Searches for 3rd generation partners

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on behalf of the ATLAS and CMS Collaborations

EPS, Vienna
July 23, 2015

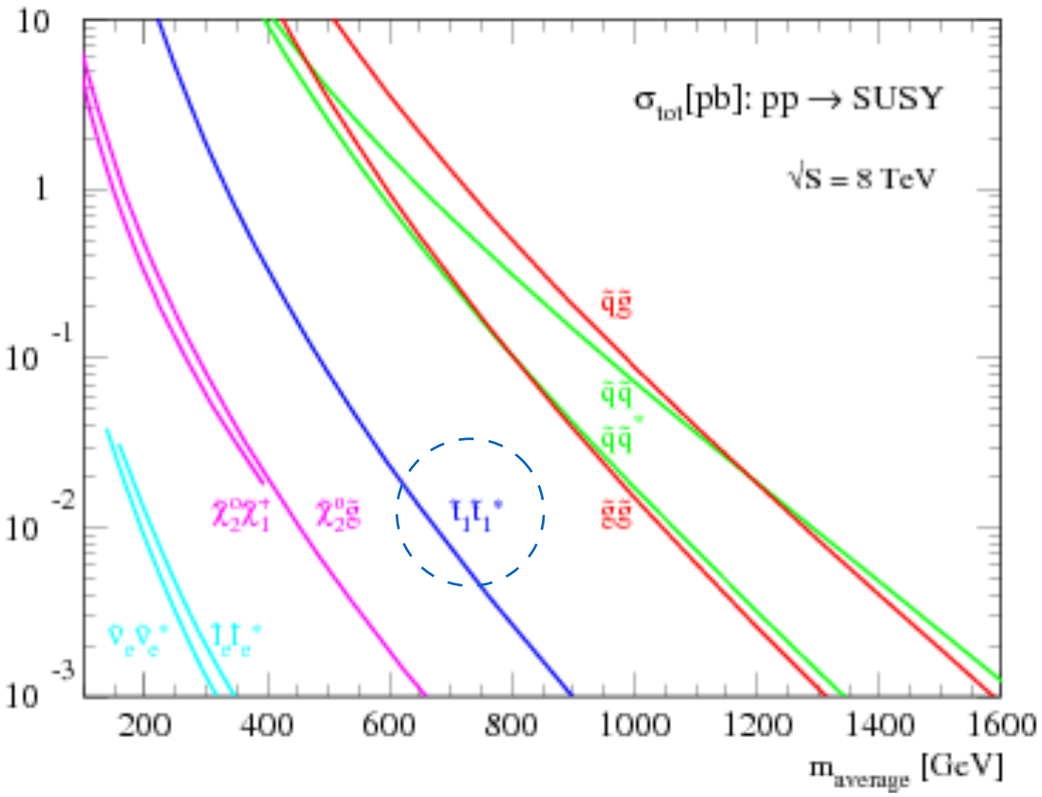
Third generation squarks

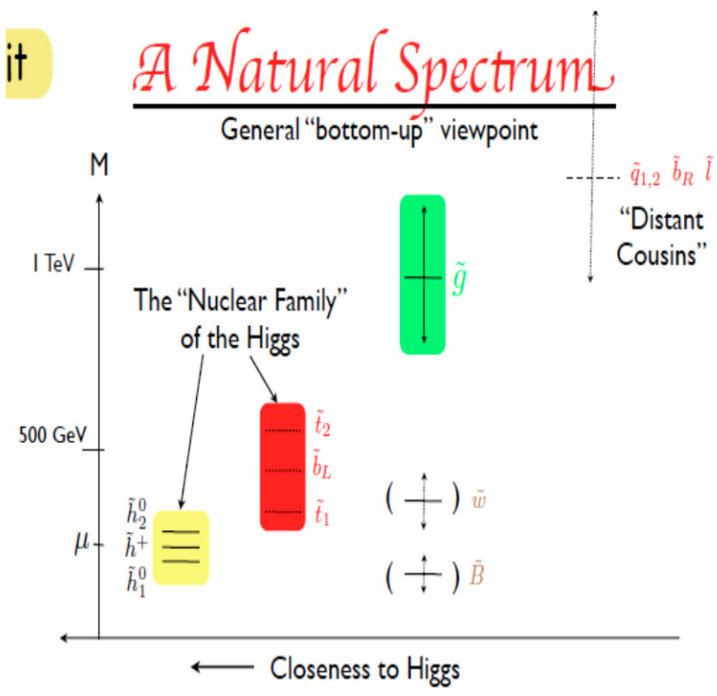
What is it about them?

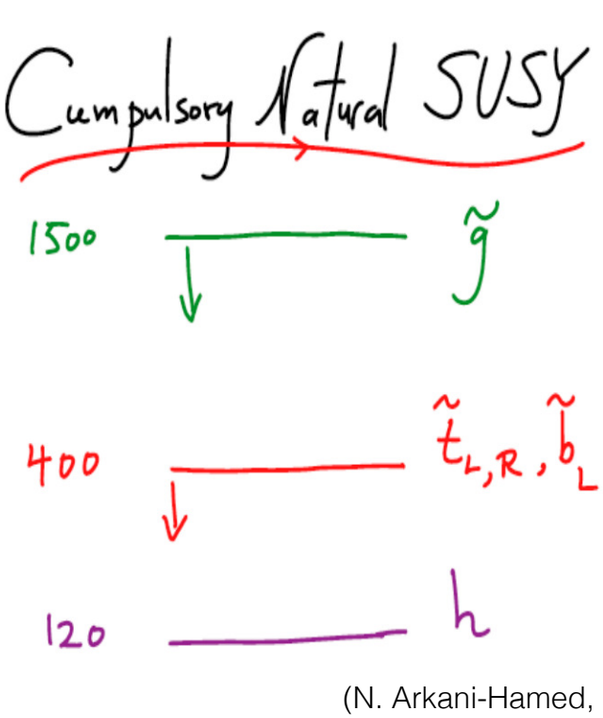
- Third generation squarks are expected to be lighter than other squarks due to mixing of the mass matrix and large Yukawa couplings.

- Light stop and sbottom are favored in several models. Their masses must be below the TeV scale to provide a ‘natural’ solution to the hierarchy problem

- —> They can be produced with large cross-sections and within the discovery reach of the LHC



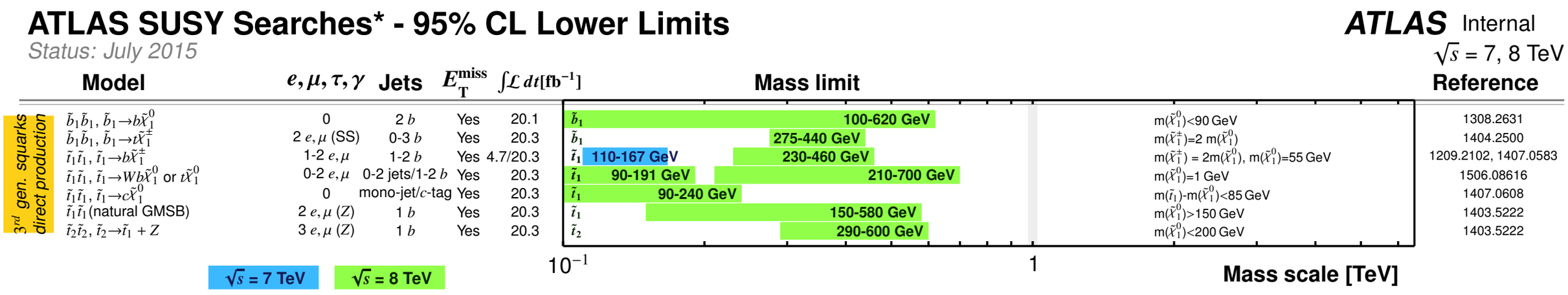


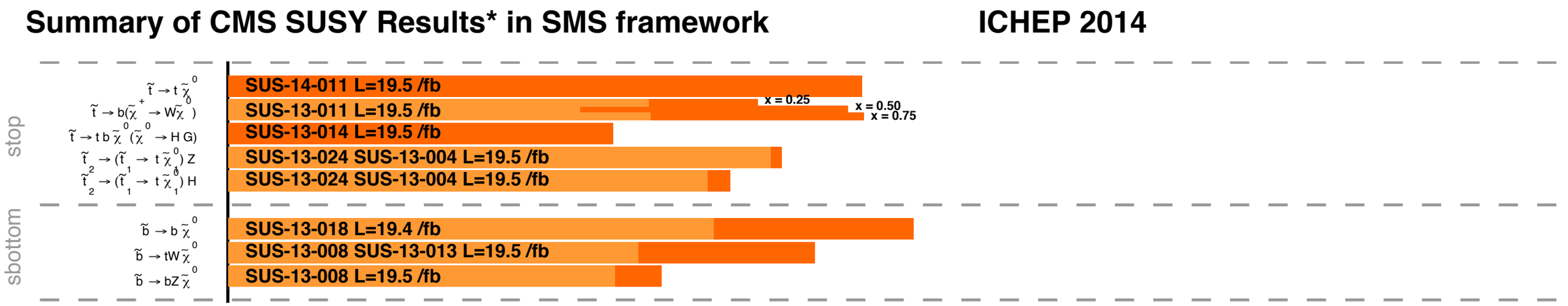


(N. Arkani-Hamed, 2011)

Run I Legacy

Comprehensive search programme for direct production of 3rd generation particles production at 7-8 TeV





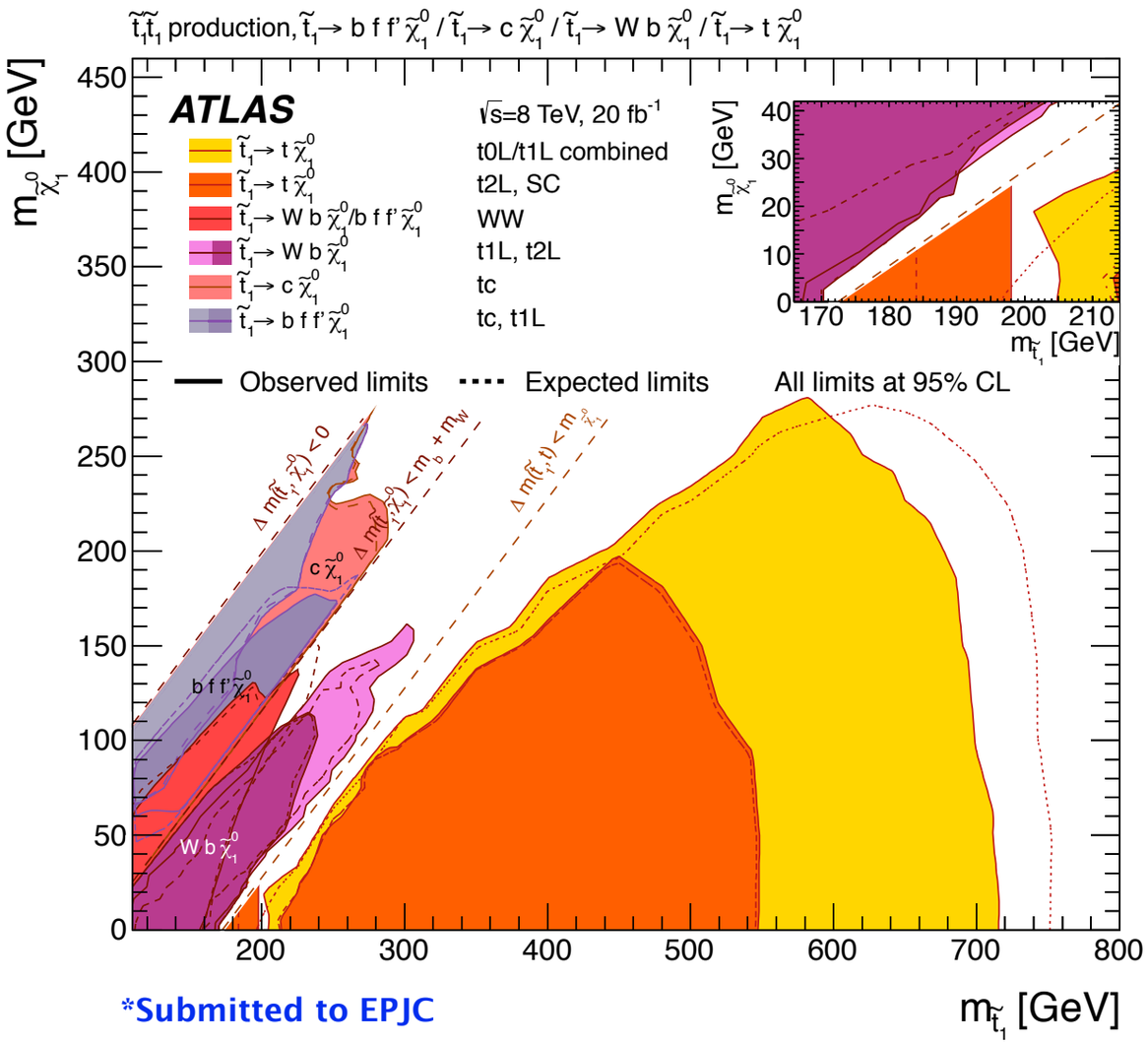
no 3G SUSY in plain sight

(no exhaustive set of results)

Run I Legacy

ATLAS Run 1 searches for direct pair production of third-generation squarks at the Large Hadron Collider

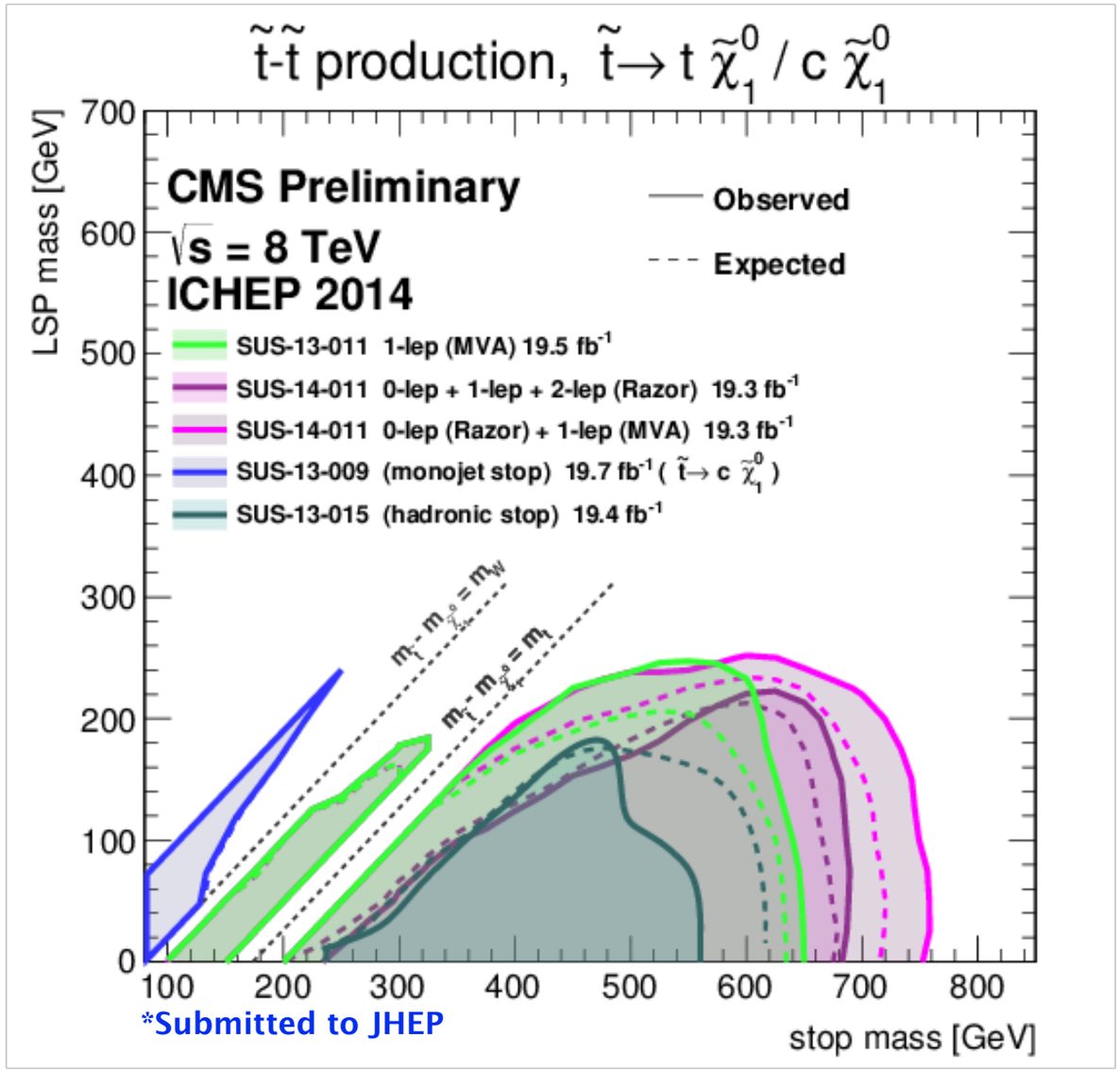
arXiv:1506.08616v1*



*Submitted to EPJC

Searches for third-generation squark production in fully hadronic final states in proton-proton collisions at √s = 8 TeV

arXiv:1503.08037v1*

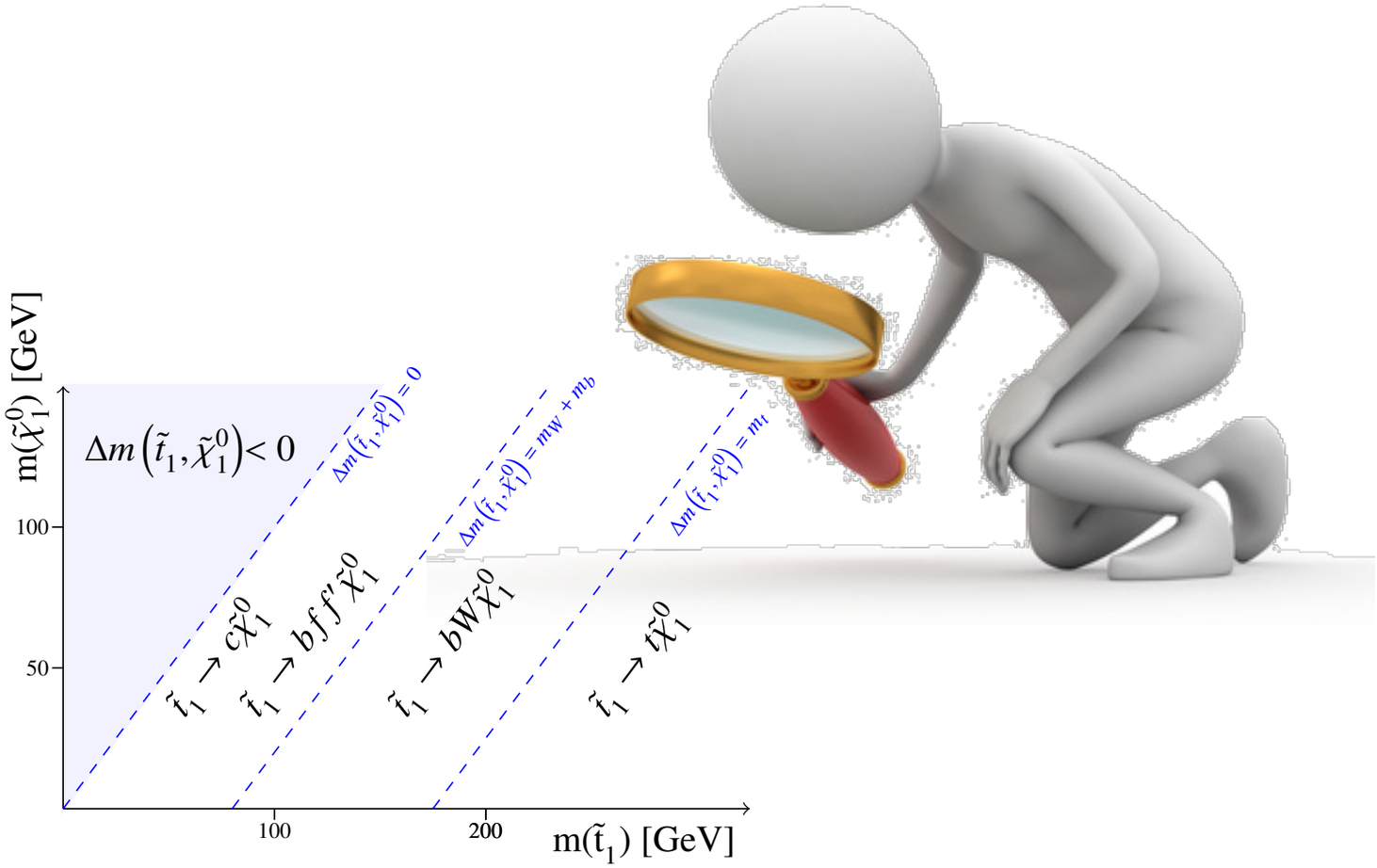


*Submitted to JHEP

→ **no 3G SUSY in plain sight** ←

(no exhaustive set of results)

HOW do we fully exploit Run1?



Focus on some of the most recent results only Today!

Please see Nick's talk for compressed scenarios searches
TJ's talk for gluino-mediated searches
David's talk for RPV stop searches
Alberto's talk for pMSSM interpretation

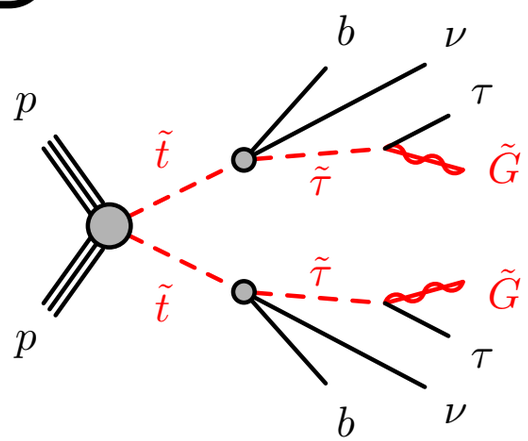
Add new modes

stop → stau

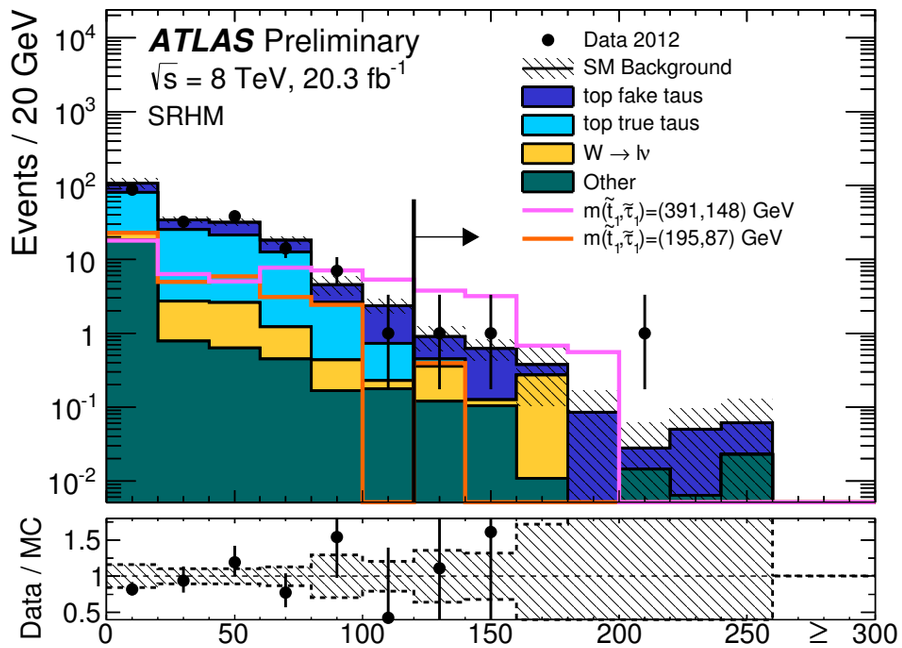
GMSB
$\tilde{G}$ LSP

Nucl.Phys. B306 (1988) 63-76

light stop?



NEW



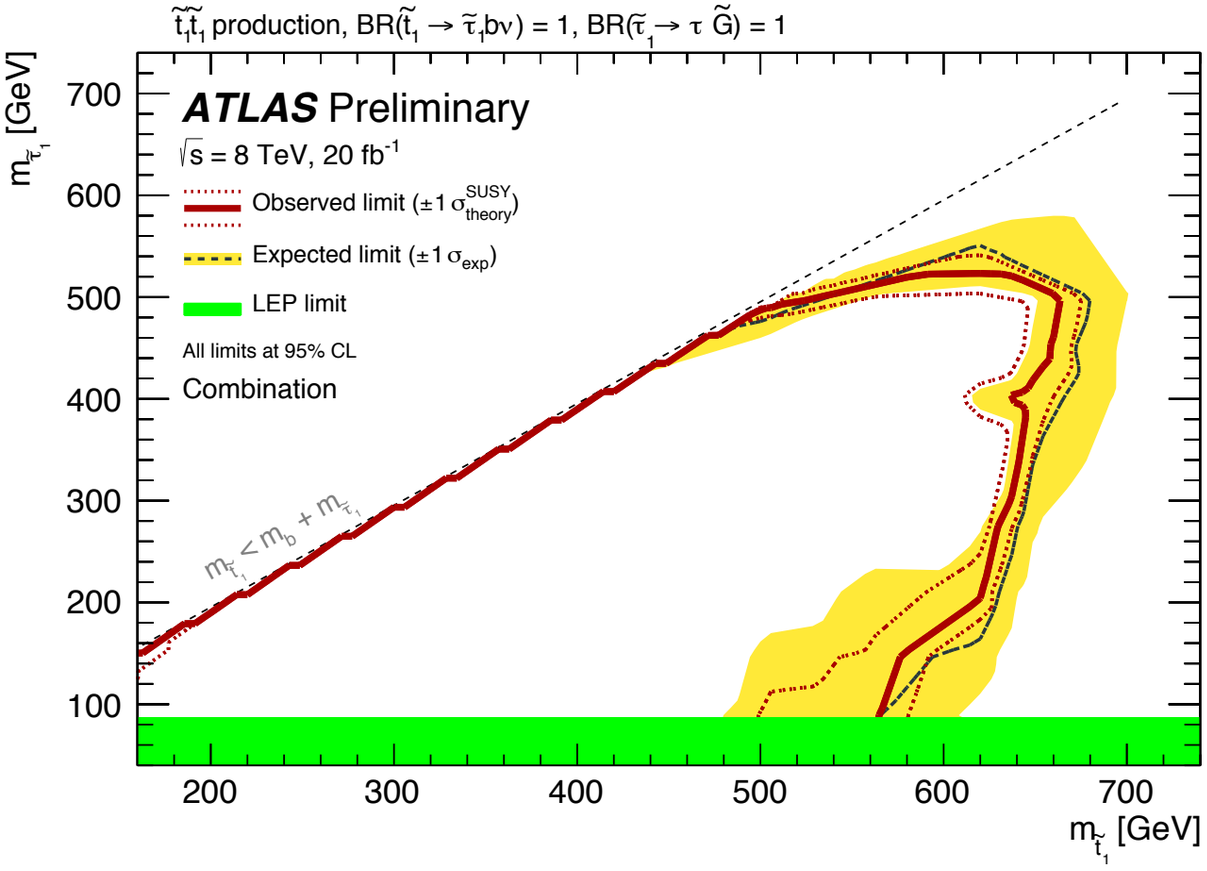
- new dedicated search for 2τ+bjets+MET
  - **First limit on 3-body stop decays to stau @LHC**
- Split by tau decay mode to maximise sensitivity
- had-had

  2 OS τ_{had} + 0lepton + >2jets (>1b) + MET

  $m_T^{sum}(\tau_{had1},\tau_{had2})$ and $m_{T2}(\tau_{had1},\tau_{had2})$
- lep-had

  τ_{had} + 1lepton + >2jets (1-2 b)

  $m_{T2}(l,\tau_{had})$, $m_{T2}(bl,b\tau_{had})$, $m_{T2}(bl,b)$
- lep-lep
  - recast from 2L search JHEP06(2014)124.



Add new modes

topbottom

NEW

both N1 and C1 lighter than stop (or sbottom)

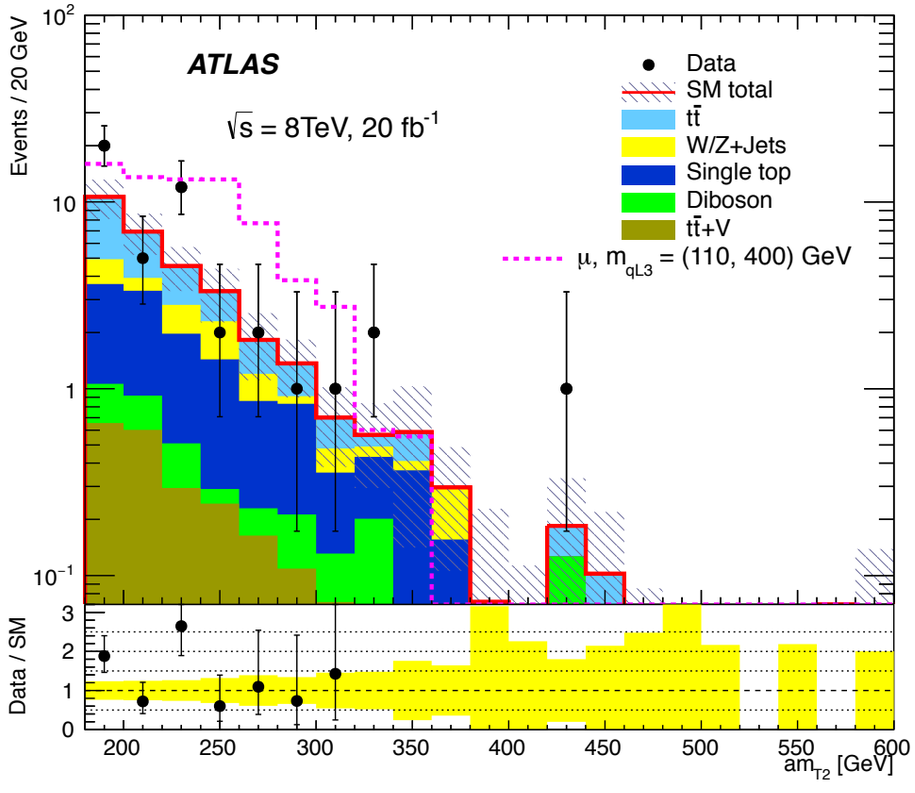
competing BRs for

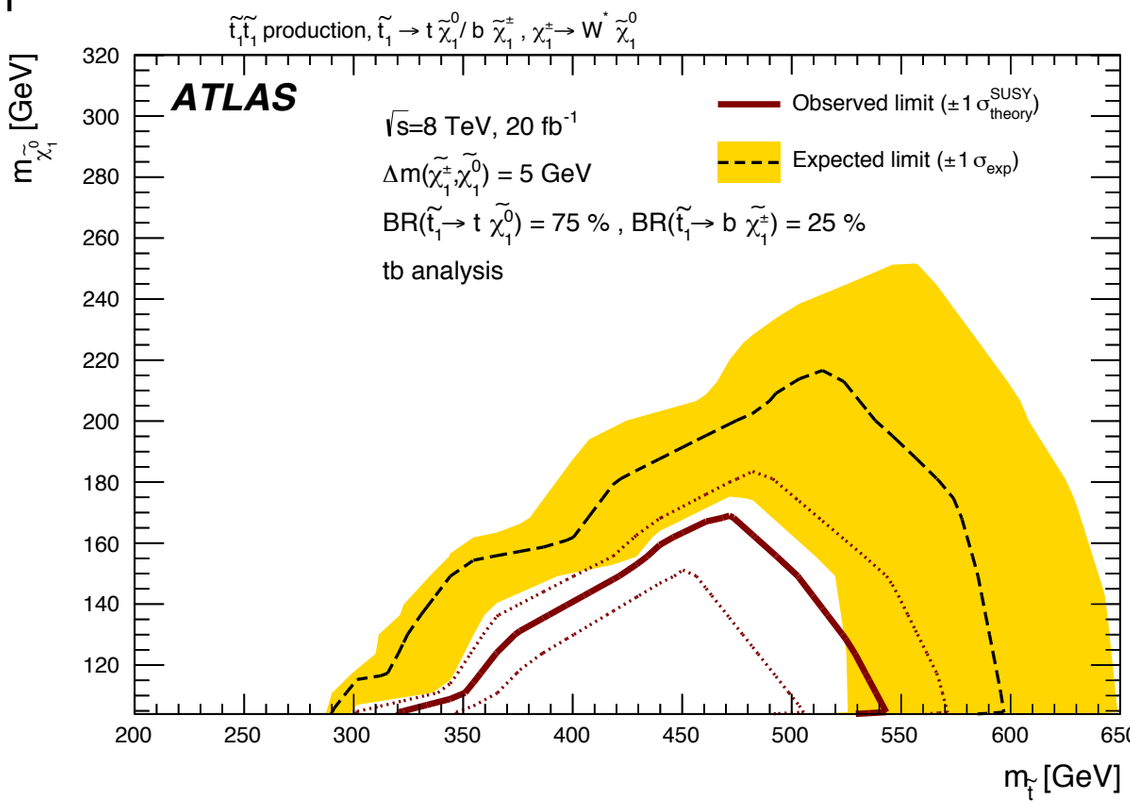
$$\tilde{t}_1 \to t\tilde{\chi}_1^0, \tilde{t}_1 \to b\tilde{\chi}_1^{\pm}$$
$$\tilde{b}_1 \to b\tilde{\chi}_1^0, \tilde{b}_1 \to t\tilde{\chi}_1^{\pm}$$

μ << M1,M2 ⟶ small Δm(N1,C1) ⟶ $\tilde{t}_1\tilde{t}_1 \to t\tilde{\chi}_1^0 b\tilde{\chi}_1^{\pm} \to tb\tilde{\chi}_1^0\tilde{\chi}_1^0 f f'$ (soft)

- $1\,l + 2b + \mathrm{MET}$
- **Bkg**: dominated by 1/2lep ttbar and single-top
  combined profile-likelihood fit on dedicated CRs

SR	tb-SREx1
b-jets	
1 lepton	
$E_{\mathrm{T}}^{\mathrm{miss}}$ (GeV)	>160
m_{T} (GeV)	>120
m_{eff}(GeV)	>300
am_{T2}(GeV)	>180
$m_{b\ell}^{\mathrm{min}}$ (GeV)	
$\Delta\phi^{b}_{\mathrm{min}}$	
$E_{\mathrm{T}}^{\mathrm{miss}}$ significance ($\mathrm{GeV}^{1/2}$)	> 10
N_{xjets}	<2





Similar exclusion achieved for Δm(N1,C1)=20GeV

Check Alberto's talk for pMSSM interpretation

Check the 'hints'

NEW arXiv:1506.08616v1

WW-like

WW cross section (2L) → light stop?

Phys.Lett. B712 (2012) 289-308
Phys.Lett. B721 (2013) 190-211
Eur. Phys. J. C 73 (2013) 2610

arXiv:1303.5696v2
arXiv:1406.0858v3
arXiv:1406.0848v2

- 2 DF OS leptons

Bkg: dominated by WW production

combined profile-likelihood fit on dedicated CRs
WW normalisation from CR in data

$$\Delta X = \frac{(p_z(\ell_1) + p(\ell_2))}{\sqrt{s}}$$

higher longitudinal boost for signal (gg initiated)

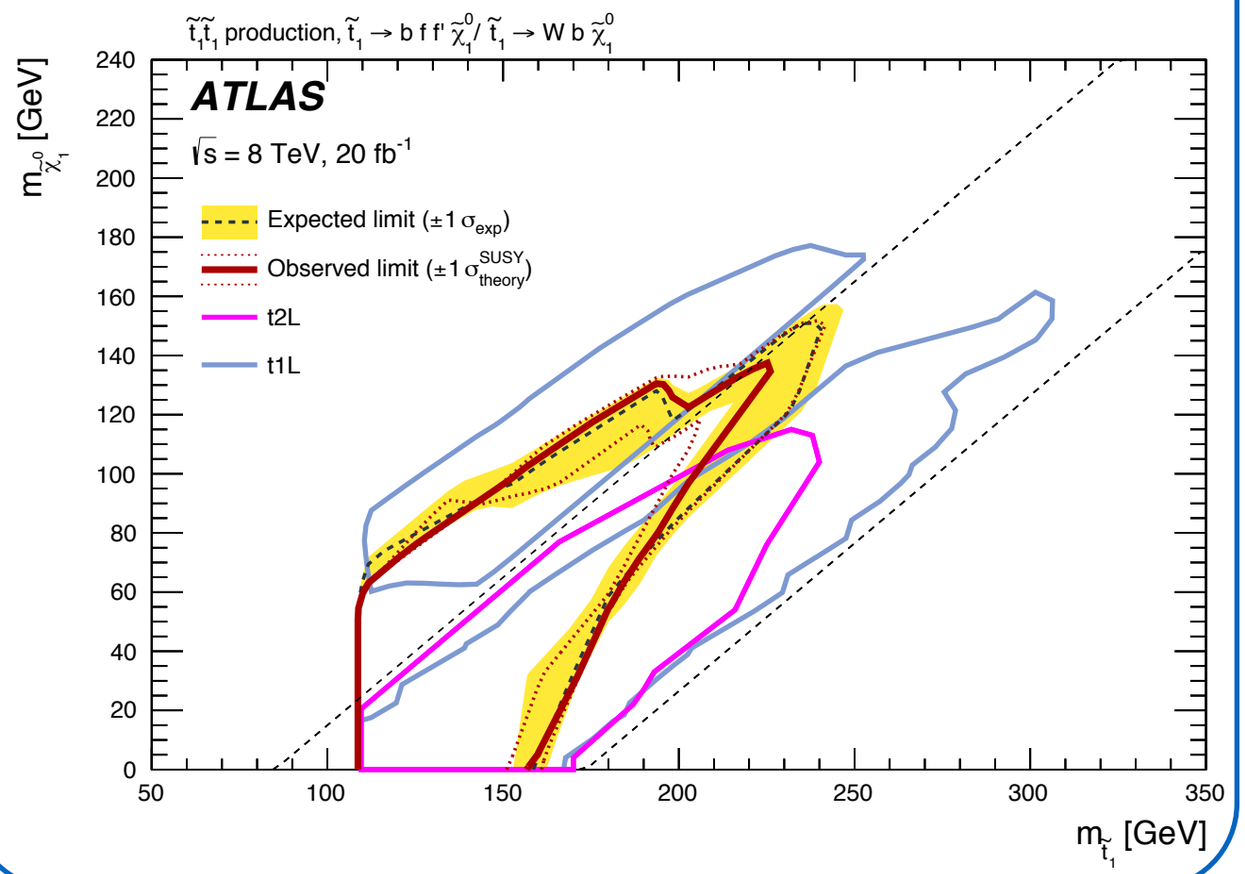
$$R_2 = \frac{E_{\mathrm{T}}^{miss}}{E_{\mathrm{T}}^{miss} + p_T(\ell_1) + p_T(\ell_2)}$$

higher for signal $(2\nu + 2\tilde{\chi}_0 + 2b)$

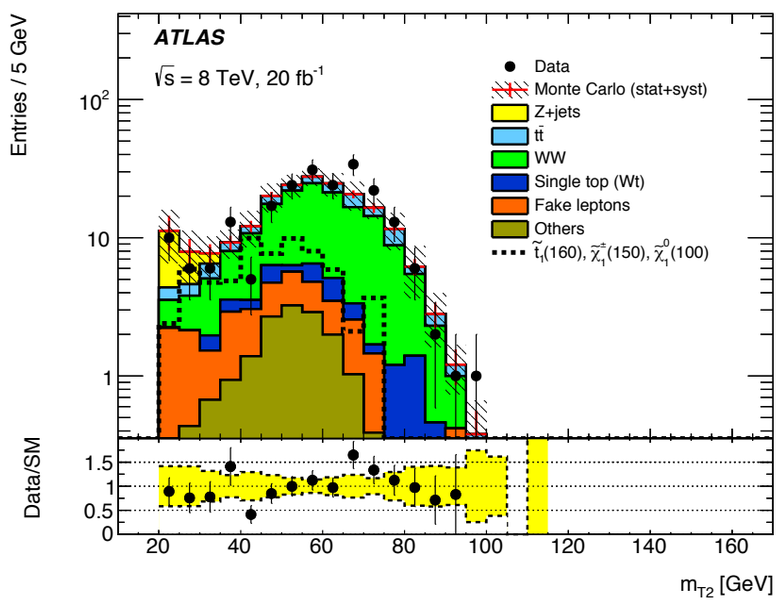
7 SRs in terms of m_{T2} and $\cos(\theta_b)$

angle between direction of motion of the 2l system and the beam axis in the c.o.m. frame of the 2l

covering transition between 3-body and 4-body decays of light stop



No excess over SM observed



Reapproach

$\tilde{t}_2 \to \tilde{t}_1 h$

$\Delta m(\tilde{t}_1 - \tilde{\chi}_1^0) \sim m(t)$ → look for stop2 instead

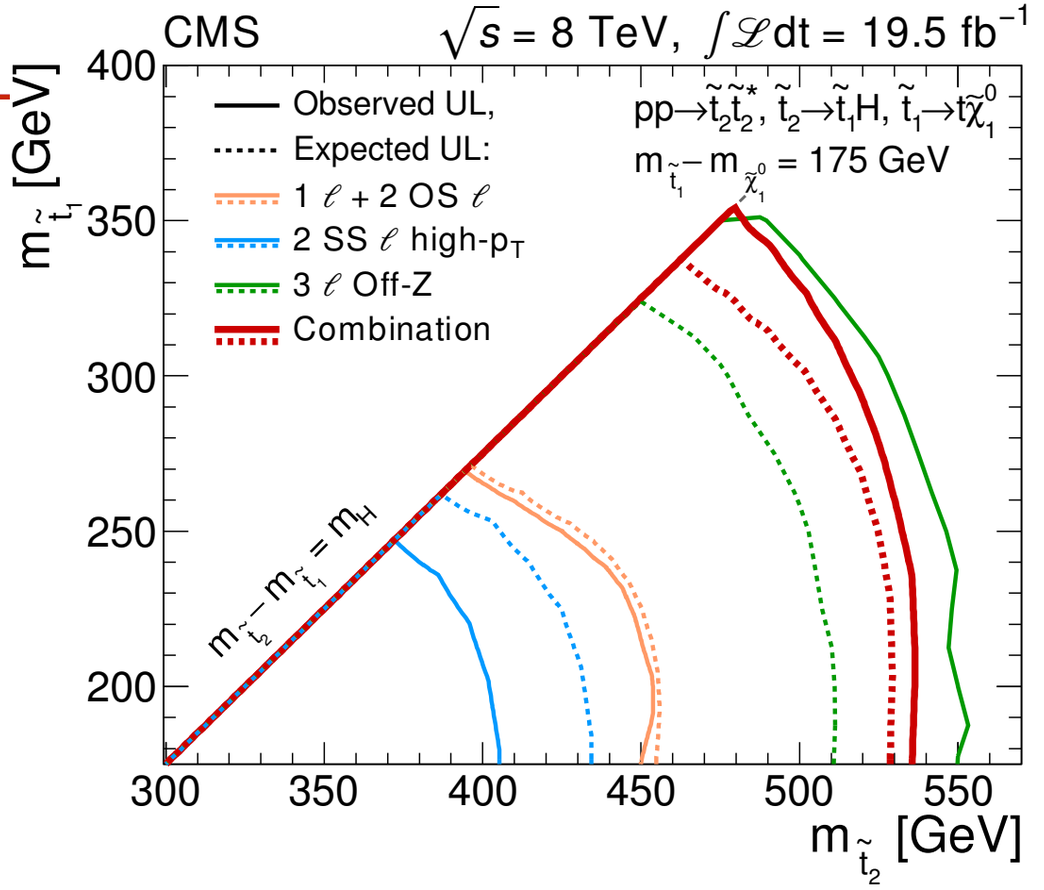
CMS Strategy arxiv:1405.3886

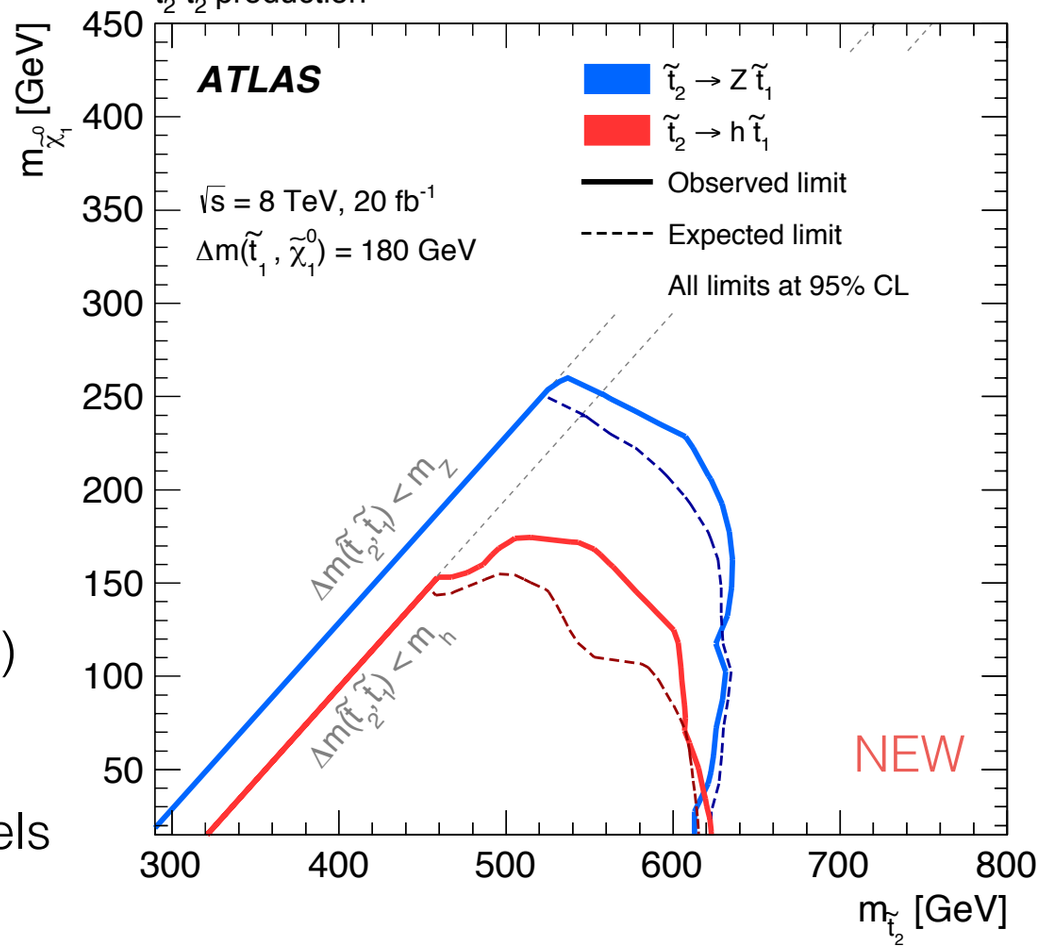
- >=1l +>=2jets (>=1b) + MET
- categorization in N leptons, jets and bjets (96 SRs!)

N_ℓ	Veto	$N_{\text{b jets}}$	N_{jets}	$E_{\text{T}}^{\text{miss}}$ [GeV]	Additional requirements [GeV]
1	track or τ_{h}	=3 ≥4	≥5 ≥4	≥50	$m_{\text{T}} > 150$ $m_{\text{T}} > 120$
2 OS	extra e/μ	= 3 ≥4	≥5 ≥4	≥50	$N_{\text{bb}} = 1$ with $100 \le m_{\text{bb}} \le 150$, $N_{\text{bb}} \ge 2$
2 SS	extra e/μ	=1 ≥2	[2,3], ≥ 4	[50,120], ≥120	for low/high-p_{T}: $H_{\text{T}} \in [200,400]$, ≥400
≥3	—	= 1 = 2 ≥3	[2,3], ≥ 4 ≥3	[50,100], [100,200], ≥200	for on/off-Z: $H_{\text{T}} \in [60,200]$, ≥200

ATLAS Strategy arXiv:1506.08616v1

- 1 l +>=6jets (>=2b) + MET
  - inspired on SM ttH search
- categorization in b-jet multiplicity (2,3,4+) and m_{T} (low,high)
  - detailed categorisation for modelling of ttbar+HF
- binned likelihood fit to HTlep simultaneously in the 6 channels

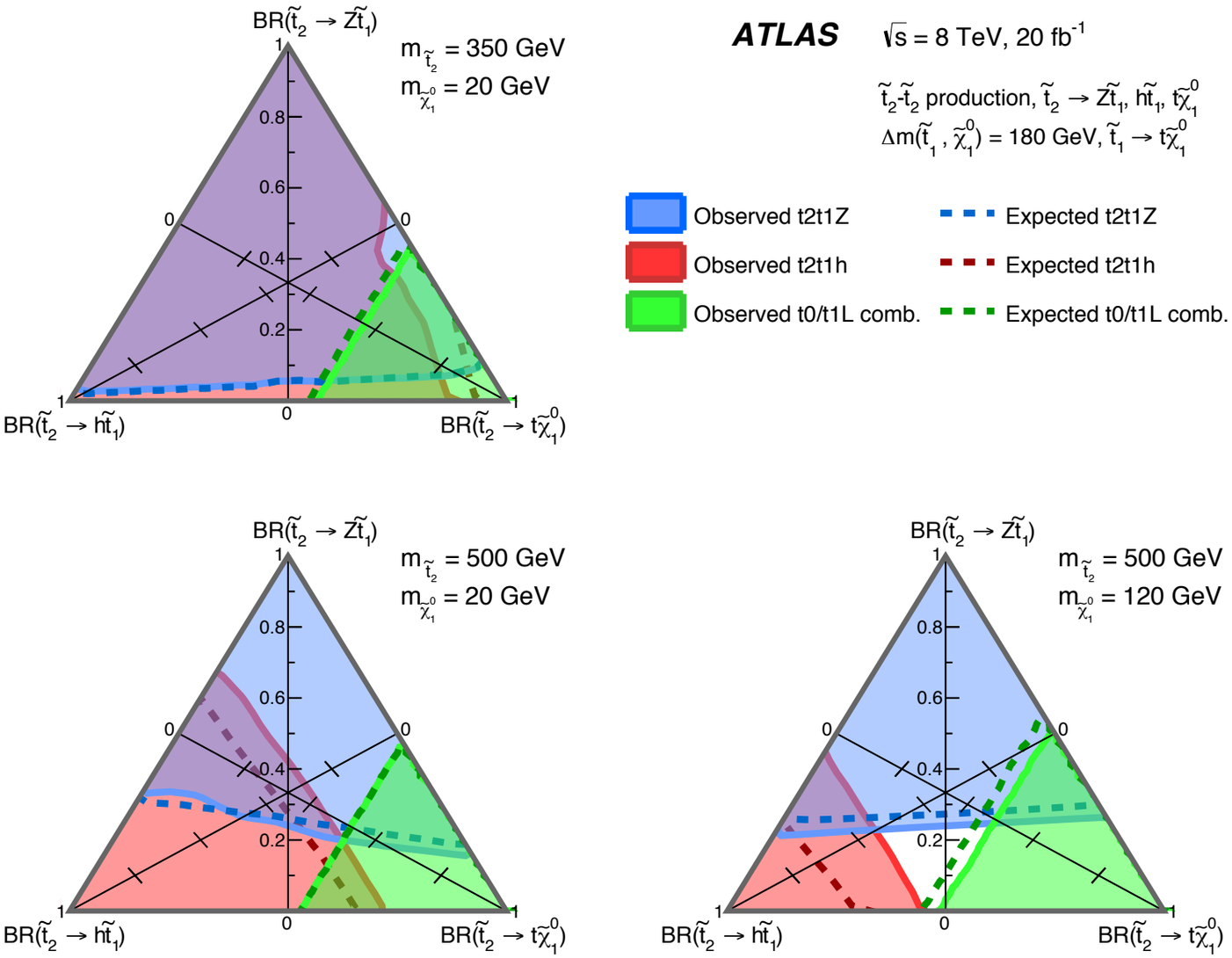


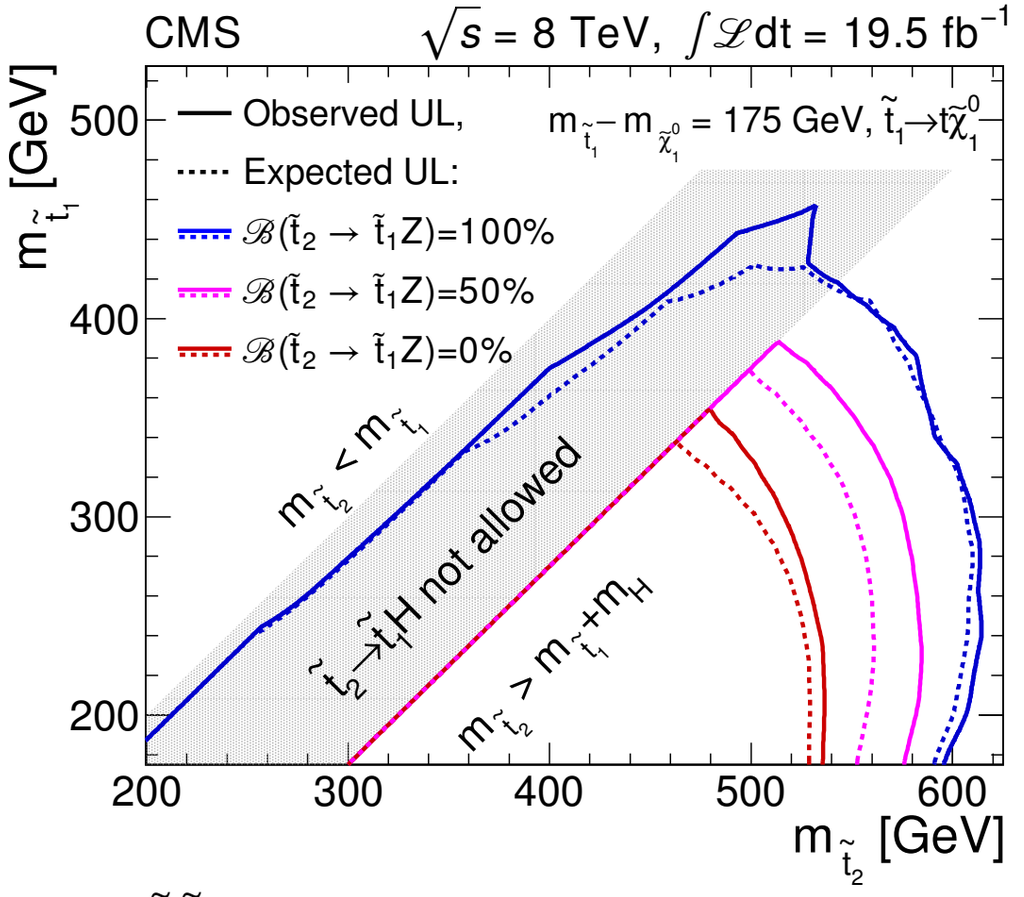


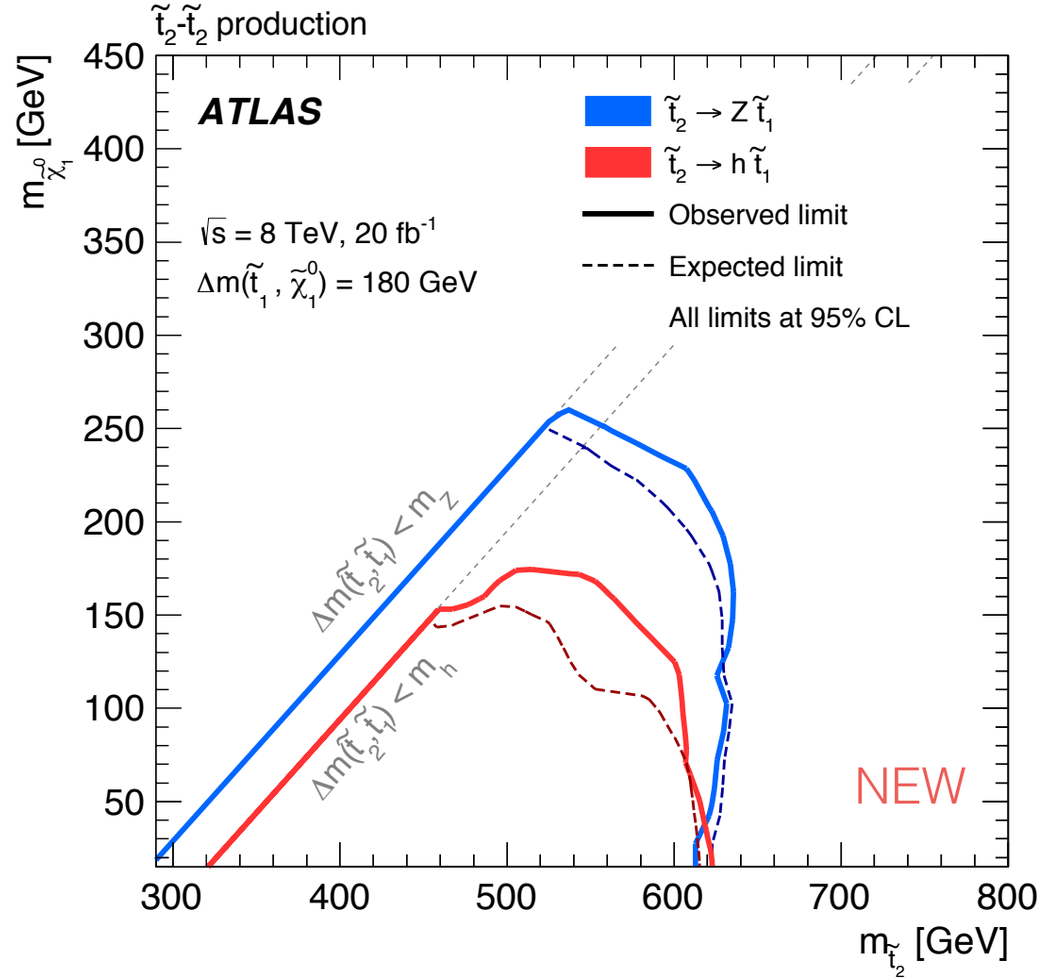
Combine and conquer!

$$\tilde{t}_2 \to \tilde{t}_1 h / \tilde{t}_1 Z / \tilde{t}_1 t$$

$\Delta m(\tilde{t}_1 - \tilde{\chi}_1^0) \sim m(t)$ → look for stop2 instead



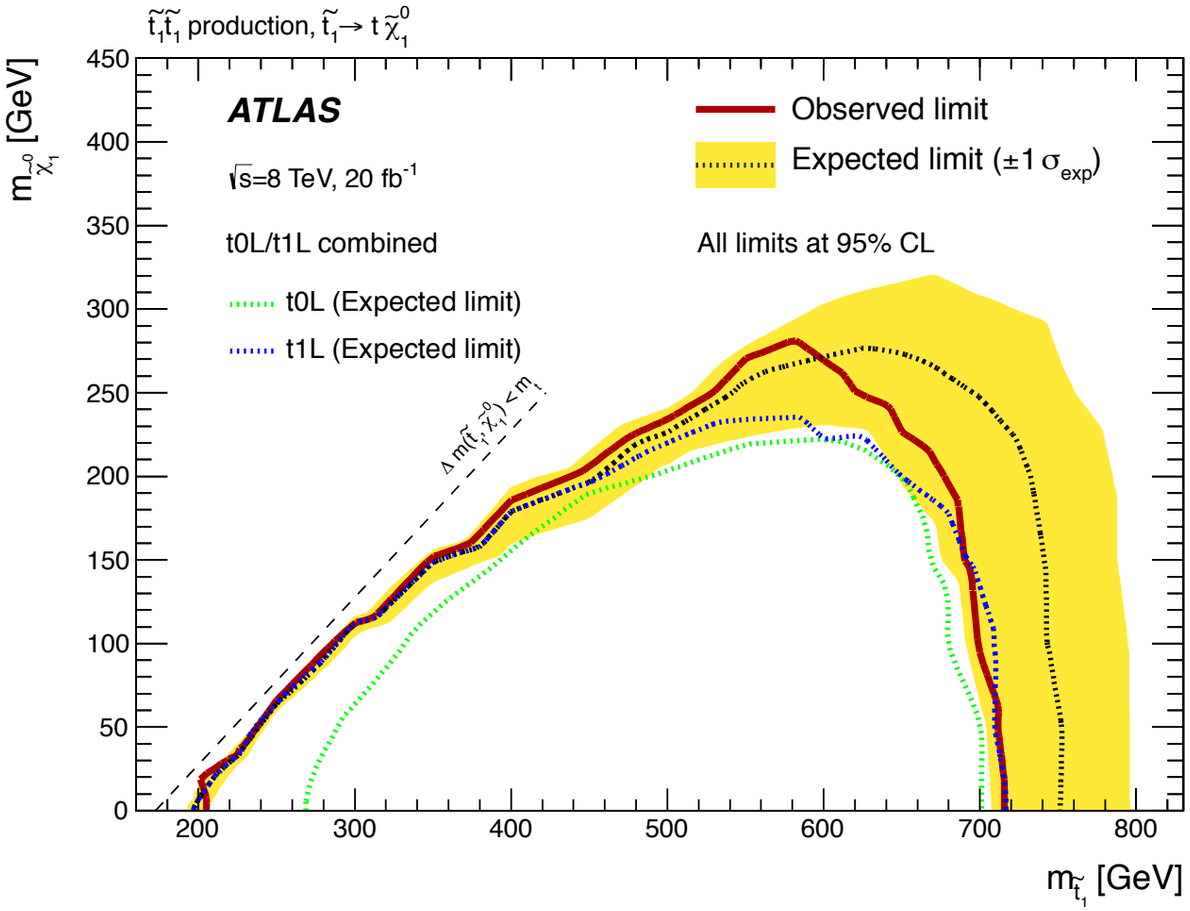




Combine and conquer!

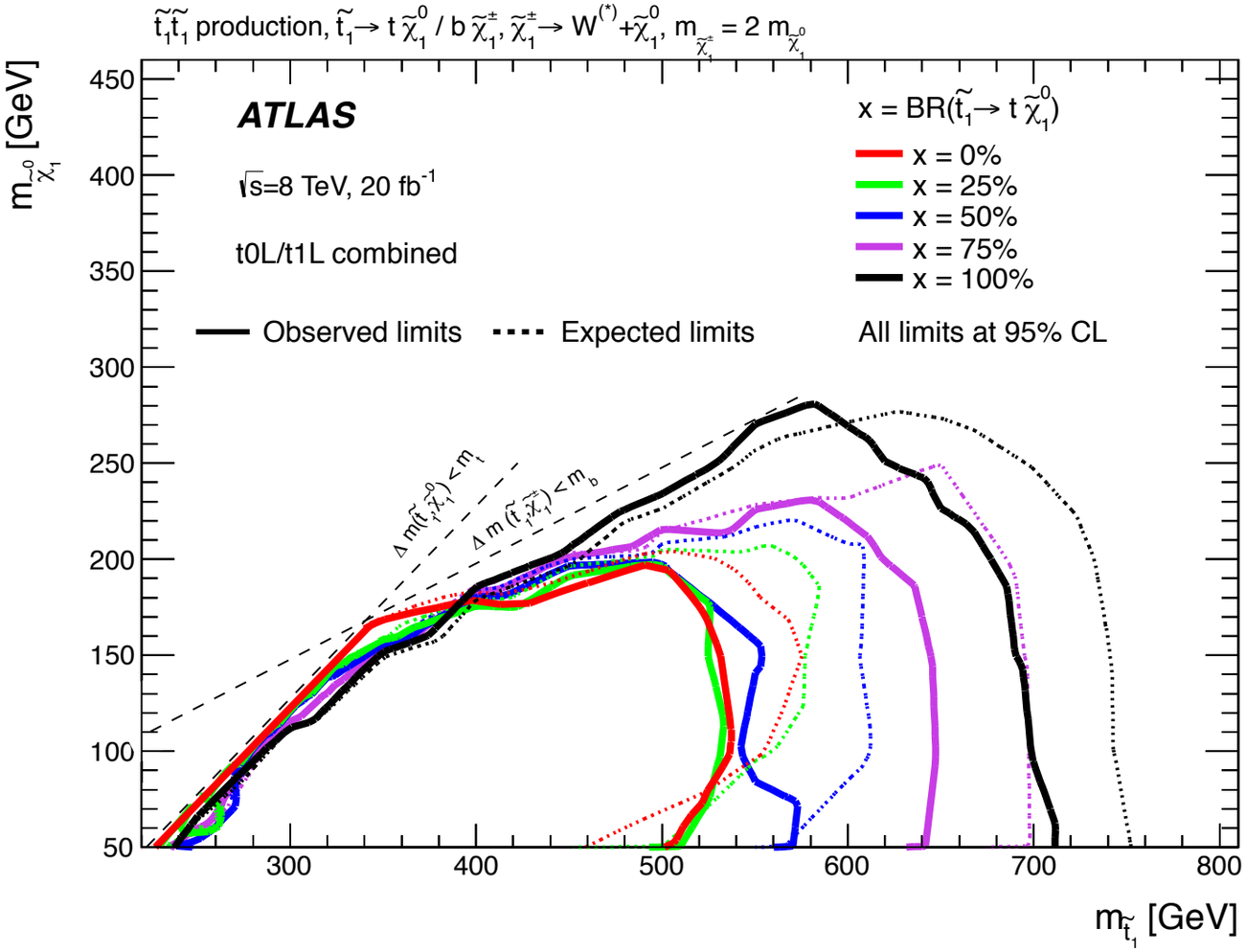
t0L+t1L

- statistical combination of stop0L and stop1L analysis with 8TeV data
  - combined fit to all control and signal regions
    - correlated systematics, independent normalisation parameters



arXiv:1506.08616v1

See TJ's talk for more details on the combination



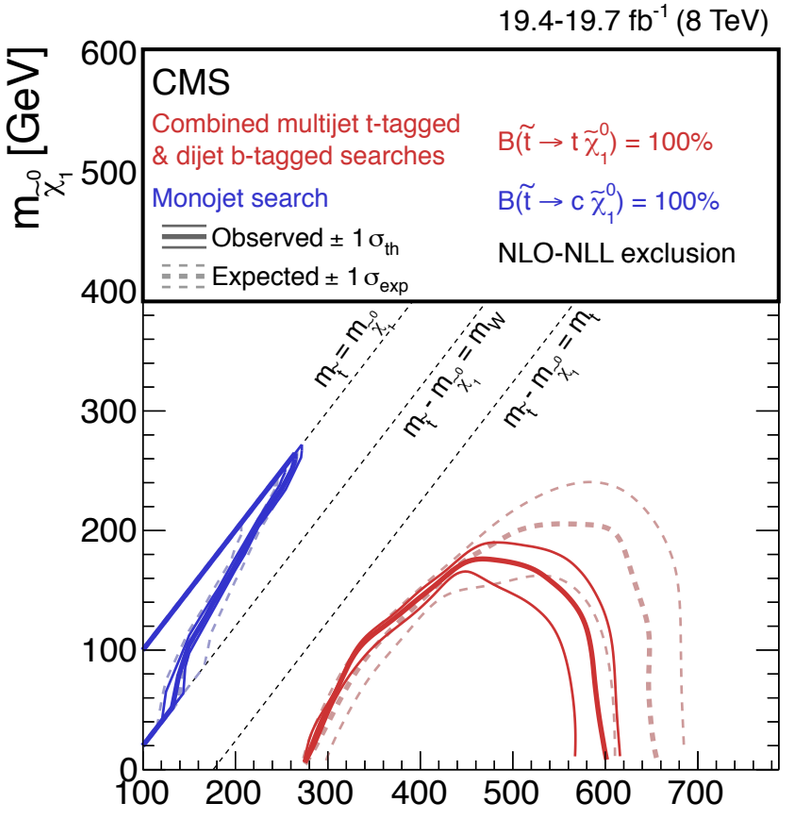
no statistical combination below x=75%, as 1L dominates ~ everywhere

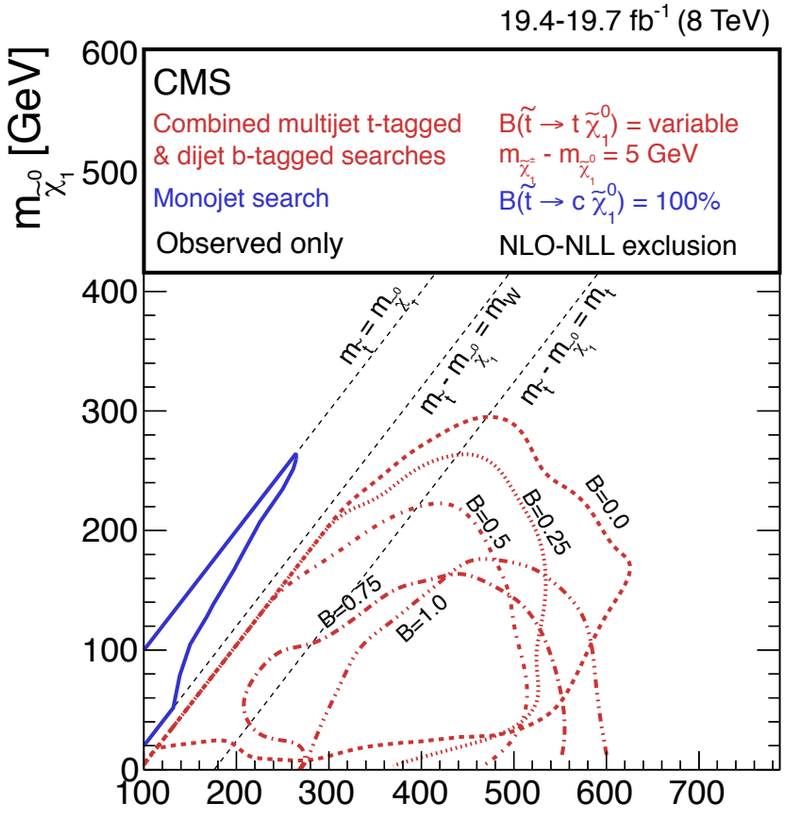
Combine and conquer!

Hadronic searches

- multijet + 1top
- dijet +1-2 bjets
- monojet

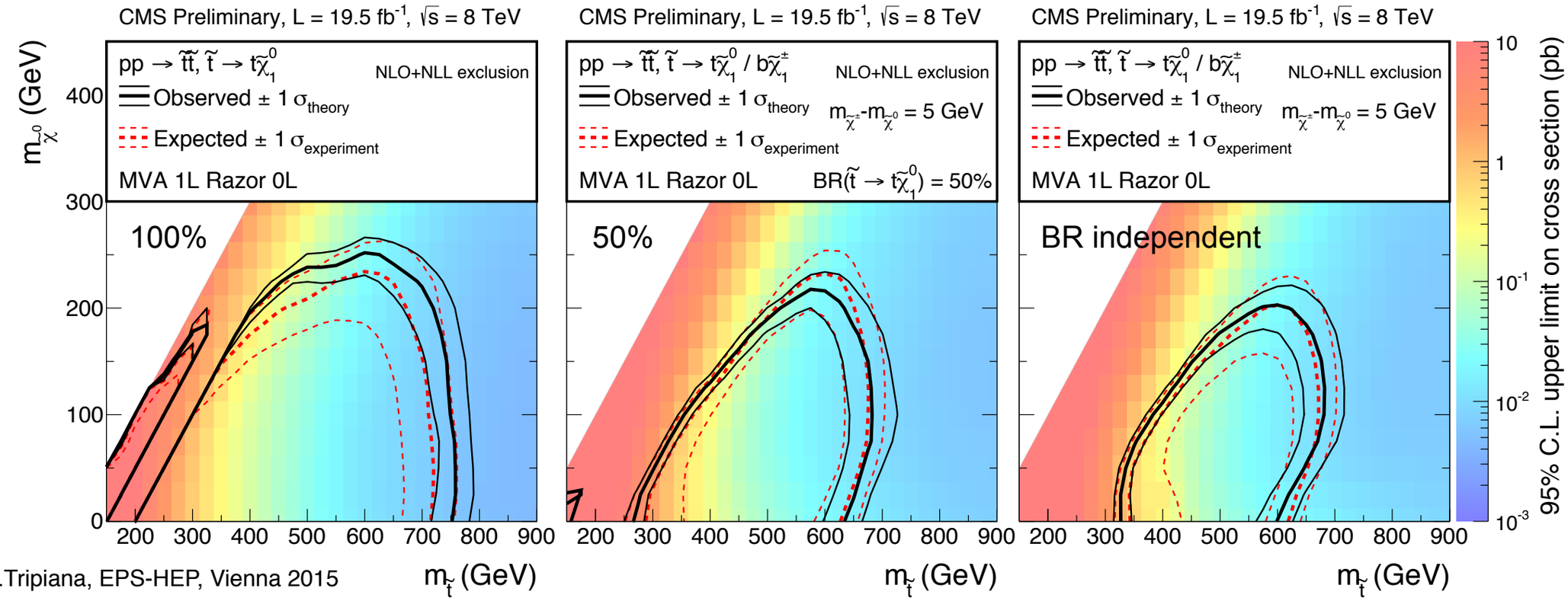
arXiv:1503.08037v1*





Razor + 1L(MVA) CMS-PAS-SUS-14-011

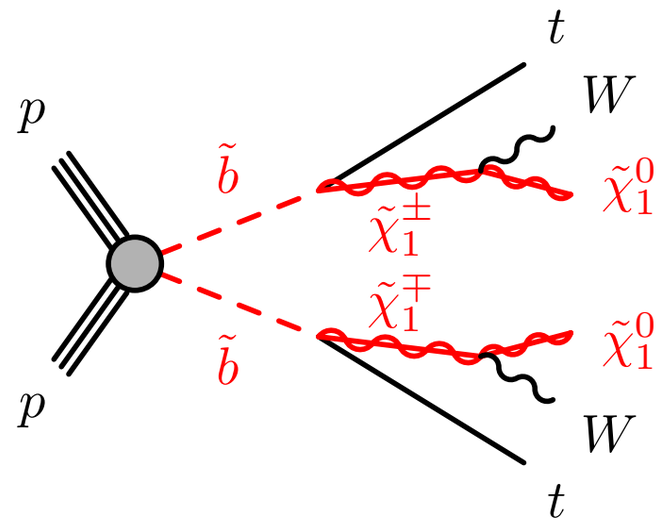
combine the LH of different searches into a global binned likelihood



Combine and conquer!

Searches for supersymmetry based on events with b jets and four W bosons in pp collisions at 8 TeV

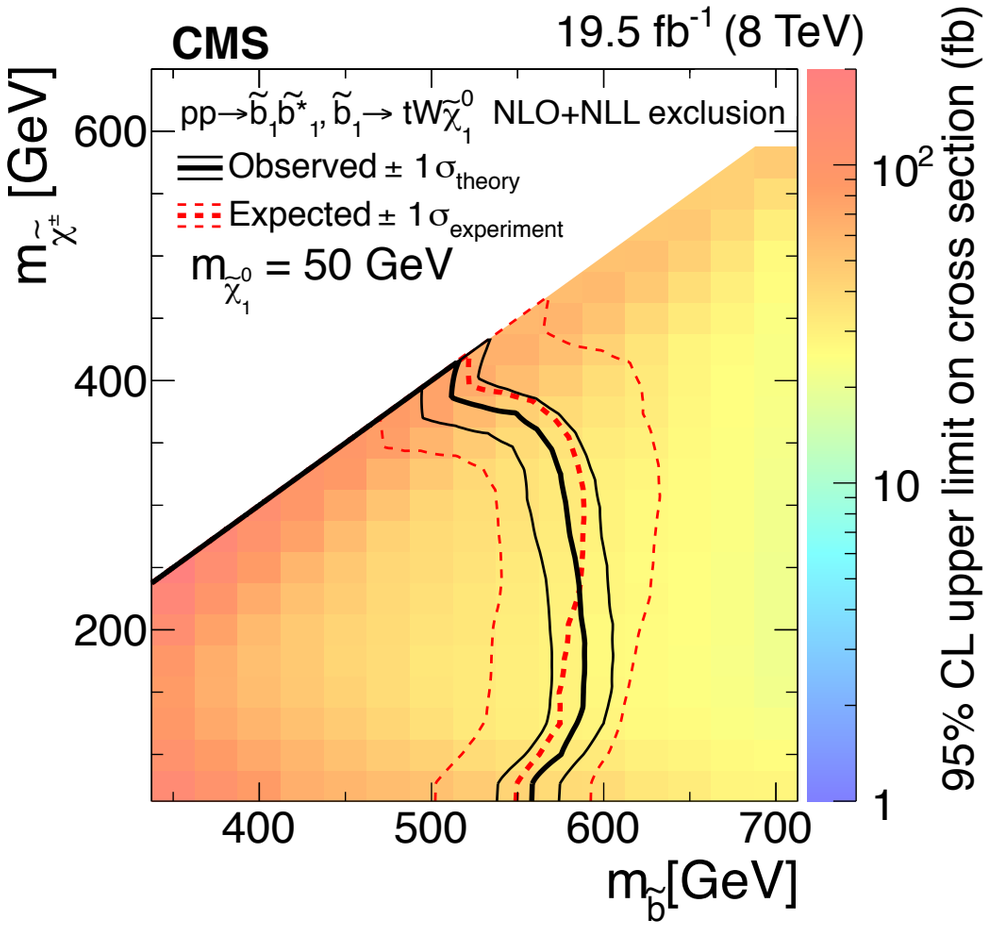
Physics Letters B745 (2015) 5–28

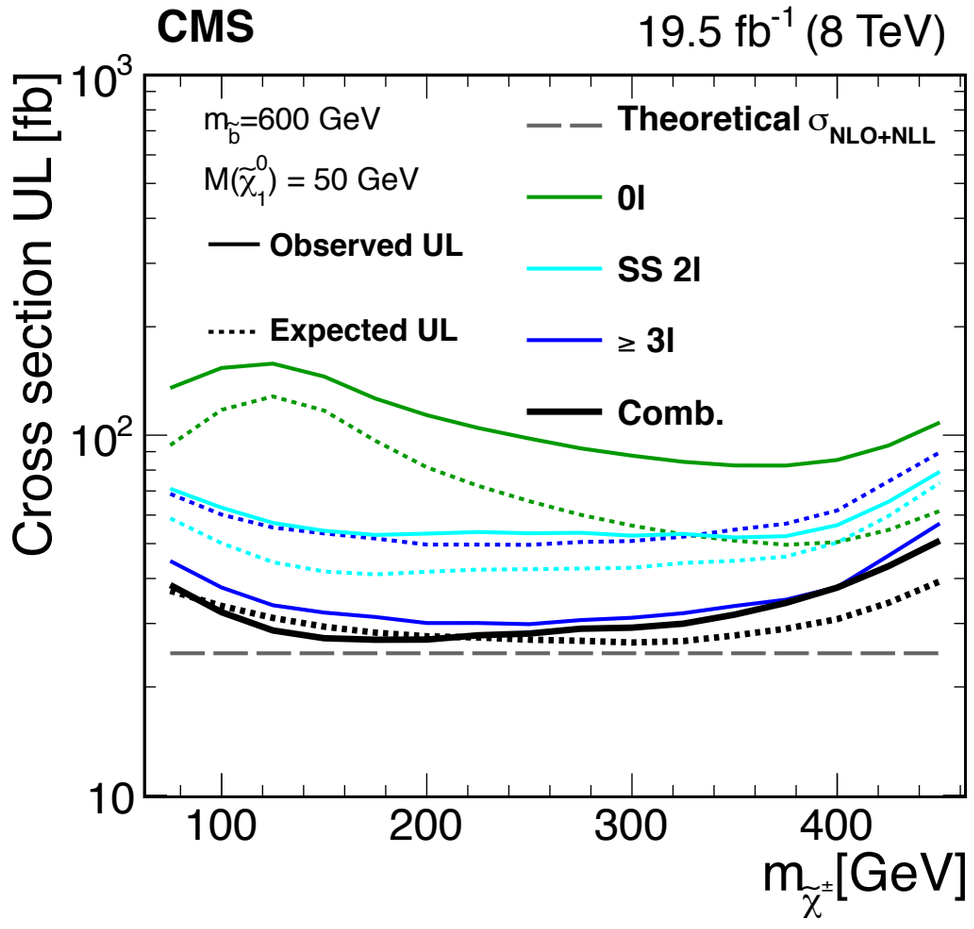


b+4W

Combination of 3 mutually exclusive searches*

0L + SS 2L + >3L

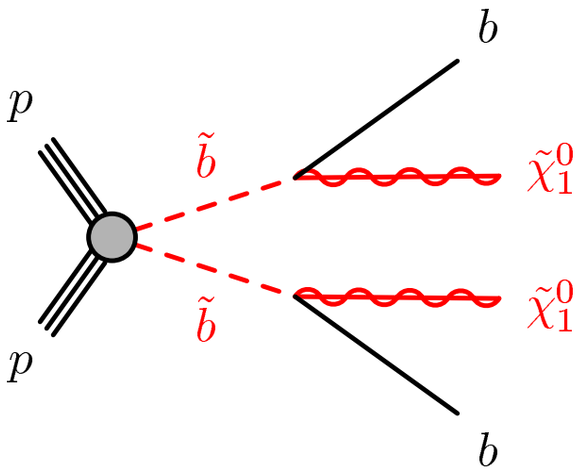




*5 searches are explored, but 0L and OS2L have no sensitivity to this particular model

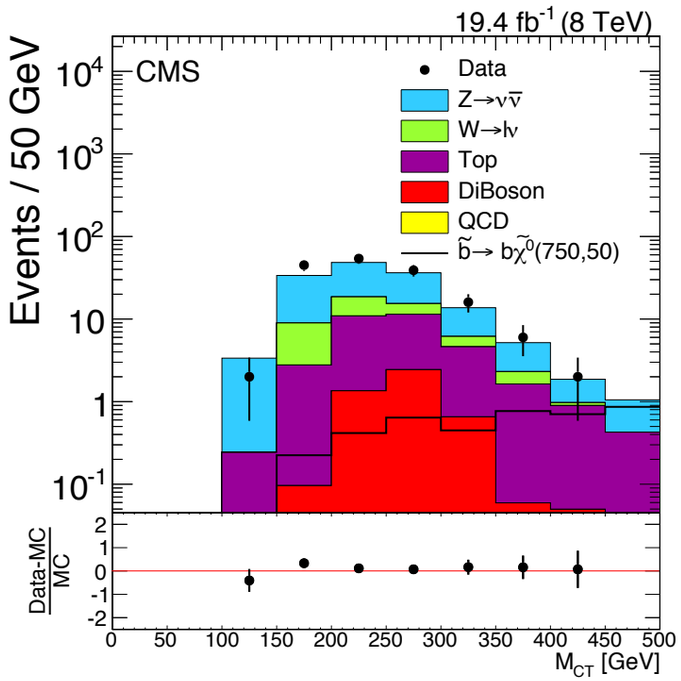
Combine and conquer!

+ sbottom decays



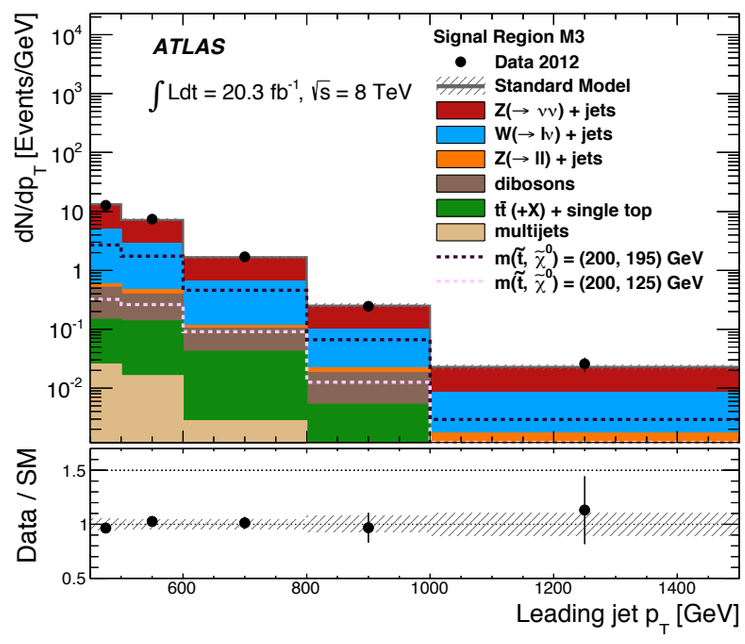
0L+2B

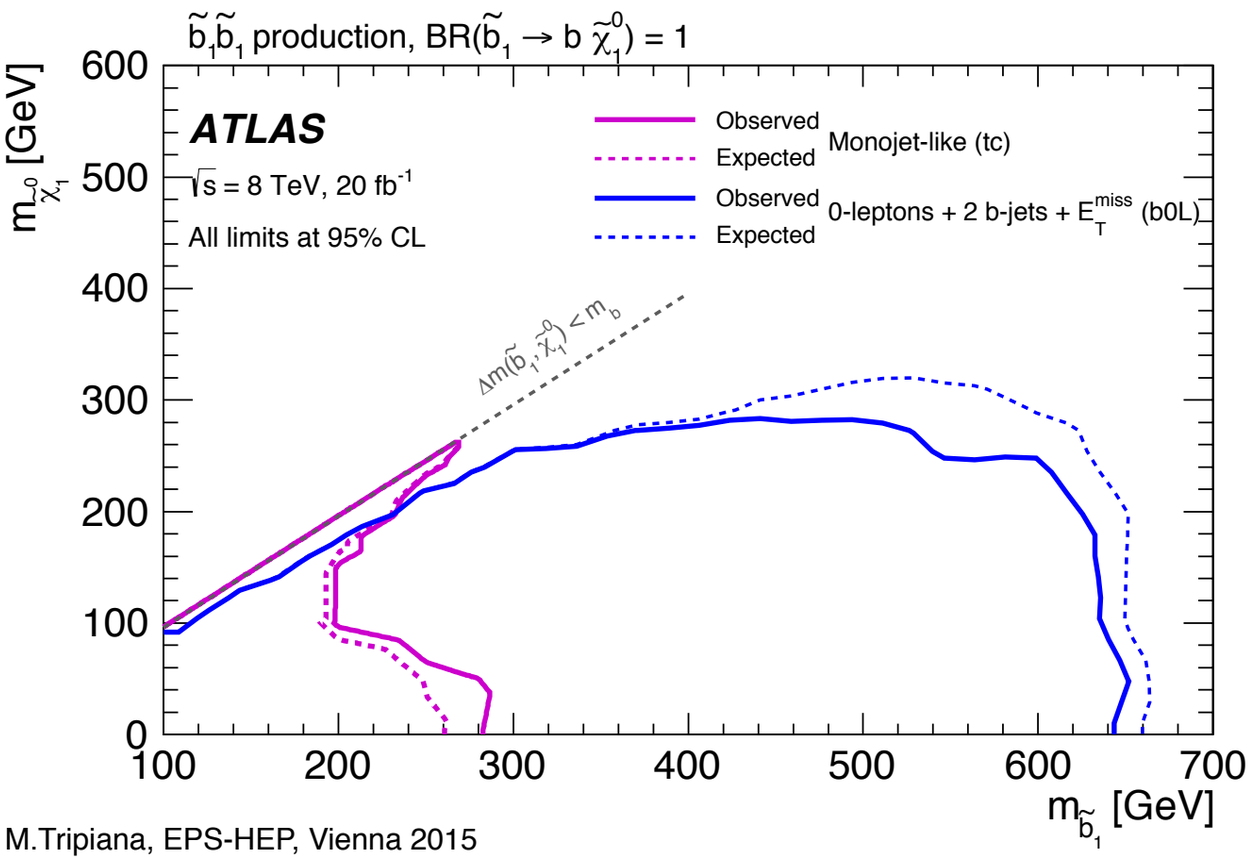
+ MET + m_{CT}

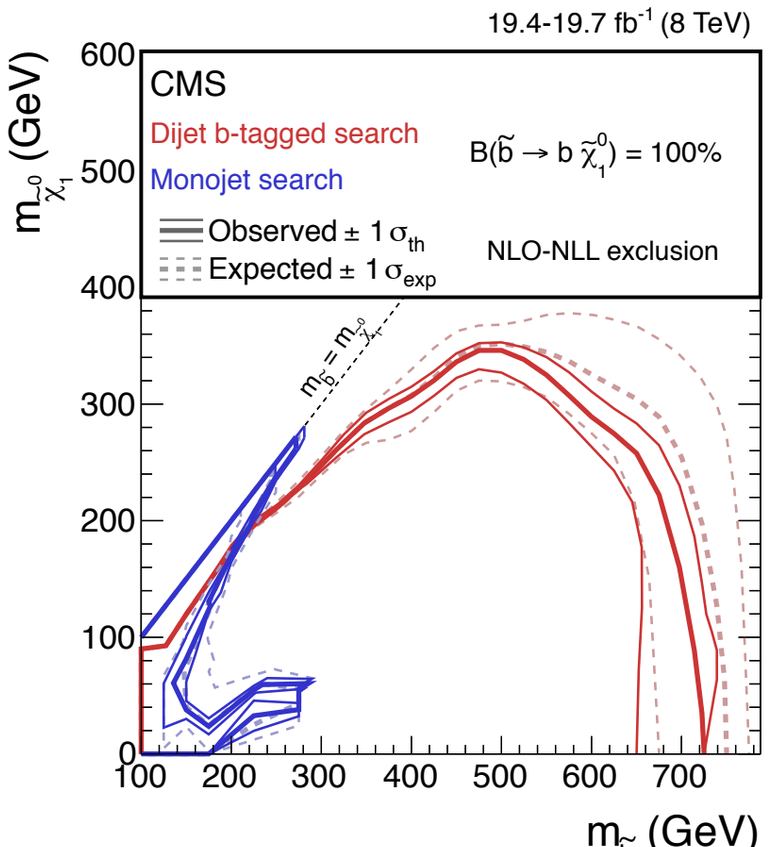


Monojet

1 hard ISR jet + MET



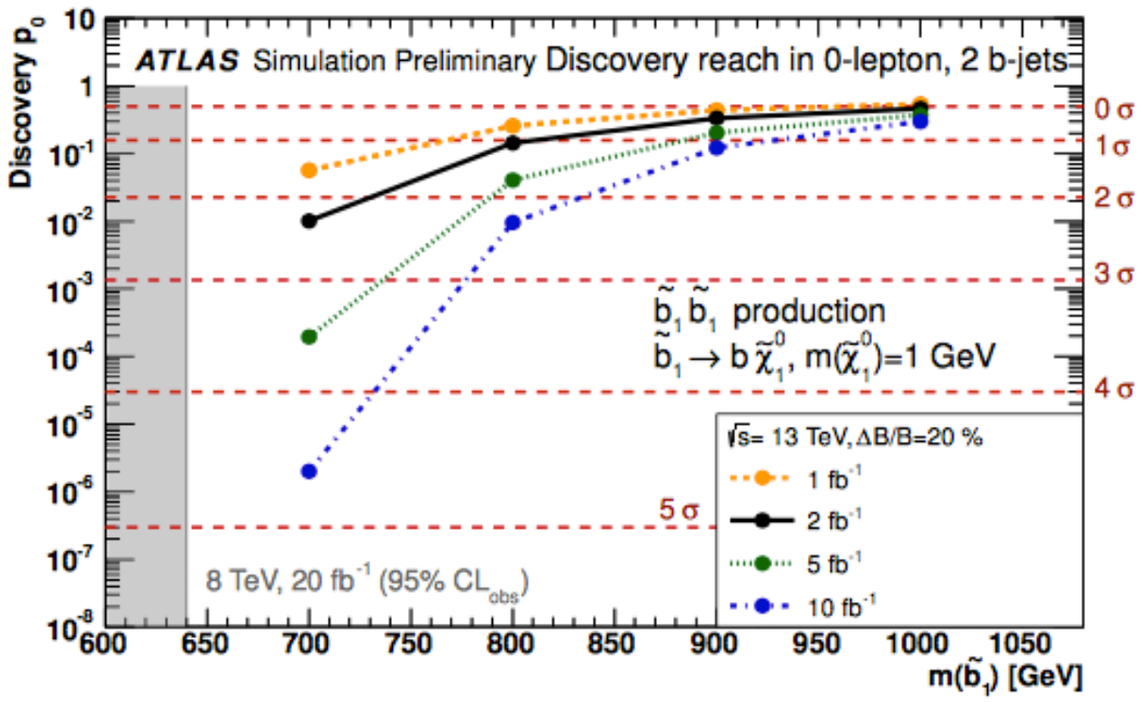




Summary

- Despite our best efforts, no evidence for SUSY 3G in Run 1
  - but we have learnt a lot!
  - and significantly squeezed the parameters phase space

- CMS and ATLAS have been preparing intensively for Run2
  - a full programme is already in place
  - all hands on the 13TeV data that's already here!



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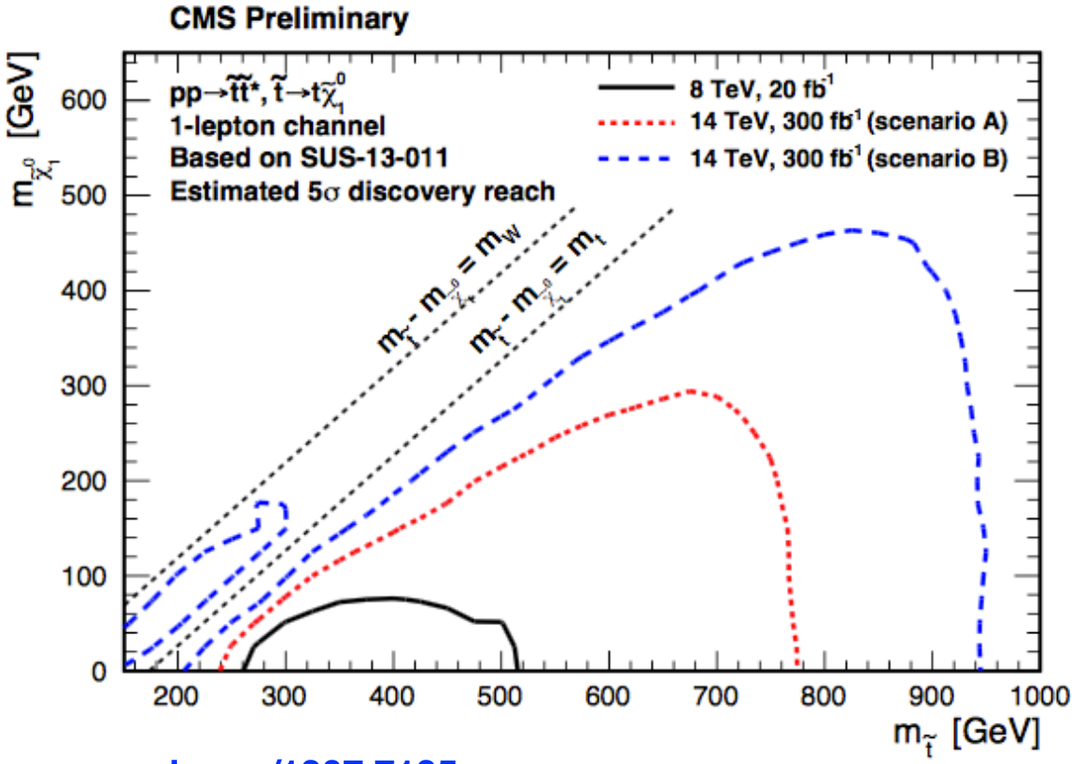

arxiv.org/1307.7135


STAY
TUNED

- BACKUP

Combine and conquer!

Stop decays with a chargino in the decay chain