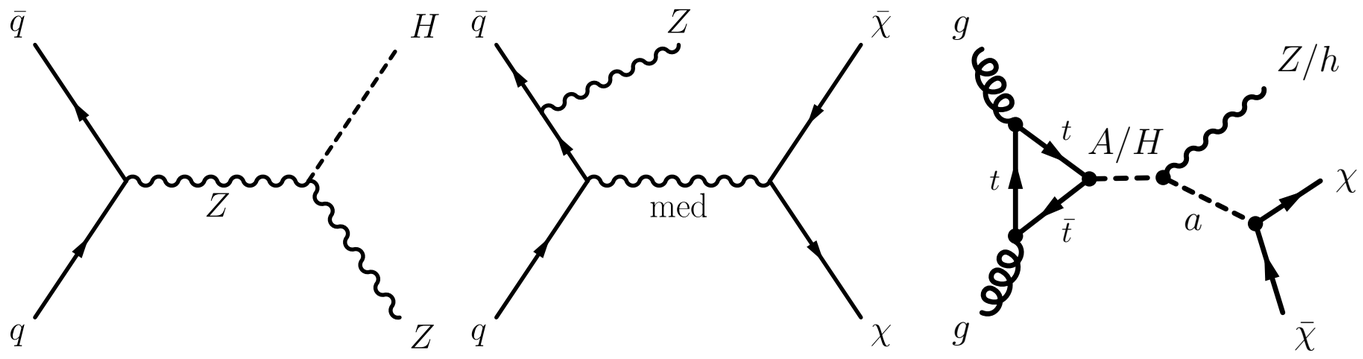
Search for dark matter in events with missing transverse momentum and a Z boson in 13 TeV proton-proton collisions with the ATLAS detector at the LHC

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



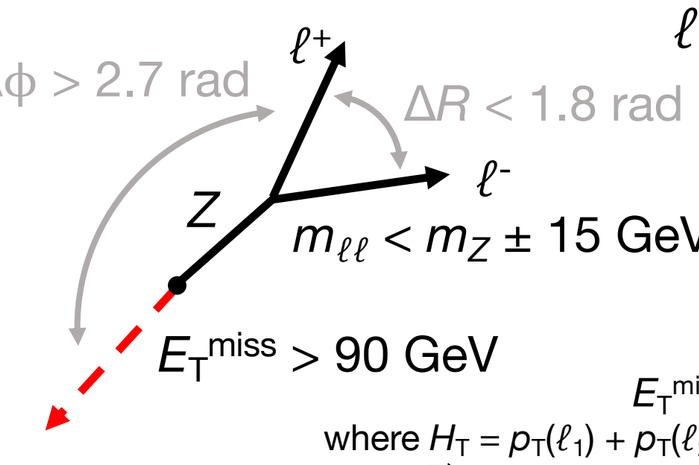
***ZH* → *ℓℓ* + invisible**
where $H \to ZZ \to 4\nu$ with SM BR = 0.1%

Simplified model
with axial-vector or vector mediator

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

Event selection

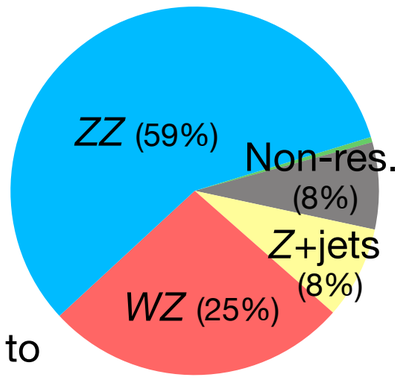
$\ell = e, \mu$



b-jet veto
$E_T^{miss}/H_T > 0.6$
where $H_T = p_T(\ell_1) + p_T(\ell_2) + \Sigma p_T(\text{jets})$
$| p_T^{\ell\ell} - |\vec{E}_T^{miss} + \Sigma\vec{p}_T^{jets}| |/p_T^{\ell\ell} < 0.2$

Backgrounds

ZZ ***ZZ → ℓℓνν:*** Lepton pair from a Z, real E_T^{miss}
Method: $qq \to ZZ$ NLO QCD MC corrected to NNLO QCD, NLO EW accuracies; $gg \to ZZ$ LO QCD scaled to NLO QCD

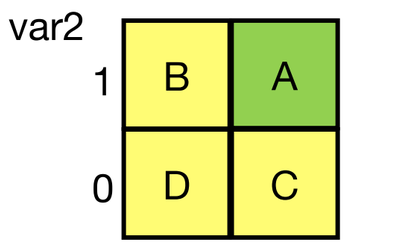


WZ ***WZ → ℓνℓℓ:*** Lepton pair from a Z, lepton from W not reconstructed
Method: Yield estimated using 3ℓ control region extrapolated to signal region

$$N^{2\ell SR}_{WZ,\text{data}} = N^{2\ell SR}_{WZ,\text{MC}} \cdot \frac{N^{3\ell CR}_{WZ,\text{data}}}{N^{3\ell CR}_{WZ,\text{MC}}}$$

***Z*+jets** ***Z → ℓℓ* + jets**: Lepton pair from a Z, jets mis-measured as fake E_T^{miss}
Method: ABCD method

$$N^{A}_{Z+j,\text{data}} = N^{C}_{Z+j,\text{data}} \times \frac{N^{B}_{Z+j,\text{data}}}{N^{D}_{Z+j,\text{data}}}$$

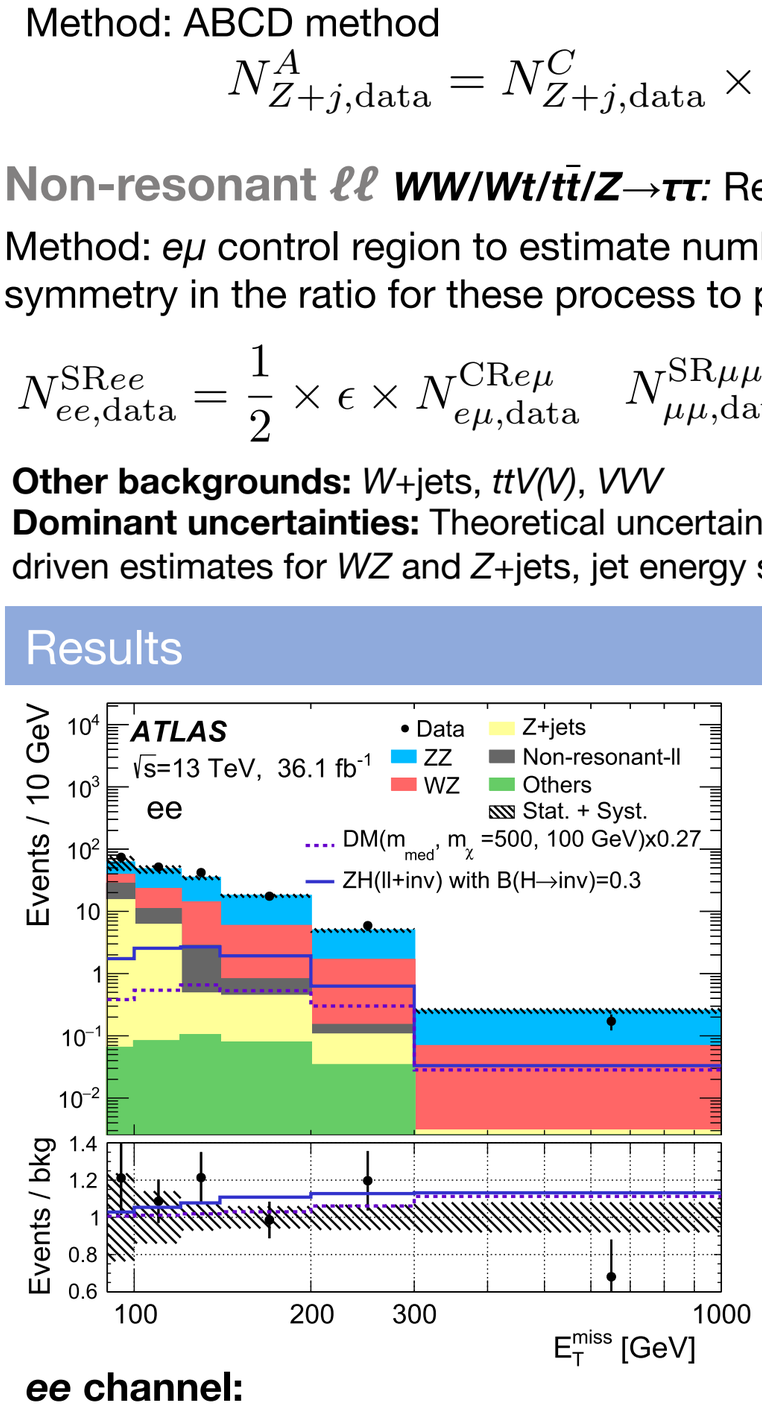


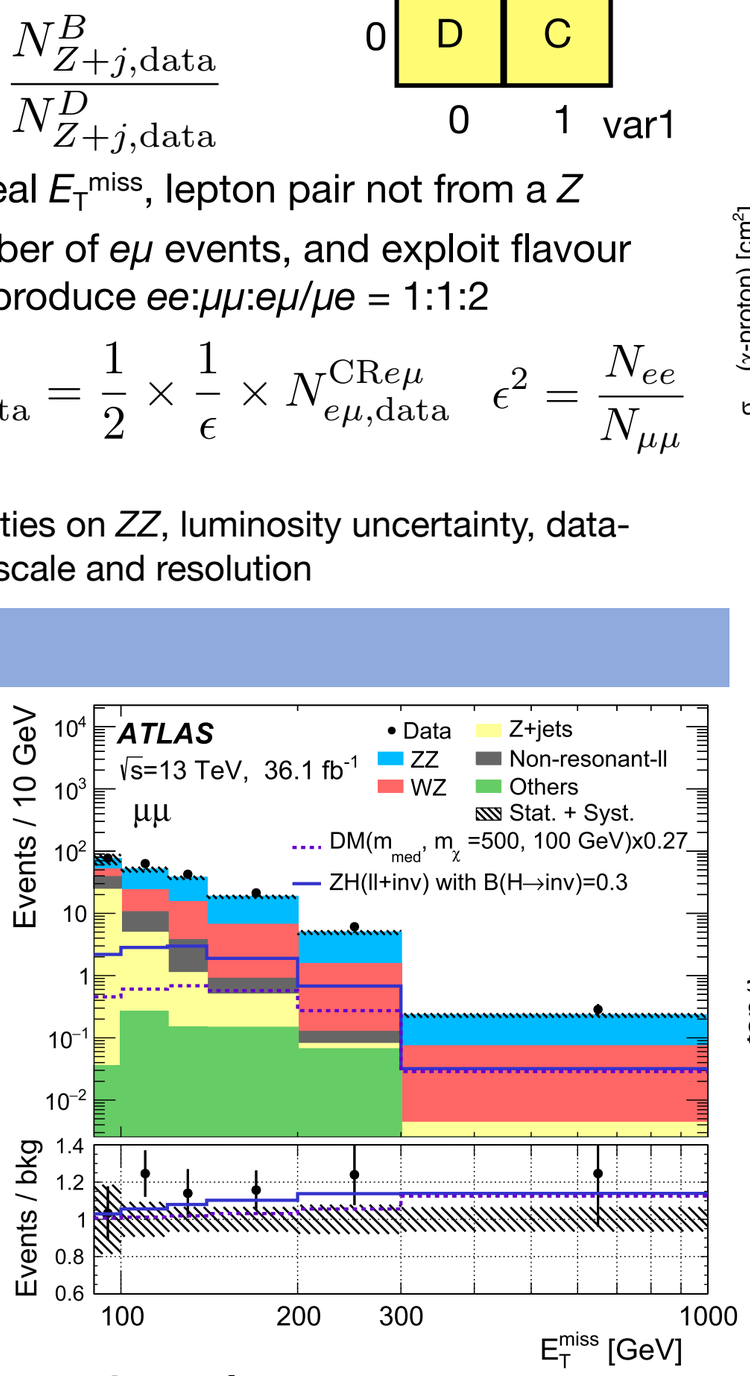
Non-resonant *ℓℓ* ***WW/Wt/tt̄/Z→ττ:*** Real E_T^{miss}, lepton pair not from a Z
Method: $e\mu$ control region to estimate number of $e\mu$ events, and exploit flavour symmetry in the ratio for these process to produce ee:$\mu\mu$:$e\mu$/μe = 1:1:2

$$N^{SR ee}_{ee,\text{data}} = \frac{1}{2} \times \epsilon \times N^{CR e\mu}_{e\mu,\text{data}} \qquad N^{SR \mu\mu}_{\mu\mu,\text{data}} = \frac{1}{2} \times \frac{1}{\epsilon} \times N^{CR e\mu}_{e\mu,\text{data}} \qquad \epsilon^2 = \frac{N_{ee}}{N_{\mu\mu}}$$

Other backgrounds: W+jets, $ttV(V)$, VVV
Dominant uncertainties: Theoretical uncertainties on ZZ, luminosity uncertainty, data-driven estimates for WZ and Z+jets, jet energy scale and resolution

Results





***ee* channel:**
Total background = 399 ± 6 (stat) ± 34 (sys)
Observed data = 437

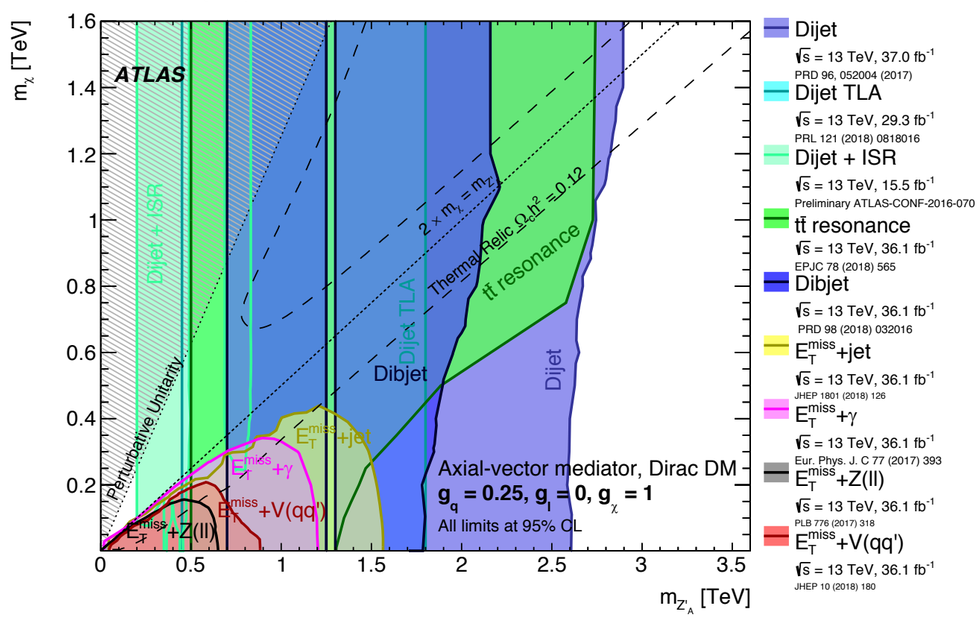
***μμ* channel:**
Total background = 426 ± 6 (stat) ± 28 (sys)
Observed data = 497

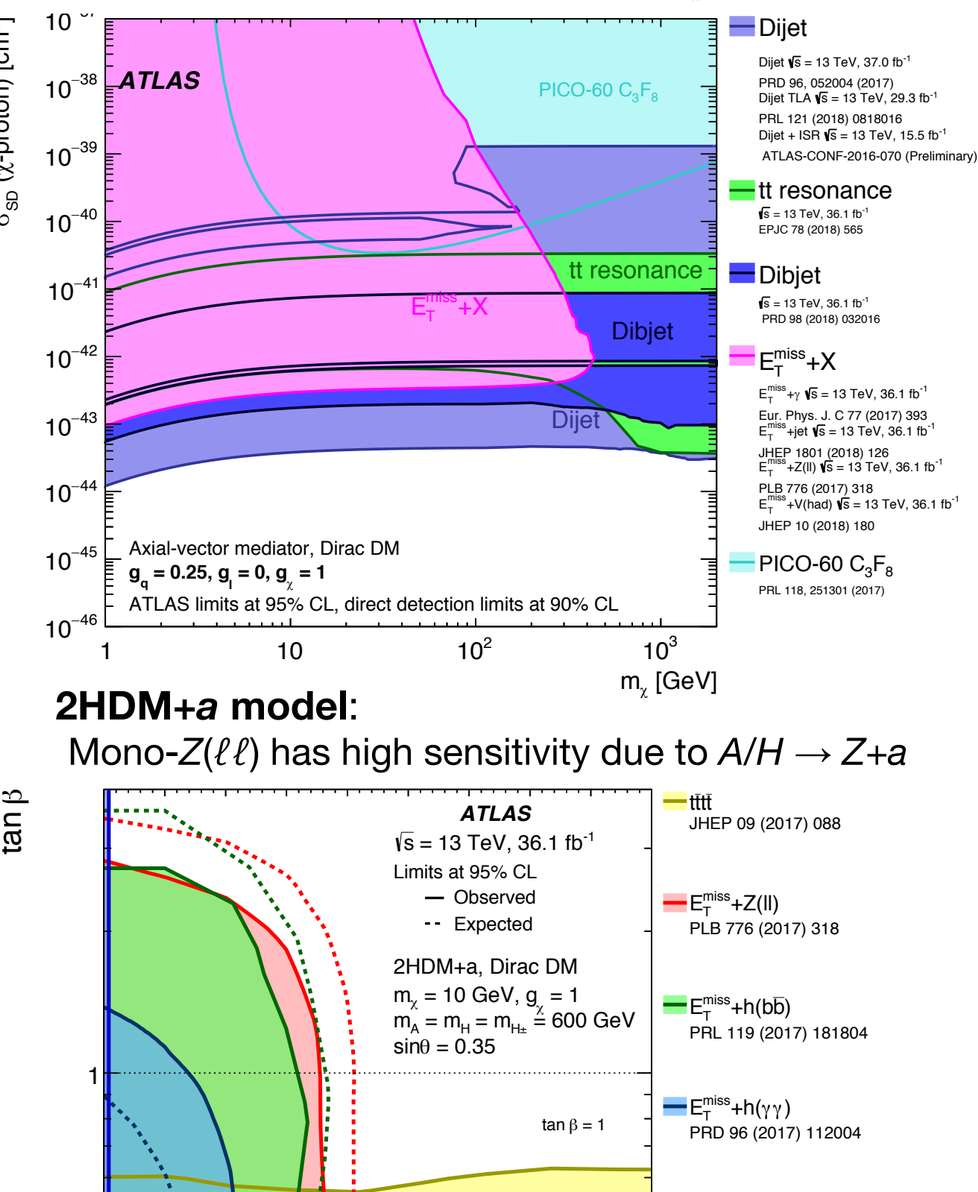
PLB 776 (2017) 318; JHEP 05 (2019) 142

Interpretation

Invisible Higgs: BR($H \to inv$) < 67% observed ($39\,^{+17}_{-11}$% expected) at 95% CL

Simplified model:
Mono-$Z(\ell\ell)$ channel most sensitive at low E_T^{miss}





2HDM+*a* model:
Mono-$Z(\ell\ell)$ has high sensitivity due to $A/H \to Z$+a