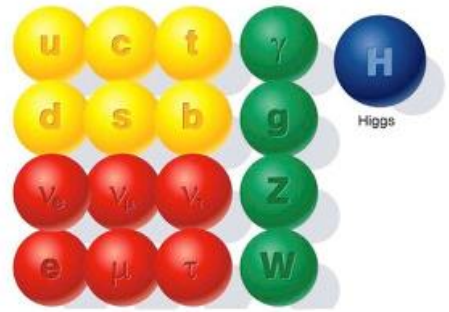
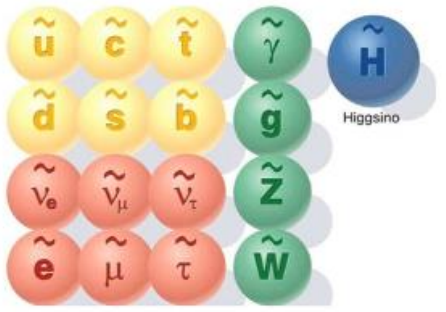


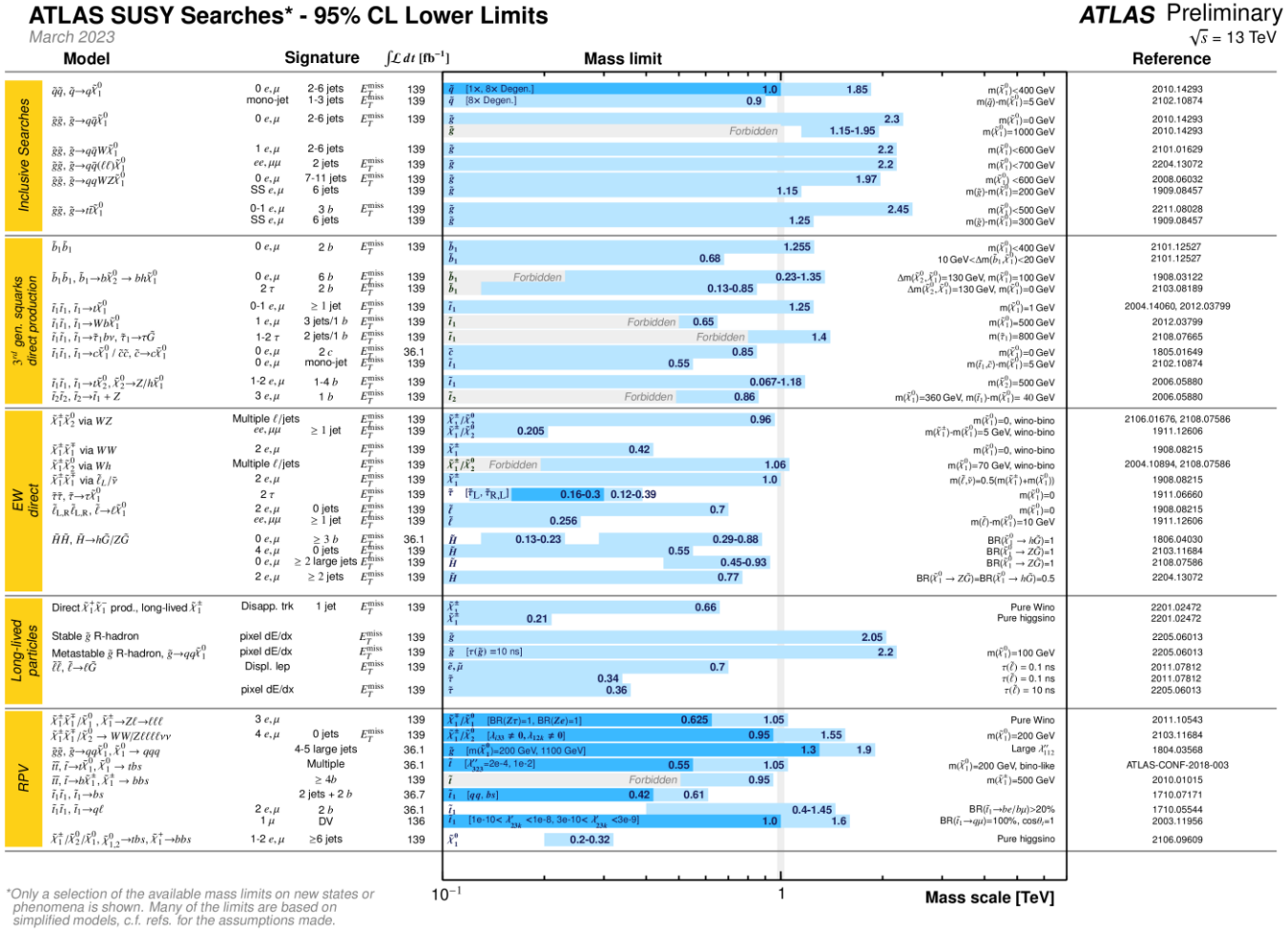


Combinations of SUSY searches

Alexander Khanov on behalf of the ATLAS collaboration

Introduction

- By now, the ATLAS experiment has produced a plethora of search results for SUSY signals in various final states
- As many analyses probe similar SUSY models, combining results from multiple searches would enhance the SUSY signal reach
- An effort has started to arrive at combinations of various SUSY searches



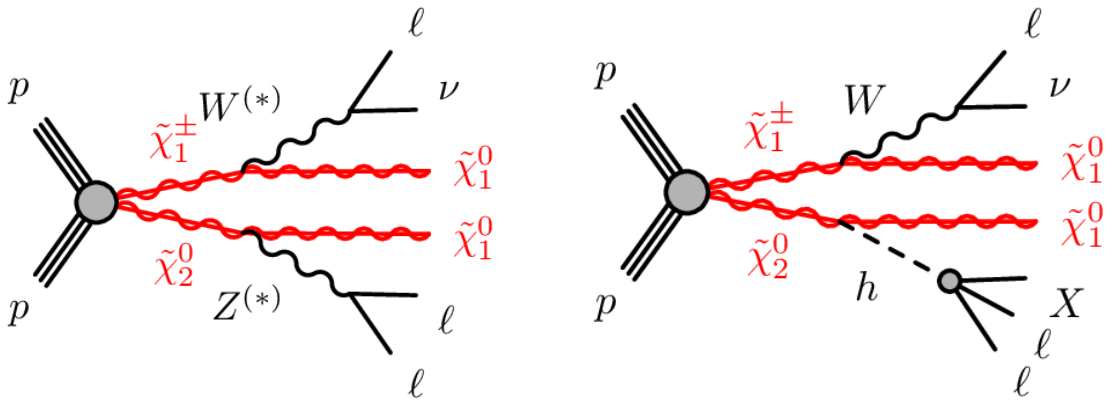
Overview

- Combinations presented in this talk: based on 139/fb of pp data collected by the ATLAS experiment from 2015 to 2018 at $\sqrt{s}$=13 TeV ("Run 2")
  - Electroweak SUSY production in final states with three leptons combined with the search in final states with two soft leptons
  - Constraints on spin-0 dark matter mediators and invisible Higgs decays in final states with two top quarks and missing transverse momentum
- Combination frameworks
- Plans and summary

EW 3L/2L

[Eur. Phys. J. C 81 (2021) 1118]

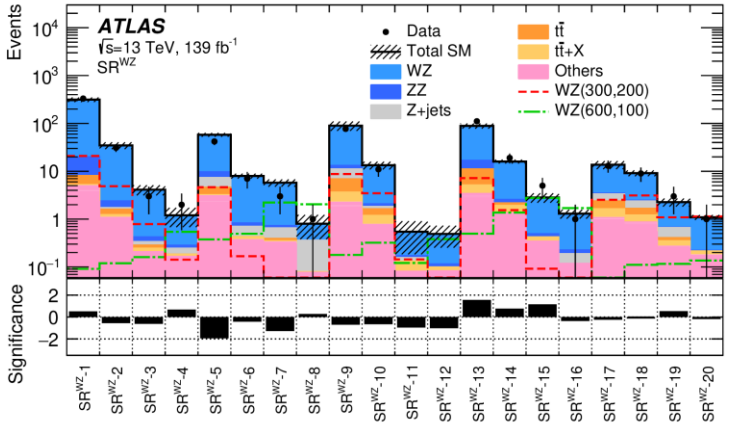
- Targeted simplified models: $\tilde{\chi}_1^{\pm}\,\tilde{\chi}_2^{0} \rightarrow WZ$ / W*Z* / Wh



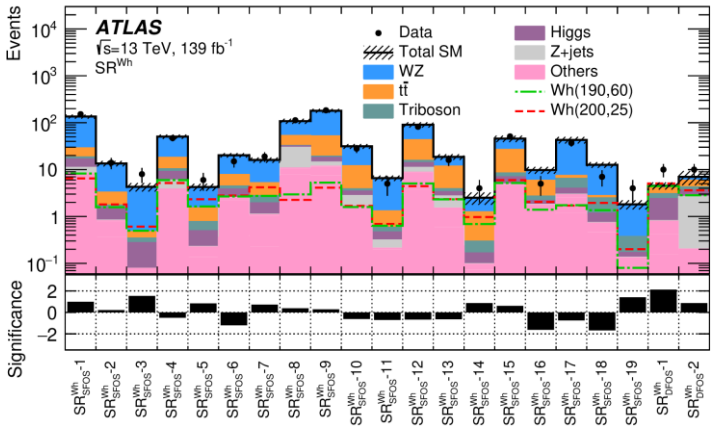
- Physics scenarios:
  - "wino/bino" ($\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^{0}$ are wino and of the same mass, $\tilde{\chi}_1^{0}$ is LSP bino)
  - "higgsino" ($\tilde{\chi}_1^{\pm}\,\tilde{\chi}_2^{0}\,\tilde{\chi}_1^{0}$ is a higgsino triplet, $\tilde{\chi}_1^{\pm}$ mass = mean of $\tilde{\chi}_2^{0}$ and $\tilde{\chi}_1^{0}$ masses)

EW 3L signal selection

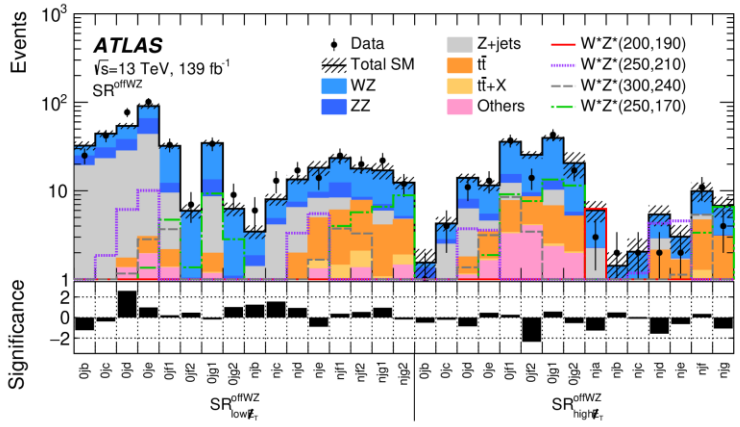
- WZ/Wh selection: =3 leptons (e,μ) with p_T>25/10/10 GeV, MET>50 GeV, b-jet veto to suppress ttbar, 75<m_{ll}<105 GeV (WZ) or m_Z veto (Wh)
- W*Z* selection: =3 leptons with p_T>10 GeV, significant MET, m_{ll}^{max}<75 GeV
- Dominant backgrounds: WZ (in most of signal regions), ZZ, Z+jets
- WZ is normalized to data in control regions (obtained by inverting kinematics)



WZ on-shell



Wh

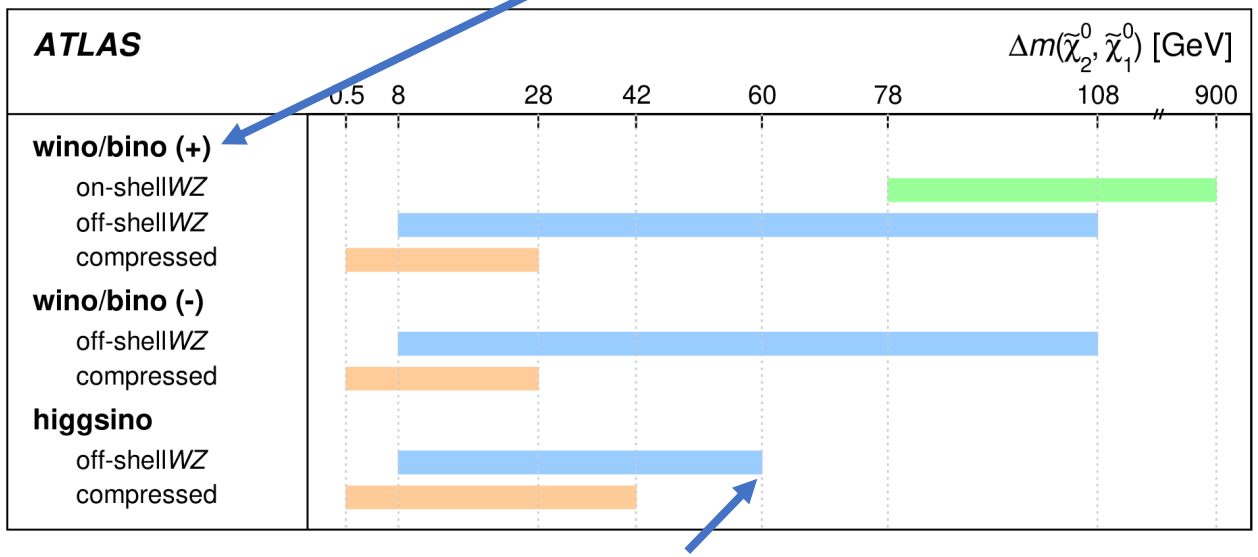


WZ off-shell

EW 3L/2L combination

- Results from 3L analysis are statistically combined with 2L analysis aiming at EW SUSY models with compressed mass spectra
  - 2L selection: = 2 leptons, MET>100 GeV, ≥1 jet with pT>100 GeV, b-jet veto
- 3L WZ on-shell, 3L WZ off-shell, and 2L ("compressed") selections are orthogonal by either m_{ll}/MET or lepton multiplicity
  - statistical combination is straightforward!
- Combined fits for WZ-mediated models:
  - wino/bino (+): on-shell WZ + off-shell WZ + compressed
  - wino/bino (-): off-shell WZ + compressed
  - higgsino: off-shell WZ + compressed
- The models considered for the combinations depend on the $\Delta m(\tilde{\chi}_2^0 \tilde{\chi}_1^0)$ region

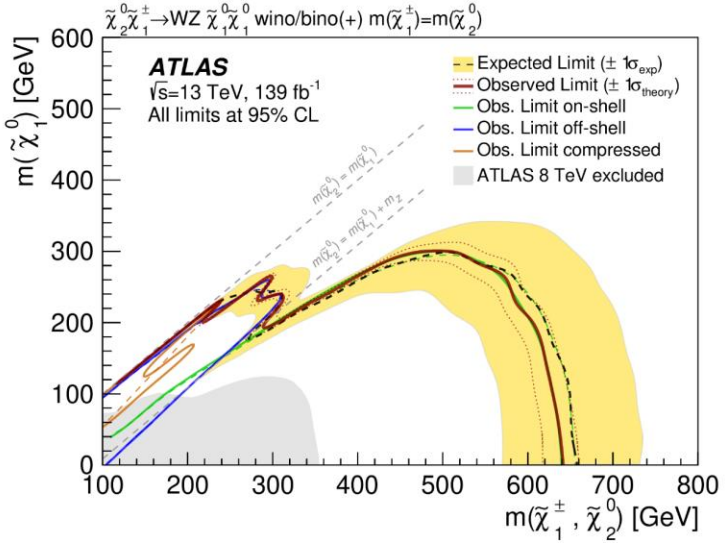
sign of the product of the two neutralino mass eigenstates

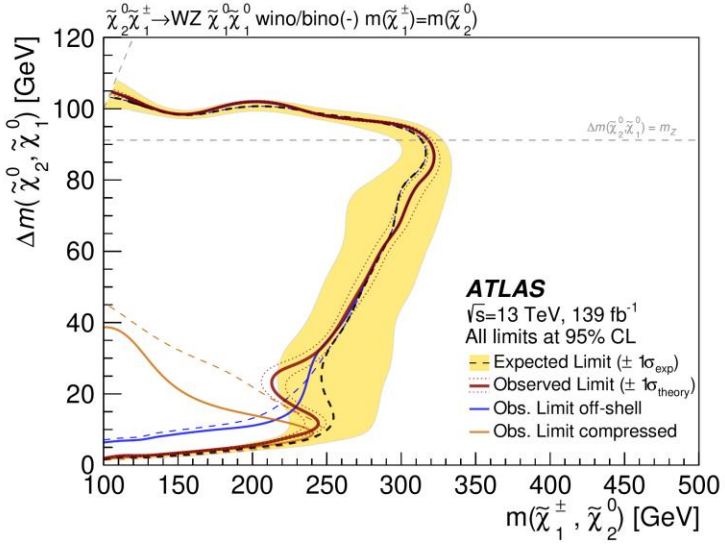


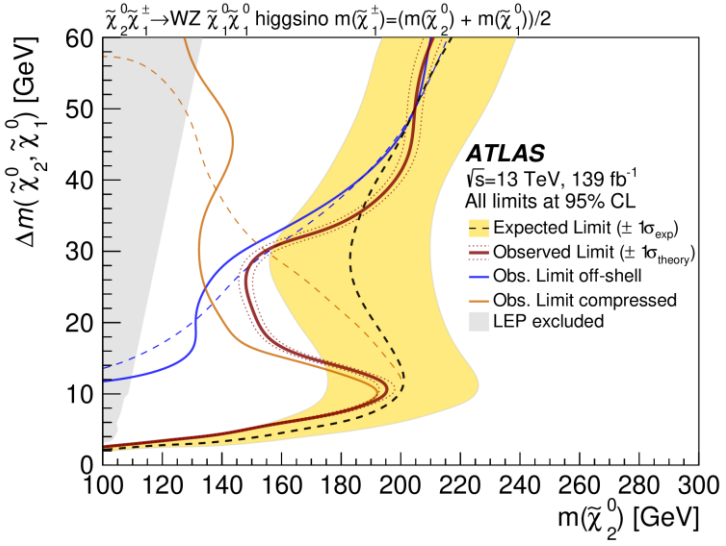
limited for model consistency

EW 3L/2L combination results

- Wino/bino scenario: limits on $m(\tilde{\chi}_2^0)$ up to 640 (300) GeV for on-shell (off-shell) WZ
- Higgsino: limits on $m(\tilde{\chi}_2^0)$ up to 210 GeV



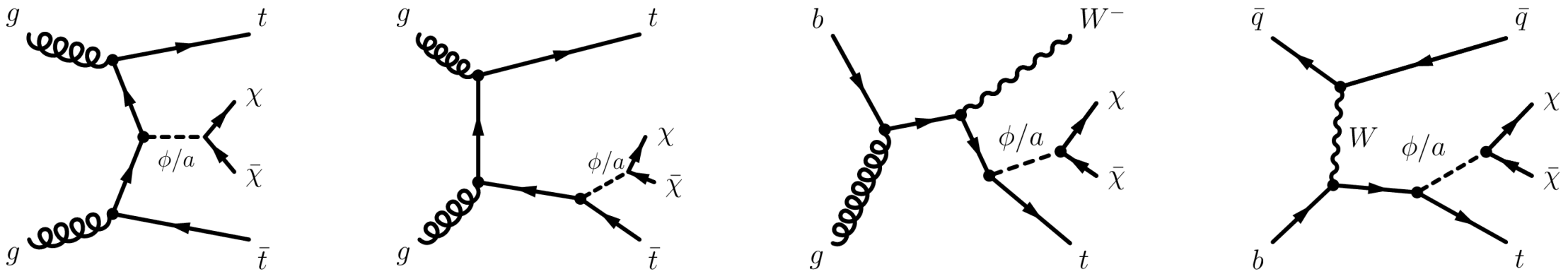




DMtt

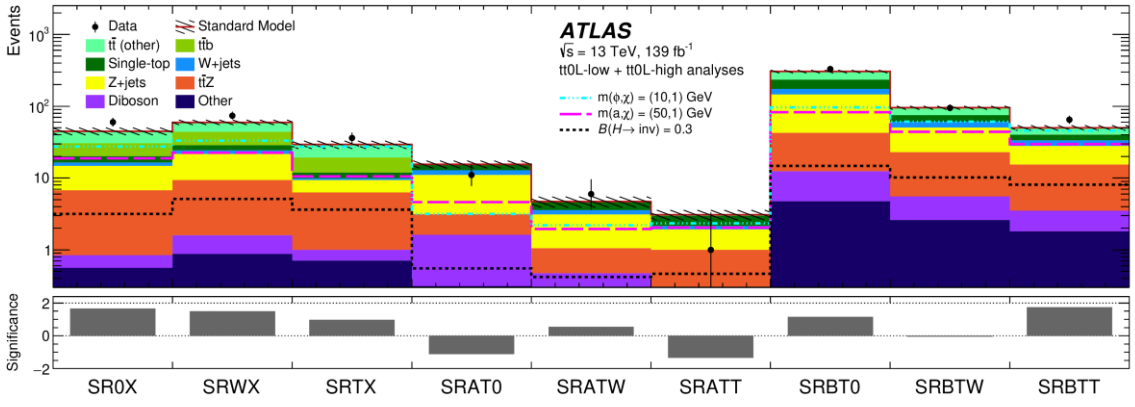
[Eur. Phys. J. C 83 (2023) 503]

- Motivation: WIMP dark matter pair-produced through exchange of a color-neutral scalar / pseudo scalar ("mediator")
  - dominant production modes: gluon fusion and associated production with top
- In addition to top-quark-pair, also consider single-top-quark production
  - scalar: impact of single top negligible for mediator masses below 50 GeV
  - pseudoscalar: σ(DM+tt)/σ(DM+t) fairly mass independent
- Depending on top decays, may have 0/1/2 leptons in the final state

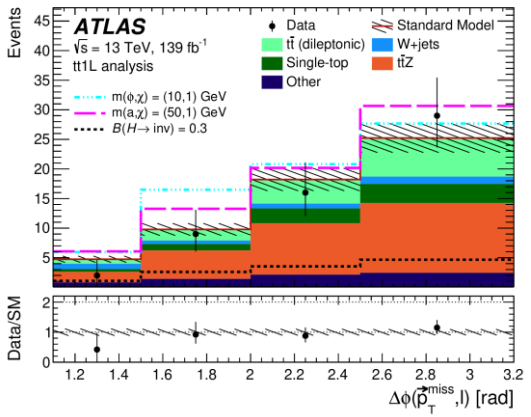


DMtt: analysis channels

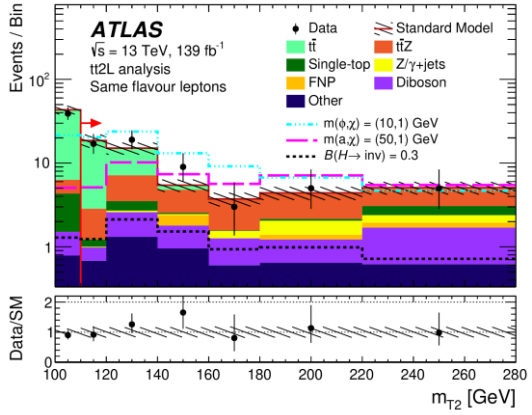
- tt0L: MET/b-triggers, =0 lepton, ≥4 jets, ≥2 b-tagged jets, MET>160 GeV
  - originally optimized for stop pair production searches
- tt1L: MET triggers, =1 lepton, ≥4 jets, ≥2 b-tagged jets, MET>230 GeV, METsig>15
  - originally designed to target spin-0 DM models
- tt2L: dilepton triggers, =2 OC leptons, ≥1 b-tagged jets, METsig>12 (+Z veto for same-flavor lepton pairs)



tt0L: signal regions



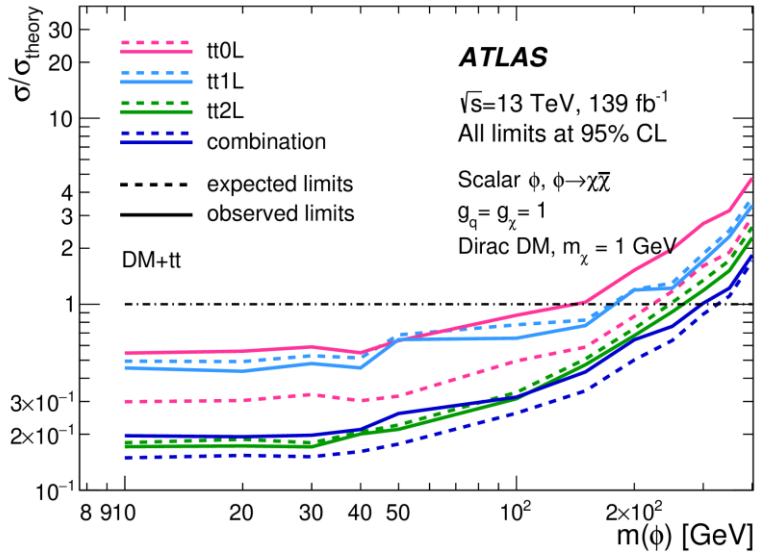
tt1L: $\Delta\varphi(p_T^{miss}, l)$

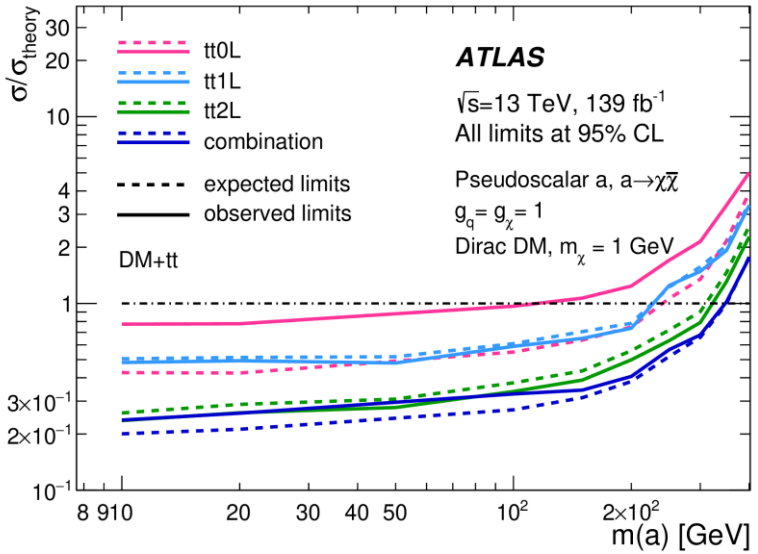


tt2L: m_{T2}

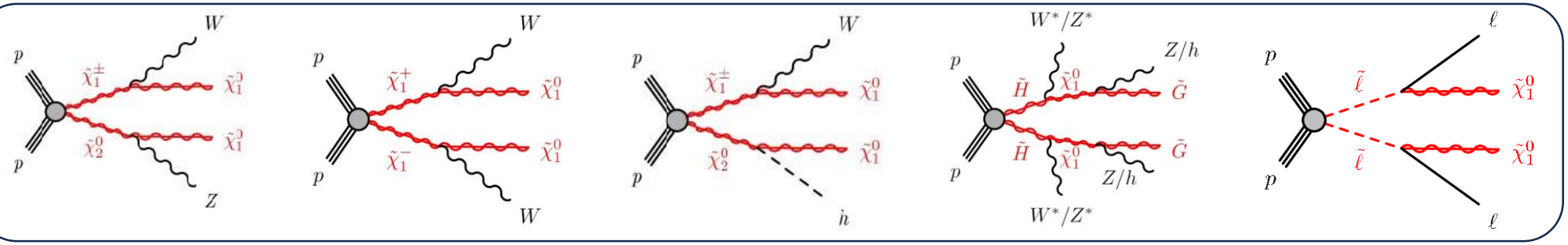
DMtt: results

- The statistical combination for scalar (pseudoscalar) DM models, extends the mass range for the best individual channel by 50 (25) GeV, excluding mediator masses up to 370 GeV
  - For DMtt only, excluded scalar (pseudoscalar) mass range is reduced by 70 (20) GeV
- The combination improves the expected coupling exclusion reach improves by 14% (24%)
- If the mediator is the SM 125 GeV Higgs boson, upper limit on observed (expected) branching at 95% CL is 0.38 (0.30 +0.13 −0.19)

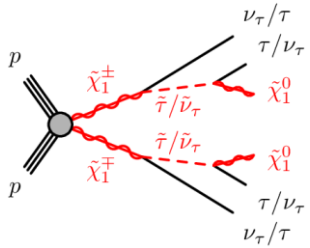




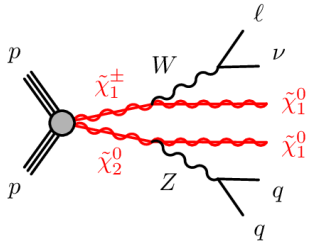
Plans: EW simplified model combination



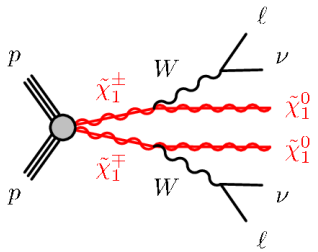
Targeted models: direct wino-bino, higgsino, and slepton production



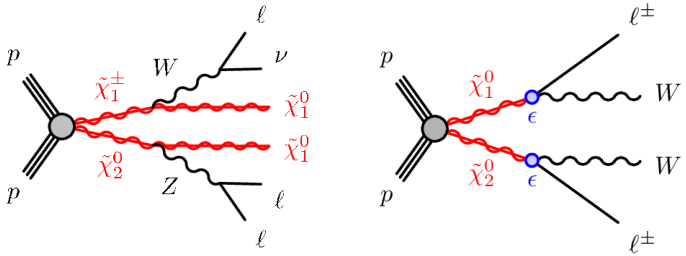
[ATLAS-CONF-2022-042]



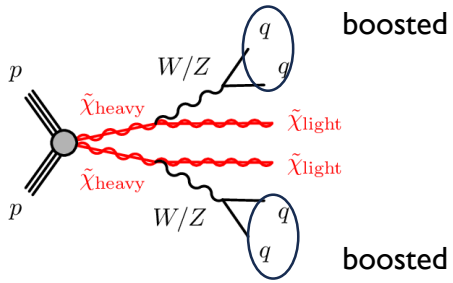
[ATLAS-CONF-2022-059]



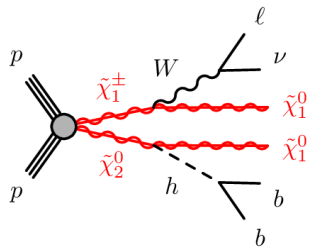
[JHEP 06 (2023) 031]



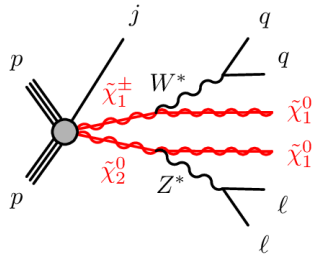
[arXiv:2305.09322]



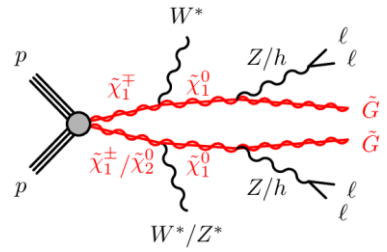
[Phys. Rev. D 104 (2021) 112010]



[Eur. Phys. J. C 80 (2020) 691]



[Phys. Rev. D 101 (2020) 052005]



[JHEP 07 (2021) 167]

DIY SUSY searches

- SUSY searches are often interpreted in terms of simplified models with fixed decay modes and limited SUSY particles set
  - good: straightforward interpretation in terms of individual sparticle production and decay vs masses
  - bad: limits obtained in such models are not necessarily a good approximation of constraints on model parameters when interpreted in more complete models
- ATLAS has started to publish full analysis likelihoods on HEPdata
  - new theories can be tested as a patch on top of original analysis likelihood
  - get an estimation of the signal yields for your theory with ATLAS SimpleAnalysis [ATL-PHYS-PUB-2022-017]
- Re-interpretation of searches can quickly become CPU heavy
  - in Run 1 19-parameter pMSSM re-interpretation [JHEP 10 (2015) 134], ~10^9 models were sampled and 3×10^5 points selected based on experimental constraints
  - a possible procedure to quickly classify models into safely (non-)excluded models and those where exclusion is uncertain: simplified likelihoods [ATL-PHYS-PUB-2021-038]

Summary

- Combination of various SUSY searches in different final states is necessary to improve the sensitivity of analyses and increase the mass reach
- Combination of existing analyses done without orthogonality of final states in mind is difficult
- ATLAS started a systematic effort in that direction, first results already look interesting
- More results to come!