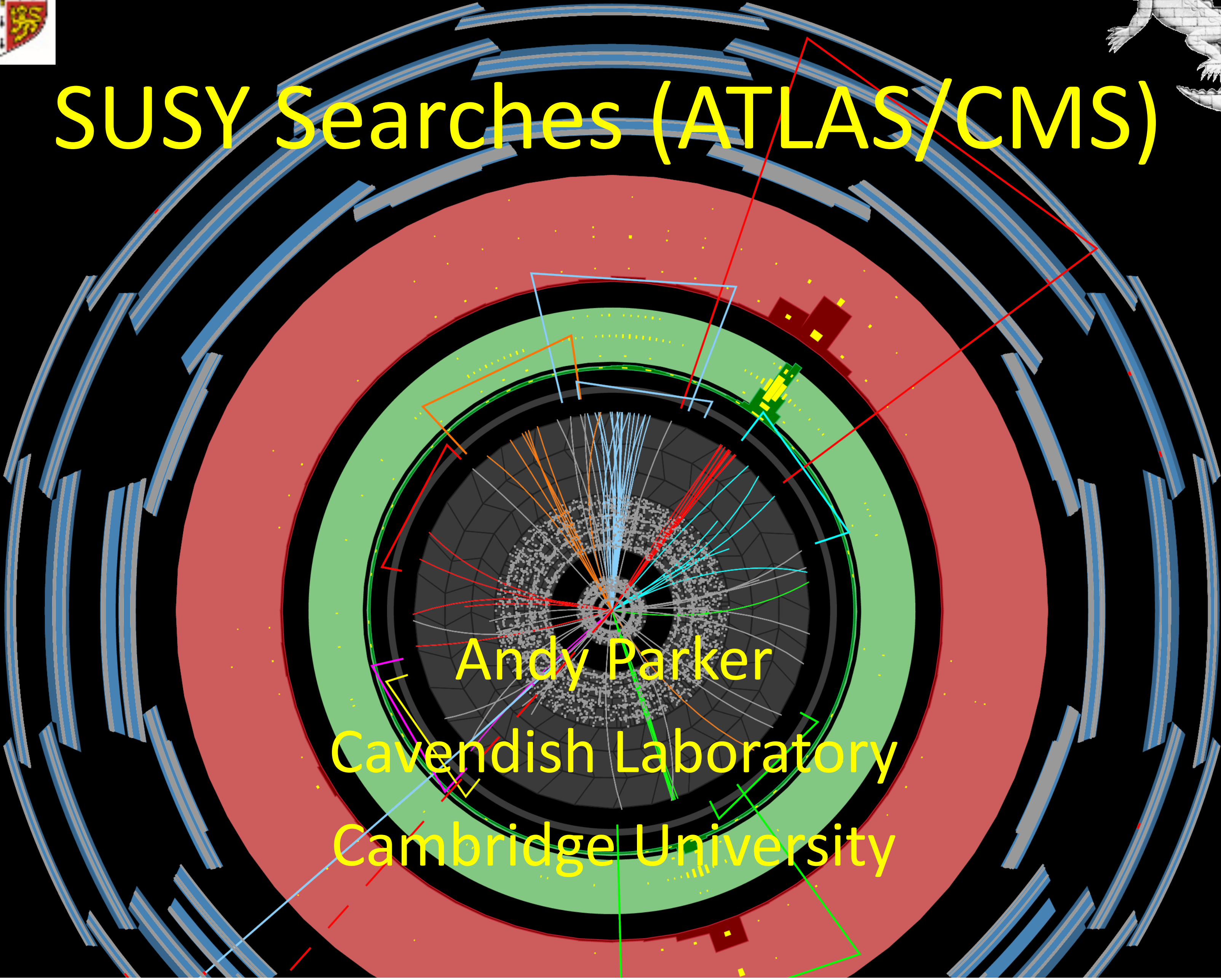
SUSY Searches (ATLAS/CMS)



Andy Parker

Cavendish Laboratory

Cambridge University

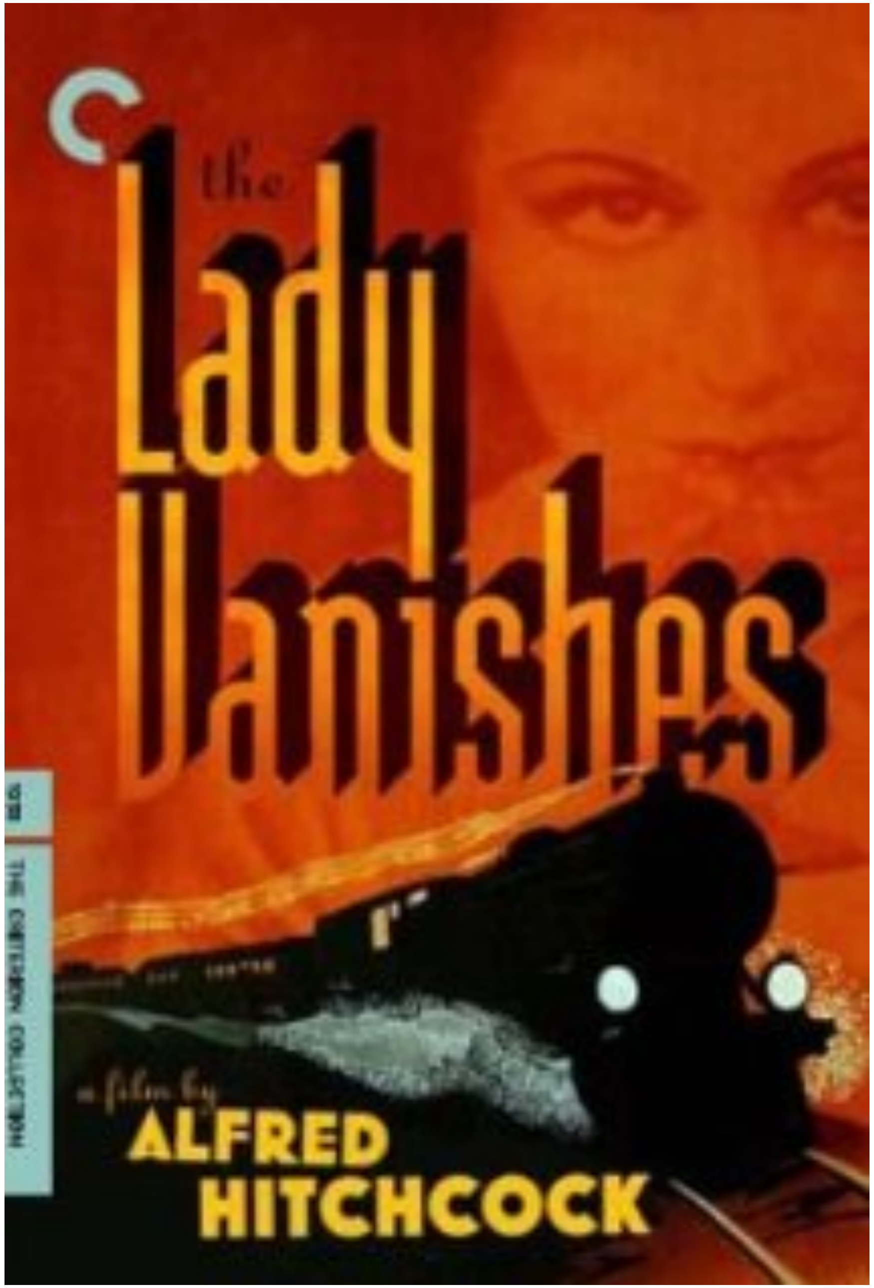
- Many new results: >30 talks in parallel session, some reporting 5 analyses…
- Impossible to cover everything…See http://cms.web.cern.ch/org/cms-papers-and-results and https://twiki.cern.ch/twiki/bin/view/AtlasPublic for full list
- Review of theory to follow: remain in your seats! Therefore will not discuss model interpretations of the data.
- Will give personal overview of status of experimental searches, focussing on what we know, and what we don't.

Is SUSY a figment of our imagination?

Is SUSY hiding or in disguise?

Is SUSY dead?

Thanks to the ATLAS and CMS SUSY convenors for their help



SUSY has been expected for a long time, but no trace has been found so far…

Like the plot of the excellent movie “The Lady Vanishes” (Alfred Hitchcock 1938).

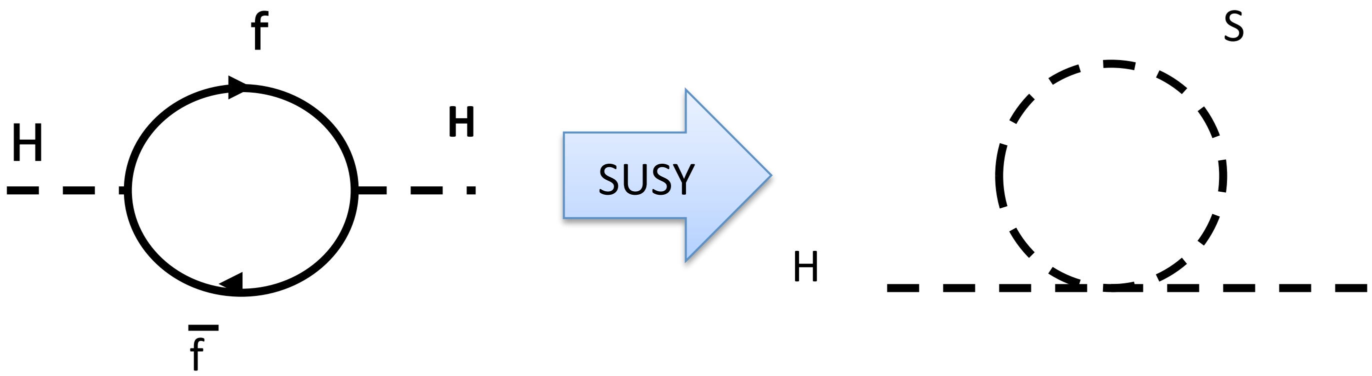
A lady is seen, then disappears on a train:

- is she imaginary?
- has she been kidnapped and hidden?
- is she in disguise?
- is she dead?

Why believe in SUSY?

Why believe in SUSY?

- Two big reasons:
- Dark matter – strong evidence from astrophysics – WIMP miracle fits with SUSY
- Light Higgs – need new physics to stabilise mass



$$\Delta m_H^2 = \frac{|\lambda_f|^2}{16\pi^2}\left[-2\Lambda_{UV}^2 + 6m_f^2\ln(\Lambda_{UV}/m_f) + \ldots\right]$$

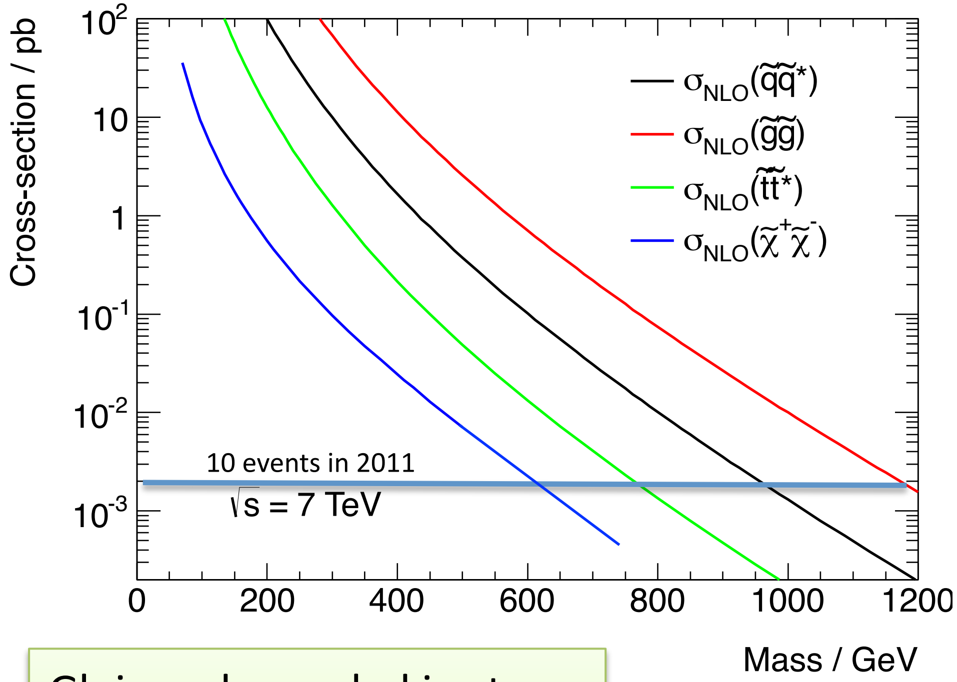
Need UV cut-off to get finite mass

$$\Delta m_H^2 = \frac{\lambda_s}{16\pi^2}\left[\Lambda_{UV}^2 - 2m_s^2\ln(\Lambda_{UV}/m_s) + \ldots\right]$$

SUSY provides correct coupling and number of states for cancellations

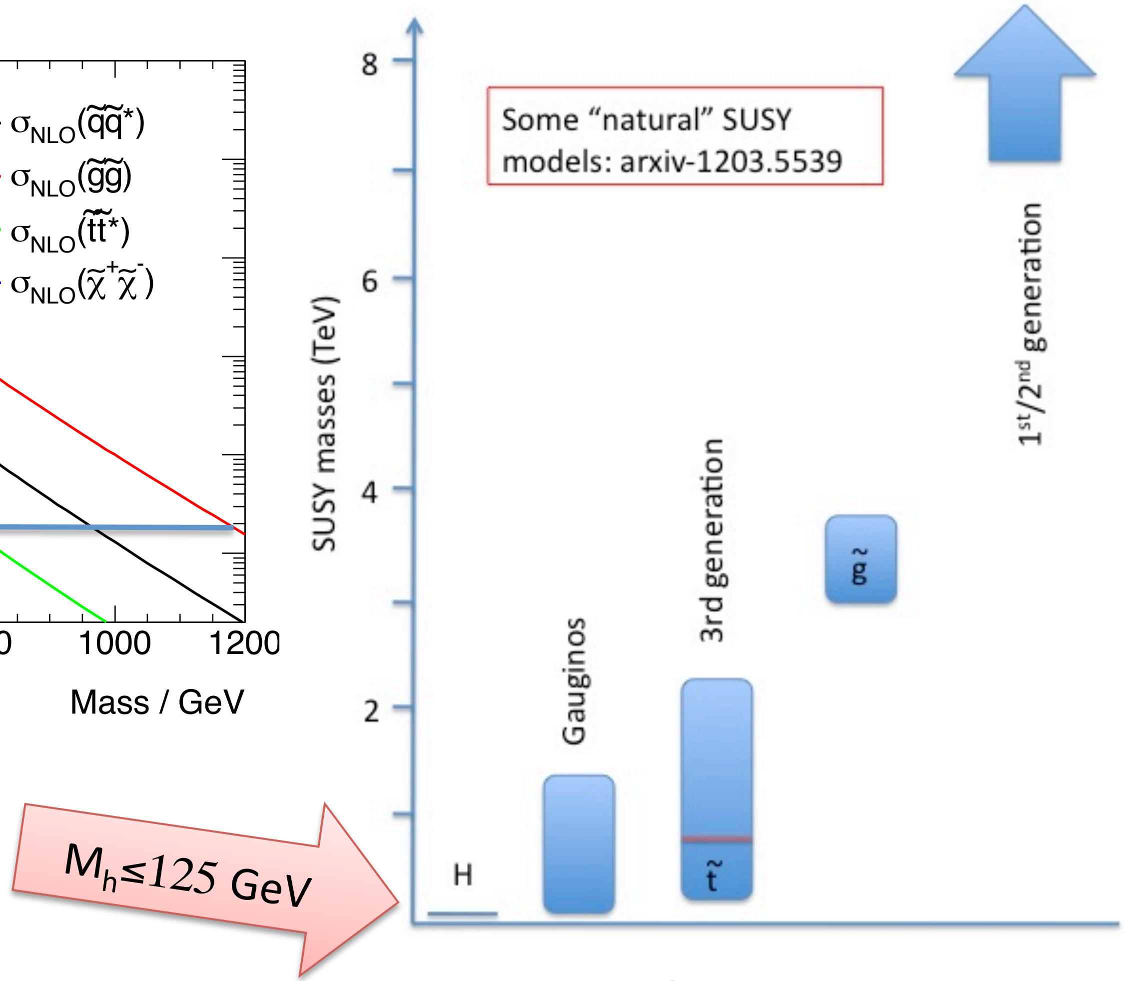
SUSY Mass spectrum and cross section

Sensitivity depends on which process is accessible.



Gluinos decoupled in stop cross-section estimate. (Thanks to TJ Khoo for plot)

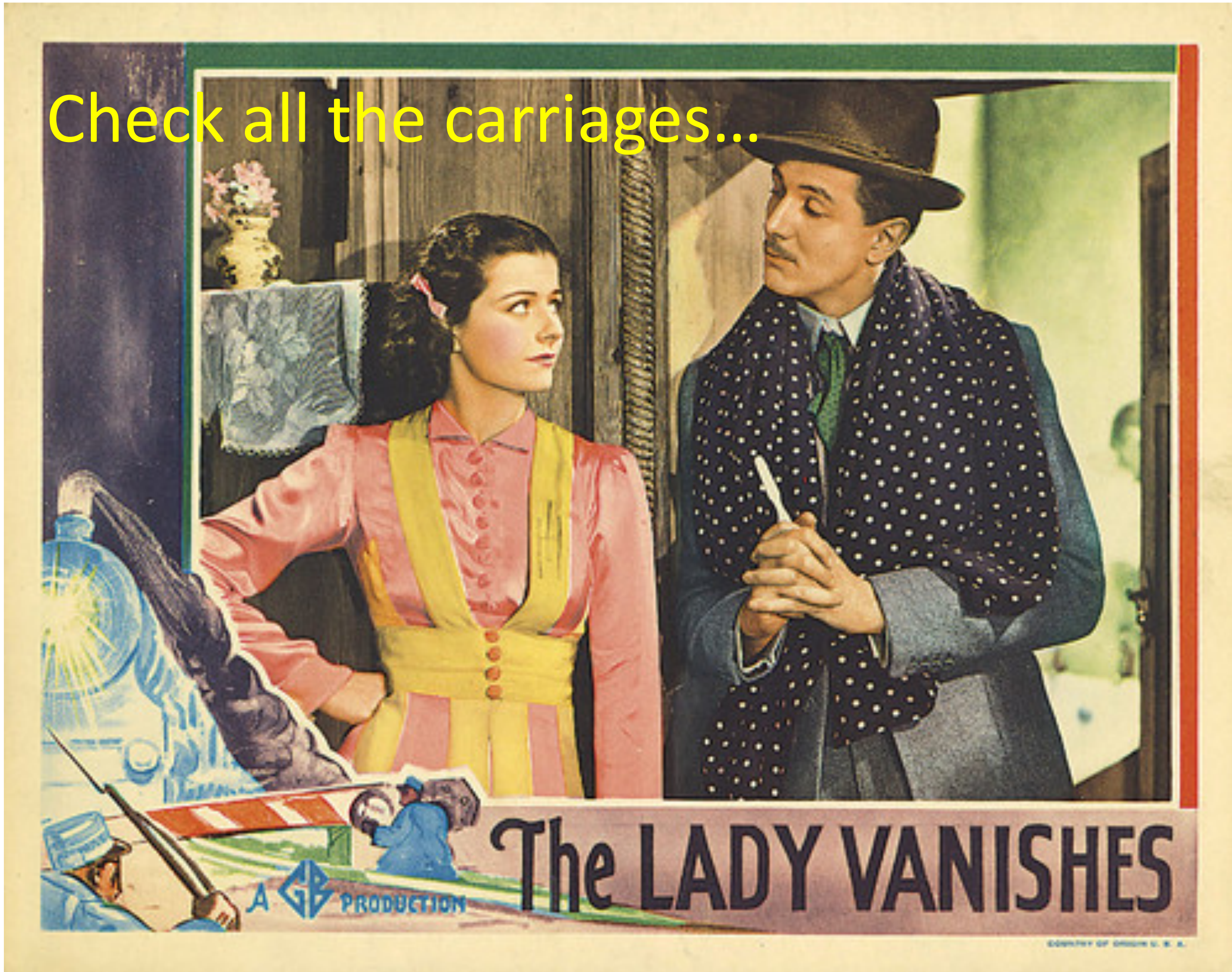
Spectrum is model dependent



Limits are model dependent – assumptions affect production and decay. Use simplified scenarios for interpretation.

First search in the most obvious places

Check all the carriages...



Search in the most obvious places

- R-parity conservation: neutral light LSP, (DM candidate), SUSY objects produced in pairs.

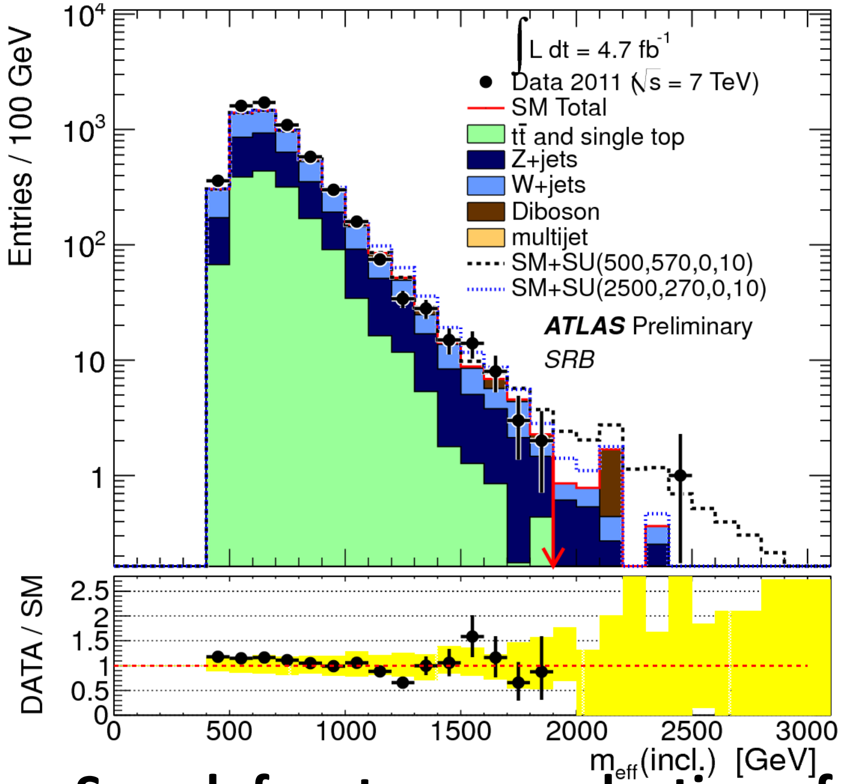
- Search for production and decay of gluinos and squarks – should have high rates.
- Search for sleptons and gauginos produced directly and also in cascade decays from strong production: lower rate, but cleaner signature.
- E_T^{miss} is key part of signatures.

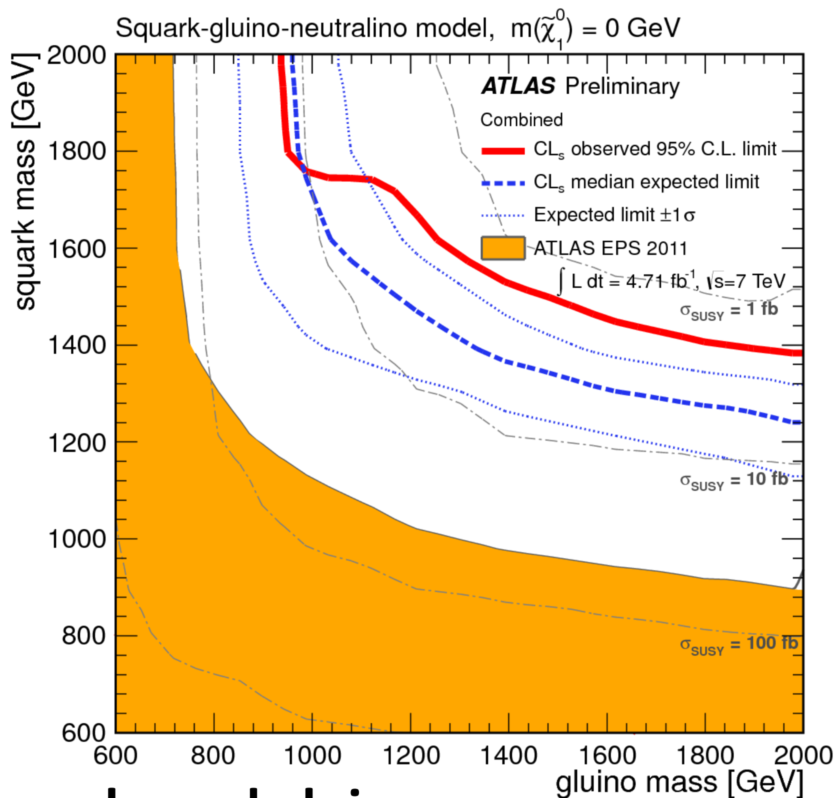
ATLAS 0-lepton search

2-6 jets + E_T^{miss}

M_{eff} defines signal regions

Look for squarks and gluinos with direct decays to SM+LSP





Search for strong production of squarks and gluinos.

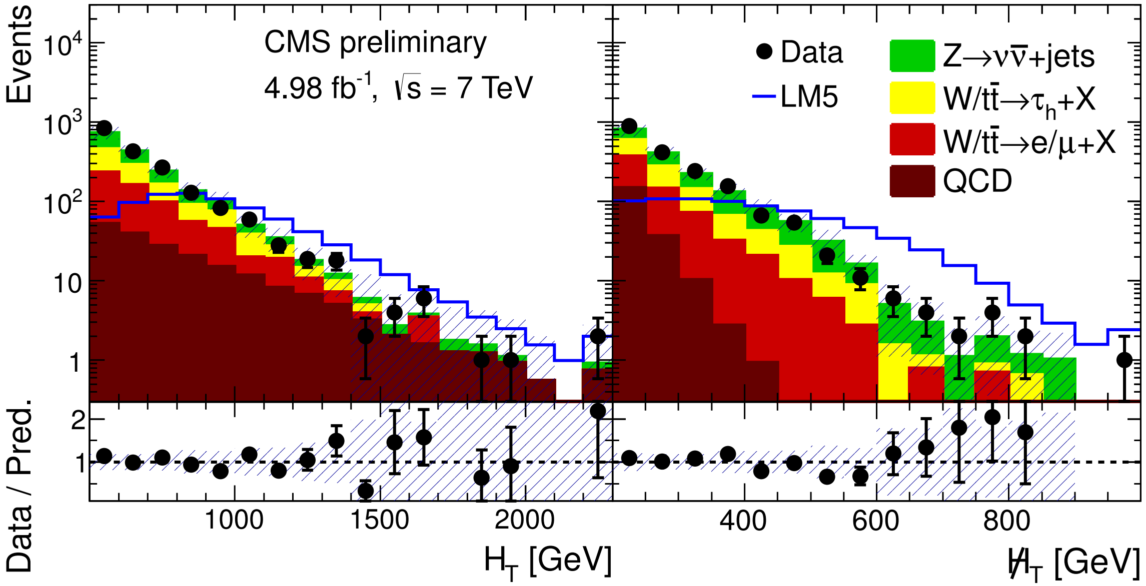
Very strong limits from counting experiment.

Dominant background from Z–> νν.

Limits do not apply to stop/sbottom production.

ATLAS-CONF-2012-033

CMS all hadronic search: 7 TeV



≥3 jets, 0-lepton, generic SUSY search, minimal model dependence.

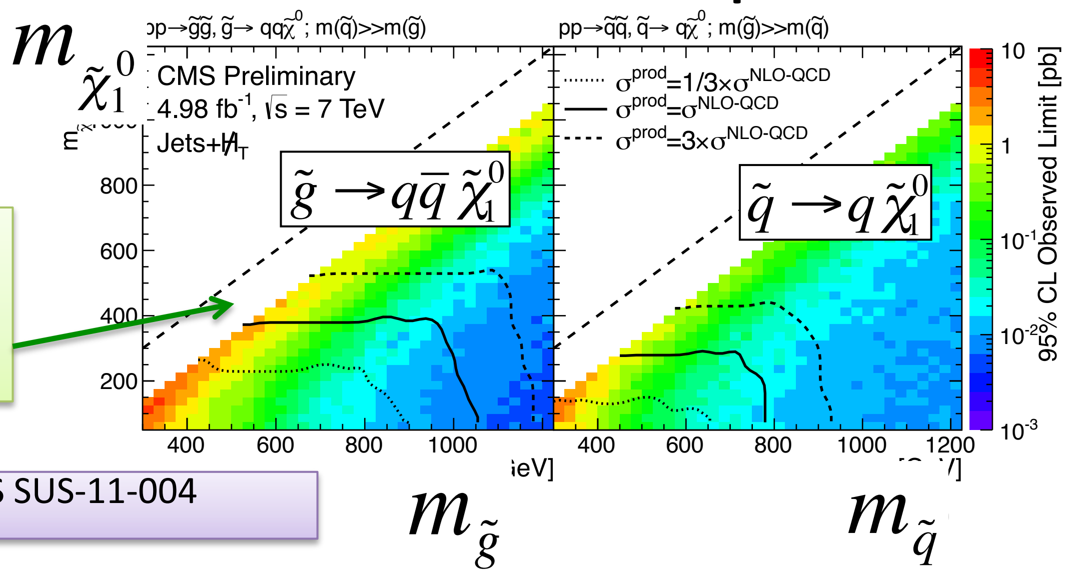
Interpretation in simplified models with only gluino or squark production

$$H_T = \sum p_T^{jet} > 350 \text{ GeV} \quad (p_T^{jet} > 50 \text{ GeV},\ \eta < 2.5)$$

$$\not{H}_T = -\sum \vec{p}_T^{\,jet} > 200 \text{ GeV} \quad (p_T^{jet} > 30 \text{ GeV},\ \eta < 5)$$

Excludes:
gluinos < 750 GeV
squarks<1200 GeV
in cMSSM model

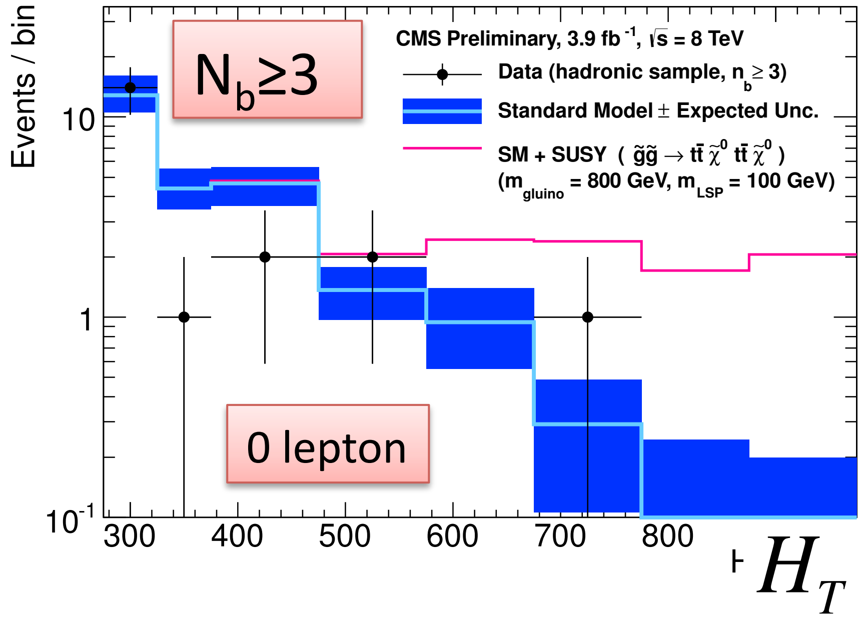
No limit at $m(\chi^0)$>400 GeV



CMS PAS SUS-11-004

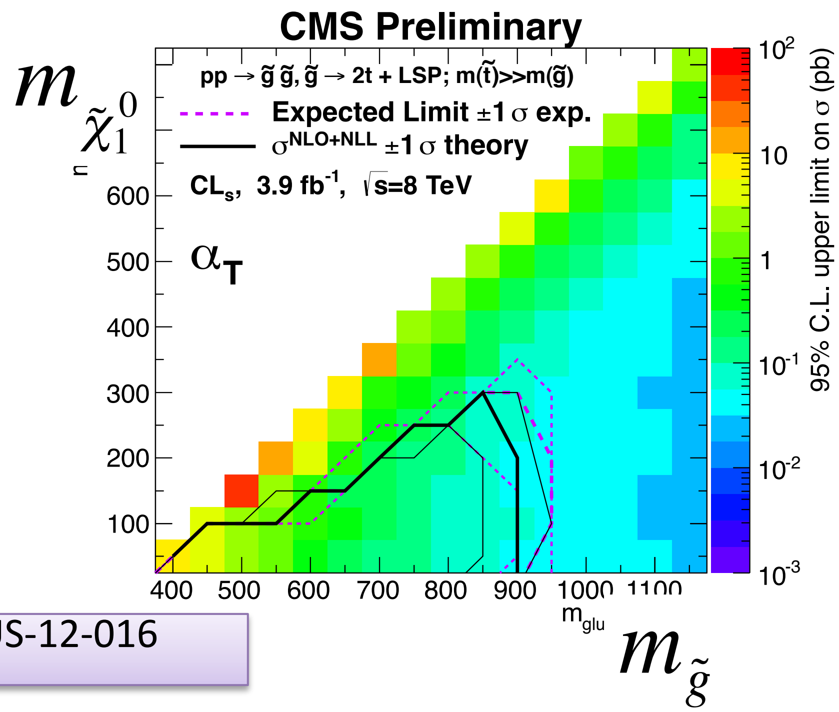
CMS α_T analysis: 2012, 3.9 fb^{-1}

8TeV



Use α_T to remove QCD, and bin in H_T and number of b jets, with hadronic and leptonic channels.

One interpretation in simplified model: $\tilde{g} \rightarrow t\,\bar{t}\,\tilde{\chi}_1^0$



Very interesting generic analysis: covers 0-3 b-tagged jets

-All hadronic

-1 muon + jets

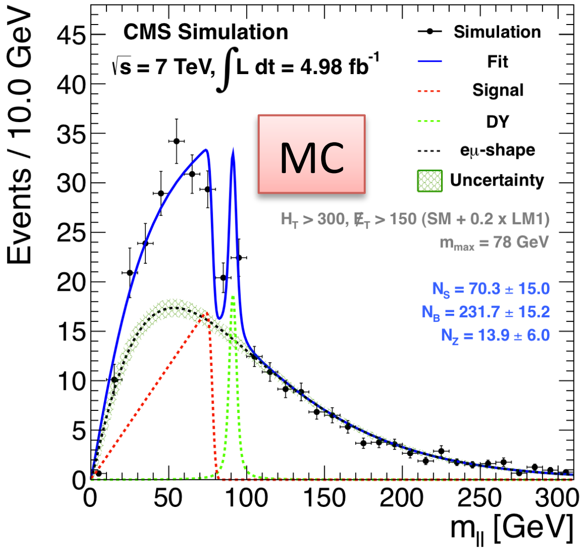
-2 muons + jets

-Photon + jets

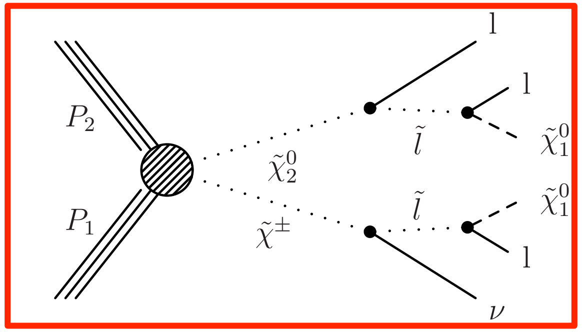
Many powerful constraints

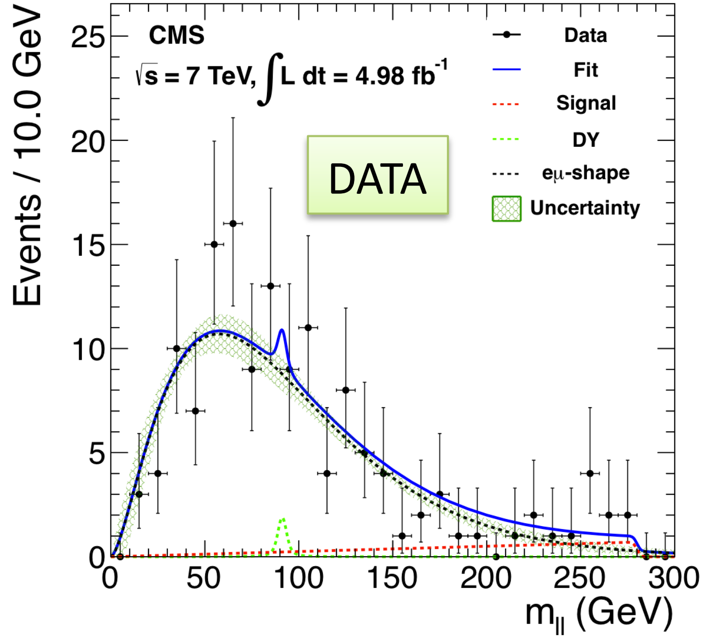
CMS PAS SUS-12-016

CMS OS-dilepton search: $\tilde{l}, \tilde{\chi}^{\pm}$



Long decay chains produce dilepton signal

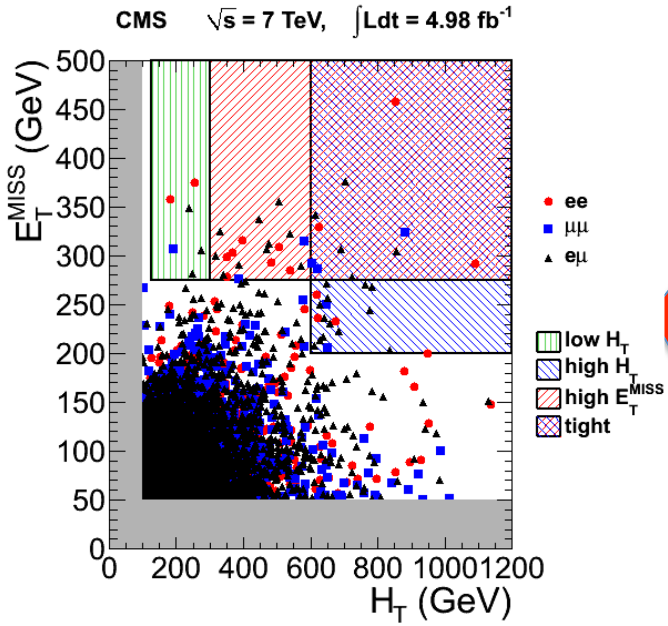




Search for edge in m(ll) from cascade decays

Exclude 5-30 events from new physics

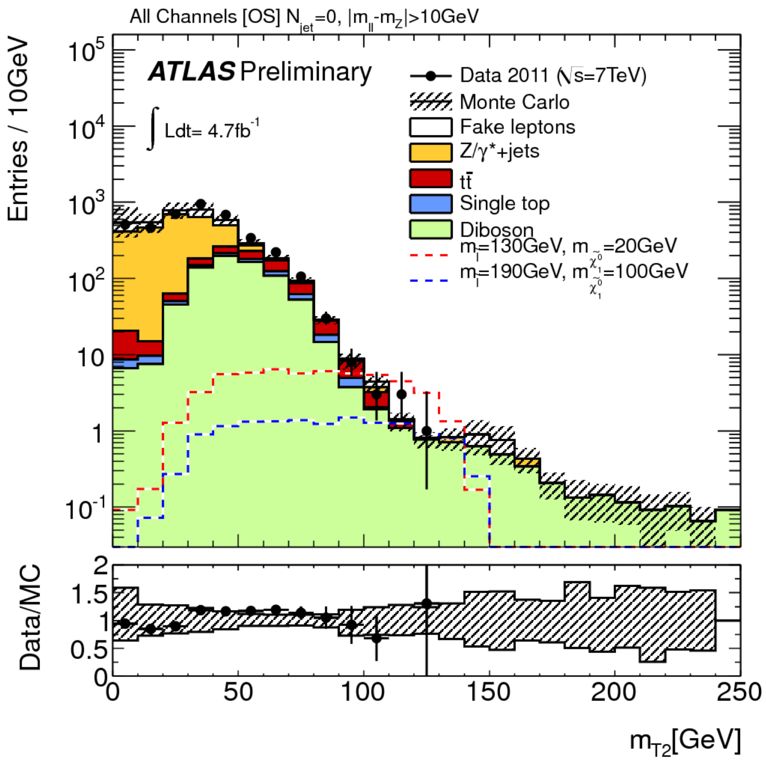
CMS-SUS-11-011



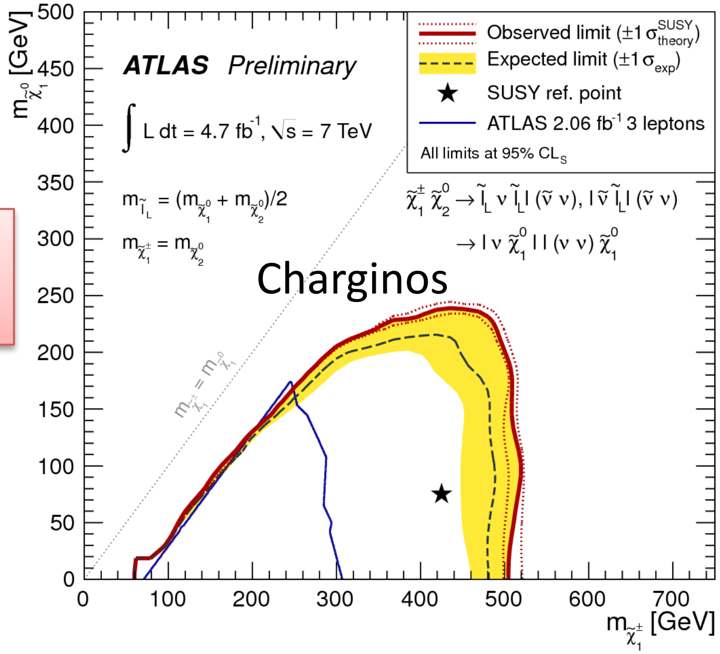
Count dileptons in H_T/ E_T^{Miss} plane.

ATLAS- direct slepton/chargino production

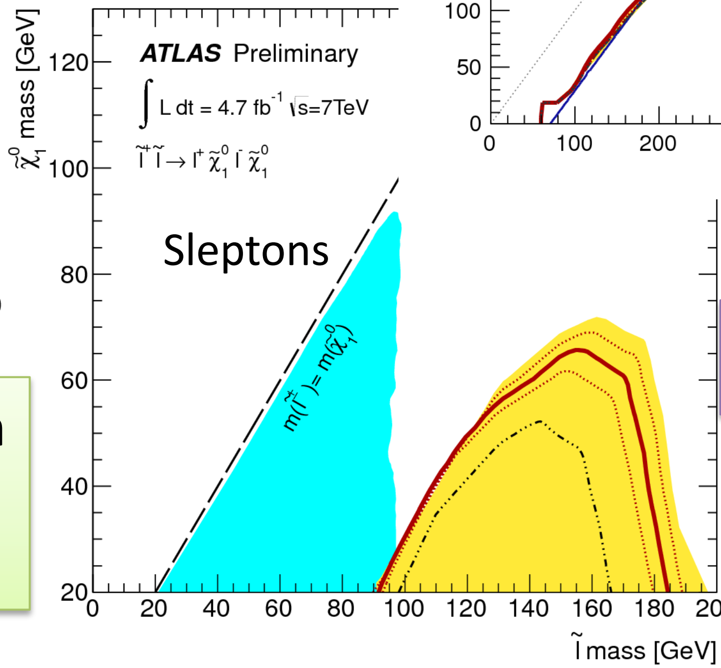
Select 2 or 3 leptons and E_T^{miss}. Use m_{T2} for pairs of semi-invisible decays



Best limit on charginos



No constraints for M_{LSP}>100 GeV

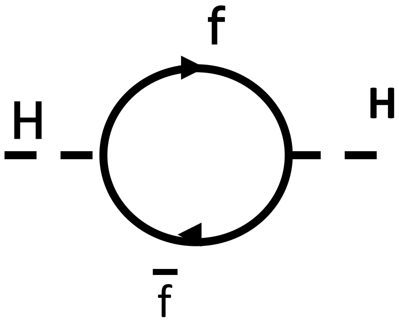


ATLAS-CONF-2012-076
ATLAS-CONF-2012-077

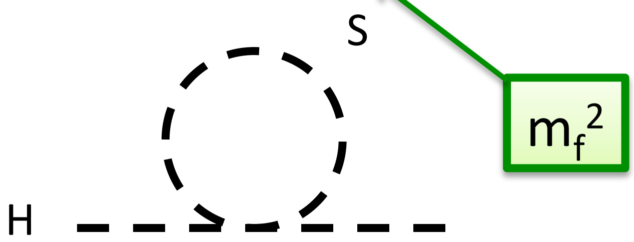
Sensitivity to weak production processes limited by lower cross-section.

Think carefully about predictions

Think carefully about predictions



$$\Delta m_H^2 = \frac{|\lambda_f|^2}{16\pi^2}\left[-2\Lambda_{UV}^2 + 6m_f^2 \ln(\Lambda_{UV}/m_f) + \ldots\right]$$



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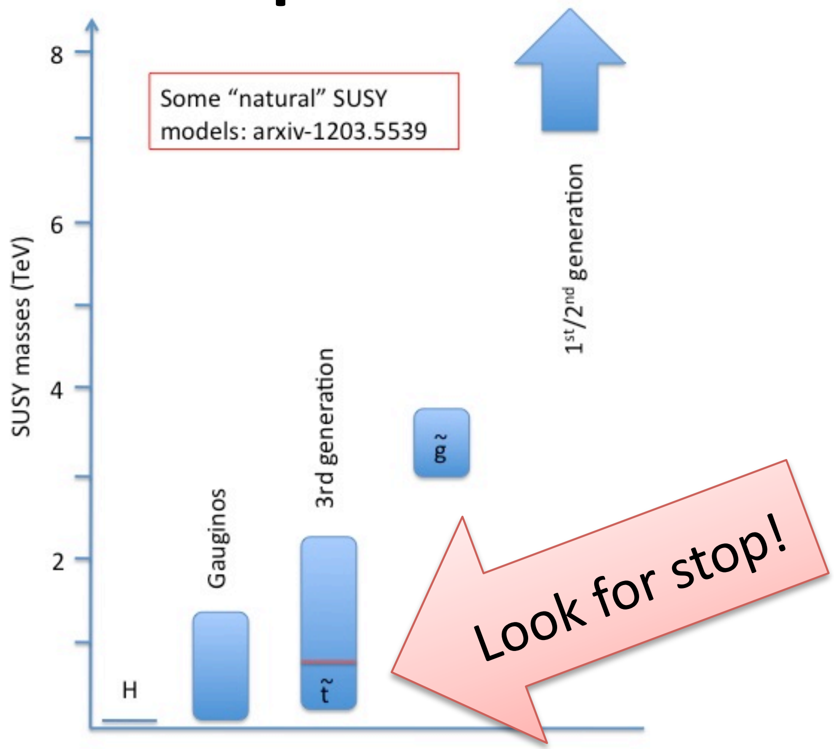


Dominant loop is from top: only need third generation squarks to be really light.

3rd generation cross section is reduced (no t/b content in proton): existing limits don't apply!

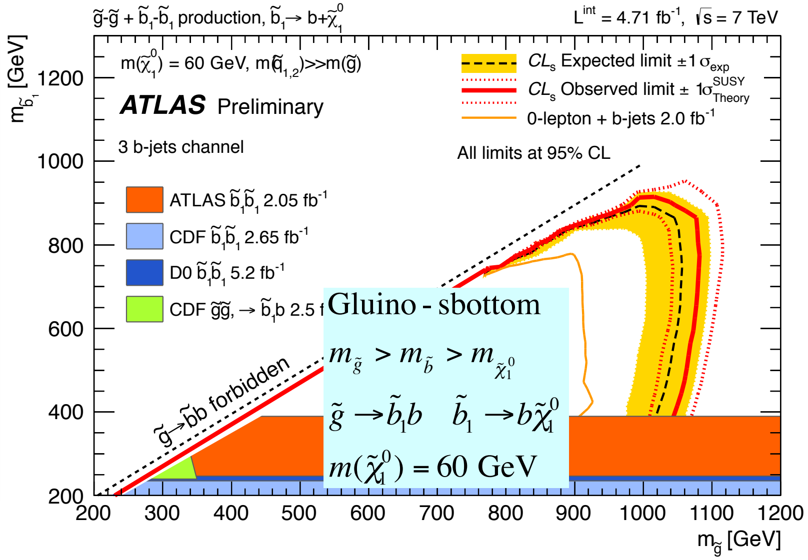
ATLAS: $\tilde{g} \rightarrow \tilde{t}\ ,\ \tilde{b}$

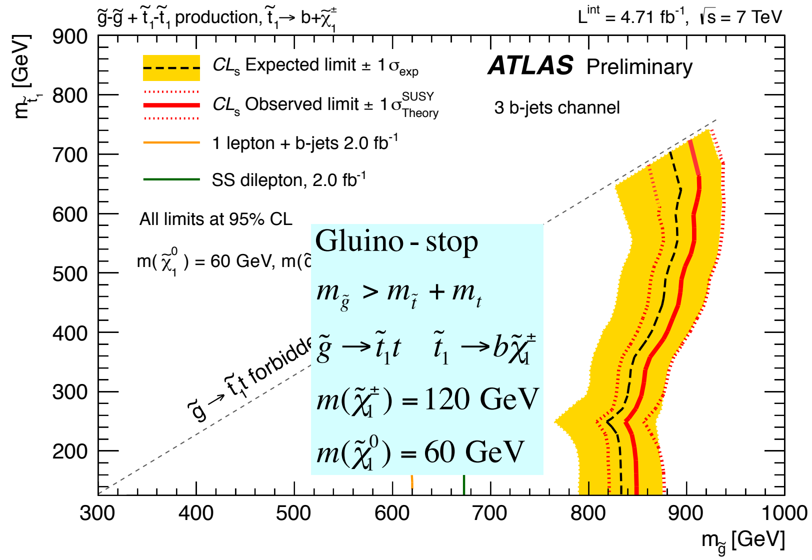
Limits on gluino mass ~1 TeV

4-6 jets (≥3 b-jets), no leptons.

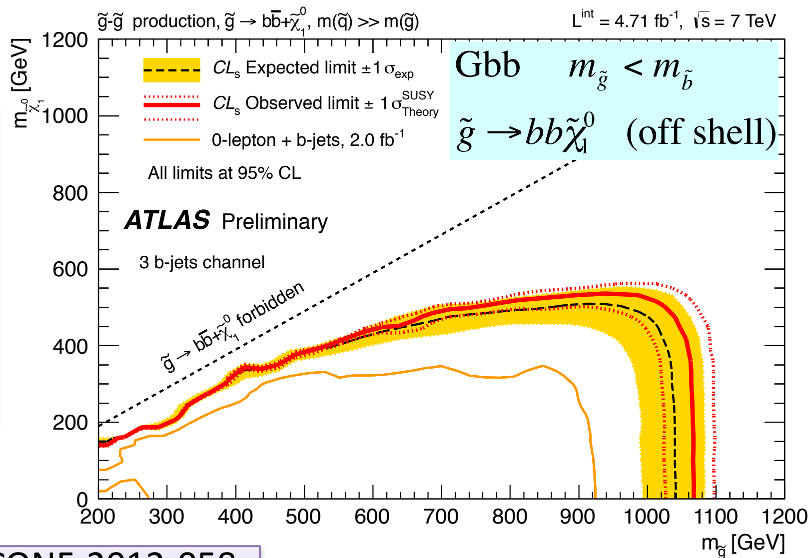
Allowed decays depend on masses

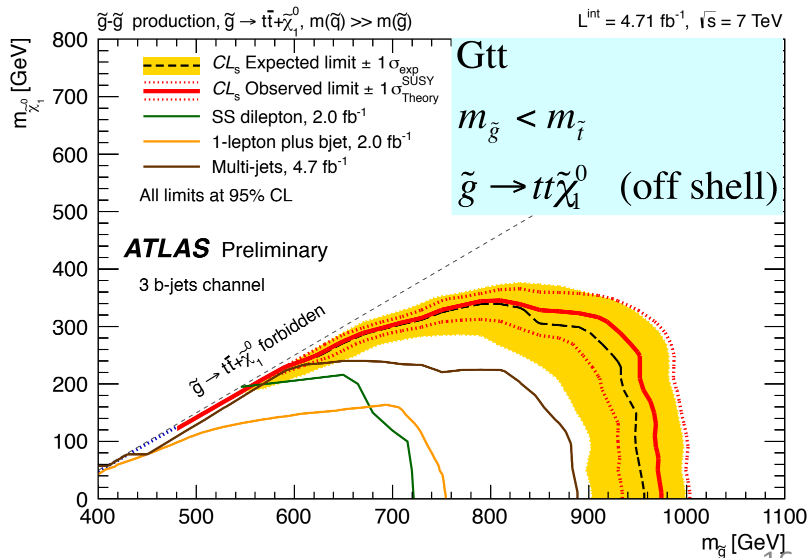
Upper plots – 2-body cascade decays





Lower plots – 3-body decays





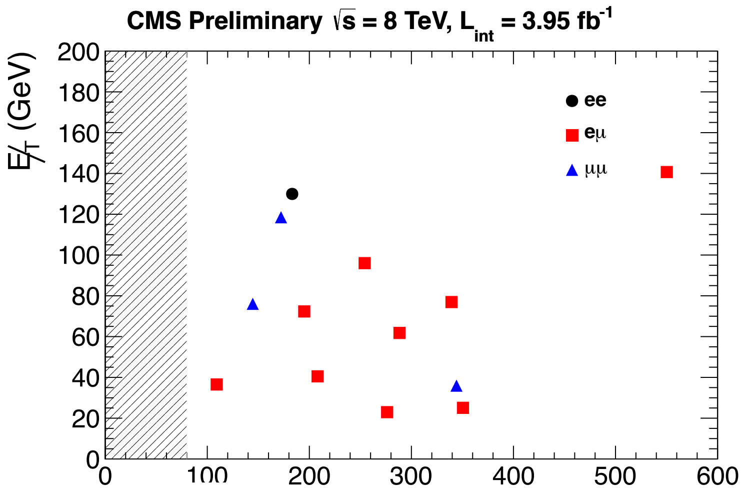
ATLAS-CONF-2012-058

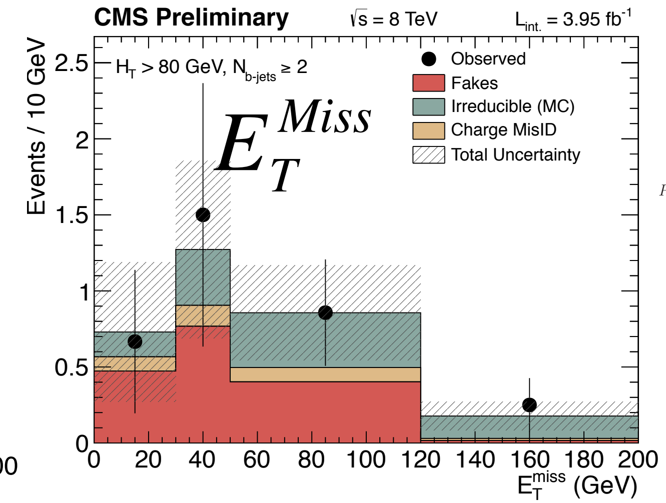
CMS SS-dilepton and ≥2 b jets

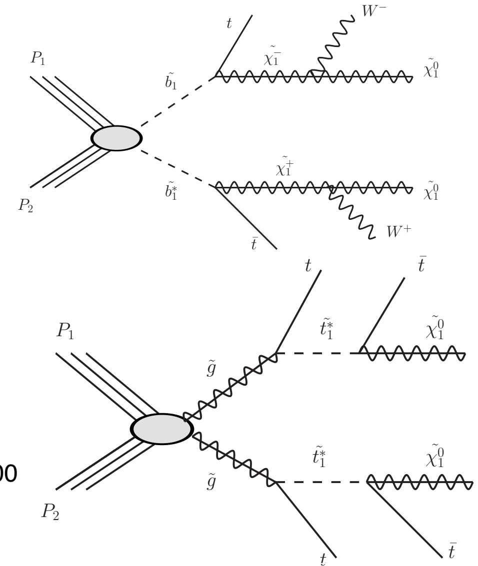
8TeV

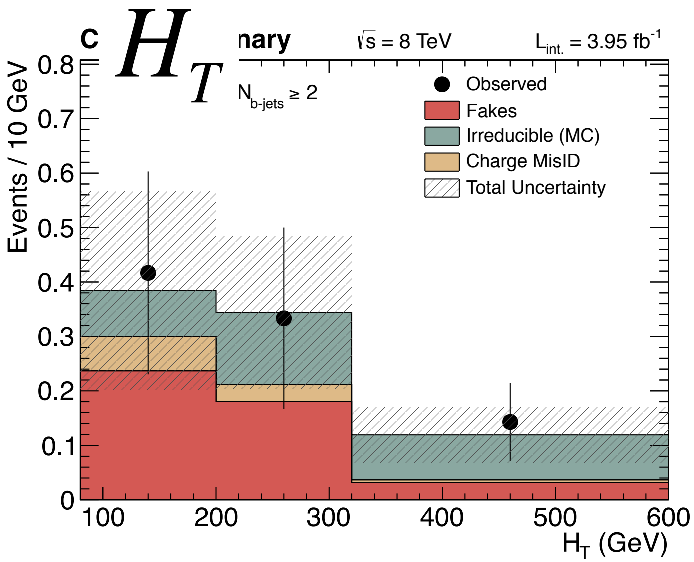
Counting experiment in H_T/ E_T^{Miss} plane: 13 events observed

Sensitive to 3[rd] generation squarks: gluino mediated, or direct production

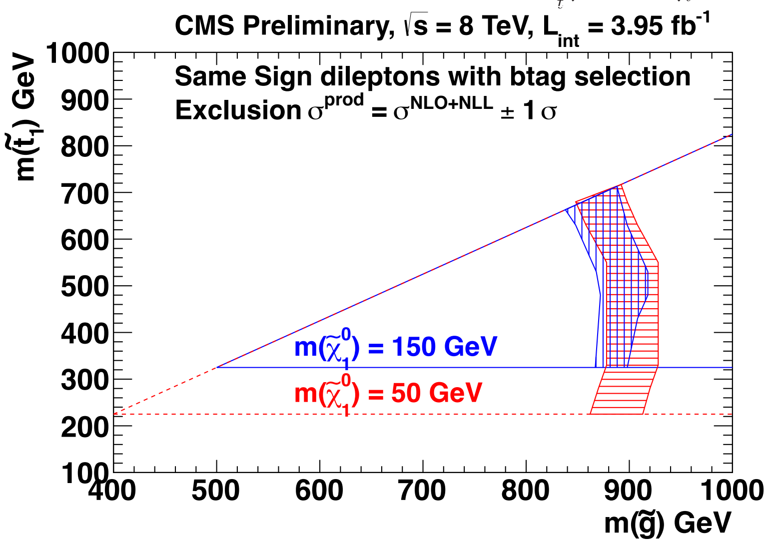






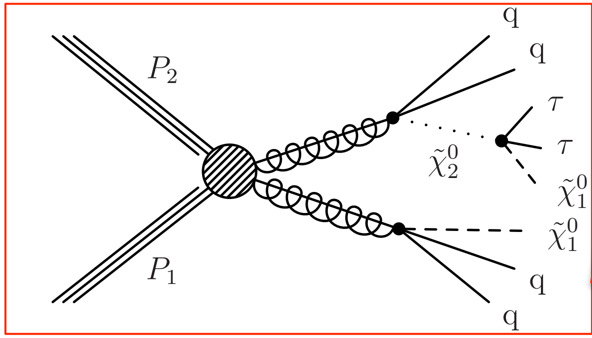


Exclusions for various BSM models. Limits in stop/gluino plane up to m(stop)>700 GeV

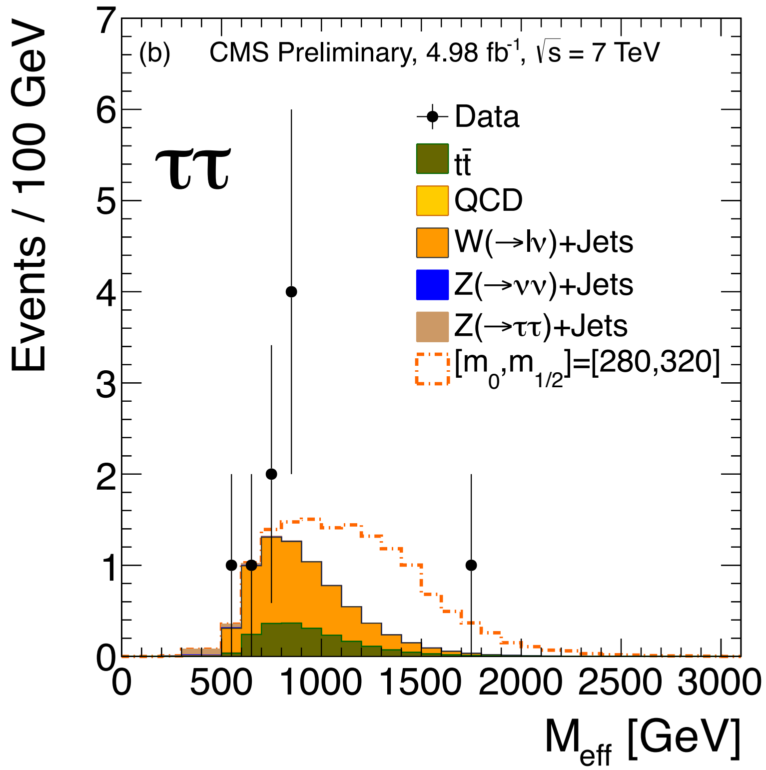


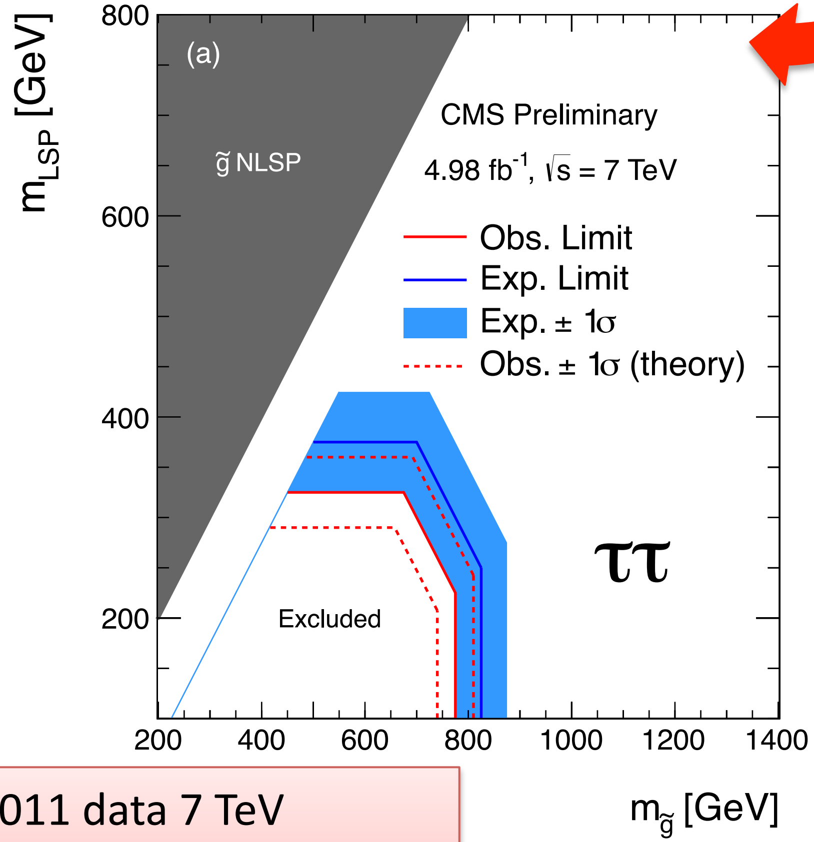
CMS τ and ττ

Light 3rd generation SUSY could mean light stau -> tau production with jets and missing energy: impressive experimental work to extract signal!



Limits in simplified model



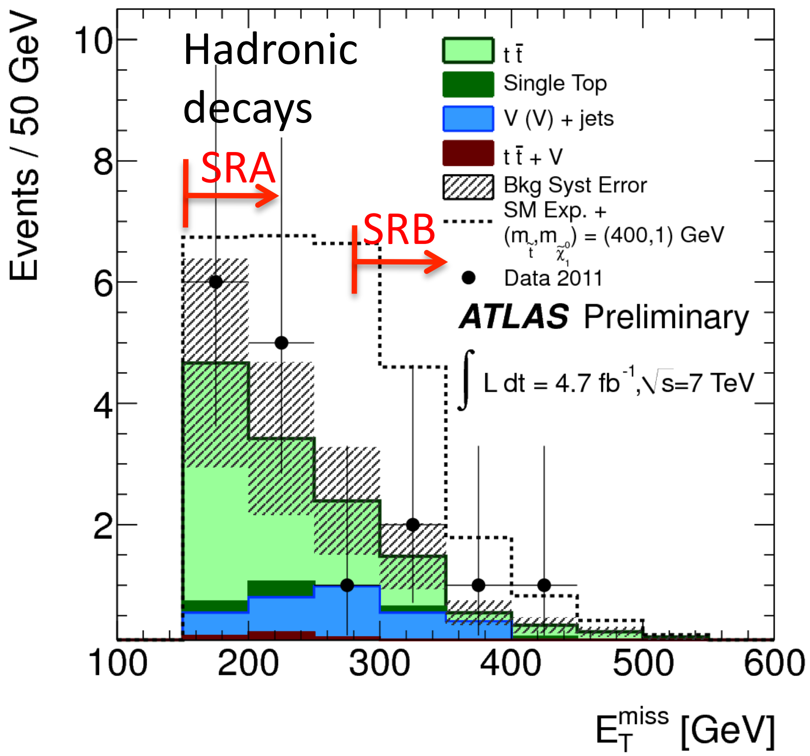


2011 data 7 TeV
9 events observed
7.5 ±0.7±0.9 expected

Direct Stop searches

Heavy stop > m_t : look for hadronic or leptonic top decays with extra E_T^{miss}

$$\tilde{t}_1 \rightarrow t\,\tilde{\chi}_1^0 \rightarrow Wb\,\tilde{\chi}_1^0$$

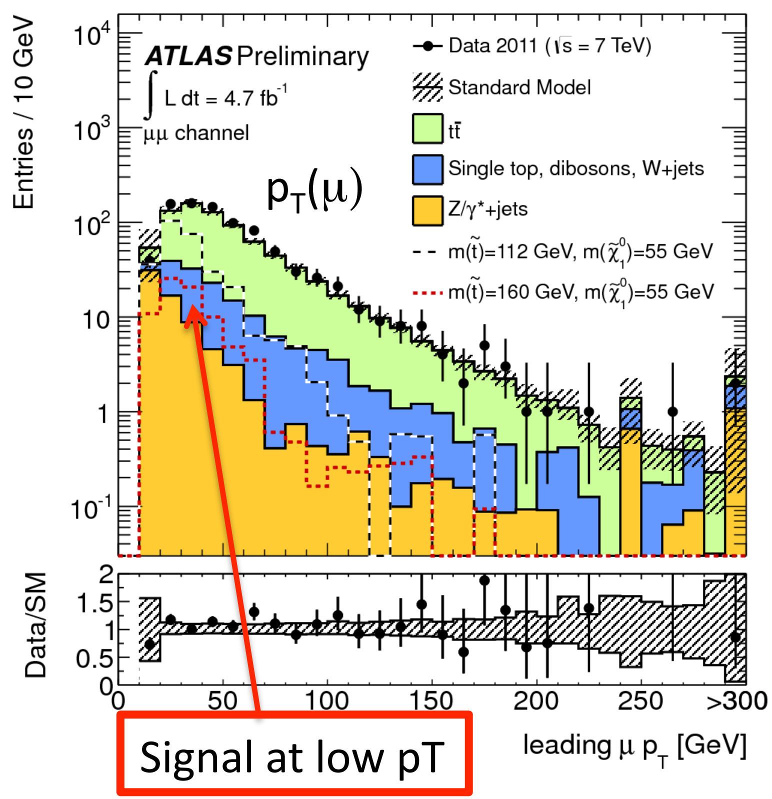


Light stop <m_t : look for top-like decay via chargino. Signal events contain lower p_T leptons, and subsystem mass below $2m_t$

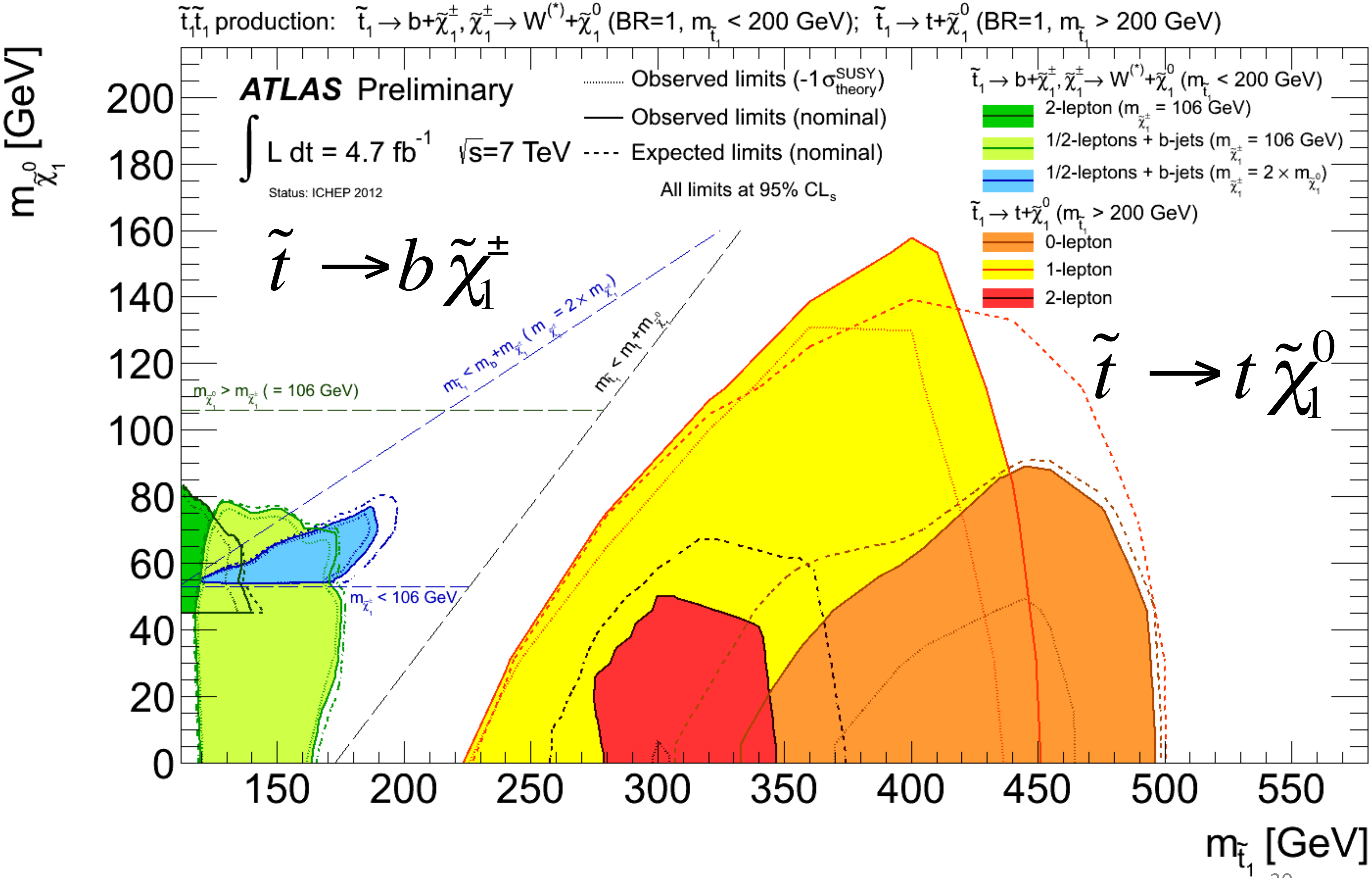
$$m_t > m_{\tilde{t}} > m_{\tilde{\chi}_1^{\pm}}$$

What mass?

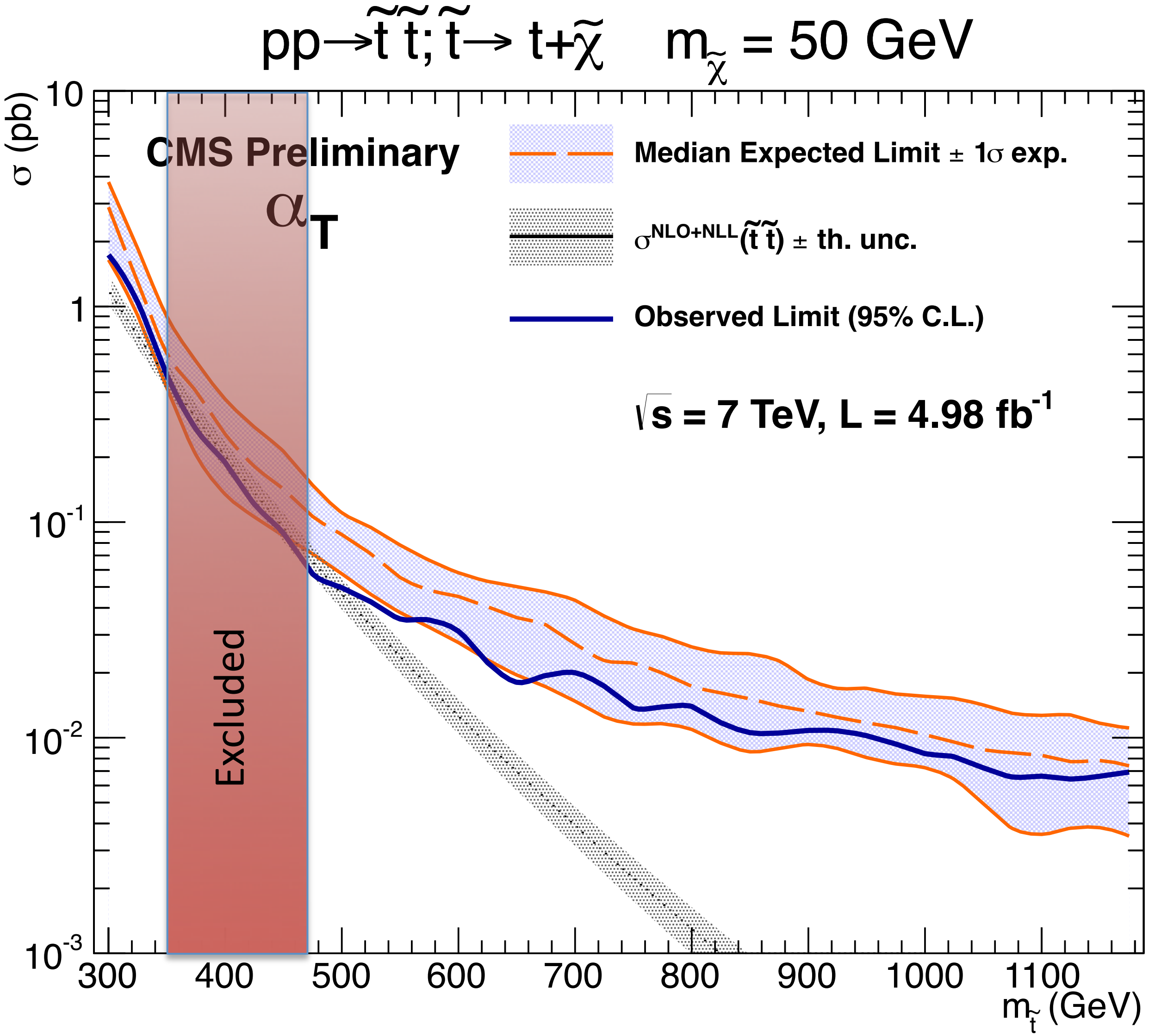
$$\tilde{t} \rightarrow b\,\tilde{\chi}_1^{\pm} \rightarrow bW^{(*)}\tilde{\chi}_1^0$$



ATLAS Combined Stop Exclusion

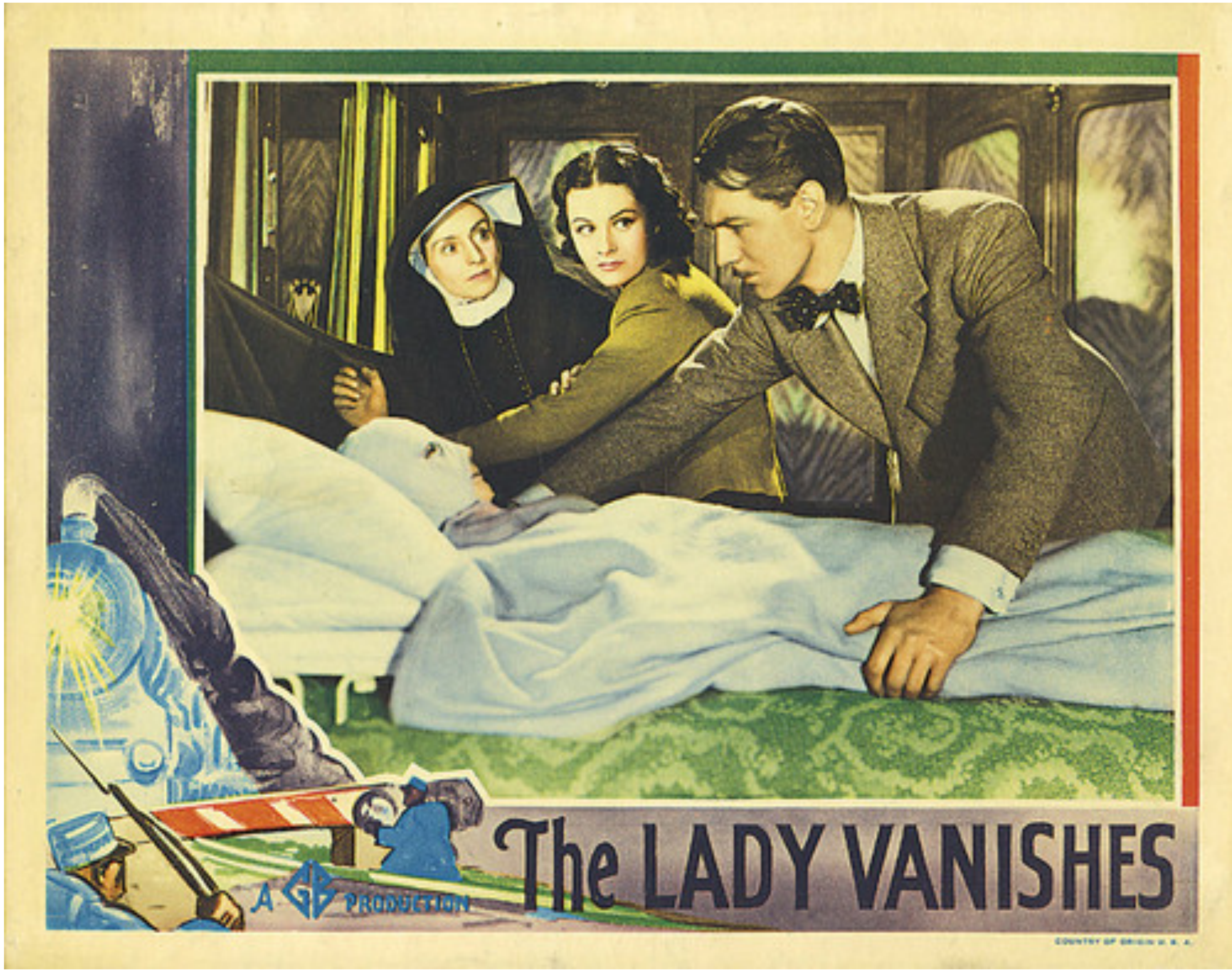


CMS limit on stop cross section



Limits on stop will improve rapidly with more data

Is SUSY hidden?



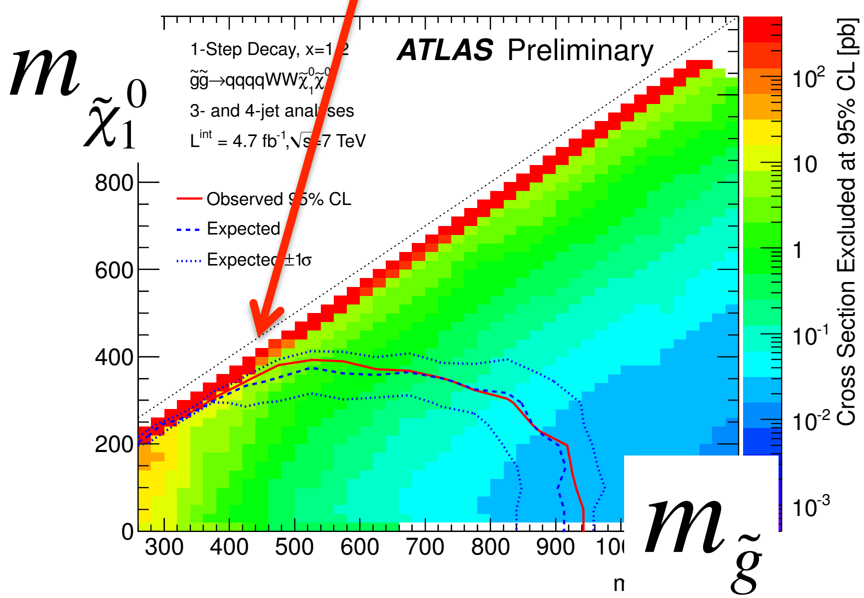
Is SUSY in the existing searches?

- If SUSY masses are close together, p_T in final state objects is reduced.
- Multiple jets, little E_T^{miss}
- Signal looks much more like QCD
- May get signal from hard ISR jets, but theoretical errors are difficult to control
- Compressed SUSY models, stealth SUSY models….

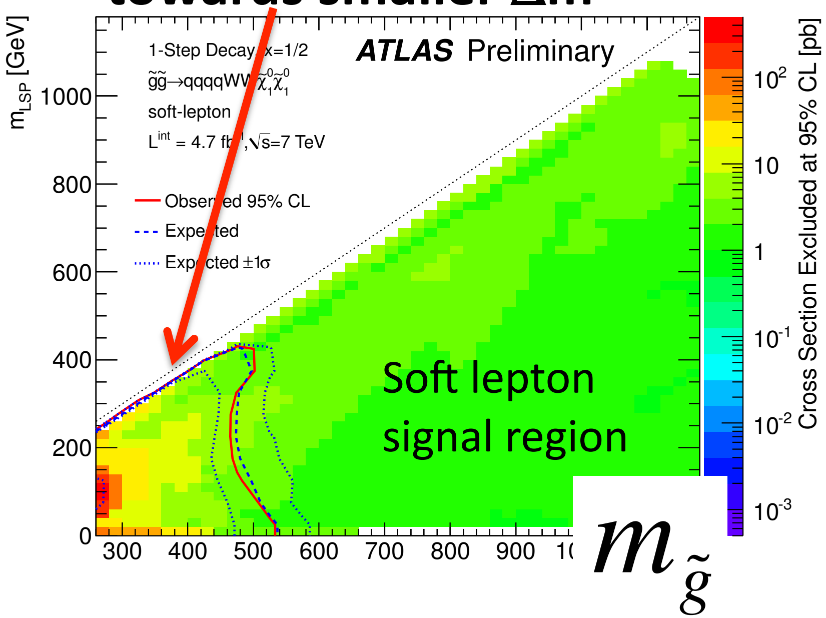
ATLAS 1-lepton: $\tilde{g} \rightarrow \tilde{q}\tilde{q}^{*} \quad \tilde{\chi}_1^{\pm} \rightarrow W^{\pm}\tilde{\chi}_1^0$

Hard to reach $m_{\tilde{g}} \approx m_{\tilde{\chi}_1^0}$

Low p_T selections push towards smaller Δm



3-4 jets+ lepton + Etmiss



Soft lepton selection (<25/20 GeV e/mu)

Search for strong production of squarks and gluinos. Use cascade decays including 3 or 4 jets and one lepton.

Exclude $m_{sq}=m_{gl}<1200$ GeV in MSUGRA

To reach small mass differences need low p_T cuts. Hard jets from ISR can help acceptance – but beware systematics

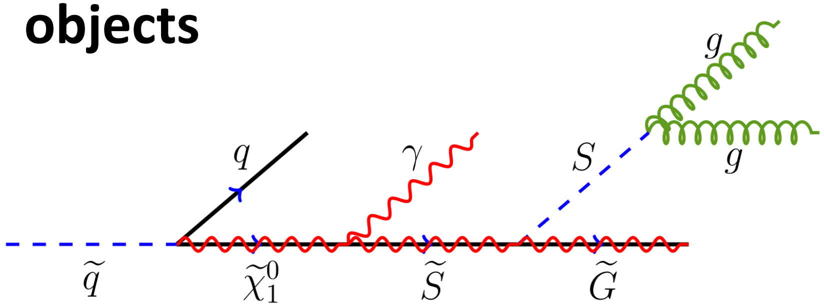
ATLAS-CONF-2012-041

CMS - Stealth SUSY

arXiv:1105.5135

SUSY requires hidden sector to break supersymmetry

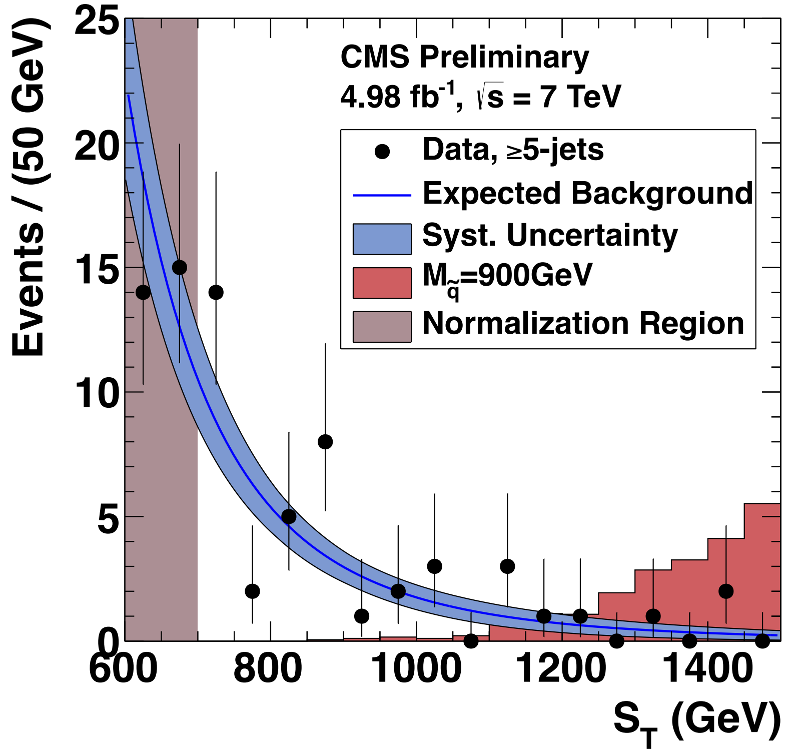
Light hidden sector particles can mediate decays to many low p_T objects



Rich phenomenology: can include many b-jets, photons, γjj resonances, long-lived particles etc

CMS-PAS-SUS-12-014

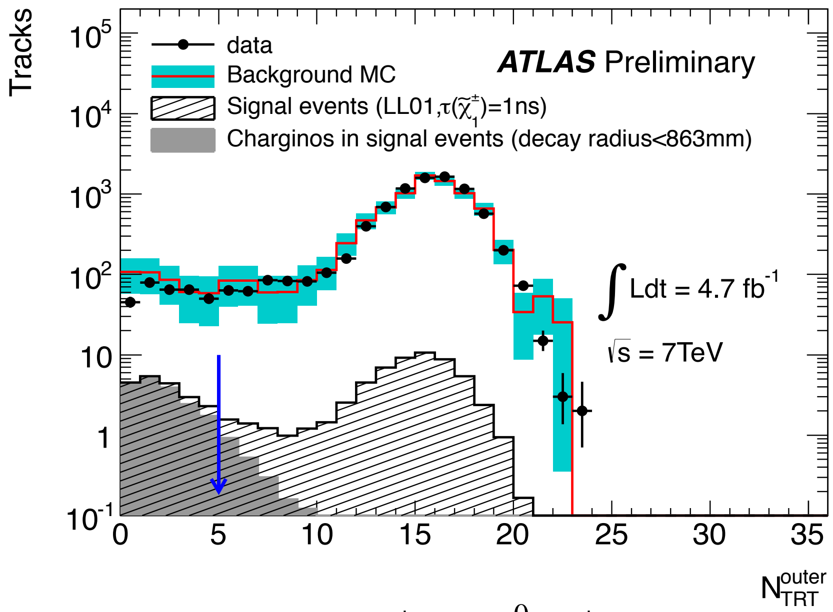
Search in events with γγ + ≤4 jets and large total energy S_T



New search @ICHEP

ATLAS – Long-lived particles

Small Δm: SUSY particle decays in flight: look for disappearing tracks



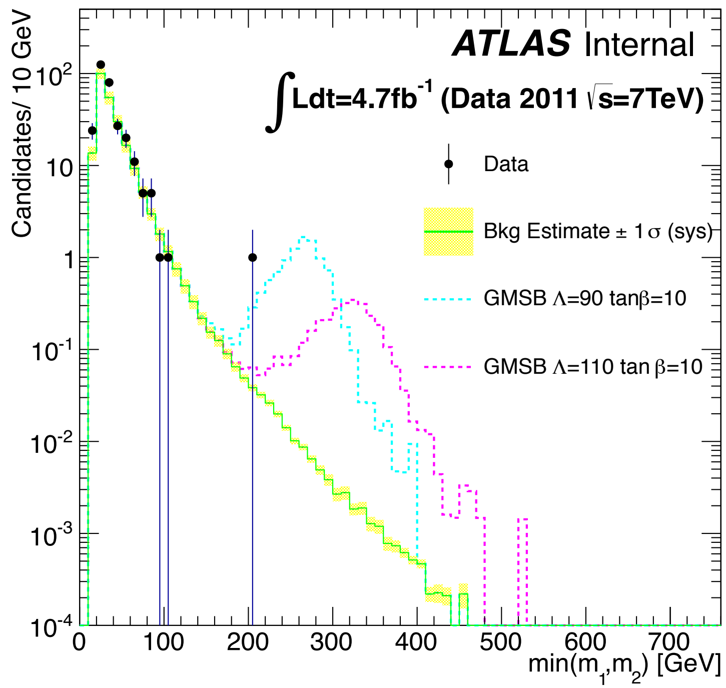
AMSB models: $\tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^{0}\ \pi^{\pm}$

Signal: high pT isolated tracks ≤ 5 hits in TRT

Exclude: m(chargino) < 90 GeV, 0.2< τ < 90 ns
m(chargino)< 118 GeV 1< τ < 2 ns

ATLAS-CONF-2012-034

Very long lifetime: SUSY particle leaves detector - look for slow tracks



Signal: high mass from time-of-flight

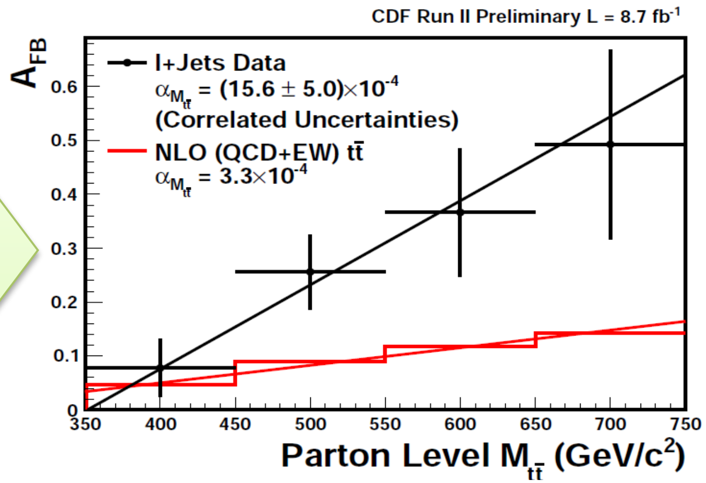
Exclude:
- stable sleptons < 297 GeV
- staus (GMSB) <310 GeV

ATLAS-CONF-2012-075

Is SUSY hidden by RPV or GMSB?

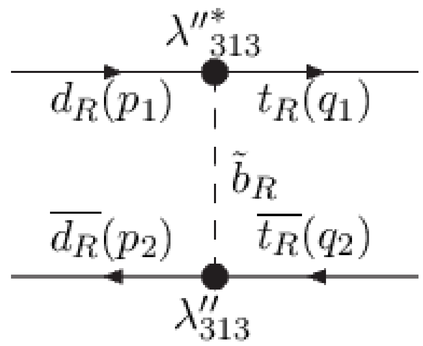
- Missing energy-based searches rely on neutral light LSP prediction. If R-parity violated, we can evade these limits. (see eg arxiv:1110.6670)
- Expect prompt decays of LSP, or long-lived heavy particle signatures.

A clue?



Tevatron top forward backward asymmetry

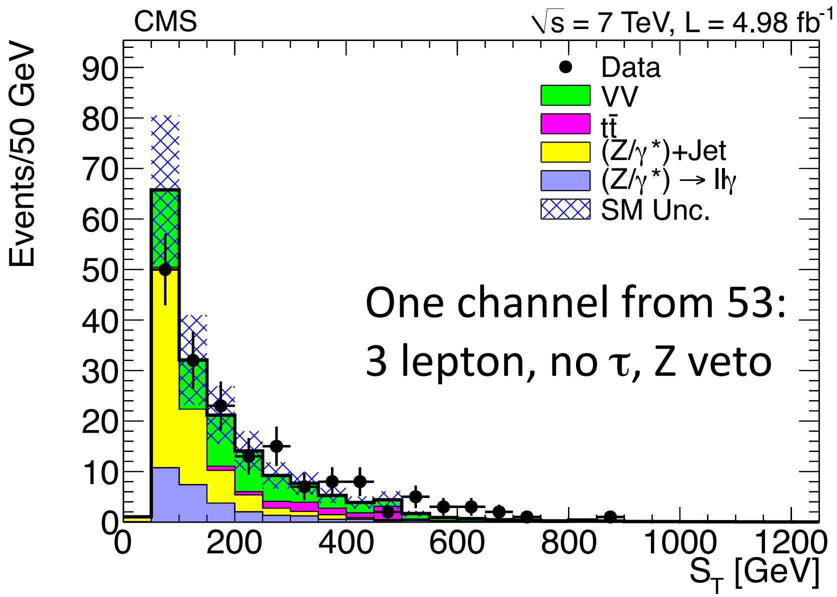
Maybe…



Arxiv:1205.5170

CMS multi-lepton search

Sensitive to RPC and RPV, and gravitino and neutralino LSP

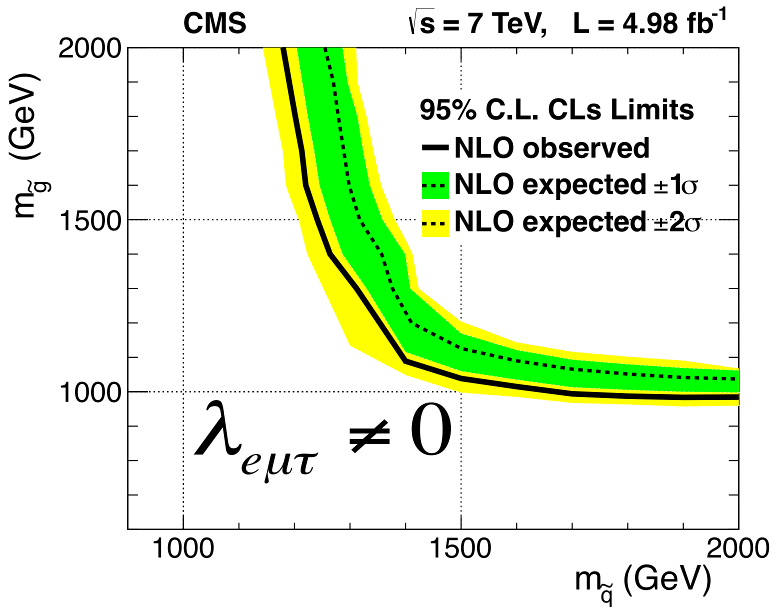


One channel from 53:
3 lepton, no τ, Z veto

$$S_T = H_T + E_T^{Miss} + \sum_{Leptons} p_T$$

RPV events have less missing energy: LSP can decay to SM particles.

Look for RPV couplings giving prompt decays (<100μm)



$$\lambda_{e\mu\tau} \neq 0$$

Limit above on leptonic RPV scenario
Analysis also sensitive to many other scenarios:

GMSB example

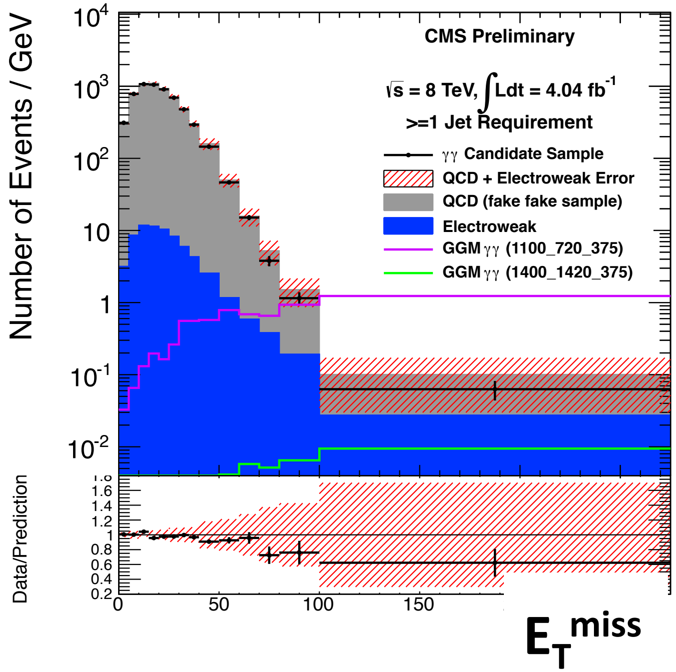
$$\tilde{g}, \tilde{q} \rightarrow \tilde{\chi}_1^0 + X$$
$$\tilde{\chi}_1^0 \rightarrow \tilde{l}\ l$$
$$\tilde{l} \rightarrow l\ \tilde{G}$$

arXiv:1204.5341

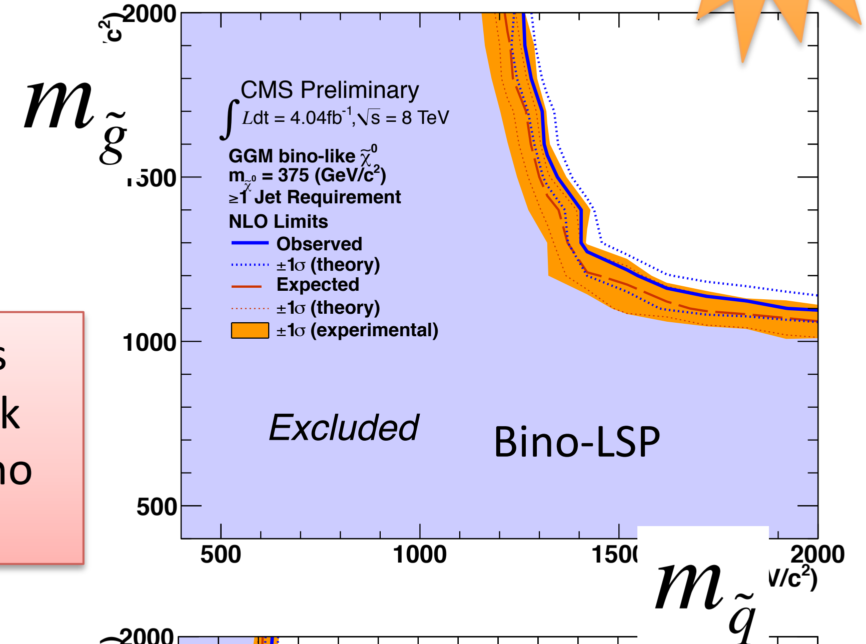
Is SUSY disguised in GGM? CMS $\gamma\gamma$

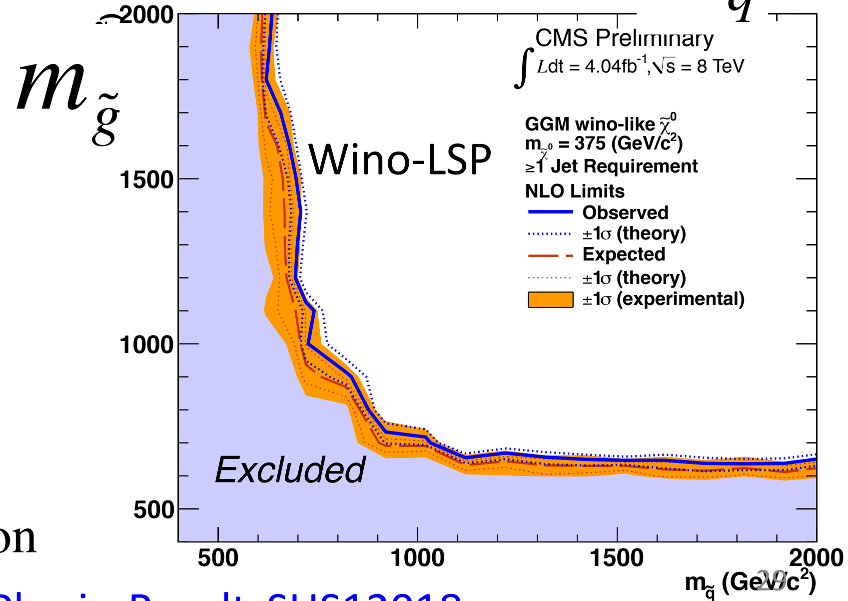
8TeV

General Gauge Mediation scenario. Look for $\gamma\gamma$+jet+E_T^{miss}



Set limits on squark and gluino masses





Exclusion is model dependent: in Wino-LSP scenario, chargino decays without photons suppress signal

$\tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^0 + X \qquad \tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$ Photon

$\tilde{\chi}_1^{\pm} \rightarrow W + X \qquad M(\tilde{\chi}_1^{\pm}) \approx M(\tilde{\chi}_1^0)$ No photon

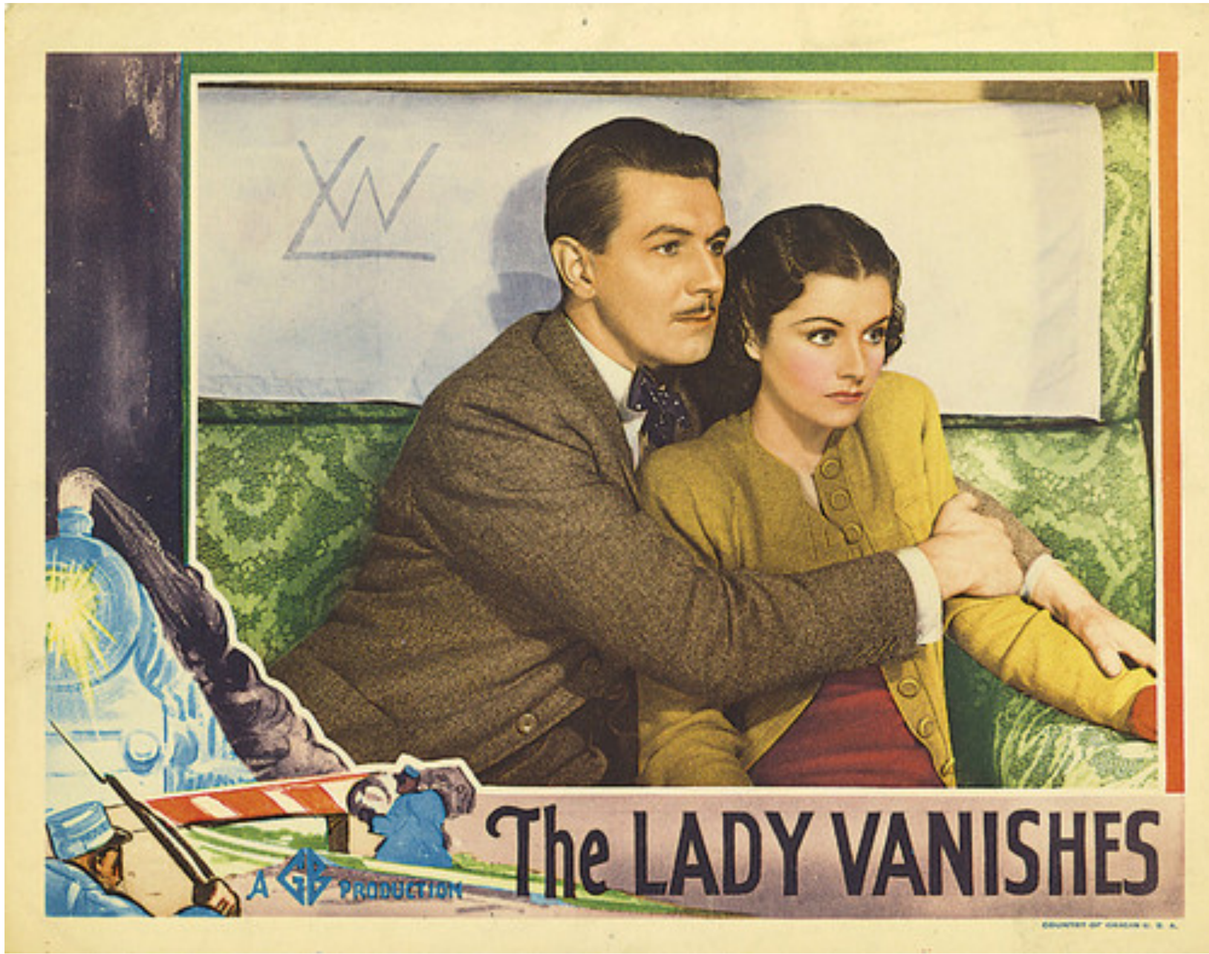
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS12018

Is SUSY Dead?

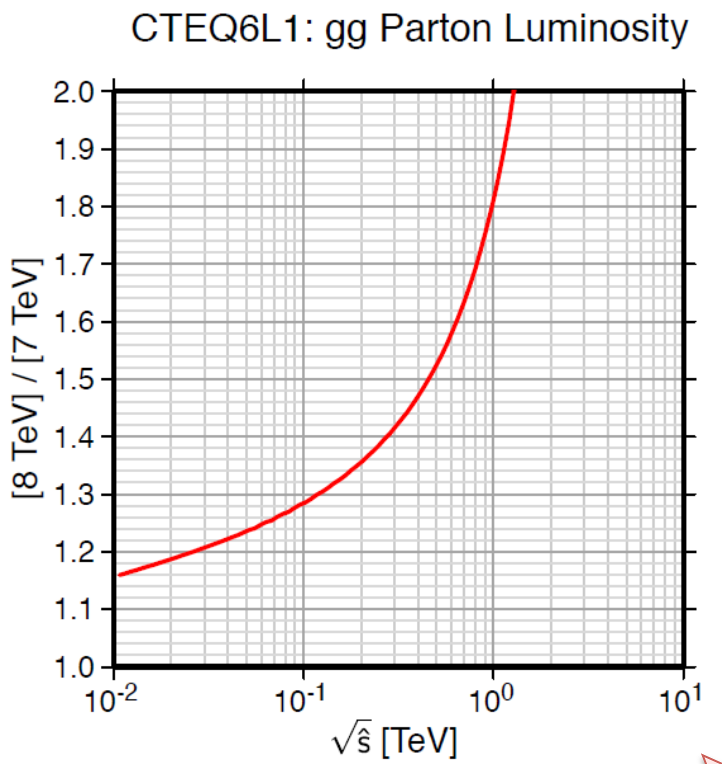
Is SUSY Dead?

- Under attack from all sides, but not dead yet.
- The searches leave little room for SUSY inside the reach of the existing data.
- But interpretations within SUSY models rely on many simplifying assumptions, and so care must be taken when making use of the limit plots
- Plausible “natural” scenarios still not ruled out: stop and/or RPV scenarios have few constraints.
- There is no reason to give up hope of finding SUSY at the LHC.

Maybe a happy ending….?

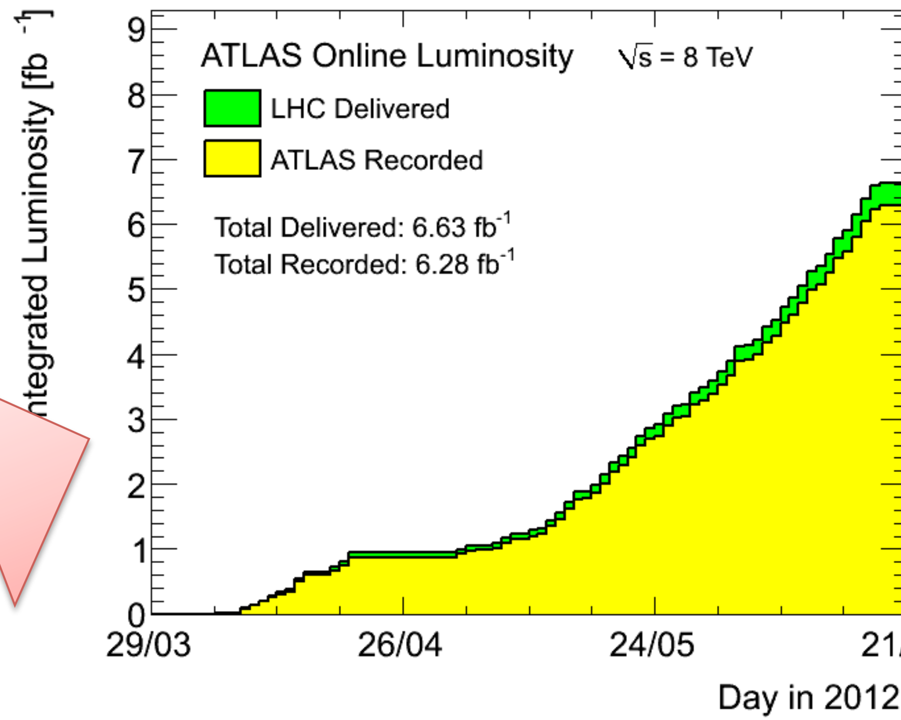


Maybe a happy ending....?

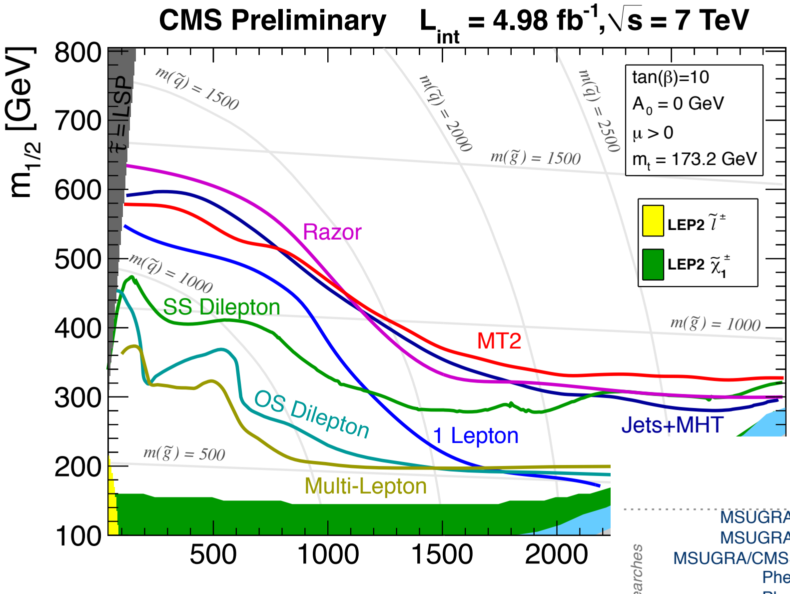


- 2012 data accumulating now, more reach.
- Many more results later this year...

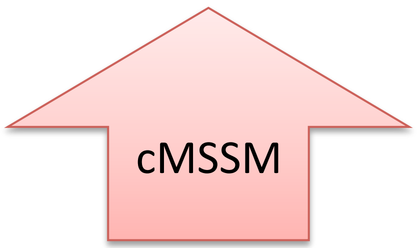
Thanks to the LHC team!



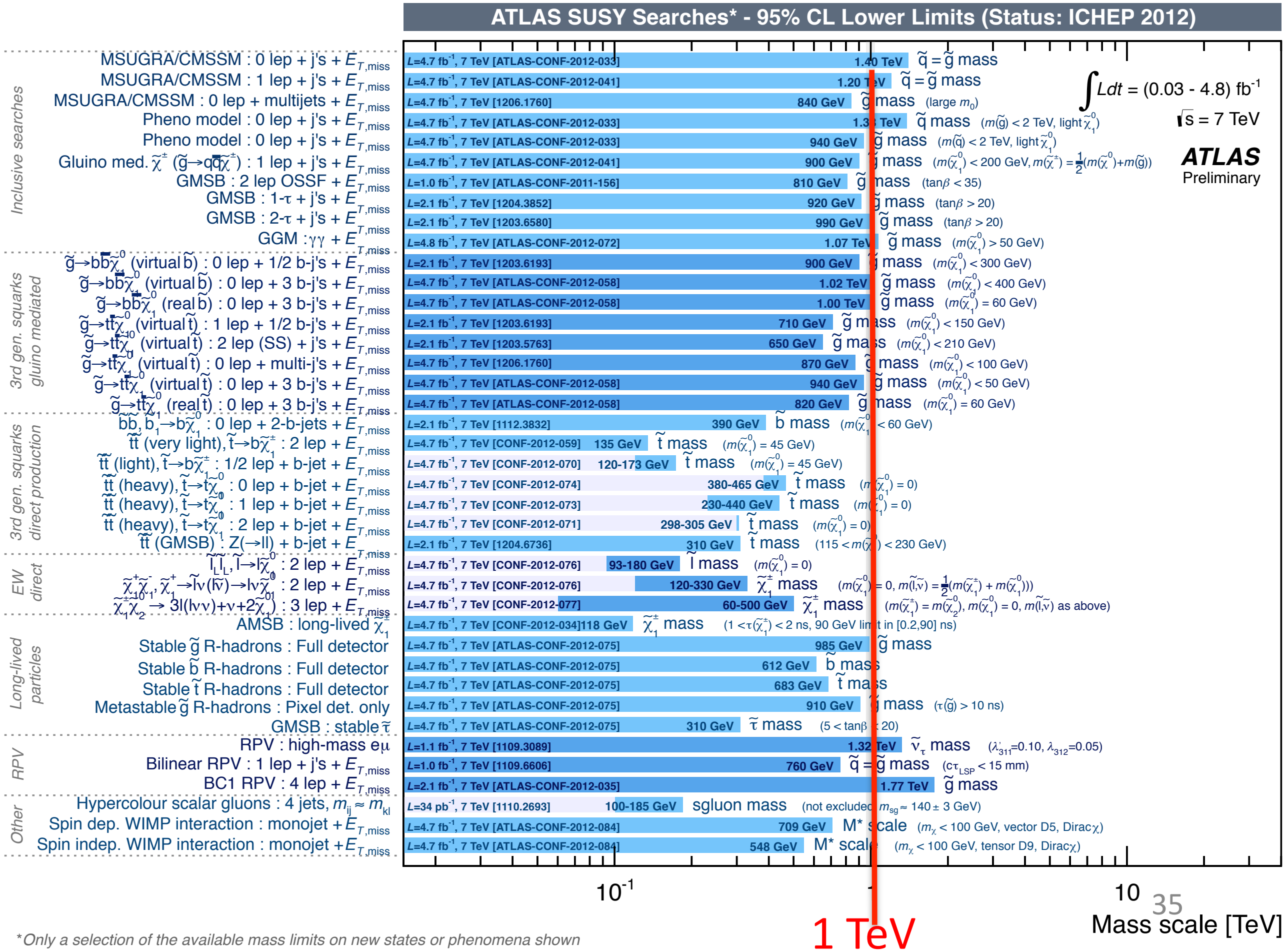
The lady is found alive and well in the final scene…



Both experiments provide nice search summaries

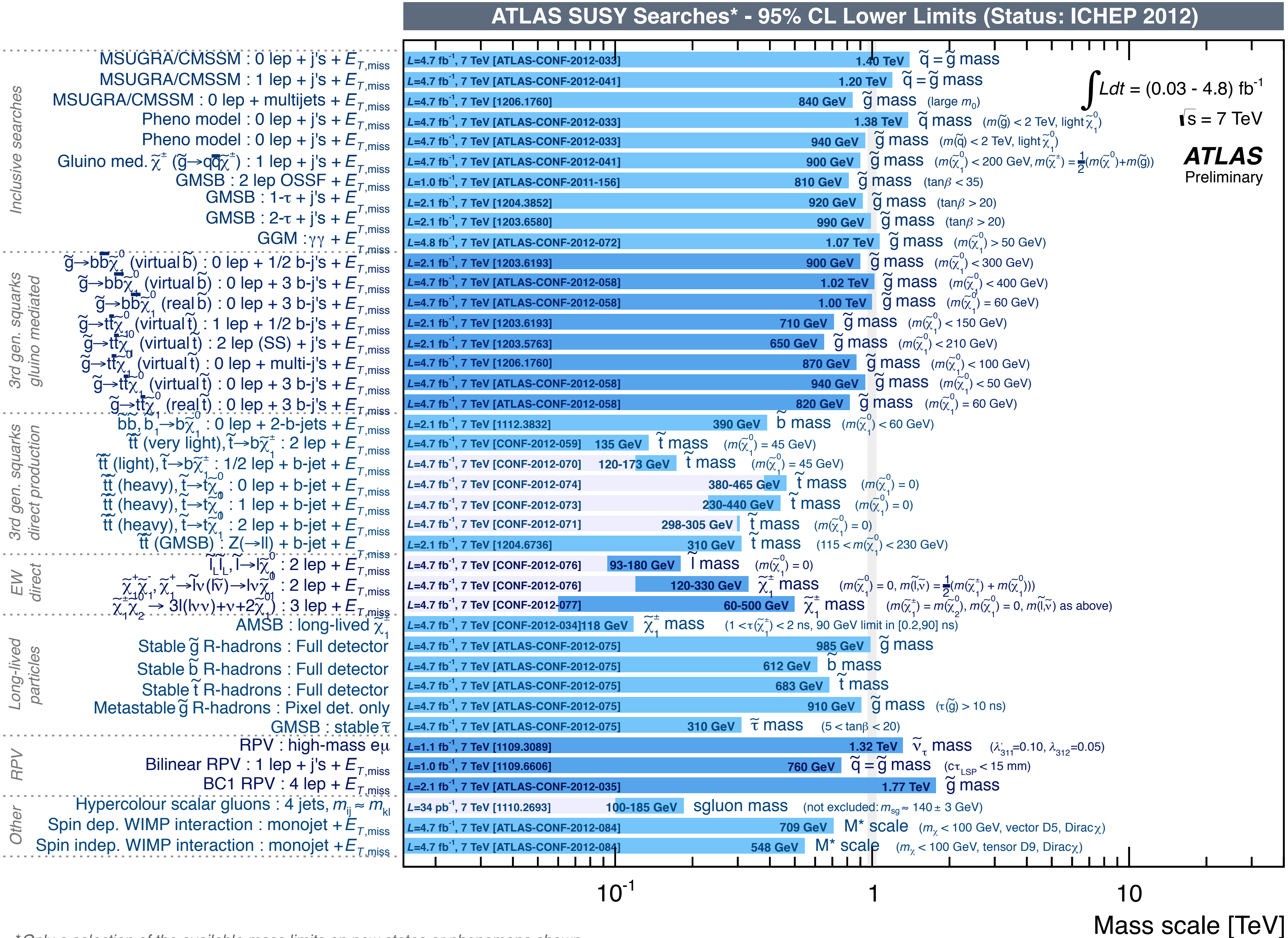


Larger versions in backup slides



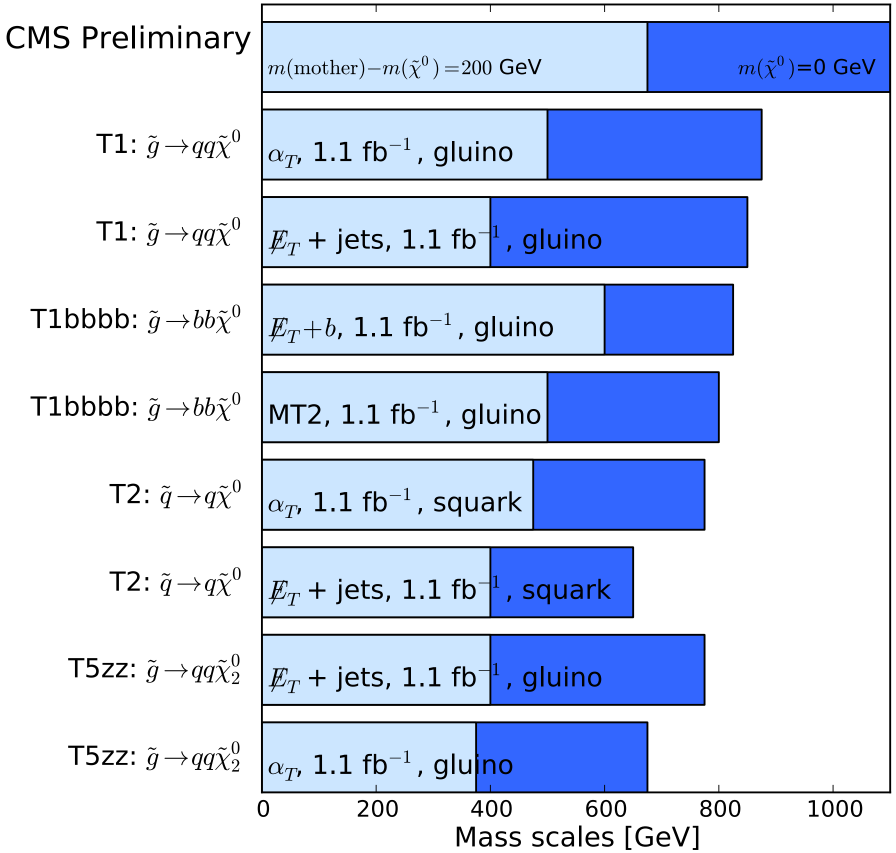

MARGARET
LOCKWOOD
MICHAEL
REDGRAVE
THE LADY VANISHES
PAUL LUKAS
DAME MAY WHITTY

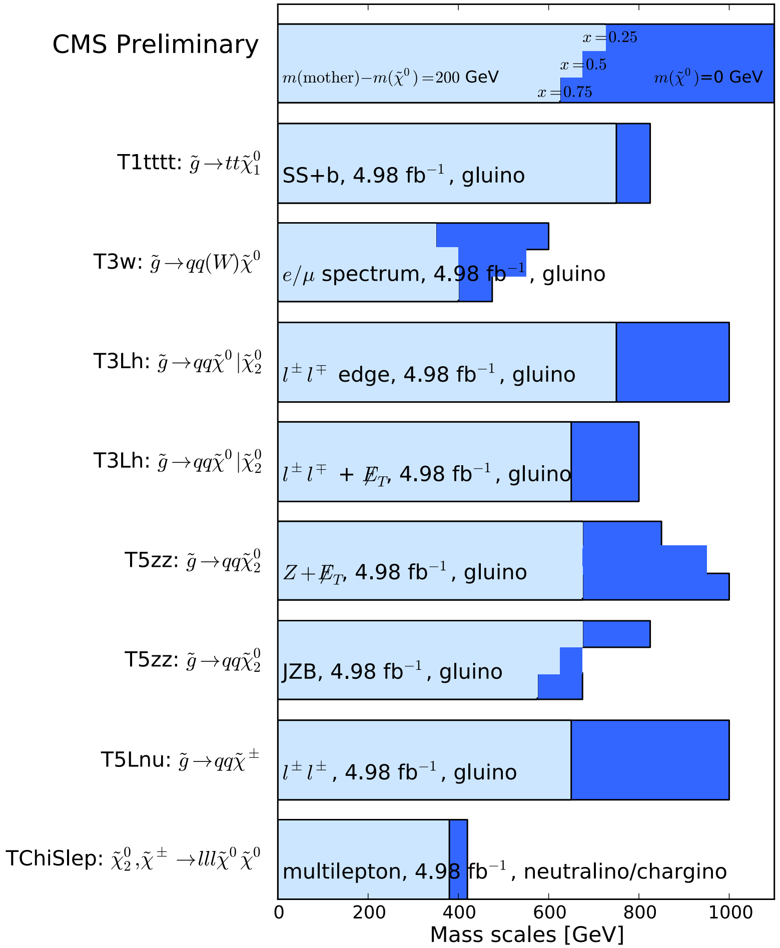
Backups



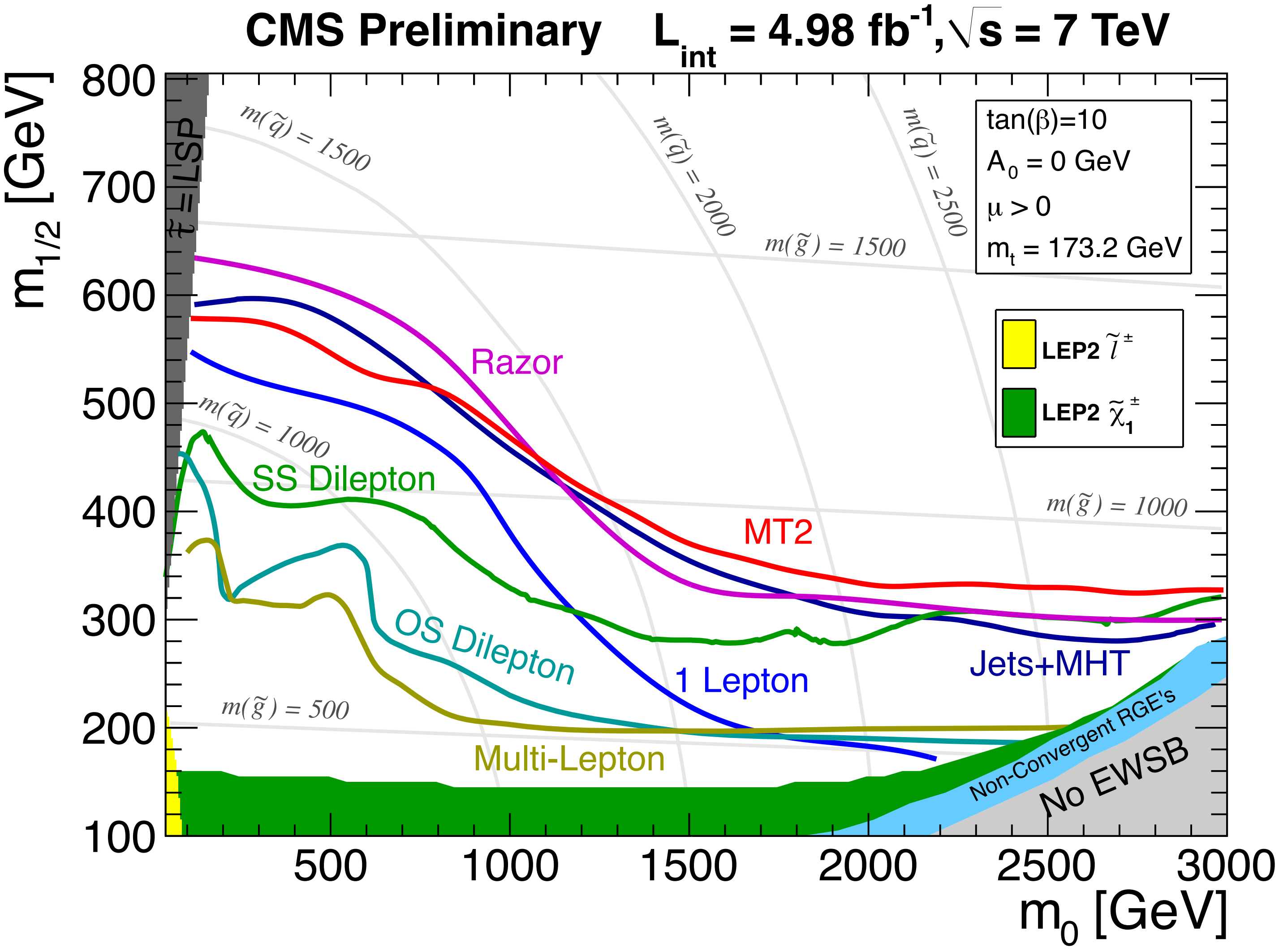
*Only a selection of the available mass limits on new states or phenomena shown

CMS results summary



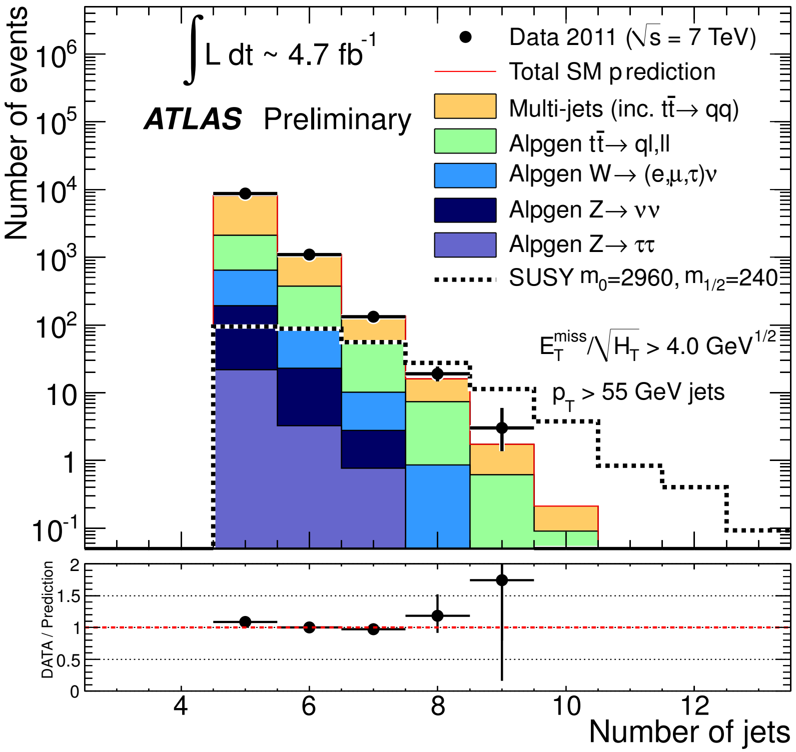


CMS CMSSSM summary

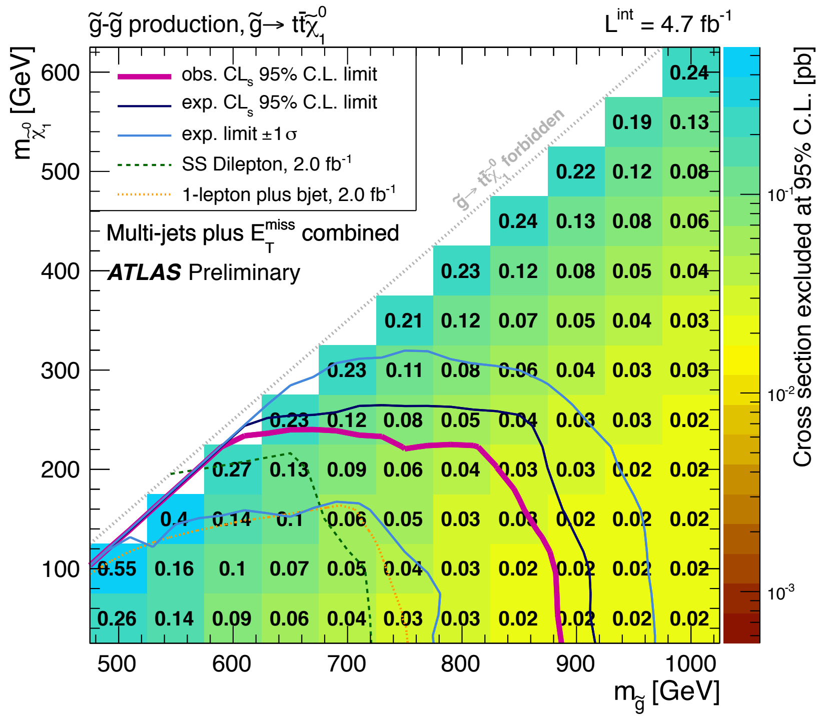


ATLAS multi-jet search

Look at high jet multiplicities, softer jets



Exclude cross-sections ~20fb (10x higher than 0-lepton), but signal would be invisible in standard search

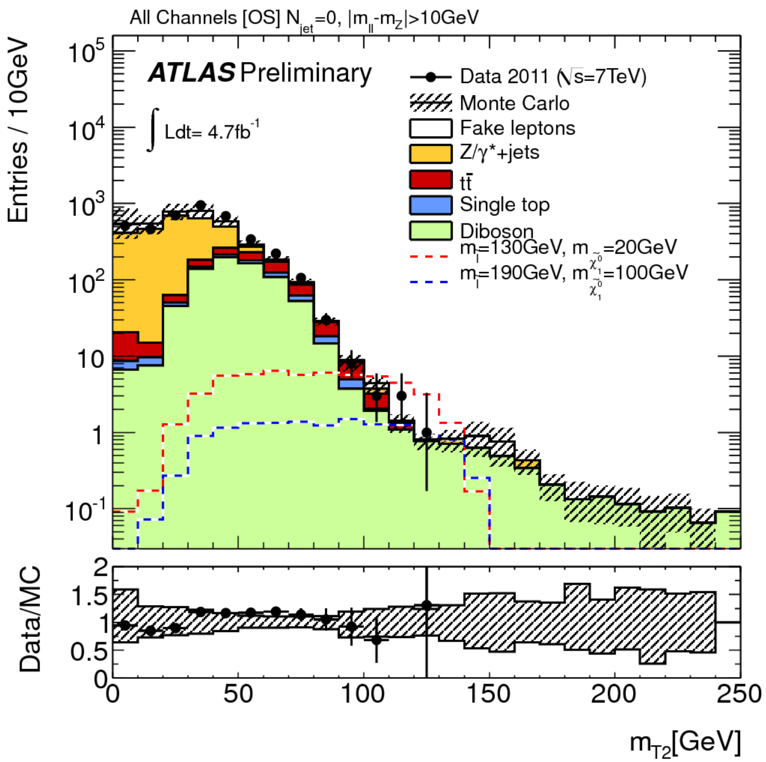


ATLAS-CONF-2012-037

For simple model with $\tilde{g} + \tilde{g} \to \left(t + \bar{t} + \tilde{\chi}_1^0\right) + \left(t + \bar{t} + \tilde{\chi}_1^0\right)$ exclude m_{gl}< 880 GeV

ATLAS- direct slepton/chargino production

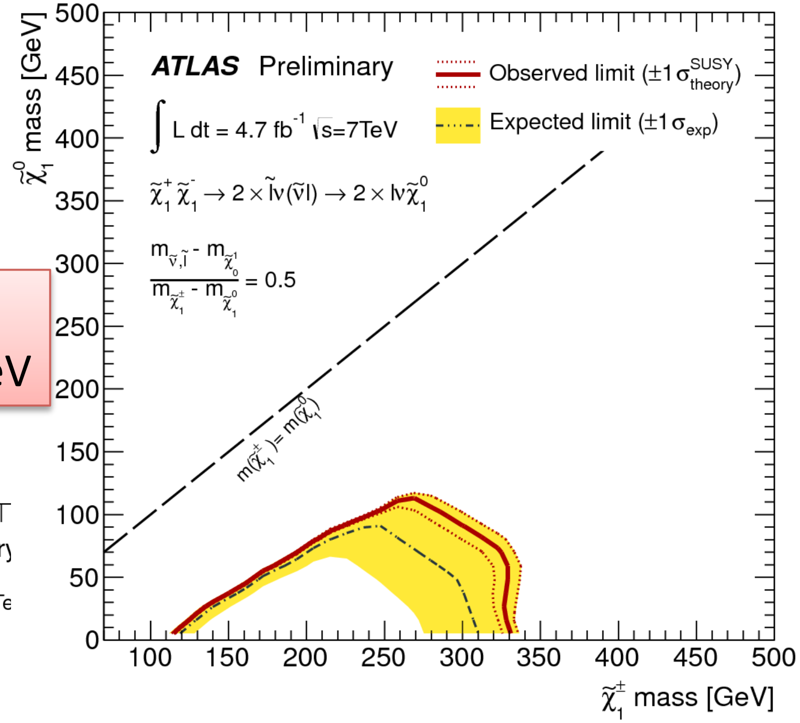
Select 2 leptons and E_T^{miss}. Use m_{T2} variable for pair production with semi-invisible decays

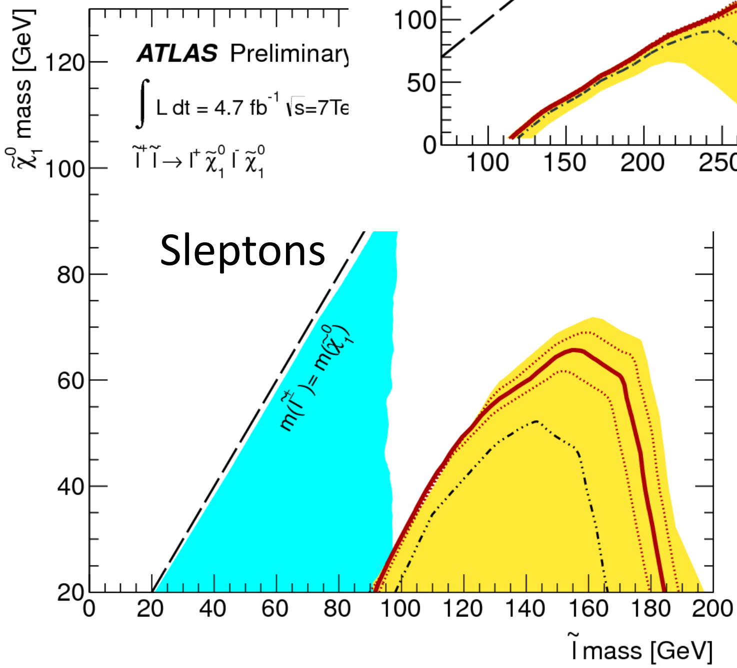


Sensitivity to weak production processes still limited, due to lower cross-section.

Best limit on charginos

No constraints for M_{LSP}>100 GeV





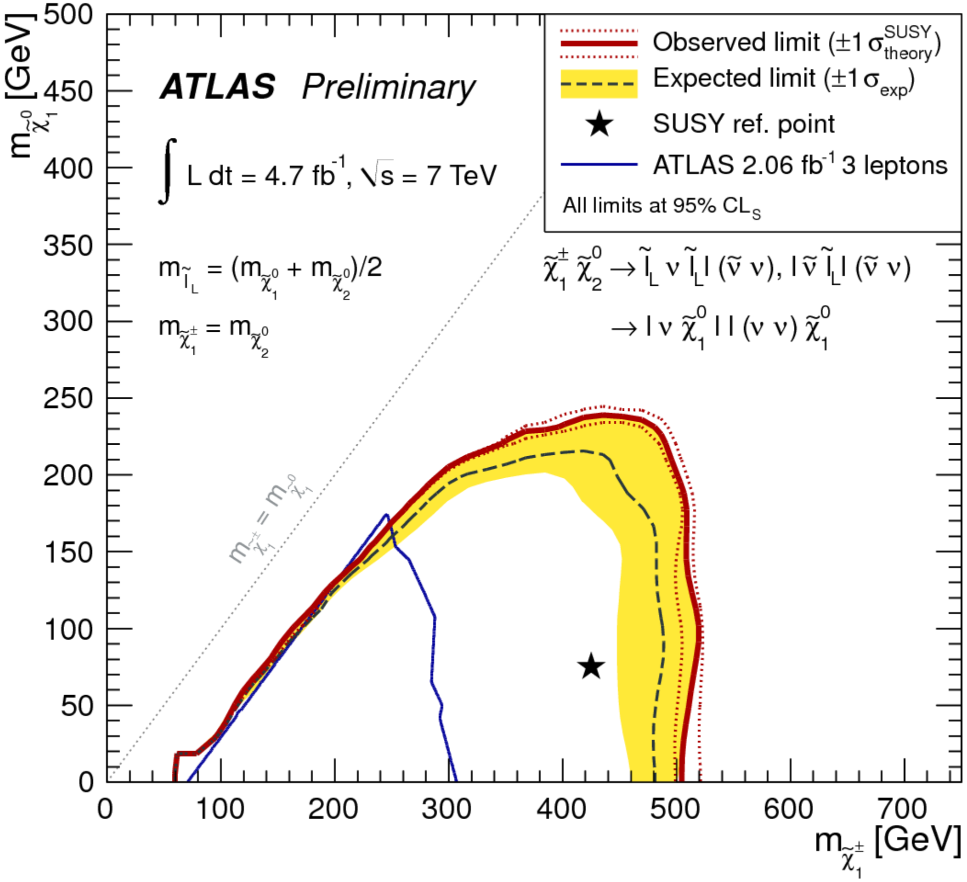
ATLAS-CONF-2012-076

ATLAS direct chargino/gaugino search

Select 3 leptons and E_T^{miss}.

- Split into Z-enriched and Z-depleted regions
- High p_T lepton selection to enhance signals with large mass splittings
- Simplified model: degenerate wino-type charginos/neutralinos (apart from bino LSP)
- Constraint >200 GeV with model assumptions.

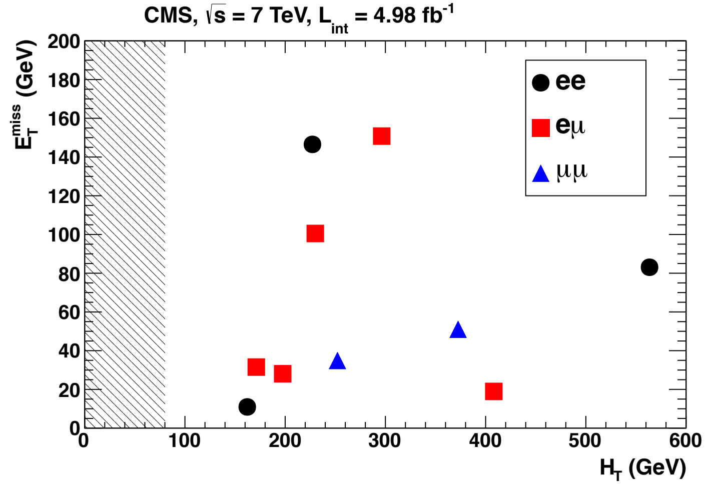
Signal expected from chargino cascade decays in simplified model

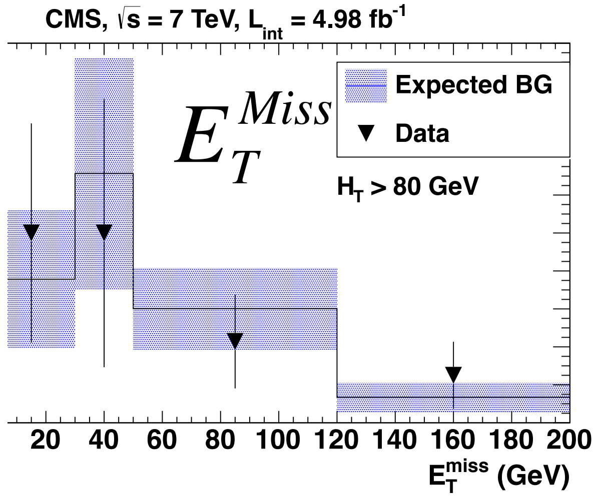


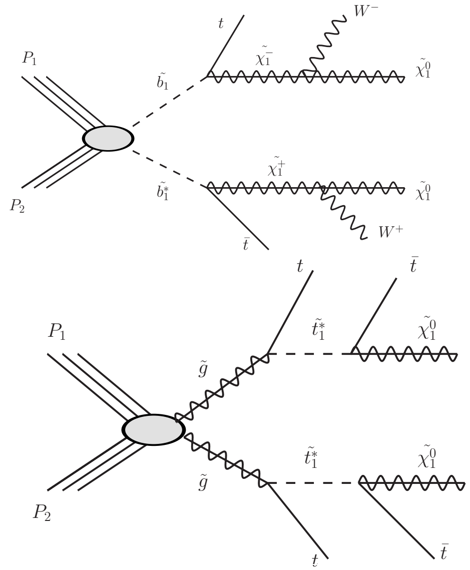
CMS SS-dilepton and >=2 b jets 7 TeV

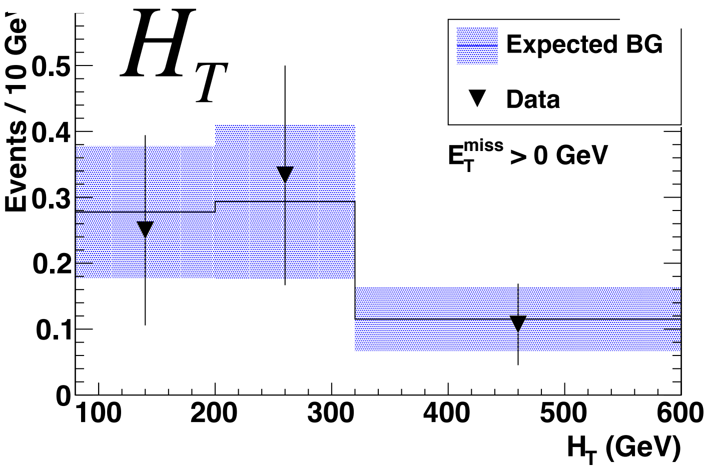
Counting experiment in H_T/ E_T^{Miss} plane: 10 events observed

Sensitive to 3rd generation squarks: gluino mediated, or direct prodution

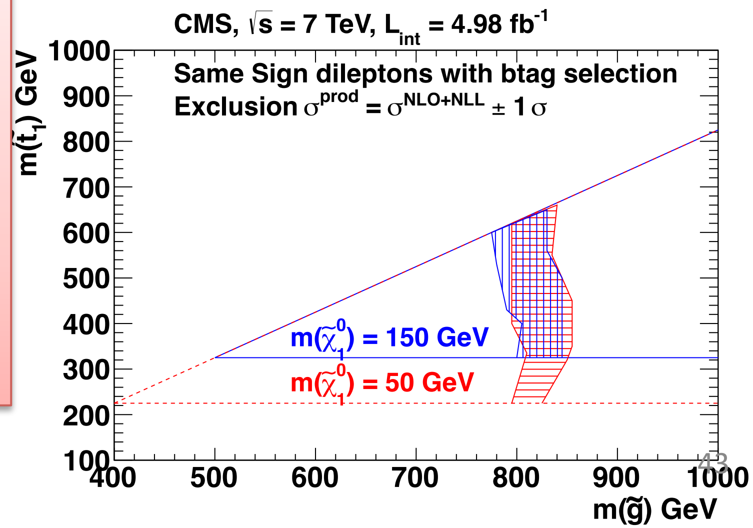








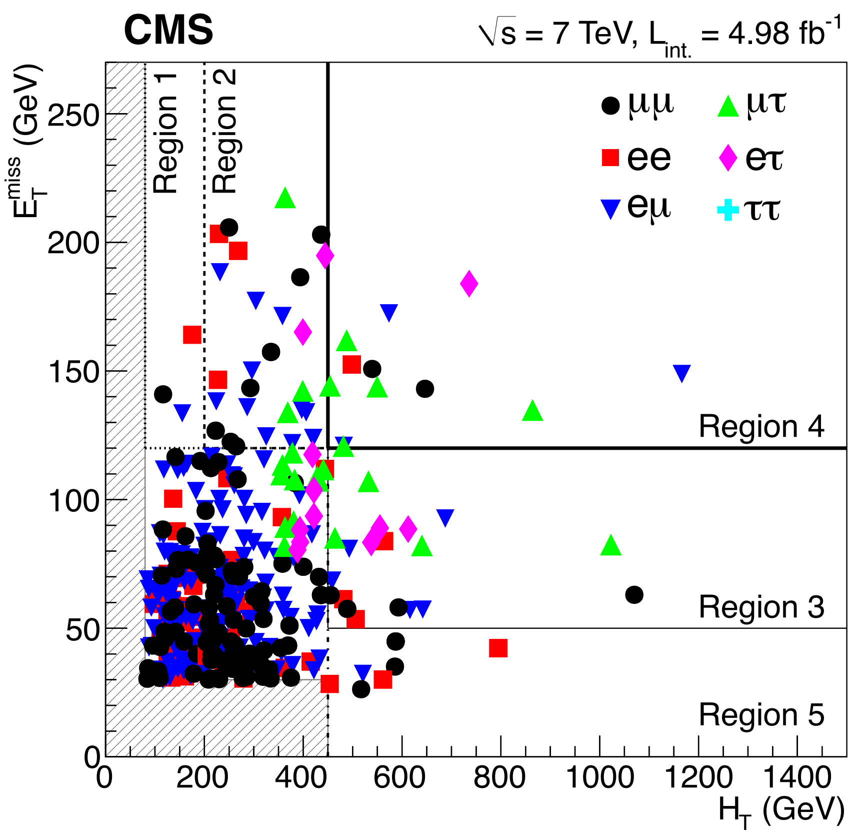
Exclusions for various BSM models. Limits in stop/gluino plane up to m(stop)>600 GeV



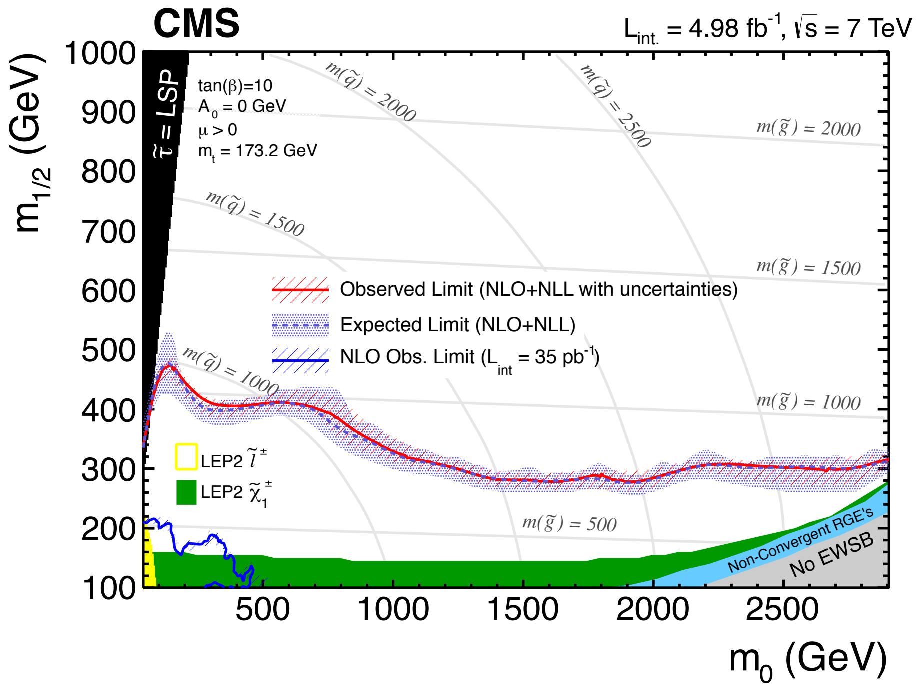
CMS SS-dilepton search: $\tilde{l}, \tilde{\chi}^{\pm}$

Include e, μ, τ.

Counting experiment in H_T, E_T^{miss} plane



Interpret in CMSSM:

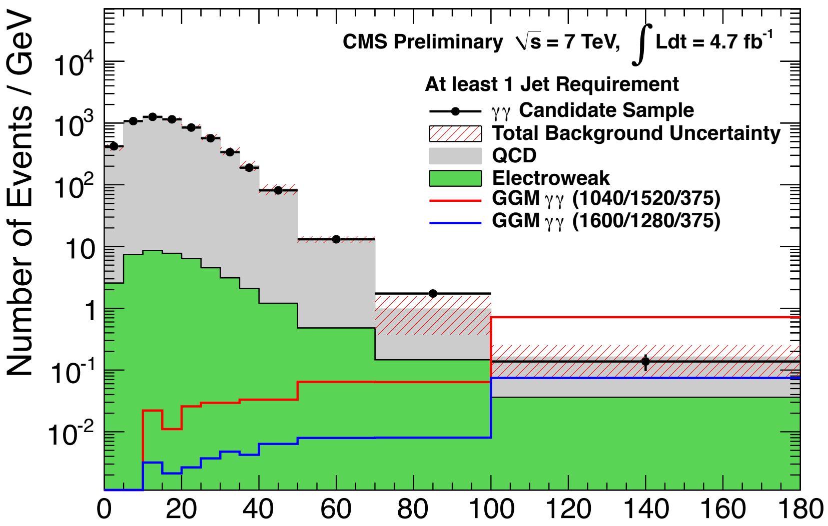


Exclude 6.2-16.9 events from new physics
Implies m(chargino)>200 GeV in CMSSM scenario

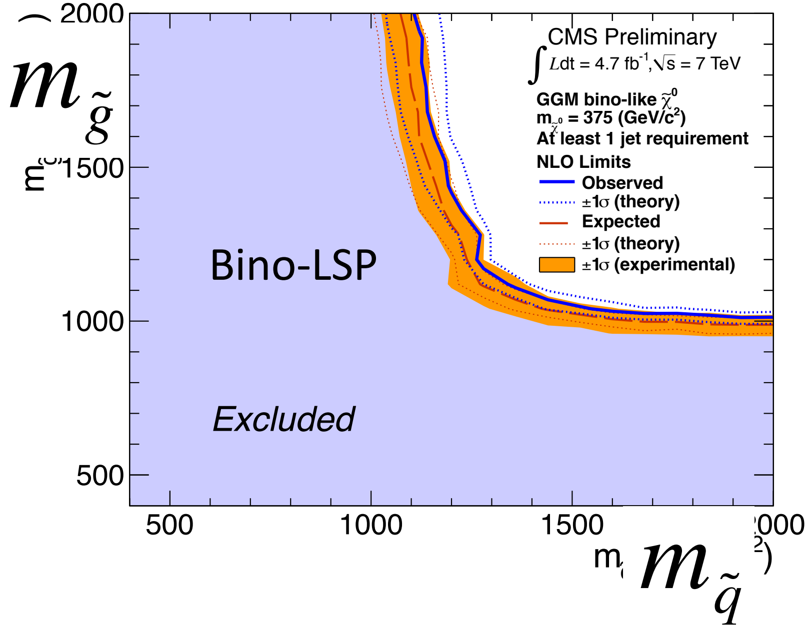
arXiv:1205.6615

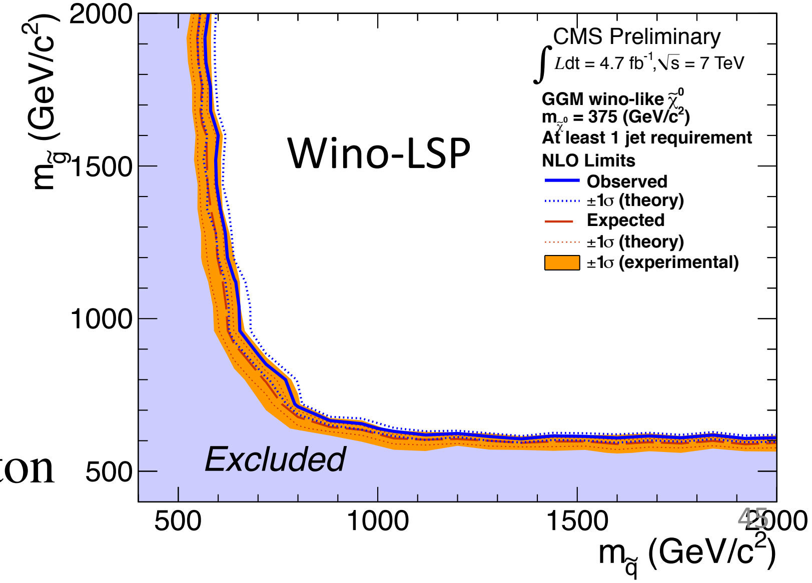
Is SUSY hidden by GGM? CMS γγ 7 TeV

General Gauge Mediation scenario. Look for γγ+jet+E_T^{miss}



E_t^{miss} in γγ events





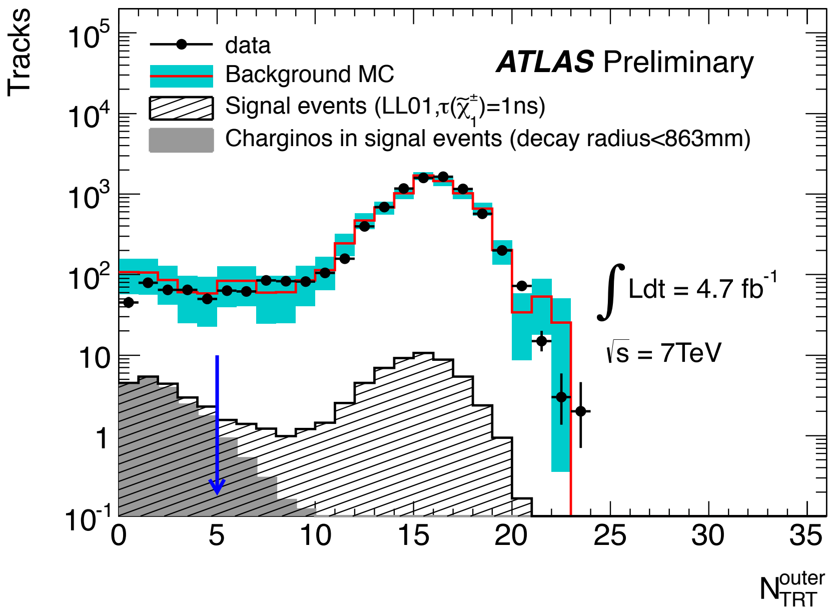
Exclusion is model dependent: in Wino-LSP scenario, chargino decays without photons suppress signal

$\tilde{\chi}_1^{\pm} \to \tilde{\chi}_1^0 + X \qquad \tilde{\chi}_1^0 \to \gamma\, \tilde{G}$ Photon

$\tilde{\chi}_1^{\pm} \to W + X \qquad M(\tilde{\chi}_1^{\pm}) \approx M(\tilde{\chi}_1^0)$ No photon

ATLAS – Disappearing track

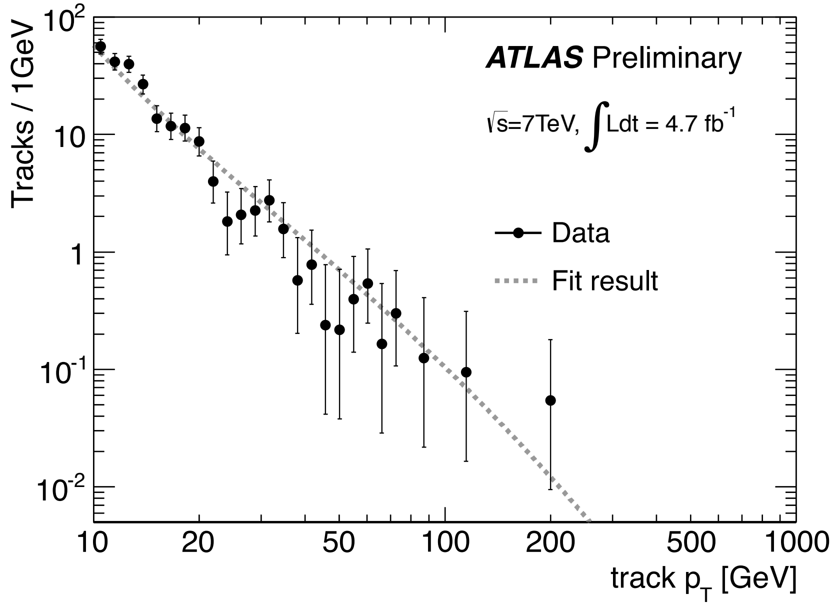
AMSB models produce almost degenerate chargino and LSP. Chargino long-lived, decays to LSP+ soft pion



Look for high pT isolated tracks which disappear leaving <=5 hits in TRT

ATLAS-CONF-2012-034

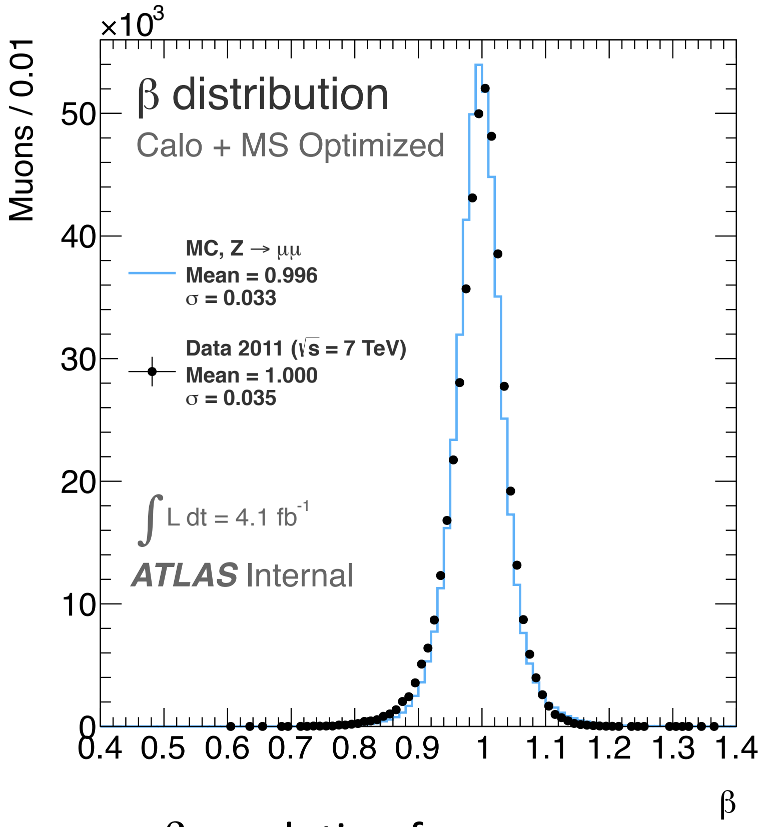
Background from interacting tracks and bad reconstruction. Fit background + signal model. Best fit has zero signal.



Constraints on chargino mass and lifetime:
Exclude: m < 90 GeV, 0.2< τ < 90 ns
m< 118 GeV 1< τ < 2 ns

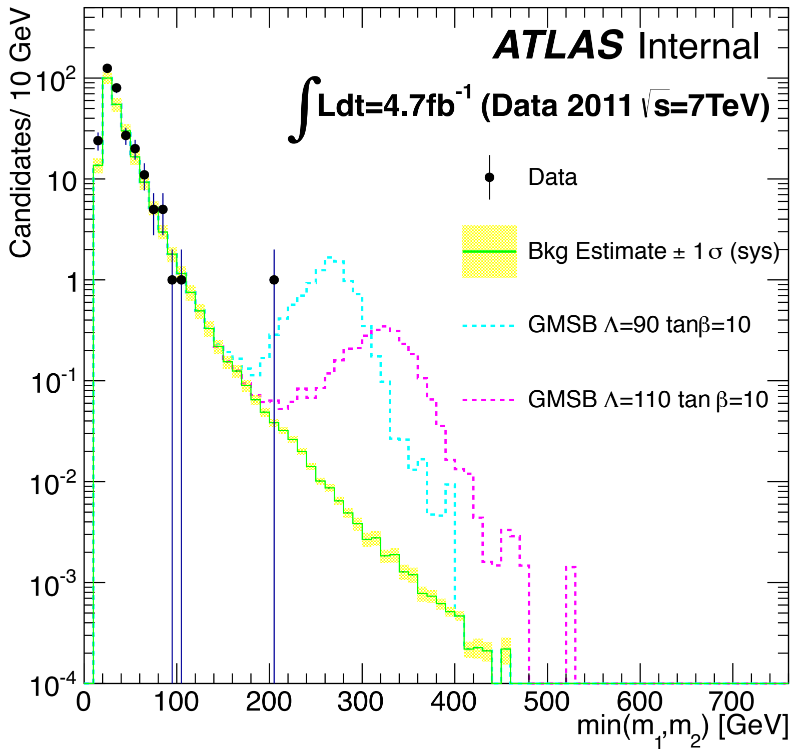
ATLAS – long lived particles

Heavy stable particles reach calo/ muon system with a delay depending on their mass. ATLAS has excellent time resolution: measure β



β resolution from muons from Z decays

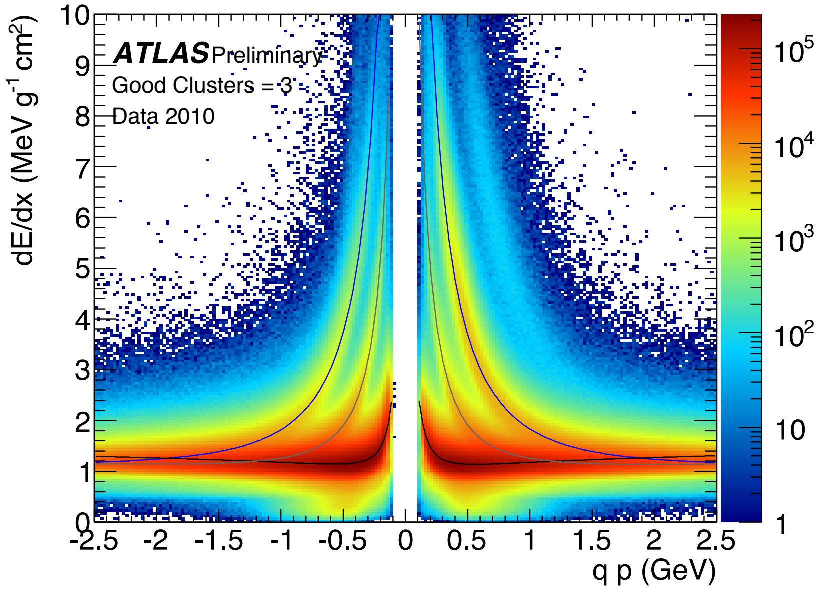
Trigger using muon system or ETmiss. Look for 2 tracks with low β using calo and muon system timing.



Exclude:
- stable sleptons < 297 GeV
- staus (GMSB) <310 GeV

ATLAS RPV: R-hadrons

Measure dE/dx and p to infer mass – use pixel ToT

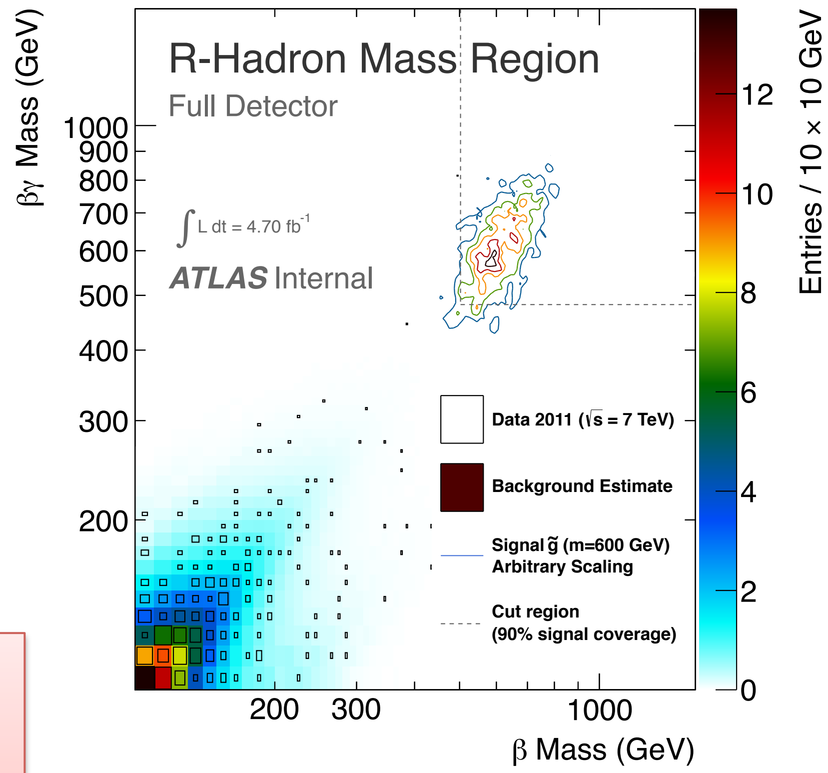


Each mass produces a different band for energy loss vs momentum.

Exclude:

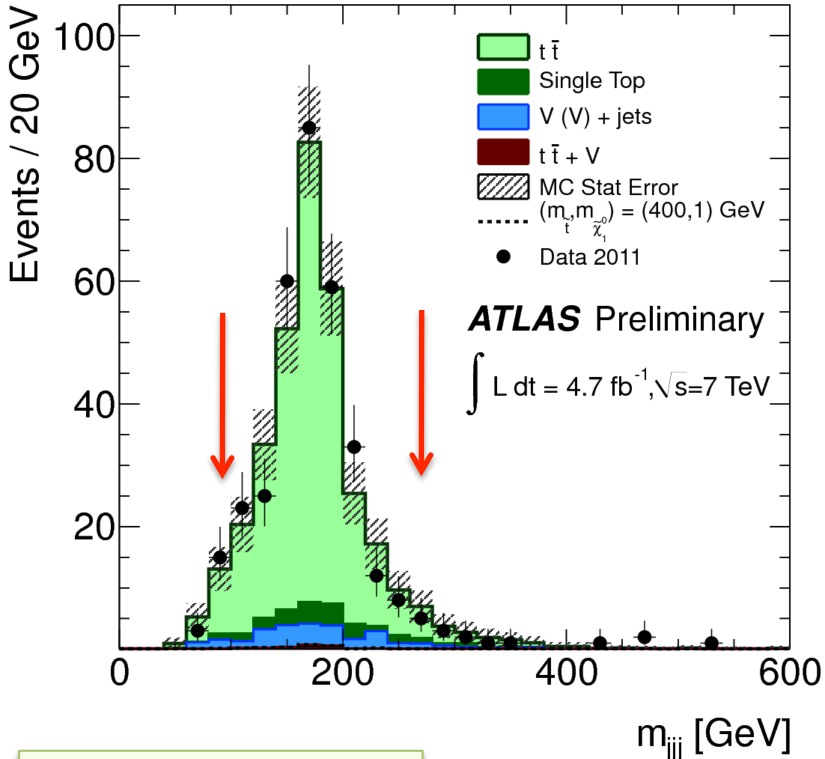
- generic R-hadrons < 985 GeV
- Stop-R-hadrons <683 GeV
- Sbottom-R-hadrons<612 GeV
- + model dependent limits

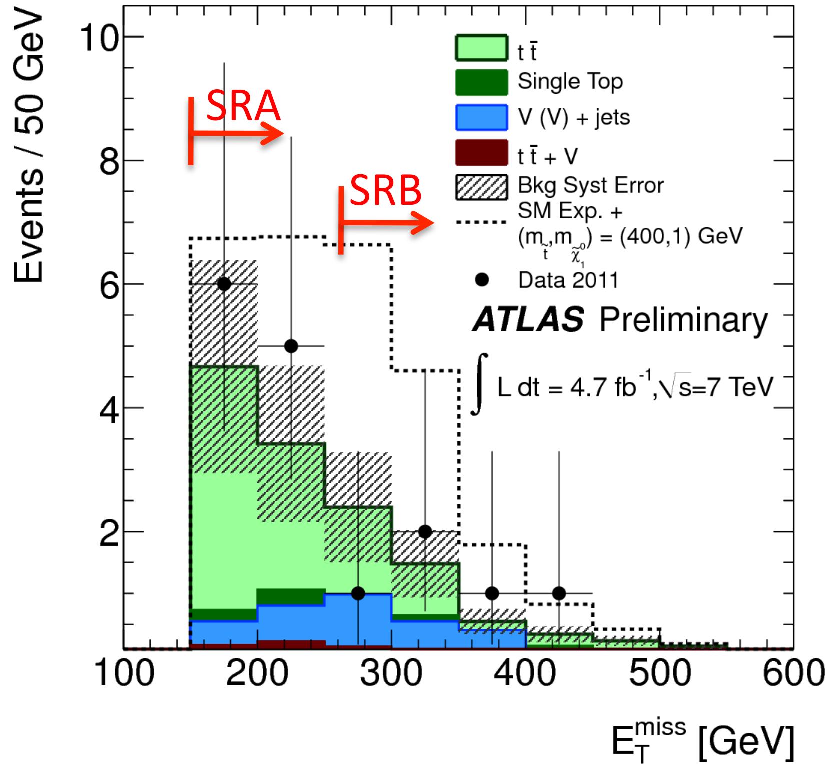
R-hadrons contain SUSY+SM objects. Behave like heavy mesons. Can change charge by interactions in detector.



ATLAS Direct Stop – 0 lepton

$\tilde{t}_1 \rightarrow t\,\tilde{\chi}_1^0 \rightarrow bjj\;\tilde{\chi}_1^0$





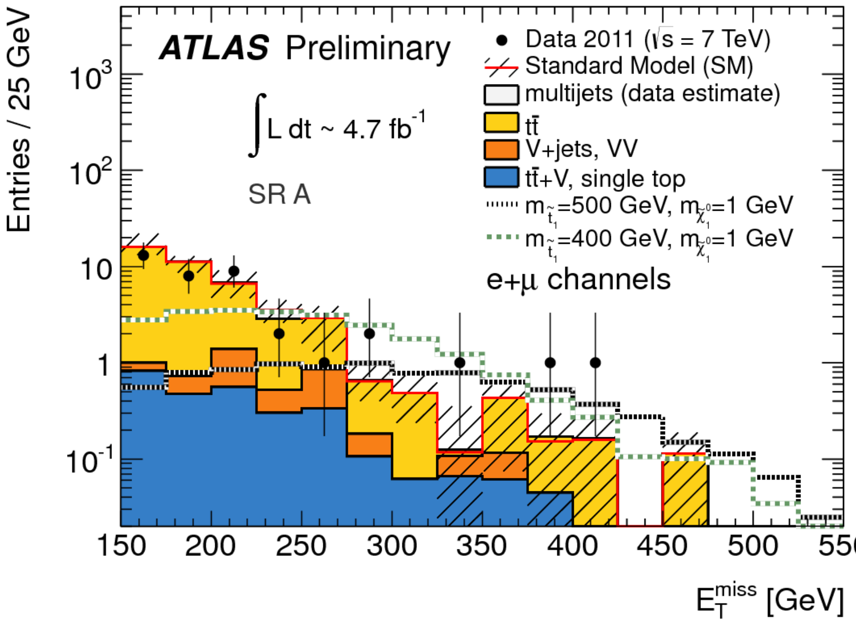
J1>130 GeV
J2-6>30 GeV
Etmiss > 150 GeV
No leptons
M_T(b,Etmiss)>M_t

Signal to noise much worse than inc. searches: optimise cuts to extract signal under large ttbar backgroun.
Require good match to top mass. Look for tt pairs in hadronic decays with Etmiss from LSP. Exclude region between 350<M(stop)<500 GeV for low LSP masses. No constraint for M(LSP)>100 GeV

ATLAS Direct Stop – 1 lepton

$$\tilde{t}_1 \rightarrow t\,\tilde{\chi}_1^0 \rightarrow Wb\,\tilde{\chi}_1^0$$

tt pairs with one semi-leptonic decay.
Stop decay to top + LSP



Regions	SR A	SR B	SR C	SR D	SR E
tt	36 ± 5	27 ± 4	11 ± 2	4.9 ± 1.3	1.3 ± 0.6
$tt + V$, single top	2.9 ± 0.7	2.5 ± 0.6	1.6 ± 0.3	0.9 ± 0.3	0.4 ± 0.1
V+jets, VV	2.5 ± 1.3	1.7 ± 0.8	0.4 ± 0.1	0.3 ± 0.1	0.1 ± 0.1
Multijet	$0.4^{+0.4}_{-0.4}$	$0.3^{+0.3}_{-0.3}$	$0.3^{+0.3}_{-0.3}$	$0.3^{+0.3}_{-0.3}$	$0.0^{+0.3}_{-0.0}$
Total background	42 ± 6	31 ± 4	13 ± 2	6.4 ± 1.4	1.8 ± 0.7
Signal benchmark 1 (2)	25.6 (8.8)	23.0 (8.1)	17.5 (6.9)	13.5 (6.2)	7.1 (4.5)
Observed events	38	25	15	8	5
p_0-values	0.5	0.5	0.32	0.24	0.015
Obs. (exp.) $N_{\text{beyond-SM}}$ <	15.1 (17.2)	10.1 (13.8)	10.8 (9.2)	8.4 (7.0)	8.2 (4.6)

Some sensitivity for
M(LSP) up to 150 GeV

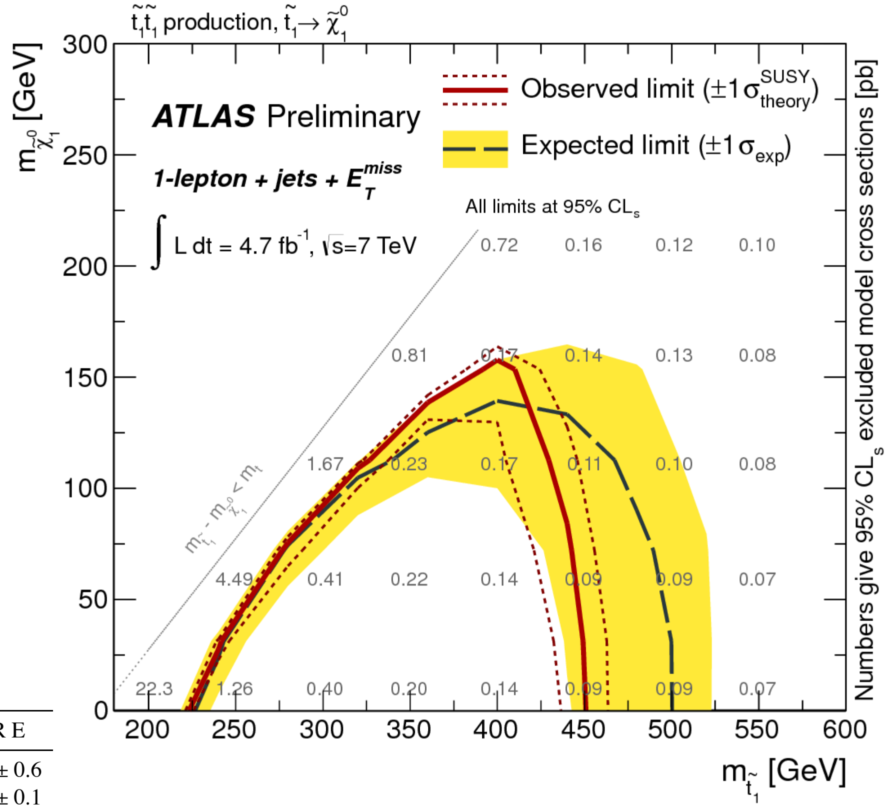


Table 1: Selection requirements defining the SR A - E.

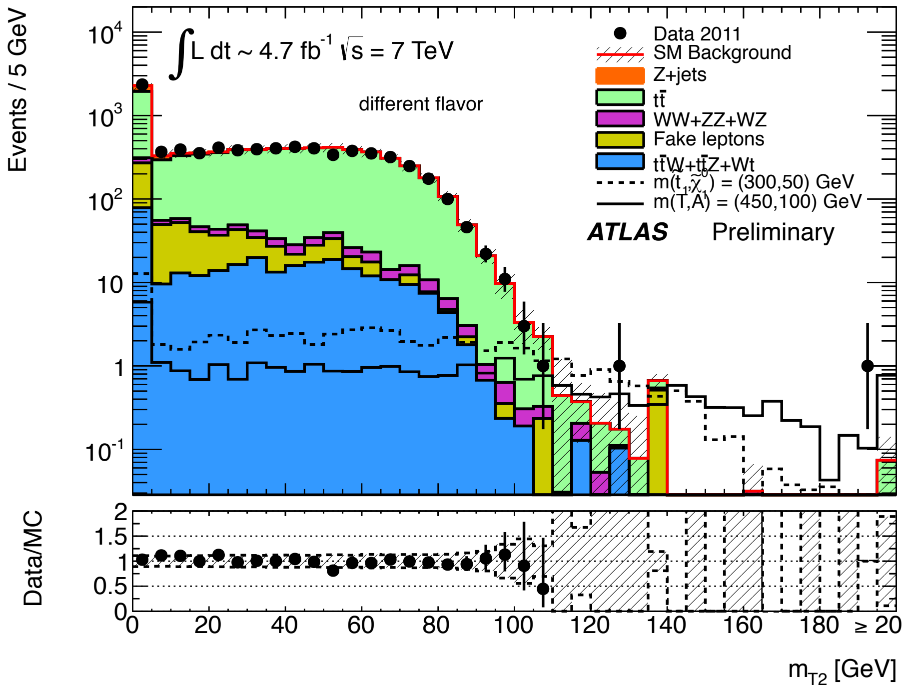
Requirement	SR A	SR B	SR C	SR D	SR E
E_T^{miss} [GeV] >	150	150	150	225	275
$E_T^{miss} / \sqrt{H_T}$ [GeV$^{1/2}$] >	7	9	11	11	11
m_T [GeV] >	120	120	120	130	140

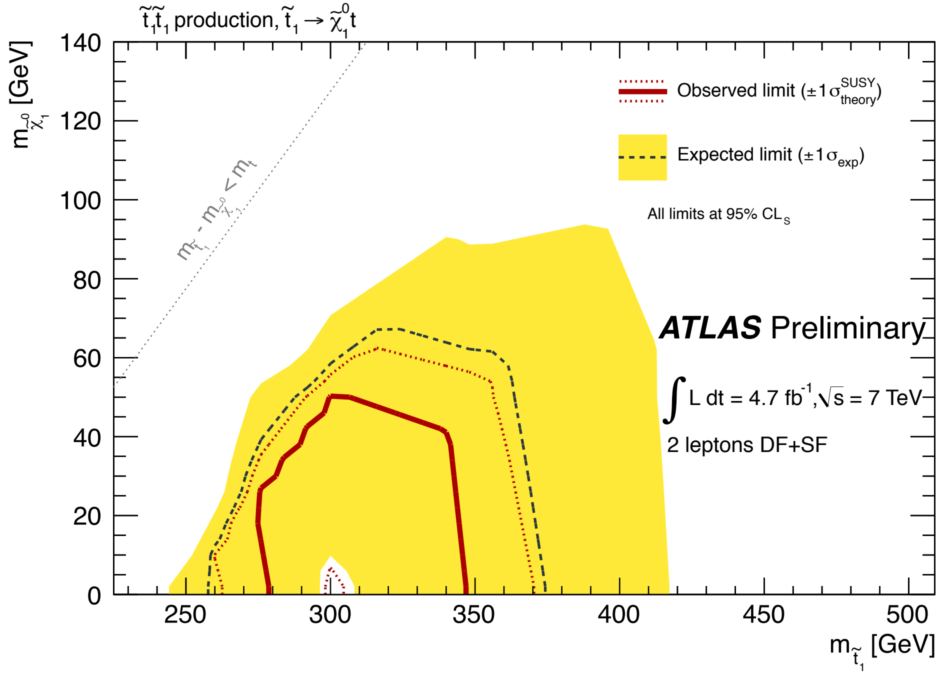
ATLAS Direct Stop – 2 lepton

$$\tilde{t}_1 \rightarrow t\,\tilde{\chi}_1^0 \rightarrow Wb\,\tilde{\chi}_1^0$$

2 semileptonic top decays – use MT2 as discriminating variable

Process	$t\bar{t}$ CR DF	$t\bar{t}$ CR SF
$t\bar{t}$	68 ± 11	39 ± 11
$t\bar{t}W + t\bar{t}Z$	0.37 ± 0.07	0.20 ± 0.05
Wt	2.7 ± 1.0	1.8 ± 0.6
$Z/\gamma^{\star}$+jets	-	3.5 ± 1.4
Fake leptons	0.4 ± 0.3	0.5 ± 1.6
Diboson	0.49 ± 0.14	0.10 ± 0.05
Total non-$t\bar{t}$	4.0 ± 1.5	6.1 ± 3.7
Total expected	72 ± 11	45 ± 12
Data	79	53

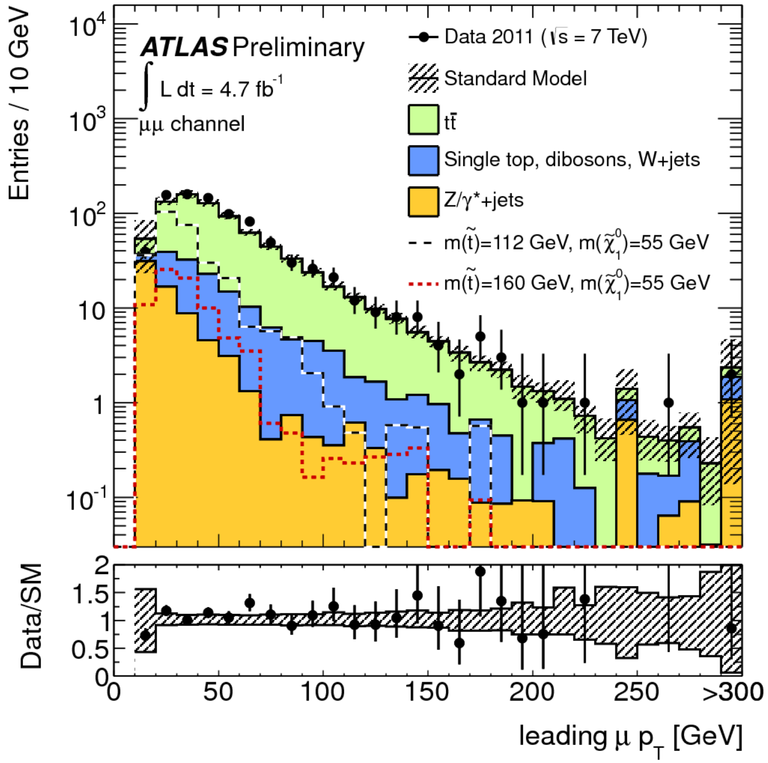


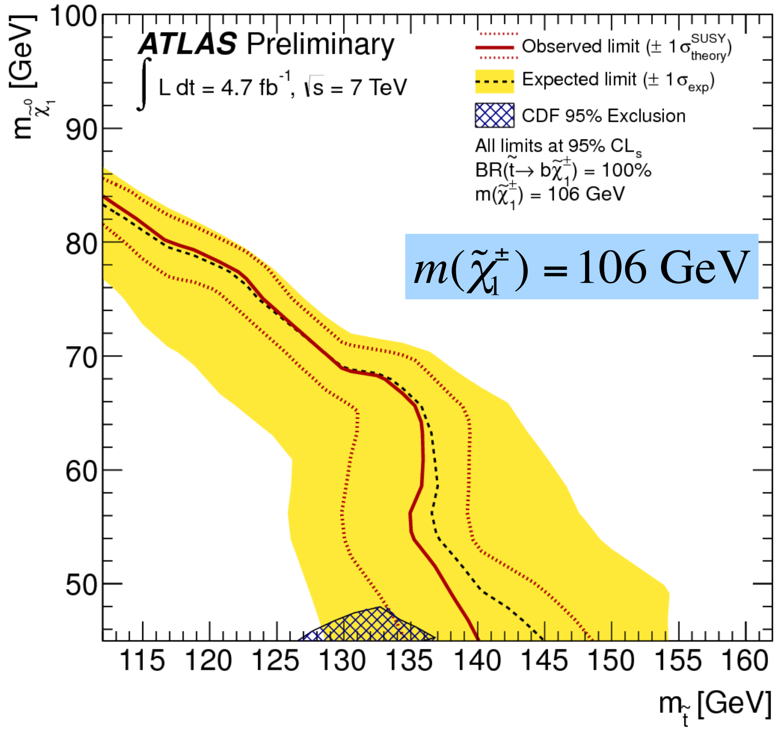


ATLAS light stop – 2 lepton

$m_t \gtrsim m_{\tilde{t}_1} > m_{\tilde{\chi}_1^\pm}$

$\tilde{t} \rightarrow b\tilde{\chi}_1^\pm \rightarrow bW^{(*)}\tilde{\chi}_1^0$





Total	440 ± 21 ± 43
Data	431
σ_{vis} (exp. limit) [fb]	22.0
σ_{vis} (obs. limit) [fb]	21.0
$m(\tilde{t}, \tilde{\chi}_1^0) = (112, 55)$ GeV	322 ± 13
$m(\tilde{t}, \tilde{\chi}_1^0) = (160, 55)$ GeV	76.6 ± 4.3

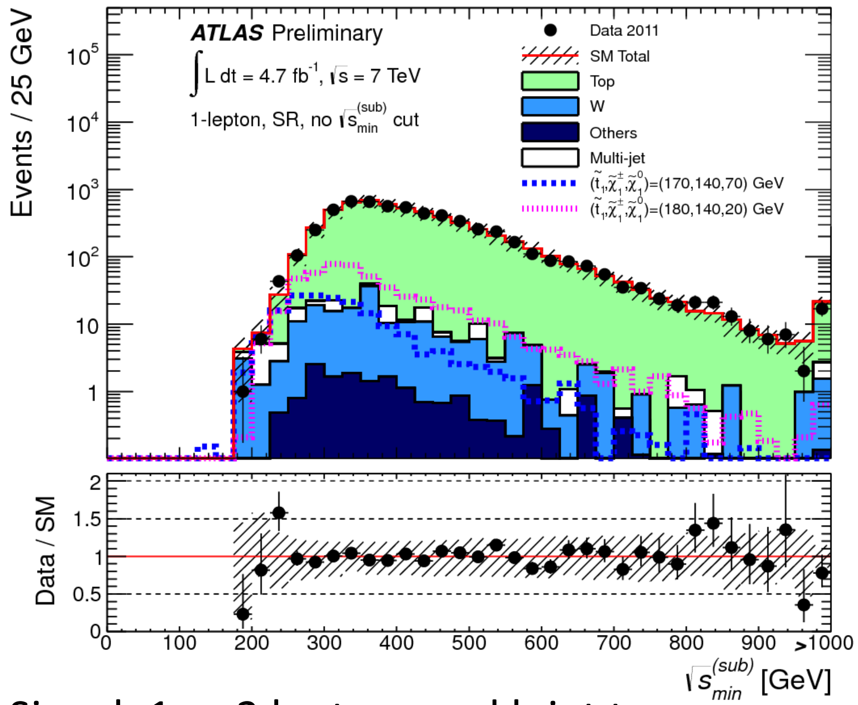
ATLAS-CONF-2012-059

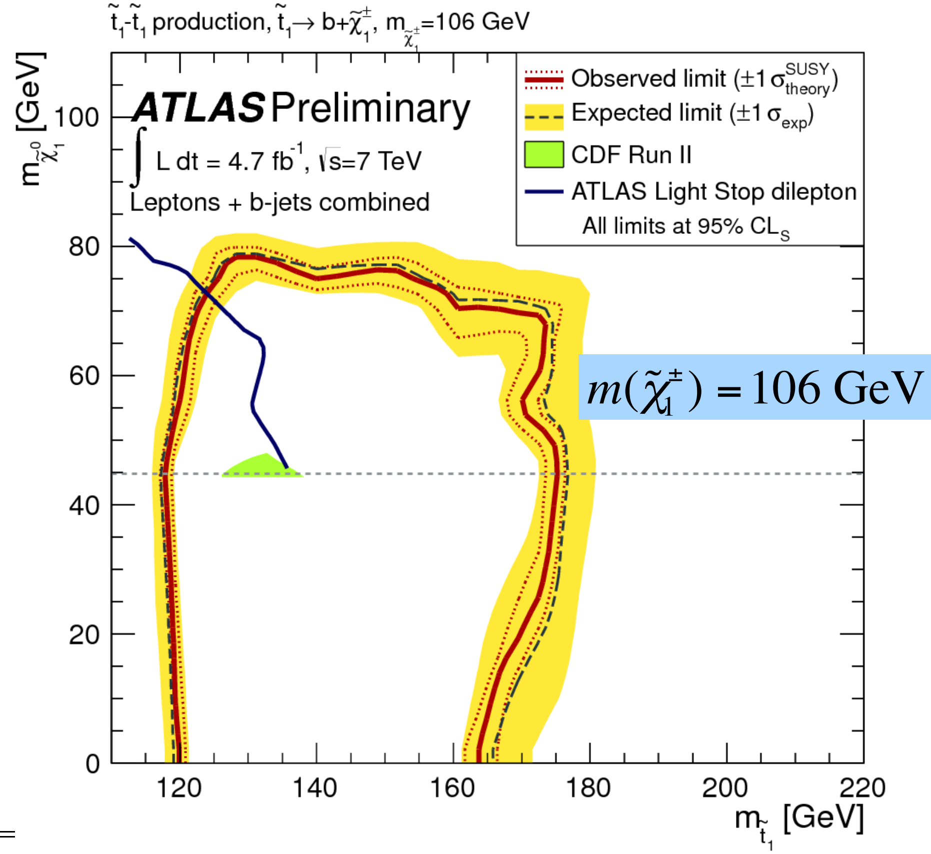
Light stop produces excess of low p_T leptons in events which look like top pairs decaying semi-leptonically. Look directly at p_T(lepton) and ET_{miss}. Low acceptance but clean.

ATLAS light stop – kinematic search

$m_t \gtrsim m_{\tilde{t}_1} > m_{\tilde{\chi}_1^\pm}$

$\tilde{t} \to b\tilde{\chi}_1^\pm \to bW^{(*)}\tilde{\chi}_1^0$





Signal: 1 or 2 leptons and b jet tag + jets as expected from tt.

Construct subsystem mass – peaks at 2m(t), lower for stop.

Limits depend on assumptions on chargino mass.

ATLAS-CONF-2012-070

Process	1LSR	2LSR1	2LSR2
Top	$24 \pm 3 \pm 5$	$89 \pm 6 \pm 10$	$36 \pm 2 \pm 5$
W+jets	$6 \pm 1 \pm 2$	n/a	n/a
Z+jets	$0.5 \pm 0.3 \pm 0.3$	$11 \pm 4 \pm 3$	$3 \pm 1 \pm 1$
Fake leptons	$7 \pm 1 \pm 2$	$12 \pm 5 \pm 11$	$6 \pm 4 \pm 4$
Others	$0.3 \pm 0.1 \pm 0.1$	$2.7 \pm 0.9 \pm 0.7$	$0.9 \pm 0.2 \pm 0.5$
Total SM	$38 \pm 3 \pm 7$	$115 \pm 8 \pm 15$	$46 \pm 4 \pm 7$
Data	50	123	47
$m_{\tilde{t}_1} = 170$ GeV, $m_{\tilde{\chi}_1^0} = 70$ GeV	$26 \pm 2 \pm 6$	$57 \pm 3 \pm 6$	$36 \pm 2 \pm 4$
$m_{\tilde{t}_1} = 180$ GeV, $m_{\tilde{\chi}_1^0} = 20$ GeV	$20 \pm 2 \pm 4$	$41 \pm 3 \pm 5$	$27 \pm 2 \pm 3$
	95% CL upper limits		
σ_{vis} (expected) [fb]	4.2	9.3	4.6
σ_{vis} (observed) [fb]	6.1	11	5.2

What is α_T?

$$\alpha_T = \frac{E_T^{j_2}}{M_T}$$

For well balanced dijet systems,
$\alpha_T = 0.5$

For an multi-jet system, jets are merged to make an equivalent dijet system such that difference in E_T of two systems (ΔH_T) is minimum.

$$\alpha_T = \frac{1}{2} \cdot \frac{H_T - \Delta H_T}{\sqrt{H_T^2 - \not{H}_T^2}}$$