Towards improved electroweakino limits

Krzysztof Rolbiecki

Norway grants

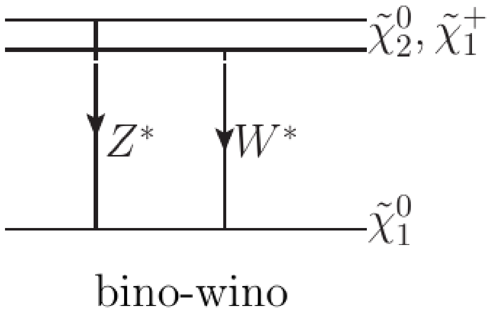
National Science Centre Poland

Contents

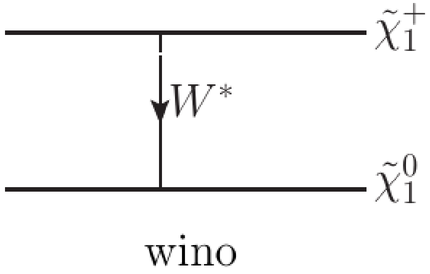
1. Short introduction
2. What we found so far – paper published
3. Way ahead: ATLAS vs CMS comparison

Light SUSY dark matter

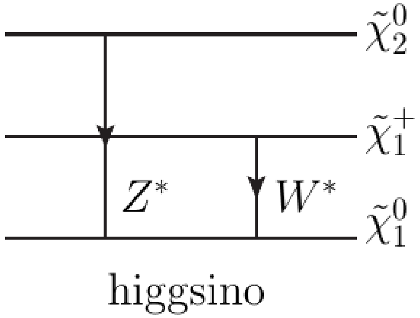
- bino-wino: almost mass degenerate winos and bino LSP



- wino LSP: $M_2 \ll M_1, \mu$, two quasi-degenerate states: χ_1^0, $\chi_1^\pm$



- higgsino LSP, $\mu \ll M_1, M_2$, three quasi-degenerate states: $\tilde{\chi}_1^0$, $\tilde{\chi}_1^\pm$, $\tilde{\chi}_2^0$

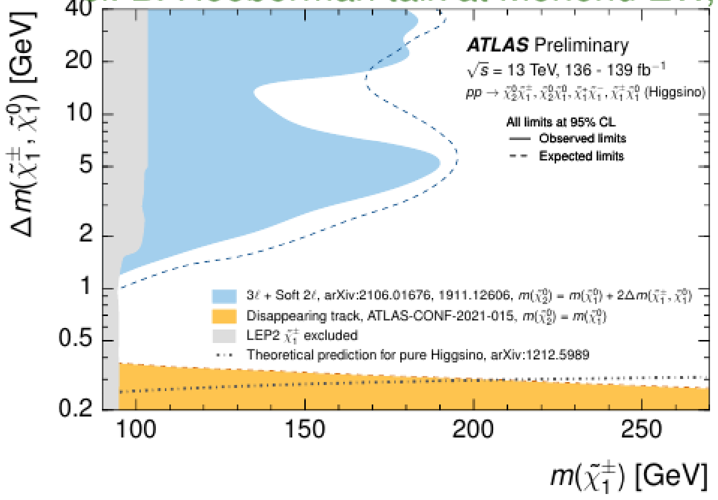


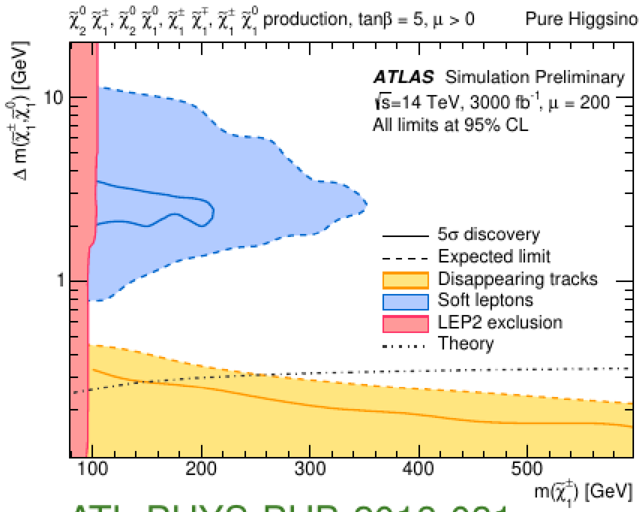
- mass splittings of order 100–1000 MeV

Search strategies

- for sufficiently small mass gap a long-lived massive particle travels macroscopic distance in the detector
- possible signatures: displaced vertex, heavy charged track, displaced jet etc.
- for a larger mass difference (> 1 GeV) look for soft decay products
- at HL the gap remains
- for winos no exclusion in soft ℓ search!

cf. B. Hooberman talk at Moriond EW, 14.03.22

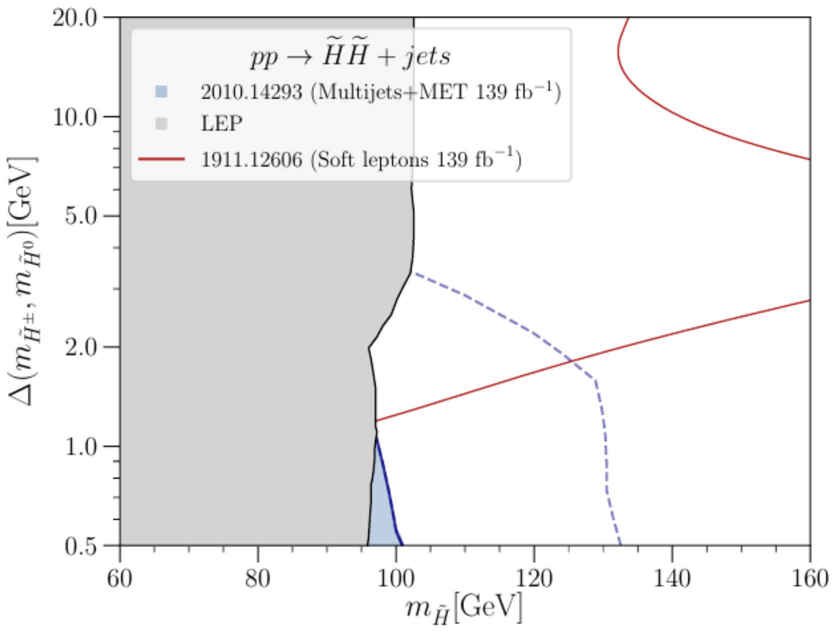




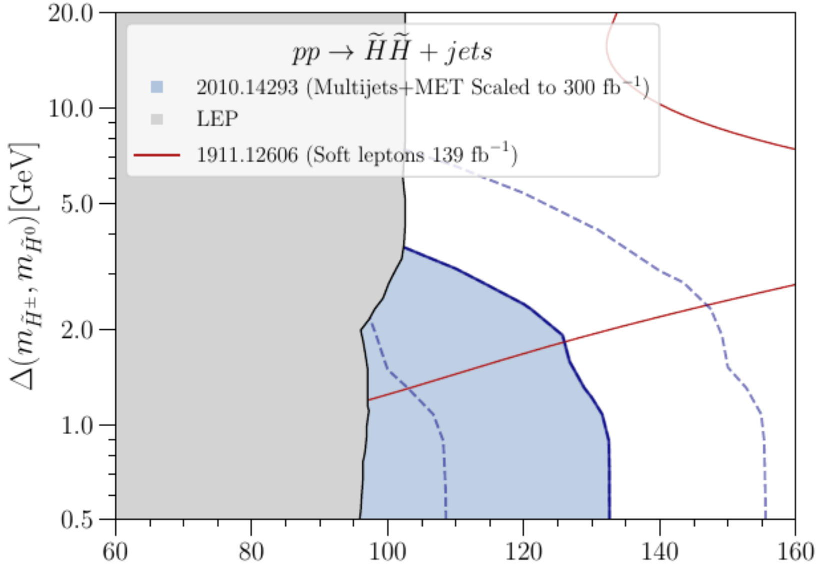
ATL-PHYS-PUB-2018-031

Limits: higgsinos

- higgsino model
- $pp \to \widetilde{H}^{\pm}\widetilde{H}^{0}_{1,2}, \widetilde{H}^{+}\widetilde{H}^{-}, \widetilde{H}^{0}_{1}\widetilde{H}^{0}_{2}$
- $\widetilde{H}^{\pm} \to \widetilde{H}^{0}_{1}W^{*}, \widetilde{H}^{0}_{2} \to \widetilde{H}^{0}_{1}Z^{*}$
- currently the limit only slightly above LEP

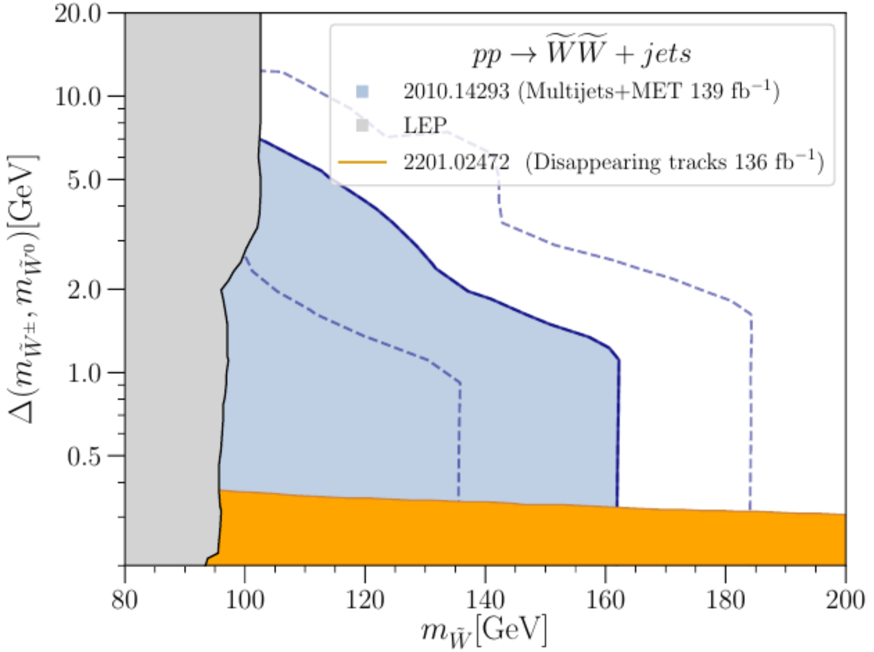


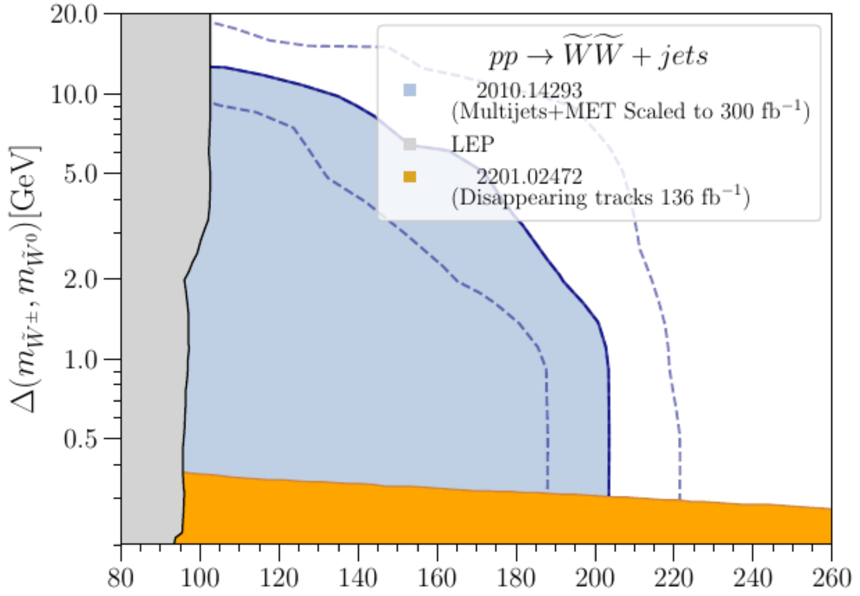
- after Run 3 the expected limit increases to 130 GeV



Limits: winos

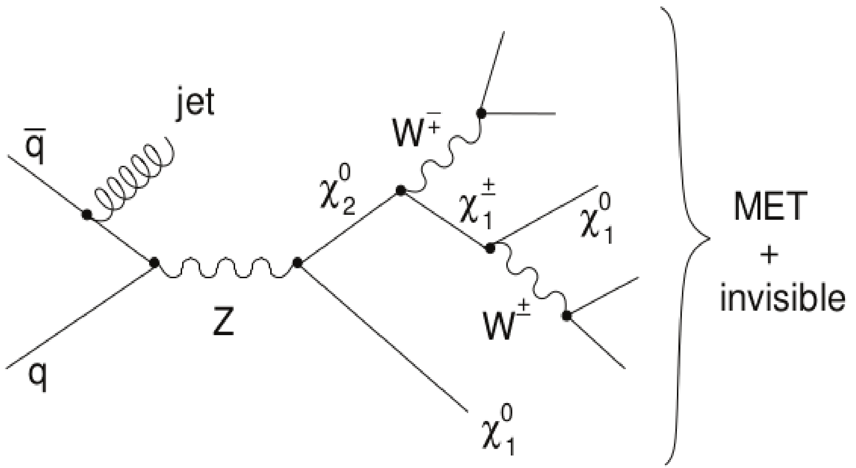
- $\widetilde{W}^{\pm} \to \widetilde{W}^{0} W^{*}$
- $\widetilde{W}^{0}$ stable (DM candidate)
- soft decay products but no same-flavour opposite-charge from Z^{*} and no limits
- the limits from LEP and the search for semi-stable chargino
- the new exclusion on top of LEP and long-lived charged wino limits
- after Run 3 the expected limit increases to 200 GeV

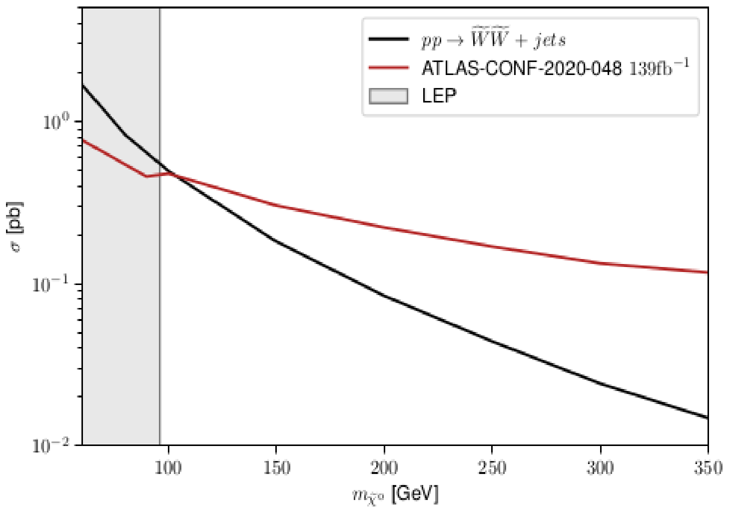


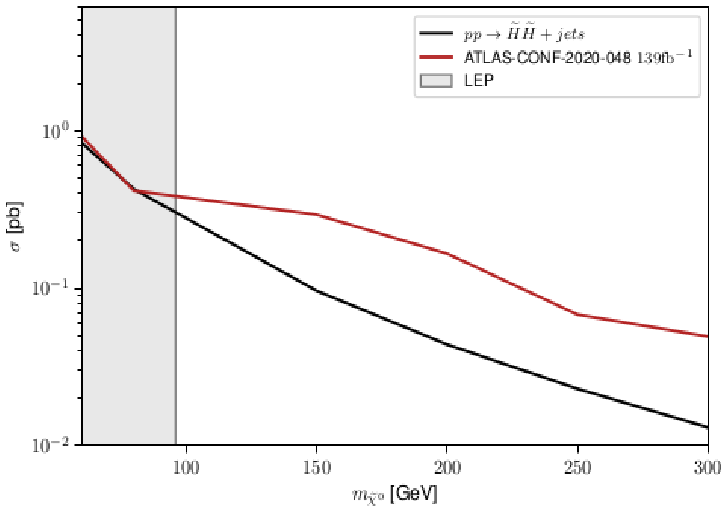


"Monojet" searches

- Monojet (and -photon) signal at ATLAS and CMS
- Requires $p^{j}_{\mathrm{leading}} > 150$ GeV, $E_{\mathrm{T}}^{\mathrm{miss}} > 200$ GeV
- Note: “mono” $\equiv$ “up to 4”
- Decay products soft and escaping detection







"Multijet" search by ATLAS

- we recast with CheckMATE a general search for squarks and gluinos, arXiv:2010.14293, in total 70 signal regions
- basic (preselection) signal requirements:
  - no electrons or muons
  - 2–6 jets
  - large missing energy > 300 GeV
  - hard leading jet $p_T > 200$ GeV
  - large effective mass > 800 GeV
- note some overlap of the final states with "mono"-jet
- we focus on bins with the largest sensitivity (originally intended for squark pair production):
  - 2–3 jets, $p_{\mathrm{T}}^{\mathrm{jet1}}, p_{\mathrm{T}}^{\mathrm{jet2}} > 250$ GeV
  - effective mass > 1600 GeV
  - $E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}} > 16\sqrt{\mathrm{GeV}}$
  - perform a multibin fit using HistFitter

Can we do better? Try CMS multijet

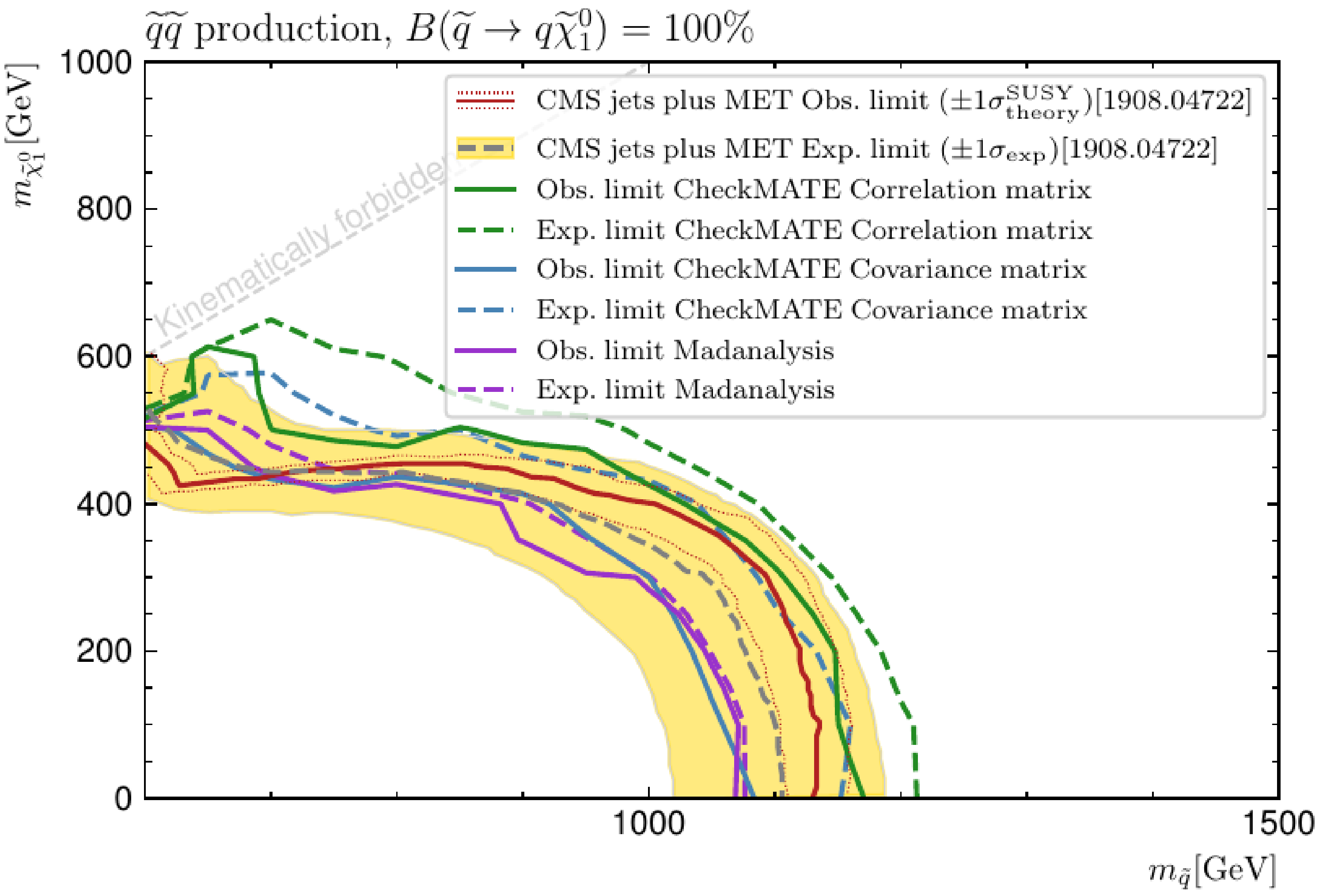
- CMS-SUS-19-006 – different selections wrt ATLAS

  - $N_{\text{jet}} \geq 2$, where jets must appear within $|\eta| < 2.4$;
  - $H_{\text{T}} > 300\,\text{GeV}$, where H_{T} is the scalar p_{T} sum of jets with $|\eta| < 2.4$;
  - $H_{\text{T}}^{\text{miss}} > 300\,\text{GeV}$, where $H_{\text{T}}^{\text{miss}}$ is the magnitude of $\vec{H}_{\text{T}}^{\text{miss}}$, the negative of the vector p_{T} sum of jets with $|\eta| < 5$; an extended η range is used to calculate $H_{\text{T}}^{\text{miss}}$ so that it better represents the total missing momentum in an event;
  - $H_{\text{T}}^{\text{miss}} < H_{\text{T}}$, because events with $H_{\text{T}}^{\text{miss}} > H_{\text{T}}$ are likely to arise from mismeasurement;
  - no identified isolated electron or muon candidate with $p_{\text{T}} > 10\,\text{GeV}$;
  - no isolated track with $m_{\text{T}} < 100\,\text{GeV}$ and $p_{\text{T}} > 10\,\text{GeV}$ ($p_{\text{T}} > 5\,\text{GeV}$ if the track is identified as a PF electron or muon), where m_{T} is the transverse mass [52] formed from $\vec{p}_{\text{T}}^{\text{miss}}$ and the isolated-track p_{T} vector, with $\vec{p}_{\text{T}}^{\text{miss}}$ the negative of the vector p_{T}
  - $\Delta\phi_{H_{\text{T}}^{\text{miss}},\text{j}_i} > 0.5$ for the two highest p_{T} jets j_1 and j_2, with $\Delta\phi_{H_{\text{T}}^{\text{miss}},\text{j}_i}$ the azimuthal angle between $\vec{H}_{\text{T}}^{\text{miss}}$ and the p_{T} vector of jet j_i; if $N_{\text{jet}} \geq 3$, then, in addition, $\Delta\phi_{H_{\text{T}}^{\text{miss}},\text{j}_3} > 0.3$ for the third-highest p_{T} jet j_3; if $N_{\text{jet}} \geq 4$, then, yet in addition, $\Delta\phi_{H_{\text{T}}^{\text{miss}},\text{j}_4} > 0.3$ for the fourth-highest p_{T} jet j_4; all considered jets must have $|\eta| < 2.4$; these requirements

CMS mutltibin fit

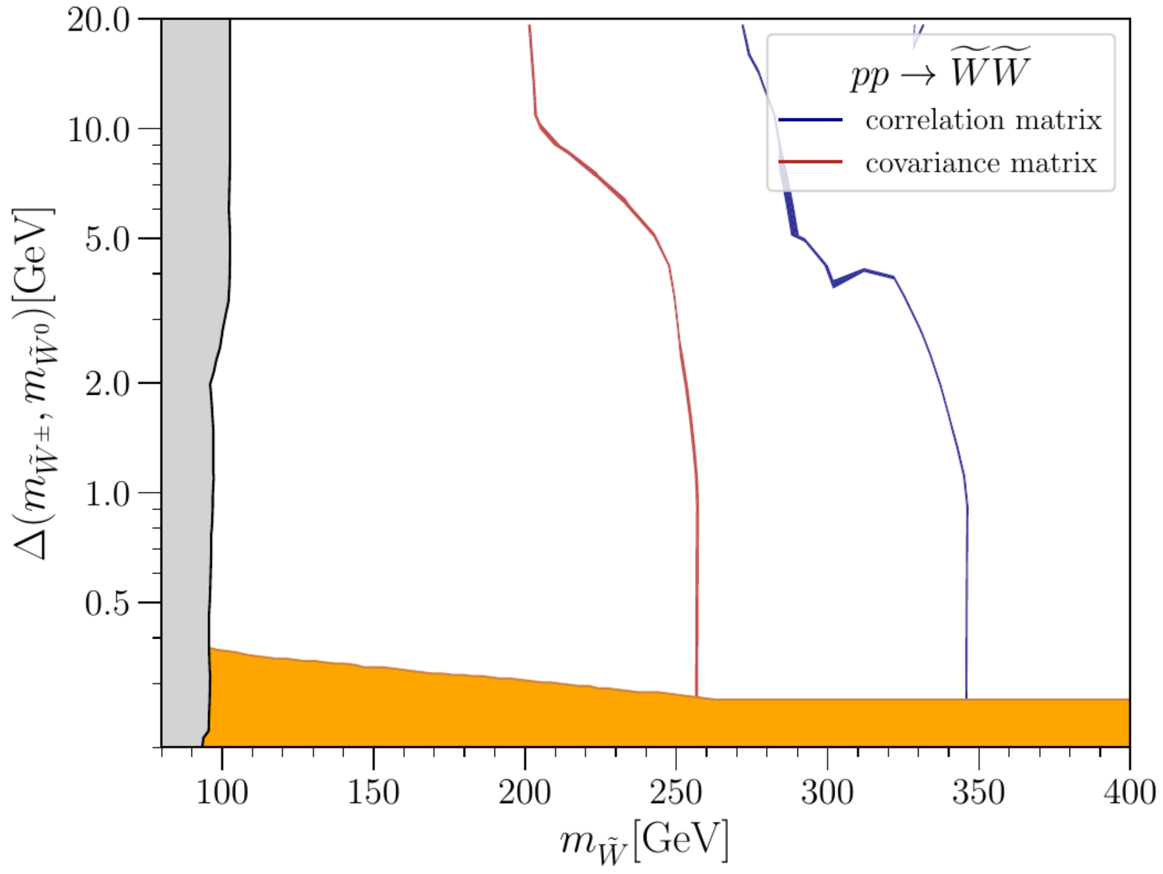
- Global fit to 174 signal regions
- Background contributions as nuisance parameters: covariance matrix provided
- Numerous problems with reinterpretation input: mixed and inconsistent prefit and postfit data
- Problems with convergence and stability of fit (using RooStats, not only us: MadAnalysis also runs into problems using pure Python)

Reproducing squark limit and sanity check

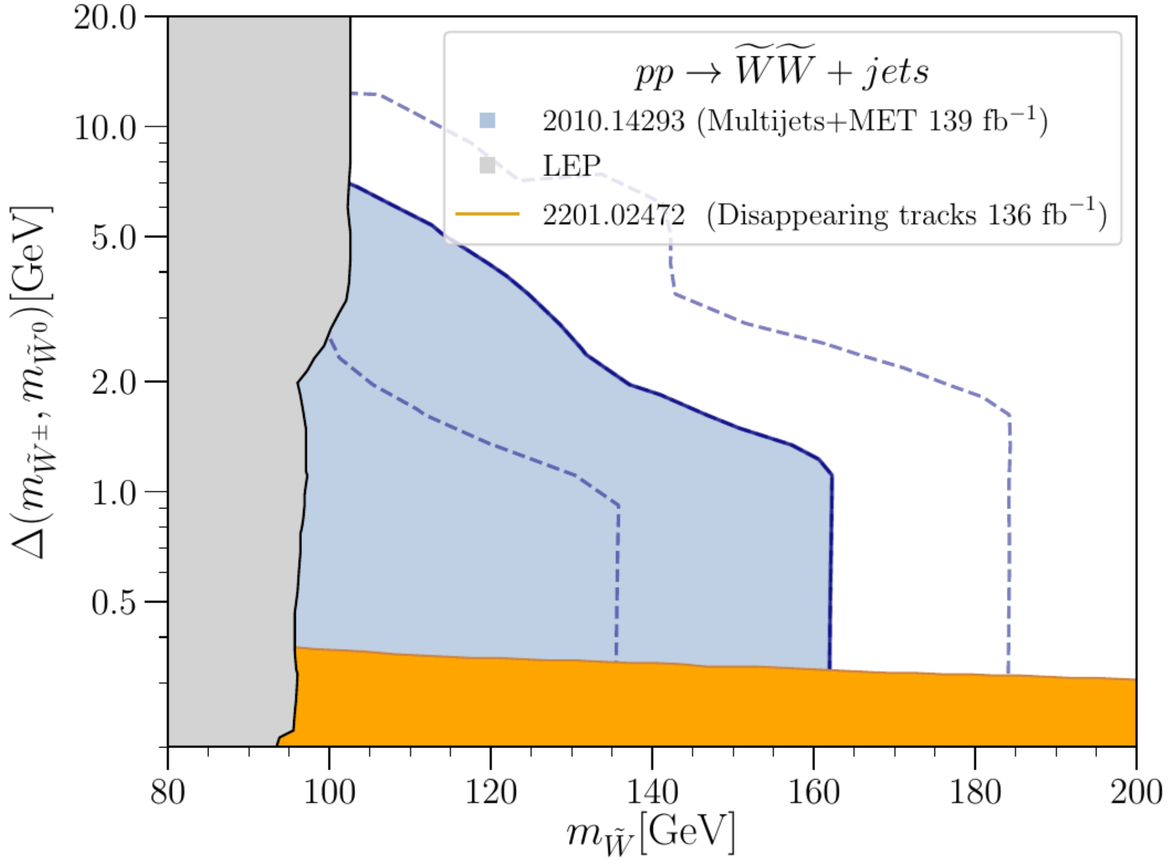


Very preliminary result

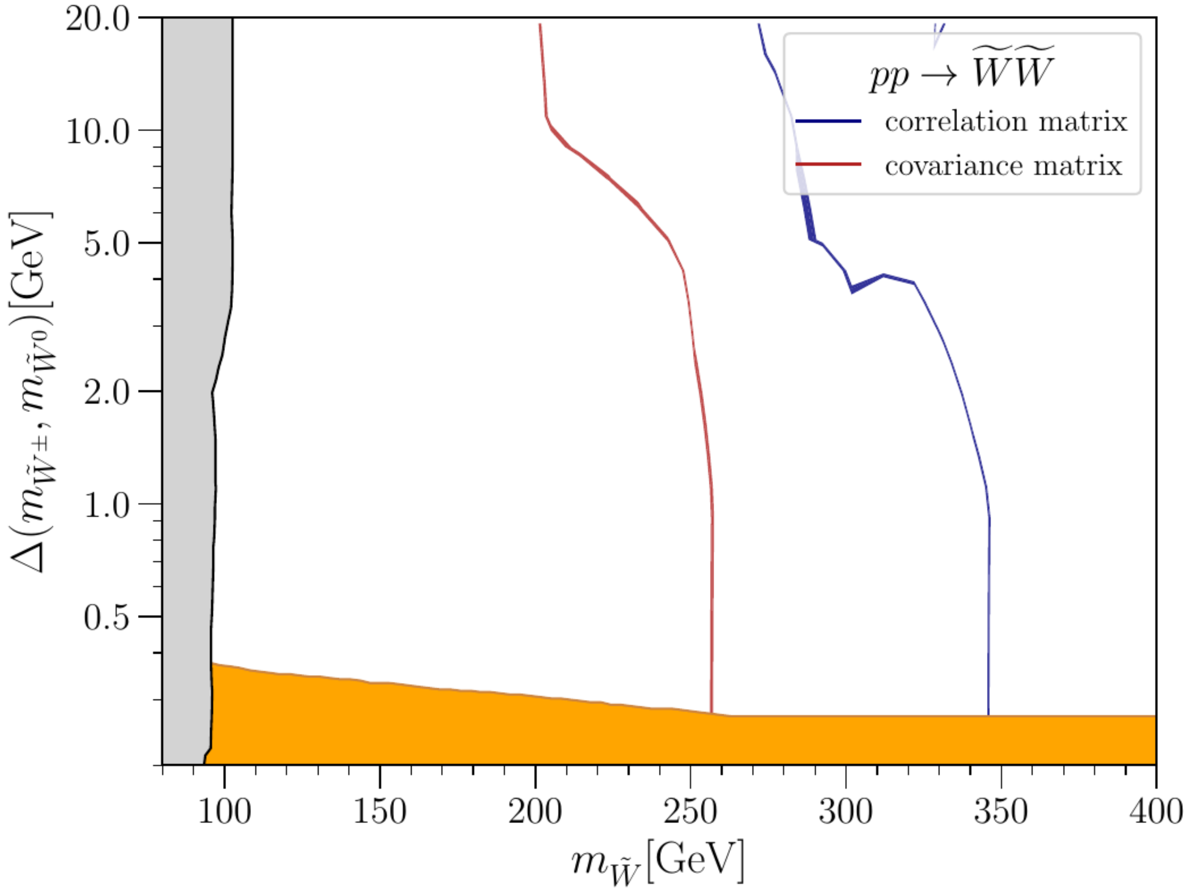
- Wino production with up to 2 jets
- Limits up to 250/350 GeV
- Ambiguity due to unclear interpretation of input
- Rough estimate for higgsinos by cross section rescaling: the limit up to ~250 GeV



Head-to-head comparison



ATLAS



CMS

What next?

- A proper experimental reanalysis would be an interesting thing to see
- Actual lower limit important for future colliders
- Perhaps also important for other DM (simplified) models
- Also, is there sensitivity to light, extremely compressed slepton scenarios below 100 GeV?
- Similar remarks regarding mono-jet reanalysis (ATLAS could try the multibin fit? CMS has poor agreement between observed and predicted which limits sensitivity)

Norway grants

NATIONAL SCIENCE CENTRE POLAND

The research leading to the results presented in this talk has received funding from the Norwegian Financial Mechanism for years 2014-2021, grant nr 2019/34/H/ST2/00707

Understanding the Early Universe:
interplay of theory and collider experiments

Joint research project between the University of Warsaw & University of Bergen