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Searches for direct pair production of third generation squarks in final states with no leptons with the ATLAS detector

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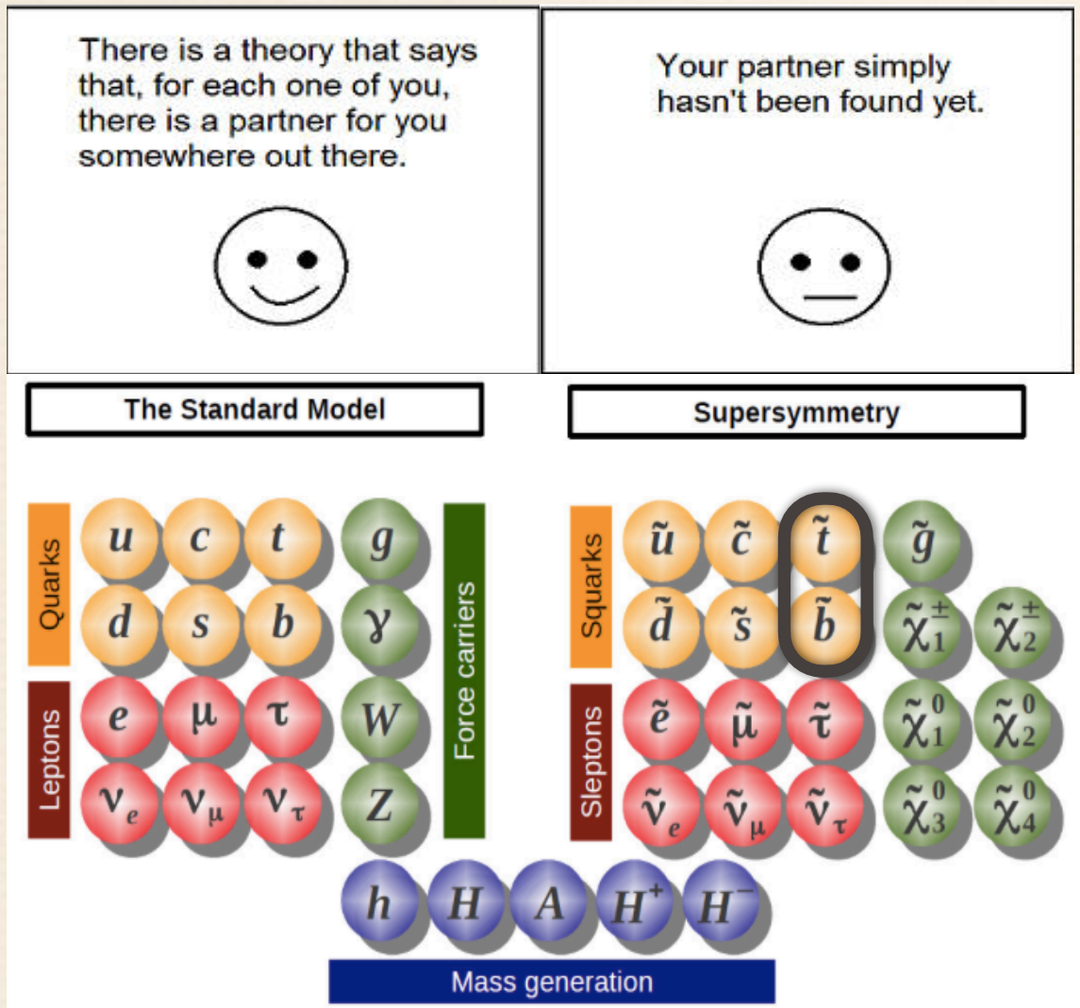
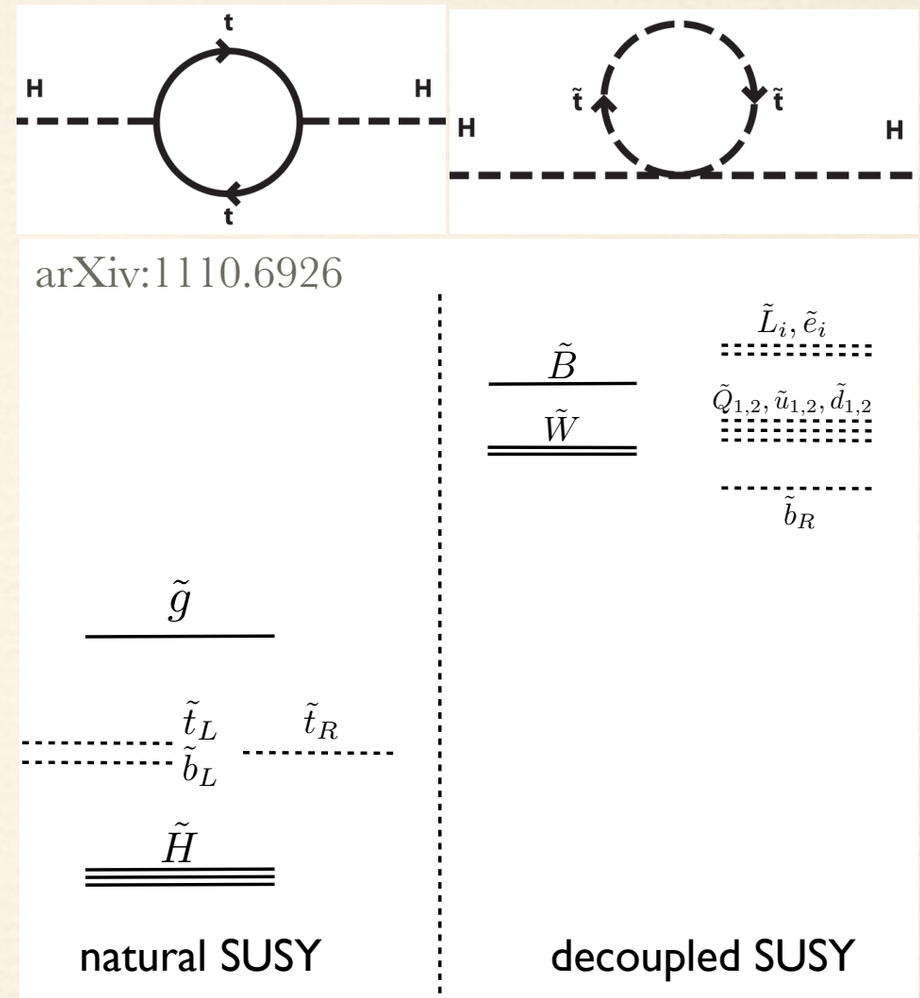
On behalf of the ATLAS collaboration

What we are looking for



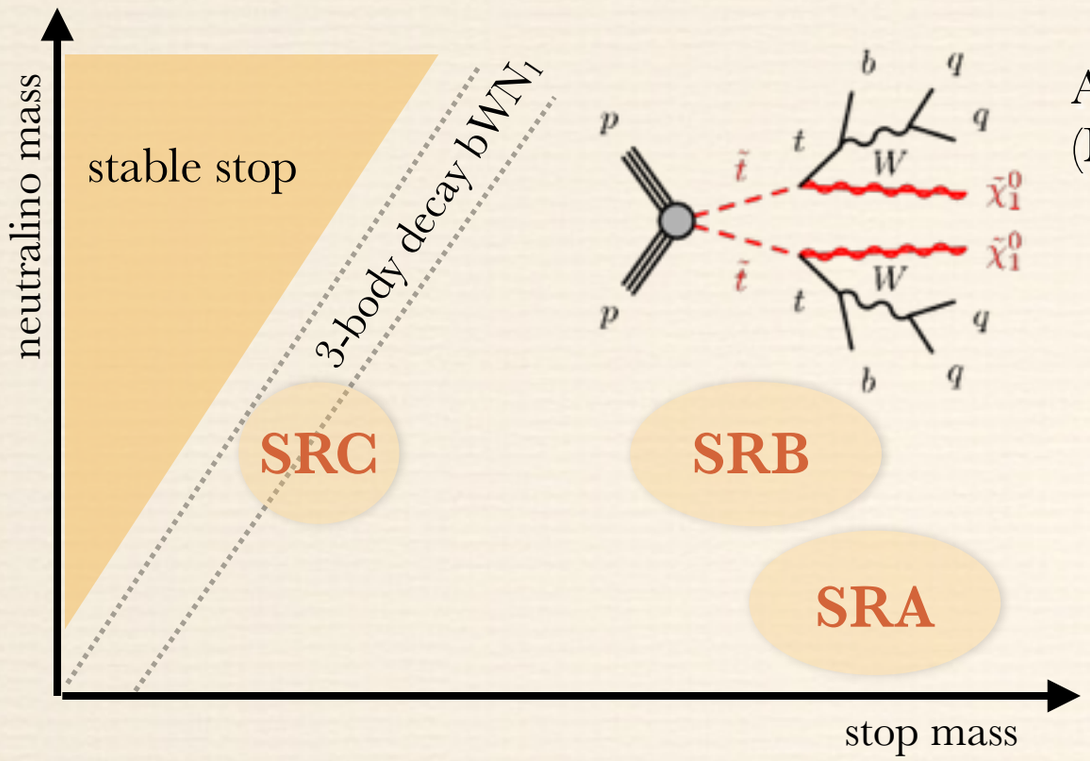


Light SUSY partners of top and bottom needed to address SM hierarchy problem

ATLAS 3rd generation squarks results

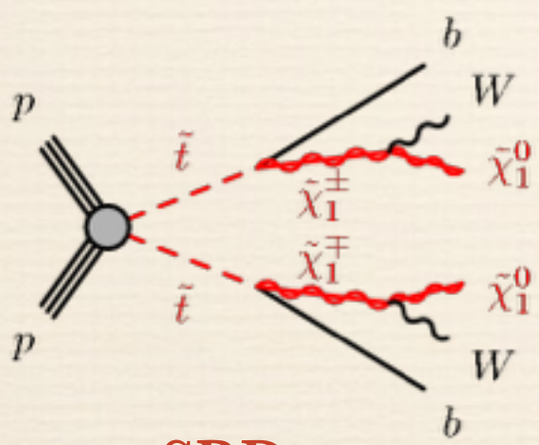
- **Covered in this talk :**
  - **Stop search in hadronic final state, ATL-CONF-SUSY-2017-020**
  - **Sbottom search, ATL-CONF-SUSY-2017-038**
- Other relevant third generation SUSY results from ATLAS in :
  - J. Maurier, compressed SUSY searches (earlier this session)
  - P. Pani, third generation squarks in leptonic final state (next talk)
  - S. Melhase, R-parity violating searches (tomorrow)
  - T. Yamazaki, stop with one lepton, poster session
  - M. Reale, stop searches for 4 body and stealth scenarios, poster session
  - L. Longo, stop with two leptons, poster session
  - S. D. Jones, stop in compressed scenarios, poster session

stop search targets

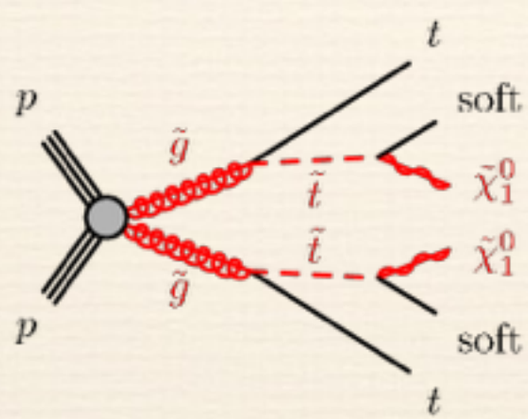


All signatures have 6 jets (2 from b) and missing momentum (MET) from neutralinos

- SRA and SRB : t $\tilde{\chi}^0_1$ decay with large ΔM. Large MET, boosted top quarks.
- SRC : t $\tilde{\chi}^0_1$ decay with small ΔM. Top squarks recoil against ISR, boost enhanced MET
- SRD : decays via chargino, no top quark in final state
- SRE : targets gluino decays, large ΔM



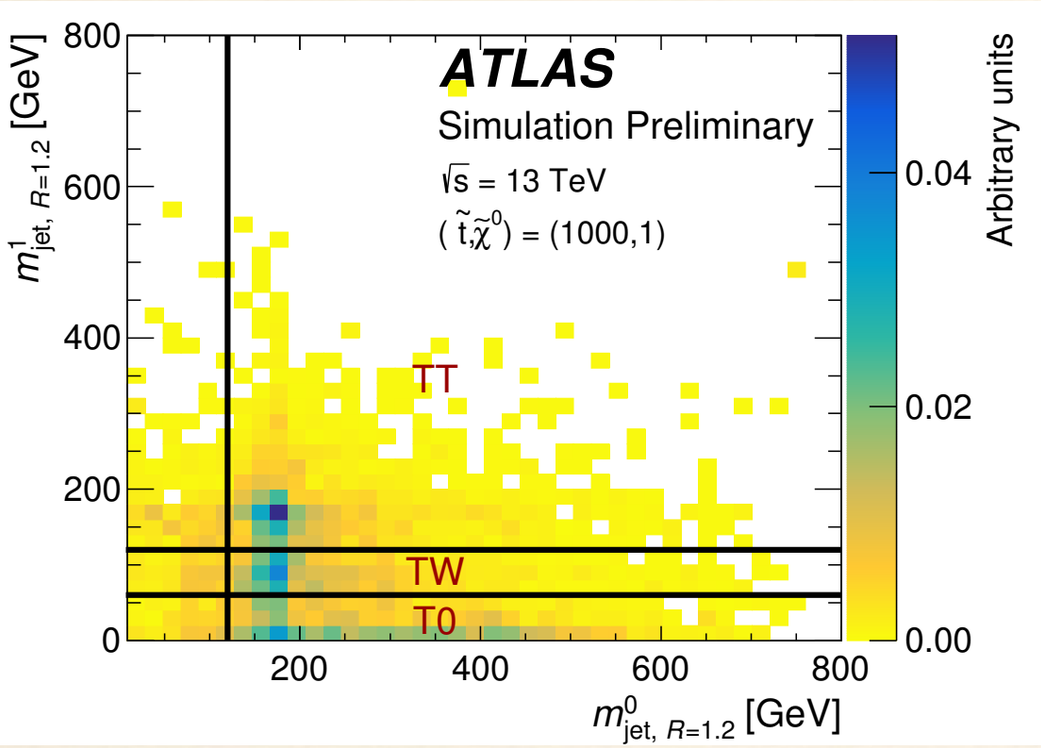
SRD



SRE

stop search selections I

Preselection : MET > 250 GeV (trigger), at least four jets, MET aligned with track MET and not aligned with any jet



Signal Region		TT	TW	T0
	$m^0_{\text{jet},R=1.2}$	> 120 GeV		
	$m^1_{\text{jet},R=1.2}$	> 120 GeV	[60, 120] GeV	< 60 GeV
	$m_{\text{T}}^{b,\text{min}}$	> 200 GeV		
	$N_{b-\text{jet}}$	≥ 2		
	τ-veto	yes		
	$\left\lvert\Delta\phi\left(\text{jet}^{0,1,2}, \mathbf{p}_{\text{T}}^{\text{miss}}\right)\right\rvert$	> 0.4		
A	$m^0_{\text{jet},R=0.8}$	> 60 GeV		
	$\Delta R\,(b,b)$	> 1	-	
	$m_{\text{T2}}^{\chi^2}$	> 400 GeV	> 400 GeV	> 500 GeV
	$E_{\text{T}}^{\text{miss}}$	> 400 GeV	> 500 GeV	> 550 GeV
B	$m_{\text{T}}^{b,\text{max}}$	> 200 GeV		
	$\Delta R\,(b,b)$	> 1.2		

- Event categories with large-radius jet masses
- Selections on MET, M_T(b,MET), top reconstructed with small-R jets, ΔR(bb)

stop search selections II

Small ΔM selections

Variable	SRC1	SRC2	SRC3	SRC4	SRC5
$N_{b-\mathrm{jet}}$	≥ 1				
$N^{\mathrm{S}}_{b-\mathrm{jet}}$	≥ 1				
$N^{\mathrm{S}}_{\mathrm{jet}}$	≥ 5				
$p^{0,\mathrm{S}}_{\mathrm{T},b}$	> 40 GeV				
m_{S}	> 300 GeV				
$\Delta\phi_{\mathrm{ISR},E^{\mathrm{miss}}_{\mathrm{T}}}$	> 3.0				
$p^{\mathrm{ISR}}_{\mathrm{T}}$	> 400 GeV				
$p^{4,\mathrm{S}}_{\mathrm{T}}$	> 50 GeV				
R_{ISR}	0.30-0.40	0.40-0.50	0.50-0.60	0.60-0.70	0.70-0.80

- Recursive Jigsaw reconstruction*, event split in ISR and stop (S) hemispheres
- R_{ISR} peak for signal : $R_{\mathrm{ISR}} \equiv \frac{E^{\mathrm{miss}}_{\mathrm{T}}}{p^{\mathrm{ISR}}_{\mathrm{T}}} \sim \frac{m_{\tilde{\chi}^0_1}}{m_{\tilde{t}}}$.

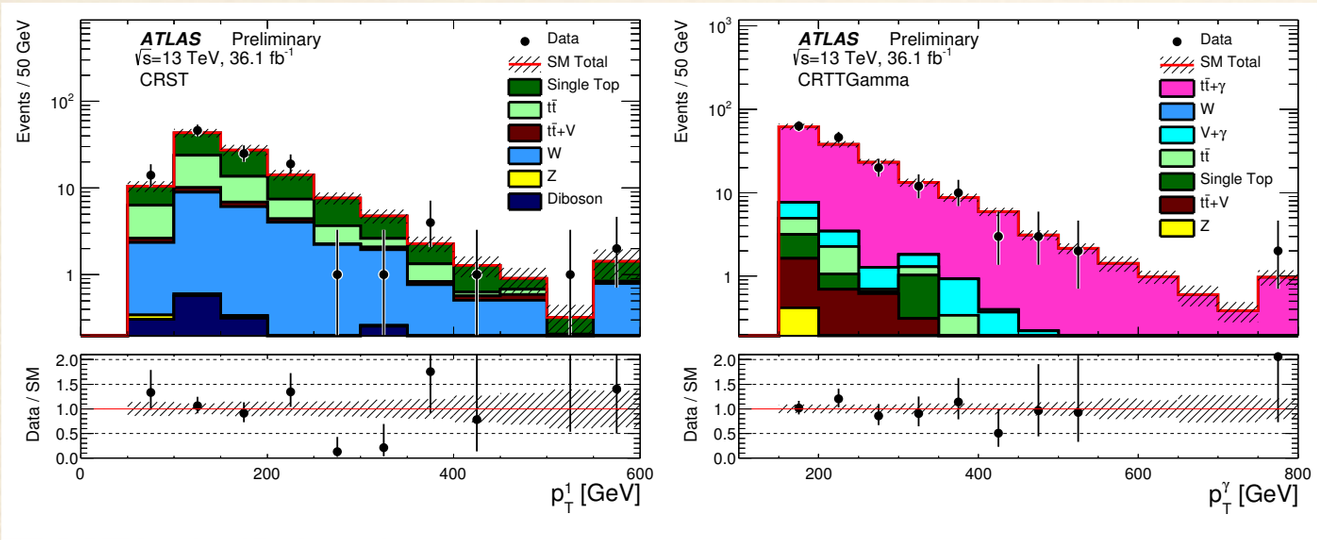
Chargino selections

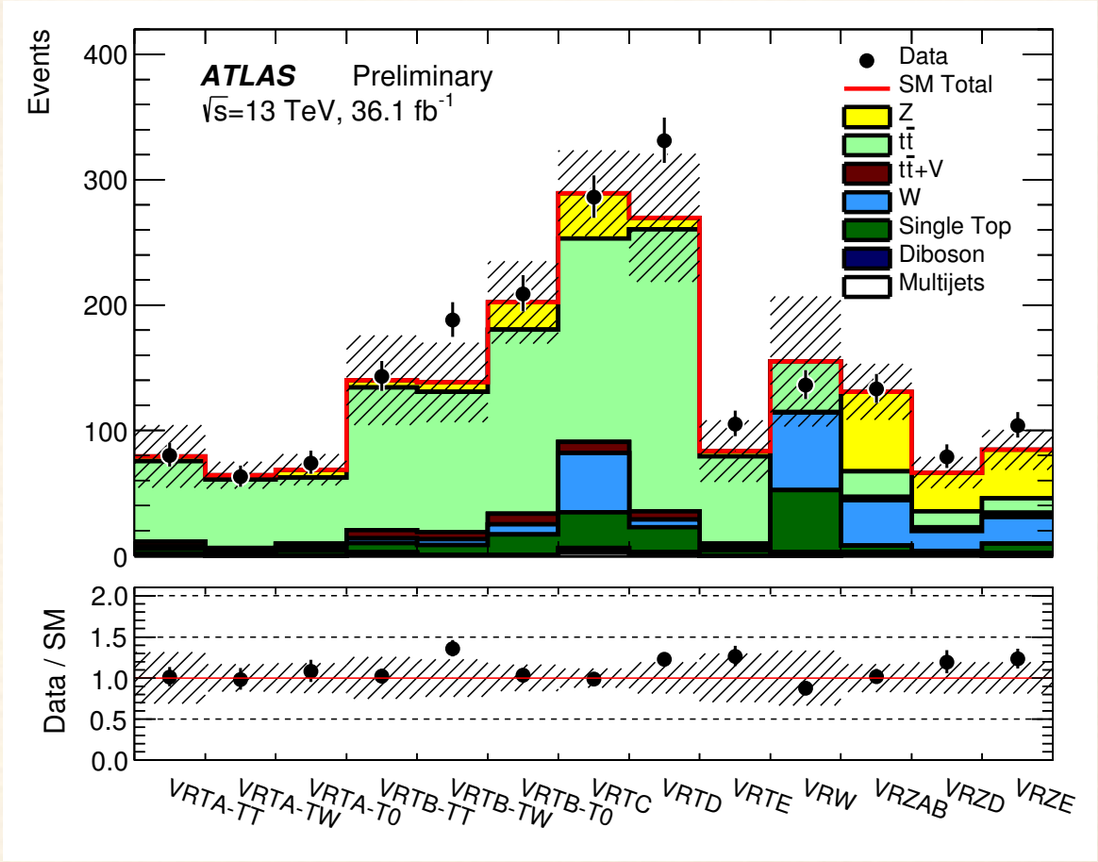
Variable	SRD-low	SRD-high
$\left\lvert\Delta\phi\left(\mathrm{jet}^{0,1,2}, \mathbf{p}^{\mathrm{miss}}_{\mathrm{T}}\right)\right\rvert$	> 0.4	
$N_{b-\mathrm{jet}}$	≥ 2	
$\Delta R\,(b,b)$	> 0.8	
$p^{0,b}_{\mathrm{T}} + p^{1,b}_{\mathrm{T}}$	> 300 GeV	> 400 GeV
τ-veto	yes	
p^{1}_{T}	> 150 GeV	
p^{3}_{T}	> 100 GeV	> 80 GeV
p^{4}_{T}	> 60 GeV	
$m^{b,\min}_{\mathrm{T}}$	> 250 GeV	> 350 GeV
$m^{b,\max}_{\mathrm{T}}$	> 300 GeV	> 450 GeV

- Chargino selections on jet p_T, m_T(b,MET), ΔR(bb)
- Optimized for two signal benchmarks

* see the talk of P.D. Jackson earlier in this session

stop search background estimate

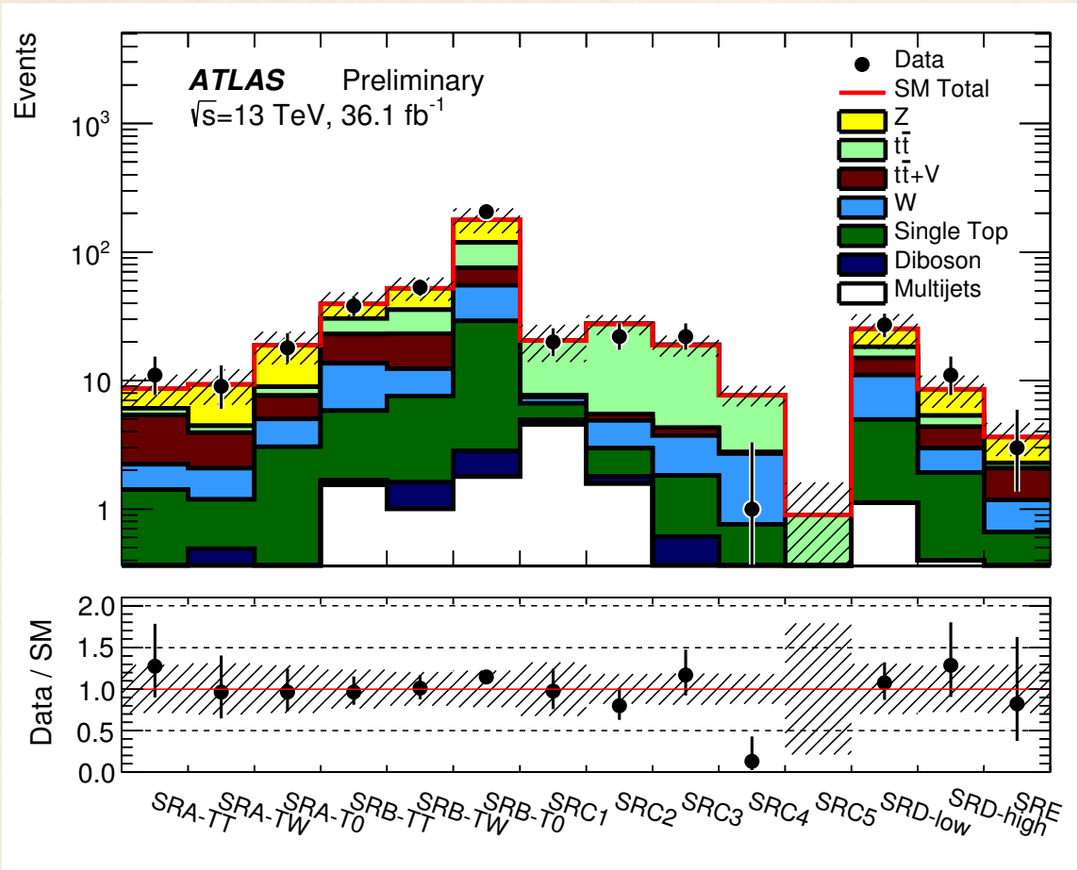




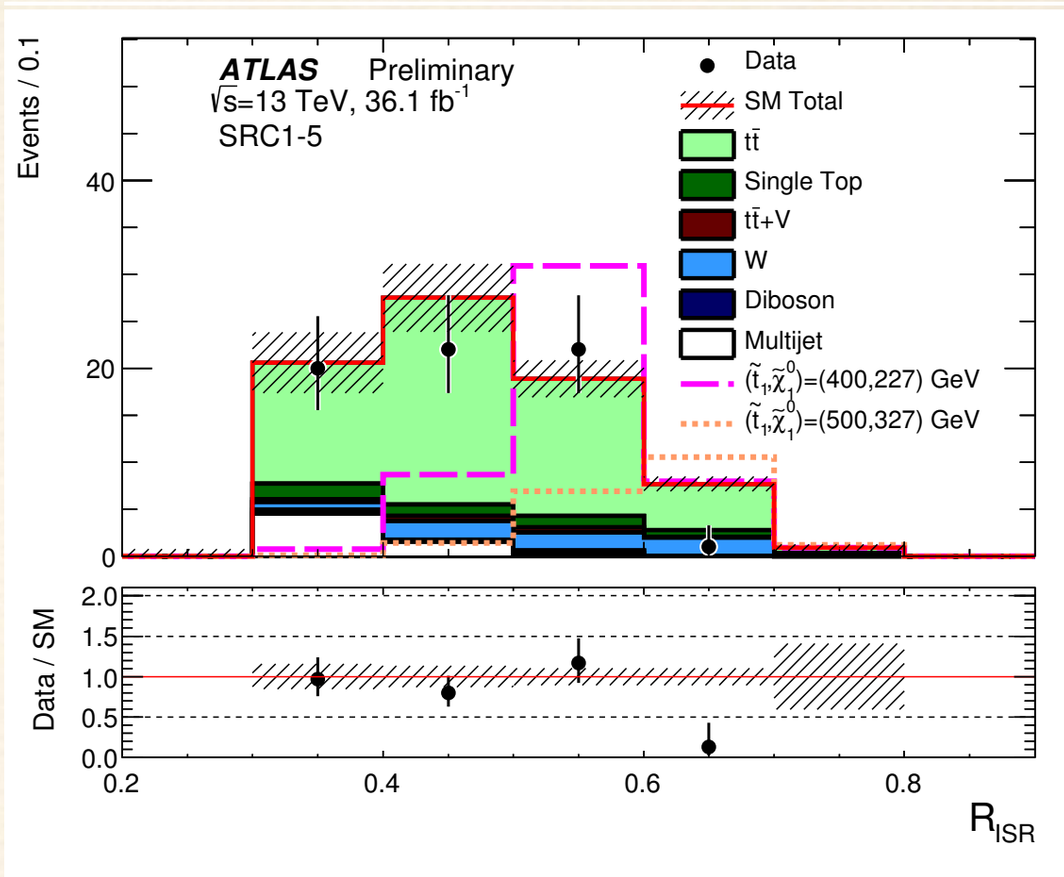
- Control regions (CR) used to normalize main backgrounds
  - Z(νν)+jets normalized in Z(ll)+bb+jets selection
  - Single top, ttbar, W+jets in single lepton selection (1 or 2 b-jets)
  - ttV normalized using ttγ selection (one lepton, one photon, 2 b-jets)

- Validation regions (VR) with kinematics between those of CR and SR find good agreement between data and estimated background

stop search results

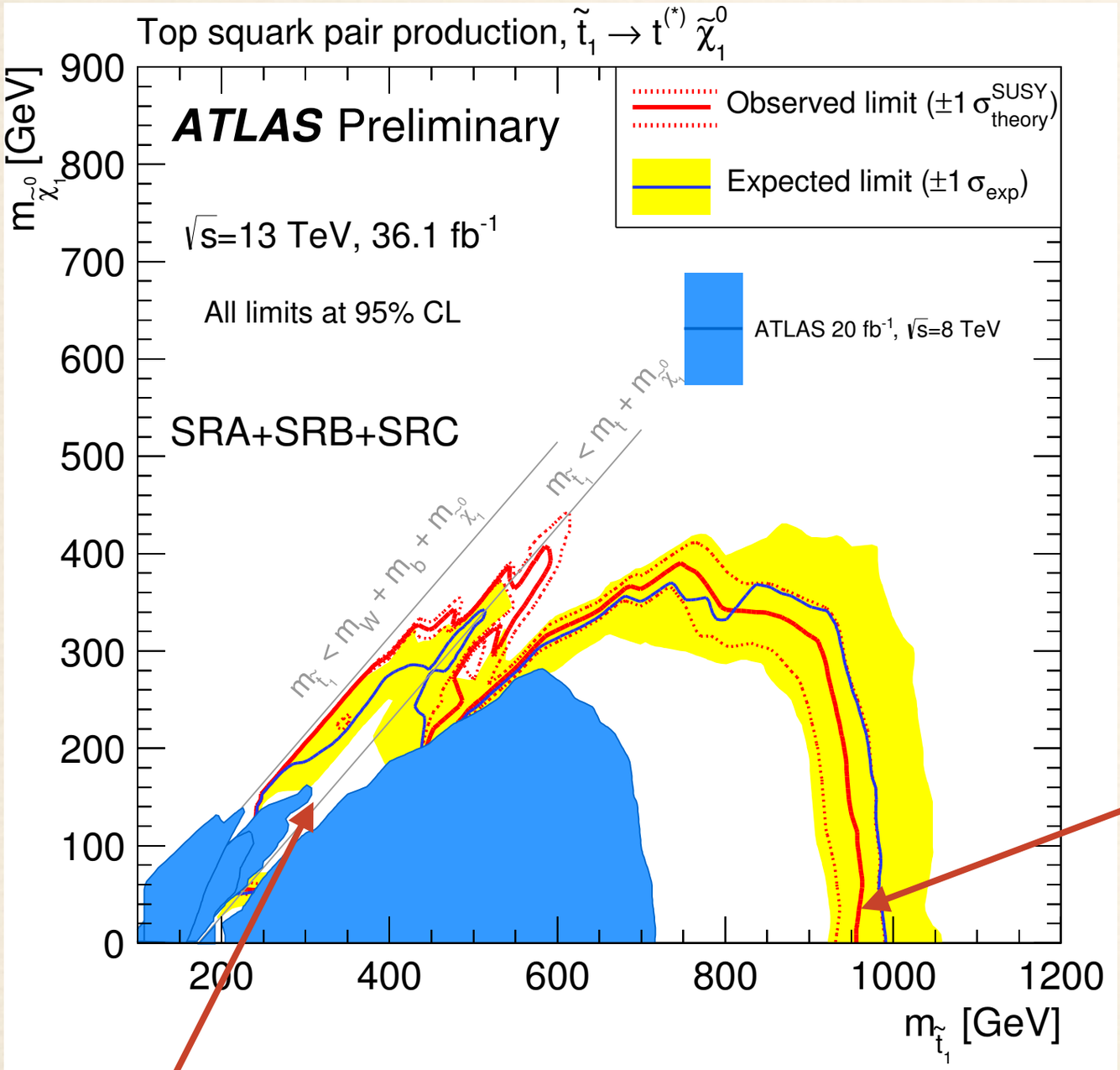


Good agreement between data and SM expectation in all signal regions



R_{ISR} for SRC events

stop search limits



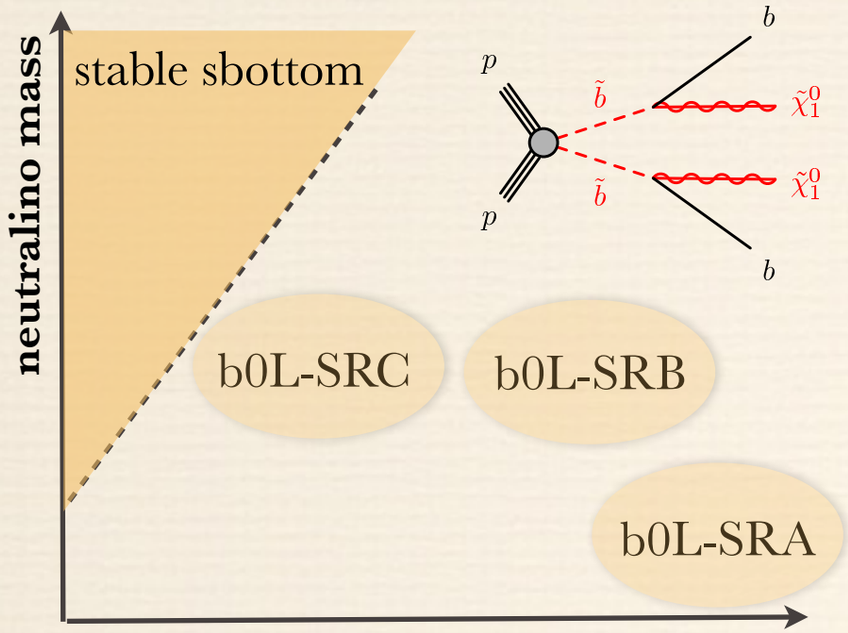
Statistical combination of categories within SRA, SRB, SRC.
Best expected of the three SR taken for each point.

Beware : limits are typically weaker in less simplified models

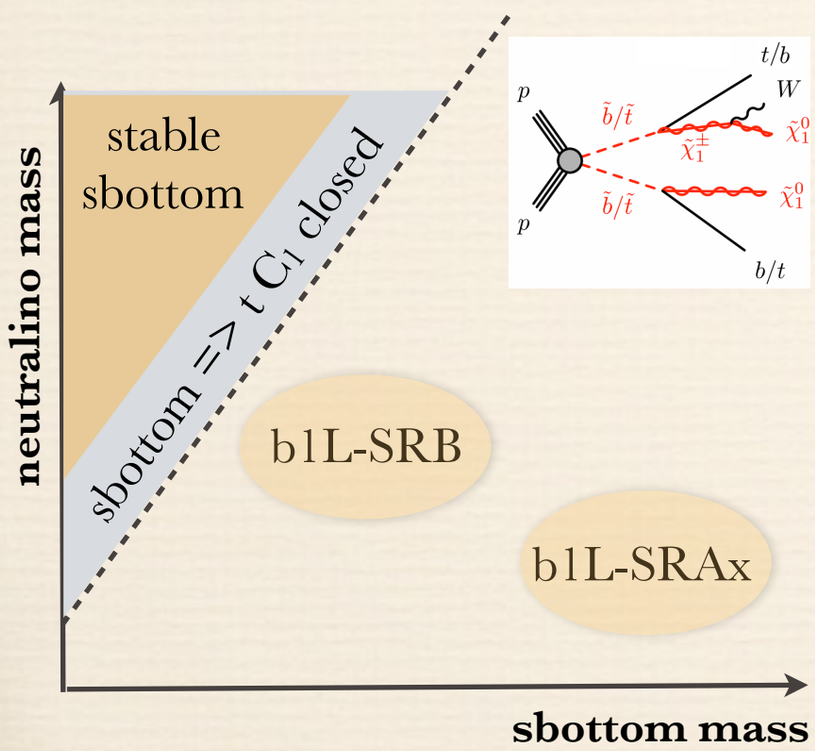
m($\tilde{t}$) > 950 GeV for light neutralino

Exclude stealth stop "diagonal" for 235 < m($\tilde{t}$) < 590 GeV.

sbottom search targets



- sbottom-neutralino (bino) simplified model
- 2 b-jets, no lepton, signal regions targeting different ΔM



- wino or higgsino LSP, nearly mass-degenerate chargino and neutralino
- chargino decay products too soft to be reconstructed
- sbottom to b neutralino adressed by 0L SRs
- $\tilde{b}\,\tilde{b} \Rightarrow t\,\chi^+_1\,b\,\chi^0_1$: one lepton, 2b, MET. One lepton selection target this final state
- $\tilde{t}\,\tilde{t} \Rightarrow b\,\chi^+_1\,t\,\chi^0_1$ has same signature !

sbottom selections

	b0L-SRAx	b0L-SRB	b0L-SRC
Lepton veto	No e/μ with p_T >10 GeV after overlap removal		
$N_{\text{jets}}(p_T > 35$ GeV)	2-4	2-4	-
$N_{\text{jets}}(p_T > 20$ GeV)	-	-	2-5
p_T (j_1) [GeV]	> 130	> 50	> 500
p_T (j_2) [GeV]	> 50	> 50	> 20
p_T (j_4) [GeV]	< 50	-	-
H_{T4} [GeV]	-	-	< 70
b-jets	j_1 and j_2	any 2	j_2 and (j_3 or j_4 or j_5)
E_T^{miss} [GeV]	> 250	> 250	> 500
$E_T^{\text{miss}}/m_{\text{eff}}$	> 0.25	-	-
$\min[\Delta\phi(\text{jet}_{1-4}, E_T^{\text{miss}})]$	> 0.4	> 0.4	-
$\min[\Delta\phi(\text{jet}_{1-2}, E_T^{\text{miss}})]$	-	-	> 0.2
$\Delta\phi(b_1, E_T^{\text{miss}})$	-	< 2.0	-
$\Delta\phi(b_2, E_T^{\text{miss}})$	-	< 2.5	-
$\Delta\phi(j_1, E_T^{\text{miss}})$	-	-	> 2.5
m_{bb}[GeV]	> 200	-	> 200
m_{CT} [GeV]	>350, 450, 550	-	-
$m_T^{\min}(\text{jet}_{1-4}, E_T^{\text{miss}})$ [GeV]	-	> 250	-
m_{eff}[TeV]	-	-	> 1.3
$\mathcal{A}$	-	-	> 0.8

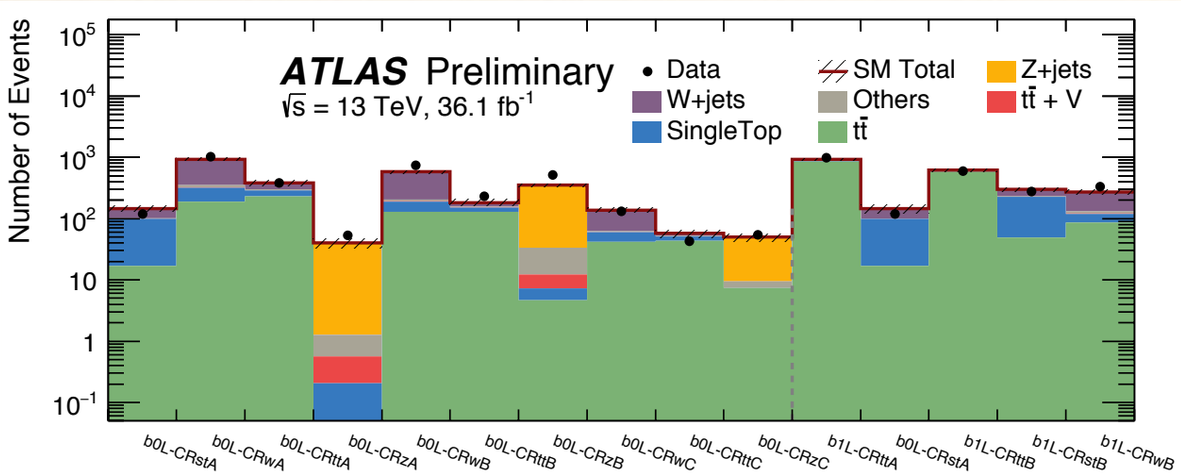
- **Lepton veto**, 2b, MET (trigger)
- Large ΔM : large M_{CT}
- Intermediate ΔM : large m_T^{min}(jets,MET)
- Low ΔM : large MET, hard ISR jet, two softer b-jets with large m(bb)

	b1L-SRAx	b1L-SRA300-2j	b1L-SRB
Number of leptons (e, μ)	1	1	1
$N_{\text{jets}}(p_T > 35$ GeV)	≥ 2	= 2	≥ 2
b-jets	any 2	j_1 and j_2	any 2
E_T^{miss} [GeV]	> 200	> 200	> 200
$E_T^{\text{miss}}/\sqrt{H_T}$ [(GeV$^{\frac{1}{2}}$)]	> 8	> 8	> 8
$m_{b\ell}^{\min}$ [GeV]	< 170	< 170	< 170
$\min[\Delta\phi(\text{jet}_{1-4}, E_T^{\text{miss}})]$	> 0.4	–	> 0.4
$\min[\Delta\phi(\text{jet}_{1-2}, E_T^{\text{miss}})]$	–	> 0.4	–
am_{T2}[GeV]	> 250	> 250	> 200
m_T [GeV]	> 140	> 140	> 120
m_{bb}[GeV]	> 200	> 200	< 200
m_{eff}[GeV]	> 600, 750	> 300	> 300
$m_T^{\min}(\text{bjet}_{1-2}, E_T^{\text{miss}})$ [GeV]	–	–	> 200
$\Delta\phi(b_1, E_T^{\text{miss}})$	–	–	> 2.0

- **One lepton**, 2b, MET (trigger)
- One bl pair consistent with top decay ($m_{bl} < m_{top}$)
- Large m_T(l,MET) suppresses W+jets, semileptonic ttbar
- Large ΔM : large m(bb) and am_{T2}
- Low ΔM : small m(bb), large am_{T2}

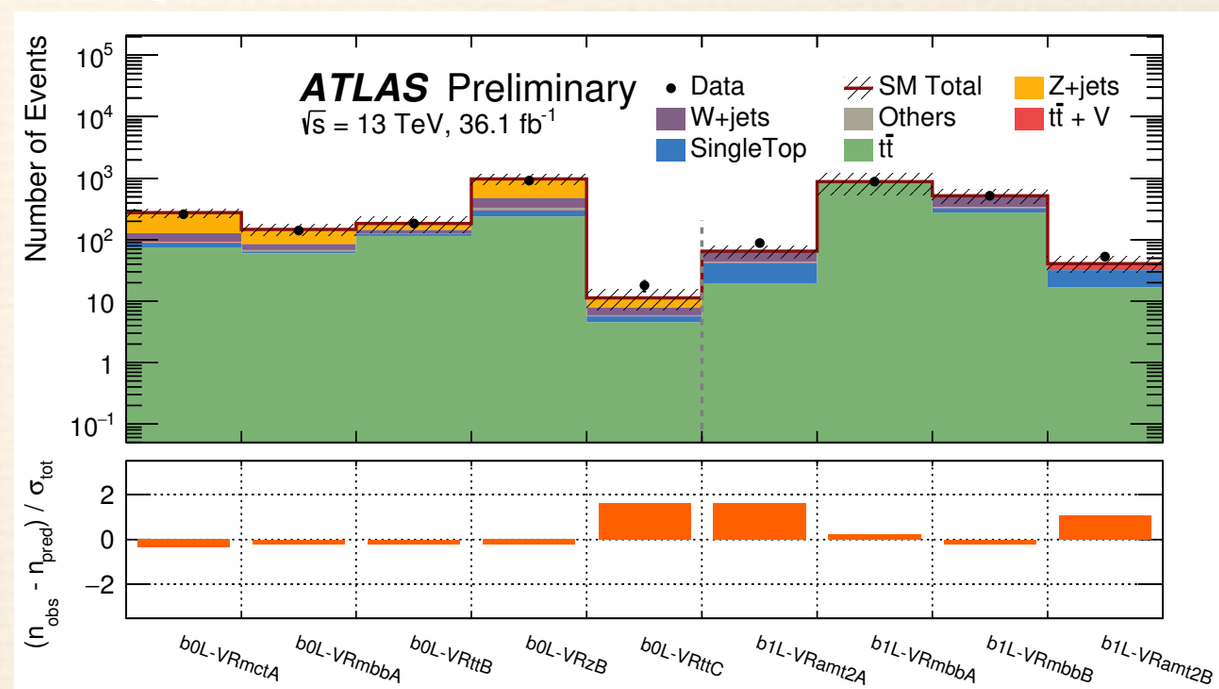
sbottom background estimate

- **Each SR has its own set of CRs to normalize main backgrounds**
  - Z(nn) normalized from Z(ll) selections
  - ttbar, single top, W+jets normalized in 1-lepton selections. b-jet multiplicity (1 or 2), m_{bb}, m_{bl}^{min} separate the three processes.
- VRs check modeling of variables used to extrapolate from CR to SR



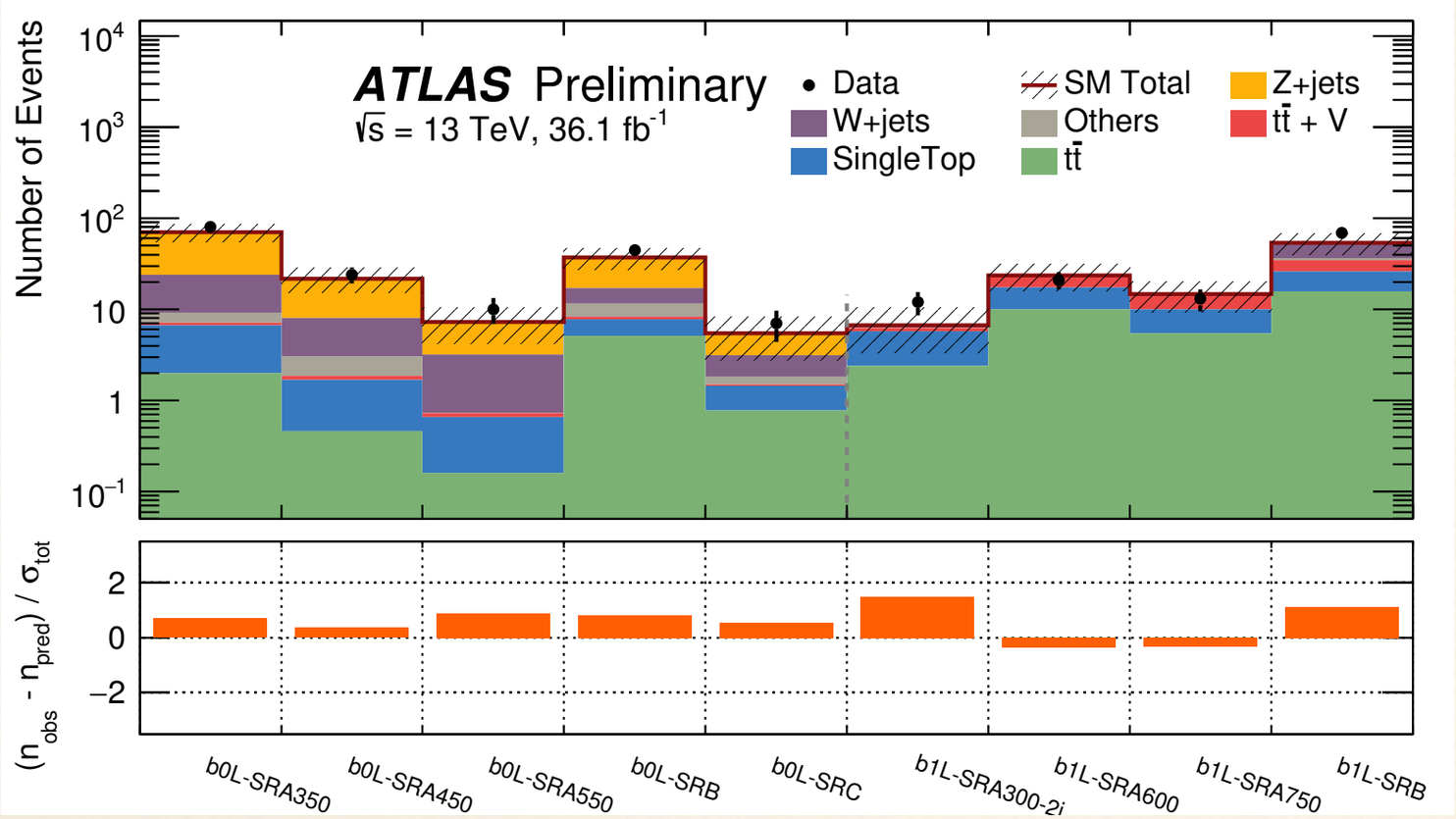
	CRA	CRB	CRC	CRA	CRB
μ_Z	1.33 ± 0.20	1.52 ± 0.07	1.17 ± 0.19		
μ_{tt}	1.03 ± 0.21	1.33 ± 0.21	0.66 ± 0.18	1.07 ± 0.04	0.97 ± 0.05
μ_W	1.26 ± 0.17	1.31 ± 0.12	1.11 ± 0.21		1.50 ± 0.22
μ_{st}	0.49 ± 0.23			0.64 ± 0.25	0.71 ± 0.19
	b0L			b1L	

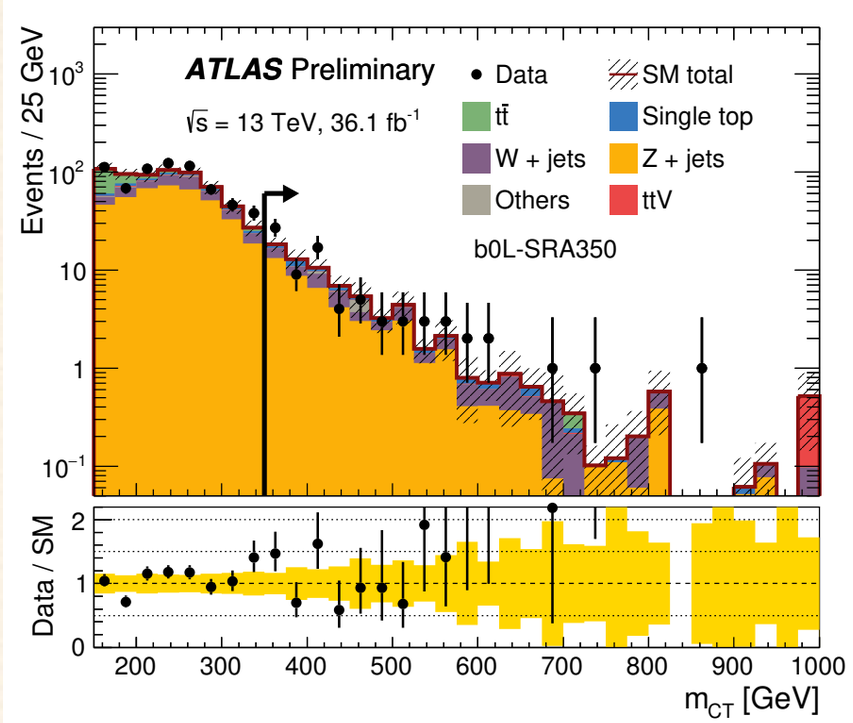
control region composition and normalization factors

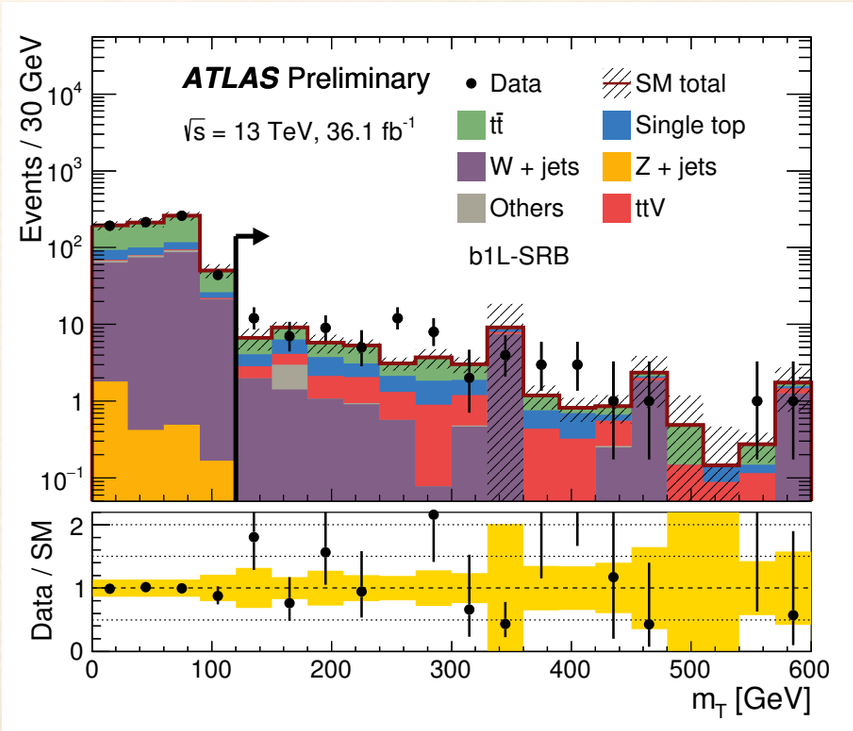


validation regions

sbottom results

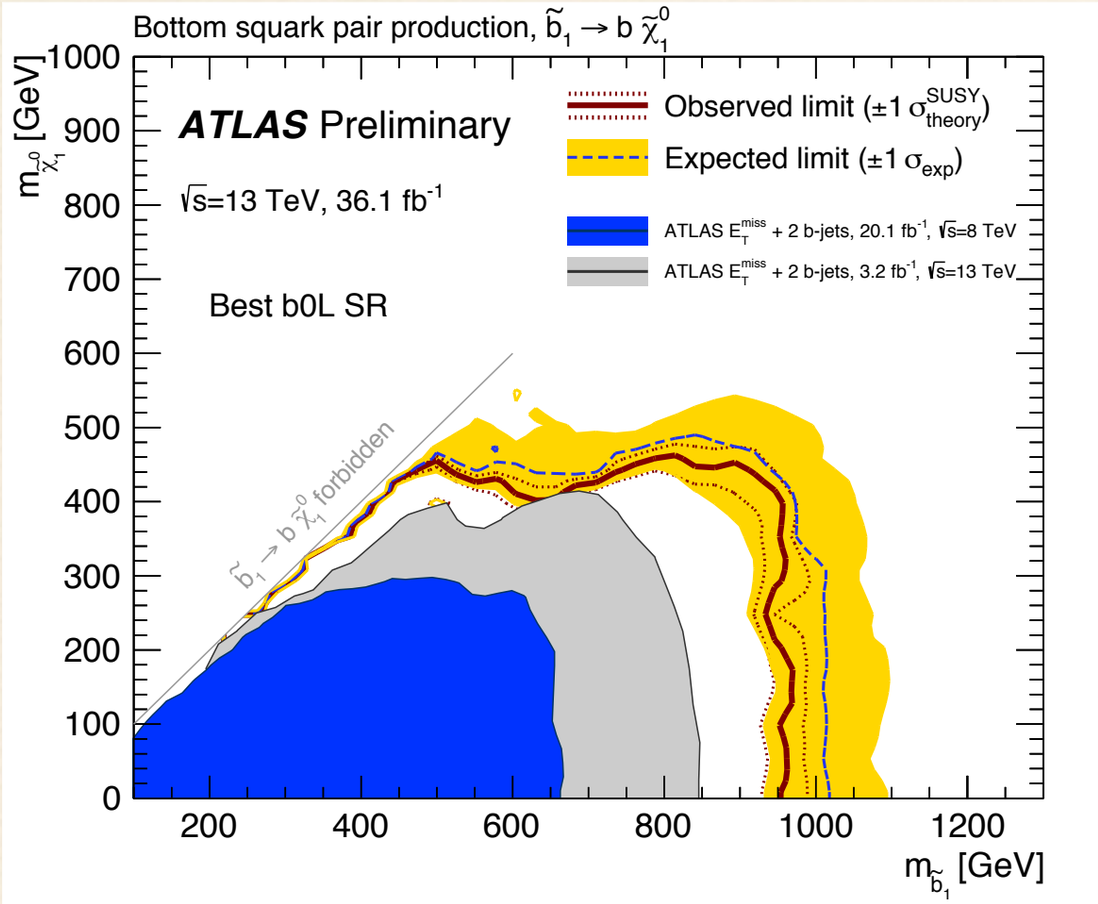


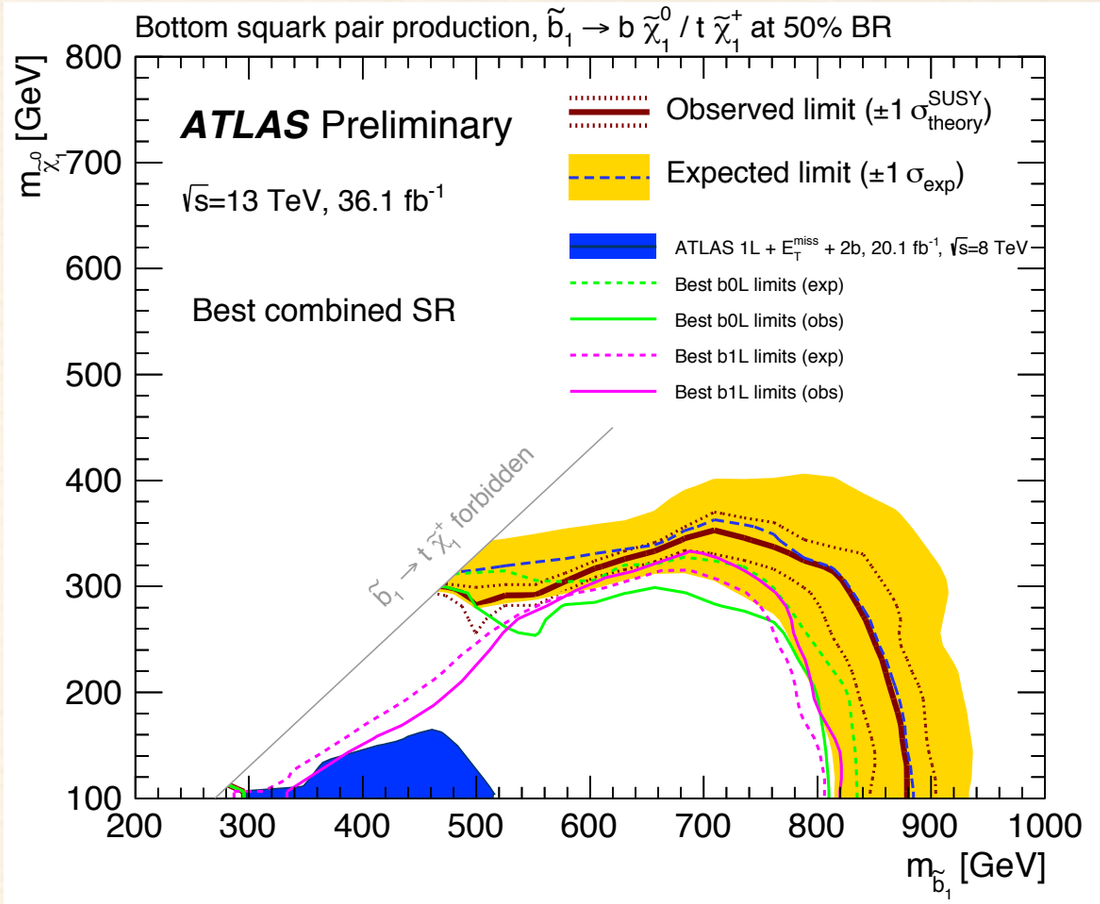




Agreement between observation and background estimate

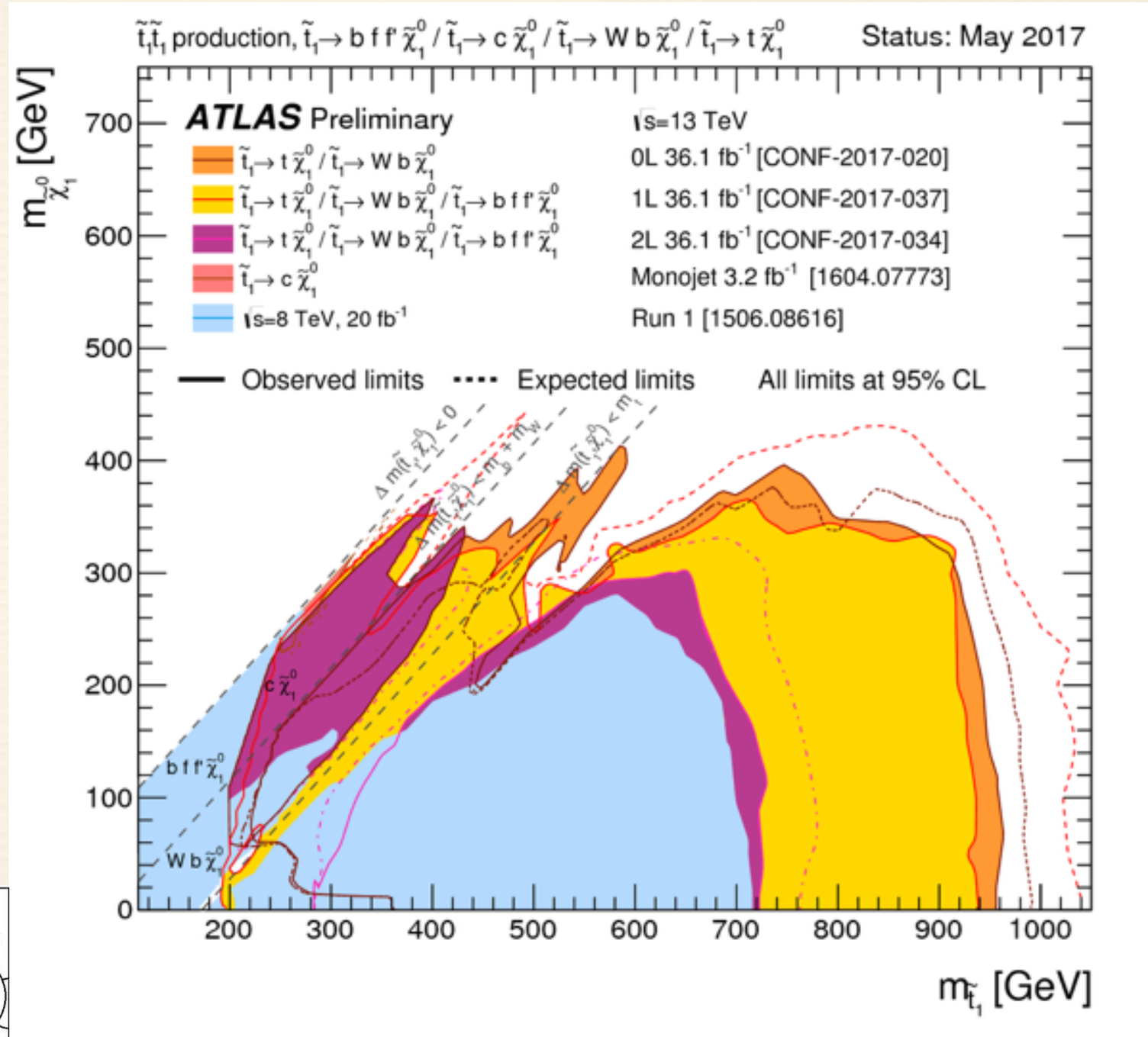
sbottom limits

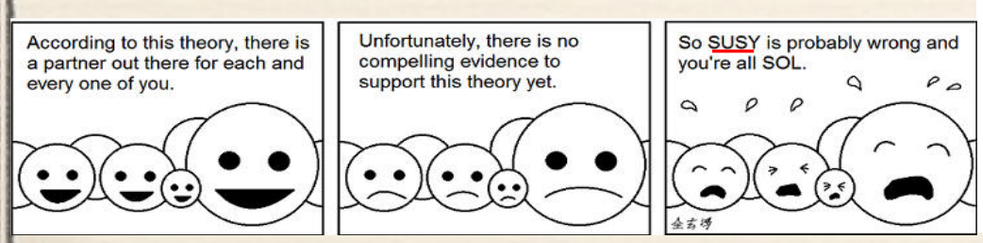




conclusions

- Searches for sbottom and stop in hadronic final states have given results consistent with SM expectations.
- Limits on the 3rd generation squark masses close to 1000 GeV for light neutralino and 500 GeV for compressed mass spectra
- The search for SUSY continues…





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