Searches for Supersymmetry with the ATLAS detector

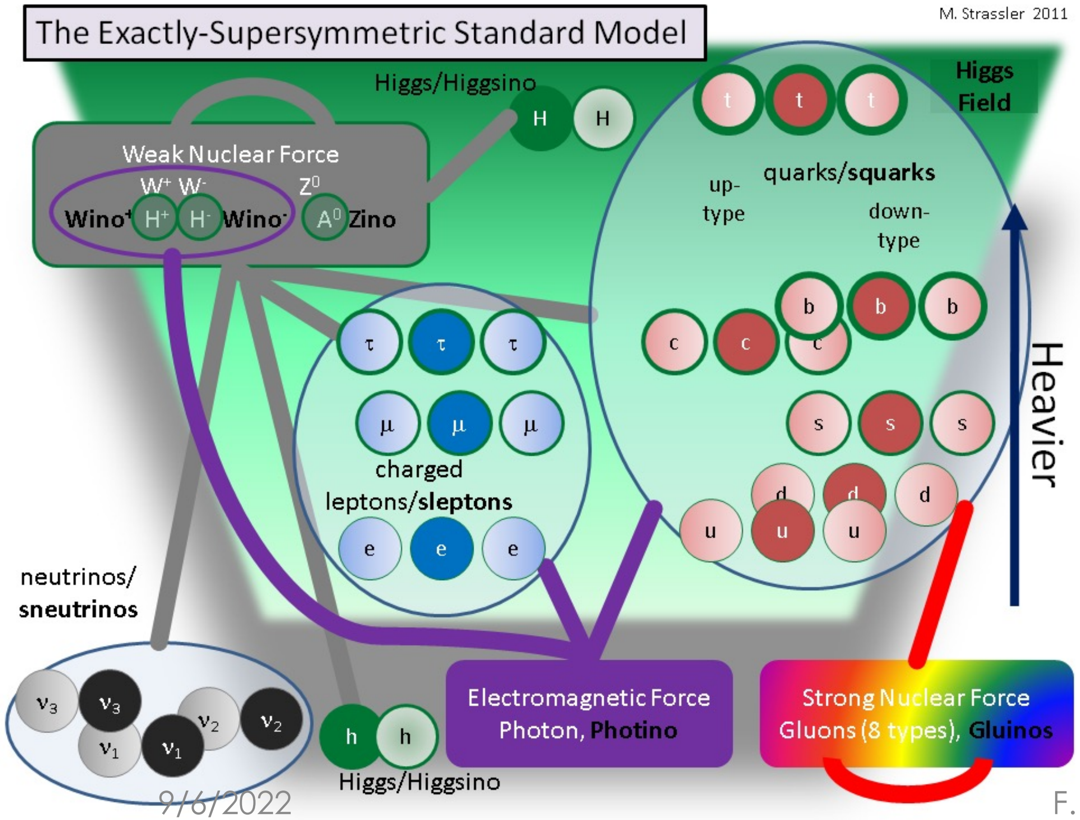
FLERA RIZATDINOVA ON BEHALF OF THE ATLAS COLLABORATION

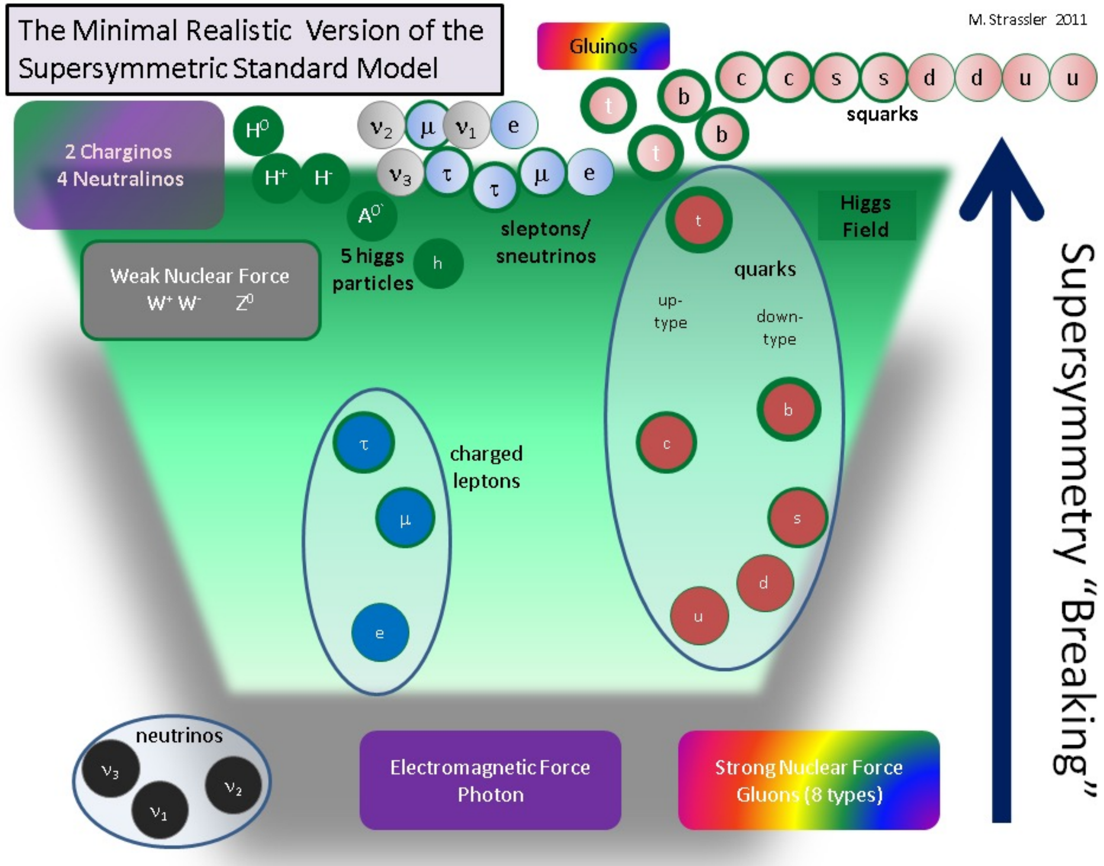
Introduction

- Supersymmetry: a set of theories that predict existence of boson (fermion) partners for existing fermion (boson) particles of the Standard Model
  - offers a mechanism to stabilize the Higgs boson mass
- Several Higgs bosons in the theory in addition to the SM boson, both neutral and charged
  - neutral higgsinos and neutral EW gauginos mix to form neutralinos
  - charged higgsinos and charged EW gauginos mix to form charginos
- If R-parity $R=(-1)^{3(B-L)+2S}$ is conserved, the lightest neutral SUSY particle (LSP) can't decay, making it a dark matter candidate

SUSY in a nutshell

- If the world were exactly supersymmetric, every particle known would have superpartners with the same interactions and the same mass





- For supersymmetry to be consistent with data, it must be hidden or "spontaneously broken," pushing the SUSY masses beyond existing experimental limits

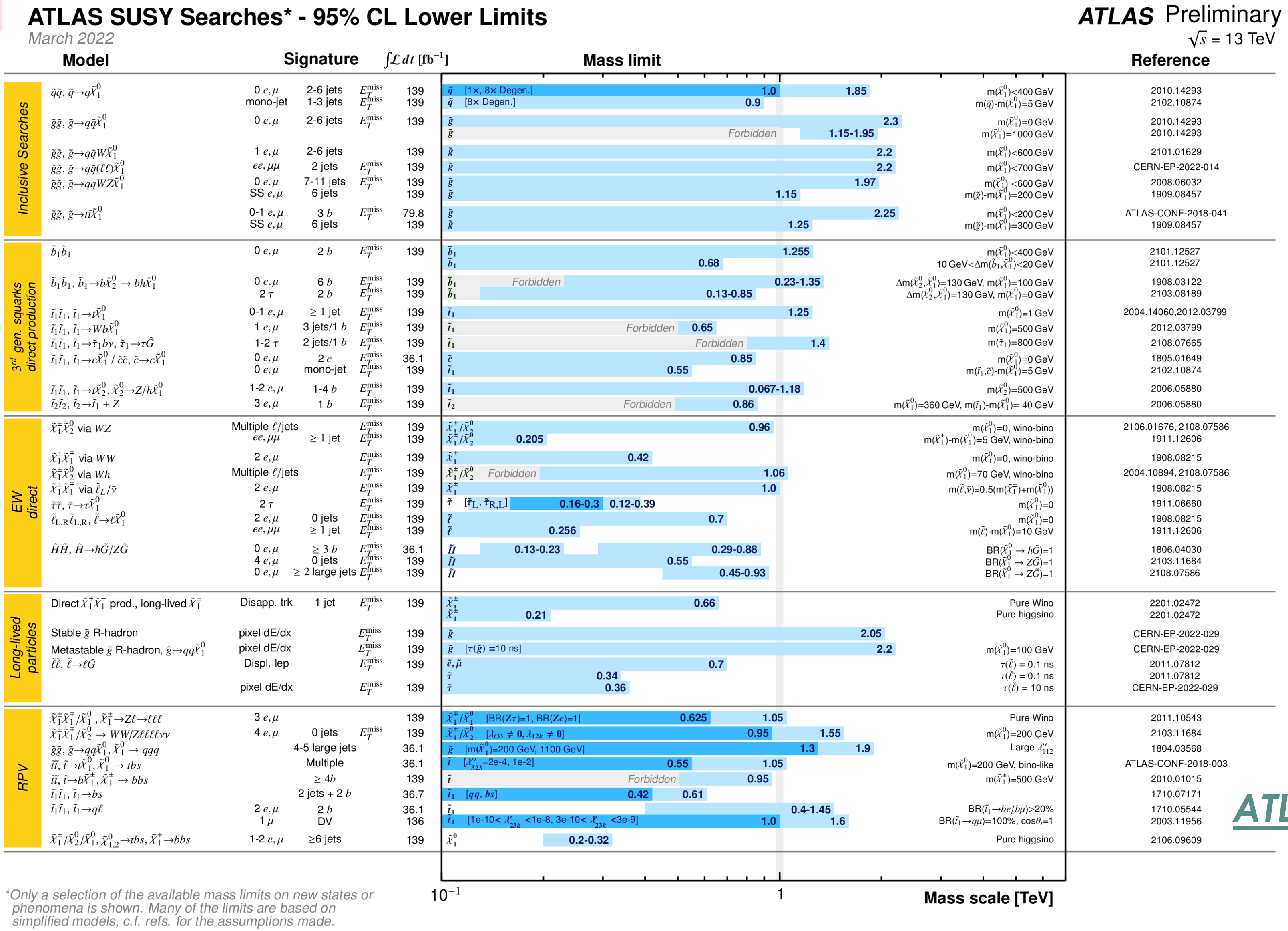
Simplified SUSY models

- Too many model parameters (124 in MSSM) – what to search for?
- The approach: make assumptions to reduce the parameter space (down to 3 - 4 parameters) and focus on specific decay chains
  - Pro: easier to make searches orthogonal, to combine, and to re-interpret
  - Con: almost guaranteed not to be what is realized in nature
- Boosted vs compressed modes
  - boosted: larger difference between decaying sparticles and resulting particles, more energy per object
  - compressed: smaller difference, less energy per object

Ways to look for SUSY signals

- Kinematics of events
  - large missing momentum: sensitive to RPC scenarios with LSP in the final state that escape detection
  - large event energy scale
  - characteristic event energy structure (invariant masses, angles)
- Specific event features
  - multiple heavy flavor jets in the final state
  - long-lived objects (in RPV scenarios)

A snapshot of SUSY results at ATLAS



ATL-PHYS-PUB-2022-013

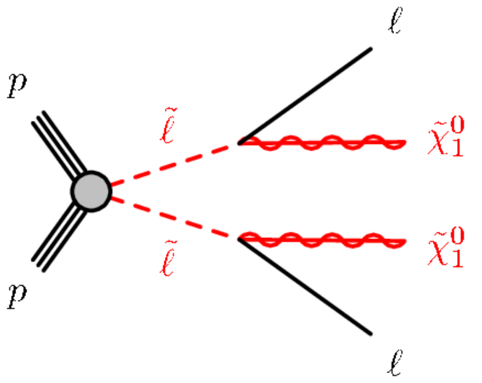
Latest ATLAS SUSY results

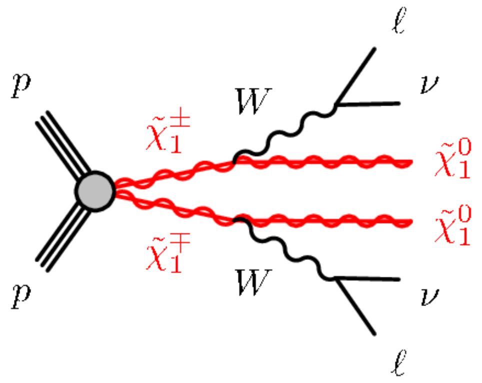
- Reviewed in this presentation:
  - sleptons/charginos in 2l+0j
  - charginos/neutralinos in 2l+2j
  - squarks/gluinos in 2l+2j
  - charginos/neutralinos in all hadronic
  - LLP: disappearing track
  - LLP: dE/dx
- Many more results are published or are coming soon!

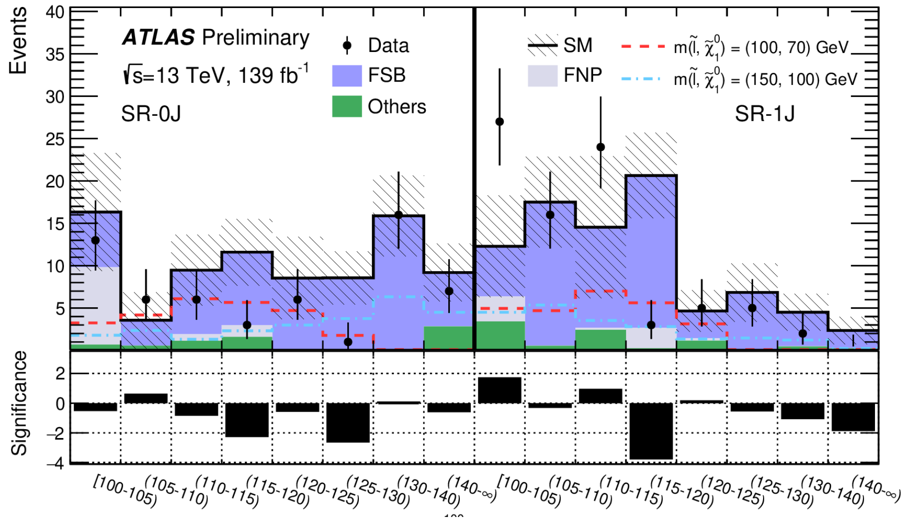
EW 2l+0j

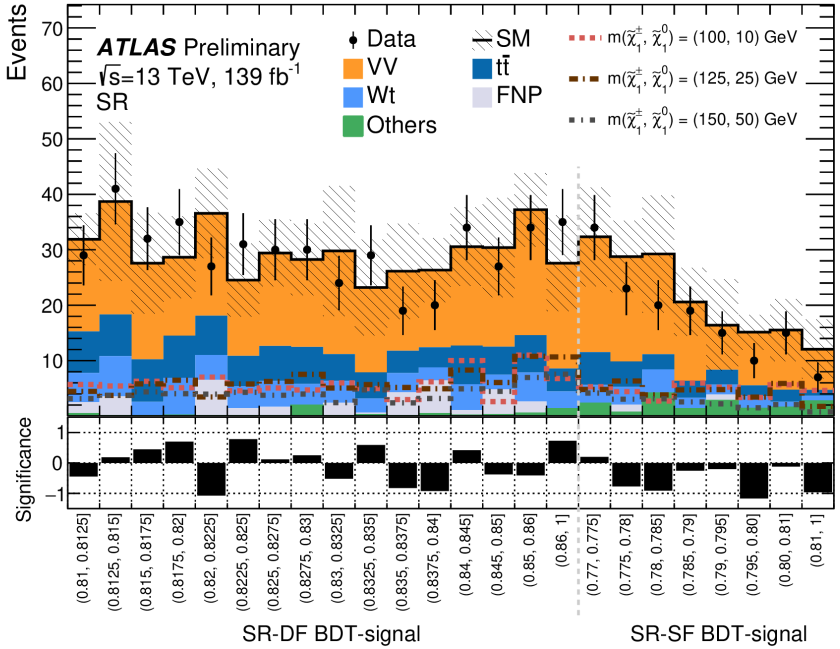
ATLAS-CONF-2022-006

- Searching for EW production of charginos and sleptons in events with two OS leptons and MET using BDT
- Searches are targeting the phase space, where mass difference between sleptons and charginos is close to the mass of W. Light smuons can provide an explanation for the muon g-2 anomaly.





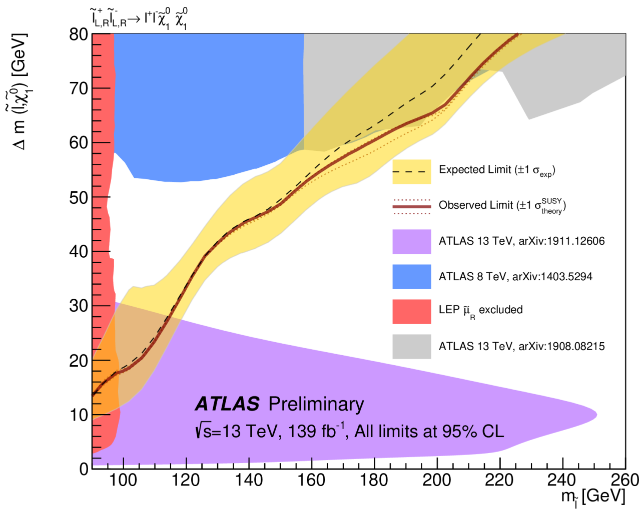


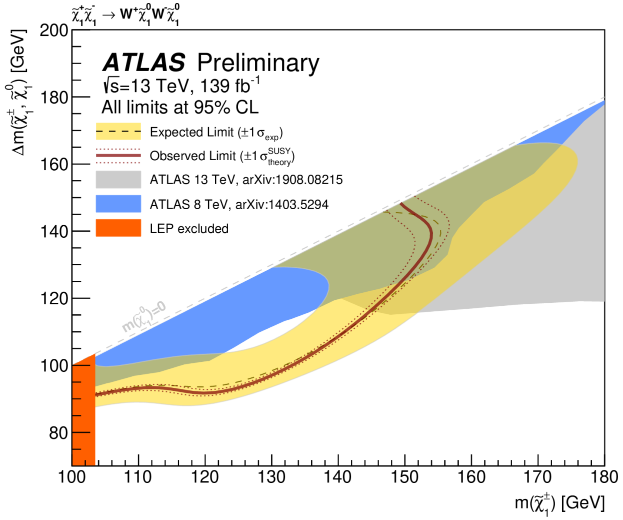


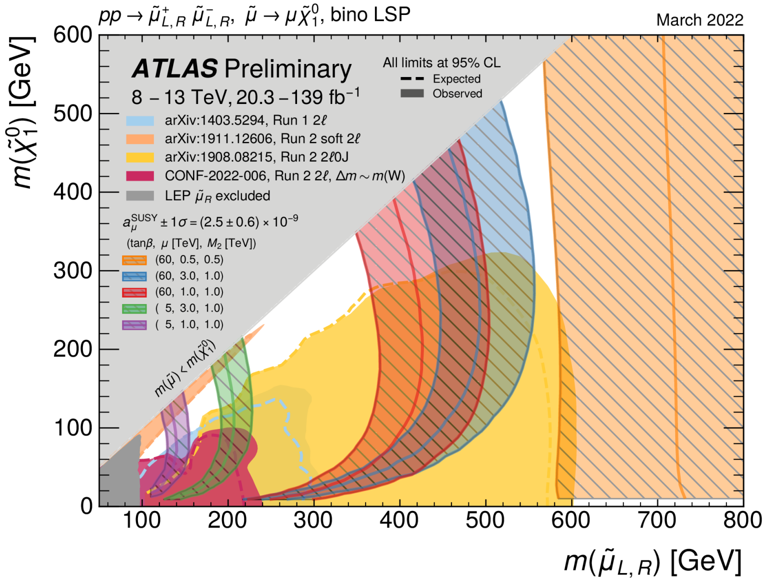
- Main backgrounds: tt, Wt, VV

EW 2l+0j: results

- Sleptons with masses up to 150 GeV are excluded for the mass splitting between slepton and LSP of 50 GeV.
- Chargino masses up to 135 GeV are excluded for the mass splitting between chargino and LSP up to 100 GeV
- Smuons exclusion limit – still have some regions compatible with results of g-2 experiment

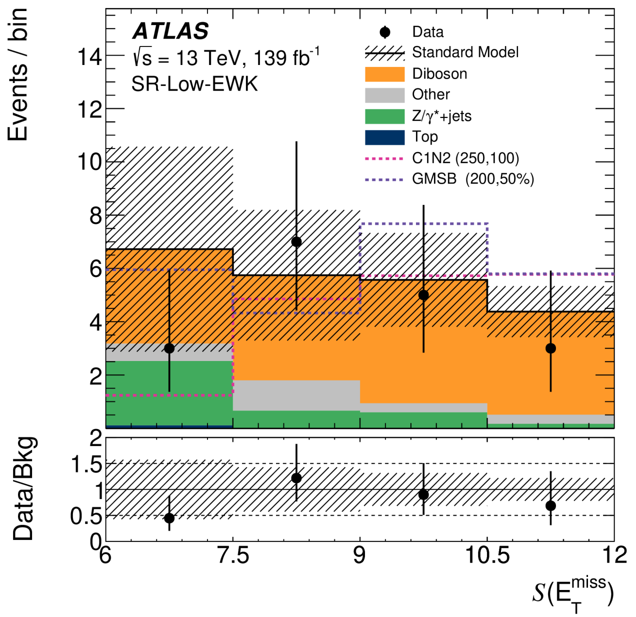


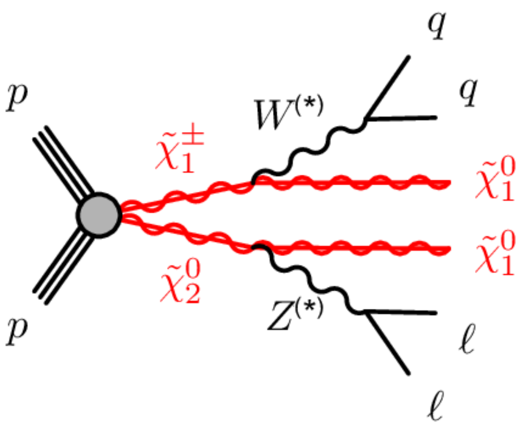


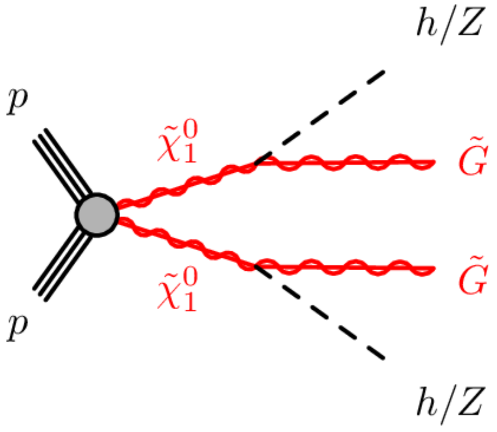


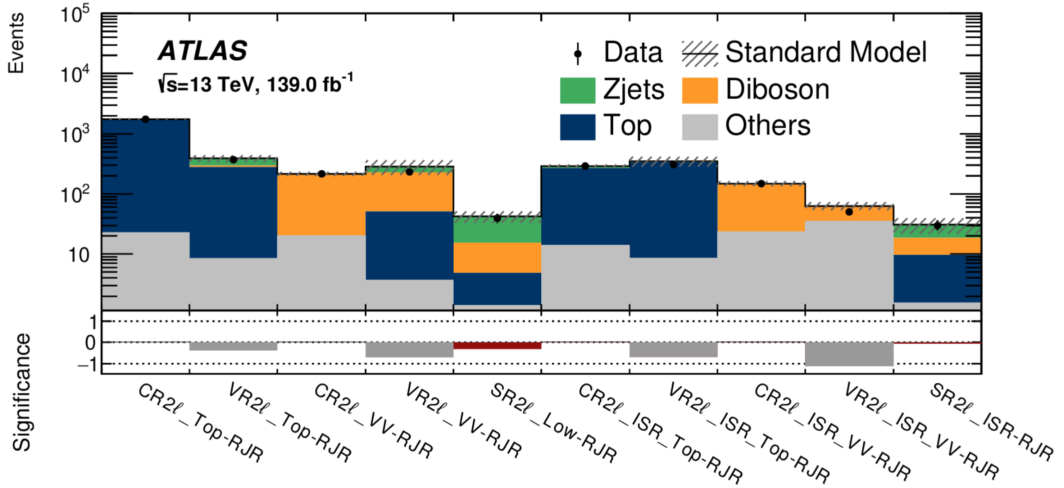
EW 2l+2j

- Searching for EW production of charginos / neutralinos in events with two OS leptons, ≥2 jets and MET
- 139/fb, recursive-jigsaw reconstruction or cut-and-count
- Models: C1N2, GMSB
- Backgrounds: VV, tt, Drell-Yan





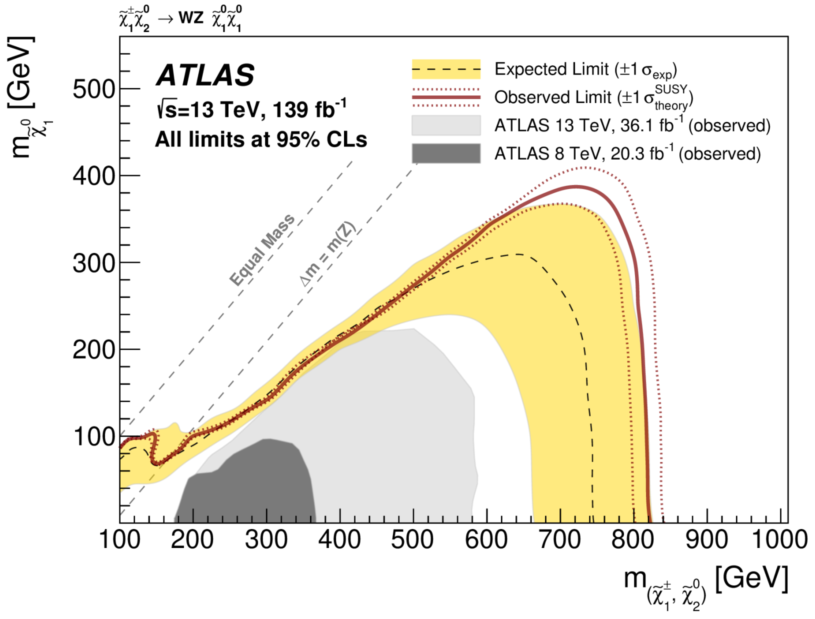


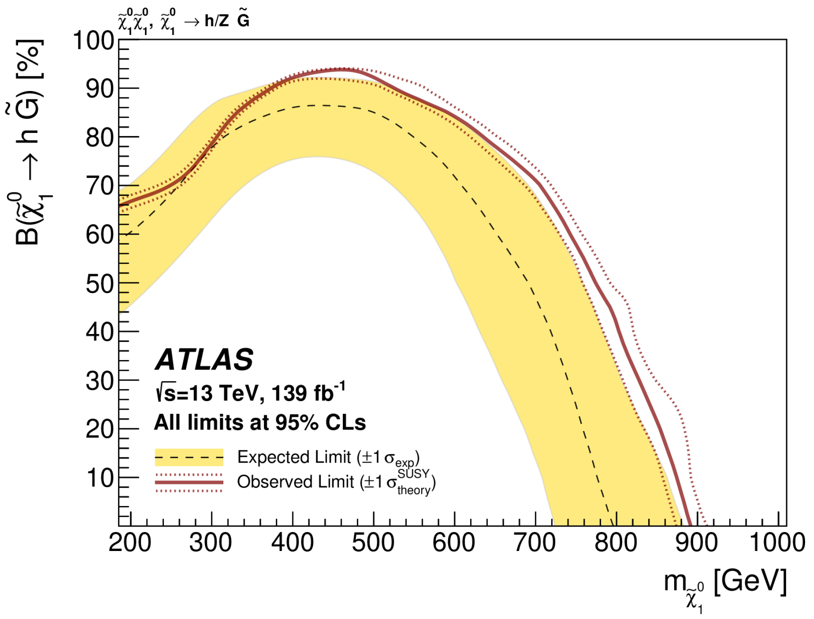


arXiv:2204.13072

EW 2l+2j: results

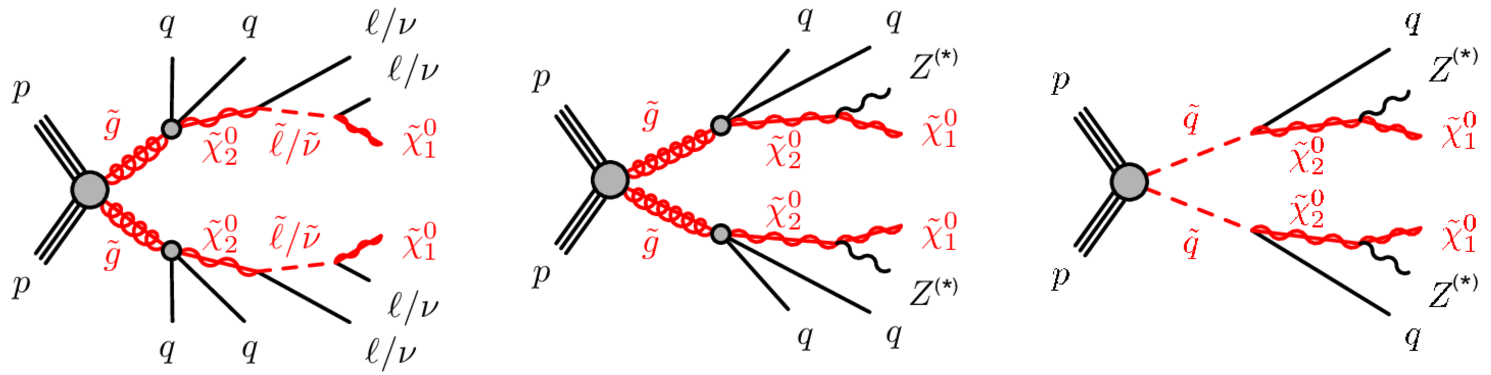
- RJR: model-independent search, a follow-up on the 36/fb 2l2j excess of 2.0σ (ISR region) / 1.4σ (low-mass region)
  - no excess in any of signal regions
- Cut-and-count search: exclude electroweakinos up to 900 GeV

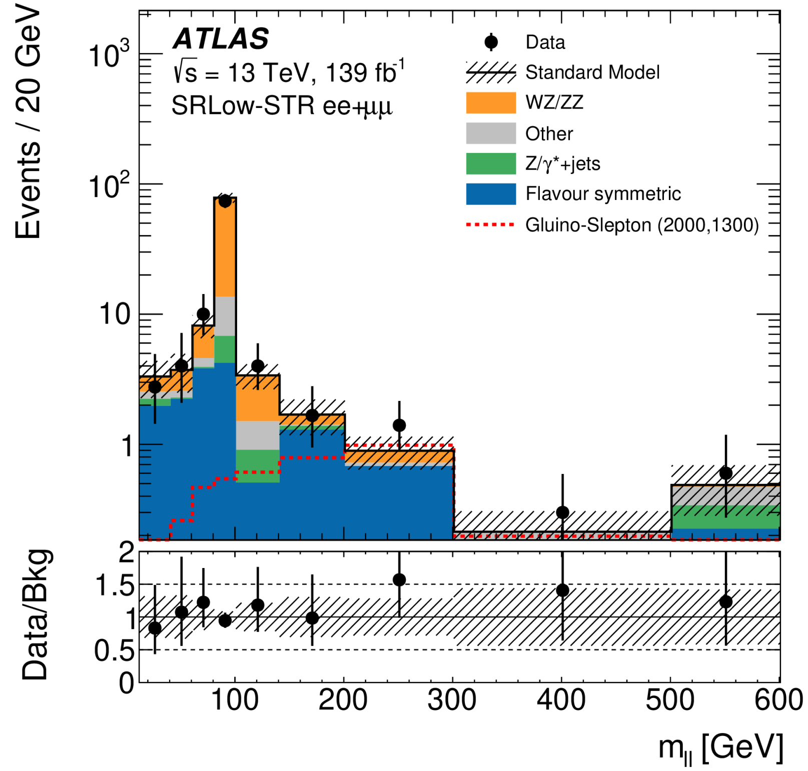


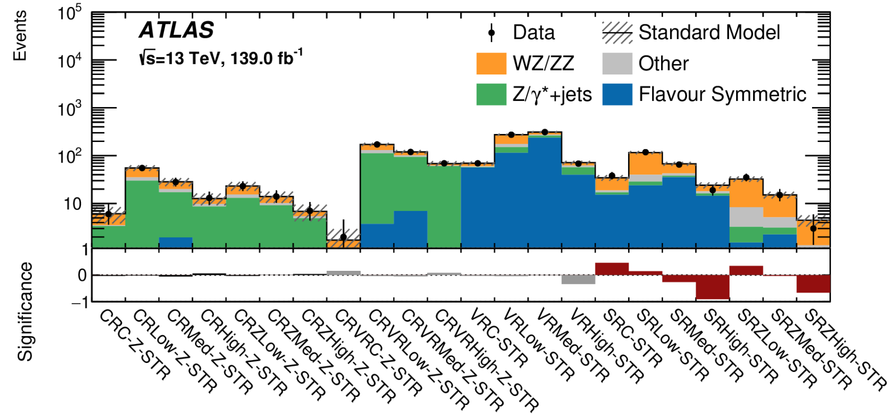


Strong 2l+2j

- Searching for production of squarks / gluinos in events with two OS leptons, ≥2 jets and MET
- 139/fb, cut-and-count
- Models: gluino-slepton, gluino-Z(*), squark-Z(*)
- Backgrounds: VV, tt, Drell-Yan, instrumental



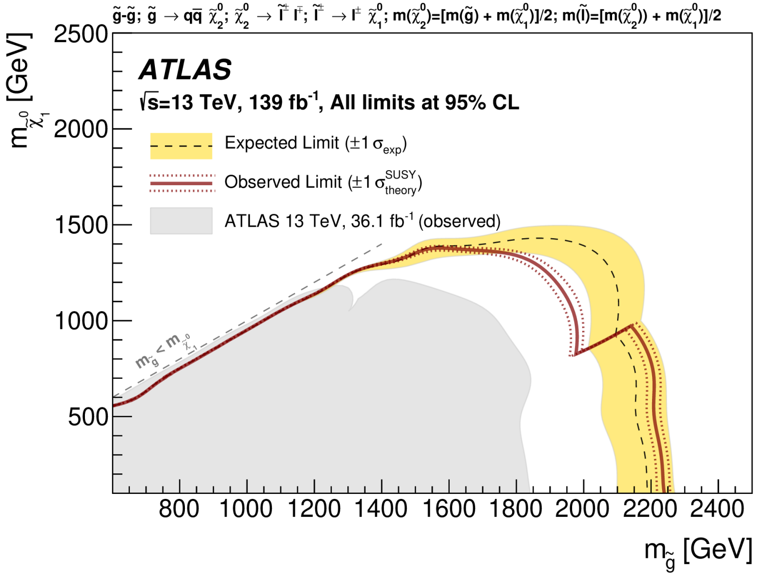


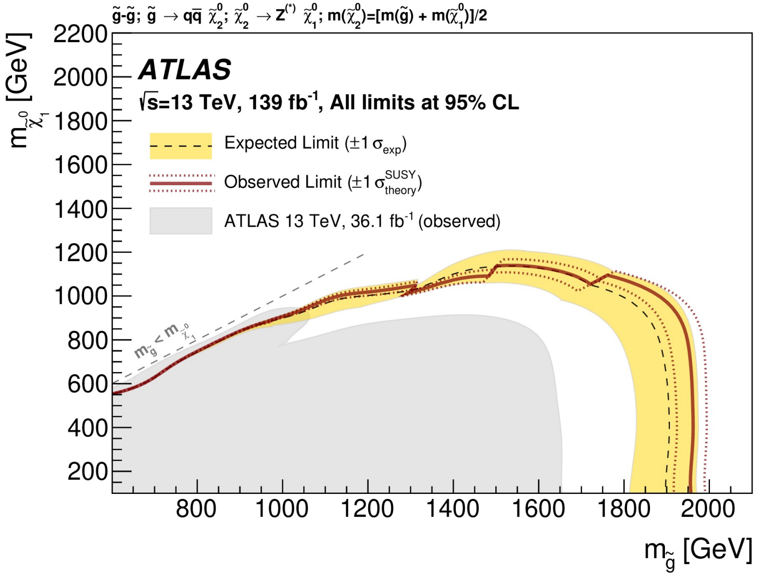


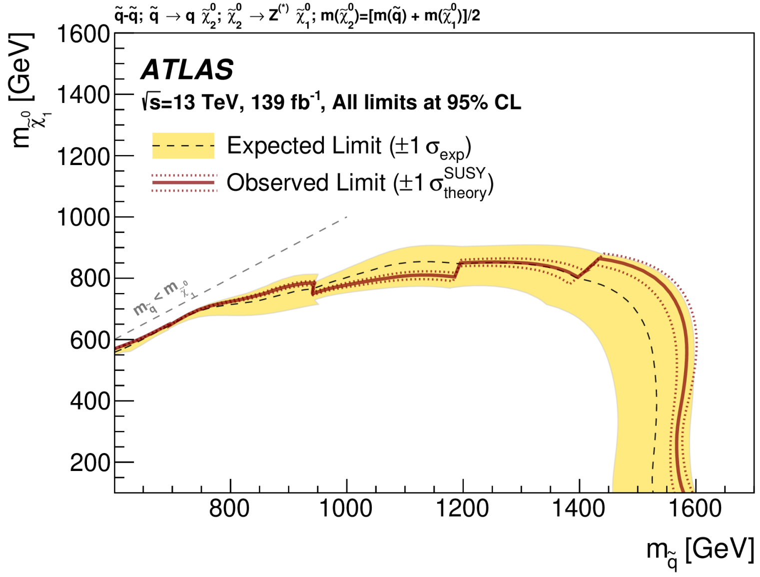
arXiv:2204.13072

Strong 2l+2j: results

- Exclude masses up to 1550 GeV for squarks and 2250 GeV for gluinos

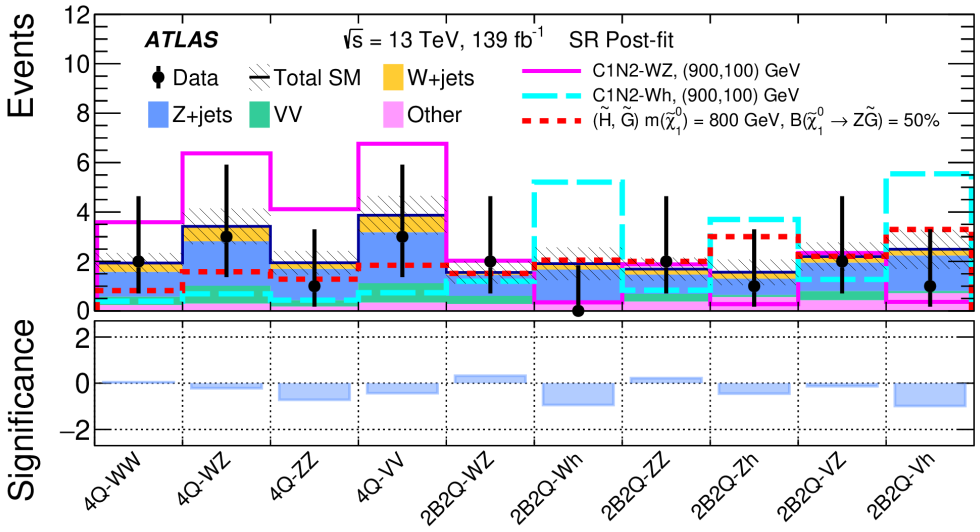


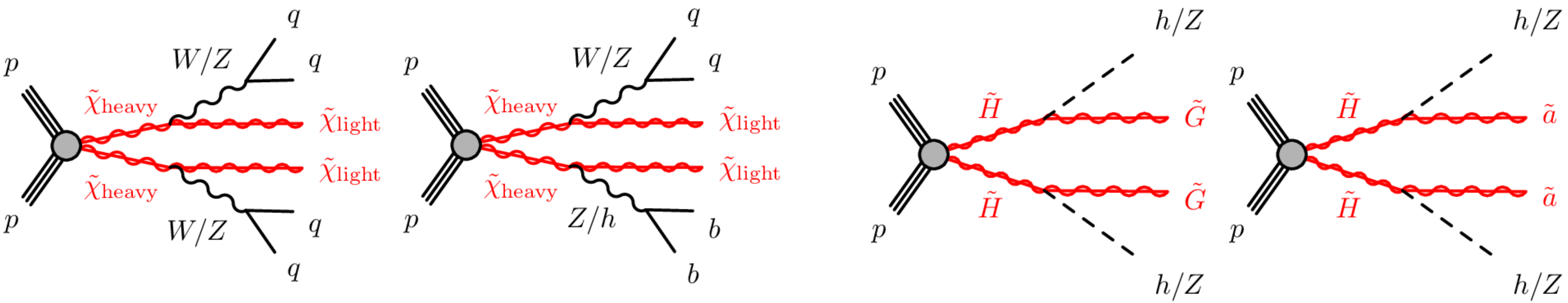




EW all hadronic

- Searching for EW production of charginos / neutralinos in events with two boosted hadronically decaying bosons and MET
- Models: baseline MSSM, GGM / naturalness-driven gravitino LSP, naturalness-driven axino LSP
- Main BG: Z(→νν) +jets – semi-data-driven estimation

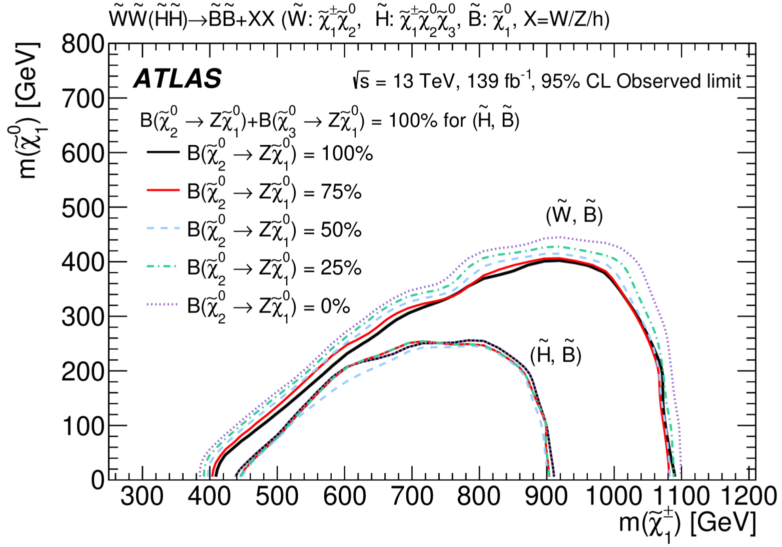


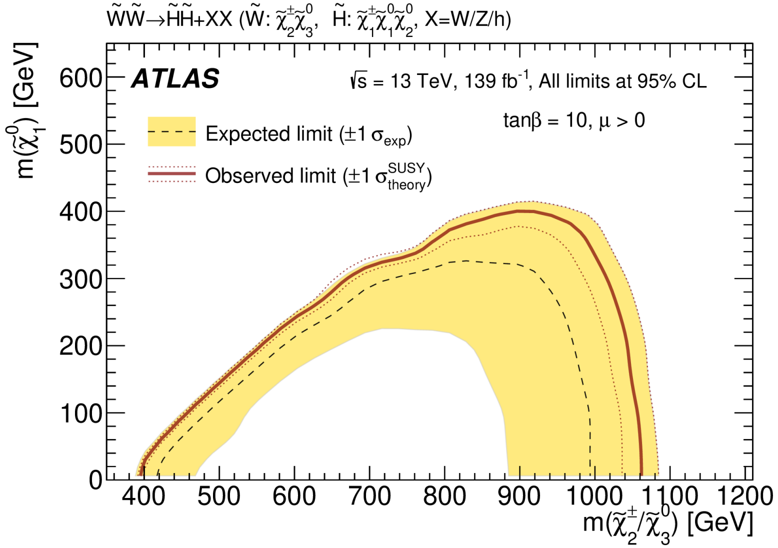


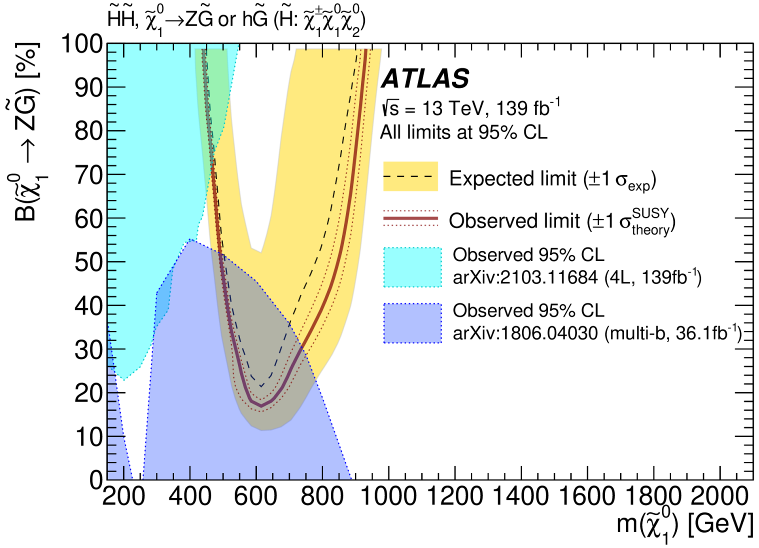
[Phys. Rev. D 104 (2021) 112010]

EW all hadronic: results

- Exclude wino (higgsino) up to 1060 (900) GeV when LSP mass is below 400 (240) GeV and mass splitting is larger than 400 (450) GeV
- Examples of exclusion plots for $(\tilde{W},\tilde{B})/(\tilde{H},\tilde{B})$, $(\tilde{W},\tilde{H})$ and $(\tilde{H},\tilde{G})$ models

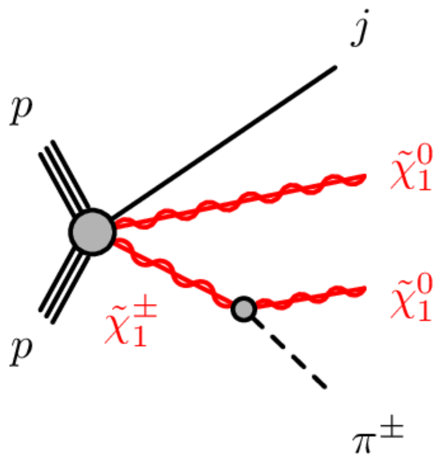


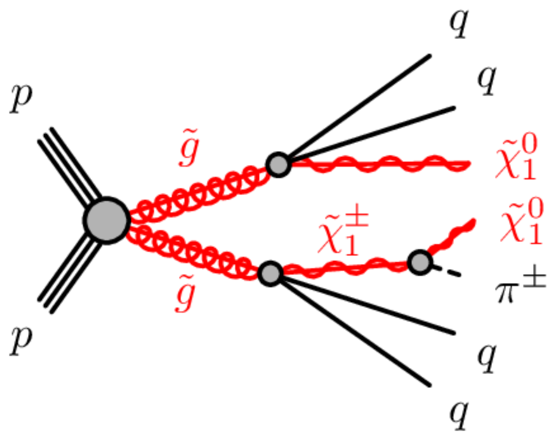


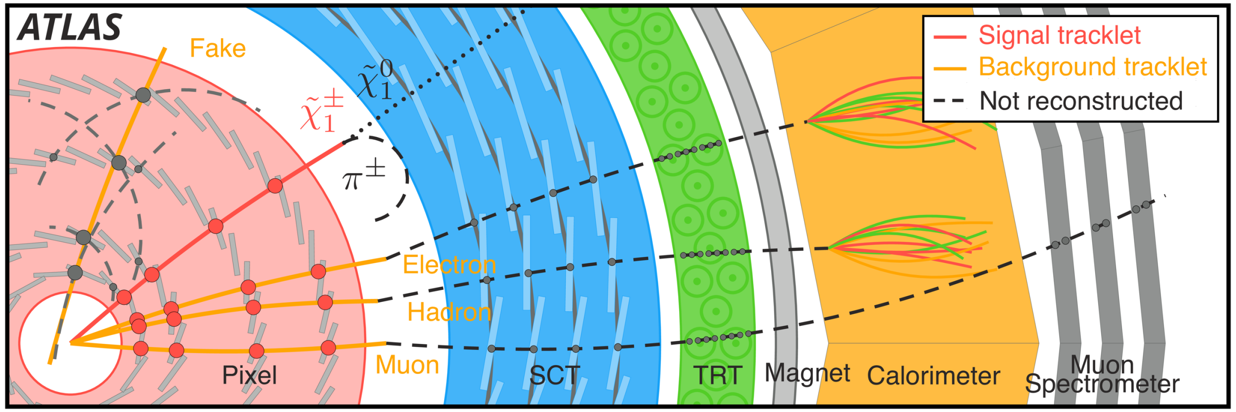


Disappearing track

- Searching for EW or strong production of long-lived charginos decaying into LSP and a low momentum π+ (due to small mass difference between chargino and neutralino)
- Signature: MET + a track that crosses pixel layers and then disappears
- Background is dominated by fake tracklets and it is estimated using a template method in the CR



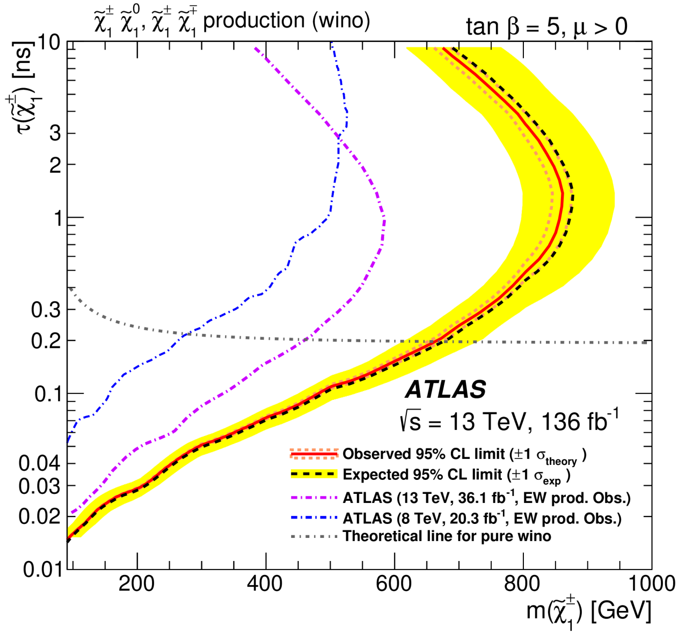


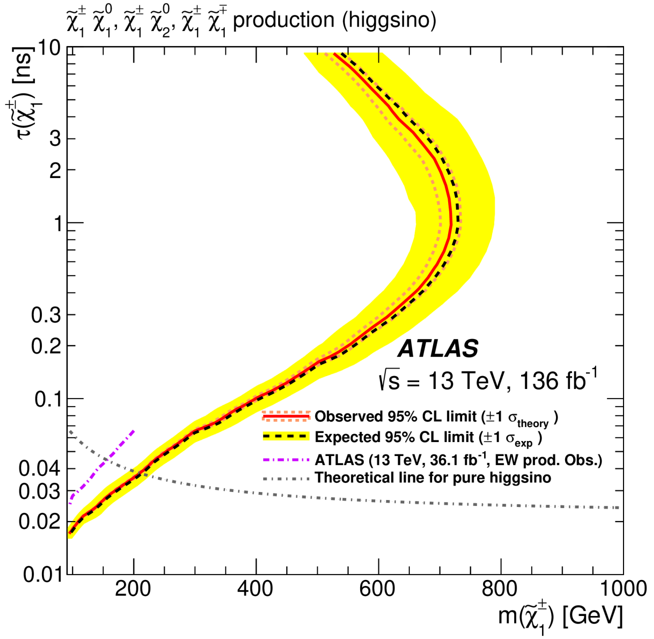


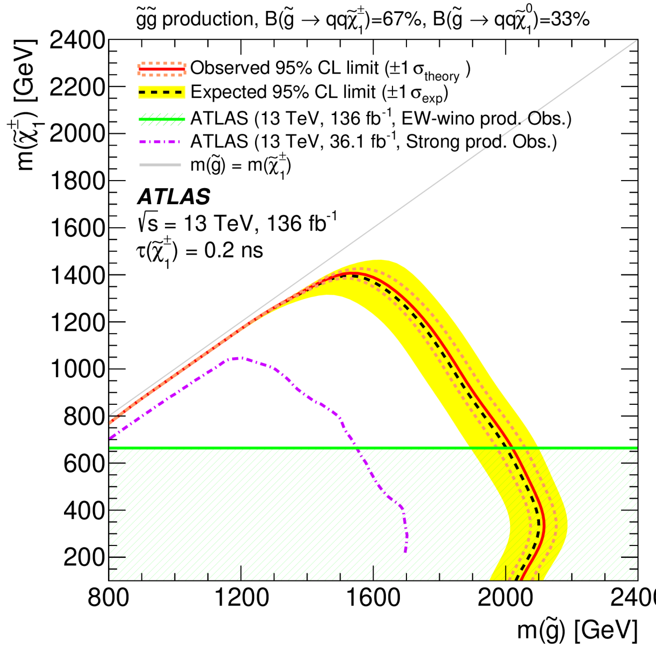
arXiv:2201.02472

Disappearing track: results

- Chargino masses excluded up to 660 (210) GeV when chargino is pure wino (higgsino)
- For charginos from gluino cascade decays, gluinos up to 2.1 TeV are excluded for charginos of 300 GeV and a lifetime of 0.2 ns

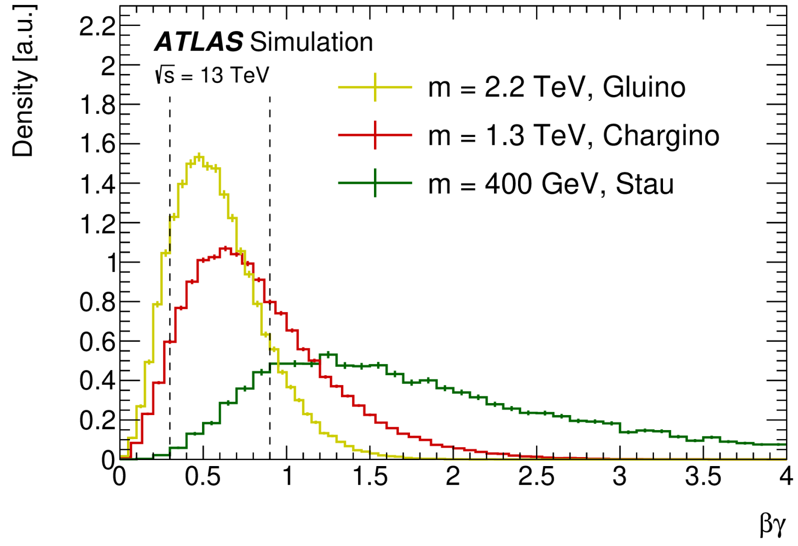


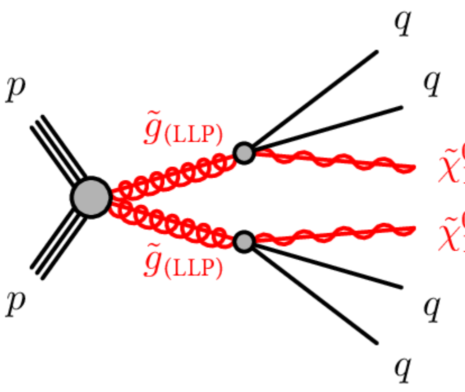


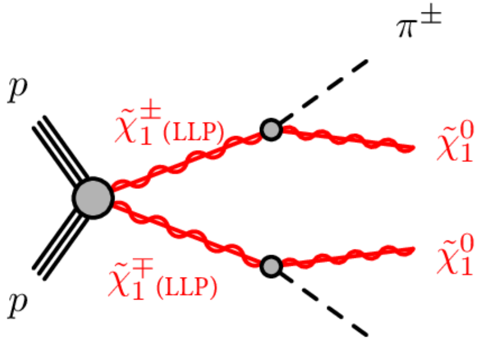


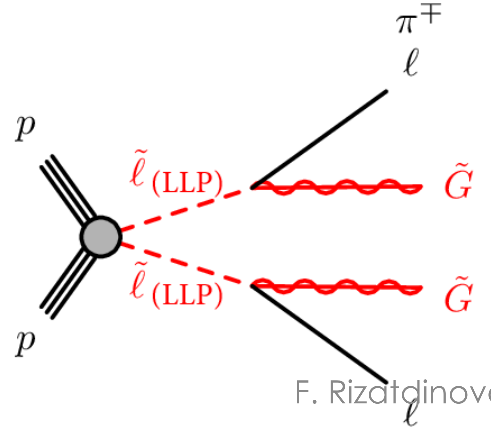
dE/dx in the pixel detector

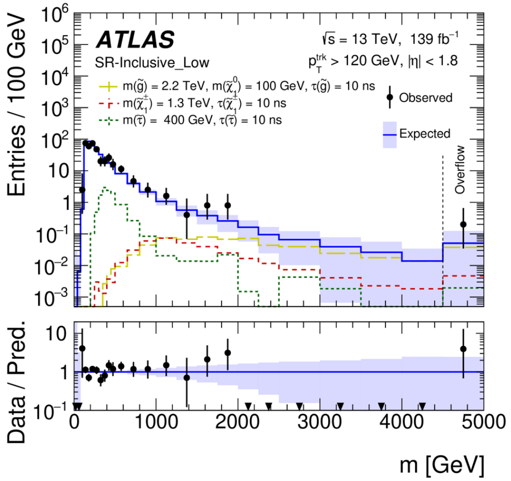
- Searching for EW or strong production of heavy, long-lived R-hadrons / charginos / sleptons
- Signature: a track with large specific ionization losses in the pixel detector + MET
- 139/fb, cut-and-count

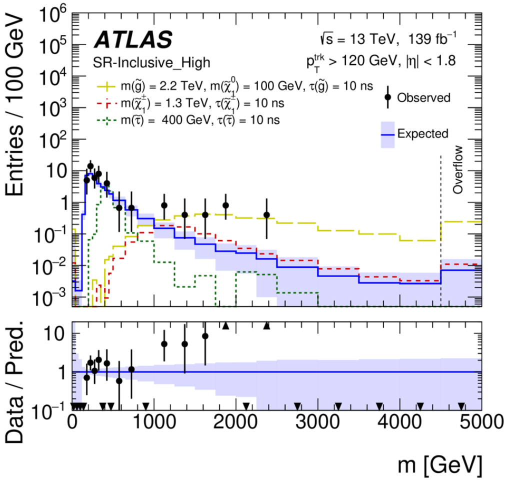








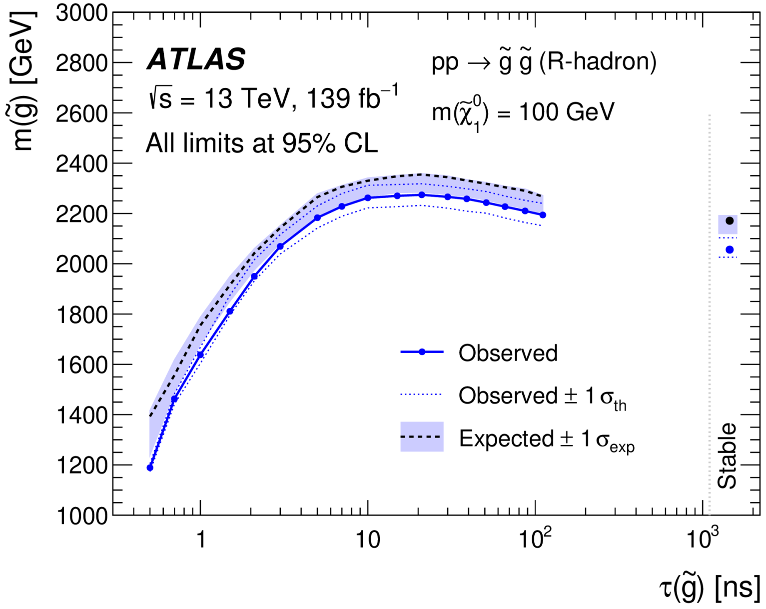


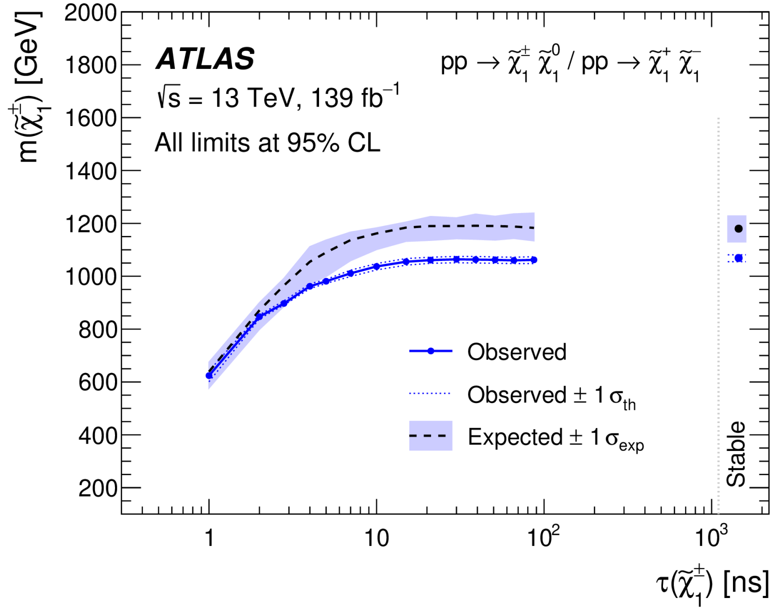


arXiv:2205.06013

dE/dx: results

- Maximum sensitivity achieved for LLPs with lifetimes τ of 10 - 30 ns
- Exclude masses up to 2.27 TeV for gluino R-hadrons with τ=20 ns and an LSP mass of 100 GeV, up to 1.07 TeV for charginos with τ=30 ns





Conclusion

- ATLAS has an extensive SUSY search program
  - various original analyses
  - expanding coverage thanks to reinterpretation of existing results
- Identifying uncovered areas and looking for new ways to explore the SUSY parameter space
- A lot of interesting results are obtained with Run 2 data, more to come
- Looking forward to taking more data with Run 3 that recently started

Thank you!

And special thanks to:

DOE for supporting this research

The ATLAS Collaboration