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A search for pair-produced resonances in 4-jet final state

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Motivation

- Paired dijet resonances are predicted in many SM extensions
  - Supersymmetry with R-parity violating (RPV) couplings allows the lightest supersymmetric particle (LSP) to decay to two jets
  - Models with Dirac gauginos, additional gluinos
  - Axigluons, colorons, compositeness, topcolor
- Naturalness suggests higgsinos and top squarks below 1 TeV
- Top squarks in R-parity conserving scenarios have been thoroughly searched for and are ~excluded below 1 TeV
- Allowing RPV couplings significantly relaxes existing bounds on mass

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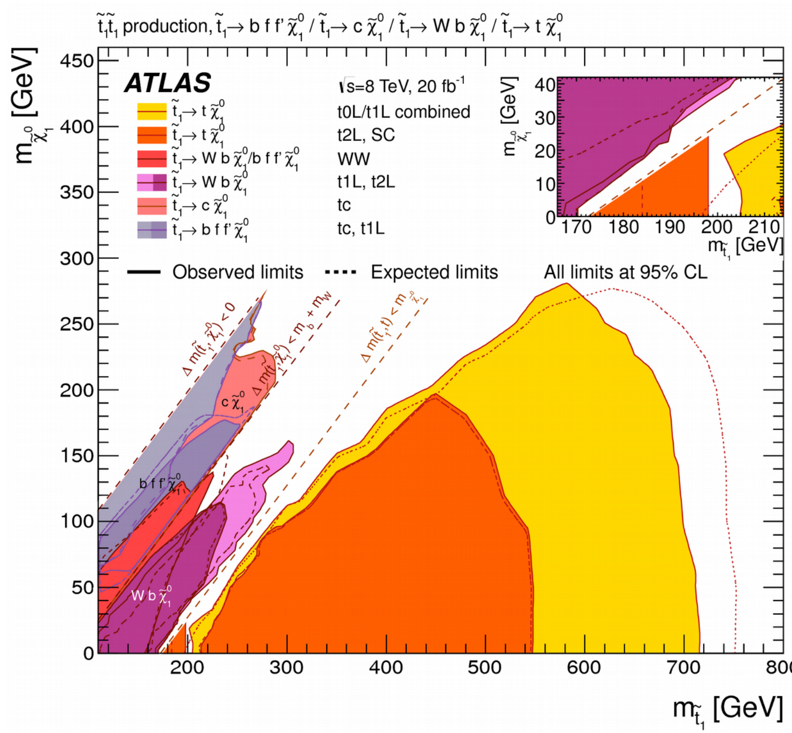
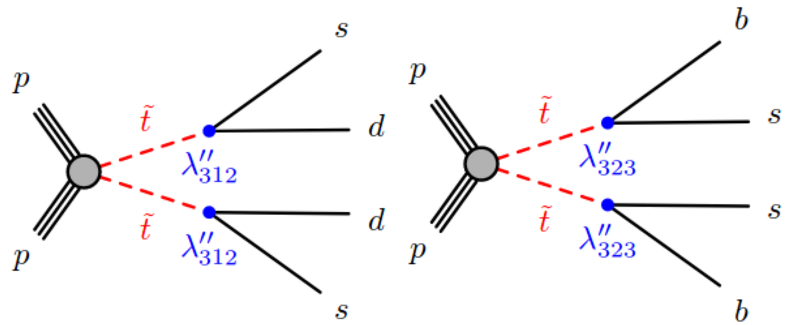


Analysis Overview

- This search for pair-produced, massive, colored particles deacying to two jets uses 36.7 fb^{-1} of $\sqrt{s}$ = 13 TeV with the ATLAS detector
- Interpreted in a SUSY simplified model where the LSP is the top squark $\tilde{t}$
- RPV couplings assumed sufficiently large for the decay to be prompt
- Additional limits set on pair-produced massive color octet



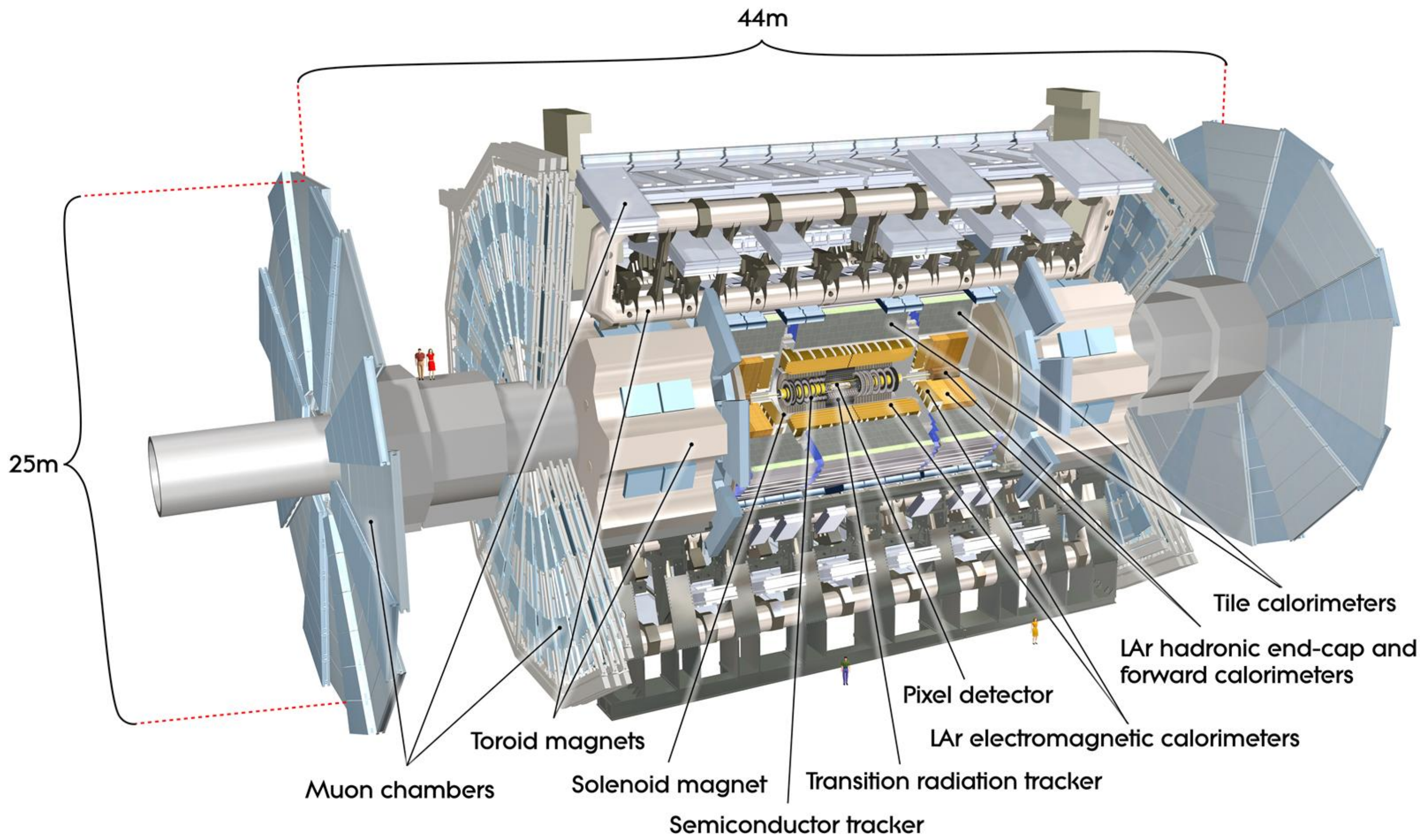
(a) $\tilde{t}\tilde{t}^* \to (\bar{d}\bar{s})(ds)$ (b) $\tilde{t}\tilde{t}^* \to (\bar{b}\bar{s})(bs)$

- Fully hadronic final states without missing E_T challenging signature due to large SM multi-jet production cross-section

  → Use b-tagging and mass symmetry of the resonances

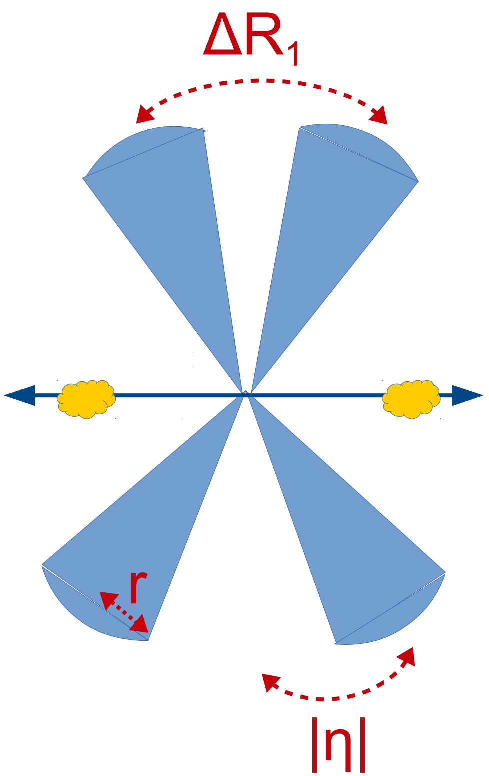
- The results have been submitted to EPJC and are available now at arXiv:1710.07171

Hmm.. ATLAS, you say.. What is that?



Event Selection

- Jets are reconstructed from 3-D topological clusters calibrated at the electromagnetic scale
- Reconstructed with Anti-kt jet algorithm with r = 0.4
- At least 4 jets with pT > 120 GeV
- $|\eta| < 2.4$
- Pairing: minimize $\Delta R_{min} = \Sigma\, |\Delta R_i - 1|$
- $\Delta R_{min} < -0.002*(m_{avg}/\text{GeV} - 225) + 0.72$
  if $m_{avg} <= 225$ GeV
- $\Delta R_{min} < -0.0013*(m_{avg}/\text{GeV} - 225) + 0.72$
  if $m_{avg} > 225$ GeV



Signal Region Selection

- The mass of the two resonances should be similar:

$$\frac{|m_1 - m_2|}{m_1 + m_2} < 0.05$$

- The jets should be central in the detector:

$$|\cos(\theta^*)| < 0.3$$

- ALSO a dedicated two-*b*-tagged SR is used for scenarios where RPV couplings involving third generation quarks dominate

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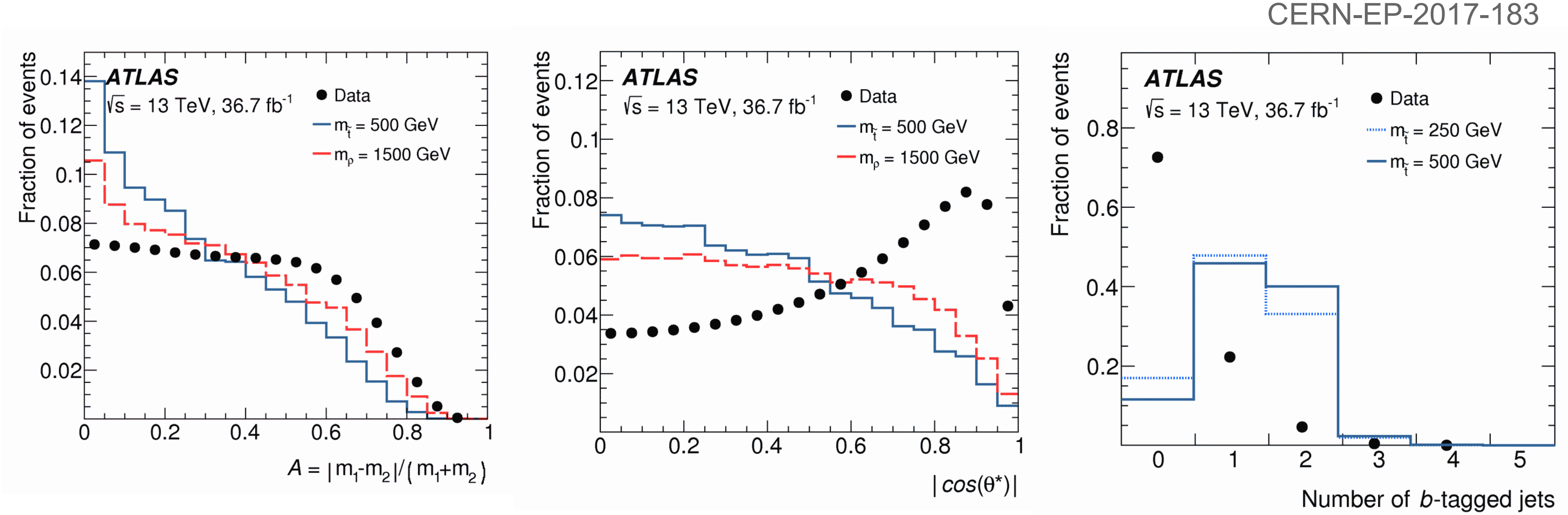

Signal Region Selection

- Final analysis discriminant is the average mass of the reconstructed resonances

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

- Smooth distribution from multi-jet processes
- Mass window defined for each mass point to maximise expected signal significance
- Counting experiment performed in each mass window

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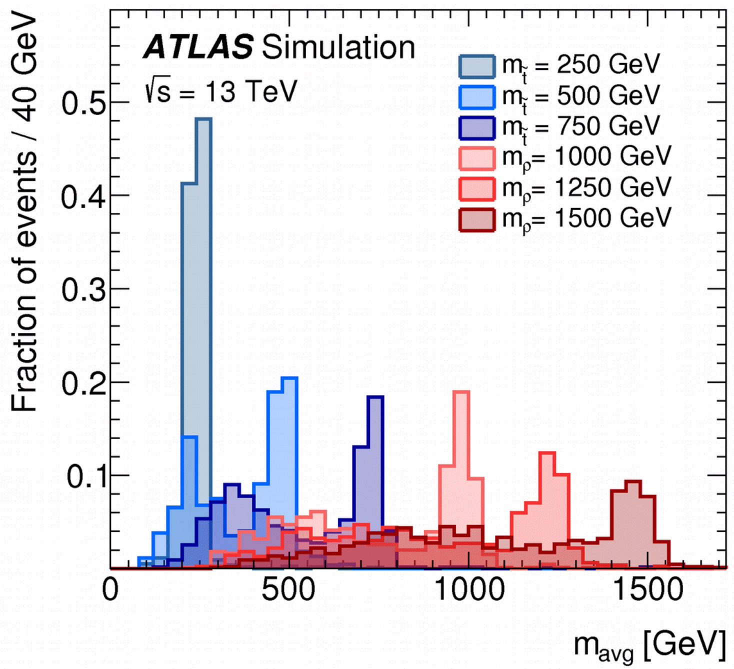
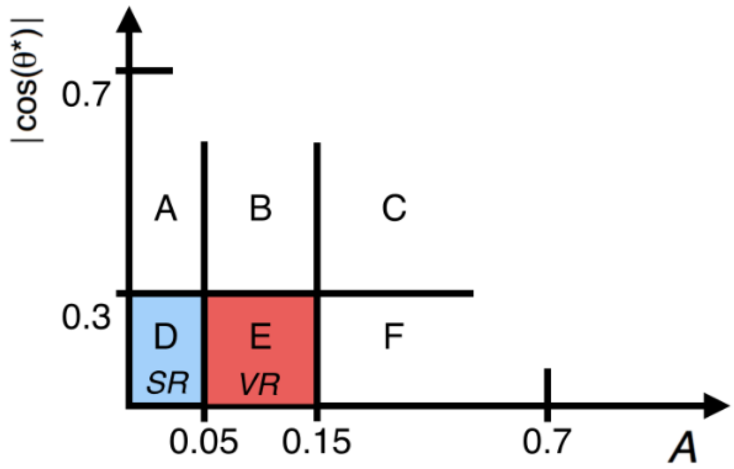


Background Estimation

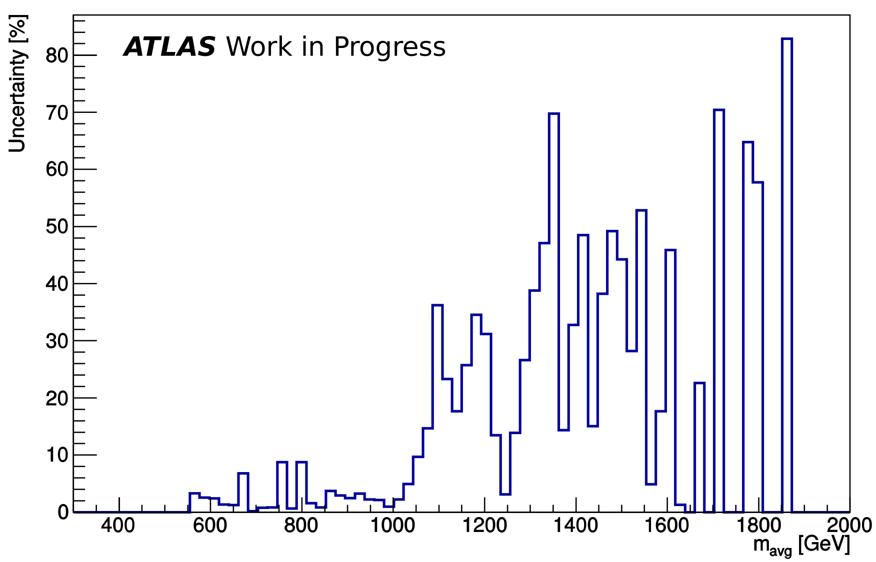
- Multi-jet background dominates the inclusive SR
  - Estimated from data
- $t\bar{t}$ background significant in the b-tagged SR
  - Estimated from simulation
- ABCD method assumes no correlation between the discriminating variables

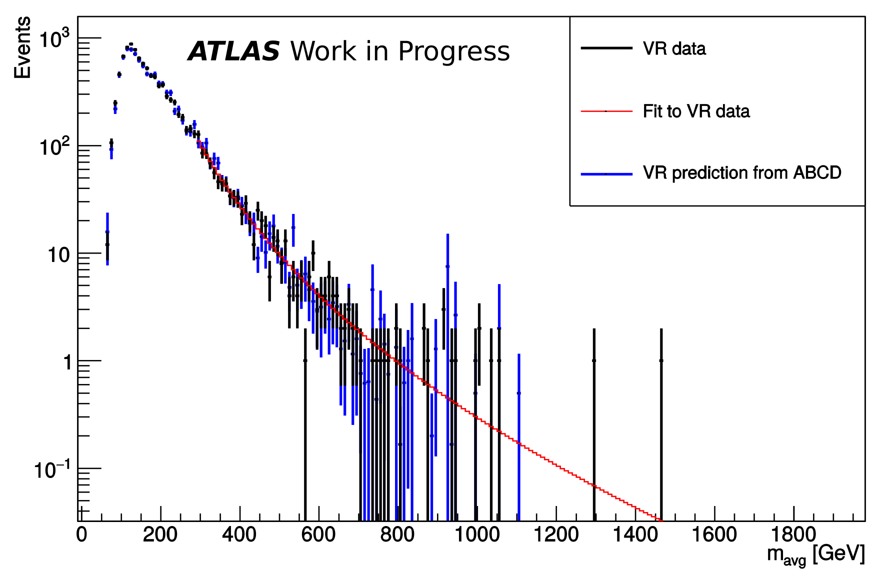


- Four control regions (CR)
- One validation region (VR) for testing performance and assigning an uncertainty to the background estimate

Background Uncertainty

- Data-driven multi-jet background estimate → No model uncertainty
- Uncertainty primarily from the method
- This is estimated by fitting data in the VR and taking the bin-by-bin difference from the ABCD prediction
- The relative deviation is then smoothed as function of m_{avg}





Systematic Uncertainties

- Top background and signal also affected by detector effects and MC modeling
  - Jet energy scale and resolution
  - B-tagging efficiency and mis-tag rate
  - Choice of MC generator
  - Renormalisation and factorisation scale

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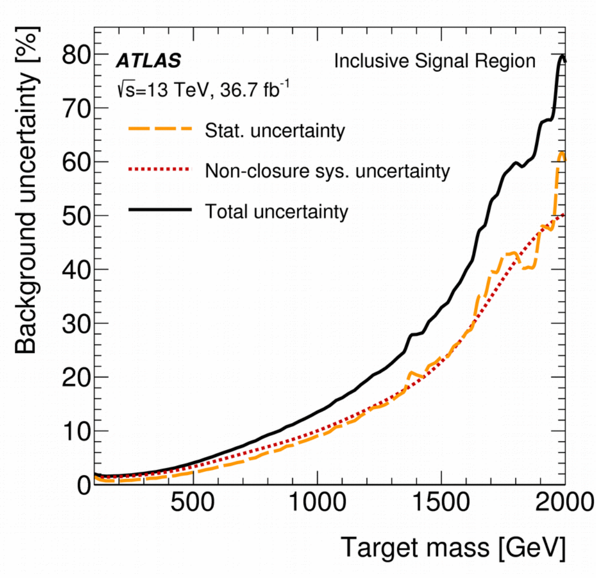
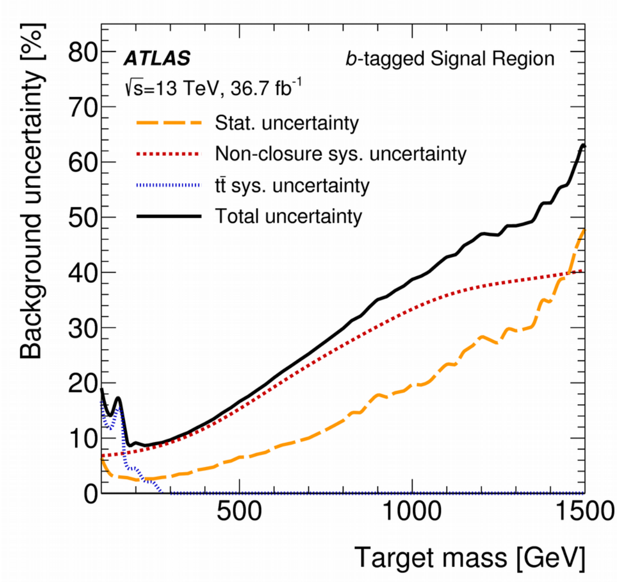
- Evaluated by comparing the nominal samples to additional samples with systematic variations





Results and Interpretation

- The m_{avg} distribution in the inclusive and *b*-tagged regions
- Agreement between data and expected background

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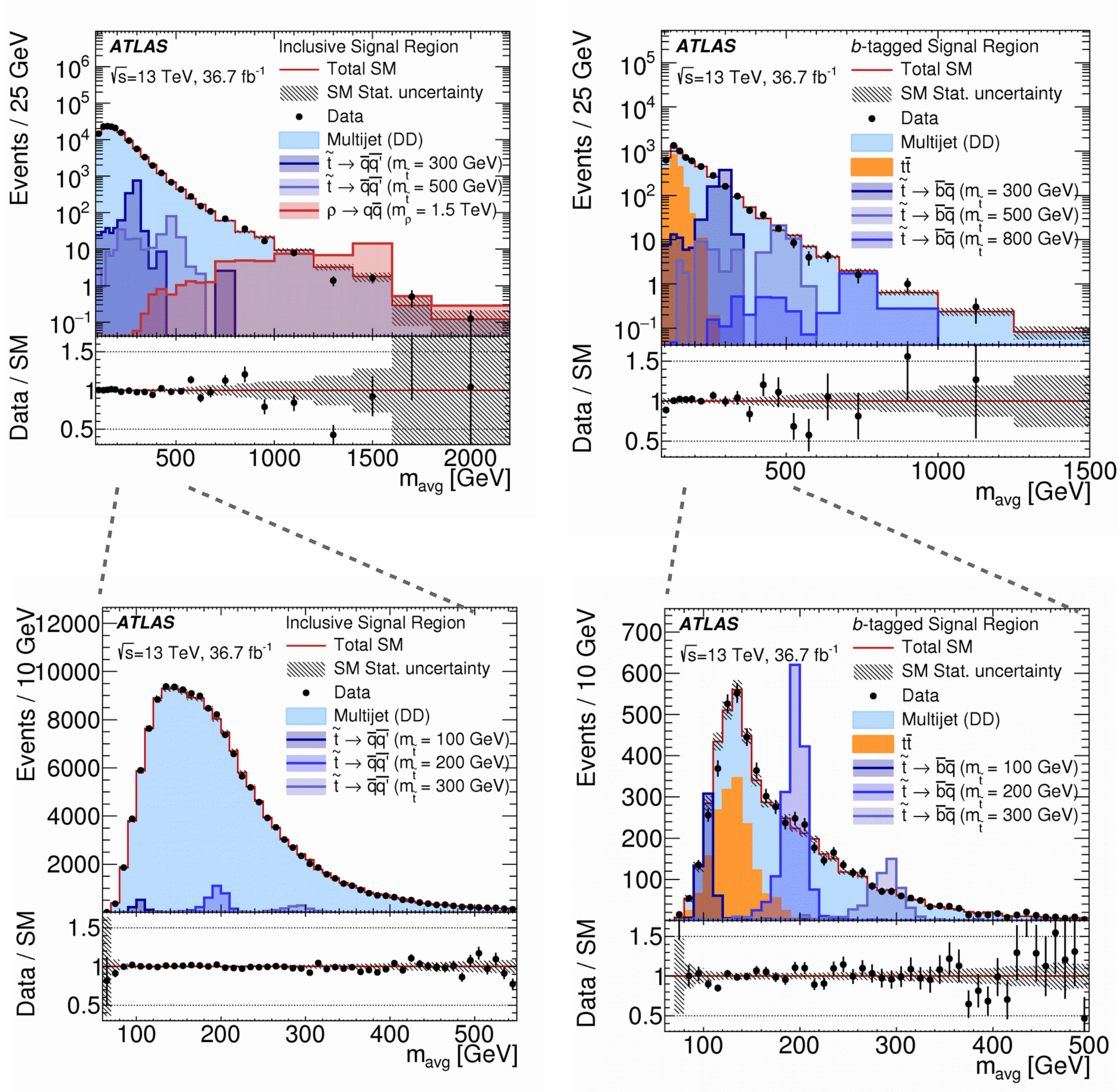

Results and Interpretation

- The inclusive SR used to set limits on stop, sgluon, and coloron production with decays in to a jet pair
- The *b*-tagged SR used for limits on stop to a *b*- and light-quark jet
- Acceptance drops below a stop mass of 200 GeV due to trigger and jet requirements

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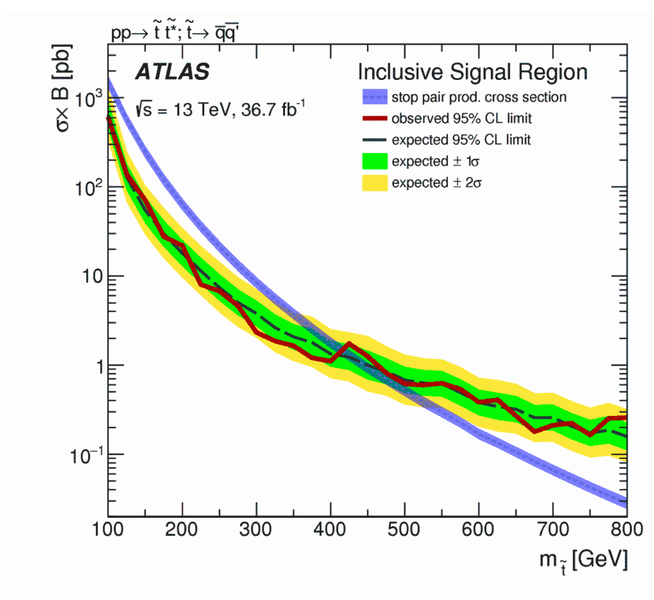
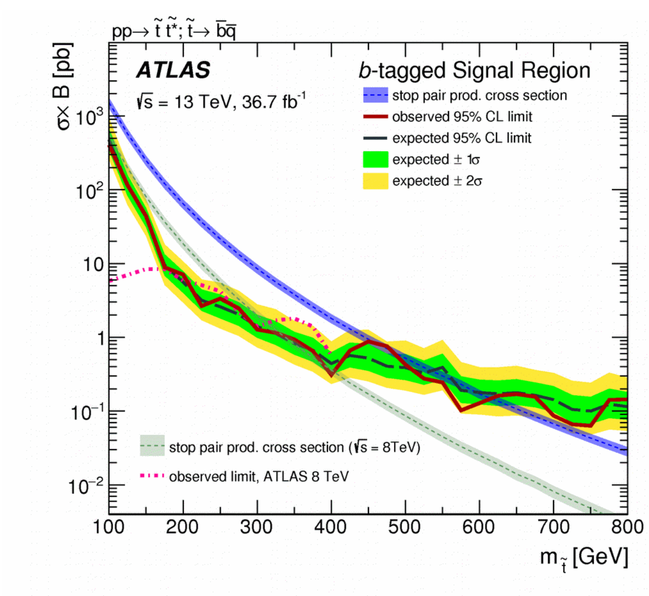
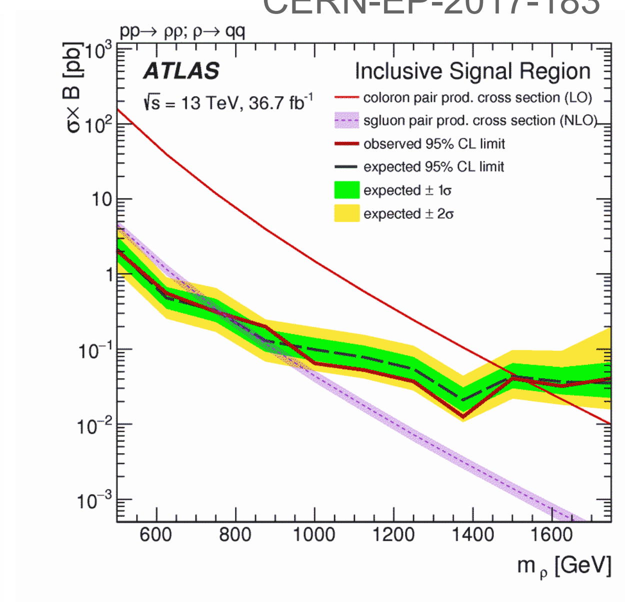
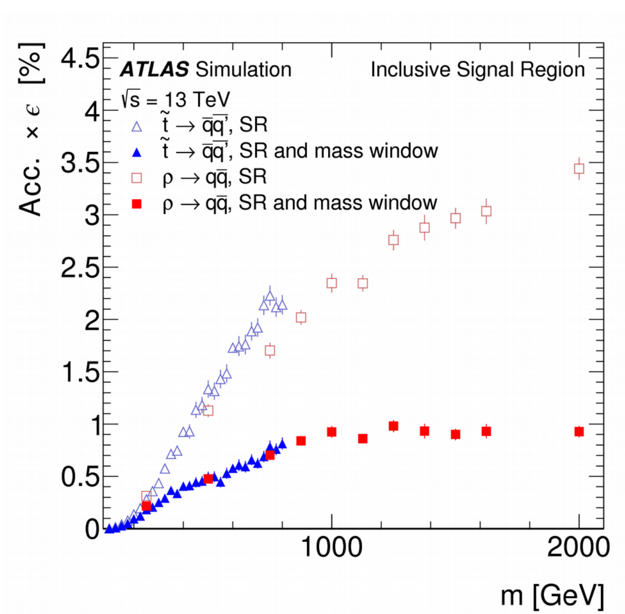


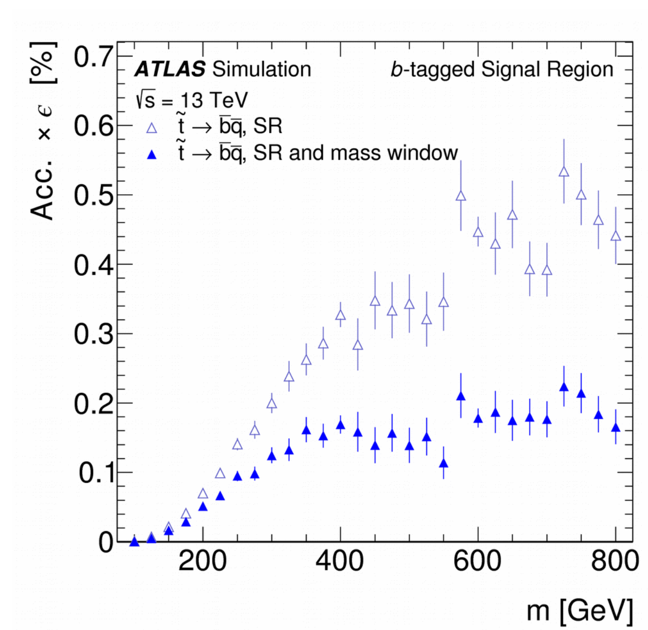




Outlook

- Use background fit as primary method for background estimation
  - Acceptance increase
  - More flexible for different signal shapes
  - Less model dependent
  - Could use two “fat jets” with substructure





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References

- [1] ATLAS Collaboration (Georges Aad (Marseille, CPPM) et al.), *ATLAS Run 1 searches for direct pair production of third-generation squarks at the Large Hadron Collider*, Jun 29, 2015. 54 pp. Published in Eur.Phys.J. C75 (2015) no.10, 510, Erratum: Eur.Phys.J. C76 (2016) no.3, 153 CERN-PH-EP-2015-138

- [2] ATLAS Collaboration (Morad Aaboud (Oujda U.) et al.), *A search for pair-produced resonances in four-jet final states at $\sqrt{s}=13$ TeV with the ATLAS detector*, Oct 19, 2017. 41 pp. CERN-EP-2017-183

Back up

- Correlation of discriminating variables

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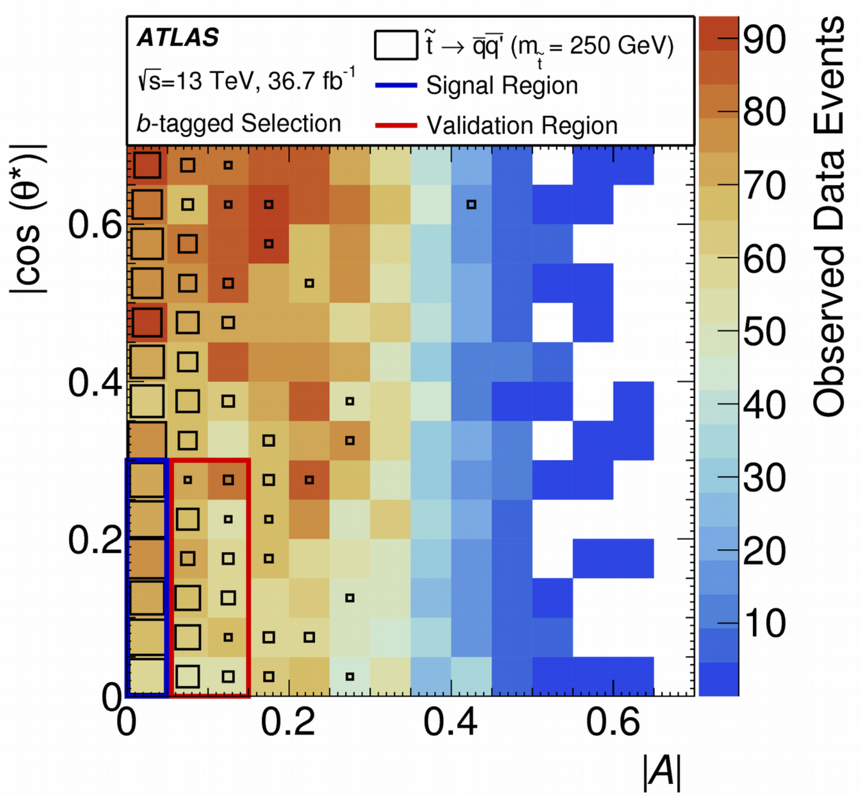

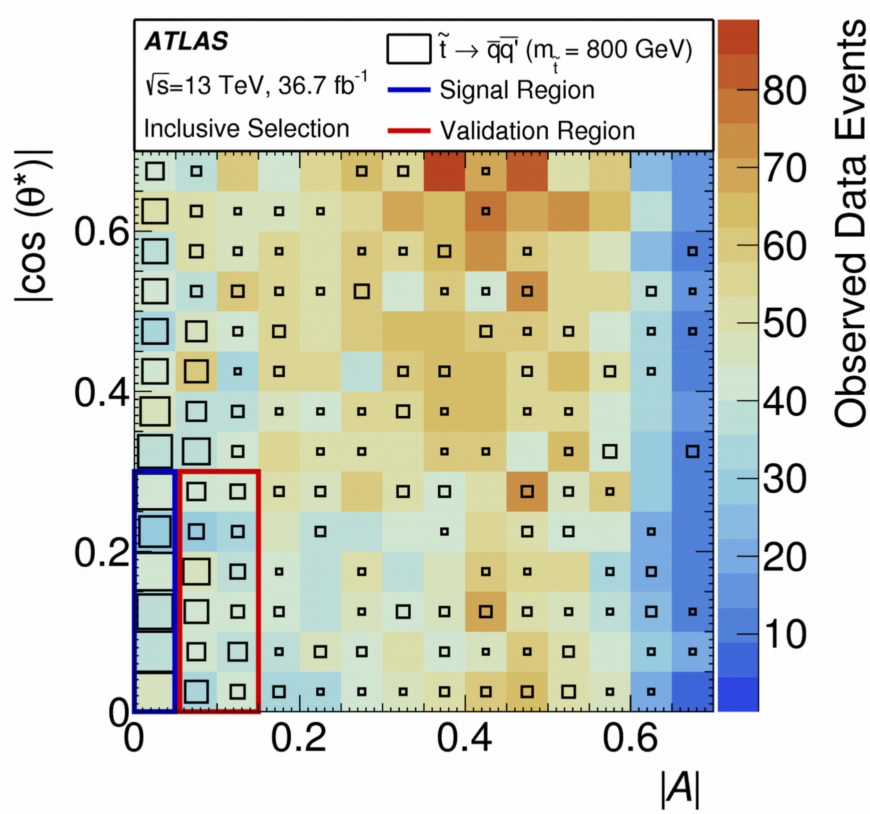

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- Observed number of events in inclusive SR

$m_{\tilde{t}}$ [GeV]	Window [GeV]	N_{Data}	N_{Bkg} (± stat. ± syst.)	N_{Sig} (± stat. ± syst.)
100	[100, 110]	5899	5910 ± 90 ± 70	519 ± 23 ± 68
125	[120, 135]	13 497	13 450 ± 120 ± 180	1890 ± 50 ± 190
150	[140, 160]	18 609	18 390 ± 130 ± 250	2540 ± 50 ± 130
175	[165, 185]	17 742	17 800 ± 130 ± 250	2280 ± 50 ± 210
200	[185, 210]	19 844	19 660 ± 140 ± 290	2250 ± 50 ± 170
225	[210, 235]	14 898	15 180 ± 120 ± 230	1620 ± 40 ± 100
250	[230, 260]	13 689	13 750 ± 110 ± 220	1440 ± 80 ± 140
275	[255, 285]	9808	9860 ± 100 ± 170	1010 ± 70 ± 80
300	[275, 310]	8514	8790 ± 90 ± 160	789 ± 52 ± 31
325	[300, 335]	6180	6330 ± 80 ± 120	600 ± 50 ± 50
350	[320, 365]	5802	5900 ± 70 ± 120	509 ± 39 ± 19
375	[345, 390]	4113	4250 ± 60 ± 90	324 ± 25 ± 31
400	[365, 415]	3531	3590 ± 60 ± 90	274 ± 14 ± 18
425	[385, 440]	3108	3010 ± 50 ± 80	198 ± 23 ± 10
450	[410, 465]	2281	2230 ± 40 ± 60	154 ± 17 ± 27
475	[430, 490]	1906	1920 ± 40 ± 60	116 ± 12 ± 8
500	[455, 515]	1495	1513 ± 35 ± 49	94 ± 10 ± 8
525	[475, 540]	1318	1327 ± 33 ± 46	71 ± 7 ± 4
550	[500, 565]	1050	1048 ± 29 ± 39	48.5 ± 5.4 ± 2.2
575	[520, 590]	924	912 ± 27 ± 36	44 ± 4 ± 4
600	[545, 620]	745	744 ± 25 ± 31	36.9 ± 1.6 ± 2.3
625	[565, 645]	645	626 ± 22 ± 28	30.3 ± 2.8 ± 3.4
650	[585, 670]	536	554 ± 21 ± 26	23.3 ± 2.1 ± 1.9
675	[610, 695]	438	473 ± 19 ± 24	20.3 ± 1.6 ± 0.9
700	[630, 720]	404	422 ± 18 ± 22	15.4 ± 1.2 ± 0.9
725	[655, 745]	341	335 ± 16 ± 18	13.6 ± 1.0 ± 0.9
750	[675, 770]	306	310 ± 16 ± 18	12.4 ± 0.9 ± 0.9
775	[700, 795]	265	243 ± 14 ± 14	9.7 ± 0.7 ± 0.7
800	[720, 820]	238	205 ± 12 ± 13	8.5 ± 0.6 ± 0.6

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Back up

- Observed number of events in the inclusive SR

$m_{\tilde{t}}$ [GeV]	Window [GeV]	N_{Data}	N_{Bkg} ($\pm$ stat. $\pm$ syst.)	N_{Sig} ($\pm$ stat. $\pm$ syst.)
100	[100, 110]	256	285 ±18 ± 51	308 ±18 ± 52
125	[120, 135]	803	798 ±28 ± 107	1090 ±40 ± 140
150	[140, 160]	809	789 ±23 ± 132	1510 ±40 ± 130
175	[165, 185]	544	555 ±16 ± 47	1300 ±40 ± 140
200	[185, 210]	592	554 ±13 ± 47	1220 ±40 ± 110
225	[210, 235]	414	436 ±11 ± 35	893 ±28 ± 90
250	[230, 260]	416	385 ±10 ± 32	750 ±60 ± 120
275	[255, 285]	302	283 ± 8 ± 24	480 ±50 ± 60
300	[275, 310]	242	250 ± 8 ± 23	390 ±40 ± 50
325	[300, 335]	181	179 ± 6 ± 17	273 ±33 ± 34
350	[320, 365]	169	161 ± 6 ± 16	225 ±25 ± 20
375	[345, 390]	110	111 ± 5 ± 12	147 ±16 ± 22
400	[365, 415]	80	96 ± 4 ± 11	114 ± 9 ± 12
425	[385, 440]	85	79 ± 4 ± 10	76 ±14 ± 11
450	[410, 465]	71	54.2± 3.0± 7.1	48 ± 9 ± 10
475	[430, 490]	67	46.8± 2.7± 6.5	40 ± 7 ± 5
500	[455, 515]	38	35.8± 2.3± 5.3	26 ± 5 ± 5
525	[475, 540]	31	35.1± 2.3± 5.5	21.7± 3.9± 2.8
550	[500, 565]	20	30.2± 2.1± 5.0	12.4± 2.5± 2.3
575	[520, 590]	14	26.3± 2.0± 4.6	17.5± 2.7± 3.5
600	[545, 620]	14	19.5± 1.6± 3.5	11.4± 0.9± 1.5
625	[565, 645]	15	15.8± 1.4± 3.0	9.3± 1.5± 1.4
650	[585, 670]	14	14.6± 1.3± 2.9	6.9± 1.2± 1.1
675	[610, 695]	13	13.6± 1.3± 2.8	5.5± 0.8± 0.6
700	[630, 720]	6	12.1± 1.2± 2.6	4.3± 0.6± 0.5
725	[655, 745]	5	9.9± 1.1± 2.2	4.4± 0.6± 0.8
750	[675, 770]	4	8.4± 0.1± 1.9	3.4± 0.5± 0.5
775	[700, 795]	8	6.9± 0.9± 1.6	2.4± 0.3± 0.5
800	[720, 820]	7	5.3± 0.7± 1.3	1.7± 0.3± 0.2

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Back up

- The observed local p_0-value
- The global p_0-value is computed from pseudo experiments

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