SUSY Searches at ATLAS
latest results and prospects

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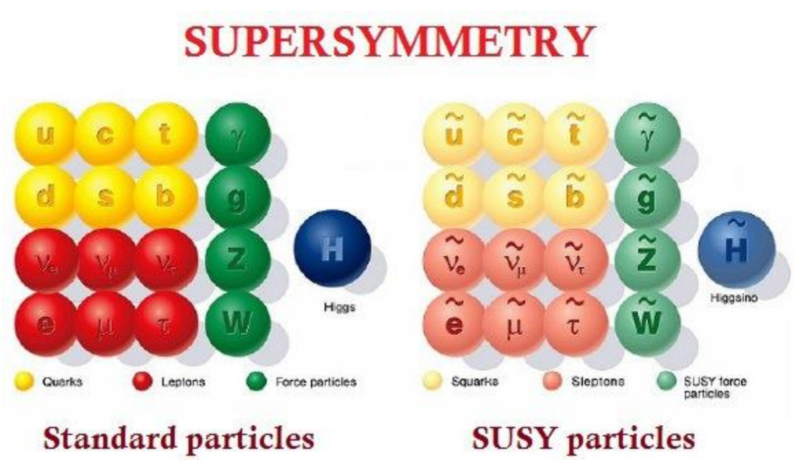
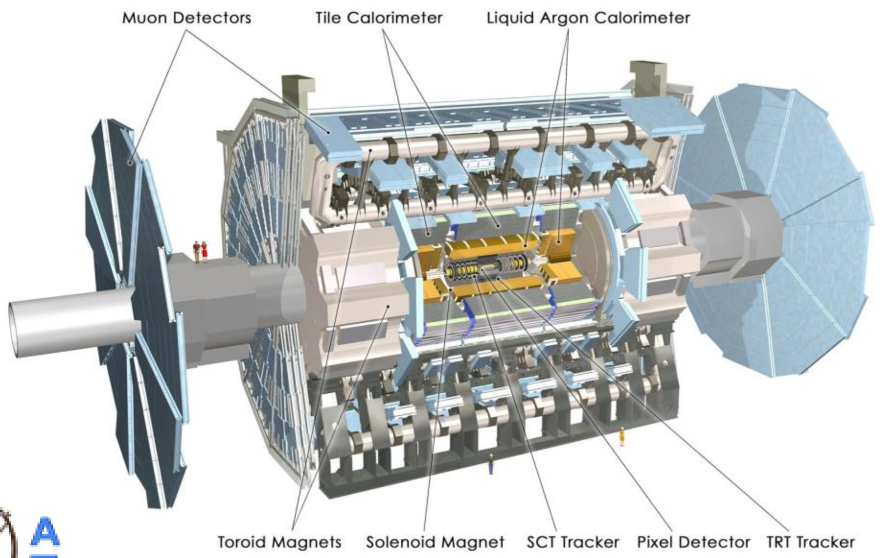
(on behalf of the ATLAS collaboration)

SUSY14, Manchester 23/7/2014





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ATLAS

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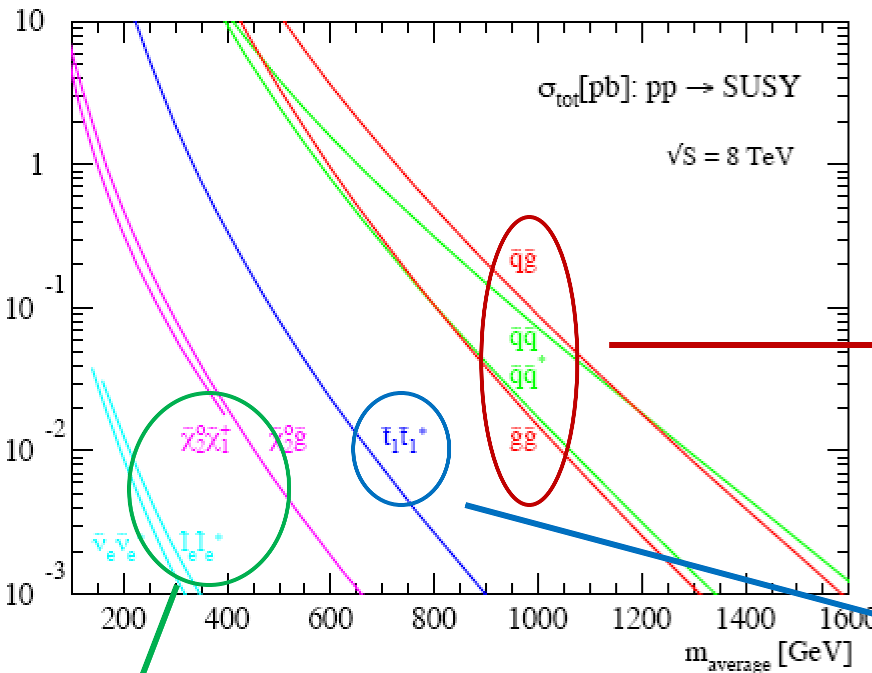
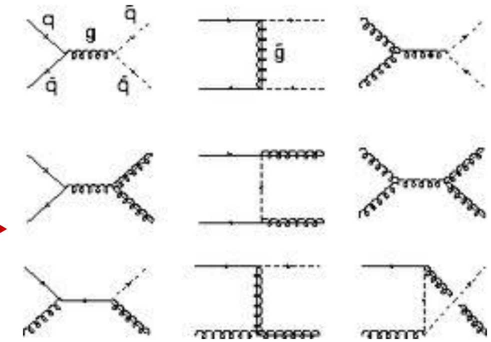
SUSY particles production at the LHC



Taken from http://www.thphys.uni-heidelberg.de/~plehn/index.php?show=prospino&visible=tools

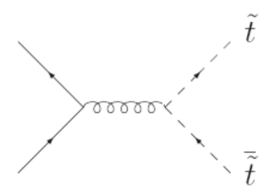
Gluinos and 1st, 2nd generation squarks:

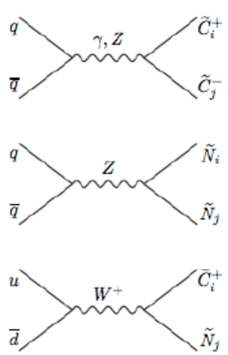
- high cross section up to > 1 TeV mass



Top and bottom squarks

- moderate cross section up to ~0.5 TeV





Charginos, neutralinos, sleptons:

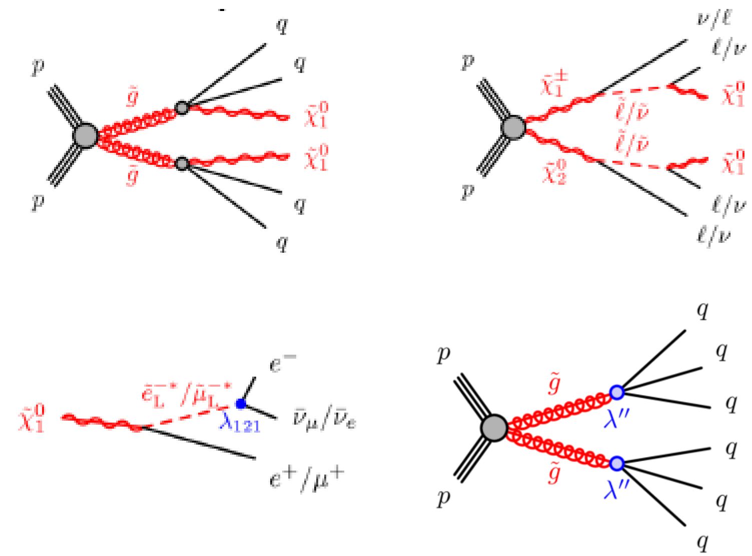
- small cross section, feasible with current dataset

SUSY breaking mechanism and R-parity determines the phenomenology

(sparticle decay modes, nature of the Lightest SUSY Particle, lifetime…)

SUSY Phenomenology

$\boxed{\text{R-parity} = (-1)^{3(B-L)+2s}}$



If R-parity is conserved (RPC)

→ sparticles produced in pairs

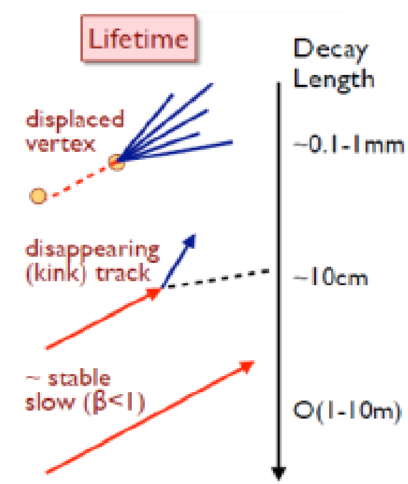
→ Lightest Supersymmetric Particle (LSP): candidate for Dark Matter, lead to high E_T^{Miss} final states

Typical LSP: lightest neutralino ($\tilde{\chi}_1^0$), gravitino ($\tilde{G}$)

If R-parity is violated (RPV)

→ LSP no longer stable, rich and diverse phenomenology depending on the involved parameters (λ, λ', λ'')

- **Prompt or Long Lived (LL)** particles could be produced in RPV and RPC scenarios. Few examples of LL:
  - **In RPV**: if lambda couplings are very small
  - **In RPC:** If very heavy squarks mediate gluinos decay (strong virtuality):
    - Long-lived gluinos → R-hadrons (eg. Split SUSY)



SUSY search strategy

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

Prompt					Long-Lived
R-Parity-Conserving			R-Parity Violation		Various ranges of lifetime
Strong 1^{st}, 2^{nd} gen. squarks, gluinos	**3^{rd} gen.** stop, sbottom	**Weak** EWK-inos, sleptons	RPC prod. RPV decays	RPV prod. RPV decays	

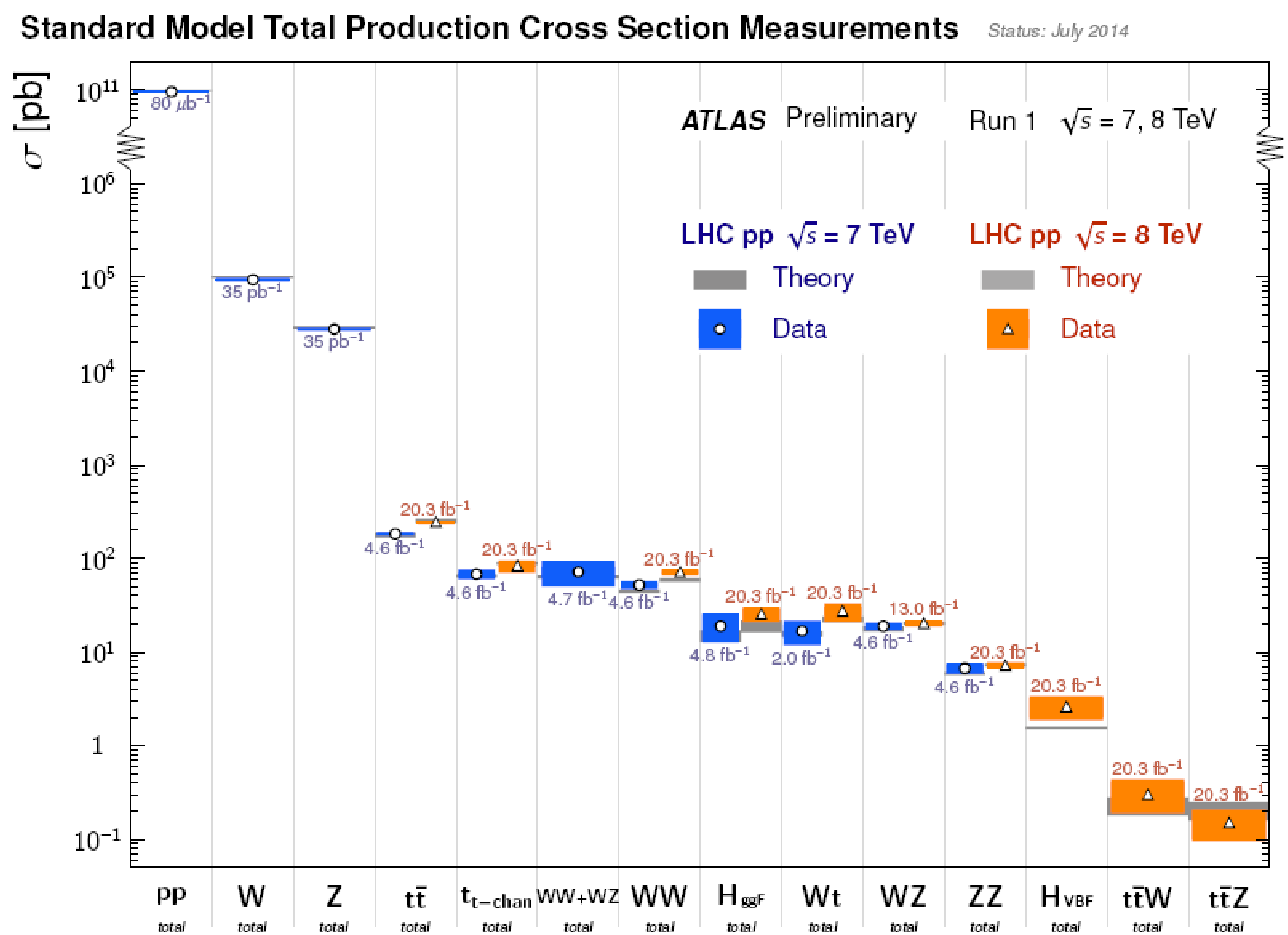
Only most recent results presented here! *More in parallel sessions: Talks from M. Fiascaris, E. Guido, A. Kuhl, D. Miller, Z. Rurikova, D. Xu*

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

Searching for SUSY

- **Step 1:**
  - understand SM background contributions

SM processes measured at ATLAS with extremely high precision



Searching for SUSY

- **Step 1:**
  - understand SM background contributions (*)
  - Search kinematic phase space usually different from SM measurements (tail of distributions at high p_T)

(*) For long-lived particle searches, need more specialized techniques

Irreducible SM backgrounds

'Semi' data-driven methods

- Normalisation done in dedicated Control Regions (CR) enriched in specific bkg. E.g.: top pair production, W+jets…
- Compromise between closeness to SR, statistics and handling of uncertainties

Reducible SM background

Data-driven methods: E.g.
• 'Jet Smearing' for multijet or Z+jets background due to fake E_T^{Miss}
• 'Matrix Method' for background from misidentified leptons

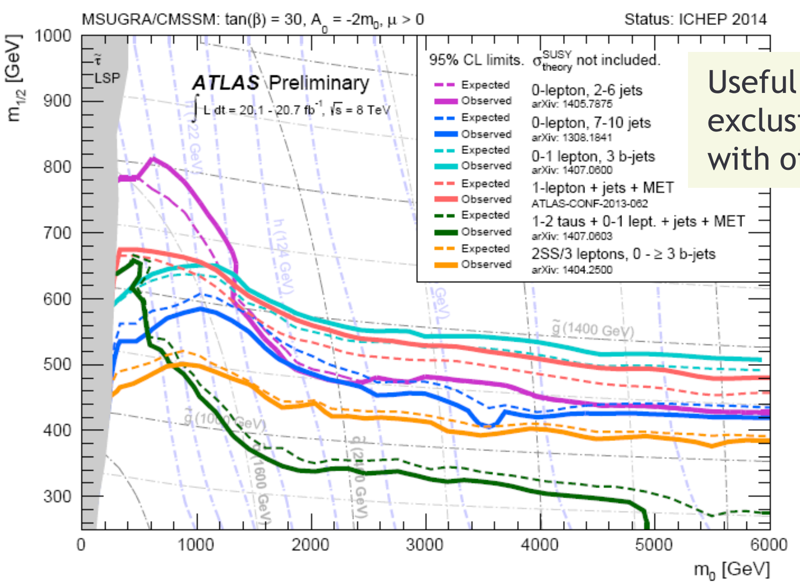
Validation of Background estimates in dedicated samples (VR)

Searching for SUSY

- **Step 2:**

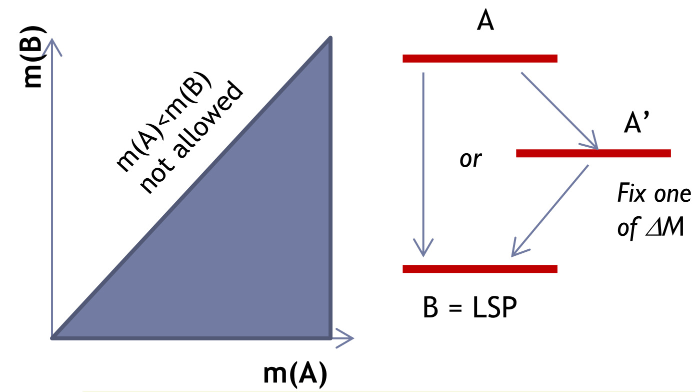
For each search, a number of signal regions is optimized based on:

'Full' Physics models
- SUSY breaking @ high scale → specific spectrum at EWK scale
- mSUGRA, Gauge Mediated Symmetry Breaking, Anomalous MSB, extended MSSM etc.



Useful to calibrate our exclusion and compare with other results

Simplified models
- Described by a minimal set of parameters (particle masses, cross section)
- Most models: fixed BR to final state of interest (e.g. 100%)

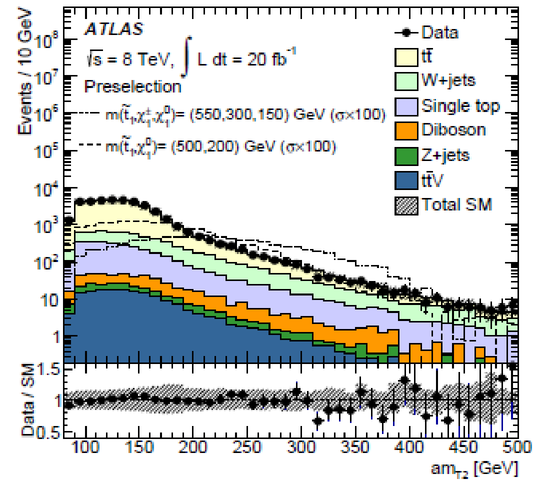


Very helpful to design analyses and understand loop-holes.

Generalized models
- Parameters @ EWK scale → spectrum at EWK scale
- pMSSM, General Gauge Mediated

Searching for SUSY

- **Step 3:**
  - Define selections based on various discriminating quantities
    - **Ex: MET, Meff = E_T^{Miss} + Scalar Sum of jets (leptons) p_T, transverse mass m_T, mT2, amT2 ....**



  - Define SRs, which are usually 'blind'
    - **Cut and count analyses or fit on shape of single or multiple discriminating variables (especially for searches with low S/B)**
  - After bkg estimates in CR and validation in VR

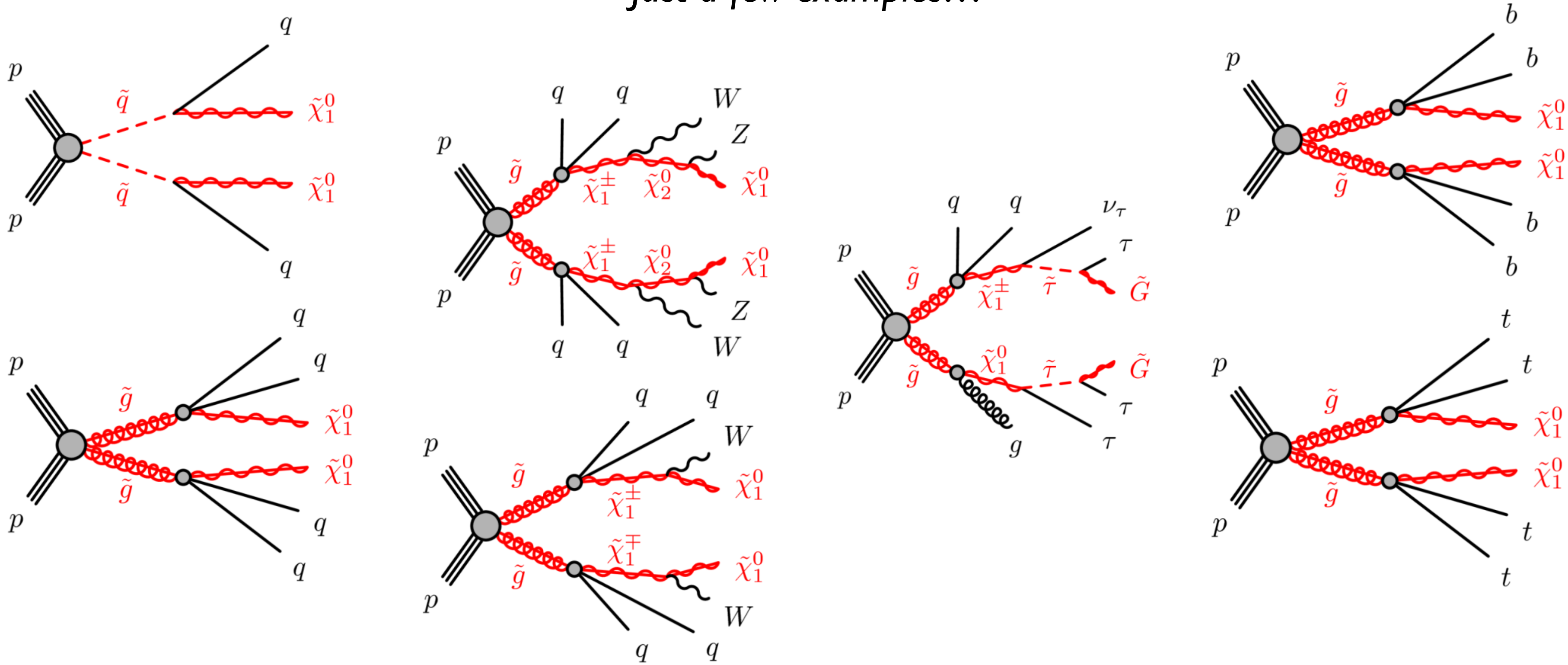
→ Proceed to unblinding data in SR
    - If excess is found, champagne!
    - If not ☹, set 95% Confidence Level limits

Strong production

1 st / 2 nd generation squarks and gluinos

→ Possibly complex final states, great variety of signatures

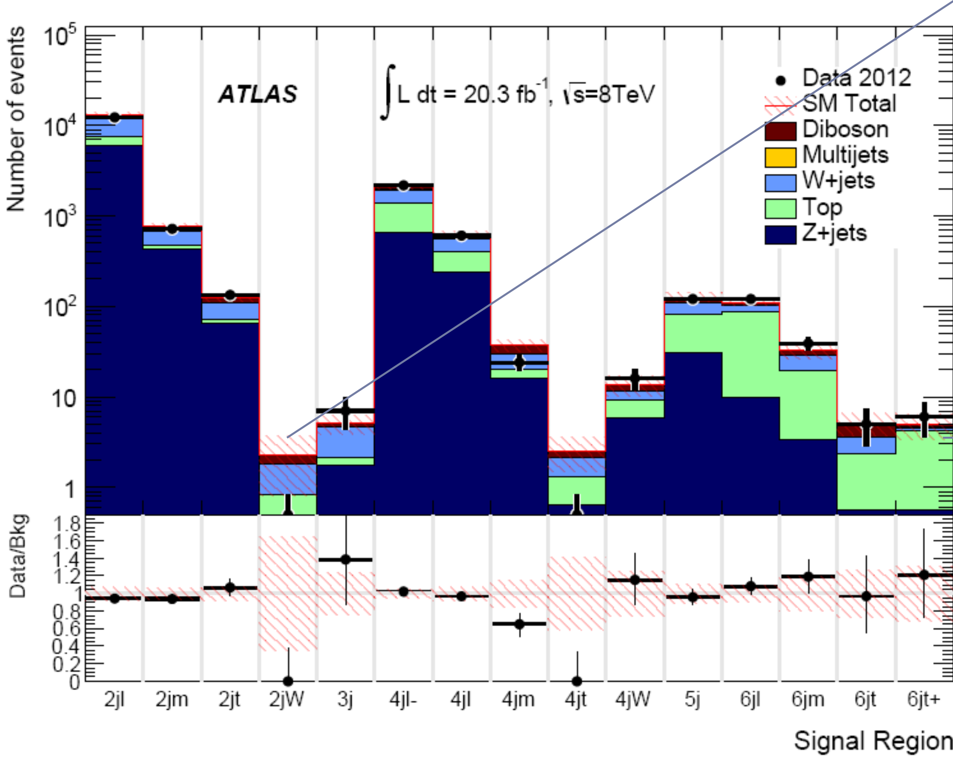
Just a few examples…

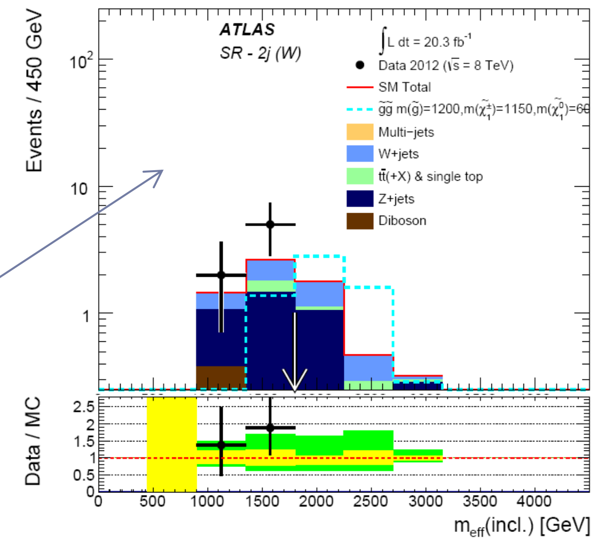


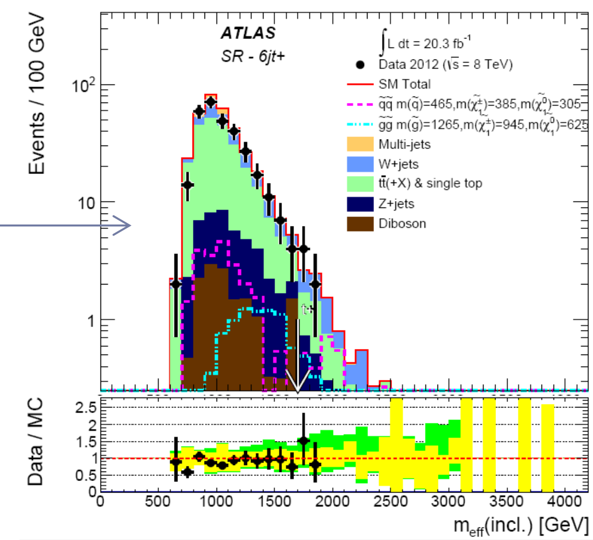
Inclusive searches with no leptons

1405.7875

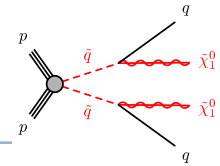
- Define various signal regions based on:
  - Minimum Jet multiplicity (2 to >=6j)
  - Effective Mass ($M_{eff}= E_T^{Miss}$ +Sum p_T jets)
    - Thresholds from 800 GeV to 2.2 TeV
  - But also: presence of boosted W→qq', also with decay products clustered in the same jet
    - Selection on jet mass (60-100 GeV)



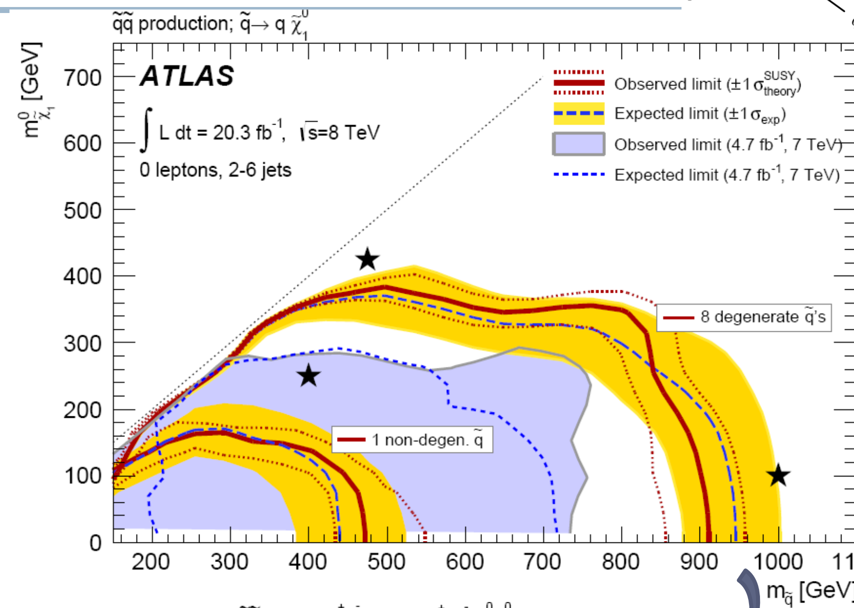


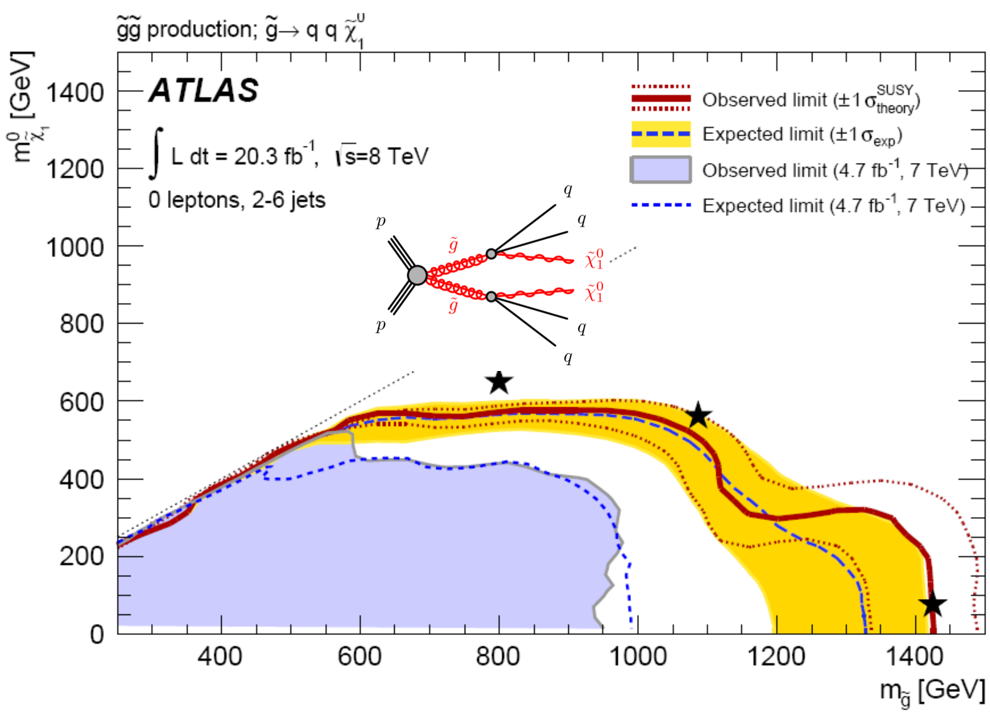


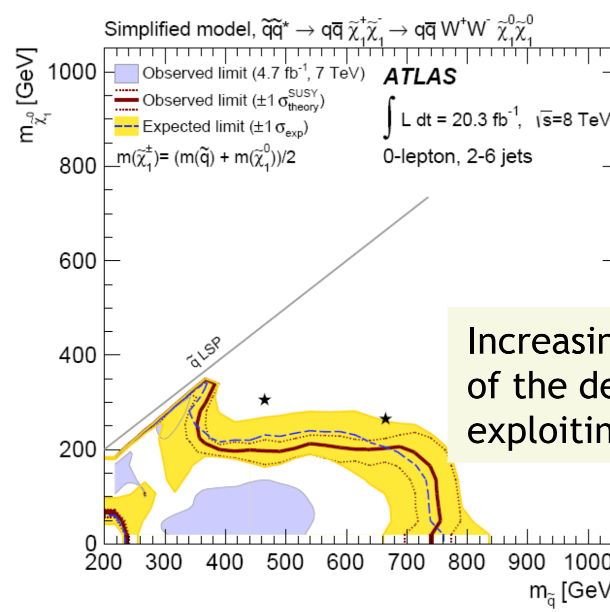
Results

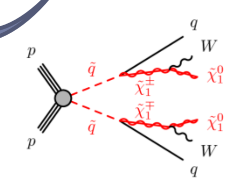


- Agreement between data and SM expectations
- Results interpreted in terms of gluino and squark pair production:
  - For the latter, 8-squark and 1-squark degeneracy considered







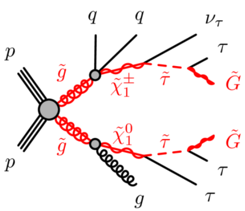


Increasing the complexity of the decay chain, exploiting boosted W

Tau-enriched final states: 1τ, 1τ+1e/μ, 2τ

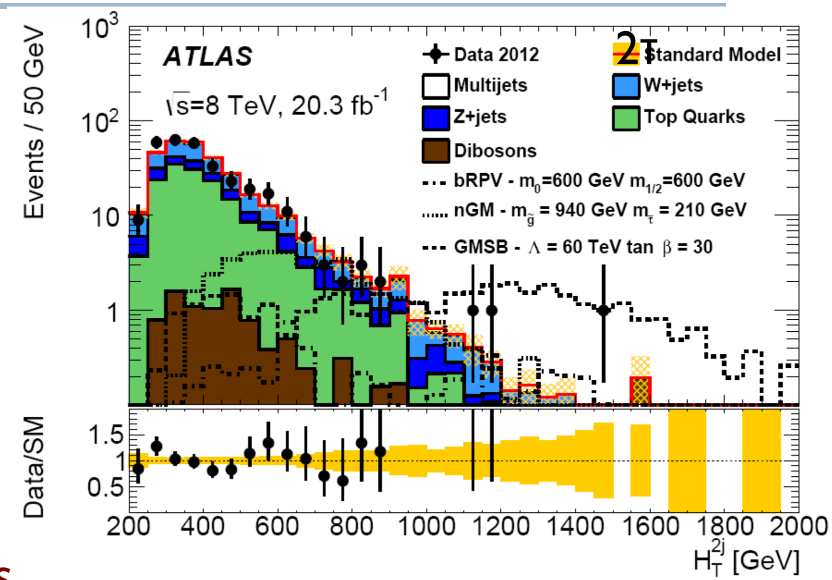
- E.g. target GMSB models

Stau is NLSP, prompt decay



where $\tilde{\chi}_1^0 \rightarrow \tau\,\tilde{\tau} \rightarrow \tau\,\tau\,\tilde{G}$ — 4 τ + jets from cascade decays

or $\tilde{\chi}_1^\pm \rightarrow \nu\,\tilde{\tau} \rightarrow \nu\,\tau\,\tilde{G}$ — 2 τ + jets from cascade decays



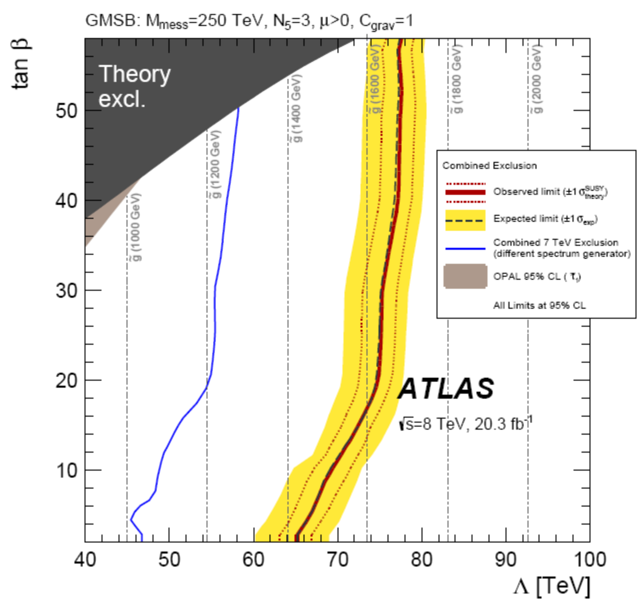
Signature:
1 or 2 hadronic τ, + 0/1 e,μ ≥ 2 jets + E_T^{Miss}

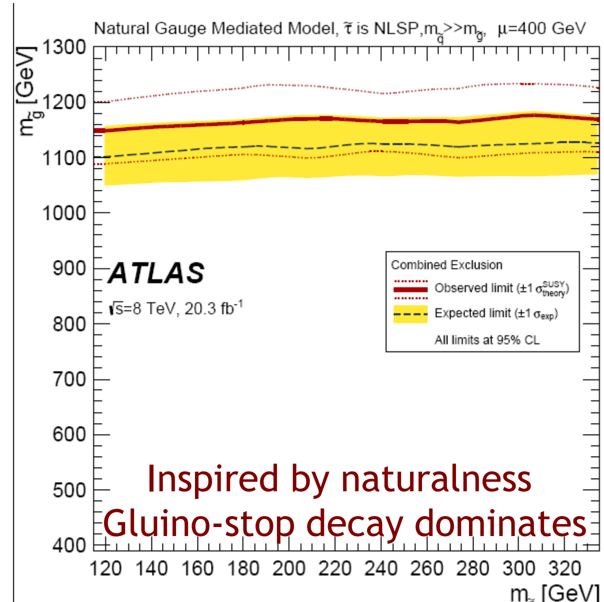
Signal regions: High m_T, H_T, Njet requirements

Backgrounds

Irreducible
ttbar, W,Z+jets, VV, Drell-Yan

Reducible
Multijets

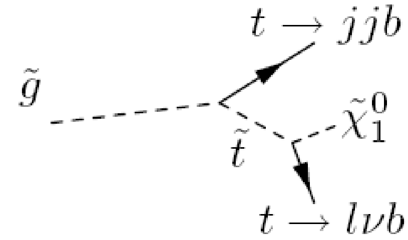




Inspired by naturalness
Gluino-stop decay dominates

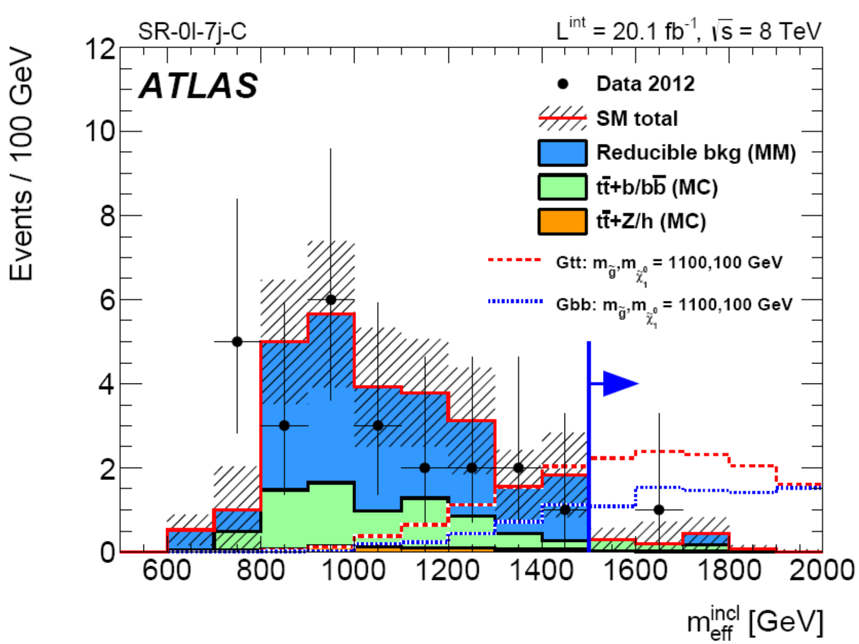
Gluino-mediated third generation

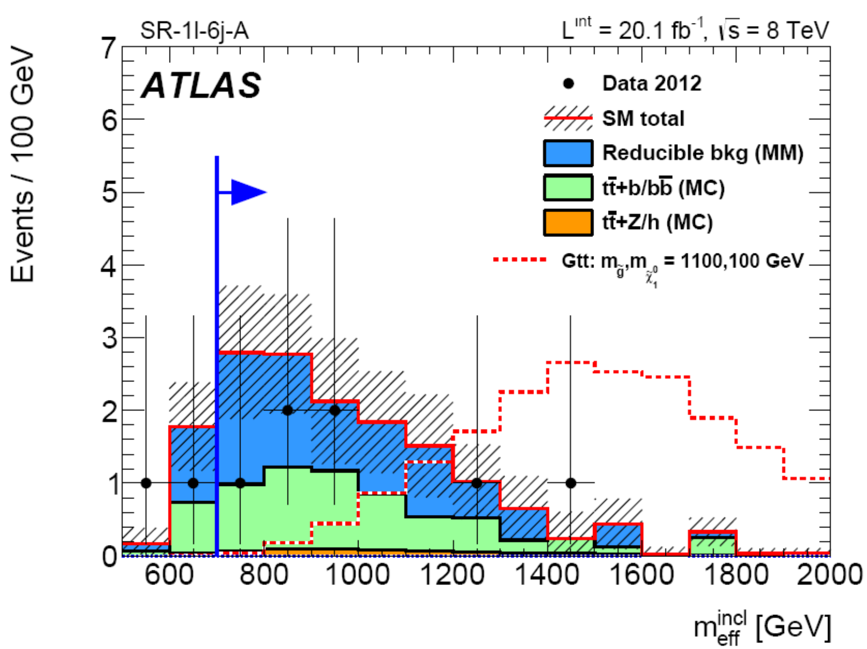
- Gluinos decaying via stop/sbottom offer a very rich phenomenology. Various analyses exploiting that:
  - 0 lepton + multijets (7-10j): 1308.1841
  - Same sign leptons + jets (b-jets): arXiv:1404.2500
  - **0/1 lepton + 3-bjets:** 1407.0600
    - 0 lepton: >= 4 jets and >= 7 jets regions (at least 3 b-jets), with Meff cuts between 1 TeV and 1.5 TeV and high ETMiss
    - 1 lepton: >= 6 jets (at least 3 b-jets), with Meff > 700-900 GeV, high ETMiss and high mT



SM Backgrounds:

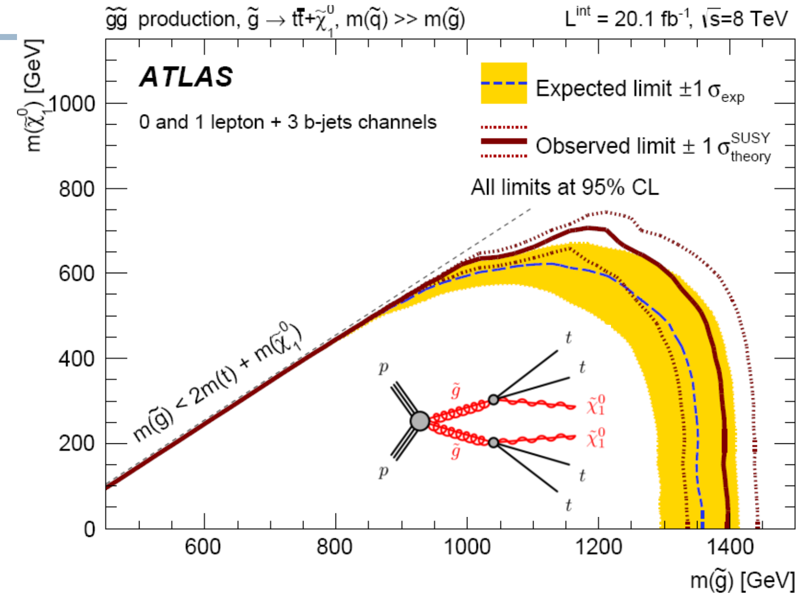
Irreducible	Reducible
ttbar+bbar	ttbar+jets
(MC-driven)	*(data-driven)*

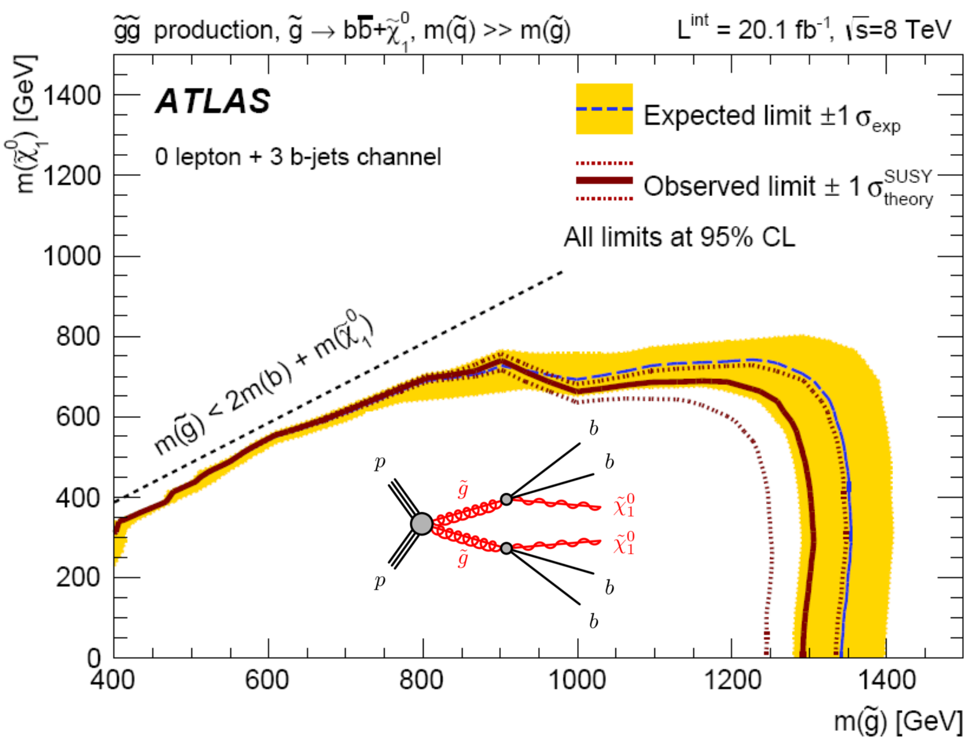


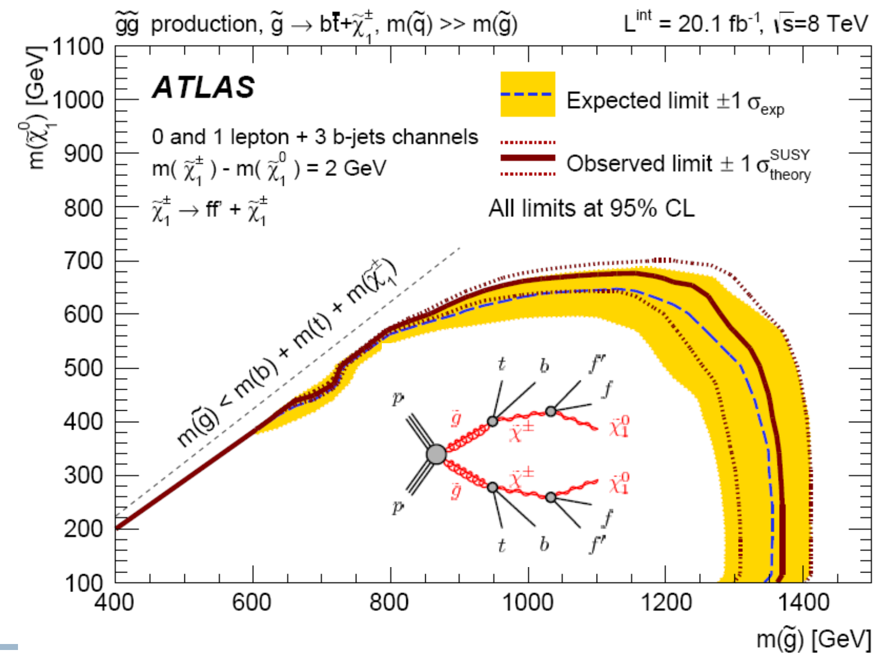


Results

- Good agreement between data and SM background expectations
- Constraints on gluino mass around 1.3-1.4 TeV for low LSP
  - Almost independent on t-b mixture

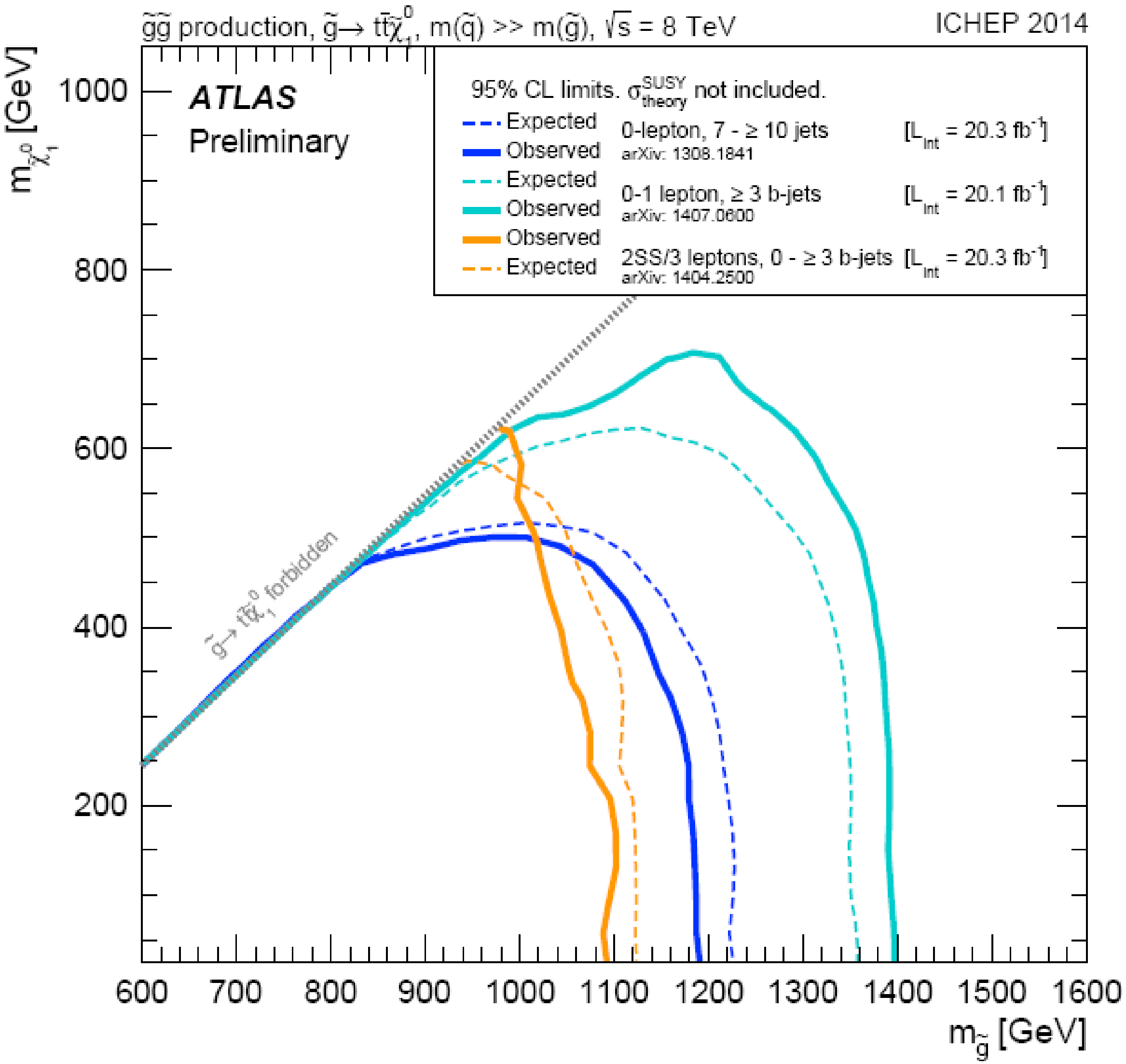


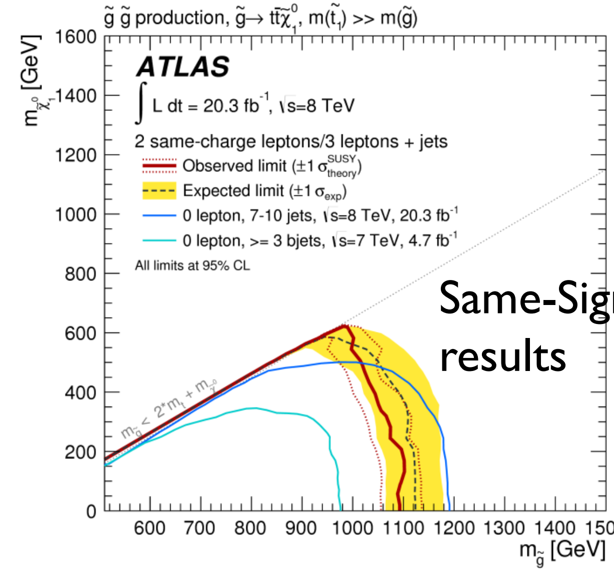




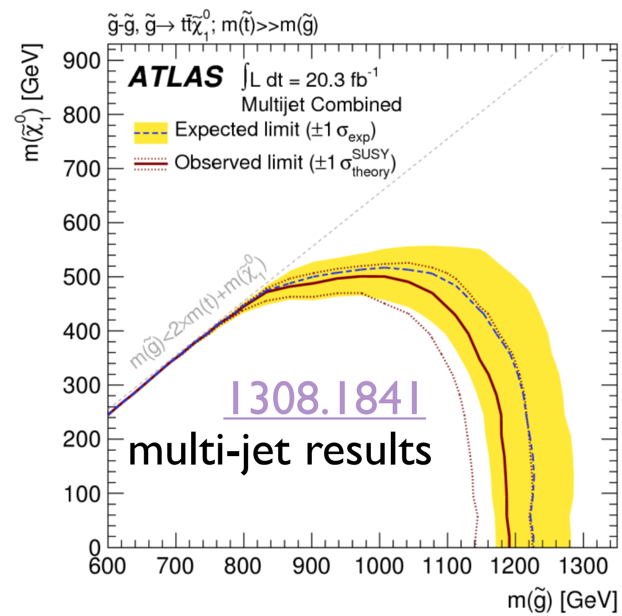
Summary: Stop via gluino pair production

Complimentarity of various analyses:





Same-Sign results

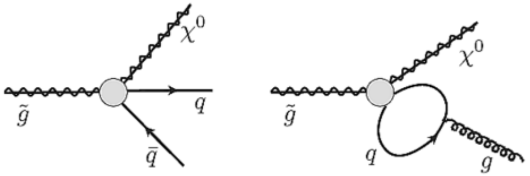


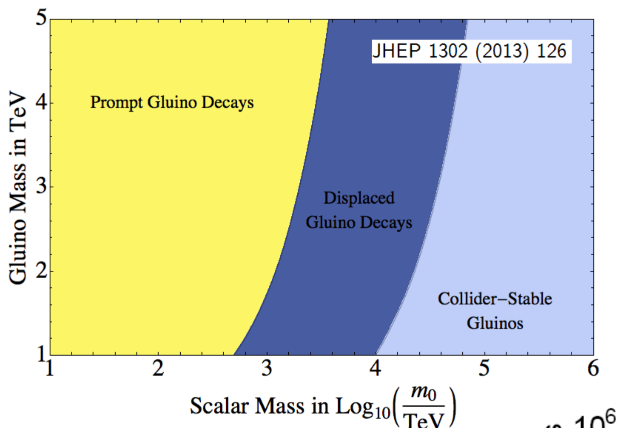
1308.1841

multi-jet results

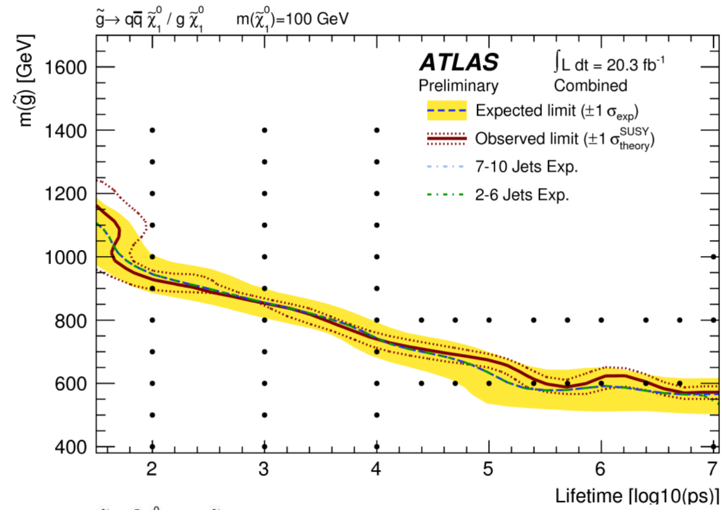
Meta-stable gluinos

- In some SUSY models (e.g. *minisplit SUSY*), gluinos could be "metastable"
  - travel a measurable distance in the detector before decaying to quarks (or a gluon) and a neutralino



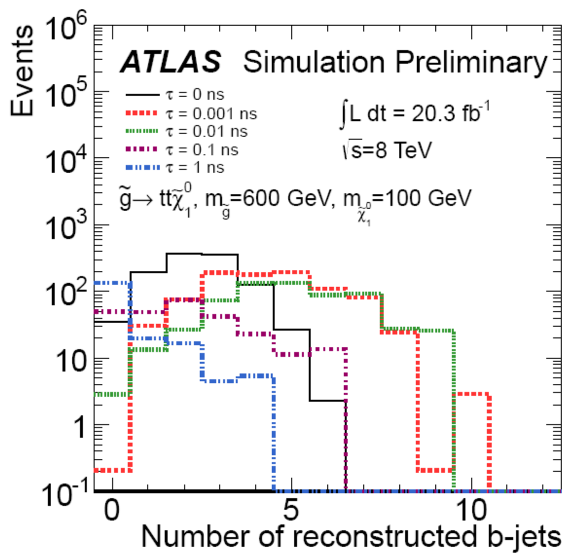


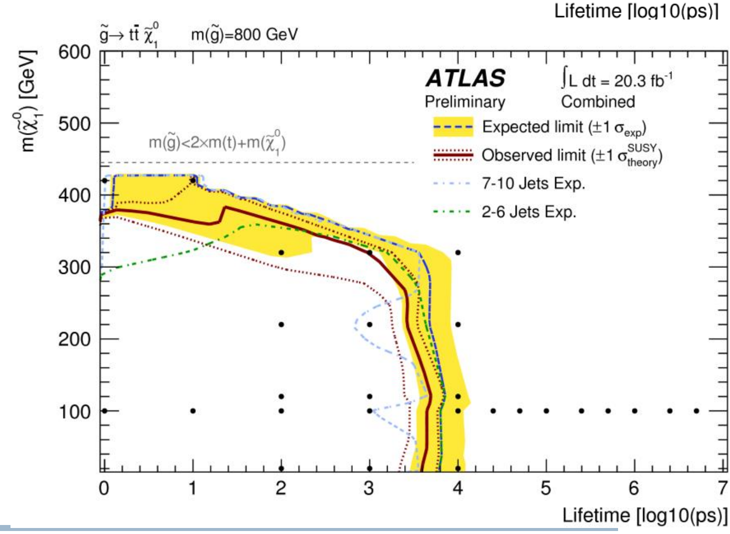
Analyses designed for prompt scenarios might be sensitive !



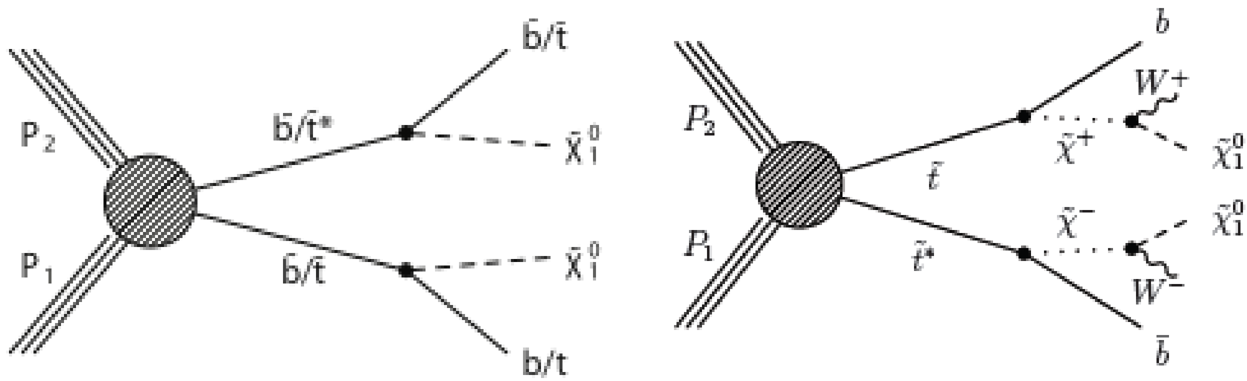
Reinterpretations of:

- Inclusive 0-lepton 2-6 jets
- Multijet (7-10 jets) , with and without b-jets





Direct stop (and sbottom) production

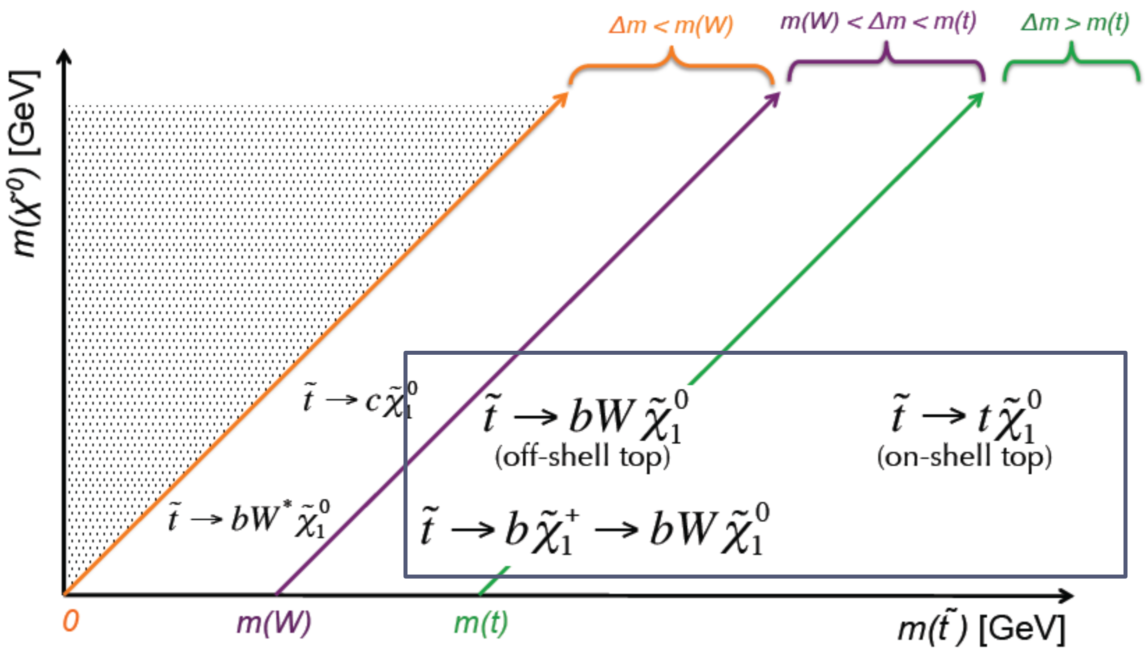


Search strategy

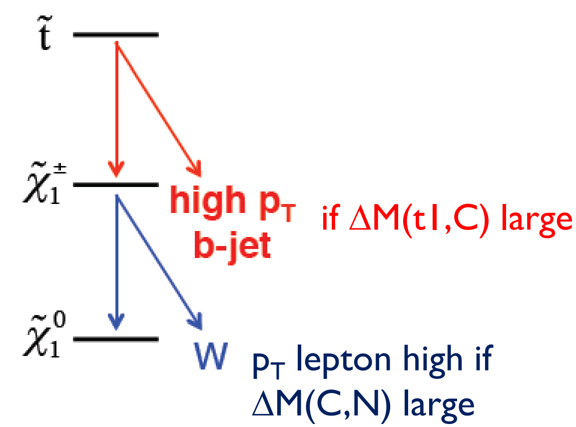
- Usually target lightest eigenstate (t1, b1)
- Several decay modes possible

$$\begin{pmatrix} \tilde{t}_1 \\ \tilde{t}_2 \end{pmatrix} = \begin{pmatrix} \cos\theta_t & \sin\theta_t \\ -\sin\theta_t & \cos\theta_t \end{pmatrix} \begin{pmatrix} \tilde{t}_L \\ \tilde{t}_R \end{pmatrix}$$

  - For stop:



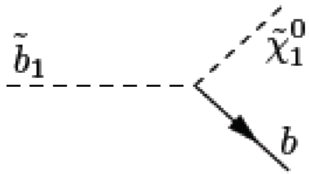
For decay modes involving charginos, phenomenology depends on ΔM chargino-neutralino and ΔM stop-chargino

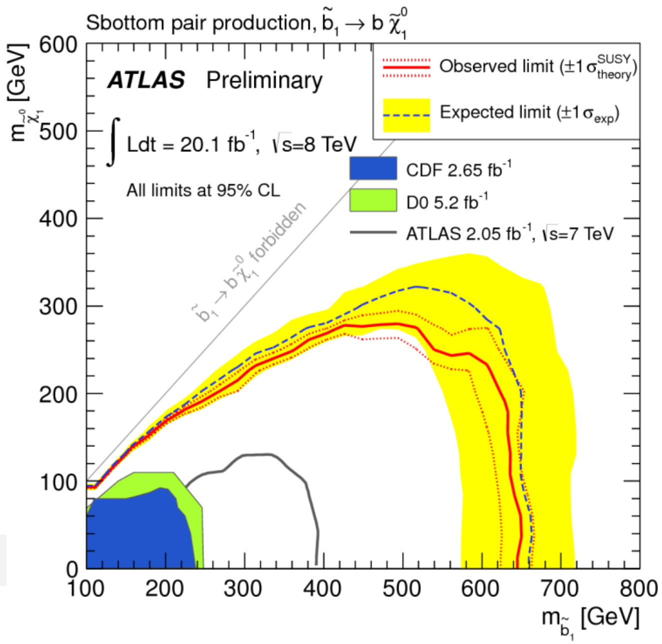


  - For sbottom:
    - Final states b+neut1, b+neut2 and t+chargino
    - In case of b+neut2: neut2 → Z / higgs + neut1

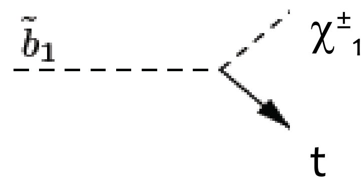
Direct Sbottom production

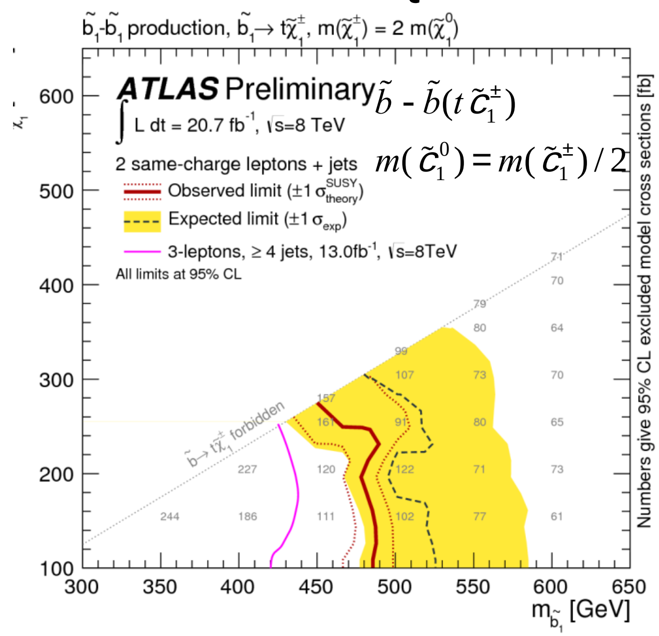
- 2-bjets+MET [1308.2631]
  - Exclusive selection sensitive to neut1 decays of the sbottom

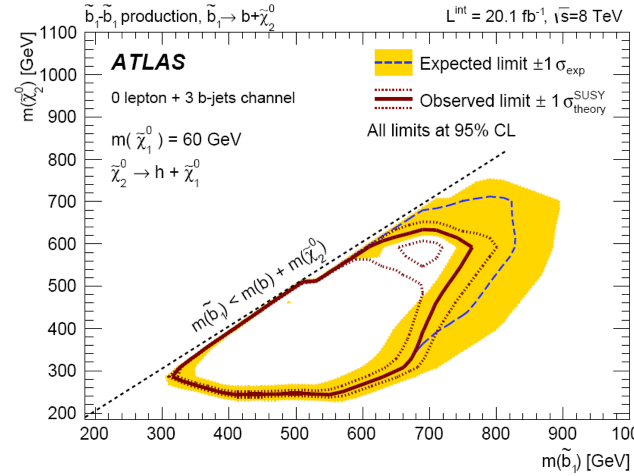


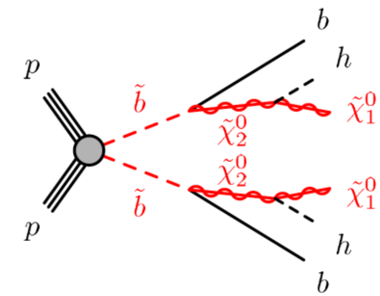


- 2 lep (SS) + jets
  - Sensitive to decays via top and charginos



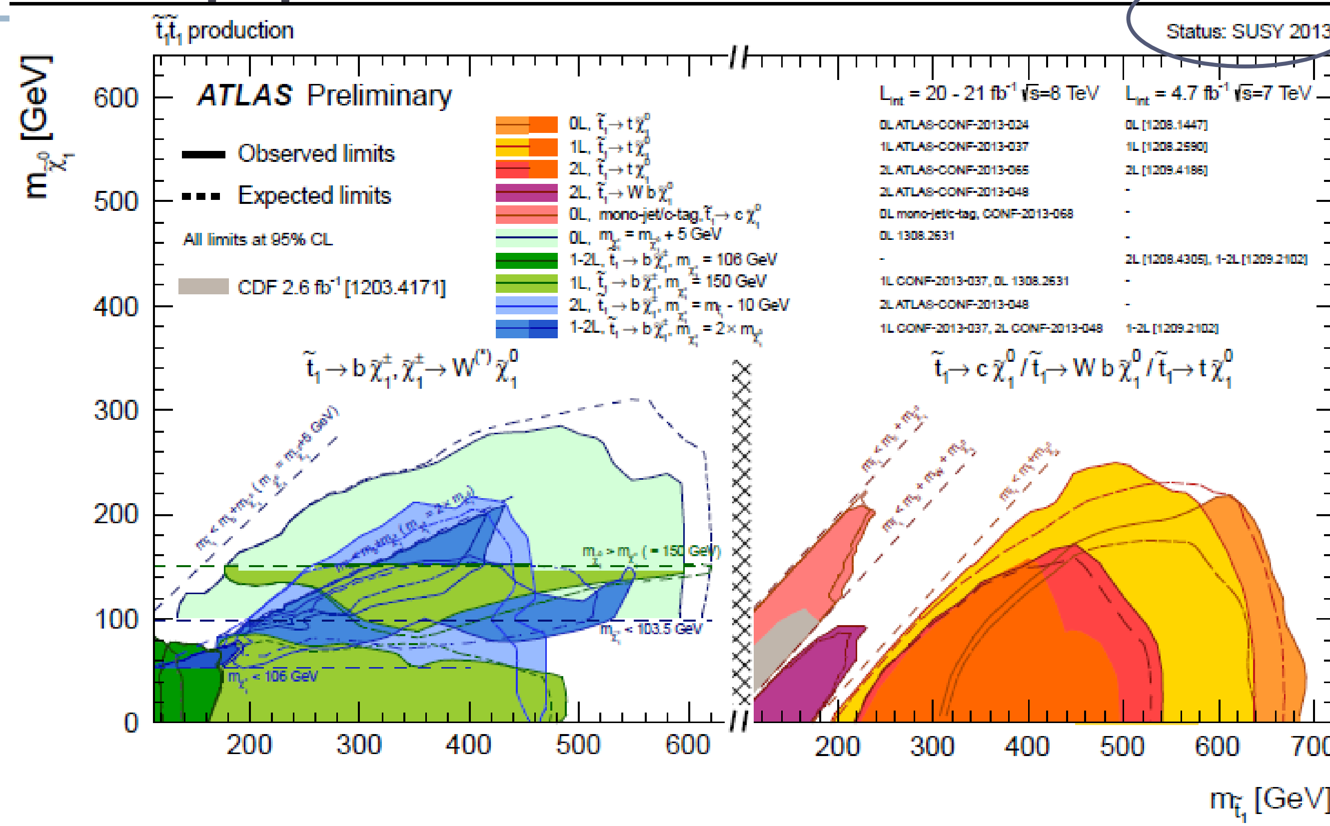




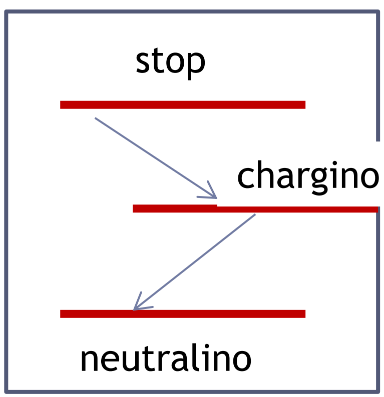


- 0 lepton + 3-bjets:
  - sensitive to higgs decays of neut2

Direct stop production

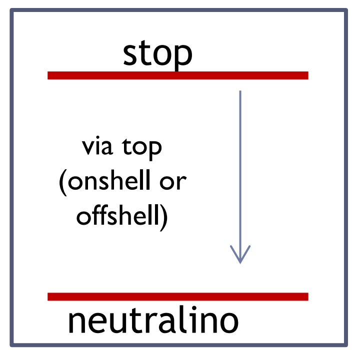


Where we were last year



Fix one of ΔM

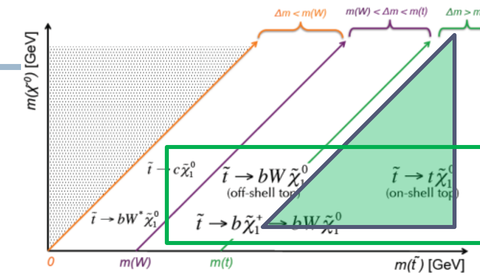
Could have 2-, 3- and 4-body decays



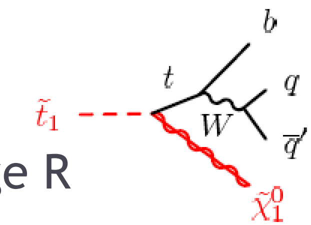
Mixture of decays also possible and to be considered!

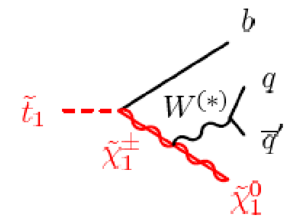
Direct stop: 0 lepton + 4-6 jets

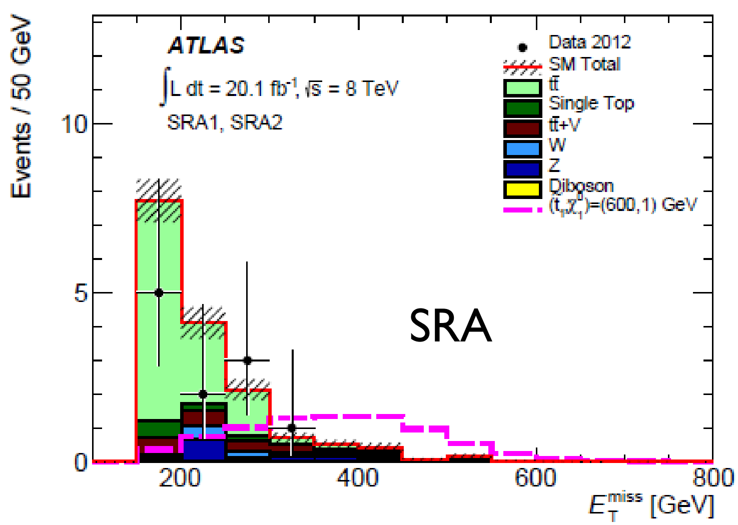
1406.1122

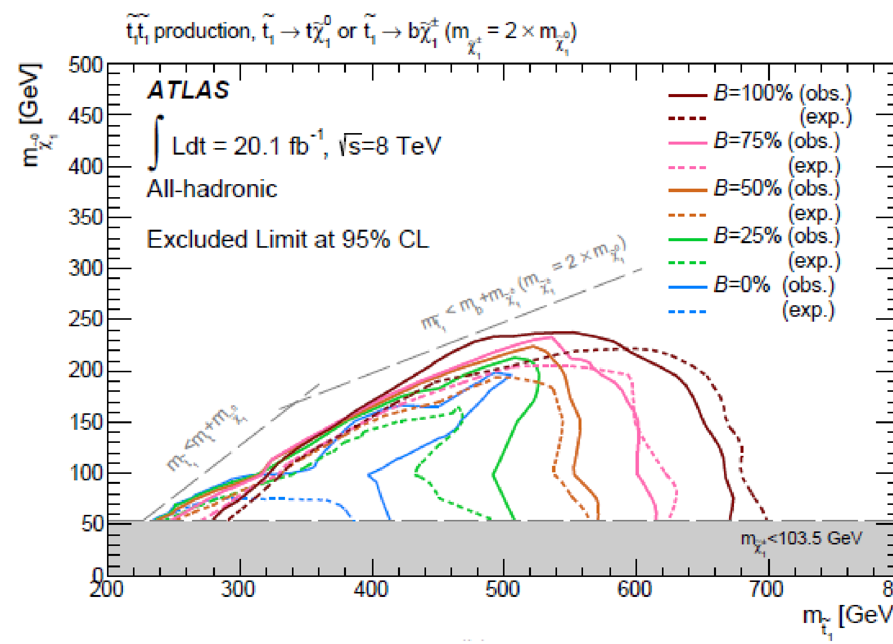


- Three sets of signal regions targeting final states with 1 or 2 fully-hadronic tops:
  - 6+ jets: two resolved tops **(SRA)**
  - 4/5+ jets: merged W or top system in large R jets (R=0.8, 1.2) **(SRB - Boosted region)**
  - 5+ jets: sensitive to b+charg decays **(SRC)**
- **Main background:**
  - **ttbar and Z→vv+jets**





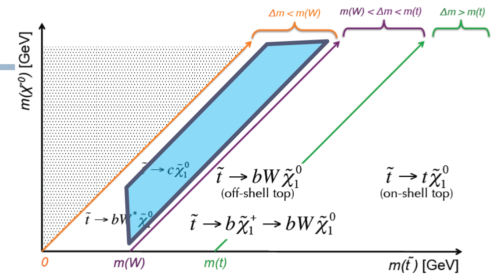




First exclusion as function of BR in t+neut1

Direct stop: 0 lep + 1-2jets (c-jets)

1407.0608

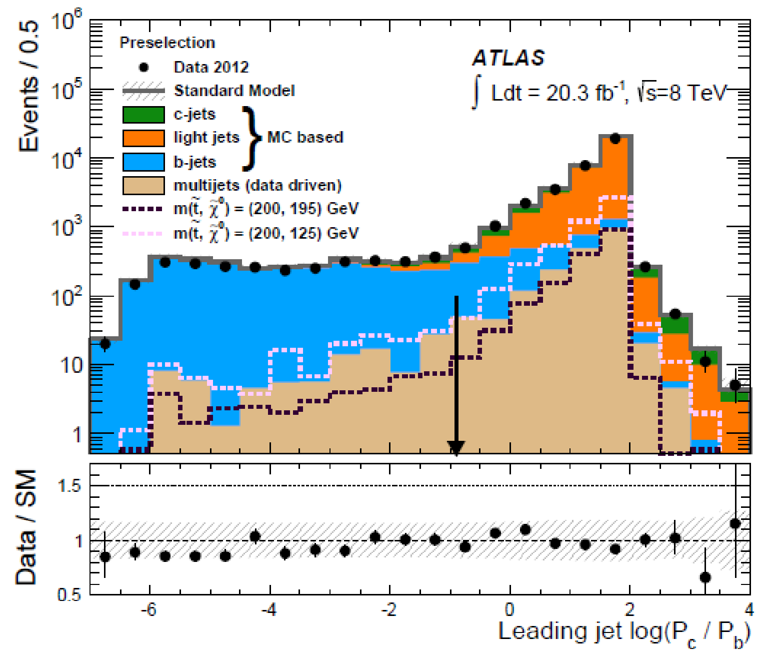


- If ΔM(stop-LSP)<m(W) ➡

$$\tilde{t} \rightarrow c\tilde{\chi}^0$$
$$\tilde{t} \rightarrow bff'\tilde{\chi}^0$$

- Use hard ISR jet to boost the stop system to trigger and separate signal from background. **Two selections:**
  - If ΔM(stop-LSP) < 20 GeV very low, the charm are too soft to be efficiently detected → '**mono-jet like**' signature
    - 1 to 3 jets, high pT leading jet, large MET

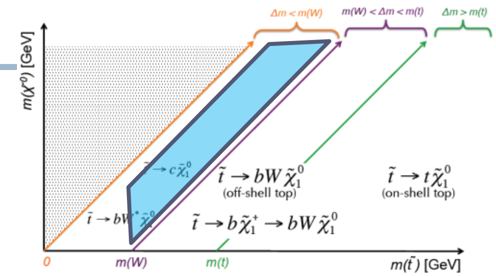
    → Selection potentially sensitive to any 'compressed scenario'
  - If ~20<ΔM(stop-LSP)<m(W), in case of stop in charm+LSP, c-jets might have sufficient pT to be detected and tagged
    - Ask for ≥4 jets, some **charm tagged**, large MET, high p_T untagged leading jet



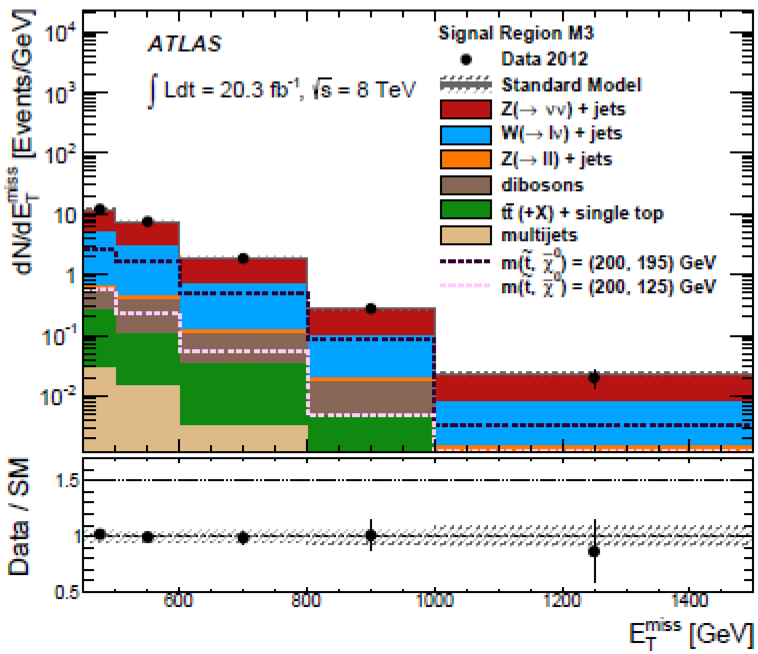
Charm-tagging: Multivariate algorithm define anti-b and anti-light discriminators

$$\text{anti}-\text{b} \equiv \log\left(\frac{P_c}{P_b}\right) \qquad \text{anti}-\text{u} \equiv \log\left(\frac{P_c}{P_u}\right)$$

0 lep + 1-2jets (c-jets): results

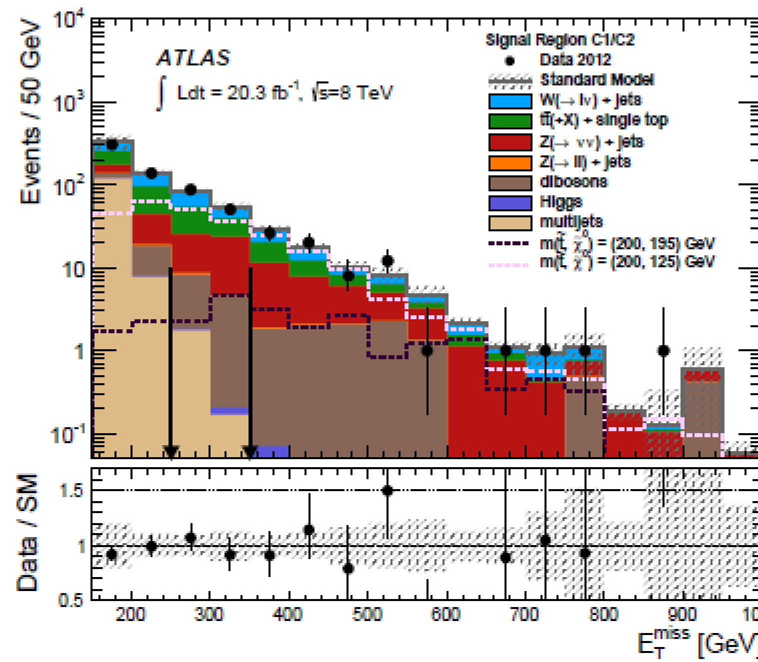


- Main Backgrounds:
  - W+jets, Z+jets estimated from W(μν), Z(μμ), W(eν)+jets control selections
  - Top pairs: from MC for mono-jet like selection, from an eμ control region for the charm tagged selection

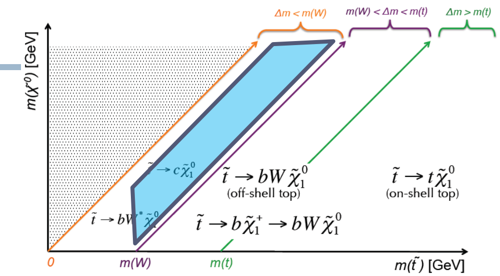


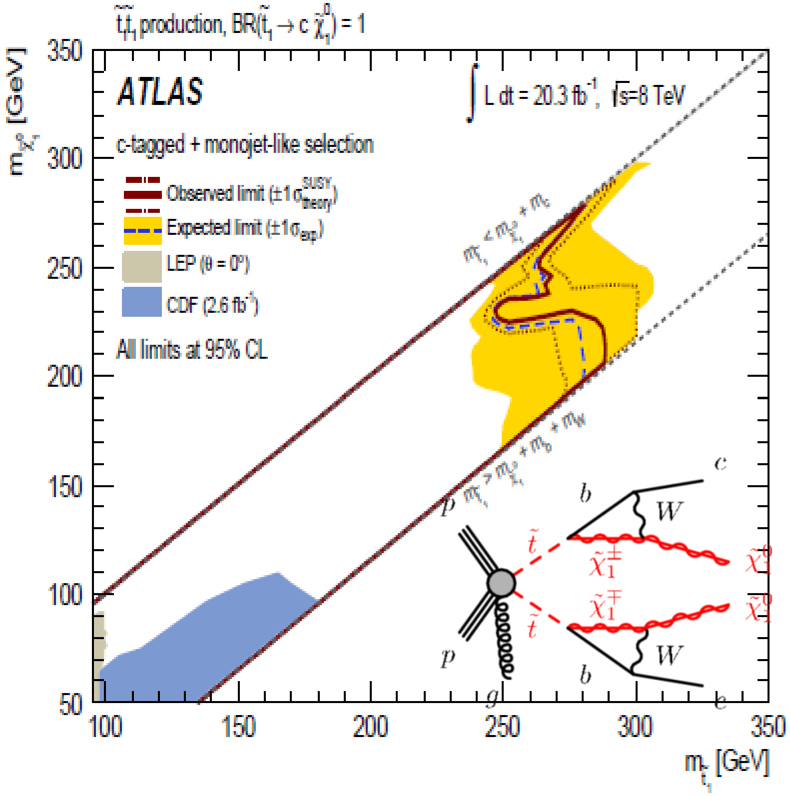
Tightest of the 3 monojet-like SRs (MET>600 GeV, pT j1 > 600 GeV)

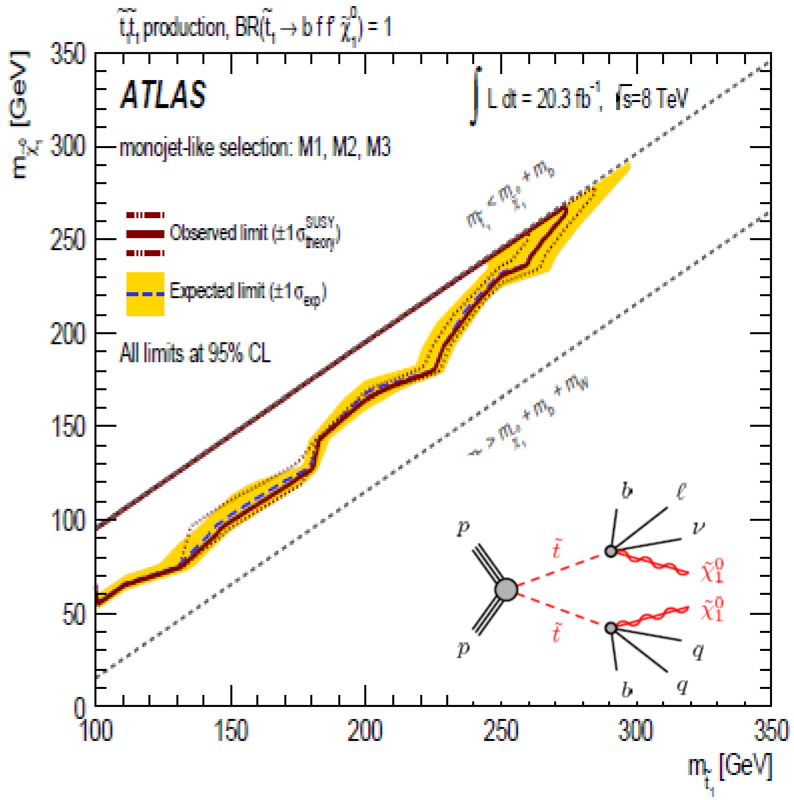
MET distribution for charm-jet based SRs



0 lep + 1-2jets (c-jets): results



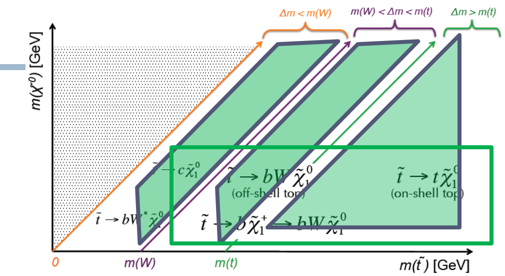




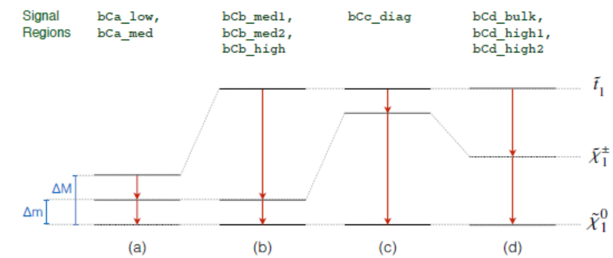
- Sensitivity of the monojet-like part independent of stop decays (soft b- c-jets, leptons)
- Similar reach for compressed scenarios in case of sbottom pair production

Direct stop: 1 lepton + >=4 jets

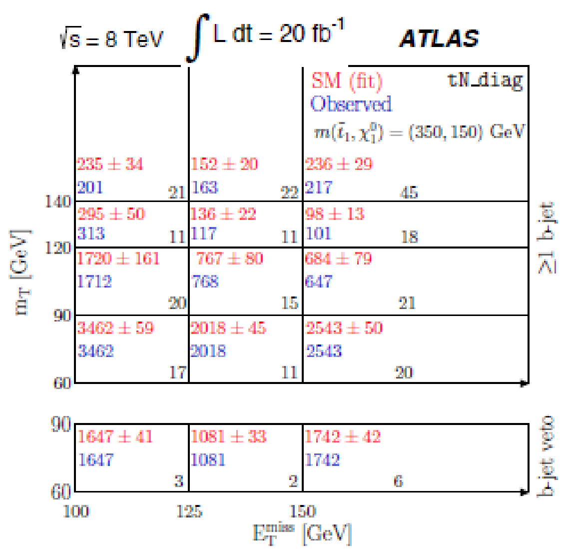
1407.0583



- ‘Hard’ (>25 GeV) and ‘soft’ (7-50 GeV) leptons
- 15 SRs sensitive to stop in various scenarios:
  - t+neut1 (stealth and high mass), 3- and 4-body decay
  - b+charg with various mass hierarchy hypothesis
- Use several complex discriminating quantities
  - Preselection: 1l + 4 or more jets, >= 1 b-jet, MET
  - ex. mT, amT2, large R jets



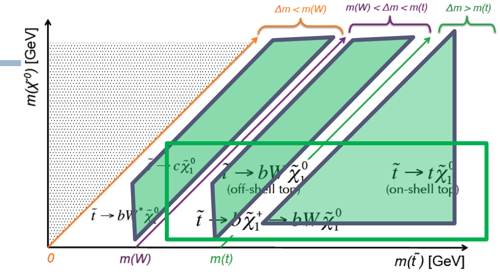
Cut and count and shape fit
(e.g. based on ETMiss – mT)

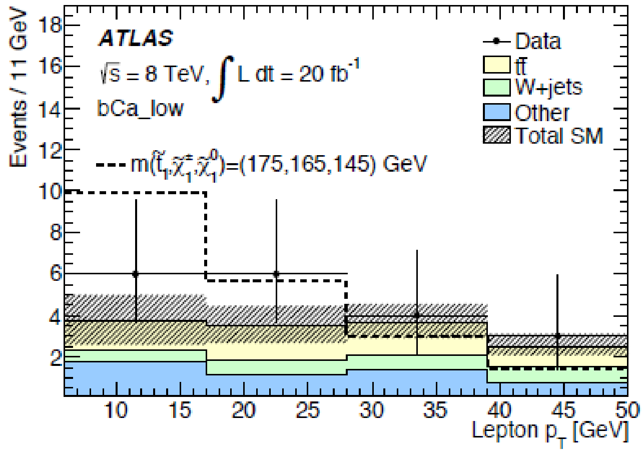


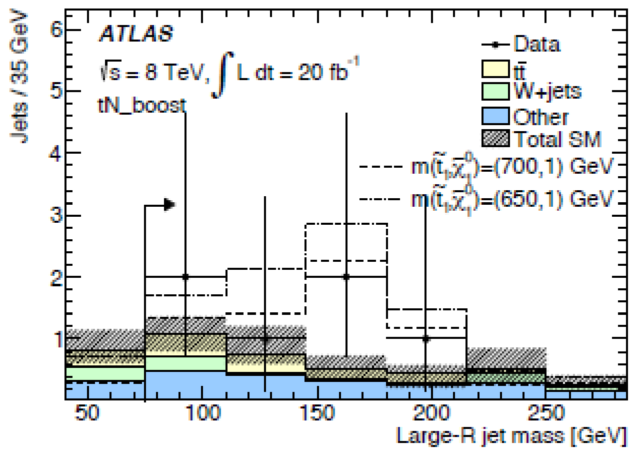
SR	Signal scenario	Exclusion technique
tN_diag	$\tilde{t}_1 \to t\tilde{\chi}^0_1$, $m_{\tilde{t}_1} \gtrsim m_t + m_{\tilde{\chi}^0_1}$	shape-fit (E_T^{miss} and m_T)
tN_med	$\tilde{t}_1 \to t\tilde{\chi}^0_1$, $m_{\tilde{t}_1} \sim 550$ GeV, $m_{\tilde{\chi}^0_1} \lesssim 225$ GeV	cut-and-count
tN_high	$\tilde{t}_1 \to t\tilde{\chi}^0_1$, $m_{\tilde{t}_1} \gtrsim 600$ GeV	cut-and-count
tN_boost	$\tilde{t}_1 \to t\tilde{\chi}^0_1$, $m_{\tilde{t}_1} \gtrsim 600$ GeV, with a large-R jet	cut-and-count
bCa_low	$\tilde{t}_1 \to b\tilde{\chi}^\pm_1$, $\Delta M \lesssim 50$ GeV $\tilde{t}_1 \to bff'\tilde{\chi}^0_1$	shape-fit (lepton p_T)
bCa_med	$\tilde{t}_1 \to b\tilde{\chi}^\pm_1$, 50 GeV $\lesssim \Delta M \lesssim 80$ GeV $\tilde{t}_1 \to bff'\tilde{\chi}^0_1$	shape-fit (lepton p_T)
bCb_med1	$\tilde{t}_1 \to b\tilde{\chi}^\pm_1$, $\Delta m \lesssim 25$ GeV, $m_{\tilde{t}_1} \lesssim 500$ GeV	shape-fit (am_{T2})
bCb_high	$\tilde{t}_1 \to b\tilde{\chi}^\pm_1$, $\Delta m \lesssim 25$ GeV, $m_{\tilde{t}_1} \gtrsim 500$ GeV	shape-fit (am_{T2})
bCb_med2	$\tilde{t}_1 \to b\tilde{\chi}^\pm_1$, $\Delta m \lesssim 80$ GeV, $m_{\tilde{t}_1} \lesssim 500$ GeV	shape-fit (am_{T2} and m_T)
bCc_diag	$\tilde{t}_1 \to b\tilde{\chi}^\pm_1$, $m_{\tilde{t}_1} \gtrsim m_{\tilde{\chi}^\pm_1}$	cut-and-count
bCd_bulk	$\tilde{t}_1 \to b\tilde{\chi}^\pm_1$, $(\Delta M, \Delta m) \gtrsim 100$ GeV, $m_{\tilde{t}_1} \lesssim 500$ GeV	shape-fit (am_{T2} and m_T)
bCd_high1	$\tilde{t}_1 \to b\tilde{\chi}^\pm_1$, $(\Delta M, \Delta m) \gtrsim 100$ GeV, $m_{\tilde{t}_1} \gtrsim 500$ GeV	cut-and-count
bCd_high2	$\tilde{t}_1 \to b\tilde{\chi}^\pm_1$, $\Delta M \gtrsim 250$ GeV, $m_{\tilde{t}_1} \gtrsim 500$ GeV	cut-and-count
3body	$\tilde{t}_1 \to bW\tilde{\chi}^0_1$, $m_{\tilde{t}_1} \lesssim 300$ GeV	shape-fit (am_{T2} and m_T)
tNbC_mix	non-symmetric ($\tilde{t}_1 \to t\tilde{\chi}^0_1$, $\tilde{t}_1 \to b\tilde{\chi}^\pm_1$)	cut-and-count

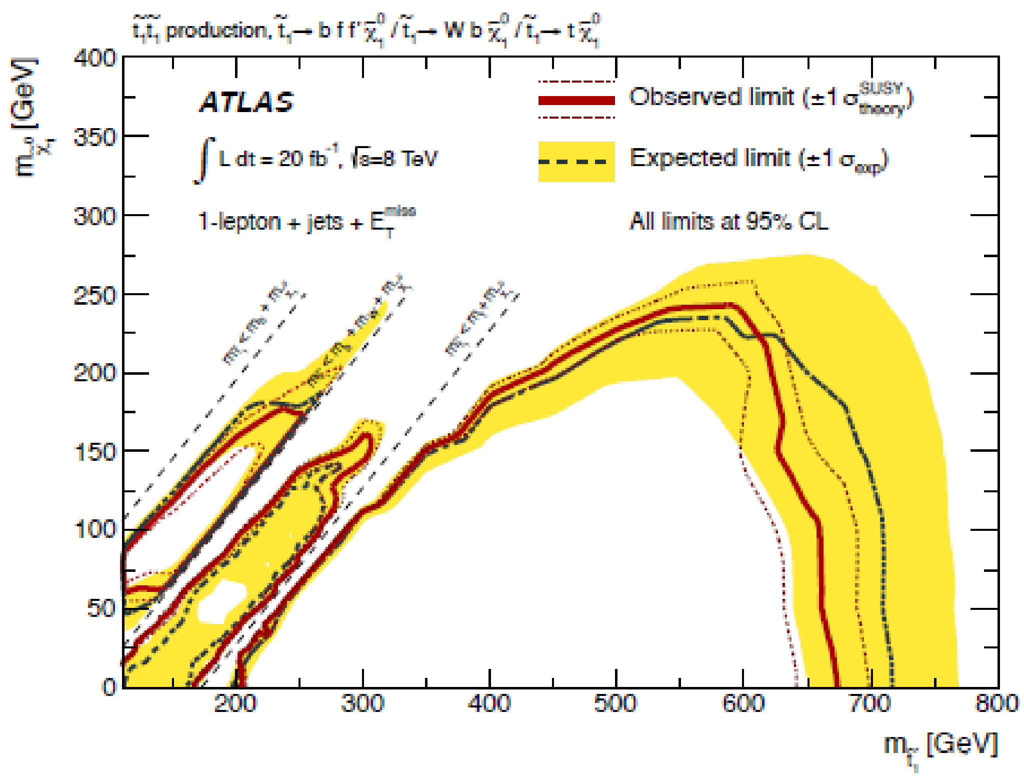
Direct stop: 1 lepton + >=4 jets

- Results consistent with SM



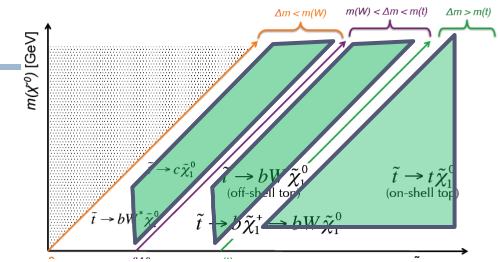




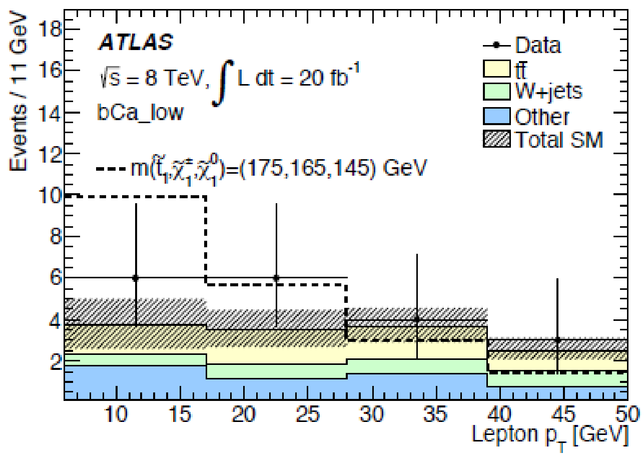


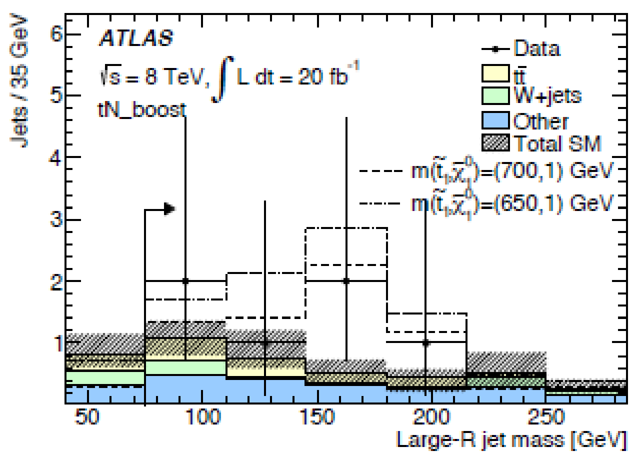
- Sensitivity at high stop mass: large R jets SR
- Soft-lepton based analyses sensitive to compressed scenarios (in particular 4-body decays)

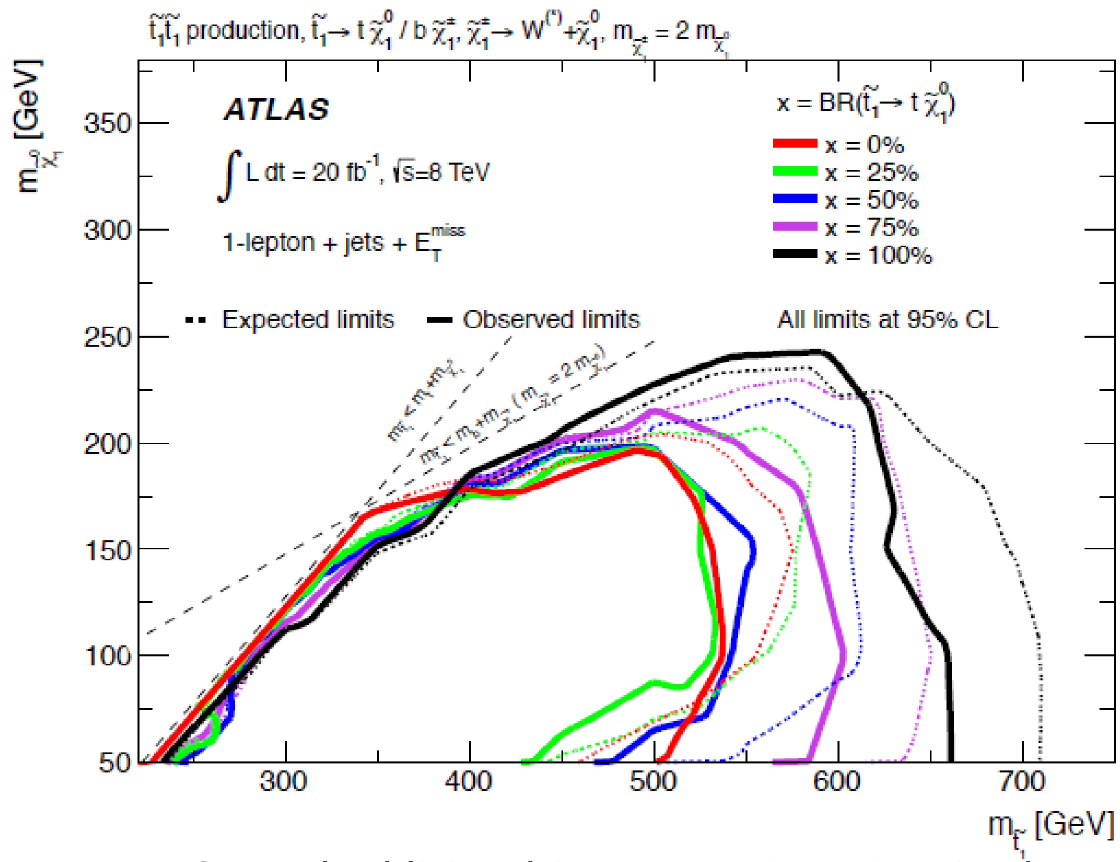
Direct stop: 1 lepton + >=4 jets



- Results consistent with SM



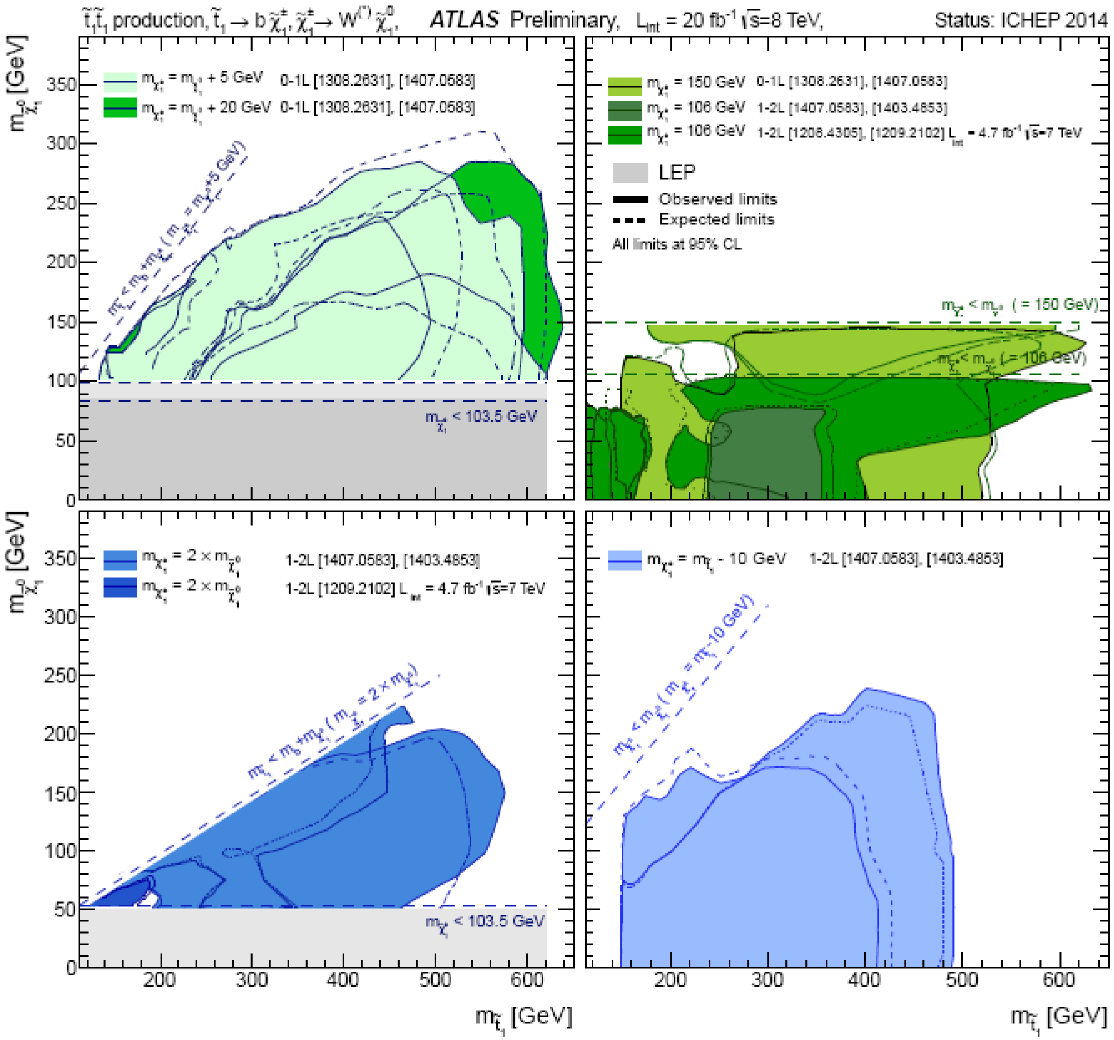


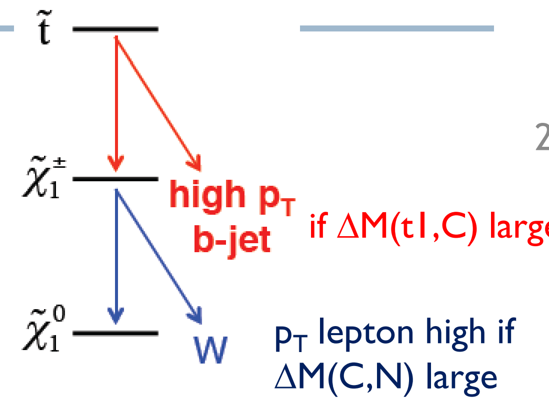


- Several additional interpretations, in mixed scenarios and in phenomenological MSSM models with longer stop decay chains

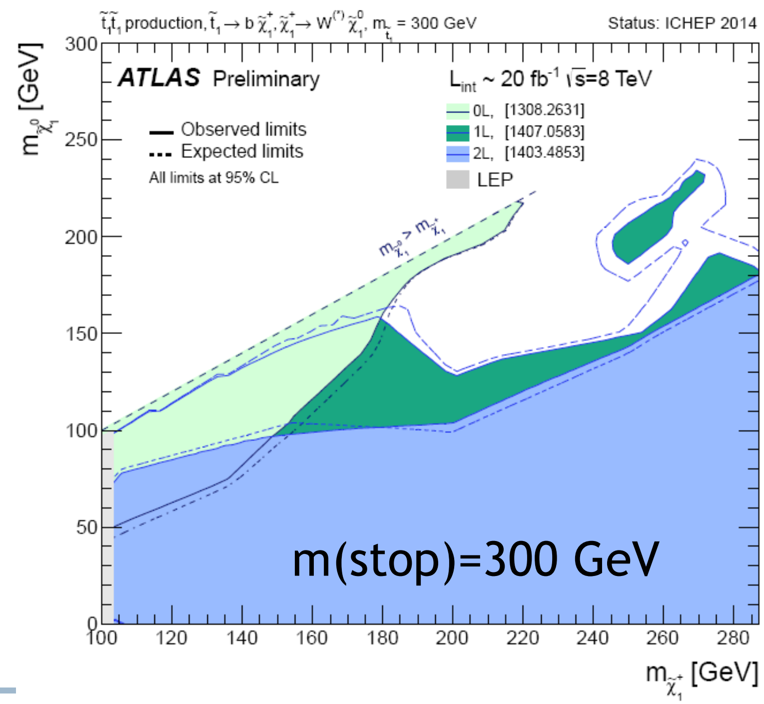
Complimentarity of searches

- Various assumptions of ΔM(stop-chargino) and ΔM(chargino-neutralino)



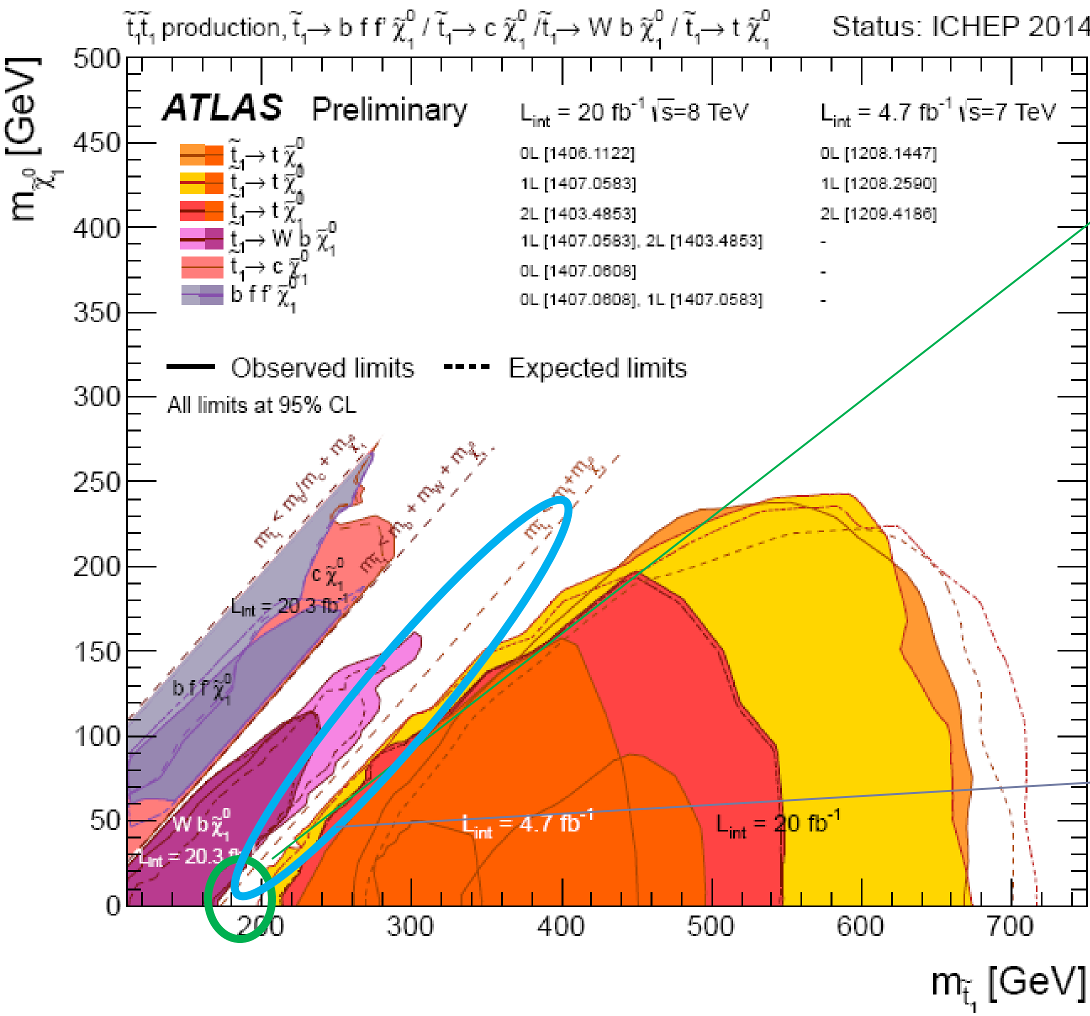


Fixed mass stop, function of chargino-neutralino mass

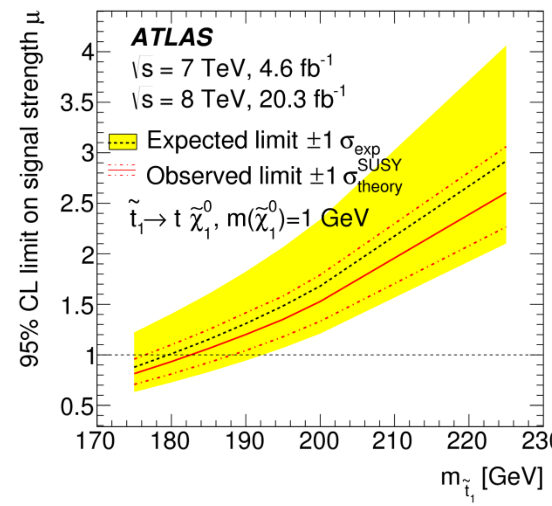


m(stop)=300 GeV

Complimentarity of searches (II)



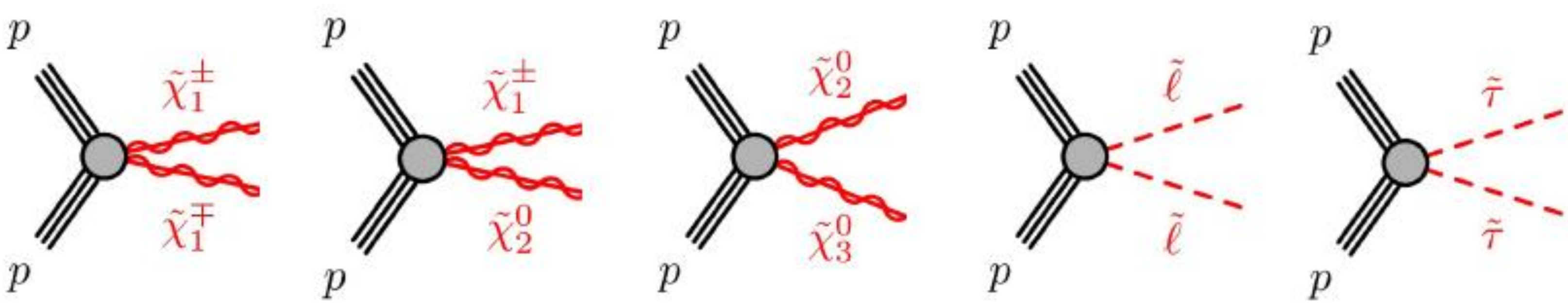
- M(stop) ~ m(top): [1406.5375]
  - New constraints from ttbar cross section measurement



- M(stop) ~ m(top)+m(neut1):
  - Compressed regions indirectly accessed via stop2 searches:
    - Stop2 → stop1 + Z/higgs
    - Stop1 → t + Neut1
  - Z-like final states targeted in [1403.5222]

Ewkinos and sleptons production

Again, many possible signatures, possibly several leptons ..



Direct sleptons and charginos (2 e,μ)

- Use mT2 or mjj (for charg-neut2 via WZ as discriminant
- Also: $\Delta\phi(ll)$, $p_T(ll)$, $m(ll)$

Background modeling:

- *Reducible:* data driven
- *Irreducible (Dominant: WW, ttbar)*

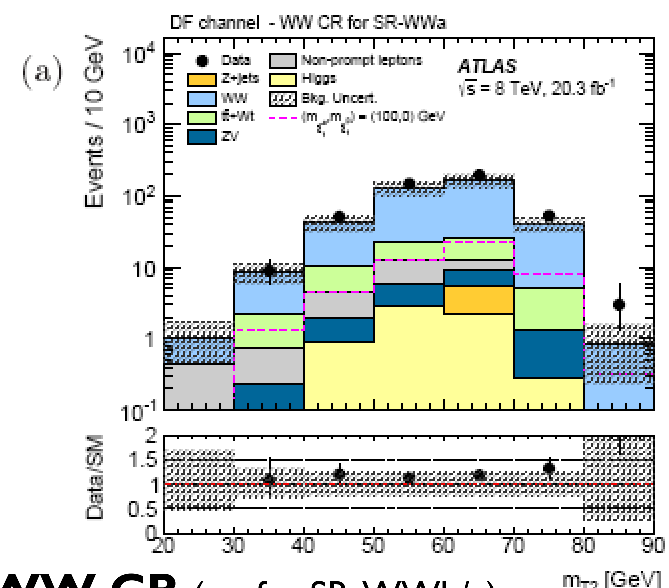
CR defined with at least one reverted cut

SR	m_{T2}^{90}	m_{T2}^{120}	m_{T2}^{150}	WWa	WWb	WWc	Zjets
lepton flavour	DF,SF	DF,SF	DF,SF	DF,SF	DF,SF	DF,SF	SF
central light jets	0	0	0	0	0	0	≥ 2
central b-jets	0	0	0	0	0	0	0
forward jets	0	0	0	0	0	0	0
$\lvert m_{\ell\ell} - m_Z\rvert$ [GeV]	> 10	> 10	> 10	> 10	> 10	> 10	< 10
$m_{\ell\ell}$ [GeV]	—	—	—	< 120	< 170	—	—
$E_{\mathrm{T}}^{\mathrm{miss,rel}}$ [GeV]	—	—	—	> 80	—	—	> 80
$p_{\mathrm{T},\ell\ell}$ [GeV]	—	—	—	> 80	—	—	> 80
m_{T2} [GeV]	> 90	> 120	> 150	—	> 90	> 100	—
$\Delta R_{\ell\ell}$	—	—	—	—	—	—	[0.3,1.5]
m_{jj} [GeV]	—	—	—	—	—	—	[50,100]

Slepton pair, charginos decaying via sleptons

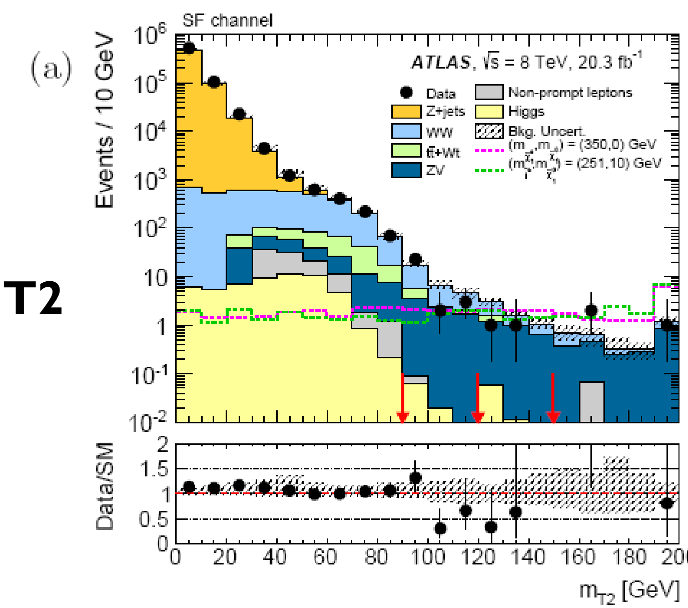
charginos decaying via W bosons

Chargino-neut2 in WZ

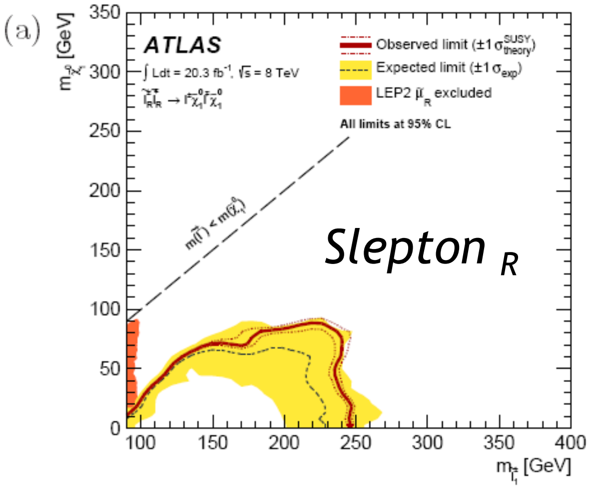


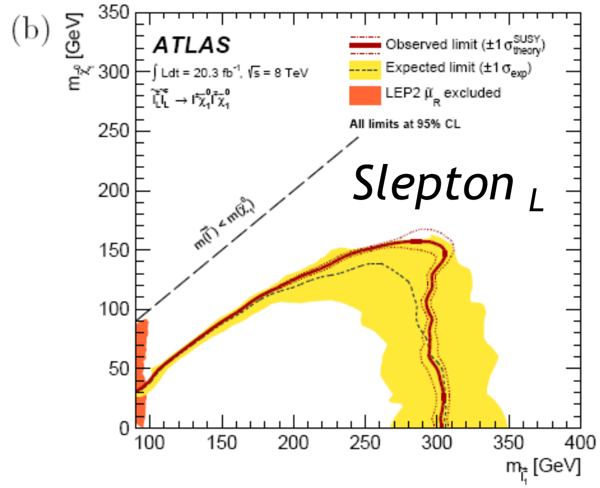
WW CR (ex. for SR-WWb/c)

SR-mT2

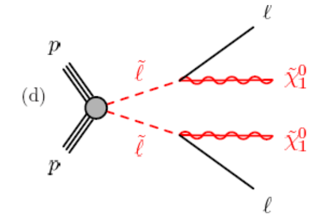


Interpretations

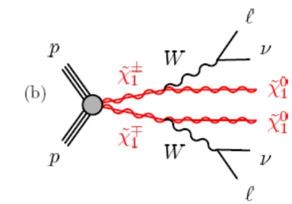


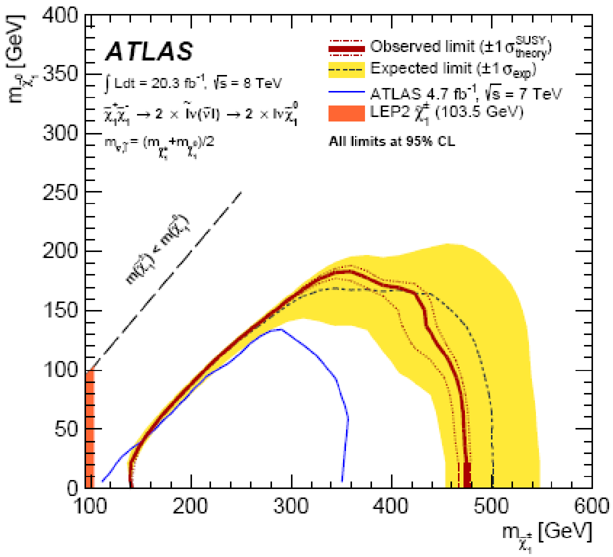


First limits from LHC on pure right-handed sleptons (σ(LH)~4 σ(RH))

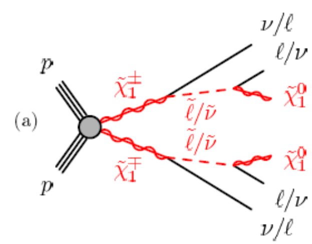


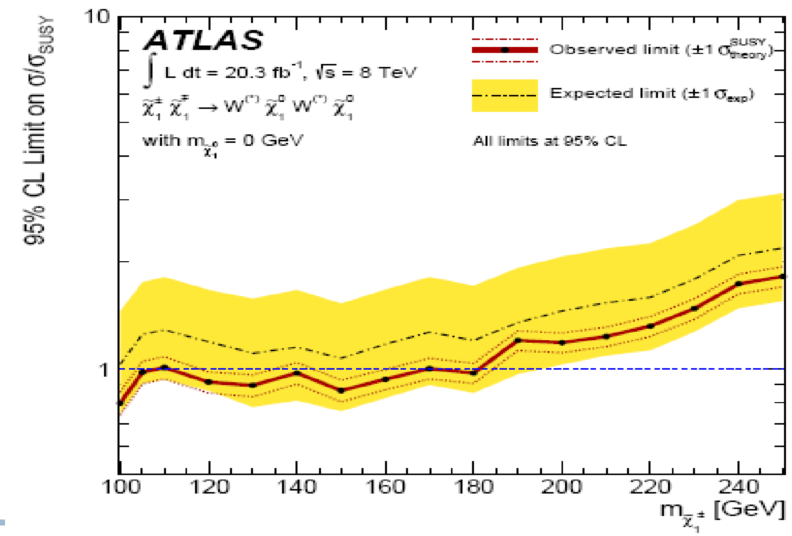
First study on chargino decays via W





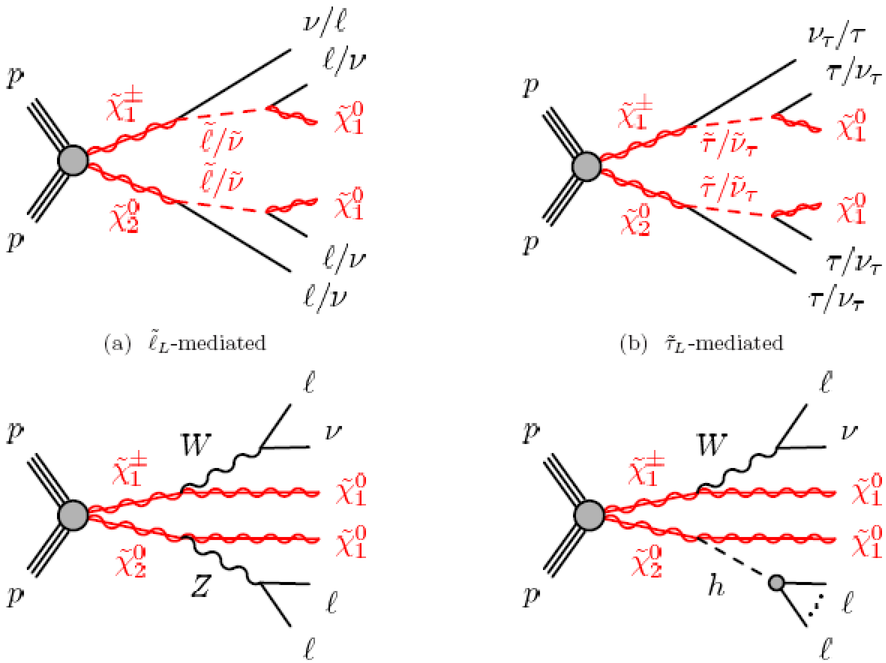
Extend ~ 150 GeV chargino limits (decay via sleptons)





Chargino-neutralino pair production in 3L (e,μ,τ)

Signature: 3 leptons (e, μ,τ), SFOS pair + E_T^{miss}



(a) $\tilde{\ell}_L$-mediated (b) $\tilde{\tau}_L$-mediated

(c) WZ-mediated (d) Wh-mediated

Signal region	SR0τa	SR0τb	SR1τ	SR2τa	SR2τb
Flavour/sign	$\ell^+\ell^-\ell$, $\ell^+\ell^-\ell'$	$\ell^\pm\ell^\pm\ell'^\mp$	$\tau^\pm\ell^\mp\ell^\mp$, $\tau^\pm\ell^\mp\ell'^\mp$	$\tau\tau\ell$	$\tau^+\tau^-\ell$
b-tagged jet	veto	veto	veto	veto	veto
E_T^{miss}	binned	> 50	> 50	> 50	> 60
Other	m_{SFOS} binned, m_T binned	$p_T^{3^{rd}\,\ell} > 20$, $\Delta\phi_{\ell\ell'}^{min} \leq 1.0$	$p_T^{2^{nd}\,\ell} > 30$, $\sum p_T^\ell > 70$, $m_{\ell\tau} < 120$, m_{ee} Z veto	$m_{T2}^{max} > 100$	$\sum p_T^\tau > 110$, $70 < m_{\tau\tau} < 120$
Target model	$\tilde{\ell}$,WZ-mediated	Wh-mediated	Wh-mediated	$\tilde{\tau}_L$-mediated	Wh-mediated

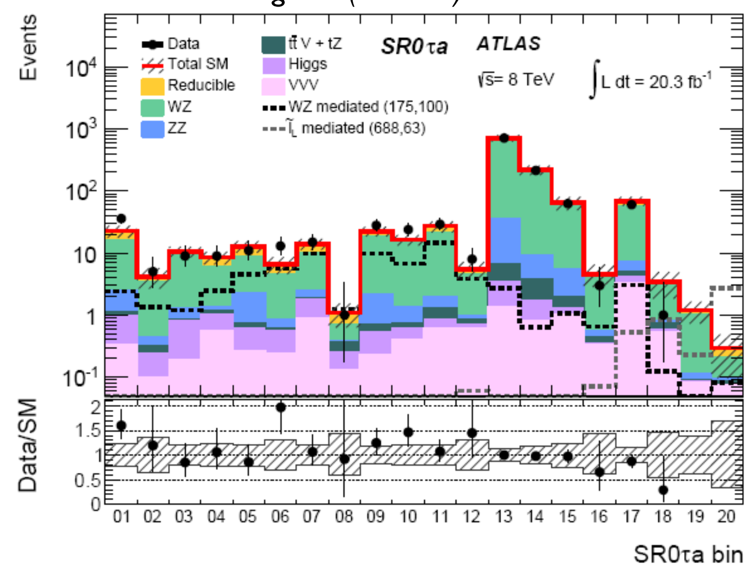
SM Backgrounds

Irreducible (MC)
WZ, ZZ, VVV, ttbar+V

Reducible (matrix method)
Ttbar, Z+jets

- SM background checked in several validation regions

Binned regions (no taus)

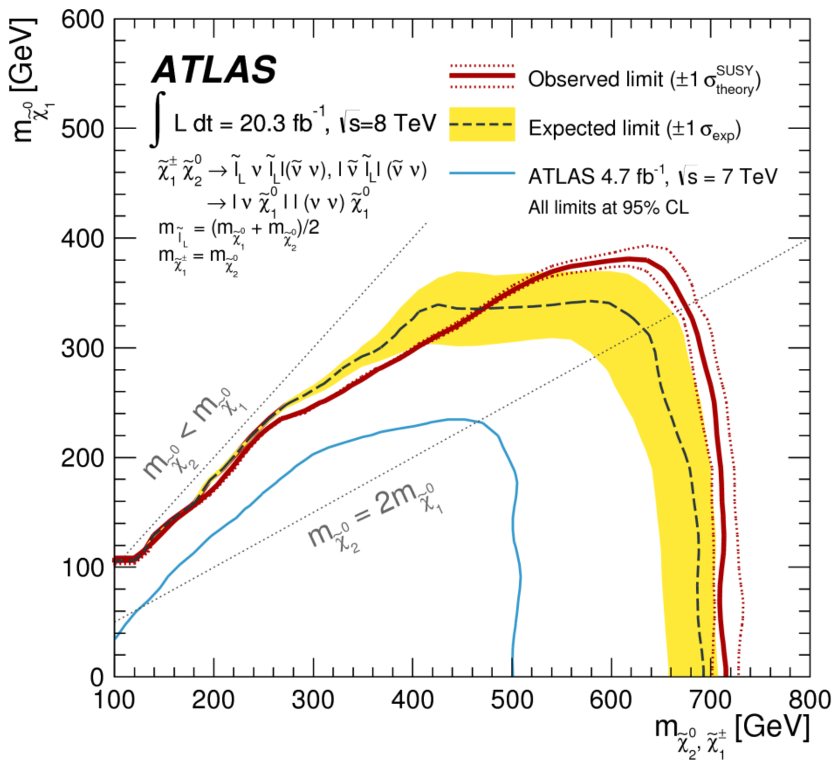


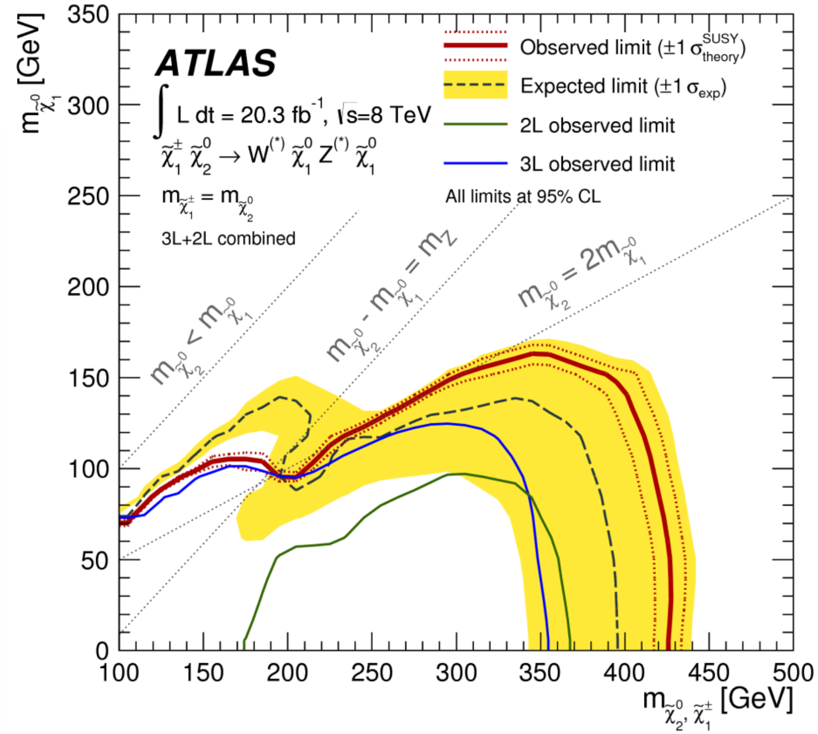
Interpretations

- Exclude degenerate chargino-neutralino2 up to 700 GeV(420 GeV) for low(high) slepton masses
  - In WZ case, combination with 2L (mjj based Z-region analysis)

heavy sleptons

light sleptons





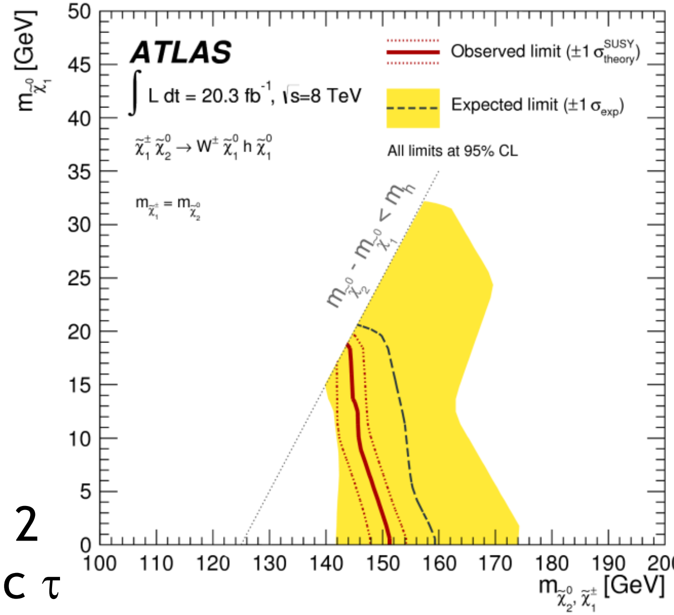
Sensitivity in the very challenging WZ* region

Complement this with searches for W+higgs - if neut2-neut1 Δm > m(h)

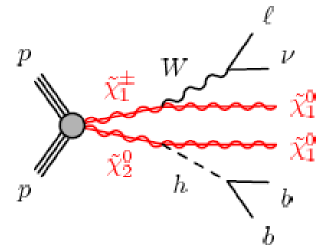
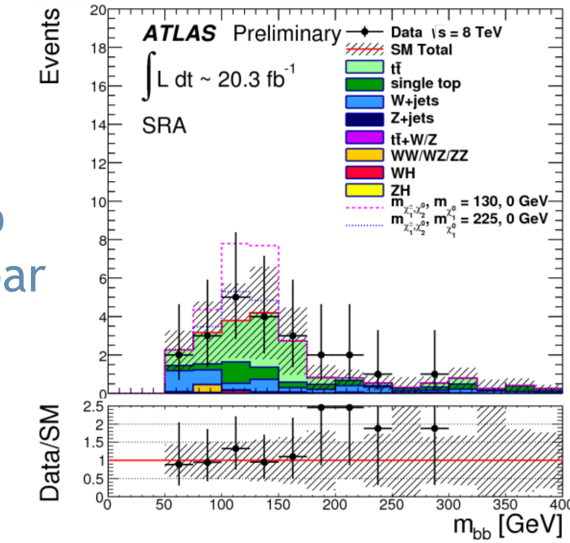
Interpretation (II)

ATLAS-CONF-2013-093

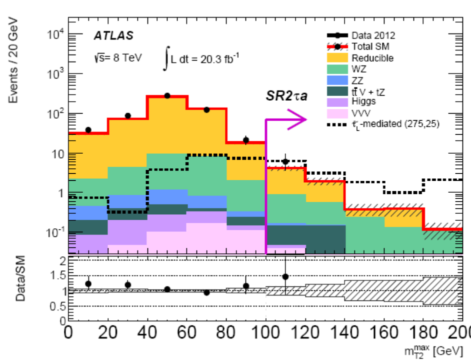
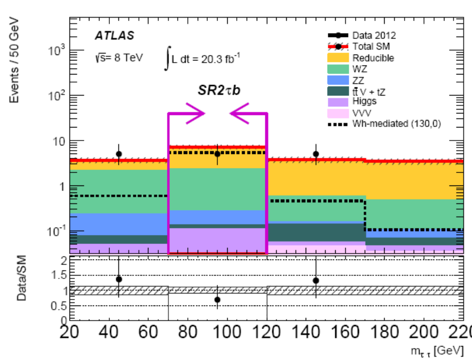
- Exclusion in challenging Wh final states
  - Target $h \to \tau\tau$ (but also $h \to WW^*$)

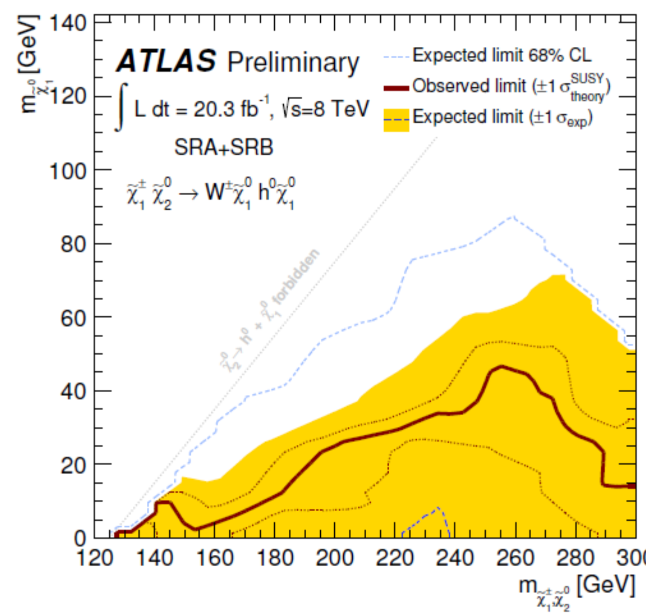


Complimentary to search for $h \to b\bar{b}$

SR with 2 hadronic τ

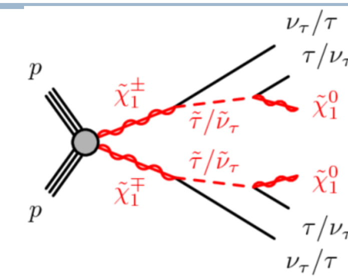


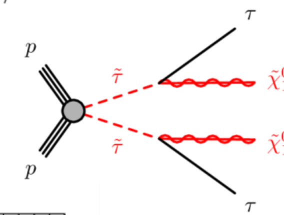
Light-stau scenarios

[1407.0350]

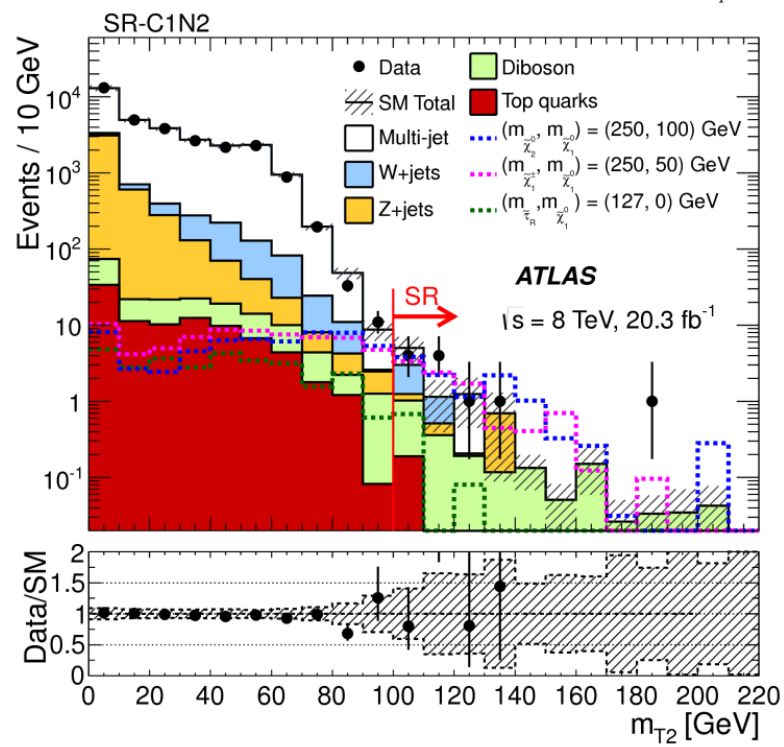
- Dedicated search for 2-hadronic taus and MET
  - Sensitive to chargino pair, chargino-neutralino and stau pair production
- 4 SRs defined to enhance sensitivity to various targeted signals (use mT2, mT tau, MET)
- Main background:

→ misidentified taus
  - Multijet (data-driven)
  - W(→τν)+jets (semi-data driven)



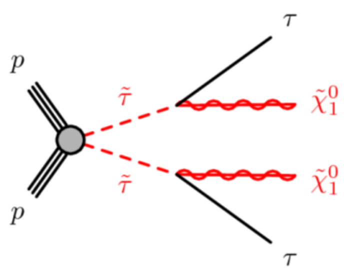


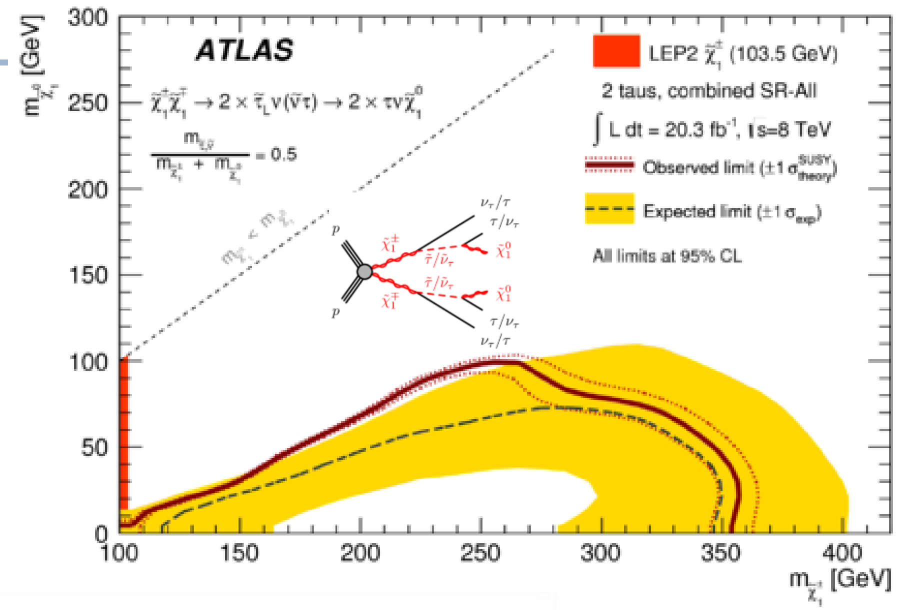
Example of discriminating variable mT2

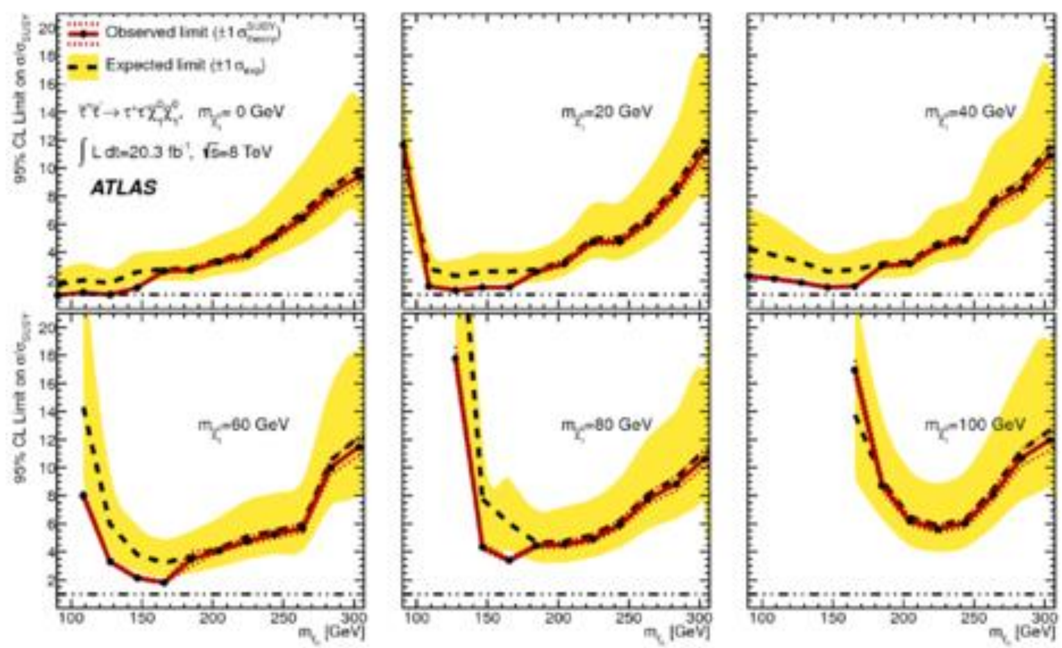


Results

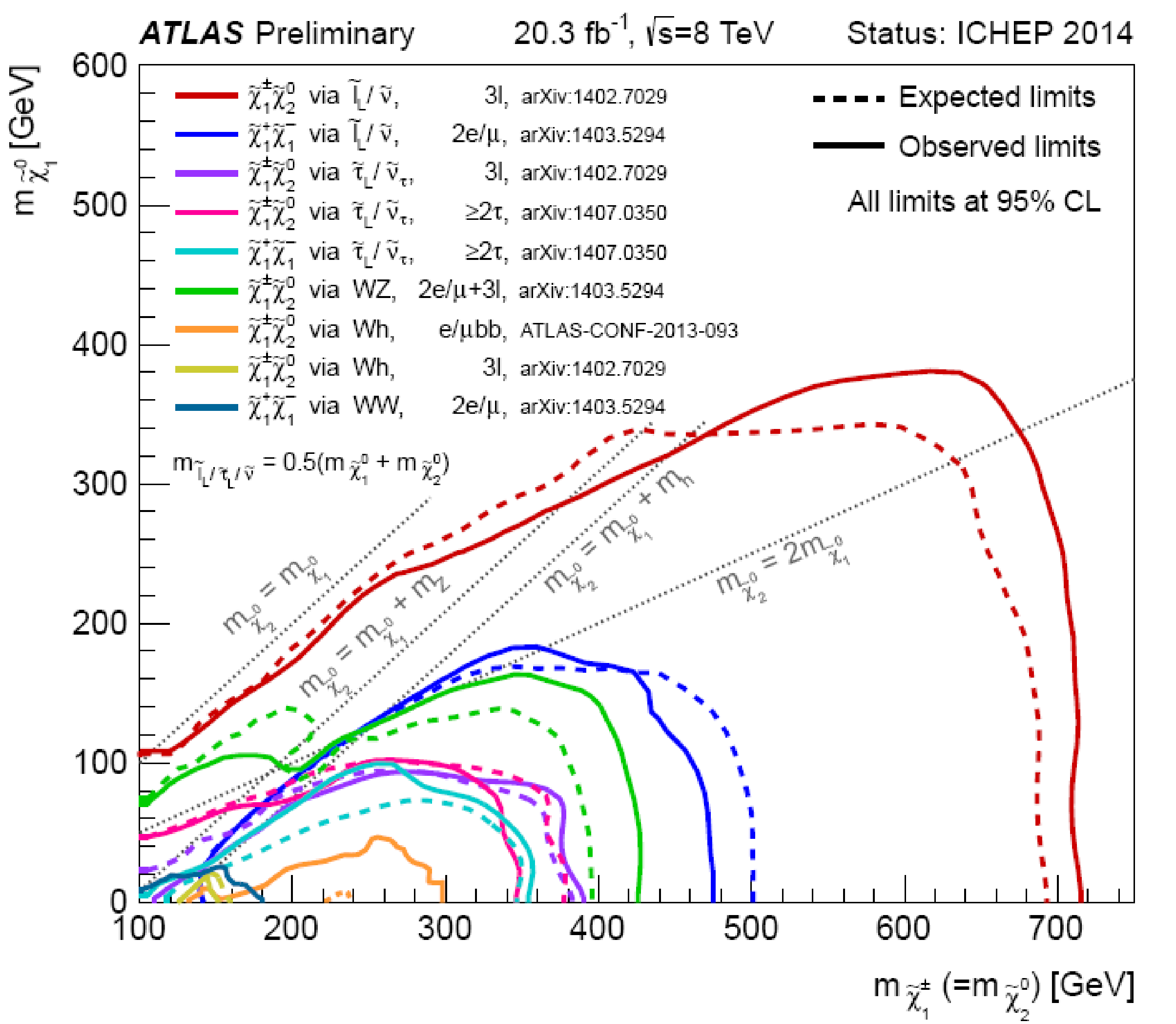
- Good agreement between data and SM expectations
- First interpretation for direct stau pair production:
  - Getting closer to sensitivity!



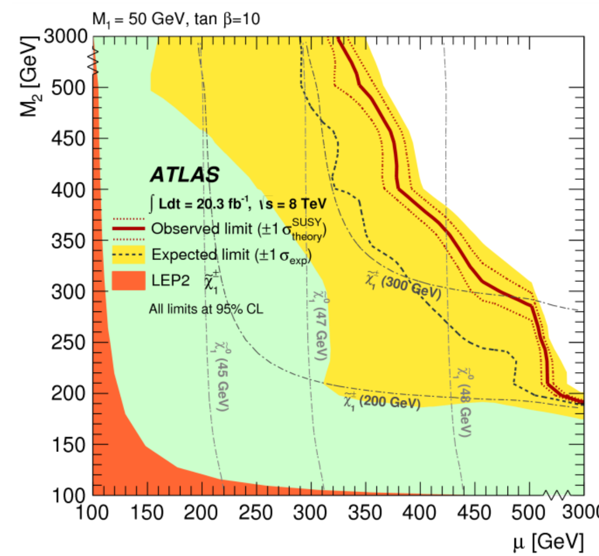




Summary of EWK searches



- *Also*: interpretations in pMSSM models:
  - Example: μ-M_2 mass plane of the pMSSM with very large slepton masses,
  - M_1 = 50 GeV and tanβ = 10.

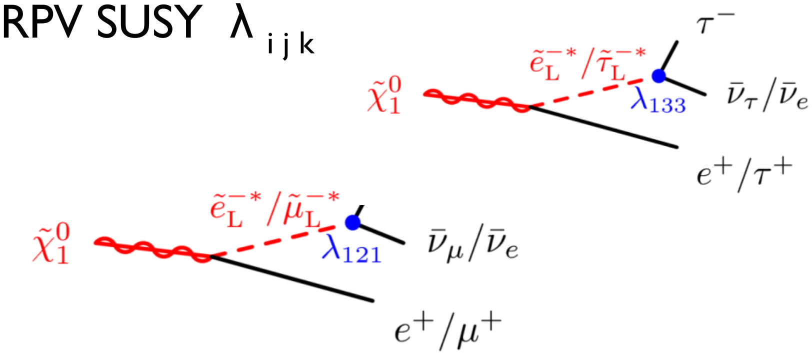


1405.5086

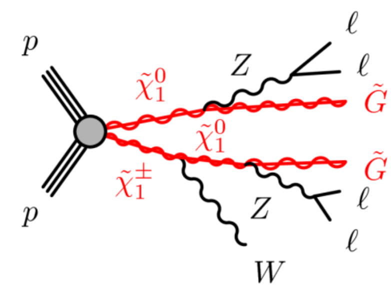
Multilepton (>=4) search

- Sensitive to EWK RPC SUSY, but also Gauge Mediated models, Strong and EWK production in RPV models. A few examples:

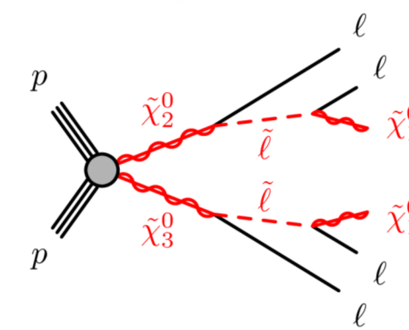
RPV SUSY λ_{ijk}



GMSB: Z-rich



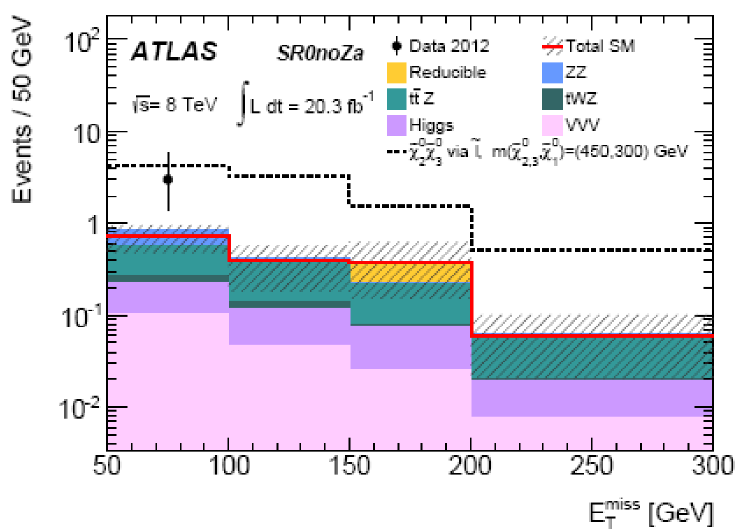
RPC $\tilde{\chi}_2^0\tilde{\chi}_3^0$

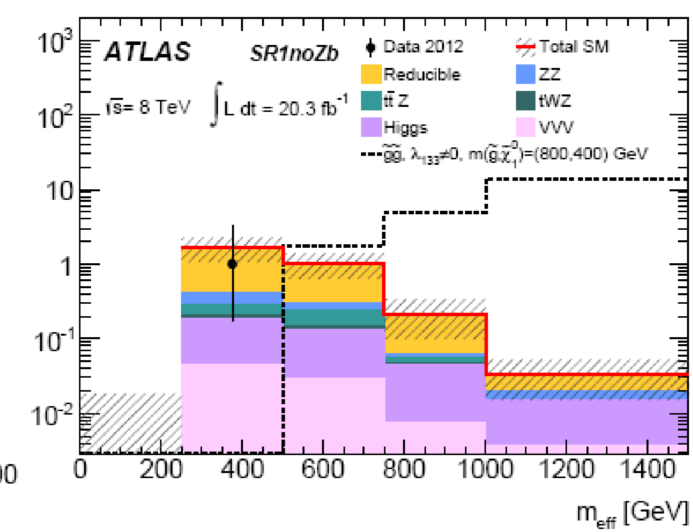


Signature: $\geq$ 4 leptons (0, 1,2 hadronic τ) + Meff/E_T^{miss}

Versatile analysis!
Low backgrounds

Signal regions
High Meff or E_t^{miss},
Z-rich / Z-depleted





Backgrounds

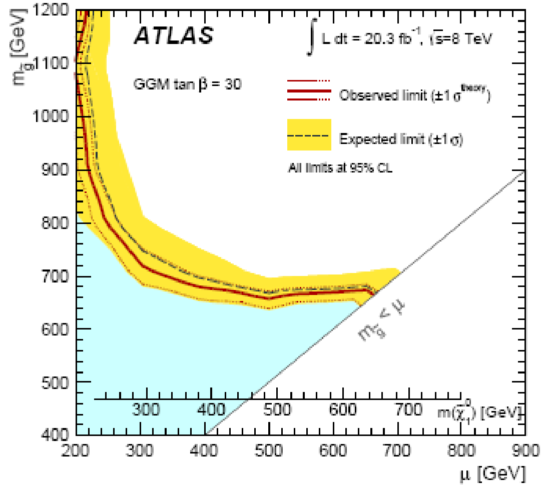
Irreducible
ZZ, ZWW,
ttbar+Z/WW, higgs

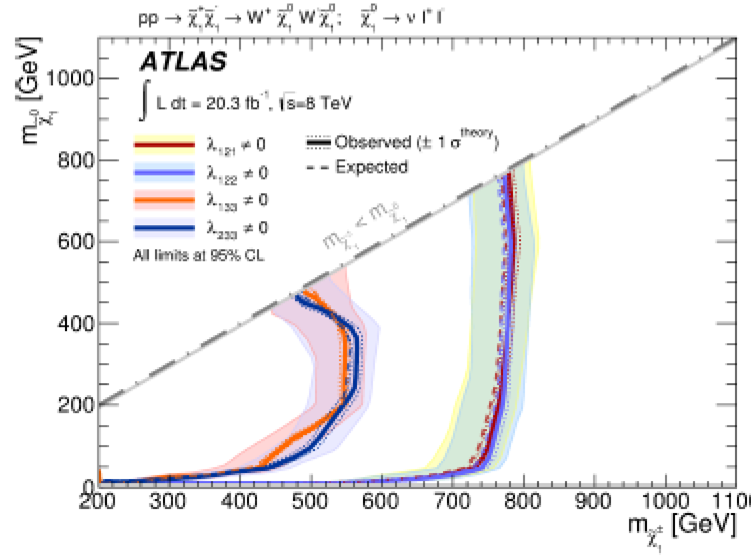
Reducible
Ttbar, Z+jets, WZ

Results

- Good agreement data/SM in all regions
- Among the many interpretations:

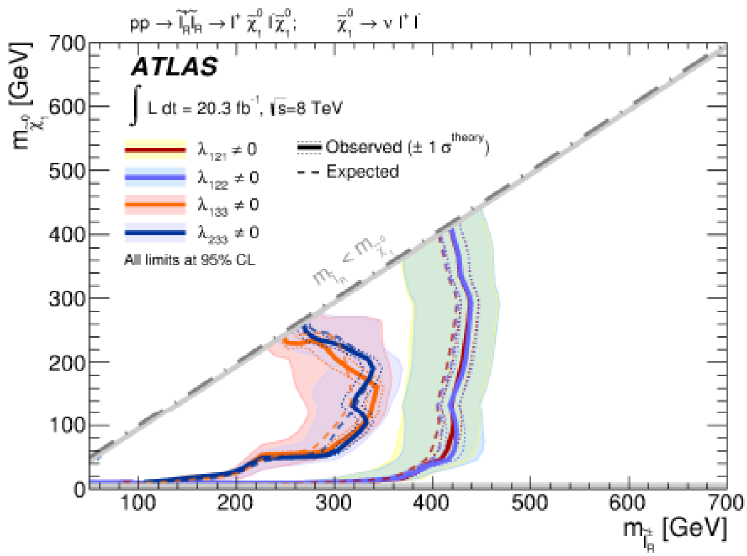
RPC: GMSB



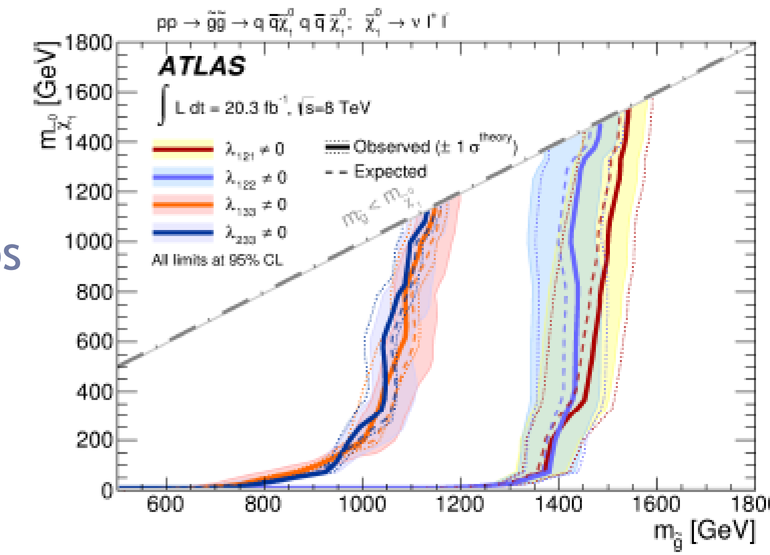


(a) Chargino NLSP

RPV ($\lambda \neq 0$)
- charginos
- Sleptons
- gluinos



(b) R-slepton NLSP

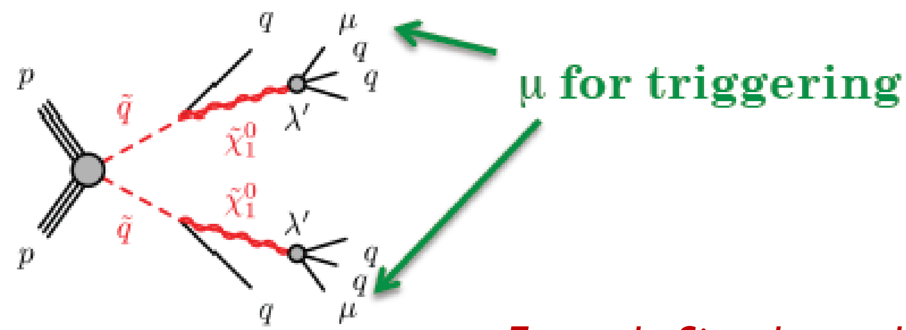


(b) Gluino NLSP

Displaced vertex (DV) searches

- If couplings are ≠ 0 but very small: non prompt particle production

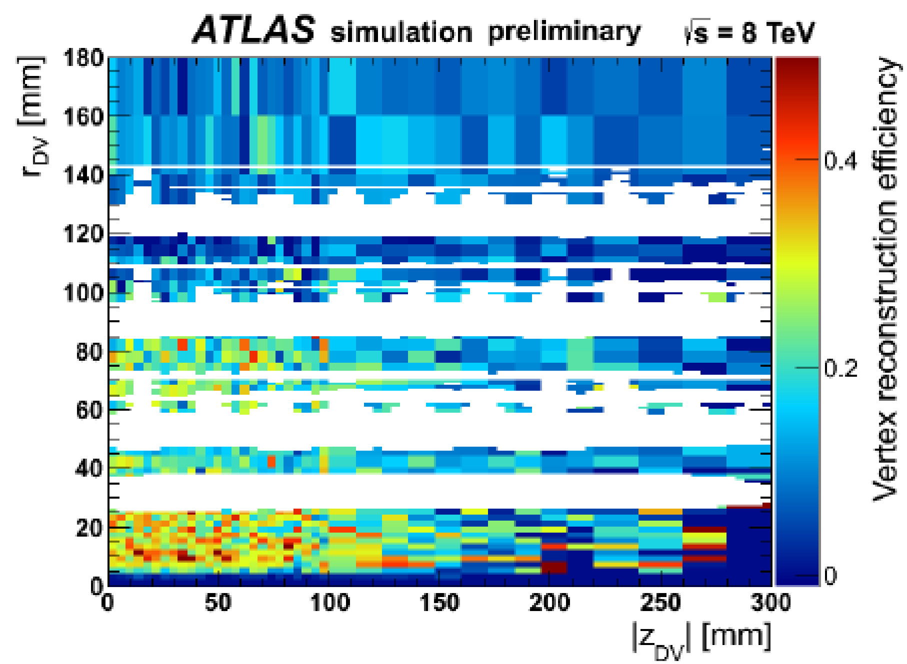
Search for displaced vertices with muons (RPV arises from λ')



ATLAS-CONF-2013-092

- Recover signal tracks performing special '**re-tracking**'
- **Vertex:** must be at least 4mm from any primary vertex, in |z|<300mm and r<180mm, and away from Inner Detector material
- **Signal region optimized on number of tracks in the vertex (>=4) and vertex mass (>10 GeV)**

Example Signal sample

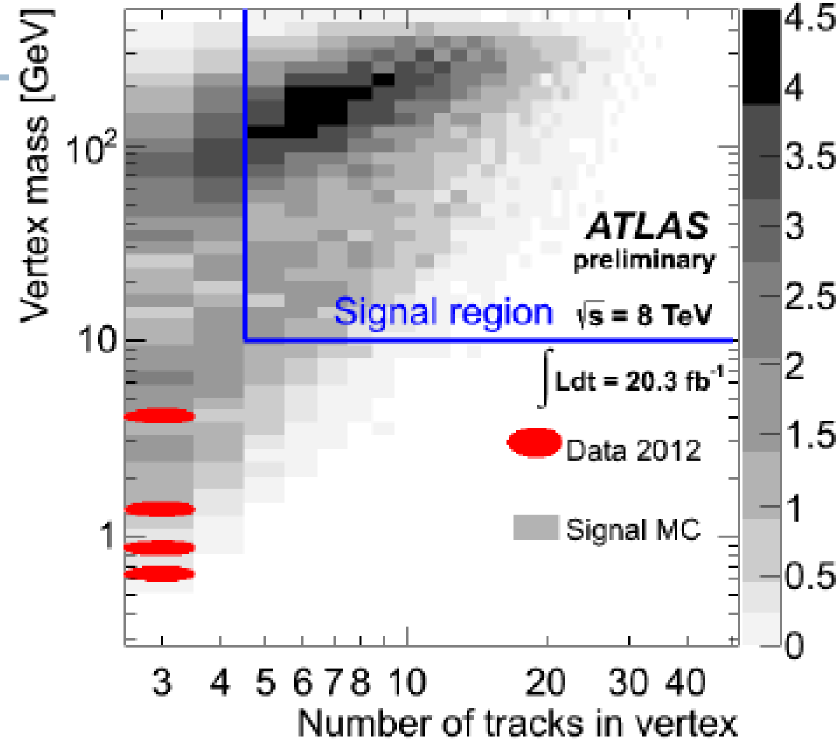


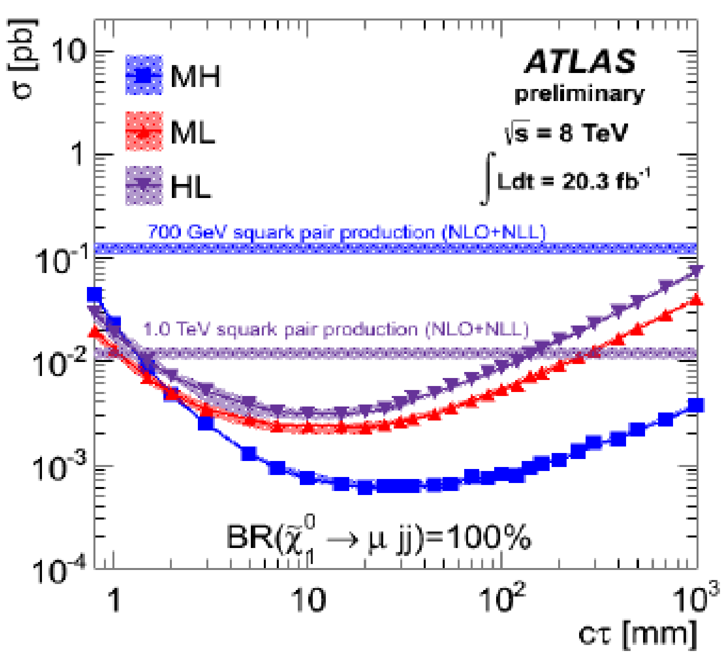
Results

- Very small background:

  0.02 ± 0.02

- Setting limits on cross section as a function of lifetime for various representative mass hypotheses
  - MH/ML/HL for medium/ medium/ heavy squark and heavy/ light/ light neutralino





More results on long-lived particles using 8 TeV data:

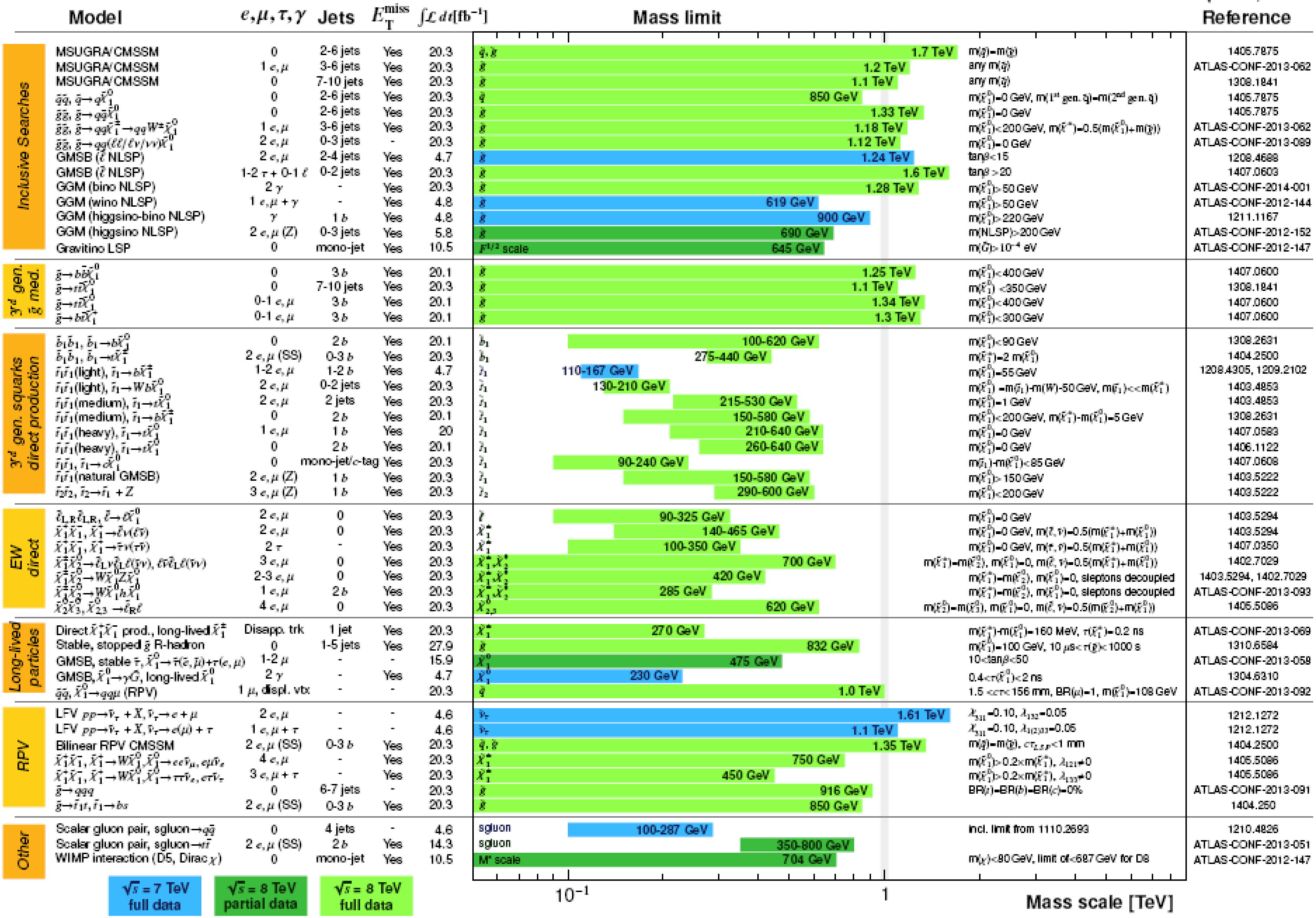
- LL Stopped R-hadrons 1310.6584
- 'Disappearing' tracks for small DM(charg-neut) 1310.3675
- Massive LL sleptons ATLAS-CONF-2013-058

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: ICHEP 2014

ATLAS Preliminary

$\sqrt{s}$ = 7, 8 TeV

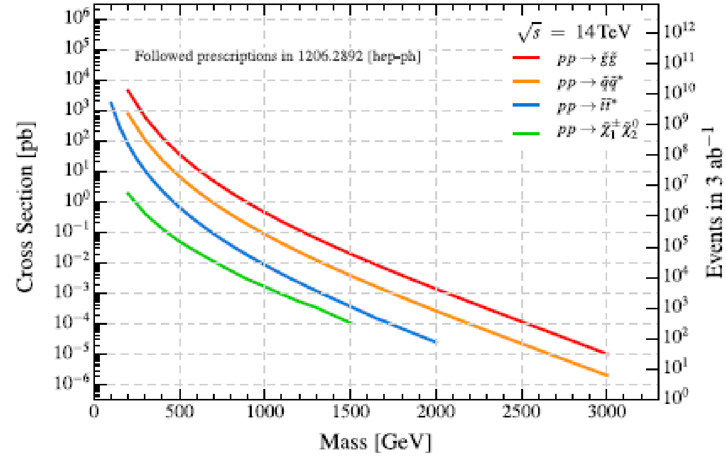


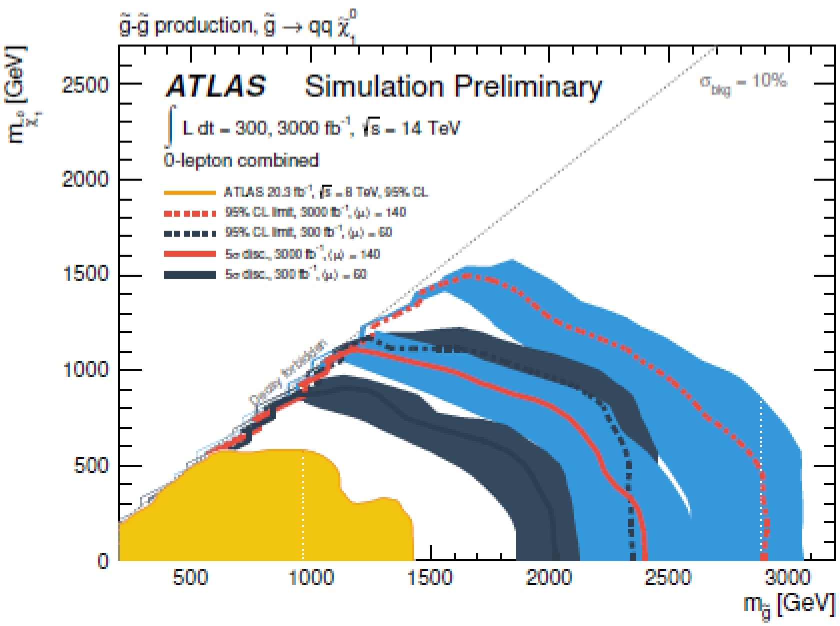
*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Long-term prospects: HL-LHC

ATL-PHYS-PUB-2014-010

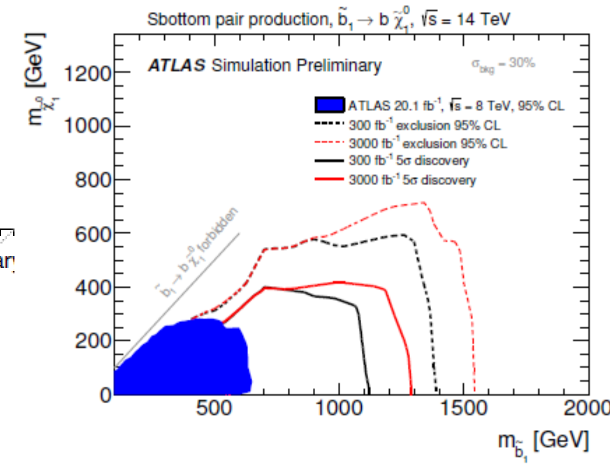
- New studies on Strong and EWK SUSY particles production with 300 and 3000 /fb at 14 TeV
- **Gluinos and squarks:**

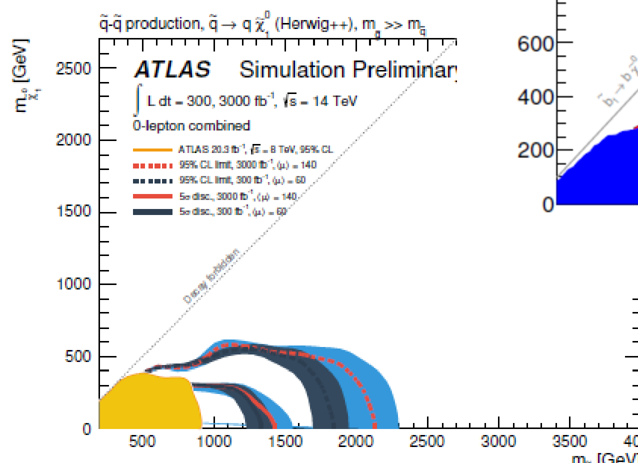




Gluinos discovery potential at 3 /ab up to 2.5 TeV

First and second gen. squarks, sbottoms

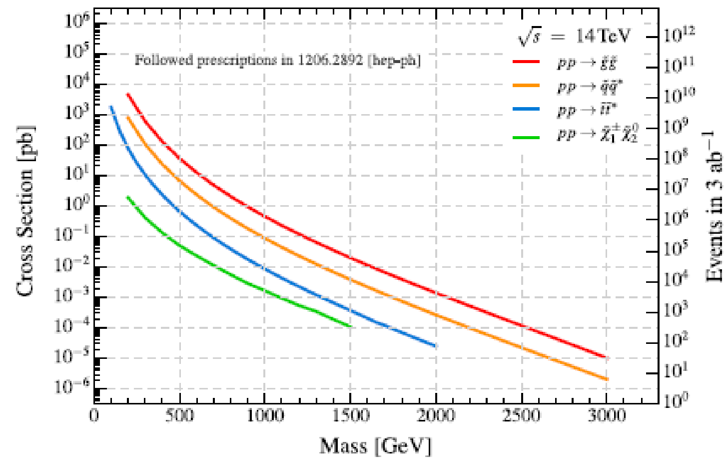


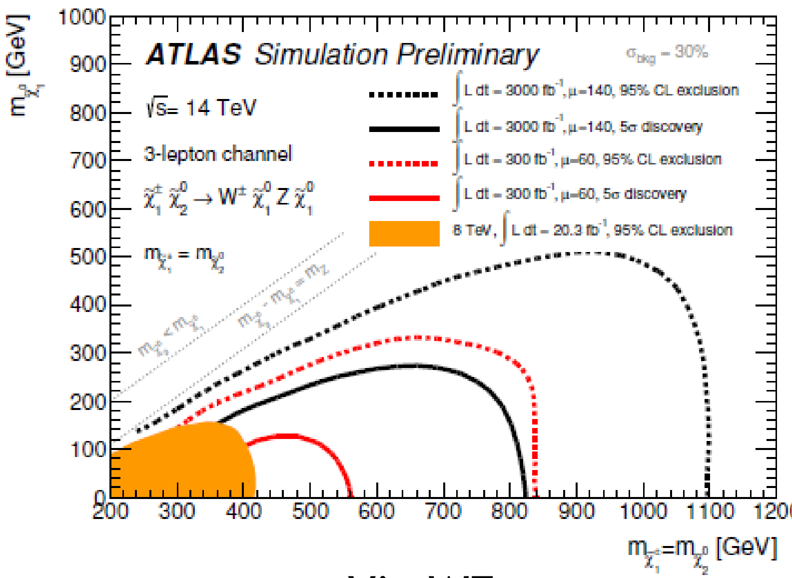


Squark discovery potential at 3 /ab up to 1.5 TeV

Long-term prospects: HL-LHC

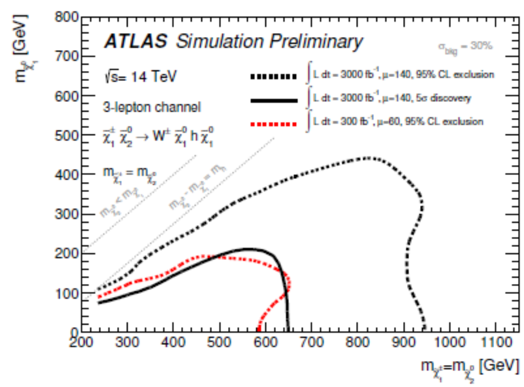
- New studies on Strong and EWK SUSY particles production with 300 and 3000 /fb at 14 TeV
- **Chargino and neutralino production:**



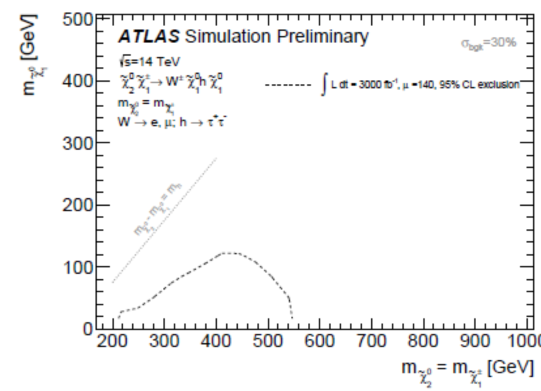


Via WZ

Via WH, with higgs in WW*, ττ



(a) 3ℓ channel



(b) 1ℓ2τ channel

Charginos/Neutralinos discovery potential at 3/ab up to 800(600) GeV depending on decays mode

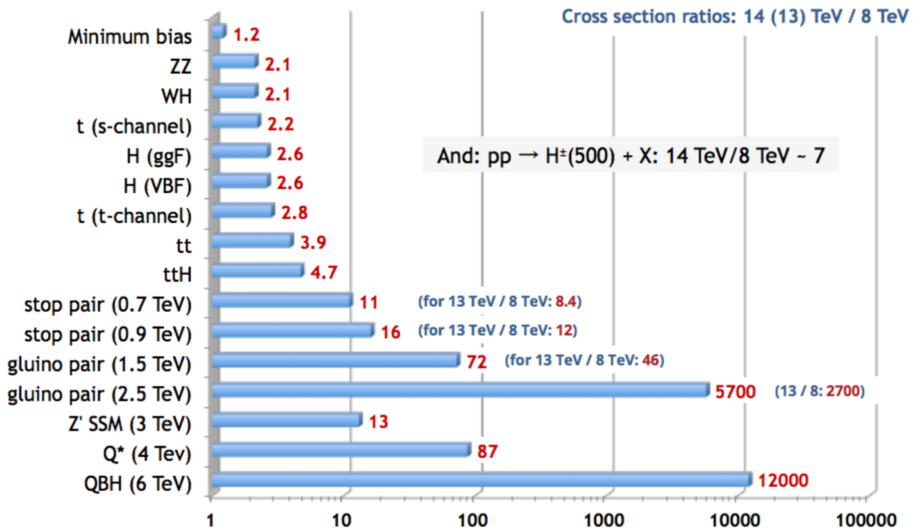
Very challenging even with 3 /ab

Conclusions

- Wide and broad program of SUSY searches at ATLAS
  - 18 papers published on the full data-set, plus several additional preliminary results in CONF Notes

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

  - Aim to cover as many final states and signatures as possible
  - No sign of SUSY yet, but great expectations from Run 2!
- Lot of work on-going in preparation for Run 2



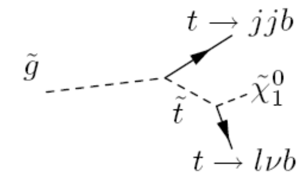
See you next year with hopefully great news for SUSY!

Back-up

Same Sign / 3-leptons

- Gluino is a majorana fermion → SS lepton final states enhanced

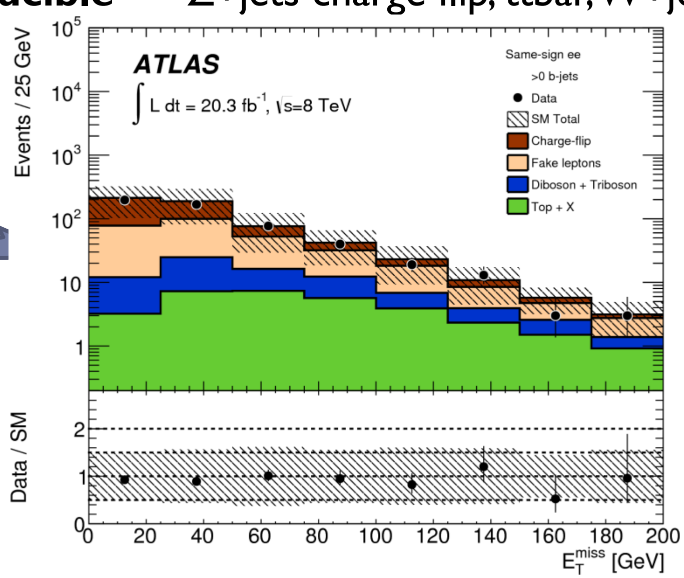
$\tilde{g} \rightarrow t\,\tilde{t}_1$
- $\rightarrow t\,\tilde{\chi}_1^0$ - - - - - gluino-mediated top squark $\rightarrow t\,\tilde{\chi}_1^0$
- $\rightarrow b\,\tilde{\chi}_1^\pm$
  - $\rightarrow W^{\pm(*)}\,\tilde{\chi}_1^0$ - - - - - gluino-mediated top squark $\rightarrow b\,\tilde{\chi}_1^\pm$
- $\rightarrow c\,\tilde{\chi}_1^0$ - - - - - gluino-mediated top squark $\rightarrow c\,\tilde{\chi}_1^0$
- $\rightarrow b\,s$ - - - - - gluino-mediated top squark $\rightarrow b\,s$ (RPV)

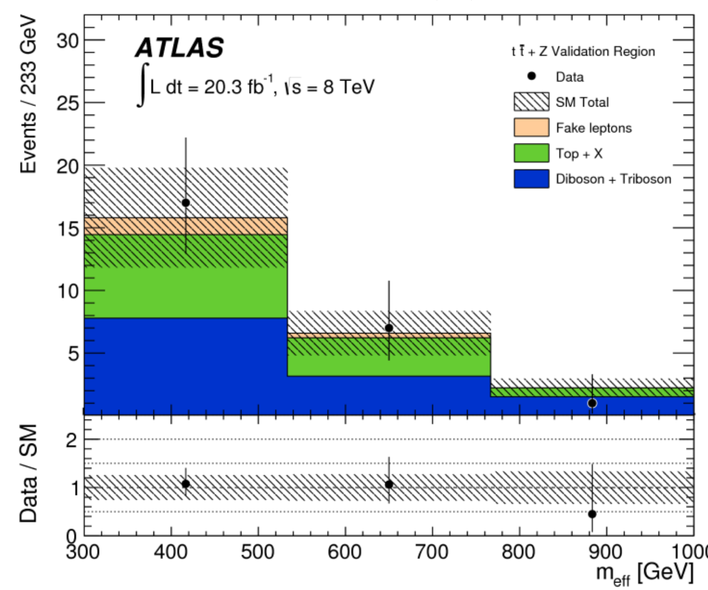


Signature: $e^\pm e^\pm$, $\mu^\pm \mu^\pm$, $e^\pm \mu^\pm$ (with/without extra lepton), $\geq$ 3, 4 jets (0, $\geq$ 1, 3 b-tagged jets) + E_T^{miss}

Backgrounds *(little reliance on MC)*
Irreducible ttbar+V,VV
Reducible Z+jets charge flip, ttbar, W+jets

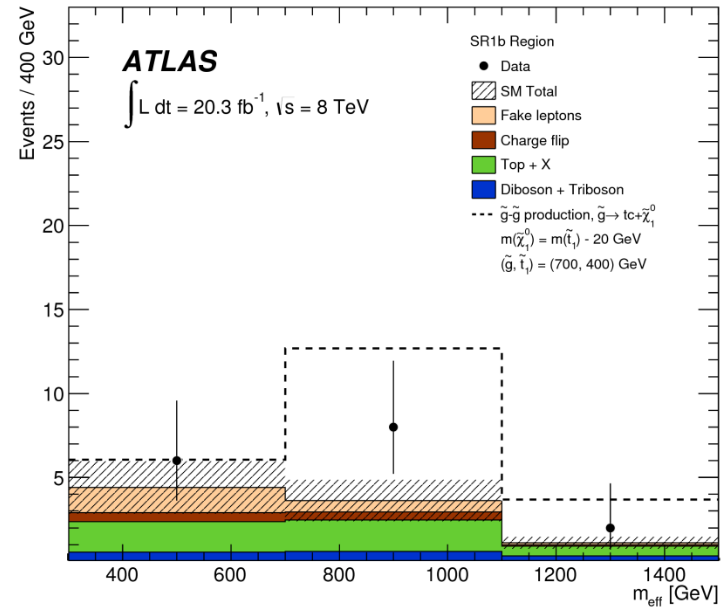
Irreducible background tested in validation regions .
Ex: ttZ VR → *3L, 86<m(ll)<96 GeV*





Same sign leptons: results

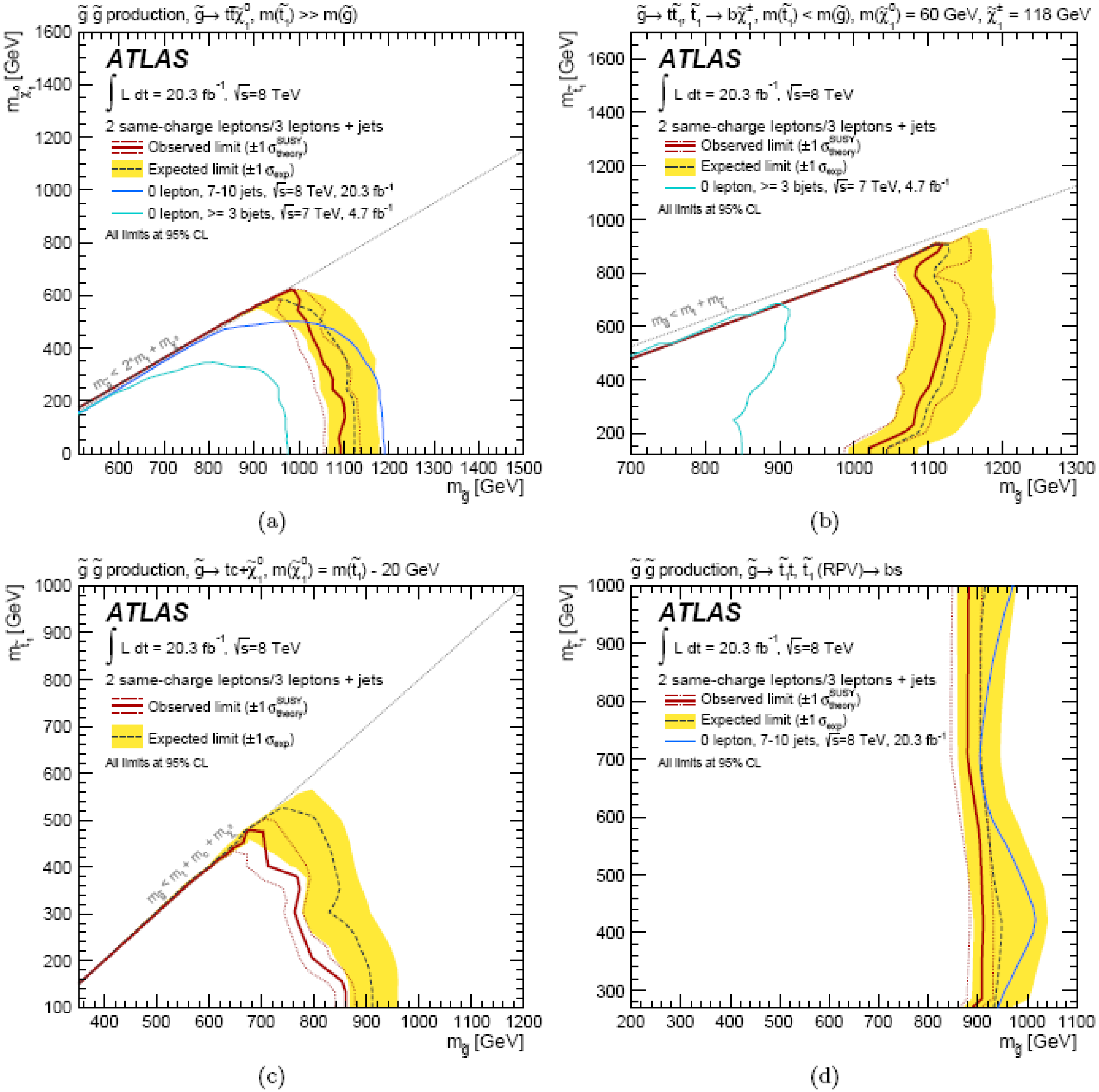
SR 1b



SR	Leptons	$N_{b-\mathrm{jets}}$	Other variables	Additional requirement on m_{eff}
SR3b	SS or 3L	$\geq$3	$N_{\mathrm{jets}} \geq 5$	m_{eff}>350 GeV
SR0b	SS	$= 0$	$N_{\mathrm{jets}} \geq 3$, $E_{\mathrm{T}}^{\mathrm{miss}}$> 150 GeV, m_{T}> 100 GeV	m_{eff}>400 GeV
SR1b	SS	$\geq$1	$N_{\mathrm{jets}} \geq 3$, $E_{\mathrm{T}}^{\mathrm{miss}}$> 150 GeV, m_{T}>100 GeV, SR3b veto	m_{eff}>700 GeV
SR3Llow	3L	-	$N_{\mathrm{jets}} \geq 4$, $50 < E_{\mathrm{T}}^{\mathrm{miss}} < 150$ GeV, Z boson veto, SR3b veto	m_{eff}>400 GeV
SR3Lhigh	3L	-	$N_{\mathrm{jets}} \geq 4$, $E_{\mathrm{T}}^{\mathrm{miss}}$> 150 GeV, SR3b veto	m_{eff}>400 GeV

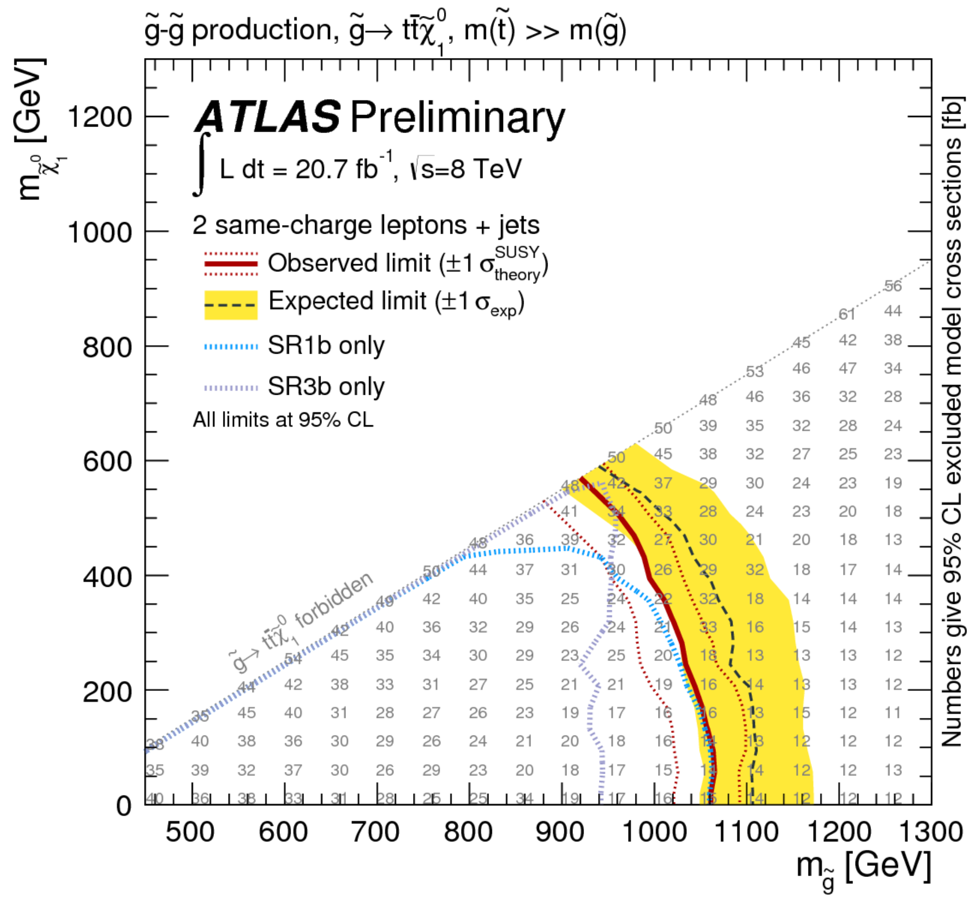
	SR3b	SR0b	SR1b	SR3Llow	SR3Lhigh
Observed events	1	14	10	6	2
Total expected background events	2.2 ± 0.8	6.5 ± 2.3	4.7 ± 2.1	4.3 ± 2.1	2.5 ± 0.9
$p(s = 0)$	0.50	0.03	0.07	0.29	0.50
Expected signal events for chosen benchmark models	3.4 ± 0.7	24.3 ± 3.5	16.4 ± 3.0	10.6 ± 1.0	5.0 ± 0.8
Components of the background					
$t\bar{t}V$, $t\bar{t}H$, tZ and $t\bar{t}t\bar{t}$	1.3 ± 0.5	0.9 ± 0.4	2.5 ± 1.7	1.6 ± 1.0	1.3 ± 0.7
Dibosons and tribosons	< 0.1	4.2 ± 1.7	0.9 ± 0.4	1.2 ± 0.6	1.2 ± 0.6
Fake leptons	0.7 ± 0.6	$1.2^{+1.5}_{-1.2}$	$0.8^{+1.2}_{-0.8}$	1.6 ± 1.6	< 0.1
Charge-flip electrons	0.2 ± 0.1	0.2 ± 0.1	0.5 ± 0.1	–	–

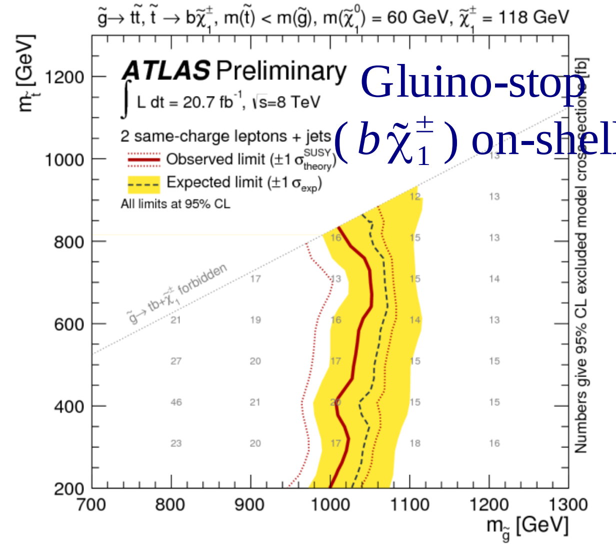
Exclusion limits

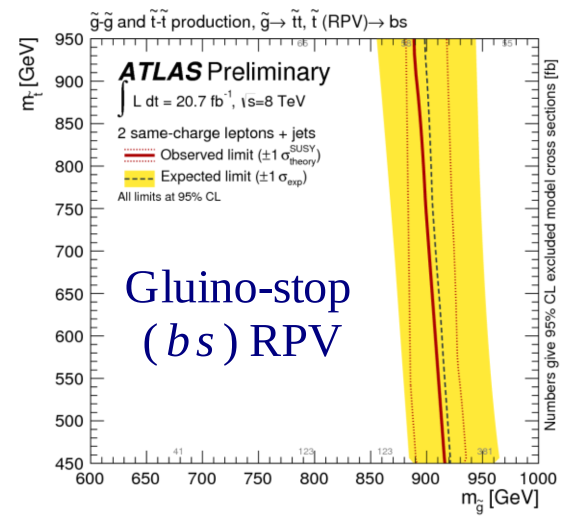


Same Sign leptons: additional interpretations

- Interpretation in a vast array of RPC/RPV simplified models







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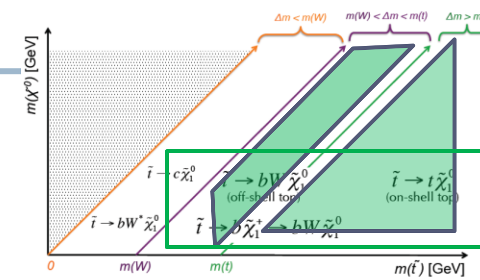
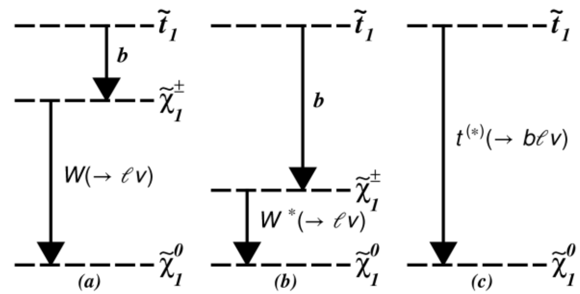
Direct Stop production: 2-leptons

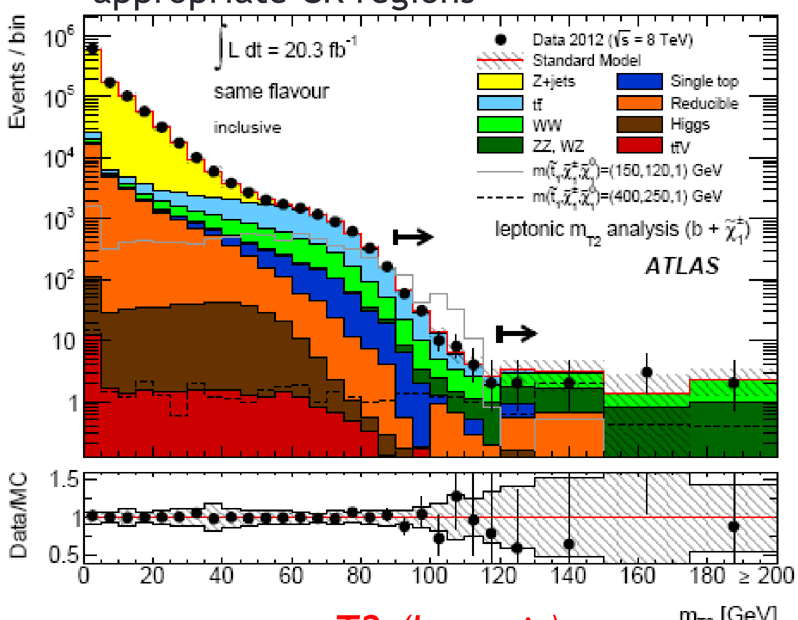
- 2lep (OS) + E_T^{miss}
  - Sensitive to decays via chargino, depending on the mass hiearchy
  - Discriminant: m_{T2} variable (leptons or b-jets) → an upper bound for W-boson events



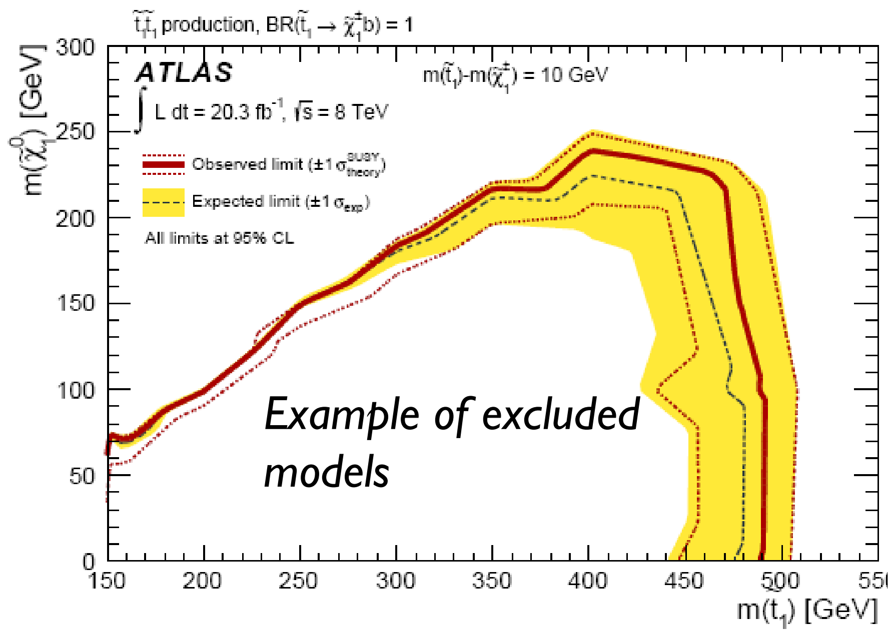


SM dominant background:

- dilepton ttbar, WW, WZ and ZZ → use appropriate CR regions



mT2 (leptonic)

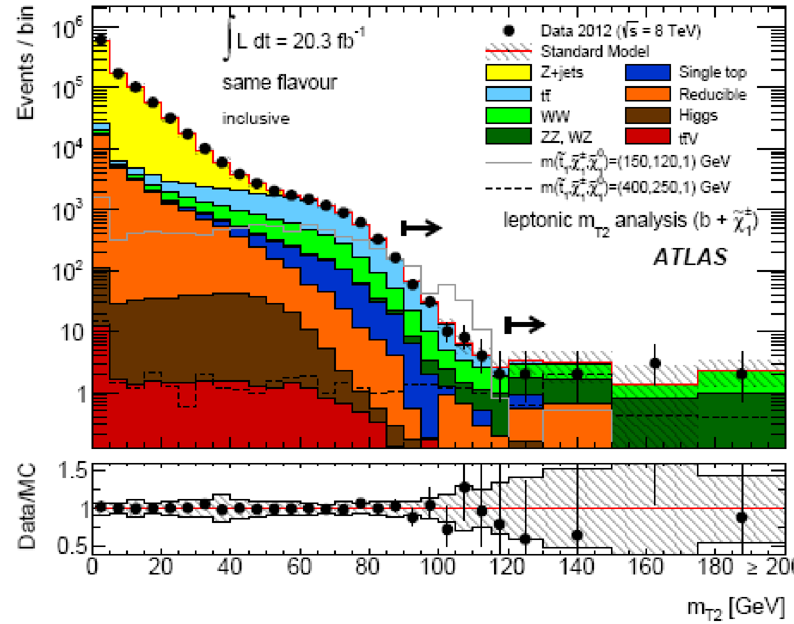


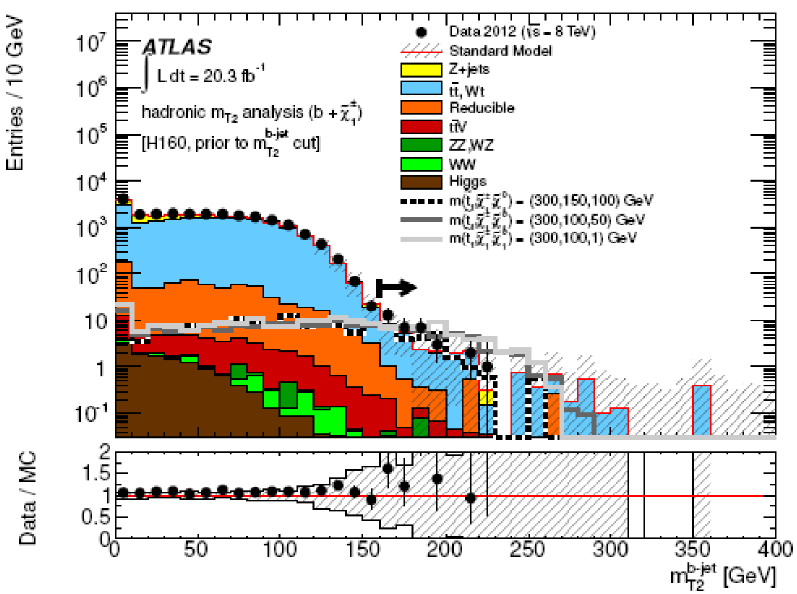
Example of excluded models

Direct stop in 2 lepton

- Results in good agreement with SM predictions

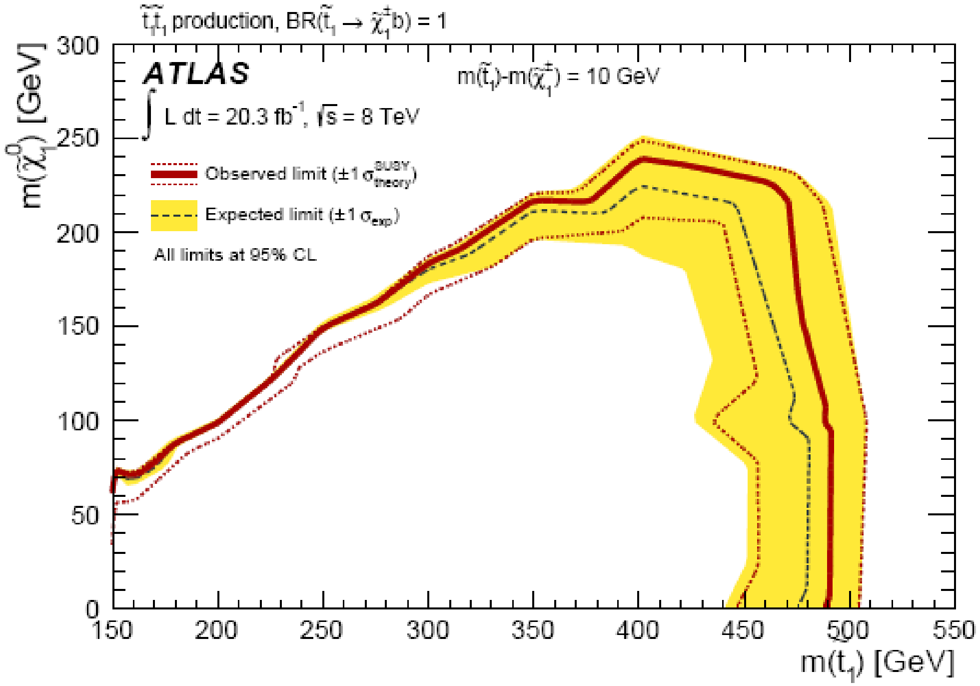
Channel	L90	L100	L110	L120
Observed events	274	3	8	18
Total bkg events	300 ± 50	5.2 ± 2.2	9.3 ± 3.5	19 ± 9
Fit output, $t\bar{t}$ events	172 ± 33	3.5 ± 2.1	3.4 ± 2.9	1.1 ± 1.1
Fit output, WW events	78 ± 20	1.0 ± 0.5	3.2 ± 1.4	12 ± 7
Fit output, WZ, ZZ events	11.6 ± 2.4	$0.22^{+0.26}_{-0.22}$	0.9 ± 0.5	4.1 ± 2.1

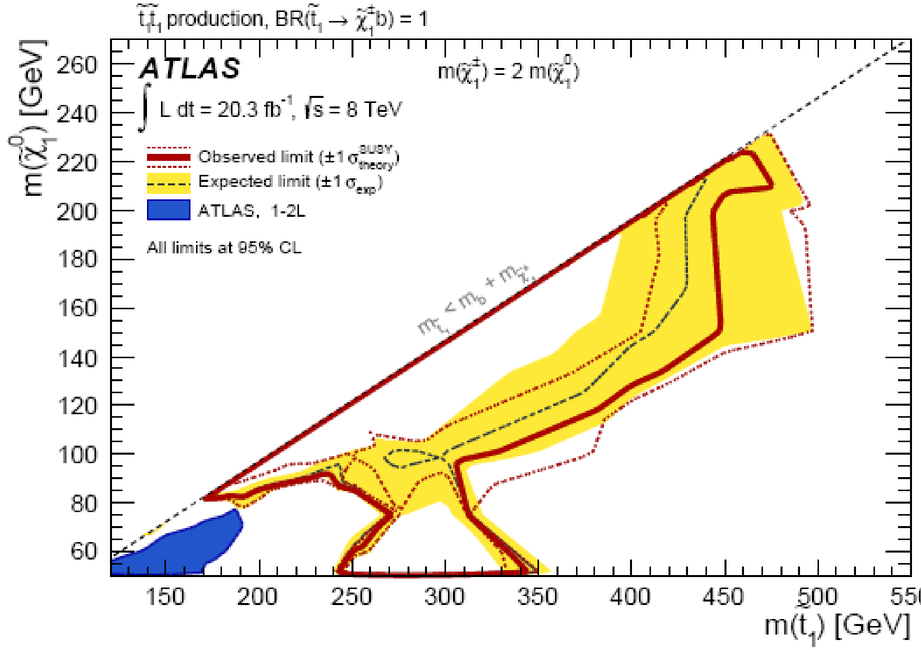


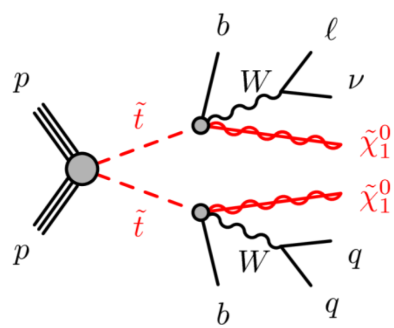


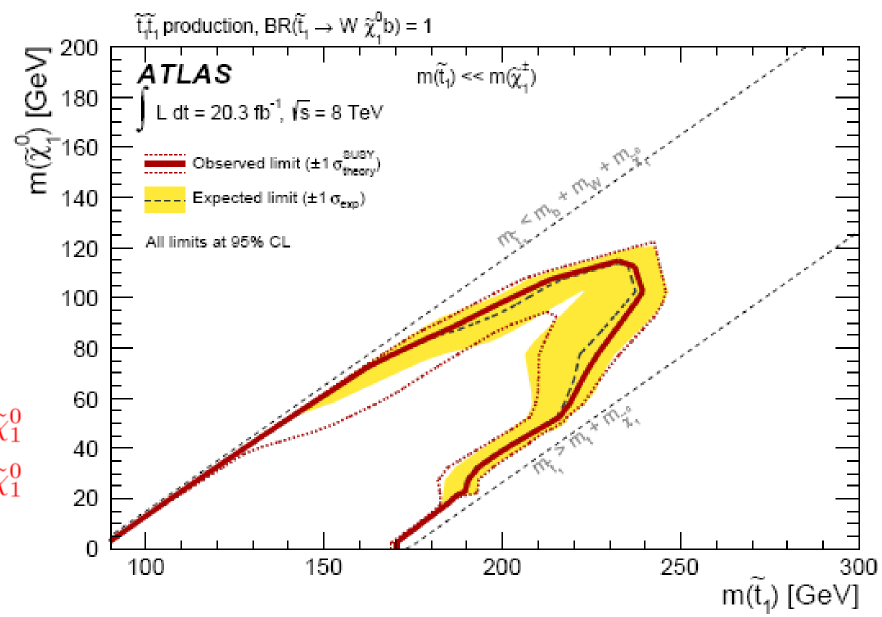
Channel	H160
Observed events	33
Total bkg events	26 ± 6
Fit output, $t\bar{t}, Wt$ events	22 ± 5
Fit output, $Z/\gamma^* \rightarrow ee, \mu\mu$+jets events	$0.2^{+1.8}_{-0.2}$

Interpretations









Direct stop production in 0-lepton,2-bjets+MET

0lep + 2b-jets + E_T^{miss}

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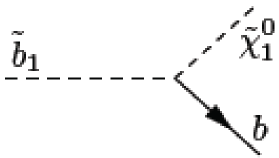
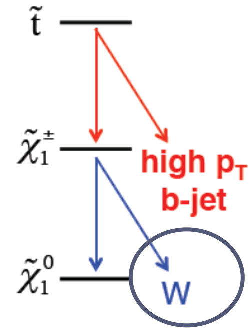
Sensitive to



$$\tilde{t} \rightarrow b\,\tilde{c}_1^{\pm}$$



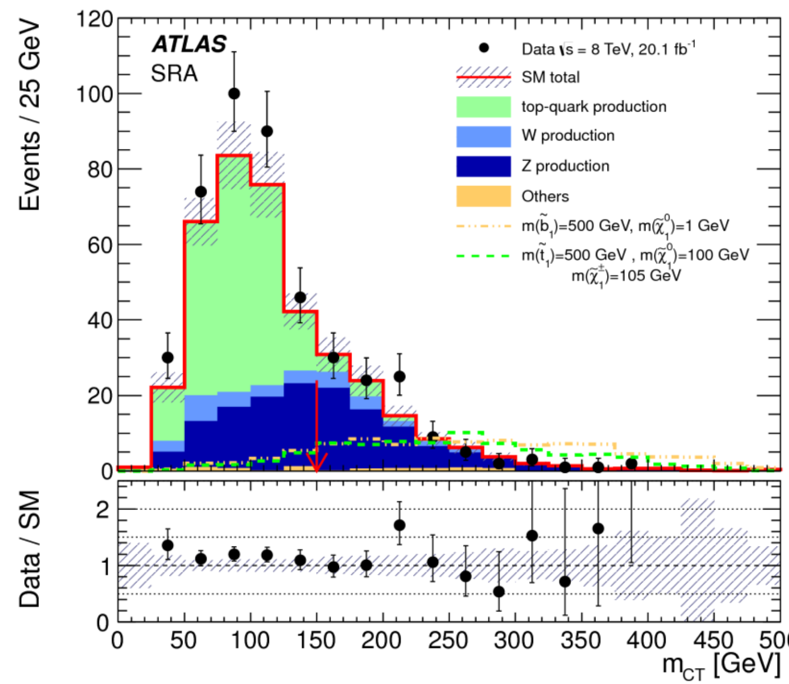
If mass splitting is small, W is virtual, → chargino decay products very soft

Exclusive selection in N jets (2), N leptons (0)

m_{cT}(bb) = boost-corrected co-transverse mass

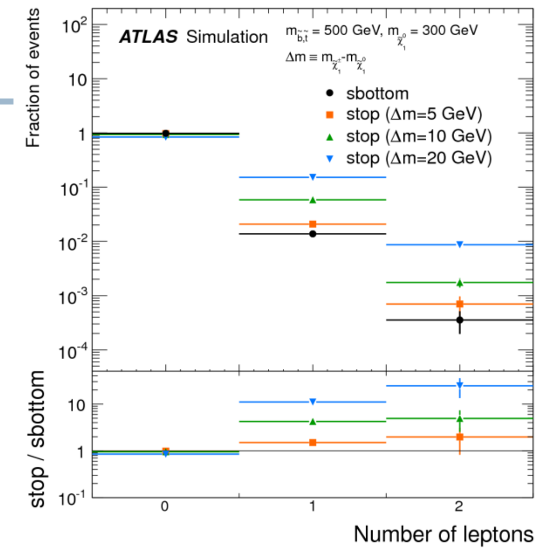
end-point at

$$\boxed{m_{cT}^{max} = \frac{m^2(\tilde{t}/\tilde{b}) - m^2(\tilde{c}_1^0)}{m(\tilde{t}/\tilde{b})}}$$

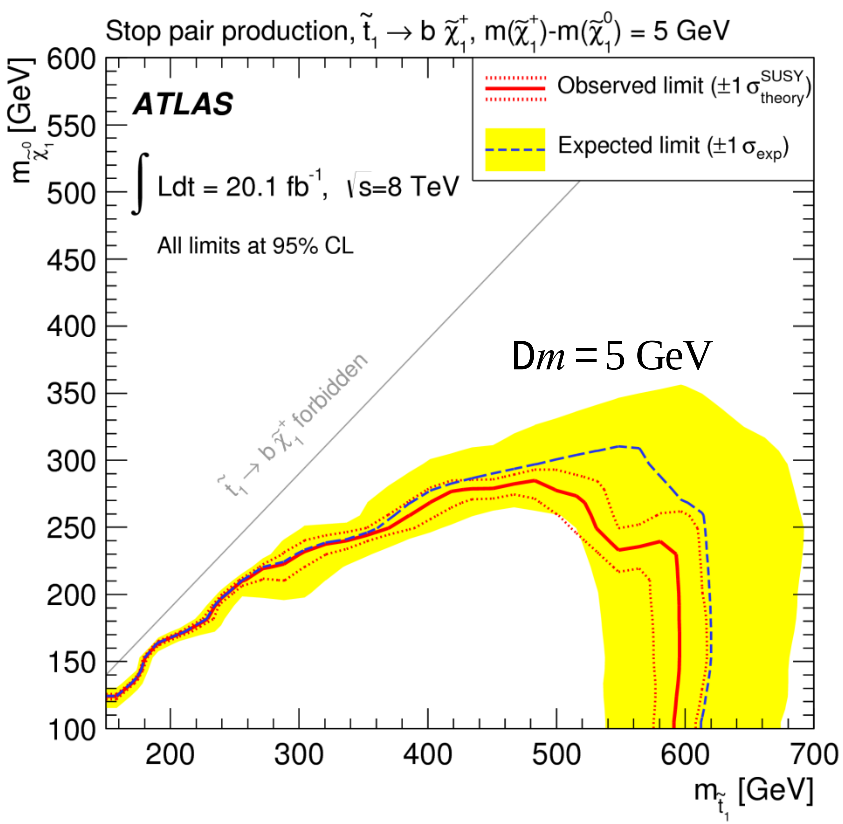


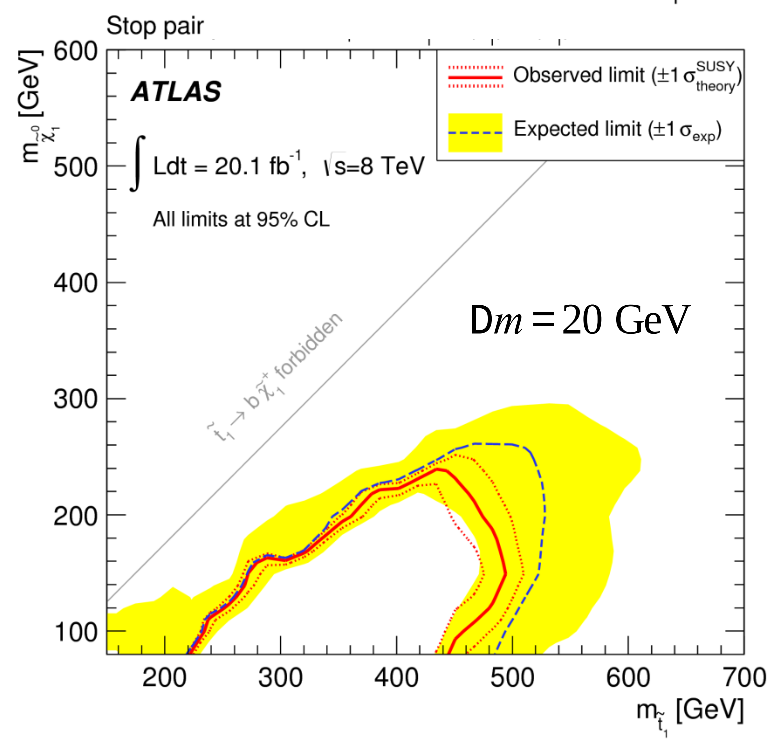
- Main bkgnds:
  - Z(→nn) +jets, semi-lep ttbar, W+jets
- Minor contribution:
  - single top, di-boson, ttbar+W/Z

Direct Stop in 2-bjets+MET



Difference in kinematics between sbottom and stop signal





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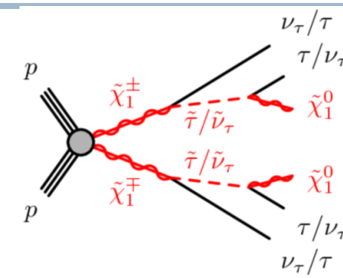
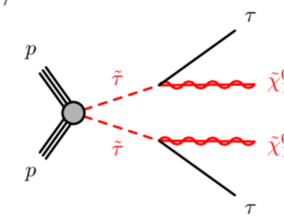
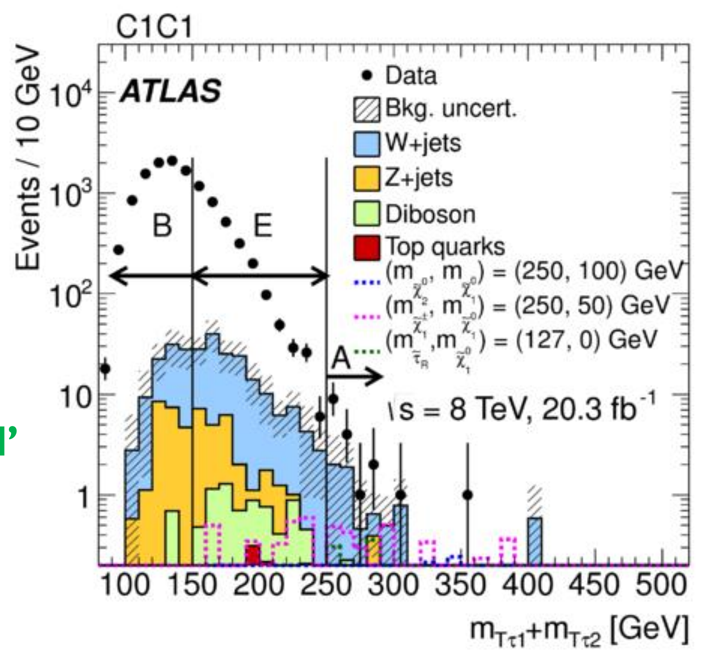
Light-stau scenarios

- Dedicated search for 2-hadronic taus and MET
  - Sensitive to chargino pair, chargino-neutralino and stau pair production
- 4 SRs defined to enhance sensitivity to various targeted signals (use mT2, mT tau, MET)
- Main background: misidentified taus
  - Multijet (data-driven), W+jets (semi-data driven)





Multijet: ‘ABCD method’



W: mu+tau CR