SUSY Chargino/Neutralino Searches at ATLAS and CMS

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on behalf of the CMS and the ATLAS Collaborations

Mitchell Institute for Fundamental Physics and Astronomy

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(SUSY 2021)

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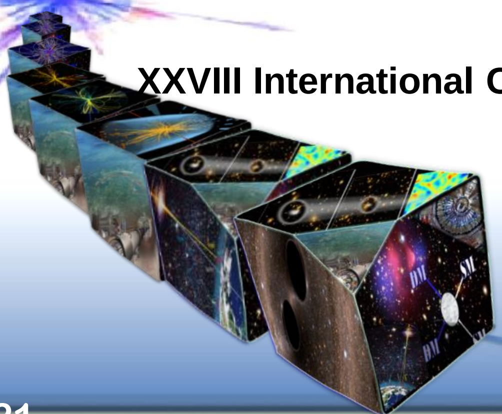


OUTLINE

I. Introduction: SUSY electroweak (EW) sector

II. ATLAS and CMS results on $\tilde{\chi}_i^{\pm}$, $\tilde{\chi}_j^0$ searches

- EPS-HEP 2021 plus CMS-SUS-21-002 ($\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_2^0$ via $WH.WZ,WW$ in hadronic channels)
- See parallel talks for technical details such as data-driven background estimates.
- Slepton searches are not covered.

III. Summary

links

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS#Run_2_Summary_plots_13_TeV
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2021-019/

Plenary and Parallel Talks

Plenary Talk: "SUSY squark/gluino searches at ATLAS and CMS" by Luigi Longo (ATLAS)

Searches for strong production of supersymmetric particles with the ATLAS detector, Kazuki TODOME (Bologna)

Searches for direct pair production of third generation squarks with the ATLAS detector, Carlos MORENO MARTINEZ (Barcelona)

Searches for charginos and neutralinos with the ATLAS detector, Sara ALDERWEIRELDT (Edinburgh)

Searches for sleptons with the ATLAS detector, Lorenzo ROSSINI (DESY)

ATLAS searches for supersymmetry with long-lived particles, Emily Anne THOMPSON (DESY)

Exploring the frontier of R-parity-violating supersymmetry with the ATLAS detector, Lorenzo FELIGIONI (Marseille CPPM)

Search for charginos and neutralinos in final states with two boosted hadronically decaying bosons and missing transverse momentum with the ATLAS experiment, Yuta OKAZAKI (Kyoto)

Search for R-parity violating supersymmetry in a final state containing leptons and many jets with the ATLAS experiment, Martin ERRENST (Wuppertal)

Search for long-lived charginos based on a disappearing-track signature with the ATLAS experiment, Paul GESSINGER-BEFURT (CERN)

Electroweak SUSY in leptonic final states with the CMS detector, Kaitlin Salyer (Boston Univ.)

Search for supersymmetry in compressed scenario's with the CMS detector, Denis Rathjens (Texas A&M Univ.)

Searches for supersymmetry in tau final states with the CMS detector, Saikat Karmakar (Tata Institute of Fundamental Research-B)

Searches for supersymmetry in hadronic final states with the CMS detector, Koushik Mandal (Eotvos Lorand University)

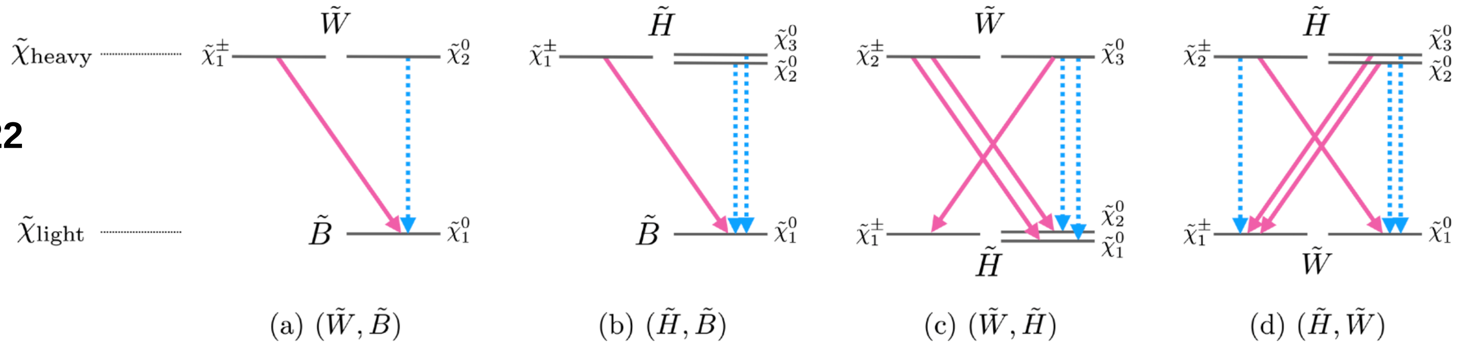
Searches for third generation squarks with the CMS detector, Caleb James Smith (The Univ. of Kansas) .

Searches for R-parity violating SUSY with the CMS detector, Christopher Madrid (Fermi National Accelerator Lab.)

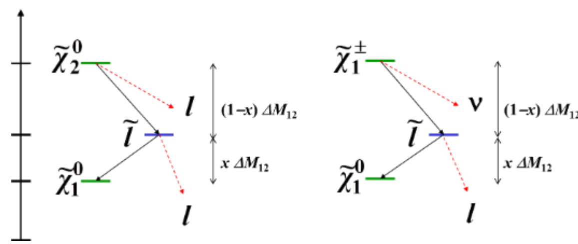
"SUSY EW Sector" Menu

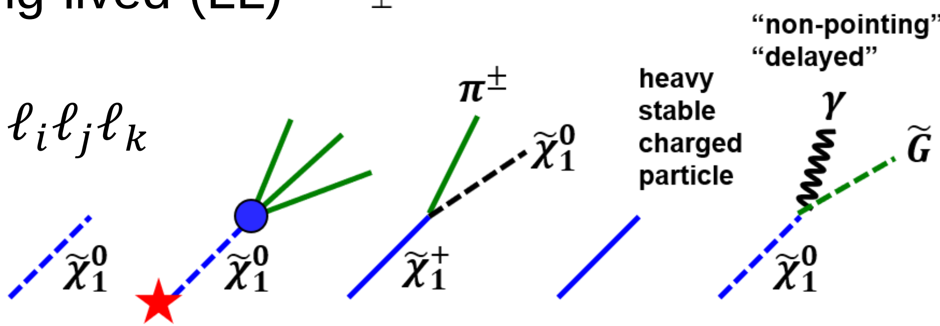
- ❑ $\tilde{\chi}_1^0 \in (\tilde{B}, \widetilde{W}, \tilde{H}_d, \tilde{H}_u)$; $\tilde{\chi}_1^+ \in (\widetilde{W}^+, \tilde{H}_u^+)$; $\tilde{\chi}_1^- \in (\widetilde{W}^-, \tilde{H}_d^-)$

ATLAS-CONF-2021-022
Fig. 2



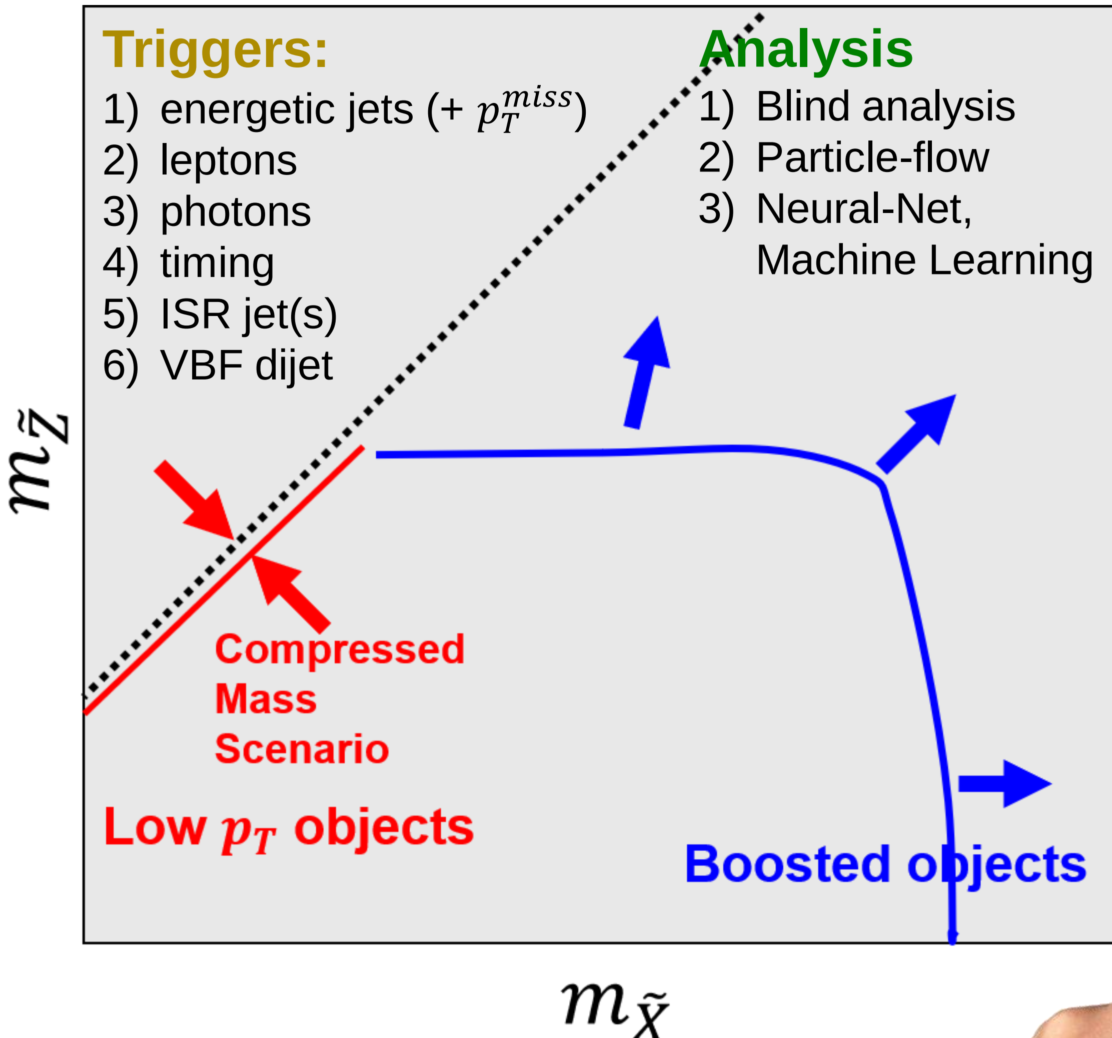
- ❑ $\tilde{\chi}_i^{\pm}, \tilde{\chi}_j^0$ decaying into leptons, H, W, and Z.
- ❑ Lightest SUSY Particle (LSP)
  - Lightest neutralino ($\tilde{\chi}_1^0$): Bino-like, Wino-like, Higgsino-like, Bino-Higgsino-like
    [Example] Higgsino LSP ⇒ chargino and neutralinos below 200 GeV, with mass splittings of order 10 GeV.
  - Gravitino: $\tilde{\chi}_1^0 \to \tilde{G}\gamma, \tilde{G}Z, \tilde{G}H,$
- ❑ Lighter slepton: e.g., $\tilde{\chi}_2^0 \to \tilde{\ell}\ell$, followed by $\tilde{\ell} \to \tilde{\chi}_1^0\ell$
- ❑ Disappearing track ($\tilde{\chi}_1^{\pm} \to \tilde{\chi}_1^0\boldsymbol{\pi}$), Long-lived (LL)
- ❑ Heavy stable charged particle
- ❑ R-parity violation (RPV): e.g., $\tilde{\chi}_1^0 \to \ell_i\ell_j\ell_k$
- ❑ Non-minimal, non-universal, …

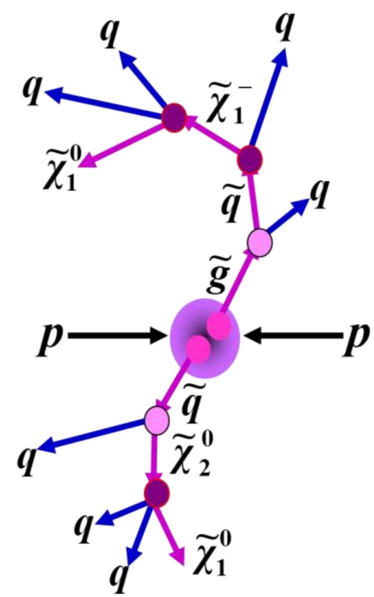


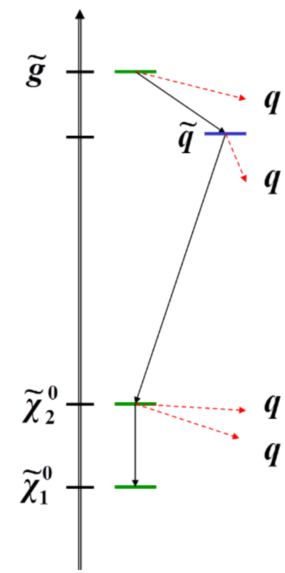


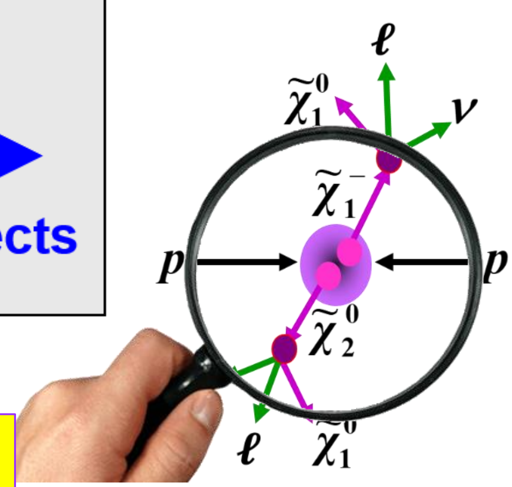
LHC SUSY Exploration Map

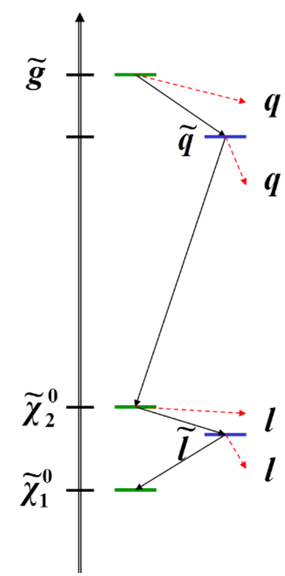
$$pp \to \tilde{X}\tilde{X} \to \cdots \to \tilde{Z}\tilde{Z} + \text{SM particles}$$









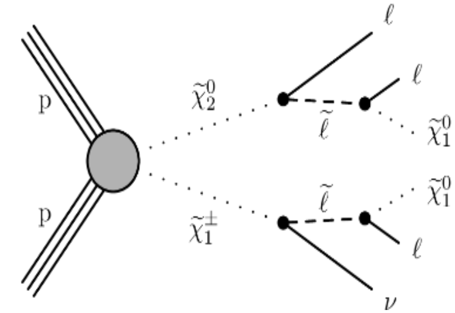


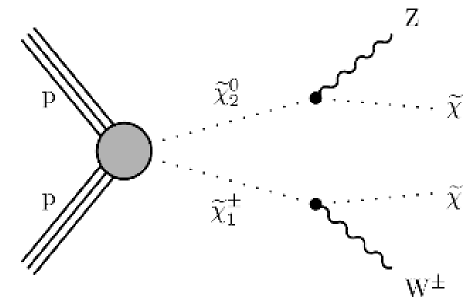
This talk: $\tilde{X} = \tilde{\chi}_i^{\pm}, \tilde{\chi}_j^0$

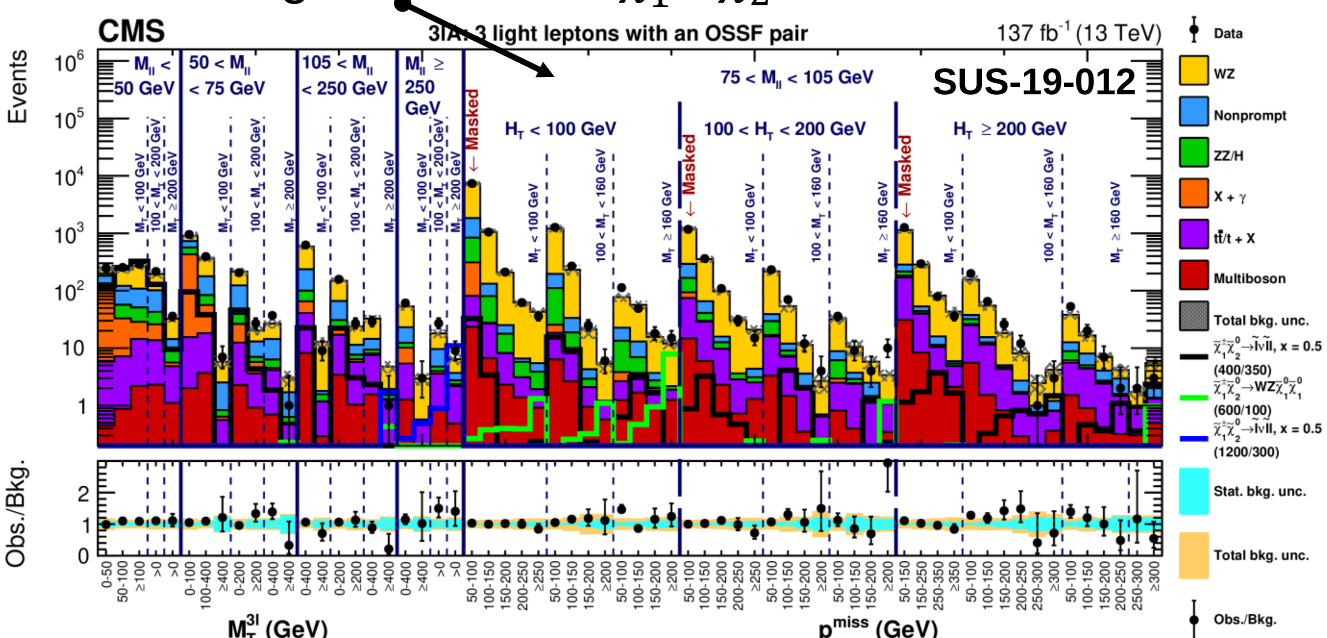
Analysis Flow

1) Advanced particle ID (e.g., particle flow ID, boosted objects)
2) Full detector simulation
3) Signal Regions (SRs) and Control Regions (CRs)
4) Blind analysis: data in CRs must be fully understood before analysis of the data in SRs.
5) Observed and expected yields (with uncertainties) in SRs: e.g., 64 SRs for $\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ with $2\ell, 3\ell, 2\tau$

SRs: characterize production and decays







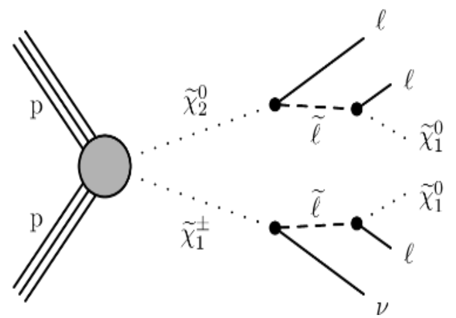
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to \tilde{l}\nu\tilde{l}l$, x = 0.5 (400/350)

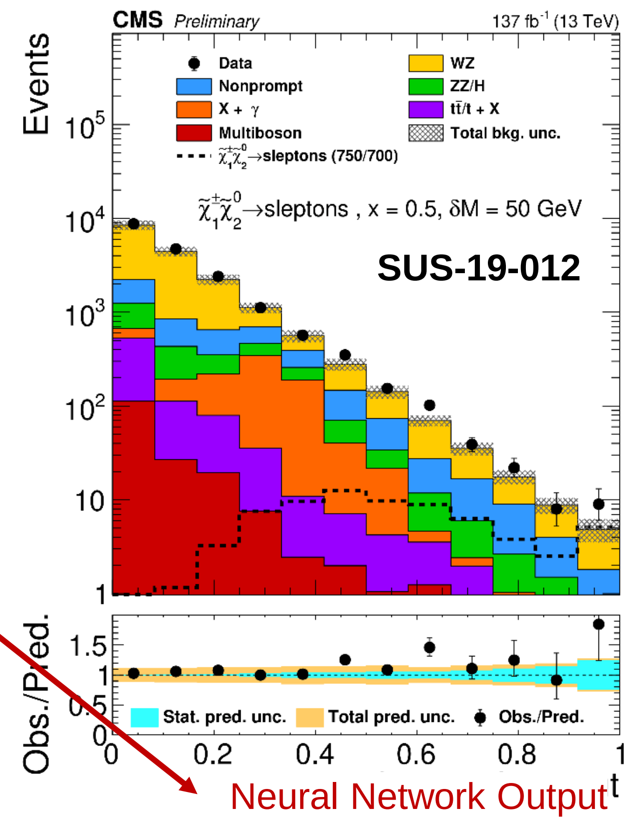
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to WZ\tilde{\chi}_1^0\tilde{\chi}_1^0$ (600/100)

$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to \tilde{l}\nu\tilde{l}l$, x = 0.5 (1200/300)

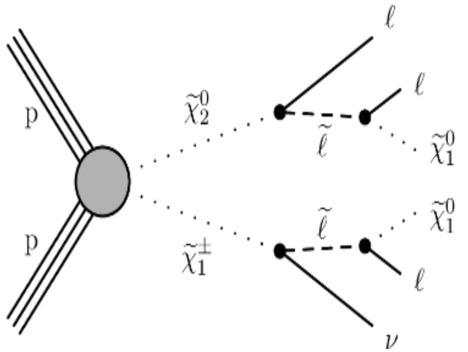
Analysis Flow

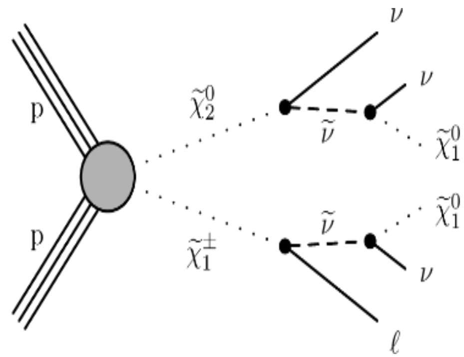
1) Advanced particle ID (e.g., particle flow ID, boosted objects)
2) Full detector simulation
3) Signal Regions (SRs) and Control Regions (CRs)
4) Blind analysis: data in CRs must be fully understood before analysis of the data in SRs.
5) Observed and expected yields (with uncertainties) in SRs: e.g., 60 SRs for $\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_2^0$ with $2\ell, 3\ell, 2\tau$
6) Maximize sensitivity (e.g., NN)

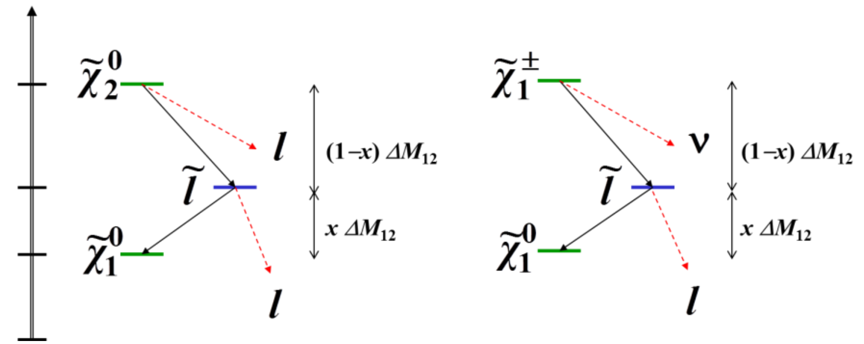




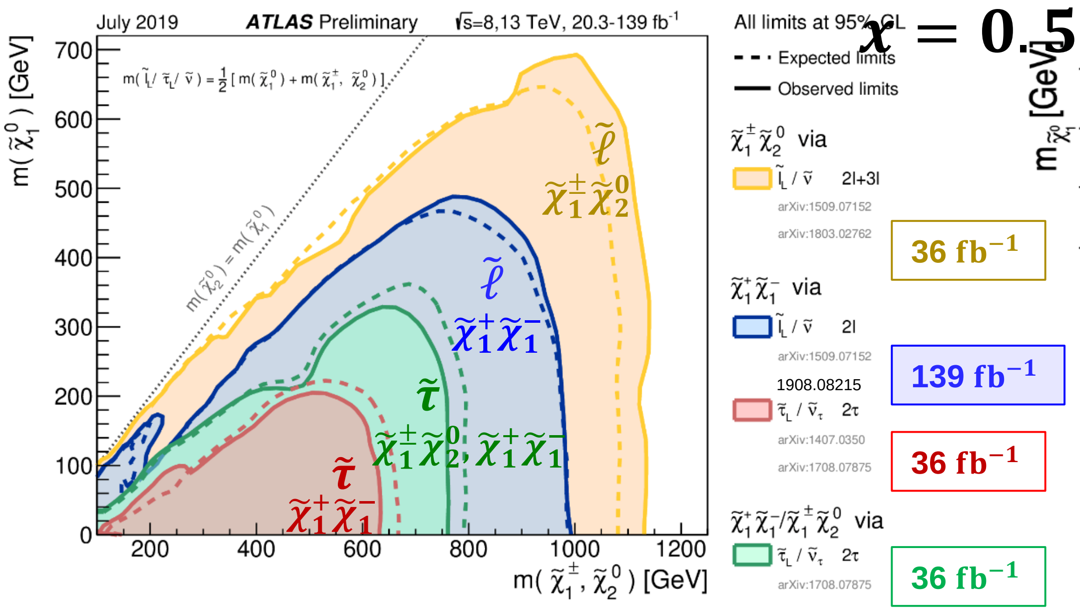
$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ (via $\tilde{\ell}$) in $2\ell, 3\ell, 2\tau$

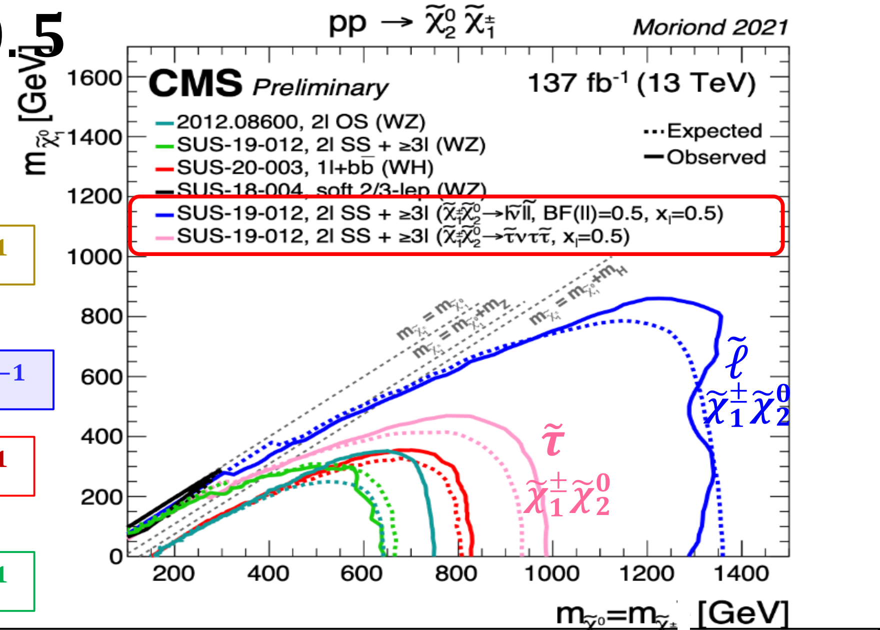






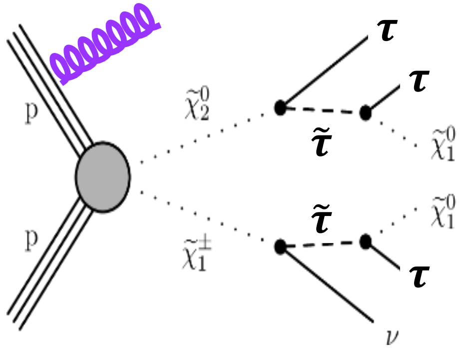
$x = 0.5$

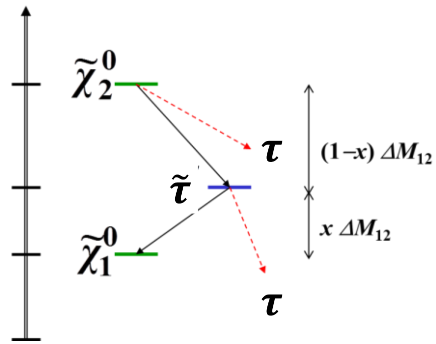


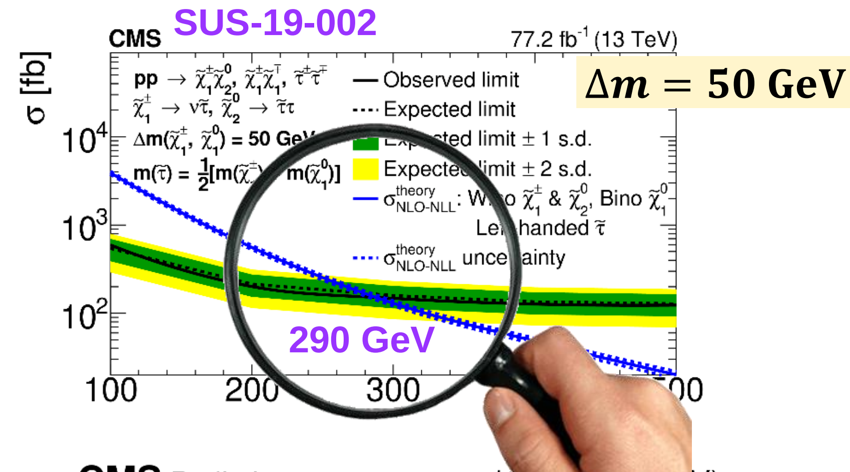


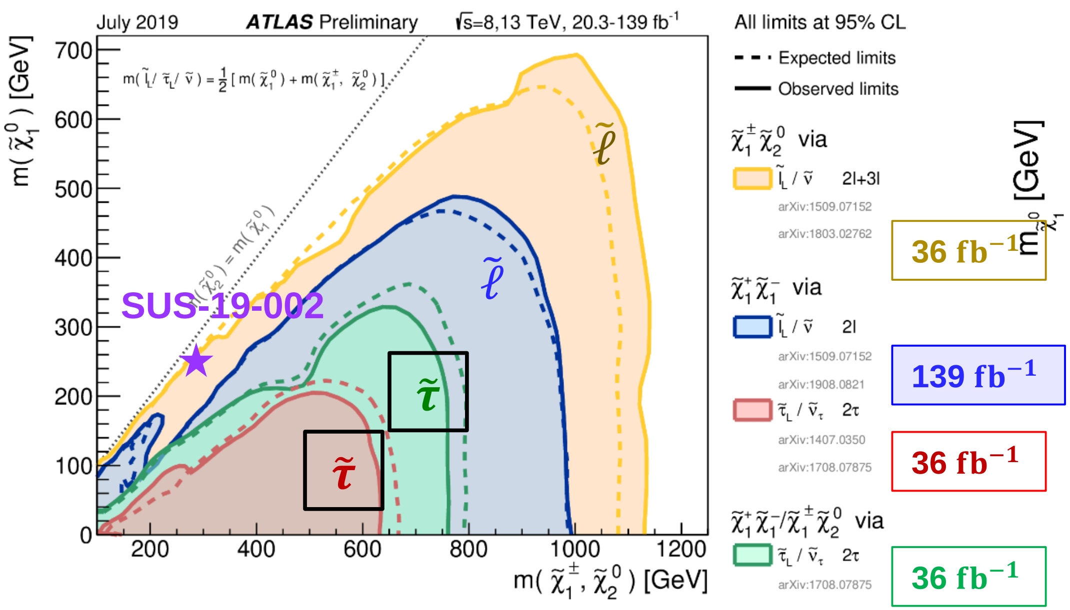
- Wino-Chargino and Bino-LSP: Up to 1300 GeV (1000 GeV) for light $\tilde{\ell}$ ($\tilde{\tau}$) case
- Weaker limits for Heavy slepton; being Higgsinos; small mass difference (compressed mass spectra)

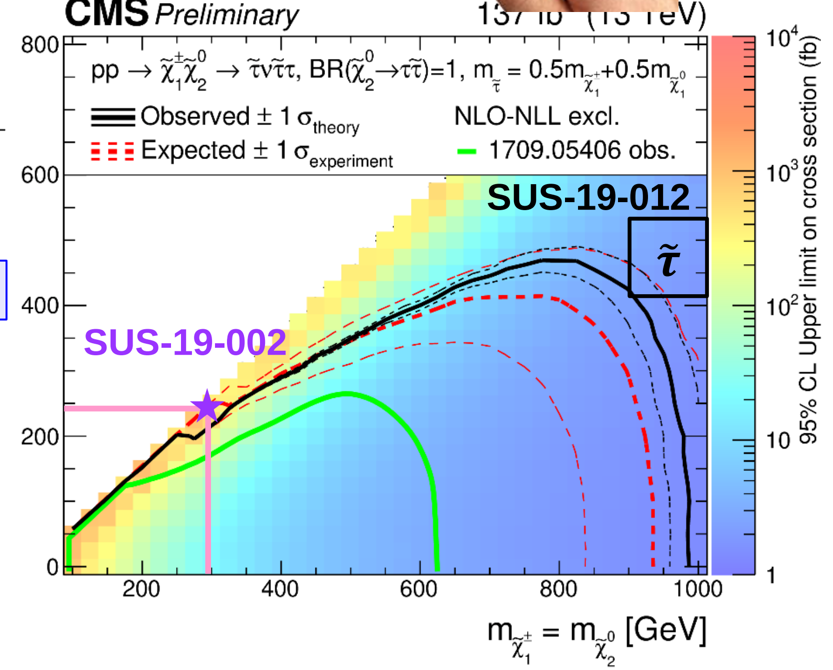
$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ (via $\tilde{\tau}$) in ISR jet + 1τ





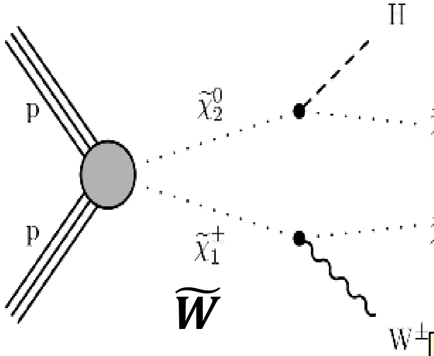


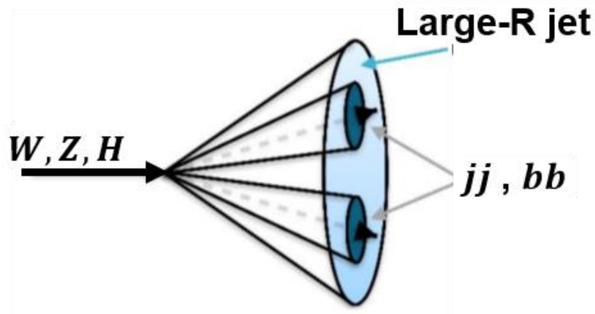


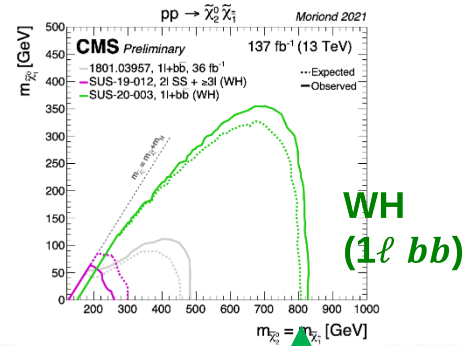


- ISR jet for compressed mass scenario (SUS-19-002)

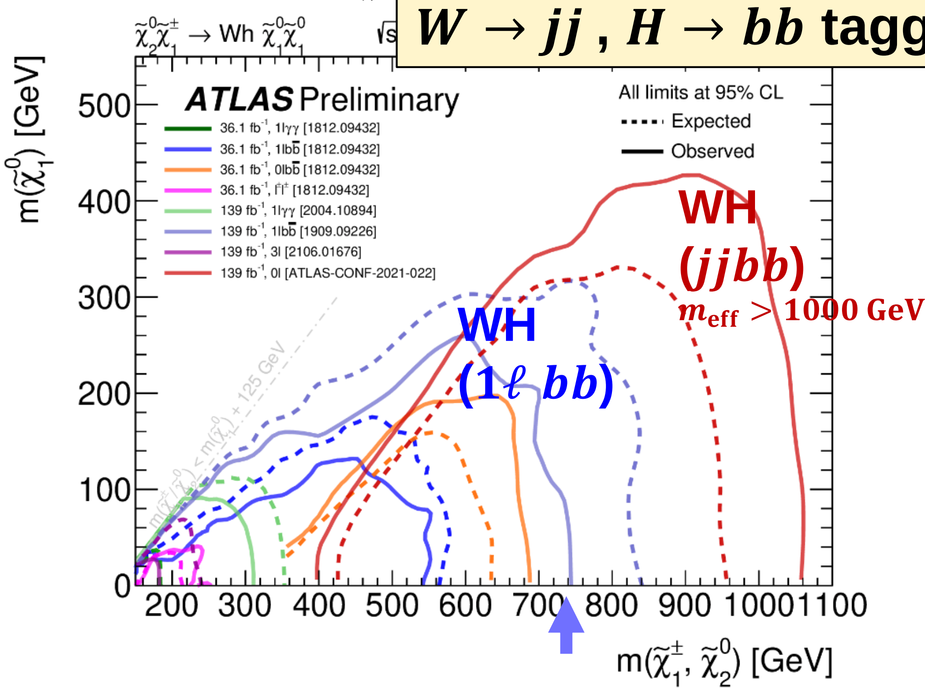
$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ (via WH) in $jjbb$ and $1\ell bb$

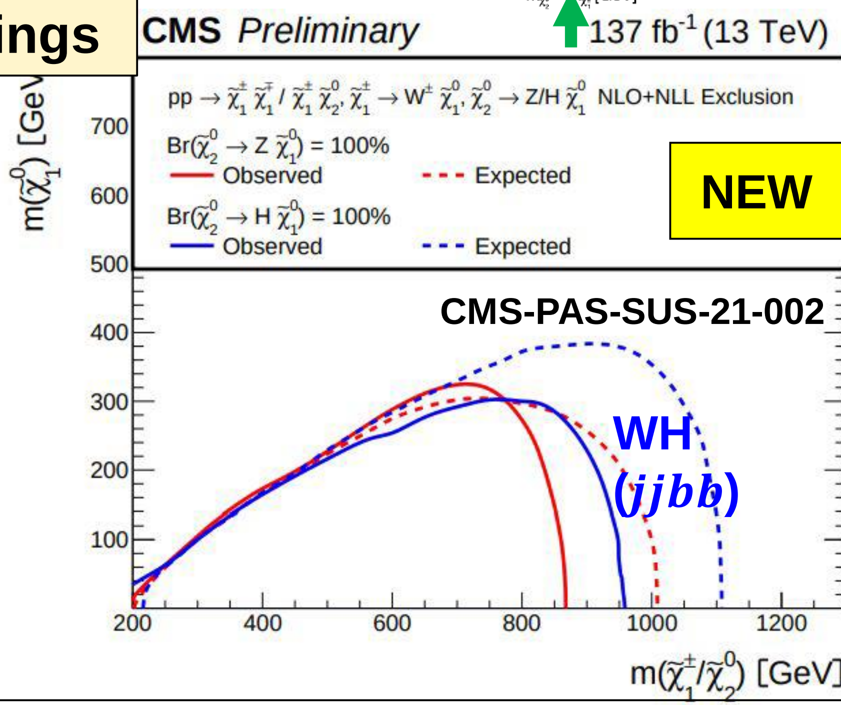






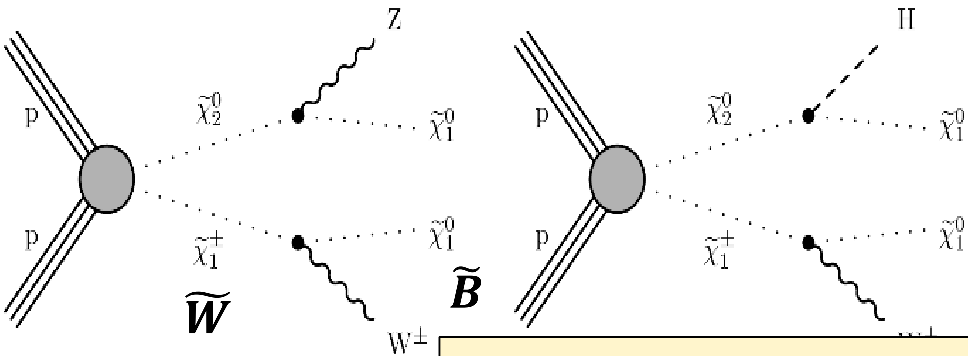
$W \rightarrow jj$, $H \rightarrow bb$ taggings

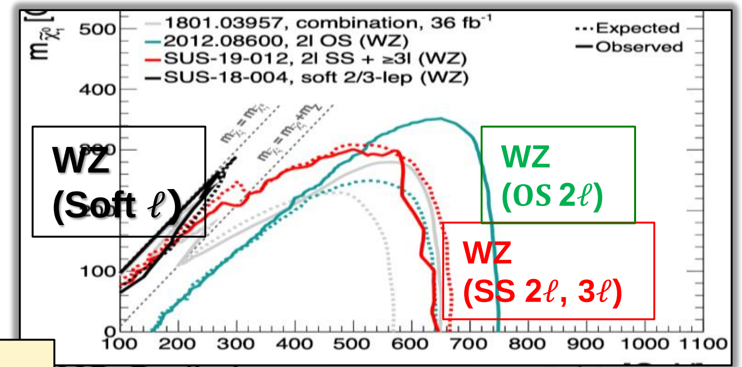




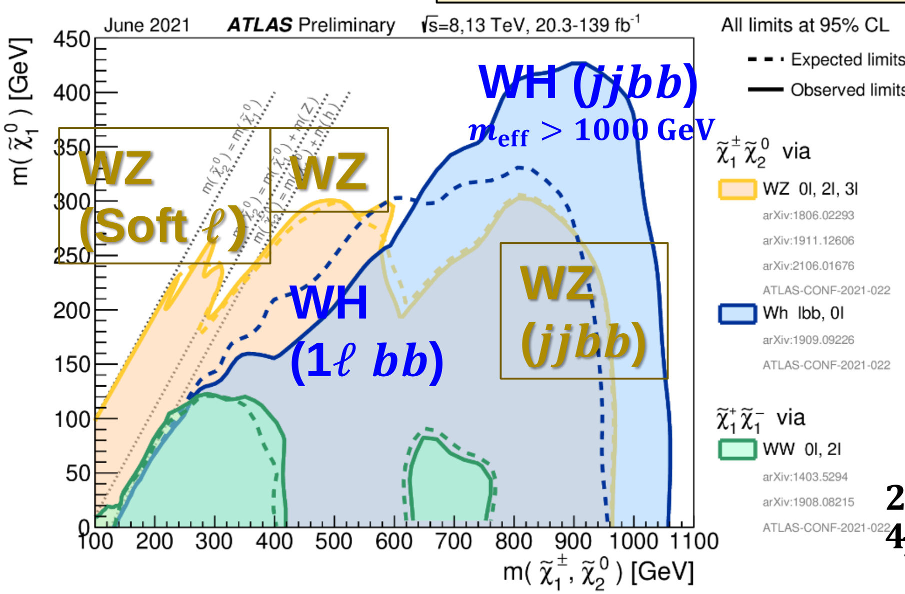
- Stringent $\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ limits of **1060 GeV (ATLAS; $> m_{\rm expected}$)** vs **950 GeV (CMS; $< m_{\rm expected}$)** for **WH $jjbb$**. Up to **750 (ATLAS)-820 (CMS) GeV** for **WH $1\ell bb$**
- Weaker limits for 3ℓ, $1\ell\gamma\gamma$

$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ (via WZ) in $jjbb$ ($jjjj$) and ℓ's

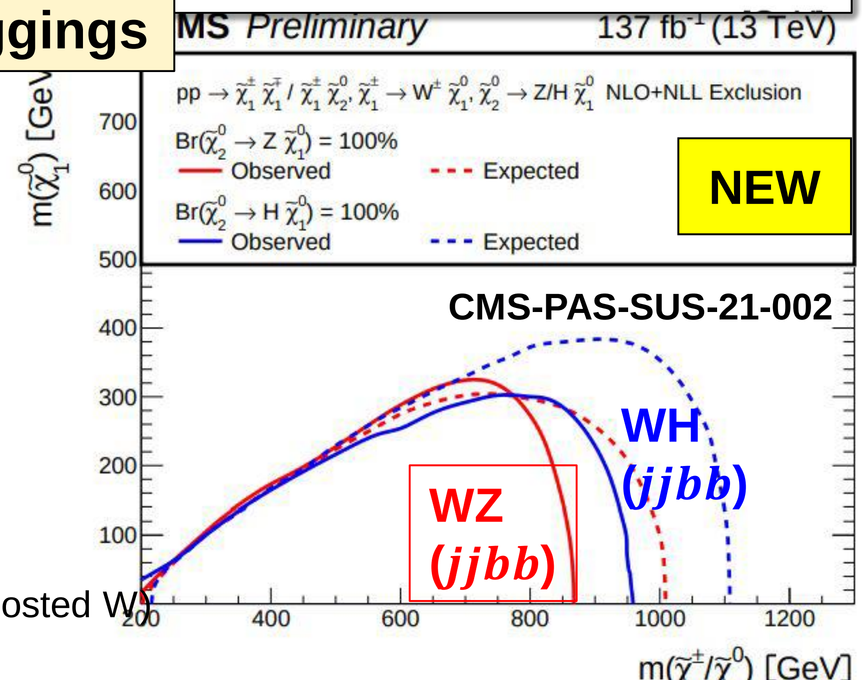




$W/Z \to jj$, $Z \to bb$ taggings

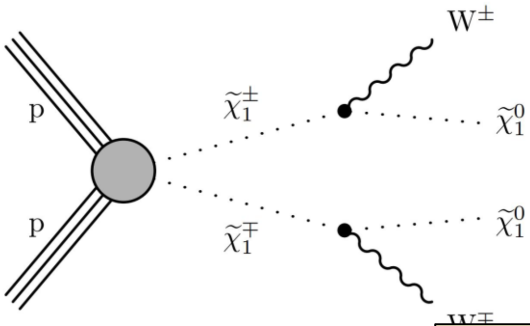


2ℓ
$4j$(boosted W)

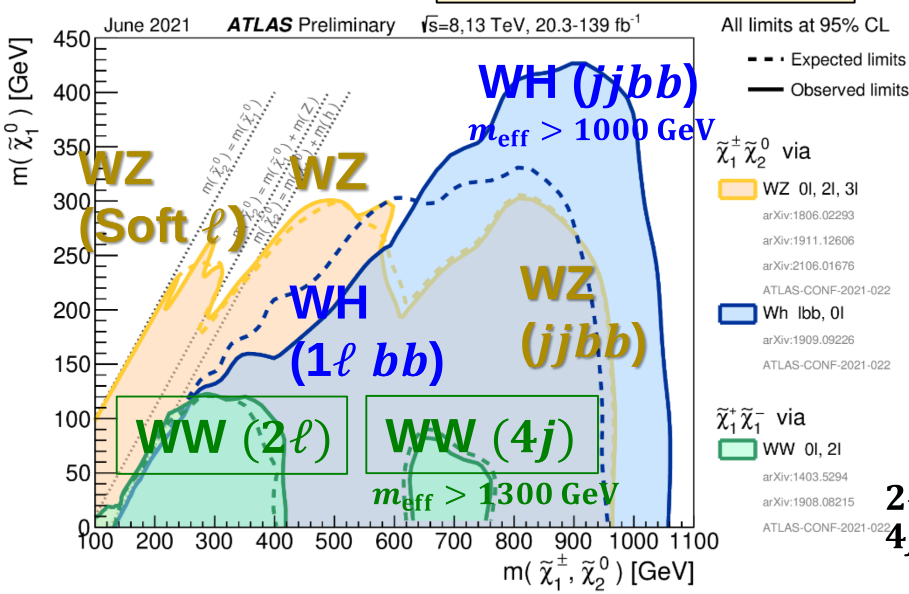


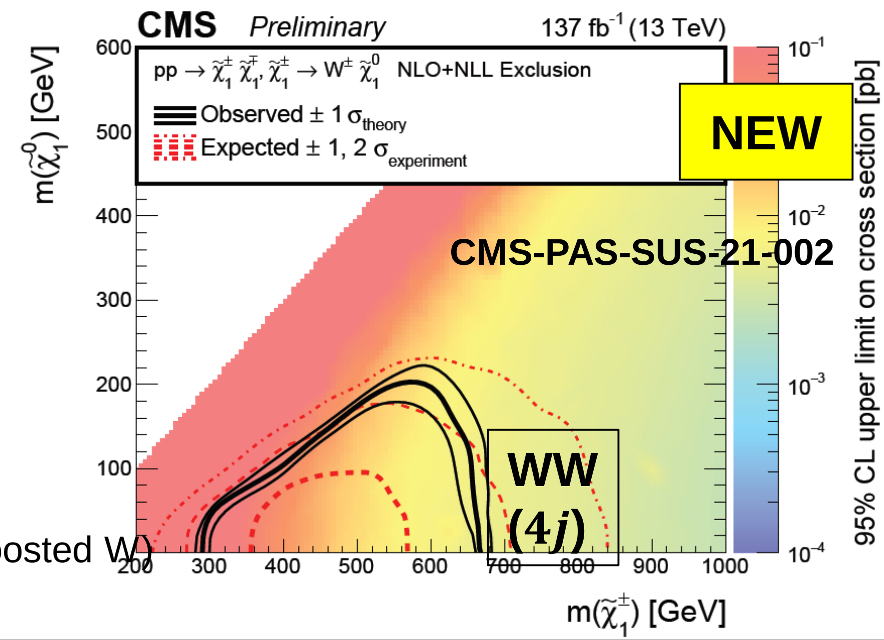
- Stringent $\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ limits of **960 GeV (ATLAS; $\approx m_{\text{expected}}$)** vs **860 GeV (CMS; $< m_{\text{expected}}$)** for **WZ $jjbb$**.
- Up to 250 GeV for small mass difference (compressed mass spectra)

$\tilde{\chi}_1^{\pm}$ (via WW) in $jjjj$ and 2ℓ



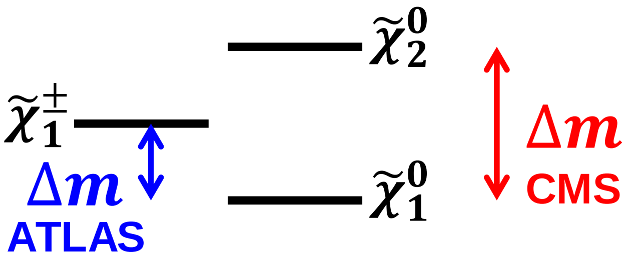
$W \to jj$ tagging





- Stringent $\tilde{\chi}_1^{\pm}$ limits of **630-760 GeV (ATLAS; $m_{\rm eff} > 1300$ GeV)** vs **290-670 GeV (CMS)** for **WW $jjjj$**. Weaker limits for WW 2ℓ

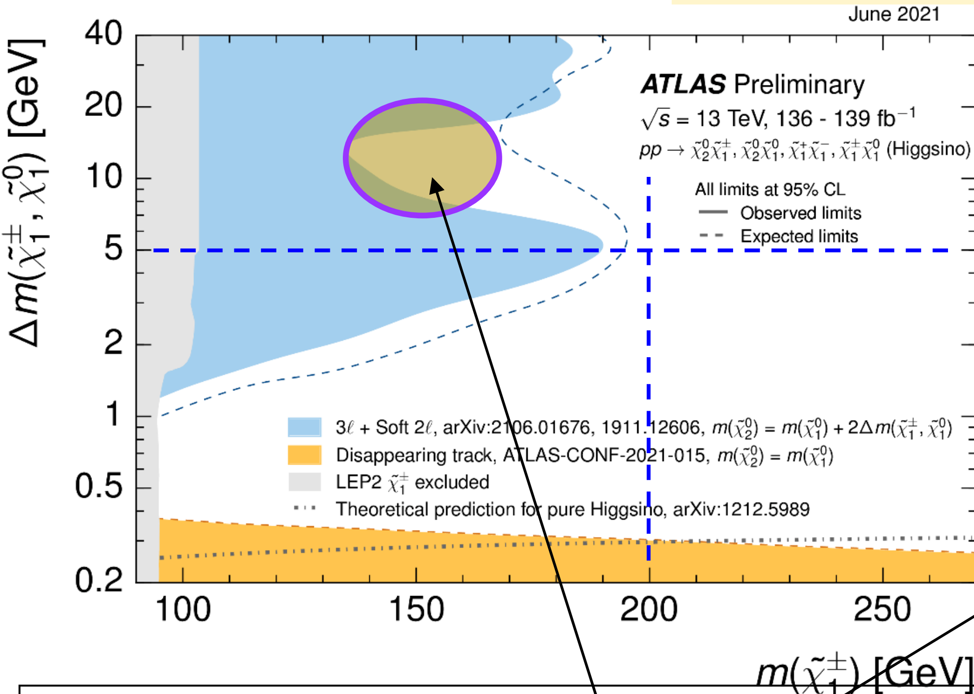
$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^{0}$ (Higgsino) – compressed mass

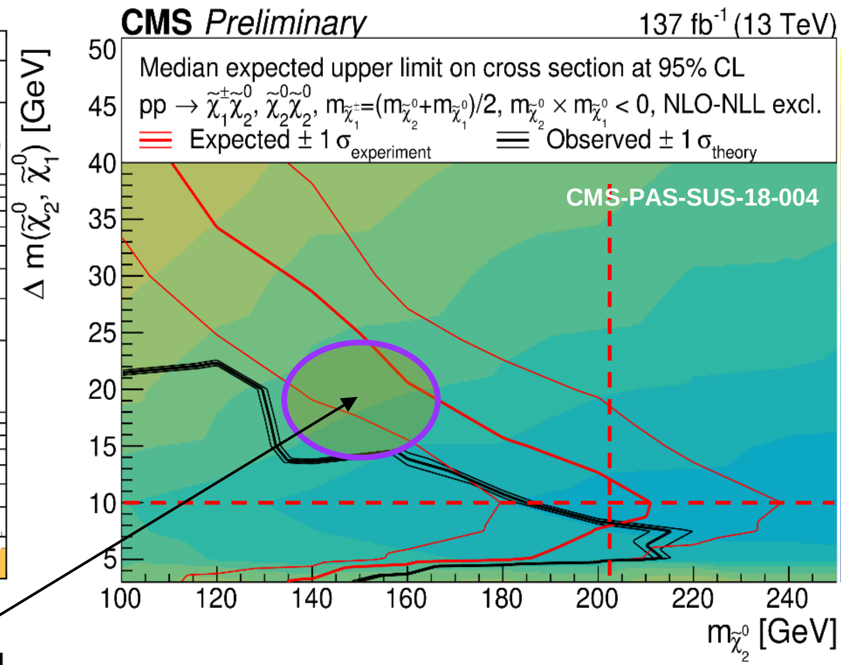


$(\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0, \tilde{\chi}_1^0) = (200,205,195) \Rightarrow (200, 205, 5)$ *vs.* $(200, 205, 10)$

$(\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0, \tilde{\chi}_1^0) = (200,240,160) \Rightarrow (200, 240, 40)$ *vs.* $(200, 240, 80)$

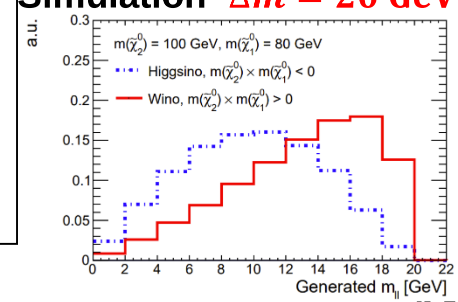
$(\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0, \tilde{\chi}_1^0) = (150,160,140) \Rightarrow (150, 160, 10)$ *vs.* $(150, 160, 20)$



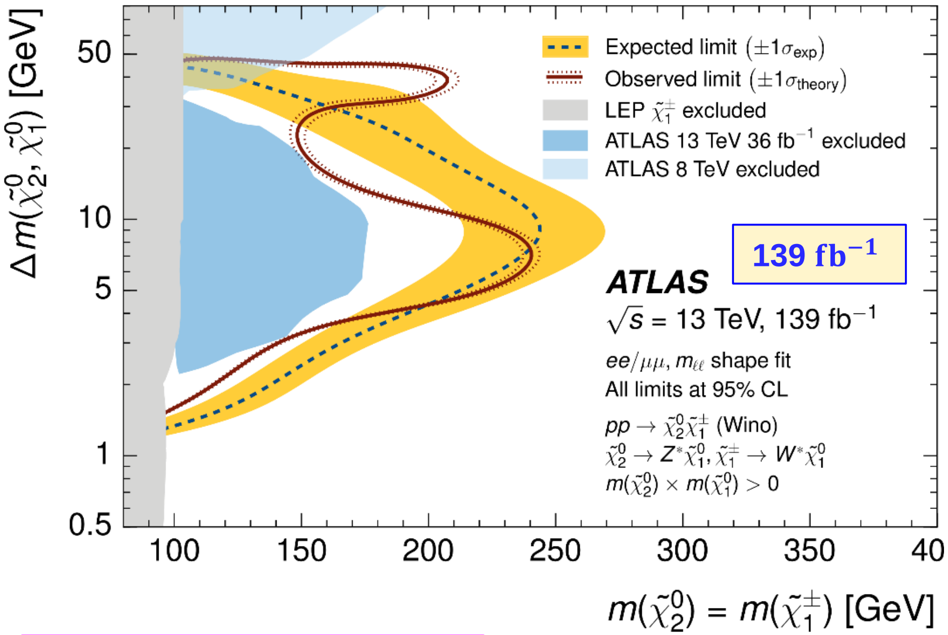


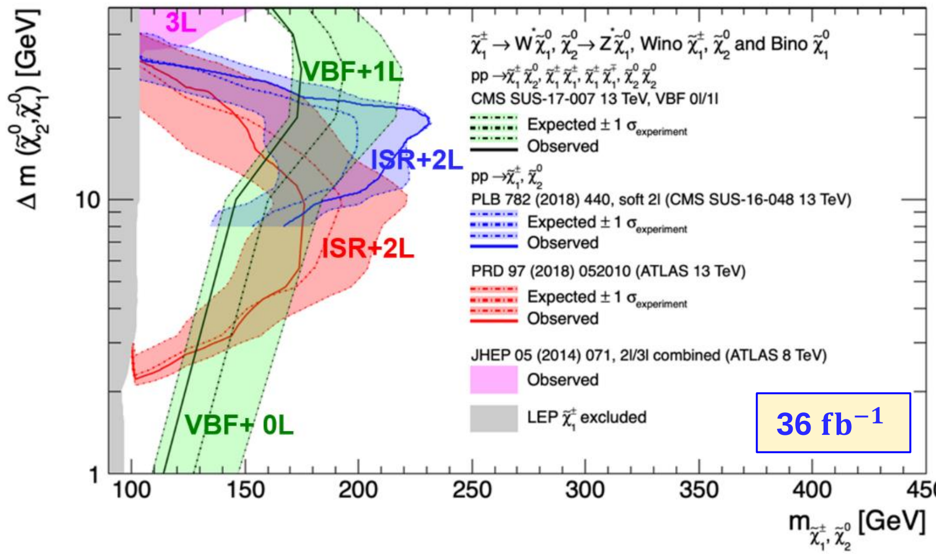
- ❑ Charginos Up to ~200 GeV
- ❑ Observed limits by ATLAS and CMS $< m_{\text{expected}}$ in the region at $(\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0, \tilde{\chi}_1^0) = (150,160,140)$: **due to a fluctuation in $m(\ell\ell)$ distribution** which is sensitive to setting limits.

Simulation $\Delta m = 20$ GeV

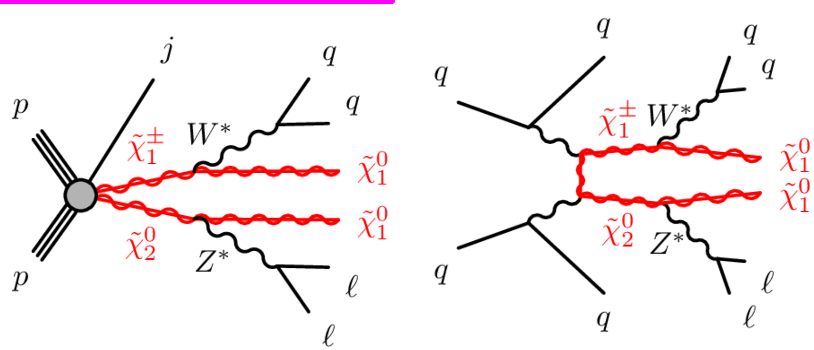


$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ (W^*, Z^*) – compressed mass

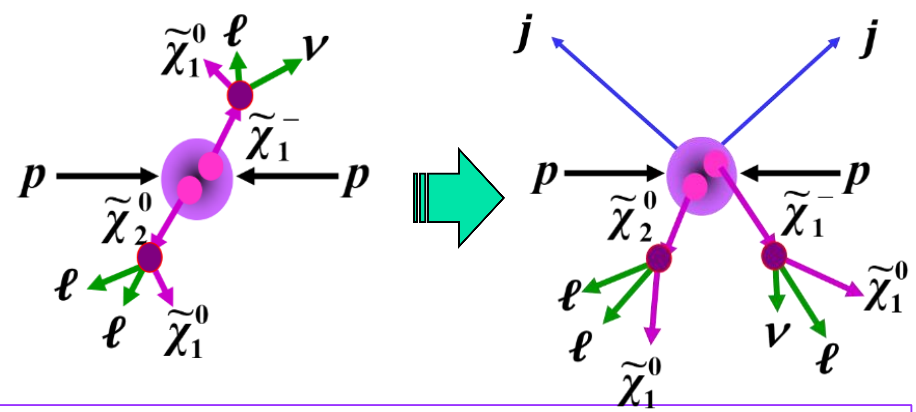




ATLAS: ISR 2ℓ or VBF 2ℓ



CMS: ISR 2ℓ or VBF $0\ell/1\ell$

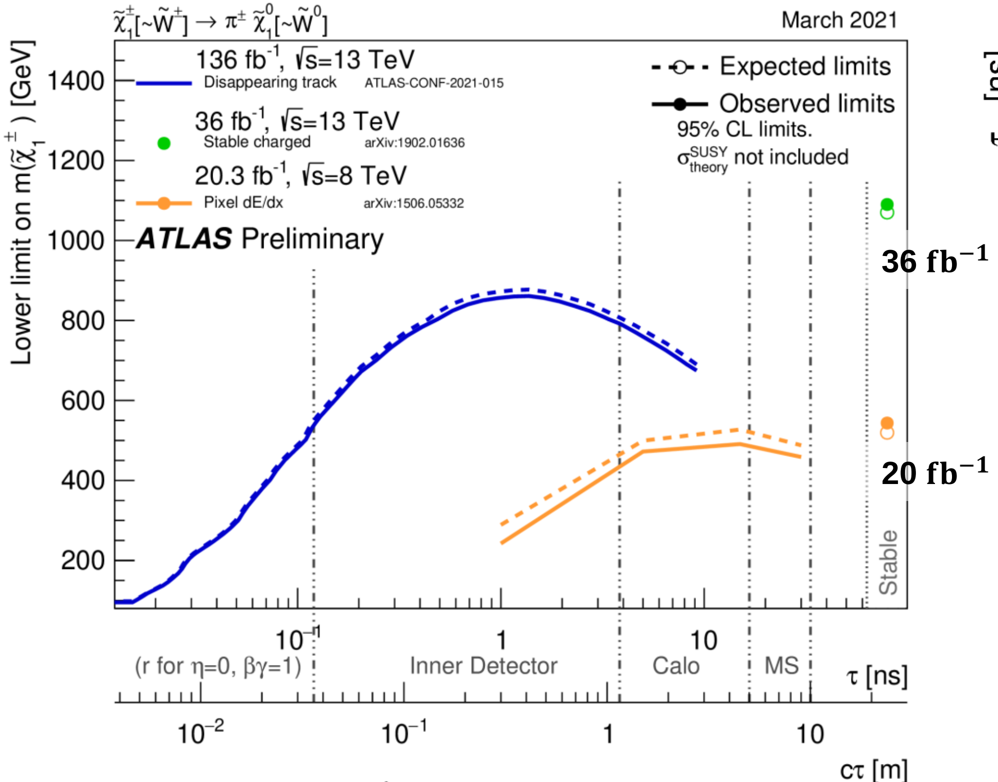


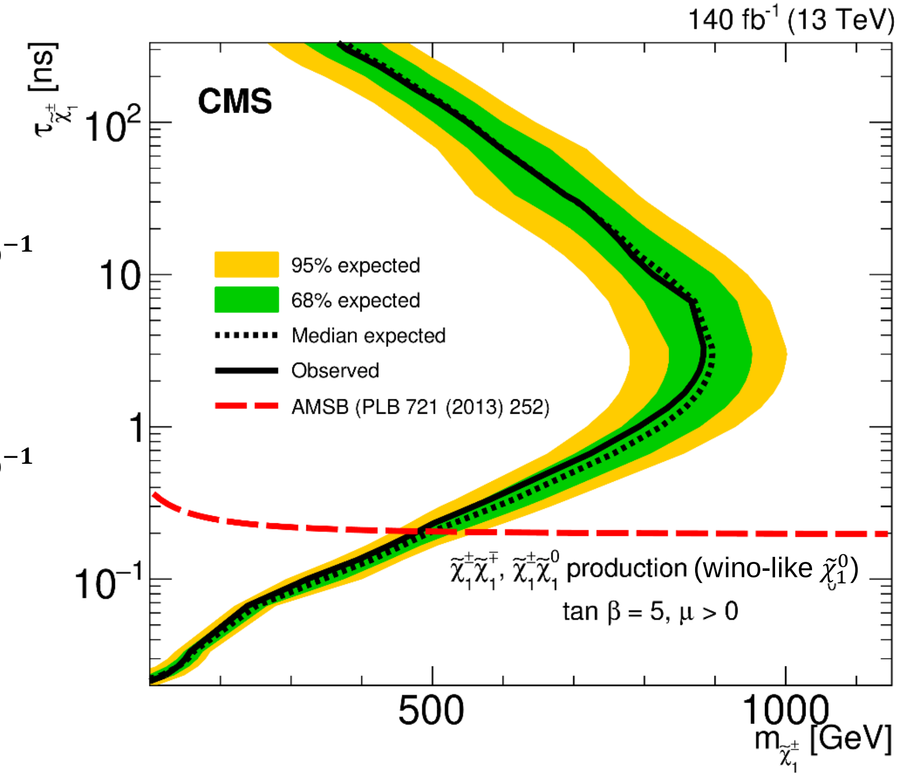
Probing compressed-mass scenarios (1-3 GeV) via ISR and VBF

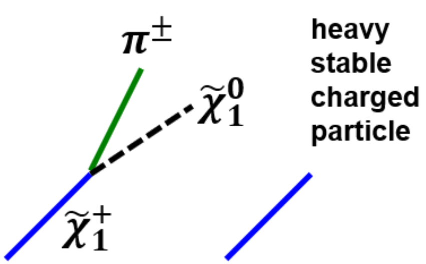
$\tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^0 \pi^{\pm}$ (Disappearing Track) & HSCP

ATLAS-CONF-2021-015

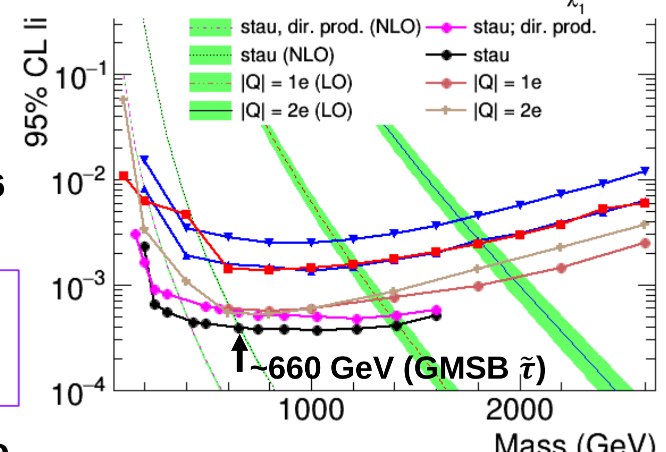
EXO-19-010





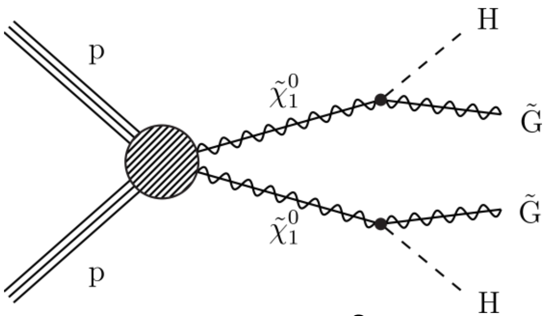


EXO-16-036
(13 fb^{-1})



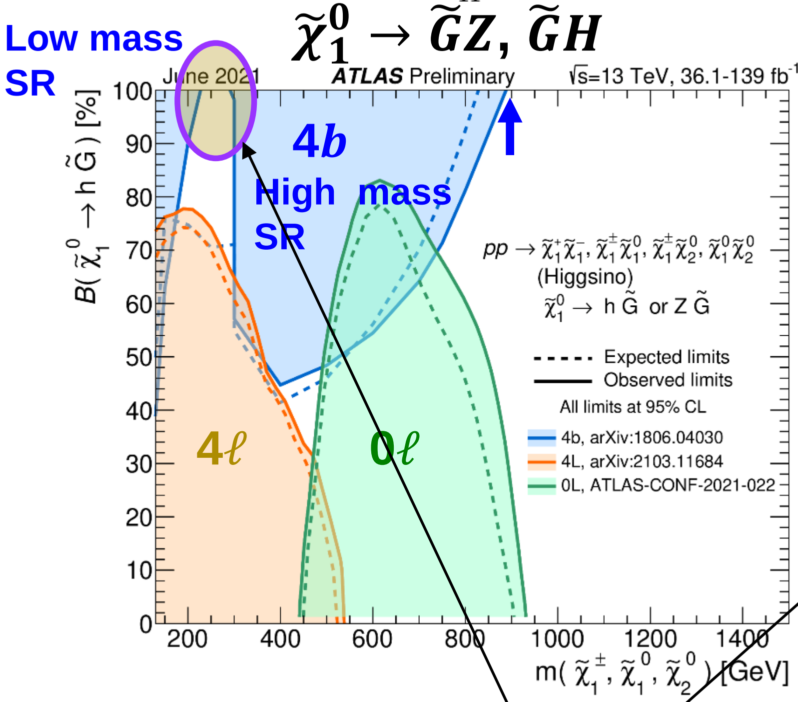
~900 GeV at τ = 1-2 ns
~1100 GeV for heavy stable charged particle

$\tilde{\chi}_1^0 \to \tilde{G}Z, \tilde{G}H$

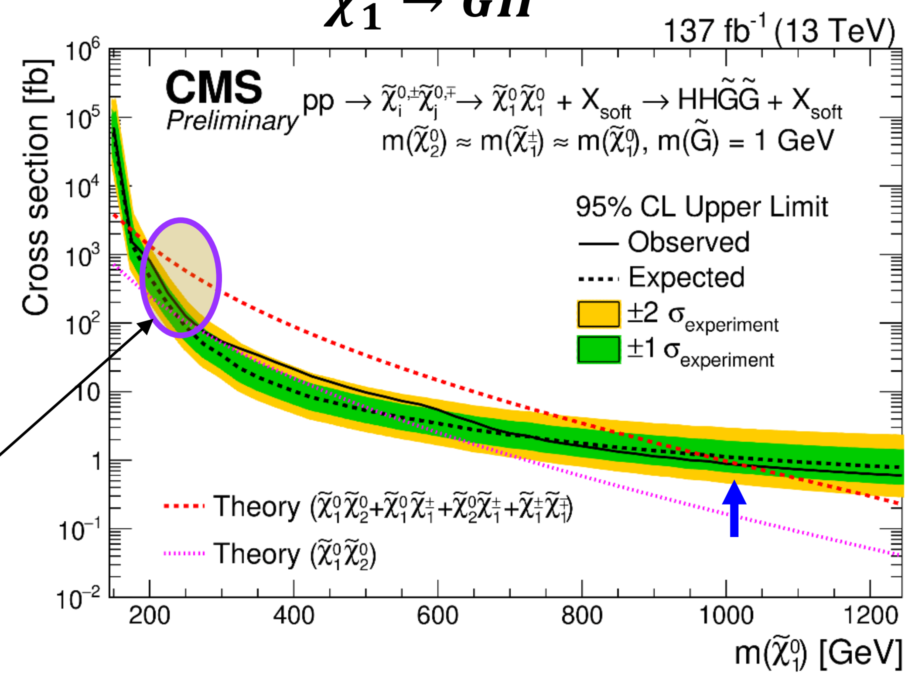


Mass-degenerate higgsino pairs of charginos or neutralinos, decaying to a Higgs boson and a gravitino.

$\tilde{\chi}_1^0 \to \tilde{G}Z, \tilde{G}H$



$\tilde{\chi}_1^0 \to \tilde{G}H$



~1 TeV for BF($\tilde{\chi}_1^0 \to \tilde{G}H$) = 1. Comprehensive searches by ATLAS: Higgsinos with masses between **230 and 290 GeV**, not excluded by ATLAS (due to fluctuation), but excluded by CMS

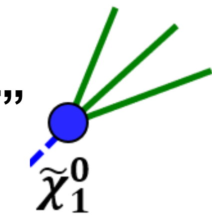
RPV $\tilde{\chi}_n^{0,\pm} \rightarrow \ell_i \ell_j \ell_k, \ell_i q_j q_k, q_i q_j q_k$

$$W_{RPV} = \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + k_i L_i H_u + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

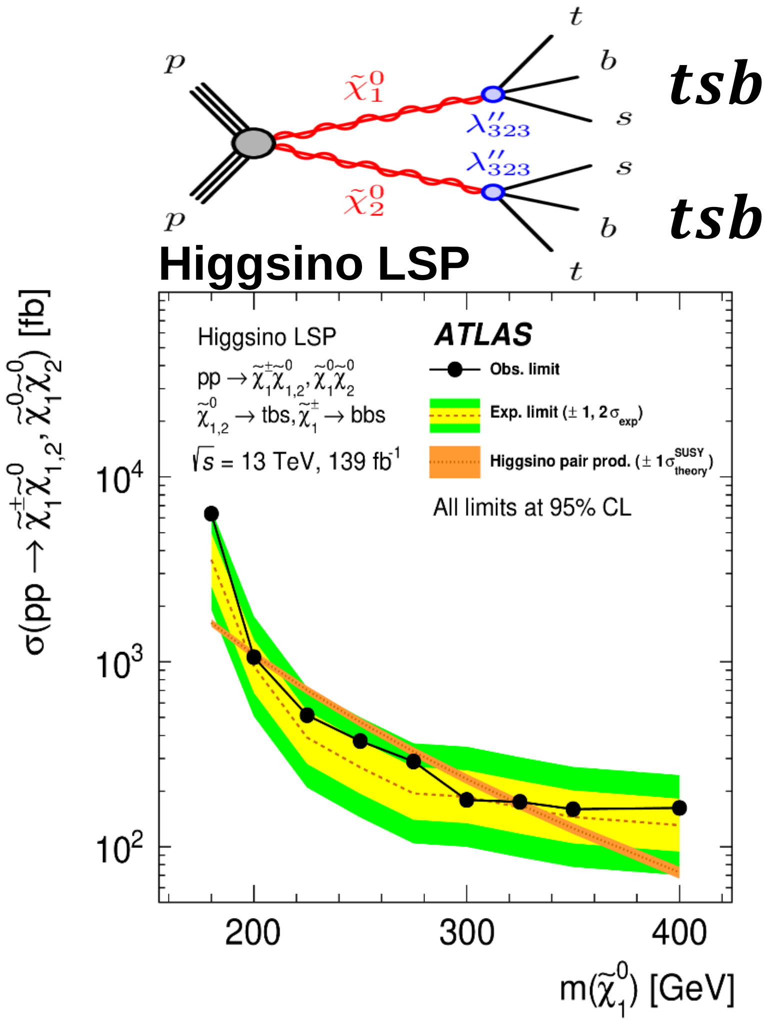
Lepton Number Violation | Baryon Number Violation

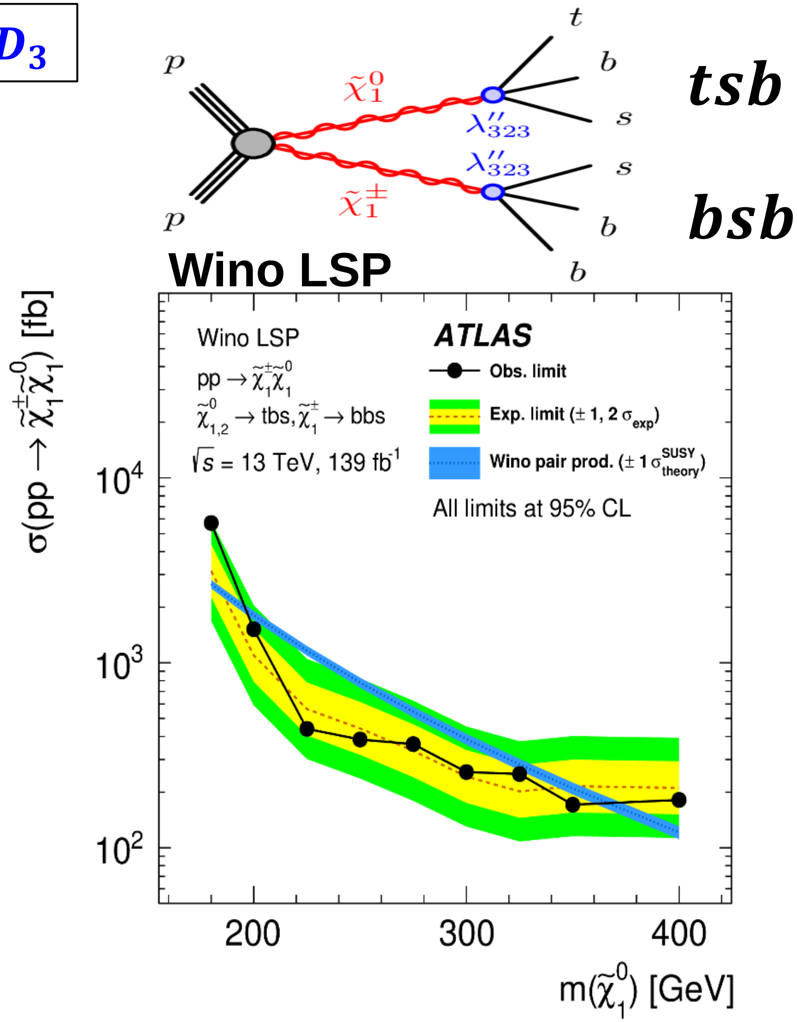
Multiple Leptons/jets + no "MET"

($1\ell + N_{j,b}$ and $2\ell + N_{j,b}$) + NN



$\lambda''_{323} U_3 D_2 D_3$



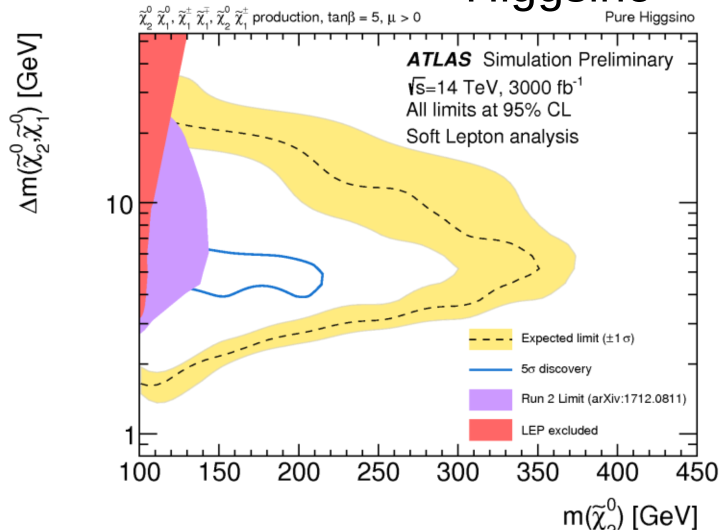


Run3 and Beyond (>3000 fb^{-1})

- **HL-LHC projection studies** for SUSY searches
  - Additional luminosity will significantly improve the reaches e.g. compressed mass scenario with soft leptons
- **Phase-2 upgrades** of the ATLAS and CMS detectors to remain competitive in its searches for new physics.
  - Provide additional handles, e.g. calorimeter timing capabilities for constraining long lived particles

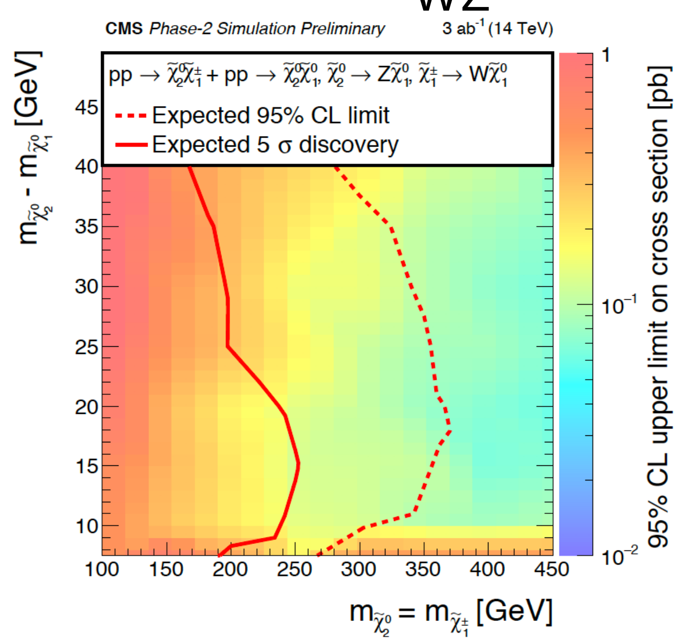
Higgsino

ATL-PHYS-PUB-2018-031



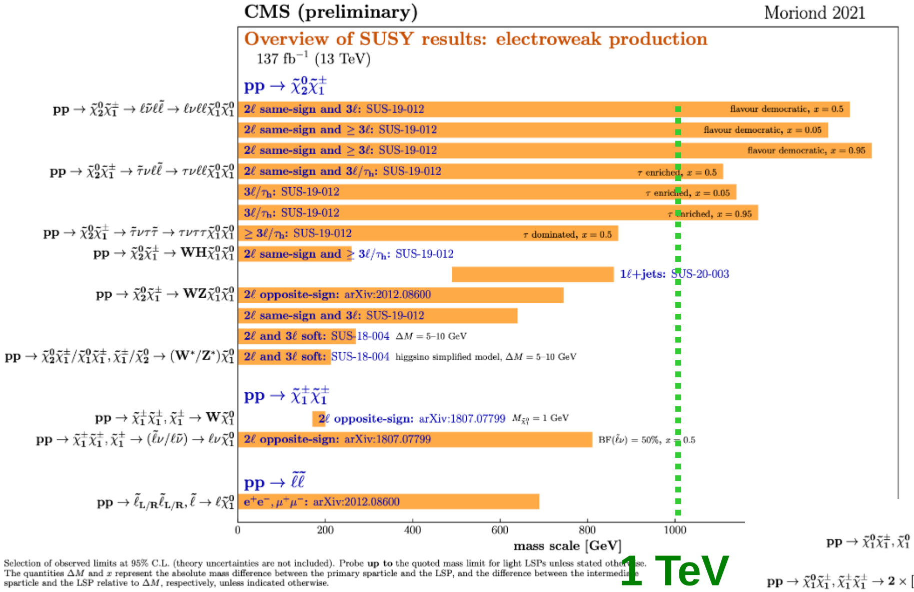
WZ

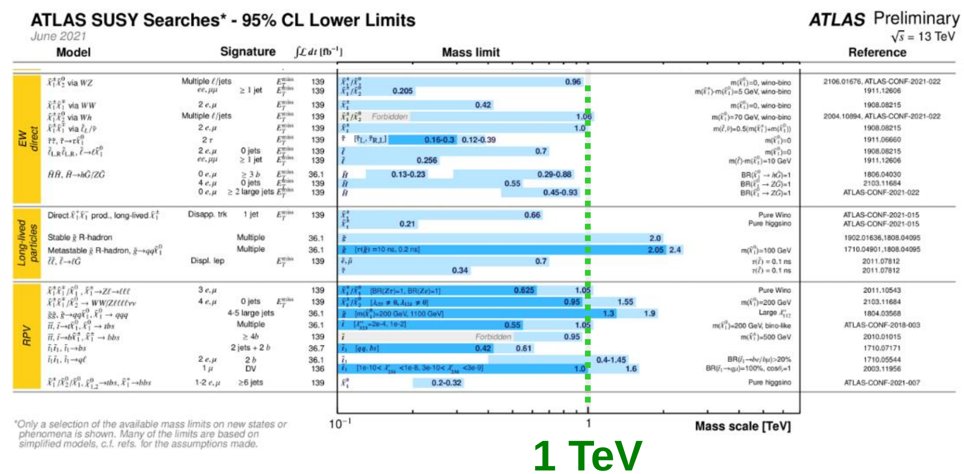
CMS-PAS-FTR-18-001

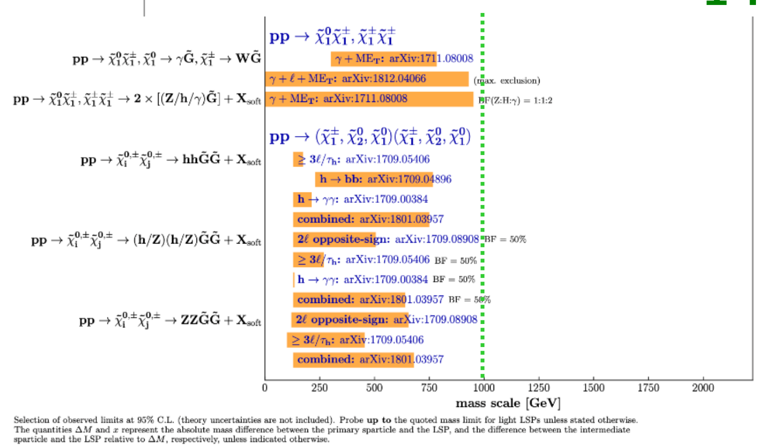


Summary

- ❑ **LHC Run-2 (140 fb^{-1}):** Stringent limits of ***O*(1 TeV)** in very diverse search scenarios including compressed mass, LL and HSCP.







Remarks

- **More results** are in the pipeline and will become public throughout the remainder of the year.

- **$\sqrt{s}$ ⇑ & $\mathcal{L}$ ⇑ at the LHC:** $140\ \mathrm{fb}^{-1}$, 13 TeV (Run-2) ⇒ $300\ \mathrm{fb}^{-1}$ (Run-3) ⇒ $3000\ \mathrm{fb}^{-1}$ ⇒ higher pileup, more radiation damage & higher occupancy.
  - **ATLAS and CMS detectors** - Capable of meeting the demands of the challenging environment
  - **New ideas & techniques** are helping to open new avenues for constraining SUSY parameter space.