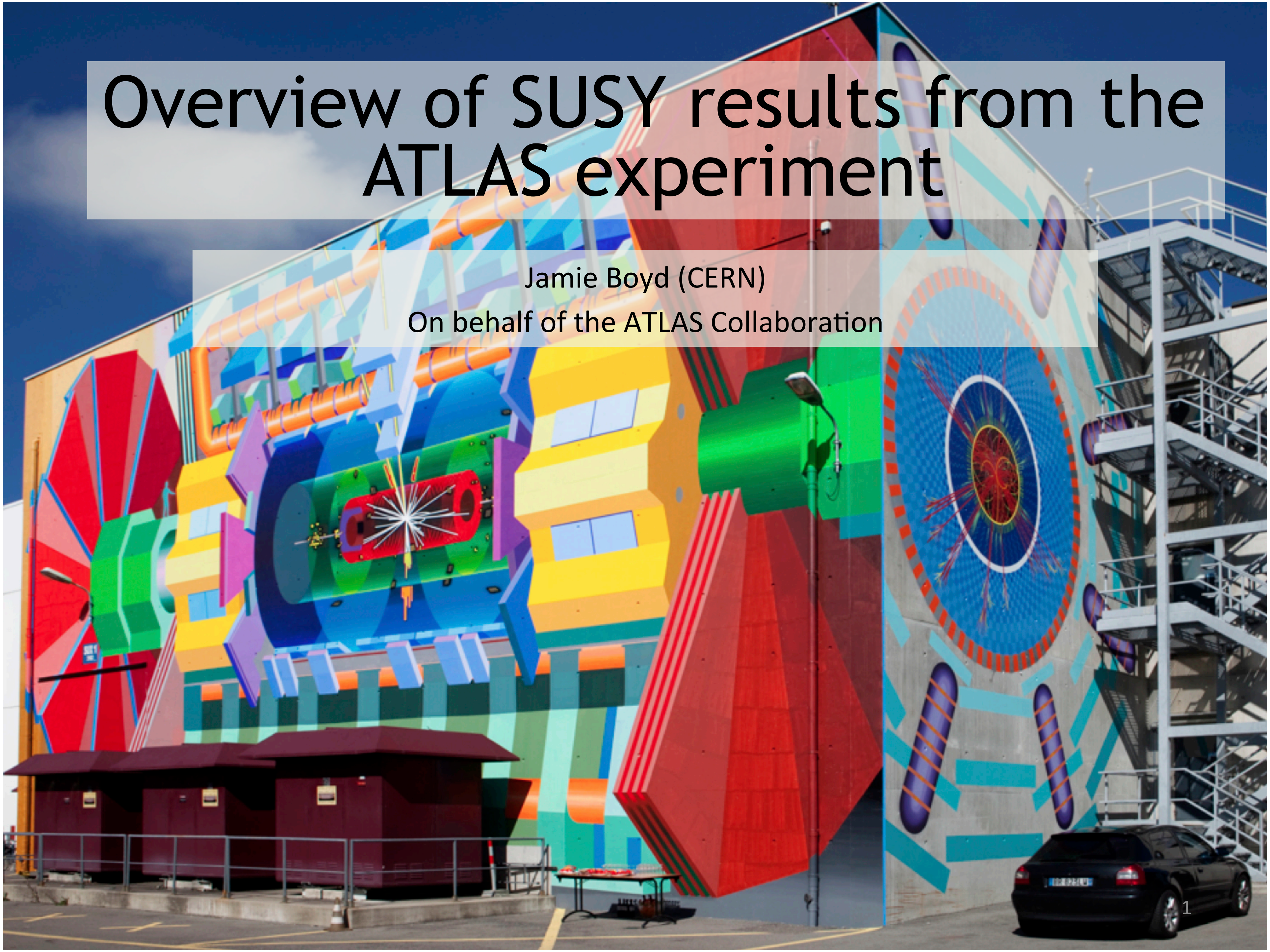
Overview of SUSY results from the ATLAS experiment

Jamie Boyd (CERN)
On behalf of the ATLAS Collaboration



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- Introduction to SUSY searches in ATLAS
- Search results
  - Inclusive searches for strong production
  - 3rd generation searches
  - Electroweak production
  - R-Parity violation and long-lived searches

} **Natural SUSY!** (brace beside "3rd generation searches" and "Electroweak production")

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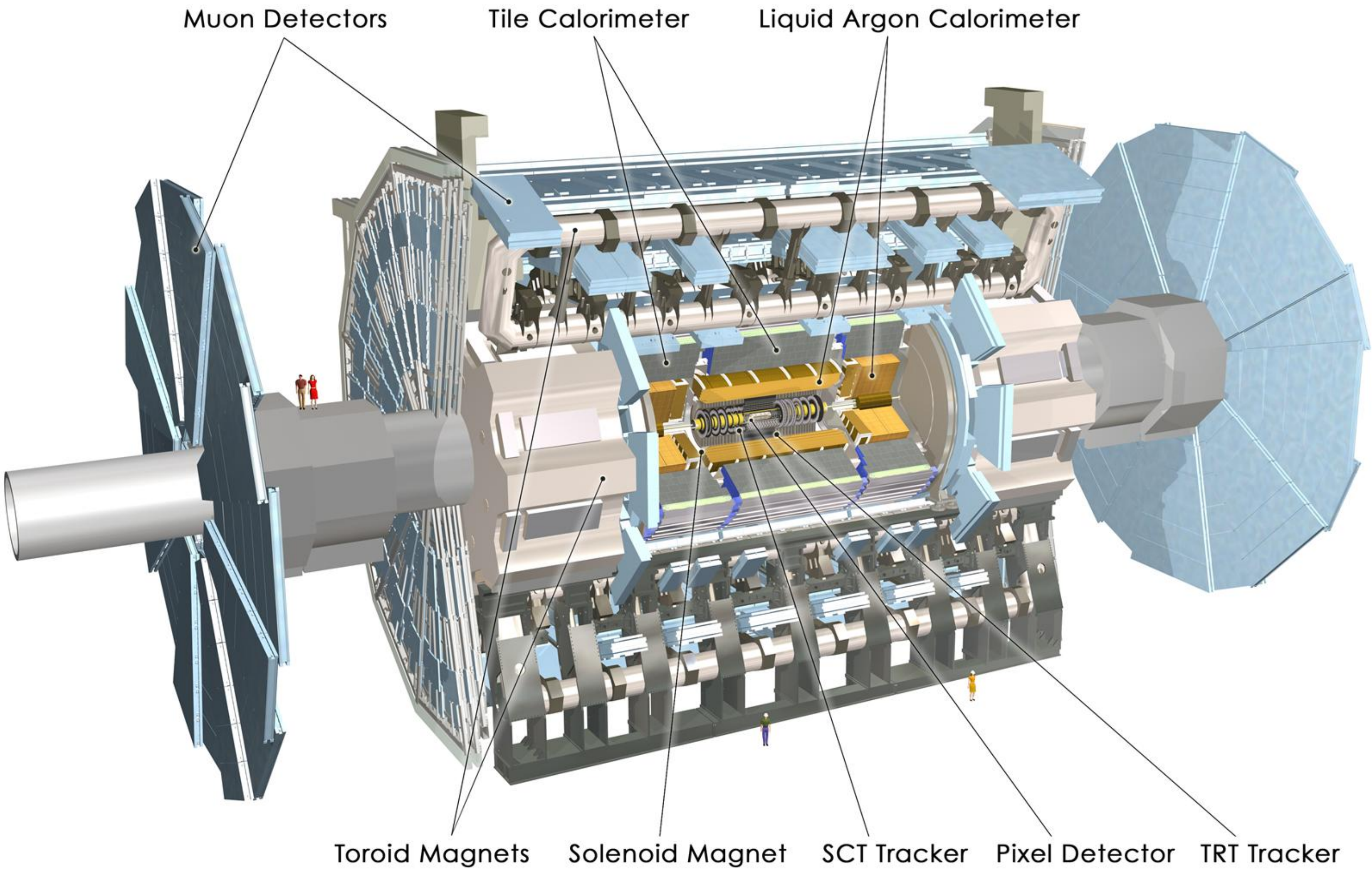
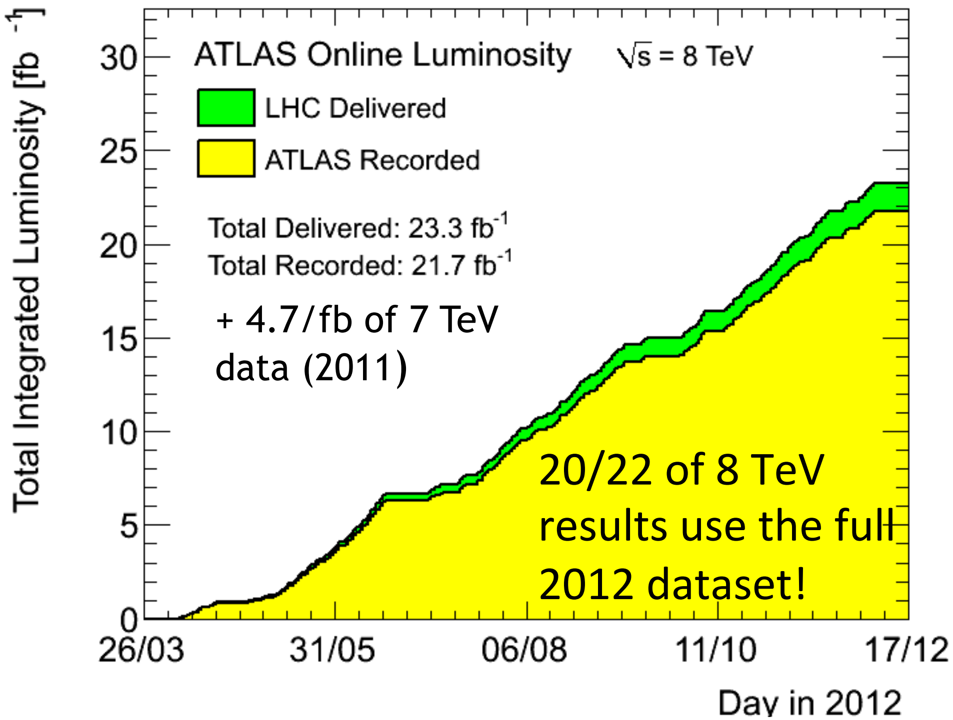
Try to give an comprehensive overview of the ATLAS SUSY programme.
Not an easy task in 40mins! Will have to go (very) fast in some places.
(More details on new results in parallel talks!)

The ATLAS detector



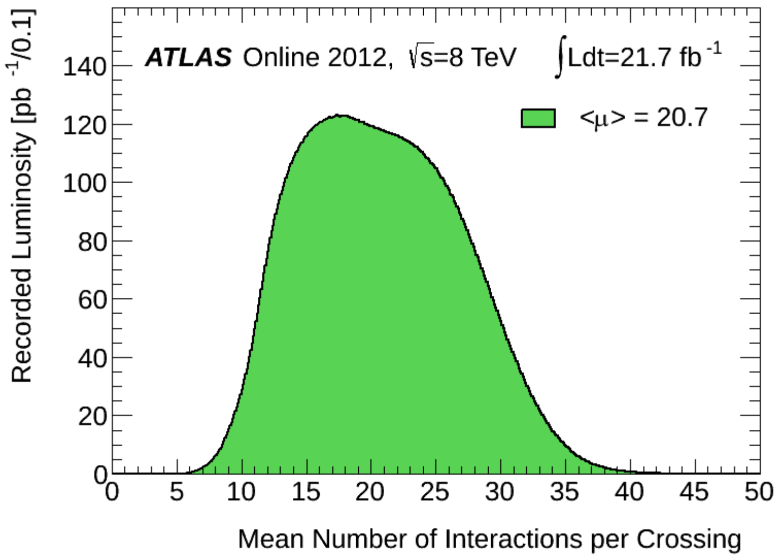
Designed for (amongst other things) detection of SUSY decays =>
excellent performance for electrons, muons, taus, photons, (b-)jets & MET.
Superb detector performance in Run-1.

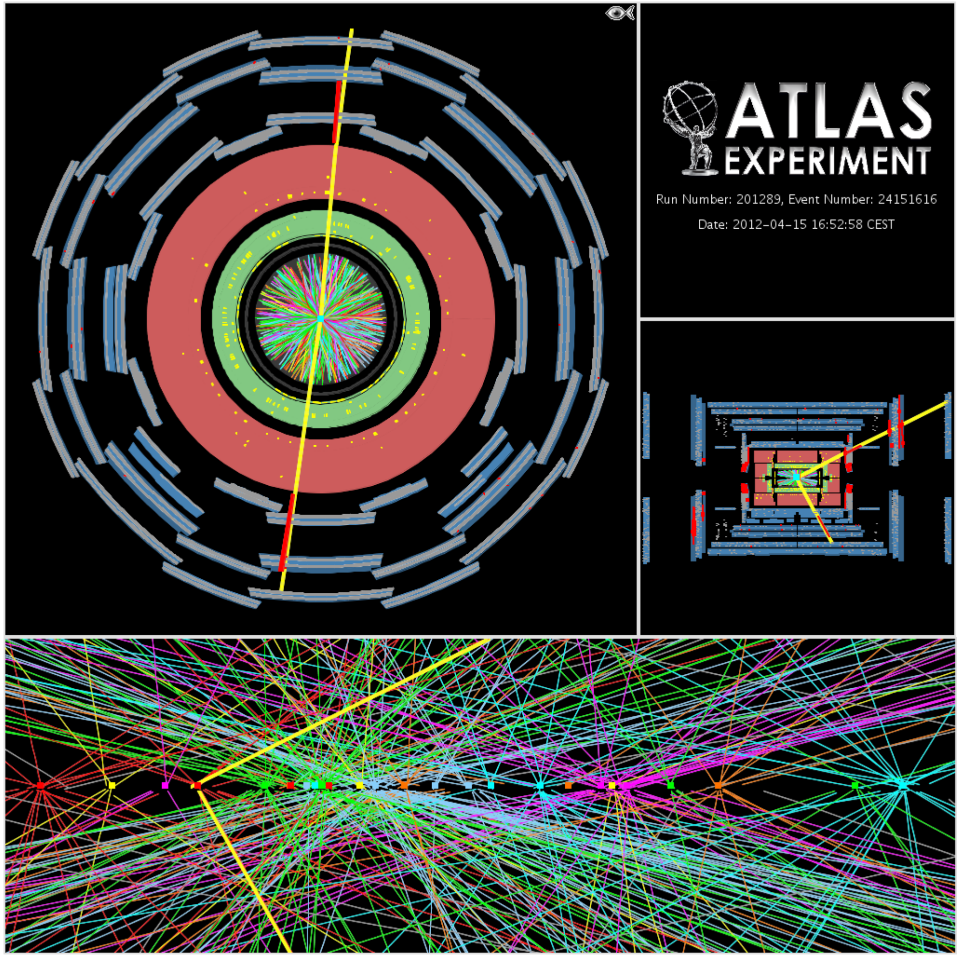
2012 ATLAS dataset – 20/fb of 8 TeV data



+ 4.7/fb of 7 TeV data (2011)

20/22 of 8 TeV results use the full 2012 dataset!





The price to pay for so much luminosity is pileup. Average pileup in 2012 ~20 interactions per bunch crossing.
A huge amount of work undertaken to achieve excellent physics performance in these challenging conditions.

How do we search for SUSY at the LHC

SUSY (more than) duplicates spectrum of particle states wrt. Standard Model

Sparticles decay in (*b*/*c*-)jets, leptons, taus, photons, invisible (MET), …

R-parity conserving (RPC) signatures:

- Sparticles produced in pairs, each decays to (WIMP) LSP, mostly lightest neutralino or gravitino
- One invisible LSP per decay chain → MET

R-parity violating (RPV) signatures:

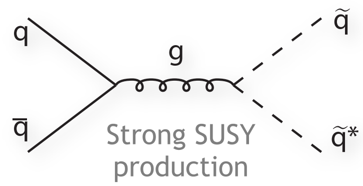
- Resonances or multijets / multileptons: single sparticle production or LSP decay
- Displaced vertices from late LSP decay

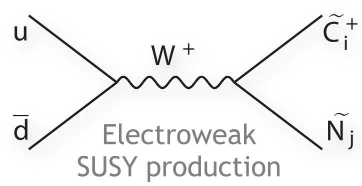
Long-lived particles from:

- Weak couplings (eg, RPV, gravitino)
- High virtuality from heavy mediator sparticles (eq, heavy squarks in split SUSY)
- Mass degeneracy (eg, *m* (chargino) ~ *m* (LSP) in AMSB)

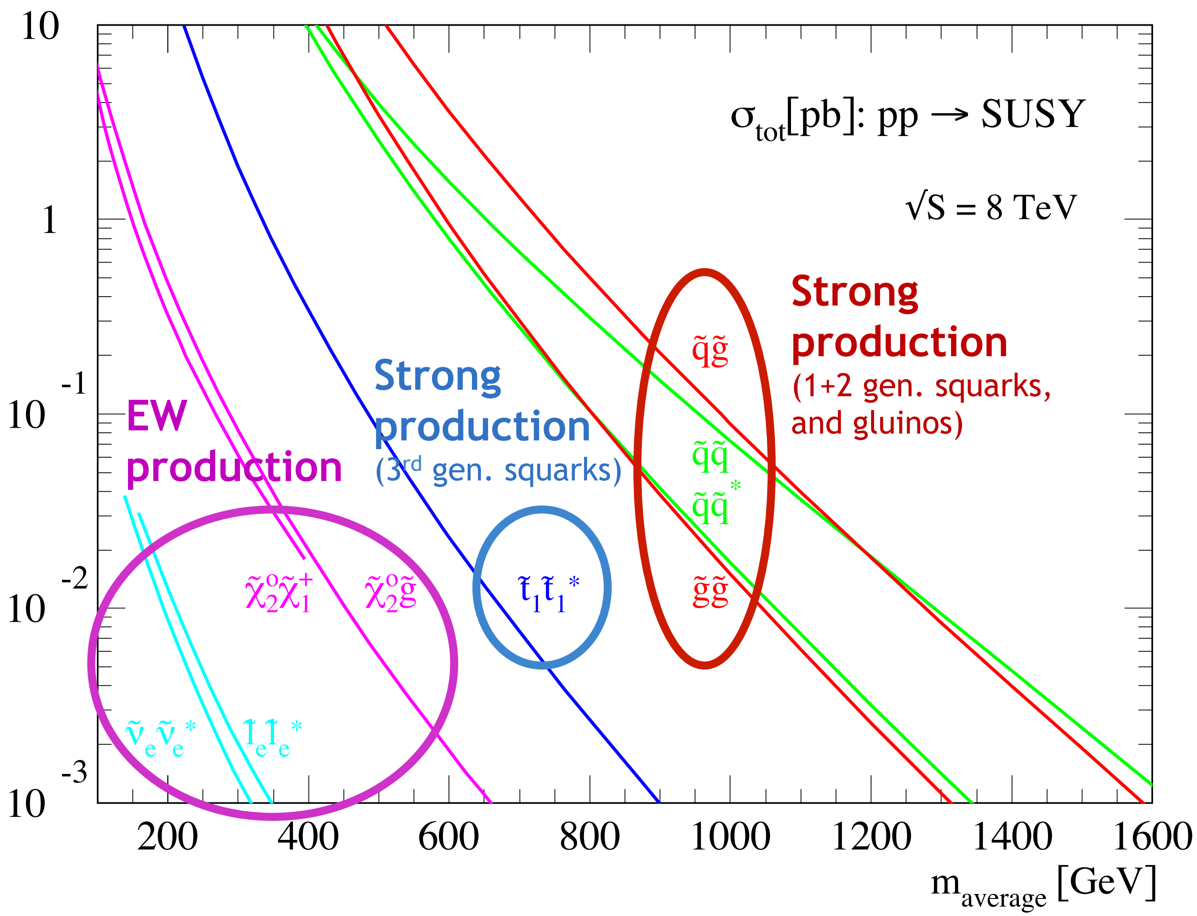
Where do we start?

Huge parameter space, but guiding principles





SUSY searches strategy driven by cross section and luminosity



Early analyses dominated by broad and inclusive searches for gluino and squark production,

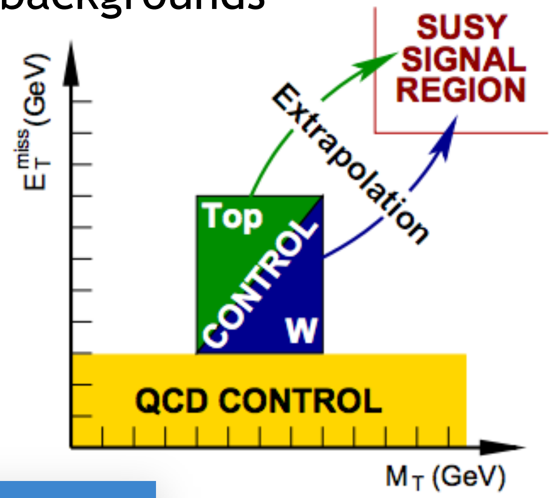
but right from the start also addressed experimentally challenging searches such as for long-lived particles and RPV

Increasing luminosity gave access to rarer production channels. Additional motivation from *Natural SUSY* paradigm

It was quickly realised that dedicated searches had to be developed to adequately cover the rich decay spectrum

How do we search for SUSY ?

SUSY searches rely primarily on the understanding of the SM backgrounds



Standard Model

Top, multijets
V, *VV*, *VVV*, Higgs
& combinations of these

Combined fit of all regions and backgrounds and incl. systematic exp. and theor. uncertainties as nuisance parameters

Reducible backgrounds

Determined from data
Backgrounds and methods depend on analyses

Irreducible backgrounds

Dominant sources: normalise MC in data control regions
Subdominant sources: MC

blinded

Validation

Validation regions used to cross check SM predictions with data

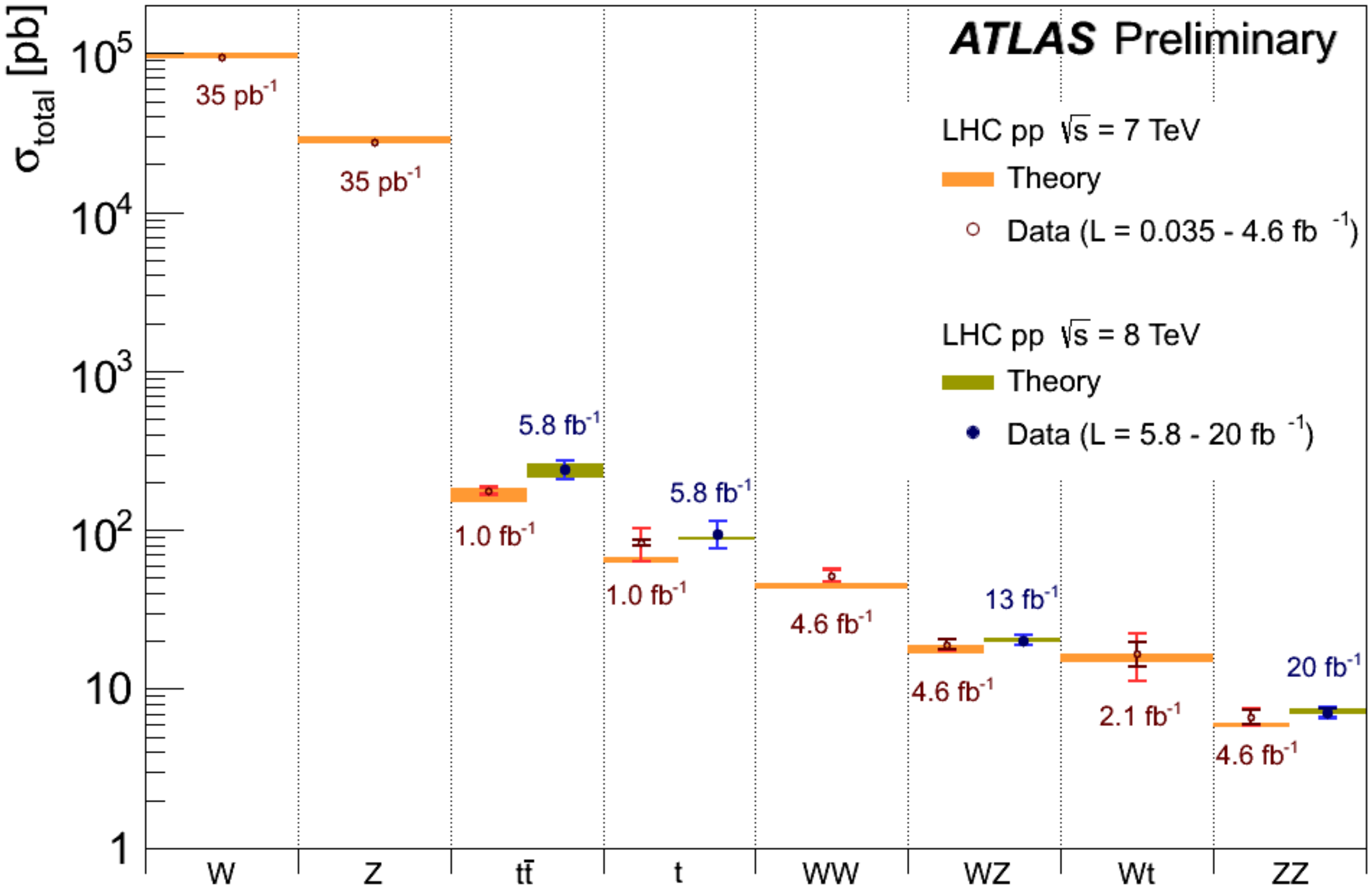
blinded

Signal regions

SM "backgrounds" — the big picture

SM processes well understood over many orders of magnitude production rate

ATLAS 1304.7098



No hints for new physics

SM “backgrounds” – the big picture

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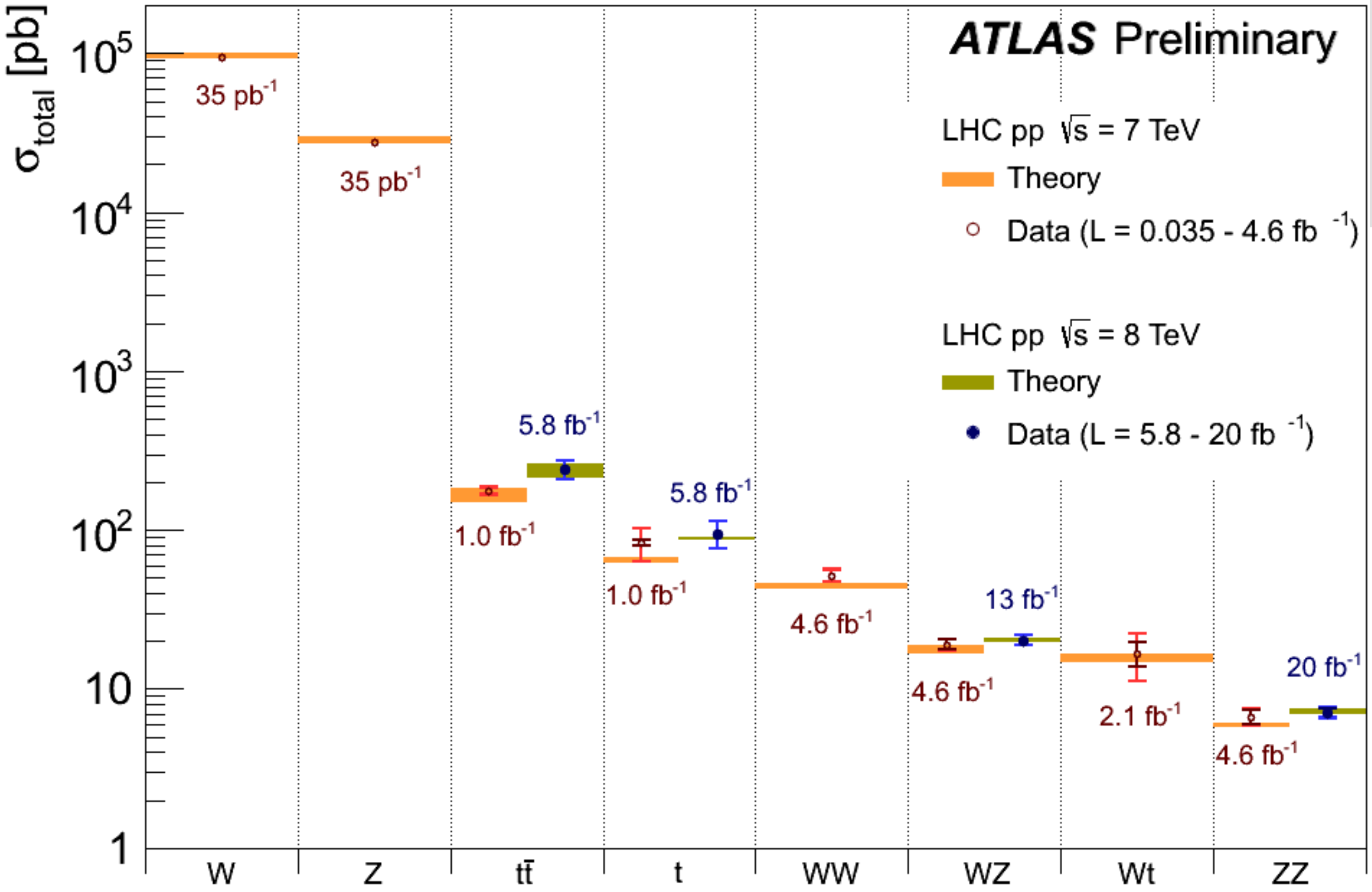

Main bkgs:
W/Z+Jets,
top pairs,
di-bosons

A comprehensive set of unfolded differential measurements carried out on these processes with the 7 TeV data => input to bkg estimates

In future will use these to tune MCs.

In general MCs do a fair-good job of describing the data.

SM "backgrounds" — the big picture

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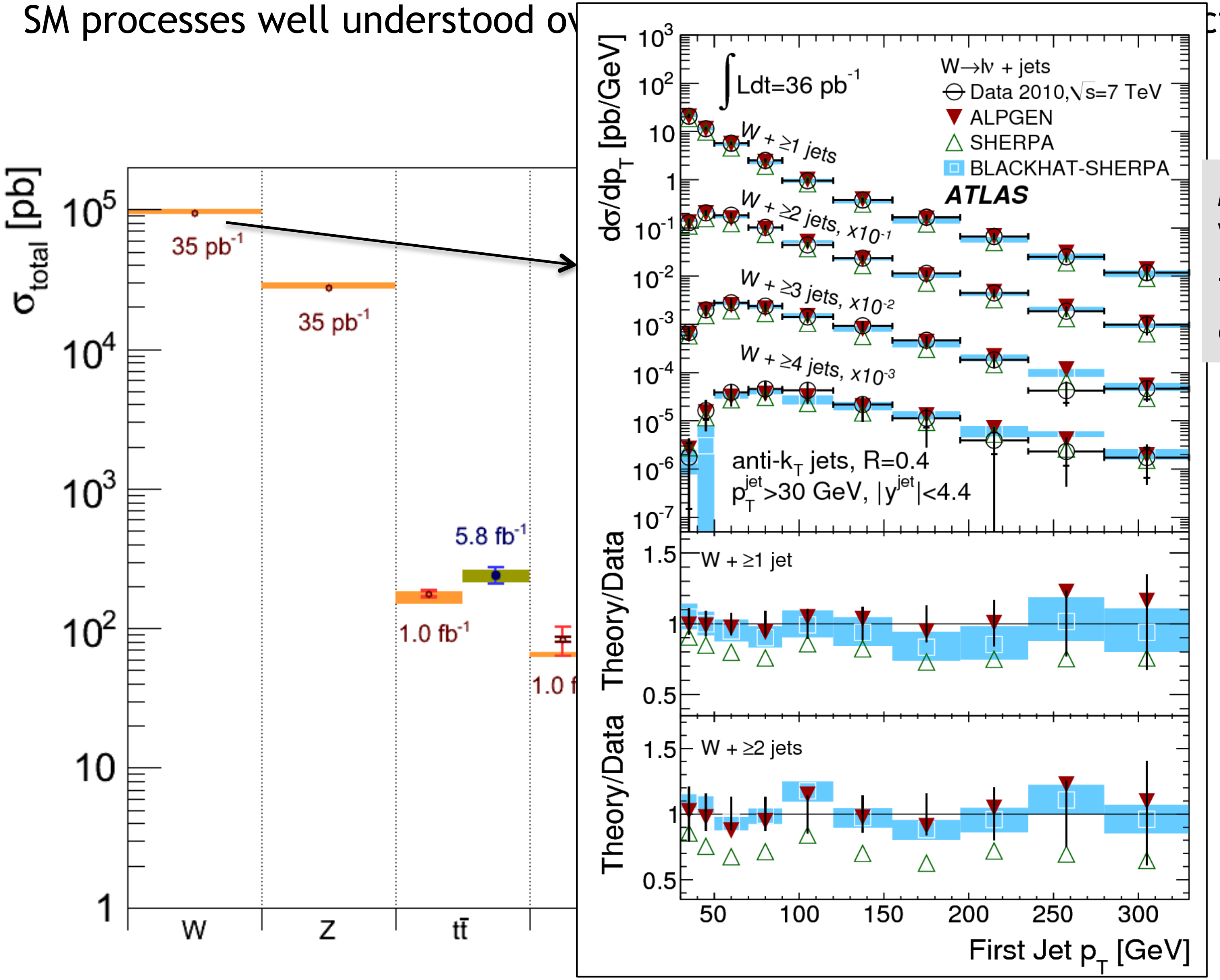

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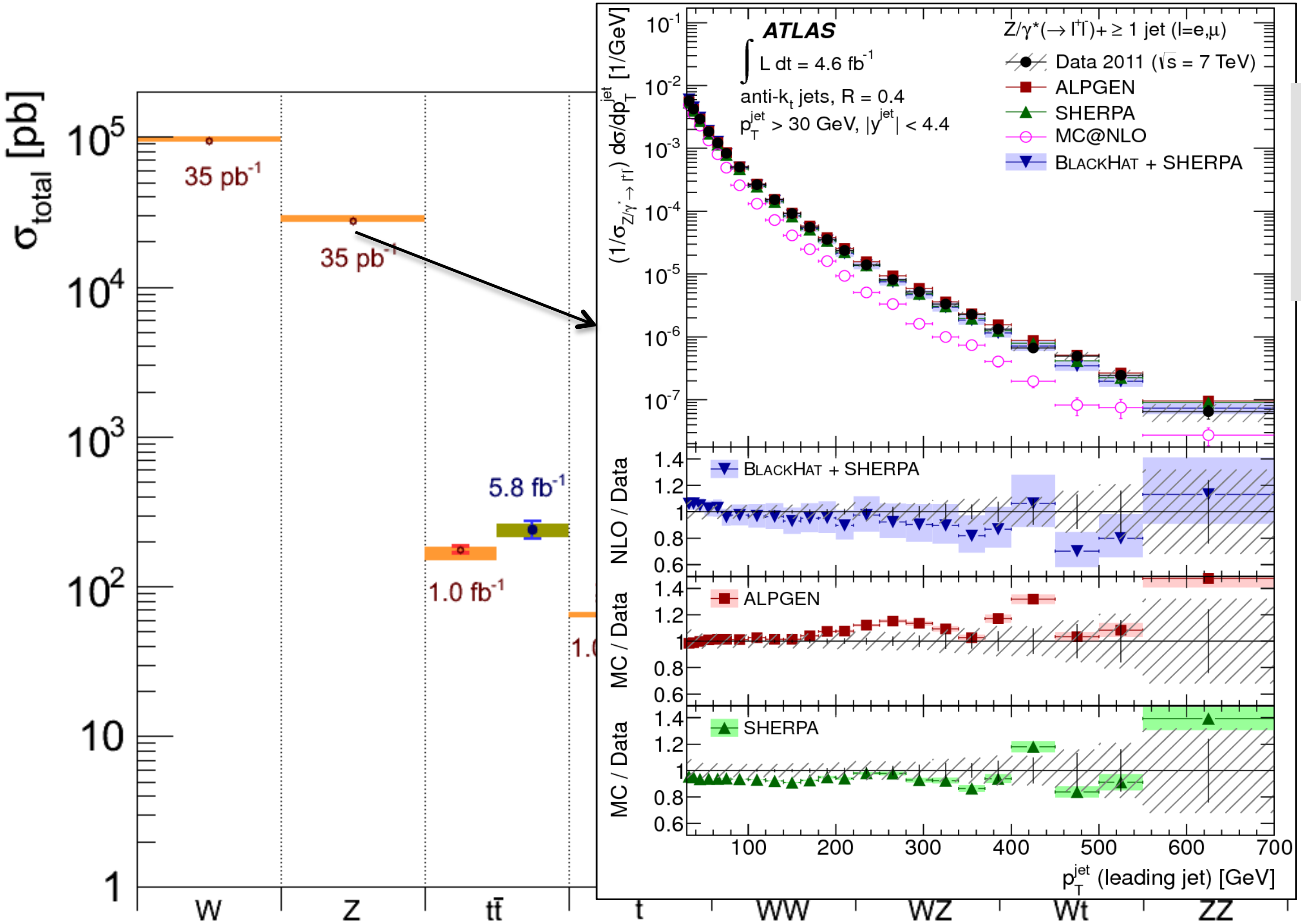

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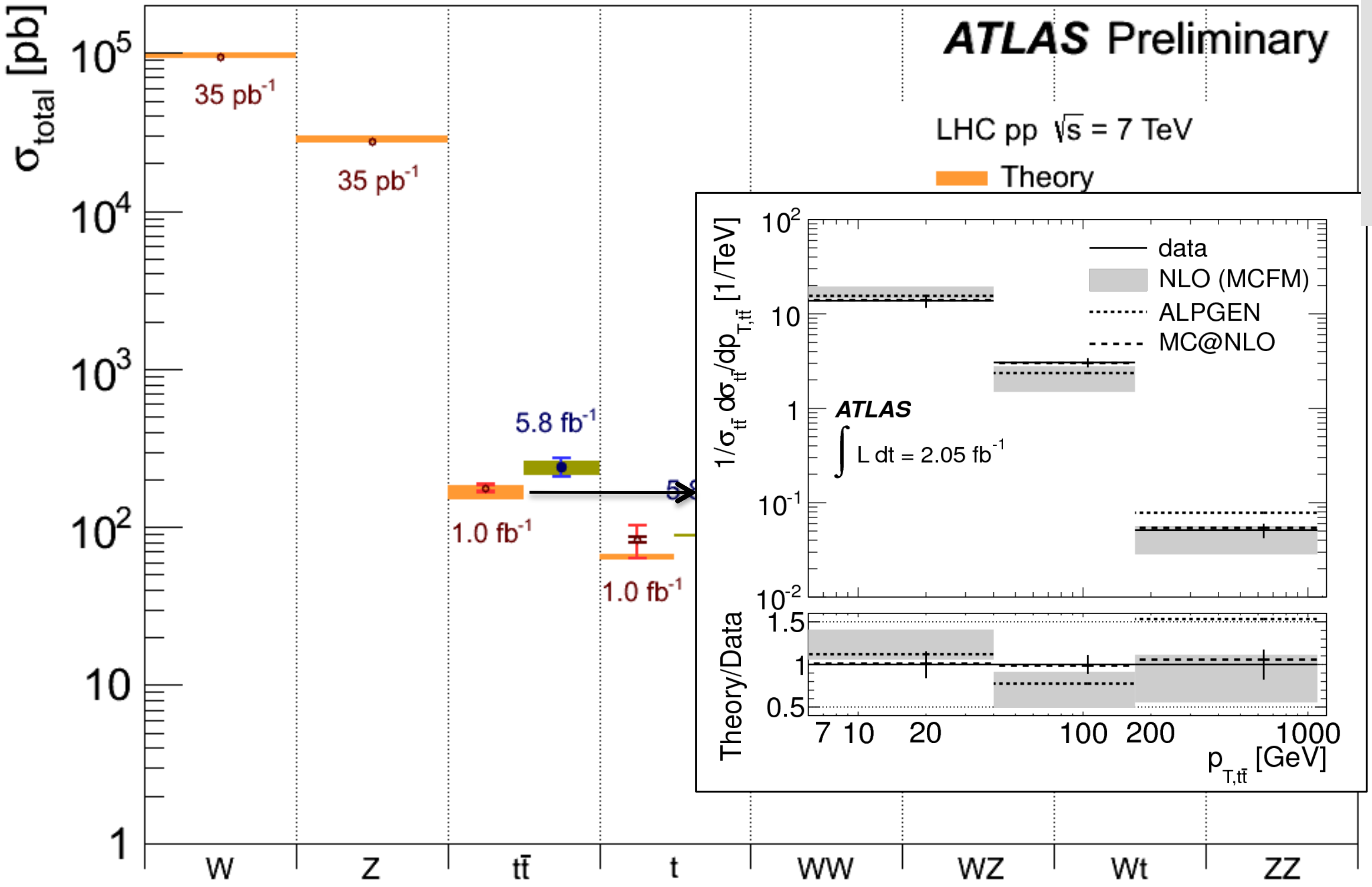

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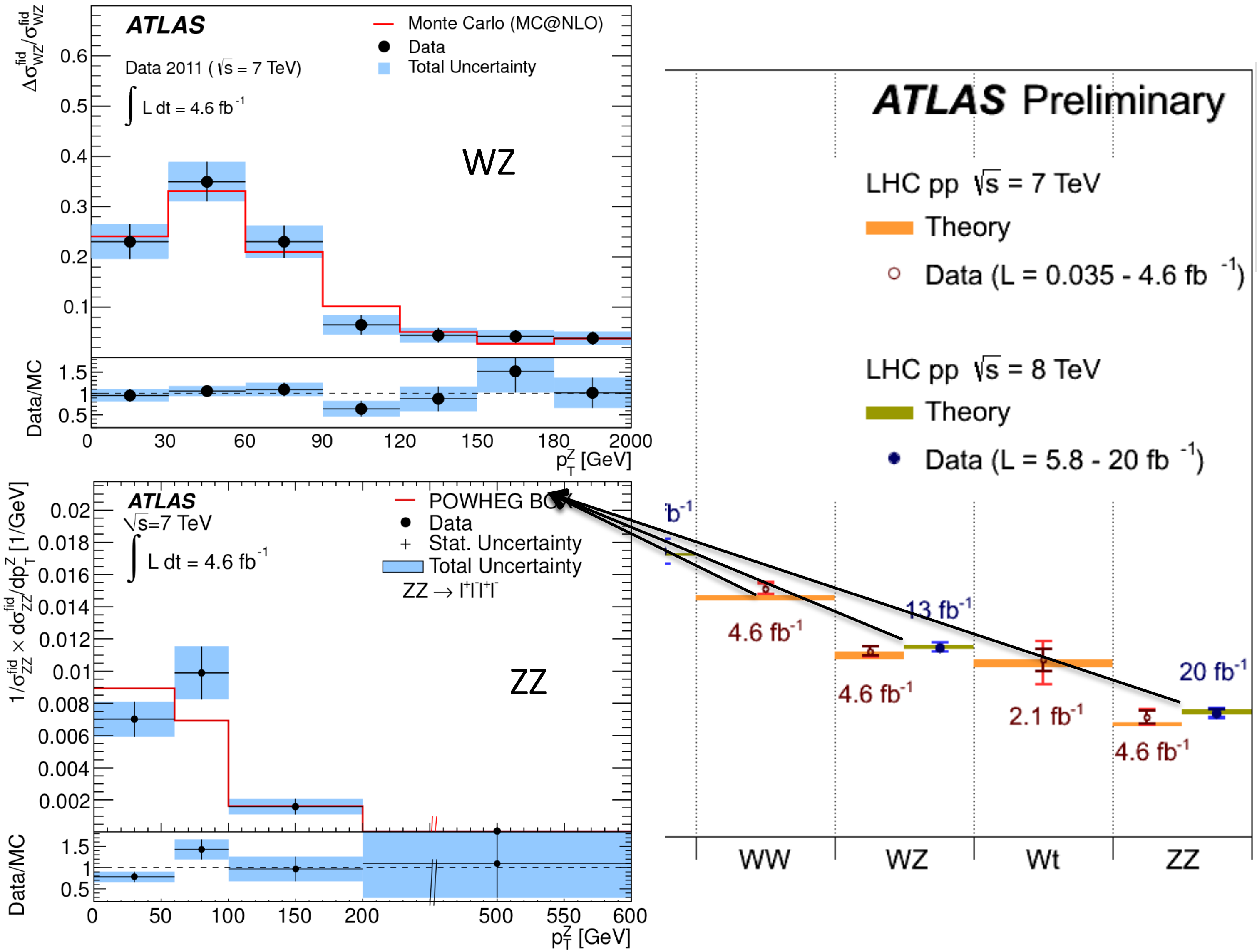

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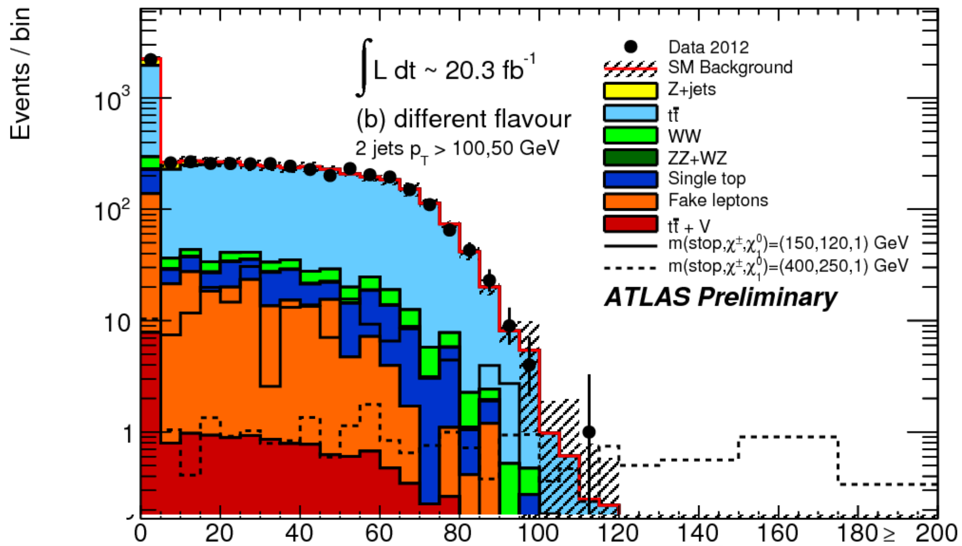
Separating SM background from SUSY signal events

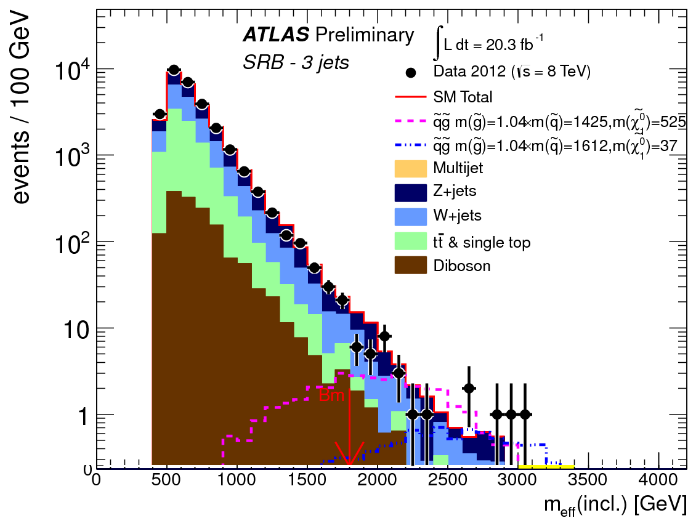
Kinematic and topological variables in SUSY searches

m_{T2} distribution in dilepton stop search; endpoint at W mass for $t\bar{t}$ events



$$m_{T2} = \min_{\mathbf{q}_T} \left[\max \left(m_T(\mathbf{p}_T^{\ell 1}, \mathbf{q}_T), m_T(\mathbf{p}_T^{\ell 2}, \mathbf{p}_T^{\text{miss}} - \mathbf{q}_T) \right) \right]$$

m_{eff} distribution in 0-lepton + 3=jet + MET analysis



Numerous variables developed to exploit kinematic information in events with two massive invisible particles for SUSY spectroscopy in case of discovery

Turned out to be also useful for SUSY vs. SM discrimination

Long list: p_T(jets/leptons), N_{jets}, $\Delta\phi$, E_T^{miss}, H_T, m_{eff}, m_T, m_{T2}, m_{CT}, Razor variables (M_R, R), MVA, …

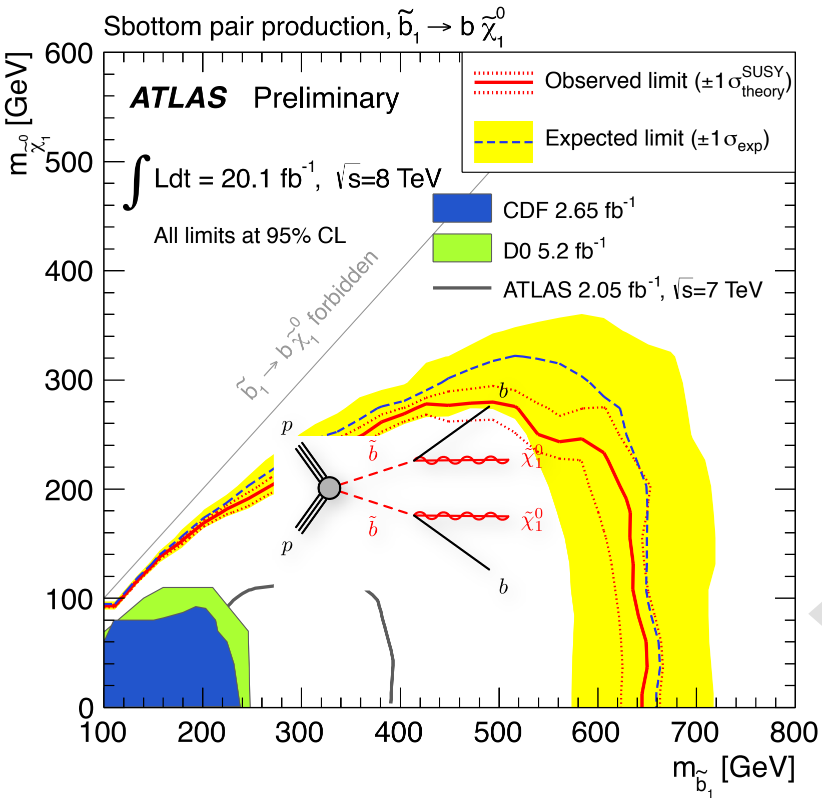
Optimal working point can be achieved in many and often fairly equivalent ways

$$m_{\text{eff}} \equiv \sum_{i=1}^{n} |\mathbf{p}_T^{(i)}| + E_T^{\text{miss}}$$

Identifying a signal / constraining SUSY parameters

Combined fits of control regions (CRs) and signal regions (SRs) fixes background prediction

Results of searches presented in form of raw numbers and (so far only) limits



- Raw results presented as number of observed and expected events and uncertainty for each signal region
- *P*-value for background-only hypothesis
- No signal → 95% CL limit on N_{events}(BSM)
- Test SUSY models
  - Constrained models (eg, mSUGRA/CMSSM, GMSB, pMSSM, …)
  - Simplified models
- Model-dependent 95% CL limits:
  - Observed and expected limits with theoretical and experimental uncertainties, respectively

Identifying a signal / constraining SUSY parameters

Combined fits of control regions (CRs) and signal regions (SRs) fixes background prediction

-Often many SRs per analysis optimized to give good sensitivity over large range of parameter space

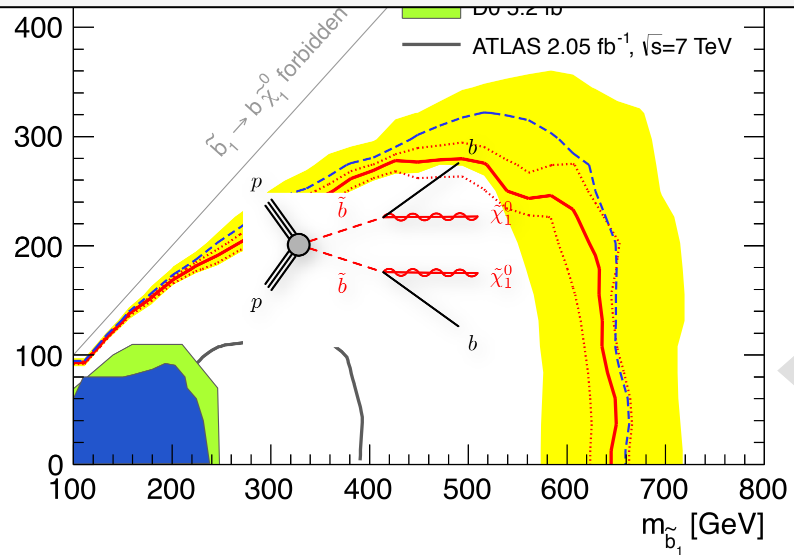
-Choose SR with best expected limit for given signal model point

-Deliberately try to make SRs (and CRs) orthogonal to allow combination of searches

-CRs chosen to minimize signal contamination (taken into account in exclusion results)

-Some analyses sensitive to different SUSY models – can be re-interpreted in different scenarios

-Try to give as much information as possible in our public results to allow new interpretations of the results in different models



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  - Simplified models
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Overview of ATLAS SUSY analyses

Inclusive squark/gluino

- 0-lepton + 2-6 jets + MET
- 0-lepton + 7-10 jets + MET Sig.
- 1-2 leptons + jets + MET
- 2-lepton + jets + MET *
- 1-2 taus + jets + MET

Electroweak production

- 2-leptons + MET
- 3-leptons + MET
- 2 taus + MET
- 1-lepton + 2 b-jets + MET *

In backup

- photon + lepton + MET
- photon + b-jet + MET
- 2-photons + MET
- non-pointing photon
- Z(ll) + jets + MET
- 4-leptons + MET

3rd generation

gluino-mediated production

- 0-1 leptons + ≥3 b-jets + MET
- 2 SS leptons (+ b-jets) + MET
- 3-leptons + jets + MET
- 2 b-jets + 0-jets + MET

direct production

- 0-leptons + 6-jets (2 b-jets) + MET
- 1-lepton + 4-jets (2 b-jets) + MET
- 2-leptons (+ 2 b-jets) + MET
- charm / mono-jet + MET
- Z(ll) + 2 b-jets + MET

RPV and long lived particles

- Disappearing track (AMSB)
- Stopped gluino
- Long lived slepton
- Displaced vertex *
- RPV gluino multijet (6,10 jets) *

*** = new for this conference**

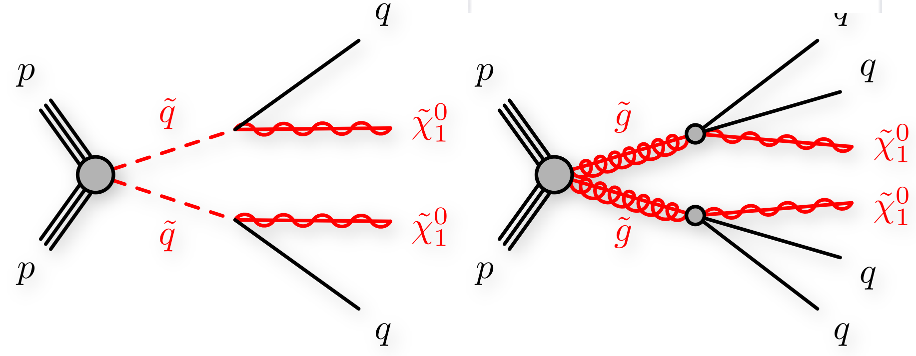
Inclusive searches for squark and gluino production

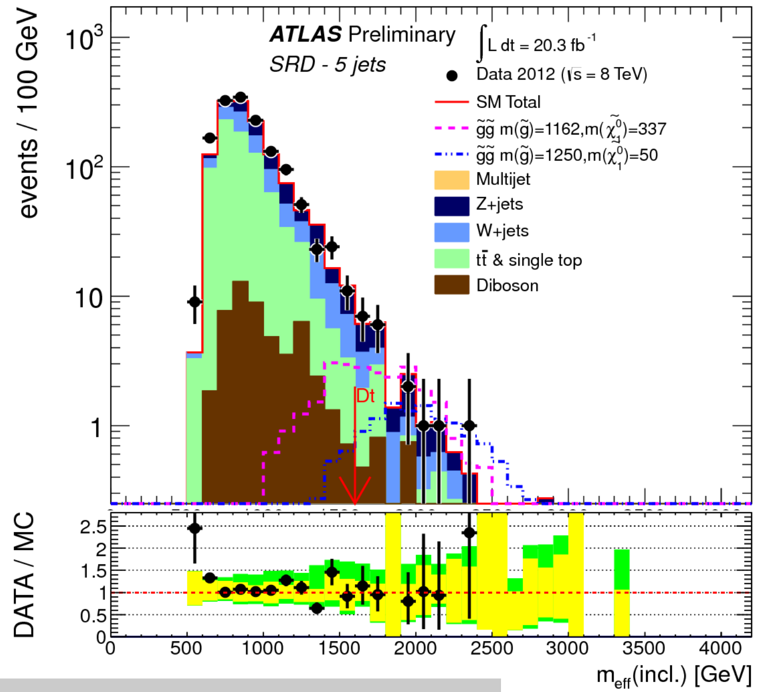
Extensive "jets + X + E_T^{miss} " programme: **0-leptons + 2-6 jets + MET**

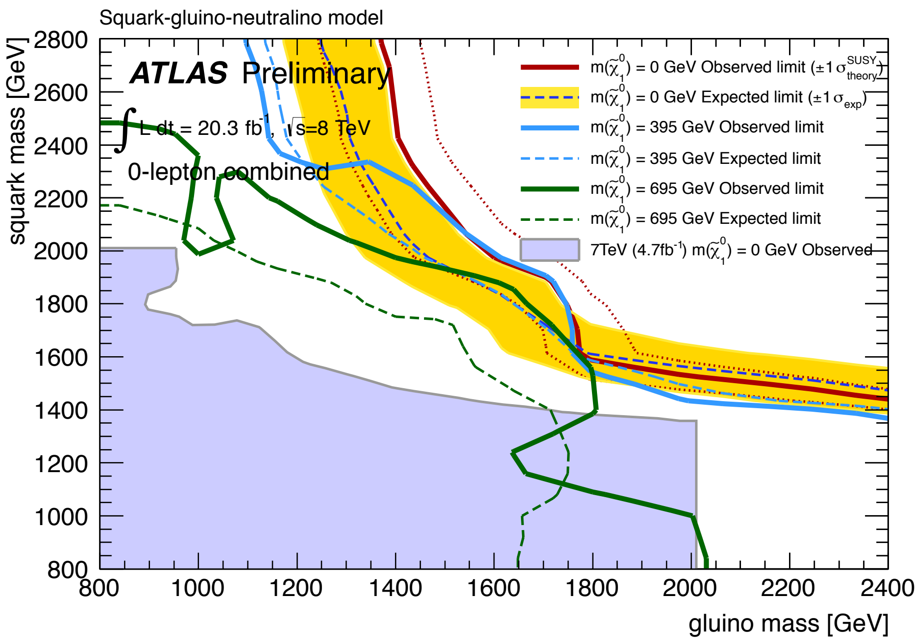
$$m_{\mathrm{eff}} \equiv \sum_{i=1}^{n} |\mathbf{p}_{\mathrm{T}}^{(i)}| + E_{\mathrm{T}}^{\mathrm{miss}}$$

Most recent ATLAS reference (8 TeV): ATLAS-CONF-2013-047

- Very powerful inclusive search
- MET + jet trigger
- M_{eff} main discriminating variable
- Up to 3 SRs for each jet multiplicity
- Backgrounds taken from dedicated data CRs







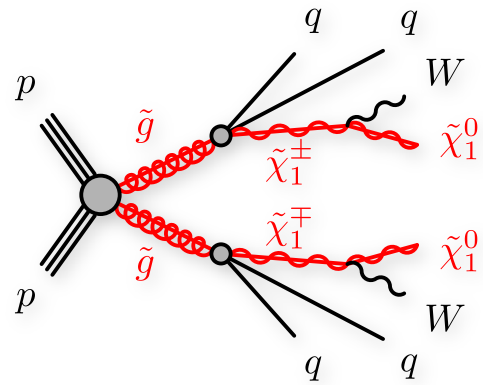
More details in talk by M Hohlfeld

Inclusive searches for squark and gluino production

Extensive "jets + X + E_T^{miss}" programme: **0-lepton + 7-10 jets + MET significance**

Most recent ATLAS reference (8 TeV): 1308.1841

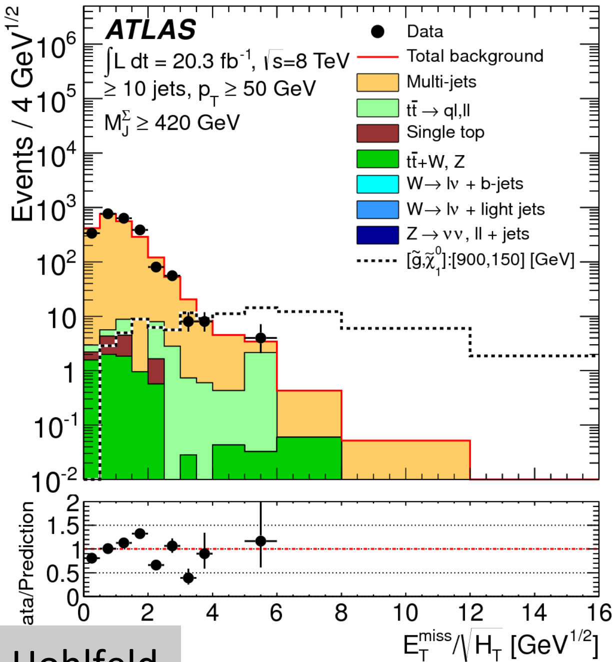
- -Powerful for gluino pair production with many jets
- -Complementary to 2-6 jets analysis, uses jet only trigger allows lower MET cut (~50GeV)
- -Data driven multi-jet background method (MET significance independent of jet multiplicity)
- -Jet pT > 50 (80) GeV, MET sig. > 4 GeV½
- -SRs w/wo b-tags and w/wo fat jets

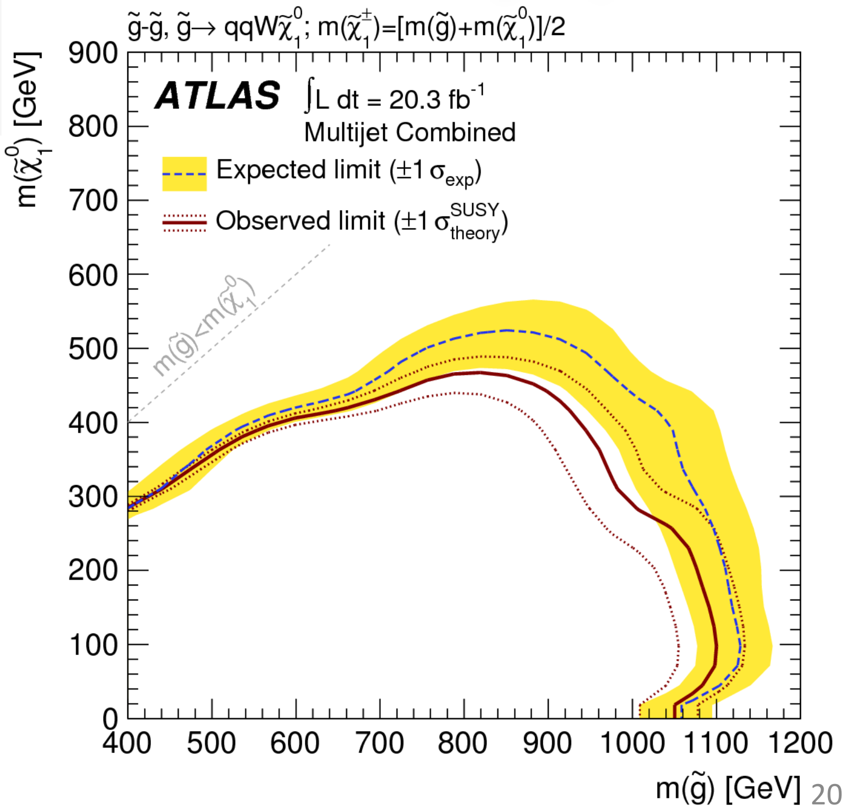


MET sig. = $E_T^{miss}/\sqrt{H_T}$

Fat jet variable:

$$M_J^{\Sigma} \equiv \sum_j m_j^{R=1.0}$$





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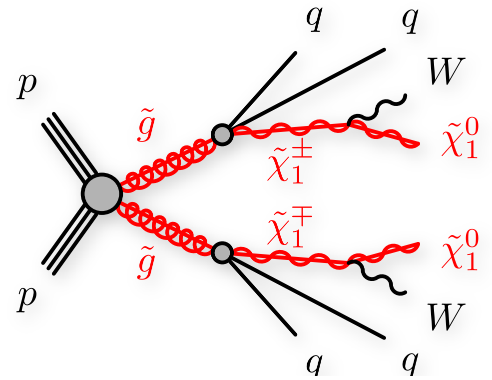
Inclusive searches for squark and gluino production

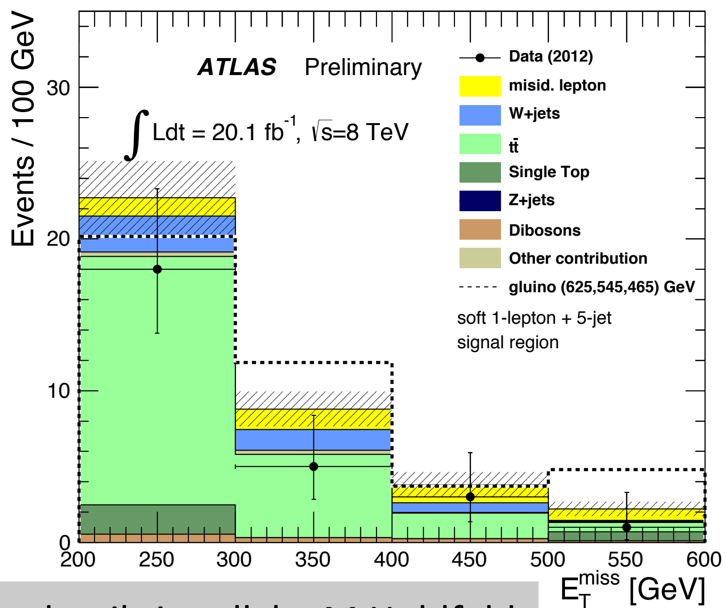
Extensive "jets + X + E_T^{miss} " programme: **1-2-leptons + jets + MET**

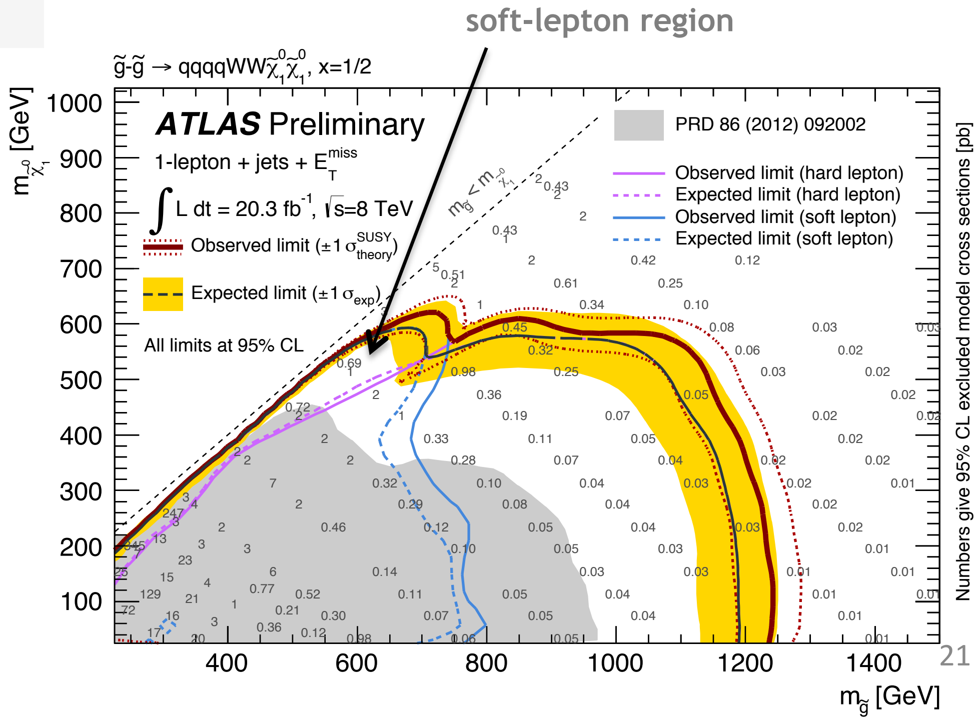
Most recent ATLAS reference (8 TeV): ATLAS-CONF-2013-062

- -Single lepton or MET trigger
- -M_T used to reduce background from W+jets and top
- -Hard lepton analyses (p_T>25GeV) complemented with soft-lepton (p_T>10[e], 6[μ] GeV) for compressed spectra
- -SRs with 3,5,6 jets and various MET, M_{eff} cuts



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





More details in talk by M Hohlfeld

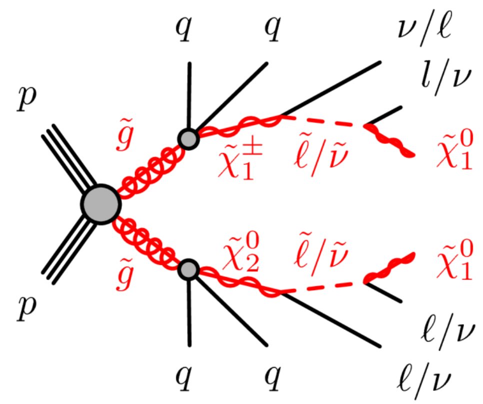
New for this conference!

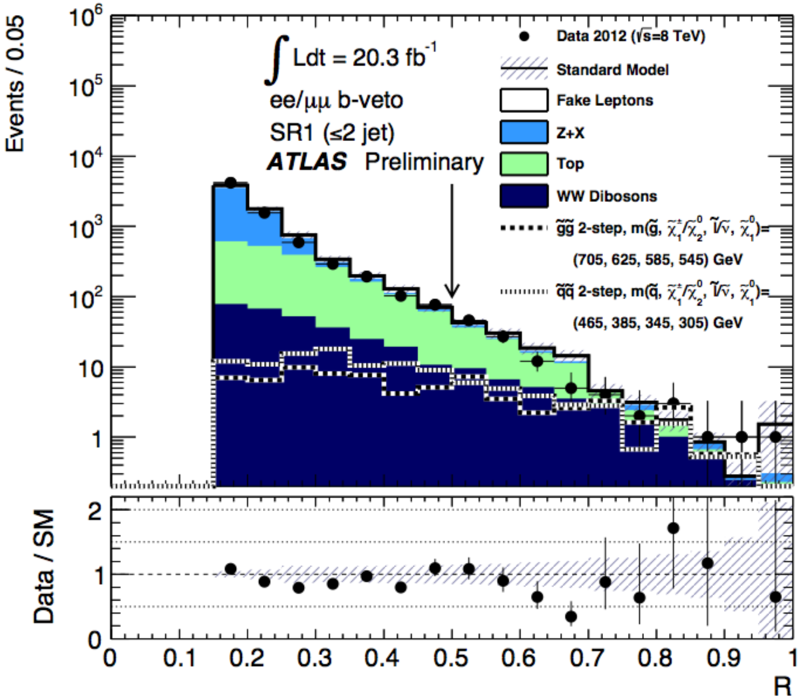
Inclusive searches for squark and gluino production

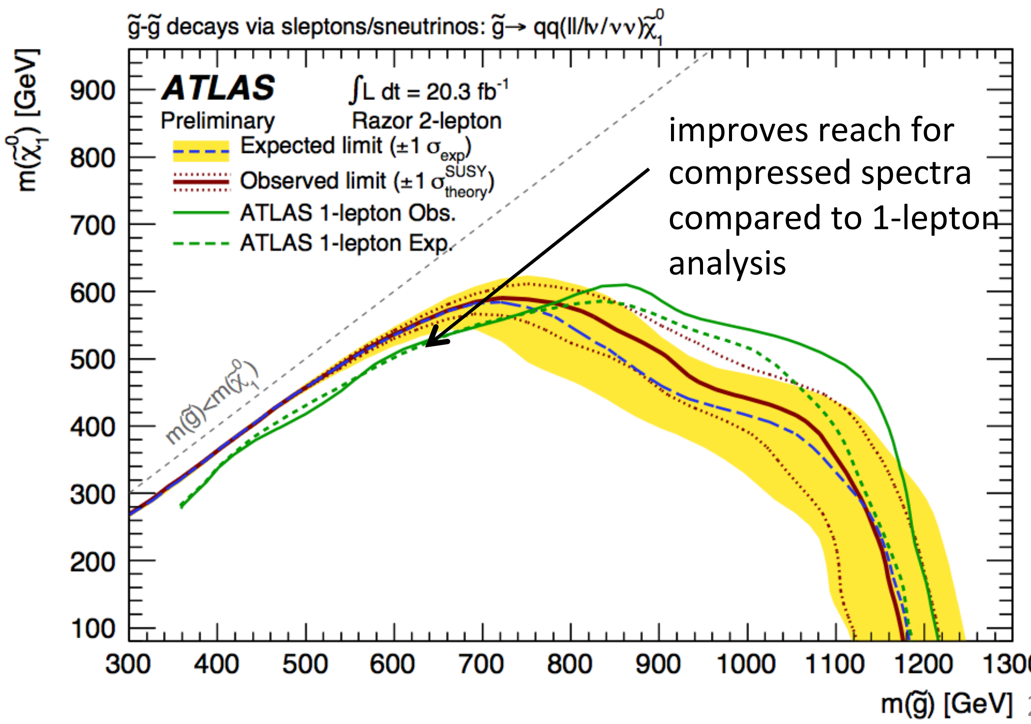
Extensive “jets + X + E_T^{miss} ” programme: **2-leptons + jets + MET**

Most recent ATLAS reference (8 TeV): ATLAS-CONF-2013-089

- -Analysis uses Razor variables to distinguish signal from bkg
- -Uses di-lepton trigger, p_T down to 8[μ], 14[e] GeV
- -Z-veto applied
- -SRs with different jet and Razor requirements



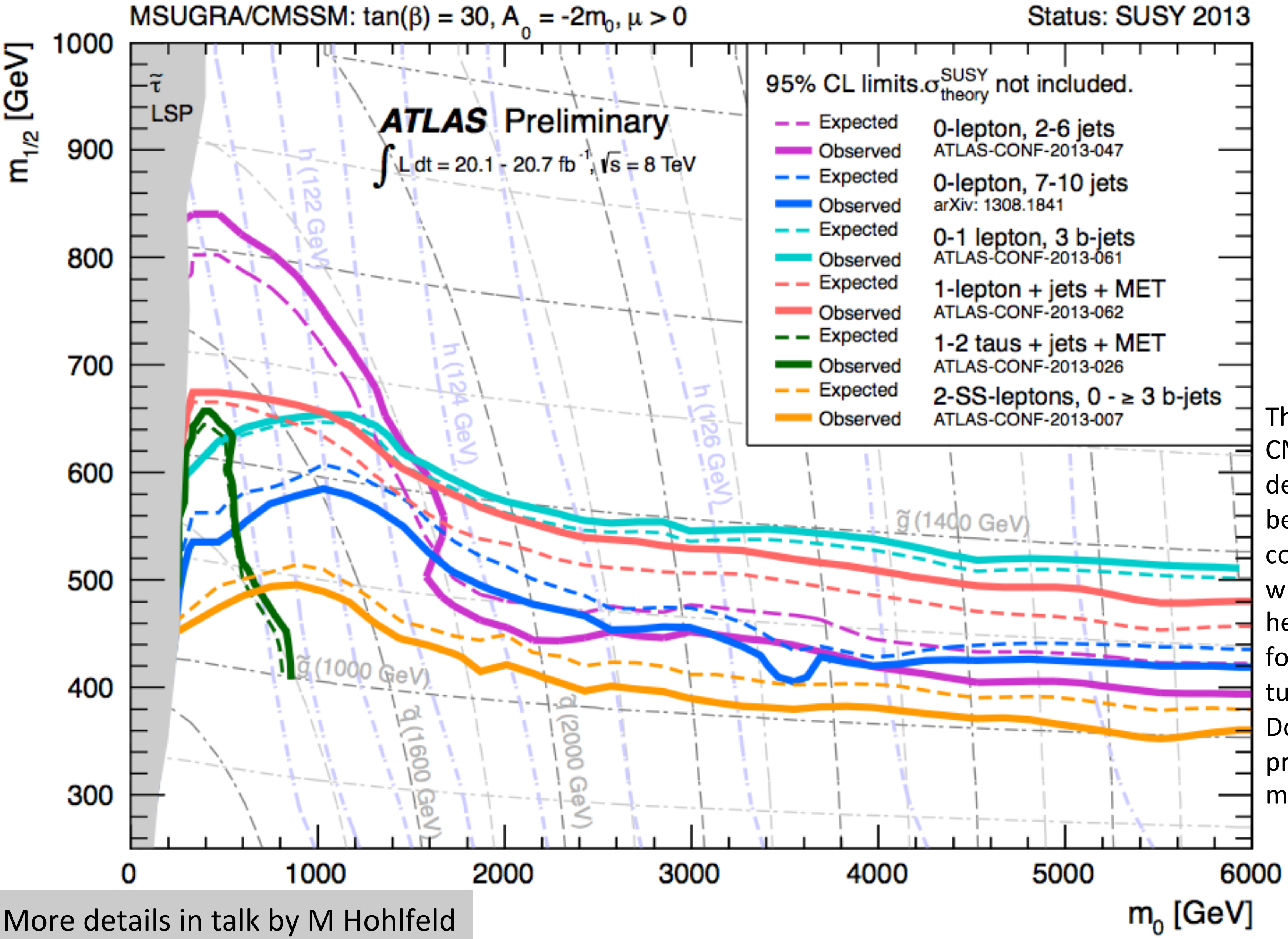




More details in talk by M Hohlfeld

Inclusive searches for squark and gluino production

Extensive “jets + X + E_T^{miss} ” programme with neutralino LSP

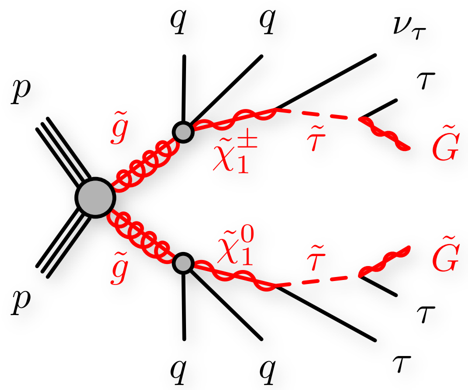


This specific CMSSM grid is designed to have better compatibility with observed heavy Higgs, and for low fine tuning. Dominant process gluino mediated stop.

More details in talk by M Hohlfeld

Inclusive searches for squark and gluino production

GMSB models can lead to enhanced tau production: **1-2 taus + jets + MET**

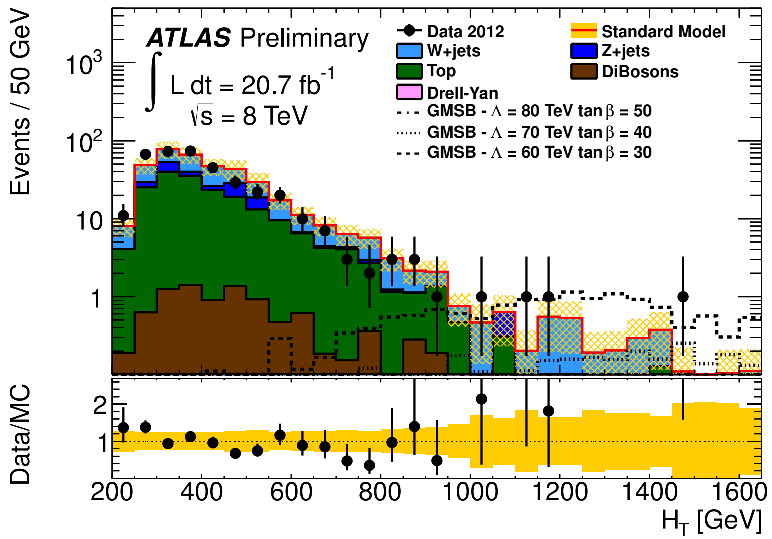


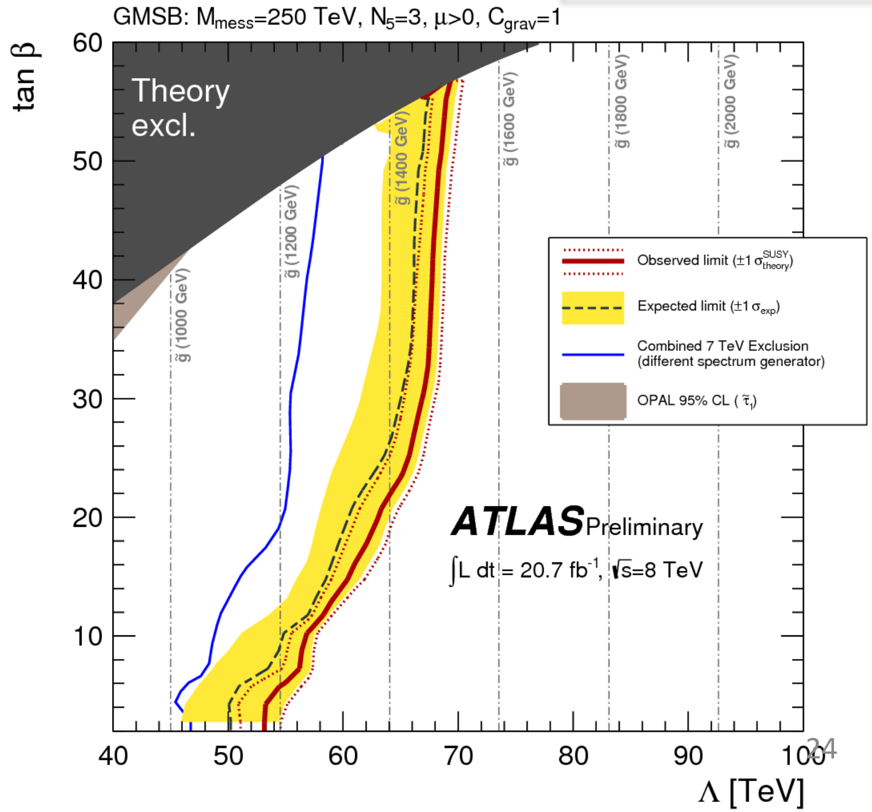
Most recent ATLAS reference (8 TeV): ATLAS-CONF-2013-026

-1, 2 hadronically decaying taus (p_T>20 or 30 GeV), 2-4 jets
-Separate SRs for GMSB and natural Gauge Mediation (nGM) scenarios
-Larger fake background for hadronic taus. However multijet background negligible after MET cut (>130 GeV)

In nGM model:

$$m(\tilde{g}) > \begin{cases} 1.2_{\text{low-}\tan\beta} \\ 1.5_{\text{large-}\tan\beta} \end{cases} \text{TeV}$$

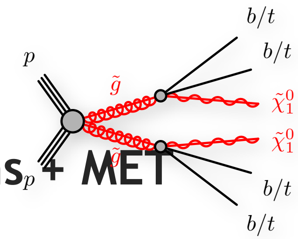




More details in talk by M Tripiana

Searches for "Natural" SUSY scenarios

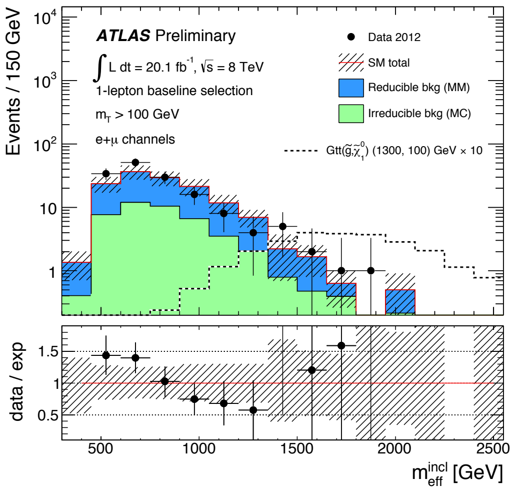
Gluino-mediated stop / sbottom production: ≥ 3 b-jets +0-1 leptons + MET



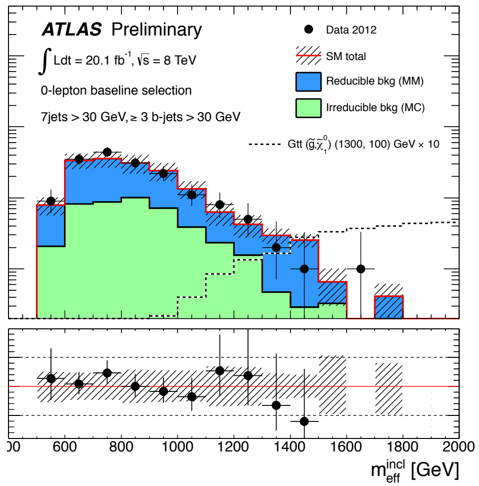
Most recent ATLAS references (8 TeV): ATLAS-CONF-2012-061

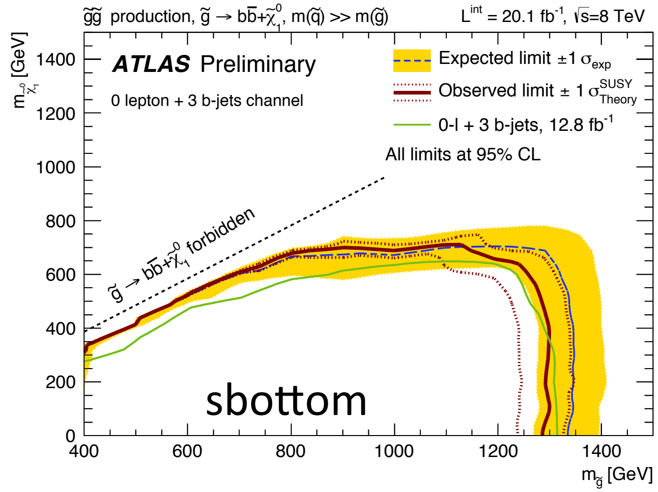
- Most powerful search for high gluino mass
- Jet + MET trigger
- Reducible bkg ($t\bar{t}$+fake b's) from matrix method
- Irreducible bkg ($t\bar{t}$+$b\bar{b}$, $t\bar{t}V$) from MC
- Also powerful for direct sbottom search

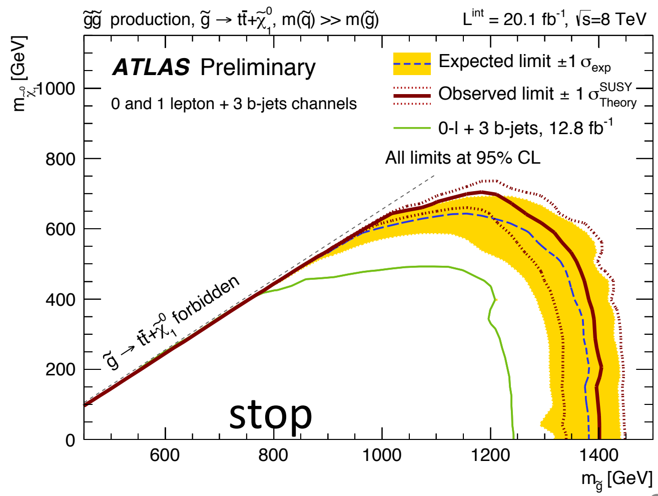
1 lepton channel



0 lepton channel



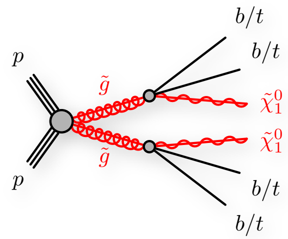




More details in talk by M Barisonzi

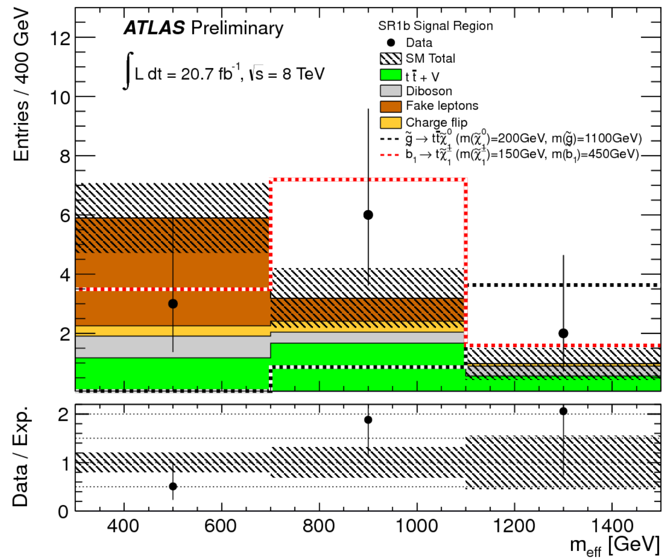
Searches for "Natural" SUSY scenarios

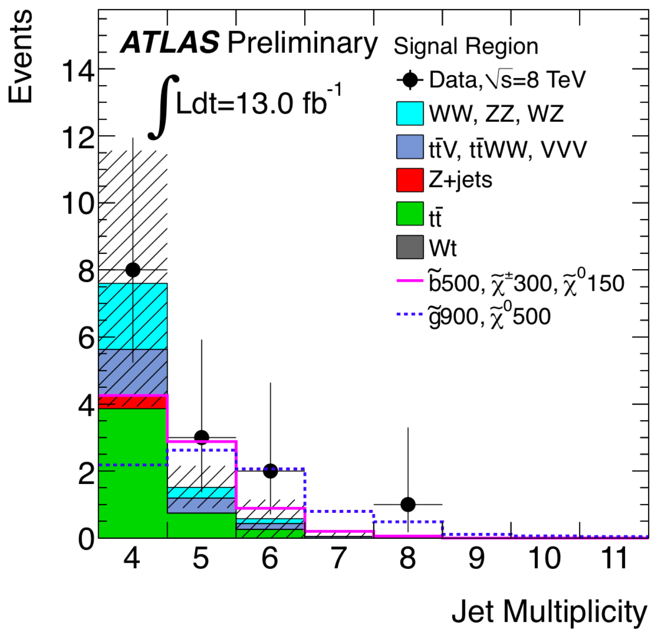
Gluino-mediated stop / sbottom production

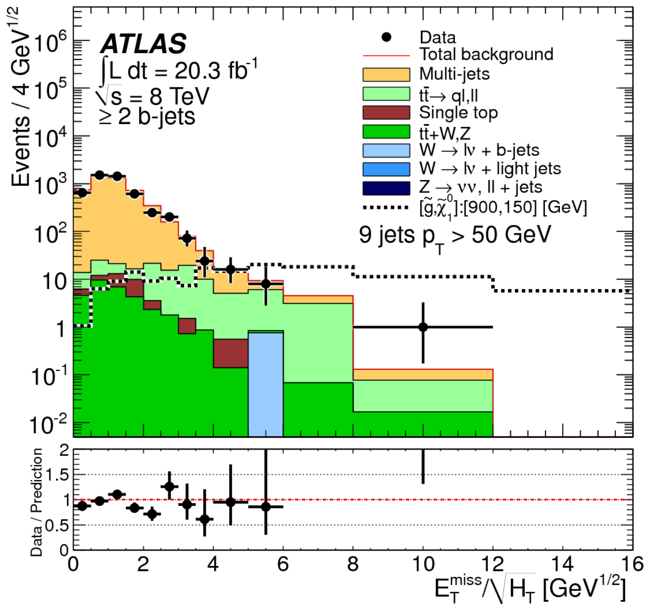


Most recent ATLAS references (8 TeV): ATLAS-CONF-2013-061, ATLAS-CONF-2013-007, ATLAS-CONF-2012-151

- -2 same-sign leptons + (0,1,3) b-jets + MET
  - -Broad analysis: good sensitivity in many models including strong production and direct sbottom
- -0-leptons + 7-10 jets + MET Significance (already discussed)
- -3-leptons + jets + MET



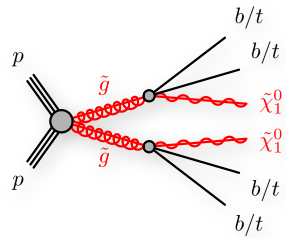


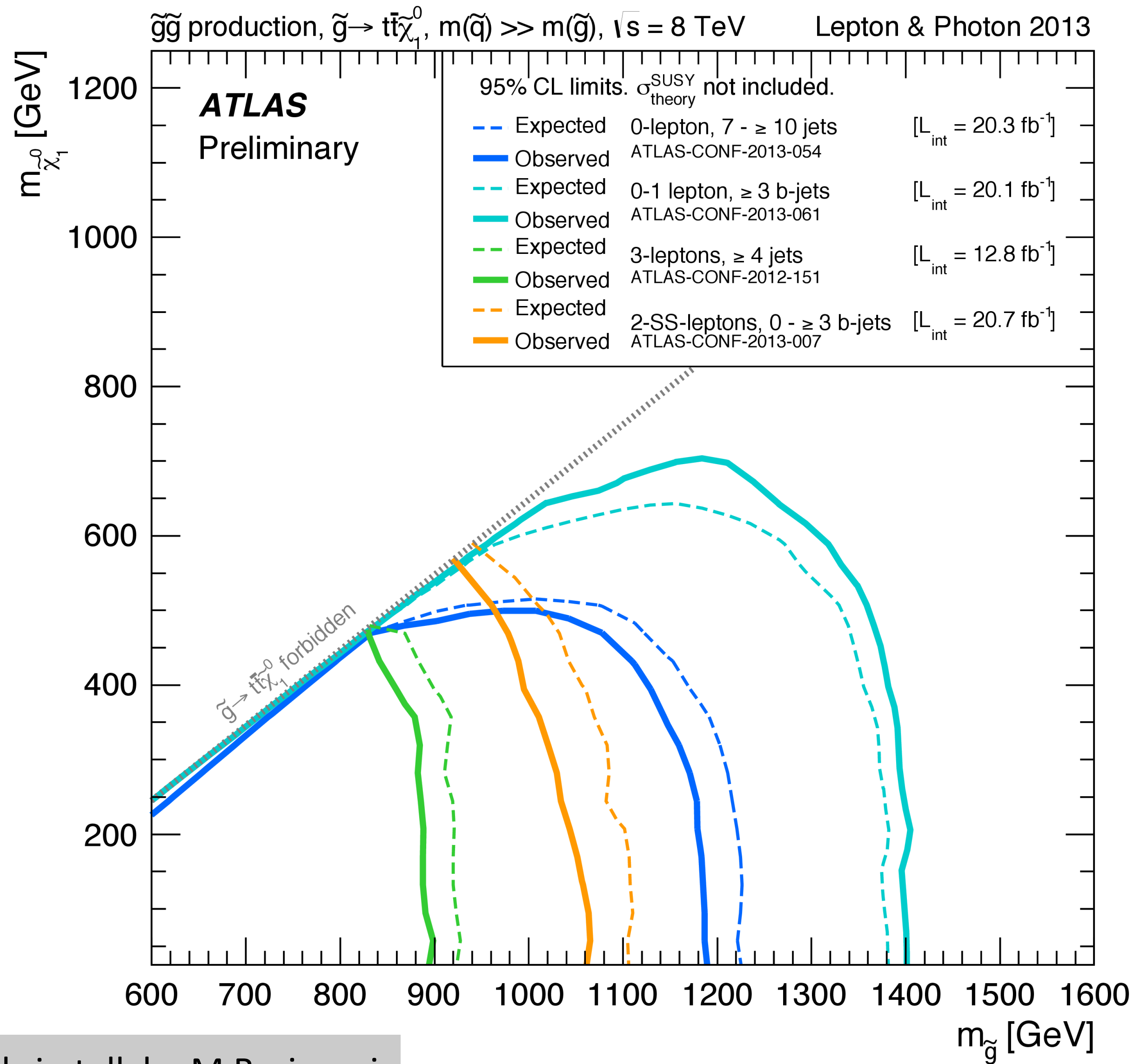


More details in talk by M Barisonzi

Searches for "Natural" SUSY scenarios

Summary of gluino-mediated stop production





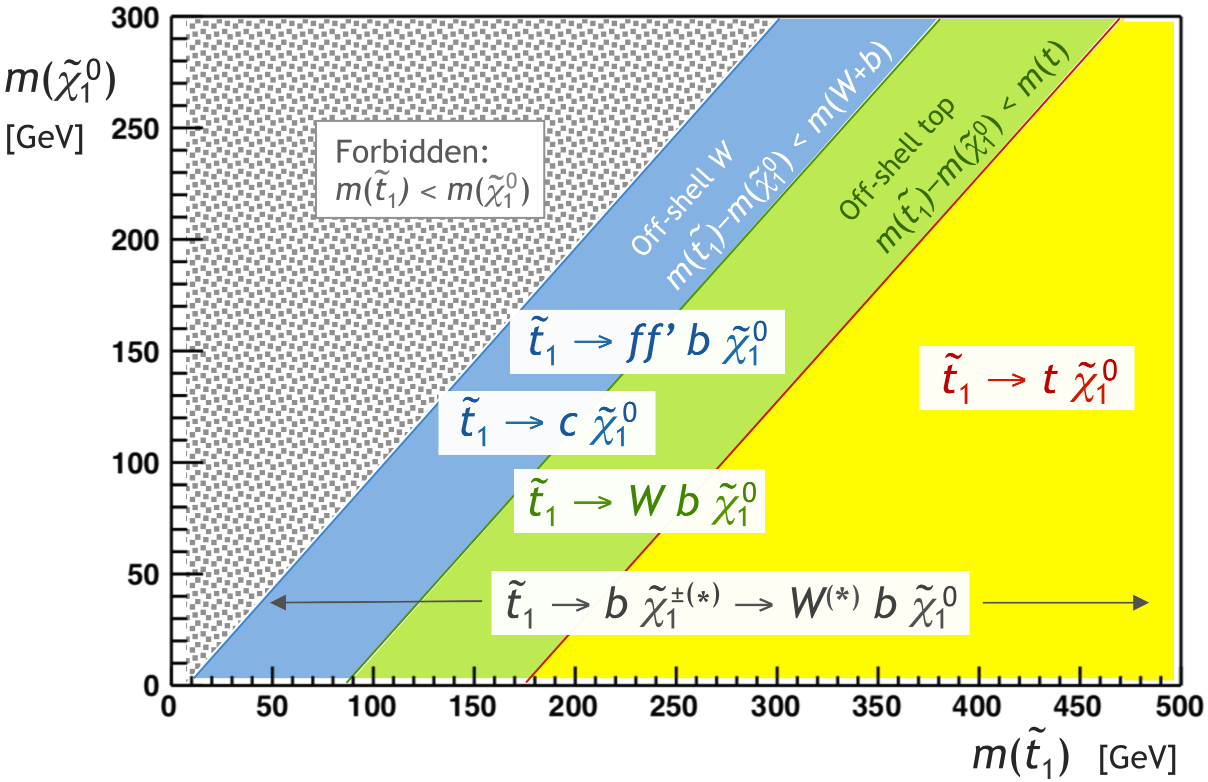
More details in talk by M Barisonzi

Searches for "Natural" SUSY scenarios

Direct stop / sbottom pair production

Most recent ATLAS references (8 TeV): 1308.2631, ATLAS-CONF-2013-024, ATLAS-CONF-2013-037, ATLAS-CONF-2013-048, ATLAS-CONF-065, ATLAS-CONF-2013-068, ATLAS-CONF-2013-025

Large spectrum of possible stop/sbottom decays. Effort so far concentrated on simplified models with 100% BRs to chosen final state. Studies of handedness dependence performed.



Dedicated effort to search for direct stop / sbottom production

sbottom decays searched for:

$\tilde{b}_1 \to b \, \tilde{\chi}_1^0$

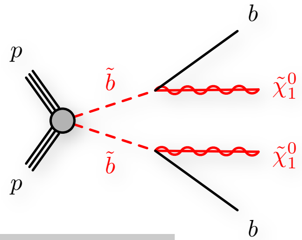
$\tilde{b}_1 \to t \, \tilde{\chi}_1^\pm$

$\tilde{b}_1 \to b \, \tilde{\chi}_2^0 \to b \, h(Z) \, \tilde{\chi}_1^0$

More details in talk by P Jackson

Searches for “Natural” SUSY scenarios

Direct sbottom / stop pair production: **2b + MET**

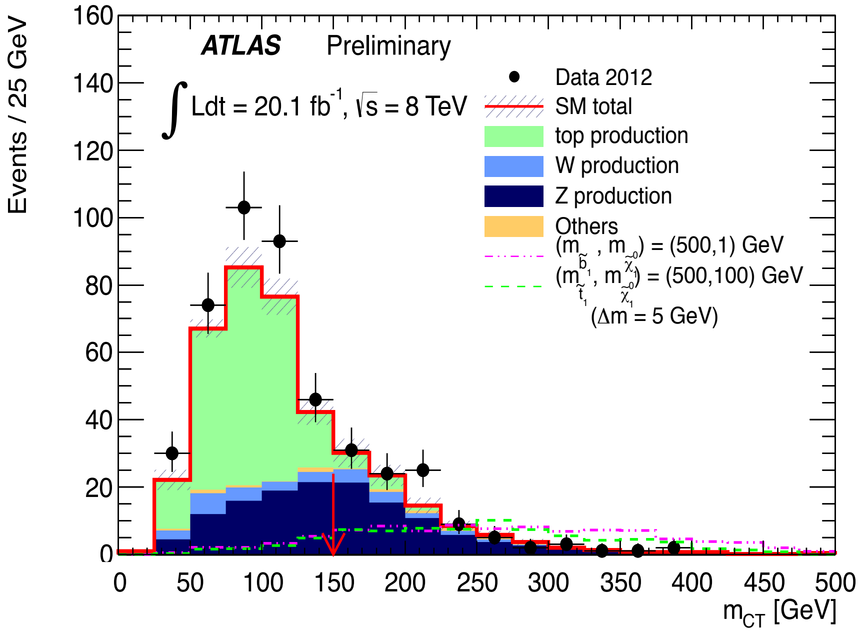


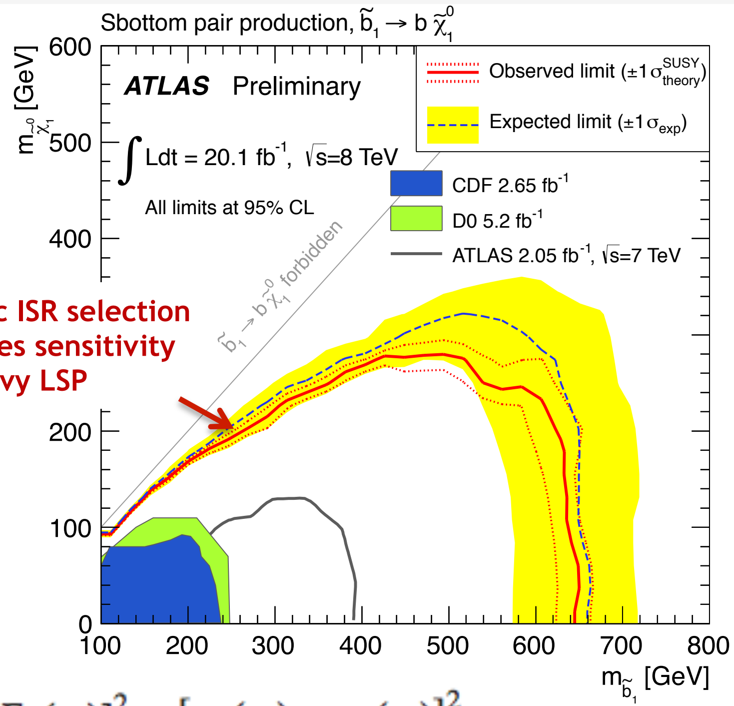
More direct sbottom results in backup

Most recent ATLAS references (8 TeV): 1308.2631

-Sensitive to direct sbottom production and direct stop where $\tilde{t}$->bC_1->bWN_1 with small mass splitting between C_1 and N_1 (virtual W with soft decay products)

-Use m_{CT} variable to reduce background from top pairs
-Remaining background dominated by Z(νν)+bb
-SR with ISR jet to help with compressed scenario





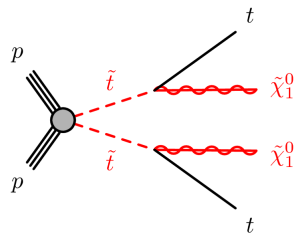
Specific ISR selection improves sensitivity for heavy LSP

More details in talk by P Jackson

$$m^2_{CT}(v_1, v_2) = [E_T(v_1) + E_T(v_2)]^2 - [\mathbf{p}_T(v_1) - \mathbf{p}_T(v_2)]^2$$

Searches for "Natural" SUSY scenarios

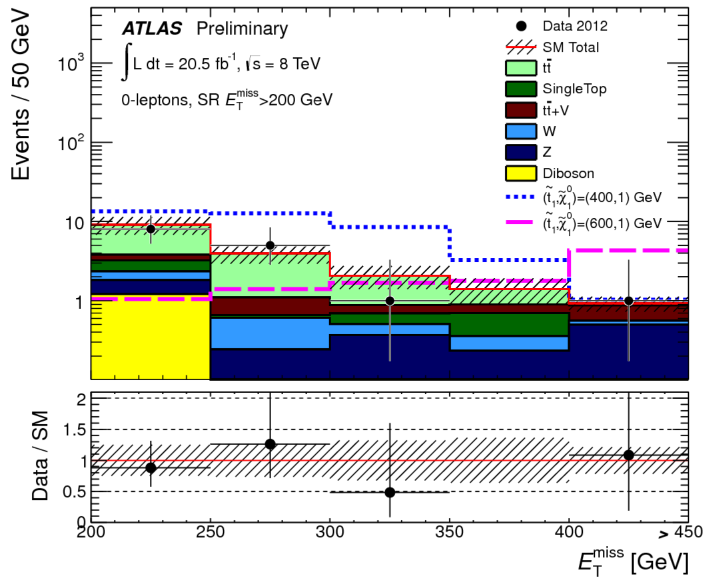
Direct stop pair production: **0-lepton + 2b + 6 jets + MET**

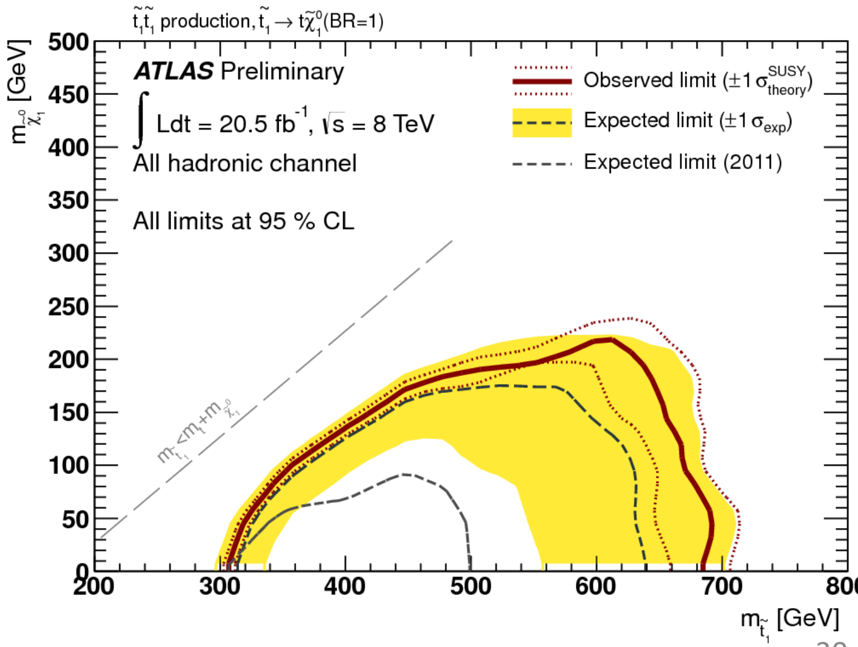


Most recent ATLAS references (8 TeV): ATLAS-CONF-2013-024

- Direct stop production $\tilde{t}$ -> t N_1
(0-lepton) final state like $t\bar{t}$+MET
- Largest background from semi-leptonic top, mitigate by fully reconstructing hadronic top system
- Also utilize m_T(b,MET) as key discriminating variable

- 3 SRs (different MET cuts) targeting medium and heavy stops
- Insensitive to top polarization
- Also present results as BR limit
    -what BF($\tilde{t}$->t N_1) would still be excluded?

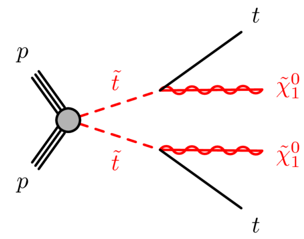




More details in talk by P Jackson

Searches for "Natural" SUSY scenarios

Direct stop pair production: **0-lepton + 2b + 6 jets + MET**



Most recent ATLAS references (8 TeV): ATLAS-CONF-2013-024

- Direct stop production t̃ -> t N_1 (0-lepton) final state like $t\bar{t}$+MET
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- Also utilize m_T(b,MET) as key discriminating variable

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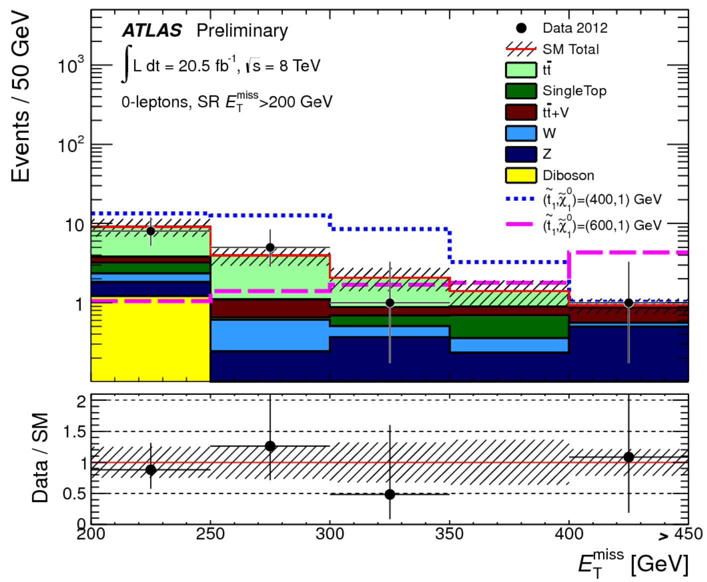
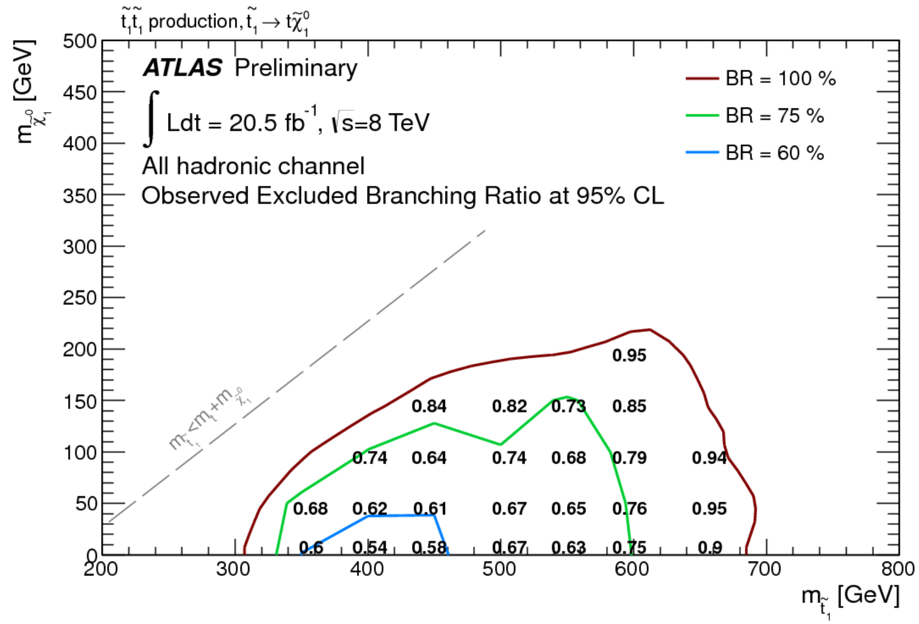
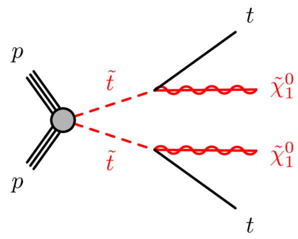




More details in talk by P Jackson

Searches for "Natural" SUSY scenarios

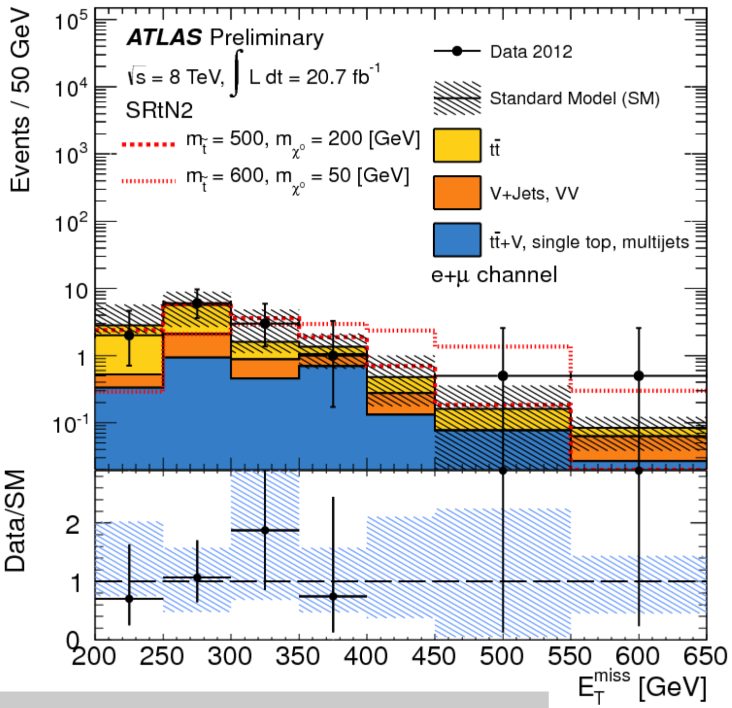
Direct stop pair production: **1-lepton + 2b + 4 jets + MET**

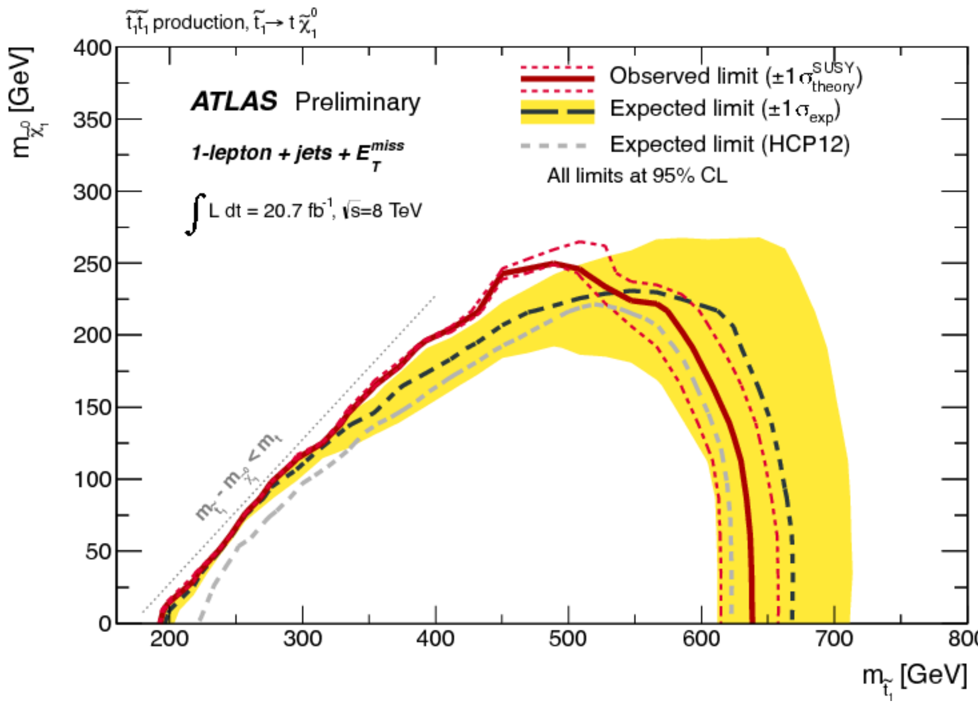


Most recent ATLAS references (8 TeV): ATLAS-CONF-2013-037

- Direct stop production (1-lepton) final state like $t\bar{t}$+MET
- Use of 2 m_{T2} variants to reduce background from di-leptonic top and W+Jets

- 6 SRs targeting different parts of the simplified model plane ($\tilde{t}$ -> t N_1/ $\tilde{t}$ -> b C_1)
- Acceptance quite sensitive to stop handedness (RH used in limit plots)

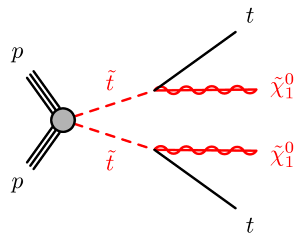




More details in talk by P Jackson

Searches for "Natural" SUSY scenarios

Direct stop pair production: **1-lepton + 2b + 4 jets + MET**



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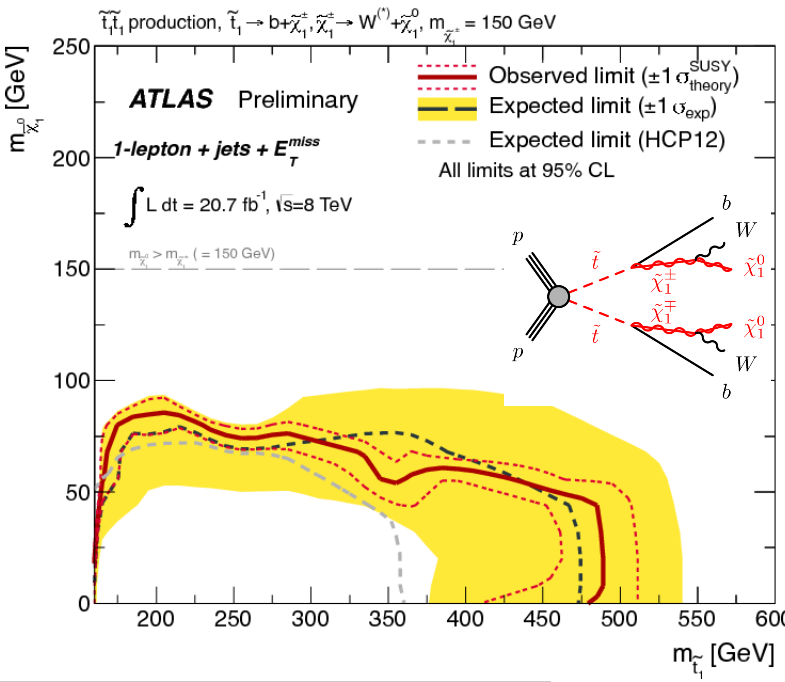
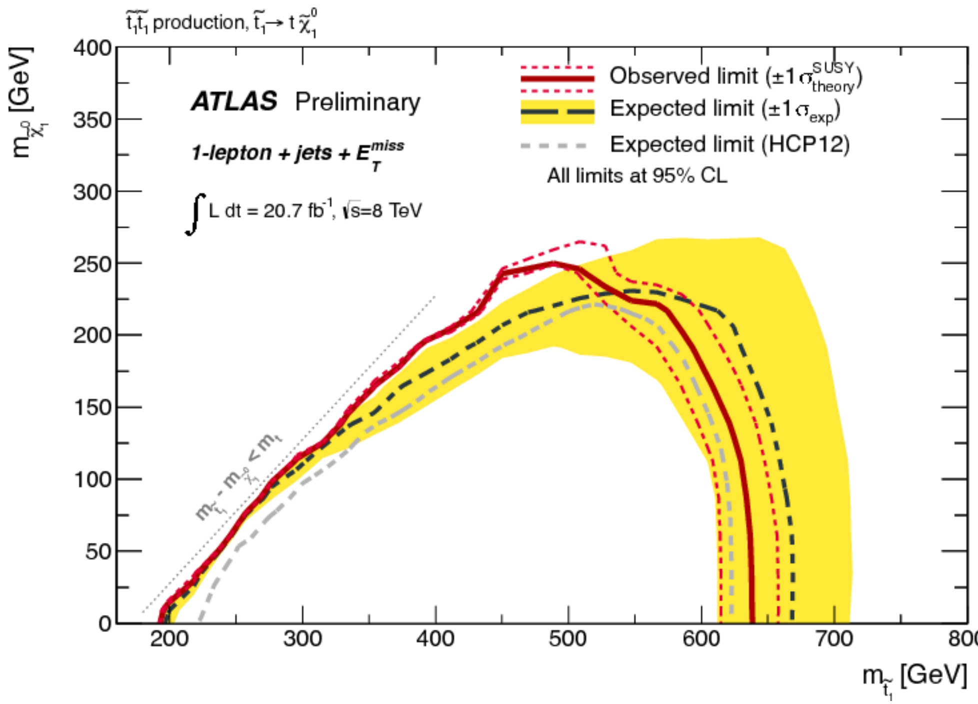
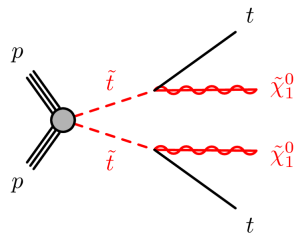




More details in talk by P Jackson

Searches for "Natural" SUSY scenarios

Direct stop pair production: **1-lepton + 2b + 4 jets + MET**



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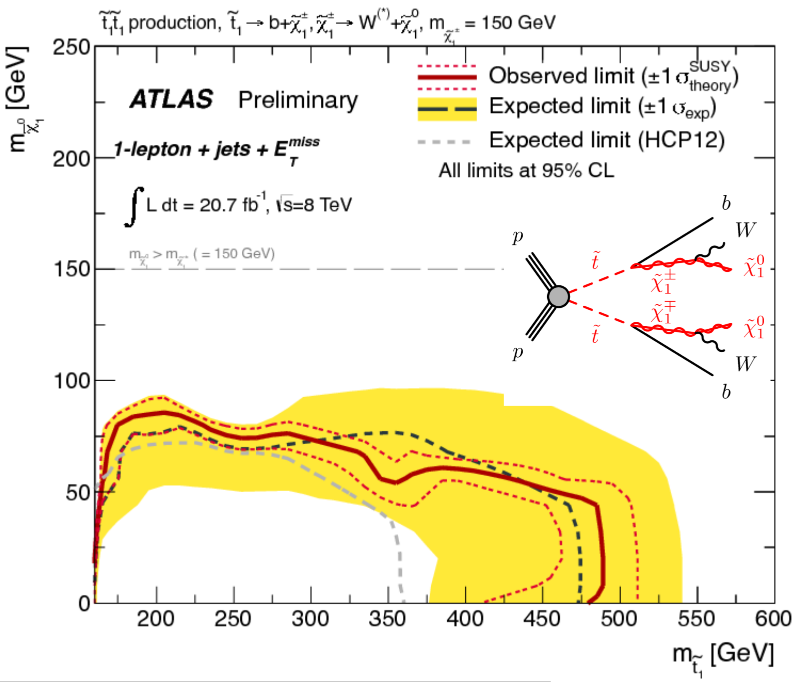

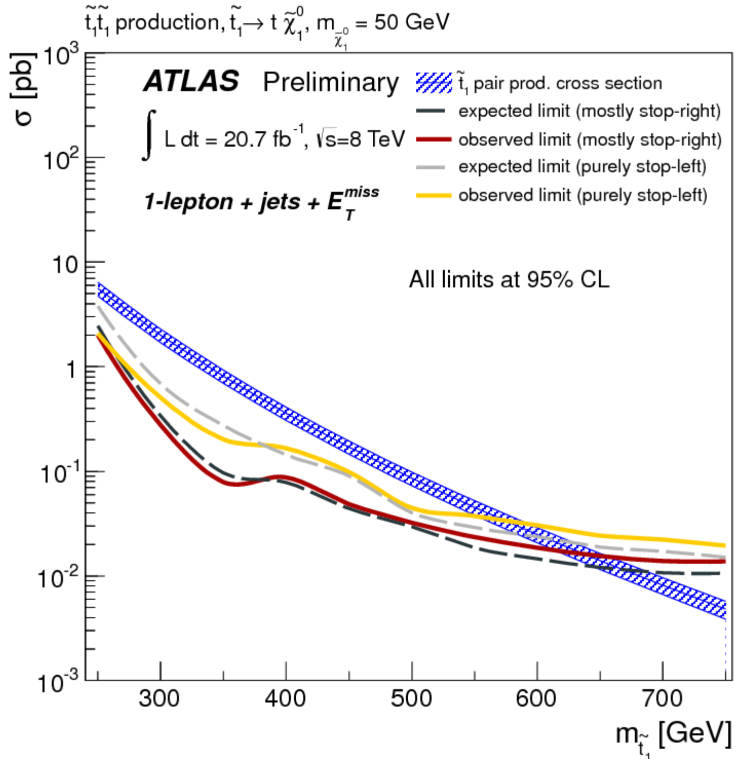

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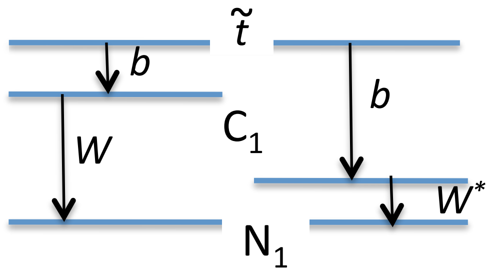
Searches for "Natural" SUSY scenarios

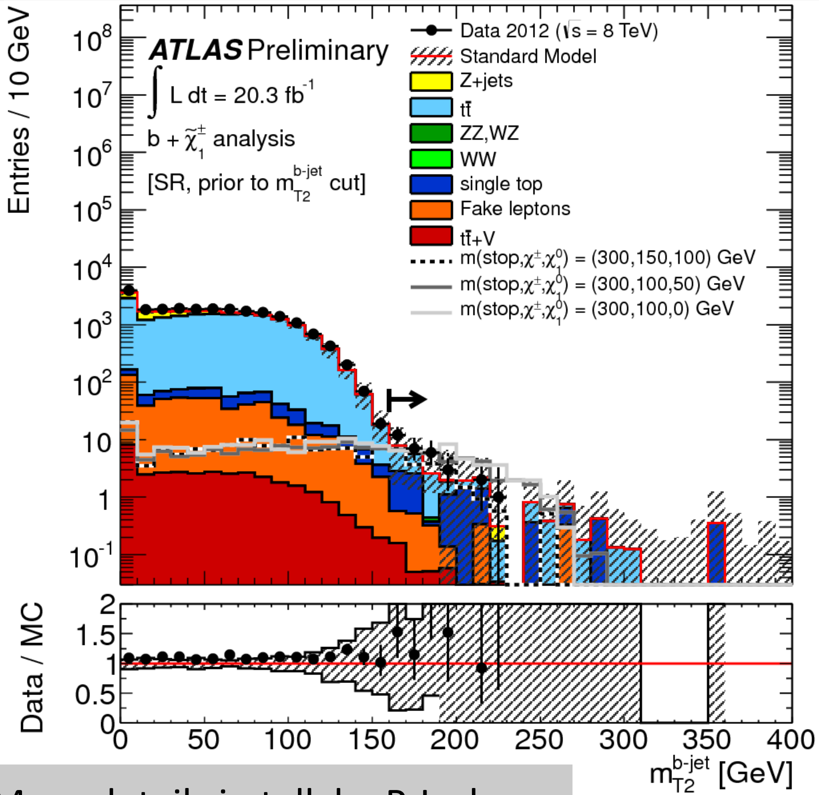
Direct stop pair production: **2-leptons (+ 1b) + MET**



Most recent ATLAS references (8 TeV): ATLAS-CONF-048, : ATLAS-CONF-065

- Targets $\tilde{t}$ -> b C_1

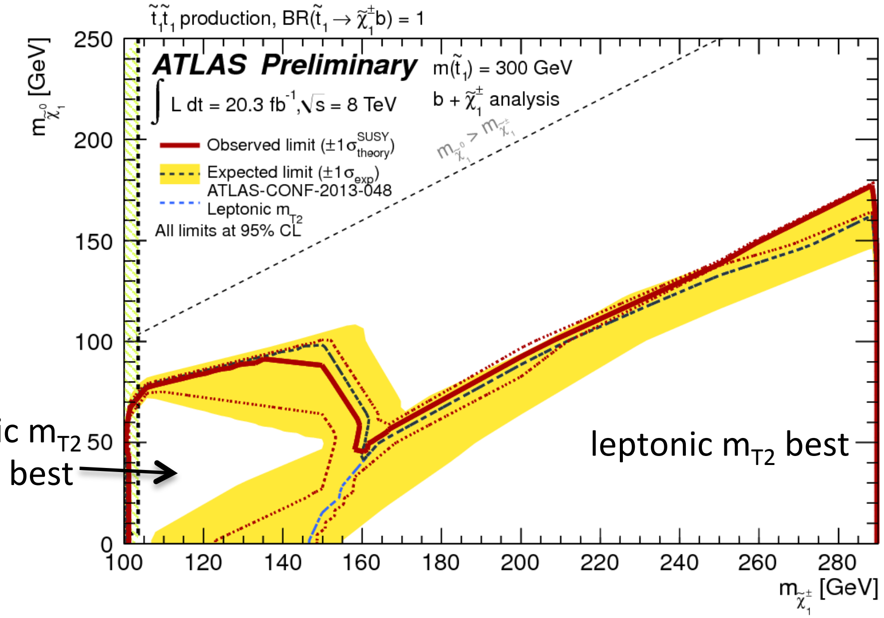
- Use of 2 versions of m_{T2} to reduce WW, Wt, $t\bar{t}$ backgrounds



- Leptonic m_{T2} analysis targeting large chargino neutralino mass splitting (main background WW) – no b-requirement

- Hadronic m_{T2} analysis targeting large stop-chargino mass splitting (main background $t\bar{t}$)

- MVA (BDT) analysis targeting $\tilde{t}$->tN_1

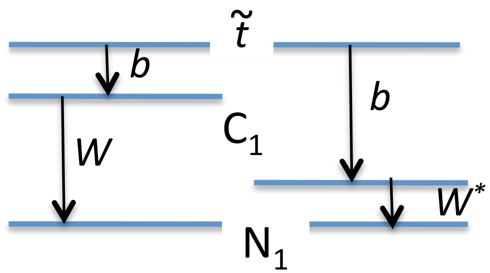


Hadronic m_{T2} analysis best

More details in talk by P Jackson

Searches for "Natural" SUSY scenarios

Direct stop pair production: **2-leptons (+ 2b) + MET**



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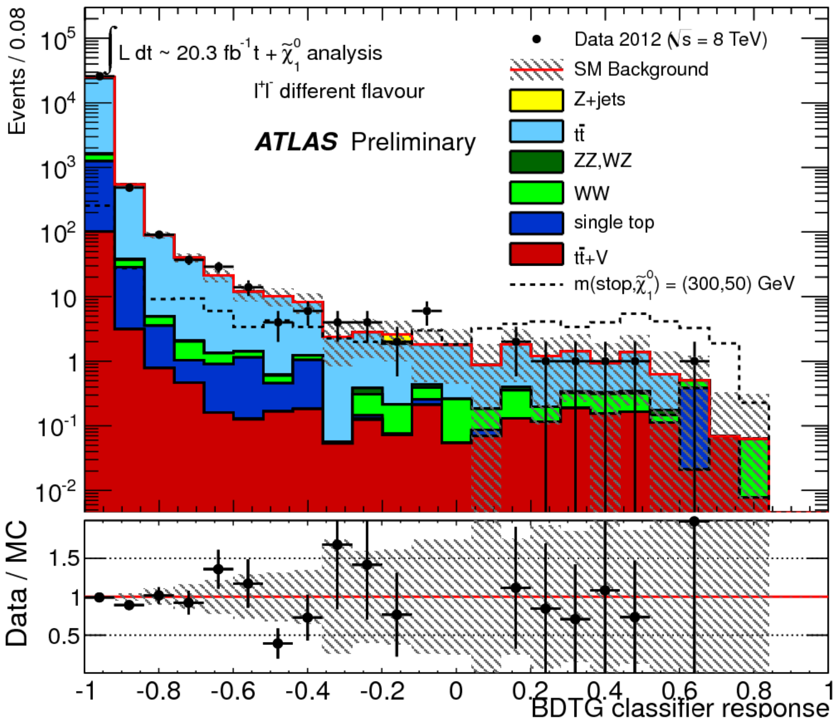

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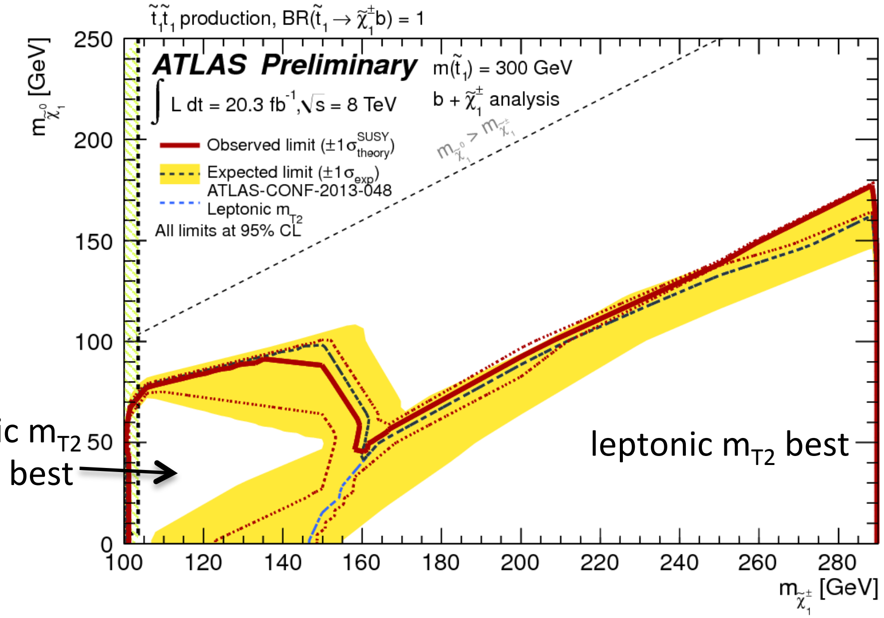
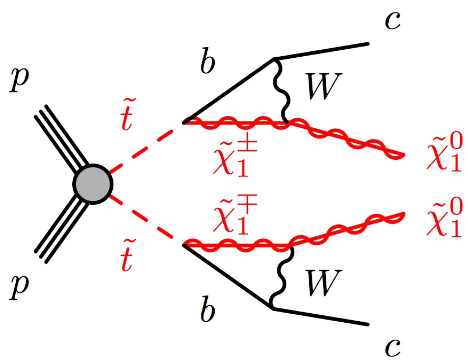


More details in talk by P Jackson

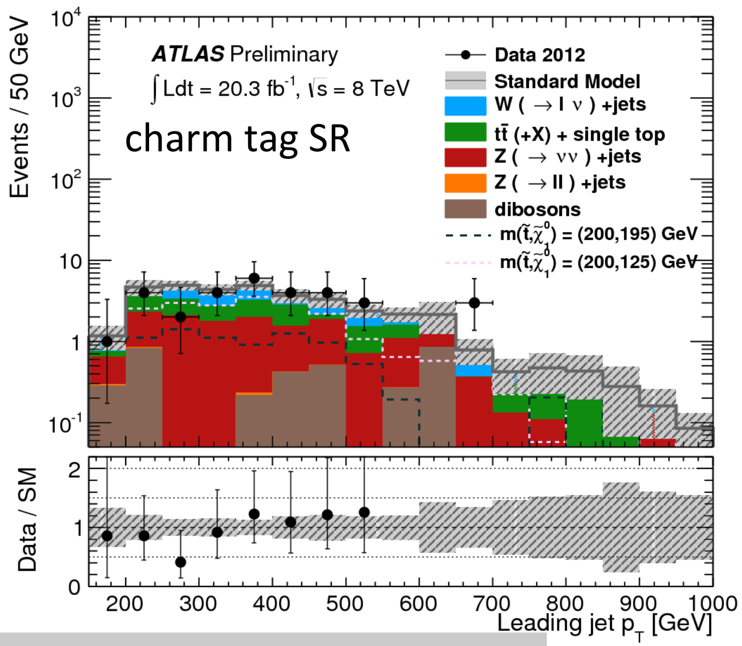
Searches for "Natural" SUSY scenarios

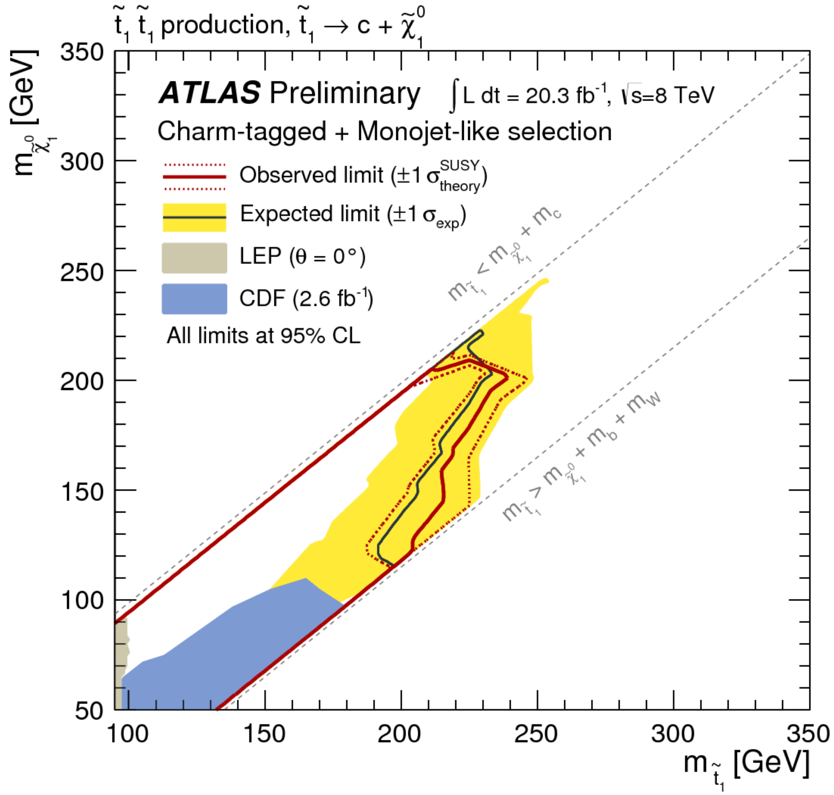
Direct stop pair production: charm analysis



Most recent ATLAS references (8 TeV): ATLAS-CONF-2013-068

- When $\tilde{t} \rightarrow t N_1$ / $\tilde{t} \rightarrow b C_1$ are not accessible $\tilde{t} \rightarrow c N_1$ becomes possible
- First LHC analysis addressing this difficult hierarchy
- 2 SRs with hard ISR jet to trigger, with/without explicit charm tag
- First LHC SUSY search with charm tagging! (calibrated on data D* sample)





More details in talk by P Jackson

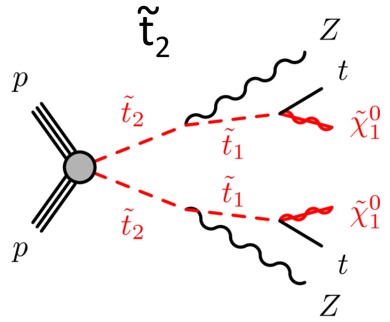
Searches for "Natural" SUSY scenarios

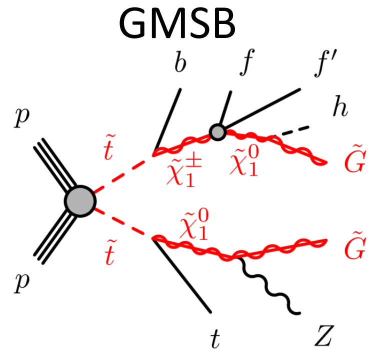
Direct stop pair production: **Z(ll) + b-jets + MET**

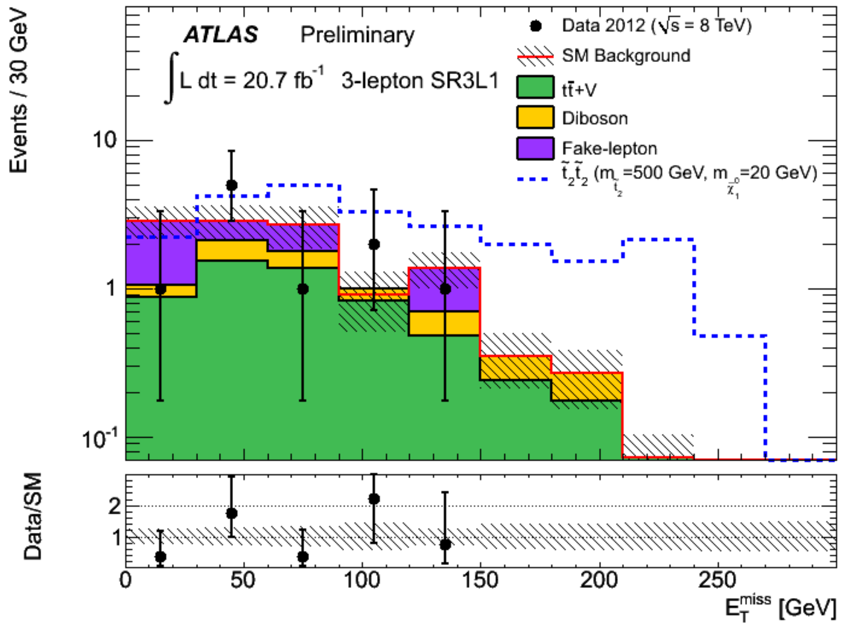
Most recent ATLAS references (8 TeV): ATLAS-CONF-2013-025

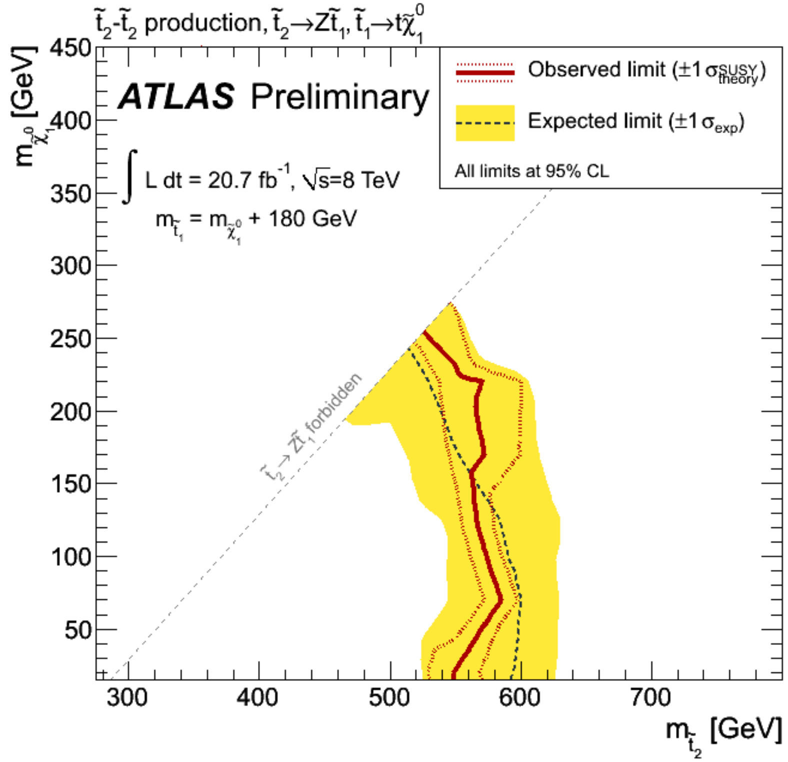
- $\tilde{t}_2$ production important when $m(t)+m(N_1)\sim m(\tilde{t}_1)$ (as then $\tilde{t}_1$ difficult to observe)

- Interpretation in GMSB and for $\tilde{t}_2$ decays





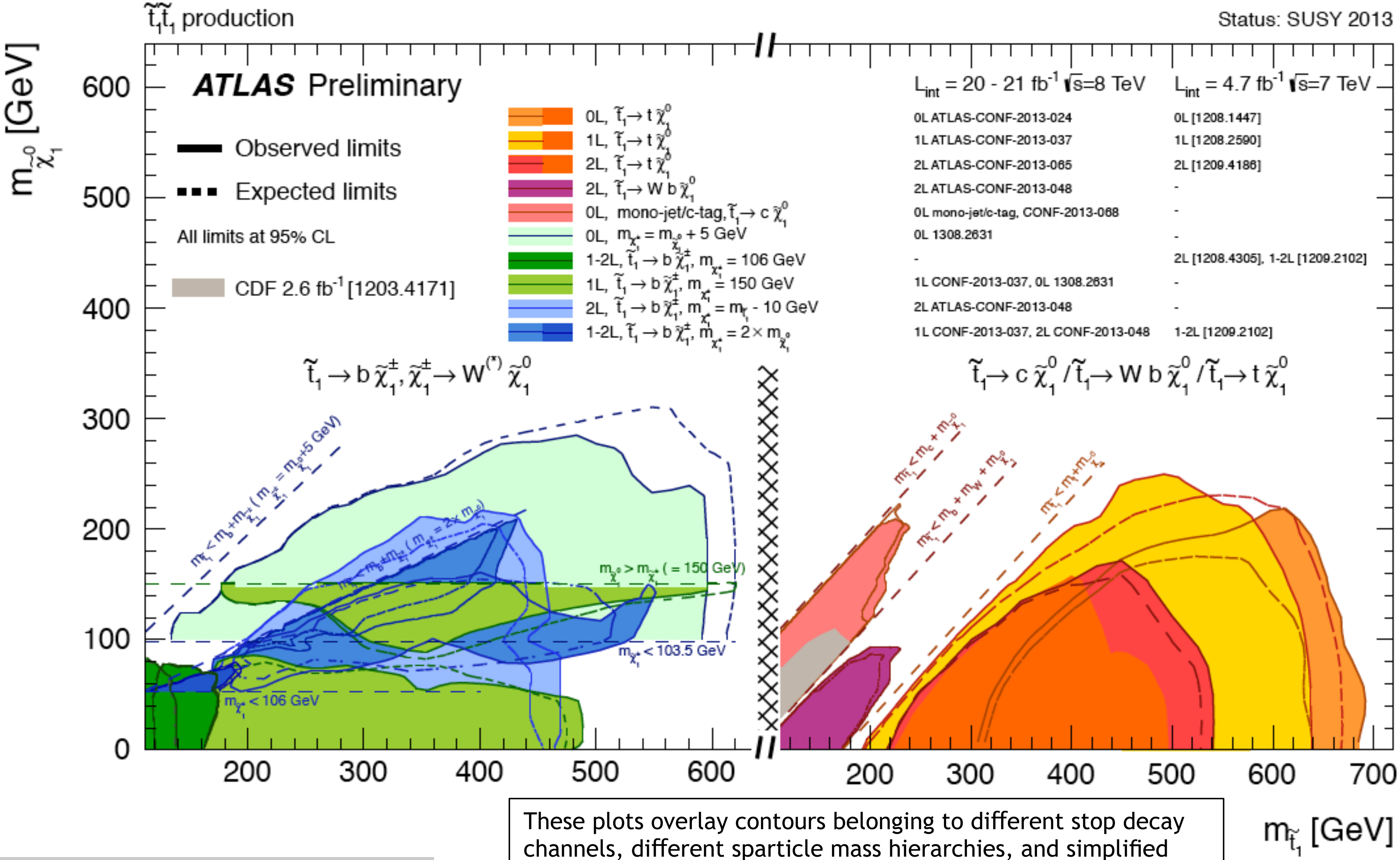




More details in talk by P Jackson

Searches for "Natural" SUSY scenarios

Direct stop pair production – summary



These plots overlay contours belonging to different stop decay channels, different sparticle mass hierarchies, and simplified decay scenarios. Care must be taken when interpreting them.

More details in talk by P Jackson

Searches for "Natural" SUSY scenarios

Electroweak neutralino & chargino and, possibly, slepton pair production

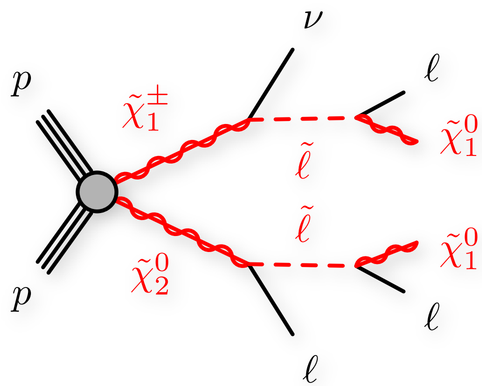
Most recent ATLAS references (8 TeV): ATLAS-CONF-2013-049, ATLAS-CONF-2013-036, ATLAS-CONF-2013-035, ATLAS-CONF-2013-028

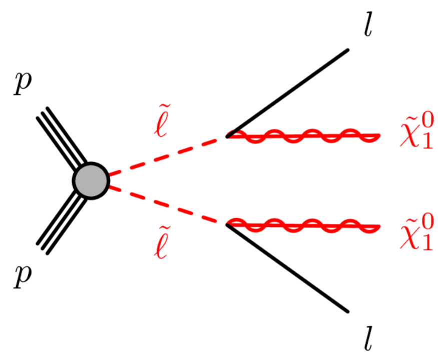
Electroweak SUSY particle production occurs through intermediate *W* and Drell-Yan processes

Search strategy depends on **slepton masses** and **gauge mixture:** 2/3/4 leptons + MET searches

Largest cross section for wino-like $\tilde{\chi}$'s. Smaller if higgsino (then also mass-degenerate with LSP)

3-lepton final state if light sleptons



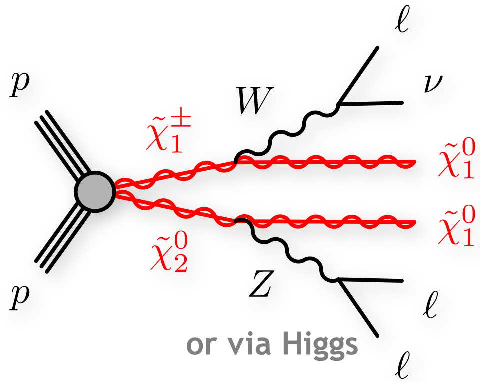


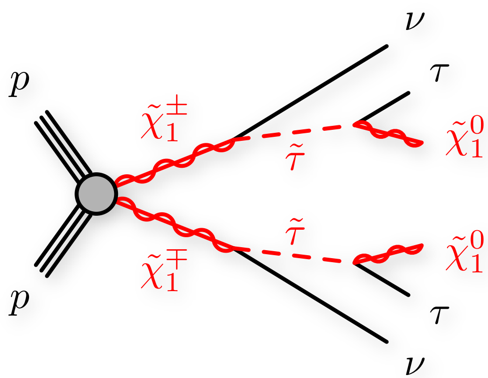
Larger cross section for slepton-left

2L + MET final state

If sleptons heavy, reduced branching ratio to leptons

Equivalent picture for chargino pair production: no-slepton case produces *WW* + MET final state



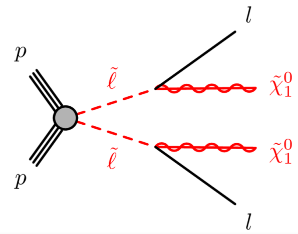


Plausible possibility for light $\tilde{\tau}_1$, while other sleptons heavy

Characteristic multi-lepton signatures with low hadronic activity: low SM BG

Searches for "Natural" SUSY scenarios

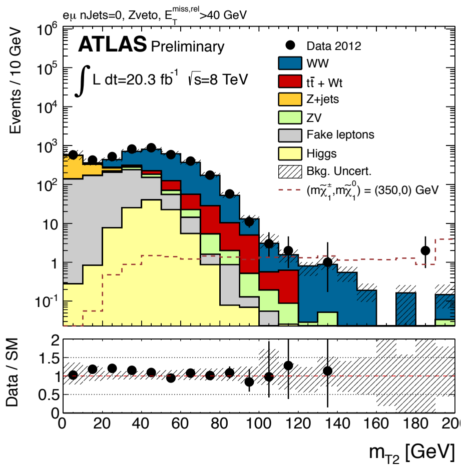
Direct slepton pair production: **2-lepton + 0-jets + MET**



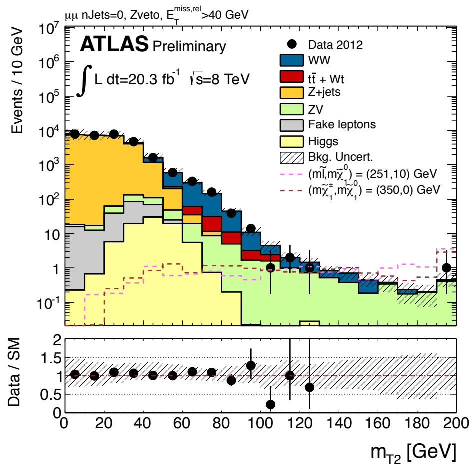
Most recent ATLAS references (8 TeV): ATLAS-CONF-2013-049

- -Separation with m_{T2} & MET
- -Jet veto to reduce top bkg
- -Dominant bkg from di-boson events
    - - large theory uncertainty from di-boson (Powheg MC)

Different flavour

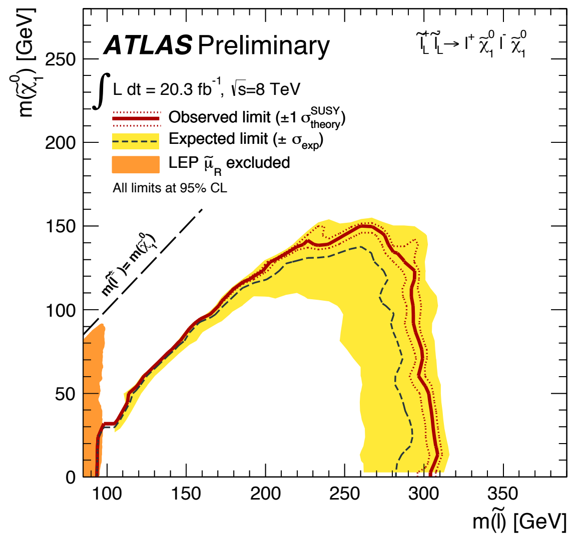


Same flavour



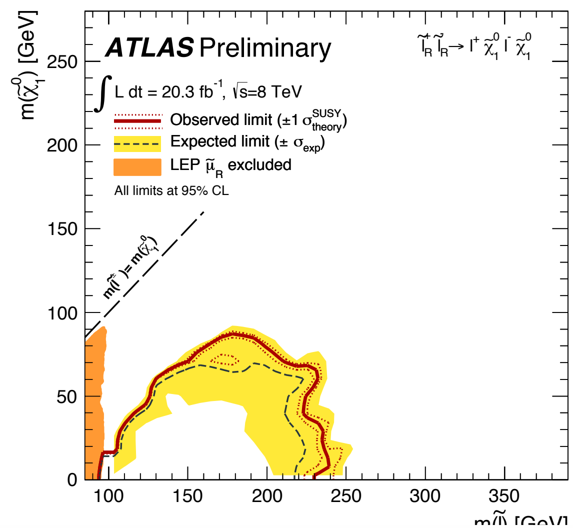
2 leptons (e/mu) + MET search

Different-flavour and same-flavour opposite charge generalised transverse mass distributions



Exclusion limits for slepton-left (top) and slepton-right (bottom)

~2.5 times smaller cross section for slepton-right



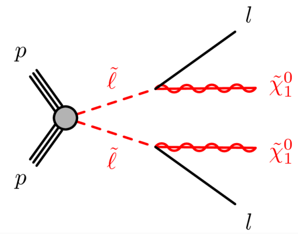
First limits on slepton-right production-only from LHC

$$m_{T2} = \min_{\mathbf{q}_T}\left[\max\left(m_T(\mathbf{p}_T^{\ell 1}, \mathbf{q}_T), m_T(\mathbf{p}_T^{\ell 2}, \mathbf{p}_T^{\mathrm{miss}} - \mathbf{q}_T)\right)\right]$$

More details in talk by C Potter

Searches for “Natural” SUSY scenarios

Direct slepton pair production: **2-lepton + 0-jets + MET**



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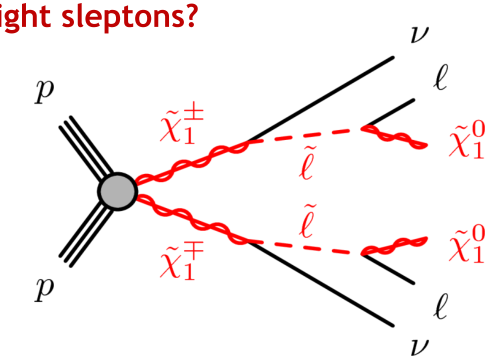
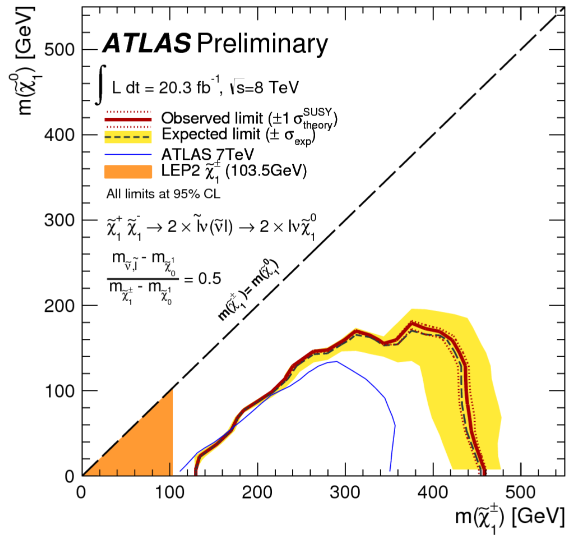
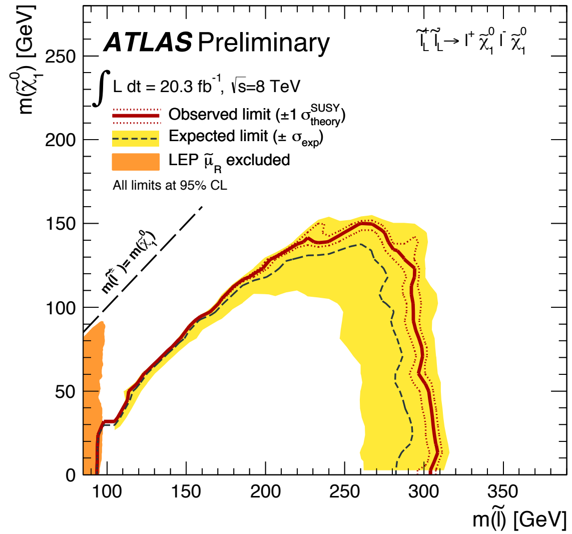
Different … ge generalised transverse mass distributions

Chargino production with light sleptons?

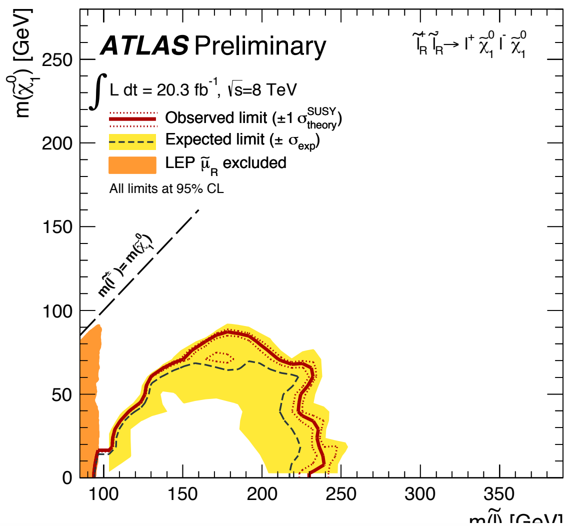






Exclusion limits for slepton-left (top) and slepton-right (bottom)

~2.5 times smaller cross section for slepton-right



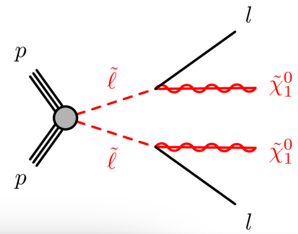
First limits on slepton-right production-only from LHC

$$m_{T2} = \min_{\mathbf{q}_T}\left[\max\left(m_T(\mathbf{p}_T^{\ell 1}, \mathbf{q}_T), m_T(\mathbf{p}_T^{\ell 2}, \mathbf{p}_T^{miss} - \mathbf{q}_T)\right)\right]$$

More details in talk by C Potter

Searches for "Natural" SUSY scenarios

Direct slepton pair production: **2-lepton + 0-jets + MET**



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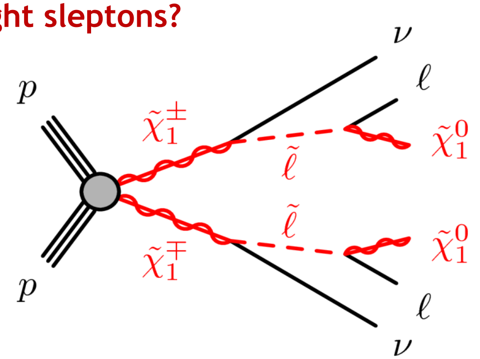
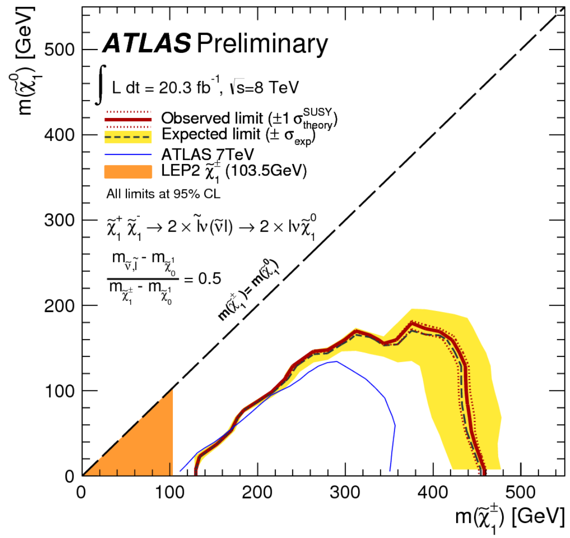
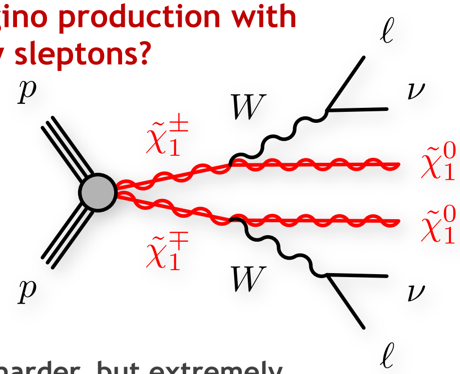
Chargino production with light sleptons?

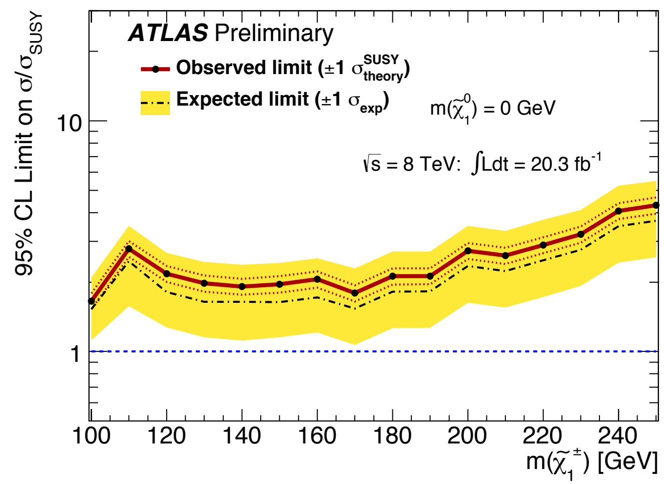




Chargino production with heavy sleptons?



Much harder, but extremely interesting scenario - barely sensitive



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Different ... ge generalised transverse mass distributions

$$m_{T2} = \min_{\mathbf{q}_T}\left[\max\left(m_T(\mathbf{p}_T^{\ell 1}, \mathbf{q}_T), m_T(\mathbf{p}_T^{\ell 2}, \mathbf{p}_T^{\text{miss}} - \mathbf{q}_T)\right)\right]$$

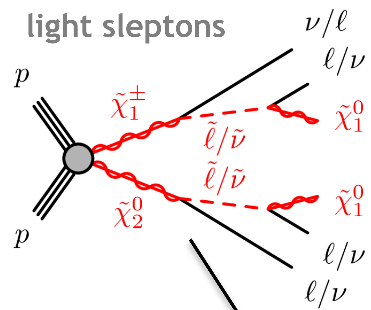
More details in talk by C Potter

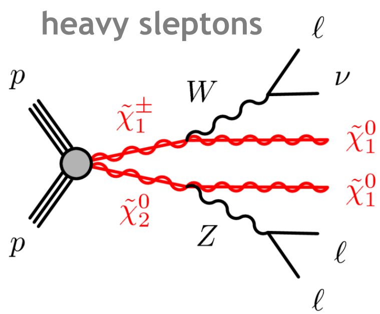
Searches for “Natural” SUSY scenarios

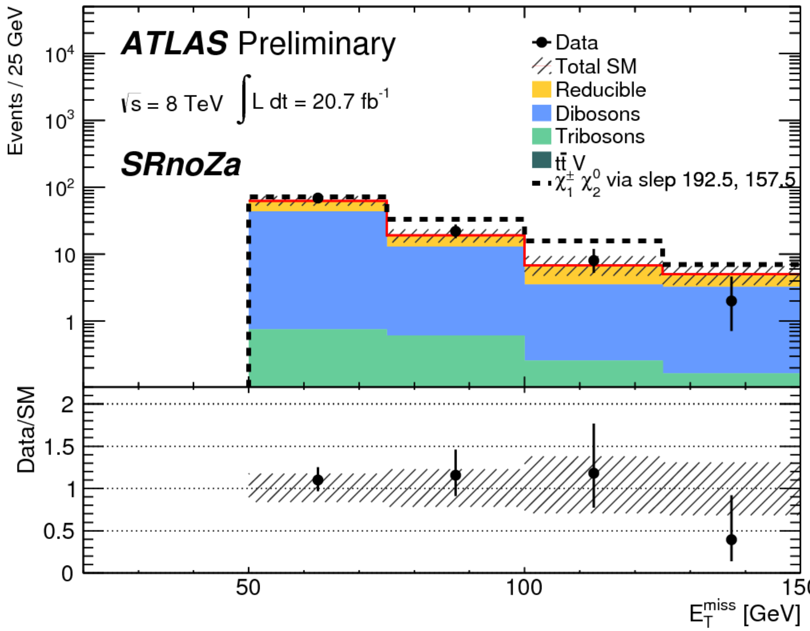
Electroweak production of SUSY: **3-lepton + 0 b-jets + MET**

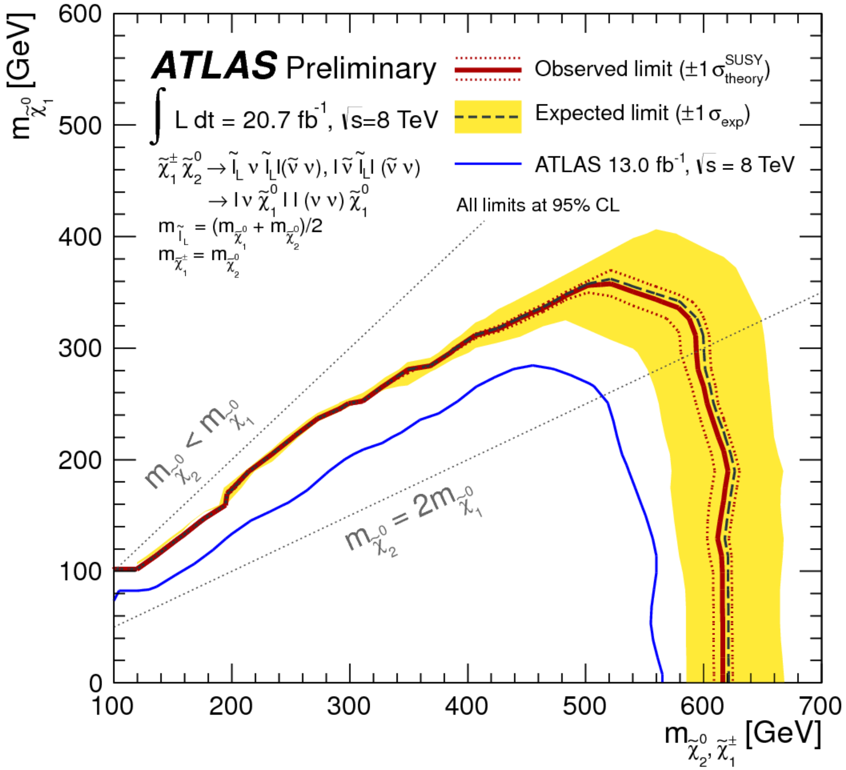
Most recent ATLAS references (8 TeV): ATLAS-CONF-2013-035

-b-jet veto to reject top
-6 SRs targeting C_1N_2 production (including Z enriched/depleted)
-Main background WZ









More details in talk by C Potter

Searches for “Natural” SUSY scenarios

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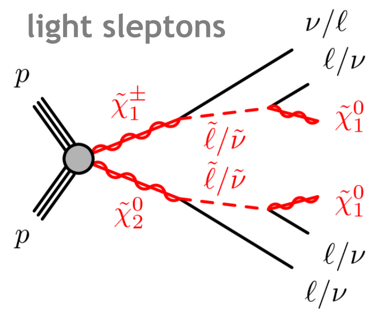
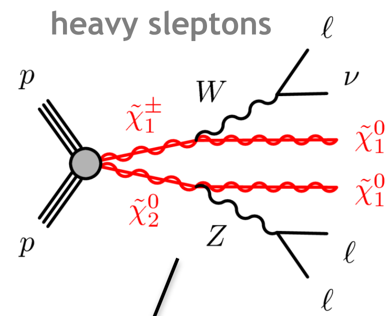
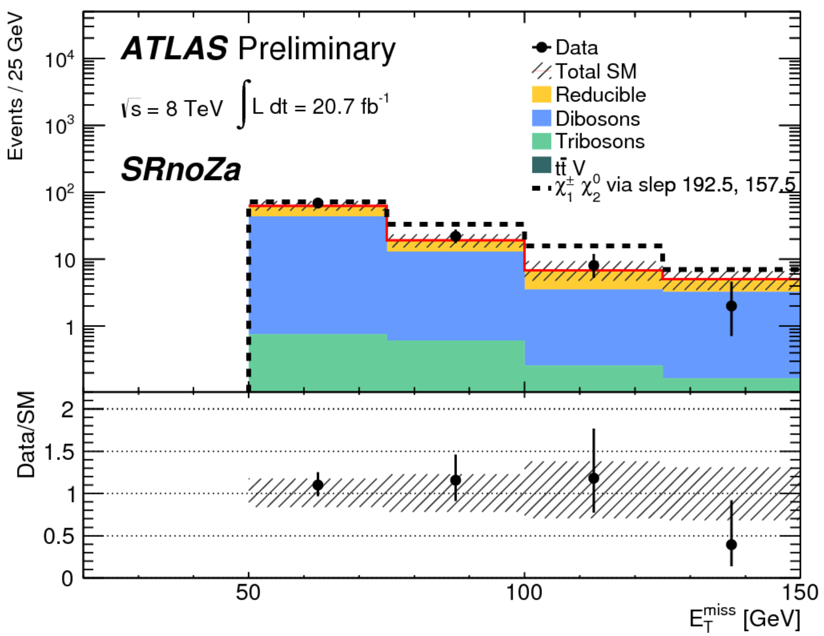
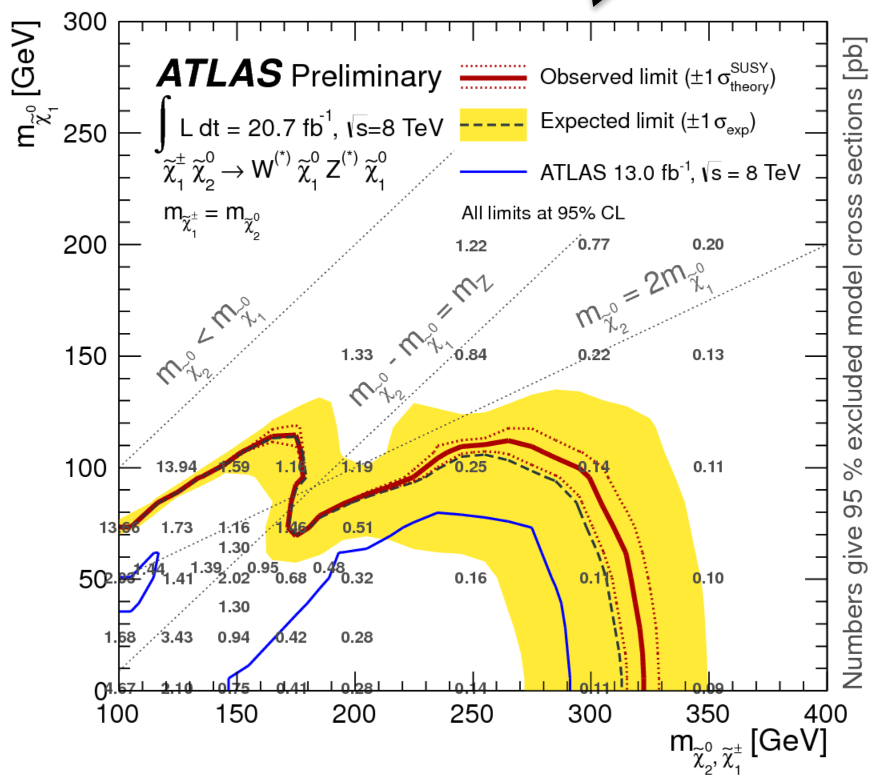




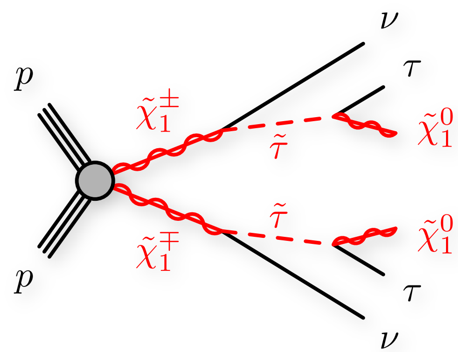




More details in talk by C Potter

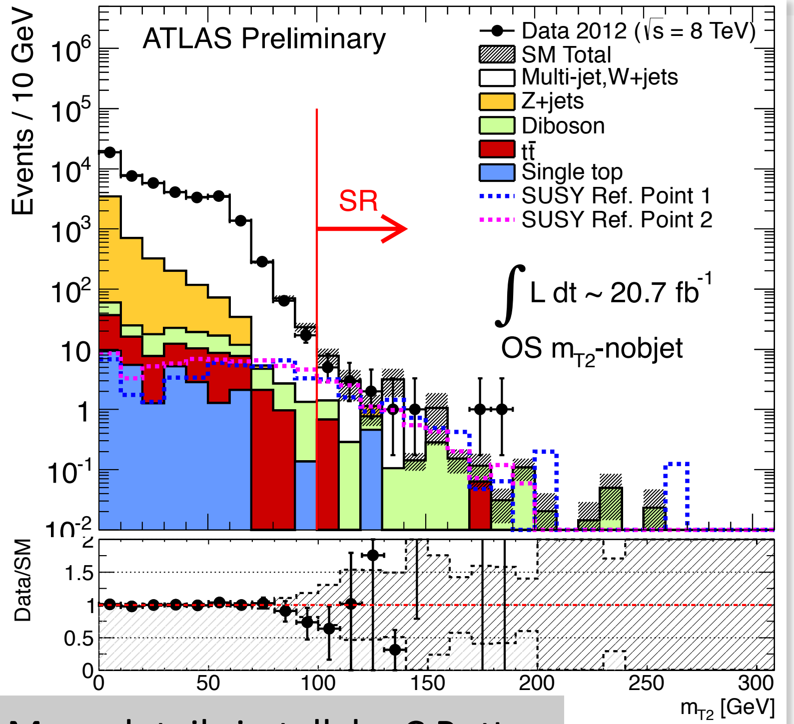
Searches for "Natural" SUSY scenarios

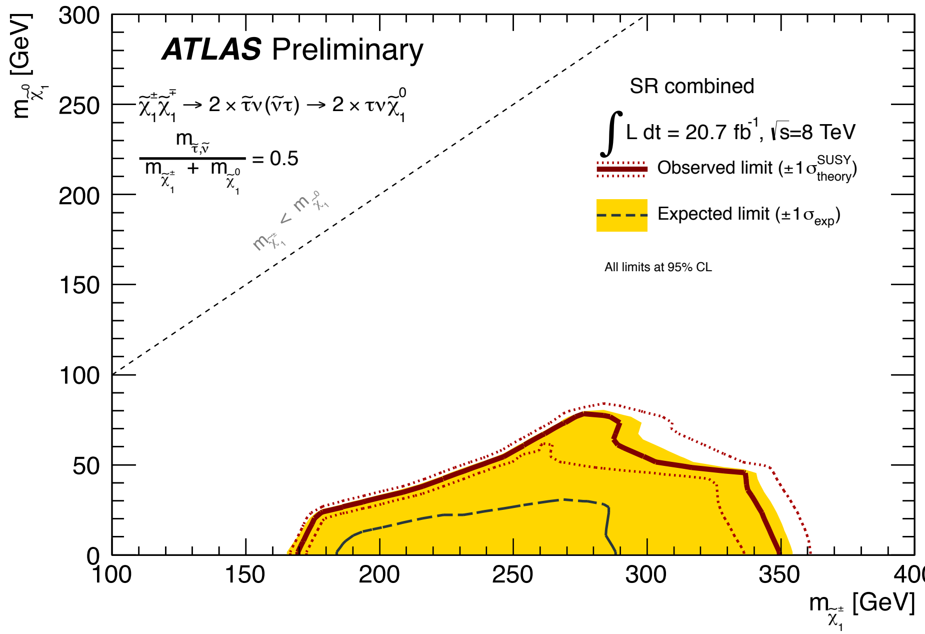
Electroweak production of SUSY: **2-taus + 0-jets + MET**



Most recent ATLAS references (8 TeV): ATLAS-CONF2013-028

- -Target chargino pair production with light staus
- -2 SRs with opposite sign hadronic taus
- -m_{T2} key variable
- -Bkg dominated by fake taus (multijet)



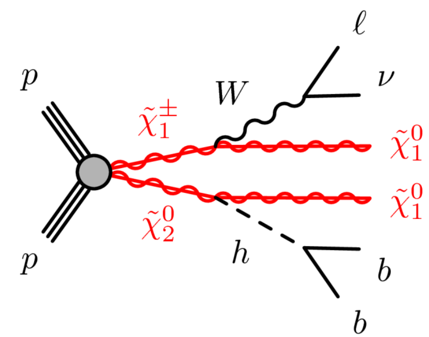


More details in talk by C Potter

New for this conference!

Searches for “Natural” SUSY scenarios

Electroweak production of SUSY: **1 lepton + bb + MET**



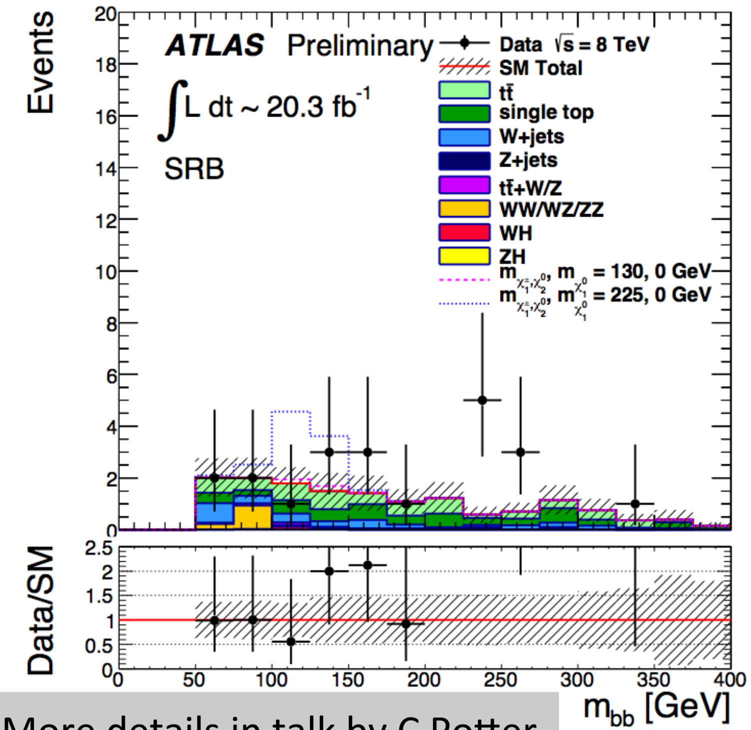
Most recent ATLAS references (8 TeV): ATLAS-CONF-2013-093

- Scenarios where N_2 dominantly decays to Higgs have not been covered by ATLAS searches so far
- New analysis to address this
- bb from Higgs (first analysis to try to reconstruct a Higgs decay!)

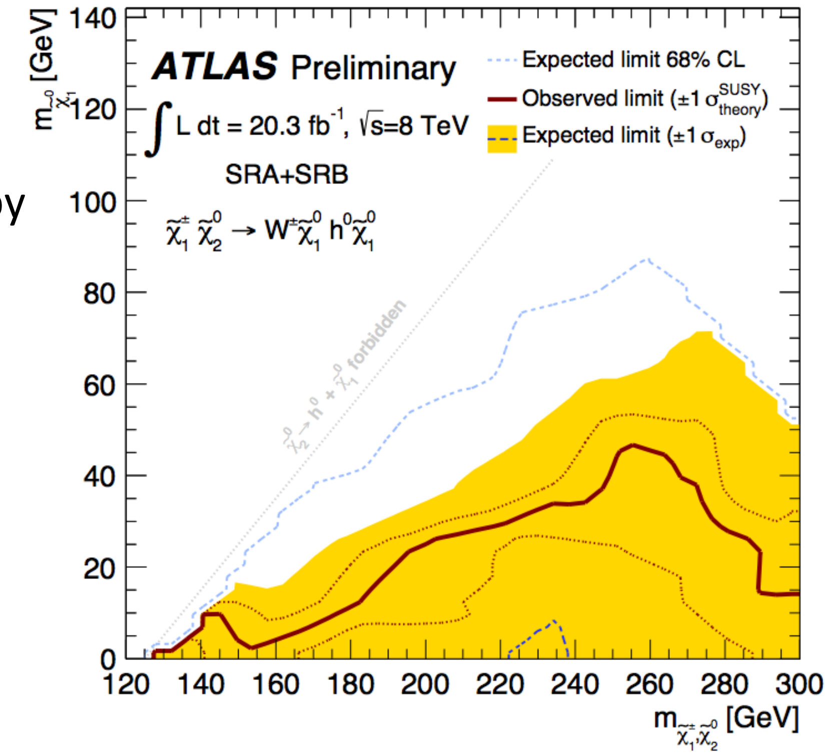
-Very difficult due to huge background from top

-m_{CT} variable used to suppress top, m_T used to suppress W+jets

-Small parameter space exclusion



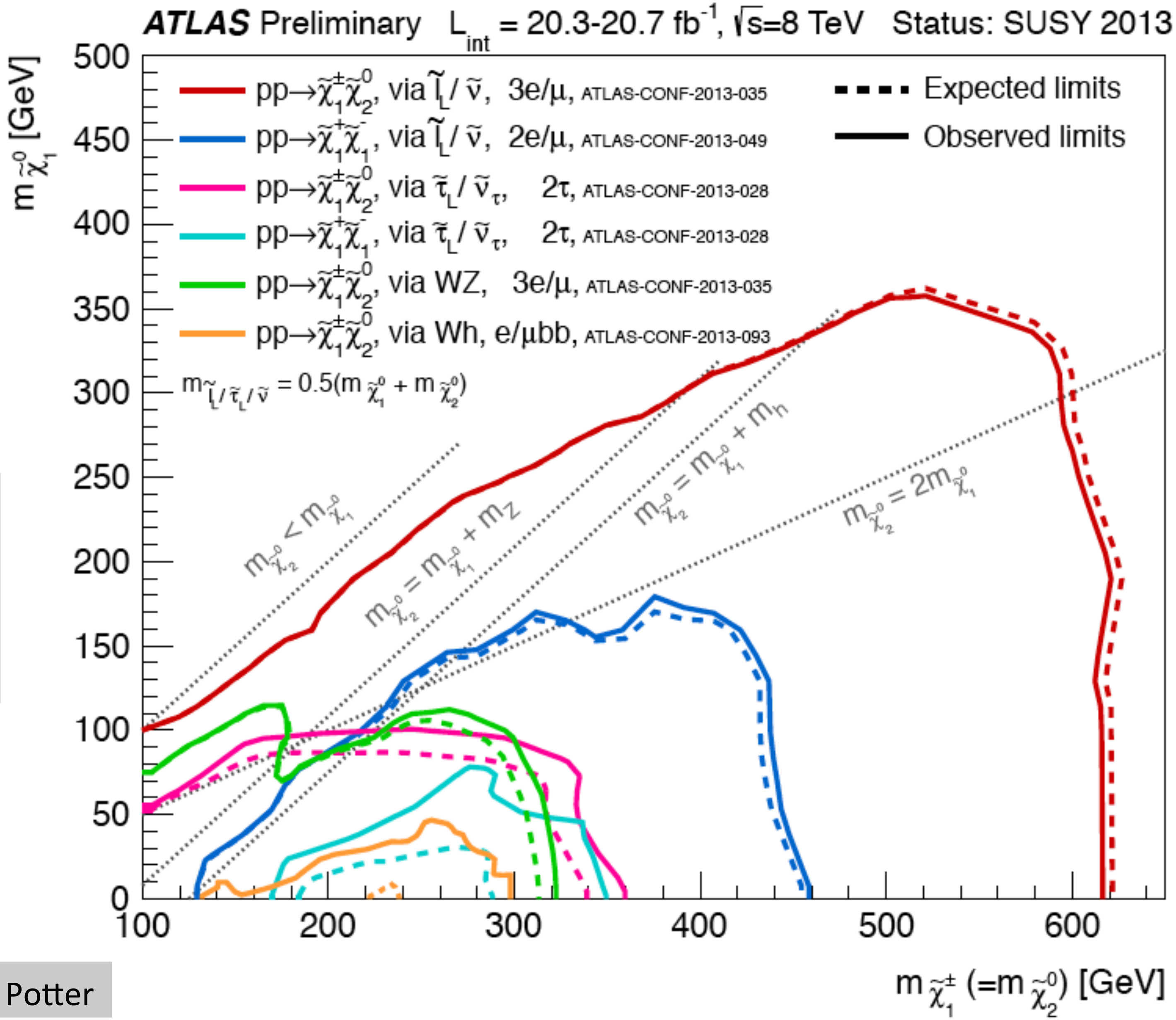
final result extracted by fit to m_{bb}



More details in talk by C Potter

Searches for "Natural" SUSY scenarios

Electroweak production of SUSY Summary



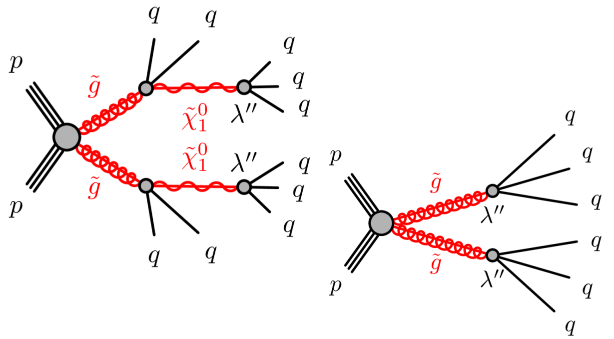
Also have a 4-lepton analysis targeting $N_{2/3}$ decays via sleptons – see backup for details

More details in talk by C Potter

New for this conference!

RP violation and long-lived particles

RPV decays giving large jet multiplicity



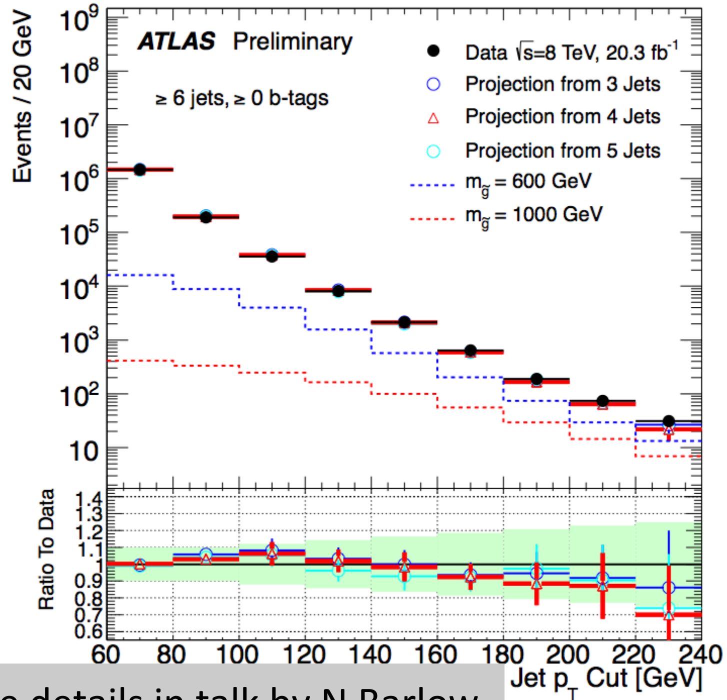
Most recent ATLAS reference (8 TeV): ATLAS-CONF-2013-091

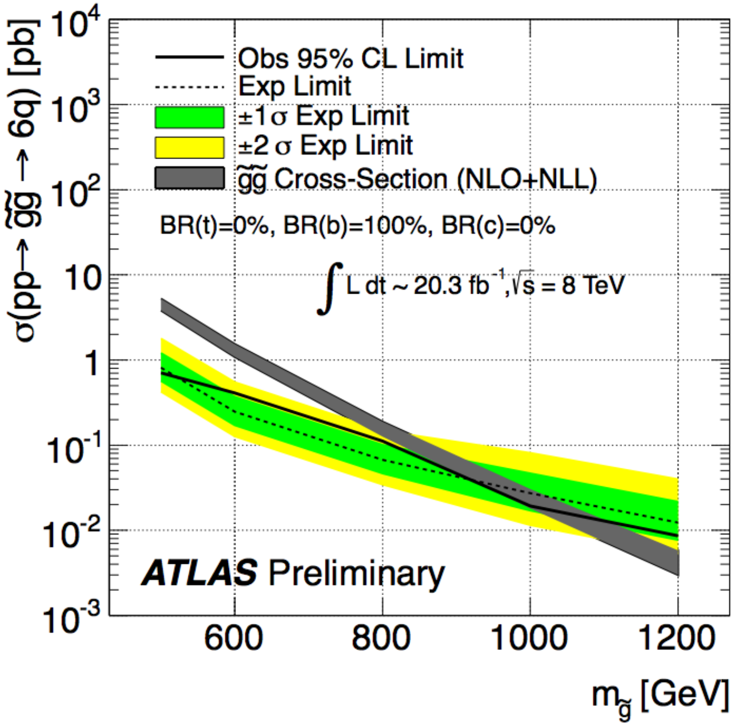
RPV coupling can allow LSP to decay to 3 quarks => many jets in final state

Analysis carried out for ≥6 and ≥7 jet signal regions with and without b-jet requirements

Background normalized to data in lower jet multiplicity CRs and extrapolated to SR with MC

Systematic uncertainties measured in data using multiple validation regions





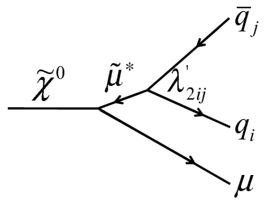
More details in talk by N Barlow

New for this conference!

RP violation and long-lived particles

RPV decays giving a displaced vertex

bench mark model

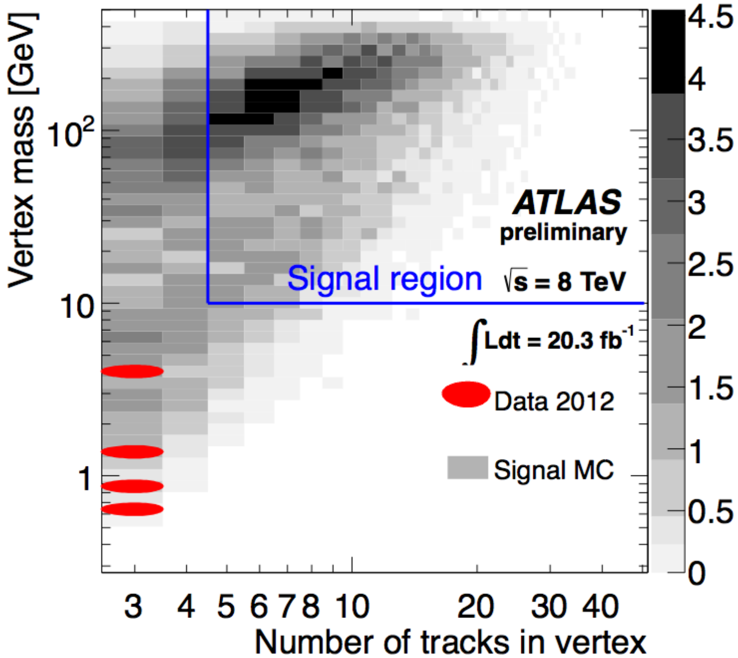


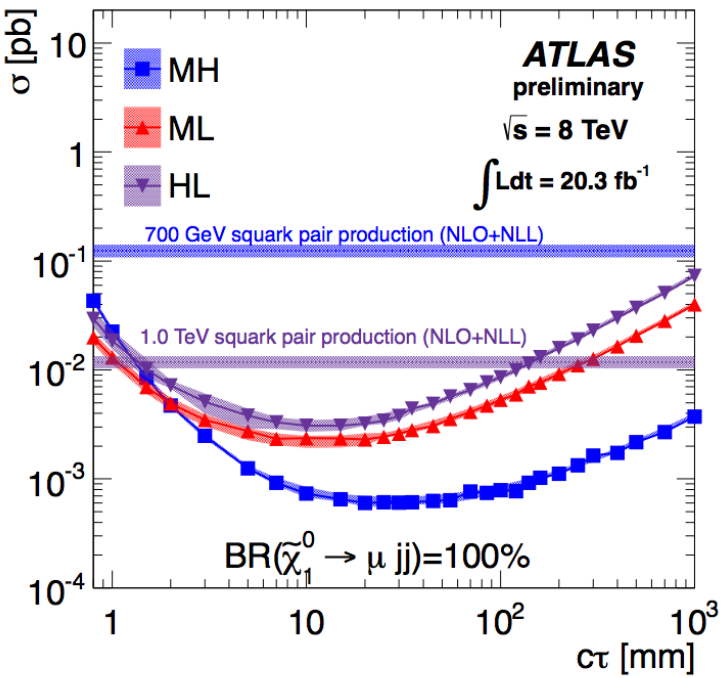
Most recent ATLAS reference (8 TeV): ATLAS-CONF-2013-092

Search for high multiplicity, high mass displaced vertex (with associated high p_T muon (>55 GeV) - used to trigger). To reduce background from hadronic interactions, vertex required to be in a low density material region of the detector. Radial range covered 0.4-18 cm.

Dedicated re-tracking algorithm used to increase acceptance at high radius.

0.02±0.02 background events expected!





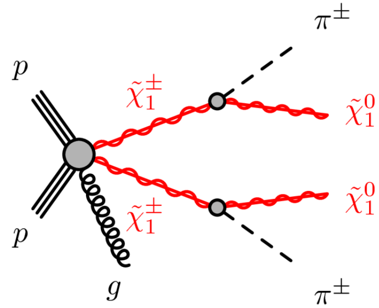
More details in talk by N Taiblum

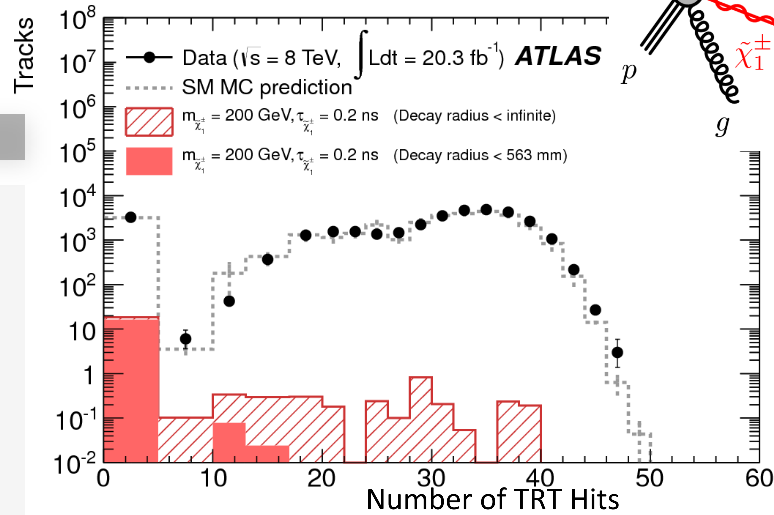
RP violation and long-lived particles

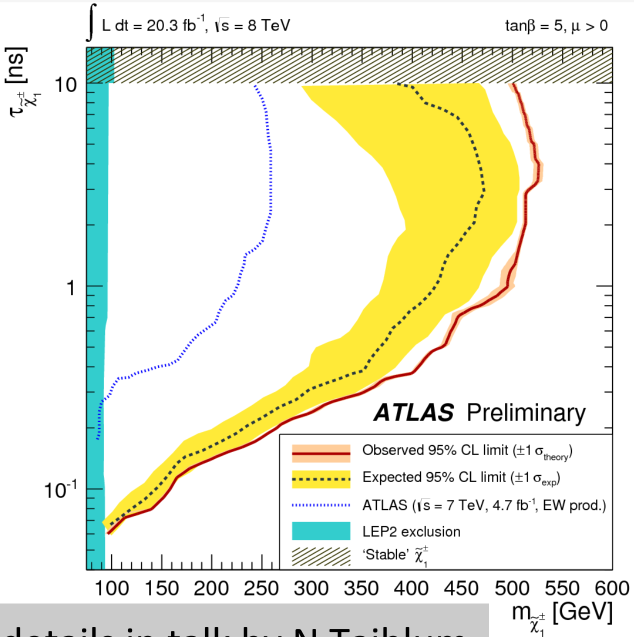
Disappearing track signature in AMSB

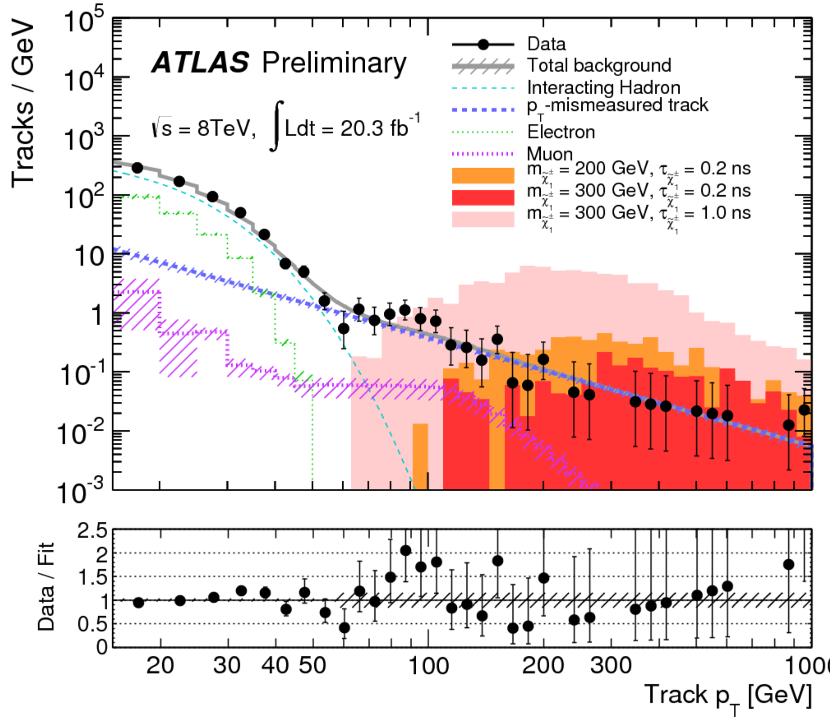
Most recent ATLAS references (8 TeV): ATLAS-CONF-2013-069

- AMSB model where chargino nearly degenerate with LSP => can travel measurable distance before decaying to an (undetectable) pion
- Search for disappearing charged track in events with high p_T ISR jet (to trigger)
- Signal extracted by fit to track p_T spectrum









More details in talk by N Taiblum

RP violation and long-lived particles

GMSB models (and others) can also lead to massive long-lived particles (LLP)

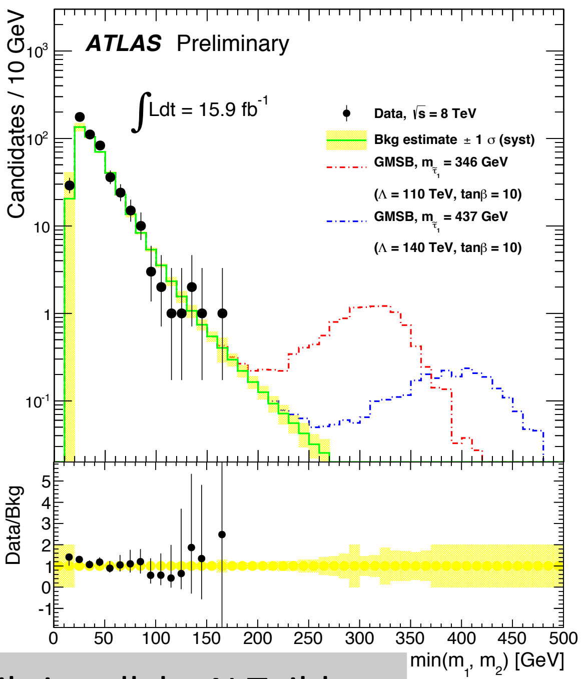
Most recent ATLAS reference (8 TeV): ATLAS-CONF-2013-058

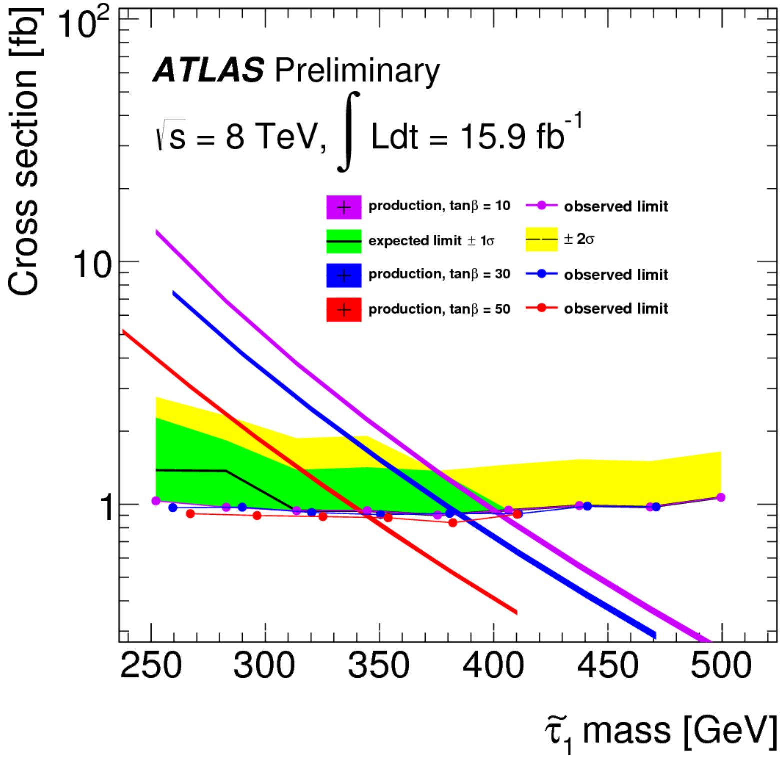
Massive long-lived particles are searched for by ATLAS via time-of-flight, specific ionization loss, and momentum measurements

Subsystems used: silicon trackers (βγ), calorimeters (β), muon systems (β)

Various combinations of subsystems to catch different possible natures of long-lived particles

Two long-lived slepton candidates





More details in talk by N Taiblum

RP violation and long-lived particles

Long-lived gluino *R*-hadrons can get stuck in the detector and decay much later

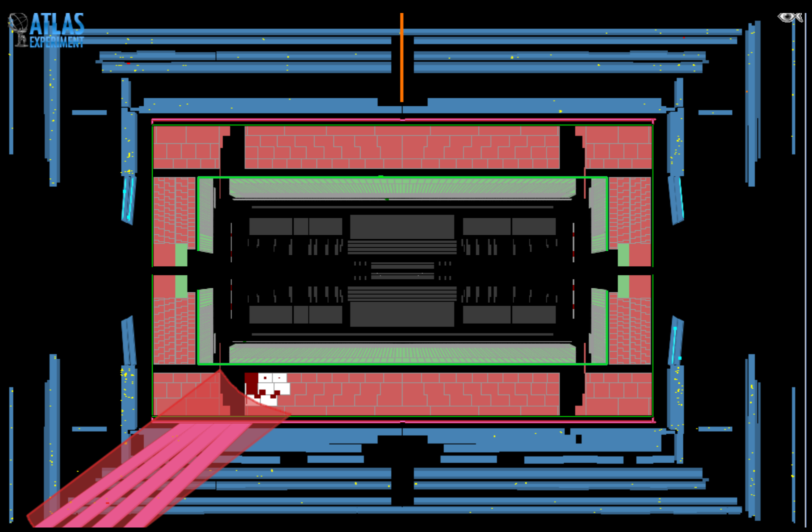
Most recent ATLAS reference (8 TeV): ATLAS-CONF-2013-057

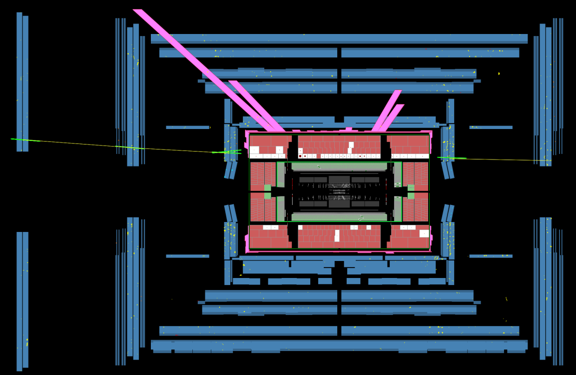
Search for hadronic calorimeter activity in out-of-time LHC collisions (using empty bunches)

Background dominated by beam-halo (measured in unpaired bunches) and cosmics (measured in low-lumi runs)

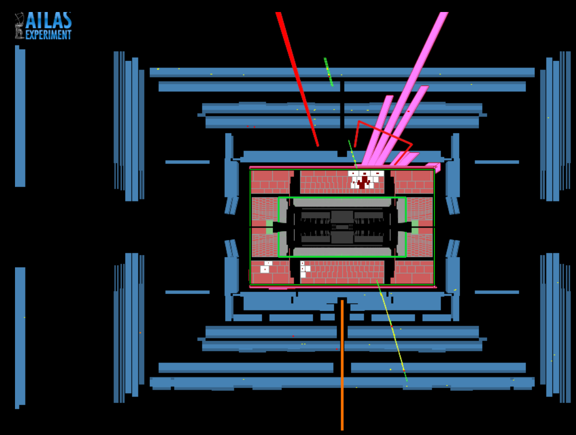
Strong model dependence in signal stopping fraction

Stopped gluino candidate in 8 TeV data





A beam-halo candidate event in the unpaired data



A cosmic ray background event passing all selection requirements except for muon segment veto

More details in talk by N Taiblum

RP violation and long-lived particles

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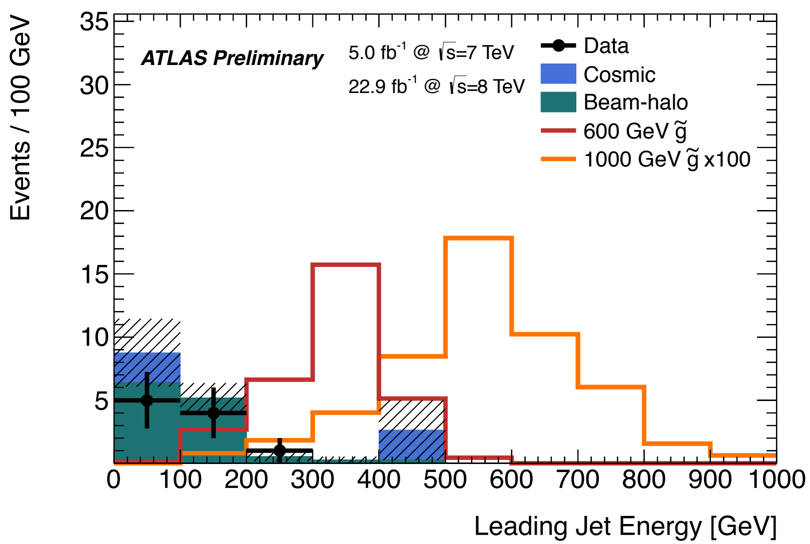
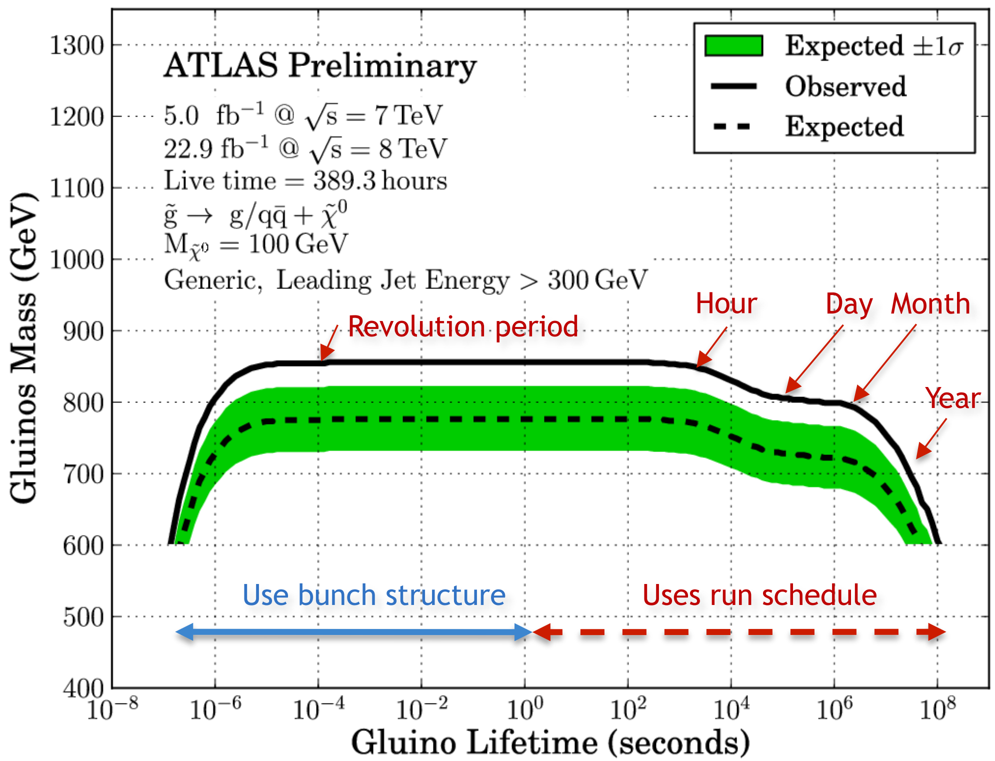




More details in talk by N Taiblum

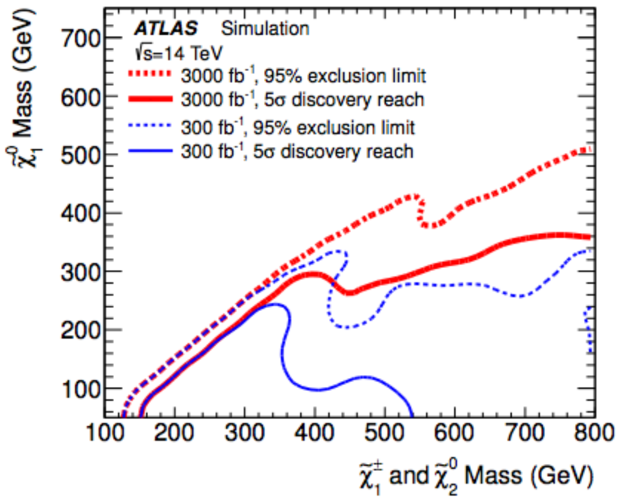
Summary

ATLAS is carrying out a detailed and thorough search for SUSY in the LHC run-1 dataset

We have to complete the job for the 2012 8 TeV data

R & D time during LS1 allows us to:

- Increase coverage for difficult SUSY regions
- Solidify our understanding of SM backgrounds by improving Monte Carlo generator predictions in collaboration with the generator authors, and by further measuring rare background channels
- Prepare for first high energy searches (in particular the trigger strategy must be finalized and validated well before first collisions)

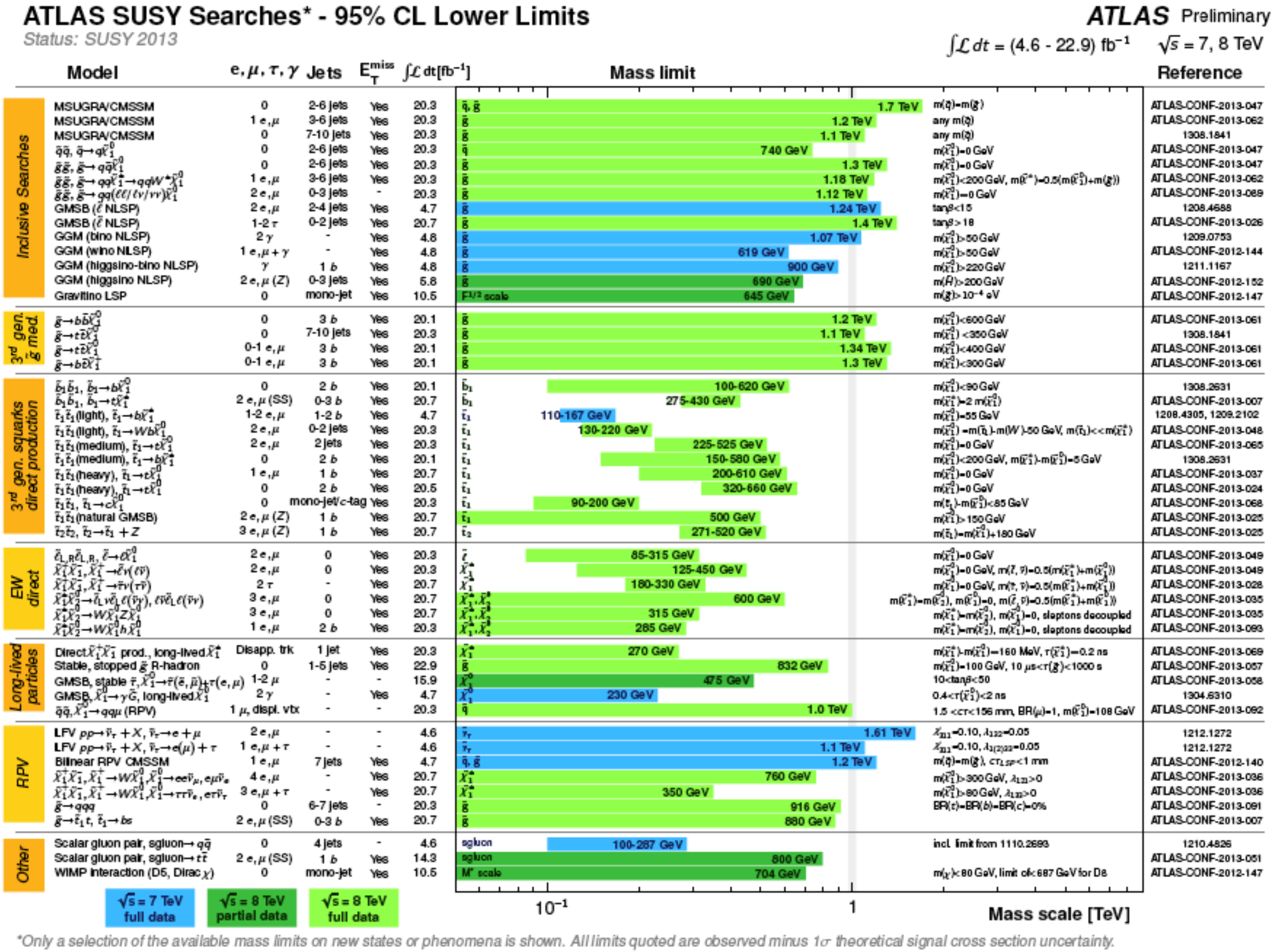


High energy running in 2015 will significantly increase our sensitivity to many SUSY scenarios

- Expect ~x10 for 600 GeV stops, ~x200 for 2 TeV gluinos

Looking forward to the next exciting years!

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults



ATLAS Parallel talks….

"Searches for gluino-mediated production of third generation squarks with the ATLAS detector"
M Barisonzi

"Search for supersymmetry in resonance production and R-parity violating signatures with the ATLAS detector"
N Barlow

"Inclusive searches for squarks and gluinos with the ATLAS detector"
M Hohlfeld

"Searches for direct pair production of third generation squarks with the ATLAS detector"
P Jackson

"Searches for electroweak production of supersymmetric neutralinos, charginos and sleptons with the ATLAS detector"
C Potter

"Search for supersymmetry in events with long-lived massive particles with the ATLAS detector"
N Taiblum

"Searches for supersymmetry in GGM or GMSB scenarios with photons or tau leptons and missing transverse momentum with the ATLAS detector"
M Tripiana

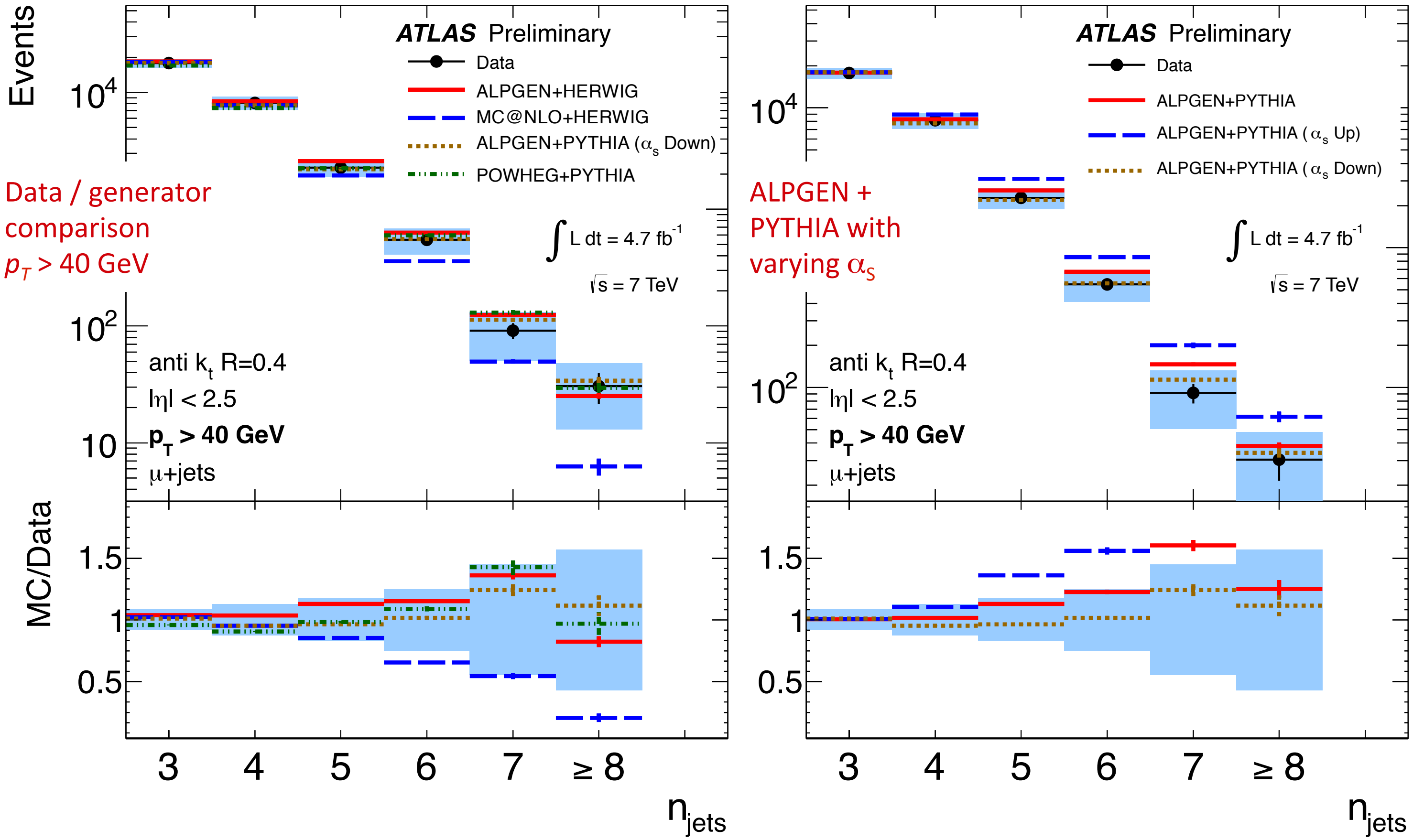
Top physics – differential measurements

Top pairs in association with jets are dominant background for most SUSY searches

ATLAS-CONF-2012-155, see also: 1203.5015

Measurement of fiducial jet multiplicity in $t\bar{t}$ production (lepton+jets) at 7 TeV (4.7 fb^{-1})

MC scaled to approx. NNLO inclusive prediction (as always)



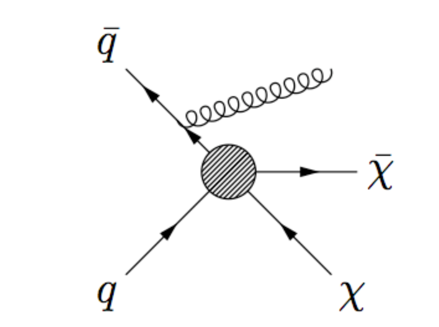
Rapidity gap fraction(*) measurements vs. |y| help to assess uncertainties related to ISR/FSR

Variation of α_S and PS parameters describes ISR/FSR uncertainties

Q_0 is the fraction of events with no additional jet radiated within a considered rapidity interval

How do we search for SUSY ?

Triggering the events



We usually use:

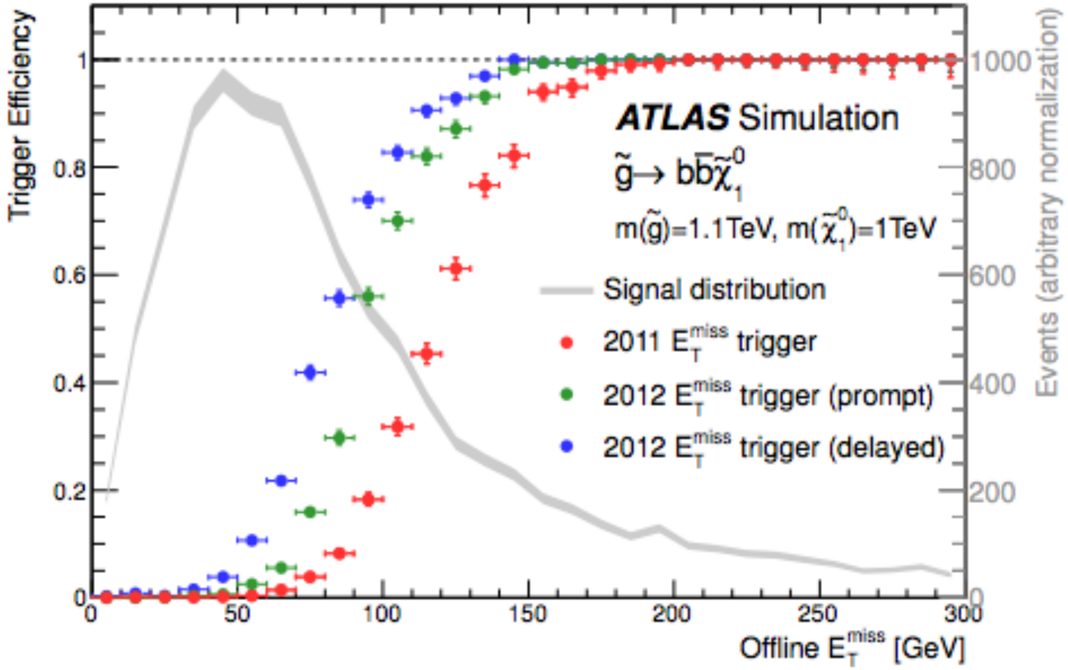
MET triggers: MET>120GeV

single lepton trigger: p_T>25GeV

multi-object triggers (di-lepton, MET+X, jet+X): lower thresholds

For low-p_T SUSY final states (compressed spectra) can use ISR jets to trigger the event

For long lived searches special dedicated triggers are needed



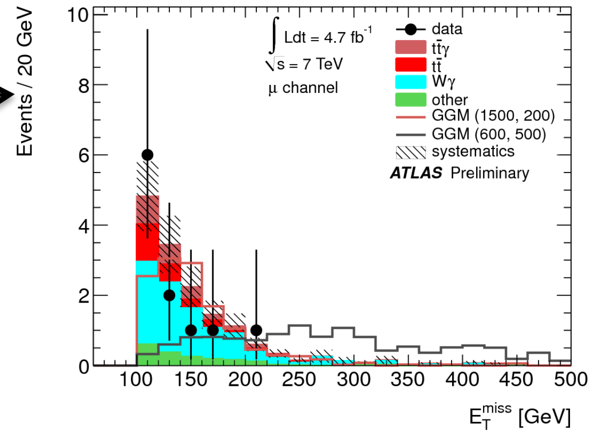
Triggering on MET difficult with pileup. Trigger improvements allowed a lower MET threshold in 2012 than 2011!

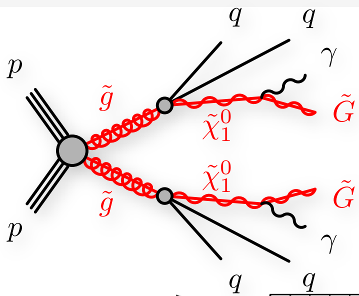
Inclusive searches for squark and gluino production

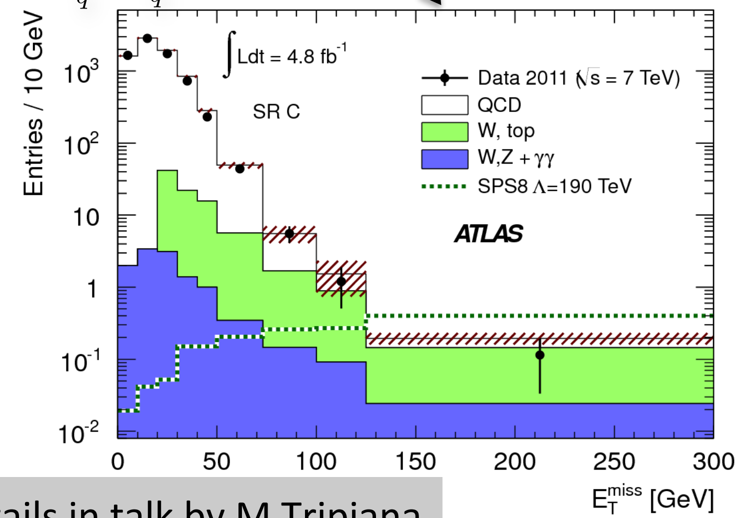
GMSB models can lead to enhanced photon production

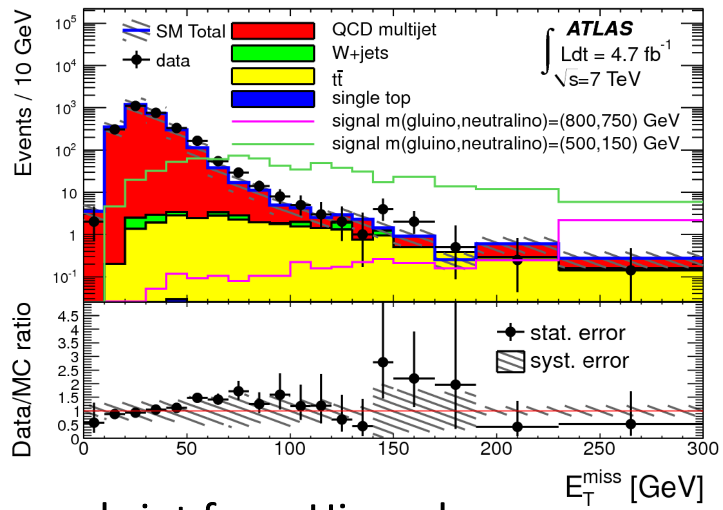
Most recent ATLAS reference (7 TeV): ATLAS-CONF-2012-144, 1209.0753, 1211.1167

- -Photon + lepton + MET
- -Photon + b-jet + MET
- -Di-photon + MET

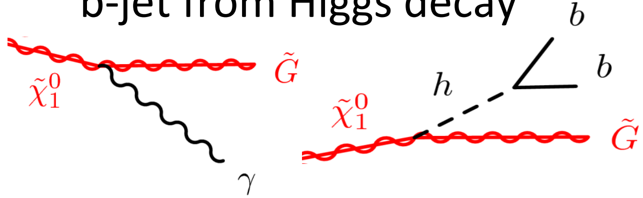








b-jet from Higgs decay



More details in talk by M Tripiana

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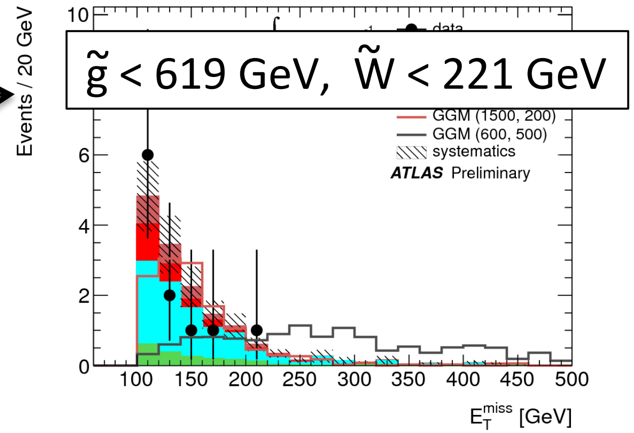
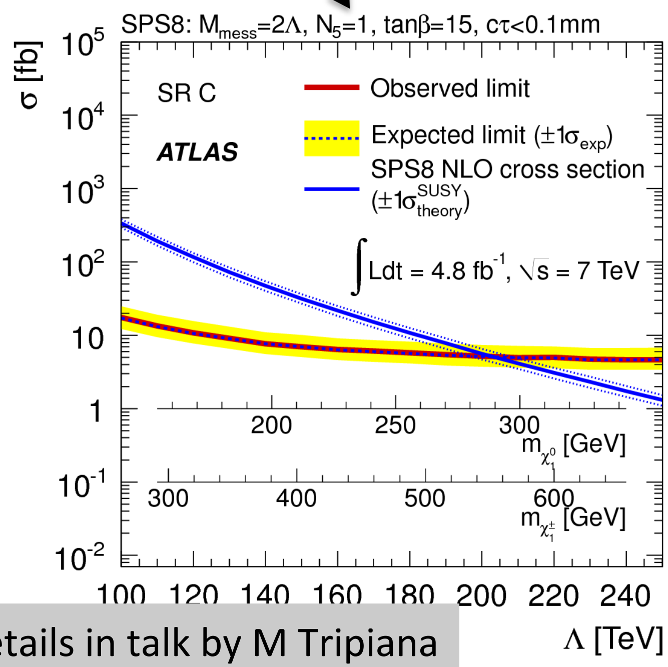
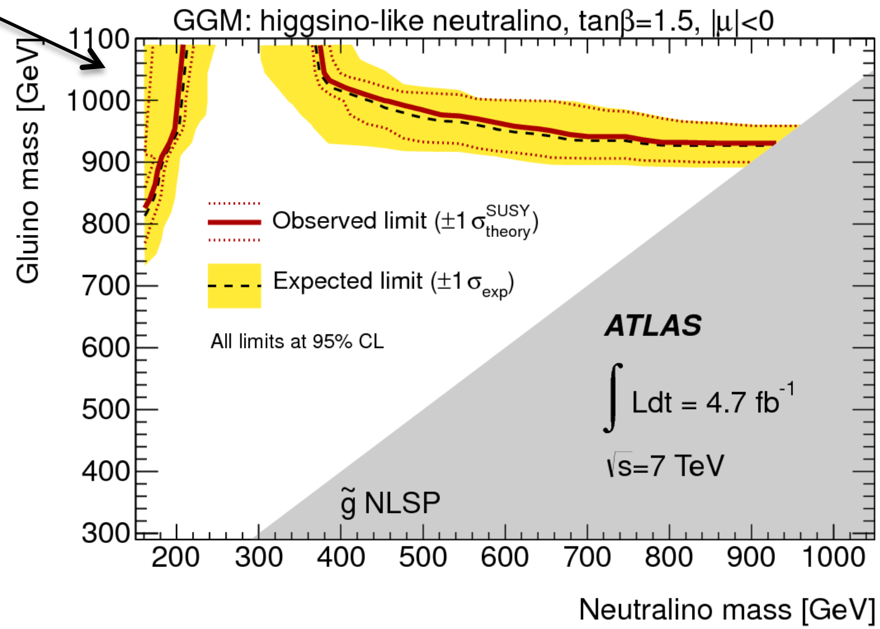






More details in talk by M Tripiana

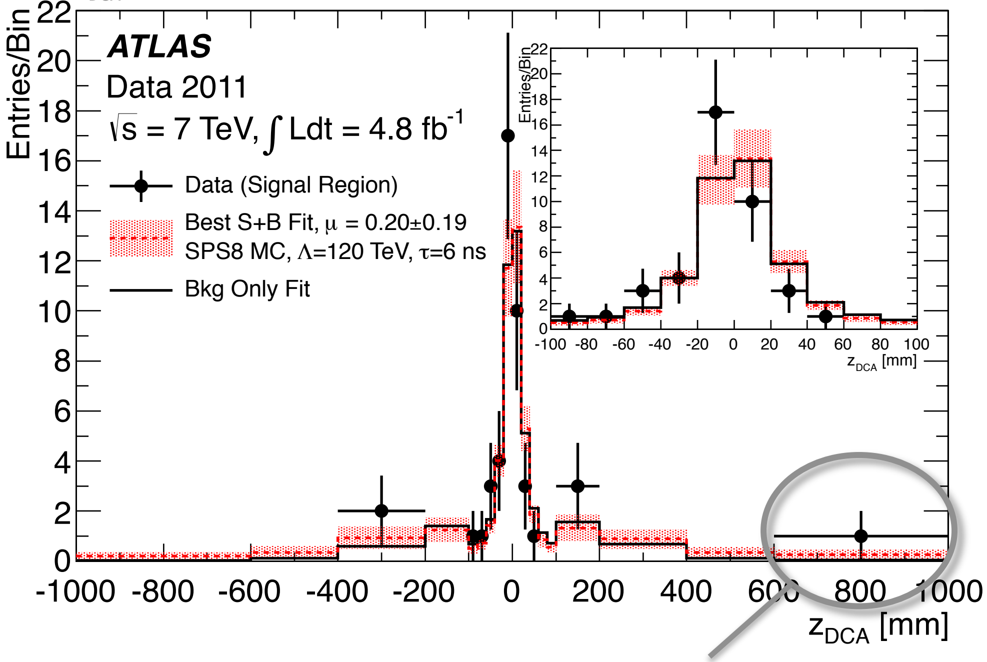
Inclusive searches for squark and gluino production

Weak gravitino coupling in GMSB may can lead to non-pointing photons

Most recent ATLAS reference (7 TeV): 1304.6310

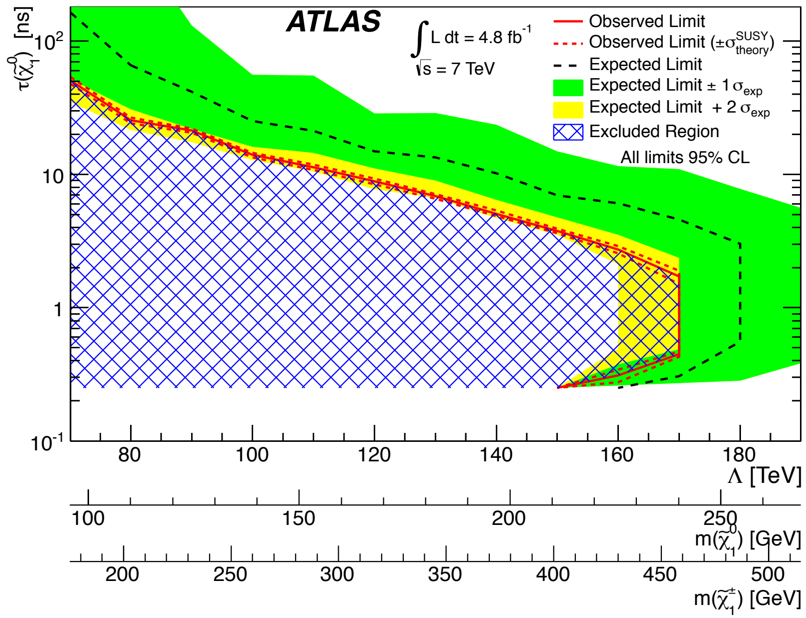
Exploit pointing capability of ATLAS EM calorimeter and timing

z_{DCA} of 46 signal photon candidates and exp. background (MET > 75 GeV)



Outlier event with arrival time consistent with prompt production, and strip distribution that may indicate π^0 background

Limit of NLSP lifetime versus mass in GMSB model



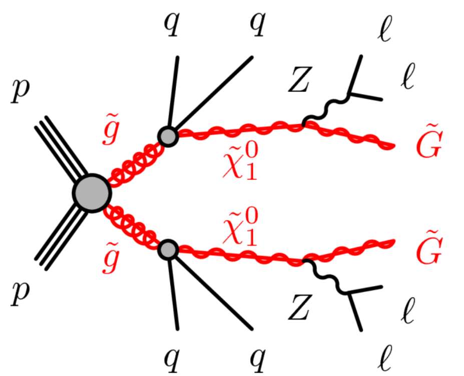
More details in talk by M Tripiana

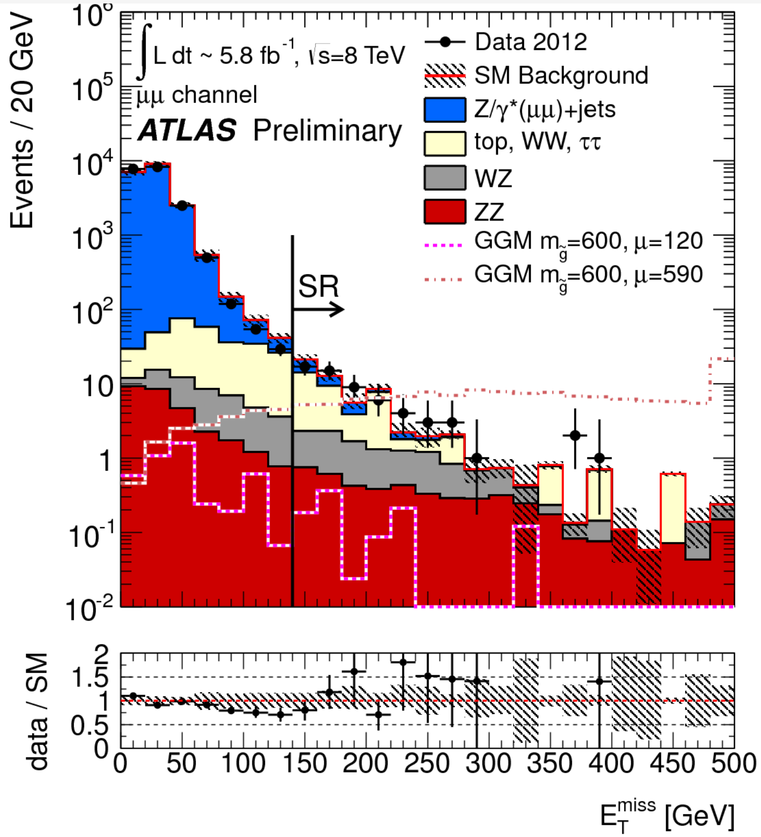
Inclusive searches for squark and gluino production

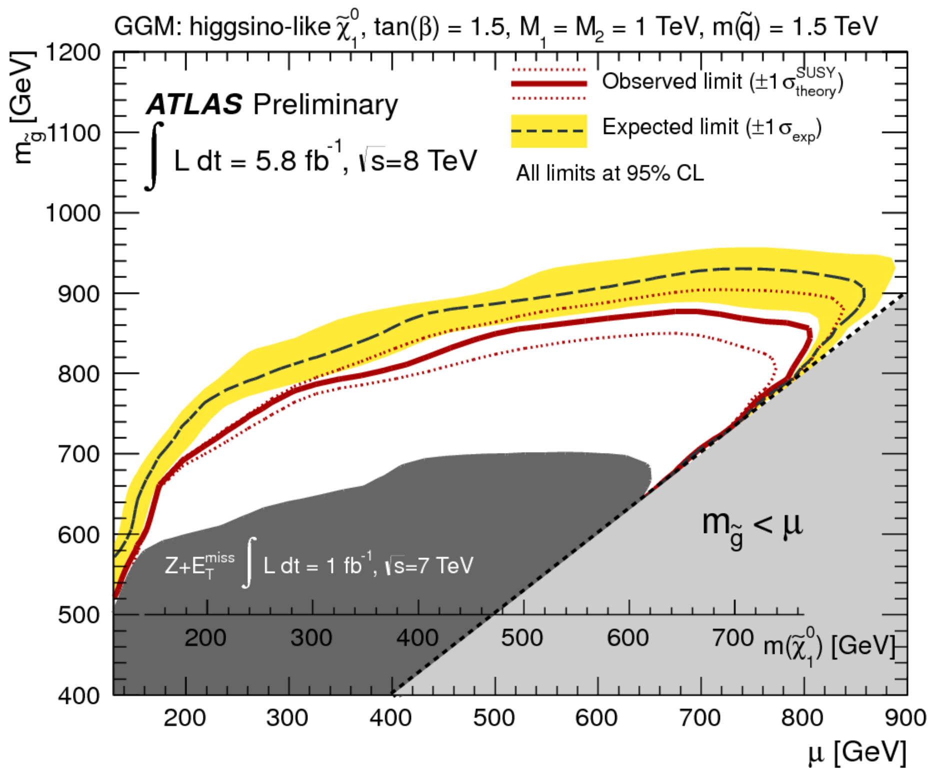
Extensive "jets + X + E_T^{miss} " programme: **Z(ll) + jets + MET**

Most recent ATLAS reference (8 TeV): ATLAS-CONF-2012-152

-Sensitive to GGM models with higgsino NLSP
-2 SRs with different MET and jet cuts
-Z+jets background evaluated with a data-driven jet smearing technique

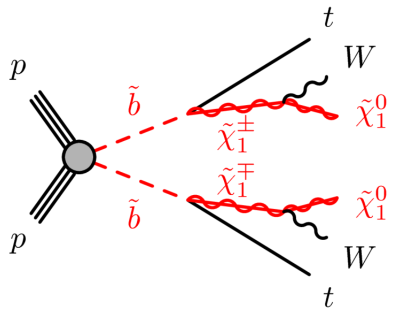


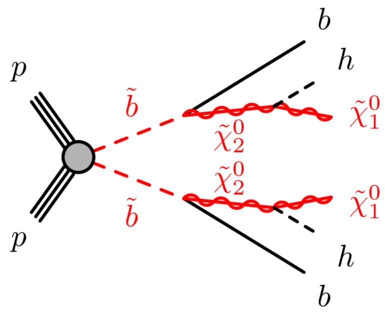




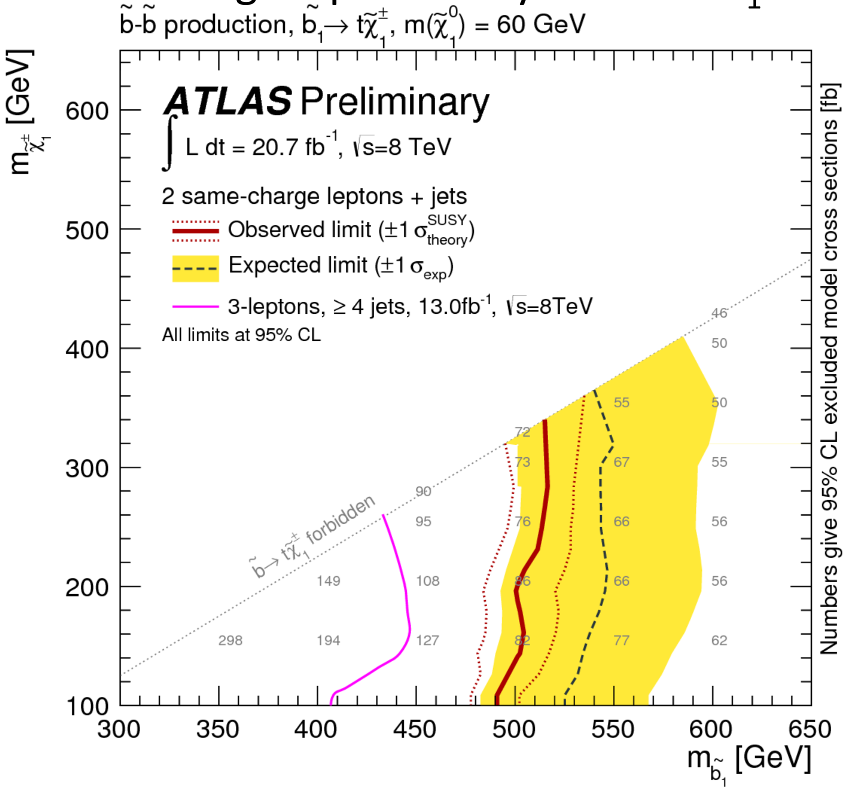
Searches for "Natural" SUSY scenarios

Direct sbottom pair production: **Other analyses**

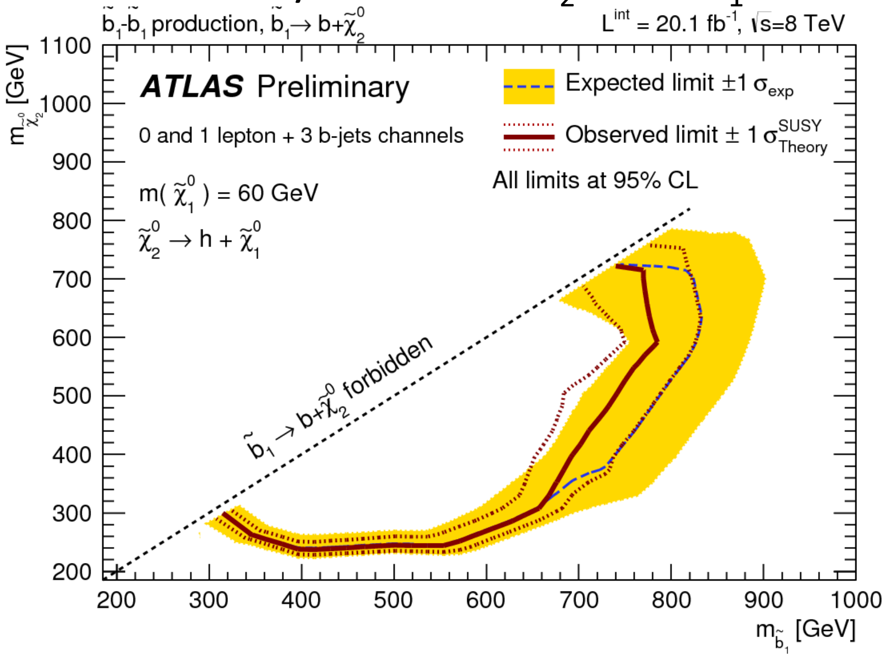




2 same-sign lepton analysis: $\tilde{b}$ -> t C_1



3b analysis in $\tilde{b}$-> b N_2-> b h N_1

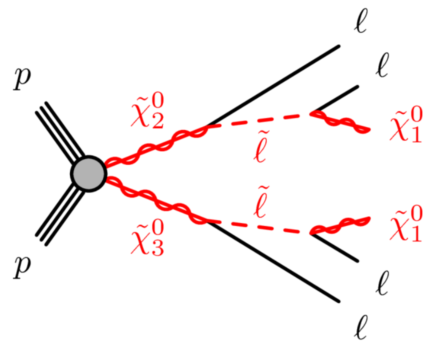


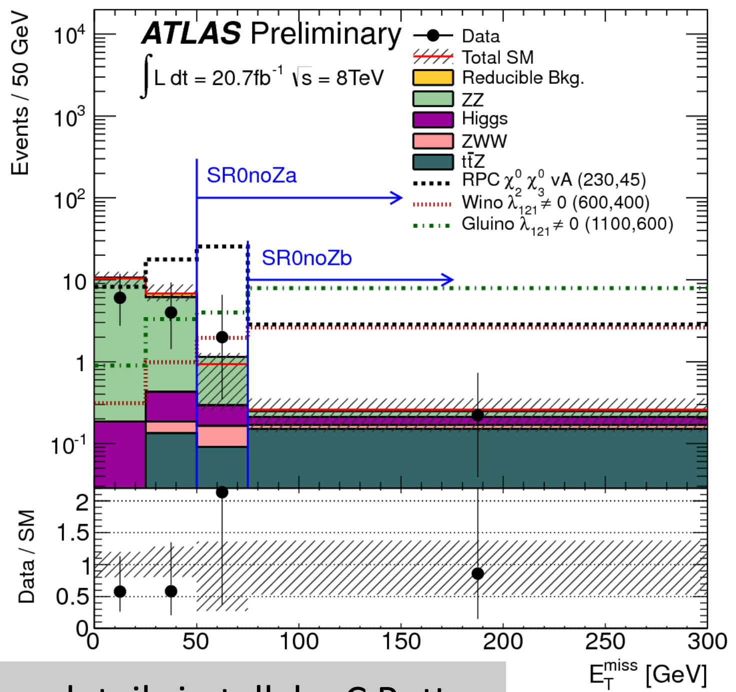
Searches for "Natural" SUSY scenarios

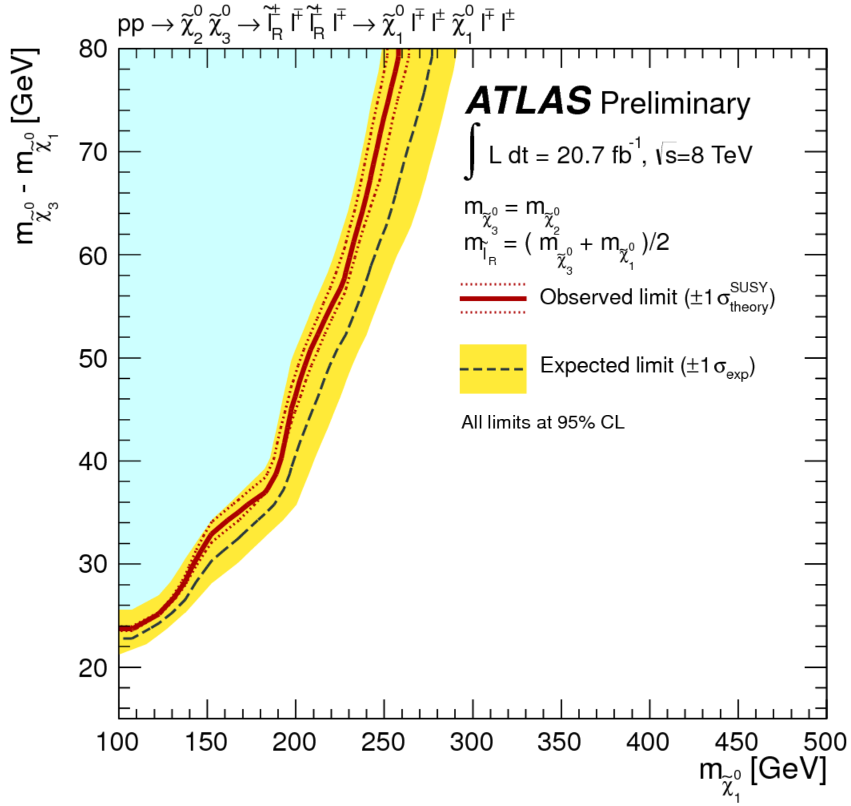
Electroweak production of SUSY: **4-lepton + MET**

Most recent ATLAS references (8 TeV): ATLAS-CONF-2013-036

- -5 SRs used to provide improved sensitivity
- -low background (ZZ, ttZ, H main bkgs)
- -ttZ main background at high MET
- Also an RPV interpretation







More details in talk by C Potter

Razor:

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

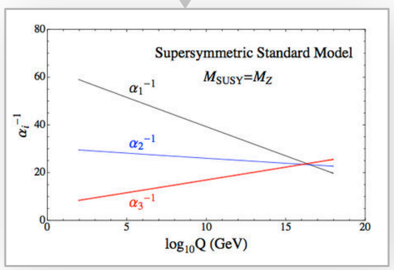
$$M_T^R = \sqrt{\frac{|\vec{p}_{\mathrm{T}}^{\,\mathrm{miss}}|(|\vec{j}_{1,\mathrm{T}}| + |\vec{j}_{2,\mathrm{T}}|) - \vec{p}_{\mathrm{T}}^{\,\mathrm{miss}} \cdot (\vec{j}_{1,\mathrm{T}} + \vec{j}_{2,\mathrm{T}})}{2}},$$

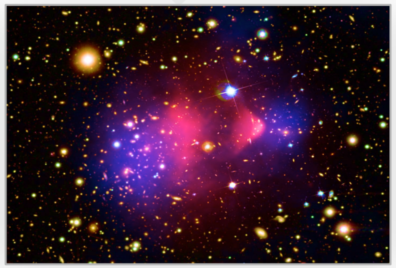
$$R = \frac{M_T^R}{M'_R}.$$

C. Rogan, *Kinematical variables towards new dynamics at the LHC*, arXiv:1006.2727 [hep-ph].

Some Motivations for Supersymmetry

- Moderate the hierarchy problem by cancelling quadratic divergence of SM scalar
- Equalise the number of fermionic and bosonic degrees of freedom, render existence of scalar particles natural
- Realise grand unification of the gauge couplings
- Provide a suitable dark matter candidate

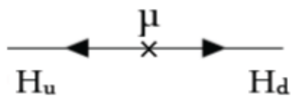




“Natural” SUSY

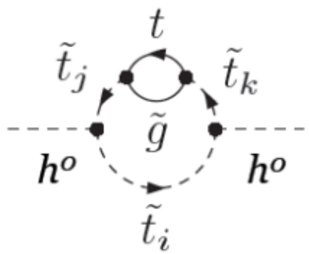
Expect light stop, sbottom, not-too heavy gluino, and light higgsinos (gauginos)

Tree-level: Higgsino < ~350 GeV



One loop: stop < ~1 TeV

Two loops: gluino < ~2 TeV



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