Searches for strong production of SUSY with ATLAS

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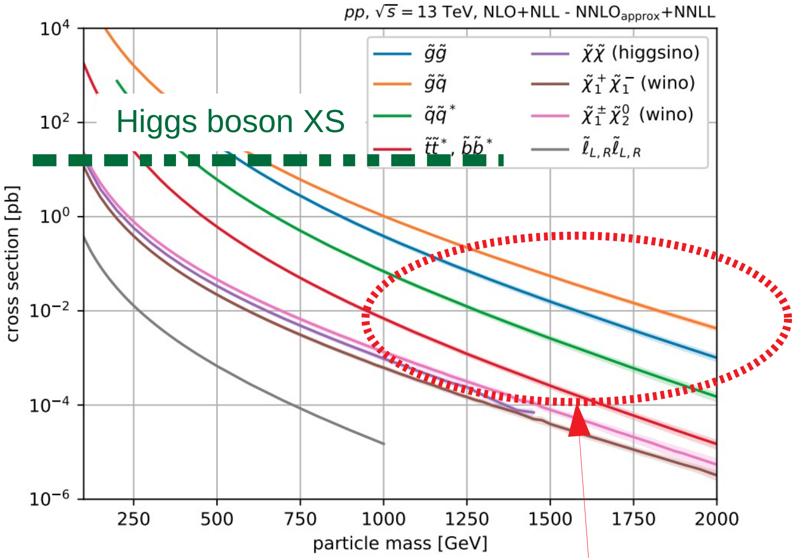
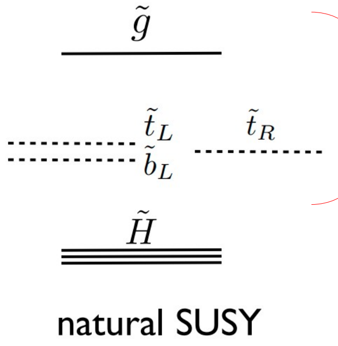
Strong SUSY at the LHC

- SUSY: additional symmetry on top of SM
  - Results in many partner particles, ideally at an LHC-reachable scale
- Many desirable properties
  - R-parity conserving SUSY→ LSP is a dark matter candidate
  - Stops cancel divergences in Higgs boson mass loops
  - High scale gauge coupling unification
- LHC is the only place for direct searches for for new heavy particles

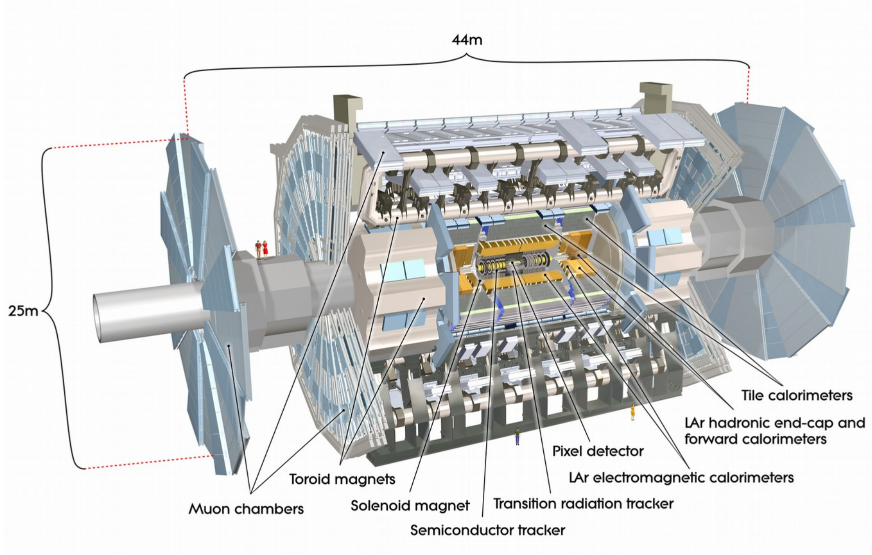
SUSYCrossSections





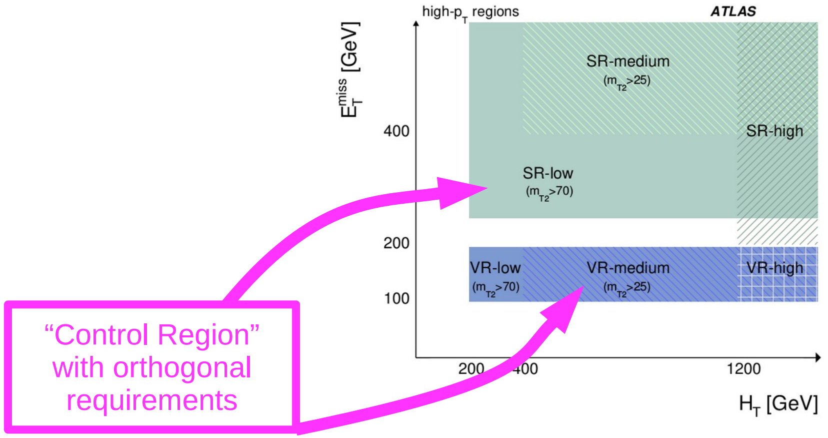
The LHC is probing the >1 TeV regime

ATLAS SUSY Search Strategy



Generally searching for events with jets, missing transverse momentum (MET), and sometimes other high momentum objects.

- **Today:** highlights from recent searches for strongly produced SUSY (squarks/gluinos) using full Run 2 dataset: bb+MET, stop to staus, photon+MET
- We make use of mass scales, MET, event kinematics, etc. to design Signal Regions (SRs)
- Predict backgrounds based on data where possible with process enriched Control Regions (CRs)
  - and validate with nearby Validation Regions (VRs)
- Interpret with simplified models and perform additional model-independent tests

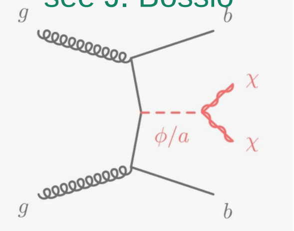


bb+MET JHEP 05 (2021) 093

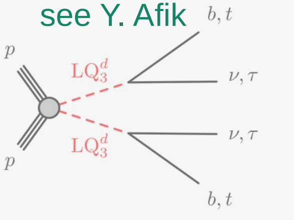
$$m_{\mathrm{CT}}^2(v_1,\ v_2) = [E_{\mathrm{T}}(v_1) + E_{\mathrm{T}}(v_2)]^2 - [\mathbf{p}_{\mathrm{T}}(v_1) - \mathbf{p}_{\mathrm{T}}(v_2)]^2$$

Also includes DM and LQ interpretations

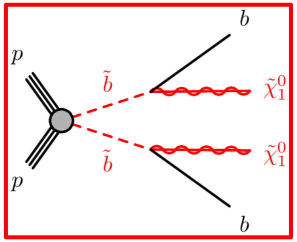
see J. Bossio



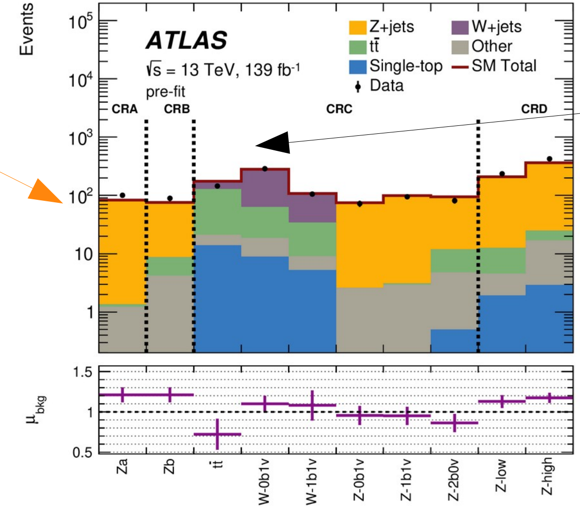
see Y. Afik



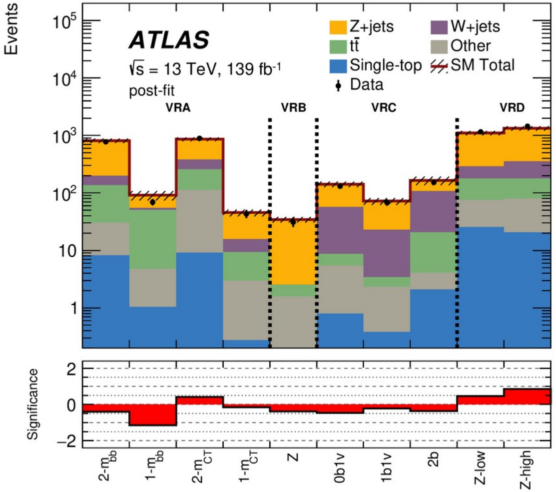
- Final state with b-jets and MET, no leptons
  - Trigger on MET (require > 250 GeV)
- SRA-C defined for large to small mass splittings
  - SRA: endpoint variable (m_{CT}) to reject ttbar
  - SRB: BDT based selection (most important: min m_T(jet1-4,MET), and jet1-3 p_T)
  - SRC: Require ISR jet and make use of soft b-tagging improvements ATLAS-CONF-2019-027 to target compressed region
    - Tags displaced vertices down to 5 GeV



SRA/B: 2 lepton CRs for Z+jets

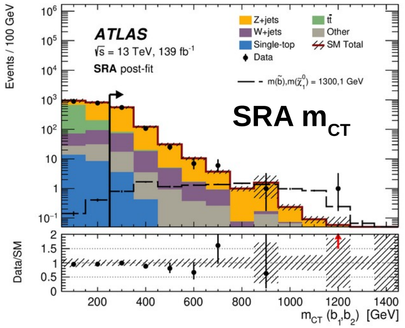


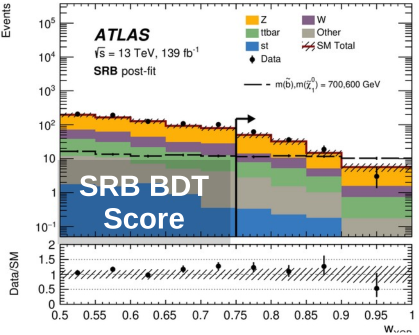
SRC: 1 lepton CRs for ttbar and W+jets

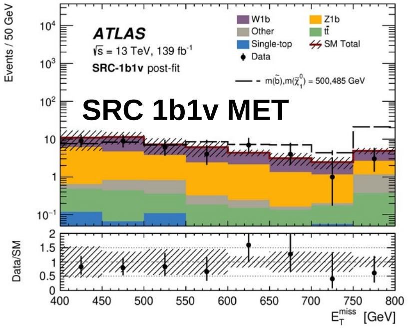


Good agreement in VRs

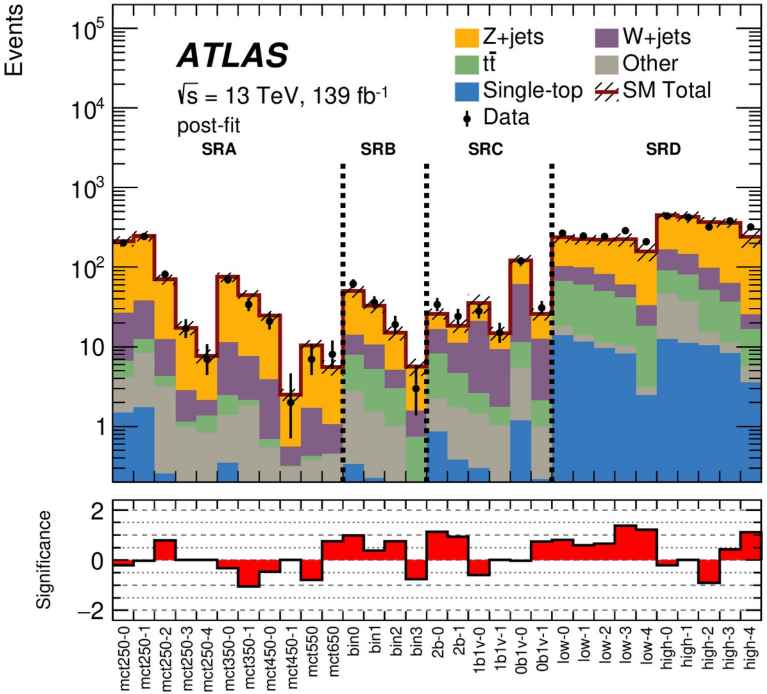
bb+MET Results



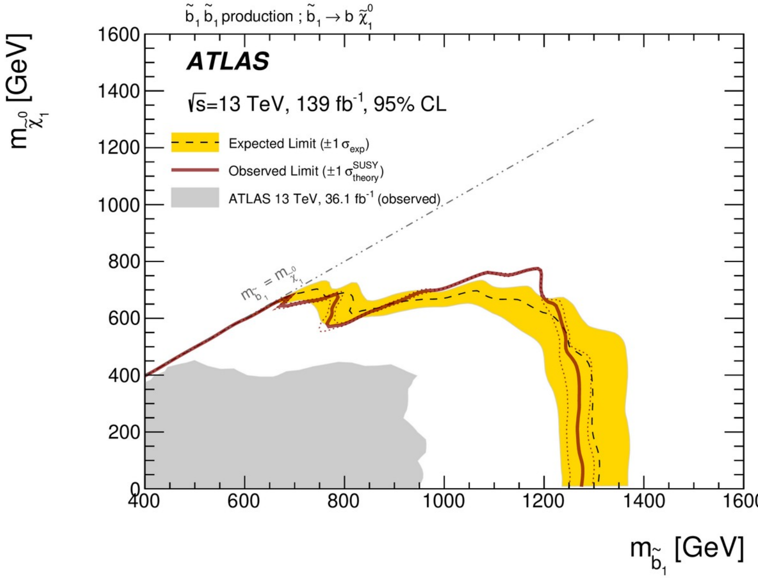


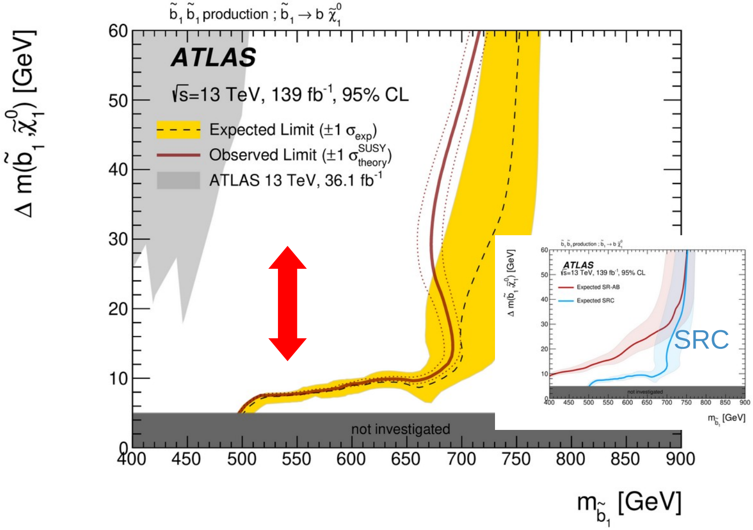


Binned Signal Region Summary



More data, but especially new techniques lead to substantial increase in sensitivity





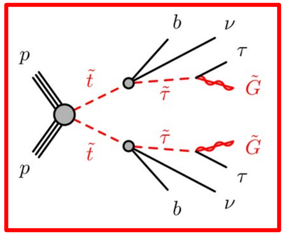
Stop to staus

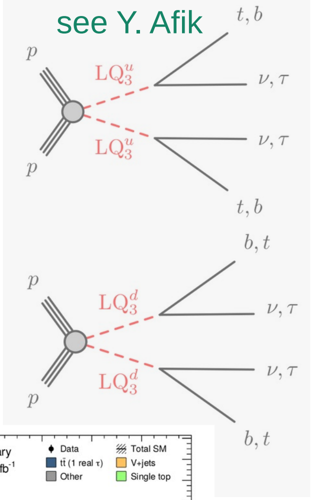
ATLAS-CONF-2021-008

Also includes LQ interpretations

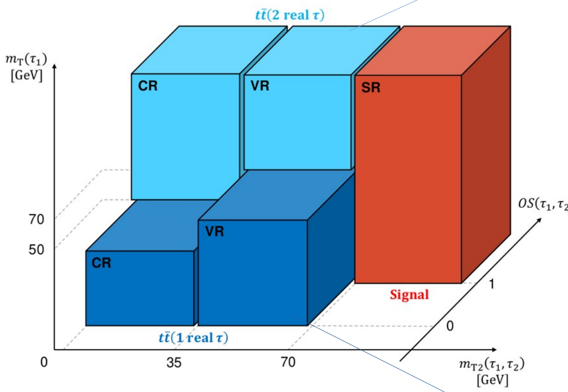
see Y. Afik

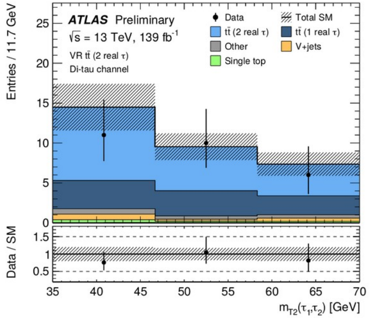
- b-jets, hadronic taus, MET, no e/mu
  - Trigger on MET (require MET>280 GeV)
- $\geq 2\tau \geq 1b$, $1\tau \geq 2b$ channels
- Use endpoint variables and scalar sum (s_T) of tau+jet1+jet2 p_T
- ttbar and tW are most important backgrounds (one or two real taus)

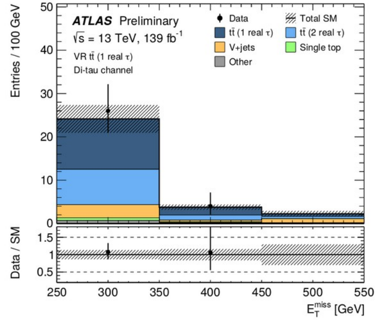




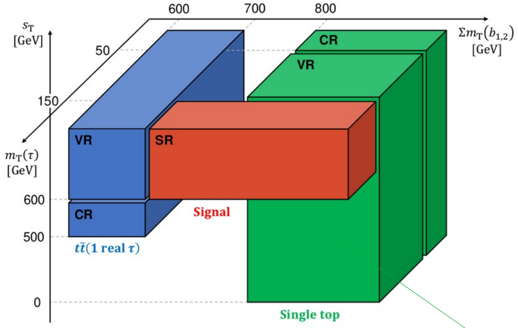
Two Tau

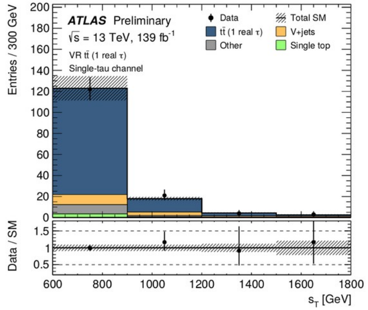


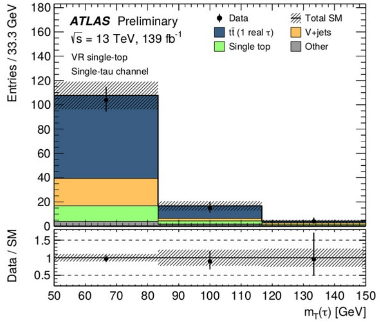




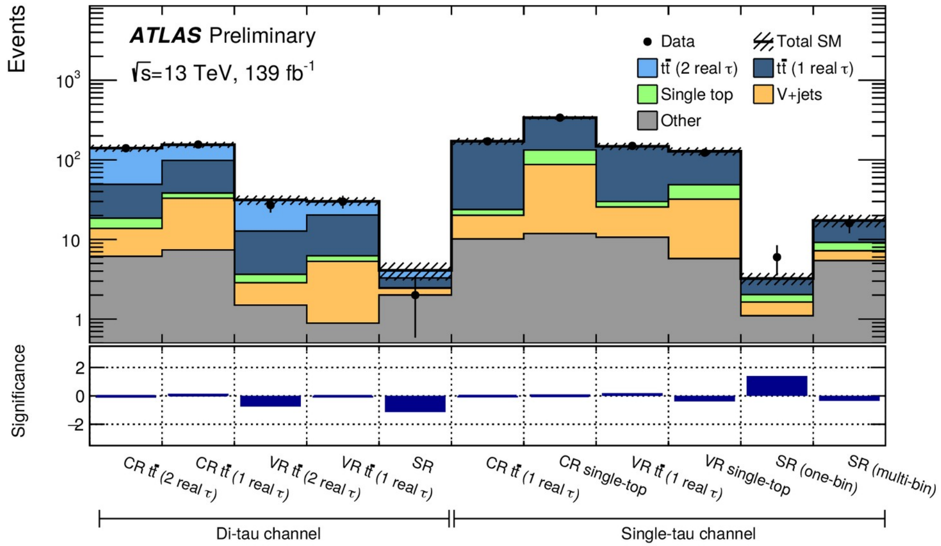
One Tau

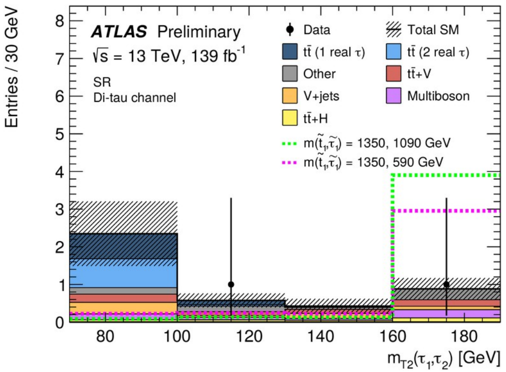


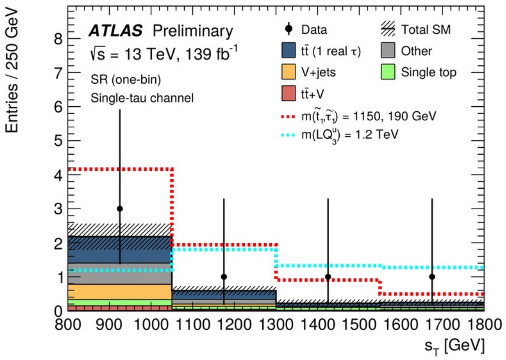


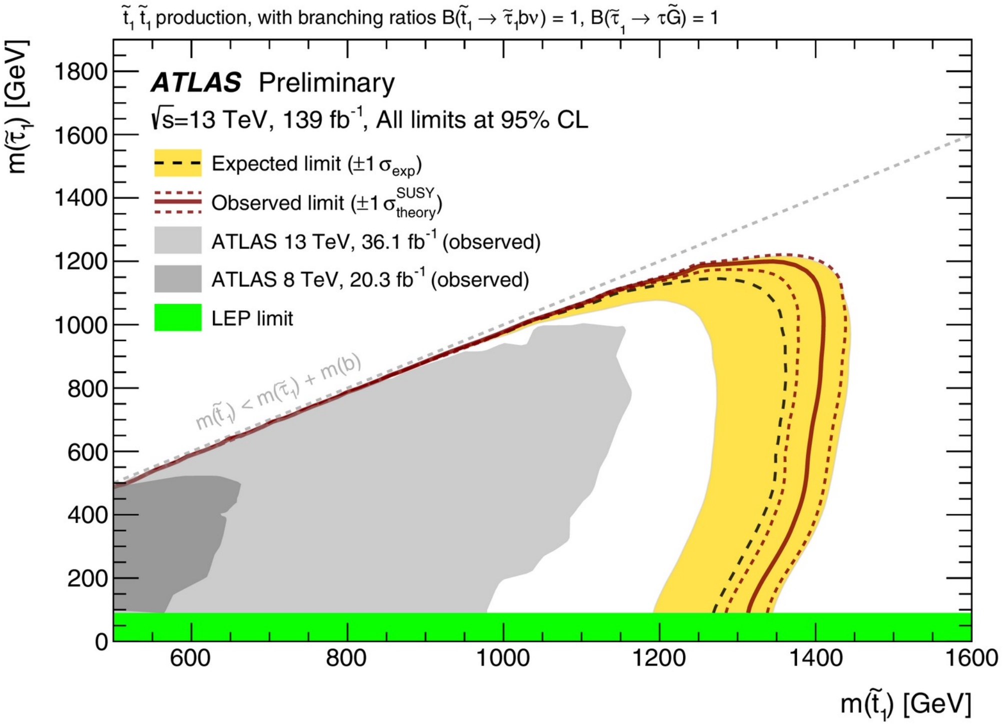


Stop to tau results





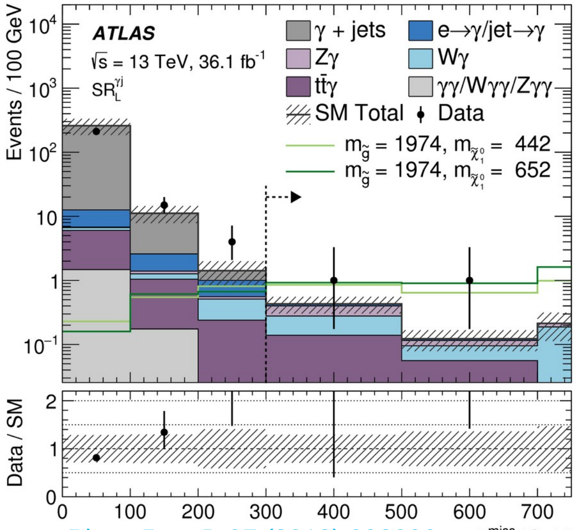




Photon(s) + jets + MET

New result!
ATLAS-CONF-2021-028

- General Gauge Mediation (GGM) inspiration
- High pT photon >145 GeV (Trigger on photon)
- MET > 250 GeV, H_T > 1600 GeV
- Jets and MET, but no leptons
- 3 SRs targeting small to large mass splittings, optimized for full dataset



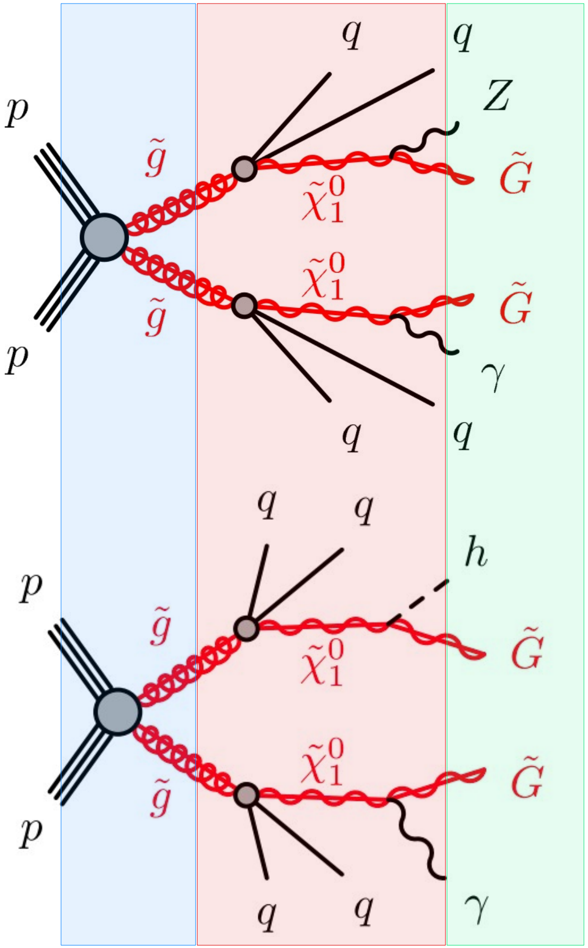
Phys. Rev. D 97 (2018) 092006

Previous search with 36 fb^{-1} resulted in 2.36σ local excess

Gluino pair production

Many jets

~50/50% Z/ɣ; Light LSP



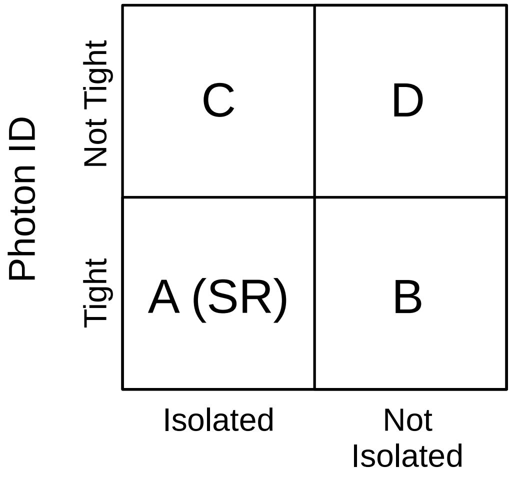
1% Higgs

10% Higgs

γ Backgrounds

- Backgrounds arise from processes with real and fake MET or real or fake Photons
- Primary background processes from MC normalized to CRs
  - γ+jets: invert Δϕ(jet, MET)
  - Wγ: >=1 leptons, 0 b-jets
  - ttγ: >=1 leptons, >=1 b-jets

Jets faking photons

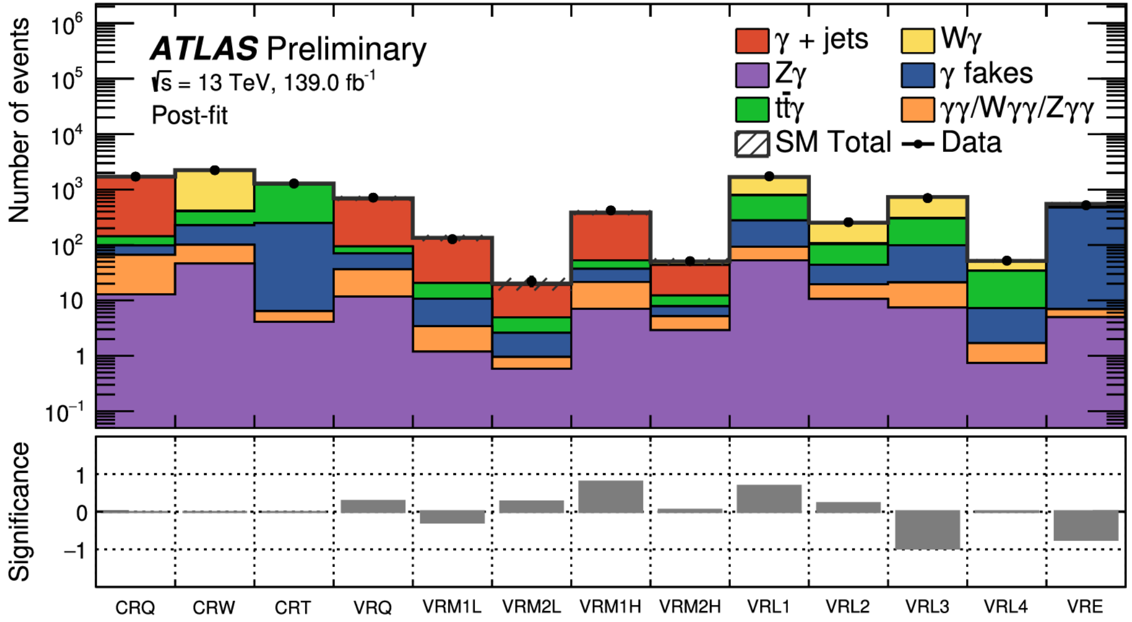


$p_T^{\text{leading}\gamma} > 145$ GeV
$N_{\text{signal-jets}} \geq 2$
$E_T^{\text{miss}} > 50$ GeV

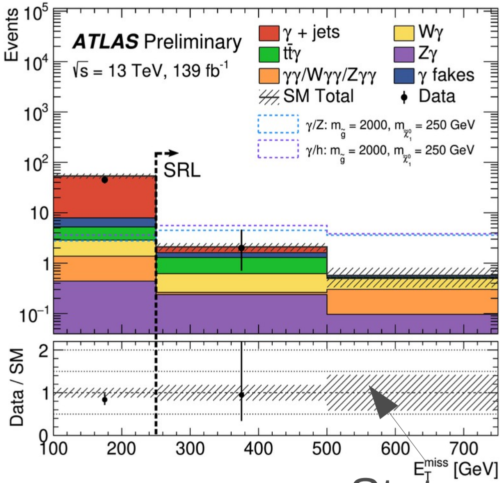
Factor of C/D binned in p_T, η, MET

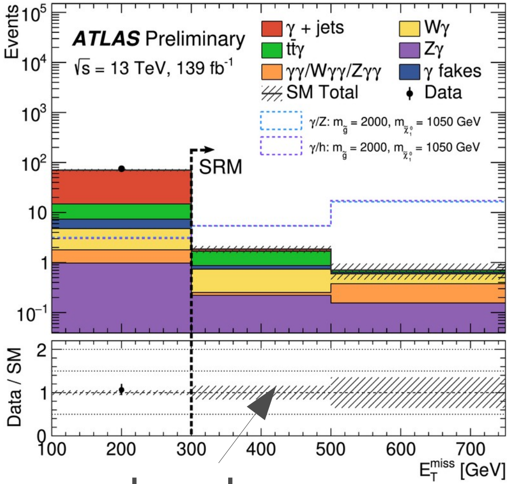
Electrons faking photons

- Misid rate measured with Zee/eγ events
- Applied to control sample selecting high p_T electrons and vetoing photons

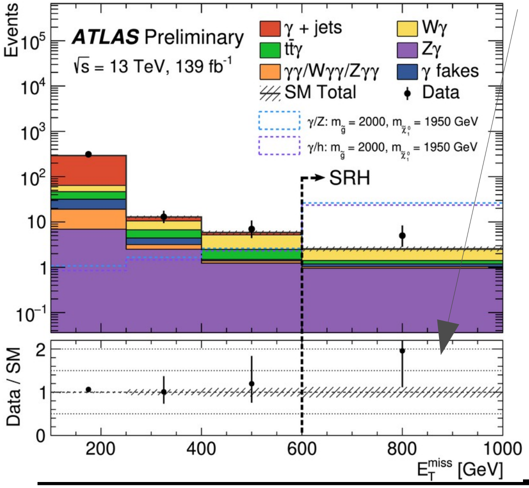


Results

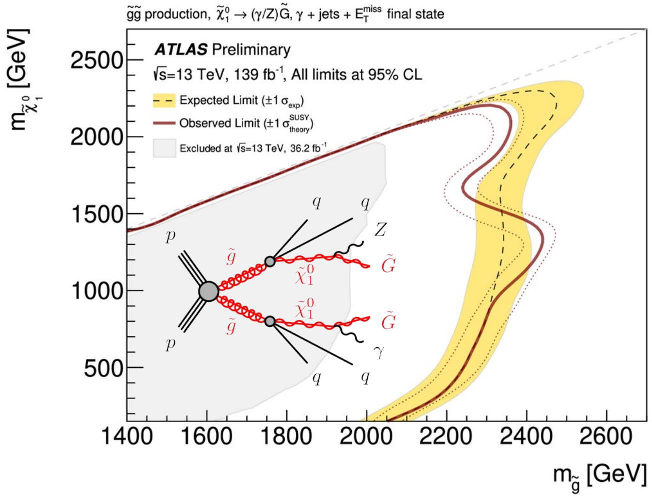


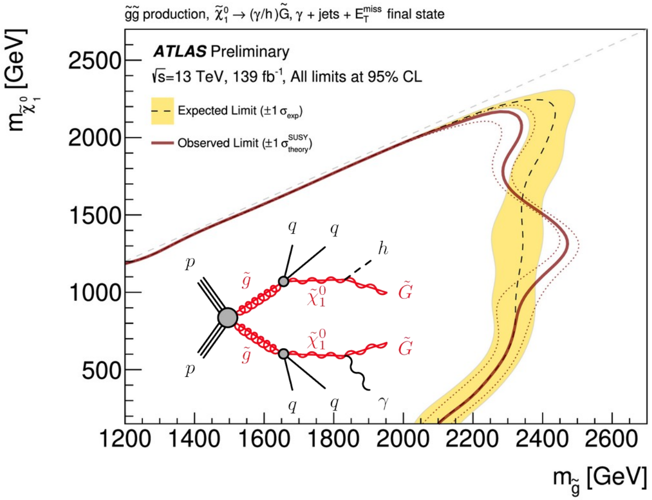


Stat only error bands



- No significant excesses above SM
- Exclusion limits from SR with best expected sensitivity at each point

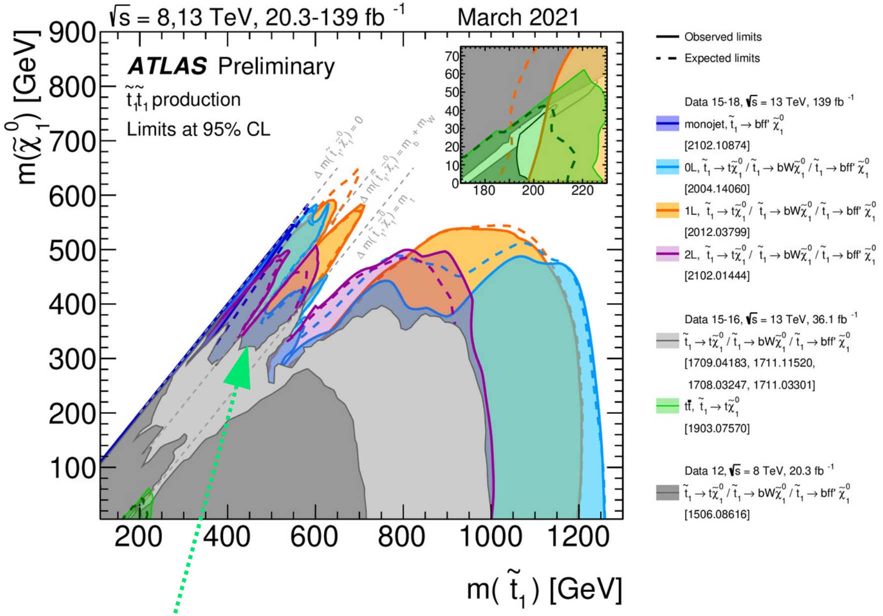


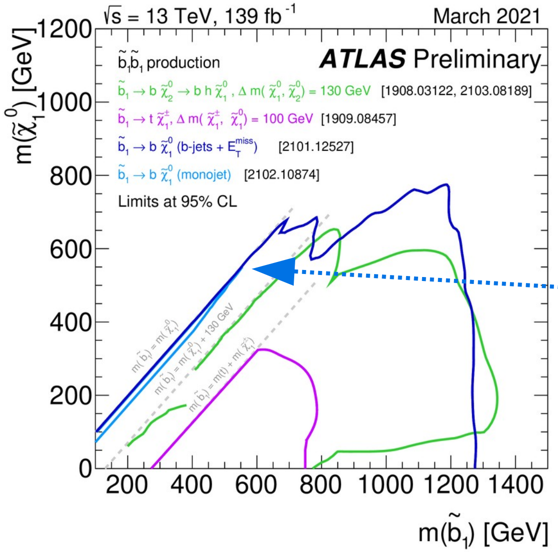


Limits on Strongly Produced SUSY

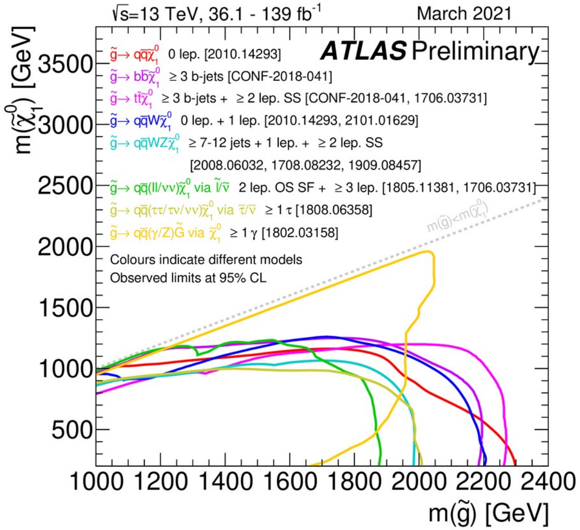
Link to ATLAS SUSY Public Results

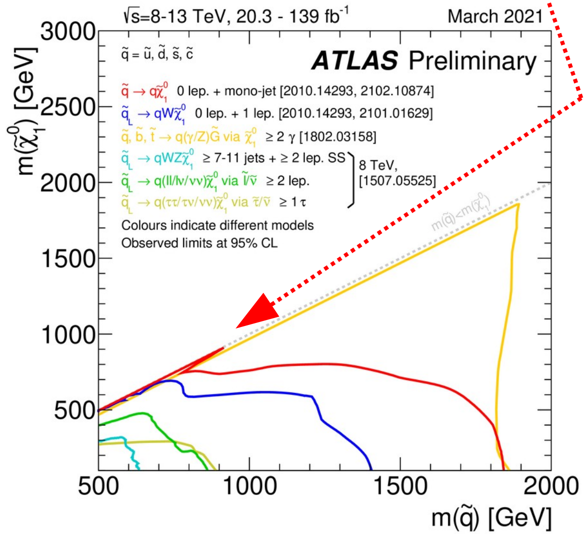
ATLAS SUSY Summary Plots





Small mass splittings are difficult, need dedicated analysis design and/or techniques to cover, e.g. bb+MET and monojet



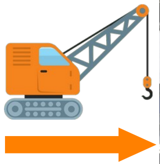


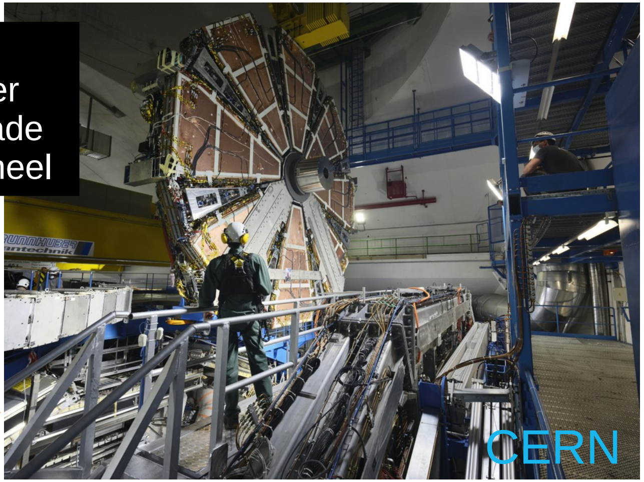
Weaker limits in regions close to and below Δm=m_top
Difficult to distinguish from backgrounds

Conclusions

- ATLAS searches for strongly produced SUSY cover a wide array of scenarios
  - Expanding and updating searches with full Run 2 dataset (139 ifb)
  - Pushing sensitivity past 1 TeV in many cases
  - Probing complex final states
- Continued consistency with Standard Model expectations
- Preparing for LHC Run 3 in parallel

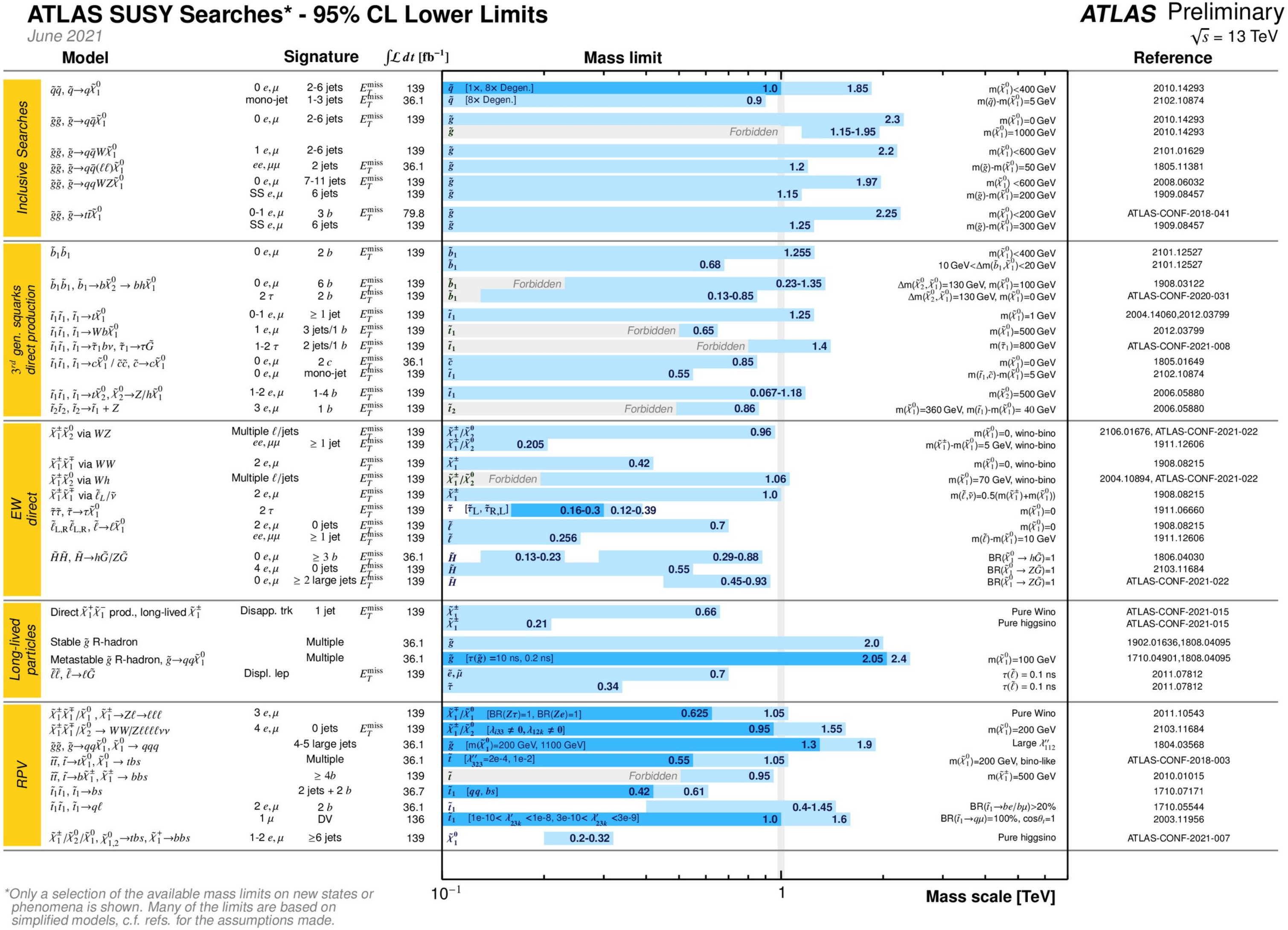
Muon spectrometer endcap upgrade new ‘small’ wheel





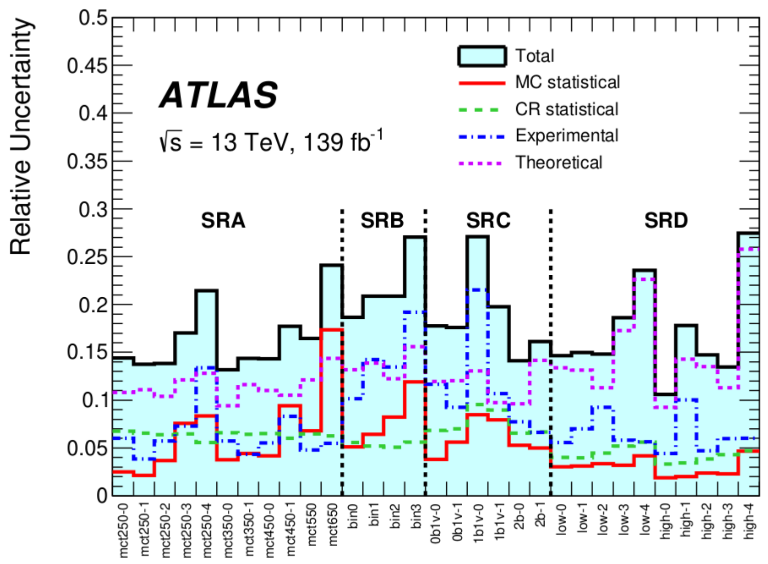
Stick around for Stefano and Michael’s talks on ATLAS EWK and RPV SUSY Searches, as well as our CMS colleagues

Backup


ATLAS SUSY Searches* - 95% CL Lower Limits
June 2021
ATLAS Preliminary
$\sqrt{s}$ = 13 TeV
Model
Signature
$\int\mathcal{L}\,dt$ [fb^{-1}]
Mass limit
Reference
Inclusive Searches
$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$ | 0 e,μ | 2-6 jets | E_T^{miss} | 139 | $\tilde{q}$ [1×, 8× Degen.] 1.0 1.85 | m($\tilde{\chi}_1^0$)<400 GeV | 2010.14293
mono-jet | 1-3 jets | E_T^{miss} | 36.1 | $\tilde{q}$ [8× Degen.] 0.9 | m($\tilde{q}$)-m($\tilde{\chi}_1^0$)=5 GeV | 2102.10874
$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}_1^0$ | 0 e,μ | 2-6 jets | E_T^{miss} | 139 | $\tilde{g}$ 2.3 | m($\tilde{\chi}_1^0$)=0 GeV | 2010.14293
$\tilde{g}$ Forbidden 1.15-1.95 | m($\tilde{\chi}_1^0$)=1000 GeV | 2010.14293
$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}W\tilde{\chi}_1^0$ | 1 e,μ | 2-6 jets | 139 | $\tilde{g}$ 2.2 | m($\tilde{\chi}_1^0$)<600 GeV | 2101.01629
$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}(\ell\ell)\tilde{\chi}_1^0$ | $ee,\mu\mu$ | 2 jets | E_T^{miss} | 36.1 | $\tilde{g}$ 1.2 | m($\tilde{g}$)-m($\tilde{\chi}_1^0$)=50 GeV | 1805.11381
$\tilde{g}\tilde{g}$, $\tilde{g}\to qqWZ\tilde{\chi}_1^0$ | 0 e,μ | 7-11 jets | E_T^{miss} | 139 | $\tilde{g}$ 1.97 | m($\tilde{\chi}_1^0$) <600 GeV | 2008.06032
SS e,μ | 6 jets | 139 | $\tilde{g}$ 1.15 | m($\tilde{g}$)-m($\tilde{\chi}_1^0$)=200 GeV | 1909.08457
$\tilde{g}\tilde{g}$, $\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$ | 0-1 e,μ | 3 b | E_T^{miss} | 79.8 | $\tilde{g}$ 2.25 | m($\tilde{\chi}_1^0$)<200 GeV | ATLAS-CONF-2018-041
SS e,μ | 6 jets | 139 | $\tilde{g}$ 1.25 | m($\tilde{g}$)-m($\tilde{\chi}_1^0$)=300 GeV | 1909.08457
3rd gen. squarks direct production
$\tilde{b}_1\tilde{b}_1$ | 0 e,μ | 2 b | E_T^{miss} | 139 | $\tilde{b}_1$ 1.255 | m($\tilde{\chi}_1^0$)<400 GeV | 2101.12527
$\tilde{b}_1$ 0.68 | 10 GeV<Δm($\tilde{b}_1$,$\tilde{\chi}_1^0$)<20 GeV | 2101.12527
$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to b\tilde{\chi}_2^0\to bh\tilde{\chi}_1^0$ | 0 e,μ | 6 b | E_T^{miss} | 139 | $\tilde{b}_1$ Forbidden 0.23-1.35 | Δm($\tilde{\chi}_2^0$,$\tilde{\chi}_1^0$)=130 GeV, m($\tilde{\chi}_1^0$)=100 GeV | 1908.03122
2 τ | 2 b | E_T^{miss} | 139 | $\tilde{b}_1$ 0.13-0.85 | Δm($\tilde{\chi}_2^0$,$\tilde{\chi}_1^0$)=130 GeV, m($\tilde{\chi}_1^0$)=0 GeV | ATLAS-CONF-2020-031
$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to t\tilde{\chi}_1^0$ | 0-1 e,μ | ≥ 1 jet | E_T^{miss} | 139 | $\tilde{t}_1$ 1.25 | m($\tilde{\chi}_1^0$)=1 GeV | 2004.14060,2012.03799
$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to Wb\tilde{\chi}_1^0$ | 1 e,μ | 3 jets/1 b | E_T^{miss} | 139 | $\tilde{t}_1$ Forbidden 0.65 | m($\tilde{\chi}_1^0$)=500 GeV | 2012.03799
$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to\tilde{\tau}_1 b\nu$, $\tilde{\tau}_1\to\tau\tilde{G}$ | 1-2 τ | 2 jets/1 b | E_T^{miss} | 139 | $\tilde{t}_1$ Forbidden 1.4 | m($\tilde{\tau}_1$)=800 GeV | ATLAS-CONF-2021-008
$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to c\tilde{\chi}_1^0$ / $\tilde{c}\tilde{c}$, $\tilde{c}\to c\tilde{\chi}_1^0$ | 0 e,μ | 2 c | E_T^{miss} | 36.1 | $\tilde{c}$ 0.85 | m($\tilde{\chi}_1^0$)=0 GeV | 1805.01649
0 e,μ | mono-jet | E_T^{miss} | 139 | $\tilde{t}_1$ 0.55 | m($\tilde{t}_1$,$\tilde{c}$)-m($\tilde{\chi}_1^0$)=5 GeV | 2102.10874
$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to t\tilde{\chi}_2^0$, $\tilde{\chi}_2^0\to Z/h\tilde{\chi}_1^0$ | 1-2 e,μ | 1-4 b | E_T^{miss} | 139 | $\tilde{t}_1$ 0.067-1.18 | m($\tilde{\chi}_2^0$)=500 GeV | 2006.05880
$\tilde{t}_2\tilde{t}_2$, $\tilde{t}_2\to\tilde{t}_1+Z$ | 3 e,μ | 1 b | E_T^{miss} | 139 | $\tilde{t}_2$ Forbidden 0.86 | m($\tilde{\chi}_1^0$)=360 GeV, m($\tilde{t}_1$)-m($\tilde{\chi}_1^0$)= 40 GeV | 2006.05880
EW direct
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ via WZ | Multiple ℓ/jets | E_T^{miss} | 139 | $\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$ 0.96 | m($\tilde{\chi}_1^0$)=0, wino-bino | 2106.01676, ATLAS-CONF-2021-022
$ee,\mu\mu$ | ≥ 1 jet | E_T^{miss} | 139 | $\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$ 0.205 | m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)=5 GeV, wino-bino | 1911.12606
$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp$ via WW | 2 e,μ | E_T^{miss} | 139 | $\tilde{\chi}_1^\pm$ 0.42 | m($\tilde{\chi}_1^0$)=0, wino-bino | 1908.08215
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ via Wh | Multiple ℓ/jets | E_T^{miss} | 139 | $\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$ Forbidden 1.06 | m($\tilde{\chi}_1^0$)=70 GeV, wino-bino | 2004.10894, ATLAS-CONF-2021-022
$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp$ via $\tilde{\ell}_L/\tilde{\nu}$ | 2 e,μ | E_T^{miss} | 139 | $\tilde{\chi}_1^\pm$ 1.0 | m($\tilde{\ell}$,$\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$)) | 1908.08215
$\tilde{\tau}\tilde{\tau}$, $\tilde{\tau}\to\tau\tilde{\chi}_1^0$ | 2 τ | E_T^{miss} | 139 | $\tilde{\tau}$ [$\tilde{\tau}_L$, $\tilde{\tau}_{R,L}$] 0.16-0.3 0.12-0.39 | m($\tilde{\chi}_1^0$)=0 | 1911.06660
$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}$, $\tilde{\ell}\to\ell\tilde{\chi}_1^0$ | 2 e,μ | 0 jets | E_T^{miss} | 139 | $\tilde{\ell}$ 0.7 | m($\tilde{\chi}_1^0$)=0 | 1908.08215
$ee,\mu\mu$ | ≥ 1 jet | E_T^{miss} | 139 | $\tilde{\ell}$ 0.256 | m($\tilde{\ell}$)-m($\tilde{\chi}_1^0$)=10 GeV | 1911.12606
$\tilde{H}\tilde{H}$, $\tilde{H}\to h\tilde{G}/Z\tilde{G}$ | 0 e,μ | ≥ 3 b | E_T^{miss} | 36.1 | $\tilde{H}$ 0.13-0.23 0.29-0.88 | BR($\tilde{\chi}_1^0\to h\tilde{G}$)=1 | 1806.04030
4 e,μ | 0 jets | E_T^{miss} | 139 | $\tilde{H}$ 0.55 | BR($\tilde{\chi}_1^0\to Z\tilde{G}$)=1 | 2103.11684
0 e,μ | ≥ 2 large jets | E_T^{miss} | 139 | $\tilde{H}$ 0.45-0.93 | BR($\tilde{\chi}_1^0\to Z\tilde{G}$)=1 | ATLAS-CONF-2021-022
Long-lived particles
Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$ | Disapp. trk | 1 jet | E_T^{miss} | 139 | $\tilde{\chi}_1^\pm$ 0.66 | Pure Wino | ATLAS-CONF-2021-015
$\tilde{\chi}_1^\pm$ 0.21 | Pure higgsino | ATLAS-CONF-2021-015
Stable $\tilde{g}$ R-hadron | Multiple | 36.1 | $\tilde{g}$ 2.0 | 1902.01636,1808.04095
Metastable $\tilde{g}$ R-hadron, $\tilde{g}\to qq\tilde{\chi}_1^0$ | Multiple | 36.1 | $\tilde{g}$ [$\tau(\tilde{g})$ =10 ns, 0.2 ns] 2.05 2.4 | m($\tilde{\chi}_1^0$)=100 GeV | 1710.04901,1808.04095
$\tilde{\ell}\tilde{\ell}$, $\tilde{\ell}\to\ell\tilde{G}$ | Displ. lep | E_T^{miss} | 139 | $\tilde{e},\tilde{\mu}$ 0.7 | $\tau(\tilde{\ell})$ = 0.1 ns | 2011.07812
$\tilde{\tau}$ 0.34 | $\tau(\tilde{\ell})$ = 0.1 ns | 2011.07812
RPV
$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp/\tilde{\chi}_1^0$, $\tilde{\chi}_1^\pm\to Z\ell\to\ell\ell\ell$ | 3 e,μ | 139 | $\tilde{\chi}_1^\pm/\tilde{\chi}_1^0$ [BR($Z\tau$)=1, BR(Ze)=1] 0.625 1.05 | Pure Wino | 2011.10543
$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp/\tilde{\chi}_2^0\to WW/Z\ell\ell\ell\ell\nu\nu$ | 4 e,μ | 0 jets | E_T^{miss} | 139 | $\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$ [$\lambda_{i33}\neq 0$, $\lambda_{12k}\neq 0$] 0.95 1.55 | m($\tilde{\chi}_1^0$)=200 GeV | 2103.11684
$\tilde{g}\tilde{g}$, $\tilde{g}\to qq\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to qqq$ | 4-5 large jets | 36.1 | $\tilde{g}$ [m($\tilde{\chi}_1^0$)=200 GeV, 1100 GeV] 1.3 1.9 | Large λ''_{112} | 1804.03568
$\tilde{t}\tilde{t}$, $\tilde{t}\to t\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to tbs$ | Multiple | 36.1 | $\tilde{t}$ [λ''_{323}=2e-4, 1e-2] 0.55 1.05 | m($\tilde{\chi}_1^0$)=200 GeV, bino-like | ATLAS-CONF-2018-003
$\tilde{t}\tilde{t}$, $\tilde{t}\to b\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm\to bbs$ | ≥ 4b | 139 | $\tilde{t}$ Forbidden 0.95 | m($\tilde{\chi}_1^\pm$)=500 GeV | 2010.01015
$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to bs$ | 2 jets + 2 b | 36.7 | $\tilde{t}_1$ [qq, bs] 0.42 0.61 | 1710.07171
$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to q\ell$ | 2 e,μ | 2 b | 36.1 | $\tilde{t}_1$ 0.4-1.45 | BR($\tilde{t}_1\to be/b\mu$)>20% | 1710.05544
1 μ | DV | 136 | $\tilde{t}_1$ [1e-10< λ'_{23k} <1e-8, 3e-10< λ'_{23k} <3e-9] 1.0 1.6 | BR($\tilde{t}_1\to q\mu$)=100%, cosθ_t=1 | 2003.11956
$\tilde{\chi}_1^\pm/\tilde{\chi}_2^0/\tilde{\chi}_1^0$, $\tilde{\chi}_{1,2}^0\to tbs$, $\tilde{\chi}_1^+\to bbs$ | 1-2 e,μ | ≥6 jets | 139 | $\tilde{\chi}_1^0$ 0.2-0.32 | Pure higgsino | ATLAS-CONF-2021-007
10^{-1}
1
Mass scale [TeV]
*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.

bb+MET SRs and Uncertainties

Variable		SRA	CRzA	$\mathrm{VR}^{m_{\mathrm{CT}}}_{\mathrm{A1}}$	$\mathrm{VR}^{m_{bb}}_{\mathrm{A1}}$	$\mathrm{VR}^{m_{\mathrm{CT}}}_{\mathrm{A2}}$	$\mathrm{VR}^{m_{bb}}_{\mathrm{A2}}$
Number of baseline leptons		0	2	0			
Number of high-purity leptons		–	2 SFOS	–			
$p_{\mathrm{T}}(\ell_1)$	[GeV]	–	> 27	–			
$p_{\mathrm{T}}(\ell_2)$	[GeV]	–	> 20	–			
$m_{\mathrm{T}}(\mathbf{p}^{\ell}_{\mathrm{T}}, \mathbf{p}^{\mathrm{miss}}_{\mathrm{T}})$	[GeV]	–	> 20	–			
$m_{\ell\ell}$	[GeV]	–	[81, 101]	–			
Number of jets		$\in [2,4]$					
Number of b-tagged jets		2					
j_1 and j_2 b-tagged		✓					
$p_{\mathrm{T}}(j_1)$	[GeV]	> 150					
$p_{\mathrm{T}}(j_2)$	[GeV]	> 50					
$p_{\mathrm{T}}(j_4)$	[GeV]	< 50					
$\min[\Delta\phi(\mathbf{p}^{\mathrm{jet}}_{1-4}, \mathbf{p}^{\mathrm{miss}}_{\mathrm{T}})]$	[rad]	> 0.4					
$E^{\mathrm{miss}}_{\mathrm{T}}$	[GeV]	> 250	< 100	> 250			
$\tilde{E}^{\mathrm{miss}}_{\mathrm{T}}$	[GeV]	–	> 250	–			
$E^{\mathrm{miss}}_{\mathrm{T}}/m_{\mathrm{eff}}$		> 0.25	–	–			
$\tilde{E}^{\mathrm{miss}}_{\mathrm{T}}/m_{\mathrm{eff}}$		–	> 0.25	–			
m_{bb}	[GeV]	> 200		< 200	> 200	< 200	> 200
m_{CT}	[GeV]	> 250		> 250	[150, 250]	> 250	[150, 250]
m_{eff}	[GeV]	> 500		[500, 1500]		> 1500	



Variable		SRB	CRzB	VRzB
Number of baseline leptons		0	2	
Number of high-purity leptons		–	2 SFOS	
$p_{\mathrm{T}}(\ell_1)$	[GeV]	–	> 27	
$p_{\mathrm{T}}(\ell_2)$	[GeV]	–	> 20	
$m_{\ell\ell}$	[GeV]	–	[76, 106]	
$m_{\mathrm{T}}(\mathbf{p}^{\ell}_{\mathrm{T}}, \mathbf{p}^{\mathrm{miss}}_{\mathrm{T}})$	[GeV]	–	> 20	
Number of jets		$\in [2,4]$		
Number of b-tagged jets		2		
$p_{\mathrm{T}}(j_1)$	[GeV]	> 100		
$p_{\mathrm{T}}(j_2)$	[GeV]	> 50		
$\min[\Delta\phi(\mathbf{p}^{\mathrm{jet}}_{1-4}, \mathbf{p}^{\mathrm{miss}}_{\mathrm{T}})]$	[rad]	> 0.4		
j_1 not b-tagged		–	✓	–
$E^{\mathrm{miss}}_{\mathrm{T}}$	[GeV]	> 250	< 100	
$\tilde{E}^{\mathrm{miss}}_{\mathrm{T}}$	[GeV]	–	> 250	
m_{CT}	[GeV]	< 250		
w_{XGB}		> 0.85	[0.3, 0.63]	> 0.63

Variable		SRC-2b	SRC-1b1v	SRC-0b1v	VRC-2b	VRC-1b1v	VRC-0b1v
Number of jets		$\in [2,5]$					
j_1 not b-tagged		✓					
Number of baseline leptons		0					
Number of b-tagged jets		≥ 2	1	0	≥ 2	1	0
N_{vtx}		≥ 0	≥ 1	≥ 1	≥ 0	≥ 1	≥ 1
m_{vtx}	[GeV]	–	> 0.6	> 1.5	–	> 0.6	> 1.5
$p^{\mathrm{vtx}}_{\mathrm{T}}$	[GeV]	–	> 3	> 5	–	> 3	> 5
$p_{\mathrm{T}}(j_1)$	[GeV]	> 500	> 400	> 400	< 500	> 400	> 400
$E^{\mathrm{miss}}_{\mathrm{T}}$	[GeV]	> 500	> 400	> 400	< 500	> 400	> 400
$H_{\mathrm{T;3}}$	[GeV]	–	< 80	< 80	–	< 80	< 80
$\mathcal{A}$		> 0.80	> 0.86	–	[0.8, 0.9]	> 0.86	-
m_{jj}	[GeV]	> 250	> 250	–	[150, 250]	> 250	-
$\Delta\phi(j_1, b_1)$	[rad]	–	> 2.2	–	–	< 2.2	–
$\Delta\phi(j_1, \mathrm{vtx})$	[rad]	–	–	> 2.2	–	–	< 2.2
$\lvert\eta_{\mathrm{vtx}}\rvert$		–	< 1.2	< 1.2	–	> 1.2	> 1.2

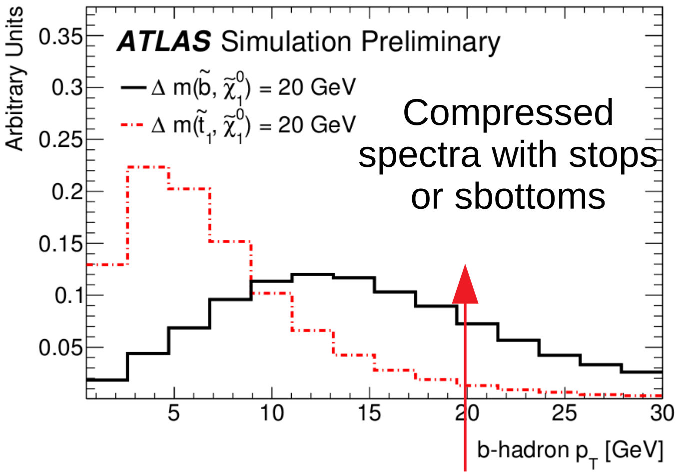
bb+MET Model Independent Tests

Table 7: Left to right: SM expectation from background-only fit for the model-independent regions, 95% CL upper limits on the visible cross-section ($\langle\epsilon\sigma\rangle^{95}_{\text{obs}}$), on the observed ($S^{95}_{\text{obs}}$) and expected (S^{95}_{exp}) number of signal events. The last two columns indicate the CL_B value, i.e. the confidence level observed for the background-only hypothesis, and the discovery p-value ($p(s = 0)$) capped at a value of 0.5.

Signal channel	Obs.	SM exp.	$\langle\epsilon\sigma\rangle^{95}_{\text{obs}}$ [fb]	S^{95}_{obs}	S^{95}_{exp}	CL_B	$p(s=0)$ (Z)
SRAmct250i	552	555 ± 75	0.94	131	133^{+47}_{-35}	0.48	0.49 (0.03)
SRAmct350i	104	120 ± 16	0.17	24	32^{+8}_{-9}	0.19	0.5 (0)
SRAmct450i	23	27.1 ± 3.8	0.06	8.7	$12.3^{+5.5}_{-3.7}$	0.17	0.5 (0)
SRAmct550i	7	10.4 ± 1.7	0.04	5.6	$8.1^{+3.9}_{-2.3}$	0.14	0.5 (0)
SRAmct650i	8	5.6 ± 1.4	0.06	8.5	$6.7^{+3.4}_{-2.0}$	0.73	0.24 (0.72)
SRB	22	20.6 ± 4.6	0.11	15.3	$14.8^{+5.2}_{-3.2}$	0.54	0.40 (0.26)
SRC-2b	58	44.4 ± 5.8	0.22	30.3	$20.7^{+8.1}_{-5.6}$	0.88	0.09 (1.33)
SRC-1b1v	43	51 ± 10	0.13	17.6	$21.2^{+8.2}_{-5.8}$	0.28	0.5 (0)
SRC-0b1v	151	148 ± 25	0.37	51	50^{+18}_{-13}	0.54	0.48 (0.2)
SRD-low	497	381 ± 76	1.8	250	155^{+65}_{-60}	0.91	0.07 (1.48)
SRD-high	320	242 ± 66	1.4	195	140^{+48}_{-44}	0.82	0.13 (1.13)

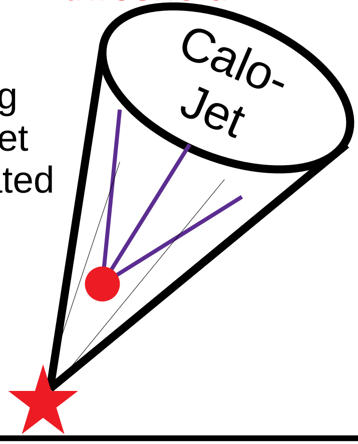
Soft b-tagging

ATLAS-CONF-2019-027

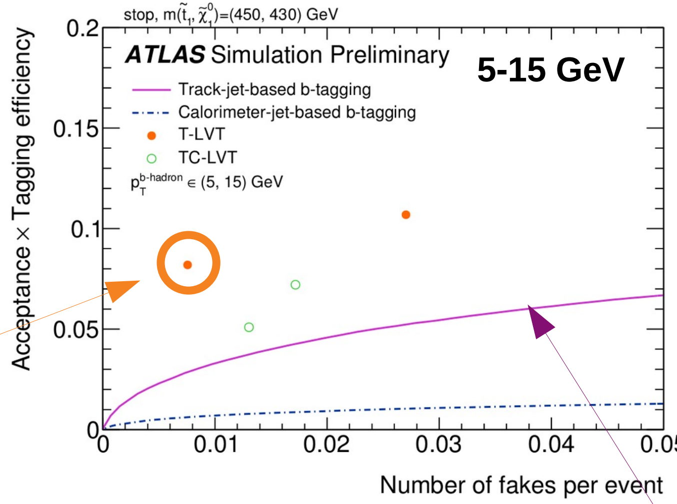


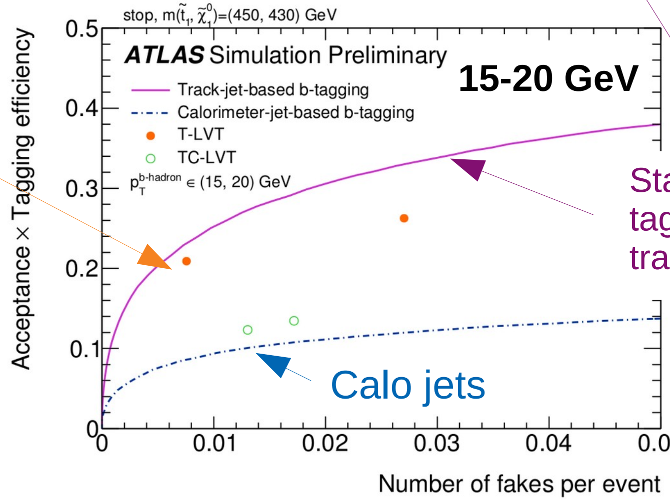
ATLAS b-tagging p_T threshold

Standard b-tagging starts from a calo-jet and looks at associated tracks



New tagging methods developed focusing on searching for displaced vertices





Standard tagger on track-jets

Stop to stau SRs

Table 2: Preselection of the di-tau and single-tau channels.

Di-tau preselection	Single-tau preselection
$E_{\mathrm{T}}^{\mathrm{miss}}$-trigger fired and $E_{\mathrm{T}}^{\mathrm{miss}} > 250$ GeV No light leptons (e/μ) At least two jets At least one b-tagged jet	
At least two hadronic tau candidates	Exactly one hadronic tau candidate At least two b-tagged jets

Variable	CR $t\bar{t}$ (2 real τ)	CR $t\bar{t}$ (1 real τ)	VR $t\bar{t}$ (2 real τ)	VR $t\bar{t}$ (1 real τ)	SR
$E_{\mathrm{T}}^{\mathrm{miss}}$	—	—	—	—	> 280 GeV
$OS(\tau_1, \tau_2)$	1	—	1	—	1
$m_{\mathrm{T2}}(\tau_1, \tau_2)$	< 35 GeV	< 35 GeV	$[35, 70]$ GeV	$[35, 70]$ GeV	> 70 GeV
$m_{\mathrm{vis}}(\tau_1, \tau_2)$	> 50 GeV	> 50 GeV	—	—	—
$m_{\mathrm{T}}(\tau_1)$	> 50 GeV	< 50 GeV	> 70 GeV	< 70 GeV	—

Variable	CR $t\bar{t}$ (1 real τ)	CR single top	VR $t\bar{t}$ (1 real τ)	VR single top	SR
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 280 GeV	> 280 GeV	> 280 GeV	> 280 GeV	> 280 GeV
s_{T}	$[500, 600]$ GeV	—	> 600 GeV	—	$> 800(600)$ GeV
$\sum m_{\mathrm{T}}(b_{1,2})$	$[600, 700]$ GeV	> 800 GeV	$[600, 700]$ GeV	> 800 GeV	> 700 GeV
$m_{\mathrm{T}}(\tau)$	—	< 50 GeV	—	$[50, 150]$ GeV	$> 300(150)$ GeV
$p_{\mathrm{T}}(\tau)$	—	> 80 GeV	—	> 80 GeV	— (binned)

Stop to Stau Uncertainties and Model Independent Tests

Systematic uncertainty	Di-tau SR	Single-tau one-bin SR	Single-tau multi-bin SR
Total	25 %	17 %	17 %
Jet-related	19 %	4.2 %	3.9 %
Tau-related	4.7 %	5.5 %	4.3 %
Other experimental	3.7 %	1.0 %	0.8 %
Theoretical modeling	13 %	17 %	19 %
MC statistics	12 %	7.5 %	4.4 %
Normalization factors	8.8 %	15 %	16 %
Luminosity	0.8 %	0.5 %	0.4 %

Signal channel	$\langle A\epsilon\sigma\rangle^{95}_{\text{obs}}$ [fb]	S^{95}_{obs}	S^{95}_{exp}	CL_b	$p(s=0)$ (Z)
Di-tau SR	0.03	4.1	$5.3^{+2.2}_{-1.5}$	0.18	0.50 (0.0)
Single-tau one-bin SR	0.06	8.2	$5.1^{+2.1}_{-1.3}$	0.91	0.08 (1.37)

Photon+Jets+Met Signal Regions and Uncertainties

	SRL	SRM	SRH
N_{photons}	≥ 1	≥ 1	≥ 1
$p_{\mathrm{T}}^{\mathrm{leading}-\gamma}$	> 145 GeV	> 300 GeV	> 400 GeV
N_{leptons}	0	0	0
N_{jets}	≥ 5	≥ 5	≥ 3
$\Delta\phi(\mathrm{jet}, E_{\mathrm{T}}^{\mathrm{miss}})$	> 0.4	> 0.4	> 0.4
$\Delta\phi(\gamma, E_{\mathrm{T}}^{\mathrm{miss}})$	> 0.4	> 0.4	> 0.4
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 250 GeV	> 300 GeV	> 600 GeV
H_{T}	> 2000 GeV	> 1600 GeV	> 1600 GeV
R_{T}^{4}	< 0.90	< 0.90	-

	SRL [%]	SRM [%]	SRH [%]
Total (stat. + syst.) uncertainty	28	25	17
Statistical uncertainty	20	15	12
Jet energy scale and resolution	18	19	4.1
b-tagging calibration	3.2	4.3	3.6
Jet fakes	2.1	2.5	2.3
MC theory	3.6	3.1	10
Electron fakes	1.4	1.9	< 1
Electron/photon energy resolution and scale	5.5	1.1	4.1
Muon reconstruction and identification	2.6	1.8	< 1
Photon ID and isolation	2.6	2.1	1.1
Pile-up reweighting	< 1	1.2	1.0
$E_{\mathrm{T}}^{\mathrm{miss}}$ soft-term scale and resolution	< 1	< 1	< 1

$$H_{\mathrm{T}} = p_{\mathrm{T}}^{\mathrm{leading}\gamma} + \sum_{\mathrm{jets}} p_{\mathrm{T}}^{i}$$

$$\Delta\phi(\mathrm{jet}, E_{\mathrm{T}}^{\mathrm{miss}}) = \min(\Delta\phi(j_1, E_{\mathrm{T}}^{\mathrm{miss}}), \Delta\phi(j_2, E_{\mathrm{T}}^{\mathrm{miss}}))$$

$$R_{\mathrm{T}}^{4} = \frac{\sum_{i=1}^{4} p_{\mathrm{T}}^{i}}{\sum_{\mathrm{j}} p_{\mathrm{T}}^{j}}$$

Jets+MET

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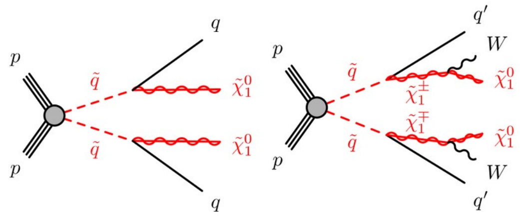
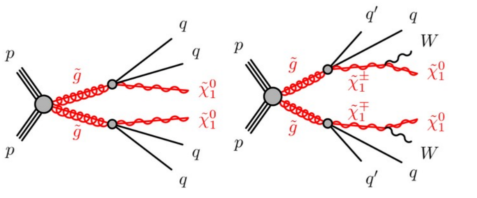
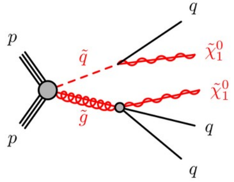
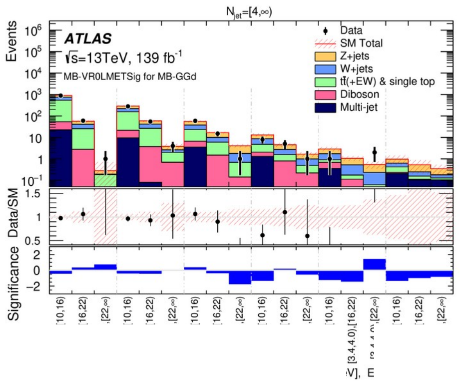
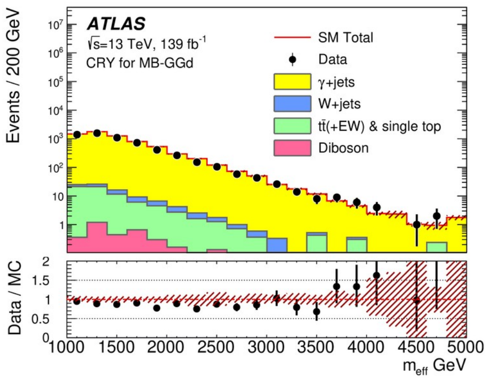
- Several jets and MET, no leptons (Trigger on MET)
- Traditional multi-bin fit and BDT for models with intermediate charginos
  - Single bin regions for model independent tests (binned in N jets and m_{eff})
- Major backgrounds normalized to control regions
  - Zvv from y+jets (y treated as MET)
  - Multi-jet from regions with jet close to MET
  - ttbar and W+jets from one-lepton regions with or without a b-tag

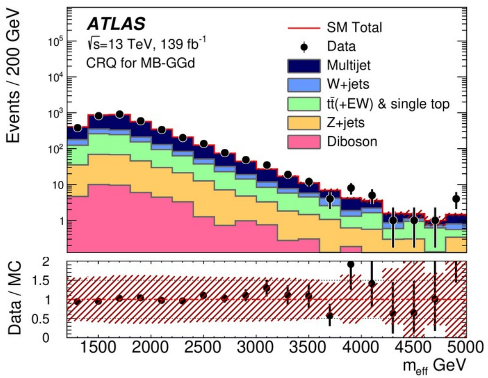


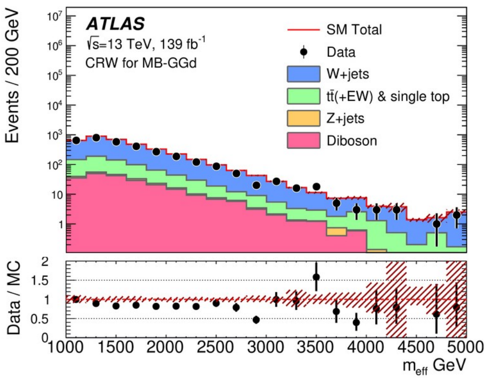


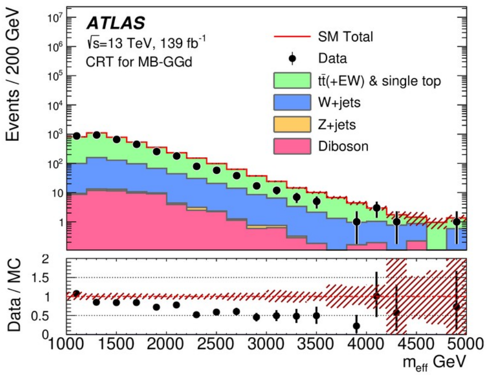




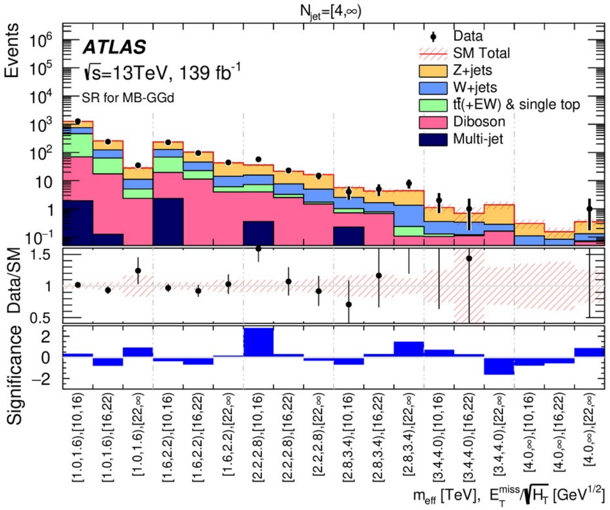




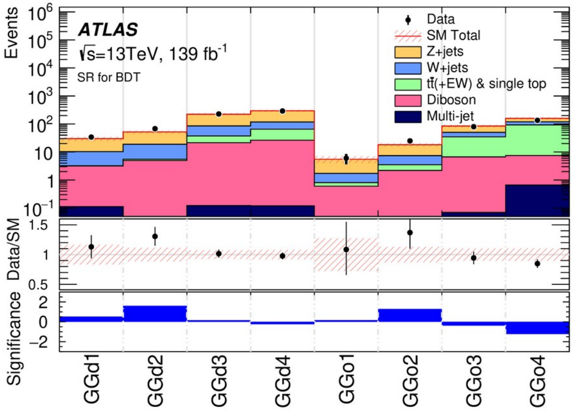




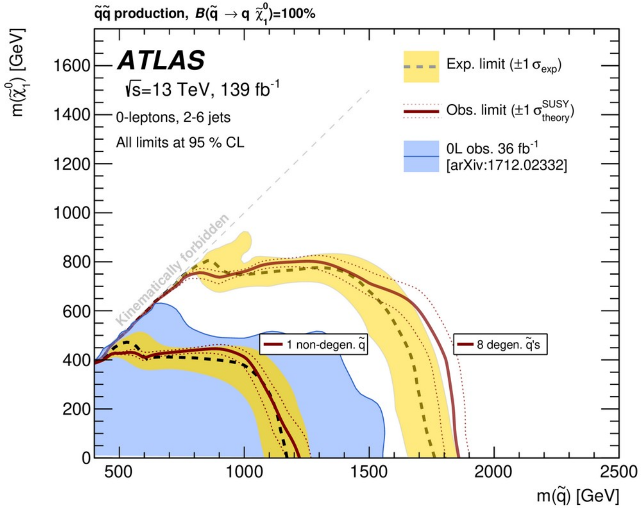
Results



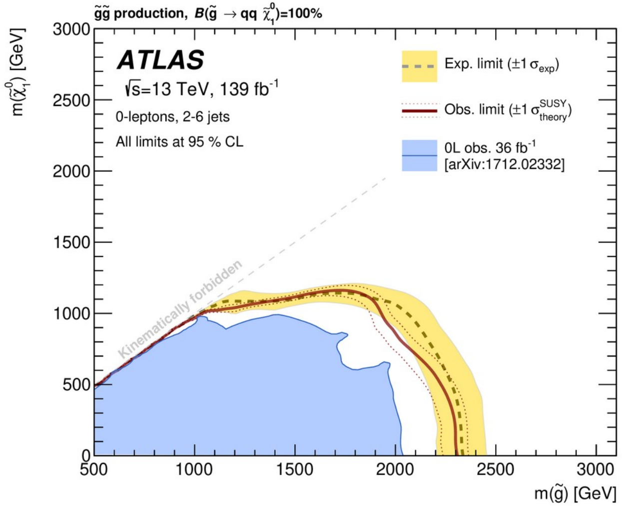
N_jet=[4,∞)
ATLAS
√s=13TeV, 139 fb-1
SR for MB-GGd
Data
SM Total
Z+jets
W+jets
tt̄(+EW) & single top
Diboson
Multi-jet
Events
Data/SM
Significance
m_eff [TeV], E_T^miss/√H_T [GeV^1/2]



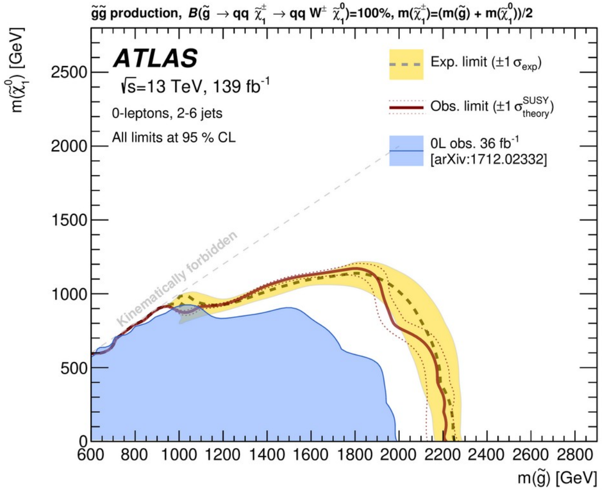
ATLAS
√s=13TeV, 139 fb-1
SR for BDT
Data
SM Total
Z+jets
W+jets
tt̄(+EW) & single top
Diboson
Multi-jet
Events
Data/SM
Significance
GGd1
GGd2
GGd3
GGd4
GGo1
GGo2
GGo3
GGo4



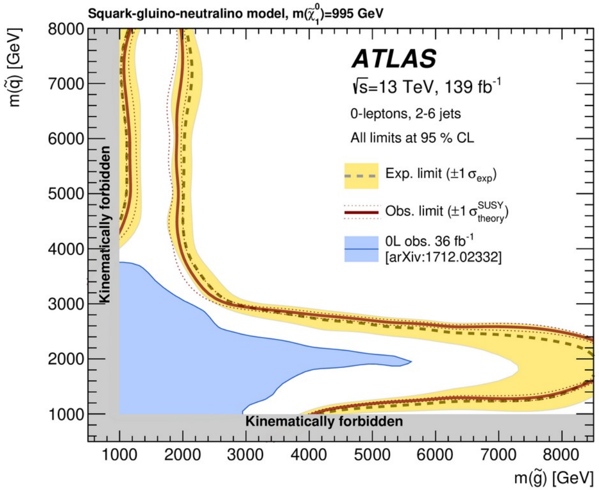
q̃q̃ production, B(q̃ → q χ̃⁰₁)=100%
ATLAS
√s=13 TeV, 139 fb-1
0-leptons, 2-6 jets
All limits at 95 % CL
Exp. limit (±1 σexp)
Obs. limit (±1 σ SUSY theory)
0L obs. 36 fb-1
[arXiv:1712.02332]
Kinematically forbidden
1 non-degen. q̃
8 degen. q̃'s
m(χ̃⁰₁) [GeV]
m(q̃) [GeV]



g̃g̃ production, B(g̃ → qq χ̃⁰₁)=100%
ATLAS
√s=13 TeV, 139 fb-1
0-leptons, 2-6 jets
All limits at 95 % CL
Exp. limit (±1 σexp)
Obs. limit (±1 σ SUSY theory)
0L obs. 36 fb-1
[arXiv:1712.02332]
Kinematically forbidden
m(χ̃⁰₁) [GeV]
m(g̃) [GeV]



g̃g̃ production, B(g̃ → qq χ̃±₁ → qq W± χ̃⁰₁)=100%, m(χ̃±₁)=(m(g̃) + m(χ̃⁰₁))/2
ATLAS
√s=13 TeV, 139 fb-1
0-leptons, 2-6 jets
All limits at 95 % CL
Exp. limit (±1 σexp)
Obs. limit (±1 σ SUSY theory)
0L obs. 36 fb-1
[arXiv:1712.02332]
Kinematically forbidden
m(χ̃⁰₁) [GeV]
m(g̃) [GeV]



Squark-gluino-neutralino model, m(χ̃⁰₁)=995 GeV
ATLAS
√s=13 TeV, 139 fb-1
0-leptons, 2-6 jets
All limits at 95 % CL
Exp. limit (±1 σexp)
Obs. limit (±1 σ SUSY theory)
0L obs. 36 fb-1
[arXiv:1712.02332]
Kinematically forbidden
Kinematically forbidden
m(q̃) [GeV]
m(g̃) [GeV]