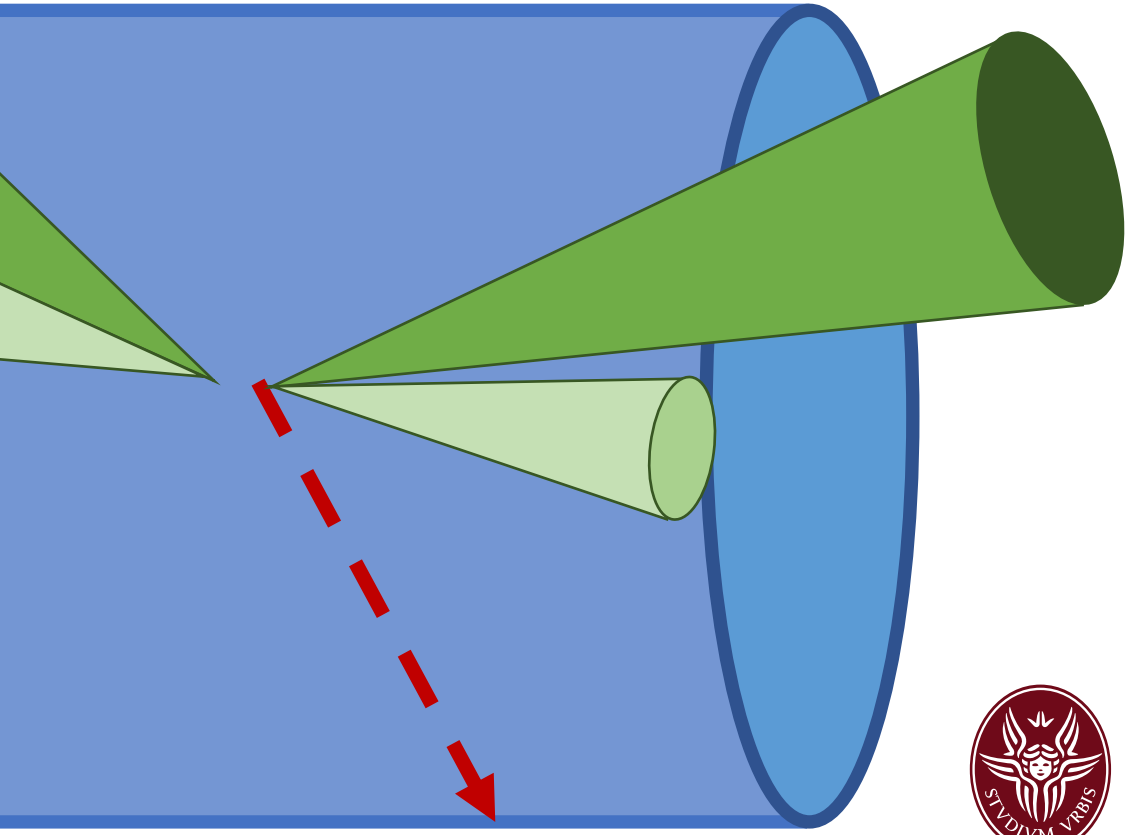
Dark matter searches with the ATLAS detector



Luigi Sabetta on behalf of the ATLAS collaboration

Phenomenology 2021 Symposium
24-26 May 2021

SAPIENZA
UNIVERSITÀ DI ROMA

INFN

ATLAS
EXPERIMENT

Talk safety instructions

This talk will cover some of the most recent results by ATLAS, touching Simplified Models and 2HDM models

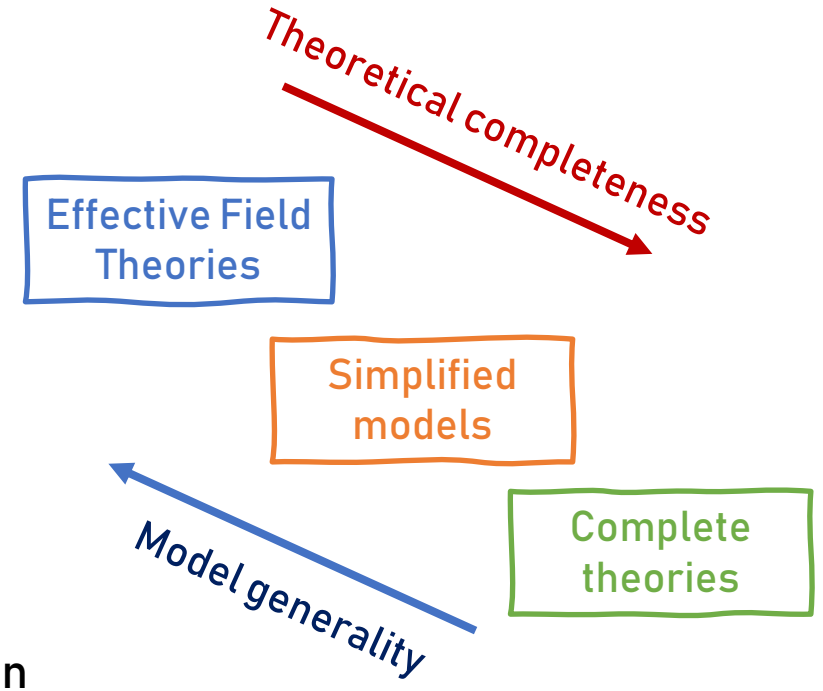
Simplified models

- Beyond EFT (Run1 approach)
- Introduce new mediator (Z') and fermionic WIMPs
- Few additional parameters

$$\{\mathrm{m}_{\chi}, m_{Z'}, g_q, g_{DM}\}$$

- More complete kinematic description

- Mono-Jet
- VBF Higgs + E_T^{miss}
- VBF Higgs + E_T^{miss} + γ



2HDM

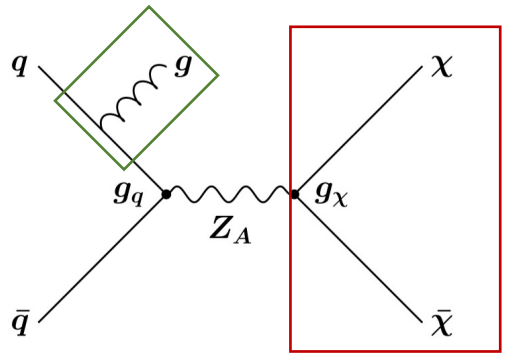
- More complex model
- Implements 2 Higgs doublets (5 Higgs bosons)
- More parameters

$$\{m_A, m_{Z'}, m_{\chi}, \tan\beta, g_{Z'}, \alpha\}$$

- Mono - $H \rightarrow \gamma\gamma$
- Mono - $H \rightarrow b\bar{b}$

Mono-Jet

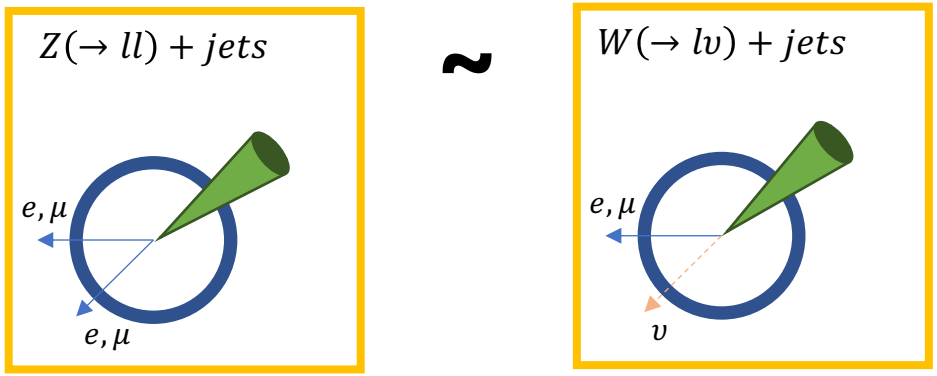
arXiv:2102.10874



The analysis aims to find an excess in the E_T^{miss} spectrum

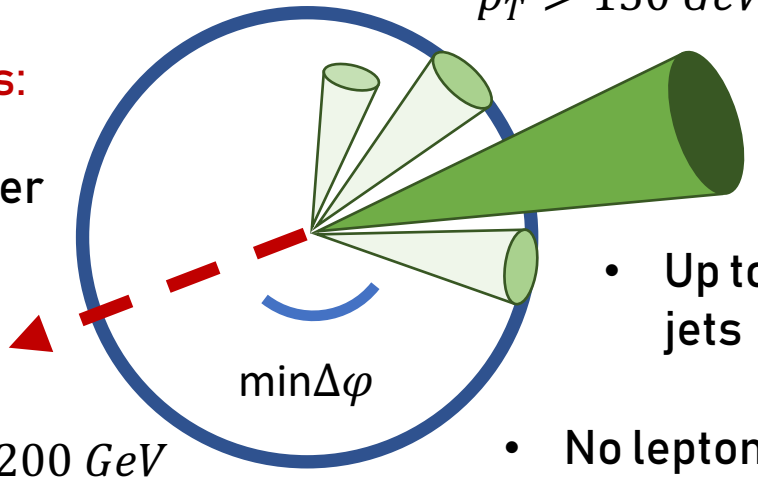
- Sensitive to a broad range of different models thanks to its general signature
- Dominant irreducible background: $Z(\rightarrow \nu\nu) + jets$
- SM predictions constrained using orthogonal CRs
- NNLO QCD & nNLO EW corrections to V+jets processes

$Z(\rightarrow \nu\nu) + jets$
$W(\rightarrow l_{lost}\nu) + jets$

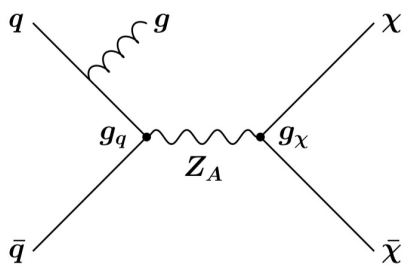


Key Events selections:

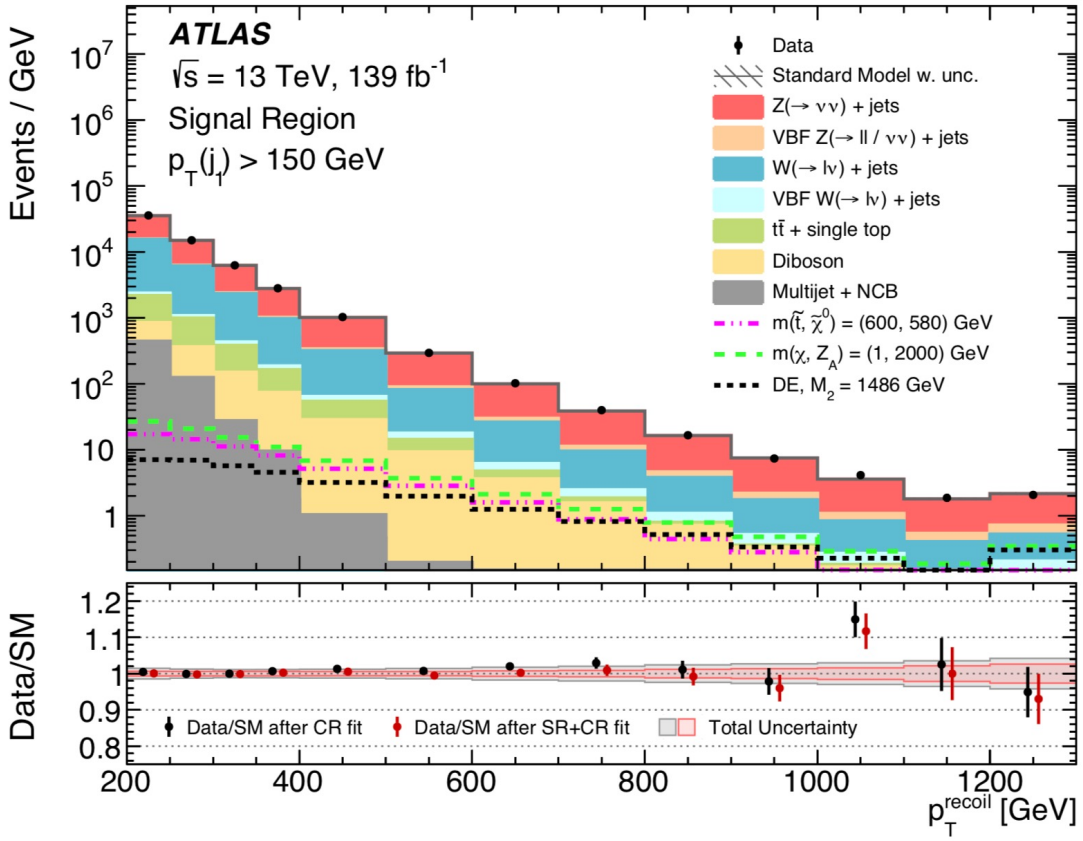
- E_T^{miss} Trigger
- $E_T^{miss} > 200\ GeV$
- At least one Jet with $p_T > 150\ GeV$
- Up to 3 additional jets
- No leptons nor photons



Mono-Jet

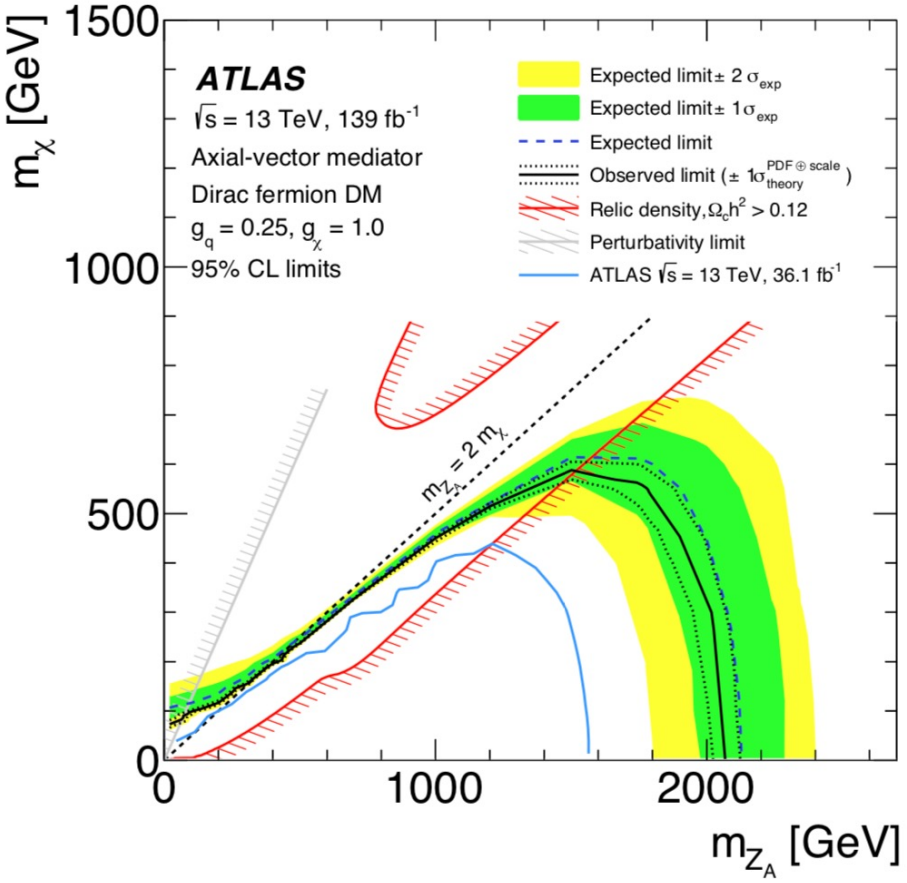


- Simultaneous likelihood fit to p_T^{recoil} distributions in CR to estimate SR total background



bkg uncertainty reached in SR (1.2-4%)

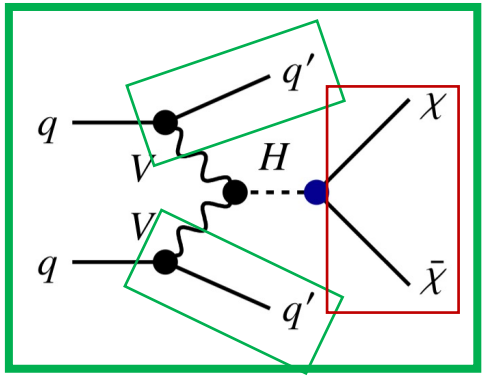
No significant excess observed



.. But many other interpretations! (backup)

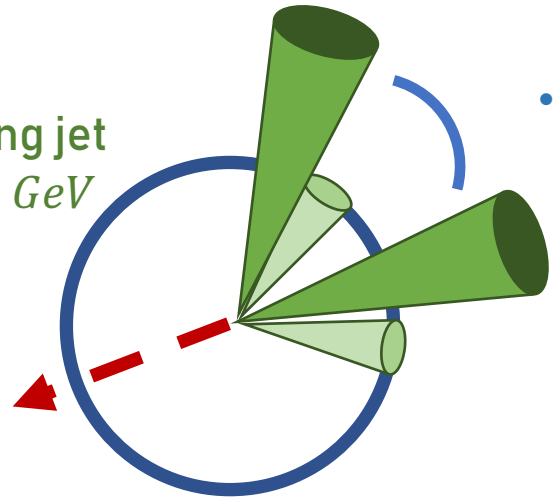
VBF $H \rightarrow invisible$

ATLAS-CONF-2020-008

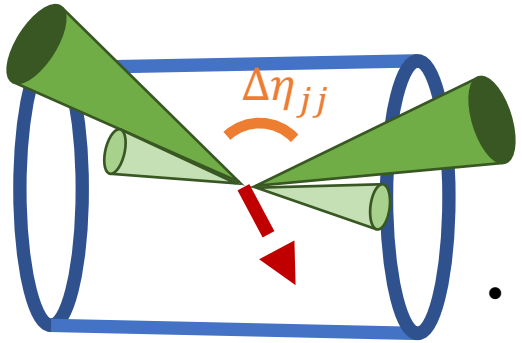


Key Events selections:

- (Sub-) Leading jet $p_T > 60\ (50)\ GeV$
- $E_T^{miss} > 200\ GeV$



- $\Delta\varphi_{jj} < 2$



- $|\Delta\eta_{jj}| > 3.8$
- No leptons nor photons

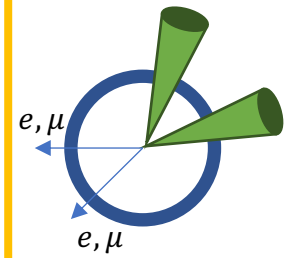
The analysis aims to find an excess in the m_{jj} spectrum

- Dominant irreducible background: $Z(\rightarrow \nu\nu) + jets$
- SM predictions constrained using orthogonal CRs

$Z(\rightarrow \nu\nu) + jets$
$W(\rightarrow l_{lost}\nu) + jets$

$\sim$

$Z(\rightarrow ll) + jets$



ATLAS-CONF-2020-008

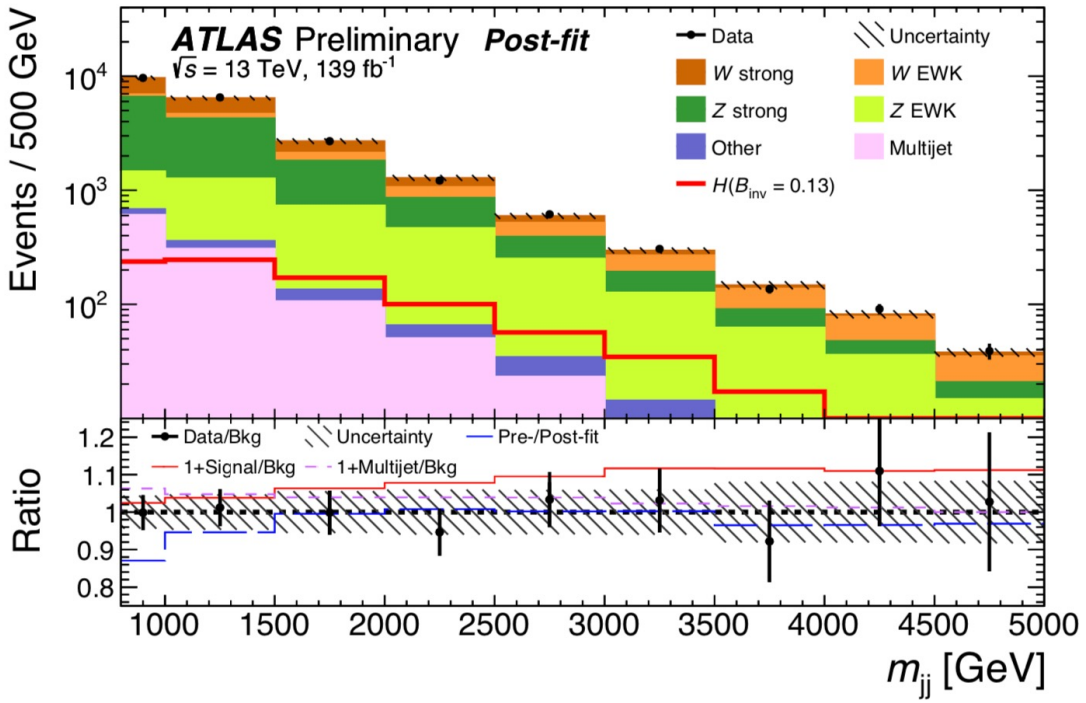
VBF $H \rightarrow invisible$

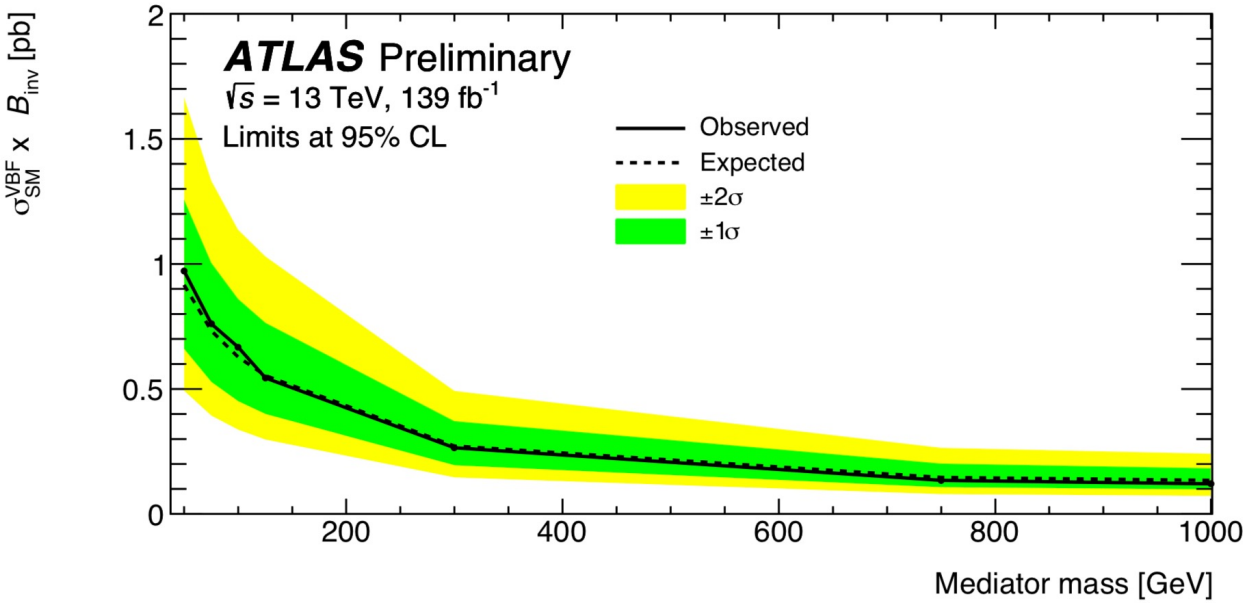
- Simultaneous likelihood fit to m_{jj} distributions in CRs to estimate SR total background

No significant excess observed

95% CL limit $BR_{H\rightarrow inv.}$ = 0.13

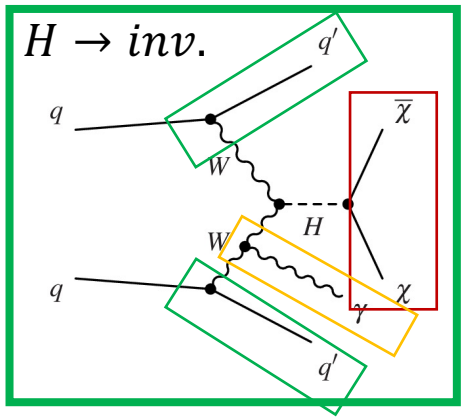
→ $36\ fb^{-1}$ result = 0.37

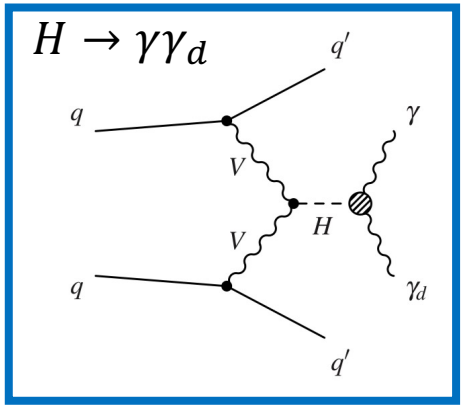




VBF $H \rightarrow invisible + \gamma$

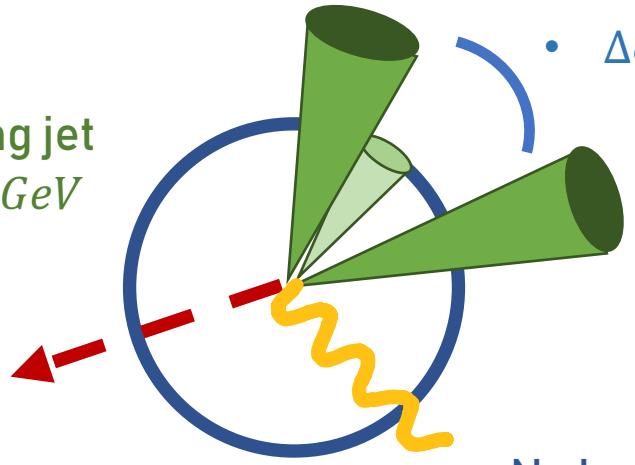
ATLAS-CONF-2021-004



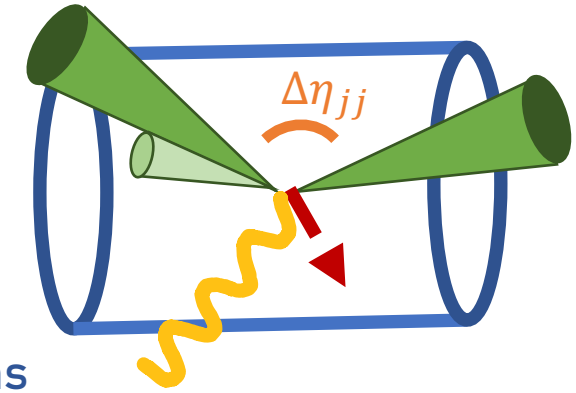


Key Events selections:

- (Sub-) Leading jet $p_T > 60\ (50)\ GeV$
- $E_T^{miss} > 150\ GeV$



- $\Delta\varphi_{jj} < 2.5$



- $|\Delta\eta_{jj}| > 3$
- No leptons
- 1 photon

Both a search for H to inv. particles and H to Dark Photons

- Dominant irreducible background:

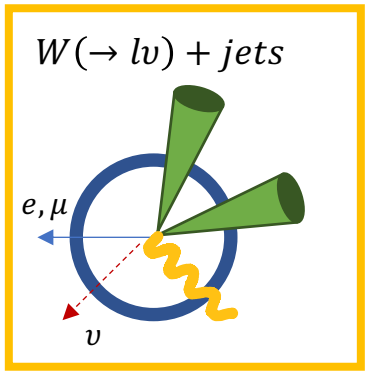
$$Z(\rightarrow \nu\nu) + jets + \gamma$$

- SM predictions constrained using orthogonal CRs

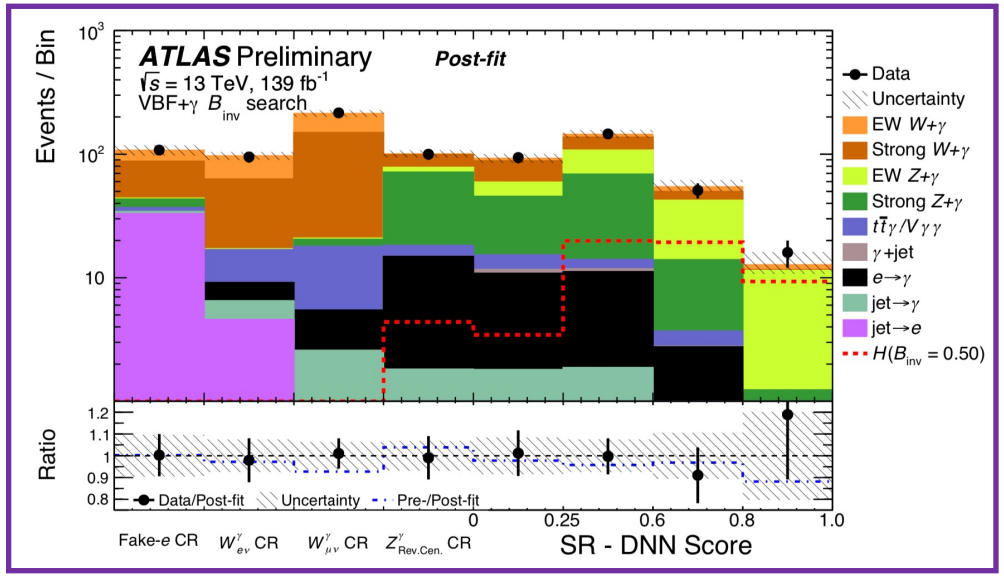
$$W(\rightarrow l_{lost}\nu) + jets + \gamma$$

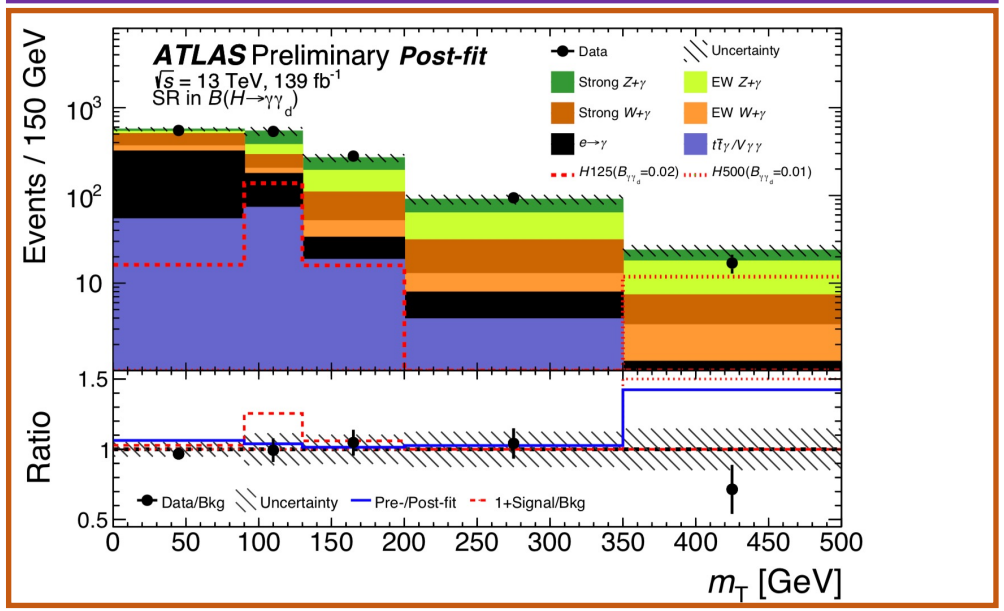
~

Z CR



VBF $H \rightarrow invisible + \gamma$





- Simultaneous likelihood fit to $DNN\ score$ (or m_T) distributions in CR to estimate SR total background

No significant excess is observed.

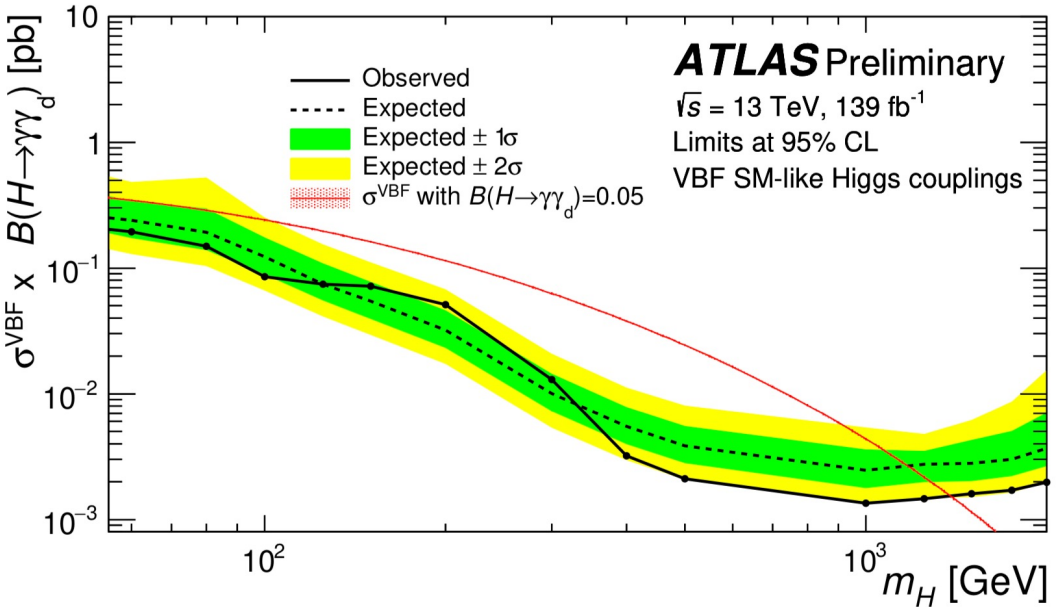
Observed (expected) 95% CL limits:

$BR_{H\rightarrow inv.} \rightarrow 0.37(0.34^{+0.15}_{-0.10})$

$BR_{H^{125GeV}\rightarrow\gamma\gamma_d} \rightarrow 0.014\ (0.017^{+0.007}_{-0.005})$

most stringent to date ✓

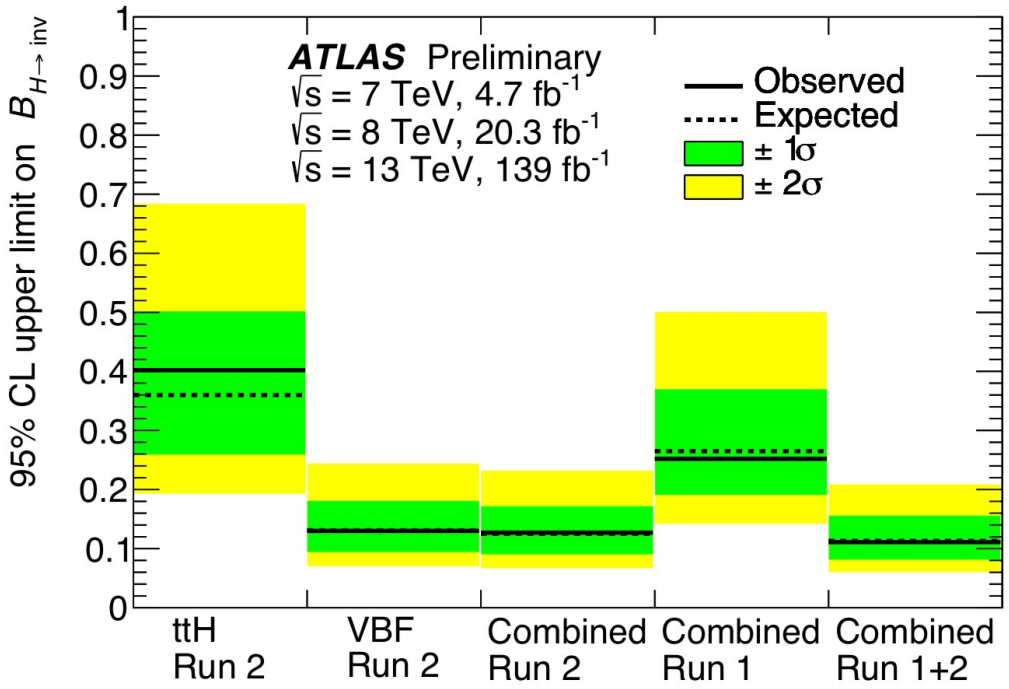
CMS result: 0.029

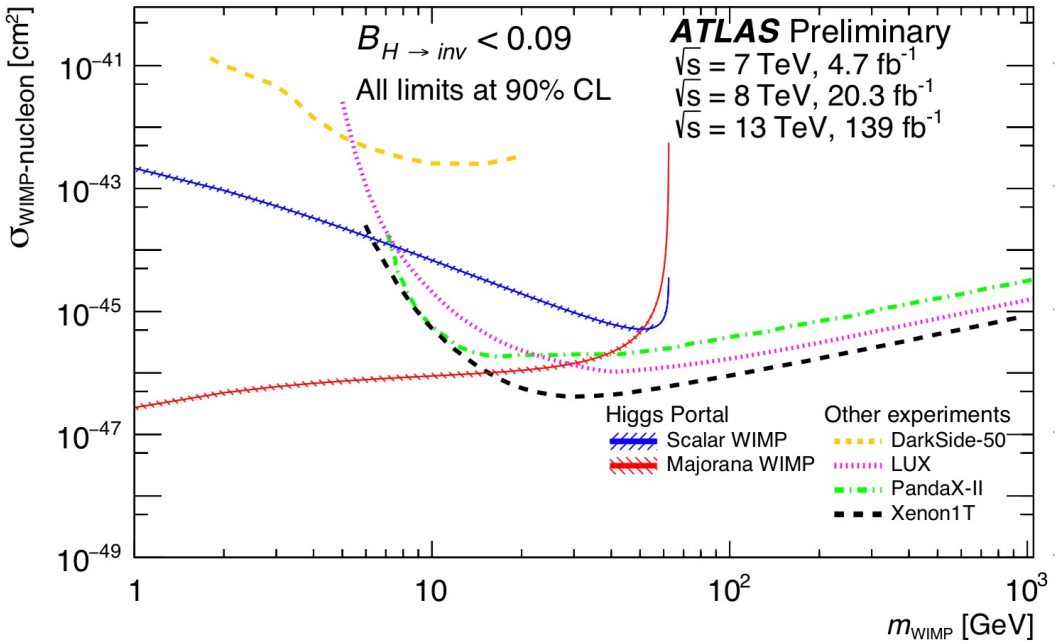


ATLAS-CONF-2021-004

ATLAS-CONF-2020-052

$H \rightarrow$ inv. combination





Run2 analysis:

- ttH
- VBF $H \rightarrow invisible$

Many others not included yet (e.g. Mono-Jet, Mono-Z(ll))

Scalar σ_{WIMP-N}: down to $10^{-45} cm^2$

Fermion Majorana σ_{WIMP-N}: down to $10^{-47} cm^2$

Combination of Run1+2 set a limit on the $BR_{H \rightarrow inv.}$ = 0.11

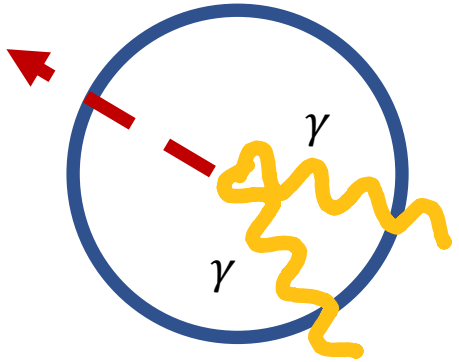
Mono-$H \rightarrow \gamma\gamma$

arxiv:2104.13240

Look for an excess in the $m_{\gamma\gamma}$ spectrum

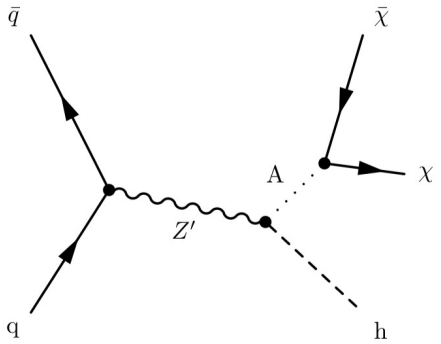
- Normalization and shape of non-resonant background obtained fitting the $m_{\gamma\gamma}$ sidebands

$(105 < m_{\gamma\gamma} < 160\ GeV)$



Di-photon trigger

- No leptons
- At least 2 photons
- $E_T^{miss} > 90\ GeV$
- $120 < m_{\gamma\gamma} < 130\ GeV$
- $\Delta E_T^{miss} < 30\ GeV$

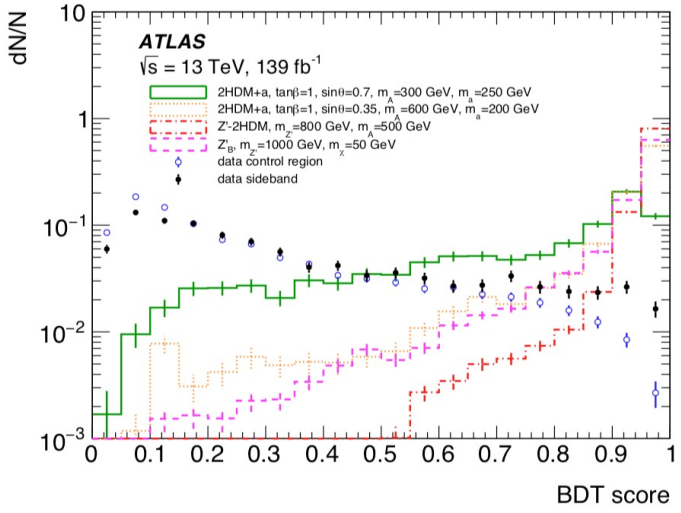


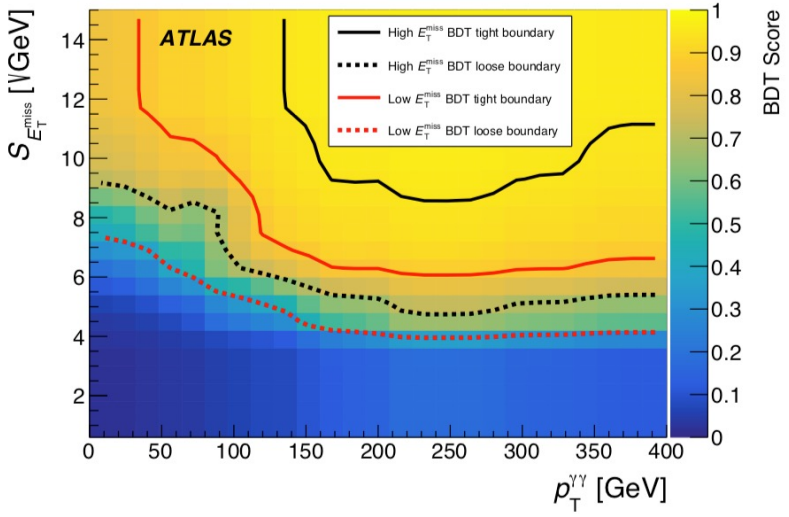
Difference beetween E_T^{miss} from NN selected vertex and E_T^{miss} from hard scatter vertex

4 Signal regions defined using E_T^{miss} and a BDT trained with :

- $S_{E_T^{miss}}$
- $p_T^{\gamma\gamma}$

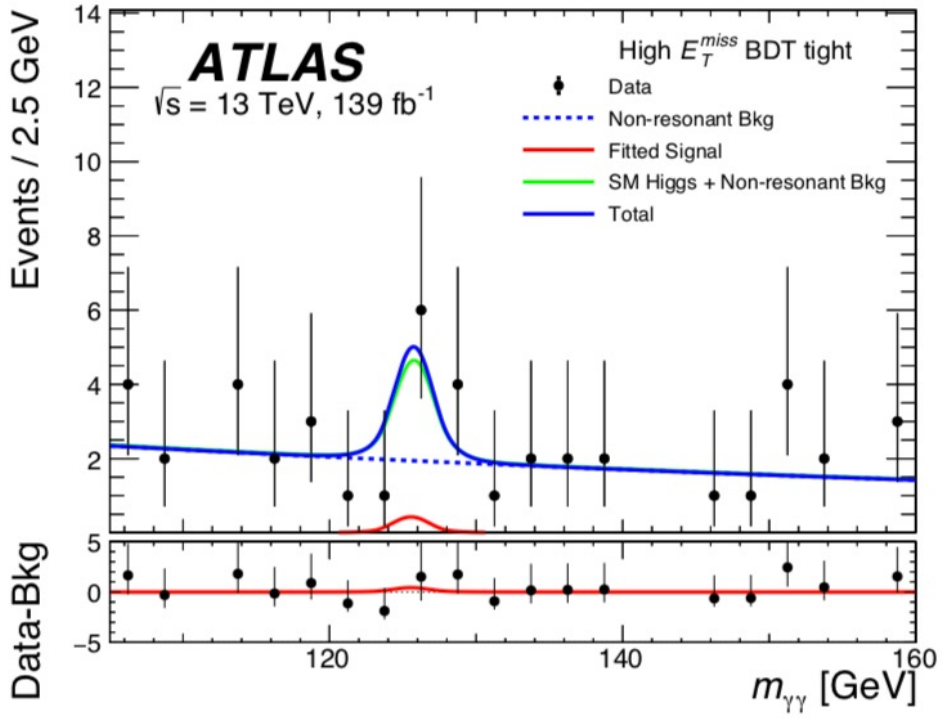
$$S_{E_T^{miss}} = E_T^{miss} / \sqrt{\sum E_T}$$

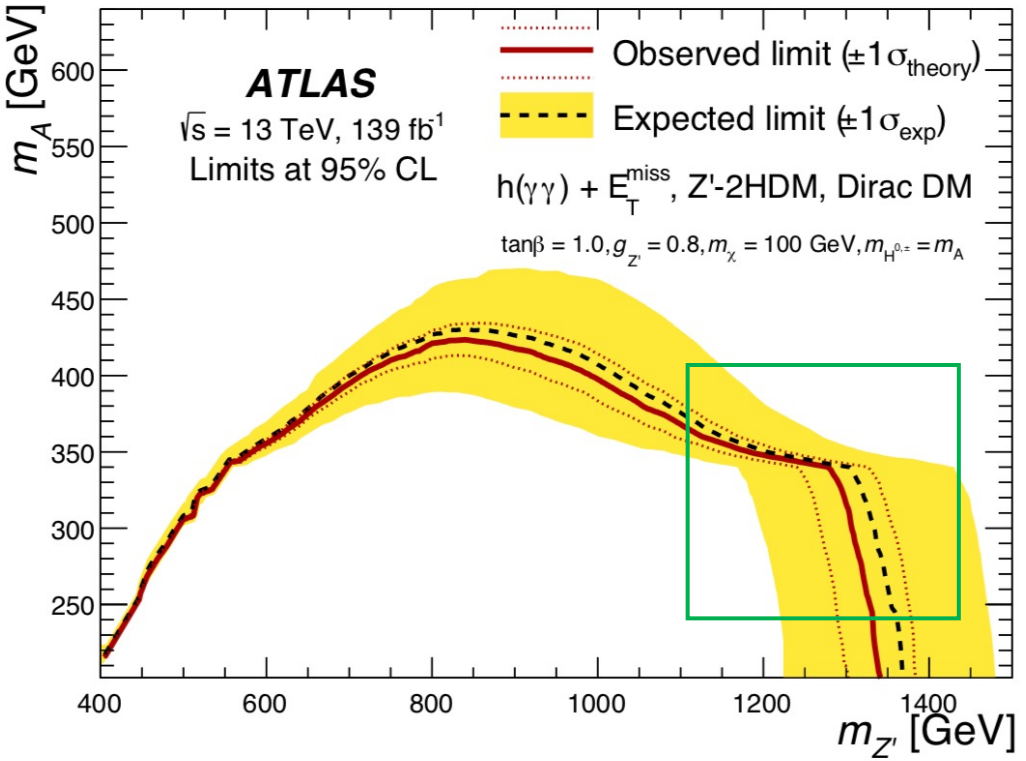




Mono-$H \rightarrow \gamma\gamma$

arxiv:2104.13240





SM resonant Higgs contribution ~30% of total background, mostly from WH and ZH production modes

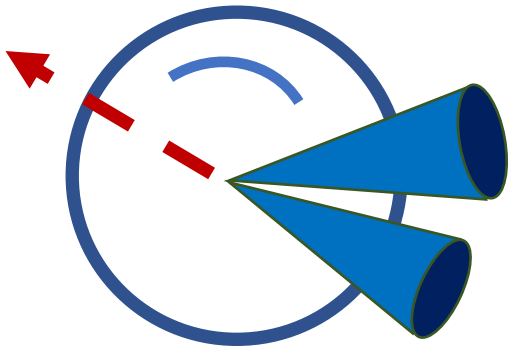
Above $m_A = 350\ GeV$ → $A \rightarrow t\bar{t}$

Mono-$H \rightarrow b\bar{b}$

ATLAS-CONF-2021-006

Key Events selections:

Resolved region

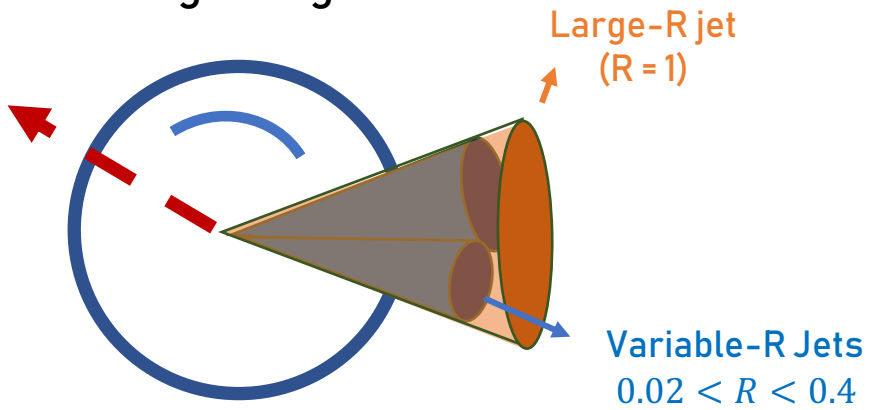


- $E_T^{miss} < 500\ GeV$

2b tagged / ≥3 b tagged jets

- At least 2 b-tagged jets
- $E_T^{miss} > 150\ GeV$
- No leptons
- $min\Delta\varphi_{jE_t^{miss}} > 20^{\circ}$
- Loose m_h selection

Merged region



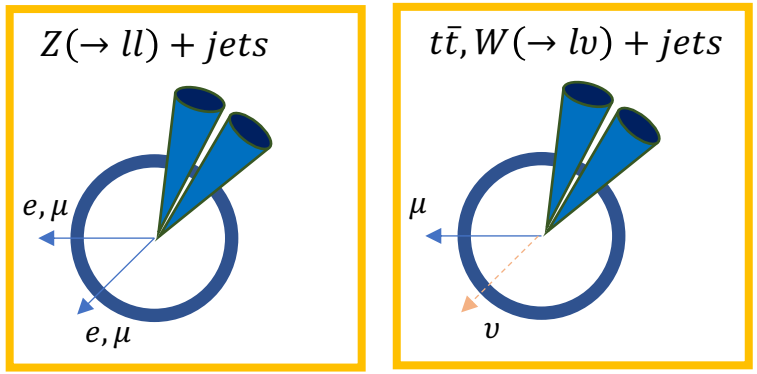
- $E_T^{miss} > 500\ GeV$

2b tagged / ≥3 b tagged jets

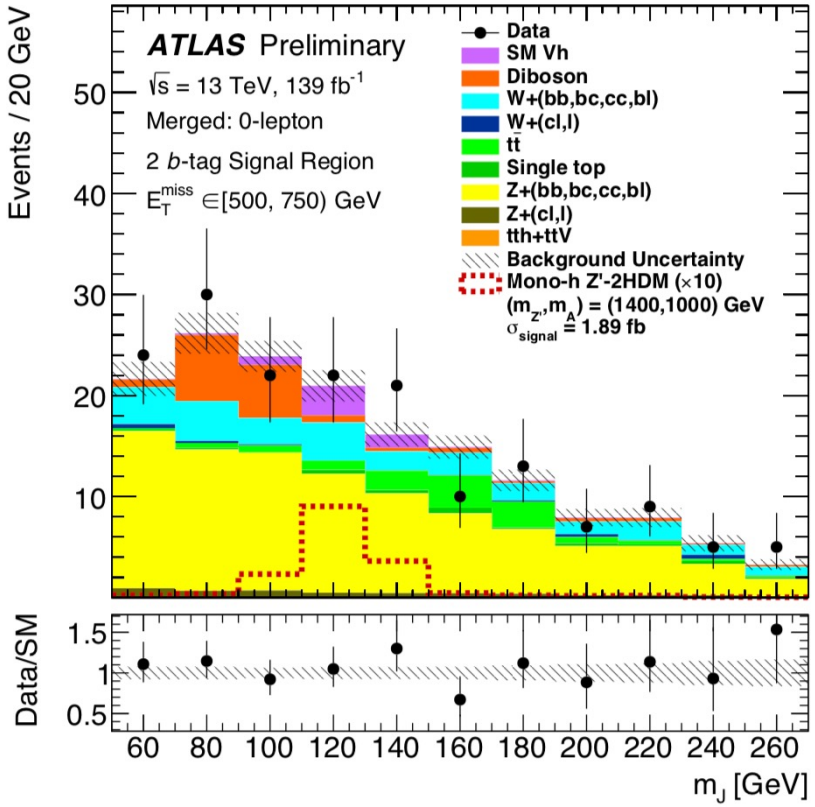
Look for an excess in m_h spectrum

Dominant backgrounds: $t\bar{t}$, W/Z +HF

- Normalization corrected using CRs

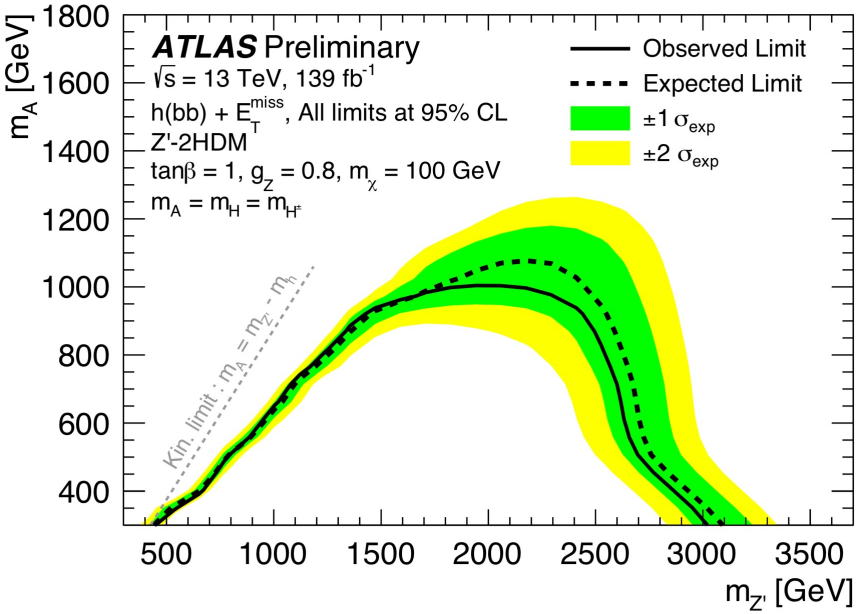


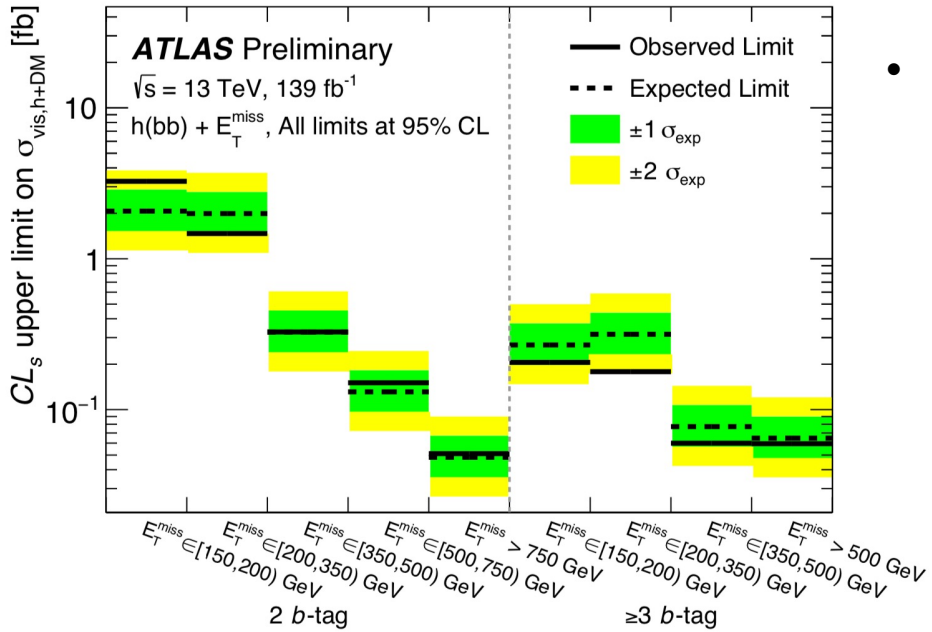
Mono-$H \to b\bar{b}$



- Simultaneous likelihood fit to all regions (SR binned in m_H)

No excess observed





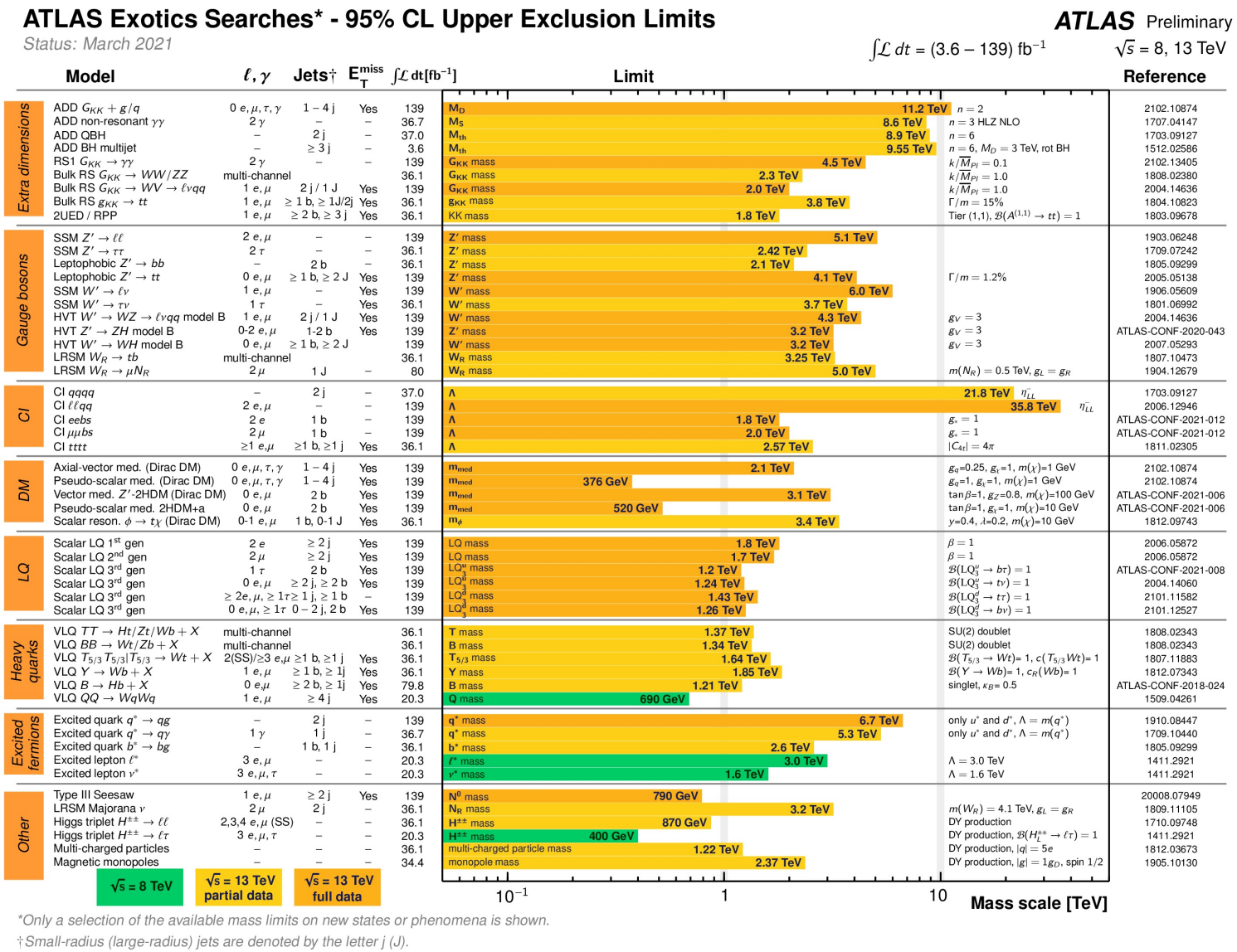
[ATLAS-CONF-2021-006]

- Z' masses up to 3.1 TeV excluded for A masses of 300 GeV at 95% CL
- Limits on the visible cross section are set with minimal assumption

Conclusions

- A brief summary in the field of DM searches as been presented, touching Simplified Models and 2HDM models
- So much done and still on-going!

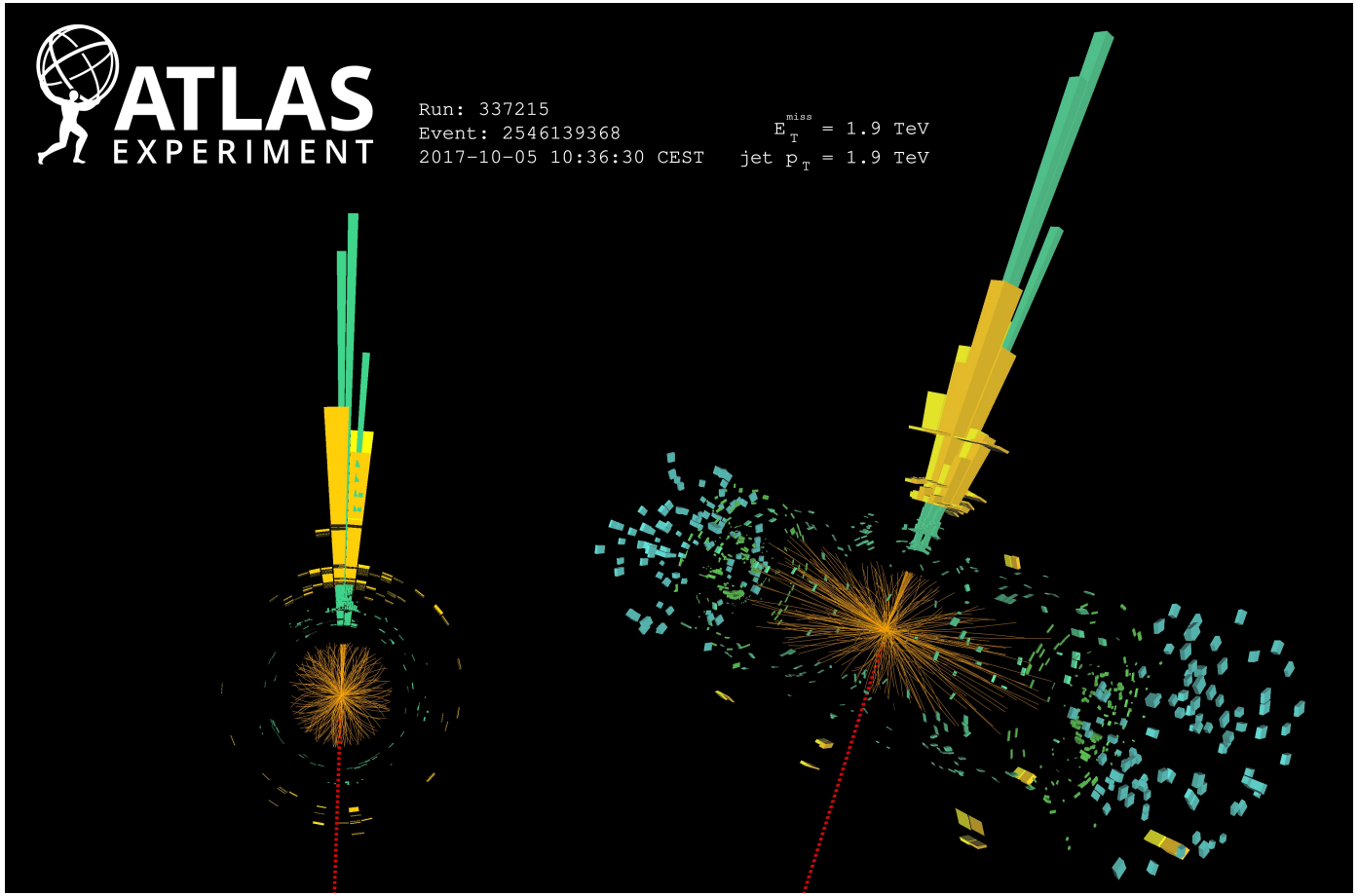
ATL-PHYS-PUB-2021-009



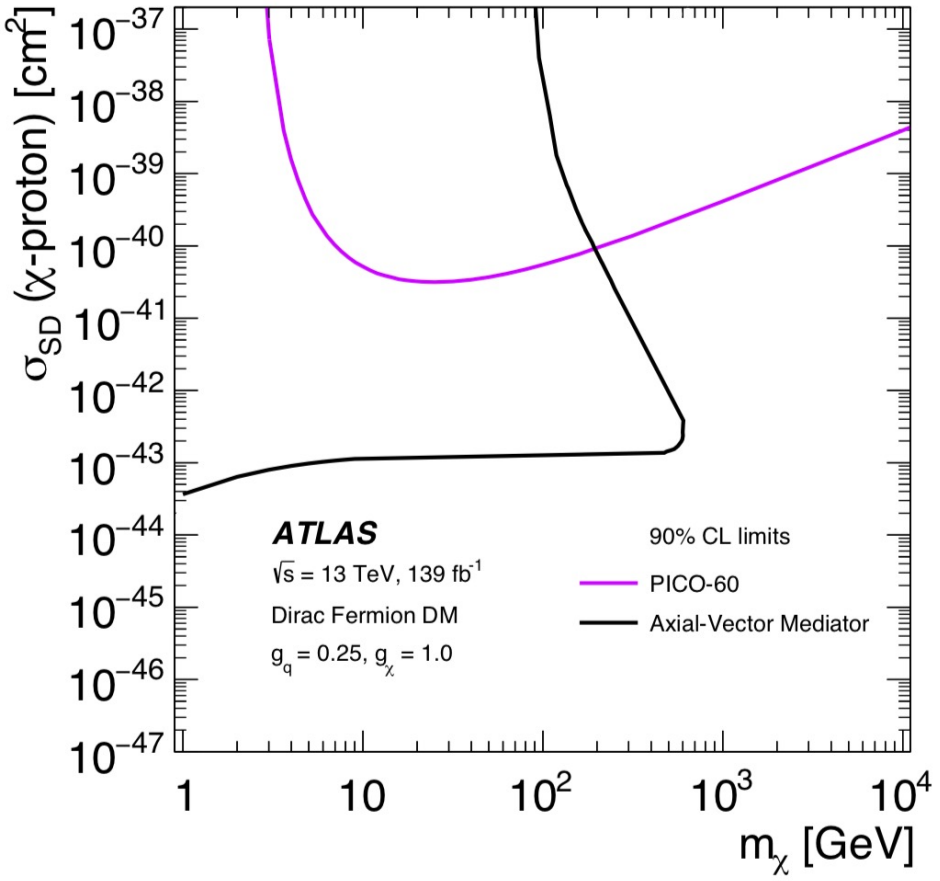
Backup

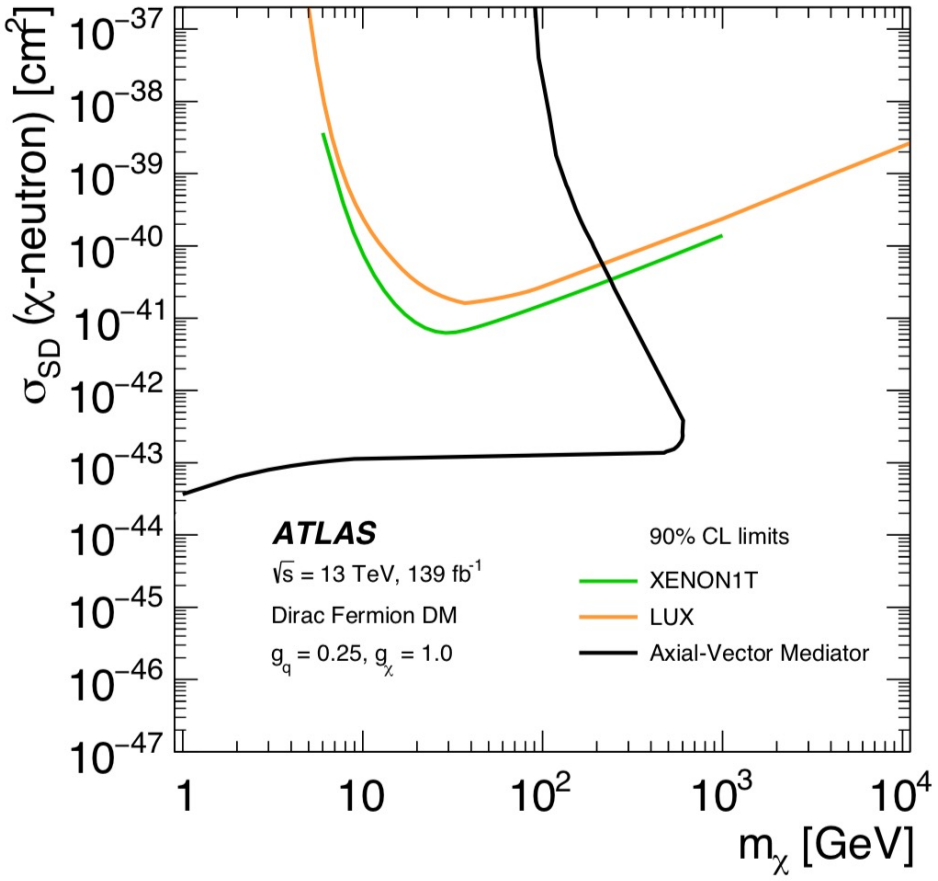
Monojet_2017_event_display_black

Mono-jet Event Display

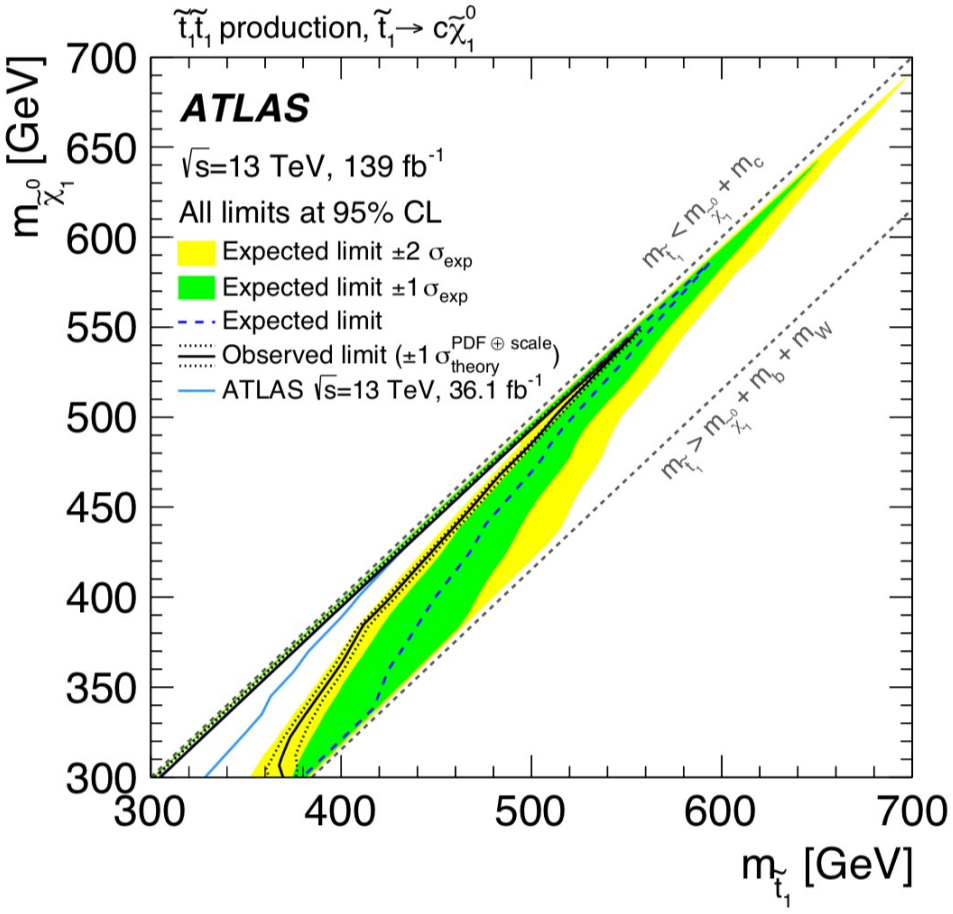


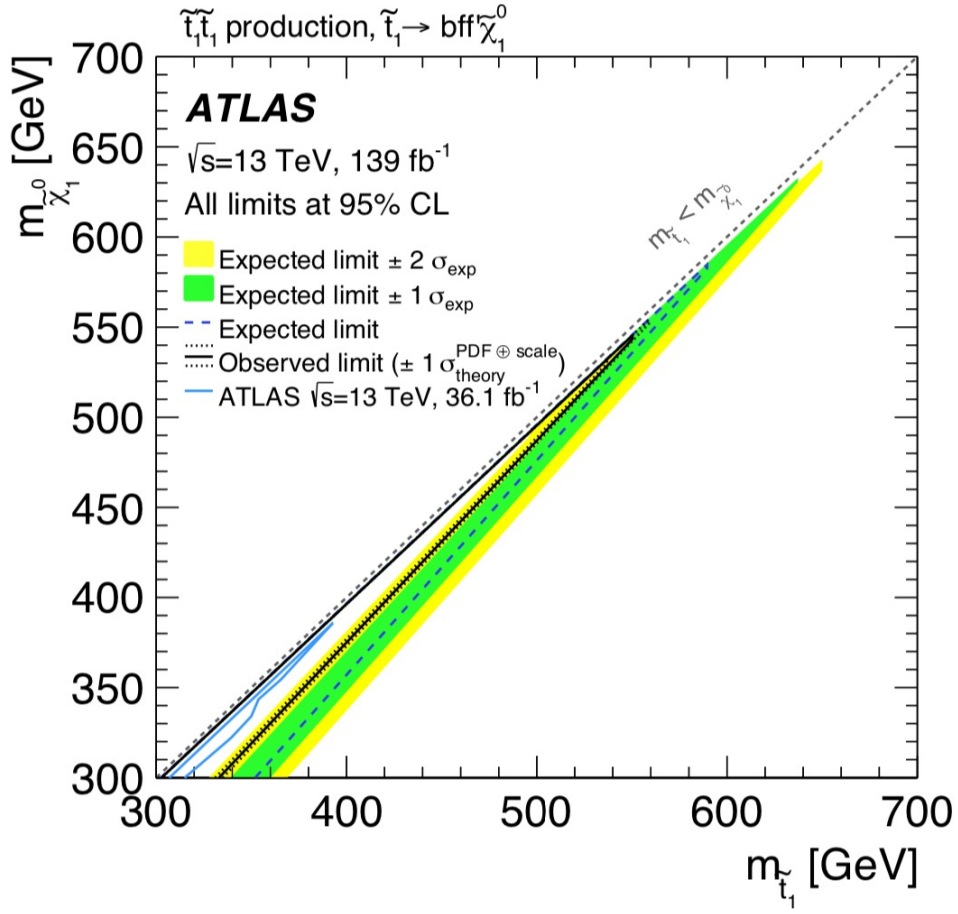
Mono-jet results – WIMP nucleon σ_{SD}





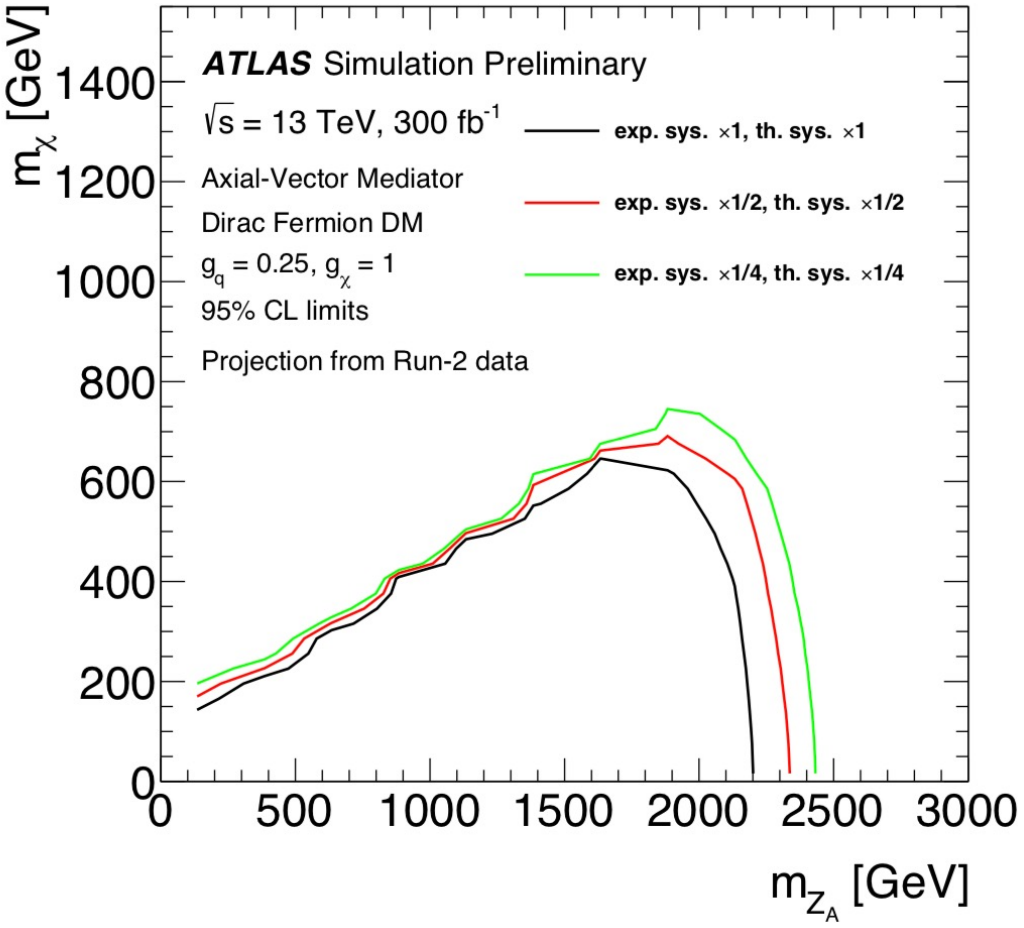
Mono-jet results – squark pair production

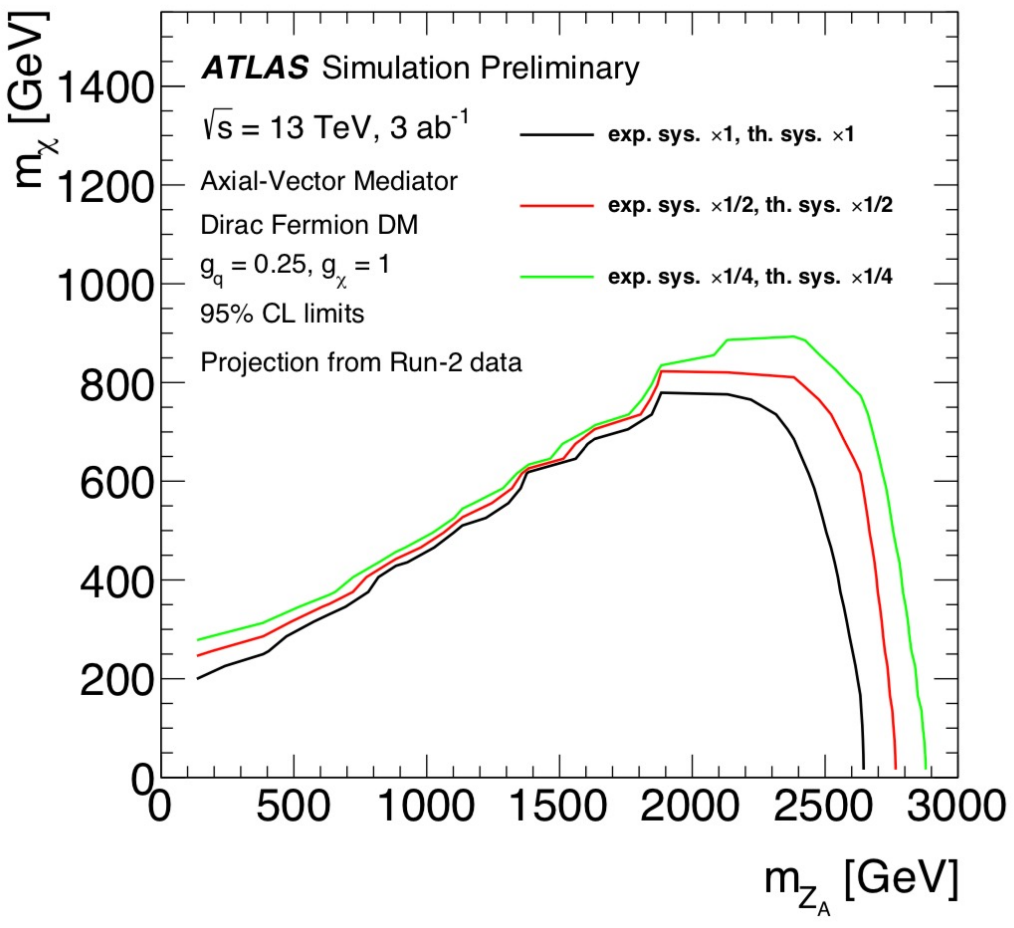




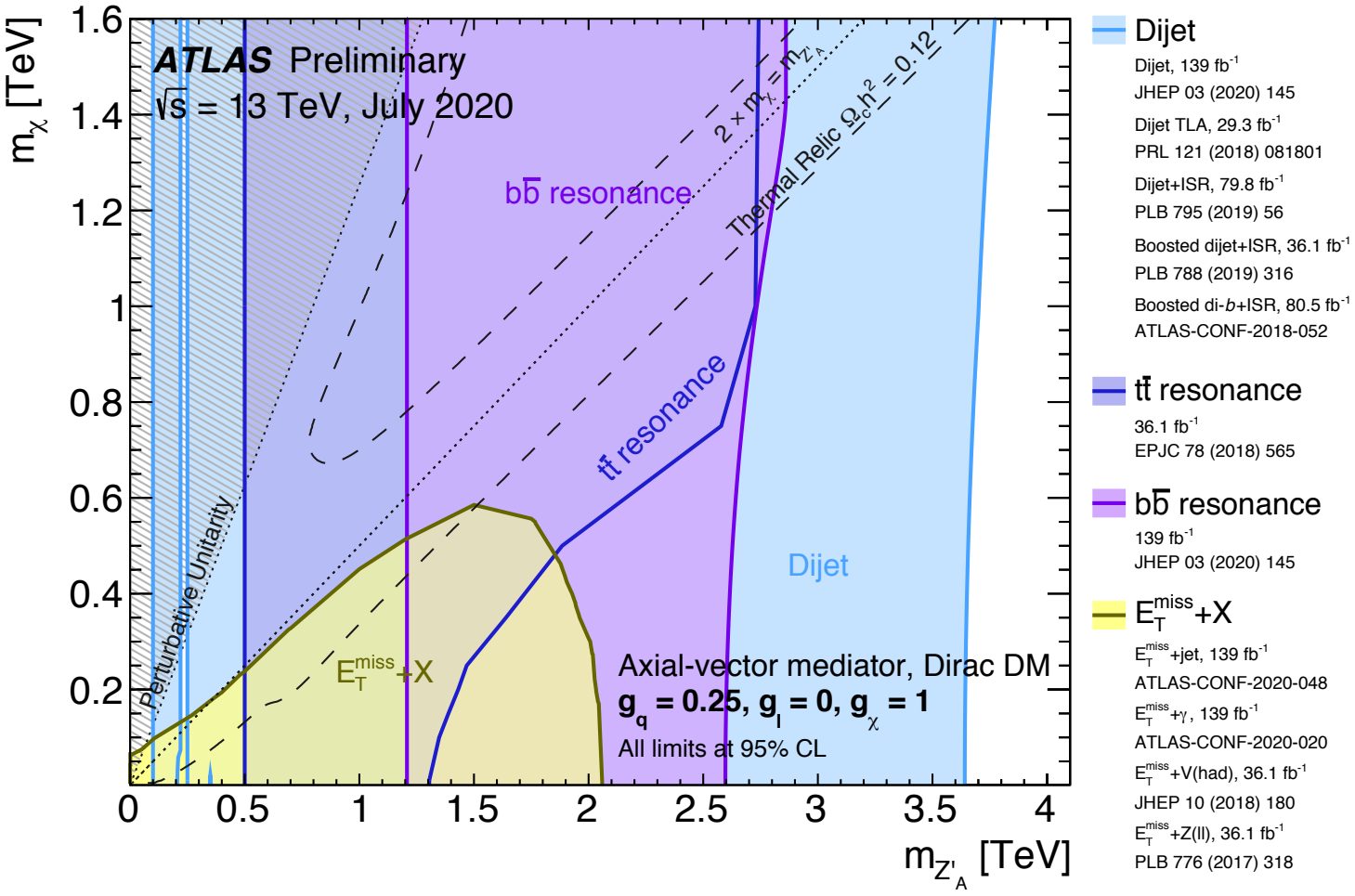
ATL-PHYS-PUB-2018-043

Mono-jet results – HL-LHC



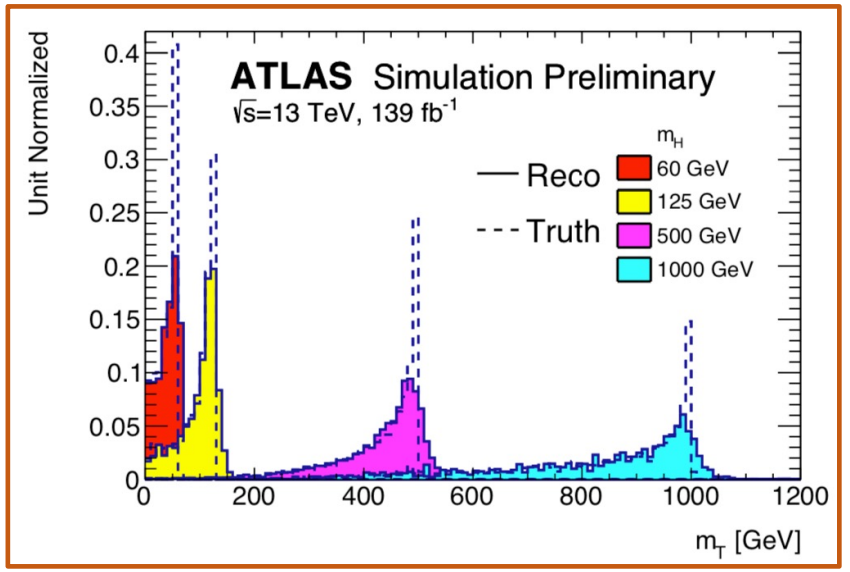


Mono-jet mono-photon combination



VBF $H \rightarrow invisible + \gamma$

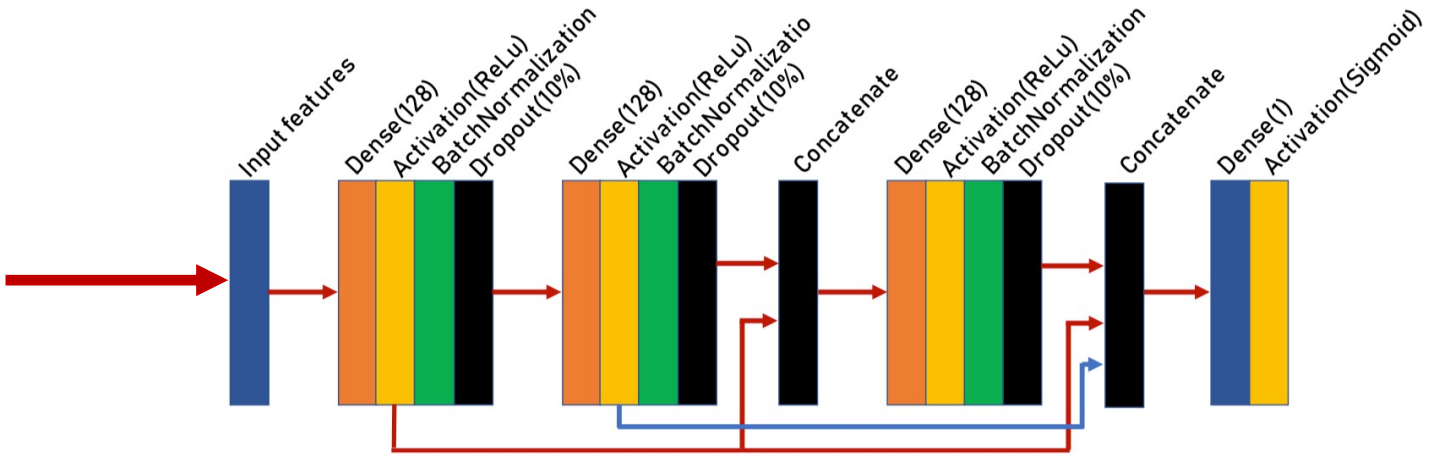
Discriminating variables for the final fit



The analysis aims to find an excess in the *DNN score spectum* for the invisible decay, in the m_T *spectrum* for the $\gamma\gamma_d$ decay

Input features

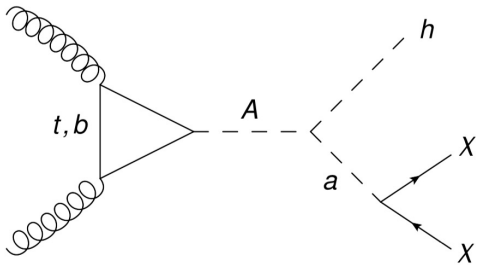
1. $\Delta\eta_{jj}$
2. $\Delta\varphi_{jj}$
3. m_{jj}
4. $E_T^{miss,no-lep}$
5. $\eta(\gamma)$
6. $p_T(j_1)$
7. $p_T(j_2)$
8. $\eta(j_2)$



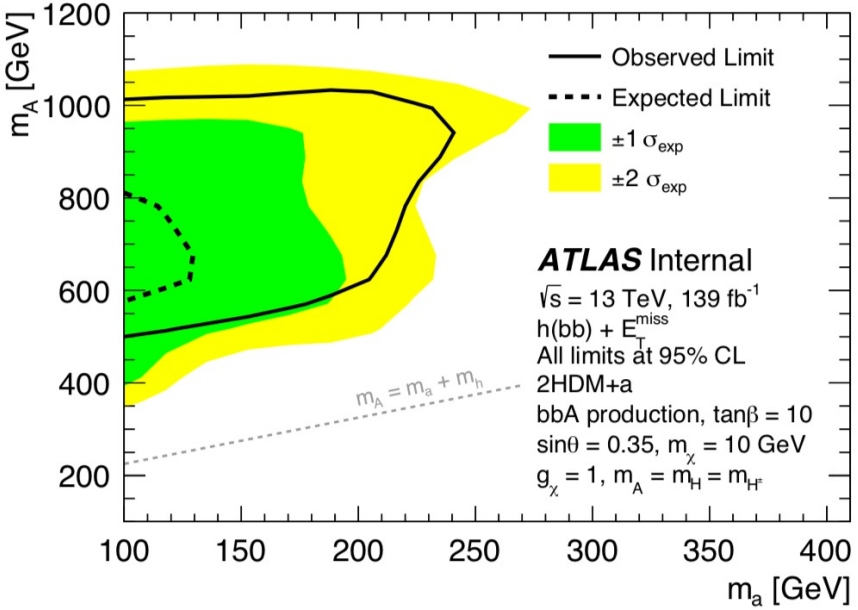
Output:
1 ~ signal like
0 ~ bkg like

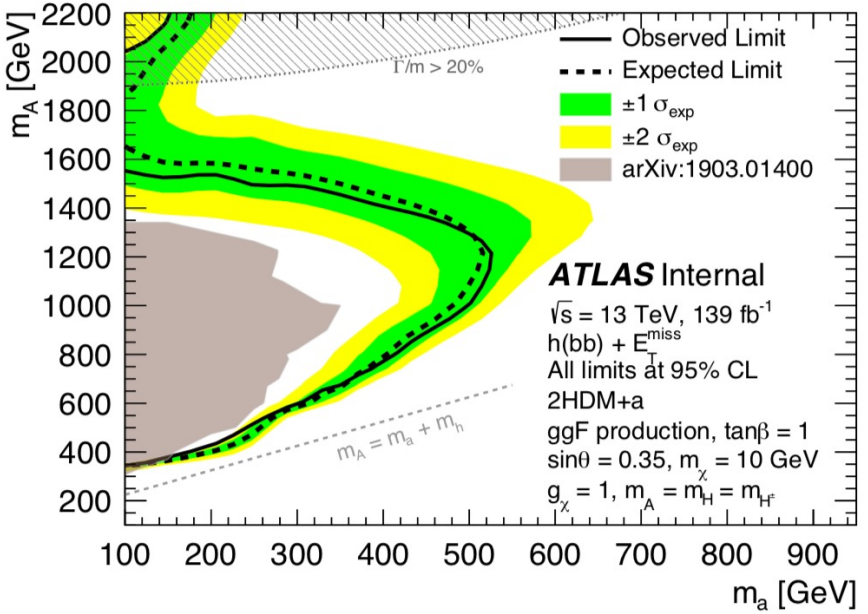
Binning = [0, 0.25, 0.6, 0.8, 1]

$H \to b\bar{b}$ - a-2HDM

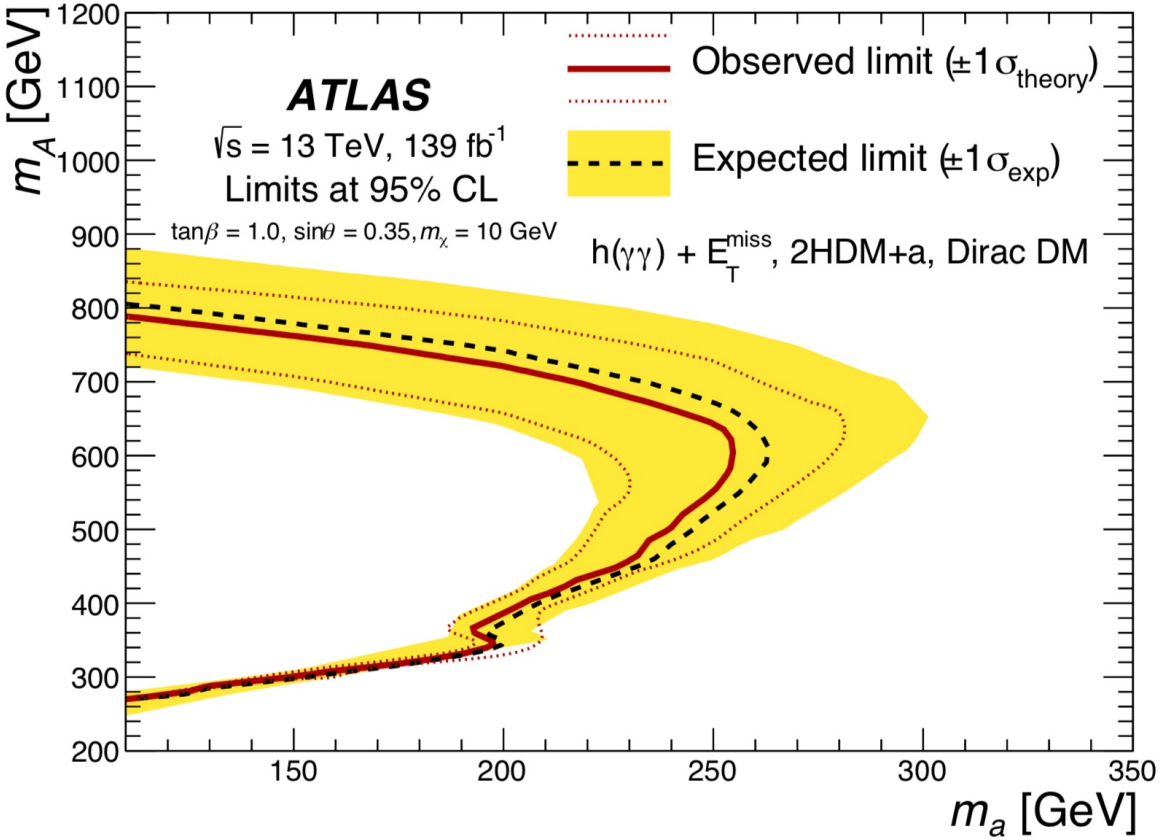


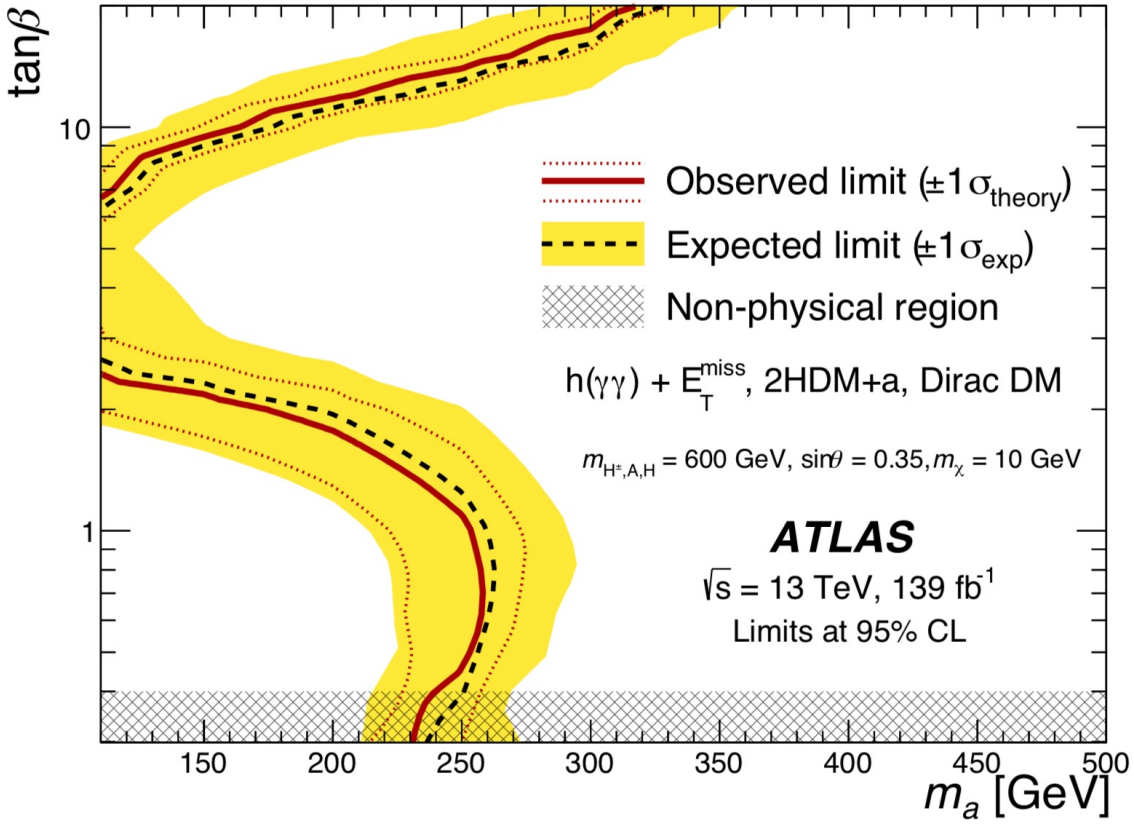
(a)



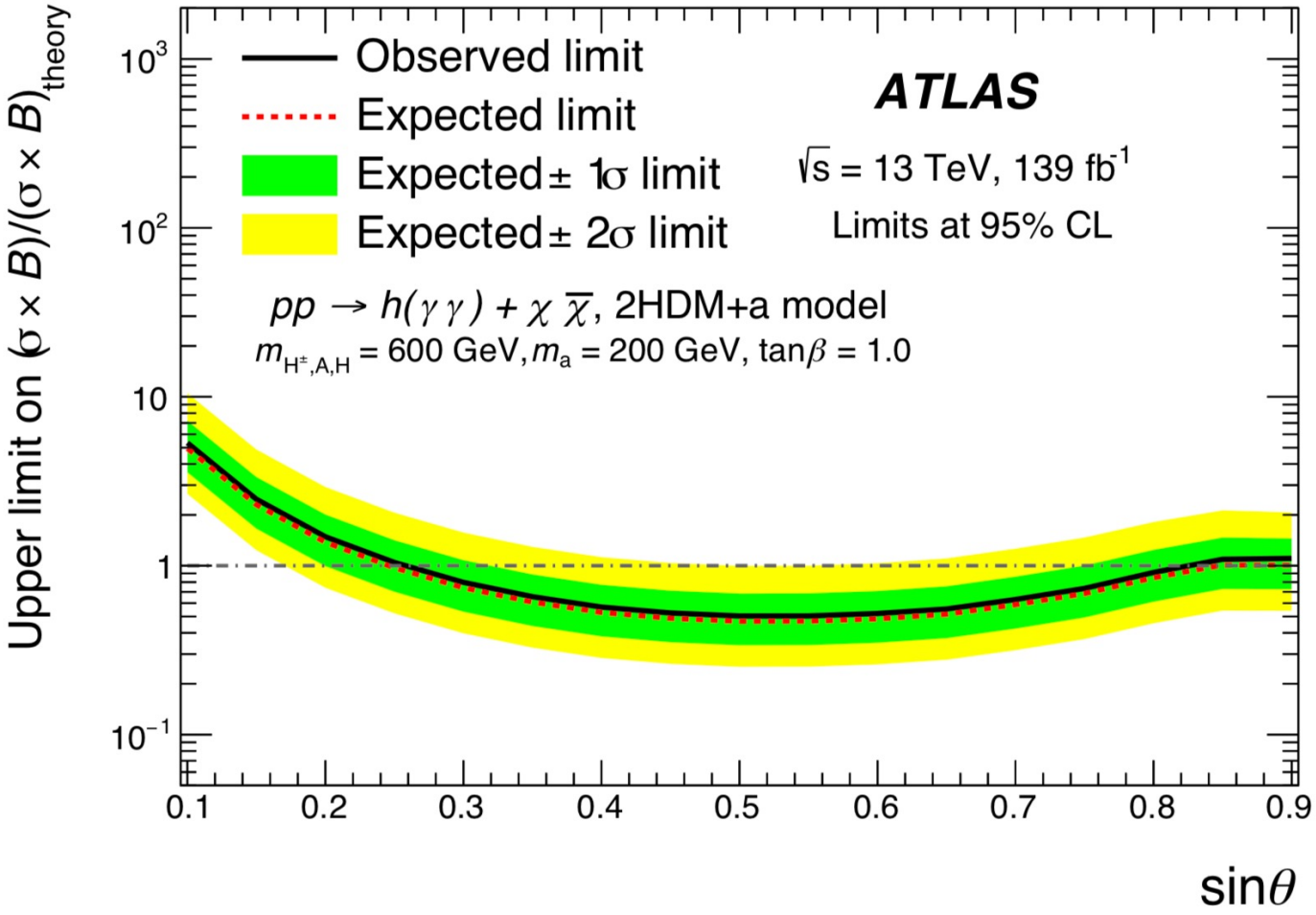


Mono-$H \rightarrow \gamma\gamma$ – a-2HDM

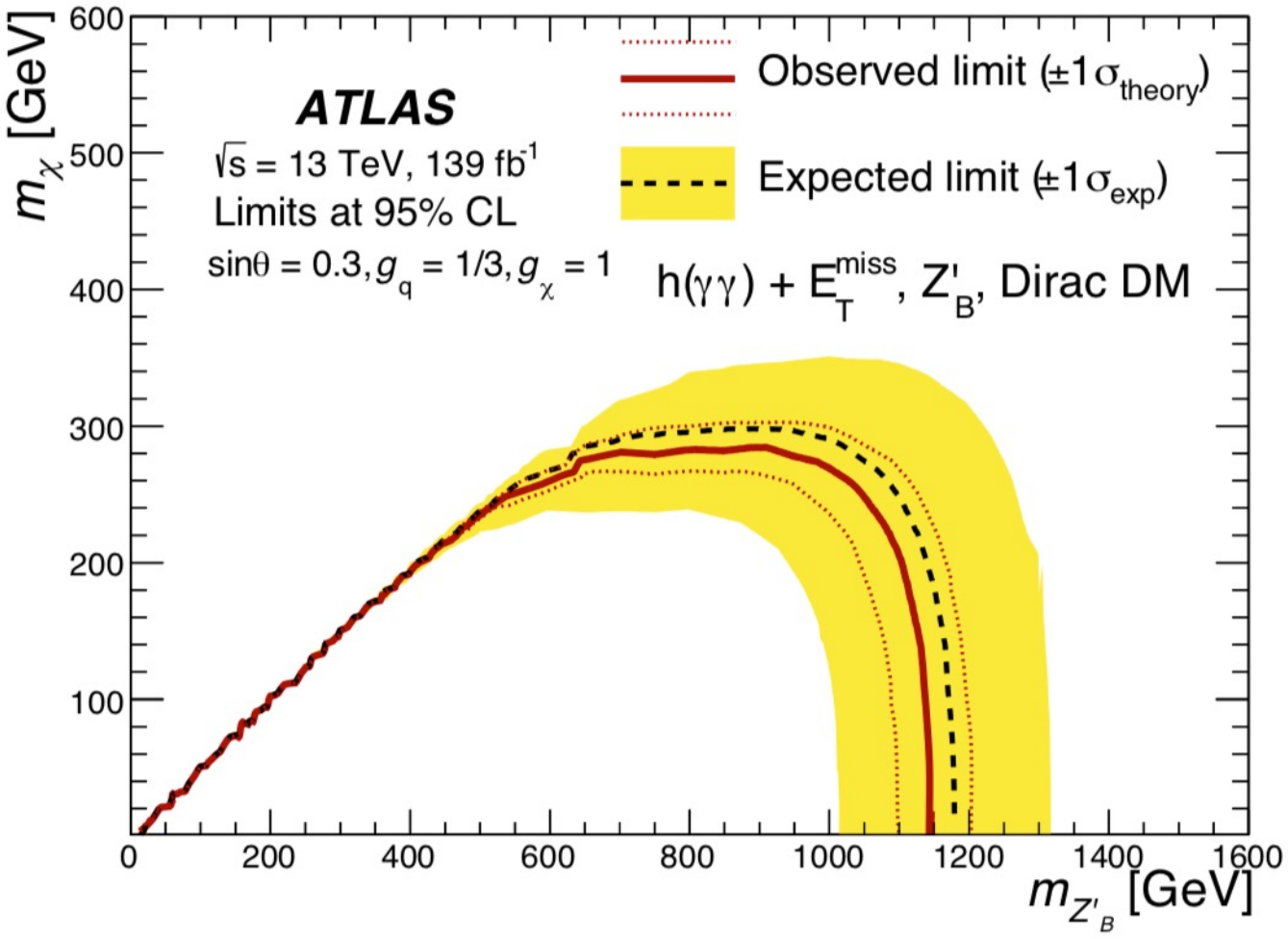


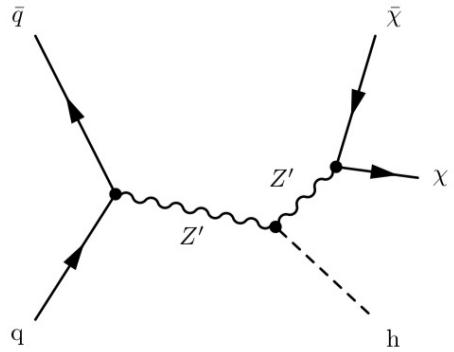


Mono-$H \rightarrow \gamma\gamma$ – a-2HDM



Mono-$H \rightarrow \gamma\gamma$ – Z'_B





arxiv.org/pdf/1903.01400

Mono-$H \rightarrow \gamma\gamma/b\bar{b}$ - $36 fb^{-1}$ combination