Searches for stops in scenarios with R-parity violating sparticle decays with ATLAS

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for the ATLAS collaboration

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R-parity violating SUSY

stop ($\tilde{t}$) pair production with R-parity violating decays

Searches in R-conserving scenario in S. Strandberg, I. M. Snyder and A. Miucci talks - not suitable in R-violating context

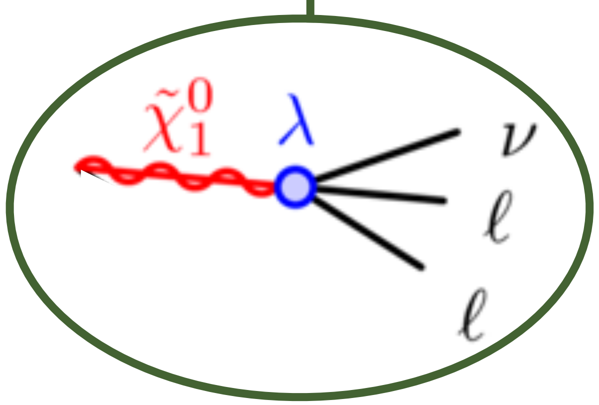
R = (-1) $^{3B+L+2S}$

Lepton-number (L) violation | **Baryon-number (B) violation** | **Bilinear coupling**

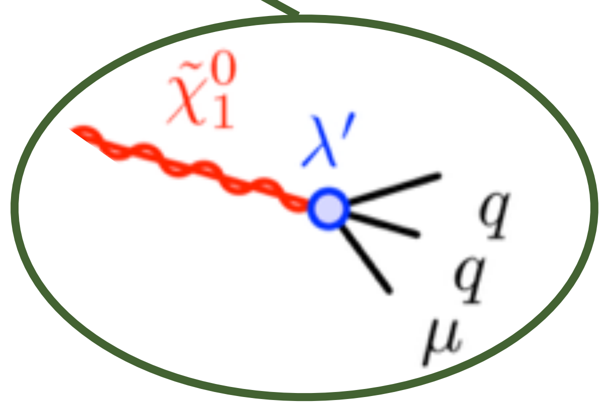
MSSM potential

$$\mathcal{W}_{\text{RPV}} = \lambda_{ijk} L_i L_j \overline{E}_k + \lambda'_{ijk} L_i Q_j \overline{D}_k + \lambda''_{ijk} \overline{U}_i \overline{D}_j \overline{D}_k + \kappa_i L_i H_u$$

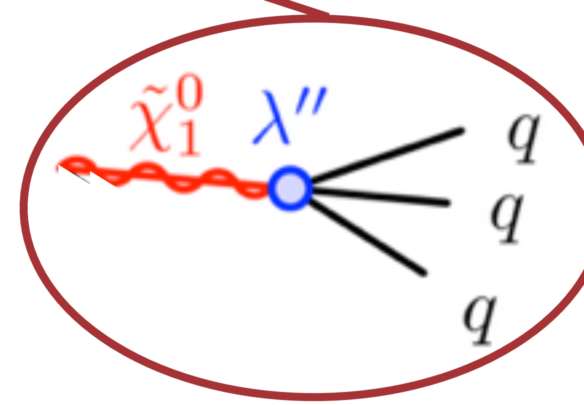
couplings



LLE



LQD



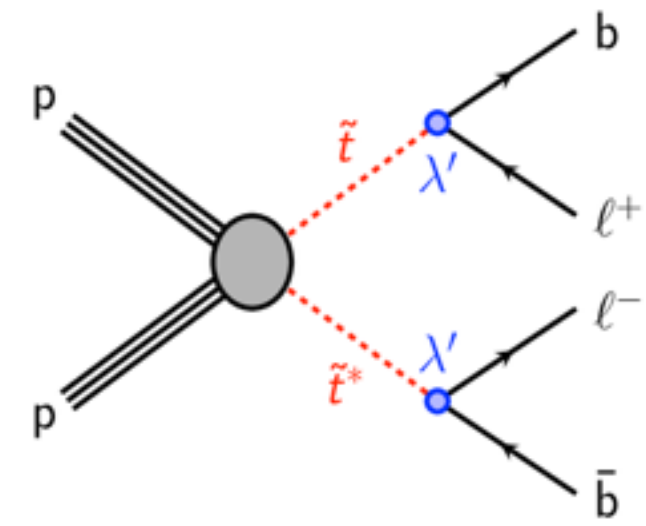
UDD

B-L Pairs

LSP stop, LQD decay

13 TeV, 36.1 / fb **arXiv:1710.05544**

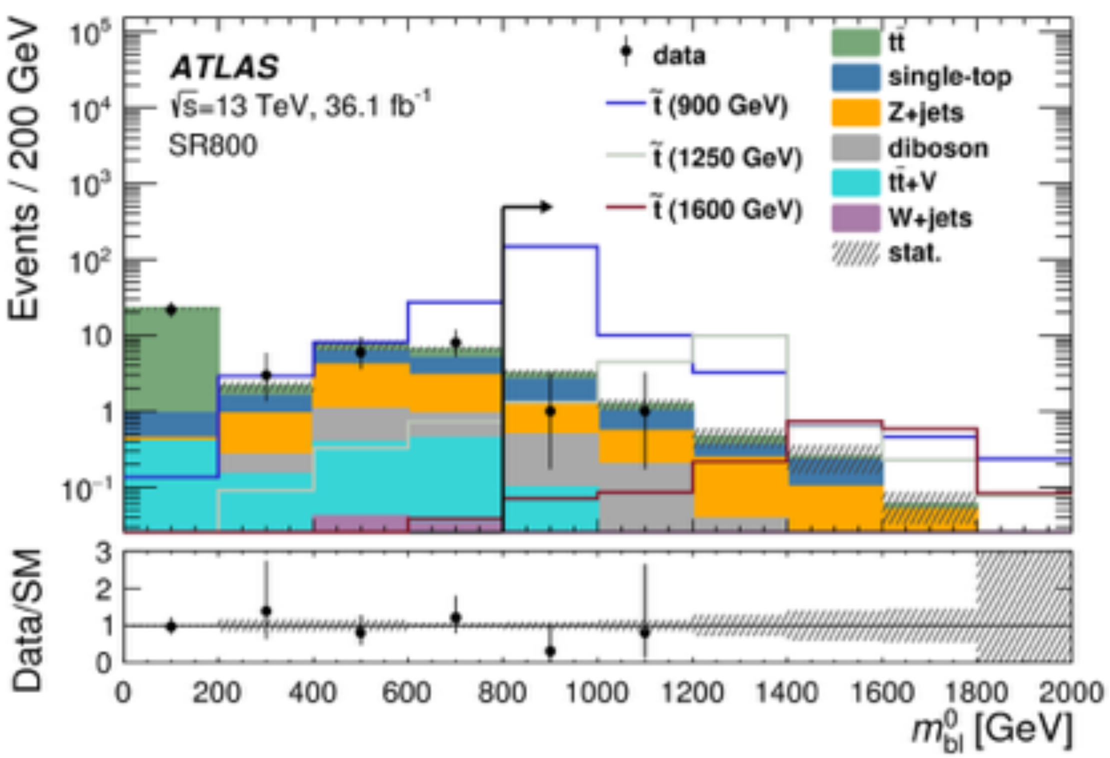
- additional $U(1)_{B-L}$ symmetry with right-handed neutrino supermultiplets
- Suppressed couplings prevent short proton lifetime



Analysis strategy

- Require two opposite charge leptons (e, μ) and two jets (at least one w/ bottom quark - *b-tagged*)
- build b-l pairs minimising the mass asymmetry

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



- require small mass asymmetry
- use larger mass as discriminator

Background estimation

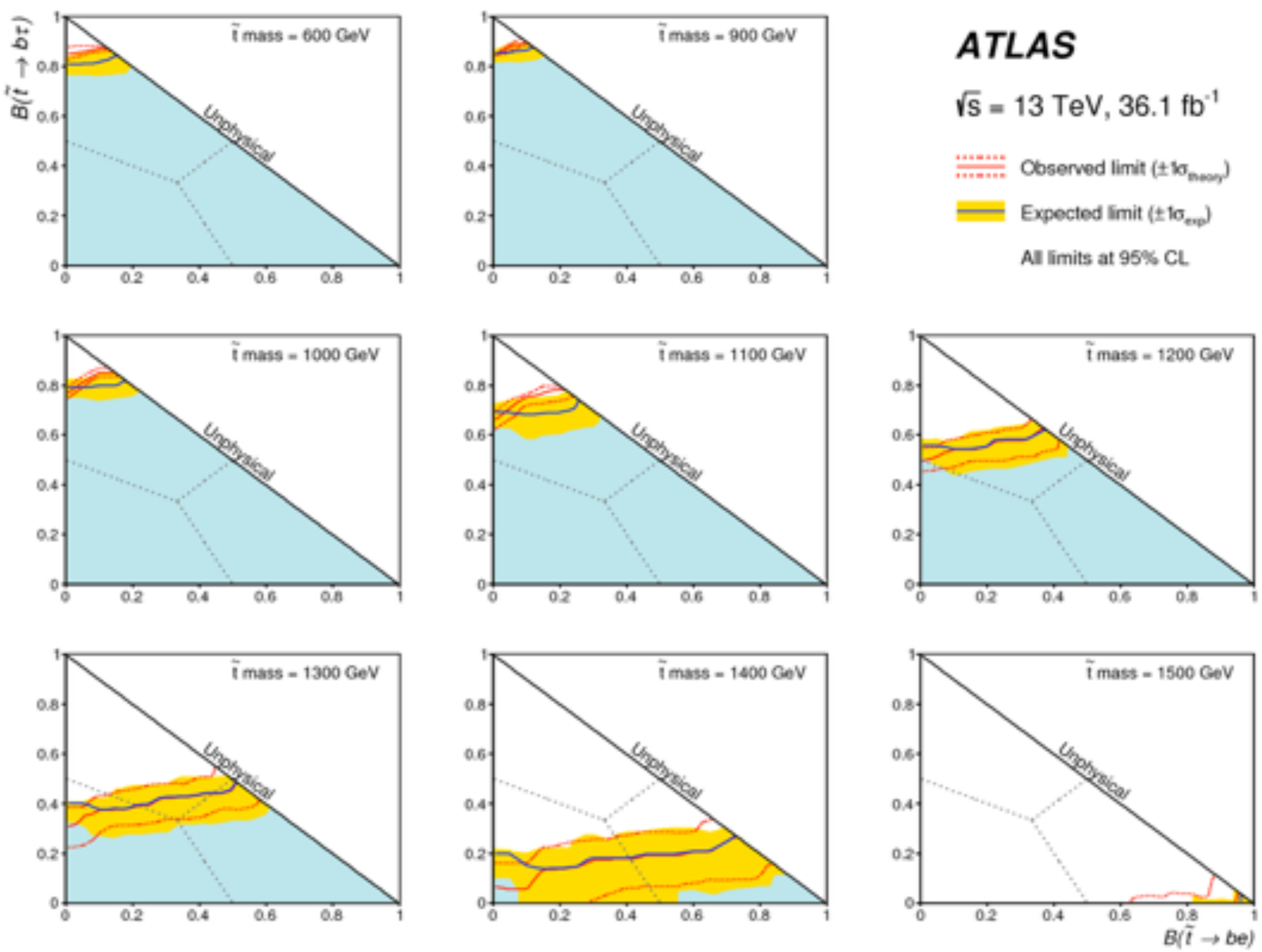
- Major backgrounds: top pairs, single-top, Z+jets
- estimated from MC normalised to data in control region

B-L Pairs

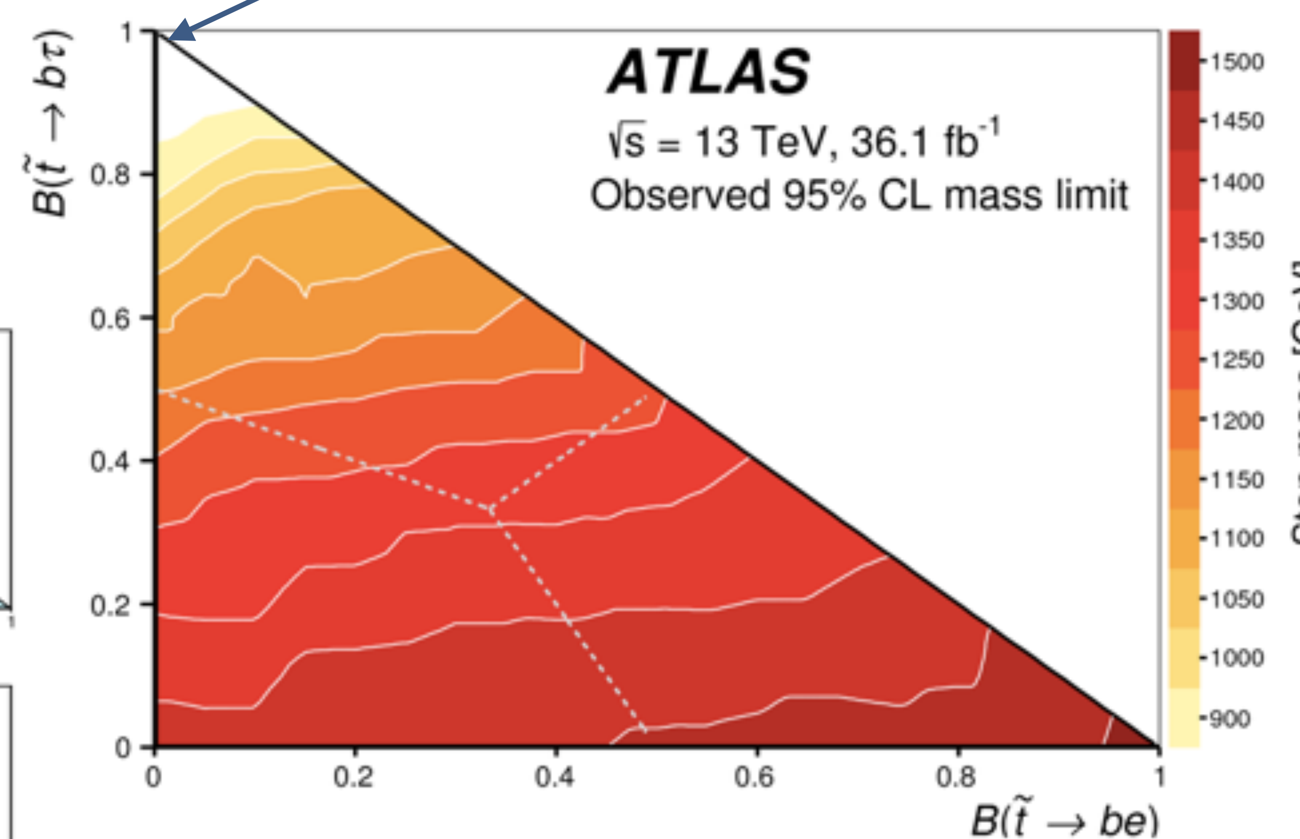
No significant execs over SM expectation

Interpret results as exclusion limits

Results derived for various assumptions on the branching ratio in different decay modes



final state targeted by searches for lepto-quarks



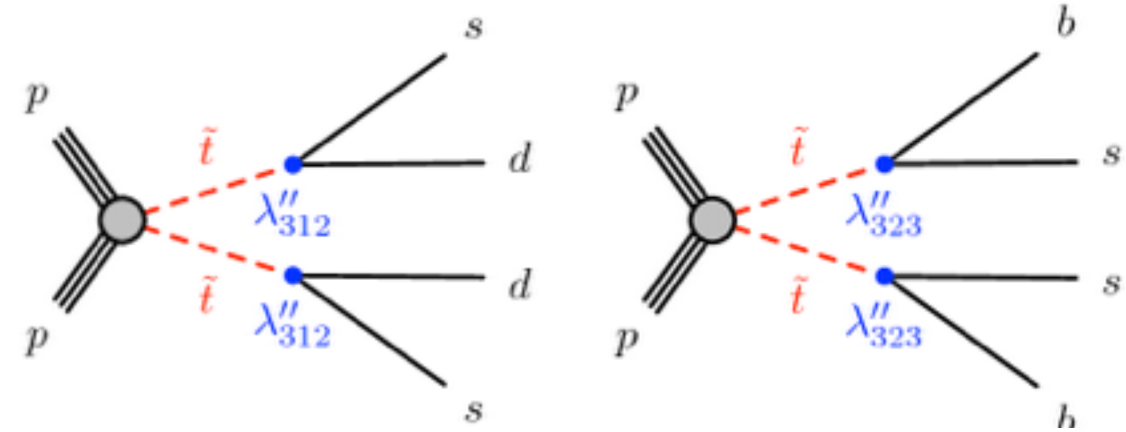
arXiv:1710.05544

Jets Resonances

13 TeV, 36.7 / fb **arXiv:1710.07171**

LSP stop, UDD decay

large enough coupling for prompt decay
(but no single top squark resonant production)



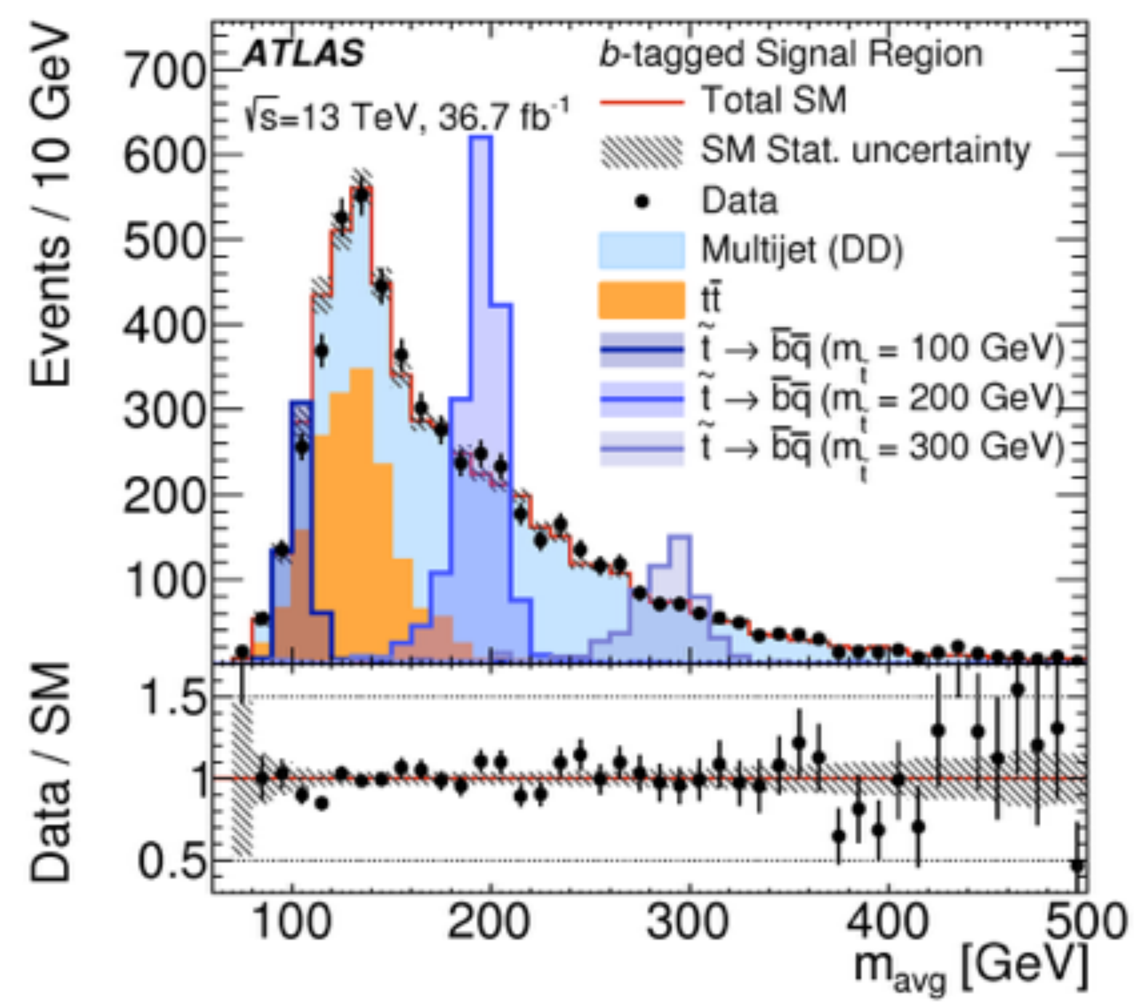
Analysis strategy

- Four jets in the final state (possibly b-tagged)
- pair jets with minimum ΔR to build stop candidate:

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

- discriminants: $|\cos(\theta^*)|$, $\mathcal{A} = \frac{|m_1 - m_2|}{m_1 + m_2}$,

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



Jets Resonances

Background estimation **arXiv:1710.07171**

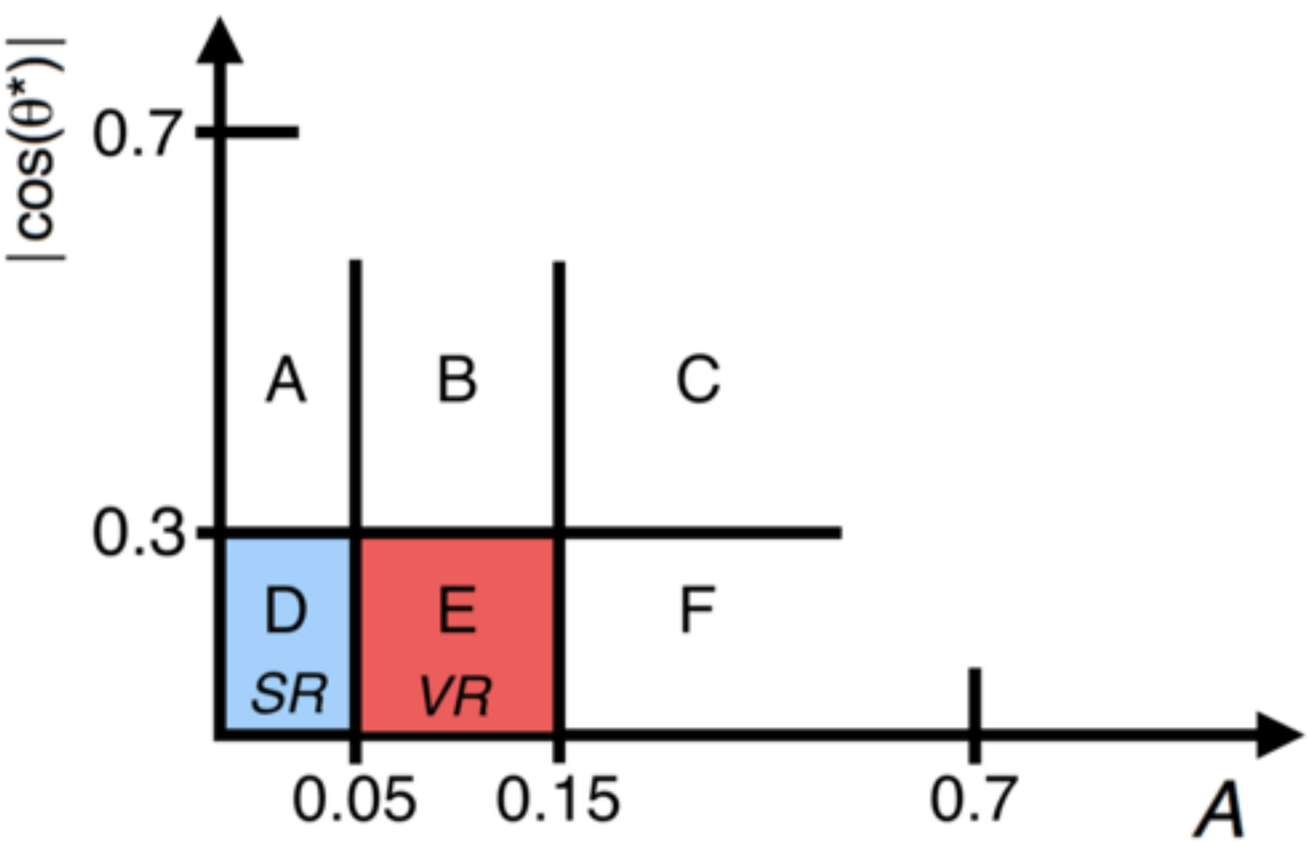
multi-jet QCD events

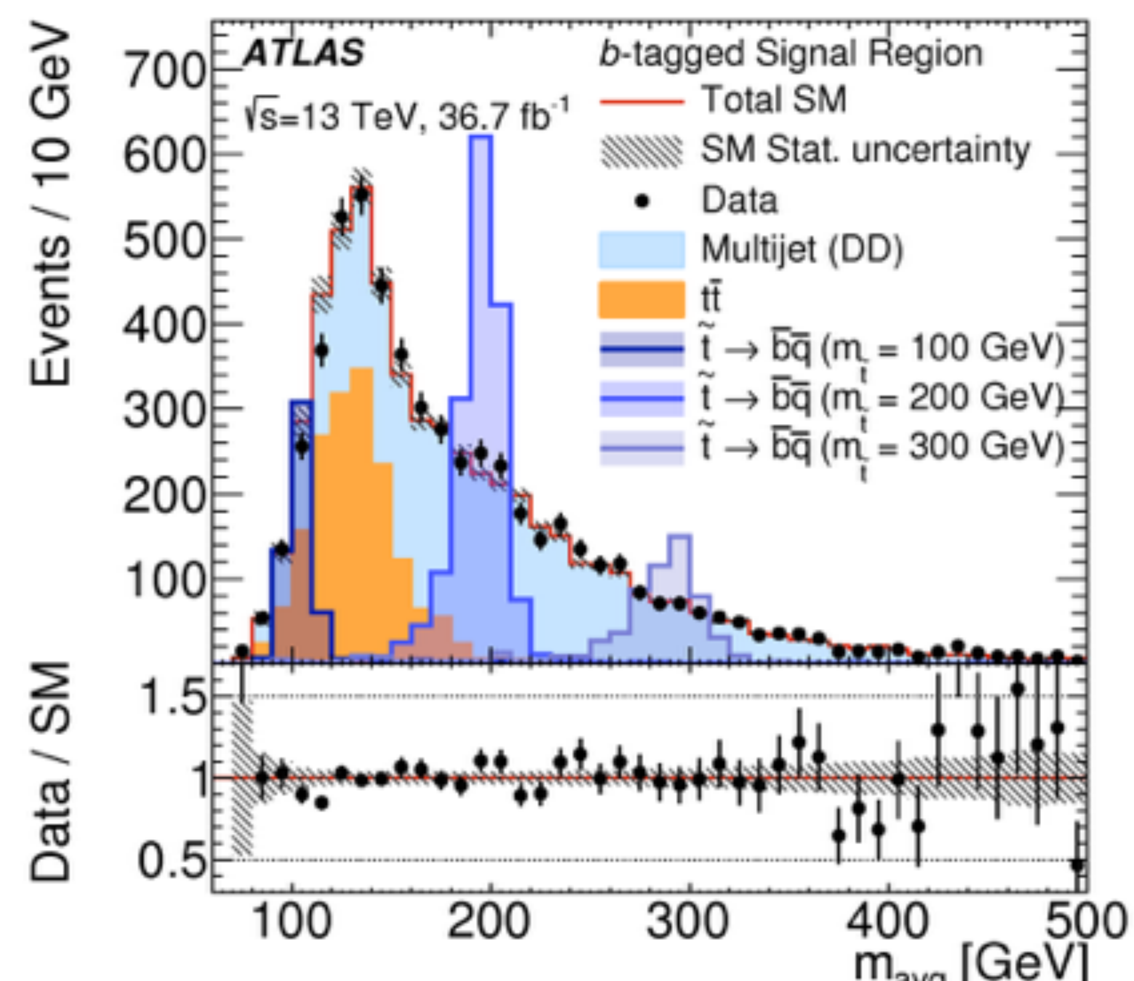
- Estimated from data with “matrix method”

$$N_{\rm D} = N_{\rm A} \times N_{\rm F}/N_{\rm C}$$

top pairs

- Estimated with Monte Carlo simulation





Jets Resonances

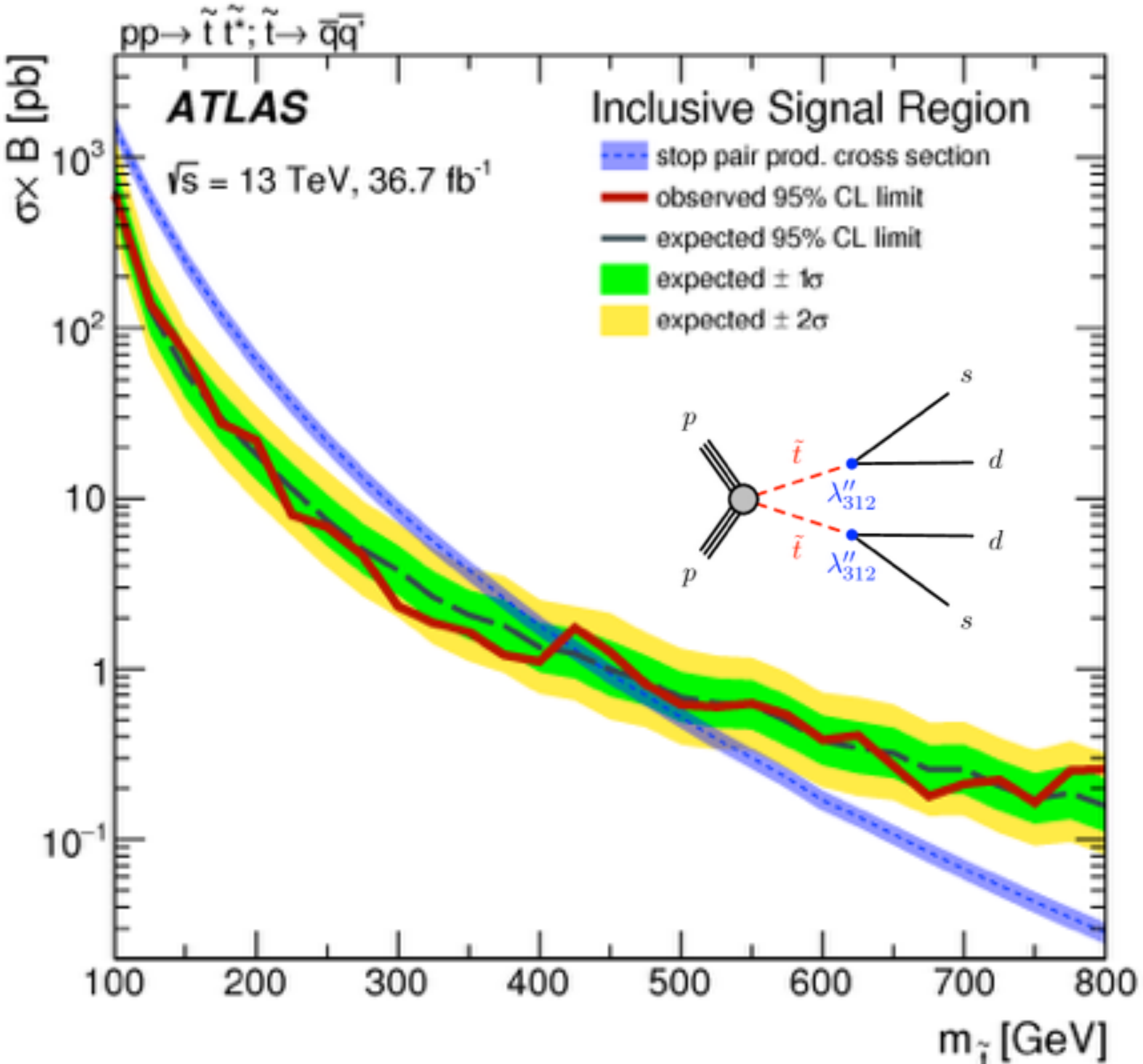
Test compatibility of results with resonance hypothesis

Scan in windows of m_{avg} of 12.5 GeV

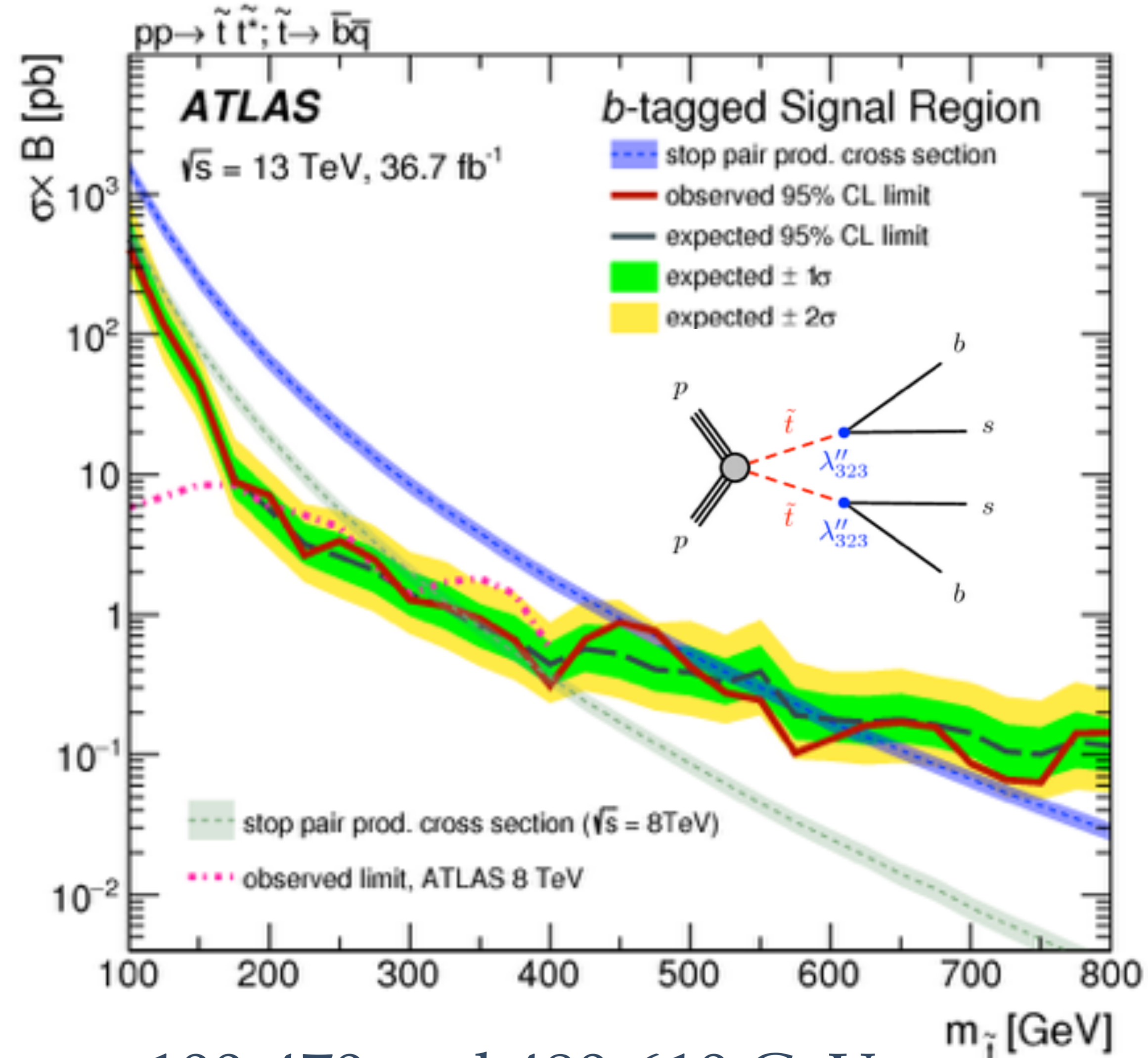
No significant excess over SM expectation

Interpret results as exclusion limits

arXiv:1710.07171



100-410 GeV



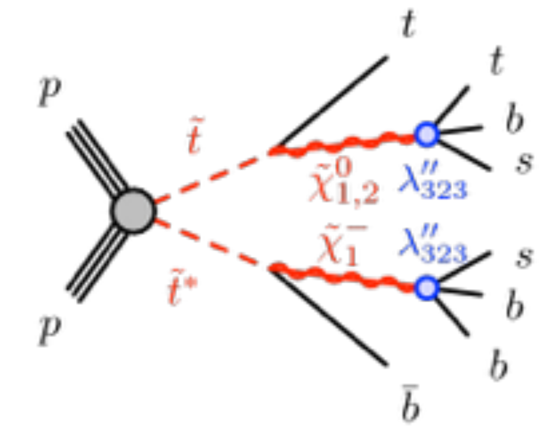
100-470 and 480-610 GeV

Multi-jet plus one lepton final state

13 TeV, 36.1 / fb **arXiv:1704.08493**

Right-handed stop

- decay into a pure bino or higgsino LSP and top or bottom quarks
- LSP decays promptly through UDD coupling



Analysis strategy

- Select events with at least one electron or muon and 8-≥12 jets
- Split events in bins of jet multiplicity and 0 or ≥3 b-jets

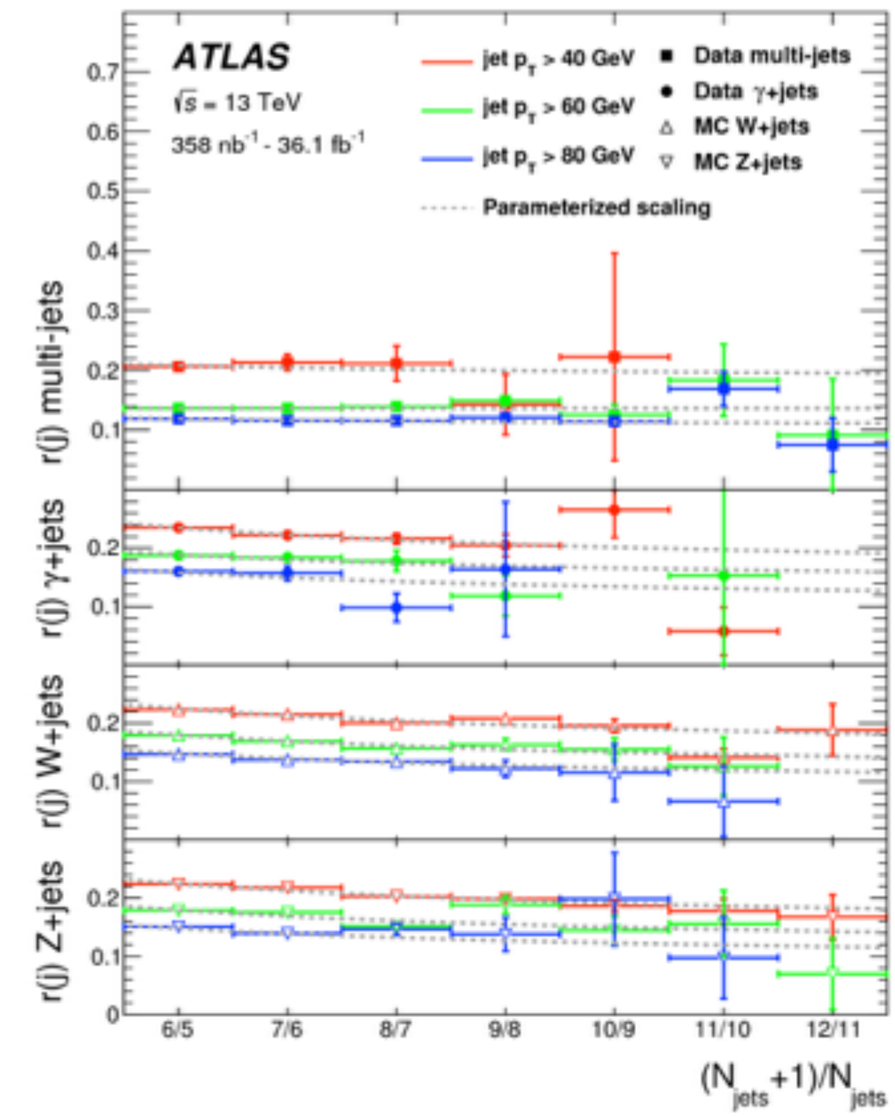
Background estimation

W/Z+jets: exploit scaling of jet multiplicity

$$r(j) \equiv N_{j+1}^{W/Z+\text{jets}} / N_{j}^{W/Z+\text{jets}}$$

$$r(j) = c_0 + c_1/(j+1)$$

- extrapolate from non b-tagged to be tagged samples with MC



Multi-jet plus one lepton final state

13 TeV, 36.1 / fb **arXiv:1704.08493**

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- decay into a pure bino or higgsino LSP and top or bottom quarks
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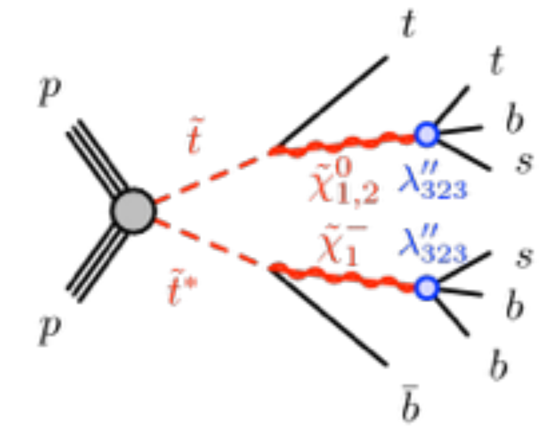


Analysis strategy

- Select events with at least one electron or muon and 8-≥12 jets
- Split events in bins of jet multiplicity and 0 or ≥3 b-jets

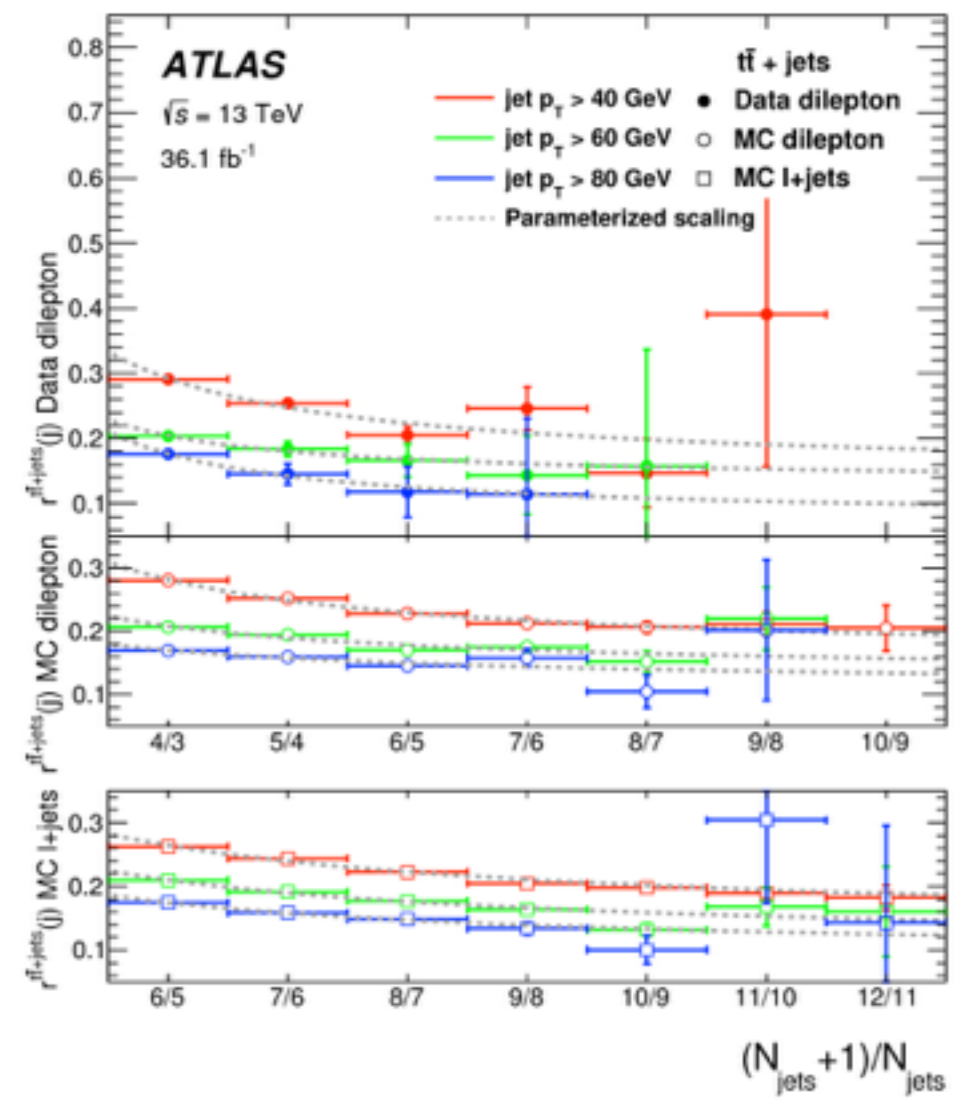
Background estimation

top pairs: data template of 5-jets events

- probability that additional jet is a b-jet

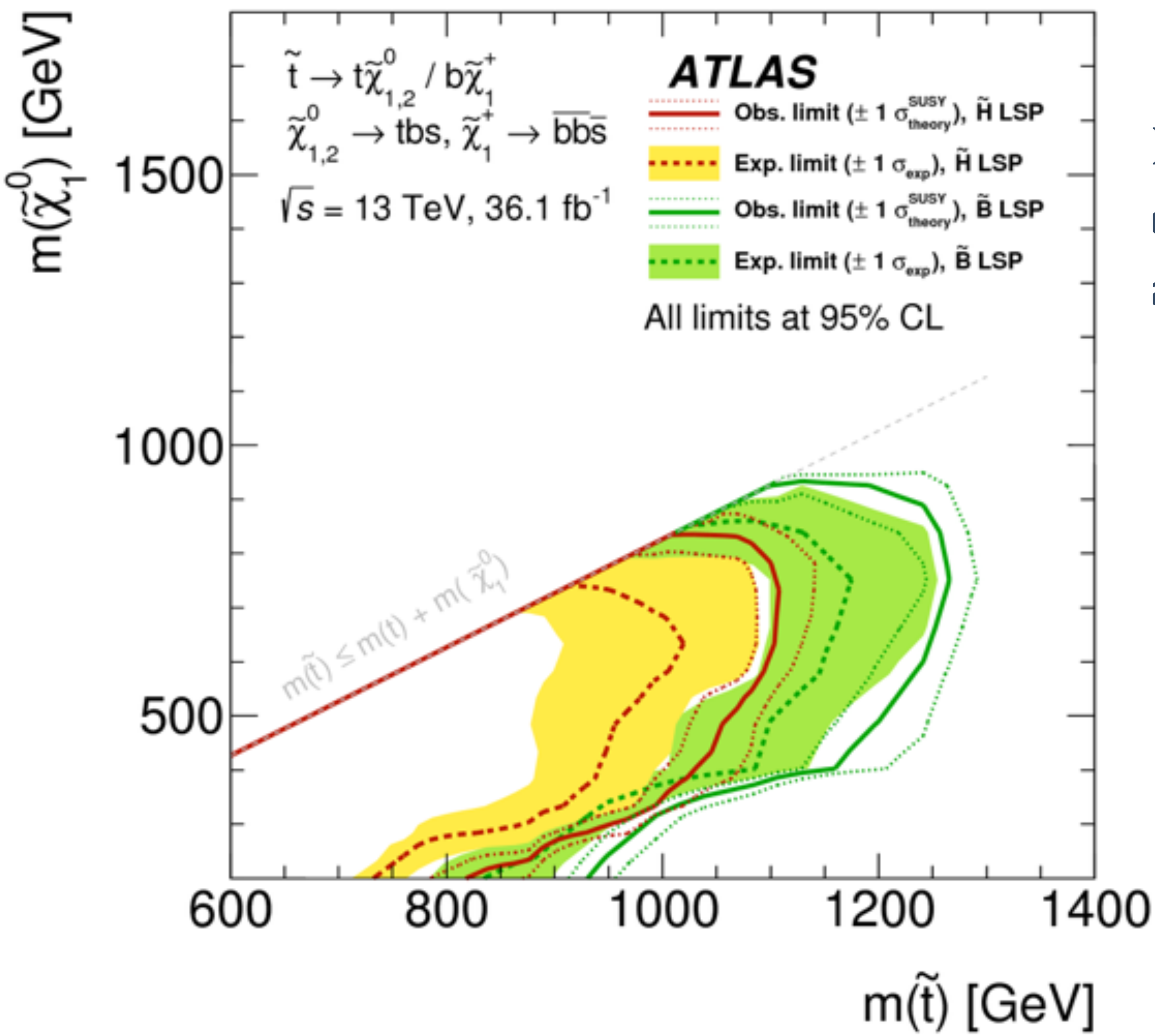
$$f_{(j+1),b} = f_{j,b} \cdot x_0 + f_{j,(b-1)} \cdot x_1 + f_{j,(b-2)} \cdot x_2$$

additional jet… non b-tagged b-tagged second b-tagged



Multi-jet plus one lepton final state

No significant excess over SM expectation



Interpret results as model-dependent exclusion limits by simultaneous fit of all analysis bins

higgsino LSP: excluded stop masses up to **1.1 TeV**
bino LSP: excluded stop masses up to **1.25 TeV**

arXiv:1704.08493

Summary

- ATLAS experiment searches for stop production in R-violating scenarios
- Results on full 2015+2016 dataset collected at $\sqrt{s}$=13 TeV
- No significant excess over the Standard Model prediction observed…

… but keep on the excitement for the full Run-2 dataset results

Thank you for your attention…

…and for bringing us here!

CERN

Taj Mahal Hotel

Back Up

B-L Pairs

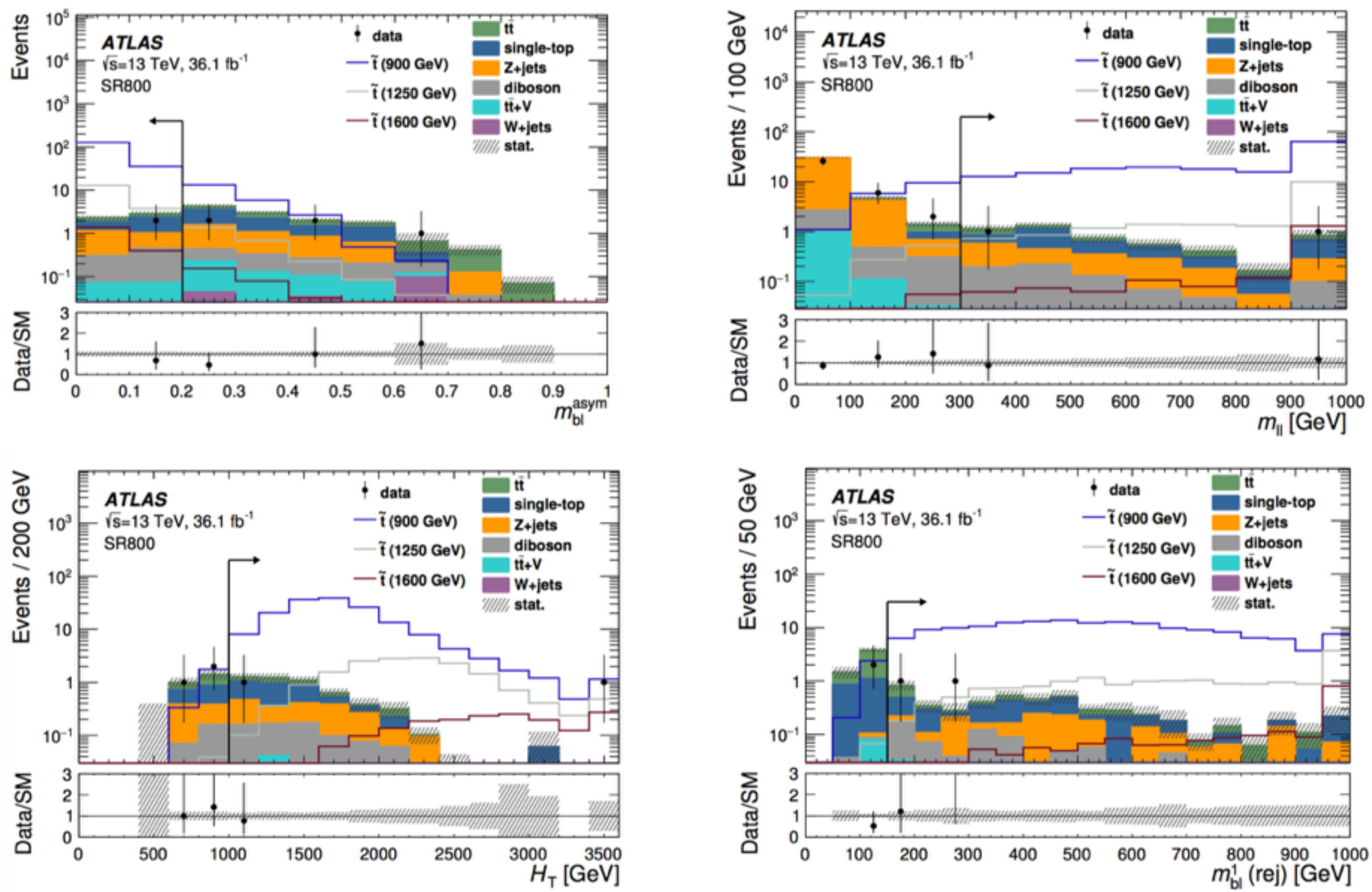
LSP stop, LQD decay

- additional $U(1)_{B-L}$ symmetry with right-handed neutrino supermultiplets
  - vev for right-handed scalar neutrino to spontaneously break B-L symmetry
  - lepton number violation only
  - RPV couplings suppressed (related to neutrino masses)

-> prevent short proton lifetime and consistent with L number violation

  - branching ratio related to neutrino mass hierarchy
    - normal mass hierarchy mu b BR up to 90%
    - reverted mass hierarchy e b decay ~100%
  - regions optimised with 50% BR

B-L Pairs


ATLAS
√s=13 TeV, 36.1 fb⁻¹
SR800
data
t̃ (900 GeV)
t̃ (1250 GeV)
t̃ (1600 GeV)
tt̄
single-top
Z+jets
diboson
tt̄+V
W+jets
stat.
Events
Data/SM
m_{bl}^{asym}
Events / 100 GeV
m_{ll} [GeV]
Events / 200 GeV
H_T [GeV]
Events / 50 GeV
m_{bl}^{1} (rej) [GeV]

B-L Pairs

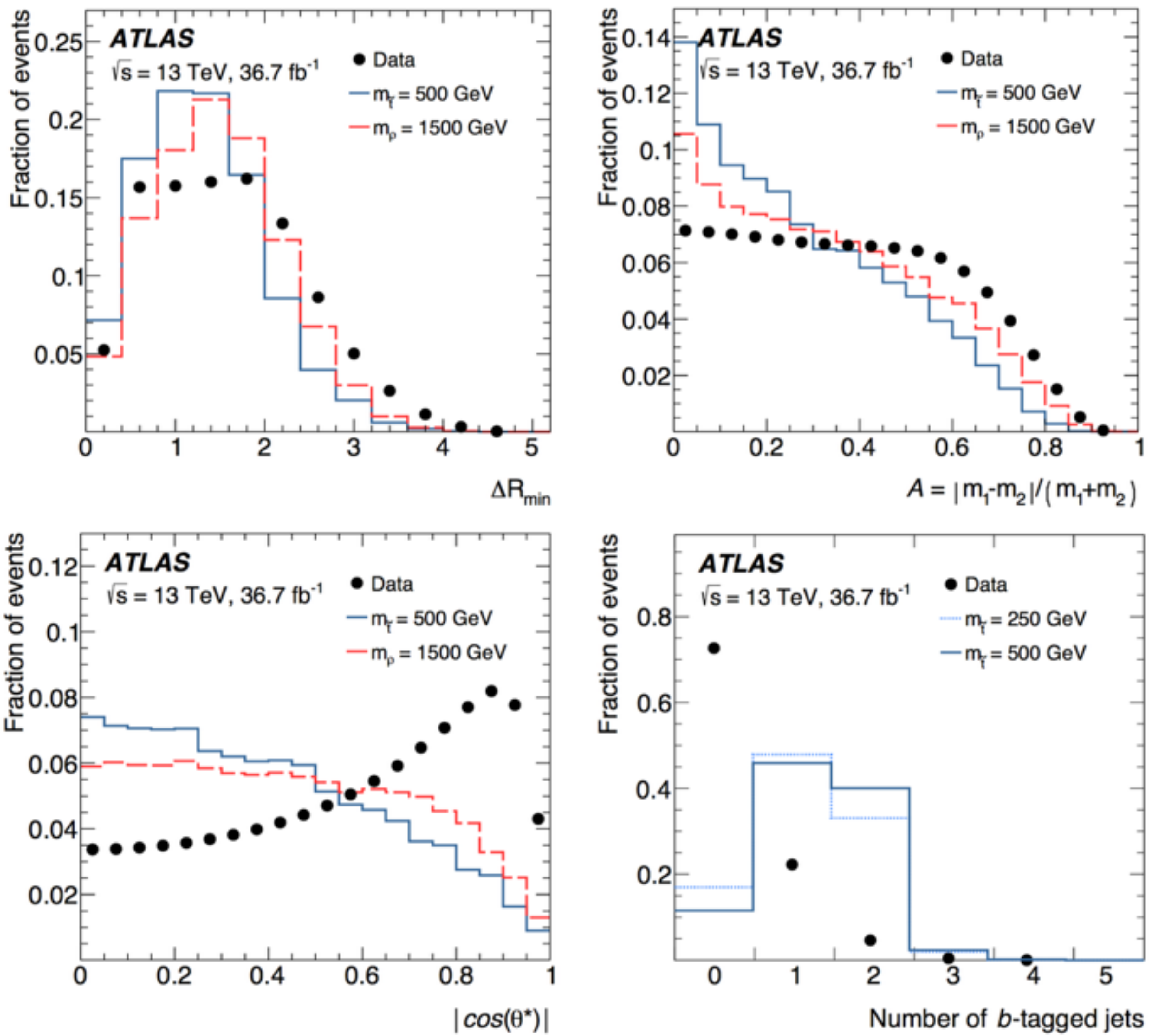
Region	N_b	$m^0_{b\ell}$ [GeV]	H_T [GeV]	$m^1_{b\ell}$(rej)[GeV]	$m_{\ell\ell}$ [GeV]	m_{CT} [GeV]
SR800	≥ 1	> 800	> 1000	> 150	> 300	–
SR1100	≥ 1	> 1100	> 1000	> 150	> 300	–
CRst	$= 2$	[200,500]	< 800	< 150	> 120	> 200
CRtt	≥ 1	[200,500]	[600,800]	< 150	> 300	$< 200^*$
CRZ	≥ 1	> 700	> 1000	–	[76.2,106.2]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

Source \ Region	SR800	SR1100
Experimental uncertainty		
b-tagging	3%	5%
Jet energy resolution	2%	10%
Jet energy scale	1%	3%
Electrons	1%	4%
Muons	1%	3%
Theoretical modeling uncertainty		
MC statistical uncertainty	8%	17%
$t\bar{t}$	8%	45%
Single-top	21%	22%
Z+jets	2%	4%
Diboson	4%	3%
$t\bar{t}+W/Z$	1%	1%
W+jets	1%	1%

B-L Pairs

	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	–	$0.01^{+0.02}_{-0.01}$	–	$0.01^{+0.02}_{-0.01}$	–
S^{95}_{exp}	$6.4^{+3.0}_{-1.9}$	$4.1^{+1.8}_{-1.1}$	$4.0^{+2.2}_{-0.9}$	$3.9^{+1.6}_{-0.7}$	$3.9^{+2.4}_{-0.5}$	$3.0^{+1.3}_{-0.0}$	$3.0^{+1.3}_{-0.0}$	$3.1^{+0.6}_{-0.1}$
S^{95}_{obs}	4.0	3.0	3.0	4.8	3.9	3.0	3.1	4.1
σ_{vis}[fb]	0.11	0.08	0.08	0.13	0.11	0.08	0.08	0.11

Jets Resonances



Jets Resonances

Selection	$m_{\tilde{t}}$ = 100 GeV	$m_{\tilde{t}}$ = 500 GeV	m_ρ = 1500 GeV
Total	$(558.0 \pm 0.6) \cdot 10^5$	$19\,000 \pm 130$	1710 ± 10
Trigger	$221\,900 \pm 420$	$11\,900 \pm 100$	1650 ± 10
ΔR_{min}	$18\,910 \pm 120$	2470 ± 50	1050 ± 5
Inclusive selection	1359 ± 36	253 ± 16	51 ± 2
b-tagged selection	569 ± 24	65 ± 8	–

Jets Resonances

inclusive

$m_{\tilde{t}}$ [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± 60	789 ±52 ± 31
325	[300, 335]	6180	6330± 80± 20	600 ±50 ± 50
350	[320, 365]	5802	5900± 70± 20	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 ± 1
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

Jets Resonances

b-tagged

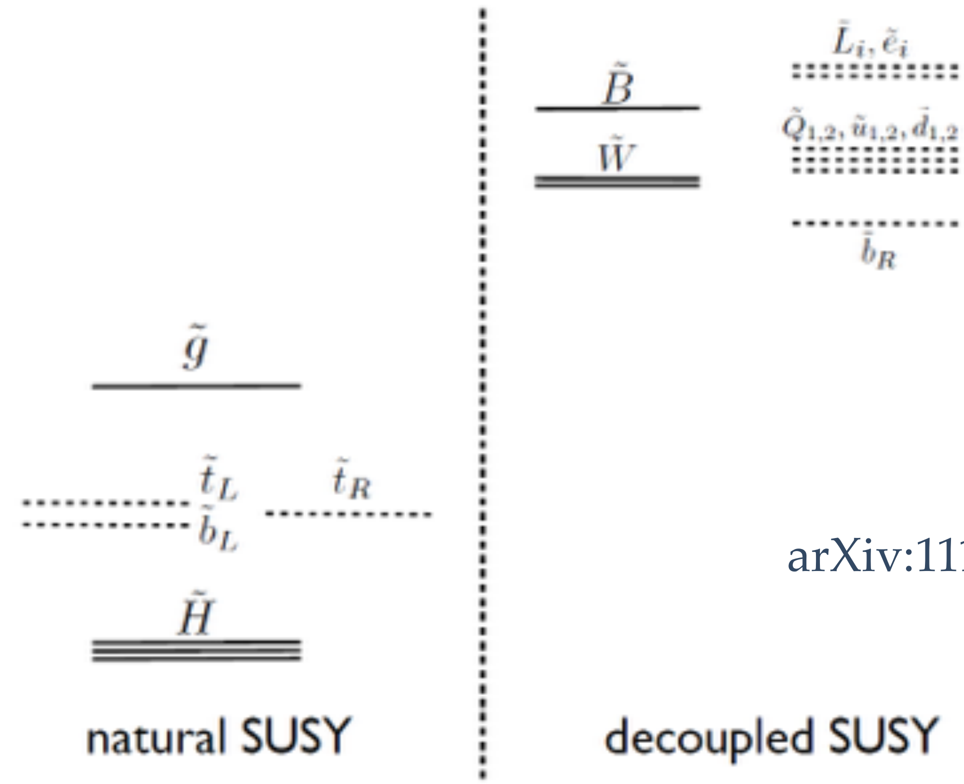
$m_{\tilde{t}}$ [GeV]	Window [GeV]	N_{Data}	N_{Bkg} (± stat. ± syst.)	N_{Sig} (± stat. ± syst.)
100	[100, 110]	256	285 ±18 ± 51	308 ±18 ± 52
125	[120, 135]	803	798 ±28 ±107	1090 ±40 ±140
150	[140, 160]	809	789 ±23 ±132	1510 ±40 ±130
175	[165, 185]	544	555 ±16 ± 47	1300 ±40 ±140
200	[185, 210]	592	554 ±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

Light stops and natural supersymmetry

Supersymmetry: additional fermion-boson symmetry

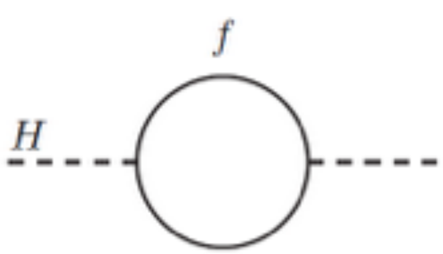
$$Q|\text{boson}>=|\text{fermion}>$$
$$Q|\text{fermion}>=|\text{boson}>$$

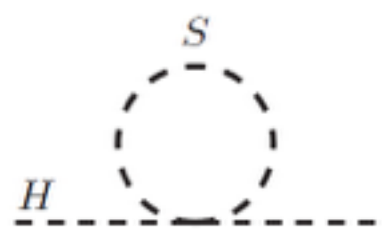
→ New quantum number **R-parity**
+1 (-1) for SM (SUSY) particles



arXiv:1110.6926

$$m_H^2 = m_{H,0}^2 + \Delta m_H^2$$





$$\Delta m_H^2 = -\frac{|\lambda_f|^2}{8\pi^2}\Lambda_{\rm UV}^2 + \frac{\lambda_s}{16\pi^2}\Lambda_{\rm UV}^2 + \ldots$$

Require low fine tuning in the MSSM:

$$-\frac{m_Z^2}{2} = |\mu|^2 + m_{H_u}^2$$

- Stop and gluino masses correct $m_{H_u}^2$
- Higgsino masses controlled by μ

→ **Stops expected to be light**