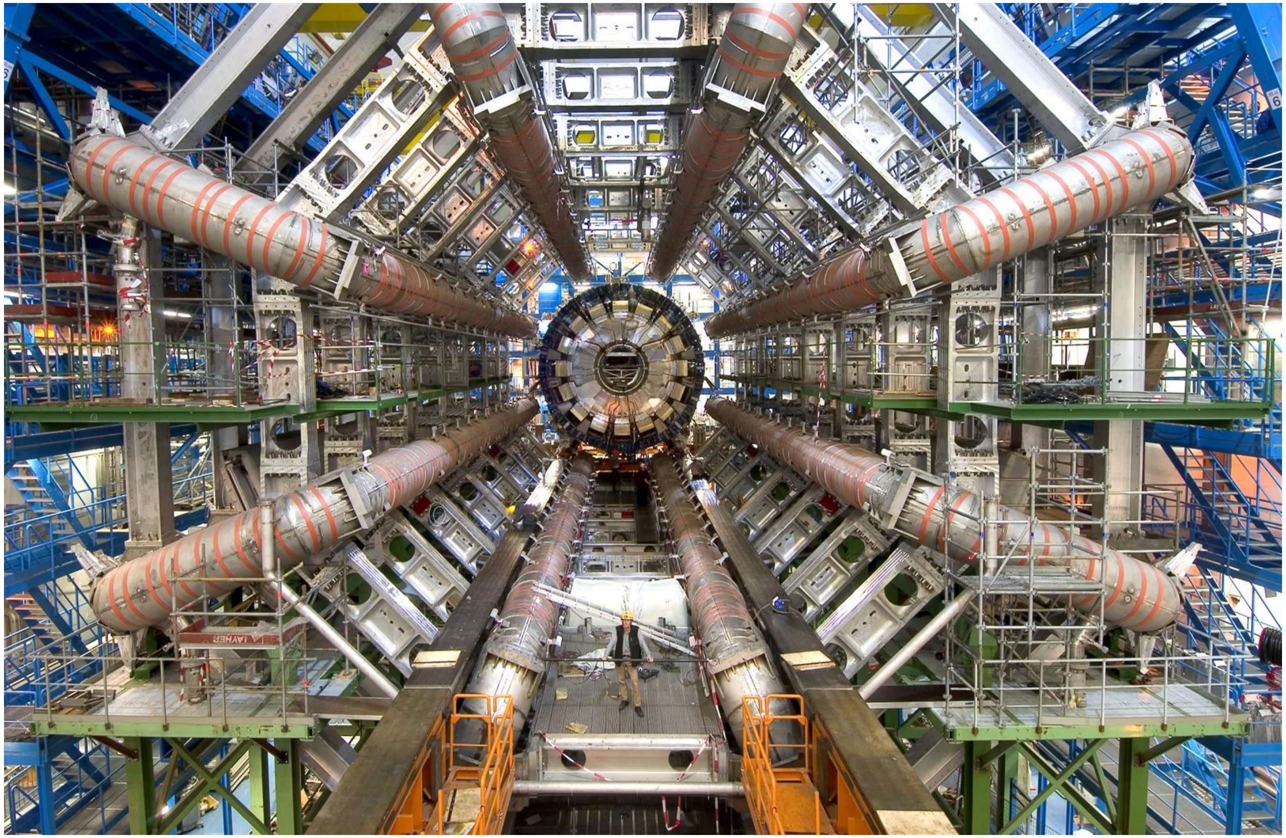
Supersymmetry searches with ATLAS: overview and latest results

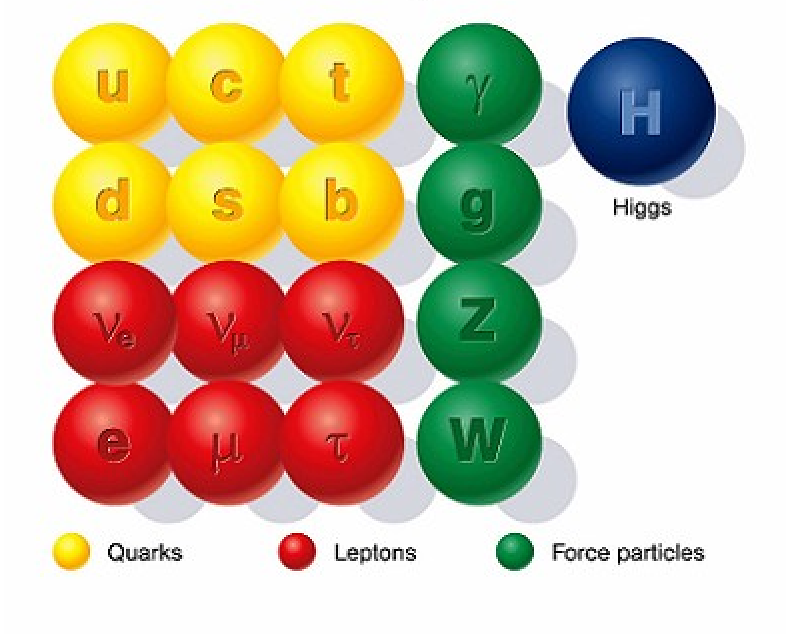


Tina Potter
On behalf of the ATLAS Collaboration

University of Sussex

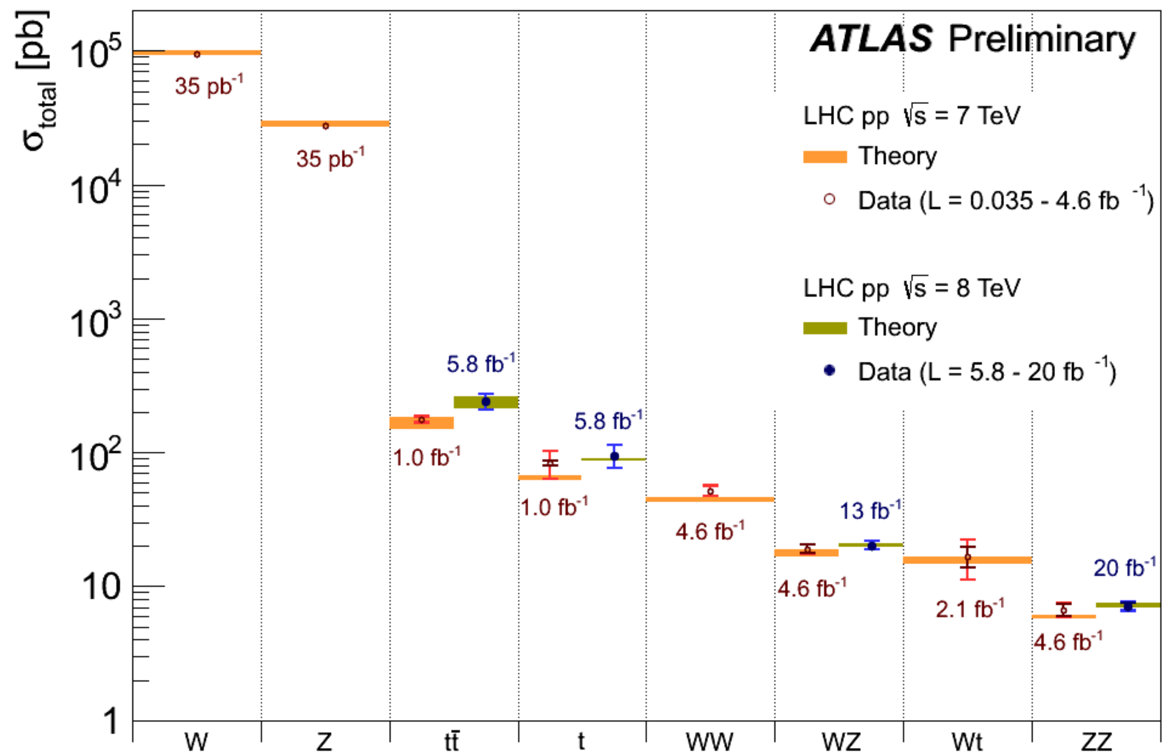
The Standard Model

Standard Model



The Standard Model of elementary particles is a very successful theory.

Precise predictions, verified by experiment over many orders of production rate.

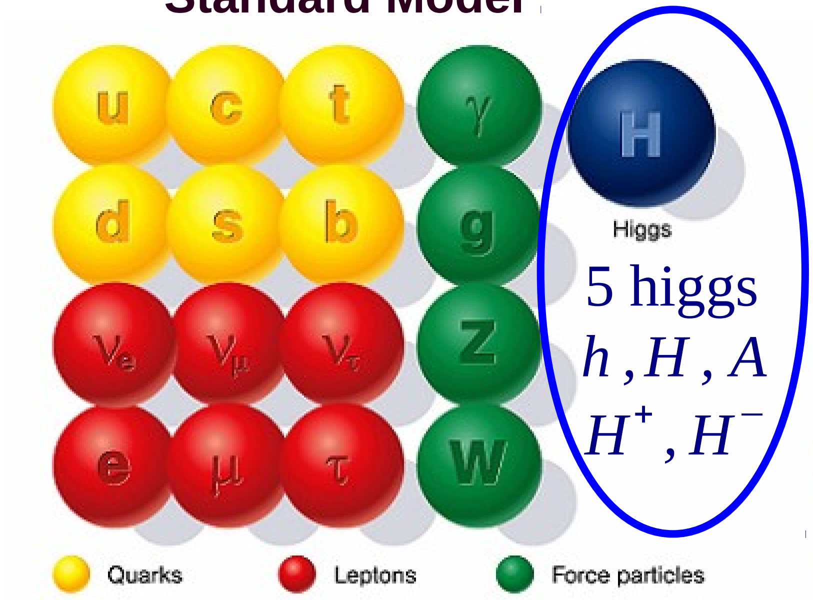


So what's the problem?

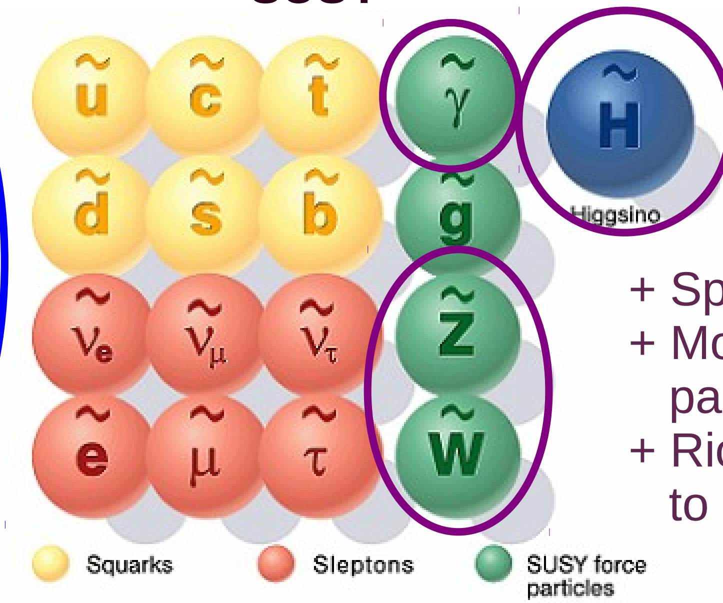
– Need high-levels of fine tuning to avoid quadratic divergences in Higgs mass corrections
– No explanation for Dark Matter
– No unification of the forces
...

Supersymmetry

Standard Model



SUSY



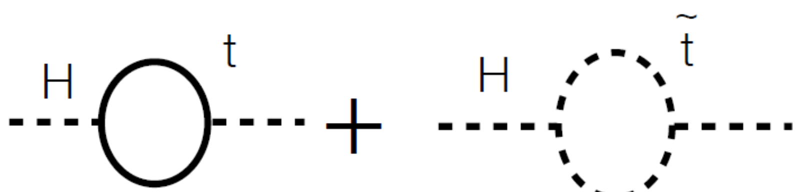
Superpartner for every SM particle

+ Spin differs by one half
+ Mostly heavier than SM partners → broken symmetry
+ Rich array of signatures to search for at the LHC

$$W^\pm \; W^0 \; B \;\overset{mixing}{\rightarrow}\; W^\pm \; Z \; \gamma$$

$$\tilde{H}_u^0 \; \tilde{H}_d^0 \; \tilde{W}^0 \; \tilde{B}^0 \;\overset{mixing}{\rightarrow}\; \tilde{\chi}_1^0 \; \tilde{\chi}_2^0 \; \tilde{\chi}_3^0 \; \tilde{\chi}_4^0 \quad \text{neutralinos}$$

$$\tilde{H}_u^+ \; \tilde{H}_d^- \; \tilde{W}^+ \; \tilde{W}^- \;\overset{mixing}{\rightarrow}\; \tilde{\chi}_1^\pm \; \tilde{\chi}_2^\pm \quad \text{charginos}$$



New superpartner loop roughly cancels the SM loop

So what's the problem?

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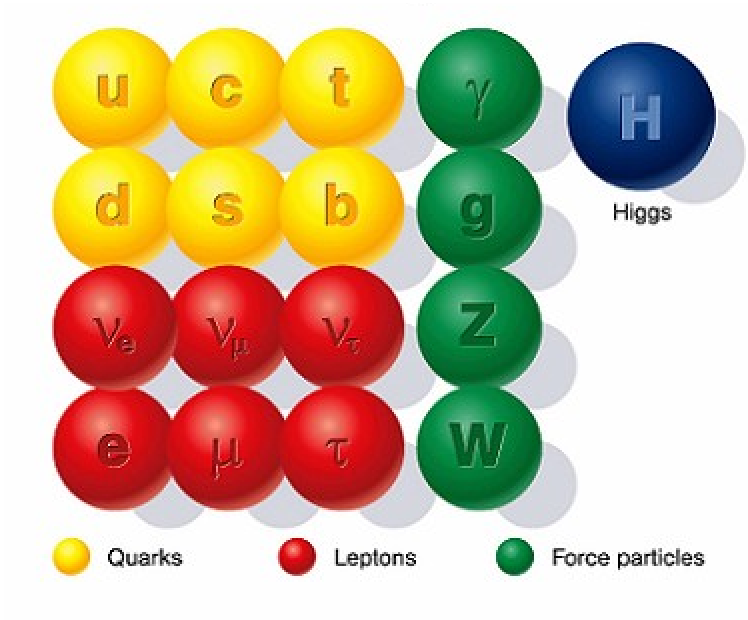
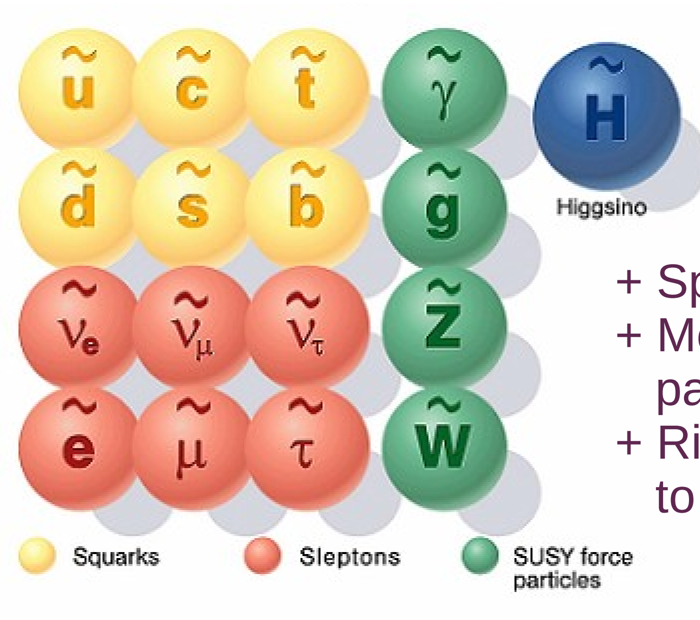
...

Supersymmetry

Standard Model



SUSY



Superpartner for every SM particle

+ Spin differs by one half
+ Mostly heavier than SM partners → broken symmetry
+ Rich array of signatures to search for at the LHC

If R-parity if conserved, lightest SUSY particle (LSP) is stable

$$P_R = (-1)^{3(B-L)+2S}$$

+1 for SM particles, -1 for SUSY particles

In many models, LSP is commonly lightest neutralino $\tilde{\chi}_1^0$

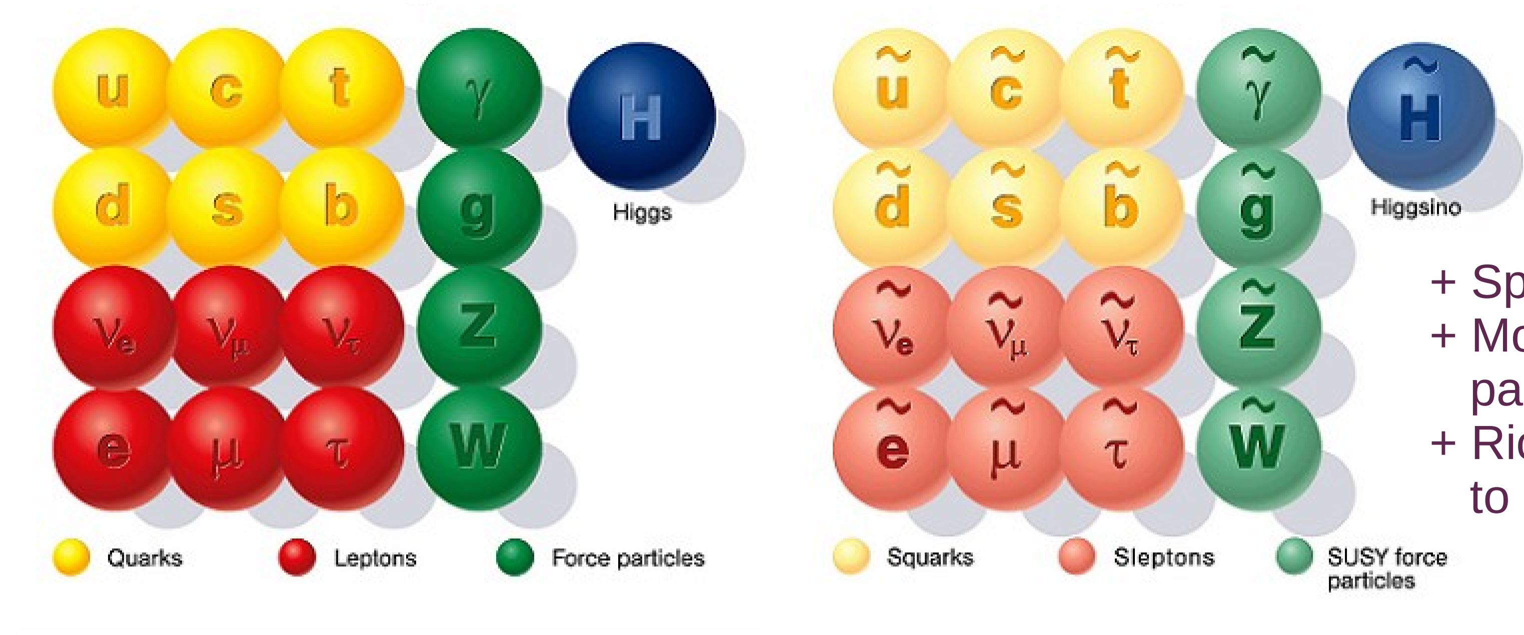
→ *good dark matter candidate!*

So what's the problem?

– Need high-levels of fine tuning to avoid quadratic divergences in Higgs mass corrections
– No explanation for Dark Matter
– No unification of the forces
...

Supersymmetry

Standard Model **SUSY**



Superpartner for every SM particle

- + Spin differs by one half
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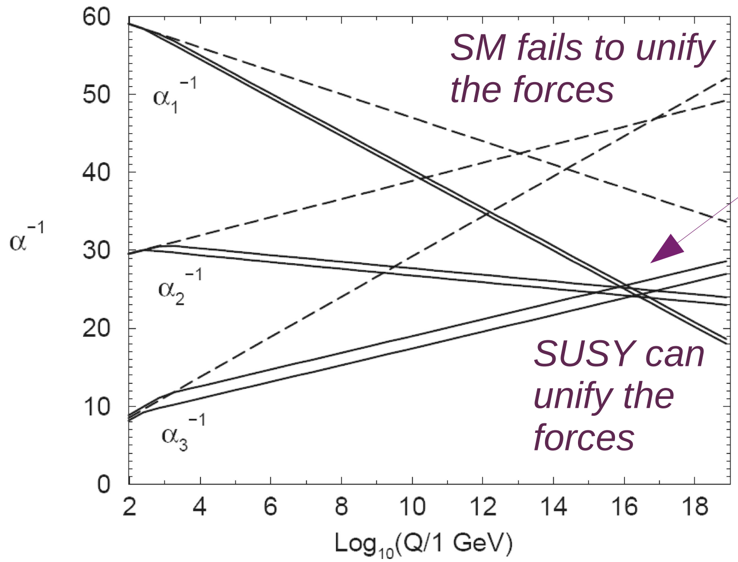


arXiv:hep-ph/9709356

High unification scale also resolves issues with proton decay

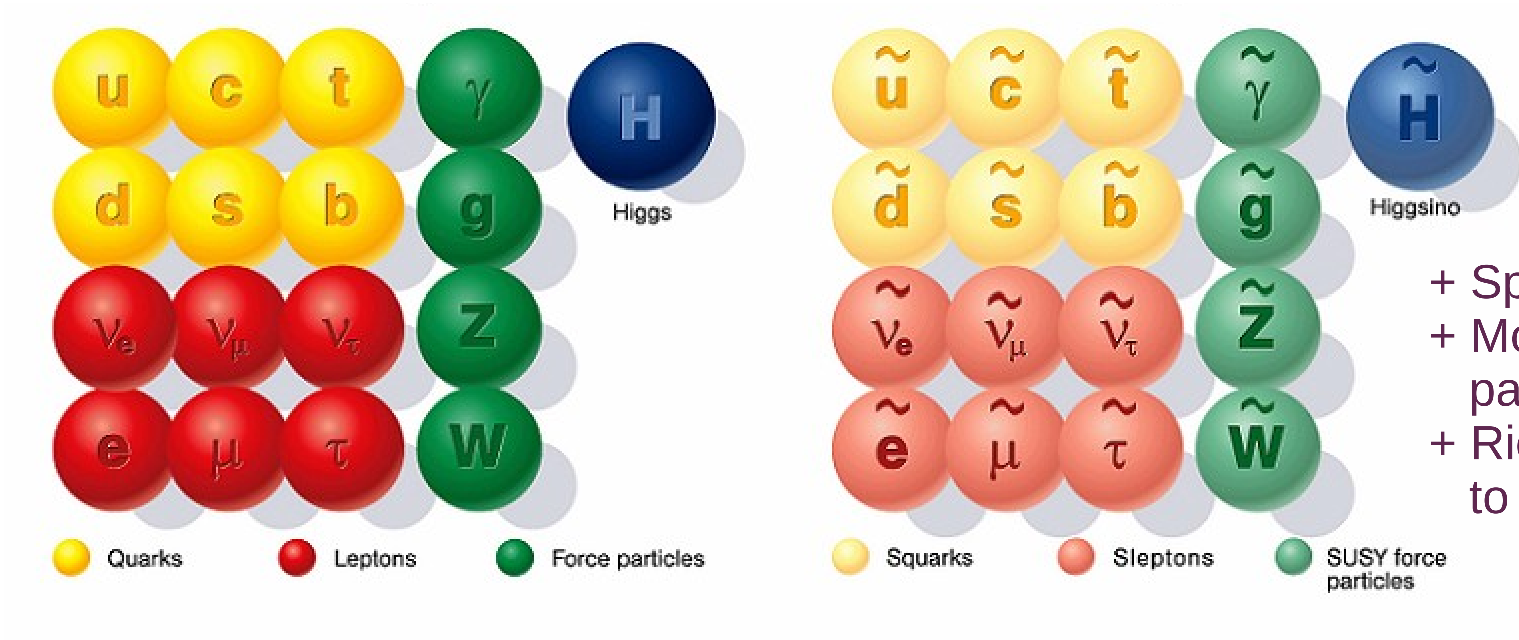
So what's the problem?

- ✓ – Need high-levels of fine tuning to avoid quadratic divergences in Higgs mass corrections
- ✓ – No explanation for Dark Matter
- ✓ – No unification of the forces

...

Supersymmetry

Standard Model **SUSY**



Superpartner for every SM particle

- \+ Spin differs by one half
- \+ Mostly heavier than SM partners → broken symmetry
- \+ Rich array of signatures to search for at the LHC

After the discovery of the higgs with mass ~125 GeV, there is renewed interest in accomodating higgs in SUSY models to help stabilise the higgs mass.
To avoid high levels of “unnatural” fine tuning, some sparticles need to be light.

$$\frac{m_H^2}{2} = -|\mu|^2 + \ldots + \delta m_H^2$$

$$\delta m_H^2\Big|_{stop} \cong -\frac{3y_t^2}{8\pi^2}\left(m_{Q_3}^2 + m_{U_3}^2 + |A_t|^2\right)\ln\left(\frac{\Lambda}{TeV}\right)$$

$$\delta m_H^2\Big|_{gluino} \cong -\frac{2y_t^2}{\pi^2}\left(\frac{\alpha_s}{\pi}\right)|M_3|^2\ln^2\left(\frac{\Lambda}{TeV}\right)$$

For natural SUSY (low levels of fine tuning)

→ Light higgsinos
→ Light stop $(<1\,\mathrm{TeV})$
→ Light gluinos $(<1-2\,\mathrm{TeV})$

Weak-scale SUSY needed for naturalness should be seen at the LHC!

Supersymmetry

R-Parity $P_R = (-1)^{3(B-L)+2S}$

B, L, S: baryon, lepton, spin
+1 for SM particles, -1 for SUSY particles

No reason to assume conservation of R-parity
Can constrain proton decay with lepton or baryon violating SUSY, but not both
LSP decays → no dark matter candidate

The MSSM potential

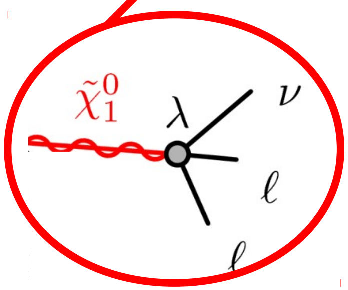
L-number violating terms

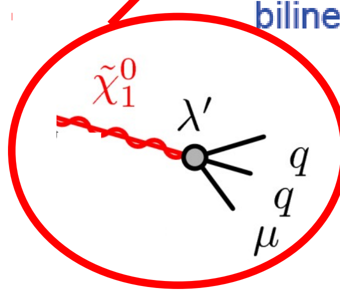
$$W_{\not R_p} = \lambda_{ijk}\hat{L}_i\hat{L}_j\hat{E}^C_k + \lambda'_{ijk}\hat{L}_i\hat{Q}_j\hat{D}^C_k + \epsilon_i\hat{L}_i\hat{H}_u + \lambda''_{ijk}\hat{U}^C_i\hat{D}^C_j\hat{D}^C_k$$

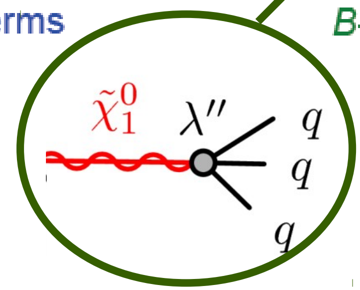
bilinear terms

B-number violating terms

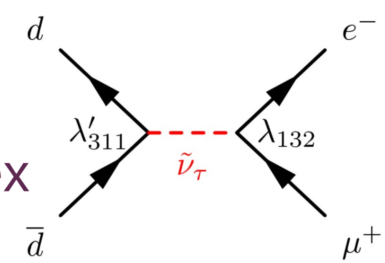
RPV couplings $\lambda, \lambda', \lambda''$







RPV can be at the production vertex and/or at decay vertices

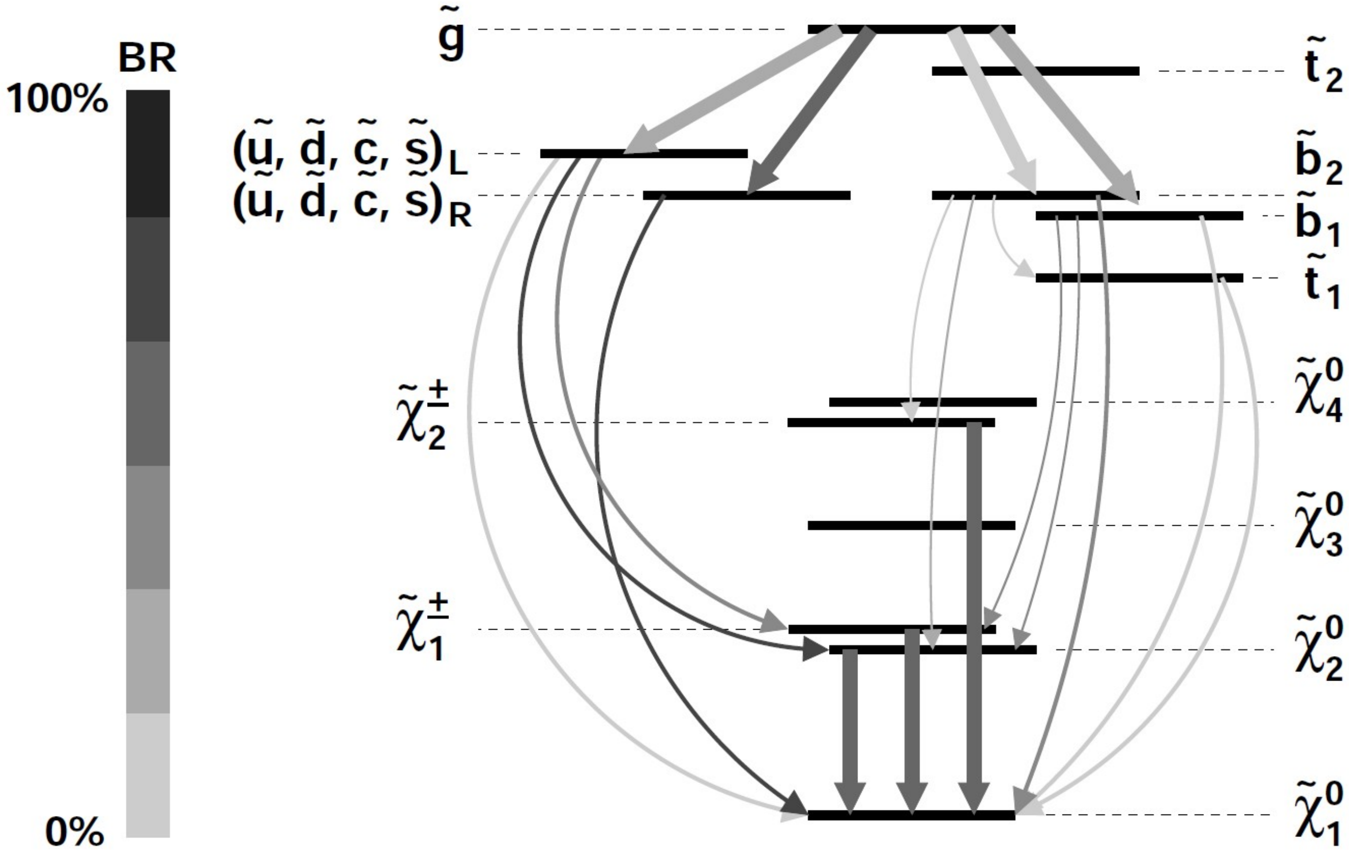


RPV also lead to
non-prompt decays
if λ couplings are small

Long-lived SUSY particles can also arise from
- Heavy mediator sparticles e.g. Split SUSY
- Mass degeneracy
- Weak couplings

Supersymmetry models

Physics model e.g. MSUGRA/CMSSM

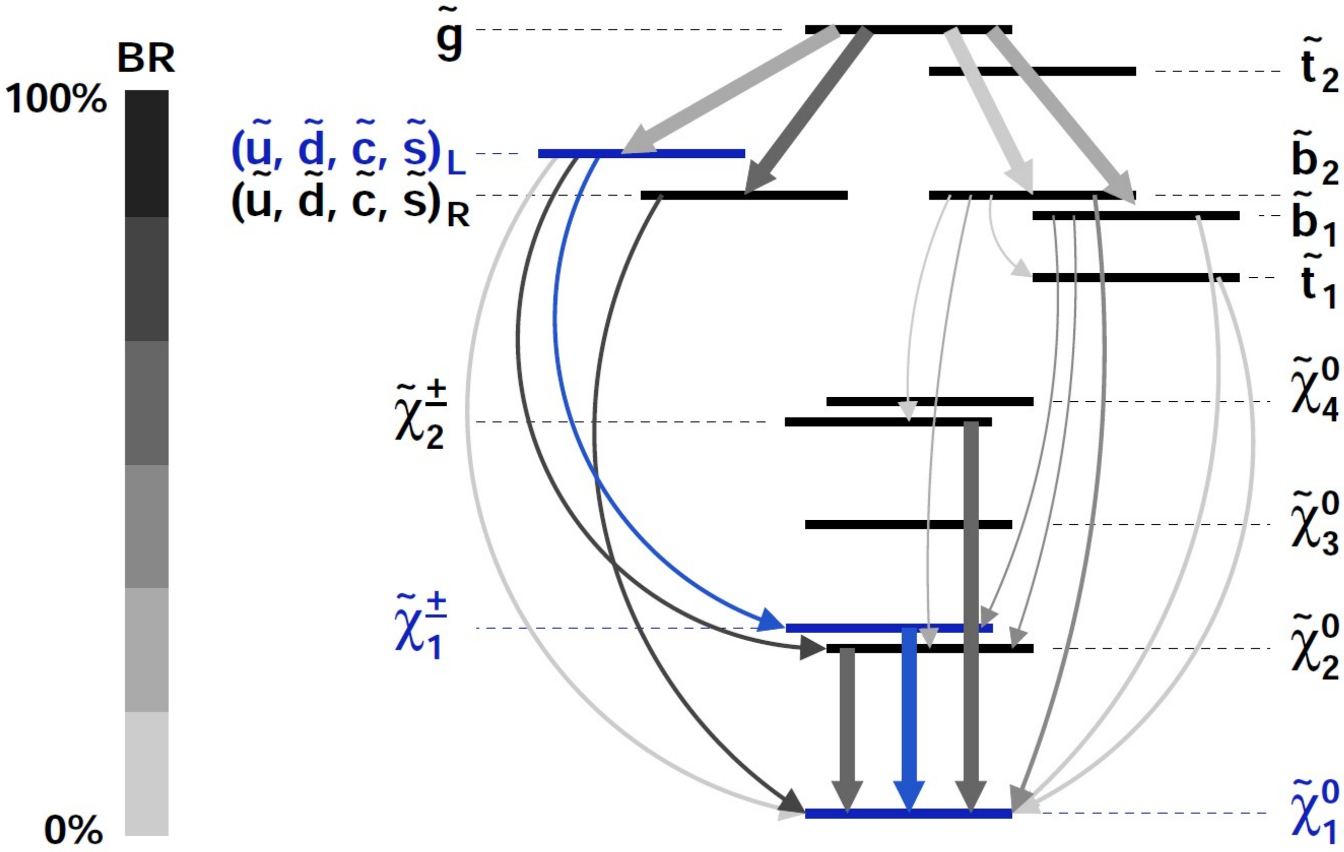


A typical SUSY spectrum involves
+ many sparticles with different masses
+ many different possible ways for each to decay

Where do we start looking?

Supersymmetry models

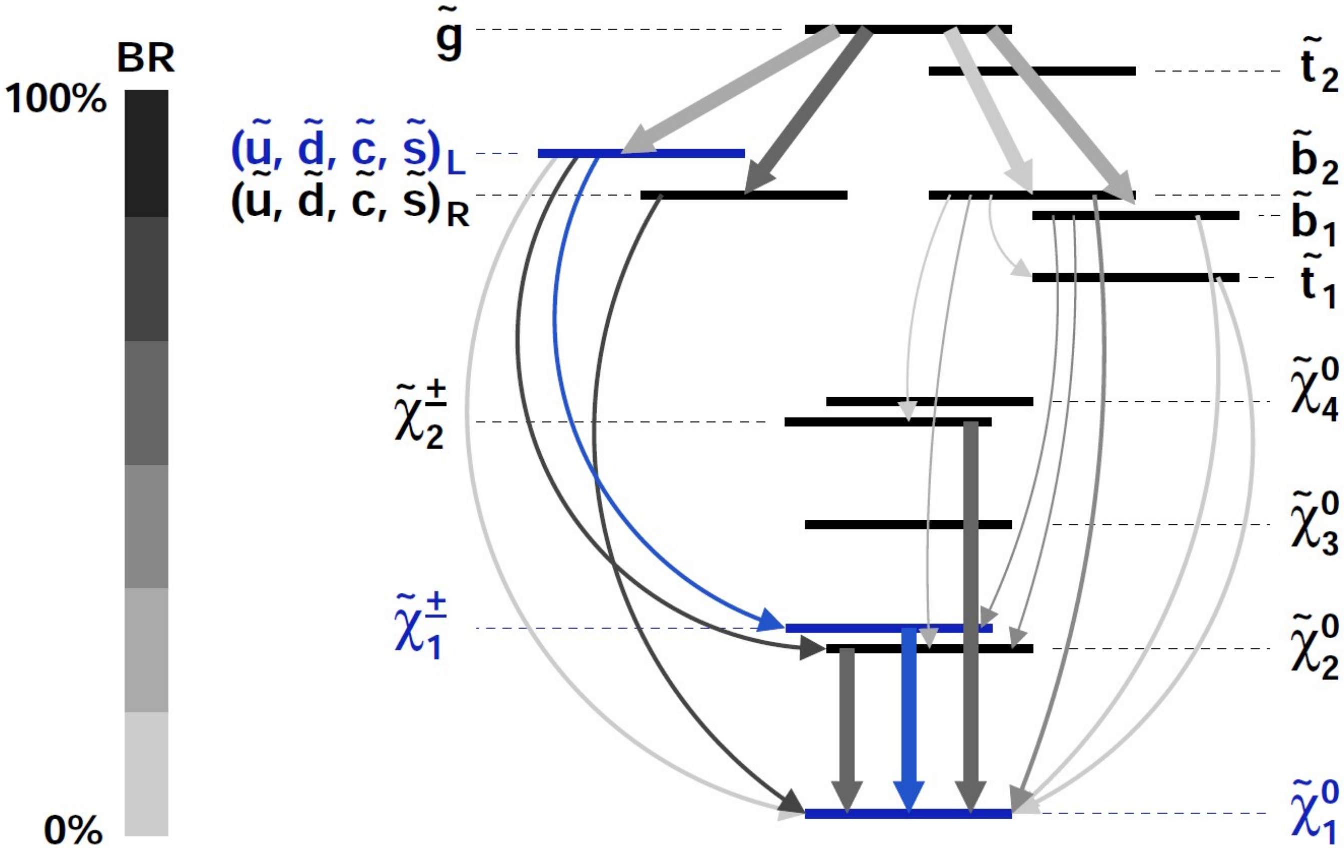
Physics model e.g. MSUGRA/CMSSM



A typical SUSY spectrum involves
+ many sparticles with different masses
+ many different possible ways for each to decay

Focus on process of interest

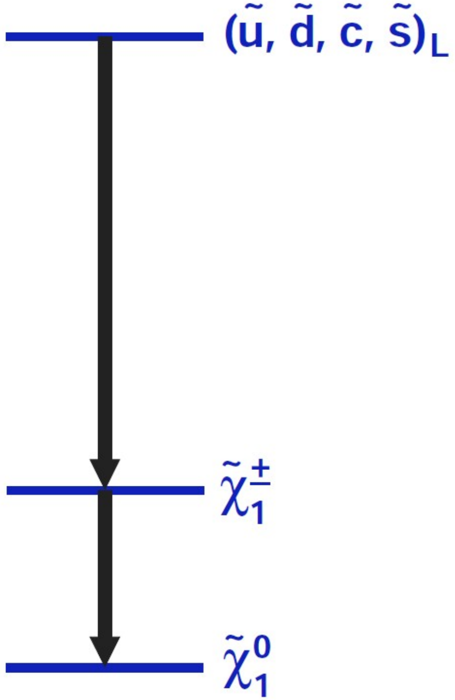
Physics model e.g. MSUGRA/CMSSM



A typical SUSY spectrum involves
+ many sparticles with different masses
+ many different possible ways for each to decay

Focus on process of interest

Simplified model
Study a specific decay chain

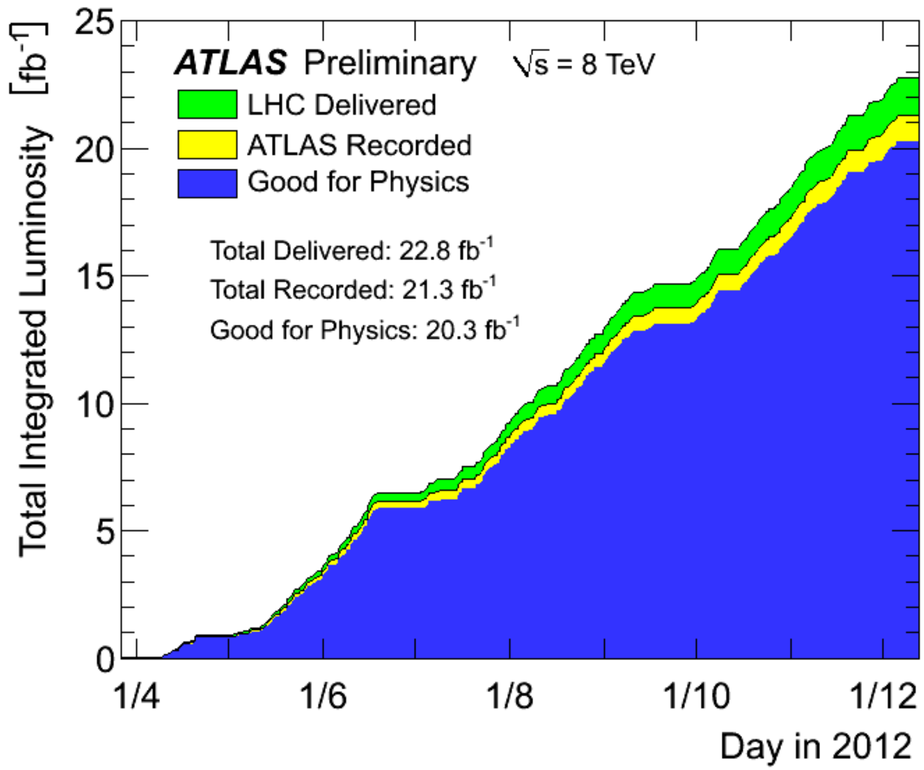


+ Small number of sparticles, assumed BR – usually 100%.
+ Described by masses and cross-sections.
+ Simple and broad approach for designing SUSY searches.

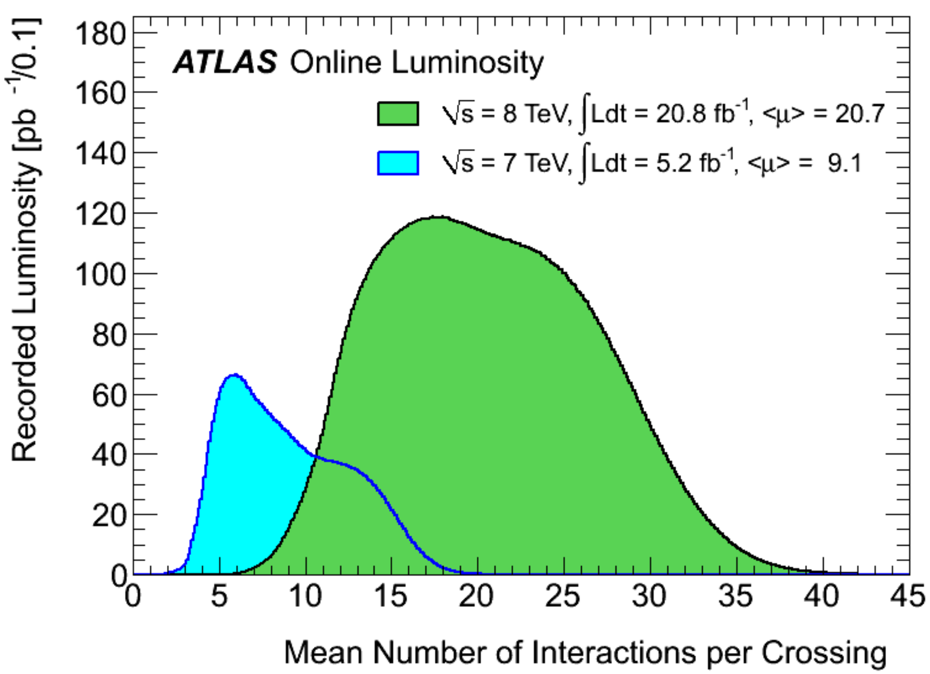
Experimental setup: Luminosity and pileup

~ 22 fb^{-1} collected at √s = 8 TeV
~ 5 fb^{-1} collected at √s = 7 TeV

with ~ 90% of the delivered data being good for physics



Most results presented here use the full 8 TeV dataset



Large luminosity results in large pileup (number of interactions per bunch crossing)

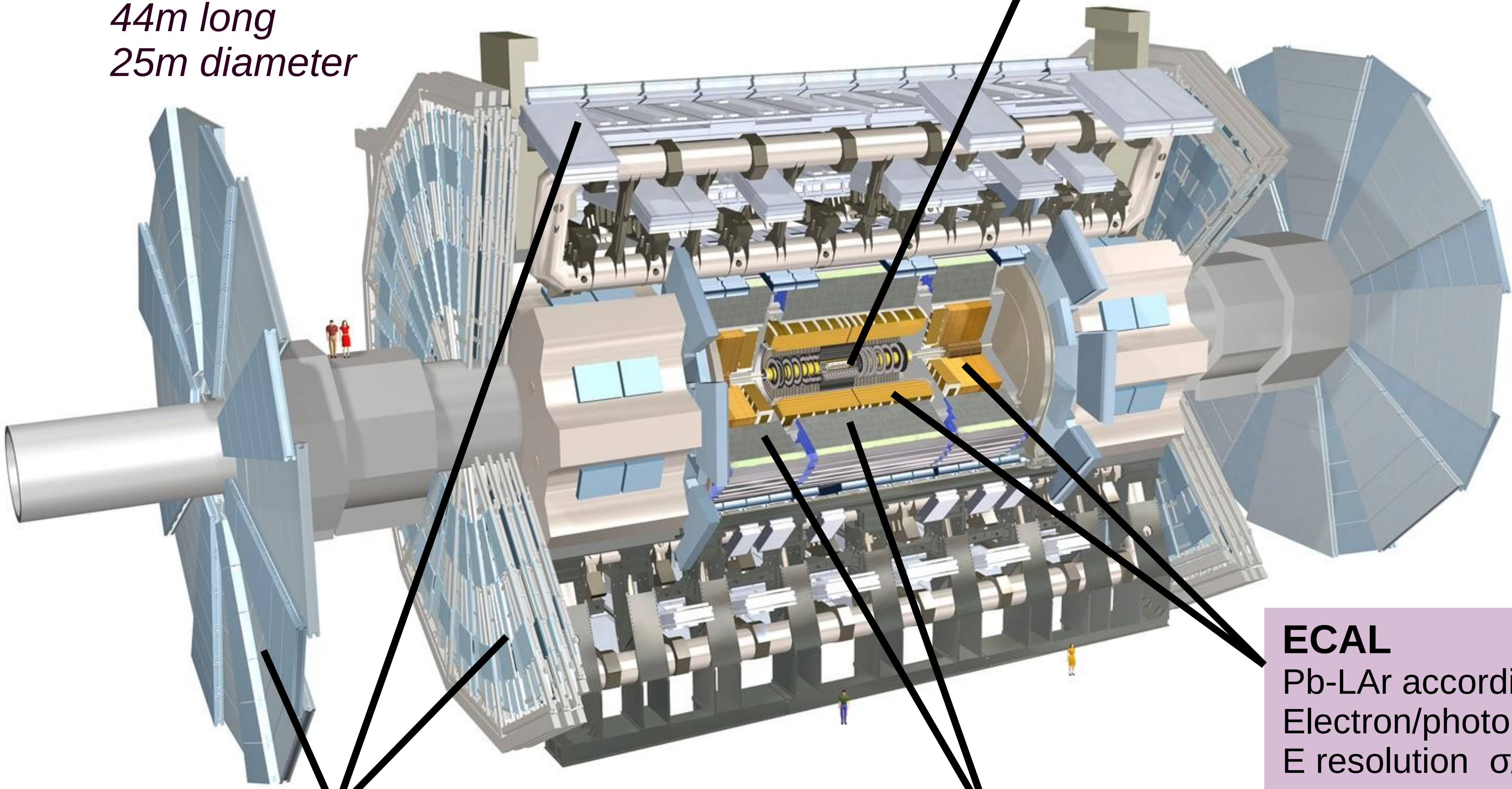
Pileup suppression strategies have been carefully developed

Experimental setup: The ATLAS detector

3-level trigger
Rate 40 MHz → ~400 Hz

Inner Detector
Silicon pixels & strips + TRT straws
Precise tracking and vertexing, electron/pion separation
p resolution σ/p_T ~$3.8\times10^{-4}\ p_T$ (GeV) $\oplus$ 0.015

44m long
25m diameter

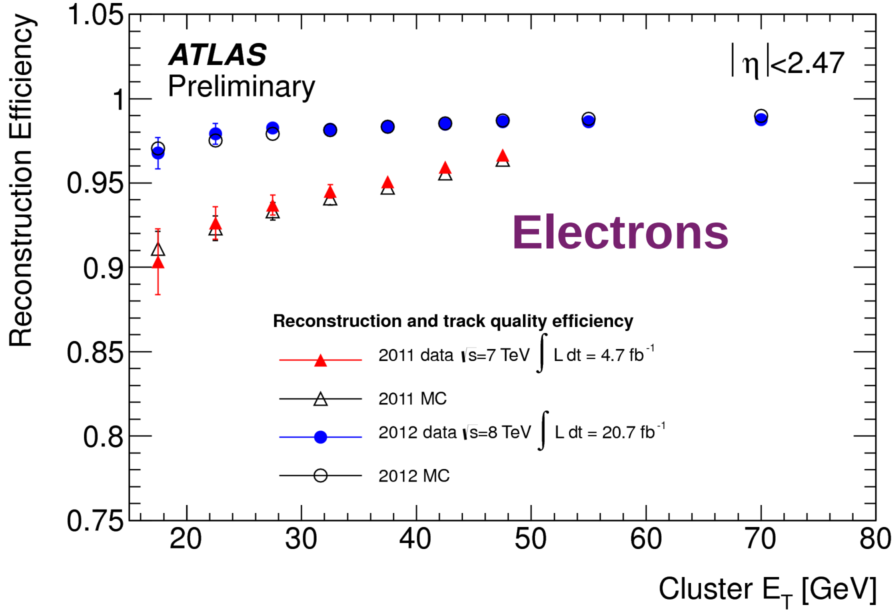


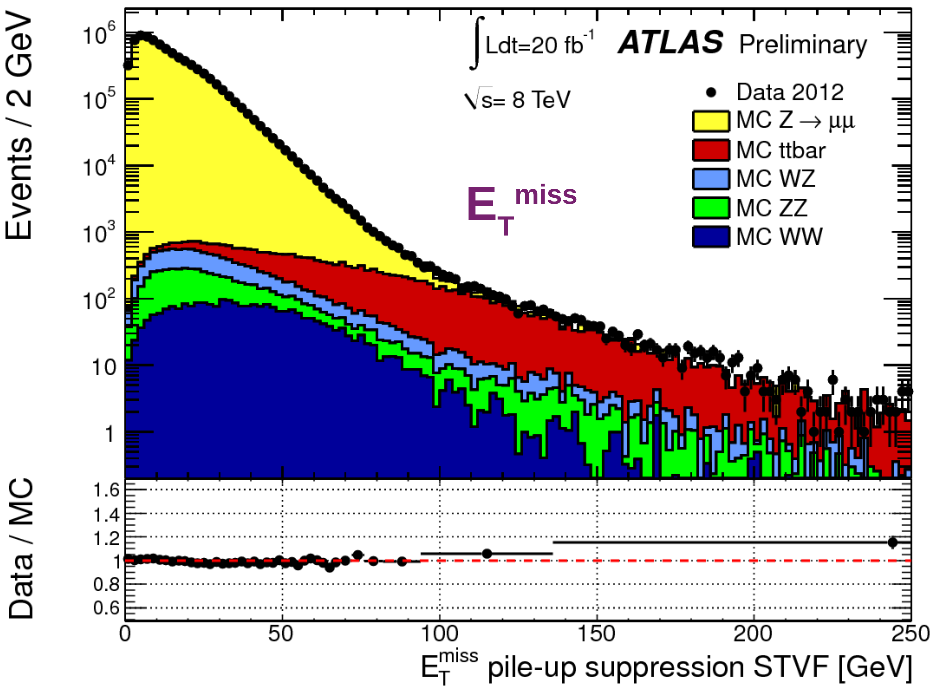
ECAL
Pb-LAr accordion
Electron/photon id & measurement
E resolution σ/E ~$10\%/\sqrt{E}$

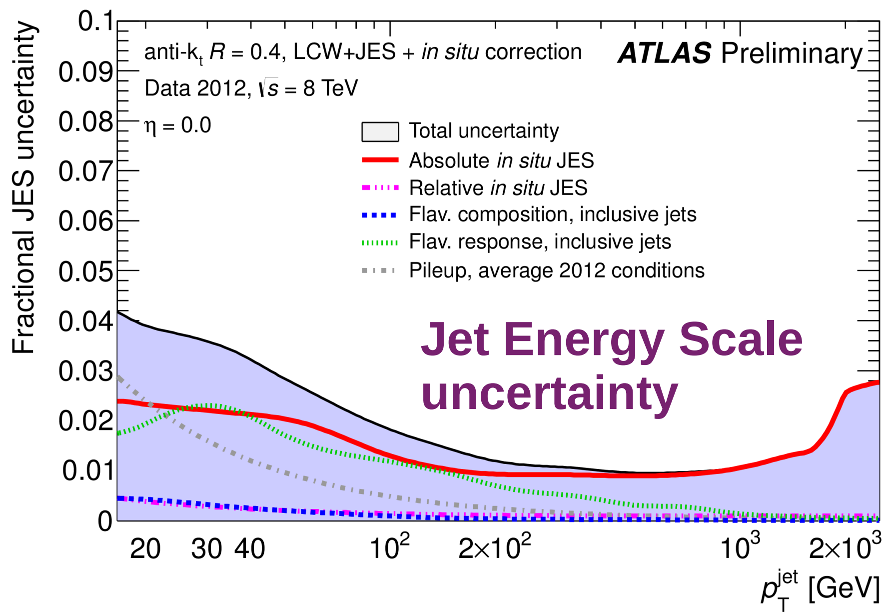
Muon Spectrometer
Air-core toroids with gas-based muon chambers
Muon measurement
p resolution $\sigma/p < 10\%$ up to p ~ 1 TeV

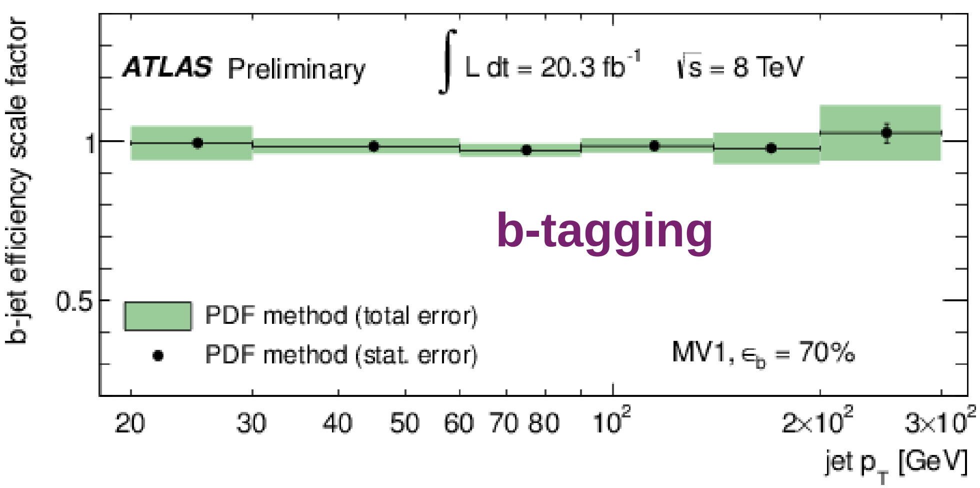
HCAL
Fe/scintillator tiles (central), Cu/Q-LAr (fwd)
Measurement of jets & missing E_T
E resolution σ/E ~$50\%/\sqrt{E} \oplus 0.03$

Experimental setup: Object Performance





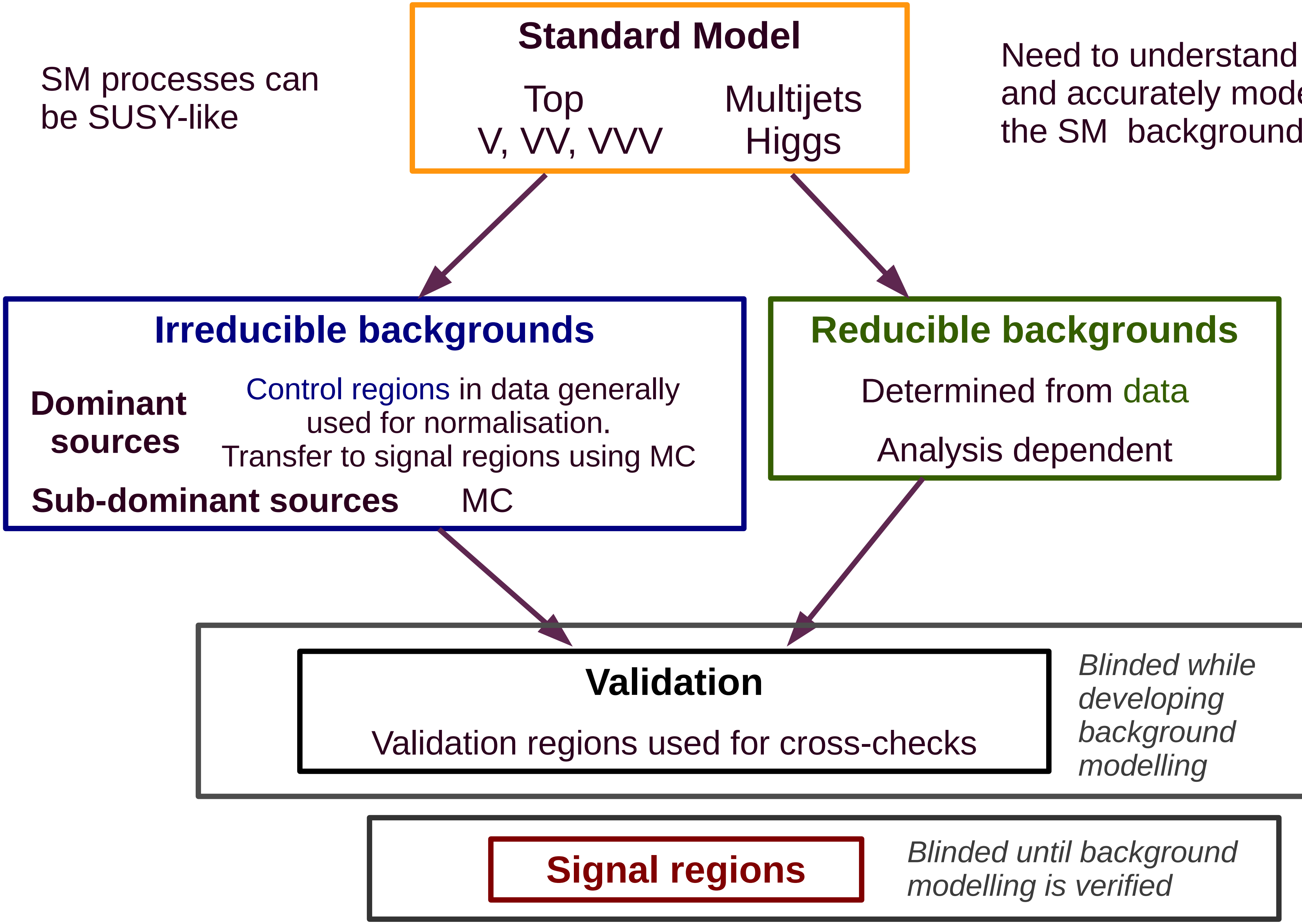




Standard Model Background Modelling

SM processes can be SUSY-like

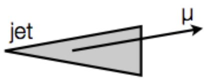
Need to understand and accurately model the SM backgrounds



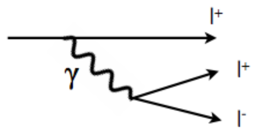
Reducible background determination

Fake leptons

HF/LF fakes from jets



Conversion leptons from photon radiation



Matrix Method

Estimate from data: set of linear equations relating the kinematic properties of the leptons to the real and fake lepton composition of the data sample

e.g. for a 1-lepton signature

- Define "loose" (pre-selected) lepton
- Define "tight" (signal) lepton
- Solve set of equations

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

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

Measure independently from data

Count in data

$$N^{tight}_{fake} = \frac{\epsilon_{fake}}{\epsilon_{real} - \epsilon_{fake}} \left(\epsilon_{real} N^{loose} - N^{tight} \right)$$

A few examples....

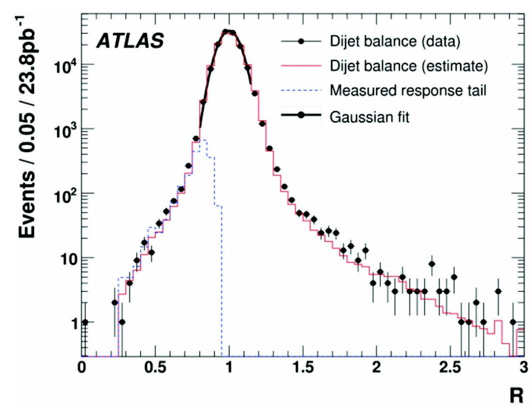
Large, fake E_T^{miss} can be induced by a jet mis-measurement

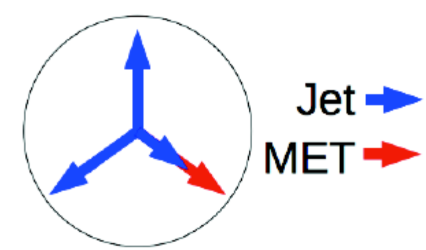
Jet Smearing

Derive a "jet response function" from MC and adapt it to data

core: p_T balance in di-jet events

tail: three-jet (Mercedes) events





Use response function to smear jets in real data events with low E_T^{miss}

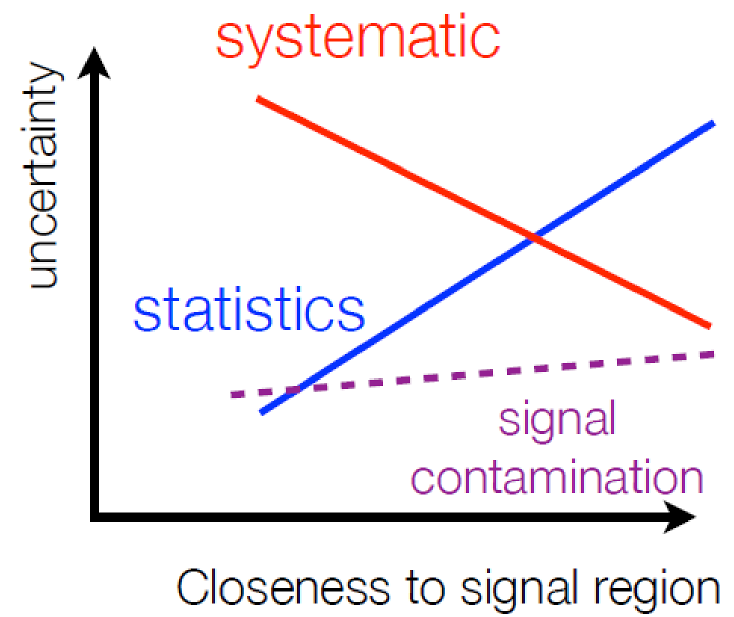
→ Obtain events with large "fake" E_T^{miss}

Irreducible background determination using control regions

Irreducible backgrounds normalised to data in dedicated control regions

$$N^{i}_{SR} = \frac{N^{i,MC}_{SR}}{N^{i,MC}_{CR}} \left(N^{i,data}_{CR} - \sum_{j=process} N^{j,MC}_{CR} \right)$$

MC "Transfer factor" | Count in data | MC or other CR



If contamination from other processes is small, all systematic uncertainty is associated to transfer factor

Need to be careful in the choice of CR

Typical uncertainties

Experimental
- Trigger efficiency
- Jet energy scale, resolution
- Lepton energy scale, efficiency
- E_T^{miss} soft component
- b-tagging
- Luminosity
- pileup modelling

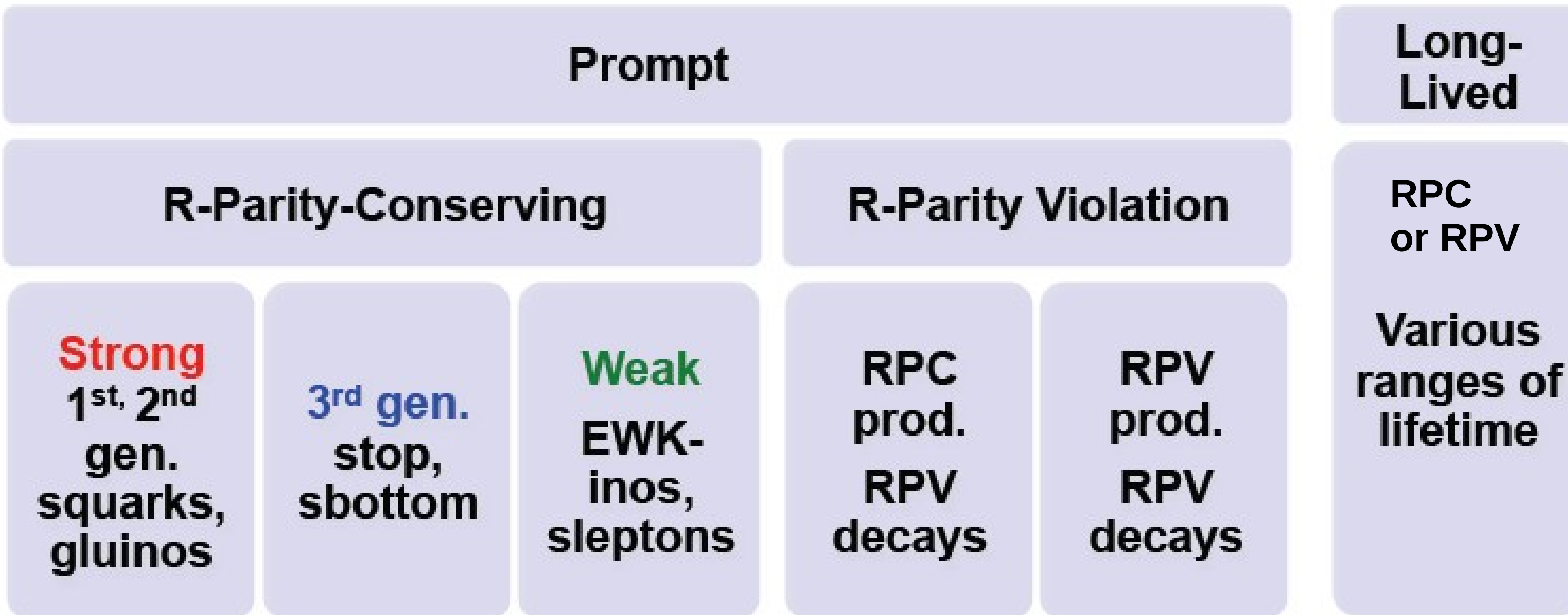
Theory
- Generator modelling
  μ_F, μ_R,
  ME/PS matching,
  α_S scale choice
- PS uncertainties
  typically compare Pythia and Herwig
- PDF choice

Background determination **verified in validation regions**

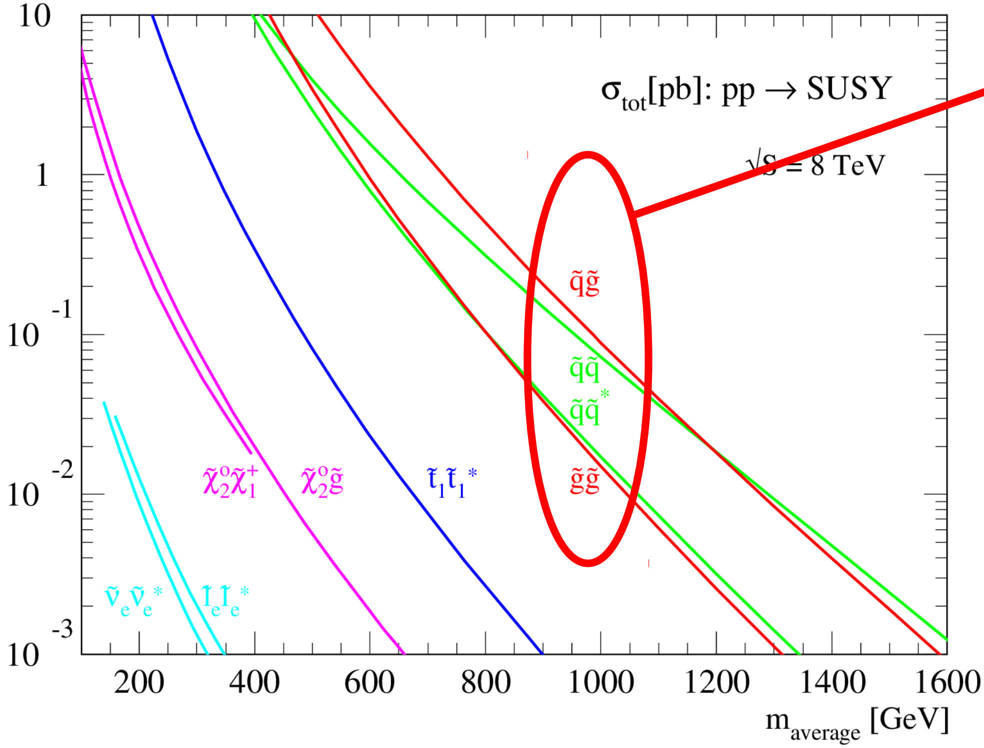
Calculation done **performing a combined fit** to all control and signal regions.
Account for signal contamination for exclusion

Search Strategy

Search strategy designed to provide coverage for a broad class of SUSY models



For each search, a number of signal regions is optimised based on a variety of models



High cross-section for strongly produced SUSY particles at the LHC

Large yield even in small datasets

Dominates total SUSY cross-section in many SUSY models

e.g. MSUGRA/CMSSM

Inclusive search channels

» 0-lepton + 2-6 jets + E_T^{miss}

» 0-lepton + 7-10 jets + E_T^{miss}sig

» 1-2 leptons + jets + E_T^{miss}

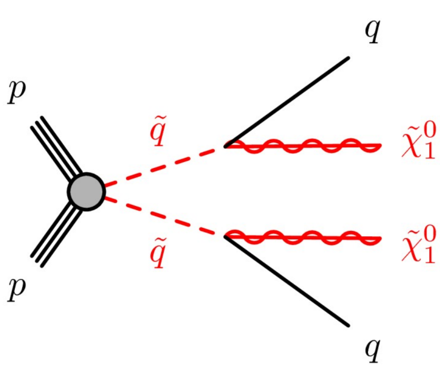
» 2-lepton + 2-6 jets + E_T^{miss}

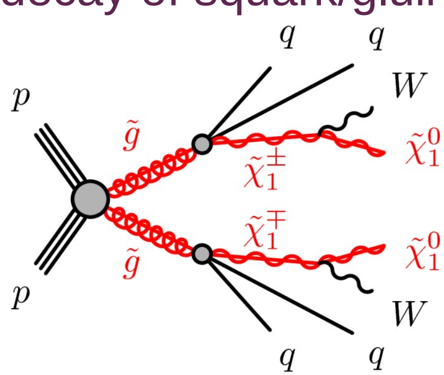
1-2 taus + jets + E_T^{miss} ATLAS-CONF-2013-026

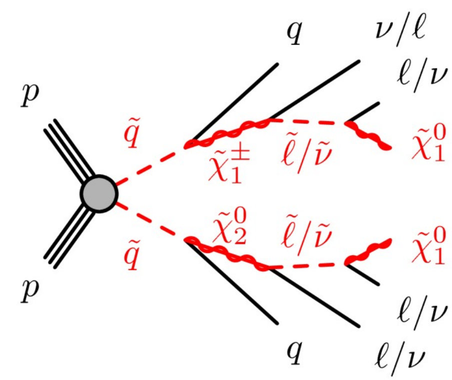
Z(ll) + jets + E_T^{miss} ATLAS-CONF-2013-152

Photon + lepton + E_T^{miss} ATLAS-CONF-2013-144

Final state depends on decay of squark/gluino

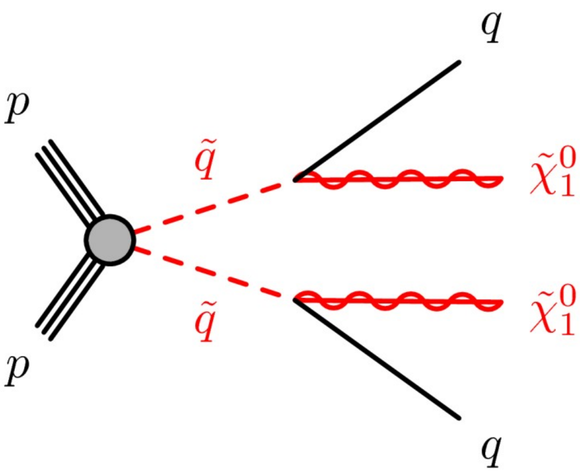


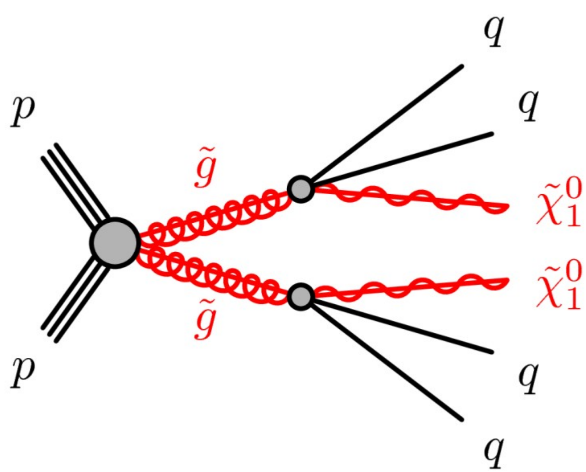


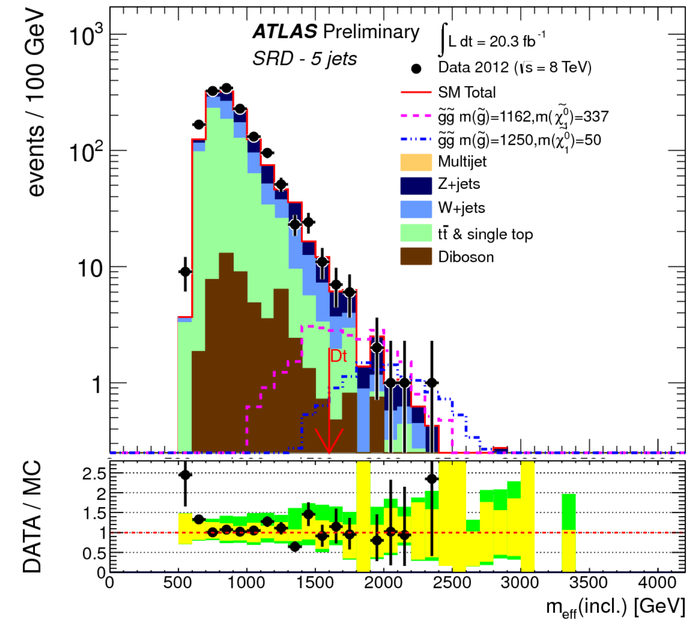


>> new result to be discussed
(since last ATLAS SUSY seminar on 26th March 2013)

Consider SUSY processes with decays to jets + LSP + no leptons







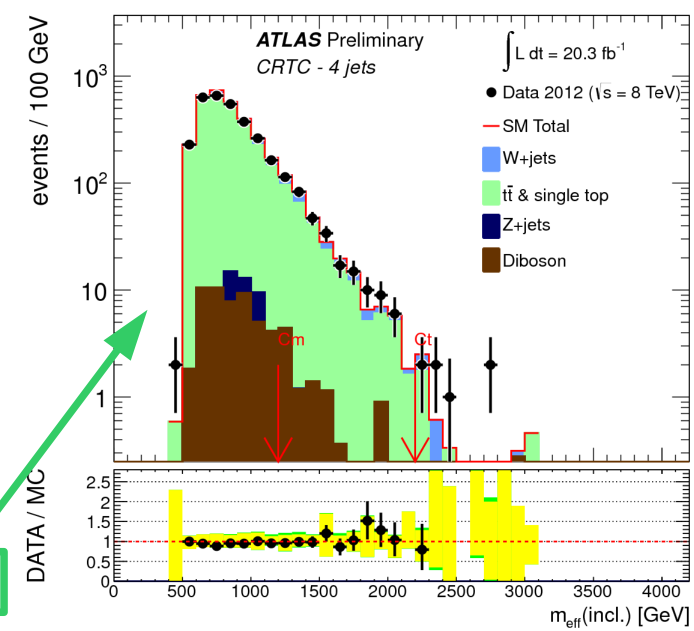
10 signal regions

- ≥ 2 to ≥ 6 jets + E_T^{miss}
- m_{eff} >1000 to >2200 GeV
- E_T^{miss} / m_{eff} > 0.15 to 0.4

Jet + E_T^{miss} trigger

$$m_{eff} = E_T^{miss} + \sum p_T^{jets}$$

No significant excess seen



4 control regions per signal region

CR	SR background	CR process	CR selection
CRY	$Z(\to \nu\nu)$+jets	γ+jets	Isolated photon
CRQ	multi-jets	multi-jets	Reversed $\Delta\phi(\text{jet}, \mathbf{E}_T^{miss})_{min}$ and $E_T^{miss}/m_{eff}(Nj)$ requirements[a]
CRW	$W(\to \ell\nu)$+jets	$W(\to \ell\nu)$+jets	30 GeV $< m_T(\ell, E_T^{miss}) <$ 100 GeV, b-veto
CRT	$t\bar{t}$ and single-t	$t\bar{t} \to bbqq'\ell\nu$	30 GeV $< m_T(\ell, E_T^{miss}) <$ 100 GeV, b-tag

Meaning of lines in interpretations

— — Expected limit

Yellow band ±1σ experimental uncertainties

—— Red line: Observed limit

— — Dashed lines ±1σ signal theory uncertainties

Signal uncertainties considered

In yellow band

- Experimental uncertainties
- ISR uncertainty on signal MC
  Up to 30% in some regions with small Δm

In red dashed lines

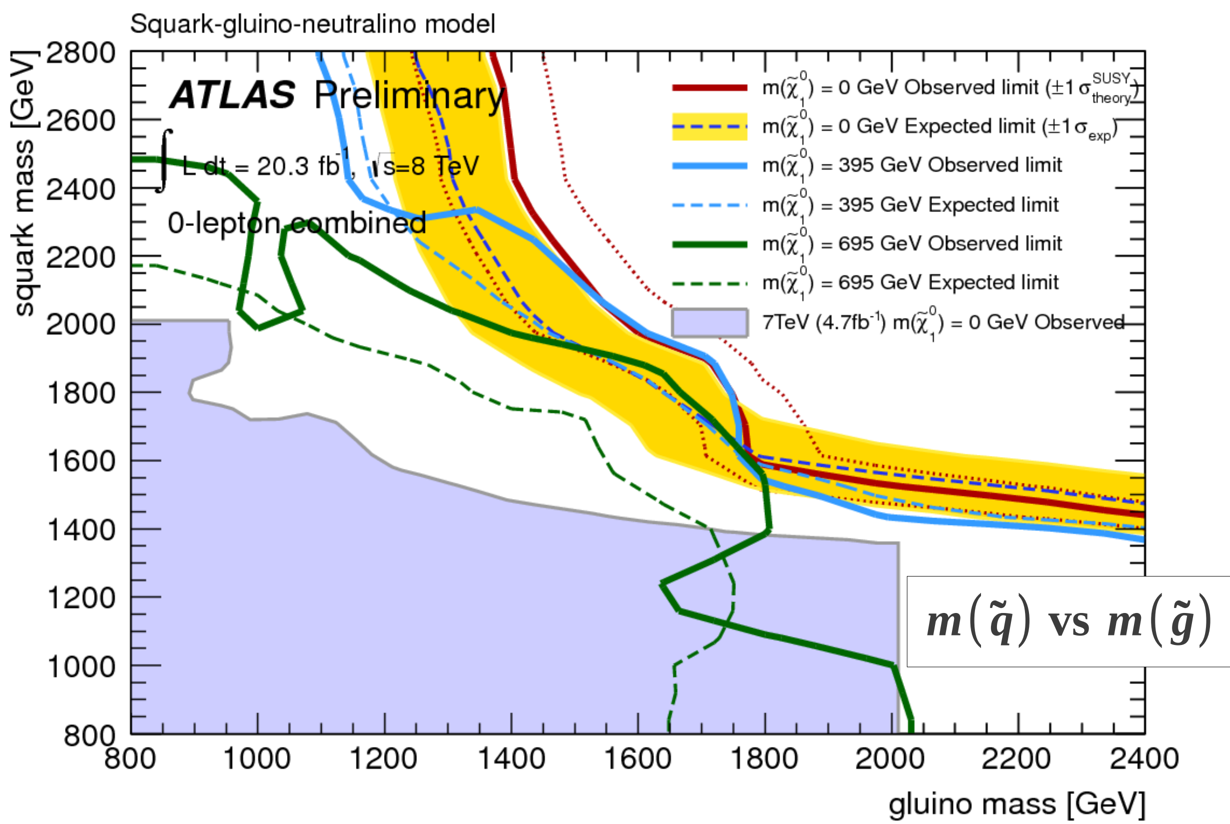
- Cross-section uncertainties
  (PDF, renormalisation/factorization scales)

$\tilde{q}$ and $\tilde{g}$ production

—— $m(\tilde{\chi}_1^0)=0$ GeV

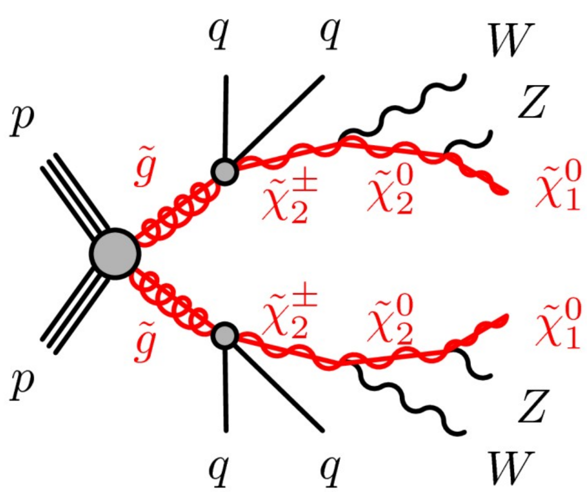
—— $m(\tilde{\chi}_1^0)=395$ GeV

—— $m(\tilde{\chi}_1^0)=695$ GeV



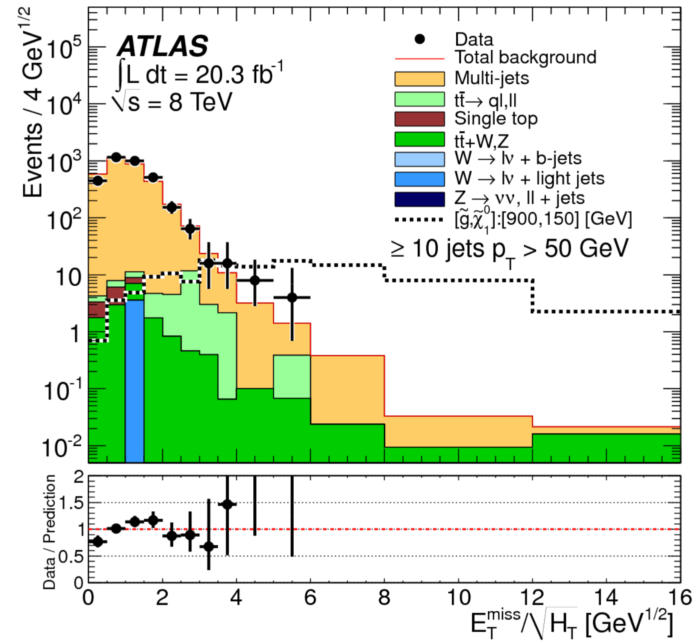
Squark/gluino searches $0\,l + 7-10$ jets + E_T^{miss} *arXiv:1308.1841*

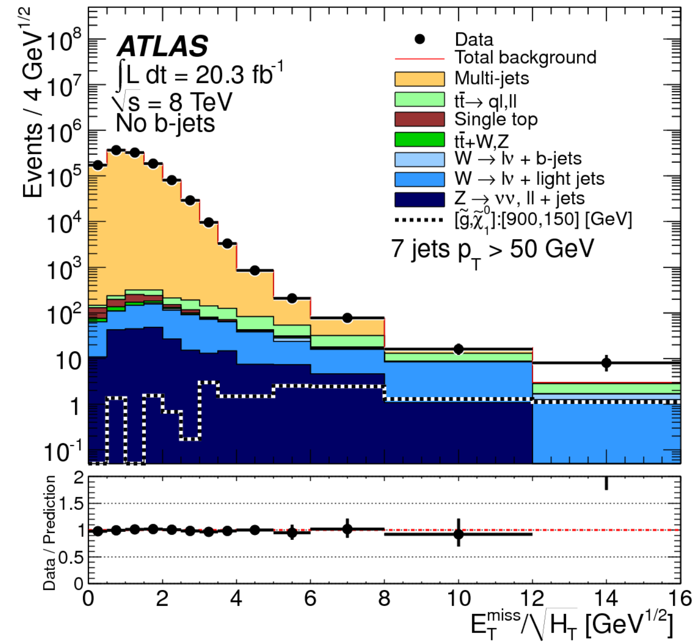
Consider SUSY processes with longer decay chains
→ more jets



Complimentary to previous analysis

Multijet trigger, possibility to look at lower E_T^{miss}





Signal regions $E_T^{miss} / \sqrt{H_T}$: > 4 GeV$^{1/2}$

High # jets + b-jets   or   High # jets + high mass composite jets - "fat jets"

$$H_T = \Sigma p_T^{jets\ p_T > 40\,\mathrm{GeV}}$$

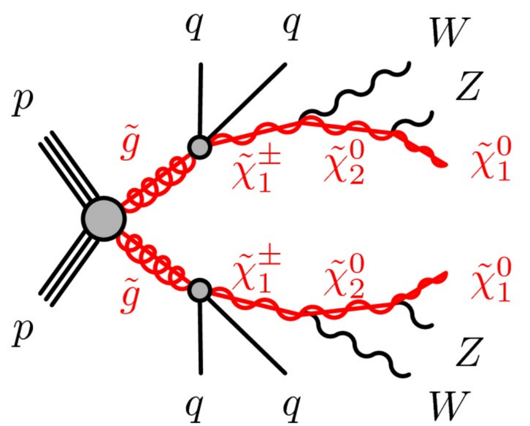
Dominated by multijet background

Use $E_T^{miss} / \sqrt{H_T}$ shape in data from lower jet multiplicities

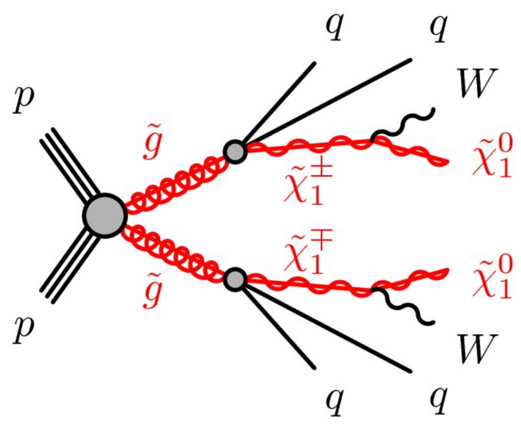
Use same number of b–jets in CR and SR to get the template for every SR

Only need to adjust out of cone energy for every Njets bin

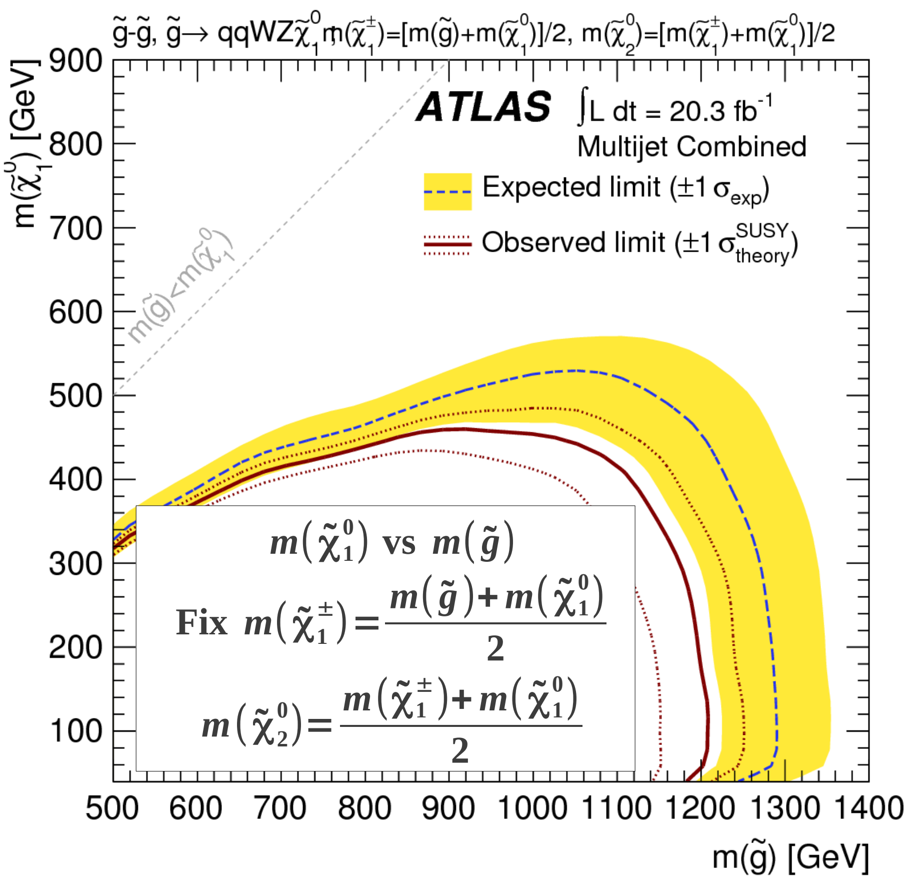
No significant excess seen



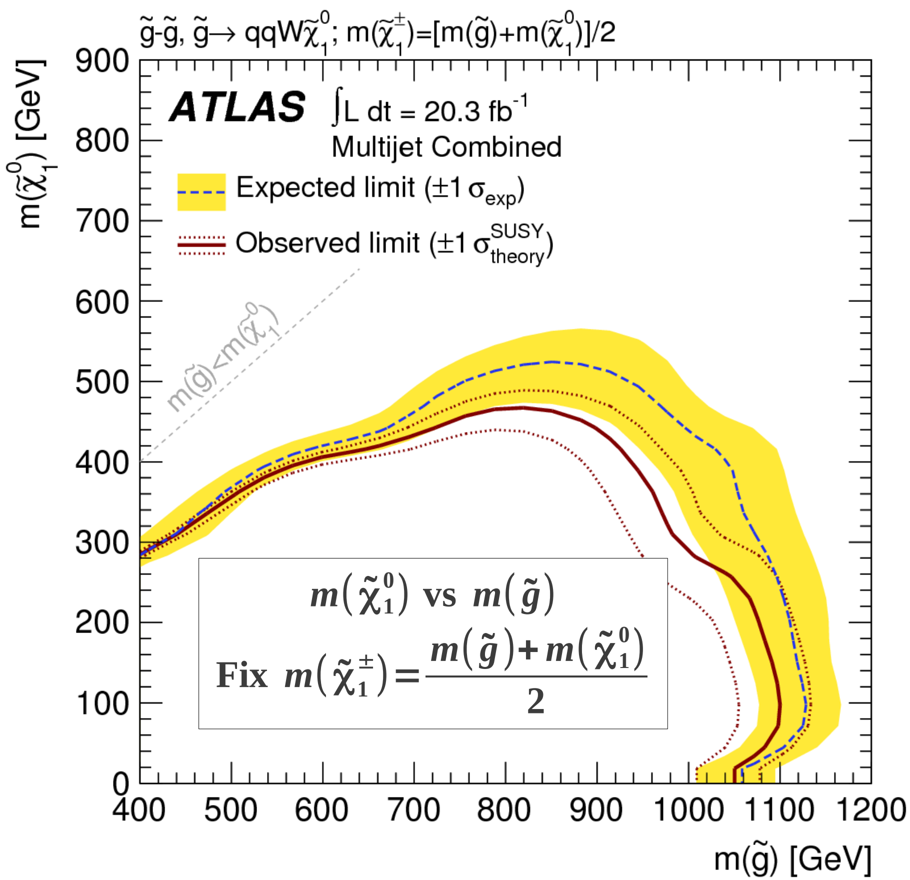
p
p
q
q
q
q
W
Z
Z
W



p
p
q
q
q
q
W
W

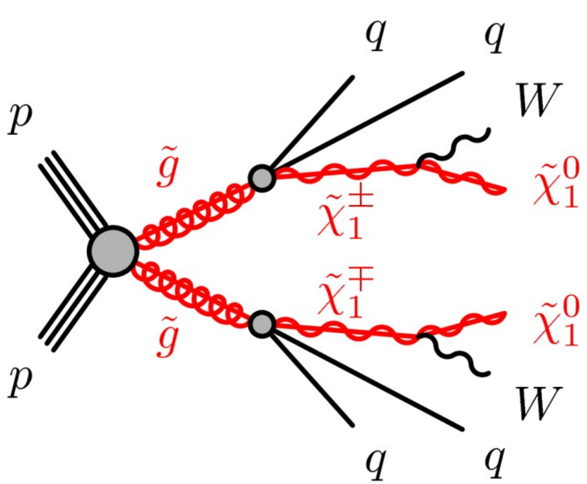


ATLAS ∫L dt = 20.3 fb-1
Multijet Combined
Expected limit (±1 σexp)
Observed limit (±1 σSUSY theory)
m(g̃) [GeV]
$m(\tilde{\chi}_1^0)$ vs $m(\tilde{g})$
Fix $m(\tilde{\chi}_1^\pm) = \frac{m(\tilde{g}) + m(\tilde{\chi}_1^0)}{2}$
$m(\tilde{\chi}_2^0) = \frac{m(\tilde{\chi}_1^\pm) + m(\tilde{\chi}_1^0)}{2}$



ATLAS ∫L dt = 20.3 fb-1
Multijet Combined
Expected limit (±1 σexp)
Observed limit (±1 σSUSY theory)
m(g̃) [GeV]
$m(\tilde{\chi}_1^0)$ vs $m(\tilde{g})$
Fix $m(\tilde{\chi}_1^\pm) = \frac{m(\tilde{g}) + m(\tilde{\chi}_1^0)}{2}$

Consider SUSY processes with leptons in the decay chain



Signal regions

High p_T jets and E_T^{miss}

"Hard lepton" regions p_T>25 GeV

"Soft lepton" regions

$6(7) < p_T\, e(\mu) < 25$ GeV

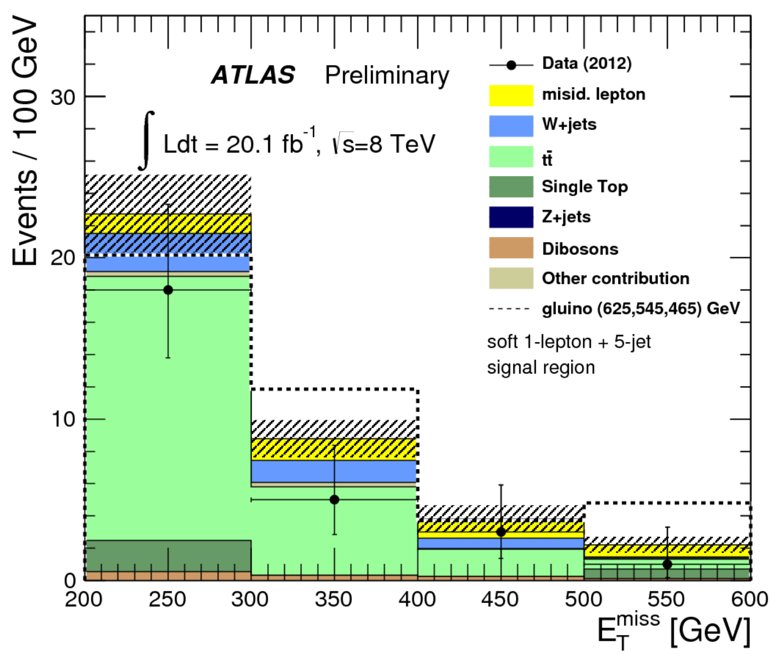
with & without b-jets

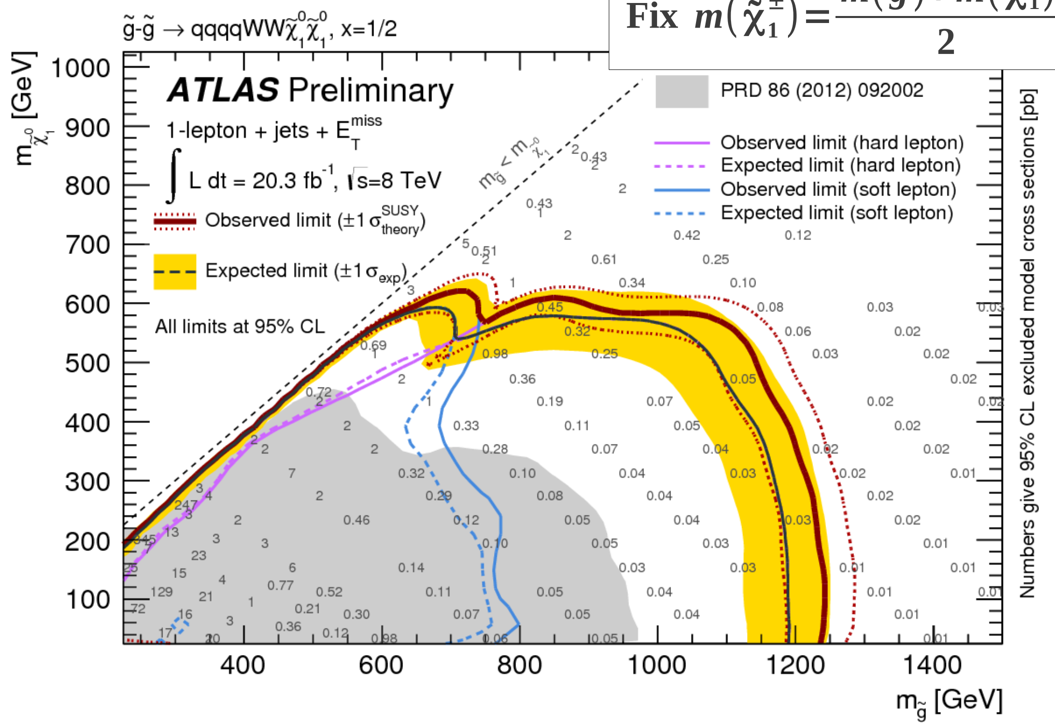
Ttbar and W+jets dominated

$m(\tilde{\chi}_1^0)$ vs $m(\tilde{g})$

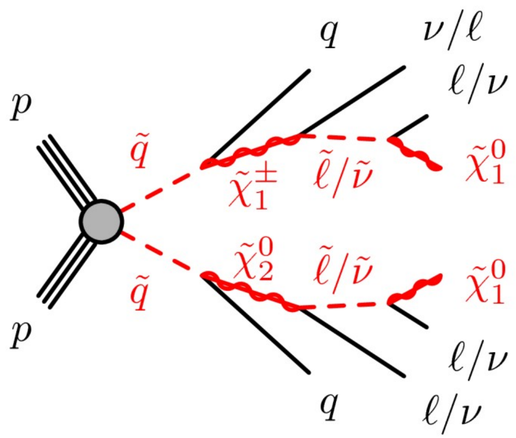
Fix $m(\tilde{\chi}_1^\pm) = \frac{m(\tilde{g}) + m(\tilde{\chi}_1^0)}{2}$

No significant excess seen





Squark/gluino searches 2*l*



Consider SUSY processes with decays to jets + LSP + 2 leptons

Rather than use m_{eff}, exploit set of "Razor" variables

Build mega-jets j_1 j_2 from visible decay products

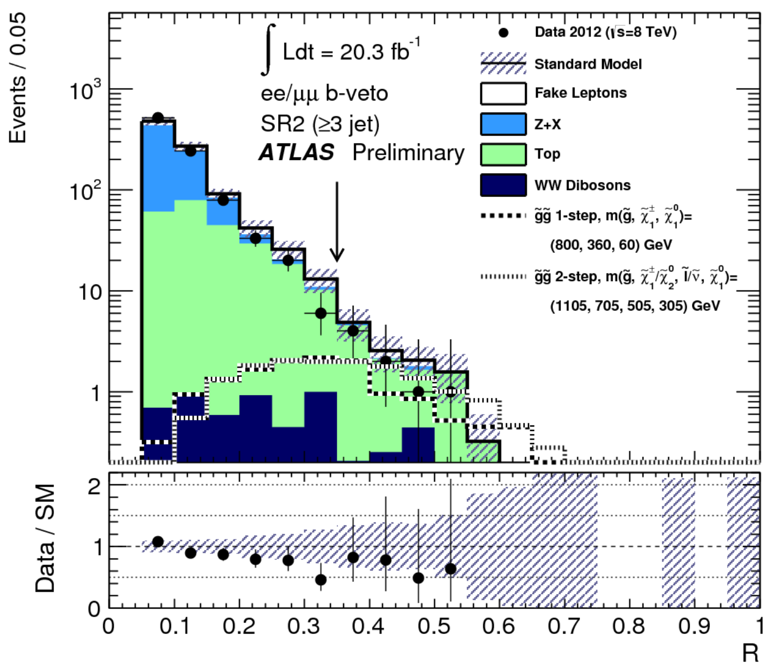
$$M'_R = \sqrt{(j_{1,E} + j_{2,E})^2 - (j_{1,p_L} + j_{2,p_L})^2}$$

$$M_T^R = \sqrt{\frac{|\vec{E}_T^{miss}|(|\vec{j}_{1,p_T}| + |\vec{j}_{2,p_T}|) - \vec{E}_T^{miss} . (\vec{j}_{1,p_T} + \vec{j}_{2,p_T})}{2}}$$

$$R = \frac{M_T^R}{M'_R}$$

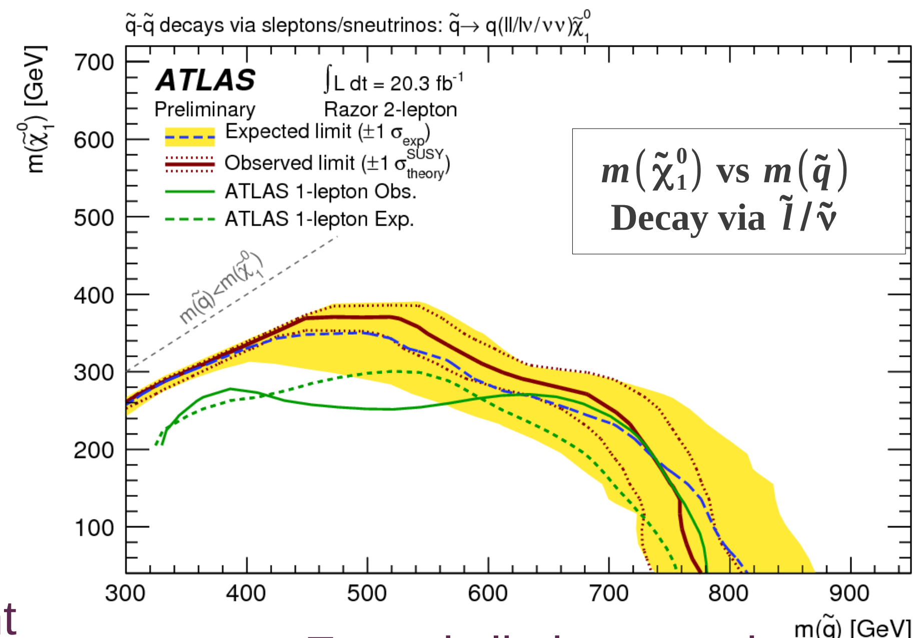
Signal regions

Z veto	Large R
< 3 or ≥ 3 jets	Large M'_R



Ttbar and Z dominated

No significant excess seen



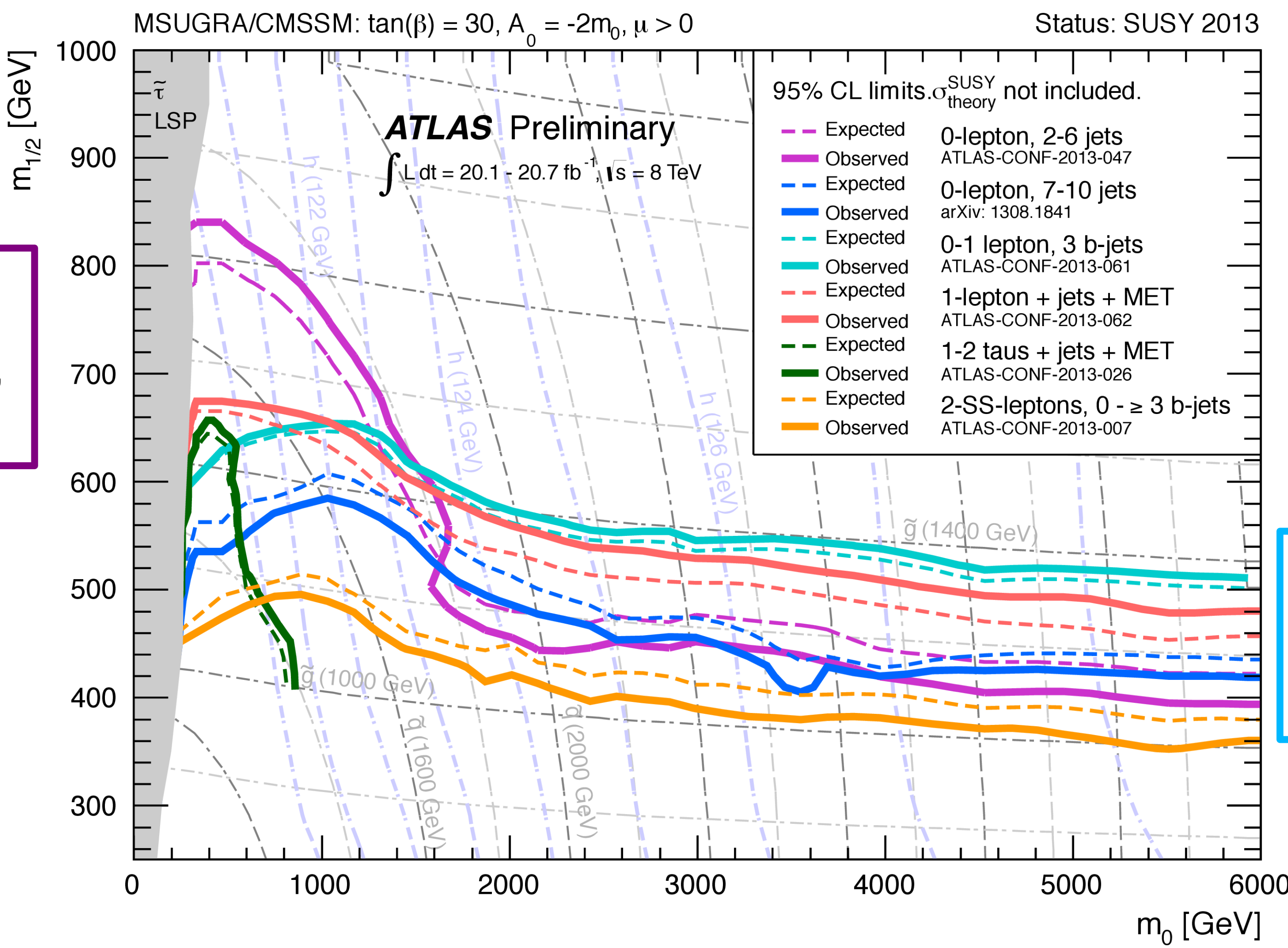
$m(\tilde{\chi}_1^0)$ vs $m(\tilde{q})$
Decay via $\tilde{l}/\tilde{\nu}$

Extends limits towards smaller mass splittings

A specific SUSY framework like mSUGRA can be used to compare the performance of seach channels

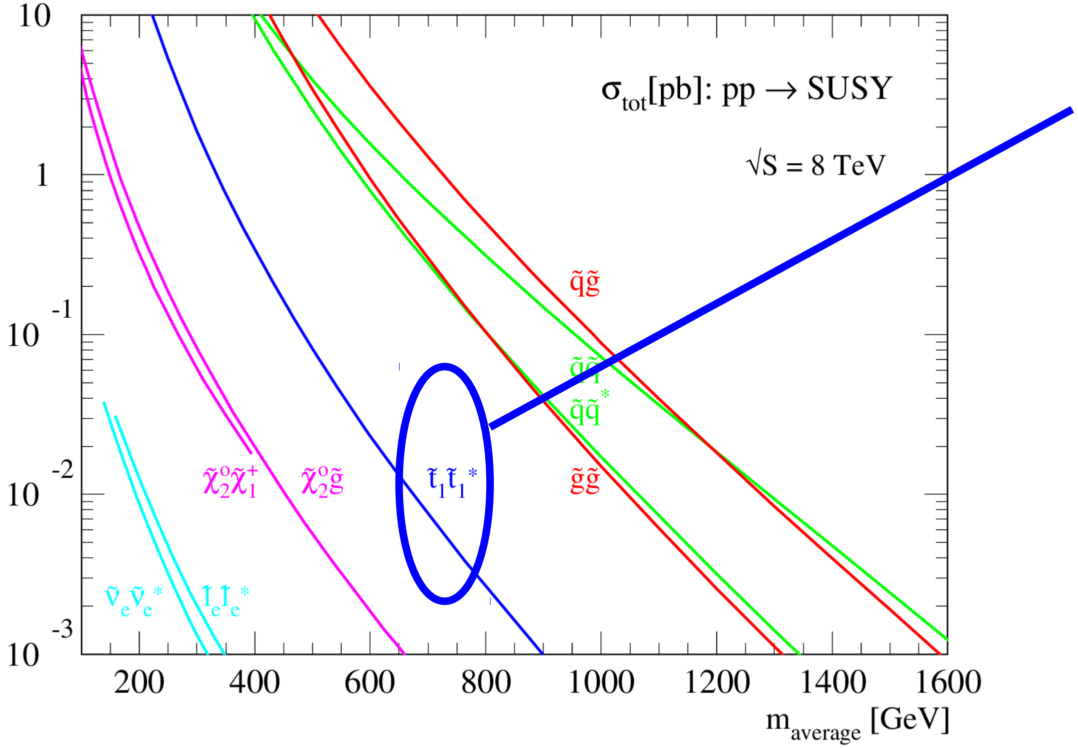
$\tilde{q}\,\tilde{q}$ dominated

0-lepton + 2-6 jets analysis strong at low m_0, high $m_{1/2}$



mostly $\tilde{g} \rightarrow \tilde{t}\,/\,\tilde{b}$

0-lepton + 3 b-jets analysis strong at high m_0, low $m_{1/2}$



Smaller cross-section than 1st/2nd gen. squarks

Light stop preferred by naturalness

Final state depends on decay of stop/sbottom

3rd gen. search channels

Gluino mediated production

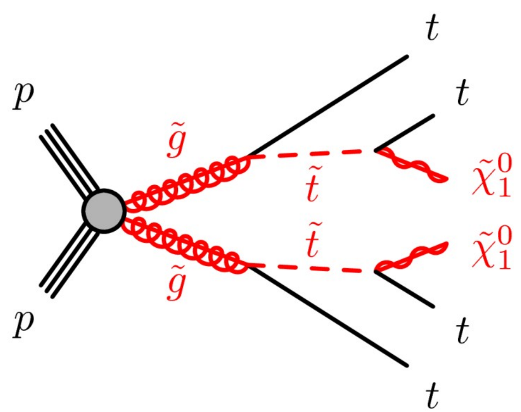
- » 0-1 leptons + ≥ 3b-jets + E_T^{miss}
- 2 SS leptons (+ b-jets) + E_T^{miss} ATLAS-CONF-2013-007
- 3 leptons + jets + E_T^{miss} ATLAS-CONF-2012-151

>> new result to be discussed
(since last ATLAS SUSY seminar on 26th March 2013)

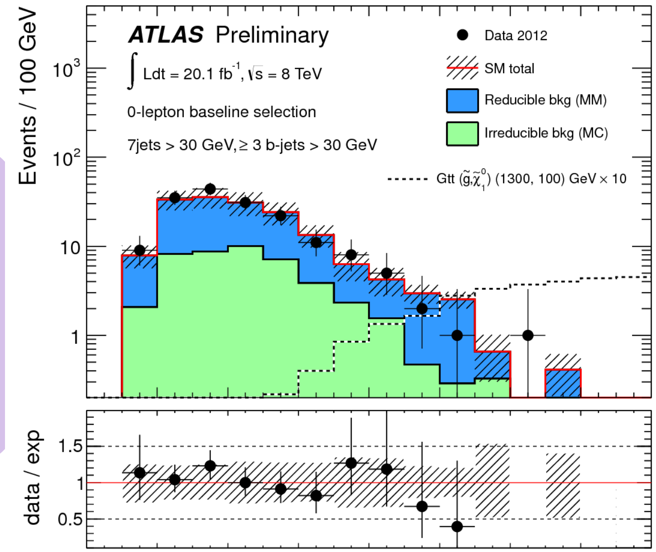
Direct production

- 0-leptons + 6-jets + 2 b-jets + E_T^{miss} ATLAS-CONF-2013-024
- » 0-leptons + 2 b-jets + E_T^{miss}
- 1-leptons + 4-jets (1 b-jets) + E_T^{miss} ATLAS-CONF-2013-037
- » 2-leptons (+ 2 b-jets) + E_T^{miss}
- » Charm/mono-jet+ E_T^{miss}
- Z(ll) + 2 b-jets + E_T^{miss} ATLAS-CONF-2012-025

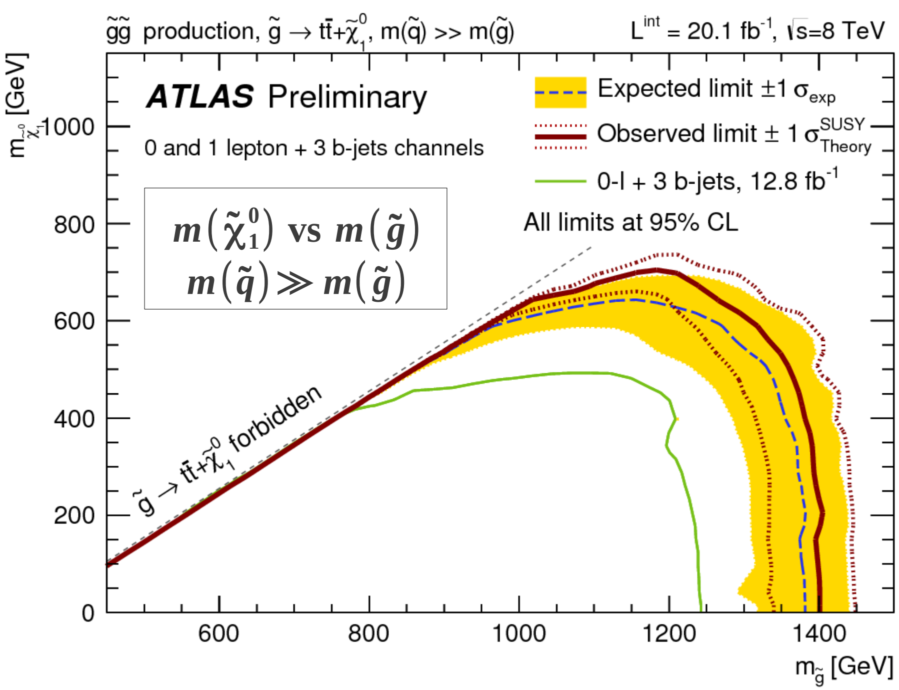
Consider SUSY processes with decays to many (b)jets + LSP + 0-1 leptons



9 signal regions
- 0 or 1 lepton
- ≥ 3 b-tagged jets
- ≥ 4 to ≥ 7 jets
- High E_T^{miss}, m_{eff}, (m_T, $E_T^{miss} / \sqrt{H_T}$)

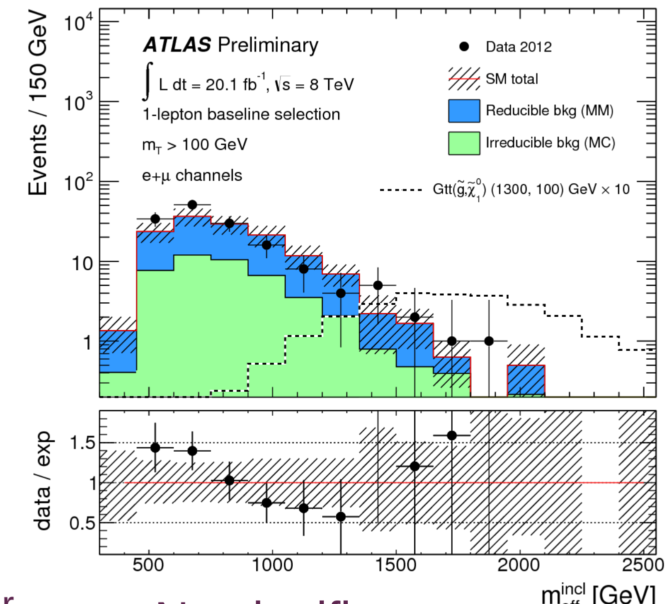


Reducible ttbar background (≥1 mis-tagged b-jet)
Irreducible ttbar+b/bb/Z/h



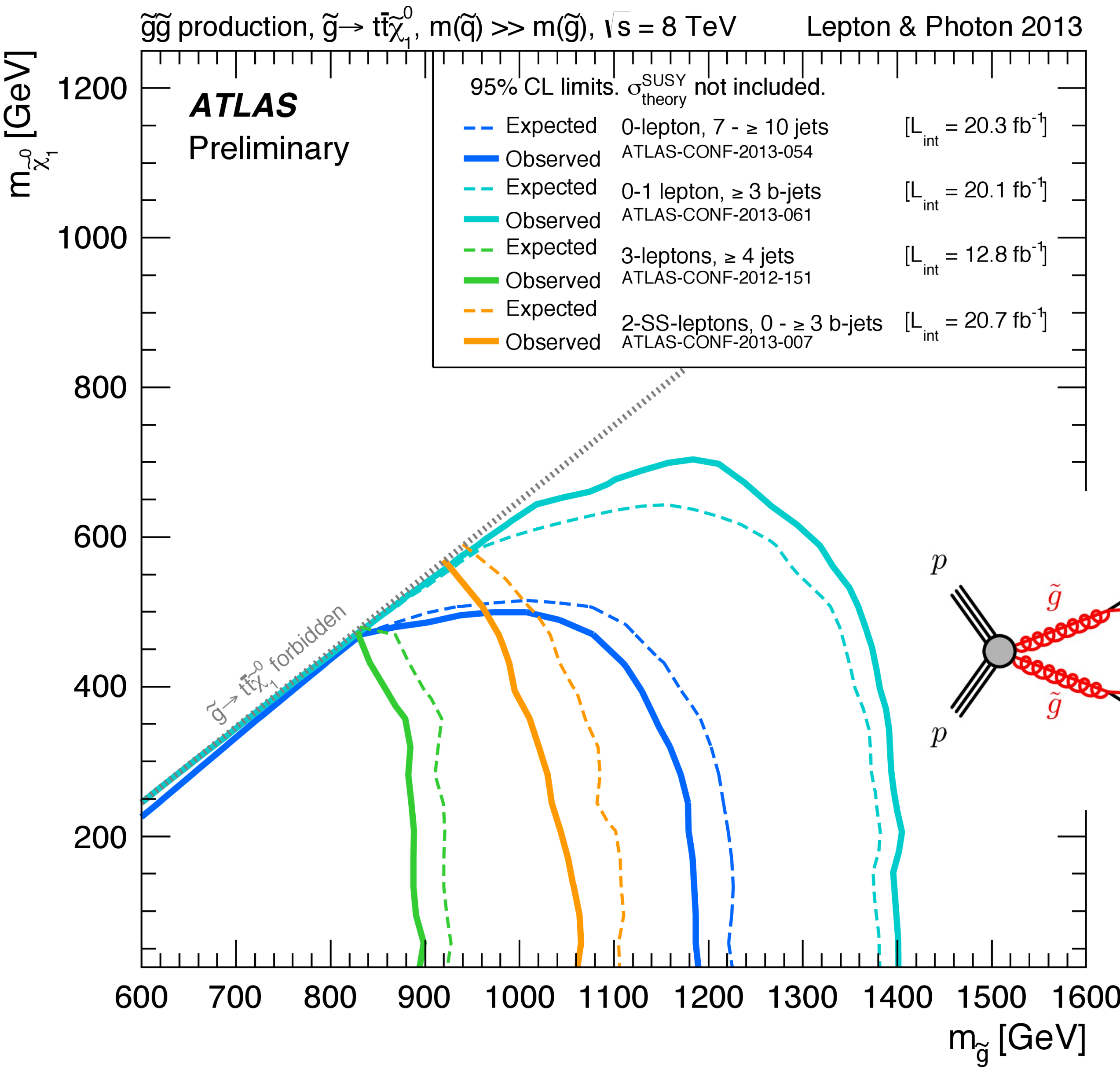
Interpretation in gluino-mediated 3rd gen. production

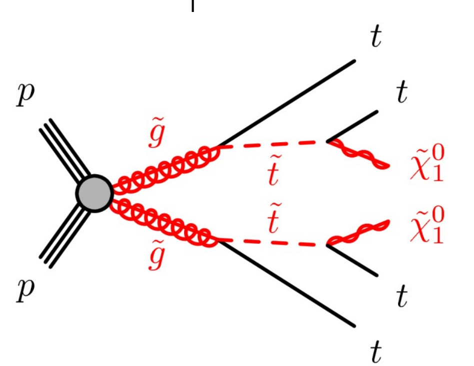
+ more interpretations for decays via heavy neutralinos



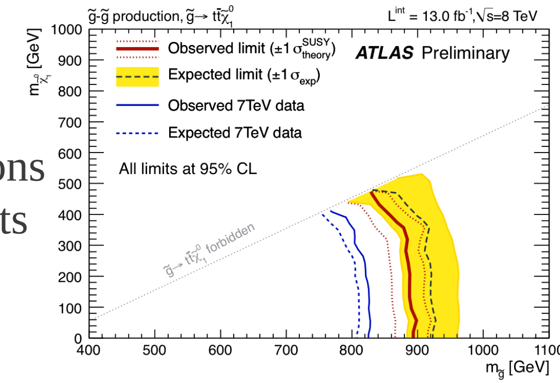
No significant excess seen

Gluino mediated stop — Summary

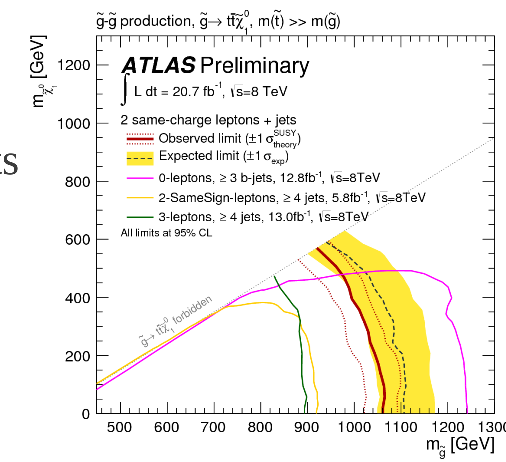




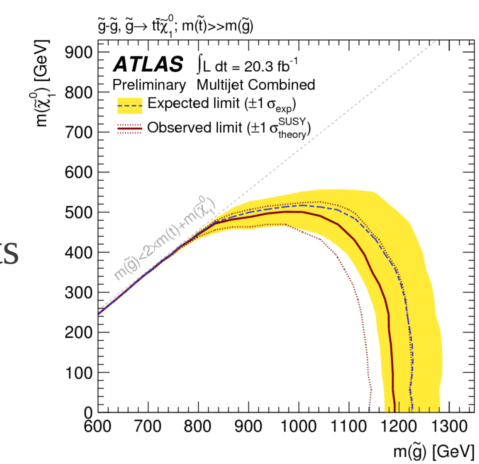
3-leptons
≥ 4 jets



SS-leptons
≥ 0 - 3 b-jets



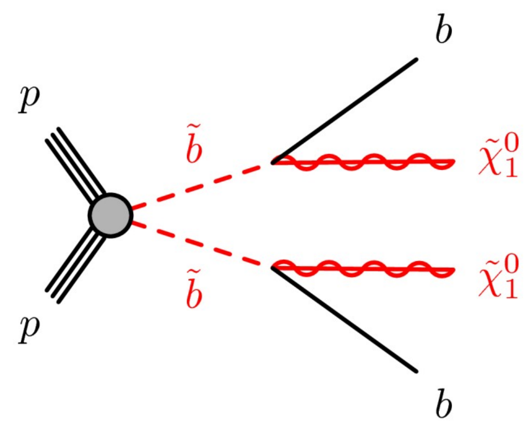
0-lepton
≥ 7 - 10 jets

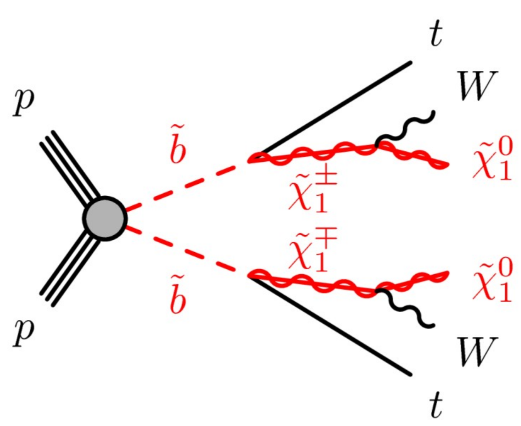


3rd gen. squark searches

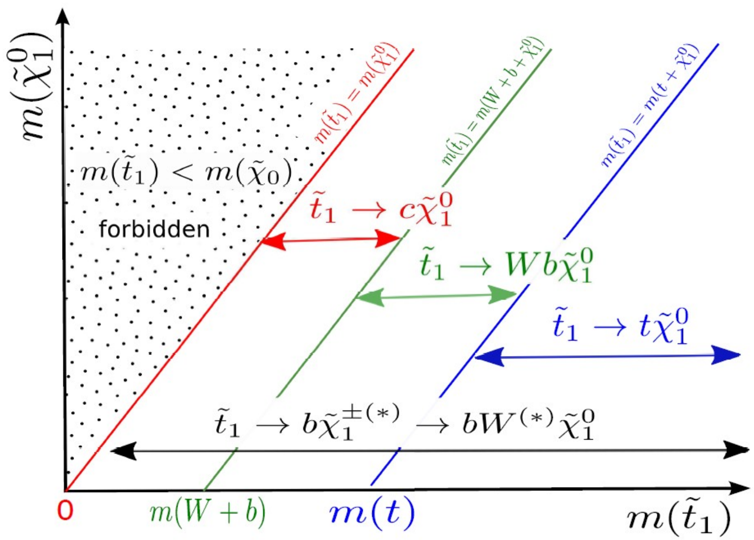
Stop/sbottom quark searches target many different scenarios
Sensitivity is dependent on sparticle mass differences and decay channels

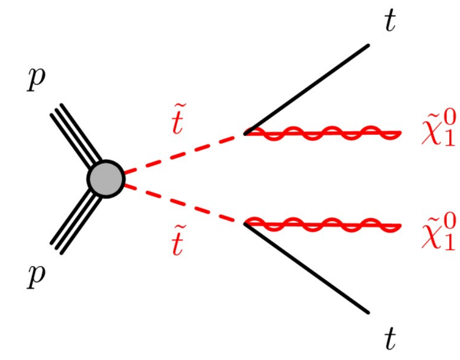
Sbottom



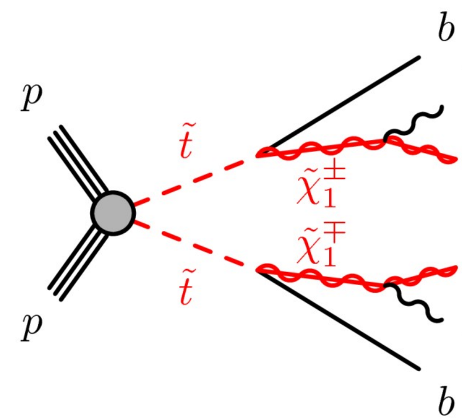


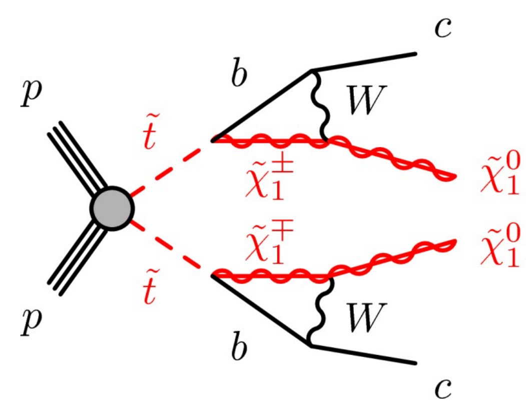
Stop



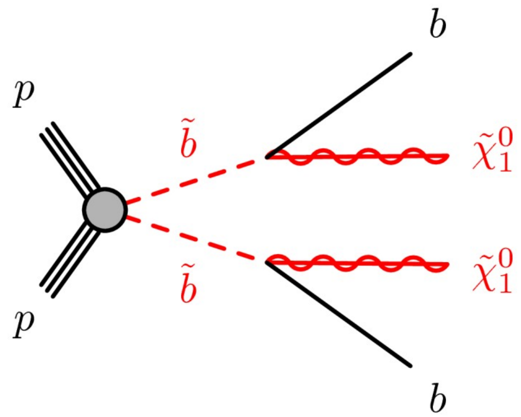


Decays to b chargino or heavy neutralinos also possible





Consider SUSY processes with decays to b-jets + LSP + no leptons



2 signal regions

Large $\Delta m(\tilde{b}, \tilde{\chi}_1^0)$
= 2 b-tagged jets
= 2 high p_T jets
high m_{CT}, m_{bb}

Small $\Delta m(\tilde{b}, \tilde{\chi}_1^0)$
= 2 b-tagged jets
additional ISR jet
+ low additional hadronic energy

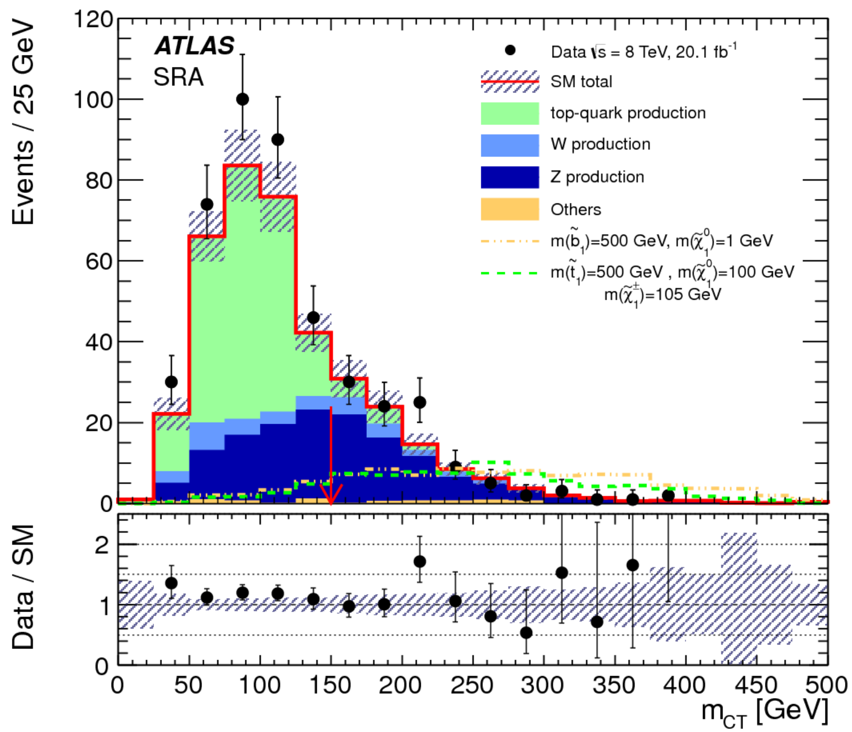
"Contransverse mass"

$$m_{CT}^2 = \left(E_T^{b_1} + E_T^{b_2}\right)^2 - \left|\mathbf{p}_T^{b_1} - \mathbf{p}_T^{b_2}\right|^2$$

For $\tilde{b}\tilde{b}$ events, end-point defined by:

$$\frac{m(\tilde{b})^2 - m(\tilde{\chi}_1^0)^2}{m(\tilde{b})}$$

For $t\bar{t}$ events, end-point ~ 135 GeV



Ttbar, W+bjets, Z+bjets dominated

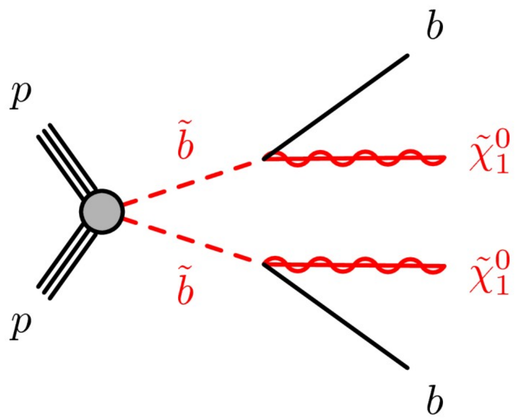
No significant excess seen

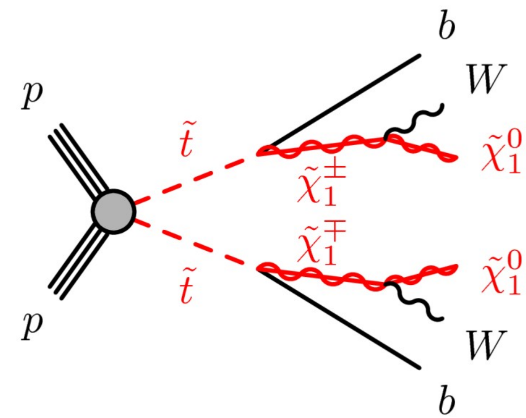
Sbottom searches

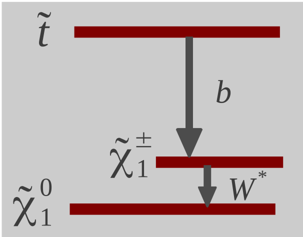
$0\,l + 2$ b-jets + E_T^{miss}

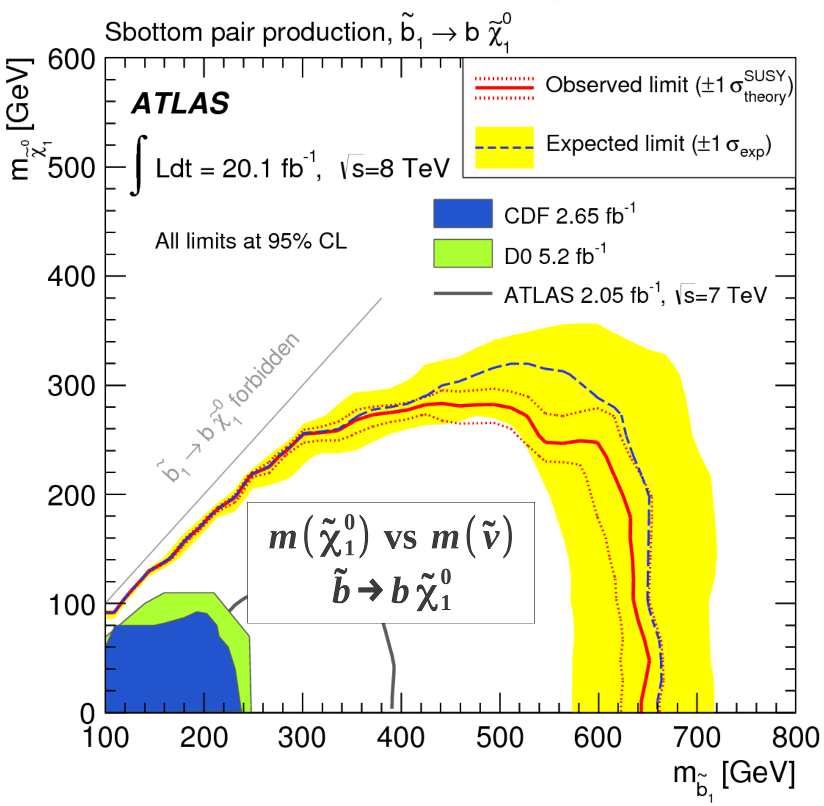
arXiv:1308.2631

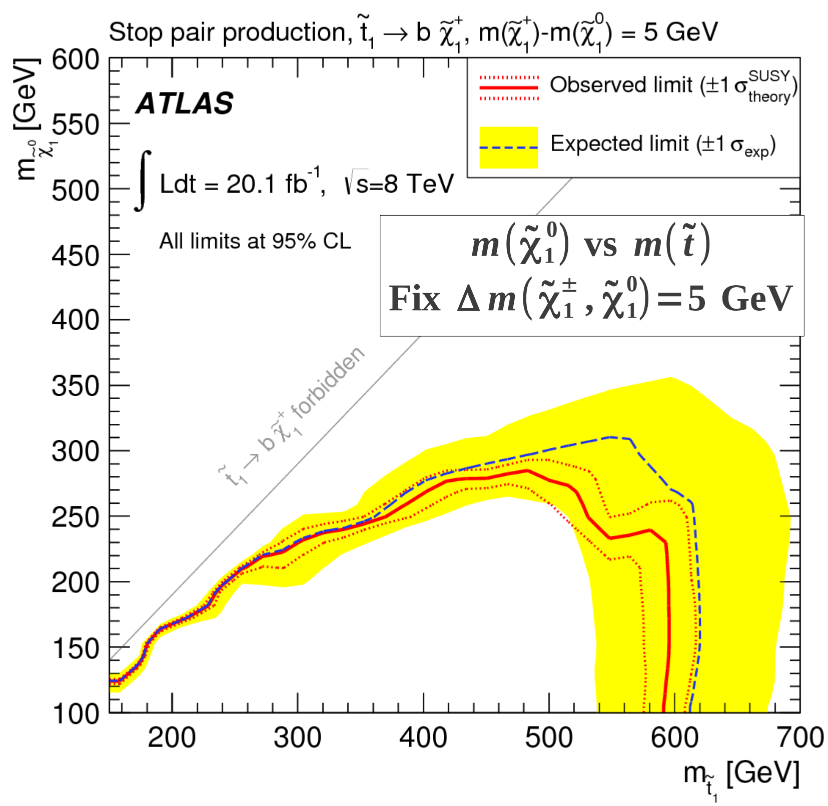
Analysis is reinterpreted for stop production

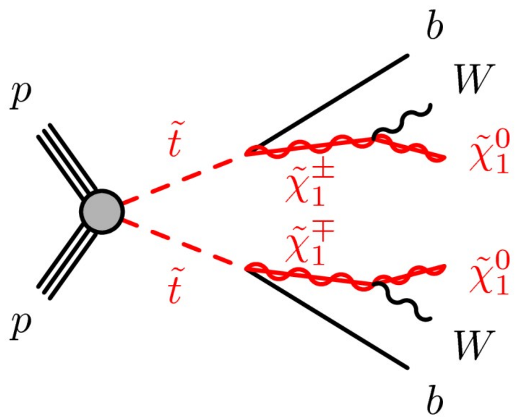






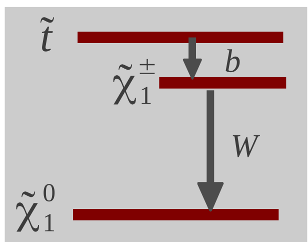






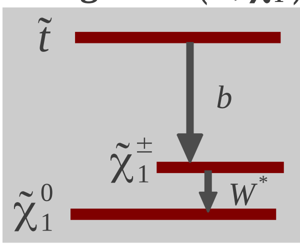
Consider SUSY processes with decays to two leptons + jets + LSP

Large $\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^{0})$



4 signal regions
- m_{T2}^{ll} > 90 to 120 GeV
- ≥ 2 jets
- one region without jets for sensitivity to small $\Delta m(\tilde{t}, \tilde{\chi}_1^{\pm})$

Large $\Delta m(\tilde{t}, \tilde{\chi}_1^{\pm})$



1 signal region
- Low p_T leptons
- = 2 b-tagged jets
- $m_{T2}^{b\text{-jet}}$ > 160 GeV

m_{T2} variable "Stransverse mass"
Kinematic endpoint
~ mass of semi-invisibly decaying particle

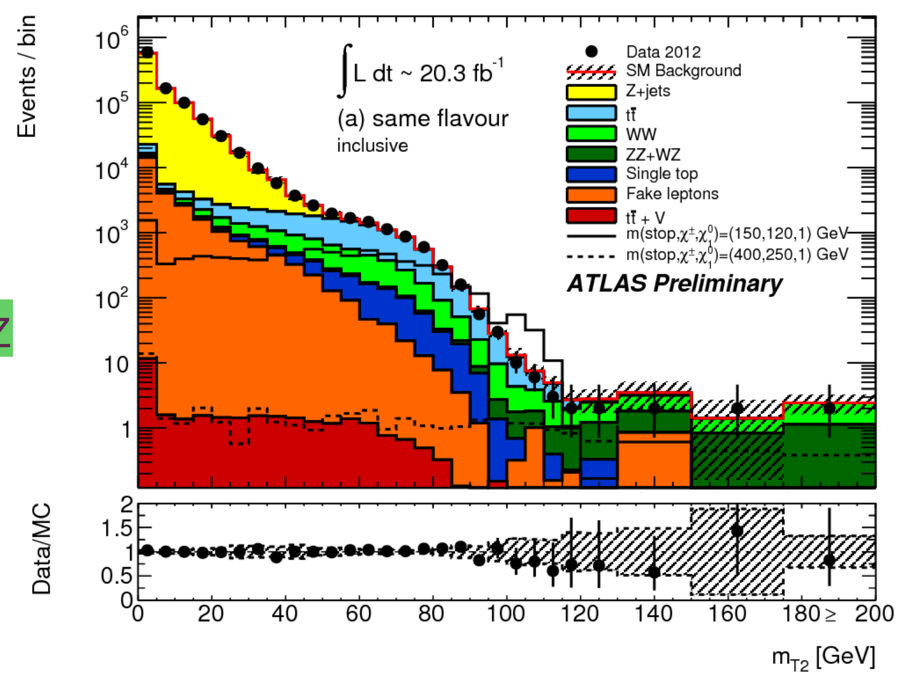
$m_{T2}^{ll}(l_1, l_2, E_T^{miss})$
Bounded by W mass for WW, Wt, ttbar

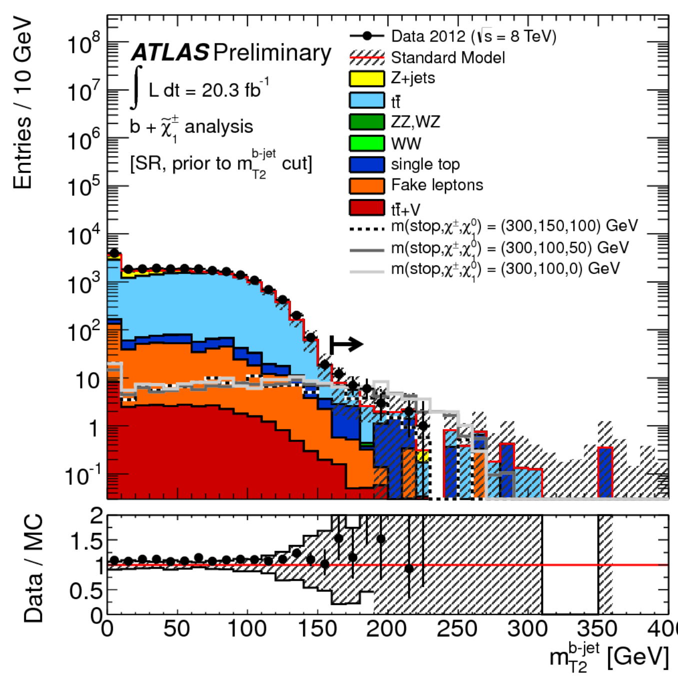
$m_{T2}^{b\text{-jet}}(b_1, b_2, l_1 + l_2 + E_T^{miss})$
Bounded by top mass for ttbar

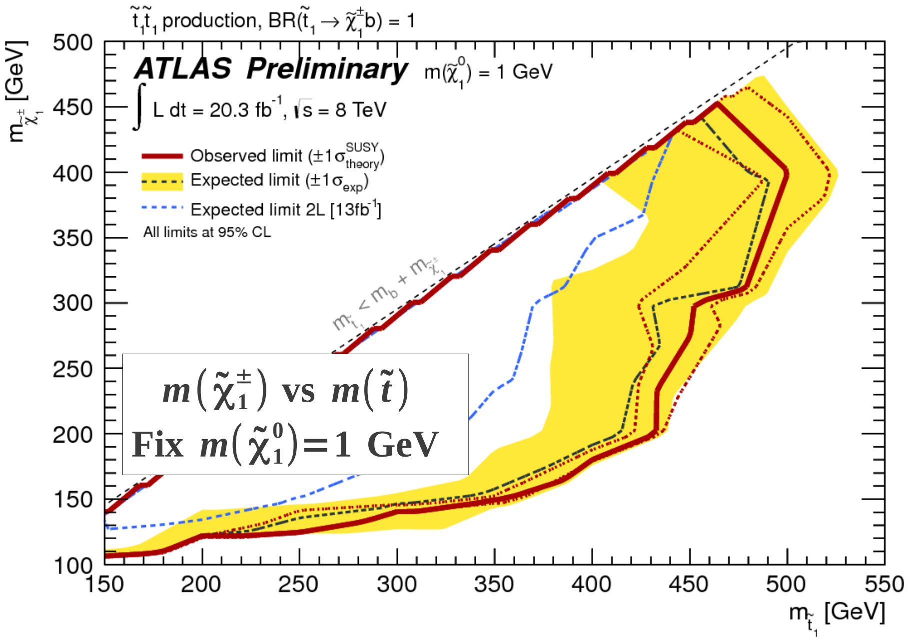
Backgrounds

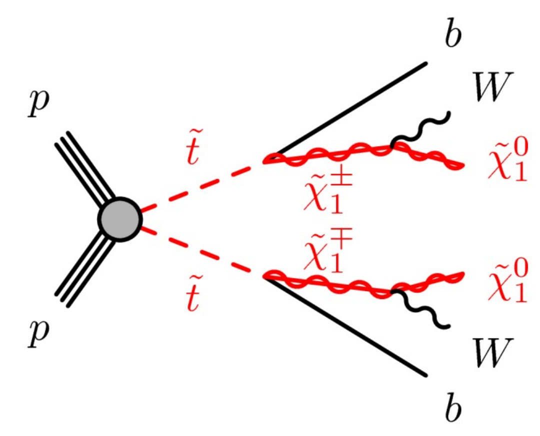
Large $\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^{0})$
Ttbar, WW, WZ, ZZ

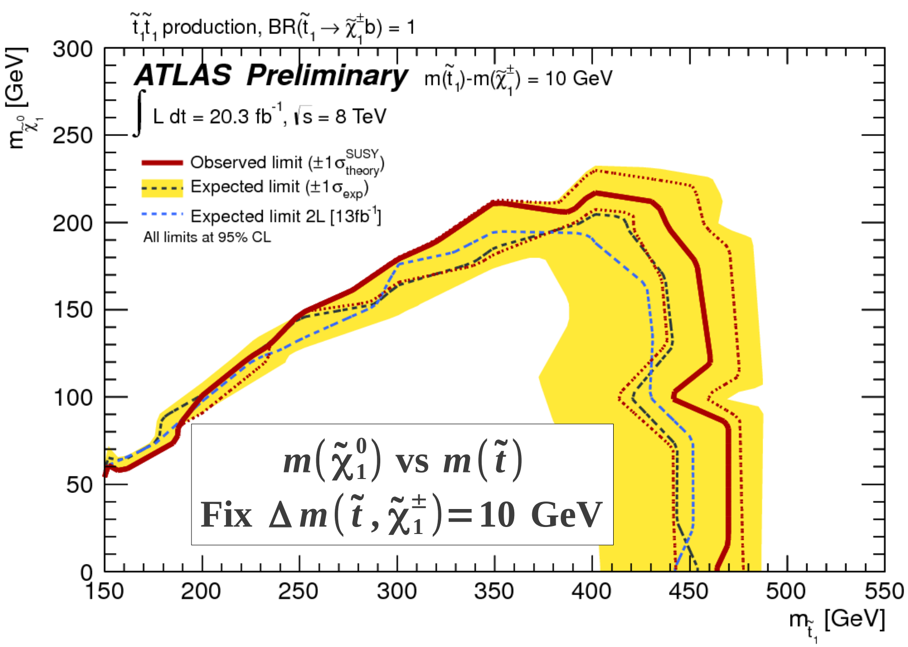
Large $\Delta m(\tilde{t}, \tilde{\chi}_1^{\pm})$
Ttbar, Wt, Z+jets

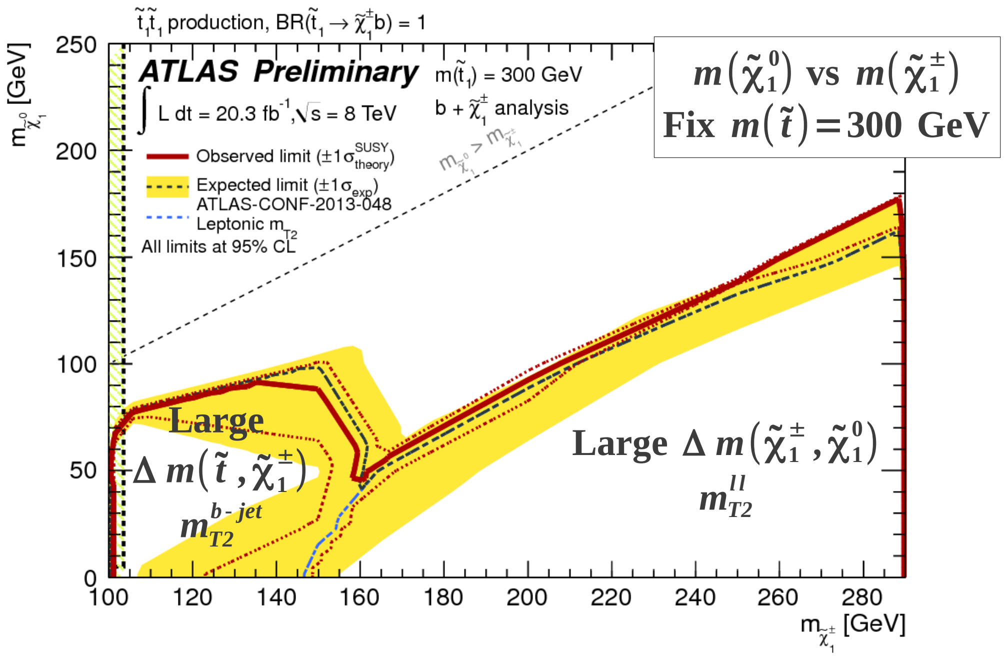




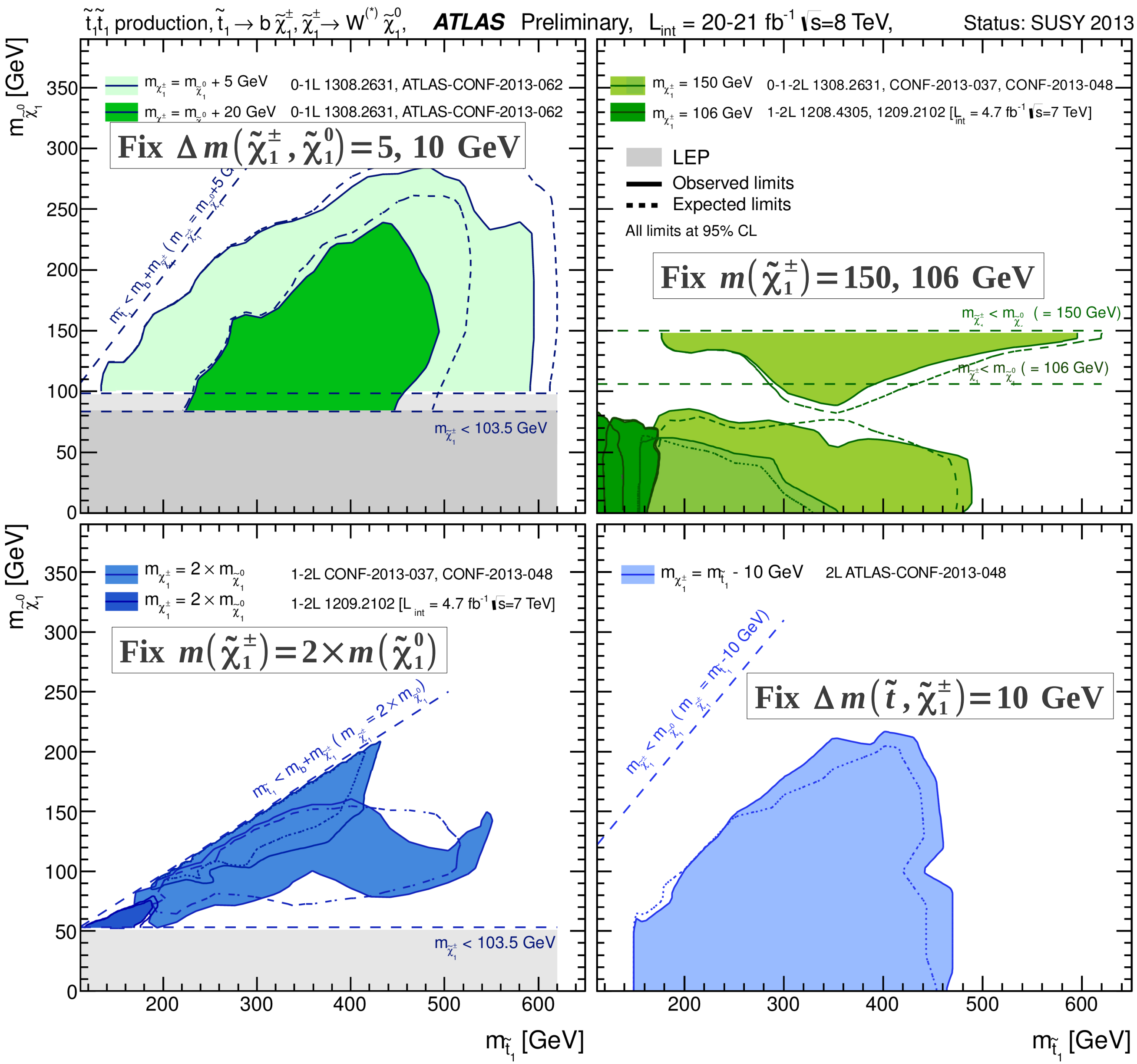

$\tilde{t}_1\tilde{t}_1$ production, BR($\tilde{t}_1 \to \tilde{\chi}_1^{\pm}$b) = 1
ATLAS Preliminary
m($\tilde{\chi}_1^0$) = 1 GeV
∫ L dt = 20.3 fb^{-1}, √s = 8 TeV
Observed limit (±1σ$^{SUSY}_{theory}$)
Expected limit (±1σ$_{exp}$)
Expected limit 2L [13fb^{-1}]
All limits at 95% CL
$m_{\tilde{\chi}_1^{\pm}}$ [GeV]
$m_{\tilde{t}_1}$ [GeV]
$m(\tilde{\chi}_1^{\pm})$ vs $m(\tilde{t})$
Fix $m(\tilde{\chi}_1^0)$=1 GeV

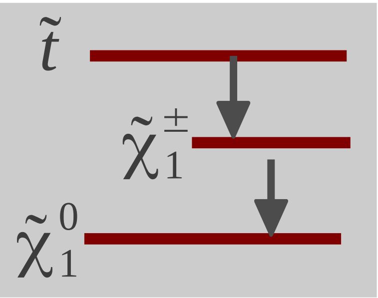

p
p
$\tilde{t}$
$\tilde{t}$
$\tilde{\chi}_1^{\pm}$
$\tilde{\chi}_1^{\mp}$
$\tilde{\chi}_1^0$
$\tilde{\chi}_1^0$
b
b
W
W

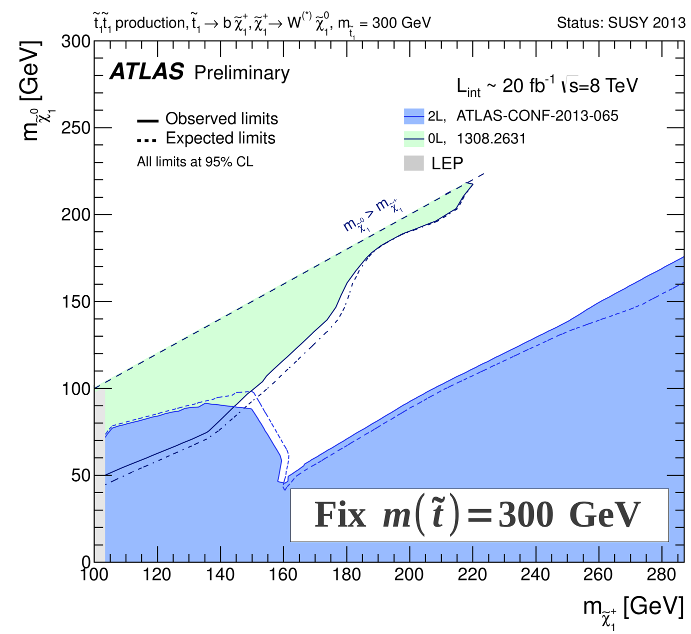

$\tilde{t}_1\tilde{t}_1$ production, BR($\tilde{t}_1 \to \tilde{\chi}_1^{\pm}$b) = 1
ATLAS Preliminary
m($\tilde{t}_1$)-m($\tilde{\chi}_1^{\pm}$) = 10 GeV
∫ L dt = 20.3 fb^{-1}, √s = 8 TeV
Observed limit (±1σ$^{SUSY}_{theory}$)
Expected limit (±1σ$_{exp}$)
Expected limit 2L [13fb^{-1}]
All limits at 95% CL
$m_{\tilde{\chi}_1^0}$ [GeV]
$m_{\tilde{t}_1}$ [GeV]
$m(\tilde{\chi}_1^0)$ vs $m(\tilde{t})$
Fix $\Delta m(\tilde{t}, \tilde{\chi}_1^{\pm})$=10 GeV

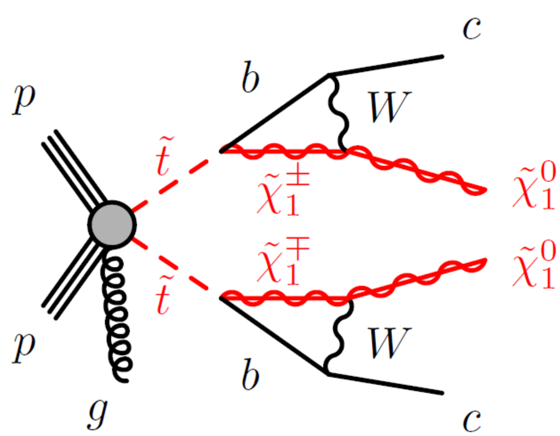

$\tilde{t}_1\tilde{t}_1$ production, BR($\tilde{t}_1 \to \tilde{\chi}_1^{\pm}$b) = 1
ATLAS Preliminary
m($\tilde{t}_1$) = 300 GeV
∫ L dt = 20.3 fb^{-1}, √s = 8 TeV
b + $\tilde{\chi}_1^{\pm}$ analysis
Observed limit (±1σ$^{SUSY}_{theory}$)
Expected limit (±1σ$_{exp}$)
ATLAS-CONF-2013-048
Leptonic m_{T2}
All limits at 95% CL
$m_{\tilde{\chi}_1^0}$ [GeV]
$m_{\tilde{\chi}_1^{\pm}}$ [GeV]
$m(\tilde{\chi}_1^0)$ vs $m(\tilde{\chi}_1^{\pm})$
Fix $m(\tilde{t})$=300 GeV
Large $\Delta m(\tilde{t}, \tilde{\chi}_1^{\pm})$
$m_{T2}^{b\text{-}jet}$
Large $\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0)$
m_{T2}^{ll}

Summary


t̃₁t̃₁ production, t̃₁ → b χ̃₁±, χ̃₁± → W(*) χ̃₁⁰,
ATLAS Preliminary, Lint = 20-21 fb-1 √s=8 TeV,
Status: SUSY 2013
m_χ̃₁⁰ [GeV]
m_χ± = m_χ̃₁⁰ + 5 GeV 0-1L 1308.2631, ATLAS-CONF-2013-062
m_χ± = m_χ̃₁⁰ + 20 GeV 0-1L 1308.2631, ATLAS-CONF-2013-062
Fix Δm(χ̃₁±, χ̃₁⁰)=5, 10 GeV
m_χ̃₁± < 103.5 GeV
m_χ± = 150 GeV 0-1-2L 1308.2631, CONF-2013-037, CONF-2013-048
m_χ± = 106 GeV 1-2L 1208.4305, 1209.2102 [Lint = 4.7 fb-1 √s=7 TeV]
LEP
Observed limits
Expected limits
All limits at 95% CL
Fix m(χ̃₁±)=150, 106 GeV
m_χ± = 2 × m_χ̃₁⁰ 1-2L CONF-2013-037, CONF-2013-048
m_χ± = 2 × m_χ̃₁⁰ 1-2L 1209.2102 [Lint = 4.7 fb-1 √s=7 TeV]
Fix m(χ̃₁±)=2×m(χ̃₁⁰)
m_χ± = m_t̃ - 10 GeV 2L ATLAS-CONF-2013-048
Fix Δm(t̃, χ̃₁±)=10 GeV
m_t̃₁ [GeV]


t̃
χ̃₁±
χ̃₁⁰


t̃₁t̃₁ production, t̃₁ → b χ̃₁±, χ̃₁± → W(*) χ̃₁⁰, m_t̃₁ = 300 GeV
Status: SUSY 2013
ATLAS Preliminary
Lint ~ 20 fb-1 √s=8 TeV
Observed limits
Expected limits
All limits at 95% CL
2L, ATLAS-CONF-2013-065
0L, 1308.2631
LEP
Fix m(t̃)=300 GeV
m_χ̃₁⁰ [GeV]
m_χ̃₁± [GeV]



For $\Delta m(\tilde{t}, \tilde{\chi}_1^0) < m_W$ and $m(\tilde{t}) < m(\tilde{\chi}_1^{\pm})$

stop can decay via loop to $\tilde{t} \rightarrow c\,\tilde{\chi}_1^0$

Soft c-jets and small E_T^{miss}

→ ISR/FSR jet for trigger and signal/background separation

2 signal regions: High E_T^{miss}, High p_T ISR/FSR jet

Small $\Delta m(\tilde{t}, \tilde{\chi}_1^0)$

≥ 1-3 jets, no c-tagging

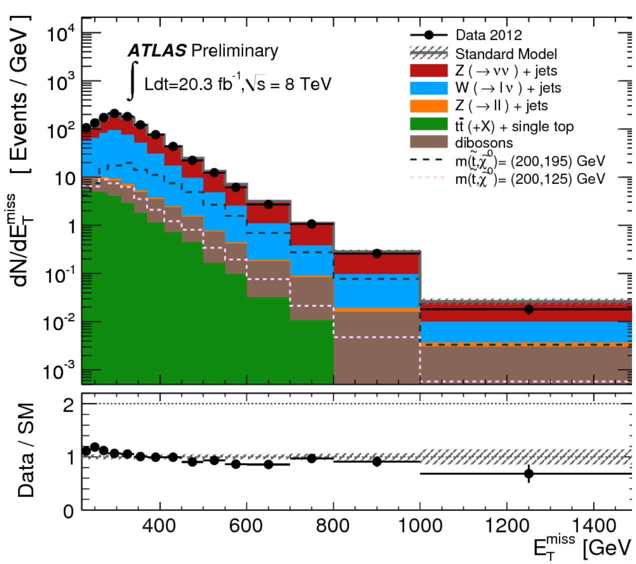
"Monojet-like"

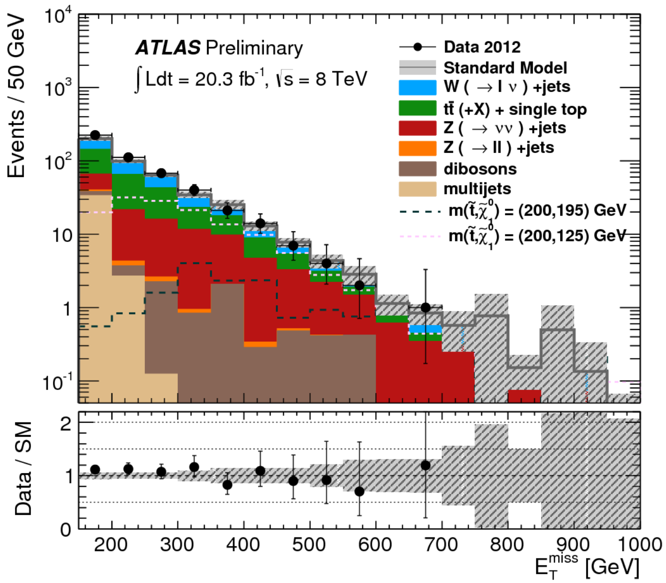
Moderate $\Delta m(\tilde{t}, \tilde{\chi}_1^0) \sim 20-80$ GeV

≥ 4 jets, some c-tagged

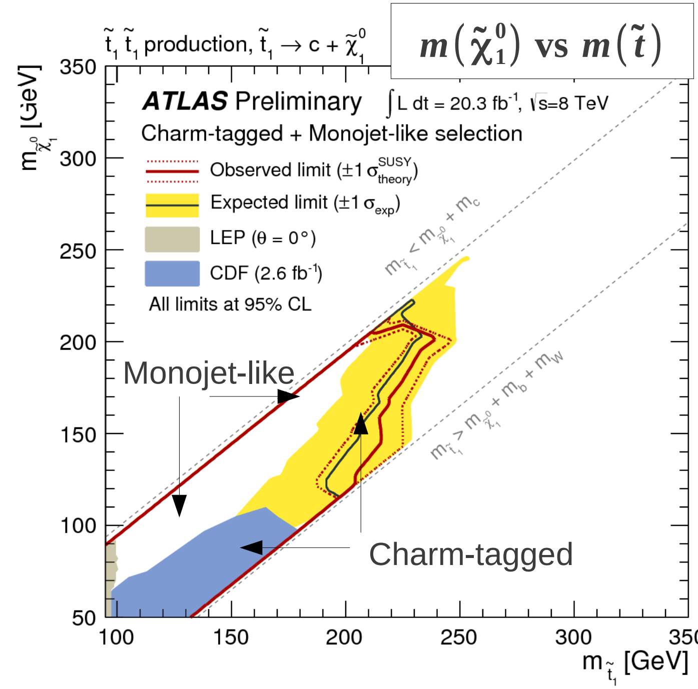
"Charm-tagged"

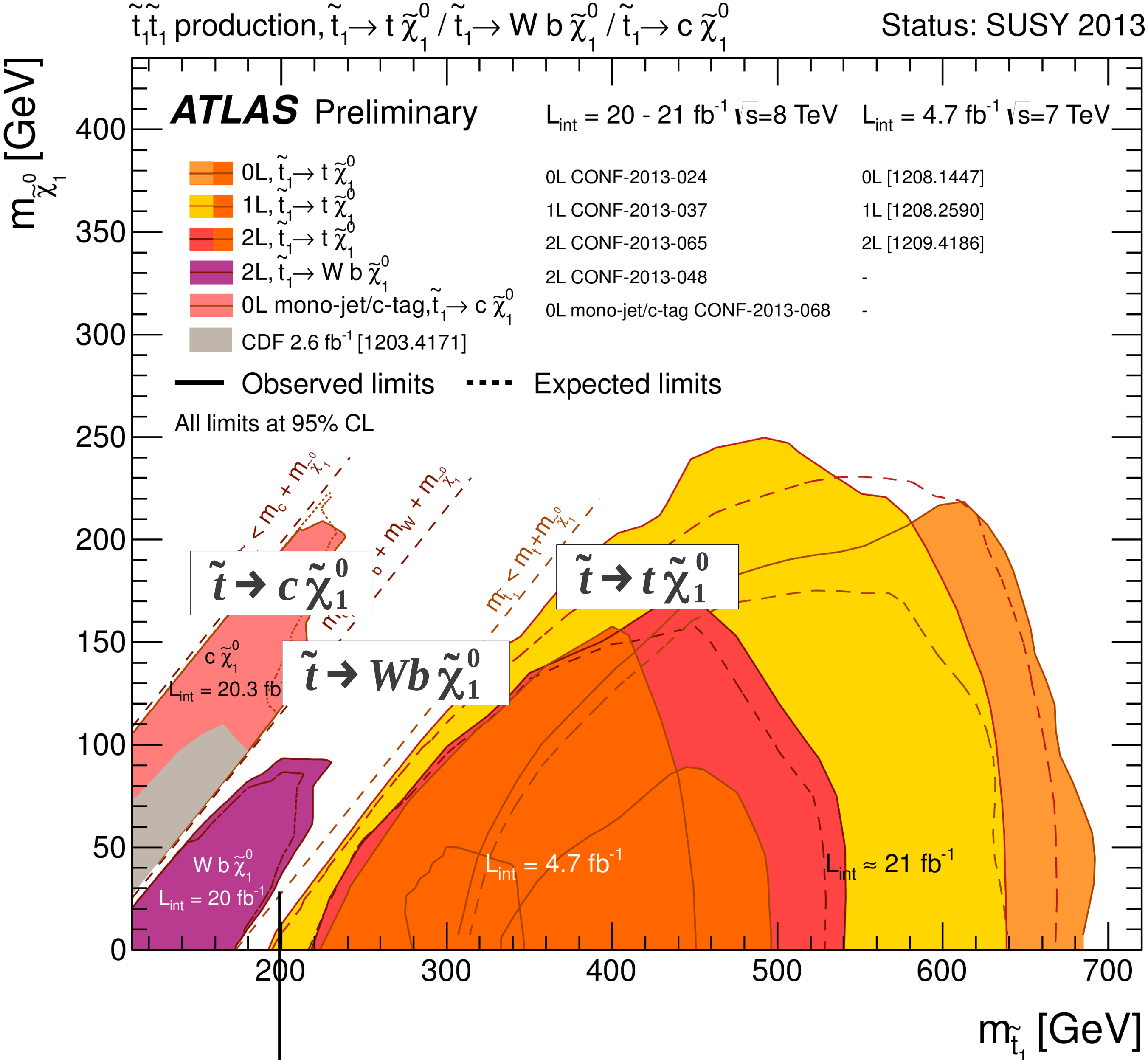
Ttbar, W+bjets, Z+bjets dominated

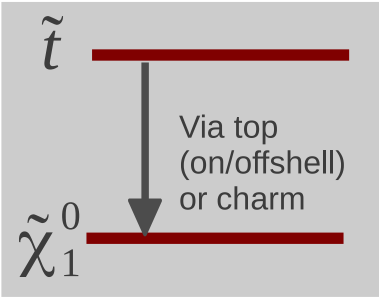




$m(\tilde{\chi}_1^0)$ vs $m(\tilde{t})$

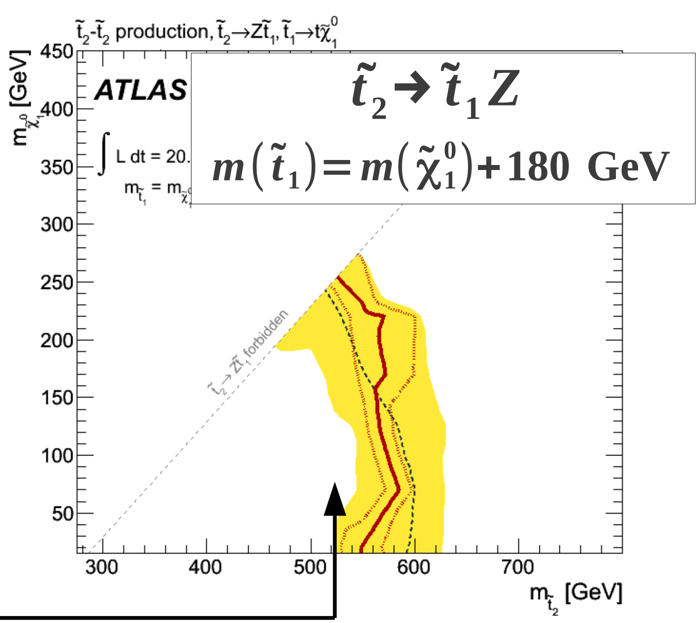


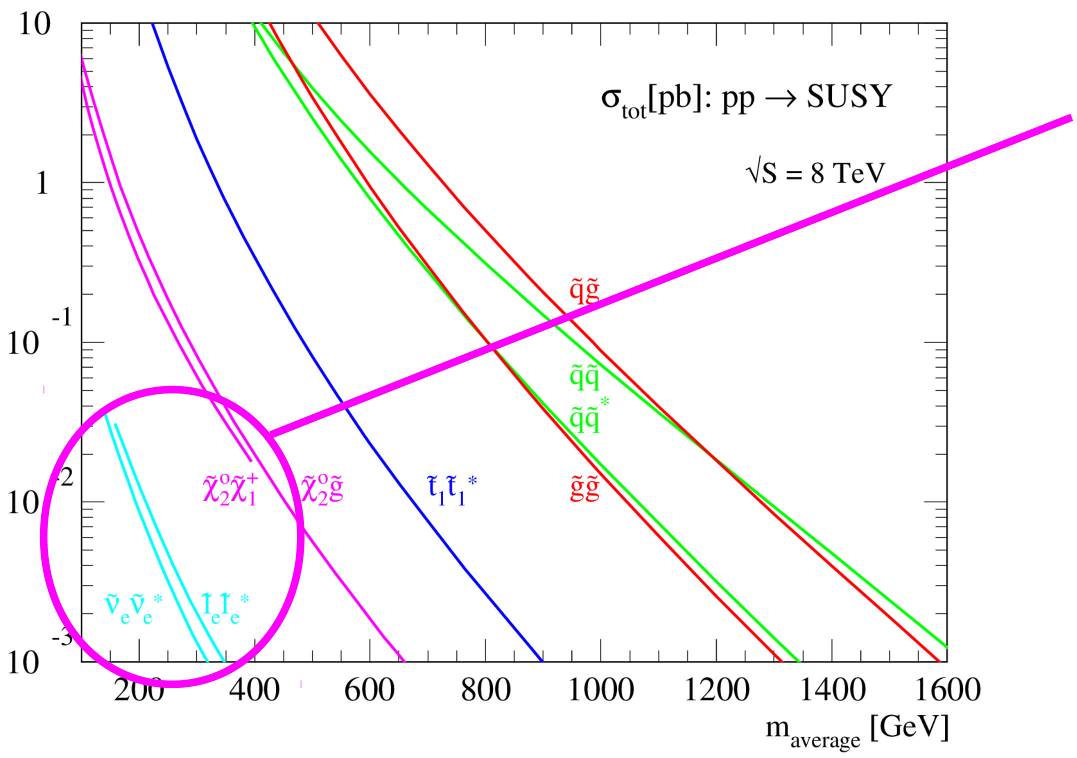




Very good coverage in stop searches, using many different channels and techniques.

Some challenging gaps remain!



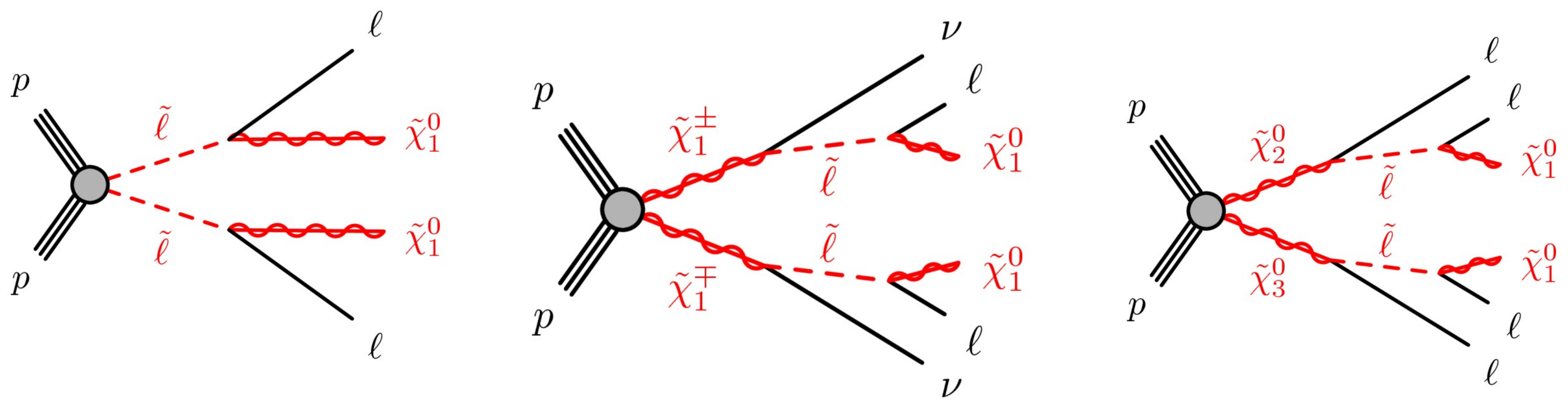


Electroweak SUSY processes have small cross-sections
Light higgsinos preferred by naturalness

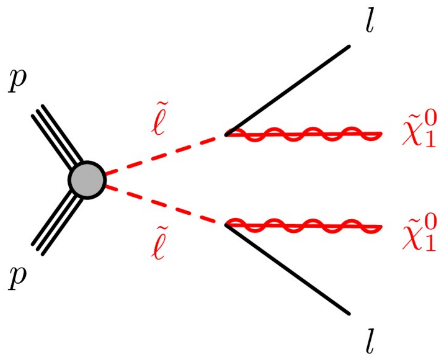
EWKino search channels

- » 2-leptons + E_T^{miss}
- 3-leptons + E_T^{miss} ATLAS-CONF-2013-035
- 4-leptons + E_T^{miss} ATLAS-CONF-2013-036
- 2-taus + E_T^{miss} ATLAS-CONF-2013-028
- » 1-lepton + 2 b-jets + E_T^{miss}

>> new result to be discussed
(since last ATLAS SUSY seminar on 26th March 2013)

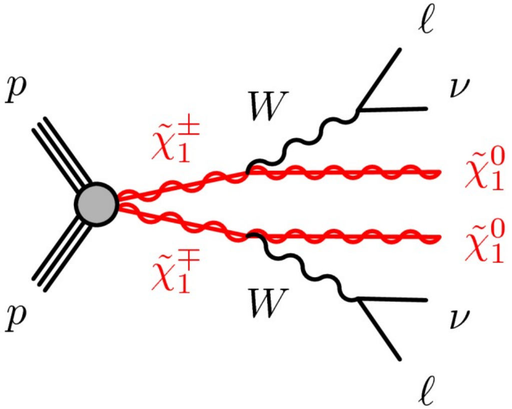


Consider SUSY processes with decays to 2 leptons + LSP



2 signal regions

Target slepton decays (direct or via chargino decays)
- SFOS or DFOS
- Z veto, jet veto
- Large $E_T^{miss, rel}$ and m_{T2}



3 signal regions

Target charginos decaying via W

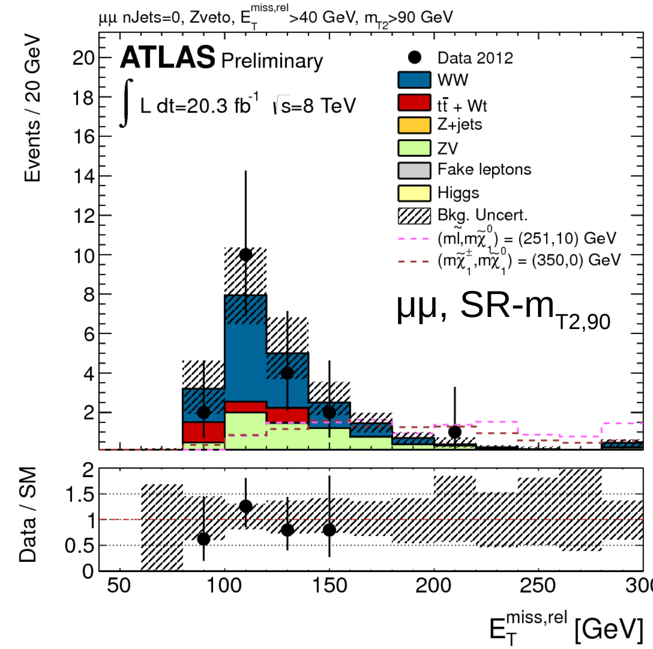
Difficult due to low BR(W→lν)
- DFOS only
- m(ll) and p_T(ll) selections
- Large $E_T^{miss, rel}$ or m_{T2}

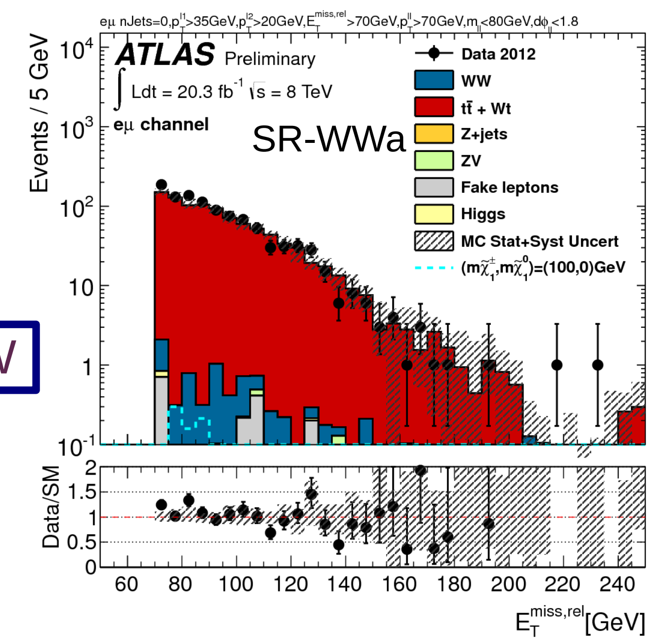
$E_T^{miss, rel}$ projection of E_T^{miss} on perpendicular axis

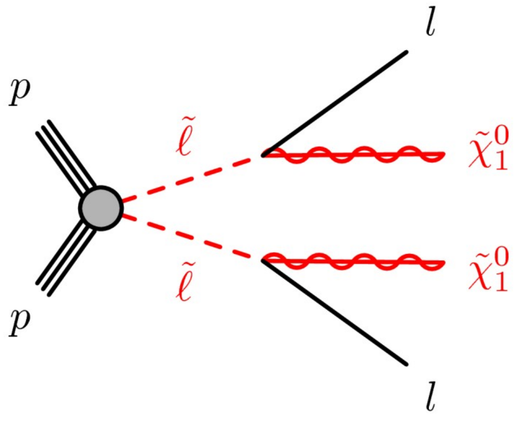
Reduces mis-measured E_T^{miss}

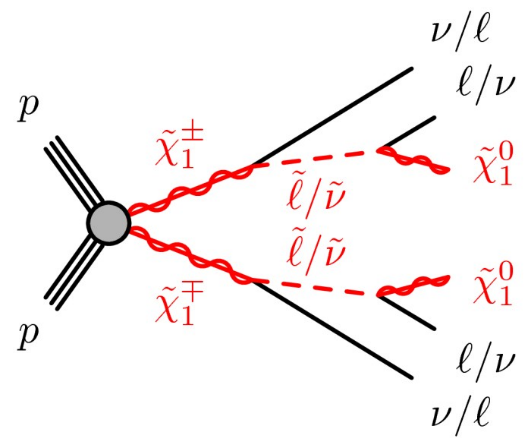
$$E_T^{\text{miss,rel.}} = \begin{cases} E_T^{\text{miss}} & \text{if } \Delta\phi_{\ell,j} \geq \pi/2 \\ E_T^{\text{miss}} \times \sin\Delta\phi_{\ell,j} & \text{if } \Delta\phi_{\ell,j} < \pi/2 \end{cases}$$

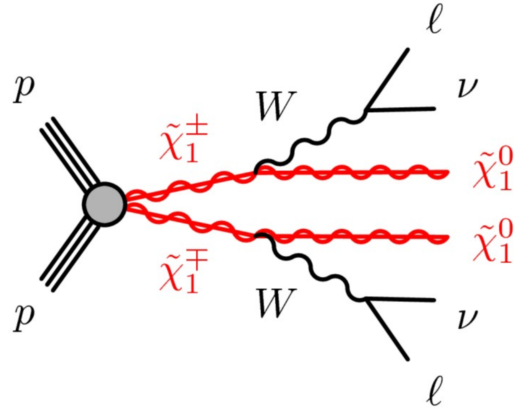
Ttbar and WW dominated



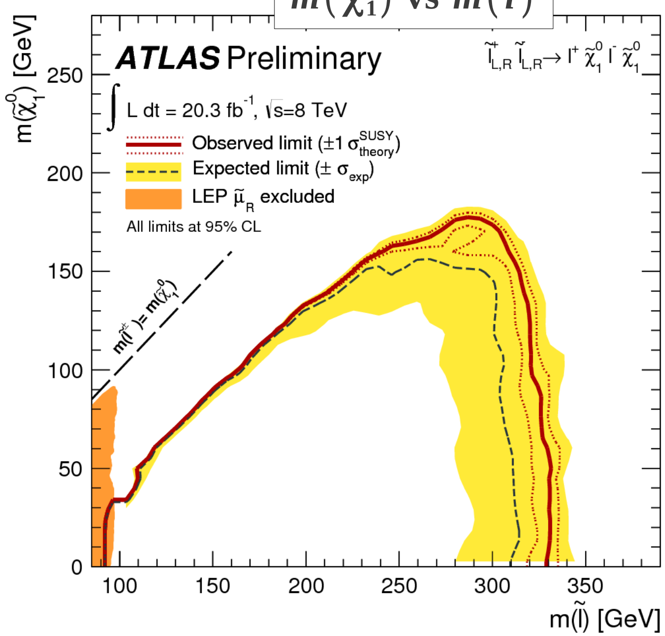






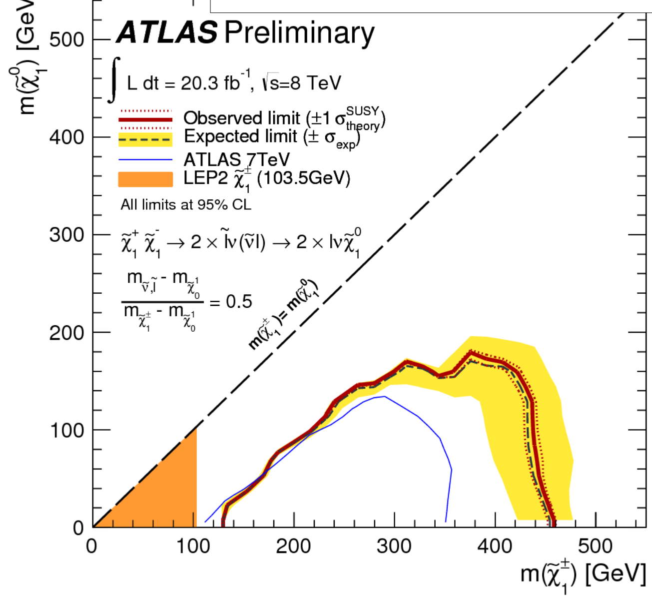


$m(\tilde{\chi}_1^0)$ vs $m(\tilde{l})$



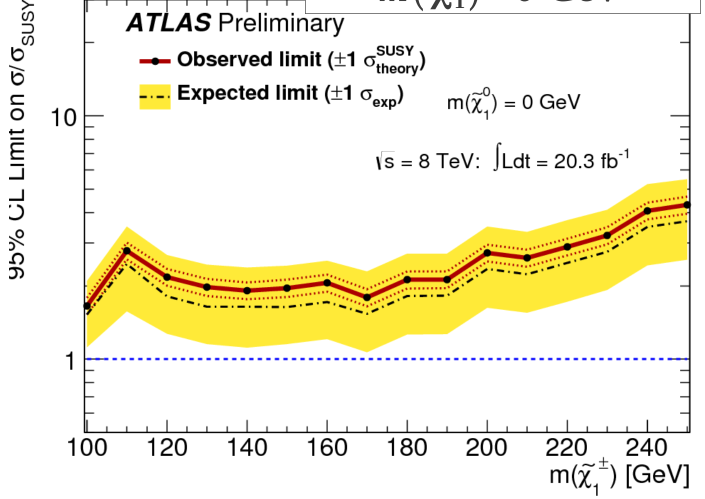
$m(\tilde{\chi}_1^0)$ vs $m(\tilde{\chi}_1^\pm)$

Fix $m(\tilde{l}) = \frac{m(\tilde{\chi}_1^\pm) + m(\tilde{\chi}_1^0)}{2}$

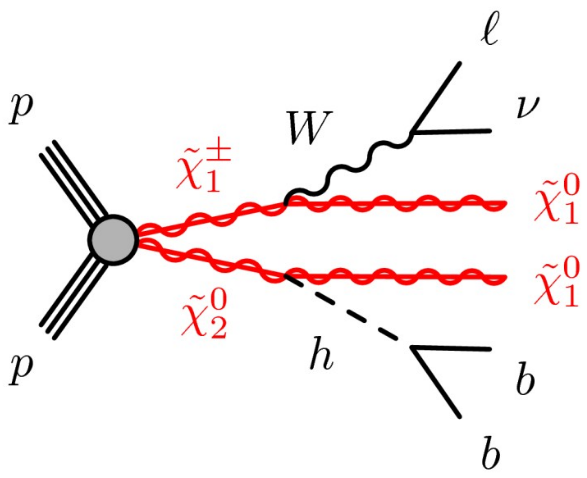


UL on $\frac{\sigma}{\sigma_{SUSY}}$ vs $m(\tilde{\chi}_1^\pm)$

$m(\tilde{\chi}_1^0) = 0$ GeV



Consider SUSY processes with decays via 125 GeV SM-like higgs



Where kinematically allowed, $\tilde{\chi}_2^0 \rightarrow h \tilde{\chi}_1^0$ could be a significant fraction of the BR

125 GeV SM-like lightest higgs decays to pair of bottom quarks with highest BR

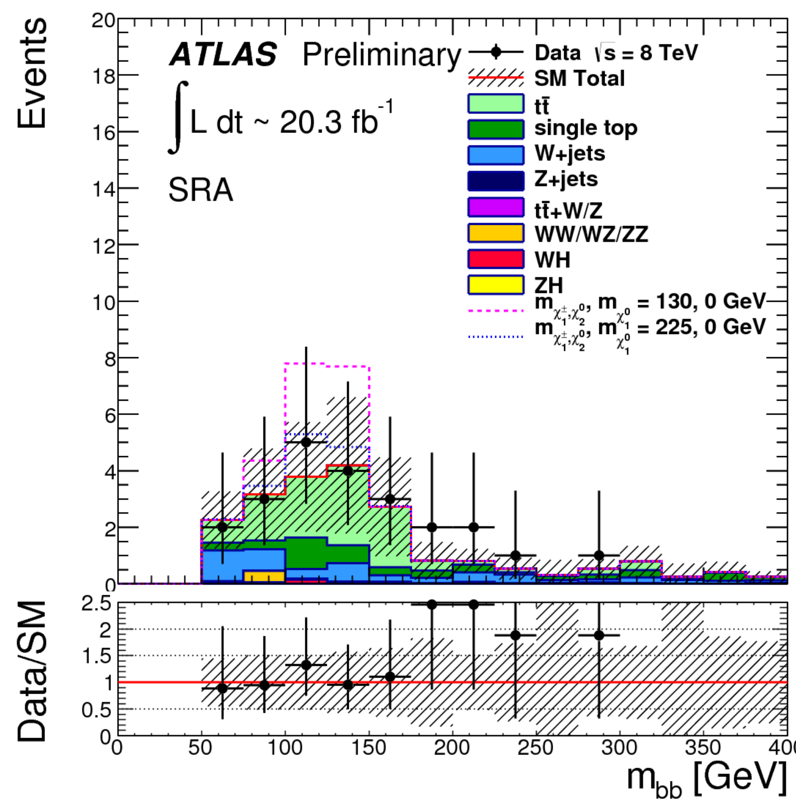
2 signal regions
=2 b-tagged jets ~m_H
Large E_T^{miss}, m_T and m_{CT}

$$m_{CT}^2 = \left(E_T^{b_1} + E_T^{b_2}\right)^2 - \left|\mathbf{p}_T^{b_1} - \mathbf{p}_T^{b_2}\right|^2$$

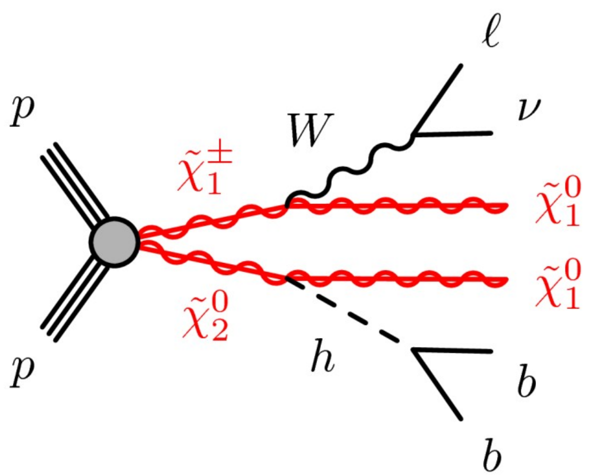
Ttbar and W+jets dominated background

Simultaneous background fit in control and signal regions

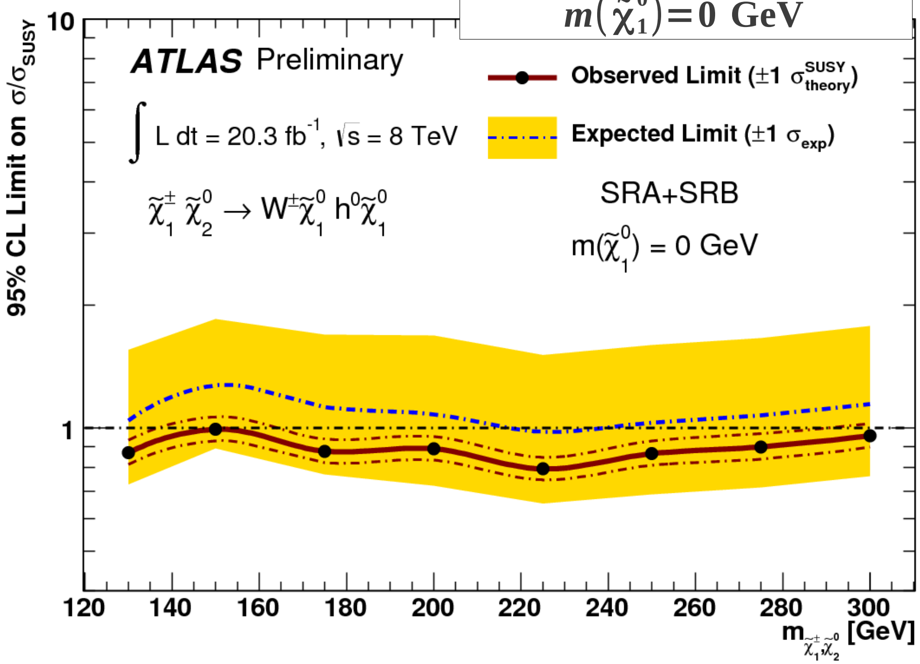
Fit using 8 bins in m_{bb} → exclude m_{bb} 105–135 GeV
to avoid signal contamination
(for background only fit, not for discovery or exclusion fit)



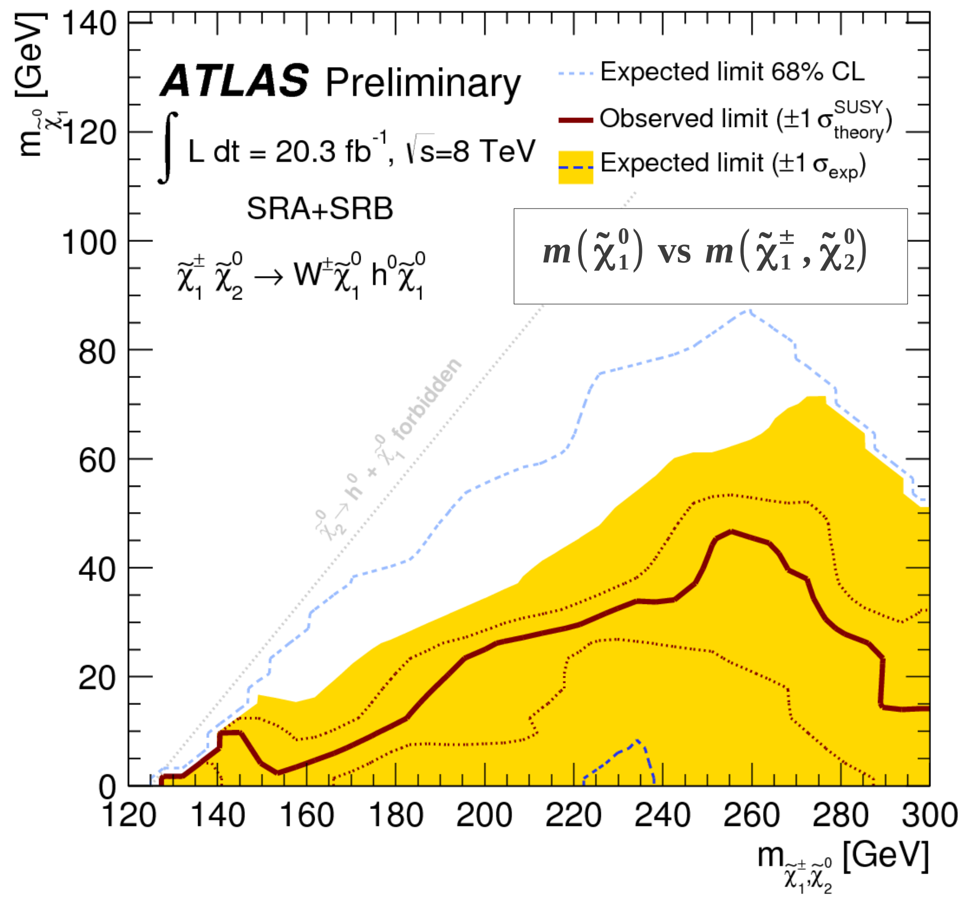
No significant excess seen

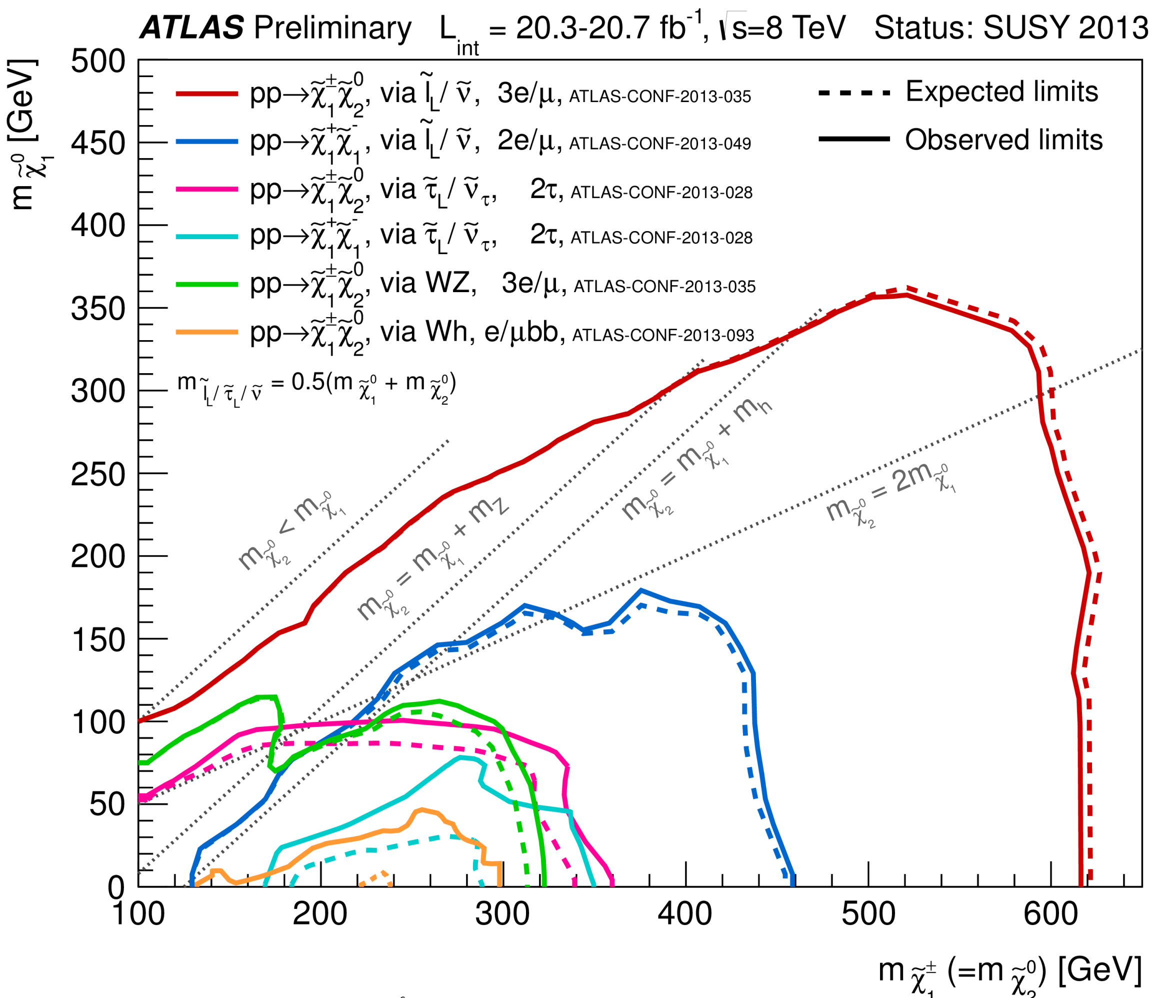


UL on $\frac{\sigma}{\sigma_{SUSY}}$ vs $m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0)$
$m(\tilde{\chi}_1^0) = 0$ GeV

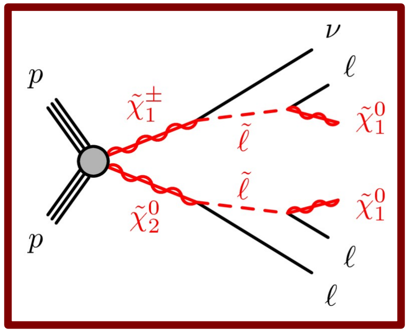


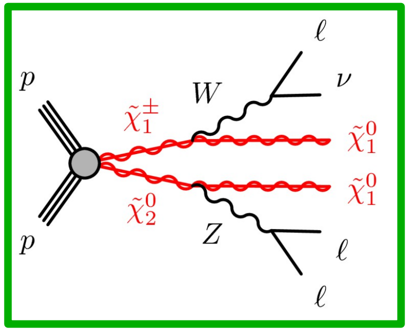
$m(\tilde{\chi}_1^0)$ vs $m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0)$



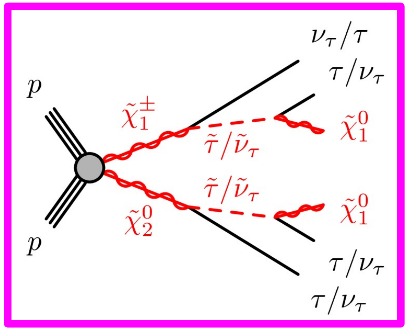


3-leptons $\tilde{\chi}_2^0\tilde{\chi}_1^{\pm}$

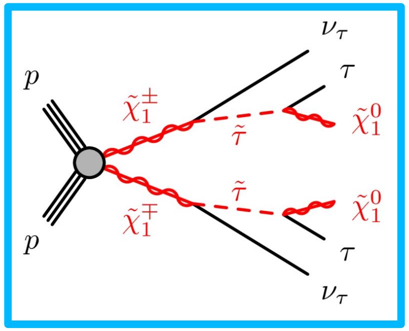




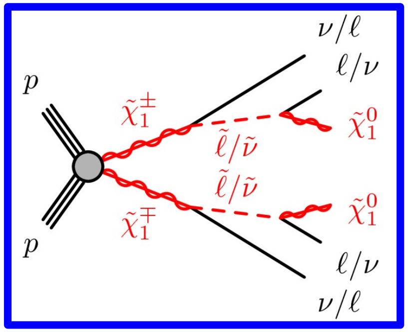
2-taus $\tilde{\chi}_2^0\tilde{\chi}_1^{\pm}$



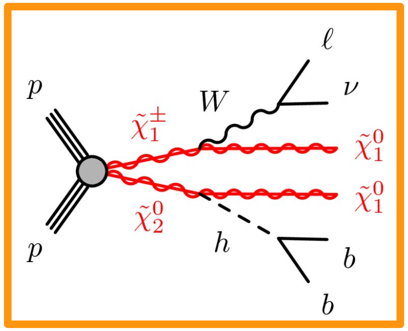
$\tilde{\chi}_1^{+}\tilde{\chi}_1^{-}$

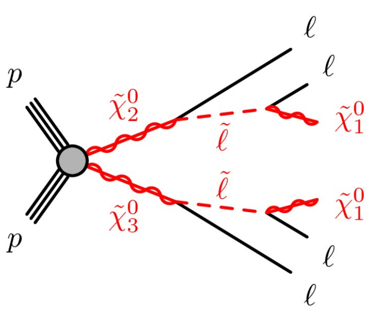


2-leptons $\tilde{\chi}_2^0\tilde{\chi}_1^{\pm}$



1-lepton + bb $\tilde{\chi}_2^0\tilde{\chi}_1^{\pm}$





+ 4-lepton interpretation for $\tilde{\chi}_2^0\tilde{\chi}_3^0$

Recall

L-number violating terms

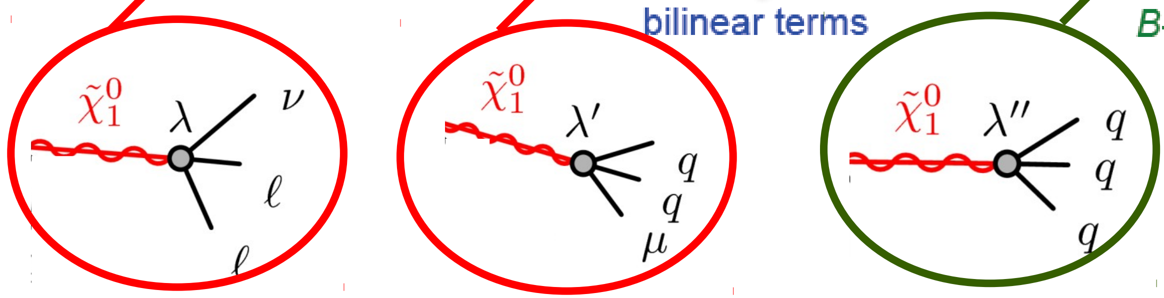
The MSSM potential

$$W_{\not R_p} = \lambda_{ijk}\hat{L}_i\hat{L}_j\hat{E}^C_k + \lambda'_{ijk}\hat{L}_i\hat{Q}_j\hat{D}^C_k + \epsilon_i\hat{L}_i\hat{H}_u + \lambda''_{ijk}\hat{U}^C_i\hat{D}^C_j\hat{D}^C_k$$

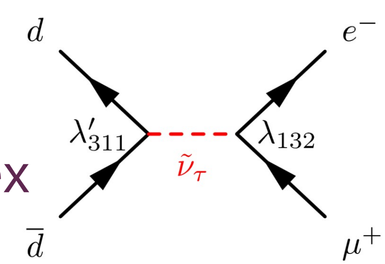
bilinear terms

B-number violating terms

RPV couplings λ,λ',λ''



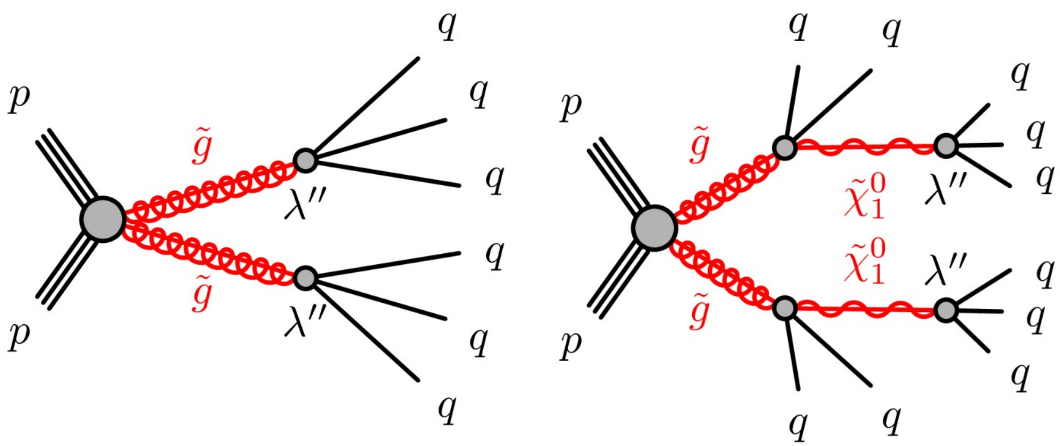
RPV can be at the production vertex and/or at decay vertices



RPV search channels

» Multijets (2x3 jets)
Heavy resonance to eμ, eτ, μτ PLB 723 (2013) 15
4-leptons ATLAS-CONF-2013-036

>> new result to be discussed
(since last ATLAS SUSY seminar on 26th March 2013)

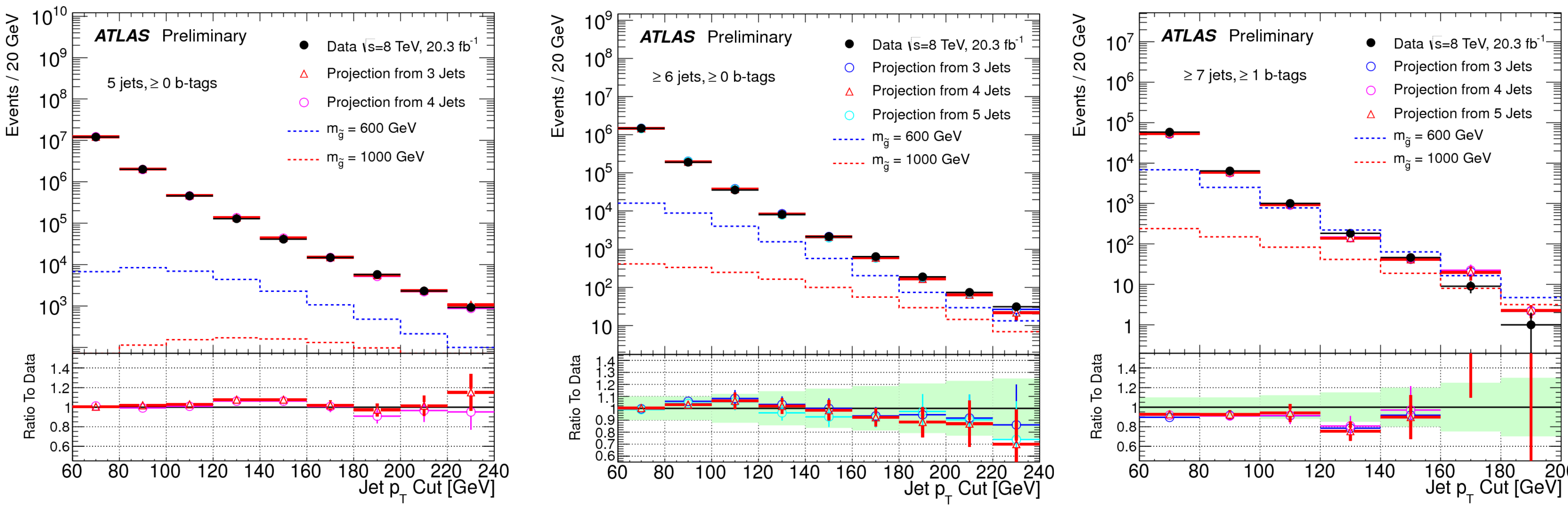


- Consider gluino or neutralino LSP decaying to jets
- Searching for resonances is difficult due to combinatorics
- Search for events with ≥ 6 or 7 high p_T jets
- 0–2 b-tagged jets to estimate BR to heavy flavour quarks

SM multijet background normalised to data in lower jet multiplicity regions

Signal regions optimised for many different models
Jet p_T ≥ 80–220 GeV, Njet ≥ 6–7, Nbjet 0–2

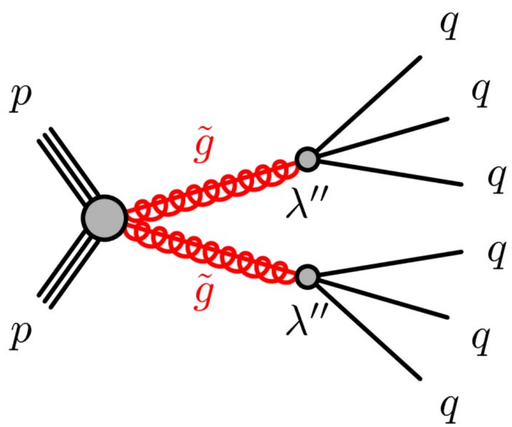
No significant excess seen

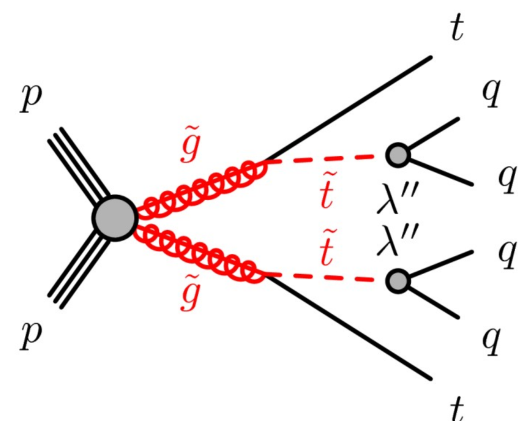


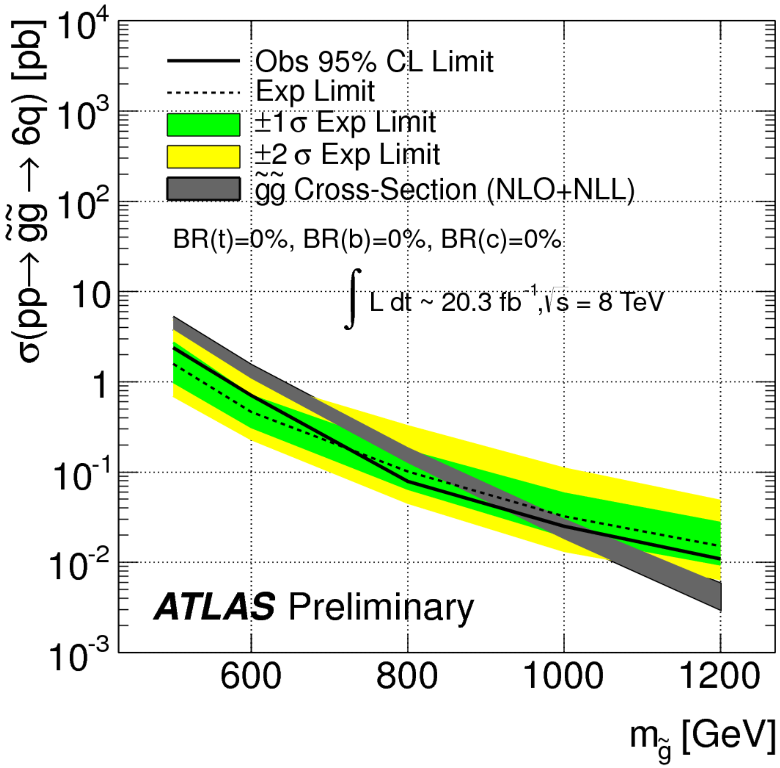
RPV searches

Multijets

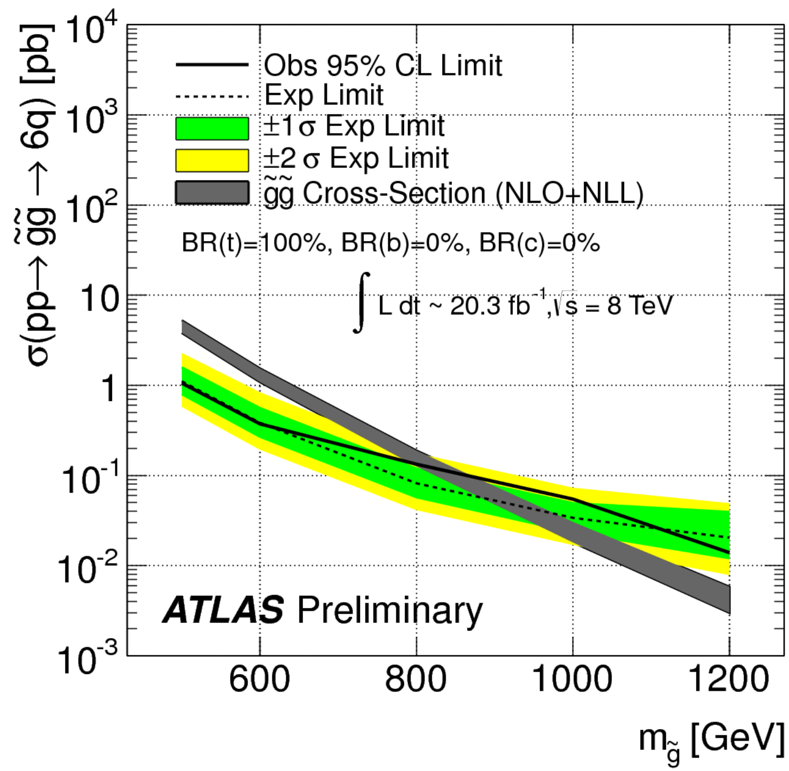
ATLAS-CONF-2013-091







Gluinos excluded up to ~900 GeV for BR(heavy quarks) = 0%

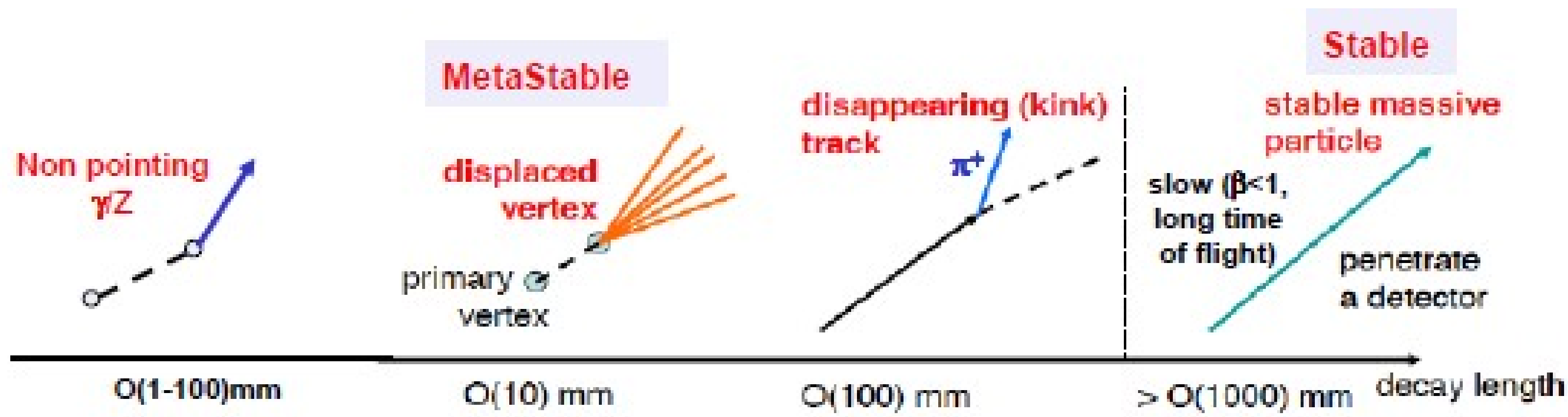


Gluinos excluded up to ~800 GeV for BR(top) = 100%

Recall

RPV also lead to **non-prompt decays** if λ couplings are small

Long-lived SUSY particles can also arise from
- Heavy mediator sparticles e.g. Split SUSY
- Mass degeneracy
- Weak couplings



Look for RPV signatures and long-lived signatures

Cover wide coverage of lifetimes

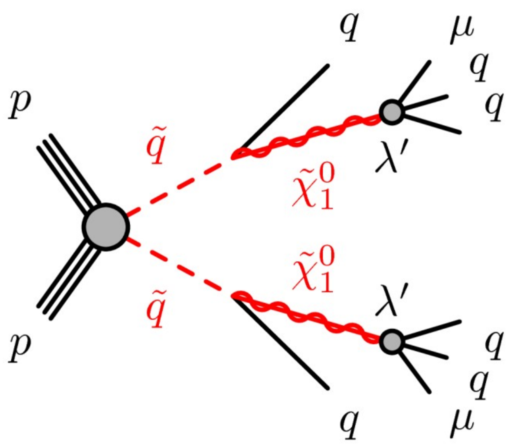
RPV & LL search channels

» Disappearing track
» Stopped gluino
» Long lived slepton
» Displaced vertex
Non-pointing photon PRD 88, 012001 (2013)

>> new result to be discussed
(since last ATLAS SUSY seminar on 26th March 2013)

μ + displaced vtx.

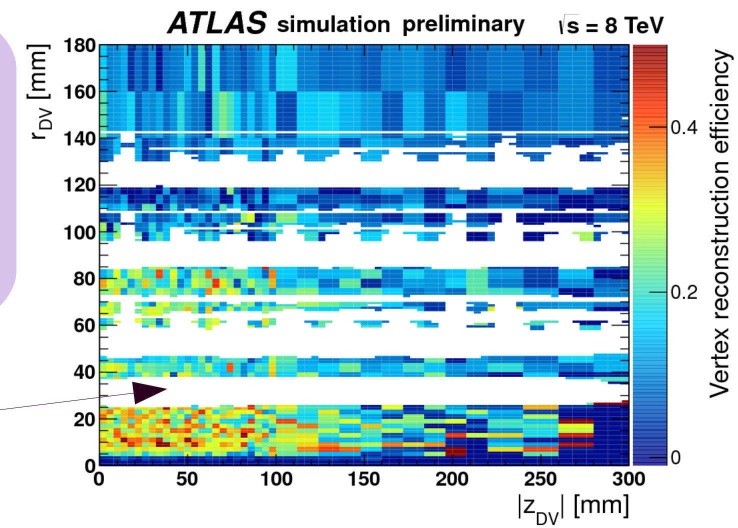
ATLAS-CONF-2013-092



Consider the LSP to be long-lived, decaying to a muon and jets
Dedicated reconstruction of tracks and vertices

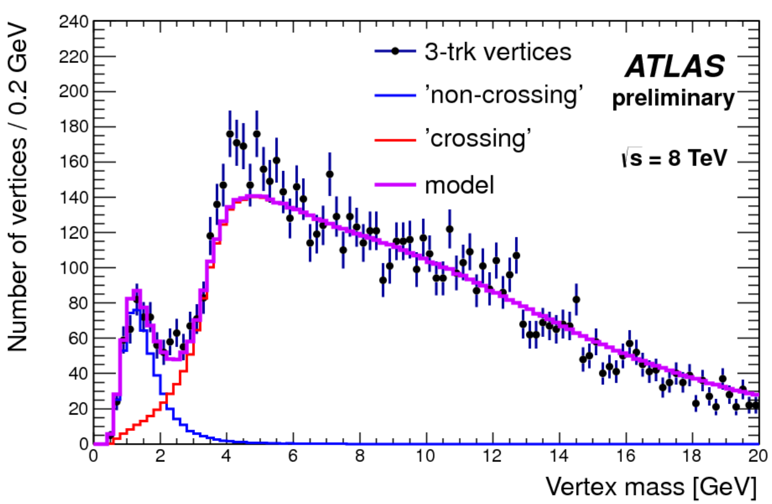
Trigger with one high-p_T muon

Search for a displaced vertex (DV)
within r < 180 mm and |z| < 300 mm
m_{DV} > 10 GeV and > 4 tracks



To suppress hadronic interactions, veto vertices from regions of high density

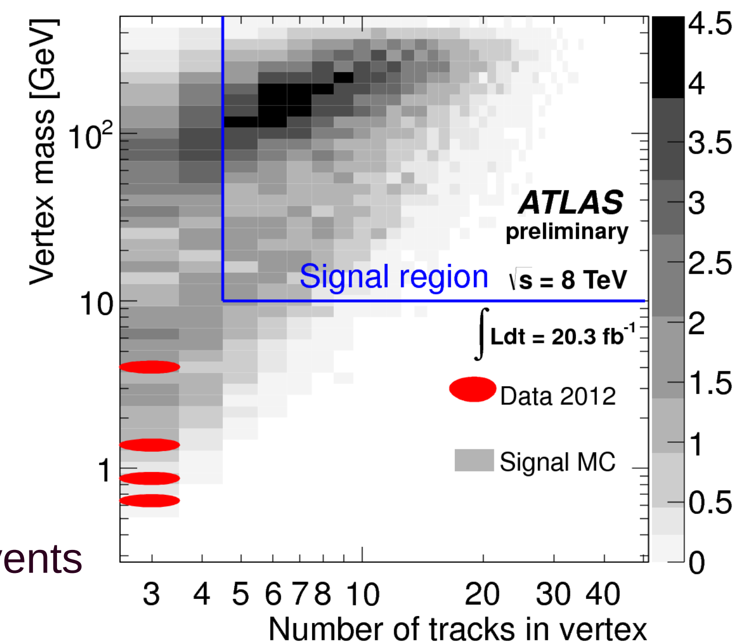
Dominating background from hadronic interactions with gas molecules (outside beampipe)
Usually low mass, but random track crossing can give high mass



Model m_{DV} with jet-triggered events

Random track combination background negligible

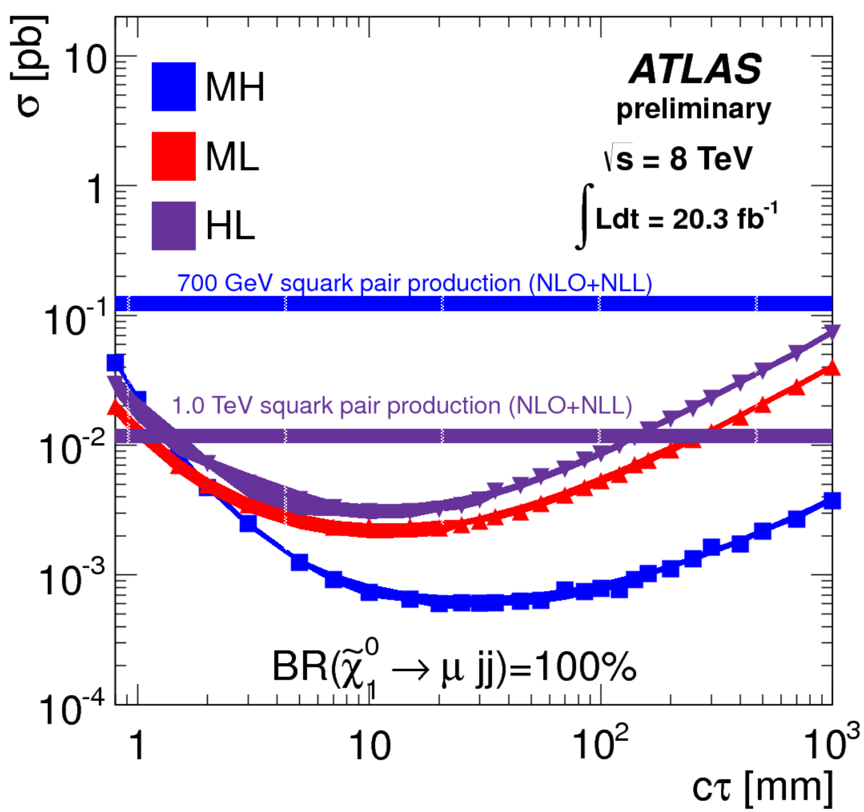
Expected 0.02 ± 0.02 events
Observed 0

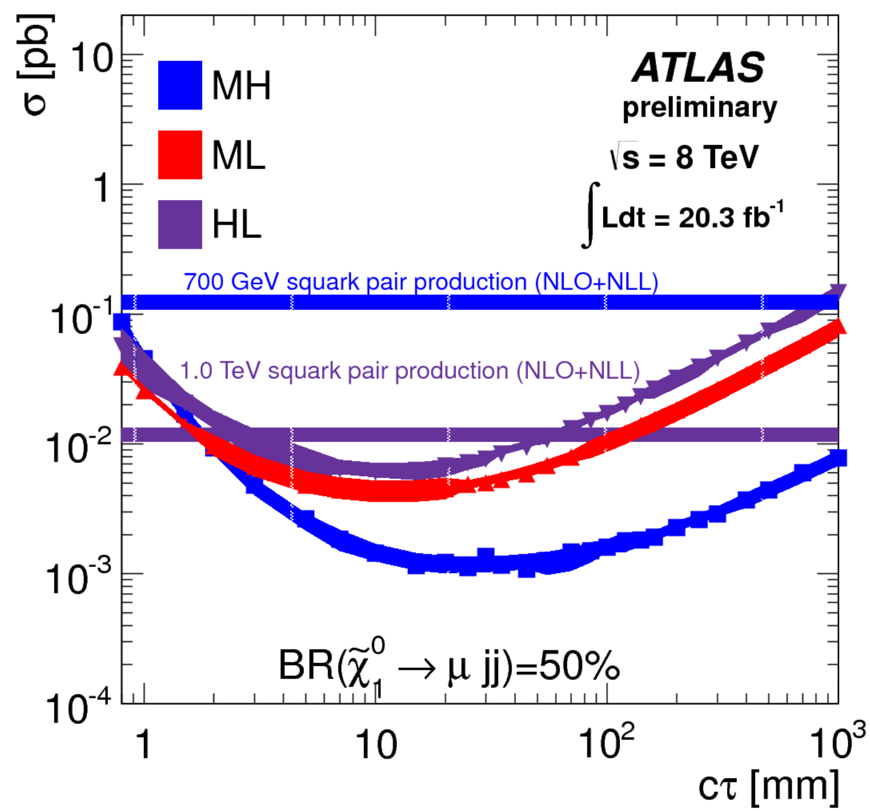


RPV and long-lived searches μ + displaced vtx. *ATLAS-CONF-2013-092*

Use efficiency maps to set limits on range of cτ

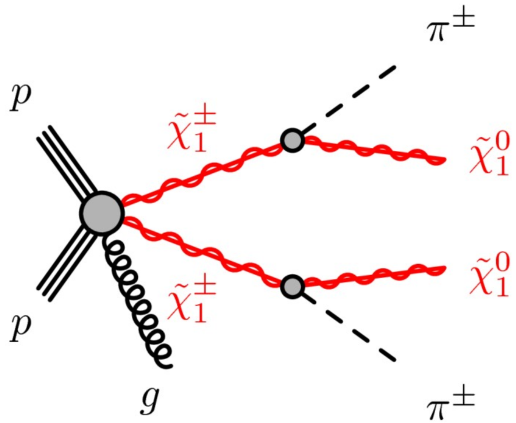
	Sample	$m_{\tilde{q}}$ [GeV]	$m_{\tilde{\chi}_1^0}$ [GeV]	σ [fb]	$\langle\gamma\beta\rangle_{\tilde{\chi}_1^0}$	$c\tau_{MC}$ [mm]	λ'_{211}
Medium-Heavy	MH	700	494	124.3	1.0	175	0.2×10^{-5}
Medium-Light	ML	700	108	124.3	3.1	101	1.5×10^{-5}
Heavy-Light	HL	1000	108	11.9	5.5	220	20.0×10^{-5}





1 TeV squarks excluded for 1.5 < cτ < 156 mm
100% BR to 108 GeV LSP

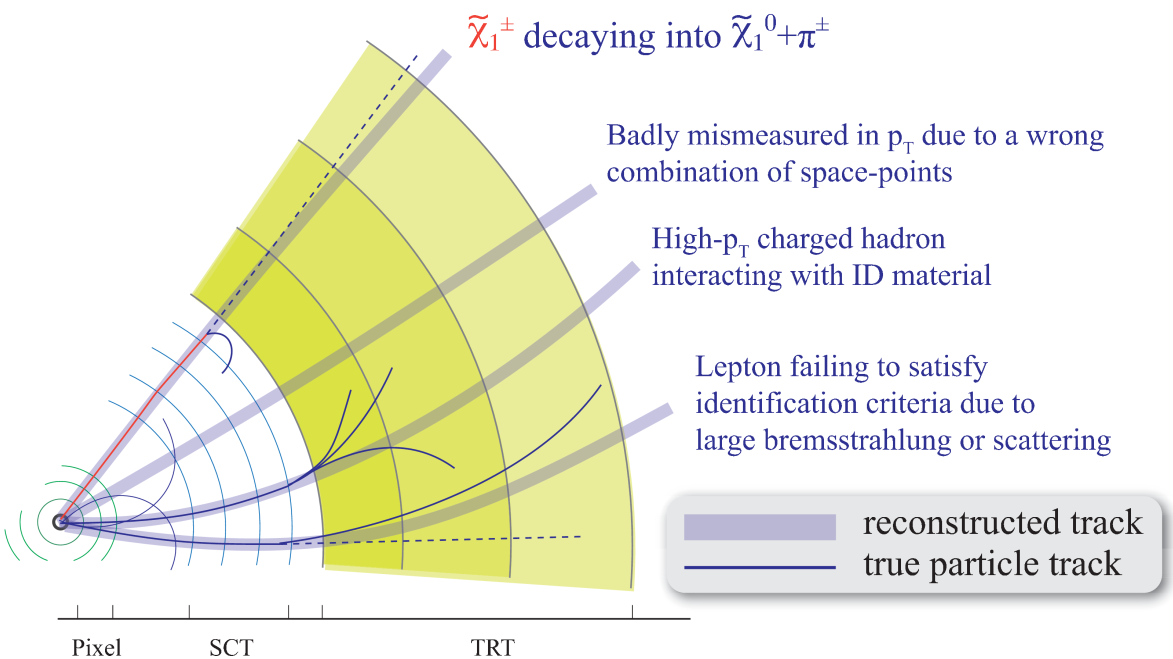
RPV and long-lived searches   Disapp. trk + E_T^{miss} *ATLAS-CONF-2013-069*

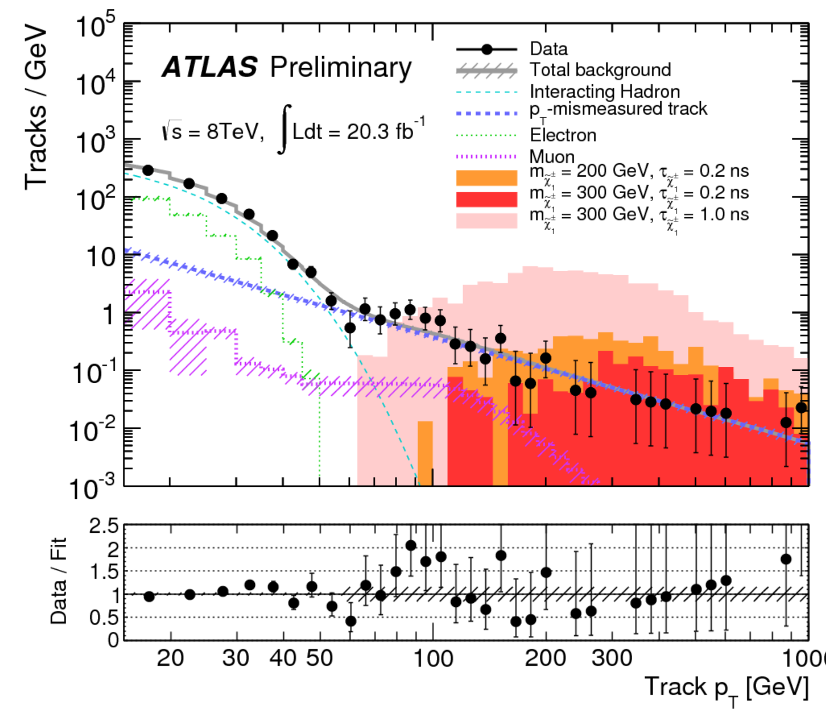


Many SUSY model e.g. AMSB have almost mass degenerate chargino and LSP → long-lived chargino

Chargino travels into detector before decaying to soft pion + LSP → disappearing track

Trigger on ISR jet
Look for isolated, high p_T tracks with < 5 TRT hits





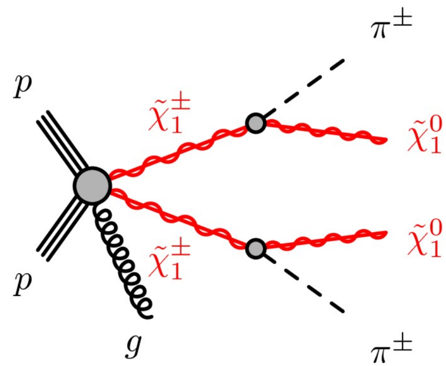
Background track p_T shape taken from data
Signal + background template fit for candidate tracks

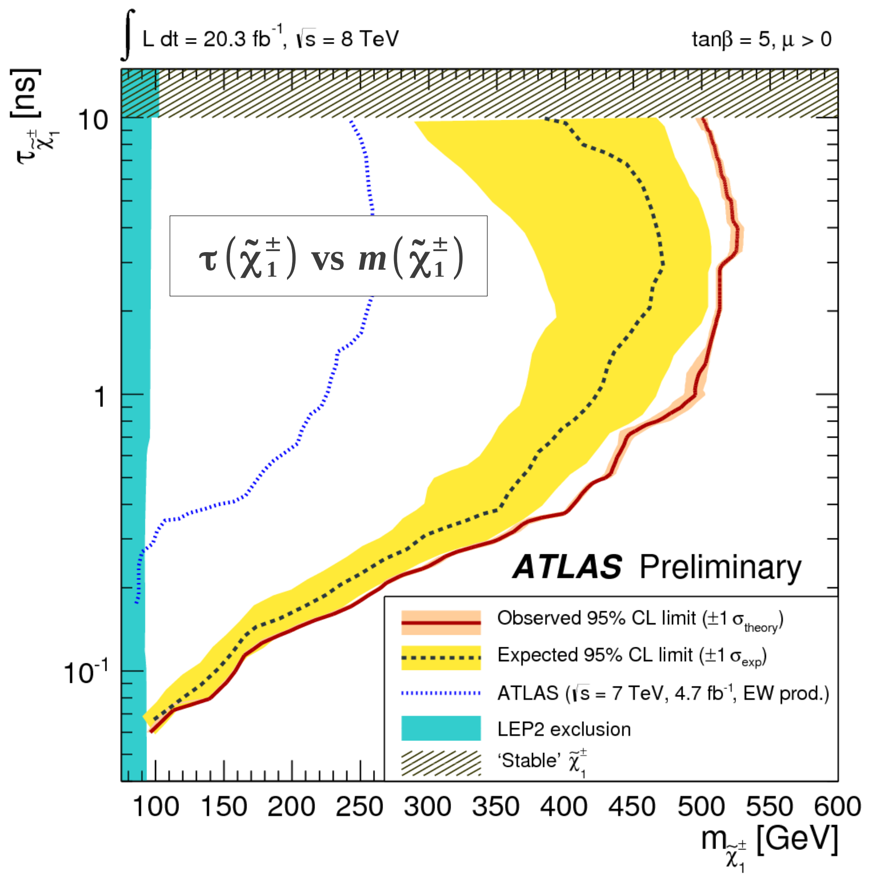
No significant excess observed

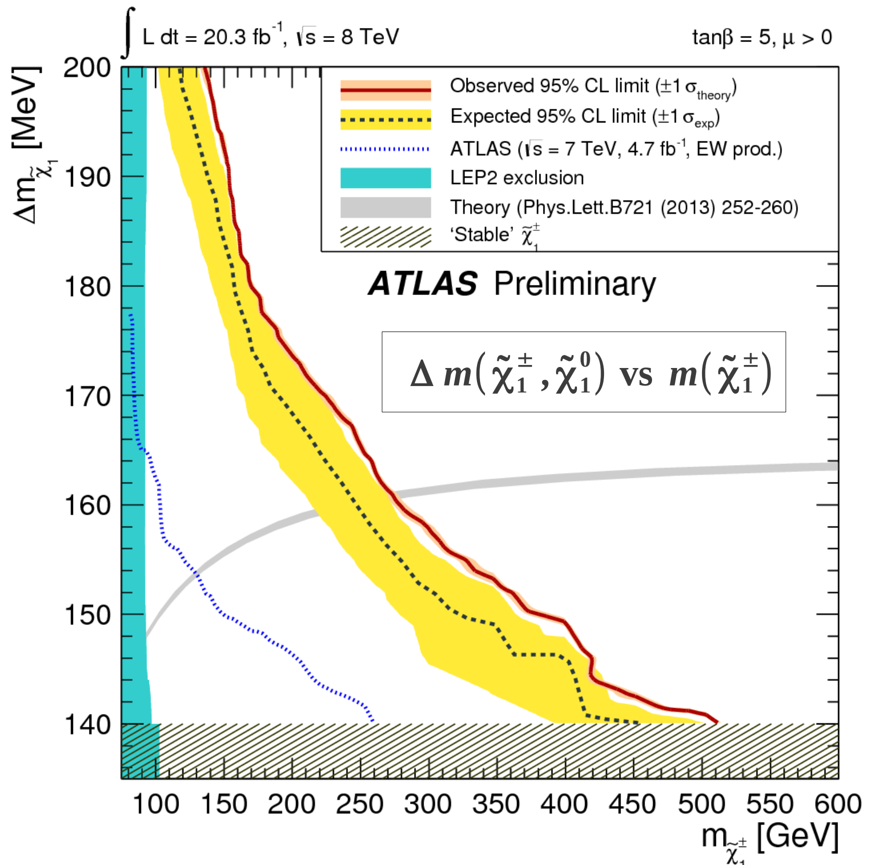
Disapp. trk + E_T^{miss}

ATLAS-CONF-2013-069

AMSB model with Δm ~ 160 MeV.





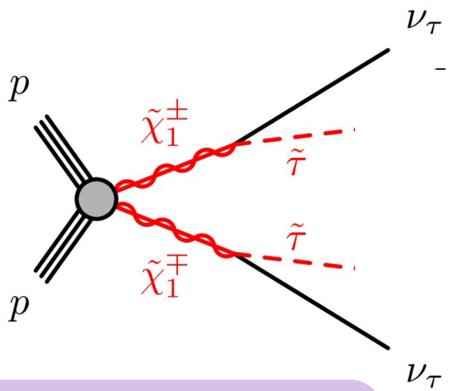


For τ ~ 0.2 ns, charginos excluded up to 270 GeV
For τ ~ 1–10 ns, chargino excluded up to 520 GeV

RPV and long-lived searches

Long lived $\tilde{l}$

ATLAS-CONF-2013-058



Many SUSY model e.g. GMSB have long-lived stau NLSP

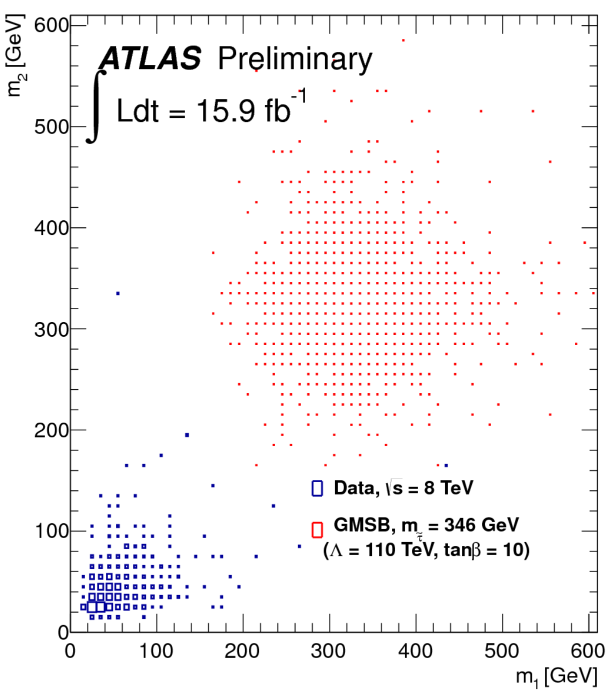
If cτ > few metres, LLP looks like a heavy muon
- Low β
- Large dE/dx
- 2 LLP per event

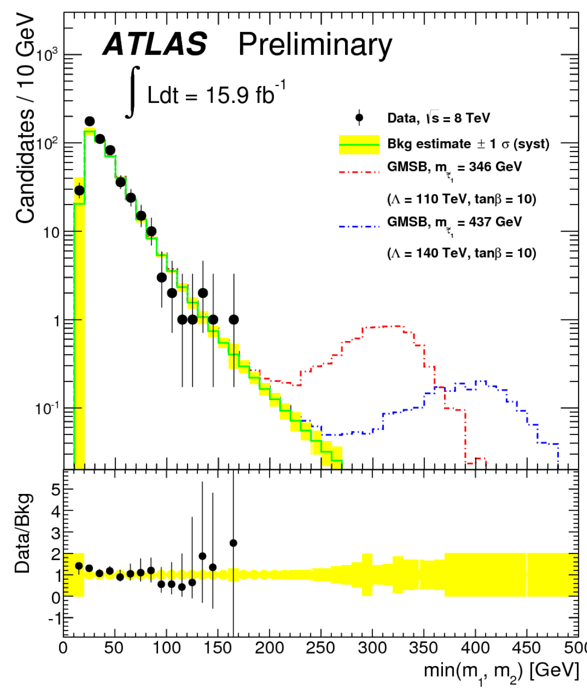
$$m = \frac{p}{\beta\gamma}$$

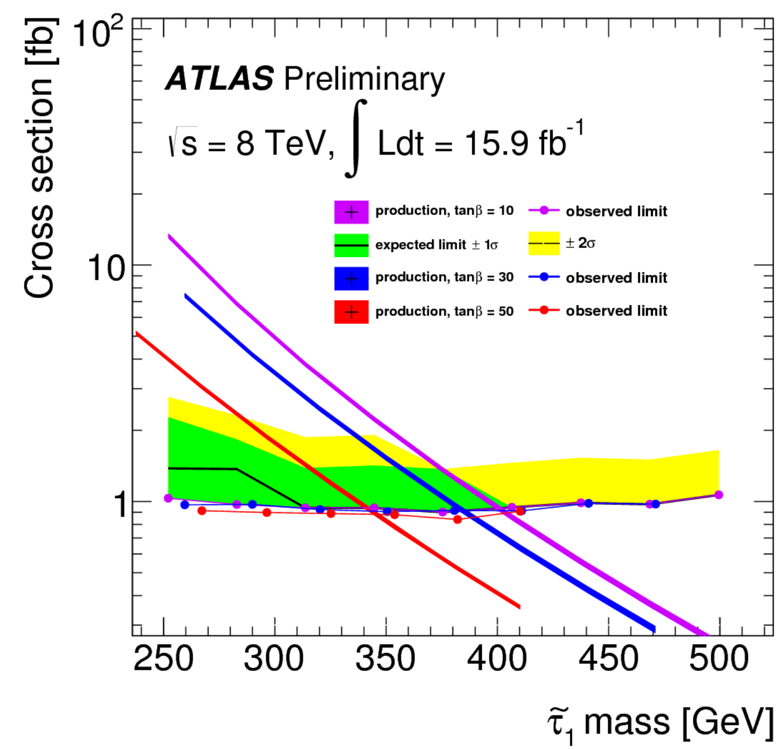
- p → from track
- $\beta\gamma$ → from pixel (dE/dx) + calorimeter + muon detector (Time of Flight)

Signal region
2 high p_T muons
$0.2 < \beta < 0.95$

Background dominated by high p_T muons with mis-measured β
Taken from data





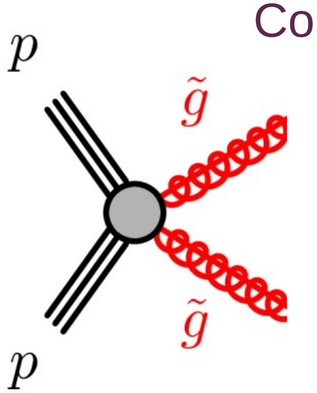


Sensitivity to stau mass depends on GMSB model parameters

No significant excess observed

Stopped $\tilde{g}$ R-hadrons

ATLAS-CONF-2013-057

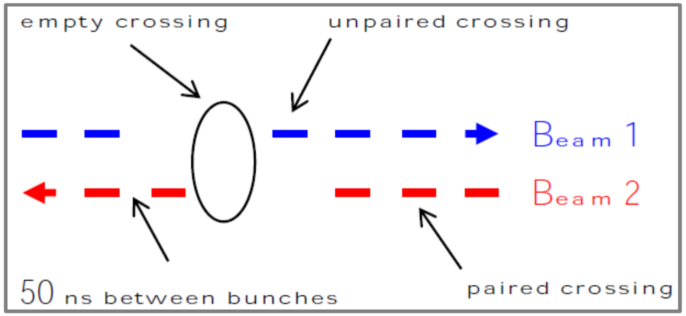


Consider gluino with long lifetime that forms R-hadrons with SM vacuum quarks

R-hadron travels through detector
Gets stuck in detector via dE/dx energy loss and nuclear scattering
Can decay at a much later time!

Also relevent for Split SUSY with a high mass intermediate squark

Use empty bunches in LHC beams to look for hadronic activity

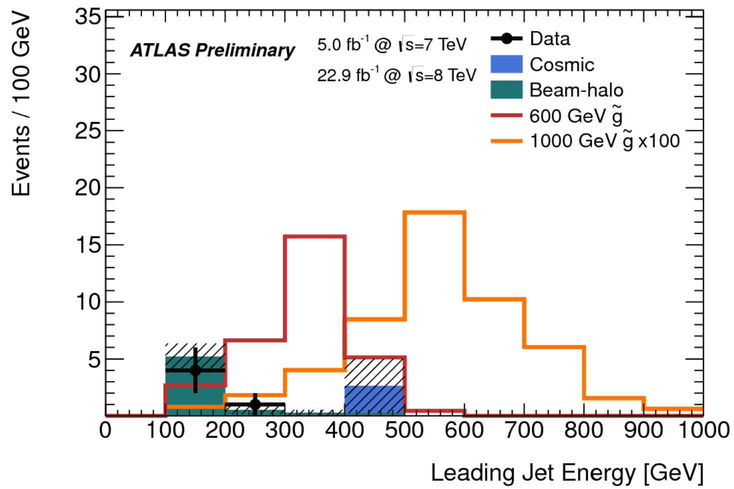


Detection efficiency depends on - stopping fraction
- probability to decay in empty bunch
- reconstruction efficiency

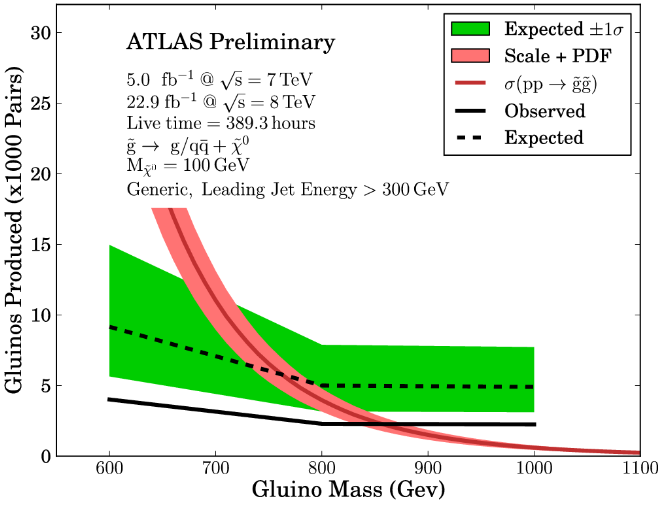
Signal region
Jet + E_T^{miss} empty bunch trigger
Jet E > 100 or 300 GeV
Veto muon activity

Cosmic muon background from low-luminosity run period

Beam halo background from unpaired crossings

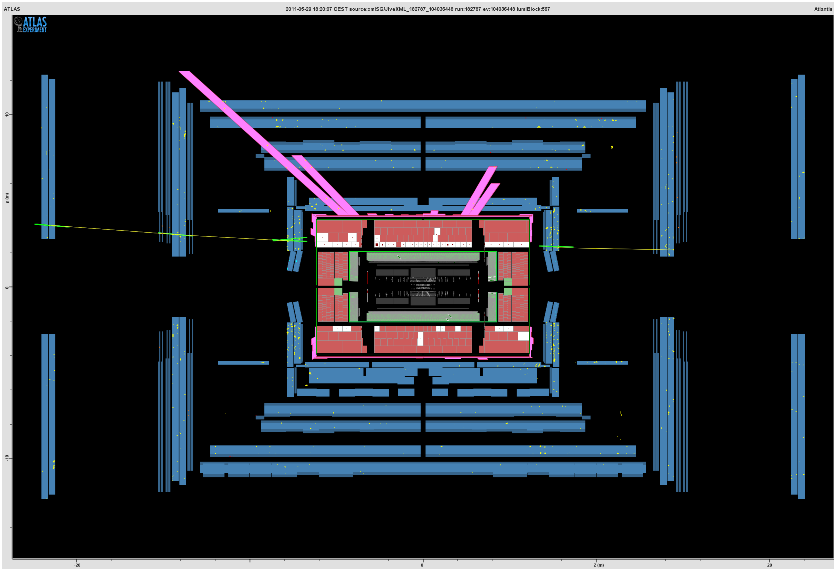


No significant excess seen

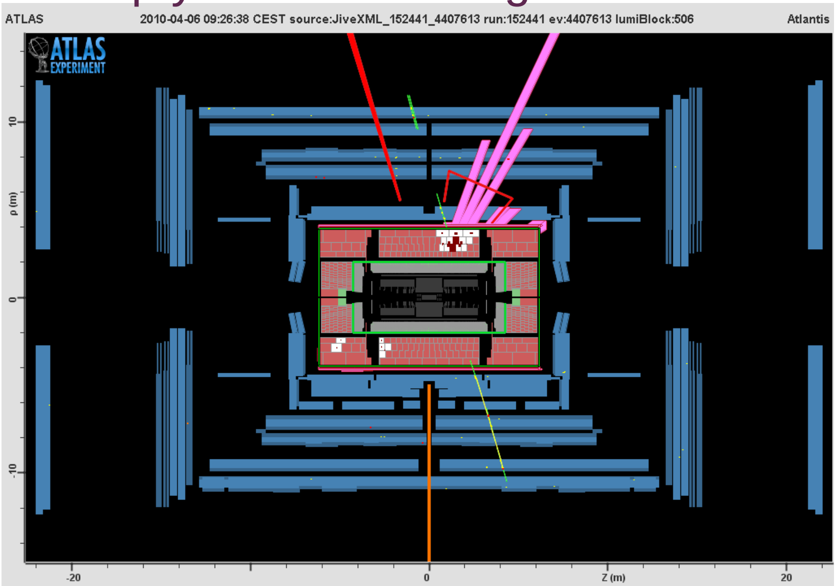


Stopped gluino R-hadrons excluded up to 832 GeV
for 10 μs < τ(gl~) < 1000 s and 100 GeV LSP
Longest lifetime excluded: 2 years!

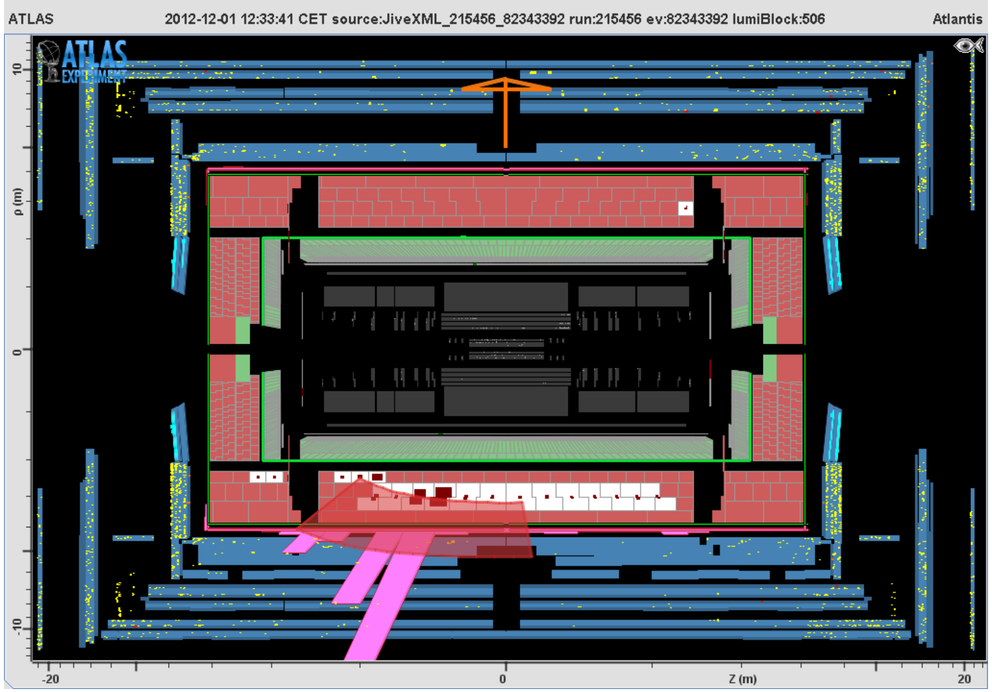
A beam-halo candidate event during an unpaired bunch crossing in data.



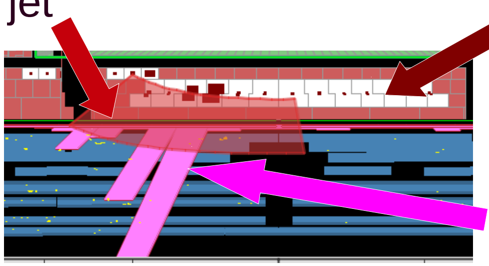
A cosmic ray muon candidate event during an empty bunch crossing in data



A candidate event display from 2011 data passing all selections



jet



energy deposits in TileCal cells fraction of red area indicates the amount of energy in the cell

histogram of total energy in projective TileCal towers

Muon segments are drawn but not reconstructed

Grand Summary of ATLAS SUSY Search Results

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: SUSY 2013

ATLAS Preliminary

$\int \mathcal{L}\,dt = (4.6 - 22.9)\ \text{fb}^{-1}$ $\sqrt{s}$ = 7, 8 TeV

Increasing σ

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\,dt[\text{fb}^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	any $m(\tilde{q})$	1308.1841
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}^0_1$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 740 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}^0_1$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}^0_1)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}^\pm_1\to qqW^\pm\tilde{\chi}^0_1$	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.18 TeV	$m(\tilde{\chi}^0_1)$<200 GeV, $m(\tilde{\chi}^\pm)=0.5(m(\tilde{\chi}^0_1)+m(\tilde{g}))$	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}^0_1$	2 e,μ	0-3 jets	-	20.3	$\tilde{g}$ 1.12 TeV	$m(\tilde{\chi}^0_1)$=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e,μ	2-4 jets	Yes	4.7	$\tilde{g}$ 1.24 TeV	$\tan\beta$<15	1208.4688
	GMSB ($\tilde{\tau}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$ 1.4 TeV	$\tan\beta$>18	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	-	Yes	4.8	$\tilde{g}$ 1.07 TeV	$m(\tilde{\chi}^0_1)$>50 GeV	1209.0753
	GGM (wino NLSP)	1 $e,\mu+\gamma$	-	Yes	4.8	$\tilde{g}$ 619 GeV	$m(\tilde{\chi}^0_1)$>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$ 900 GeV	$m(\tilde{\chi}^0_1)$>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e,μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$ 690 GeV	$m(\tilde{H})$>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale 645 GeV	$m(\tilde{G})>10^{-4}$ eV	ATLAS-CONF-2012-147
3rd gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}^0_1$	0	3 b	Yes	20.1	$\tilde{g}$ 1.2 TeV	$m(\tilde{\chi}^0_1)$<600 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}^0_1$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	$m(\tilde{\chi}^0_1)$ <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}^0_1$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.34 TeV	$m(\tilde{\chi}^0_1)$<400 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}^+_1$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}^0_1)$<300 GeV	ATLAS-CONF-2013-061
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}^0_1$	0	2 b	Yes	20.1	$\tilde{b}_1$ 100-620 GeV	$m(\tilde{\chi}^0_1)$<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}^\pm_1$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$ 275-430 GeV	$m(\tilde{\chi}^\pm_1)=2\,m(\tilde{\chi}^0_1)$	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}^\pm_1$	1-2 e,μ	1-2 b	Yes	4.7	$\tilde{t}_1$ 110-167 GeV	$m(\tilde{\chi}^0_1)$=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}^0_1$	2 e,μ	0-2 jets	Yes	20.3	$\tilde{t}_1$ 130-220 GeV	$m(\tilde{\chi}^0_1)=m(\tilde{t}_1)-m(W)$-50 GeV, $m(\tilde{t}_1)<<m(\tilde{\chi}^\pm_1)$	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}^0_1$	2 e,μ	2 jets	Yes	20.3	$\tilde{t}_1$ 225-525 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	ATLAS-CONF-2013-065
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}^\pm_1$	0	2 b	Yes	20.1	$\tilde{t}_1$ 150-580 GeV	$m(\tilde{\chi}^0_1)$<200 GeV, $m(\tilde{\chi}^\pm_1)-m(\tilde{\chi}^0_1)$=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}^0_1$	1 e,μ	1 b	Yes	20.7	$\tilde{t}_1$ 200-610 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}^0_1$	0	2 b	Yes	20.5	$\tilde{t}_1$ 320-660 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}^0_1$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$ 90-200 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}^0_1)$<85 GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_1$ 500 GeV	$m(\tilde{\chi}^0_1)$>150 GeV	ATLAS-CONF-2013-025
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1+Z$	3 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_2$ 271-520 GeV	$m(\tilde{t}_1)=m(\tilde{\chi}^0_1)$+180 GeV	ATLAS-CONF-2013-025
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to\ell\tilde{\chi}^0_1$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$ 85-315 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	ATLAS-CONF-2013-049
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}^\pm_1$ 125-450 GeV	$m(\tilde{\chi}^0_1)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}^\pm_1)+m(\tilde{\chi}^0_1))$	ATLAS-CONF-2013-049
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.7	$\tilde{\chi}^\pm_1$ 180-330 GeV	$m(\tilde{\chi}^0_1)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}^\pm_1)+m(\tilde{\chi}^0_1))$	ATLAS-CONF-2013-028
	$\tilde{\chi}^\pm_1\tilde{\chi}^0_2\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.7	$\tilde{\chi}^\pm_1, \tilde{\chi}^0_2$ 600 GeV	$m(\tilde{\chi}^\pm_1)=m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}^\pm_1)+m(\tilde{\chi}^0_1))$	ATLAS-CONF-2013-035
	$\tilde{\chi}^\pm_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1 Z\tilde{\chi}^0_1$	3 e,μ	0	Yes	20.7	$\tilde{\chi}^\pm_1, \tilde{\chi}^0_2$ 315 GeV	$m(\tilde{\chi}^\pm_1)=m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, sleptons decoupled	ATLAS-CONF-2013-035
	$\tilde{\chi}^\pm_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1 h\tilde{\chi}^0_1$	1 e,μ	2 b	Yes	20.3	$\tilde{\chi}^\pm_1, \tilde{\chi}^0_2$ 285 GeV	$m(\tilde{\chi}^\pm_1)=m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, sleptons decoupled	ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}^+_1\tilde{\chi}^-_1$ prod., long-lived $\tilde{\chi}^\pm_1$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}^\pm_1$ 270 GeV	$m(\tilde{\chi}^\pm_1)-m(\tilde{\chi}^0_1)$=160 MeV, $\tau(\tilde{\chi}^\pm_1)$=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$ 832 GeV	$m(\tilde{\chi}^0_1)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}^0_1\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}^0_1$ 475 GeV	10<$\tan\beta$<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}^0_1\to\gamma\tilde{G}$, long-lived $\tilde{\chi}^0_1$	2 γ	-	Yes	4.7	$\tilde{\chi}^0_1$ 230 GeV	0.4<$\tau(\tilde{\chi}^0_1)$<2 ns	1304.6310
	$\tilde{q}\tilde{q}, \tilde{\chi}^0_1\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$ 1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, $m(\tilde{\chi}^0_1)$=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\to e+\mu$	2 e,μ	-	-	4.6	$\tilde{\nu}_\tau$ 1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\to e(\mu)+\tau$	1 $e,\mu+\tau$	-	-	4.6	$\tilde{\nu}_\tau$ 1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	1 e,μ	7 jets	Yes	4.7	$\tilde{q}, \tilde{g}$ 1.2 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	ATLAS-CONF-2012-140
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to W\tilde{\chi}^0_1, \tilde{\chi}^0_1\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.7	$\tilde{\chi}^\pm_1$ 760 GeV	$m(\tilde{\chi}^0_1)$>300 GeV, λ_{121}>0	ATLAS-CONF-2013-036
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to W\tilde{\chi}^0_1, \tilde{\chi}^0_1\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e,\mu+\tau$	-	Yes	20.7	$\tilde{\chi}^\pm_1$ 350 GeV	$m(\tilde{\chi}^0_1)$>80 GeV, λ_{133}>0	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$ 880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon 100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e,μ (SS)	1 b	Yes	14.3	sgluon 800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale 704 GeV	$m(\chi)$<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

$\sqrt{s}$ = 7 TeV full data | $\sqrt{s}$ = 8 TeV partial data | $\sqrt{s}$ = 8 TeV full data

10^{-1} 1 Mass scale [TeV]

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

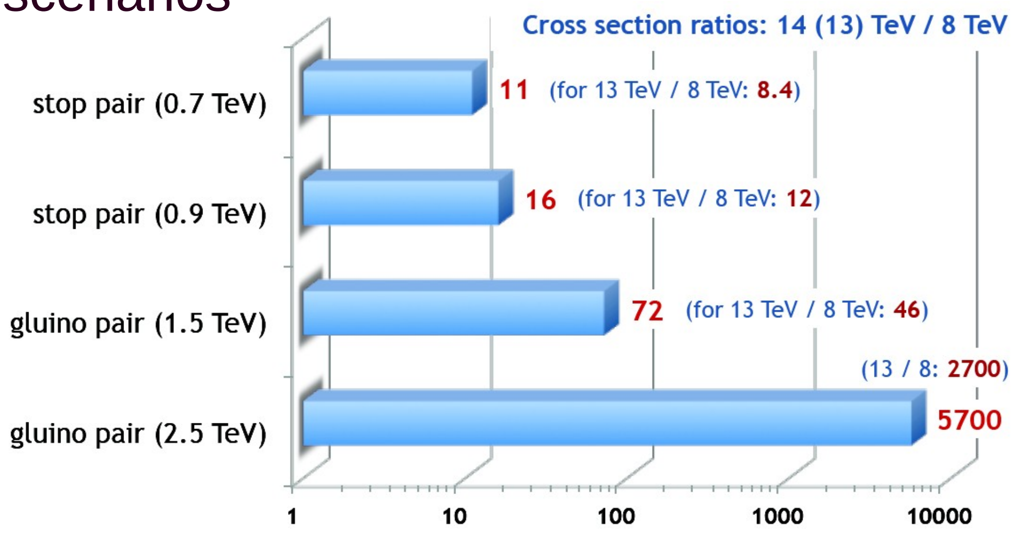
Summary and Outlook

LHC run-1 dataset

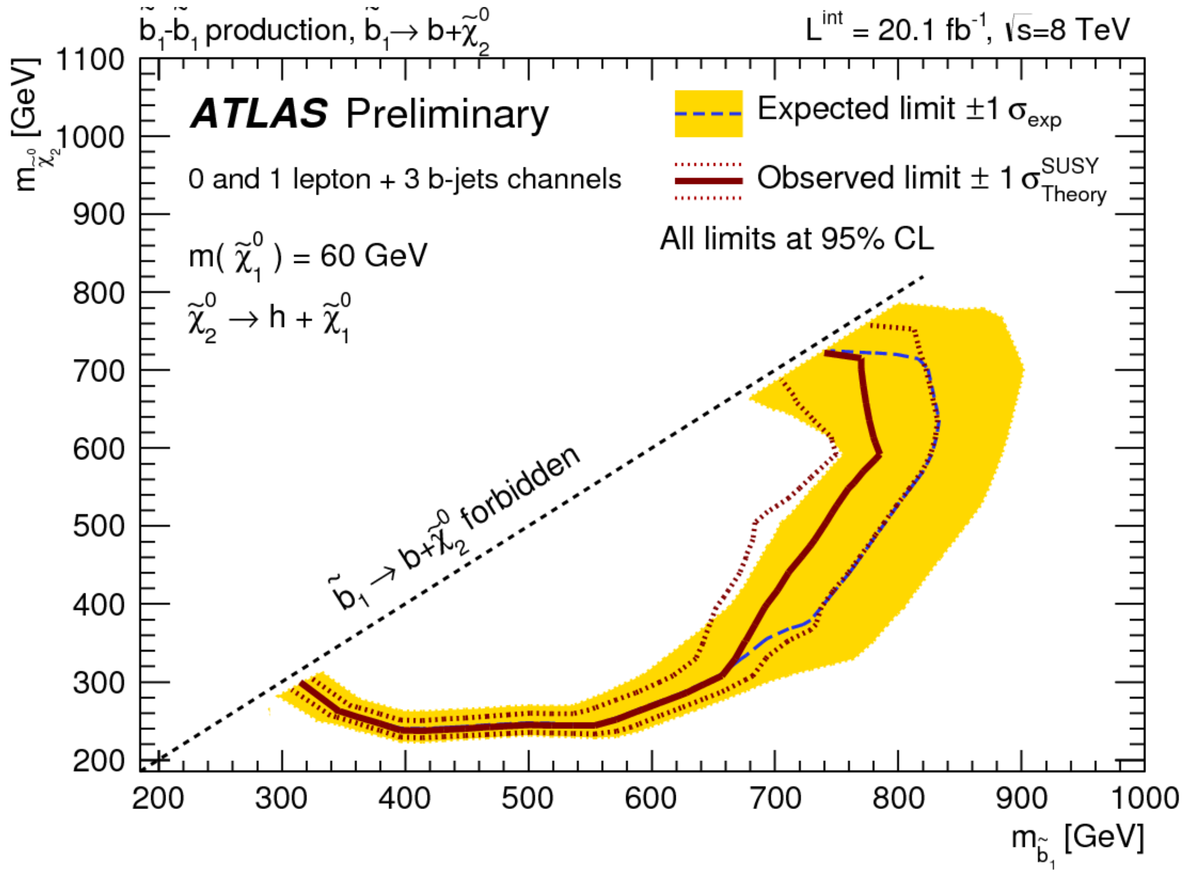
- ★ Broad SUSY programme developed
- ★ Effort to probe maximum area of SUSY parameter space possible
  Using simplified models, pheno models and full models
- ★ Detailed and thorough searches, wide range of signatures covered
  Focus on natural SUSY, strong production, RPV, long-lived SUSY searches
- ★ No sign of SUSY yet

What is next?

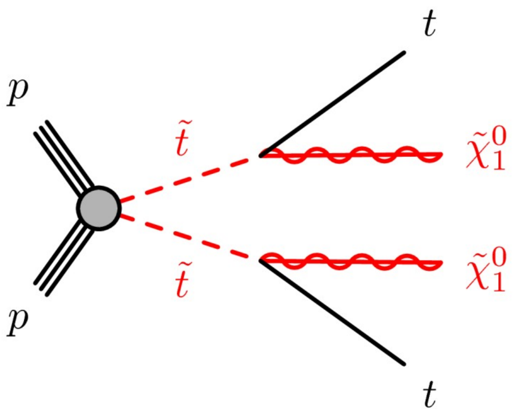
- ★ Increase sensitivity to difficult SUSY scenarios
- ★ Explore new channels,
  probe more parameter space
- ★ **Prepare for $\sqrt{s}$ = 13 TeV**
  LHC run-2 in 2015
  Increased sensitivity
  to many SUSY scenarios



Backup



$\tilde{b}_1$-$\tilde{b}_1$ production, $\tilde{b}_1 \rightarrow b+\tilde{\chi}_2^0$
L^{int} = 20.1 fb^{-1}, $\sqrt{s}$=8 TeV
ATLAS Preliminary
0 and 1 lepton + 3 b-jets channels
m($\tilde{\chi}_1^0$) = 60 GeV
$\tilde{\chi}_2^0 \rightarrow h + \tilde{\chi}_1^0$
Expected limit $\pm 1\ \sigma_{exp}$
Observed limit $\pm\ 1\ \sigma_{Theory}^{SUSY}$
All limits at 95% CL
$\tilde{b}_1 \rightarrow b+\tilde{\chi}_2^0$ forbidden
$m_{\tilde{\chi}_2^0}$ [GeV]
$m_{\tilde{b}_1}$ [GeV]
200
300
400
500
600
700
800
900
1000
1100



Consider SUSY processes with decays to two leptons + jets + LSP

Signal regions
- 2 leptons
- ≥ 2 jets
- High E_T^{miss}, m_{eff}

Train a BDT using

E_T^{miss}, m_{ll}, $m_{T2}(l_1, l_2, E_T^{miss})$

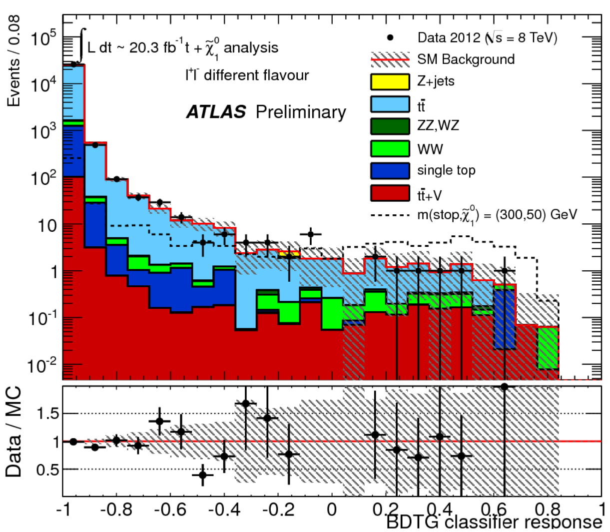
$\Delta\theta_{ll}$, $\Delta\varphi_{ll}$

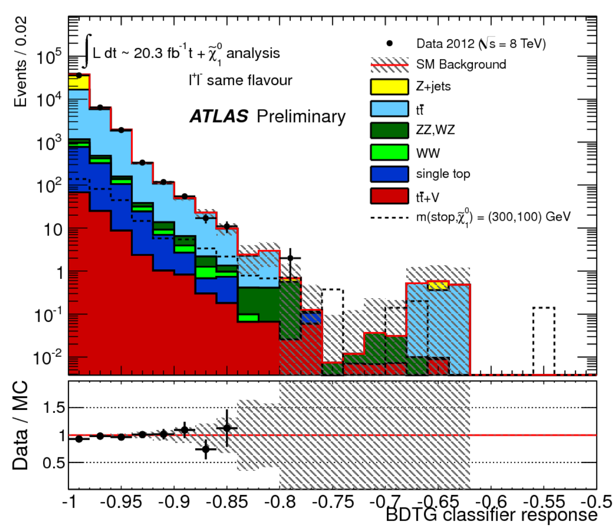
$\Delta\varphi(E_T^{miss}, j_1)$, $\Delta\varphi(l_1, j_1)$

Train Same Flavour (SF) and Different Flavour (DF) seperately

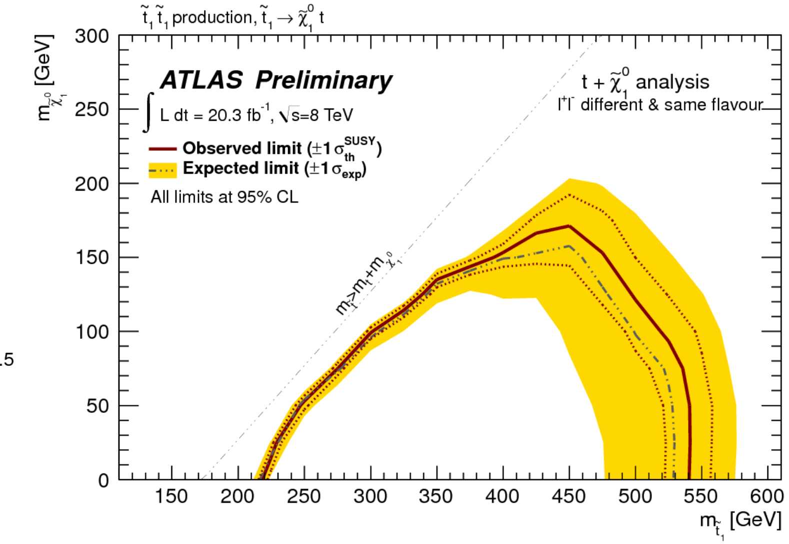
Ttbar normalised to data in low-BDT control regions
Fake lepton background taken from data

4 SF and 7 DF signal regions



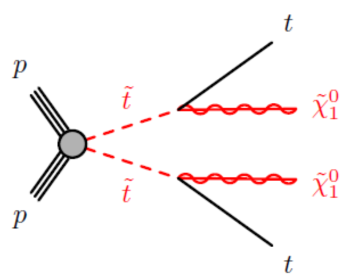


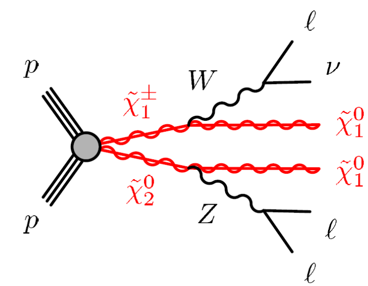
channel	SR_1^{DF}	SR_2^{DF}	SR_3^{DF}	SR_4^{DF}	SR_5^{DF}	SR_6^{DF}	SR_7^{DF}
Observed events	9	3	12	5	3	2	1
Total (constrained) bkg events	4.7 ± 2.0	2.5 ± 1.9	11 ± 5	6.3 ± 2.5	1.0 ± 0.8	$0.33^{+1.1}_{-0.33}$	1.6 ± 1.4



High-energy LHC running in 2015 will significantly increase our sensitivity to many SUSY scenarios
- expect ~x10 for 600 GeV stops, ~x200 for 2 TeV gluinos

With $\sqrt{s}$ = 14 TeV and 300 fb^{-1}, we expect to significantly improve our reach!





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