Searches for Supersymmetry

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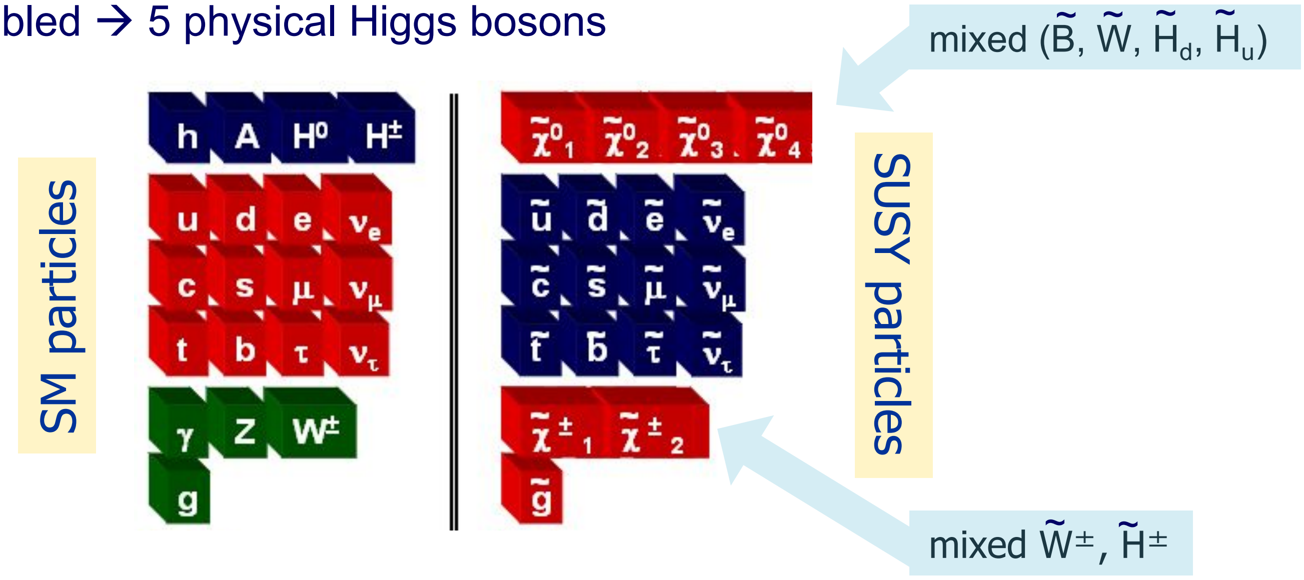
on behalf of the ATLAS and CMS collaborations

Supersymmetry

- Minimal supersymmetric model (MSSM): Assign to each SM particle a SUSY particle with spin differing by ½
- Higgs field is doubled → 5 physical Higgs bosons



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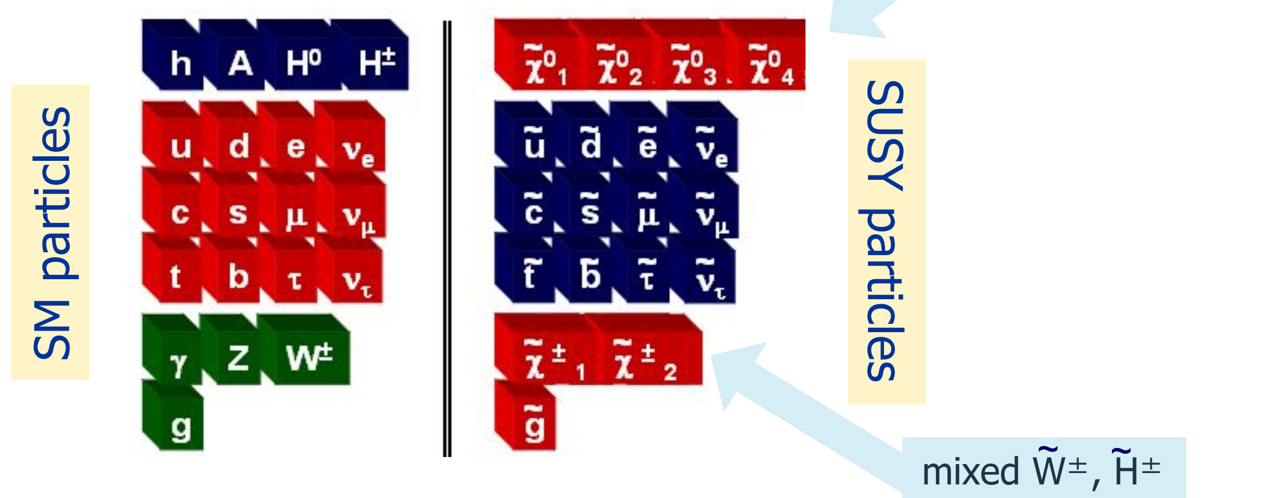
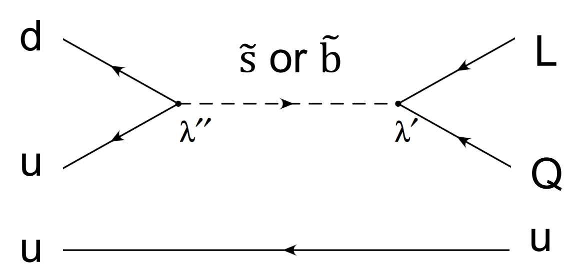


- In the MSSM, **proton could decay** through SUSY particle exchange with new couplings:

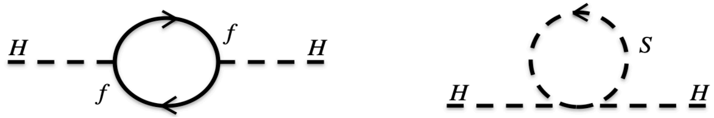
$$W = \lambda'' UDD + \lambda' LQD + \lambda LLE$$



- Solution: define the quantum number **R-parity** with
  - $R = 1$: SM particle
  - $R = -1$: SUSY particle

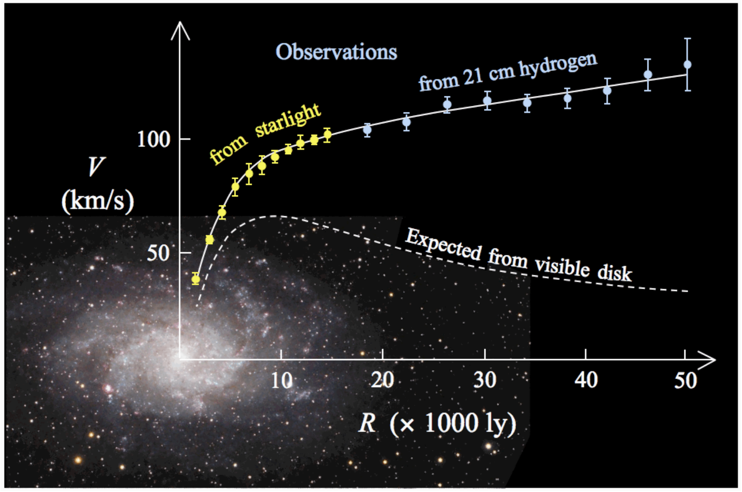
Why Supersymmetry?

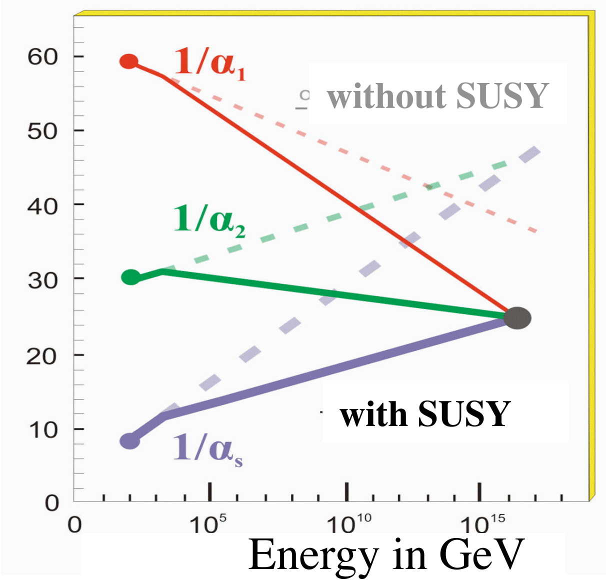
- Lightest SUSY particle in R-parity conserving models:
  → **viable dark matter candidate**
- **Corrections to the Higgs mass cancelled by extra loops with SUSY particles**



- Gravity can be included in SUSY
- Neutrinos masses are expected in SUSY
- **Unification of the forces at about 10^{16} GeV**

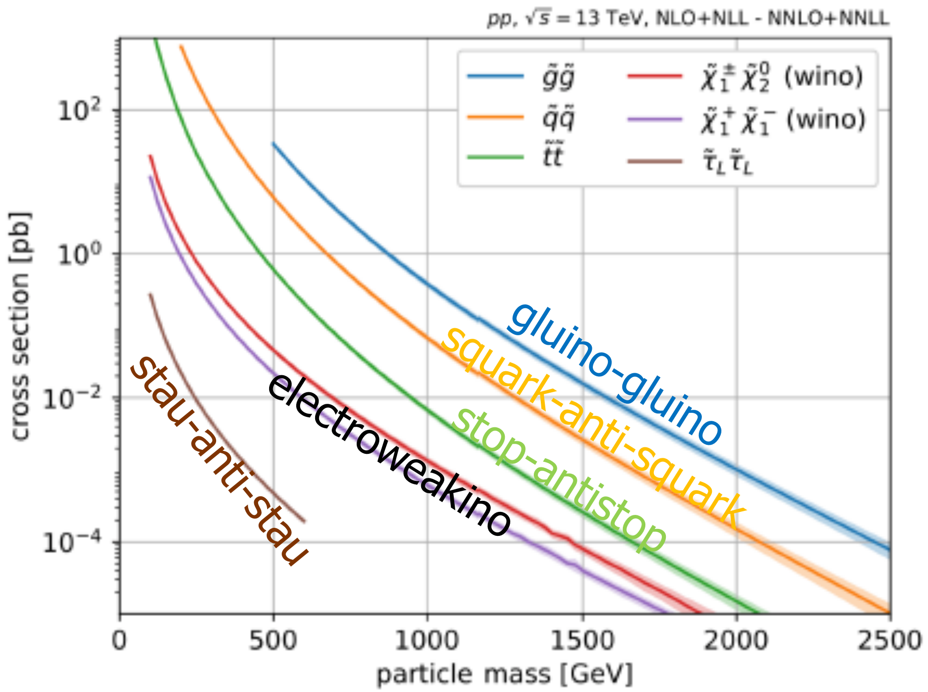
SUSY is not just a model, it's a consistent theory





Search strategy

- **Cross section drives sensitivity!**
  - **Mass reach for strong production higher than for electroweak production**
- **Systematic approach to cover all possible production and decay modes including dedicated searches targeting special scenarios**
  (e.g. compressed spectra, long-lived particles)
- Address both R-parity conserving and violating models
- Determination of main backgrounds from data in control regions
- Analysis results presented using simplified models



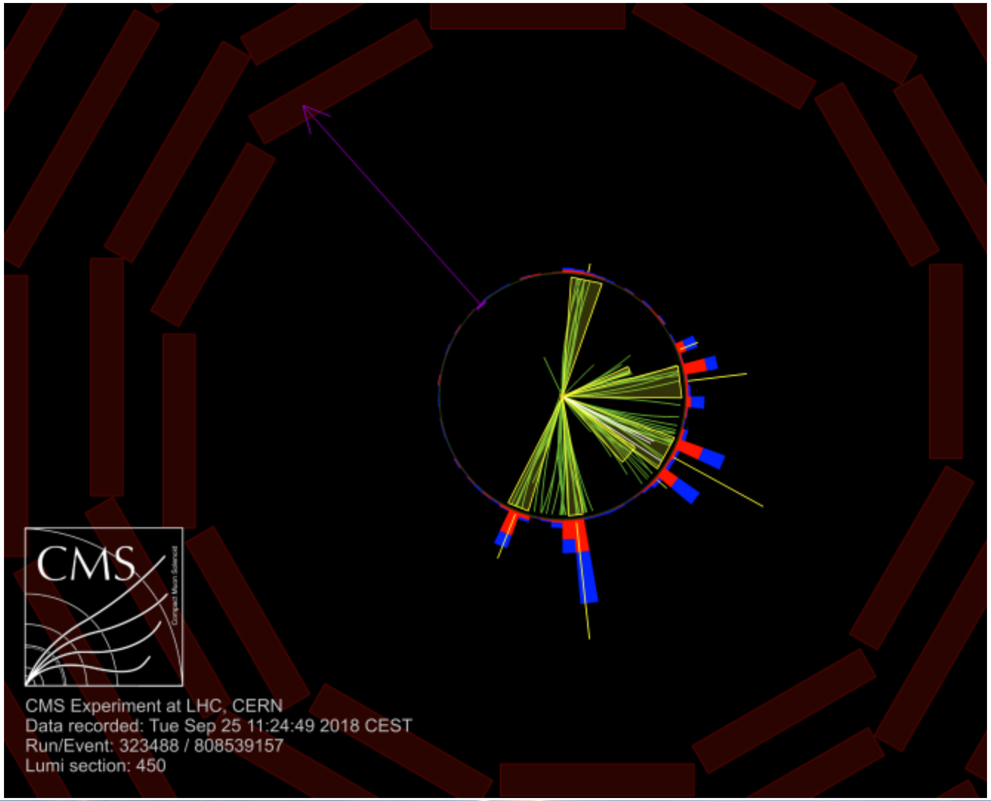
Overview of discussed searches

Focus on new results mostly with full Run 2 data:

- **Strong production**
  - Generic searches for gluino and squark production
    - Full-hadronic channel
    - Leptonic channels (2 same-sign leptons and 3 leptons)
- **Electroweak production**
  - Neutralino-Chargino production
  - Slepton production
- **Long-lived particles**
  - Delayed photons
  - Displaced opposite-sign leptons
  - Disappearing tracks

Search for gluinos and squarks

- **Main discriminators in most searches:**
  - **Missing transverse momentum (p_T^{miss})** from the lightest SUSY particle (LSP) escaping the detector
  - **Large hadronic activity** due to heavy SUSY particles
  - (Large) number of **jets**
  - Possibly (several) **b-tagged jets**

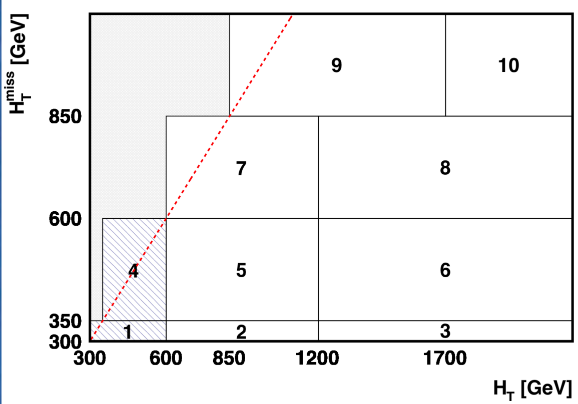


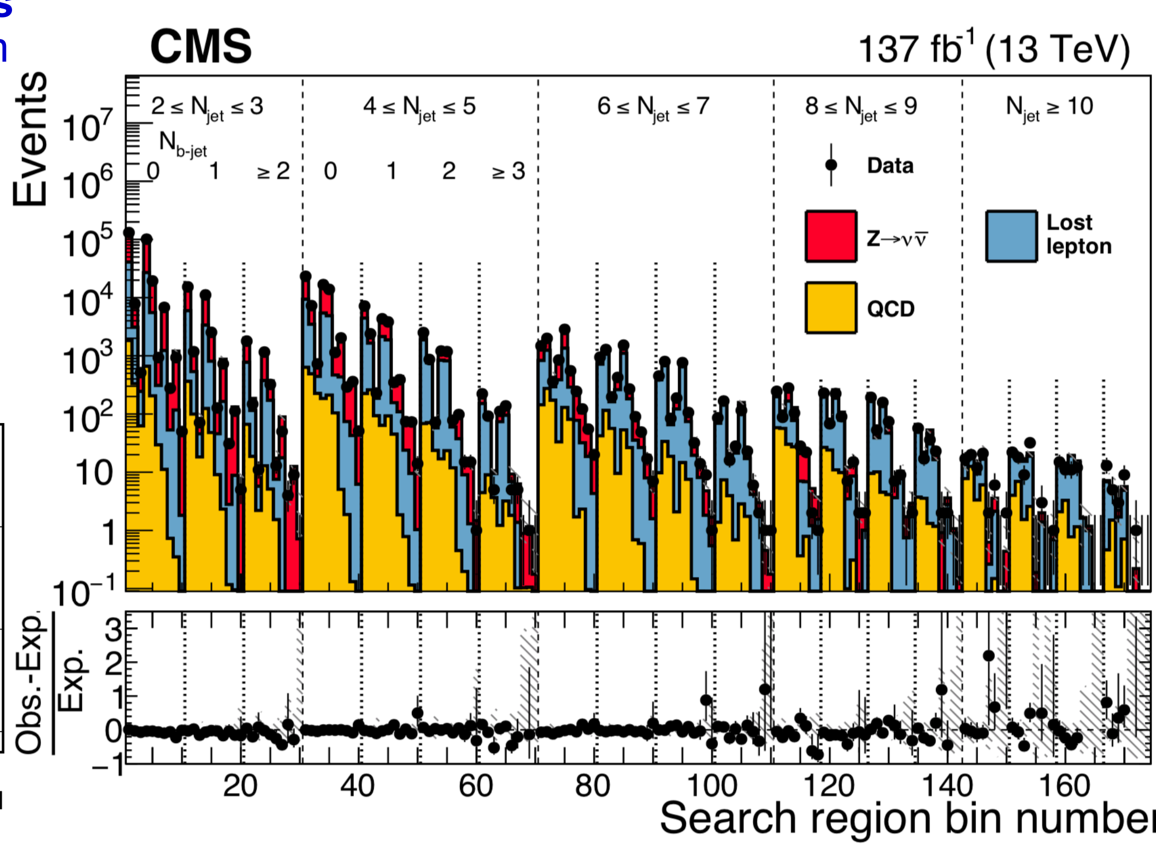
Search for gluinos and squarks: Full-hadronic final state

NEW

CMS-SUS-19-006

- **Main backgrounds:**
  - **Lost lepton events** (mainly W+jets, ttbar):
    - Determined in single-lepton control region in data
  - **Irreducible background with genuine p_T^{miss}, mainly** Z→ νν
    - Determined in a Z → ll control sample in data
  - **QCD multijet events**
    - Determined from data
- **Signal regions categorized in bins of:**
  - **H_T, H_T^{miss}, number of jets and b-jets**

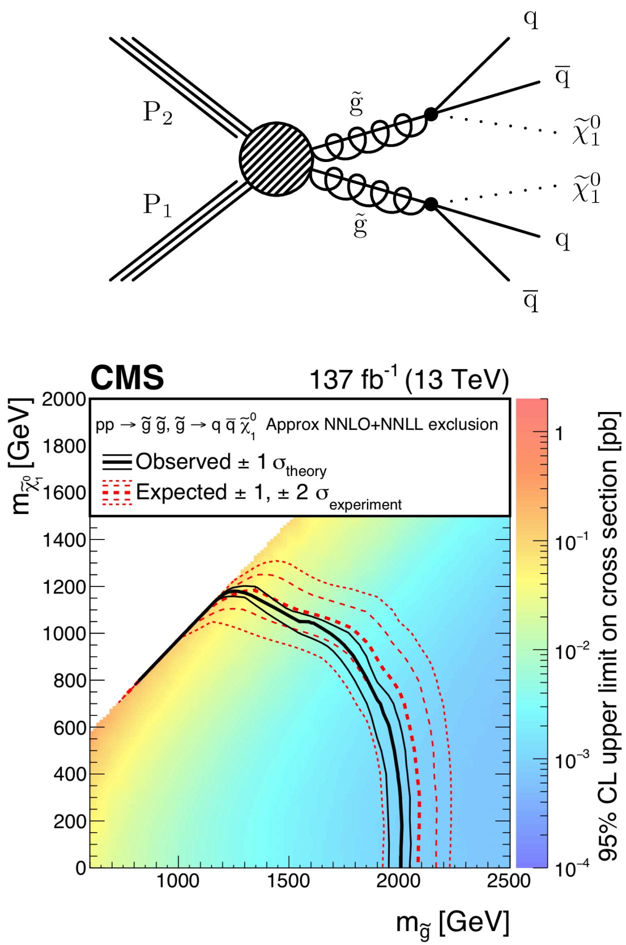


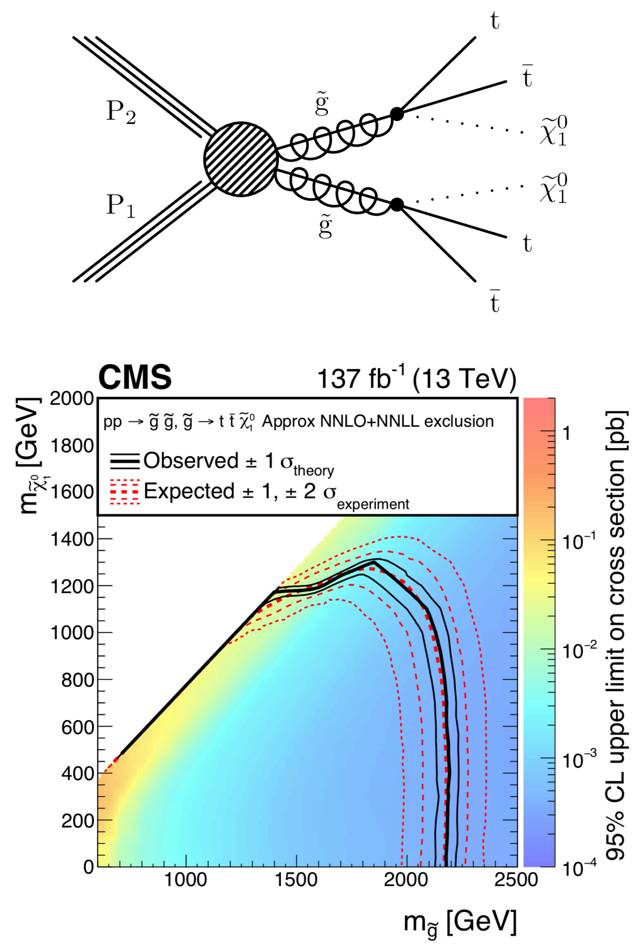


Search for gluinos and squarks: Limits on gluino production

NEW

CMS-SUS-19-006

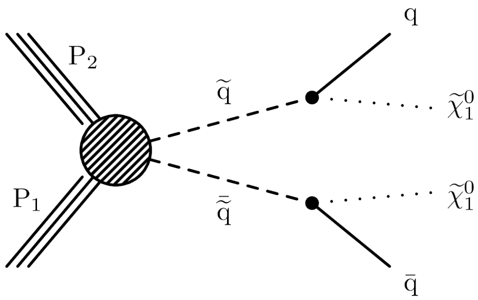


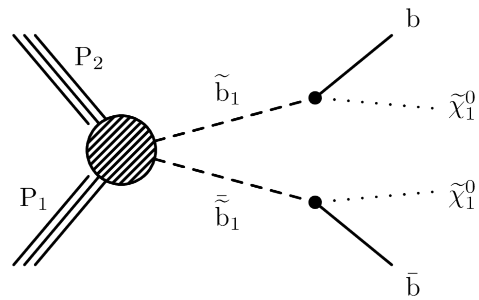


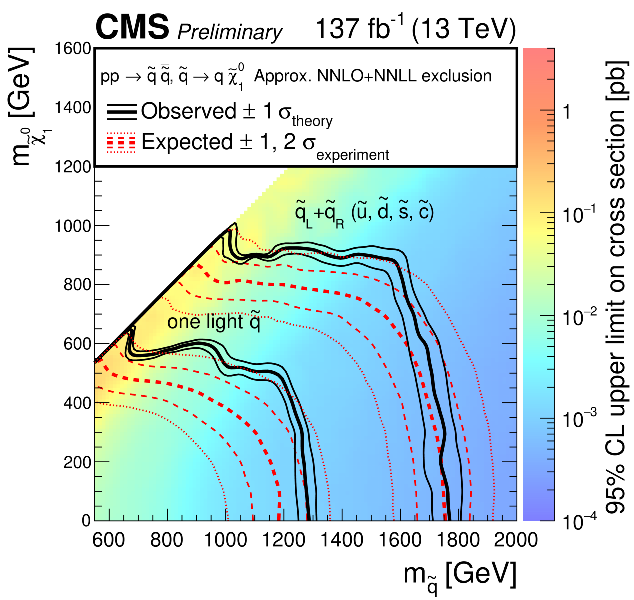
Exclude gluinos decaying to 1st or 2nd generation below 2 TeV, and below 2.2 TeV for decay to 3rd generation squarks

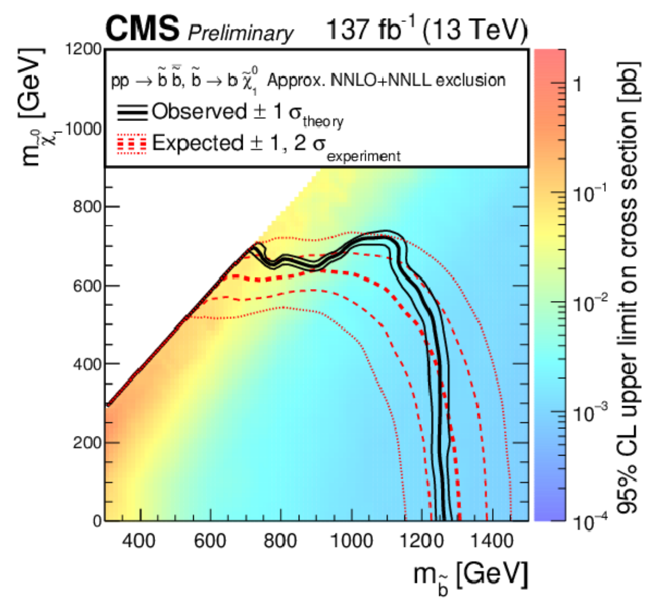
Search for gluinos and squarks: Limits on squark production

CMS-SUS-19-005







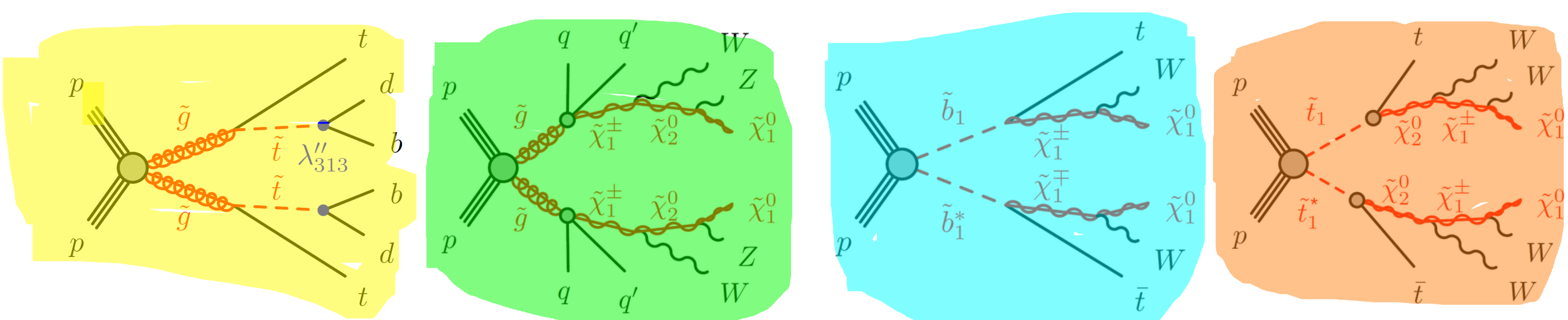


Exclude 1st and 2nd generation squarks below 1.75 TeV (1.3 TeV if only one squark is light), and bottom squarks below 1.25 TeV

Search for gluinos and squarks: Leptonic final states

- Require **2 same-sign leptons** with p_T > 20 GeV (allow 3rd lepton with p_T > 10 GeV)
- **Five complementary signal regions** for a coarse scan of the phase space:

SR	n_ℓ	n_b	n_j	E_T^{miss} [GeV]	m_{eff} [GeV]	E_T^{miss}/m_{eff}
Rpv2L	$\geq 2\ (\ell^\pm\ell^\pm)$	≥ 0	$\geq 6\ (p_T > 40\,\text{GeV})$	–	> 2600	–
Rpc2L0b	$\geq 2\ (\ell^\pm\ell^\pm)$	$= 0$	$\geq 6\ (p_T > 40\,\text{GeV})$	> 200	> 1000	> 0.2
Rpc2L1b	$\geq 2\ (\ell^\pm\ell^\pm)$	≥ 1	$\geq 6\ (p_T > 40\,\text{GeV})$	–	–	> 0.25
Rpc2L2b	$\geq 2\ (\ell^\pm\ell^\pm)$	≥ 2	$\geq 6\ (p_T > 25\,\text{GeV})$	> 300	> 1400	> 0.14
Rpc3LSS1b	$\geq 3\ (\ell^\pm\ell^\pm\ell^\pm)$	≥ 1	no cut but veto 81 GeV $< m_{e^\pm e^\pm} <$ 101 GeV			> 0.14

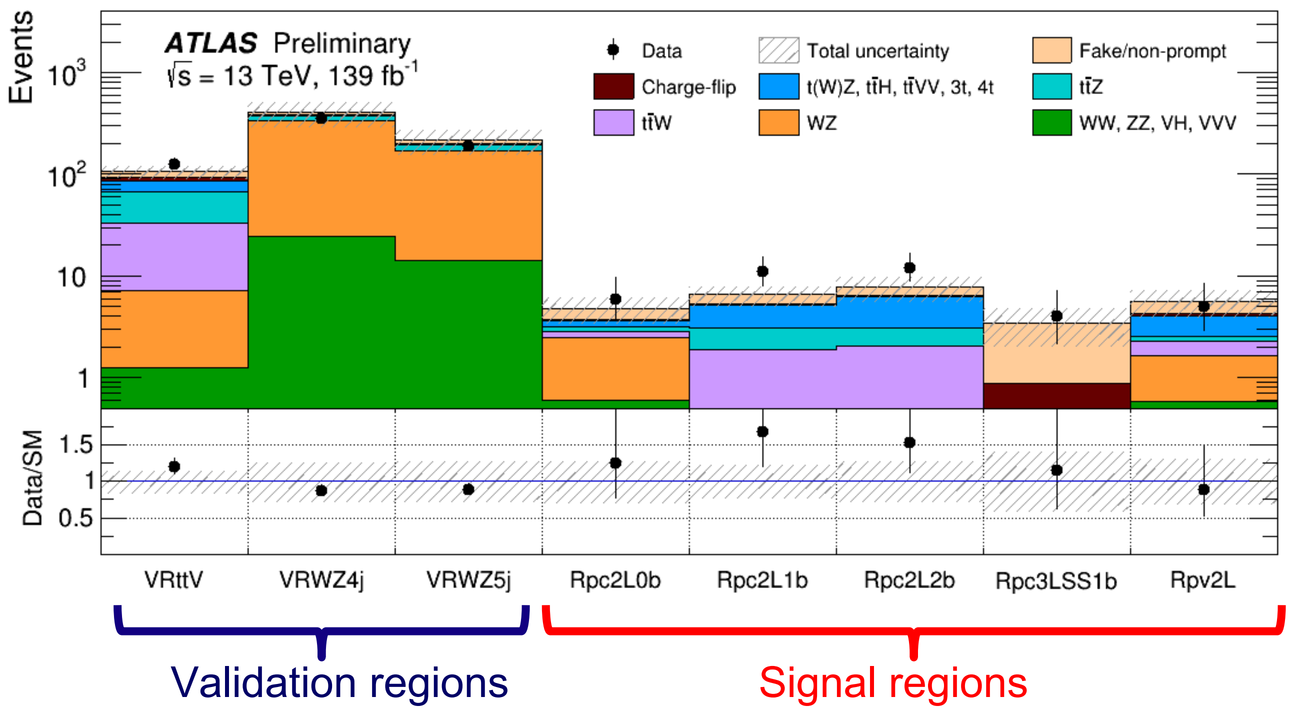


ATLAS-CONF-2019-015

Search for gluinos and squarks: Leptonic final states

ATLAS-CONF-2019-015

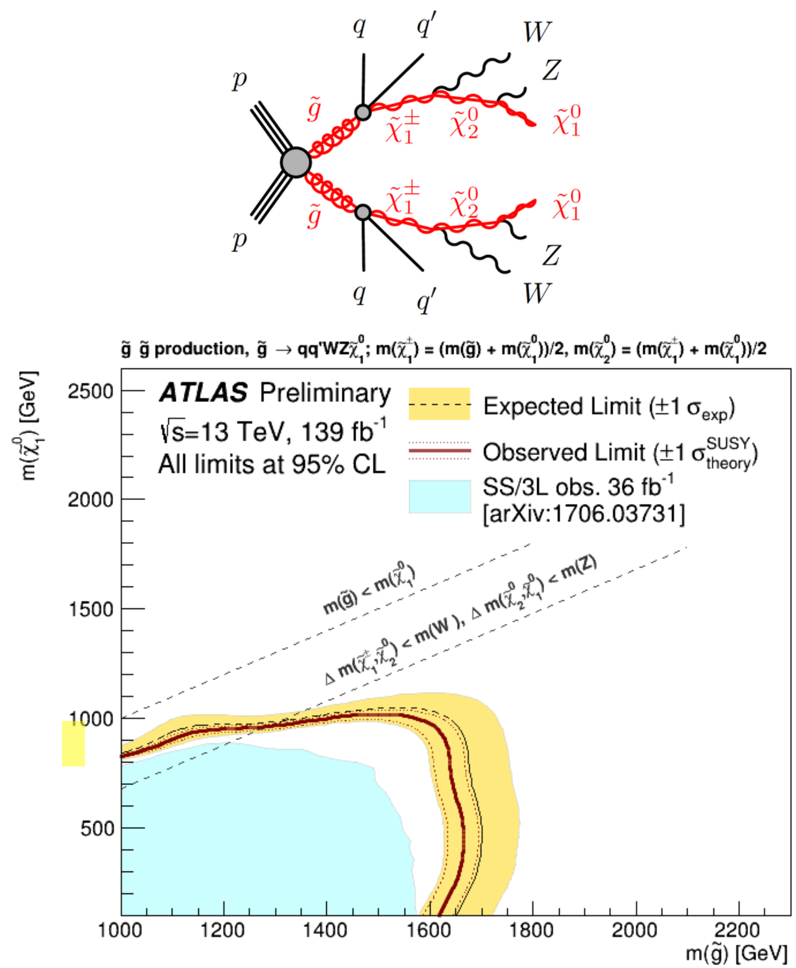
- **Main backgrounds:**
  - **WZ+jets** in SR with 0 b-jets and **ttbar+V** in SRs with b-jets
    - Both estimated from simulation with theory cross section
  - **Events with charge flipped electron** (mainly ttbar and Z+jets)
    - Estimated from data by weighting OS data by the flip rate
  - **Fake / non-prompt leptons**
    - Estimated from data



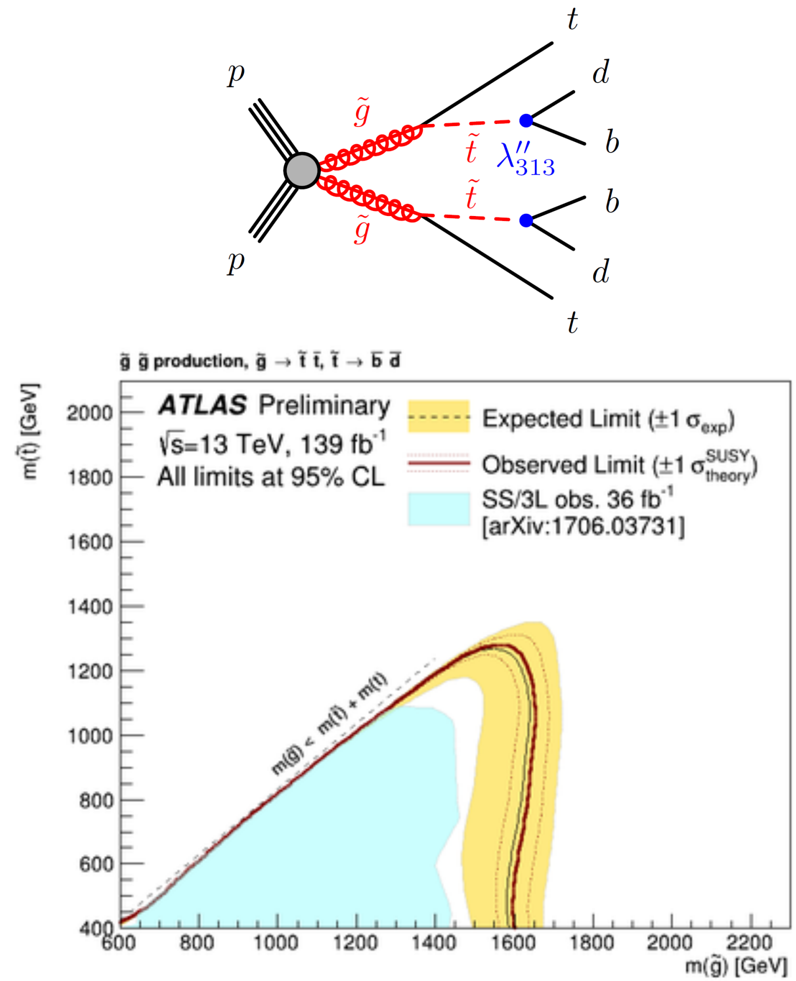
Search for gluinos and squarks : Limits on gluino production

ATLAS-CONF-2019-015

R-Parity conserving model



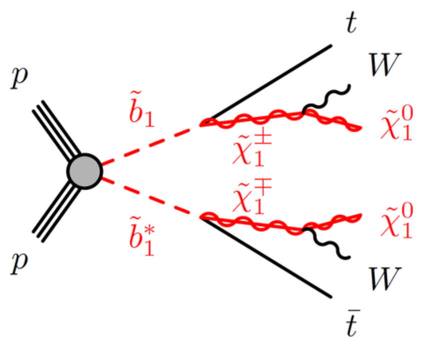
R-Parity violating model

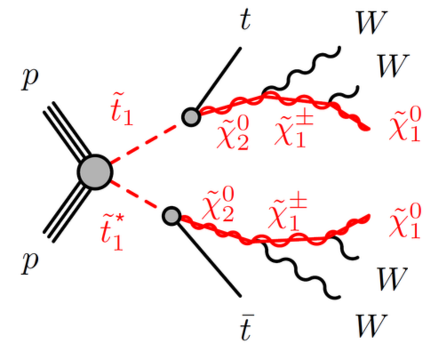


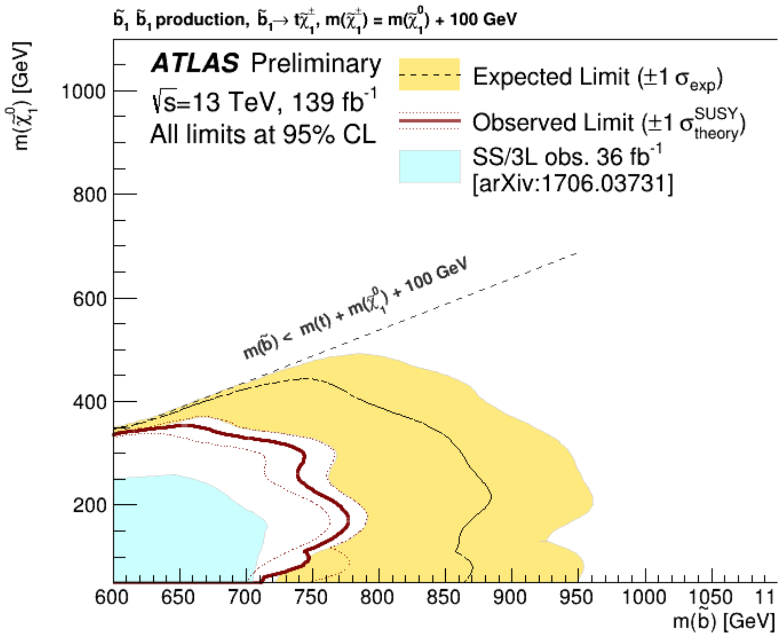
Exclude gluinos with mass below 1.65 (1.6) TeV in RPC (RPV) model

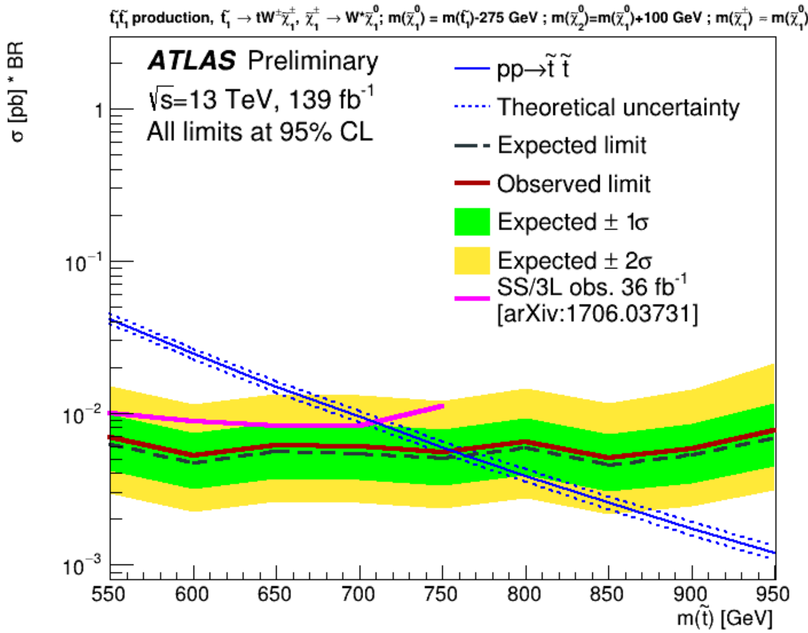
Search for gluinos and squarks : Limits on squark production

ATLAS-CONF-2019-015



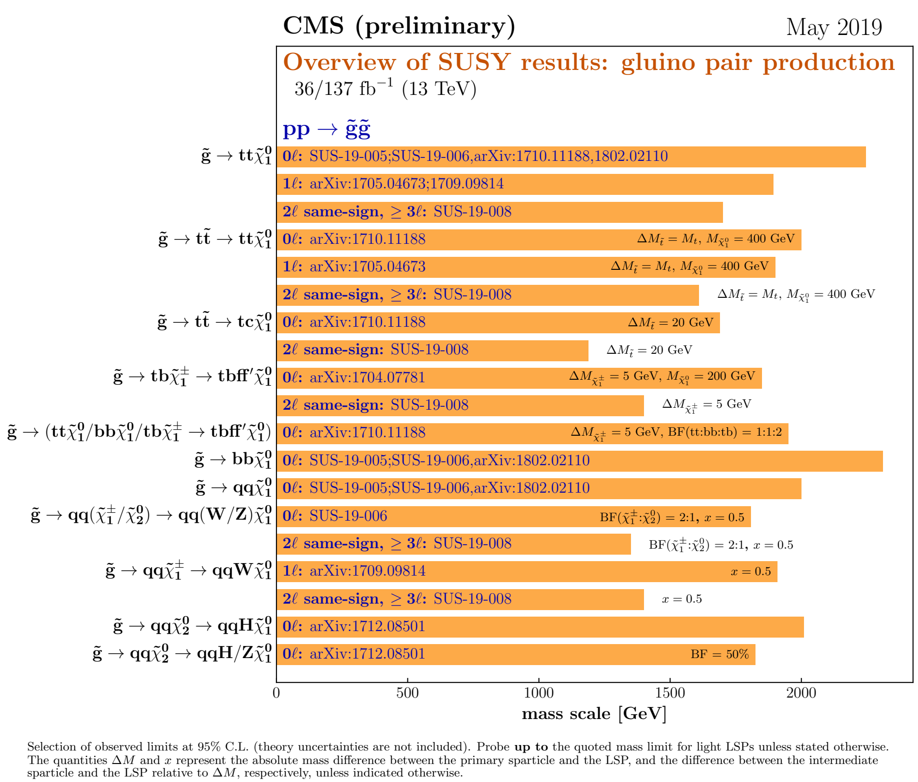


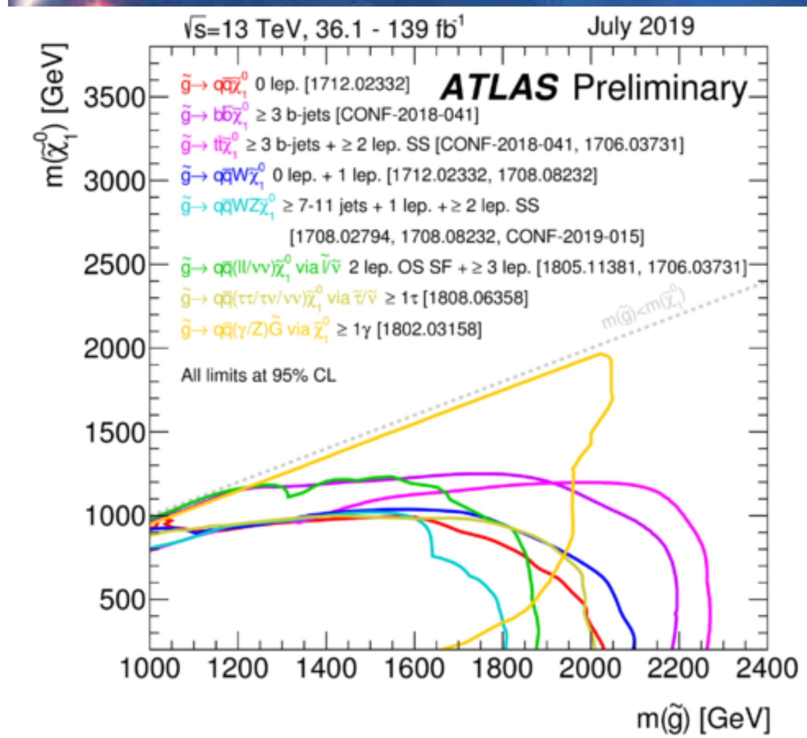




Exclude sbottoms and stops with mass below 750 GeV

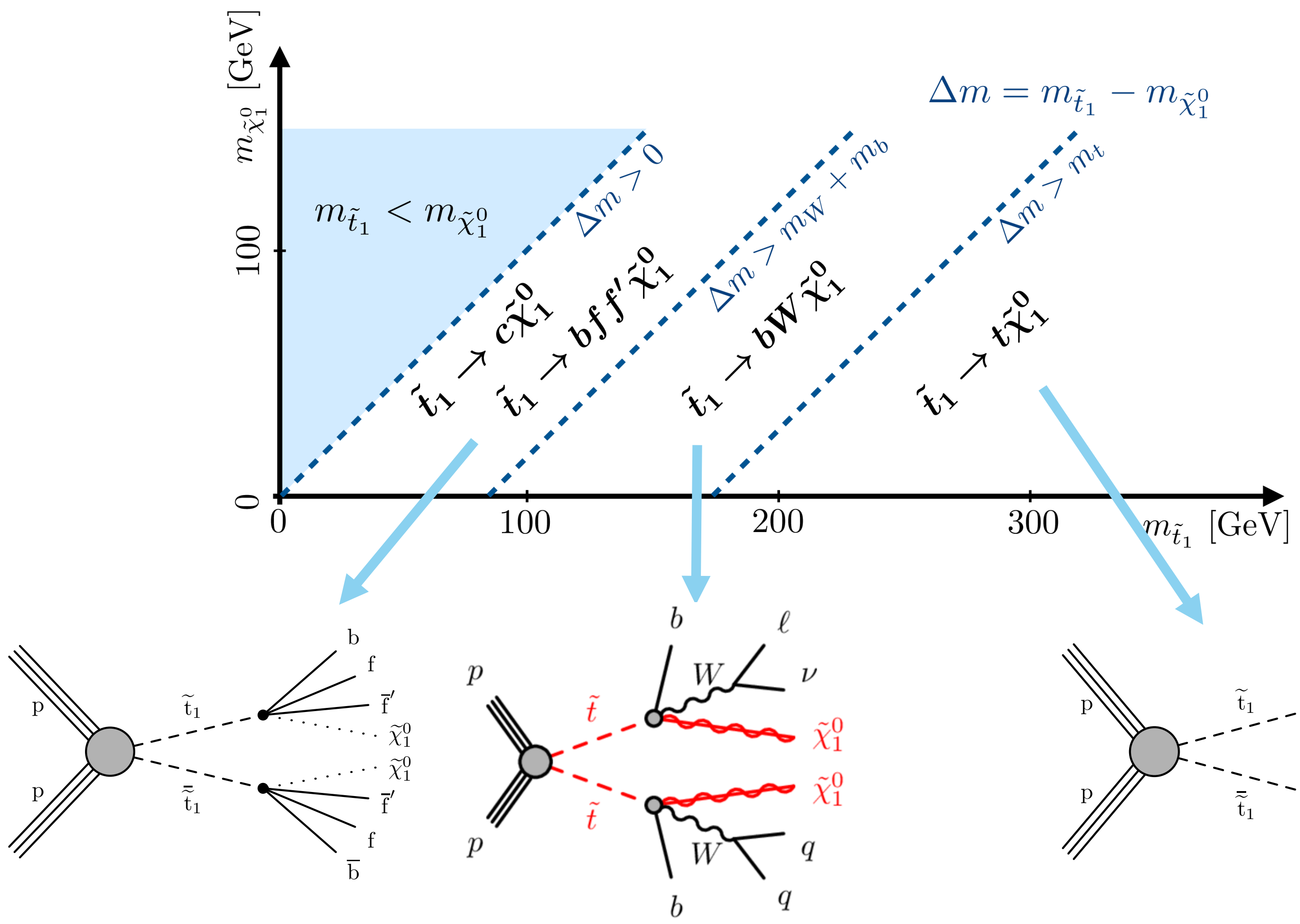
Summary on gluino production





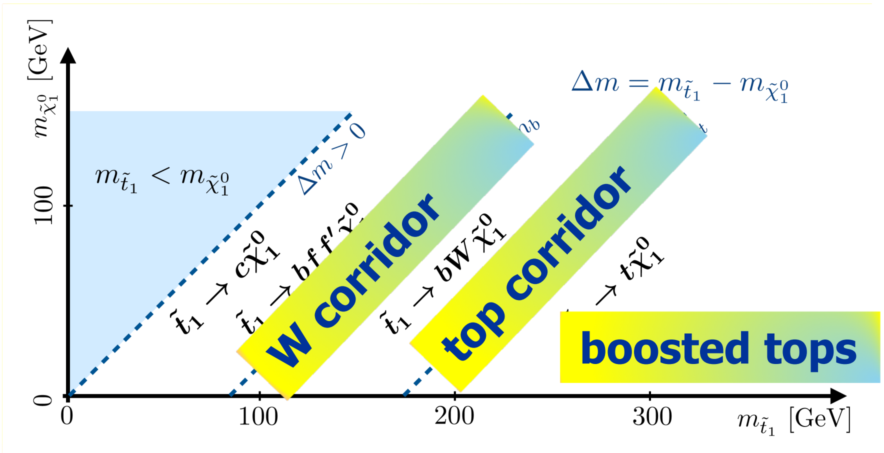
- Sensitivity depends strongly on the underlying model
- Simplified models often assume branching ratios of 100% for one decay channel, expect lower sensitivity if several decay channels are possible

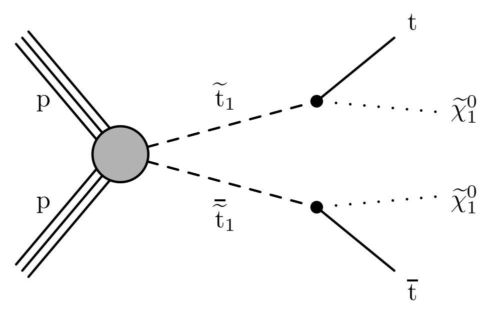
Dedicated stop searches: Results with full Run 2



Dedicated stop searches: Single-lepton final state

NEW





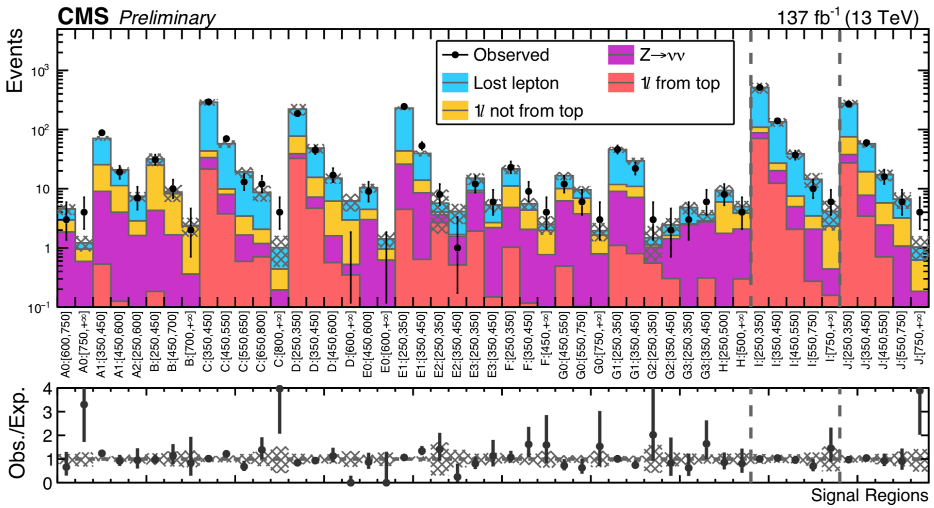
CMS PAS-SUS-19-009

- **Special selections to enhance sensitivity:**
  - **W corridor:** soft b-tags
  - **top corridor:** ISR jet +soft lepton
  - **High stop mass region:** resolved and boosted top tagging

- **Main backgrounds:**
  - **2-lepton events** (mainly ttbar and Wt production) with one lost lepton
    - Determined in dilepton control region in data
  - **Events with one genuine lepton**
    - ttbar taken from simulation, W+jets from 0-b control region in data

Dedicated stop searches: Single-lepton final state

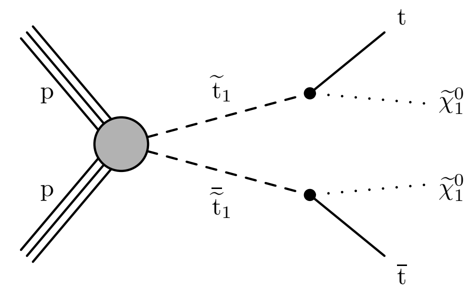
NEW

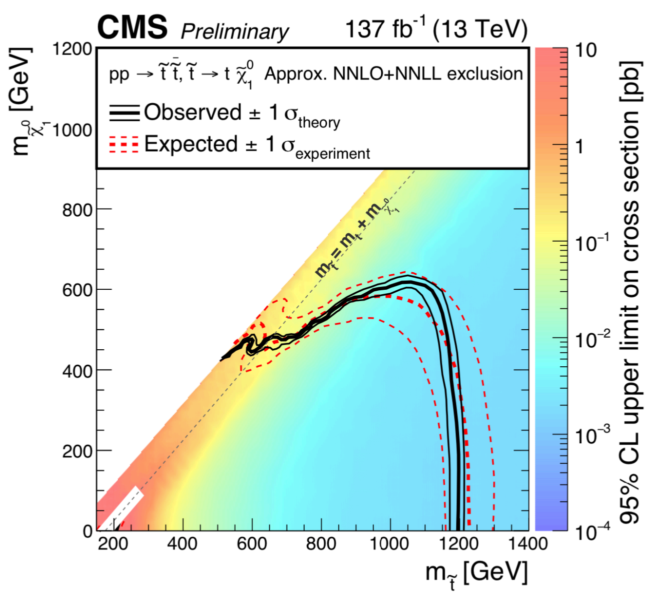


	N_J	t_{mod}	$M_{\ell b}$ [GeV]
A	2–3	> 10	≤ 175
B	2–3	> 10	> 175
C	≥ 4	≤ 0	≤ 175
D	≥ 4	≤ 0	> 175
E	≥ 4	0–10	≤ 175
F	≥ 4	0–10	> 175
G	≥ 4	> 10	≤ 175
H	≥ 4	> 10	> 175

X0: Inclusive
X1: Untagged
X2: Boosted top
X3: Resolved top

I: $N_J \geq 5$, $N_{b,med} \geq 1$
J: $N_J \geq 3$, $N_{b,soft} \geq 1$

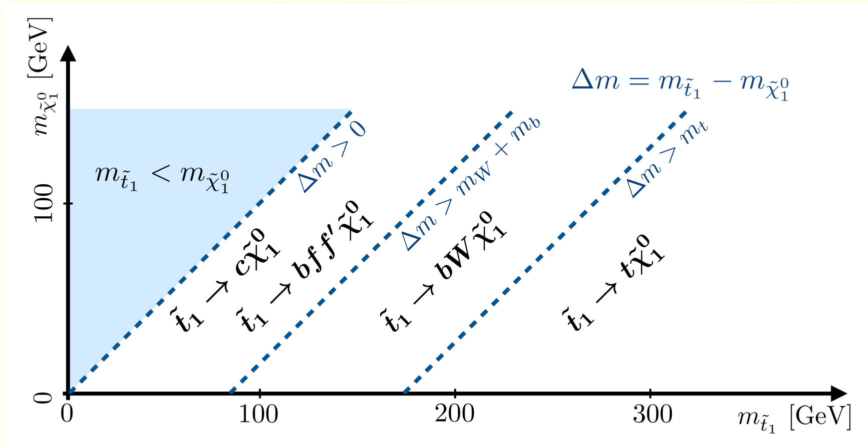


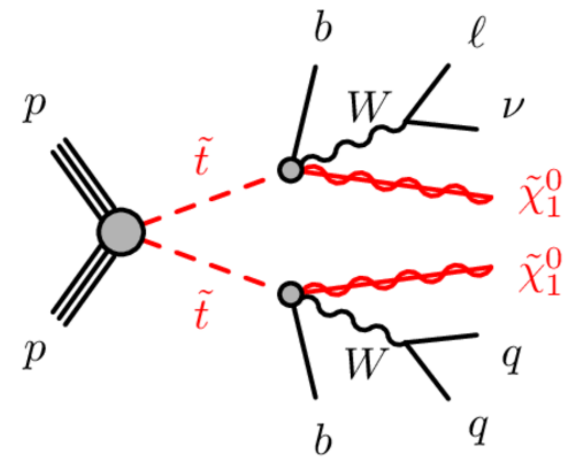


CMS PAS-SUS-19-009

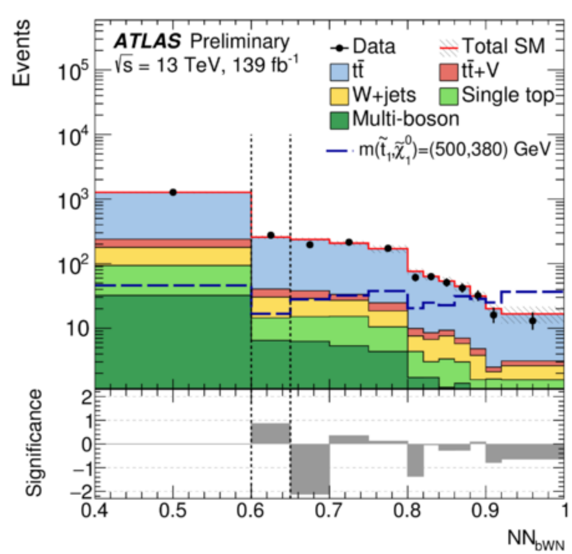
Exclude top squarks below 1.2 TeV

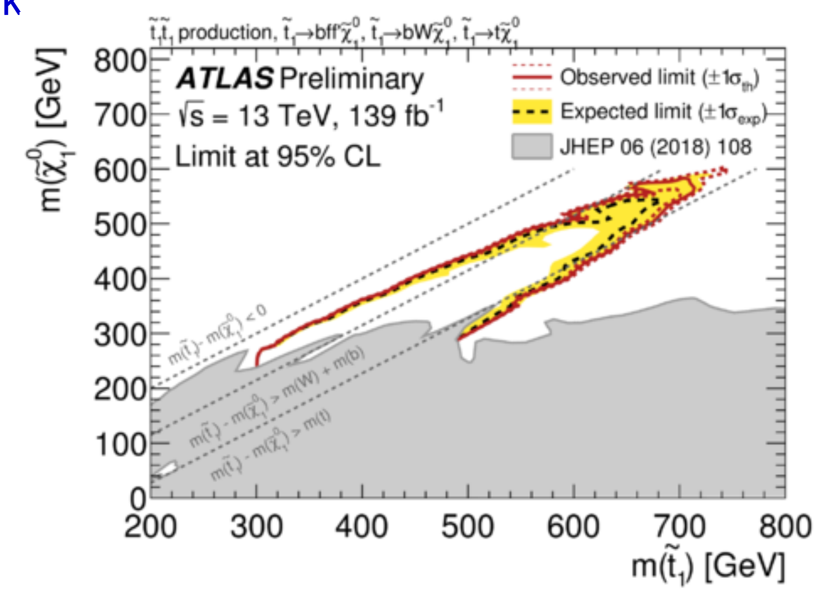
Dedicated stop searches: Single-lepton final state





- Specific search targeting three-body decay
  - Sensitivity enhanced by neural network





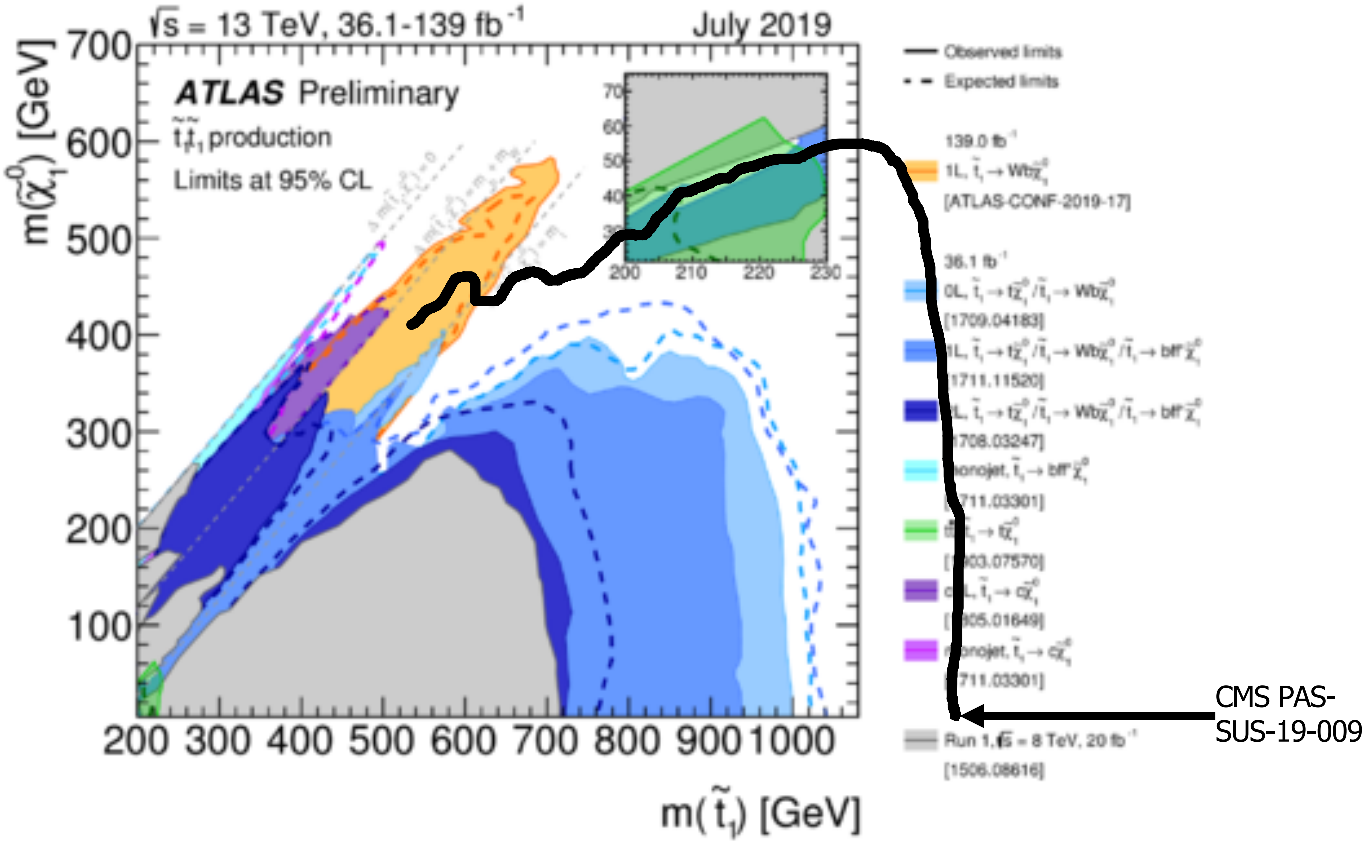
ATLAS-CONF-2019-017

Dedicated stop searches: Summary

NEW

ATLAS-CONF-2019-017

CMS PAS-SUS-19-009



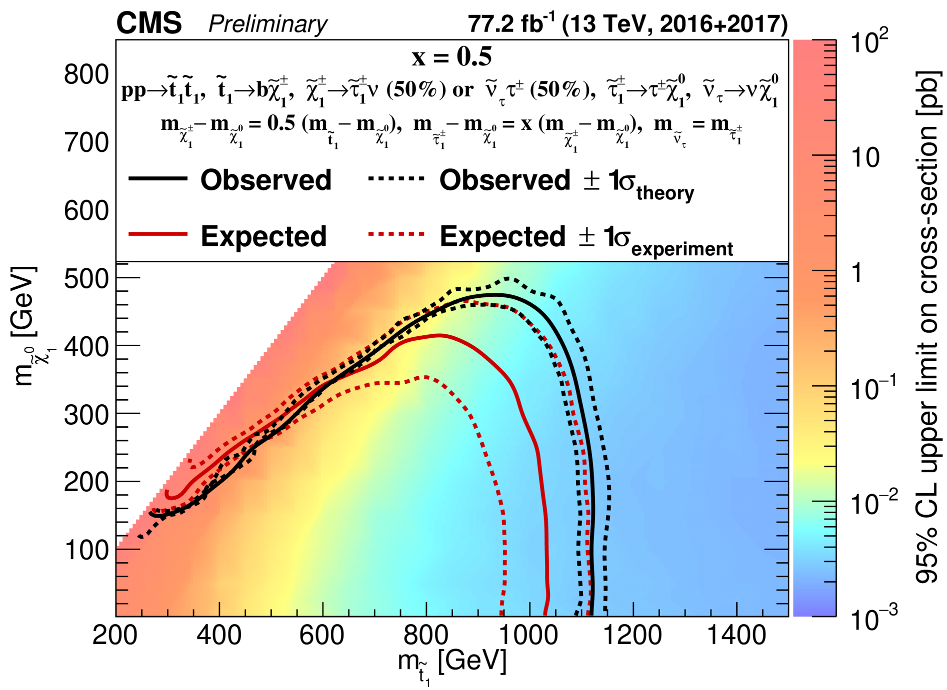
Stringent limits on top squark production, also in compressed region

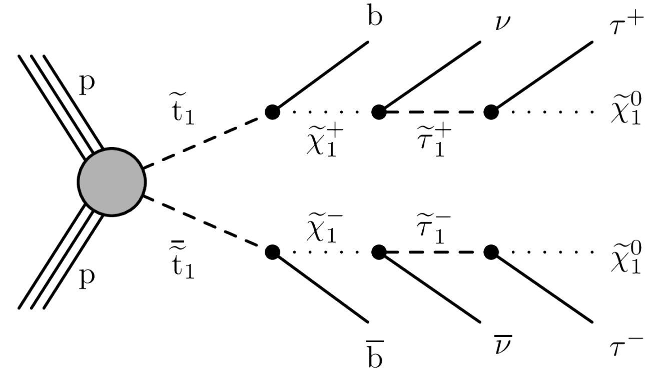
Specific stop search: Focus on decay to tau leptons

NEW

CMS PAS-SUS-19-003

- **Electroweakino-fermion interaction includes gauge and Yukawa coupling:**
  - Tau-Yukawa coupling large for high tanβ
  - Large tanβ can make the $\widetilde{\tau_1}$ much lighter than 1st or 2nd generation sleptons
  - Higgsino-like gauginos preferentially couple to third generation fermions



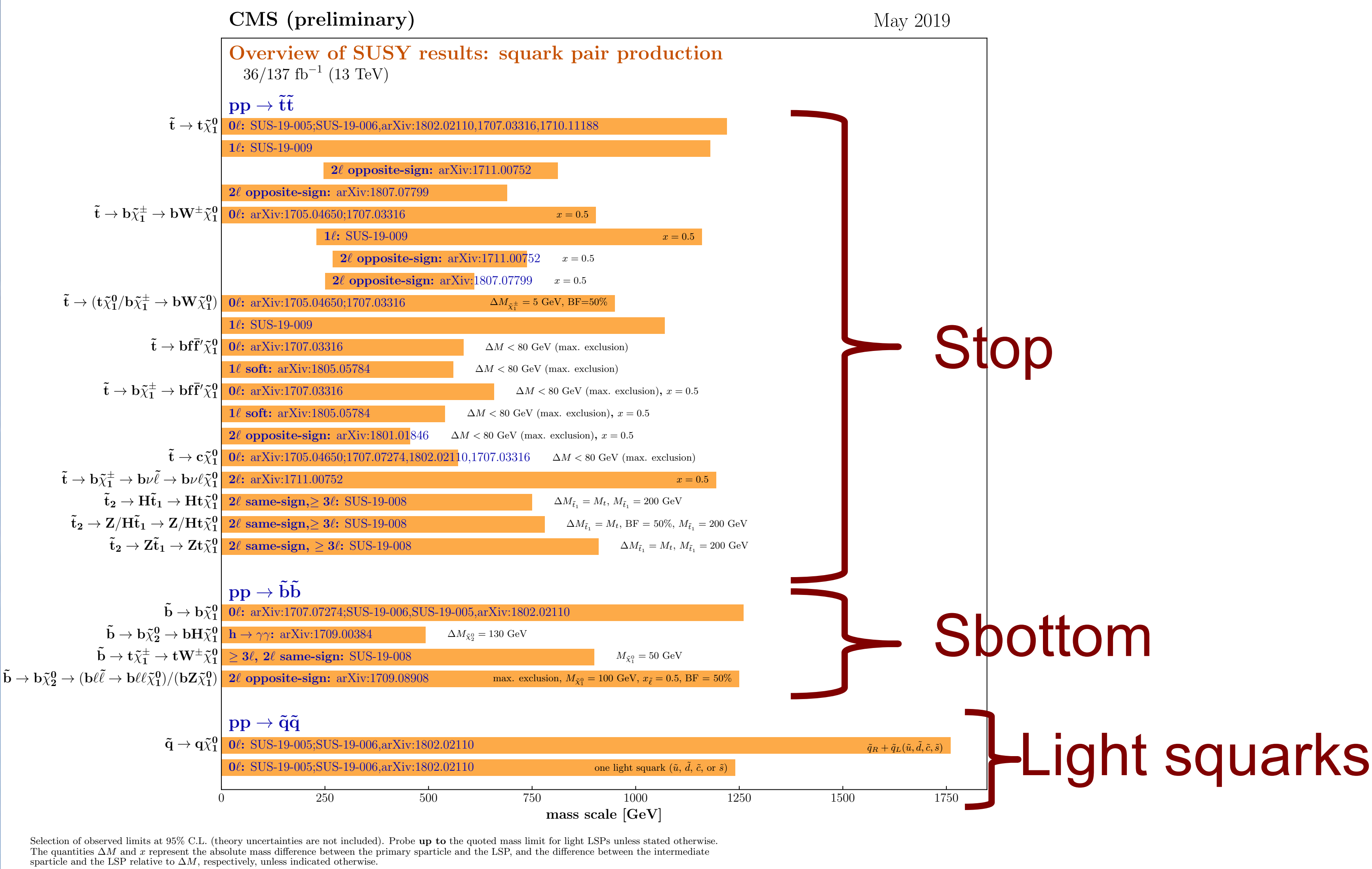


$$m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 0.5\left(m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0}\right)$$

$$m_{\tilde{\tau}_1} - m_{\tilde{\chi}_1^0} = 0.5\left(m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0}\right)$$

Exclude top squarks decaying to staus with masses below 1.1 TeV

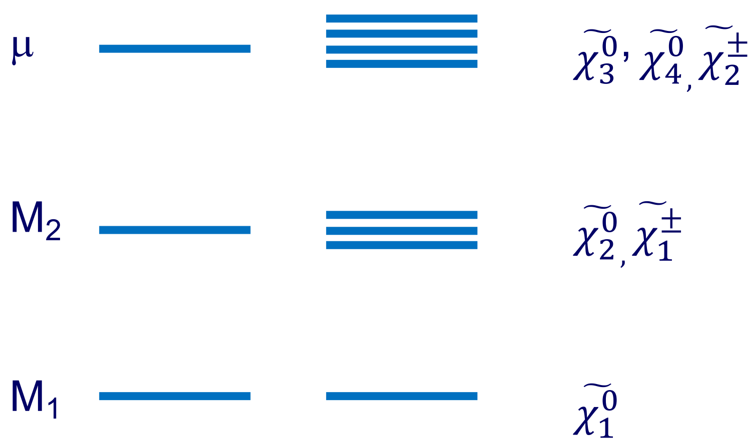
Summary on squark production



EWKino production

- Mass splitting of the EWKinos depends on M_1, M_2, μ and $\tan\beta$

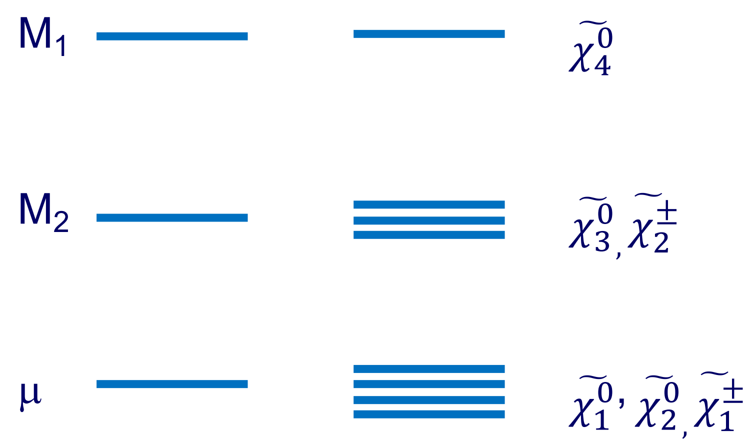
Bino-Wino case



Larger mass gap between $\tilde{\chi}^0_1$ and $\tilde{\chi}^0_2, \tilde{\chi}^\pm_1$

→ p_T^{miss} + leptons

Higgsino case



$\tilde{\chi}^0_1$ $\tilde{\chi}^0_2$, and $\tilde{\chi}^\pm_1$ almost mass-degenerate

→ experimentally challenging
→ possibly long-lived particles

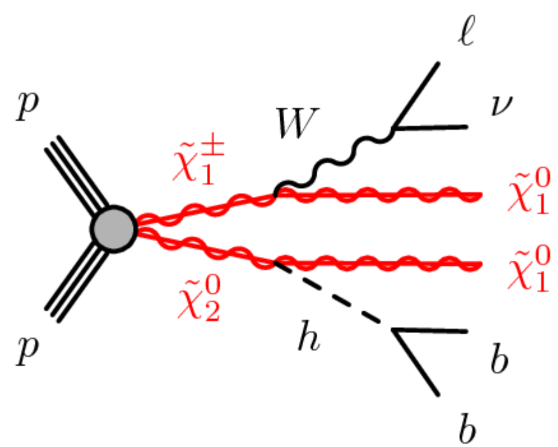
Chargino-Neutralino production: 1 lepton + bb (Bino/Wino)

NEW

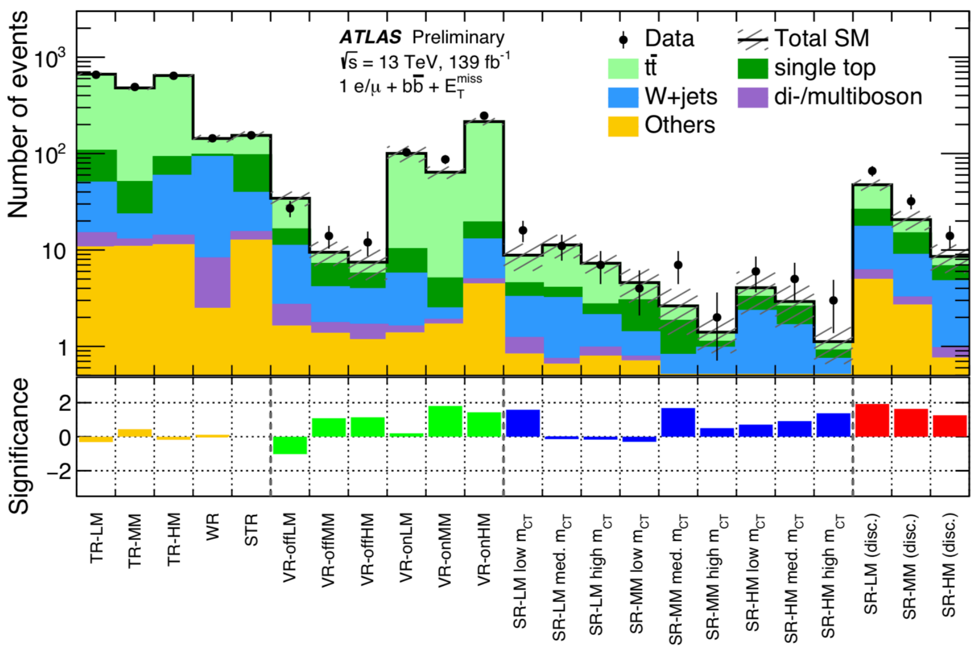
ATLAS-CONF-2019-031

- **Here: $\tilde{\chi}^0_2, \tilde{\chi}^\pm_1$ are purely Wino and decay to W and h**

  Decay of $\tilde{\chi}^0_2$ via h dominant for many choices of the parameters if mass-splitting between the two lightest neutralinos is larger than h mass and the higgsinos are heavier than the winos



- **Main backgrounds:**
  - **ttbar, tW, W+jets**
    - normalized in control regions

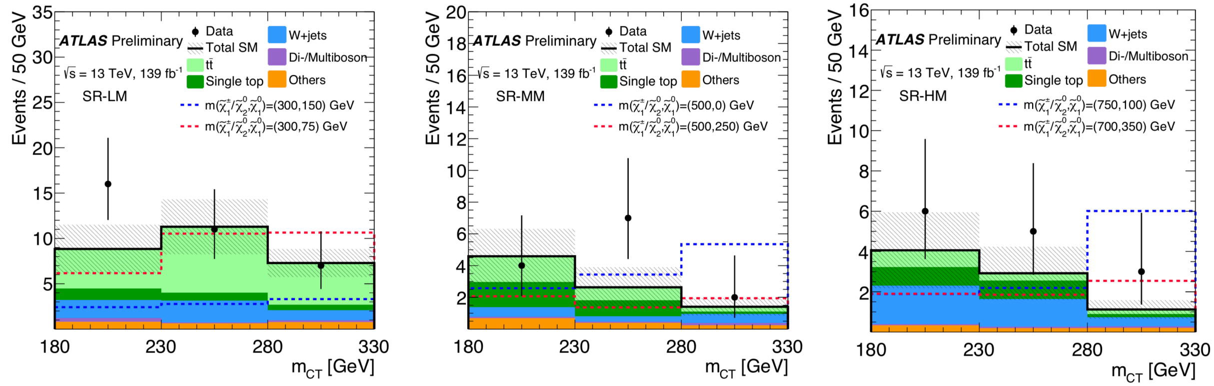


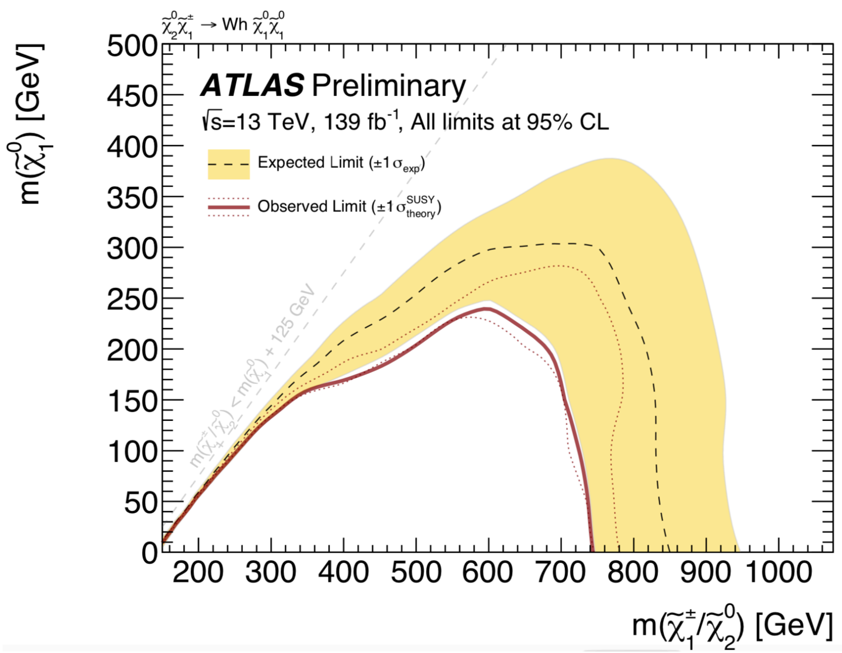
Chargino-Neutralino production: 1 lepton + bb (Bino/Wino)

NEW

ATLAS-CONF-2019-031

- Signal regions dedicated to low mass, medium mass and high mass region:

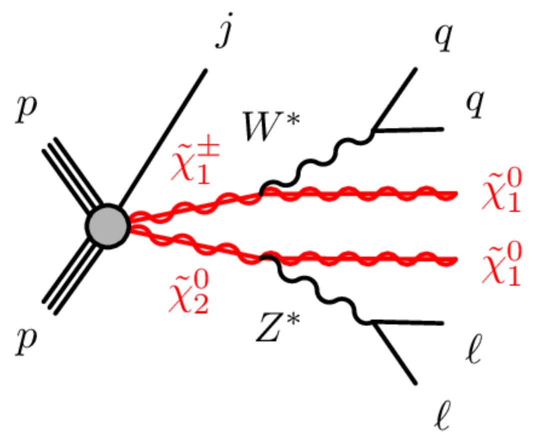




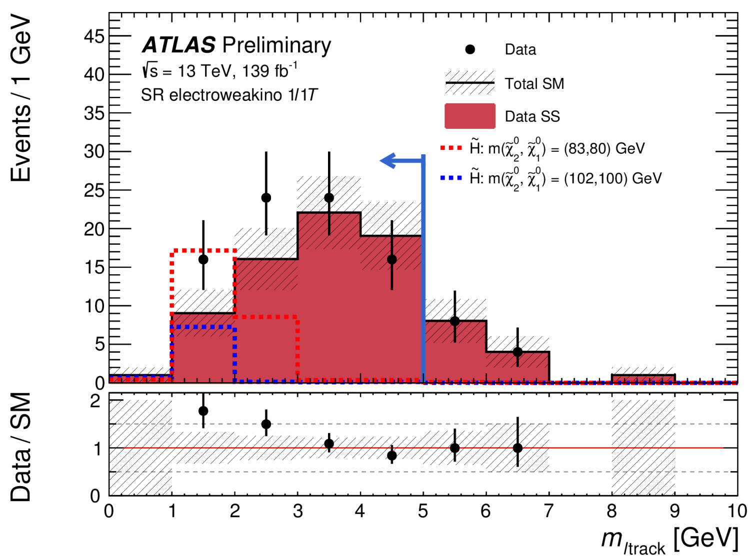
Exclude $\tilde{\chi}_2^0\,\tilde{\chi}_1^\pm$ with mass below 750 GeV

Chargino-Neutralino production: soft-lepton final state (Higgsino)

- Here: $\tilde{\chi}_2^0$, $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^\pm$ are higgsino-like and nearly mass-degenerate



- Search strategy: require 2 soft opposite-sign same-flavor leptons + ISR jet
  - Electrons with p_T > 4.5 GeV and |η| < 2.47 (or matched track with p_T > 1 GeV)
  - Muons with p_T > 3 GeV and |η| < 2.5 (or matched track with p_T > 2 GeV)



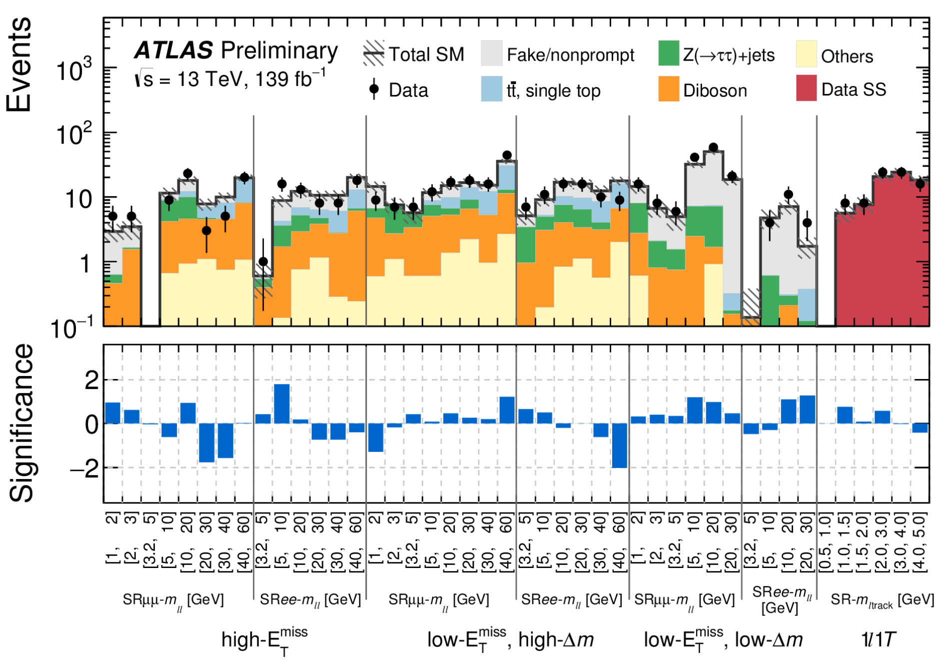
ATLAS-CONF-2019-014

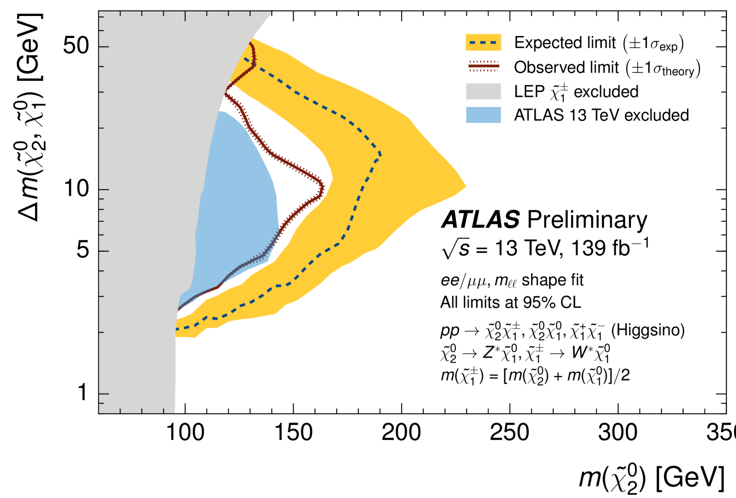
Chargino-Neutralino production: soft-lepton final state (Higgsino)

ATLAS-CONF-2019-014

Backgrounds:

- **Reducible background from fake/non-prompt leptons** (mainly from heavy flavor decay)
  - ☞ Determined from data
- **Irreducible background with two prompt leptons** (ttbar, tW, WW, WZ, Z→ ττ+jets) ☞ Determined with MC normalized to data in dedicated CRs



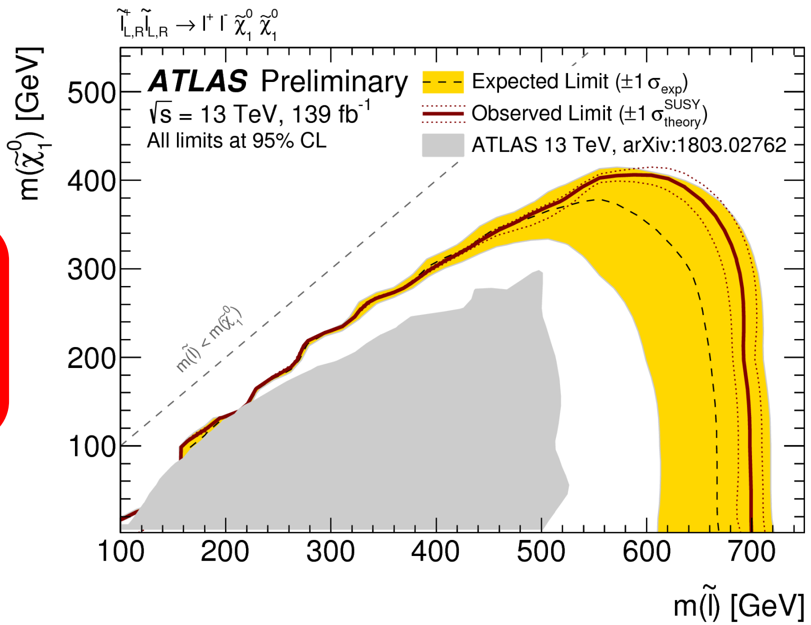


Exclude higgsinos below 162 GeV at a mass splitting of 10 GeV, and extending down to a mass splitting of 2.6 GeV at the LEP limit

Slepton production

- Select two opposite-sign same-flavor leptons, large p_T^{miss}
- Main discriminating variable: M_{T2}
- Main irreducible background:
  - WZ, WW, ZZ, and ttbar production
    - Both estimated using simulation, normalised using a simultaneous likelihood fit to data in dedicated CRs
- Main reducible background:
  - Fake non-prompt leptons
    - Estimated from data

Slepton masses up to 700 GeV excluded assuming three generation of mass-degenerate sleptons

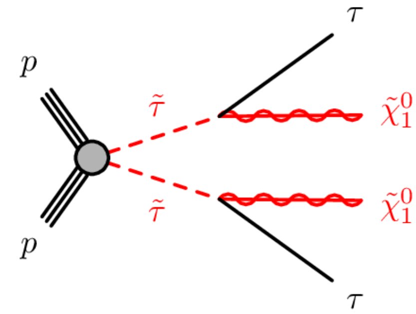


ATLAS-CONF-2019-014

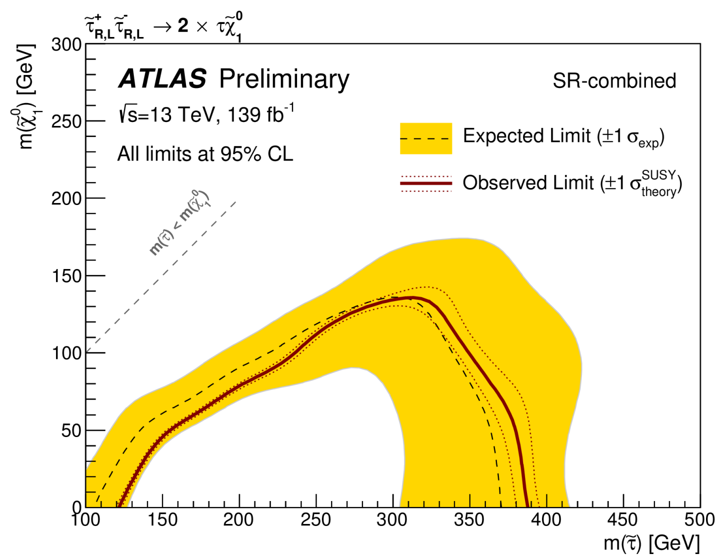
Search for tau sleptons

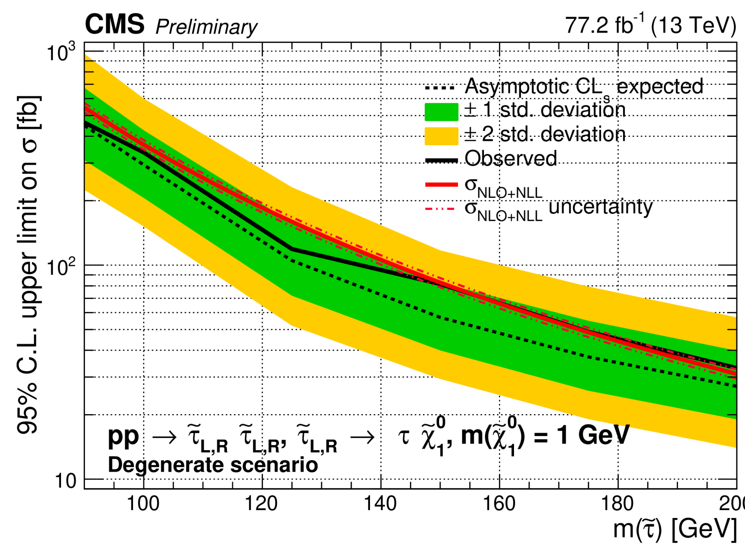
- ATLAS: Full Run 2 result in full-hadronic channel
- CMS: 2016+17 with combination of full-hadronic and semileptonic channel

- **Main backgrounds:**
  - Multijet events → one jet misidentified as τ (data driven)
  - W+jets → at least one jet misidentified as τ (control regions)



- **Interpretation in mass-degenerate scenario:**





ATLAS analysis excludes tau sleptons with masses between 120 and 390 GeV, by including the semileptonic analysis CMS closes the hole between 90 and 120 GeV

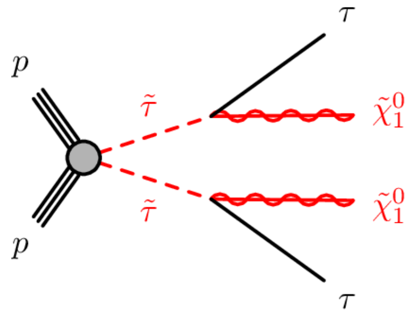
CMS-PAS-SUS-18-006

ATLAS-CONF-2019-018

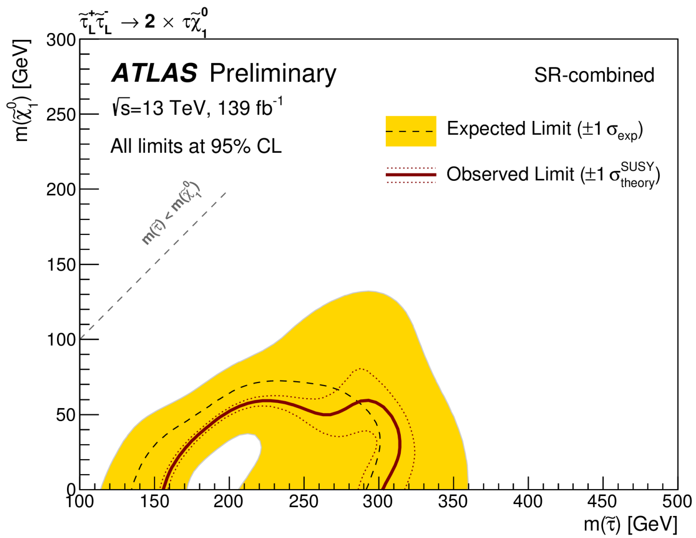
Search for tau sleptons

- ATLAS: Full Run 2 result in full-hadronic channel
- CMS: 2016+17 with combination of full-hadronic and semileptonic channel

- Main backgrounds:
  - Multijet events → one jet misidentified as τ (data driven)
  - W+jets → at least one jet misidentified as τ (control regions)



- Interpretation in left-handed scenario:

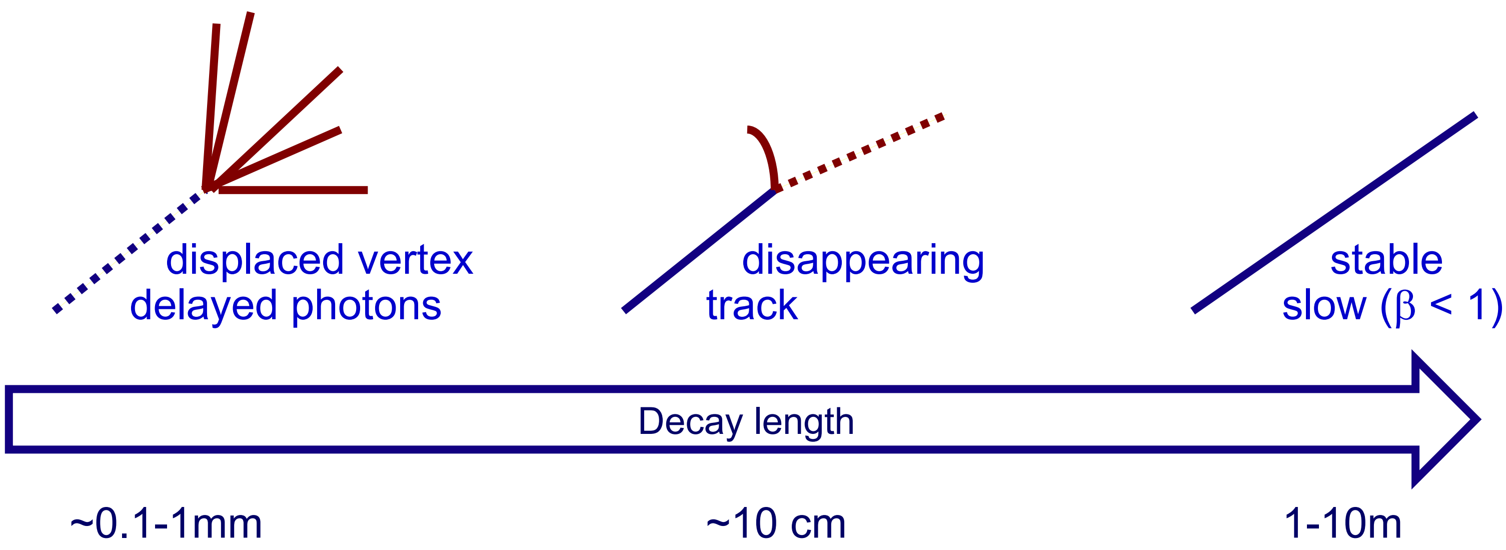


ATLAS-CONF-2019-018

ATLAS analysis excludes for the first time tau sleptons in the left-handed scenario with masses between 150 and 300 GeV

Search for long-lived particles

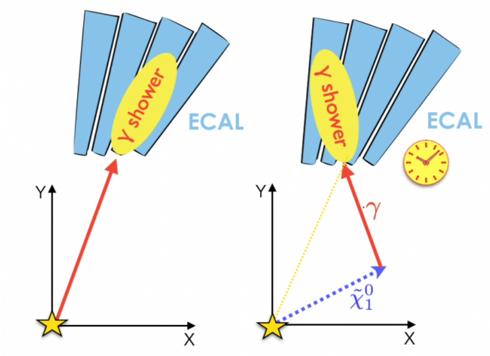
- Apart from the LSP other particles could be long-lived as well:
  - **Very weak χ_1^0-gravitino coupling [GMSB]**
    → Non pointing γ or Z
  - **RPV: Lifetime proportional to RPV coupling**
    → **Displaced vertex** if λ, λ', λ'' ~0(10^{-5})
  - **Low mass difference**, e.g $\Delta M(\chi^{\pm}\chi^0)$~100 MeV
    → Soft pion emission, **disappearing track**
  - **Stable Massive Particle**
    → Stable R-hadron (gluino or squark), sleptons

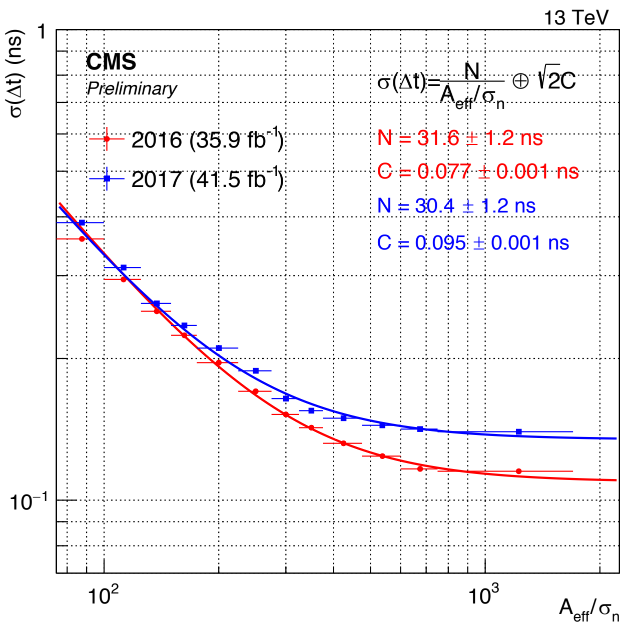


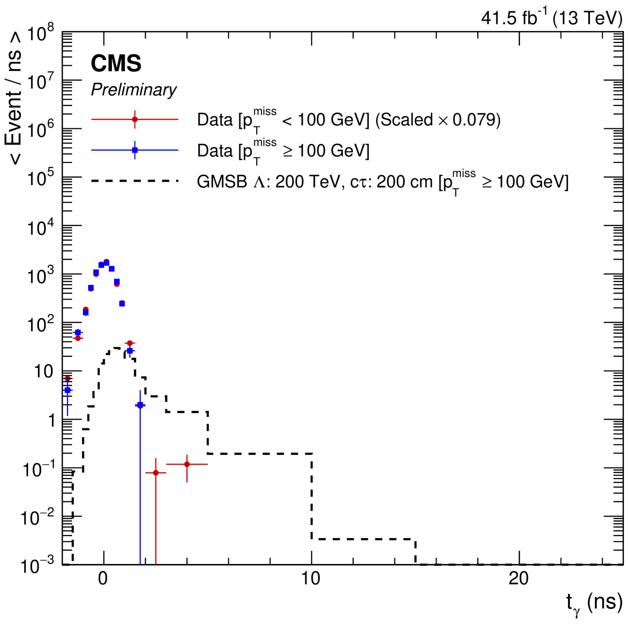
Delayed photons

NEW

- **Weak coupling of the neutralino to the gravitino in GMSB models can lead to long $\tilde{\chi}_1^0$ lifetimes:**
  - Impact angles pointing significantly away from the primary interaction vertex
  - Delayed arrival times at the ECAL (order of ns)
    Time resolution of the ECAL for a single object: 400 ps





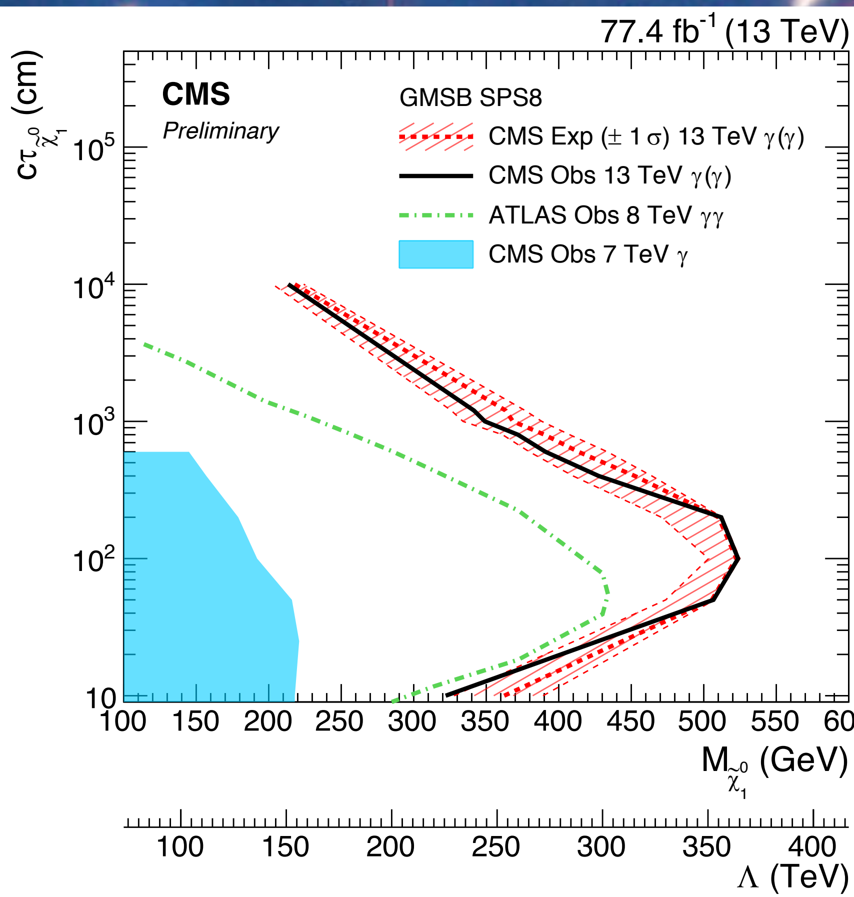


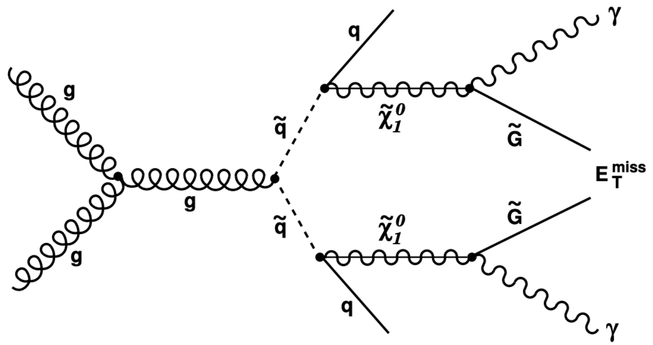
CMS-PAS-EXO-19-005

Delayed photons

NEW

CMS-PAS-EXO-19-005





Requirement of single photon increases sensitivity to long lifetimes

Exclude neutralinos with masses up to 320, 525, 360, and 215 GeV with *cτ* of 10 cm, 1 m, 10 m, and 100m

Displaced leptons

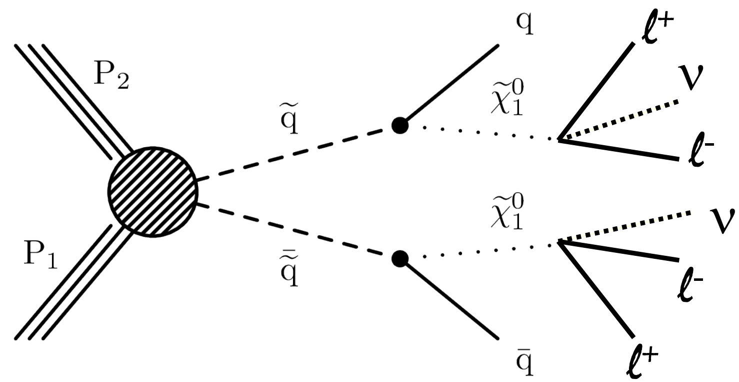
NEW

ATLAS EXPERIMENT

CERN-EP-2019-139

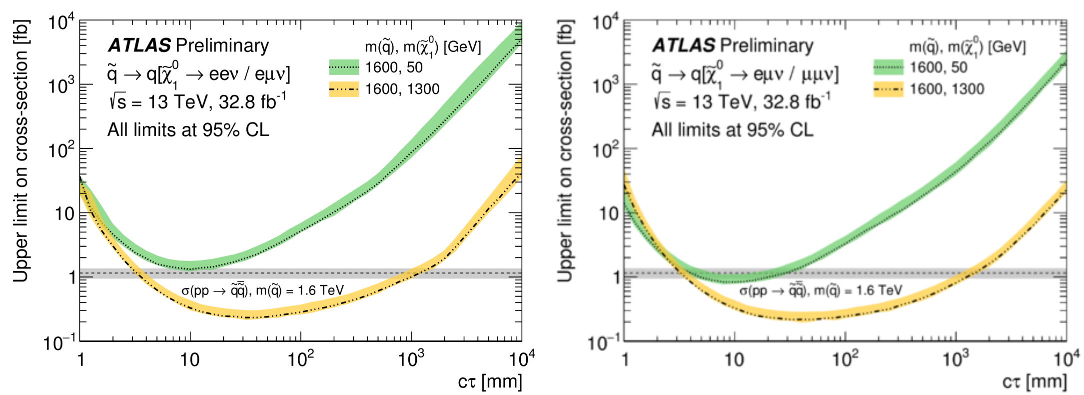
- **Squark production and RPV decay of bino-like neutralino through RPV coupling:**

$$W_{\text{LLE}} = \frac{1}{2}\lambda_{ijk} L_i L_j \bar{E}_k$$



- **Assume coupling λ_{121} or λ_{122}:**
  - $\mathcal{B}(\tilde{\chi}_1^0 \to ee\nu) = \mathcal{B}(\tilde{\chi}_1^0 \to e\mu\nu) = 0.5$
  - $\mathcal{B}(\tilde{\chi}_1^0 \to \mu\mu\nu) = \mathcal{B}(\tilde{\chi}_1^0 \to e\mu\nu) = 0.5$
- Special trigger on muon chamber tracks and photons
- Special large-radius tracking and **displaced vertex reconstruction**
- **Main backgrounds:**
  - Cosmic-ray muons and random crossing of two uncorrelated leptons

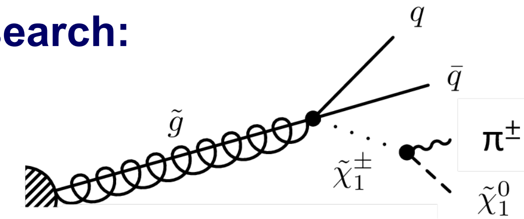
For quark mass of 1.6 TeV, $c\tau$ between 3 mm and 1 m are excluded for a 1.3 TeV neutralino



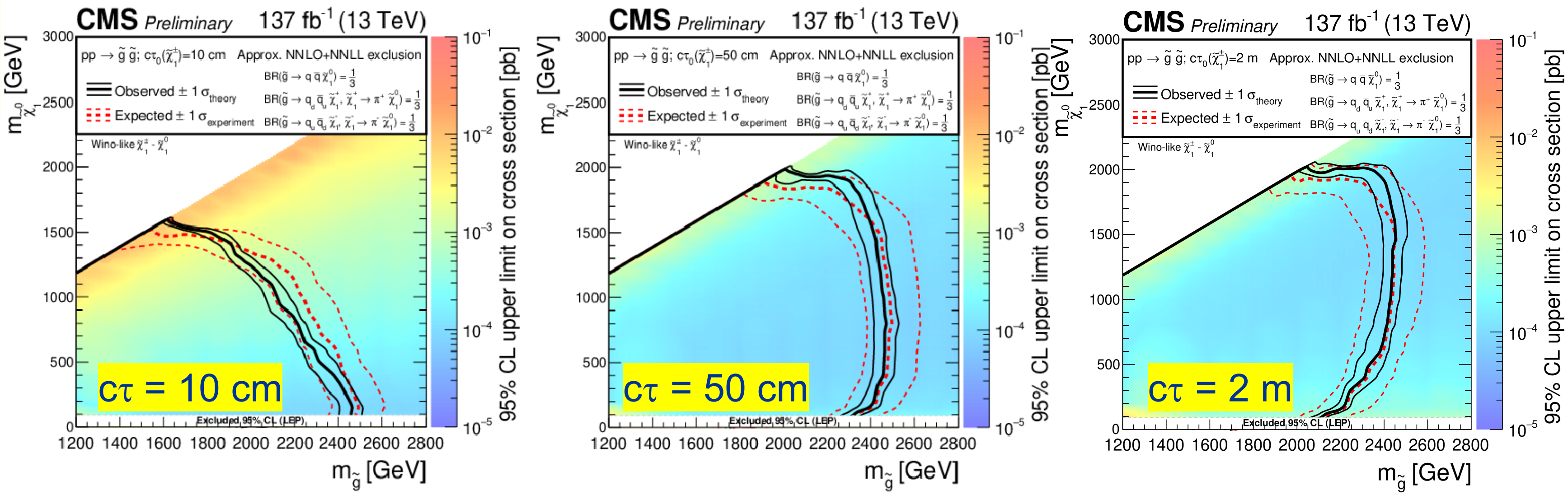
Disappearing tracks

CMS-SUS-19-005

- **Add disappearing track requirement to classic gluino search:**
  - Sensitivity to models with long-lived charginos
  - Extend sensitivity, since other analysis cuts can be loosened when adding disappearing track requirement



- Categorization into short (Pixel-only), medium (<7 layers), and long (at least 7 layers) tracks
- **Main background:**
  - Fake tracks, charged pions and leptons
    - Estimated with from a control region in data with looser short track requirements

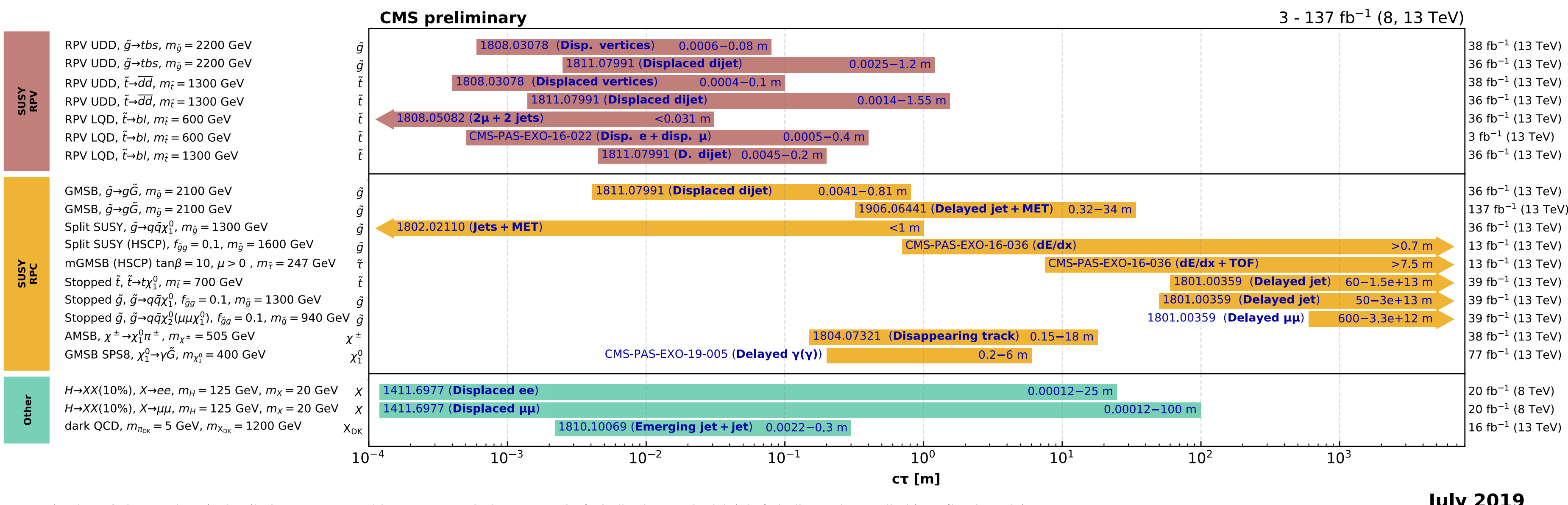


Sensitivity to gluino and neutralino masses is enhanced

Summary of long-lived results

- Impossible to cover all signatures in one talk!

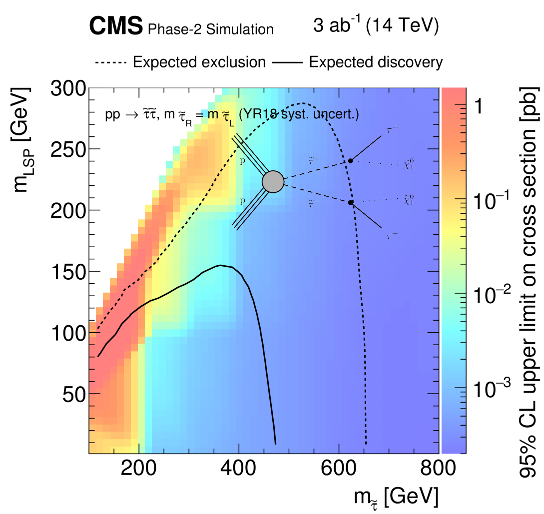
Overview of CMS long-lived particle searches

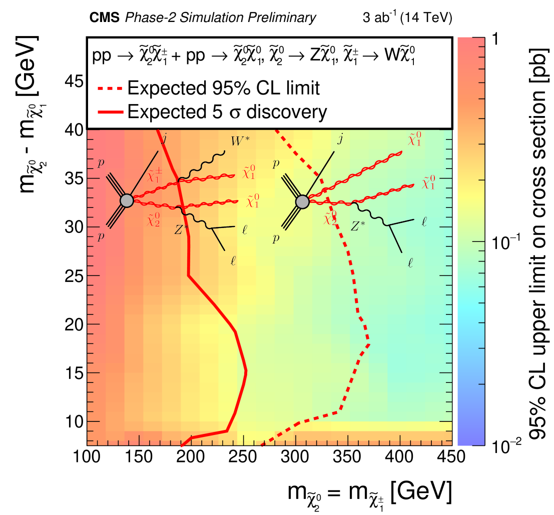


Selection of observed exclusion limits at 95% C.L. (theory uncertainties are not included). The y-axis tick labels indicate the studied long-lived particle.

Summary

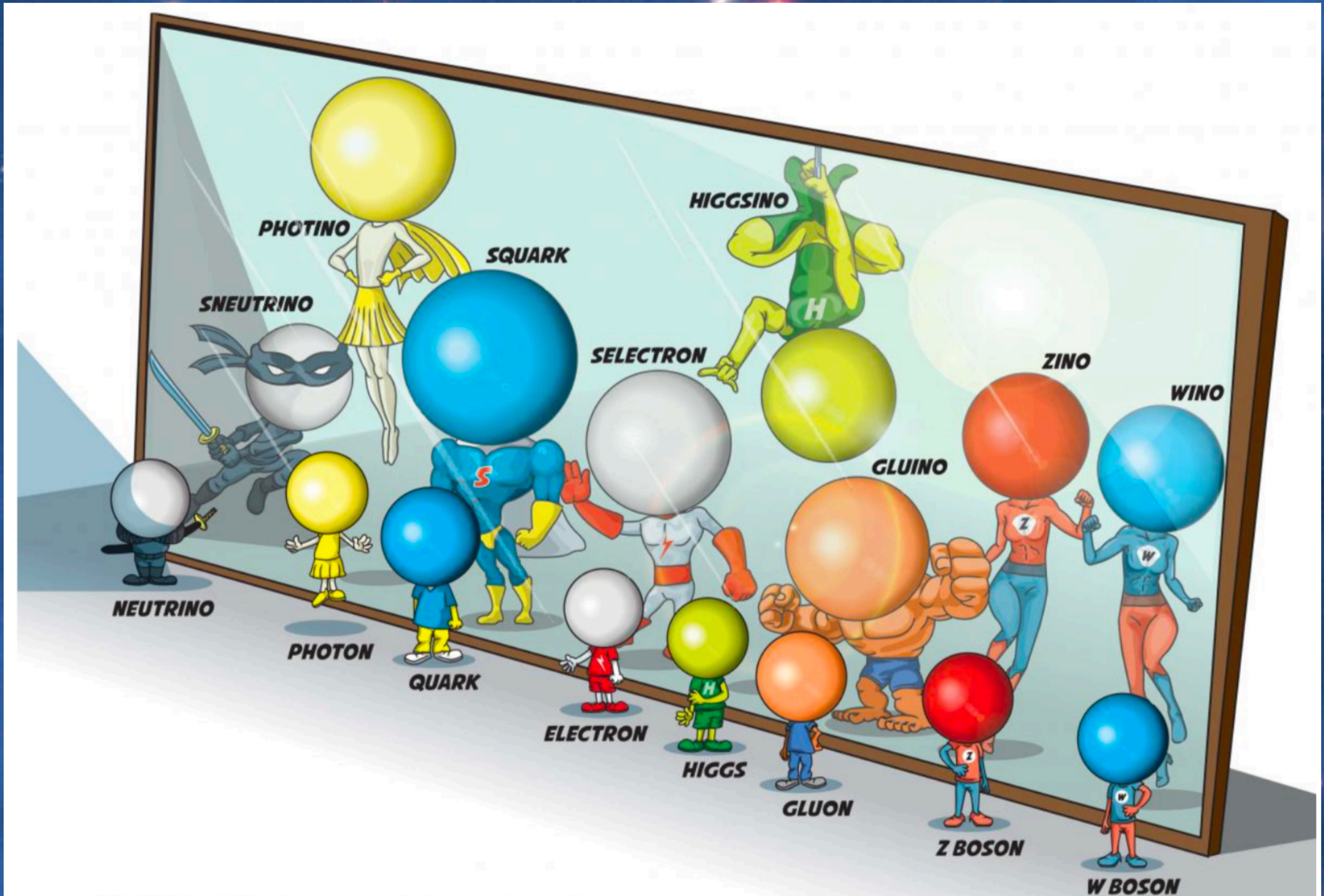
- A number of analyses already updated with full Run 2 luminosity
- Searches cover simplified models and specific signatures
- More Run 2 results to come in the next months
- Experiments are already in preparation of Run 3
- HL-LHC will be important to cover rare processes
- Stay tuned!





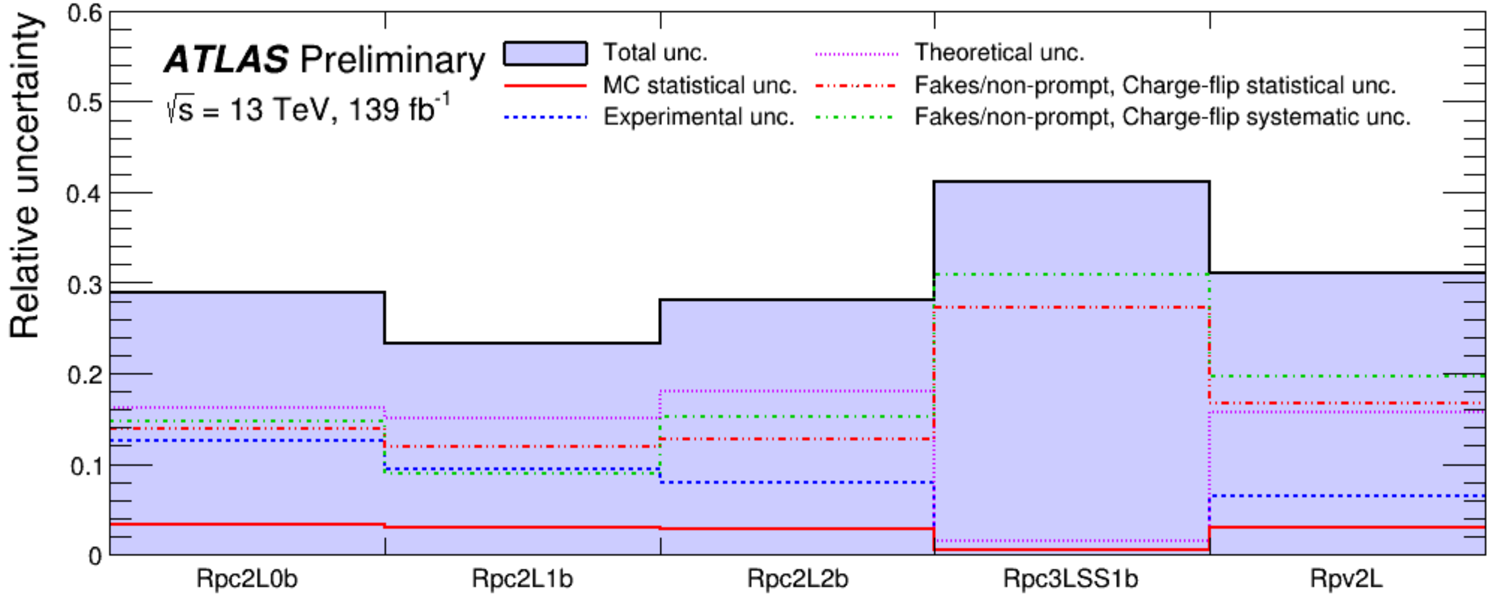
- Overview of current SUSY results:
  - **ATLAS:** https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults
  - **CMS:** https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS
- **HL-LHC studies:** https://cds.cern.ch/record/2651134/files/1902.10229.pdf

BACKUP


PHOTINO
SQUARK
SNEUTRINO
HIGGSINO
SELECTRON
ZINO
WINO
GLUINO
NEUTRINO
PHOTON
QUARK
ELECTRON
HIGGS
GLUON
Z BOSON
W BOSON

ATLAS-CONF-2019-015

- Systematic uncertainties:



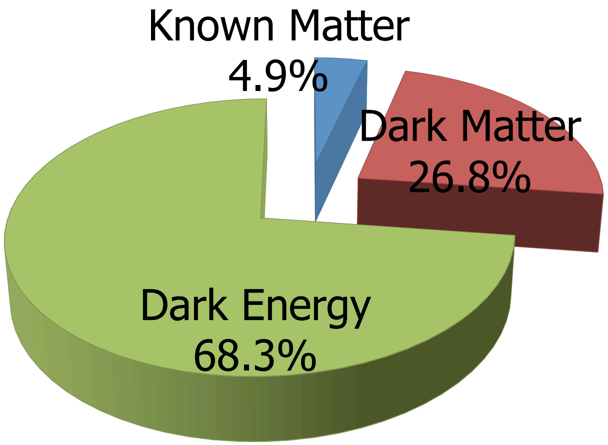
ATLAS-CONF-2019-014

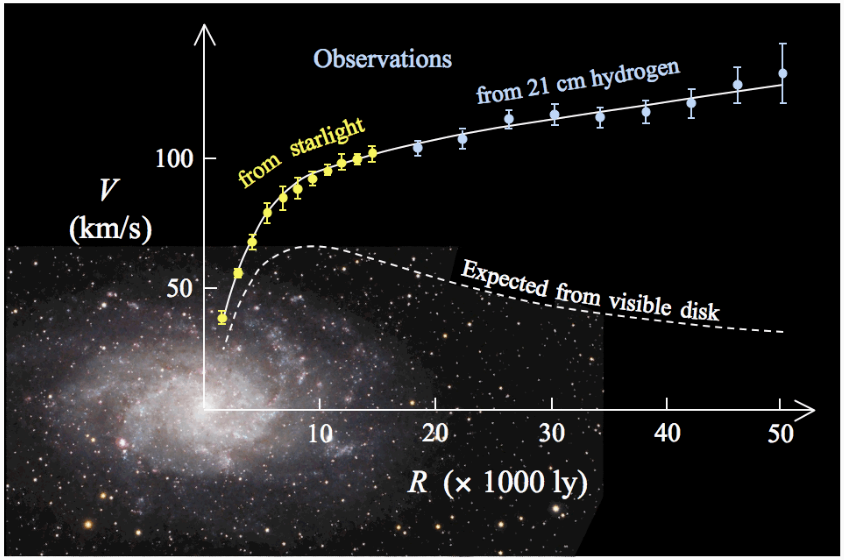
Preselection

Variable	Preselection requirements 2ℓ	Preselection requirements 1ℓ1T
Number of leptons (tracks)	$= 2$ leptons	$= 1$ lepton and ≥ 1 track
Lepton p_{T} [GeV]	$p_{\mathrm{T}}^{\ell_1} > 5$	$p_{\mathrm{T}}^{\ell} < 10$
$\Delta R_{\ell\ell}$	$\Delta R_{ee} > 0.30$, $\Delta R_{\mu\mu} > 0.05$, $\Delta R_{e\mu} > 0.2$	$0.05 < \Delta R_{\ell\mathrm{track}} < 1.5$
Lepton (track) charge and flavor	$e^{\pm}e^{\mp}$ or $\mu^{\pm}\mu^{\mp}$	$e^{\pm}e^{\mp}$ or $\mu^{\pm}\mu^{\mp}$
Lepton (track) invariant mass [GeV]	$3 < m_{ee} < 60$, $1 < m_{\mu\mu} < 60$	$0.5 < m_{\ell\mathrm{track}} < 5$
J/ψ invariant mass [GeV]	veto $3 < m_{\ell\ell} < 3.2$	veto $3 < m_{\ell\mathrm{track}} < 3.2$
$m_{\tau\tau}$ [GeV]	< 0 or > 160	no requirement
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 120	> 120
Number of jets	≥ 1	≥ 1
Number of b-tagged jets	$= 0$	no requirement
Leading jet p_{T} [GeV]	≥ 100	≥ 100
$\min(\Delta\phi(\text{any jet}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}))$	> 0.4	> 0.4
$\Delta\phi(j_1, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}})$	≥ 2.0	≥ 2.0

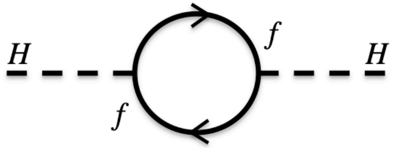
Remaining open questions

- Dark matter and dark energy



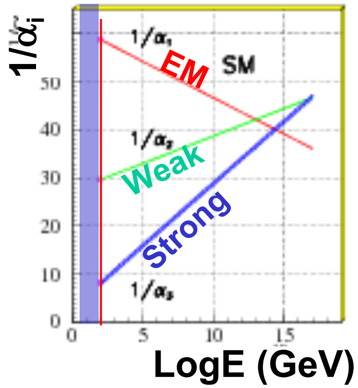


- Corrections to the Higgs mass



$$m_h^2 = (m_h^2)_0 - 3\frac{3G_F}{4\sqrt{2}\,\pi}(4m_t^2)\,\Lambda_{NP}^2$$

- Unification of the forces

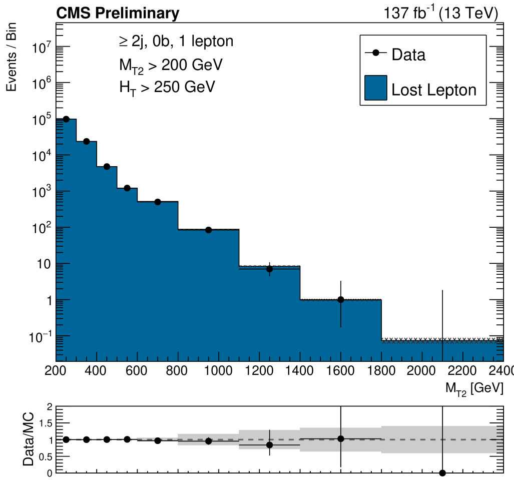


Search for gluinos and squarks: Full-hadronic final state

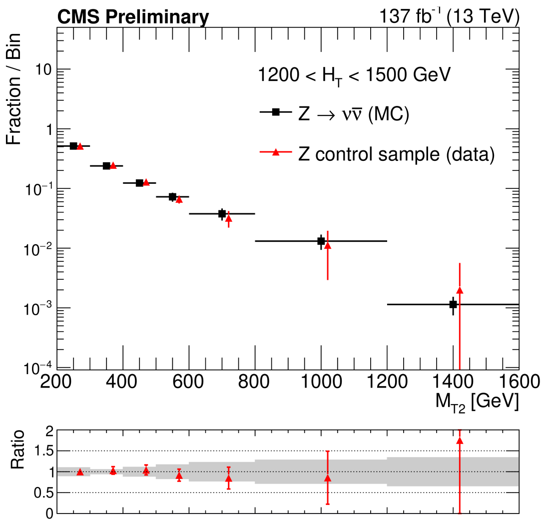
CMS-SUS-19-005

Main backgrounds:

- **Lost lepton events** (mainly W+jets, ttbar):
  ☞ Determined in single-lepton CR, with transfer factor determined in simulation (corrected for measured differences of lepton efficiencies)



- **Irreducible background with genuine p_T^{miss}** (e.g. Z→ νν)
  ☞ Determined in a Z → ll control sample for each SR (main systematic due to limited statistics in dilepton CR)



- **Instrumental background** (mainly QCD multijet events with mismeasured jet(s))
  ☞ Determined with rebalance & smear method

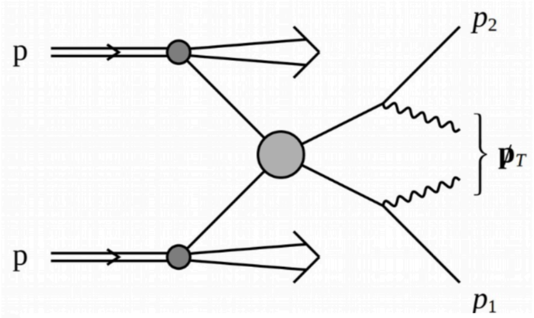
Search for gluinos and squarks

- **Reduce SM background exploiting additional p_T^{miss} - and jet-related kinematic variables like:**
  - **Transverse mass m_T:**

    $$m_T^2 = \left(E_{T,1} + E_{T,2}\right)^2 + \left(\vec{p}_{T,1} + \vec{p}_{T,2}\right)^2$$

    - m_T has an endpoint at mother particle mass
    - Constrains e.g. background from leptonic W decays
  - **Stransverse mass M_{T2}:**

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

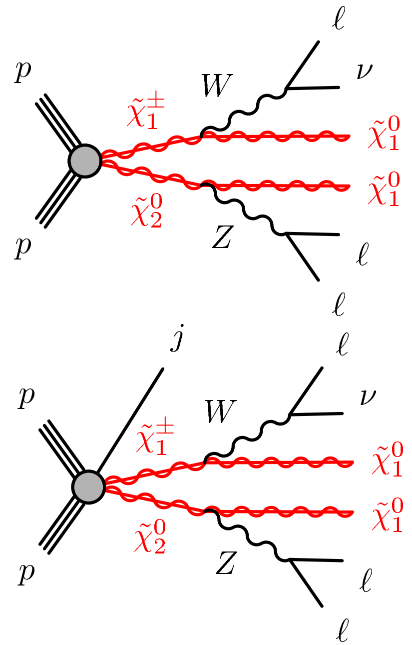


    - Generalization of m_T for decay chains with two unobserved particles (SUSY-like)
    - In case of more than two jets these are clustered into two pseudo-jets, each representing an event *hemisphere*
  - **Effective mass m_{eff}:**
    - Sum of $H_T = \sum p_T^{jet}$ and p_T^{miss}
    - Correlated to the mass of the highest colored object, the LSP and their mass difference → typically m_{eff} will peak at $1.8(m_{SUSY}^2 - m_{LSP}^2)/\ m_{SUSY}$

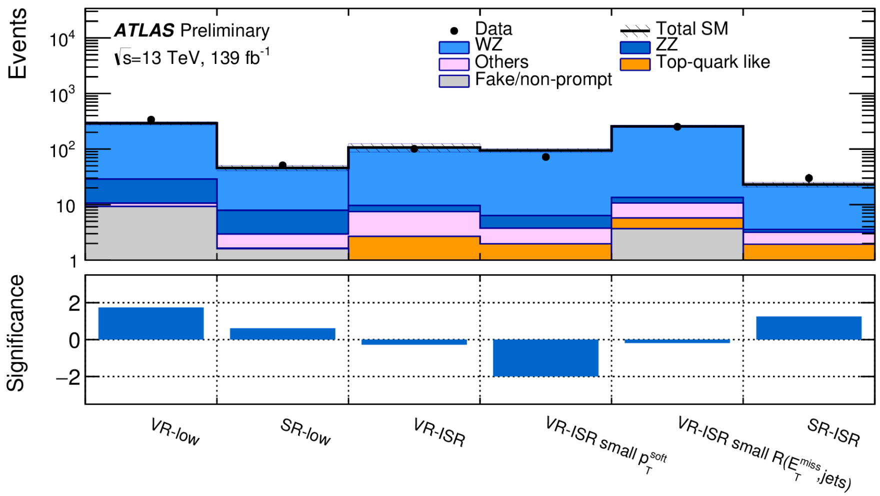
Chargino-Neutralino production: 3-lepton final state (Bino/Wino)

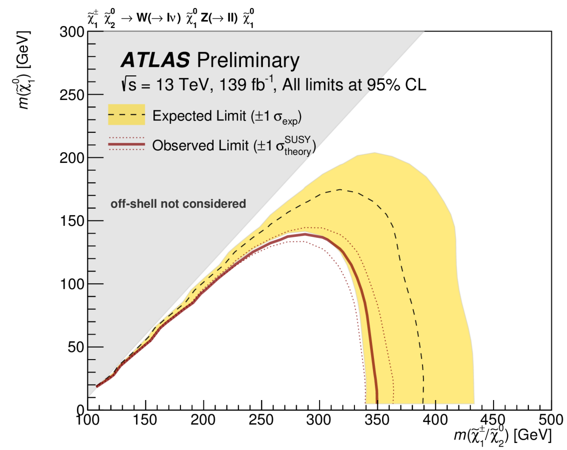
ATLAS-CONF-2019-020

- Here: $\tilde{\chi}^0_2, \tilde{\chi}^\pm_1$ are purely Wino and decay to W and Z
- Investigate 3-lepton final state (ISR jet enhances signature)



- Previous analysis on 2016 data saw slight excess
- Refined analysis on full Run 2 data compatible with SM expectation





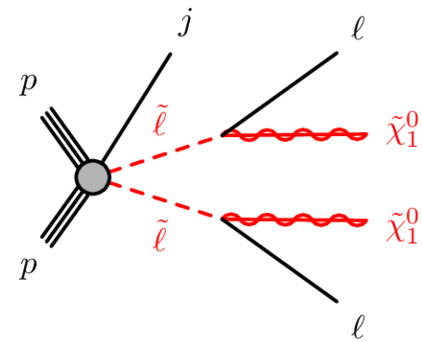
Exclude $\tilde{\chi}^0_2, \tilde{\chi}^\pm_1$ with mass below 350 GeV

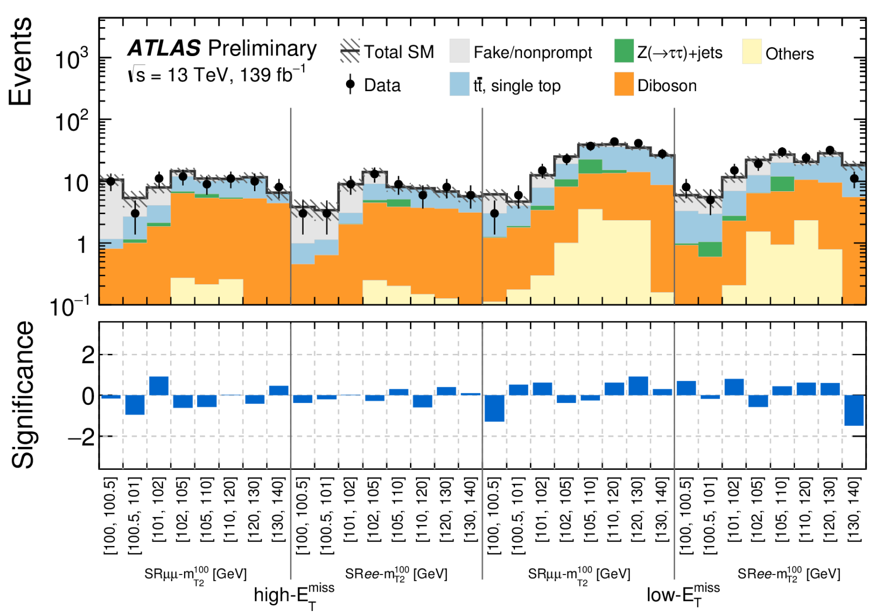
Slepton production: small mass splitting

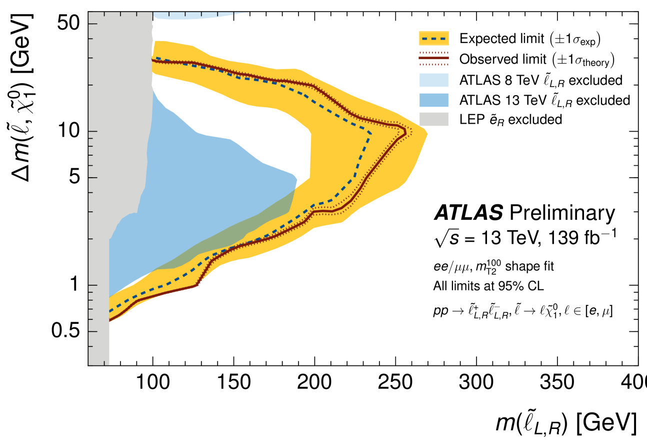
ATLAS-CONF-2019-014

- Soft lepton search with tuned signal regions can be interpreted in direct slepton pair production model
- Slepton signal regions:

Variable	Slepton SR Requirements: Low-E_T^{miss}	Slepton SR Requirements: High-E_T^{miss}
E_T^{miss} [GeV]	$[150, 200]$	> 200
m_{T2} [GeV]	< 140	< 140
$p_T^{\ell_2}$ [GeV]	$> \min(15, 7.5 + 0.75 \times (m_{T2} - 100))$	$> \min(20, 2.5 + 2.5 \times (m_{T2} - 100))$
R_{ISR}	$[0.8,\ 1.0]$	$[\max(0.85, 0.98 - 0.02 \times (m_{T2} - 100)),\ 1.0]$





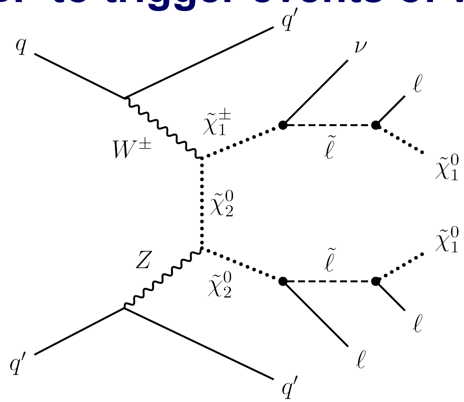


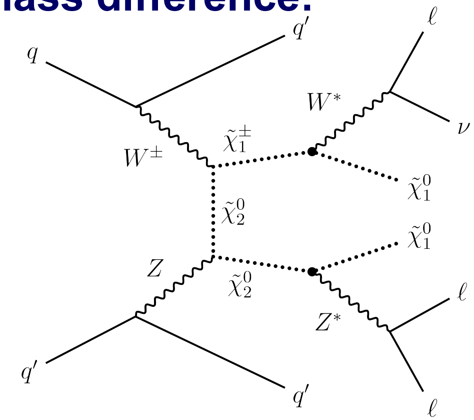
Exclude sleptons below 256 GeV at a mass splitting of 10 GeV, and extending down to a mass splitting of 590 MeV at the LEP limit

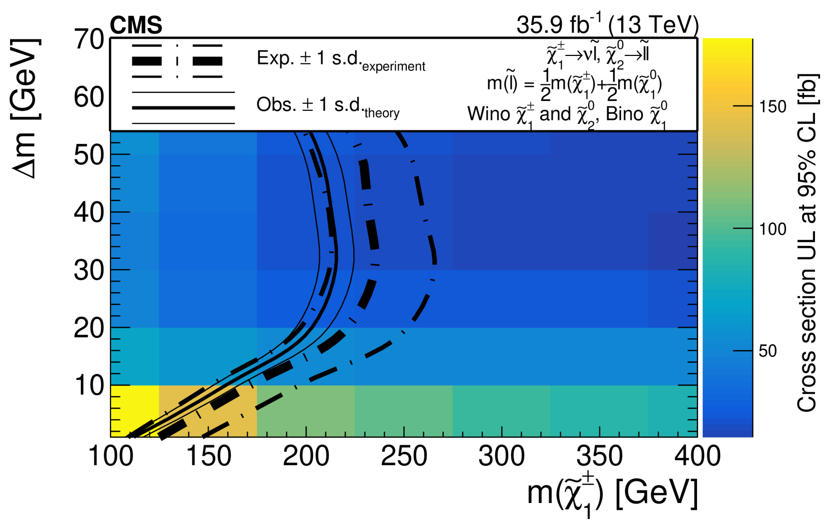
Chargino-Neutralino production in Vector Boson Fusion

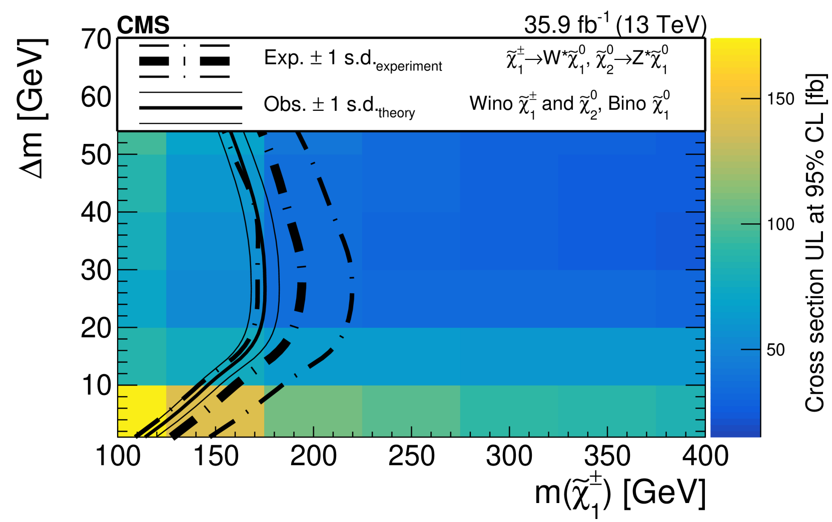
arXiv:1905.13059; CMS-SUS-17-007

Use VBF to trigger events of with very small mass difference:







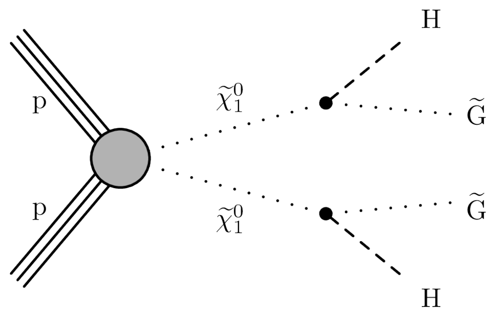


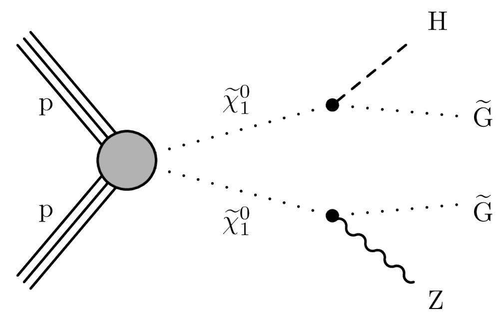
For a mass difference between $\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0$, $\tilde{\chi}_1^{\pm}$ of 1 (30) GeV exclude $\tilde{\chi}_2^0$, $\tilde{\chi}_1^{\pm}$ below 112 (215) GeV

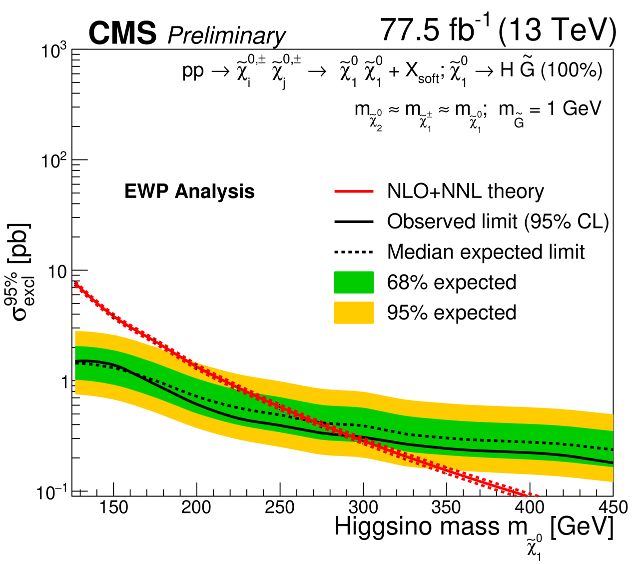
Neutralino-Neutralino production: photon final state (Higgsino)

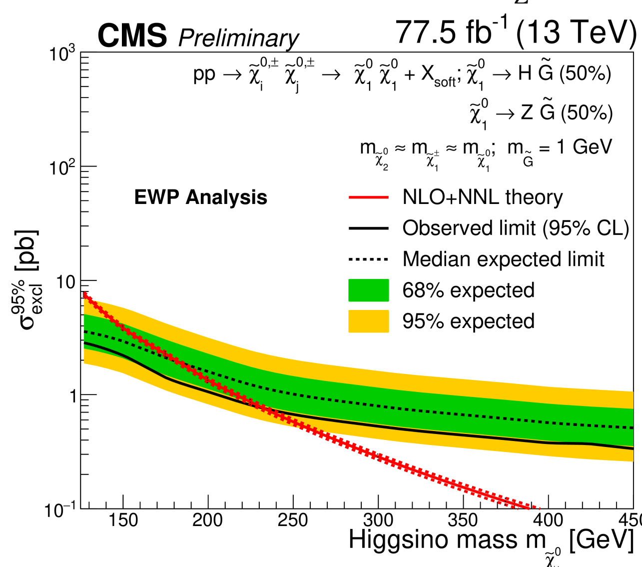
CMS-PAS-SUS-18-007

- **In case the lightest neutralino decays further to gravitino and SM-like H(→γγ) or Z**









Exclude neutralinos below 300 GeV (100% decay to H) and 180 GeV (50% decay to H and 50% decay to Z)