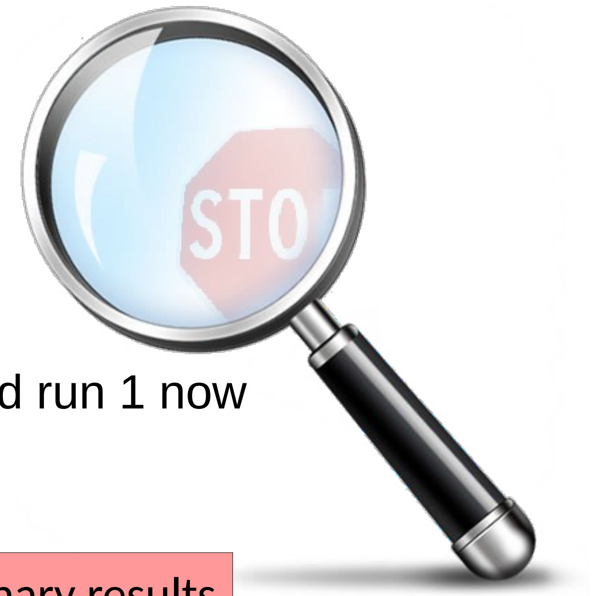
Kilian Rosbach on behalf of the ATLAS collaboration
ICHEP 2016 - 4 August 2016

Search for third generation squarks in pp collisions at 13 TeV with ATLAS

Albert-Ludwigs-Universität Freiburg

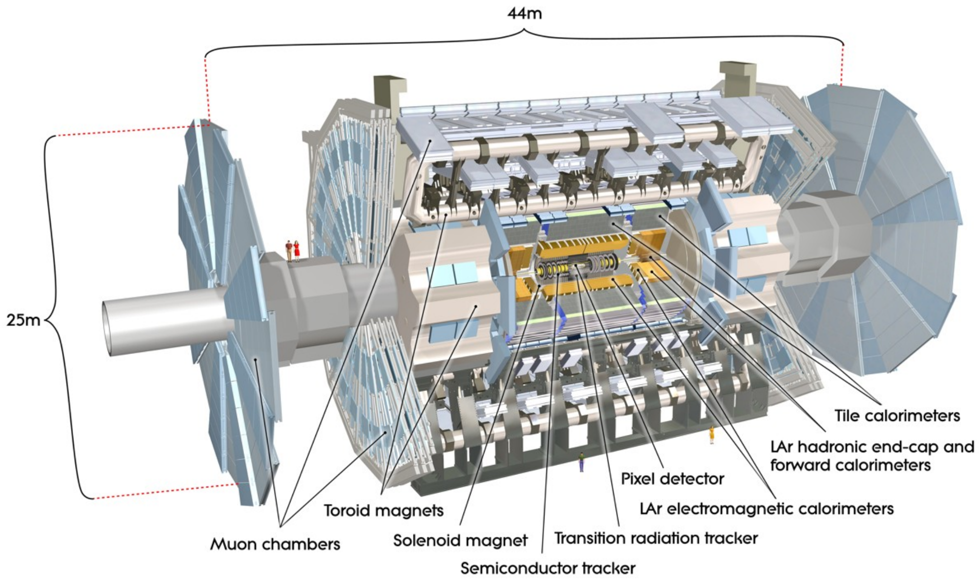
SUSY Third Generation Squark Searches

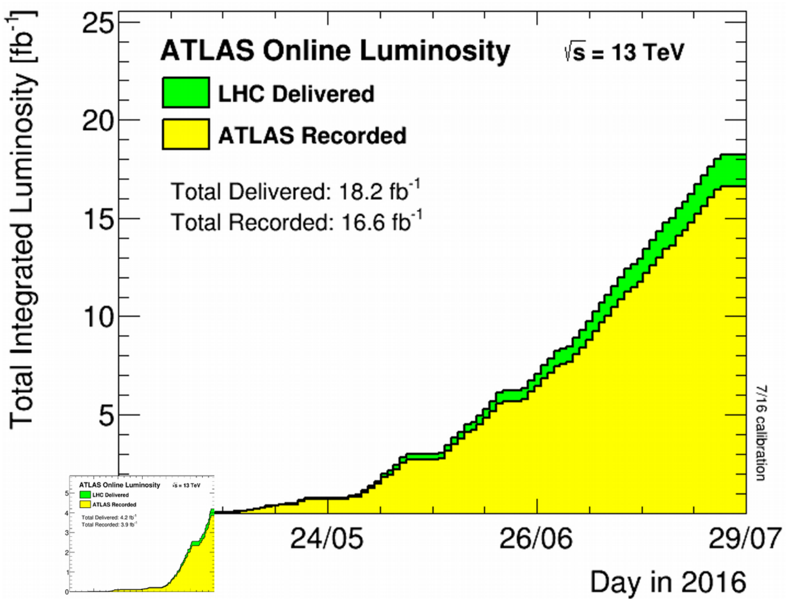
- Stop and sbottom are the SUSY partners of top and bottom quarks
- Light $\tilde{t}_L$, $\tilde{t}_R$, $\tilde{b}_L$ favoured by naturalness
- Perfect time for direct stop & sbottom searches:
  - Lumi × cross-section at 13 TeV significantly beyond run 1 now
- Updates since Moriond:
  - stop in 0, 1, or 2 lepton final states
  - $\text{stop}_2 \rightarrow \text{stop}_1 + Z$ search
  - stop search in tau final states
- Not covered here:
  - **Gluino-mediated** $\tilde{t}$ → see talk by **David Miller** this morning
  - Recent stop 1-lepton and sbottom 0-lepton papers with 2015 data
  - Stop searches in R-parity violating models (4-jet search, talk by **Suen Hou**)



New preliminary results
~13 fb^{-1} (2015+16)

ATLAS Detector & Recorded Dataset

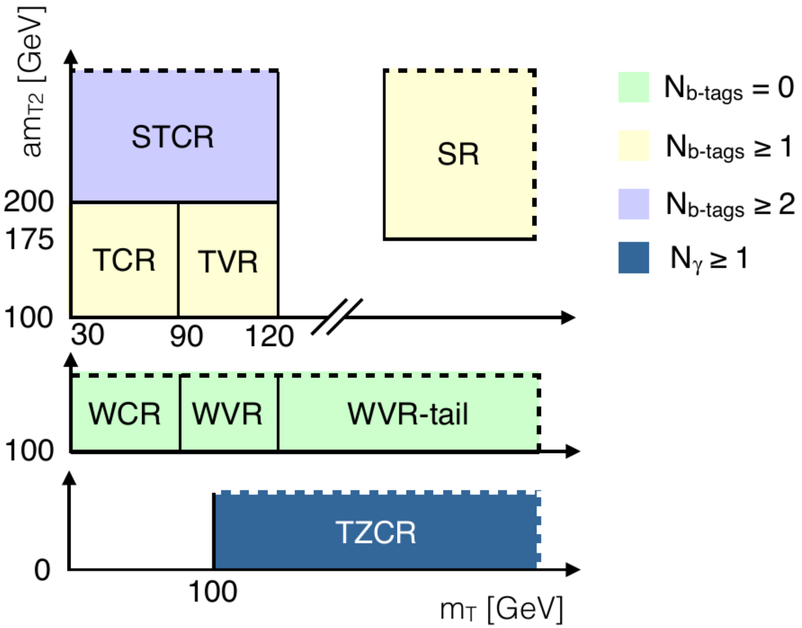




- ATLAS detector and LHC performing very well!
- IBL upgrade: improved tracking → improved flavour tagging
- 2016 pp data-taking at full swing, expecting ~30 fb^{-1} this year
- Analyses shown here use 13-15 fb^{-1} of 2015+2016 data

Data-driven Background Normalisation

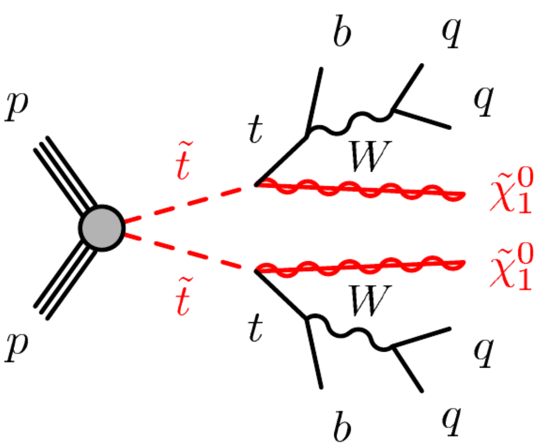
Example from stop 1-lepton:
Relation between SR, CR and VRs



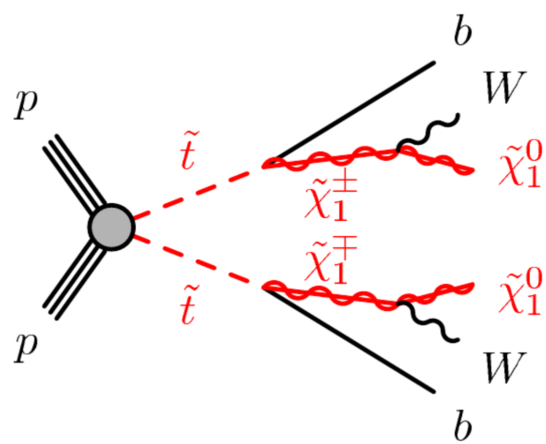
SR = signal region
CR = control region
VR = validation region

- Aim: SR enriched in signal, well-understood background estimate
- Dominant backgrounds (typically): $t\bar{t}$, W+jets, single-top, $t\bar{t}$+V
- Estimate normalisation in CRs
- CR = SR with minimal changes to ...
  - ... enrich targeted background,
  - ... suppress possible signal contamination,
  - ... achieve sufficient event yield,
  - … be orthogonal to other selections

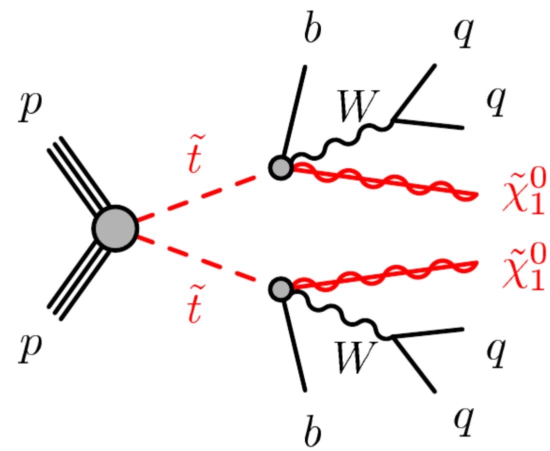
Searches in 0, 1, 2 Lepton Final States



tN: 0L and 1L

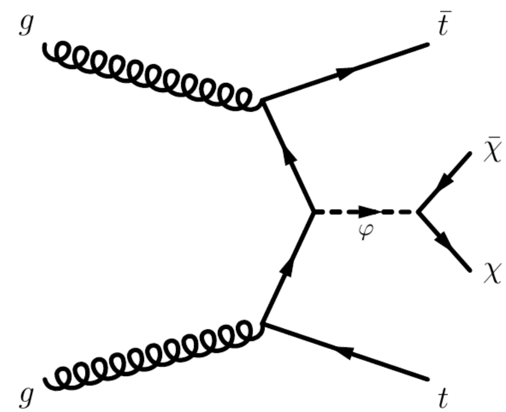


bC: 0L, 1L, 2L



three-body: 0L and 2L

- 3 searches in 2015+2016 data, targeting varying number of leptons (e or μ)
- Direct stop pair production with several decay chains considered
- Also cover $t\bar{t}$+DM final state

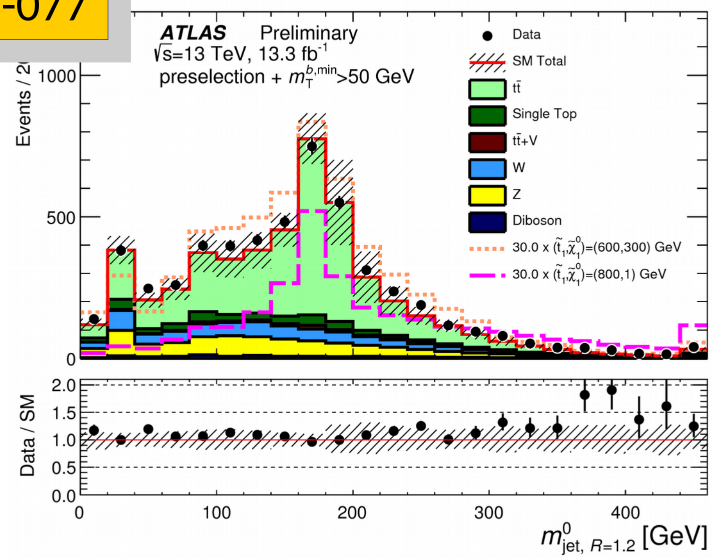


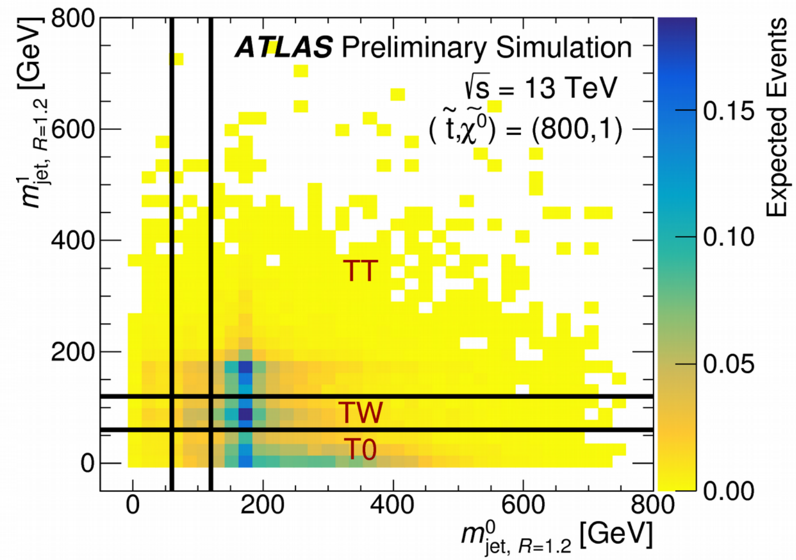
DM: 0L, 1L, 2L

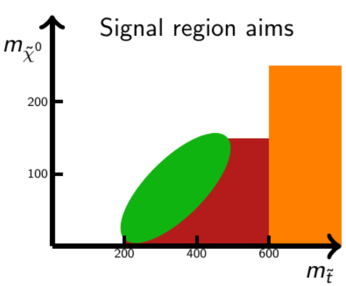
Direct stop (All-hadronic Final State)

ATLAS-CONF-2016-077

Signal channel	$\langle \epsilon \sigma \rangle^{95}_{\text{obs}}$ [fb]
SRA_TT	0.72
SRA_TW	0.46
SRA_T0	1.05
SRB_TT	1.17
SRB_TW	0.97
SRB_T0	3.61
SRC_low	2.19
SRC_med	1.10
SRC_high	0.66
SRD1	0.45
SRD2	0.47
SRD3	0.69
SRD4	0.67
SRD5	0.69
SRD6	0.50
SRD7	0.50
SRD8	0.28
SRE	0.72
SRF	0.42







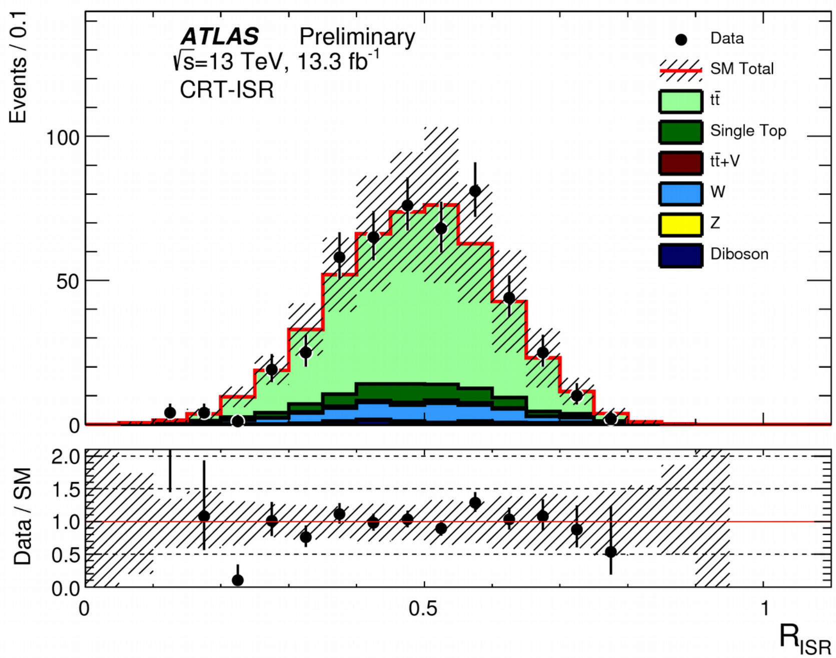
- Multitude of SRs, targeting different scenarios / masses
- SR A & B: tN scenario, events categorised using 2 large R-jets
- SR D: tN scenario, high sensitivity near diagonal

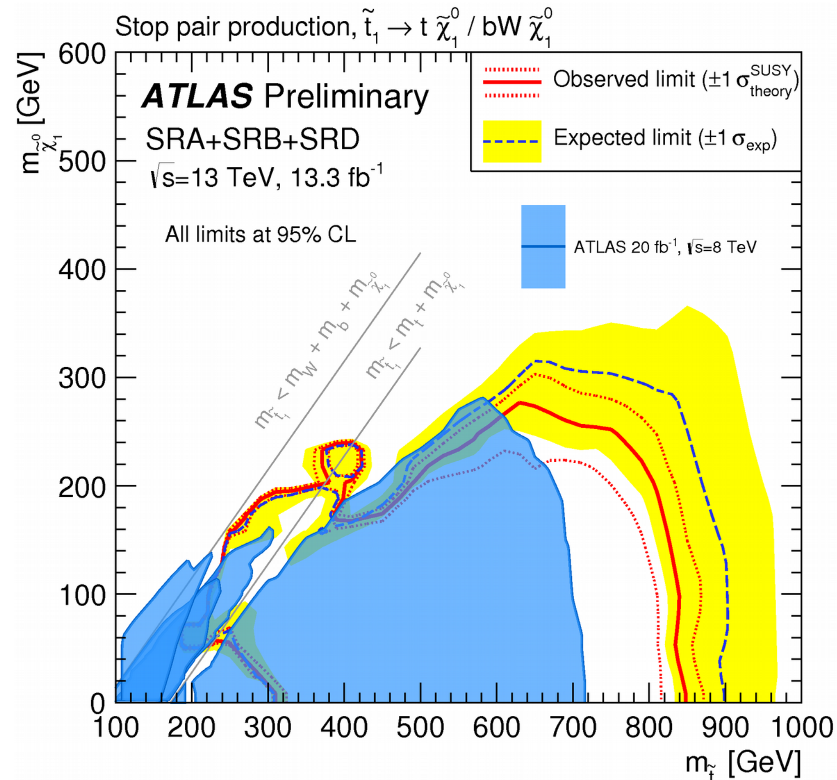
$$R_{\text{ISR}} \equiv \frac{E_{\text{T}}^{\text{miss}}}{p_{\text{T}}^{\text{ISR}}} \sim \frac{m_{\tilde{\chi}_1^0}}{m_{\tilde{t}}}$$

- SR C: bC scenario, SR E: DM scenario, SR F: highly boosted tN

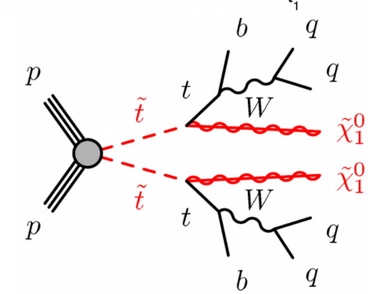
Direct stop (All-hadronic Final State)

ATLAS-CONF-2016-077



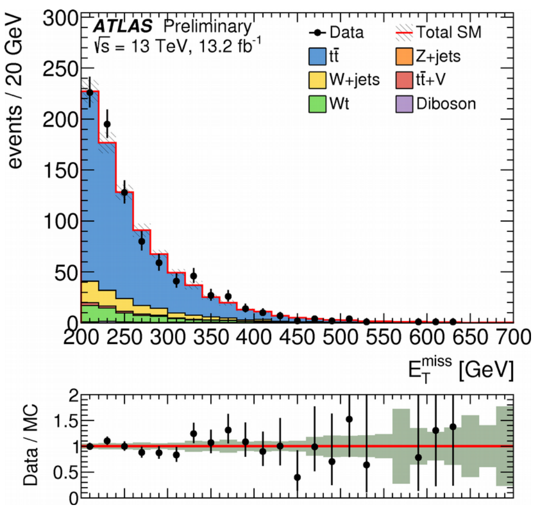


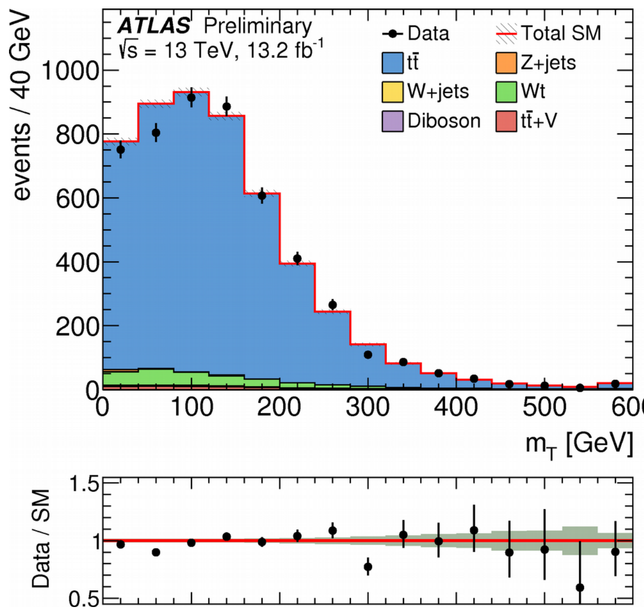
- Further discriminating variables: E_T^{miss} and m_T^{b}
- Main backgrounds: Z+jets, $t\bar{t}$(+W/Z), normalised on data.
- Extended run 1 limits: m($\tilde{t}$)>820 GeV for m($\tilde{\chi}^0$)<220 GeV

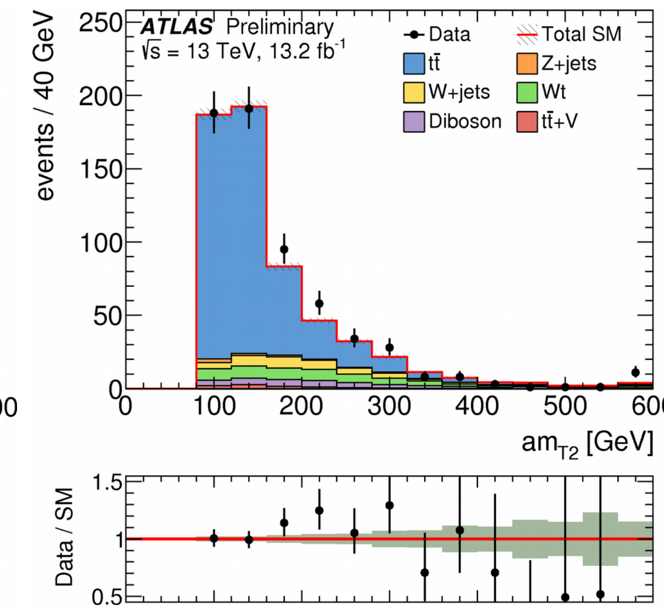


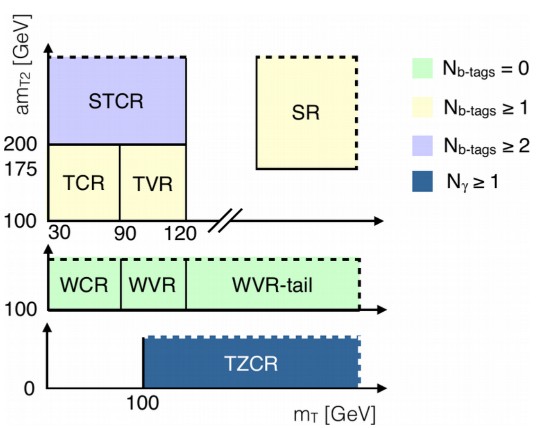
Direct stop (1 Lepton Final States)

ATLAS-CONF-2016-050





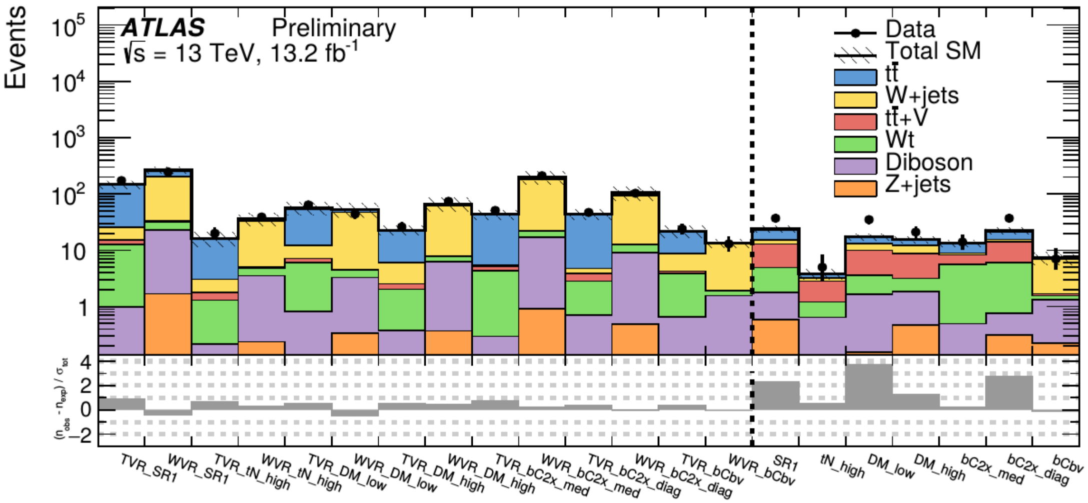


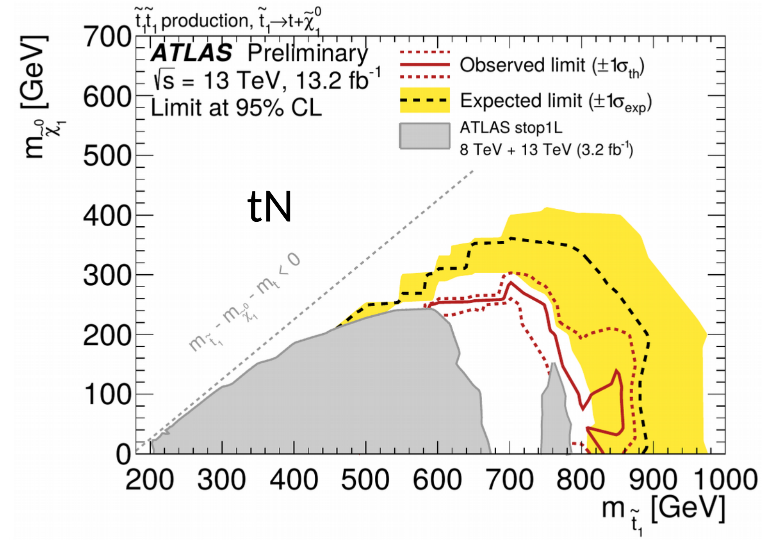


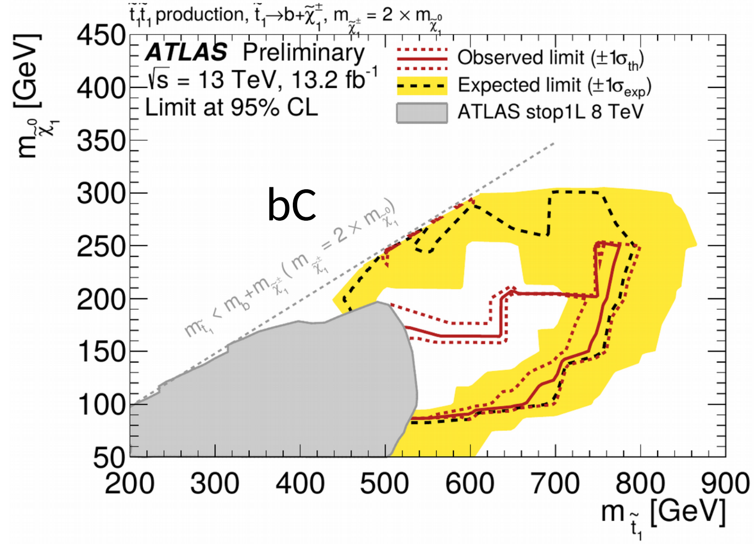
- 7 signal regions (tN, bC, DM), main variables: E_T^{miss}, m_T, am_{T2}, topness
- $t\bar{t}$, $t\bar{t}$+Z, single-top and W+jets backgrounds normalised using data

Direct stop (1 Lepton Final States)

ATLAS-CONF-2016-050



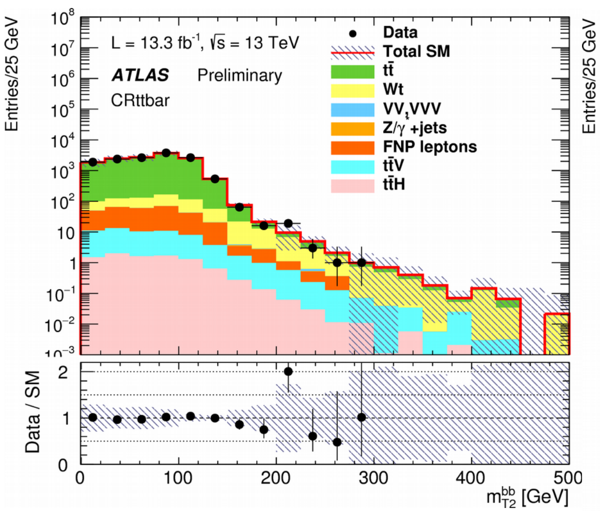


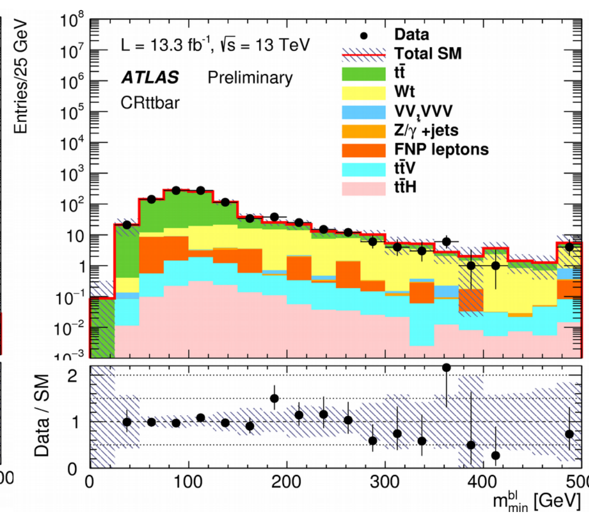


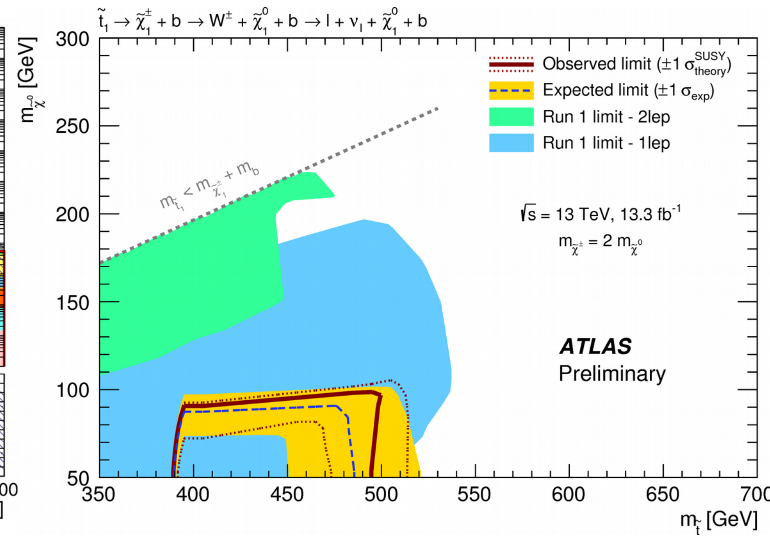
- Excess of 3.3 sigma observed in DM_low
  - only 2.2 sigma in SR1 (optimised for tN)
- Exclusion extended beyond 2015 result:
  - tN: m(t̃)>830 GeV for massless $\tilde{\chi}^0$
  - bC: various limits

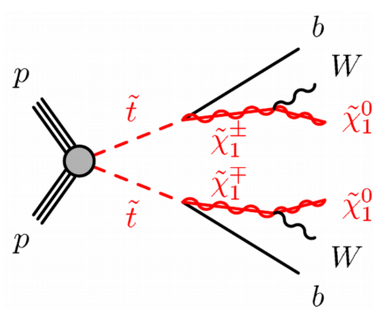
Direct stop (2 Lepton Final States), bC

ATLAS-CONF-2016-076





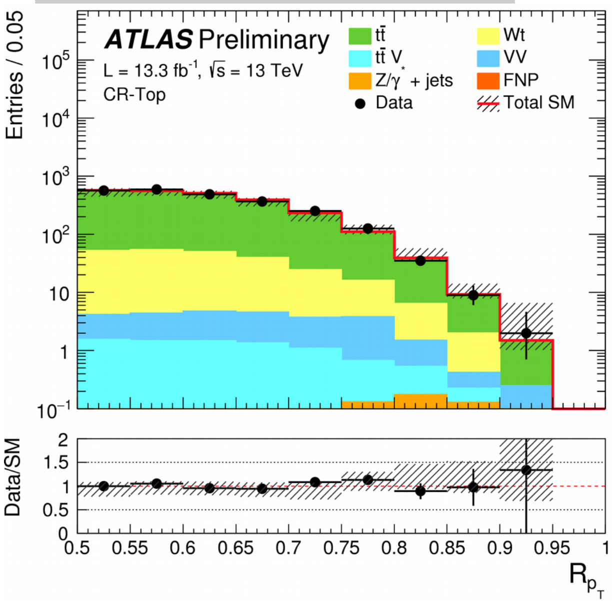


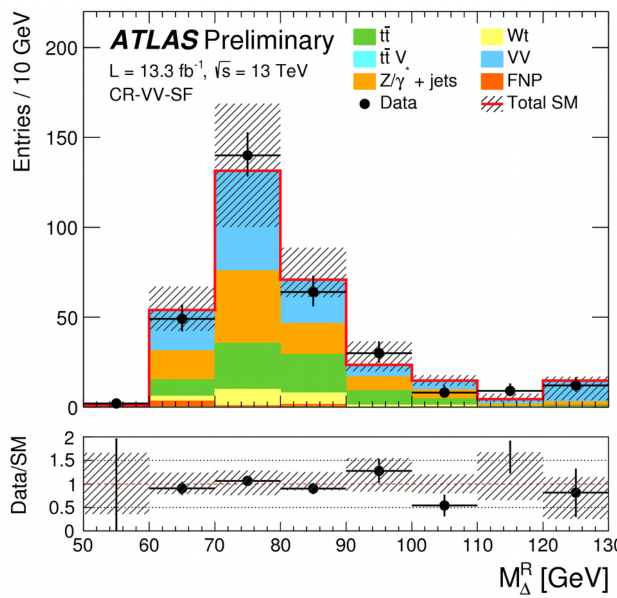


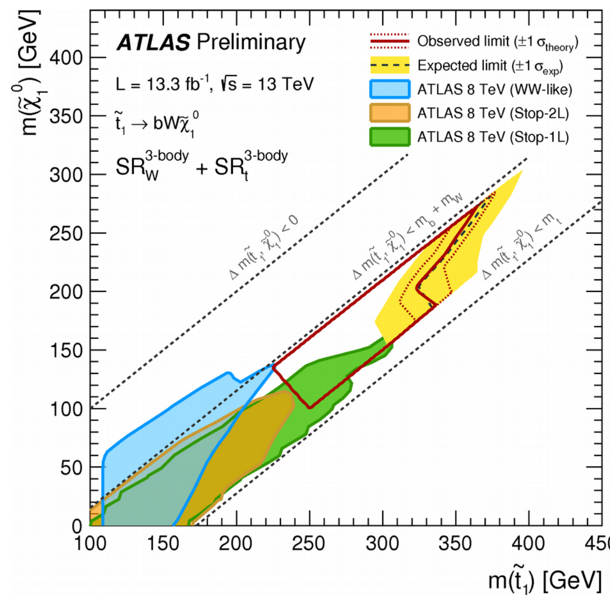
- Final states: 2 leptons, 2 b-jets, ETmiss from ν and χ^0
- Main backgrounds: $t\bar{t}$, singletop (Wt), normalised in CRs
- Event selection: m_{T2}(b,b), m(b,ℓ)
- No significant excess → run 1 exclusion not yet extended much

Direct stop (2 Lepton Final States), 3-body

ATLAS-CONF-2016-076

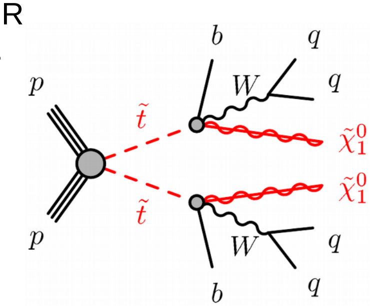






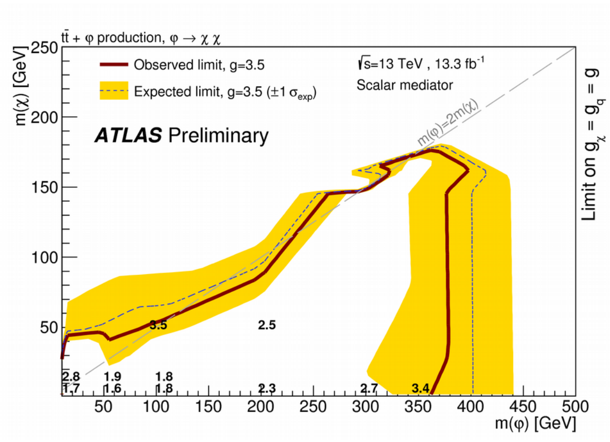
- Three-body selection: "super-razor" variables R p_T and M_Δ^R

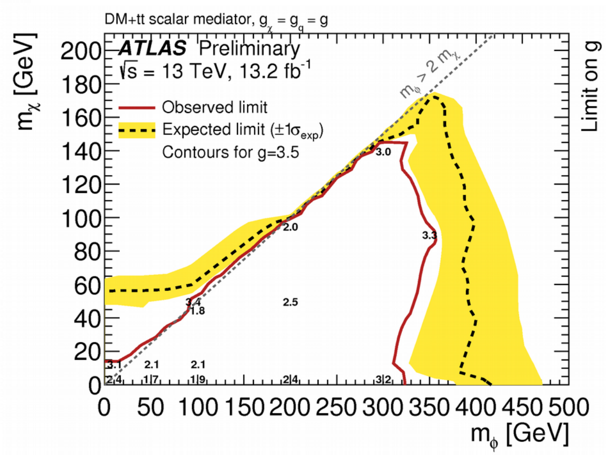
$$R_{p_T} = \frac{|\vec{J}_T|}{|\vec{J}_T| + \sqrt{\hat{s}_R}/4} \qquad M_\Delta^R = \frac{\sqrt{\hat{s}_R}}{\gamma_{R+1}}$$

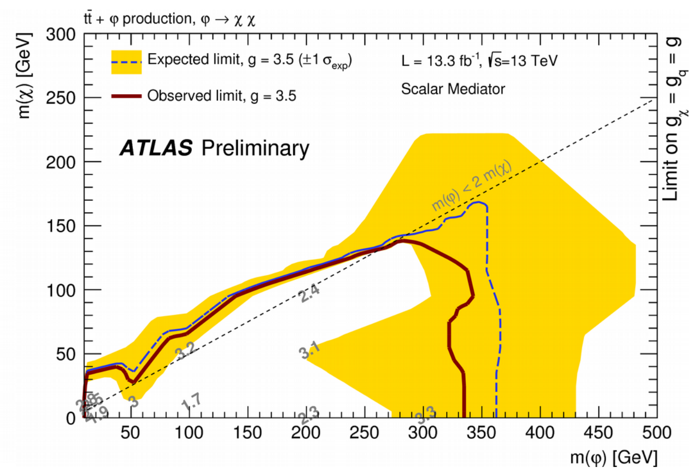


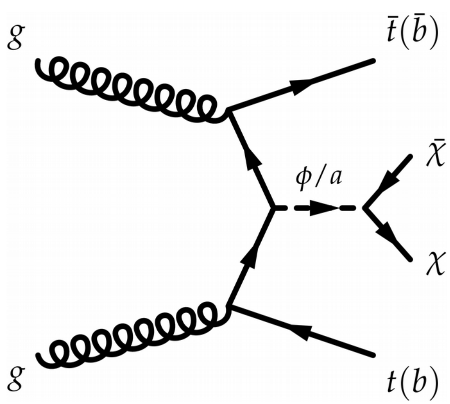
- Extended three-body exclusion: m($\tilde{t}$)>350 GeV

Dark Matter Interpretations for scalar mediator



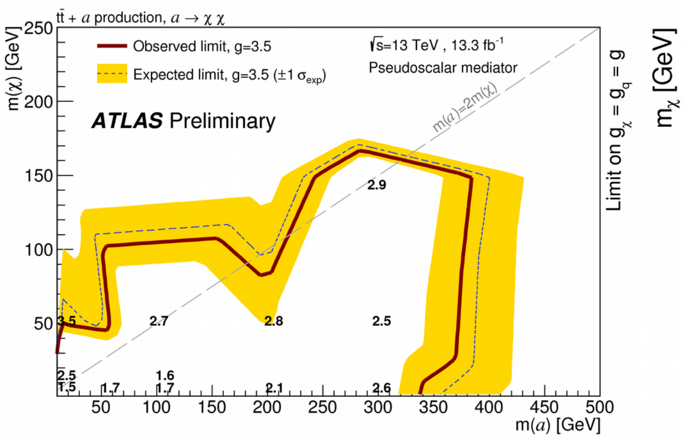


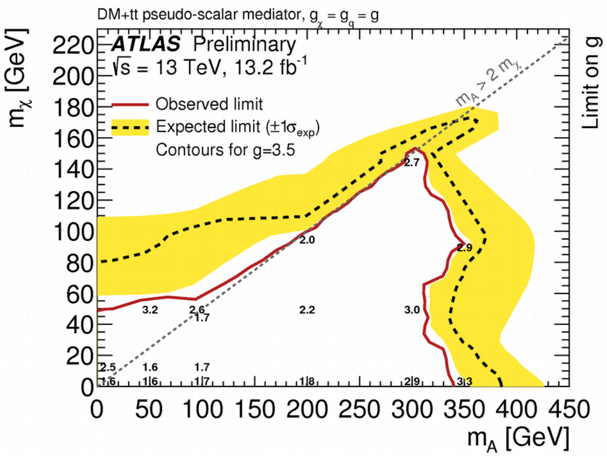


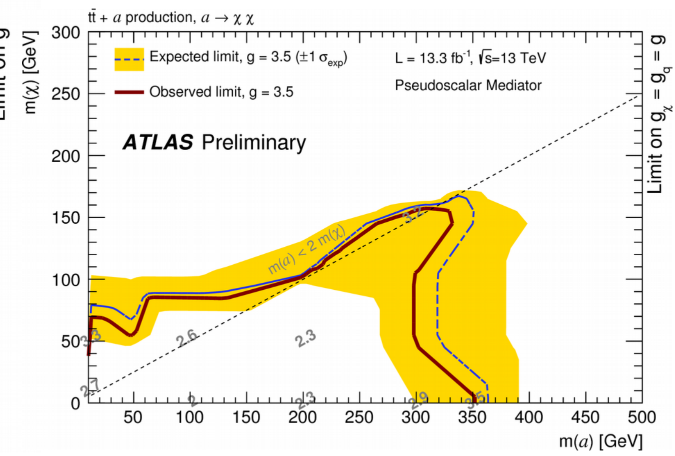


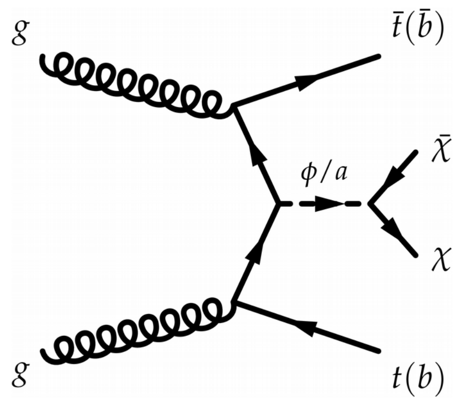
- Comparable limits between stop 0, 1, 2 lepton searches on mediator and neutralino masses
- For scalar mediator

Dark Matter Interpretations for pseudo-scalar





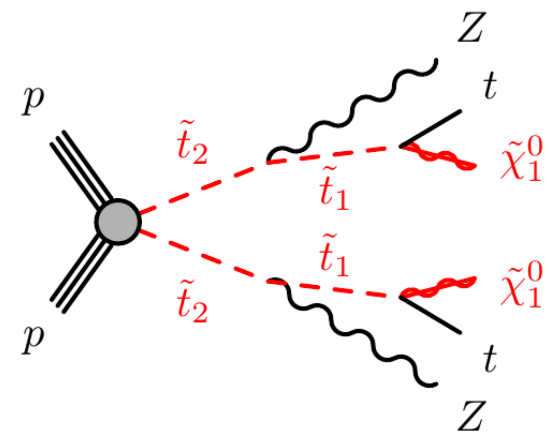




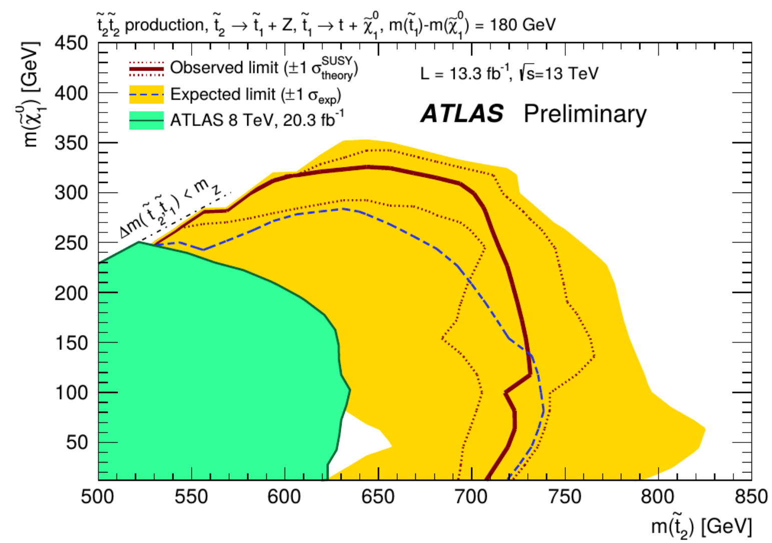
- Comparable limits between stop 0, 1, 2 lepton searches on mediator and neutralino masses
- For scalar mediator ...
- and pseudo-scalar mediator.

Search in stop + Z Final States

ATLAS-CONF-2016-038

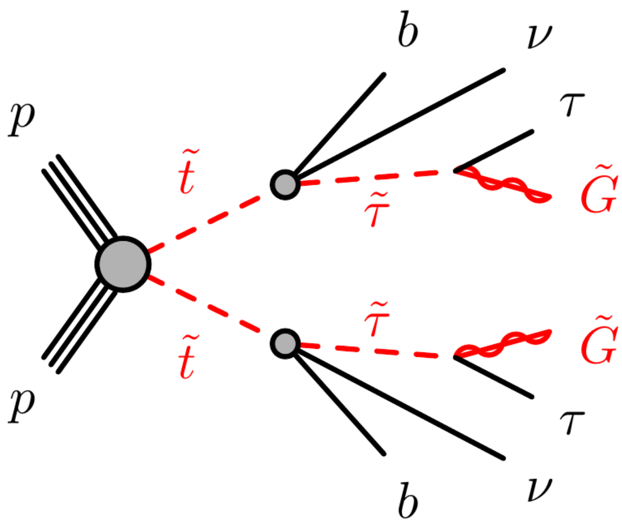


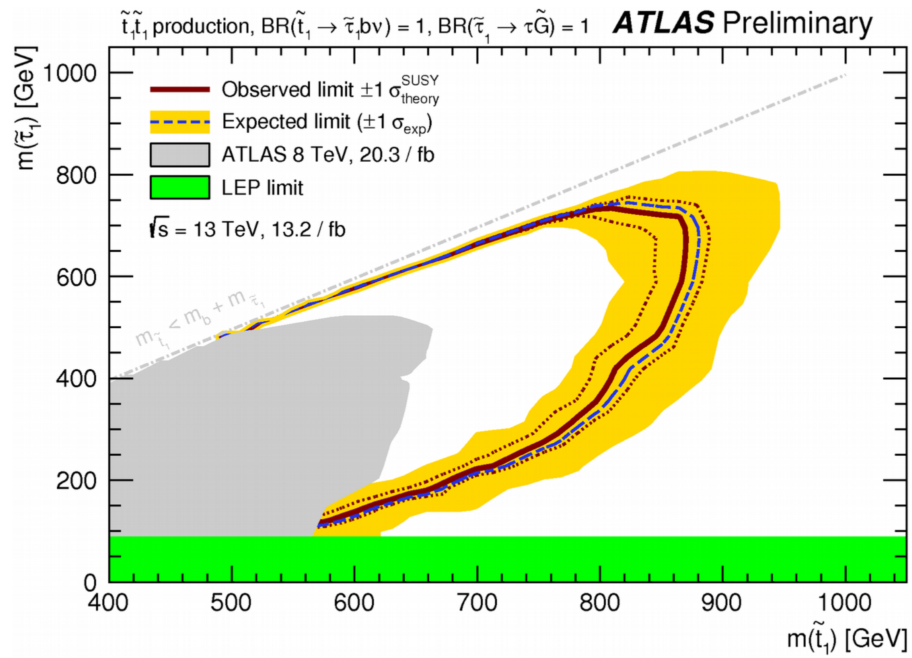
- Search for heavy $\tilde{t} \rightarrow$ light $\tilde{t}$ + Z
- Assume $\tilde{t}_1$ and $\tilde{\chi}^0_1$ are compressed.
- Final states with ≥3 leptons
  - 1 opposite-sign, same-flavour pair with $m_{\ell\ell} \sim m_Z$
- 3 SRs, for different mass-splittings between $\tilde{t}_2, \tilde{t}_1$
  - E_T^{miss}>100 GeV; different requirements on #jets, leading jet p_T, $p_T(\ell,\ell)$
- Main backgrounds: $t\bar{t}$+Z and VV
  - normalisation estimated in CRs
- No excess in any SR, improved limits beyond run 1:
  $m(\tilde{t}_2)$>730 GeV, $m(\tilde{\chi}^0_1)$>325 GeV



Direct stop (Tau Final States)

ATLAS-CONF-2016-048

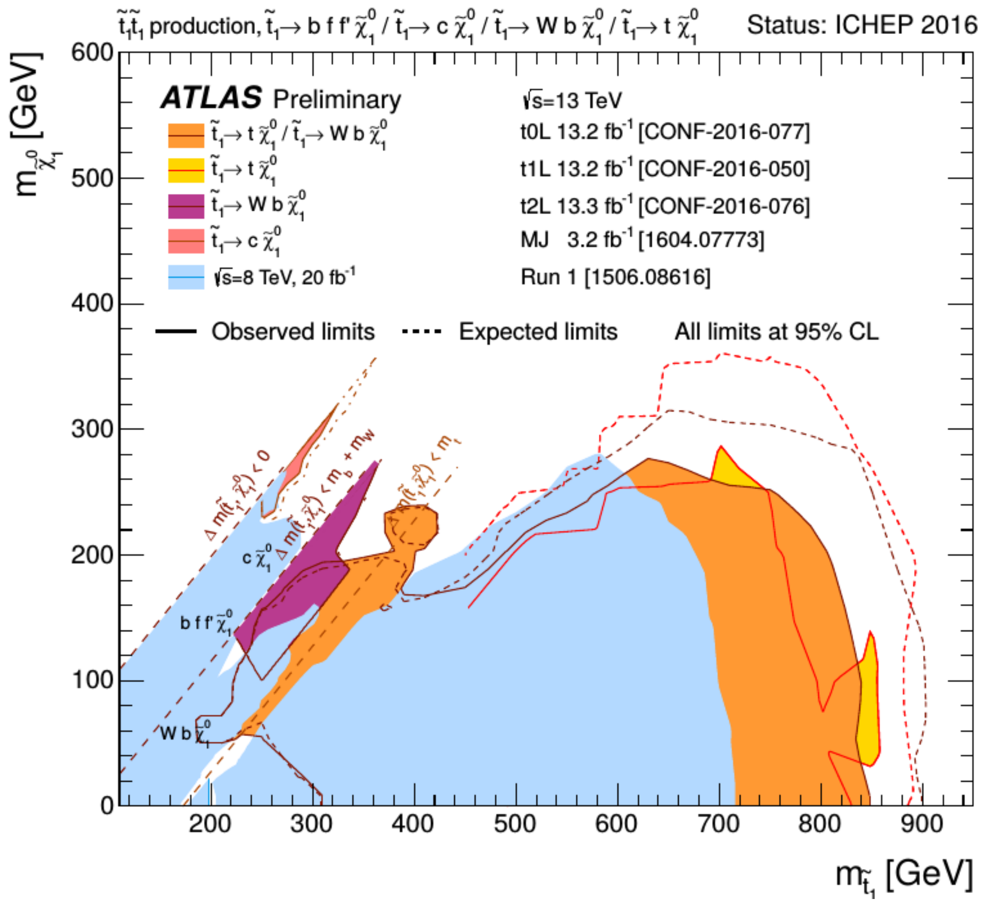




- Motivated within natural gauge mediation framework
- Stop pair-production, decay via stau, gravitino as LSP (~massless)
- Main discriminating variables: E_T^{miss}, $m_{T2}(\ell,\tau)$
- Main background: top events with fake tau → dedicated CR
- Significantly extended exclusion beyond run 1 result

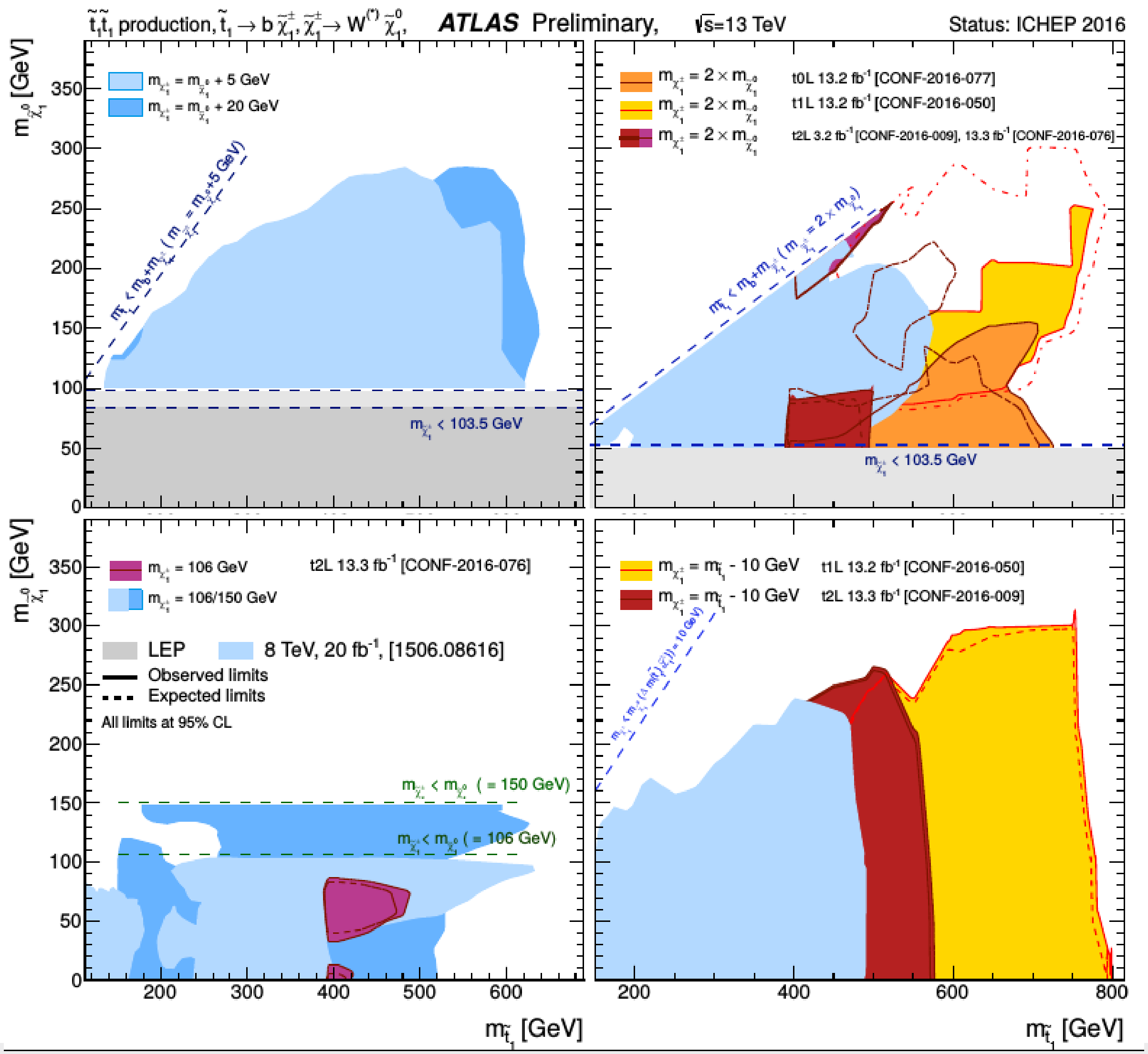
Summary & Conclusions

- Stop searches updated with available run 2 data.
- Many final states & simplified models covered.
- No observation of SUSY…
- … but some excesses that will be interesting to follow as more data is recorded!

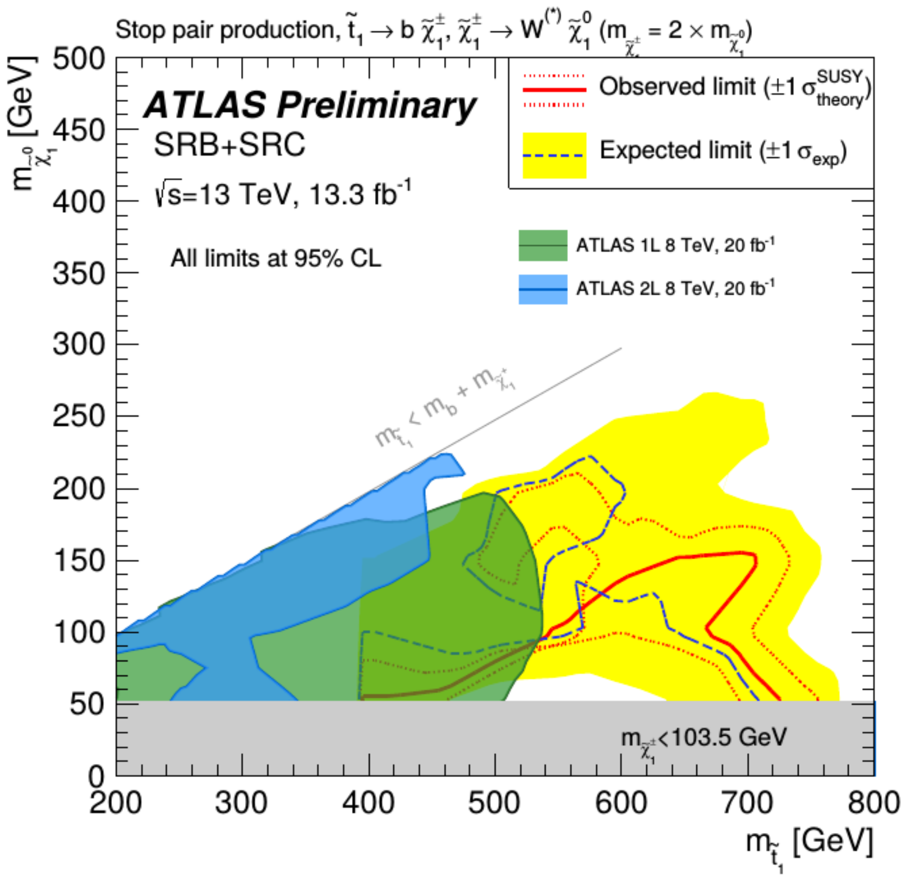


B A C K U P

stop exclusion in b+chargino scenarios



stop 0 lepton, exclusion in b-chargino



stop 0 lepton, SRs

Signal Region		TT	TW	T0
	$m^0_{\text{jet},R=1.2}$	$>$ 120 GeV	$>$ 120 GeV	$>$ 120 GeV
	$m^1_{\text{jet},R=1.2}$	$>$ 120 GeV	60 – 120 GeV	$<$ 60 GeV
SRA	$m^0_{\text{jet},R=0.8}$	$>$ 60 GeV		
	b-tagged jets	≥ 2		
	$m_T^{b,\min}$	$>$ 200 GeV		
	τ-veto	yes		
	E_T^{miss}	$>$ 400 GeV	$>$ 450 GeV	$>$ 500 GeV
SRB	b-tagged jets	≥ 2		
	$m_T^{b,\min}$	$>$ 200 GeV		
	$m_T^{b,\max}$	$>$ 200 GeV		
	τ-veto	yes		
	$\Delta R\,(b,b)$	$>$ 1.2		
	E_T^{miss}	$>$ 250 GeV		

Variable	SRD1	SRD2	SRD3	SRD4	SRD5	SRD6	SRD7	SRD8
min R_{ISR}	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60
max R_{ISR}	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75
b-tagged jets	≥ 2				≥ 1			
N^S_{jet}	≥ 5							
p_T^{ISR}	$>$ 400 GeV							
$p_T^{b\text{-tag},S}$	$>$ 40 GeV							
$p_T^{\text{jet}\,4,S}$	$>$ 50 GeV							
M_T^S	$>$ 300 GeV							
$\Delta\phi_{\text{ISR}}$	$>$ 3.0 radians							

Variable	SRC-low	SRC-med	SRC-high
m_{bjj}	$>$ 250 GeV		
b-tagged jets	≥ 2		
p_T^0	$>$ 150 GeV	$>$ 200 GeV	$>$ 250 GeV
p_T^1	$>$ 100 GeV	$>$ 150 GeV	$>$ 150 GeV
$m_T^{b,\min}$	$>$ 250 GeV	$>$ 300 GeV	$>$ 350 GeV
$m_T^{b,\max}$	$>$ 350 GeV	$>$ 450 GeV	$>$ 500 GeV
$\Delta R(b,b)$	$>$ 0.8		
$E_T^{\text{miss}}/\sqrt{H_T}$	$[5,12]\sqrt{\text{GeV}}$	$[5,12]\sqrt{\text{GeV}}$	$[5,17]\sqrt{\text{GeV}}$
E_T^{miss}	$>$ 250 GeV		

Variable	SRE	SRF
b-tagged jets	≥ 2	
$m^0_{\text{jet},R=1.2}$	$>$ 140 GeV	-
$m^1_{\text{jet},R=1.2}$	$>$ 60 GeV	-
$m^0_{\text{jet},R=0.8}$	-	$>$ 120 GeV
$m^1_{\text{jet},R=0.8}$	-	$>$ 60 GeV
$m_T^{b,\min}$	$>$ 200 GeV	$>$ 175 GeV
$\tau-$veto	yes	no
$\Delta R(b,b)$	$>$ 1.5	-
E_T^{miss}	$>$ 300 GeV	$>$ 250 GeV
H_T	-	$>$ 1100 GeV
$E_T^{\text{miss}}/\sqrt{H_T}$	$>14\sqrt{\text{GeV}}$	$>15\sqrt{\text{GeV}}$

stop 1 lepton, SRs

Variable	SR1	tN_high
Number of (jets, b-tags)	$(\geq 4, \geq 1)$	$(\geq 4, \geq 1)$
Jet $p_T >$ [GeV]	(80 50 40 40)	(120 80 50 25)
E_T^{miss} [GeV]	> 260	> 450
$E_{T,\perp}^{miss}$ [GeV]	–	> 180
$H_{T,sig}^{miss}$	> 14	> 22
m_T [GeV]	> 170	> 210
am_{T2} [GeV]	> 175	> 175
topness	> 6.5	–
m_{top}^{χ} [GeV]	< 270	–
$\Delta R(b, \ell)$	< 3.0	< 2.4
Leading large-R jet p_T [GeV]	–	> 290
Leading large-R jet mass [GeV]	–	> 70
$\Delta\phi(\vec{p}_T^{miss}$, 2nd large-R jet)	–	> 0.6

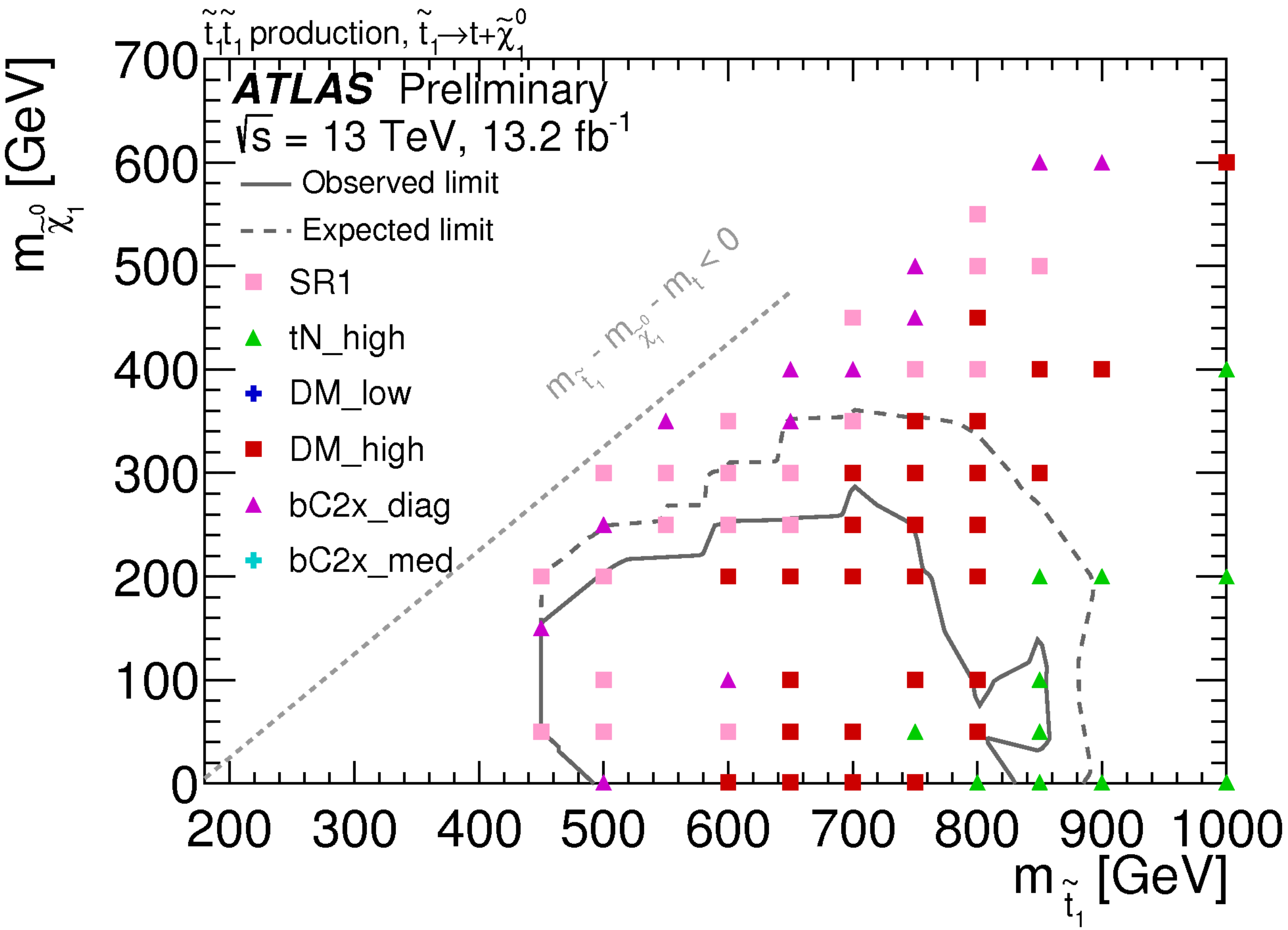
Variable	DM_low	DM_high
Number of (jets, b-tags)	$(\geq 4, \geq 1)$	$(\geq 4, \geq 1)$
Jet $p_T >$ [GeV]	(60 60 40 25)	(50 50 50 25)
E_T^{miss} [GeV]	> 300	> 330
$H_{T,sig}^{miss}$	> 14	> 9.5
m_T [GeV]	> 120	> 220
am_{T2} [GeV]	> 140	> 170
$\min(\Delta\phi(\vec{p}_T^{miss}, \text{jet}_i))(i \in \{1-4\})$	> 1.4	> 0.8
$\Delta\phi(\vec{p}_T^{miss}, \ell)$	> 0.8	–

Variable	bC2x_diag	bC2x_med	bCbv
Number of (jets, b-tags)	$(\geq 4, \geq 2)$	$(\geq 4, \geq 2)$	$(\geq 2, = 0)$
Jet $p_T >$ [GeV]	(70 60 55 25)	(170 110 25 25)	(120 80)
b-tagged jet $p_T >$ [GeV]	(25 25)	(105 100)	–
E_T^{miss} [GeV]	> 230	> 210	> 360
$H_{T,sig}^{miss}$	> 14	> 7	> 16
m_T [GeV]	> 170	> 140	> 200
am_{T2} [GeV]	> 170	> 210	–
$\lvert\Delta\phi(\text{jet}_i, \vec{p}_T^{miss})\rvert(i = 1)$	> 1.2	> 1.0	> 2.0
$\lvert\Delta\phi(\text{jet}_i, \vec{p}_T^{miss})\rvert(i = 2)$	> 0.8	> 0.8	> 0.8
Leading large-R jet mass [GeV]	–	–	[70, 100]
$\Delta\phi(\vec{p}_T^{miss}, \ell)$	–	–	> 1.2

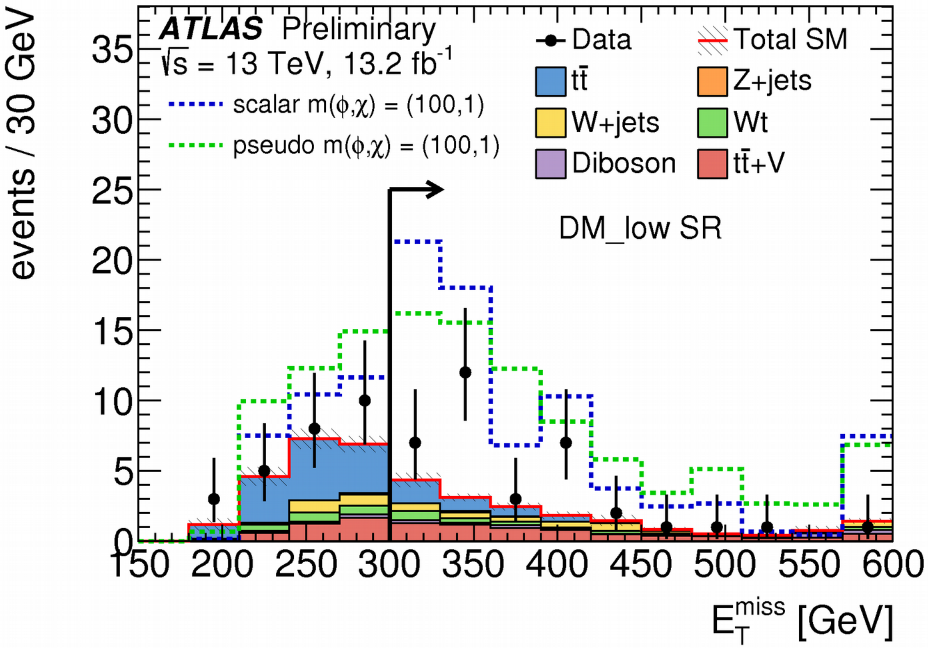
stop 1 lepton, yields

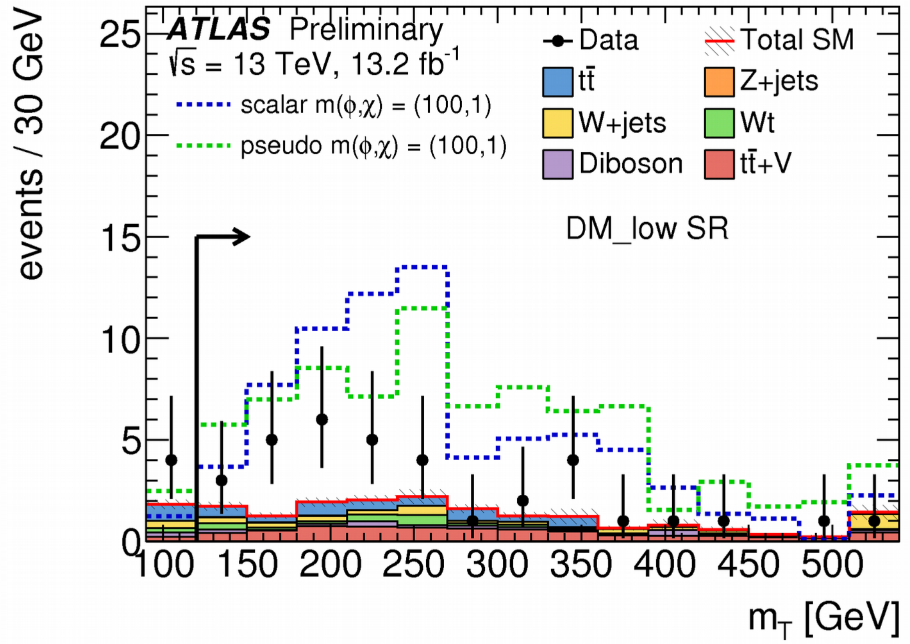
Signal region	SR1	tN_high	bC2x_diag	bC2x_med	bCbv	DM_low	DM_high
Observed	37	5	37	14	7	35	21
Total background	24 ± 3	3.8 ± 0.8	22 ± 3	13 ± 2	7.4 ± 1.8	17 ± 2	15 ± 2
$t\bar{t}$	8.4 ± 1.9	0.60 ± 0.27	6.5 ± 1.5	4.3 ± 1.0	0.26 ± 0.18	4.2 ± 1.3	3.3 ± 0.8
W+jets	2.5 ± 1.1	0.15 ± 0.38	1.2 ± 0.5	0.63 ± 0.29	5.4 ± 1.8	3.1 ± 1.5	3.4 ± 1.4
Single top	3.1 ± 1.5	0.57 ± 0.44	5.3 ± 1.8	5.1 ± 1.6	0.24 ± 0.23	1.9 ± 0.9	1.3 ± 0.8
$t\bar{t} + V$	7.9 ± 1.6	1.6 ± 0.4	8.3 ± 1.7	2.7 ± 0.7	0.12 ± 0.03	6.4 ± 1.4	5.5 ± 1.1
Diboson	1.2 ± 0.4	0.61 ± 0.26	0.45 ± 0.17	0.42 ± 0.20	1.1 ± 0.4	1.5 ± 0.6	1.4 ± 0.5
Z+jets	0.59 ± 0.54	0.03 ± 0.03	0.32 ± 0.29	0.08 ± 0.08	0.22 ± 0.20	0.16 ± 0.14	0.47 ± 0.44
$t\bar{t}$ NF	1.03 ± 0.07	1.06 ± 0.15	0.89 ± 0.10	0.95 ± 0.12	0.73 ± 0.22	0.90 ± 0.17	1.01 ± 0.13
W+jets NF	0.76 ± 0.08	0.78 ± 0.08	0.87 ± 0.07	0.85 ± 0.06	0.97 ± 0.12	0.94 ± 0.13	0.91 ± 0.07
Single top NF	1.07 ± 0.30	1.30 ± 0.45	1.26 ± 0.31	0.97 ± 0.28	–	1.36 ± 0.36	1.02 ± 0.32
$t\bar{t} + W/Z$ NF	1.43 ± 0.21	1.39 ± 0.22	1.40 ± 0.21	1.30 ± 0.23	–	1.47 ± 0.22	1.42 ± 0.21
p_0 (σ)	0.012 (2.2)	0.26 (0.6)	0.004 (2.6)	0.40 (0.3)	0.50 (0)	0.0004 (3.3)	0.09 (1.3)
$N^{\text{limit}}_{\text{non-SM}}$ exp. (95% CL)	$12.9^{+5.5}_{-3.8}$	$5.5^{+2.8}_{-1.1}$	$12.4^{+5.4}_{-3.7}$	$9.0^{+4.2}_{-2.7}$	$7.3^{+3.5}_{-2.2}$	$11.5^{+5.0}_{-3.4}$	$9.9^{+4.6}_{-2.9}$
$N^{\text{limit}}_{\text{non-SM}}$ obs. (95% CL)	26.0	7.2	27.5	9.9	7.2	28.3	15.6

stop 1 lepton, best expected region (CLs)

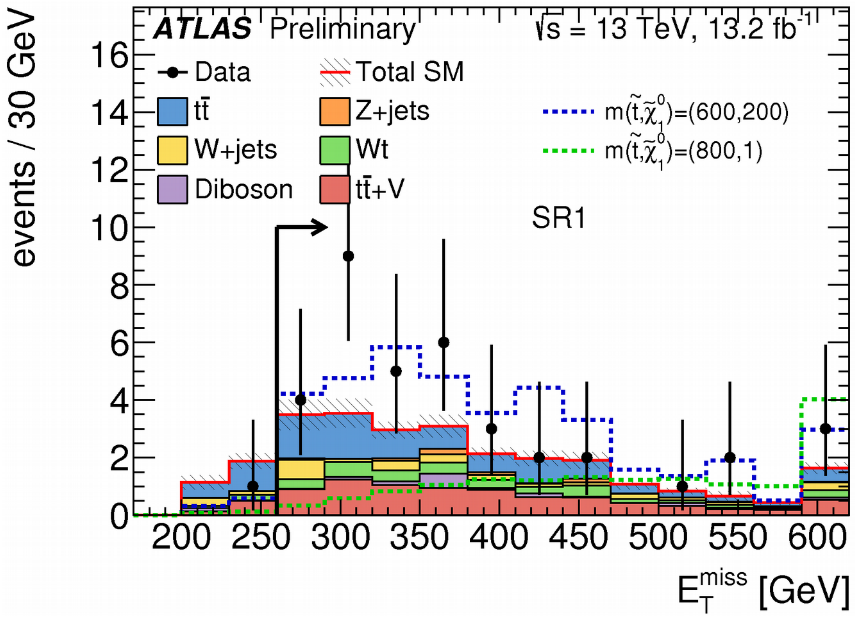


stop 1 lepton SR DM_low kinematics





stop 1 lepton SR1 kinematics



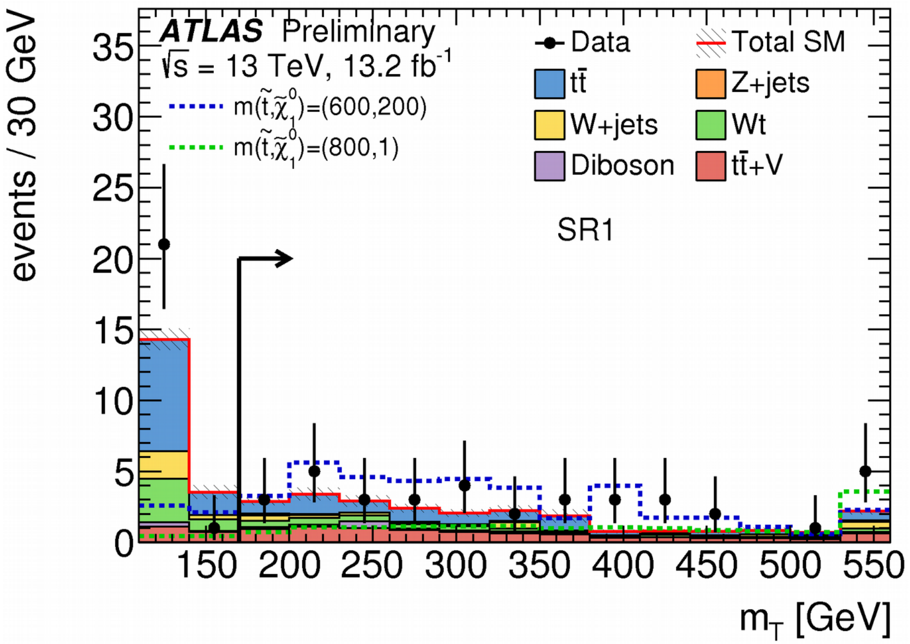
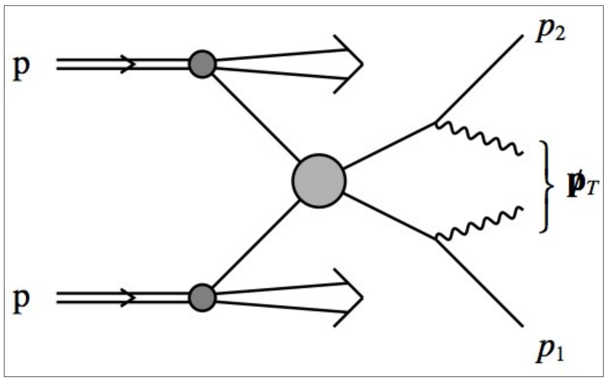
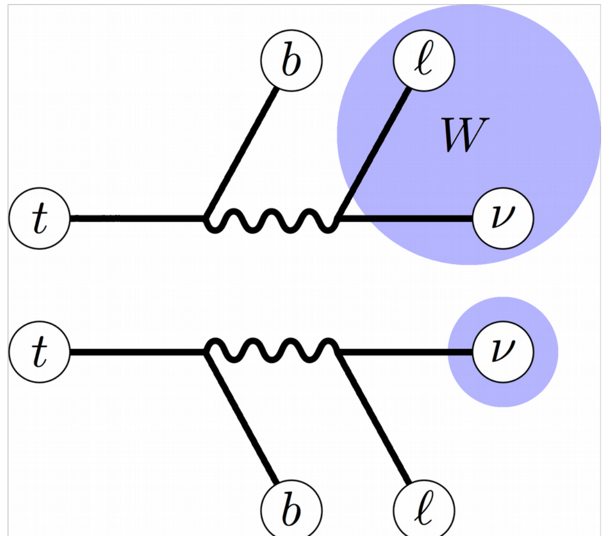
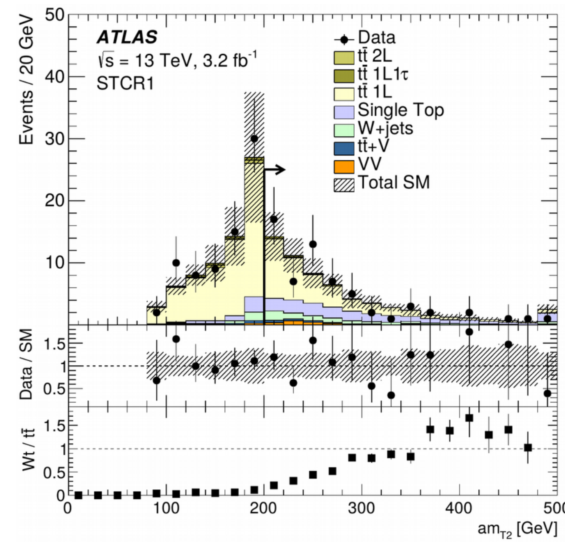


Illustration of asymmetric m_{T2}





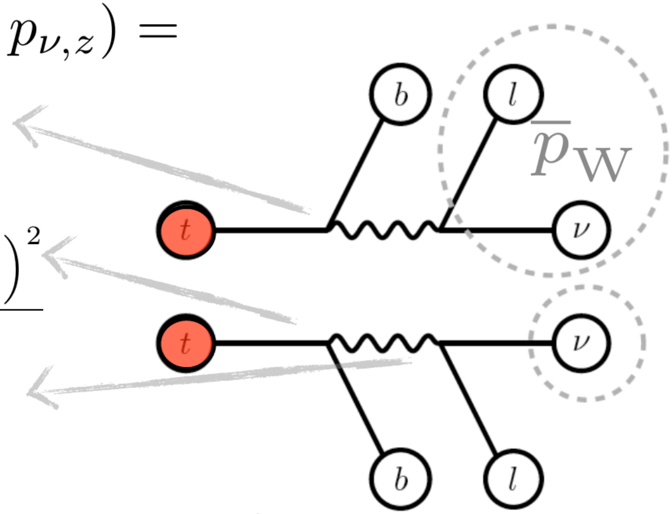


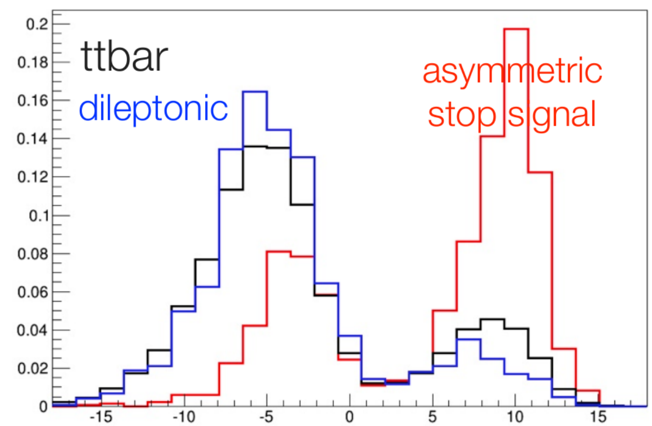
$$M_{T2}^2 \equiv \min_{\not{p}_1+\not{p}_2=\not{p}_T} \left[\max\left\{ m_T^2(\mathbf{p}_{Tl^-}, \not{p}_1), m_T^2(\mathbf{p}_{Tl^+}, \not{p}_2) \right\} \right]$$

- m_{T2}: transverse mass in case of 2 invisible particles
- Dileptonic $t\bar{t}$ background, one lepton not reconstructed
  → one "invisible W", one neutrino
- Combine b1 + W, and b2 + ℓ + ν to define am_{T2}

How to compute topness

$$S(p_{W,x}, p_{W,y}, p_{W,z}, p_{\nu,z}) = \frac{\left(m_t^2 - (\overline{p}_{\mathrm{b}_2} + \overline{p}_{\mathrm{W}})^2\right)^2}{a_t^4} + \frac{\left(m_t^2 - (\overline{p}_{\mathrm{b}_1} + \overline{p}_\ell + \overline{p}_\nu)^2\right)^2}{a_t^4} + \frac{\left(m_W^2 - (\overline{p}_\ell + \overline{p}_\nu)^2\right)^2}{a_W^4} + \frac{\left(4\, m_t^2 - (\overline{p}_\ell + \overline{p}_\nu + \overline{p}_{\mathrm{b}_1} + \overline{p}_{\mathrm{b}_2} + \overline{p}_{\mathrm{W}})^2\right)^2}{a_{CM}^4}$$





- S describes incomplete dileptonic $t\bar{t}$ event in terms of not-reconstructed W and $p_z(\nu)$. Topness := *min(ln(S))*.
- Low topness → dileptonic $t\bar{t}$ event.
- Particularly powerful to select asymmetric stop decays.

stop 2 lepton regions

Variable	SR^{hadMT2}_{Low}	SR^{hadMT2}_{High}
$\lvert m_{\ell\ell} - m_Z \rvert$ [GeV] (SF only)	>20	>20
b-jet multiplicity	2	2
m^{bb}_{T2} [GeV]	>220	>220
p^{lep1}_{T} [GeV]	<120	<120
$E^{bl}_{T,min}$ [GeV]	-	>180

Variable	DM-SRL	DM-SRH
$\lvert m_{\ell\ell} - m_Z \rvert$ [GeV] (SF only)	>20	>20
b-jet multiplicity	> 0	> 0
$\Delta\phi_{boost}$	< 1.0	< 1.0
m^{ll}_{T2} [GeV]	>120	>120
E^{miss}_{T} [GeV]	> 180	> 260

Common selection		
Lepton flavour	SF, DF	
$\lvert m_{\ell\ell} - m_Z \rvert$ [GeV] (SF only)	>10	
R_{p_T}	>0.5	
$1/\gamma_{R+1}$	>0.8	
$\Delta\phi^R_\beta$	$> 0.85 \lvert\cos\theta_b\rvert + 1.8$	
Region specific	SR^{3-body}_{W}	SR^{3-body}_{t}
b-jet multiplicity	$= 0$	> 0
M^R_Δ [GeV]	> 95	> 110

stop 2 lepton yields

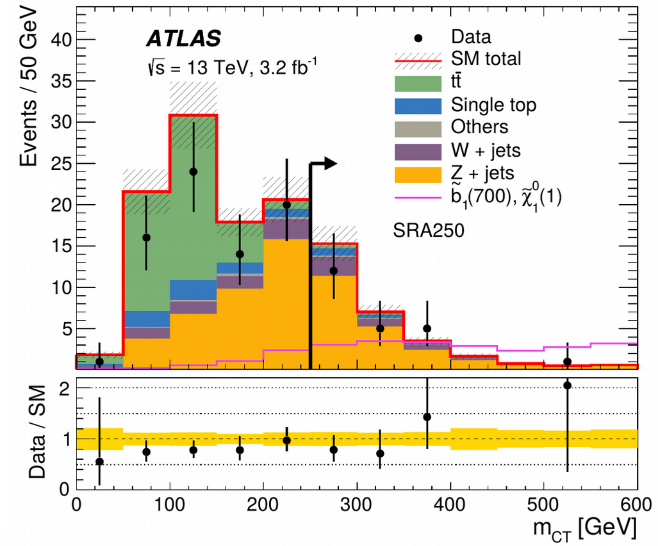
	SR^{hadMT2}_{Low}	SR^{hadMT2}_{High}
Observed	21	8
Total Standard Model	35 ± 14	17.3 ± 7.5
Fitted $t\bar{t}$	7.6 ± 3.4	3.3 ± 2.3
Fitted Wt	22 ± 15	11.7 ± 8.3
Diboson	0.44 ± 0.17	0.29 ± 0.15
$Z/\gamma*$+jet	0.15 ± 0.12	0.07 ± 0.05
Fakes and non-prompt	3.7 ± 1.5	1.5 ± 1.0
$t\bar{t}$ V	0.81 ± 0.10	0.42 ± 0.05
$t\bar{t}$ H	0.21 ± 0.03	0.09 ± 0.02
MC exp. Standard Model	30	14.7
MC exp. $t\bar{t}$	7.6	3.4
MC exp. Wt	17	9.0
$\tilde{t}_1\,\tilde{t}_1\ m(\tilde{t}_1, \tilde{\chi}^{\pm}_1, \tilde{\chi}^0_1) = (400, 106, 50)$ GeV	27.4 ± 3.4	12.4 ± 2.5
$\tilde{t}_1\,\tilde{t}_1\ m(\tilde{t}_1, \tilde{\chi}^{\pm}_1, \tilde{\chi}^0_1) = (500, 106, 50)$ GeV	16.2 ± 1.6	10.8 ± 1.1

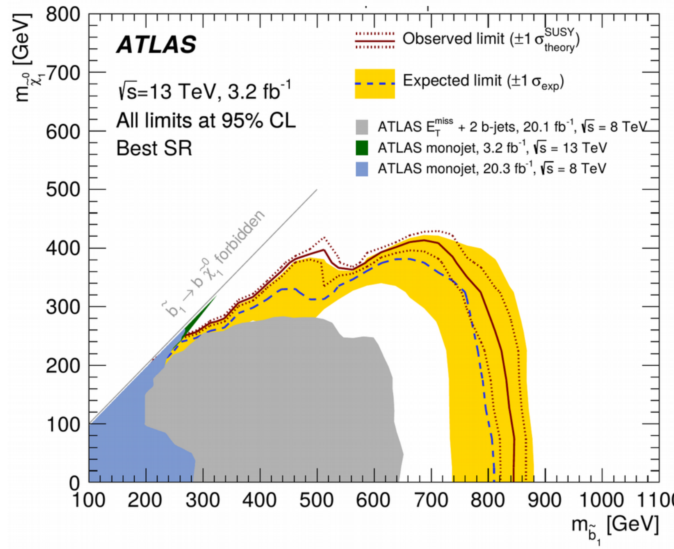
Region	SR^{3-body}_{W}-SF	SR^{3-body}_{W}-DF
Observed events	13	6
Total Standard Model	12 ± 4	5.3 ± 2.2
Fitted $t\bar{t}$	3.9 ± 2.2	2.3 ± 1.4
Wt	0.38 ± 0.16	0.21 ± 0.08
$t\bar{t}\ V$	0.11 ± 0.03	0.10 ± 0.03
Fitted VVDF	—	2.1 ± 1.1
Fitted VVSF	5.8 ± 2.6	—
Z/γ^*+jets	0.79 ± 0.35	—
Fake and non-prompt	0.98 ± 0.13	0.58 ± 0.12
MC exp. Standard Model	11	4.9
MC exp. $t\bar{t}$	3.9	2.3
MC exp. VVDF	—	1.6
MC exp. VVSF	4.8	—
$\tilde{t}_1\,\tilde{t}_1\ m(\tilde{t}_1, \tilde{\chi}^0_1) = (250, 160)$ GeV	21.8 ± 1.8	18.1 ± 2.0
$\tilde{t}_1\,\tilde{t}_1\ m(\tilde{t}_1, \tilde{\chi}^0_1) = (300, 150)$ GeV	5.3 ± 0.8	5.1 ± 0.6

Direct sbottom (0 lepton final state)

1606.08772, submitted to EPJ-C

- Sbottom pair-production, with $\tilde{b} \rightarrow b\ \tilde{\chi}^0$
- ≥2 b selection with lepton veto
- Using E_T^{miss}, leading jet p_T, m(b,b) and contransverse mass m_{CT}
- Main backgrounds: $t\bar{t}$ and single-top
- Exclusion extended beyond run 1 with 2015 dataset:
  - $m(\tilde{b}) \geq 800$ GeV for $m(\tilde{\chi}^0)<360$ GeV





Definition of m_{CT}

$$m^2_{\mathrm{CT}}(v_1, v_2) = [E_{\mathrm{T}}(v_1) + E_{\mathrm{T}}(v_2)]^2 - [\boldsymbol{p}_{\mathrm{T}}(v_1) - \boldsymbol{p}_{\mathrm{T}}(v_2)]^2 .$$

In this analysis, v_1 and v_2 are the two leading b-jets. For signal events, these correspond to the b-jets from the squark decays and the invisible particles are the two neutralinos. The contransverse mass is invariant under equal and opposite boosts of the parent particles in the transverse plane. For systems of parent particles produced with small transverse boosts, m_{CT} is bounded from above by an analytical combination of particle masses. This bound is saturated when the two visible objects are collinear. For $t\bar{t}$ events, this kinematic bound is at 135 GeV, while for production of bottom squark pairs the bound is given by $m^{\mathrm{max}}_{\mathrm{CT}} = (m^2_{\tilde{b}_1} - m^2_{\tilde{\chi}^0_1})/m_{\tilde{b}_1}$. The selection on m_{CT} is optimized based on the bottom squark and neutralino masses considered and SRA is further divided into three overlapping regions, SRA250, SRA350 and SRA450, where the naming conventions reflects the minimum value allowed for m_{CT}. Finally, a selection on the invariant mass of the two b-jets ($m_{bb} > 200$ GeV) is applied to further enhance the signal yield over the SM background contributions. For a signal model corresponding to $m_{\tilde{b}_1} = 800$ GeV and $m_{\tilde{\chi}^0_1} = 1$ GeV, 10%, 8% and 5% of the simulated signal events are retained by the SRA250, SRA350 and SRA450 selections, respectively.

Definition of R_{ISR} (stop 0 lepton)

SRD is optimized for direct top squark pair production where $\Delta m(\tilde{t}, \tilde{\chi}_1^0) \sim m_t$, a regime in which the signal topology is extremely similar to SM $t\bar{t}$ production. However, in the presence of high-momentum ISR, the di-top-squark system is boosted in the transverse plane. To leading order, the ratio of the $E_{\mathrm{T}}^{\mathrm{miss}}$ to the p_{T} of the ISR system in the CM frame ($p_{\mathrm{T}}^{\mathrm{ISR}}$), defined as R_{ISR}, is proportional to the ratio of the $\tilde{\chi}_1^0$ and $\tilde{t}$ masses [60, 61]:

$$R_{\mathrm{ISR}} \equiv \frac{E_{\mathrm{T}}^{\mathrm{miss}}}{p_{\mathrm{T}}^{\mathrm{ISR}}} \sim \frac{m_{\tilde{\chi}_1^0}}{m_{\tilde{t}}}. \qquad (2)$$

A recursive jigsaw reconstruction technique, as described in Ref. [62], is used to divide each event into an ISR hemisphere and a sparticle hemisphere, where the latter consists of the pair of candidate top squarks, each of which decays via a top quark and $\tilde{\chi}_1^0$. Objects are grouped together based on their proximity in the lab frame transverse plane by minimizing the reconstructed transverse masses of the ISR system and sparticle system simultaneously over all choices of object assignment. Kinematic variables are then defined based on this assignment of objects to either the ISR system or the sparticle system.

Definition of R_{pT} (stop 2 lepton)

R_{p_T}: The quantity R_{p_T} is defined as:

$$R_{p_T} = \frac{|\vec{J}_T|}{|\vec{J}_T| + \sqrt{\hat{s}}_R/4} \quad (1)$$

where $\vec{J}_T$ is the vector sum of the momenta of all visible particles and the missing transverse momentum, and $\sqrt{\hat{s}}_R$ is the approximate centre of mass energy in the razor frame R (the pair production centre-of-mass frame). Since only the leptons are considered in the visible system the $|\vec{J}_T|$ will be over-estimated in events with additional activity, i.e. signal and top-quark production, which biases R_{p_T} towards unity and provides rejection power against diboson production which tends towards zero.

Definition of M_{Δ}^{R} (stop 2 lepton)

- $1/\gamma_{R+1}$: This quantity is the inverse of the Lorentz factor, γ_{R+1}, associated with the boosts from the razor frame R to the approximations of the two decay frames of the parent particles. It is a measure of how the two visible systems are distributed, tending towards unity when visible particles are equal in momenta and collinear, while preferring lower values when they are back-to-back or having different momenta. It is observed to provide rejection power against both top-quark and diboson production processes.

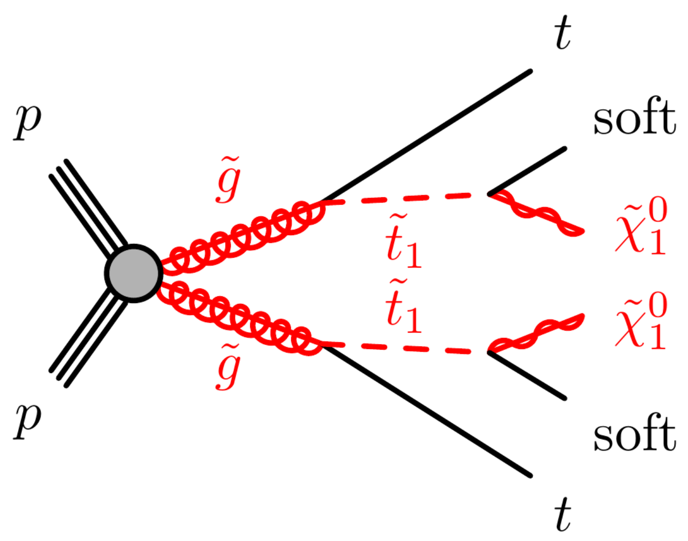
- M_{Δ}^{R}: The quantity M_{Δ}^{R} is defined as:

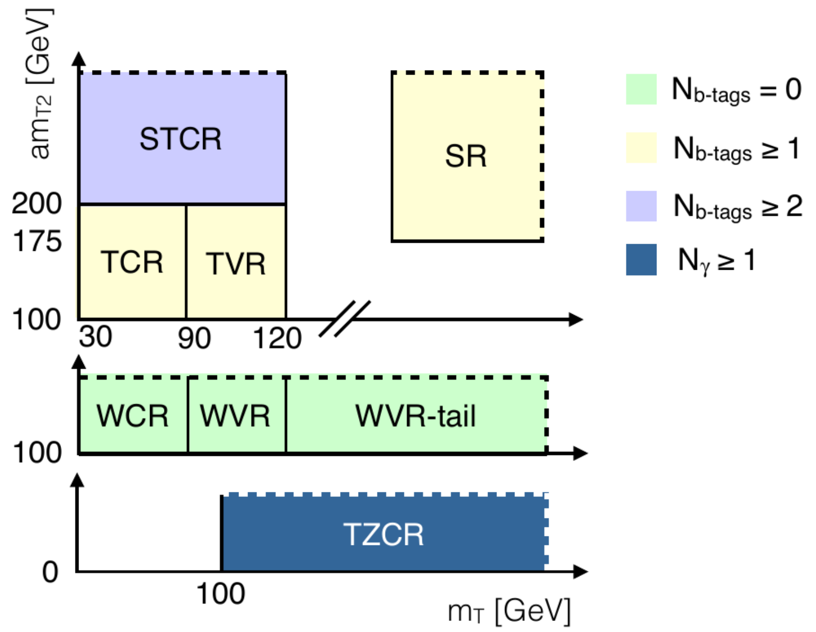
$$M_{\Delta}^{R} = \frac{\sqrt{\hat{s}_R}}{\gamma_{R+1}} \tag{2}$$

This variable has a kinematic end-point that is proportional to the mass-splitting between the parent particle and the invisible particle. Therefore, it provides rejection against both top-quark and diboson production processes when it is required to be greater than the pole-mass of the W-boson, in which regime it also helps reject the residual Z/γ^*+jets background.

Gluino-mediated stop (1 lepton final states)

1606.03903, submitted to PRD

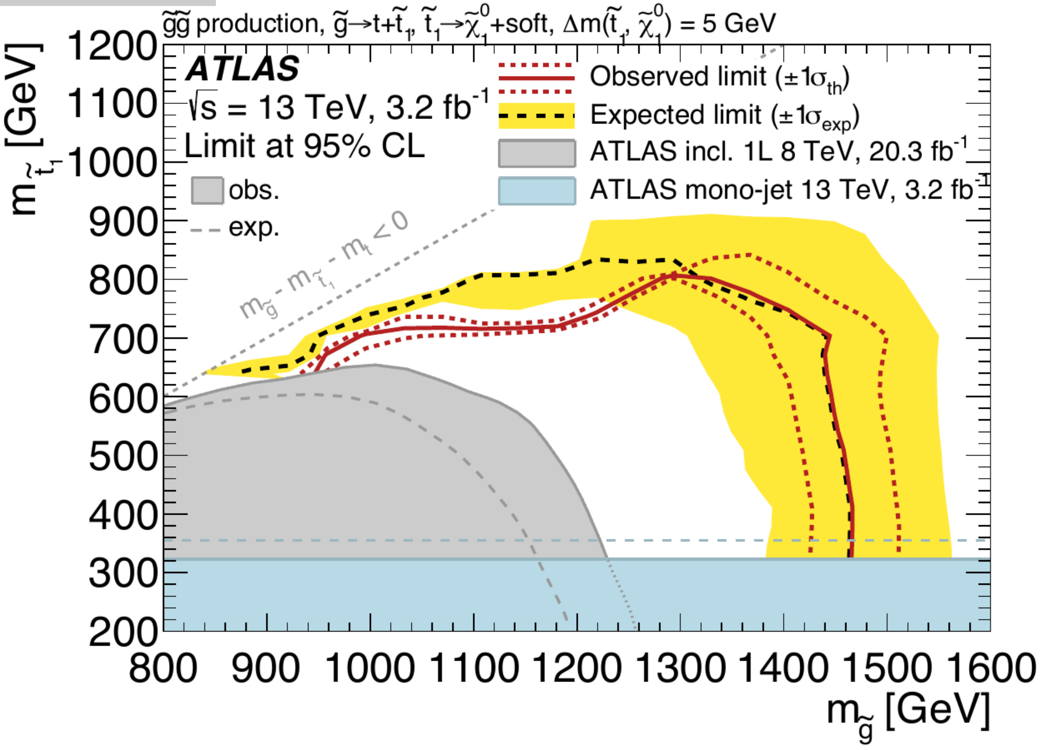




- Refinement of Moriond result, using 2015 data only
- 3 signal regions, main variables: E_T^{miss}, m_T, am_{T2}, topness
- $t\bar{t}$, single-top and W+jets backgrounds normalised using data

Gluino-mediated stop (1 lepton final states)

1606.03903, submitted to PRD



- No limit set on stop mass in this scenario
- Exclusion extended beyond run 1 with 2015 data:
  - $m(\tilde{g}) \geq 1460$ GeV, for low $m(\tilde{t})$ and $\Delta m(\tilde{t},\tilde{\chi}^0_1) = 5$ GeV