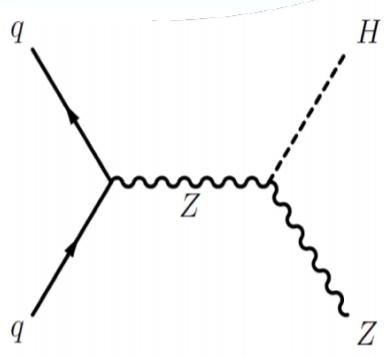# Search for associated production of a Z boson with an invisibly decaying Higgs boson or dark matter candidates with the ATLAS detector using full Run-II Data at LHC
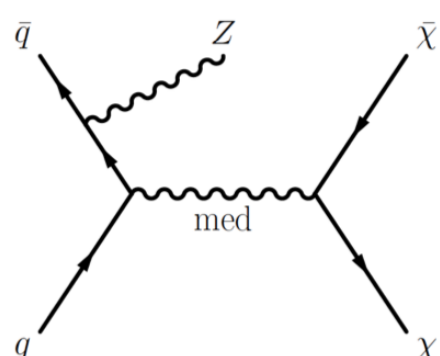
Student: Eloisa Arena
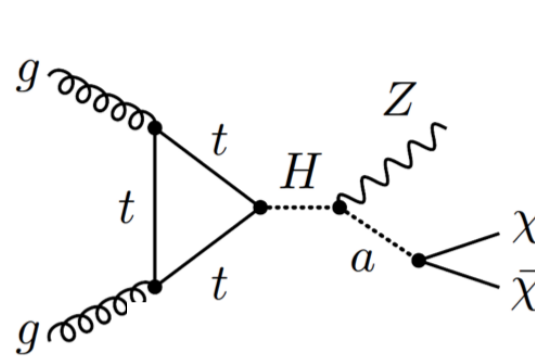Supervisors: Andrew Mehta, Monica D'Onofrio, Sarah Heim (DESY)

1. Mono-Z($\ell\ell$) signal models

$ZH \to \ell\ell$ +invisible
where H→ZZ→4ν
with SM BR=0.1%

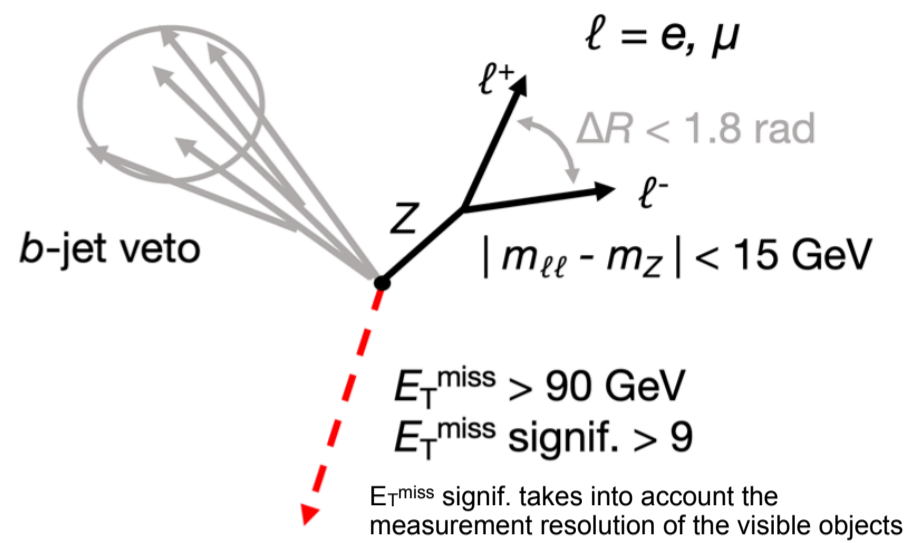*Simplified model* with axial-vector or vector mediator

2HDM+a model where *a* is a pseudo-scalar mediator

2. Event selection

$\ell = e, \mu$

$\Delta R < 1.8$ rad

$|m_{\ell\ell} - m_Z| < 15$ GeV

b-jet veto

$E_T^{miss} > 90$ GeV
E_T^{miss} signif. > 9

E_T^{miss} signif. takes into account the measurement resolution of the visible objects

Common selection for all the models (SR, signal region).

Specific discriminating variables for the various models:

- Boost Decision Tree (BDT) for H to invisible. It uses several kinematic variables with the most important being the dilepton pair rapidity and their angular separation;

- m_T for Dark Matter models, with:

$$m_T = \sqrt{\left[\sqrt{m_Z^2 + (p_T^{\ell\ell})^2} + \sqrt{m_Z^2 + (E_T^{miss})^2}\right]^2 - \left[\vec{p}_T^{\ell\ell} + \vec{E}_T^{miss}\right]^2}$$

3. Background estimation

Main SM background: qq/gg→ZZ

Three Control Regions (CRs) used to constrain SM background Monte Carlo predictions in SR for all signal models:

- 4ℓ CR→ ZZ: use random dilepton pair to mimic E_T^{miss};

- 3ℓ CR → WZ: region containing exactly three leptons;

- $e\mu$ CR→ non-resonant (tt, Wt, WW) backgrounds: similar to SR, but different flavours for lepton pair.

NLO electroweak corrections are applied to the qq→ZZ Monte Carlo processes.
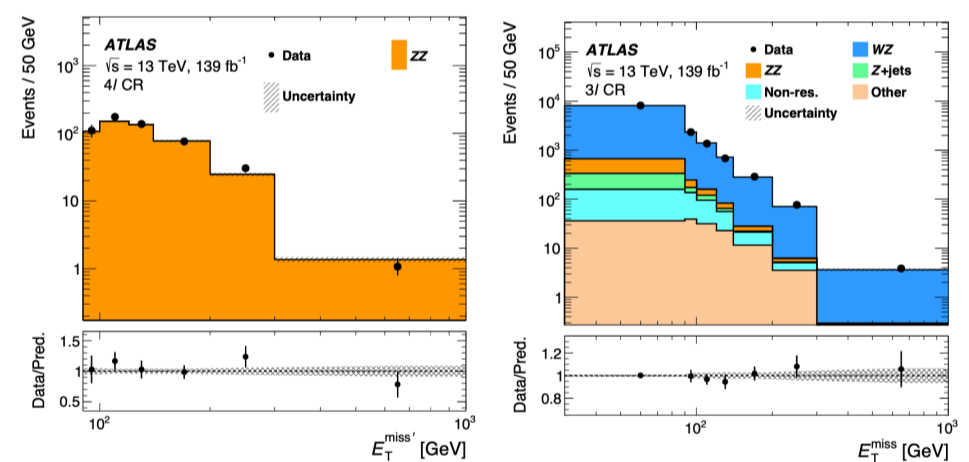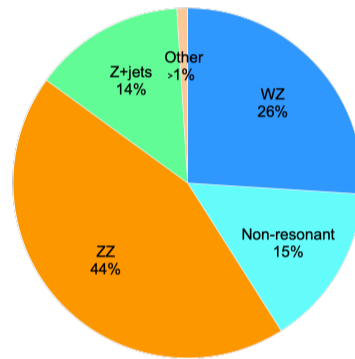
4. Results

Data are compared with expectation by performing simultaneous maximum-likelihood fits in SR and CRs, using simulation as input and taking into account uncertainties. Good agreement between data and background predictions is found. Upper limits on the branching ratio of the Higgs boson to invisible particles and exclusion limits for simplified dark matter models and 2HDM+a models are set. Dark Matter constraints are also extracted.
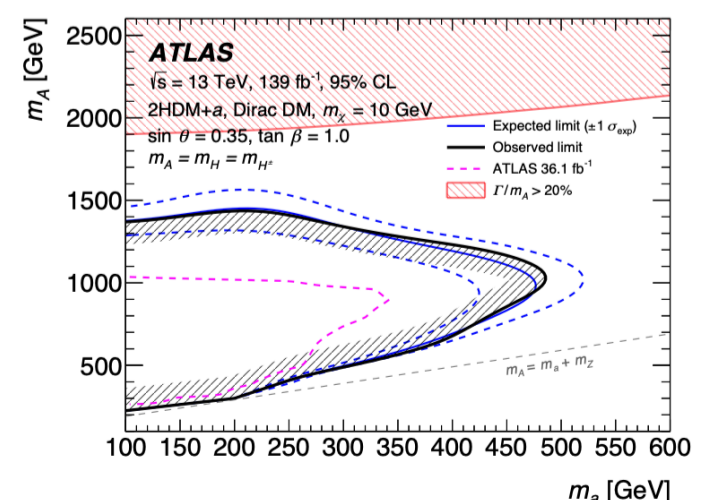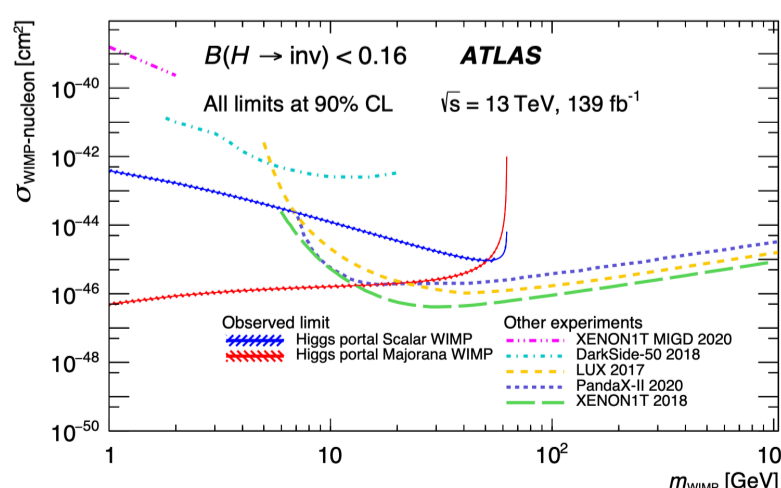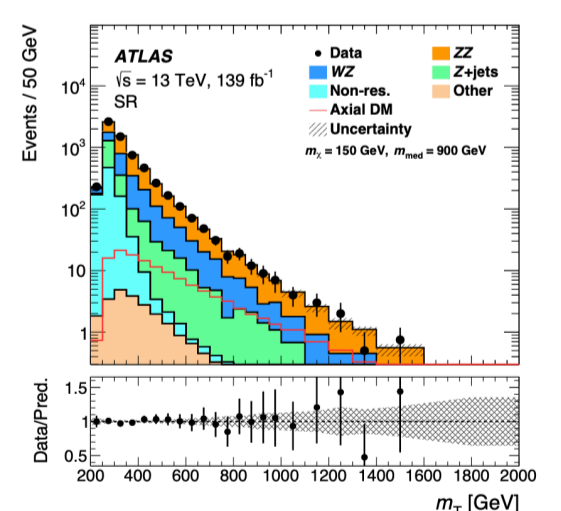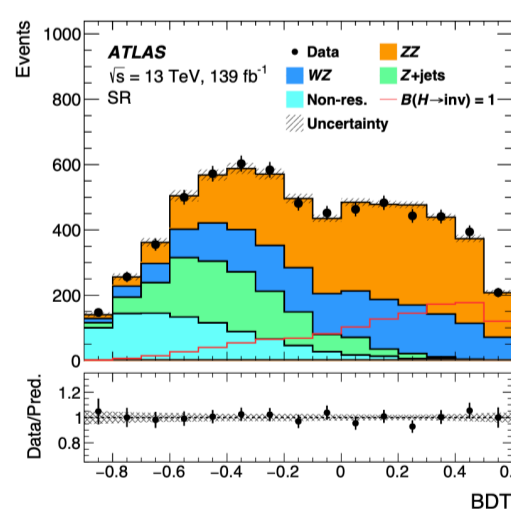
Higgs invisible decay
Observed (exp) limit at 95% CL:

BR$_{H\to inv}$ =0.19 (0.19)

Early Run-II ATLAS H invisible combination observed (exp) limit at 95% CL:
BR$_{H\to inv}$ =0.38 (0.21)

[1] ATLAS Collaboration - 'Search for associated production of a Z boson with an invisibly decaying Higgs boson or dark matter candidates at √s = 13 TeV with the ATLAS detector ' - arXiv:2111.08372
[2] ATLAS Collaboration - 'Combination of Searches for Invisible Higgs Boson Decays with the ATLAS Experiment ' - PhysRevLett.122.231801