

Searches for strong production of supersymmetric particles

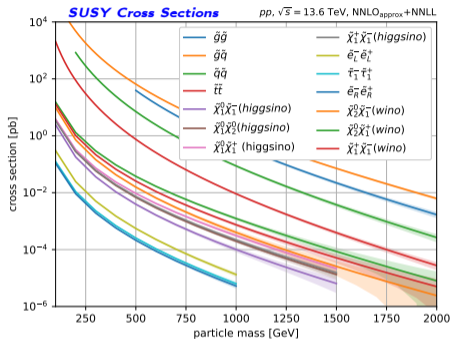
Francesco Giuseppe Gravili on behalf of the ATLAS Collaboration

University of Salento & INFN Unit of Lecce

35th Rencontres de Blois - October, 23rd 2024



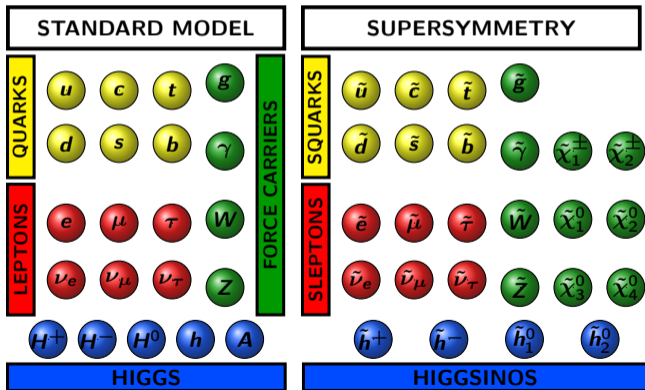
Supersymmetry (SUSY)



- Broad search program at the LHC
- *Simplified Models* for optimisation:
 - ▶ 100% Branching Ratios (BR)
 - ▶ A few particle masses as free parameters
- Electroweak searches in *Ben's talk*
- Long-lived searches in *Ian Alejandro's talk*

Possible solution for Standard Model shortcomings:

- Dark Matter (DM)
- Fine-tuning of the Higgs mass
- Unification of the forces (gravity)



ATLAS Latest Results

● CERN-EP-2024-136

R-Parity Violating
 $\tilde{t}_1 \rightarrow bl$

● JHEP 03 (2024) 139

Search for new phenomena with top-quark pairs and large missing transverse momentum

● JHEP 07 (2024) 250

$\tilde{t}_1 \rightarrow (t/c) + \tilde{\chi}_1^0$ **NEW**

● CERN-EP-2024-218

Search for supersymmetry in final states with missing transverse momentum and c-tagged jets at 139 fb^{-1}

ATLAS SUSY Searches* - 95% CL Lower Limits

July 2024

SUSY Public Results

ATLAS Preliminary

$\sqrt{s} = 13 \text{ TeV}$

	Model	Signature	$[L dt] [\text{fb}^{-1}]$	Mass limit	Reference
Inclusive Searches	$\tilde{g}, \tilde{q} \rightarrow q\tilde{g}^0$	0 ν, μ , mono-jet	$L_{\text{int}}^{\text{mono-jet}}$ 140	\tilde{g} [14, 84 Dapkin] 1.28	$m(\tilde{g}) > 450 \text{ GeV}$
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{g}^0$	1-3 jets	$L_{\text{int}}^{\text{1-3 jets}}$ 140	\tilde{g} [84 Dapkin] 0.9	$m(\tilde{g})-m(\tilde{t}_1) > 5 \text{ GeV}$
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{g}^0$	2-6 jets	$L_{\text{int}}^{\text{2-6 jets}}$ 140	\tilde{g} 2.3	$m(\tilde{g}) > 9 \text{ GeV}$
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{g}^0$	0 ν, μ , 2 jets	$L_{\text{int}}^{\text{0 } \nu, \mu, \text{ 2 jets}}$ 140	Forbidden 1.15-1.98	$m(\tilde{g}) > 1000 \text{ GeV}$
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{g}^0$	0 ν, μ , 7-11 jets	$L_{\text{int}}^{\text{0 } \nu, \mu, \text{ 7-11 jets}}$ 140	\tilde{g} 2.2	$m(\tilde{g}) > 800 \text{ GeV}$
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{g}^0$	0 ν, μ , 3 b jets	$L_{\text{int}}^{\text{0 } \nu, \mu, \text{ 3 b jets}}$ 140	\tilde{g} 1.97	$m(\tilde{g}) > 800 \text{ GeV}$
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{g}^0$	0 ν, μ , 3 b jets	$L_{\text{int}}^{\text{0 } \nu, \mu, \text{ 3 b jets}}$ 140	\tilde{g} 1.15	$m(\tilde{g}) > 200 \text{ GeV}$
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{g}^0$	0 ν, μ , 6 jets	$L_{\text{int}}^{\text{0 } \nu, \mu, \text{ 6 jets}}$ 140	\tilde{g} 2.45	$m(\tilde{g}) > 200 \text{ GeV}$
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{g}^0$	0 ν, μ , 6 jets	$L_{\text{int}}^{\text{0 } \nu, \mu, \text{ 6 jets}}$ 140	\tilde{g} 1.25	$m(\tilde{g}) > 300 \text{ GeV}$
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{g}^0$	0 ν, μ , 2 b	$L_{\text{int}}^{\text{0 } \nu, \mu, \text{ 2 b}}$ 140	\tilde{g} 1.255	$m(\tilde{g}) > 400 \text{ GeV}$
3 rd gen. states direct production	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	0 ν, μ , 2 b	$L_{\text{int}}^{\text{0 } \nu, \mu, \text{ 2 b}}$ 140	\tilde{t}_1 0.68	$m(\tilde{t}_1) > 10 \text{ GeV}, m(\tilde{b}_1) > 10 \text{ GeV}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	0 ν, μ , 6 b	$L_{\text{int}}^{\text{0 } \nu, \mu, \text{ 6 b}}$ 140	\tilde{t}_1 0.25-1.35	$m(\tilde{t}_1) > 100 \text{ GeV}, m(\tilde{b}_1) > 100 \text{ GeV}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	0 ν, μ , 2 τ	$L_{\text{int}}^{\text{0 } \nu, \mu, \text{ 2 } \tau}$ 140	\tilde{t}_1 0.13-0.85	$m(\tilde{t}_1) > 100 \text{ GeV}, m(\tilde{b}_1) > 100 \text{ GeV}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	1 ν, μ , 3 jets+1 b	$L_{\text{int}}^{\text{1 } \nu, \mu, \text{ 3 jets+1 b}}$ 140	\tilde{t}_1 1.05	$m(\tilde{t}_1) > 200 \text{ GeV}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	0 ν, μ , 2 c	$L_{\text{int}}^{\text{0 } \nu, \mu, \text{ 2 c}}$ 140	\tilde{t}_1 0.85	$m(\tilde{t}_1) > 100 \text{ GeV}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	0 ν, μ , 1 b	$L_{\text{int}}^{\text{0 } \nu, \mu, \text{ 1 b}}$ 140	\tilde{t}_1 0.44	$m(\tilde{t}_1) > 200 \text{ GeV}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	1-2 ν, μ , 1-4 b	$L_{\text{int}}^{\text{1-2 } \nu, \mu, \text{ 1-4 b}}$ 140	\tilde{t}_1 0.067-1.18	$m(\tilde{t}_1) > 200 \text{ GeV}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	2 ν, μ , 1 b	$L_{\text{int}}^{\text{2 } \nu, \mu, \text{ 1 b}}$ 140	Forbidden 0.86	$m(\tilde{t}_1) > 300 \text{ GeV}, m(\tilde{b}_1) > 40 \text{ GeV}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	Multiple ℓ jets	$L_{\text{int}}^{\text{Multiple } \ell \text{ jets}}$ 140	\tilde{t}_1 0.205	$m(\tilde{t}_1) > 200 \text{ GeV}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	Multiple ℓ jets	$L_{\text{int}}^{\text{Multiple } \ell \text{ jets}}$ 140	\tilde{t}_1 0.42	$m(\tilde{t}_1) > 200 \text{ GeV}, m(\tilde{b}_1) > 40 \text{ GeV}$
EW direct	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	2 ν, μ , 2 jets	$L_{\text{int}}^{\text{2 } \nu, \mu, \text{ 2 jets}}$ 140	\tilde{t}_1 1.06	$m(\tilde{t}_1) > 70 \text{ GeV}, m(\tilde{b}_1) > 70 \text{ GeV}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	2 ν, μ , 2 jets	$L_{\text{int}}^{\text{2 } \nu, \mu, \text{ 2 jets}}$ 140	\tilde{t}_1 1.0	$m(\tilde{t}_1) > 50 \text{ GeV}, m(\tilde{b}_1) > 50 \text{ GeV}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	2 ν, μ , 2 jets	$L_{\text{int}}^{\text{2 } \nu, \mu, \text{ 2 jets}}$ 140	\tilde{t}_1 0.38	$m(\tilde{t}_1) > 0$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	2 ν, μ , 2 jets	$L_{\text{int}}^{\text{2 } \nu, \mu, \text{ 2 jets}}$ 140	\tilde{t}_1 0.7	$m(\tilde{t}_1) > 0$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	0 jets	$L_{\text{int}}^{\text{0 jets}}$ 140	\tilde{t}_1 0.26	$m(\tilde{t}_1) > 10 \text{ GeV}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	0 ν, μ , ≥ 3 b	$L_{\text{int}}^{\text{0 } \nu, \mu, \geq 3 \text{ b}}$ 140	\tilde{t}_1 0.94	$BR(\tilde{t}_1 \rightarrow t\tilde{b}_1^0) > 1$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	4 ν, μ , 0 jets	$L_{\text{int}}^{\text{4 } \nu, \mu, \text{ 0 jets}}$ 140	\tilde{t}_1 0.55	$BR(\tilde{t}_1 \rightarrow t\tilde{b}_1^0) > 1$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	0 ν, μ , ≥ 2 large jets	$L_{\text{int}}^{\text{0 } \nu, \mu, \geq 2 \text{ large jets}}$ 140	\tilde{t}_1 0.45-0.93	$BR(\tilde{t}_1 \rightarrow t\tilde{b}_1^0) > 1$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	2 ν, μ , ≥ 2 jets	$L_{\text{int}}^{\text{2 } \nu, \mu, \geq 2 \text{ jets}}$ 140	\tilde{t}_1 0.77	$BR(\tilde{t}_1 \rightarrow t\tilde{b}_1^0) > 1$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	0 ν, μ , ≥ 2 jets	$L_{\text{int}}^{\text{0 } \nu, \mu, \geq 2 \text{ jets}}$ 140	\tilde{t}_1 0.66	$BR(\tilde{t}_1 \rightarrow t\tilde{b}_1^0) > 1$
Long-lived particles	Direct \tilde{t}_1, \tilde{b}_1 prod., long-lived \tilde{t}_1^0	Disapp. t+k	$L_{\text{int}}^{\text{Disapp. t+k}}$ 140	\tilde{t}_1^0 0.21	Pure Wino Pure Higgsino
	Stable β R-hadron	pixel dE/dx	$L_{\text{int}}^{\text{pixel dE/dx}}$ 140	\tilde{t}_1^0 2.05	$m(\tilde{t}_1^0) > 100 \text{ GeV}$
	Metastable β R-hadron, $\beta \rightarrow q\tilde{g}^0$	pixel dE/dx	$L_{\text{int}}^{\text{pixel dE/dx}}$ 140	\tilde{t}_1^0 [2] ($\beta > 10 \text{ ns}$)	$m(\tilde{t}_1^0) > 100 \text{ GeV}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	Diapl. lep	$L_{\text{int}}^{\text{Diapl. lep}}$ 140	\tilde{t}_1^0 0.74	$m(\tilde{t}_1^0) > 0.1 \text{ ns}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	pixel dE/dx	$L_{\text{int}}^{\text{pixel dE/dx}}$ 140	\tilde{t}_1^0 0.36	$m(\tilde{t}_1^0) > 0.1 \text{ ns}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	pixel dE/dx	$L_{\text{int}}^{\text{pixel dE/dx}}$ 140	\tilde{t}_1^0 0.36	$m(\tilde{t}_1^0) > 10 \text{ ns}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	0 jets	$L_{\text{int}}^{\text{0 jets}}$ 140	\tilde{t}_1^0 0.625	Pure Wino
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	4 ν, μ , 0 jets	$L_{\text{int}}^{\text{4 } \nu, \mu, \text{ 0 jets}}$ 140	\tilde{t}_1^0 1.05	$m(\tilde{t}_1^0) > 200 \text{ GeV}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	≥ 8 jets	$L_{\text{int}}^{\geq 8 \text{ jets}}$ 140	\tilde{t}_1^0 1.55	Large \tilde{t}_1^0
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	Multiple	$L_{\text{int}}^{\text{Multiple}}$ 36.1	\tilde{t}_1^0 0.95	$m(\tilde{t}_1^0) > 200 \text{ GeV}, m(\tilde{b}_1) > 200 \text{ GeV}$
RPV	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	$\geq 4b$	$L_{\text{int}}^{\geq 4b}$ 140	Forbidden 0.95	$m(\tilde{t}_1^0) > 200 \text{ GeV}$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	2 ν, μ , 2 b	$L_{\text{int}}^{\text{2 } \nu, \mu, \text{ 2 b}}$ 140	\tilde{t}_1^0 0.4-1.85	$BR(\tilde{t}_1 \rightarrow t\tilde{b}_1^0) > 20\%$
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	1-2 ν, μ , ≥ 6 jets	$L_{\text{int}}^{\text{1-2 } \nu, \mu, \geq 6 \text{ jets}}$ 140	\tilde{t}_1^0 0.2-0.32	Pure Higgsino
	$\tilde{t}_1, \tilde{b}_1 \rightarrow t\tilde{b}_1^0$	1-2 ν, μ , ≥ 6 jets	$L_{\text{int}}^{\text{1-2 } \nu, \mu, \geq 6 \text{ jets}}$ 140	\tilde{t}_1^0 0.2-0.32	Pure Higgsino

*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

10⁻¹ 1 Mass scale [TeV]

RPV $\tilde{t} \rightarrow b\ell$: Introduction

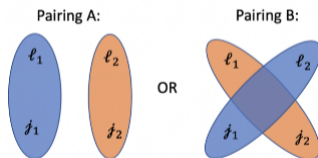
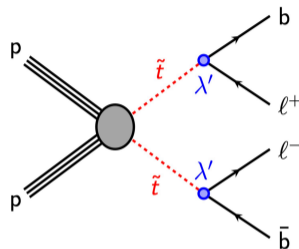
CERN-EP-2024-136

- B-L Model motivated by *theory*
- *Previous analysis* done on partial Run 2 dataset
- Identical branching ratios $\mathcal{B}(\tilde{t} \rightarrow \ell b) = 1/3$
- Final state: 2 oppositely charged leptons + 2 b -jets
- Search for resonances in combined b -jet + lepton ($b\ell$) invariant mass distribution ($m_{b\ell}^0$)

- $b\ell$ leading and sub-leading mass pairs, with smallest asymmetry

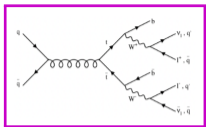
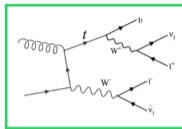
$$m_{b\ell}^{asym} = \frac{m_{b\ell}^0 - m_{b\ell}^1}{m_{b\ell}^0 + m_{b\ell}^1} > 0$$

- Multi-bin fit over $m_{b\ell}^0$, optimized with variable bin widths

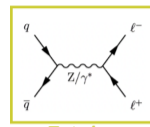


RPV $\tilde{t} \rightarrow b\bar{l}$: Background Estimation

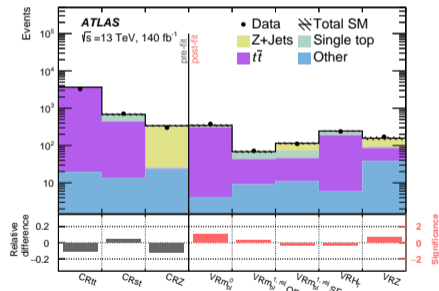
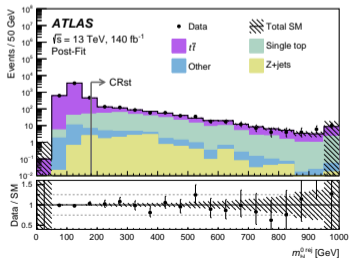
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 $t\bar{t}$ 

Single top

 $Z + jets$

- Top backgrounds: $2l$ from $W + \geq 1 b$ -jets
- 2 Control Regions (CR) with mis-paired ($b\bar{l}$)
- CRZ: leptons from Z , jets from ISR/FSR



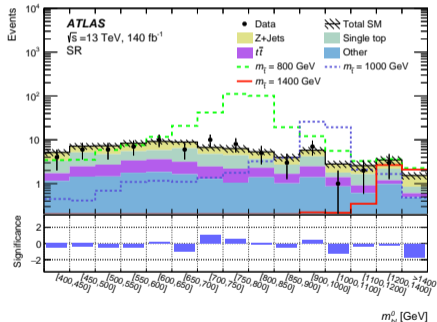
Good agreement in the 5 Validation Regions (VR)

RPV $\tilde{t} \rightarrow bl$: Results

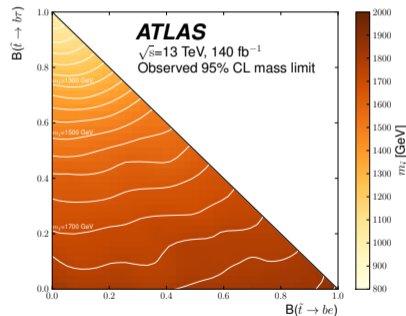
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Two exclusion fits for each stop mass and lepton BR combination, after reweighting events accordingly:

- 15 SRs, flavor-agnostic configuration
 - 45 SRs, three lepton flavor channels (ee , $e\mu$, $\mu\mu$)
 - Results with the strictest expected limits are used
- } SRs binned in m_{bl}^0



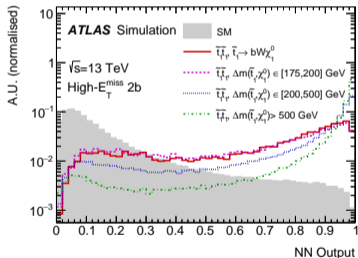
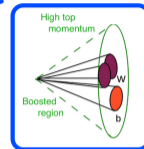
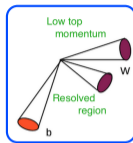
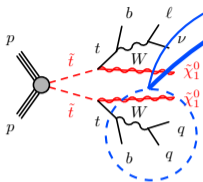
No excess found in both configurations



Improved early Run 2 limits on $m_{\tilde{t}}$
 $\sim 0.80/1.8/1.9$ TeV for $b\tau/b\mu/be$ 100% BRs

Stop to top and $E_T^{miss} - 1L$: Introduction

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2 ($\tilde{t}_1 \tilde{t}_1$ and DM) event-based NN classifiers trained to define CRs/VRs/SRs

Resolved High-MET

- $200 < p_T^{top} < 600$ GeV
- No large- R jets
- NN approach for 2-3 small- R jet combinations with exactly 1 b -jet
- 70% tagging efficiency
- Additional region split in = 1 and ≥ 2 b -jet

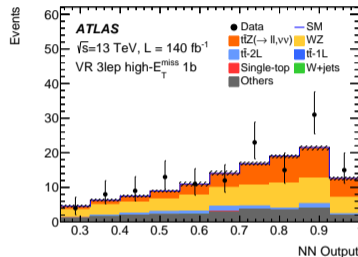
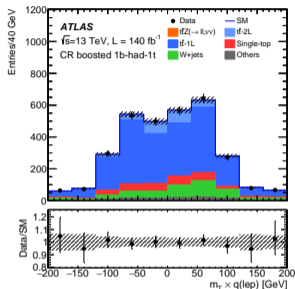
Boosted

- $p_T^{top} > 600$ GeV
- ≥ 1 large- R jets
- Multivariate classifier using jet substructure
- 80% tagging efficiency
- 6 extra regions: [0, 1] large- R t -jet, [1, ≥ 2] b -jets and (in/out)side the large- R jet

Stop to top and E_T^{miss} - 1L: Background Estimation

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Dominant sources (SFs): $t\bar{t}$ (split in $t\bar{t}$ -1L and $t\bar{t}$ -2L), Single-top, W +jets

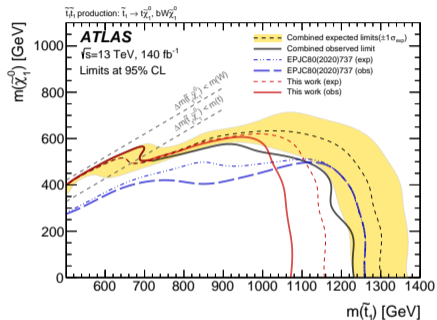
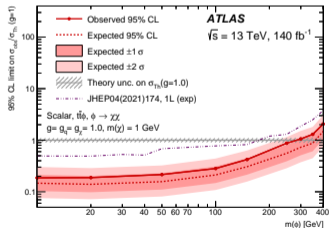
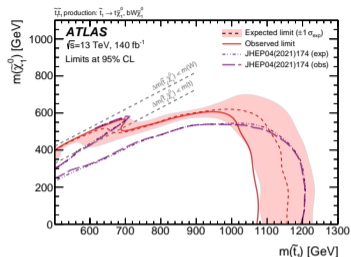


- CRs binned in $m_T \times q(\text{lep})$: simultaneous determination of $t\bar{t}$ and W +jets backgrounds
- Background with only one $W \rightarrow \ell\nu$ have an endpoint at m_W , but $t\bar{t}$ -2L
- Lepton charge to discriminate between $t\bar{t}$ -1L and W +jets

- $t\bar{t}Z(\rightarrow \nu\bar{\nu})$ has low cross-section, but signal-like signature
- Background not fitted
- Validated in 3 VRs with 2 SFOS leptons at Z-peak, added to p_T^{miss} to mimic ν in SRs

Stop to top and E_T^{miss} - 1L: Results

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- No excess in SRs \rightarrow 95% CL exclusion limits
- Combination with *stop 0L* results
- Combined exclusion up to ~ 1.25 TeV for nearly massless $\tilde{\chi}_1^0$

Combination with *previous 1L* results, both DM and $\tilde{t}_1 \tilde{t}_1$, improving exclusion in the **compressed region**

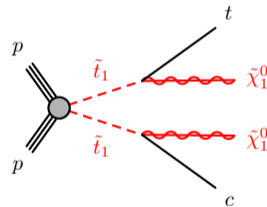
$\tilde{t}_1 \rightarrow (t/c) + \tilde{\chi}_1^0$: Introduction

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- First LHC results targeting t/c final states without leptons
- Motivated by *Non-Minimal Flavor Violation* extension of MSSM
- Final state signature: hadronically decaying top, charm quark and missing transverse energy

c-tagging recipes not well-established!

- Based on the well-known *DL1r algorithm*
- 3 output probabilities $p_{i=b,c,\ell}$ combined together with optimised parameters for c-jets
- *DL1r* and *DL1r_c* algorithms ran in sequence, with *b*-tag precedence avoiding high *b*-mistag rates



$$DL1r^{77\%} = \ln \left(\frac{p_b}{f_c p_c + (1 - f_c) p_\ell} \right)$$

 \rightarrow

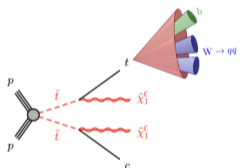
$$DL1r_c^{20\%} = \ln \left(\frac{p_c}{f_b p_b + (1 - f_b) p_\ell} \right)$$

$\tilde{t}_1 \rightarrow (t/c) + \tilde{\chi}_1^0$: Selection

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Boosted

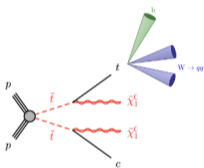
$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \gg m_t$$



- E_T^{miss} trigger + 0L
- ≥ 1 b -jet, ≥ 1 c -jet

Intermediate

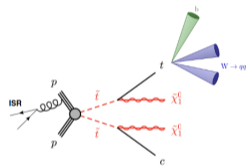
$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) > m_t$$



- E_T^{miss} trigger + 0L
- ≥ 1 b -jet, ≥ 1 c -jet

Resolved

$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \simeq m_t$$



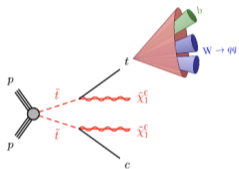
- E_T^{miss} trigger + 0L
- ≥ 1 b -jet, ≥ 1 c -jet

$\tilde{t}_1 \rightarrow (t/c) + \tilde{\chi}_1^0$: Selection

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Boosted

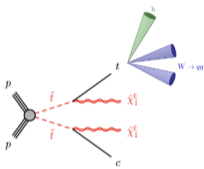
$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \gg m_t$$



- E_T^{miss} trigger + 0L
- ≥ 1 b -jet, ≥ 1 c -jet
- Leading c - or b -jet

Intermediate

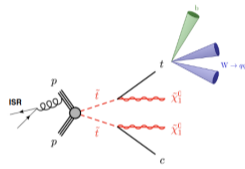
$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) > m_t$$



- E_T^{miss} trigger + 0L
- ≥ 1 b -jet, ≥ 1 c -jet
- Leading c - or b -jet

Resolved

$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \simeq m_t$$



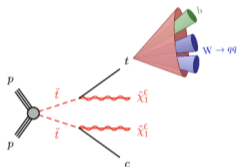
- E_T^{miss} trigger + 0L
- ≥ 1 b -jet, ≥ 1 c -jet
- **ISR**, no c - or b -jet

$\tilde{t}_1 \rightarrow (t/c) + \tilde{\chi}_1^0$: Selection

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Boosted

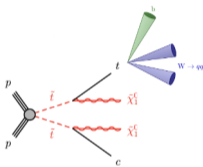
$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \gg m_t$$



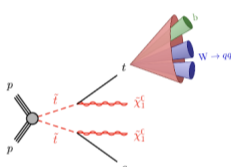
- E_T^{miss} trigger + 0L
- ≥ 1 b -jet, ≥ 1 c -jet
- Leading c - or b -jet
- $N_{top,R=1.0}^{DNN} \geq 1$

Intermediate

$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) > m_t$$



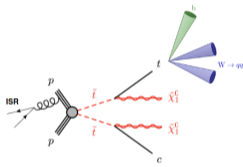
- E_T^{miss} trigger + 0L
- ≥ 1 b -jet, ≥ 1 c -jet
- Leading c - or b -jet
- $N_{top,R=1.0}^{DNN} = 0$



- E_T^{miss} trigger + 0L
- ≥ 1 b -jet, ≥ 1 c -jet
- Leading c - or b -jet
- $N_{top,R=1.0}^{DNN} \geq 1$

Resolved

$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \simeq m_t$$



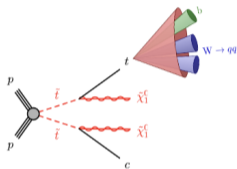
- E_T^{miss} trigger + 0L
- ≥ 1 b -jet, ≥ 1 c -jet
- **ISR**, no c - or b -jet

$\tilde{t}_1 \rightarrow (t/c) + \tilde{\chi}_1^0$: Selection

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Boosted

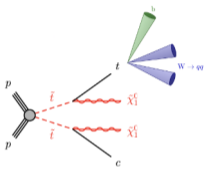
$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \gg m_t$$



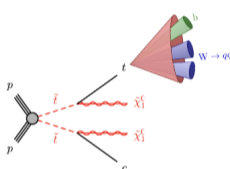
- E_T^{miss} trigger + 0L
- ≥ 1 b -jet, ≥ 1 c -jet
- Leading c - or b -jet
- $N_{top, R=1.0}^{DNN} \geq 1$
- $m_{T2} \geq 450$ GeV

Intermediate

$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) > m_t$$



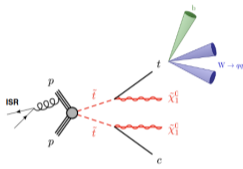
- E_T^{miss} trigger + 0L
- ≥ 1 b -jet, ≥ 1 c -jet
- Leading c - or b -jet
- $N_{top, R=1.0}^{DNN} = 0$



- E_T^{miss} trigger + 0L
- ≥ 1 b -jet, ≥ 1 c -jet
- Leading c - or b -jet
- $N_{top, R=1.0}^{DNN} \geq 1$
- $m_{T2} \in [200, 450]$ GeV

Resolved

$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \simeq m_t$$



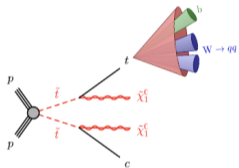
- E_T^{miss} trigger + 0L
- ≥ 1 b -jet, ≥ 1 c -jet
- **ISR**, no c - or b -jet

$\tilde{t}_1 \rightarrow (t/c) + \tilde{\chi}_1^0$: Analysis Strategy

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Boosted

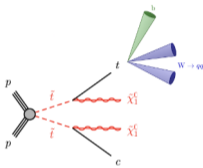
$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \gg m_t$$



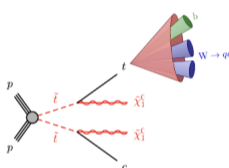
- ◆ Binned in $m_{T2}(j_{R=1.0}^b, c)$
- ◆ High m_{T2} and object-based E_T^{miss}

Intermediate

$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) > m_t$$



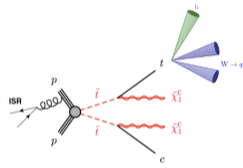
- ◆ Binned in $m_T(j, E_T^{miss})_{close}$
- ◆ Resolved topology



- ◆ Binned in $m_T(j, E_T^{miss})_{close}$
- ◆ Boosted topology, orthogonality thanks to reversed m_{T2} cut

Resolved

$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \simeq m_t$$



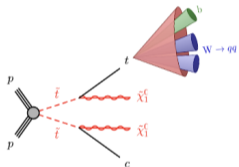
- ◆ Binned in m_{eff} and $m_T(j, E_T^{miss})_{close}$
- ◆ Multi-class NN to discriminate signal from $t\bar{t}$ and V +jets events

$\tilde{t}_1 \rightarrow (t/c) + \tilde{\chi}_1^0$: Background Estimation

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Boosted

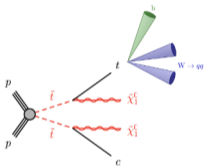
$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \gg m_t$$



- ▶ Z+jets: 2L selection. Added to E_T^{miss} , mimicking $Z \rightarrow \nu\nu$

Intermediate

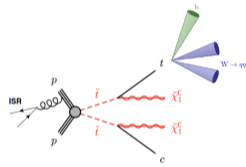
$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) > m_t$$



- ▶ Z+jets: 2L selection. Added to E_T^{miss} , mimicking $Z \rightarrow \nu\nu$

Resolved

$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \simeq m_t$$



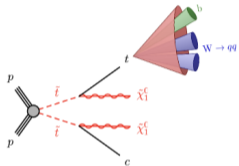
- ▶ Z+jets: 2L selection. Added to E_T^{miss} , mimicking $Z \rightarrow \nu\nu$

$\tilde{t}_1 \rightarrow (t/c) + \tilde{\chi}_1^0$: Background Estimation

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Boosted

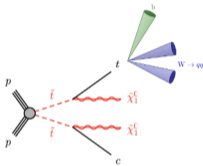
$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \gg m_t$$



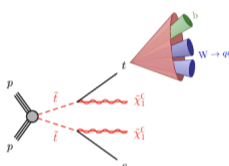
- ▶ Z+jets: 2L selection. Added to E_T^{miss} , mimicking $Z \rightarrow \nu\nu$
- ▶ Single-top: 1L selection

Intermediate

$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) > m_t$$



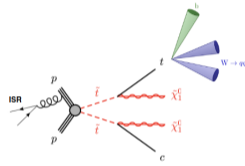
- ▶ Z+jets: 2L selection. Added to E_T^{miss} , mimicking $Z \rightarrow \nu\nu$



- ▶ Z+jets: 2L selection. Added to E_T^{miss} , mimicking $Z \rightarrow \nu\nu$
- ▶ Single-top: 1L selection

Resolved

$$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \simeq m_t$$

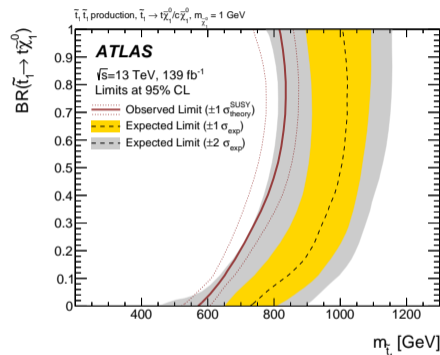
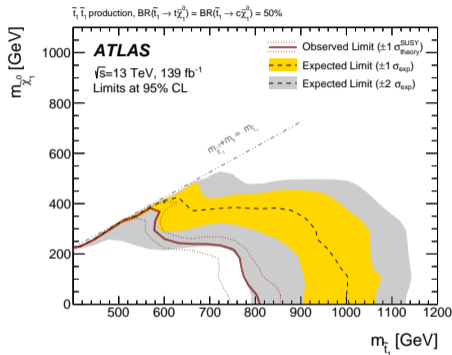


- ▶ Z+jets: 2L selection. Added to E_T^{miss} , mimicking $Z \rightarrow \nu\nu$
- ▶ $t\bar{t}$, W+jets: 1L selection. Treat lepton as jet (τ)

$\tilde{t}_1 \rightarrow (t/c) + \tilde{\chi}_1^0$: Results

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No significant excess in SRs: setting first LHC exclusion limits in this final state!

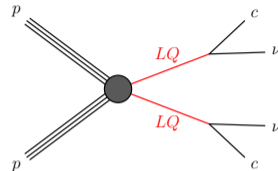
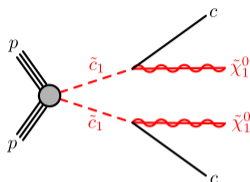
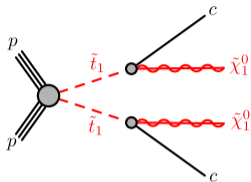


- Results for $\mathcal{B}(\tilde{t}_1 \rightarrow (t/c)\tilde{\chi}_1^0) = 50\%$
- $m(\tilde{t}_1) \lesssim 800$ GeV excluded for high mass
- $m(\tilde{t}_1) \lesssim 600$ GeV excluded for compressed spectra

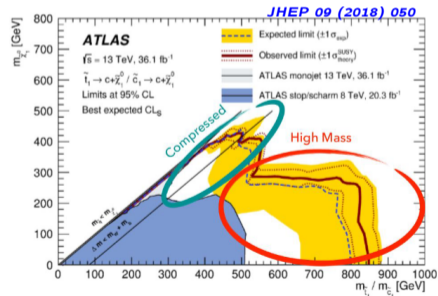
- Scan in $\mathcal{B}(\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0)$ at fixed $m(\tilde{\chi}_1^0) = 1$ GeV

SUSY search with E_T^{miss} and c-jets: Introduction

CERN-EP-2024-218

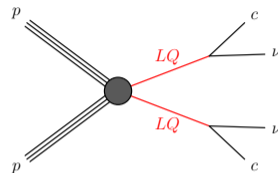
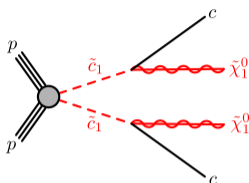
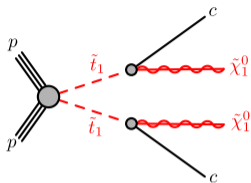


- *Minimal Flavor Violation*: when $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) < m_W$, $\mathcal{B}(\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0)$ can dominate
- Scalar LQ decaying to c quarks and e/μ
- Vector LQ decaying to $c + \tau$, with minimal or YM coupling
- No LHC limits on the LQ model

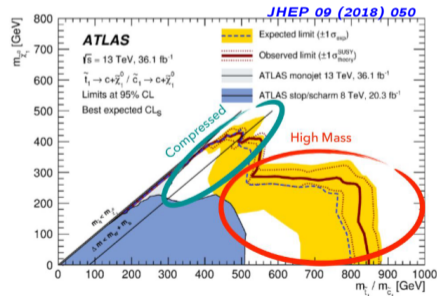


SUSY search with E_T^{miss} and c-jets: Introduction

CERN-EP-2024-218

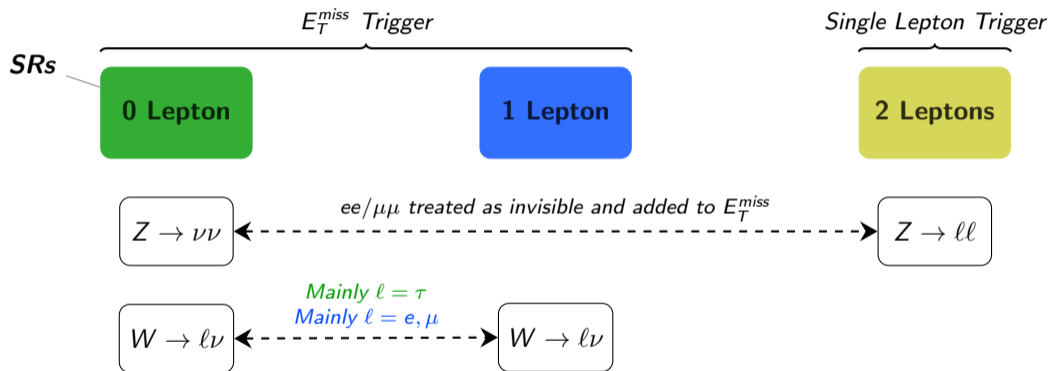


- ▶ $DL1r$ to veto b -jets and tune $DL1r_c$ for 20% c -tag efficiency
- ◆ Object-based E_T^{miss} selection focusing on **High Mass** signal models
- ◆ *Recursive Jigsaw Reconstruction* selection, using ISR jet, for **Compressed** signal models
- ◆ **Orthogonality**: c -tagging of the leading jet



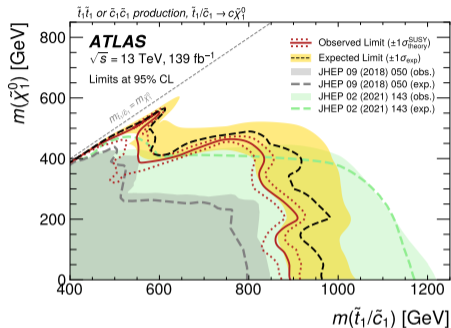
SUSY search with E_T^{miss} and c-jets: Background Estimation

CERN-EP-2024-218

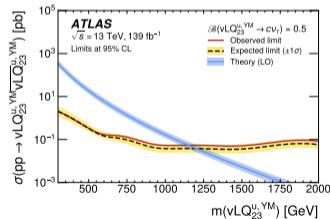
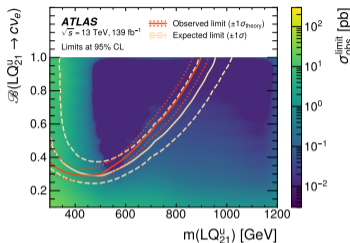


SUSY search with E_T^{miss} and c-jets: Results

CERN-EP-2024-218



- No significant excesses observed over the expected SM backgrounds
- $m(t_1/c_1) \lesssim 900 \text{ GeV}$ for nearly massless $\tilde{\chi}_1^0$
- $\sim 100 \text{ GeV}$ more than previous effort
- Better results at compressed spectra wrt *single squark production search* w/o c-tagging



Scalar (Vector) LQ masses excluded up to
 ~ 0.900 (1.15) TeV

Conclusion

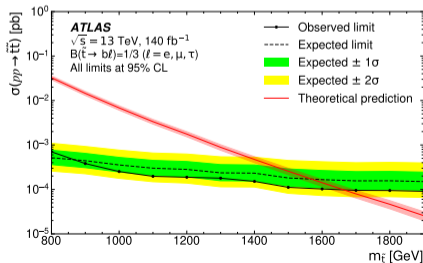
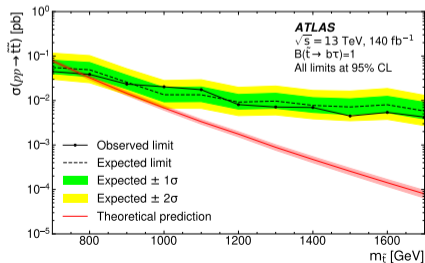
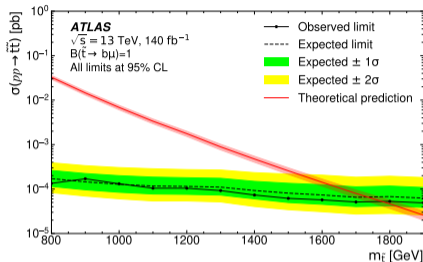
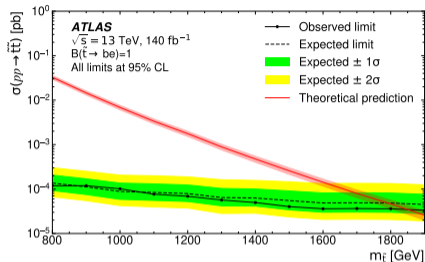
- 4 recent results using full Run 2 dataset have been presented:
 - ▶ Strong production of top squarks motivated by RPV/RPC SUSY
 - ▶ ML-based approaches being largely used for several tasks, i.e. object reconstruction, identification, S/B discrimination
 - ▶ New signature being explored using II generation squarks
- No significant excess over SM backgrounds. Several exclusion limits in place:
 - ▶ Top squarks pair production cross-section
 - ▶ Top squarks branching ratios
 - ▶ Interpretations in DM and LQ models

Many full Run 2 results already public and Run 3 analyses

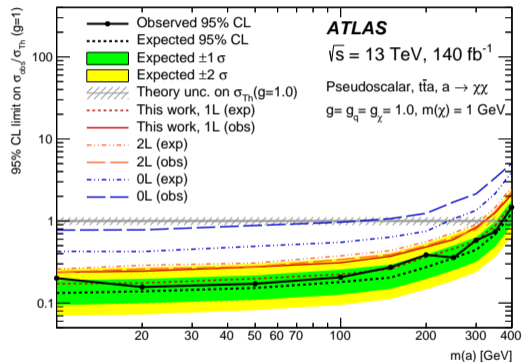
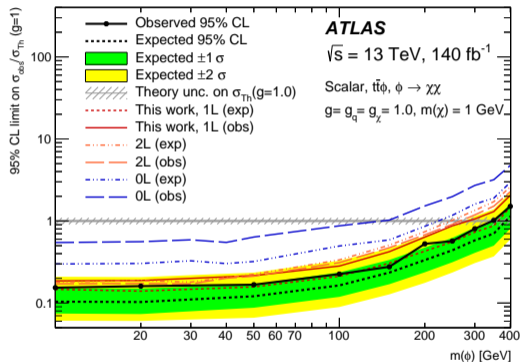


Backup

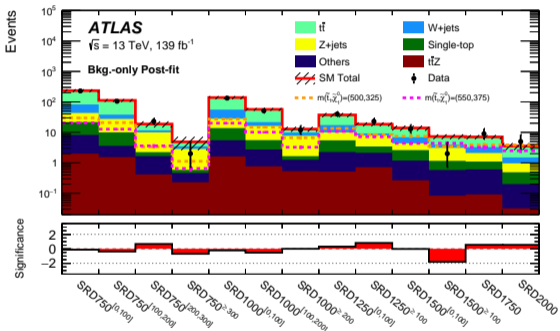
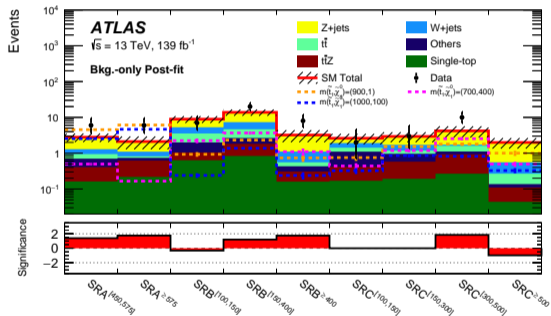
RPV $\tilde{t} \rightarrow b\ell$: Upper Limits



Stop to top and E_T^{miss} - 1L: DM Combination



$$\tilde{t}_1 \rightarrow (t/c) + \tilde{\chi}_1^0: \text{SRs}$$



SUSY search with E_T^{miss} and c-jets: VRs/SRs

