Searches for Strong SUSY Production

Hannsjörg Weber (Fermilab)

on behalf of the ATLAS and CMS collaborations

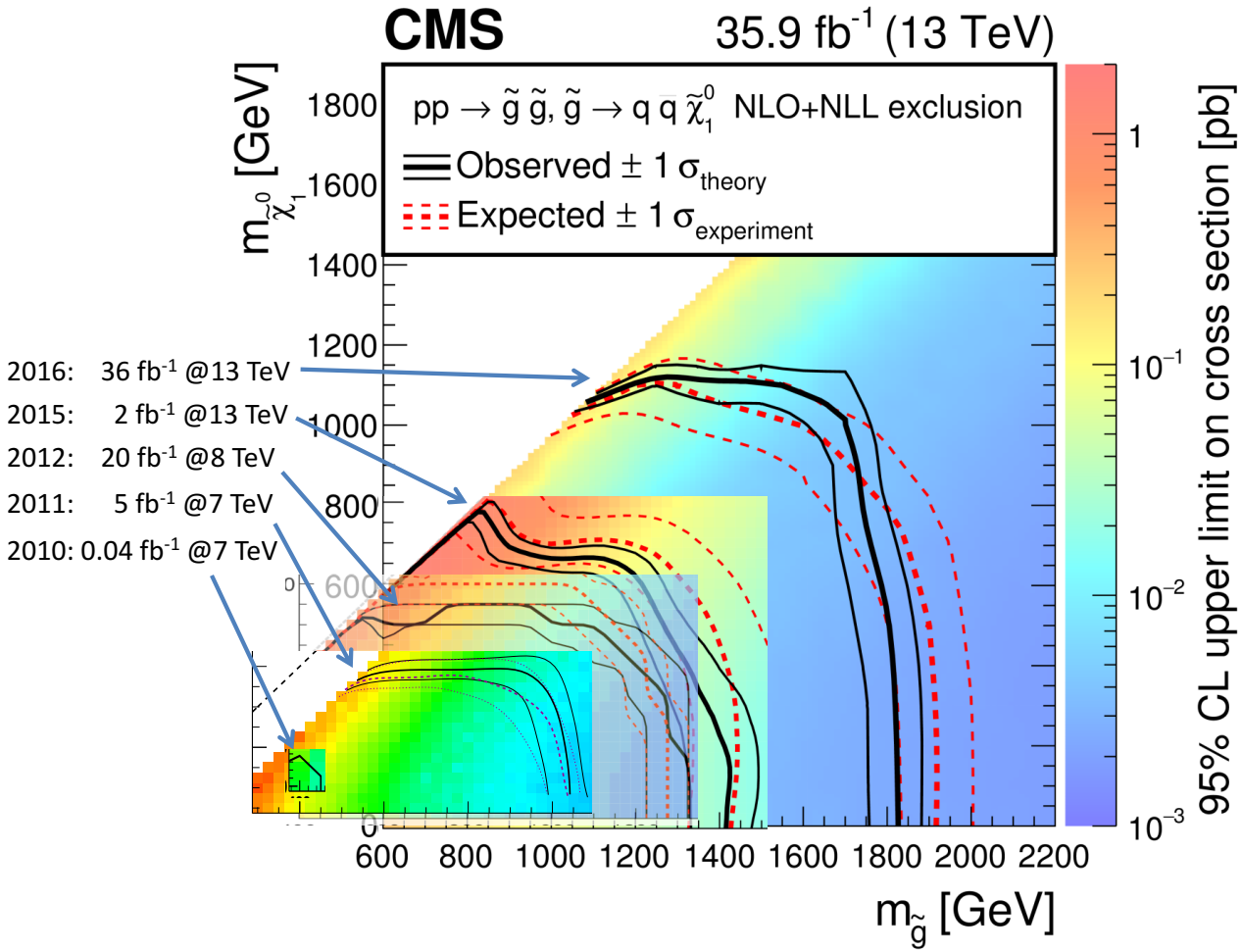
Strong SUSY production

- Strong production has been and still is one of the benchmarks in SUSY searches.
- Should be easy: "look for high p_T particles and large missing energy and you can't miss it."
- As we haven't found SUSY (yet), the landscape is changing now:
  - **Lower cross sections** (e.g. electroweak SUSY)
    → the next talk
  - **More complex signatures** (e.g. long-lived signatures)
    → Laura Jenty's talk for long-lived on Wednesday
  - **More challenging signatures** (e.g. RPV – no E_T^{miss})
  - **More targeted searches** (e.g. compressed SUSY)

This Talk.

A plot from last year

Gluino Mass Reach



Taken from Keith Ulmer's talk at SUSY2017

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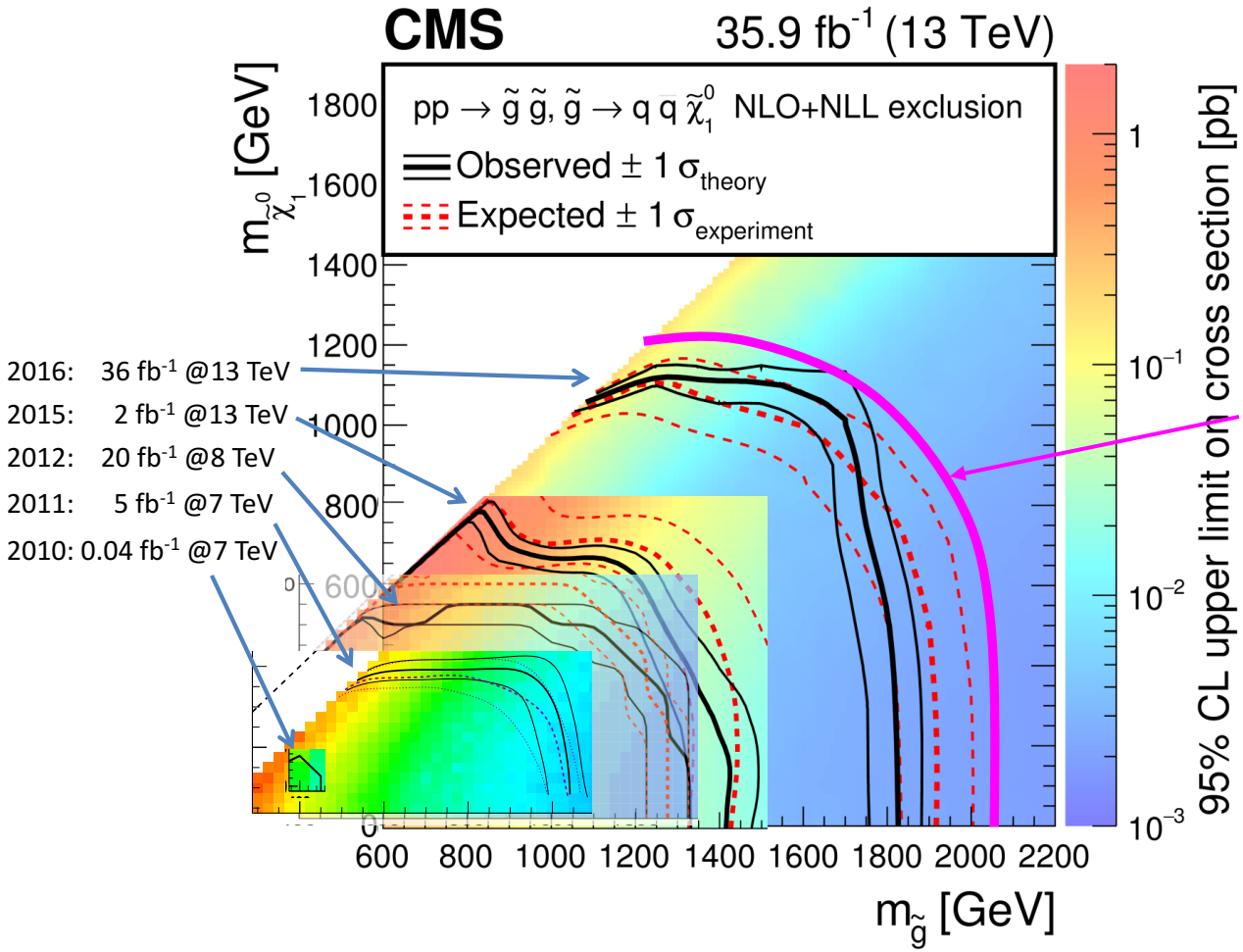

Taken from Keith Ulmer's talk at SUSY2017

- My naïve luminosity extrapolation to 70-80 fb^{-1}.
- Most analyses don't gain a lot by doubling the statistics.
- Need an updated strategy!

Run-2 strong SUSY searches @ 36 fb^{-1}

ATLAS publications		CMS publications	
1804.03568	RPV multijets	1801.01846	Soft opposite-sign dileptons
1803.10178	$\tilde{t} \to \tilde{\tau}$ pair production	1712.08920	RPV gluinos
1802.03158	Photon signatures in GMSB	1712.08501	$\tilde{g} \to$ boosted h pair production
1712.02332	Jets + E_T^{miss}	1711.08008	Photon signatures in GMSB
1712.02118	Disappearing tracks	1711.00752	$\tilde{t}$ pair production (2 leptons)
1711.11520	$\tilde{t}$ pair production (1 lepton)	1710.11188	$\tilde{t}/\tilde{g}$ pair production (0 leptons)
		1710.09154	Multilepton search
1710.07171	RPV $\tilde{t}$ (pair-produced jet resonances)	1709.09814	1 lepton + jets + E_t^{miss} ($\Delta\phi(W, \ell)$)
1710.05544	RPV $\tilde{t}$ (lepton-jet resonances)	1709.08908	Opposite sign dileptons
1710.04901	Displaced vertices	1709.00384	$\tilde{b}/\tilde{\chi} \to h(\gamma\gamma)$ with Razor
1709.04183	$\tilde{t}$ pair production (0 leptons)	1707.07274	$\tilde{b}$ pair production
1708.09266	$\tilde{b}$ pair production	1707.06193	1 photon signatures in GMSB
1708.08232	1 lepton + jets + E_T^{miss}	1707.03316	$\tilde{t}$ pair production (0 leptons)
1708.03247	$\tilde{t}$ pair production (2 leptons)	1706.04402	$\tilde{t}$ pair production (1 leptons)
1708.02794	Large jet multiplicities (large-R jets)	1705.04673	1 lepton + jets + E_t^{miss} (M_J)
1706.03986	$\tilde{t} \to h/Z$ pair production	1705.04650	Jets + E_T^{miss} (M_{T2})
1706.03731	Same sign di-/multi-leptons	1704.07781	Jets + H_T^{miss}
1704.08493	RPV signatures (1 lepton + jets)	1704.07323	Same sign dileptons

Run-2 strong SUSY searches @ 36 fb^{-1}

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1711.11			
			t, t))
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1		1707.06193	
17	jets + E_T^{miss}	1707.033	
170	t pair production (2 leptons)	1706.0440	
1708.02794	Large jet multiplicities (large-R jets)	1705.0467	
1706.03986	$\tilde{t} \to h/Z$ pair production	1705.04650	
1706.03731	Same sign di-/multi-leptons	1704.07781	
1704.08493	RPV signatures (1 lepton + jets)	1704.07323	Same sign dileptons

Impressive program of both ATLAS and CMS, performed during 2017.

All these results had been presented at SUSY2017 and will be updated with full Run-2 data.

Many of these results will be/have been shown in parallel sessions here in Barcelona.

Outline - new searches

My talk will be mostly about **dedicated** efforts for accessing new parameter spaces.

Generic searches:

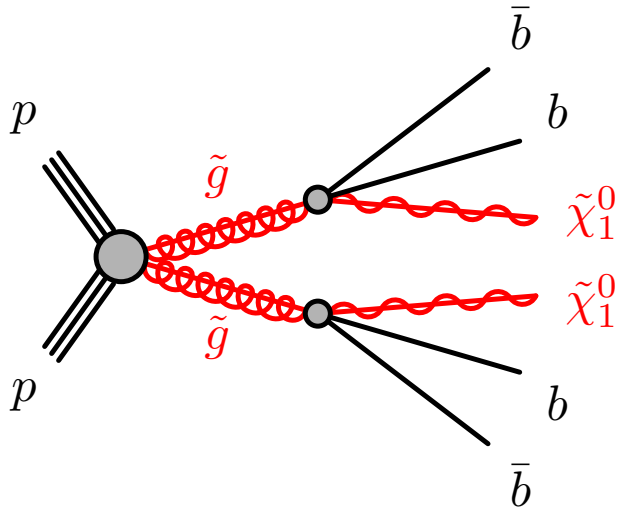
- Multi-b search (updated search with 80 fb^{-1})
- Inclusive hadronic SUSY
- Z/edge OS lepton search
- GMSB search with leptons and photons.

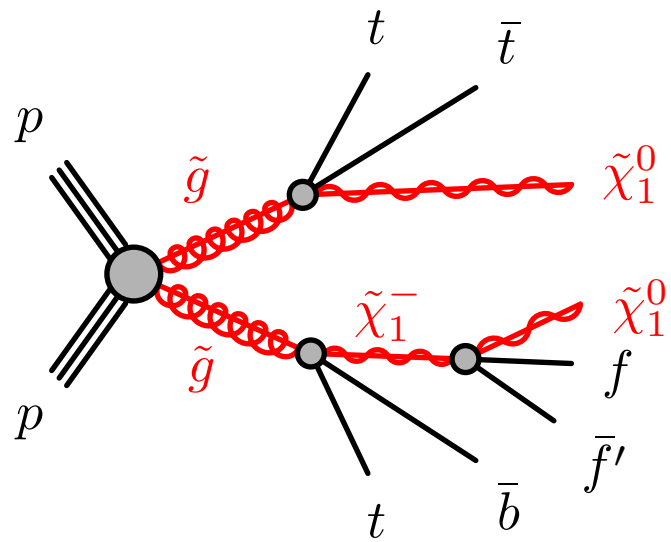
- More targeted searches:
  - Gluino production involving taus
  - Squark production involving charm
  - Compressed SUSY: Soft 1ℓ top squark search
  - Bottom squark + Higgs search (incl. 2017 data)
- RPV searches:
  - 2, 3 or $\geq$4 jet resonances

2017 update of multi-b search

2017 data

- The ATLAS multi-b search (prev: JHEP06(2018)107) updated its results with 2017 data.
- The goal of this search is to target gluino production with decays involving 3rd generation quarks (b, t).





2017 update of multi-b search

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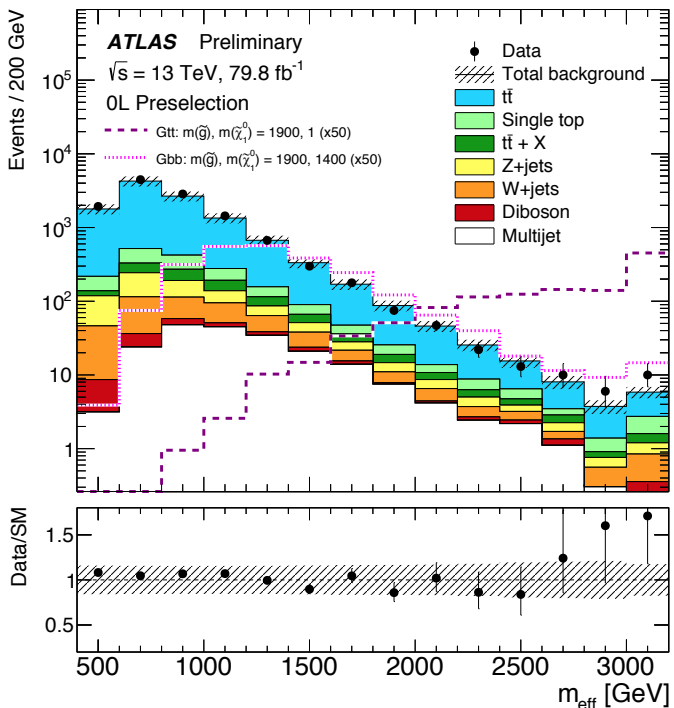
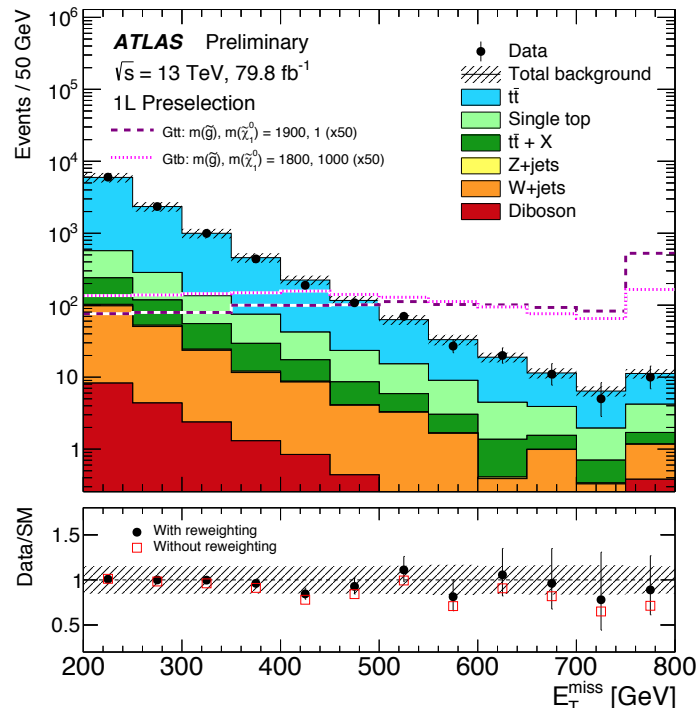
- The ATLAS multi-b search (prev: JHEP06(2018)107) updated its results with 2017 data.
- The general strategy is to select multi-b events (≥3 or 4 b-jets), many jets (≥5 up to ≥9), high E_T^{miss} (> 300 – 600 GeV), high $m_{T,min}^{b\ jets}$, and high M_{eff} (e.g. binning in it).
  - Selecting 0 or 1 lepton events: if 1 lepton also high m_T^{ℓ}.
  - Signal and (most) control region definitions unchanged.

ATLAS-CONF-2018-041





2017 update of multi-b search

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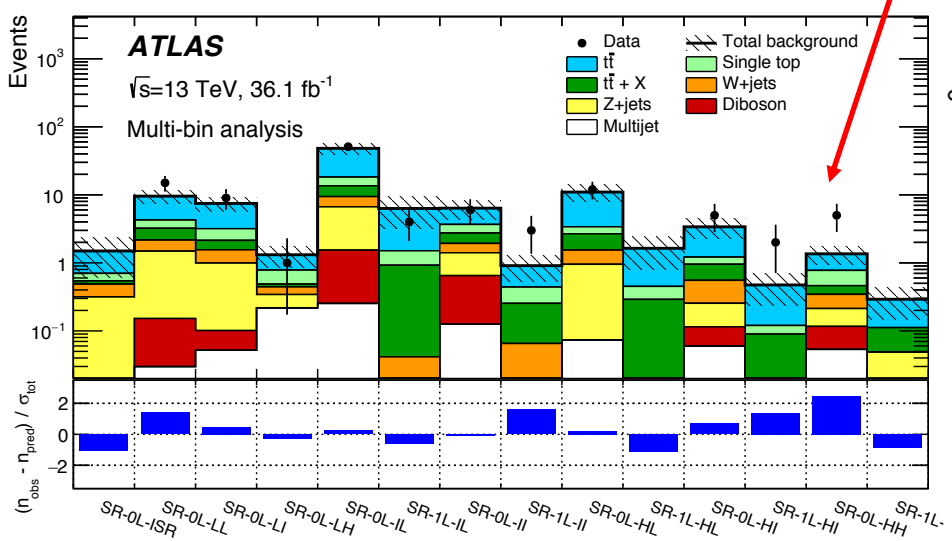
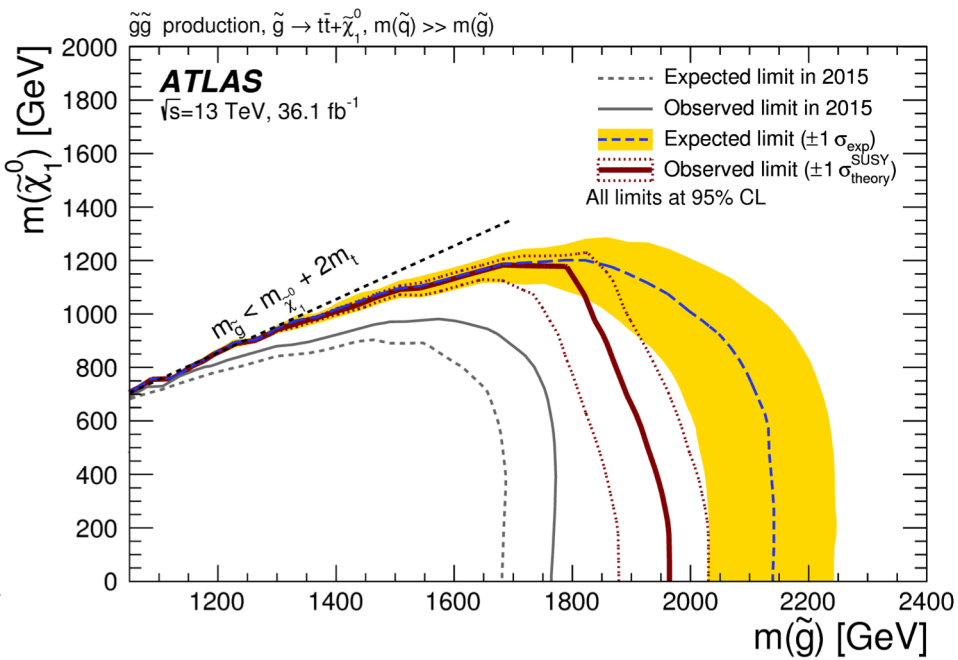
- In the multibin search, there was a small excess → not confirmed.





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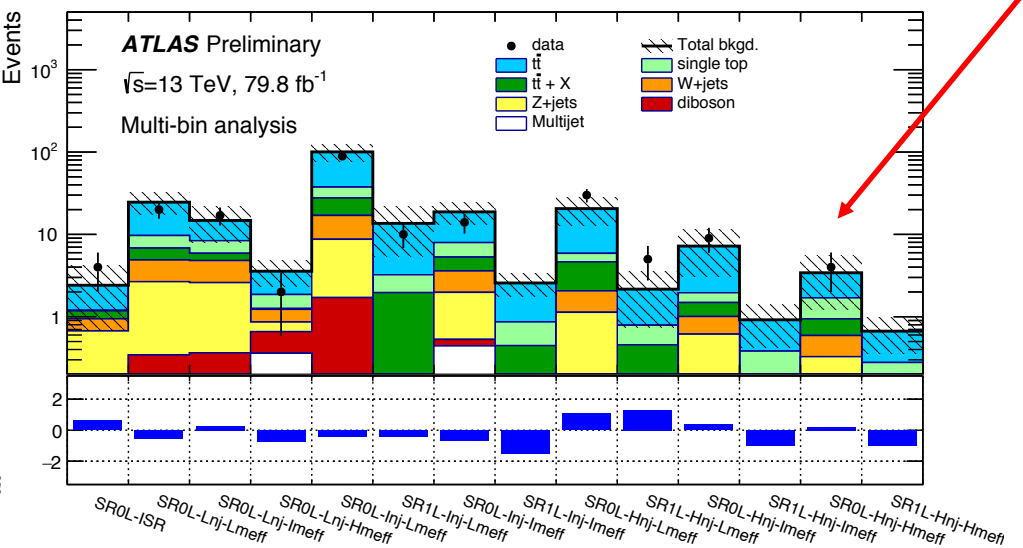
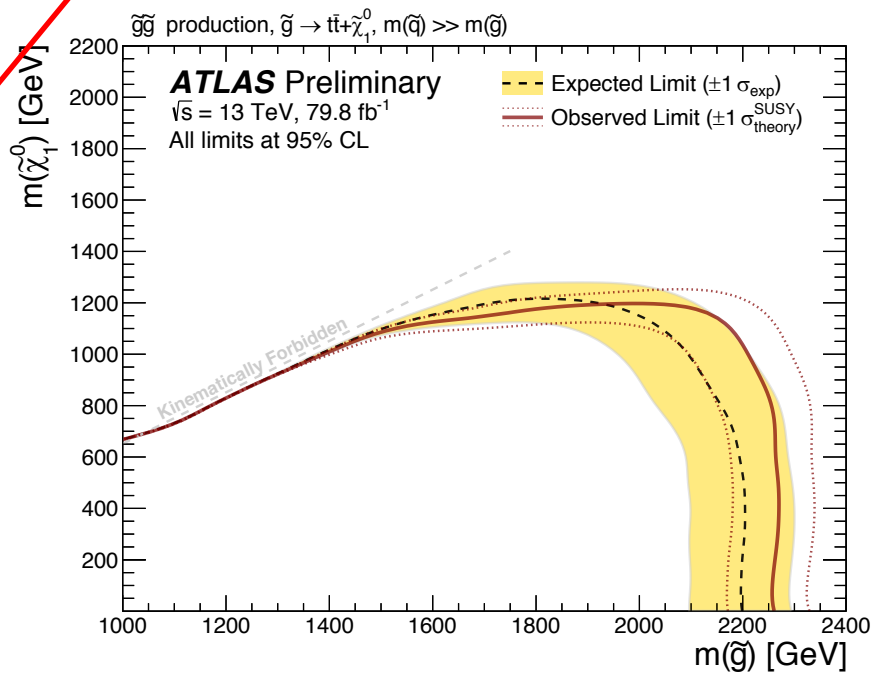


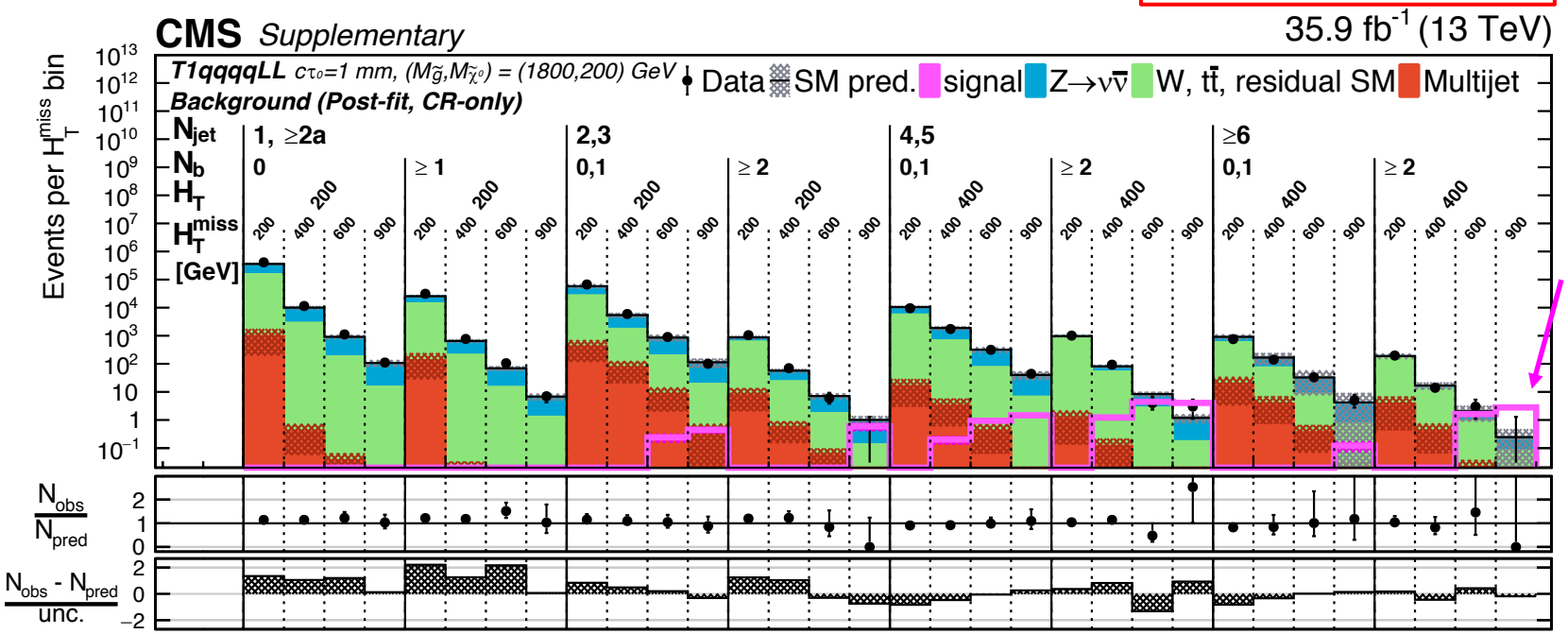


ATLAS-CONF-2018-041

Inclusive hadronic SUSY search

- One inclusive hadronic CMS search uses a running α_T and min$\Delta\phi$* cuts to reject QCD multijet production.
- The remaining phase space is divided into 254 signal regions depending on
  - Jet and b-jet multiplicities, H_T, and H_T^{miss}.

JHEP 05 (2018) 025

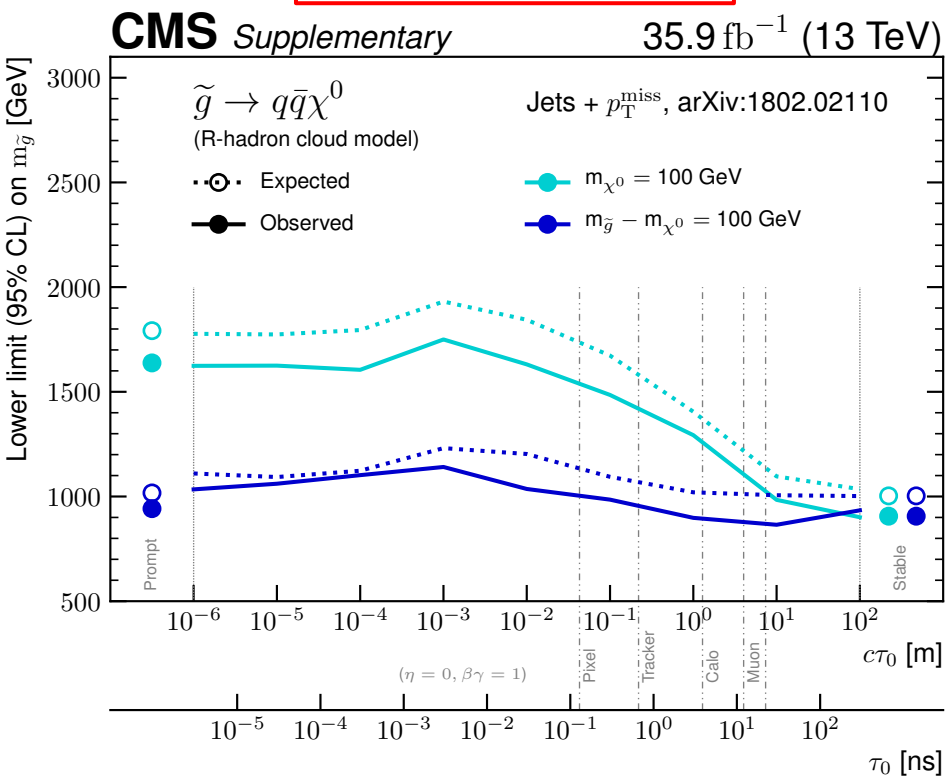


long-lived $\tilde{g}$ signal: $c\tau = 1$mm

Inclusive hadronic SUSY search

- Besides generic interpretation, this includes split SUSY interpretation:
  - Fermions light, others heavy (give up on naturalness) → $\tilde{g}$ can be long-lived
- Also ATLAS has done a re-interpretation for split SUSY.

JHEP 05 (2018) 025



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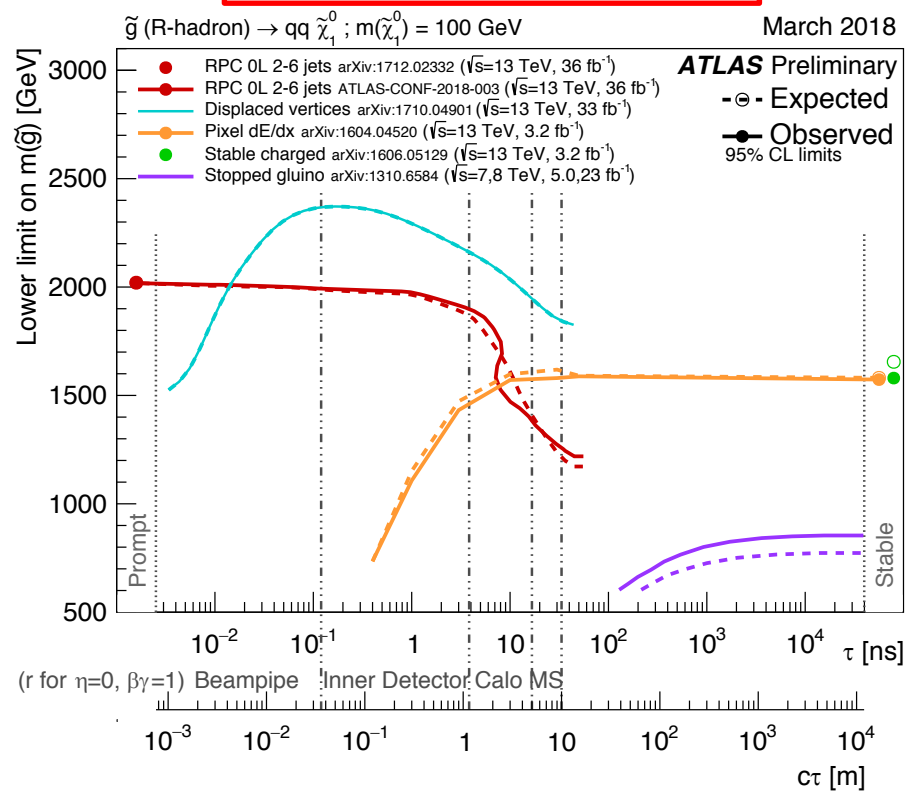
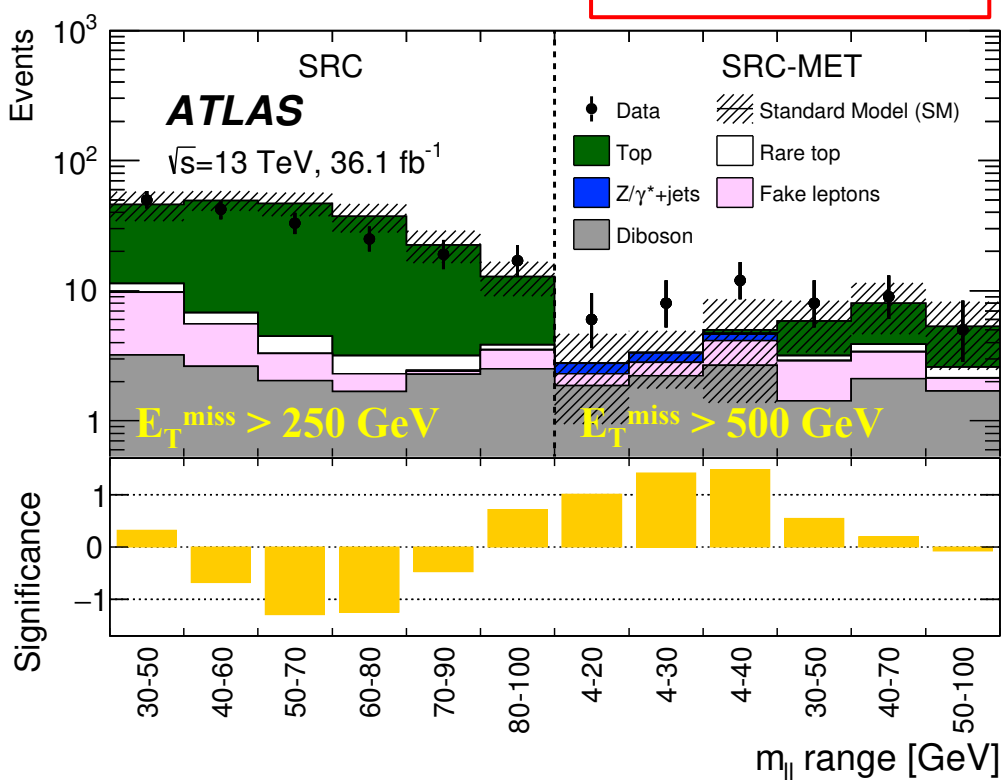
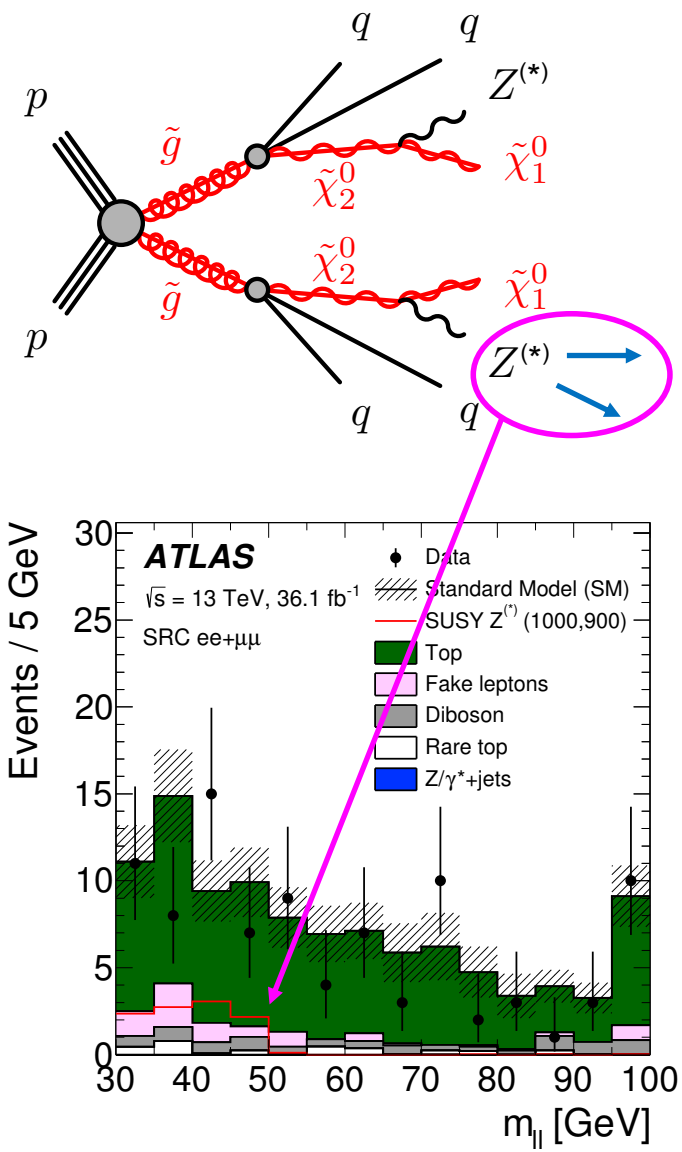


Edge SFOS lepton search

- Look for a edge in the dilepton mass spectrum for two same-flavor oppositely-charged leptons.
- The latest ATLAS search includes a soft dilepton region ($p_T > 7$ GeV).

arXiv:1805.11381





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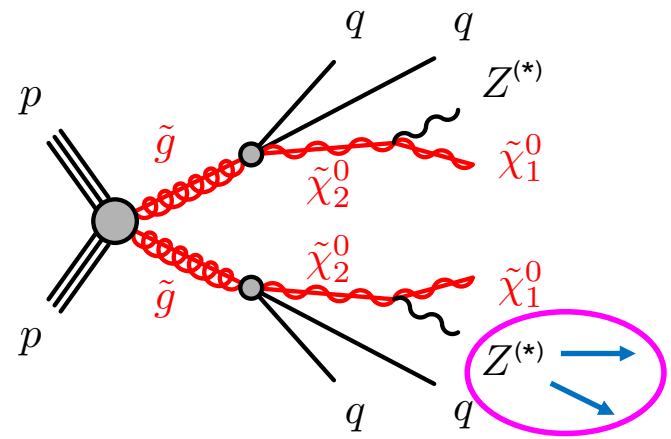
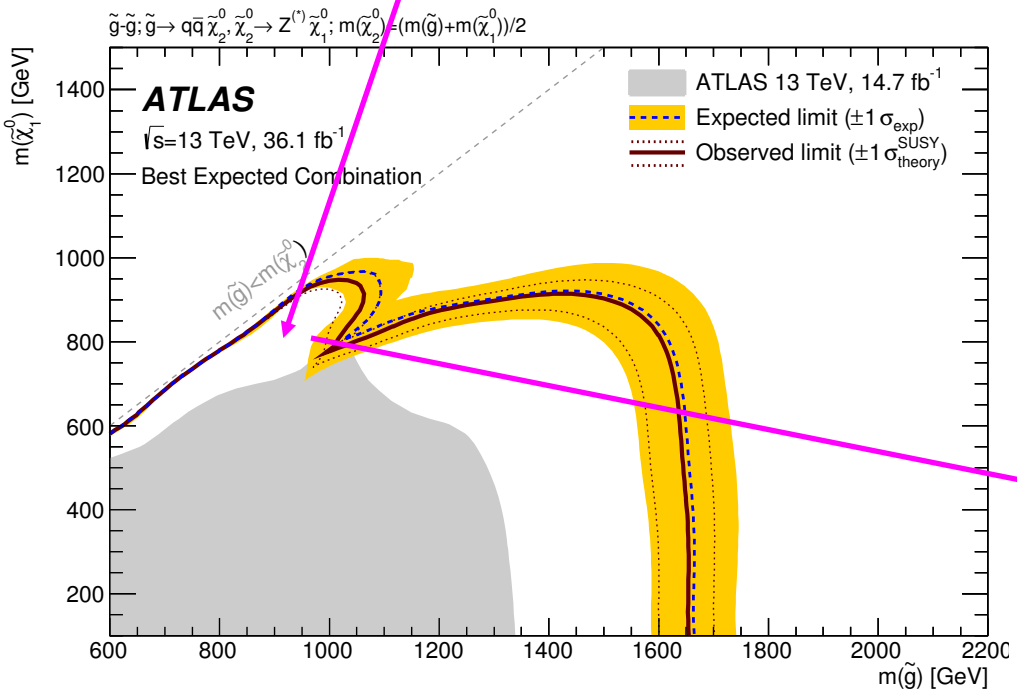


Increased sensitivity at low ΔM



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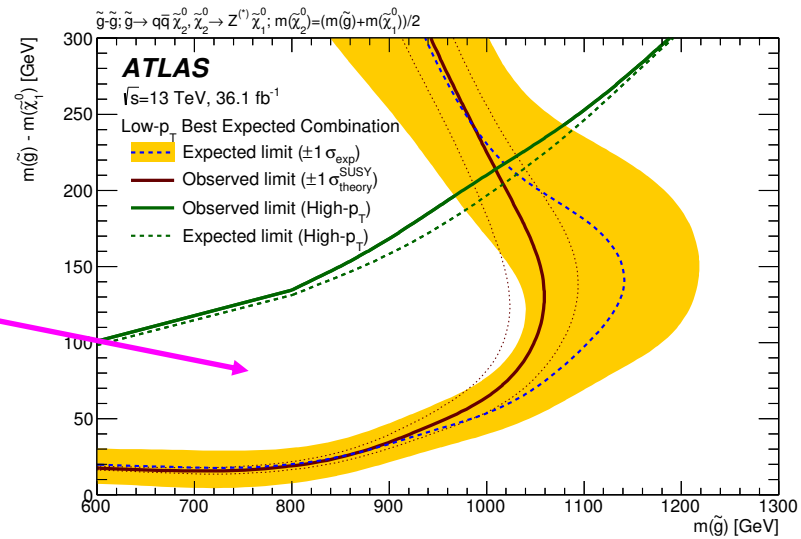
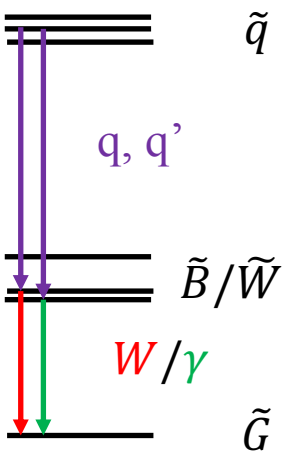
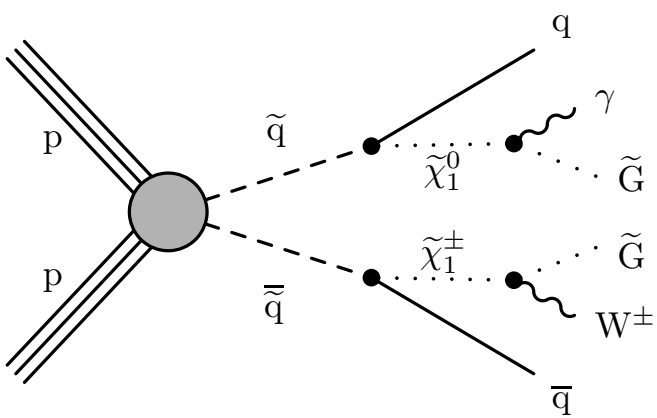


GMSB search with 1γ and 1ℓ

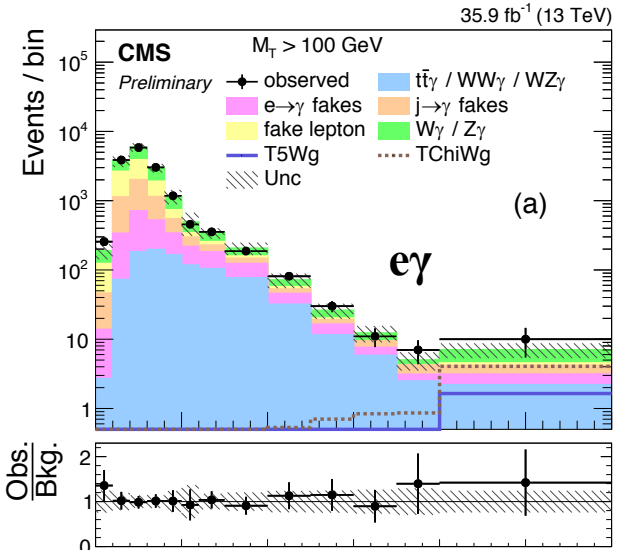
- Most GMSB searches look for multilepton ($\tilde{\chi}_1^0 \to Z/h\tilde{G}$) or photons ($\tilde{\chi}_1^0 \to \gamma\tilde{G}$) signatures.
- If NLSP has significant Wino content, also have decays like $\tilde{\chi}_1^\pm \to W\tilde{G}$.
- CMS search for GMSB strong production in events with one lepton, one photon, several jets, and E_T^{miss}.

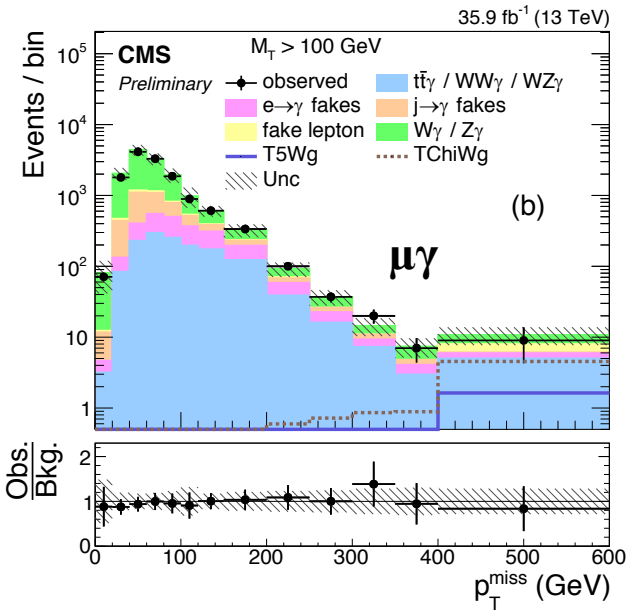


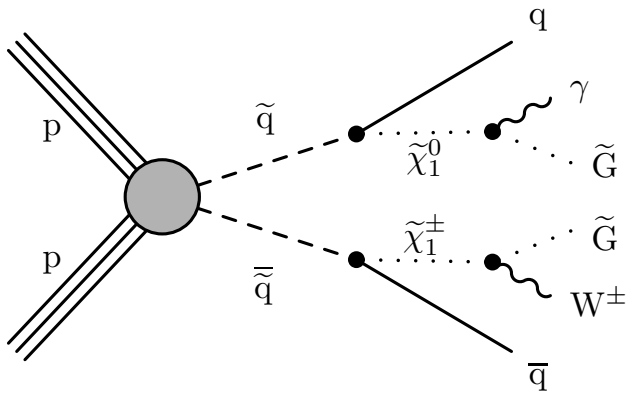


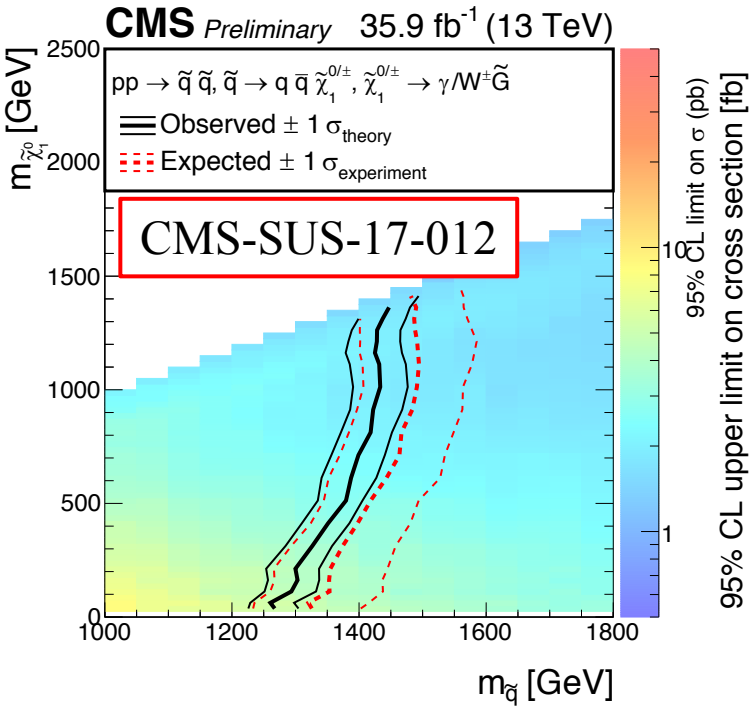
CMS-SUS-17-012

GMSB search with 1γ and 1ℓ





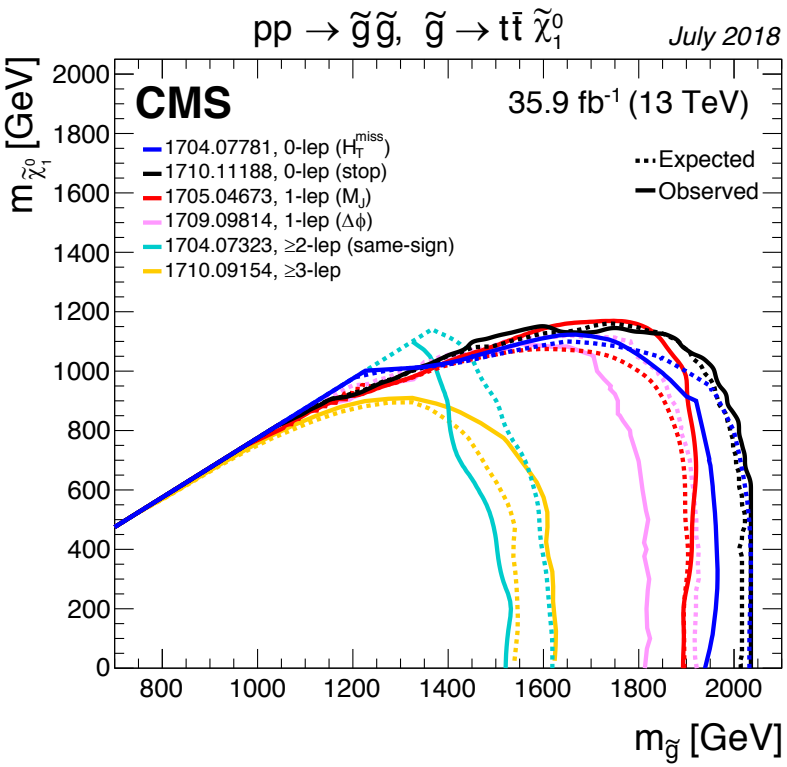


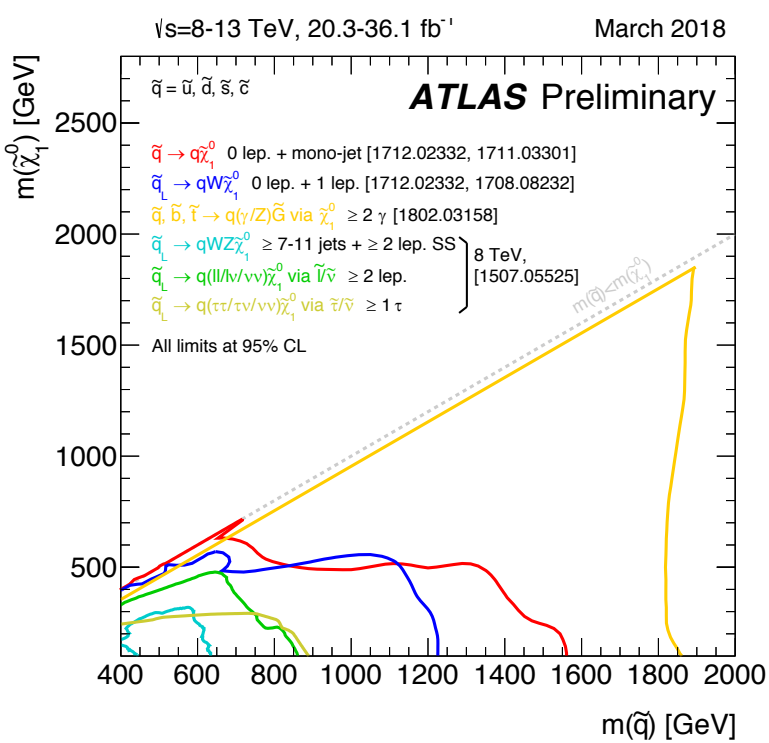


Summary of generic RPC searches

- In simplified model approach (depending on decay mode and/or mass splittings):
  - $M_{\tilde{g}} \lesssim \mathcal{O}(1\ \text{TeV}) - \mathcal{O}(2\ \text{TeV})$ @ 95% CL
  - $M_{\tilde{q}} \lesssim \mathcal{O}(0.5\ \text{TeV}) - \mathcal{O}(1.5\ \text{TeV})$@ 95% CL
  - $M_{\tilde{t}} \lesssim \mathcal{O}(0.7\ \text{TeV}) - \mathcal{O}(1.1\ \text{TeV})$@ 95% CL

  Can be even worse in some corners of simplified model space.





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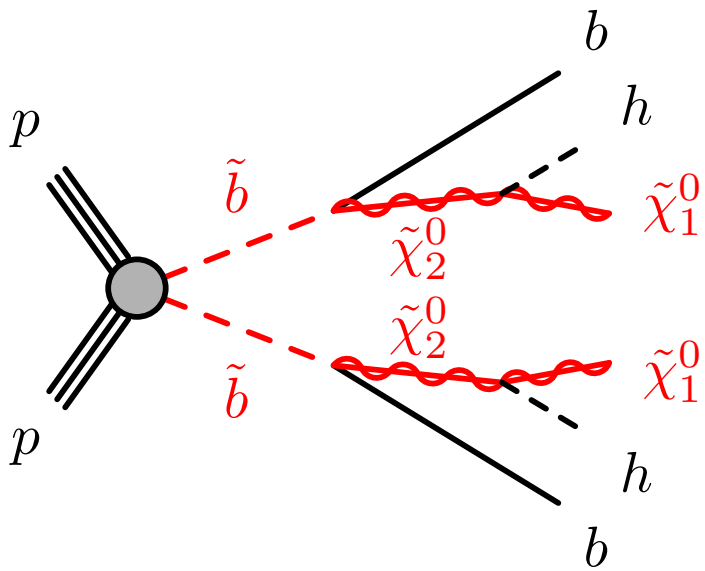
  - Gluino production involving taus
  - Squark production involving charm
  - Compressed SUSY: Soft 1ℓ top squark search
- RPV searches:
  - 2, 3 or $\geq$4 jet resonances

Search for h decay in $\tilde{b}$ production

- Most current squark searches look for the simplest decays $\tilde{q} \to q\tilde{\chi}_1^0$.
- What if the decay chain is longer?
  - Reconstructing the Higgs bosons in the decay

2017 data

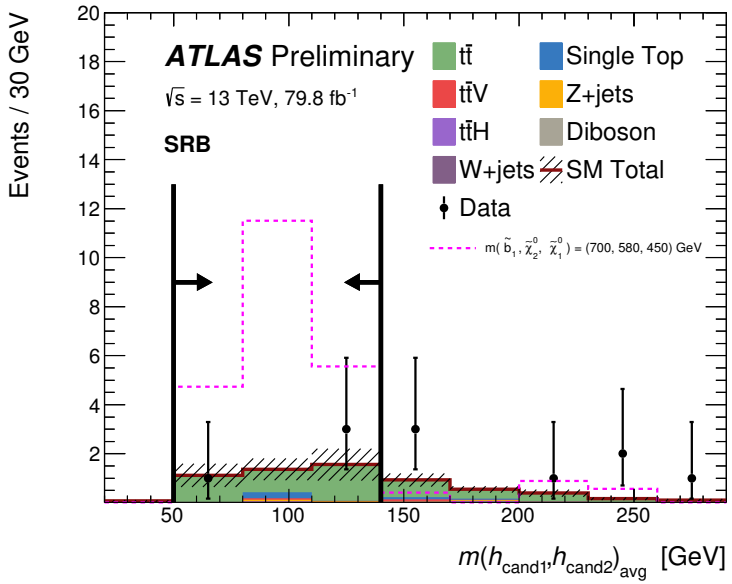


Search for h decay in $\tilde{b}$ production

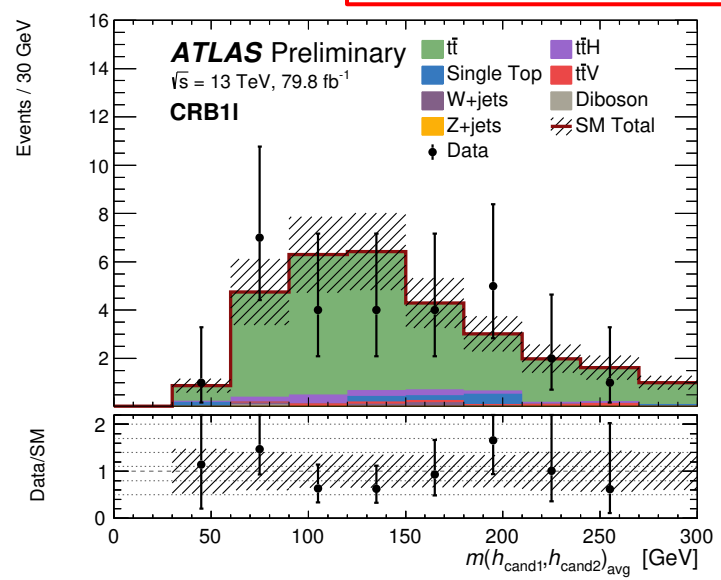
- A new ATLAS search looks for the longer decay chain $\tilde{b} \rightarrow b\tilde{\chi}_2^0 \rightarrow bh\tilde{\chi}_1^0$
- General: ≥ 6 jets, ≥ 4 (3) b-jets, no leptons and E_T^{miss} > 250 GeV.
  - Signal extraction in M_{eff}
- Different selections if in compressed regime $\Delta M(\tilde{b}, \tilde{\chi}_2^0)$ or $\Delta M(\tilde{\chi}_2^0, \tilde{\chi}_1^0)$
- Also use Higgs mass tagging using two b-jets with smallest ΔR.

2017 data

ATLAS-CONF-2018-040



m(h) in compressed signal region



m(h) modeling in 1ℓ control region

Search for h decay in $\tilde{b}$ production

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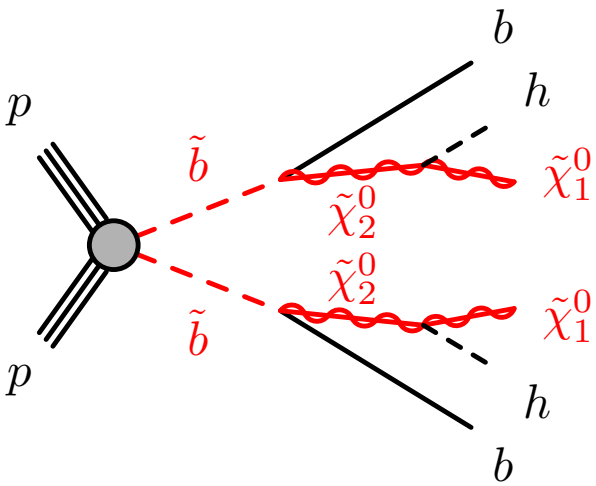
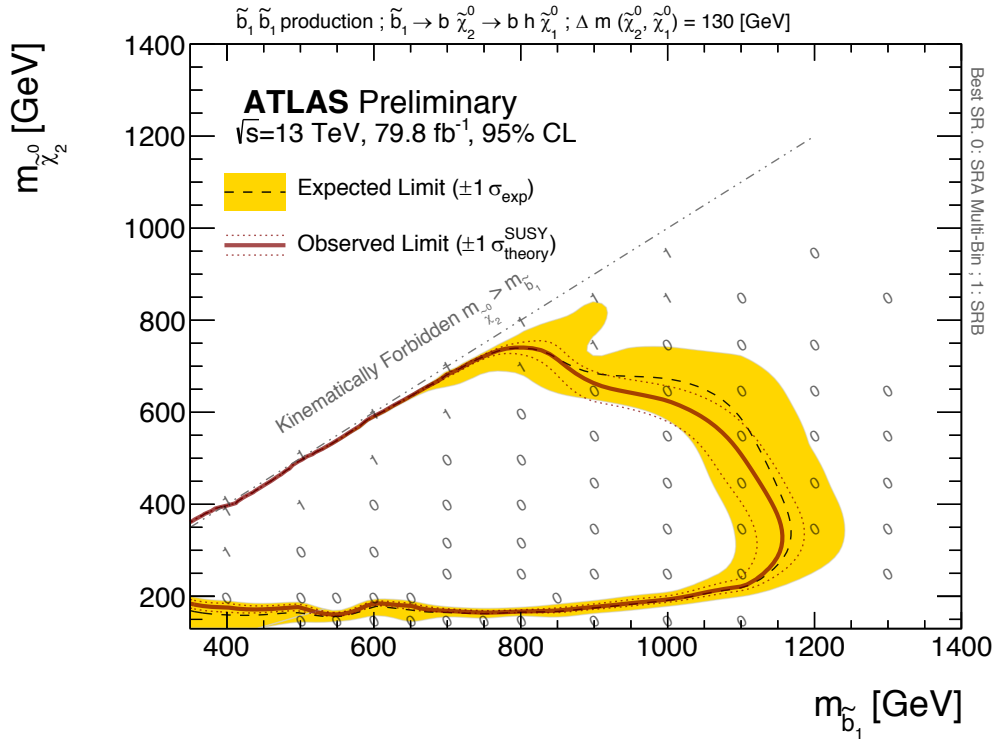
2017 data

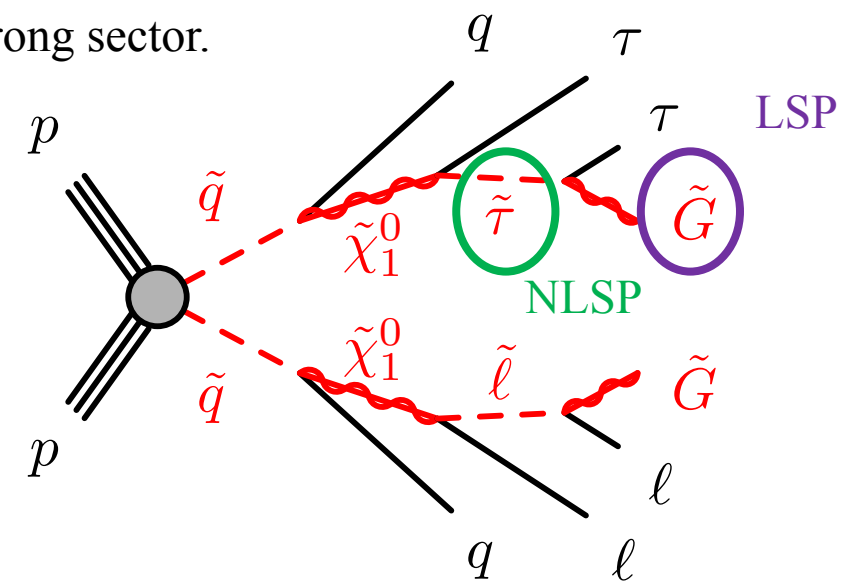




ATLAS-CONF-2018-040

Taus in strong SUSY

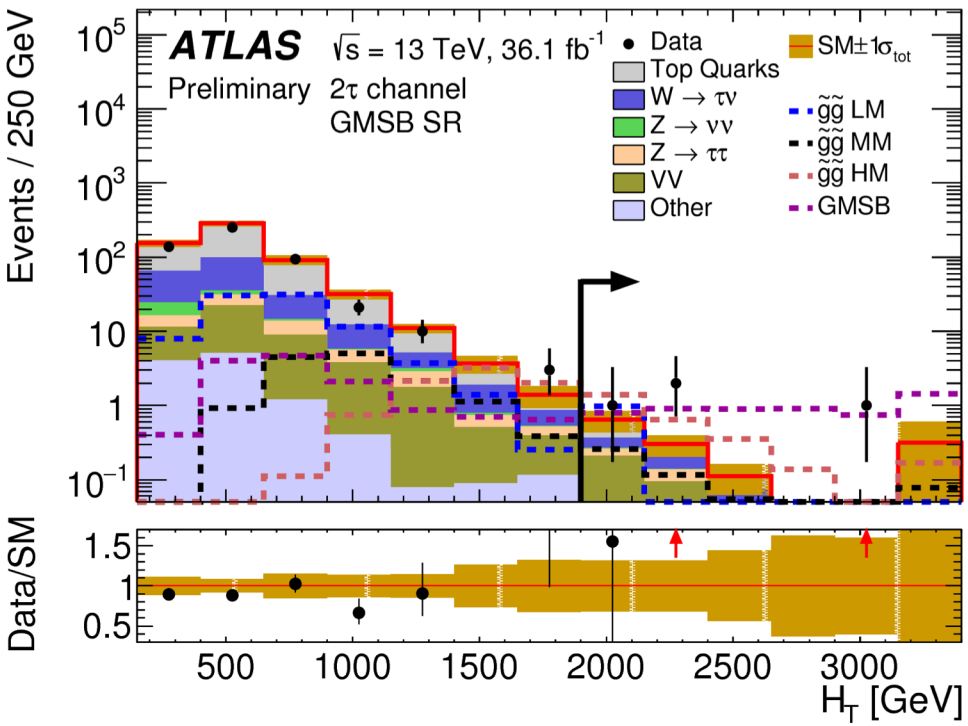
- In many scenarios, $\tilde{\tau}$s are among the lightest electroweak sparticles.
  - e.g. in many GMSB models, the $\tilde{\tau}$ is the next-to-LSP.
- However, most inclusive strong production searches, final states with τ leptons are rejected to remove $t\bar{t}$ or W+jets backgrounds.
- Dedicated searches are needed also in the strong sector.
- ATLAS performed a search for both $\tilde{g}\tilde{g}$ and $\tilde{q}\tilde{q}$ pair production.

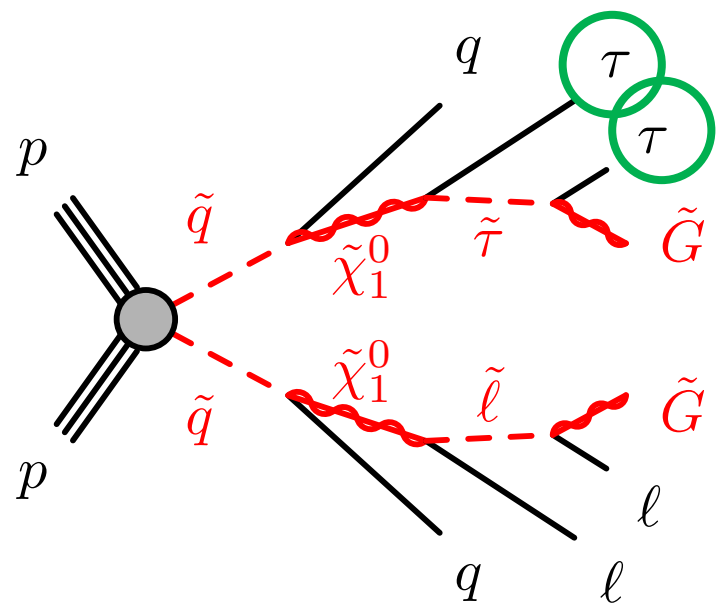


Taus in strong SUSY

- In ATLAS, hadronic τ leptons are identified with 2 BDTs (for 1- or 3-prong) using 12 input variables, such track and track+EM mass.
- The new ATLAS search selects events with 1 or $\geq$2 τ_{had} leptons, $\geq$ 2 jets, and E_T^{miss} > 400 (180) GeV for 1 ($\geq$2) τ_{had}.
- Signal is selected having by high H_T and $\sum m_T^{\tau_i}$.

SUSY-2016-30





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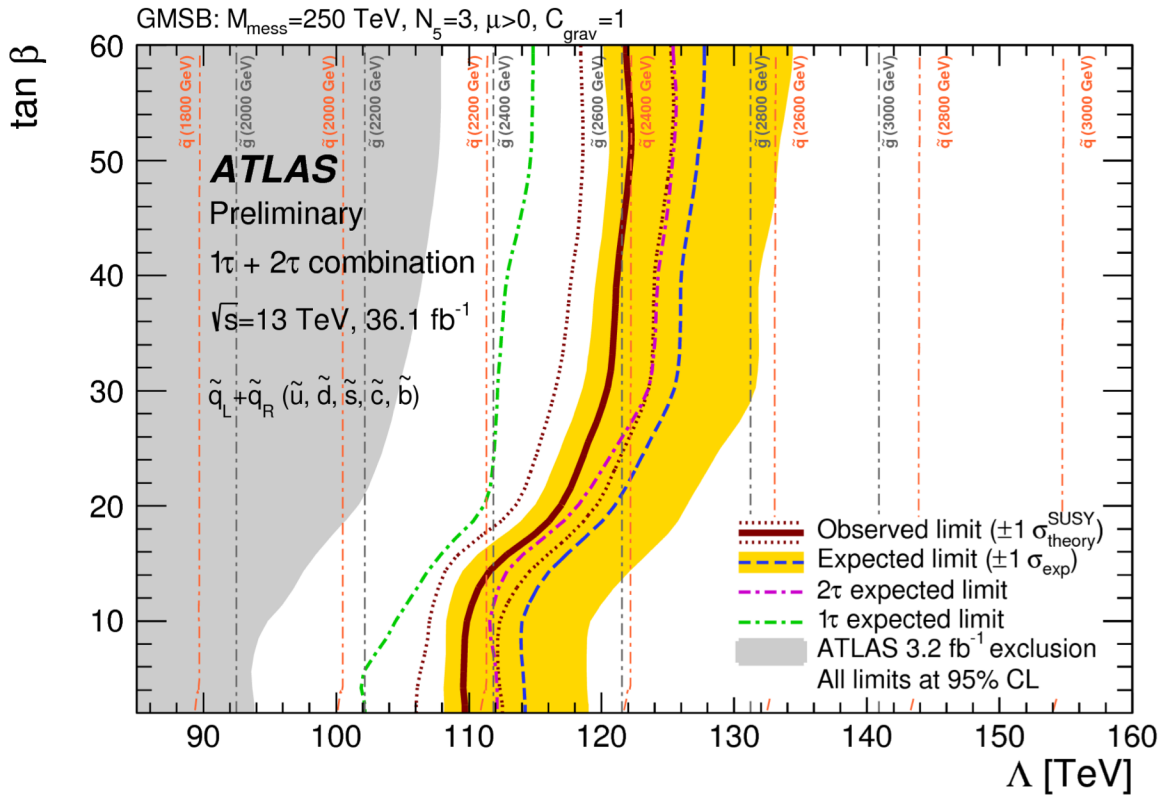
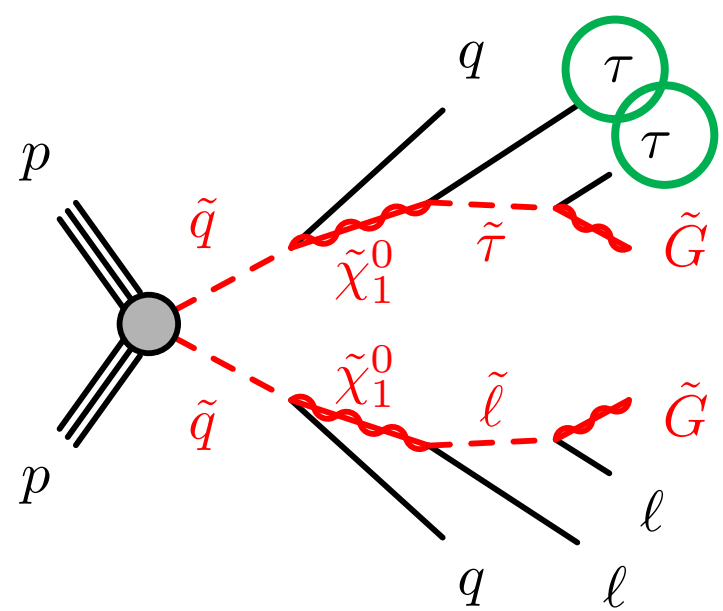
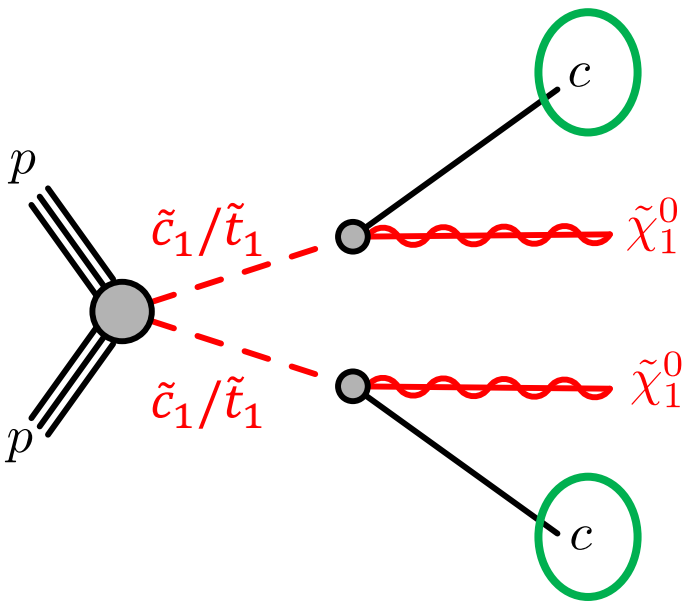


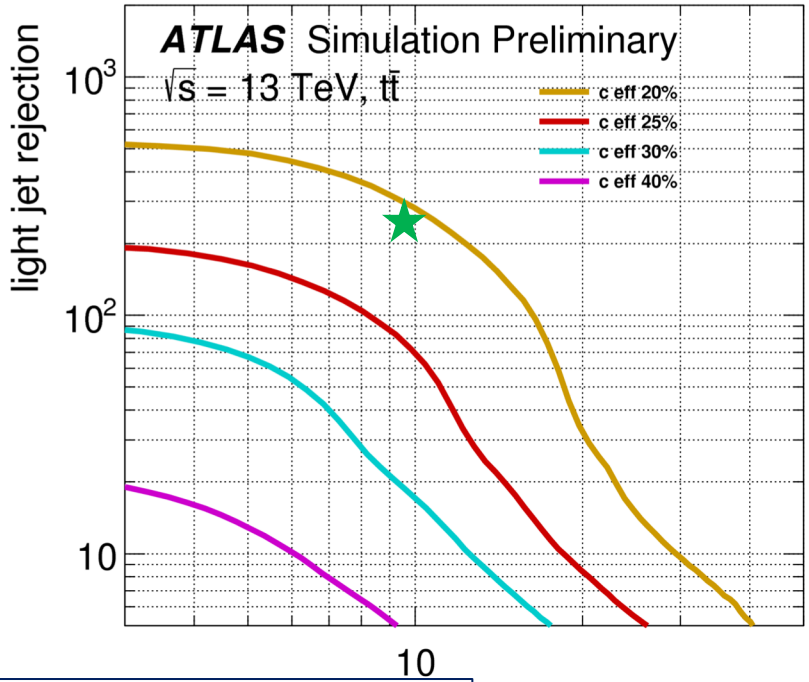
SUSY-2016-30



Not only taus are challenging: charm

- Even more challenging than taus are the identification of charm quarks.
  - Charm quarks could play an important role in SUSY, e.g. in very compressed $\tilde{t}$ scenarios.
- ATLAS deploys two BDTs with the same input variables as for b-tagging, but special training to separate charm jets from both bottom or light jets.

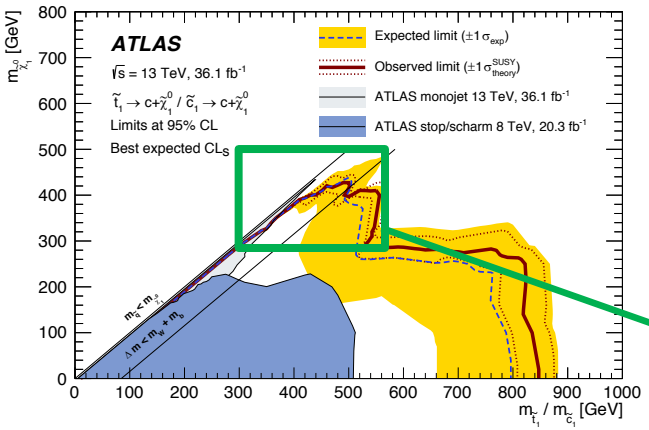


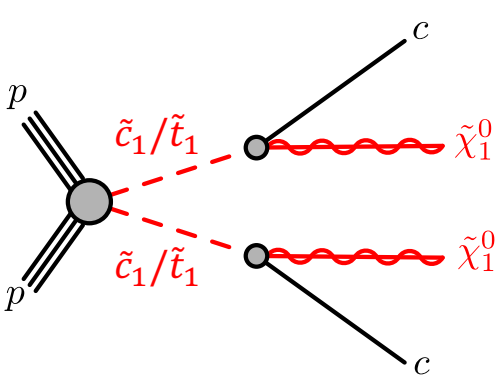


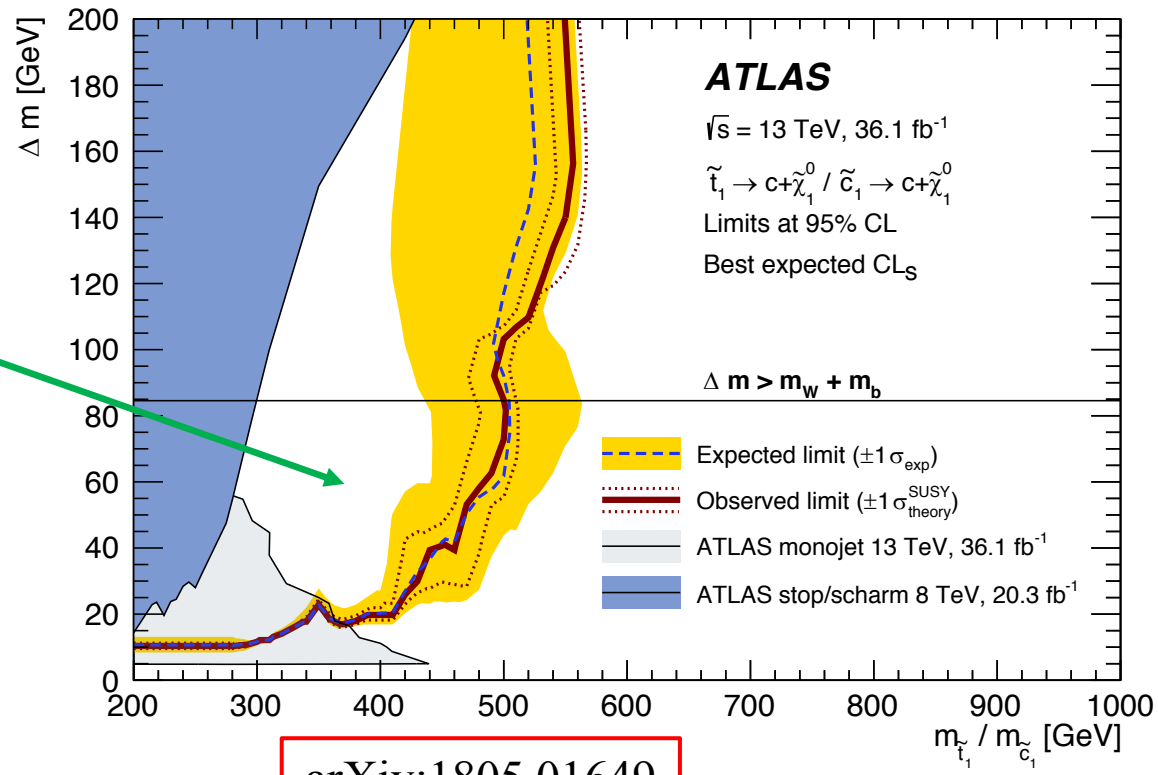
ATL-PHYS-PUB-2017-013

SUSY using charm tagging

- The ATLAS search targets both direct $\tilde{c}$ pair production as well $\tilde{t} \rightarrow c\tilde{\chi}_0^1$ decays.
- General selection requires ≥2 jets, ≥ c-tagged jets, E_T^{miss} > 500 GeV.
  - For compressed region, require ≥3 jets with leading jet not c-tagged (ISR tagging).



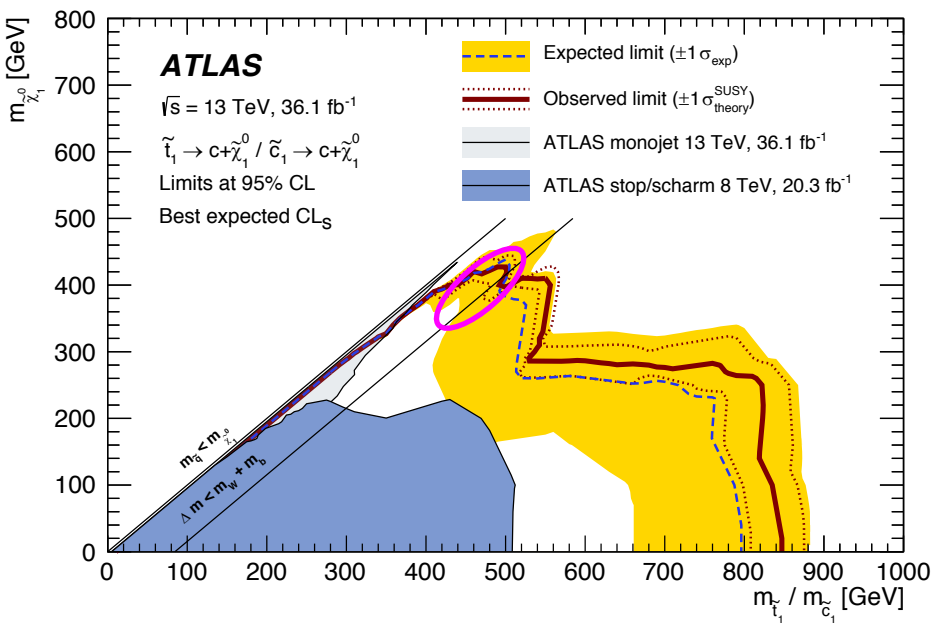


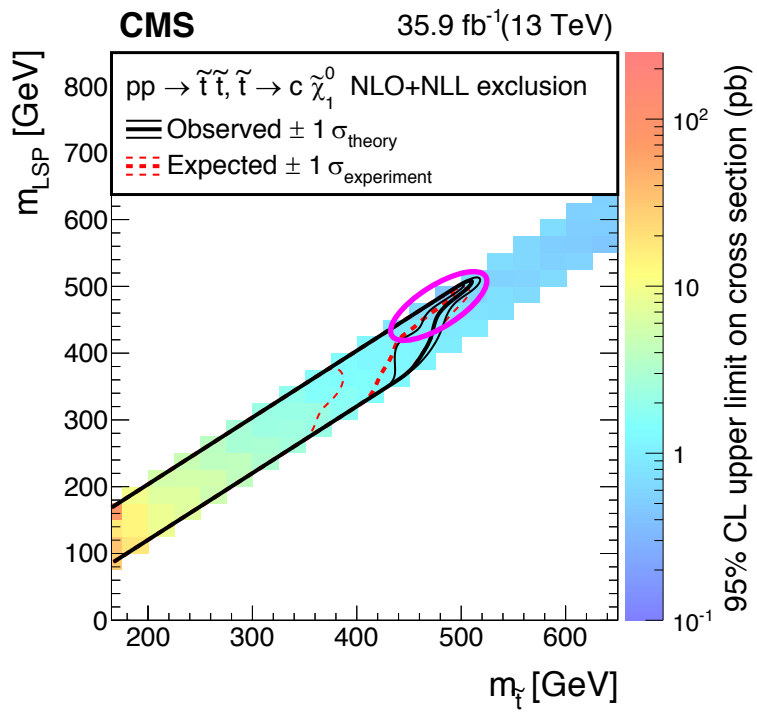


arXiv:1805.01649

SUSY using charm tagging

- The ATLAS search targets both direct $\tilde{c}$ pair production as well $\tilde{t} \to c\tilde{\chi}_0^1$ decays.
- Similar CMS search also performed for $\tilde{t} \to c\tilde{\chi}_0^1$ decays.





arXiv:1805.01649

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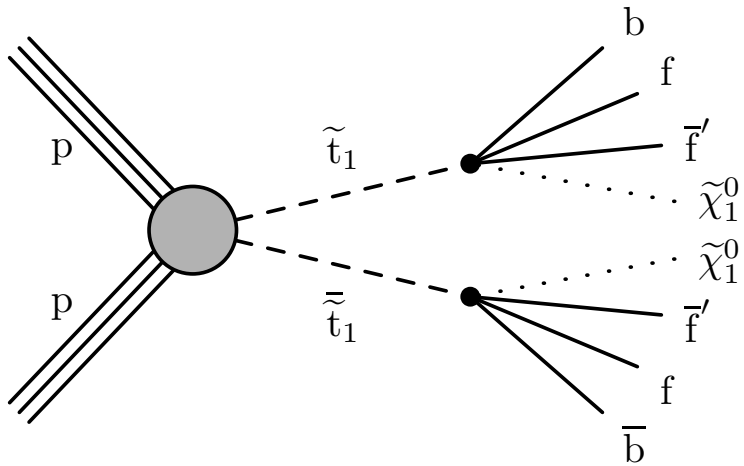
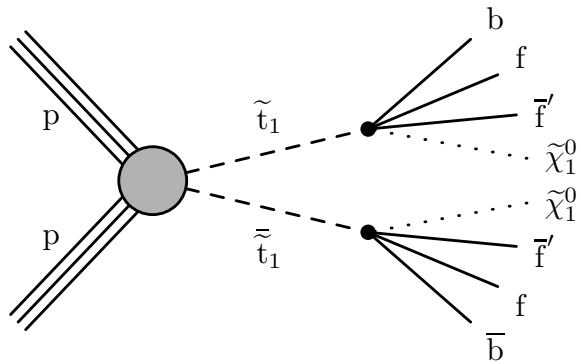
Compressed $\tilde{t}$ might decay differently

- In the very compressed regime, also the 4-body decay of the $\tilde{t}$ might happen.



- A CMS search looks in the single-lepton final state with very a soft lepton:
  - $p_T > 5$ (3.5) GeV for e (μ)
- A BDT is trained to discriminate the $\tilde{t}$ pair production signal from SM background.
  - Using 12 input variables such as E_T^{miss} or $p_T(\ell)$.
  - Multiple trainings performed depending on $\Delta M(\tilde{t}, \tilde{\chi}_1^0)$.

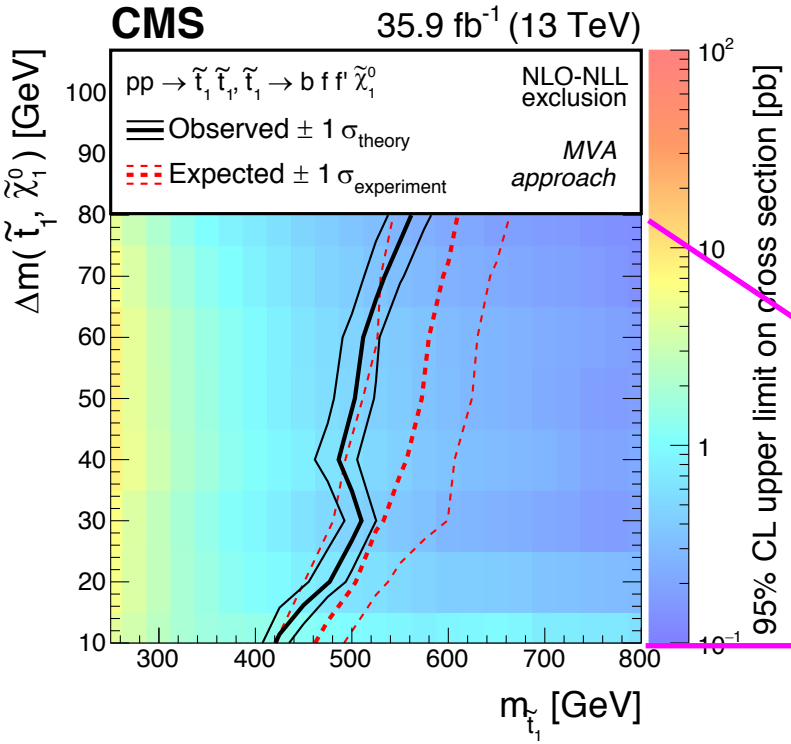
Compressed $\tilde{t}$ might decay differently

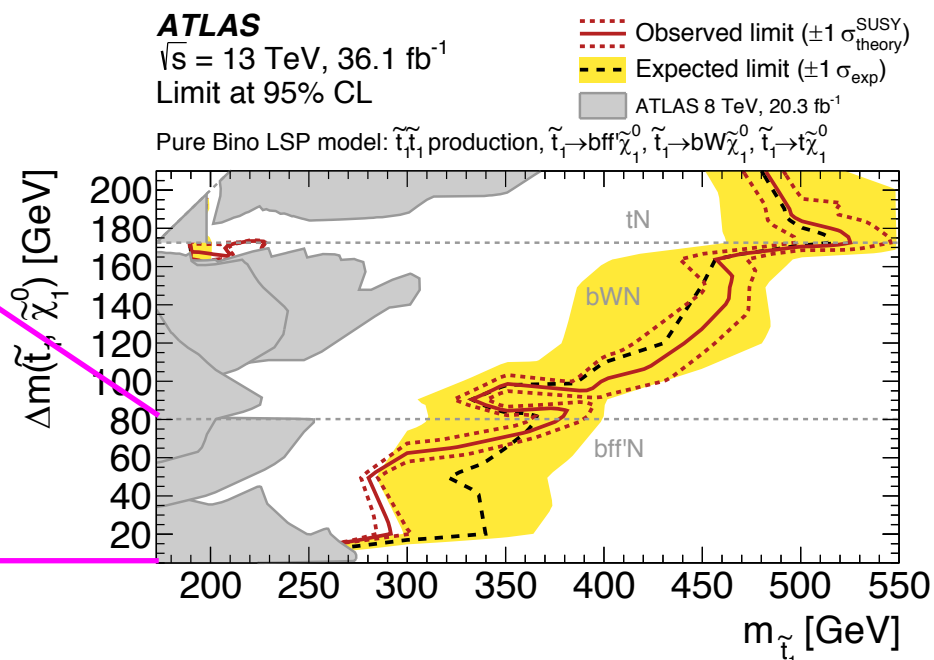


arXiv:1805.05784

ATLAS $\tilde{t}(1\ell)$ paper
cut-based search

JHEP 06 (2018) 108





Outline - new searches

My talk will be mostly about **dedicated** efforts for accessing new parameter spaces.

Generic searches:

- Multi-b search (updated search with 80 fb^{-1})
- Inclusive hadronic SUSY
- Z/edge OS lepton search
- GMSB search with leptons and photons.

- More targeted searches:
  - Bottom squark + Higgs search (incl. 2017 data)
  - Gluino production involving taus
  - Squark production involving charm
  - Compressed SUSY: Soft 1ℓ top squark search
- RPV searches:
  - 2, 3 or ≥4 jet resonances

R-Parity violating SUSY

- With general R-parity violation couplings, one could have
  - rapid proton decay, or other other low energy constraints (e.g. neutrinoless β decay, flavor-changing current)

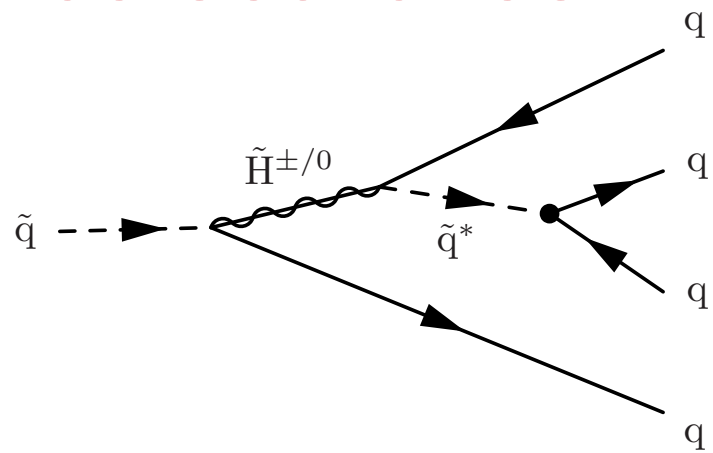
  → R-parity violating couplings are strongly constrained by low energy measurements.

- These constraints can be avoided if only one kind of R-parity violating coupling is allowed to be non-zero.

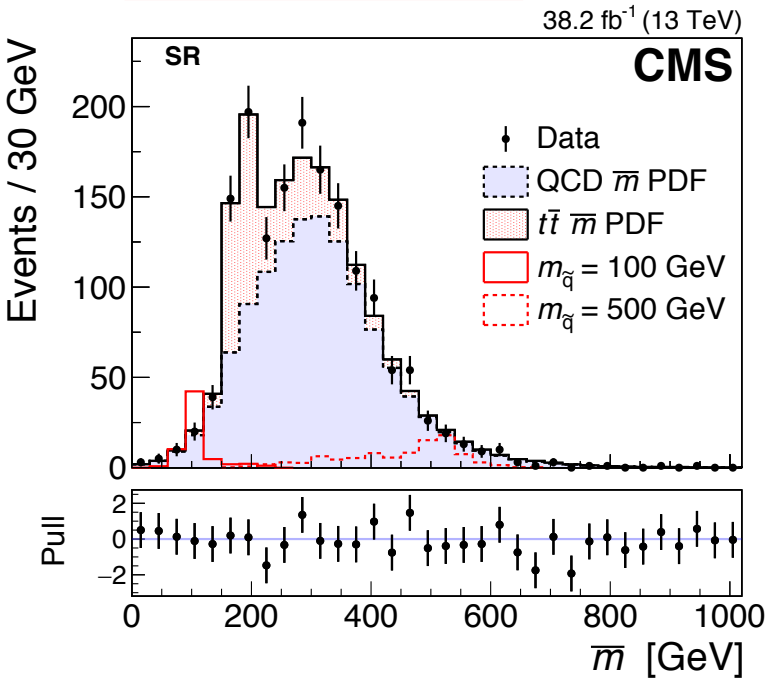
- Both ATLAS and CMS have a search program for RPV SUSY.
  - Several new results from CMS since SUSY2017.

Hadronic RPV resonance searches

- CMS search for $\tilde{q}\bar{\tilde{q}} \to 2\times4q$ or $\tilde{g}\tilde{g} \to 2\times5q$ pair production for masses $\lesssim$ 1 (1.5) TeV for $\tilde{q}$ ($\tilde{g}$).
  - Allowed through $\lambda'' \neq 0$.



arXiv:1806.01058

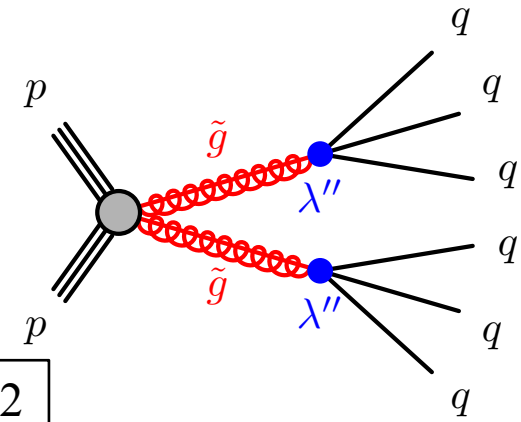


- 4 jet resonance for low mass squarks/gluinos:
  - Select two high p_T (>400 GeV) fat jets (CA, R = 1.2) with substructure (τ_{43} < 0.8, τ_{42} < 0.45) and reconstruct average mass.
- Fit signal, QCD, and $t\bar{t}$ PDFs to extract squark (or gluino) pair production from average fat jet mass spectrum.

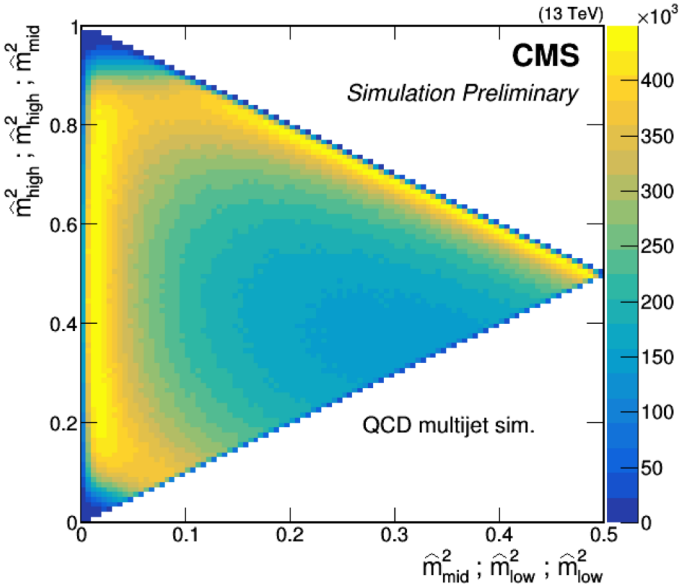
Hadronic RPV resonance searches

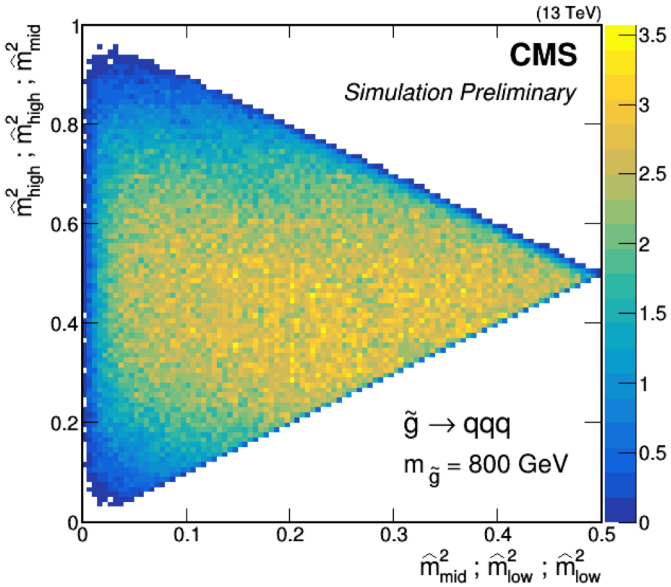
- CMS search for $\tilde{g}\tilde{g} \rightarrow 2\times 3q$ pair production
  - Use Dalitz plot variables of normalized dijet masses within each jet triplet to discriminate signal and background.
- At low masses, scouting data is used!
  - $H_T > 410$ GeV triggered @ 2 kHz
  - Only feasible by storing reduced event content.

CMS-DP2012-022



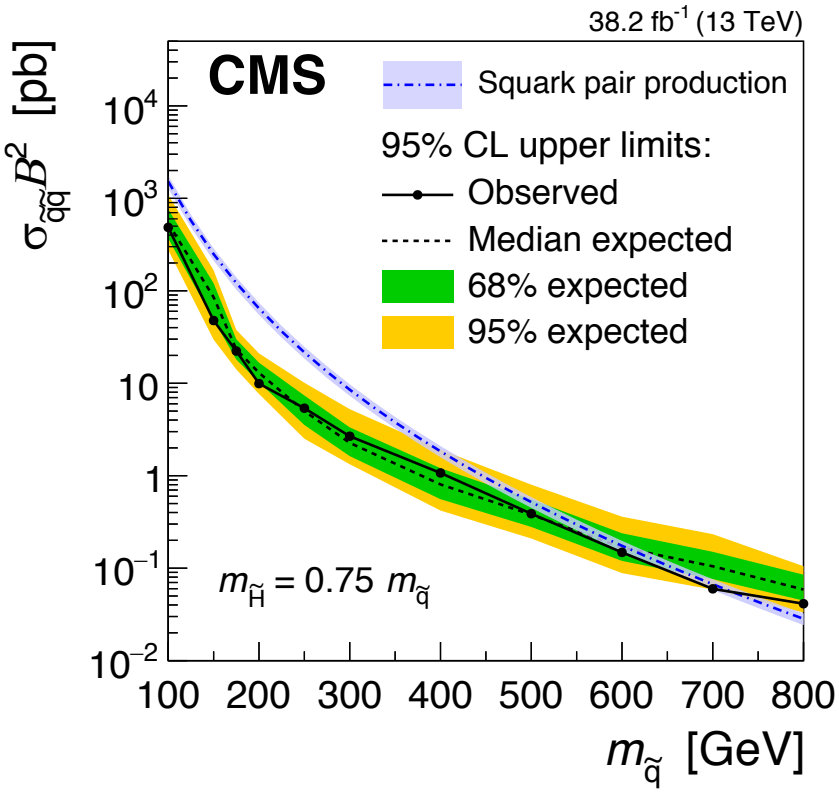
CMS-EXO-17-030



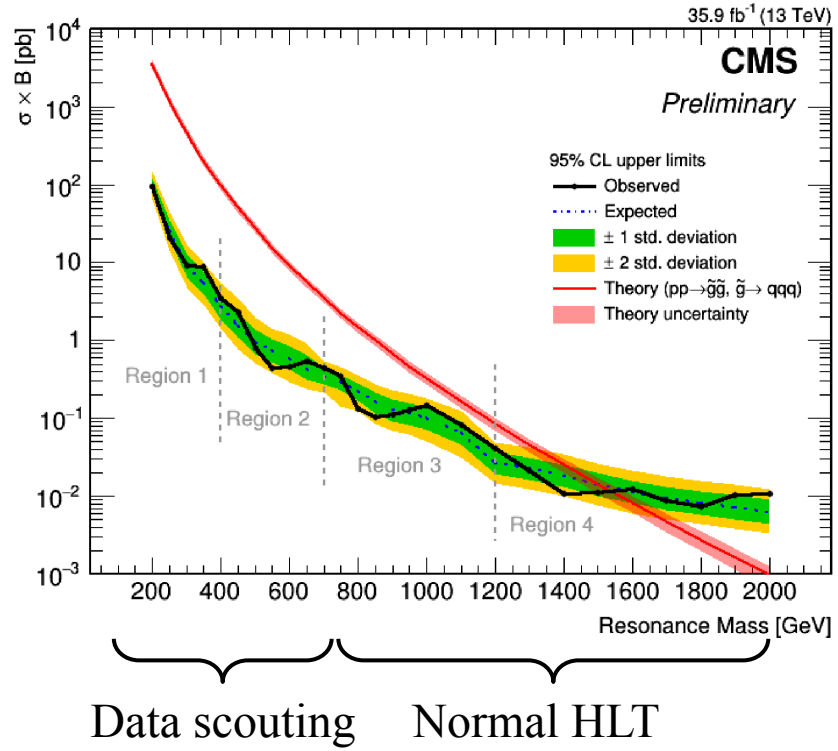


Hadronic RPV resonance searches

$\tilde{q}\bar{\tilde{q}} \rightarrow 2\times 4q$ arXiv:1806.01058

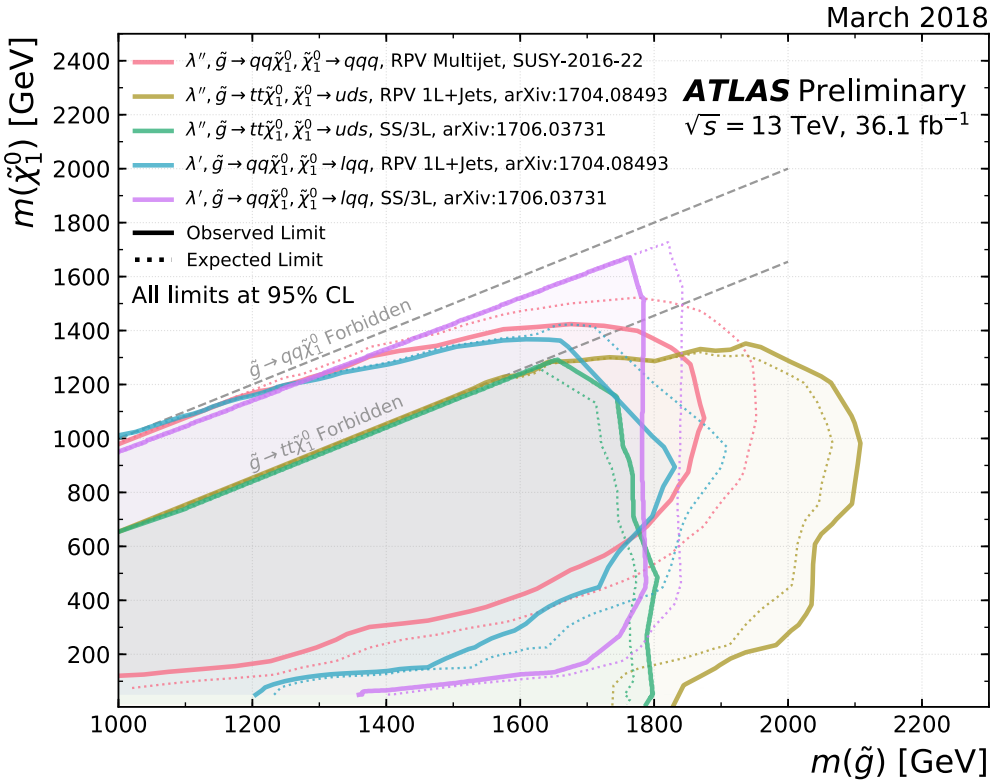


$\tilde{g}\tilde{g} \rightarrow 2\times 3q$ CMS-EXO-17-030



- CMS also release a paired dijet search: see backup or Wednesday's parallel session

RPV in ATLAS


March 2018
$\lambda'', \tilde{g} \to qq\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to qqq$, RPV Multijet, SUSY-2016-22
$\lambda'', \tilde{g} \to tt\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to uds$, RPV 1L+Jets, arXiv:1704.08493
$\lambda'', \tilde{g} \to tt\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to uds$, SS/3L, arXiv:1706.03731
$\lambda', \tilde{g} \to qq\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to lqq$, RPV 1L+Jets, arXiv:1704.08493
$\lambda', \tilde{g} \to qq\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to lqq$, SS/3L, arXiv:1706.03731
Observed Limit
Expected Limit
All limits at 95% CL
ATLAS Preliminary
$\sqrt{s} = 13$ TeV, 36.1 fb^{-1}
$\tilde{g} \to qq\tilde{\chi}_1^0$ Forbidden
$\tilde{g} \to tt\tilde{\chi}_1^0$ Forbidden
$m(\tilde{\chi}_1^0)$ [GeV]
$m(\tilde{g})$ [GeV]
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400

Parallel talks

- For more details and also more analyses, please see also these parallel talks.
- Most of them were presented yesterday, Monday –photon searches will be presented on Tuesday, RPV searches on Wednesday.

Louis-Guillame Gagnon (1st/2nd gen @ ATLAS)

Myriam Schönenberger (1st/2nd gen 0ℓ @ CMS)

Mateusz Zarucki / Isabell Melzer-Pellmann (1st/2nd gen ≥1ℓ @ CMS)

Christian Lüdtke (3rd gen SUSY @ ATLAS)

Pedram Bargasse (3rd gen @ CMS)

Joe Pastika (boosted objects @ CMS)

Johannes Schulz (photon searches @ CMS)

Michael Edward Nelson (less conventional/RPV @ ATLAS)

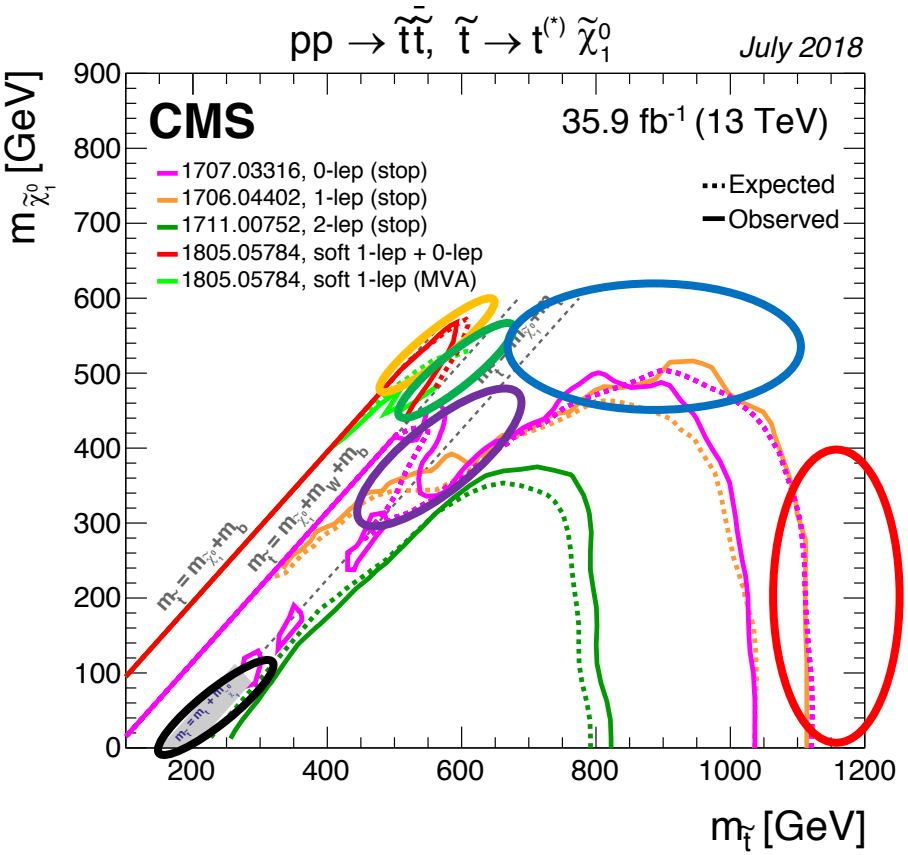
Alejandro Gomez (less conventional/RPV @ CMS)

Summary

- The experiments are developing more dedicated strategies to unveil potentially uncovered parameter spaces.
  - More dedicated: tau tagging for strong SUSY involving light $\tilde{\tau}$.
  - More challenging: charm tagging for compressed top squarks
  - More challenging: Multijet resonances in RPV
  - More targeted: soft leptons to look into compressed SUSY
  - …
- Both the ATLAS and CMS collaborations will continue the extensive search for "traditional natural" SUSY searches in the strong sectors.
  - New results with the full Run-2 dataset (2016–2018) will come next years.
- Therefore, we are not yet done with the strong SUSY search program for the LHC.

Outlook

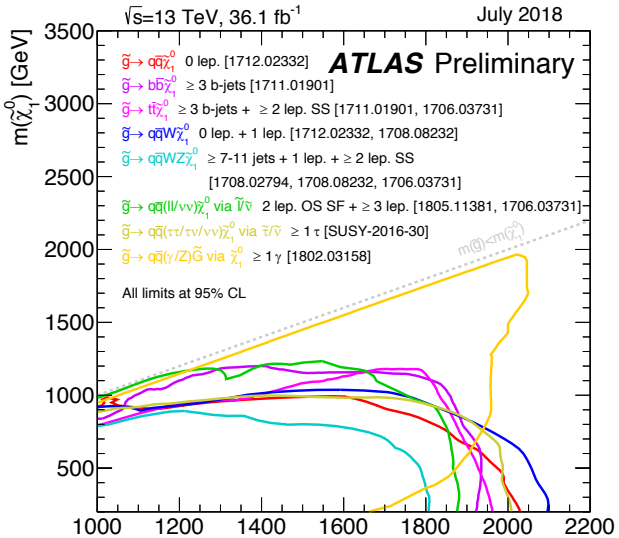
- Many searches still need to be performed or need further optimization to fill in gaps.
  - E.g. in top squark searches

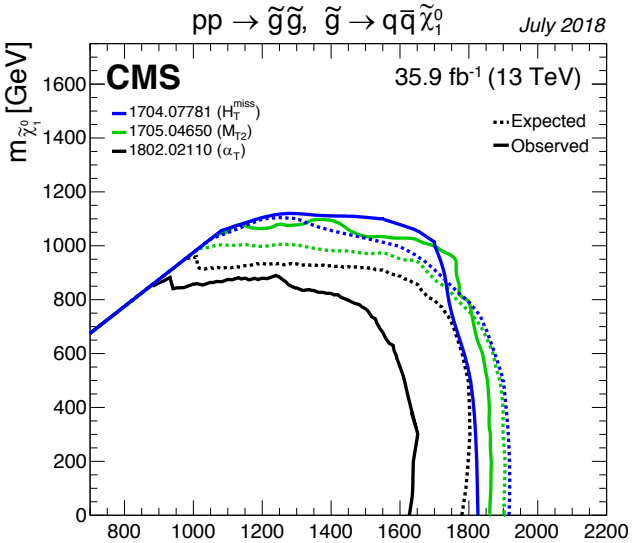


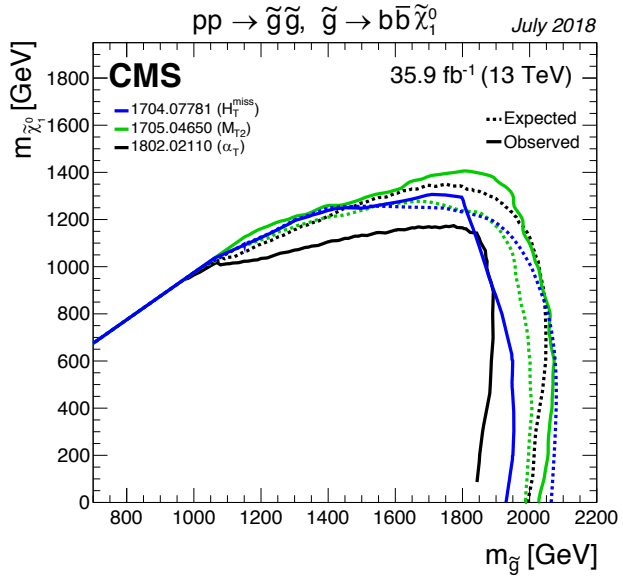
- Access high $M_{\tilde{t}}$ search
- Access high $M_{\tilde{\chi}_1^0}$ search
- $\Delta M(\tilde{t}, \tilde{\chi}_1^0) \sim M_t$
- $\Delta M(\tilde{t}, \tilde{\chi}_1^0) \sim M_W$
- $\Delta M(\tilde{t}, \tilde{\chi}_1^0) \sim 0$
- Access $\tilde{t}$ degenerate with the top quark

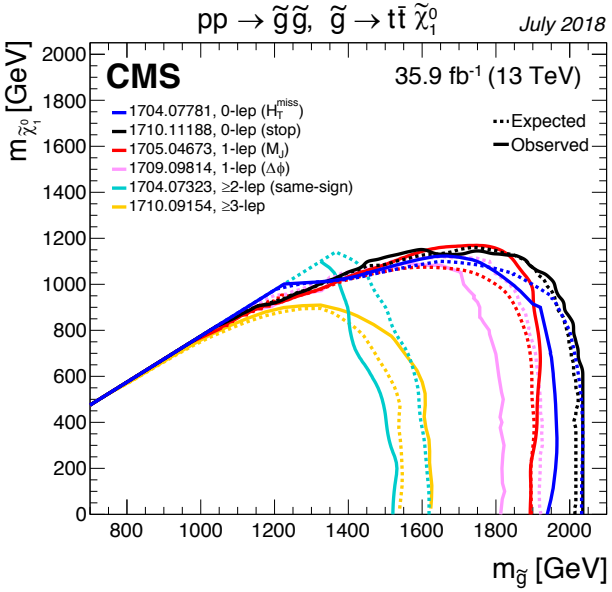
Backup

Summary of strong SUSY: gluinos

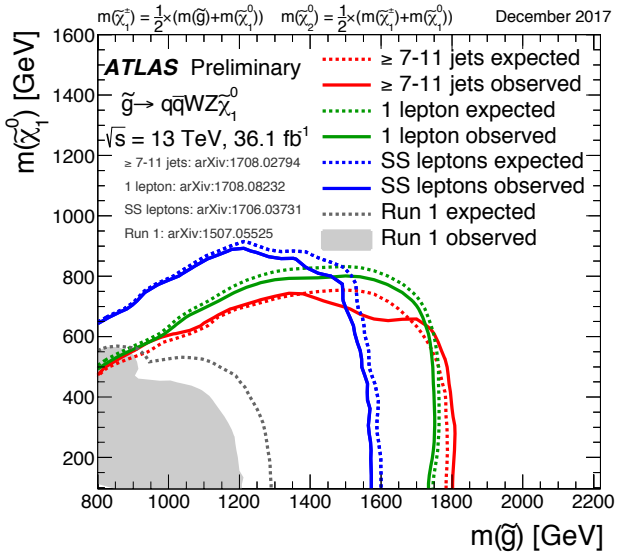


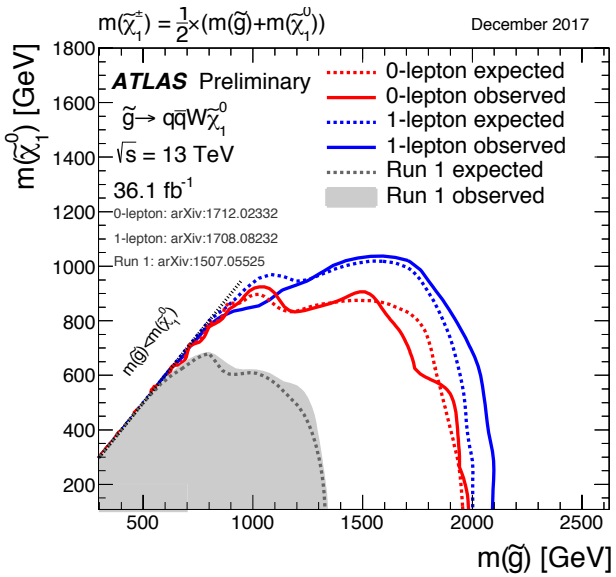


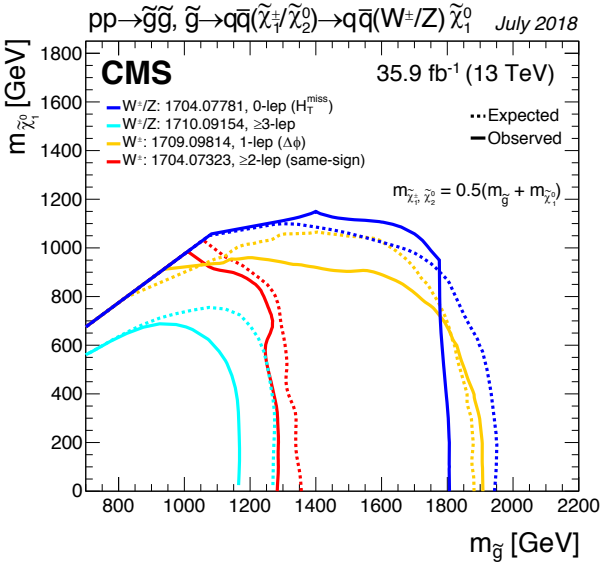




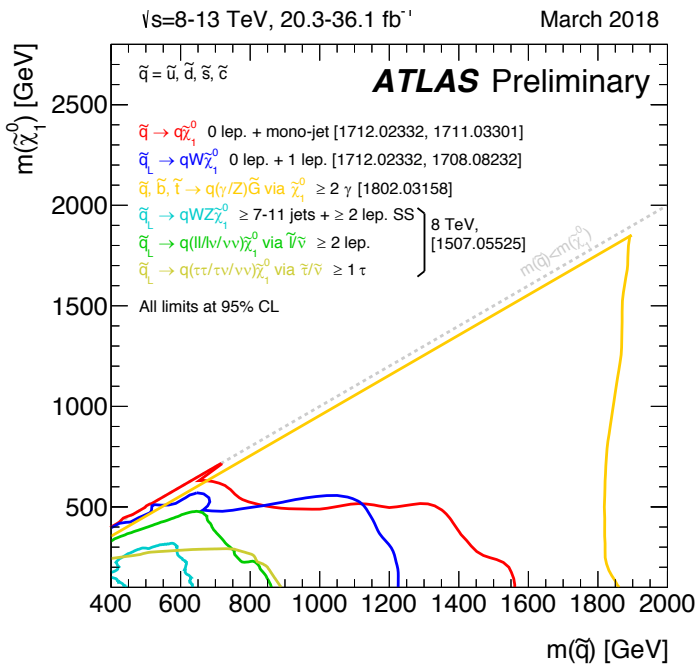
Summary of strong SUSY: gluinos

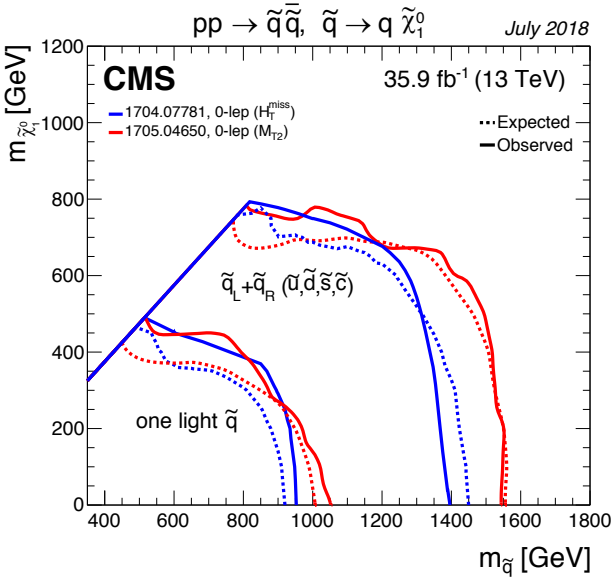


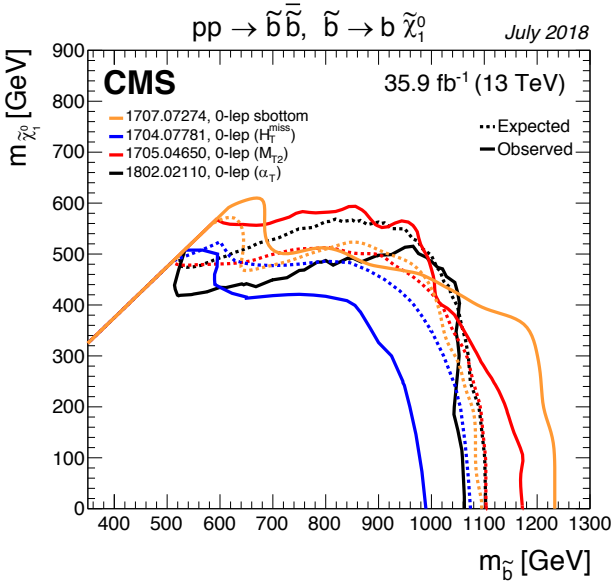




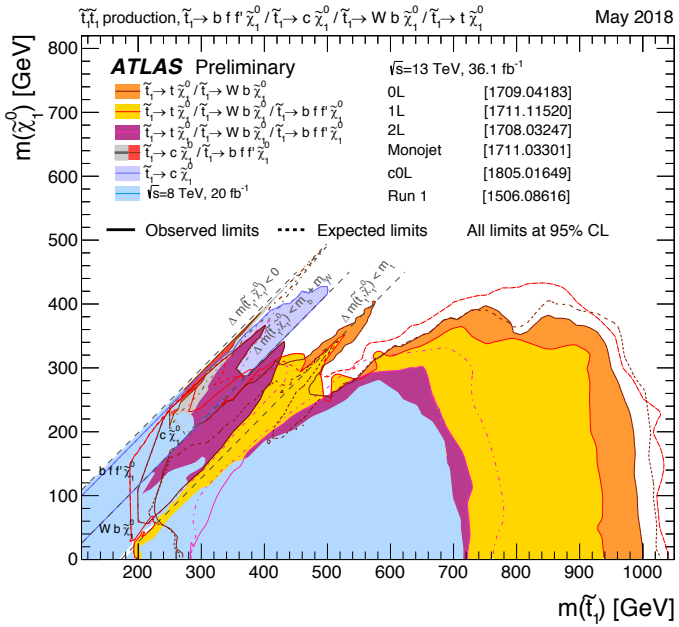
Summary of strong SUSY: squarks

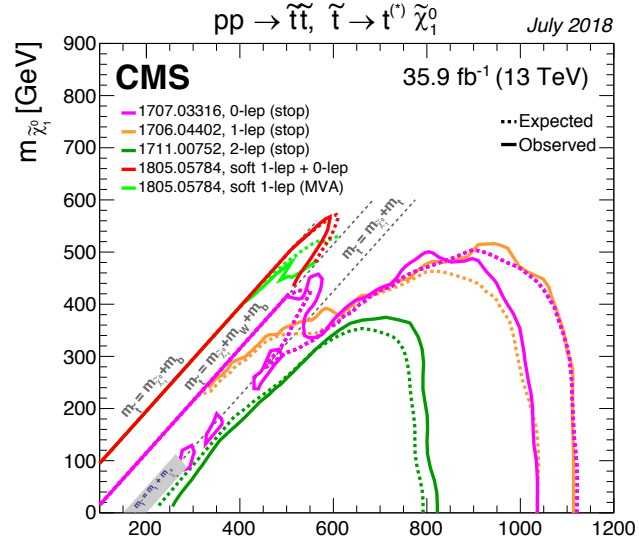


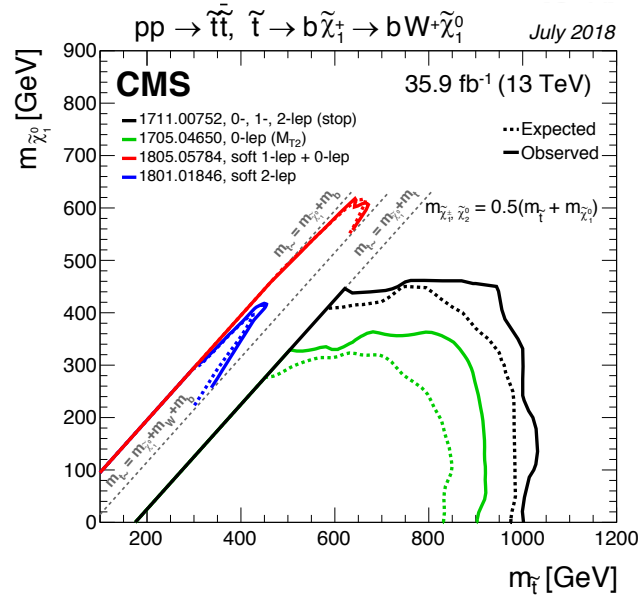




Summary of strong SUSY: squarks







2017 update of multi-b search

2017 data

- The ATLAS multi-b search (prev: JHEP06(2018)107) updated its results with 2017 data.

ATLAS-CONF-2018-041

Gtt 1-lepton

Criteria common to all regions: ≥ 1 signal lepton, $N_{b\text{-jets}} \geq 3$

Targeted kinematics	Type	N_{jet}	m_{T}	$m_{\text{T,min}}^{b\text{-jets}}$	$E_{\text{T}}^{\text{miss}}$	$m_{\text{eff}}^{\text{incl}}$	M_J^{Σ}
Region B (Boosted, Large Δm)	SR	≥ 5	> 150	> 120	> 500	> 2200	> 200
	CR	$= 5$	< 150	–	> 300	> 1700	> 150
Region M (Moderate Δm)	SR	≥ 6	> 150	> 160	> 450	> 1800	> 200
	CR	$= 6$	< 150	–	> 400	> 1500	> 100
Region C (Compressed, small Δm)	SR	≥ 7	> 150	> 160	> 350	> 1000	–
	CR	$= 7$	< 150	–	> 350	> 1000	–

Gtt 0-lepton

Targeted kinematics	Type	N_{lepton}	$N_{b\text{-jets}}$	N_{jet}	$\Delta\phi_{\text{min}}^{4\text{j}}$	m_{T}	$m_{\text{T,min}}^{b\text{-jets}}$	$E_{\text{T}}^{\text{miss}}$	$m_{\text{eff}}^{\text{incl}}$	M_J^{Σ}
Region B (Boosted, Large Δm)	SR	$= 0$	≥ 3	≥ 7	> 0.4	–	> 60	> 350	> 2600	> 300
	CR	$= 1$	≥ 3	≥ 6	–	< 150	–	> 275	> 1800	> 300
Region M (Moderate Δm)	SR	$= 0$	≥ 3	≥ 7	> 0.4	–	> 120	> 500	> 1800	> 200
	CR	$= 1$	≥ 3	≥ 6	–	< 150	–	> 400	> 1700	> 200
Region C (Compressed, moderate Δm)	SR	$= 0$	≥ 4	≥ 8	> 0.4	–	> 120	> 250	> 1000	> 100
	CR	$= 1$	≥ 4	≥ 7	–	< 150	–	> 250	> 1000	> 100

Gbb

Criteria common to all regions: $N_{\text{jet}} \geq 4$

Targeted kinematics	Type	N_{lepton}	$N_{b\text{-jets}}$	$\Delta\phi_{\text{min}}^{4\text{j}}$	m_{T}	$m_{\text{T,min}}^{b\text{-jets}}$	$E_{\text{T}}^{\text{miss}}$	m_{eff}	Others
Region B (Boosted, Large Δm)	SR	$= 0$	≥ 3	> 0.4	–	–	> 400	> 2800	–
	CR	$= 1$	≥ 3	–	< 150	–	> 400	> 2500	–
Region M (Moderate Δm)	SR	$= 0$	≥ 4	> 0.4	–	> 90	> 450	> 1600	–
	CR	$= 1$	≥ 4	–	< 150	–	> 300	> 1600	–
Region C (Compressed, small Δm)	SR	$= 0$	≥ 4	> 0.4	–	> 155	> 450	–	–
	CR	$= 1$	≥ 4	–	< 150	–	> 375	–	–
Region VC (Very Compressed, very small Δm)	SR	$= 0$	≥ 3	> 0.4	–	> 100	> 600	–	$p_{\text{T}}^{\text{j}_1} > 400$, $\text{j}_1 \neq b$, $\Delta\phi^{\text{j}_1} > 2.5$
	CR	$= 1$	≥ 3	–	< 150	–	> 600	–	

	SR-Gtt-1L		
Targeted kinematics	B	M	C
Observed events	0	0	5
Fitted background	0.64 ± 0.34	1.1 ± 0.4	5.1 ± 2.2
$t\bar{t}$	0.32 ± 0.23	0.52 ± 0.30	2.6 ± 1.7
Single-top	0.17 ± 0.22	0.29 ± 0.19	1.0 ± 1.0
$t\bar{t} + X$	0.15 ± 0.09	0.27 ± 0.15	1.4 ± 0.7
Z+jets	< 0.01	< 0.01	0.0018 ± 0.0015
W+jets	< 0.01	0.009 ± 0.031	0.007 ± 0.008
Diboson	< 0.01	< 0.01	< 0.01
MC-only background	0.8	1.1	5.3

	SR-Gtt-0L		
Targeted kinematics	B	M	C
Observed events	5	9	50
Fitted background	3.0 ± 1.1	6.6 ± 2.6	54 ± 17
$t\bar{t}$	1.5 ± 0.7	3.2 ± 1.8	42 ± 16
Single-top	0.7 ± 0.6	1.4 ± 0.7	3.2 ± 3.4
$t\bar{t} + X$	0.35 ± 0.19	0.9 ± 0.4	5.7 ± 3.1
Z+jets	0.2 ± 0.5	0.6 ± 1.7	1.1 ± 2.9
W+jets	0.19 ± 0.17	0.4 ± 0.4	1.0 ± 1.0
Diboson	< 0.01	0.06 ± 0.04	0.19 ± 0.13
Multijet	0.04 ± 0.04	0.029 ± 0.029	0.030 ± 0.030
MC-only background	3.3	7.2	52

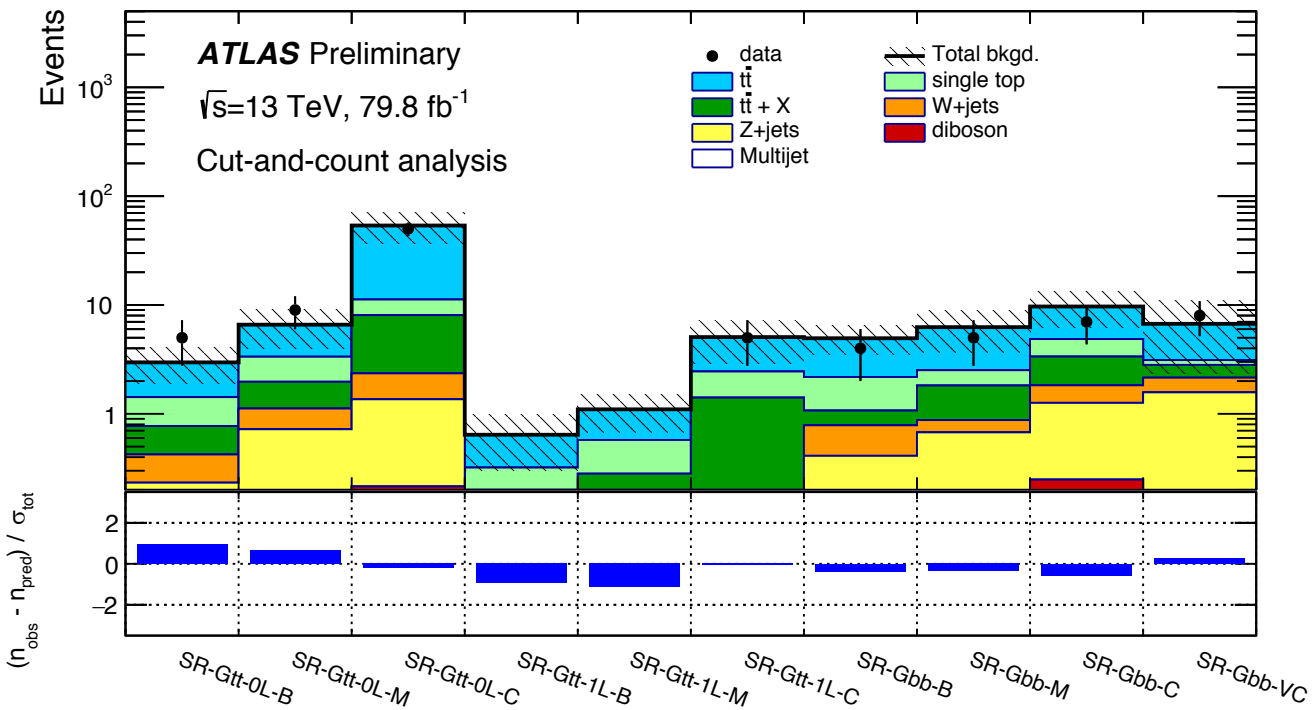
	SR-Gbb			
Targeted kinematics	B	M	C	VC
Observed events	4	5	7	8
Fitted background	4.9 ± 1.5	6.3 ± 2.6	9.7 ± 3.5	7 ± 4
$t\bar{t}$	2.8 ± 0.9	3.7 ± 2.1	4.8 ± 1.4	3.6 ± 2.2
Single-top	1.1 ± 0.7	0.7 ± 0.4	1.5 ± 1.6	0.30 ± 0.26
$t\bar{t} + X$	0.29 ± 0.17	0.9 ± 0.5	1.5 ± 0.8	0.67 ± 0.35
Z+jets	0.3 ± 0.8	0.5 ± 1.3	1.0 ± 2.6	1 ± 4
W+jets	0.4 ± 0.4	0.20 ± 0.23	0.6 ± 0.5	0.6 ± 0.5
Diboson	0.03 ± 0.14	0.19 ± 0.24	0.25 ± 0.19	0.16 ± 0.11
Multijet	0.08 ± 0.08	< 0.01	< 0.01	< 0.01
MC-only background	4.5	7.0	9.0	7

2017 update of multi-b search

2017 data

- The ATLAS multi-b search (prev: JHEP06(2018)107) updated its results with 2017 data.

ATLAS-CONF-2018-041



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ATLAS-CONF-2018-041

High-N_{jet} regions

Criteria common to all regions: $N_{b\text{-jets}} \geq 3$

Targeted kinematics	Type	N_{lepton}	$\Delta\phi^{4j}_{\text{min}}$	m_{T}	N_{jet}	$m^{b\text{-jets}}_{\text{T,min}}$	M_J^{Σ}	$E_{\text{T}}^{\text{miss}}$	m_{eff}
High-m_{eff} (HH) (Large Δm)	SR-0L	$= 0$	> 0.4	–	≥ 7	> 100	> 200	> 400	> 2500
	SR-1L	≥ 1	–	> 150	≥ 6	> 120	> 200	> 500	> 2300
	CR	≥ 1	–	< 150	≥ 6	> 60	> 150	> 300	> 2100
Intermediate-m_{eff} (HI) (Intermediate Δm)	SR-0L	$= 0$	> 0.4	–	≥ 9	> 140	> 150	> 300	[1800, 2500]
	SR-1L	≥ 1	–	> 150	≥ 8	> 140	> 150	> 300	[1800, 2300]
	CR	≥ 1	–	< 150	≥ 8	> 60	> 150	> 200	[1700, 2100]
Low-m_{eff} (HL) (Small Δm)	SR-0L	$= 0$	> 0.4	–	≥ 9	> 140	–	> 300	[900, 1800]
	SR-1L	≥ 1	–	> 150	≥ 8	> 140	–	> 300	[900, 1800]
	CR	≥ 1	–	< 150	≥ 8	> 130	–	> 250	[900, 1700]

Low-N_{jet} regions

Criteria common to all regions: $N_{b\text{-jets}} \geq 3$

Targeted kinematics	Type	N_{lepton}	$\Delta\phi^{4j}_{\text{min}}$	m_{T}	N_{jet}	$j_1 = b$ or $\Delta\phi^{j_1} \leq 2.9$	$p_{\text{T}}^{j_4}$	$m^{b\text{-jets}}_{\text{T,min}}$	$E_{\text{T}}^{\text{miss}}$	m_{eff}
High-m_{eff} (LH) (Large Δm)	SR	$= 0$	> 0.4	–	[4, 6]	–	> 90	–	> 300	> 2400
	CR	≥ 1	–	< 150	[4, 5]	–	-	–	> 200	> 2100
Intermediate-m_{eff} (LI) (Intermediate Δm)	SR	$= 0$	> 0.4	–	[4, 6]	✓	> 90	> 140	> 350	[1400, 2400
	CR	≥ 1	–	< 150	[4, 5]	✓	> 70	–	> 300	[1400, 2000
Low-m_{eff} (LL) (Low Δm)	SR	$= 0$	> 0.4	–	[4, 6]	✓	> 90	> 140	> 350	[800, 1400
	CR	≥ 1	–	< 150	[4, 5]	✓	> 70	–	> 300	[800, 1400

Intermediate-N_{jet} regions

Criteria common to all regions: $N_{b\text{-jets}} \geq 3$

Targeted kinematics	Type	N_{lepton}	$\Delta\phi^{4j}_{\text{min}}$	m_{T}	N_{jet}	$j_1 = b$ or $\Delta\phi^{j_1} \leq 2.9$	$m^{b\text{-jets}}_{\text{T,min}}$	M_J^{Σ}	$E_{\text{T}}^{\text{miss}}$	m_{eff}
Intermediate-m_{eff} (II) (Intermediate Δm)	SR-0L	$= 0$	> 0.4	–	[7, 8]	✓	> 140	> 150	> 300	[1600, 2
	SR-1L	≥ 1	–	> 150	[6, 7]	–	> 140	> 150	> 300	[1600, 2
	CR	≥ 1	–	< 150	[6, 7]	✓	> 100	> 150	> 300	[1600, 2
Low-m_{eff} (IL) (Low Δm)	SR-0L	$= 0$	> 0.4	–	[7, 8]	✓	> 140	–	> 300	[800, 16
	SR-1L	≥ 1	–	> 150	[6, 7]	–	> 140	–	> 300	[800, 16
	CR	≥ 1	–	< 150	[6, 7]	✓	> 130	–	> 300	[800, 16

ISR regions

Criteria common to all regions: $N_{b\text{-jets}} \geq 3$, $\Delta\phi^{j_1} > 2.9$, $p_{\text{T}}^{j_1} > 400$ GeV and $j_1 \neq b$

Type	N_{lepton}	$\Delta\phi^{4j}_{\text{min}}$	m_{T}	N_{jet}	$m^{b\text{-jets}}_{\text{T,min}}$	$E_{\text{T}}^{\text{miss}}$	m_{eff}
SR	$= 0$	> 0.4	–	[4, 8]	> 100	> 600	< 2200
CR	≥ 1	–	< 150	[4, 7]	–	> 400	< 2000

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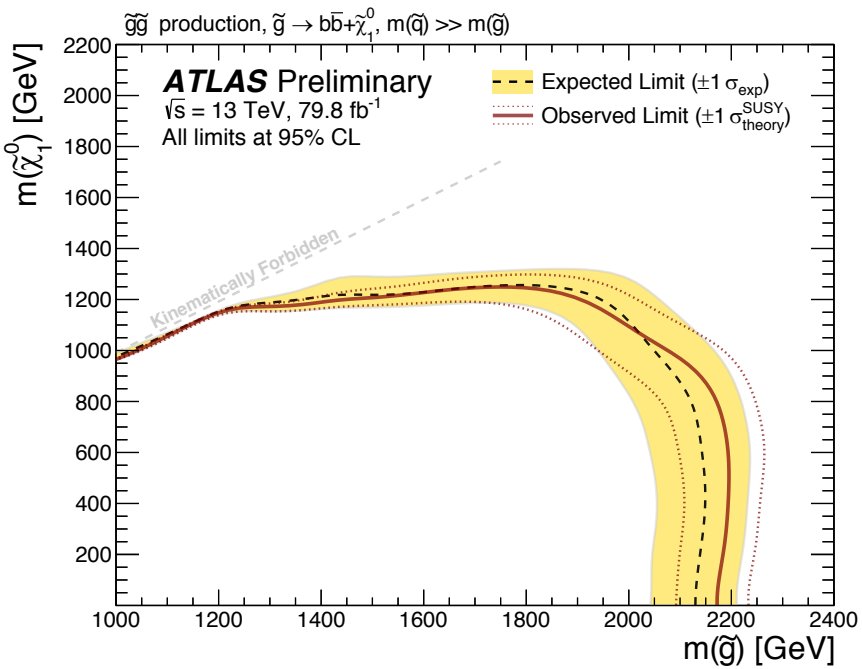
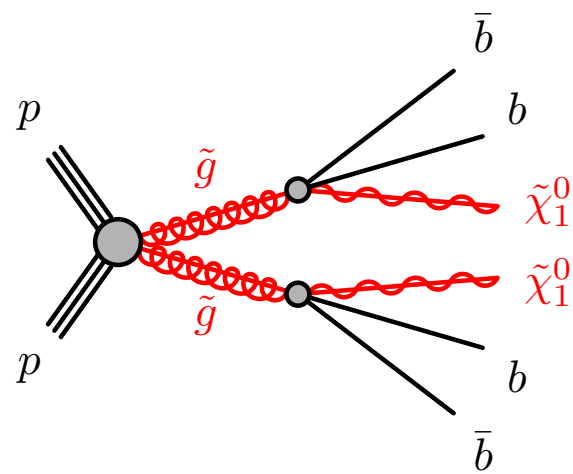
ATLAS-CONF-2018-041





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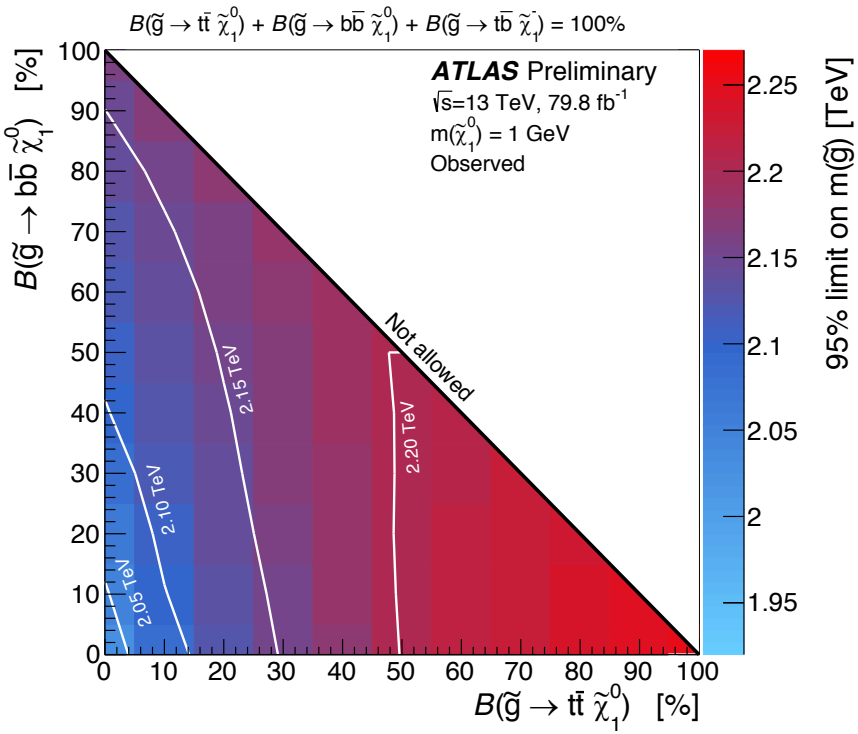
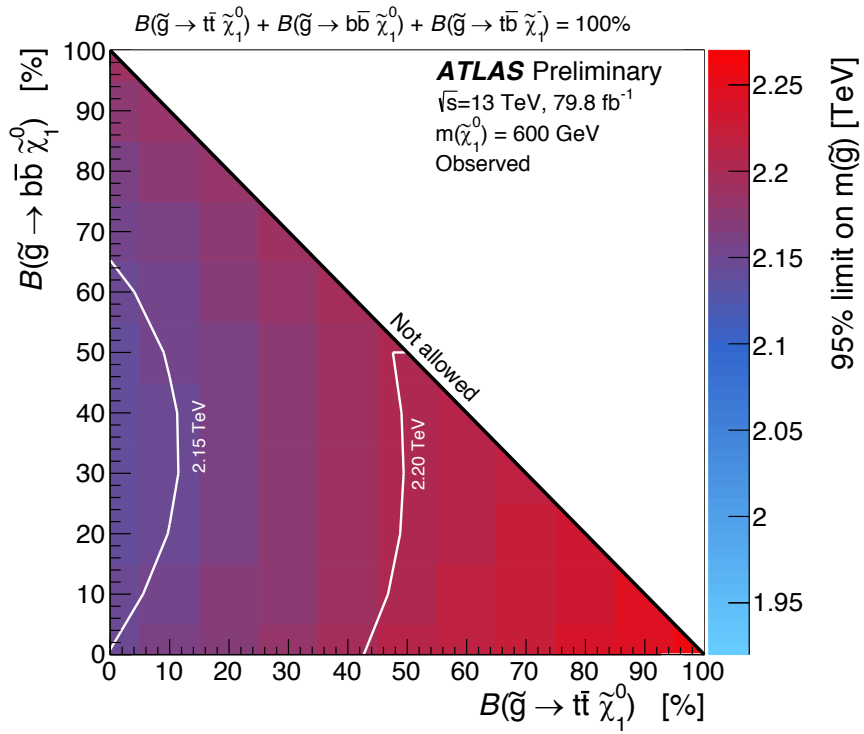




Inclusive hadronic SUSYsearch

- One inclusive hadronic CMS search uses a running α_T and min$\Delta\phi$* cuts to reject QCD multijet production.

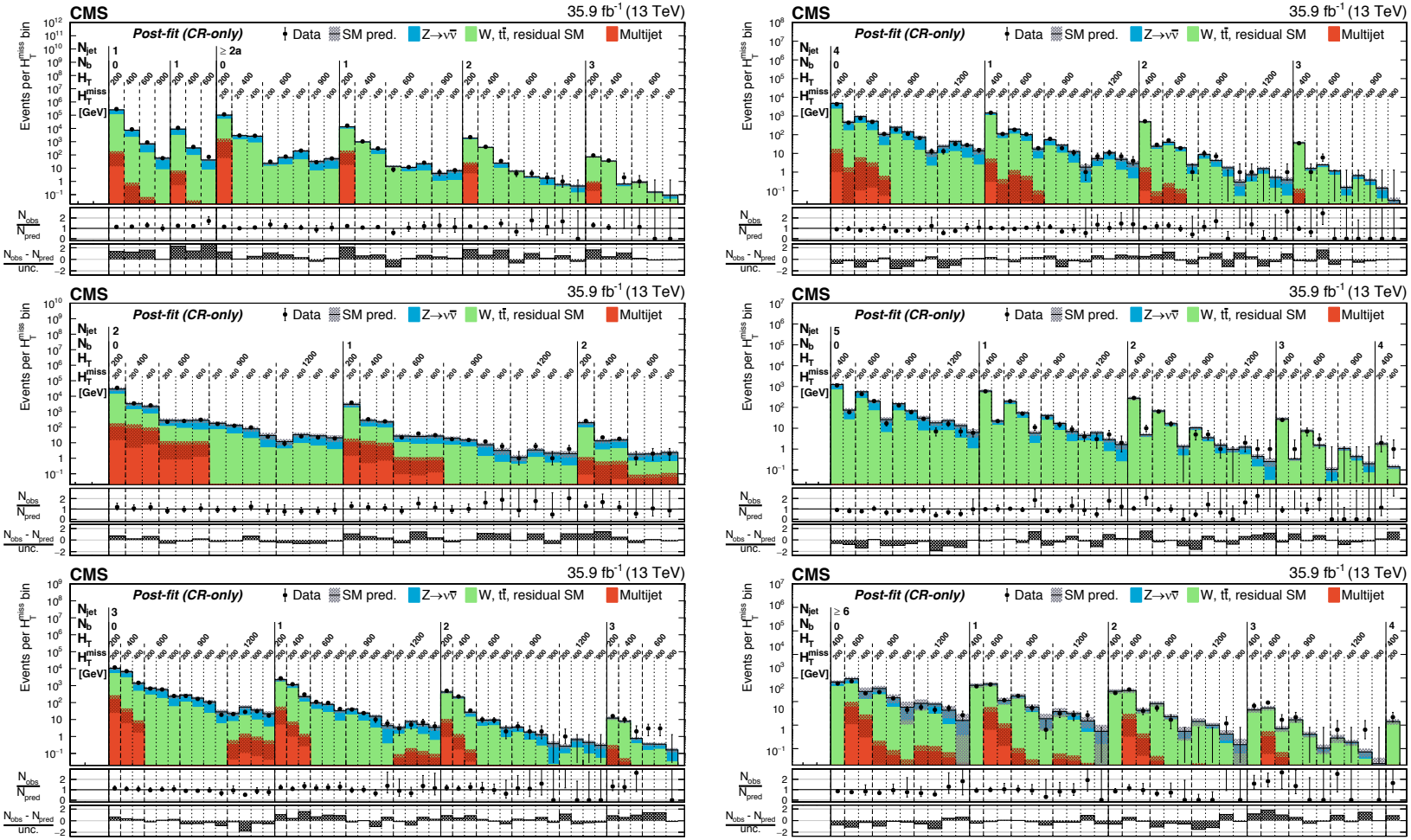
JHEP 05 (2018) 025

Physics object acceptances		
Jet	$p_T > 40\,\text{GeV}$, $\lvert\eta\rvert < 2.4$	
Photon	$p_T > 25\,\text{GeV}$, $\lvert\eta\rvert < 2.5$, isolated in cone $\Delta R < 0.3$	
Electron	$p_T > 10\,\text{GeV}$, $\lvert\eta\rvert < 2.5$, $I^{\text{rel}} < 0.1$ in cone $0.05 < \Delta R(p_T) < 0.2$	
Muon	$p_T > 10\,\text{GeV}$, $\lvert\eta\rvert < 2.5$, $I^{\text{rel}} < 0.2$ in cone $0.05 < \Delta R(p_T) < 0.2$	
Single isolated track (SIT)	$p_T > 10\,\text{GeV}$, $\lvert\eta\rvert < 2.5$, $I^{\text{track}} < 0.1$ in cone $\Delta R < 0.3$	
Baseline event selection		
All-jet final state	Veto events containing photons, electrons, muons, and SITs within acceptance	
p_T^{miss} quality	Veto events based on filters related to beam and instrumental effects	
Jet quality	Veto events containing jets that fail identification criteria or $0.1 < f_{h^\pm}^{j_1} < 0.95$	
Jet energy and sums	$p_T^{j_1} > 100\,\text{GeV}$, $H_T > 200\,\text{GeV}$, $H_T^{\text{miss}} > 200\,\text{GeV}$	
Jets outside acceptance	$H_T^{\text{miss}}/p_T^{\text{miss}} < 1.25$, veto events containing jets with $p_T > 40\,\text{GeV}$ and $\lvert\eta\rvert > 2.4$	
Signal region	Baseline selection +	
α_T threshold (H_T range)	0.65 (200–250 GeV), 0.60 (250–300), 0.55 (300–350), 0.53 (350–400), 0.52 (400–900)	
$\Delta\phi^*_{\text{min}}$ threshold	$\Delta\phi^*_{\text{min}} > 0.5$ ($n_{\text{jet}} \geq 2$), $\Delta\phi^{*25}_{\text{min}} > 0.5$ ($n_{\text{jet}} = 1$)	
Nominal categorization schema		
n_{jet}	1	(monojet)
	$\geq 2a$	(a denotes asymmetric, $40 < p_T^{j_2} < 100\,\text{GeV}$)
	2, 3, 4, 5, ≥ 6	(symmetric, $p_T^{j_2} > 100\,\text{GeV}$)
n_b	0, 1, 2, 3, ≥ 4	(can be dropped/merged *vs.* n_{jet})
H_T boundaries	200, 400, 600, 900, 1200 GeV	(can be dropped/merged *vs.* n_{jet}, n_b)
H_T^{miss} boundaries	200, 400, 600, 900 GeV	(can be dropped/merged *vs.* n_{jet}, n_b, H_T)
Simplified categorization schema		
Topology (n_{jet}, n_b)	Monojet-like	$(1 \cap \geq 2a, 0)$, $(1 \cap \geq 2a, \geq 1)$
	Low n_{jet}	$(2 \cap 3, 0 \cap 1)$, $(2 \cap 3, \geq 2)$
	Medium n_{jet}	$(4 \cap 5, 0 \cap 1)$, $(4 \cap 5, \geq 2)$
	High n_{jet}	$(\geq 6, 0 \cap 1)$, $(\geq 6, \geq 2)$
H_T boundaries	$H_T > 200\,\text{GeV}$ ($n_{\text{jet}} \leq 3$), $H_T > 400\,\text{GeV}$ ($n_{\text{jet}} \geq 4$)	
H_T^{miss} boundaries	200, 400, 600, 900 GeV	
Control regions	Baseline selection +	
μ+jets (inverted μ veto)	$p_T^{\mu_1} > 30\,\text{GeV}$, $\lvert\eta^{\mu_1}\rvert < 2.1$, $\Delta R(\mu, j_i) > 0.5$, $30 < m_T(\vec{p}_T^{\,\mu}, \vec{p}_T^{\,\text{miss}}) < 125\,\text{GeV}$	
$\mu\mu$+jets (inverted μ veto)	$p_T^{\mu_{1,2}} > 30\,\text{GeV}$, $\lvert\eta^{\mu_{1,2}}\rvert < 2.1$, $\Delta R(\mu_{1,2}, j_i) > 0.5$, $\lvert m_{\mu\mu} - m_Z\rvert < 25\,\text{GeV}$	
Multijet-enriched	Sidebands to signal region: $H_T^{\text{miss}}/p_T^{\text{miss}} > 1.25$ and/or $\Delta\phi^*_{\text{min}} < 0.5$	

Inclusive hadronic SUSYsearch

JHEP 05 (2018) 025

- One inclusive hadronic CMS search uses a running α_T and min$\Delta\phi$* cuts to reject QCD multijet production.



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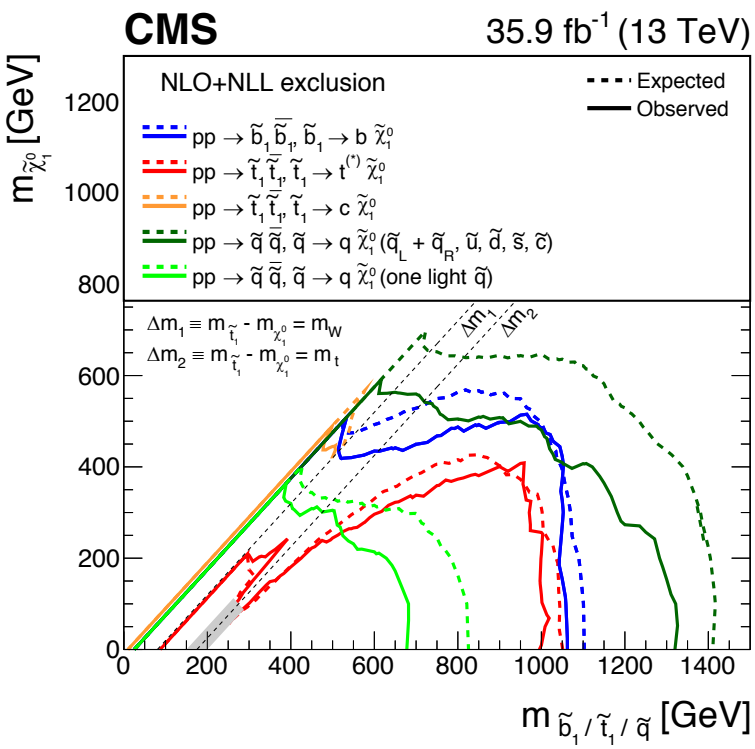

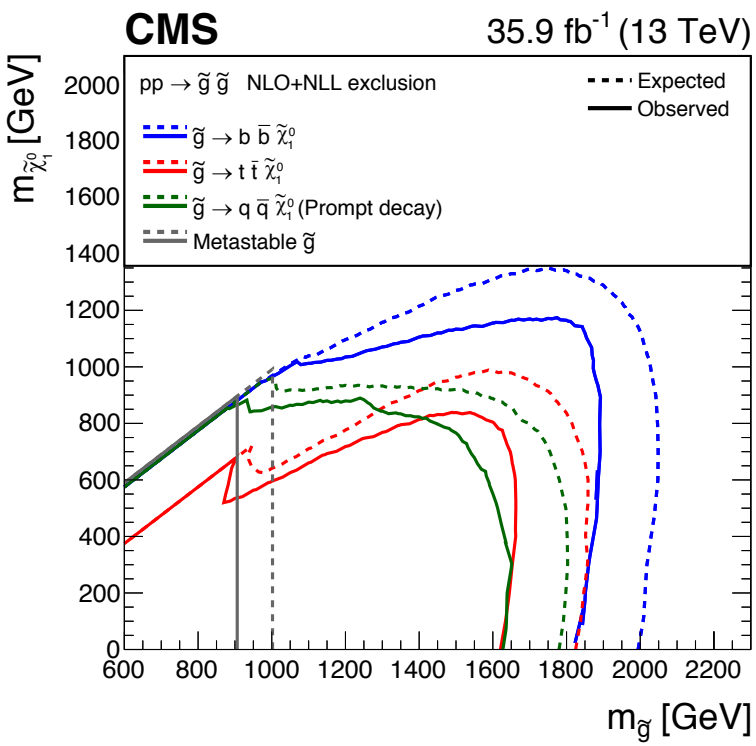

JHEP 05 (2018) 025

Edge OS lepton search

arXiv:1805.11381

- Look for a edge in the dilepton mass spectrum for two same-flavor oppositely-charged leptons.

High-p_T regions	E_T^{miss} [GeV]	H_T [GeV]	n_{jets}	$m_{\ell\ell}$ [GeV]	m_{T2} [GeV]	**SF/DF**	$n_{b\text{-jets}}$	$\Delta\phi(\text{jet}_{12}, p_T^{miss})$	$m_{\ell\ell}$ **windows**
Signal regions									
SR-low	> 250	> 200	≥ 2	> 12	> 70	SF	–	> 0.4	10
SR-medium	> 400	> 400	≥ 2	> 12	> 25	SF	–	> 0.4	9
SR-high	> 200	> 1200	≥ 2	> 12	–	SF	–	> 0.4	10
Control regions									
CR-FS-low	> 250	> 200	≥ 2	> 12	> 70	**DF**	–	> 0.4	–
CR-FS-medium	> 400	> 400	≥ 2	> 12	> 25	**DF**	–	> 0.4	–
CR-FS-high	> 100	> 1100	≥ 2	> 12	–	**DF**	–	> 0.4	–
CRγ-low	–	> 200	≥ 2	–	–	0ℓ, 1γ	–	–	–
CRγ-medium	–	> 400	≥ 2	–	–	0ℓ, 1γ	–	–	–
CRγ-high	–	> 1200	≥ 2	–	–	0ℓ, 1γ	–	–	–
CRZ-low	< 100	> 200	≥ 2	> 12	> 70	SF	–	–	–
CRZ-medium	< 100	> 400	≥ 2	> 12	> 25	SF	–	–	–
CRZ-high	< 100	> 1200	≥ 2	> 12	–	SF	–	–	–
Validation regions									
VR-low	**100–200**	> 200	≥ 2	> 12	> 70	SF	–	> 0.4	–
VR-medium	**100–200**	> 400	≥ 2	> 12	> 25	SF	–	> 0.4	–
VR-high	**100–200**	> 1200	≥ 2	> 12	–	SF	–	> 0.4	–
VR-$\Delta\phi$-low	> 250	> 200	≥ 2	> 12	> 70	SF	–	$\mathbf{< 0.4}$	–
VR-$\Delta\phi$-medium	> 400	> 400	≥ 2	> 12	> 25	SF	–	$\mathbf{< 0.4}$	–
VR-$\Delta\phi$-high	> 200	> 1200	≥ 2	> 12	–	SF	–	$\mathbf{< 0.4}$	–
VR-WZ	**100–200**	> 200	≥ 2	> 12	–	$\mathbf{3\ell}$	0	> 0.4	–
VR-ZZ	< 50	> 100	≥ 1	> 12	–	$\mathbf{4\ell}$	0	> 0.4	–

Low-p_T regions	E_T^{miss} [GeV]	$p_T^{\ell\ell}$ [GeV]	n_{jets}	$n_{b\text{-jets}}$	$m_{\ell\ell}$ [GeV]	**SF/DF**	**OS/SS**	$\Delta\phi(\text{jet}_{12}, p_T^{miss})$	m_T [GeV]	$m_{\ell\ell}$ **windows**
Signal regions										
SRC	> 250	< 20	≥ 2	–	> 30	SF	OS	> 0.4	–	6
SRC-MET	> 500	< 75	≥ 2	–	$> 4, \notin [8.4, 11]$	SF	OS	> 0.4	–	6
Control regions										
CRC	> 250	< 20	≥ 2	–	> 30	**DF**	OS	> 0.4	–	–
CRC-MET	> 500	< 75	≥ 2	–	$> 4, \notin [8.4, 11]$	**DF**	OS	> 0.4	–	–
CR-real	–	–	≥ 2	–	**81–101**	2ℓ SF	OS	–	–	–
CR-fake	$\mathbf{< 125}$	–	–	–	$> 4, \notin [8.4, 11]$ $> 4, \notin [8.4, 11], \mathbf{\notin [81, 101]}$	2ℓ μe 2ℓ $\mu\mu$	**SS**	–	–	–
Validation regions										
VRA	**200–250**	< 20	≥ 2	–	> 30	SF	OS	> 0.4	–	–
VRA2	**200–250**	> 20	≥ 2	–	$> 4, \notin [8.4, 11]$	SF	OS	> 0.4	–	–
VRB	**250–500**	**20–75**	≥ 2	–	$> 4, \notin [8.4, 11]$	SF	OS	> 0.4	–	–
VRC	**250–500**	> 75	≥ 2	–	$> 4, \notin [8.4, 11]$	SF	OS	> 0.4	–	–
VR-WZ-low-p_T	> 200	–	$\mathbf{\geq 1}$	**0**	$> 4, \notin [8.4, 11]$	$\mathbf{3\ell}$	–	> 0.4	–	–
VR-ZZ-low-p_T	> 200	–	–	**0**	$> 4, \notin [8.4, 11]$	$\mathbf{4\ell}$	–	> 0.4	–	–
VR-$\Delta\phi$	> 250	–	≥ 2	–	$> 4, \notin [8.4, 11]$	SF	OS	$\mathbf{< 0.4}$	–	–
VR-fakes	> 225	–	≥ 2	–	$> 4, \notin [8.4, 11]$	**DF**	OS	> 0.4	$\ell_1, \ell_2 < 100$	–
VR-SS	> 225	–	≥ 2	–	$> 4, \notin [8.4, 11]$	SF	SS	> 0.4	$\ell_1, \ell_2 < 100$	–

Edge OS lepton search

arXiv:1805.11381

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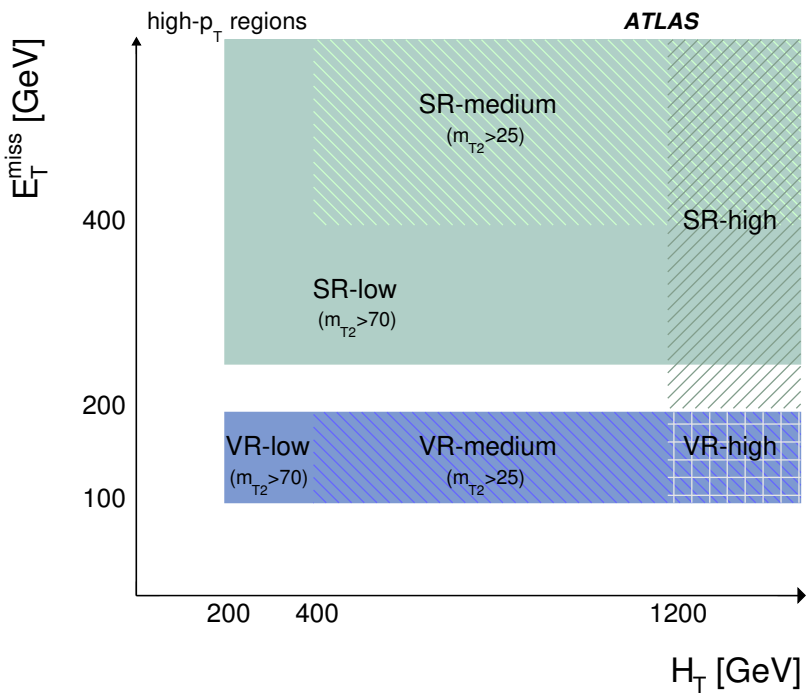

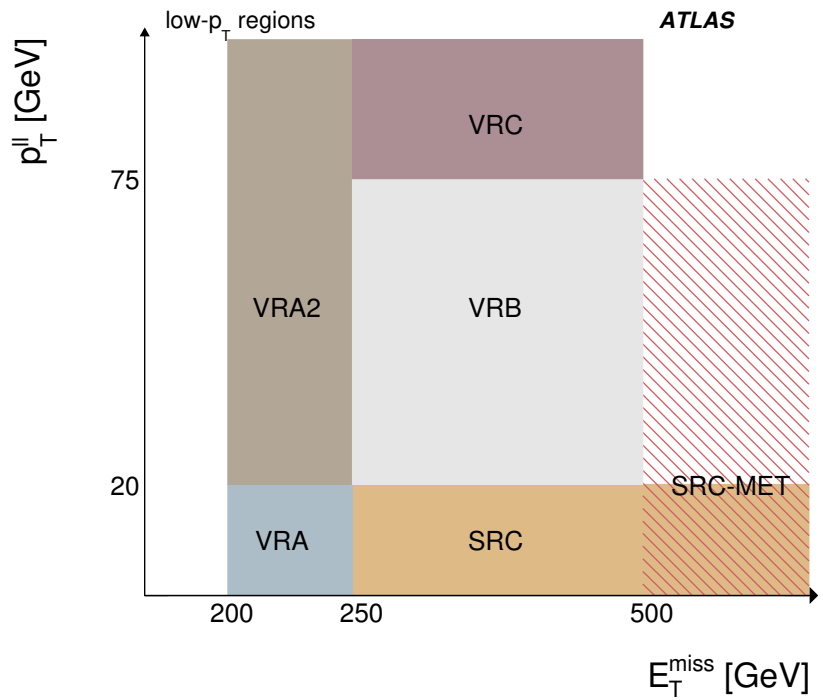

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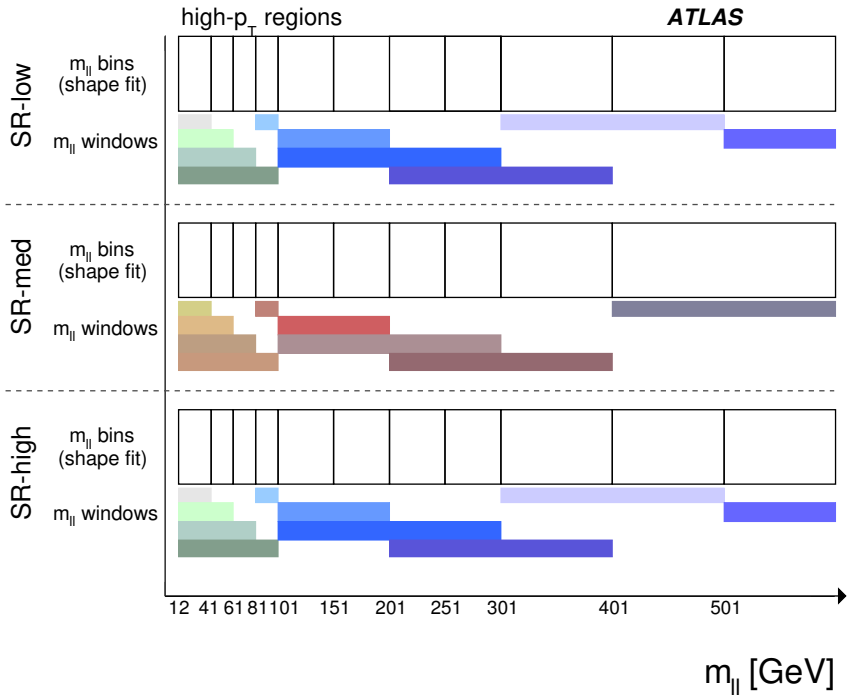

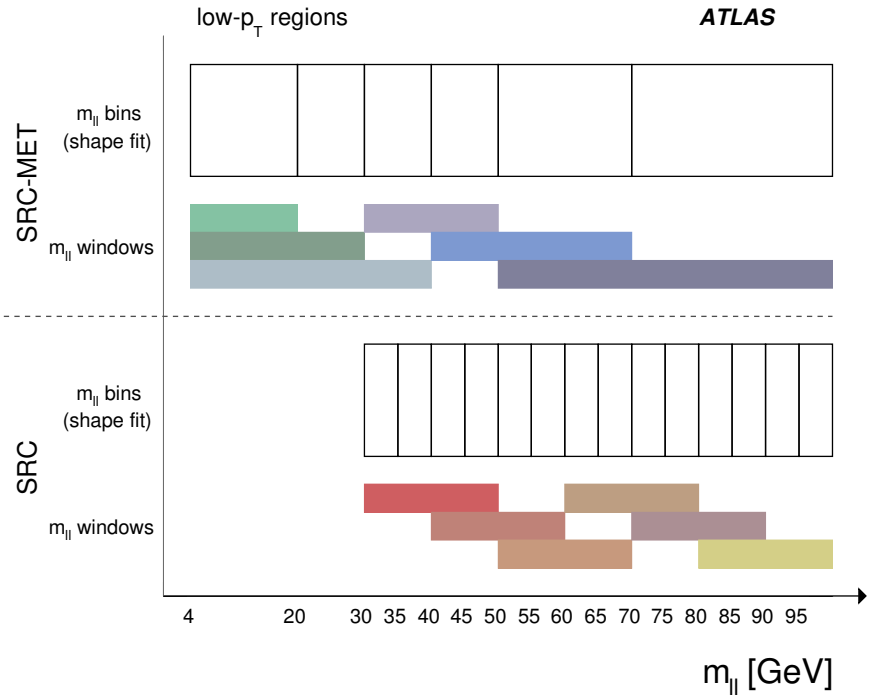

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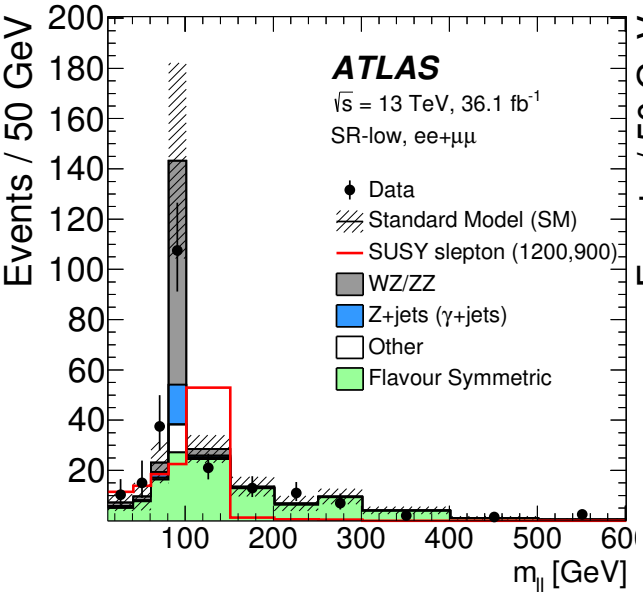

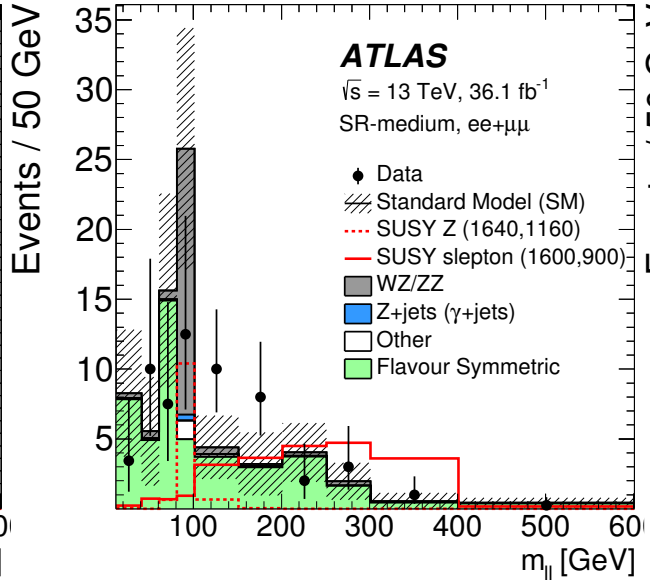

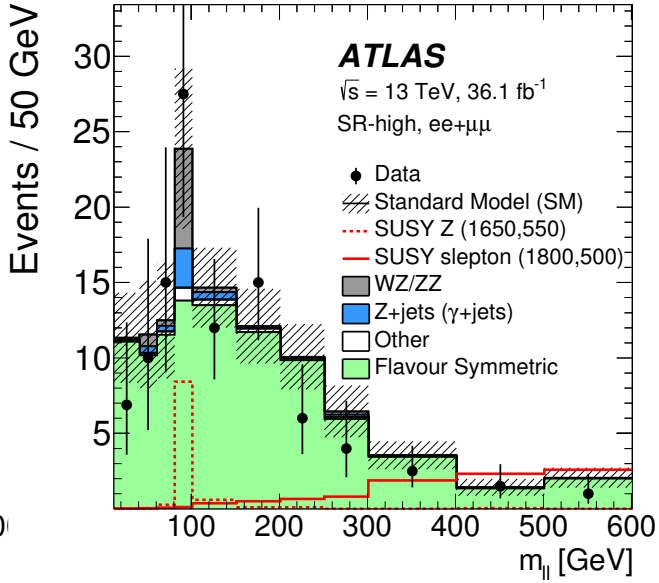

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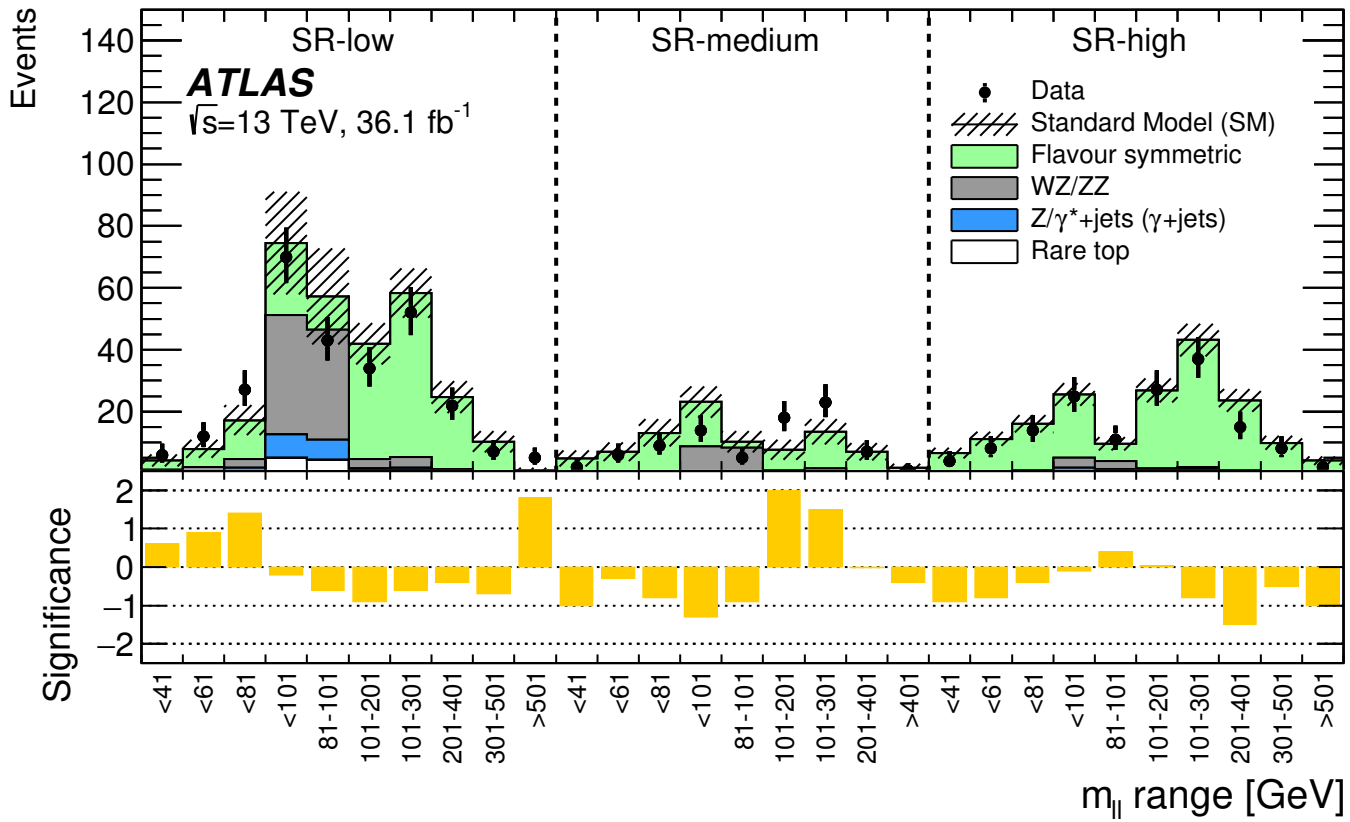

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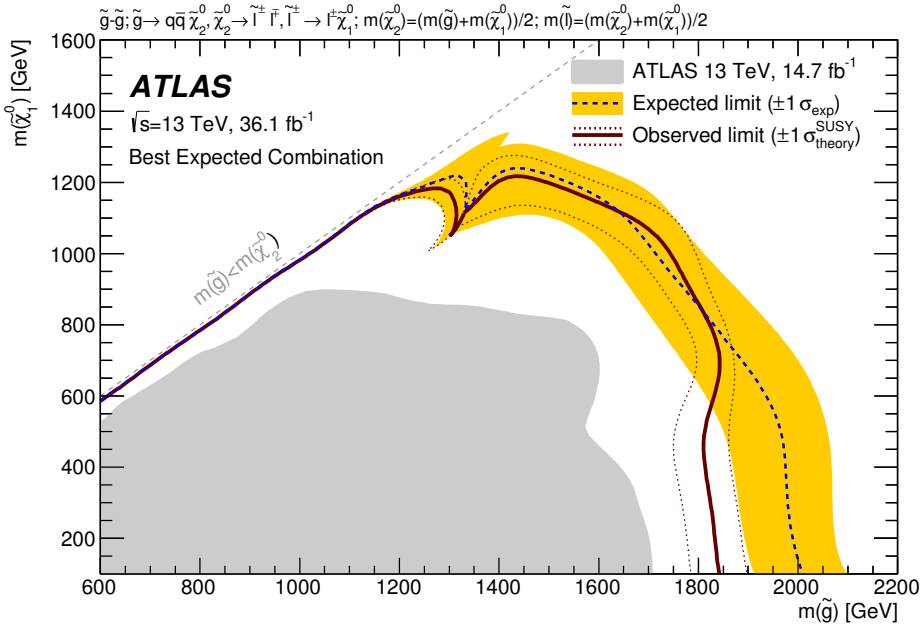

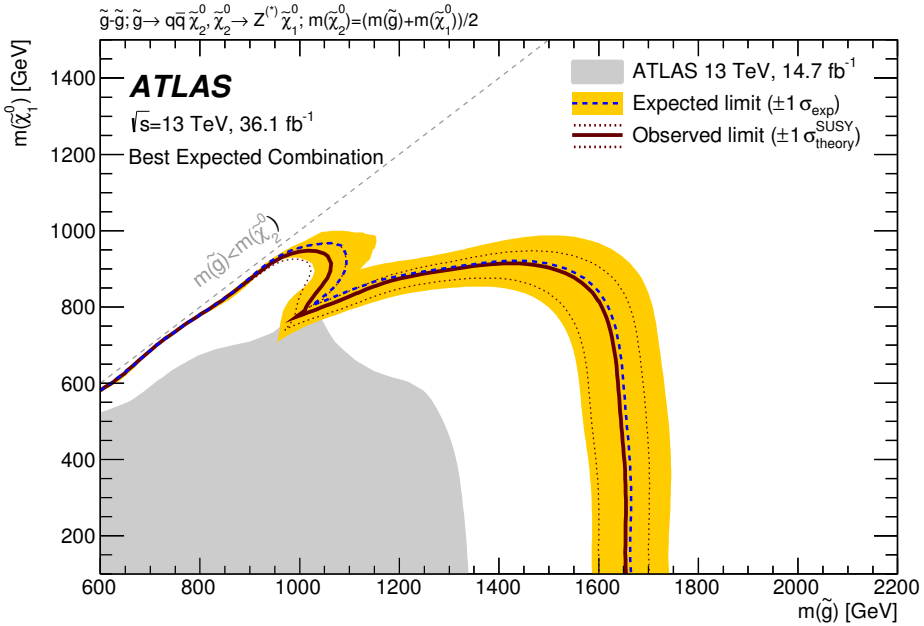

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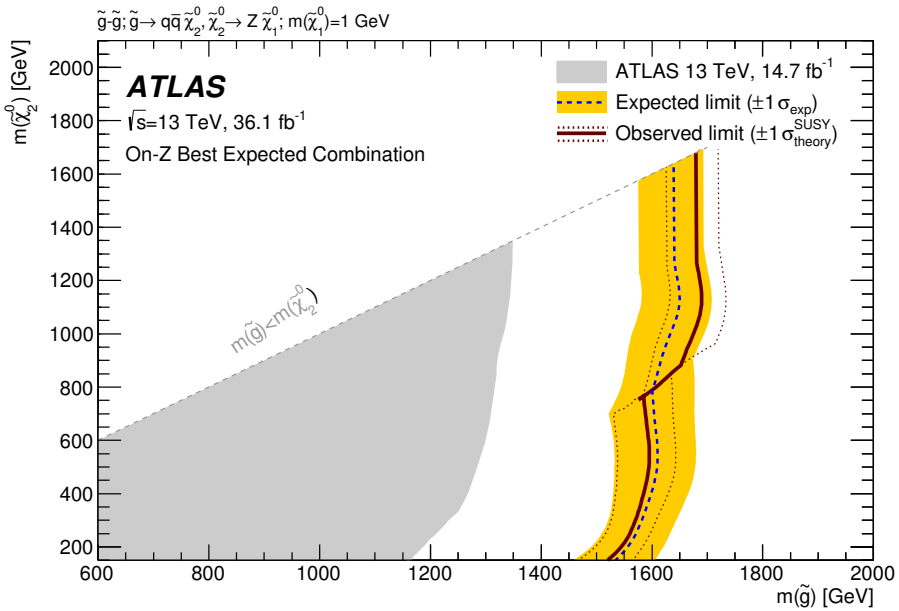

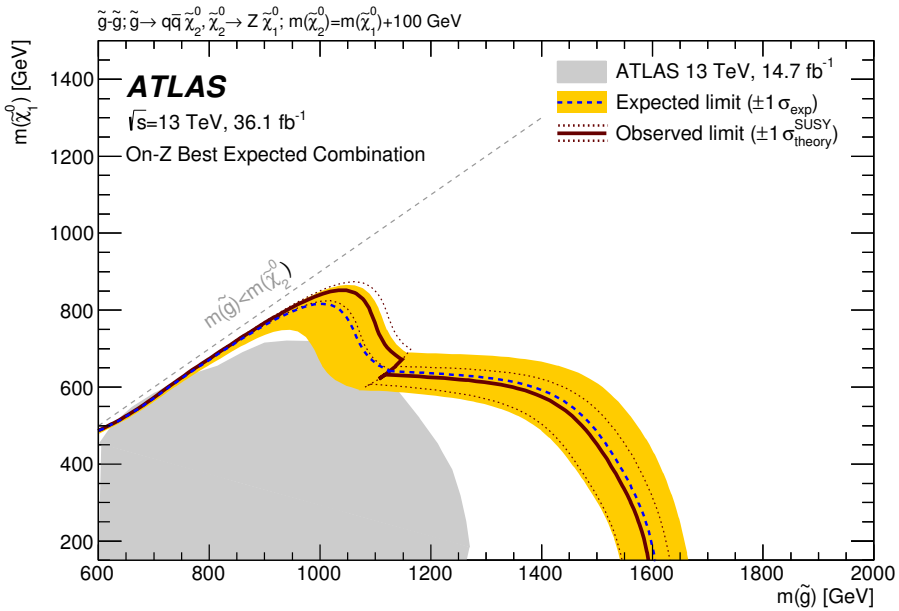

GMSB search with 1γ and 1ℓ

CMS-SUS-17-012

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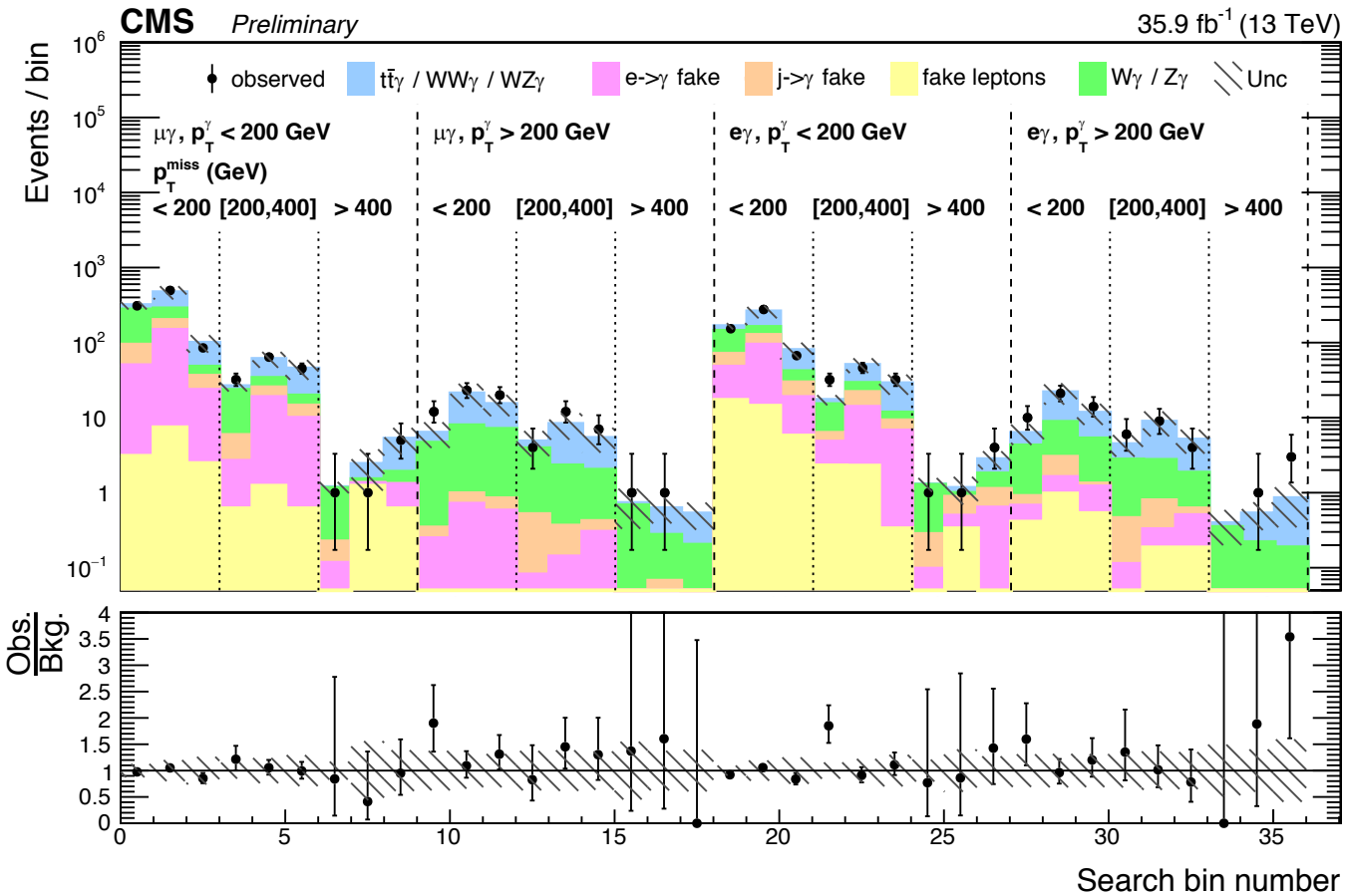

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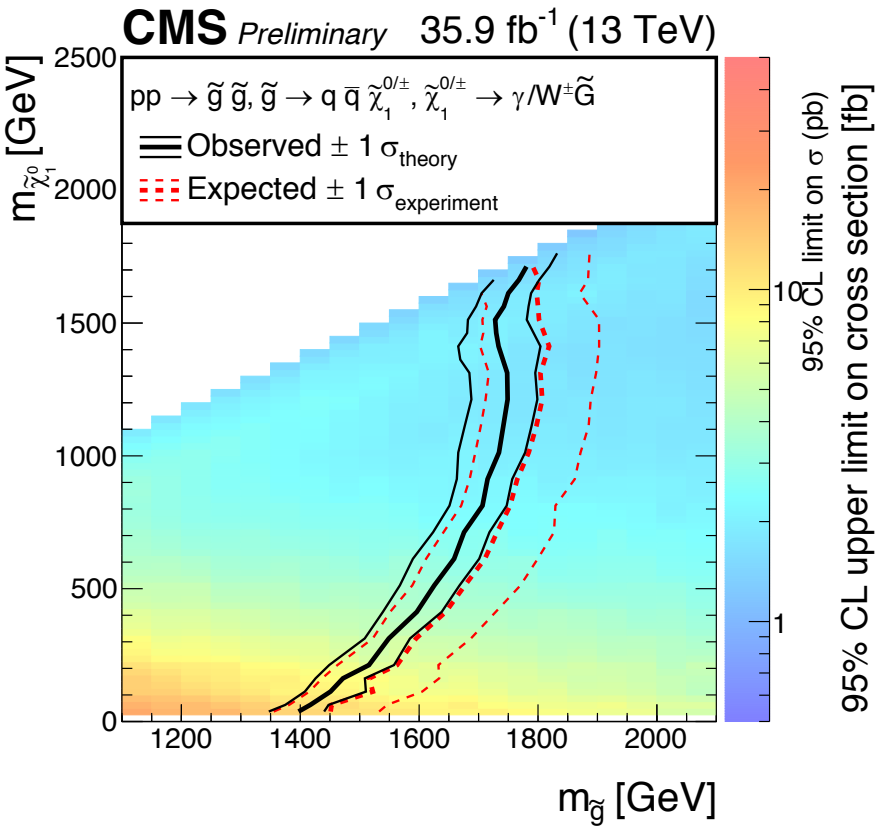

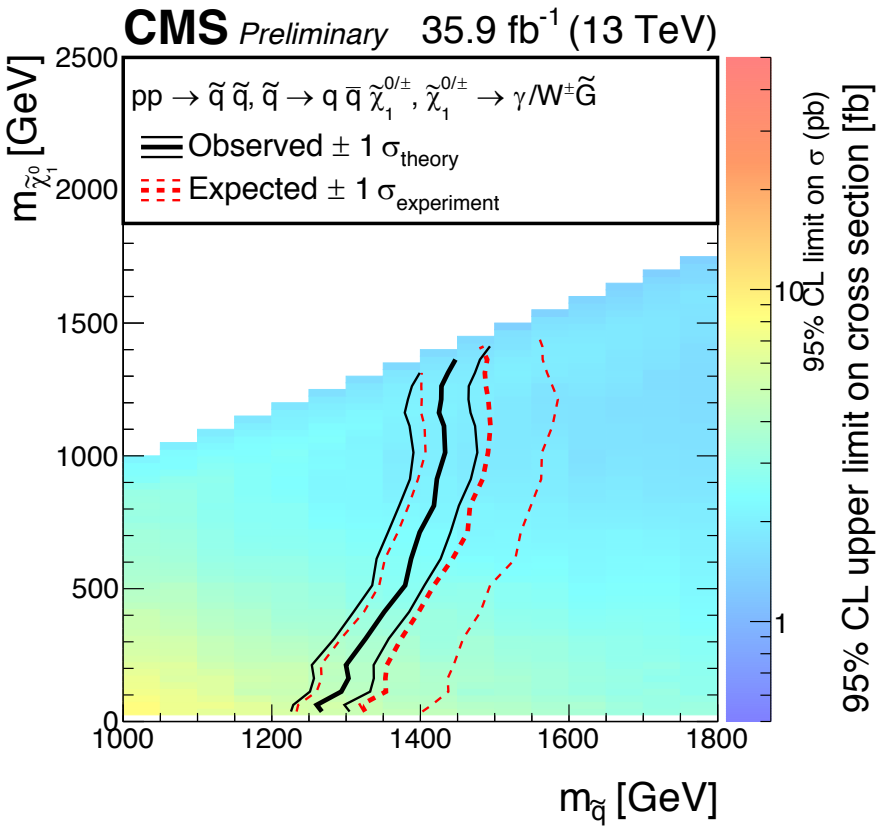

Search for h decay in $\tilde{b}$ production

- A new ATLAS search looks for the longer decay chain $\tilde{b} \to b\tilde{\chi}_2^0 \to bh\tilde{\chi}_1^0$

2017 data

ATLAS-CONF-2018-040

Variable	SRA	SRA-L	SRA-M	SRA-H
N_{leptons} (baseline)		$= 0$		
N_{jets}		≥ 6		
$N_{\text{b-jets}}$		≥ 4		
$E_{\text{T}}^{\text{miss}}$ [GeV]		> 250		
$\min \Delta\phi(\text{jet}_{1-4}, \mathbf{p}_{\text{T}}^{\text{miss}})$ [rad]		> 0.4		
τ veto		Yes		
$p_{\text{T}}(b_1)$ [GeV]		> 200		
$\Delta R_{\text{max}}(b, b)$		¿ 2.5		
$\Delta R_{\text{max-min}}(b, b)$		¡ 2.5		
$m(h_{\text{cand}})$ [GeV]		> 80		
m_{eff} [TeV]	> 1.0	$\in [1.0, 1.2]$	$\in [1.2, 1.5]$	> 1.5

Variable	SRB
N_{leptons} (baseline)	$= 0$
N_{jets}	≥ 5
$N_{\text{b-jets}}$	≥ 4
$E_{\text{T}}^{\text{miss}}$ [GeV]	> 300
$\min \Delta\phi(\text{jet}_{1-4}, \mathbf{p}_{\text{T}}^{\text{miss}})$ [rad]	> 0.4
τ veto	Yes
$m(h_{\text{cand1}}, h_{\text{cand2}})_{\text{avg}}$ [GeV]	$\in [50, 140]$
non-b leading jet	Yes
$p_{\text{T}}(j_1)$ [GeV]	> 300
$\lvert\Delta\phi(j_1, E_{\text{T}}^{\text{miss}})\rvert$ [rad]	> 2.8
m_{eff} [TeV]	> 1

Variable	SRC25	SRC27	SRC30	SRC32
N_{leptons} (baseline)		$= 0$		
N_{jets}		≥ 4		
$N_{\text{b-jets}}$		≥ 3		
$E_{\text{T}}^{\text{miss}}$ [GeV]		> 250		
$\min \Delta\phi(\text{jet}_{1-4}, \mathbf{p}_{\text{T}}^{\text{miss}})$ [rad]		> 0.4		
$\mathcal{S}$	> 25	> 27	> 30	> 32

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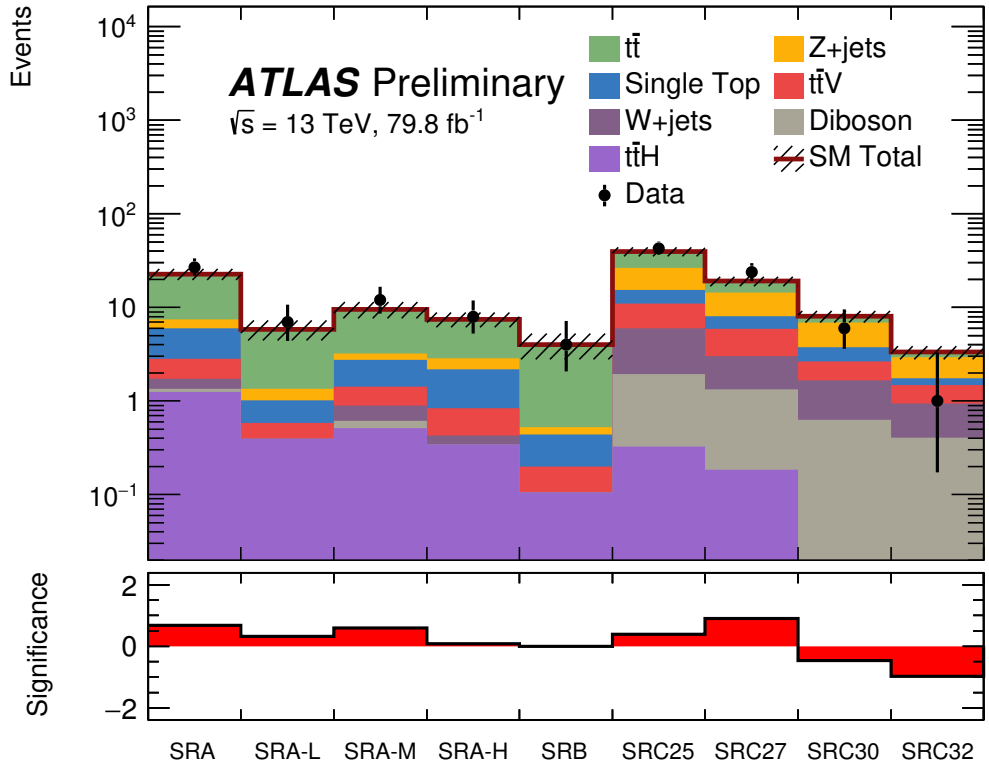
2017 data



ATLAS-CONF-2018-040

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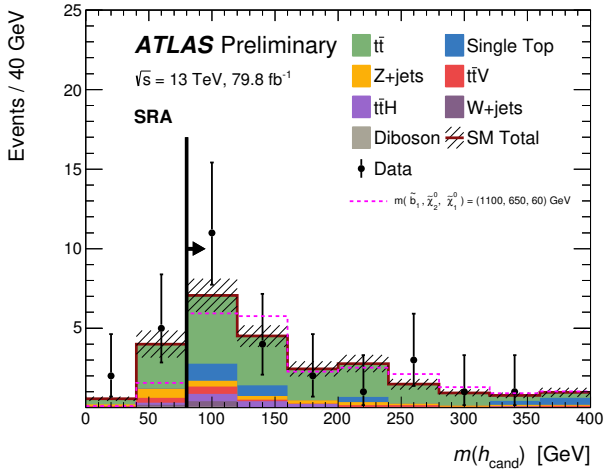
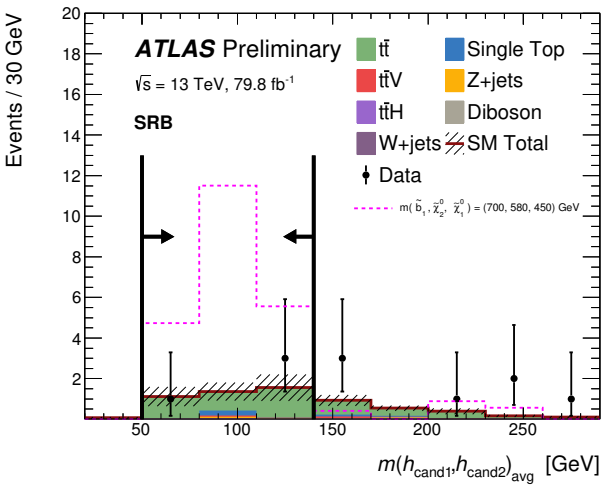
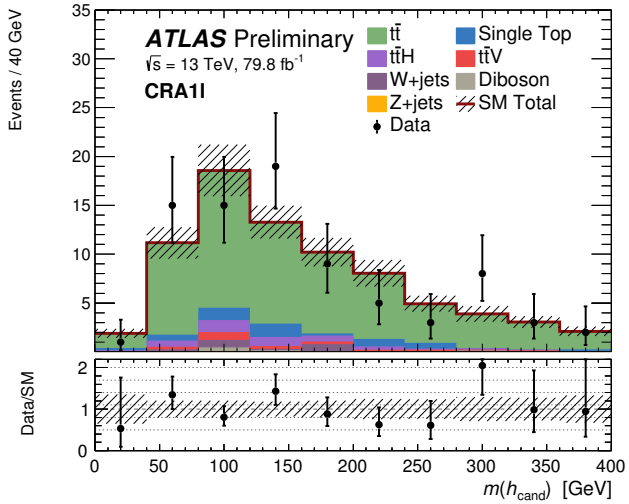
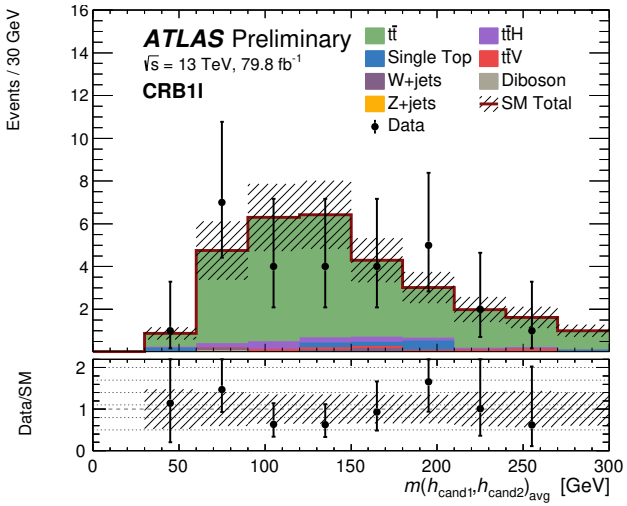




2017 data

ATLAS-CONF-2018-040





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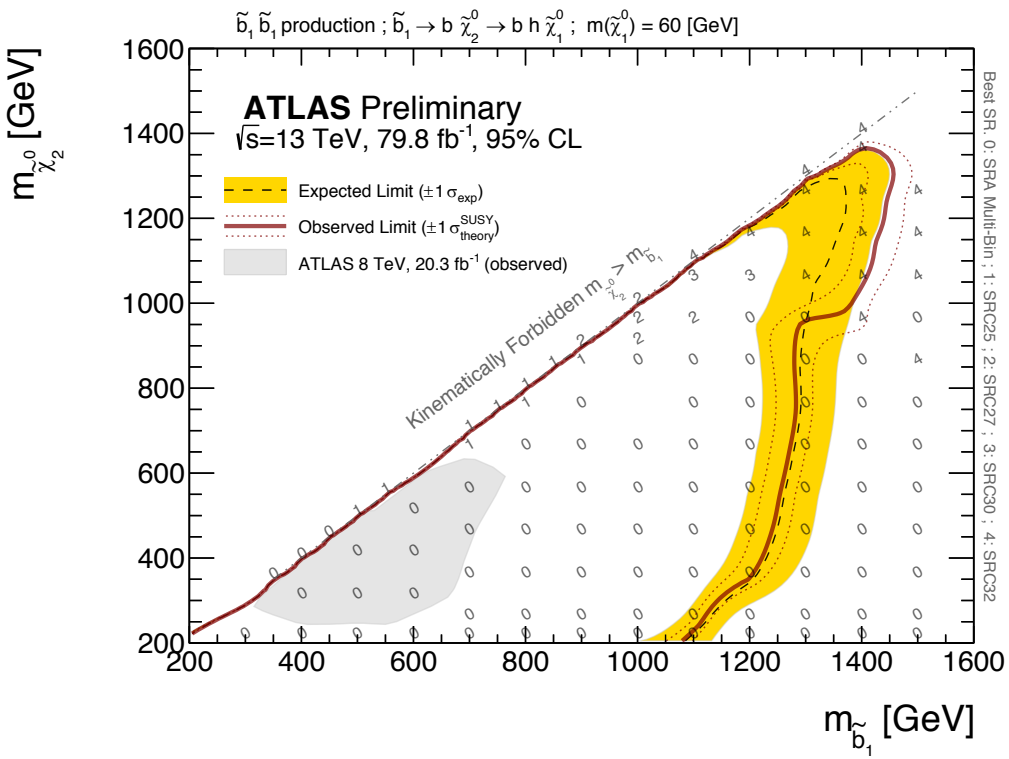
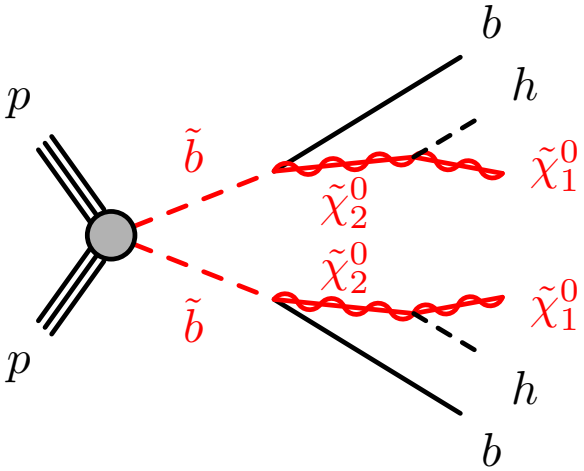
2017 data

ATLAS-CONF-2018-040

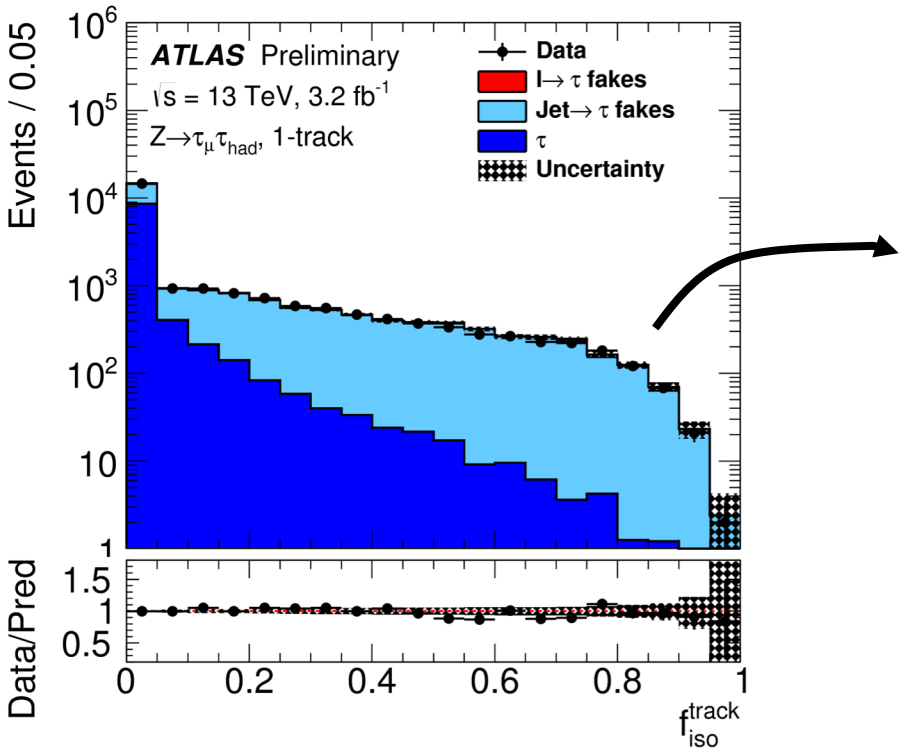


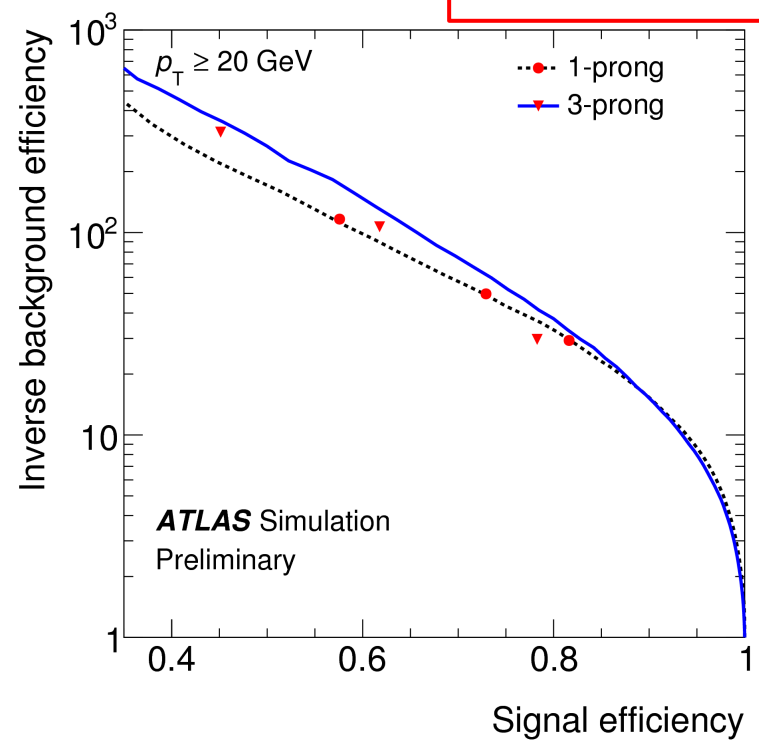


Taus in strong SUSY

- In ATLAS, τ leptons are identified with 2 BDTs (for 1- or 3-prong) using 12 input variables, such as fraction of charged tracks momentum in the isolation cone.

SUSY-2016-30



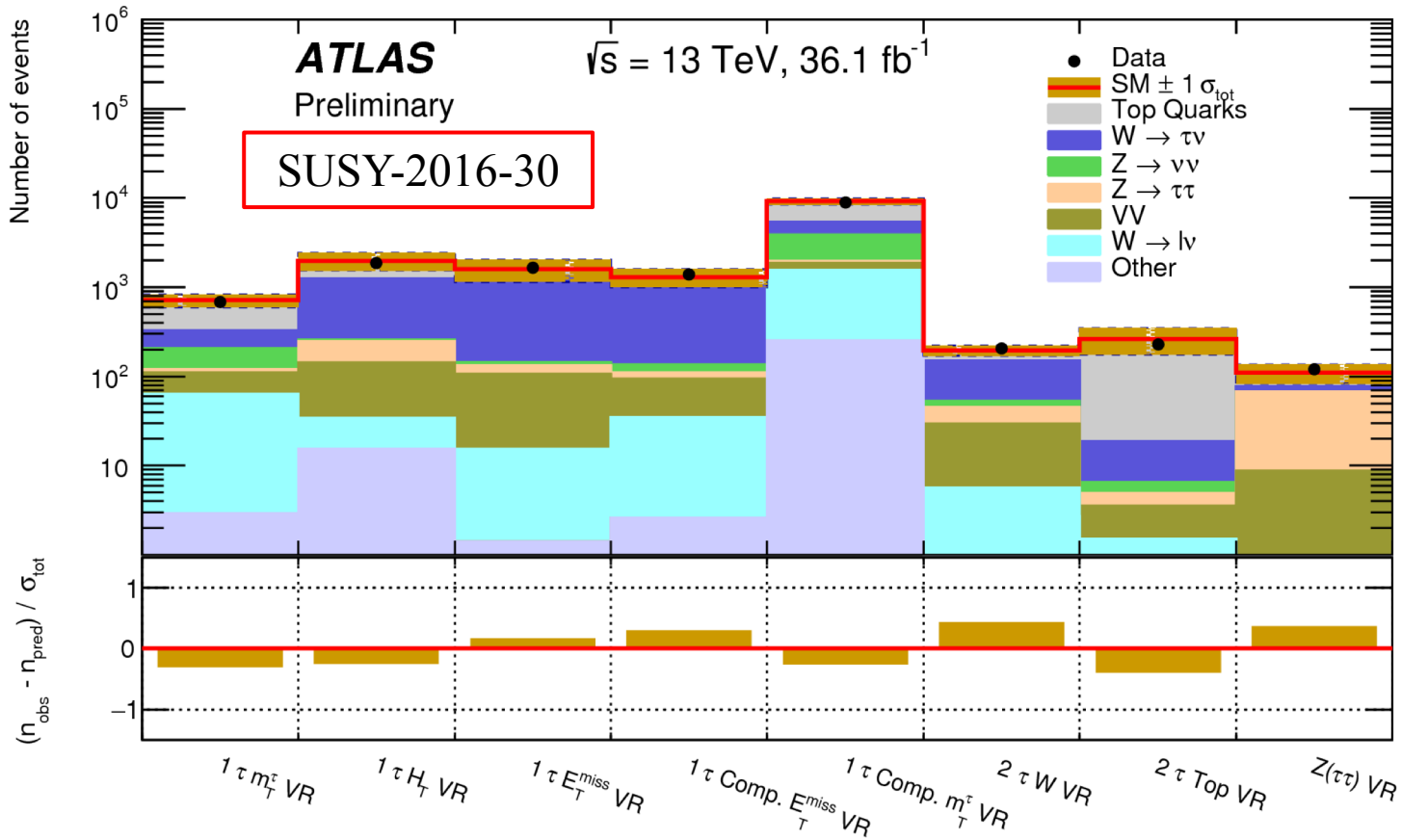


ATLAS-CONF-2017-029

ATL-PHYS-PUB-2015-045

Taus in strong SUSY

- The new ATLAS search selects events with 1 or ≥2 τ_{had} leptons, ≥ 2 jets, and E_T^{miss} > 400 (180) GeV for 1 (≥2) τ_{had}. Signal is selected having by high H_T and $\sum m_T^{\tau_i}$.



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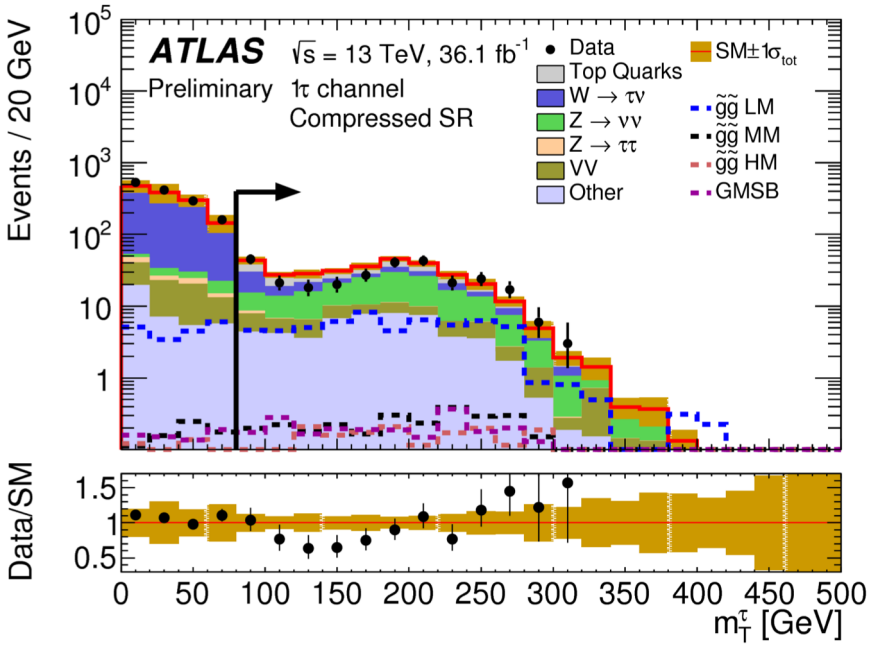
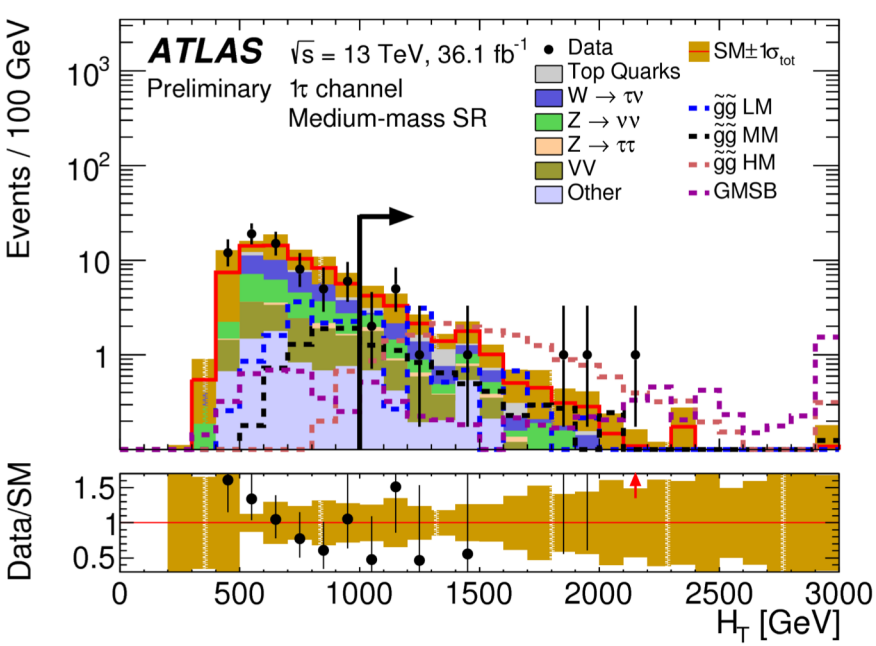
SUSY-2016-30





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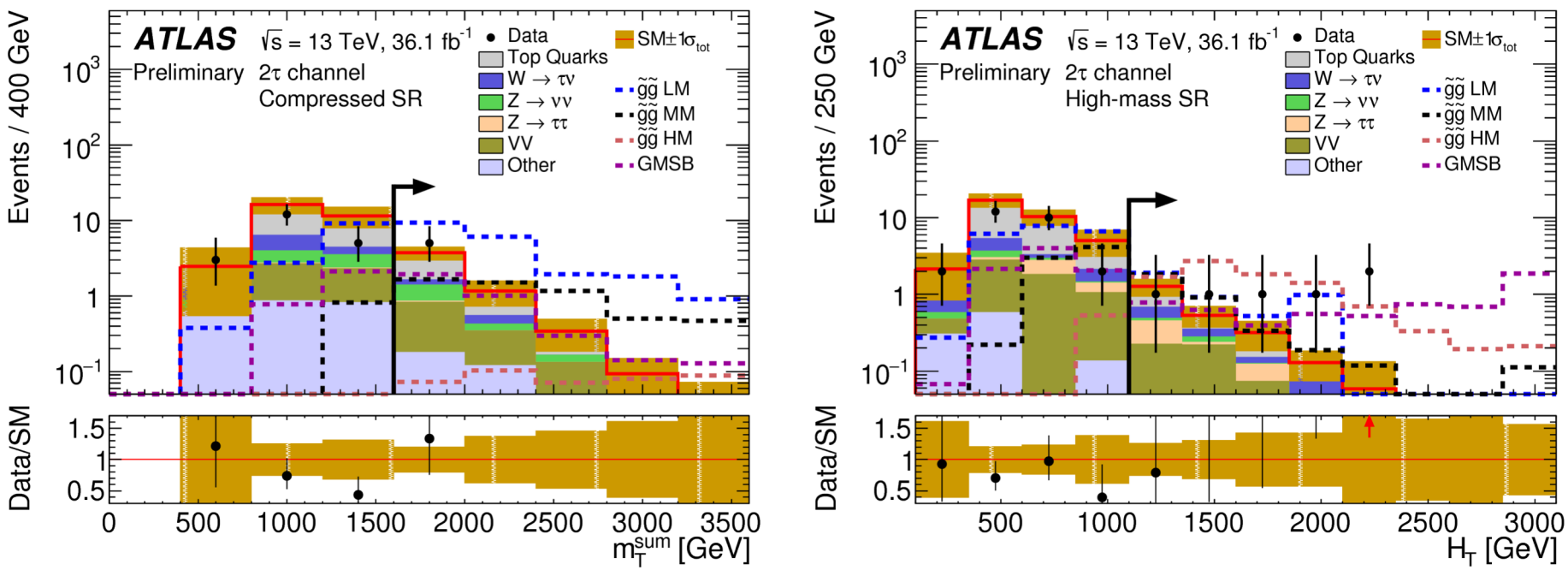

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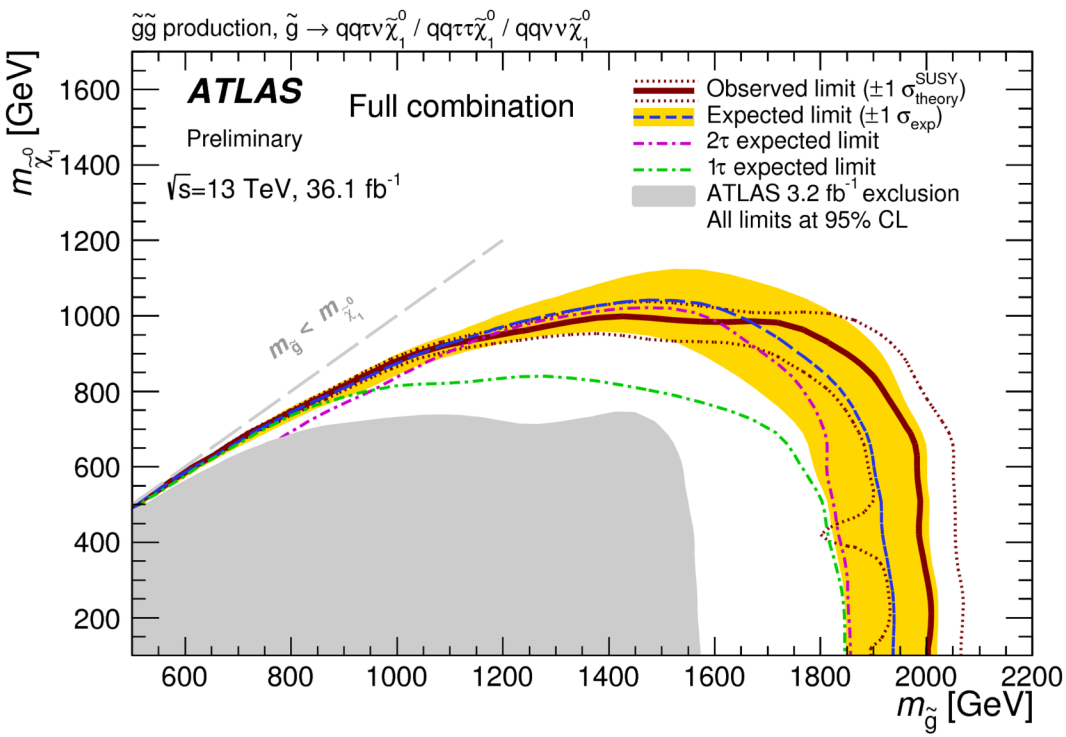
SUSY-2016-30



SUSY using charm tagging

arXiv:1805.01649

- The new ATLAS search targets both direct $\tilde{c}$ pair production as well $\tilde{t} \to c\tilde{\chi}_0^1$ decays.
- General selection requires ≥2 jets, ≥ c-tagged jets, $E_T^{miss} > 500$ GeV.
  - For compressed region, require ≥3 jets with leading jet not c-tagged (ISR tagging).

	SR1	SR2	SR3	SR4	SR5
Trigger	E_T^{miss} triggers				
Leptons	0 e AND 0 μ				
E_T^{miss} [GeV]	> 500				
$\Delta\phi_{min}(\text{jet}, \boldsymbol{E}_T^{miss})$ [rad]	> 0.4				
$N_{c-\text{jets}}$	≥ 1				
N_{jets}	≥ 2	≥ 3	≥ 3	≥ 3	≥ 3
Leading jet c-tag veto	yes	yes	yes	yes	no
$p_T^{j_1}$ [GeV]	> 250	> 250	> 250	> 250	> 300
$p_T^{j_2}$ [GeV]	–	–	> 100	> 140	> 200
$p_T^{j_3}$ [GeV]	–	–	> 80	> 120	> 150
$p_T^{c_1}$ [GeV]	< 100	> 60	> 80	> 100	> 150
m_T^c [GeV]	$\in (120, 250)$	$\in (120, 250)$	$\in (175, 400)$	> 200	> 400

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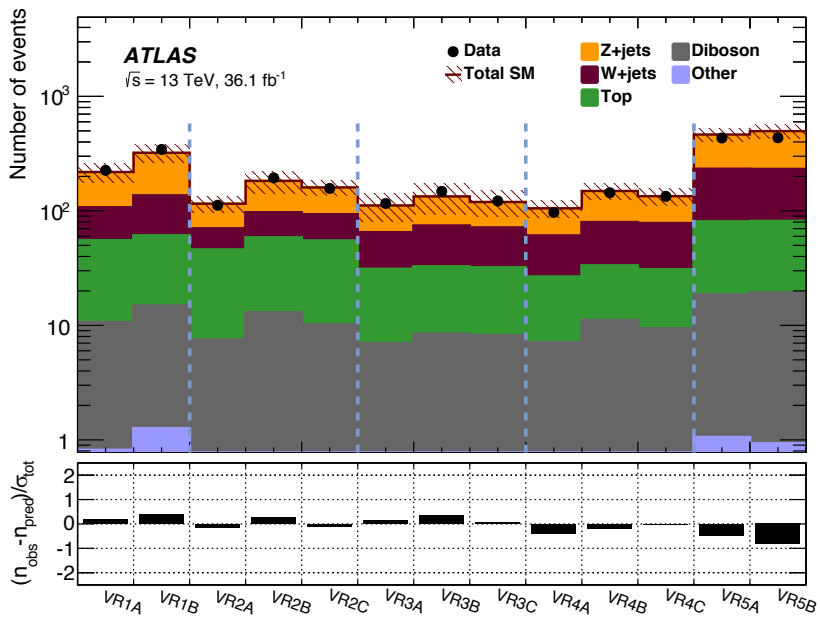

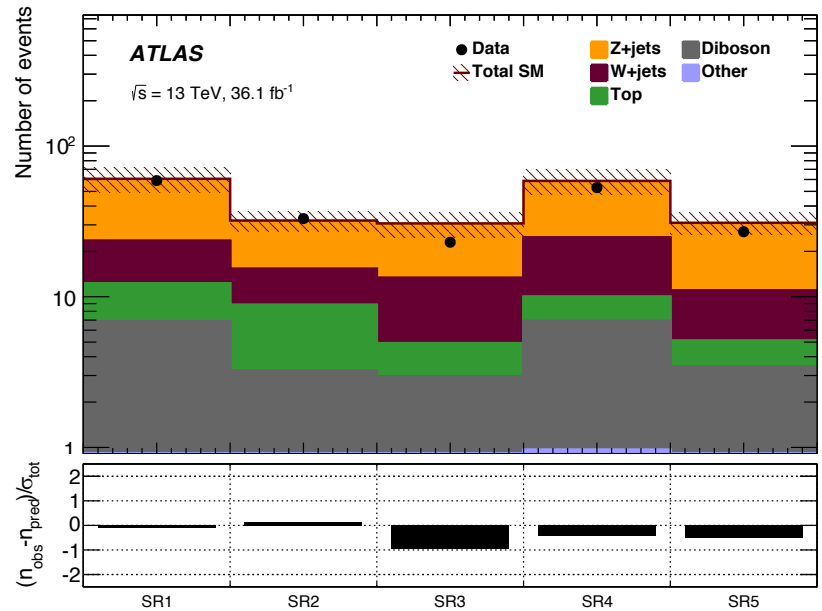

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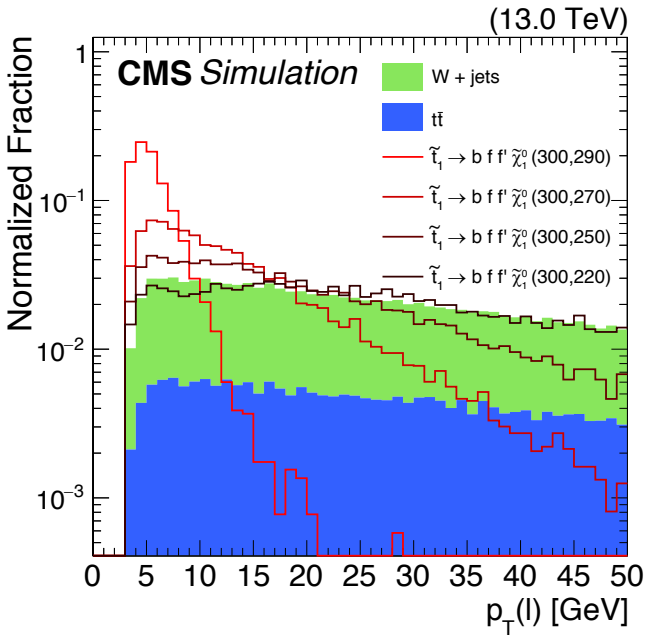
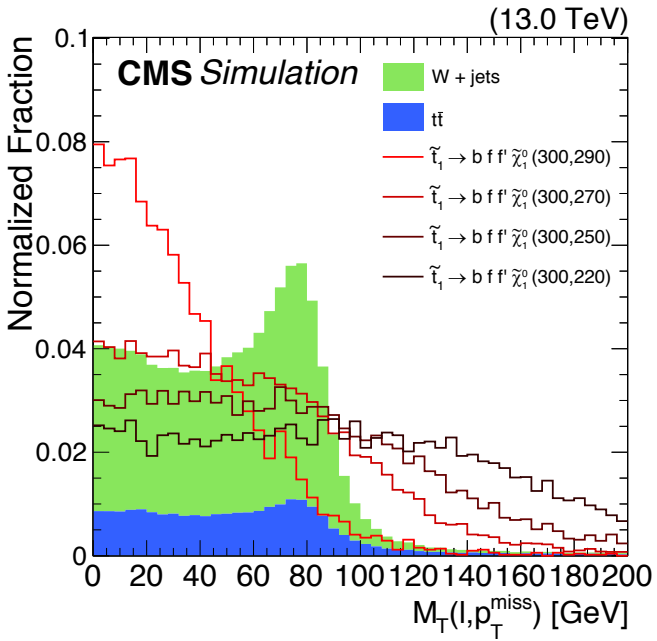
Yields	SR1	SR2	SR3	SR4	SR5
Observed	59	33	23	53	27
Total SM	61 ± 11	32 ± 5	31 ± 6	59 ± 11	31 ± 5
Z+jets	37.1 ± 7.8	16.7 ± 3.2	17 ± 5	34 ± 8	20 ± 4
W+jets	11.2 ± 5.1	6.5 ± 2.3	8.4 ± 2.0	15 ± 4	5.9 ± 1.5
Top	5.4 ± 2.0	5.6 ± 2.6	2.0 ± 2.0	3.1 ± 1.8	1.7 ± 0.7
Diboson	6.3 ± 2.1	2.7 ± 1.7	2.4 ± 0.7	5.9 ± 2.3	3.2 ± 1.6
Other	0.6 ± 0.1	0.5 ± 0.1	0.5 ± 0.1	1.0 ± 0.1	0.3 ± 0.1
Signal benchmarks					
$(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}) = (450, 425)$ GeV	22.7 ± 4.0	9.1 ± 2.6	1.6 ± 1.0	1.84 ± 0.71	0.45 ± 0.27
$(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}) = (500, 420)$ GeV	18.3 ± 3.4	19.7 ± 4.9	15.2 ± 4.1	8.0 ± 2.2	1.26 ± 0.64
$(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}) = (500, 350)$ GeV	5.4 ± 2.0	11.6 ± 3.3	26.1 ± 6.7	18.7 ± 5.4	3.0 ± 1.1
$(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}) = (600, 350)$ GeV	1.91 ± 0.87	3.2 ± 1.3	10.5 ± 3.0	24.0 ± 5.9	7.0 ± 2.2
$(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}) = (900, 1)$ GeV	0.67 ± 0.19	0.61 ± 0.21	1.61 ± 0.50	11.7 ± 2.0	10.2 ± 1.8
$\langle\sigma_{\text{vis}}\rangle_{obs}^{95}$ [fb]	0.67	0.46	0.33	0.59	0.40
S_{obs}^{95}	24.2	16.6	11.9	21.3	14.3
S_{exp}^{95}	$24.4^{+13.2}_{-7.6}$	$16.0^{+5.6}_{-4.4}$	$15.0^{+5.2}_{-3.1}$	$24.9^{+9.6}_{-7.1}$	$15.3^{+6.8}_{-2.2}$
$p(s = 0)$	0.5	0.41	0.5	0.5	0.5

Compressed $\tilde{t}$ might decay differently

arXiv:1805.05784

- The new CMS search looks in the single-lepton final state with very a soft lepton.
- BDT input:
  - E_T^{miss}, $p_T(\ell)$, M_T
  - $\eta(\ell)$, $Q(\ell)$
  - $p_T(ISR)$, $p_T(b)$, N_{jets}, H_T
  - $N(b)$, $\Delta R(\ell,b)$, $D(b)$





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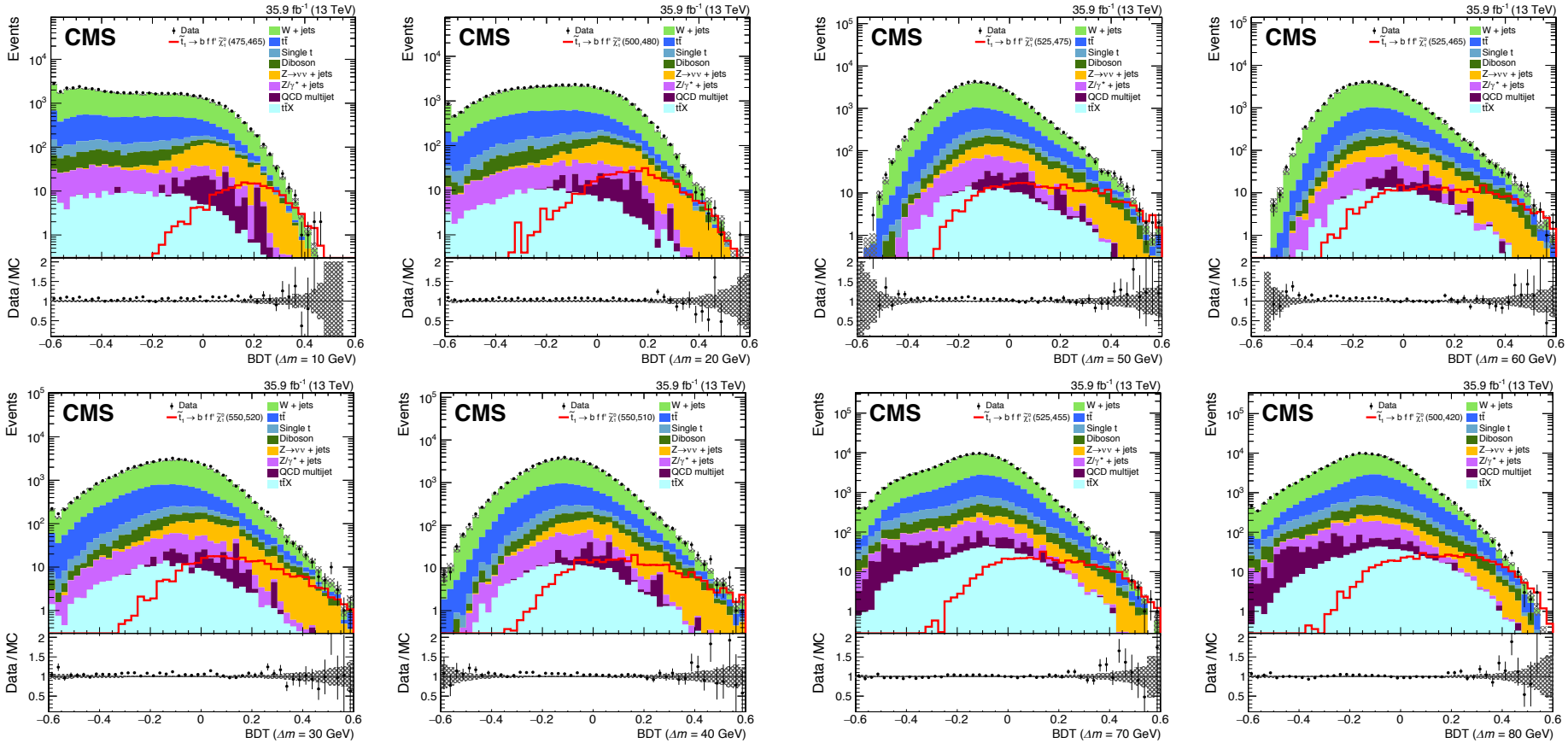
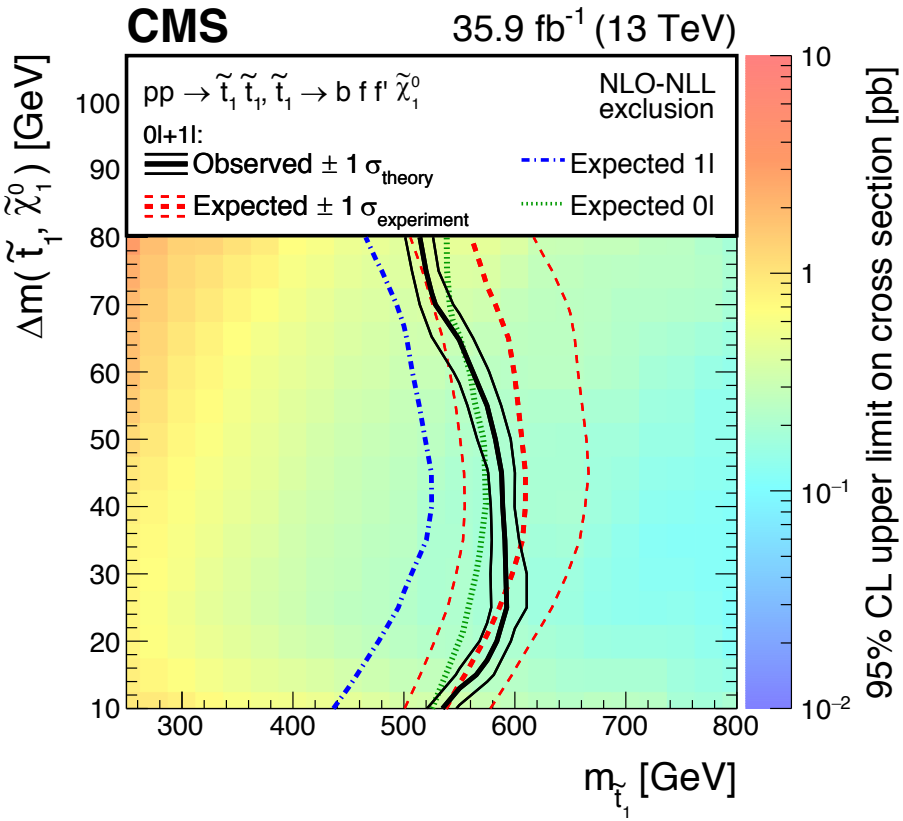
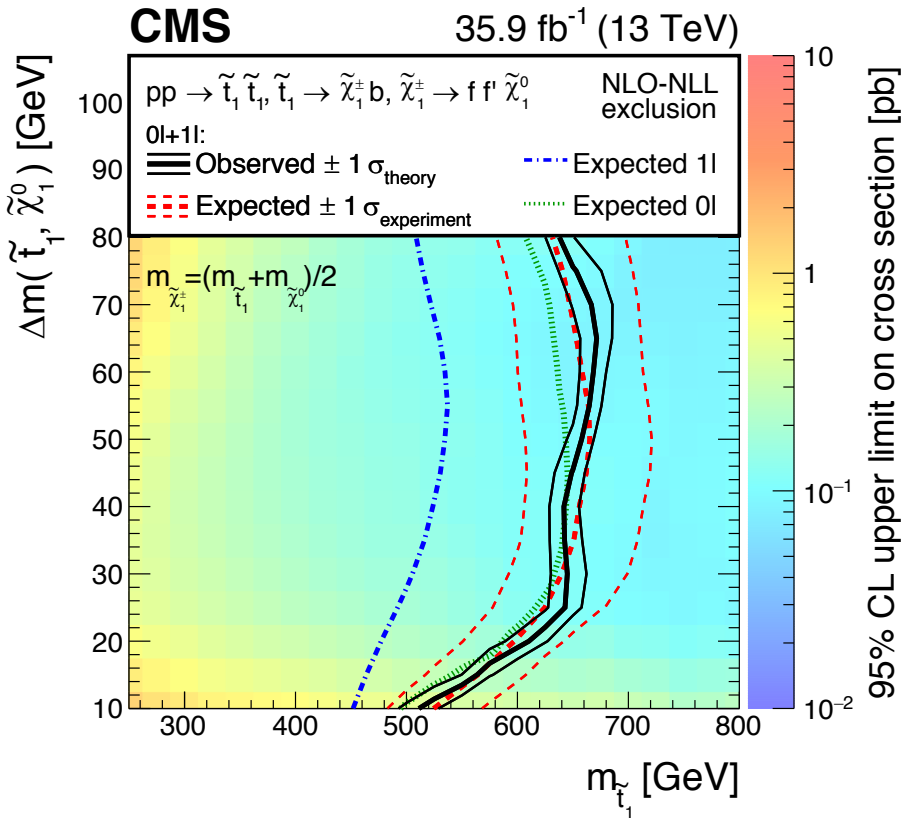


Compressed $\tilde{t}$ might decay differently

- arXiv:1805.05784 also contains a cut-and-count analysis that has combined its results with the 0ℓ top squark search (JHEP 10 (2017) 005).

arXiv:1805.05784

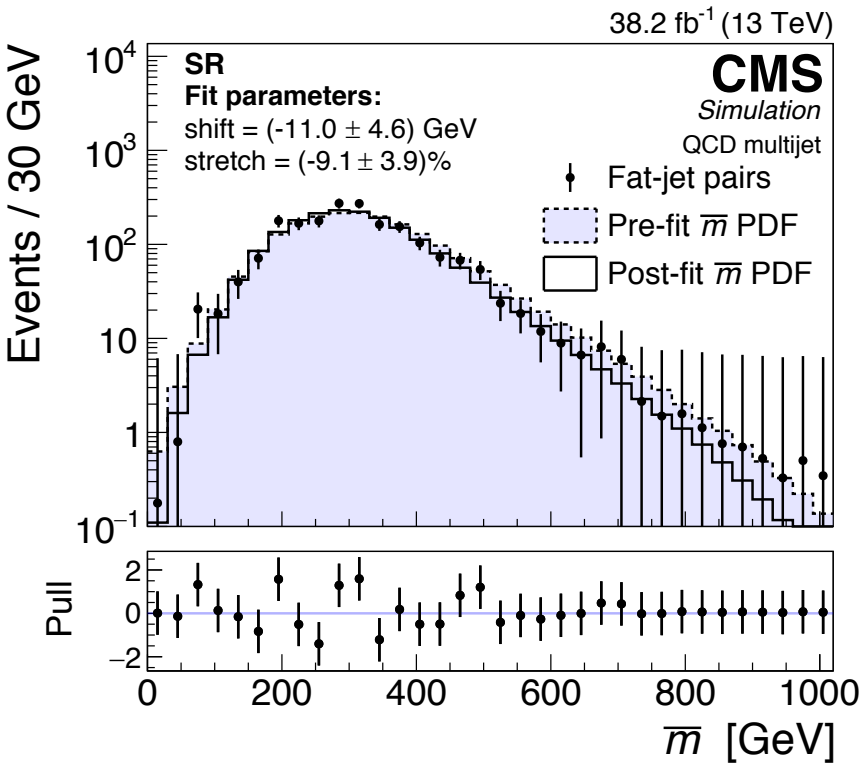


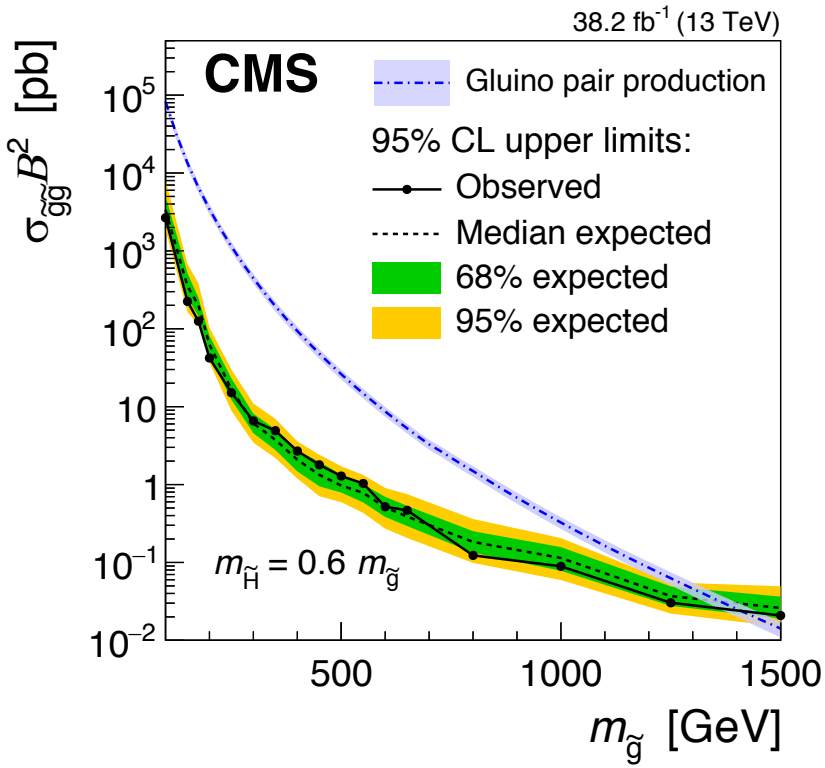


arXiv:1806.01058

Hadronic RPV resonance searches

- CMS search for $\tilde{q}\bar{\tilde{q}} \to 2\times4q$ or $\tilde{g}\tilde{g} \to 2\times5q$ pair production for masses $\lesssim$ 1 (1.5) TeV for $\tilde{q}$ ($\tilde{g}$).





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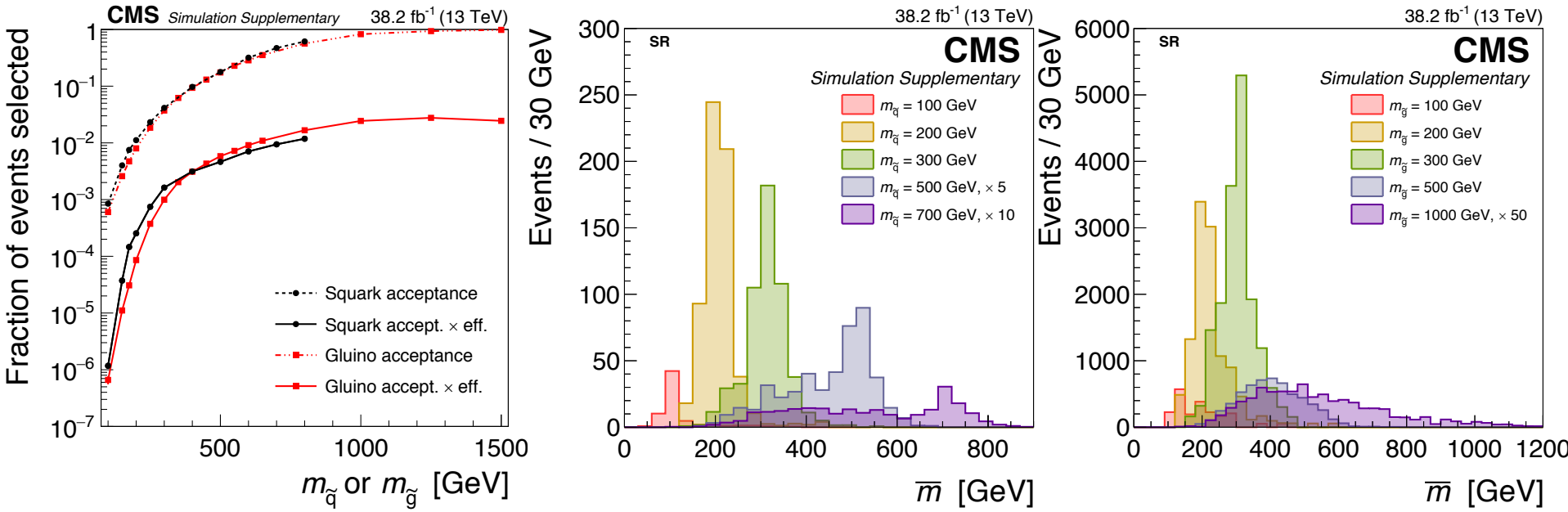

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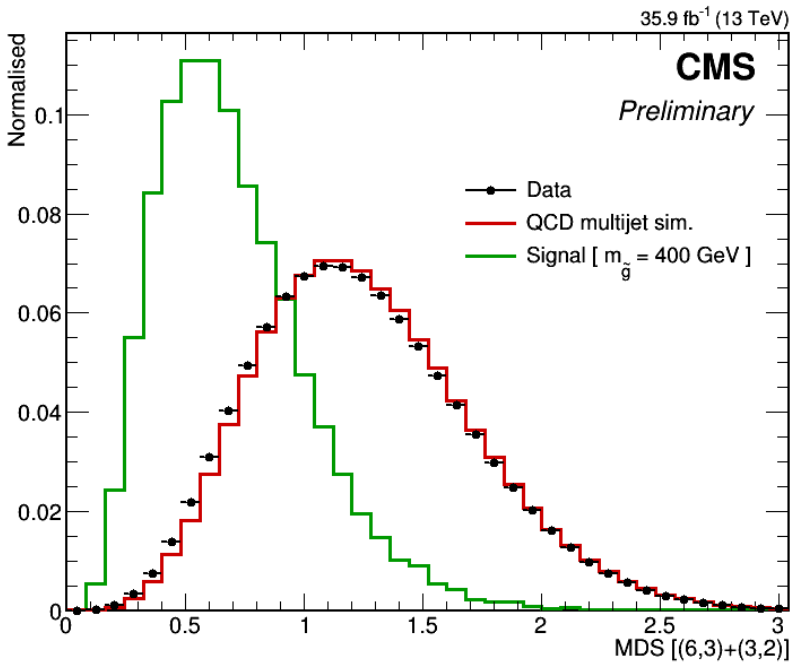
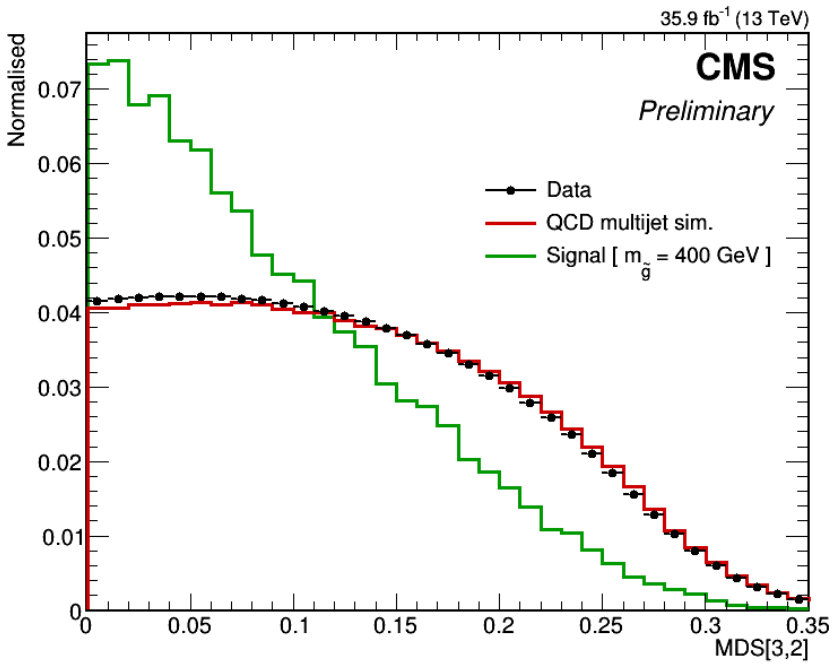
Parameter	Pre-fit value	Post-fit value
QCD normalization [events]	floating	1222 ± 35
QCD shift [GeV]	0 ± 17	-8 ± 4
QCD stretch	$(0 \pm 18)\%$	$(-1 \pm 3)\%$
$t\bar{t}$ normalization	1.00 ± 0.24	1.08 ± 0.14
$t\bar{t}$ and signal shift [GeV]	0 ± 16	-10 ± 6
$t\bar{t}$ and signal stretch	$(0 \pm 20)\%$	$(15 \pm 9)\%$
Signal normalization	1.00 ± 0.24	—

CMS-EXO-17-030

Hadronic RPV resonance searches

- CMS search for $\tilde{g}\tilde{g} \rightarrow 2\times 3q$ pair production





CMS-EXO-17-030

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Region	Mass Range	$p_T >$	$H_T >$	6^{th}Jet$p_T >$	MDS[(6,3)+(3,2)]<	$A_m <$	$\Delta >$	MDS[3,2]<
1	200-400 GeV	30 GeV	650 GeV	40 GeV	1.25	0.25	250 GeV	0.05
2	400-700 GeV	30 GeV	650 GeV	50 GeV	1.00	0.175	180 GeV	0.175
3	700-1200 GeV	50 GeV	900 GeV	125 GeV	0.9	0.15	20 GeV	0.2
4	1200-2000 GeV	50 GeV	900 GeV	175 GeV	0.75	0.15	-120 GeV	0.25

CMS-EXO-17-030

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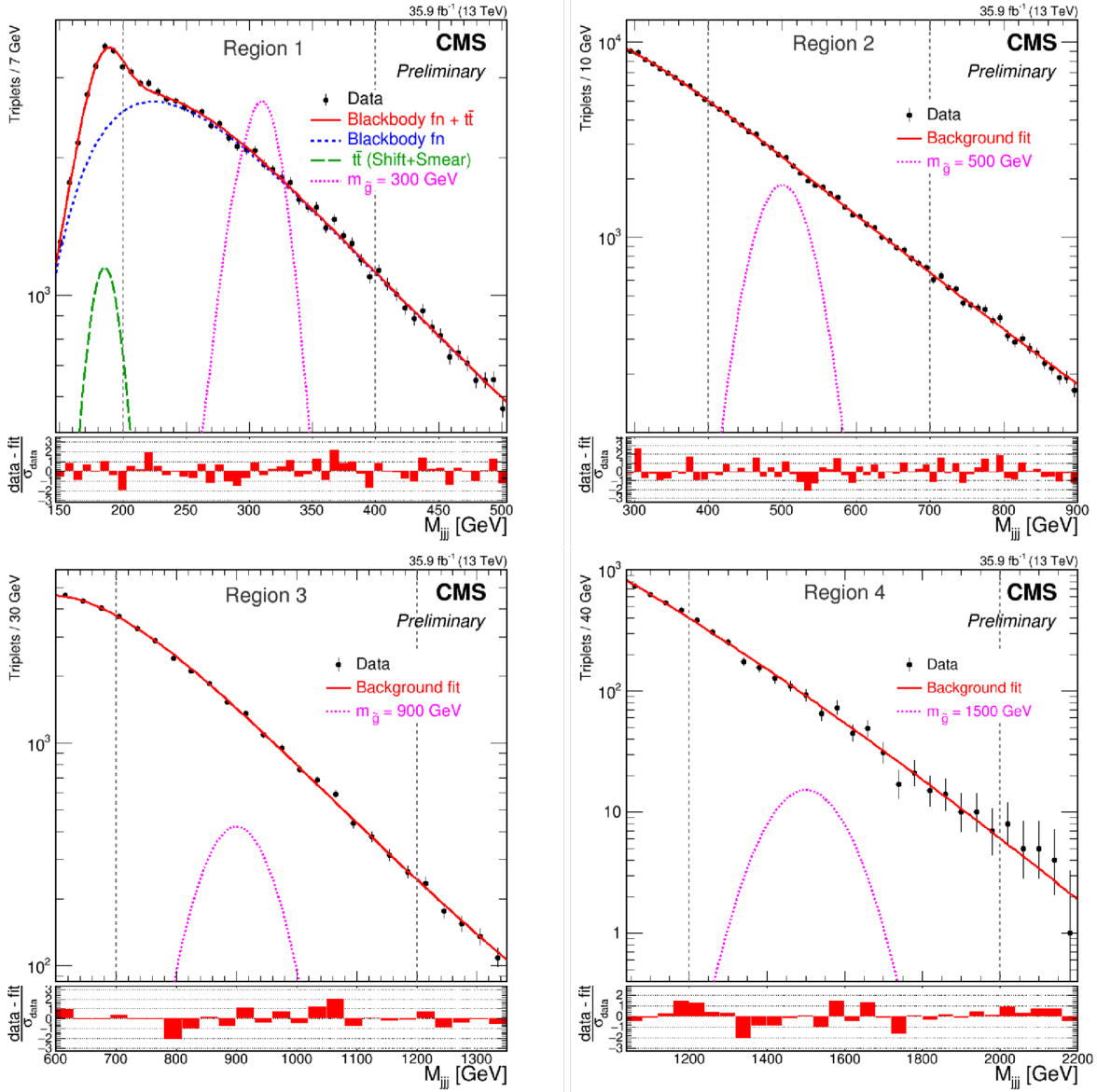
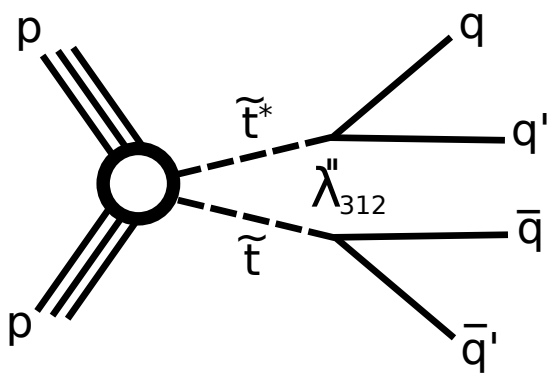
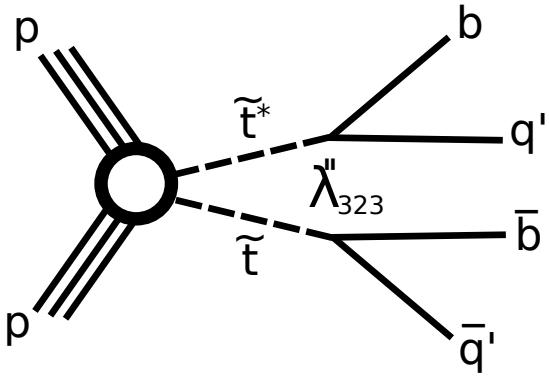


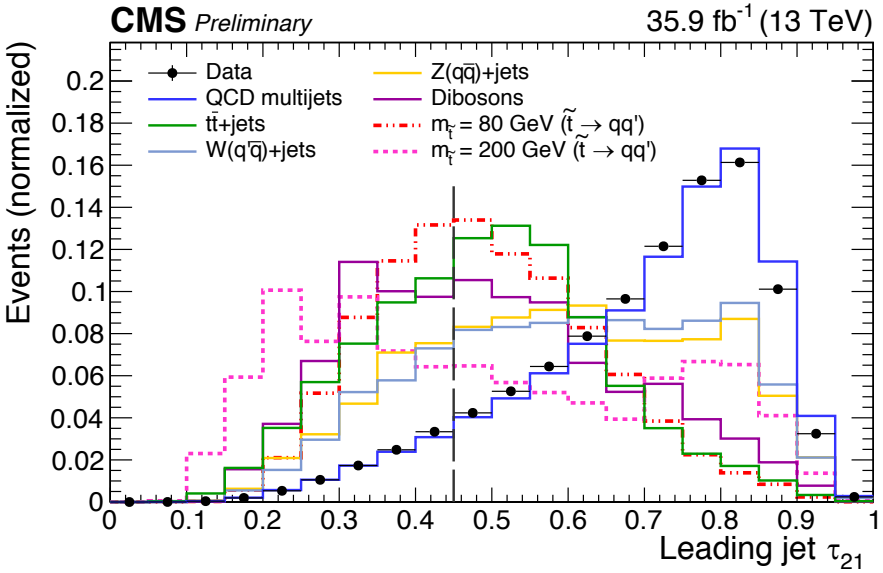
RPV $\tilde{t}$: paired dijet resonances

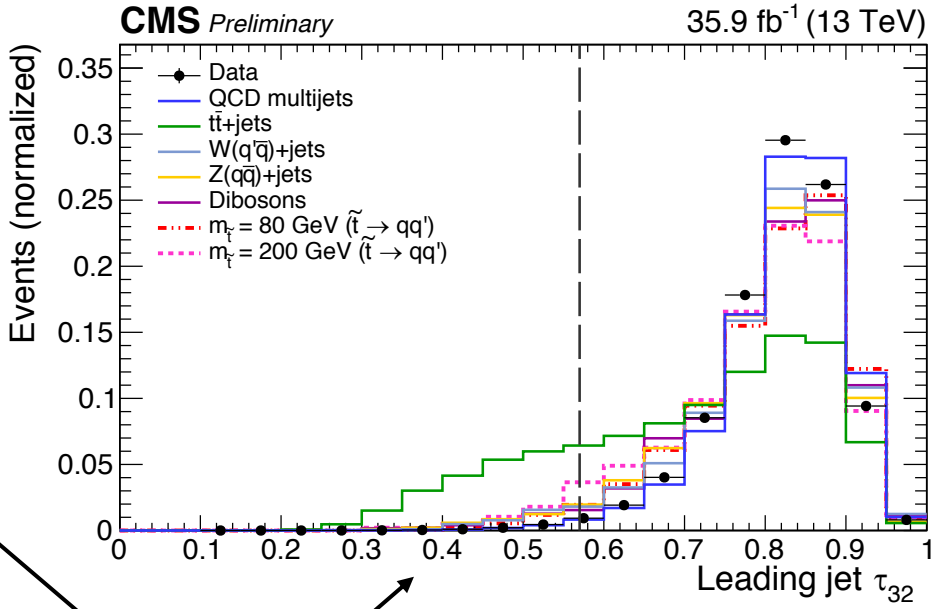


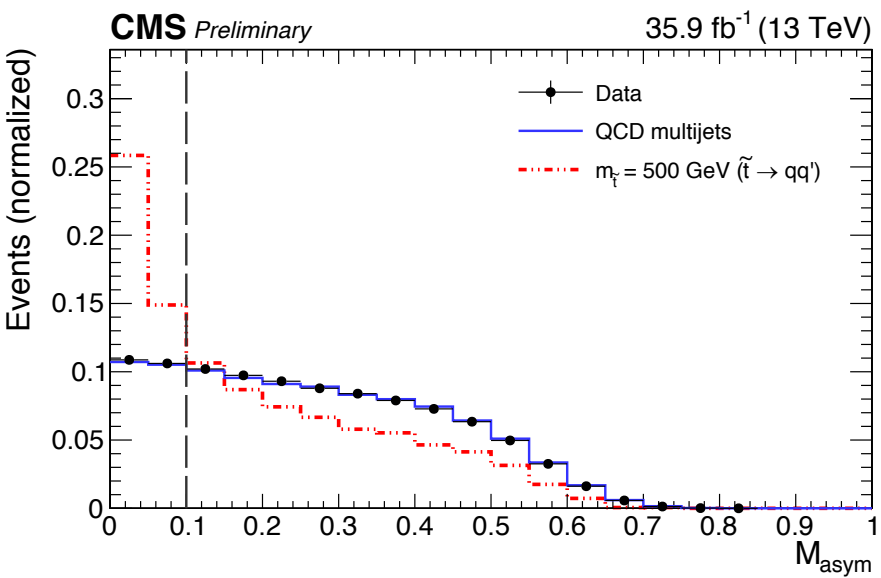


	Boosted search $60 < \overline{m} < 450\,\text{GeV}$ $(80 \leq m_{\tilde{t}} < 400\,\text{GeV})$	Resolved search $\overline{M} > 350\,\text{GeV}$ $(m_{\tilde{t}} \geq 400\,\text{GeV})$
Inclusive selection	AK8 jets jet $p_T > 150\,\text{GeV}$ jet $\lvert\eta\rvert < 2.5$ $N_{jet} \geq 2$ $H_T^{AK8} > 900\,\text{GeV}$ $m_{asym} < 0.1$ $\tau_{21} < 0.45$ $\tau_{32} > 0.57$ $\Delta\eta < 1.5$	AK4 jets jet $p_T > 80\,\text{GeV}$ jet $\lvert\eta\rvert < 2.5$ $N_{jet} \geq 4$ $H_T^{AK4} > 900\,\text{GeV}$ $M_{asym} < 0.1$ $\Delta\eta_{dijet} < 1.0$ $\Delta > 200\,\text{GeV}$
B-tagged selection	Inclusive selection plus two loose b-tagged jets	Inclusive selection plus two loose b-tagged jets

RPV $\tilde{t}$: paired dijet resonances



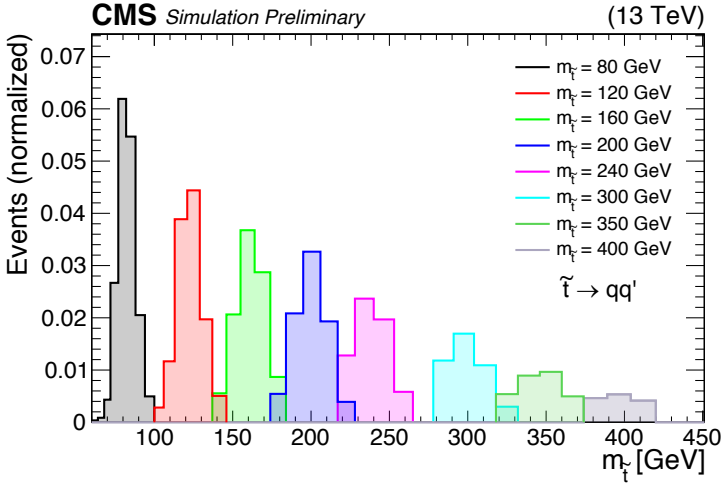


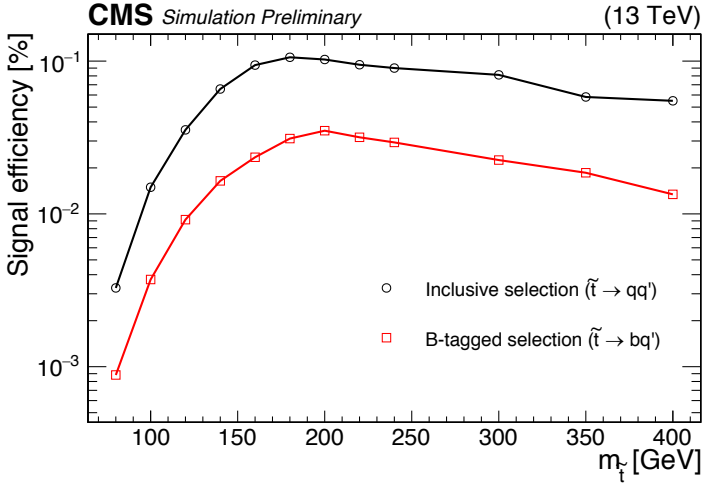


Boosted

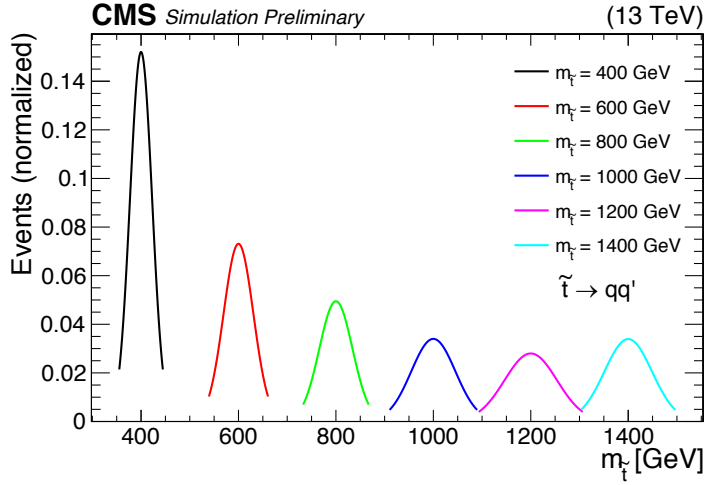
Resolved

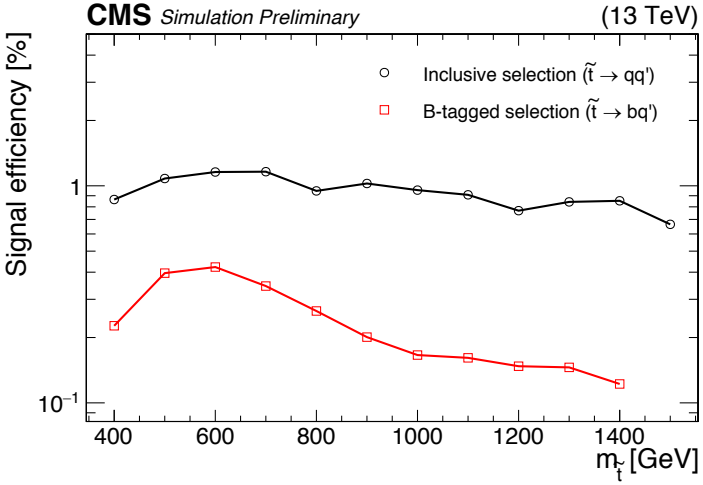
RPV $\tilde{t}$: paired dijet resonances





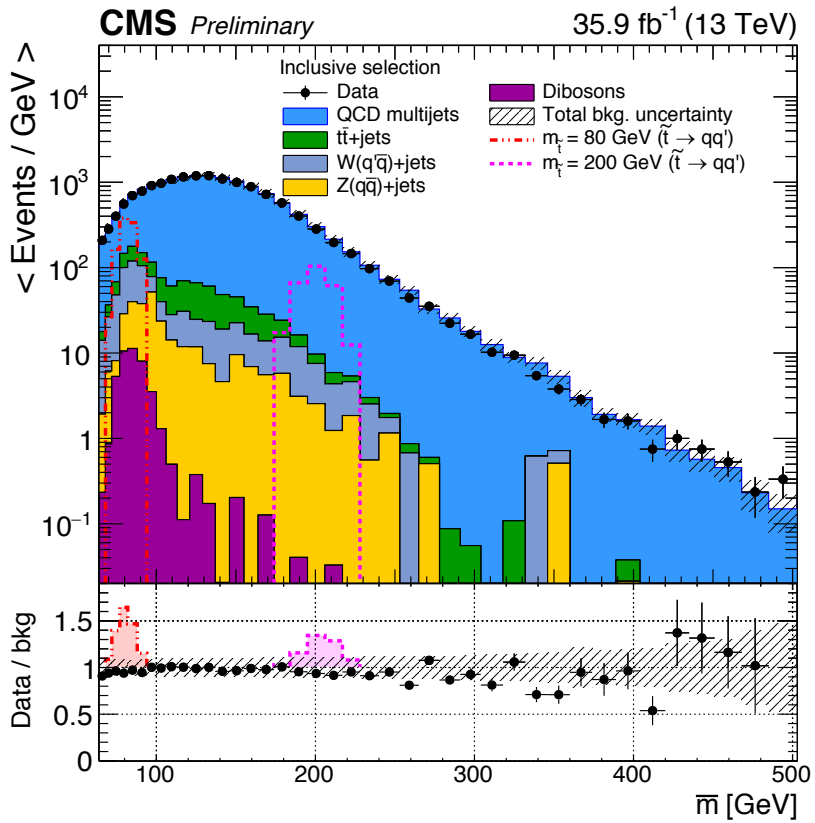
Boosted

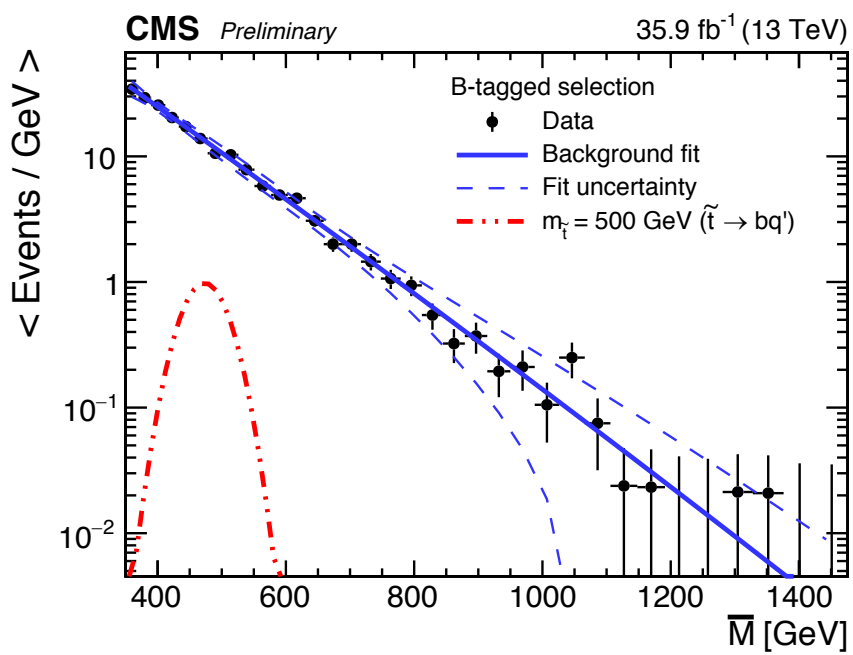




Resolved

RPV $\tilde{t}$: paired dijet resonances

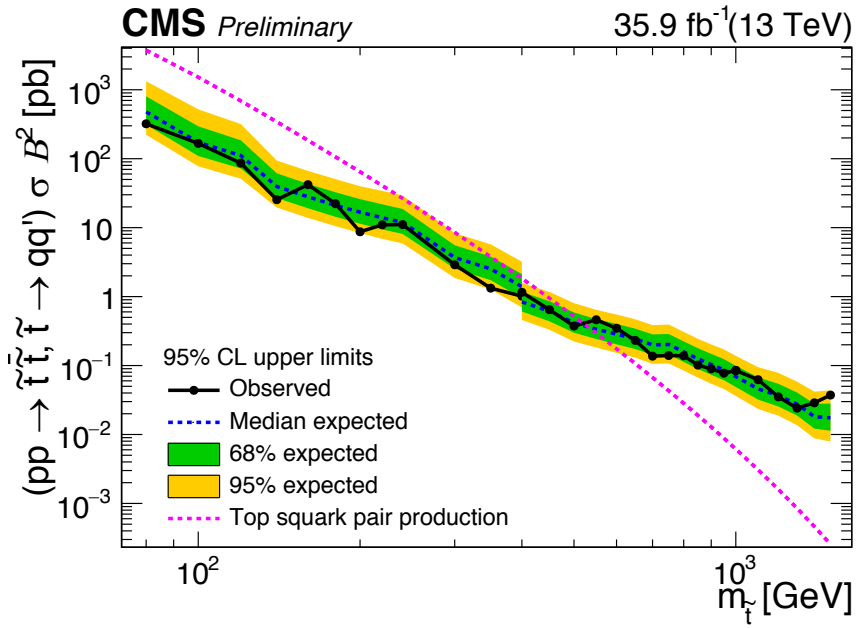


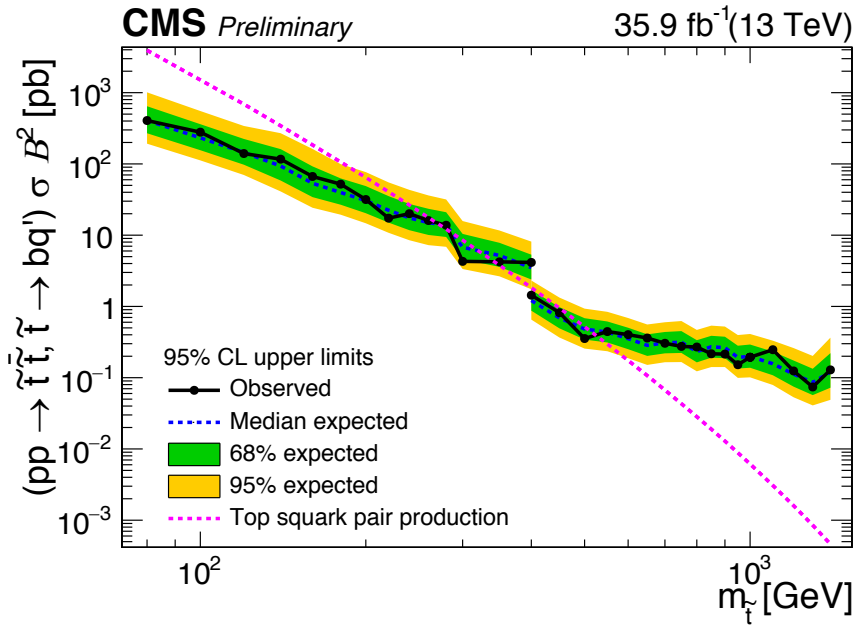


Boosted
Inclusive

Resolved
b-tagged

RPV $\tilde{t}$: paired dijet resonances





Exclusion: $80 < m_{\tilde{t}} < 520$ GeV

for λ''_{312} coupling

Exclusion: $m_{\tilde{t}} \in (80,270)$, $(285,340)$, or $(400,525)$ GeV for λ''_{323} coupling