SUSY

a review of the results from
the LHC experiments

ICHEP2018, Seoul, 10 July 2018

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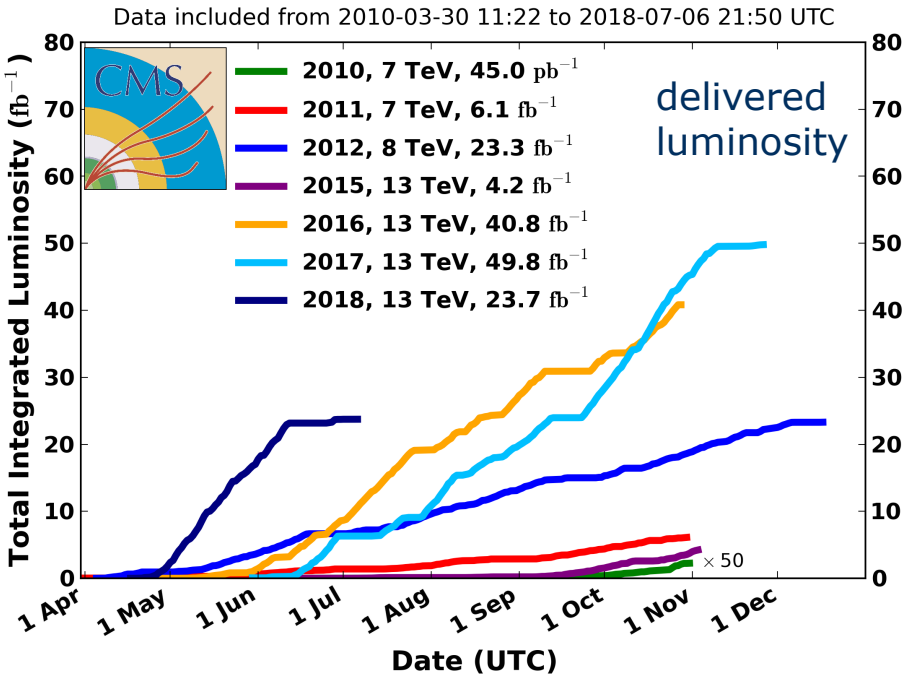
on behalf of the
ATLAS, CMS and
LHCb Collaborations

Why SUSY?

- SUSY has the potential to
  - provide a dark matter candidate;
  - unify the forces at high energy;
  - solve the fine-tuning problem of the Higgs mass.
- Only problem with SUSY is that we have not found it yet.
- Still many places for SUSY to hide.

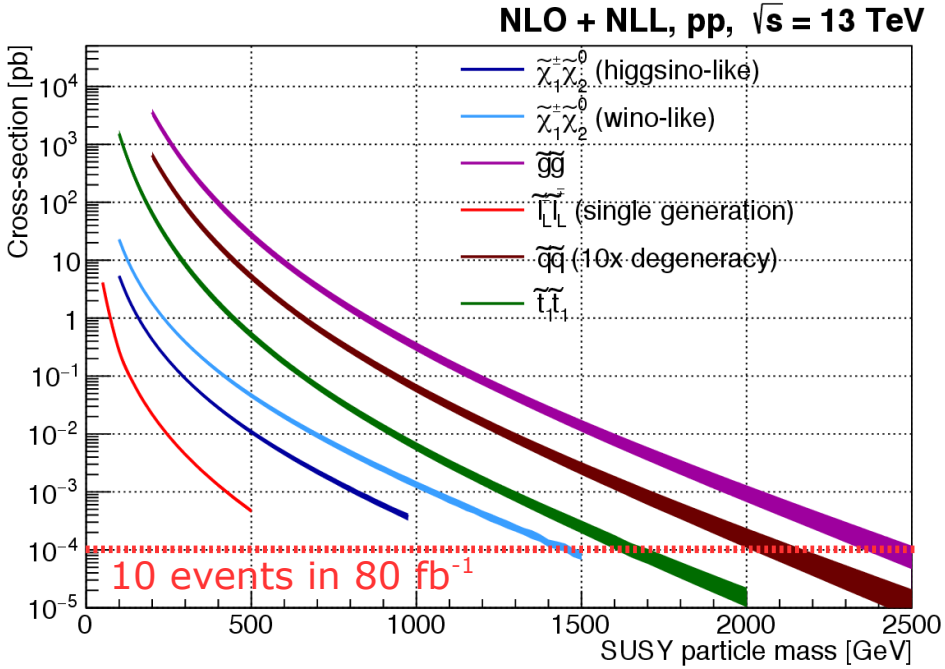
  → Our job to keep searching.
- Broad search program to ensure that we get the most out of the LHC data.
- And we are getting a lot of data!
- Most results presented today with the 36 fb^{-1} of 2015-2016 data.
- Some results use the 80 fb^{-1} of 2015-2017 data.

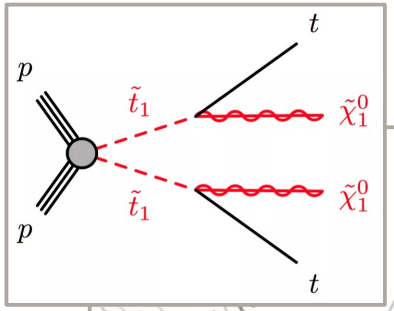
CMS Integrated Luminosity, pp

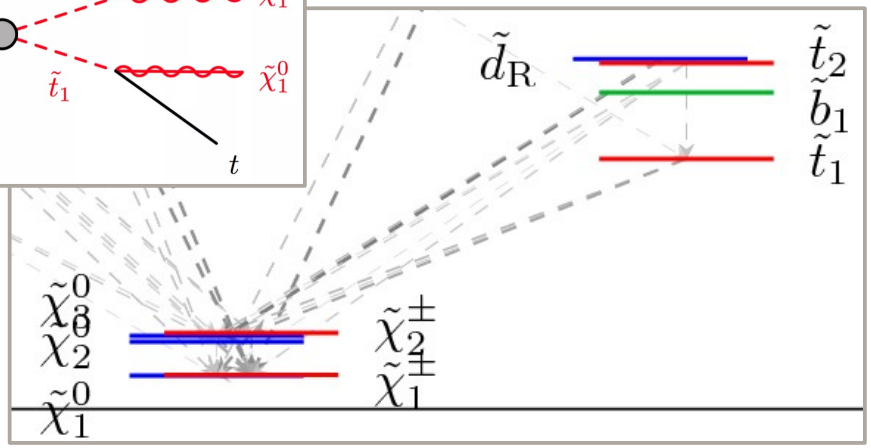


SUSY search program at the LHC

- Huge set of scenarios and final states covered.
  - Strong production.
  - Electroweak production.
  - R-parity conserved and violated.
- Driven by simplified models.
  - Masses of non-relevant SUSY particles put very high.
  - 100% BR to single final state.
- Simplified models for model-dependent exclusion limits.
- Check coverage in large pMSSM scans.
- Model-independent upper limits, HEP data, ...







Selection

- Strategy: General overview, then new results.
- Disclaimer: Personal and biased selection of results.
- Please see links below for more complete picture.
- ATLAS Public SUSY Results:

  https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults
- CMS Public SUSY Results:

  http://cms-results.web.cern.ch/cms-results/public-results/publications/SUS/
- LHCb Public Exotica Results:

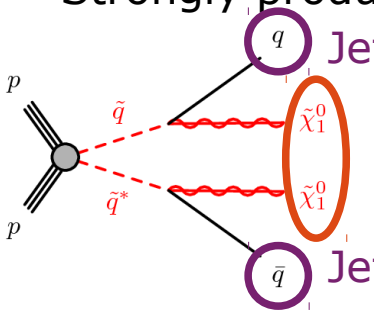
  http://lhcbproject.web.cern.ch/lhcbproject/Publications/LHCbProjectPublic/Summary_QEE.html
- Many detailed SUSY talks in parallel sessions (see next slide).
- Also many great SUSY posters.

Parallel Session Talks

- Searches for strongly-produced SUSY at CMS (Ana Ovcharova) [Link]
- Searches for squarks and gluinos in final states involving dark matter candidates with ATLAS (Hernan Wahlberg) [Link]
- Searches for direct pair production of stops and sbottoms with the ATLAS detector (Giacomo Polesello) [Link]
- Searches for SUSY with boosted objects at CMS (Rishi Gautam Patel) [Link]
- Searches for electroweak production of supersymmetric particles involving the Higgs boson and the higgsino with ATLAS (Anyes Taffard) [Link]
- Searches for sleptons with the ATLAS detector (Margherita Primavera) [Link]
- Searches for electroweakly produced supersymmetry with CMS (Valentina Dutta) [Link]
- Searches for electroweak production of supersymmetric gauginos and sleptons at LHC (Zinonas Zinonos) [Link]
- Searches for long-lived particles and other non-conventional signatures at CMS (Alberto Escalante Del Valle) [Link]
- Search for New Physics through the Reconstruction of Challenging Signatures with the ATLAS detector (Marianna Testa) [Link]
- Reconstruction techniques in supersymmetry searches in the ATLAS experiment (Mark Hodgkinson) [Link]
- Searches for Long Lived Particles at LHCb (Carlos Vazquez Sierra)[Link]

Searches for squarks and gluinos

- Strongly produced → largest cross sections.



Missing transverse momentum

$|\vec{p}_T^{miss}| = p_T^{miss} = E_T^{miss}$

Searches for squarks and gluinos

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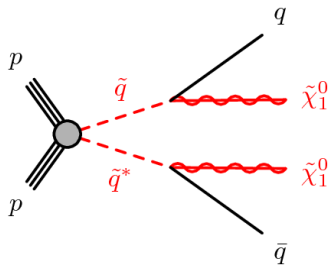
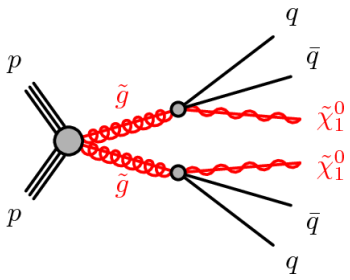
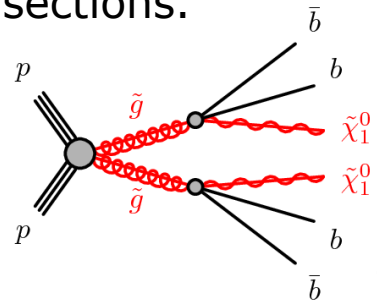
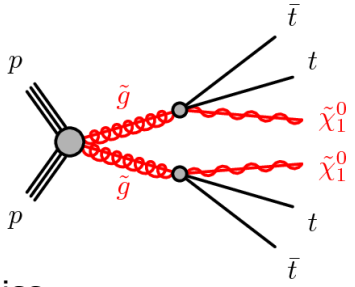




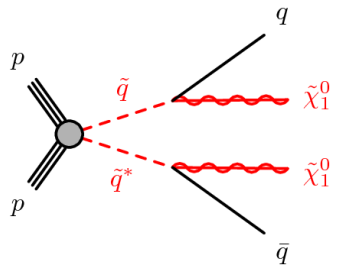


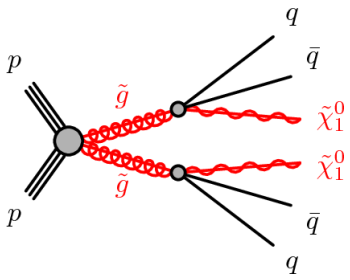


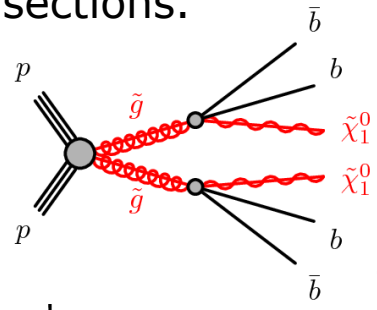
- E_T^{miss}, (b) jets, (leptons).

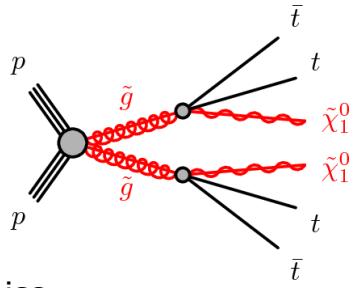
Searches for squarks and gluinos

- Strongly produced → largest cross sections.

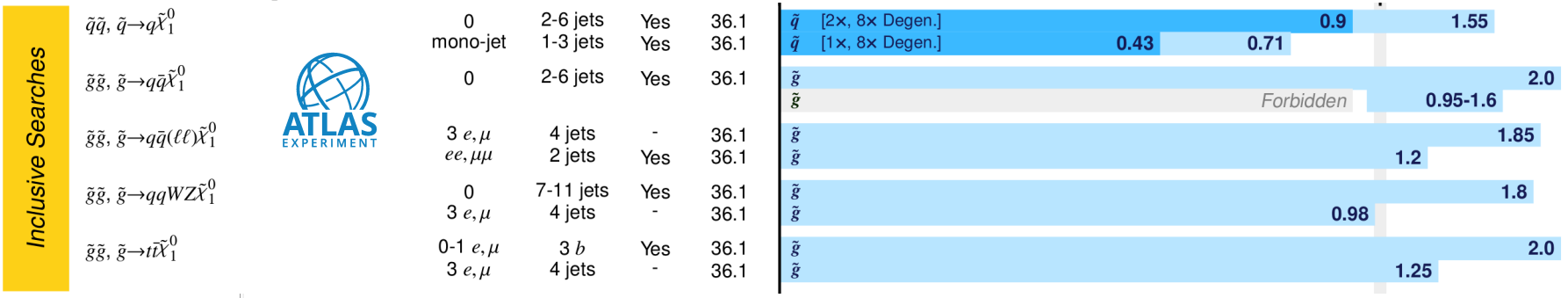


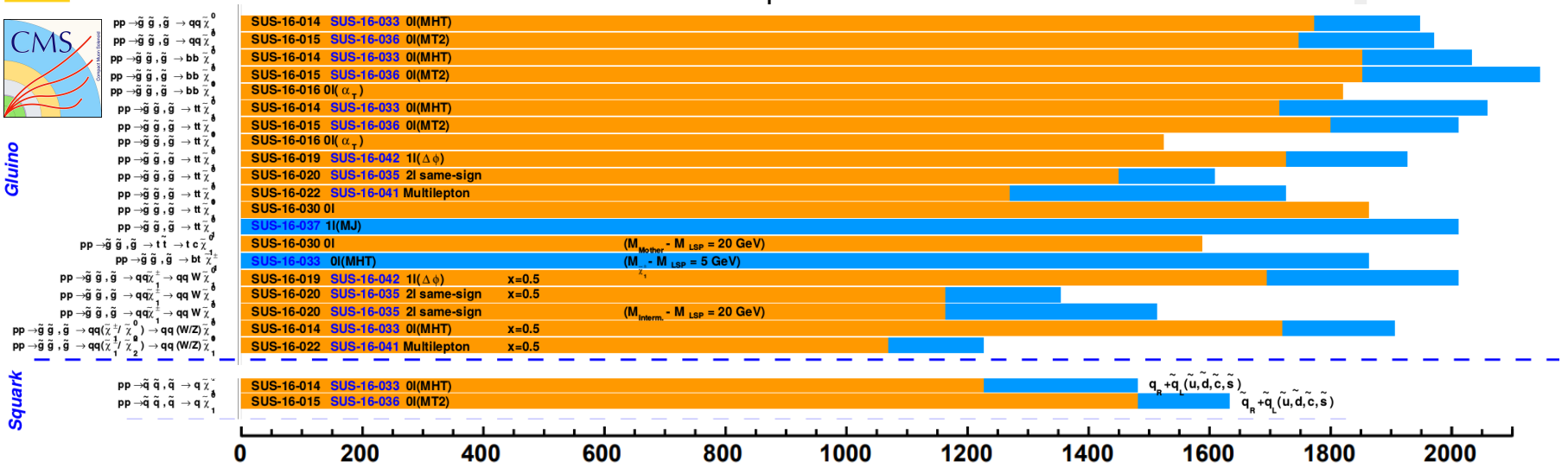






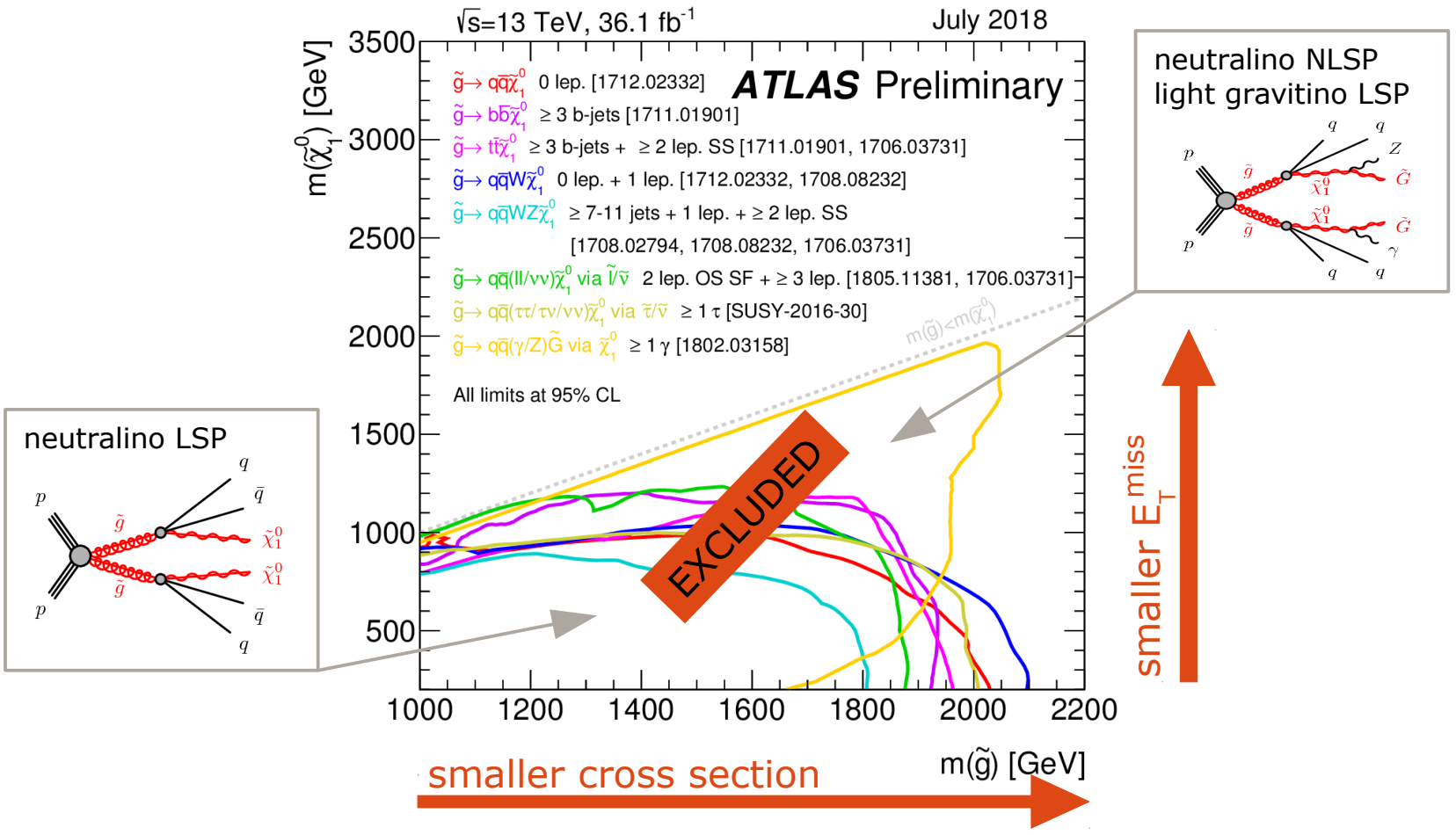
- E_T^{miss}, (b) jets, (leptons).





- Limits reach 2 TeV (gluinos) 1.5 TeV (squarks) in most favourable models.

Gluino pair production

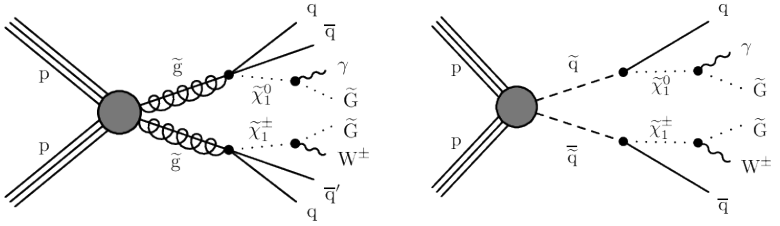


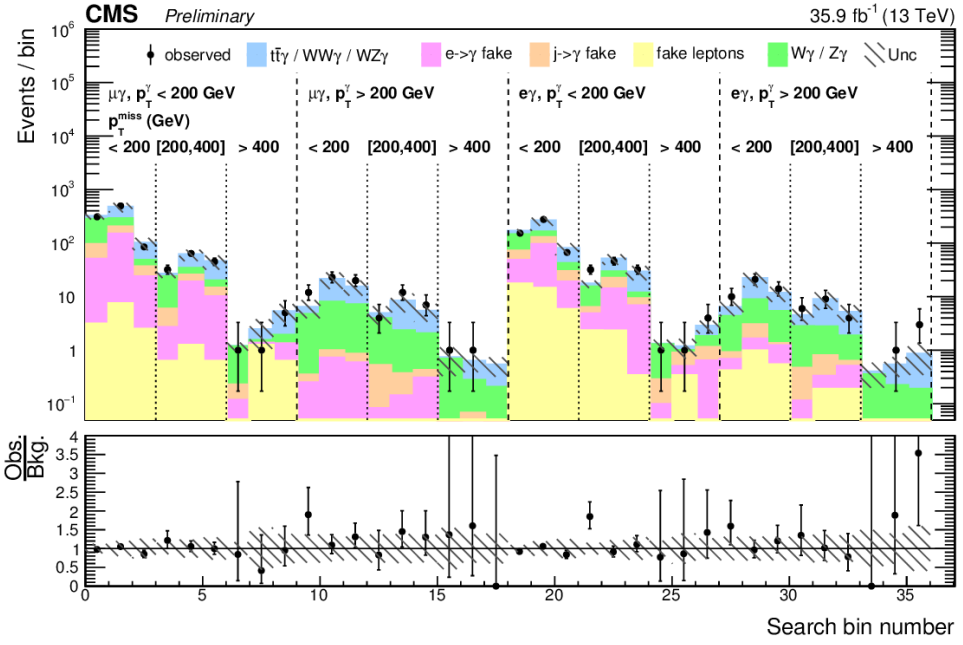
- Special focus on heavy neutralino scenarios and more complex decay chains.

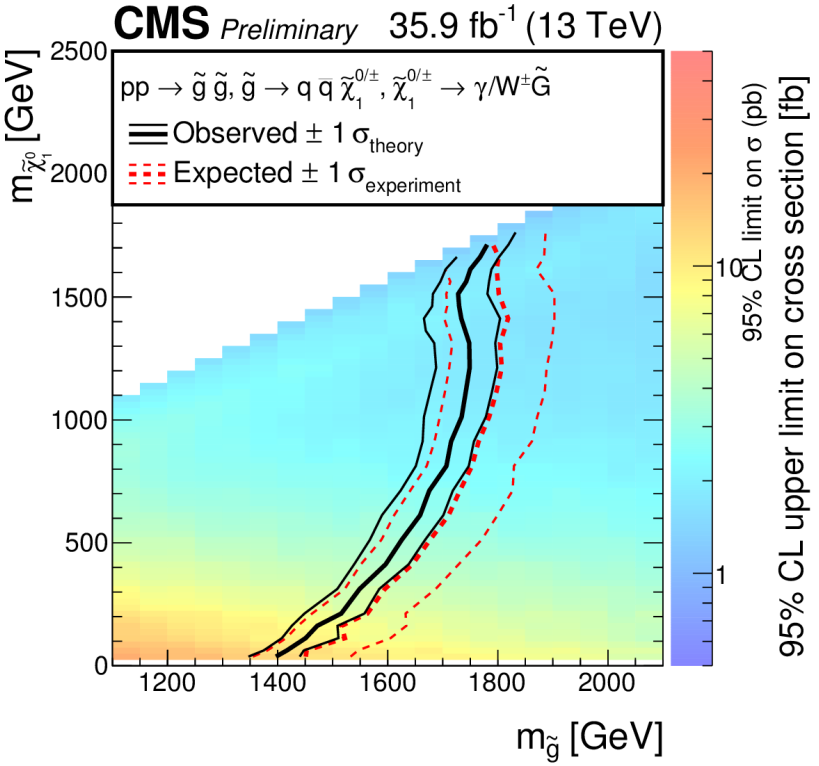
Photon, lepton and p_T^{miss}

NEW

- Target scenarios with neutralino NLSP and gravitino LSP. CMS-PAS-SUS-17-012
- Final states with a photon, an electron or muon and large p_T^{miss}.
- Bin data in p_T^{γ}, p_T^{miss} and H_T.
- Excludes gluinos (squarks) with masses of up to 1700 (1400) GeV.







SUSY – a review of the results from the LHC experiments

Leptons and E_T^{miss}

- Same-flavour opposite-sign dilepton pairs and E_T^{miss} (Z mass or edge).
- Reach compressed scenarios using low-p_T (> 7 GeV) leptons.
- Excess in Run 1 not confirmed.

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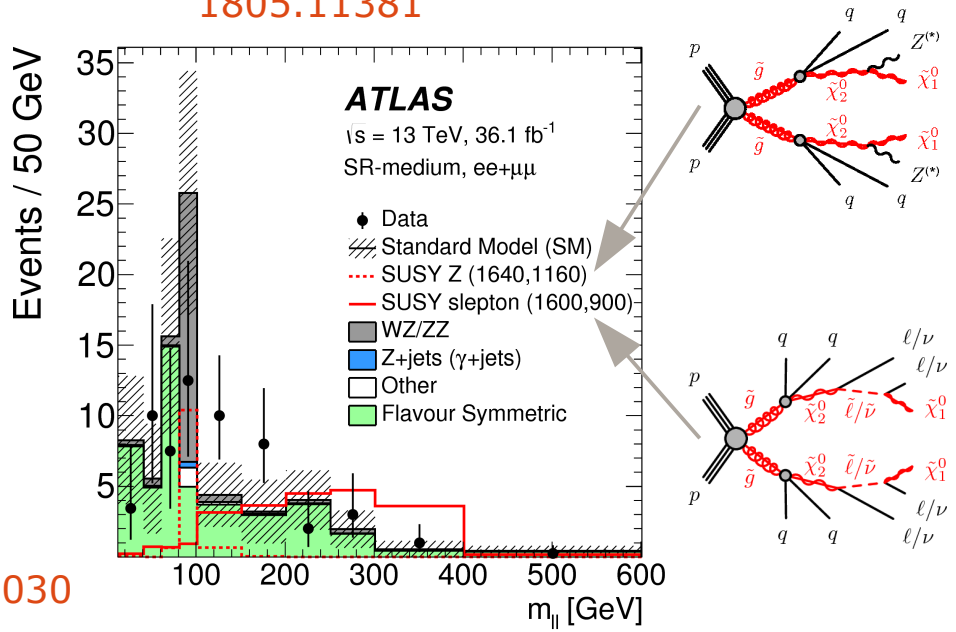
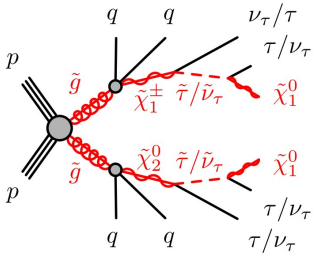


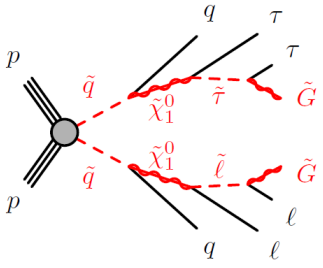
NEW

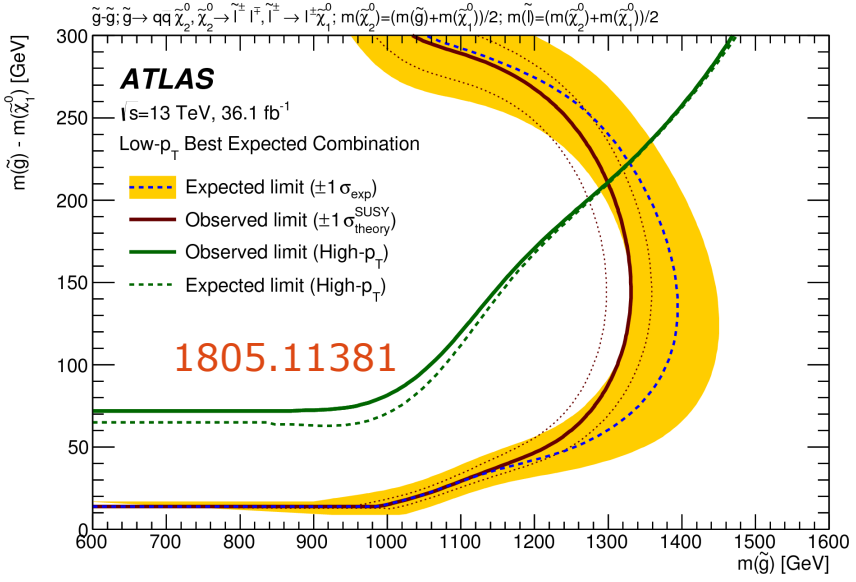
- One or two hadronically decaying tau leptons.

SUSY-2016-030

- Target scenarios with neutralino LSP as well as neutralino NLSP and gravitino LSP.
- Limits on gluino mass reach 2 TeV for light neutralino LSP.

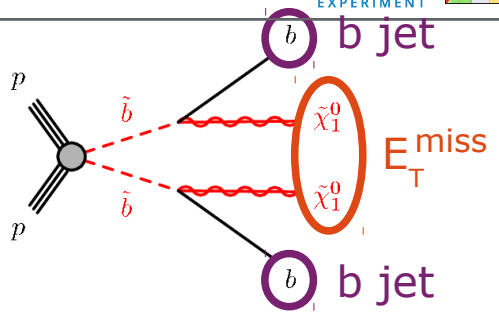






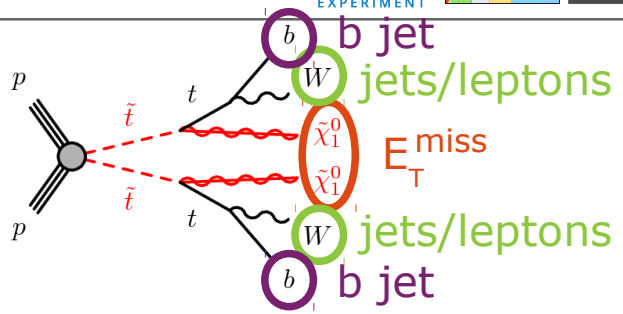
Searches for sbottom and stop

- Light stops needed for natural SUSY.
- Large mixing (heavy top) favours light stop.



Searches for sbottom and stop

- Light stops needed for natural SUSY.
- Large mixing (heavy top) favours light stop.
- 0/1/2 leptons, (b) jets and E_T^{miss}.



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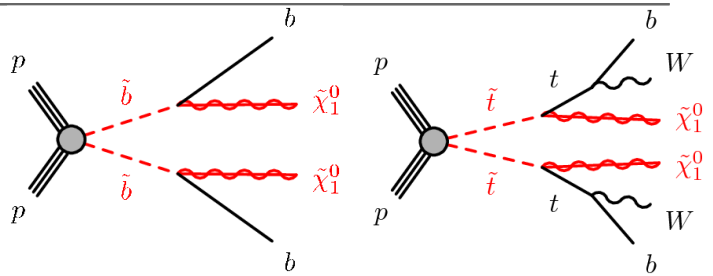
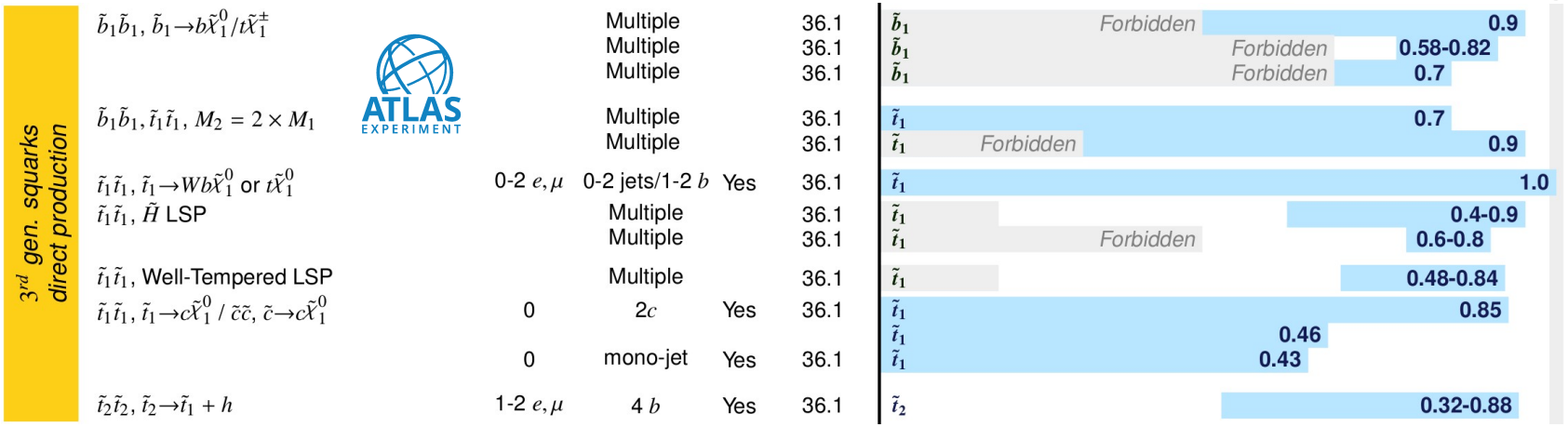
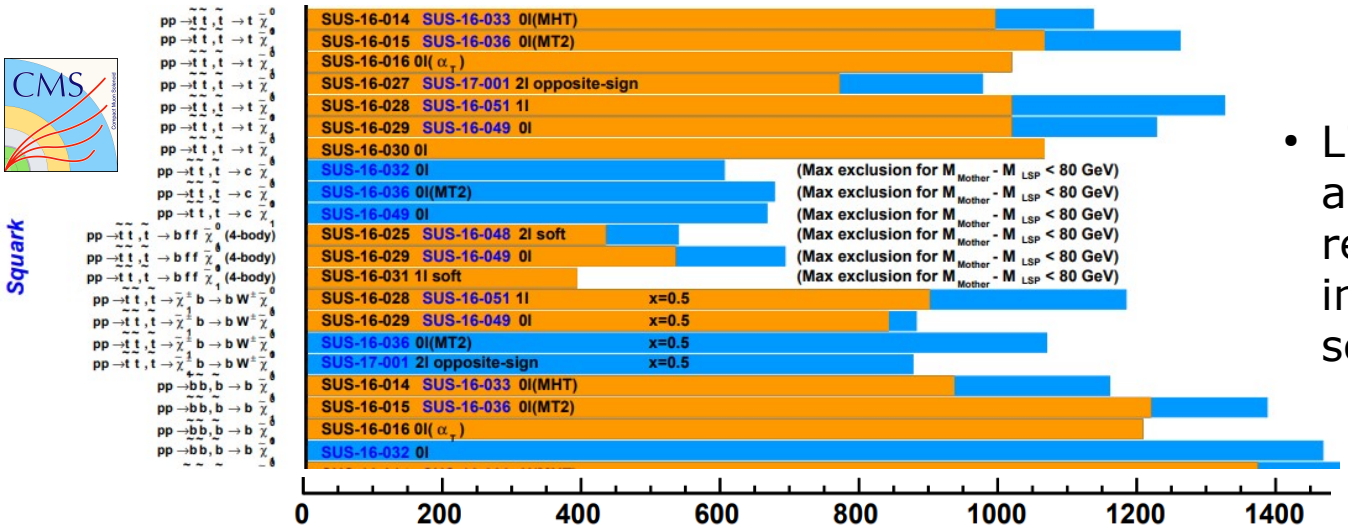
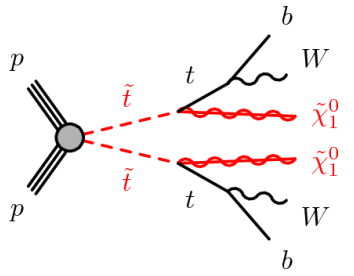




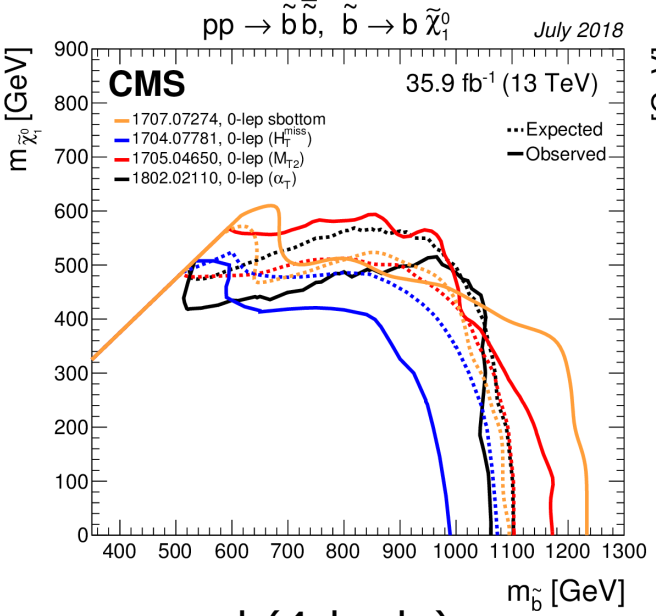


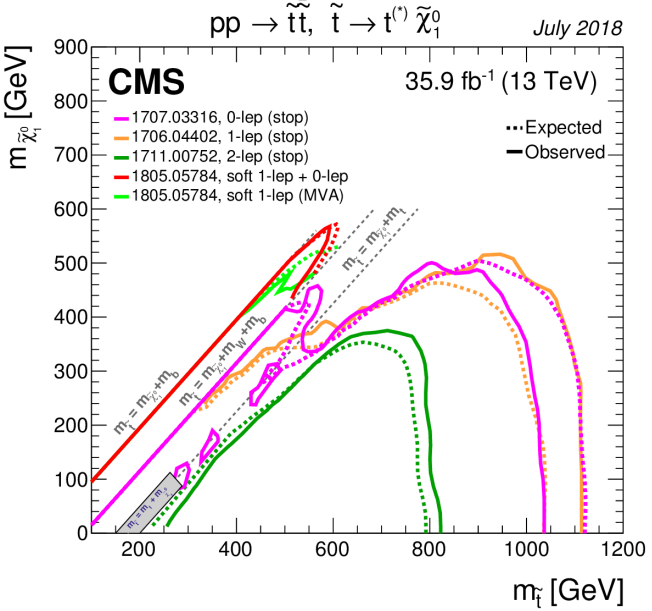
- Limits on sbottom and stop masses reach beyond 1 TeV in most favourable scenarios.

Sbottom and stop production

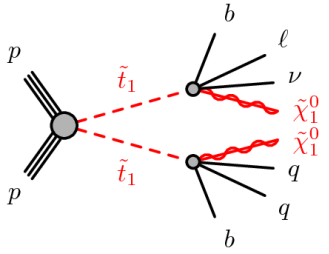


- Weaker limits for larger neutralino masses.

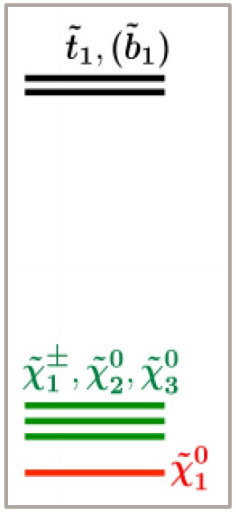




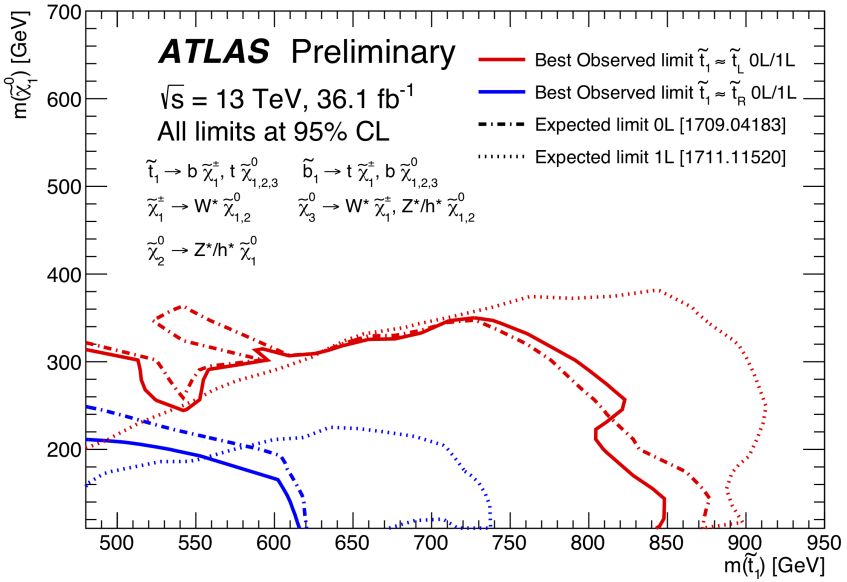
- Special focus on compressed (4-body) final states.



- Weaker limits e.g. in Bino/Higgsino LSP models with compressed mass spectra.



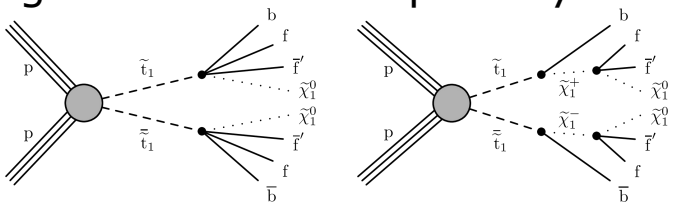
Bino/Higgsino Mix Model: $\tilde{t}_1\tilde{t}_1^*$, $\tilde{b}_1\tilde{b}_1^*$ production, $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0)$ = 20-50 GeV, March 2018



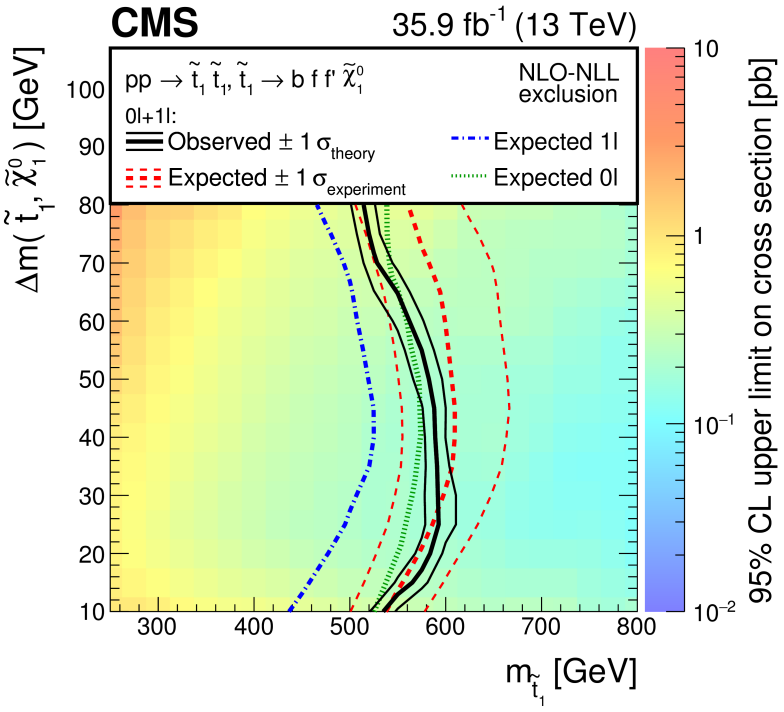
Stop in compressed scenarios

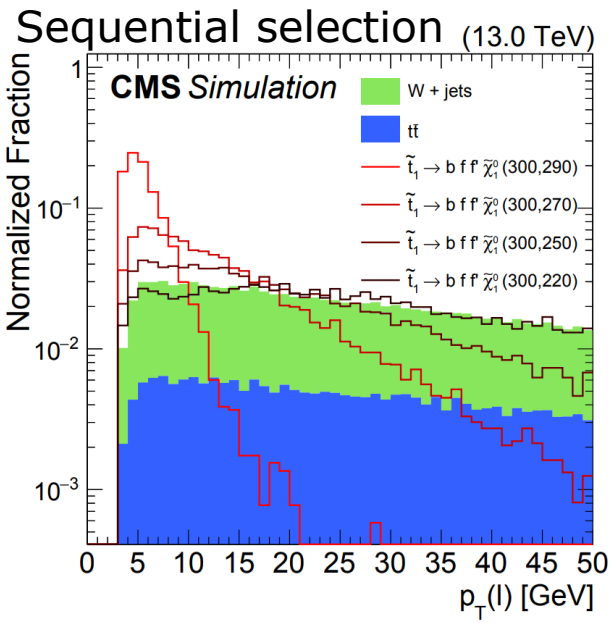
- Target compressed scenarios with 4-body or chargino-mediated stop decays.

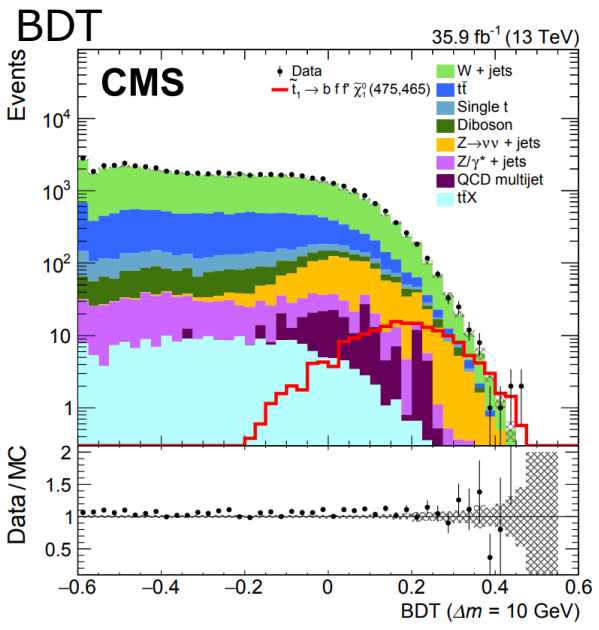
CMS-SUS-17-005



- Require hard (p_T > 100 GeV) ISR jet to boost system and recover some E_T^{miss}.
- Soft leptons (p_T^{μ} > 3.5 GeV and p_T^{e} > 5 GeV).



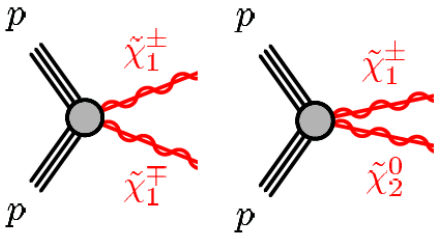




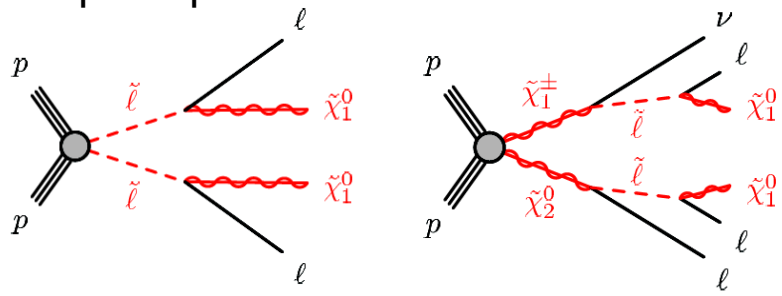
Searches for EW processes

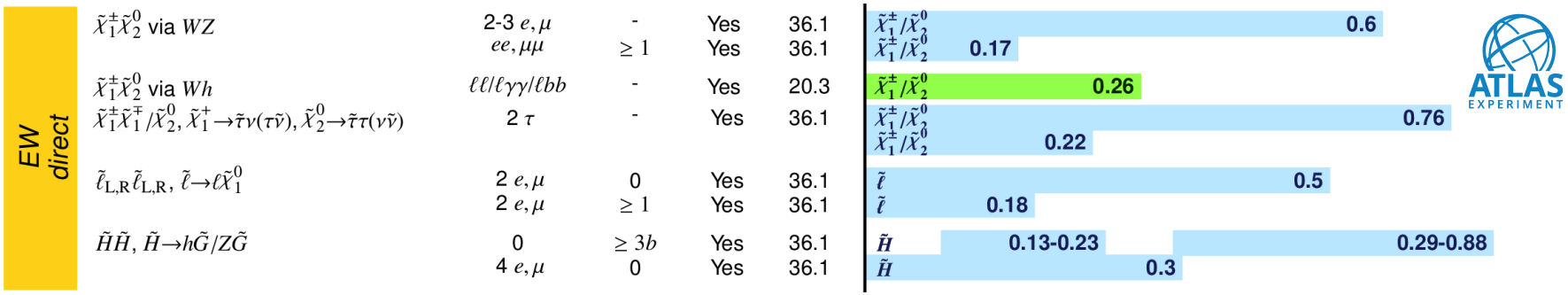
- Low cross sections → particularly relevant if squarks and gluinos are heavy.

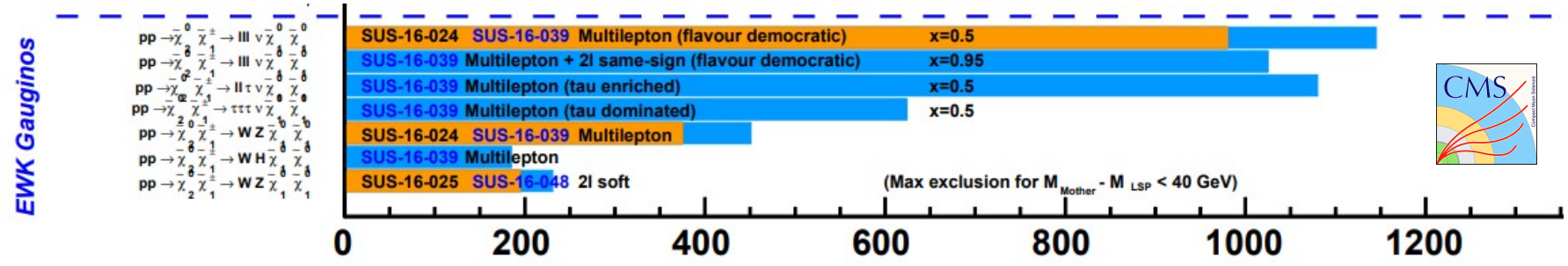
Chargino/neutralino production



Slepton production

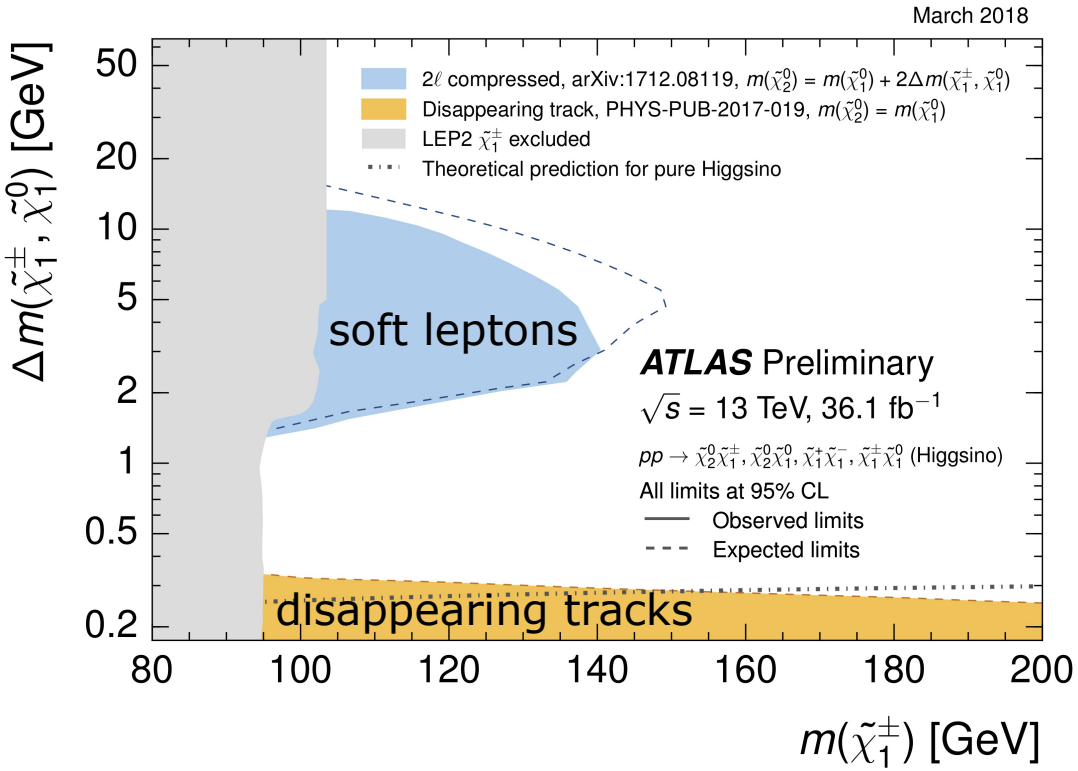




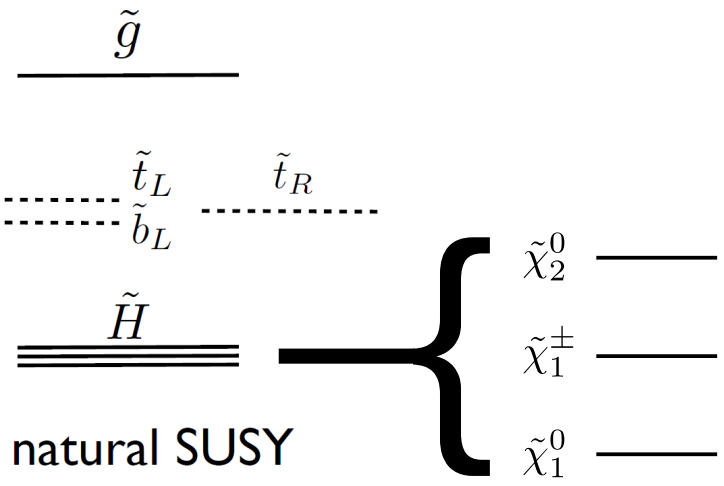


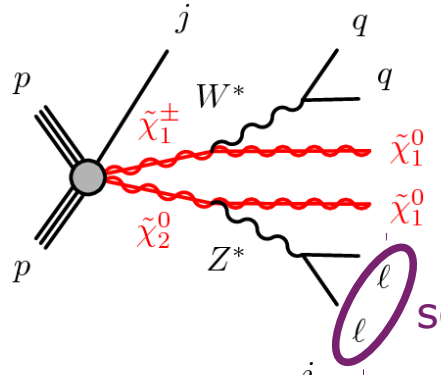
Chargino/neutralino production

- Higgsinos expected to be light in natural SUSY since mass controlled by μ.
- If LSP is purely Higgsino, mass splitting can be as small as 𝒪(100 MeV).



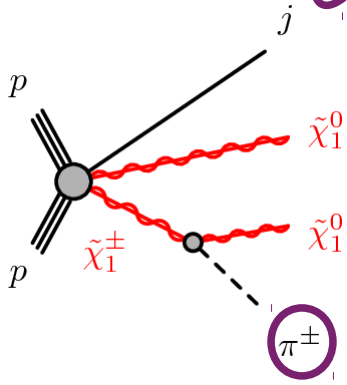
- Probing territory beyond LEP.





1712.08119

soft leptons



1712.02118

soft pion → disappearing chargino track

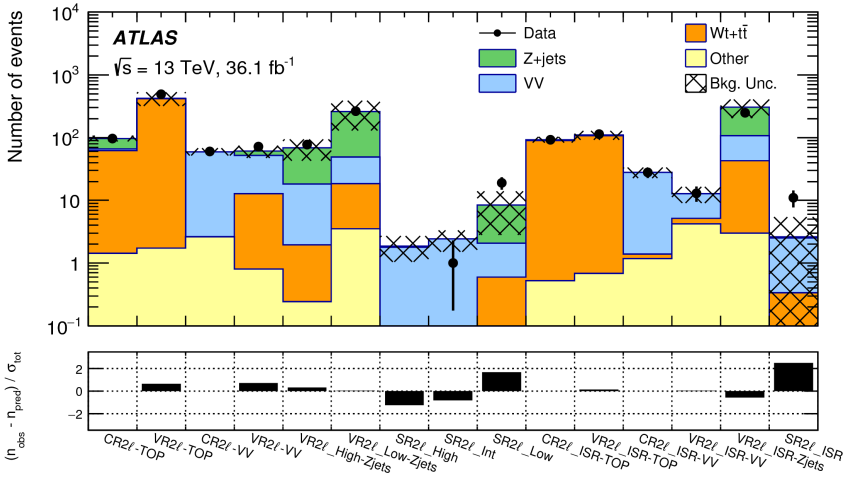
Chargino/neutralino production

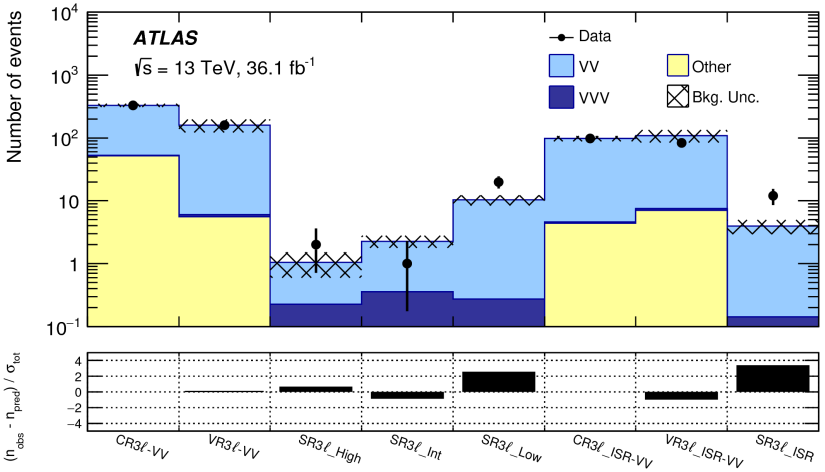
NEW

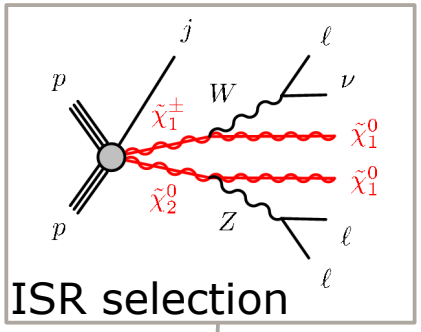
- Search for chargino and neutralino production in final states with two or three charged leptons.

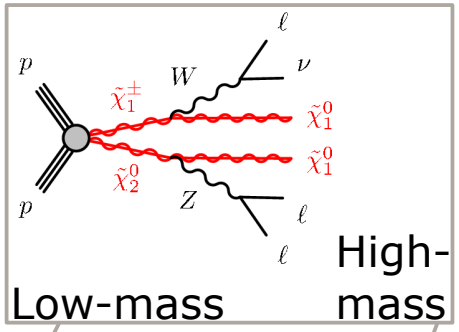
1806.02293

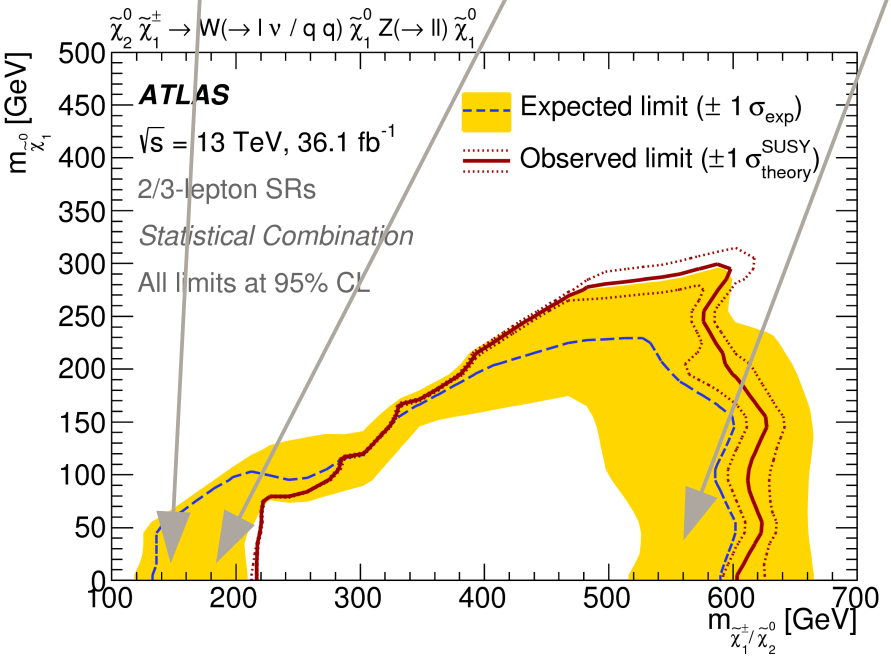
- 3.0 σ excess in 3 lepton ISR selection (compressed scenarios).









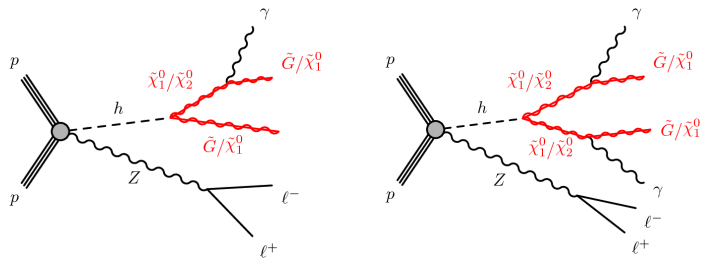


SUSY – a review of the results from the LHC experiments

Chargino/neutralino in h decays

NEW

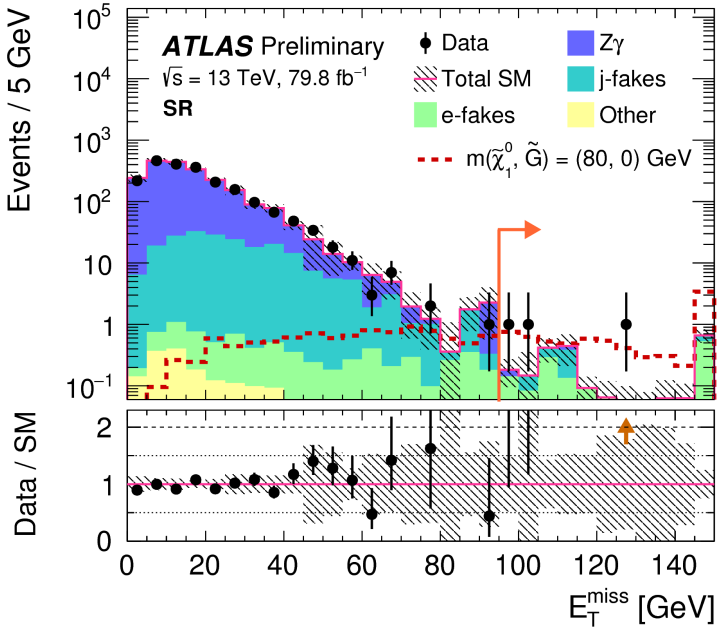
- Search for Zh production with exotic Higgs decays.

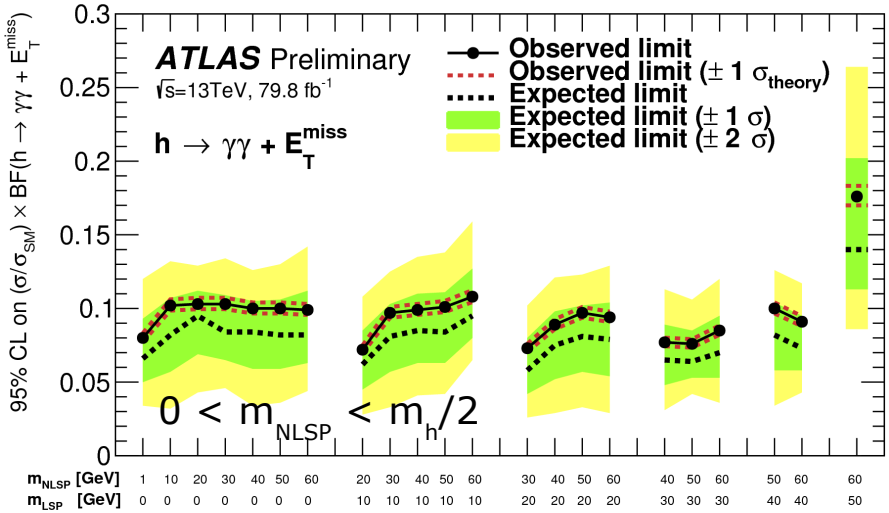


80 fb^{-1}

ATLAS-CONF-2018-19

- One and two photon final state.
- Background mainly reduced with E_T^{miss} cut and variables exploiting the balance of the Z and γ+E_T^{miss}.





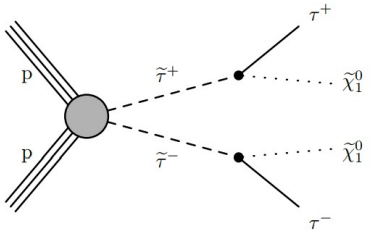
- Upper limits at
  - 11% for massless LSP.
  - 18% for massive LSP and NLSP.

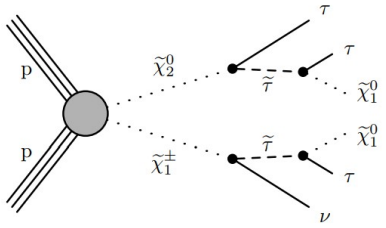
Stau production

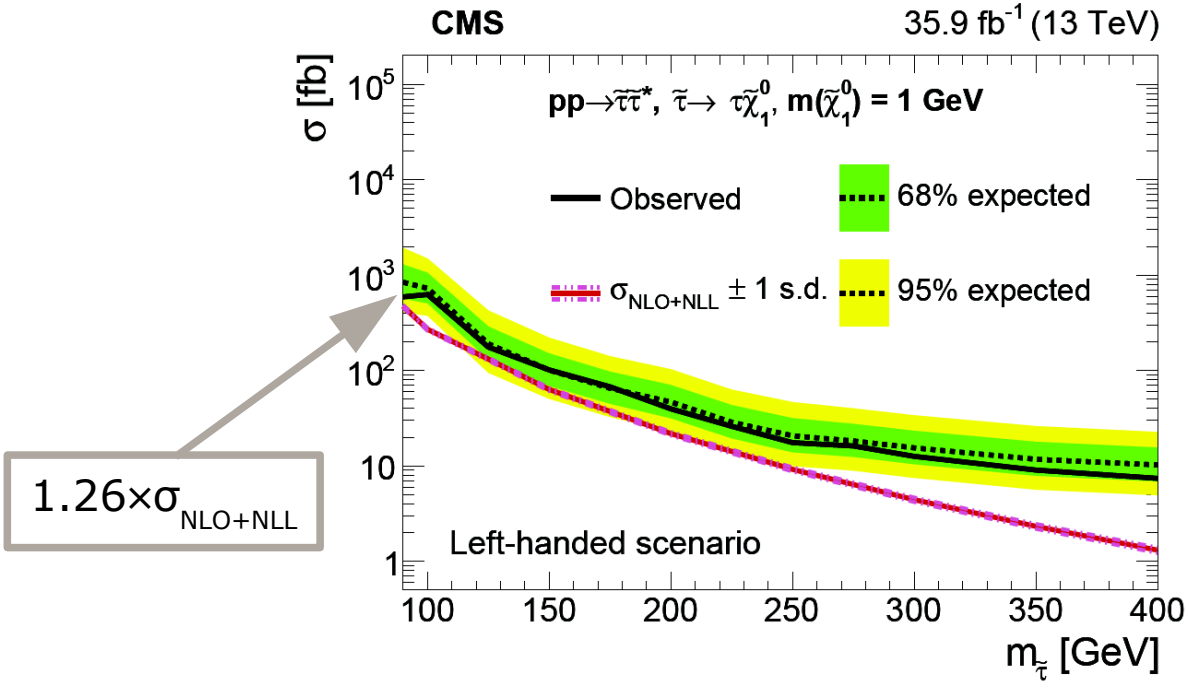
NEW

- Combination of leptonic and hadronic searches for direct stau production and indirect production via decays of charginos and neutralinos.
- Require two tau leptons.
- Stau is expected to be lightest slepton (large mixing).
- Light stau and small Δm can yield right DM relic density via stau-neutralino coannihilation.

1807.02048







- Strongest limits achieved when lightest stau is partner of left-handed tau, approaching sensitivity to SUSY models.

Searches for RPV SUSY and LLPs

- RPC stronger than requirement from proton decay (B-L).
- Many viable RPV scenarios.
- LSP decays → no large E_T^{miss}.
- Can also yield long lifetimes.

strong intermediate weak

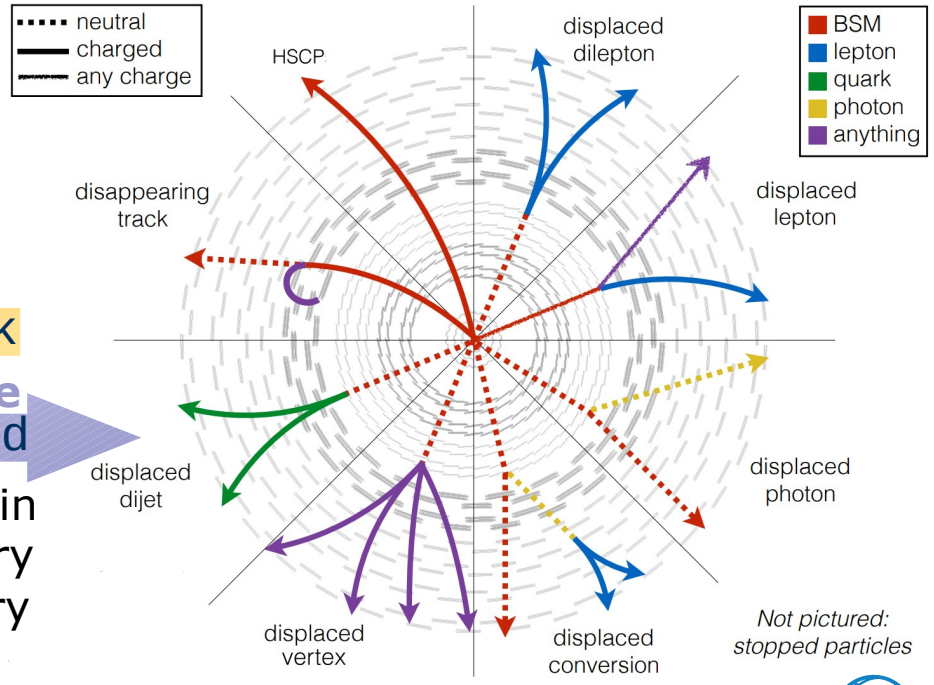
RPV coupling

lifetime

prompt metastable long-lived

- Long-lived particles can also arise in RPC SUSY e.g. from decays via very virtual particles (split SUSY) or very compressed mass spectra.

Image from J. Antonelli, ICHEP2016



Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	36.1	$\tilde{\chi}_1^\pm$ 0.46
						$\tilde{\chi}_1^\pm$ 0.15
	Stable $\tilde{g}$ R-hadron	SMP	-	-	3.2	$\tilde{g}$ 1.6
	Metastable $\tilde{g}$ R-hadron, $\tilde{g}\to qq\tilde{\chi}_1^0$		Multiple		32.8	$\tilde{g}$ [$\tau(\tilde{g})$ =100 ns, 0.2 ns] 1.6 2.4
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	20.3	$\tilde{\chi}_1^0$ 0.44
	$\tilde{g}\tilde{g}$, $\tilde{\chi}_1^0\to eev/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde{g}$ 1.3
RPV	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e\mu/e\tau/\mu\tau$	$e\mu,e\tau,\mu\tau$	-	-	3.2	$\tilde{\nu}_\tau$ 1.9
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp/\tilde{\chi}_2^0\to WW/Z\ell\ell\ell\ell\nu\nu$	4 e,μ	0	Yes	36.1	$\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$ [$\lambda_{i33}\neq 0, \lambda_{12k}\neq 0$] 0.82 1.33
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq\tilde{\chi}_1^0, \tilde{\chi}_1^0\to qqq$	0	4-5 large-R jets	-	36.1	$\tilde{g}$ [m($\tilde{\chi}_1^0$)=200 GeV, 1100 GeV] 1.3 1.9
			Multiple		36.1	$\tilde{g}$ [λ''_{112}=2e-4, 2e-5] 1.05 2.0
	$\tilde{g}\tilde{g}$, $\tilde{g}\to tbs$ / $\tilde{g}\to t\bar{t}\tilde{\chi}_1^0, \tilde{\chi}_1^0\to tbs$		Multiple		36.1	$\tilde{g}$ [λ''_{323}=1, 1e-2] 1.8 2.1
	$\tilde{t}\bar{t}$, $\tilde{t}\to t\tilde{\chi}_1^0, \tilde{\chi}_1^0\to tbs$		Multiple		36.1	$\tilde{g}$ [λ''_{323}=2e-4, 1e-2] 0.55 1.05
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to bs$	0	2 jets + 2 b	-	36.7	$\tilde{t}_1$ [qq, bs] 0.42 0.61
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to b\ell$	2 e,μ	2 b	-	36.1	$\tilde{t}_1$ 0.4-1.45

ATLAS EXPERIMENT

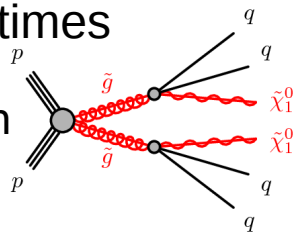
LLP/RPV reinterpretation

- Reinterpret RPC and RPV searches in

$\tilde{g}$ q $\bar{q}$

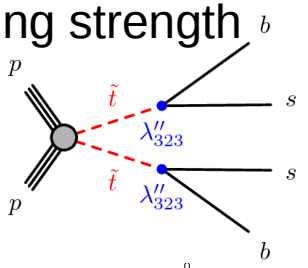
(a) RPC SUSY models with variable R-hadron lifetimes

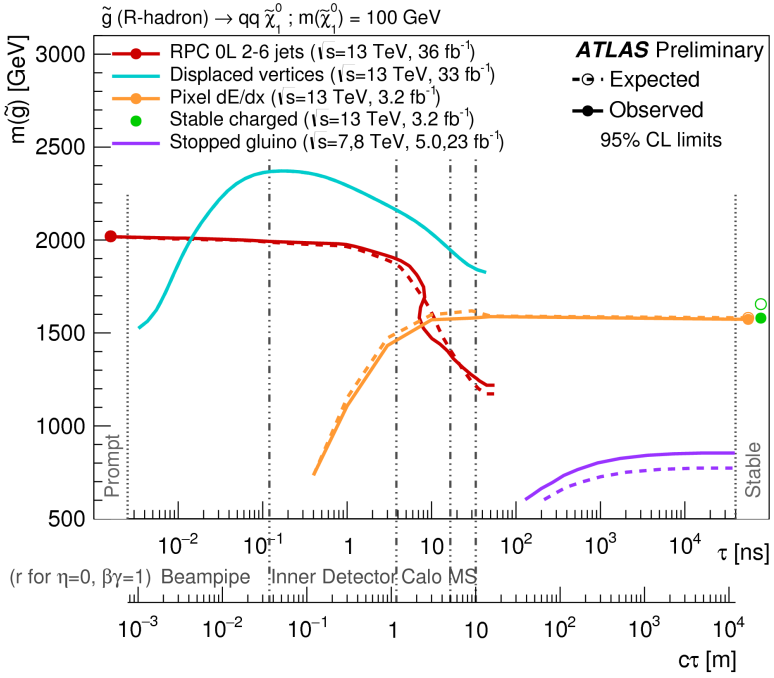
gluino pair production

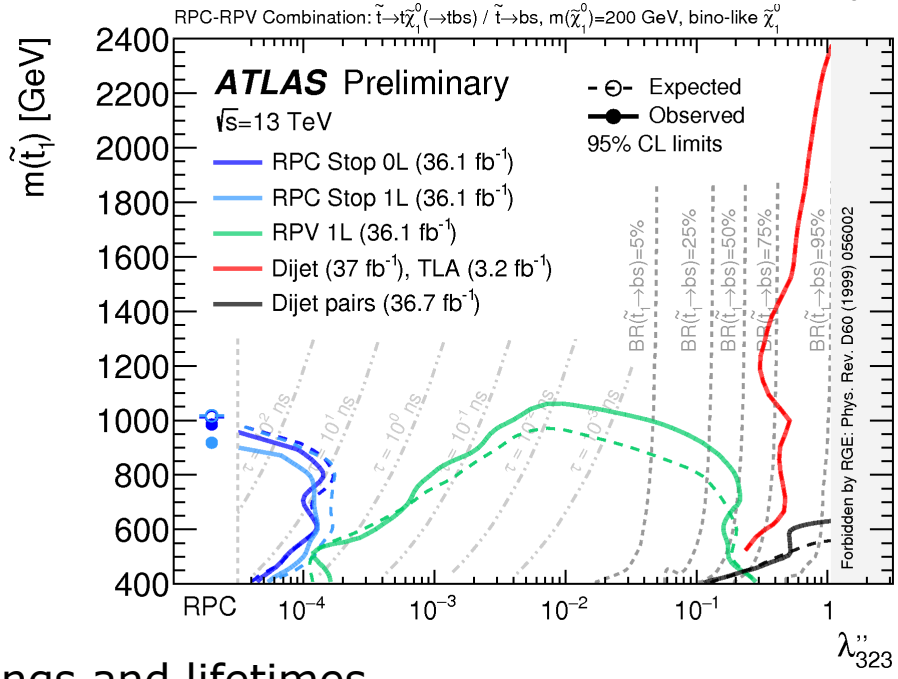


(b) RPV SUSY models with variable RPV-coupling strength

stop pair production







- Analyses cover wide range of couplings and lifetimes.
- Potential improvements in transition regions.

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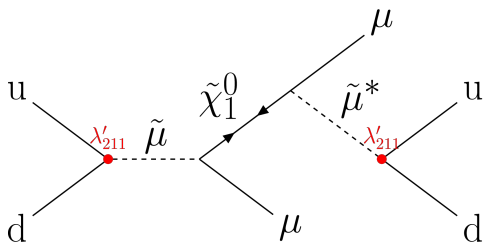
Second generation sleptons

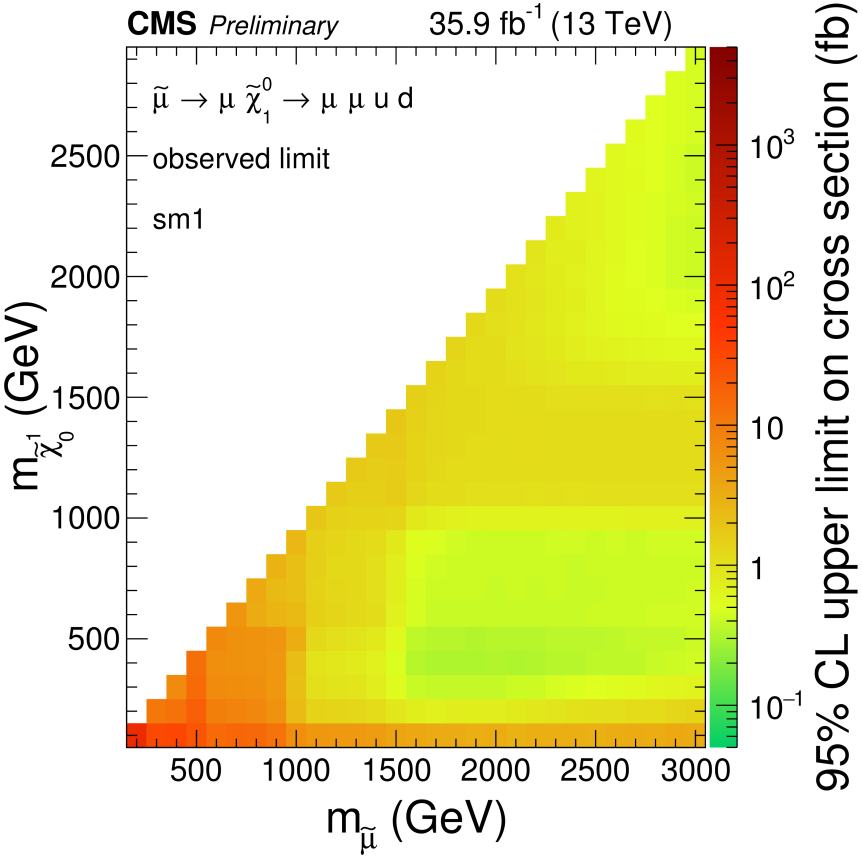
NEW

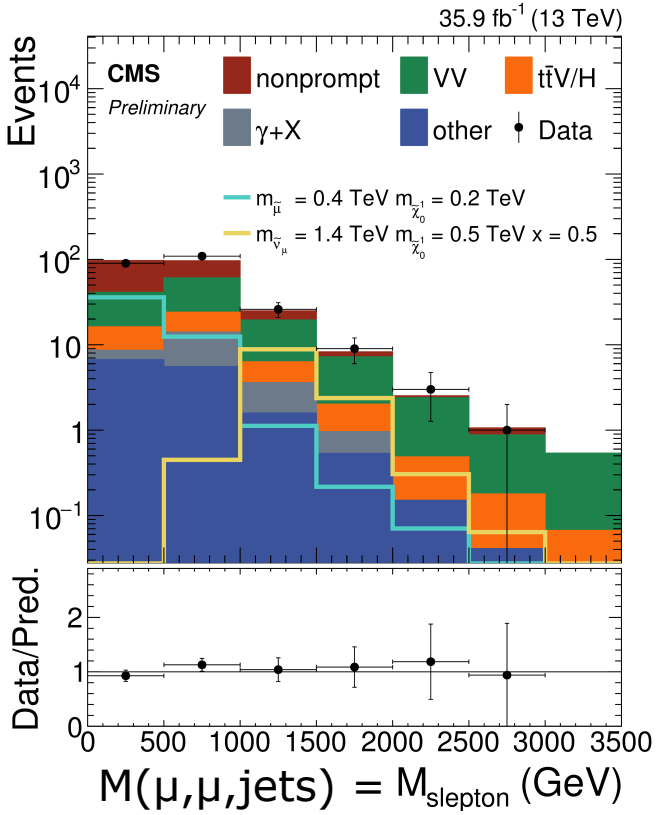
- Search for resonant production of second generation sleptons via RPV coupling.
- Final state with two same-sign muons and at least two jets.

CMS-PAS-SUS-17-008



simplified model 1

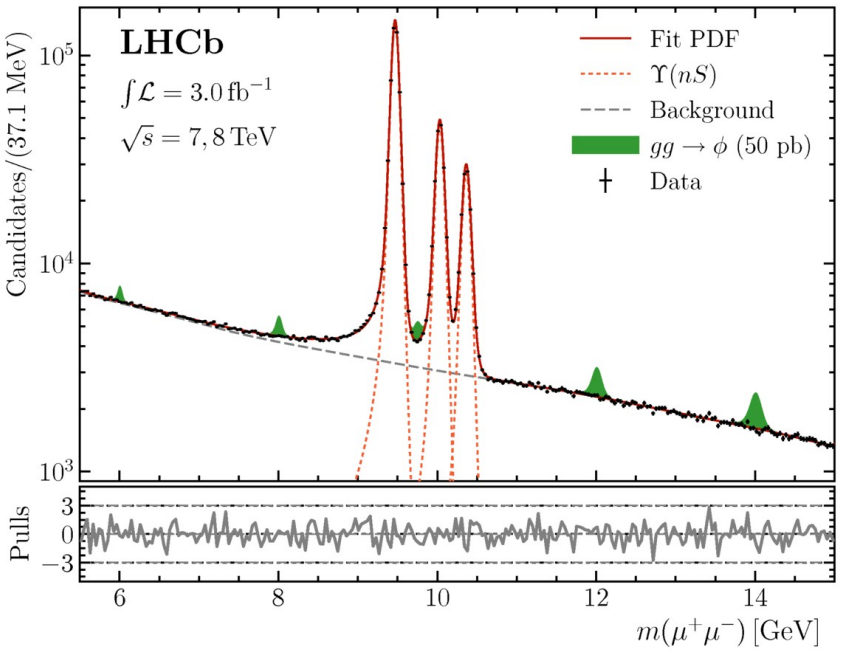


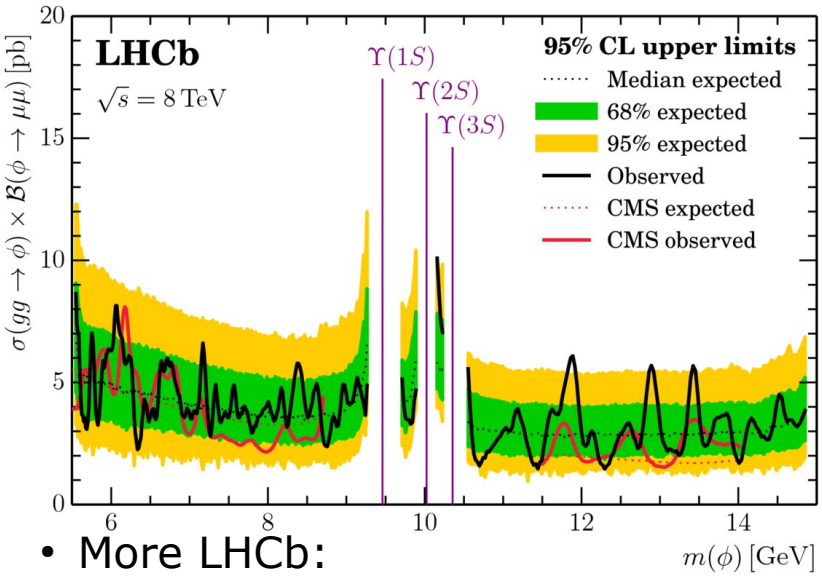


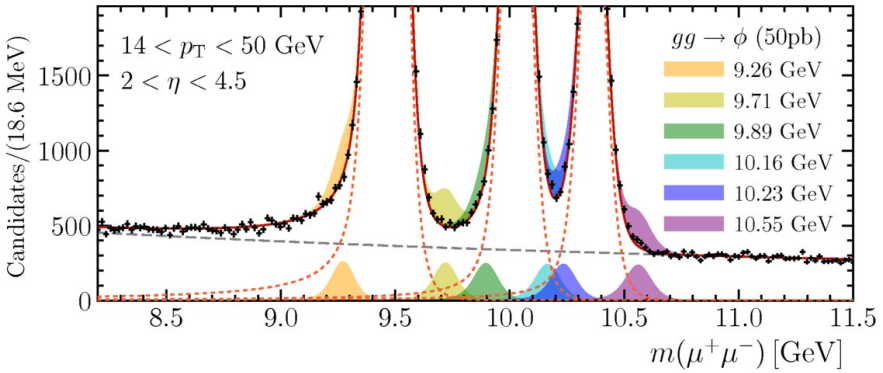
Dimuon resonance in the Υ region

- Search for a scalar resonance decay to a pair of muons.
- Light scalars can appear e.g. in NMSSM scenarios.
- Target difficult region around Υ (5.5-15 GeV).
- Limits comparable to CMS, but extend closer to the Υ mass.

1805.09820







- More LHCb:

  LLPs decaying semileptonically (1612.00945) and to jets (1705.07332)

  Indirect (1703.05747, 1703.02508, 1609.02032, 1712.08606, 1611.07704)

Summary and outlook

- New results at 13 TeV are being produced at a steady pace.
- Completing the program with 36 fb^{-1} (2015+2016) dataset.
- Start to see first results with 80 fb^{-1} dataset (2015+2016+2017).
- Vast and versatile search program for SUSY.
- No evidence for SUSY yet → strong message from the LHC.
- In most favourable / challenging scenarios we exclude
  - gluinos up to $\mathcal{O}(2)$ / $\mathcal{O}(1)$ TeV.
  - squarks up to $\mathcal{O}(1.5)$ / $\mathcal{O}(0.5)$ TeV.
  - stops and sbottoms up to $\mathcal{O}(1)$ / $\mathcal{O}(0.7)$ TeV.
  - EW produced sparticles up to $\mathcal{O}(0.5\text{-}1)$ / $\mathcal{O}(0.1)$ TeV.
- Regions of parameter space still not well covered.
- Next step is to complete the program with the full Run 2 dataset (150 fb^{-1} expected).
- Ensure we cover all signatures within our reach.

Backup

Summary ATLAS

ATLAS SUSY Searches* - 95% CL Lower Limits

July 2018

ATLAS Preliminary

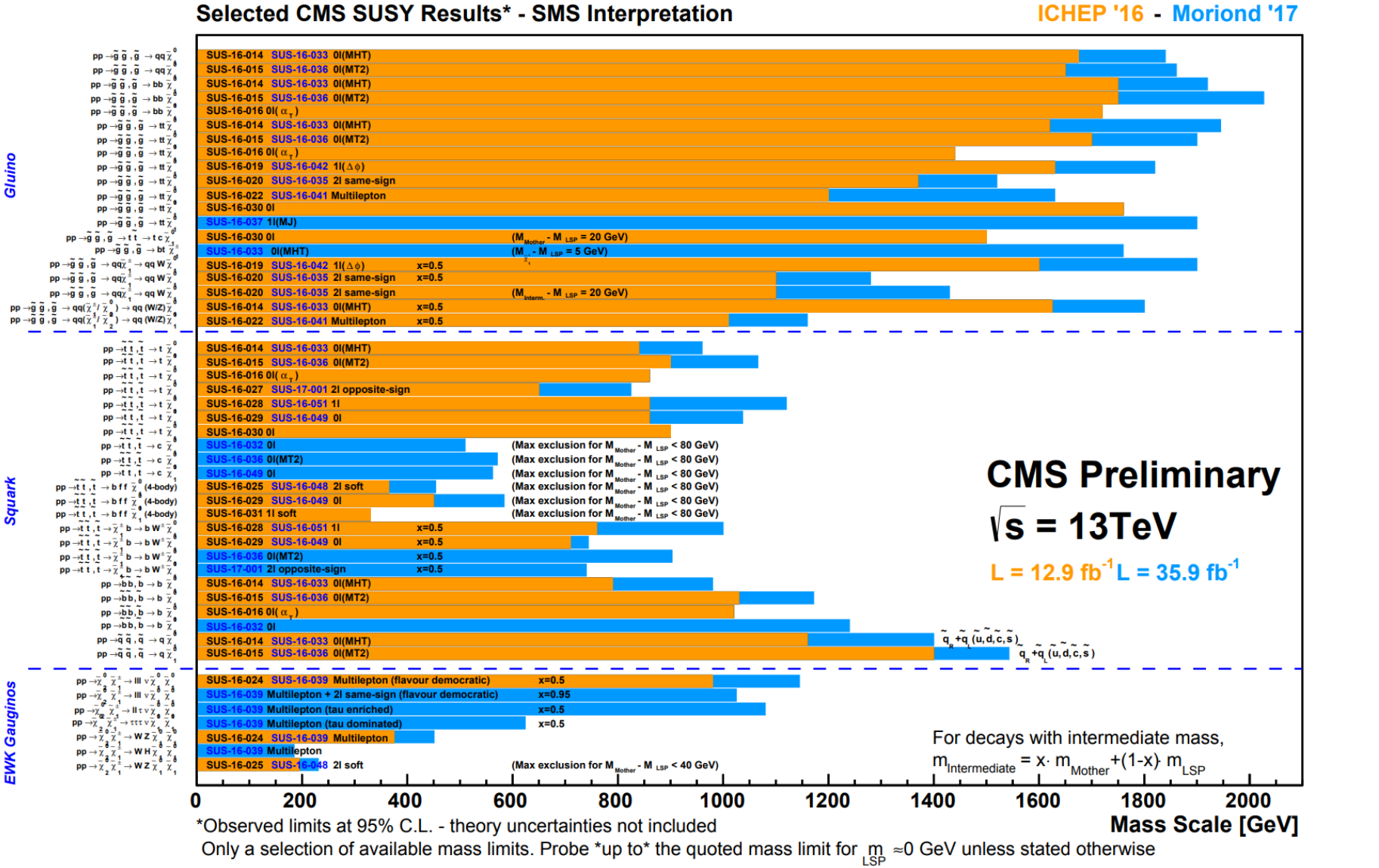
$\sqrt{s}$ = 7, 8, 13 TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt$[fb^{-1}]	Mass limit	$\sqrt{s}$ = 7, 8 TeV	$\sqrt{s}$ = 13 TeV	Reference
Inclusive Searches	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	$\tilde{q}$ [2×, 8× Degen.]	0.9	1.55	m($\tilde{\chi}_1^0$)<100 GeV	1712.02332
		mono-jet	1-3 jets	Yes	36.1	$\tilde{q}$ [1×, 8× Degen.]	0.43	0.71	m($\tilde{q}$)-m($\tilde{\chi}_1^0$)=5 GeV	1711.03301
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	$\tilde{g}$		2.0	m($\tilde{\chi}_1^0$)<200 GeV	1712.02332
						$\tilde{g}$ Forbidden	0.95-1.6		m($\tilde{\chi}_1^0$)=900 GeV	1712.02332
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}(\ell\ell)\tilde{\chi}_1^0$	3 e,μ	4 jets	-	36.1	$\tilde{g}$		1.85	m($\tilde{\chi}_1^0$)<800 GeV	1706.03731
		$ee,\mu\mu$	2 jets	Yes	36.1	$\tilde{g}$	1.2		m($\tilde{g}$)-m($\tilde{\chi}_1^0$)=50 GeV	1805.11381
	$\tilde{g}\tilde{g}, \tilde{g}\to qqWZ\tilde{\chi}_1^0$	0	7-11 jets	Yes	36.1	$\tilde{g}$		1.8	m($\tilde{\chi}_1^0$) <400 GeV	1708.02794
		3 e,μ	4 jets	-	36.1	$\tilde{g}$	0.98		m($\tilde{g}$)-m($\tilde{\chi}_1^0$)=200 GeV	1706.03731
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	36.1	$\tilde{g}$		2.0	m($\tilde{\chi}_1^0$)<200 GeV	1711.01901
		3 e,μ	4 jets	-	36.1	$\tilde{g}$	1.25		m($\tilde{g}$)-m($\tilde{\chi}_1^0$)=300 GeV	1706.03731
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}_1^0/t\tilde{\chi}_1^\pm$		Multiple		36.1	$\tilde{b}_1$ Forbidden	0.9		m($\tilde{\chi}_1^0$)=300 GeV, BR($b\tilde{\chi}_1^0$)=1	1708.09266, 1711.03301
			Multiple		36.1	$\tilde{b}_1$ Forbidden	0.58-0.82		m($\tilde{\chi}_1^0$)=300 GeV, BR($b\tilde{\chi}_1^0$)=BR($t\tilde{\chi}_1^\pm$)=0.5	1708.09266
			Multiple		36.1	$\tilde{b}_1$ Forbidden	0.7		m($\tilde{\chi}_1^0$)=200 GeV, m($\tilde{\chi}_1^\pm$)=300 GeV, BR($t\tilde{\chi}_1^\pm$)=1	1706.03731
	$\tilde{b}_1\tilde{b}_1, \tilde{t}_1\tilde{t}_1, M_2 = 2\times M_1$		Multiple		36.1	$\tilde{t}_1$	0.7		m($\tilde{\chi}_1^0$)=60 GeV	1709.04183, 1711.11520, 1708.03247
			Multiple		36.1	$\tilde{t}_1$ Forbidden	0.9		m($\tilde{\chi}_1^0$)=200 GeV	1709.04183, 1711.11520, 1708.03247
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to Wb\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$	0-2 e,μ	0-2 jets/1-2 b	Yes	36.1	$\tilde{t}_1$	1.0		m($\tilde{\chi}_1^0$)=1 GeV	1506.08616, 1709.04183, 1711.11520
	$\tilde{t}_1\tilde{t}_1$, $\tilde{H}$ LSP		Multiple		36.1	$\tilde{t}_1$	0.4-0.9		m($\tilde{\chi}_1^0$)=150 GeV, m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)=5 GeV, $\tilde{t}_1 \approx \tilde{t}_L$	1709.04183, 1711.11520
			Multiple		36.1	$\tilde{t}_1$ Forbidden	0.6-0.8		m($\tilde{\chi}_1^0$)=300 GeV, m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)=5 GeV, $\tilde{t}_1 \approx \tilde{t}_L$	1709.04183, 1711.11520
	$\tilde{t}_1\tilde{t}_1$, Well-Tempered LSP		Multiple		36.1	$\tilde{t}_1$	0.48-0.84		m($\tilde{\chi}_1^0$)=150 GeV, m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)=5 GeV, $\tilde{t}_1 \approx \tilde{t}_L$	1709.04183, 1711.11520
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$ / $\tilde{c}\tilde{c}, \tilde{c}\to c\tilde{\chi}_1^0$	0	2c	Yes	36.1	$\tilde{t}_1$	0.85		m($\tilde{\chi}_1^0$)=0 GeV	1805.01649
						$\tilde{t}_1$	0.46		m($\tilde{t}_1$,$\tilde{\chi}_1^0$)=50 GeV	1805.01649
		0	mono-jet	Yes	36.1	$\tilde{t}_1$	0.43		m($\tilde{t}_1$,$\tilde{c}$)-m($\tilde{\chi}_1^0$)=5 GeV	1711.03301
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1 + h$	1-2 e,μ	4 b	Yes	36.1	$\tilde{t}_2$	0.32-0.88		m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{t}_1$)-m($\tilde{\chi}_1^0$)= 180 GeV	1706.03986
EW direct	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ via WZ	2-3 e,μ	-	Yes	36.1	$\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$	0.6		m($\tilde{\chi}_1^0$)=0	1403.5294, 1806.02293
		$ee,\mu\mu$	≥ 1	Yes	36.1	$\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$	0.17		m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)=10 GeV	1712.08119
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ via Wh	$\ell\ell/\ell\gamma\gamma/\ell bb$	-	Yes	20.3	$\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$	0.26		m($\tilde{\chi}_1^0$)=0	1501.07110
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp/\tilde{\chi}_2^0, \tilde{\chi}_1^\pm\to\tilde{\tau}\nu(\tau\tilde{\nu}), \tilde{\chi}_2^0\to\tilde{\tau}\tau(\nu\tilde{\nu})$	2 τ	-	Yes	36.1	$\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$	0.76		m($\tilde{\chi}_1^0$)=0, m($\tilde{\tau}$, $\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	1708.07875
						$\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$	0.22		m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)=100 GeV, m($\tilde{\tau}$, $\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	1708.07875
	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e,μ	0	Yes	36.1	$\tilde{\ell}$	0.5		m($\tilde{\chi}_1^0$)=0	1803.02762
		2 e,μ	≥ 1	Yes	36.1	$\tilde{\ell}$	0.18		m($\tilde{\ell}$)-m($\tilde{\chi}_1^0$)=5 GeV	1712.08119
	$\tilde{H}\tilde{H}, \tilde{H}\to h\tilde{G}/Z\tilde{G}$	0	≥ 3b	Yes	36.1	$\tilde{H}$	0.13-0.23	0.29-0.88	BR($\tilde{\chi}_1^0\to h\tilde{G}$)=1	1806.04030
		4 e,μ	0	Yes	36.1	$\tilde{H}$	0.3		BR($\tilde{\chi}_1^0\to Z\tilde{G}$)=1	1804.03602
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	36.1	$\tilde{\chi}_1^\pm$	0.46		Pure Wino	1712.02118
						$\tilde{\chi}_1^\pm$	0.15		Pure Higgsino	ATL-PHYS-PUB-2017-019
	Stable $\tilde{g}$ R-hadron	SMP	-	-	3.2	$\tilde{g}$		1.6		1606.05129
	Metastable $\tilde{g}$ R-hadron, $\tilde{g}\to qq\tilde{\chi}_1^0$		Multiple		32.8	$\tilde{g}$ [$\tau(\tilde{g})$ =100 ns, 0.2 ns]		1.6 2.4	m($\tilde{\chi}_1^0$)=100 GeV	1710.04901, 1604.04520
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	20.3	$\tilde{\chi}_1^0$	0.44		1<$\tau(\tilde{\chi}_1^0)$<3 ns, SPS8 model	1409.5542
	$\tilde{g}\tilde{g}, \tilde{\chi}_1^0\to ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde{g}$		1.3	6 <$c\tau(\tilde{\chi}_1^0)$< 1000 mm, m($\tilde{\chi}_1^0$)=1 TeV	1504.05162
RPV	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e\mu/e\tau/\mu\tau$	$e\mu,e\tau,\mu\tau$	-	-	3.2	$\tilde{\nu}_\tau$		1.9	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07	1607.08079
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp/\tilde{\chi}_2^0\to WW/Z\ell\ell\ell\ell\nu\nu$	4 e,μ	0	Yes	36.1	$\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$ [$\lambda_{133}\neq 0, \lambda_{12k}\neq 0$]	0.82	1.33	m($\tilde{\chi}_1^0$)=100 GeV	1804.03602
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^0, \tilde{\chi}_1^0\to qqq$	0	4-5 large-R jets	-	36.1	$\tilde{g}$ [m($\tilde{\chi}_1^0$)=200 GeV, 1100 GeV]	1.3	1.9	Large λ''_{112}	1804.03568
			Multiple		36.1	$\tilde{g}$ [λ''_{112}=2e-4, 2e-5]	1.05	2.0	m($\tilde{\chi}_1^0$)=200 GeV, bino-like	ATLAS-CONF-2018-003
	$\tilde{g}\tilde{g}, \tilde{g}\to tbs$ / $\tilde{g}\to t\bar{t}\tilde{\chi}_1^0, \tilde{\chi}_1^0\to tbs$		Multiple		36.1	$\tilde{g}$ [λ''_{323}=1, 1e-2]		1.8 2.1	m($\tilde{\chi}_1^0$)=200 GeV, bino-like	ATLAS-CONF-2018-003
	$\tilde{t}\tilde{t}, \tilde{t}\to t\tilde{\chi}_1^0, \tilde{\chi}_1^0\to tbs$		Multiple		36.1	$\tilde{g}$ [λ''_{323}=2e-4, 1e-2]	0.55	1.05	m($\tilde{\chi}_1^0$)=200 GeV, bino-like	ATLAS-CONF-2018-003
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to bs$	0	2 jets + 2 b	-	36.7	$\tilde{t}_1$ [qq, bs]	0.42	0.61		1710.07171
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\ell$	2 e,μ	2 b	-	36.1	$\tilde{t}_1$		0.4-1.45	BR($\tilde{t}_1\to be/b\mu$)>20%	1710.05544

10^{-1} 1 **Mass scale [TeV]**

**Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.*

Summary CMS



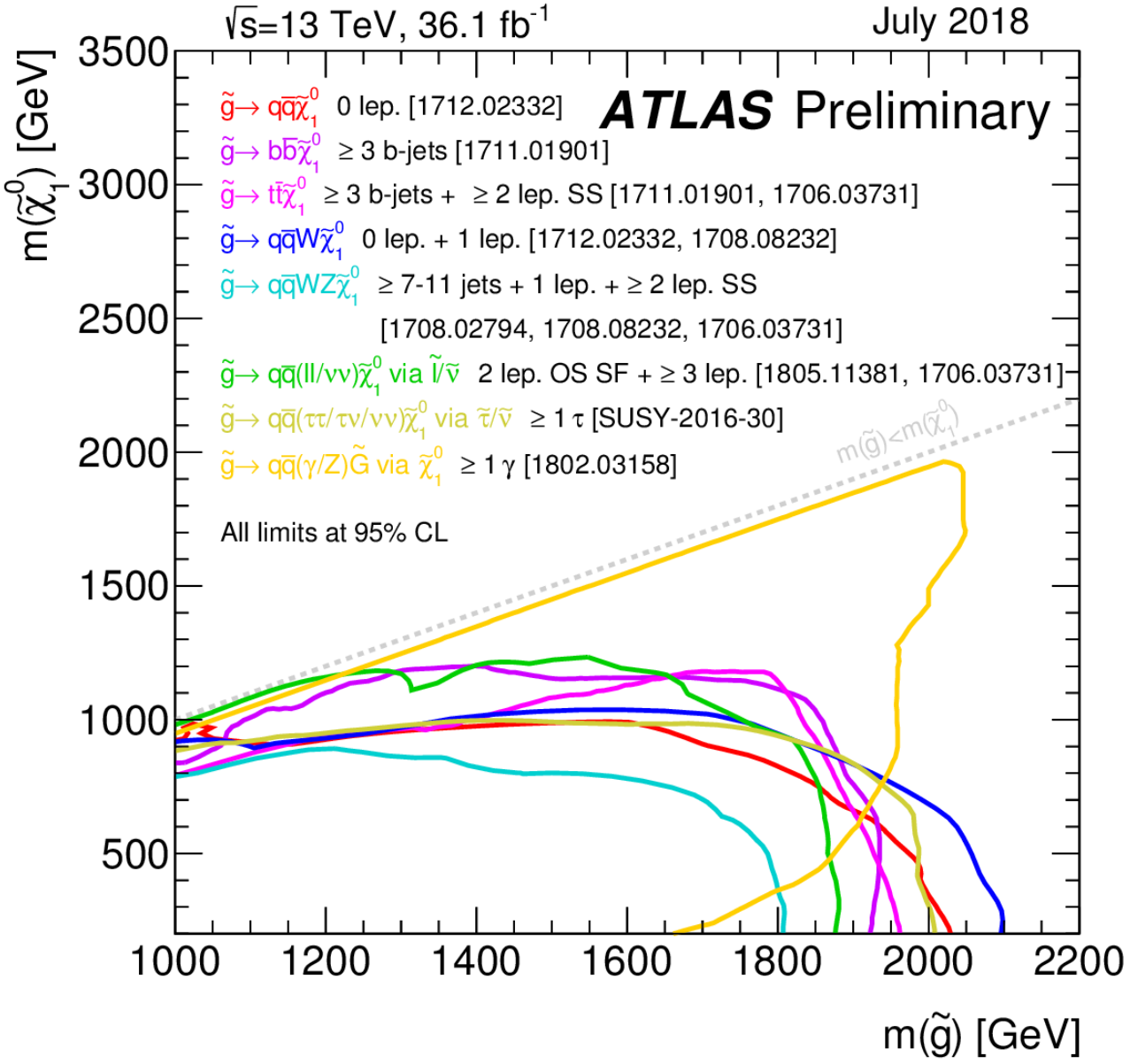
*Observed limits at 95% C.L. - theory uncertainties not included

Only a selection of available mass limits. Probe *up to* the quoted mass limit for $m_{LSP} \approx 0$ GeV unless stated otherwise

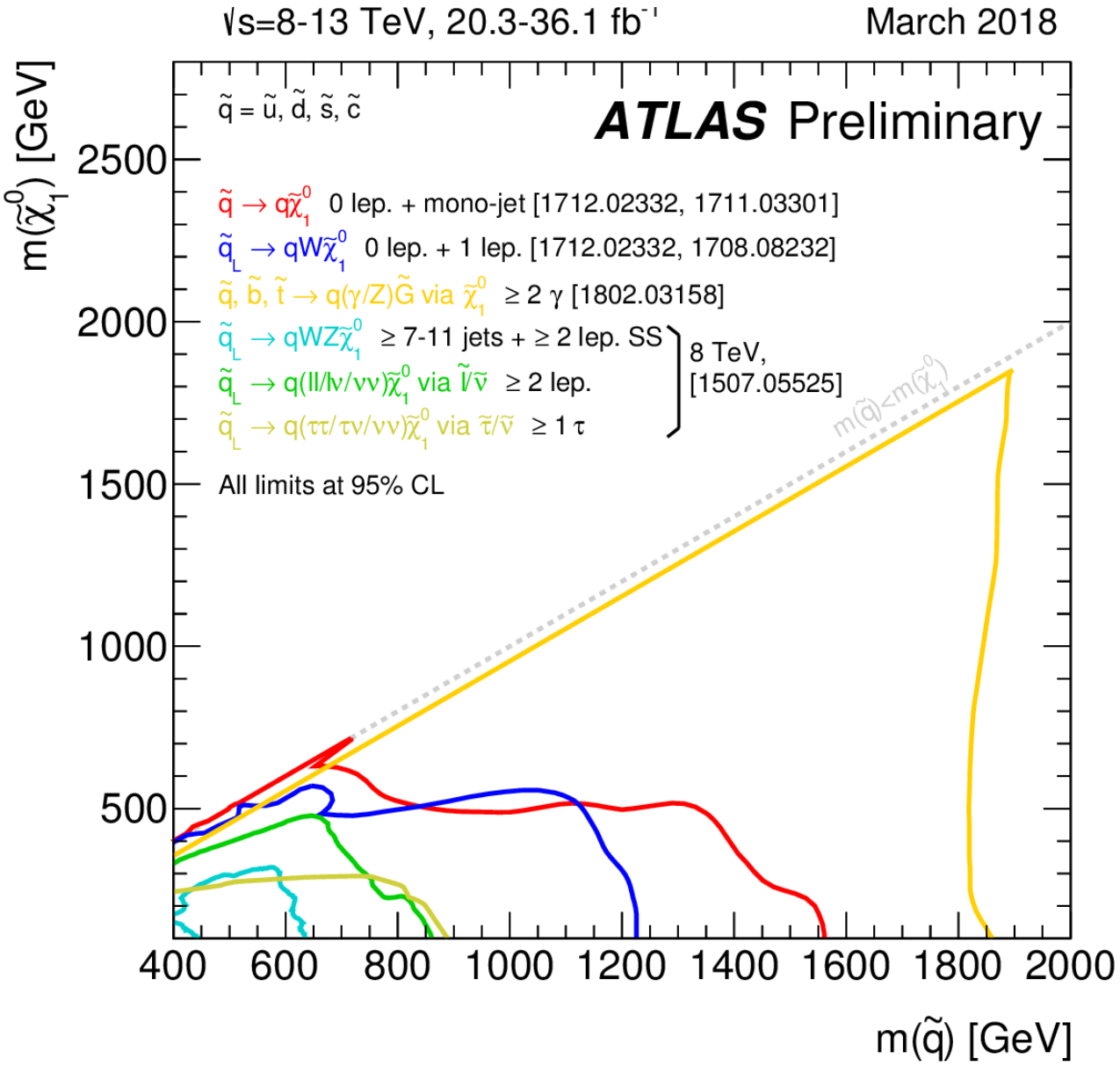
Estimates of future LHC sensitivity at 95% CL

	~35 ifb 13 TeV	Run2 (140 ifb) 13 TeV	Run3 (~300 ifb) 13/14 TeV	HL-LHC (3000 ifb) 13/14 TeV
gluino	2 TeV (prel.)	~2.3 TeV (my est.)	2.4 TeV (upgrade), 2.4/2.6 TeV (my est.)	2.9 TeV (upgrade), 2.9/3.1 TeV (my est.)
squark (x8) decoupled	1.5 TeV (prel.)	1.75 TeV (my est.)	1.9/2.0 TeV (my est.)	2.3/2.4 TeV (my est.)
stop	1-1.1 TeV (prel.)	~1.3 TeV (my est.)	1.4x TeV (my est.)	1.85 TeV (my est.)
wino C1N2 to WZ bino	~600 GeV (prel.)	670 GeV (my est.)	780 GeV (my est.), 750 GeV (CMS est.), 840 GeV (upgrade)	1150 GeV (my est.), 1.2 TeV (CMS est.), 1.1 TeV (upgrade)
wino C1C1 to WW bino	225 GeV (based on x-section ratio for 180 GeV Run1)	~320 GeV (my est.)	380-400 GeV (my est.)	~630 GeV (my est.)
wino LSP, pixel-trklet	420 GeV (prel.)	580 GeV (my est.)	680 GeV (my est.)	1030 GeV (my est.)
higgsino LSP, DM=3-20 GeV	150 GeV	200-250 GeV (my est.)	250-300 GeV (my est.)	450-500 GeV (my est.)
higgsino LSP, DM=0.3-3 GeV	?			
slepton (sel, smu)	~500 GeV (prel.)	670 GeV (my est.)		
stau	?			700 GeV (upgrade)

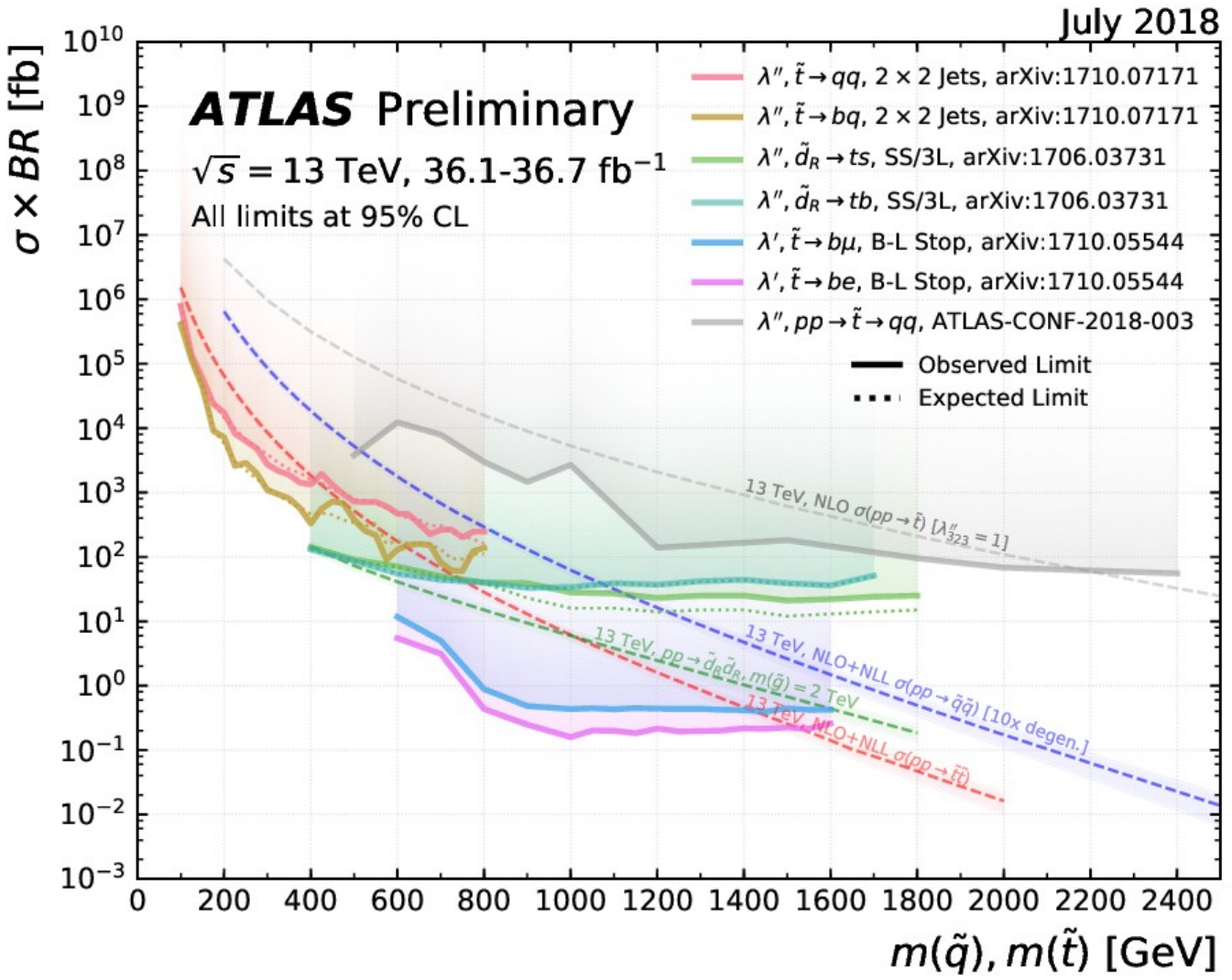
ATLAS summary gluino production



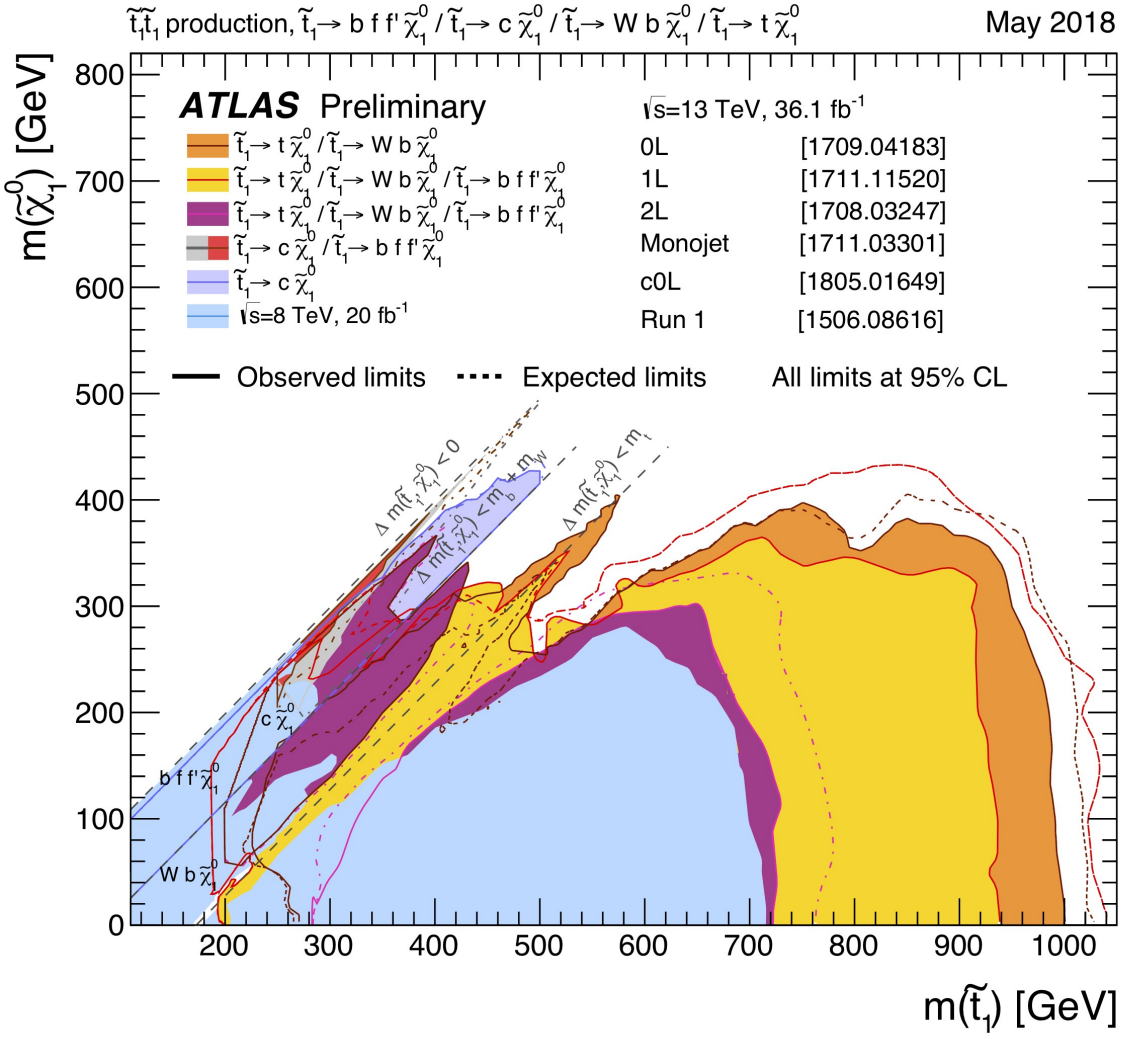
ATLAS summary squark production



ATLAS summary RPV-squark prod.

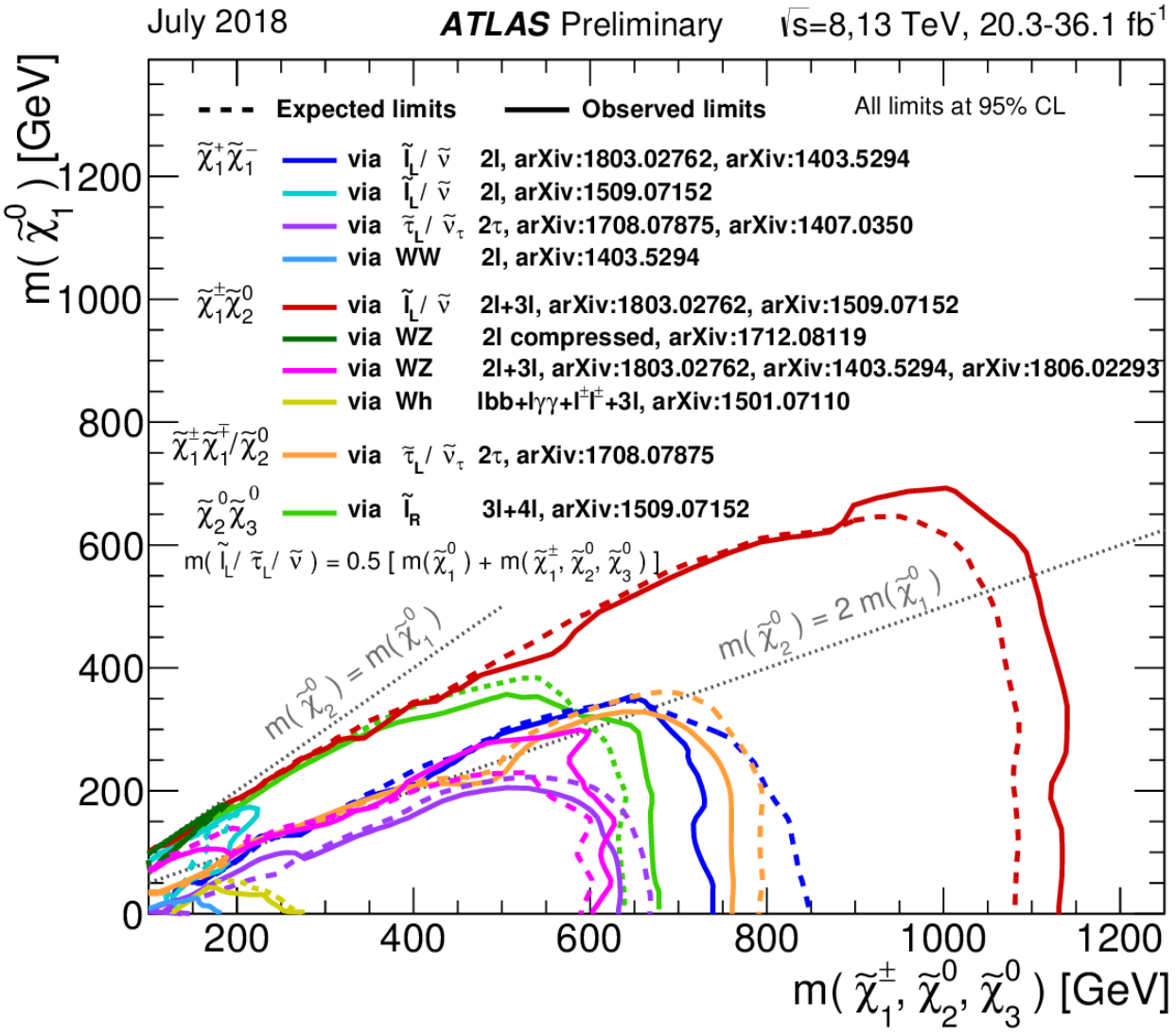


ATLAS summary stop production

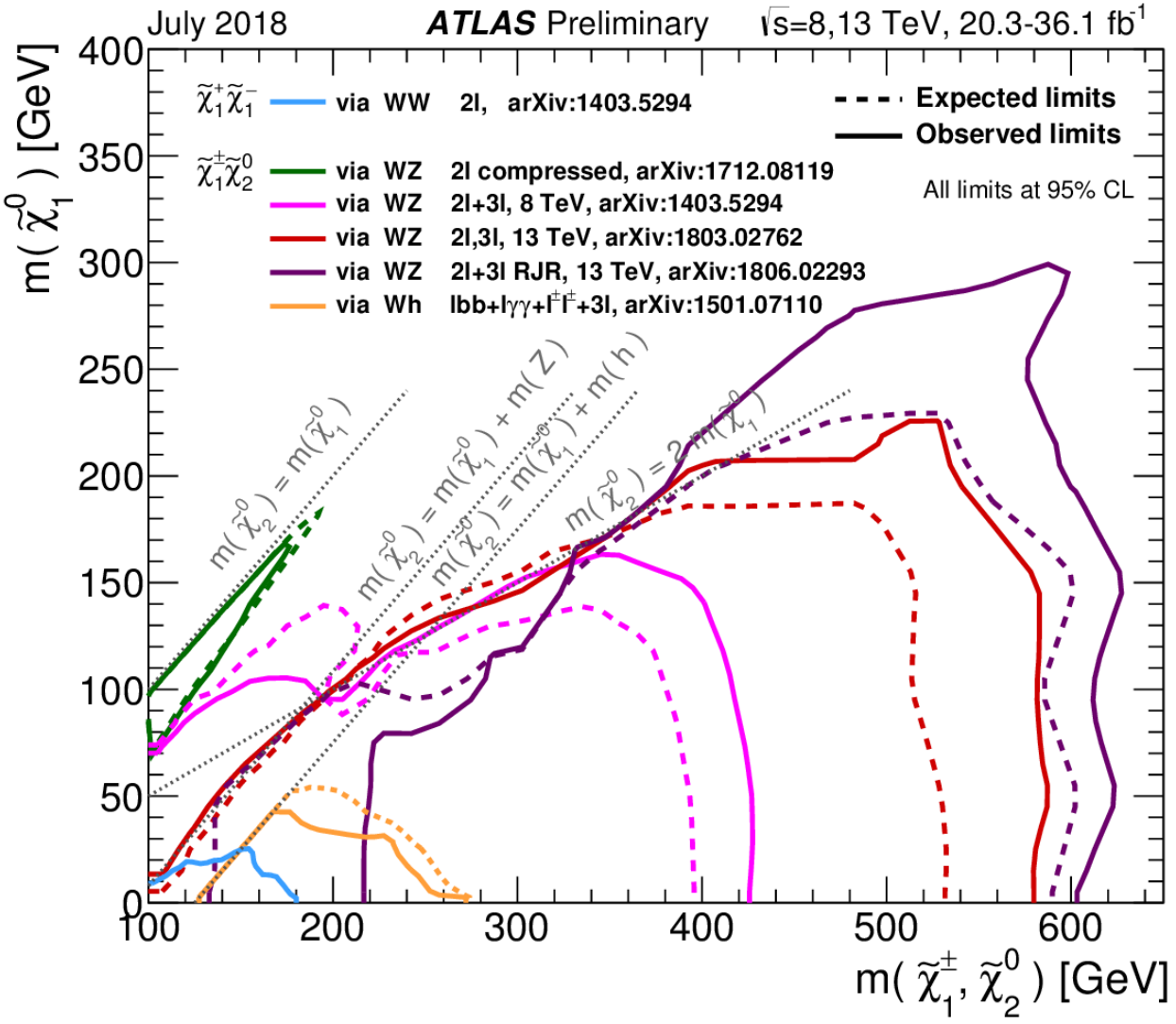


SUSY – a review of the results from the LHC experiments

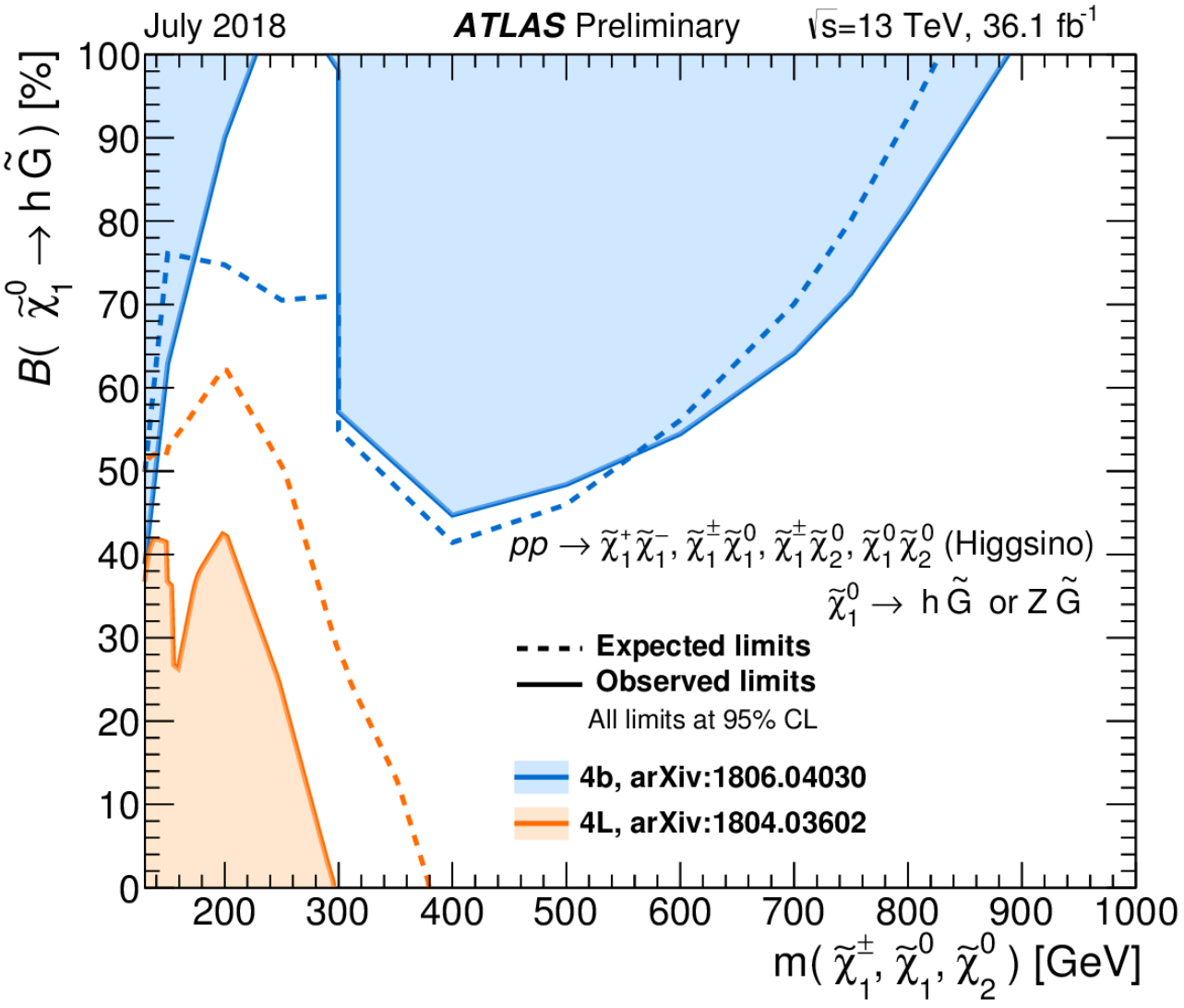
ATLAS summary EW production



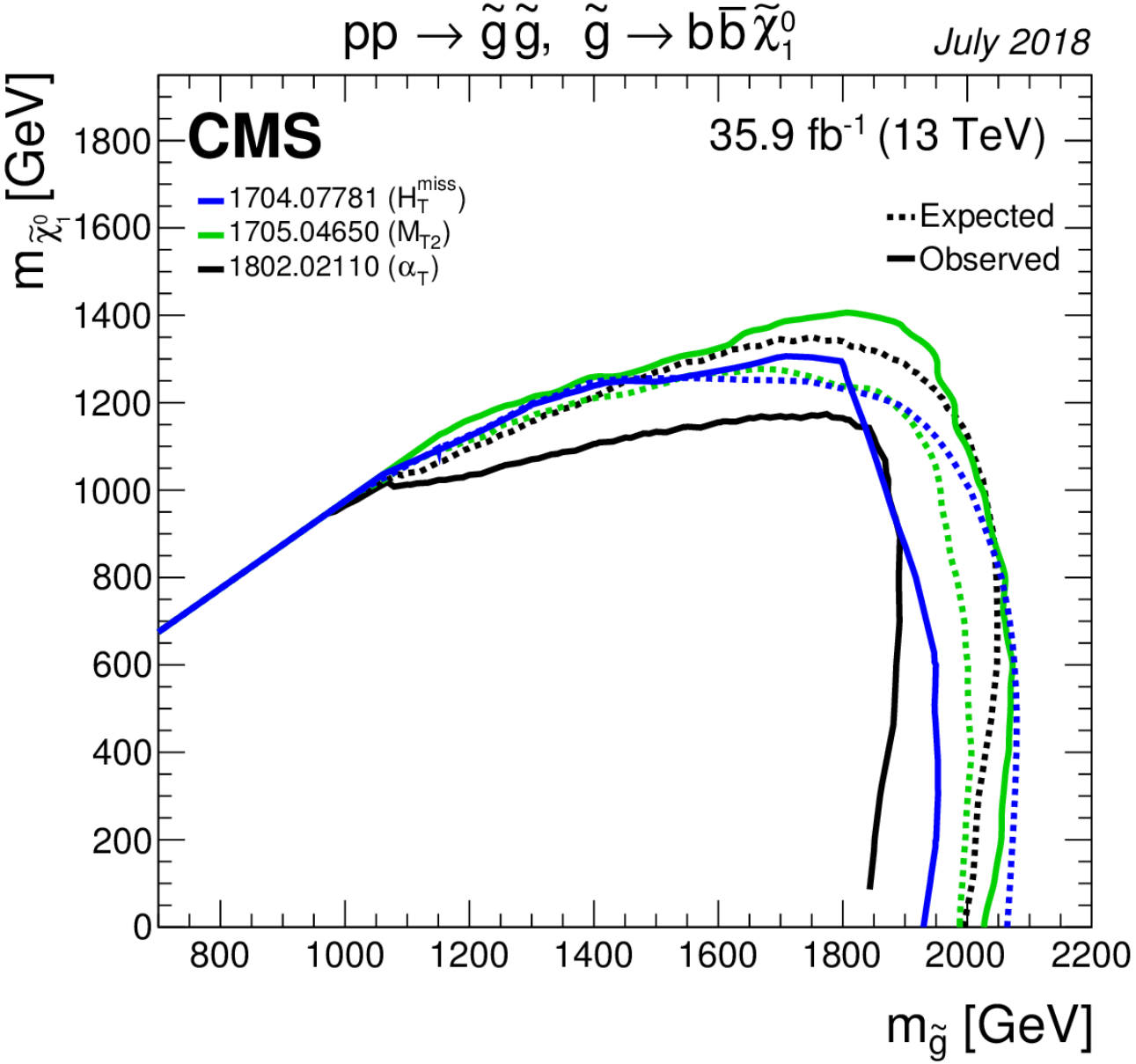
ATLAS summary EW production



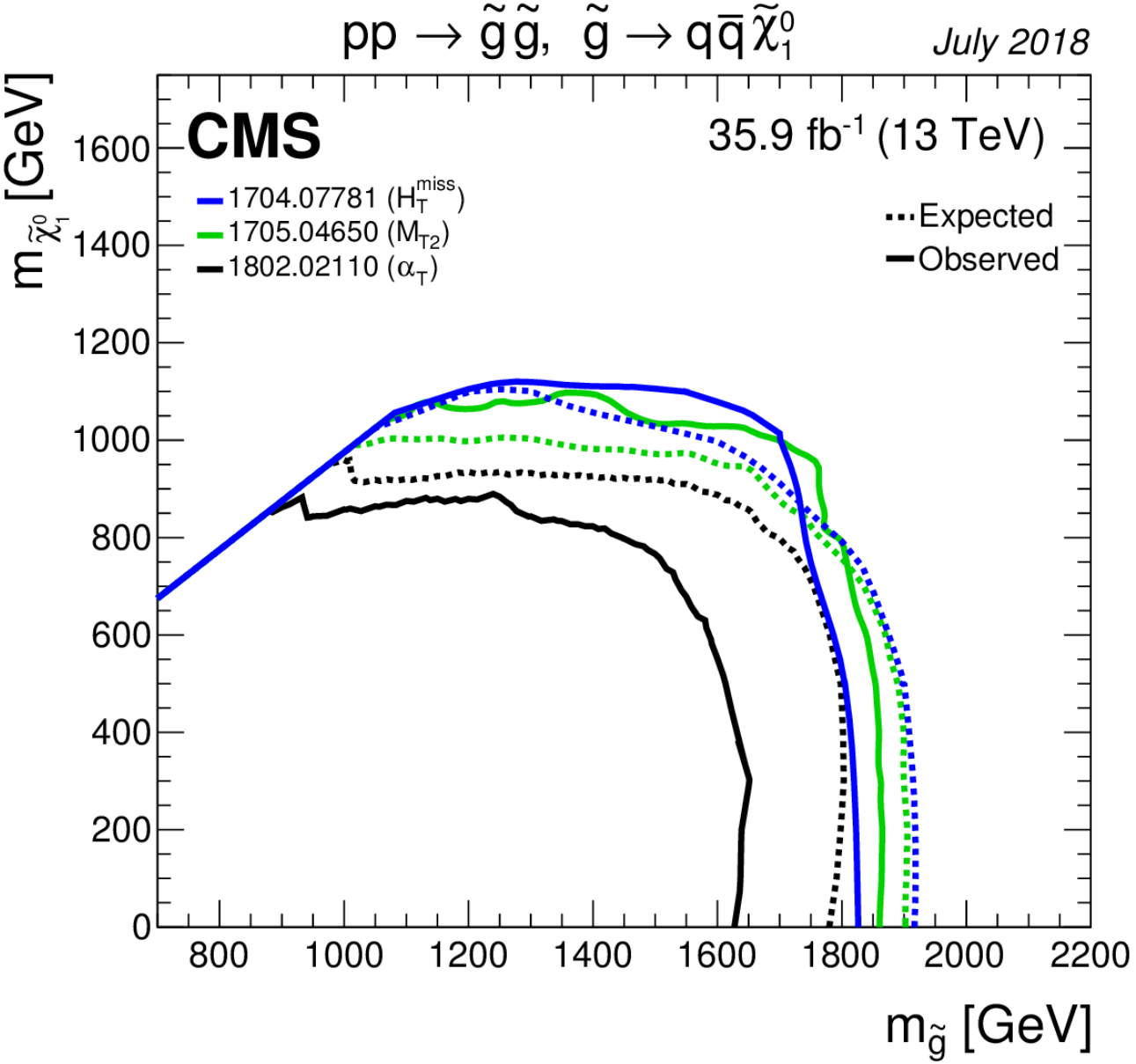
ATLAS summary EW production



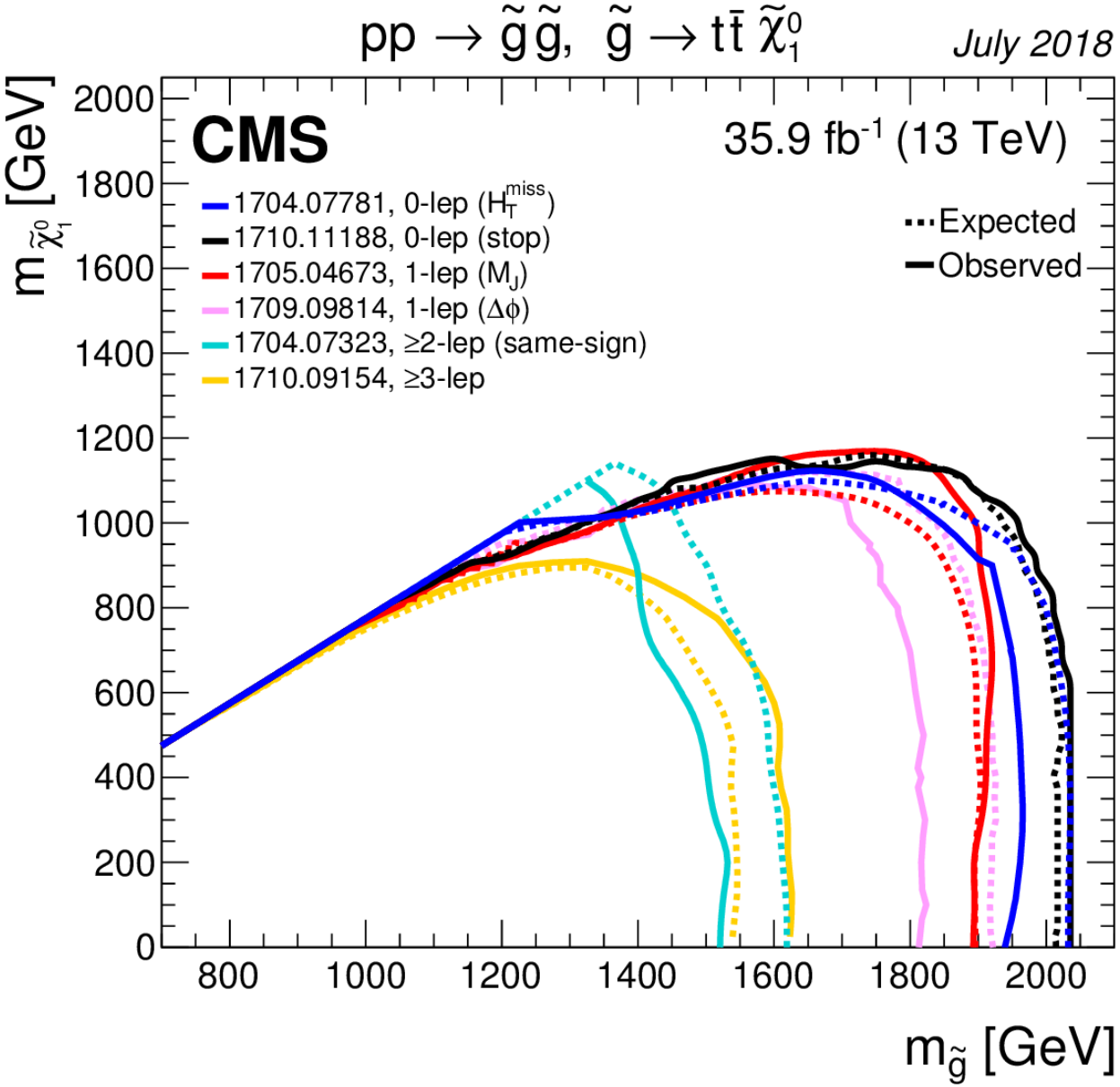
CMS summary gluino production



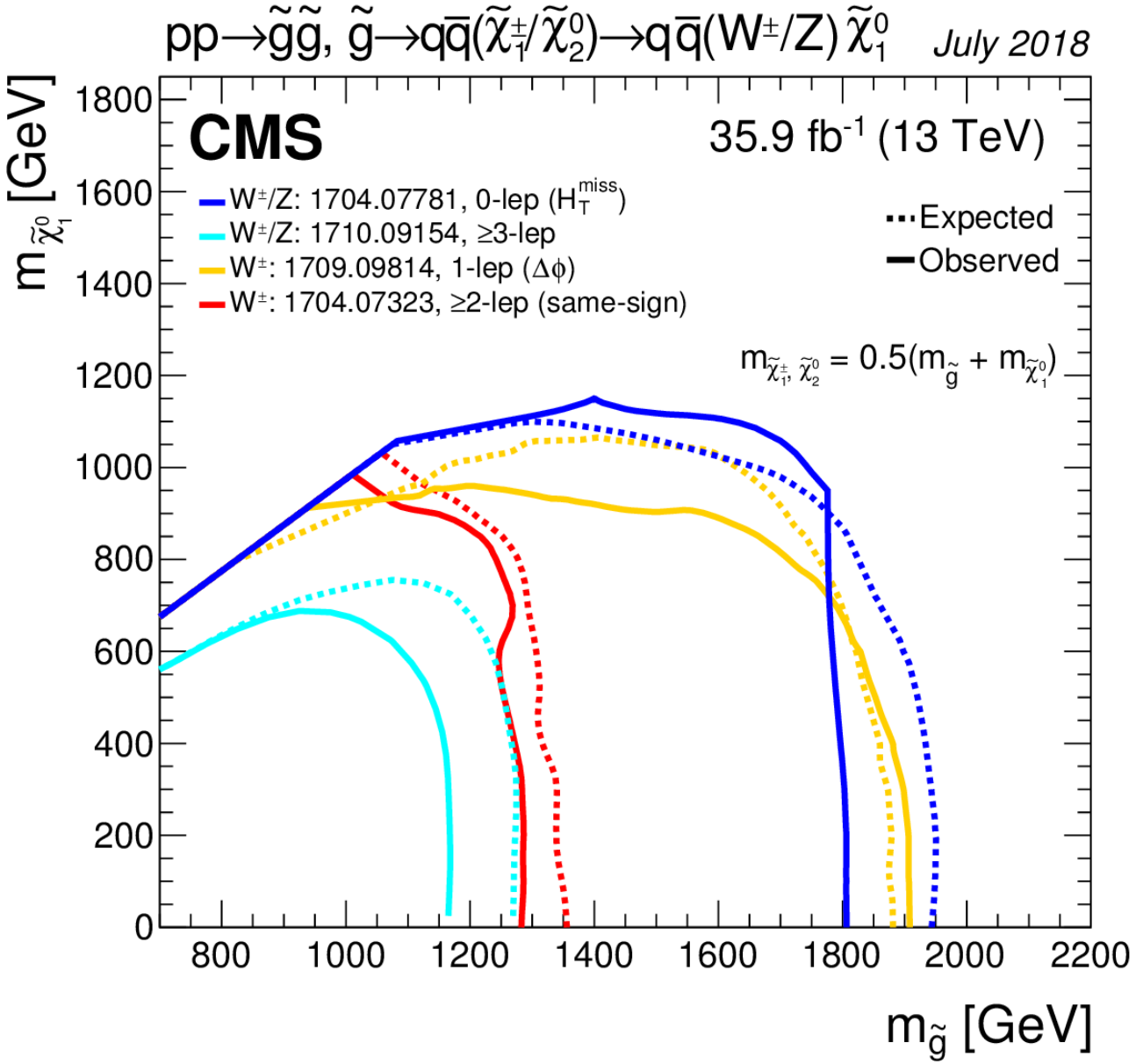
CMS summary gluino production



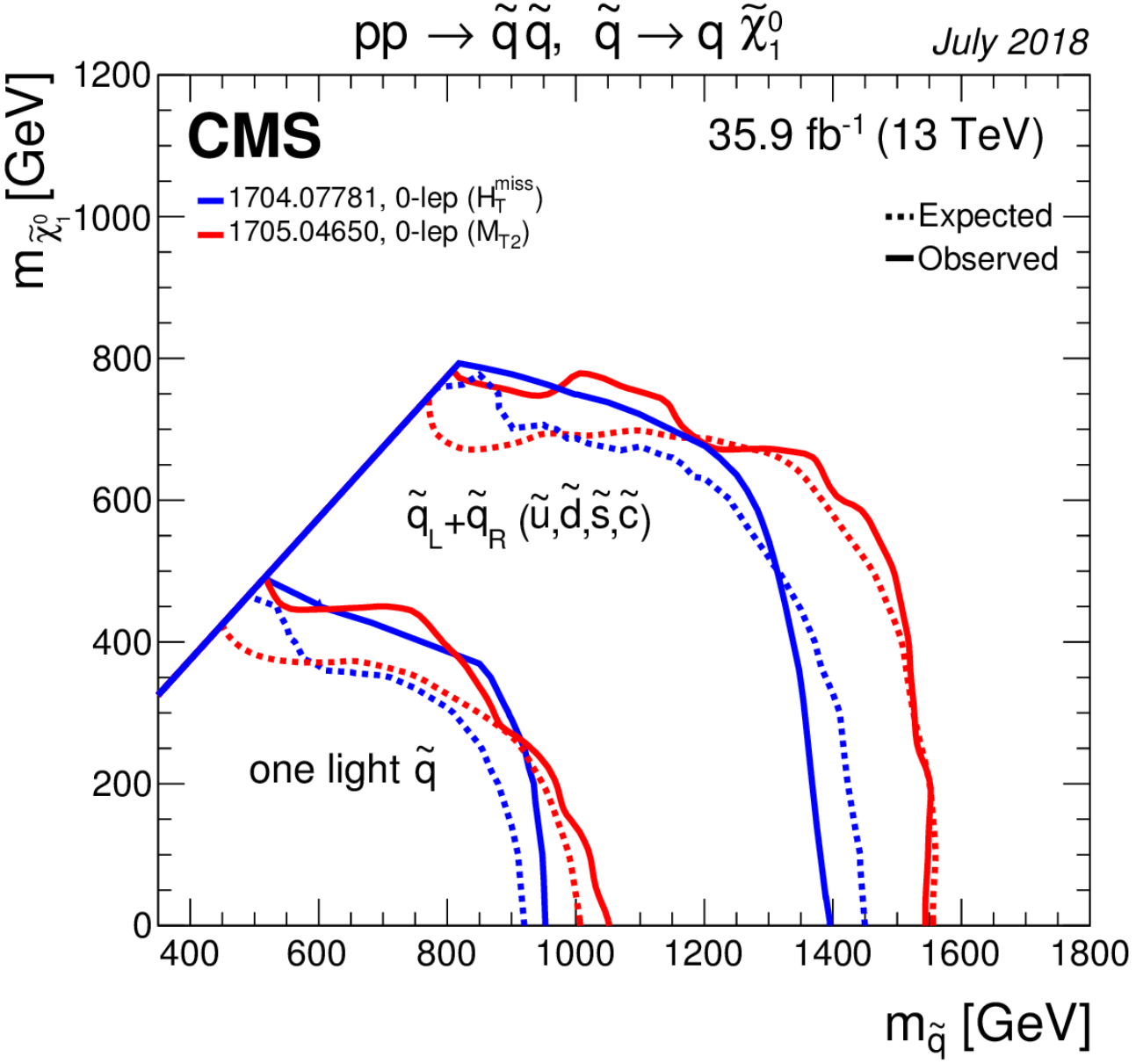
CMS summary gluino production



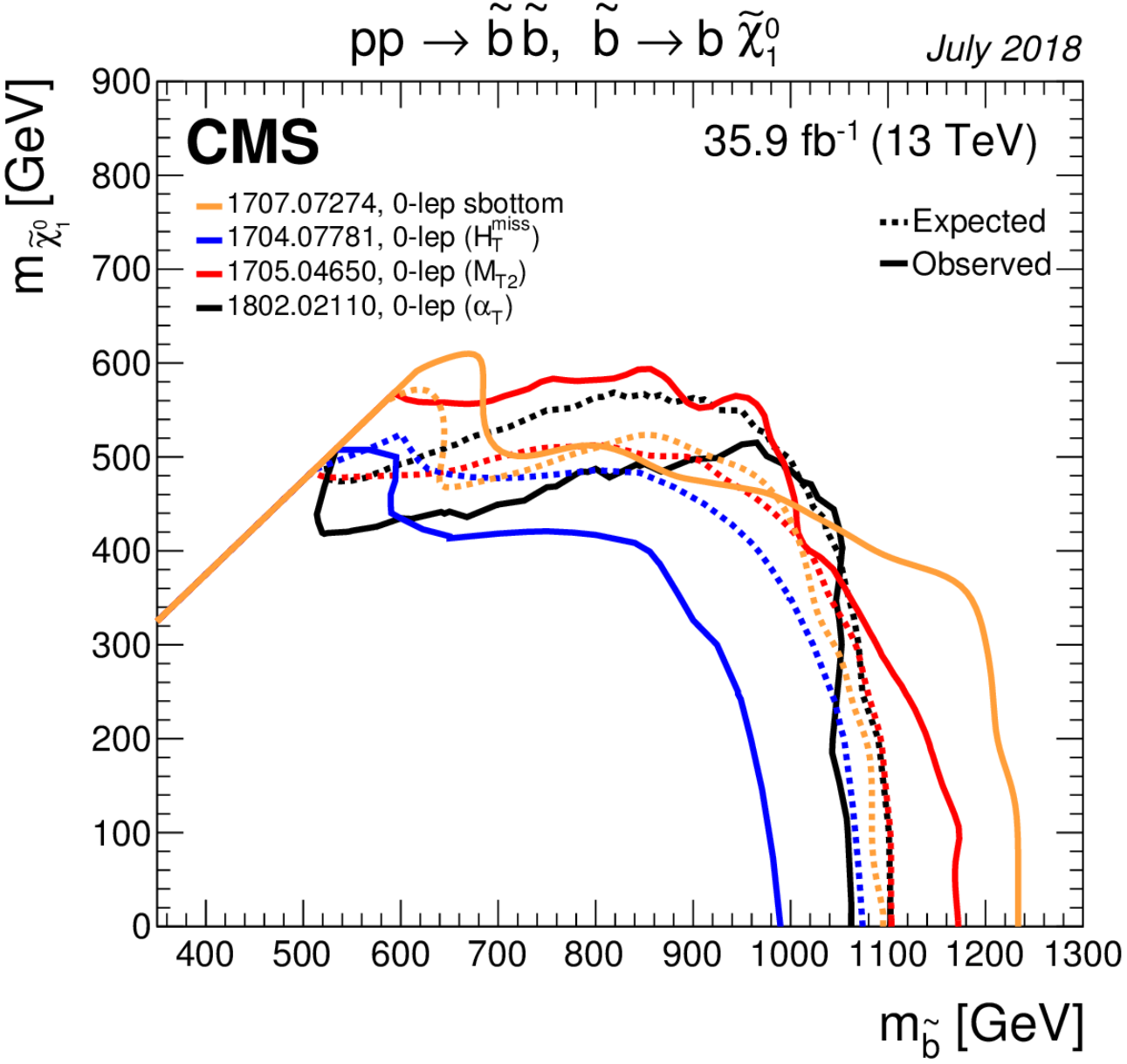
CMS summary gluino production



CMS summary squark production

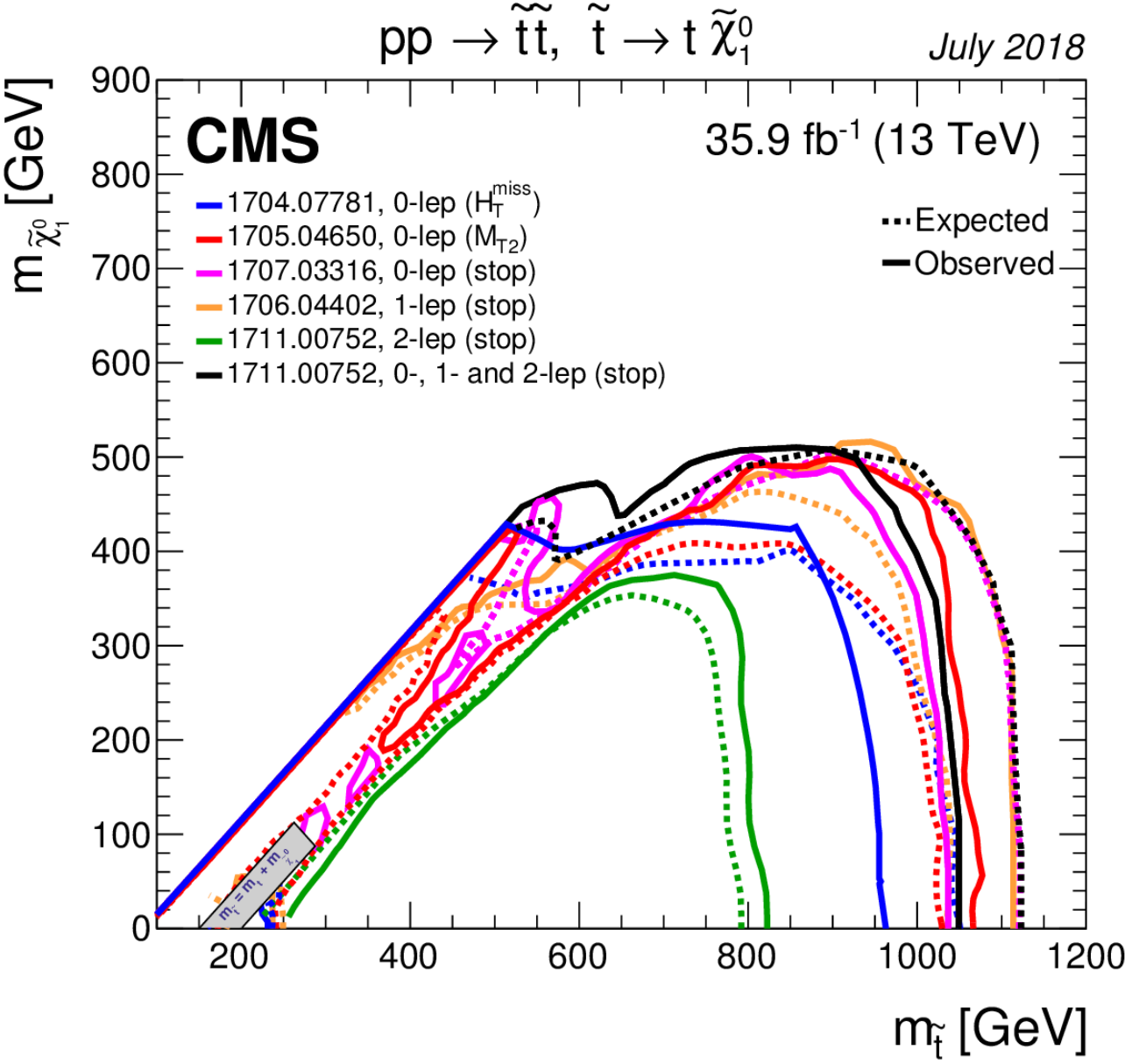


CMS summary sbottom production

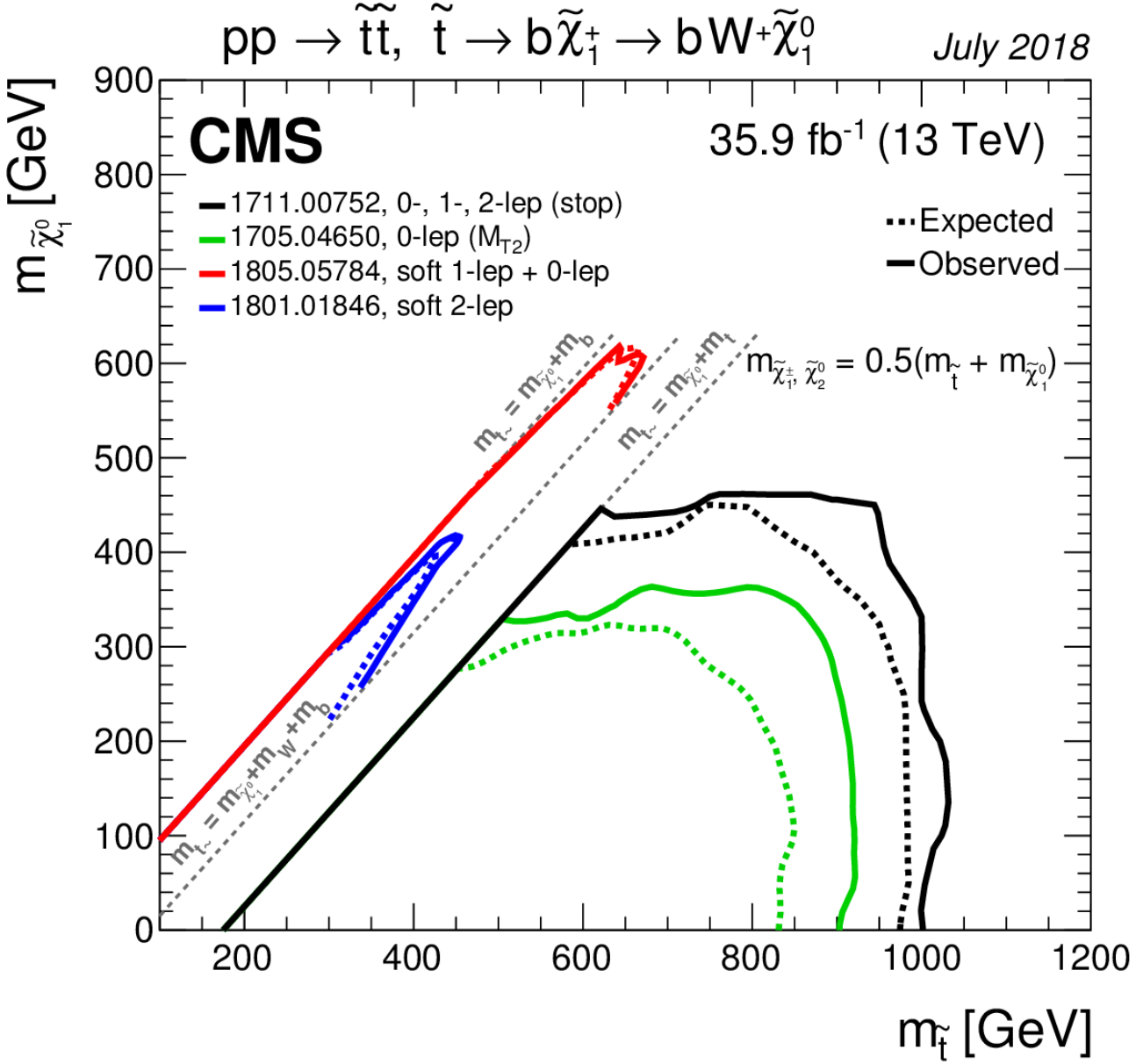


CMS summary stop prod. 2-body

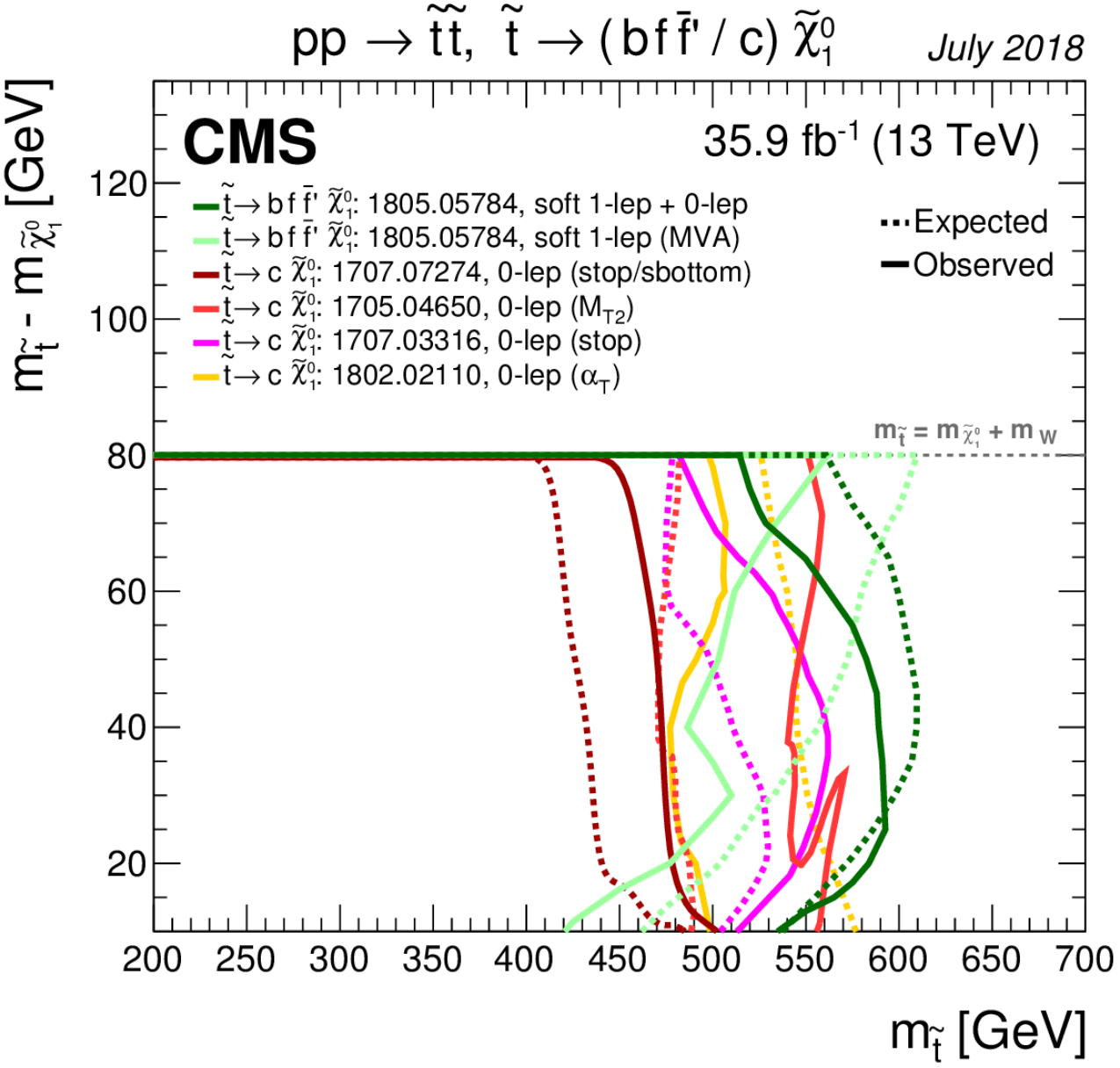
SUSY – a review of the results from the LHC experiments



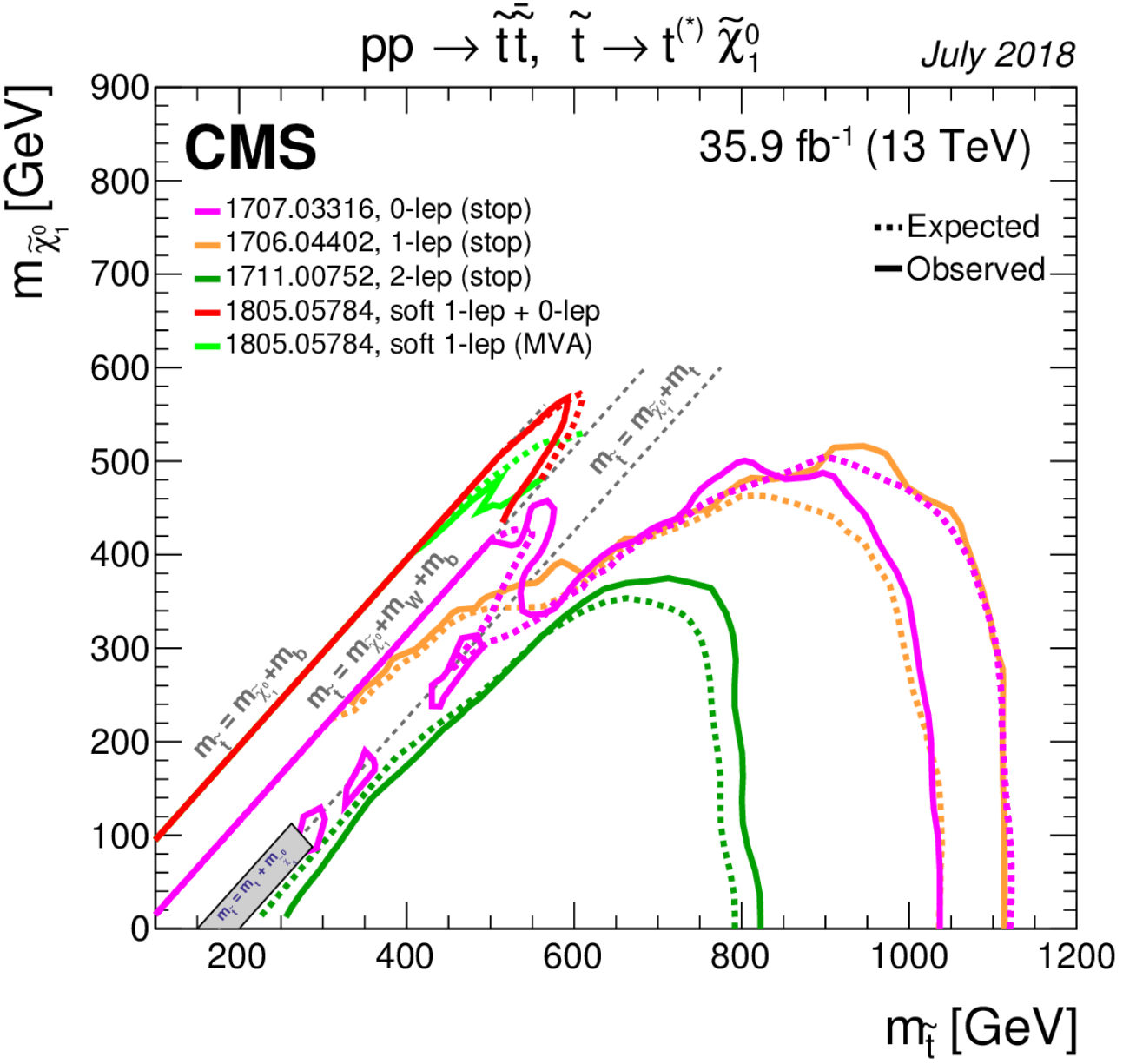
CMS summary stop prod. 3-body



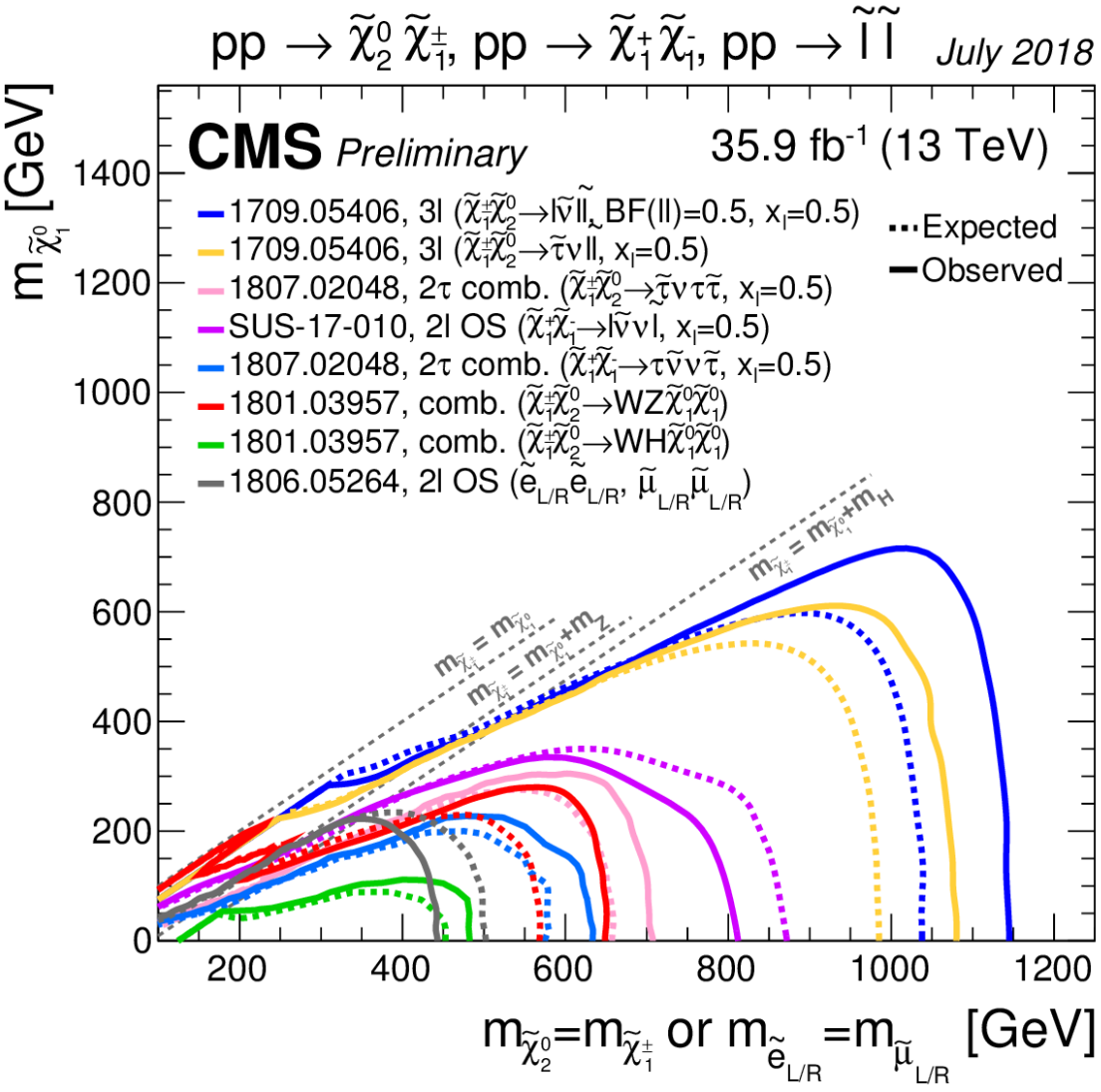
CMS summary stop prod. 4-body/cN



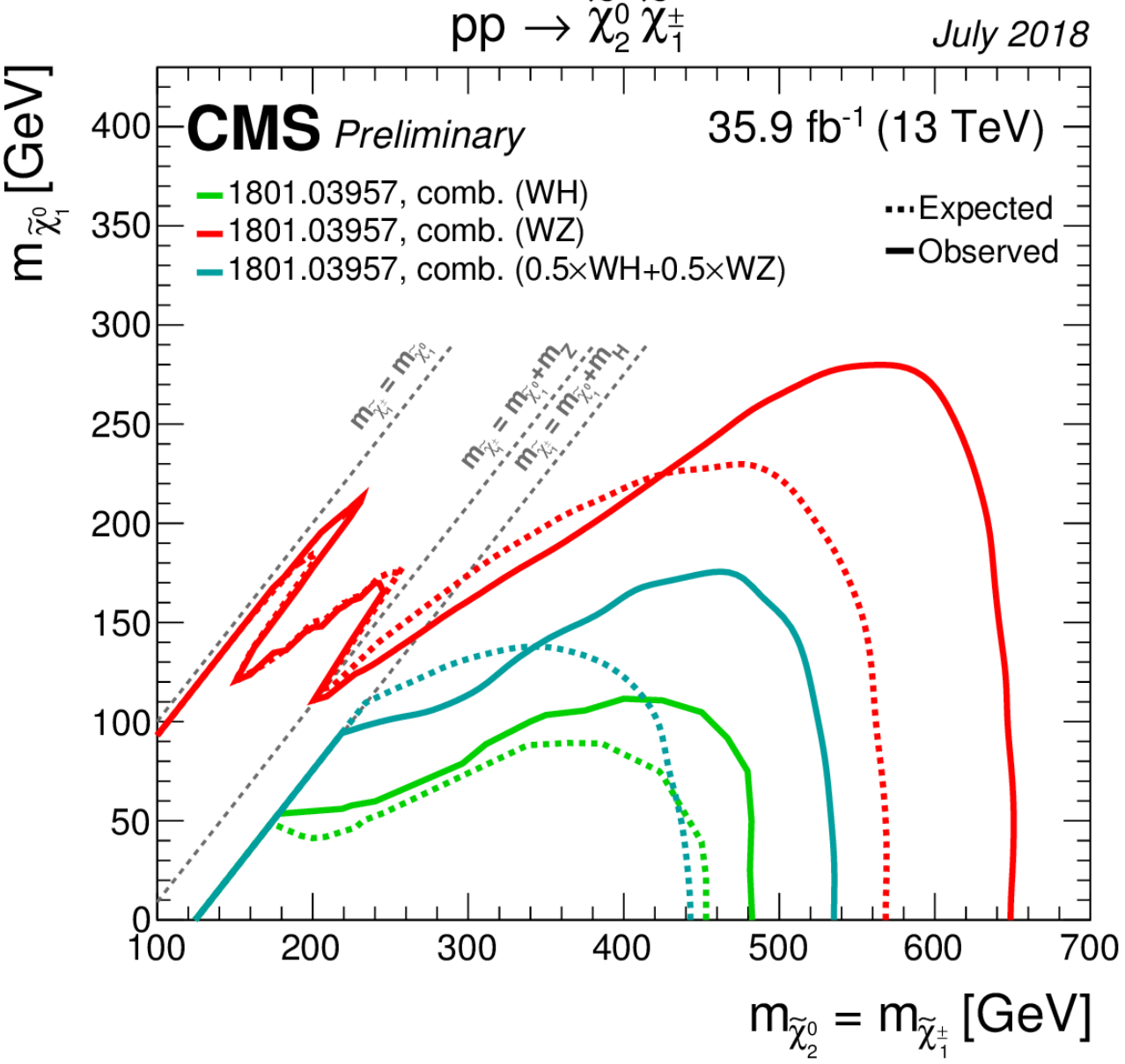
CMS summary stop prod. 2/3/4-body



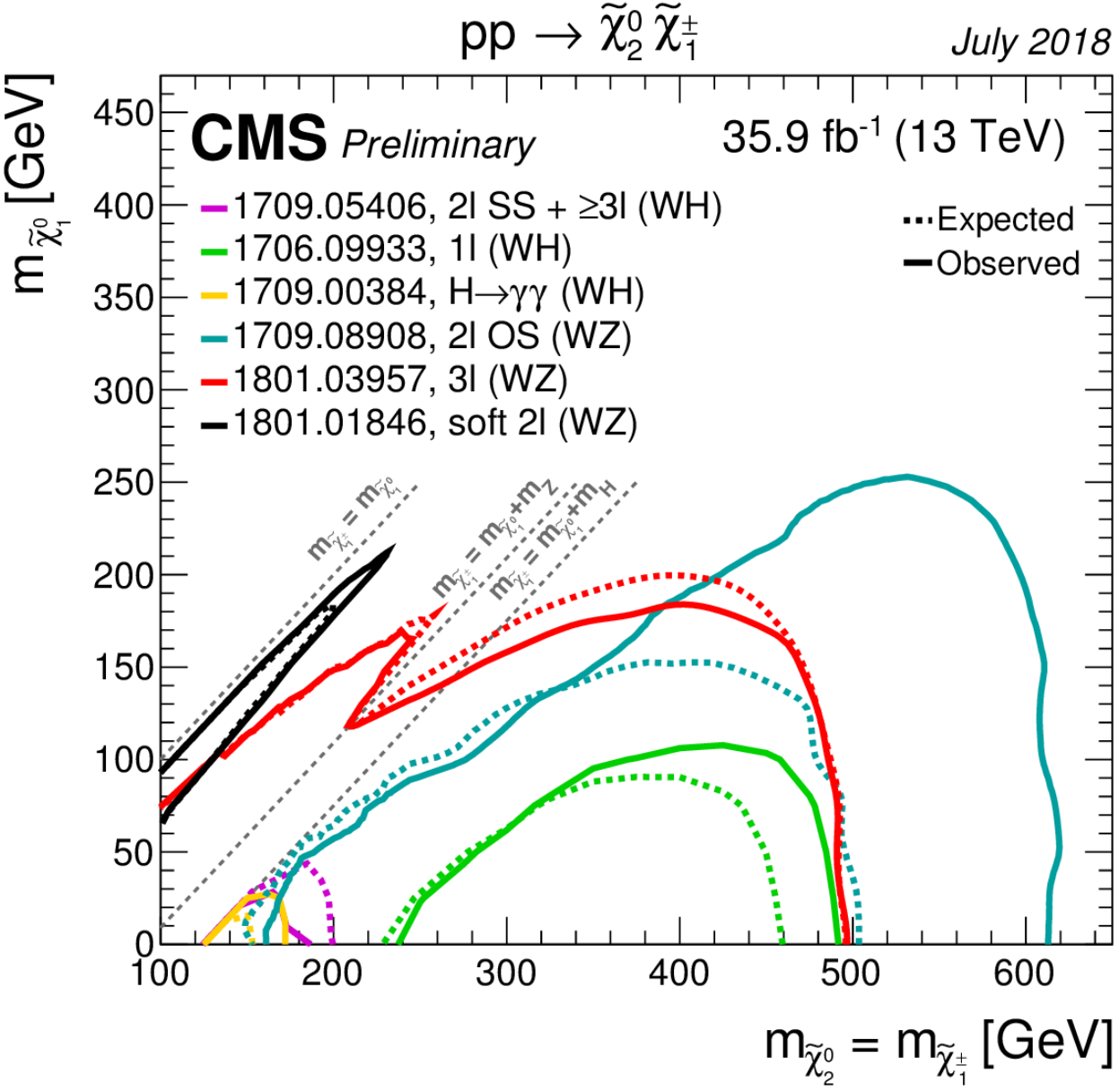
CMS summary EW



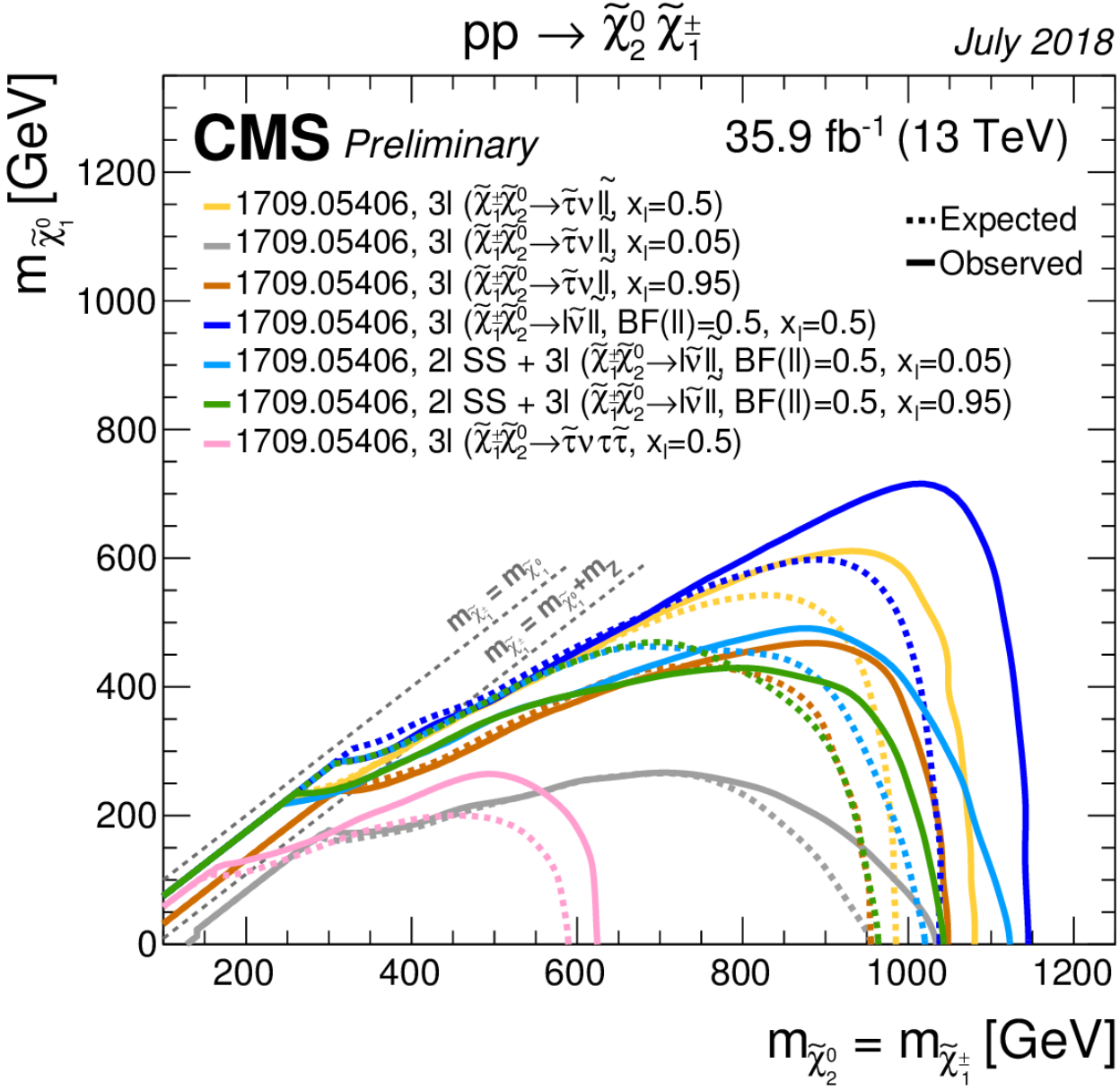
CMS summary EWino comb.



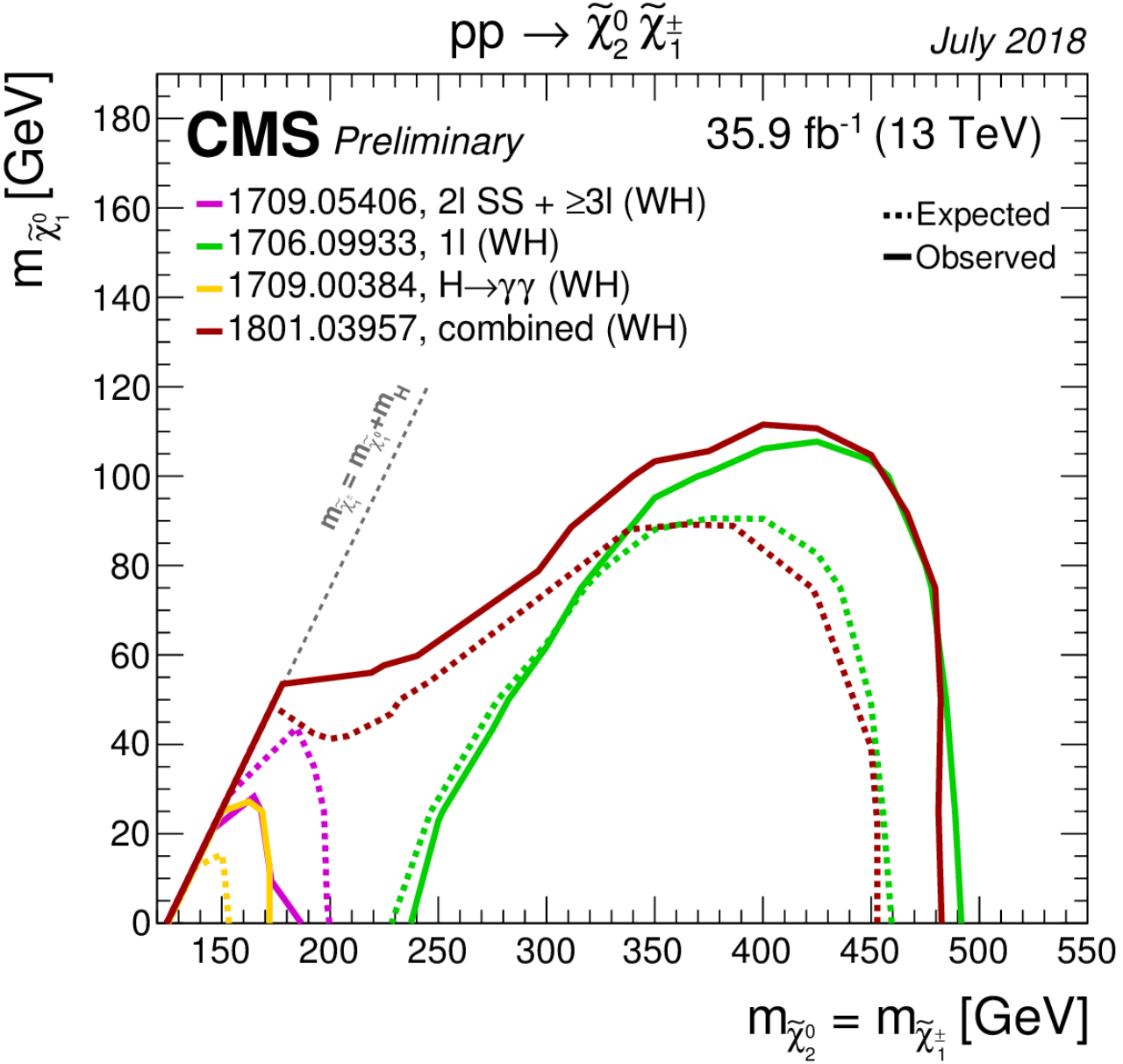
CMS summary EWino prod.



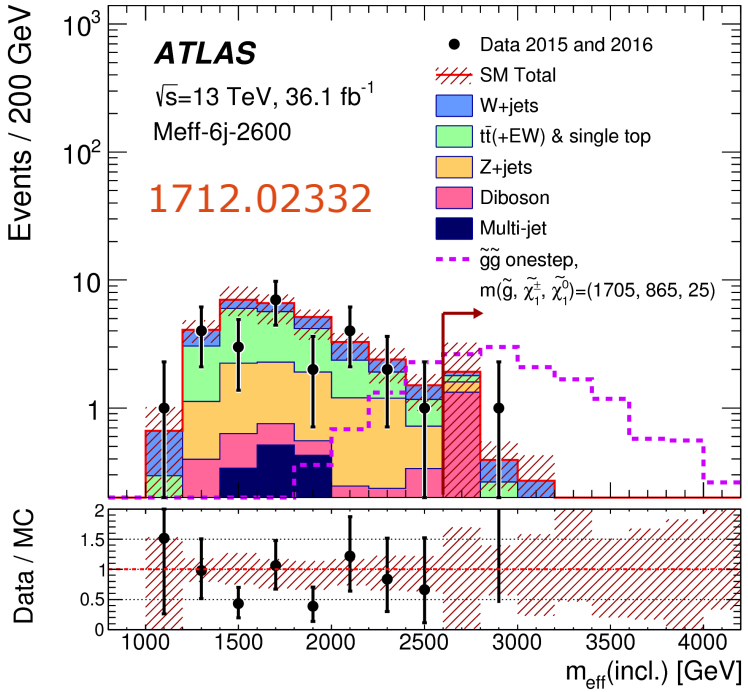
CMS summary slepton production

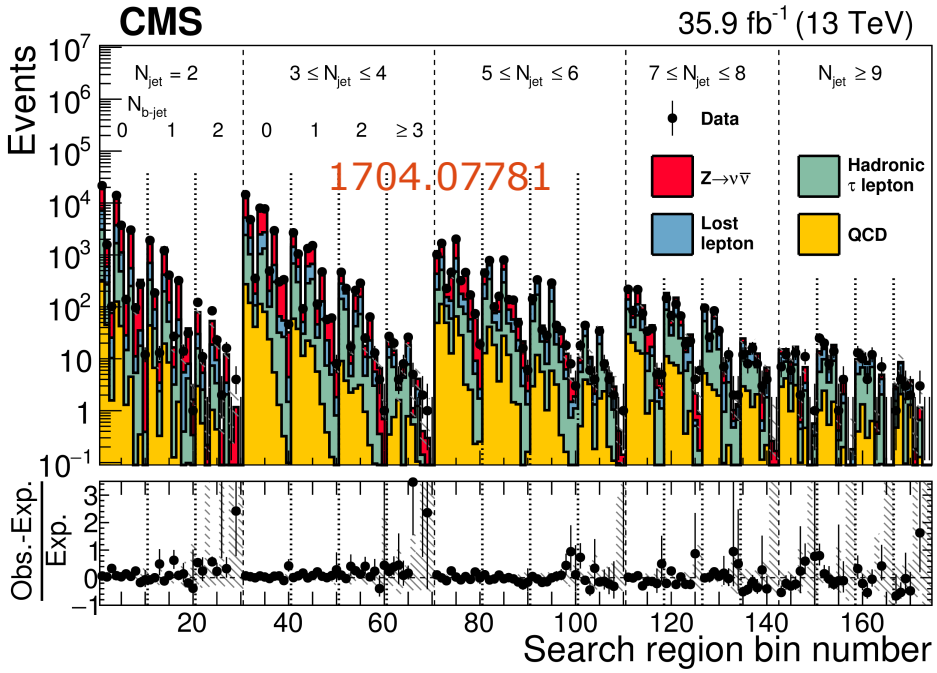


CMS summary EWino prod. (WH)



Gluino pair production

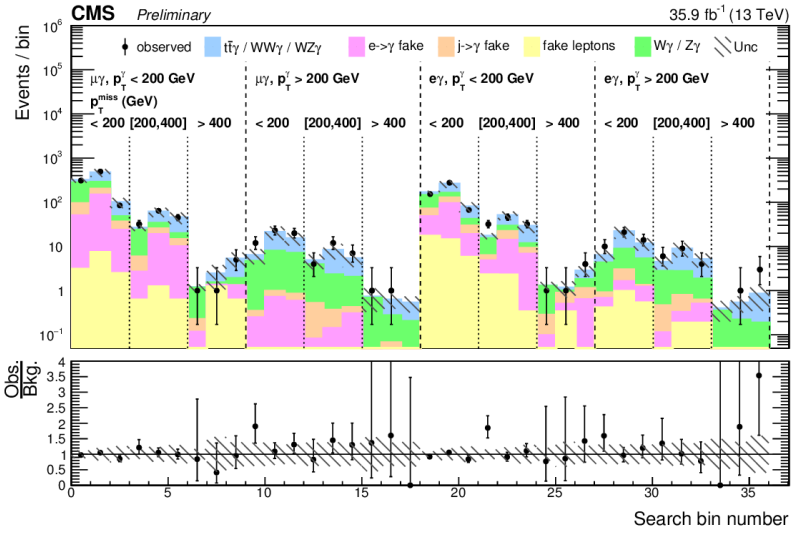


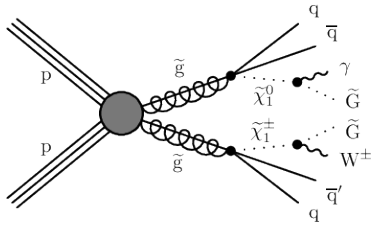


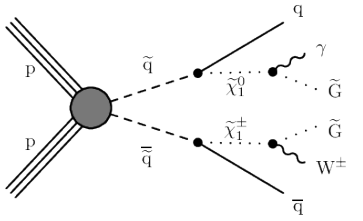
Photon, lepton and p_T^{miss}

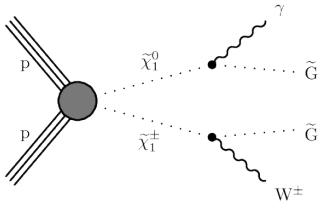
NEW

CMS-PAS-SUS-17-012

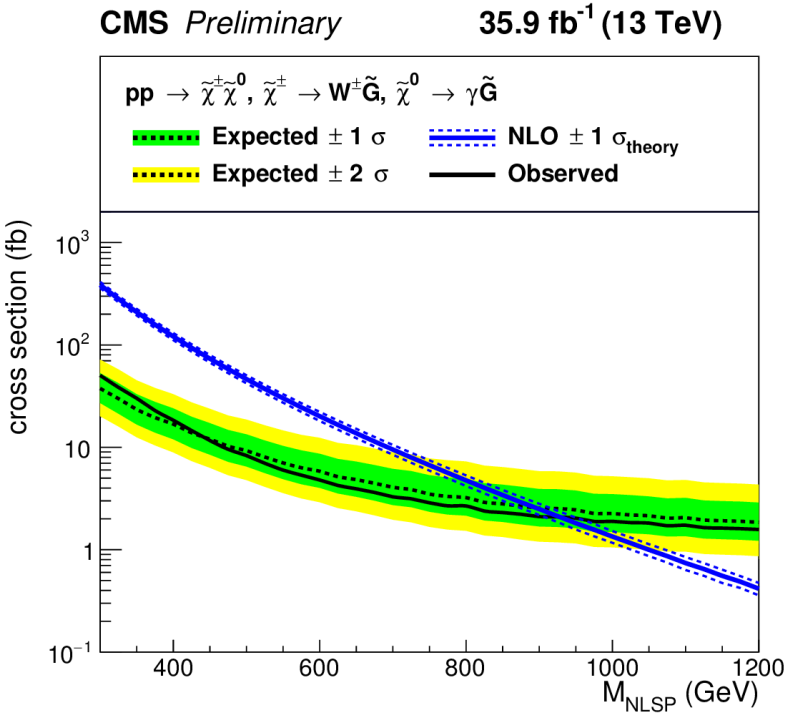








- Also exclude NLSP masses below 900 GeV in simplified model with direct EW production of a neutralino and chargino.

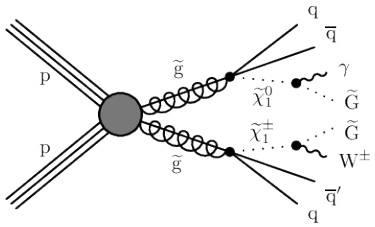


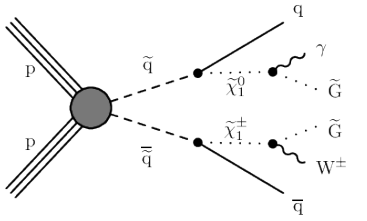
Photon, lepton and p_T^{miss}

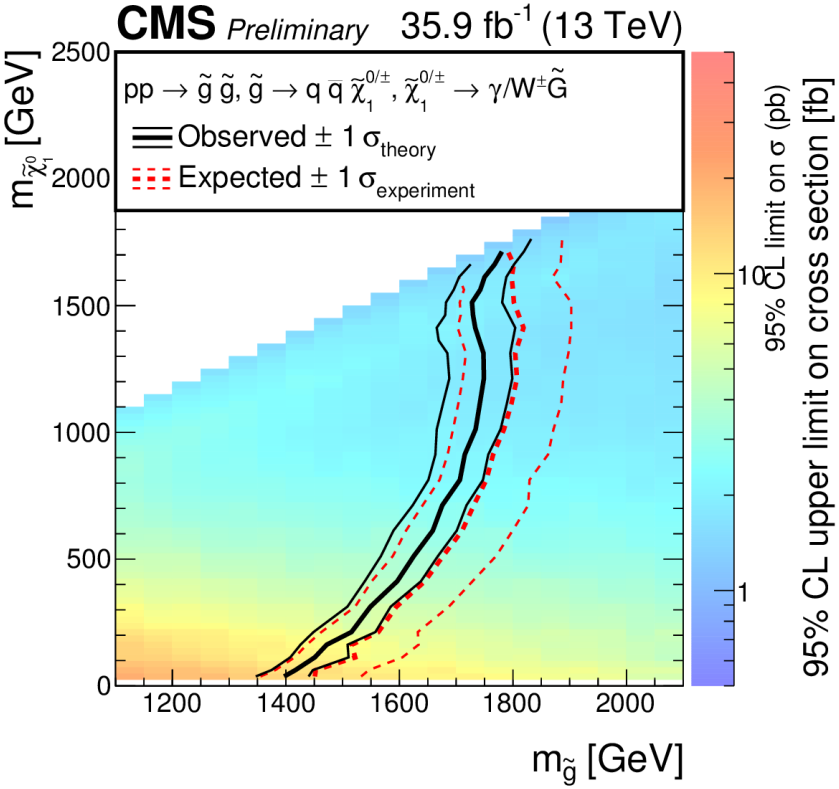
NEW

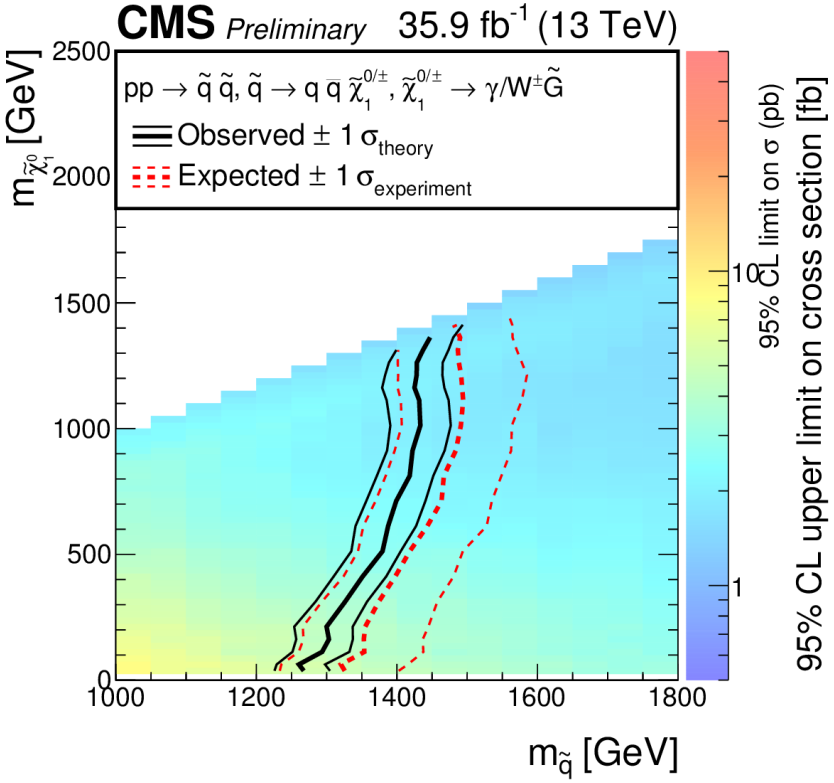
- Excludes gluinos (squarks) with masses of up to 1700 (1400) GeV.

CMS-PAS-SUS-17-012

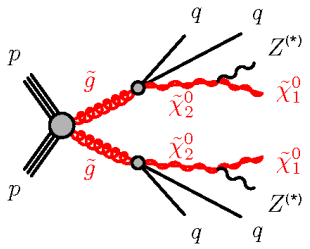


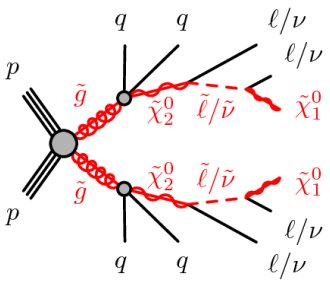


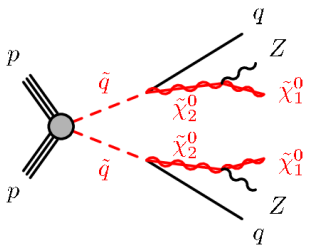




Lepton pairs and E_T^{miss}





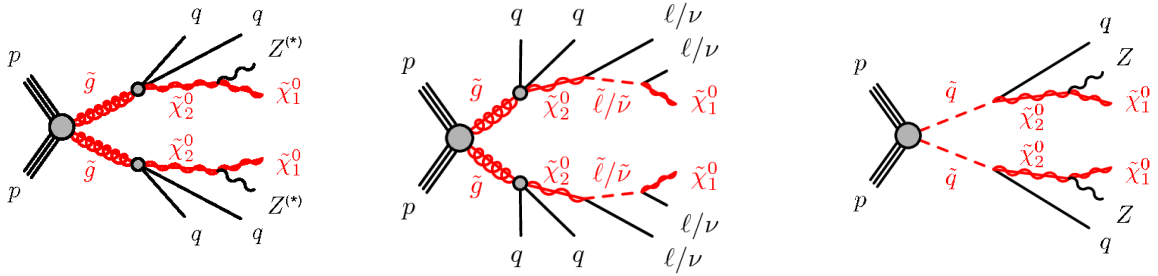


1805.11381

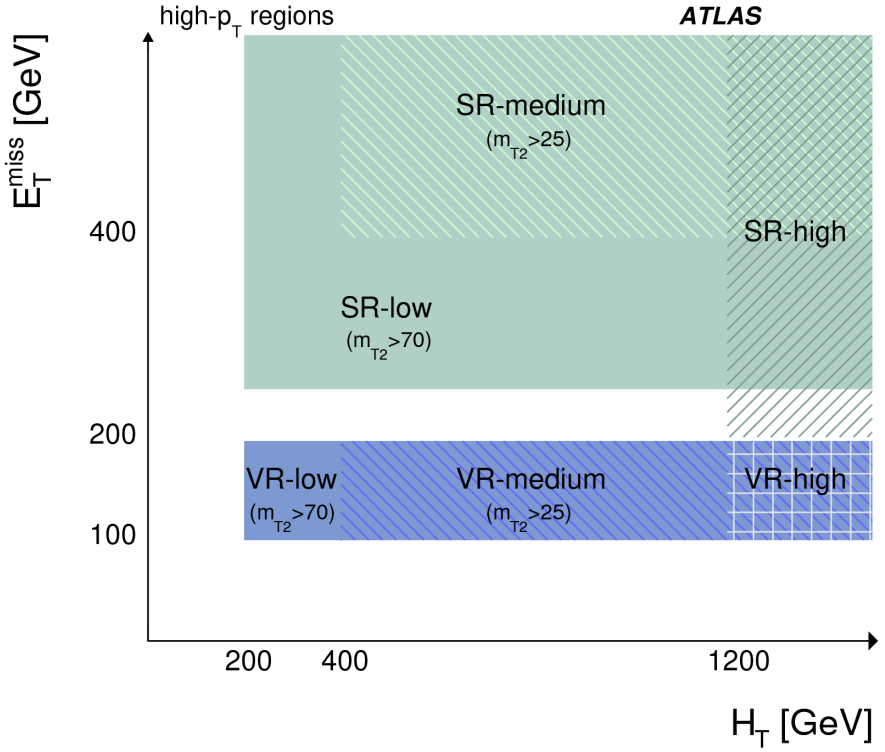
Model	Production mode	Quark flavours	$m(\tilde{g})/m(\tilde{q})$	$m(\tilde{\chi}_2^0)$	$m(\tilde{\chi}_1^0)$
slepton	$\tilde{g}\tilde{g}$	u, d, c, s, b	x	$[m(\tilde{g}) + m(\tilde{\chi}_1^0)]/2$	y
$Z^{(*)}$	$\tilde{g}\tilde{g}$	u, d, c, s, b	x	$[m(\tilde{g}) + m(\tilde{\chi}_1^0)]/2$	y
$\tilde{g}$–$\tilde{\chi}_2^0$ on-shell	$\tilde{g}\tilde{g}$	u, d, c, s	x	y	1 GeV
$\tilde{q}$–$\tilde{\chi}_2^0$ on-shell	$\tilde{q}\tilde{q}$	u, d, c, s	x	y	1 GeV
$\tilde{g}$–$\tilde{\chi}_1^0$ on-shell	$\tilde{g}\tilde{g}$	u, d, c, s	x	$m(\tilde{\chi}_1^0) + 100$ GeV	y

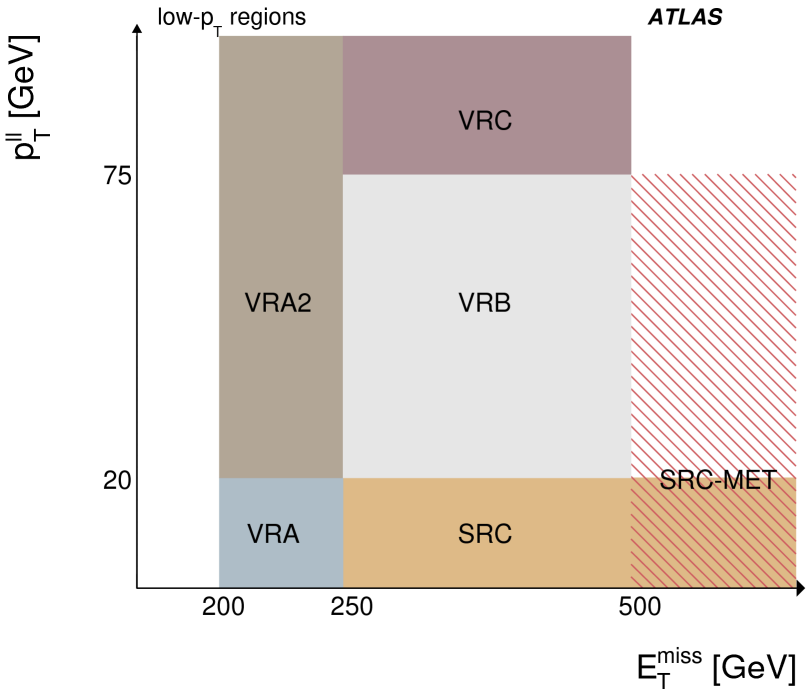
Lepton pairs and E_T^{miss}

SUSY – a review of the results from the LHC experiments

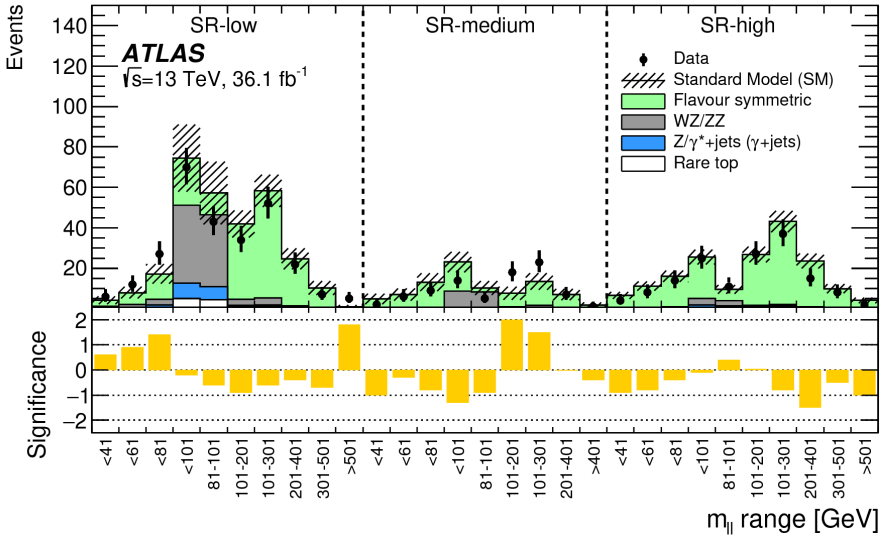


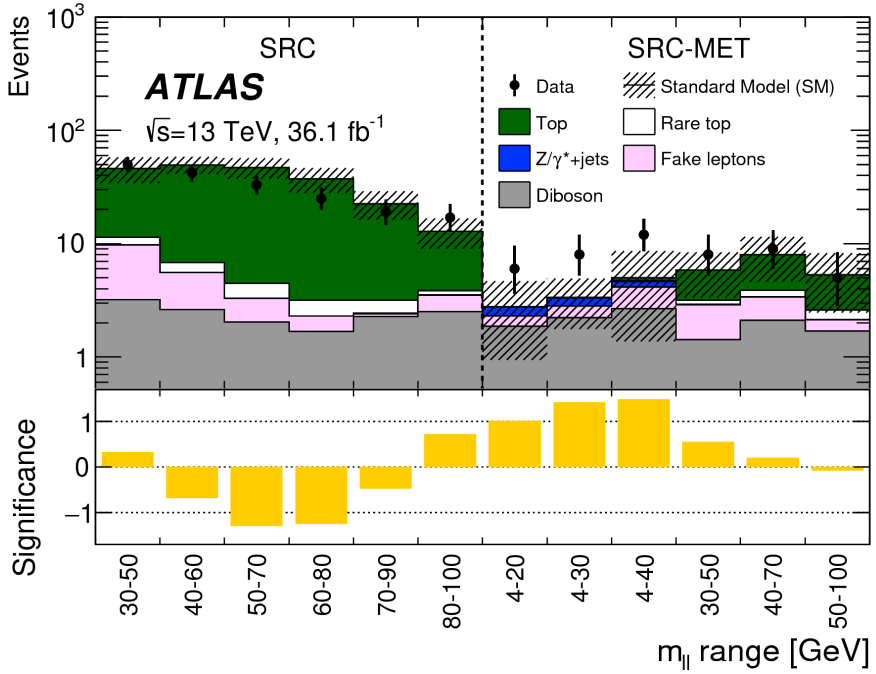
1805.11381





Lepton pairs and E_T^{miss}





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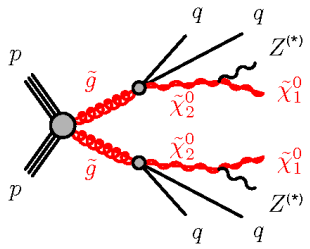

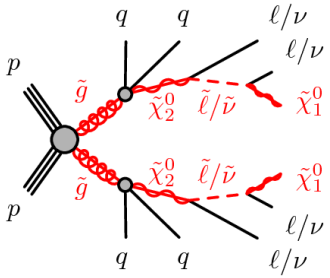

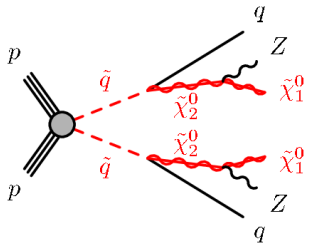

Lepton pairs and E_T^{miss}

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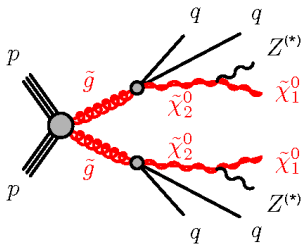
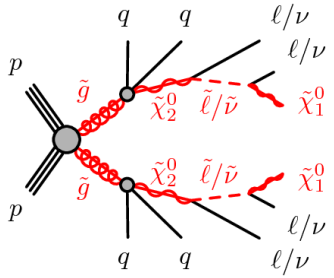
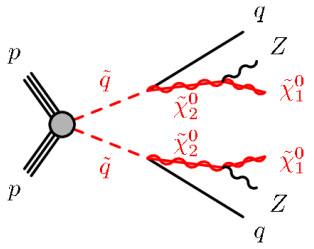
High-p_T regions	E_T^{miss} [GeV]	H_T [GeV]	n_{jets}	$m_{\ell\ell}$ [GeV]	m_{T2} [GeV]	**SF/DF**	$n_{b\text{-jets}}$	$\Delta\phi(\text{jet}_{12}, \boldsymbol{p}_T^{miss})$	$m_{\ell\ell}$ **windows**
Signal regions									
SR-low	> 250	> 200	≥ 2	> 12	> 70	SF	–	> 0.4	10
SR-medium	> 400	> 400	≥ 2	> 12	> 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	–







Lepton pairs and E_T^{miss}

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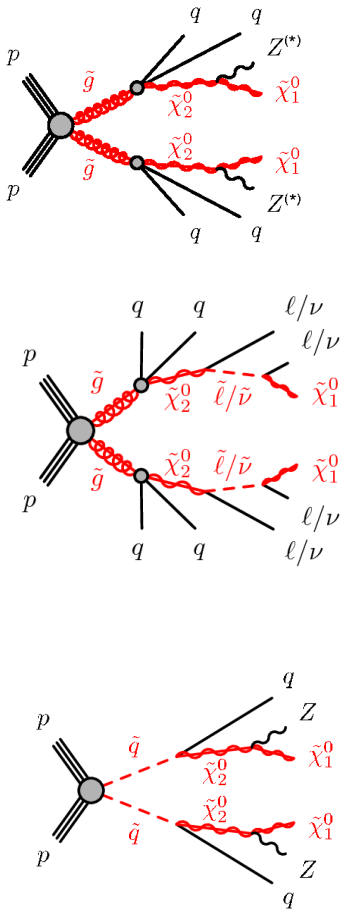
Low-p_T regions	E_T^{miss} **[GeV]**	$p_T^{\ell\ell}$ **[GeV]**	n_{jets}	$n_{b\text{-jets}}$	$m_{\ell\ell}$ **[GeV]**	**SF/DF**	**OS/SS**	$\Delta\phi(\text{jet}_{12}, p_T^{miss})$	m_T **[GeV]**	$m_{\ell\ell}$ **windows**
Signal regions										
SRC	> 250	< 20	≥ 2	–	> 30	SF	OS	> 0.4	–	6
SRC-MET	> 500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



Lepton pairs and E_T^{miss}

Signal Region $m_{\ell\ell}$ range [GeV]	Total Bkg.	Data	$\langle A\epsilon\sigma\rangle^{95}_{\rm obs}$[fb]	$S^{95}_{\rm obs}$	$S^{95}_{\rm exp}$	$p(s=0)$	$Z(s=0)$
SR-low							
12–41	4.2 ± 2.0	6	0.28	10.2	$6.9^{+3.3}_{-1.3}$	0.27	0.6
12–61	8.0 ± 3.0	12	0.44	15.8	$9.9^{+4}_{-2.5}$	0.19	0.9
12–81	17 ± 5	27	0.73	26.3	15^{+6}_{-4}	0.086	1.4
12–101	75 ± 17	70	1.56	56.2	60^{+7}_{-5}	0.6	−0.2
81–101	57 ± 16	43	1.13	40.6	47^{+6}_{-6}	0.73	−0.6
101–201	42 ± 7	34	0.38	13.8	19^{+9}_{-5}	0.81	−0.9
101–301	58 ± 8	52	0.46	16.5	23^{+9}_{-8}	0.72	−0.6
201–401	25 ± 5	22	0.37	13.4	15^{+11}_{-4}	0.65	−0.4
301–501	10.2 ± 3.5	7	0.20	7.1	$9.4^{+4}_{-2.8}$	0.77	−0.7
501–	$0.9^{+0.95}_{-0.9}$	5	0.27	9.9	$6.0^{+2.3}_{-1.0}$	0.039	1.8
SR-medium							
12–41	4.8 ± 2.6	2	0.16	5.7	$6.9^{+3.2}_{-1.3}$	0.83	−1.0
12–61	7.0 ± 3.0	6	0.20	7.4	$8.2^{+4}_{-2.1}$	0.6	−0.3
12–81	13 ± 4	9	0.22	7.8	$11.0^{+4}_{-3.3}$	0.78	−0.8
12–101	23 ± 5	14	0.25	9.1	$13.5^{+5}_{-3.5}$	0.91	−1.3
81–101	10.3 ± 3.4	5	0.22	8.0	$10.0^{+2.8}_{-2.5}$	0.82	−0.9
101–201	7.6 ± 3.2	18	0.53	19.1	$11.1^{+4}_{-2.7}$	0.024	2.0
101–301	14 ± 4	23	0.68	24.5	14^{+6}_{-4}	0.063	1.5
201–401	7.1 ± 2.8	7	0.27	9.8	$8.6^{+4}_{-2.4}$	0.51	−0.0
401–	1.8 ± 1.4	1	0.12	4.3	$4.8^{+2.5}_{-1.0}$	0.67	−0.4
SR-high							
12–41	6.6 ± 1.7	4	0.14	5.0	$7.0^{+2.7}_{-2.1}$	0.82	−0.9
12–61	11.2 ± 2.3	8	0.18	6.5	$8.6^{+4}_{-2.5}$	0.8	−0.8
12–81	16.1 ± 2.9	14	0.25	9.1	$10.7^{+4}_{-2.5}$	0.67	−0.4
12–101	26 ± 4	25	0.37	13.4	14^{+5}_{-4}	0.54	−0.1
81–101	9.6 ± 2.1	11	0.30	11.0	$10.8^{+3.4}_{-2.2}$	0.35	0.4
101–201	27 ± 4	27	0.35	12.8	$12.9^{+7}_{-3.1}$	0.49	0.0
101–301	43 ± 5	37	0.35	12.7	17^{+6}_{-5}	0.77	−0.8
201–401	24 ± 4	15	0.19	6.8	12^{+5}_{-4}	0.94	−1.5
301–501	9.9 ± 2.2	8	0.21	7.5	$8.6^{+4}_{-2.7}$	0.7	−0.5
501–	4.1 ± 1.3	2	0.12	4.3	$5.6^{+2.3}_{-1.5}$	0.84	−1.0

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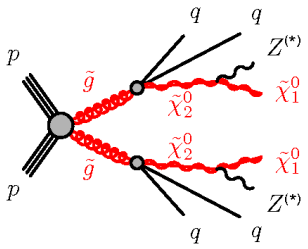

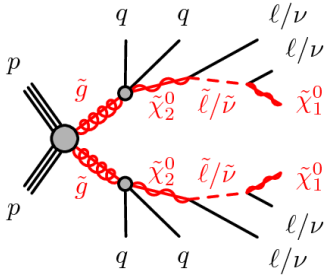

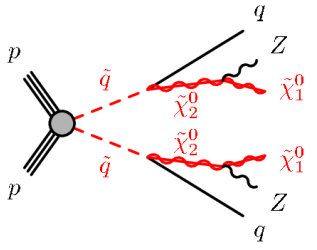

Lepton pairs and E_T^{miss}

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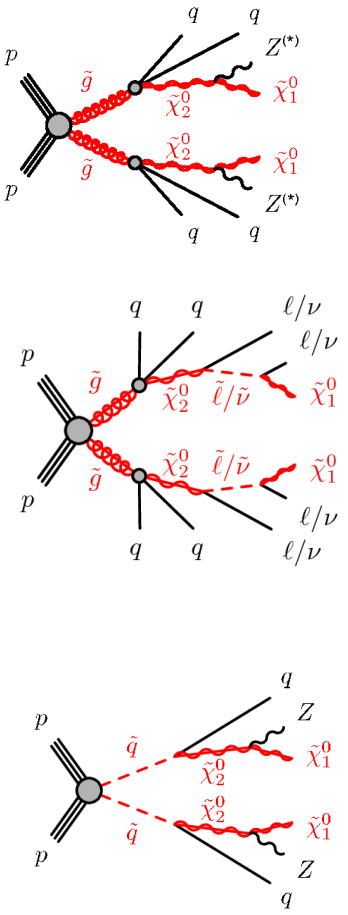
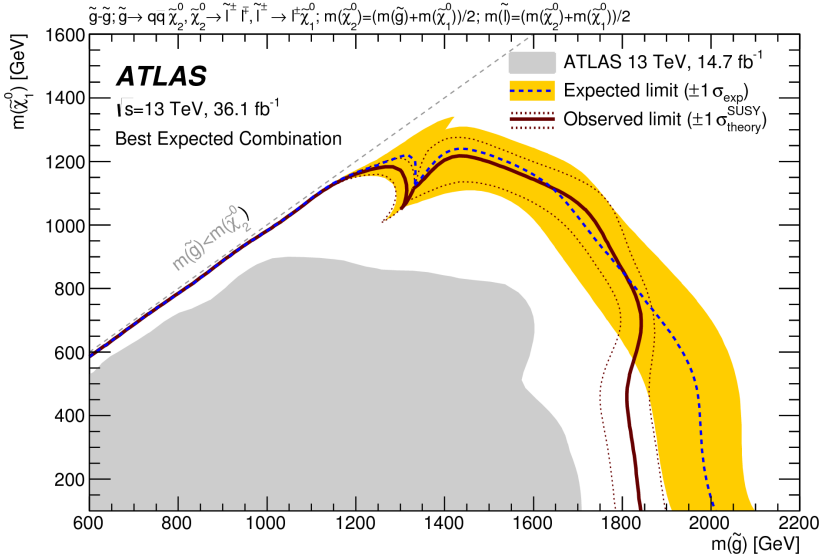
Signal Region $m_{\ell\ell}$ range [GeV]	Total Bkg.	Data	$\langle A\epsilon\sigma\rangle^{95}_{\rm obs}$[fb]	$S^{95}_{\rm obs}$	$S^{95}_{\rm exp}$	$p(s=0)$	$Z(s=0)$
SRC							
30-50	46 ± 12	50	1.29	46.4	42^{+10}_{-8}	0.38	0.3
40-60	50 ± 9	42	0.54	19.5	25^{+9}_{-8}	0.75	−0.7
50-70	47 ± 10	33	0.43	15.6	24^{+9}_{-7}	0.90	−1.3
60-80	37 ± 9	25	0.37	13.3	28^{+4}_{-12}	0.89	−1.3
70-90	23 ± 6	19	0.31	11.1	16^{+6}_{-4}	0.68	−0.5
80-	13 ± 4	17	0.42	15.3	12.8^{+5}_{-4}	0.24	0.7
SRC-MET							
4-20	2.8 ± 1.9	6	0.31	11.0	$8.4^{+5}_{-2.2}$	0.15	1.0
4-30	3.3 ± 1.6	8	0.35	12.5	$8.6^{+4}_{-2.0}$	0.078	1.4
4-40	5 ± 4	12	0.45	16.3	$10.2^{+5}_{-1.9}$	0.069	1.5
30-50	5.9 ± 2.5	8	0.30	10.7	$8.8^{+4}_{-2.2}$	0.29	0.6
40-70	8.0 ± 3.4	9	0.32	11.5	$10.6^{+4}_{-2.8}$	0.42	0.2
50-	5.3 ± 2.9	5	0.24	8.8	$8.8^{+3.4}_{-1.9}$	0.53	−0.1



Lepton pairs and E_T^{miss} – slepton limits



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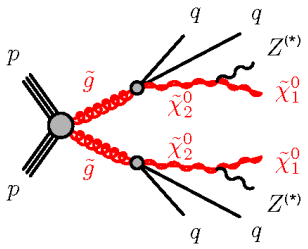
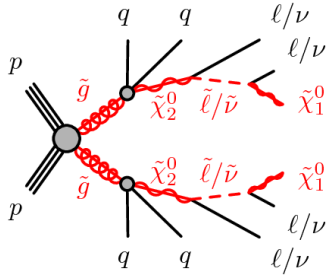
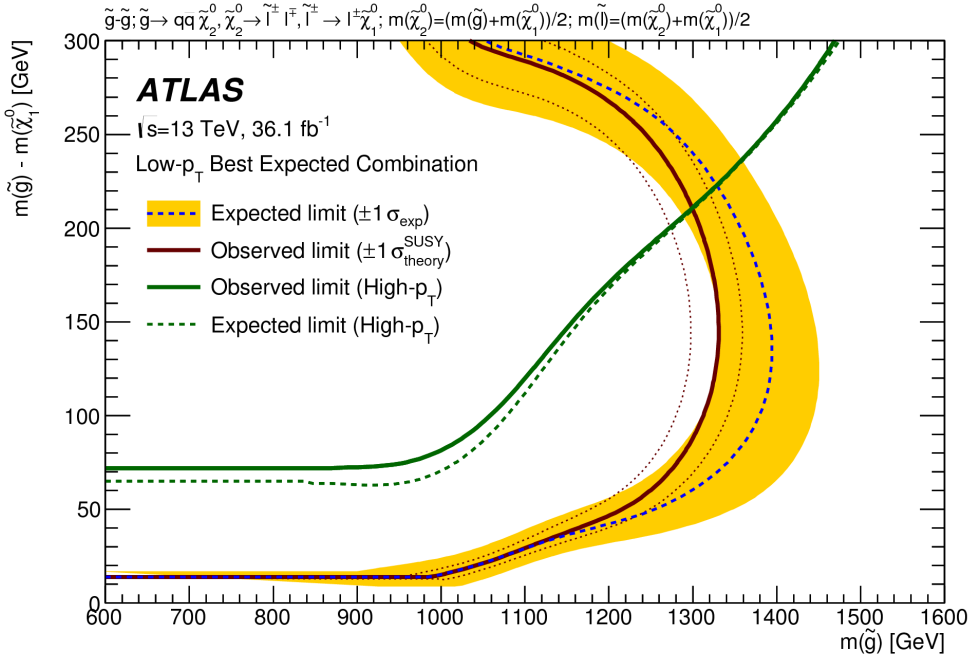
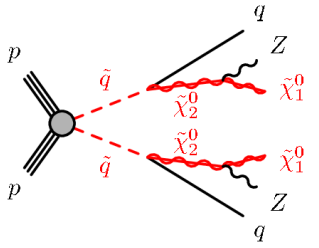
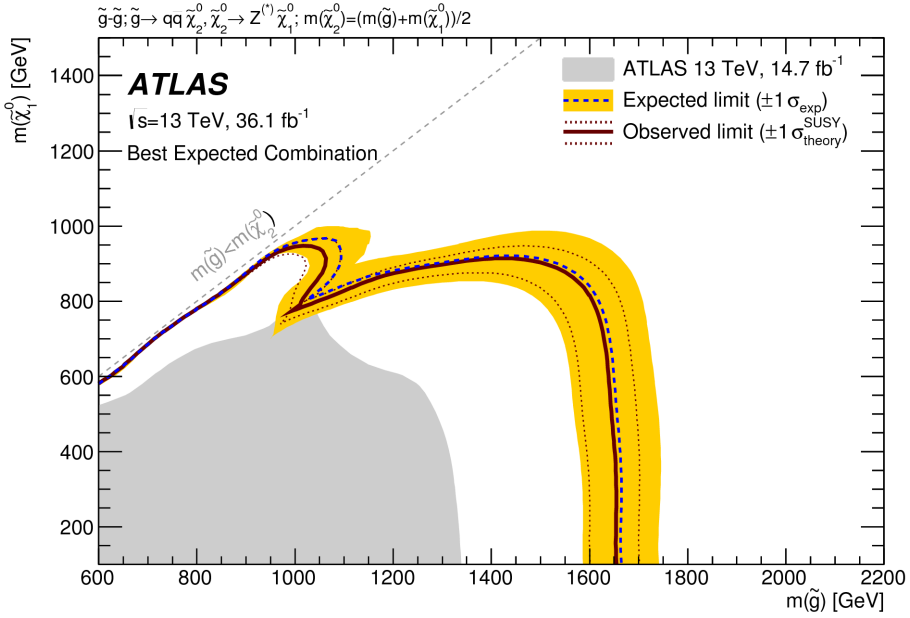








Lepton pairs and E_T^{miss} – $Z^{(*)}$ limits



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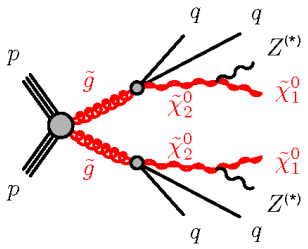
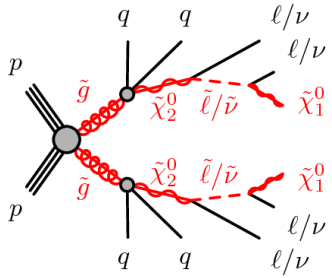
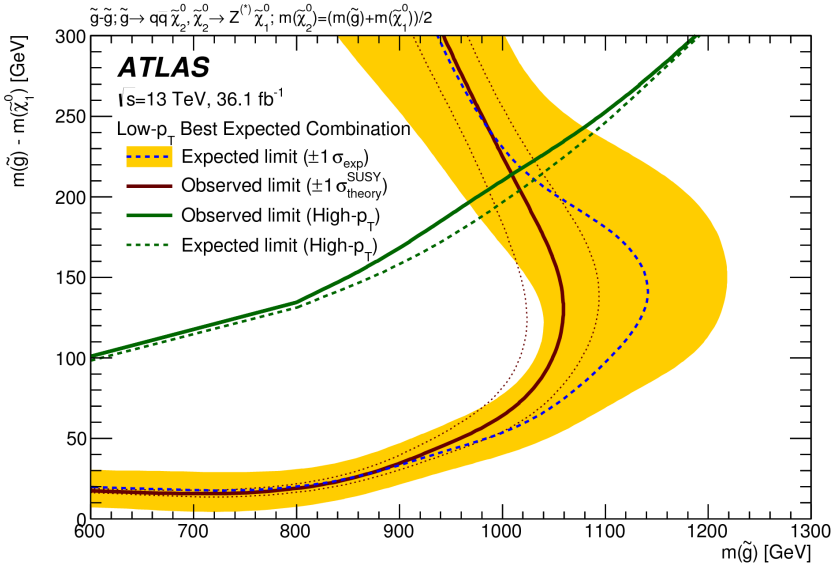
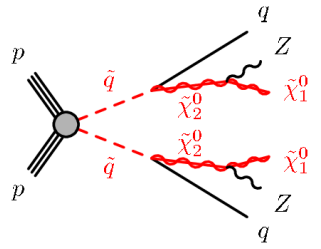


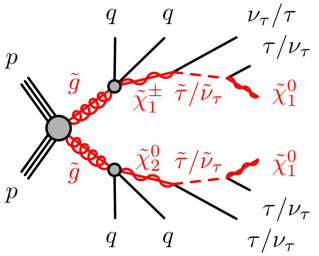


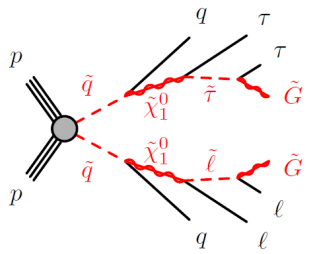


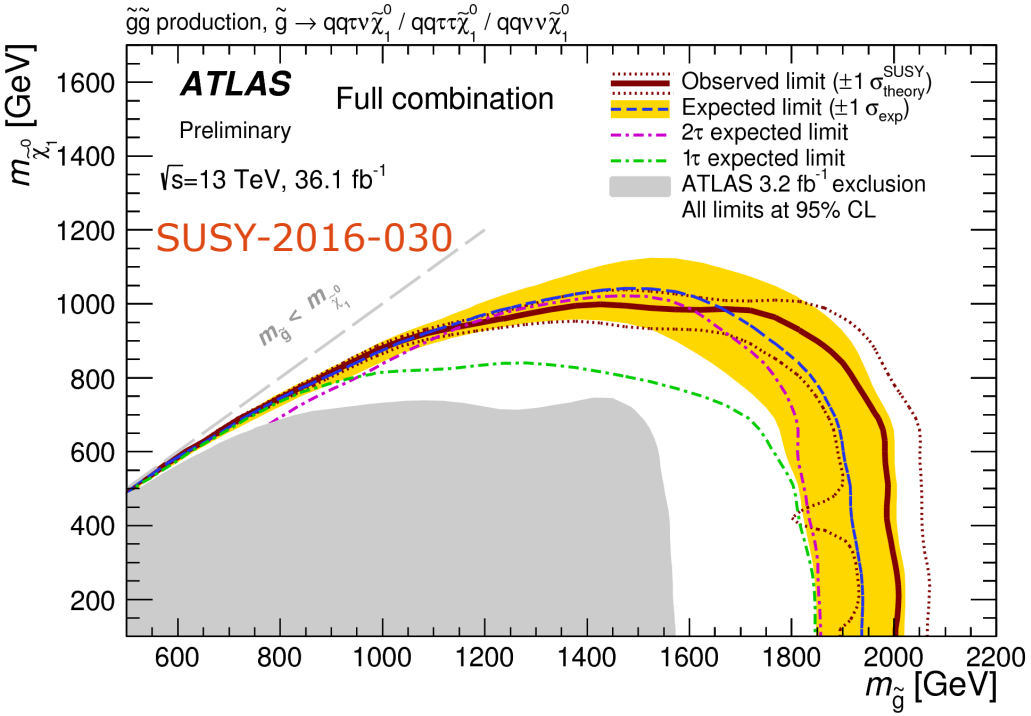


Tau leptons

- One or two hadronically decaying tau leptons.
- Target scenarios with neutralino LSP as well as neutralino NLSP and gravitino LSP.
- Limits on gluino mass reach 2 TeV with neutralino LSP.



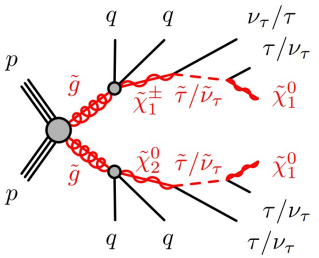


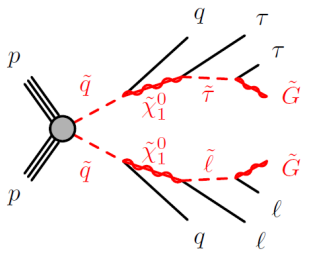


Tau leptons

NEW

- One or two hadronically decaying tau leptons.
- Target scenarios with neutralino LSP as well as neutralino NLSP and gravitino LSP.
- Limits on gluino mass reach 2 TeV with neutralino LSP.





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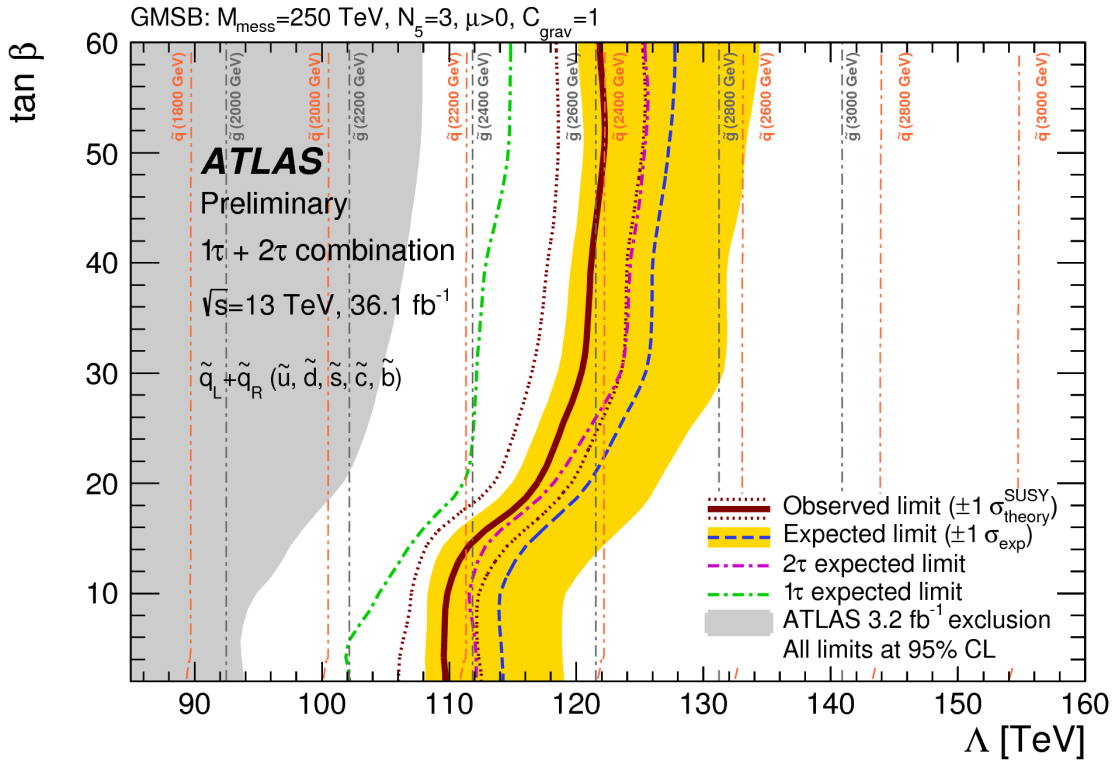

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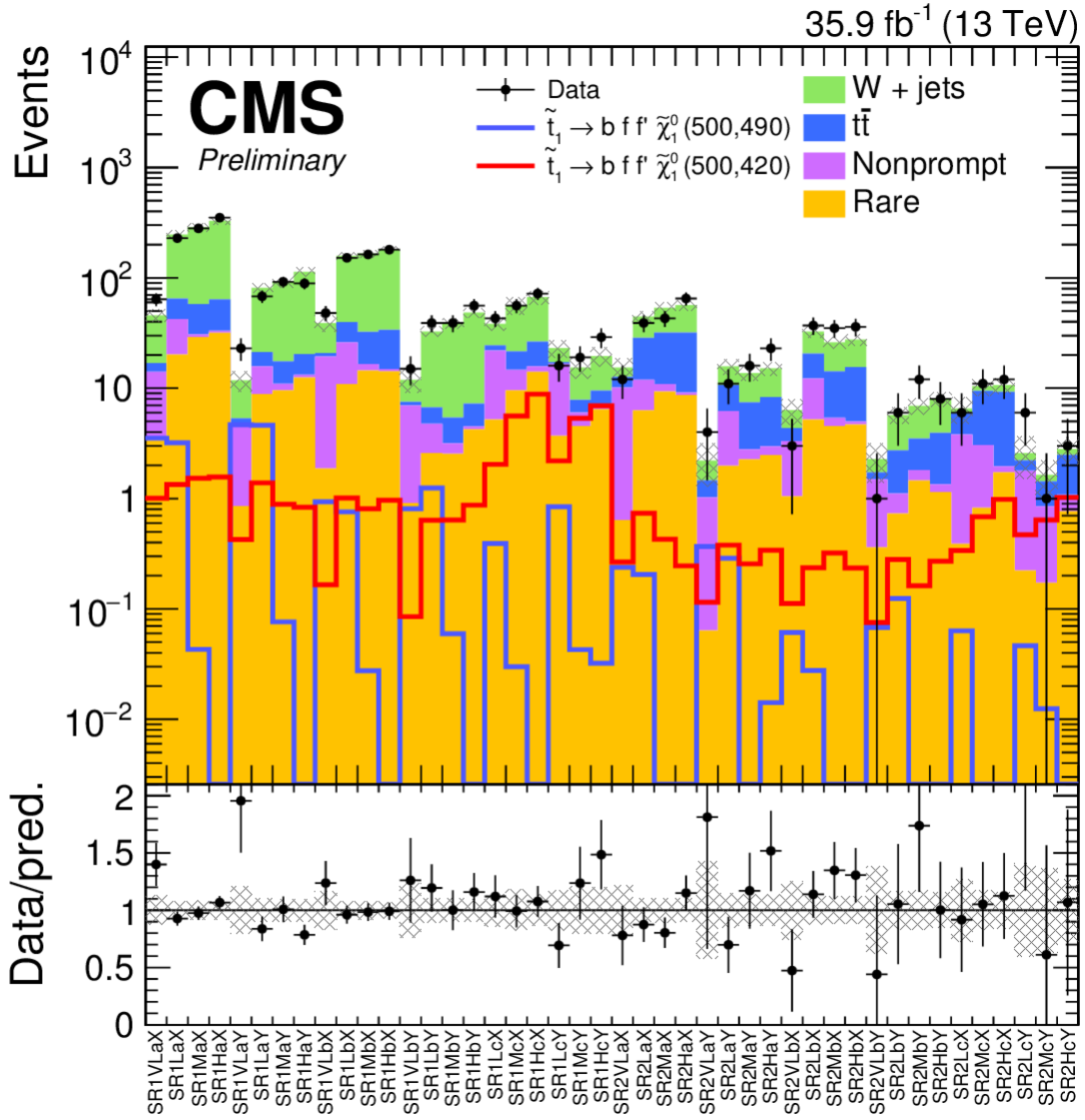

Chargino/neutralino production

- Search for chargino and neutralino production in final states with two or three charged leptons.
- Use recursive jigsaw reconstruction techniques.
- 3.0 σ excess in 3 lepton ISR selection (compressed scenarios).

NEW

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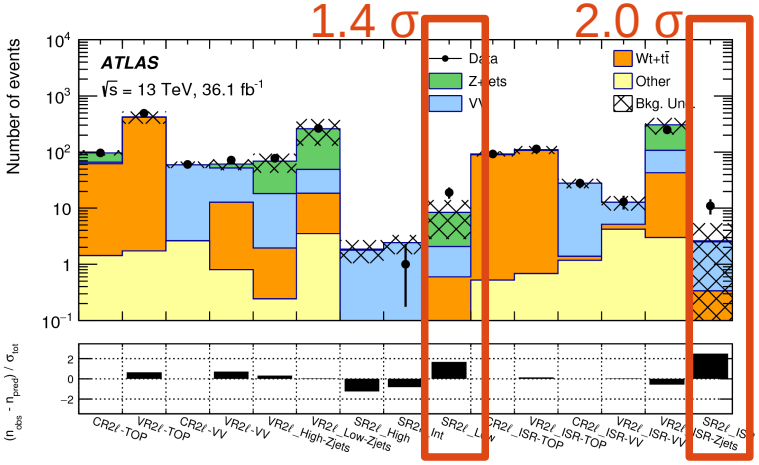

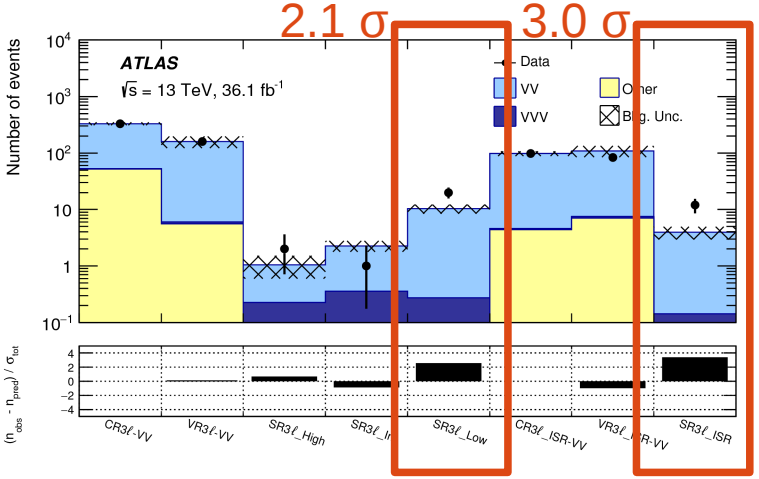

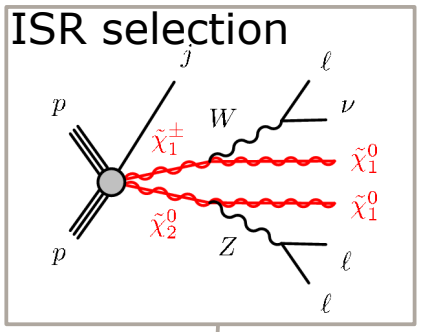

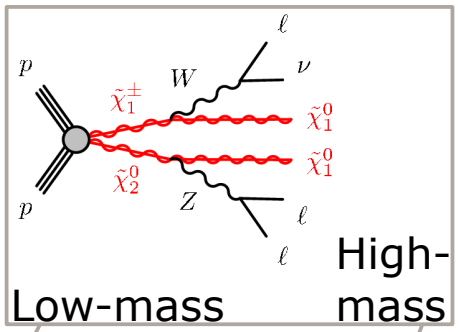

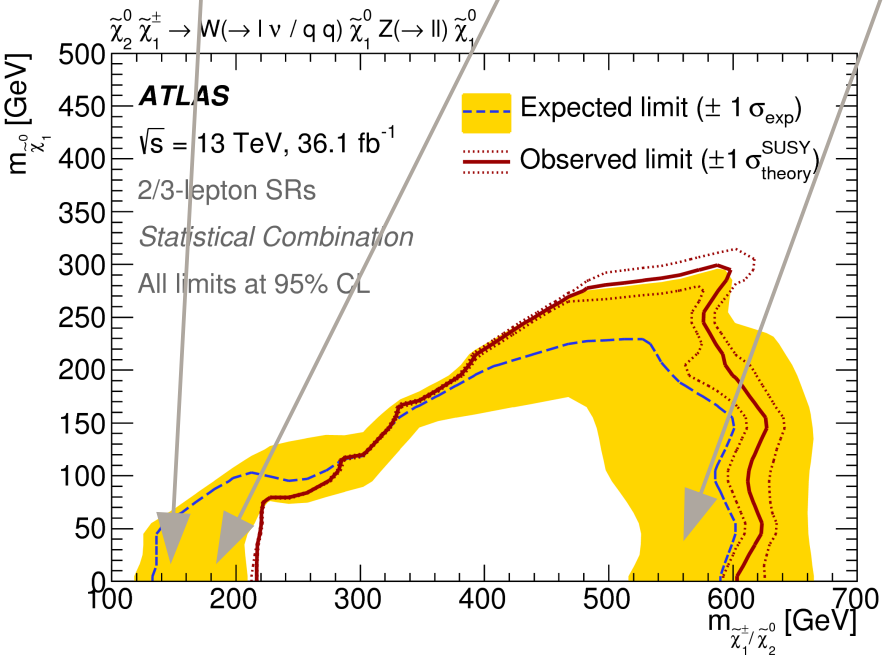

Chargino/neutralino production

NEW

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Region	m_Z [GeV]	m_J [GeV]	$\Delta\phi^{\mathrm{CM}}_{\mathrm{ISR,I}}$	R_{ISR}	$p^{\mathrm{CM}}_{\mathrm{T\ ISR}}$ [GeV]	$p^{\mathrm{CM}}_{\mathrm{T\ I}}$ [GeV]	$p^{\mathrm{CM}}_{\mathrm{T}}$ [GeV]
CR2ℓ_ISR-VV	$\in (80, 100)$	> 20	> 2.0	$\in (0.0, 0.5)$	> 50	> 50	< 30
CR2ℓ_ISR-Top	$\in (50, 200)$	$\in (50, 200)$	> 2.8	$\in (0.4, 0.75)$	> 180	> 100	< 20
VR2ℓ_ISR-VV	$\in (20, 80)$ or > 100	> 20	> 2.0	$\in (0.0, 1.0)$	> 70	> 70	< 30
VR2ℓ_ISR-Top	$\in (50, 200)$	$\in (50, 200)$	> 2.8	$\in (0.4, 0.75)$	> 180	> 100	> 20
VR2ℓ_ISR-Zjets	$\in (80, 100)$	< 50 or > 110	–	–	> 180	> 100	< 20
SR2ℓ_ISR	$\in (80, 100)$	$\in (50, 110)$	> 2.8	$\in (0.4, 0.75)$	> 180	> 100	< 20

Region	$m_{\ell\ell}$ [GeV]	m^W_{T} [GeV]	$\Delta\phi^{\mathrm{CM}}_{\mathrm{ISR,I}}$	R_{ISR}	$p^{\mathrm{CM}}_{\mathrm{T\ ISR}}$ [GeV]	$p^{\mathrm{CM}}_{\mathrm{T\ I}}$ [GeV]	$p^{\mathrm{CM}}_{\mathrm{T}}$ [GeV]
CR3ℓ_ISR-VV	$\in (75, 105)$	< 100	> 2.0	$\in (0.55, 1.0)$	> 80	> 60	< 25
VR3ℓ_ISR-VV	$\in (75, 105)$	> 60	> 2.0	$\in (0.55, 1.0)$	> 80	> 60	> 25
SR3ℓ_ISR	$\in (75, 105)$	> 100	> 2.0	$\in (0.55, 1.0)$	> 100	> 80	< 25

Chargino/neutralino production

Table 11: Expected and observed yields from the background fit for the 2ℓ VRs. The nominal predictions from MC simulation are given for comparison for the $Wt + t\bar{t}$ and VV backgrounds. The "Other" category contains the contributions from Higgs boson processes, $V\gamma$, VVV, $t\bar{t}V$ and non-prompt and non-isolated lepton production. The dashes indicate that these backgrounds are negligible and are included in the category "Other". Combined statistical and systematic uncertainties are given. The individual uncertainties can be correlated and do not necessarily add in quadrature to the total systematic uncertainty.

Region	VR2ℓ_Low-Zjets	VR2ℓ_High-Zjets	VR2ℓ-VV	VR2ℓ-Top	VR2ℓ_ISR-VV	VR2ℓ_ISR-Top	VR2ℓ_ISR-Zjets
Observed events	263	77	72	491	13	113	248
Total (post-fit) SM events	261 ± 130	69 ± 26	61 ± 13	423 ± 105	12 ± 4	110 ± 18	310 ± 100
Other	3.5 ± 1.5	$0.25^{+0.62}_{-0.25}$	0.80 ± 0.09	2.3 ± 0.4	4.2 ± 0.5	0.68 ± 0.22	3.0 ± 0.6
Fit output, $Wt + t\bar{t}$	15 ± 5	1.7 ± 0.7	12 ± 4	415 ± 105	–	107 ± 18	40 ± 8
Fit output, VV	30 ± 7	16 ± 3	40 ± 13	3.7 ± 0.9	7.9 ± 3.6	0.97 ± 0.25	67 ± 15
Z+jets	210 ± 130	51 ± 25	8.4 ± 4.1	2.4 ± 1.2	–	1.6 ± 0.8	200 ± 100
Fit input, $Wt + t\bar{t}$	16	1.9	13	455	–	108	41
Fit input, VV	33	17	43	4.1	8.4	1.1	71

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Chargino/neutralino production

Table 12: Expected and observed yields from the background fit for the 3ℓ CRs and VRs. The normalization factors for VV for the standard and compressed decay trees are different and are extracted from separate fits. The nominal predictions from MC simulation are given for comparison for the VV background. The "Other" category contains the contributions from Higgs boson processes, $t\bar{t}V$ and non-prompt and non-isolated lepton production. Combined statistical and systematic uncertainties are given. The individual uncertainties can be correlated and do not necessarily add in quadrature to the total systematic uncertainty.

Region	CR3ℓ-VV	VR3ℓ-VV	CR3ℓ_ISR-VV	VR3ℓ_ISR-VV
Observed events	331	160	98	83
Total (post-fit) SM events	331 ± 18	159 ± 37	98 ± 10	109 ± 24
Other	52 ± 2	5.6 ± 1.2	4.4 ± 1.2	7.1 ± 1.6
Tribosons	1.1 ± 0.1	0.44 ± 0.03	0.22 ± 0.14	0.42 ± 0.04
Fit output, VV	278 ± 18	153 ± 38	93 ± 10	102 ± 24
Fit input, VV	255	140	83	90

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Chargino/neutralino production

Table 13: Summary of the main systematic uncertainties and their impact (in %) on the total SM background prediction in each of the 2ℓ SRs. The total systematic uncertainty can be different from the sum in quadrature of individual sources due to the correlations between them resulting from the fit to the data.

Signal Region	SR2ℓ_High	SR2ℓ_Int	SR2ℓ_Low	SR2ℓ_ISR
Total uncertainty [%]	42	38	70	103
Z+jets data-driven estimate	42	31	69	96
VV theoretical uncertainties	28	27	6	34
MC statistical uncertainties	16	12	5	9
VV fitted normalization	13	14	2	16
FNP leptons	-	5	13	12
Jet energy resolution	5	10	4	3
Jet energy scale	1	2	< 1	3
$E_{\mathrm{T}}^{\mathrm{miss}}$ modeling	3	4	< 1	< 1
$t\bar{t}$ fitted normalization	< 1	< 1	2	2
Lepton reconstruction / identification	< 1	< 1	< 1	< 1

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Chargino/neutralino production

Table 14: Summary of the main systematic uncertainties and their impact (in %) on the total SM background prediction in each of the 3ℓ SRs. The total systematic uncertainty can be different from the sum in quadrature of individual sources due to the correlations between them resulting from the fit to the data.

Signal Region	SR3ℓ_High	SR3ℓ_Int	SR3ℓ_Low	SR3ℓ_ISR
Total uncertainty [%]	44	22	19	26
VV theoretical uncertainties	18	9	12	19
MC statistical uncertainties	37	17	8	10
VV fitted normalization	8	7	9	11
FNP leptons	7	< 1	3	5
Jet energy resolution	4	< 1	7	3
Jet energy scale	7	< 1	2	3
$E_{\mathrm{T}}^{\mathrm{miss}}$ modeling	2	< 1	1	4
Lepton reconstruction / identification	3	4	2	2

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Chargino/neutralino production

Table 15: Expected and observed yields from the background-only fit for the 2ℓ SRs. The errors shown are the statistical plus systematic uncertainties. Uncertainties in the predicted background event yields are quoted as symmetric, except where the negative error reaches down to zero predicted events, in which case the negative error is truncated.

Signal region	SR2ℓ_High	SR2ℓ_Int	SR2ℓ_Low	SR2ℓ_ISR
Total observed events	0	1	19	11
Total background events	1.9 ± 0.8	2.4 ± 0.9	8.4 ± 5.8	$2.7^{+2.8}_{-2.7}$
Other	0.02 ± 0.01	$0.05^{+0.12}_{-0.05}$	$0.02^{+1.07}_{-0.02}$	$0.06^{+0.33}_{-0.06}$
Fit output, $Wt + t\bar{t}$	0.00 ± 0.00	0.00 ± 0.00	0.57 ± 0.20	$0.28^{+0.34}_{-0.28}$
Fit output, VV	1.8 ± 0.7	2.4 ± 0.8	1.5 ± 0.9	2.3 ± 1.1
Z+jets	$0.07^{+0.78}_{-0.07}$	$0.00^{+0.74}_{-0.00}$	6.3 ± 5.8	$0.10^{+2.58}_{-0.10}$
Fit input, $Wt + t\bar{t}$	0.00	0.00	0.63	0.28
Fit input, VV	1.9	2.6	1.6	2.4

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Chargino/neutralino production

Table 16: Expected and observed yields from the background-only fit for the 3ℓ SRs. The errors shown are the statistical plus systematic uncertainties. Uncertainties in the predicted background event yields are quoted as symmetric, except where the negative error reaches down to zero predicted events, in which case the negative error is truncated.

Signal region	SR3ℓ_High	SR3ℓ_Int	SR3ℓ_Low	SR3ℓ_ISR
Total observed events	2	1	20	12
Total background events	1.1 ± 0.5	2.3 ± 0.5	10 ± 2	3.9 ± 1.0
Other	$0.03^{+0.07}_{-0.03}$	0.04 ± 0.02	$0.02^{+0.34}_{-0.02}$	$0.06^{+0.19}_{-0.06}$
Triboson	0.19 ± 0.07	0.32 ± 0.06	0.25 ± 0.03	0.08 ± 0.04
Fit output, VV	0.83 ± 0.39	1.9 ± 0.5	10 ± 2	3.8 ± 1.0
Fit input, VV	0.76	1.8	9.2	3.4

NEW

1806.02293

Chargino/neutralino production

Table 18: Breakdown of the observed and expected (in parentheses) number of events in terms of flavor composition in the SRs with an excess.

Signal region	SR2ℓ_Low	SR2ℓ_ISR
ee	9 (4.5±3.9)	3 (1.2±1.2)
$\mu\mu$	10 (3.9±2.6)	8 (1.5±1.5)
Signal region	SR3ℓ_Low	SR3ℓ_ISR
eee	6 (3.5±0.7)	3 (1.1±0.3)
$ee\mu$	6 (2.0±0.4)	3 (0.9±0.3)
$\mu\mu\mu$	7 (2.7±0.6)	4 (1.5±0.4)
$\mu\mu e$	1 (1.9±0.4)	2 (0.4±0.1)

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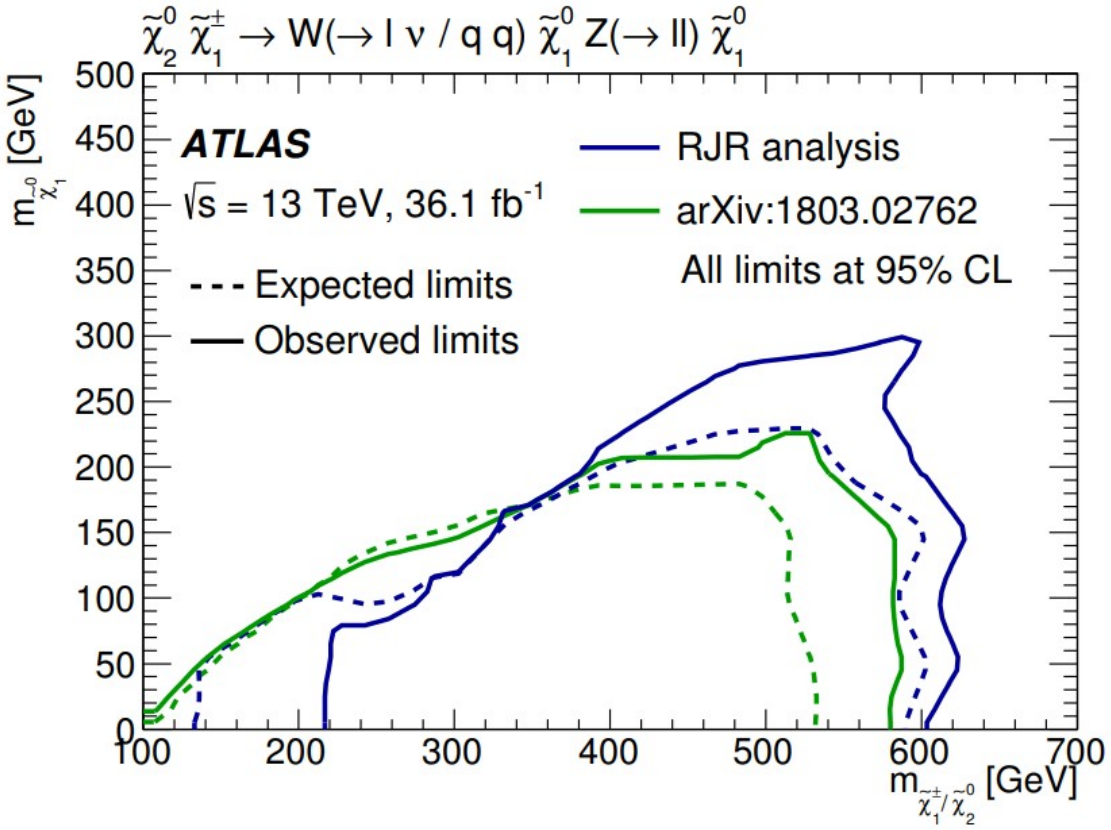
Chargino/neutralino production



NEW

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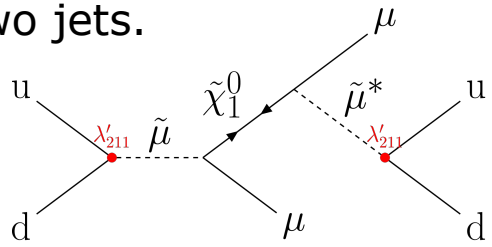
Second generation sleptons

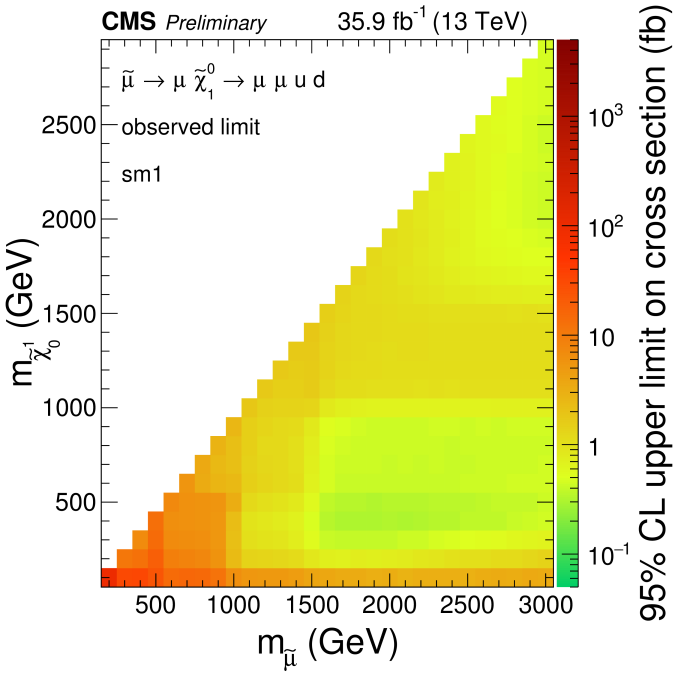
NEW

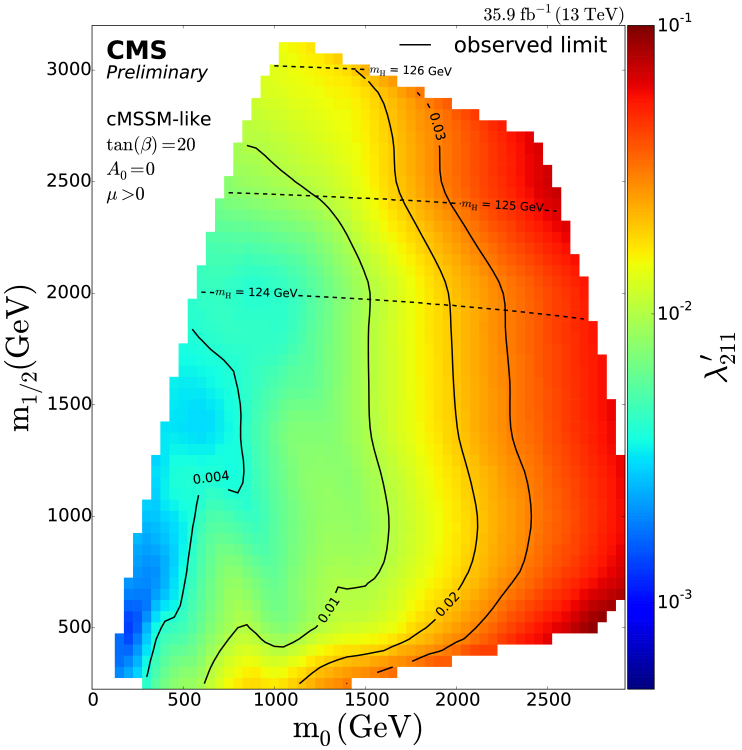
CMS-PAS-SUS-17-008

- Search for resonant production of second generation sleptons via RPV coupling.
- Final state with two same-sign muons and at least two jets.



simplified model 1

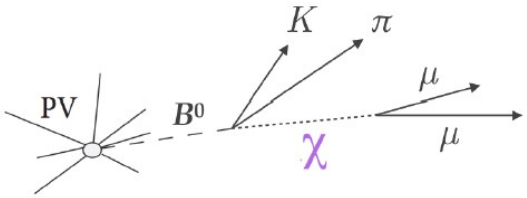




- Upper limit on cross section translated to upper limit on λ'_{211} coupling strength in cMSSM with λ'_{211} as additional coupling.

Semileptonic LLP decays

- Search for long-lived particles through a displaced vertex with several tracks including a high p_T muon.
- Forward coverage ($2<\eta<5$) and low trigger p_T threshold gives sensitivity to small LLP masses.
- Cover LLP lifetimes from 5 ps up to 100 ps and masses in the range 20–80 GeV.



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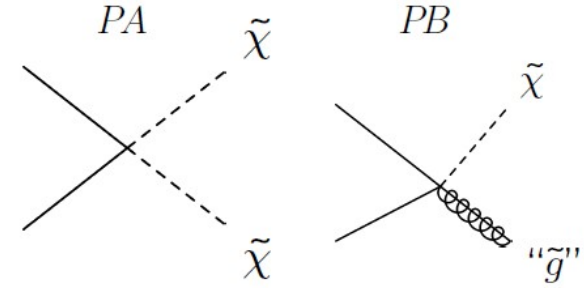
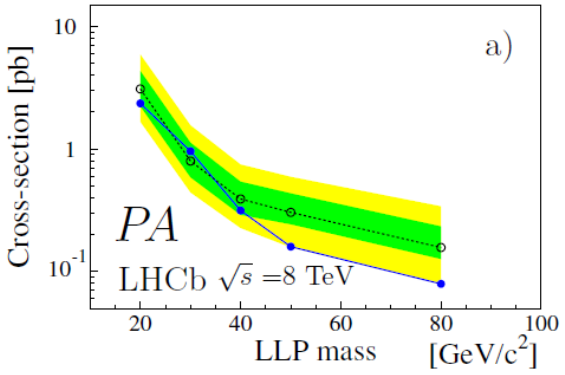
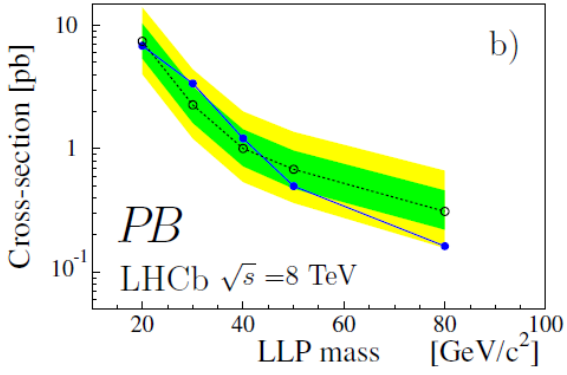
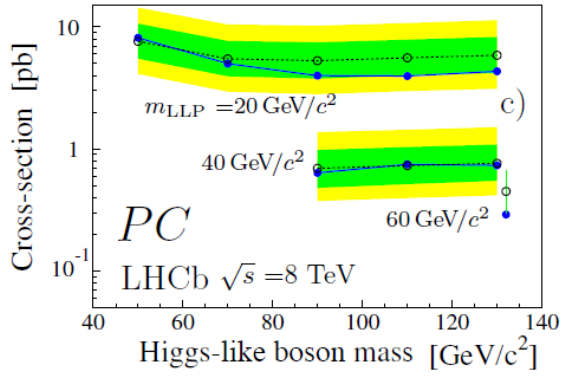
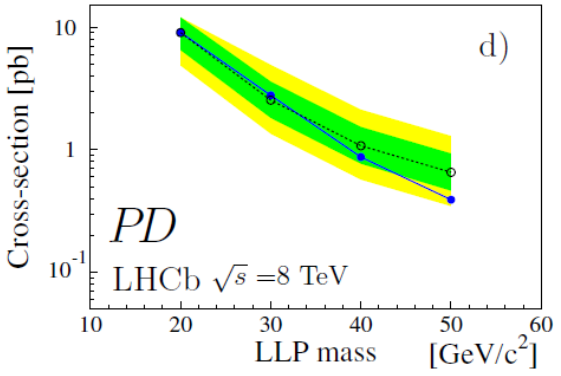










- Also neutralino production in RPV models with mass in 23-98 GeV range.

SUSY search methods

- **Objects and observables to enrich S/B:**

Standard objects
- (soft) isolated leptons
- (b) jets
- E_T^{miss}
- …

Displaced objects
- displaced vertices
- disappearing tracks
- …

Boosted objects
- jet substructure
- W, Z, h, top taggers
- topness
- …

Hadronic energy
- m_{eff}
- H_T
- …

Kinematic variables
- invariant mass
- m_T
- m_{T2}
- …

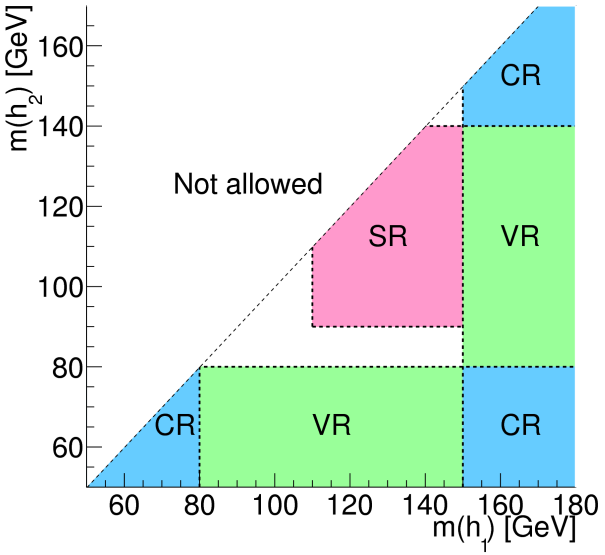
Event kinematics
- razor variables
- recursive jigsaw reconstruction
- …

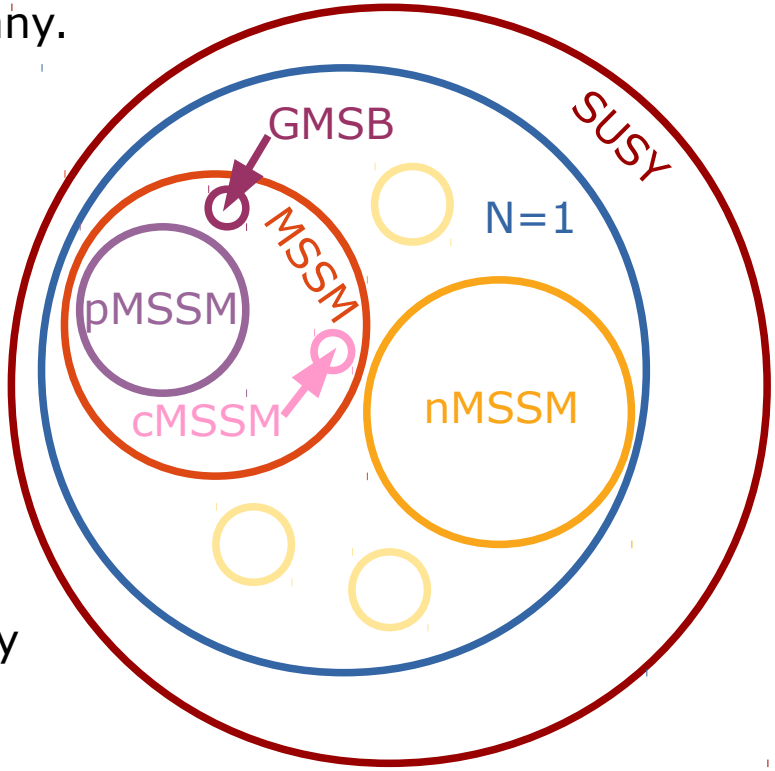
- **Background estimates:**

Reducible backgrounds from data (e.g. matrix method)

Dominant irreducible backgrounds from MC, normalized in data control region (CR). Extrapolated to signal region (SR) after test in validation region (VR)

Sub-dominant irreducible backgrounds from MC only



Which SUSY?

- SUSY is not one model, rather infinitely many.
- MSSM
  - Minimal new particle content.
  - No assumption on SUSY breaking → 120 additional free parameters.
- pMSSM
  - Reduce MSSM to 19 free parameters by imposing phenomenological and experimental constrains.
- cMSSM
  - Reduce MSSM to 5 free parameters by assuming universality at GUT scale.
- GMSB/AMSB
  - Reduce MSSM to 5 free parameters by assuming SUSY breaking mechanism.
- NMSSM
  - Extend MSSM by adding an additional singlet chiral superfield.
- Simplified Models
  - Masses of non-relevant SUSY particles are put very large.
  - 100% BR to single final state.