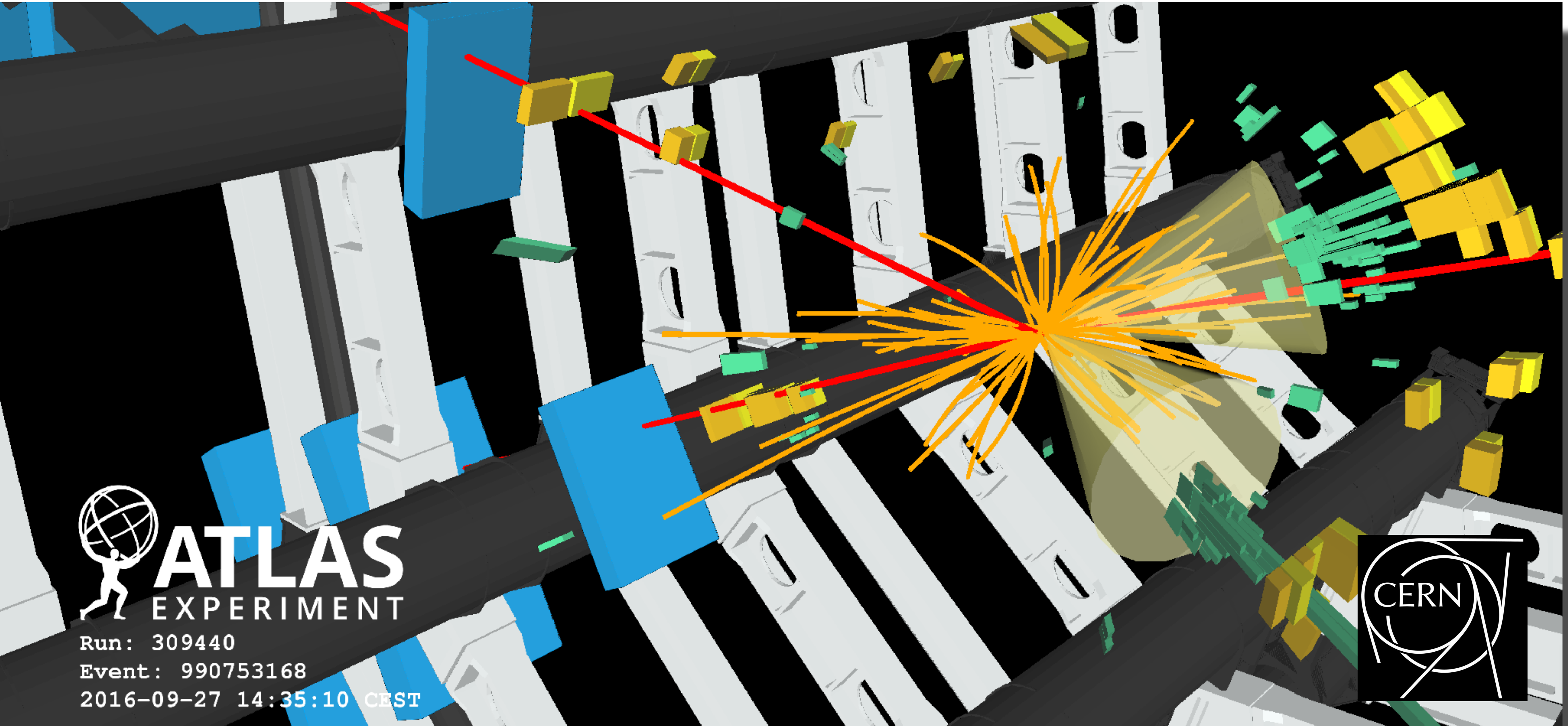
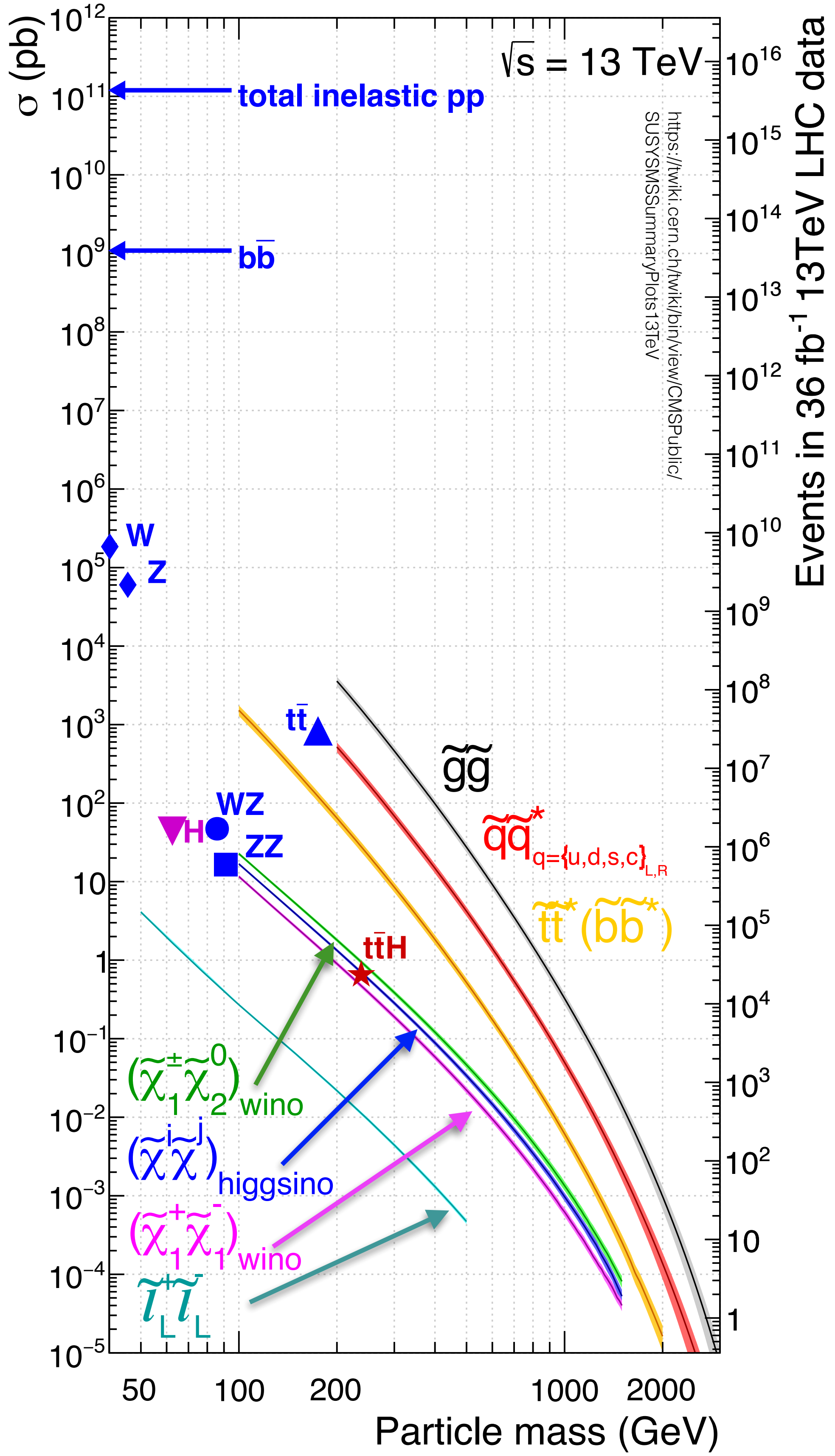
Stefano Zambito, CERN
On Behalf of the ATLAS Collaborations

Electroweak SUSY Searches with ATLAS

EPS-HEP 2021

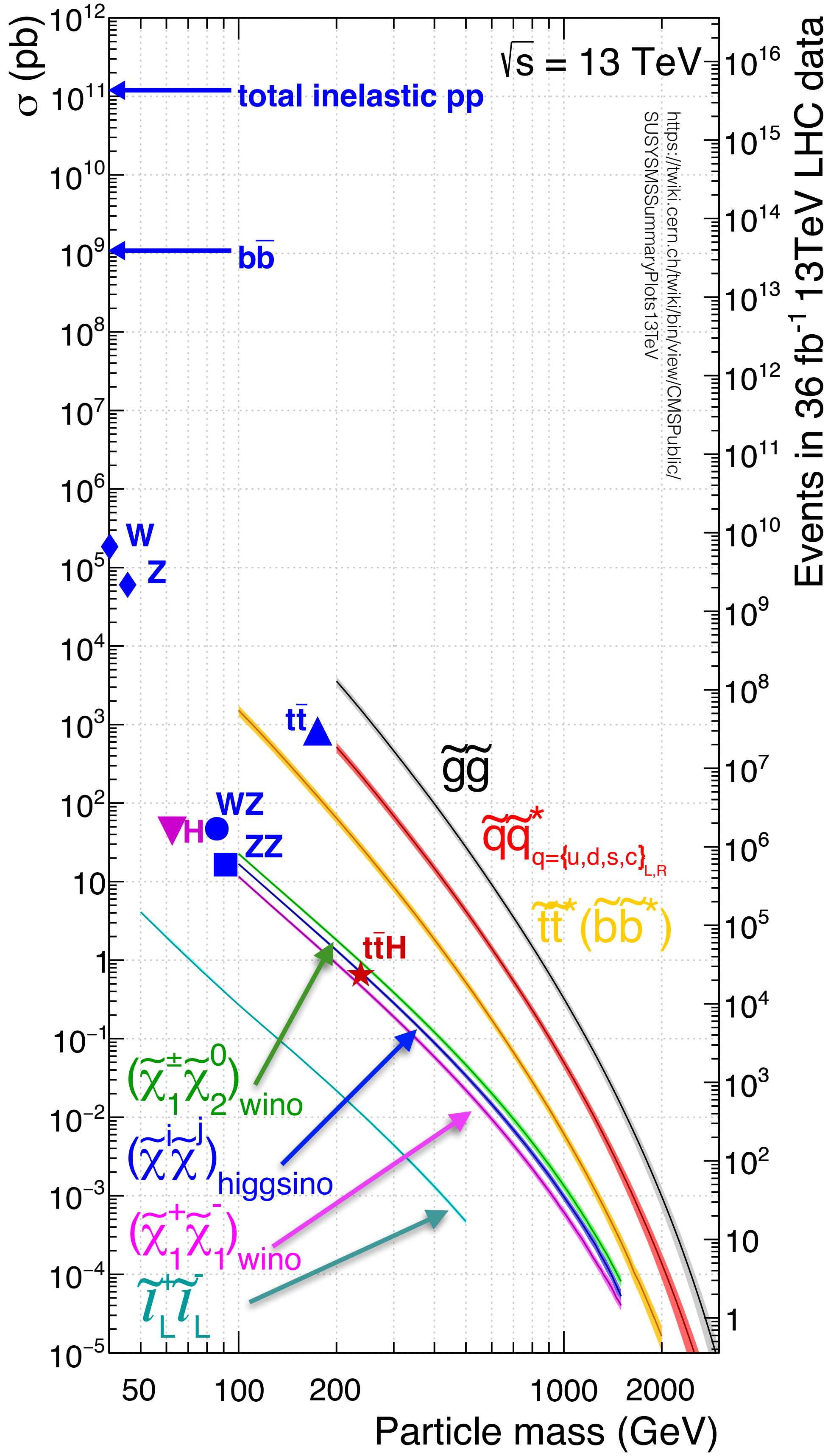


Electroweak SUSY Production



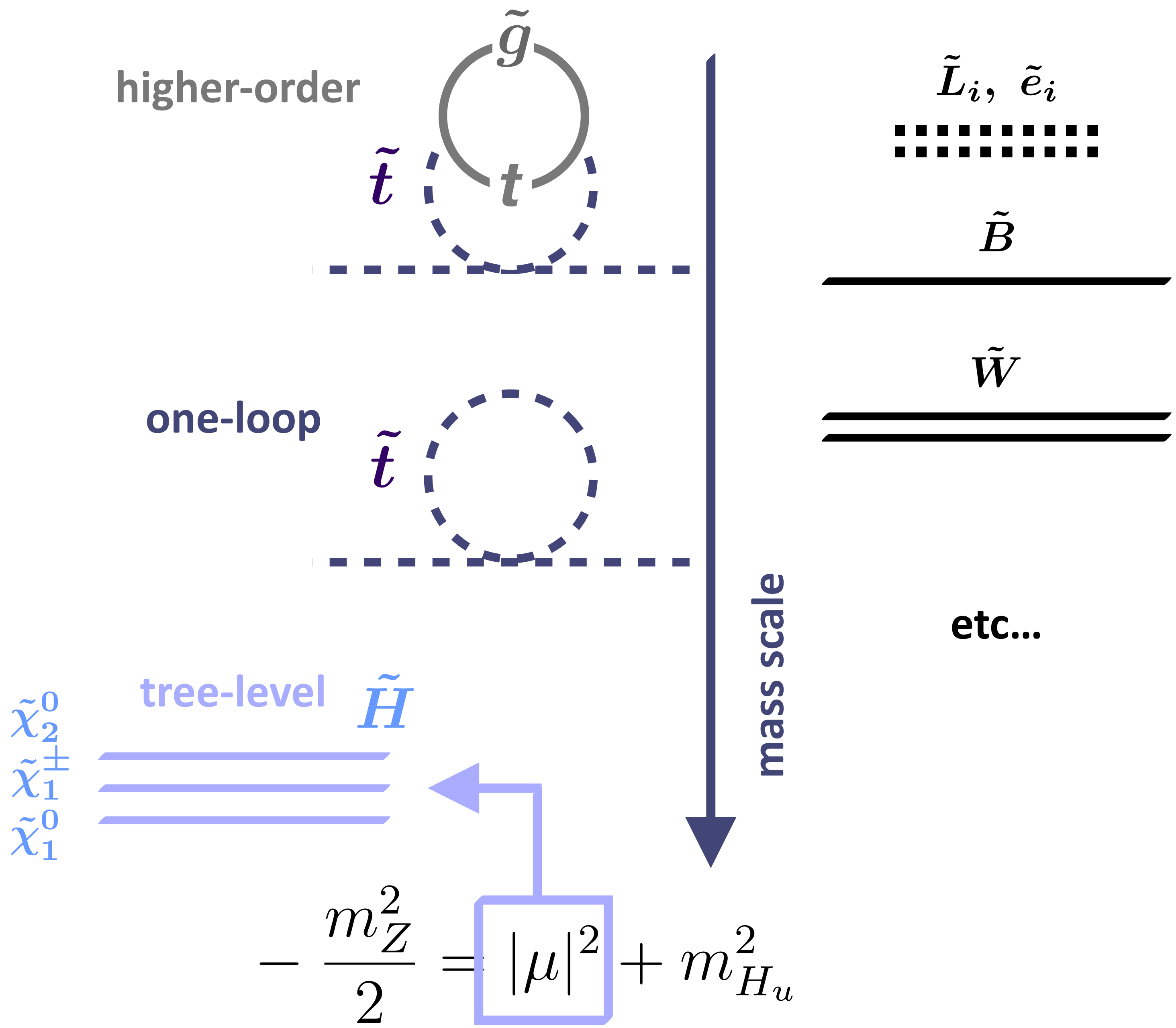
Rare processes, fairly clean signatures

Electroweak SUSY Production



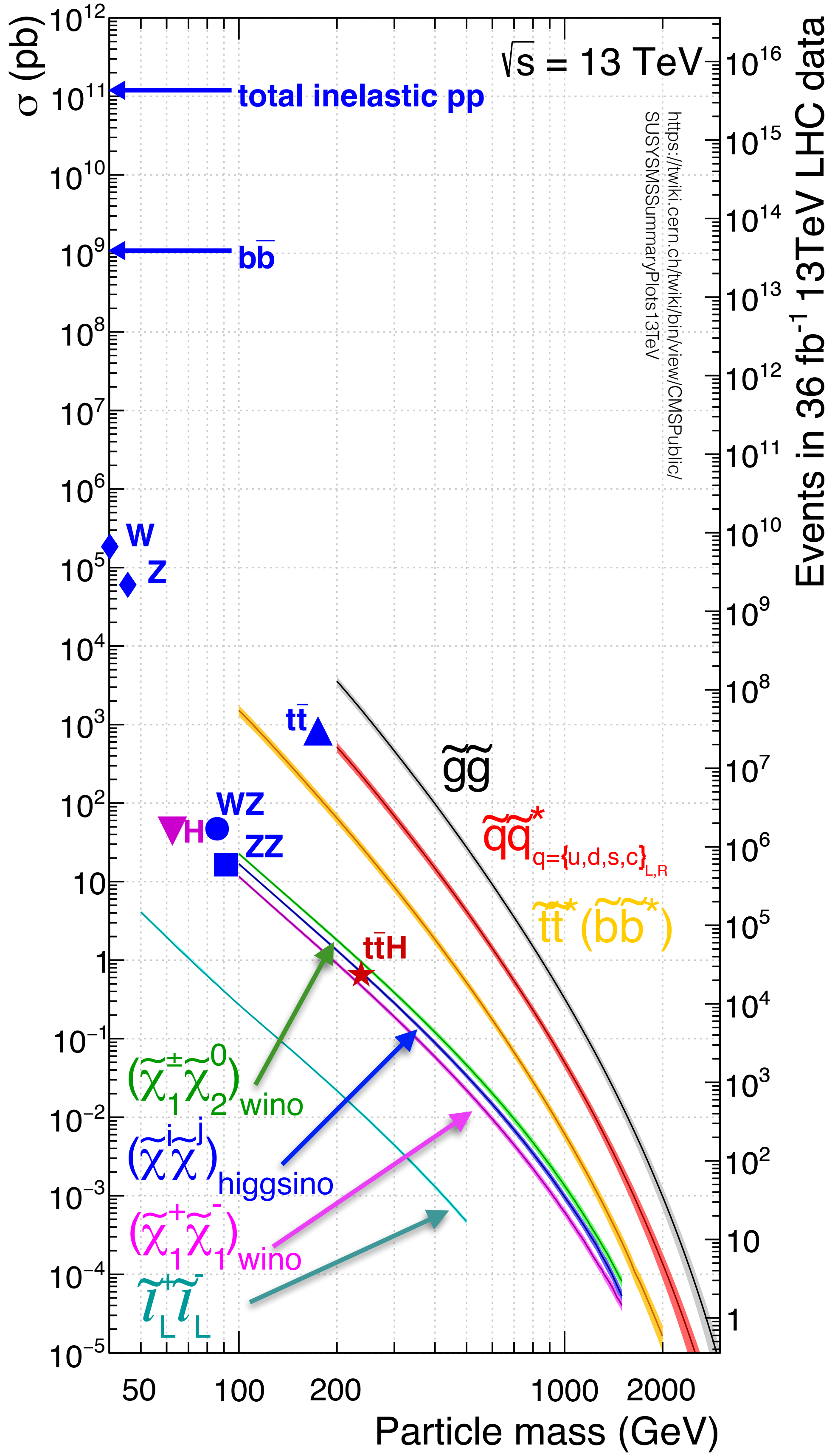
Rare processes, fairly clean signatures

weak-scale SUSY motivated by naturalness



arXiv:1110.6926v1

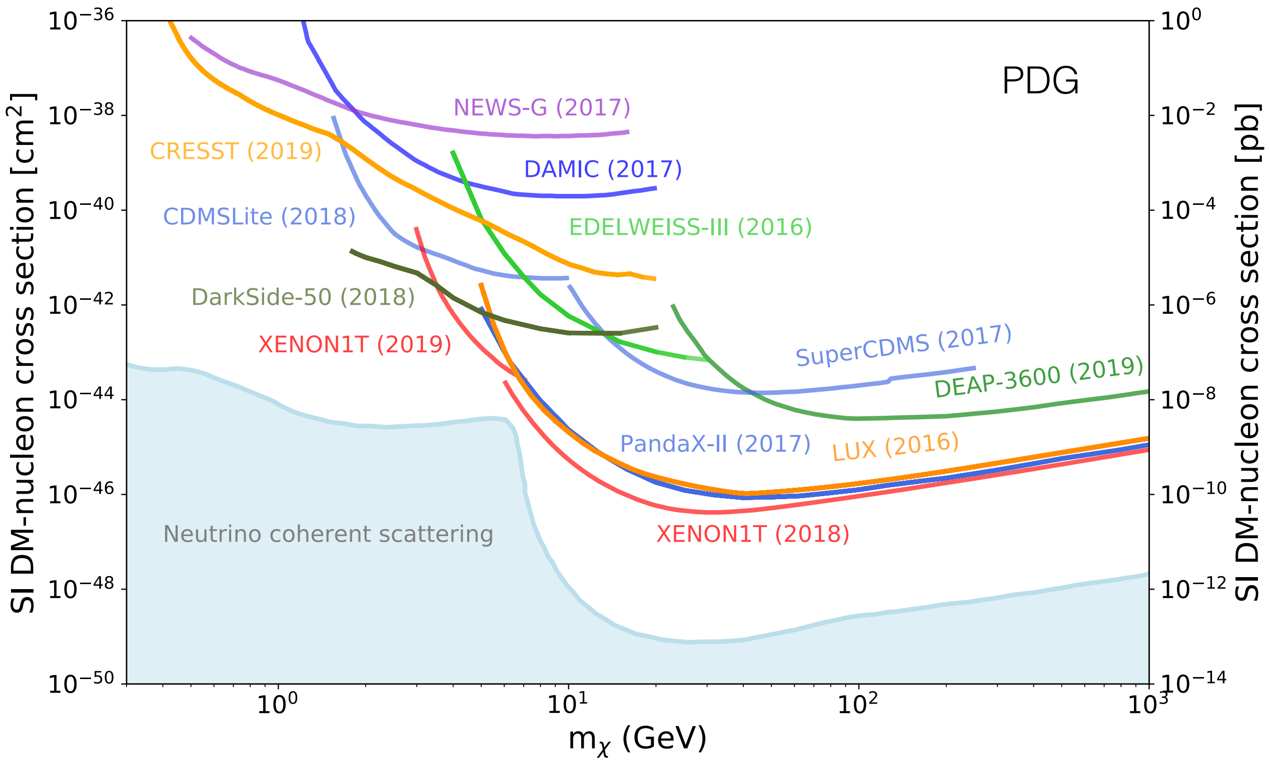
Electroweak SUSY Production



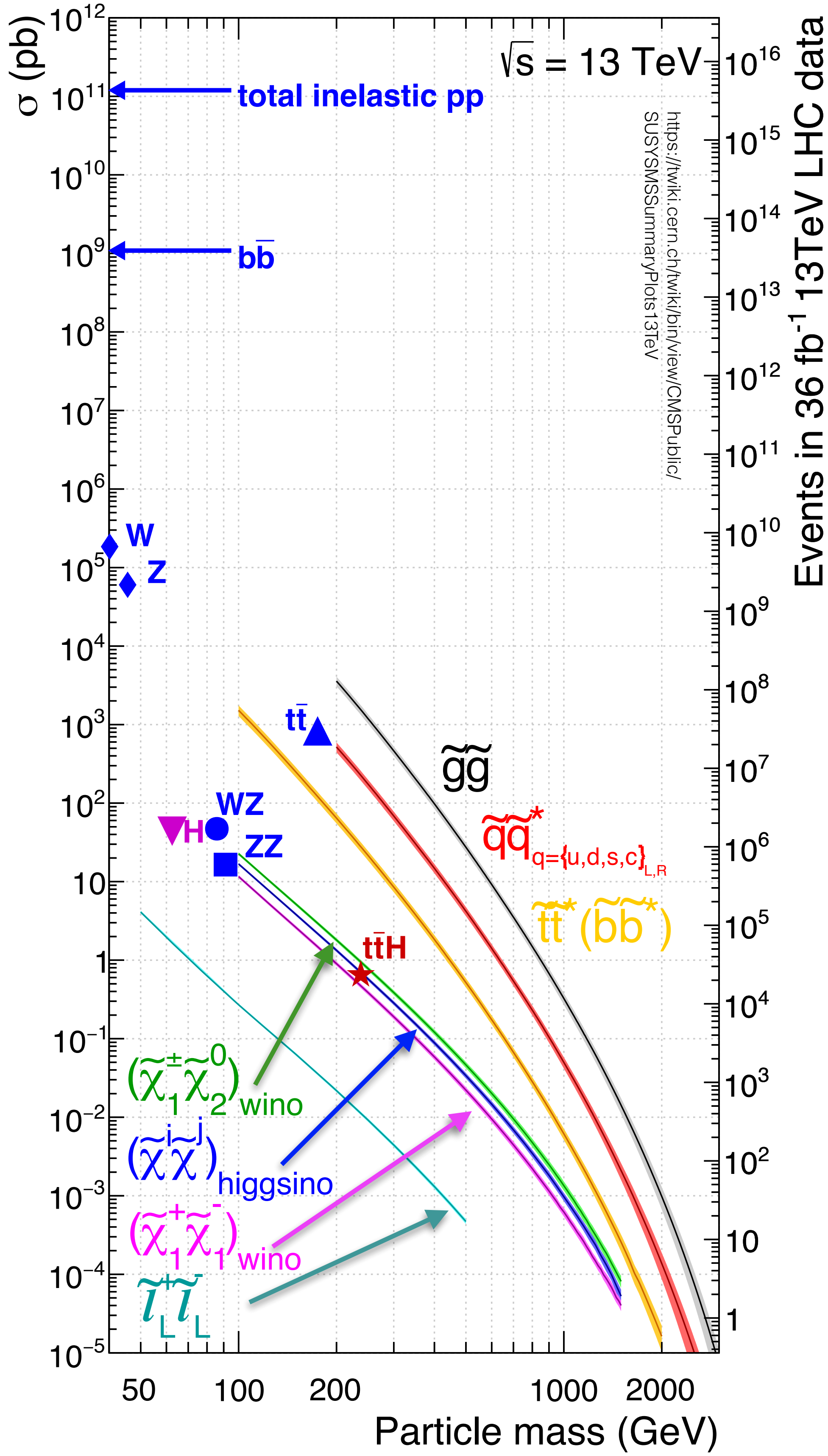
Rare processes, fairly clean signatures

weak-scale SUSY motivated by naturalness

dark matter Ωh^2 favors light $\tilde{W}/\tilde{B}/\tilde{H}$ and $\tilde{\ell}$



Electroweak SUSY Production



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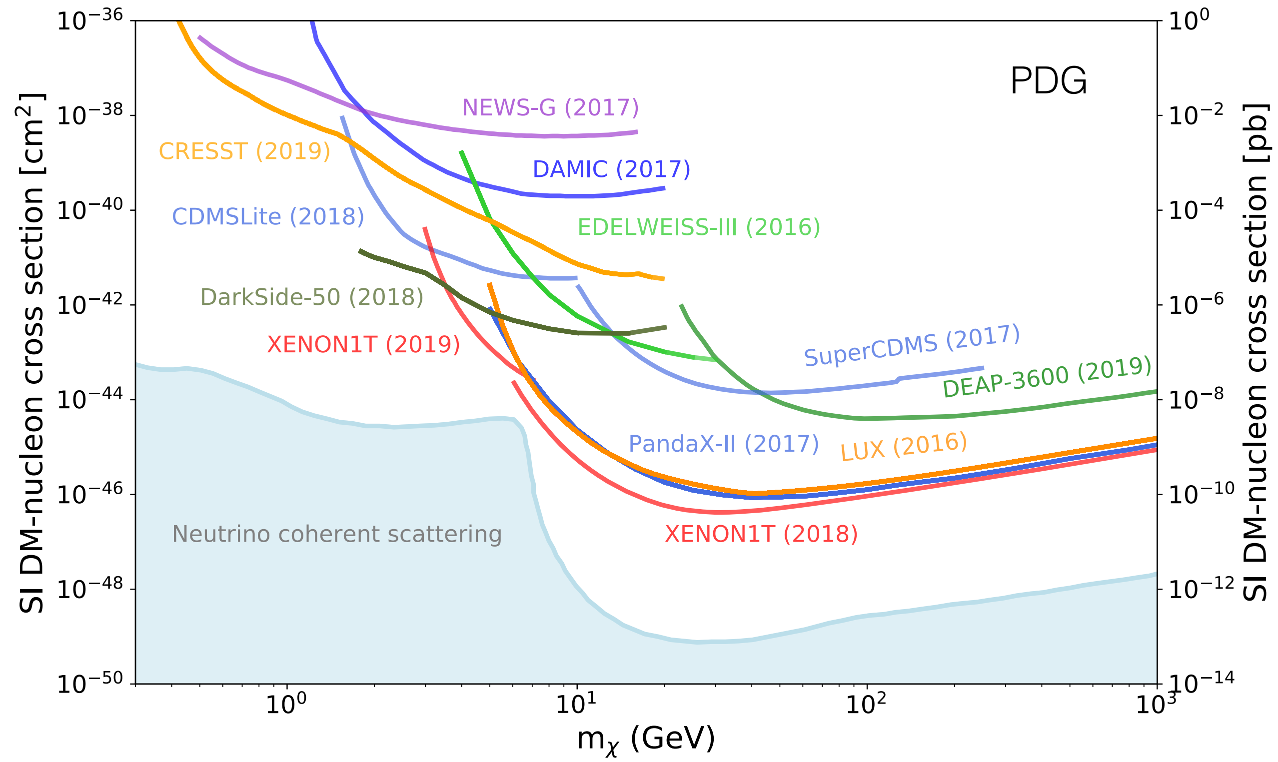
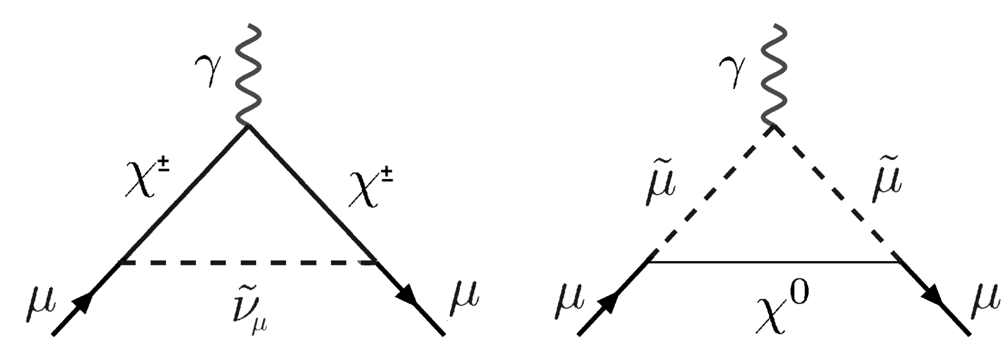


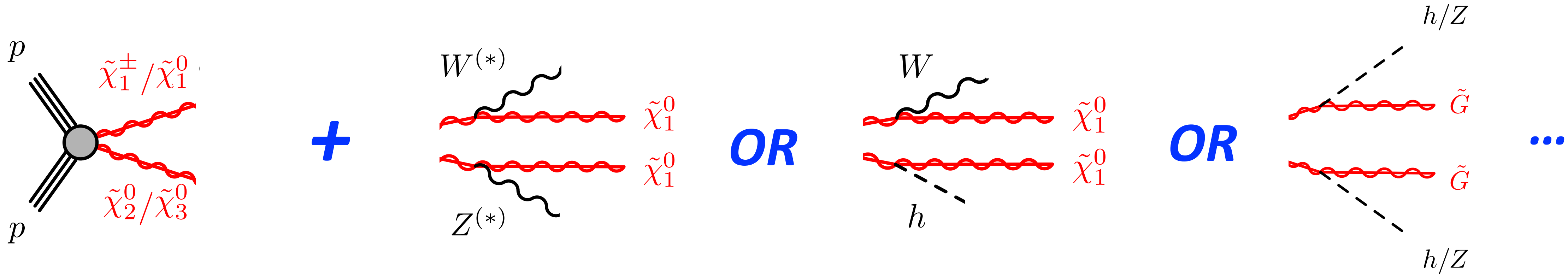
EWKinos / sleptons contribute to muon's g-2

$$\Delta a_\mu = a_\mu^{\rm exp} - a_\mu^{\rm SM} = (251 \pm 59) \times 10^{-11} \;\; (4.2\sigma)$$



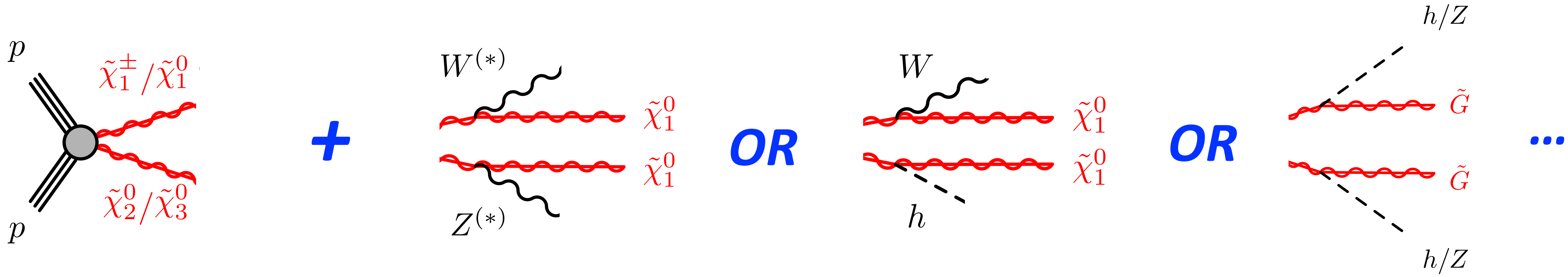
Experimental Landscape

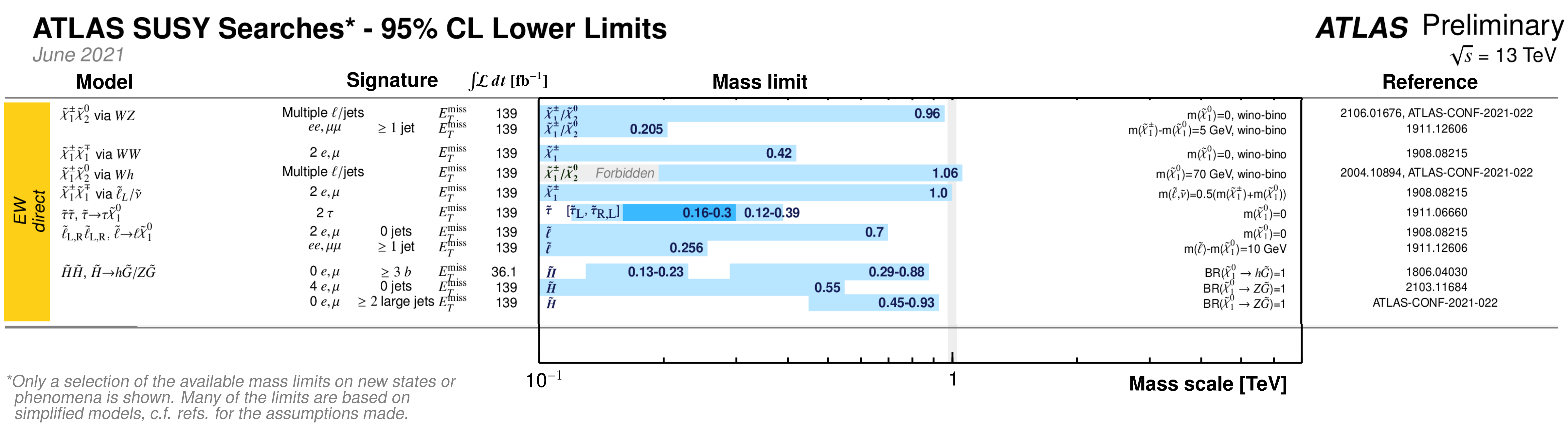
$\tilde{\chi}_i^{\pm}/\tilde{\chi}_i^0$ *production* ⇒ *decay chains involving W, Z, h bosons + LSP*



Experimental Landscape

$\tilde{\chi}_i^{\pm}/\tilde{\chi}_i^{0}$ production $\Rightarrow$ decay chains involving W, Z, h bosons + LSP





ATLAS-CONF-2021-022: two boosted hadronically decaying bosons + E_T^{miss}

CERN-EP-2021-021: three leptons + E_T^{miss}

CERN-EP-2021-059: four leptons + E_T^{miss}

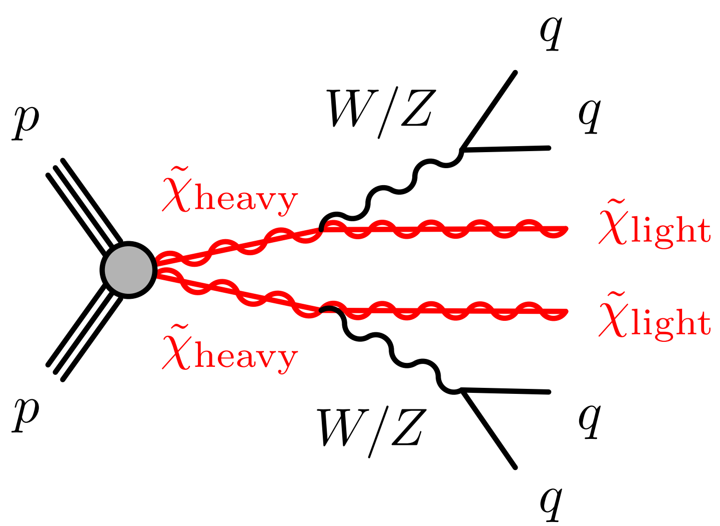
RPV scenarios covered in M. Holzbock's talk!

Further, L. Corpe's talk on *long-lived particles*!

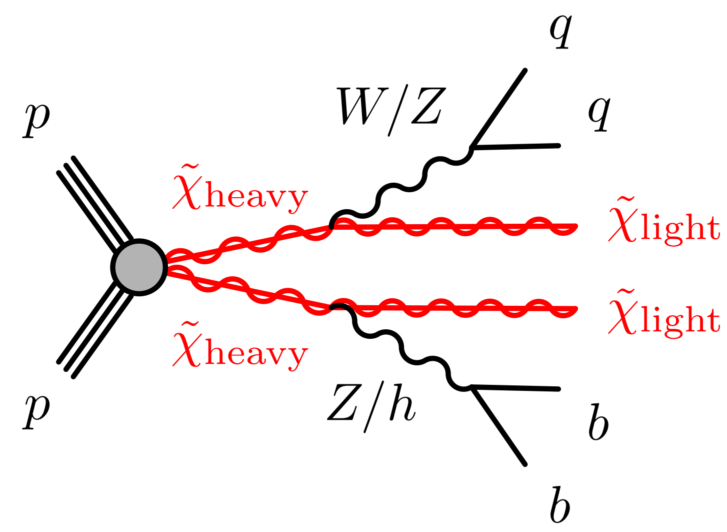
Fully Hadronic Final State

Experimental signature: two hadronically decaying boosted bosons (W, Z, h) and E_T^{miss}

qq qq final state



qq bb final state



Signal models driven by three physics scenarios

→ a baseline MSSM scenario focusing on pairs of Wino, Bino and Higgsino

$(\tilde{\chi}_{\text{heavy}}, \tilde{\chi}_{\text{light}}) = (\tilde{W}, \tilde{H}), (\tilde{W}, \tilde{B}), (\tilde{H}, \tilde{B}), \ldots$

→ a GGM + naturalness scenario with light Higgsinos and *gravitino LSP*

$(\tilde{\chi}_{\text{heavy}}, \tilde{\chi}_{\text{light}}) = (\tilde{H}, \tilde{G})$

→ a Peccei-Quinn + naturalness scenario with light Higgsinos and *axino LSP*

$(\tilde{\chi}_{\text{heavy}}, \tilde{\chi}_{\text{light}}) = (\tilde{H}, \tilde{a})$

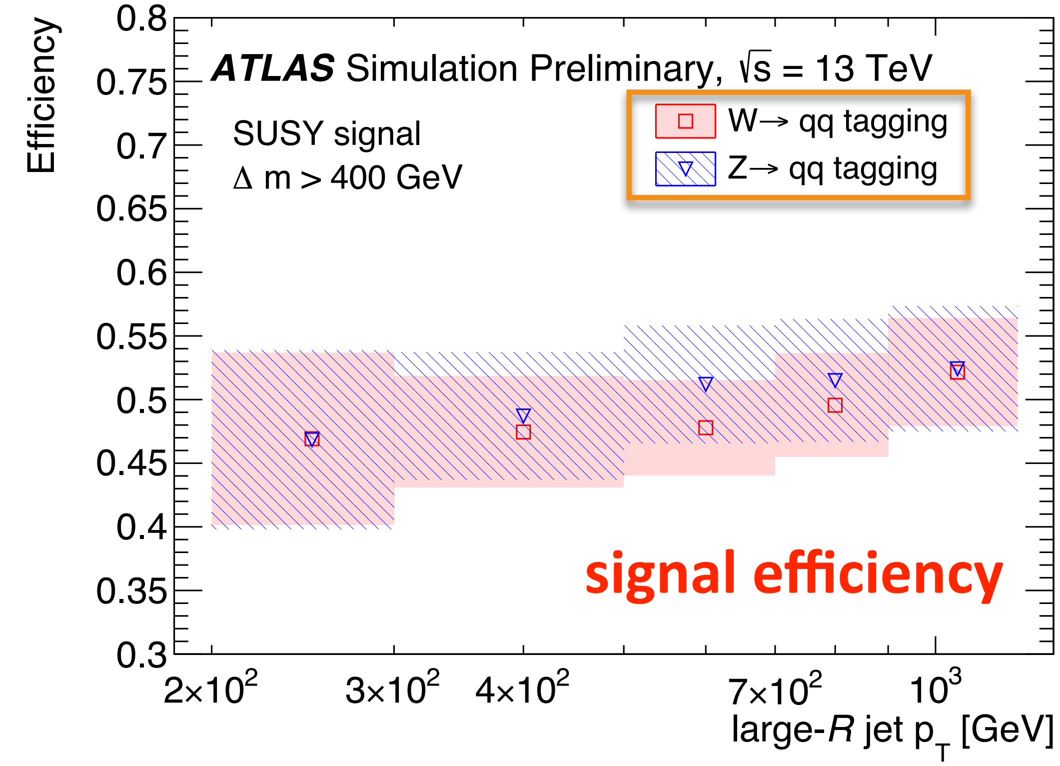
Fully Hadronic Final State

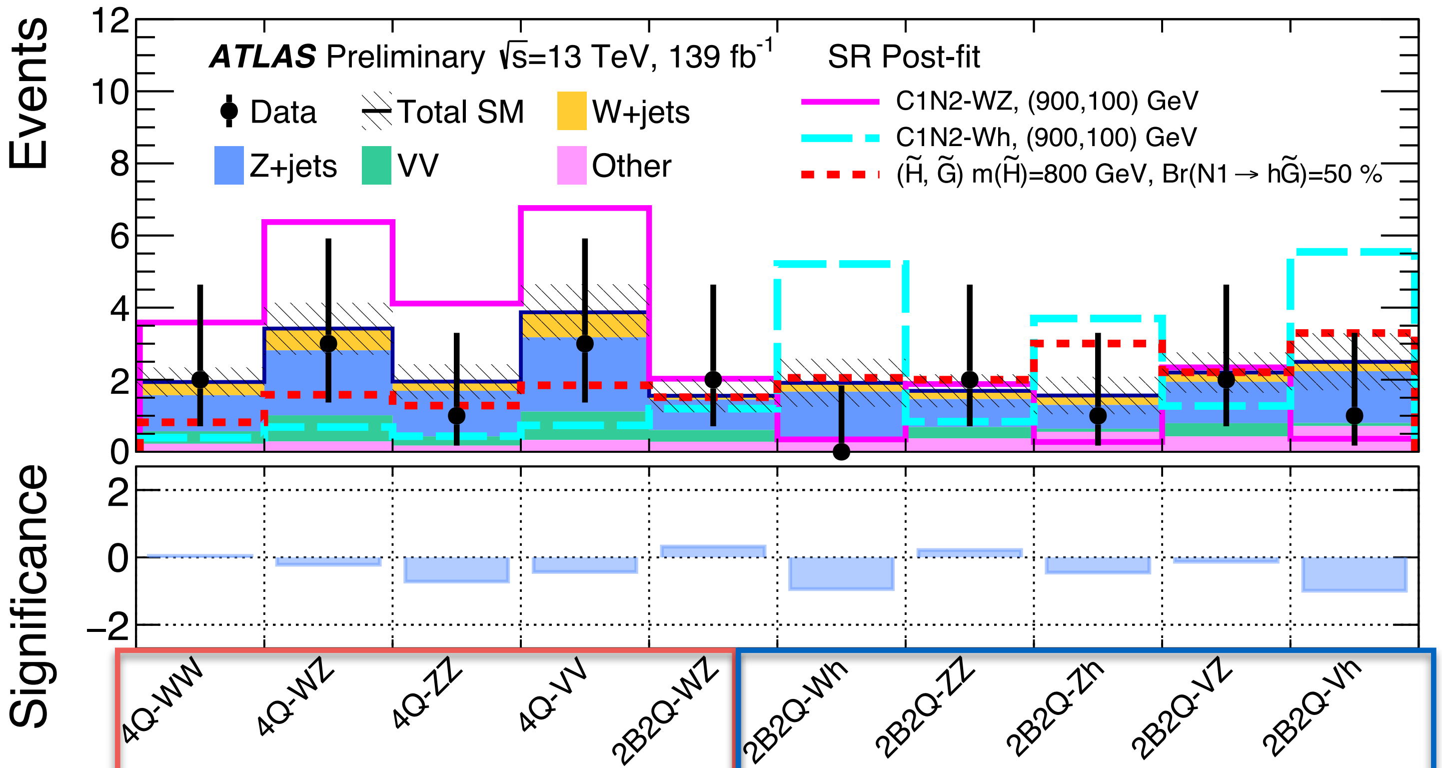
Large-R jets (J) to identify boosted W, Z, h decays

- ➞ dedicated taggers for W,Z→qq
  - ↳ m_J, N_{tracks} and energy correlation func. D_2
- ➞ $m_{J(bb)}$ to select Z→bb and h→bb

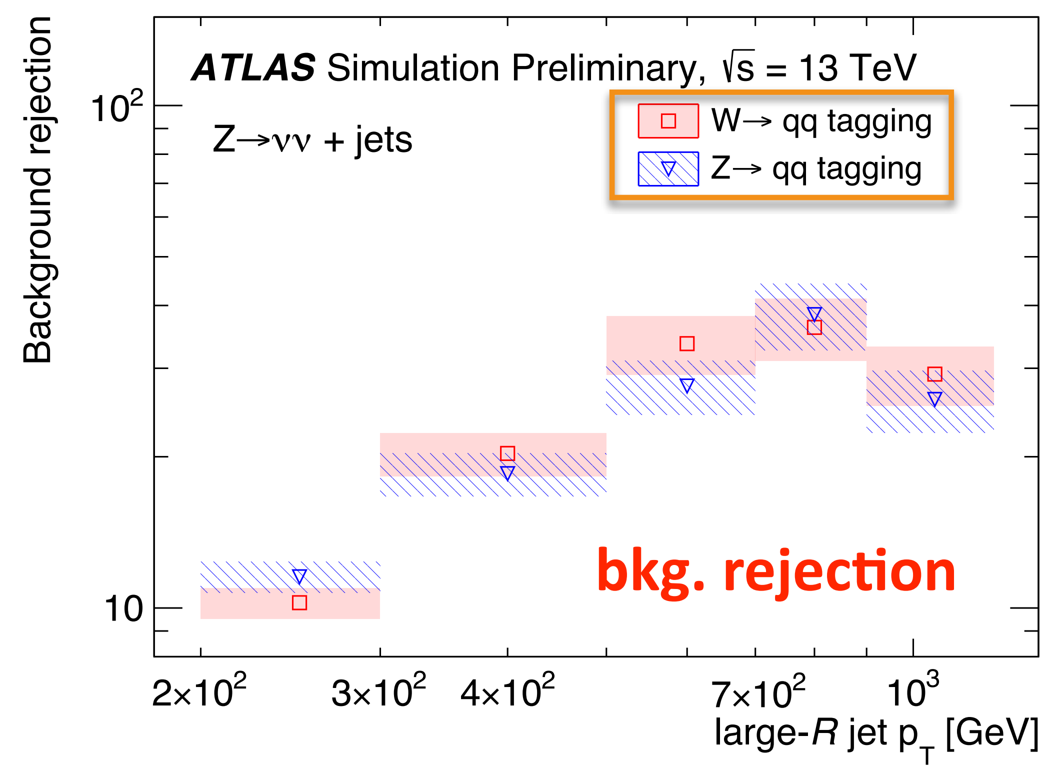
Main backgrounds

- ➞ **Reducible**: *Z*+jets and *W*+jets, "semi-data-driven"
- ➞ **Irreducible**: *VVV* and *tt+X*, taken from MC

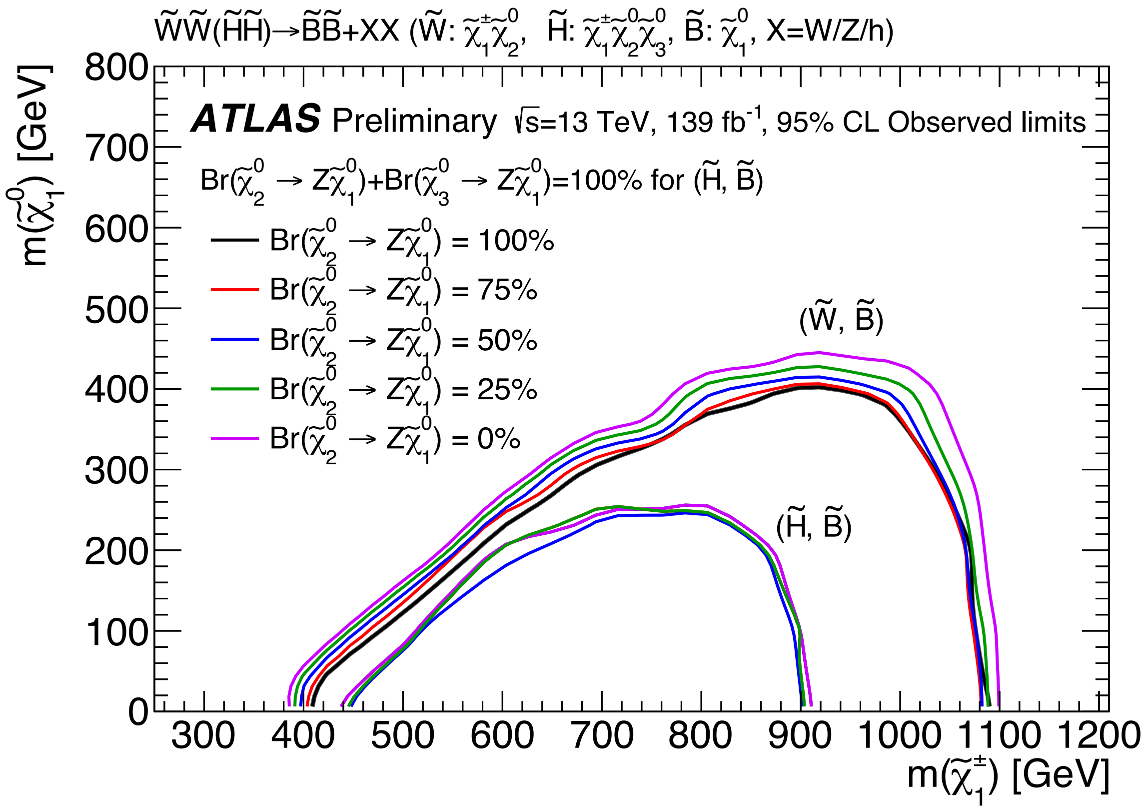


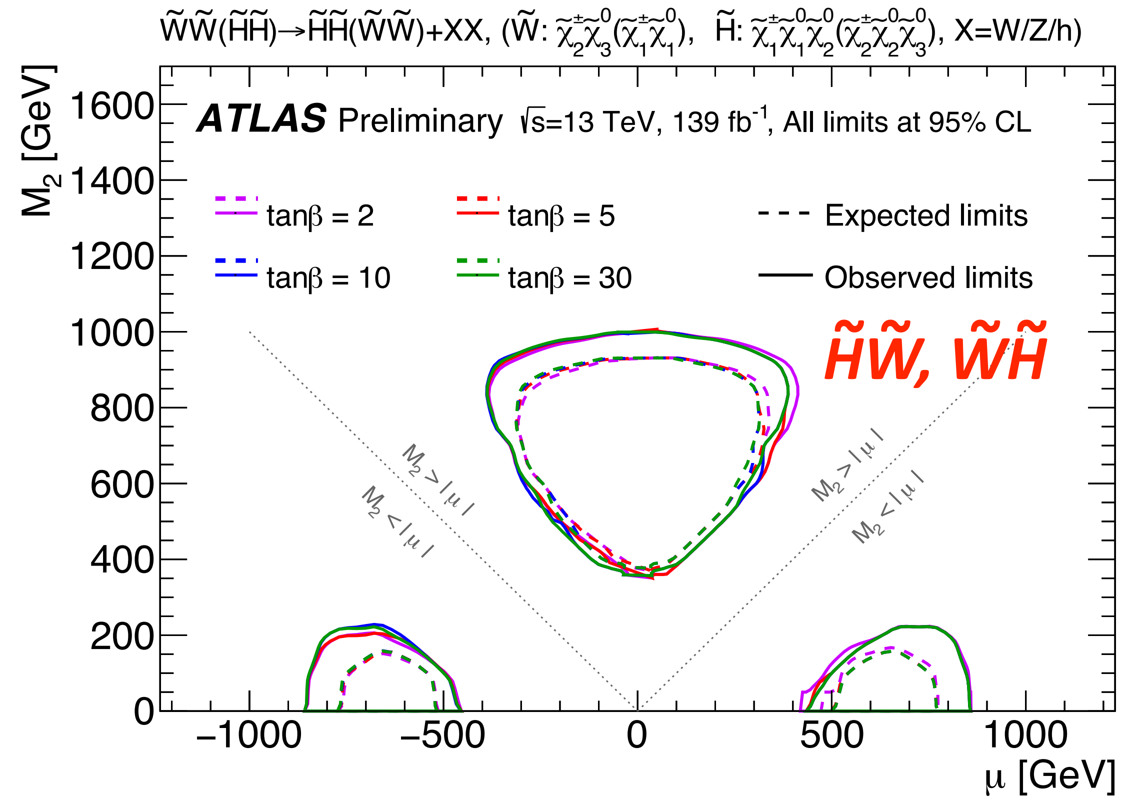


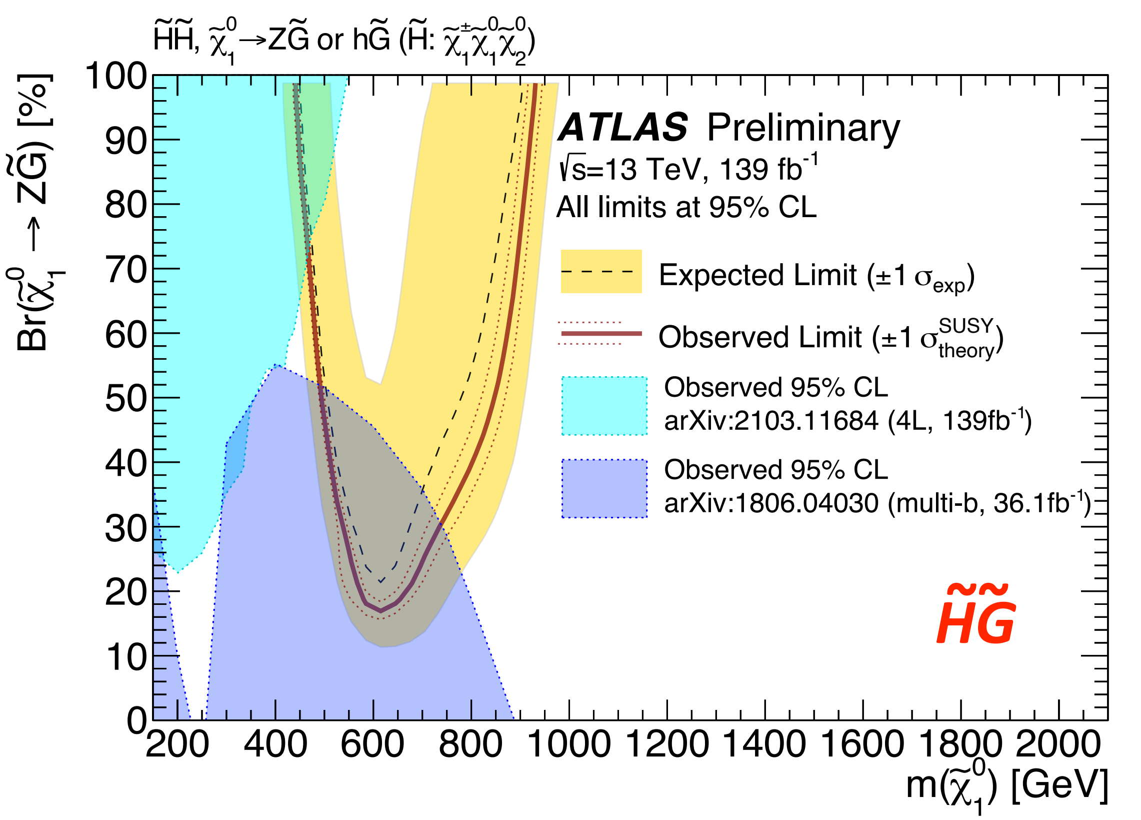
qq qq final state *qq bb final state*

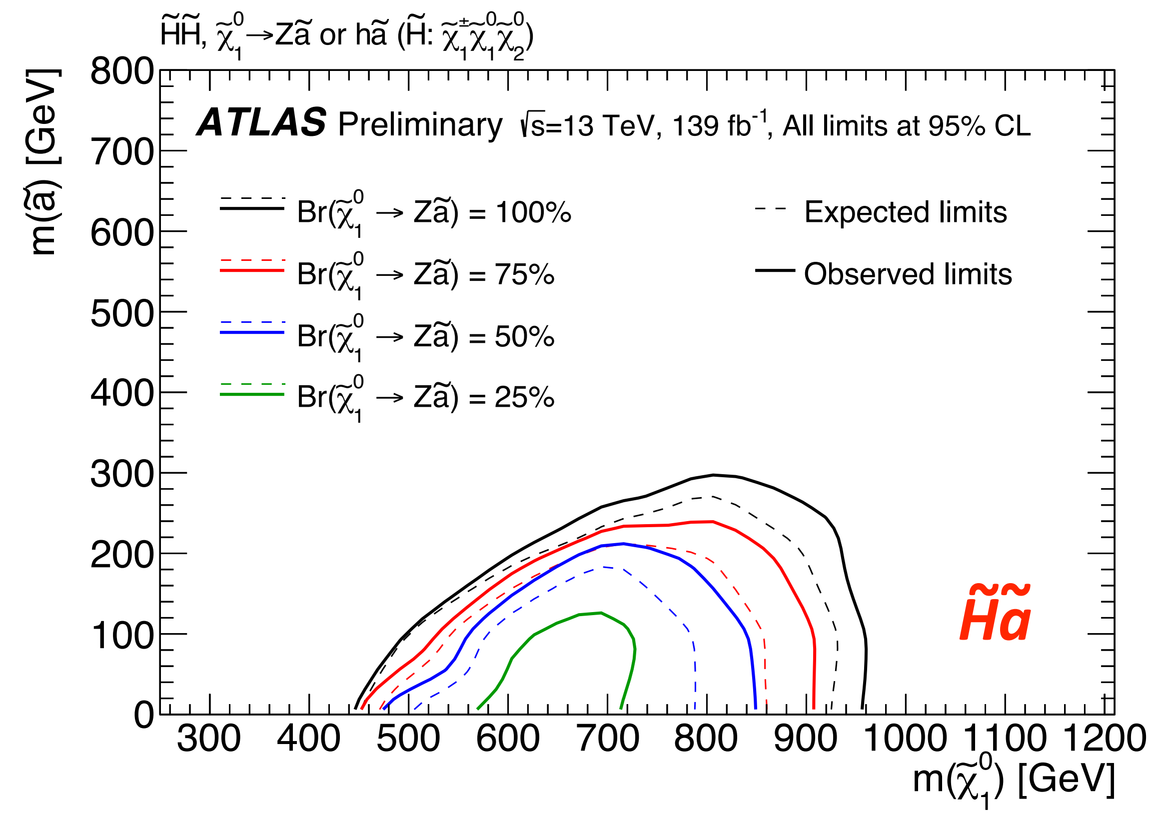


Fully Hadronic Final State







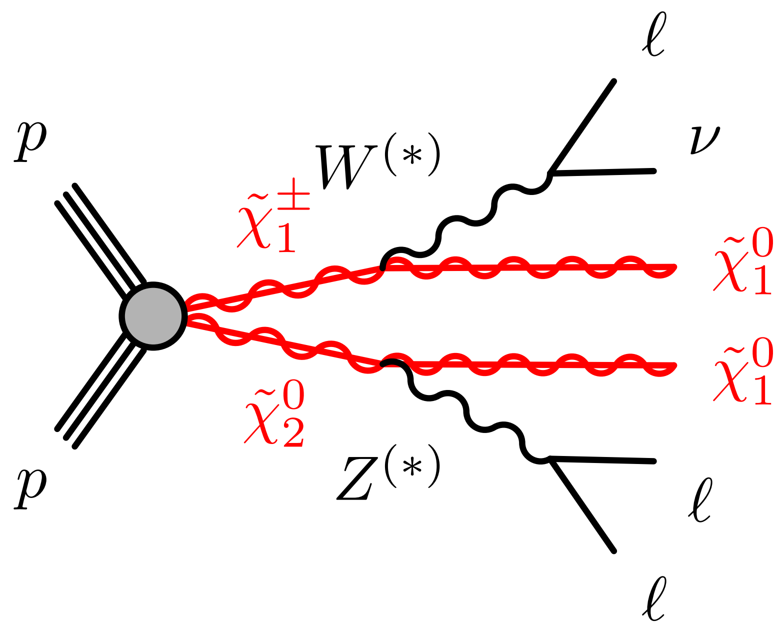


Final State With Three Leptons

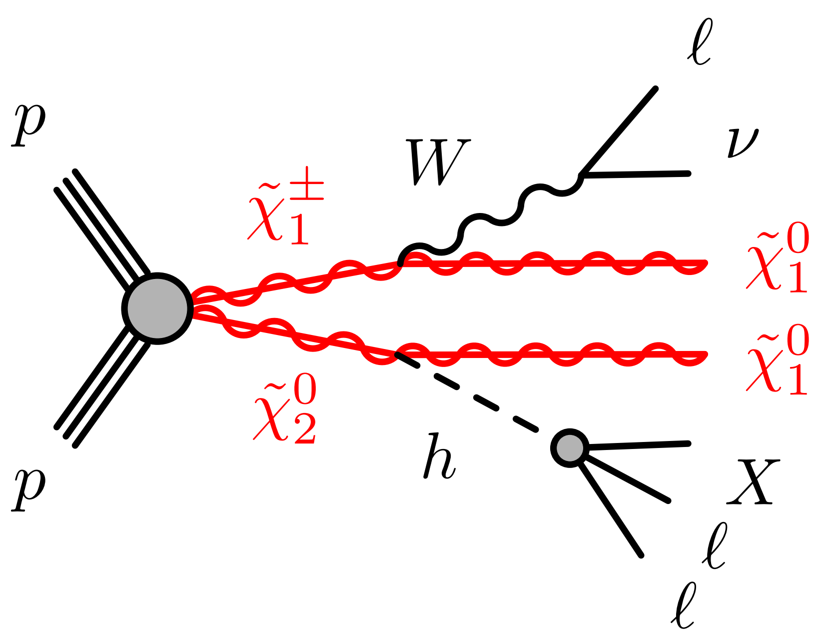
Final state with 3 leptons from chargino + neutralino direct production

➙ one lepton stemming from a $W^{(*)}$ decay, a pair from either $Z^{(*)}$ or SM $h \rightarrow WW/ZZ/\tau\tau$

WZ-mediated models



Wh-mediated models



Signal models driven by two different scenarios within MSSM

➙ $|M_1|<|M_2|<<|\mu|$ resulting in Bino-like stable LSP and Wino-like degenerate $\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$

➙ $|\mu|\approx$EWK scale and an Higgsino triplet of quasi-degenerate $\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0, \tilde{\chi}_1^0$

Analysis layout

On-shell selection: $\tilde{\chi}_2^0 \rightarrow Z\tilde{\chi}_1^0$ with 100% BR
Off-shell selection: $\tilde{\chi}_2^0 \rightarrow Z^*\tilde{\chi}_1^0$ with 100% BR
Wh selection: $\tilde{\chi}_2^0 \rightarrow h\tilde{\chi}_1^0$ with 100% BR

Final State With Three Leptons

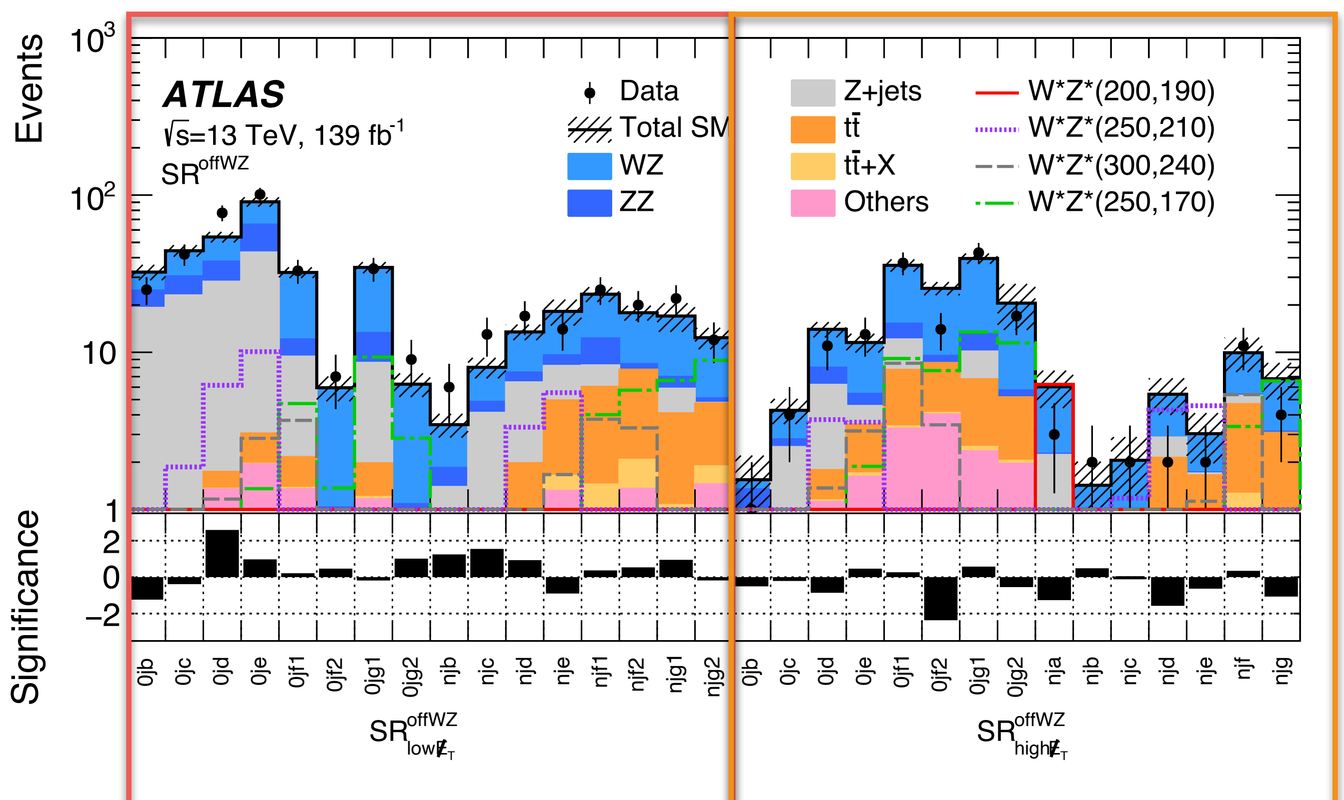
SRs with many bins to cover different signal scenarios and masses

- → Exploiting several observables: jet multiplicity, H_T, m_T (*W* decay), E_T^{miss}, $m_{\ell\ell min}$; vetoing *b*-jets

Main backgrounds

- → **Irreducible**: mainly *WZ,* and *SM Higgs*, MC simulation normalized to data in CRs
- → **Reducible**: ≥ 1 misidentified lepton, data-driven, mainly at low E_T^{miss}

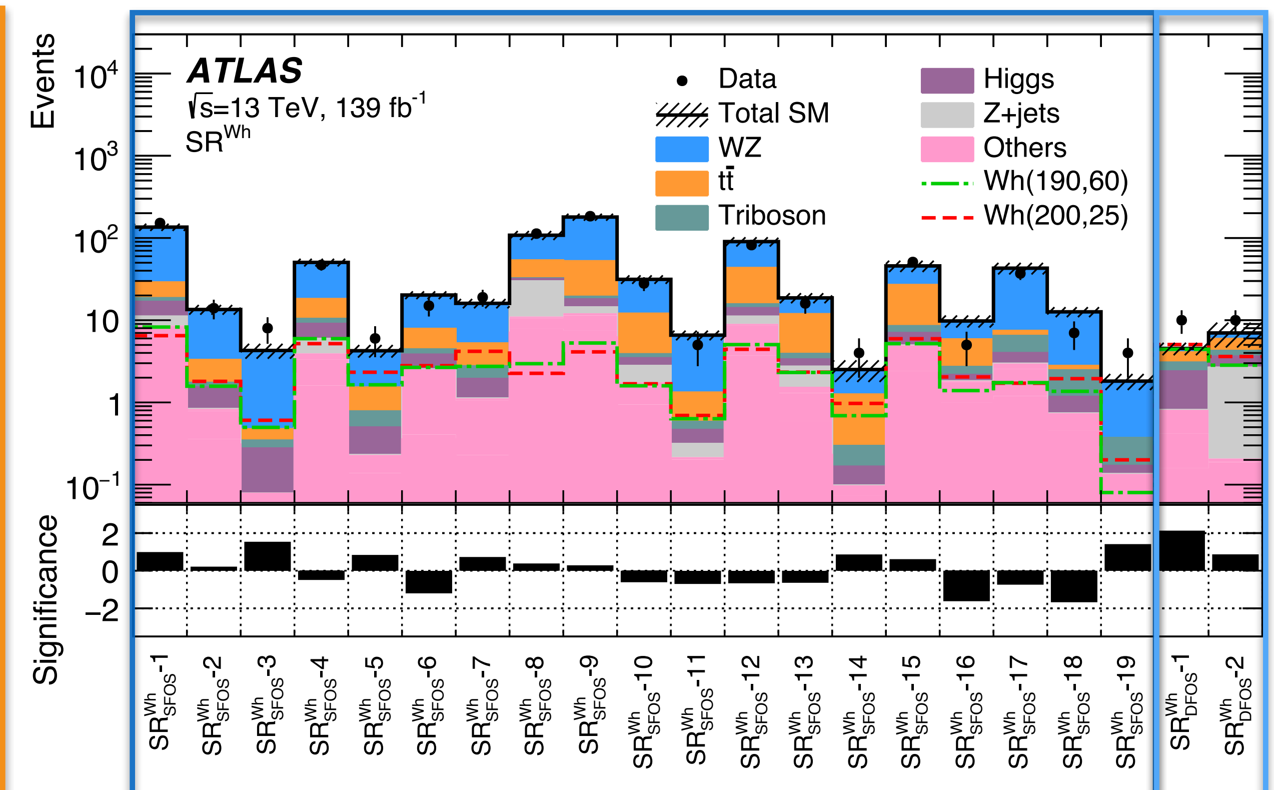
Off-shell WZ SRs



moderate mass splittings

compressed mass spectra

Wh SRs



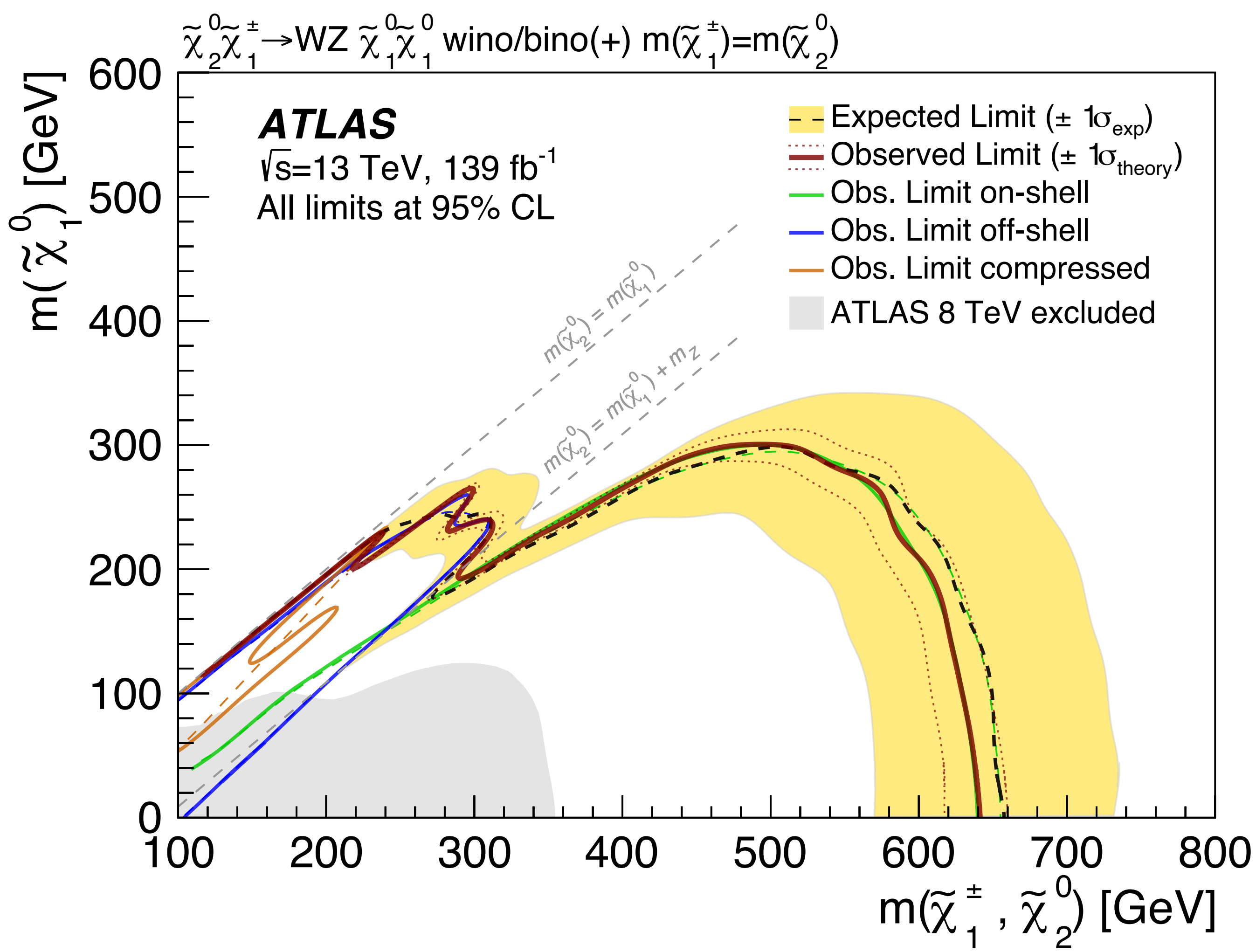
same-flavor leptons

opposite-flavor leptons

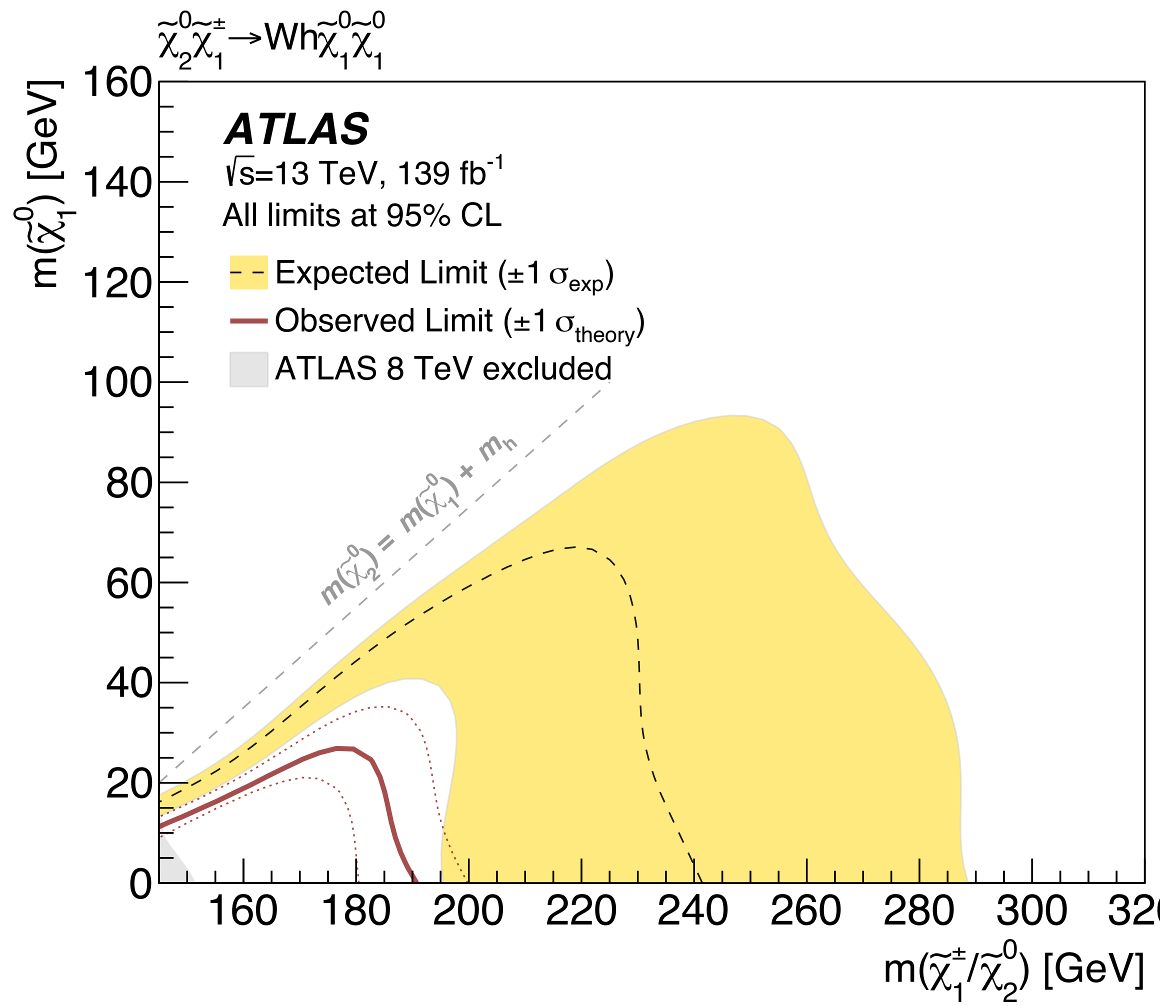
Final State With Three Leptons

CERN-EP-2021-059

WZ-mediated models
exclusions up to 640 GeV



Wh-mediated models
exclusions up to 185 GeV



Followed up previous excess (≈3.0σ): PRD 98 092012
good agreement now with SM

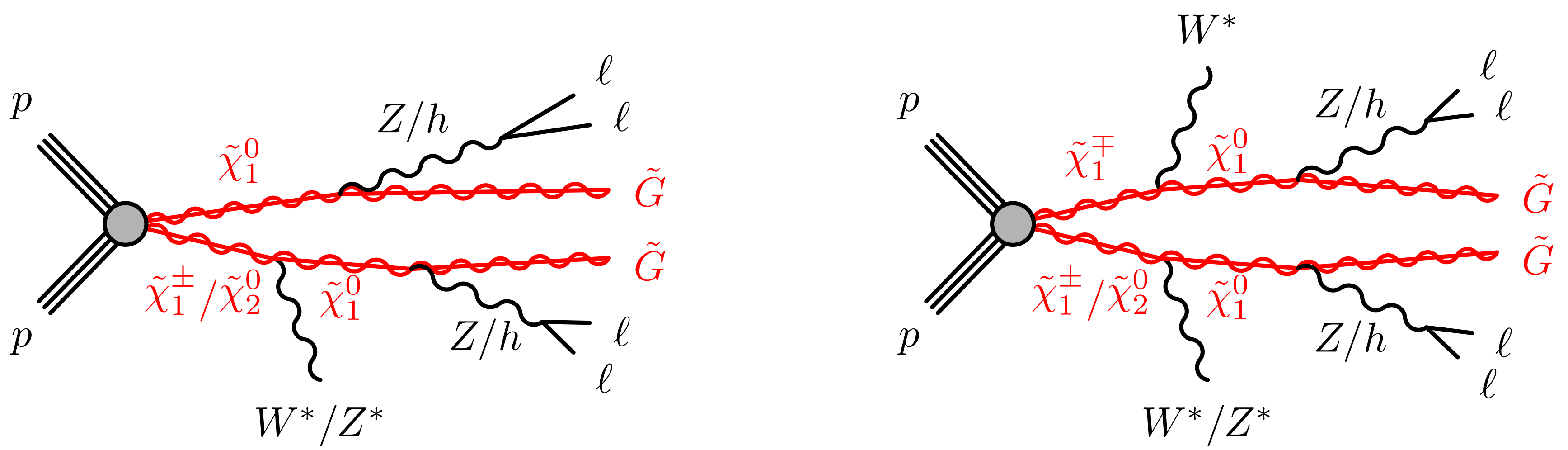
Recursive Jigsaw SRs	$\sigma_{\mathrm{vis}}^{95}$ [fb]	S_{obs}^{95}	S_{exp}^{95}	$\mathrm{CL_b}$	$p(s=0)\ (Z)$
SR3ℓ-Low	0.24	33	30^{+10}_{-8}	0.61	0.39 (0.28)
SR3ℓ-ISR	0.14	19	12^{+5}_{-4}	0.89	0.09 (1.32)

Final State With Four Leptons

CERN-EP-2021-021

Final state with 4 leptons from chargino + neutralino or chargino + chargino production

➙ same-flavor opposite-charge pairs stemming from Z/h decays



For RPC SUSY, focusing on single scenario driven by GGM, with *gravitino LSP*

➙ $\tilde{\chi}_1^\pm, \tilde{\chi}_2^0, \tilde{\chi}_1^0$ assumed to be quasi-degenerate *higgsinos* (1 GeV splittings)

➙ *W*/ Z** from their decay chain are too soft, and thus undetectable

➙ *GGM* gives a mechanism where they can be cornered experimentally

↳ leptonic decays of Z/h from $\tilde{\chi}_1^0 \rightarrow \tilde{G}$ transitions lead to clean signature

Analysis also considers *several RPV scenarios:* see M. Holzbock's talk

Final State With Four Leptons

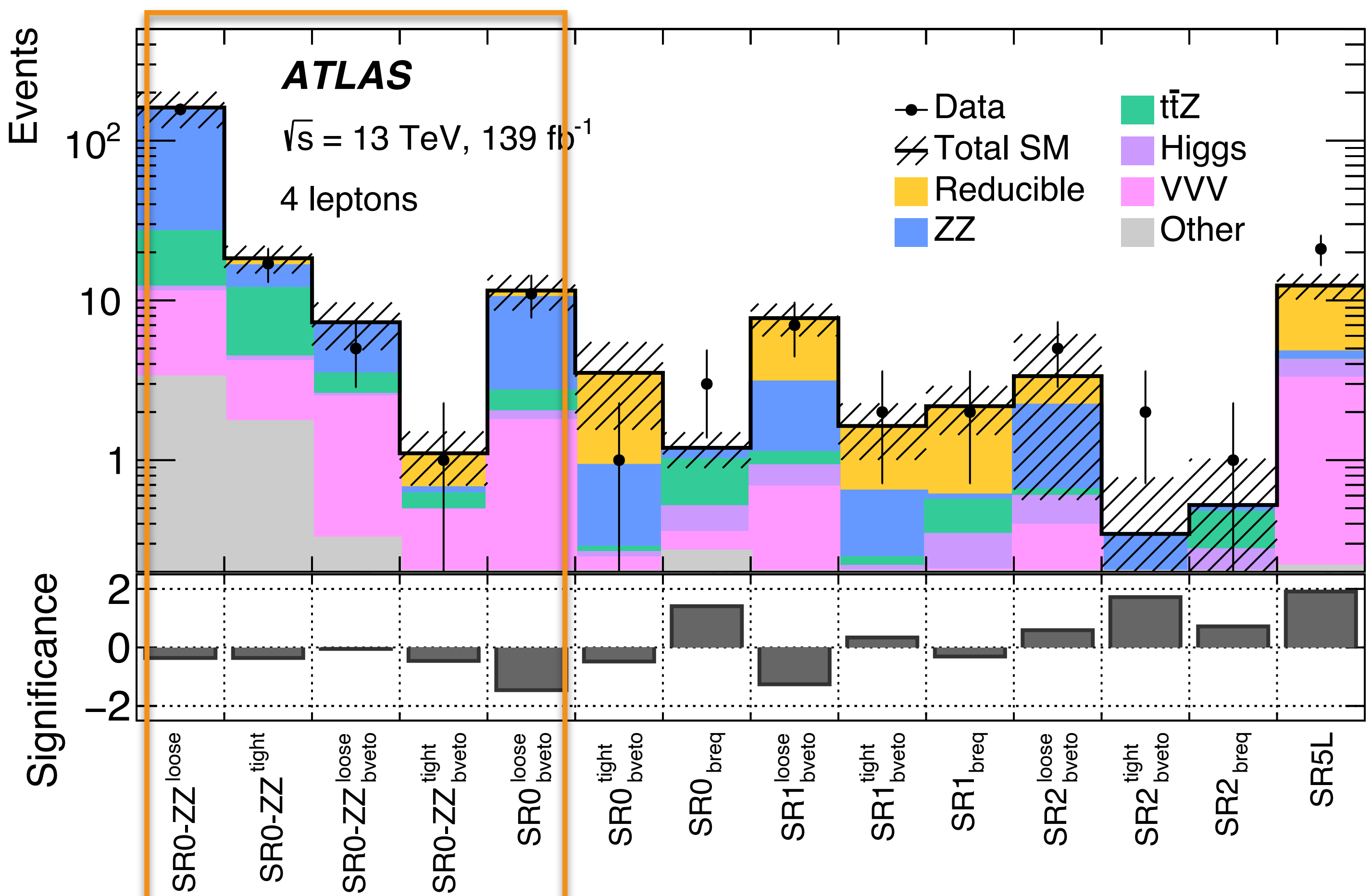
Looser / Tighter SRs with different τ multiplicities

→ Main observables are E_T^{miss} and effective mass (m_{eff})

Main backgrounds

→ **Irreducible**: mainly *ZZ* and *ttZ*, MC normalized in CRs

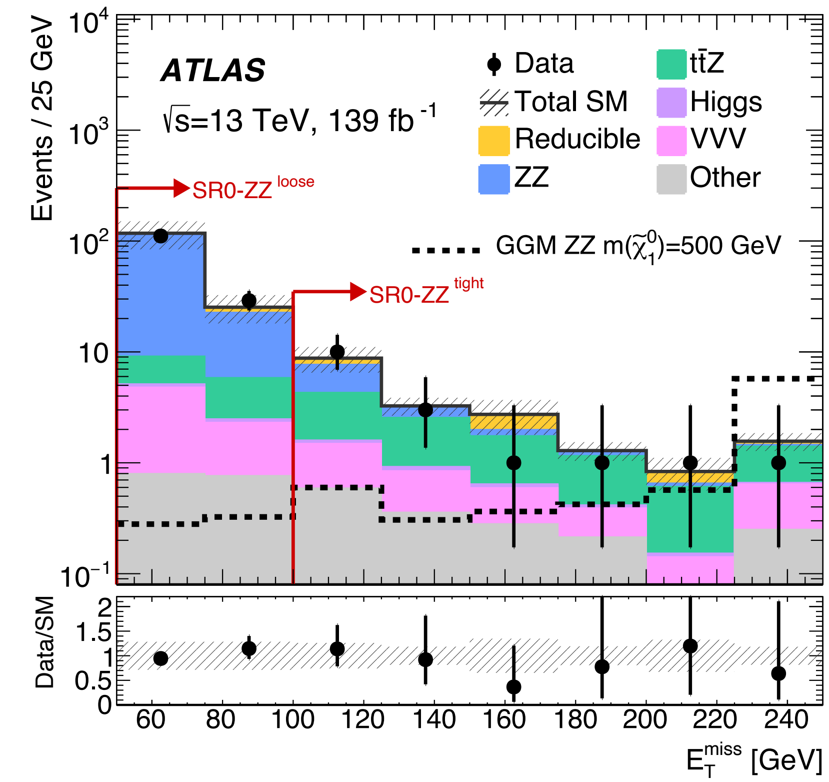
→ **Reducible**: ≥ 1 misidentified lepton, data-driven



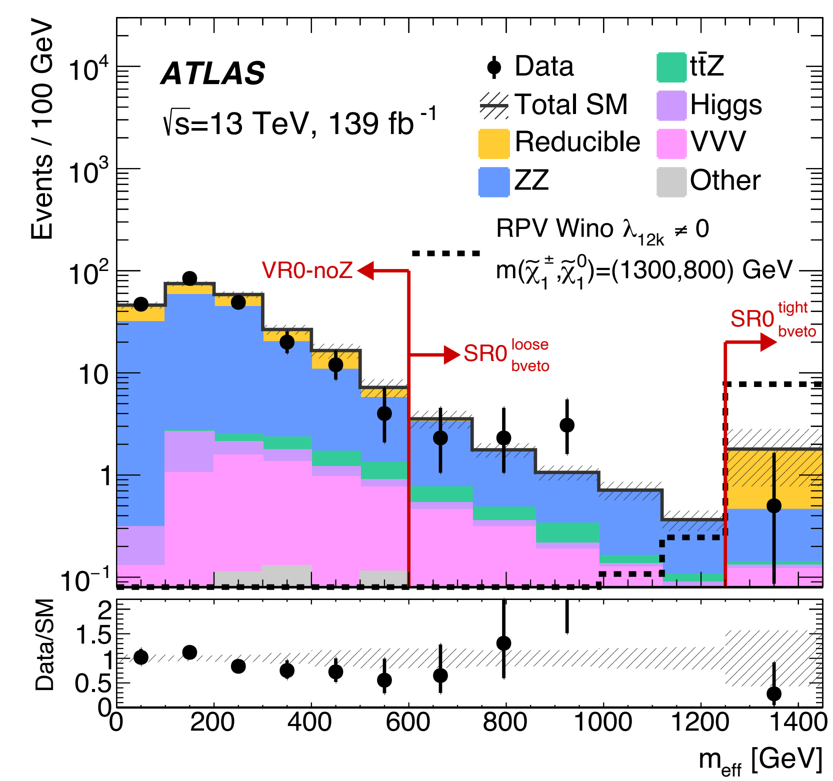
RPC GGM

RPV

b-jet agnostic

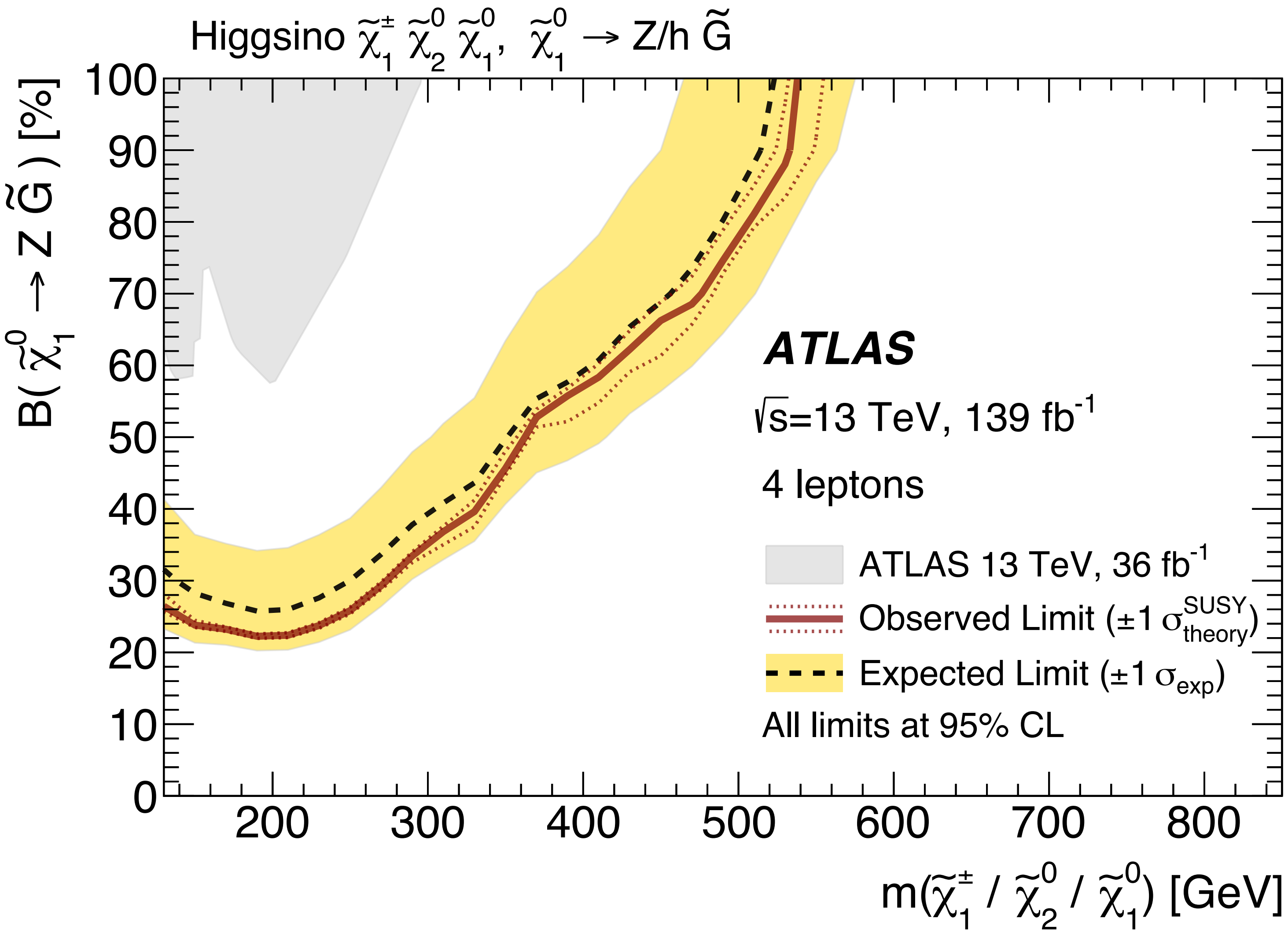


b-jet veto



Final State With Four Leptons

Model-dependent exclusions



Model-independent limits

	$\langle\epsilon\sigma\rangle^{95}_{\rm obs}$ [fb]	$S^{95}_{\rm obs}$	$S^{95}_{\rm exp}$
SR0-ZZ$^{\rm loose}$	0.481	66.86	$67.43^{+20.43}_{-15.71}$
SR0-ZZ$^{\rm tight}$	0.081	11.28	$11.52^{+4.81}_{-3.34}$
SR0-ZZ$^{\rm loose}_{\rm bveto}$	0.043	6.01	$7.10^{+2.82}_{-1.90}$
SR0-ZZ$^{\rm tight}_{\rm bveto}$	0.028	3.87	$3.63^{+1.44}_{-0.63}$
SR0$^{\rm loose}_{\rm bveto}$	0.070	9.79	$8.28^{+3.58}_{-2.30}$
SR0$^{\rm tight}_{\rm bveto}$	0.028	3.87	$4.29^{+1.56}_{-0.86}$
SR0$_{\rm breq}$	0.046	6.33	$3.78^{+1.59}_{-0.66}$
SR1$^{\rm loose}_{\rm bveto}$	0.046	6.37	$7.46^{+2.92}_{-2.04}$
SR1$^{\rm tight}_{\rm bveto}$	0.032	4.47	$4.22^{+1.63}_{-1.04}$
SR1$_{\rm breq}$	0.033	4.56	$4.59^{+1.77}_{-1.22}$
SR2$^{\rm loose}_{\rm bveto}$	0.061	8.45	$7.45^{+2.36}_{-1.24}$
SR2$^{\rm tight}_{\rm bveto}$	0.041	5.63	$3.53^{+1.06}_{-0.15}$
SR2$_{\rm breq}$	0.030	4.17	$3.16^{+1.20}_{-0.16}$
SR5L	0.129	17.88	$9.88^{+4.08}_{-2.44}$

Followed up previous
small excess: PRD 98 032009
good agreement now with SM

	SR0-ZZ$^{\rm loose}$	SR0-ZZ$^{\rm tight}$
Observed	157	17
Total SM	161^{+41}_{-43}	$18.4^{+3.6}_{-3.3}$

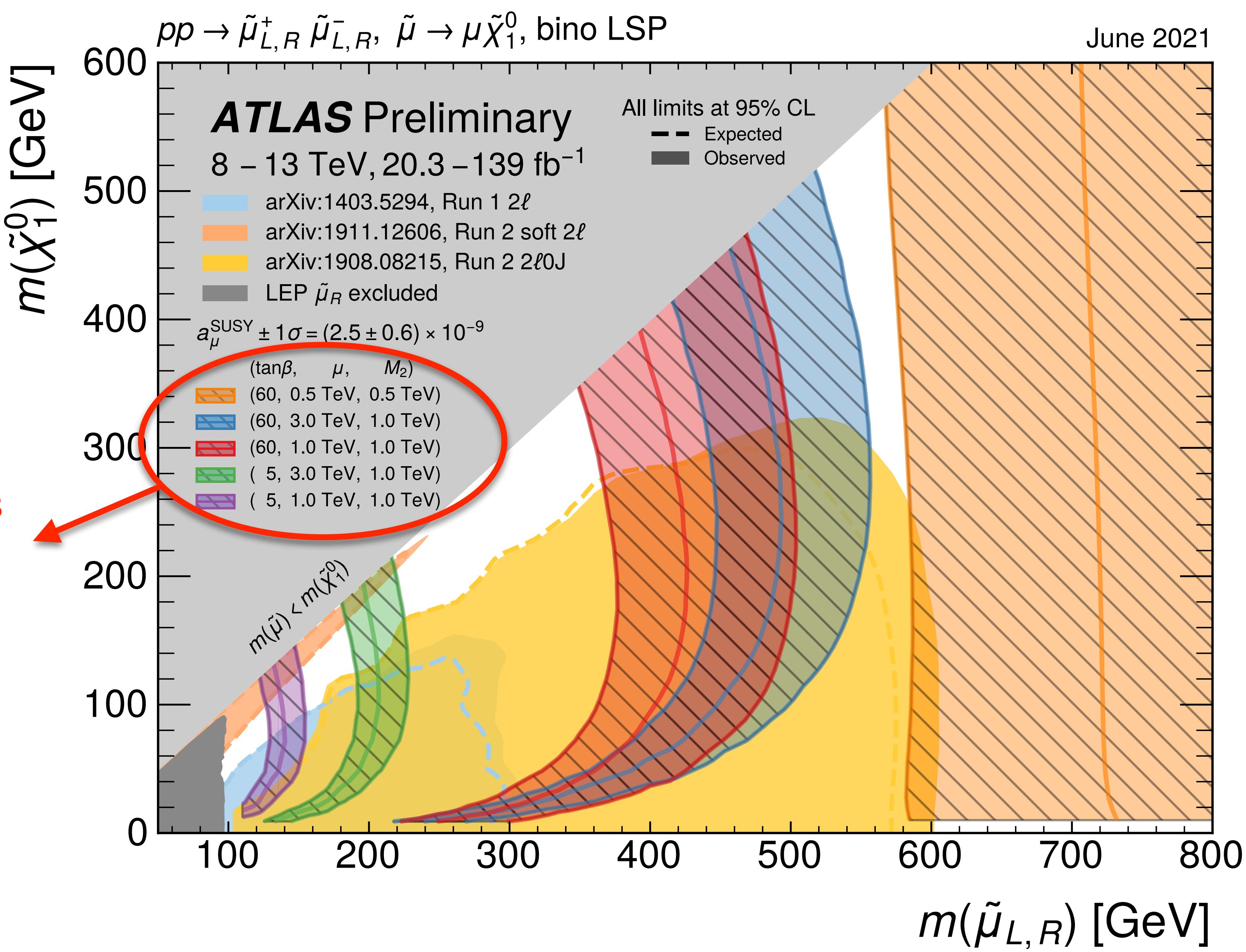
Summary & Conclusions

Extensive search program, no significant excess, stringent exclusions…

… yet, good portions of well-motivated parameter space still unexplored!!!

Good news is, plenty of data will be collected in coming years: stay tuned!

Examples of pMSSM parameters compatible with μ g-2 anomaly



Prototypical EWK SUSY Search

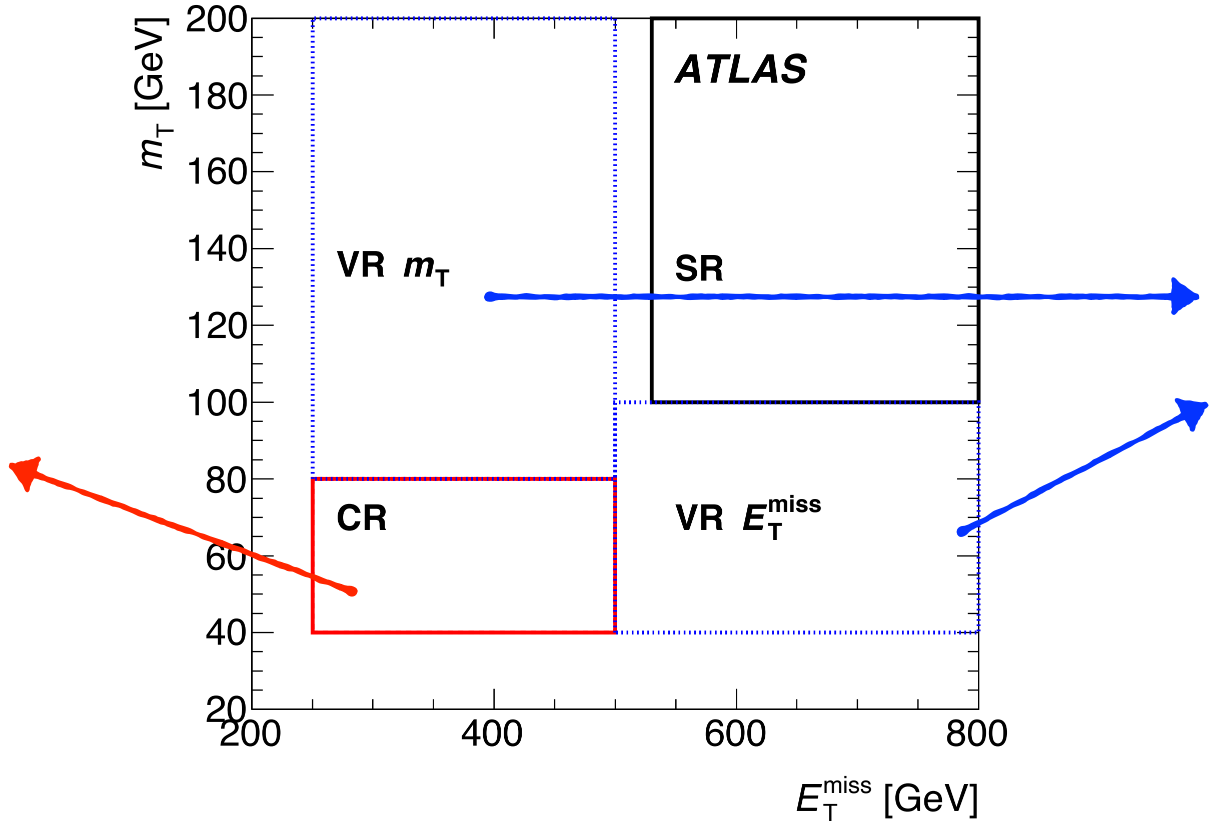
Dominant backgrounds are in general WZ, ZZ, WW, W/Z+jets, top processes

Signal Regions (SRs) → set of requirements maximize S/B
↳ multiple bins often used to target different signal masses

Control Regions (CRs) → normalize simulated backgrounds to data
↳ extrapolate to SR using MC-based transfer factors
→ or, extract background predictions entirely from data

Validation Regions (VRs) → validate background estimates against data

kinematic region close to SR, with negligible signal contamination



validate CR → SR extrapolation along each variable, separately