



Hints of BSM Physics in ATLAS



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On behalf of the ATLAS Collaboration

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Introduction



- So far haven't discovered any Beyond the SM Physics yet
- ATLAS analyses showed a couple of small excesses
- Expected as $O(100)$ searches on same data set
 - Need more statistics - but for small excesses Run3 data set only brings small improvement to significance
 - Future and already ongoing analyses need to make use of new techniques/ideas
- Can only present small subset of results - some covered (in depth) later on:
 - S. Solomon - Electroweak measurements (VBS) at the LHC
 - D. Rousso - Search for Long-Lived particles in ATLAS with Displaced Vertex Signatures in Multi-Jet-Triggered events
 - S. Sinha - Not a jet all the way: a search for semi-visible jets in non- resonant production mode in ATLAS
 - T. Park - EFT at the LHC

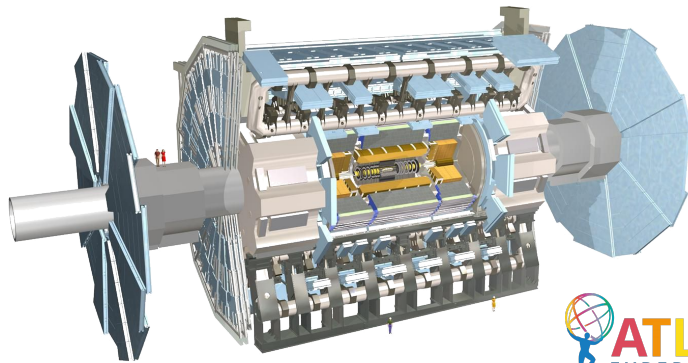
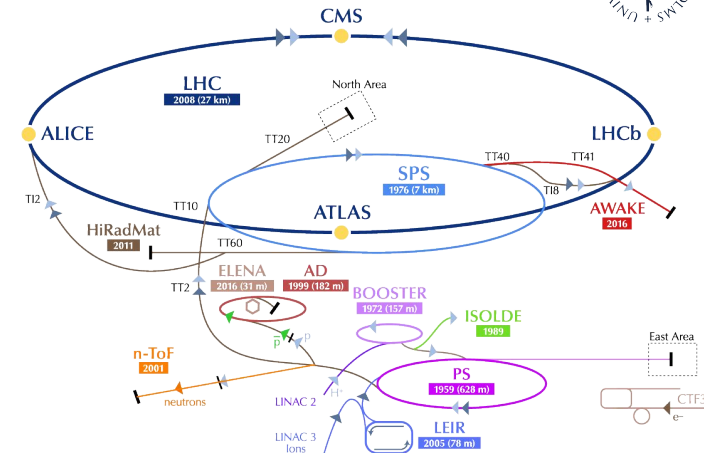


ATLAS detector and the Large Hadron Collider



Run 2 2015 – 2018

- completed very successfully
- delivered total 156 fb⁻¹ of proton – proton collisions at $\sqrt{s} = 13$ TeV
 - up to 2748 bunches circulating
 - each bunch contains ~ 1011 protons
 - bunches collide at interaction points every 25 ns
- peak luminosity: 2.1e34 cm⁻²s⁻¹
- average number of interactions per bunch crossing: 33.7
- 'good for physics' data set 139 fb⁻¹

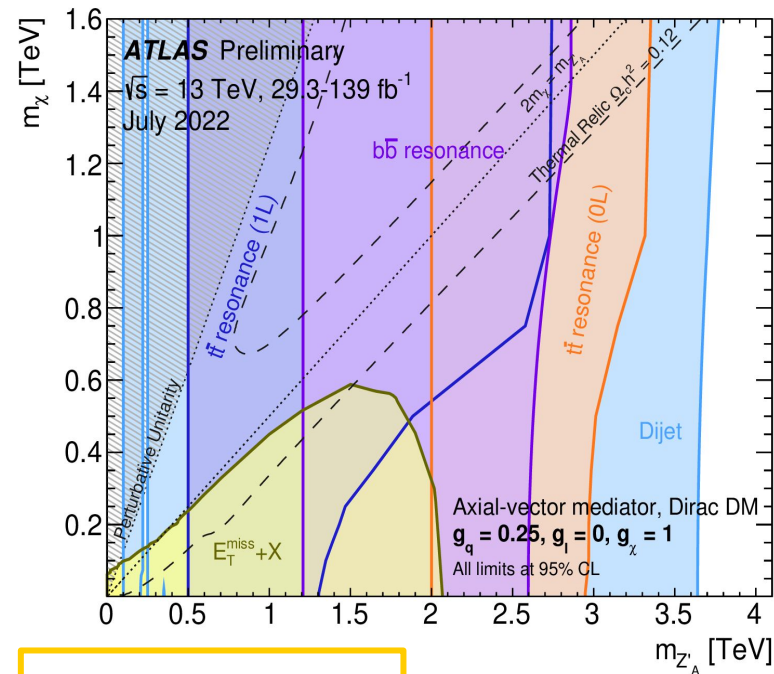


Large multi-purpose detector

- Complete azimuthal coverage of interaction point
- consist of tracking systems – calorimeters– muon systems – strong magnetic fields
- different design and technologies used to CMS → able to verify results with two independent experiments
- Large range of physic research program, from precision SM measurements to BSM searches



Overview exclusion reach



ATL-PHYS-PUB-2022-036

- Dijet
- $b\bar{b}$ resonance
- $t\bar{t}$ resonance (1L)
- $t\bar{t}$ resonance (0L)
- $b\bar{b}$ resonance
- $E_{T}^{\text{miss}} + X$

ATLAS SUSY Searches* - 95% CL Lower Limits

March 2022

Model	Signature	$[L_{di}(\text{fb}^{-1})]$	Mass limit	Reference	
Inclusive Searches	$\tilde{g}\tilde{g} \rightarrow q\bar{q}\tilde{g}$	0 μm mono jet	2.6 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 495$ GeV	2010.14293
	$\tilde{g}\tilde{g} \rightarrow q\bar{q}\tilde{g}$	0 μm 2 jets	1.0 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 505$ GeV	2102.10874
	$\tilde{g}\tilde{g} \rightarrow q\bar{q}\tilde{g}$	0 μm 2 jets	2.6 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 100$ GeV	2010.14293
	$\tilde{g}\tilde{g} \rightarrow q\bar{q}W\tilde{g}$	1 μm 2 jets	1.9 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 600$ GeV	2101.01829
	$\tilde{g}\tilde{g} \rightarrow q\bar{q}W\tilde{g}$	0 μm 7.11 jets	1.9 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 700$ GeV	CERN-EP-2022-014
	$\tilde{g}\tilde{g} \rightarrow q\bar{q}W\tilde{g}$	SS μm 6 jets	1.9 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 200$ GeV	2008.06032
	$\tilde{g}\tilde{g} \rightarrow q\bar{q}\tilde{g}$	0.1 μm 3 jets	3.6 jets $E_{T}^{\text{miss}} > 78.8$	$m(\tilde{t}_1) > 200$ GeV	1909.08437
	$\tilde{g}\tilde{g} \rightarrow q\bar{q}\tilde{g}$	SS μm 3 jets	3.6 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 200$ GeV	1909.08437
	$\tilde{g}\tilde{g} \rightarrow q\bar{q}\tilde{g}$	0 μm 2 jets	2.6 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 400$ GeV	2101.12037
	$\tilde{g}\tilde{g} \rightarrow q\bar{q}\tilde{g}$	0 μm 2 jets	2.6 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 505$ GeV	2101.12037
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1 \rightarrow b\bar{b}$	0 μm 0 jets	0 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 130$ GeV, $m(\tilde{b}_1) > 20$ GeV	1908.03122
	$\tilde{b}_1\tilde{b}_1 \rightarrow b\bar{b}$	2 τ	2.6 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 130$ GeV, $m(\tilde{b}_1) > 100$ GeV	2103.08189
	$\tilde{b}_1\tilde{b}_1 \rightarrow b\bar{b}$	0.1 μm ≥ 1 jet	1 jet $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 100$ GeV	2004.14060, 2012.03739
	$\tilde{b}_1\tilde{b}_1 \rightarrow b\bar{b}$	1 μm ≥ 1 jet	1 jet $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 500$ GeV	2012.03739
	$\tilde{b}_1\tilde{b}_1 \rightarrow b\bar{b}$	1.2 τ ≥ 1 jet	1 jet $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 500$ GeV	2108.07865
	$\tilde{b}_1\tilde{b}_1 \rightarrow b\bar{b}$	0 μm ≥ 2 jets	2 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 500$ GeV	1805.01649
	$\tilde{b}_1\tilde{b}_1 \rightarrow b\bar{b}$	0 μm mono jet	1 jet $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 500$ GeV	2102.10874
	$\tilde{b}_1\tilde{b}_1 \rightarrow b\bar{b}$	1.2 μm 1.4 jets	1.4 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 500$ GeV	2006.05980
	$\tilde{b}_1\tilde{b}_1 \rightarrow b\bar{b}$	3 μm 1.6 jets	1.6 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 500$ GeV	2006.05980
	$\tilde{b}_1\tilde{b}_1 \rightarrow b\bar{b}$	0 μm ≥ 1 jet	1 jet $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 500$ GeV, $m(\tilde{b}_1) > 100$ GeV	2108.01676, 2108.07586
EW direct	$\tilde{W}\tilde{W} \rightarrow WZ$	Multiple ℓ jets	Multiple jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 0$, $m(\tilde{b}_1) > 500$ GeV	1908.08215
	$\tilde{W}\tilde{W} \rightarrow WZ$	μm 2 jets	2 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 0$, $m(\tilde{b}_1) > 500$ GeV	2004.10884, 2108.07586
	$\tilde{W}\tilde{W} \rightarrow WZ$	Multiple ℓ jets	Multiple jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 0$, $m(\tilde{b}_1) > 500$ GeV	1908.08215
	$\tilde{W}\tilde{W} \rightarrow WZ$	2 τ	2 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 0$	1911.00660
	$\tilde{W}\tilde{W} \rightarrow WZ$	0 μm 0 jets	0 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 0$	1908.08215
	$\tilde{W}\tilde{W} \rightarrow WZ$	0 μm ≥ 1 jet	1 jet $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 0$	1911.00660
	$\tilde{W}\tilde{W} \rightarrow WZ$	0 μm ≥ 3 jets	3 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 0$	1804.04030
	$\tilde{W}\tilde{W} \rightarrow WZ$	0 μm 0 jets	0 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 0$	2103.11684
	$\tilde{W}\tilde{W} \rightarrow WZ$	0 μm ≥ 2 large jets	2 large jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 0$	2108.07586
	$\tilde{W}\tilde{W} \rightarrow WZ$	Multiple ℓ jets	Multiple jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 0$, $m(\tilde{b}_1) > 500$ GeV	2006.05980
Long-lived particles	Direct $\tilde{t}_1\tilde{t}_1$ prod., long-lived \tilde{t}_1	Disapp. \tilde{t}_1	1 jet $E_{T}^{\text{miss}} > 139$	Pure Wino	2201.02472
	Stable β R-hadron	pixel dE/dx	1 jet $E_{T}^{\text{miss}} > 139$	Pure Higgsino	2201.02472
	Metastable β R-hadron, $\beta \rightarrow q\bar{q}\tilde{g}$	pixel dE/dx	1 jet $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 100$ GeV	CERN-EP-2022-029
	$\tilde{t}_1 \rightarrow t\tilde{g}$	Disap. lep	1 jet $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 0.1$ ns	2011.07412
	$\tilde{t}_1 \rightarrow t\tilde{g}$	pixel dE/dx	1 jet $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 1$ ns	2011.07412
	$\tilde{t}_1 \rightarrow t\tilde{g}$	pixel dE/dx	1 jet $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 10$ ns	CERN-EP-2022-029
	$\tilde{t}_1 \rightarrow t\tilde{g}$	3 μm 0 jets	0 jets $E_{T}^{\text{miss}} > 139$	Pure Wino	2011.10543
	$\tilde{t}_1 \rightarrow t\tilde{g}$	4 μm 4-5 large jets	4-5 large jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 200$ GeV	2103.11684
	$\tilde{t}_1 \rightarrow t\tilde{g}$	Multiple	Multiple jets $E_{T}^{\text{miss}} > 139$	Large τ_1	1804.03068
	$\tilde{t}_1 \rightarrow t\tilde{g}$	2 jets $\rightarrow 4b$	2 jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 200$ GeV	CERN-EP-2018-003
RPV	$\tilde{t}_1\tilde{t}_1 \rightarrow W\tilde{g}$	Multiple	Multiple jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 400$ GeV	ATLAS-COUP-2018-003
	$\tilde{t}_1\tilde{t}_1 \rightarrow W\tilde{g}$	Multiple	Multiple jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 400$ GeV	ATLAS-COUP-2018-003
	$\tilde{t}_1\tilde{t}_1 \rightarrow W\tilde{g}$	Multiple	Multiple jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 400$ GeV	ATLAS-COUP-2018-003
	$\tilde{t}_1\tilde{t}_1 \rightarrow W\tilde{g}$	Multiple	Multiple jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 400$ GeV	ATLAS-COUP-2018-003
	$\tilde{t}_1\tilde{t}_1 \rightarrow W\tilde{g}$	Multiple	Multiple jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 400$ GeV	ATLAS-COUP-2018-003
	$\tilde{t}_1\tilde{t}_1 \rightarrow W\tilde{g}$	Multiple	Multiple jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 400$ GeV	ATLAS-COUP-2018-003
	$\tilde{t}_1\tilde{t}_1 \rightarrow W\tilde{g}$	Multiple	Multiple jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 400$ GeV	ATLAS-COUP-2018-003
	$\tilde{t}_1\tilde{t}_1 \rightarrow W\tilde{g}$	Multiple	Multiple jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 400$ GeV	ATLAS-COUP-2018-003
	$\tilde{t}_1\tilde{t}_1 \rightarrow W\tilde{g}$	Multiple	Multiple jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 400$ GeV	ATLAS-COUP-2018-003
	$\tilde{t}_1\tilde{t}_1 \rightarrow W\tilde{g}$	Multiple	Multiple jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 400$ GeV	ATLAS-COUP-2018-003
$\tilde{t}_1\tilde{t}_1 \rightarrow W\tilde{g}$	Multiple	Multiple jets $E_{T}^{\text{miss}} > 139$	$m(\tilde{t}_1) > 400$ GeV	ATLAS-COUP-2018-003	

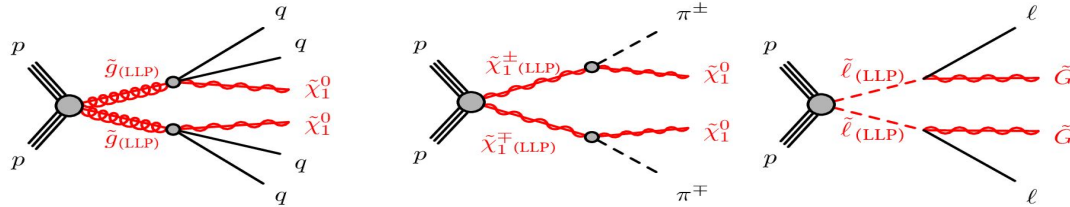
*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

ATL-PHYS-PUB-2022-013

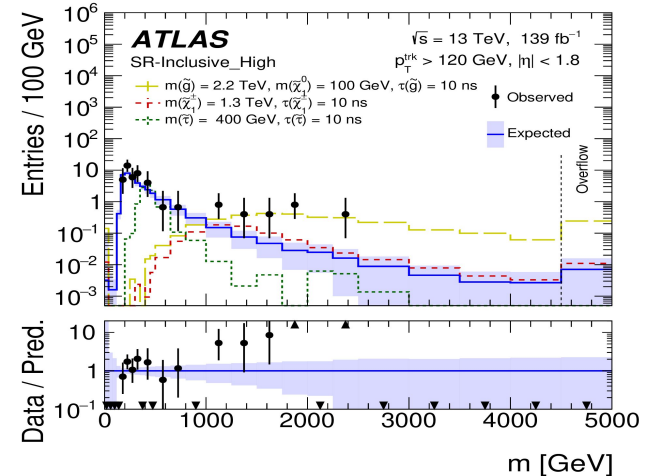
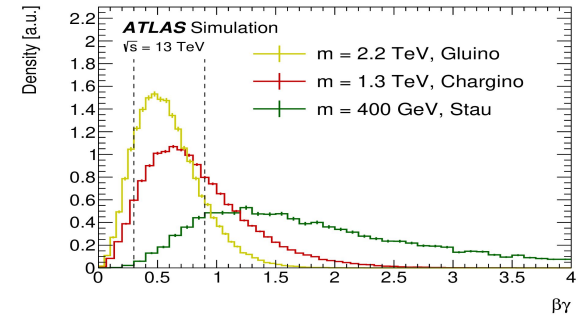


Long Lived Particles - Pixel dE/dx

SUSY-2018-42



- Long lived, charged particle search inspired by SUSY models with $\beta \ll 1$, high p_T and dE/dx
- Relying on Inner Detector information
- Significance of 3.6σ local at [1100,2800] GeV (3.3σ global)
 - Corresponding to 1.4 TeV in long lifetime regime
- Follow up analysis under way including additional detector information



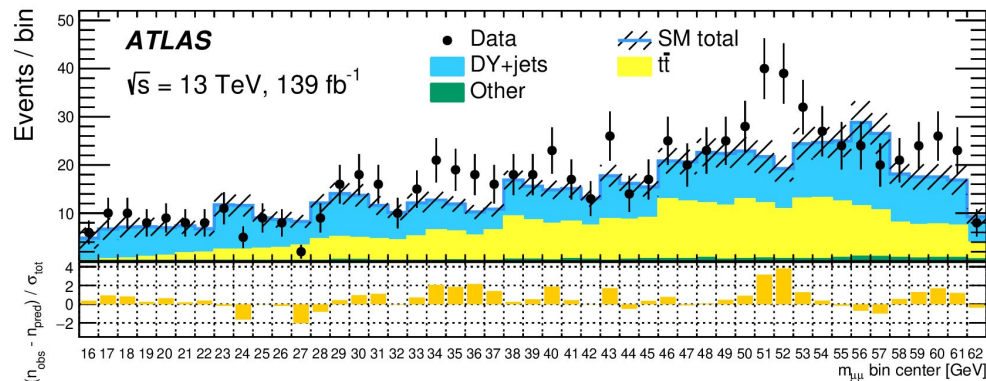
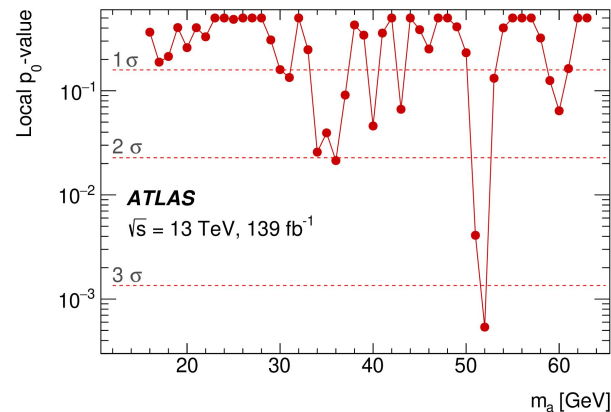
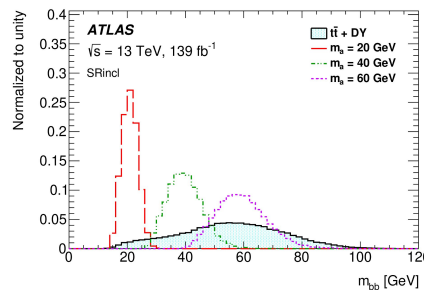


$H \rightarrow aa \rightarrow \mu\mu bb$

HDBS-2021-03



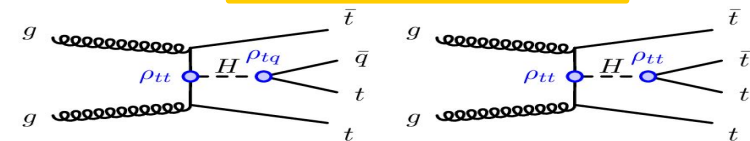
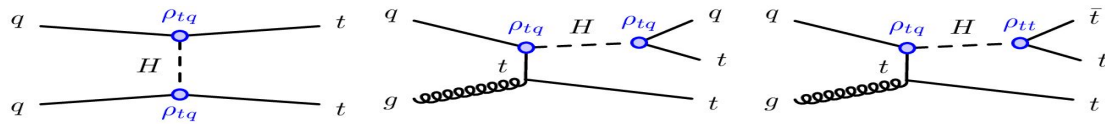
- Search for narrow di-muon resonance - $m_{\mu\mu}$ [16,62] GeV
- Very good mass resolution due to the muons plus high BR (bb)
- Making use of BDT to separate signal and standard model background (Z +jets, $t\bar{t}$)
- Several excesses, largest:
- 3.3σ local (1.7σ global) in $m_{\mu\mu} = 52$ GeV



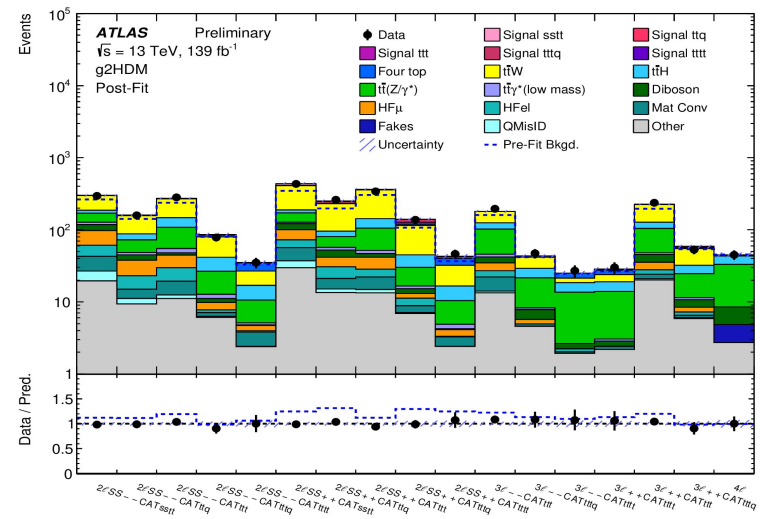
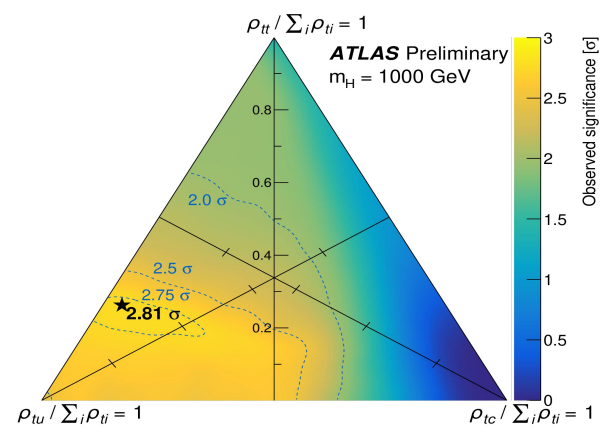


g2HDM

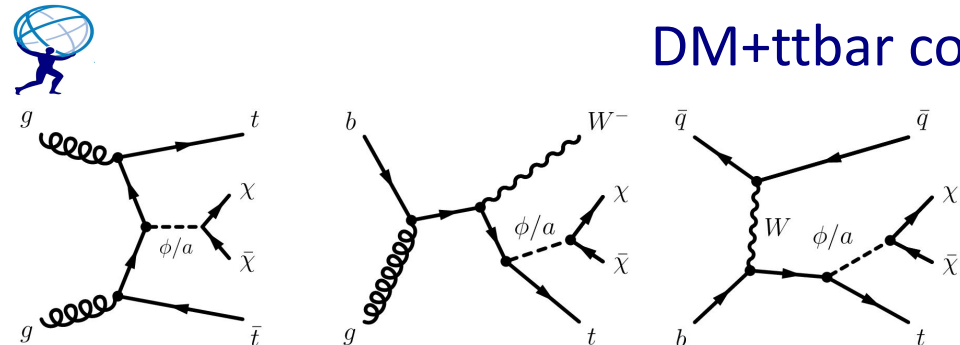
ATLAS-CONF-2022-039



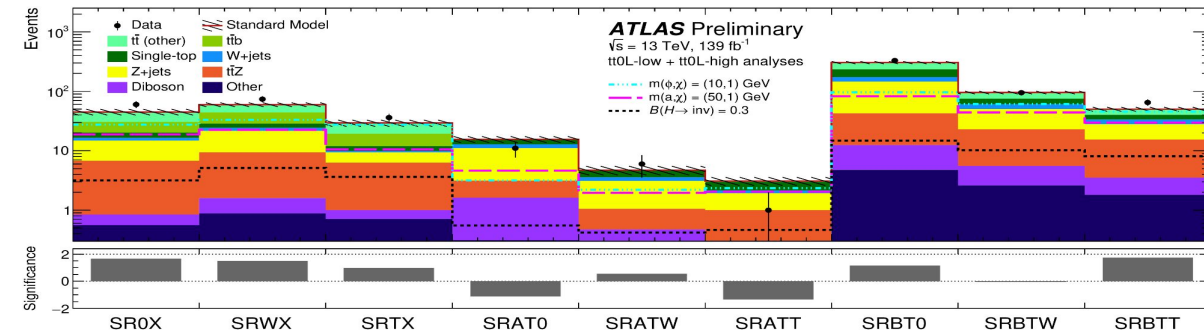
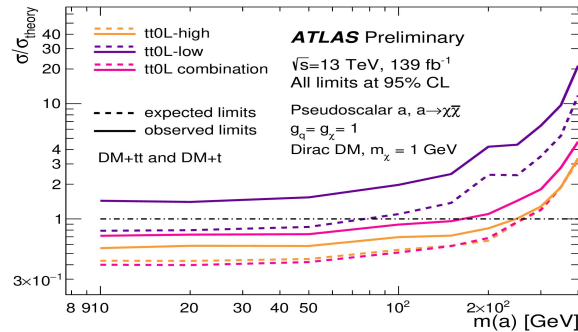
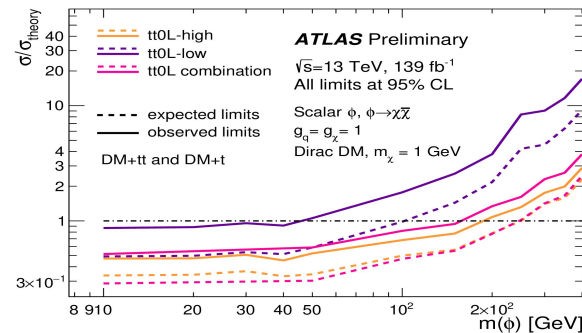
- First ATLAS analysis to probe g2HDM
 - Search for heavy Higgs boson in multilepton plus b-jets final state
- Using DNN to separate signal and background (ttbar+X, VV)
- SRs characterised by lepton multiplicity, charge and DNN score
- Largest excess: 2.81σ and H(1000)



DM+ttbar combination



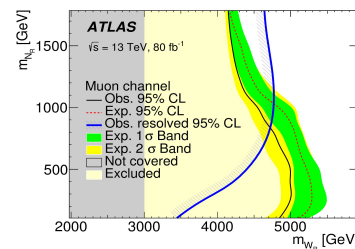
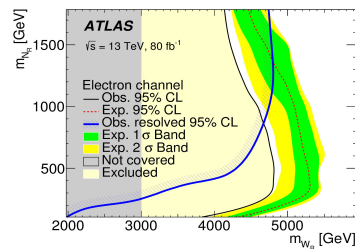
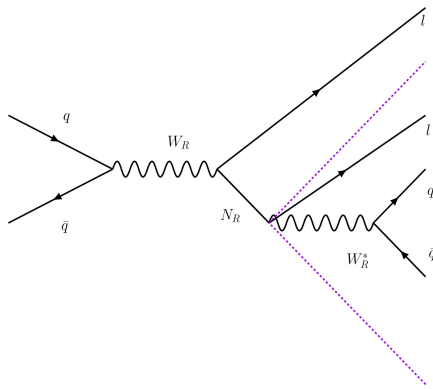
- Combination of analyses with ttbar + lepton + X final states
- Interpretation in spin-0 DM mediators
- Also upper limit on invisible SM Higgs branching ratio



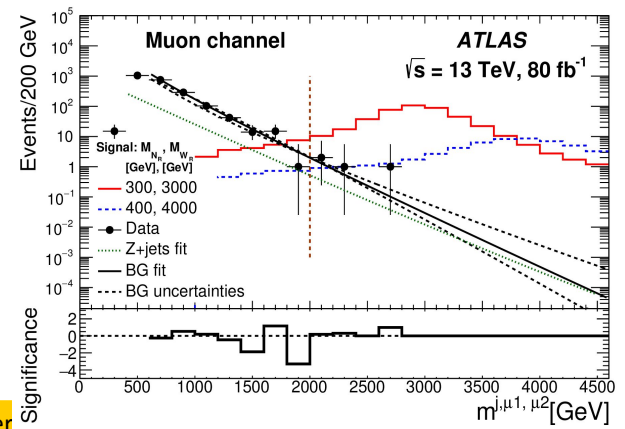
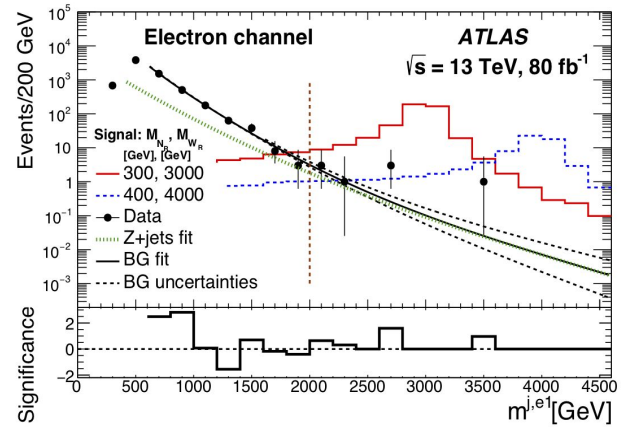


RH neutrinos

EXOT-2018-15



- Signal Model : righthanded W decaying to a lepton and boosted jet via heavy righthanded neutrino
 - Using 80 fb⁻¹, analysis with full Run 2 dataset for boosted and resolved topology close to being published
- Large radius jet can be used to distinguish background and signal
- Small excess of 2.4 σ in electron and 1.2 σ in muon channel





Multilepton general

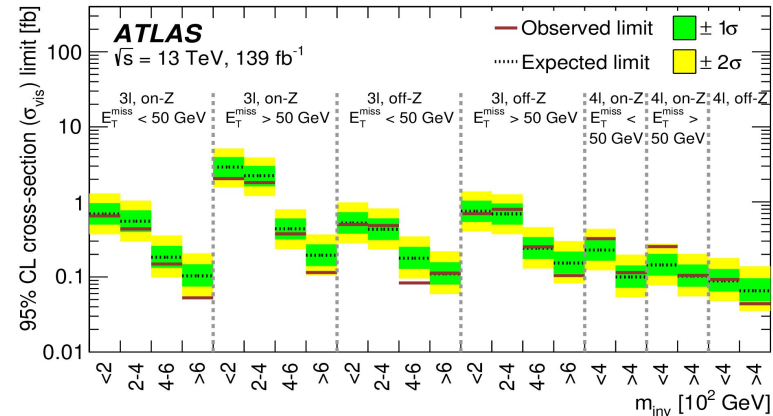
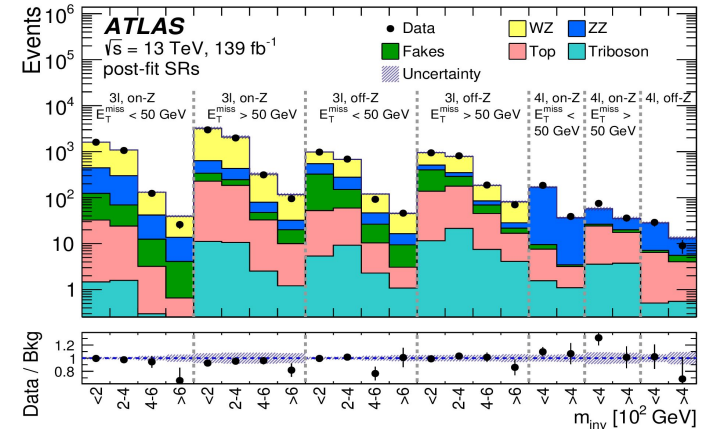
EXOT-2019-36



- Looking at 3l and 4l final states without ‘bias’ of specific model assumptions
 - also providing signal dependent interpretations
- SRs characterized by lepton multiplicity, E_T^{miss} , Z boson presence and m_{inv}
 - In total 22 SRs
- Results interpreted as limit on visible cross section of BSM signal
- 2 SRs with 4l show locally significant excess - largest 1.8σ
 - Largest significance for 4l, On-Z, $E_T^{\text{miss}} < 50$ GeV
 - Follow up analysis ongoing

SR	0–200 GeV	200–400 GeV	400–600 GeV	>600 GeV
3 ℓ , On-Z, $E_T^{\text{miss}} < 50$ GeV	-0.2	-0.7	-0.6	-2.5
3 ℓ , On-Z, $E_T^{\text{miss}} > 50$ GeV	-1.0	-0.5	-0.4	-1.6
3 ℓ , Off-Z, $E_T^{\text{miss}} < 50$ GeV	-0.1	0.3	-2.7	0.1
3 ℓ , Off-Z, $E_T^{\text{miss}} > 50$ GeV	-0.2	0.5	0.2	-1.2
SR	0–400 GeV	>400 GeV		
4 ℓ , On-Z, $E_T^{\text{miss}} < 50$ GeV	1.0	0.4		
4 ℓ , On-Z, $E_T^{\text{miss}} > 50$ GeV	1.8	0.1		
4 ℓ , Off-Z	0.1	-1.3		

Local significance for indicated SR in bins of m_{inv}





Outlook



- Stay tuned for reinterpretations, combinations, less model dependent scans - many Run 2 analyses still going to be published and first Run 3 data at 13.6 TeV is coming in
- Large amount of analyses - only small fraction covered
 - See public [SUSY](#), [Exotics](#) and [HDBS](#) pages for more results
- ATLAS wide effort to improve public materials that can be used for reinterpretations etc
 - Often pyhf workspaces of histfitter available in addition to simple simpleAnalysis implementation of SRs
 - Available files can be found on hepdata
- Small excesses in several places being followed up
 - Run 3 won't bring significant increase in statistics
 - Already started to dive into
 - more sophisticated analysis techniques
 - characterizing searches by final state instead of specific BSM model
 - new ideas being explored ●●●
- It stays interesting!

