ATLAS searches for supersymmetry with prompt particles

SILAFAE 2022

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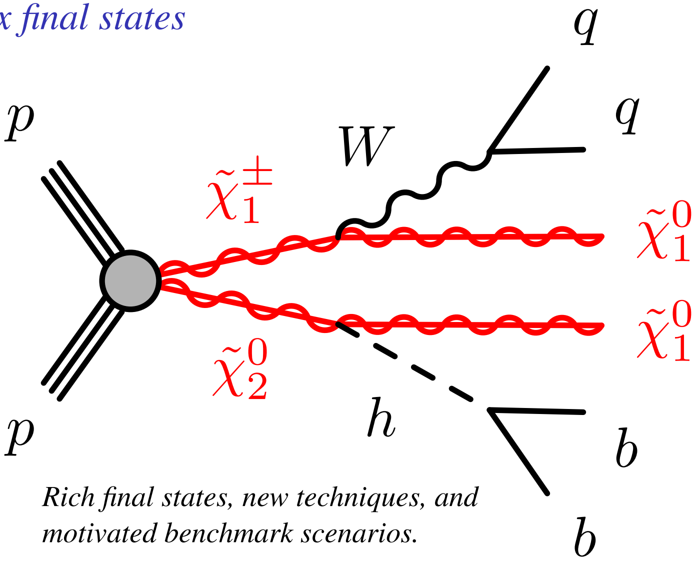
November 17, 2022

Pushing the boundaries of electroweak processes and complex final states



Rich final states, new techniques, and motivated benchmark scenarios.

Supersymmetry (SUSY) Searches and Strategies

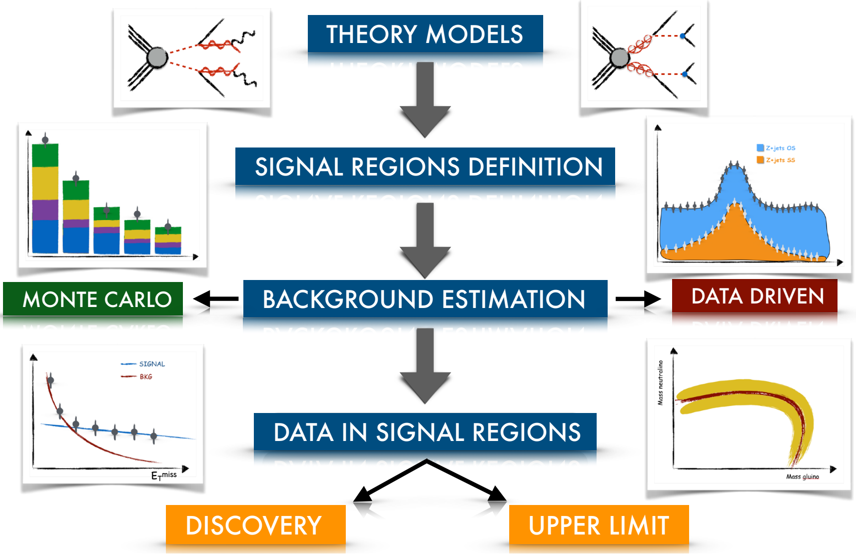


Image Credit: Peter Tornambè

Supersymmetry (SUSY) Searches and Strategies

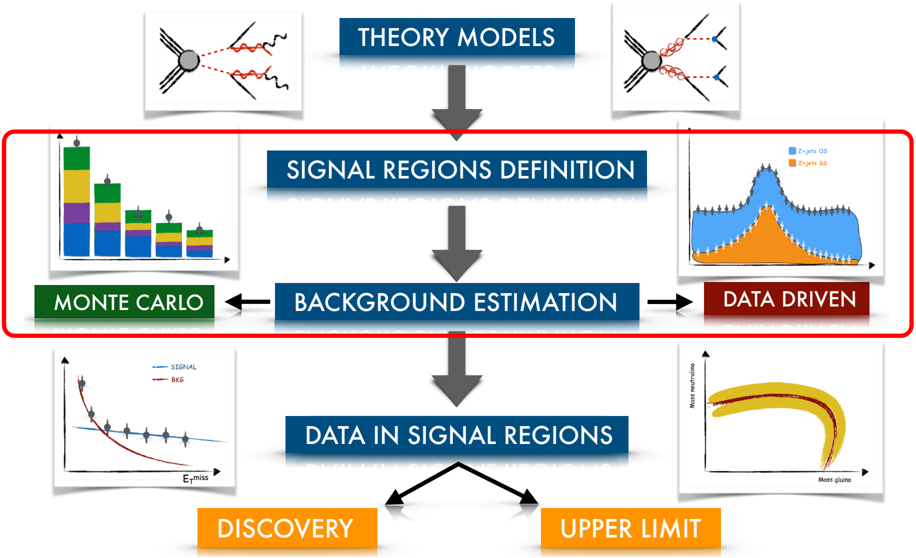
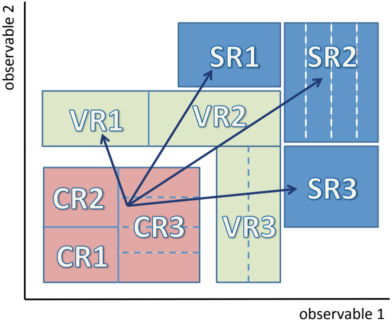
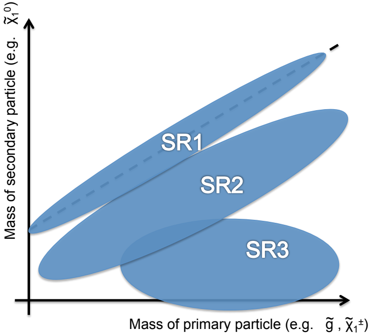


Image Credit: Peter Tornambè

Search strategies employed (briefly)

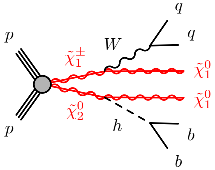




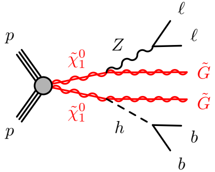
- Design **signal regions** to target **specific regions of parameter space**
- Use **dedicated search techniques**, in particular for **hadronic** signatures
- Tailor observables to target corners dominated by **initial state radiation**

ATLAS search highlights covered in this talk

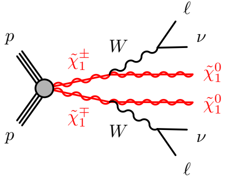
1. **Searches for electroweakinos and axinos in all-hadronic $W/Z/h$ final states**
   → arXiv:1812.09432 arXiv:2108.07586



2. **Searches for electroweakinos and higgsinos with leptons and jets**
   → arXiv:2204.13072



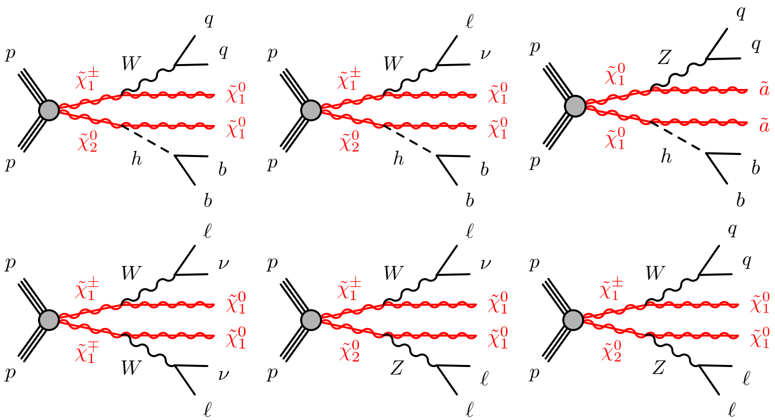
3. **Searches for charginos with multilepton signatures**
   → arXiv:2209.13935



See also: Risa Ushioda's long-lived particle talk (Mon@15:45)

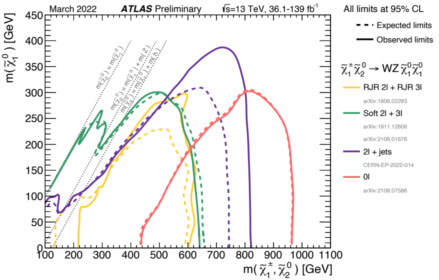
Comprehensive W/Z/h search program in ATLAS

▸ arXiv:1812.09432 ▸ arXiv:2108.07586 ▸ arXiv:2204.13072 ▸ arXiv:2209.13935 ▸ ATLAS-CONF-2022-057 *& more!*

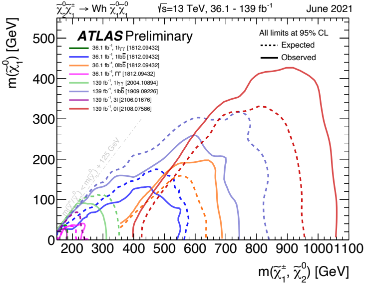


Where do we stand with these $W/Z/h$ final states?

$100\%\ \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 + Z$



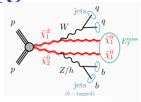
$100\%\ \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 + h$

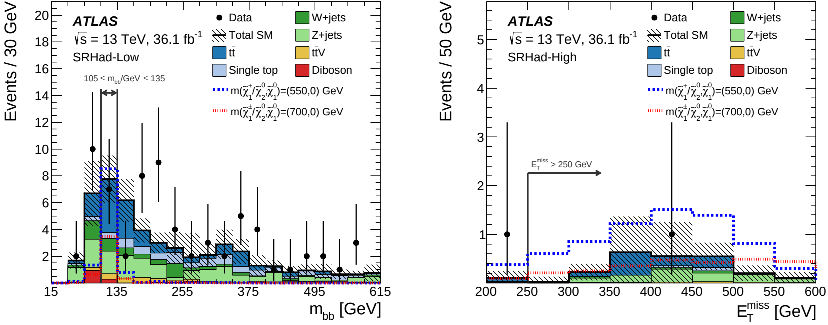


- **Hadronic searches are driving sensitivity** at high-mass, **regardless of $\tilde{\chi}_2^0$ decay (h or Z)**
- Leptonic searches and $E_{\mathrm{T}}^{\mathrm{miss}}$ **drive sensitivity for compressed regions**
  - 3 leptons and soft 2 leptons for $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 + Z$, 1 lepton for $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 + h$
- **Higgs and W/Z masses** often used to construct control (CR), validation (VR), and signal regions (SR)
  - Excellent jet reconstruction and boosted object tagging needed

First search for EWK hadronic Wh signatures: 36 fb^{-1}

▸ arXiv:1812.09432 (Dec 2018)





- Tight selections on **moderately boosted Higgs and *W* bosons**
- **E_T^{miss} (triggers), lepton veto, large M_{eff}** required for all signal regions
- **Higgs and *W* masses** used to construct CR, VR, and SR definitions

First search for EWK hadronic Wh signatures: 36 fb^{-1}

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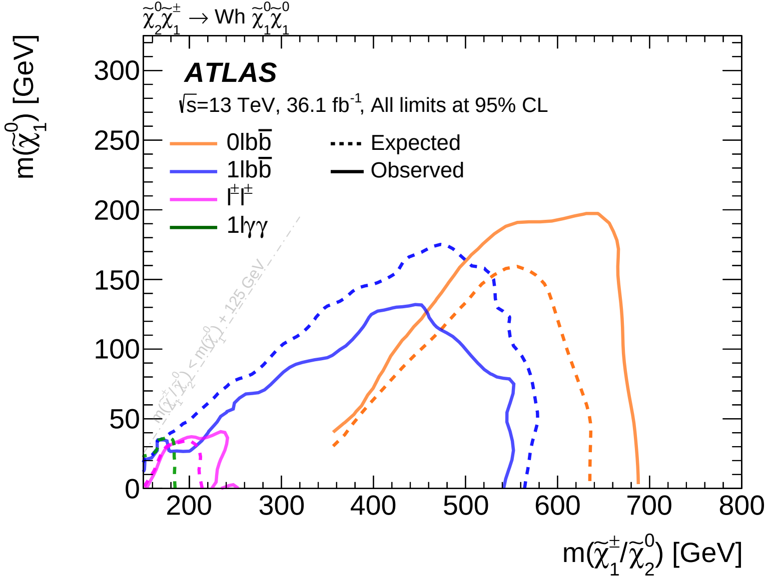
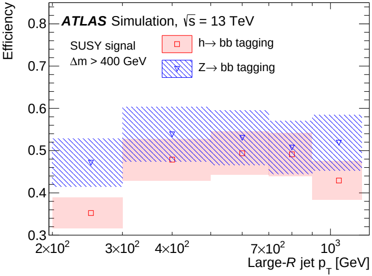
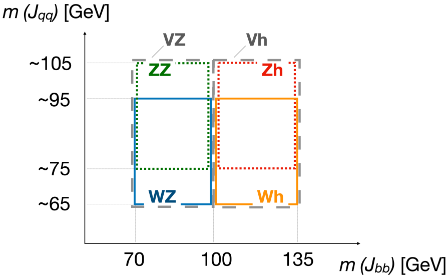


Full run 2 search with boosted hadronic $W/Z/h$ signatures

▸ *arXiv:2108.07586*





- **Boosted boson tagging for $W(Z) \to q\bar{q}$ & $Z(h) \to b\bar{b}$**
- **Fat jets, D_2, & N_{track}, with loosened N_{track} cut:** $N_{\text{track}} \leq 32\ (34)$ for $W(Z)$ tagging compared to standard ATLAS tagging
- **$Z \to b\bar{b}$ and $h \to b\bar{b}$-tagging** requires two b-jets inside the fat jet and mass peak consistent with $Z(h)$ bosons.

Full run 2 search with boosted hadronic W/Z/h signatures

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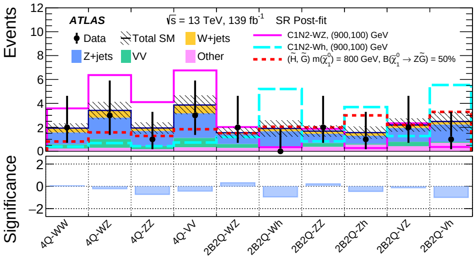

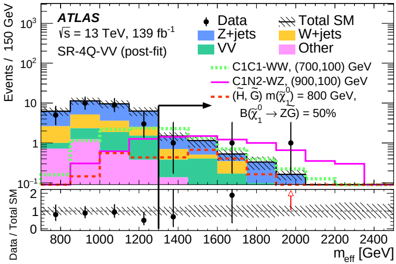

- No signs of anomalous excesses or deficits across 10 signal regions
- Distributions and event yields for key observables such as M_{eff} and m_{T2}

Full run 2 search with boosted hadronic $W/Z/h$ signatures

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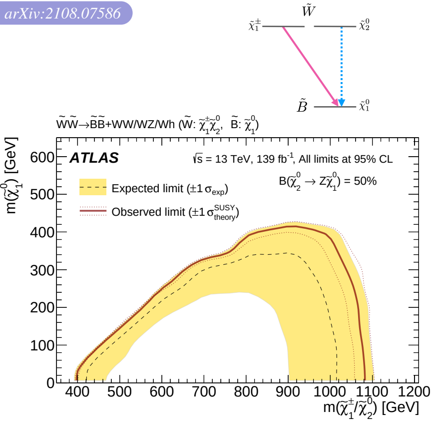
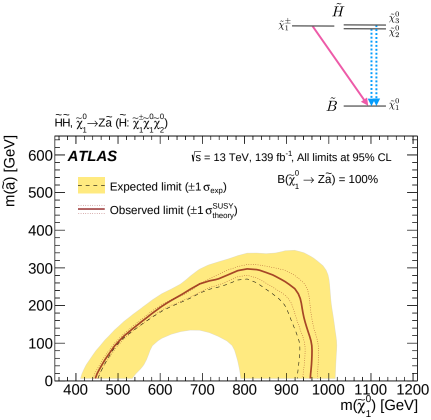
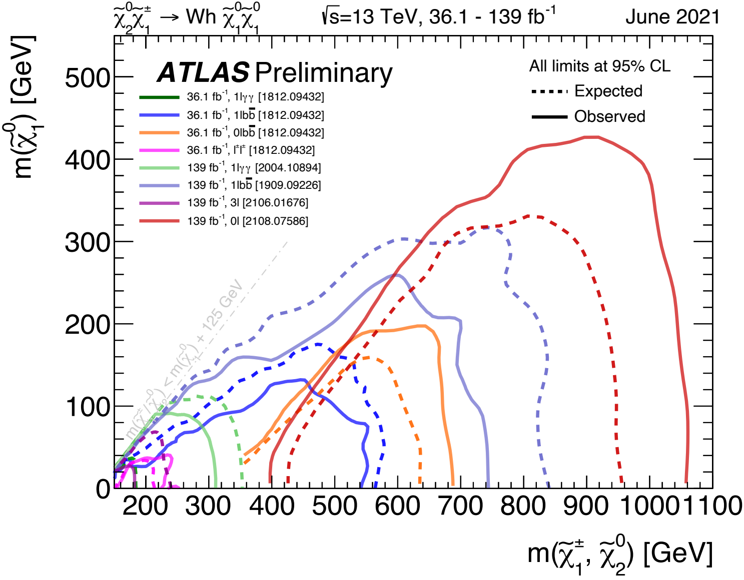




- **Dramatic increase in sensitivity: ~700 GeV → ~1 TeV exclusions!**
  - 50% branching fraction for $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 + Z/h$ (left), all hadronic search relatively insensitive to nature of $\tilde{\chi}_2^0$ decay
- **First interpretation of EWK signatures with an axino ($\tilde{a}$) LSP**

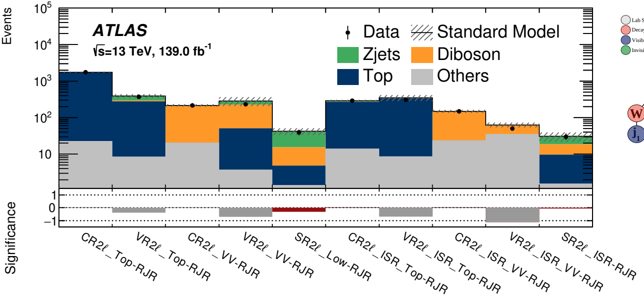
Search for EWK SUSY using Wh signatures: 139 fb^{-1}

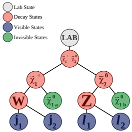
▸ *arXiv:2108.07586*



Searches for EWK-inos and higgsinos with leptons and jets

Phys. Rev. D 98 (2018) 092012 | *(arXiv:1806.02293)* → *arXiv:2204.13072*





- Recursive jigsaw reconstruction (RJR) decomposes events according to **a particular decay topology assumption** and partitions kinematics to **estimate missing degrees of freedom**
- Analysis aimed at checking previously observed excesses of 2.0σ and 1.4σ from $36\ \mathrm{fb}^{-1}$ persist with more data.
  - *The same 36* fb^{-1} *13 TeV analysis also included 3ℓ regions which had* 3.0σ *and* 2.1σ *excesses above the Standard Model expectations, which were not observed with more data (see Phys. Rev. D 101 (2020) 072001 [arXiv:1912.08479])*

Searches for EWK-inos and higgsinos with leptons and jets

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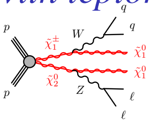
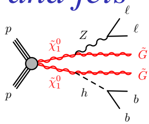
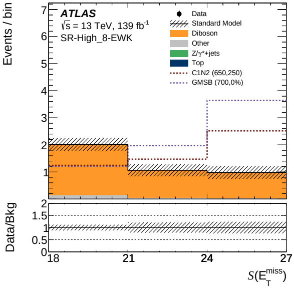
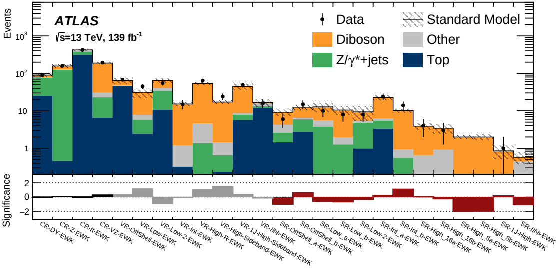




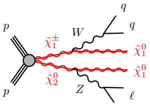


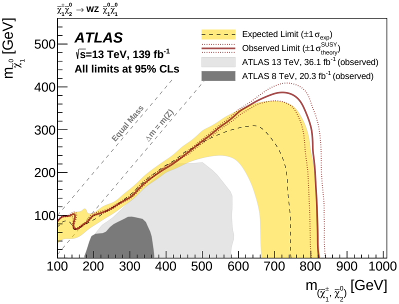


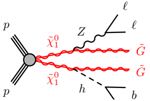
- 2 leptons with opposite-sign charge, at least 2 jets, and $E_{\mathrm{T}}^{\mathrm{miss}}$
- MC simulations normalized from control regions
- Fake or non-prompt leptons estimated using data-driven matrix method
- Observe a deficit in SR for high NLSP-LSP mass splitting

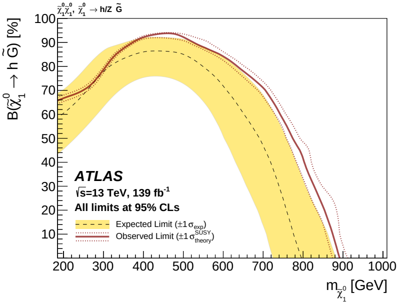
Searches for EWK-inos and higgsinos with leptons and jets

arXiv:2204.13072





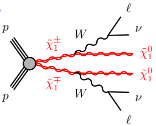


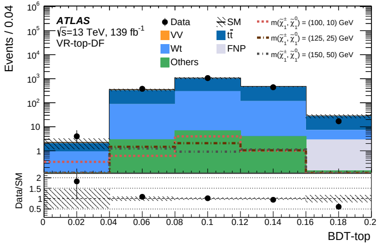


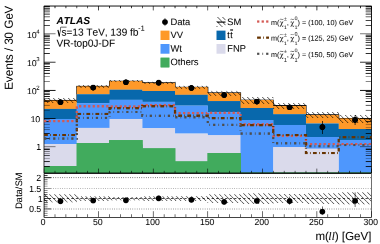
- Observations **agree with predictions** from MC simulations
- Observe **exclusions for chargino/neutralino mass below 820 GeV**
- Can exclude the mass of a **higgsino Next-to-LSP below 900 GeV**

Searches for charginos with multilepton signatures

arXiv:2209.13935







- Direct chargino production with **2 opposite charge leptons** $+ E_{\mathrm{T}}^{\mathrm{miss}}$
- Extending sensitivity to small mass splittings $\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^{0}) \sim m_W$
  - *Signal similar to SM WW, see WW unfolding analysis [arXiv:2206.15231]*
- Same-flavour (SF) and different-flavour (DF) lepton signal regions
- SRs use **binned BDT output** for DF and SF events

Searches for charginos with multilepton signatures

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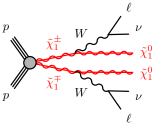
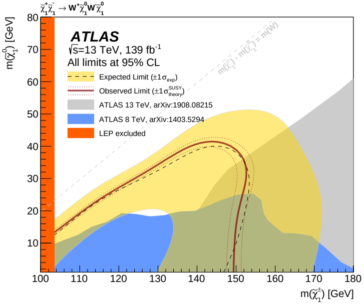
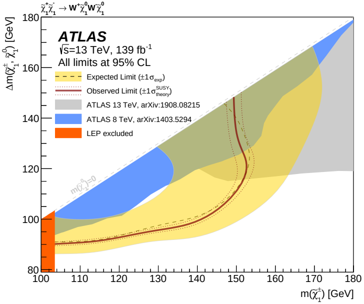






- Significantly extend the limits in low to moderate mass difference region (up to 150 GeV) between chargino and neutralino

Summary and conclusions

- **Electroweak SUSY searches with sensitive hadronic and leptonic final state observables are pushing sensitivities to the TeV scale!**
  - *Fully-hadronic searches important even for electroweak searches*
- **Significant increases in sensitivity for Electroweak / Higgsino searches with the full Run 2 dataset**
  - *Extending the interpretations even farther by varying branching fractions and introducing additional models, such as the axino LSP*
- **Search strategies are successful, but also need to move into more complex models and phase space**
  - *Taking an inclusive perspective where possible, and investigating additional model parameters to vary in order to assess and eventually expand sensitivity*

Thank you!

Additional Material

Common observables used in 13 TeV searches for SUSY

For the 13 TeV ATLAS searches, we utilize each of these classes:

- **Missing energy-type:**
  - **Missing transverse momentum:** $E_{\mathrm{T}}^{\mathrm{miss}}$ and $\vec{p_{\mathrm{T}}}^{\mathrm{miss}}$
  - **Missing transverse momentum significance:** $E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}}$
  - **RJigsaw H-scale for 1 visible, 1 invisible state:** $H_{1,1}^{\mathrm{PP}}$ (Similar to $E_{\mathrm{T}}^{\mathrm{miss}}$)
- **Energy scale-type:**
  - **Effective mass:** $M_{\mathrm{eff}} = \sum_{\mathrm{jets}} p_{\mathrm{T}} + \sum_{\mathrm{leptons}} + E_{\mathrm{T}}^{\mathrm{miss}}$ (also considering only first 4 jets)
  - **Scalar sum of visible momenta:** H_{T},
  - **Transverse mass:** $m_{\mathrm{T}} = \sqrt{2p_{\mathrm{T}}^{\ell}E_{\mathrm{T}}^{\mathrm{miss}}(1-\cos(\Delta\phi(\vec{p_{\mathrm{T}}}^{\mathrm{miss}},\ell))}$ (b-quarks can also replace the lepton)
  - **RJigsaw H-scale:** $H_{2,1}^{\mathrm{PP}}$, $H_{4,1}^{\mathrm{PP}}$ (Similar to M_{eff})
  - **RJigsaw ISR p_{T} scale:** $|p_{TS}^{\mathrm{ISR}}|$ (sum p_{T} of ISR jets
- **Energy structure-type:**
  - **Jet multiplicity:** N_{jet}, $N_{b-\mathrm{jet}}$
  - **Total jet mass:** $M_{\mathrm{J}}^{\Sigma} = \sum m^{\mathrm{jet}}$ (also considering only first 4 large-radius jets)
  - **Angular distributions:** $\Delta\phi_{\mathrm{min}}^{4j} = \min(|\phi_{\mathrm{any-jet}} - \vec{p_{\mathrm{T}}}^{\mathrm{miss}}|) > 0.4$ (for all 0ℓ selections)
  - **Aplanarity:** $A = (3/2)\lambda_3$
  - **QCD $E_{\mathrm{T}}^{\mathrm{miss}}$ alignment:** Δ_{QCD} (signed asymmetry between $E_{\mathrm{T}}^{\mathrm{miss}}$ and jet azimuthal directions)

Full run 2 search with boosted hadronic $W/Z/h$ signatures

arXiv:2108.07586

Model	Production	Final states	SRs simultaneously fitted	Branching ratio
$(\widetilde{W},\widetilde{B})$	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp$, $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$	WW, WZ, Wh	4Q-VV, 2B2Q-WZ, 2B2Q-Wh	$\mathcal{B}(\tilde{\chi}_1^\pm \to W\tilde{\chi}_1^0) = 1$ $\mathcal{B}(\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0)$ scanned
$(\widetilde{H},\widetilde{B})$	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp$, $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$, $\tilde{\chi}_1^\pm\tilde{\chi}_3^0$, $\tilde{\chi}_2^0\tilde{\chi}_3^0$	WW, WZ, Wh, ZZ, Zh, hh	4Q-VV, 2B2Q-VZ, 2B2Q-Vh	$\mathcal{B}(\tilde{\chi}_1^\pm \to W\tilde{\chi}_1^0) = 1$ $\mathcal{B}(\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0)$ scanned $\mathcal{B}(\tilde{\chi}_3^0 \to Z\tilde{\chi}_1^0) = 1 - \mathcal{B}(\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0)$
$(\widetilde{W},\widetilde{H})$	$\tilde{\chi}_2^\pm\tilde{\chi}_2^\mp$, $\tilde{\chi}_2^\pm\tilde{\chi}_3^0$	WW, WZ, Wh, ZZ, Zh, hh	4Q-VV, 2B2Q-VZ, 2B2Q-Vh	Determined from $(M_2, \mu, \tan\beta)$
$(\widetilde{H},\widetilde{W})$	$\tilde{\chi}_2^\pm\tilde{\chi}_2^\mp$, $\tilde{\chi}_2^\pm\tilde{\chi}_2^0$, $\tilde{\chi}_2^\pm\tilde{\chi}_3^0$, $\tilde{\chi}_2^0\tilde{\chi}_3^0$	WW, WZ, Wh, ZZ, Zh, hh	4Q-VV, 2B2Q-VZ, 2B2Q-Vh	Determined from $(M_2, \mu, \tan\beta)$
$(\widetilde{H},\widetilde{G})$	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp$, $\tilde{\chi}_1^\pm\tilde{\chi}_1^0$, $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$, $\tilde{\chi}_1^0\tilde{\chi}_2^0$	ZZ, Zh, hh	4Q-ZZ, 2B2Q-ZZ, 2B2Q-Zh	$\mathcal{B}(\tilde{\chi}_1^0 \to Z\widetilde{G})$ scanned
$(\widetilde{H},\tilde{a})$	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp$, $\tilde{\chi}_1^\pm\tilde{\chi}_1^0$, $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$, $\tilde{\chi}_1^0\tilde{\chi}_2^0$	ZZ, Zh, hh	4Q-ZZ, 2B2Q-ZZ, 2B2Q-Zh	$\mathcal{B}(\tilde{\chi}_1^0 \to Z\tilde{a})$ scanned
$(\widetilde{W},\widetilde{B})$ simplified models: $(\widetilde{W},\widetilde{B})$-SIM				
C1C1-WW	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp$	WW	4Q-WW	$\mathcal{B}(\tilde{\chi}_1^\pm \to W\tilde{\chi}_1^0) = 1$
C1N2-WZ	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$	WZ	4Q-WZ, 2B2Q-WZ	$\mathcal{B}(\tilde{\chi}_1^\pm \to W\tilde{\chi}_1^0) = \mathcal{B}(\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0) = 1$
C1N2-Wh	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$	Wh	2B2Q-Wh	$\mathcal{B}(\tilde{\chi}_1^\pm \to W\tilde{\chi}_1^0) = \mathcal{B}(\tilde{\chi}_2^0 \to h\tilde{\chi}_1^0) = 1$

Full run 2 search with boosted hadronic W/Z/h signatures

arXiv:2108.07586

	SR(CR0L)		VR(CR)1L		VR(CR)1Y		VRTTX
	4Q	2B2Q	4Q	2B2Q	4Q	2B2Q	
$n_{\text{Large-}R\text{ jets}}$	≥ 2		≥ 2		≥ 2		$= 1$
n_{lepton}	$= 0$		$= 1$		$= 0$		$= 3$
$p_{\text{T}}(\ell_1)$ [GeV]	-		> 30		-		> 30
n_{photon}	-		-		$= 1$		-
$n(V_{qq})$	$= 2\ (= 1)$	$= 1\ (= 0)$	$= 2\ (= 1)$	$= 1\ (= 0)$	$= 2\ (= 1)$	$= 1\ (= 0)$	-
$n(!V_{qq})$	$= 0\ (= 1)$	$= 0\ (= 1)$	$= 0\ (= 1)$	$= 0\ (= 1)$	$= 0\ (= 1)$	$= 0\ (= 1)$	-
$n(J_{bb})$	$= 0$	$= 1$	$= 0$	$= 1$	$= 0$	$= 1$	$= 1$
$m(J_{bb})$ [GeV]	-	$\in [70, 135\ (150)]$	-	$\in [70, 150]$	-	$\in [70, 150]$	-
$n_{b\text{-jet}}^{\text{unmatched}}$	$= 0$		$= 0$		$= 0$		-
$n_{b\text{-jet}}$	≤ 1	-	$= 0$	-	≤ 1	-	-
$E_{\text{T}}^{\text{miss}}$ [GeV]	> 300	> 200	> 50		< 200		-
$p_{\text{T}}(W)$ [GeV]	-		> 200		-		-
$p_{\text{T}}(\gamma)$ [GeV]	-		-		> 200		-
m_{eff} [GeV]	> 1300	$> 1000\ (> 900)$	> 1000	> 900	> 1000	> 900	-
$\min \Delta\phi(E_{\text{T}}^{\text{miss}}, j)$	> 1.0		> 1.0		> 1.0		-
m_{T2} [GeV]	-	> 250	-	> 250	-	> 250	-

Full run 2 search with boosted hadronic $W/Z/h$ signatures

▸ *arXiv:2108.07586*

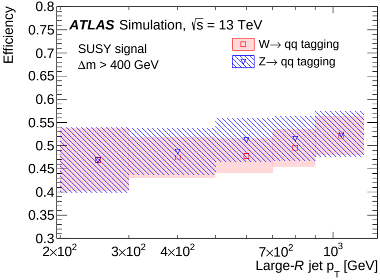
Region	CR1L-4Q	VR1L-4Q	CR1L-2B2Q	VR1L-2B2Q
Observed	439	13	96	5
Post-fit	439 ± 21	22.0 ± 3.4	96 ± 10	7.8 ± 1.5
W+jets	325 ± 16	13.4 ± 2.2	48 ± 5	3.4 ± 0.7
Z+jets	4.45 ± 0.21	0.198 ± 0.035	0.58 ± 0.06	0.044 ± 0.012
γ+jets	< 1	-	0.57 ± 0.06	0.22 ± 0.10
VV	65.4 ± 3.1	4.1 ± 0.8	6.9 ± 0.7	0.55 ± 0.15
$V\gamma$	< 1	-	< 0.1	-
VVV	1.3 ± 0.6	0.52 ± 0.28	0.14 ± 0.08	0.09 ± 0.05
$t\bar{t}$	30.4 ± 1.5	2.7 ± 0.4	24.0 ± 2.5	1.8 ± 0.4
t+X	11.0 ± 0.5	0.91 ± 0.21	13.2 ± 1.4	1.27 ± 0.34
$t\bar{t}$+X	1.5 ± 1.2	0.16 ± 0.12	1.5 ± 1.1	0.4 ± 0.4
Vh	< 0.1	< 0.001	0.69 ± 0.07	0.046 ± 0.009

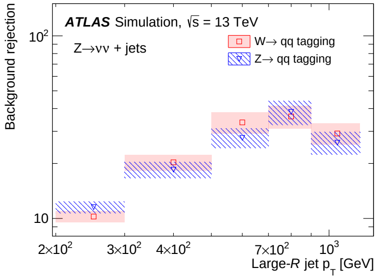
Region	CR1Y-4Q	VR1Y-4Q	CR1Y-2B2Q	VR1Y-2B2Q
Observed	1001	38	127	14
Post-fit	1001 ± 32	43 ± 8	127 ± 11	8.6 ± 2.0
W+jets	2.59 ± 0.08	< 0.1	< 0.1	-
Z+jets	< 1	-	< 0.01	-
γ+jets	856 ± 28	37 ± 7	107 ± 11	6.4 ± 1.6
VV	< 1	-	-	-
$V\gamma$	131 ± 4	5.0 ± 0.9	12.6 ± 1.3	1.13 ± 0.27
VVV	< 0.1	< 0.01	-	-
$t\bar{t}$	1.28 ± 0.04	-	0.57 ± 0.06	0.28 ± 0.18
t+X	< 1	-	< 0.1	-
$t\bar{t}$+X	9 ± 6	0.6 ± 0.5	7 ± 5	0.8 ± 0.6
Vh	< 0.001	-	< 0.01	-

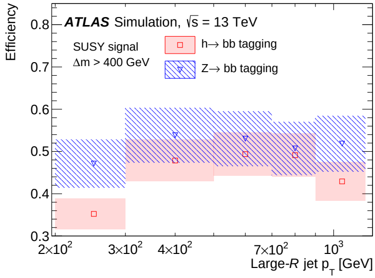
	$n(W_{qq})$	$n(Z_{qq})$	$n(V_{qq})$	$n(Z_{bb})$	$n(h_{bb})$
4Q-WW	= 2	-	= 2	= 0	= 0
4Q-WZ	≥ 1	≥ 1	= 2	= 0	= 0
4Q-ZZ	-	= 2	= 2	= 0	= 0
4Q-VV	-	-	= 2	= 0	= 0
2B2Q-WZ	= 1	-	= 1	= 1	= 0
2B2Q-ZZ	-	= 1	= 1	= 1	= 0
2B2Q-Wh	= 1	-	= 1	= 0	= 1
2B2Q-Zh	-	= 1	= 1	= 0	= 1
2B2Q-VZ	-	-	= 1	= 1	= 0
2B2Q-Vh	-	-	= 1	= 0	= 1

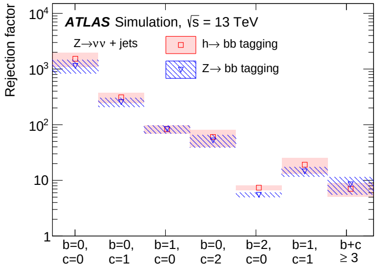
Full run 2 search with boosted hadronic W/Z/h signatures

arXiv:2108.07586



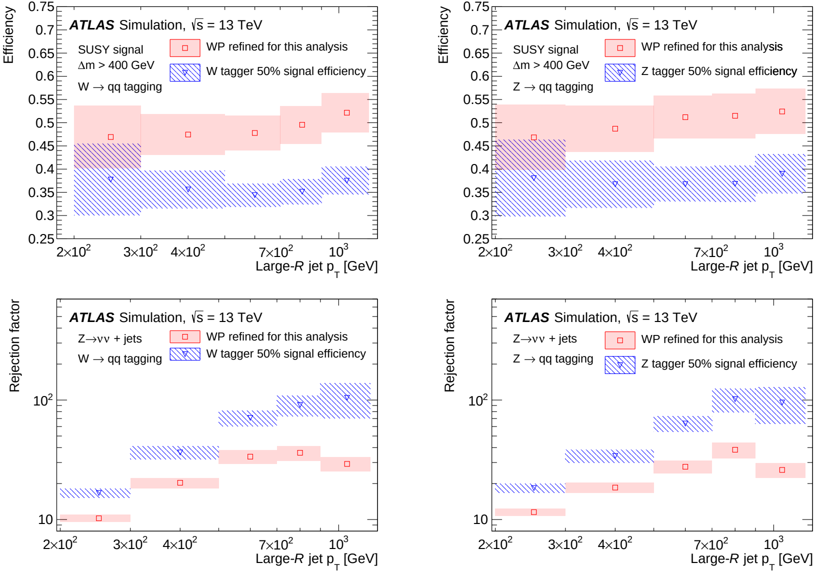






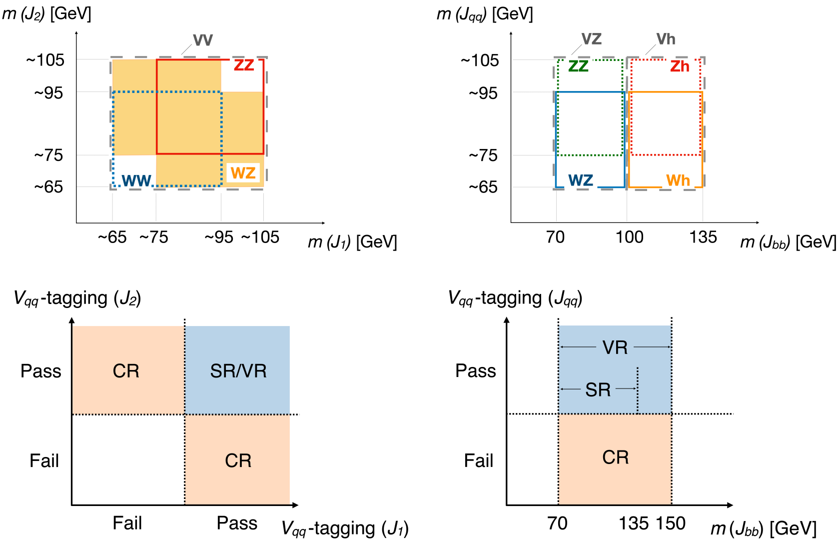
Full run 2 search with boosted hadronic $W/Z/h$ signatures

arXiv:2108.07586



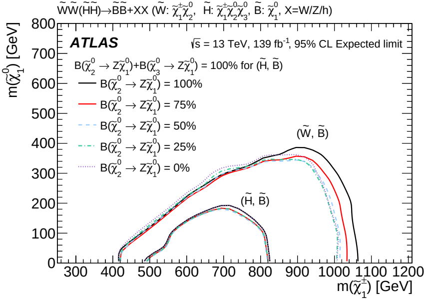
Full run 2 search with boosted hadronic W/Z/h signatures

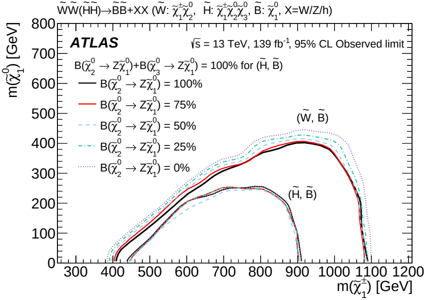
arXiv:2108.07586



Full run 2 search with boosted hadronic W/Z/h signatures

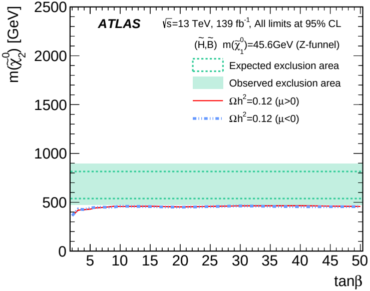
arXiv:2108.07586

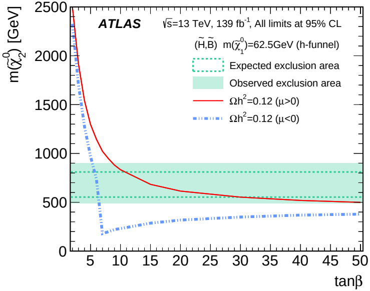


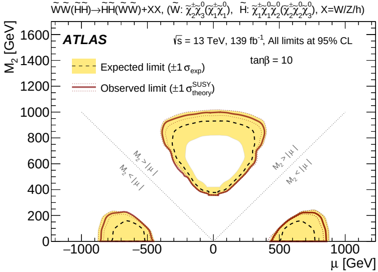


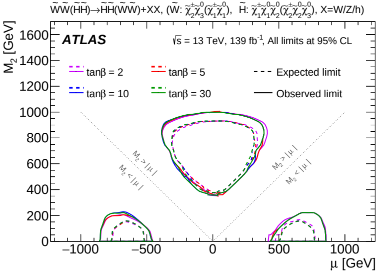
Full run 2 search with boosted hadronic W/Z/h signatures

▸ *arXiv:2108.07586*



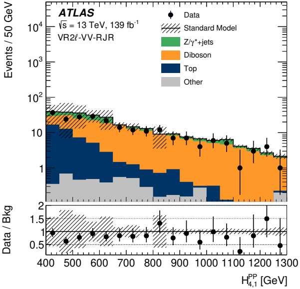


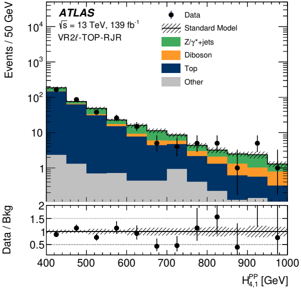


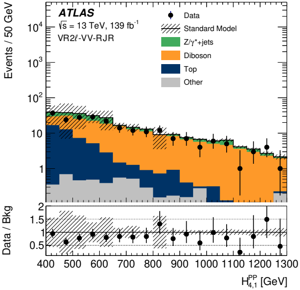


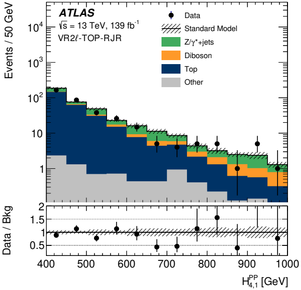
Searches for EWK-inos and higgsinos with leptons and jets

arXiv:2204.13072









Searches for EWK-inos and higgsinos with leptons and jets

arXiv:2204.13072

Region	n_{jets}	$n_{\text{jets}}^{b\text{-tag}}$	$\mathcal{S}(E_{\text{T}}^{\text{miss}})$	$m_{\ell\ell}$ [GeV]	m_X [GeV]	m_{T2} [GeV]	ΔR_X	$p_{\text{T}}^{j_1}$ [GeV]
SR-High-EWK	≥ 2	≤ 1	$(18, 21, \infty)$	71–111	$60 < m_{jj} < 110$	> 80	$\Delta R_{jj} \in (0, 0.8, 1.6)$	–
VR-High-Sideband-EWK	≥ 2	≤ 1	> 18	71–111	$\mathbf{20 < m_{jj} < 60 \cup m_{jj} > 110}$	> 80	$\Delta R_{jj} < 1.6$	–
VR-High-R-EWK	≥ 2	≤ 1	> 18	71–111	$\mathbf{m_{jj} > 20}$	> 80	$\mathbf{\Delta R_{jj} > 1.6}$	–
SR-1J-High-EWK	1	≤ 1	> 12	71–111	$60 < m_{j_1} < 110$	> 80	–	–
VR-1J-High-Sideband-EWK	1	≤ 1	> 12	71–111	$\mathbf{20 < m_{j_1} < 60 \cup m_{j_1} > 110}$	> 80	–	–
SR-$\ell\ell bb$-EWK	≥ 2	≥ 2	> 18	71–111	$60 < m_{bb} < 150$	> 80	–	–
VR-$\ell\ell bb$-EWK	≥ 2	≥ 2	**12–18**	71–111	$60 < m_{bb} < 150$	> 80	–	–
SR-Int-EWK	≥ 2	0	$(12, 15, 18)$	81–101	$60 < m_{jj} < 110$	> 80	–	> 60
VR-Int-EWK	≥ 2	0	12–18	81–101	$60 < m_{jj} < 110$	> 80	–	$\mathbf{< 60}$
CR-VZ-EWK	≥ 2	0	12–18	81–101	$\mathbf{20 < m_{jj} < 60 \cup m_{jj} > 110}$	> 80	–	**–**
CR-tt-EWK	≥ 2	$\mathbf{\geq 1}$	**9–12**	81–101	$\mathbf{m_{jj} > 20}$	> 80	–	> 60

	SR-High_16a-EWK	SR-High_8a-EWK	SR-1J-High-EWK	SR-$\ell\ell bb$-EWK
Observed events	4	0	1	0
Total exp. bkg. events	3.9 ± 0.7	2.00 ± 0.23	0.85 ± 0.34	0.58 ± 0.20
Diboson events	3.2 ± 0.6	1.86 ± 0.22	0.80 ± 0.31	0.13 ± 0.03
Top events	$0.00^{+0.01}_{-0.00}$	0.0 ± 0.0	$0.03^{+0.04}_{-0.03}$	$0.05^{+0.08}_{-0.05}$
Z/γ^* + jets events	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Other events	0.7 ± 0.4	0.15 ± 0.07	$0.02^{+0.04}_{-0.02}$	0.39 ± 0.16

	SR-High_16b-EWK	SR-High_8b-EWK
Observed events	3	0
Total exp. bkg. events	3.4 ± 0.9	2.00 ± 0.33
Diboson events	2.5 ± 0.6	1.94 ± 0.33
Top events	0.0 ± 0.0	0.0 ± 0.0
Z/γ^* + jets events	0.0 ± 0.0	0.0 ± 0.0
Other events	0.9 ± 0.7	0.06 ± 0.04

Searches for EWK-inos and higgsinos with leptons and jets

arXiv:2204.13072

Region	n_{jets}	$n_{\text{jets}}^{b\text{-tag}}$	$\mathcal{S}(E_{\text{T}}^{\text{miss}})$	$m_{\ell\ell}$ [GeV]	m_X [GeV]	m_{T2} [GeV]	ΔR_X	$\Delta\phi(p_{\text{T}}^{\ell\ell}, \vec{p}_{\text{T}}^{\text{miss}})$
SR-Low-EWK	2	0	(6, 9, 12)	81–101	$60 < m_{jj} < 110$	> 80	$\Delta R_{\ell\ell} < 1$	–
VR-Low-EWK	2	0	6–12	81–101	$60 < m_{jj} < 110$	> 80	$\mathbf{1 < \Delta R_{\ell\ell} < 1.4}$	–
SR-Low-2-EWK	2	0	6–9	81–101	$60 < m_{jj} < 110$	< 80	$\Delta R_{\ell\ell} < 1.6$	< 0.6
VR-Low-2-EWK	2	0	6–9	81–101	$\mathbf{20 < m_{jj} < 60 \cup m_{jj} > 110}$	< 80	$\Delta R_{\ell\ell} < 1.6$	< 0.6
CR-Z-EWK	2	0	6–9	81–101	$\mathbf{20 < m_{jj} < 60 \cup m_{jj} > 110}$	**> 80**	**–**	**–**

Region	n_{jets}	$n_{\text{jets}}^{b\text{-tag}}$	$\mathcal{S}(E_{\text{T}}^{\text{miss}})$	$m_{\ell\ell}$ [GeV]	m_{T2} [GeV]	$p_{\text{T}}^{j_1}$ [GeV]	$\Delta\phi(p_{\text{T}}^{j_1}, \vec{p}_{\text{T}}^{\text{miss}})$
SR-OffShell-EWK	≥ 2	0	> 9	(12, 40, 71)	> 100	> 100	> 2
VR-OffShell-EWK	≥ 2	0	> 9	12–71	**80–100**	> 100	> 2
CR-DY-EWK	≥ 2	0	**6–9**	12–71	> 100	**–**	**–**

	SR-Int_a-EWK	SR-Low_a-EWK	SR-Low-2-EWK	SR-OffShell_a-EWK
Observed events	24	10	8	6
Total exp. bkg. events	22.8 ± 3.5	12.8 ± 3.4	9 ± 4	9.2 ± 1.7
Diboson events	16.5 ± 1.7	7.3 ± 1.3	4.0 ± 2.1	4.9 ± 1.3
Top events	4 ± 4	$0.06^{+0.14}_{-0.06}$	$1.0^{+1.2}_{-1.0}$	1.4 ± 0.7
$Z/\gamma^* + $jets events	2.1 ± 0.7	3.7 ± 3.3	4 ± 4	1.2 ± 1.2
Other events	0.44 ± 0.13	1.7 ± 0.4	0.58 ± 0.3	1.6 ± 0.4

	SR-Int_b-EWK	SR-Low_b-EWK		SR-OffShell_b-EWK
Observed events	14	8		15
Total exp. bkg. events	10.1 ± 1.0	10.5 ± 2.5		12.5 ± 1.9
Diboson events	9.2 ± 1.0	8.6 ± 1.2		6.1 ± 1.5
Top events	0.22 ± 0.13	0.0 ± 0.0		2.8 ± 1.4
$Z/\gamma^* + $jets events	0.51 ± 0.31	$1.3^{+2.2}_{-1.3}$		3.1 ± 1.4
Other events	0.19 ± 0.08	0.70 ± 0.11		0.54 ± 0.24

Searches for charginos with multilepton signatures

arXiv:2209.13935

Control region (CR)	CR-VV		CR-top	
$E_{\mathrm{T}}^{\mathrm{miss}}$ significance	> 8			
m_{T2} [GeV]	> 50			
$n_{\text{non-}b\text{-tagged jets}}$	$= 0$			
Leptons flavour	DF	SF	DF	SF
$n_{b\text{-tagged jets}}$	$= 0$	$= 0$	$= 1$	$= 1$
BDT-other	-	< 0.01	-	< 0.01
BDT-signal	$\in (0.2, 0.65]$	$\in (0.2, 0.65]$	$\in (0.5, 0.7]$	$\in (0.7, 0.75]$
BDT-VV	> 0.2	> 0.2	-	-
BDT-top	< 0.1	< 0.1	-	-

Validation region (VR)	VR-VV-DF	VR-VV-SF	VR-top-DF	VR-top-SF	VR-top0J-DF	VR-top0J-SF
$E_{\mathrm{T}}^{\mathrm{miss}}$ significance	> 8					
m_{T2} [GeV]	> 50					
$n_{\text{non-}b\text{-tagged jets}}$	$= 0$					
$n_{b\text{-tagged jets}}$	$= 0$	$= 0$	$= 1$	$= 1$	$= 0$	$= 0$
BDT-other	-	< 0.01	-	< 0.01	-	< 0.01
BDT-signal	$\in (0.65, 0.81]$	$\in (0.65, 0.77]$	$\in (0.7, 1]$	$\in (0.75, 1]$	$\in (0.5, 0.81]$	$\in (0.5, 0.77]$
BDT-VV	> 0.2	> 0.2	-	-	< 0.15	< 0.15
BDT-top	< 0.1	< 0.1	-	-	-	-

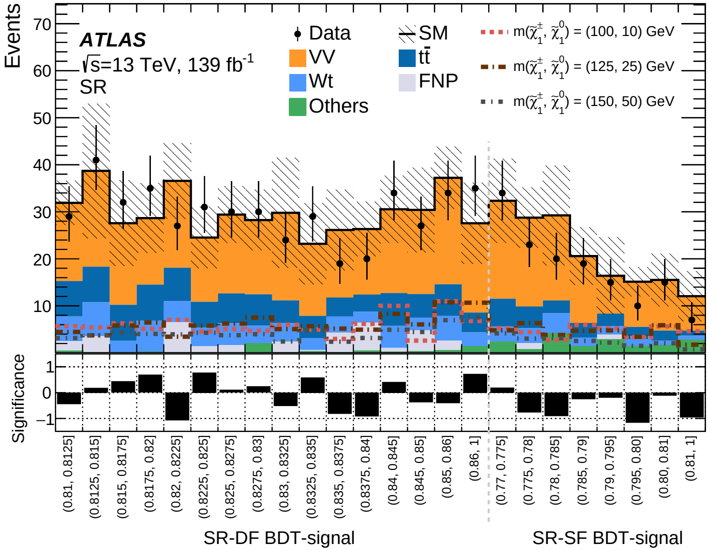
Searches for charginos with multilepton signatures

arXiv:2209.13935

Signal region (SR)	SR-DF	SR-SF
$n_{b\text{-tagged jets}}$	$= 0$	
$n_{\text{non-}b\text{-tagged jets}}$	$= 0$	
$E_{\mathrm{T}}^{\mathrm{miss}}$ significance	>8	
m_{T2} [GeV]	>50	
BDT-other		< 0.01
Binned SRs		
BDT-signal	$\in$(0.81,0.8125]	$\in$(0.77,0.775]
	$\in$(0.8125,0.815]	$\in$(0.775,0.78]
	$\in$(0.815,0.8175]	$\in$(0.78,0.785]
	$\in$(0.8175,0.82]	$\in$(0.785,0.79]
	$\in$(0.82,0.8225]	$\in$(0.79,0.795]
	$\in$(0.8225,0.825]	$\in$(0.795,0.80]
	$\in$(0.825,0.8275]	$\in$(0.80,0.81]
	$\in$(0.8275,0.83]	$\in$(0.81,1]
	$\in$(0.83,0.8325]	
	$\in$(0.8325,0.835]	
	$\in$(0.835,0.8375]	
	$\in$(0.8375,0.84]	
	$\in$(0.84,0.845]	
	$\in$(0.845,0.85]	
	$\in$(0.85,0.86]	
	$\in$(0.86,1]	
Inclusive SRs		
BDT-signal	$\in$(0.81,1]	$\in$(0.77,1]
	$\in$(0.81,1]	
	$\in$(0.82,1]	
	$\in$(0.83,1]	
	$\in$(0.84,1]	
	$\in$(0.85,1]	
		$\in$(0.77,1]
		$\in$(0.78,1]
		$\in$(0.79,1]
		$\in$(0.80,1]

Searches for charginos with multilepton signatures

arXiv:2209.13935



Searches for charginos with multilepton signatures

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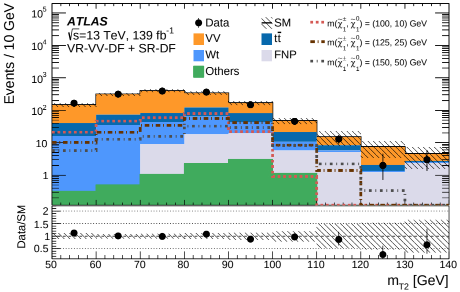
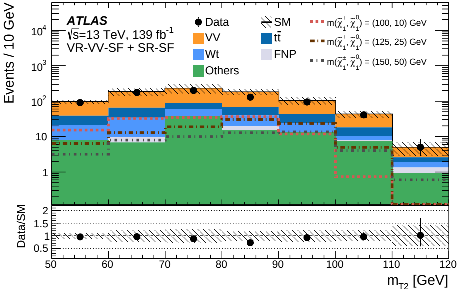
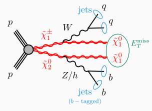
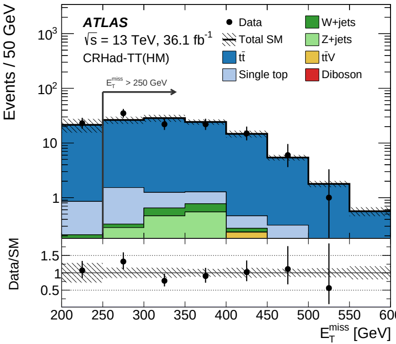


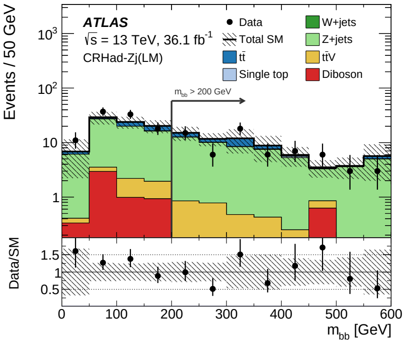


Wh search in 2b+2q final states (0ℓbb): 36 fb^{-1}

arXiv:1812.09432 (Dec 2018)



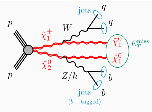


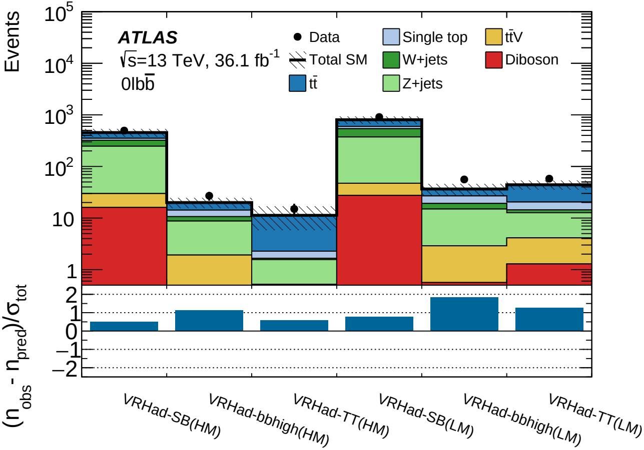


- Control region kinematic distributions

Wh search in 2b+2q final states (0ℓbb): 36 fb^{-1}

arXiv:1812.09432 (Dec 2018)





- Validation region yields

Wh region definitions: $0\ell bb$

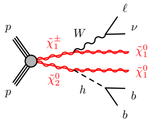
arXiv:1812.09432 (Dec 2018)

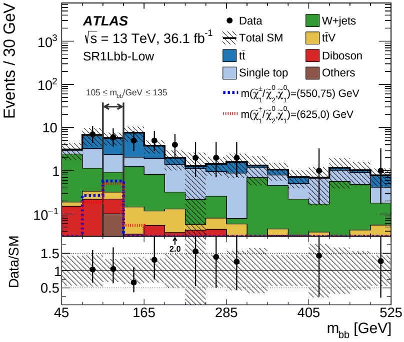
Variable	SRHad-High	SRHad-Low
N_{lepton}	$= 0$	$= 0$
N_{jet} ($p_{\text{T}} > 30$ GeV)	$\in [4,\ 5]$	$\in [4,\ 5]$
$N_{b\text{-jet}}$	$= 2$	$= 2$
$\Delta\phi^{4j}_{\text{min}}$	> 0.4	> 0.4
$E_{\text{T}}^{\text{miss}}$ [GeV]	> 250	> 200
m_{eff} [GeV]	> 900	> 700
$m_{b\bar{b}}$ [GeV]	$\in [105, 135]$	$\in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

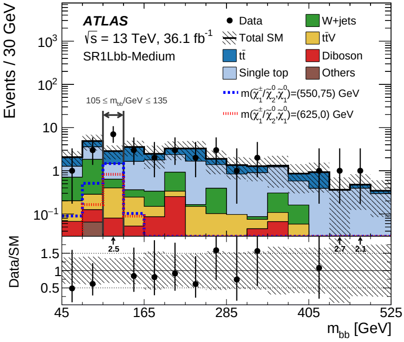
CR channels	CRHad-TT(HM)	CRHad-ST(HM)	CRHad-Zj(HM)	CRHad-TT(LM)	CRHad-ST(LM)	CRHad-Zj(LM)
Observed events	102	17	39	695	23	78
Fitted bkg events	102 ± 10	17 ± 4	39 ± 6	695 ± 26	23 ± 5	78 ± 9
$t\bar{t}$	97 ± 11	3.7 ± 2.0	2.9 ± 2.4	659 ± 34	4.7 ± 2.3	10^{+12}_{-10}
Single top	$2.7^{+3.5}_{-2.7}$	10 ± 5	$0.8^{+0.9}_{-0.8}$	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

Wh search in 2b+1ℓ final states (1ℓ*bb*)*: 36* fb^{-1}

arXiv:1812.09432 (Dec 2018)







- Signal region $b\bar{b}$ mass distributions

Wh region definitions: $1\ell bb$

arXiv:1812.09432 (Dec 2018)

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]		$\in [105, 135]$	

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

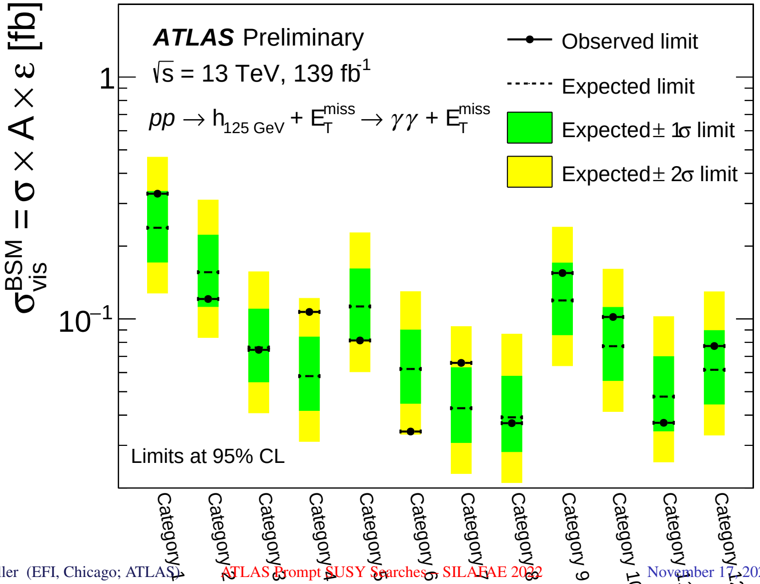
Wh region definitions: $1\ell\gamma\gamma$

arXiv:1812.09432 (Dec 2018)

Variable	SR1L$\gamma\gamma$-a	SR1L$\gamma\gamma$-b
N_γ	$= 2$	
p_{T}^{γ} [GeV]	$> (40, 31)$	
N_{lepton}	$= 1$	
p_{T}^{ℓ} [GeV]	> 25	
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 40	
$\Delta\phi_{W,h}$	> 2.25	
$m_{\gamma\gamma}$ [GeV]	$\in [120, 130]$	
$N_{b\text{-jet}}$ ($p_{\mathrm{T}} > 30$ GeV)	$= 0$	
$m_{\mathrm{T}}^{W\gamma_1}$ [GeV]	≥ 150	
$m_{\mathrm{T}}^{W\gamma_2}$ [GeV]	> 140	$\in [80, 140]$
m_{T} [GeV]	> 110	< 110

Wh region definitions: $1\ell\gamma\gamma$ *follow-up (139* fb^{-1}*)*

ATLAS-CONF-2019-019 (May 2019)



Wh region definitions: $1\ell\gamma\gamma$ *follow-up (139* fb^{-1}*)*

ATLAS-CONF-2019-019 (May 2019)

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

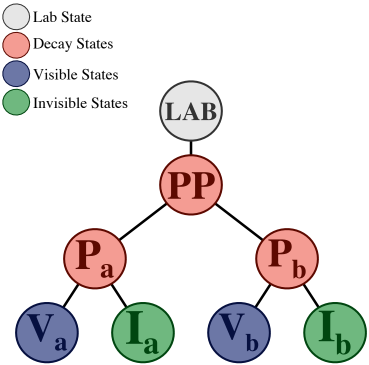
Wh region definitions: $\ell\ell$

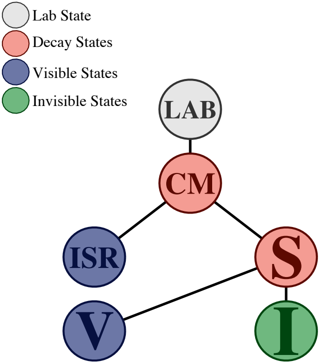
arXiv:1812.09432 (Dec 2018)

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

Recursive Jigsaw Reconstruction (RJR) for SUSY at 13 TeV

ATLAS 36 fb^{-1} paper (arXiv:1806.02293), *ATLAS 139 fb^{-1} paper* (arXiv:1806.02293), *and RJR paper* (arXiv:1607.08307)





- Decompose events according to **particular decay topology assumption** and partition kinematics to **estimate missing degrees of freedom**
- **"Hemispheres"** defined using thrust axis of event
- Observables are computed by **minimizing hemisphere masses** and assigning missing degrees of freedom with each

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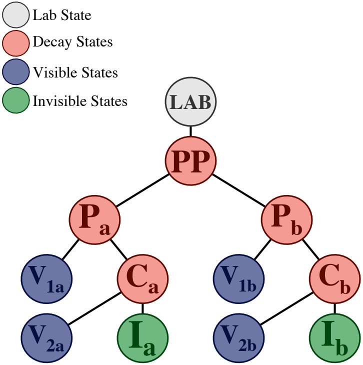

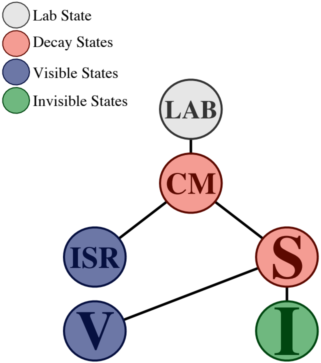

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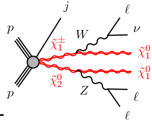
Follow-up of recursive jigsaw analysis with 139 fb^{-1}

Phys. Rev. D 98 (2018) 092012 *(arXiv:1806.02293)* → *ATLAS-CONF-2019-020*



Region	$m_{\ell\ell}$ [GeV]	m_T^W [GeV]	$H_{3,1}^{PP}$ [GeV]	$\frac{p_{T\,PP}^{lab}}{p_{T\,PP}^{lab}+H_{T\,3,1}^{PP}}$	$\frac{H_{T\,3,1}^{PP}}{H_{3,1}^{PP}}$	$\frac{H_{1,1}^{P_b}}{H_{2,1}^{P_b}}$
CR3ℓ-VV	$\in (75, 105)$	$\in (0, 70)$	> 250	< 0.2	> 0.75	–
VR3ℓ-VV	$\in (75, 105)$	$\in (70, 100)$	> 250	< 0.2	> 0.75	–
SR3ℓ_High	$\in (75, 105)$	> 150	> 550	< 0.2	> 0.75	> 0.8
SR3ℓ_Int	$\in (75, 105)$	> 130	> 450	< 0.15	> 0.8	> 0.75
SR3ℓ_Low	$\in (75, 105)$	> 100	> 250	< 0.05	> 0.9	–

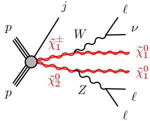
Region	$m_{\ell\ell}$ [GeV]	m_T^W [GeV]	$\Delta\phi_{ISR,I}^{CM}$	R_{ISR}	$p_{T\,ISR}^{CM}$ [GeV]	$p_{T\,I}^{CM}$ [GeV]	p_T^{CM} [GeV]
CR3ℓ_ISR-VV	$\in (75, 105)$	< 100	> 2.0	$\in (0.55, 1.0)$	> 80	> 60	< 25
VR3ℓ_ISR-VV	$\in (75, 105)$	> 60	> 2.0	$\in (0.55, 1.0)$	> 80	> 60	> 25
SR3ℓ_ISR	$\in (75, 105)$	> 100	> 2.0	$\in (0.55, 1.0)$	> 100	> 80	< 25

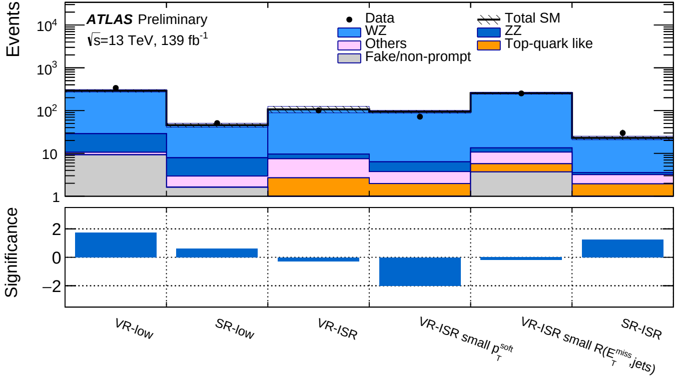
	SR-low	SR-ISR
Observed events	51	30
Fitted SM events	46 ± 5	23.0 ± 2.2
WZ	38 ± 5	19.5 ± 2.0
ZZ	4.9 ± 0.6	0.38 ± 0.07
Others	1.3 ± 0.7	1.2 ± 0.7
Top-quark like	$0.03^{+0.18}_{-0.03}$	1.9 ± 0.8
Fake/non-prompt	1.6 ± 1.3	$0.01^{+0.05}_{-0.01}$

- Relevant signal region definitions

Follow-up of recursive jigsaw analysis with 139 fb^{-1}

▸ *Phys. Rev. D 98 (2018) 092012* ▸ *(arXiv:1806.02293)* → ▸ *ATLAS-CONF-2019-020*





- **Emulated Recursive Jigsaw Reconstruction (eRJR)** confirmed the 3σ excess with 36 fb^{-1}, but **sees a reduction in excess significance to** 1σ **with full 139** fb^{-1}

Follow-up of recursive jigsaw analysis with 139 fb^{-1}

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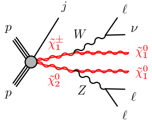
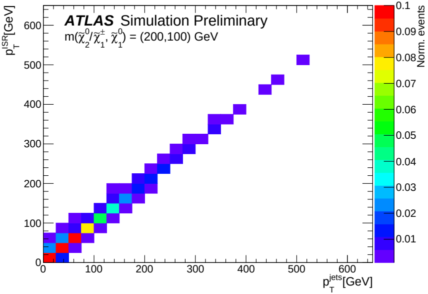
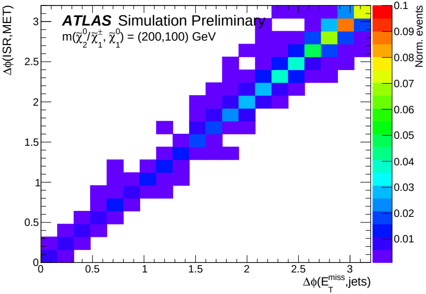


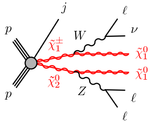


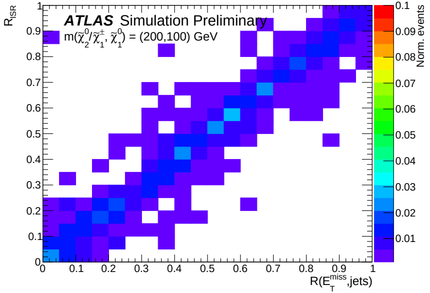


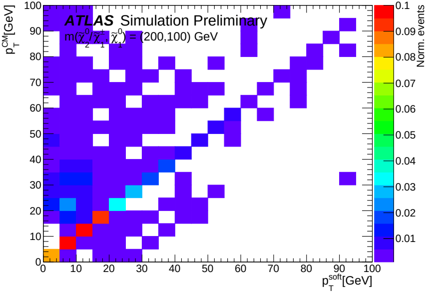
- Emulated reconstruction techniques map onto the RJR observables with very high fidelity

Follow-up of recursive jigsaw analysis with 139 fb^{-1}

▸ *Phys. Rev. D 98 (2018) 092012* ▸ *(arXiv:1806.02293)* → ▸ *ATLAS-CONF-2019-020*







- Some ISR observables not as exact