Search for Dark Matter in events with missing transverse momentum and a Higgs boson decaying to two photons in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector

Moriond Electroweak 2021

DD. 03. 2021

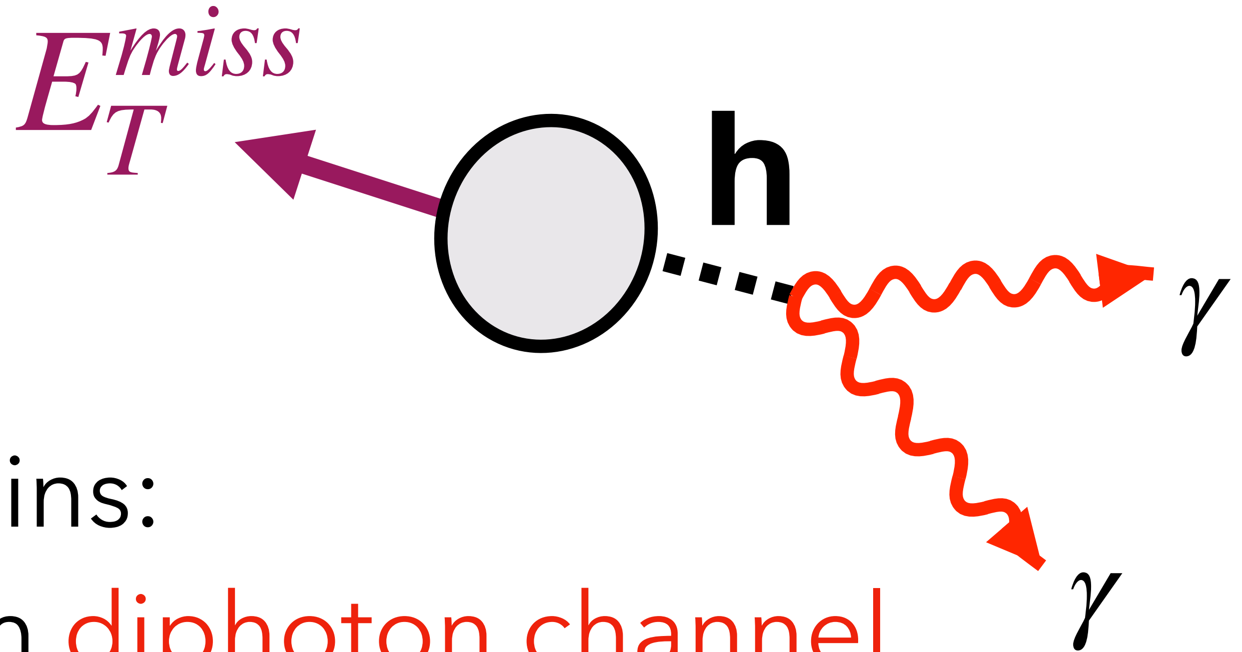
Alexander Leopold, on behalf of the ATLAS collaboration

ATLAS EXPERIMENT

Rencontres de Moriond since 1966

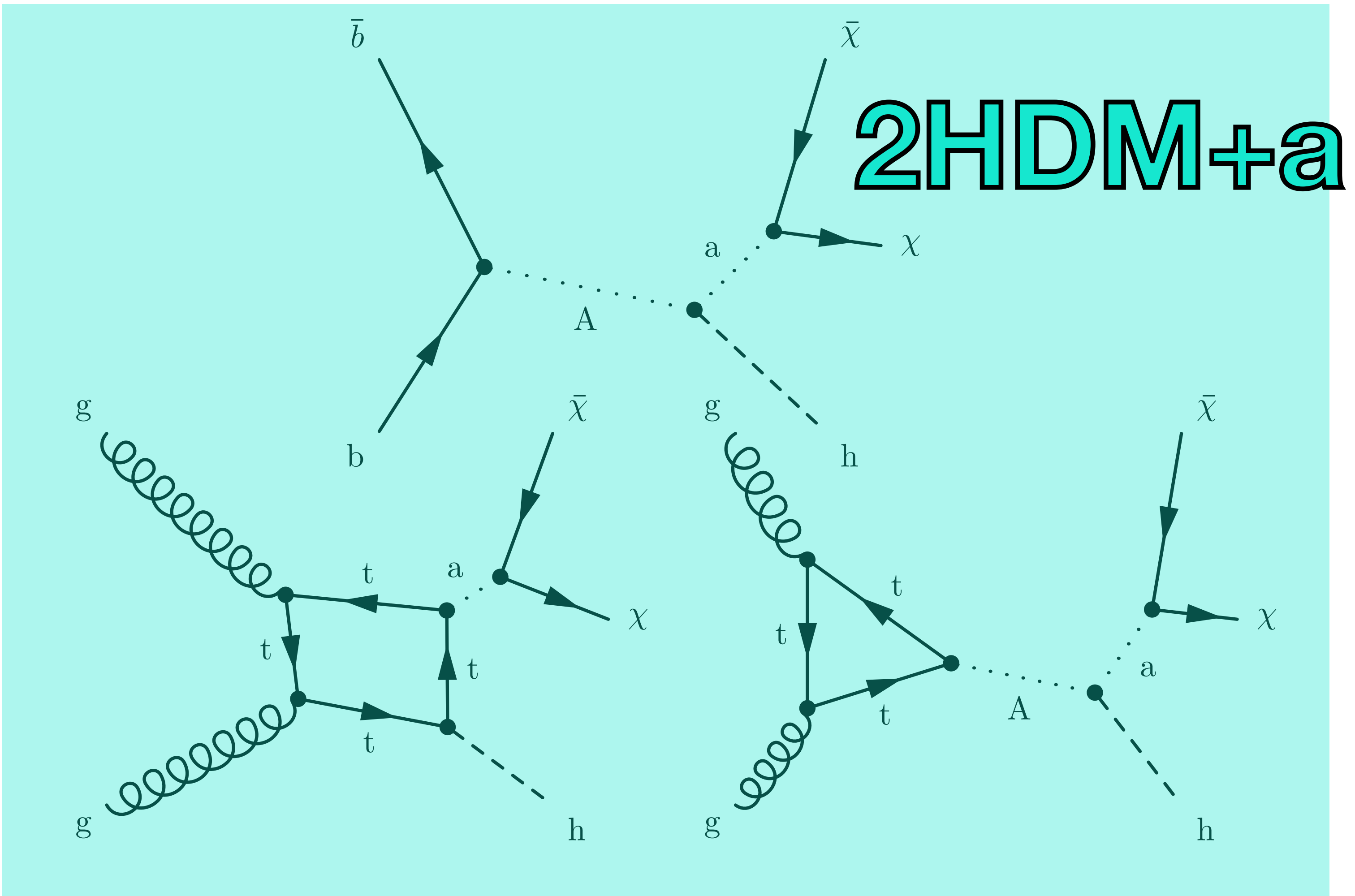
COPPE UFRJ

Motivation

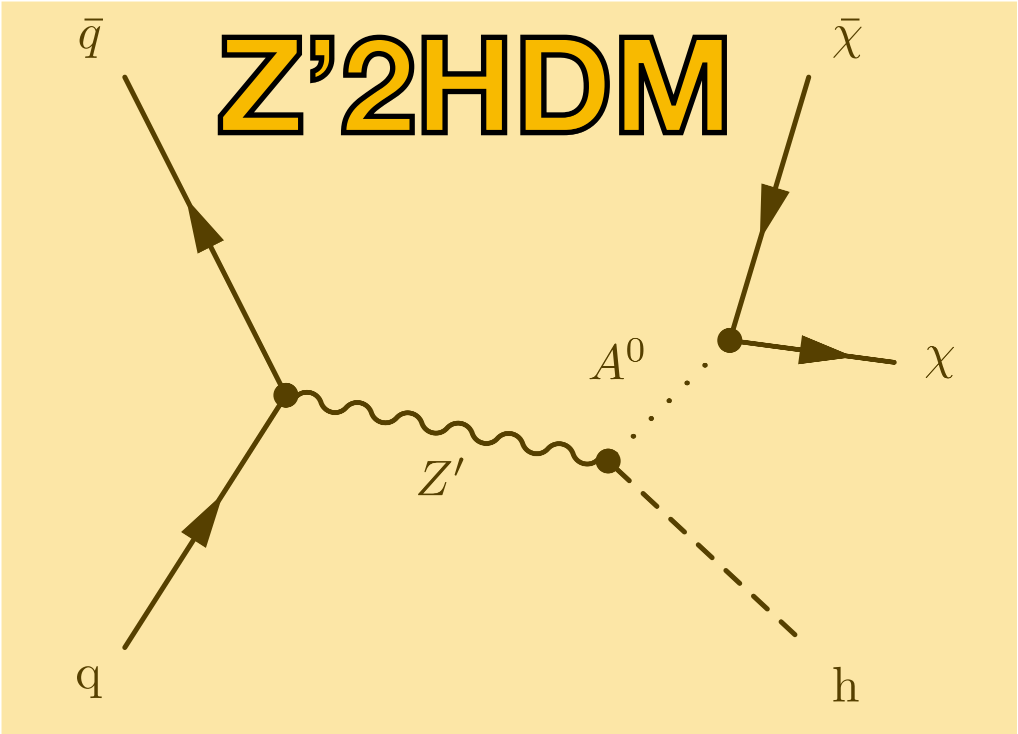


The "Mono-Higgs" signature contains:

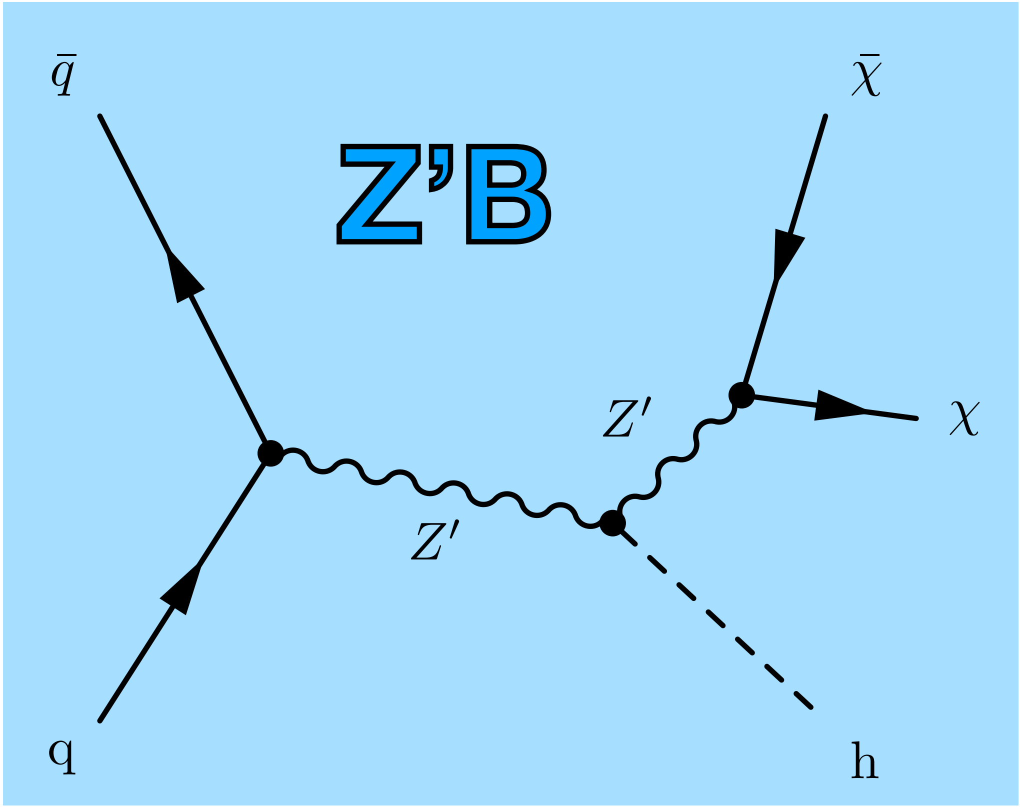
- Higgs boson, reconstructed from diphoton channel
- DM particles recoil against diphoton system, don't leave any observable signal in the detector ↠ missing transverse momentum



- Analysis profits from **diphoton trigger** (instead of E_T^{miss} trigger)
- Good sensitivity in the lower E_T^{miss} range
- Provides complementarity with $h(\to b\bar{b}) + E_T^{miss}$ channel
- Uses full Run 2 data (139 fb^{-1})



3 models considered in this analysis:
2HDM+a model used for the category optimisation
Results also interpreted in Z'2HDM and Z'B model



↠ Higgs boson h in all models assumed to have mass of 125 GeV!

Conf Note: ATLAS-CONF-2020-054

Analysis overview

Event pre-selection: 2 photons ($105 \leq m_{\gamma\gamma} \leq 160$ GeV) and $E_T^{miss} > 90$ GeV

↞ *all objects reconstruted w.r.t. the diphoton vertex (VX)*

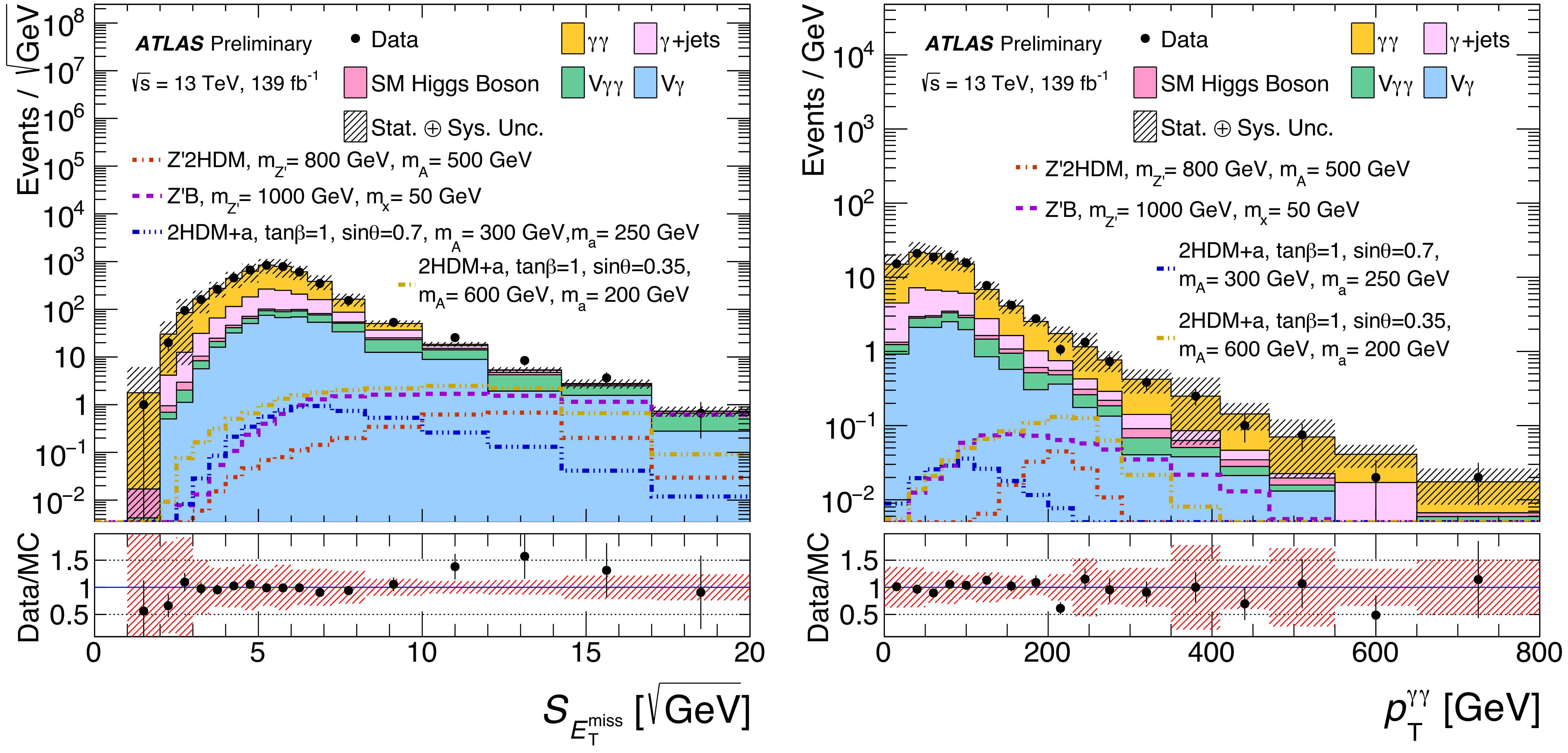
Background rejection cuts:

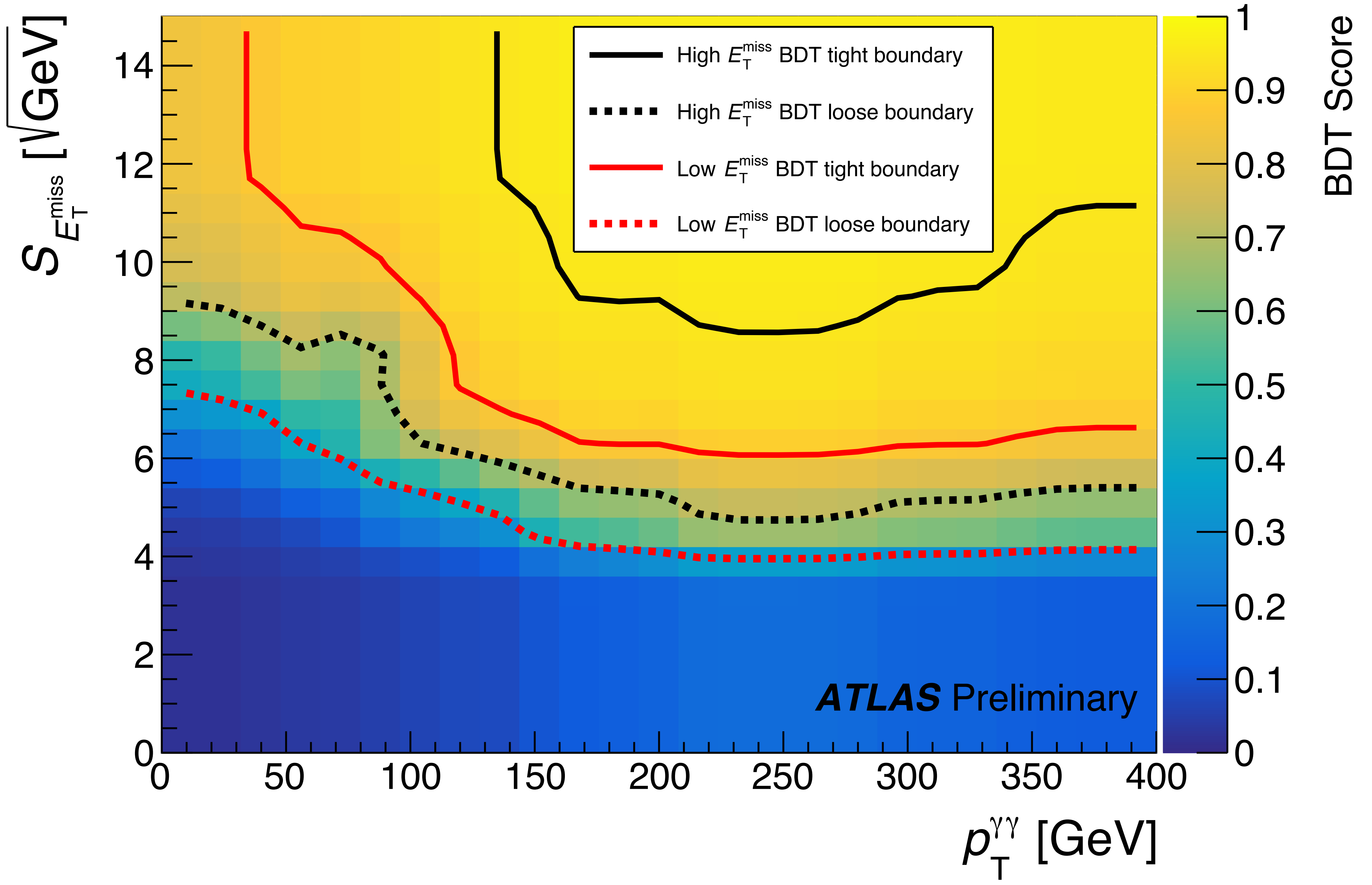
- ΔE_T^{miss}(diphoton VX, hardest VX) < 30 GeV ↞ *reject fake E_T^{miss}*
- electron & muon veto ↞ *reject $V\gamma$ and $V\gamma\gamma$ backgrounds*

Categorisation performed with BDT, using 2 input variables:

- $S_{E_\mathrm{T}^\mathrm{miss}} = E_\mathrm{T}^\mathrm{miss} / \sqrt{\sum E_\mathrm{T}}$
- $p_\mathrm{T}^{\gamma\gamma}$

Category	Category name	Selection
1	high $E_\mathrm{T}^\mathrm{miss}$, BDT tight	$E_\mathrm{T}^\mathrm{miss} > 150$ GeV, $0.950 <$ BDT score < 1
2	high $E_\mathrm{T}^\mathrm{miss}$, BDT loose	$E_\mathrm{T}^\mathrm{miss} > 150$ GeV, $0.694 <$ BDT score < 0.950
3	low $E_\mathrm{T}^\mathrm{miss}$, BDT tight	$E_\mathrm{T}^\mathrm{miss} < 150$ GeV, $0.864 <$ BDT score < 1
4	low $E_\mathrm{T}^\mathrm{miss}$, BDT loose	$E_\mathrm{T}^\mathrm{miss} < 150$ GeV, $0.386 <$ BDT score < 0.864





Exp. and theor. uncertainties

ATLAS

Uncertainty on non-resonant background modelling estimated via “spurious signal” test

PU reweighting to obtain same profile in data and MC

Signal interpolation method concerns the limit setting only

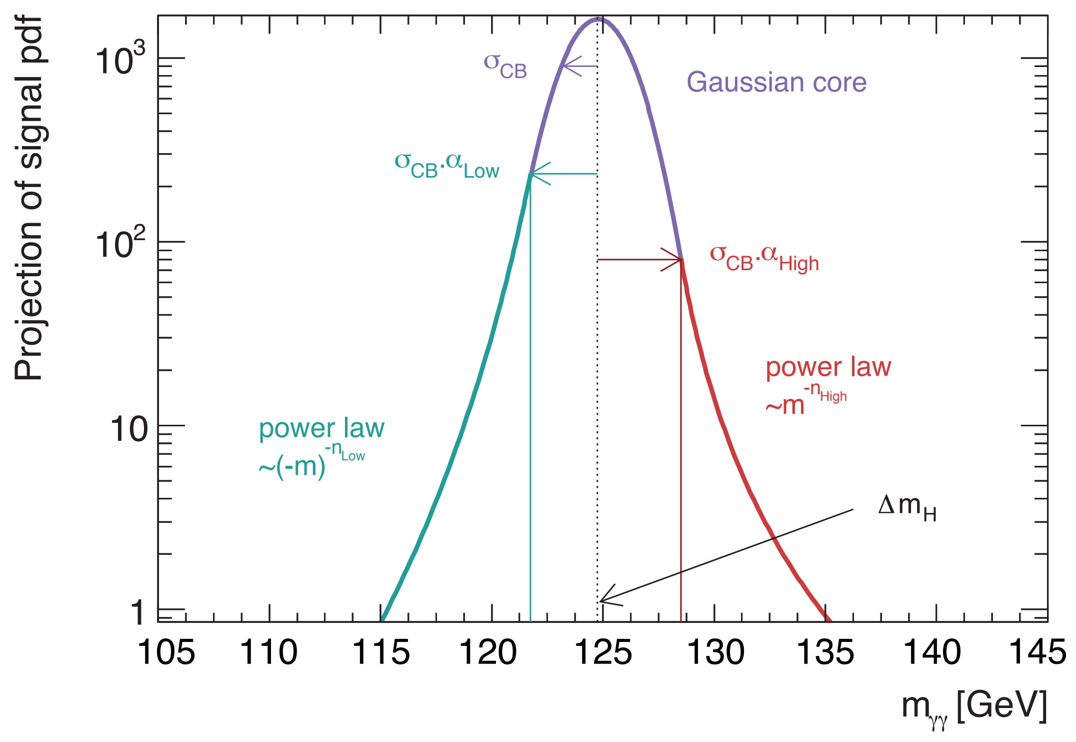
QCD scale uncertainty:
uncertainty on the cross-section from higher order terms

PDF & α_S uncertainty

Source	Signals [%]	Backgrounds [%]	
		SM Higgs boson	Non-resonant background
Experimental			
Luminosity	1.7	1.7	-
Trigger efficiency	1.0	1.0	-
Vertex selection (inclusive cat.)	< 0.01	< 0.01	-
Photon energy scale	1.0	1.2	-
Photon energy resolution	0.3	0.4	-
Photon identification efficiency	1.3	1.3	-
Photon isolation efficiency	1.3	1.4	-
AtlFastII simulation	2.0	–	-
E_T^{miss} reconstruction and jet uncertainty	2.8	1.7	-
Pileup reweighting	2.3	2.0	-
Signal efficiency interpolation	< 13	–	-
Non-resonant background modeling	–	–	6.8
Theoretical			
Factorization and renormalization scale in migration	1.3	3.5	-
PDF+α_S in migration	1.2	1.0	-
Factorization and renormalization scale in cross section	< 20	< 2.8	-
PDF+α_S in cross section	< 32	2.8	-
Multi-parton interactions, ISR/FSR, hadronization	3.0	3.0	-
$\mathcal{B}(H \to \gamma\gamma)$	1.73	1.73	-

Table shows representative values for the impact on the most sensitive category (high E_T^{miss}, tight BDT)

Results

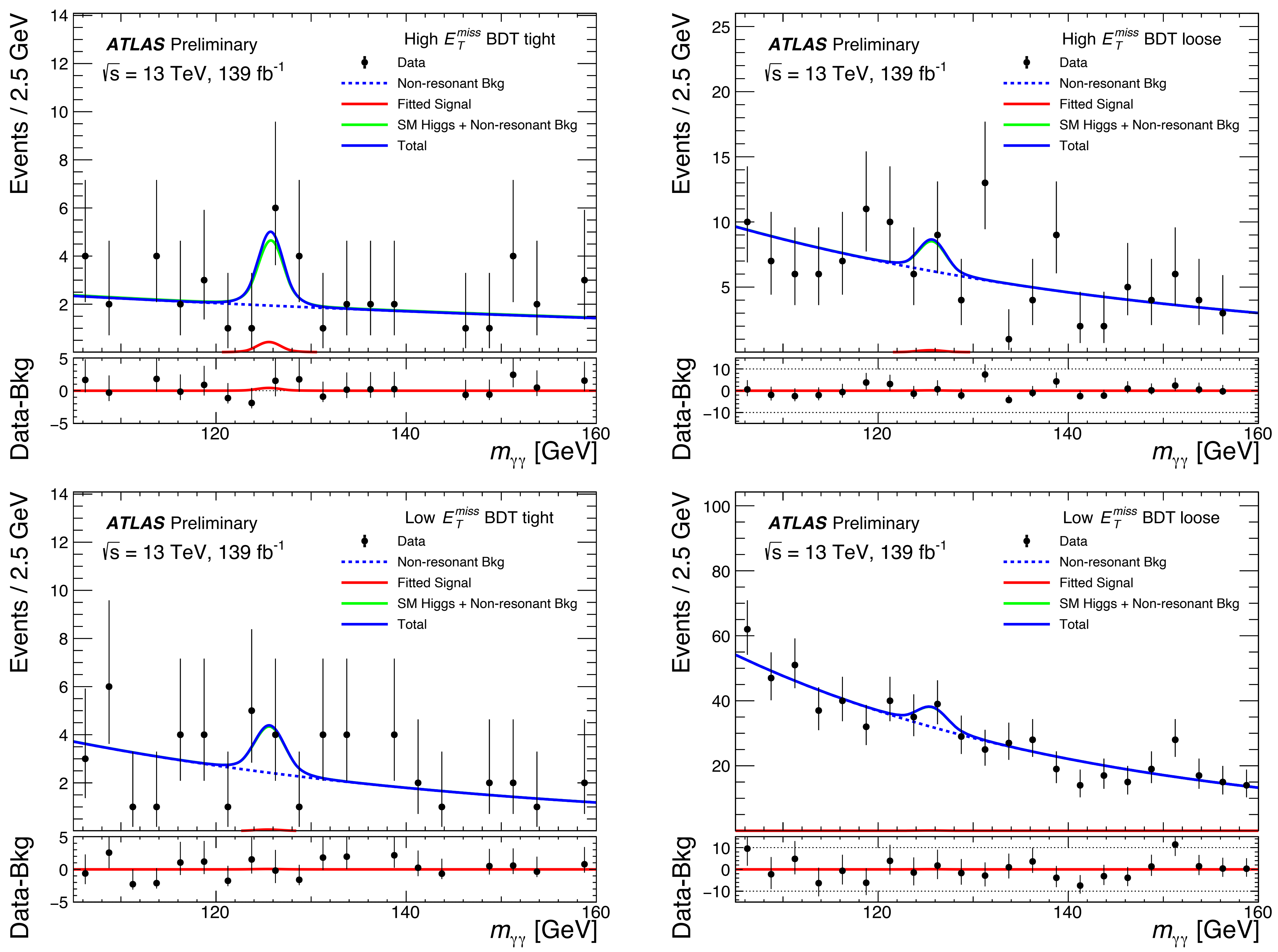


"SM Higgs" peak and signal modelled with double-sided Crystal Ball function (gaussian core and power laws in the tails)

Non-resonant BG modelled by smoothly falling function
↠ template method, parameters estimated from $m_{\gamma\gamma}$ sidebands
(105 < $m_{\gamma\gamma}$ < 120 GeV, 130 < $m_{\gamma\gamma}$ < 160 GeV)

Unbinned maximum likelihood fit performed simultaneously on all 4 signal categories to extract the signal strength

↠ *No significant excess above the SM prediction observed*



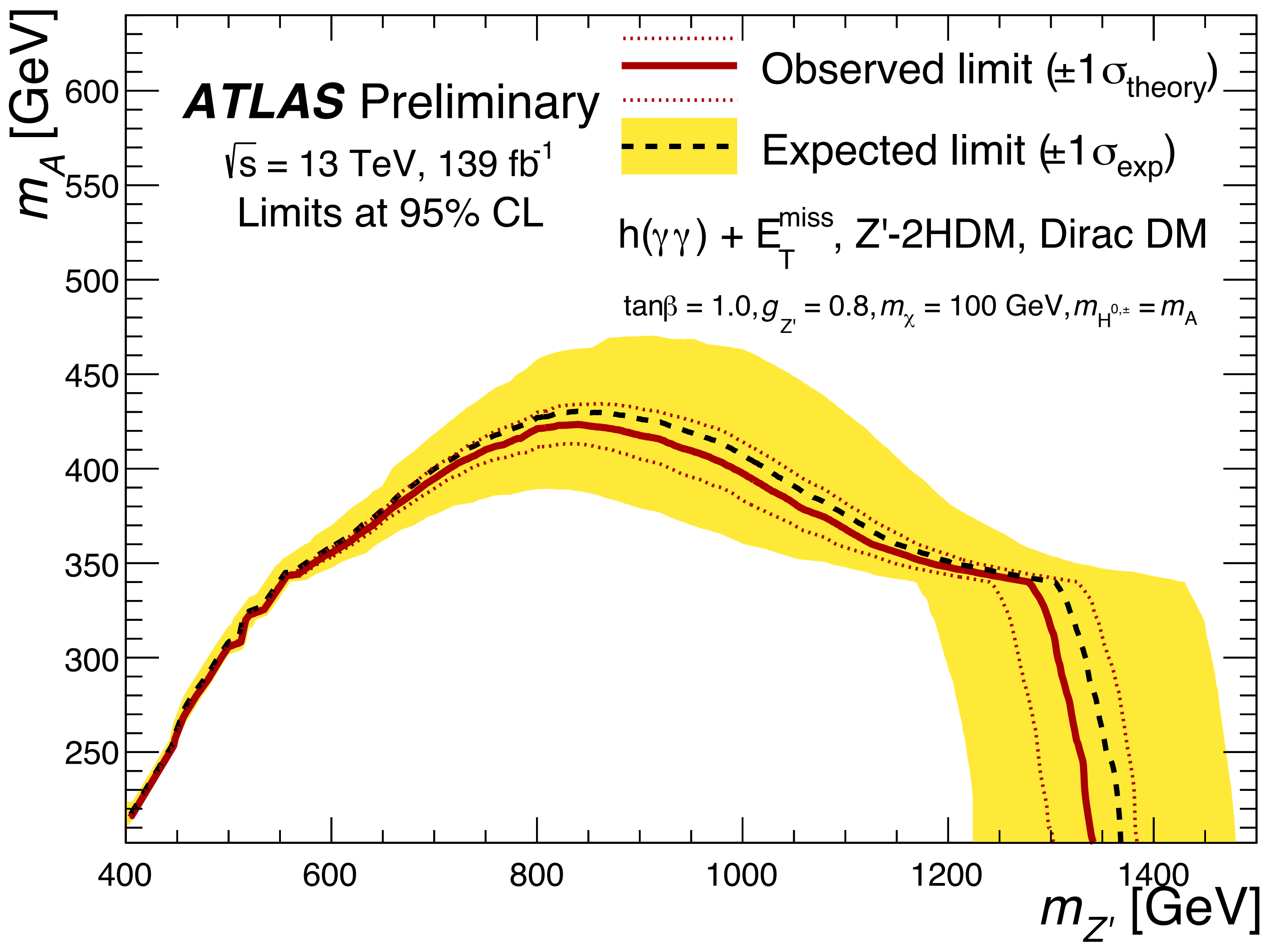
Category	High E_T^{miss} BDT tight	High E_T^{miss} BDT loose	Low E_T^{miss} BDT tight	Low E_T^{miss} BDT loose
Data	12	29	11	143
Backgrounds				
SM Higgs boson	3.74 ± 0.25	3.40 ± 0.28	3.12 ± 0.23	9.9 ± 1.5
Non-resonant	7.8 ± 1.3	25.3 ± 2.3	9.8 ± 1.5	130 ± 5
Total	11.6 ± 1.3	28.7 ± 2.3	12.9 ± 1.5	140 ± 5
Z'_B model, $m_{Z'_B}$ = 1000 GeV, m_χ = 50 GeV				
Signal yields	0.7 ± 3.1	0.1 ± 0.6	0.1 ± 0.6	0.1 ± 0.6
Z'-2HDM model, m_A = 800 GeV and m_χ = 500 GeV				
Signal yields	0.6 ± 3.1	0.1 ± 0.4	0.05 ± 0.26	0.03 ± 0.17
2HDM+a model, m_A = 600 GeV, m_a = 200 GeV, $\tan\beta$ = 1.0, $\sin\theta$ = 0.35				
Signal yields	0.6 ± 3.1	0.2 ± 1.2	0.1 ± 0.5	0.1 ± 0.7

Interpretation

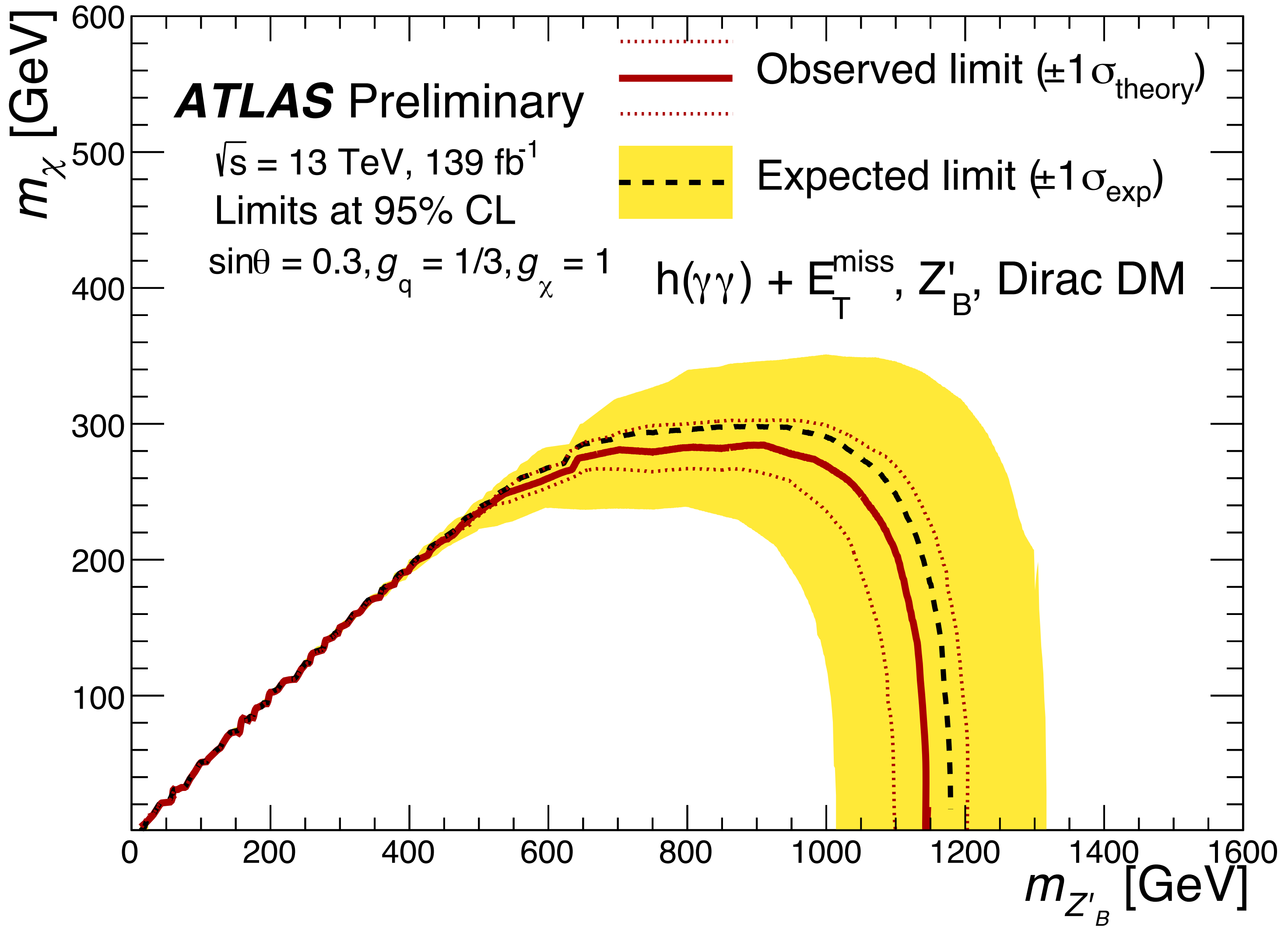
Results are interpreted in the framework of 95% CL upper limits on the cross sections times branching fraction of the considered models

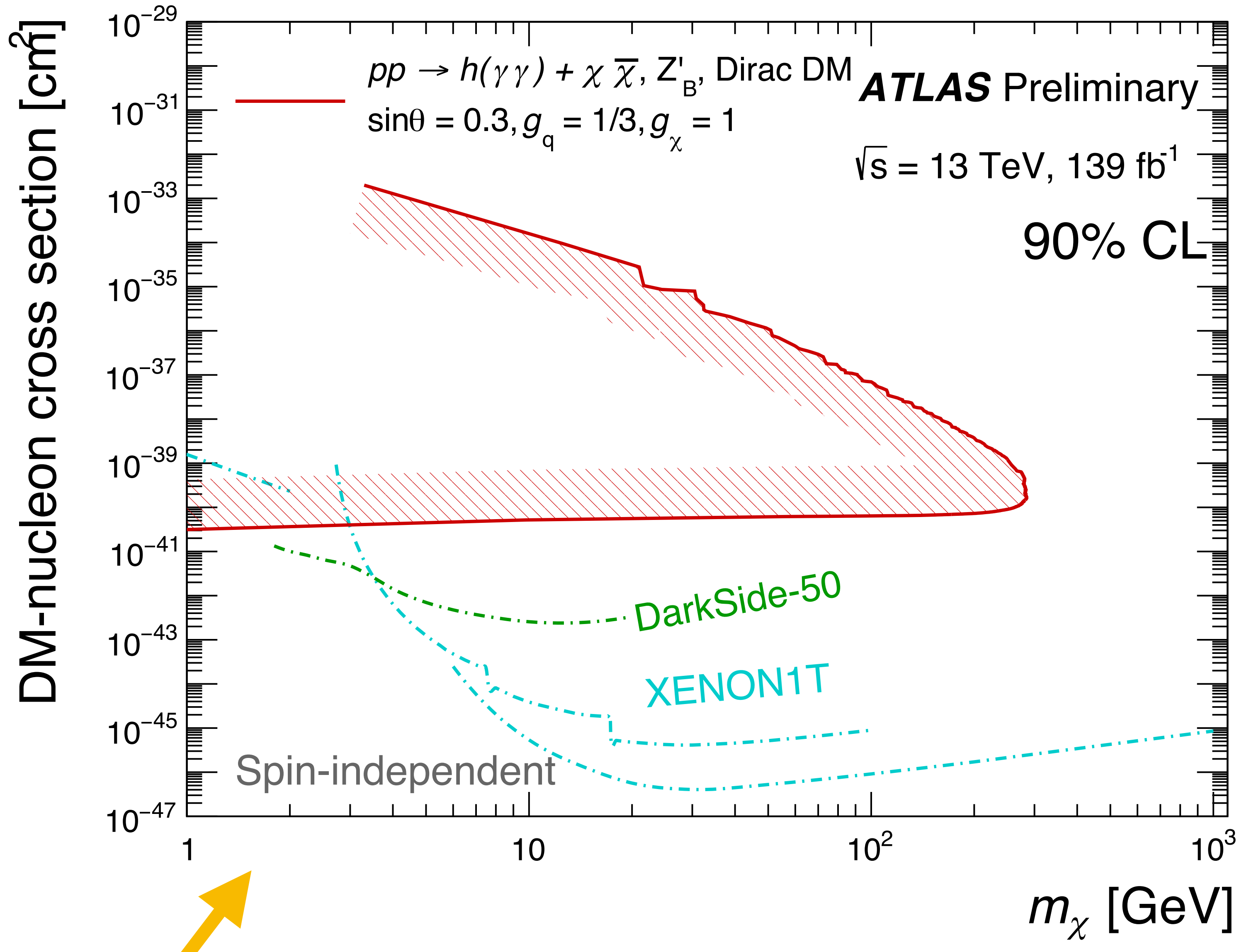
↠ displayed as exclusion contours

Z'2HDM



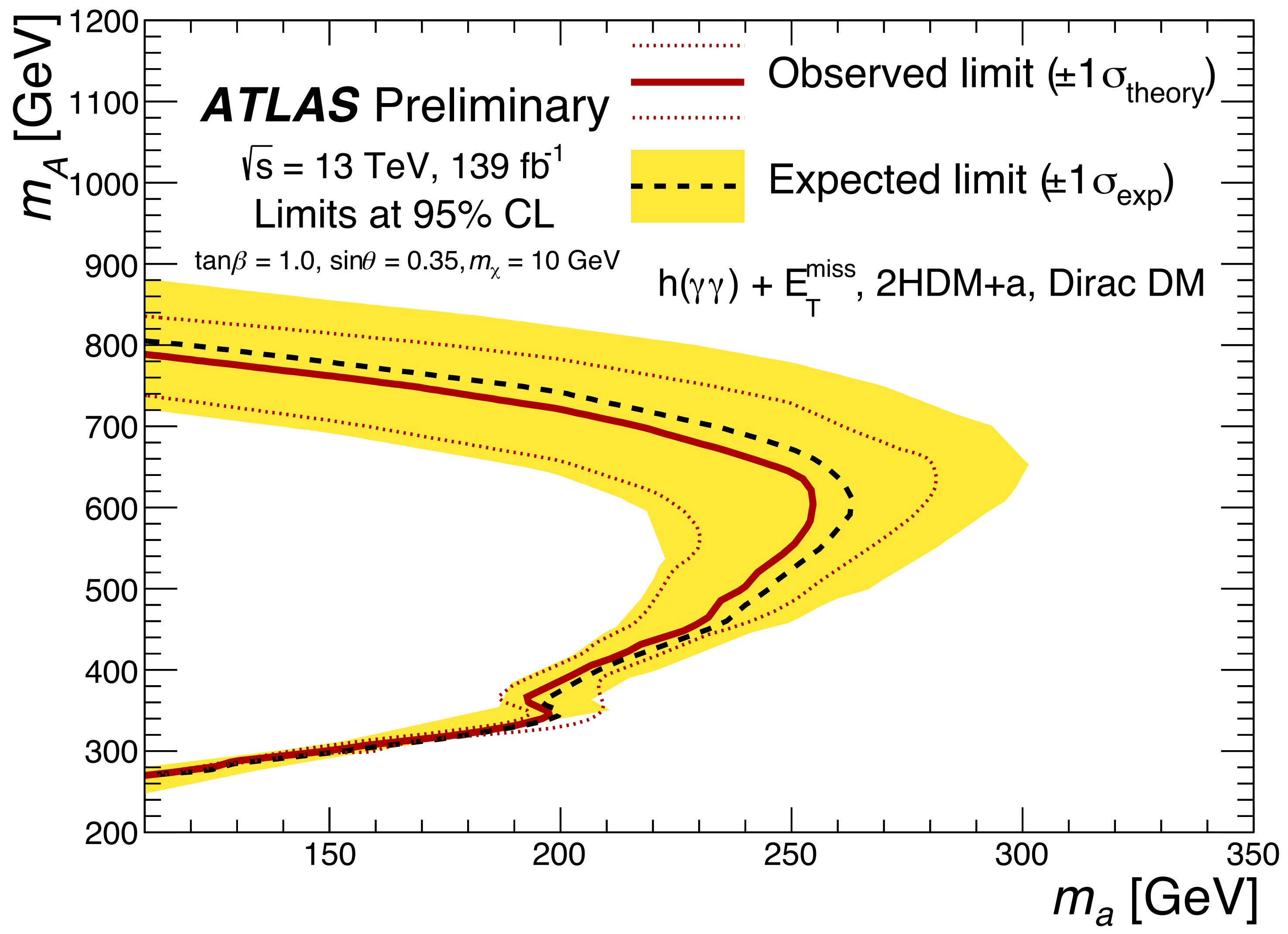
Z'B

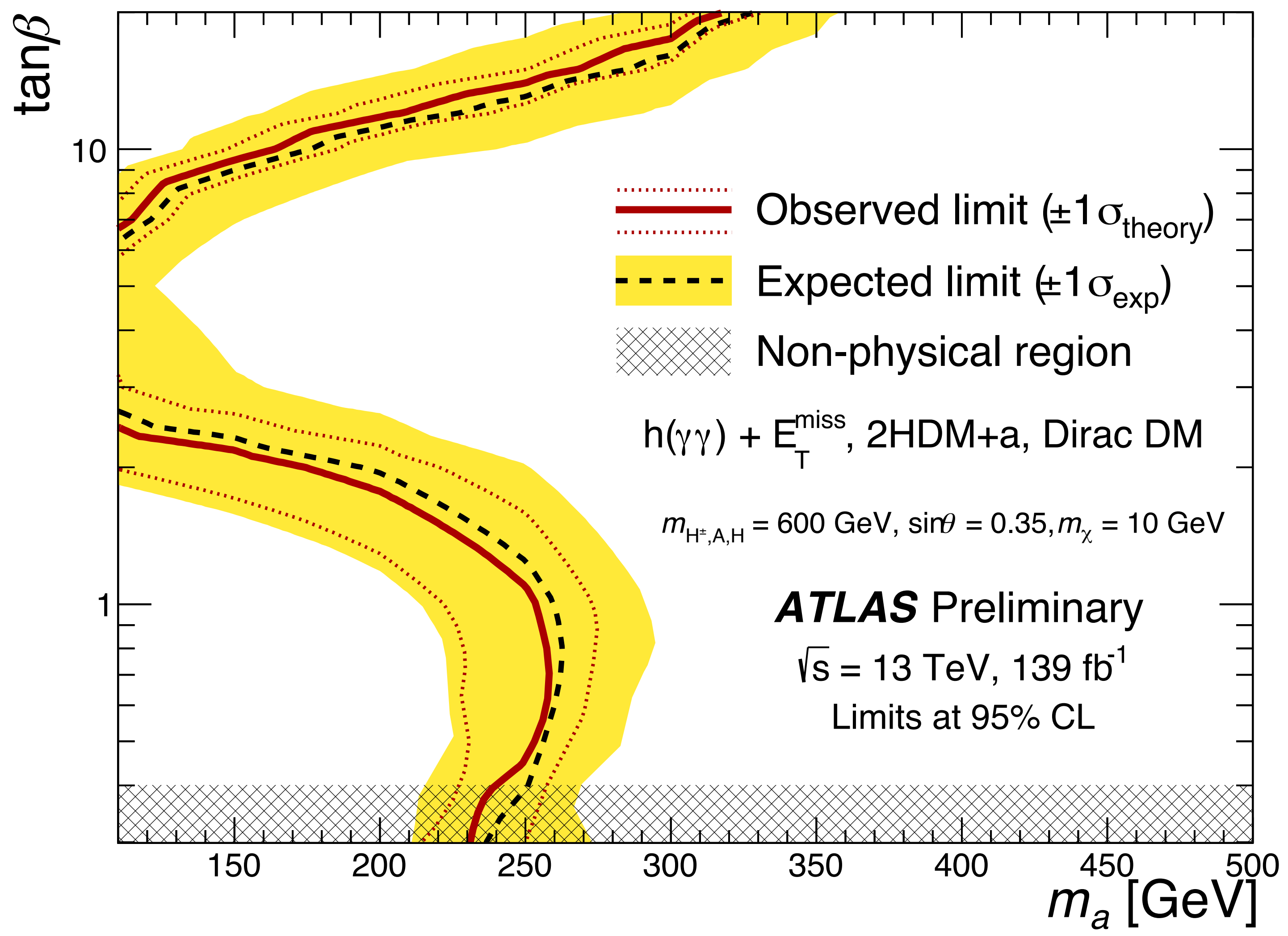




only valid for the specified model parameters!

2HDM+a





BACKUP

$h \rightarrow \gamma\gamma$ "common" pre-selection

Trigger:

2015 - 2016: 2 loose photons (35 GeV, 25 GeV)

2017 - 2018: 2 *medium* photons (35 GeV, 25 GeV) ↞ *keep trigger rates constant*

- ≥1 Vertex reconstructed
- **2 photons** (p_T > 25 GeV) within $|\eta| < 2.37$, excluding $1.37 < |\eta| < 1.52$ (crack region)
- tight photon identification and isolation requirements
- (Sub) leading photon needs to pass $p_T/m_{\gamma\gamma} < 0.35(0.25)$ ↞ optimised for 125 GeV resonance
- found within $105 \leq m_{\gamma\gamma} \leq 160$ GeV

Jets:

- Particle flow jets
- p_T > 25 GeV, |η|<4.4
- pileup suppression cuts

Electrons:

- p_T > 10 GeV, |η|<2.47
- exclude crack region
- medium WP
- $|d_0|/\sigma_{d_0} < 5.0$, $|z_0|\sin\theta < 0.5$

Muons:

- p_T > 10 GeV, |η|<2.7
- medium WP
- $|d_0|/\sigma_{d_0} < 3.0$, $|z_0|\sin\theta < 0.5$

Missing transverse momentum (E_T^{miss}):

- neg. vector sum of the transverse momenta of all hard object
- soft E_T^{miss} reconstructed from tracks

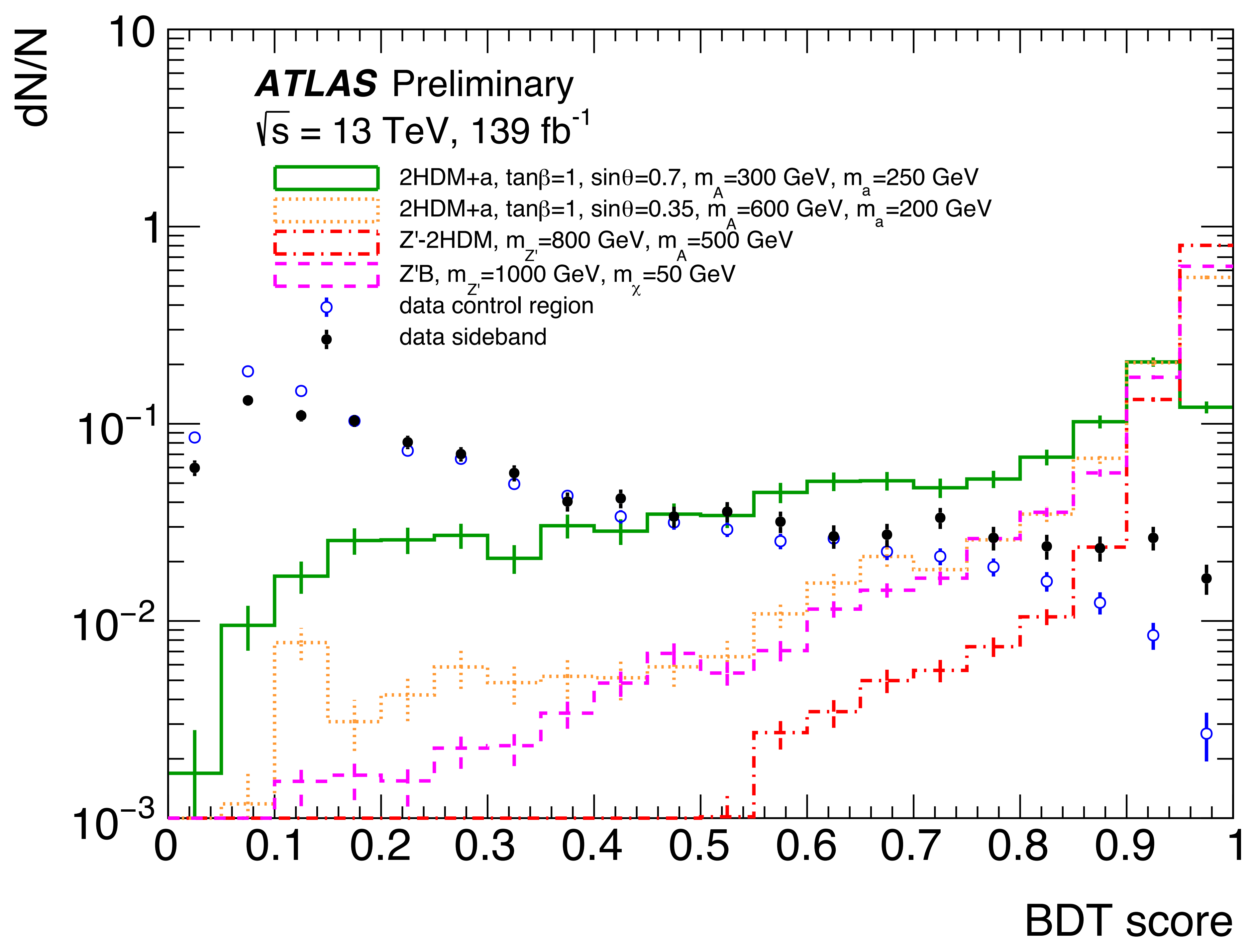
- Diphoton vertex: spatial resolution provided by granularity of EM calorimeter is used to improve the vertex selection in diphoton events (NN)

BDT training

Goal: train single BDT, retain good BG/Signal separation power for all models and parameter spaces

- Background: Data control region (NTI data, at least one photon fails tight ID or isolation req.)
- Signal: 2HDM+a *with low -E_T^{miss} spectrum* (tanβ=1, sinθ=0.7, m_A=300 GeV, m_a=250 GeV)

↠ *"BG-like" signal chosen to exploit correlations low E_T^{miss} region with the BDT and preserve good sensitivity in the high E_T^{miss} region*



Presentation title

ATLAS