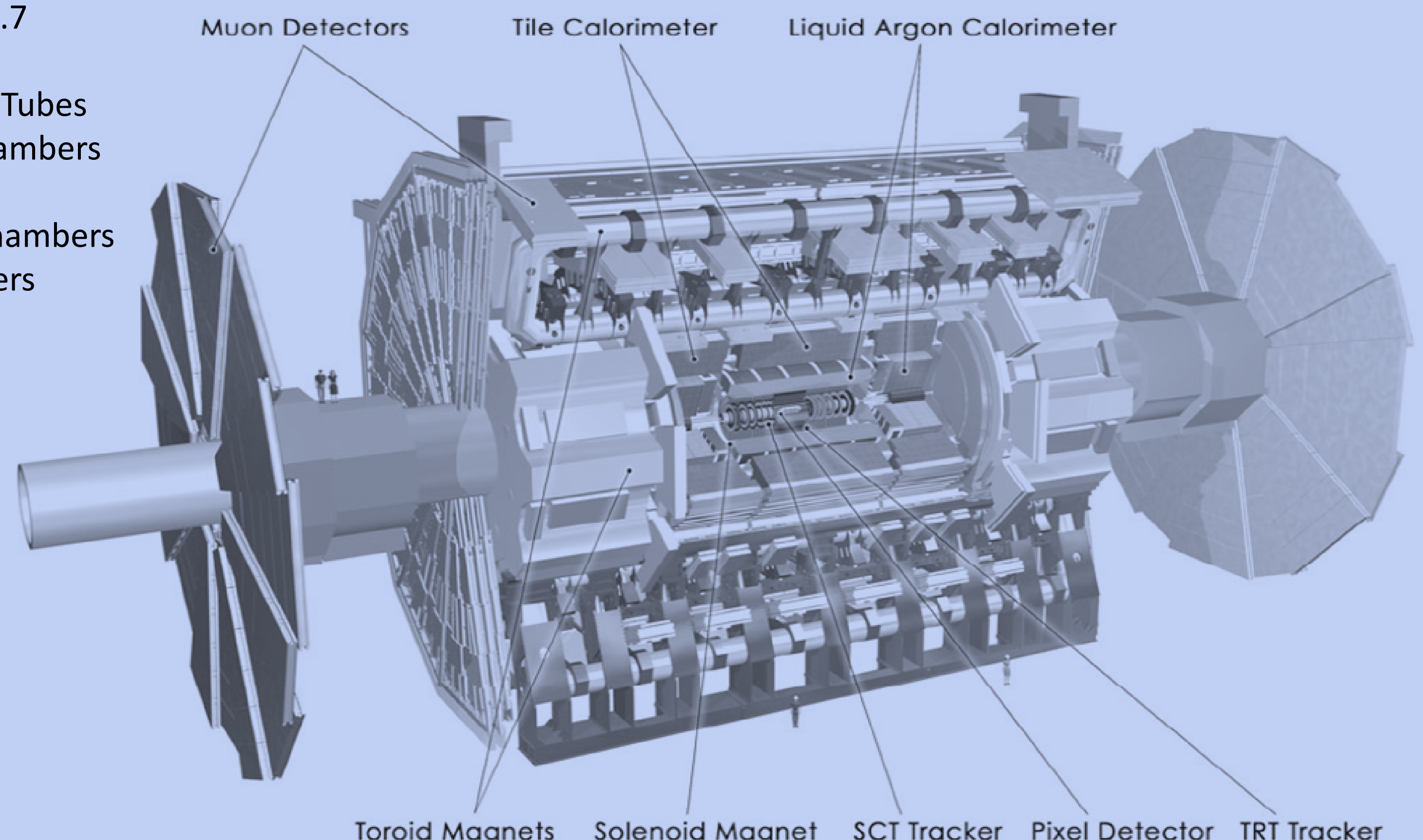
Trigger chambers

RPC Resistive Plate Chambers

TGC Thin Gap Chambers

Air core toroid system

→ strong bending power in large volume



Inner Detector

~6m long 1.1m radius inside 2T **Solenoid**

Pixels

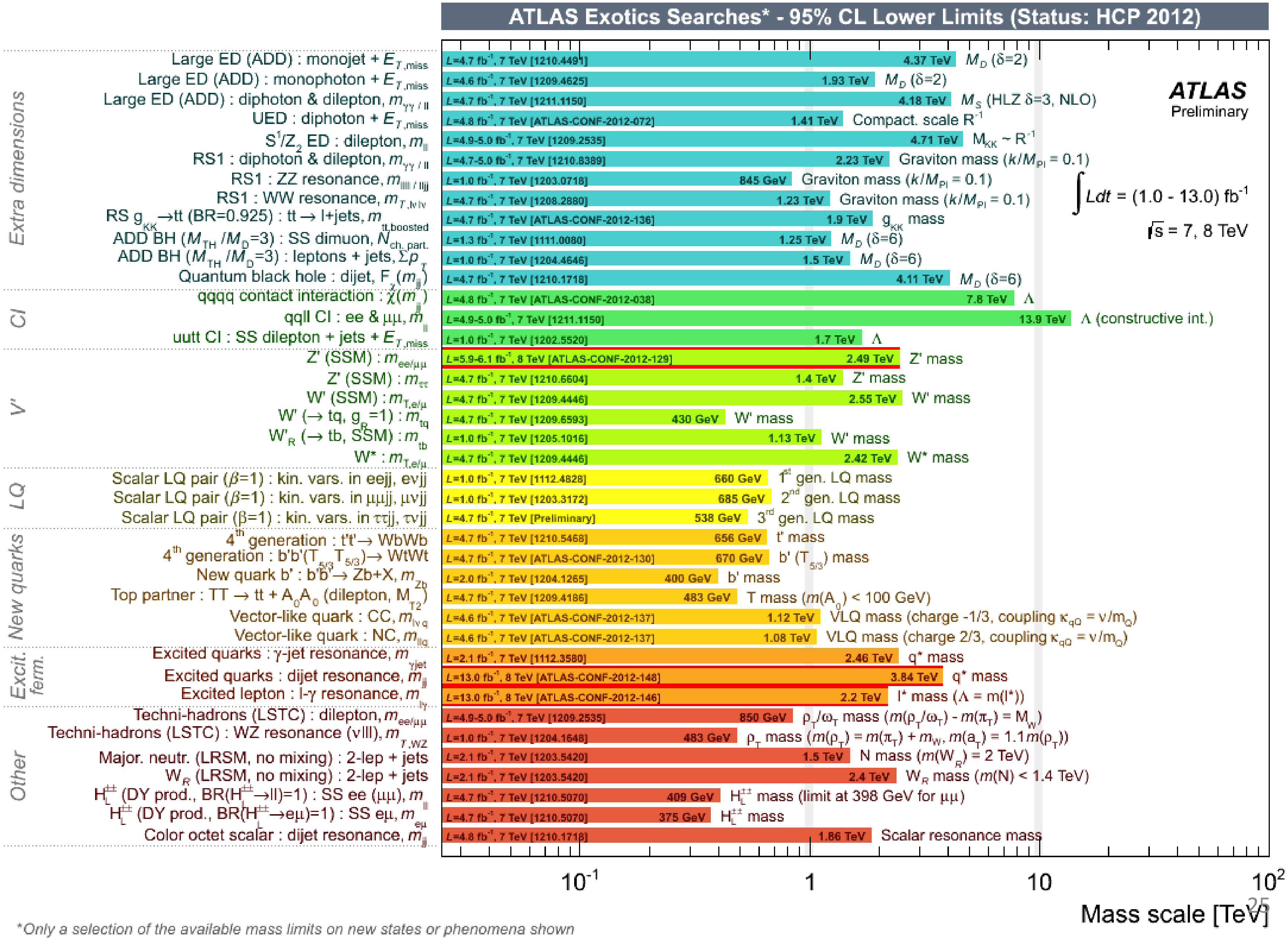
SCT Silicon Strips

TRT Transition Radiation Tracker e/π separation

3 trigger levels : L1, L2, Event Filter (L2+EF=HLT)

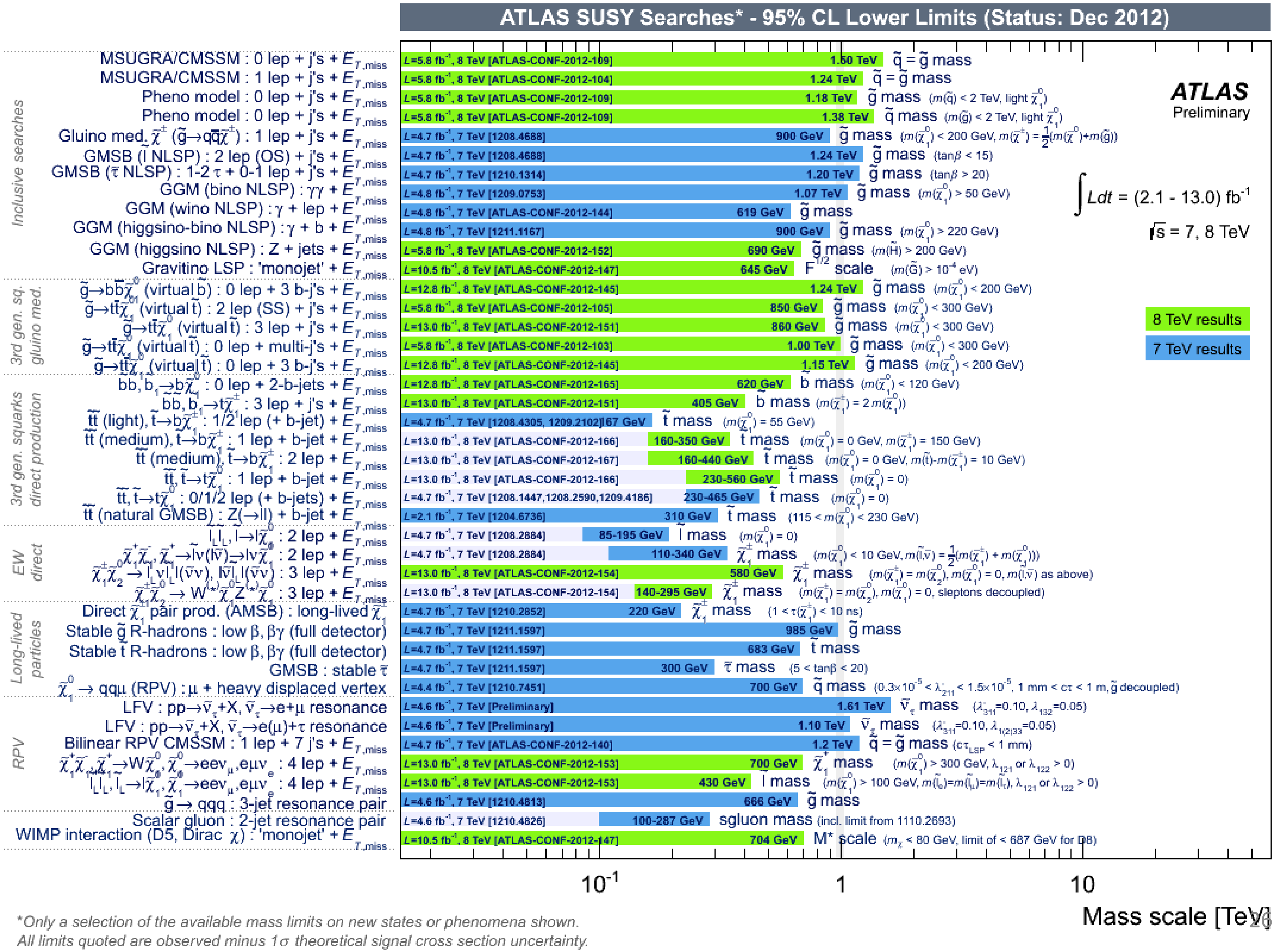
40 MHz → 200 Hz

Summary

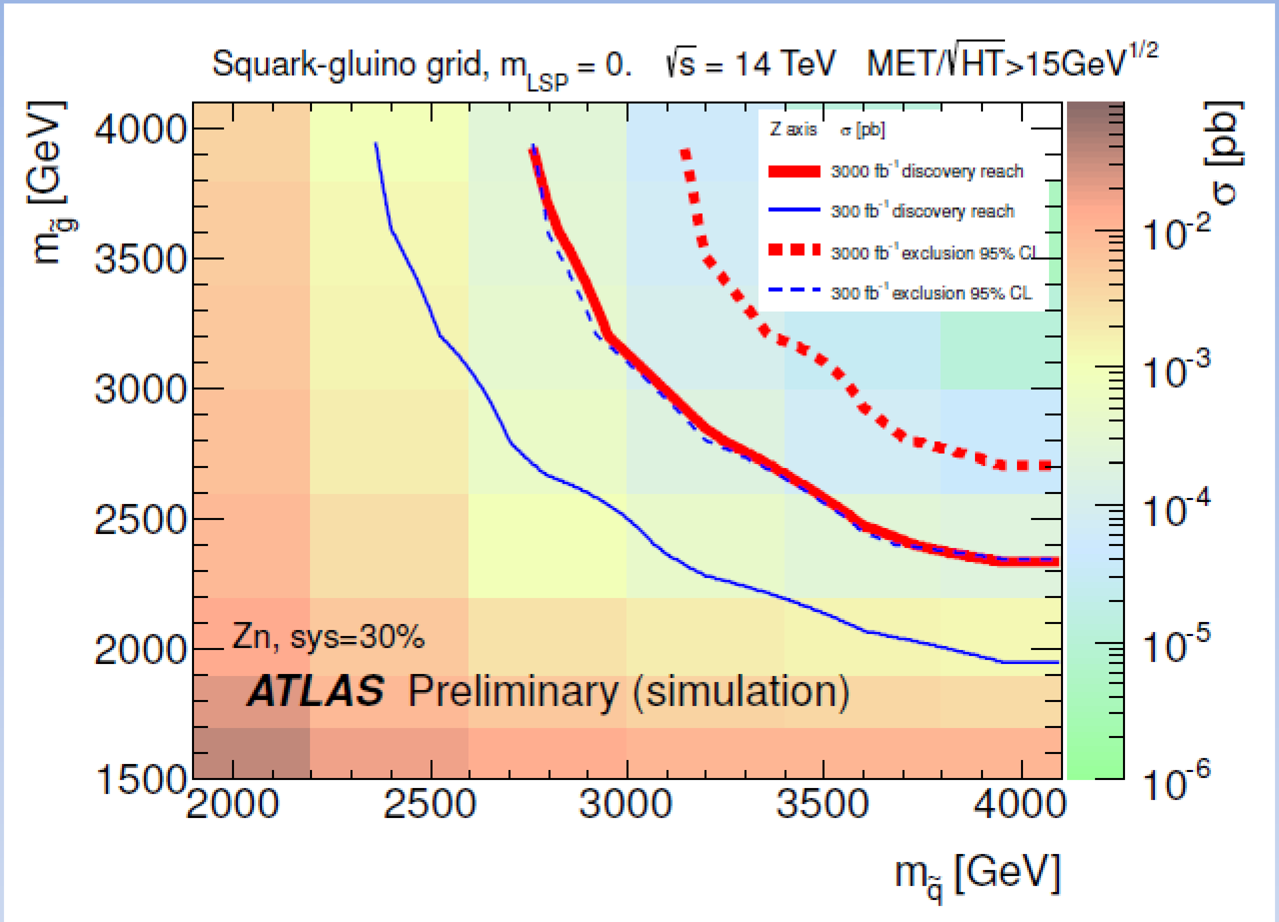


ATLAS Exotics Searches* - 95% CL Lower Limits (Status: HCP 2012)
ATLAS
Preliminary
∫Ldt = (1.0 - 13.0) fb^-1
√s = 7, 8 TeV
Extra dimensions
Large ED (ADD) : monojet + E_T,miss
L=4.7 fb^-1, 7 TeV [1210.4491]
4.37 TeV
M_D (δ=2)
Large ED (ADD) : monophoton + E_T,miss
L=4.6 fb^-1, 7 TeV [1209.4625]
1.93 TeV
M_D (δ=2)
Large ED (ADD) : diphoton & dilepton, m_γγ / ll
L=4.7 fb^-1, 7 TeV [1211.1150]
4.18 TeV
M_S (HLZ δ=3, NLO)
UED : diphoton + E_T,miss
L=4.8 fb^-1, 7 TeV [ATLAS-CONF-2012-072]
1.41 TeV
Compact. scale R^-1
S^1/Z_2 ED : dilepton, m_ll
L=4.9-5.0 fb^-1, 7 TeV [1209.2535]
4.71 TeV
M_KK ~ R^-1
RS1 : diphoton & dilepton, m_γγ / ll
L=4.7-5.0 fb^-1, 7 TeV [1210.8389]
2.23 TeV
Graviton mass (k/M_Pl = 0.1)
RS1 : ZZ resonance, m_llll / lljj
L=1.0 fb^-1, 7 TeV [1203.0718]
845 GeV
Graviton mass (k/M_Pl = 0.1)
RS1 : WW resonance, m_T,lνlν
L=4.7 fb^-1, 7 TeV [1208.2880]
1.23 TeV
Graviton mass (k/M_Pl = 0.1)
RS g_KK→tt (BR=0.925) : tt→ l+jets, m_tt,boosted
L=4.7 fb^-1, 7 TeV [ATLAS-CONF-2012-136]
1.9 TeV
g_KK mass
ADD BH (M_TH /M_D=3) : SS dimuon, N_ch. part.
L=1.3 fb^-1, 7 TeV [1111.0080]
1.25 TeV
M_D (δ=6)
ADD BH (M_TH /M_D=3) : leptons + jets, Σp_T
L=1.0 fb^-1, 7 TeV [1204.4646]
1.5 TeV
M_D (δ=6)
Quantum black hole : dijet, F_χ(m_jj)
L=4.7 fb^-1, 7 TeV [1210.1718]
4.11 TeV
M_D (δ=6)
CI
qqqq contact interaction : χ(m_jj)
L=4.8 fb^-1, 7 TeV [ATLAS-CONF-2012-038]
7.8 TeV
Λ
qqll CI : ee & μμ, m_ll
L=4.9-5.0 fb^-1, 7 TeV [1211.1150]
13.9 TeV
Λ (constructive int.)
uutt CI : SS dilepton + jets + E_T,miss
L=1.0 fb^-1, 7 TeV [1202.5520]
1.7 TeV
Λ
V'
Z' (SSM) : m_ee/μμ
L=5.9-6.1 fb^-1, 8 TeV [ATLAS-CONF-2012-129]
2.49 TeV
Z' mass
Z' (SSM) : m_ττ
L=4.7 fb^-1, 7 TeV [1210.6604]
1.4 TeV
Z' mass
W' (SSM) : m_T,e/μ
L=4.7 fb^-1, 7 TeV [1209.4446]
2.55 TeV
W' mass
W' (→ tq, g_R=1) : m_tq
L=4.7 fb^-1, 7 TeV [1209.6593]
430 GeV
W' mass
W'_R (→ tb, SSM) : m_tb
L=1.0 fb^-1, 7 TeV [1205.1016]
1.13 TeV
W' mass
W* : m_T,e/μ
L=4.7 fb^-1, 7 TeV [1209.4446]
2.42 TeV
W* mass
LQ
Scalar LQ pair (β=1) : kin. vars. in eejj, eνjj
L=1.0 fb^-1, 7 TeV [1112.4828]
660 GeV
1st gen. LQ mass
Scalar LQ pair (β=1) : kin. vars. in μμjj, μνjj
L=1.0 fb^-1, 7 TeV [1203.3172]
685 GeV
2nd gen. LQ mass
Scalar LQ pair (β=1) : kin. vars. in ττjj, τνjj
L=4.7 fb^-1, 7 TeV [Preliminary]
538 GeV
3rd gen. LQ mass
New quarks
4th generation : t't'→ WbWb
L=4.7 fb^-1, 7 TeV [1210.5468]
656 GeV
t' mass
4th generation : b'b'(T_5/3T_5/3)→ WtWt
L=4.7 fb^-1, 7 TeV [ATLAS-CONF-2012-130]
670 GeV
b' (T_5/3) mass
New quark b' : b'b'→ Zb+X, m_Zb
L=2.0 fb^-1, 7 TeV [1204.1265]
400 GeV
b' mass
Top partner : TT → tt + A_0A_0 (dilepton, M_T2)
L=4.7 fb^-1, 7 TeV [1209.4186]
483 GeV
T mass (m(A_0) < 100 GeV)
Vector-like quark : CC, m_lνq
L=4.6 fb^-1, 7 TeV [ATLAS-CONF-2012-137]
1.12 TeV
VLQ mass (charge -1/3, coupling κ_qQ = v/m_Q)
Vector-like quark : NC, m_llq
L=4.6 fb^-1, 7 TeV [ATLAS-CONF-2012-137]
1.08 TeV
VLQ mass (charge 2/3, coupling κ_qQ = v/m_Q)
Excit. ferm.
Excited quarks : γ-jet resonance, m_γjet
L=2.1 fb^-1, 7 TeV [1112.3580]
2.46 TeV
q* mass
Excited quarks : dijet resonance, m_jj
L=13.0 fb^-1, 8 TeV [ATLAS-CONF-2012-148]
3.84 TeV
q* mass
Excited lepton : l-γ resonance, m_lγ
L=13.0 fb^-1, 8 TeV [ATLAS-CONF-2012-146]
2.2 TeV
l* mass (Λ = m(l*))
Other
Techni-hadrons (LSTC) : dilepton, m_ee/μμ
L=4.9-5.0 fb^-1, 7 TeV [1209.2535]
850 GeV
ρ_T/ω_T mass (m(ρ_T/ω_T) - m(π_T) = M_W)
Techni-hadrons (LSTC) : WZ resonance (νlll), m_T,WZ
L=1.0 fb^-1, 7 TeV [1204.1648]
483 GeV
ρ_T mass (m(ρ_T) = m(π_T) + m_W, m(a_T) = 1.1m(ρ_T))
Major. neutr. (LRSM, no mixing) : 2-lep + jets
L=2.1 fb^-1, 7 TeV [1203.5420]
1.5 TeV
N mass (m(W_R) = 2 TeV)
W_R (LRSM, no mixing) : 2-lep + jets
L=2.1 fb^-1, 7 TeV [1203.5420]
2.4 TeV
W_R mass (m(N) < 1.4 TeV)
H_L^±± (DY prod., BR(H_L^±±→ll)=1) : SS ee (μμ), m_ll
L=4.7 fb^-1, 7 TeV [1210.5070]
409 GeV
H_L^±± mass (limit at 398 GeV for μμ)
H_L^±± (DY prod., BR(H_L^±±→eμ)=1) : SS eμ, m_eμ
L=4.7 fb^-1, 7 TeV [1210.5070]
375 GeV
H_L^±± mass
Color octet scalar : dijet resonance, m_jj
L=4.8 fb^-1, 7 TeV [1210.1718]
1.86 TeV
Scalar resonance mass
10^-1
1
10
10^2
Mass scale [TeV]
*Only a selection of the available mass limits on new states or phenomena shown

Summary



ATLAS SUSY Searches* - 95% CL Lower Limits (Status: Dec 2012)
ATLAS Preliminary
∫Ldt = (2.1 - 13.0) fb-1
√s = 7, 8 TeV
8 TeV results
7 TeV results
Inclusive searches
MSUGRA/CMSSM : 0 lep + j's + ET,miss | L=5.8 fb-1, 8 TeV [ATLAS-CONF-2012-109] | 1.50 TeV | q̃ = g̃ mass
MSUGRA/CMSSM : 1 lep + j's + ET,miss | L=5.8 fb-1, 8 TeV [ATLAS-CONF-2012-104] | 1.24 TeV | q̃ = g̃ mass
Pheno model : 0 lep + j's + ET,miss | L=5.8 fb-1, 8 TeV [ATLAS-CONF-2012-109] | 1.18 TeV | g̃ mass (m(q̃) < 2 TeV, light χ̃01)
Pheno model : 0 lep + j's + ET,miss | L=5.8 fb-1, 8 TeV [ATLAS-CONF-2012-109] | 1.38 TeV | q̃ mass (m(g̃) < 2 TeV, light χ̃01)
Gluino med. χ̃± (g̃→qq̄χ̃±) : 1 lep + j's + ET,miss | L=4.7 fb-1, 7 TeV [1208.4688] | 900 GeV | g̃ mass (m(χ̃01) < 200 GeV, m(χ̃±) = ½(m(χ̃0)+m(g̃)))
GMSB (l̃ NLSP) : 2 lep (OS) + j's + ET,miss | L=4.7 fb-1, 7 TeV [1208.4688] | 1.24 TeV | g̃ mass (tanβ < 15)
GMSB (τ̃ NLSP) : 1-2 τ + 0-1 lep + j's + ET,miss | L=4.7 fb-1, 7 TeV [1210.1314] | 1.20 TeV | g̃ mass (tanβ > 20)
GGM (bino NLSP) : γγ + ET,miss | L=4.8 fb-1, 7 TeV [1209.0753] | 1.07 TeV | g̃ mass (m(χ̃01) > 50 GeV)
GGM (wino NLSP) : γ + lep + ET,miss | L=4.8 fb-1, 7 TeV [ATLAS-CONF-2012-144] | 619 GeV | g̃ mass
GGM (higgsino-bino NLSP) : γ + b + ET,miss | L=4.8 fb-1, 7 TeV [1211.1167] | 900 GeV | g̃ mass (m(χ̃01) > 220 GeV)
GGM (higgsino NLSP) : Z + jets + ET,miss | L=5.8 fb-1, 8 TeV [ATLAS-CONF-2012-152] | 690 GeV | g̃ mass (m(H̃) > 200 GeV)
Gravitino LSP : 'monojet' + ET,miss | L=10.5 fb-1, 8 TeV [ATLAS-CONF-2012-147] | 645 GeV | F1/2 scale (m(G̃) > 10-4 eV)
3rd gen. sq. gluino med.
g̃→bb̄χ̃01 (virtual b̃) : 0 lep + 3 b-j's + ET,miss | L=12.8 fb-1, 8 TeV [ATLAS-CONF-2012-145] | 1.24 TeV | g̃ mass (m(χ̃01) < 200 GeV)
g̃→tt̄χ̃01 (virtual t̃) : 2 lep (SS) + j's + ET,miss | L=5.8 fb-1, 8 TeV [ATLAS-CONF-2012-105] | 850 GeV | g̃ mass (m(χ̃01) < 300 GeV)
g̃→tt̄χ̃01 (virtual t̃) : 3 lep + j's + ET,miss | L=13.0 fb-1, 8 TeV [ATLAS-CONF-2012-151] | 860 GeV | g̃ mass (m(χ̃01) < 300 GeV)
g̃→tt̄χ̃01 (virtual t̃) : 0 lep + multi-j's + ET,miss | L=5.8 fb-1, 8 TeV [ATLAS-CONF-2012-103] | 1.00 TeV | g̃ mass (m(χ̃01) < 300 GeV)
g̃→tt̄χ̃01 (virtual t̃) : 0 lep + 3 b-j's + ET,miss | L=12.8 fb-1, 8 TeV [ATLAS-CONF-2012-145] | 1.15 TeV | g̃ mass (m(χ̃01) < 200 GeV)
3rd gen. squarks direct production
b̃b̃, b̃1→bχ̃01 : 0 lep + 2-b-jets + ET,miss | L=12.8 fb-1, 8 TeV [ATLAS-CONF-2012-165] | 620 GeV | b̃ mass (m(χ̃01) < 120 GeV)
b̃b̃, b̃1→tχ̃±1 : 3 lep + j's + ET,miss | L=13.0 fb-1, 8 TeV [ATLAS-CONF-2012-151] | 405 GeV | b̃ mass (m(χ̃±1) = 2 m(χ̃01))
t̃t̃ (light), t̃→bχ̃±1 : 1/2 lep (+ b-jet) + ET,miss | L=4.7 fb-1, 7 TeV [1208.4305, 1209.2102] | 167 GeV | t̃ mass (m(χ̃01) = 55 GeV)
t̃t̃ (medium), t̃→bχ̃±1 : 1 lep + b-jet + ET,miss | L=13.0 fb-1, 8 TeV [ATLAS-CONF-2012-166] | 160-350 GeV | t̃ mass (m(χ̃01) = 0 GeV, m(χ̃±1) = 150 GeV)
t̃t̃ (medium), t̃→bχ̃±1 : 2 lep + ET,miss | L=13.0 fb-1, 8 TeV [ATLAS-CONF-2012-167] | 160-440 GeV | t̃ mass (m(χ̃01) = 0 GeV, m(t̃)-m(χ̃±1) = 10 GeV)
t̃t̃, t̃→tχ̃01 : 1 lep + b-jet + ET,miss | L=13.0 fb-1, 8 TeV [ATLAS-CONF-2012-166] | 230-560 GeV | t̃ mass (m(χ̃01) = 0)
t̃t̃, t̃→tχ̃01 : 0/1/2 lep (+ b-jets) + ET,miss | L=4.7 fb-1, 7 TeV [1208.1447,1208.2590,1209.4186] | 230-465 GeV | t̃ mass (m(χ̃01) = 0)
t̃t̃ (natural GMSB) : Z(→ll) + b-jet + ET,miss | L=2.1 fb-1, 7 TeV [1204.6736] | 310 GeV | t̃ mass (115 < m(χ̃01) < 230 GeV)
EW direct
l̃Ll̃L, l̃→lχ̃01 : 2 lep + ET,miss | L=4.7 fb-1, 7 TeV [1208.2884] | 85-195 GeV | l̃ mass (m(χ̃01) = 0)
χ̃+1χ̃-1, χ̃+1→l̃ν(lν̃)→lνχ̃01 : 2 lep + ET,miss | L=4.7 fb-1, 7 TeV [1208.2884] | 110-340 GeV | χ̃±1 mass (m(χ̃01) < 10 GeV, m(l̃,ν̃) = ½(m(χ̃±1) + m(χ̃01)))
χ̃±1χ̃02→l̃Lνl̃Ll(ν̃ν), lν̃l̃Ll(ν̃ν) : 3 lep + ET,miss | L=13.0 fb-1, 8 TeV [ATLAS-CONF-2012-154] | 580 GeV | χ̃±1 mass (m(χ̃±1) = m(χ̃02), m(χ̃01) = 0, m(l̃,ν̃) as above)
χ̃±1χ̃02 → W(*)χ̃01Z(*)χ̃01 : 3 lep + ET,miss | L=13.0 fb-1, 8 TeV [ATLAS-CONF-2012-154] | 140-295 GeV | χ̃±1 mass (m(χ̃±1) = m(χ̃02), m(χ̃01) = 0, sleptons decoupled)
Long-lived particles
Direct χ̃±1 pair prod. (AMSB) : long-lived χ̃±1 | L=4.7 fb-1, 7 TeV [1210.2852] | 220 GeV | χ̃±1 mass (1 < τ(χ̃±1) < 10 ns)
Stable g̃ R-hadrons : low β, βγ (full detector) | L=4.7 fb-1, 7 TeV [1211.1597] | 985 GeV | g̃ mass
Stable t̃ R-hadrons : low β, βγ (full detector) | L=4.7 fb-1, 7 TeV [1211.1597] | 683 GeV | t̃ mass
GMSB : stable τ̃ | L=4.7 fb-1, 7 TeV [1211.1597] | 300 GeV | τ̃ mass (5 < tanβ < 20)
χ̃01 → qqμ (RPV) : μ + heavy displaced vertex | L=4.4 fb-1, 7 TeV [1210.7451] | 700 GeV | q̃ mass (0.3×10-5 < λ'211 < 1.5×10-5, 1 mm < cτ < 1 m, g̃ decoupled)
RPV
LFV : pp→ν̃τ+X, ν̃τ→e+μ resonance | L=4.6 fb-1, 7 TeV [Preliminary] | 1.61 TeV | ν̃τ mass (λ'311=0.10, λ132=0.05)
LFV : pp→ν̃τ+X, ν̃τ→e(μ)+τ resonance | L=4.6 fb-1, 7 TeV [Preliminary] | 1.10 TeV | ν̃τ mass (λ'311=0.10, λ1(2)33=0.05)
Bilinear RPV CMSSM : 1 lep + 7 j's + ET,miss | L=4.7 fb-1, 7 TeV [ATLAS-CONF-2012-140] | 1.2 TeV | q̃ = g̃ mass (cτLSP < 1 mm)
χ̃+1χ̃-1, χ̃+1→Wχ̃01, χ̃01→eeνμ, eμνe : 4 lep + ET,miss | L=13.0 fb-1, 8 TeV [ATLAS-CONF-2012-153] | 700 GeV | χ̃±1 mass (m(χ̃01) > 300 GeV, λ121 or λ122 > 0)
l̃Ll̃L, l̃L→lχ̃01, χ̃01→eeνμ, eμνe : 4 lep + ET,miss | L=13.0 fb-1, 8 TeV [ATLAS-CONF-2012-153] | 430 GeV | l̃ mass (m(χ̃01) > 100 GeV, m(l̃e)=m(l̃μ)=m(l̃τ), λ121 or λ122 > 0)
g̃ → qqq : 3-jet resonance pair | L=4.6 fb-1, 7 TeV [1210.4813] | 666 GeV | g̃ mass
Scalar gluon : 2-jet resonance pair | L=4.6 fb-1, 7 TeV [1210.4826] | 100-287 GeV | sgluon mass (incl. limit from 1110.2693)
WIMP interaction (D5, Dirac χ) : 'monojet' + ET,miss | L=10.5 fb-1, 8 TeV [ATLAS-CONF-2012-147] | 704 GeV | M* scale (mχ < 80 GeV, limit of < 687 GeV for D8)
10-1
1
10
Mass scale [TeV]
*Only a selection of the available mass limits on new states or phenomena shown.
All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.



Expected limits in TeV

Z'(SSM) → ee and Z'(SSM)→ mumu for pp collisions at 14 TeV

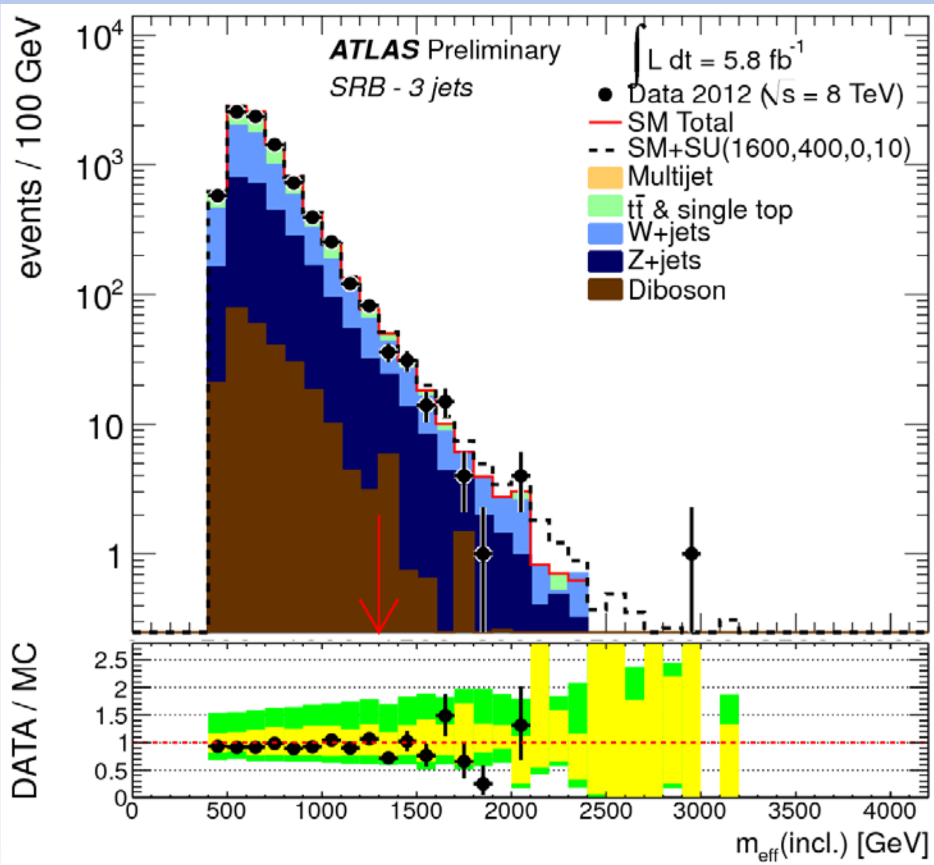
model	$300\,\text{fb}^{-1}$	$1000\,\text{fb}^{-1}$	$3000\,\text{fb}^{-1}$
$Z'_{SSM} \rightarrow ee$	6.5	7.2	7.8
$Z'_{SSM} \rightarrow \mu\mu$	6.4	7.1	7.6

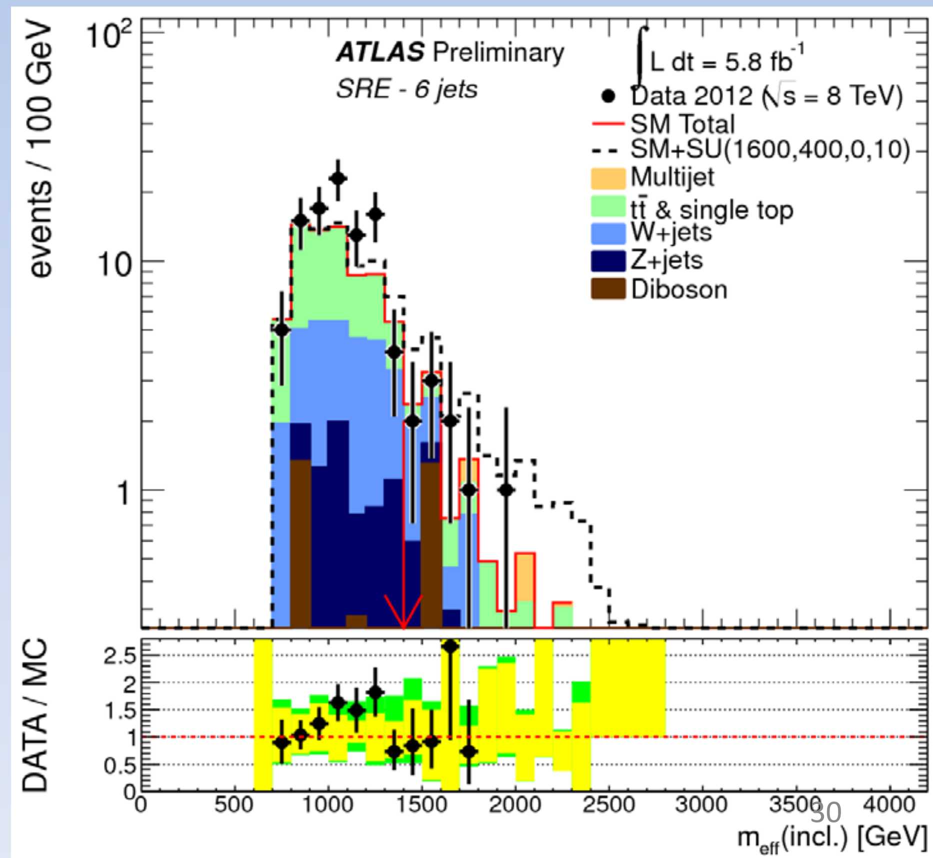
Backup slides

SUSY searches

Jets + missing momentum - MSUGRA/CMSSM interpretation

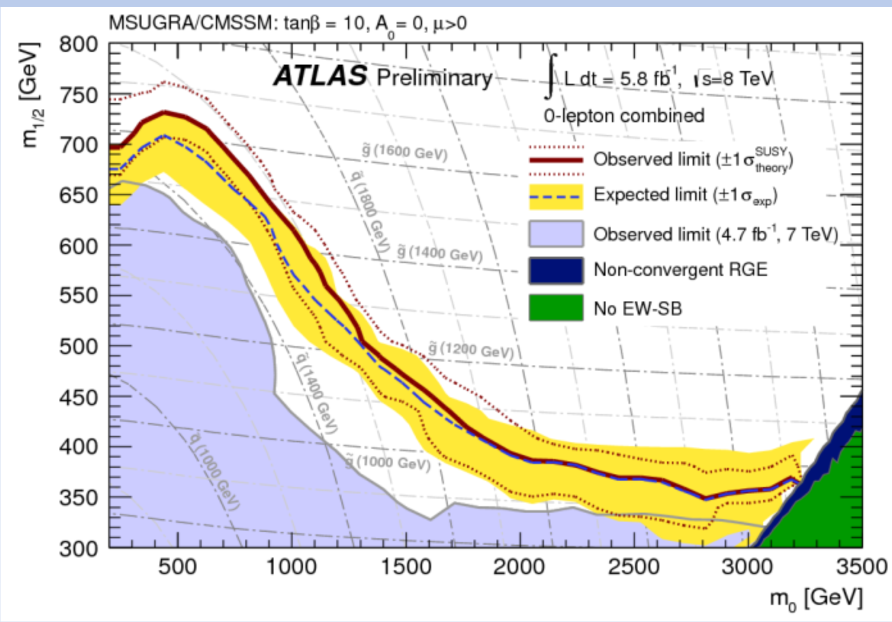
8TeV data – 5 signal regions Njets=2 - ≥6 with loose-medium-tight selection – each signal has 4 CRs for background estimatio
Meff=$\sum p_T^{jets}$ + $E_t$miss (+p_T^{lepton})
Observed m_{eff}(incl.) distributions for medium (left) and loose (right) cuts.
The histogram denotes the MC background expectations, normalised to cross section times integrated luminosity.
In the lower panels the yellow error bands denote the experimental and MC statistical uncertainties,
while the green bands show the total uncertainty.
The red arrows indicate the values at which the cuts on m_{eff}(incl.) are applied.
The expected distributions for a MSUGRA/CMSSM benchmark model point with
m_{0}=1600 GeV, m_{1/2}=400 GeV, A_{0}=0, tan(beta)=10 and mu>0 are also shown for comparison.

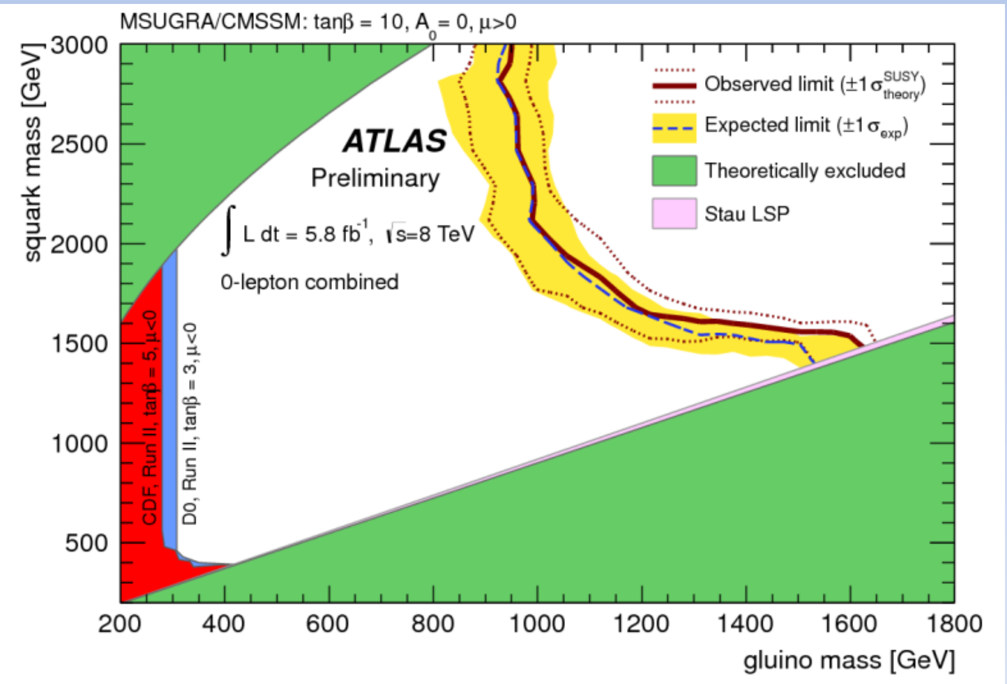




SUSY Jets + MET

95% CL exclusion limits for MSUGRA/CMSSM models with tan(beta)=10, A_{0}=0 and mu>0 presented in the m_{gluino}--m_{squark} plane. Exclusion limits are obtained by using the signal region with the best expected sensitivity at each point. The blue dashed lines show the expected limits at 95% CL, with the light (yellow) bands indicating the 1σ excursions due to experimental uncertainties. Observed limits are indicated by medium (maroon) curves, where the solid contour represents the nominal limit, and the dotted lines are obtained by varying the cross section by the theoretical scale and PDF uncertainties. The theoretically excluded regions (green and blue) are described in Ref. [63].

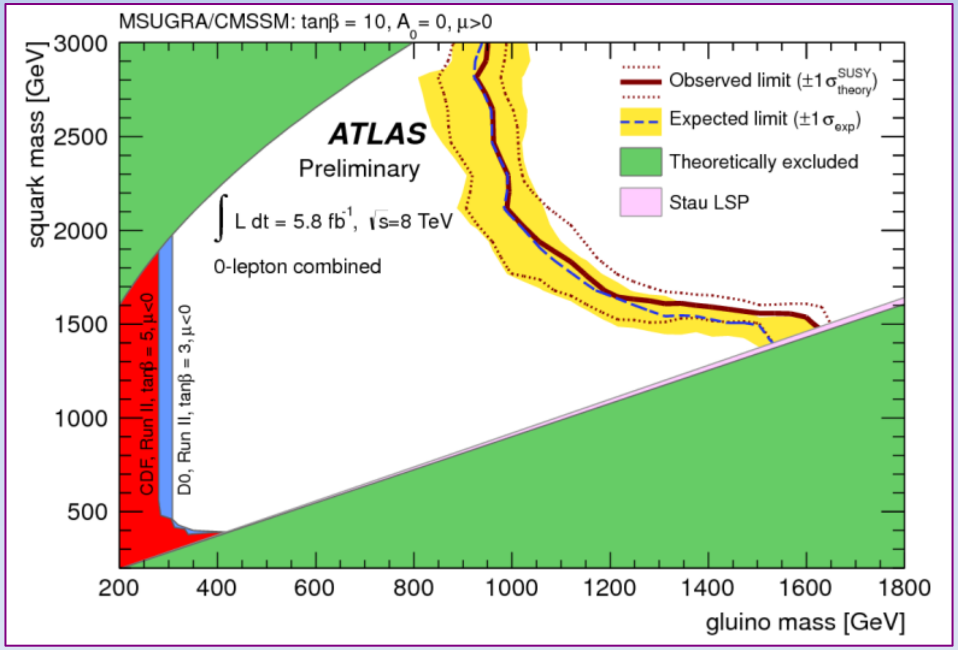


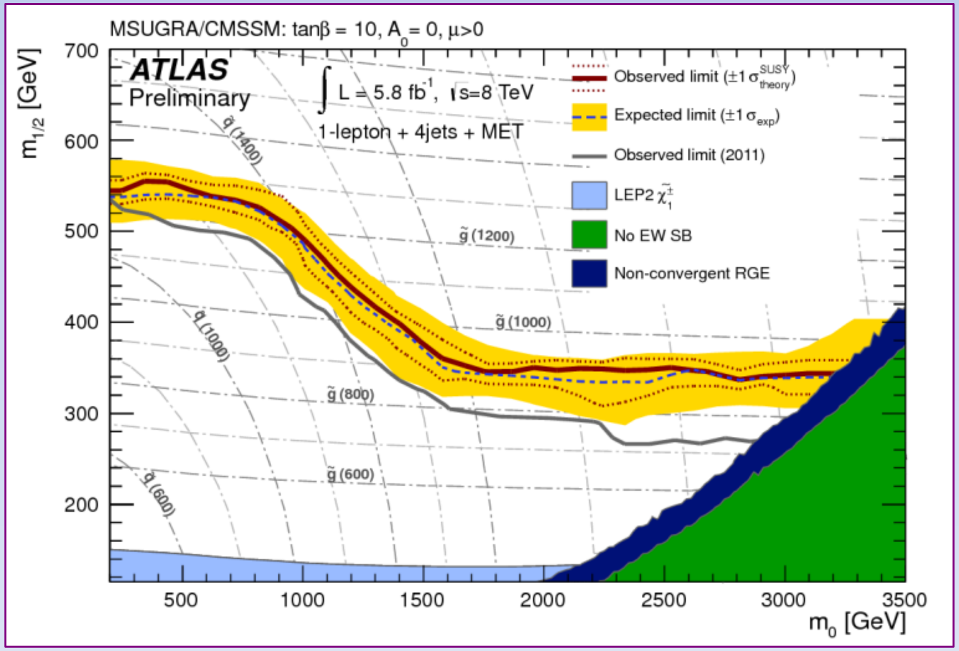


Inclusive searches : (one isolated lepton +) jets + MET (2)

MSUGRA/CMSSM
tanβ=10, A_0=0 and μ>0

Exclude @95% C.L.
$m_{1/2}$ < 350 GeV for all m_0
$m_{1/2}$ < 740 GeV for low m_0 from jets+MET
m(squark)=m(gluino) < 1500 (1240) GeV from jets+MET (lepton+jets+MET)
m(gluino)< ~900 GeV at high m_0 from lepton+jets+MET
Also interpretations in various "process-driven" simplified models





ATLAS-CONF-2012-109

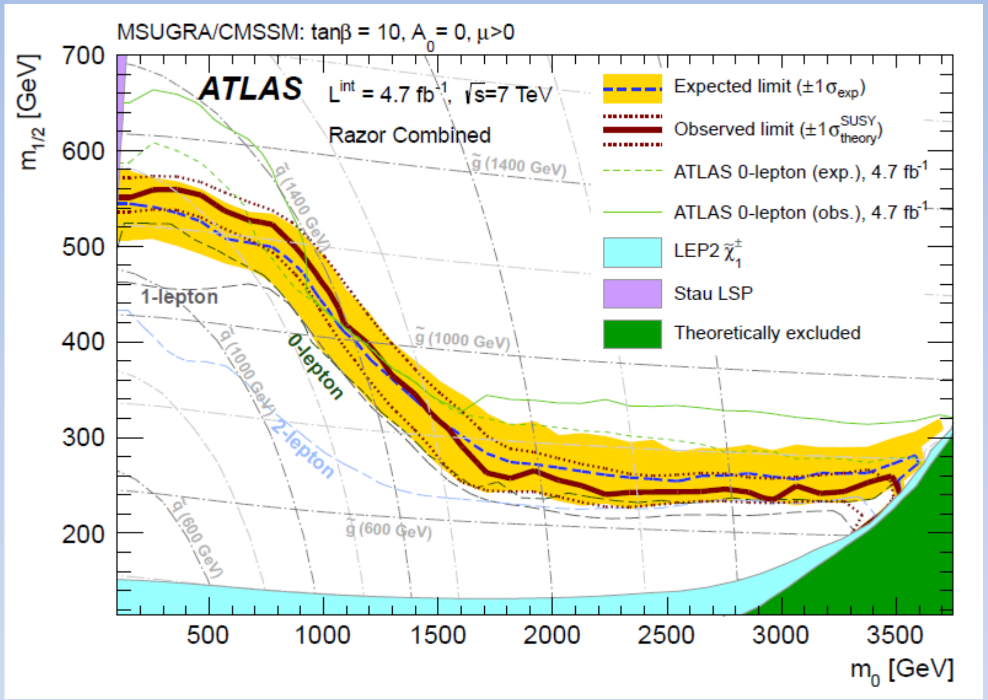
ATLAS-CONF-2012-104 (103)

Multichannel search for squarks/gluinos : 0-1-2 lepton(s)+jets + MET
Razor variable
N.B. E_{cm}= 7 TeV

razor $R \equiv \frac{M_T^R}{M_R}$

$$M_R \equiv \sqrt{(E_{j_1} + E_{j_2})^2 - (p_z^{j_1} + p_z^{j_2})^2}$$

$$M_T^R \equiv \sqrt{\frac{E_T^{miss}(p_T^{j1} + p_T^{j2}) - \vec{E}_T^{miss} \cdot (\vec{p}_T^{\,j1} + \vec{p}_T^{\,j2})}{2}}$$



Exclusion :
ly between m_{gluino} and m_{LSP}
For 0-1-2 lepton + jets + MET

arXiv:1211.6149

Gluino pair production : 3 b-jets + MET (1)

Gluino pair production gluino→ sbottom$_1$+b or stop$_1$+ t

6 signal regions

Main backgrounds

ttbar + jets : from data CR

QCD multijet : from data → negligible

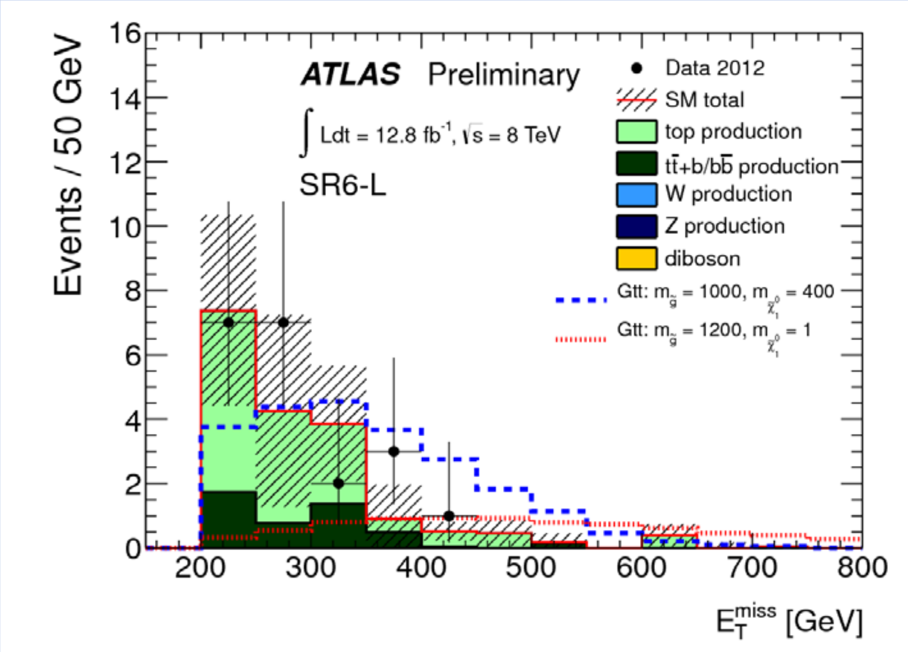
Other backgrounds → from MC

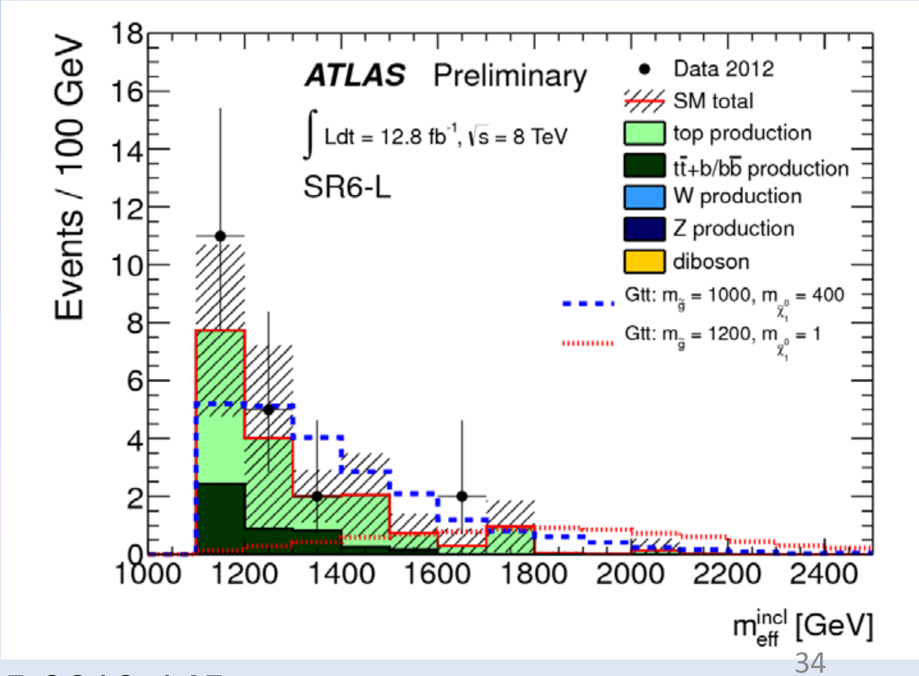
Discriminating variables

Etmiss, Meff+variants???,

$\Delta\phi_{min}^{4j}$: minimum azimuthal separation between any of the 4 leading jets and the MET

Common criteria: lepton veto, $p_T^{j_1} > 90$ GeV, $E_T^{miss} > 200$ GeV, ≥ 3 b-jets, $E_T^{miss}/m_{eff}^{4j} > 0.2$, $\Delta\phi_{min}^{4j} > 0.4$			
SR	N_J ($p_T > 50$ GeV)	p_T b-jets	m_{eff}
SR4-L/M/T	≥ 4 jets	> 50 GeV	$m_{eff}^{4j} > 900/1100/1300$ GeV
SR6-L/M/T	≥ 6 jets	> 30 GeV	$m_{eff}^{incl} > 1100/1300/1500$ GeV





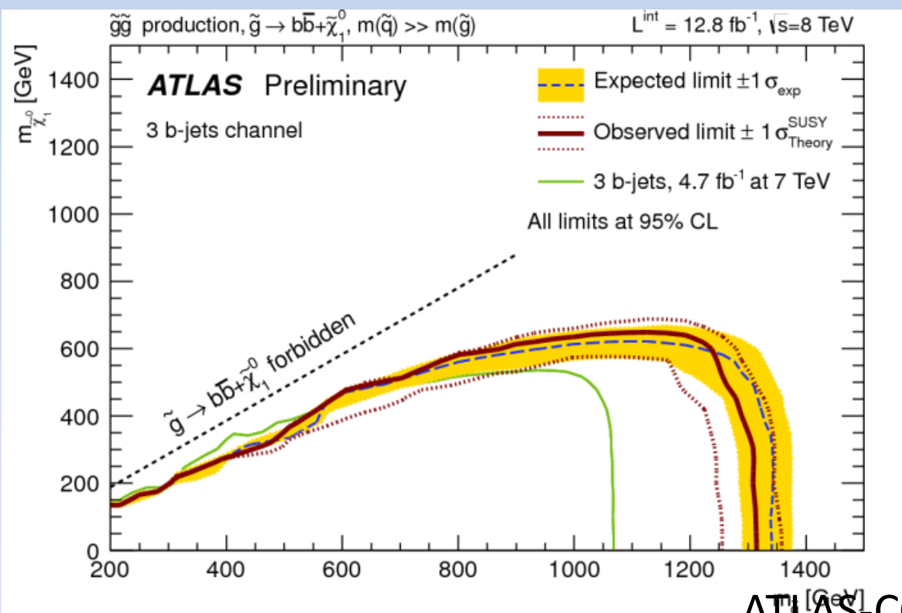
ATLAS-CONF-2012-145

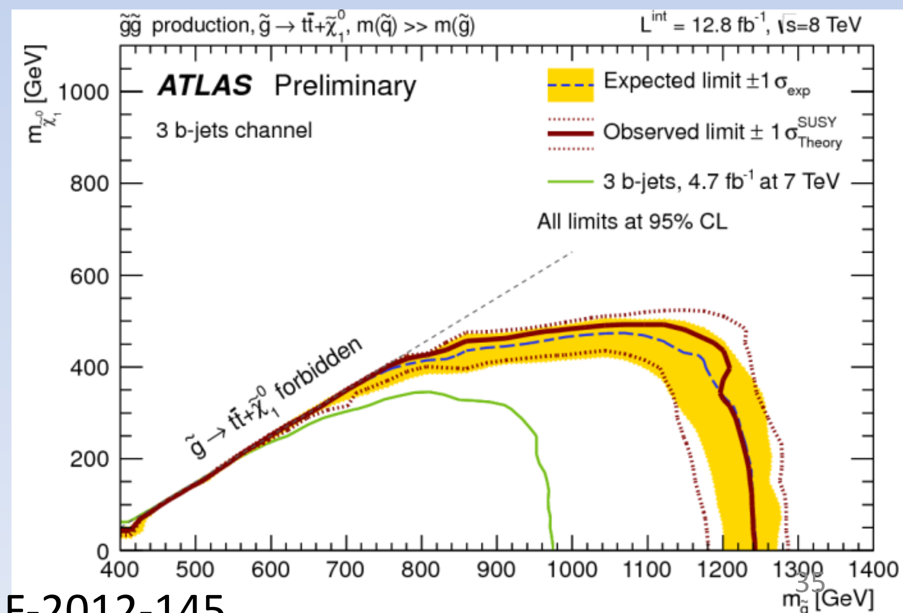
Gluino pair production : 3 b-jets + MET (2)

Gbb model : BR(~g→bbar χ_1^0)=100%
Gtt model : BR(~g→ttbar χ_1^0)=100%

The shaded (yellow) bands around the expected limits show the impact of the experimental uncertainties while the dotted red lines show the impact on the observed limit of the variation of the nominal signal cross-section by 1 sigma theoretical uncertainty. Also shown for reference are the results of the previous analysis.

- $m_{\chi_1^0} < 200$ GeV : exclude $\tilde{g}$ mass up to 1240 (1100) GeV in *Gbb* (*Gtt*) model.
- $m_{\tilde{g}} = 1100$ GeV : exclude χ_1^0 mass below 570 (440) GeV in *Gbb* (*Gtt*) model.





ATLAS-CONF-2012-145

Feeling a bit cramped?
Relaxing the constraints using "Simplified models"
???Which atl conf or note???

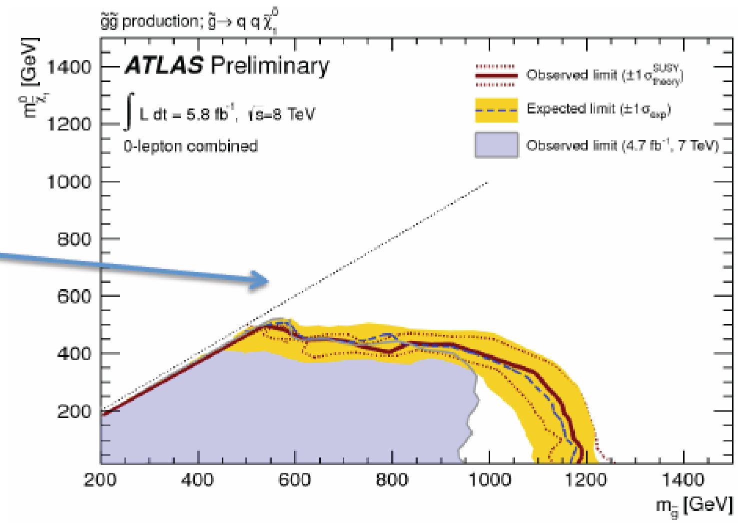
ATLAS

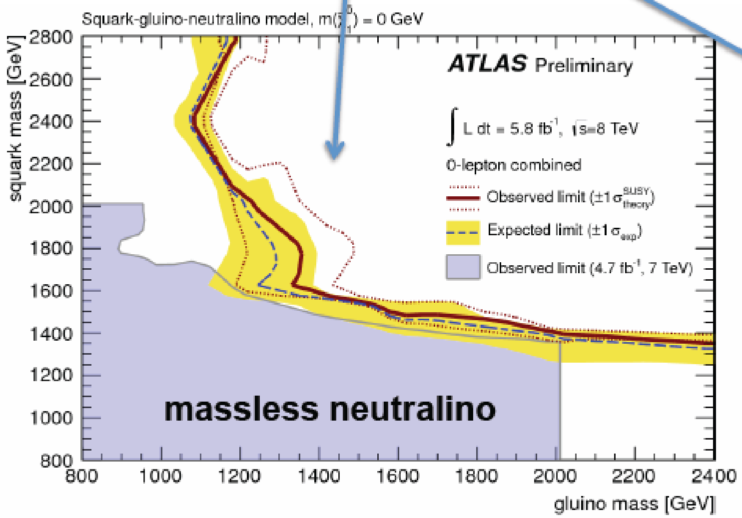
(conclusions agree with those of CMS)

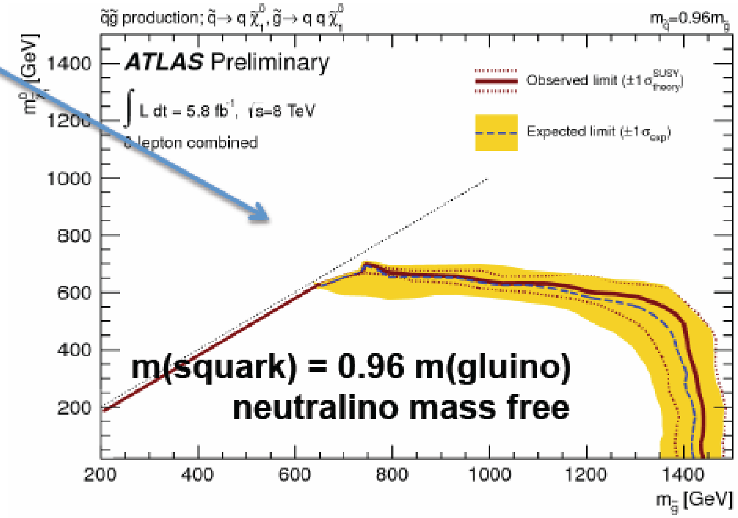
gluino pair production

ATLAS-CONF-2012-109

squark + gluino production







Gauge mediation put 7TeV photon + b-jets + MET 1211.1167

N.B. E_{cm}= 7 TeV

Light gravitino LSP → several candidates for NLSP

Stau/slepton/neutralino→tau/lepton/X + gravitino

If neutralino NSLP → decay depends on bino/wino/higgsino mixture

bino/wino/higgsino-like : neutralino → photon/Z/h + gravitino

Search for combinations of photons/Z/h + missing transverse momentum

Prompt or non-prompt decay

Prompt diphoton + MET

also Extra Dimensional interpretation

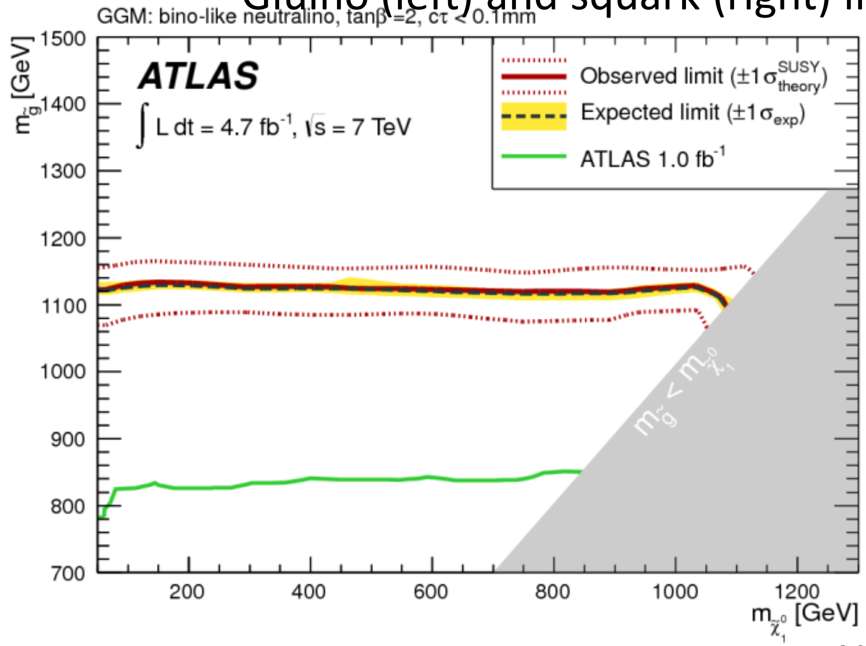
Signal

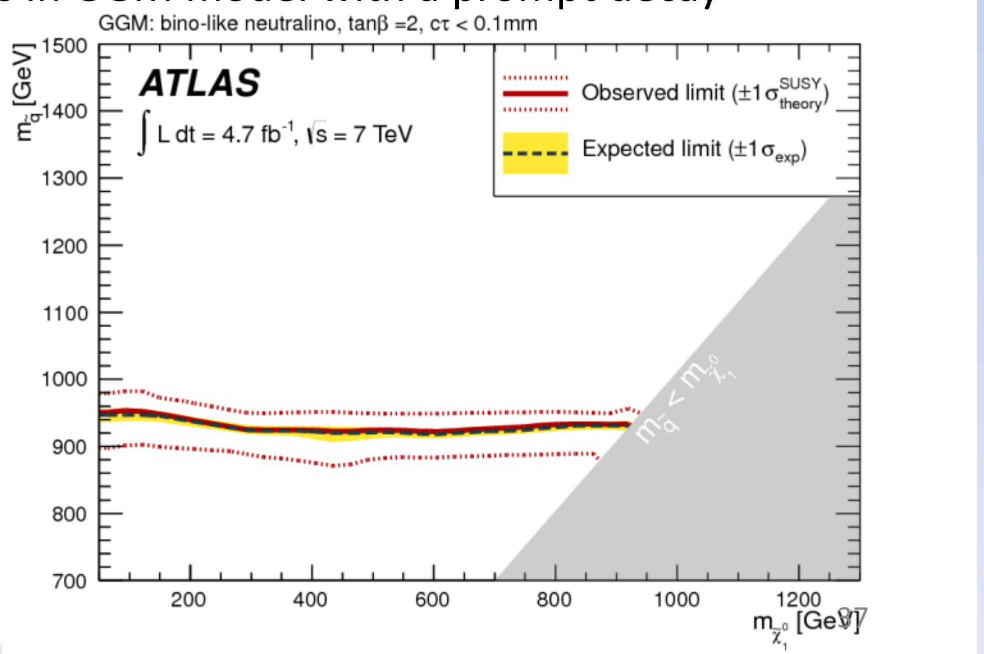
Backgrounds

Discriminating variables

Conclusion???

Gluino (left) and squark (right) limits in GGM model with a prompt decay





arXiv:12[illegible]

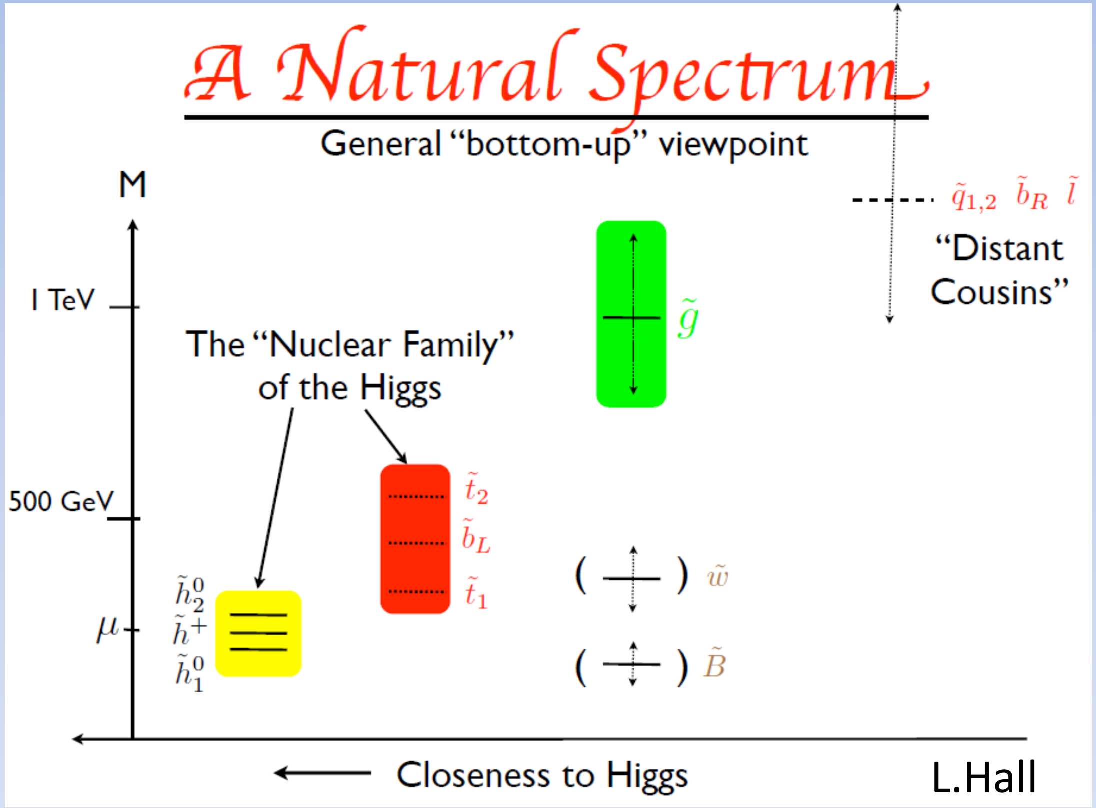
Previous results impose severe constraints on SUSY

If m(Higgs)~125 GeV

then in a “Natural spectrum”

m(light-stop-bottom, charginos) <~ 500 GeV

m(gluino) <~ 1100-1500??? GeV [arxiv 1302.2146v1, 1110.6670]

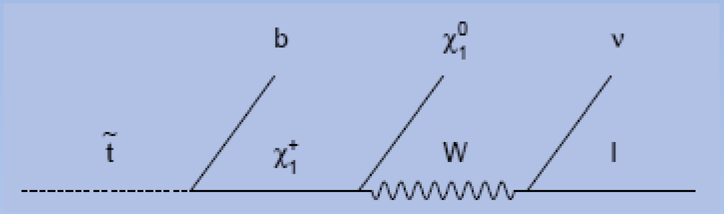


Hence emphasize search for

→ gluino mediated and direct production of stops or sbottoms

→ direct production of charginos and neutralinos (see Stewart Martin-Haugh’s talk)

Direct medium stop production : two leptons + MET



3 signal regions

Background

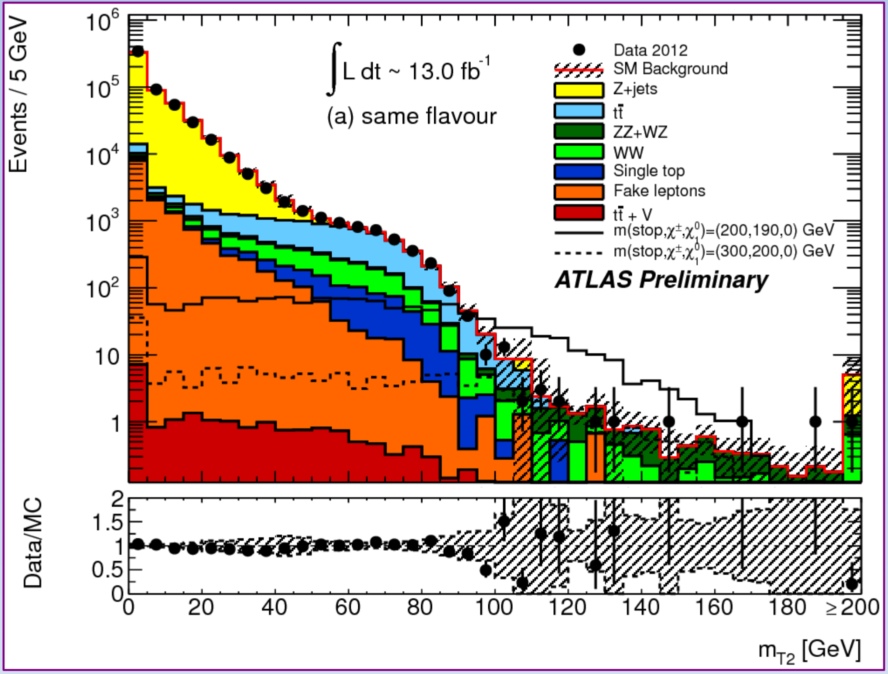
Top production, diboson: from data CR

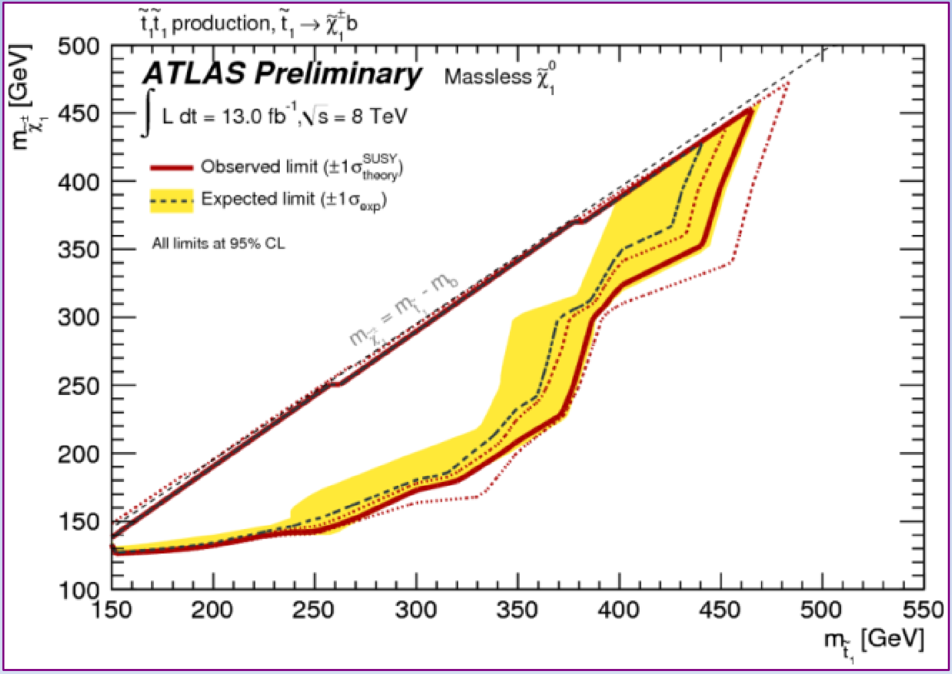
Fake leptons, QCD multijet : from data ;

Other backgrounds : MC

Discriminating variable MT2

$$m_{T2}(\mathbf{p}_T^{\ell_1}, \mathbf{p}_T^{\ell_2}, \mathbf{p}_T^{\text{miss}}) = \min_{\mathbf{q}_T + \mathbf{r}_T = \mathbf{p}_T^{\text{miss}}} \left\{ \max[\, m_T(\mathbf{p}_T^{\ell_1}, \mathbf{q}_T), m_T(\mathbf{p}_T^{\ell_2}, \mathbf{r}_T) \,] \right\}$$





Exclude

150 GeV < m_{stop} <450 GeV

for $m_{chargino}$ and m_{stop} approximately degenerate and $m\chi_1^0 = 0$

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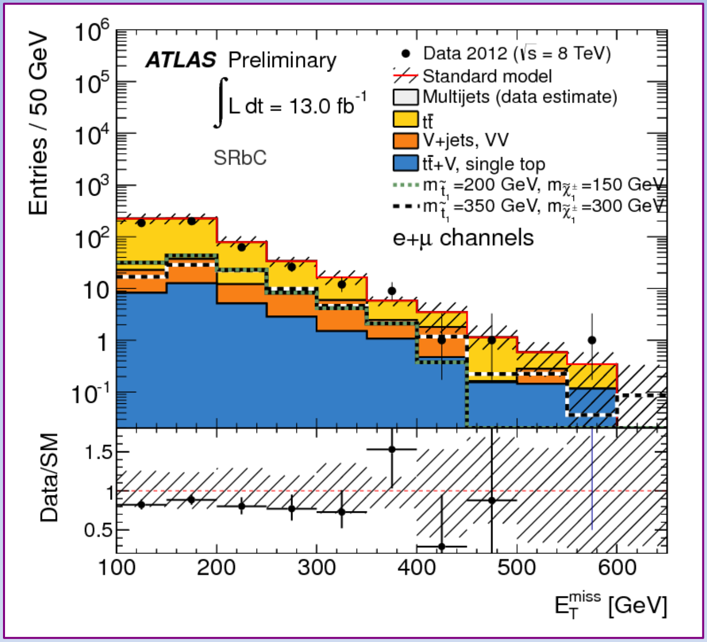
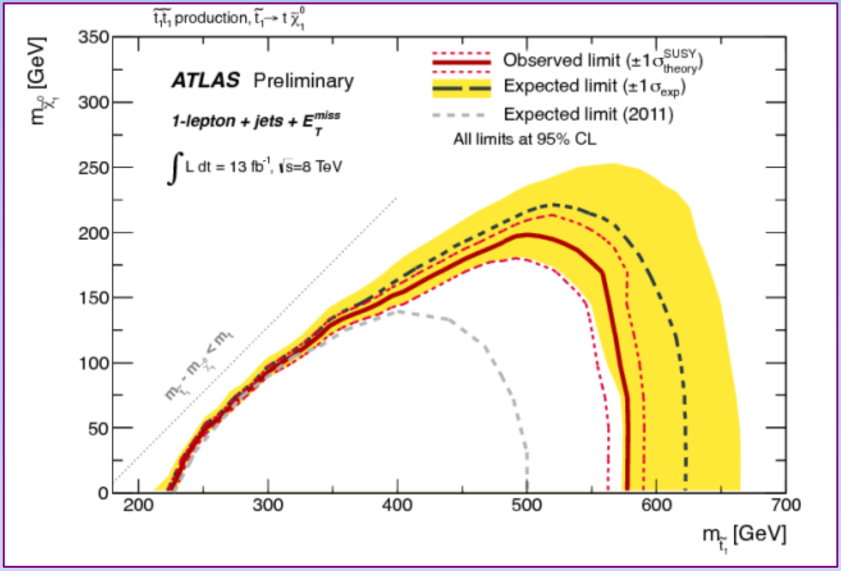
Direct stop production : one lepton + jets + MET

Both stop1→b χ_1^+ with $\chi_1^+ \to W^{(*)} \chi_1^0$
or both stop1→t χ_1^0

6 signal regions
Background
Dileptonic ttbar, W+jets, top : from data CR
QCD multijet : from data
Other : from MC
Discriminating variables
MET, MET/√HT, mT, mT2





Exclude
If both stop→ top + LSP
225 GeV < m_{stop} < 560 GeV for m_{LSP}=0
and m_{stop} < 500 GeV for m_{LSP}<175 GeV
If both stop→ b + chargino
m_{stop} < 350 GeV for m_{LSP}=0 and $m_{chargino}$=150GeV

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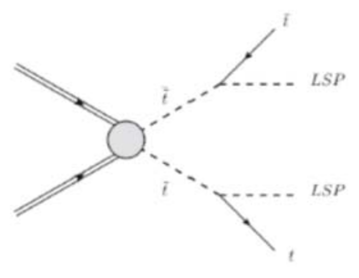
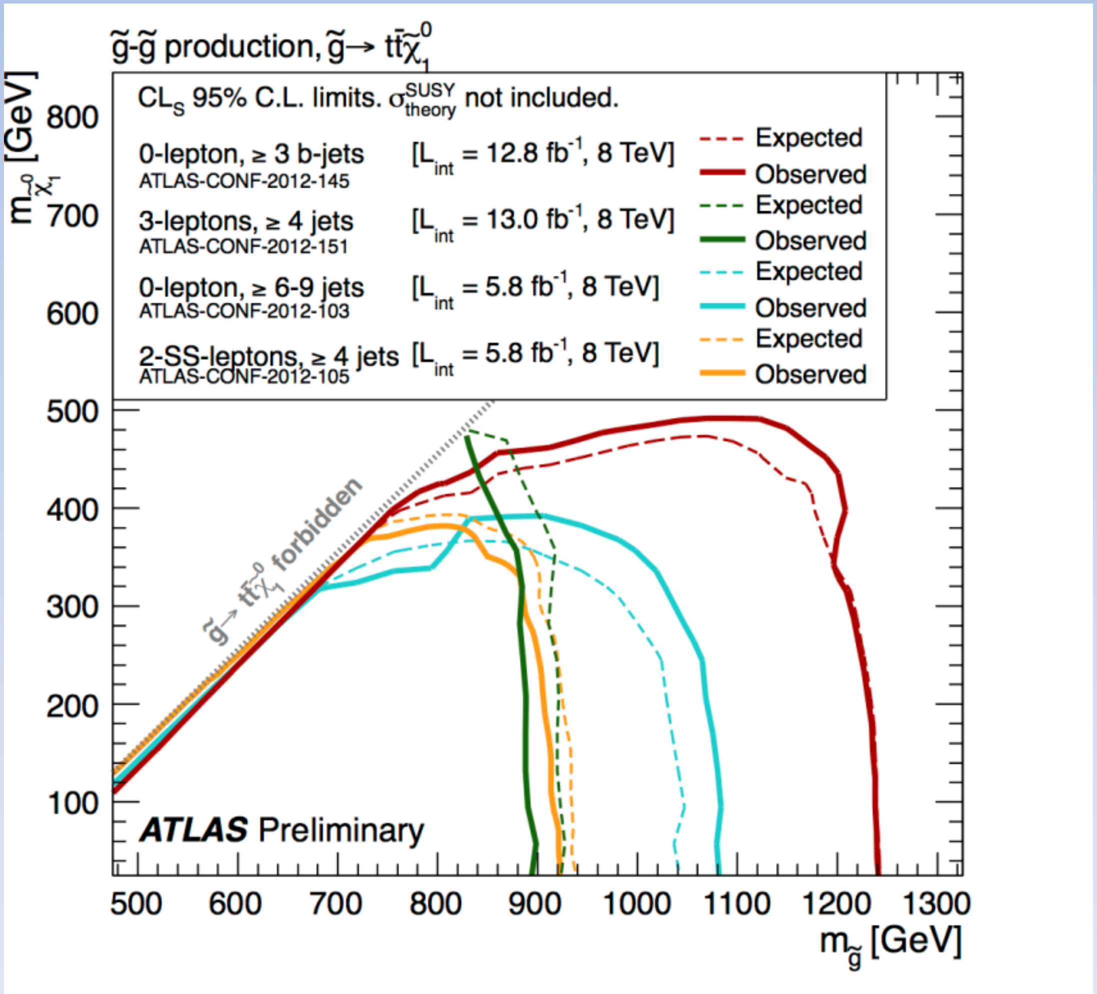
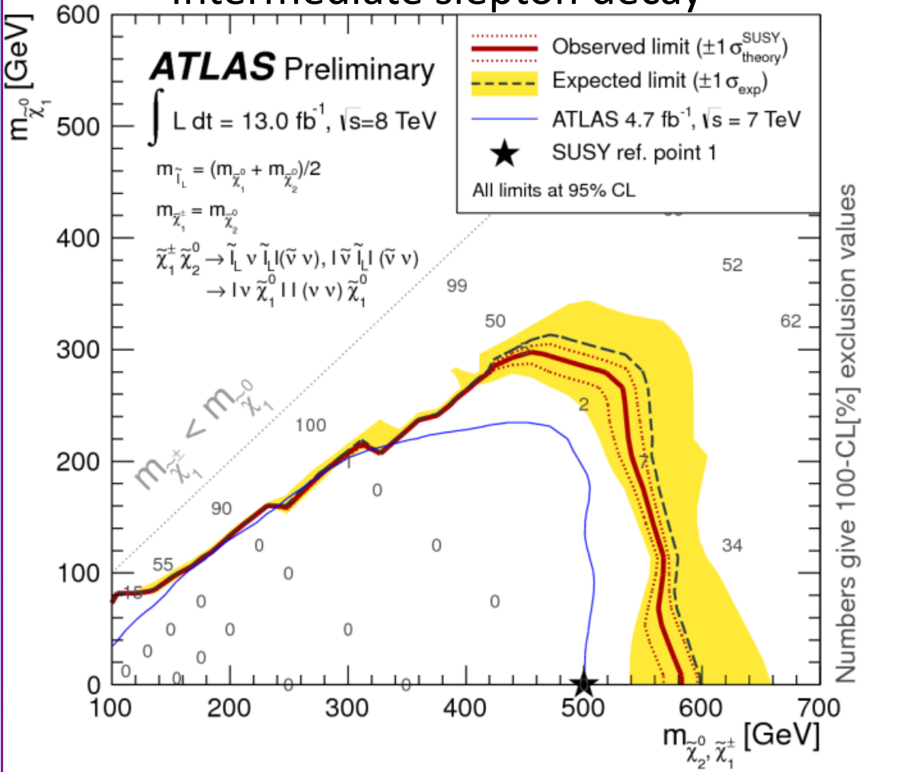
Gluino mediated stop production



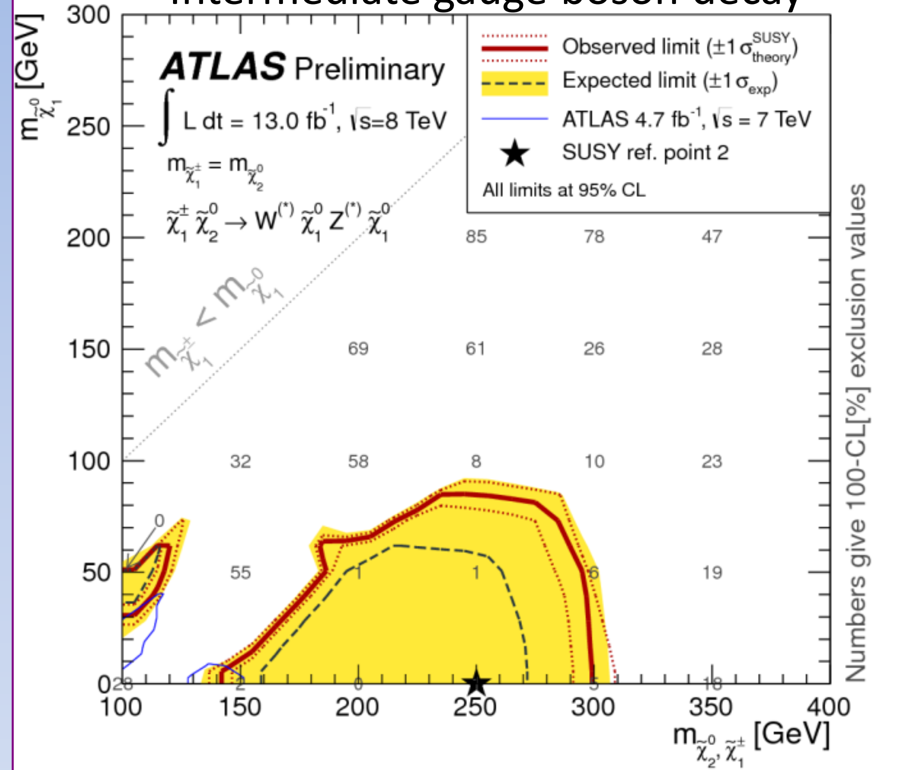


Searches for gaugino pair production : 3 leptons + MET

Intermediate slepton decay



Intermediate gauge boson decay



Simplified models i.e. $m\chi_1^0 = 0$
exclude
$m_{chargino} <$ 580 GeV when light sleptons
150 GeV $< m_{chargino} <$ 300 GeV when heavy sleptons

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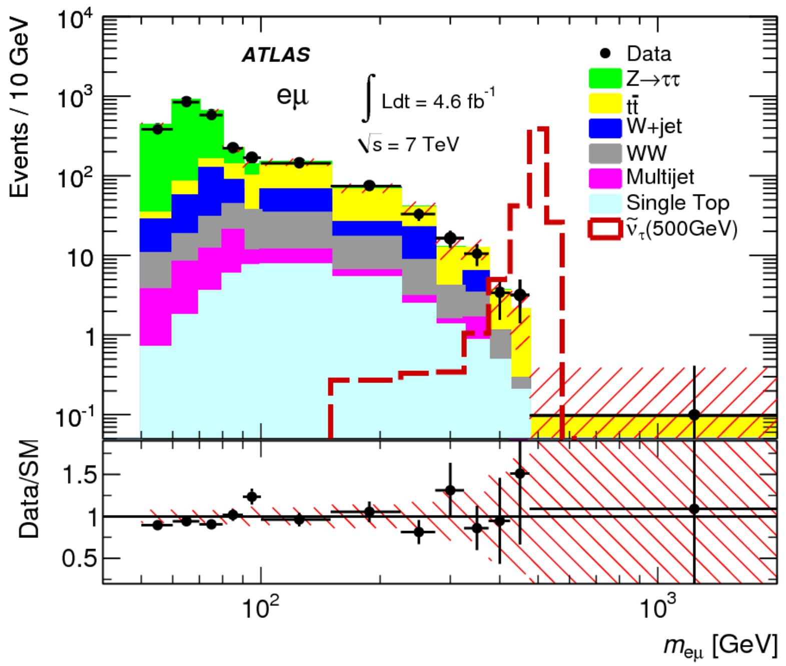
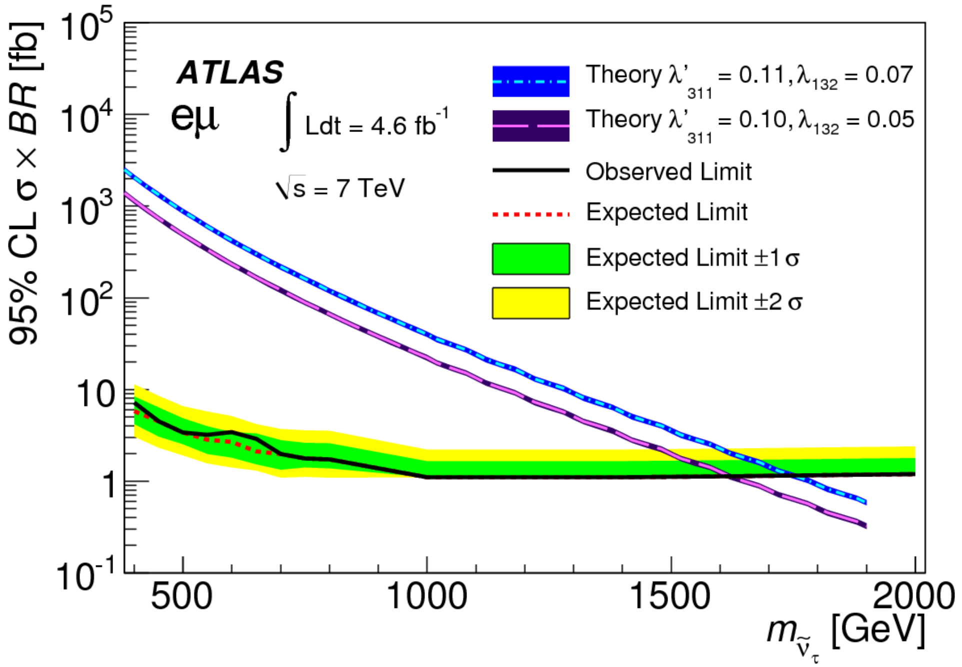
RPV tau sneutrino :
search for heavy narrow resonance → eμ, eτ, μτ

RPV lagrangian = ½ $\lambda_{ijk}L_iL_je_k$ + $\lambda'_{ijk}L_iQ_jd_k$ = Multileptons + Leptoquarks



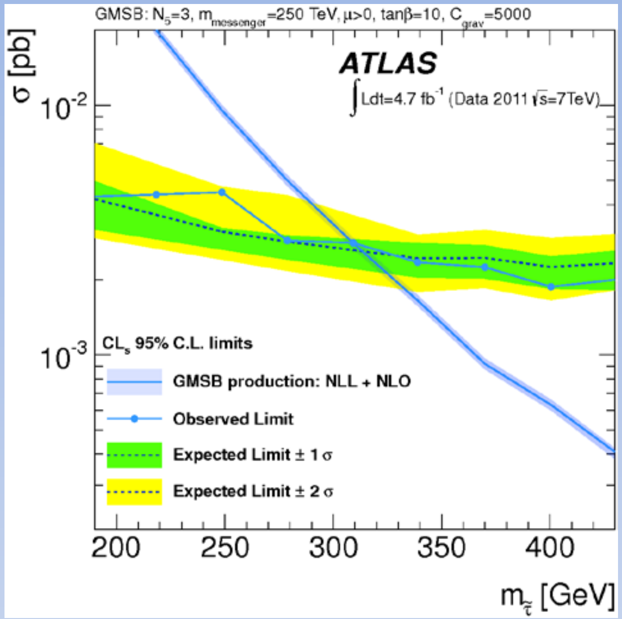


Upper limit on σ_{prod} x B.R. versus $m_{sneutrino}$ for the eμ mode

arXiv:1212.1272

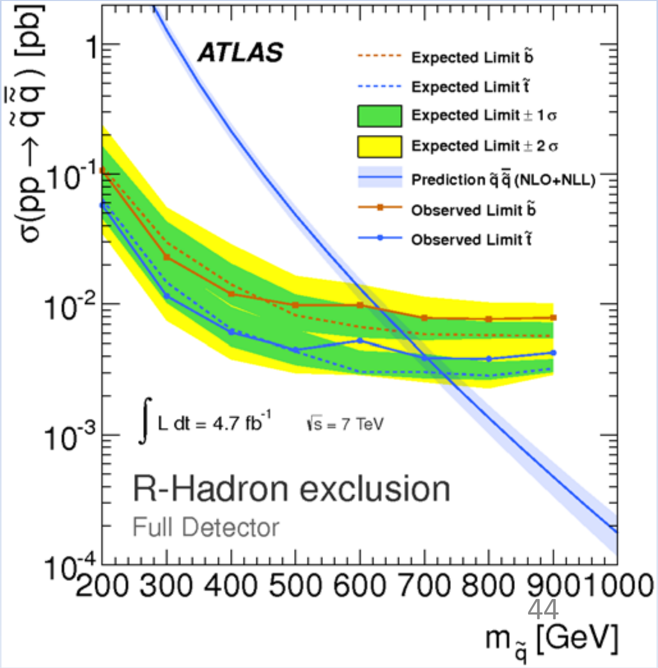
Long lived sleptons and R-hadrons

Signal
Sleptons (two muons)
and R-hadrons (3 different detector analyses)
i.e. bound colourless states
of Long-Lived-Particle (squarks/gluinos)
with quarks/gluons
Background
High pT muons with mis-measured
β=v/c or large ionisation : from data



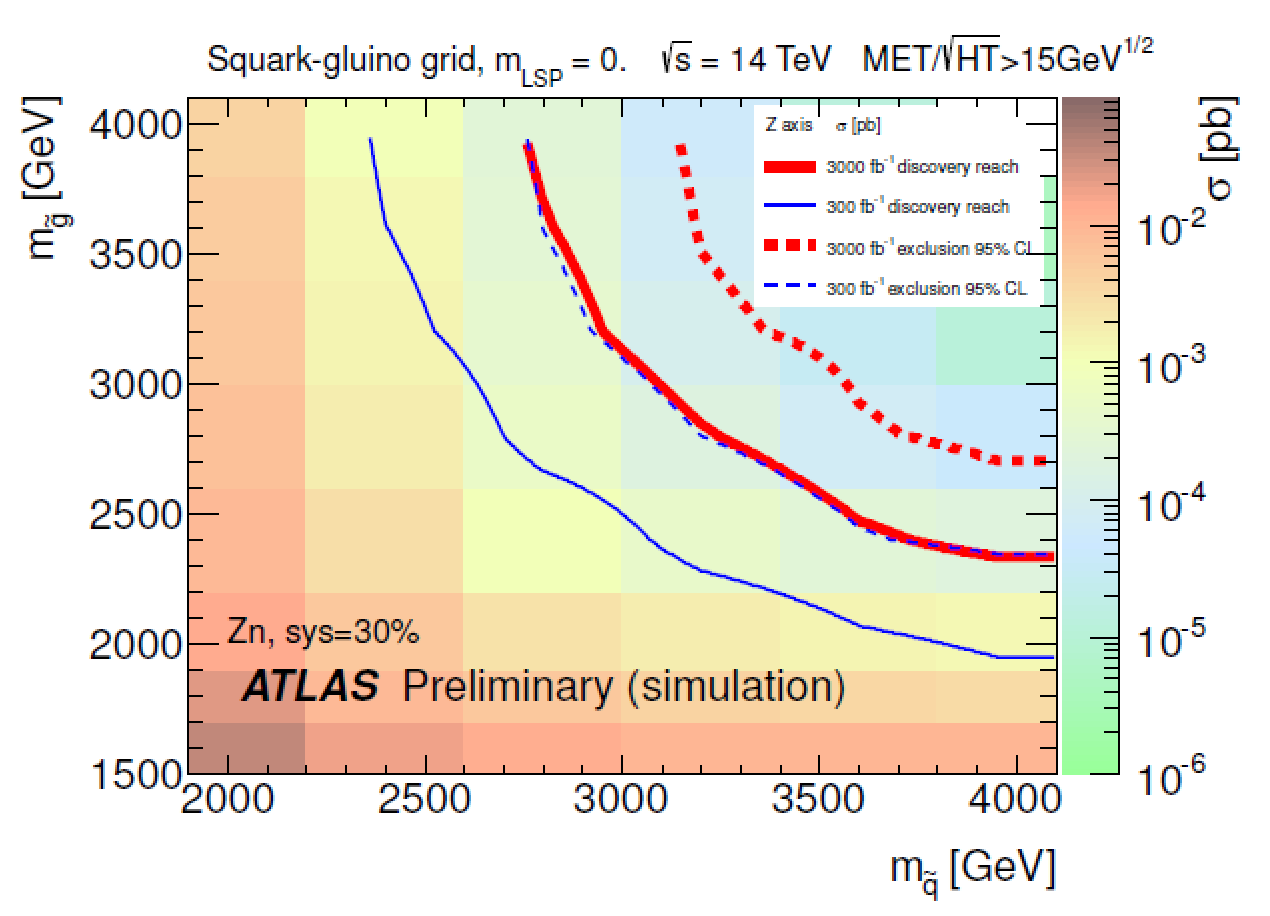
Long-lived staus in GMSB models excluded for
$M_{stau} < 300$ GeV for tan β = 5-20.
Directly produced long-lived sleptons are excluded for
$M_{slepton} < 278$ GeV.

R-hadrons,
composites of gluino (stop, sbottom) and light quarks, excluded for
$m_{R\text{-}hadron} < 985$ GeV (683 GeV, 612 GeV)
when using a generic interaction model.
Additionally 2 sets of limits on R-hadrons
obtained less sensitive to interaction model .

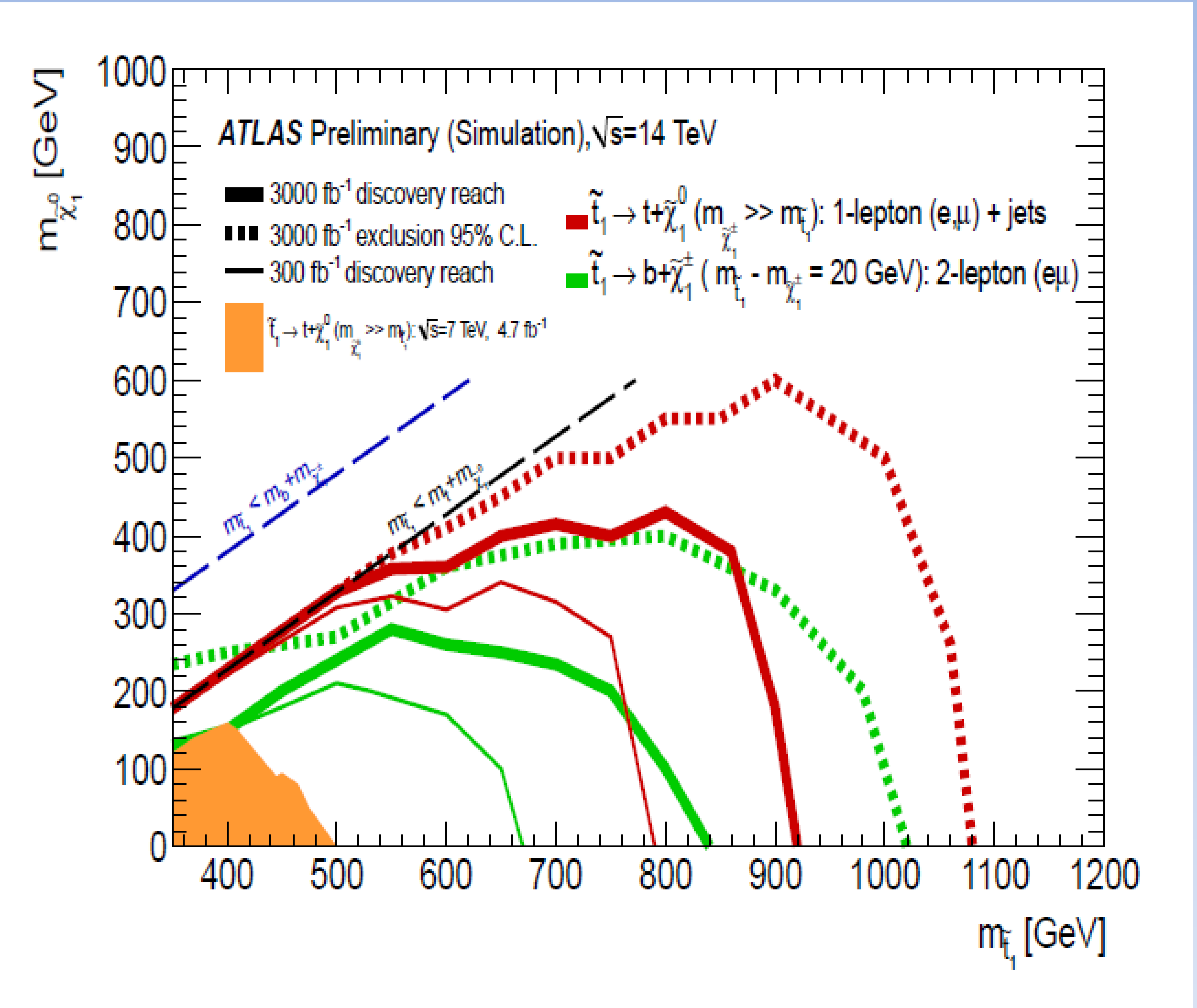


arXiv:1212.1597

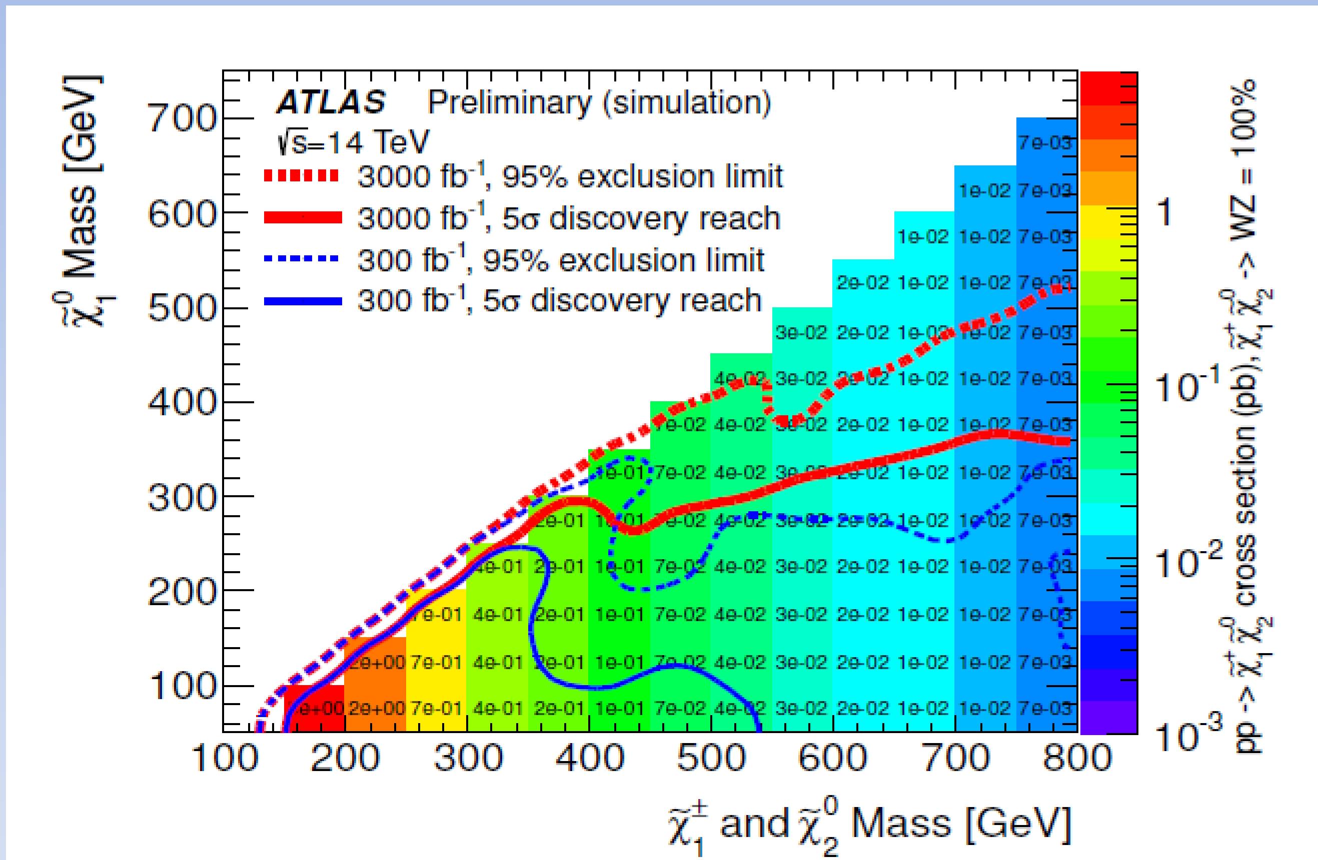
SUSY - Upgrade



SUSY - Upgrade



SUSY - Upgrade



Exotics searches

Searches in the dijet mass distribution

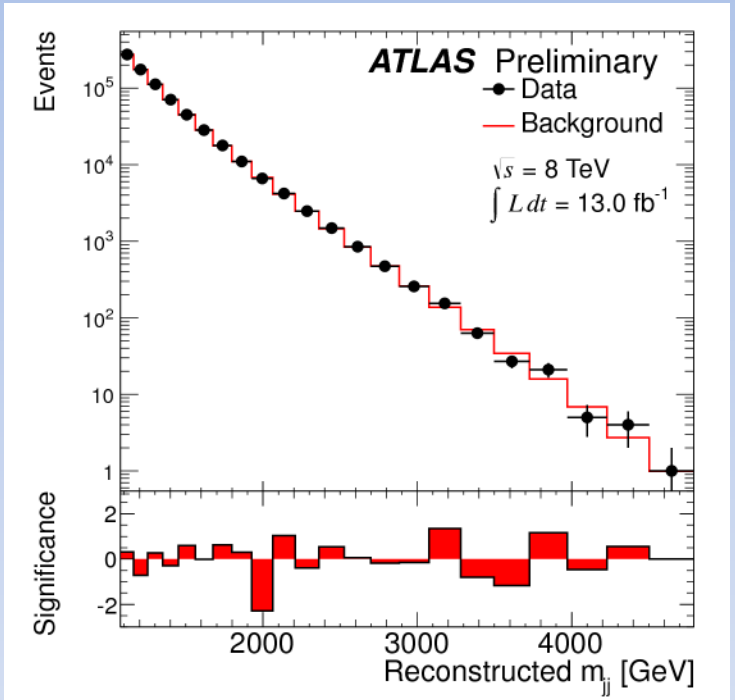
The models

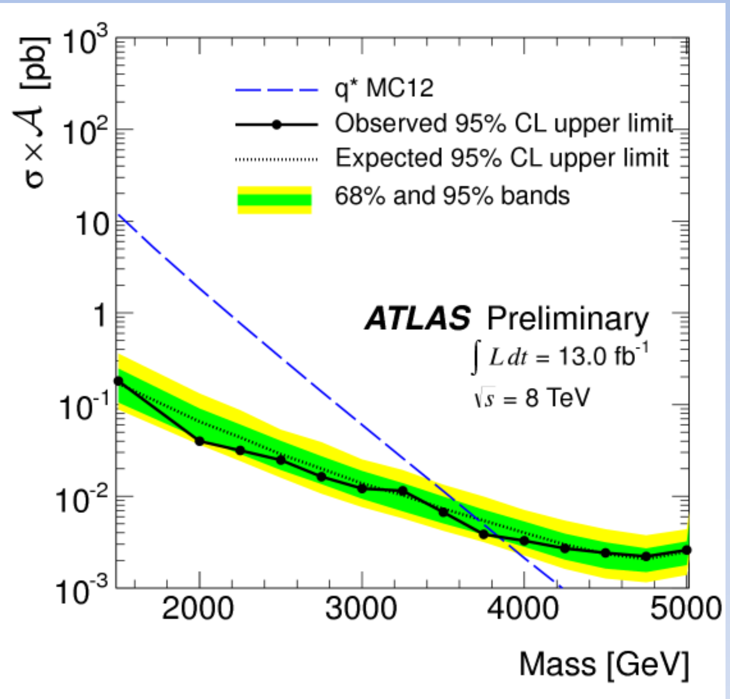
- **Excited quarks** (Pythia6/8)
- Also looked at

Axigluon, Quantum Black Hole, RS Graviton
in arXiv:1210.1718

Background
Fitting smooth functional form to data

Variable
Dijet invariant mass





Exclude
excited quark mass m(q*) < 3.84 TeV

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