Search for chargino pair-production and chargino-neutralino production with *R*-Parity Violating decays in *pp* collisions at 13 TeV with ATLAS

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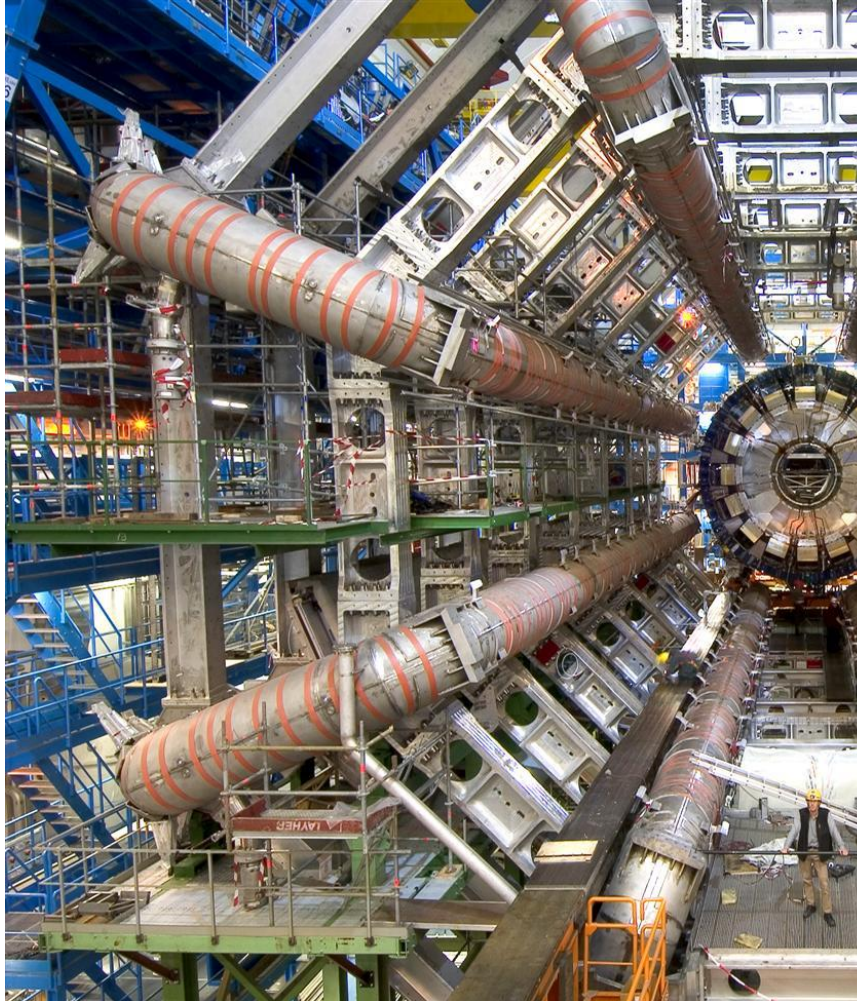
ATLAS and the LHC

- LHC produces *pp* collisions
- ATLAS is a multipurpose detector with ≈ 4π coverage, consisting of:
  - 2 T solenoid and 4 T toroid magnets
  - Inner charged-particle tracker
  - EM and hadronic calorimeters
  - Muon spectrometer
- 140 fb^{-1} of *pp* data collected in Run 2 (2015–2018)
- Run 3 ongoing (2022–)



Supersymmetry (SUSY) and *R*-parity violation (RPV)

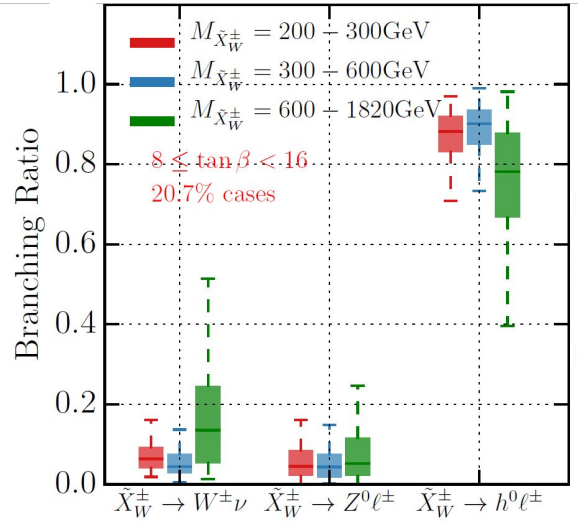
- SUSY has a "superpartner" for each Standard Model particle state
- Superpartners of electroweak sector (W, Z, Higgs) mix together and produce *electroweakinos:*
  - Charged states are **charginos**, numbered by mass (C1, C2, …)
  - Neutral states are **neutralinos**, numbered by mass (N1, N2, …)
- RPV: allows direct SUSY→SM decays, subject to phenomenological requirements

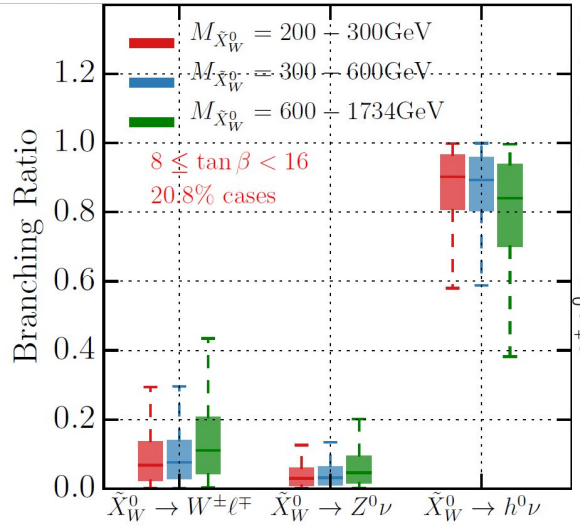
$$W^{\pm}, W^0, B^0, h^0, \ldots \quad \Longleftrightarrow \quad \tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0, \tilde{\chi}_2^0, \tilde{\chi}_3^0, \ldots$$

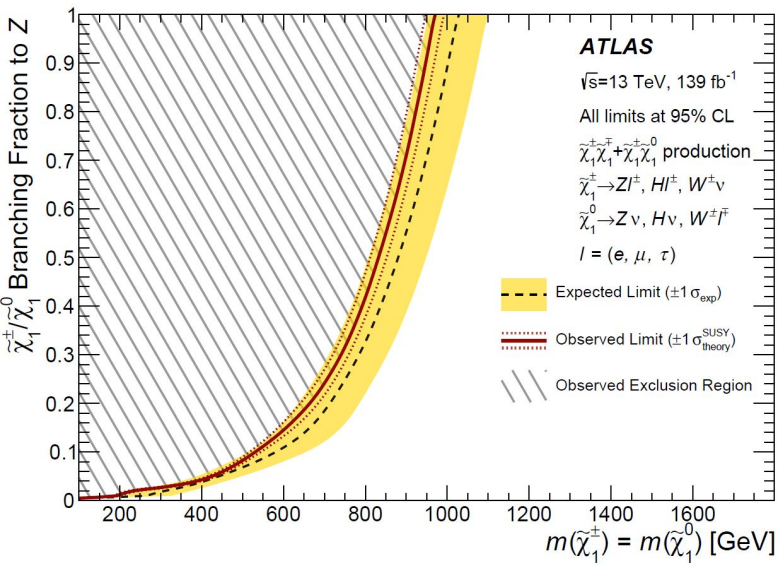
i.e. **C1, N1,** N2, N3, …

The B−L Minimal Supersymmetric Model (B−L MSSM)

- B−L MSSM adds $U(1)_{B-L}$ baryon minus lepton number symmetry
- We search for preferred, RPV decay of mass-degenerate **C1/N1 to *hℓ/hν***
- Previous ATLAS search explored trilepton signature, C1/N1 decay to *Zℓ/Zν*







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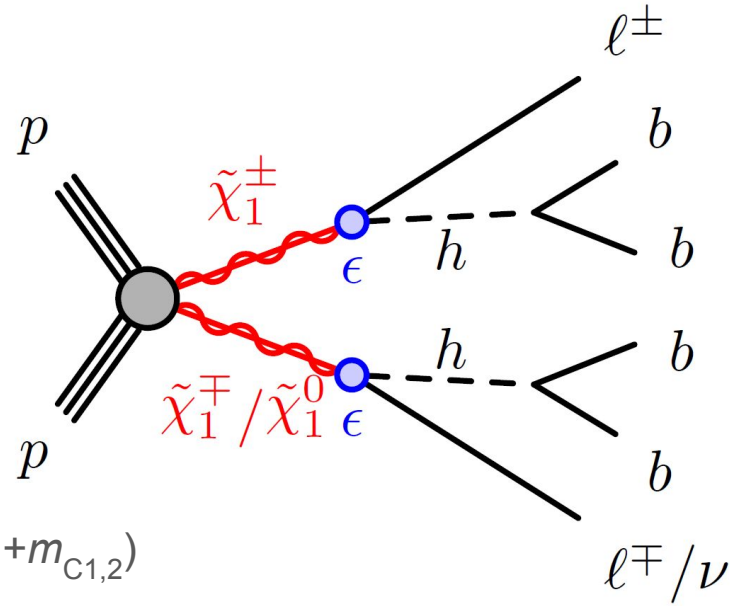
10.1103/PhysRevD.103.112003

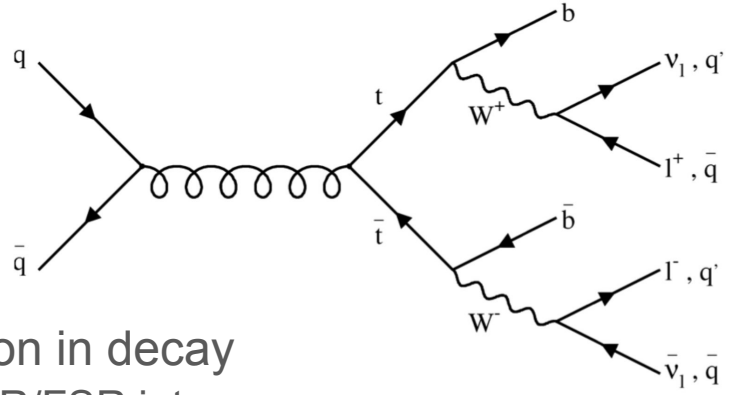
C1C1/C1N1 signal model, analysis strategy

- $4b2\ell$ and $4b1\ell$+E_T^{miss} final states
- Focus on $h \to bb$
  - BR($h \to bb$)^2 ≈ 34%
  - *b*-jets have distinct signature, tagged with 77% efficiency
  - Pair *b*-jets into h_1 and h_2 based on minimizing ΔR between jets in each Higgs
- Chargino-chargino (C1C1)
  - 2 opposite-sign leptons
  - Pair Higgs and lepton into C1 candidates
  - Minimize *mass asymmetry* $|m_{C1,1} - m_{C1,2}| / (m_{C1,1} + m_{C1,2})$
- Chargino-neutralino (C1N1)
  - Exploring pairing into C1, N1



Cuts, regions, and major backgrounds

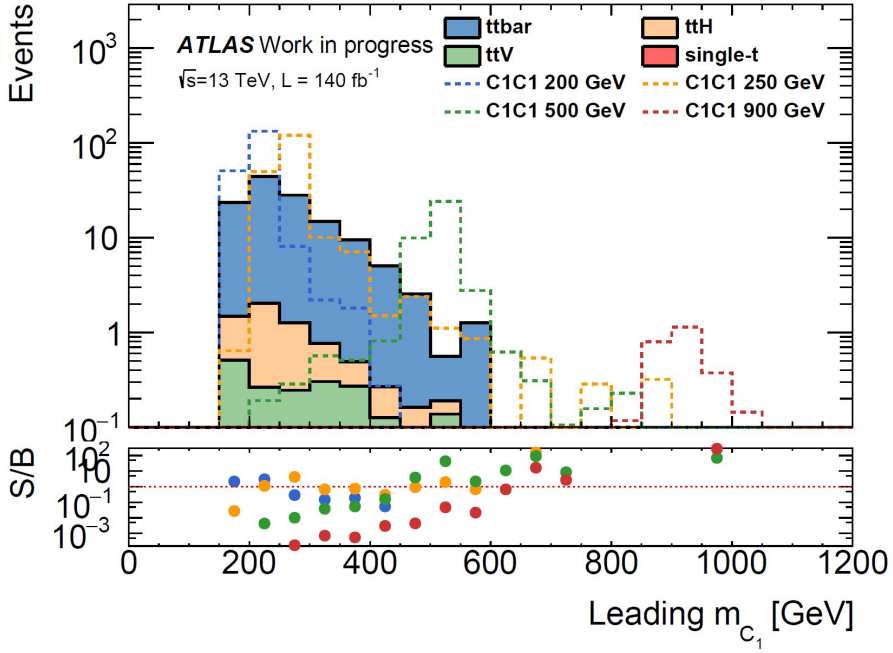
- Identify discriminating variables using Monte Carlo simulation of signal and background
- Place cuts on these variables to create different types of region:
  - Signal region (SR): optimized for signal to background significance
  - Control regions (CR): normalize backgrounds
  - Validation regions (VR): test background model close to SR

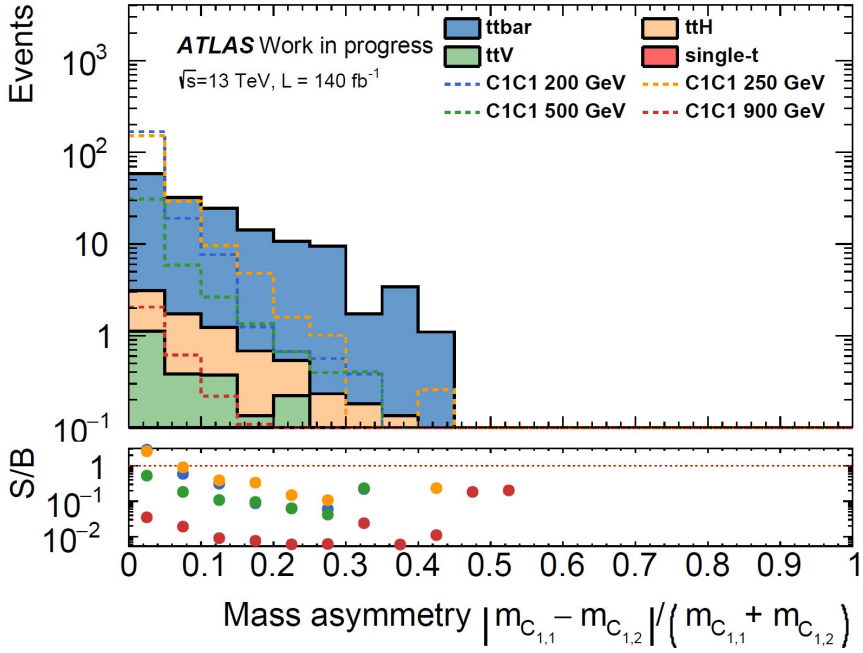


- C1C1 primary backgrounds:
  - ttbar: $t\bar{t}$ decaying to $bb\ell\ell\nu\nu$ with an ISR/FSR jet
  - ttH: $t\bar{t}$ with a Higgs decaying to $b\bar{b}$
  - ttV: $t\bar{t}$ with a W or Z boson
- For C1N1, these backgrounds need only 1 lepton in decay
  - Additional major background single-t: Wt with ISR/FSR jet

C1C1 Signal Region optimization

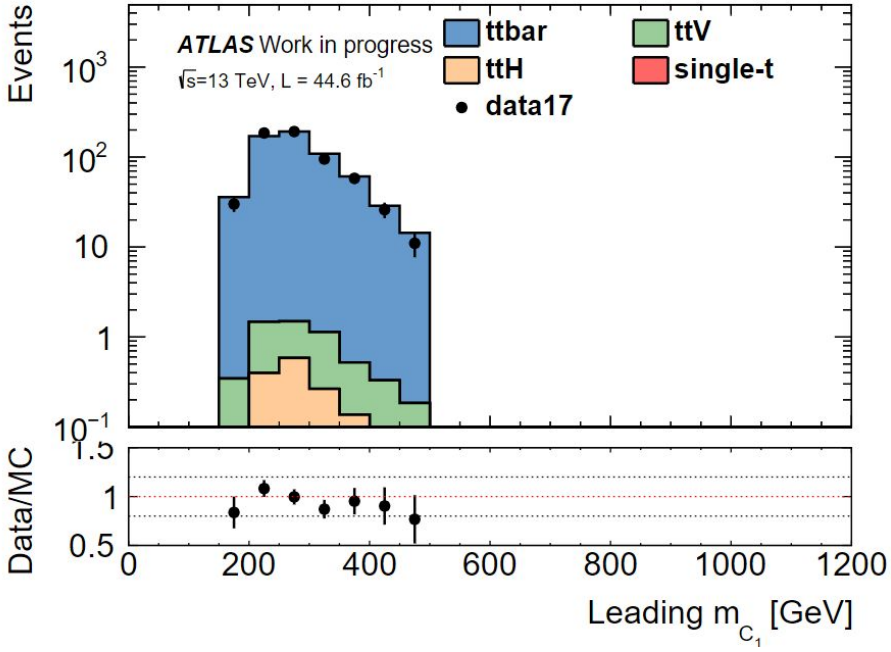
- Left: Leading reconstructed chargino mass m_{C1}, good S/B
- Right: Mass asymmetry $N-1$ in SR; cut at 0.2 strongly rejects background

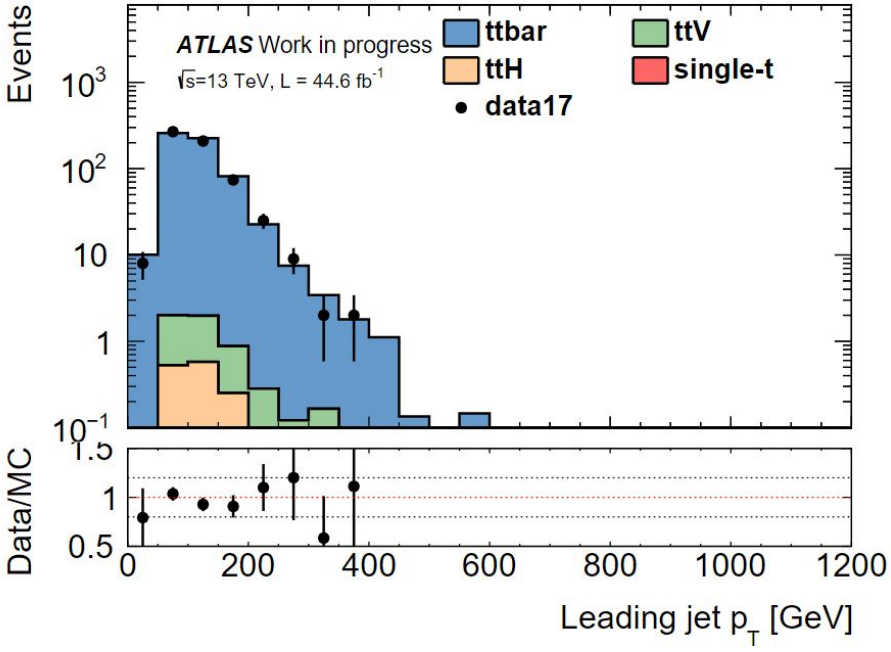




C1C1 2 *b*-jet Control Region Data/MC comparison

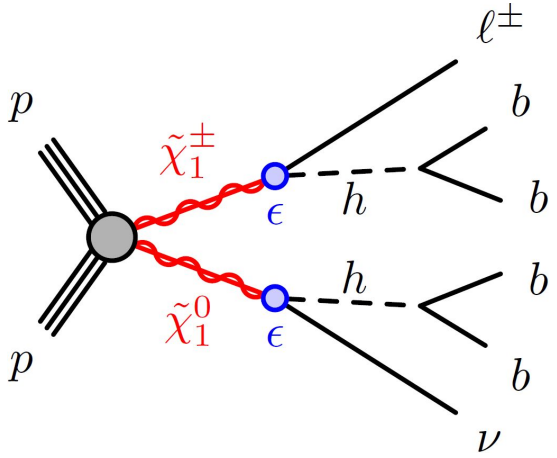
- Good agreement in leading reconstructed chargino mass $m_{C1,}$ leading jet p_T

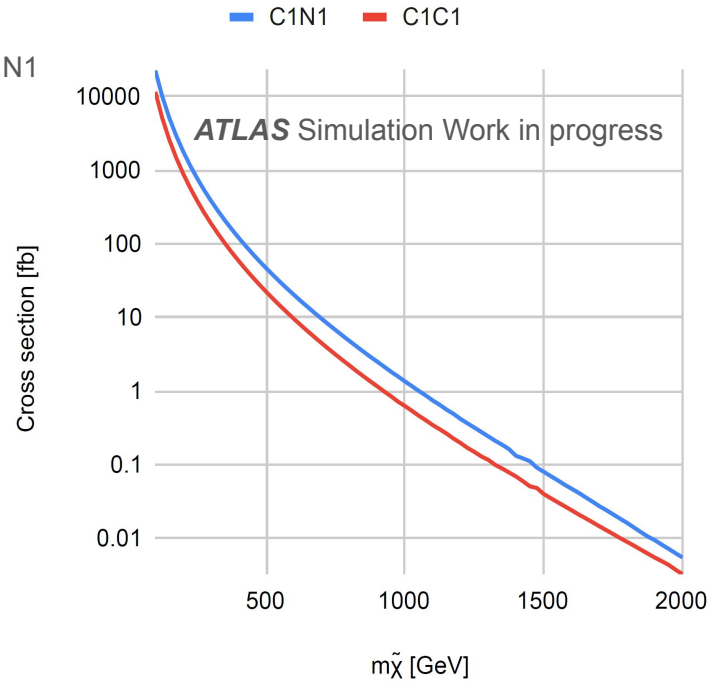




C1N1 extension

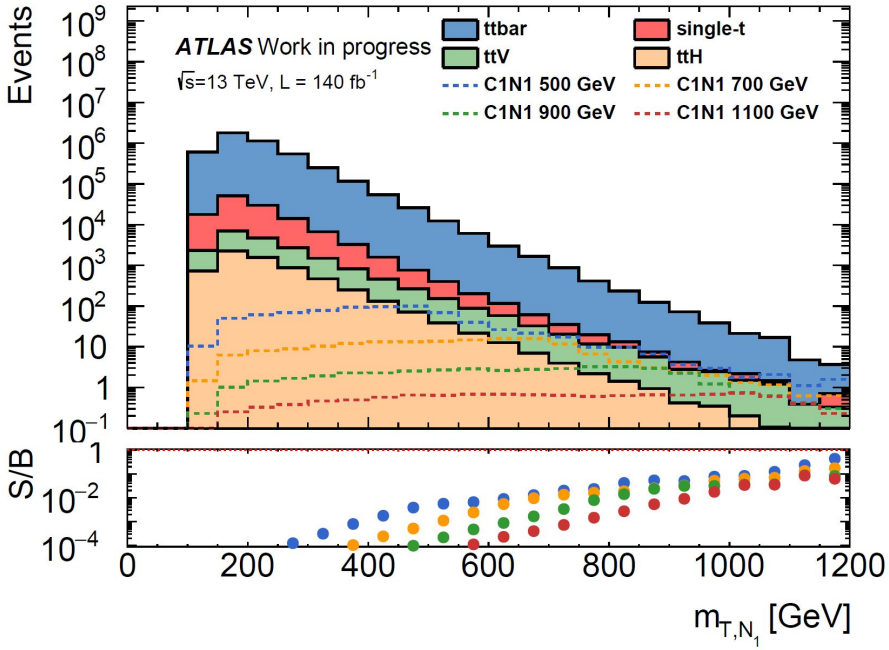
- Motivation: C1N1 production has 2× cross section of C1C1
- Challenges:
  - For N1, can only reconstruct transverse mass $m_{T,N1}$
    - Pairing more difficult, currently using max ΔR between Higgs and lepton
  - $t\bar{t}$ backgrounds larger with 1 lepton
  - New major background: single-top production

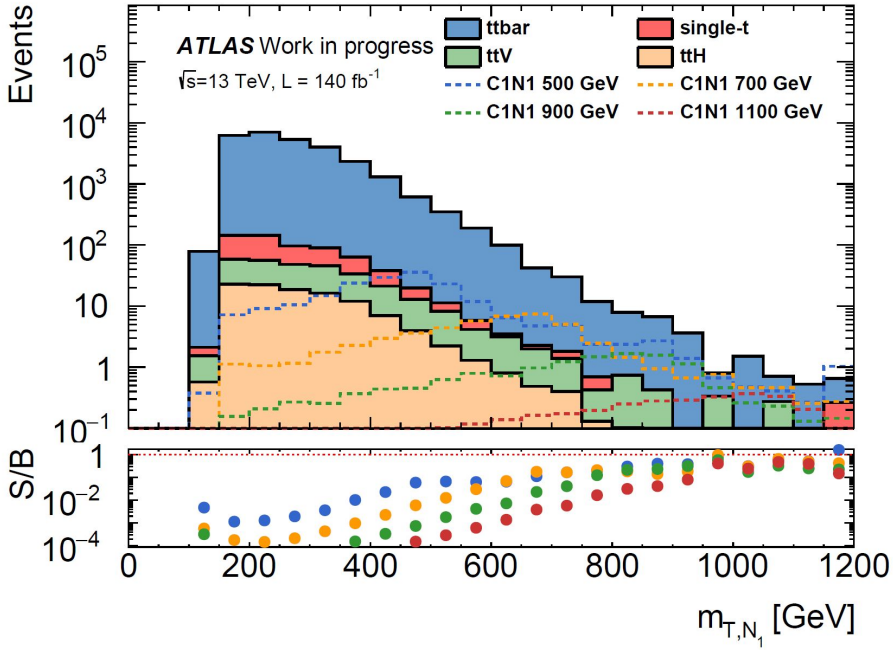




C1N1 Signal Region optimization

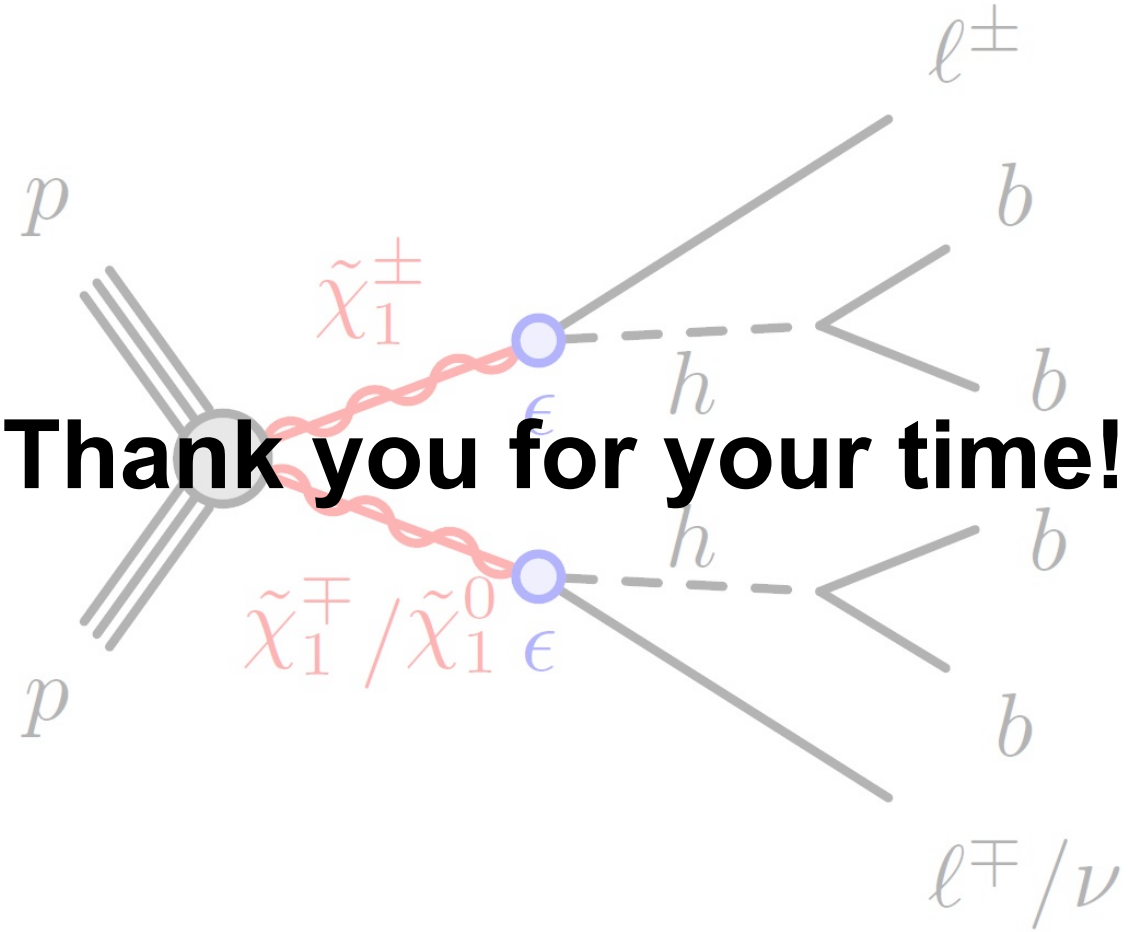
- Left: only 4-jet, 1-lepton selection; Right: exploratory cuts ($m_{h1,2}$, H_T, E_T^{miss})
  - S/B low before optimization, greatly improved by cuts
- Optimization is ongoing, expect further improvement





Conclusion

- C1C1
  - Searching for RPV chargino-chargino production with $4b2\ell$ final state
  - Defined and optimized signal, validation, and control regions
  - Data/Monte Carlo comparisons ongoing, with reasonable agreement
- C1N1
  - Searching for RPV chargino-neutralino production with $4b1\ell+E_{\mathrm{T}}^{\mathrm{miss}}$ final state
  - Possibility of significantly extending reach of C1C1 analysis
  - Defining and optimizing analysis regions



Thank you for your time!

References

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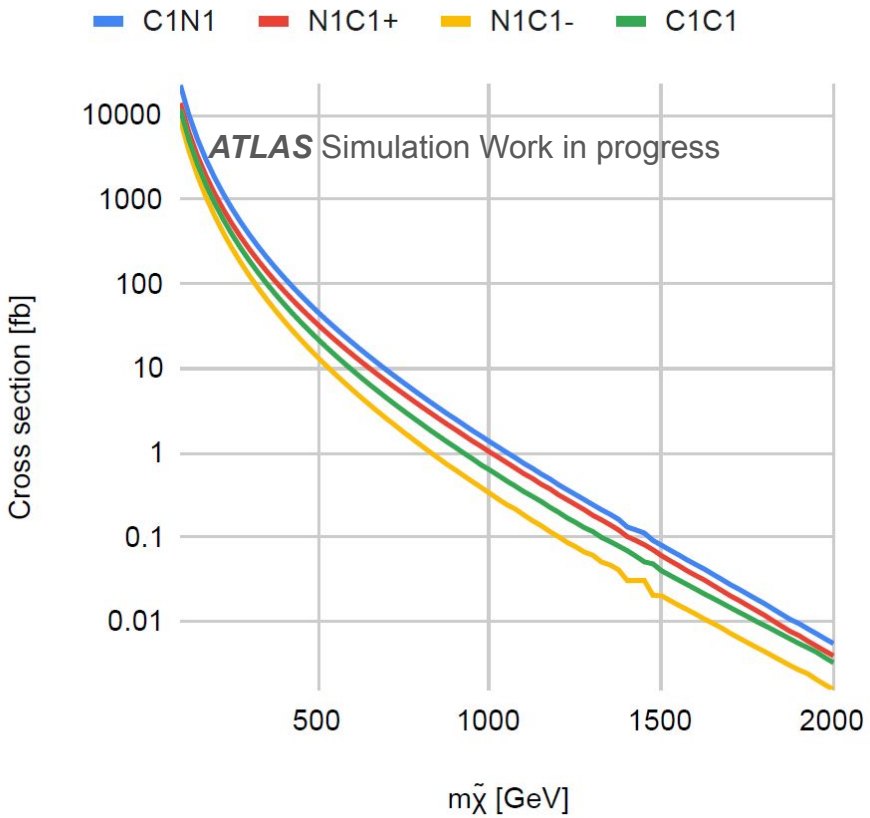
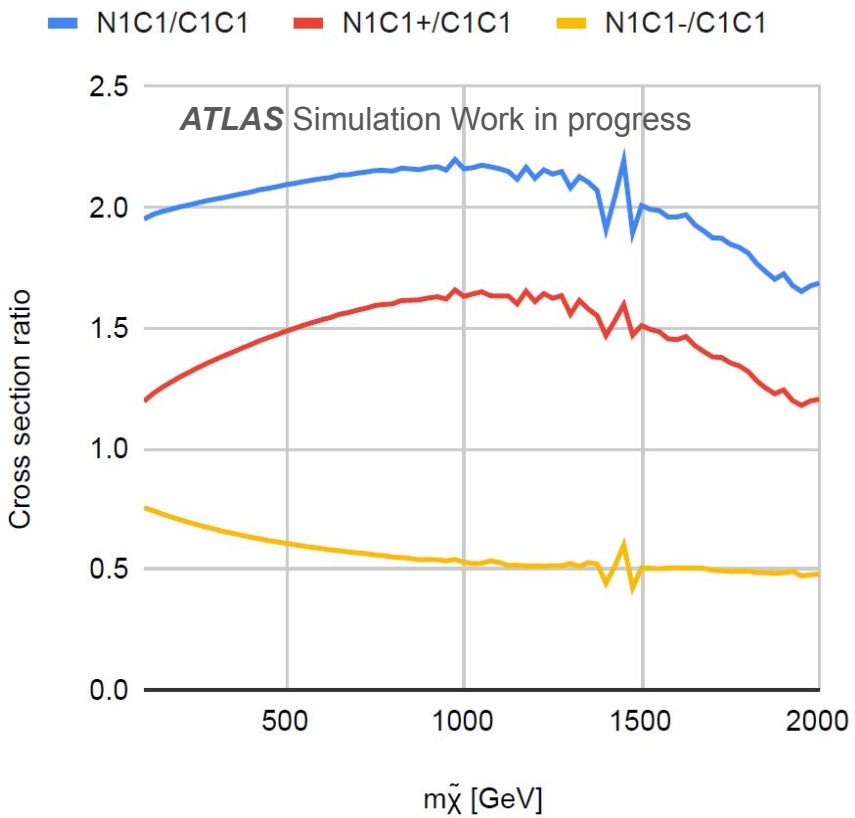
Backup

Simulated cross sections



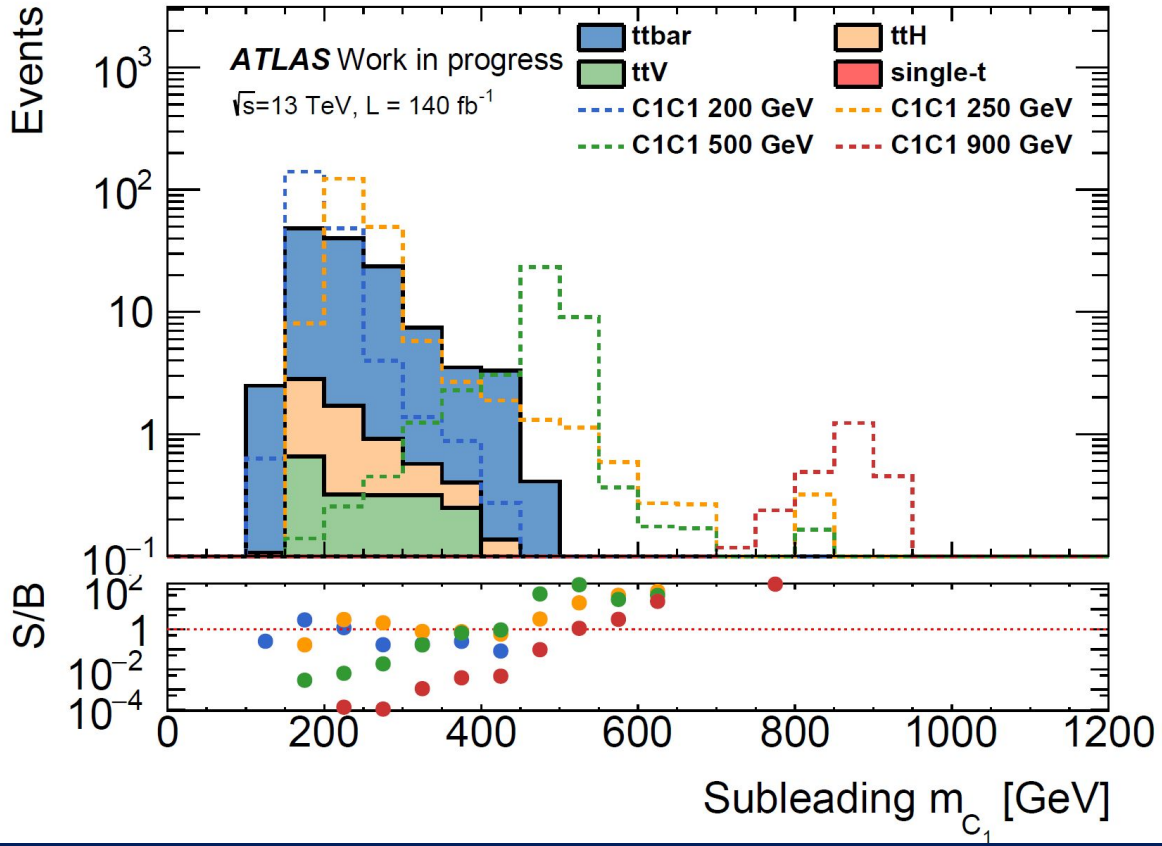


C1C1 analysis region definitions

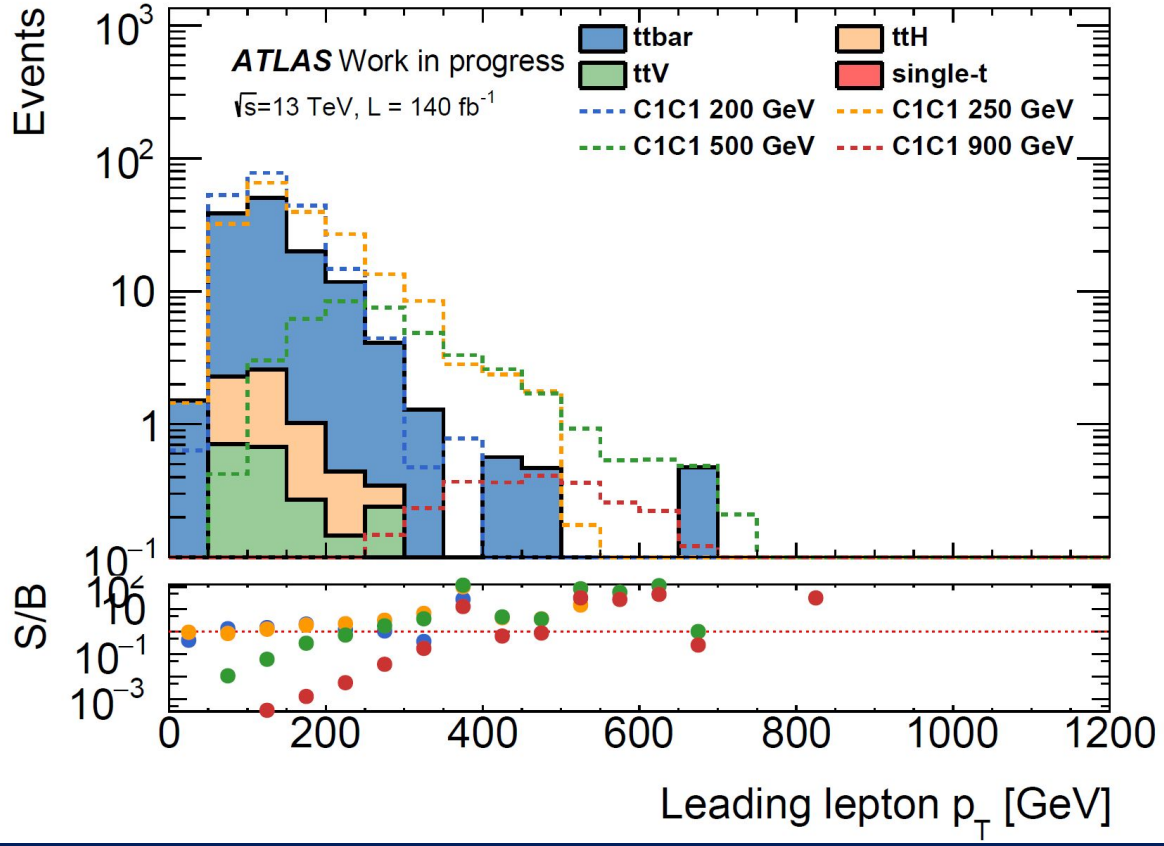
Region	*b*-jets	m_{h1} [GeV]	m_{h2} [GeV]	H_T [GeV]	$m_{\ell\ell}$ [GeV]	asymm.	$m_{C1,2}$ (rej.) [GeV]	$m_{C1,1}$ [GeV]	Lepton flavor
SR	≥ 3	[100,150]	[85, 135]	> 400	> 106.2	< 0.2	> 200		All
CR2b	= 2	[100,150]	[85, 135]		> 106.2	< 0.2	< 200	< 500	All
CR3b	= 3	![100,150]	![85, 135]	> 400	> 106.2	< 0.2		< 700	All
CR4b	≥ 4	![100,150]	![85, 135]		> 106.2	< 0.2			All
VR2b	= 2	[100,150]	[85, 135]				> 200	< 500	Opposite
VR3b1	≥ 3	![100,150]	[85, 135]	> 400					Opposite
VR3b2	≥ 3	![100,150]	![85, 135]	> 400					Opposite

All regions have ≥ 4 jets with p_T > 20 GeV and 2 opposite-sign light leptons with p_T > 40 GeV

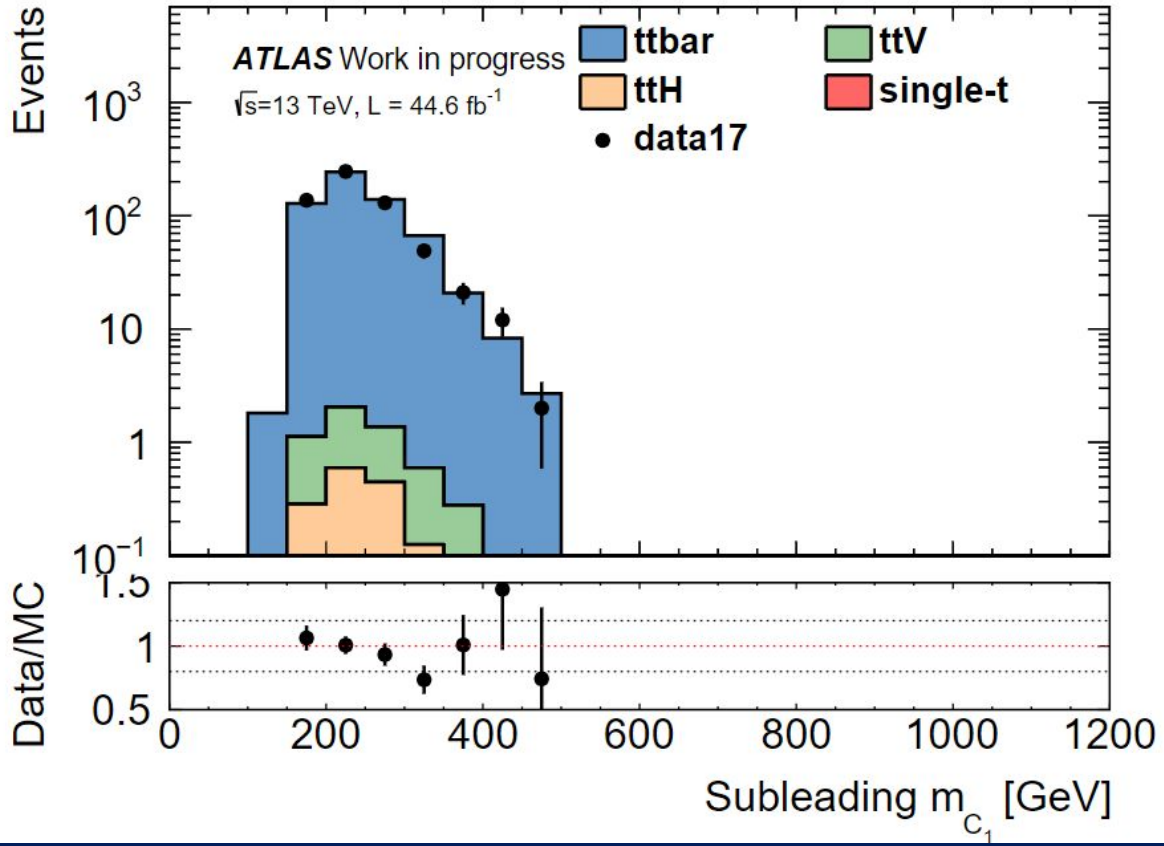
C1C1 SR: Subleading chargino mass



C1C1 SR: Leading lepton p_T



C1C1 CR2b: Subleading chargino mass Data/MC



C1N1: preselection Higgs masses