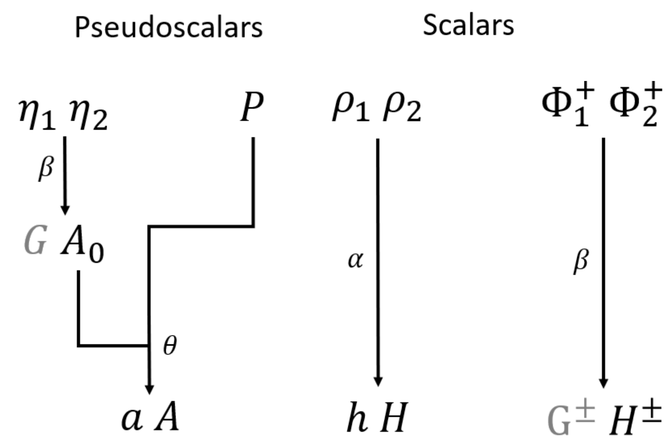
Search for $t\bar{t}H/A/a \rightarrow t\bar{t}t\bar{t}$ production in the multilepton final state in proton-proton collisions at 13 TeV with the ATLAS detector

Motivation and Theory

The 2HDM+a model introduces 5 new Higgs bosons, *a, A, H* and $H^{\pm}$.

These Higgs bosons mix via the parameters *α, β,* and *θ.*

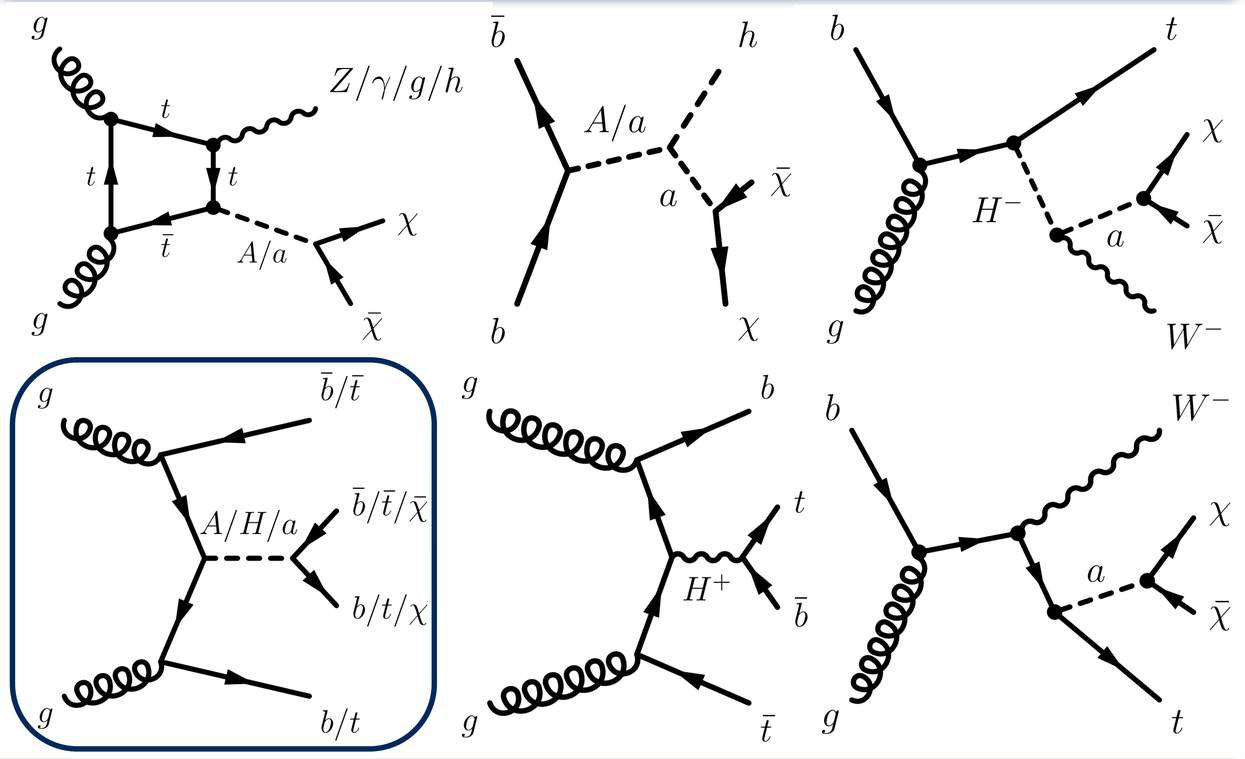
The studied benchmark model introduces a fermionic dark matter candidate *χ* with a Yukawa coupling to the pseudoscalar *a.*



Value of sin($\beta - \alpha$) is fixed to 1 in order to be in the alignment limit where *h* is the 125 GeV SM Higgs boson and *v* = 246 GeV.

To simplify the phenomenology we set $m_A = m_H = m_{H^{\pm}}$ leaving 5 free parameters.

2HDM+a signals of interest



$t\bar{t}H/A/a \rightarrow t\bar{t}t\bar{t}$ Analysis Strategy

A baseline signal region is constructed from events with same-sign dilepton and multilepton (SSML), ≥ 6 jets, ≥ 2 b-jets and $H_T \geq 500$ GeV.

Backgrounds from physics processes include SM $t\bar{t}t\bar{t}$, $t\bar{t}W$, $t\bar{t}H$, $t\bar{t}Z$, and $t\bar{t}\gamma^*$.

Background from instrumental and fake sources include charge mis-ID, fake leptons from heavy flavour decays and photon conversion.

Template fit method is used to estimate the backgrounds from 4 fake sources and $t\bar{t}W$ *QCD.*

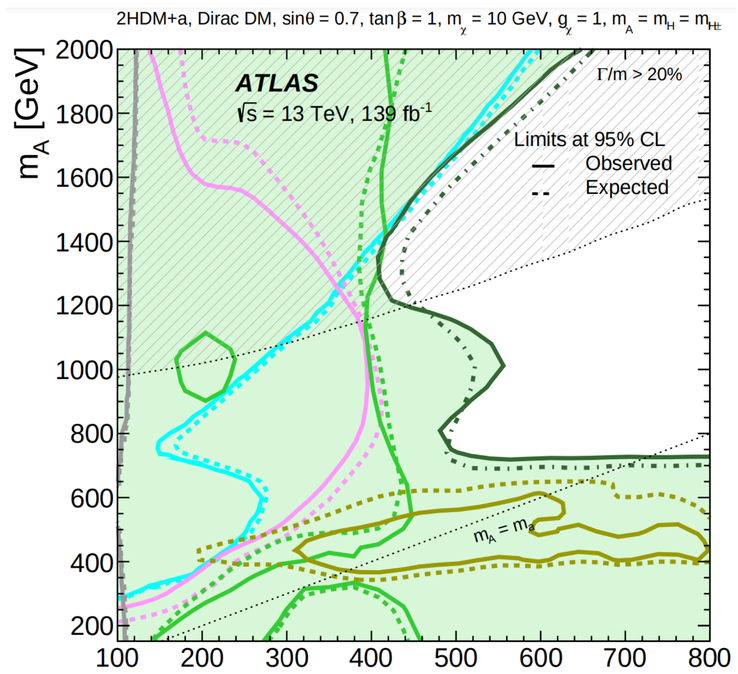
Two BDTs are used to separate (1) $tttt$-like processes from other background [SM BDT] and (2) BSM $t\bar{t}t\bar{t}$ from SM $t\bar{t}t\bar{t}$ trained on individual 2HDM $t\bar{t}t\bar{t}$ mass points [BSM pBDT].

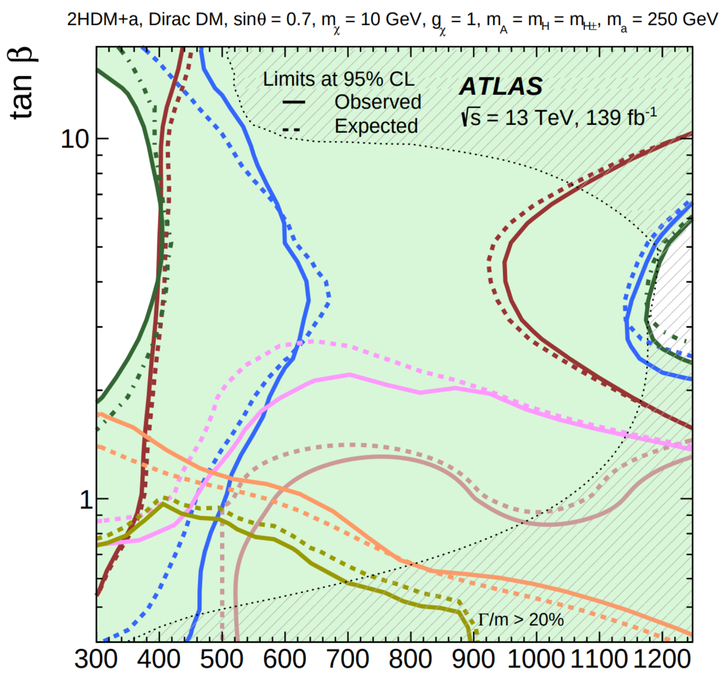
Region	Channel	N_j	N_b	Other selection cuts	Fitted variable
CR Conv	$e^{\pm}e^{\pm}$ || $e^{\pm}\mu^{\pm}$	$4 \leq N_j < 6$	≥ 1	$m_{ee}^{CV} \in [0, 0.1]$ GeV $200 < H_T < 500$ GeV	m_{ee}^{PV}
CR HF *e*	*eee* || *eeμ*		= 1	$100 < H_T < 250$ GeV	Yield
CR HF *μ*	*eμμ* || *μμμ*		= 1	$100 < H_T < 250$ GeV	Yield
CR $t\bar{t}W$	$e^{\pm}\mu^{\pm}$ || $\mu^{\pm}\mu^{\pm}$	≥ 4	≥ 2	$m_{ee}^{CV} \notin [0, 0.1]$ GeV, $\|\eta(e)\| < 1.5$ for $N_b = 2$, $H_T < 500$ GeV or $N_j < 6$; for $N_b \geq 3$, $H_T < 500$ GeV	$\sum p_T^{\ell}$
CR lowBDT	SS+3L	≥ 6	≥ 2	$H_T > 500$ GeV, SM BDT < 0.55	SM BDT
BSM SR	SS+3L	≥ 6	≥ 2	$H_T > 500$ GeV, SM BDT ≥ 0.55	BSM pBDT

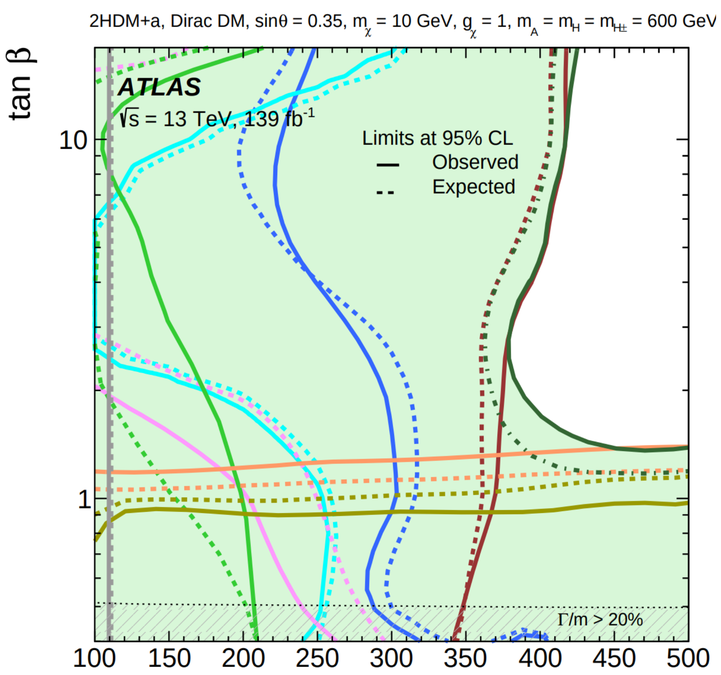
Parameter	$\lambda_{t\bar{t}W\,QCD}$	$\lambda_{Mat.\ Conv.}$	$\lambda_{Low\ m_{\gamma^*}}$	$\lambda_{HF\ e}$	$\lambda_{HF\ \mu}$
Value	1.3 ± 0.3	1.5 ± 0.5	0.6 ± 0.5	0.9 ± 0.4	1.0 ± 0.2

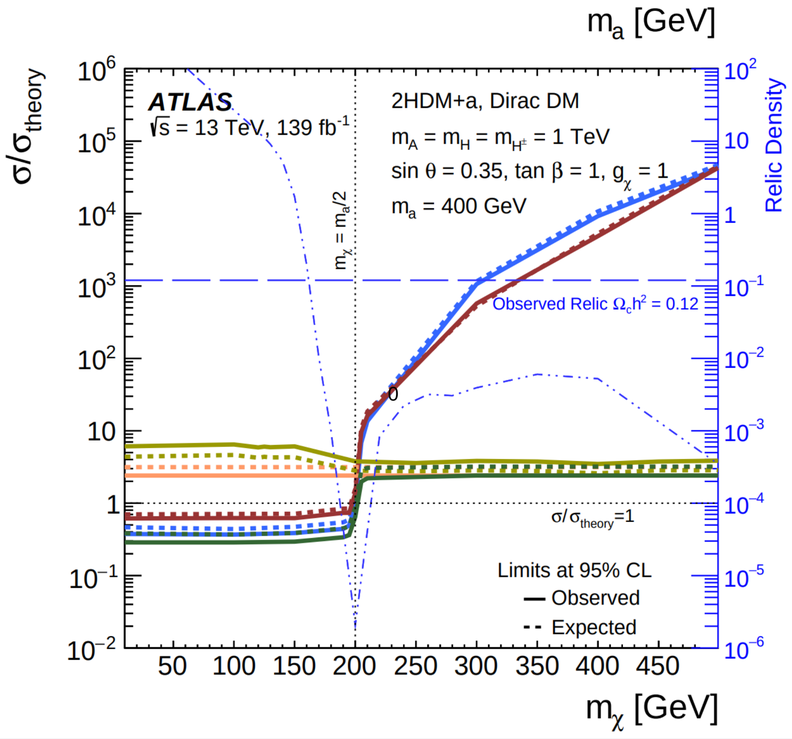
*extracted from background only fit

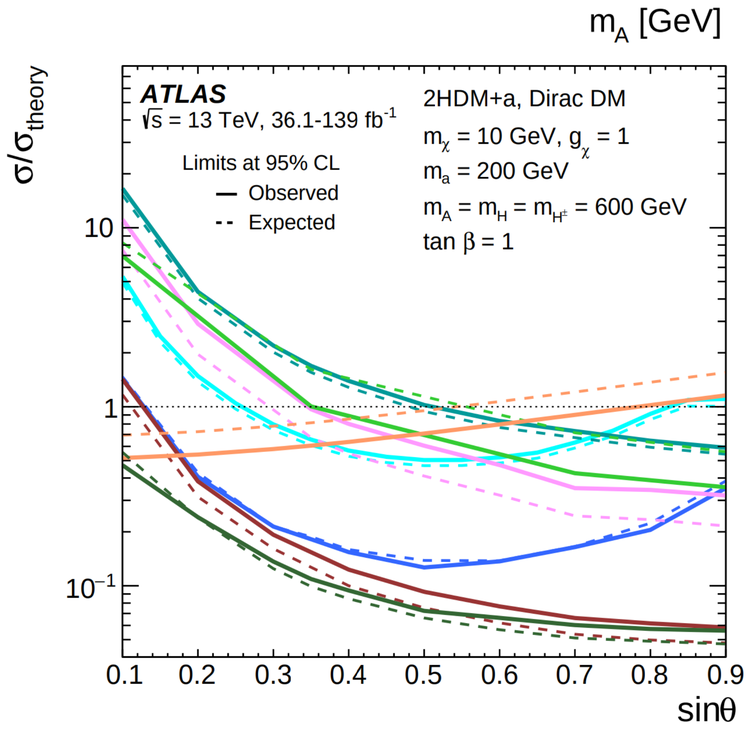
Analysis Results

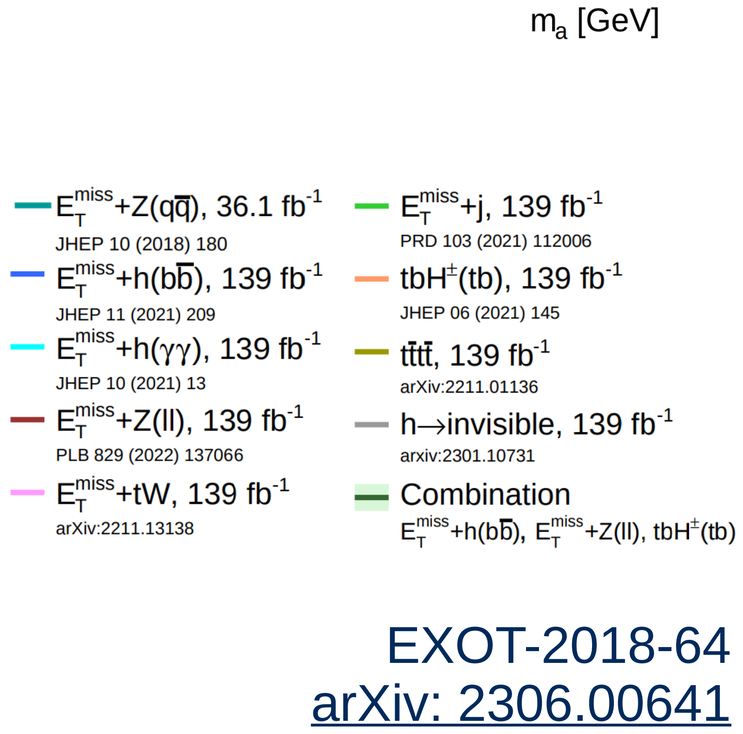












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