Search for electroweak production of supersymmetric particles with the ATLAS detector

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ICEPP
The University of Tokyo

ATLAS
EXPERIMENT

ICHEP 2022
BOLOGNA

ICHEP 2022
XLI
International Conference
on High Energy Physics
Bologna (Italy)

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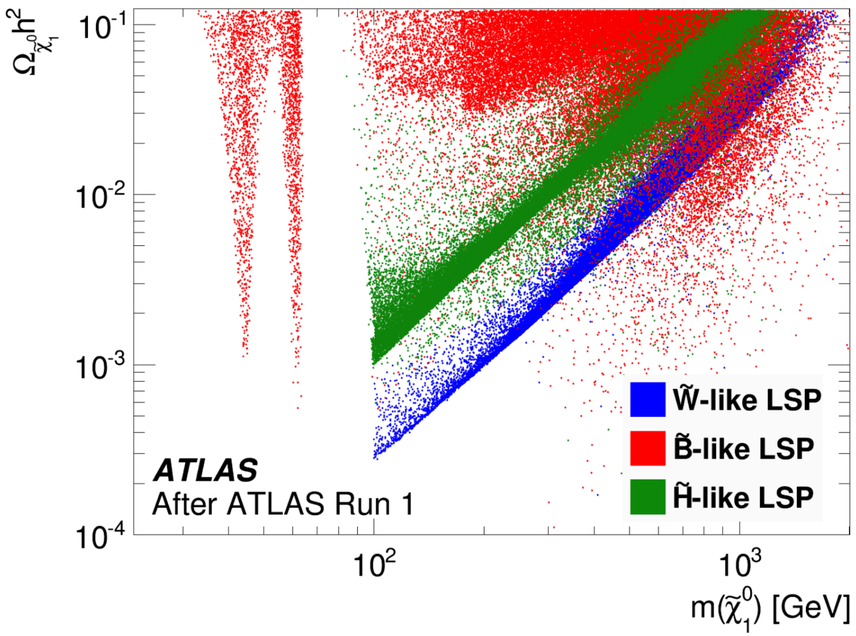
Why electroweak SUSY?

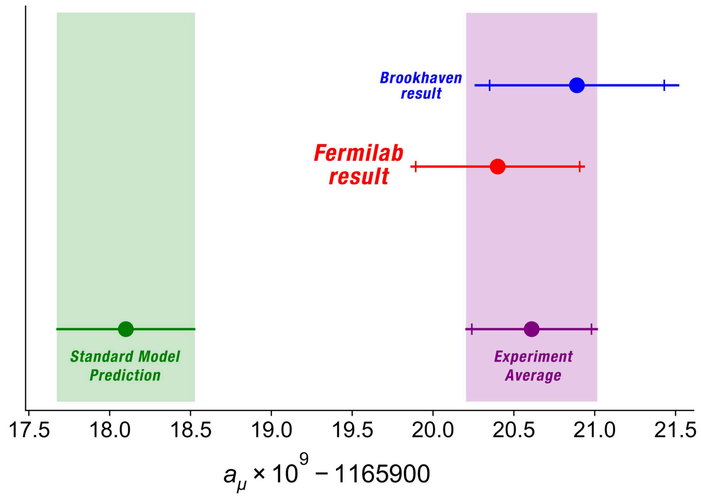


pMSSM scan after the ATLAS Run-1

$m_{\tilde{\chi}_1^0} < 3$ TeV for Ω_{DM}=0.12

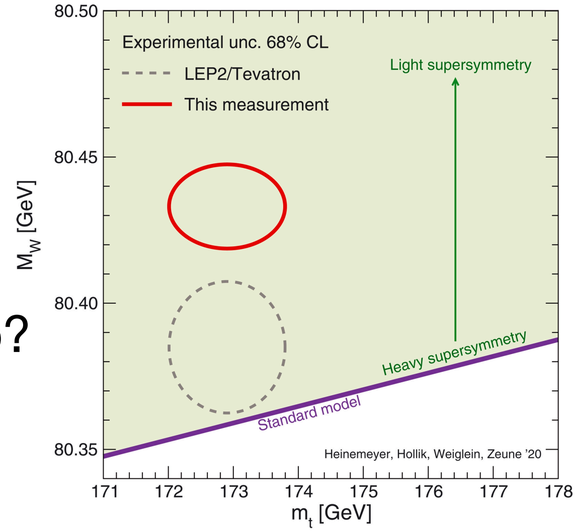
Muon g-2 anomaly

O(100)GeV slepton and neutralino?



CDF W-boson mass

O(100)GeV slepton and chargino/neutralino?

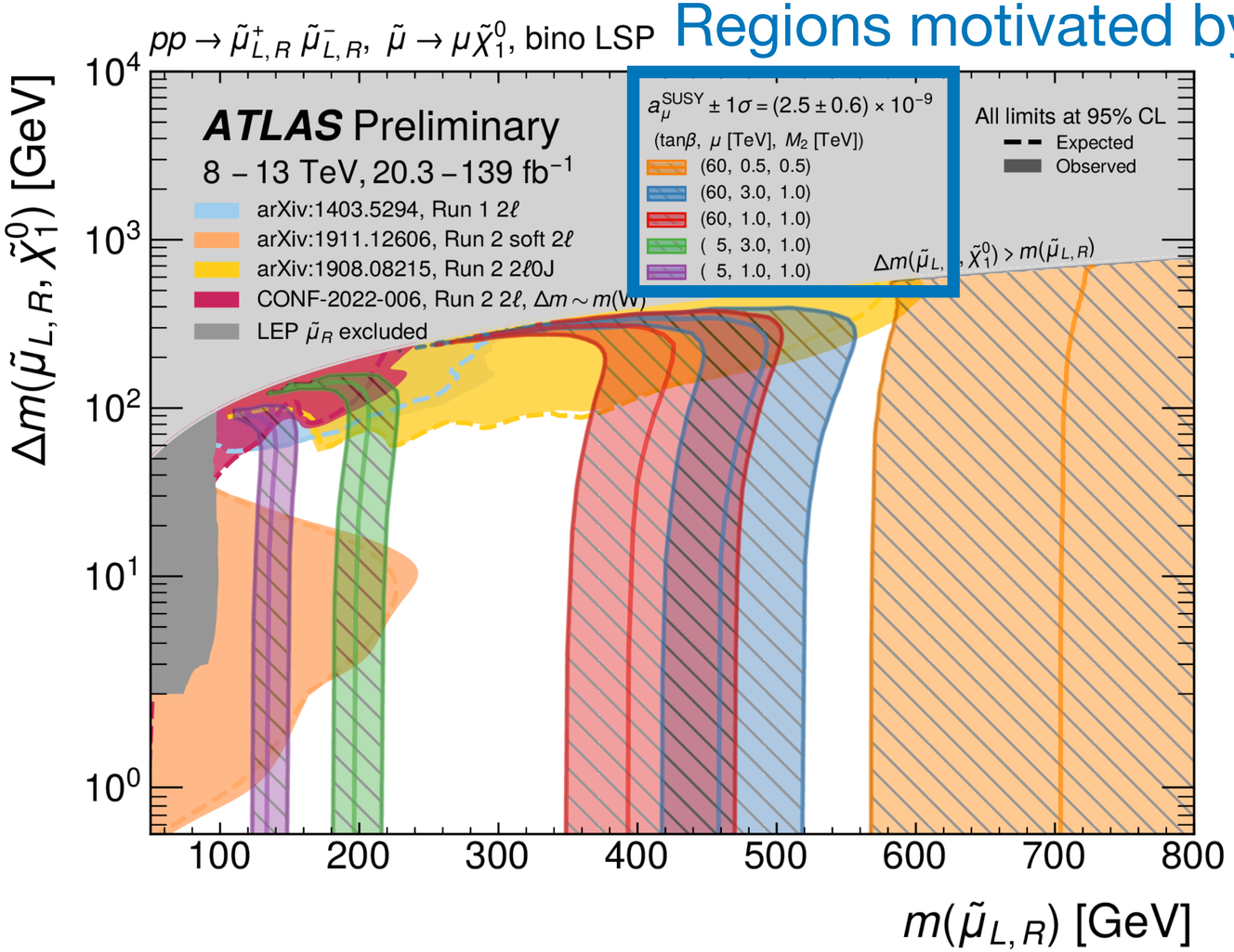


<u>O(100)GeV-O(1)TeV EW SUSY is highly motivated!</u>

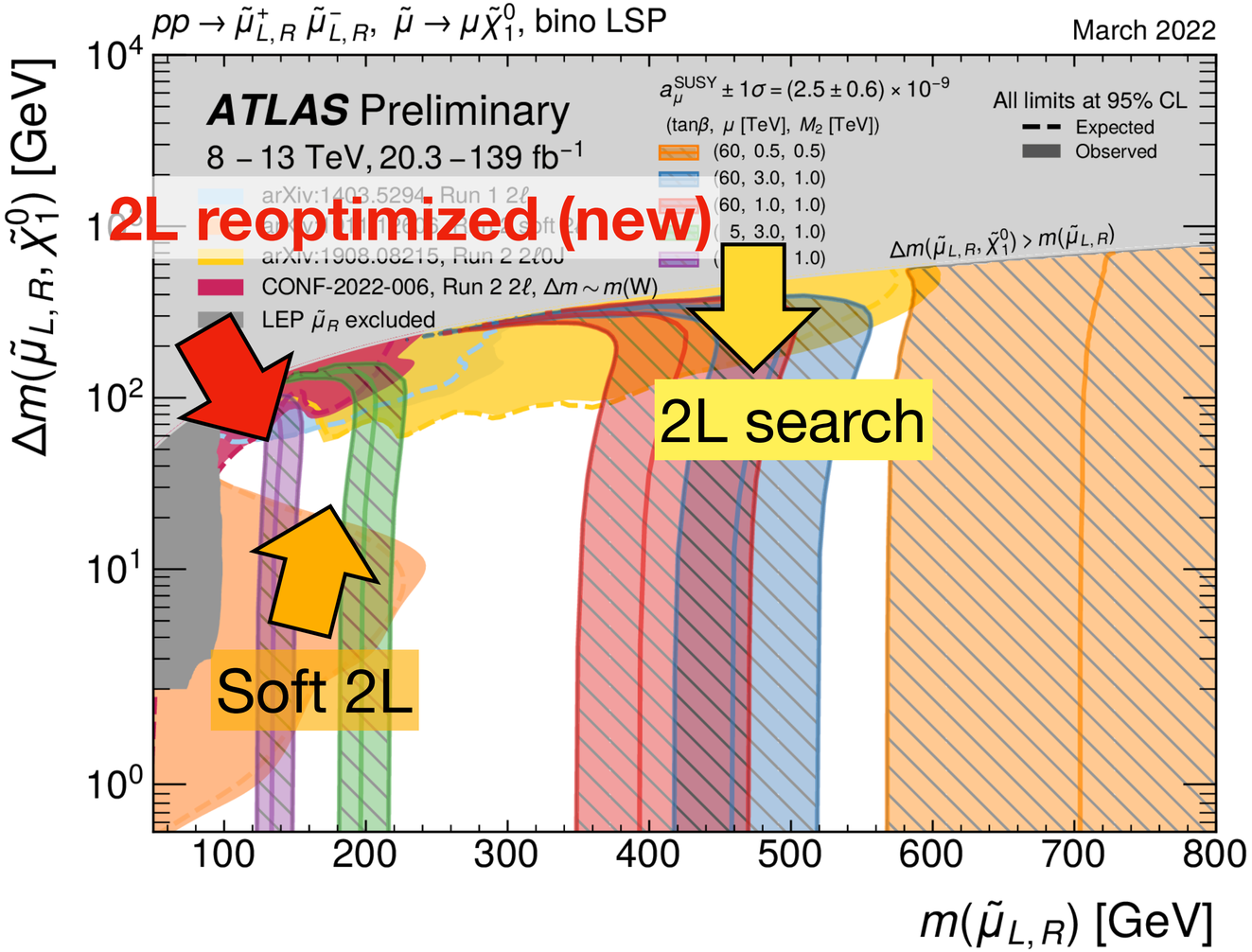
And it is in the scope of the LHC run-2 physics program

Slepton search current limit

Regions motivated by muon g-2



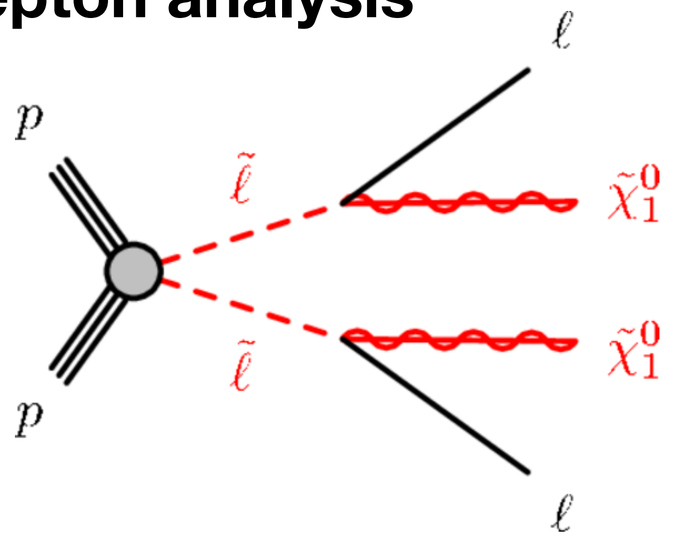
Slepton search current limit



Just started to reach to the region of interest now!

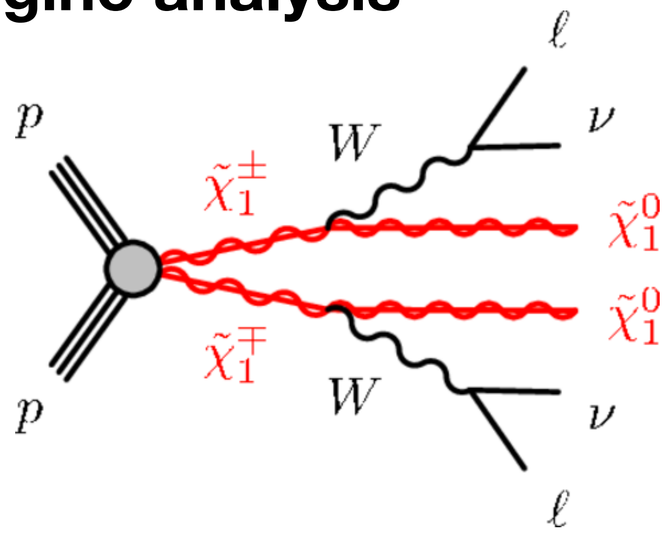
2L + mET, reoptimized for “moderate compressed” region

slepton analysis



- Analysis reoptimzied for $\Delta m = m_{\tilde{\ell}_{L,R}} - m_{\tilde{\chi}_1^0} < m_W$
- Same-flavor (SF) and opposite charge lepton pair (e^+e^- or $\mu^+\mu^-$)
- Optimized the cuts on angular distributions
- Multi-bin fit using $m_{T,2}$ distribution
  ($m_{T,2}$: reconstructed slepton transverse mass, assuming a symmetric pair of 2-body decays to visible and invisible particles)

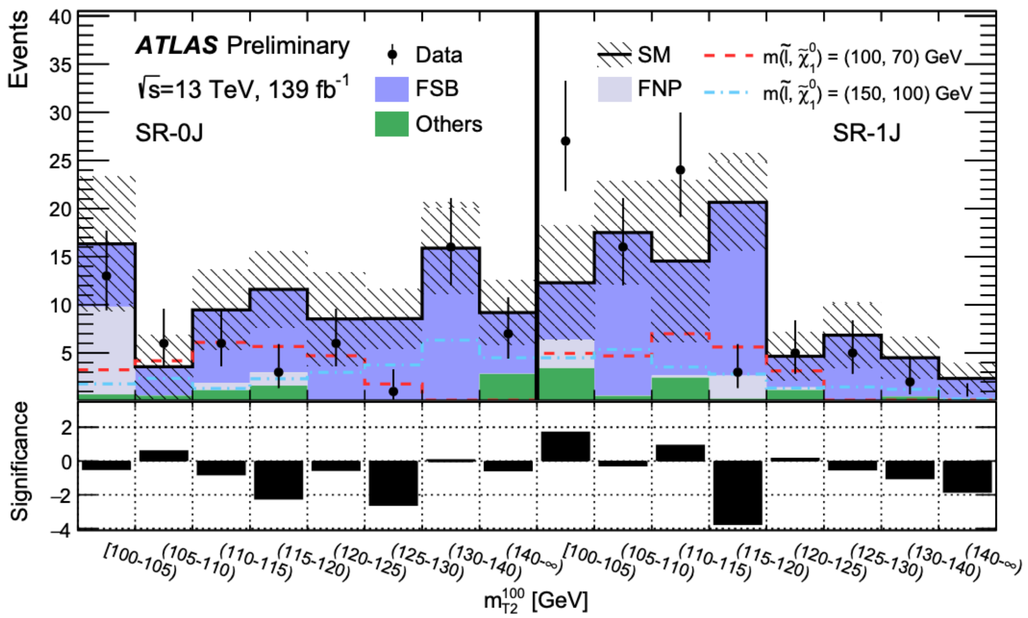
chargino analysis



- Analysis reoptimzied for $\Delta m = m_{\tilde{\chi}_1^{\pm}} - m_{\tilde{\chi}_1^0} < m_W$
- Both SF and different-flavor (DF) channels ($e^+\mu^-$)
- New BDT-based classifier
  *multi-class classifier to have 4 output scores
  (BDT-signal, BDT-VV, BDT-top, and BDT-other)

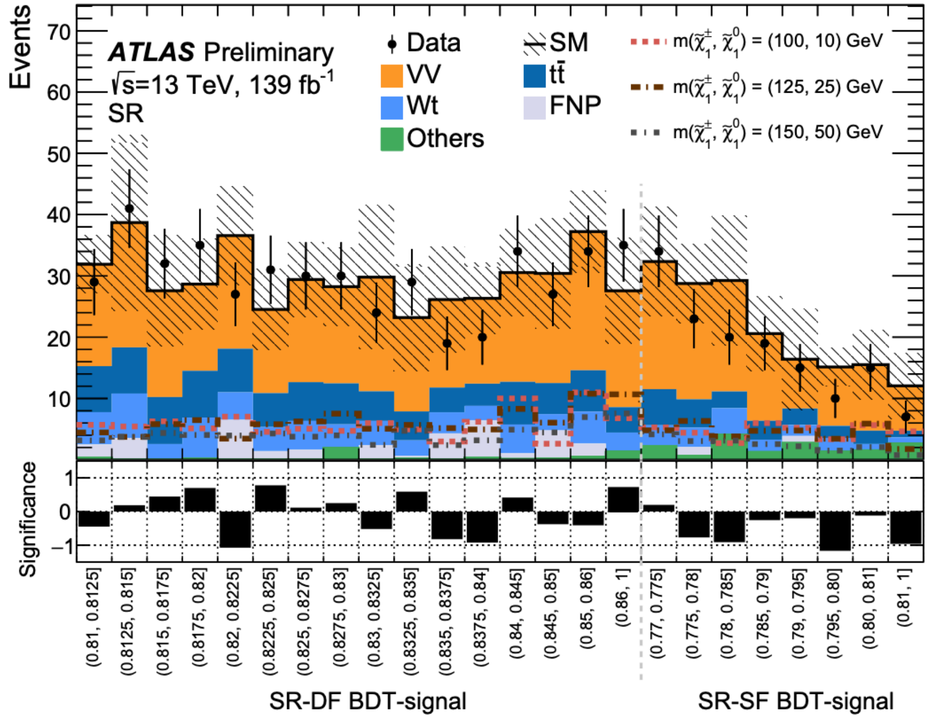
2L + mET cont'd

slepton analysis



- Main bkg: WW, ttbar, Z→ττ are flavor symmetric background (FSB)
- Data-driven estimation: DF (eμ) events used to estimate SF (ee/μμ) events
  considering different reconstruction/trigger efficiencies for e and μ

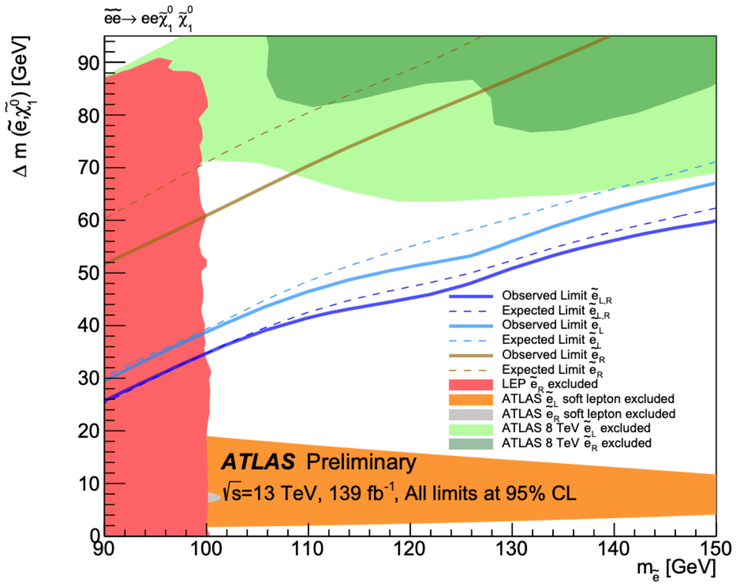
chargino analysis



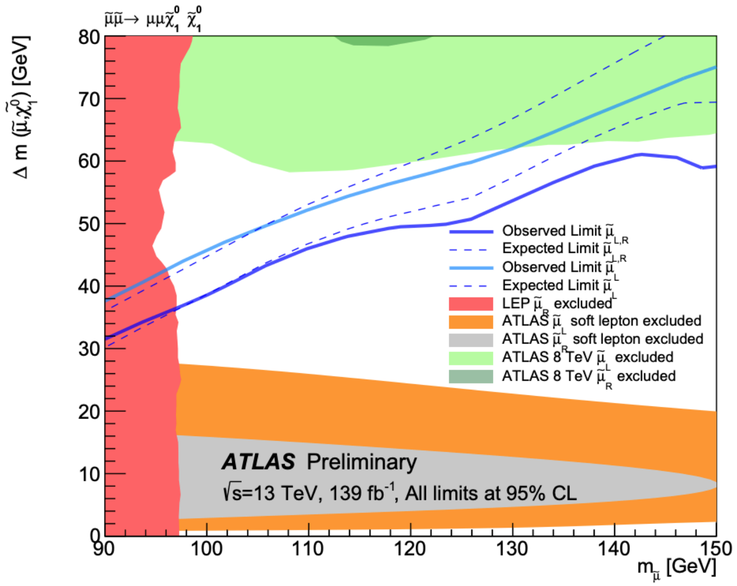
- Simultaneous fit to SR and CRs
  - VV CR: lower BDT-signal and higher BDT-WW
  - top CR: requiring at least one b-jets

2L + mET exclusion limits

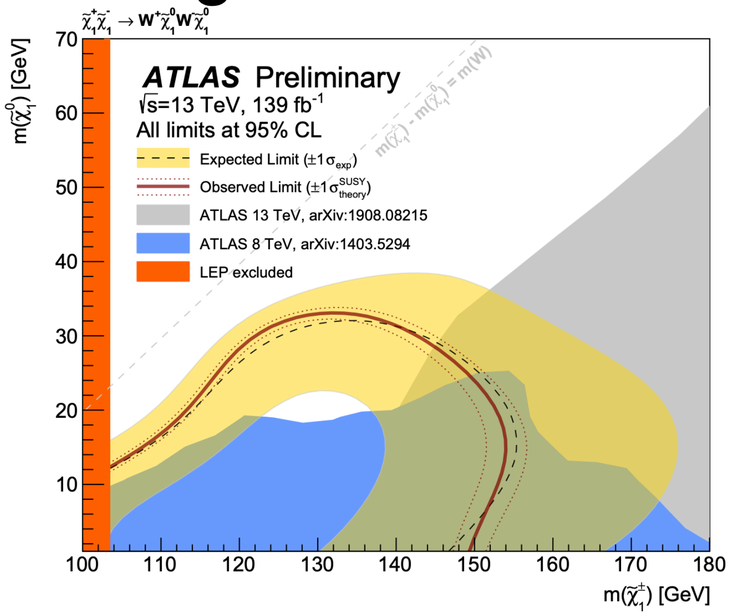
selectron



smuon

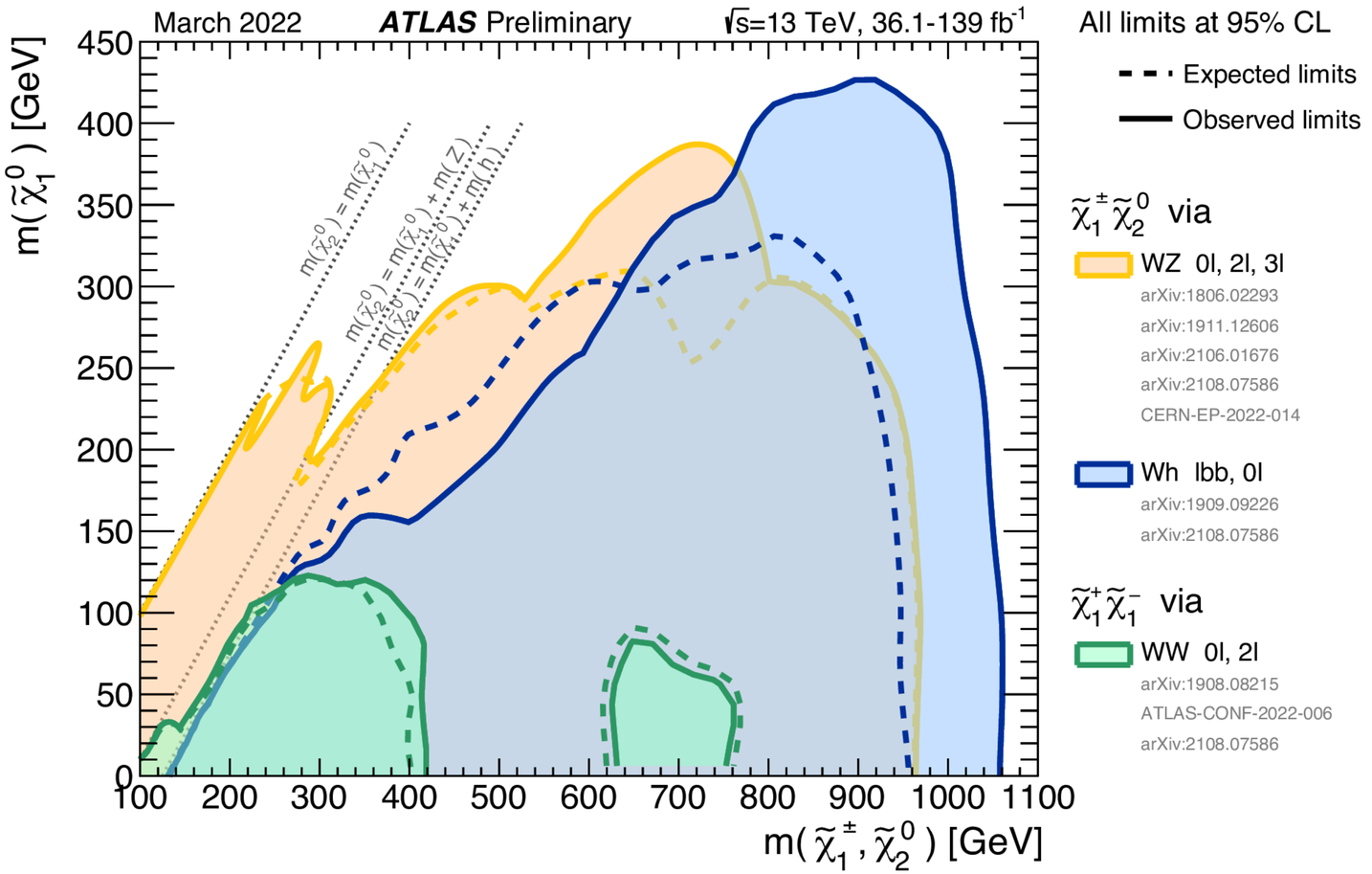


chargino



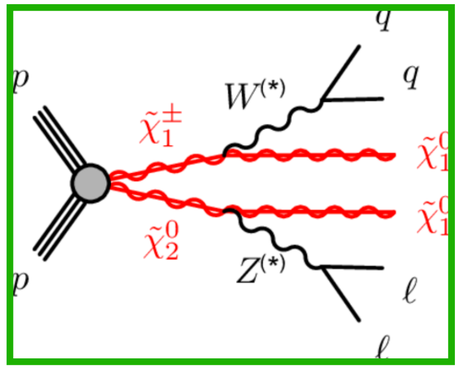
- **Blue**: $\tilde{\ell}_L = \tilde{\ell}_R$, **Cyan**: $\tilde{\ell}_L$, and **Brown**: $\tilde{\ell}_R$ limits
- The limit is set on 30 < Δm < 70 GeV for the fist time since LEP

Wino pair production / Bino LSP current limits

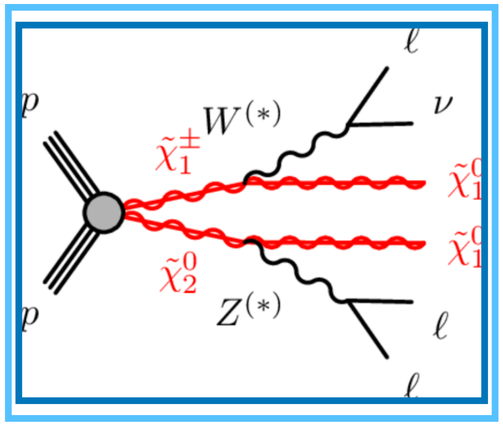


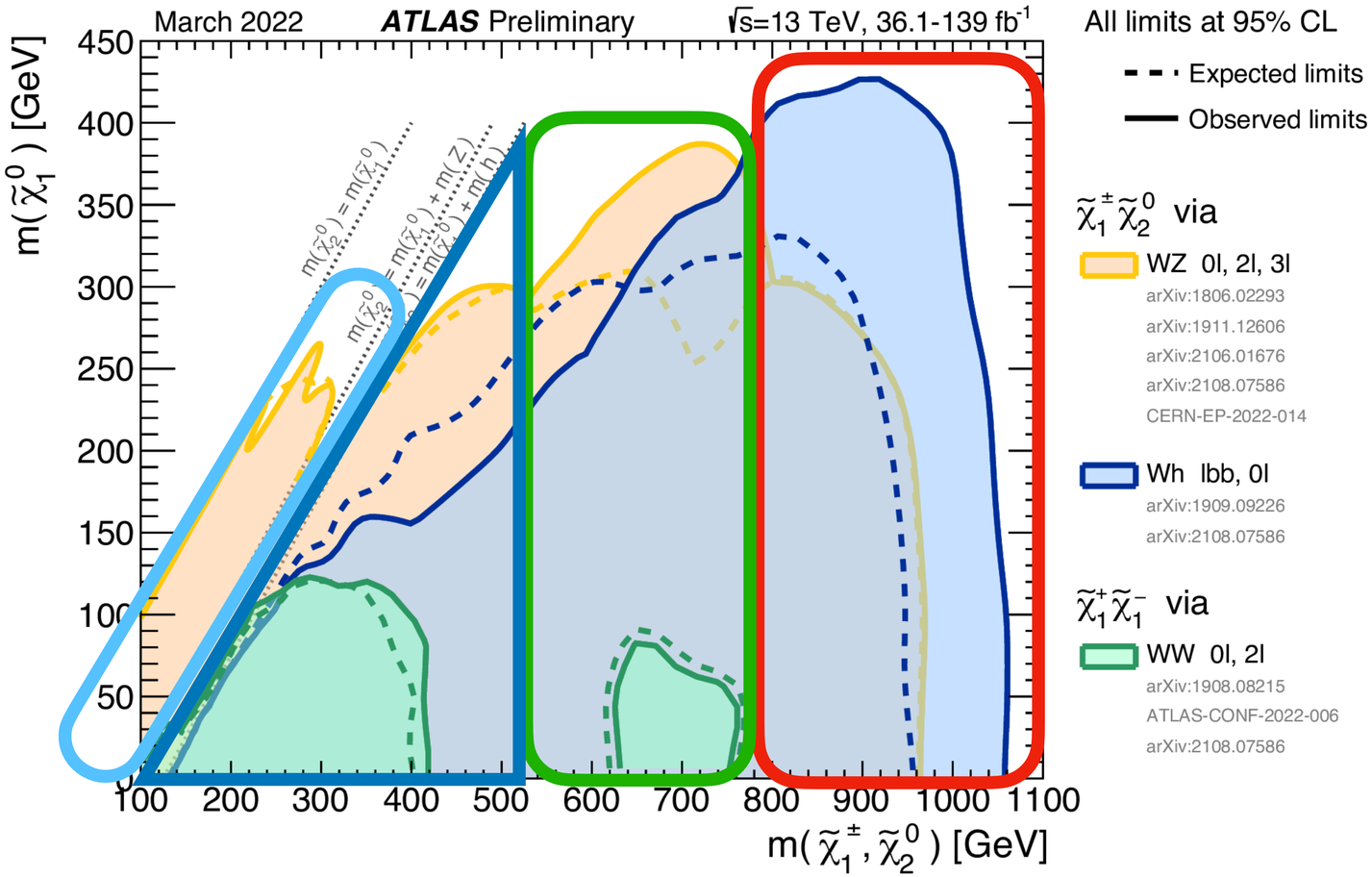
Wino pair production / Bino LSP current limits

2L+2j 2204.13072

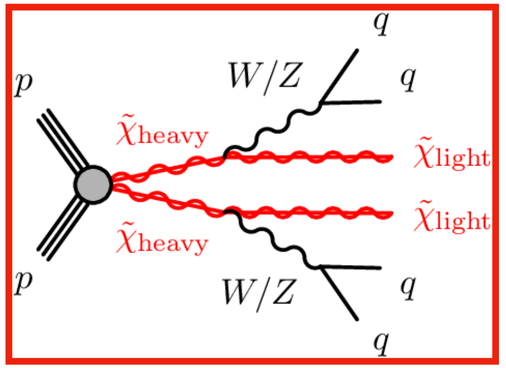


3L+mET
EPJC81(2021)1118

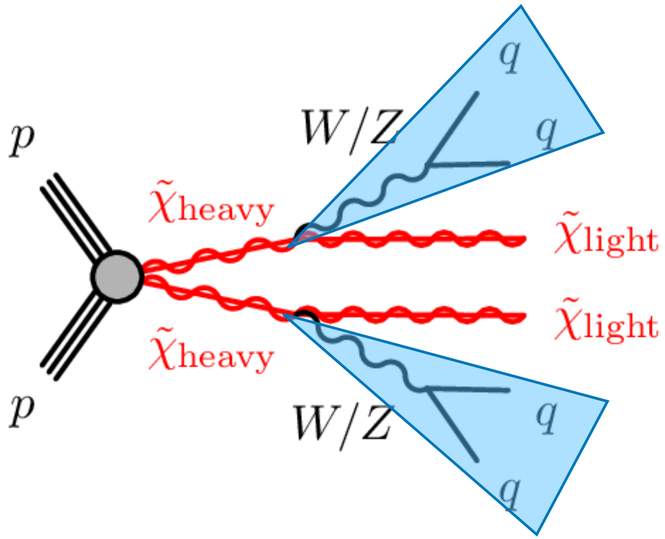




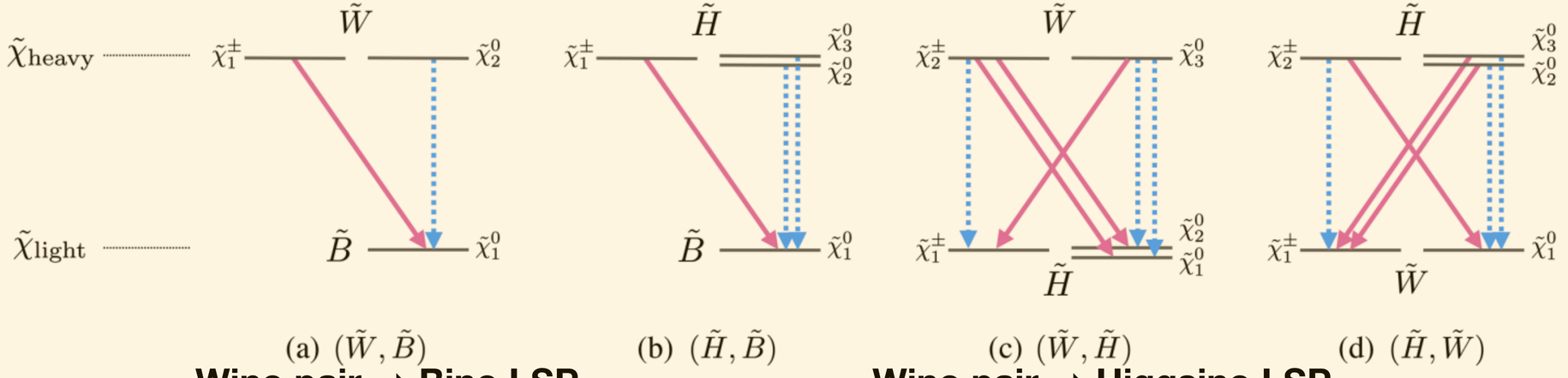
Full-hadronic
PRD104(2021)112010



2 large-R jets + mET



- **Boosted W/Z/h→qq tagging** using large-R jet substructure strongly suppresses multi-jet background
  (O(100) rejection for 50% efficiency)
- And makes it possible to use the **large BR** of full-hadronic final state
  e.g. BR($WZ \to qqqq$)~50% v.s. BR($WZ \to \ell\nu\ell\ell$)~1%
- W and Z cannot be separated completely
  → **"Inclusive" search** requiring (W || Z) bosons in the final state



Wino pair → Bino LSP

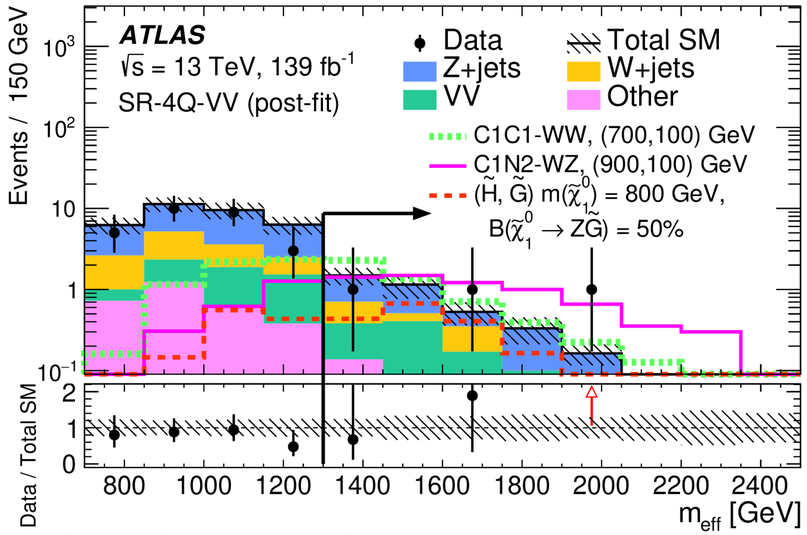
Higgsino pair → Bino LSP

Wino pair → Higgsino LSP

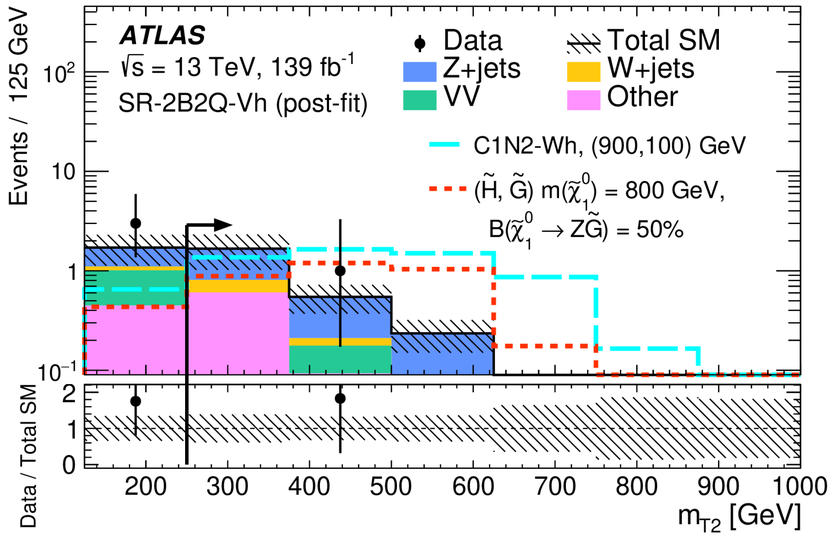
Higgsino pair → Wino LSP

2 large-R jets + mET cont'd

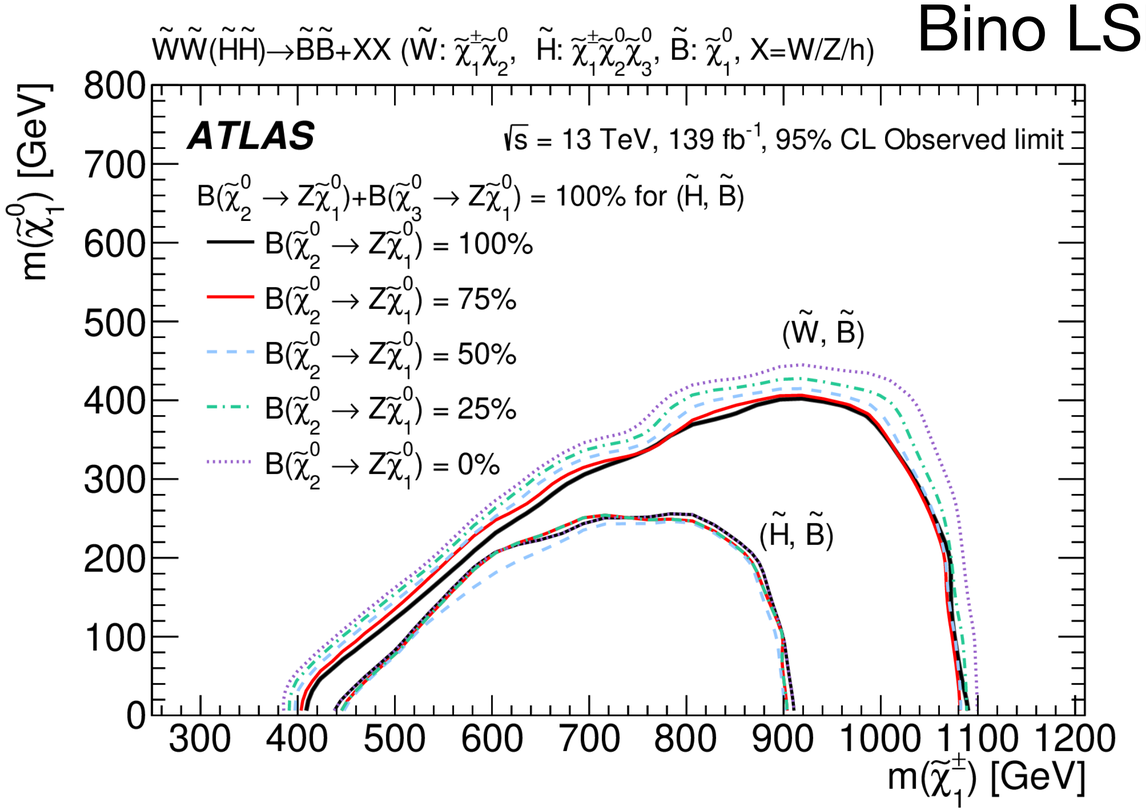
qqqq channel



qqbb channel



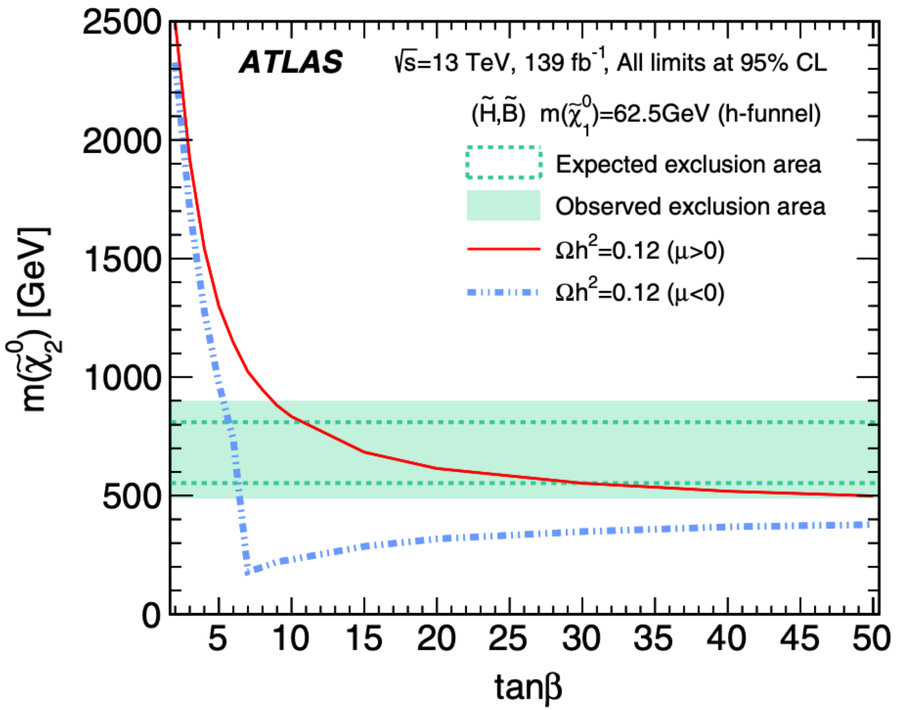
Bino LSP

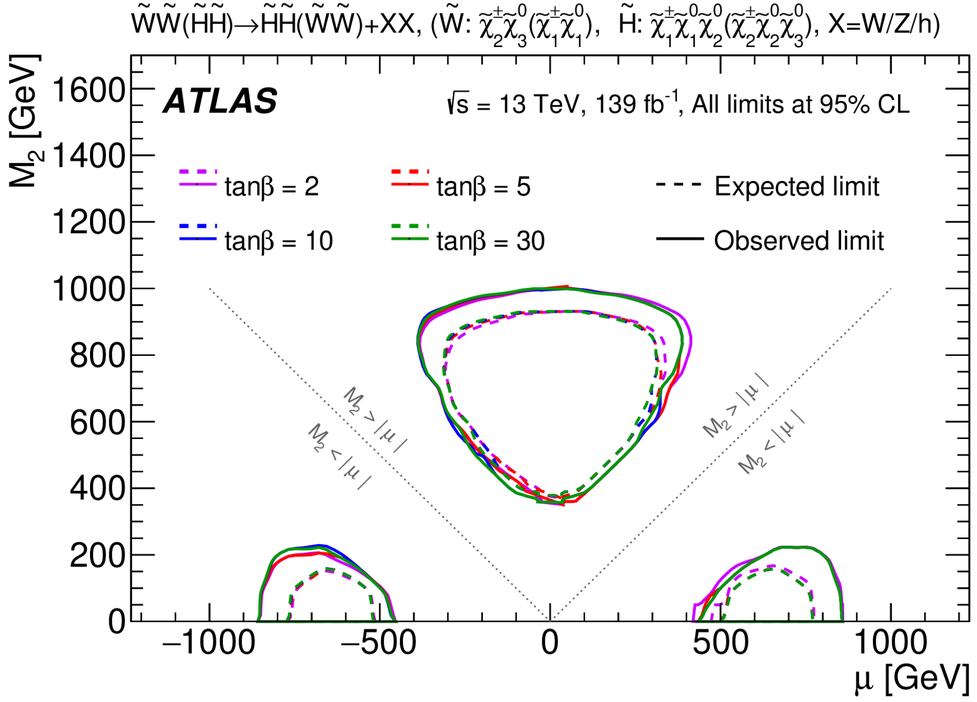


- Data agree well with SM bkg…
- As designed, the exclusion limit does not so depends on signal decay mode (WZ or Wh)
  and depends only on production mode (wino pair or higgsino pair production)

2 large-R jets + mET interpretations

Not only simplified model but also many “realistic” SUSY models are tested





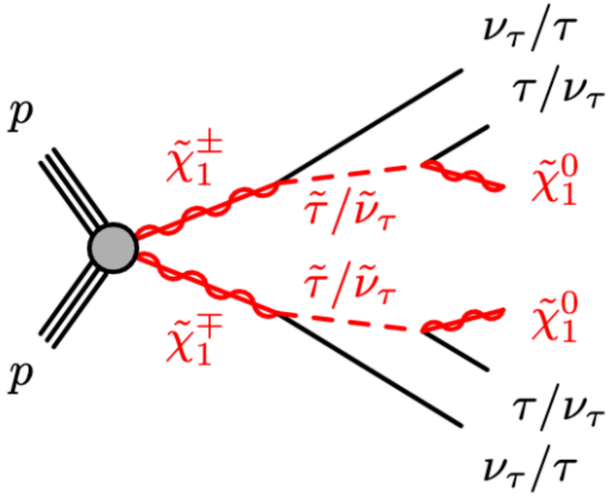
- Interpretation with fixed $m_{\tilde{\chi}_1^0} = m_h/2$
  (“h-funnel” scenario to explain the dark matter relic density with bino LSP)
- tanβ>8.5 for μ>0 (5<tanβ<7.5 for μ<0) is excluded

- Wino→higgsino and higgsino→wino results are interpreted as a limit on (tanβ, M_2, μ) phase spaces in MSSM
- The results do not depends on tanβ so much

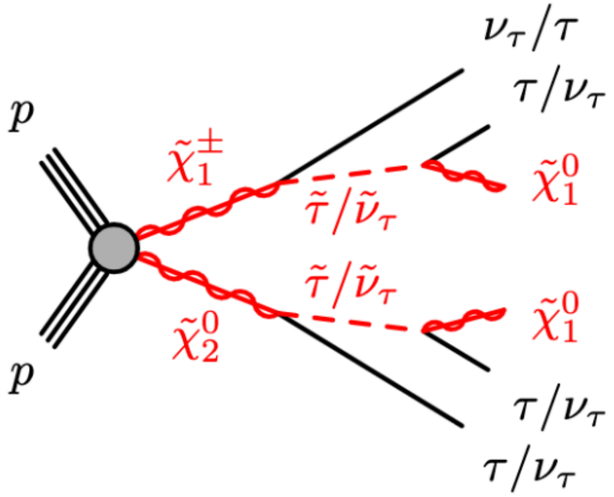
DiTau + mET analysis (new for ICHEP'22)

DiTau + mET -reoptimized for intermediate Δm region

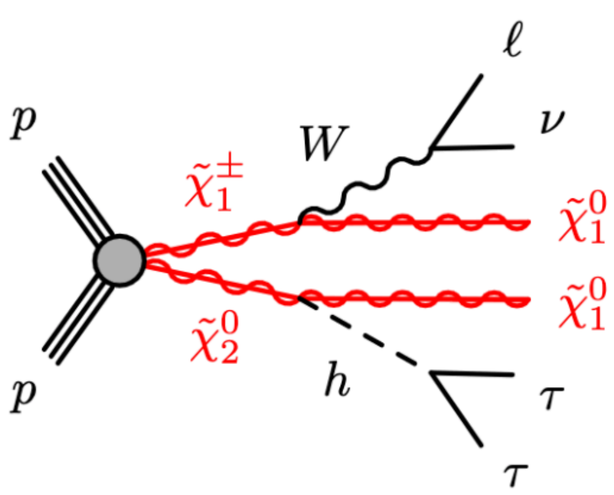
- Considering muon g-2 and W-mass anomalies, light stau is also preferable
- Chargino/neutralino pair production decaying to LSP via stau using >=2 tau final states
- Hadronically-decaying taus are identified by RNN classifier (+ BDT for e/τ separation for 1-prong τ); calibrated in Z→ττ events
- Categorized into same-sign (SS)/opposite-sign (OS) and high-mass (HM)/low-mass (LM) channels
- m_{T2}: reconstructed chargino/neutralino transverse mass using 2 taus and mET
  assuming a pair of symmetric decays into visible (tau) and invisible particles (LSP and ν)



Chargino-chargino (C1C1) channel



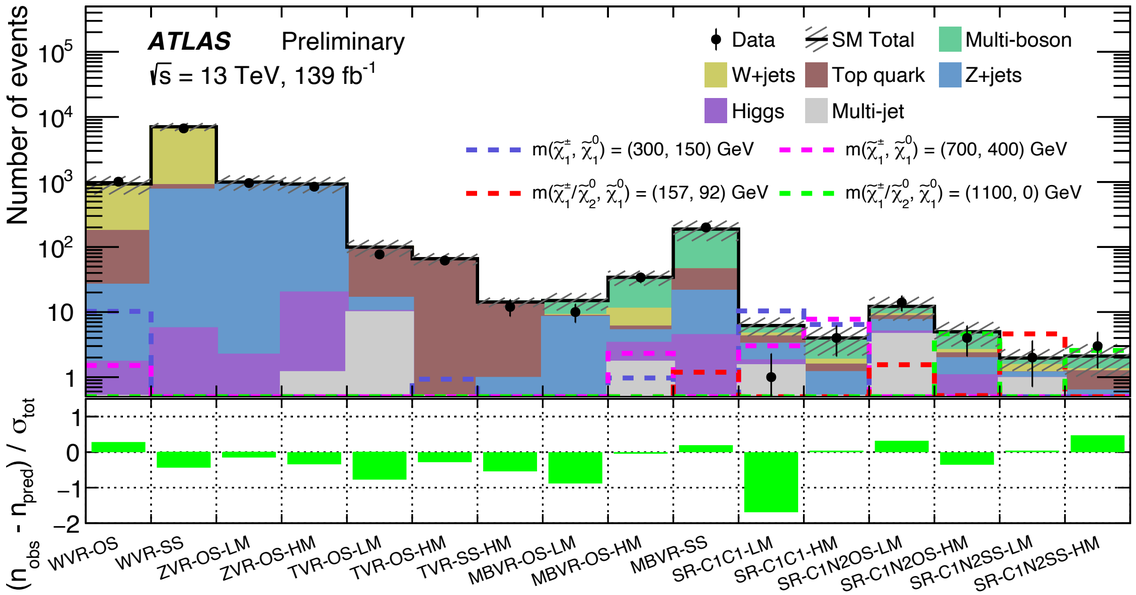
Chargino-neutralino (C1N2) channels SS and OS

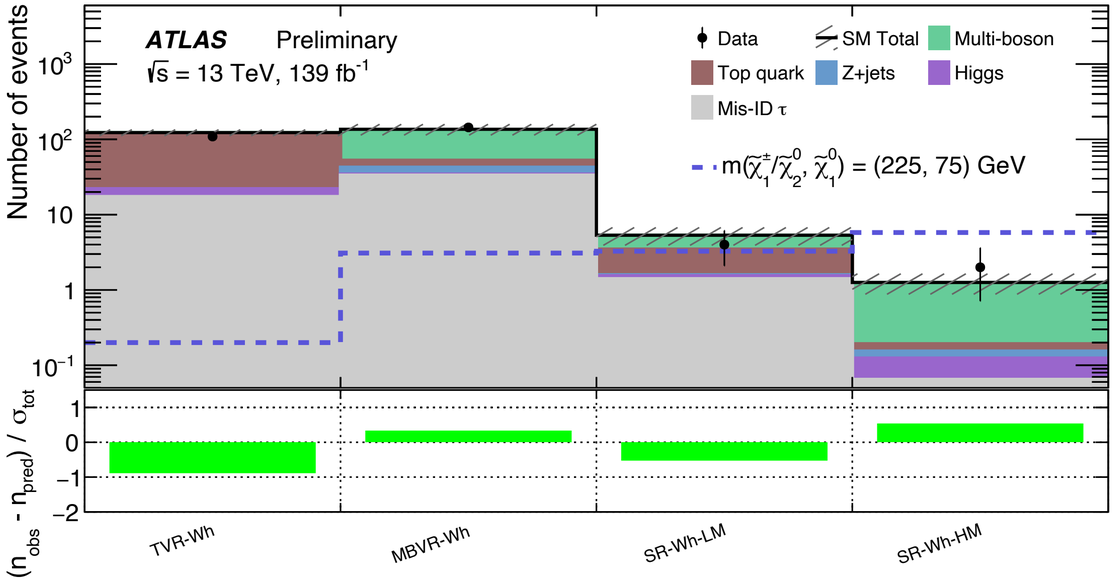


Wh channel ($m_{\tau\tau}$ ~ m_h)

DiTau + mET cont'd

- Multi-boson production (WZ→lllν) is the main source of the background
  - Estimated by MC and checked in VRs
- W/Z+jets and top estimated in dedicated CRs and validated in VRs
- Multi-jet with fake taus estimated by data-driven methods

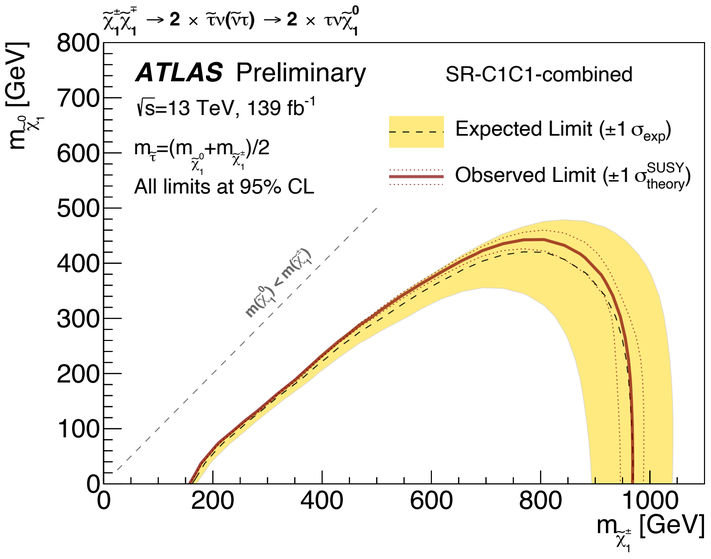




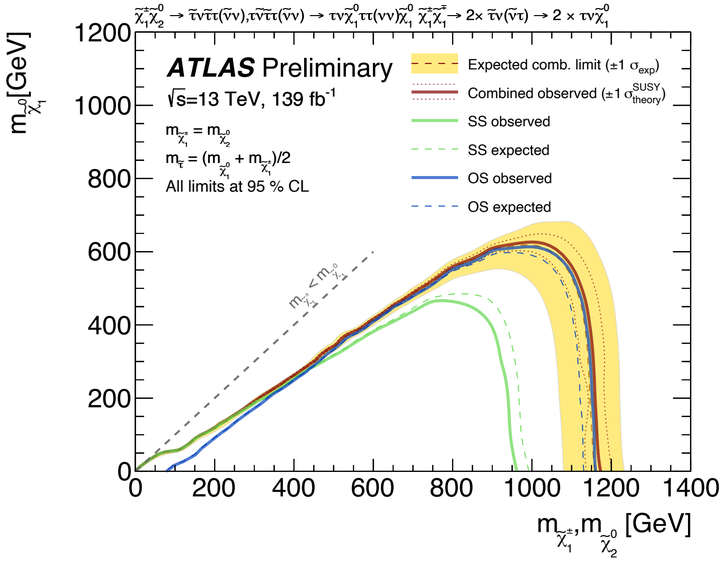
DiTau + mET exclusion limits

- The sensitivity does not so depend on stau mass
- C1C1/C1N2 channels: Chargino/neutralino mass < ~1TeV is excluded
- Wh channel: chargino/neutralino mass < ~300GeV is excluded

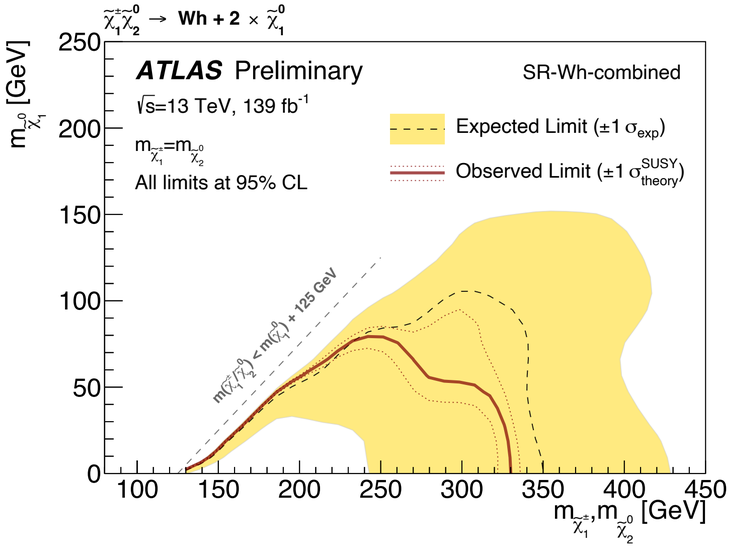
C1C1 channel



C1N2 channel



Wh channel

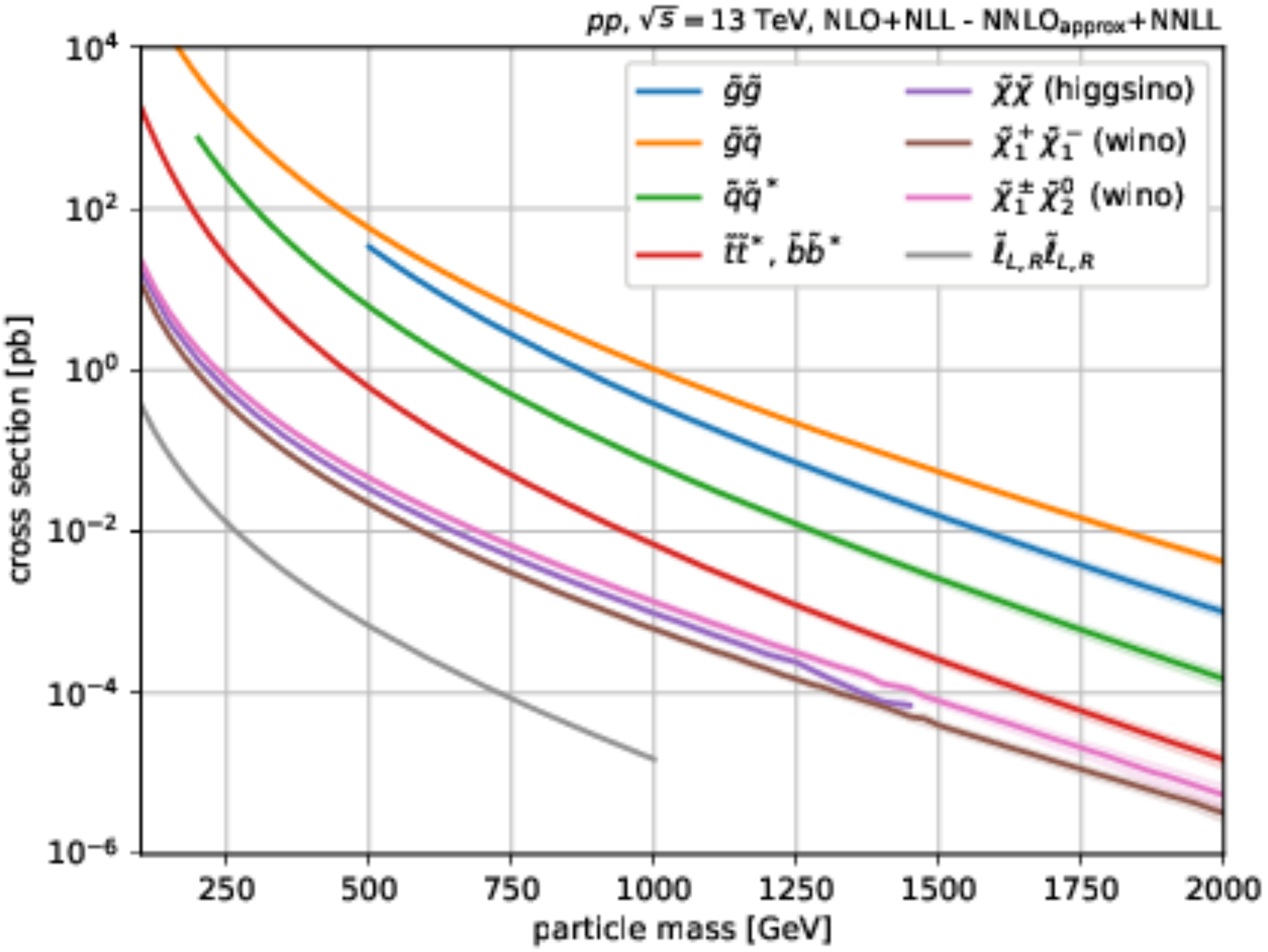


$$m_{\tilde{\tau}} = (m_{\tilde{\chi}_1^{\pm}} + m_{\tilde{\chi}_1^0})/2$$

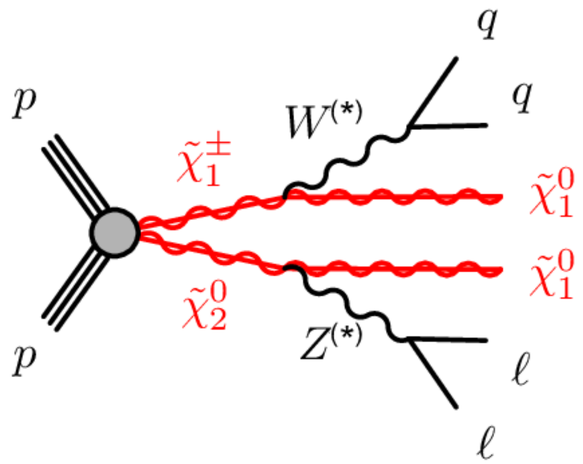
Summary

- O(100)GeV-O(1)TeV slepton and chargino/neutralino are highly motivated
- We just started to obtain the sensitivity to signals in the region of interest with Run-2 data
- In this presentation:
  - **Slepton search** extended to small Δm region and the limit on $30 < \Delta m < 70$ GeV for the fist time since LEP!
  - Chargino/neutralino search in fully-hadronic final states tested many **realistic SUSY models** inspired by DM, g-2, naturalness, etc.
  - A new **ditau+mET** analysis extended chargino/neutralino mass reach to O(1) TeV
- Many other very interesting results are found in backup slides and ATLAS web page!

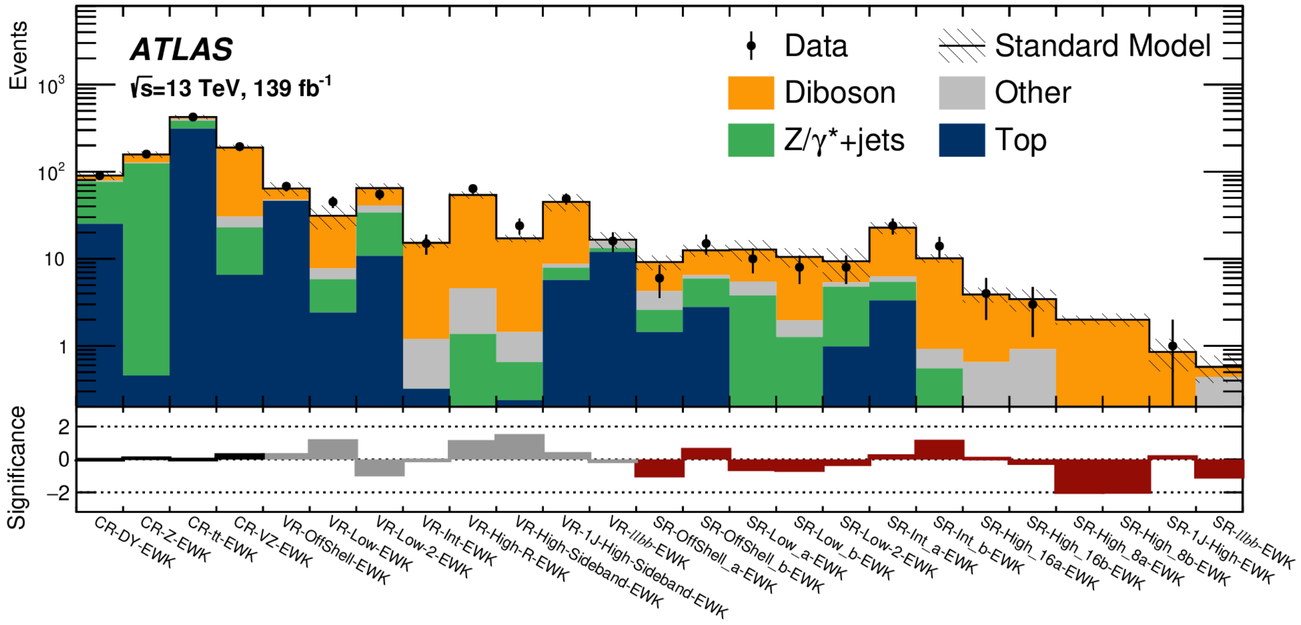
Backup

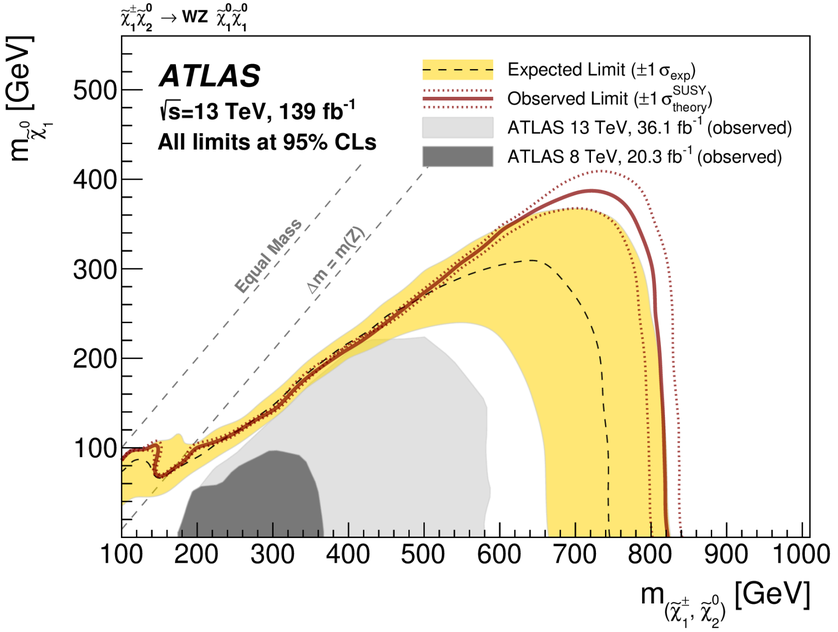

pp, √s = 13 TeV, NLO+NLL - NNLOapprox+NNLL
g̃g̃
g̃q̃
q̃q̃*
t̃t̃*, b̃b̃*
χ̃χ̃ (higgsino)
χ̃1+χ̃1− (wino)
χ̃1±χ̃20 (wino)
ℓ̃L,Rℓ̃L,R
cross section [pb]
10^4
10^2
10^0
10^−2
10^−4
10^−6
250
500
750
1000
1250
1500
1750
2000
particle mass [GeV]

2L + 2j

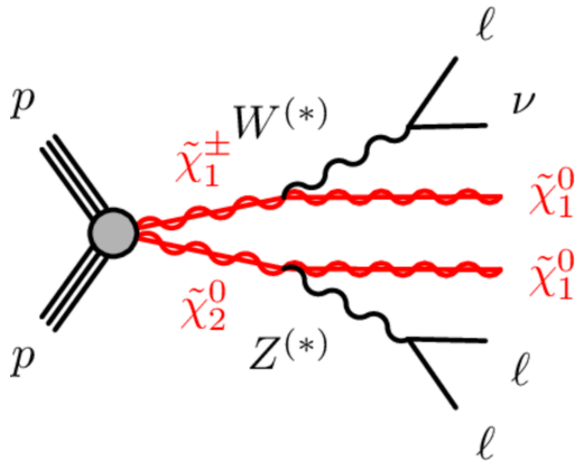


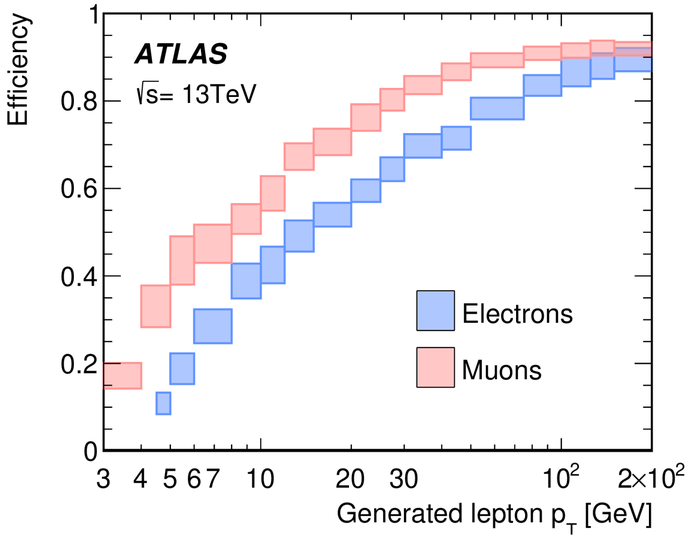
- 2 SFOS leptons + 2 jets (W/Z→qq) + mET
- Extended from early Run 2 to cover off-shell W/Z, low, intermediate and high Δm with SRs targeting llbb final states (from Z/h→bb)
- We also reperformed RJR analysis, in which we found ~2σ excess in early Run 2



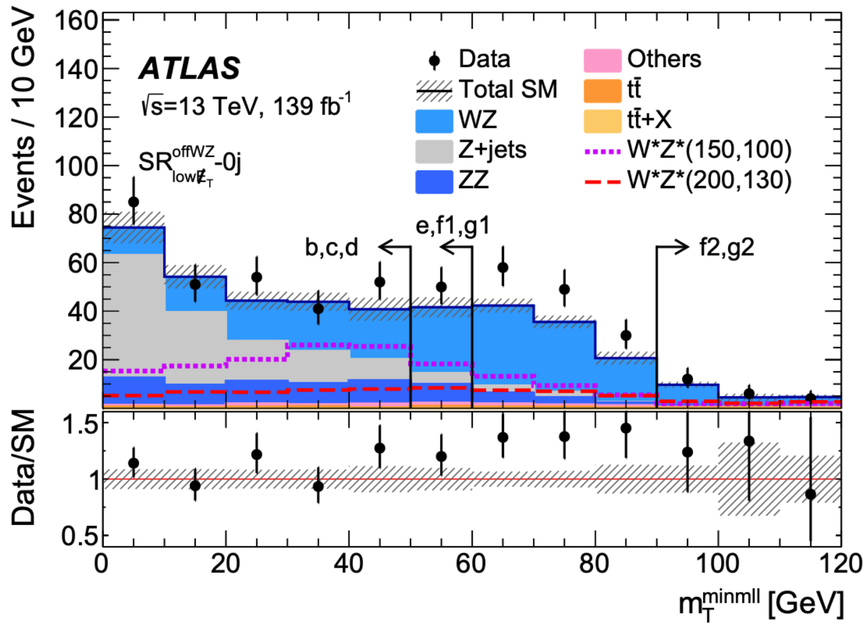


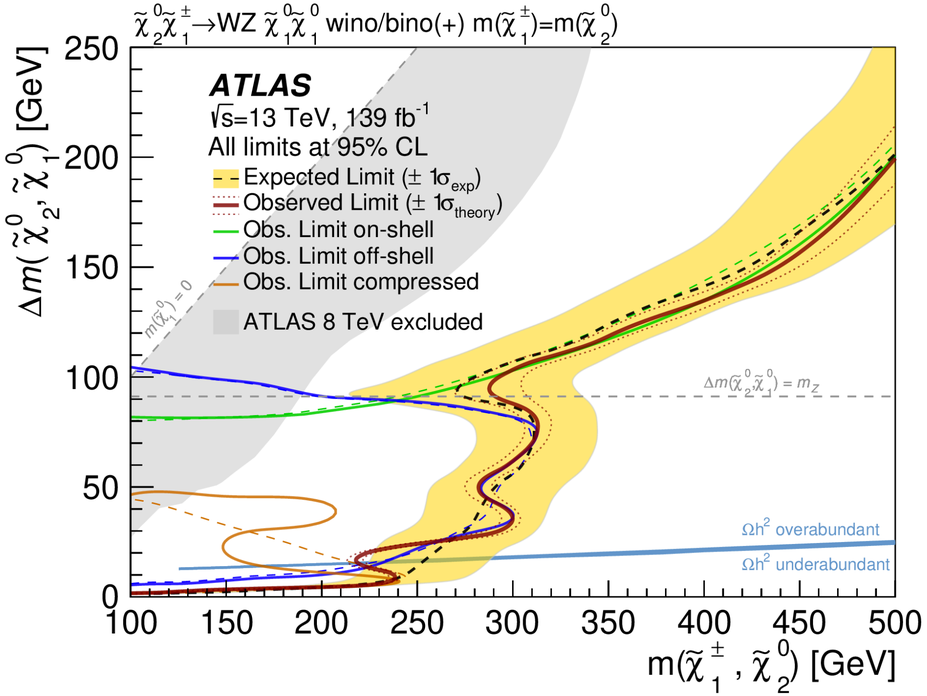
3L + mET





- A new ML-based prompt lepton tagger improved the lepton reconstruction efficiency at low-pT region
- SRs categorized into onshell, offshell and “compressed” W/Z scenarios in the final state

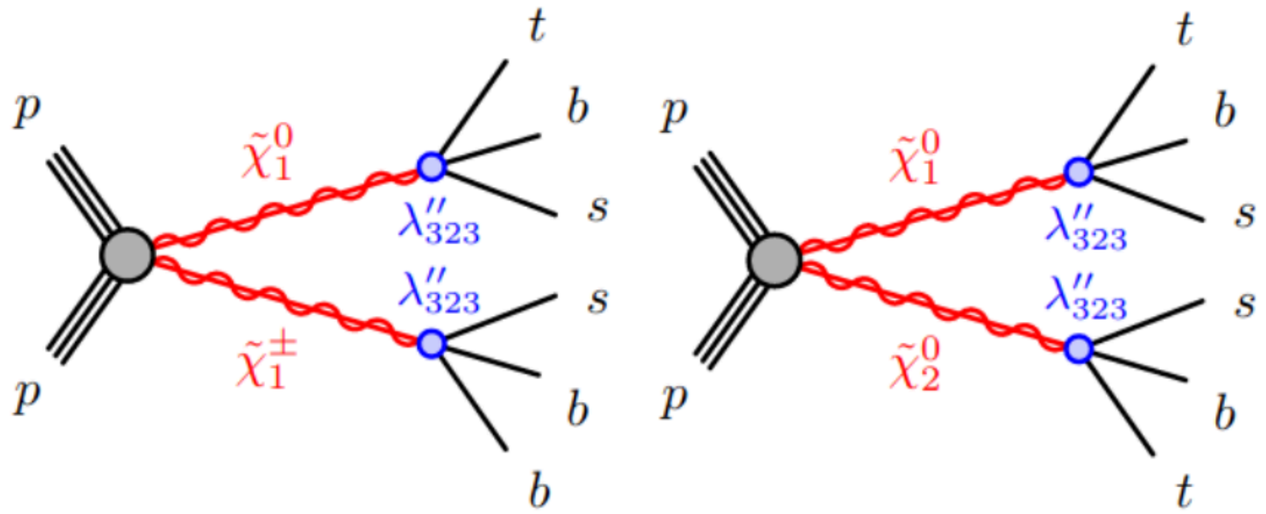




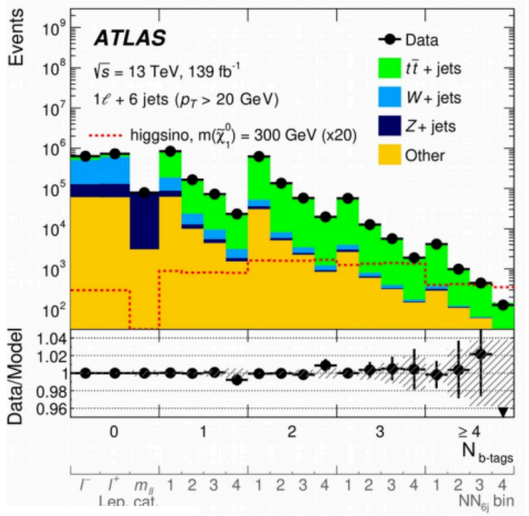
EPJC81(2021)1023

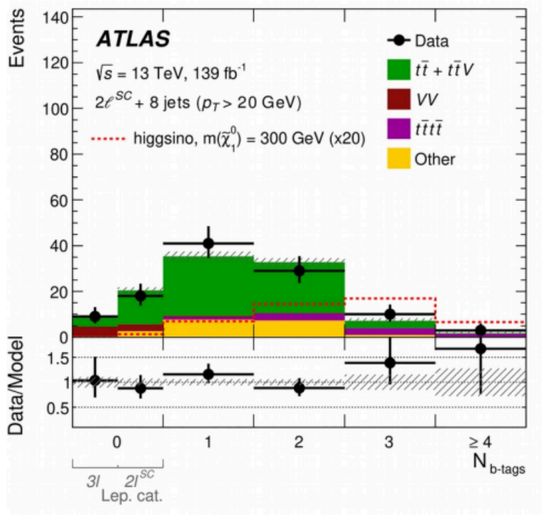
RPV SUSY

- >=1 lepton + multi-b-jets without mET

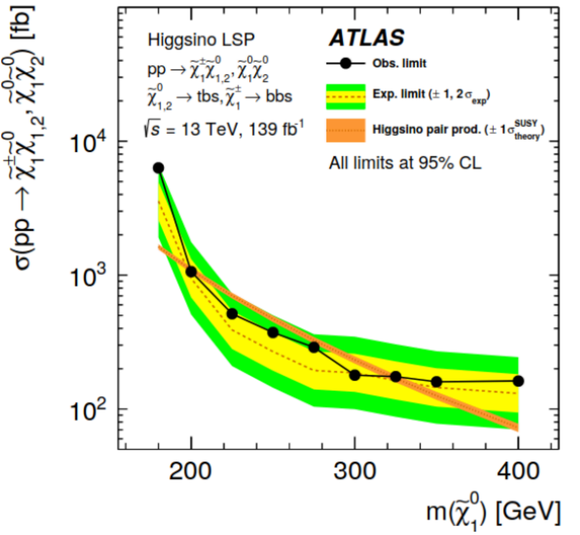


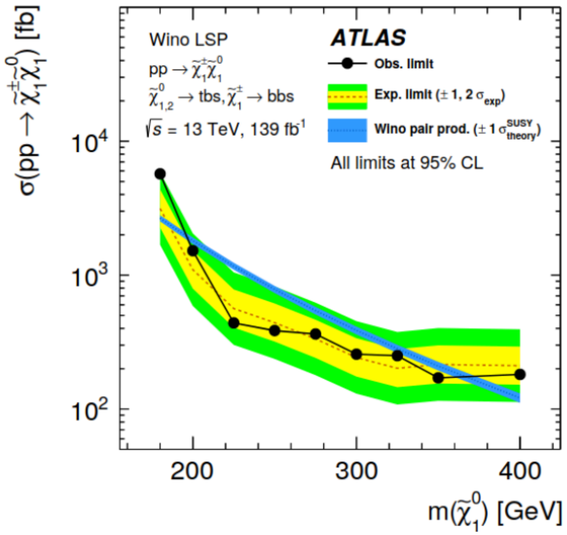
RPV SUSY





- Two SR categories:
  - 1 lepton (with a NN-based discriminant)
  - 2 same-sign leptons
- A data-driven technique to estimate contribution of main backgrounds in each N_j and N_b slice
  - Approach based on fixed probability of extra jet radiation
    → predict background as a function of N_j
  - Freely-floating parameters in final fit to data (Normalization, N_j scaling, b-jet fraction, extra b-jet correlation)
    → better constraining of jet uncertainties





- Model-dependent limits set
- Higgsino (Wino) masses between 200 (197) GeV and 320 (365) GeV are excluded