ATLAS SUSY Searches Using a Higgs Boson in the Final State

Steve Muanza

CPPM Marseille, CNRS-IN2P3 & AMU
On behalf of the ATLAS Collaboration

First Mediterranean Conference on Higgs Physics, Tangier, Morocco

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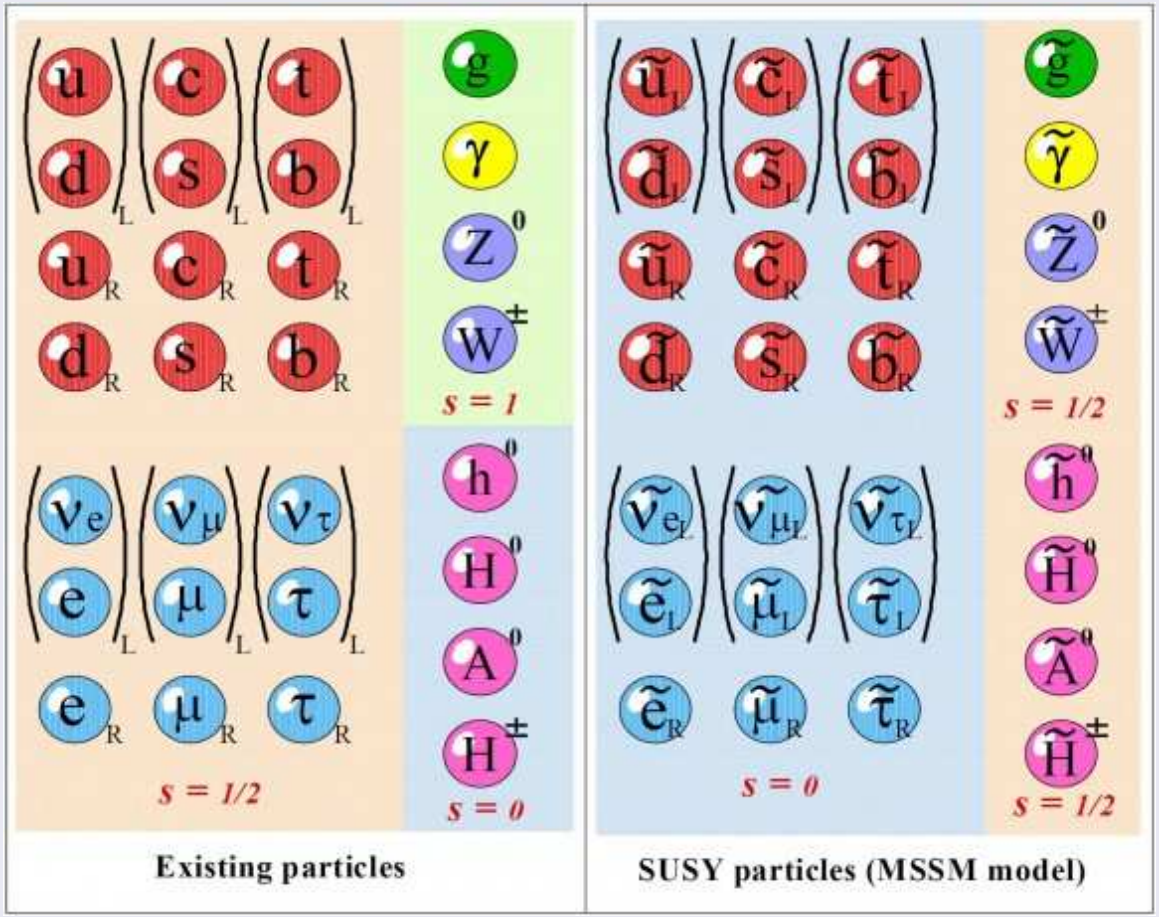
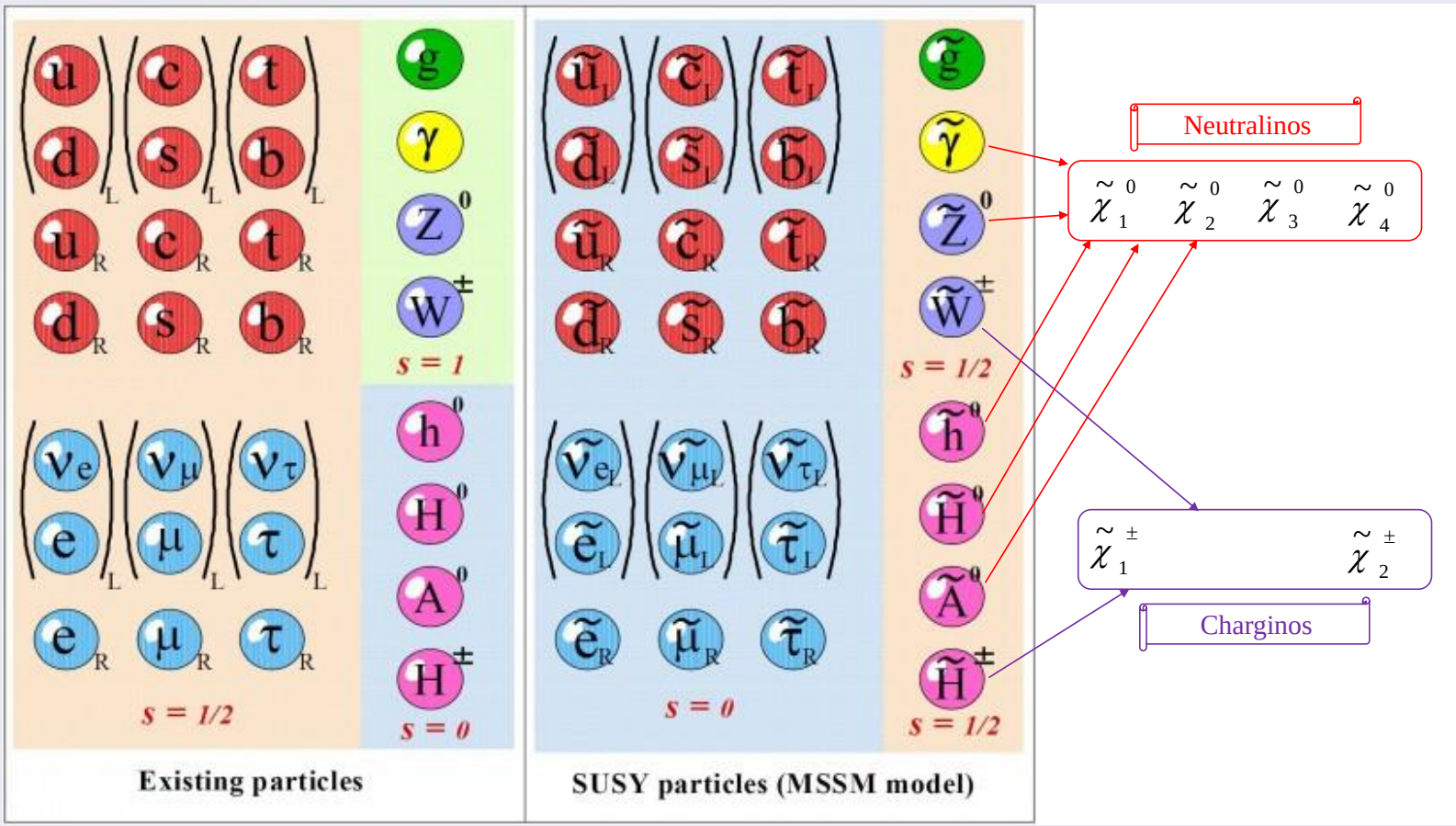
Outline

Talk based upon ATLAS Run 2 Analyses

1.a MSSM: Particle Content



1.a MSSM: Particle Content



1.b Neutralino Mixing

- Neutralinos are linear combinations of bino, neutral wino and neutral higgsinos

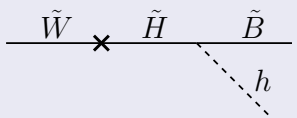
$$|\tilde{\chi}_2^0 >= N_{21} \cdot |\tilde{B}^0 > + N_{22} \cdot |\tilde{W}_3^0 > + N_{23} \cdot |\tilde{H}_d^0 > + N_{24} \cdot |\tilde{H}_u^0 >$$

- Origin of the neutralino mixing is the EWK symmetry breaking

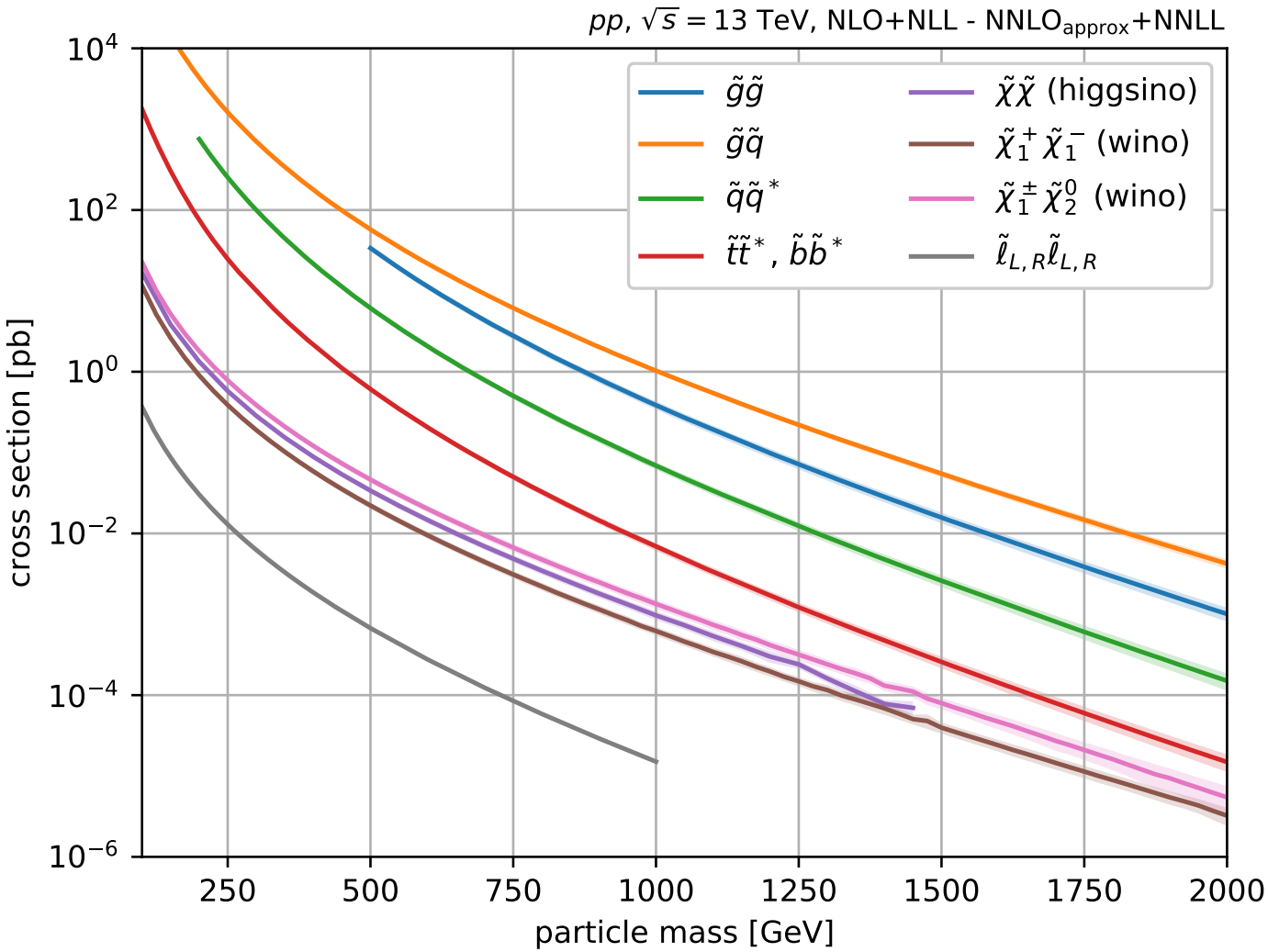
$\tilde{\chi}_2^0 - h^0 - LSP$ Coupling

- Consider 2 cases:
  - Gauge-mediated SUSY breaking: higgsino $\tilde{\chi}_1^0$ (NLSP), gravitino $\tilde{G}$ (LSP)
    - Required phase space: $\Delta M = m_{\tilde{\chi}_1^0} > m_h$
  - Gravity-mediated SUSY breaking: mostly wino $\tilde{\chi}_2^0$ (NLSP), mostly bino $\tilde{\chi}_1^0$ (LSP)
    - Required phase space: $\Delta M = m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} > m_h$
    - Coupling: non-vanishing iff neutralinos are gaugino-higgsino admixtures

$$g_{\tilde{\chi}_2^0 - h^0 - \tilde{\chi}_1^0} = \frac{-1}{2 sin\theta_W} [(N_{22} - tan\theta_W \cdot N_{21})(sin\alpha \cdot N_{13} + cos\alpha \cdot N_{14}) + (N_{12} - tan\theta_W \cdot N_{11})(sin\alpha \cdot N_{23} + cos\alpha \cdot N_{24})$$



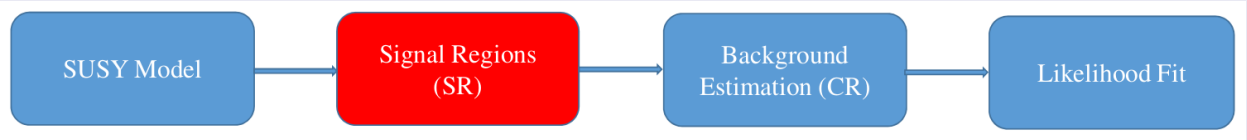
1.c SUSY Particles Cross-Sections



1.d SUSY Searches at the LHC

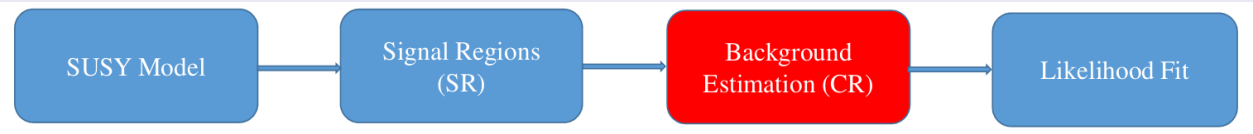
Analyses	Link to Reference	Int. Lumi. $[fb^{-1}]$
Electroweakinos		
$\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W(\rightarrow \ell^{\pm}\nu) + h(\rightarrow b\bar{b}) + X$	ATLAS-CONF-2019-031	139
$\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W(\rightarrow \ell^{\pm}\nu) + h(\rightarrow \gamma\gamma) + X$	ATLAS-CONF-2019-019	139
$\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W(q\bar{q}') + h(\rightarrow b\bar{b}) + X$	Phys. Rev. D100 (2019)	36
$\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W(\rightarrow \ell^{\pm}\nu) + h(\rightarrow b\bar{b}) + X$	"	"
$\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W(\rightarrow \ell^{\pm}\nu) + h(\rightarrow \gamma\gamma) + X$	"	"
$\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W(\rightarrow \ell^{\pm}\nu) + h(\rightarrow WW/ZZ/\tau\tau) \rightarrow \ell^{\pm}\ell^{\pm}/3\ell^{\pm} + X$	"	"
$\tilde{H}^0 \rightarrow Z/h(\rightarrow b\bar{b}) + \tilde{G}$ pairs	Phys. Rev. D 98 (2018) 092002	36
Third Generation Squarks		
$\tilde{t}_1 \rightarrow t + \tilde{\chi}_2^0(\rightarrow Z/h + \tilde{\chi}_1^0)$ pairs	ATLAS-CONF-2019-016 JHEP 08 (2017) 006	139 (36)
$\tilde{b}_1 \rightarrow b + \tilde{\chi}_2^0(\rightarrow h + \tilde{\chi}_1^0)$ pairs	ATLAS-CONF-2019-011 ATLAS-CONF-2018-040	139 (80)

1.e Analyses Strategy: Signal Regions

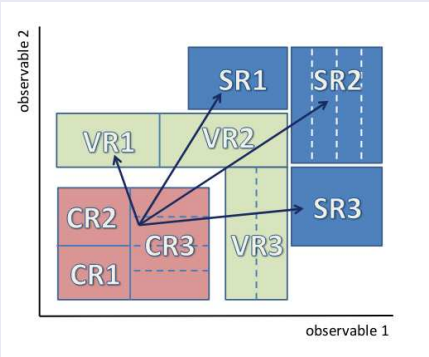


- SR: Phase space regions with highest signal to noise ratios

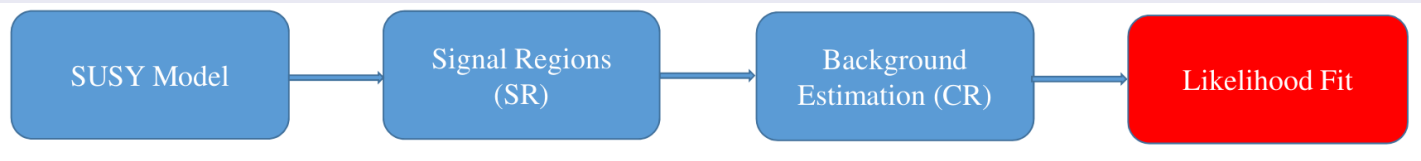
1.e Analyses Strategy: Control & Validation Regions



- CR: Phase space region dominated by a background process
- VR: Phase space region between CR & SR
  Verify backgrounds extrapolation from CR to SR



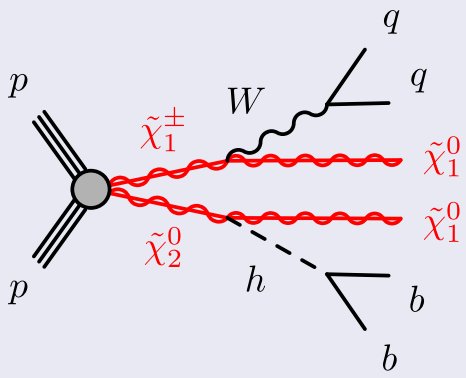
1.e Analyses Strategy: Likelihood Fit

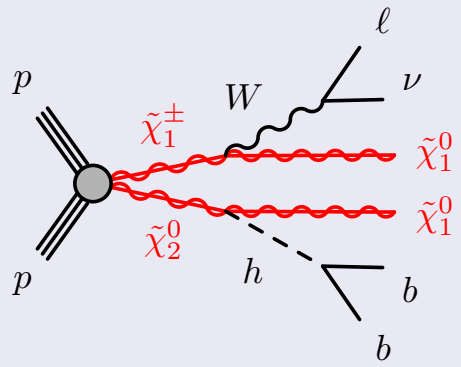


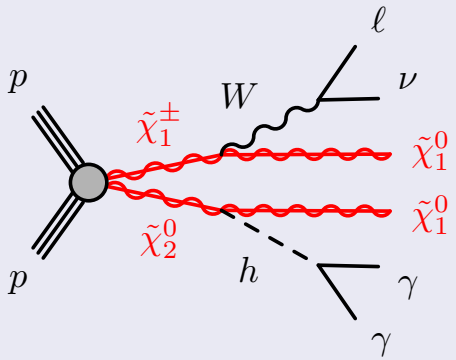
- Fits are performed in CRs and SRs, not in VRs
- Background-only fit: main backgrounds normalized to data in their CRs (profiling syst. uncert.), neglecting signal contamination in CRs, predict backrgound contamination in SRs and VRs, calculates p($s=0$)-value in SRs
- Model dependent exclusion fit:
  CL_S limits on cross-section and SUSY particles masses in a given model
- Model independent exclusion fit:
  CL_S limit on σ^{95}_{vis}, calculate p(s)-value separately for each SR

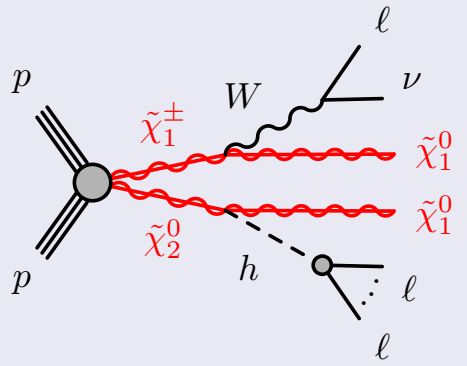
2.a Comprehensive Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \to W^{\pm} + h^0 + \not{E}_T$ with $L = 36.1\ fb^{-1}$

- Ref: Phys. Rev. D100 (2019)
- Four signatures explored









2.a Comprehensive Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0 + \not{E}_T$ with $L = 36.1\ fb^{-1}$

- Fully hadronic channel: $W^{\pm}(\rightarrow q\bar{q}')$ and $h^0(\rightarrow b\bar{b})$
- Trigger: $\not{E}_T$, with offline cut: $\not{E}_T > 200$ GeV
- SR Definition:

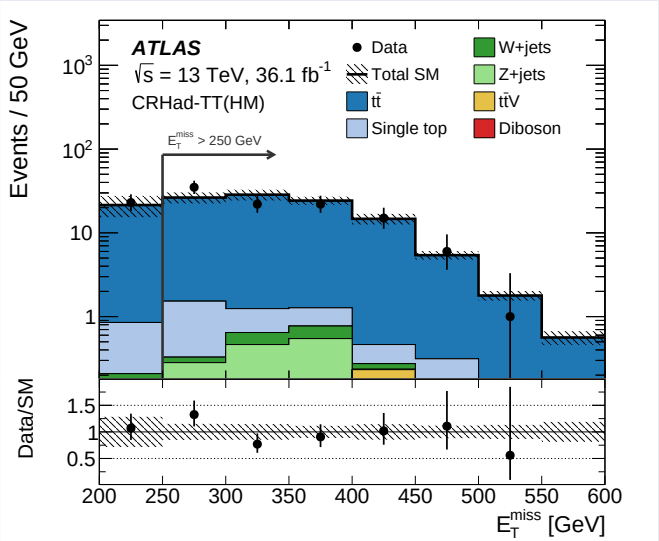
Variable	SRHad-High	SRHad-Low
N_{lepton}	$= 0$	$= 0$
N_{jet} $(p_{\text{T}} > 30\ GeV)$	$\in [4,\ 5]$	$\in [4,\ 5]$
$N_{b\text{-jet}}$	$= 2$	$= 2$
$\Delta\phi_{\text{min}}^{4j}$	> 0.4	> 0.4
$E_{\text{T}}^{\text{miss}}$ [GeV]	> 250	> 200
m_{eff} [GeV]	> 900	> 700
$m_{b\bar{b}}$ [GeV]	$\in [105, 135]$	$\in [105, 135]$
$m_{q\bar{q}}$ [GeV]	$\in [75, 90]$	$\in [75, 90]$
m_{CT} [GeV]	> 140	> 190
$m_{\text{T}}^{b,\text{min}}$ [GeV]	> 160	> 180

$$\begin{cases} M_{eff} = \sum p_T^{jets} + \sum p_T^{\ell^{\pm}} + \not{E}_T \\ M_T = \sqrt{2 p_T^{\ell^{\pm}} \not{E}_T \left[1 + cos\Delta\phi(\vec{p}_T^{\ell^{\pm}}, \vec{\not{E}}_T)\right]} \\ M_{CT} = \sqrt{2 p_T^{b1} p_T^{b2} \left[1 + cos\Delta\phi(\vec{p}_T^{b1}, \vec{p}_T^{b2})\right]} \end{cases}$$

2.a Comprehensive Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0 + \not{E}_T$ with $L = 36.1\ fb^{-1}$

- Fully hadronic channel: $W^{\pm}(\rightarrow q\bar{q}')$ and $h^0(\rightarrow b\bar{b})$

- Background: $t\bar{t}$ dominant in all SRs
- Main Systematic Uncertainties: theoretical ($t\bar{t}$) in SR-HadLow, experimental (JES) in SR-HadHigh
- CRs:



2.a Comprehensive Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0 + \not{E}_T$ with $L = 36.1\ fb^{-1}$

- Fully hadronic channel: $W^{\pm}(\rightarrow q\bar{q}')$ and $h^0(\rightarrow b\bar{b})$

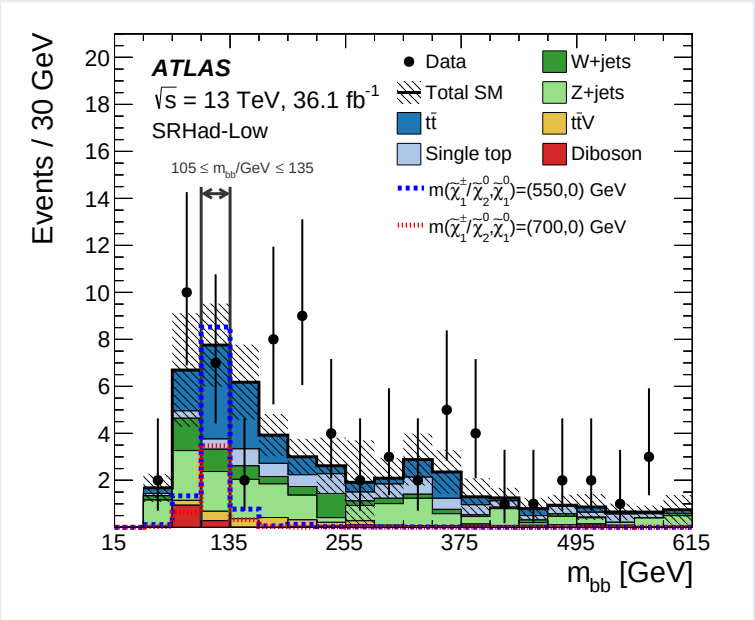
- Background-only fit: systematics profiled

CR channels	CRHad-TT(HM)	CRHad-ST(HM)	CRHad-Zj(HM)	CRHad-TT(LM)	CRHad-ST(LM)	CRHad-Zj(LM)
Observed events	102	17	39	695	23	78
Fitted bkg events	102 ± 10	17 ± 4	39 ± 6	695 ± 26	23 ± 5	78 ± 9
$t\bar{t}$	97 ± 11	3.7 ± 2.0	2.9 ± 2.4	659 ± 34	4.7 ± 2.3	10^{+12}_{-10}
Single top	$2.7^{+3.5}_{-2.7}$	10 ± 5	$0.8^{+0.9}_{-0.8}$	19 ± 19	15 ± 6	1.0 ± 0.9
$W+$jets	$0.5^{+0.6}_{-0.5}$	2.2 ± 1.1	0.0059 ± 0.0025	3.9 ± 3.1	2.8 ± 1.2	0.0059 ± 0.0026
$Z+$jets	1.1 ± 0.6	0.08 ± 0.07	32 ± 7	9.5 ± 3.2	0.09 ± 0.04	63 ± 17
$t\bar{t}+V$	0.63 ± 0.14	0.62 ± 0.16	2.0 ± 0.4	3.1 ± 0.5	0.80 ± 0.17	3.7 ± 0.6
Diboson	$0.08^{+0.14}_{-0.08}$	< 0.07	0.8 ± 0.8	1.16 ± 0.34	< 0.07	0.8 ± 0.5

2.a Comprehensive Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0 + \not{E}_T$ with $L = 36.1\ fb^{-1}$

- Fully hadronic channel: $W^{\pm}(\rightarrow q\bar{q}')$ and $h^0(\rightarrow b\bar{b})$

- SR Unblinded:



2.a Comprehensive Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0 + \not{E}_T$ with $L = 36.1\ fb^{-1}$

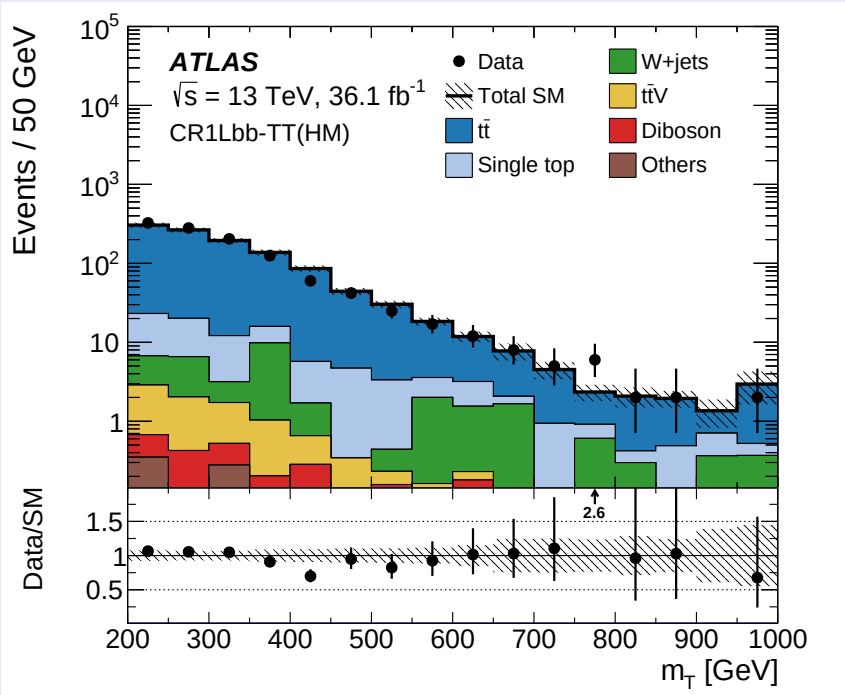
- Semi-leptonic channel: $W^{\pm}(\rightarrow \ell^{\pm}\nu)$ and $h^0(\rightarrow b\bar{b})$
- Trigger: $\not{E}_T$, with offline cut: $\not{E}_T > 200$ GeV
- SR Definition:

Variable	SR1Lbb-Low	SR1Lbb-Medium	SR1Lbb-High
N_{lepton}		$= 1$	
p_{T}^{ℓ} [GeV]		> 27	
N_{jet} $(p_{\text{T}} > 25\ GeV)$		$= 2$ or 3	
$N_{b\text{-jet}}$		$= 2$	
$E_{\text{T}}^{\text{miss}}$ [GeV]		> 200	
m_{CT} [GeV]		> 160	
m_{T} [GeV]	$\in [100, 140]$	$\in [140, 200]$	> 200
$m_{b\bar{b}}$ [GeV]		$\in [105, 135]$	

2.a Comprehensive Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0 + \not{E}_T$ with $L = 36.1\ fb^{-1}$

- Semi-leptonic channel: $W^{\pm}(\rightarrow \ell^{\pm}\nu)$ and $h^0(\rightarrow b\bar{b})$

- Background: $t\bar{t}$ dominant
- Systematic Uncertainties: theoretical dominant in all SRs, experimental (JER) sub-dominant
- CRs:



2.a Comprehensive Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0 + \not{E}_T$ with $L = 36.1\ fb^{-1}$

- Semi-leptonic channel: $W^{\pm}(\rightarrow \ell^{\pm}\nu)$ and $h^0(\rightarrow b\bar{b})$

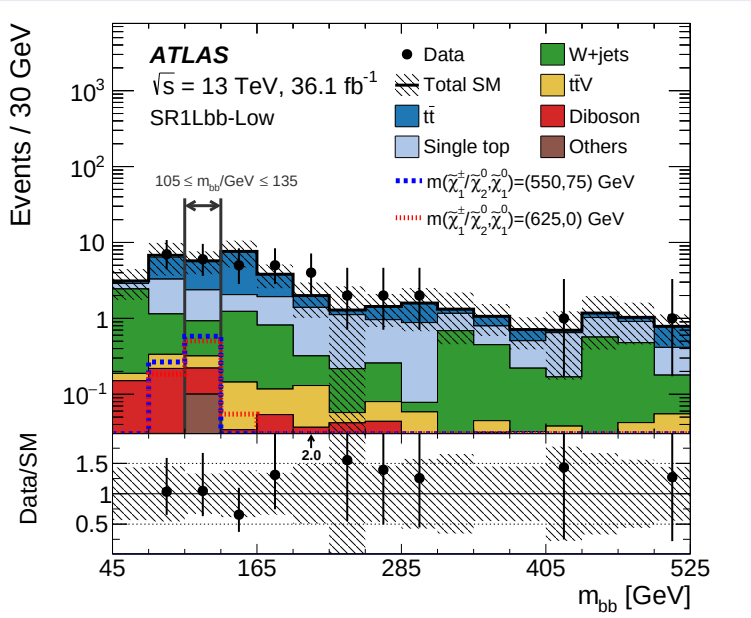
- Background-only fit: systematics profiled

CR channels	CR1Lbb-TT(LM)	CR1Lbb-TT(MM)	CR1Lbb-TT(HM)	CR1Lbb-Wj	CR1Lbb-ST
Observed events	192	359	1115	72	65
Fitted bkg events	192 ± 14	359 ± 19	1115 ± 34	72 ± 9	65 ± 8
$t\bar{t}$	147 ± 33	325 ± 32	1020 ± 90	15 ± 14	20^{+23}_{-20}
Single top	28 ± 25	22^{+24}_{-22}	60^{+70}_{-60}	4^{+6}_{-4}	33 ± 25
W+jets	16 ± 7	7.3 ± 2.7	25 ± 11	51 ± 17	8 ± 4
$t\bar{t} + V$	1.16 ± 0.20	2.8 ± 0.4	6.9 ± 1.1	0.079 ± 0.022	3.2 ± 0.6
Diboson	0.57 ± 0.24	0.92 ± 0.29	1.3 ± 0.4	2.1 ± 1.1	0.84 ± 0.28
Others	0.125 ± 0.032	0.20 ± 0.06	1.9 ± 0.5	0.24 ± 0.17	0.10 ± 0.04

2.a Comprehensive Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0 + \not{E}_T$ with $L = 36.1\ fb^{-1}$

- Semi-leptonic channel: $W^{\pm}(\rightarrow \ell^{\pm}\nu)$ and $h^0(\rightarrow b\bar{b})$

- SR Unblinded:



2.a Comprehensive Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0 + \not{E}_T$ with $L = 36.1\ fb^{-1}$

- Leptonic channel: $W^{\pm}(\rightarrow \ell^{\pm}\nu)$ and $h^0(\rightarrow WW/ZZ/\tau\tau)$
- Trigger: 1 Lepton *OR* 2 Leptons, with offline cut: $p_T(\ell^{\pm}) > 25$ GeV
- SR Definition: $\ell^{\pm}\ell^{\pm} + \not{E}_T$ channel

Variable	SRSS-j1	SRSS-j23
$\Delta\eta_{\ell\ell}$	< 1.5	-
N_{jet} $(p_{\text{T}} > 20\ GeV)$	$= 1$	$= 2$ or 3
$N_{b\text{-jet}}$	$= 0$	$= 0$
$E_{\text{T}}^{\text{miss}}$ [GeV]	> 100	> 100
m_{T} [GeV]	> 140	> 120
m_{eff} [GeV]	> 260	> 240
$m_{\ell j(j)}$ [GeV]	< 180	< 130
m_{T2} [GeV]	> 80	> 70

$$M_{T2} = min_{\vec{q}_T}\left[max\left(M_T(\overset{vis_A}{T}, \vec{q}_T|M_\chi), M_T(\overset{vis_B}{T}, \not{E}_T - \vec{q}_T|M_\chi)\right)\right]$$

2.a Comprehensive Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0 + \not{E}_T$ with $L = 36.1\ fb^{-1}$

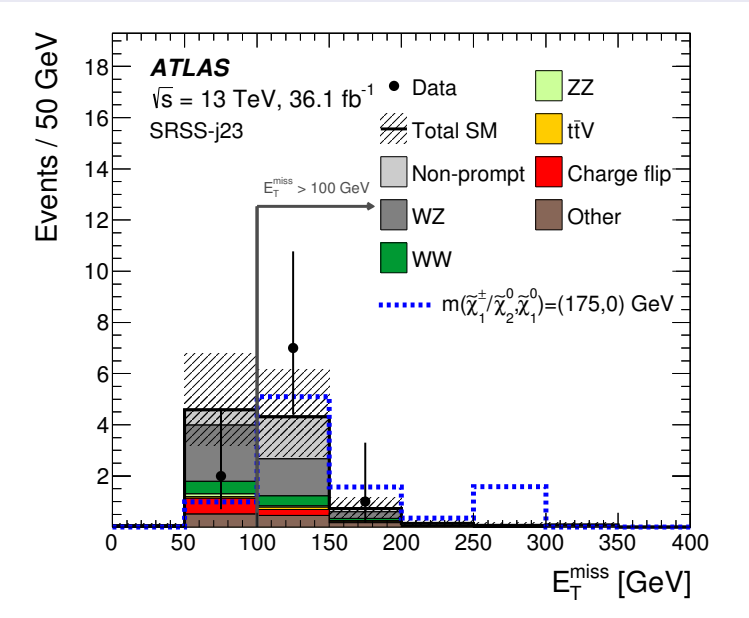
- Leptonic channel: $W^{\pm}(\rightarrow \ell^{\pm}\nu)$ and $h^0(\rightarrow WW/ZZ/\tau\tau)$

- Main Background: Fake and Non-Prompt (FNP) leptons
- Main Systematic Uncertainties: experimental uncertainties in estimates of FNP

2.a Comprehensive Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0 + \not{E}_T$ with $L = 36.1\ fb^{-1}$

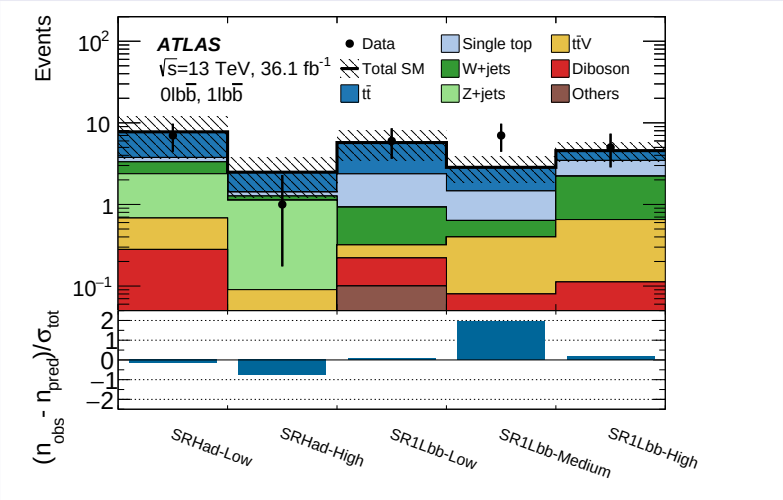
- Leptonic channel: $W^{\pm}(\rightarrow \ell^{\pm}\nu)$ and $h^0(\rightarrow WW/ZZ/\tau\tau)$

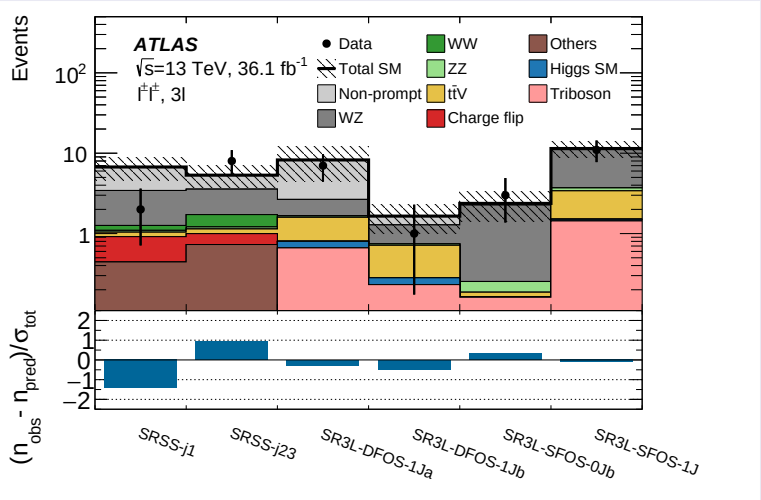
- SR Unblinded:



2.a Comprehensive Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0 + \not{E}_T$ with $L = 36.1\ fb^{-1}$

- Events Yields in SRs:





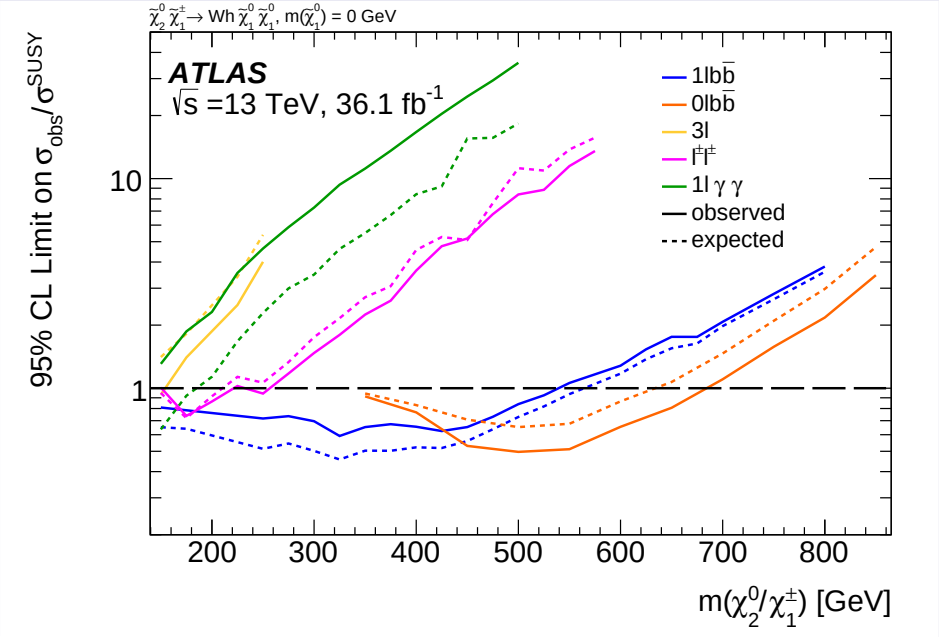
2.a Comprehensive Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0 + \not{E}_T$ with $L = 36.1\ fb^{-1}$

- Model Independent Limits:

	σ_{vis} [fb]	S_{obs}^{95}	S_{exp}^{95}	p_0-value
SRHad-Low	0.26	9.4	$9.5^{+3.3}_{-1.9}$	0.50
SRHad-High	0.10	3.6	$4.3^{+1.6}_{-1.0}$	0.50
SR1Lbb-Low	0.23	8.3	$8.0^{+3.3}_{-2.2}$	0.46
SR1Lbb-Medium	0.28	10.0	$5.6^{+2.9}_{-1.7}$	0.04
SR1Lbb-High	0.18	6.4	$6.1^{+3.1}_{-1.9}$	0.44
SR1L$\gamma\gamma$-a	0.15	5.5	$3.2^{+0.9}_{-0.1}$	0.03
SR1L$\gamma\gamma$-b	0.28	10.1	$6.4^{+2.6}_{-1.6}$	0.09
SRSS-j1	0.12	4.2	$6.1^{+2.7}_{-1.5}$	0.50
SRSS-j23	0.27	9.9	$6.6^{+3.4}_{-1.1}$	0.17
SR3L-SFOS-0Ja	0.08	3.0	$4.4^{+1.9}_{-1.3}$	0.47
SR3L-SFOS-0Jb	0.16	5.9	$5.0^{+2.0}_{-1.2}$	0.35
SR3L-SFOS-1J	0.26	9.2	$9.4^{+3.8}_{-2.5}$	0.50
SR3L-DFOS-0J	0.08	3.0	$3.8^{+1.4}_{-0.9}$	0.43
SR3L-DFOS-1Ja	0.25	9.0	$9.2^{+3.3}_{-2.0}$	0.50
SR3L-DFOS-1Jb	0.10	3.7	$4.0^{+1.6}_{-0.5}$	0.50

2.a Comprehensive Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0 + \not{E}_T$ with $L = 36.1\ fb^{-1}$

- All Channels:



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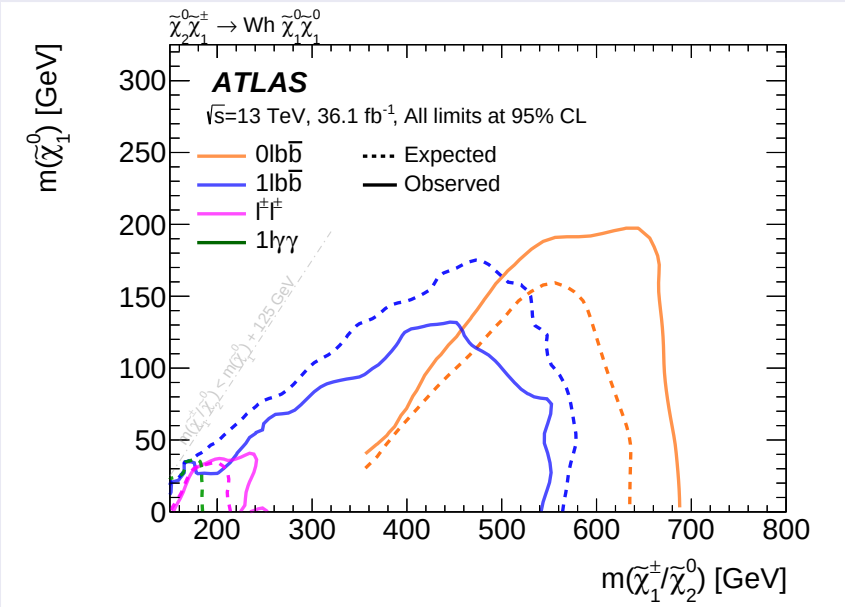
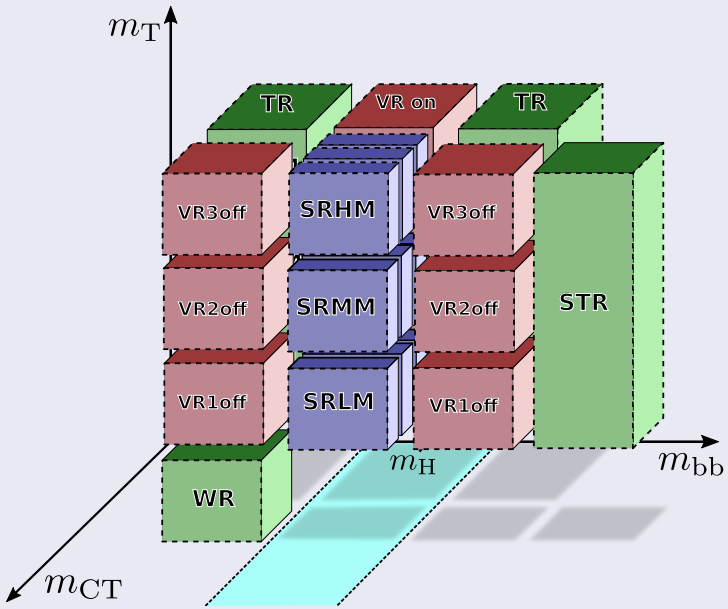


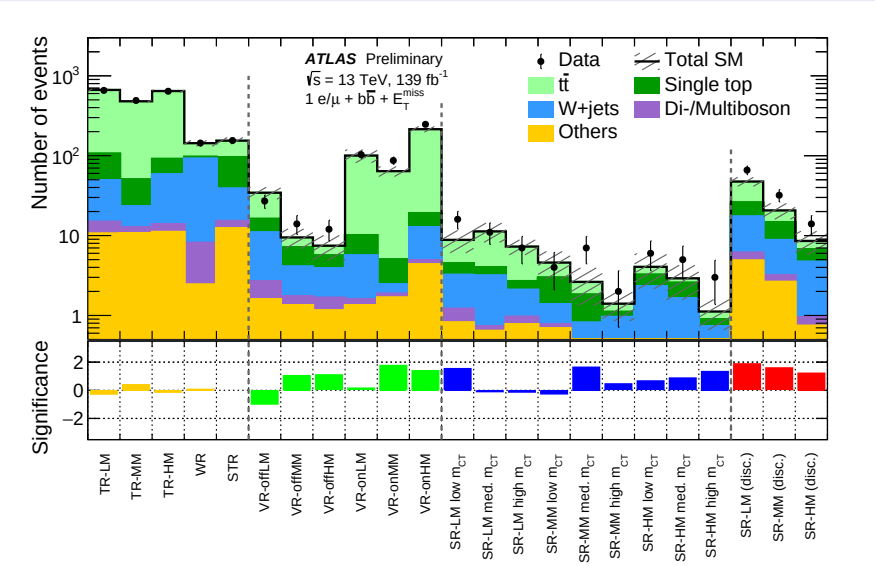
2.b Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \to W^{\pm}(\to \ell^{\pm}\nu) + h^0(\to b\bar{b}) + \not{E}_T$ with $L = 139\ fb^{-1}$

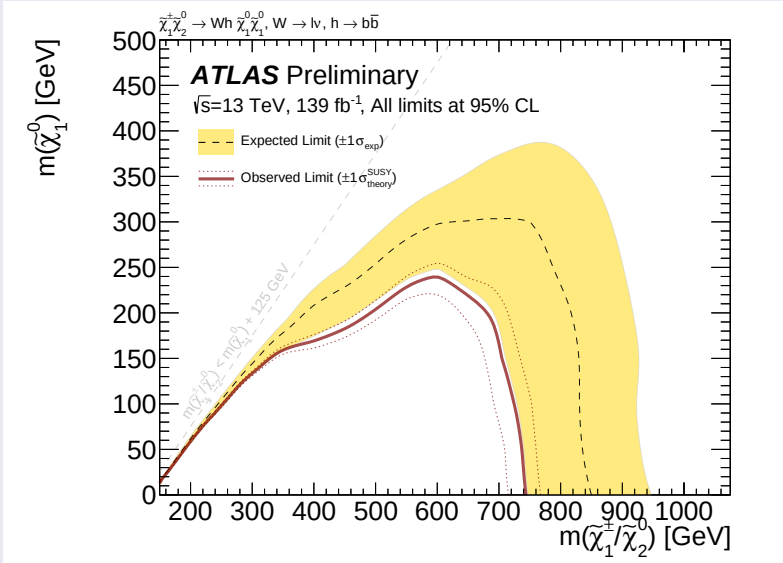
- Ref: ATLAS-CONF-2019-031



2.b Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm}(\rightarrow \ell^{\pm}\nu) + h^0(\rightarrow b\bar{b}) + \not{E}_T$ with $L = 139\ fb^{-1}$

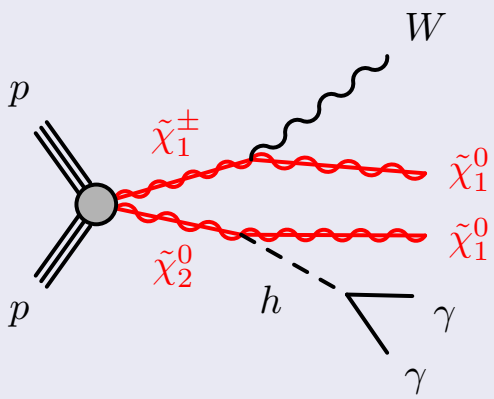
- Ref: ATLAS-CONF-2019-031





2.c. Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0(\rightarrow \gamma\gamma) + \not{E}_T$ with $L = 139\ fb^{-1}$

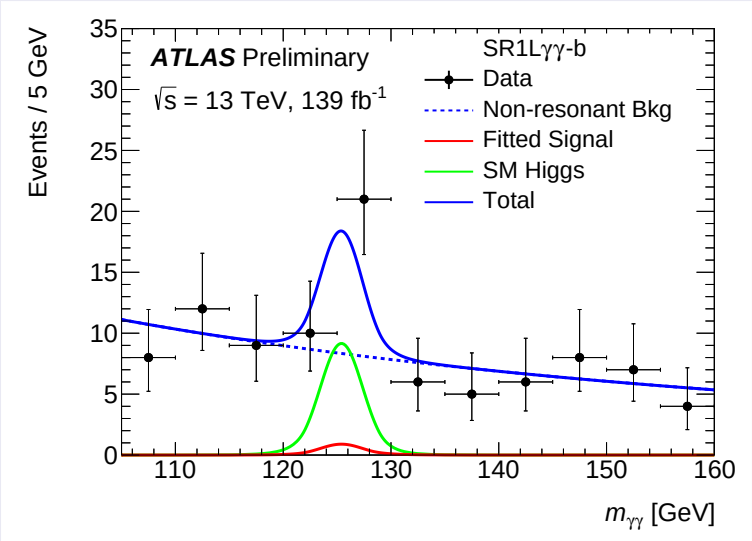
- Ref: ATLAS-CONF-2019-019

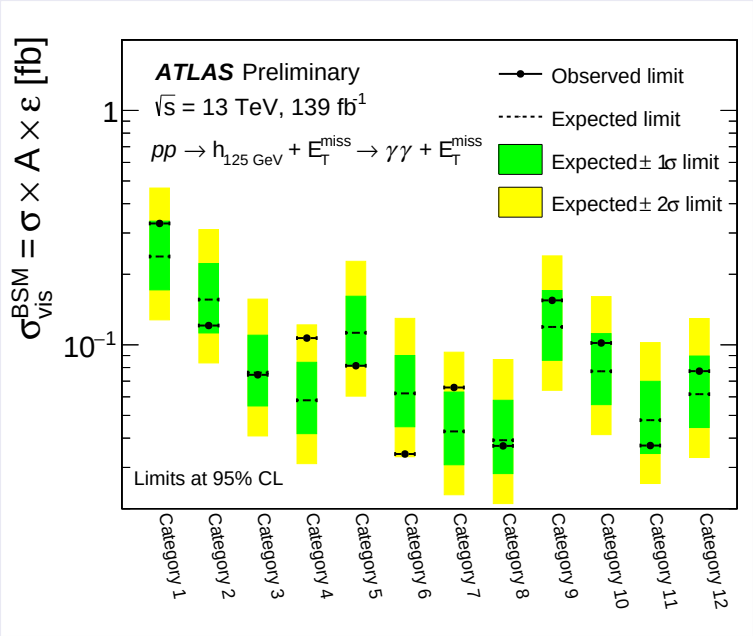


Channels	Names	Selection
Leptonic	Category 1	$0 < S_{E_T^{miss}} \leq 2,\ N_\ell \geq 1$
	Category 2	$2 < S_{E_T^{miss}} \leq 4,\ N_\ell \geq 1$
	Category 3	$4 < S_{E_T^{miss}} \leq 6,\ N_\ell \geq 1$
	Category 4	$S_{E_T^{miss}} > 6,\ N_\ell \geq 1$
Hadronic	Category 5	$5 < S_{E_T^{miss}} \leq 6,\ N_\ell = 0,\ N_j \geq 2,\ M_{jj} \in [40, 120]\ GeV$
	Category 6	$6 < S_{E_T^{miss}} \leq 7,\ N_\ell = 0,\ N_j \geq 2,\ M_{jj} \in [40, 120]\ GeV$
	Category 7	$7 < S_{E_T^{miss}} \leq 8,\ N_\ell = 0,\ N_j \geq 2,\ M_{jj} \in [40, 120]\ GeV$
	Category 8	$S_{E_T^{miss}} > 8,\ N_\ell = 0,\ N_j \geq 2,\ M_{jj} \in [40, 120]\ GeV$
Rest	Category 9	$6 < S_{E_T^{miss}} \leq 7,\ N_\ell = 0,\ N_j < 2$ or ($N_j \geq 2,\ M_{jj} \notin [40, 120]\ GeV$)
	Category 10	$7 < S_{E_T^{miss}} \leq 8,\ N_\ell = 0,\ N_j < 2$ or ($N_j \geq 2,\ M_{jj} \notin [40, 120]\ GeV$)
	Category 11	$8 < S_{E_T^{miss}} \leq 9,\ N_\ell = 0,\ N_j < 2$ or ($N_j \geq 2,\ M_{jj} \notin [40, 120]\ GeV$)
	Category 12	$S_{E_T^{miss}} > 9,\ N_\ell = 0,\ N_j < 2$ or ($N_j \geq 2,\ M_{jj} \notin [40, 120]\ GeV$)

2.c. Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0(\rightarrow \gamma\gamma) + \not{E}_T$ with $L = 139\ fb^{-1}$

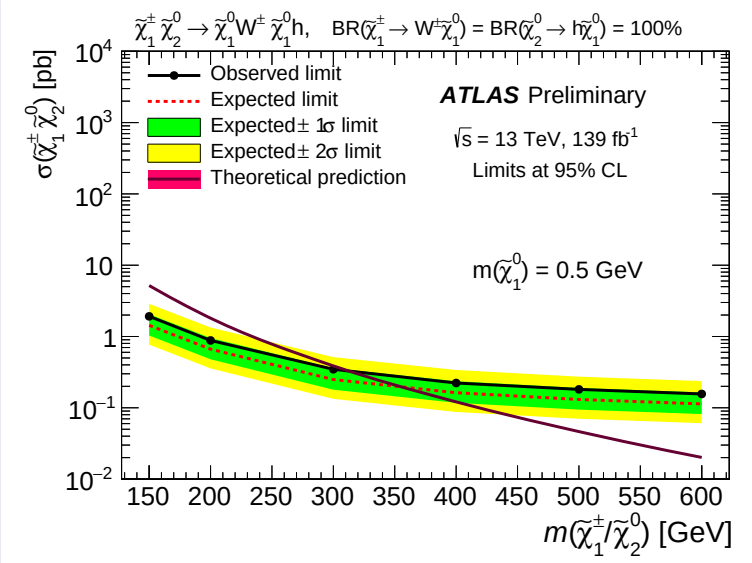
- Ref: ATLAS-CONF-2019-019

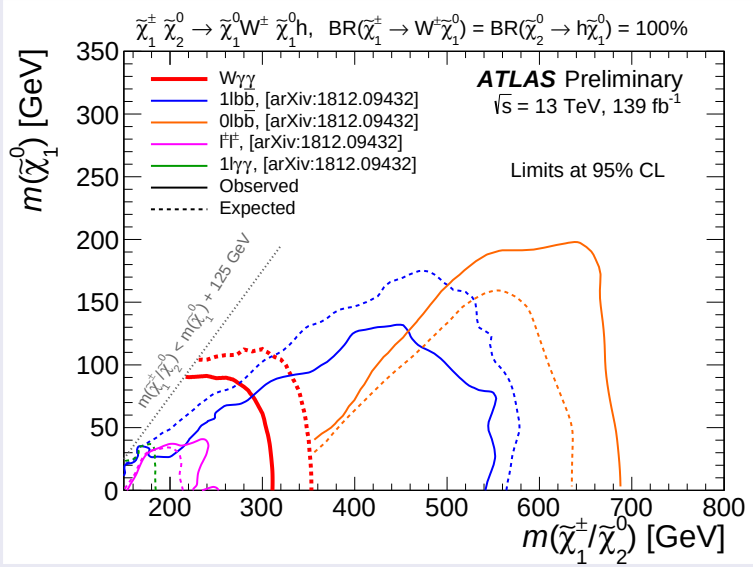




2.c. Search for $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W^{\pm} + h^0(\rightarrow \gamma\gamma) + \not{E}_T$ with $L = 139\ fb^{-1}$

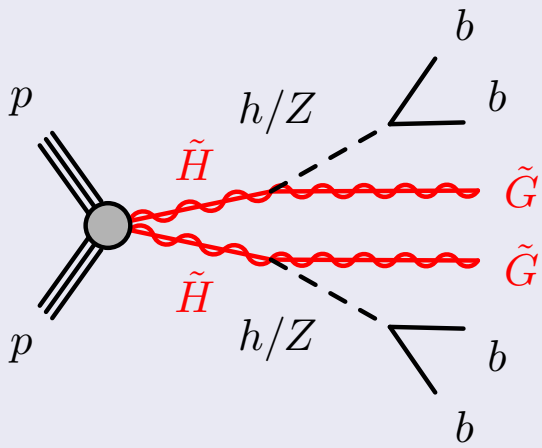
- Ref: ATLAS-CONF-2019-019

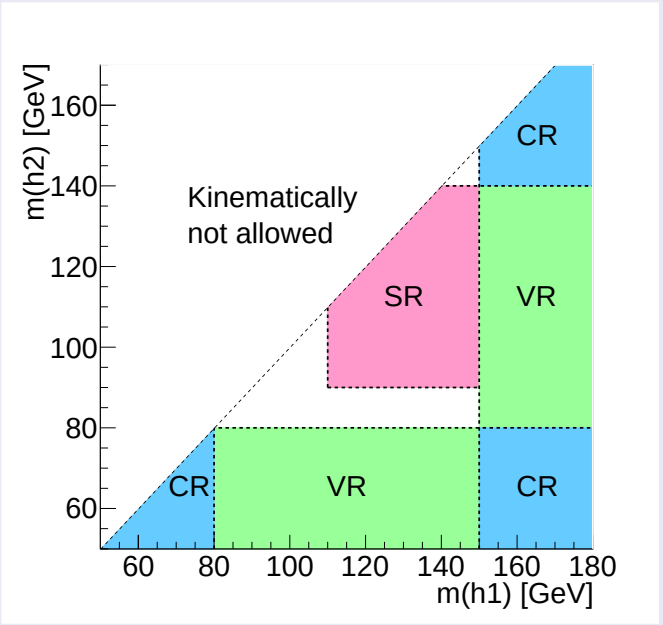




2.d Search for $\tilde{H} \to \tilde{Z}^0/h^0(\to b\bar{b}) + \tilde{G}$ pairs with up to $L = 36.1\ fb^{-1}$

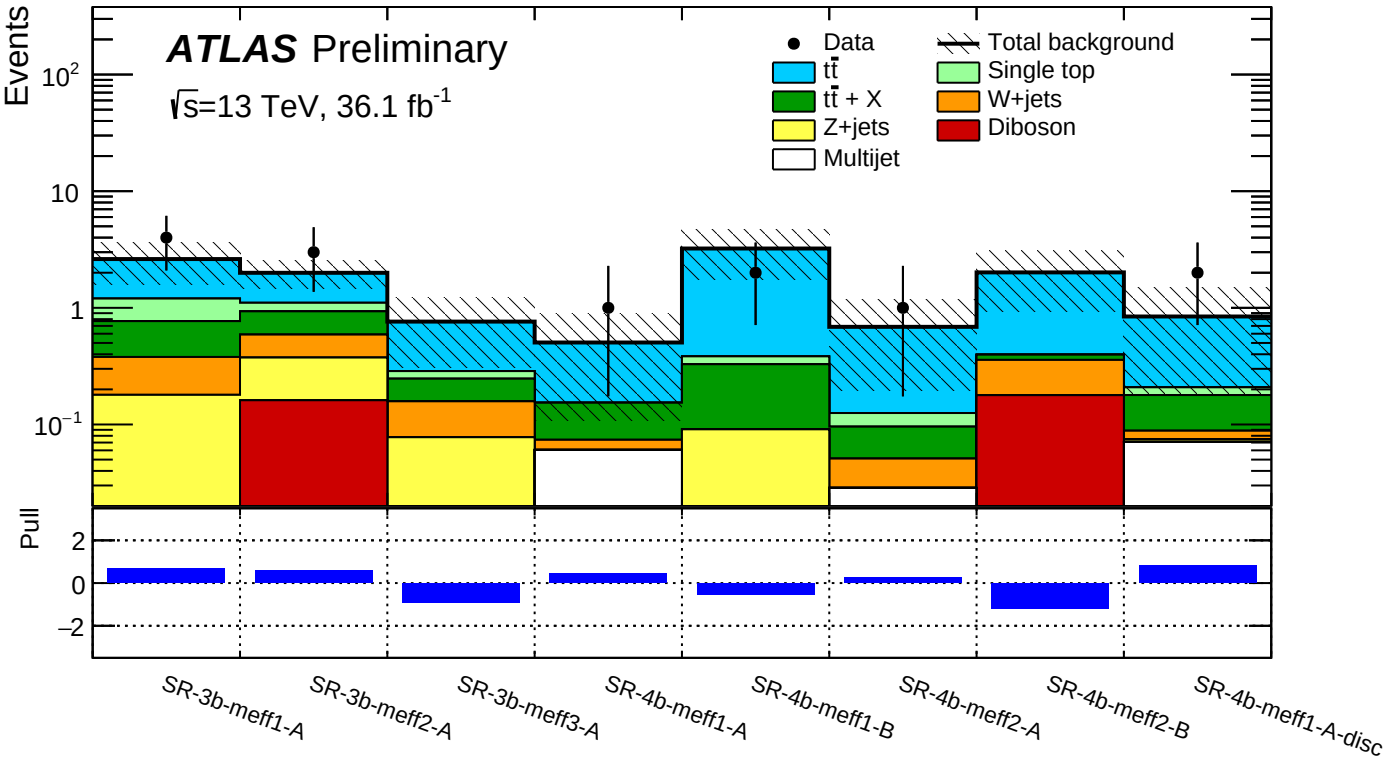
- Ref: Phys. Rev. D 98 (2018) 092002
- Search topology: at least 3 b-jets+$\not{E}_T$





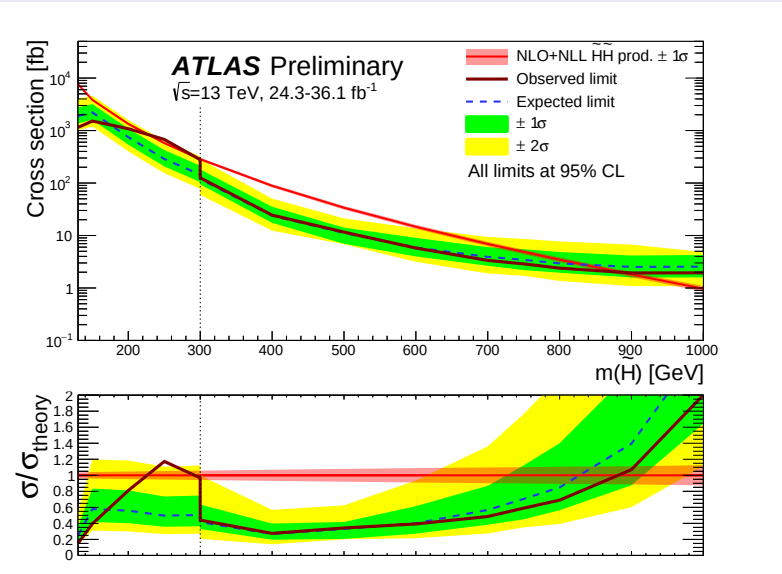
2.d Search for $\tilde{H} \to \tilde{Z}^0/h^0(\to b\bar{b}) + \tilde{G}$ pairs with up to $L = 36.1\ fb^{-1}$

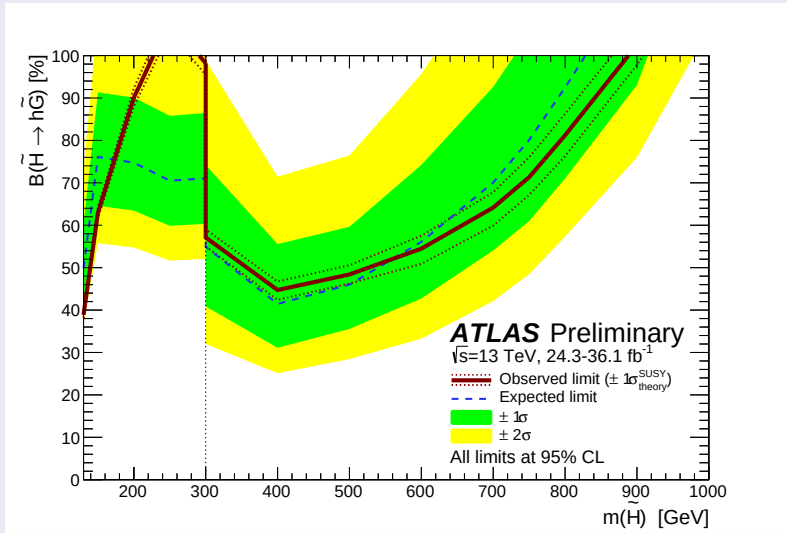
- Ref: Phys. Rev. D 98 (2018) 092002
- Search topology: at least 3 b-jets+$\not{E}_T$



2.d Search for $\tilde{H} \to \tilde{Z}^0/h^0(\to b\bar{b}) + \tilde{G}$ pairs with up to $L = 36.1\ fb^{-1}$

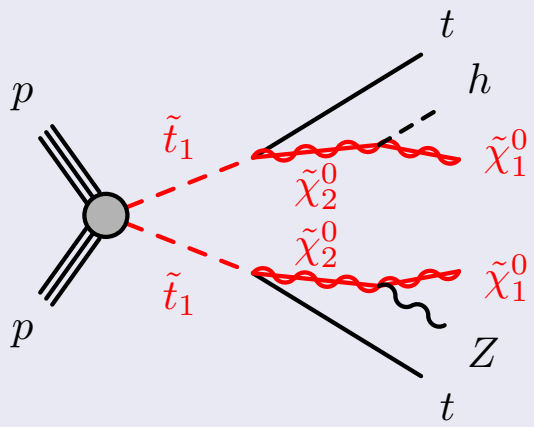
- Ref: Phys. Rev. D 98 (2018) 092002
- Search topology: at least 3 b-jets+$\not{E}_T$





3.a Search for stop pairs in $t\bar{t} + hZ + \not{E}_T$ final states with $L = 139\ fb^{-1}$

- Ref: ATLAS-CONF-2019-016

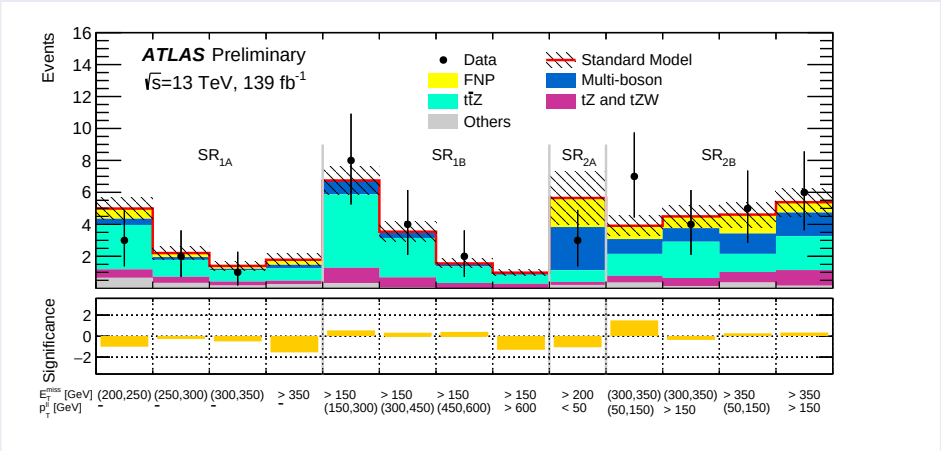


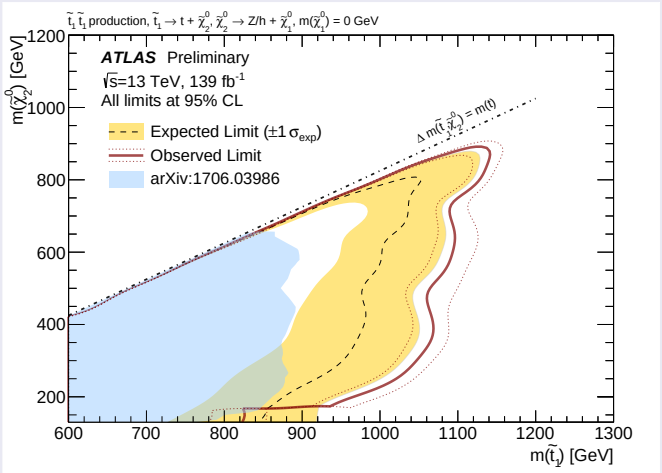
	Pre-selection
Number of signal leptons	≥ 3
Number of SF-OS pairs	≥ 1
Leading lepton p_{T} [GeV]	> 40
Subleading lepton p_{T} [GeV]	> 20
$\lvert m_{\ell\ell}^{\text{SF-OS}} - m_Z \rvert$ [GeV]	< 15

Requirement / Region	$\mathrm{SR}_{1\mathrm{A}}$	$\mathrm{SR}_{1\mathrm{B}}$	$\mathrm{SR}_{2\mathrm{A}}$	$\mathrm{SR}_{2\mathrm{B}}$
Third leading lepton p_{T} [GeV]	> 20	> 20	< 20	< 60
n_{jets} ($p_{\mathrm{T}} > 30$ GeV)	≥ 4	≥ 5	≥ 3	≥ 3
$n_{b-\text{tagged jets}}$ ($p_{\mathrm{T}} > 30$ GeV)	≥ 1	≥ 1	–	≥ 1
Leading jet p_{T} [GeV]	–	–	> 150	–
Leading b-tagged jet p_{T} [GeV]	–	> 100	–	–
$E_{\mathrm{T}}^{\text{miss}}$ [GeV]	> 250	> 150	> 200	> 350
$p_{\mathrm{T}}^{\ell\ell}$ [GeV]	–	> 150	< 50	> 150
$m_{\mathrm{T2}}^{3\ell}$ [GeV]	> 100	–	–	–

3.a Search for stop pairs in $t\bar{t} + hZ + \not{E}_T$ final states with $L = 139\ fb^{-1}$

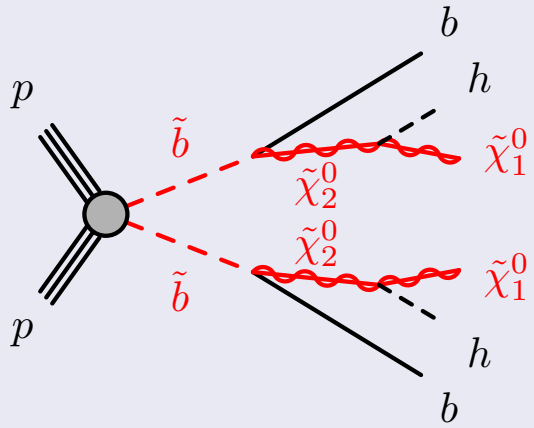
- Ref: ATLAS-CONF-2019-016

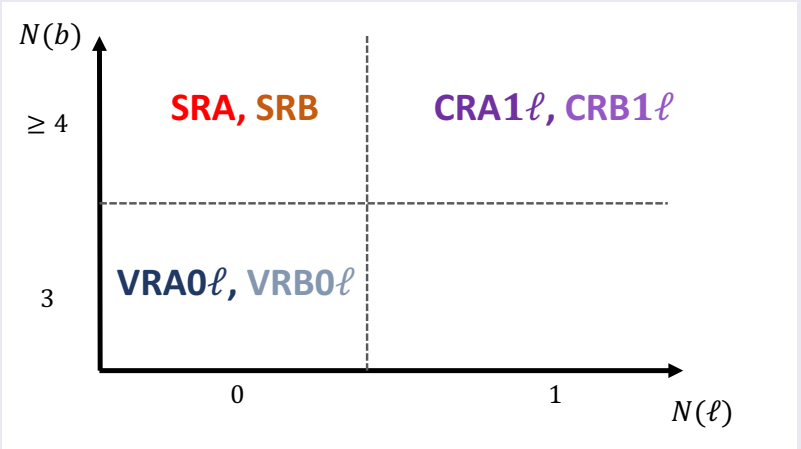




3.b Search for sbottom pairs in $+\not{E}_T$ final states with $L = 139\ fb^{-1}$

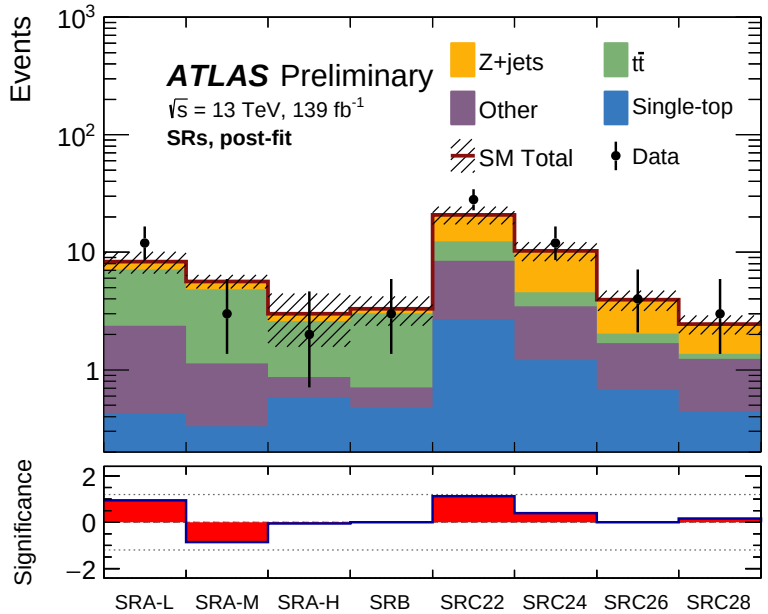
- Ref: ATLAS-CONF-2019-011

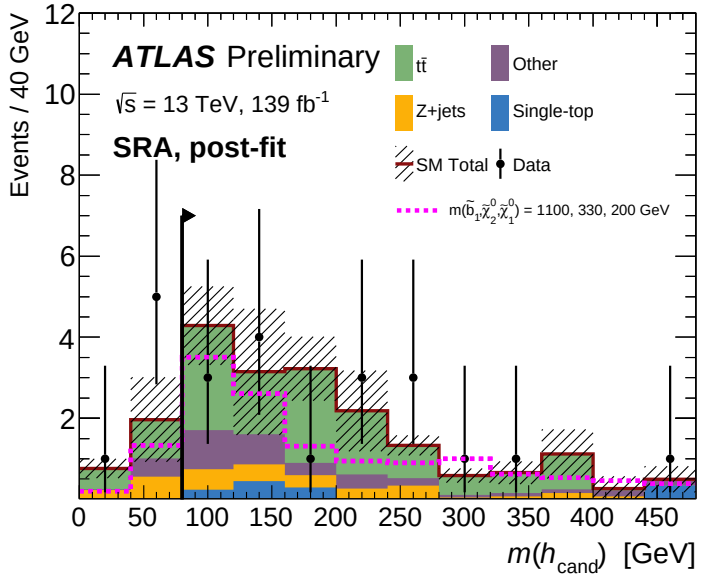




3.b Search for sbottom pairs in $+\not{E}_T$ final states with $L = 139\ fb^{-1}$

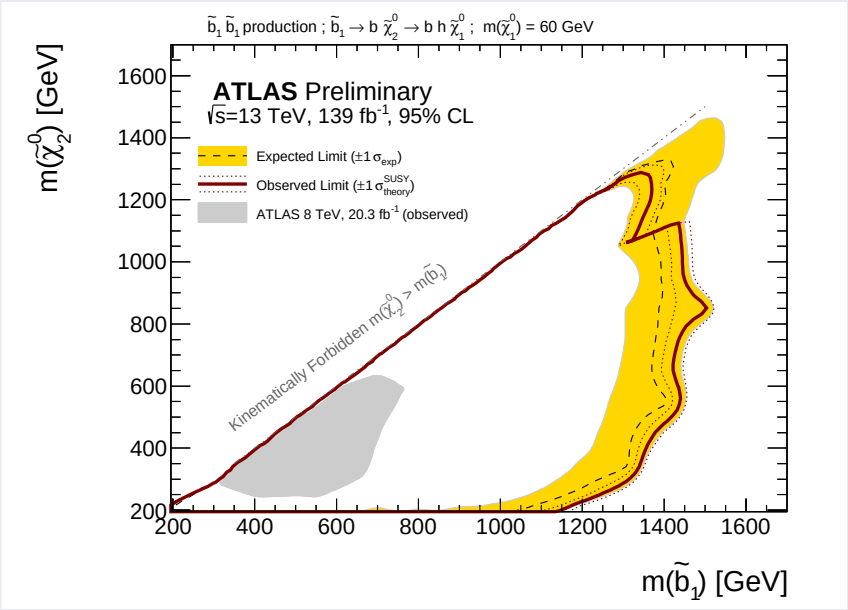
- Ref: ATLAS-CONF-2019-011

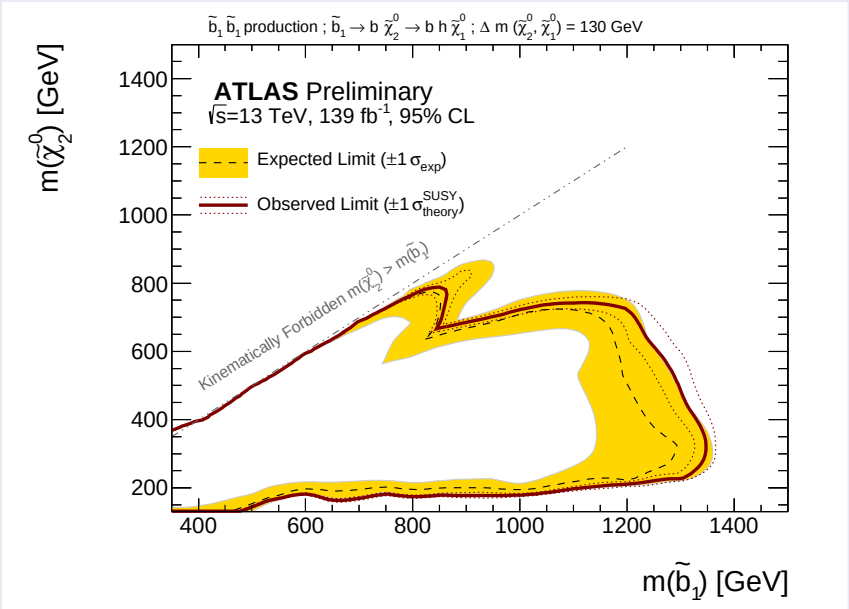




3.b Search for sbottom pairs in $+\not{E}_T$ final states with $L = 139\ fb^{-1}$

- Ref: ATLAS-CONF-2019-011





Conclusions (1/3)

Higgs Boson as a Probe for SUSY

- LHC experiments have started to be sensitive to SUSY production with a Higgs boson in the final state at Run2
- Analyses started probing the following couplings:
  - Gravity-mediated SUSY breaking models: $g_{\tilde{\chi}_2^0 - h^0 - \tilde{\chi}_1^0}$
  - Gauge-mediated SUSY breaking models: $g_{\tilde{H}_{1,2}^0 - h^0 - \tilde{G}}$
- Most of these analyses already cover the full Run2 dataset, corresponding to $L = 139\ fb^{-1}$
- No significant excess of data over the SM expectations are found

Status of the Exclusion Limits

Analyses	Largest Excluded Mass at 95%$C.L.$ [GeV]	Int. Lumi. [fb^{-1}]
Electroweakinos		
$\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W(\rightarrow \ell^{\pm}\nu) + h(\rightarrow b\bar{b}) + X$	$M_{\tilde{\chi}_2^0, \tilde{\chi}_1^{\pm}} > 740$ for $M_{\tilde{\chi}_1^0} = 0$	139
$\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W + h(\rightarrow \gamma\gamma) + X$	$M_{\tilde{\chi}_2^0, \tilde{\chi}_1^{\pm}} > 310$ for $M_{\tilde{\chi}_1^0} = 0$	139
$\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W(q\bar{q}') + h(\rightarrow b\bar{b}) + X$	$M_{\tilde{\chi}_2^0, \tilde{\chi}_1^{\pm}} > 680$ for $M_{\tilde{\chi}_1^0} = 0$	36
$\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W(\rightarrow \ell^{\pm}\nu) + h(\rightarrow b\bar{b}) + X$	$M_{\tilde{\chi}_2^0, \tilde{\chi}_1^{\pm}} > 540$ for $M_{\tilde{\chi}_1^0} = 0$	36
$\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W(\rightarrow \ell^{\pm}\nu) + h(\rightarrow WW/ZZ)$ $\rightarrow \ell^{\pm}\ell^{\pm}/3\ell^{\pm} + X$	$M_{\tilde{\chi}_2^0, \tilde{\chi}_1^{\pm}} > 275$ for $M_{\tilde{\chi}_1^0} = 10$	36
$\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0 \rightarrow W(\rightarrow \ell^{\pm}\nu) + h(\rightarrow \gamma\gamma) + X$	$M_{\tilde{\chi}_2^0, \tilde{\chi}_1^{\pm}} > 180$ for $M_{\tilde{\chi}_1^0} = 0$, **(Exp. Limit)**	36
$\tilde{H}^0 \rightarrow Z/h(\rightarrow b\bar{b}) + \tilde{G}$ pairs	$M_{\tilde{H}} > 880$ for $M_{\tilde{G}} = 0$	36

Conclusions (3/3)

Status of the Exclusion Limits

Analyses	Largest Excluded Mass at 95%$C.L.$ [GeV]	Int. Lumi. [fb^{-1}]
Third Generation Squarks		
$\tilde{t}_1 \rightarrow t + \tilde{\chi}_2^0 (\rightarrow Z/h + \tilde{\chi}_1^0)$ pairs	$M_{\tilde{t}_1} > 1120$ for $M_{(\tilde{\chi}_2^0, \tilde{\chi}_1^0)} = (875, 0)$	139
	$M_{\tilde{t}_1} > 830$ for $M_{(\tilde{\chi}_2^0, \tilde{\chi}_1^0)} = (520, 0)$	(36)
$\tilde{b}_1 \rightarrow b + \tilde{\chi}_2^0 (\rightarrow h + \tilde{\chi}_1^0)$ pairs	$M_{\tilde{b}_1} > 1500$ for $M_{(\tilde{\chi}_2^0, \tilde{\chi}_1^0)} = (1100, 60)$	139
	$M_{\tilde{b}_1} > 1400$ for $M_{(\tilde{\chi}_2^0, \tilde{\chi}_1^0)} = (1250, 60)$	(80)

Prospects

- More results are in the "pipeline", check regularly "ATLAS SUSY Limits Summary Plot"
- Reminder: these limits hold only for the considered Simplified Models
- An effort to interpret ATLAS Run2 SUSY searches in complete models (pMSSM) is ongoing...

BACK-UP

Minimal Supersymmetric Standard Model

- Associates a new field with $S \pm \frac{1}{2}$ to each SM field, with "$\mathcal{N} = 1$" SUSY operator (rep. for chiral fermions)
- Same gauge group as the SM (no new gauge interactions)
- Needs two $SU(2)_L$ Higgs doublets (avoid anomalies from higgsinos)
- Parametrize the SUSY breaking through 109 parameters, in addition to the 19 SM parameters
- These are soft SUSY breaking parameters (don't re-introduce quadratic divergences)
- SUSY broken in a high energy "hidden sector" (unknow mechanism)
- SUSY breaking is mediated to the "visible sector" O(1 TeV) via
  - gravitational interactions (or anomalies)
  - gauge interactions
- R-parity: $R_P = (-1)^{L+2S+3B}$ is conserved
  - SUSY particles are pair-produced
  - Unstable SUSY particle decays into 1 lighter SUSY particle
  - Lisghtest SUSY particle (LSP) is stable $\Rightarrow$ good candidate for Cold Dark Matter

Neutralino Mixing

- MSSM Lagrangian: $\mathcal{L} \supset \frac{-1}{2}(\bar{\Psi}^0_R)^t M_N \Psi^0_L + h.c.$
- Interaction basis: $(\Psi^0)^t = \left(-i\tilde{B}^0, -i\tilde{W}^0_3, \tilde{H}^0_d, \tilde{H}^0_u\right)$
- Neutralino interaction eigenstates:
  $|\tilde{\chi}^0_{i=1,2,3,4} >= N_{i1} \cdot |\tilde{B}^0 > + N_{i2} \cdot |\tilde{W}^0_3 > + N_{i3} \cdot |\tilde{H}^0_d > + N_{i4} \cdot |\tilde{H}^0_u >$
- Neutralino mass matrix:

$$M_N = \begin{pmatrix} M_1 & 0 & -M_Z cos\beta sin\theta_W & M_Z sin\beta sin\theta_W \\ 0 & M_2 & M_Z cos\beta cos\theta_W & -M_Z sin\beta cos\theta_W \\ -M_Z cos\beta sin\theta_W & M_Z cos\beta cos\theta_W & 0 & -\mu \\ M_Z sin\beta sin\theta_W & -M_Z sin\beta cos\theta_W & -\mu & 0 \end{pmatrix}$$

- Neutralino mass eigenstates: $|M_{\tilde{\chi}^0_{i=1,2,3,4}}| = diag\,(M_N) = U^\dagger M_N U^\star$

Thanks for your attention