Experimental SUSY overview

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for the ATLAS, CMS and LHCb Collaborations

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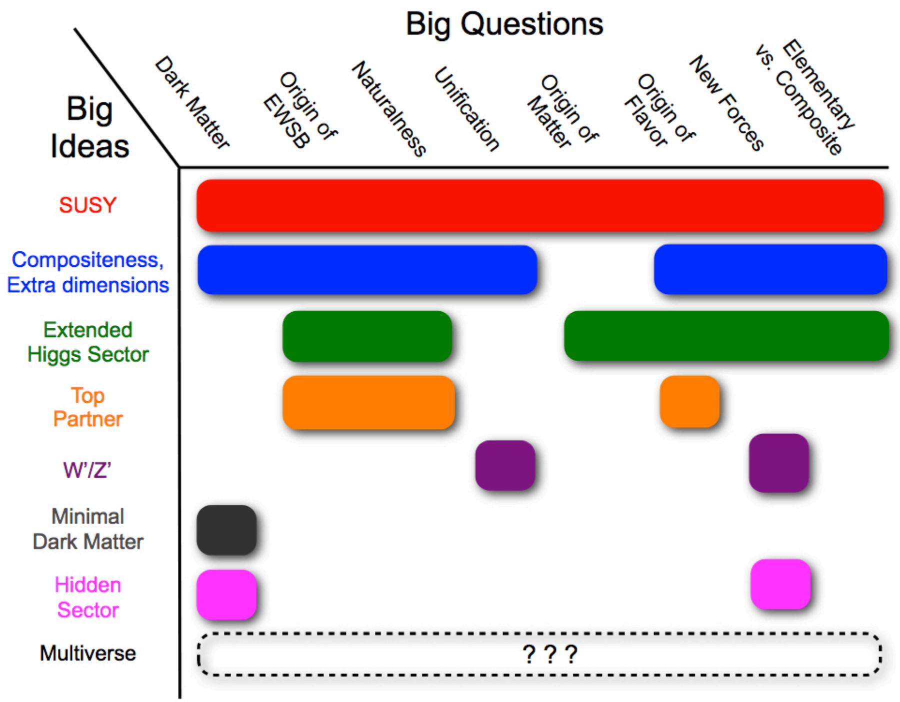
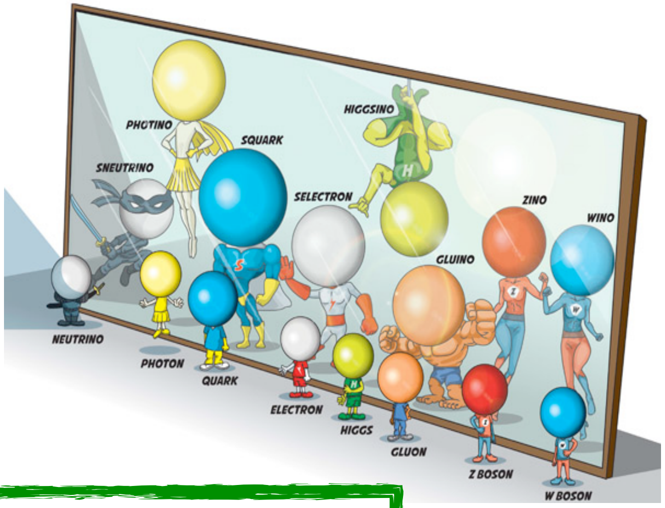
What Supersymmetry can do for you ?

arXiv:1311.0299

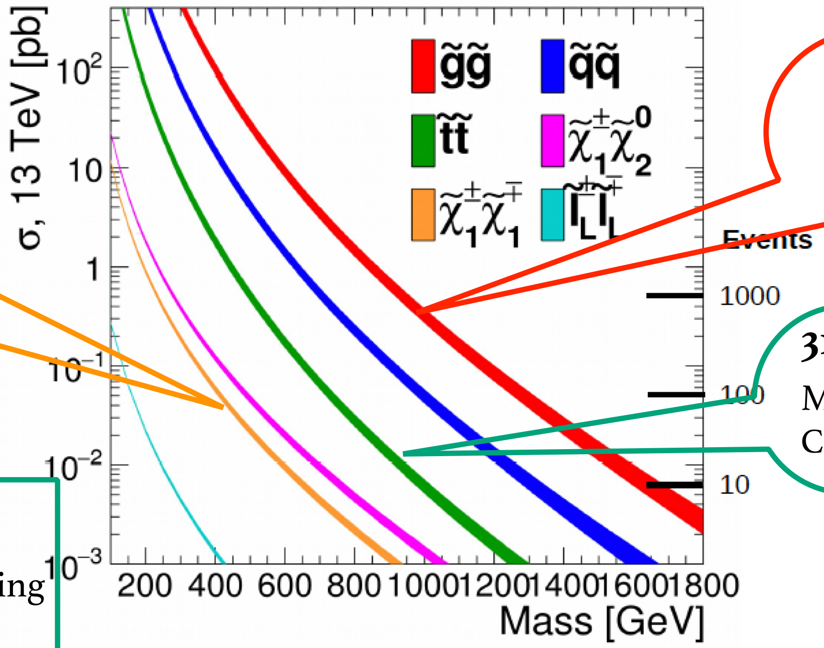


- **SUSY is one of the most promising theories we have for new physics**
  - ✓ Stabilises the EW scale
  - ✓ Predicts a light higgs w. $m_h < 130$ GeV
  - ✓ Accommodates heavy top quark
  - ✓ …



- ✓ Each SM particle, gets a new super-partner
- ✓ SUSY must be a broken symmetry (heavy s-particles)
- ✓ R-parity $R = (-1)^{3(B-L)+2s}$ If conserved :
  - SUSY particles are produced in pairs
  - The lightest SUSY particle (LSP) is stable, making it the perfect DM candidate

Introduction



Electroweak Production

Small production cross section

Often targeting small mass splitting

Strong Production

High production xsec

Mostly inclusive searches

3rd gen. production

More targeted analyses

Can be lighter than other squarks

Long-lived analysis

Displaced jets/ℓ and disappearing tracks, delayed γ

(B.Gomber plenary talk)

R-parity Conservation (RPC)

Stable LSP, sparticles produced in pairs

R-parity Violation (RPV)

More leptons /jet, small p_T^{miss}

Impossible to overview all of them today.

Reporting only full Run 2 new results

See also EW SUSY (C.Cid), Soft SUSY (M.Zarucki), 3rd Gen (M.Hodgkinson), RPV (I.Dyckes) talks.

Although, LHCb has no recent SUSY results, its worth mentioning MSSM searches, long-lived particles and BSM scalars (low mass di-muon region).

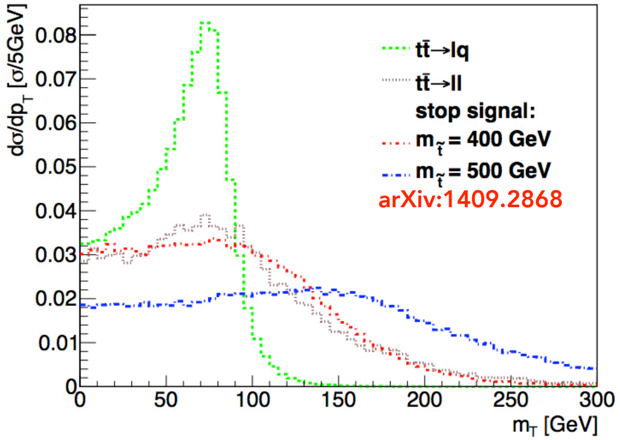
How to look for SUSY

The challenge: *SUSY comes w. small production cross-section.*

Strategy:

- SUSY : p_T^{miss} , high p_T objects like multi jets and multi b jets
- Build variables exploiting the above
  - *example* : in m_T , semi-leptonic tt have a kinematic endpoint
- Search Regions vs sensitive variables to optimize reach
  - Further optimization vs number of leptons/γ etc

$$m_T^2 = 2p_T^{miss} p_T^{\ell}[1 - cos\Delta\phi(\ell, p_T^{miss})]$$



arXiv:1409.2868

Roadmap

Standard Model processes

tt, W+jets, DY, VV, tt+X …

Irreducible sources

Shape from MC,

yield from control region

Reducible sources

Estimated from data, many different methods

Typical : lost ℓ, mismeasured p_T^{miss}/jets etc

Validation Regions

Perform closure tests before unblinding

Search regions

Used to extract signal

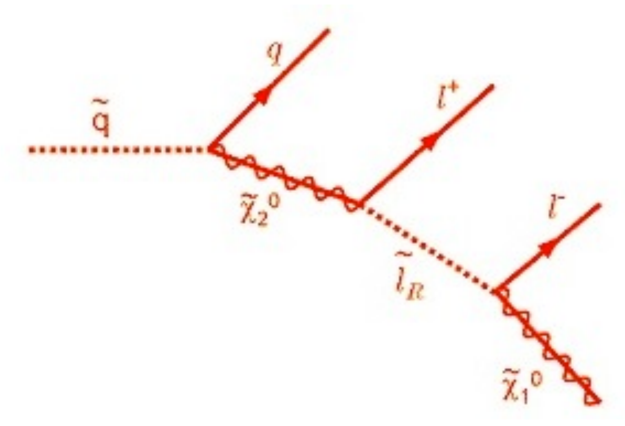
SUSY sensitive variables

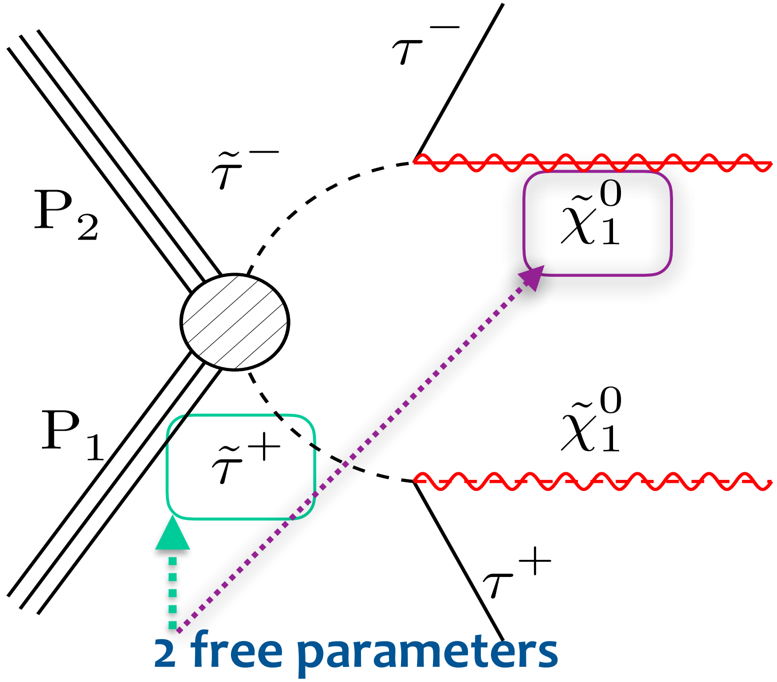
Interpretations

The challenge: *Long cascade decays can have many free parameters*

***Experimentalist's approach*:**

- Simpler decay chains ➙ Simplified Models of Supersymmetry (SMS)
  - Specific decay chain producing a well defined final state/topology
  - Interpretations are much easier





2 free parameters

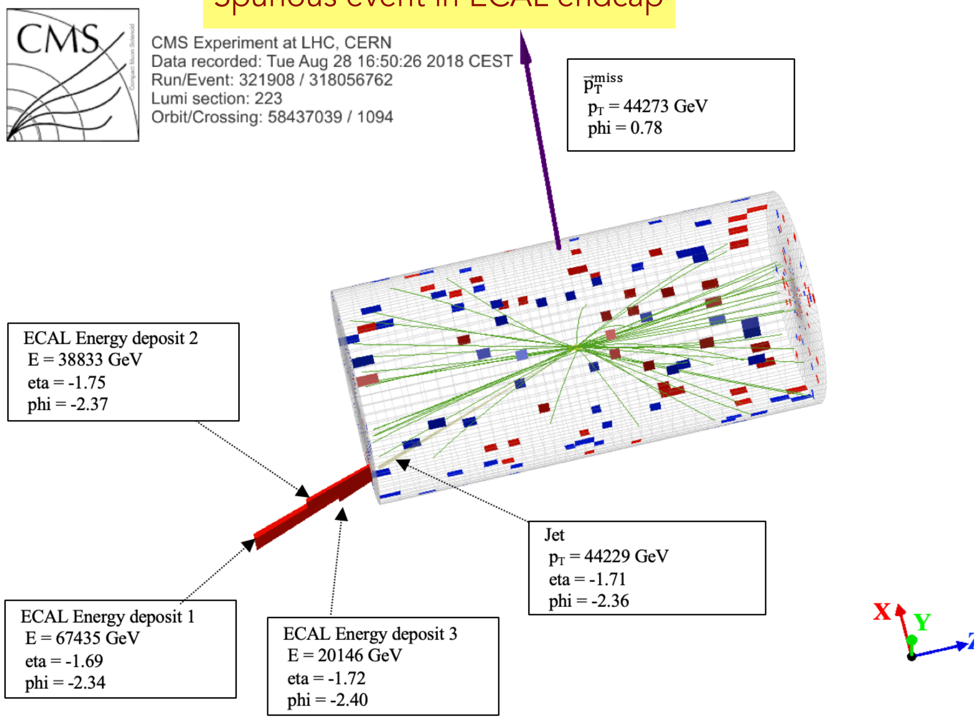
The experimentalists challenge

Understanding the detector is of paramount importance

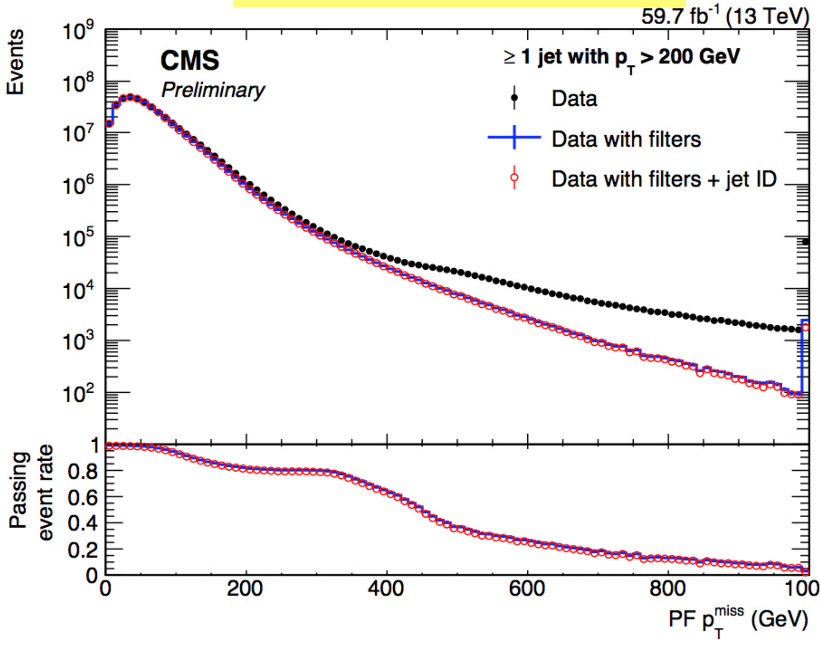
- Detector effects can result into mismeasured p^T_{miss}, jets and “fake" objects.
- Dedicated efforts to understand better the detector’s performance.
  - Tedious task, can span over long periods.
  - Derive offline “patches/filters” to exclude noisy events from analyses.

NEW

Spurious event in ECAL endcap



Effects of offline p_T^{miss} “filters"



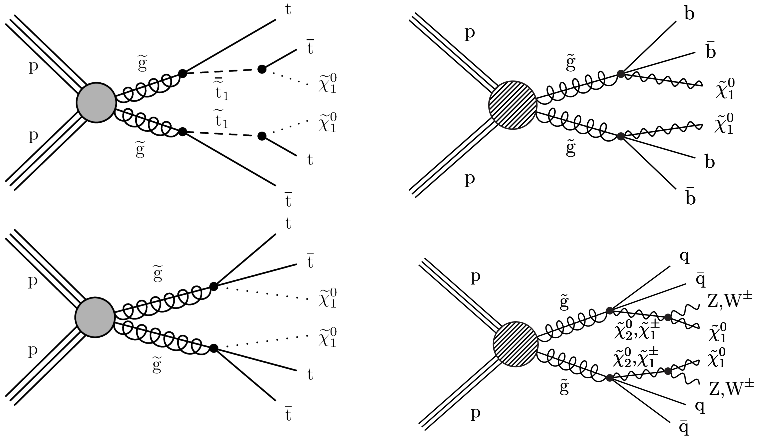
CMS DP2020-018

Gluinos/Squarks production

Gluinos, 1rst/2nd generation squarks pair production

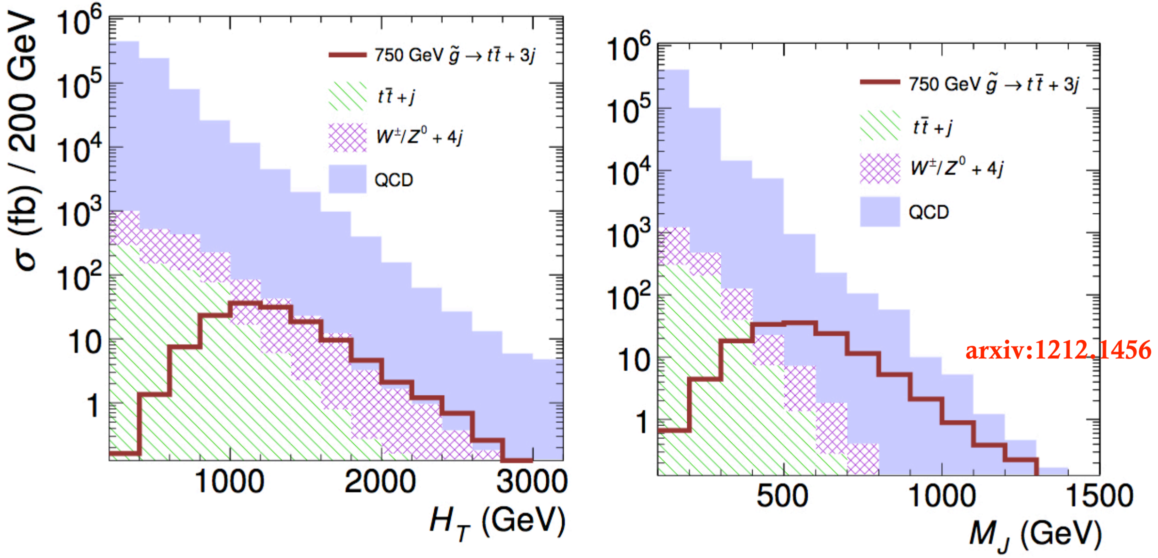
Very rich phenomenology, signatures typically include:

- ✓ large p_T^{miss}, 0➞3 leptons,
- ✓ multi jets, multi b-tag jets, photons



Typically, sensitive variables like H_T, Mj aim capturing the hadronic activity,

$$H_T = \sum_{j=1}^{N_j} p_T^j \qquad M_j = \sum_{j=1}^{N_j} m_j$$



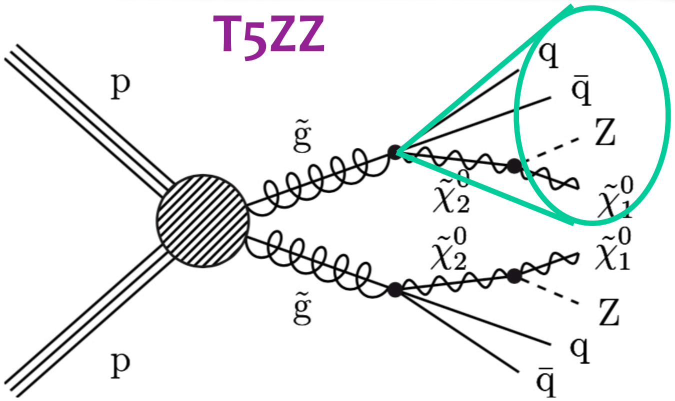
arxiv:1212.1456

CMS-SUS-19-013

0-ℓ with boosted Z+p_T^{miss}

NEW

T5ZZ



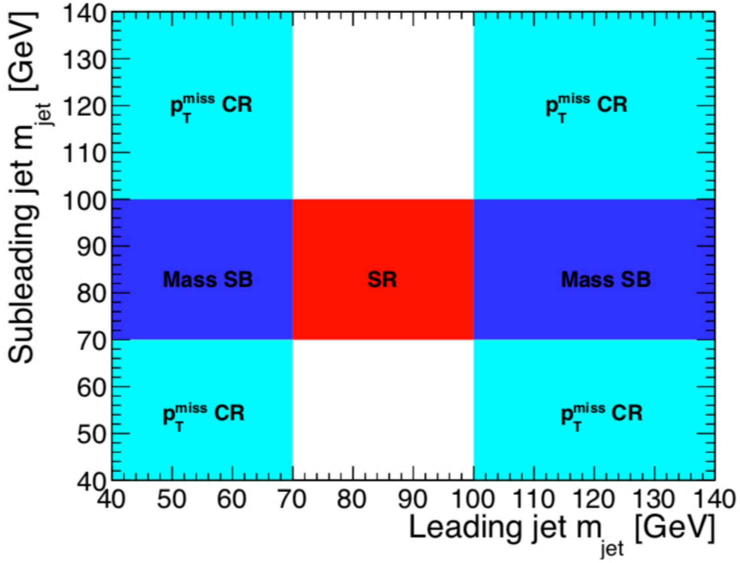
$$\left.\begin{aligned}\Delta m(\tilde{g},\tilde{\chi}_2^0) &= 50\ \text{GeV}\\ m(\tilde{\chi}_1^0) &= 1\ \text{GeV}\end{aligned}\right\}$$

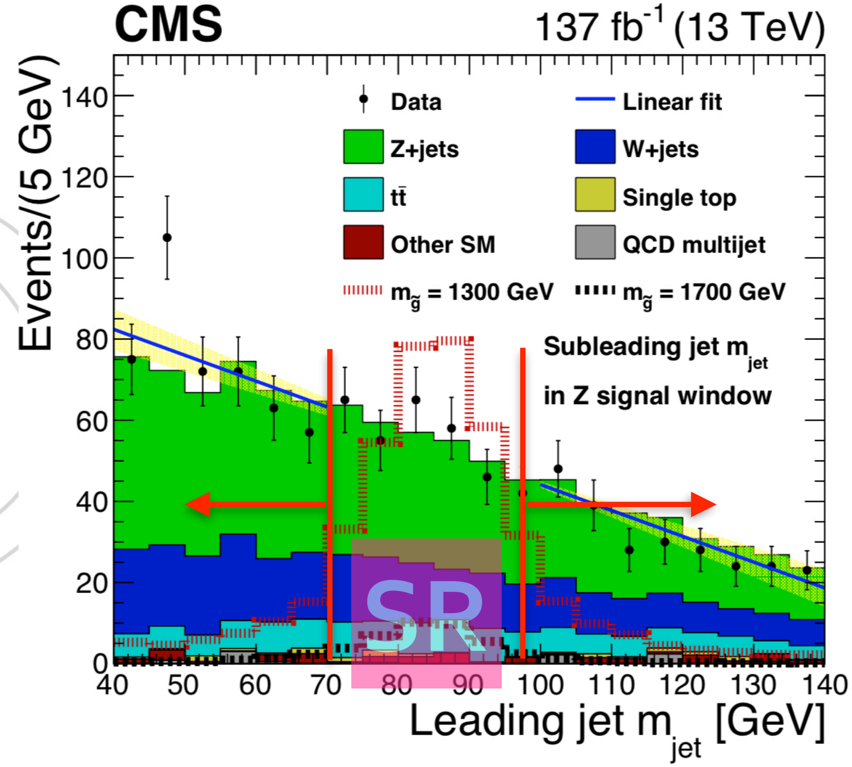
Boosted Z with large p_T^{miss}

Z Boson decay products can be contained in a large radius jet

Optimized cuts to "capture" *Z→jets candidates*

- Mass SB : estimate background normalization
- p_T^{miss} CR : derive p_T^{miss} shape

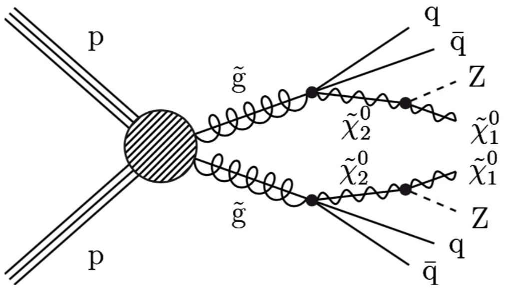




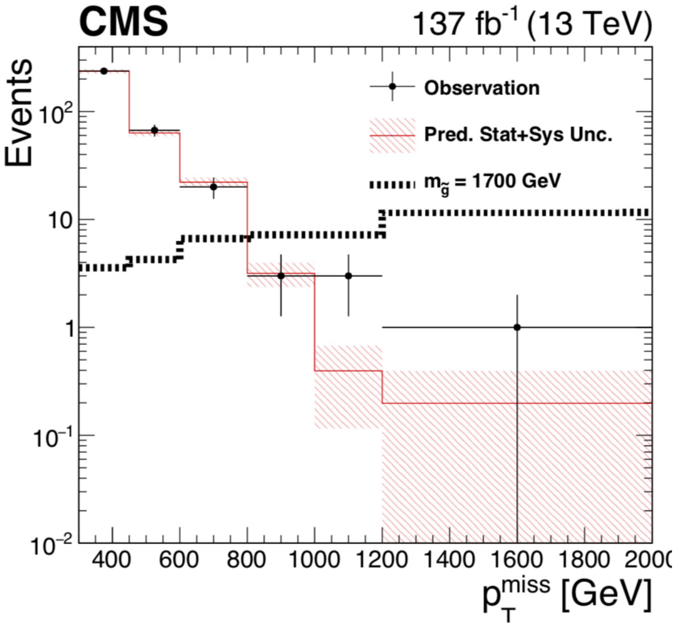
CMS-SUS-19-013

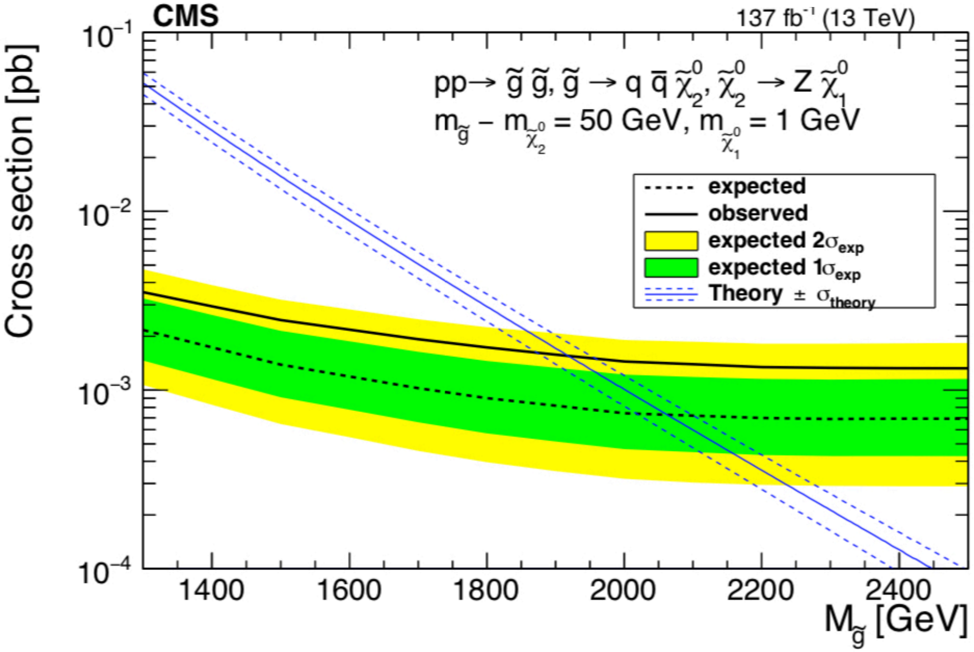
0-ℓ with boosted Z+p_T^{miss}

NEW



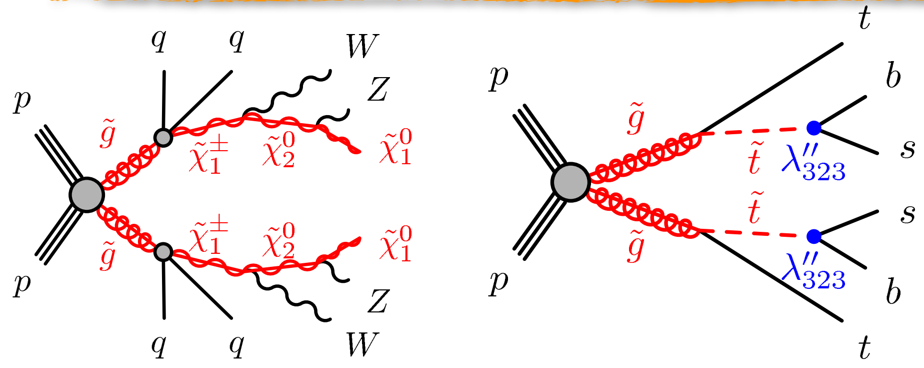
Results





Excluding gluinos up to ~1.9 TeV

0-ℓ with jets and p_T^{miss}



Baryon number violation model

$$\tilde{t}_1 \rightarrow s + b$$
$$\tilde{t}_1 \rightarrow d + b$$

multi-jets (>7) + b tag jets + p_T^{miss}

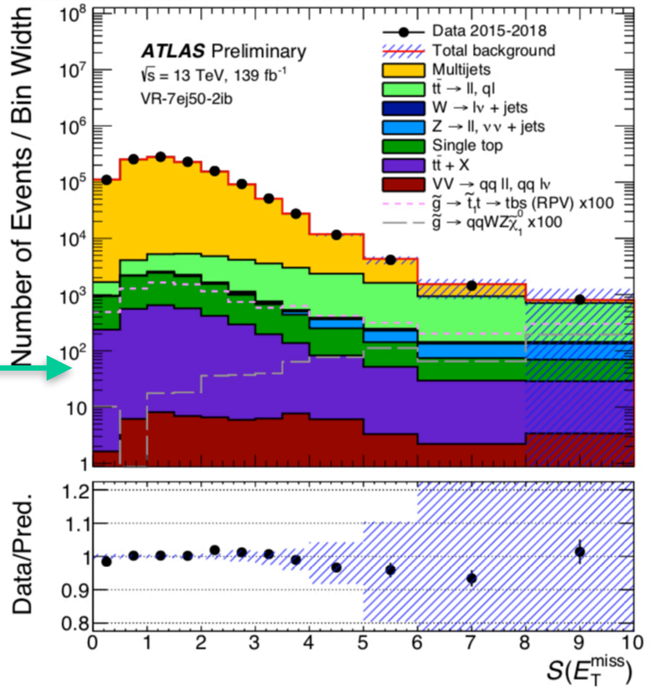
- Search regions in bins of (N_j, $N_{b\ tag}$, Mj)

Use of p_T^{miss} Significance (*S*) : Quantifies how compatible p_T^{miss} is with non-interacting particles

Large radius jets mass : Can characterise signal events

QCD : Semi-leptonic b/c-hadrons, jet mismeasurements etc. Estimated from in low-jet-multiplicity CR validated in VR

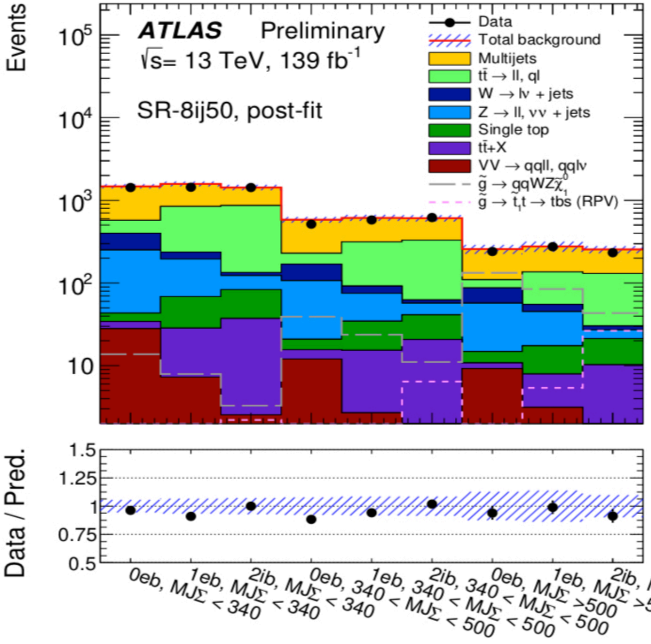
Top, W+jets : Genuine p_T^{miss}. Using MC validated in 1ℓ CRs



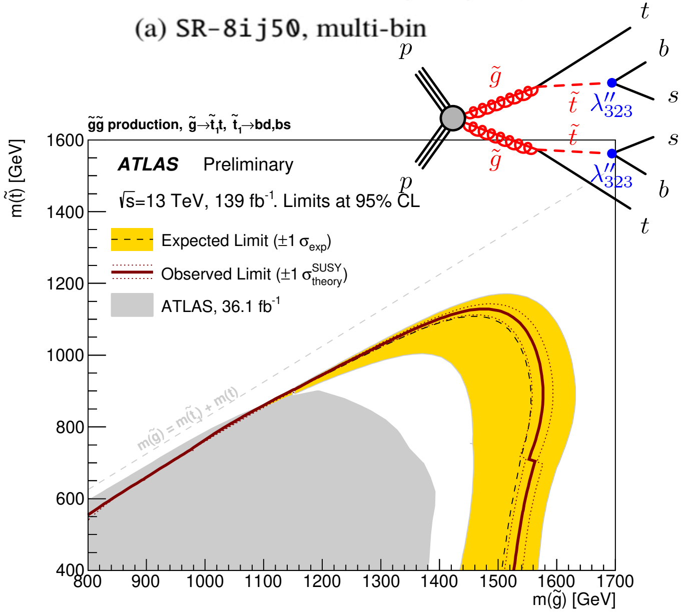
(a) $N_{jet}^{50} = 7$, $N_{b\text{-jet}} \geq 2$

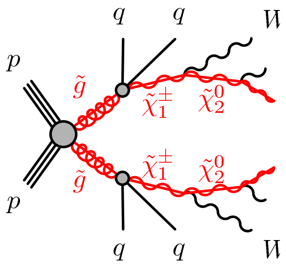
0-ℓ with jets and p_T^{miss}

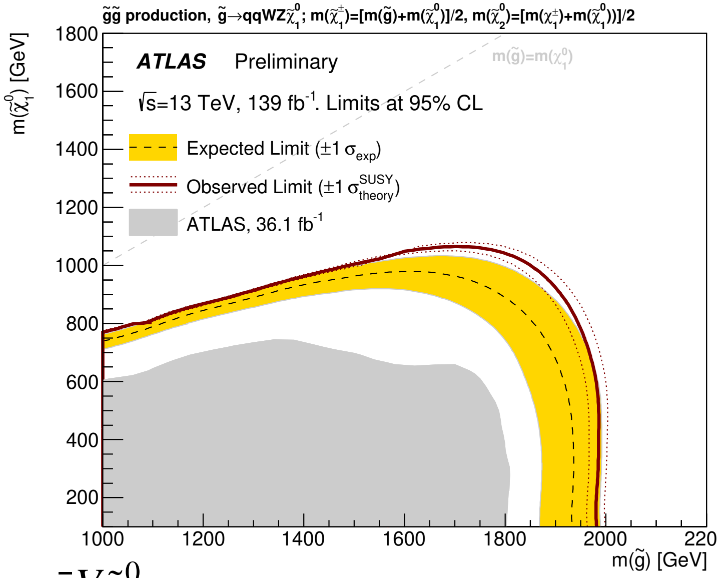
Yields



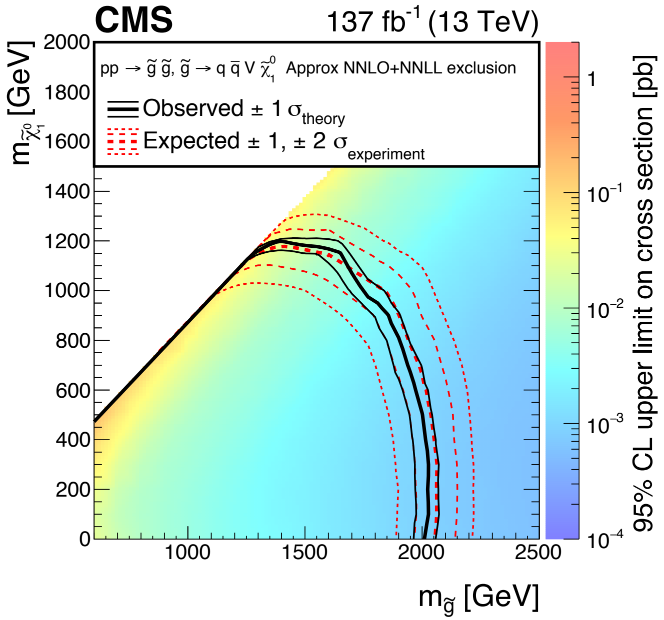
(a) SR-8ij50, multi-bin







$\tilde{g} \to q\bar{q}V\tilde{\chi}^0_1$



10.1007/JHEP10(2019)244

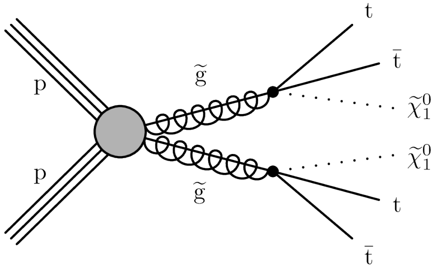
Very comparable results from ATLAS/CMS

CMS-SUS-19-007

1-ℓ with m_T and M_J

10.1103/PhysRevD.101.052010

T1tttt



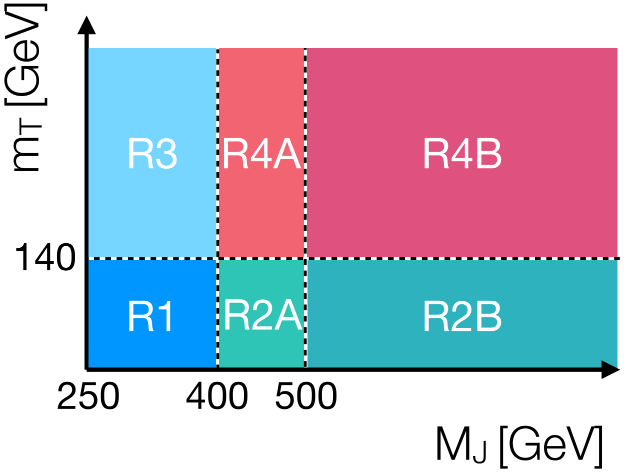
1ℓ + multi-jets + b tag jets + p_T^{miss} signature

- Benefit from large cross-section and the presence of ISR jets

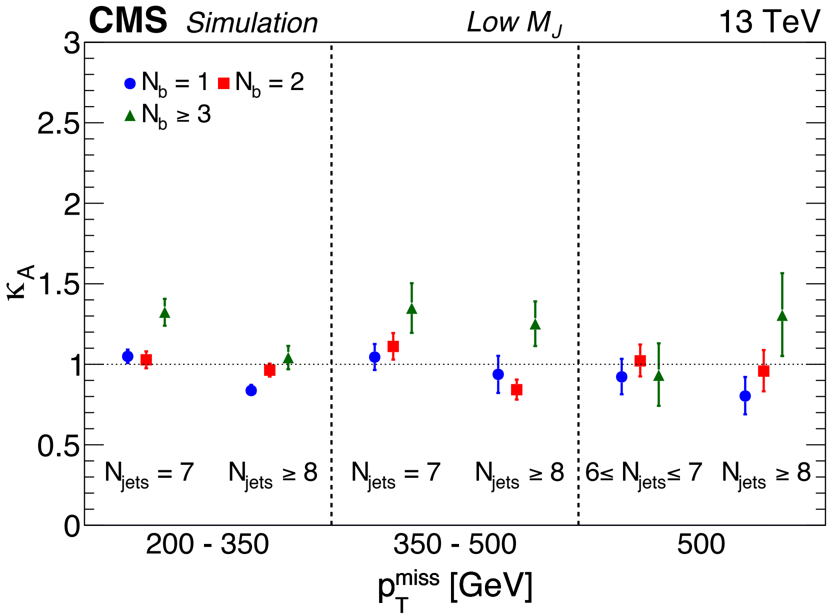
Multiple search/control regions vs (M_J, m_T, p_T^{miss}, N_j, N_{btag})

R1-3 : Bkg dominated

R4 : SR



k-factors : quantify correlation of m_T vs M_J

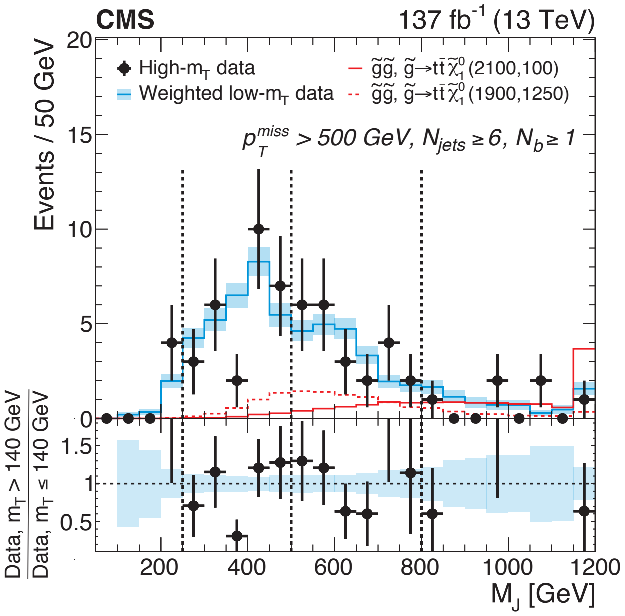


Estimation of bkg : Mainly tt events; estimated from data in a low m_T CR

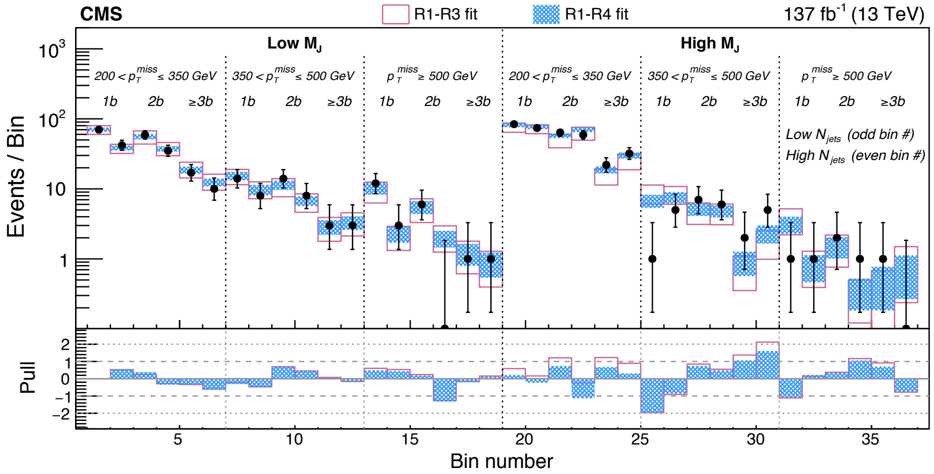
CMS-SUS-19-007

1-ℓ with m_T and M_J

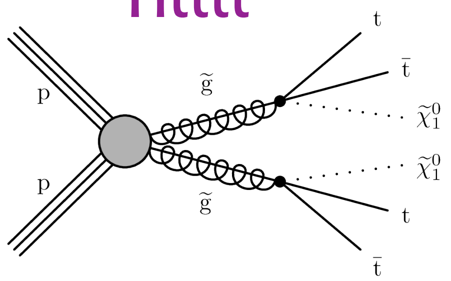
10.1103/PhysRevD.101.052010

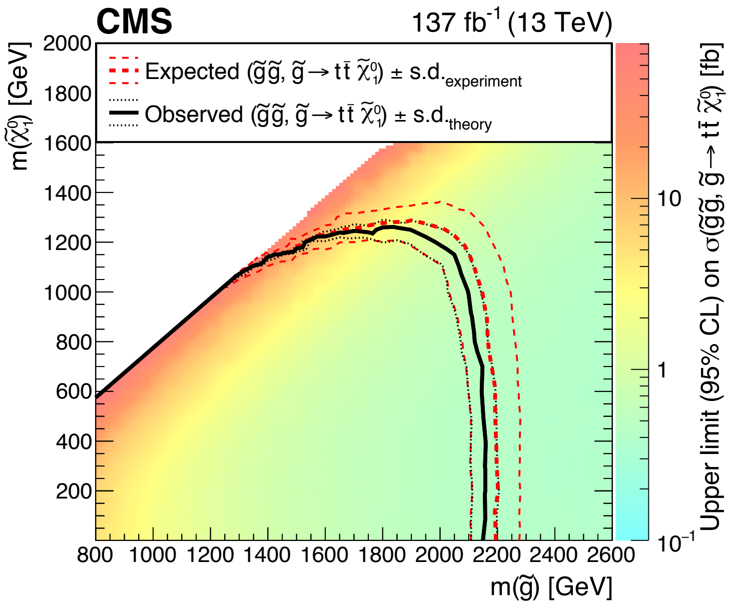


No significant excess



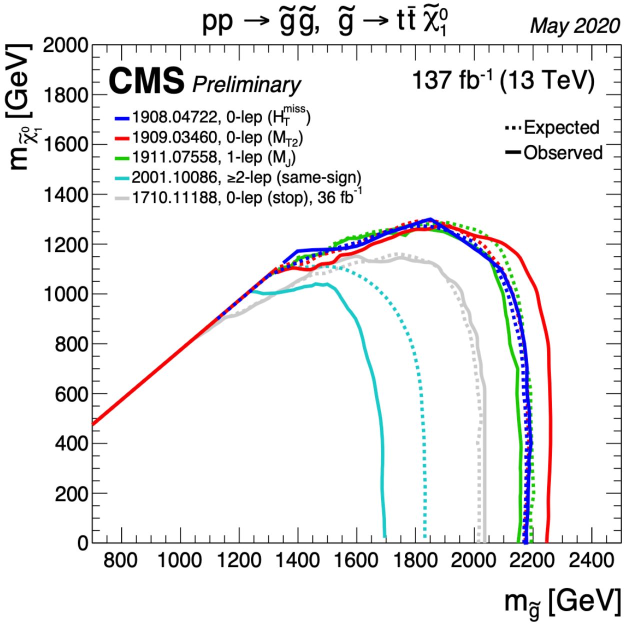
T1tttt

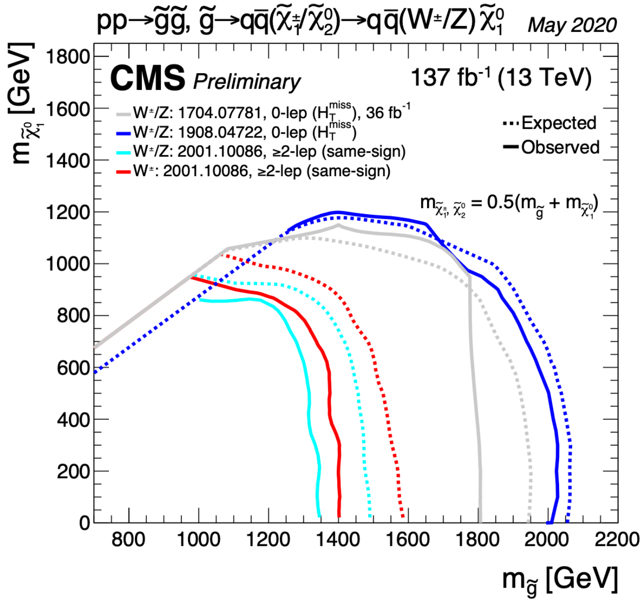


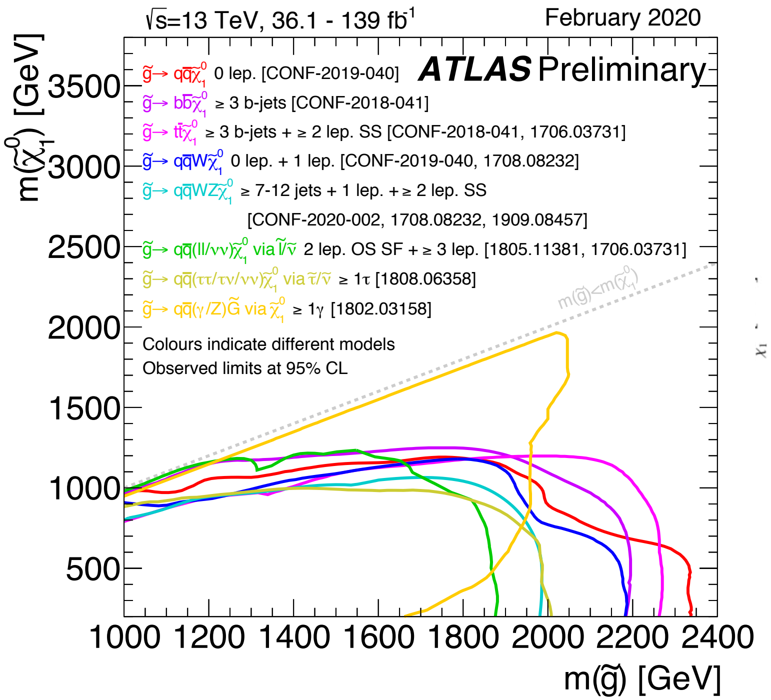


Gluinos below 2.2 TeV are excluded

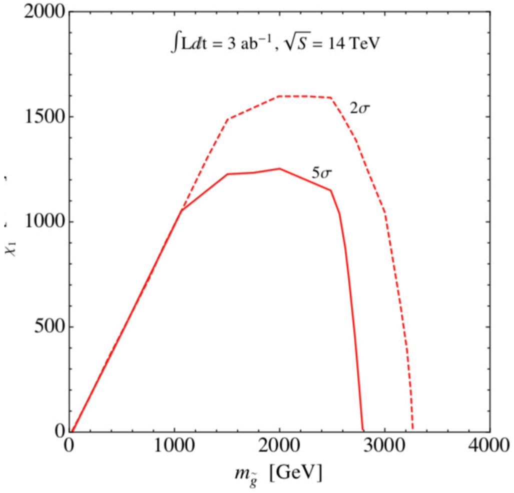
Overview of Gluino searches







More than 3 TeV @ HL-LHC!



Exclude gluinos below 2.2 (1.6) in RPC (RPV) scenarios

Stronger limits $\tilde g \to q\bar q\tilde\chi^0_1$

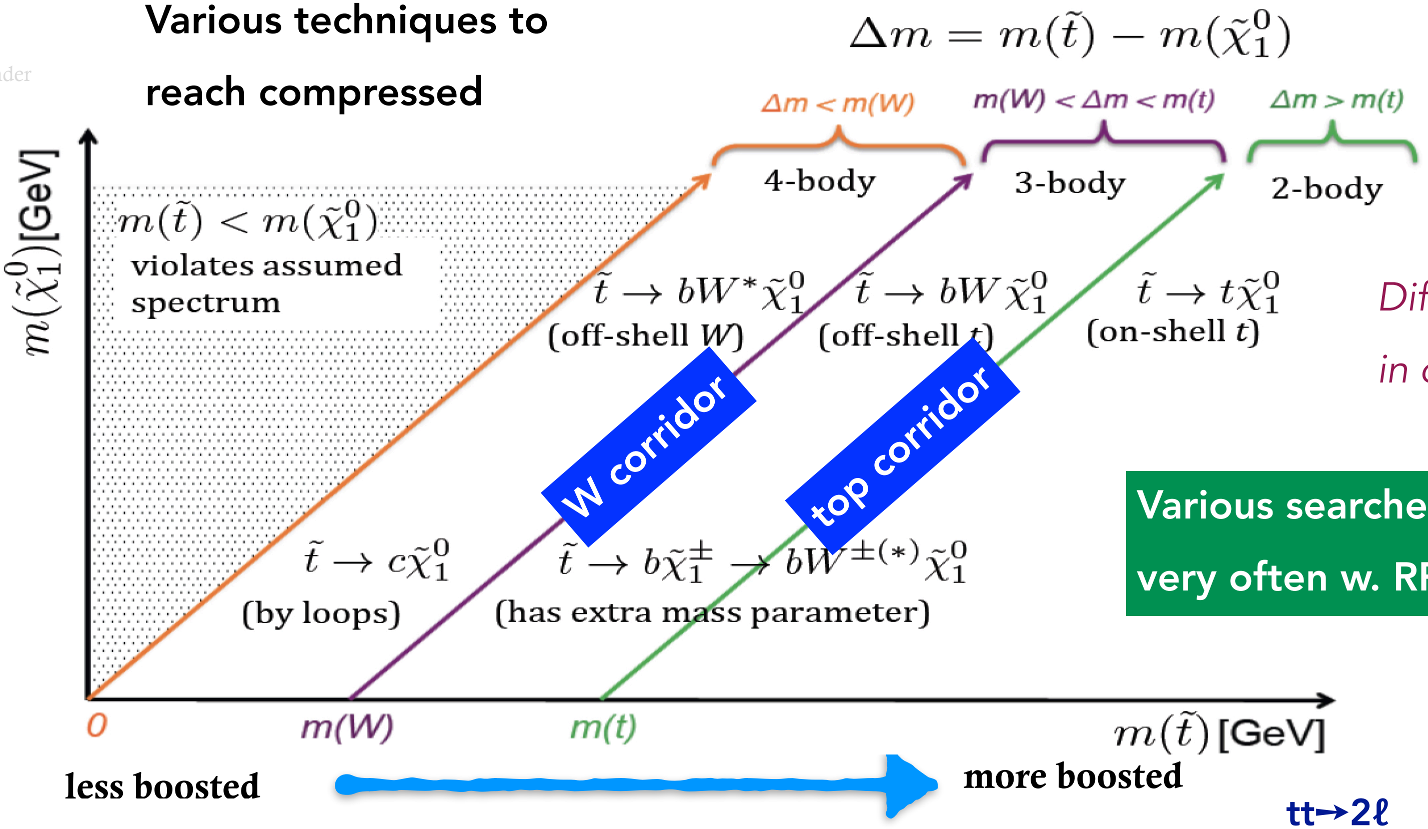
Weaker limits $\tilde g \to q\bar q V\tilde\chi^0_1$

Stop searches

Various techniques to

reach compressed

C.Sander

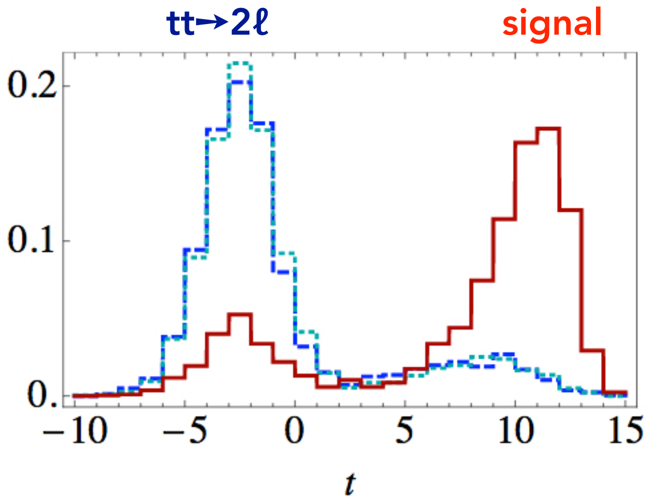


Different kinematics

in different corners

Various searches in 0ℓ, 1ℓ, 2ℓ

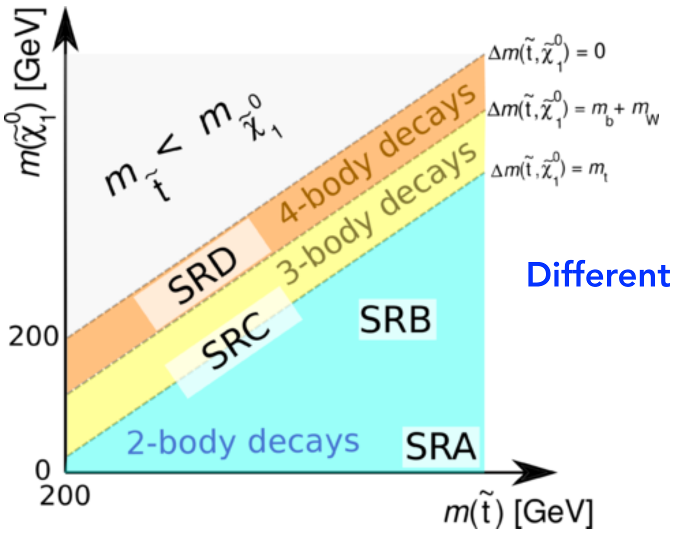
very often w. RPV and DM models

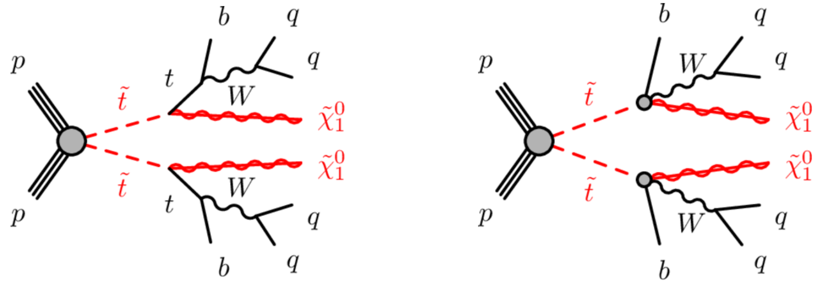


- ✓ Variables like “topness” try to differentiate “true" 2ℓ tt events
- ✓ Many more in use like m_T, M_{T2} and other similar variants exploit the additional p_T^{miss} in signal

ATLAS-2018-12

Stop pair in 0-ℓ



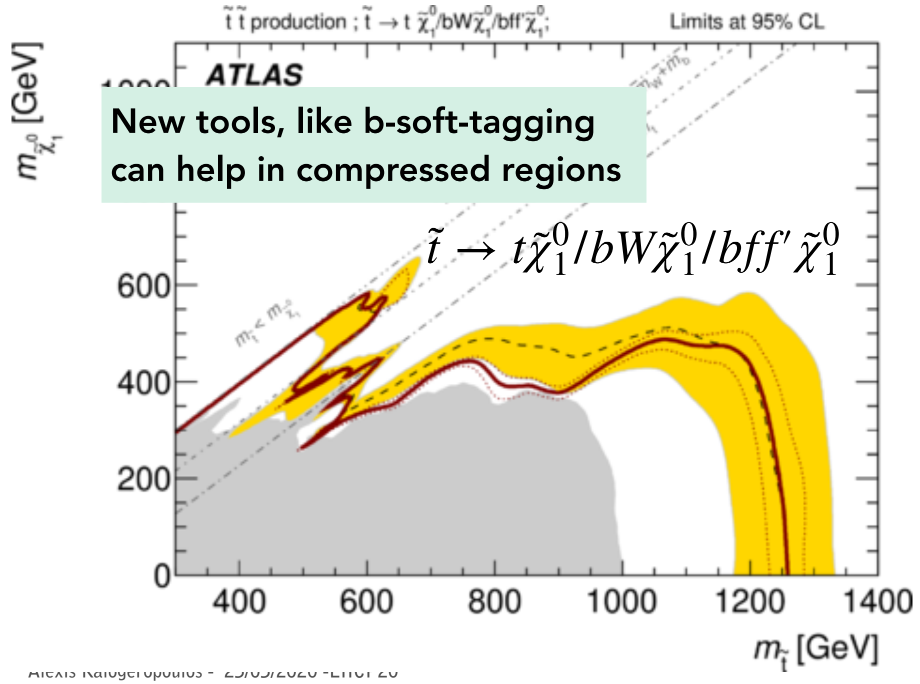


Different observables for SRs (S, p_T^{miss} , ISR= $p_T^{miss}/p_T(ISR)$ for top corridor)

Z→νν (Top): Main background for SRAB-D (SRC)

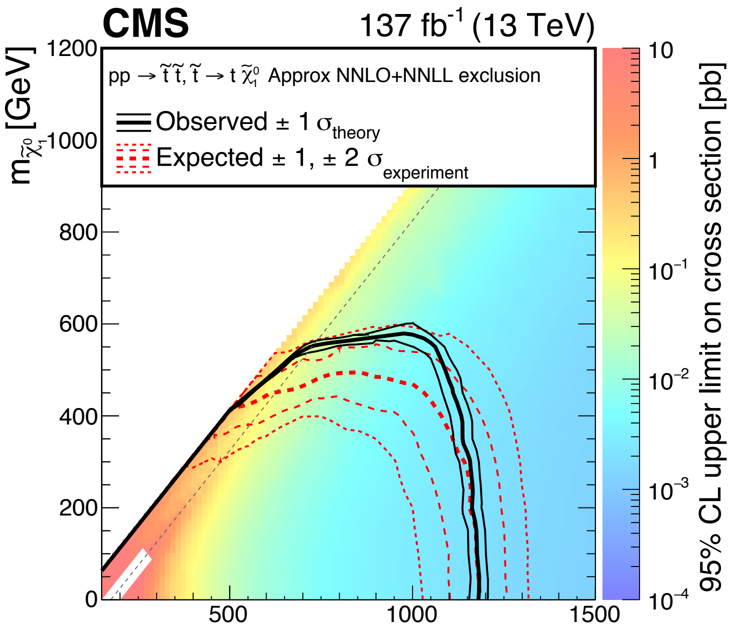
Other : Mostly irreducible ttZ, tt, W+jets and single-top

Normalization : From fits in CRs



New tools, like b-soft-tagging can help in compressed regions

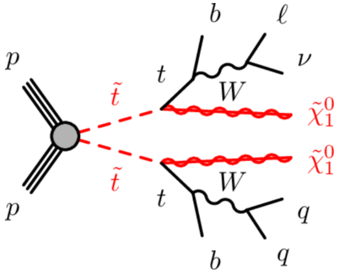
$\tilde{t} \to t\tilde{\chi}_1^0/bW\tilde{\chi}_1^0/bff'\tilde{\chi}_1^0$



CMS-SUS-19-006

CMS analysis not optimized for 3/4 body-decays

Stop pair in 1-ℓ

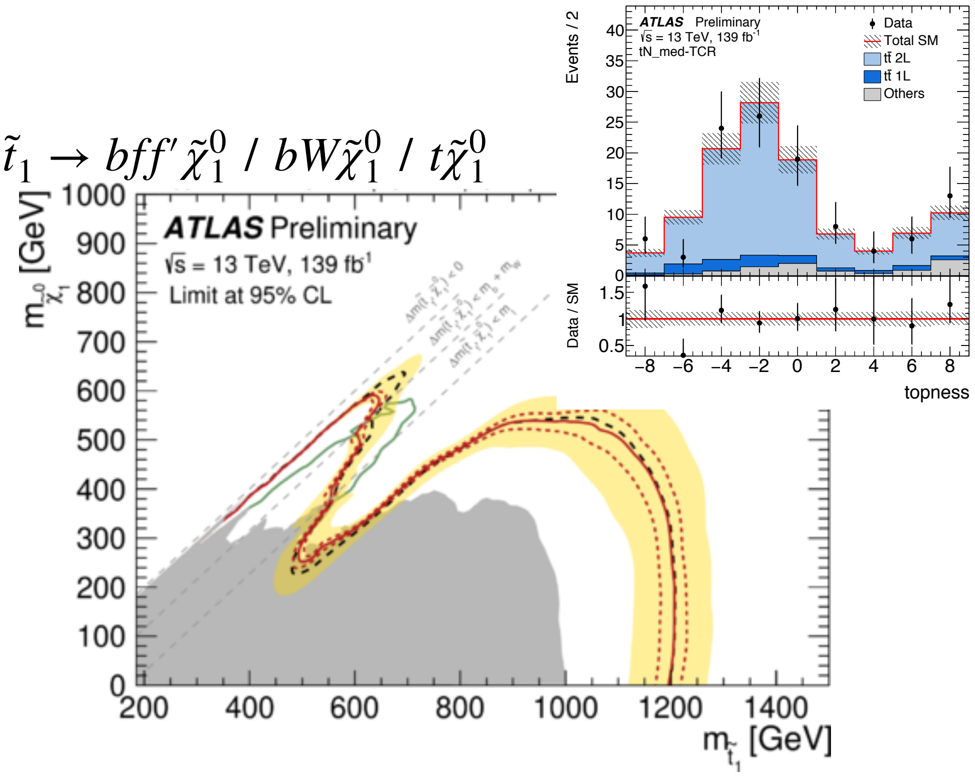


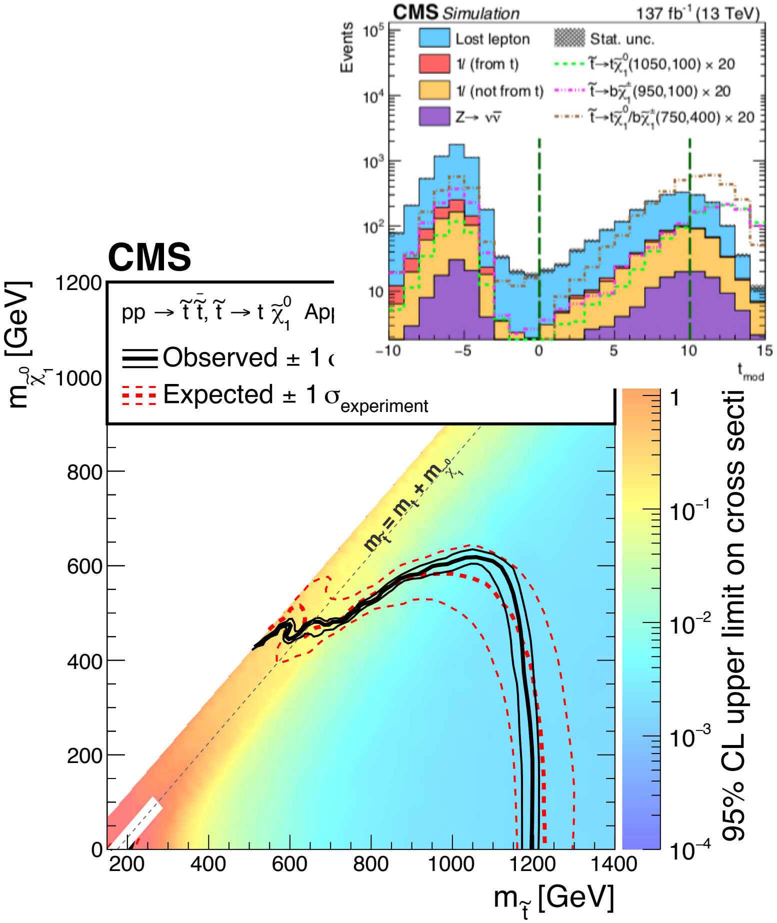
- ◉ Employing both cut-and-count and shape-fit methods
- ◉ m_T is main discriminating variable ; SR in bins of (p_T^{miss}, m_T)

Mismeasured p_T^{miss} : Can enter the mT tails

tt, tt+Z : Important for lost lepton

$\tilde{t}_1 \to bff'\tilde{\chi}^0_1$ / $bW\tilde{\chi}^0_1$ / $t\tilde{\chi}^0_1$





10.1007/JHEP05(2020)032

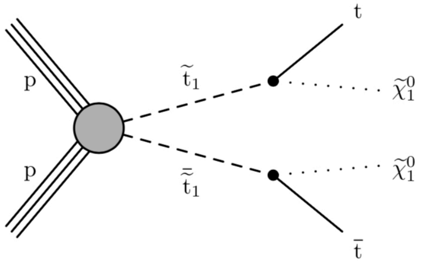
Both ATLAS/CMS use topness

CMS-SUSY-19-011

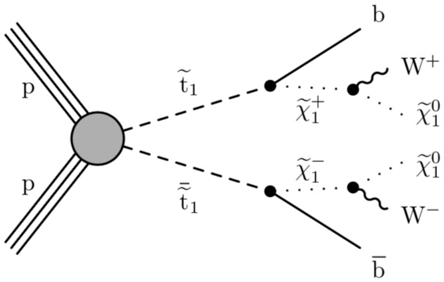
Stop pair in 2-ℓ

NEW

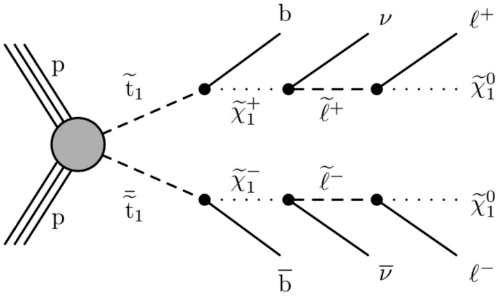
T2tt



T2bW



T8bbℓℓνν



Two opposite charge leptons (μ,e)

- Covering three SMS models
- Involving chargino mediated decays

Search regions in (M_{T2}, S) bins

Main search variables are $M_{T2}(\ell\ell)$ and $M_{T2}(b\ell b\ell)$

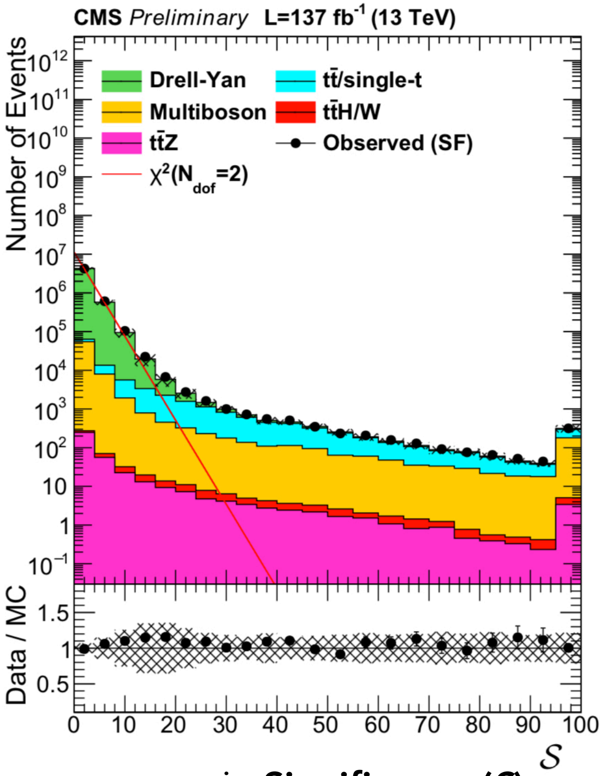
↳ Key feature : kinematic endpoint even w. if two ν in the event.

↳ Signal populates the tails of the distributions.

p_T^{miss} significance (S) is also used

Can suppress DY+jets as there is no genuine p_T^{miss}

Mismeasured jets/p_T^{miss} : Main bkg, estimated from 3ℓ CRs



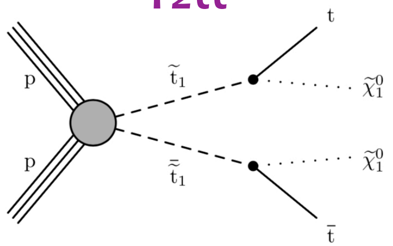
p_T^{miss} Significance ($\mathcal{S}$)

CMS-SUSY-19-011

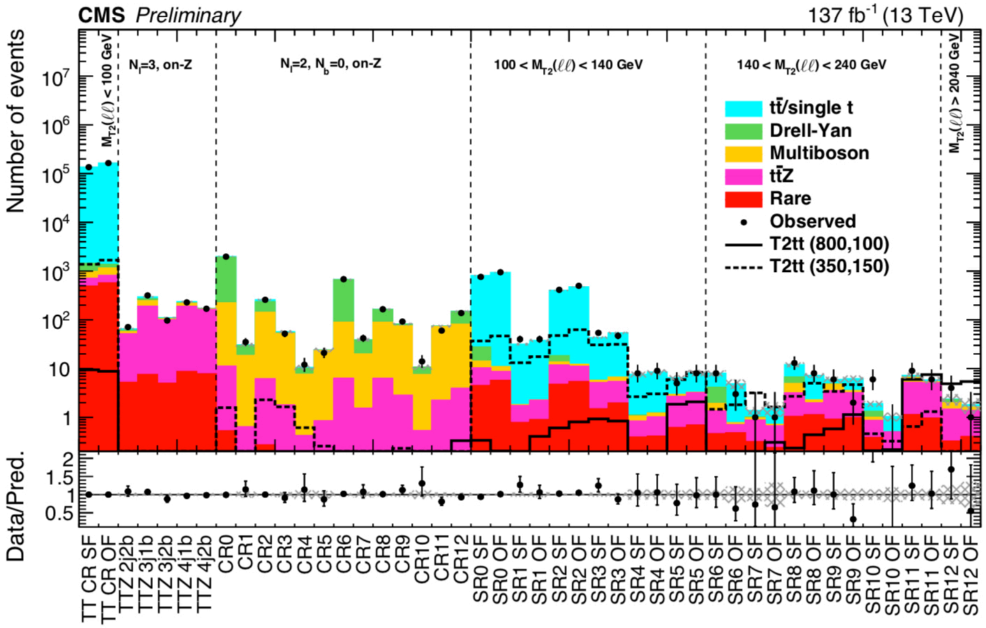
Stop pair in 2-ℓ

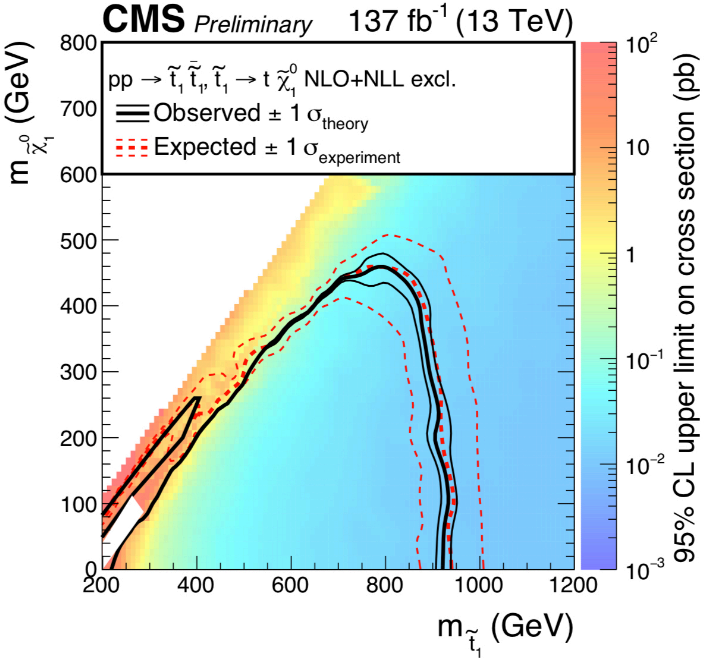
NEW

T2tt



Yields in CR/SRs



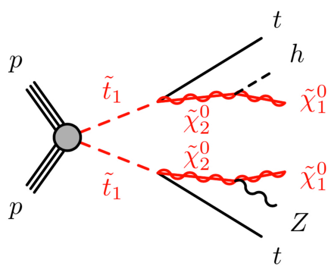


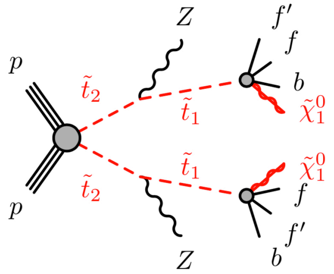
Extending previous T2tt 13 TeV results by ~ 125 GeV

ATLAS-SUSY-2018-21

Stop pair production w. H/Z boson

NEW





Presence of (on-shell) H/Z bosons

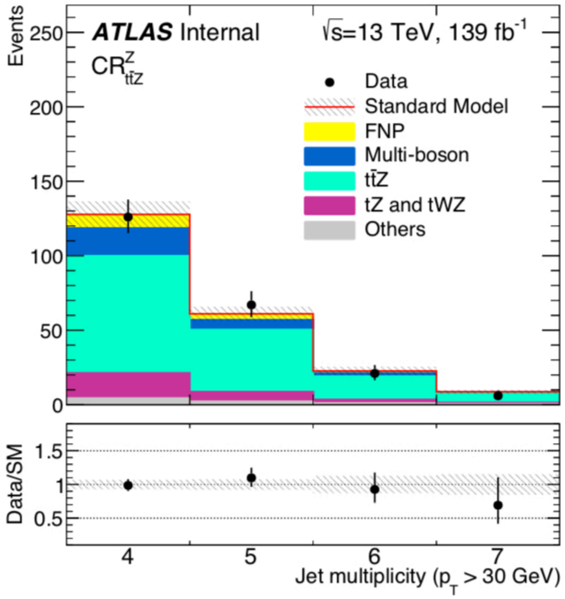
- Z→ℓℓ or h→bb increase sensitivity
- 3ℓ (SFOS) and 1ℓ (H→bb) SR vs (m_T, *S*, N_j, N_b)

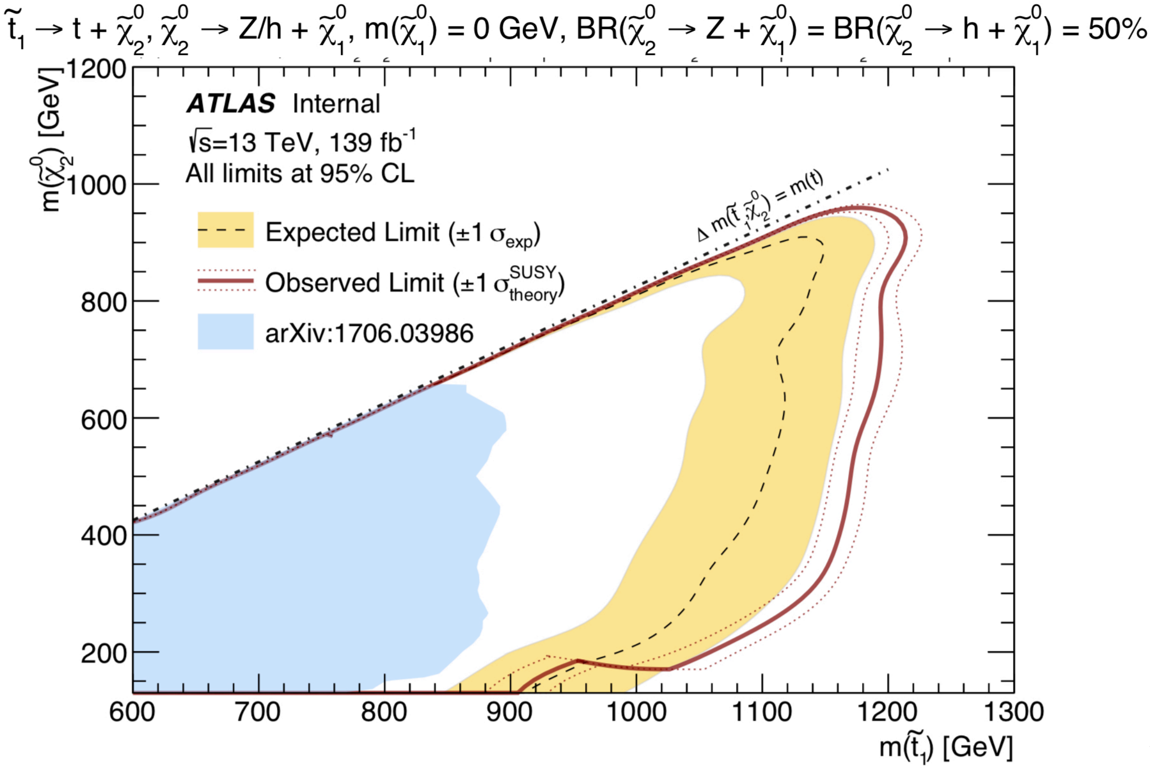
3ℓ : ttZ dominates. Estimated from data in a CR

1ℓ : tt + h.fl; estimated from data

Fake/non-prompt ℓ : from tight-to-lose method in a Z-enriched region

ttZ in Z-enriched

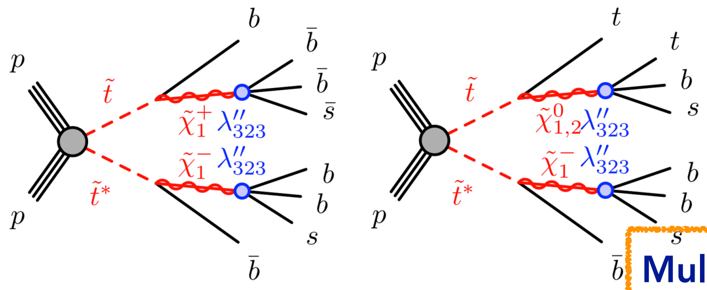




ATLAS-CONF-2020-016

Stop pair w. multi b jets in RPV

NEW



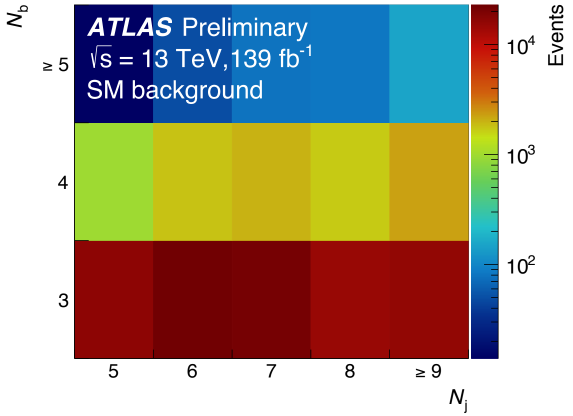
Non-zero RPV couplings

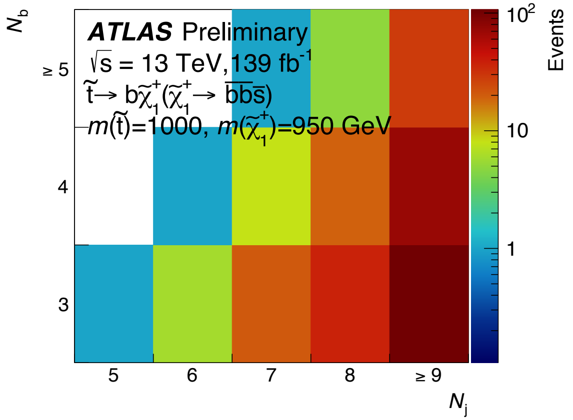
- SR vs ($N_j > 5$, $N_{btag} > 1$)

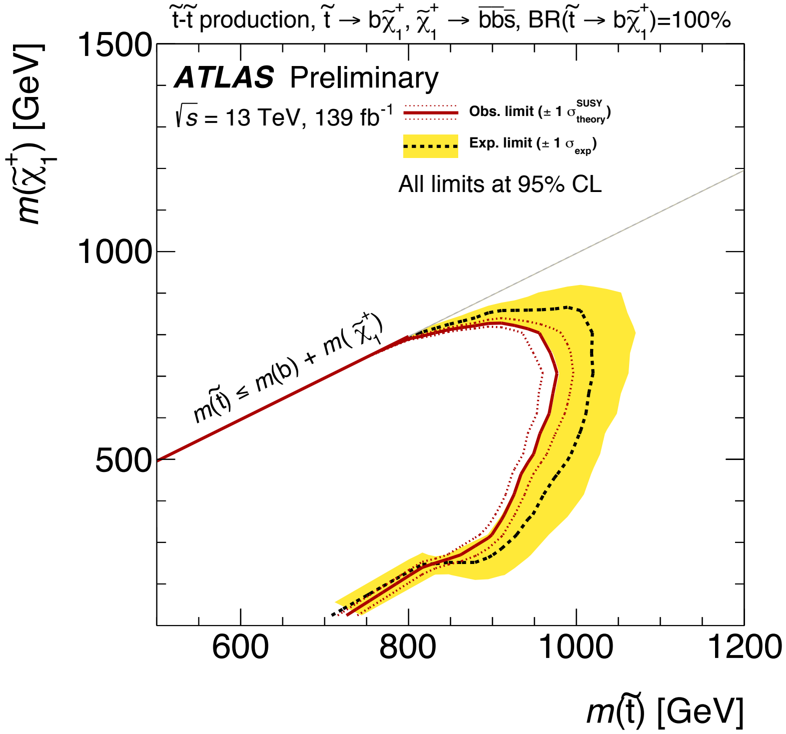
Multijet : Estimated from data with a tag-rate-function.

Fake/non-prompt ℓ : From tight-to-lose method in a Z-enriched region.

Signal Yields in (Nj, Nbtag)

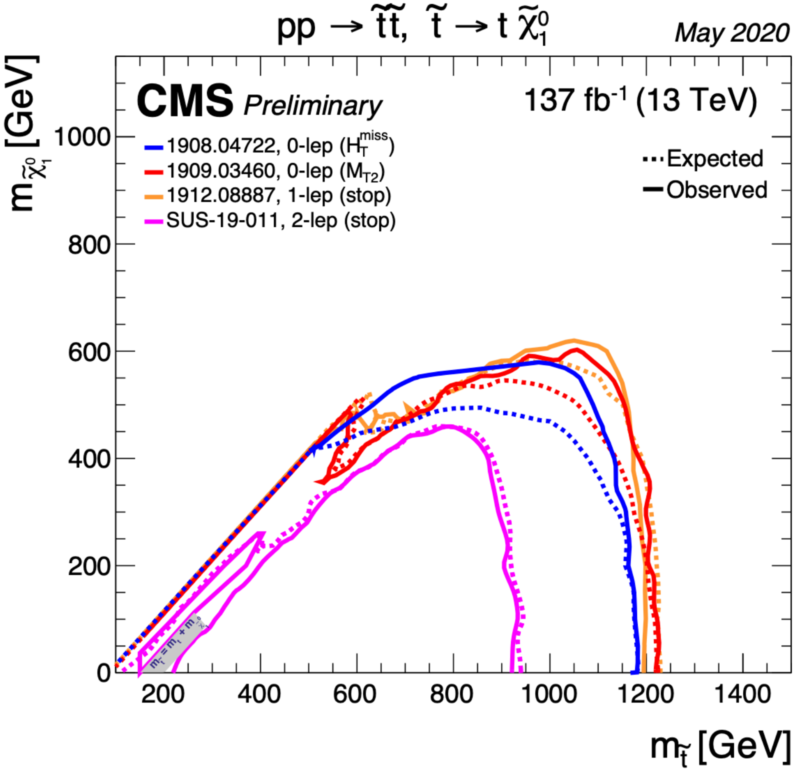


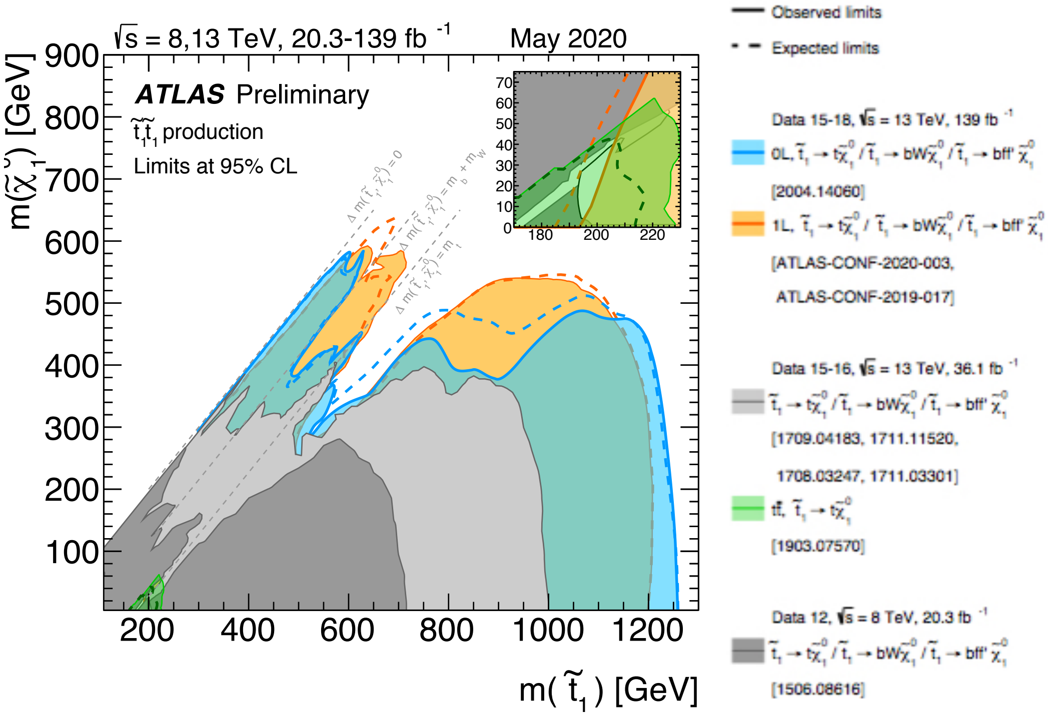




first limits for the top squark production decaying exclusively into a chargino and a *b*-quark

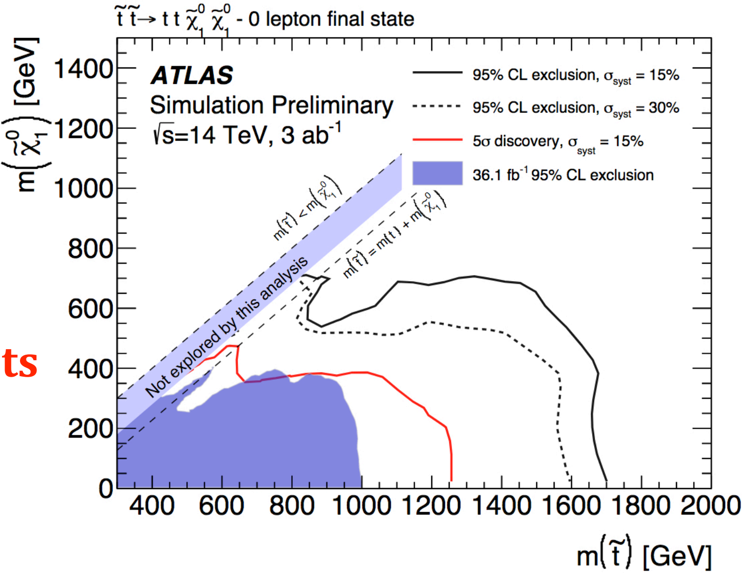
Stop quarks overview





Stops lighter than 1.2 TeV are excluded

Weaker limits in compressed regions (<700 GeV)



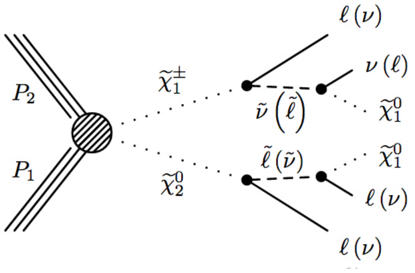
Significant improvements expected at HL-LHE

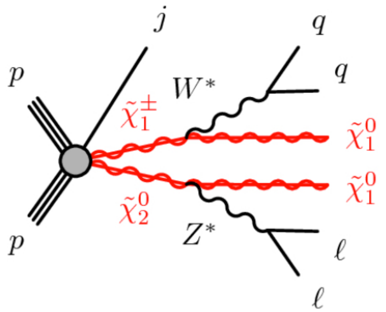
Electroweak searches

Involves chargino, neutralino, slepton production

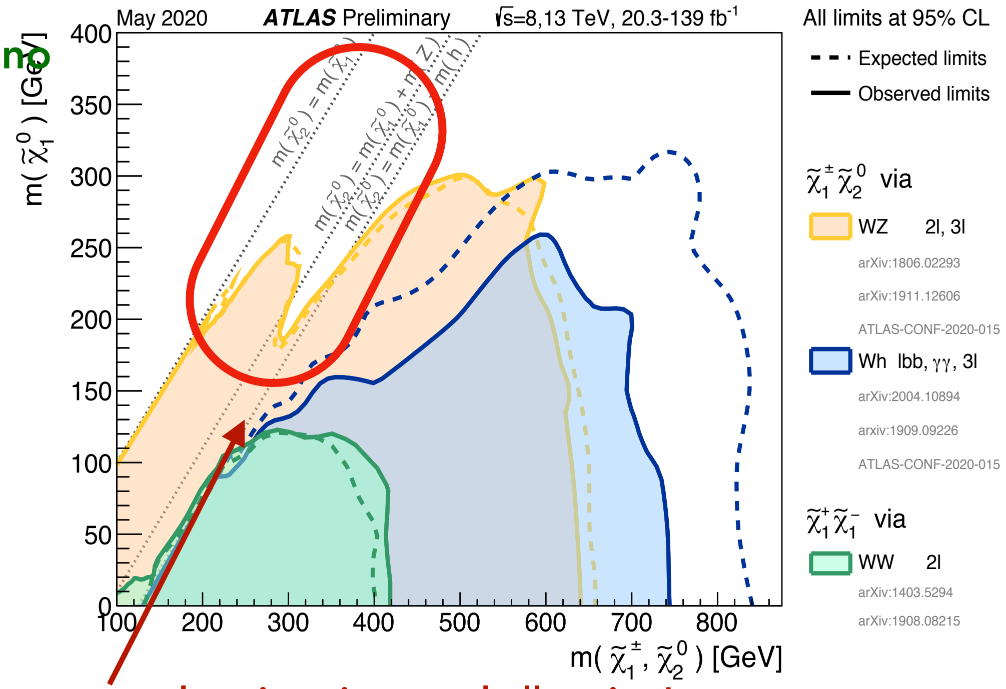
Low xsec but very clean signatures:

- ✓ p_T^{miss} , multi-leptons
- ✓ hadronic taus
- ✓ (di) bosons





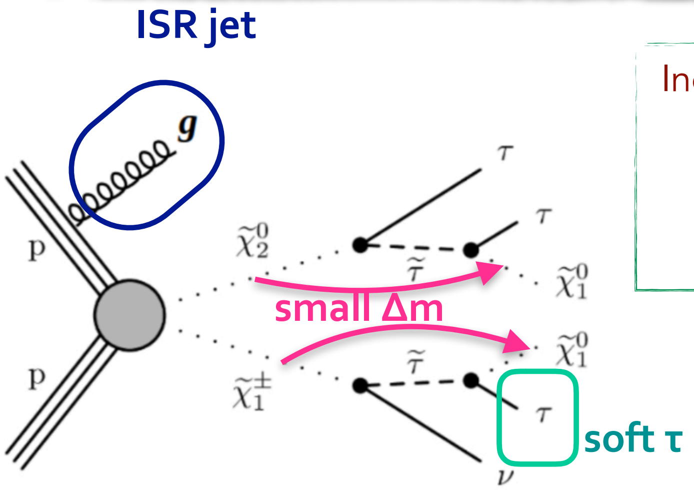
- ◉ **Direct searches of Chargino/Neutralino**
- ◉ **Gauge medicated SUSY breaking**
  - Gravitino as LSP
  - $\ell + \gamma + p_T^{miss}$
  - $\gamma + p_T^{miss}$ + b (Higgs)
- ◉ **Direct WIMP production**
- ◉ **RPV : lepton flavour violation :**
  - Pairs of eτ, τμ



Reaching compressed regions is very challenging!

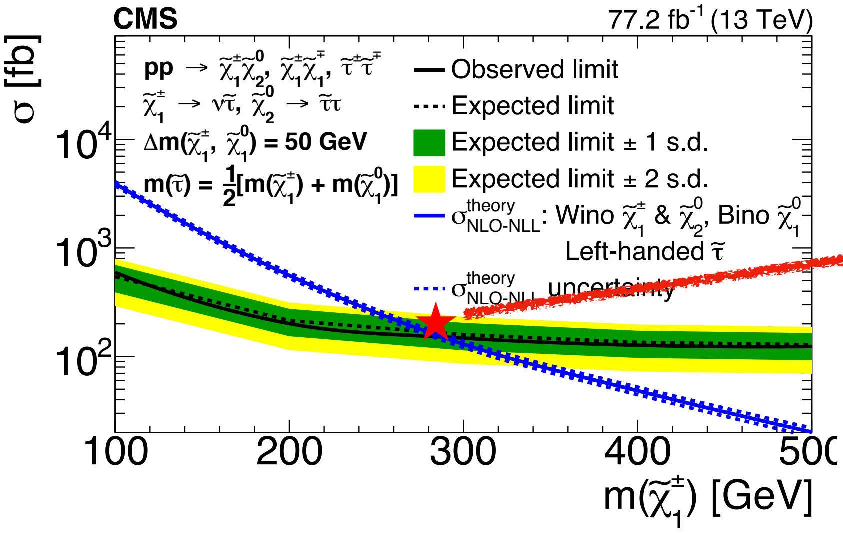
Use VBF topologies and presence of ISR to increase acceptance

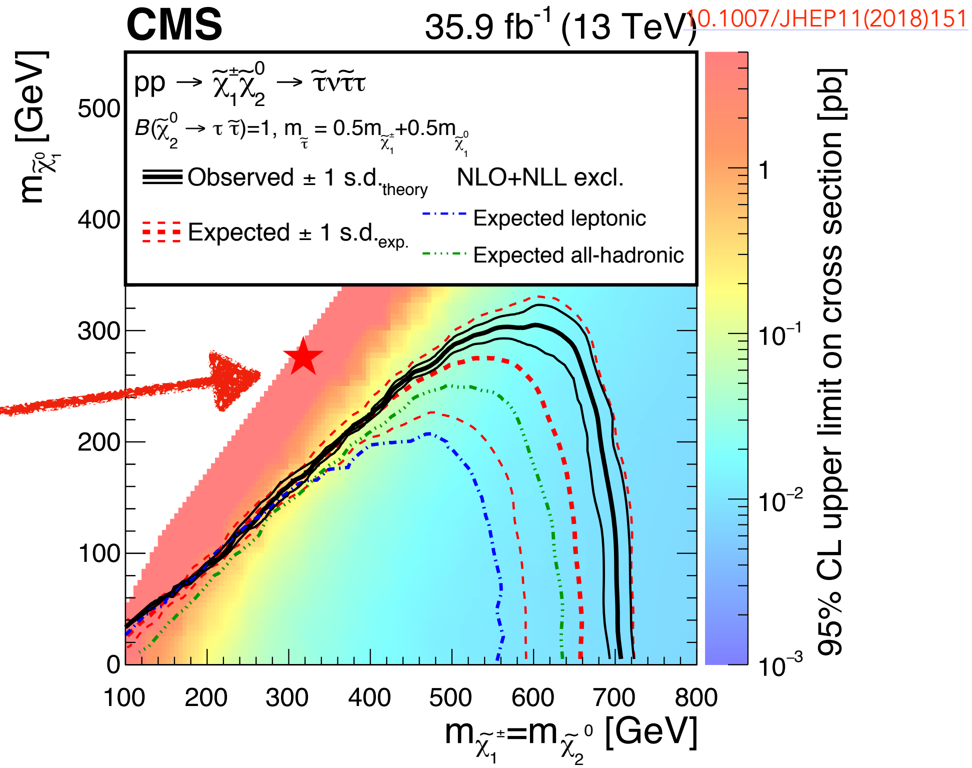
Probing the compressed region



Indirect stau production via C1N2 production

- Recoil from ISR facilitates detection
- Soft τ ➞ Very challenging analysis
  - τ_h < 40 GeV and $\Delta\Phi(j, p_T^{miss})$ cut to suppress backgrounds

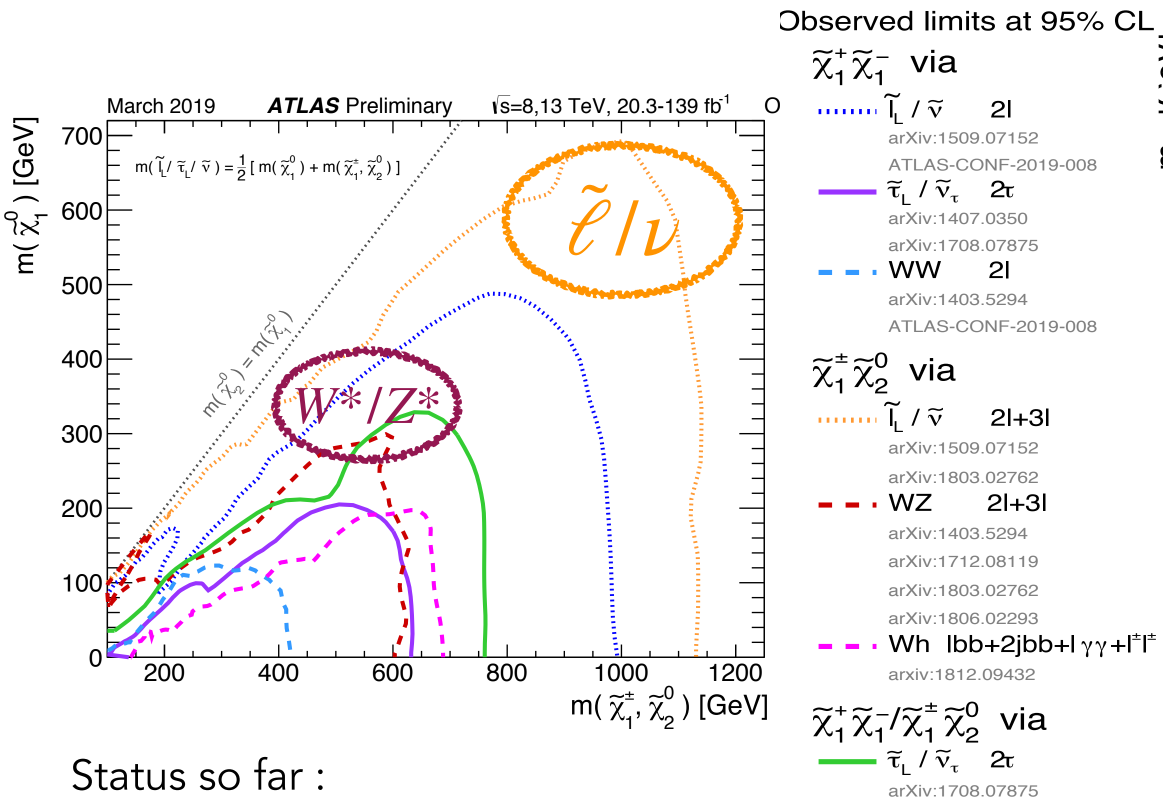


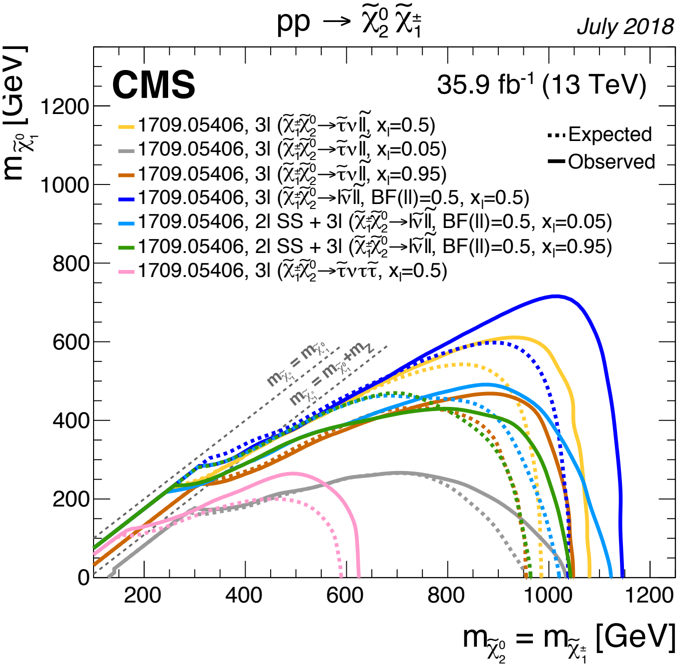


10.1007/JHEP11(2018)151

Credits to T.Kamon

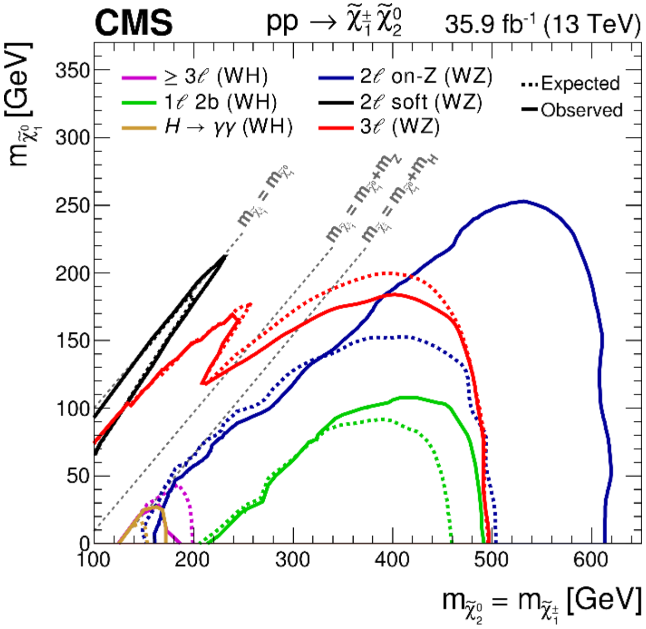
Electroweak limits





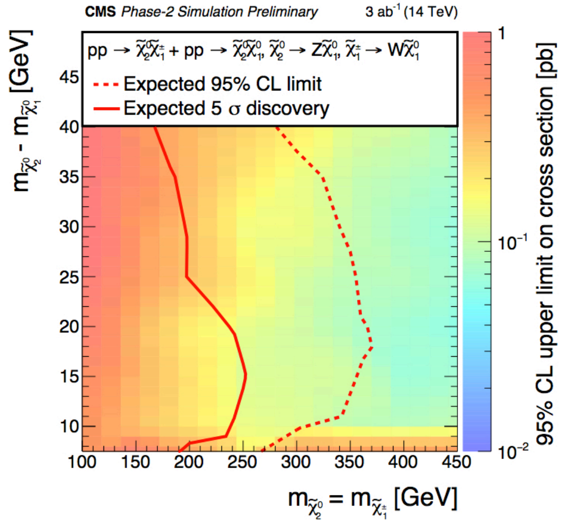
Status so far :

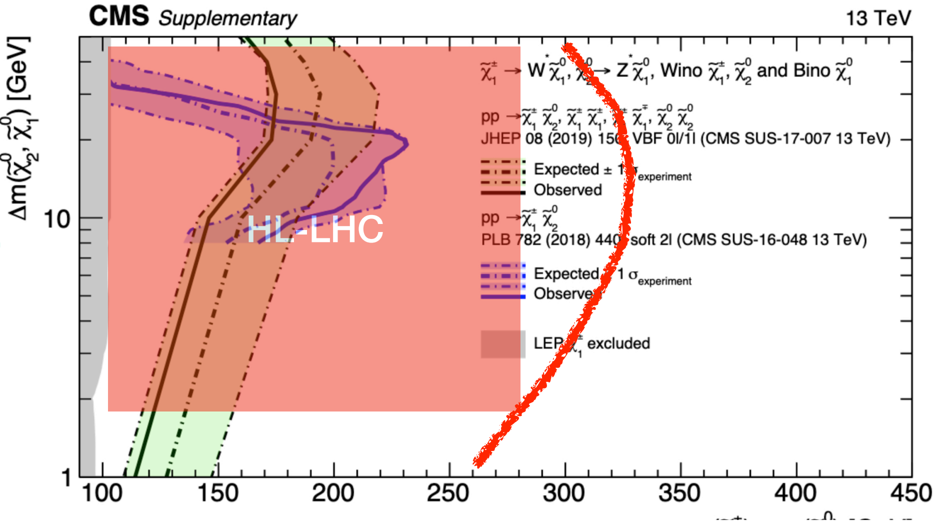
- **Stronger limits via sleptons mediated decays (0.6-1.1 TeV)**
- **Weaker limits via bosons mediated decays (~400-700 GeV)**
- **Even weaker for compressed and direct staus**

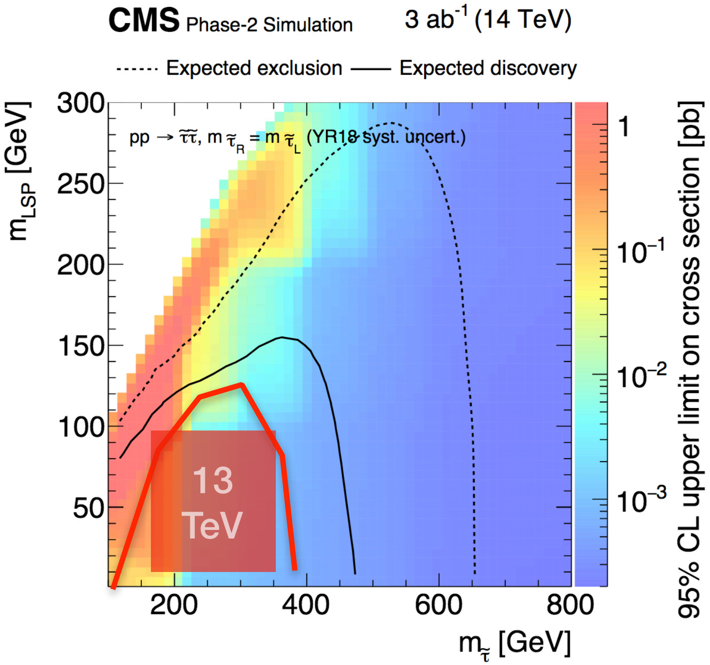


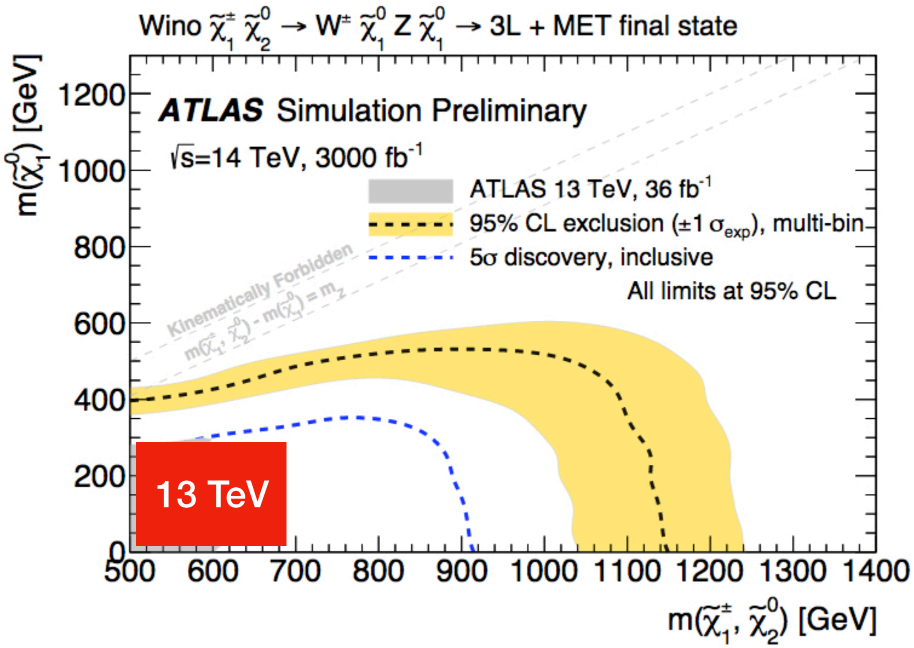
Electroweak and future prospects

HL-LHC will help to cover a lot of the phase space, but we still have some way to go!



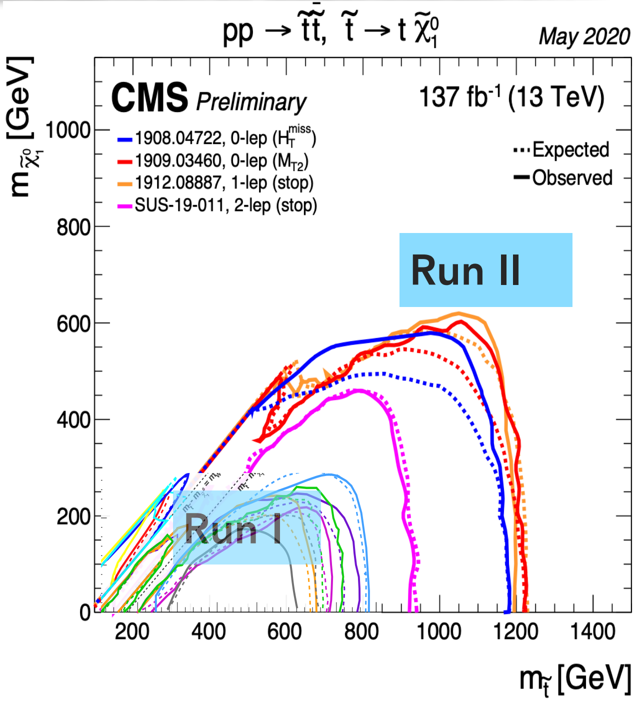


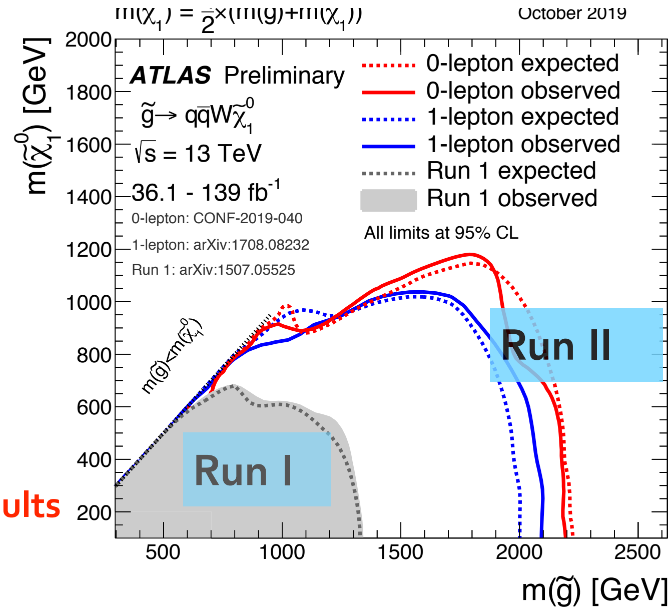




Summary

- Both ATLAS and CMS have rich SUSY physics programs setting strong limits on many models.
- More full Run 2 results will appear soon !
  - Including for instance full-likelihoods being released by ATLAS.
- Eagerly waiting and preparing for Run 3 as:
  - Additional lumi will help difficult corners i.e. compressed, low Δm, direct-staus.
  - Use of more targeted triggers and more sophisticated and refined tools/techniques.
  - Upgraded detectors will provide more possibilities *(HL-HE-LHC WG3 arXiv:1902.10229).*



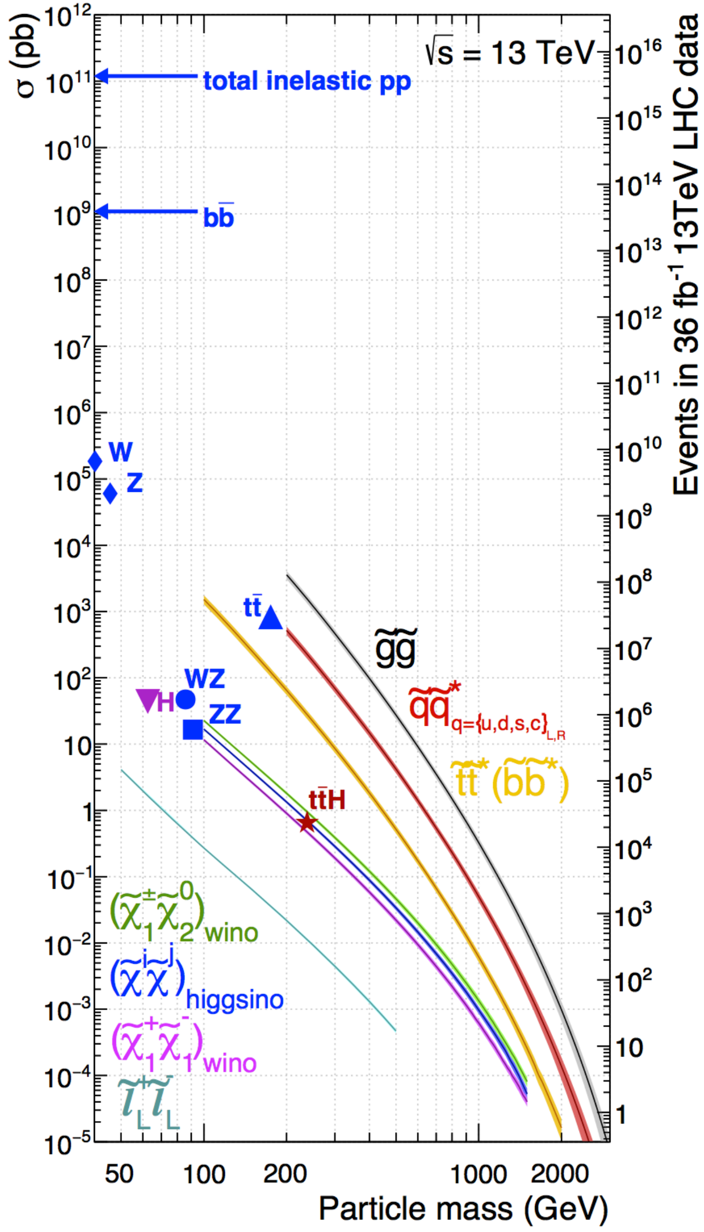


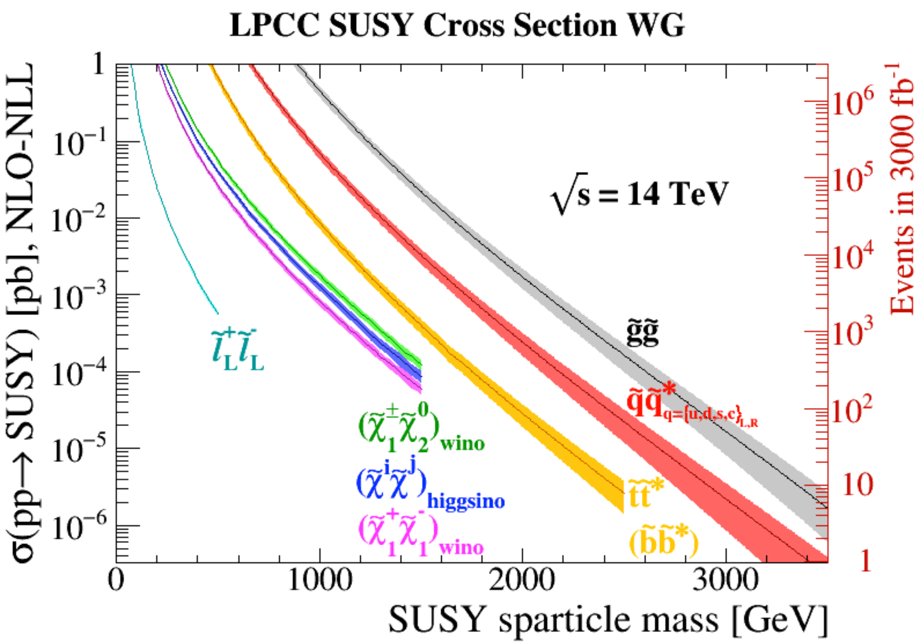
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

Backup

Cross sections



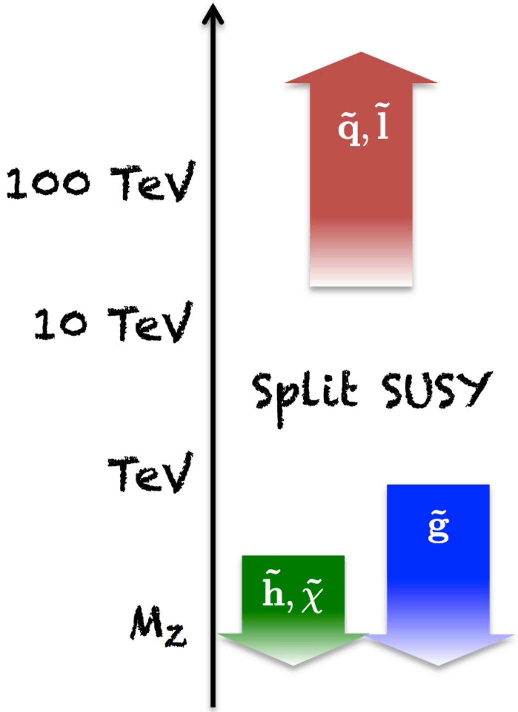


https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SUSYCrossSections arXiv:1407.5066

Split SUSY

Not natural, but still provides DM candidate and gauge unification

- ◉ Light EWKinos
- ◉ if “heavy” gluinos ➙ long lived gluinos forming R-hadron
  - ◉Decay : gl➙ g + N1 (pTmiss + jet w. no tracks
- ◉Strategy : Lookis for “jets" in trigger able beam gaps
  - ◉Bkgs : beam halo, HCAL noise, etc

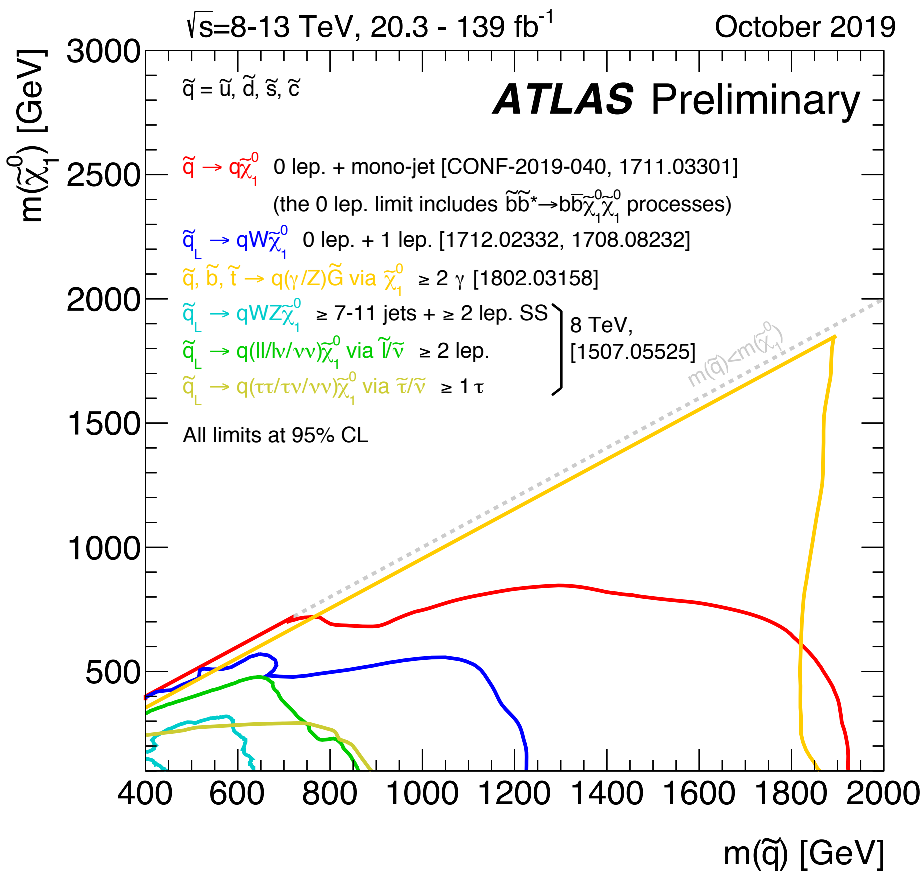


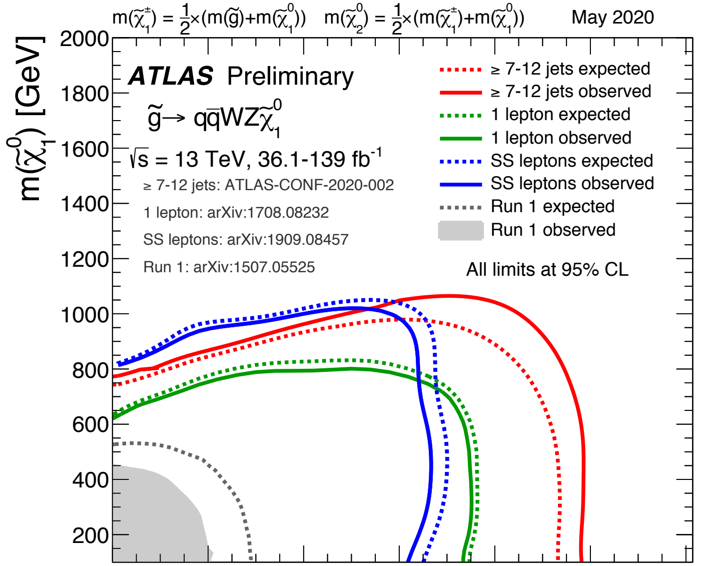
R-Mesons: $\tilde{g}q\bar{q}$

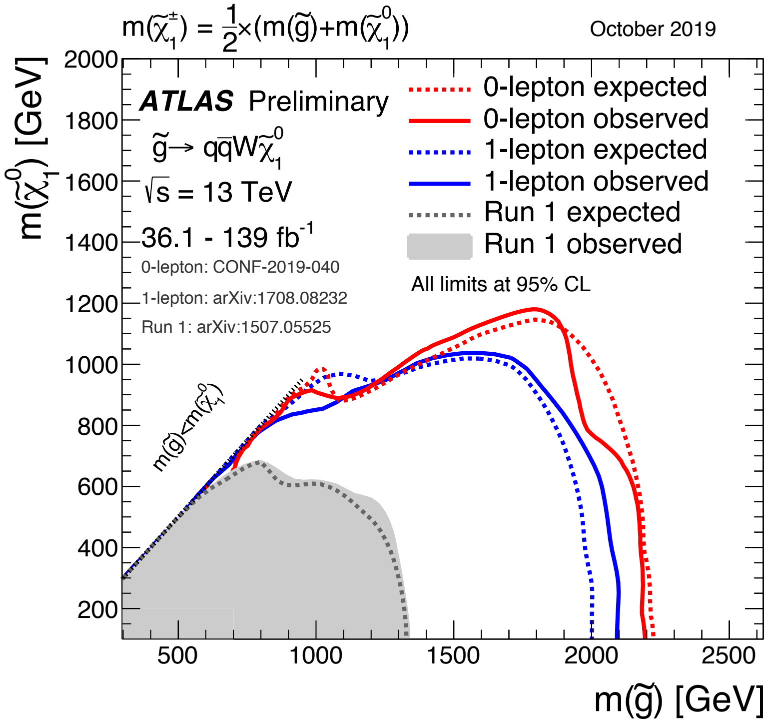
R-Baryons: $\tilde{g}qqq$

R-Gluinoballs: $\tilde{g}g$

Summary plots



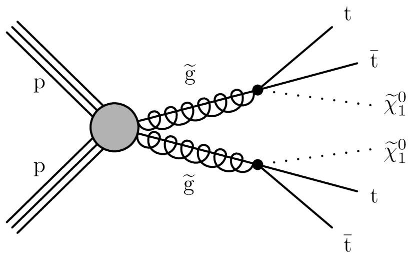




CMS-SUS-19-007

1ℓepton with m_T and M_J

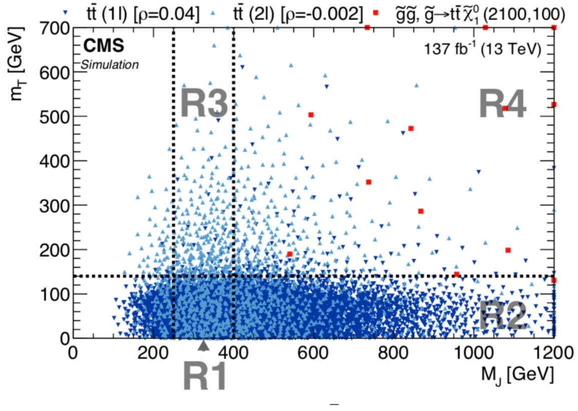
T1tttt



1ℓ + multi-jets + b tag jets + MET signature

◉ Benefit from large cross-section and the presence of ISR

R4 : Signal Region



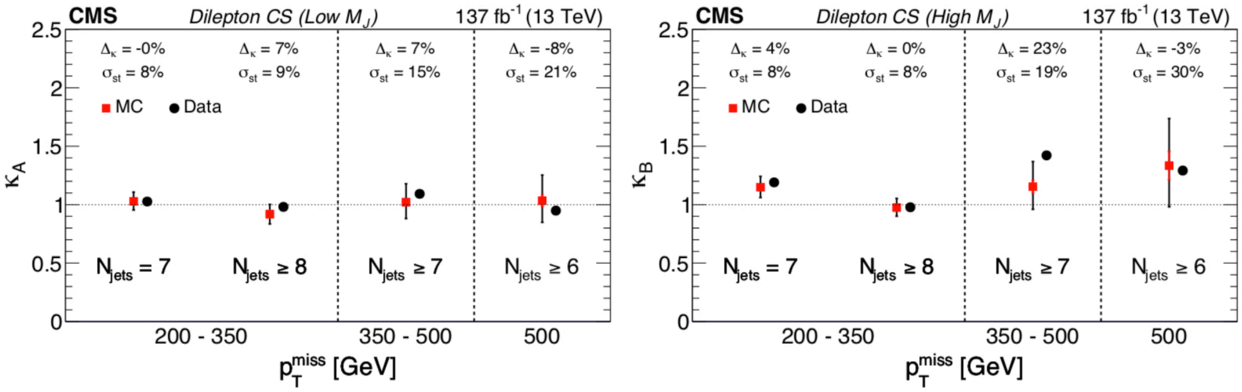
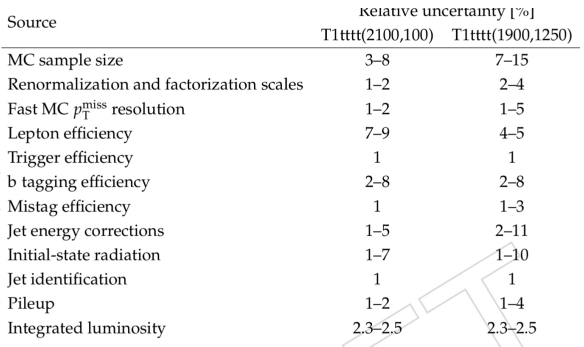


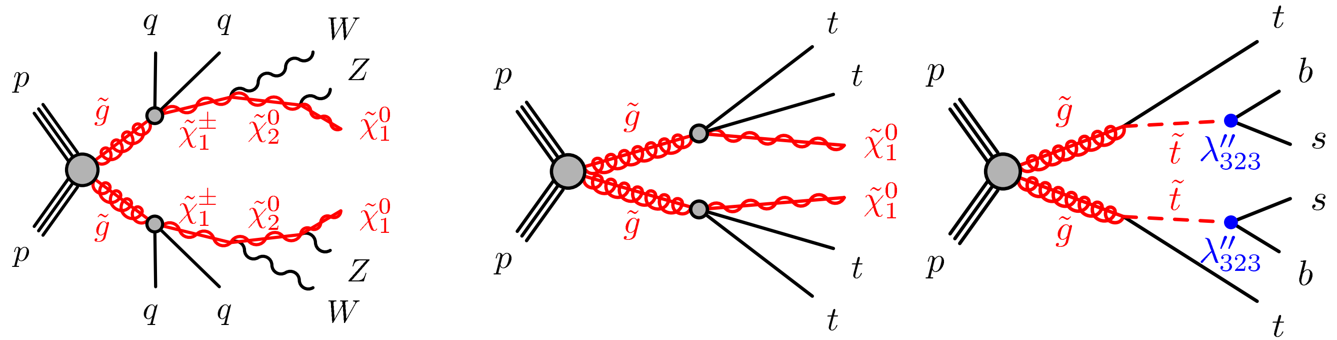
Figure 5: Dilepton control sample (CS): validation of the κ factor values found in simulation vs. data for low M_J (left) and high M_J (right). The data and simulation are shown as black and red points, respectively. No statistical uncertainties are plotted for the data points, but instead, the expected statistical uncertainty for the data points, summed in quadrature with the statistical uncertainty of the simulated samples, is given by the error bar on the red points and is quoted as σ_{st}. The red portion of the error bar on the red points indicates the contribution from the simulated samples. The quoted values of Δ_κ are defined as the relative difference between the κ values found in simulation and in data.



Source	Relative uncertainty [%]	
	T1tttt(2100,100)	T1tttt(1900,1250)
MC sample size	3–8	7–15
Renormalization and factorization scales	1–2	2–4
Fast MC p_T^{miss} resolution	1–2	1–5
Lepton efficiency	7–9	4–5
Trigger efficiency	1	1
b tagging efficiency	2–8	2–8
Mistag efficiency	1	1–3
Jet energy corrections	1–5	2–11
Initial-state radiation	1–7	1–10
Jet identification	1	1
Pileup	1–2	1–4
Integrated luminosity	2.3–2.5	2.3–2.5

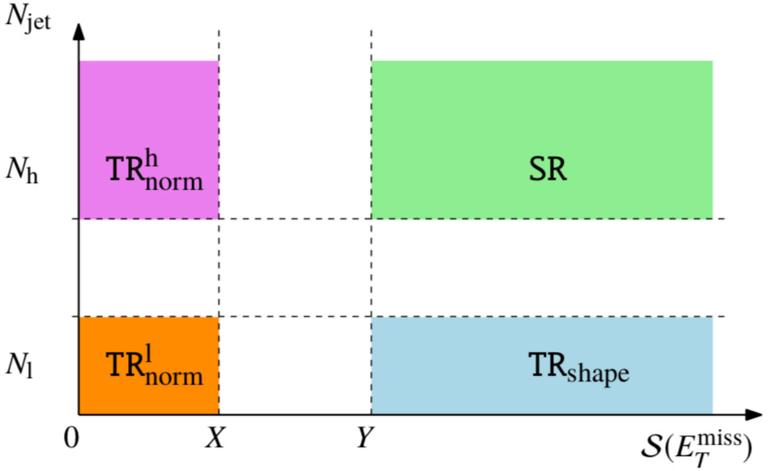
ATLAS-CONF-2020-002

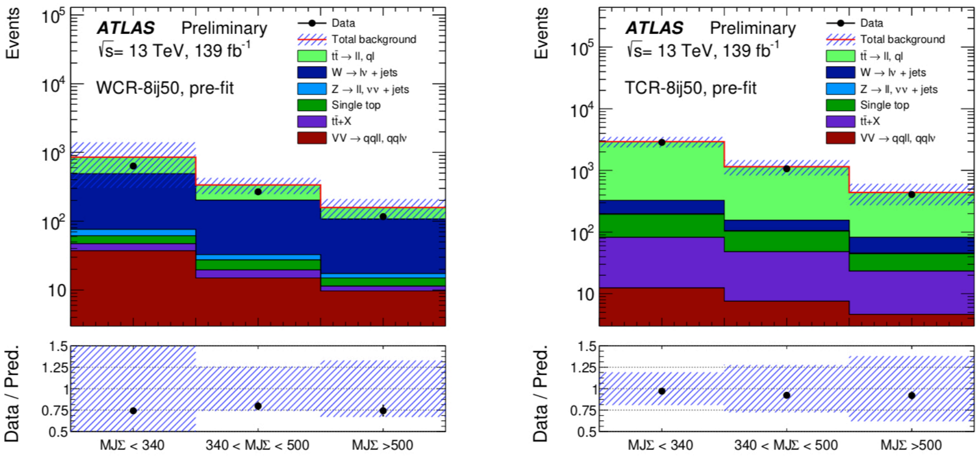
Search with jets and p_T^{miss}



Baryon number violation model

$\tilde{t}_1 \longrightarrow \bar{s} + \bar{b}$





(a) WCR, pre-fit

(b) TCR, pre-fit

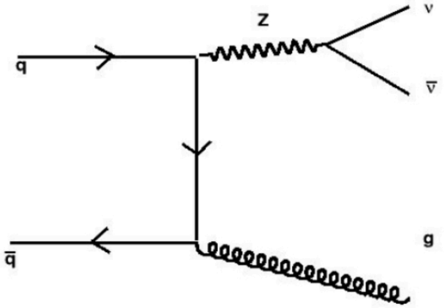
he predicted multijet background yield in a region $\hat{N}[a < S(E_T^{miss}) < b]$ with high jet multiplicity (N_h) nd $S(E_T^{miss})$ in the range (a, b) is obtained from the measured yield $N_{TR_{shape}}$ in a lower jet multiplicity (N_l) emplate region TR_{shape} through the relation

$$\hat{N}[a < S(E_T^{miss}) < b] = \frac{N_{TR^h_{norm}}}{N_{TR^l_{norm}}} N_{TR_{shape}}[a < S(E_T^{miss}) < b]. \qquad (2)$$

Boosted Z+p_T^{miss}

Z($\nu\nu$)+jets

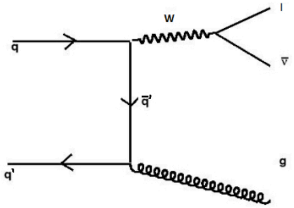
- This background has the same final state of jets+p_T^{miss} as signal



Photon control region

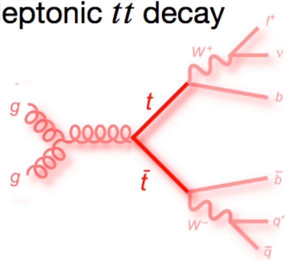
W($l\nu$)+jets

- In a case where lepton is lost, final states of jets+p_T^{miss}



$t\bar{t}$+jets

- Similar topology of W+jets would follow for a semi-leptonic $t\bar{t}$ decay



Single-lepton control region

Boosted Z+p_T^{miss}

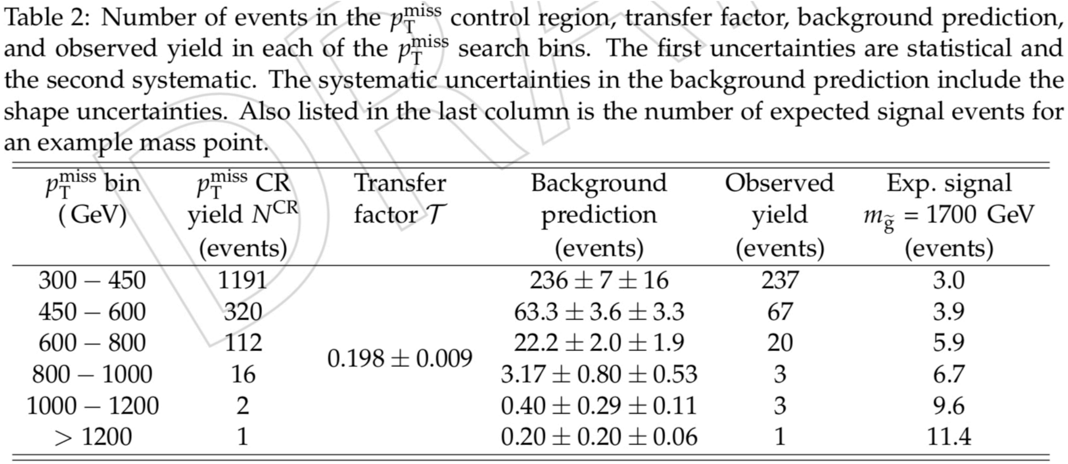
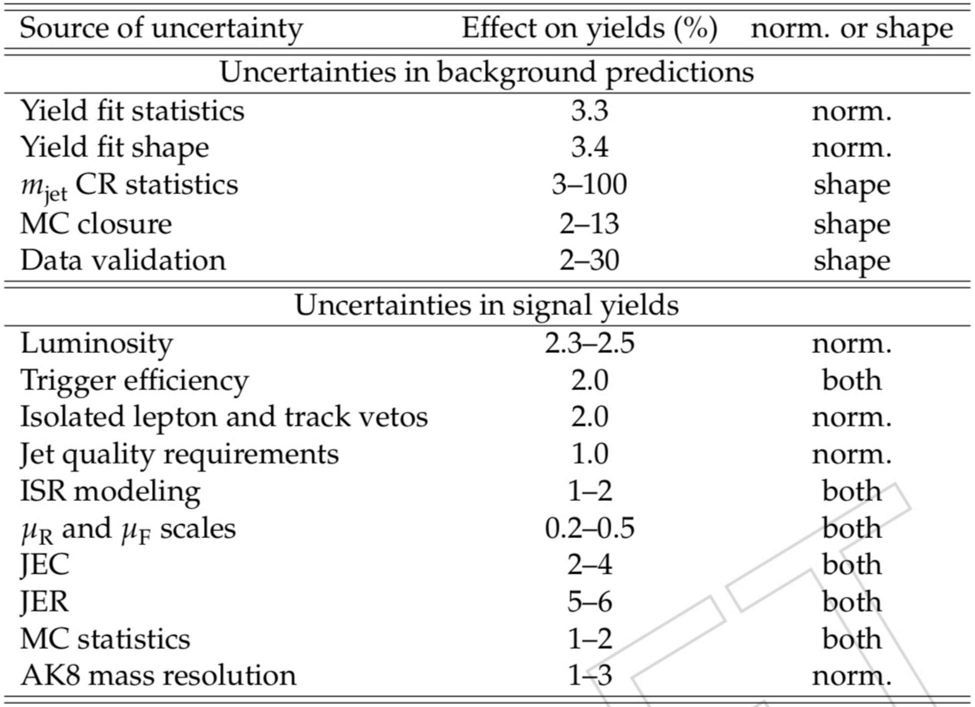


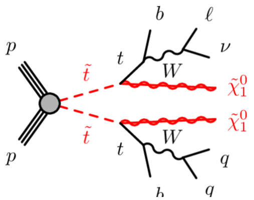
Table 2: Number of events in the p_T^{miss} control region, transfer factor, background prediction, and observed yield in each of the p_T^{miss} search bins. The first uncertainties are statistical and the second systematic. The systematic uncertainties in the background prediction include the shape uncertainties. Also listed in the last column is the number of expected signal events for an example mass point.

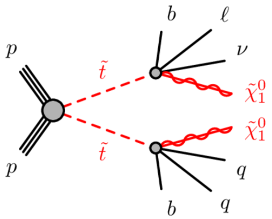
p_T^{miss} bin (GeV)	p_T^{miss} CR yield N^{CR} (events)	Transfer factor $\mathcal{T}$	Background prediction (events)	Observed yield (events)	Exp. signal $m_{\tilde{g}}$ = 1700 GeV (events)
$300-450$	1191	0.198 ± 0.009	$236 \pm 7 \pm 16$	237	3.0
$450-600$	320		$63.3 \pm 3.6 \pm 3.3$	67	3.9
$600-800$	112		$22.2 \pm 2.0 \pm 1.9$	20	5.9
$800-1000$	16		$3.17 \pm 0.80 \pm 0.53$	3	6.7
$1000-1200$	2		$0.40 \pm 0.29 \pm 0.11$	3	9.6
> 1200	1		$0.20 \pm 0.20 \pm 0.06$	1	11.4



Source of uncertainty	Effect on yields (%)	norm. or shape
Uncertainties in background predictions		
Yield fit statistics	3.3	norm.
Yield fit shape	3.4	norm.
m_{jet} CR statistics	3–100	shape
MC closure	2–13	shape
Data validation	2–30	shape
Uncertainties in signal yields		
Luminosity	2.3–2.5	norm.
Trigger efficiency	2.0	both
Isolated lepton and track vetos	2.0	norm.
Jet quality requirements	1.0	norm.
ISR modeling	1–2	both
μ_R and μ_F scales	0.2–0.5	both
JEC	2–4	both
JER	5–6	both
MC statistics	1–2	both
AK8 mass resolution	1–3	norm.

Stop pair production in 1-ℓ





Topness : log(min(S))

Signal scenario	Benchmark	Signal Region	Exclusion technique
$\tilde{t}_1 \to t + \tilde{\chi}_1^0$	$\mathrm{m}(\tilde{t}_1,\ \tilde{\chi}_1^0) = (800{,}400)$ GeV	`tN_med`	shape-fit of $E_{\mathrm{T}}^{\mathrm{miss}}$ and m_{T}
$\tilde{t}_1 \to t + \tilde{\chi}_1^0$	$\mathrm{m}(\tilde{t}_1,\ \tilde{\chi}_1^0) = (950{,}1)$ GeV	`tN_high`	-
$\tilde{t}_1 \to t + \tilde{\chi}_1^0$	$\mathrm{m}(\tilde{t}_1,\ \tilde{\chi}_1^0) = (225{,}52)$ GeV	`tN_diag_low`	cut-and-count
$\tilde{t}_1 \to t + \tilde{\chi}_1^0$	$\mathrm{m}(\tilde{t}_1,\ \tilde{\chi}_1^0) = (500{,}327)$ GeV	`tN_diag_high`	cut-and-count
$\tilde{t}_1 \to bff'\tilde{\chi}_1^0$	$\mathrm{m}(\tilde{t}_1,\ \tilde{\chi}_1^0) = (500{,}450)$ GeV	`bffN_btag`	shape-fit in $p_{\mathrm{T}}^{\ell}/E_{\mathrm{T}}^{\mathrm{miss}}$ and $\Delta\phi(\vec{\mathrm{p}}_{\mathrm{T}}^{\mathrm{b-jet}}, \vec{p}_{\mathrm{T}}^{\mathrm{miss}})$
$\tilde{t}_1 \to bff'\tilde{\chi}_1^0$	$\mathrm{m}(\tilde{t}_1,\ \tilde{\chi}_1^0) = (450{,}430)$ GeV	`bffN_softb`	shape-fit in $p_{\mathrm{T}}^{\ell}/E_{\mathrm{T}}^{\mathrm{miss}}$
spin-0 mediator	$\mathrm{m}(\phi/a,\ \chi) = (20{,}1)$ GeV	`DM`	shape-fit in $\Delta\phi(\vec{p}_{\mathrm{T}}^{\mathrm{miss}}, \ell)$

$$\mathcal{S}(p_{Wx}, p_{Wy}, p_{Wz}, p_{\nu z}) = \frac{(m_{\mathrm{W}}^2 - p_{\mathrm{W}}^2)^2}{a_{\mathrm{W}}^4} + \frac{(m_t^2 - (p_{b1} + p_\ell + p_\nu)^2)^2}{a_t^4} + \frac{(m_t^2 - (p_{b2} + p_{\mathrm{W}})^2)^2}{a_t^4} + \frac{(4m_t^2 - (\Sigma_i p_i)^2)^2}{a_{\mathrm{CM}}^4},$$

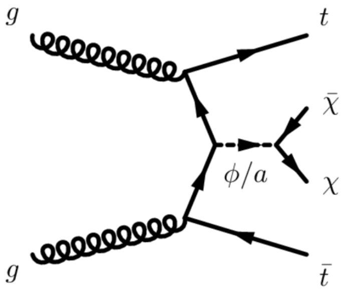


Table 7: Event selections defining the DM signal regions.

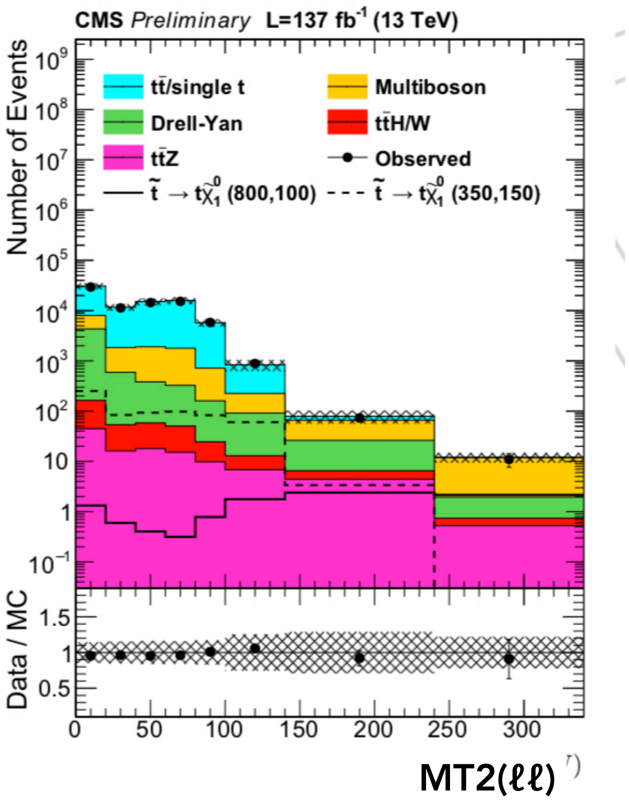
Selection		`DM_scalar`	`DM_pseudo`
Preselection		hard-lepton preselection	
$N_{\mathrm{jet}}, N_{b\text{-jet}}$		$\geq (4, 2)$	
Jet p_{T}	[GeV]	$> (80, 60, 30, 25)$	
b-tagged jet p_{T}	[GeV]	$> (80, 25)$	
$E_{\mathrm{T}}^{\mathrm{miss}}$	[GeV]	> 230	
$H_{\mathrm{T,sig}}^{\mathrm{miss}}$		> 15	
m_{T}	[GeV]	> 180	
topness		> 8	
$m_{\mathrm{top}}^{\mathrm{reclustered}}$	[GeV]	> 150	
$\Delta\phi(\mathrm{jet}_i, \vec{p}_{\mathrm{T}}^{\mathrm{miss}}), i \in [1, 4]$	[rad]	> 0.9	
$\Delta\phi(\vec{p}_{\mathrm{T}}^{\mathrm{miss}}, \ell)$	[rad]	> 1.1	> 1.5
Exclusion technique		Based on shape fit in $\Delta\phi(\vec{p}_{\mathrm{T}}^{\mathrm{miss}}, \ell)$	
Bin boundaries in $\Delta\phi(\vec{p}_{\mathrm{T}}^{\mathrm{miss}}, \ell)$		$\{1.1, 1.5, 2.0, 2.5, \pi\}$	

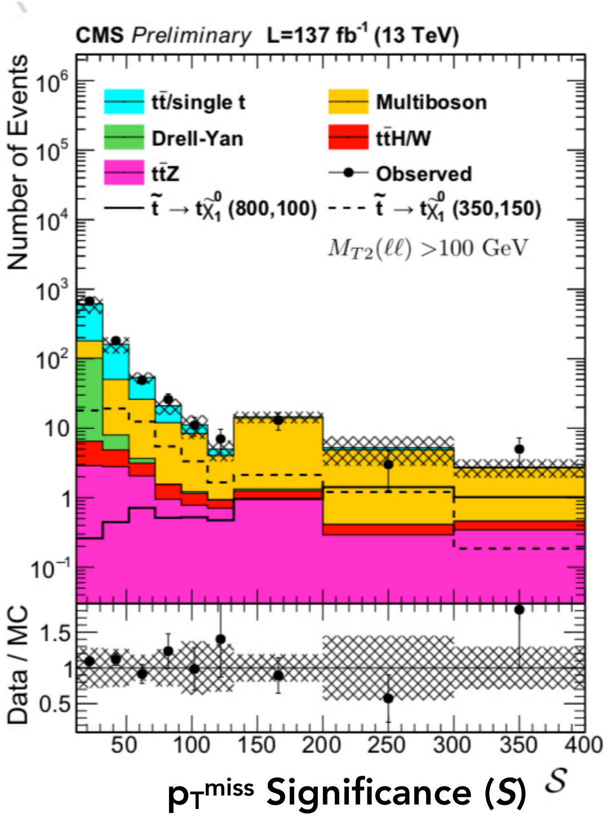
Stop pair production in 2-ℓ

Top : Important when entering the M_{T2} tails due to jet mismeasurement, ℓ-mis-iD/reco'ed.

Top+X : Irreducible background ; estimated from a CR w. 3ℓ.

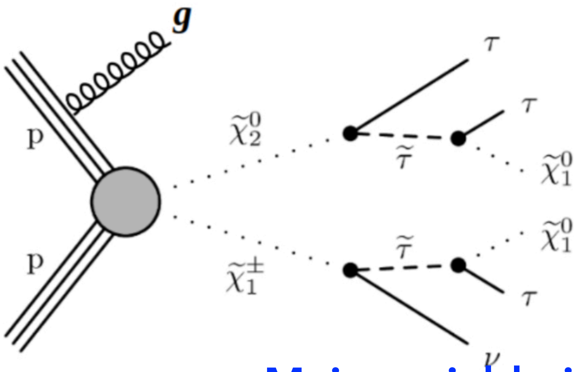
Validation regions show good agreement





CMS-SUSY-19-002

Search for soft taus



Indirect stau production via C1N2 production

- Recoil from ISR facilitates detection
- Soft τ are very challenging
- Fixed Δm(C1,N1) = 50 GeV, Δm(C1,stau) = 25 GeV

Main variable is m_T along w. several cuts to suppress bkg

- Require exactly 1 τ_h + p_T^{miss} and one ISR jet w. $p_T > 100$ GeV
  - $\tau_h < 40$ GeV to suppresses W/Z/top-quark pair
- $\Delta\Phi(j, p_T^{miss})$ to suppress QCD
- Veto b tag jet events, require large p_T^{miss}

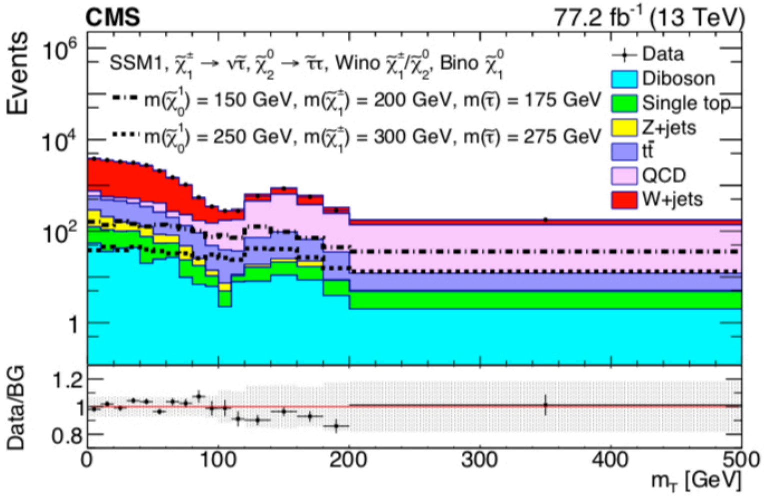
QCD : Shape from SR like events that fail the τ_h tight but pass the loose isolation. Yield using tight-to-loose in an QCD enriched CR.

Top, W/Z+jets : Using simulation to extrapolate yields to the SR from CRs. Validate modelling of the τ_h and extract scale factors to correct modelling of ISR and p_T^{miss} in SR.

VV,rest : Taken from simulation.

CMS-SUSY-19-002

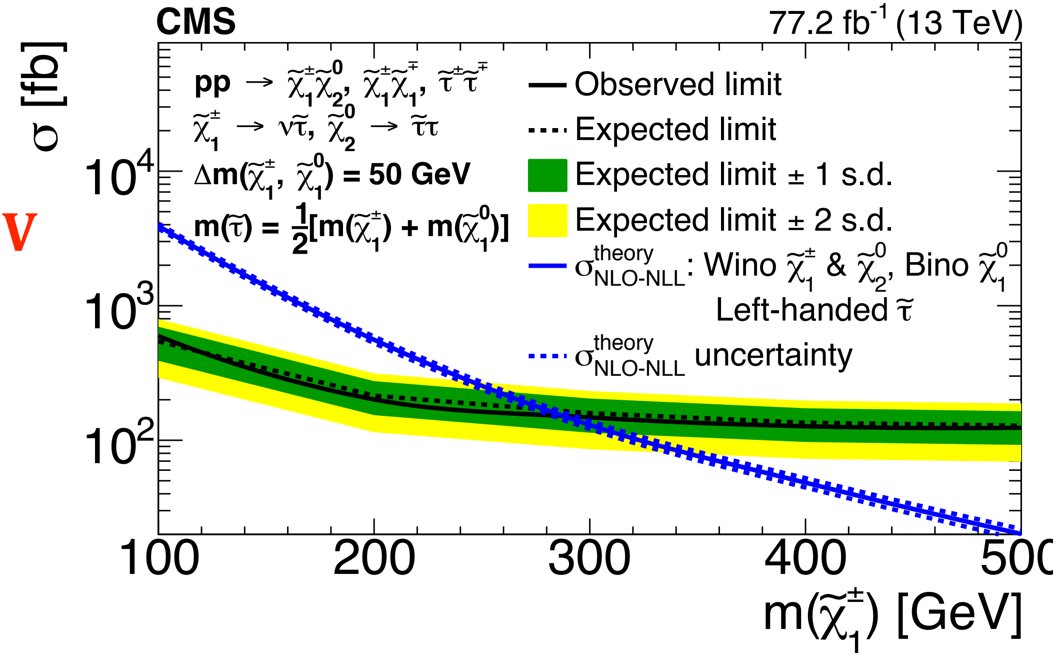
Search for soft taus



m_T in the SR : W+jets dominate low values, QCD high

Major source of systematic : closure of bkg estimation

Excluding C1/N2 up to 290 GeV
Extending previous searches
from LEP ~ 103.5 GeV !!



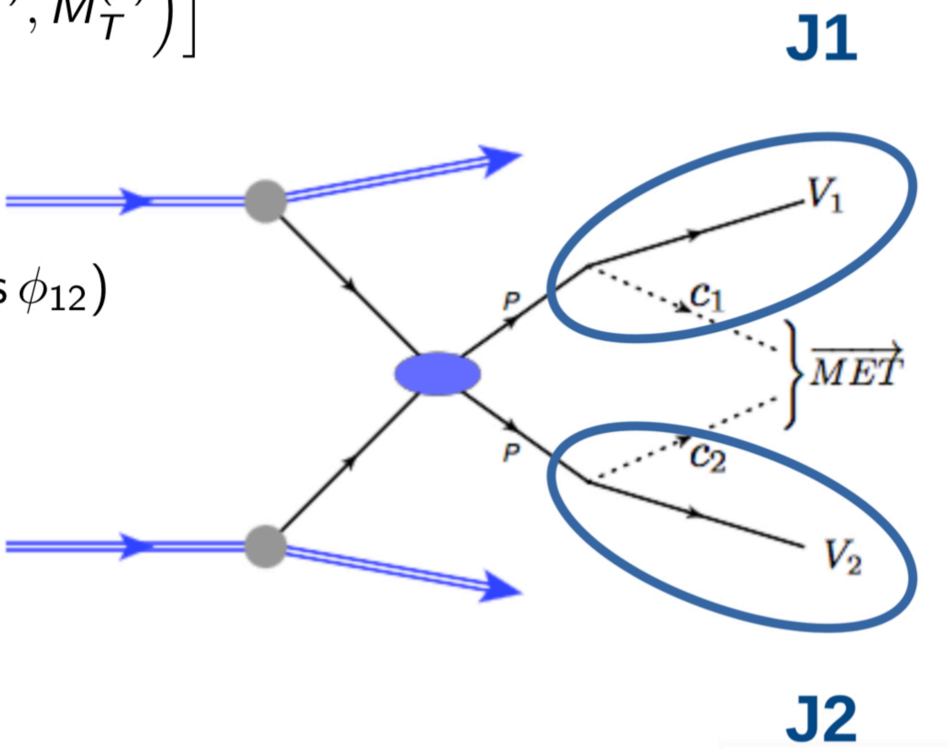
The M_{T2} Vairable

- M_{T2} is a generalize MET like variable for decays with two unobserved particles
- Split the visible part of the event into two hemispheres (pseudojets) for the calculation of M_{T2}

$$M_{T2}(m_c) = \min_{\vec{p}_T^{\,c(1)} + \vec{p}_T^{\,c(2)} = \vec{p}_T^{\,miss}} \left[\max\left(M_T^{(1)}, M_T^{(2)} \right) \right]$$

- Approximate formula:

$$(M_{T2})^2 \sim p_T(J1) \cdot p_T(J2) \cdot (1 + \cos\phi_{12})$$

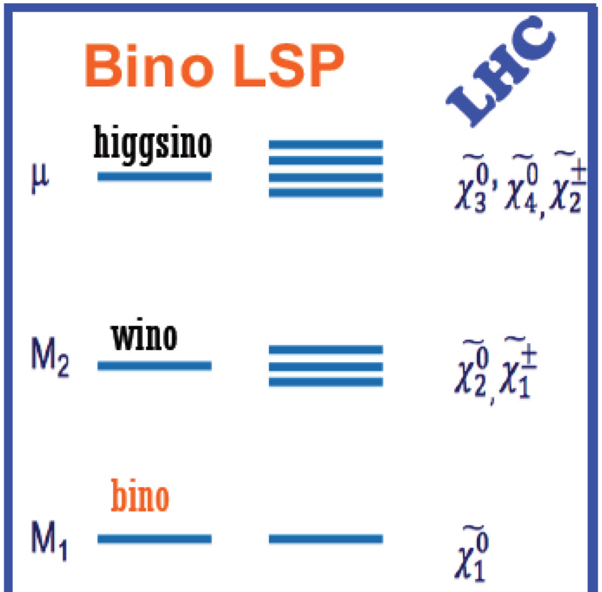


A.Perloff

EWK production

Mass splitting of the EWKinos depends on M1, M2, μ and tanβ

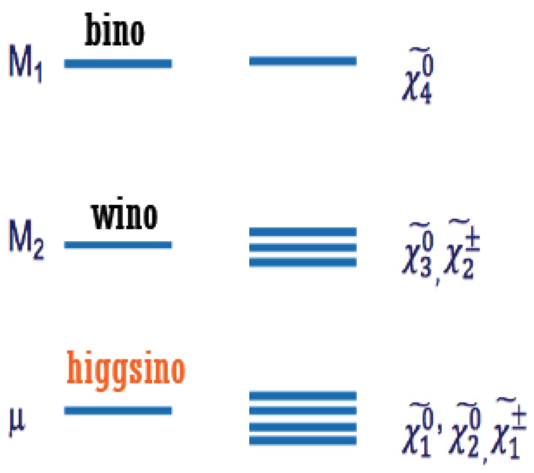
Bino LSP



Standard wino-bino case: large Δm between N1 and C1/N2;

➔ **MET + hard leptons**

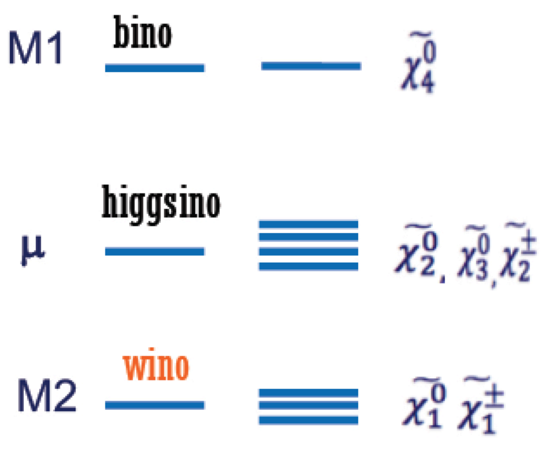
Higgsino LSP



N1,N2,C1 almost degenerate: experimental challenging;

➔ **MET + soft leptons**

Wino LSP



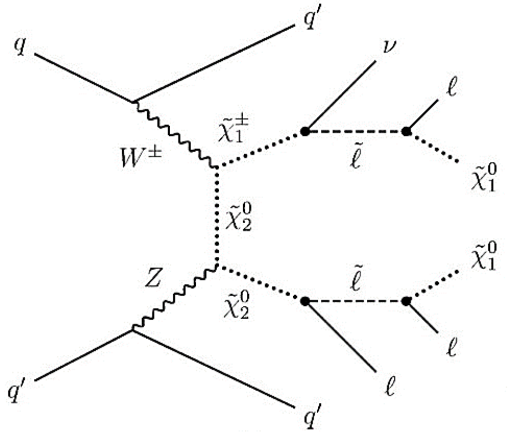
➔ **Lower xsec than higgsino LSP;**

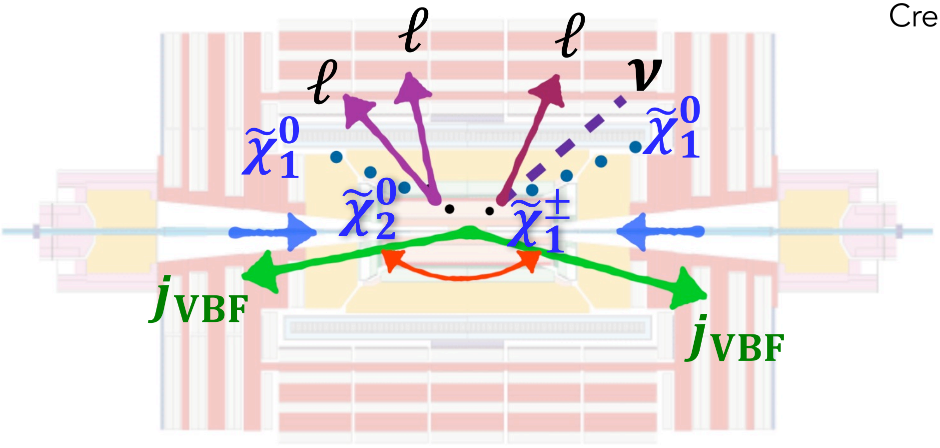
➔ **WW+MET dominant;**

➔ **No sensitivity from LHC yet**

X.Zhuang

VBF topologies



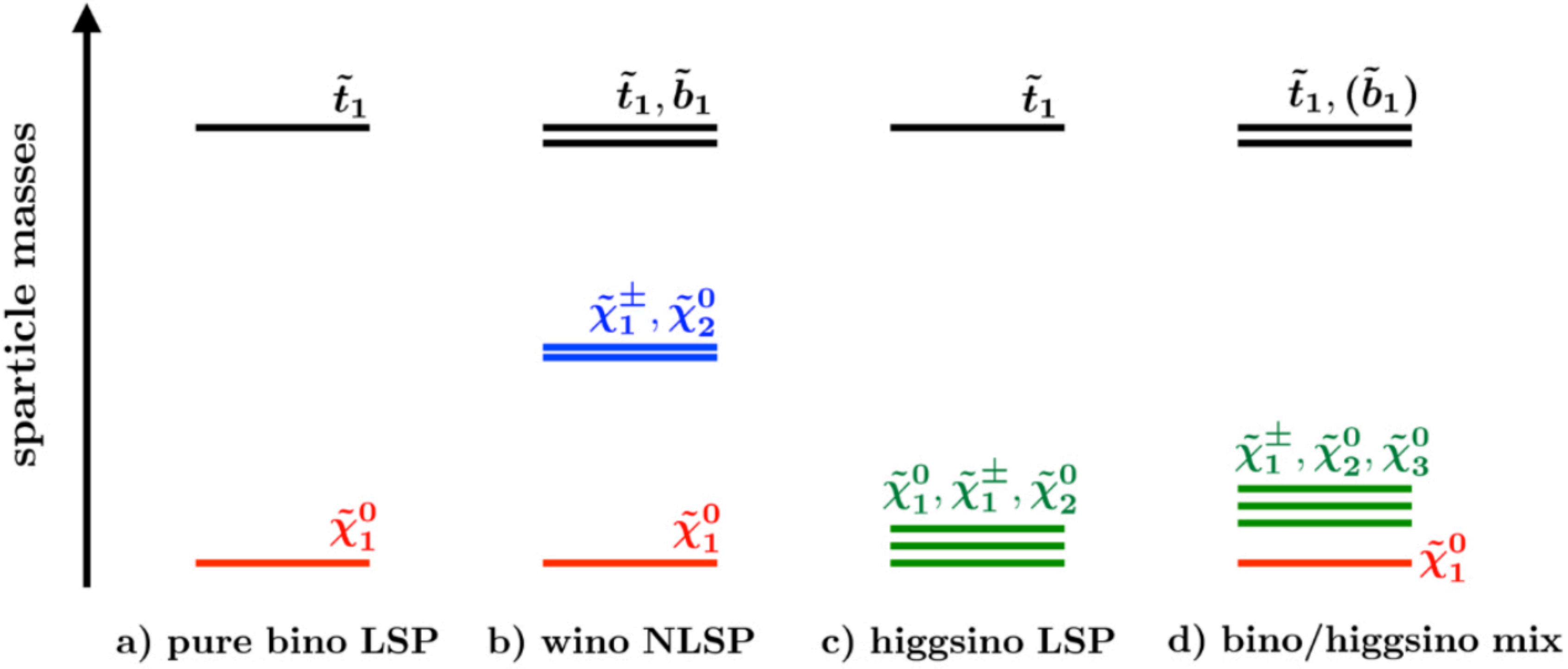


Credits to T.Kamon

In compressed mass scenarios :

- Leptons w. low momenta and might not be reconstructed.
- Requiring two VBF jets with large mass will boost the SUSY system, increasing the acceptance

Mixing scenarios for charginos/neutralinos



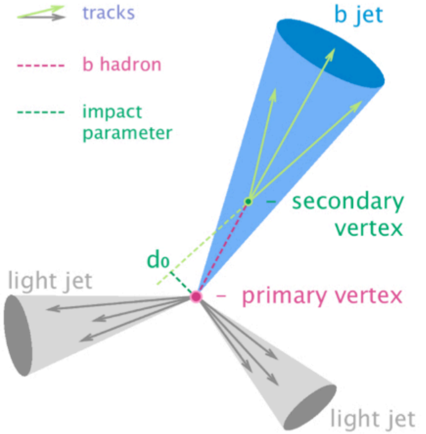
R-parity

- To remove lepton & baryon number violating interactions we introduce a new multiplicative quantum number R-parity

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

  - All interactions have an even number of sparticles.
  - Sparticles can only be pair-produced.
  - The lightest sparticle (LSP) is absolutely stable. (Usually the lightest neutralino.)

Soft B-Tagging

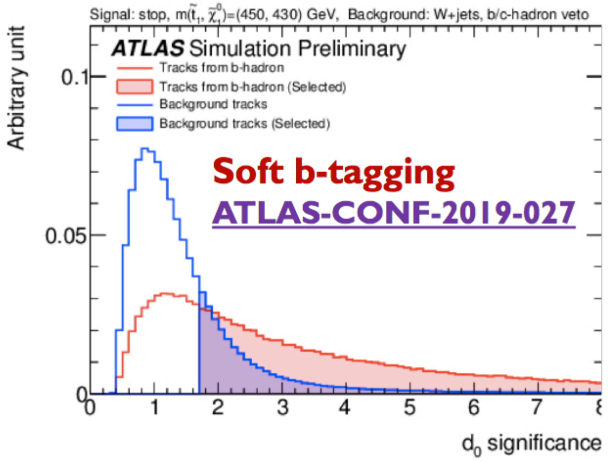


Stop decays → top decays → final states with **b-jets**

- tagging b-jets with $p_T > 1$ GeV
- sensitivity to compressed models
  - signal efficiency and background rejection

- **Soft b-tagging** algorithms:
  - **Inclusive Vertex Finder (IVF)** (JHEP03(2011)136)
    - used in all-hadronic (CMS-SUS-16-049)
    - used in stop 1L (CMS-SUS-19-009) for $\Delta m \sim m_W$
  - **Track-based Low-p_T Vertex Tagger (T-LVT)** (ATLAS-CONF-2019-027)
    - used in all-hadronic (ATLAS-CONF-2020-003)
    - used in stop 1L (ATLAS SUSY-2018-12)
  - DeepJet/DeepCSV
    - used in 1L (CMS-SUS-19-009) for $\Delta m \sim m_t$

- jets reconstructed from tracks
- identifying SVs without the presence of a jet



Soft b-tagging
ATLAS-CONF-2019-027