Mono-searches

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Norway grants

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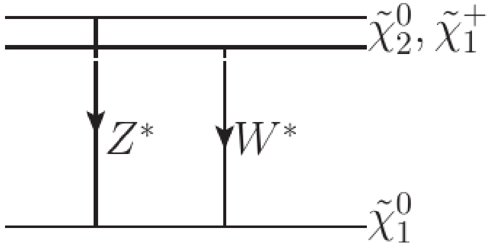
Contents

1. Mono- vs. multi-jets (in collaboration with Trygve, Kazuki and Inaki)
2. Mono-Z (in collaboration with Tania Robens and Jayita Lahiri)

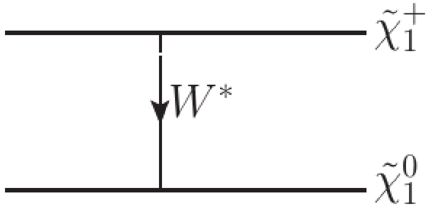
Light SUSY dark matter

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



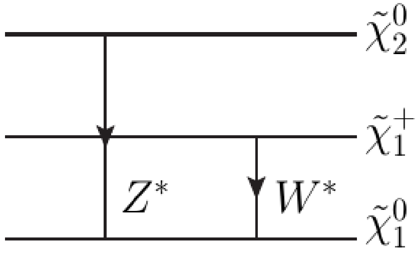
bino-wino

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



wino

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



higgsino

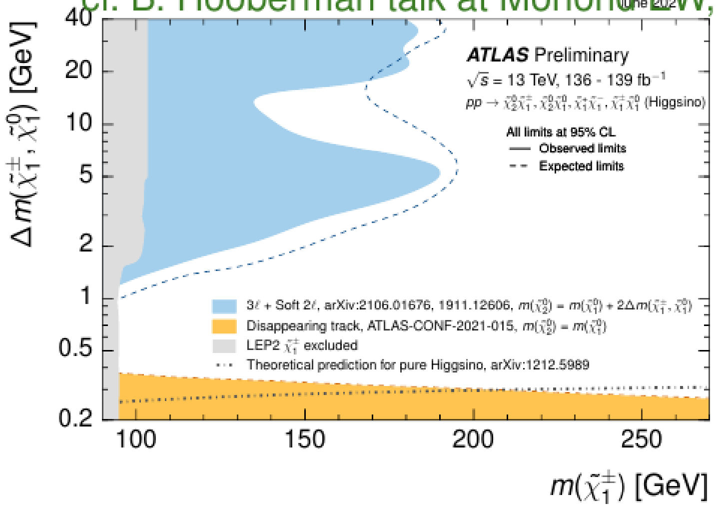
- mass splittings of order 100–1000 MeV

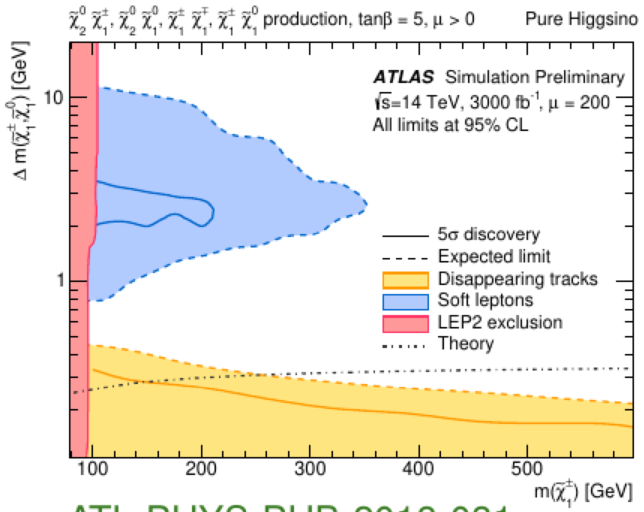
Search strategies

- 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

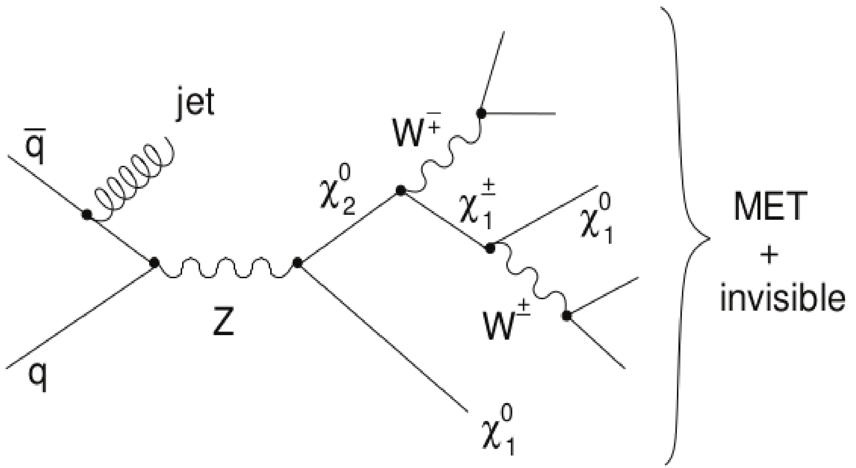


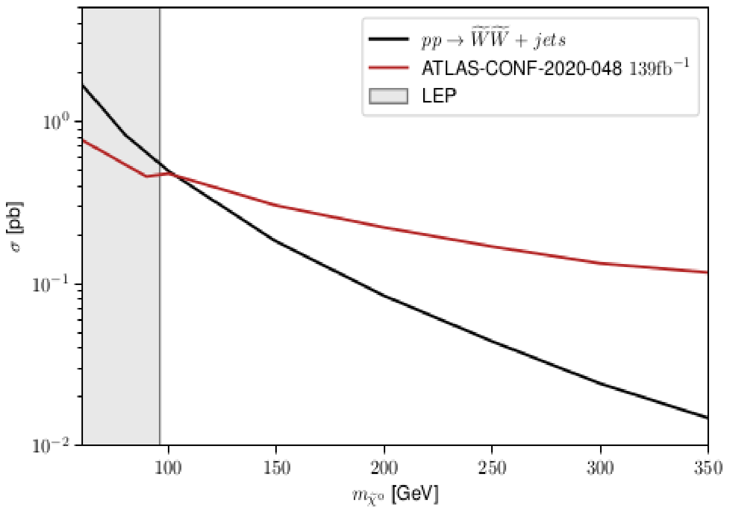


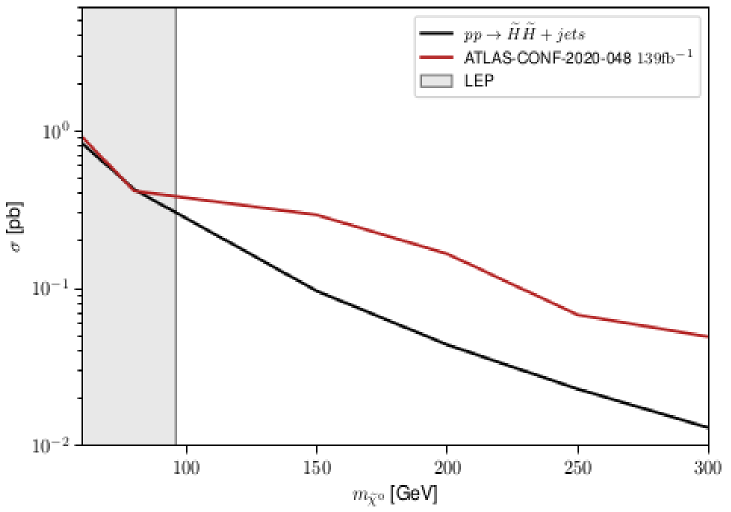
ATL-PHYS-PUB-2018-031

"Monojet" searches

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







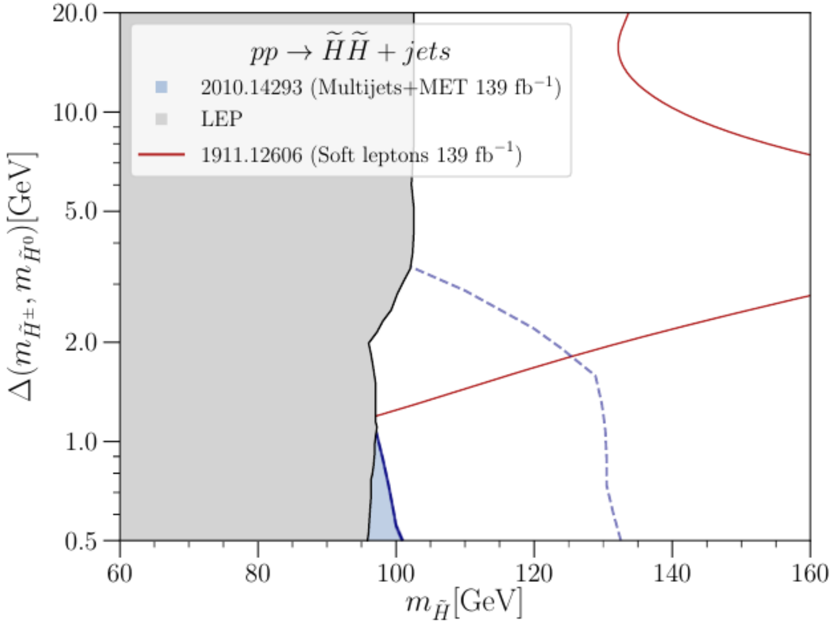
"Multijet" search by ATLAS

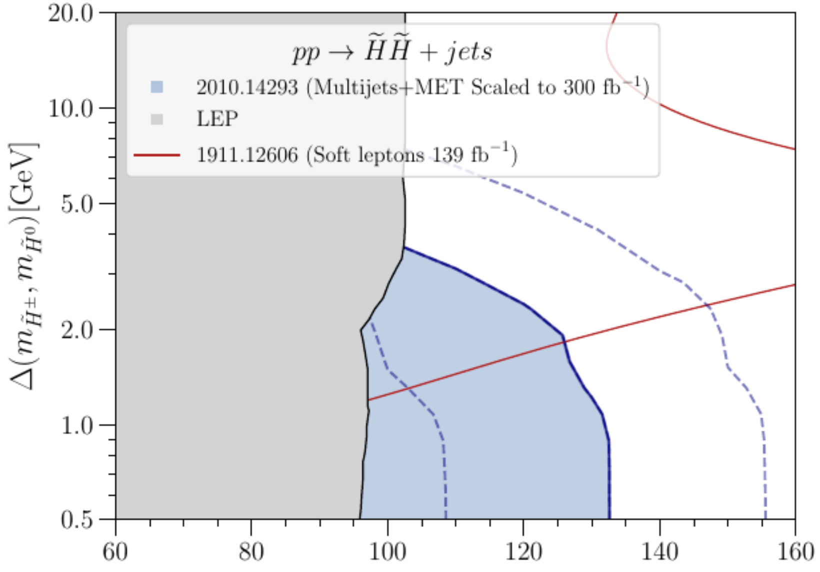
- we recast with CheckMATE a general search for squarks and gluinos, arXiv:2010.14293, in total 70 signal regions
- basic (preselection) signal requirements:
  - no electrons or muons
  - 2–6 jets
  - large missing energy > 300 GeV
  - hard leading jet $p_T > 200$ GeV
  - large effective mass > 800 GeV
- 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

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

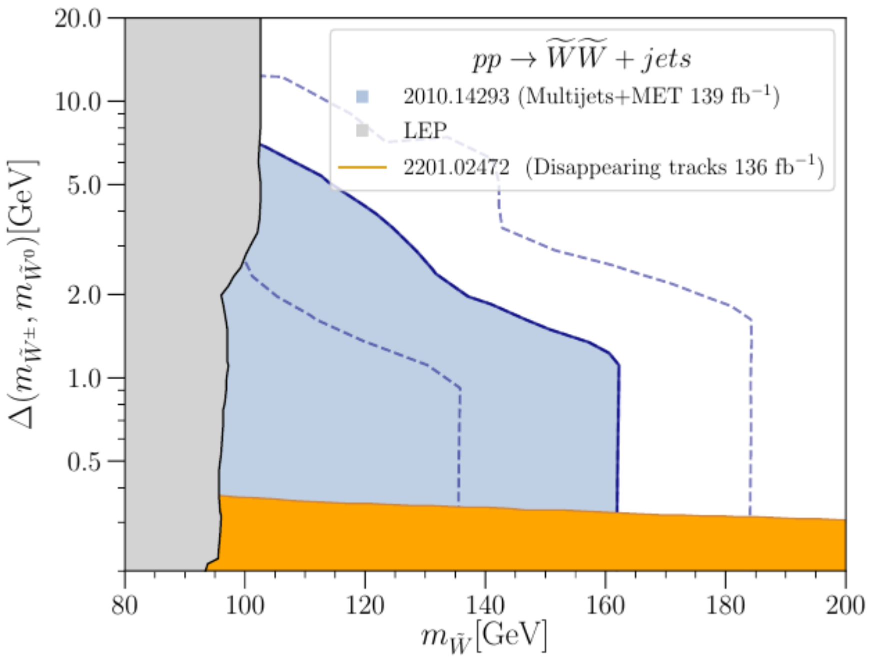
- after Run 3 the expected limit increases to 130 GeV

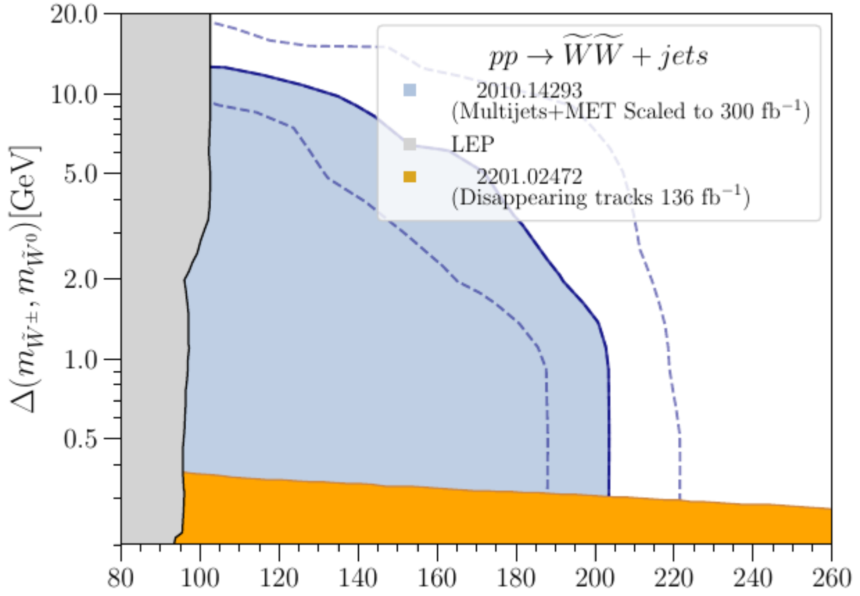




Limits: winos

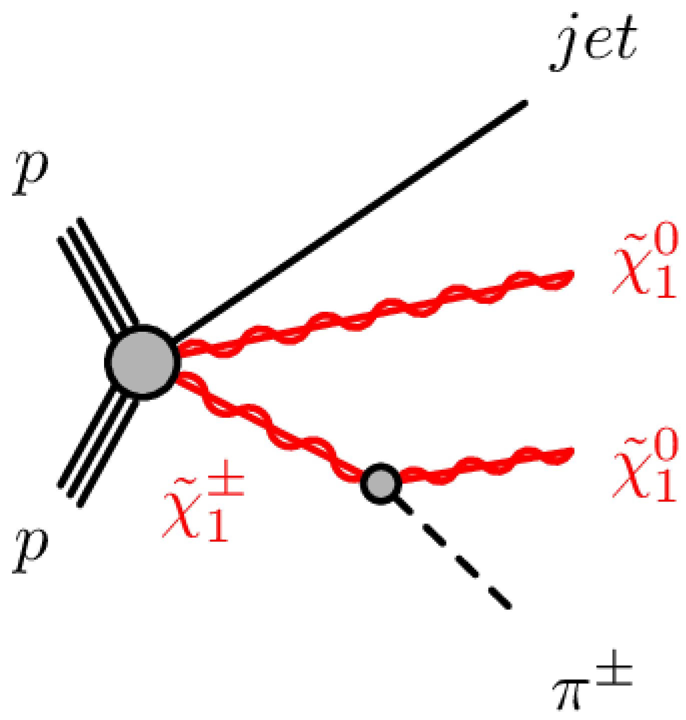
- $\widetilde{W}^{\pm} \to \widetilde{W}^0 W^*$
- $\widetilde{W}^0$ stable (DM candidate)
- soft decay products but no same-flavour opposite-charge from Z^* and no limits
- the limits from LEP and the search for semi-stable chargino
- the new exclusion on top of LEP and long-lived charged wino limits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

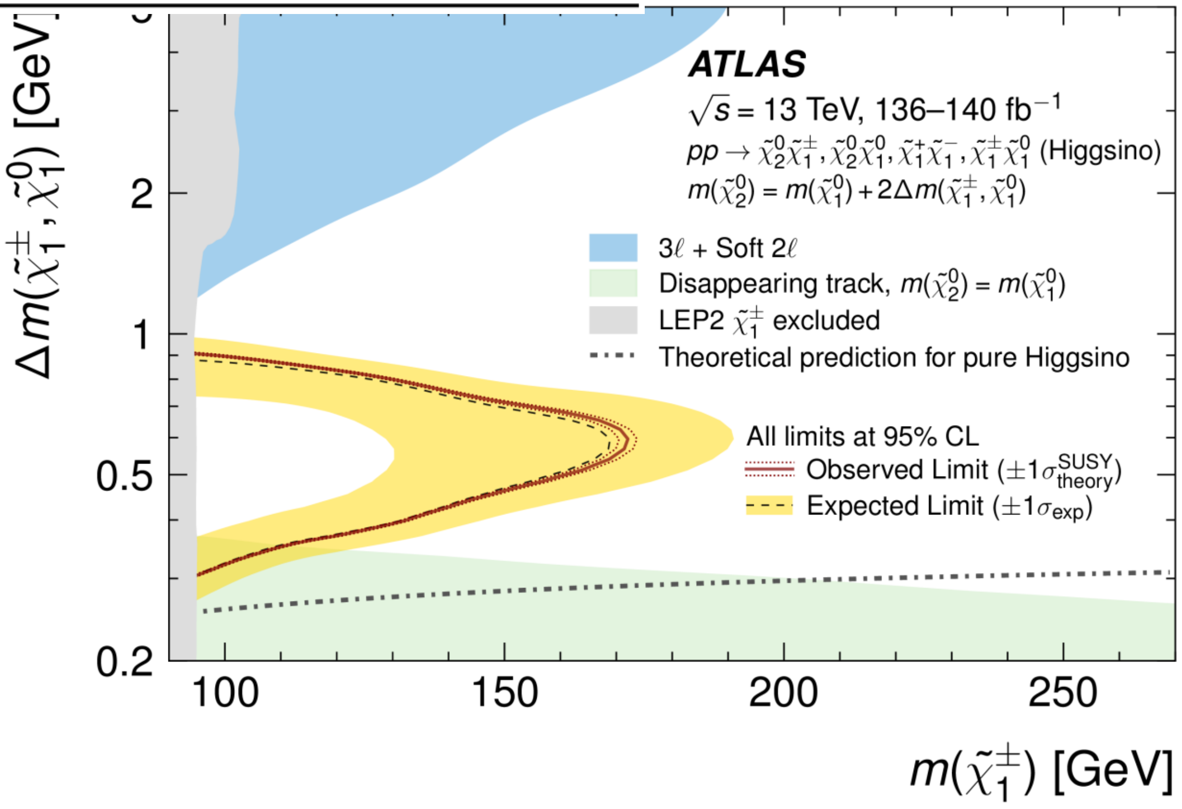




New search from ATLAS SUSY-2020-004

Variable	SR	CR-τ_h	CR-τ_ℓ	VR(CR2)-τ_h	VR(CR2)-τ_ℓ
N_ℓ	$= 0$	$= 0$	$= 1$	$= 0$	$= 1$
m_{T} [GeV]	–	–	< 50	–	< 50
$p_{\mathrm{T}}^{\mathrm{recoil}}$ [GeV]	> 600	> 600		[300,400]	
Track p_{T}	[2,5]	[8,20]		[5,8] ([8,20])	
Track $S(d_0)$	> 8	> 3		> 3	





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Inert doublet model

- idea: take **two Higgs doublet model, add additional Z_2 symmetry**

$$\phi_D \;\rightarrow\; -\phi_D, \phi_S \;\rightarrow\; \phi_S, \text{SM} \;\rightarrow\; \text{SM}$$

(⇒ implies CP conservation)

⇒ obtain a **2HDM with (a) dark matter candidate(s)**

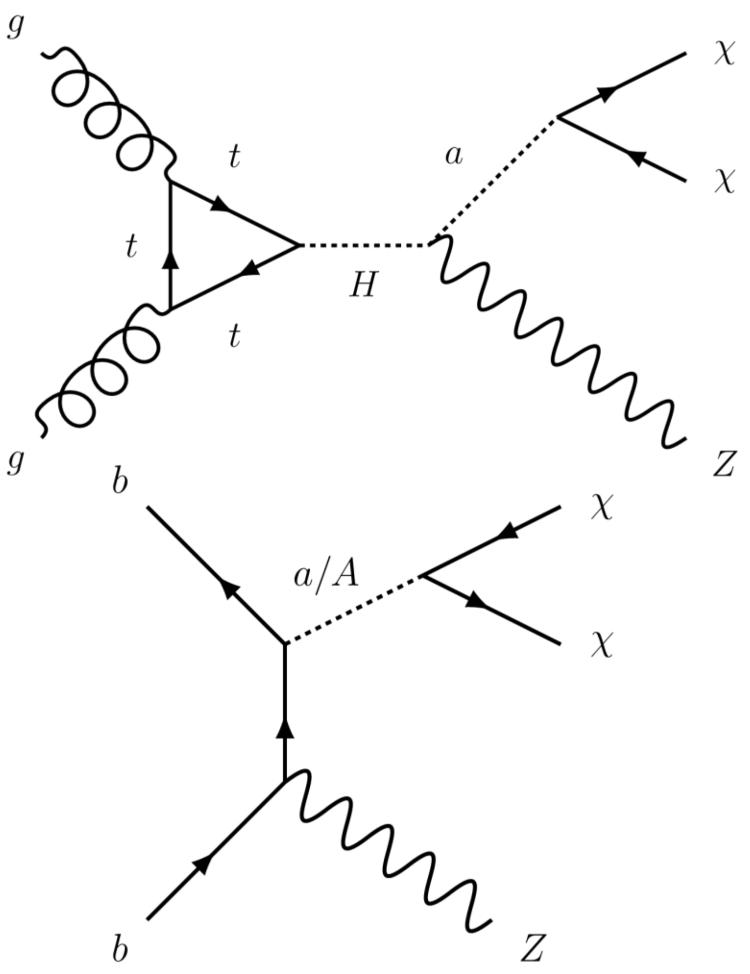
- potential

$$V = -\frac{1}{2}\left[m_{11}^2(\phi_S^\dagger\phi_S)+m_{22}^2(\phi_D^\dagger\phi_D)\right] + \frac{\lambda_1}{2}(\phi_S^\dagger\phi_S)^2+\frac{\lambda_2}{2}(\phi_D^\dagger\phi_D)^2$$
$$+\lambda_3(\phi_S^\dagger\phi_S)(\phi_D^\dagger\phi_D)+\lambda_4(\phi_S^\dagger\phi_D)(\phi_D^\dagger\phi_S) + \frac{\lambda_5}{2}\left[(\phi_S^\dagger\phi_D)^2+(\phi_D^\dagger\phi_S)^2\right]$$

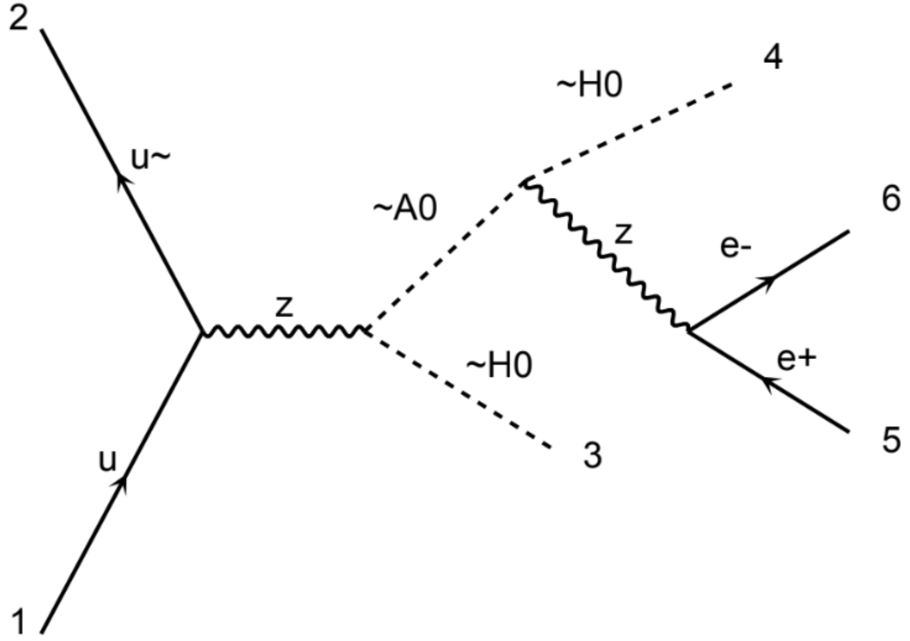
- only one doublet acquires VeV v, as in SM
(⇒ implies analogous EWSB)

Search strategy: mono-Z

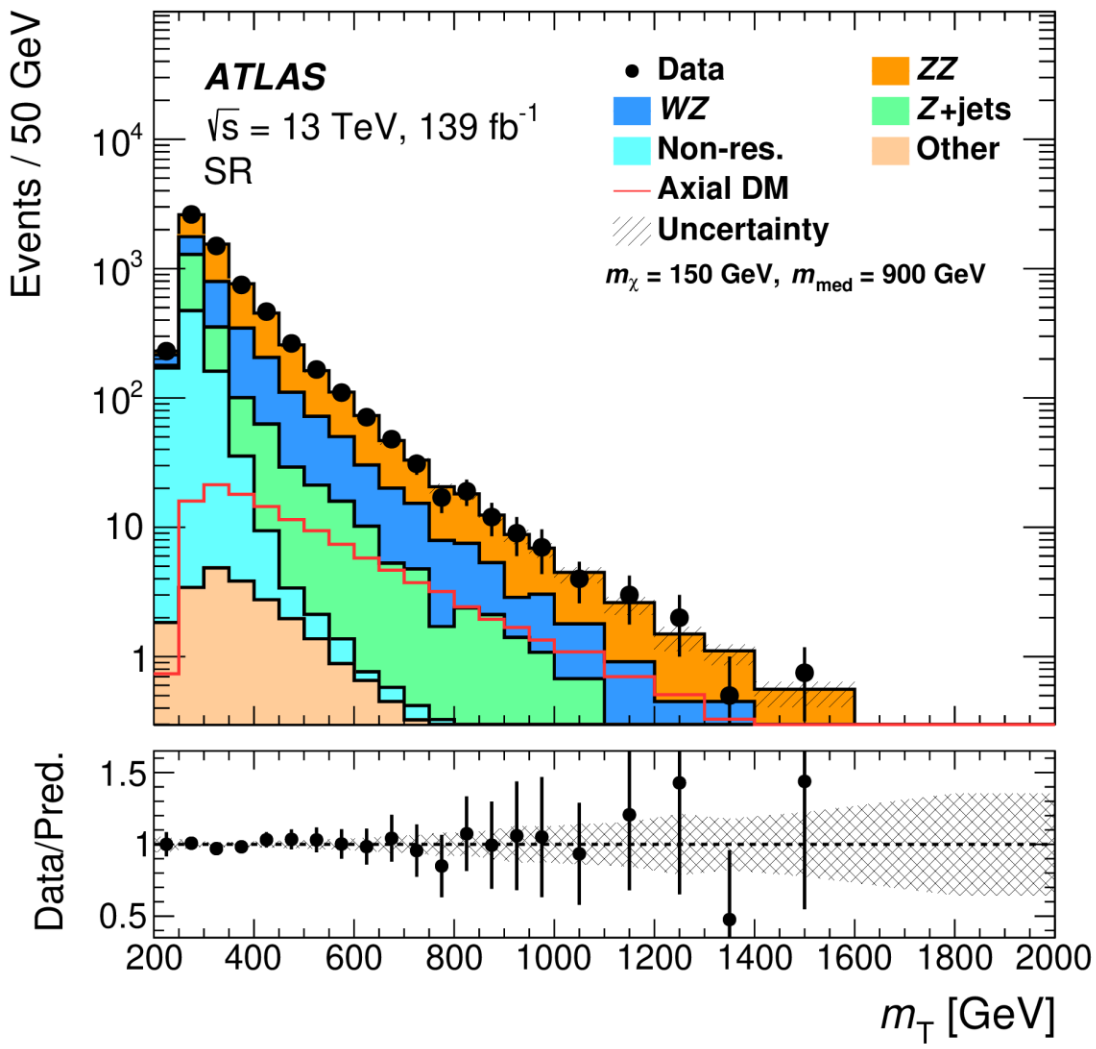
2HDM+a:



Inert DM

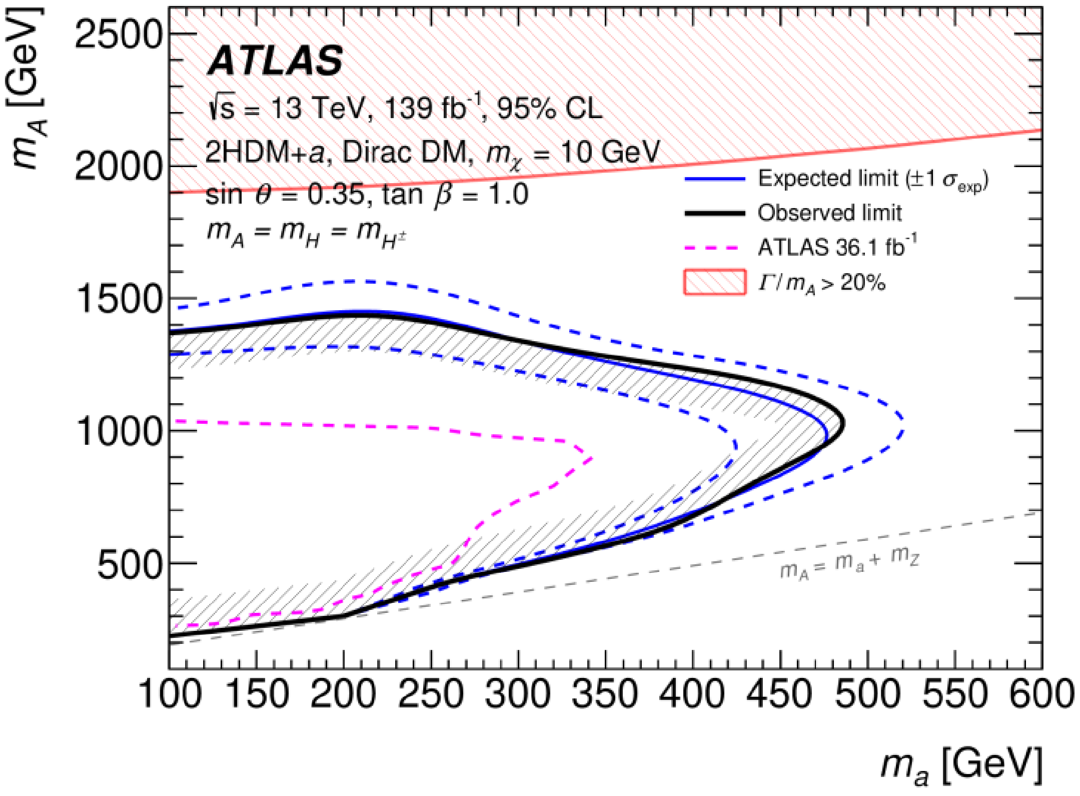


Search strategy: mono-Z

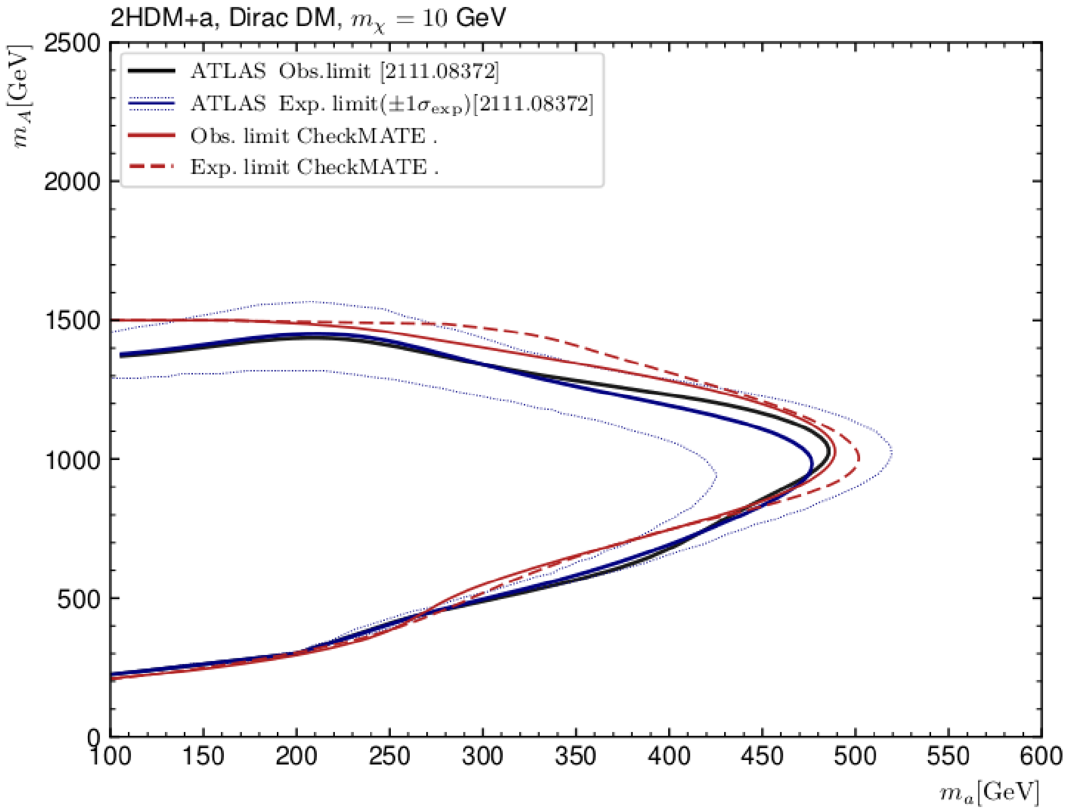


mT shape fit for signal-background discrimination

Mono-Z to constrain 2HDM+a



ATLAS HIGG-2018-26



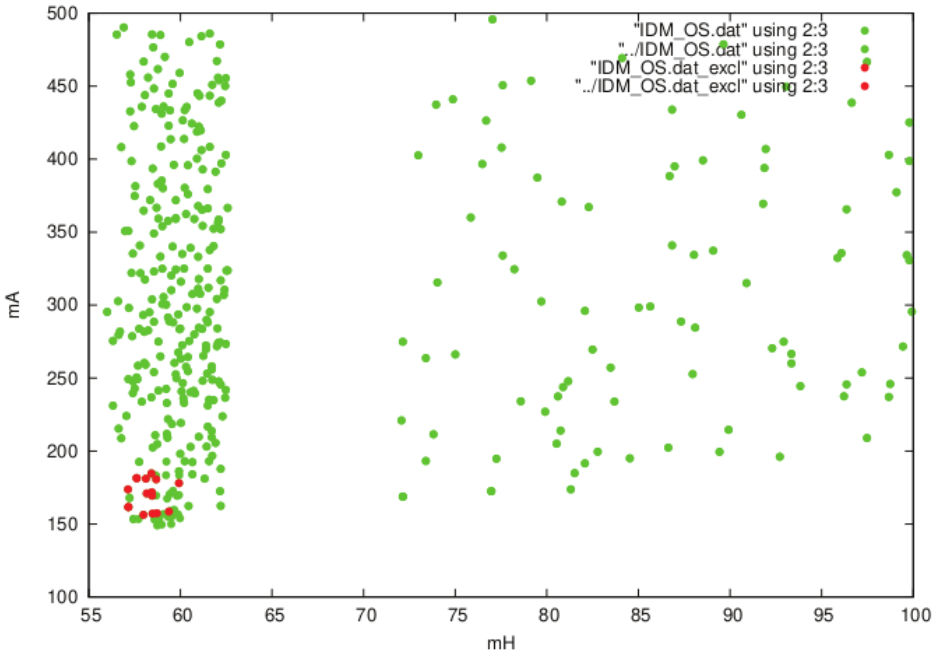
CheckMATE recast/validation

IDM constraints preliminary

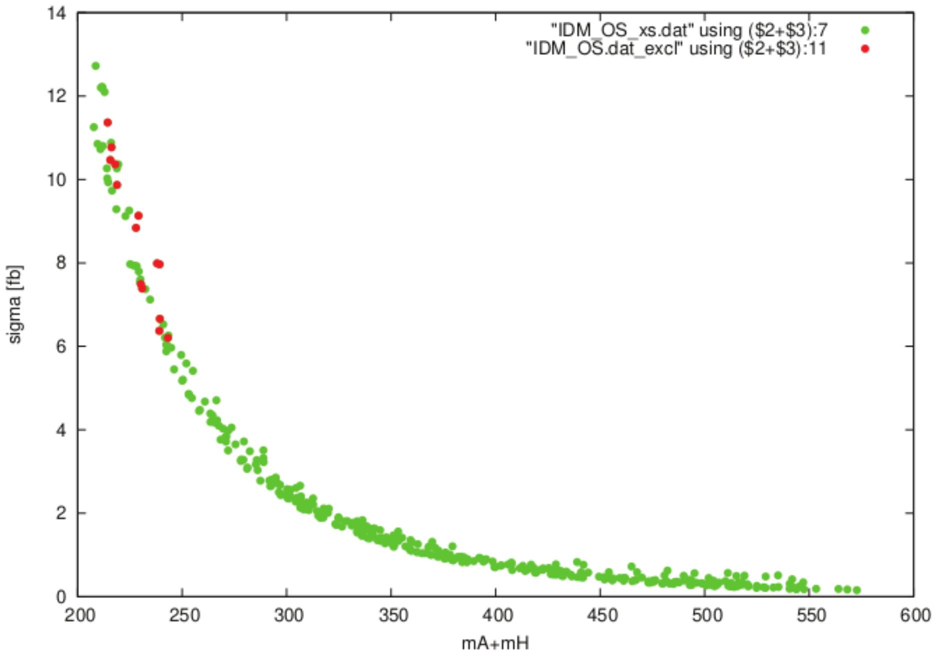
specific sample, concentrates on low $m_H \leq 100\,\mathrm{GeV}$

dominant production: $p\,p \to Z^* \to H\,A,\ A \to H\,\ell^+\,\ell^-$

In principle: only m_A, m_H should matter



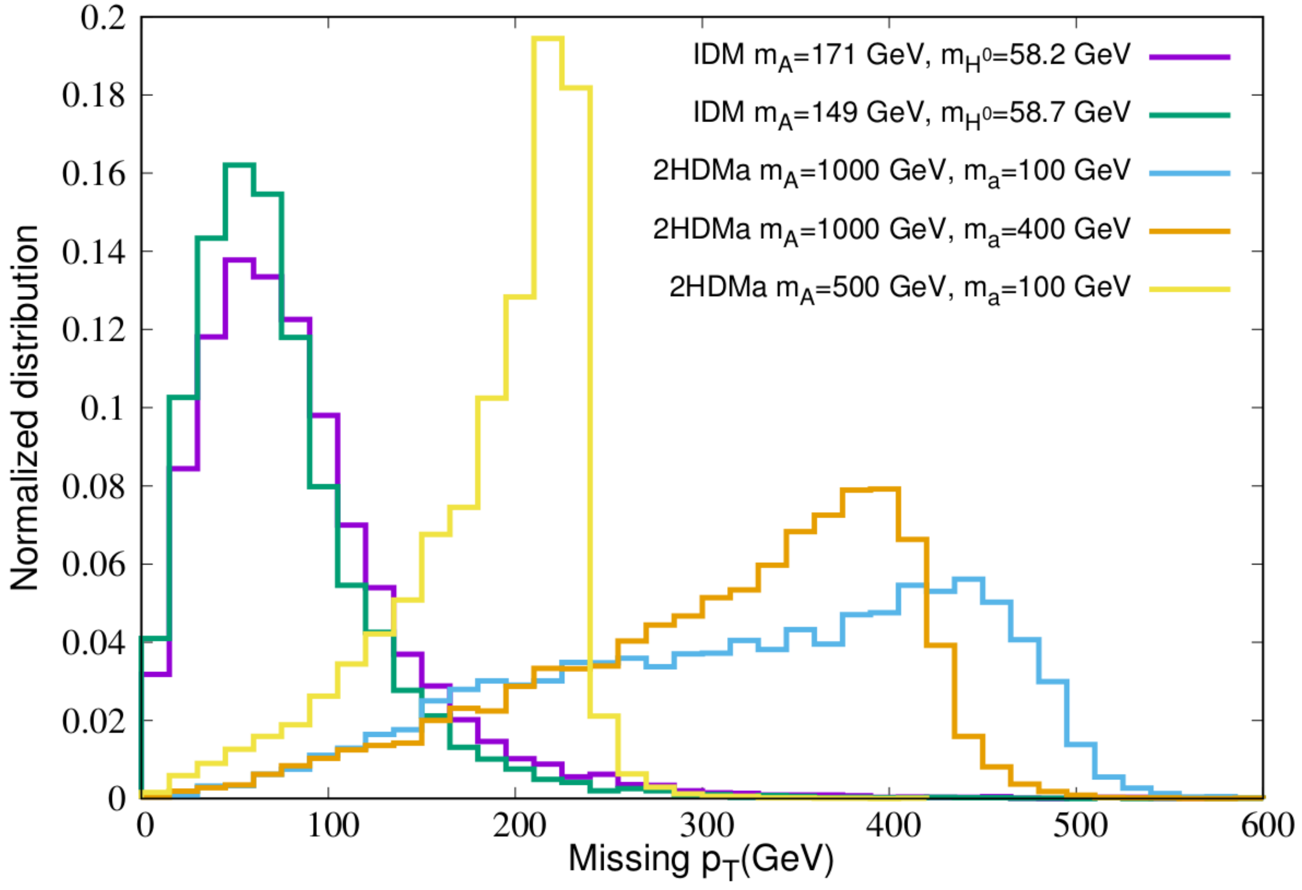
allowed and excluded points, $(m_H,\ m_A)$ plane



allowed and excluded points $\left(m_H + m_A, \sigma_{HA}^{\text{cuts}}\right)$ plane

Constraints much weaker than for the 2HDM+a

IDM constraints preliminary



- MET cut in ATLAS analysis > 90 GeV
- IDM signal escapes detection even for largish cross sections
- Possible optimization of the search?
  Lower MET cut?... but large SM background

Next steps

- Include VBF + Higgs to invisible
- Improve parameter space sampling
- Other constraints, eg. soft leptons
- ….

Norway grants

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Understanding the Early Universe:
interplay of theory and collider experiments

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