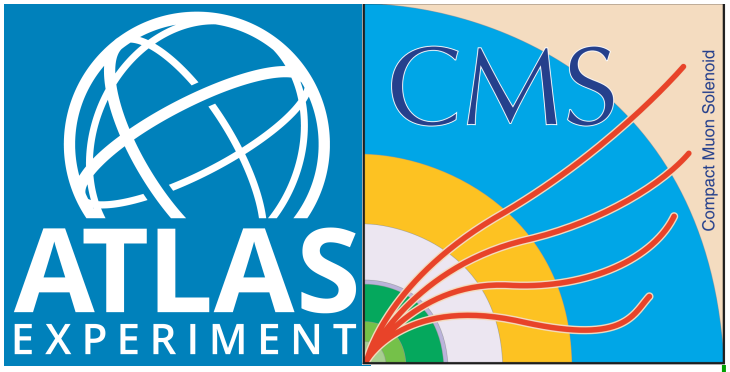


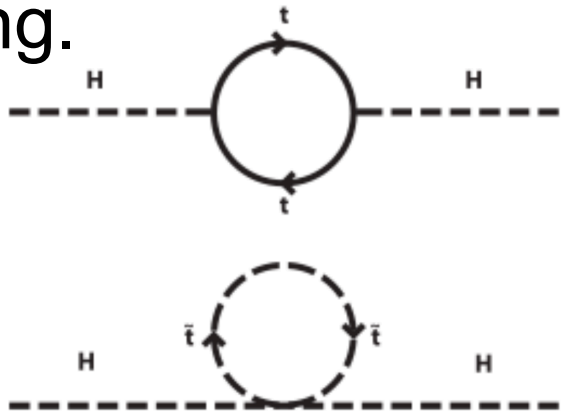
Searches for direct production of 3rd generation squarks (RPC and RPV)

LHCP2018 on 4-9 June

Yu Nakahama (Nagoya University)
for the ATLAS and CMS collaborations

Introduction: Naturalness

- Light stop “O(1) TeV” is required for SUSY to solve the fine tuning problem of the Higgs mass 125 GeV.
- Yukawa can give large stop$_{LR}$ mixing.

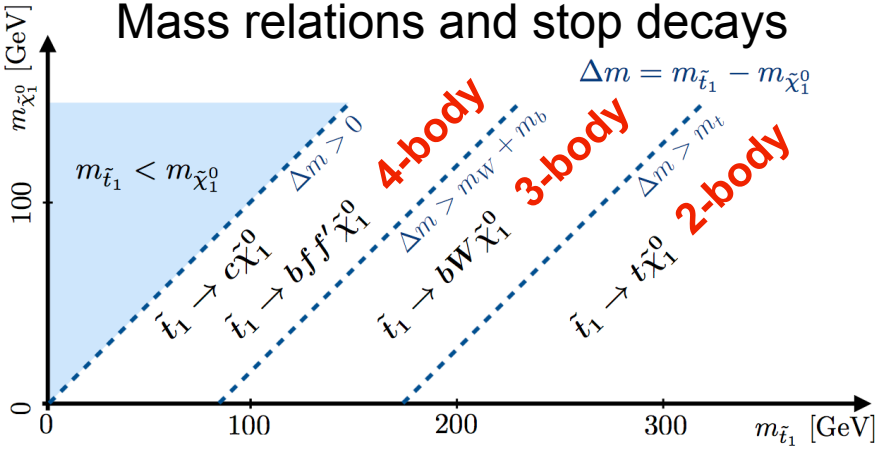


- Stop and sbottom via direct pair production can be within our reach at LHC.
  - e.g. In the 2015+2016 36 fb^{-1} pp data, would expect 10 events with stop pairs each with a mass of 1.5 TeV.

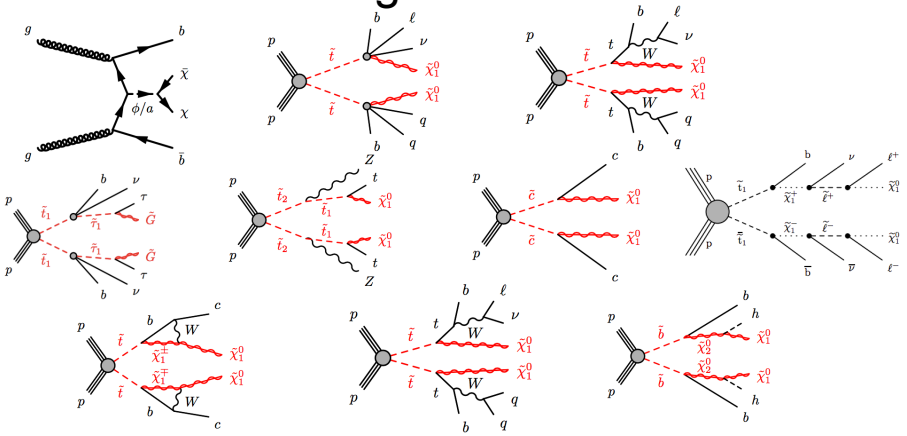
Overview of stop searches

- With bino LSP, stop$_1$ and neutralino$_1$ can be the only light sparticles.
  - Depending on (stop$_1$, N$_1$) mass splitting, stop$_1$ can decay via 2,3,4-body.
- With wino NLSP or Higgsino LSP, even more light sparticles exist.

Mass relations and stop decays



Considered diagrams



→In order to fully cover these rich signatures with various final states, a broad search program has been performed both in ATLAS and CMS since Run-1.

Publications in stop/sbottom searches

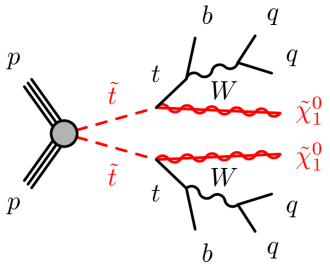
- This talk reviews the current status, with focus on the conventional analyses with recent technique improvements and NEW results.

Channel	ATLAS	CMS
Stop 0L	JHEP 12 (2017) 085	JHEP 10 (2017) 005
Stop 1L	arXiv: 1711.11520, to JHEP (with DM interpretation)	JHEP 10 (2017) 019, arXiv: 1805.05784 (for compressed mass spectra)
Stop 2L	EPJC 77 (2017) 898	Phys. Rev. D 97 (2018) 032009 (with DM and longer-decay interpretations), arXiv:1801.01846 (2 soft OS L), SUS-17-010 (2L OS for compressed mass spectra)
Stop with Z/h	JHEP 08 (2017) 006	JHEP 02 (2018) 067 (multi leptons)
Stop to stau	arXiv: 1803.10178, to PRD	-
Stop to charm	arXiv: 1805.01649, to JHEP NEW	Phys. Lett. B 778 (2018) 263, EPJC 77 (2017) 710 (0L)
Sbottom	JHEP 11 (2017) 195	Phys. Lett. B 778 (2018) 263
RPV stop	Eur. Phys. J. C 78 (2018) 250 (4j paired resonance), Phys. Rev. D 97 (2018) 032003 (B-L), JHEP09 (2017) 088 (1L+multi-jets)	CMS-PAS-EXO-16-029 (4 quarks via two fat jets with 2.7 fb^{-1}) CMS-PAS-EXO-17-021 NEW
RPV re-interpretation	ATLAS-CONF-2018-003	-

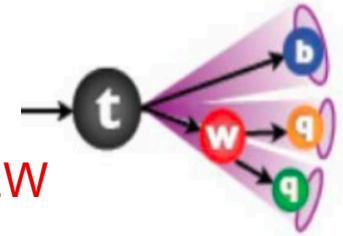
Full list of publications at:
ATLAS: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults
CMS: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

Stop 0L

JHEP 10 (2017) 005



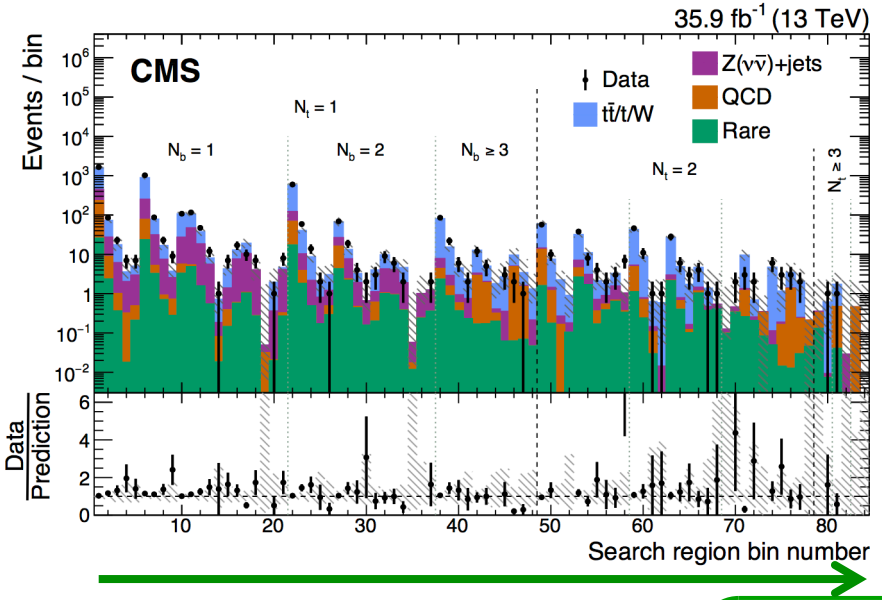
- Signature: 0L + E_T^{miss} + ≥2 jets with ≥1 *b*-tagged
- Customized top reconstruction for a large range of *t*-quark p_T
  - Fully merged (boosted top)
  - Partially merged (merged W-jet) NEW
  - Resolved (by MVA trained on jet properties e.g. p_T, mass)



- Low-p_T *b*-tagging 10 GeV based on presence of secondary vtx.
- 84 Signal Regions (binned in N_{top}, N_{bjets}, E_T^{miss}, and M_{T2}/H_T)

→ No significant excess from the SM background in data SR

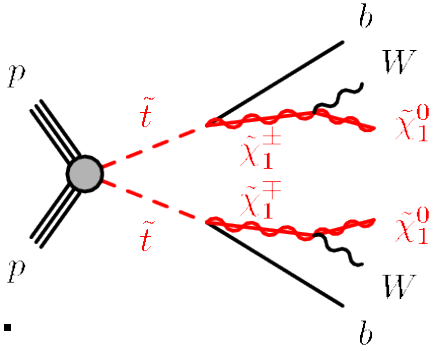
- 10 aggregate SRs (for simplifying re-interpretation)

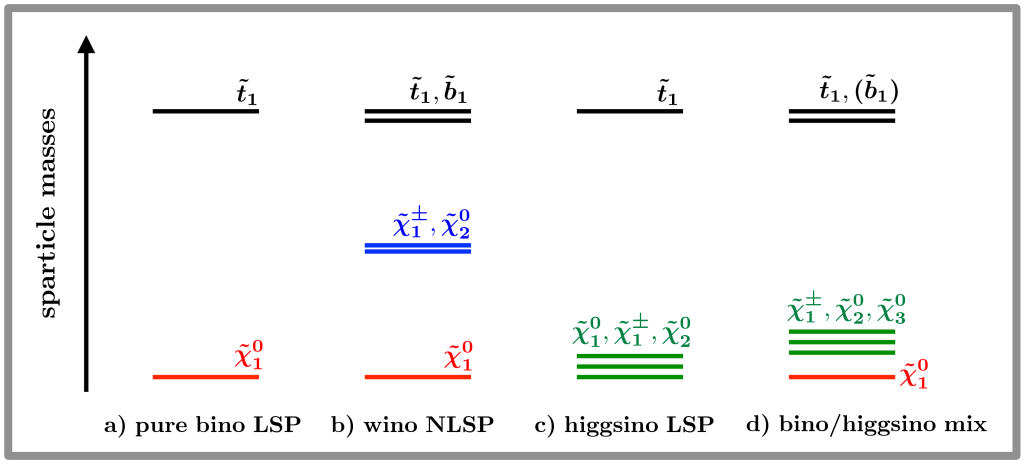


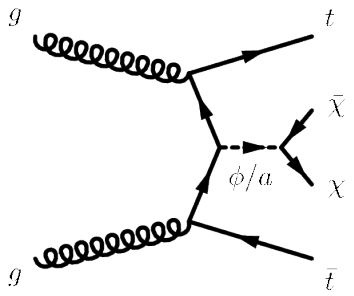
Stop 1L

arXiv: 1711.11520, submitted to JHEP

- Signature: 1 isolated μ/e + E_T^{miss} + ≥4 jets with one *b*-tagged
- Many SRs cover various mass spectra under different LSP scenarios and DM-inspired model.







DM-inspired model

- Inclusive SRs and dedicated SRs to fill gaps.
  - For compressed mass spectra in 2-body decay, use BDT. NEW
  - For 3-body decay, shape-fit in asymmetric stransverse mass am_{T2}.
  - For 4-body decay, soft-lepton selection with shape-fit in $p(l)/E_T^{miss}$.

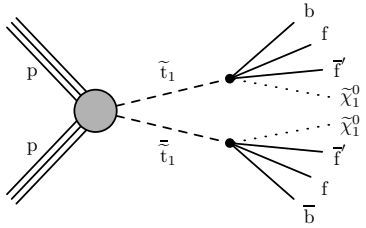
→ No significant excess from SM background in data SR.

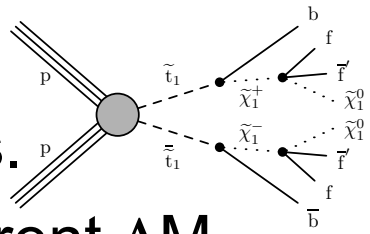
Stop soft-1L

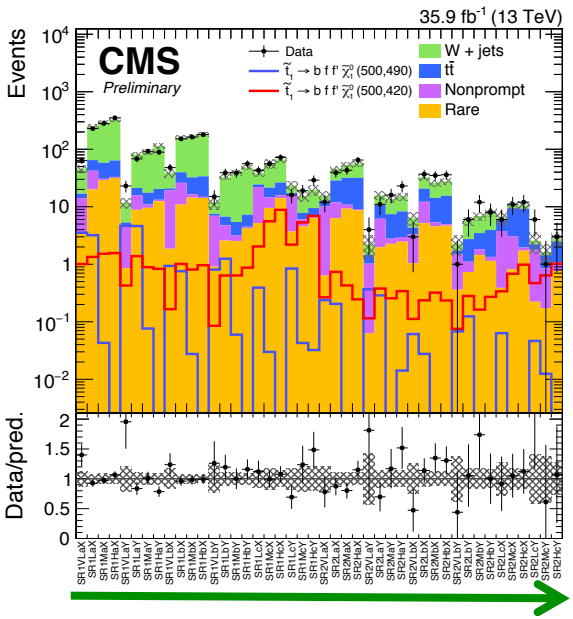
arXiv: 1805.05784

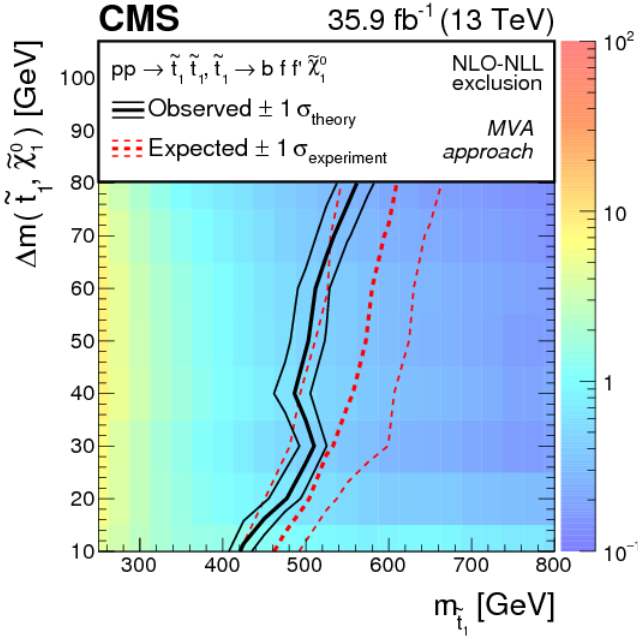
- Dedicated search for compressed stops with $\Delta M < m(W_{off\text{-}shell})$ in 4-body and C-mediated decays.
- Use ISR jet to boost the system and detect soft products with sizable E_T^{miss}.
- Signature: 1 soft-μ/e p_T>3.5(5) GeV+E_T^{miss}+≤2 jets.
- Two approaches: cut & count. 8 BDT SRs for different ΔM.

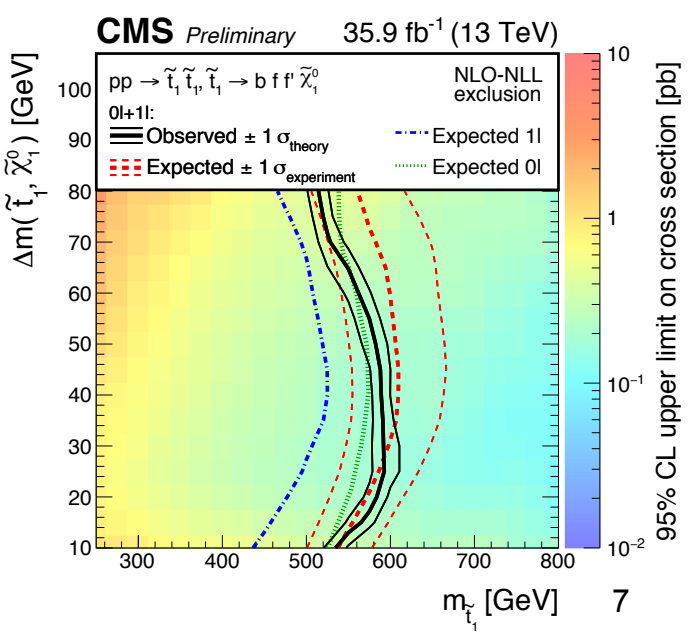
→ No significant excess. Interpreted by soft 1L and comb of 0/1L.



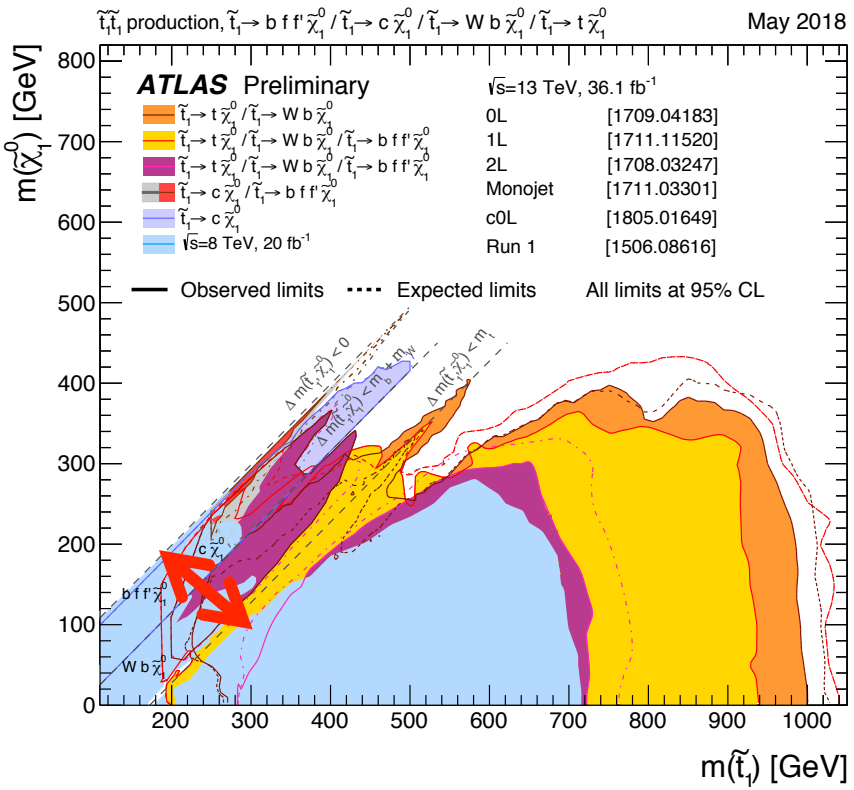


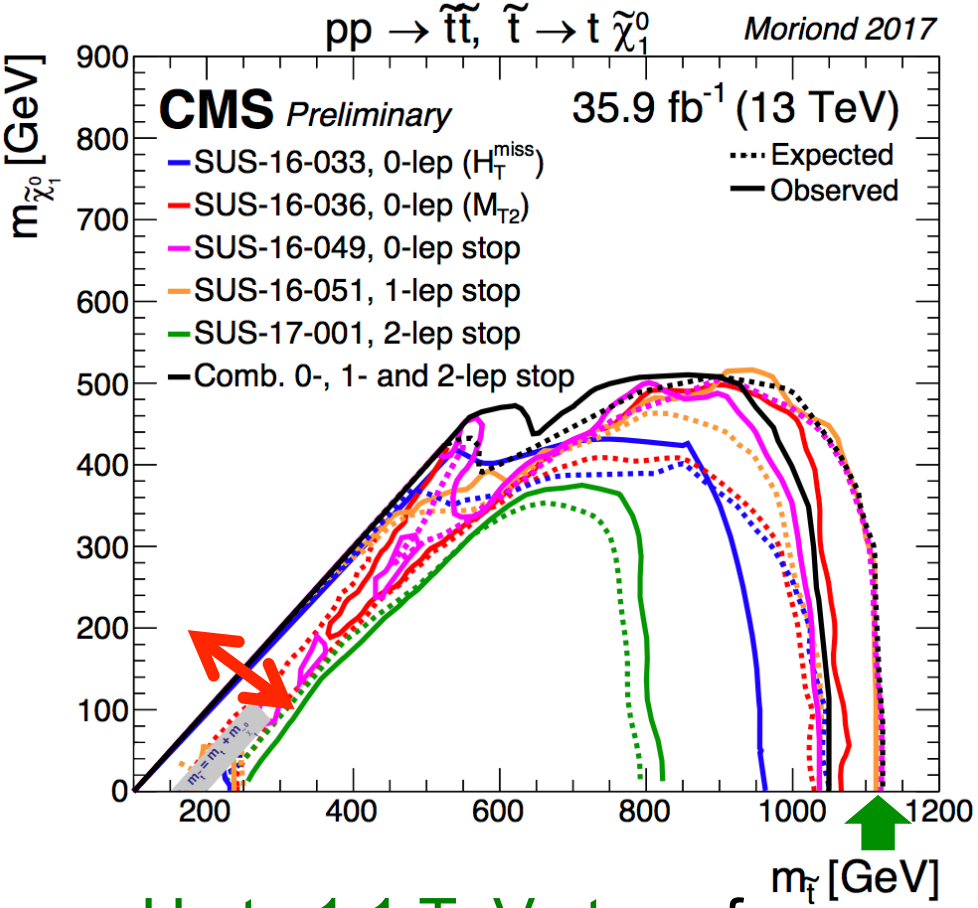






Interpretations by 0L/1L, 2L and monojet





- Dedicated SRs improved sensitivities to 2-body diagonal, 3-body and 4-body decays.
- Up to 1.1 TeV stops for a massless neutralino1.

Additional stop interpretations by stop 0L/1L

- Interpreted on different LSP scenarios and assumptions.

Wino NLSP: M_2=2xM_1

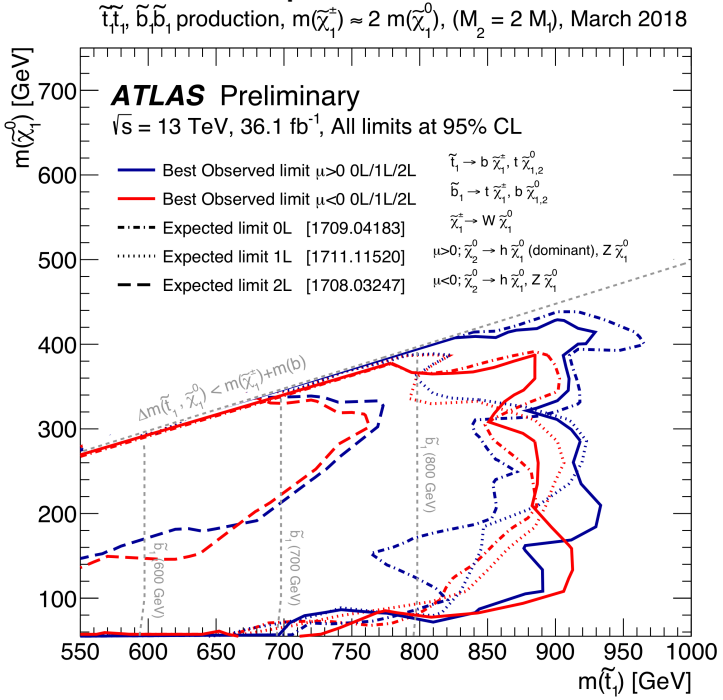
BRs can be different if one of considered decays is kinematically accessible.

Different colors correspond to different assumption here.

$\tilde{t}_1, \tilde{b}_1$

$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$

$\tilde{\chi}_1^0$

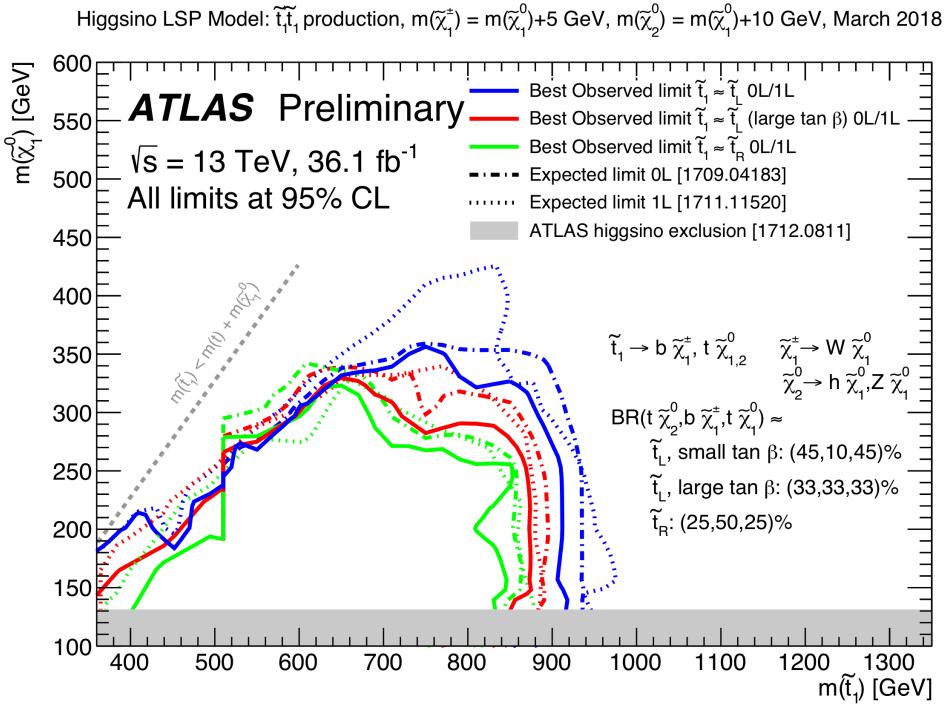


Higgsino LSP:

Three sets of BRs are assumed.

$\tilde{t}_1$

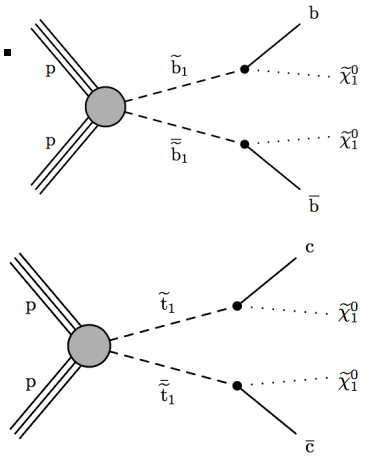
$\tilde{\chi}_1^0, \tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$



- Limits are weaker than in more simplified model with 100 % BR.

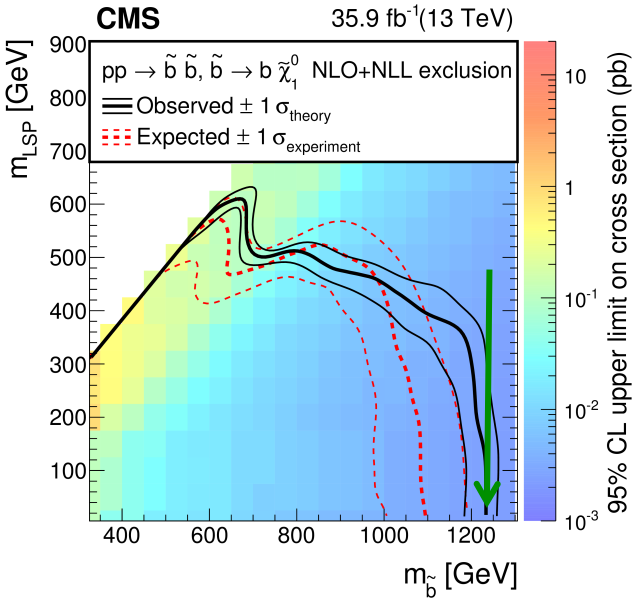
sbottom and stop to charm Phys. Lett. B 778 (2018) 263

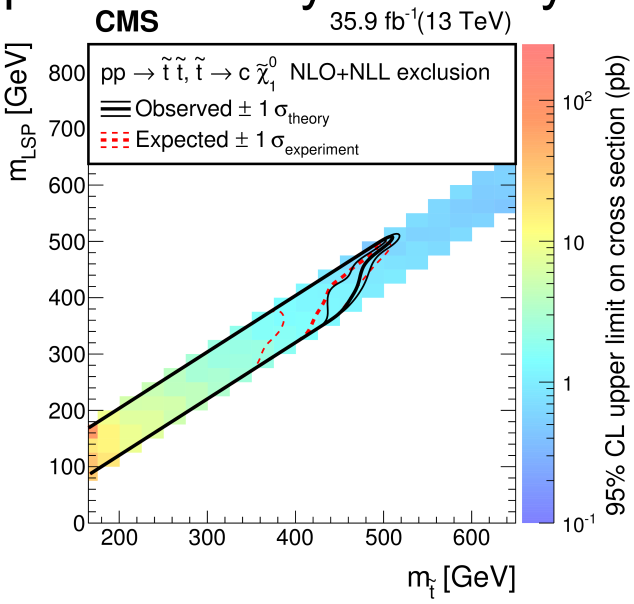
- Direct sbottom or stop pair production with *b*/*c* jets.
- Two channels:
  - Non-compressed: two leading jets with *b*-tagged.
  - Compressed (ΔM <10GeV): ISR jet. Binned in H_T, N_{bjets}, N_{cjets} and N_{SV}.

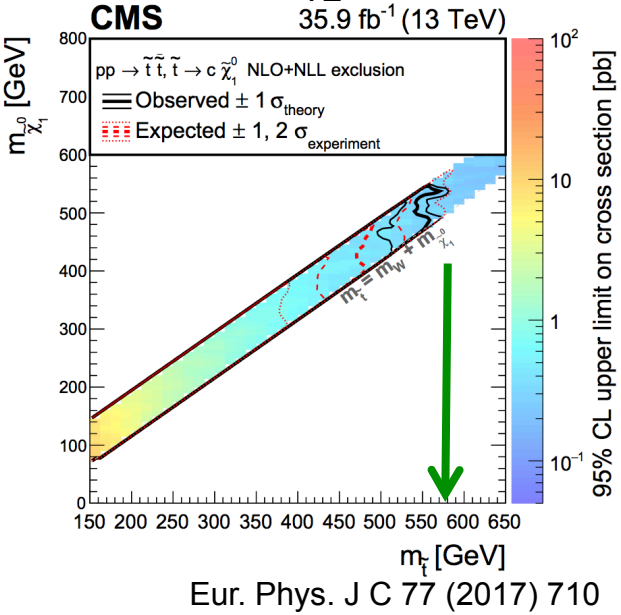


→ No significant excess in data SR.

Sbottom Stop to charm by this analysis by 0L M_{T2}







Eur. Phys. J C 77 (2017) 710

→ Up to 1.23 TeV sbottoms and 560 GeV stops (to charm).

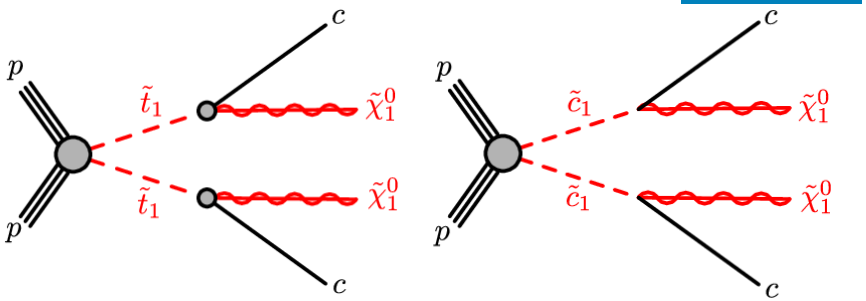
stop to charm

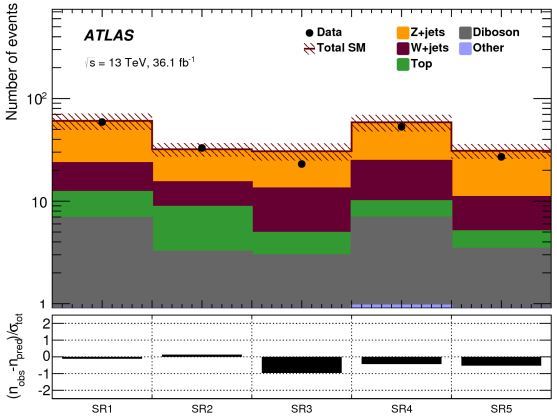
NEW

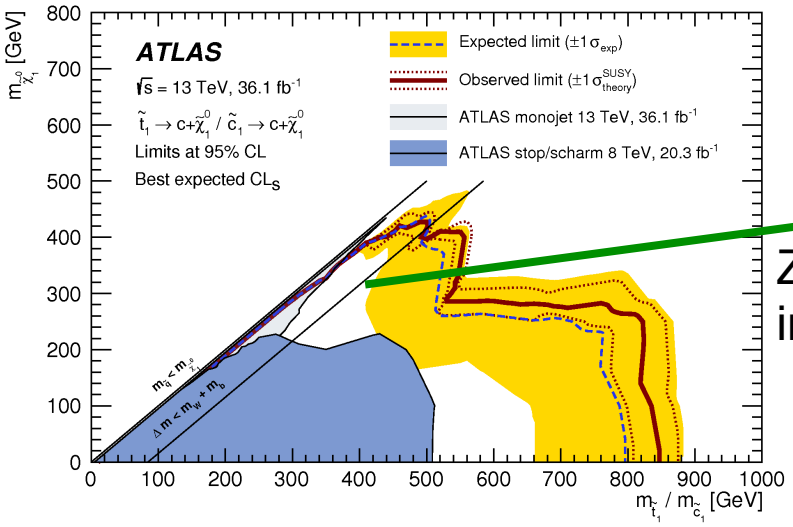
arXiv: 1805.01649, to JHEP

- Signature: 0L + E_T^{miss} + ≥2 jets with ≥1 *c*-tagged.
- Use charm tagging and ISR jet.
- Five loose SRs with different N_{jets}, M_T, $p_T(j)$ for a wide range of Δm.

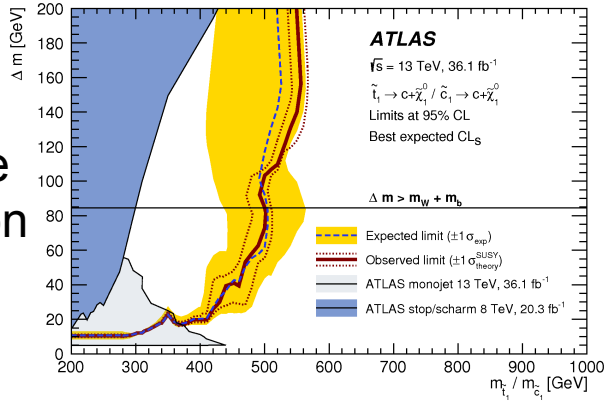
→ No significant excess in data SR.







Zooming here in Δm direction



stop to stau

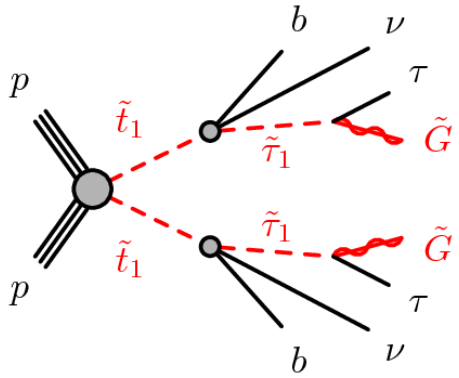
arXiv: 1803.10178, submitted to PRD

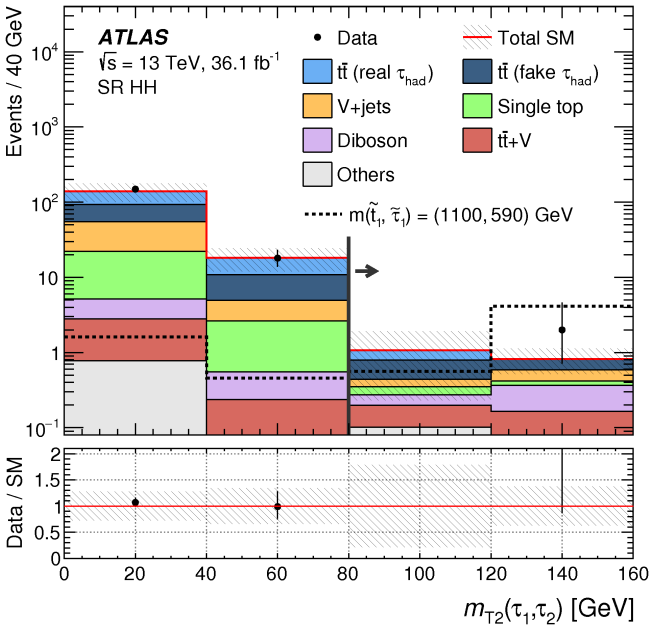
- Motivated by tau-rich GGM/GMSB models.
- Two channels: $\tau_{lep}\tau_{had}$, $\tau_{had}\tau_{had}$ with large E_T^{miss} and m_{T2}.

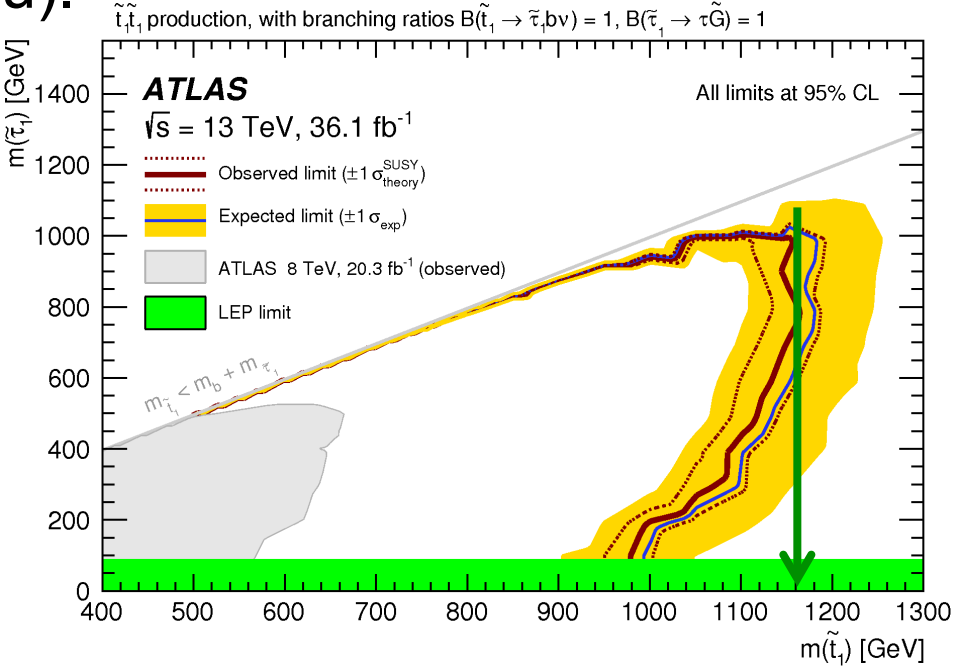
→ No significant excess in data SR.

- Interpreted by combination of the two channels.

→ Up to 1.16 TeV stops (to stau).



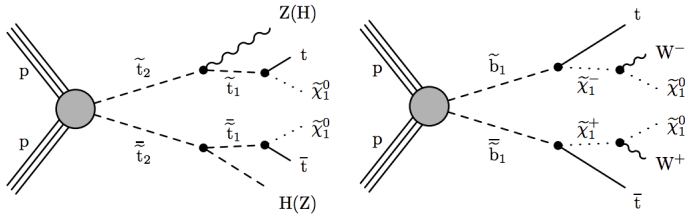


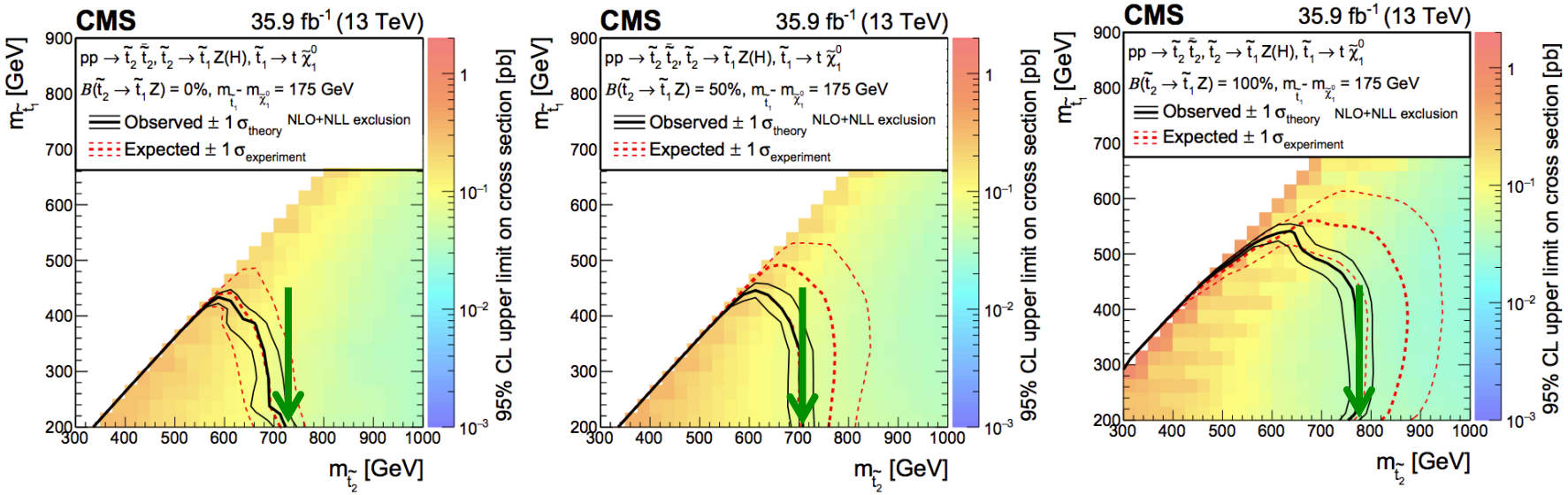


stop multi-lepton

JHEP 02 (2018) 067

- Stop2 production with Z and H.
- Two channels: for on-Z and off-Z each with ≥ 3L + ≥ 2jets + m(ll) window.
  - 23 SRs each, depending on N_{bjets}, H_T, E_T^{miss} selections.
- No significant excess in data SR.
- Interpreted on m(stop2)-m(stop1) with different BR assumption.





  - Competitive results from ATLAS using dedicated Z(→ll) and H(→bb) SRs on the same stop2 decay model, slightly different Δm assumptions.

RPV stop

Phys. Rev. D 97 (2018) 032003
Eur. Phys. J. C 78 (2018) 250
ATLAS-CONF-2018-003

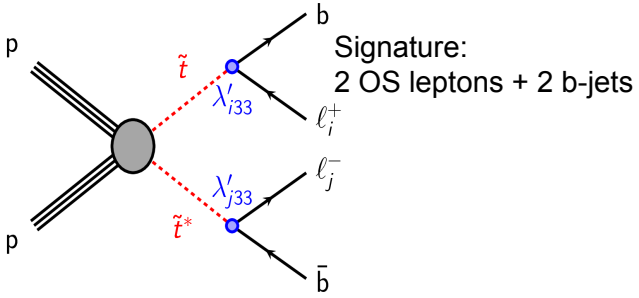
Lepton number (L) Violation

Baryon number (B) Violation

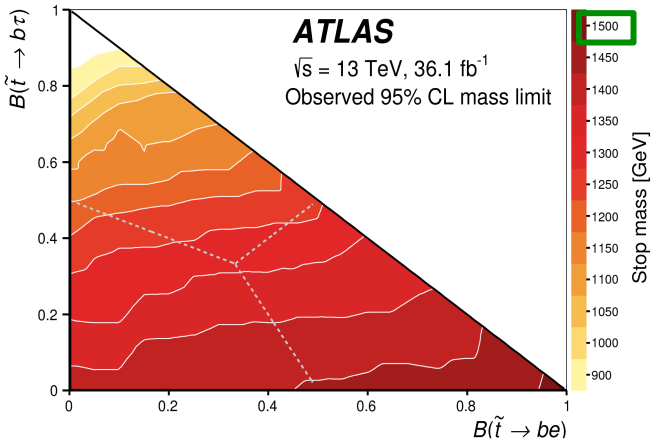
$$\mathcal{W}_{\mathrm{RPV}} = \frac{\lambda_{ijk}}{2} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \frac{\lambda''_{ijk}}{2} \bar{U}_i \bar{D}_j \bar{D}_k + \kappa_i L_i H_u$$

$R = (-1)^{3B+L+2S}$

LQD - λ'

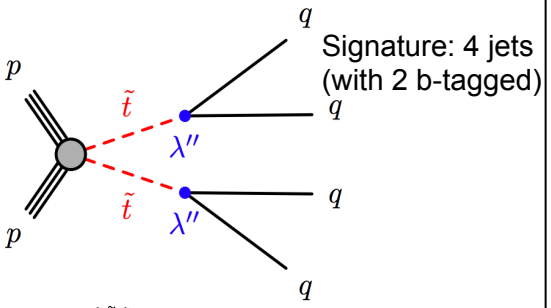


Signature:
2 OS leptons + 2 b-jets

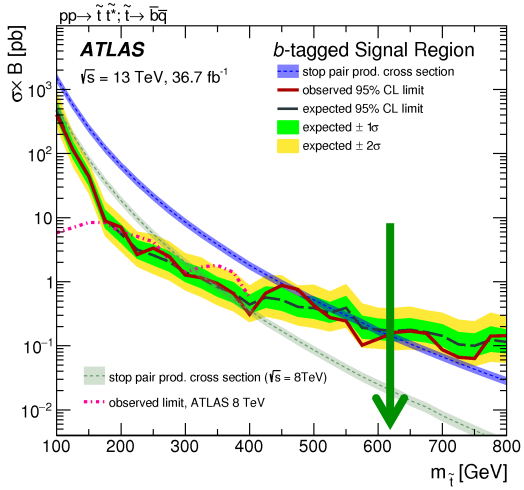


Excluded up to 1.5 TeV stops, depending on BR.

UDD - λ''



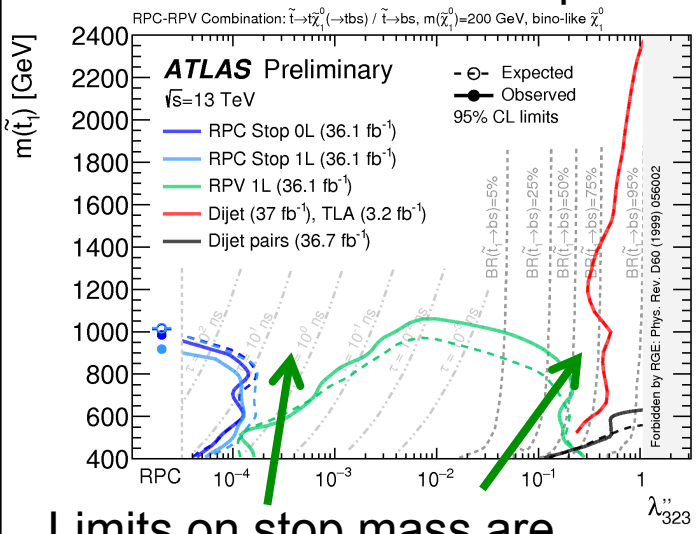
Signature: 4 jets
(with 2 b-tagged)



Up to 610 GeV stops.

Varied the strength of UDD - λ''.
Interpreted by existing RPC and RPV analyses.

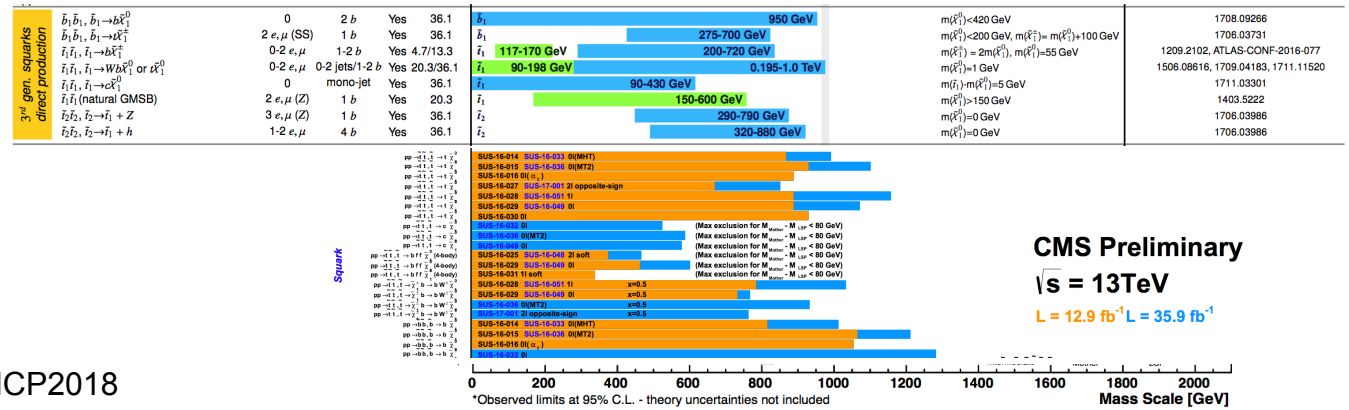
Transitions from
Stable N → RPV N →stop RPV



Limits on stop mass are weaker in the gaps.

Summary

- Many results from ATLAS and CMS in searches for 3rd generation squarks with the 2015+2016 dataset 36 fb^{-1}.
  - A comprehensive search program to cover considered mass spectra and also to fill the gaps.
  - New scenarios and significant improvements in analysis techniques from the previous searches.
- No significant excess above the SM expectation found.
  - Limits are set on the stop and sbottom masses.
- Stay tuned for results with the full Run-2 dataset.

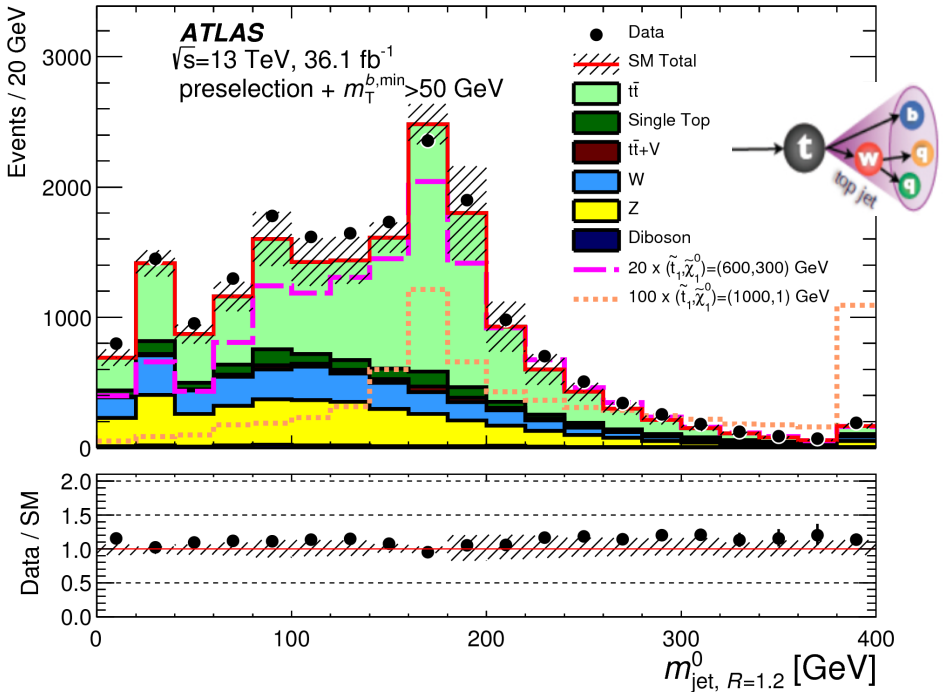


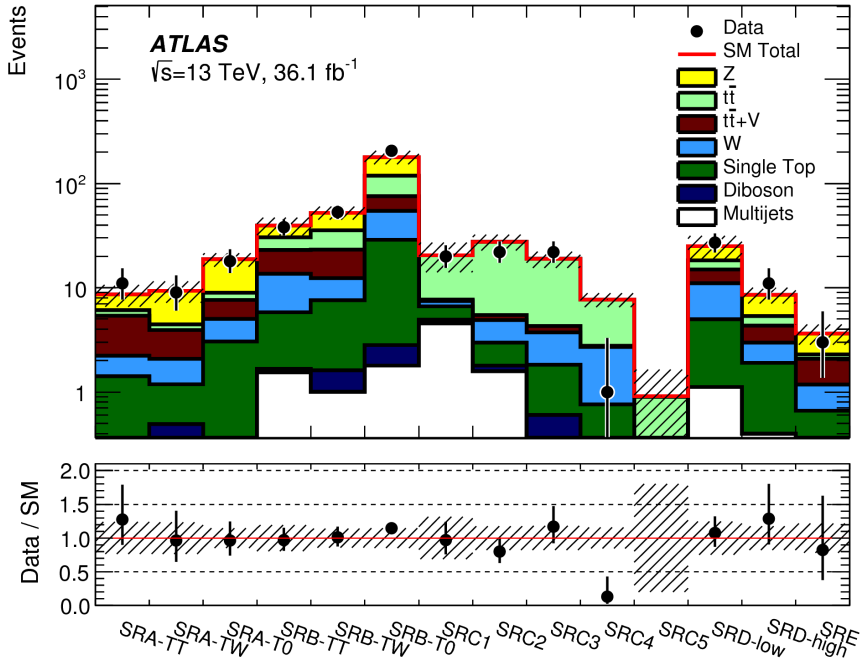
- Backup

Stop 0L

JHEP 12 (2017) 085

- Signature: 0L + E_T^{miss} + ≥4 jets with two *b*-tagged.
- For high mass stop, top reconstruction with large-radius jets (R=1.2) in boosted topology.
- For compressed mass spectra, Rjigsaw techniques.
- 14 SRs → No significant excess from SM background in data.





stop to Z/H

JHEP 08 (2017) 006

- Stop1 production with Z and H.
- Two channels
  - Z→ll: three SRs for different ΔM with 3L + 1 bjet + E_T^{miss}.
  - H→bb: three SRs with with ≥1L + 4 bjets+ large E_T^{miss}.
- No significant excess in data SR
- Also reinterpreted on stop2 pair production.