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Search for R-parity violating supersymmetry with the ATLAS detector

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version 1707060954

Outline

- ATLAS has an extensive search programme for both R-parity conserving (RPC) and violating (RPV) supersymmetric signatures
- I will focus on recent searches aiming primarily on RPV signatures
  - pair-produced resonances in four jets final states [ATLAS-CONF-2017-025]
  - B-L scalar-top pair production [ATLAS-CONF-2017-036]
  - lepton plus high jet multiplicity final state [arXiv:1704.08493]
- other searches with RPV interpretations are presented at EPS and/or can be found on our public results web page

R-parity violation

- definition of *R*-parity

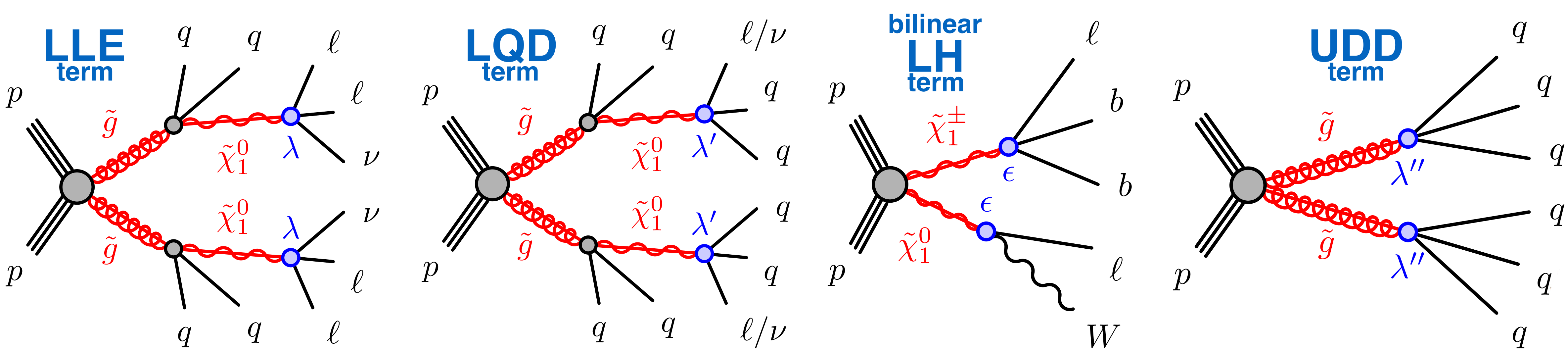
$$P_R = (-1)^{3B+L+2s} = (-1)^{3(B-L)+2s}$$

- most general renormalisable, *R*-parity odd superpotential consistent with the gauge symmetry and field content of the MSSM

$$W_{RPV} = \frac{1}{2}\lambda_{ijk}L_iL_jE^c_k + \lambda'_{ijk}L_iQ_jD^c_k + \kappa_iL_iH_u + \frac{1}{2}\lambda''_{ijk}U^c_iD^c_jD^c_k$$

lepton-number violation — baryon-number violation

trilinear coupling — bilinear coupling — trilinear coupling

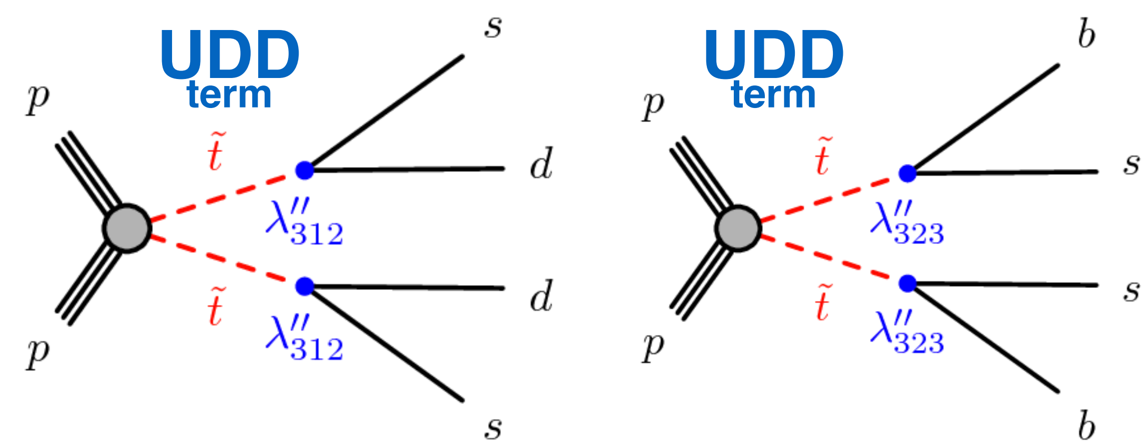


- acceptable proton decay rate can be assured by other discrete or continuous symmetries or with specific combinations of λ's

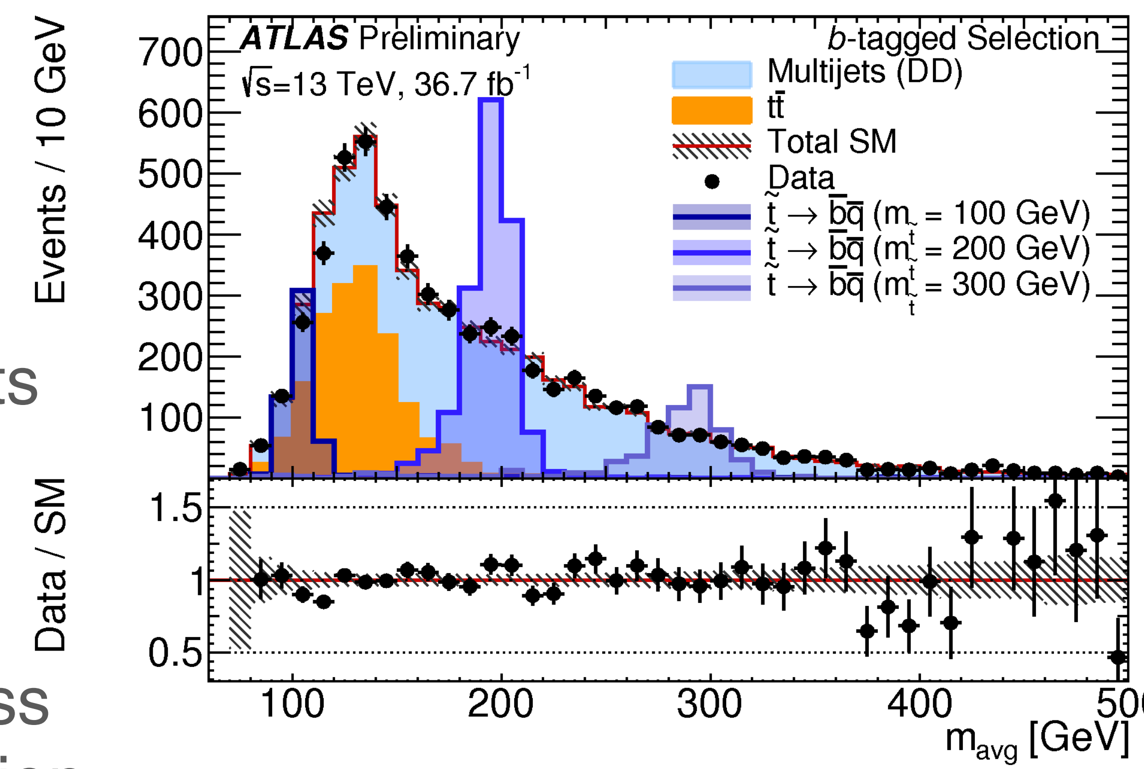
(e.g. only either lepton or baryon-number violation)

Pair-produced resonances in four jets final states

- benchmark models
  - top squark as lightest SUSY particle
  - couplings large enough for prompt decay, but small enough to forbid single-top-squark resonant production



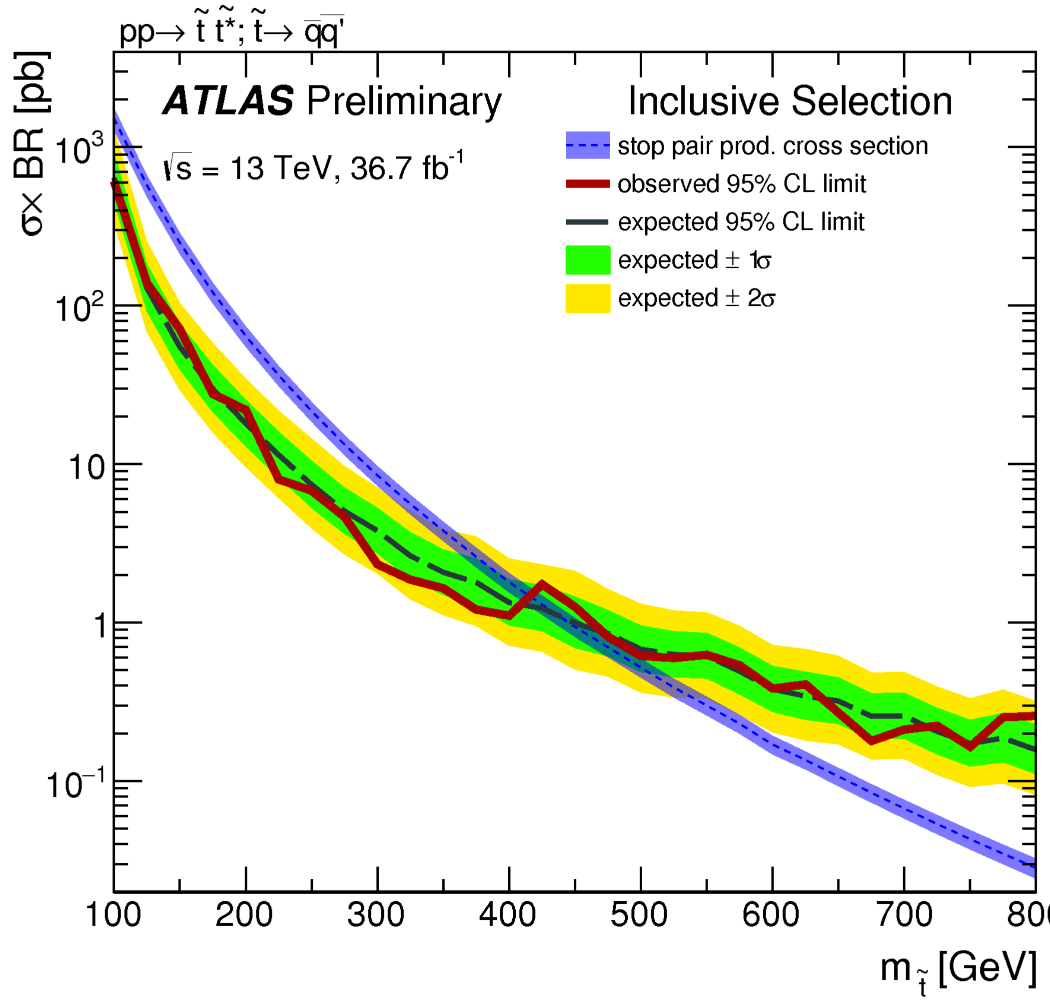
- signatures
  - two jet pairs, each possibly containing a bottom quark, with same mass resonances
- analysis strategy
  - require at least four central high-momentum jets
  - put mass-dependent requirement on angular distance between jets in pairs ΔR_{min}
  - define signal regions in angle of resonances to beams in global centre-of-mass frame and mass asymmetry, plus at least two *b*-jets for λ''_{3i3} region
  - final discriminant is average mass
  - data-driven multi-jet, MC-based ttbar background estimate

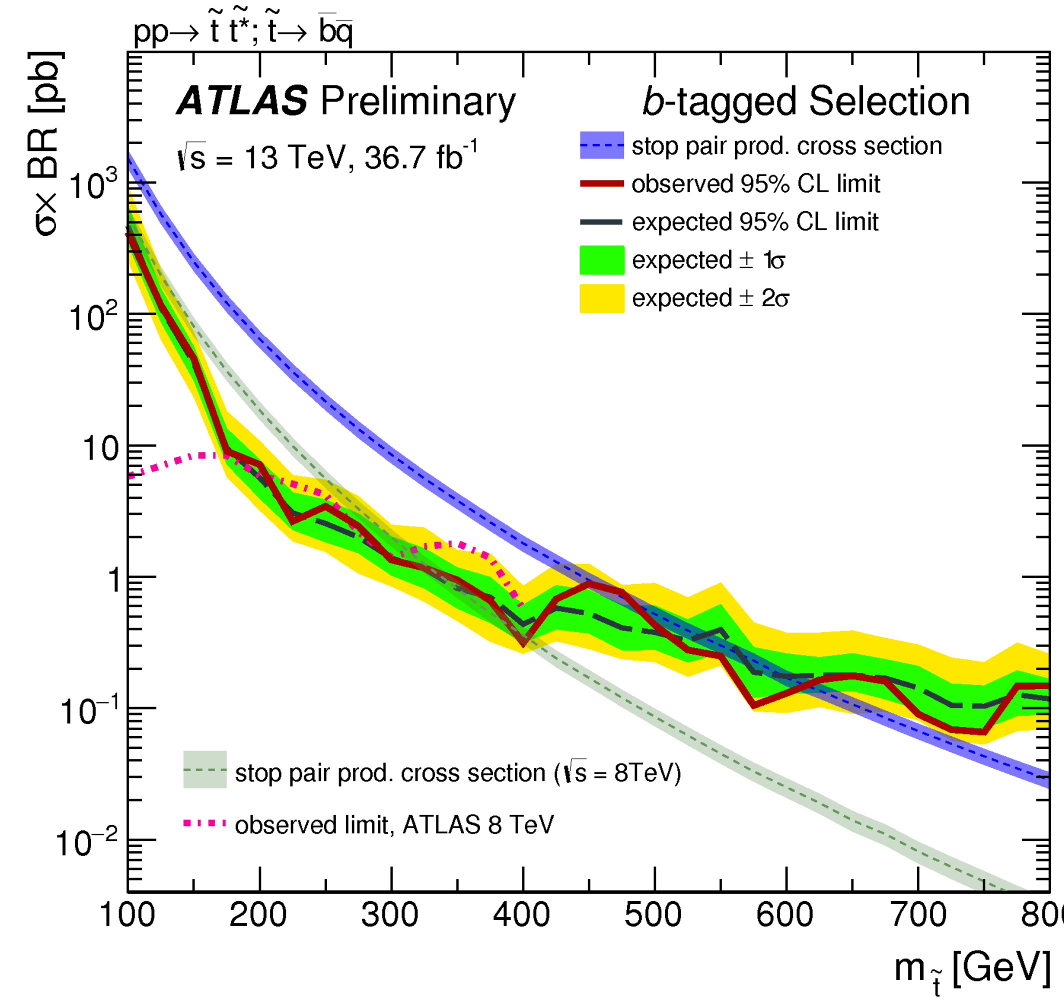


13 TeV, 36.7/fb ATLAS-CONF-2017-025

Pair-produced resonances in four jets final states

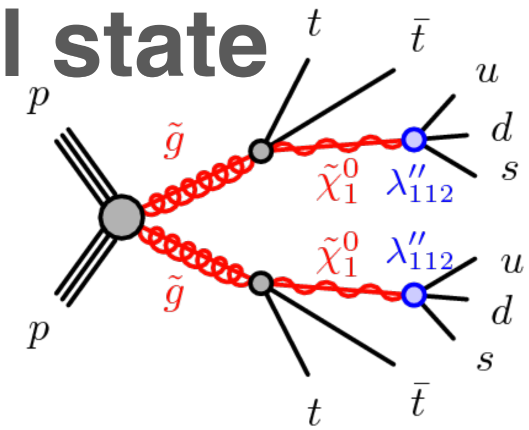
- results
  - no significant excess seen in any signal region
  - top-squark mass exclusion limits
    - 100 — 410 GeV in inclusive selection
    - 100 — 470 GeV and 480 — 610 GeV for decays to *b*-quarks (*b*-tag selection)
  - also place lower-mass limits for
    - pair production of scalar gluons (800 GeV)
    - vector colour octet resonances coupling only to light quarks (1500 GeV)

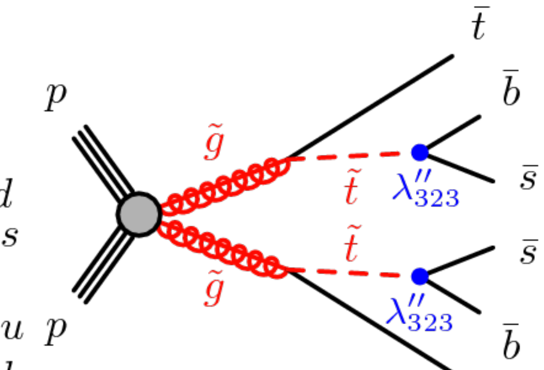


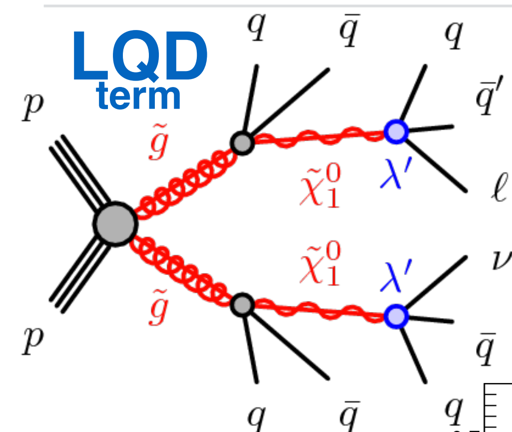


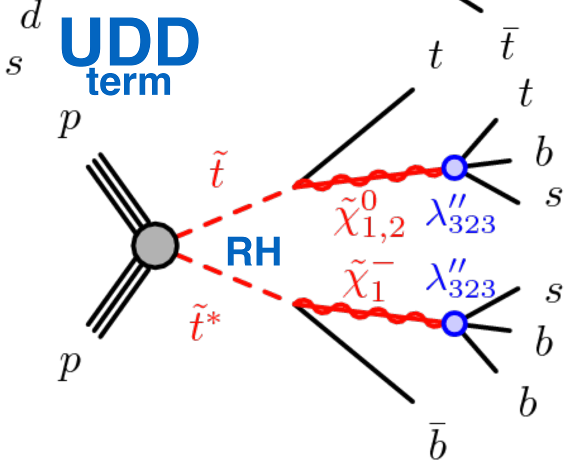
13 TeV, 36.7/fb ATLAS-CONF-2017-025

Lepton plus high jet multiplicity final state

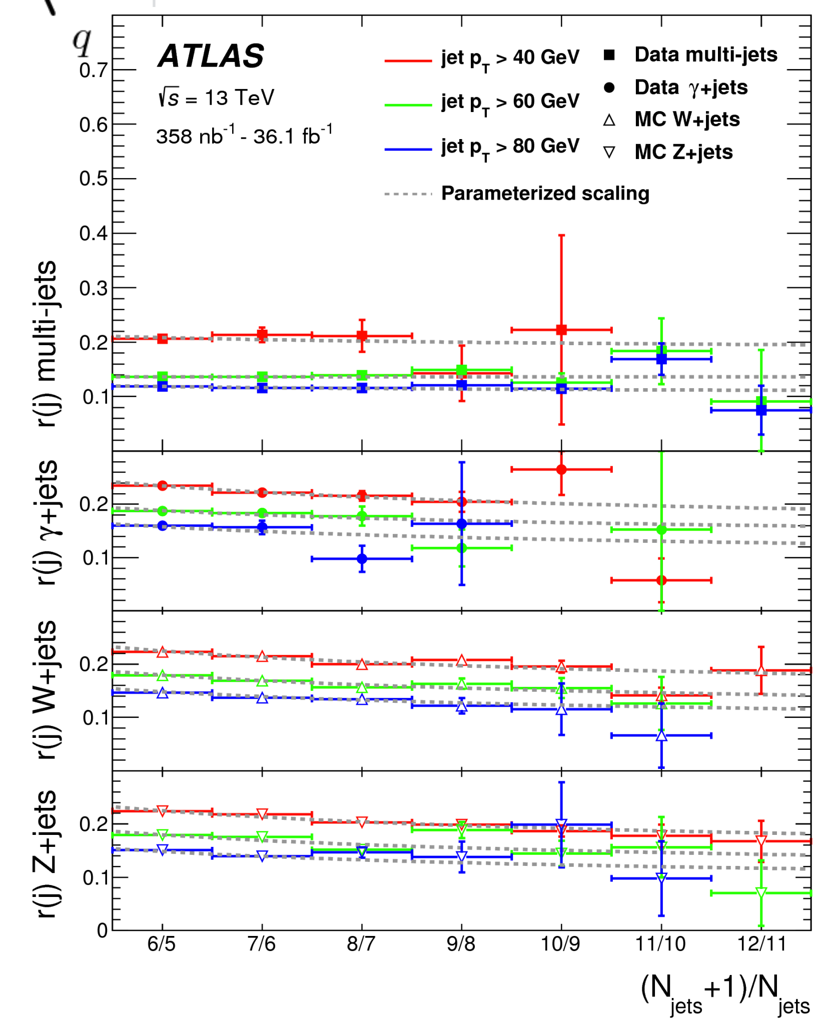








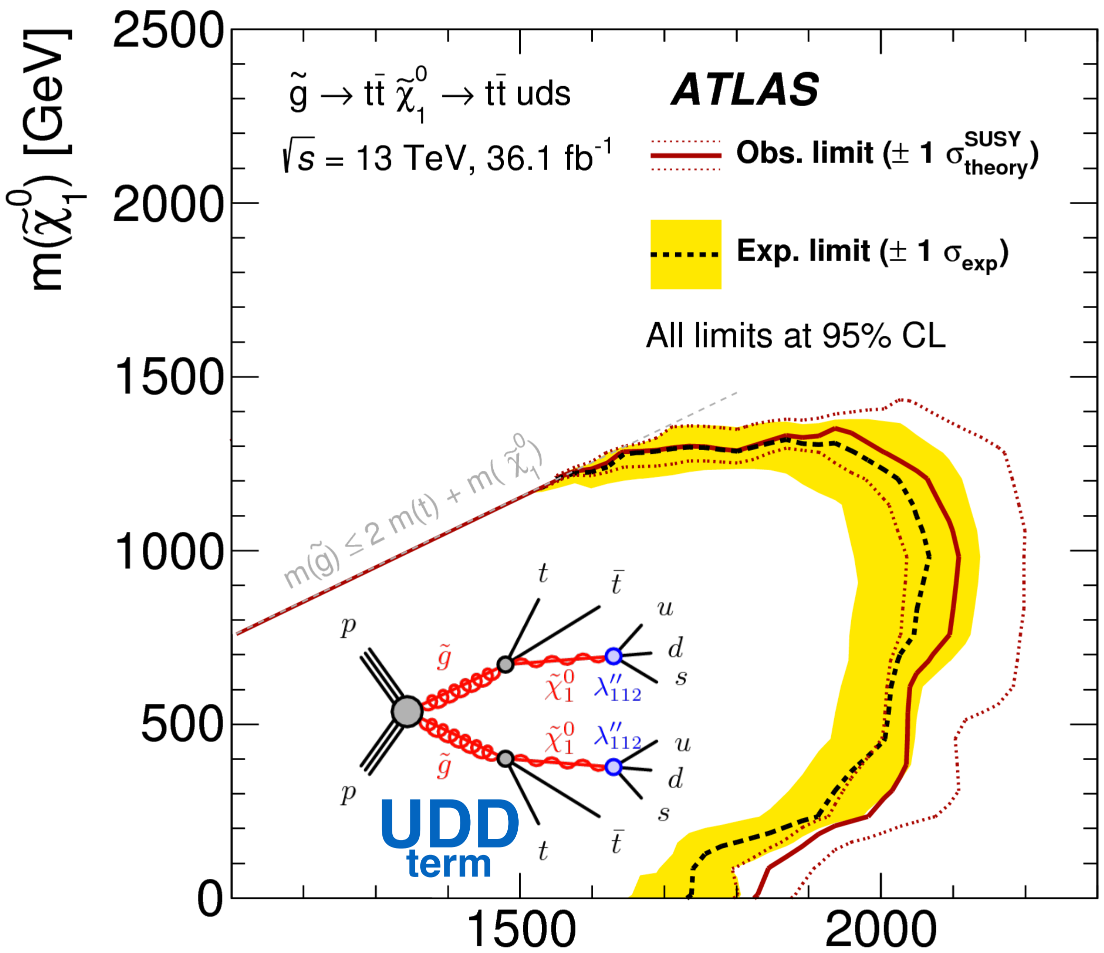
- benchmark models
  - gluino and RH stop pair production
  - prompt decay of all sparticles
  - λ' decay with equal light-lepton probability
  - stop pair production considers only pure bino or higgsino LSP (no lepton in wino LSP case)
- signatures
  - isolated lepton (*e*, *μ*), ≥ 8—12 jets, 0 or ≥ 3 *b*-jets and little E_T^{miss}
- analysis strategy
  - no explicit E_T^{miss} requirement requires stringent lepton identification and isolation to suppress fake or non-prompt lepton background
  - require at least one lepton (*e*, *μ*)
  - dominant ttbar and W/Z+jets background (using parametrised extrapolations from lower jet multiplicities)
  - bins in jet and *b*-jet multiplicity used in model-dependent multi-bin fit
  - dedicated signal regions used in model-independent test



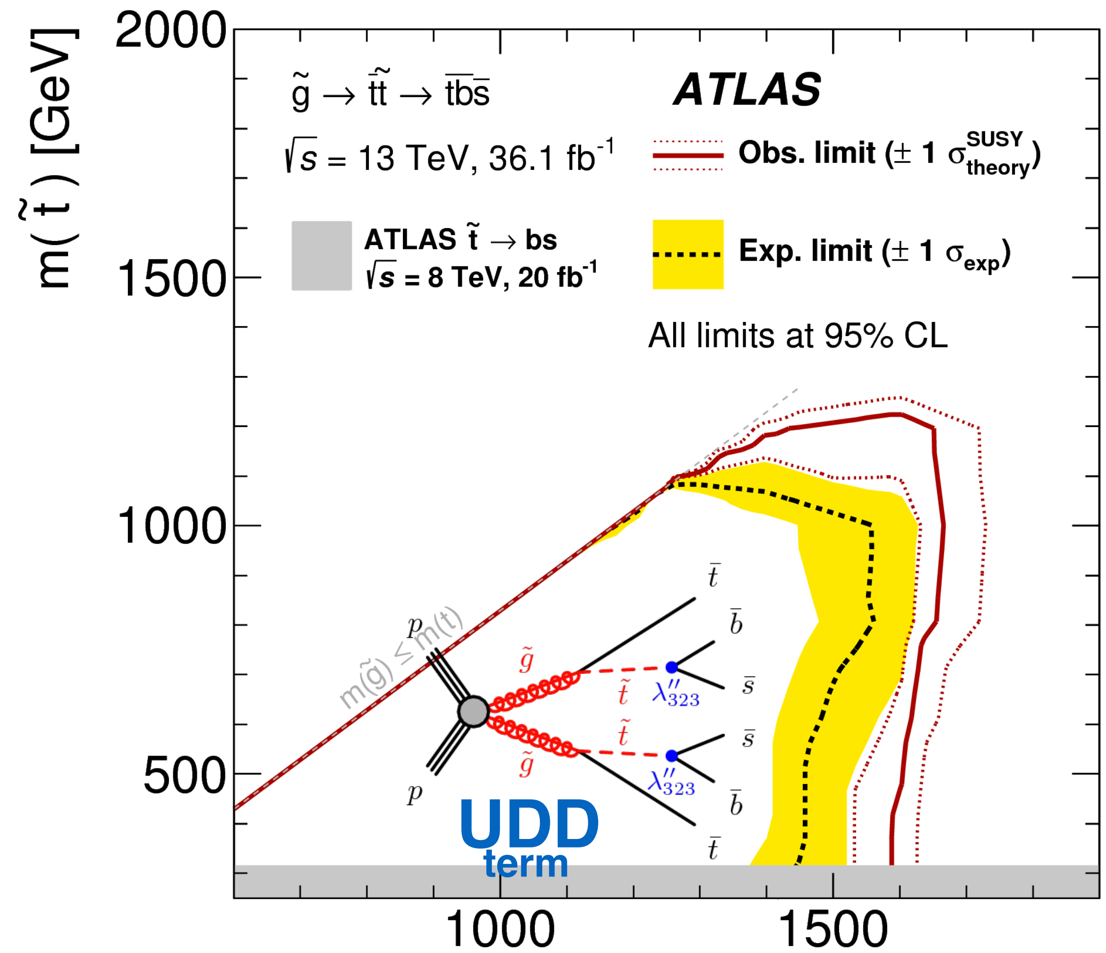
13 TeV, 36.1/fb arXiv:1704.08493

Lepton plus high jet multiplicity final state

- results
  - no significant excess seen in any signal region
  - model-dependent lower limits on mass
    - for gluinos up to between 1.65 and 2.10 TeV (depending on model)
    - for stop up to between 1.1 and 1.25 TeV (depending on LSP nature)
  - also upper limit of 60 fb on four-top-production cross section (6.5 × SM prediction) and model-independent upper limits on visible BSM cross section ($\sigma \cdot A \cdot \varepsilon$)



$m_{gluino} \geq$ 2.10 TeV



$m_{gluino} \geq$ 1.65 TeV

13 TeV, 36.1/fb arXiv:1704.08493

Lepton plus high jet multiplicity final state

- results
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  - model-dependent lower limits on mass
    - for gluinos up to between 1.65 and 2.10 TeV (depending on model)
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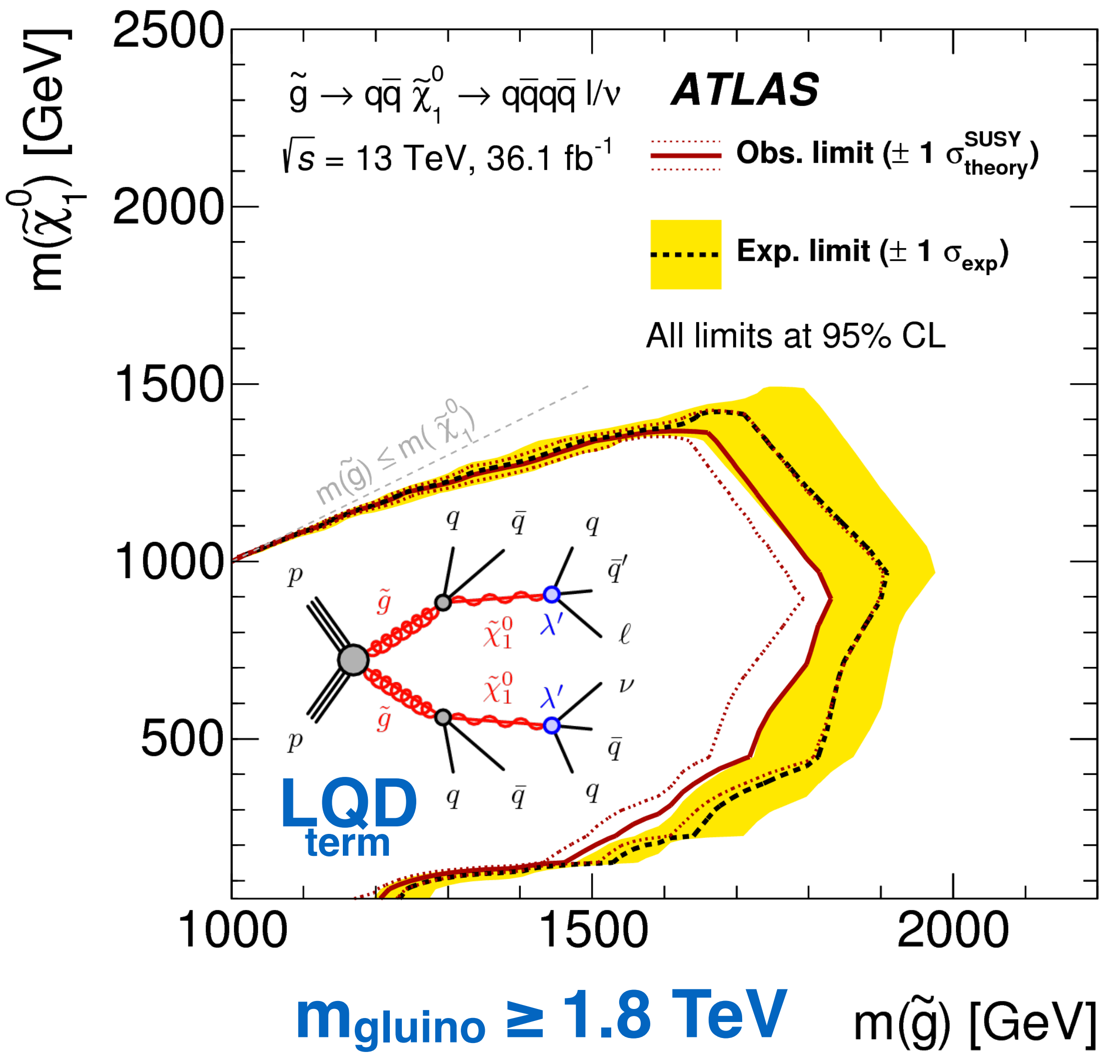
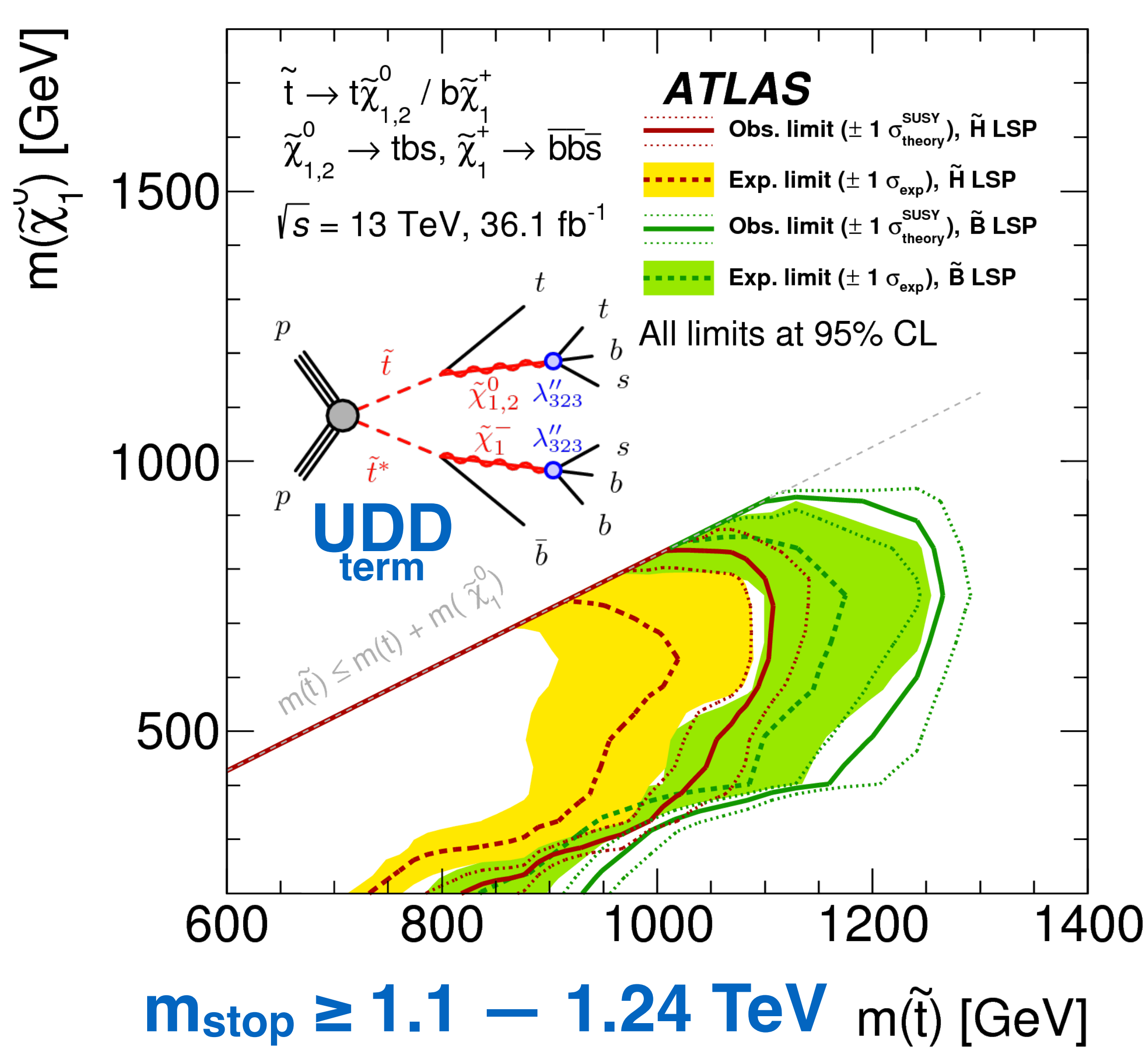


$m_{gluino} \geq$ 1.8 TeV

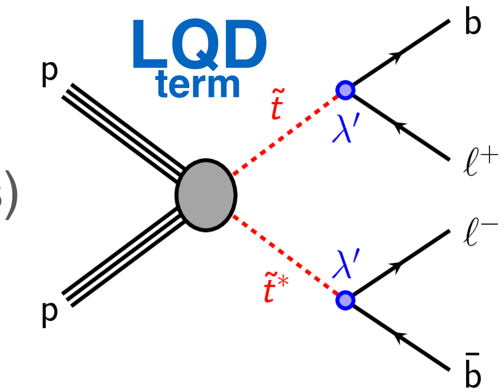


$m_{stop} \geq$ 1.1 — 1.24 TeV

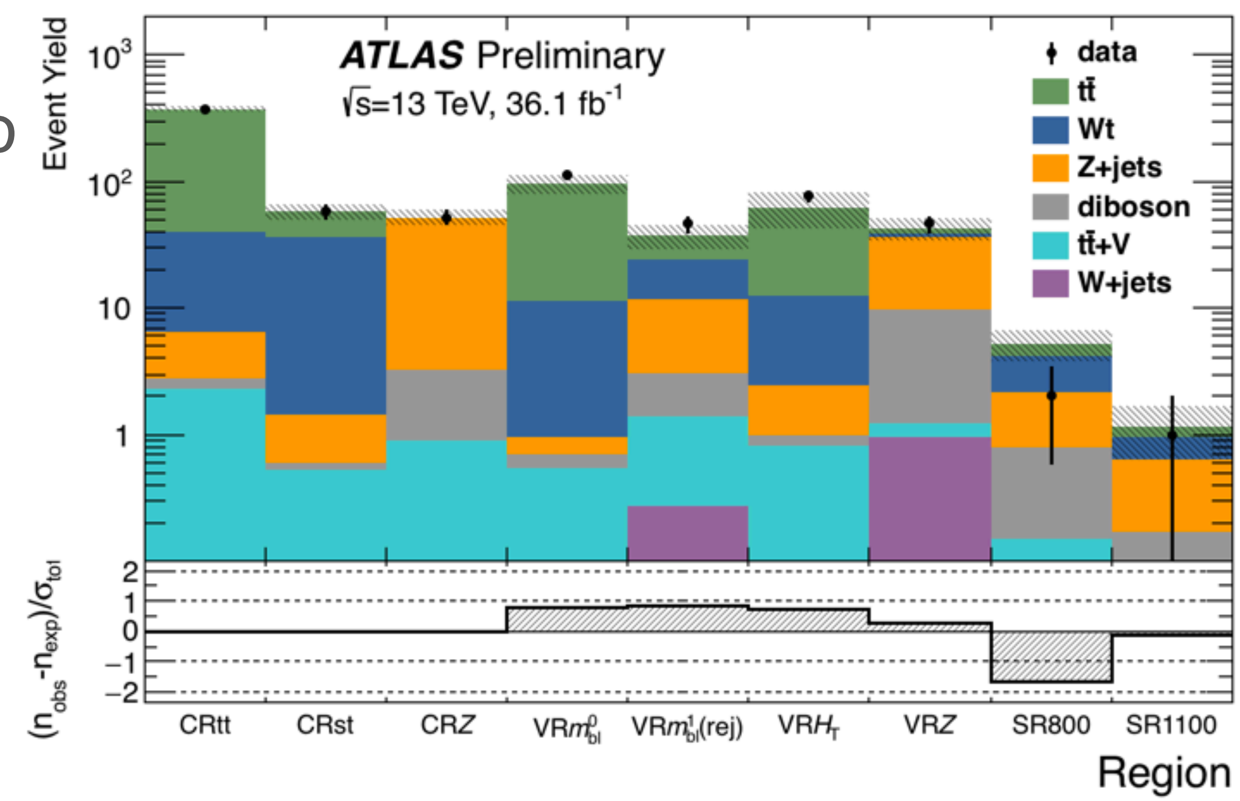
13 TeV, 36.1/fb arXiv:1704.08493

B-L scalar-top pairs

- benchmark models
  - additional local symmetry $U(1)_{B-L}$ (with right-handed neutrino supermultiplets)
  - highly suppressed couplings to prevent short proton lifetimes
  - stop pair production with prompt decays bottom quark and lepton



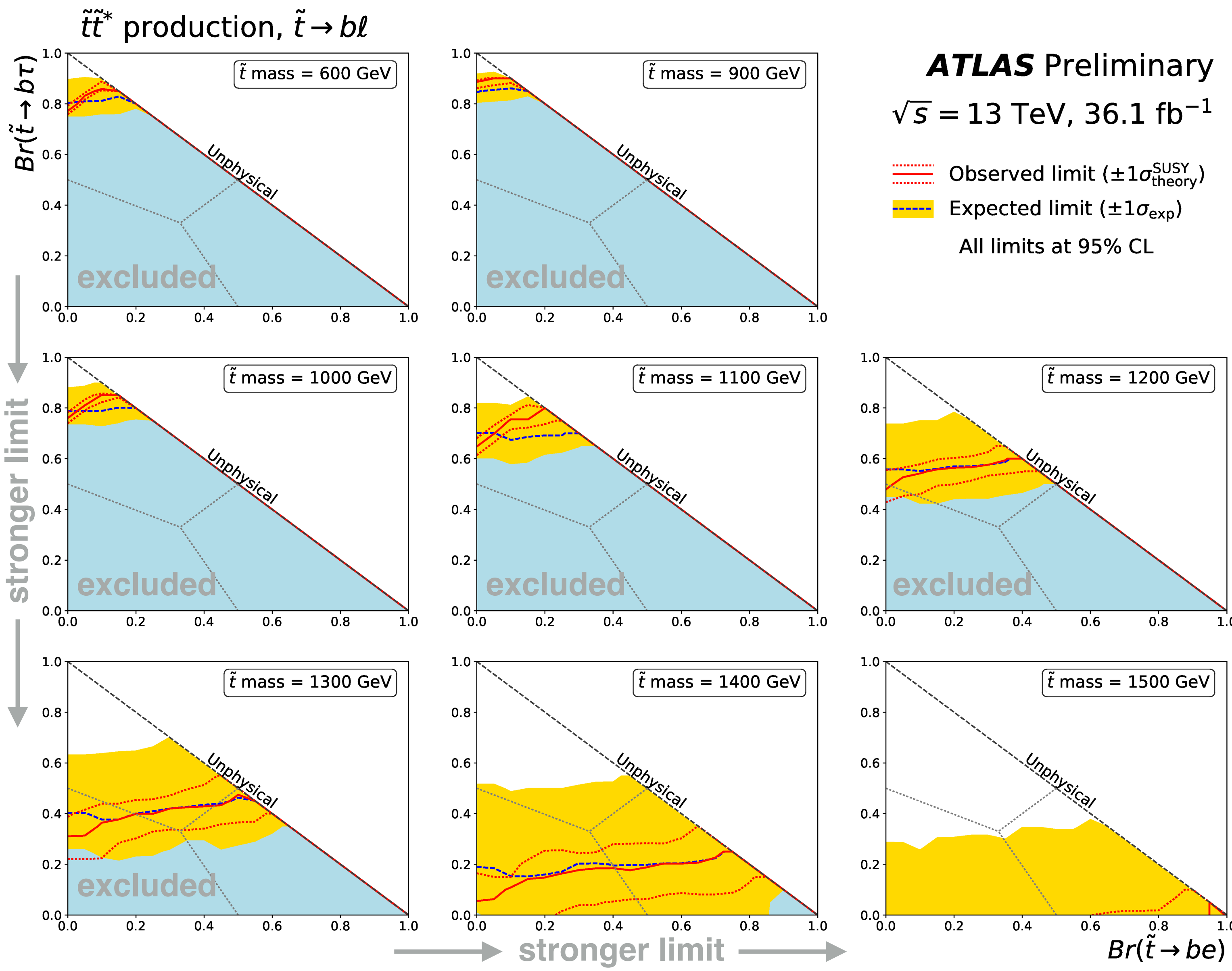
- signatures
  - two oppositely charged leptons and two *b*-jets
- analysis strategy
  - require at least two leptons (e, μ), at least two jets (at least one *b*-tagged), leading leptons to have opposite charge, and agreement between reconstructed stop masses
  - require small mass asymmetry ($m_{bl}^{asym} < 0.2$) and choose minimal pairing
  - signal regions defined via larger mass ($m_{bl}^{0} > 800/1100$ GeV)
  - dominant backgrounds (ttbar, single top, Z+jets) estimated from MC normalised to data in control regions

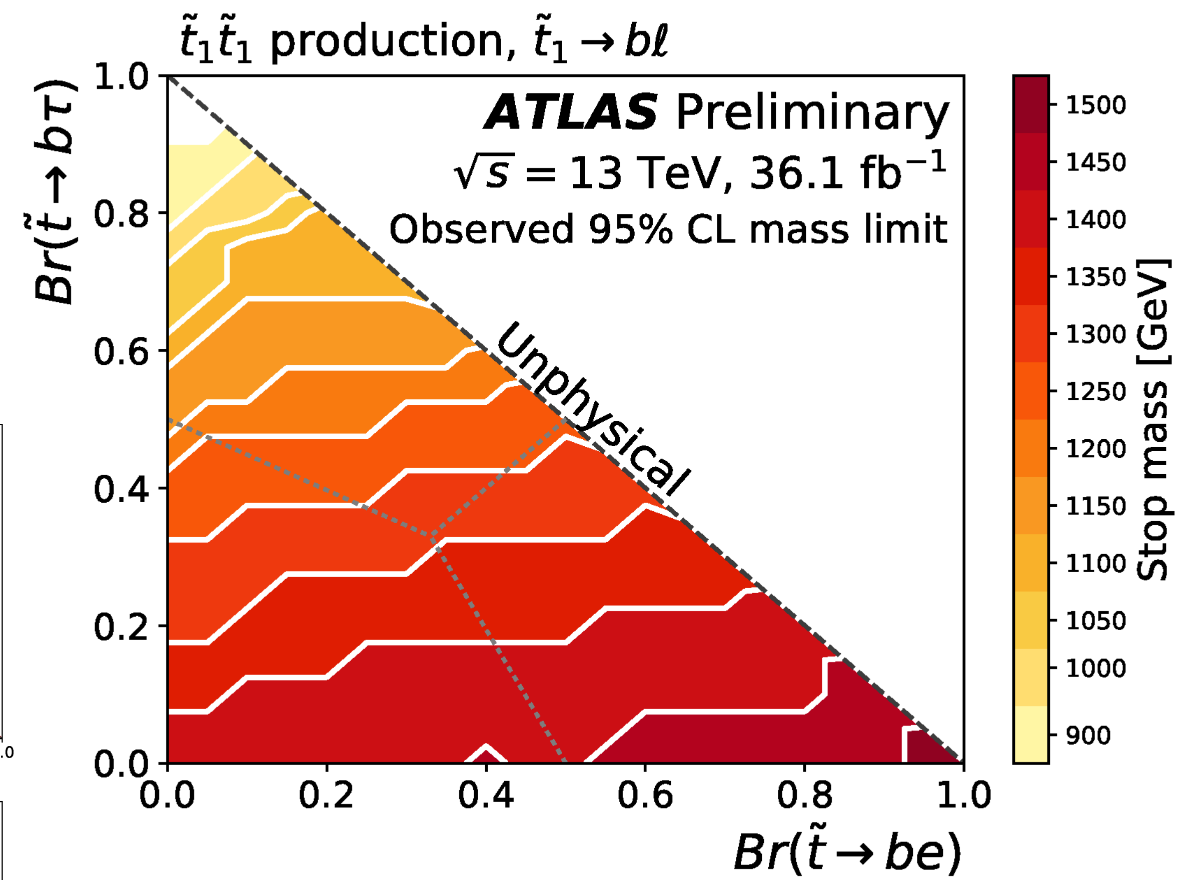


13 TeV, 36.1/fb ATLAS-CONF-2017-036

B-L scalar-top pairs

- results
  - no significant excess seen in any signal region
  - multi-bin fit to control and signal regions, performed for various branching ratios
  - also model-independent upper limits on visible cross section of BSM processes

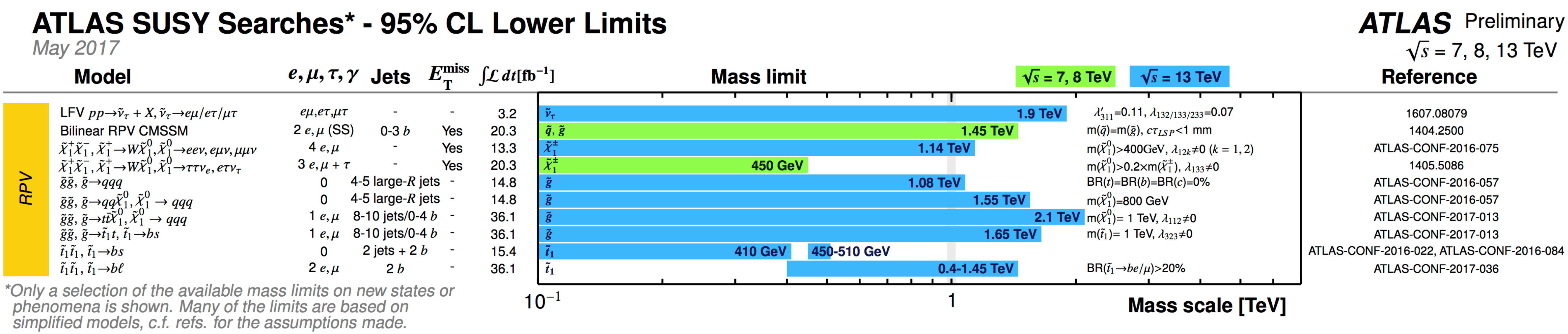




13 TeV, 36.1/fb ATLAS-CONF-2017-036

Summary

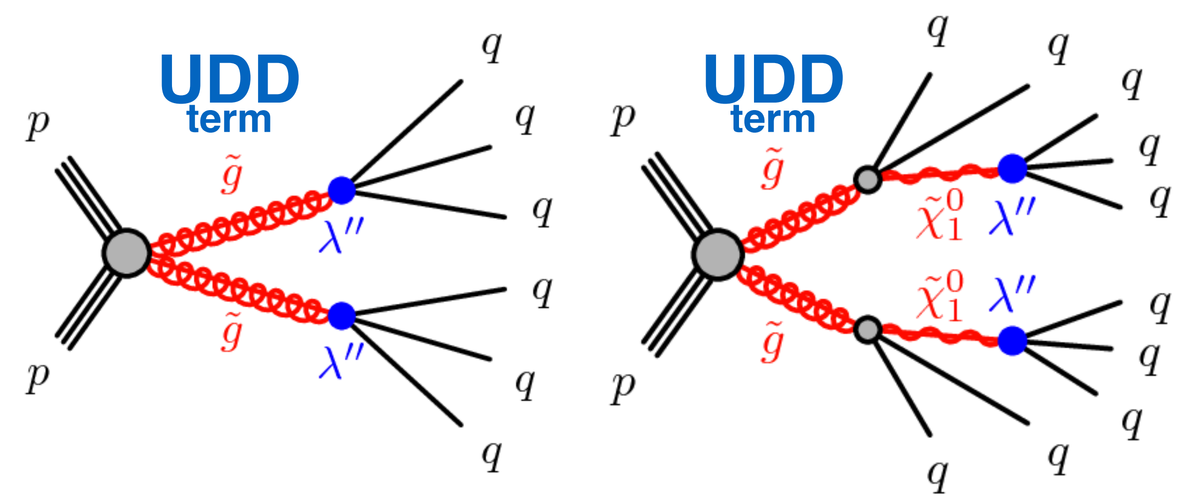
- ATLAS has an extensive search programme for both R-parity conserving (RPC) and violating (RPV) supersymmetric signatures
- presented a subset of searches aiming primarily on RPV signatures



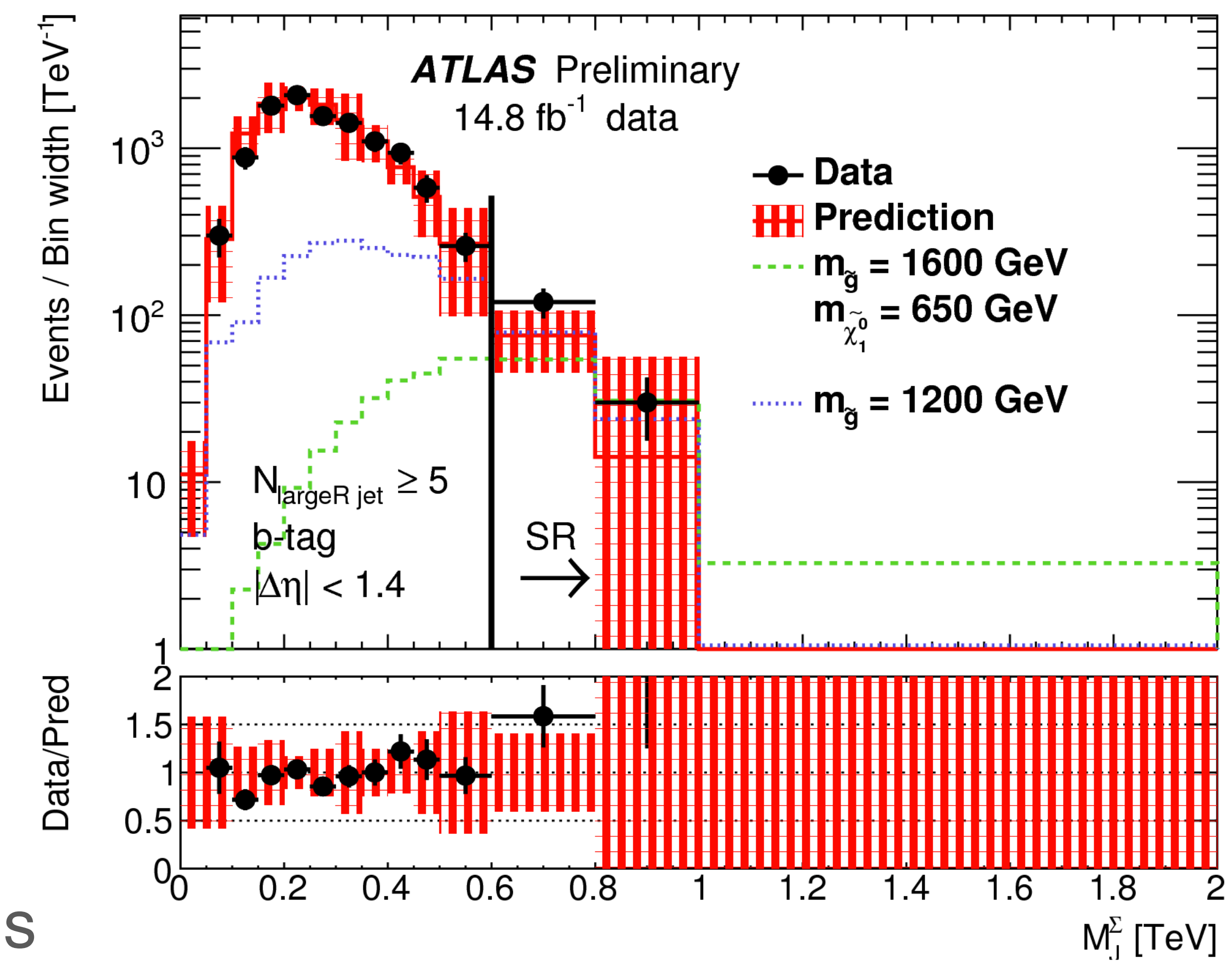
- other searches with RPV interpretations are presented at EPS and/or can be found on our public results web page

Multi-jet final states from gluino pair production

- benchmark models
  - only UDD coupling non-zero
  - gluino pair production independent of λ"
  - all possible λ" flavour combinations equal
  - prompt gluino and neutralino decays
  - gluino masses between 900 and 1900 GeV, neutralino masses between 50 and 1650 GeV



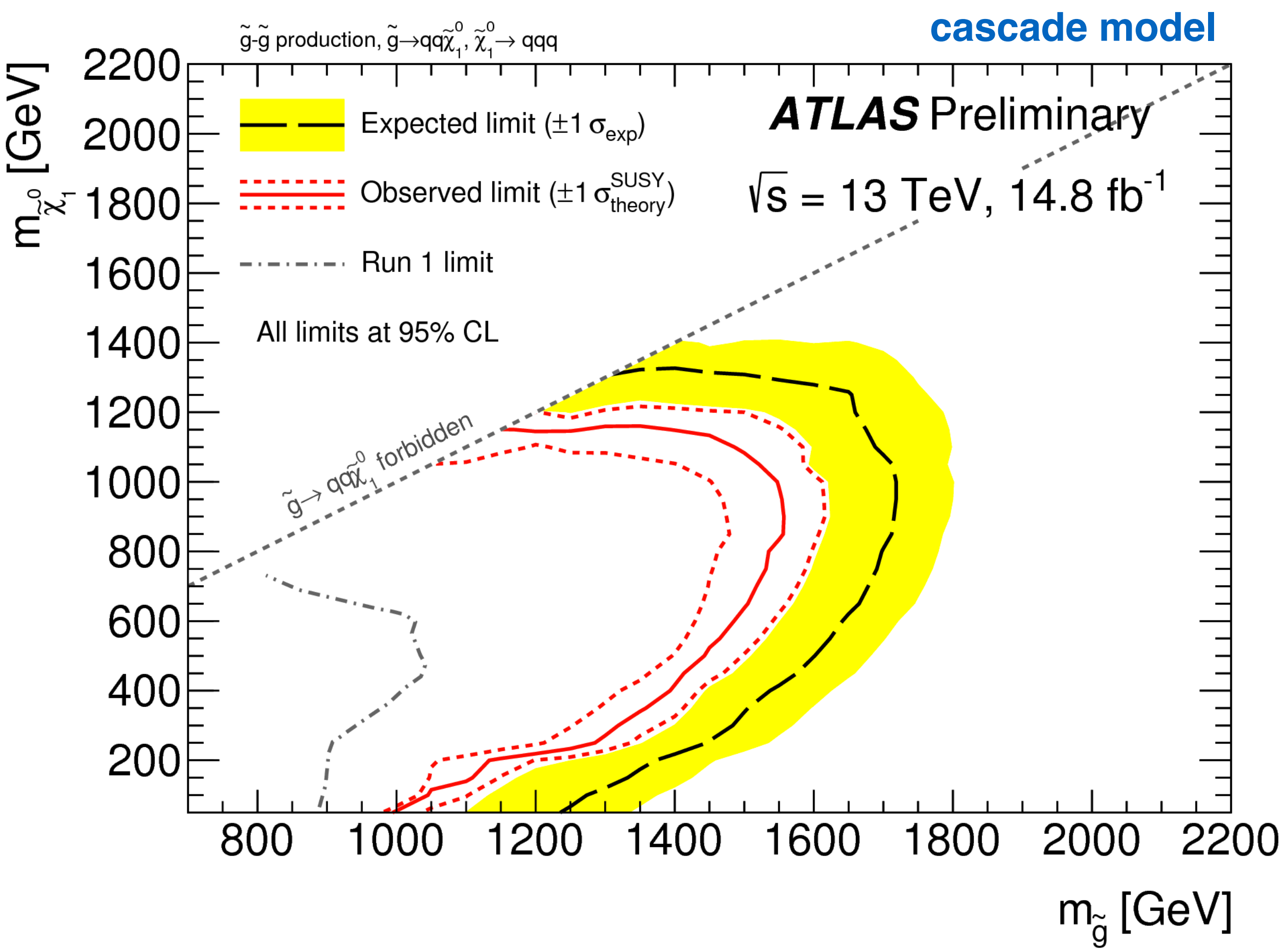
- signatures
  - high multiplicity of jets, likely at least one bottom or top quark
- analysis strategy
  - require at least four central large-radius jets (anti-k_T, R=1.0)
  - *b*-tag, *b*-veto, inclusive selection
  - primary signal—background discrimination based on total jet mass M_J^Σ (scalar sum of four leading central large-radius jets)
  - $|\Delta\eta_{12}|$ to define control and validation regions
  - data-driven jet-mass template method to estimate background

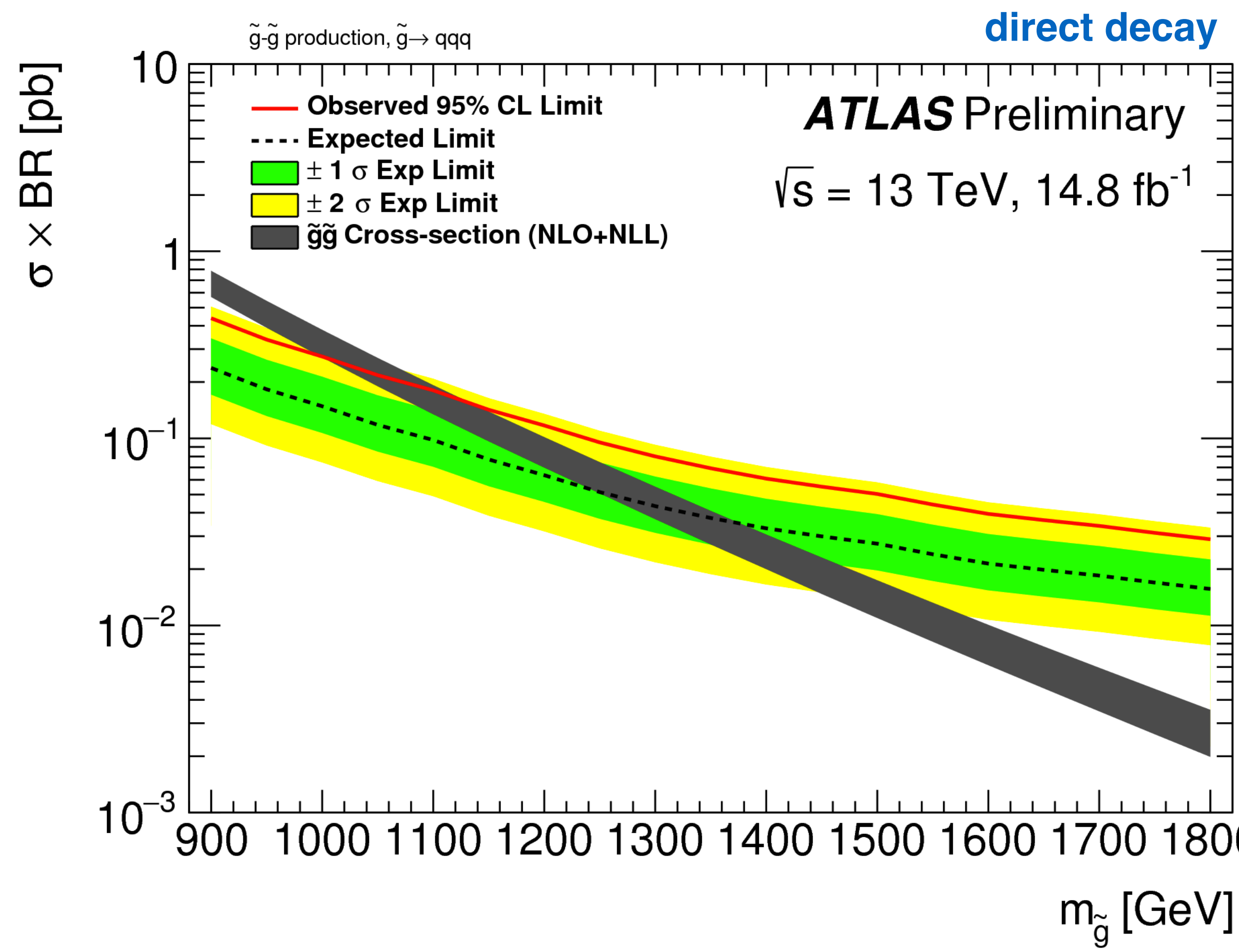


13 TeV, 14.8/fb ATLAS-CONF-2016-057

Multi-jet final states from gluino pair production

- results
  - no significant excess seen in any signal region
  - limits on gluino mass
    - between 1000 and 1550 GeV in cascade model
    - up to 1080 GeV in direct-decay model
  - also model-independent limits on production cross section





13 TeV, 14.8/fb ATLAS-CONF-2016-057

Pair-produced resonances in four jets final states

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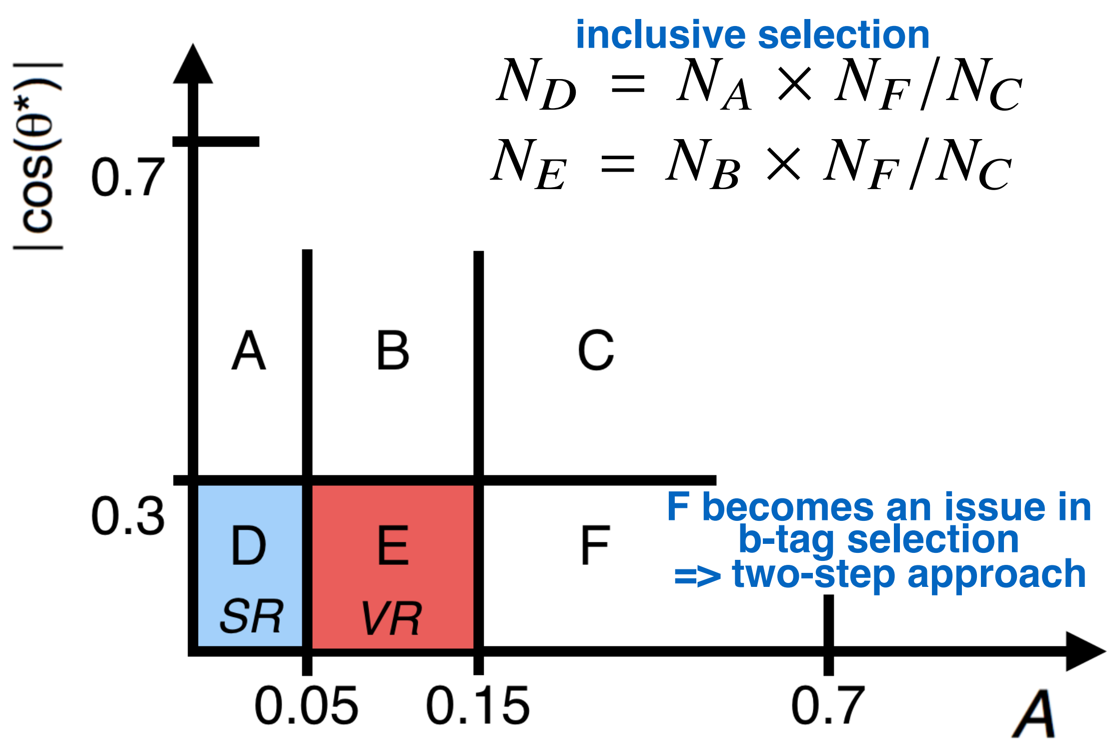
$$\Delta R_{\min} = \sum_{i=1,2} |\Delta R_i - 1|$$

$$\Delta R_{\min} > -0.002 \cdot (m_{\text{avg}}/\text{GeV} - 225) + 0.72 \qquad \text{if } m_{\text{avg}} \leq 225 \text{ GeV}$$

$$\Delta R_{\min} > +0.0013 \cdot (m_{\text{avg}}/\text{GeV} - 225) + 0.72 \qquad \text{if } m_{\text{avg}} > 225 \text{ GeV}$$

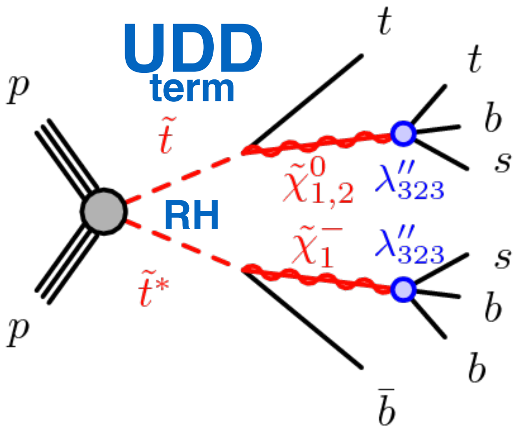
$$\mathcal{A} = \frac{|m_1 - m_2|}{m_1 + m_2}$$

$$m_{\text{avg}} = \frac{1}{2}(m_1 + m_2)$$



13 TeV, 36.7/fb ATLAS-CONF-2017-025

Lepton plus high jet multiplicity final state



$\tilde{t} \rightarrow t\tilde{\chi}_1^0$ bino-like LSP

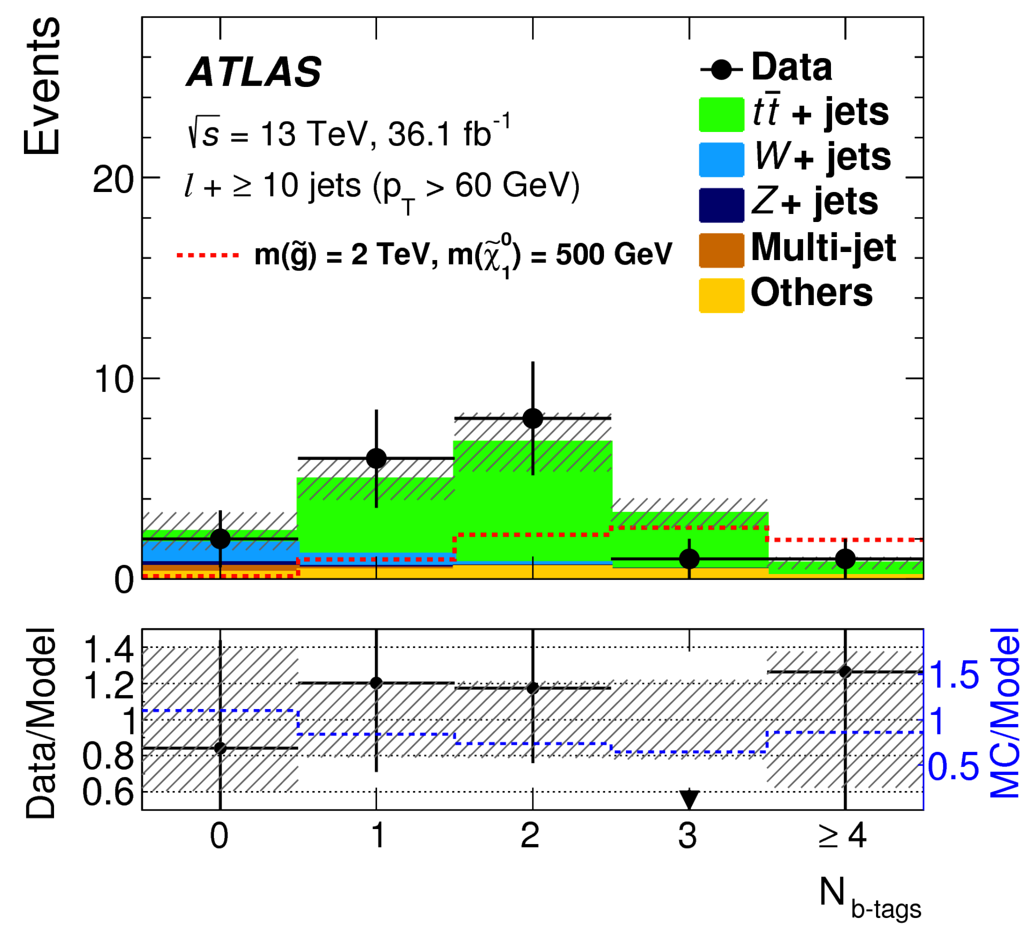
$\tilde{t} \rightarrow t\tilde{\chi}_2^0$ $(\approx 25\%)$, $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ $(\approx 25\%)$, $\tilde{t} \rightarrow b\tilde{\chi}_1^+$ $(\approx 50\%)$ higgsino-like LSP

$\tilde{t} \rightarrow \bar{b}\bar{s}$ wino-like LSP, no leptons

$\tilde{\chi}_{1/2}^0 \rightarrow tbs$

$\tilde{\chi}_1^\pm \rightarrow bbs$

- search done with different jet-p_T thresholds (40, 60, 80 GeV)
- *b*-tag multiplicity shape per jet slice from MC for W/Z+jets and data for ttbar
- model-independent approach assumes no significant signal in low jet-multiplicity bins
- multi-jets fake or non-prompt background estimated using matrix method and data control regions



13 TeV, 36.1/fb arXiv:1704.08493

Lepton plus high jet multiplicity final state

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Jet multiplicity	0 b obs. [fb]	0 b exp. [fb]	$\geq$ 3 b obs. [fb]	$\geq$ 3 b exp. [fb]
≥ 10 jets ($p_T > 40$ GeV)	0.32	$0.36^{+0.16}_{-0.10}$	0.57	$0.54^{+0.24}_{-0.15}$
≥ 11 jets ($p_T > 40$ GeV)	0.17	$0.16^{+0.08}_{-0.05}$	0.33	$0.25^{+0.12}_{-0.07}$
≥ 12 jets ($p_T > 40$ GeV)	0.08	$0.09^{+0.05}_{-0.01}$	0.17	$0.13^{+0.07}_{-0.04}$
≥ 8 jets ($p_T > 60$ GeV)	0.73	$0.71^{+0.27}_{-0.20}$	1.02	$1.03^{+0.39}_{-0.29}$
≥ 9 jets ($p_T > 60$ GeV)	0.35	$0.28^{+0.12}_{-0.08}$	0.19	$0.32^{+0.15}_{-0.09}$
≥ 10 jets ($p_T > 60$ GeV)	0.12	$0.14^{+0.07}_{-0.04}$	0.11	$0.15^{+0.08}_{-0.04}$
≥ 8 jets ($p_T > 80$ GeV)	0.38	$0.31^{+0.14}_{-0.09}$	0.21	$0.28^{+0.13}_{-0.08}$
≥ 9 jets ($p_T > 80$ GeV)	0.15	$0.13^{+0.07}_{-0.04}$	0.09	$0.13^{+0.07}_{-0.04}$
≥ 10 jets ($p_T > 80$ GeV)	0.10	$0.08^{+0.04}_{-0.00}$	0.08	$0.08^{+0.04}_{-0.00}$

13 TeV, 36.1/fb arXiv:1704.08493

B-L scalar-top pairs

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$$m_{b\ell}^{\text{asym}} = \frac{m_{b\ell}^0 - m_{b\ell}^1}{m_{b\ell}^0 + m_{b\ell}^1}$$

$$H_{\mathrm{T}} = \sum_{i=1}^{2} p_{\mathrm{T}}^{\ell_i} + \sum_{j=1}^{2} p_{\mathrm{T}}^{\text{jet}_j}$$

$H_{\mathrm{T}} > 1000$ GeV
invariant mass of two same-flavor leptons, with $m_{\ell\ell} > 300$ GeV
$m_{b\ell}^1(\text{rej}) < 150$ GeV

Region	N_b	$m_{b\ell}^0$ [GeV]	$m_{b\ell}^1(\text{rej})$[GeV]	H_{T} [GeV]	$m_{\ell\ell}$ [GeV]	m_{CT} [GeV]
SR800	≥ 1	> 800	> 150	> 1000	> 300	–
SR1100	≥ 1	> 1100	> 150	> 1000	> 300	–
CRtt	≥ 1	[200,500]	< 150	[600,800]	> 300	$< 200^*$
CRst	$= 2$	[200,500]	< 150	< 800	> 120	> 200
CRZ	≥ 1	> 700	–	> 1000	[76.2,106.2]	–
VR$m_{b\ell}^0$	≥ 1	> 500	< 150	[600,800]	> 300	–
VR$m_{b\ell}^1$(rej)	≥ 1	[200,500]	> 150	[600,800]	> 300	–
VRH_{T}	≥ 1	[200,500]	< 150	> 800	> 300	–
VRZ	$= 0$	[500,800]	> 150	> 1000	> 300	–

13 TeV, 36.1/fb ATLAS-CONF-2017-036

B-L scalar-top pairs

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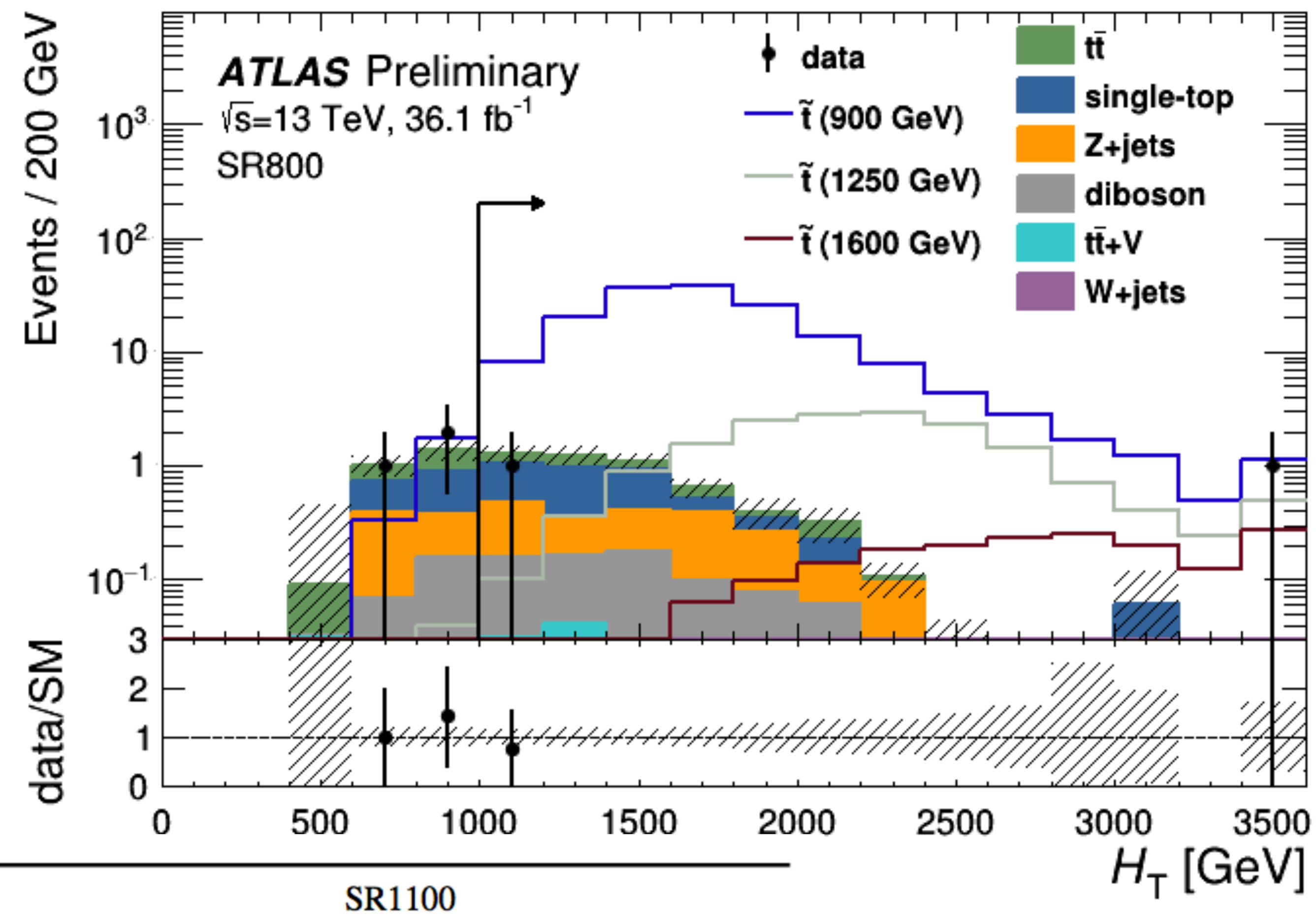

	SR800				SR1100			
	inclusive	ee	$e\mu$	$\mu\mu$	inclusive	ee	$e\mu$	$\mu\mu$
Observed yield	2	0	0	2	1	0	0	1
Total post-fit bkg yield	5.2 ± 1.4	1.8 ± 0.5	2.1 ± 0.8	1.35 ± 0.32	$1.2^{+0.6}_{-0.5}$	$0.51^{+0.22}_{-0.20}$	$0.44^{+0.39}_{-0.33}$	0.22 ± 0.13
Post-fit single-top yield	2.0 ± 1.3	0.6 ± 0.4	1.1 ± 0.7	0.32 ± 0.20	0.32 ± 0.29	0.11 ± 0.10	0.21 ± 0.19	–
Post-fit Z+jets yield	1.40 ± 0.33	0.80 ± 0.24	0.01 ± 0.01	0.59 ± 0.14	0.47 ± 0.15	0.28 ± 0.10	–	0.19 ± 0.11
Post-fit $t\bar{t}$ yield	1.0 ± 0.5	0.27 ± 0.14	0.54 ± 0.25	0.21 ± 0.10	$0.21^{+0.55}_{-0.21}$	$0.06^{+0.16}_{-0.06}$	$0.13^{+0.34}_{-0.13}$	$0.01^{+0.03}_{-0.01}$
Post-fit diboson yield	0.64 ± 0.23	0.14 ± 0.05	0.31 ± 0.12	0.19 ± 0.08	0.13 ± 0.05	0.06 ± 0.03	0.07 ± 0.03	0.01 ± 0.01
Post-fit $t\bar{t}+V$ yield	0.12 ± 0.03	0.01 ± 0.01	0.07 ± 0.02	0.04 ± 0.02	0.03 ± 0.01	–	0.01 ± 0.01	0.01 ± 0.01
Post-fit W+jets yield	0.03 ± 0.03	–	0.04 ± 0.04	–	$0.01^{+0.02}_{-0.01}$	–	$0.01^{+0.02}_{-0.01}$	–
Total MC bkg yield	4.9 ± 1.2	1.7 ± 0.4	2.0 ± 0.7	1.23 ± 0.28	$1.1^{+0.6}_{-0.5}$	$0.46^{+0.21}_{-0.19}$	$0.43^{+0.40}_{-0.33}$	0.18 ± 0.10
MC single-top yield	1.9 ± 1.0	0.57 ± 0.34	1.0 ± 0.6	0.29 ± 0.17	0.29 ± 0.25	0.10 ± 0.08	0.19 ± 0.17	–
MC Z+jets yield	1.15 ± 0.21	0.65 ± 0.17	0.01 ± 0.01	0.48 ± 0.09	0.38 ± 0.10	0.23 ± 0.07	–	0.15 ± 0.09
MC $t\bar{t}$ yield	1.1 ± 0.5	0.29 ± 0.14	0.57 ± 0.26	0.22 ± 0.10	$0.22^{+0.57}_{-0.22}$	$0.07^{+0.18}_{-0.07}$	$0.14^{+0.36}_{-0.14}$	$0.01^{+0.03}_{-0.01}$
MC diboson yield	0.64 ± 0.23	0.14 ± 0.05	0.31 ± 0.12	0.19 ± 0.08	0.13 ± 0.05	0.06 ± 0.03	0.07 ± 0.03	0.01 ± 0.01
MC $t\bar{t}+V$ yield	0.12 ± 0.03	0.01 ± 0.01	0.07 ± 0.02	0.04 ± 0.02	0.03 ± 0.01	–	0.01 ± 0.01	0.01 ± 0.01
MC W+jets yield	0.03 ± 0.03	–	0.04 ± 0.04	–	$0.01^{+0.02}_{-0.01}$	–	$0.01^{+0.02}_{-0.01}$	–
$N^{\mathrm{limit}}_{\mathrm{BSM}}$ exp (95% CL)	$6.4^{+3.0}_{-1.9}$	$4.1^{+1.8}_{-1.1}$	$4.0^{+2.2}_{-0.9}$	$3.9^{+1.6}_{-0.7}$	$3.9^{+2.4}_{-0.5}$	$3.0^{+1.3}_{-0.0}$	$3.0^{+1.3}_{-0.0}$	$3.1^{+0.6}_{-0.1}$
$N^{\mathrm{limit}}_{\mathrm{BSM}}$ obs (95% CL)	4.0	3.0	3.0	4.8	3.9	3.0	3.1	4.1
$\sigma^{\mathrm{vis}}_{\mathrm{BSM}}$[fb]	0.11	0.08	0.08	0.13	0.11	0.08	0.08	0.11

13 TeV, 36.1/fb ATLAS-CONF-2017-036