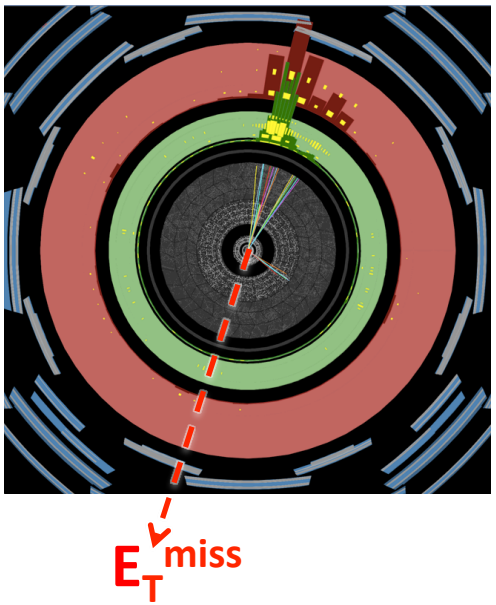
Dark Interactions:
Perspectives from Theory and Experiment
June 11-13, 2014 • Brookhaven National Laboratory

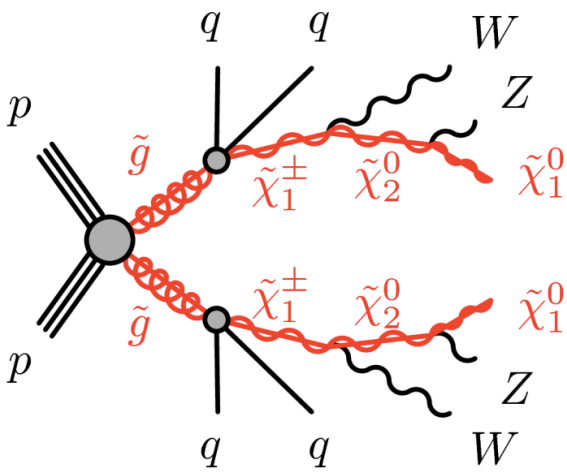
Dark Matter in ATLAS SUSY searches

Estel Perez Codina (TRIUMF)
On behalf of the ATLAS Collaboration

Introduction

- Overwhelming evidence for dark matter (DM)
- In SUSY models with RPC, the lightest supersymmetric particle (**LSP**) is an **excellent WIMP candidate**
- DM at collider experiments [ATLAS]:
  - **Escapes detector** ⇒ imbalance of visible momentum (E_T^{miss})
  - Favorite SUSY DM candidates:
    - Neutralino
    - Gravitino
  - **Direct production of LSPs** not accessible due to low cross-section
  - In SUSY the LSP is typically produced in the **decay chain** of heavier SUSY particles



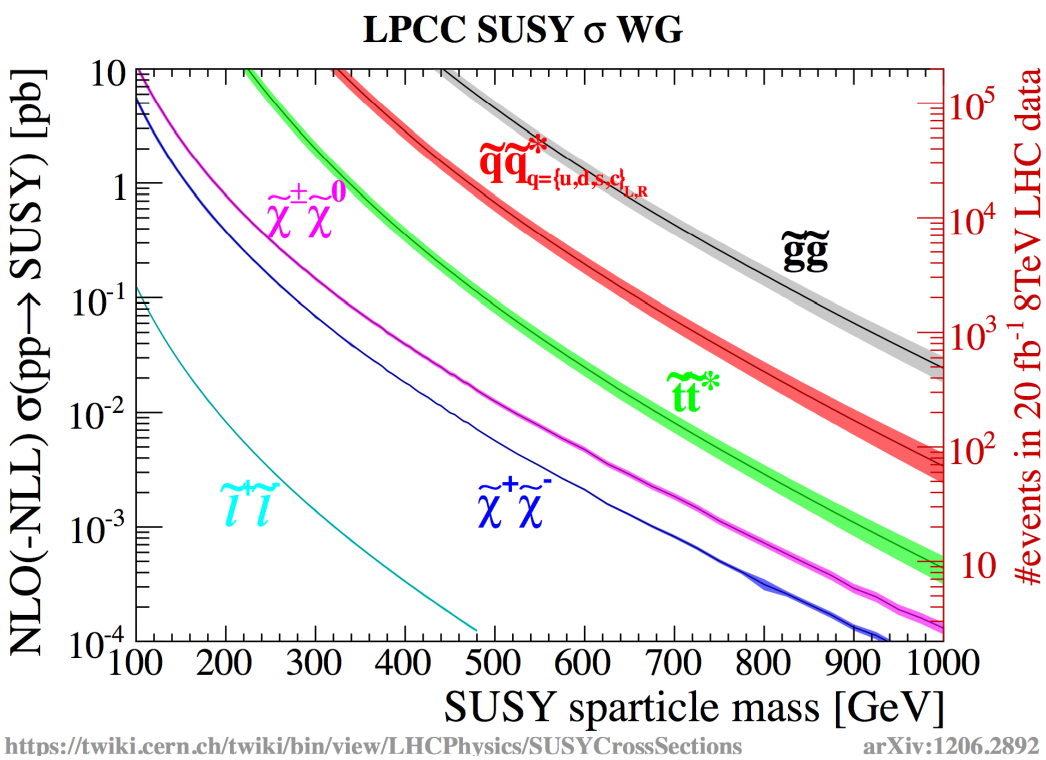


Signature: E_T^{miss} + SM particles

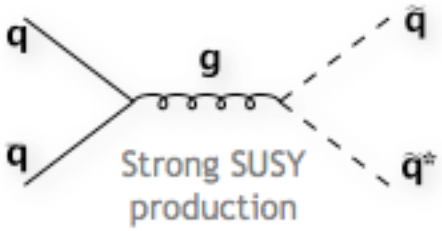
Outline
- SUSY production
- Analysis strategy
- Neutralino LSP results (*)
- Gravitino LSP results (*)
- Summary & Outlook

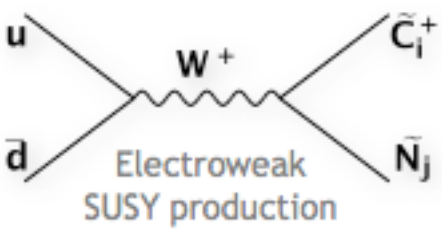
*Focus on latest SUSY results relevant to dark matter

SUSY Production



- SUSY searches strategy driven by cross section and luminosity
- Inclusive searches:
  - Strong (gluino and 1st&2nd gen. squark) production
- Exclusive searches:
  - Strong (3rd gen. squark) production
  - Weak production (Direct gaugino / sleptons)



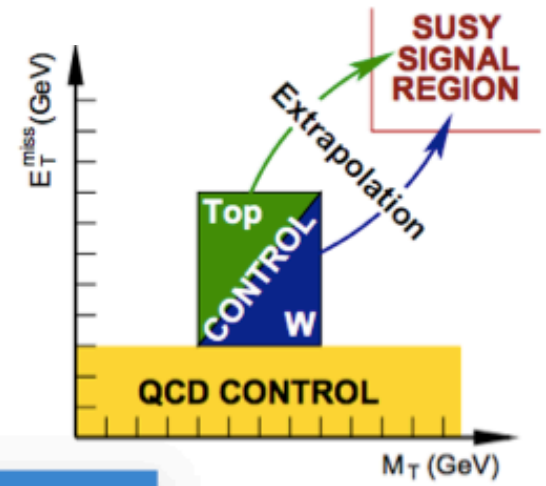


Constrains on the LSP mass are relative to the spectrum considered (masses of strongly/ weakly produced particles)

Analysis strategy

SUSY searches rely on understanding the SM backgrounds

Strategy for a "typical" SUSY analysis:



Standard Model

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

Reducible backgrounds

Determined from data
Backgrounds and methods depend on analyses

Irreducible backgrounds

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

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

blinded

Validation

Validation regions used to cross check SM predictions with data

blinded

Signal regions

Large number of SR optimized for each scenario
Account for potential signal contamination in control regions when setting limits

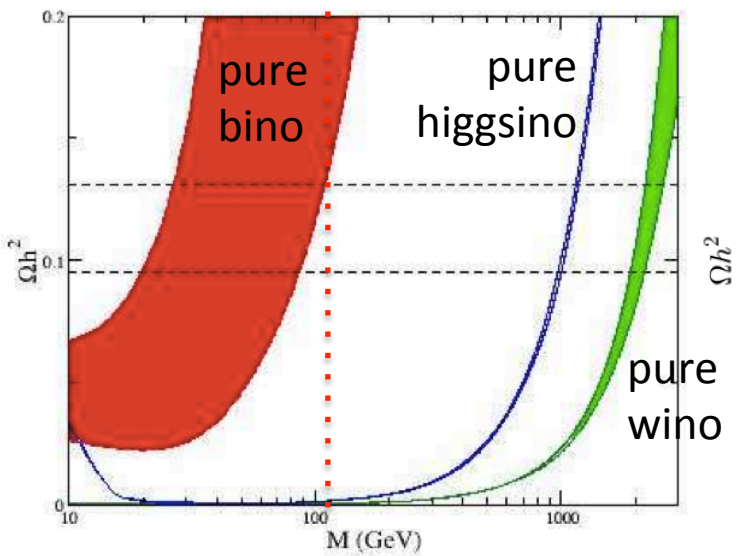
Neutralino LSP

- The super-partners of:
  - gauge bosons (winos, bino)
  - higgs boson (higgsinos)

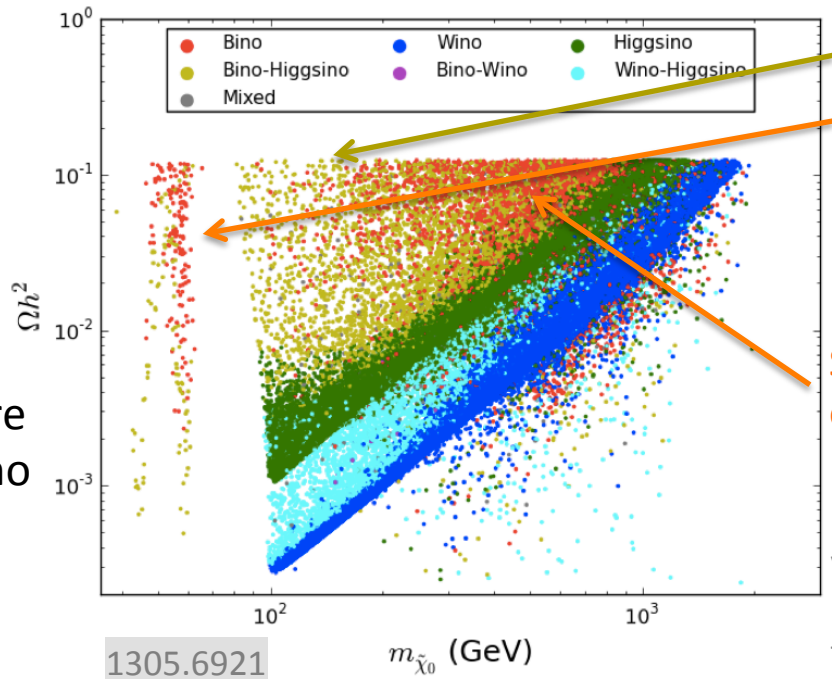
mix to give **charginos and neutralinos**: $\tilde{\chi}^{+/-}$, $\tilde{\chi}^{0}$.

- Lightest Neutralino ($\tilde{\chi}^{0}_{1}$) likely to be the LSP

  DM candidate ⇒ Constrains on its composition from observed relic density



arXiv:hep-ph/0601041



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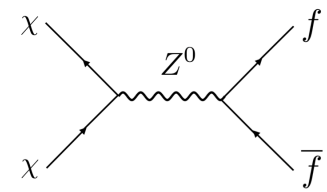
Well-tempered

Z- and h-funnel



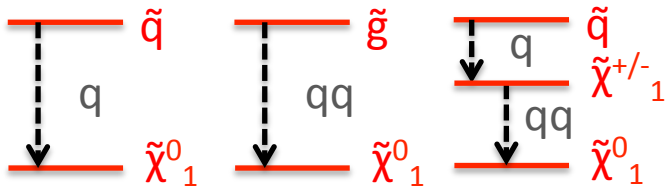
Slepton-coannihilation or A-funnel

Each point represents a pMSSM model (fixed values of the mass parameters) surviving the DM constrains

In the following results, the LSP is the **bino-like** $\tilde{\chi}^{0}_{1}$, unless otherwise stated

Strong production (gluinos, 1st/2nd gen. squarks)

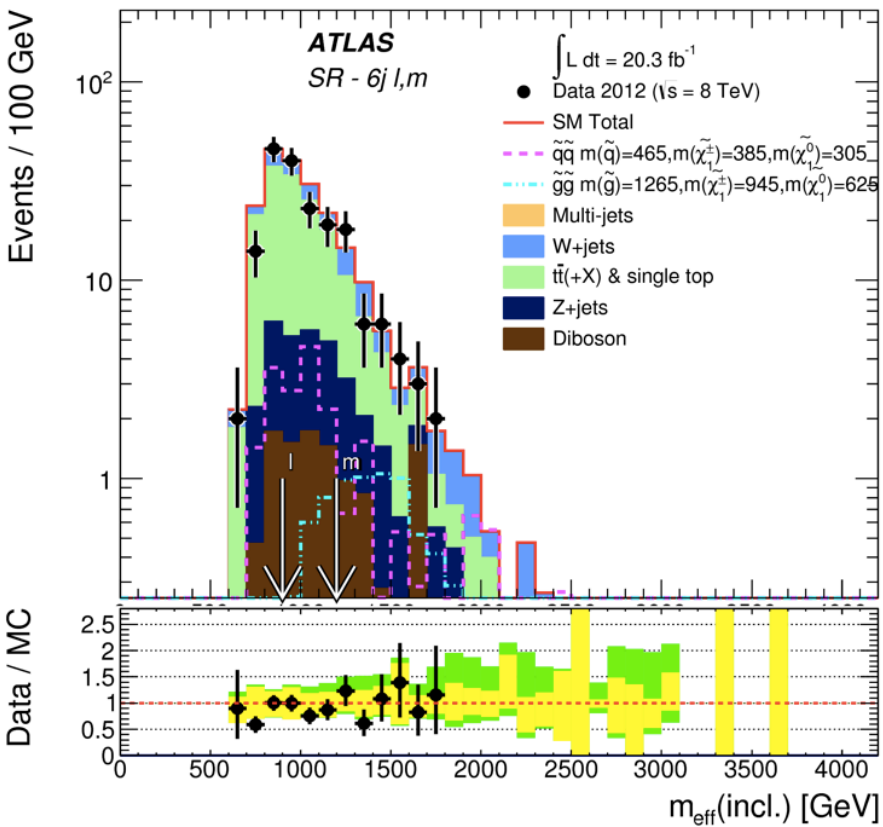
q̃q̃, g̃g̃, q̃g̃ production

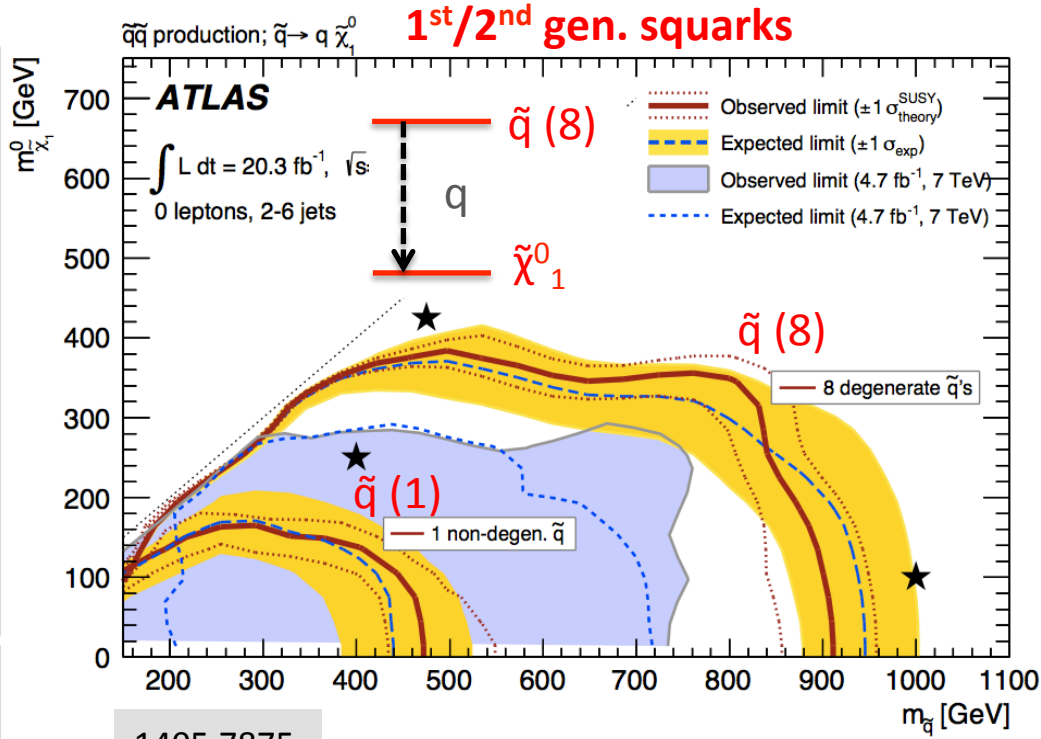


0-lepton + 2-6 jets

Use m_{eff} as discriminant

E_T^{miss}/m_{eff} reduce multijets bkg.





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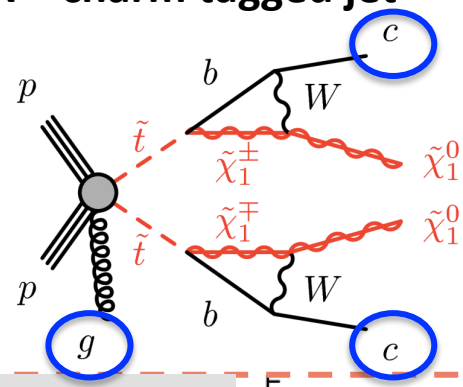
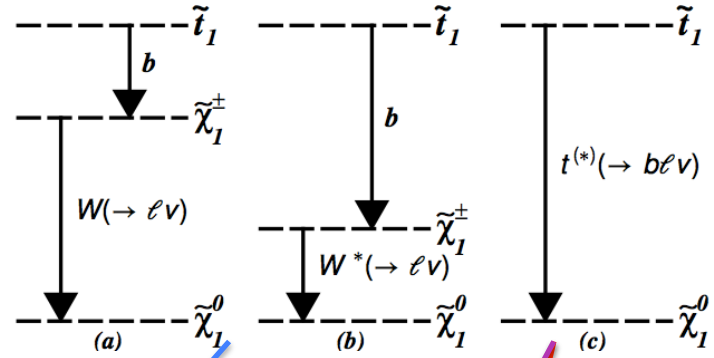
Strong production (stop)

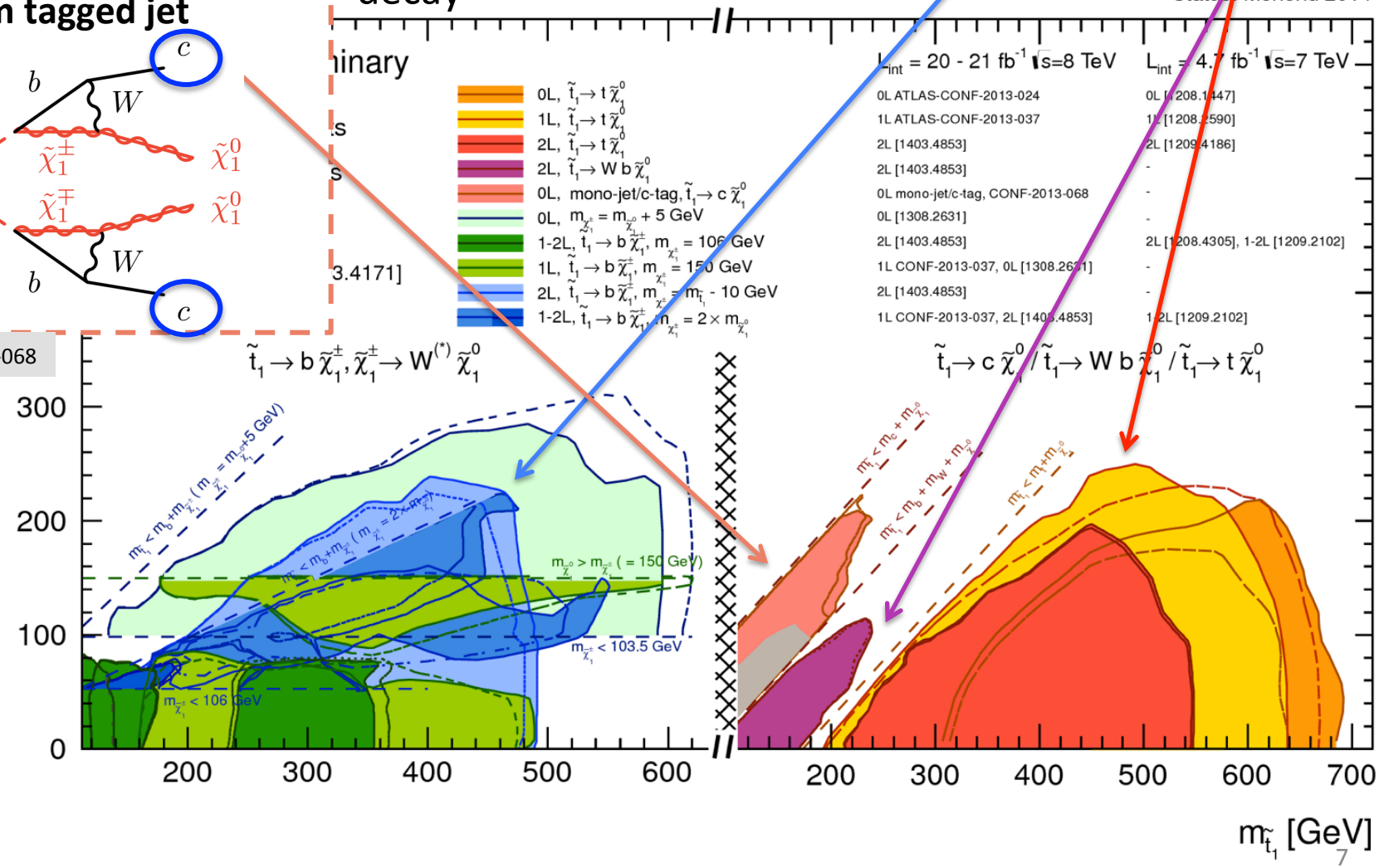
$\Delta m(\tilde{t}, \tilde{\chi}^0_1)$ small
$\Rightarrow$ b not accessible
$\tilde{t} \longrightarrow c\, \tilde{\chi}^0_1$
ISR + charm tagged jet



ATLAS-CONF-2013-068

Several analysis target **stop** pair production: two-step or one-step decay





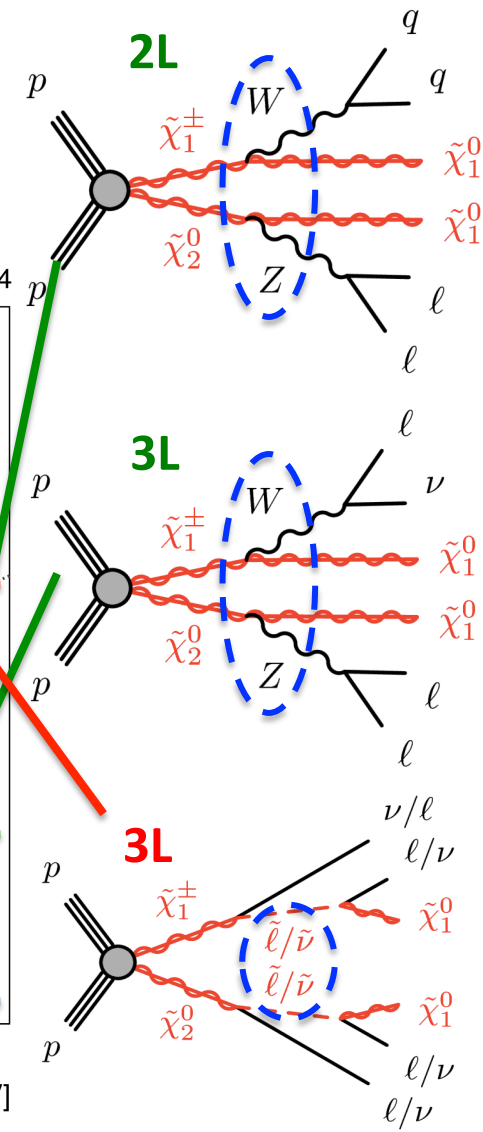
Electroweak production

Cover as many final states as possible

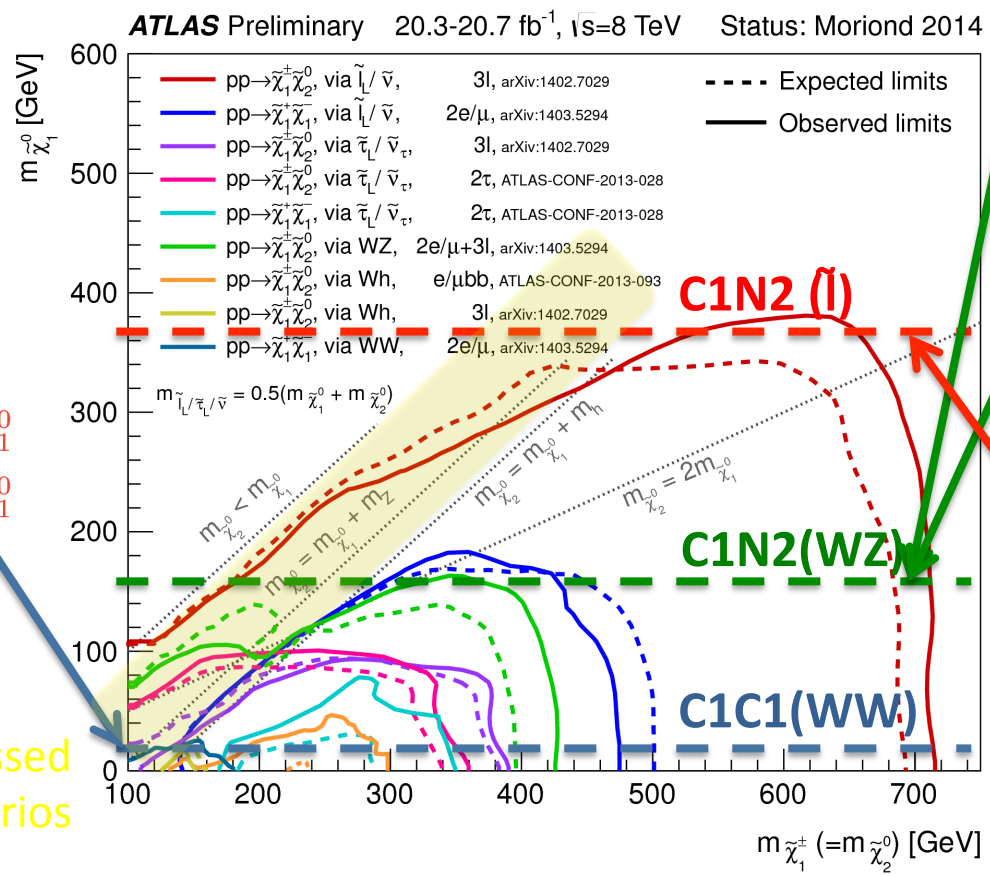
Exploiting Higgs in decay chain for the first time!

Multileptons: Use m_{T2} , m_{ll} , lepton charge and flavor

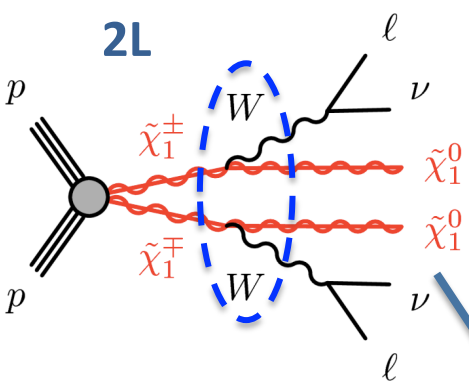
$\tilde{\chi}^{+/-}_1 \tilde{\chi}^0_2$ production



3lep, 2lep, 2tau, 1lep+b$\bar{b}$



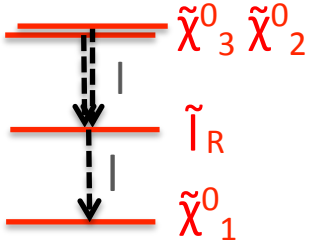
$\tilde{\chi}^+_1 \tilde{\chi}^-_1$ production

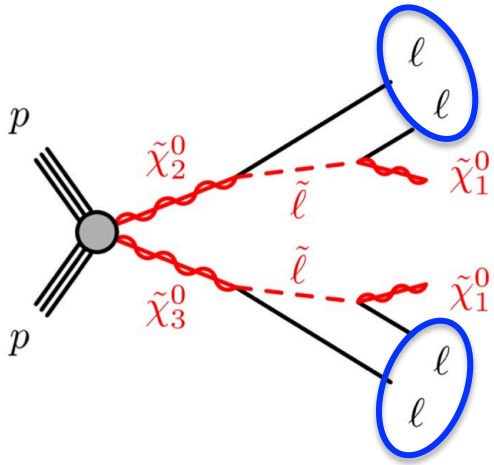


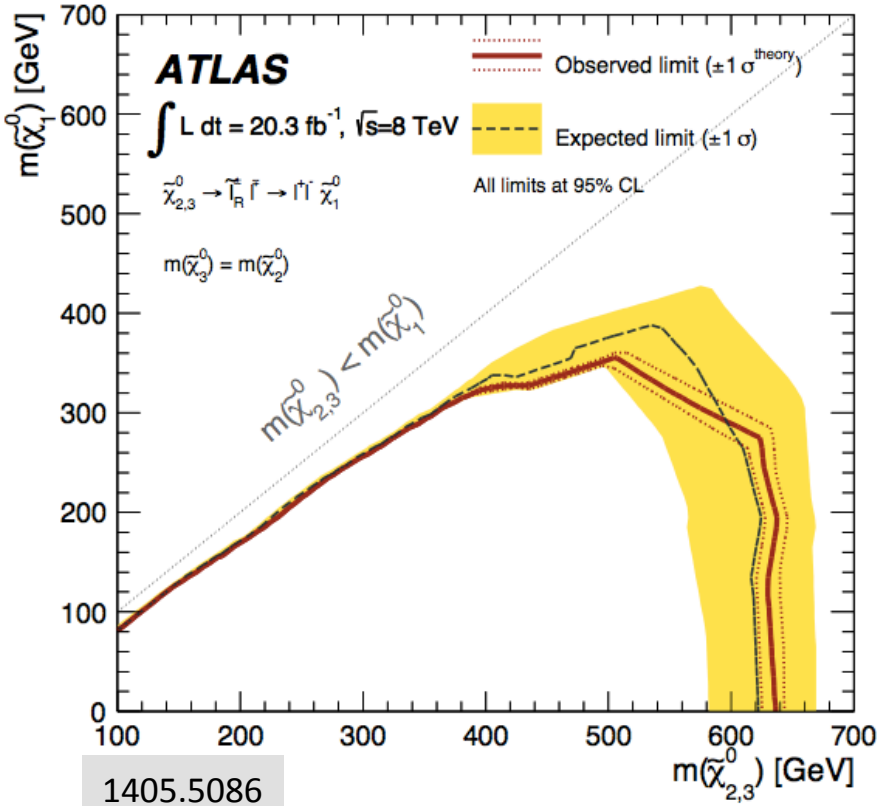
Compressed scenarios

Electroweak production

Intermediate **right-handed sleptons**
⇒ $\tilde{\chi}^{+}_{1}$ has to decay via W (lower BR)
production of higgsino-like $\tilde{\chi}^{0}_{2}\,\tilde{\chi}^{0}_{3}$ interesting
4lep + MET , Z veto







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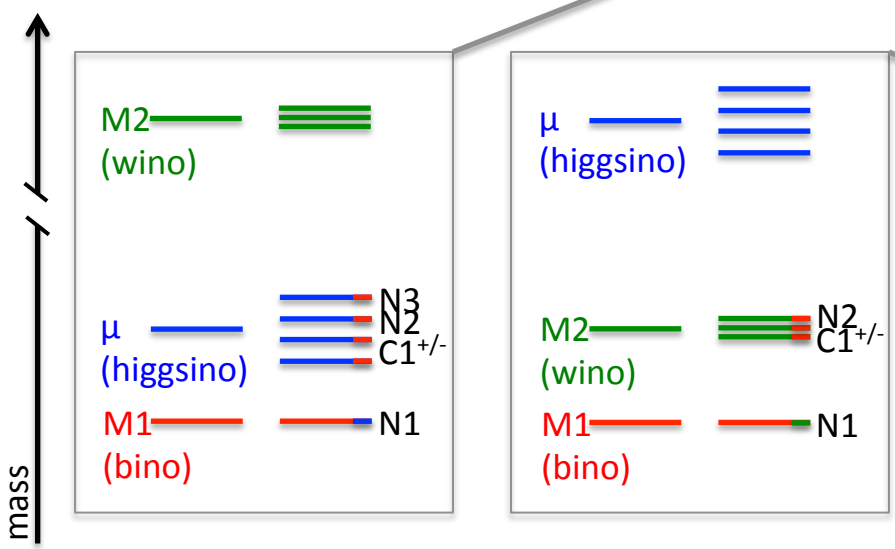
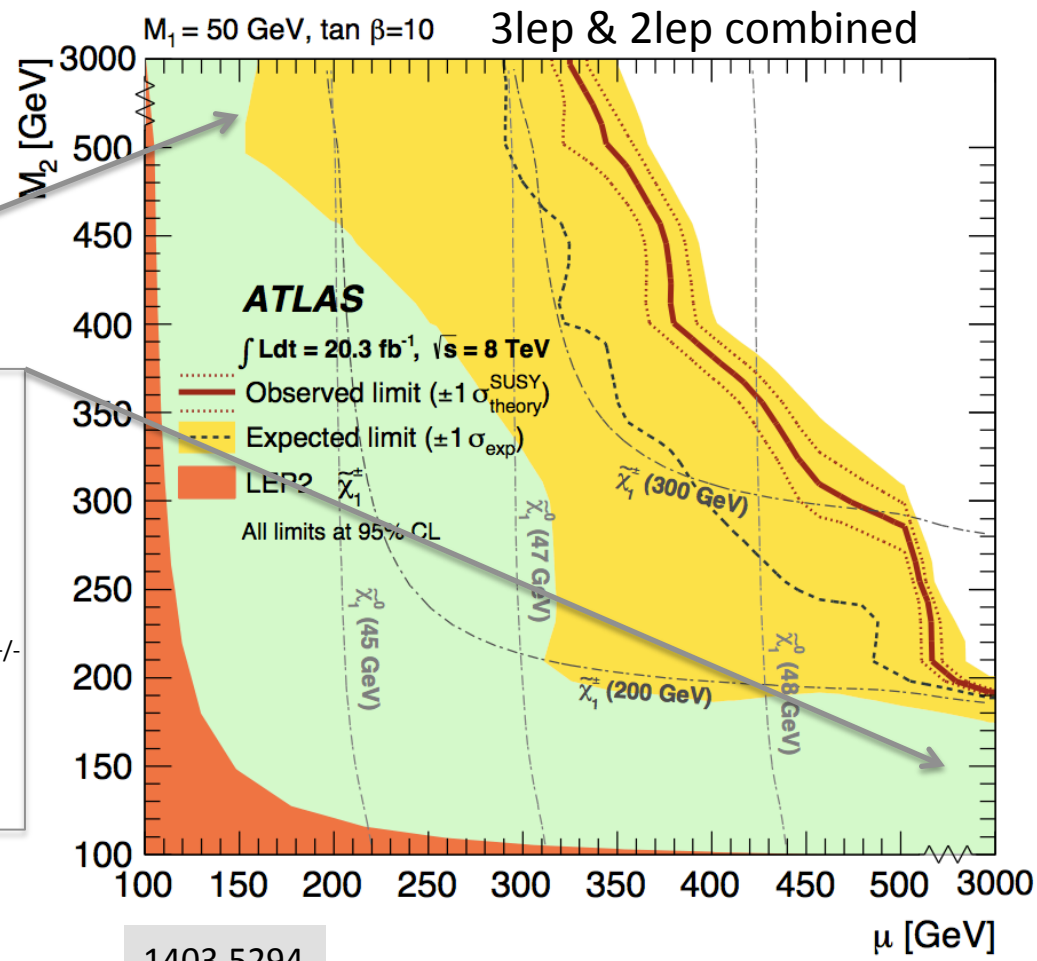
Electroweak production (pMSSM)

Phenomenological model: **pMSSM** (with $\tilde{\chi}^0_1$ LSP)
Composition of electroweakinos controlled by **wino (M2)** and **higgsino (μ)** mass parameters

Bino mass **M1=50 GeV** ⇒ Z "funnel" ⇒ high annihilation rate ⇒ can **satisfy DM relic abundance** constrains





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Electroweak production (AMSB)

$\tilde{\chi}^0_1$ wino-like

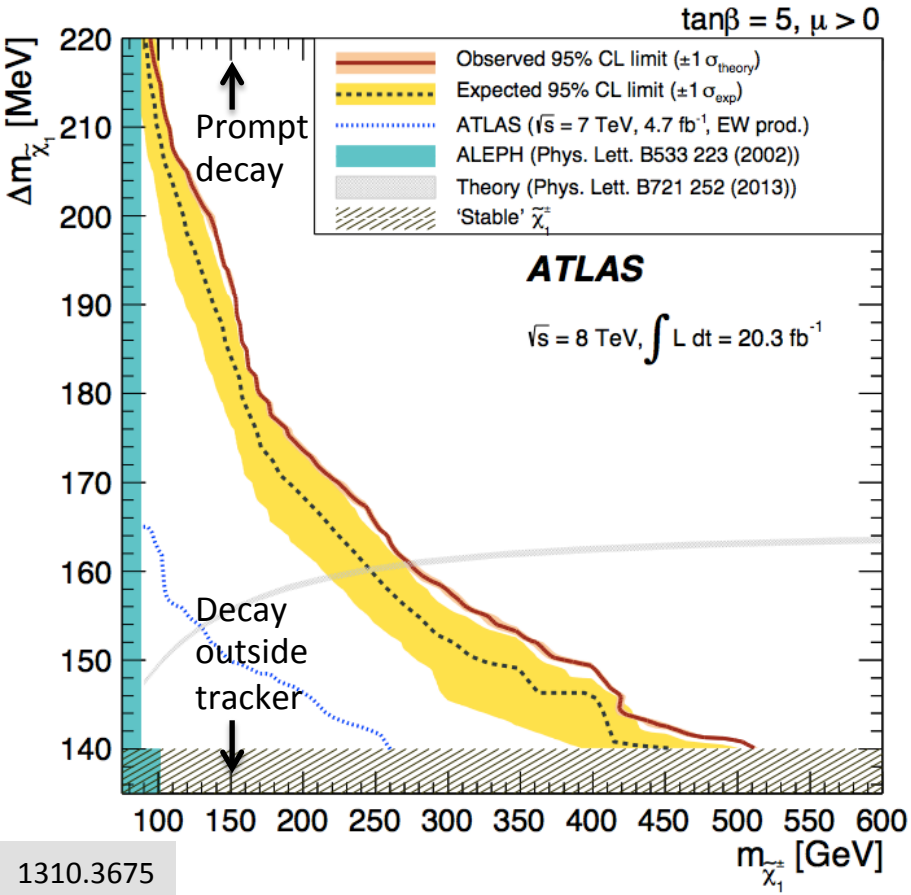
AMBS model: $\tilde{\chi}^0_1$, $\tilde{\chi}^{+/-}_1$ **wino-like co-LSPs** ⇒ **degenerate**

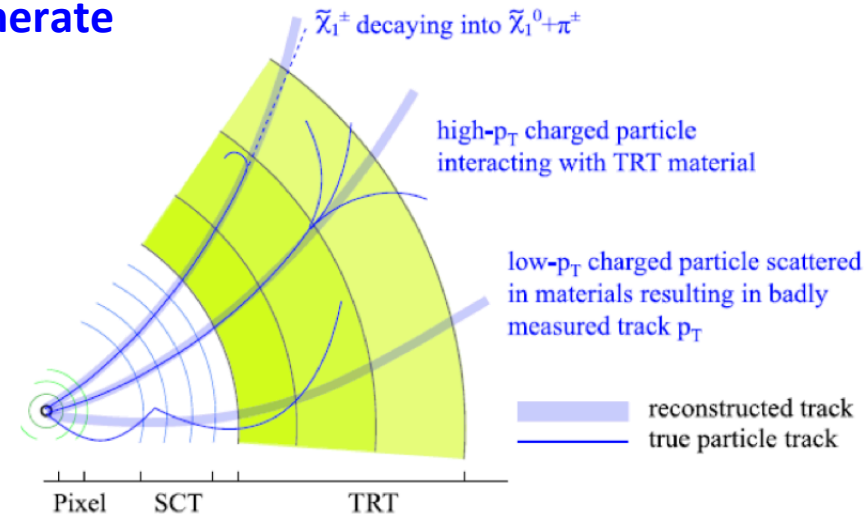
$\Delta m < 1$ GeV ⇒ $\tilde{\chi}^{+/-}_1 \longrightarrow \tilde{\chi}^0_1\, \pi^{+/-}$

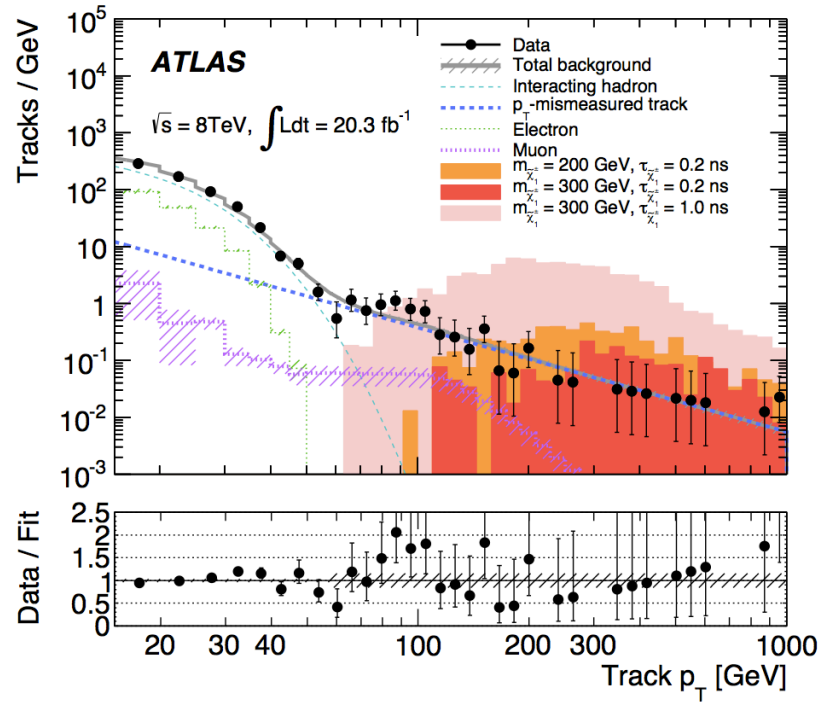
⇒ $\tilde{\chi}^{+/-}_1$ **long-lived** ⇒(0.1- 10 ns) decay in tracker

Disappearing track

$\tilde{\chi}^0_1\, \tilde{\chi}^{+/-}_1$ **or** $\tilde{\chi}^+_1 \tilde{\chi}^-_1$ production **(+ ISR jet)**







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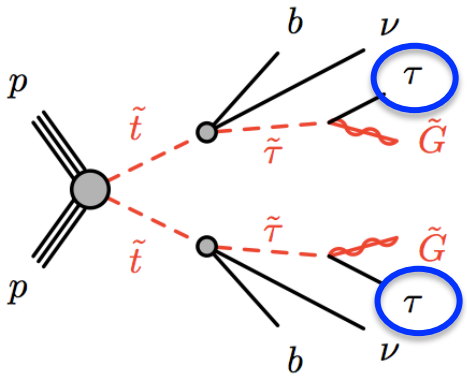
Gravitino LSP

- **GMSB/GGM** scenarios:
  - **Gravitino** ($\tilde{G}$, supersymmetric partner of the graviton) **is always the LSP**
    - **very light** (< keV)→ harder spectrum (w.r.t. $\tilde{\chi}^0_1$ LSP case)
    - **Phenomenology** driven by the nature of the **NLSP**:
      - **Typically $\tilde{\chi}^0_1$, staus, …**
      - NLSP ⟶ $\tilde{G}$ + SM particle

Stau NLSP

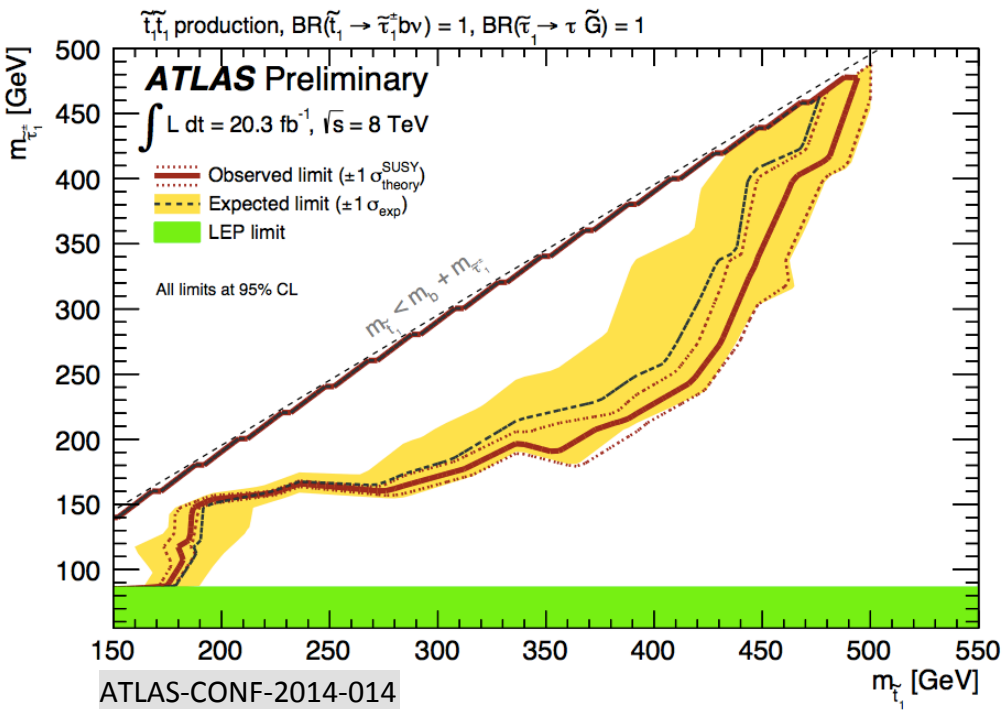
Stop pair production



(leptonic tau decay)

2 lep OS

Bin in m_{T2}, #jets



ATLAS-CONF-2014-014

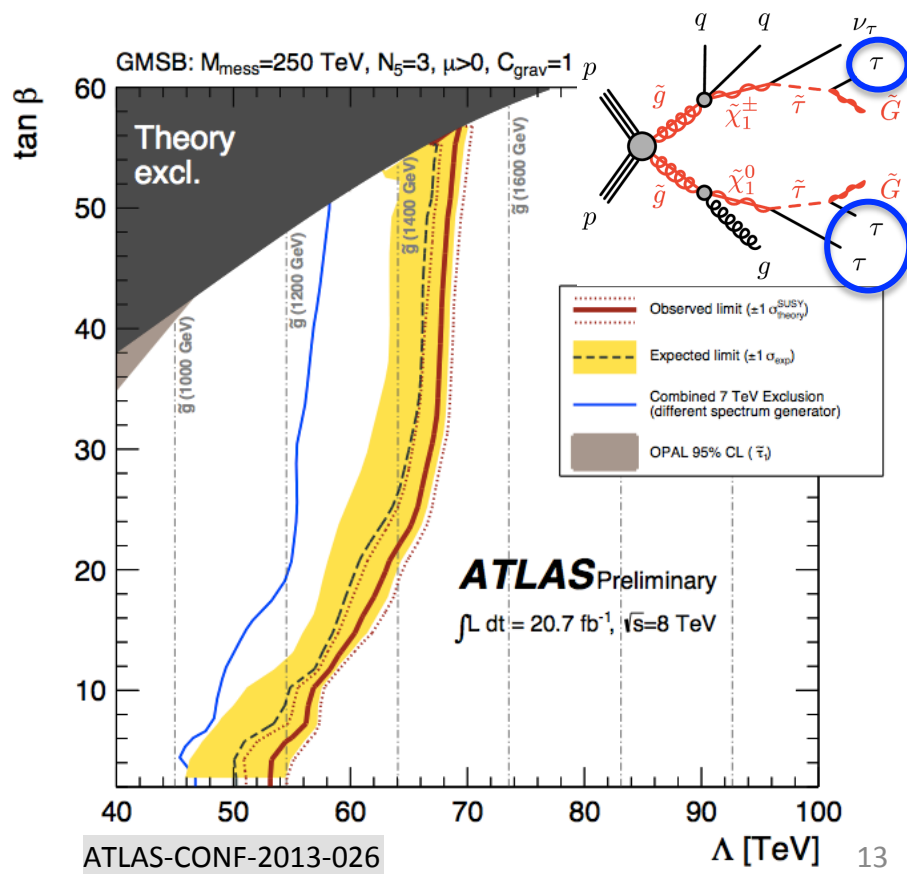
Squark / gluino pair production

NLSP mostly **stau** at high tanβ

(hadronic tau decay)

2 taus

Uses m_T, H_T, m_{eff} as discriminants



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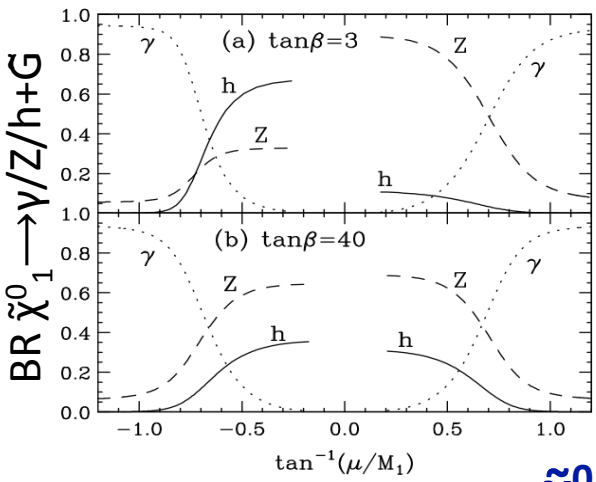
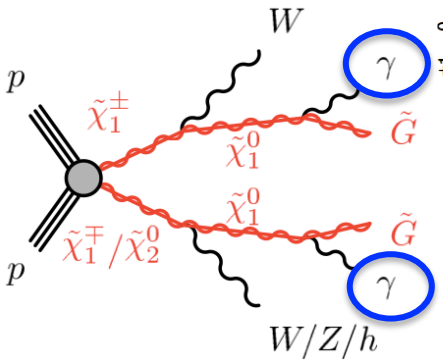
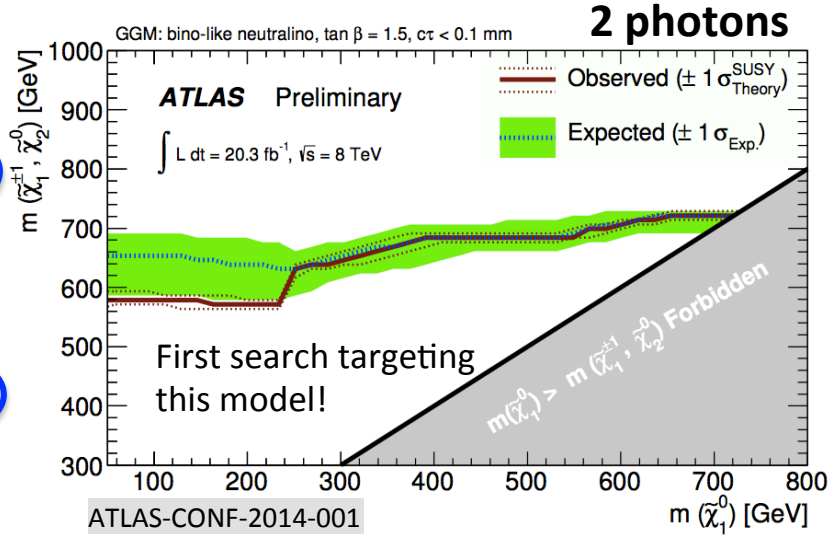
$\tilde{\chi}^0_1$ NLSP

$\tilde{\chi}^0_1$ bino-like ⇒ $\tilde{\chi}^0_1 \longrightarrow \gamma\, \tilde{G}$



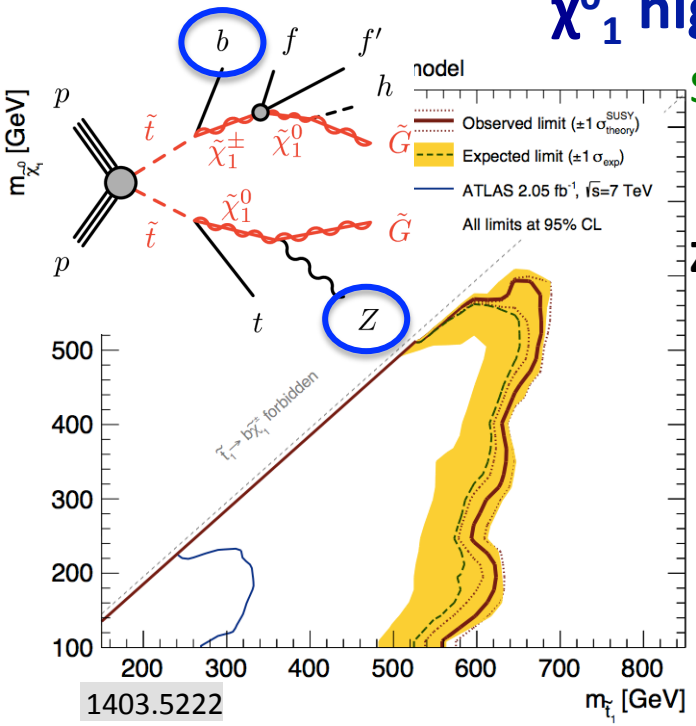


2 photons



ATLAS-CONF-2014-001

$\tilde{\chi}^0_1$ higgsino-like ⇒ $\tilde{\chi}^0_1 \longrightarrow Z/h\, \tilde{G}$



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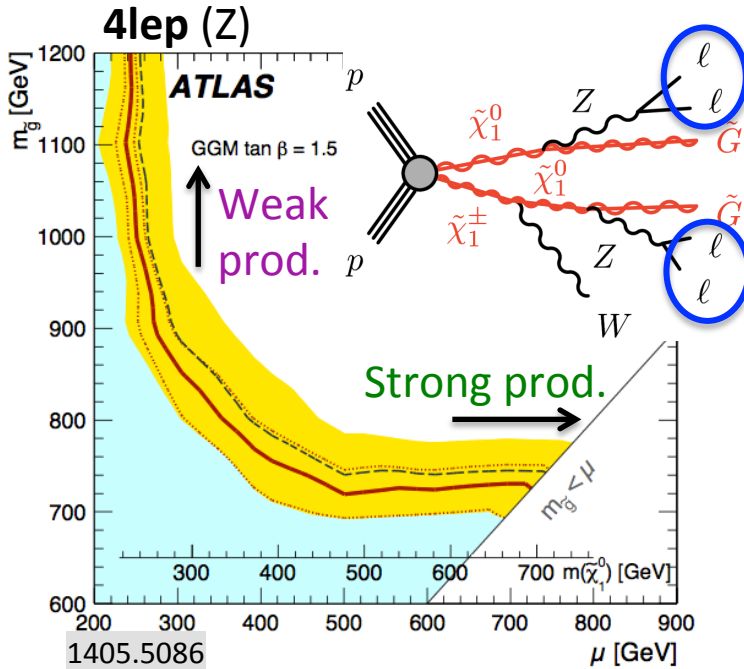
Stop pair production

$\tilde{t} \longrightarrow b\, \tilde{\chi}^{+/-}_1$ or

$\tilde{t} \longrightarrow t\, \tilde{\chi}^0_{1/2}$

Z+b-jets

4lep (Z)



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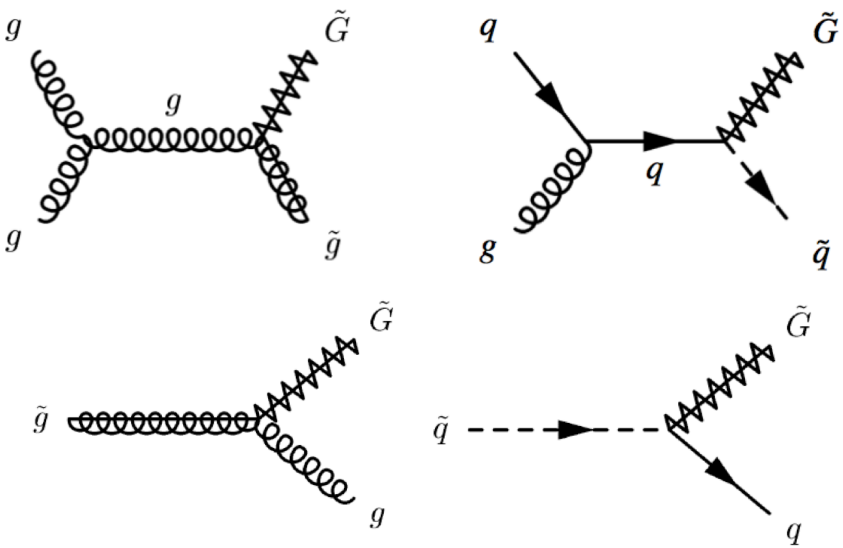
Squark/gluino NLSP

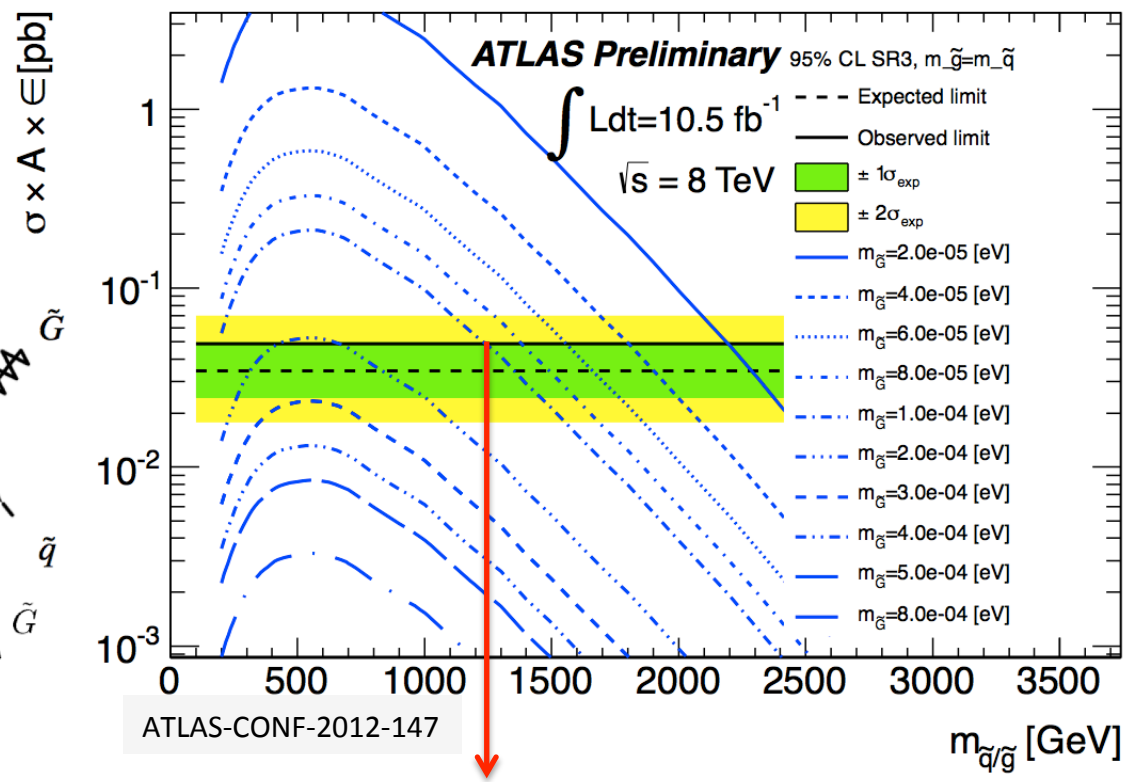
Direct production of **$\tilde{G}$+$\tilde{q}$/$\tilde{g}$**

Decay $\tilde{q}/\tilde{g} \longrightarrow \tilde{G}+q/g$

⇒ **Mono-jet** signature

Probe **gravitino mass**





m($\tilde{q}/\tilde{g}$) <1250 GeV

⇒ m($\tilde{G}$)< 10^{-4} eV excluded

Analysis covered by Steven Schramm in his talk "Dark Matter Searches at ATLAS"

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: Moriond 2014

ATLAS Preliminary

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

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt[\mathrm{fb}^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	any $m(\tilde{q})$	1308.1841
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 740 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.18 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}^\pm)=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e, μ	0-3 jets	-	20.3	$\tilde{g}$ 1.12 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e, μ	2-4 jets	Yes	4.7	$\tilde{g}$ 1.24 TeV	$\tan\beta$<15	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$ 1.4 TeV	$\tan\beta$ >18	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$ 1.28 TeV	$m(\tilde{\chi}_1^0)$>50 GeV	ATLAS-CONF-2014-001
	GGM (wino NLSP)	1 $e, \mu + \gamma$	-	Yes	4.8	$\tilde{g}$ 619 GeV	$m(\tilde{\chi}_1^0)$>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$ 900 GeV	$m(\tilde{\chi}_1^0)$>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e, μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$ 690 GeV	$m(\tilde{H})$>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale 645 GeV	$m(\tilde{g})>10^{-4}$ eV	ATLAS-CONF-2012-147
3rd gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$ 1.2 TeV	$m(\tilde{\chi}_1^0)$<600 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	$m(\tilde{\chi}_1^0)$ <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$ 1.34 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	ATLAS-CONF-2013-061
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$ 100-620 GeV	$m(\tilde{\chi}_1^0)$<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$ 275-430 GeV	$m(\tilde{\chi}_1^\pm)=2\ m(\tilde{\chi}_1^0)$	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e, μ	1-2 b	Yes	4.7	$\tilde{t}_1$ 110-167 GeV	$m(\tilde{\chi}_1^0)$=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$ 130-210 GeV	$m(\tilde{\chi}_1^0)=m(\tilde{t}_1)-m(W)$-50 GeV, $m(\tilde{t}_1)<<m(\tilde{\chi}_1^\pm)$	1403.4853
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e, μ	2 jets	Yes	20.3	$\tilde{t}_1$ 215-530 GeV	$m(\tilde{\chi}_1^0)$=1 GeV	1403.4853
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	0	2 b	Yes	20.1	$\tilde{t}_1$ 150-580 GeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)$=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e, μ	1 b	Yes	20.7	$\tilde{t}_1$ 200-610 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$ 320-660 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$ 90-200 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}_1^0)$<85 GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e, μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$ 150-580 GeV	$m(\tilde{\chi}_1^0)$>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1 + Z$	3 e, μ (Z)	1 b	Yes	20.3	$\tilde{t}_2$ 290-600 GeV	$m(\tilde{\chi}_1^0)$<200 GeV	1403.5222
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e, μ	0	Yes	20.3	$\tilde{\ell}$ 90-325 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$ 140-465 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.7	$\tilde{\chi}_1^\pm$ 180-330 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 700 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	1402.7029
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	2-3 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 420 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0$	1 e, μ	2 b	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 285 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^\pm$ 270 GeV	$m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)$=160 MeV, $\tau(\tilde{\chi}_1^\pm)$=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$ 832 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$ 475 GeV	10<$\tan\beta$<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$ 230 GeV	0.4<$\tau(\tilde{\chi}_1^0)$<2 ns	1304.6310
	$\tilde{q}\tilde{q}, \tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$ 1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, $m(\tilde{\chi}_1^0)$=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e + \mu$	2 e, μ	-	-	4.6	$\tilde{\nu}_\tau$ 1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV							1212.1272
	Bil							ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+$							ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+$							ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$ 880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon 100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e, μ (SS)	2 b	Yes	14.3	sgluon 350-800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M^* scale 704 GeV	$m(\chi)$<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

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

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

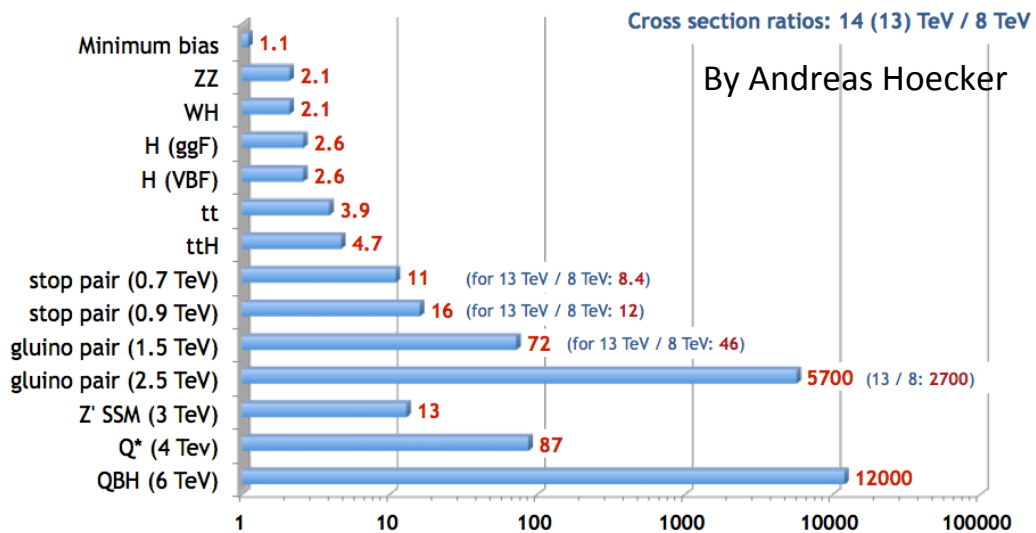
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

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

Summary and Outlook

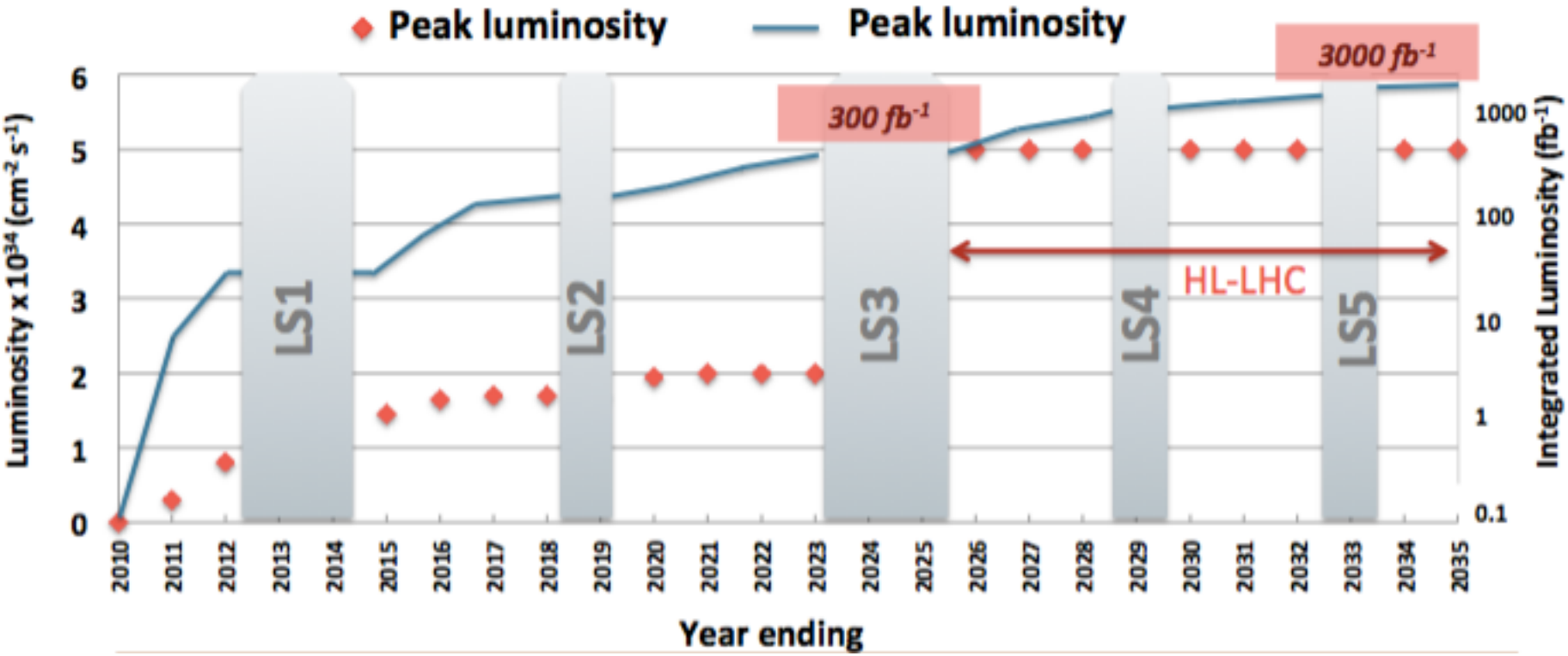
- **LSP** is an excellent **candidate for DM**
- Most of the SUSY scenarios predict the **LSP** to be either $\tilde{\chi}^0_1$ **or** $\tilde{G}$
- ATLAS has **excellent sensitivity** to dark matter produced in **cascade decays** of susy particles
- No significant excess is seen ⇒ **limits** set on mass and cross section
- **Explore new regions** of parameter and phase space with the LHC Run2 data at ~**14 TeV** to be collected **starting in 2015**

Stay tuned!



Backup

Upgrade Timeline and luminosity



The $m_{\mathrm{T2}}^{\ell\ell}$ variable is calculated as

$$m_{\mathrm{T2}}(\mathbf{p}_{\mathrm{T},1}, \mathbf{p}_{\mathrm{T},2}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}) = \min_{\mathbf{q}_{\mathrm{T},1}+\mathbf{q}_{\mathrm{T},2}=\mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}} \{\max[\, m_{\mathrm{T}}(\mathbf{p}_{\mathrm{T},1}, \mathbf{q}_{\mathrm{T},1}), m_{\mathrm{T}}(\mathbf{p}_{\mathrm{T},2}, \mathbf{q}_{\mathrm{T},2})\,]\}\,, \tag{1}$$

where m_{T} indicates the transverse mass, $\mathbf{p}_{\mathrm{T},1}$ and $\mathbf{p}_{\mathrm{T},2}$ are the transverse momentum vectors of the two leptons, and $\mathbf{q}_{\mathrm{T},1}$ and $\mathbf{q}_{\mathrm{T},2}$ are transverse vectors which satisfy $\mathbf{q}_{\mathrm{T},1} + \mathbf{q}_{\mathrm{T},2} = \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}$. The minimisation is performed over all the possible decompositions of $\mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}$.

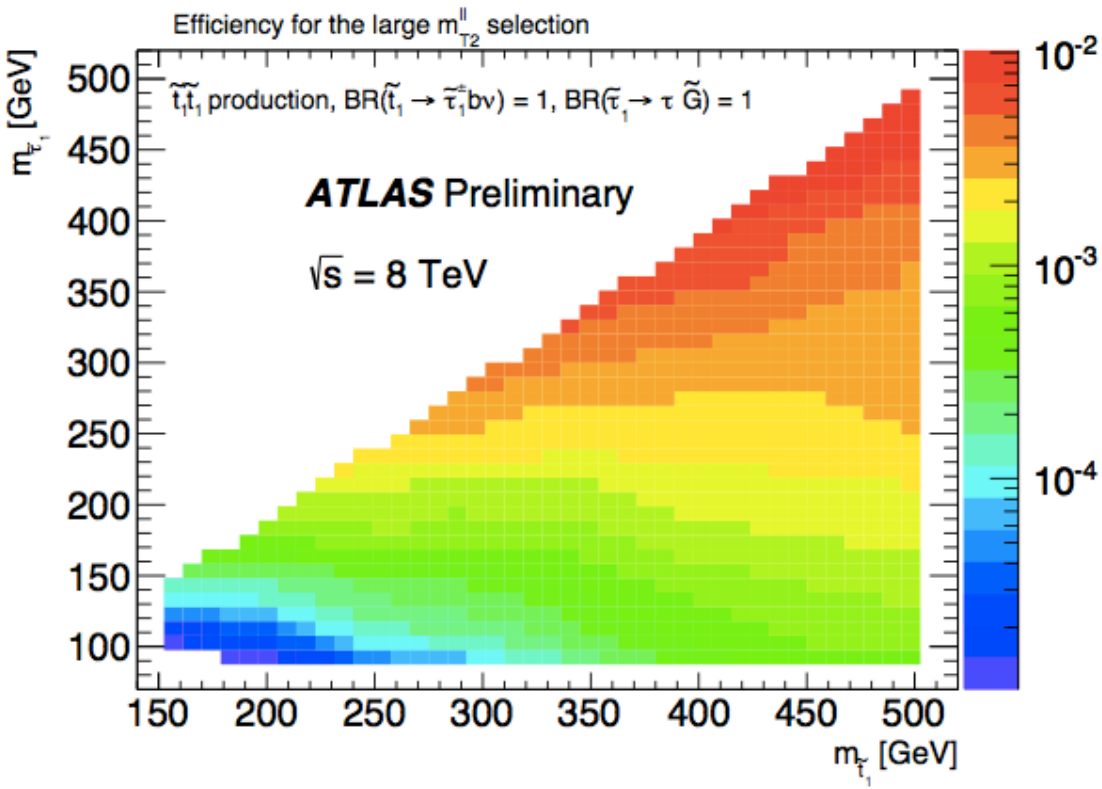


Figure 3: Efficiency of large $m_{\mathrm{T2}}^{\ell\ell}$ selection: fraction of signal events that are selected by at least one SR of Ref. [30] as a function of top squark and τ slepton masses.