

LHCHXS WG3 - conveners meeting  
Nov 7 2018

# ATLAS updates

Ljiljana Morvaj, Stony Brook

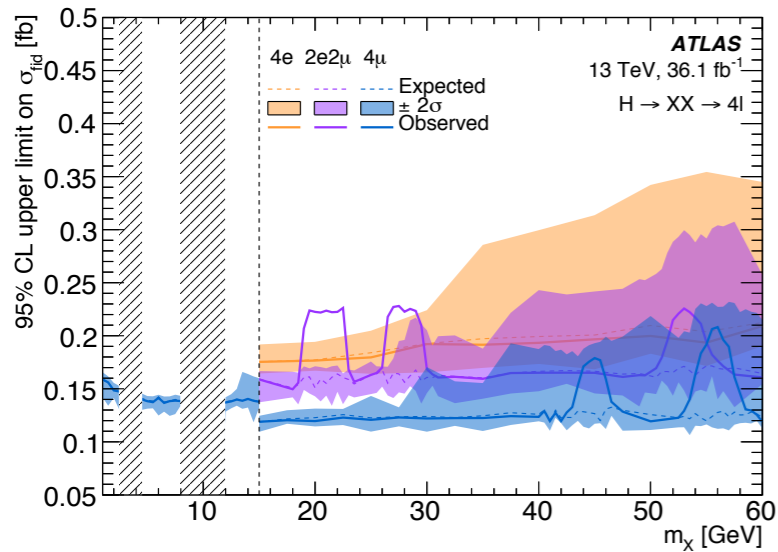
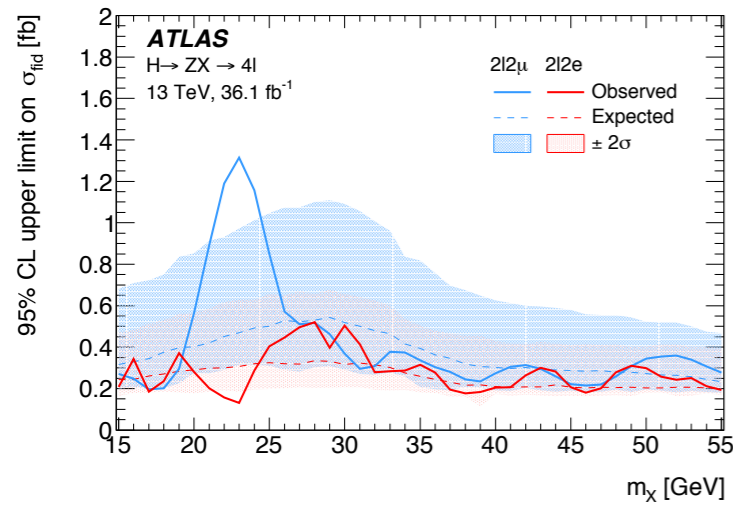




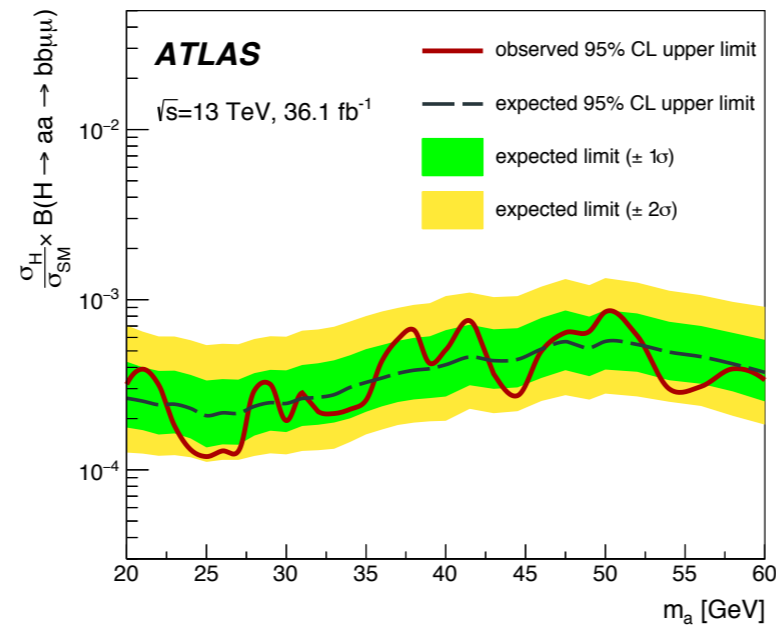
# H → aa → XXYY

• 36 fb<sup>-1</sup> @ 13 TeV

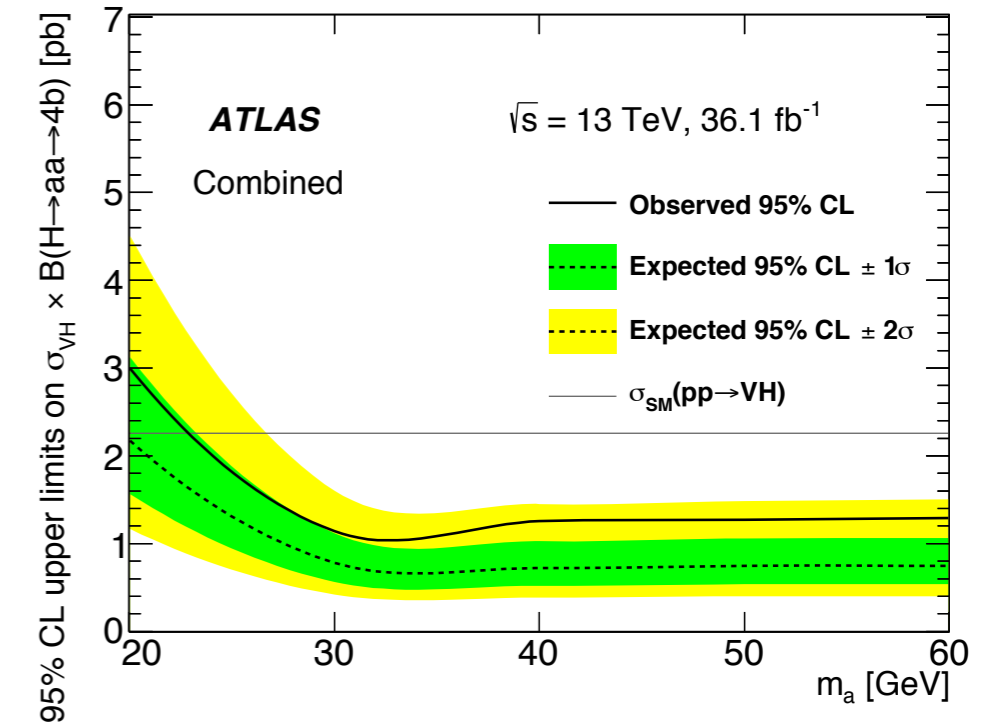
## h → ZdZd → 4lep



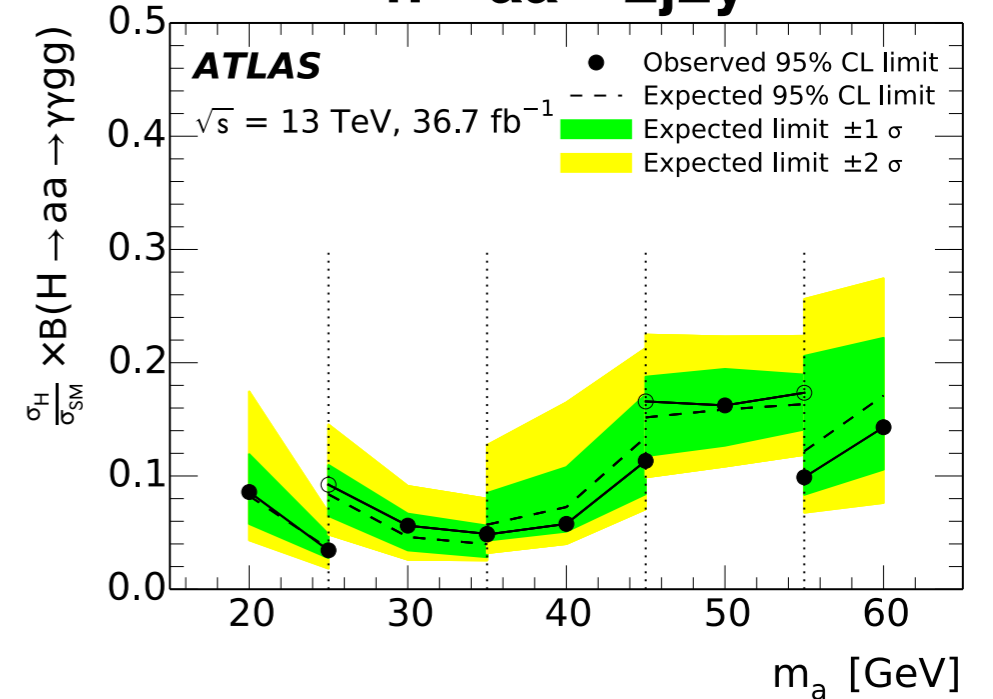
## h → aa → 2b2μ

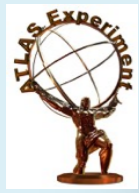


## h → aa → 4b



## h → aa → 2j2γ





# HLR benchmarks

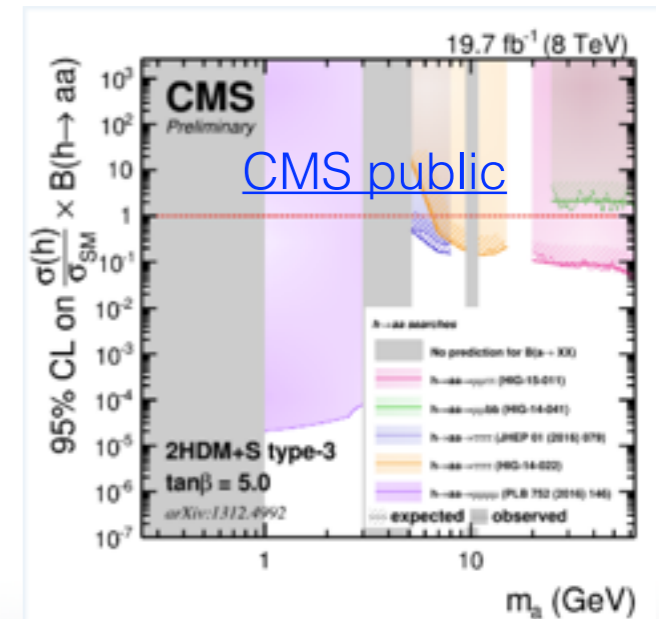
## Benchmark models

Signature	Motivation	Parameter calculations	MC implementation	C
H(125)→aa (ss) →XXYY	<a href="#">1312.4992</a>	Br(a(s)→XX) for plots from the <a href="#">paper</a> , outside of the quarkonia regions <a href="#">plotdata.zip</a>		S Z
H(125)→aa (ss) →XXYY	<a href="#">1802.02156</a>	<a href="#">BR.tgz</a> . Calculations provide Br(a→xx) values for multiple tan(beta) values and cover also the quarkonia regions. Please read the <a href="#">README.txt</a> to know how to use them.		U
H(125)→2Zd→4 lep	<a href="#">1412.0018</a>	Table2 of <a href="#">1412.0018</a>	<a href="#">hahm_mg</a>	J S C
H(125)→2Hd→4Ad→8 lep	<a href="#">Hto8lepChannel_Stolarski</a>	Table2 of <a href="#">1412.0018</a>	<a href="#">hahm_mg</a>	D
H(125)→aa (ss) → 4y/2j2y				
H(125)→aa (ss) →XXYY/invis	mixture of visible & invisible (DM) decays			



# HLR benchmarks

- $H \rightarrow aa \rightarrow XXYY$ 
  - Usually use 2HDM+S



## Benchmark models

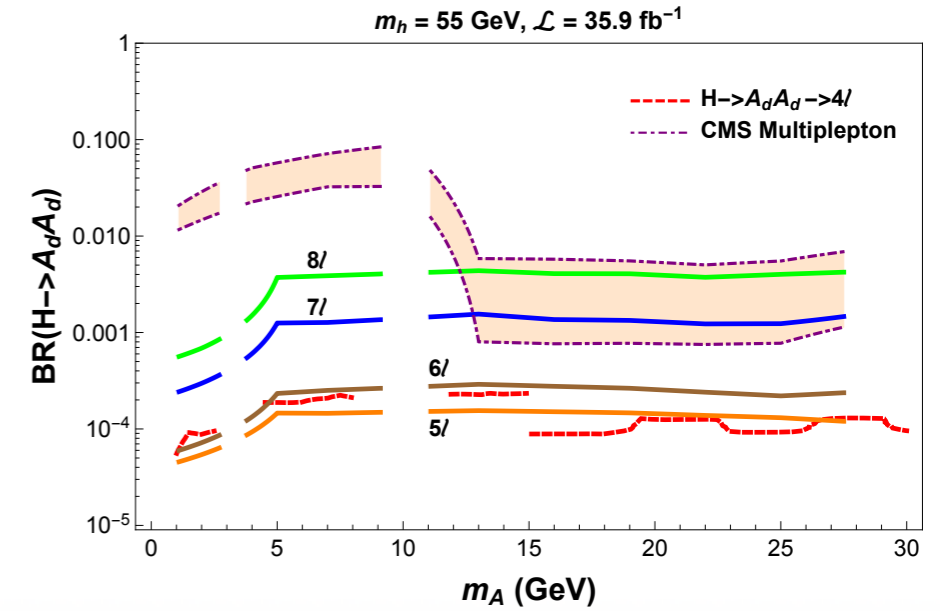
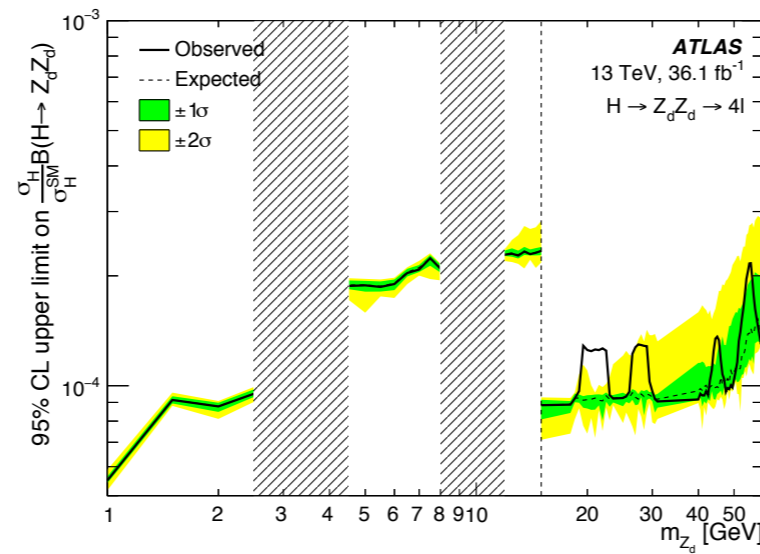
<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWGExoticDecay#Benchmark%20models>

Signature	Motivation	Parameter calculations	MC implementation
$H(125) \rightarrow aa (ss) \rightarrow XXYY$	<a href="#">1312.4992</a>	$Br(a(s) \rightarrow XX)$ for plots from the <a href="#">paper</a> , outside of the quarkonia regions <a href="#">plotdata.zip</a>	
$H(125) \rightarrow aa (ss) \rightarrow XXYY$	<a href="#">1802.02156</a>	<a href="#">BR.tgz</a> . Calculations provide $Br(a \rightarrow xx)$ values for multiple $\tan(\beta)$ values and cover also the quarkonia regions. Please read the <a href="#">README.txt</a> to know how to use them.	
$H(125) \rightarrow 2Zd \rightarrow 4 \text{ lep}$	<a href="#">1412.0018</a>	Table2 of <a href="#">1412.0018</a>	<a href="#">hahm_mg</a>
$H(125) \rightarrow 2Hd \rightarrow 4Ad \rightarrow 8 \text{ lep}$	<a href="#">Hto8lepChannel_Stolarski</a>	Table2 of <a href="#">1412.0018</a>	<a href="#">hahm_mg</a>
$H(125) \rightarrow aa (ss) \rightarrow 4y/2j2y$			
$H(125) \rightarrow aa (ss) \rightarrow XXYY/invis$	mixture of visible & invisible (DM) decays		



# HLR benchmarks

- $H \rightarrow Z_d Z_d \rightarrow XXYY$ 
  - Zdark models



## Benchmark models

<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWGExoticDecay#Benchmark%20models>

Signature	Motivation	Parameter calculations	MC implementation
$H(125) \rightarrow aa(ss) \rightarrow XXYY$	<a href="#">1312.4992</a>	$Br(a(s) \rightarrow XX)$ for plots from the <a href="#">paper</a> , outside of the quarkonia regions <a href="#">plotdata.zip</a>	
$H(125) \rightarrow aa(ss) \rightarrow XXYY$	<a href="#">1802.02156</a>	<a href="#">BR.tgz</a> . Calculations provide $Br(a \rightarrow xx)$ values for multiple $\tan(\beta)$ values and cover also the quarkonia regions. Please read the <a href="#">README.txt</a> to know how to use them.	
$H(125) \rightarrow 2Z_d \rightarrow 4 \text{ lep}$	<a href="#">1412.0018</a>	Table2 of <a href="#">1412.0018</a>	<a href="#">hahm_mg</a>
$H(125) \rightarrow 2H_d \rightarrow 4A_d \rightarrow 8 \text{ lep}$	<a href="#">Hto8lepChannel_Stolarski</a>	Table2 of <a href="#">1412.0018</a>	<a href="#">hahm_mg</a>
$H(125) \rightarrow aa(ss) \rightarrow 4y/2j2y$			
$H(125) \rightarrow aa(ss) \rightarrow XXYY/invis$	mixture of visible & invisible (DM) decays		



# HLR benchmarks

- $H \rightarrow aa \rightarrow 4j, 2y2j$ 
  - ALPs?

## Benchmark models

<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWGExoticDecay#Benchmark%20models>

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$H(125) \rightarrow aa (ss) \rightarrow 4y/2j2y$				
$H(125) \rightarrow aa (ss) \rightarrow XXYY/invis$	mixture of visible & invisible (DM) decays			



# HLR benchmarks

- H-> aa -> XXYY / invis
  - DM inspired invisible+visible mediator decays

## Benchmark models

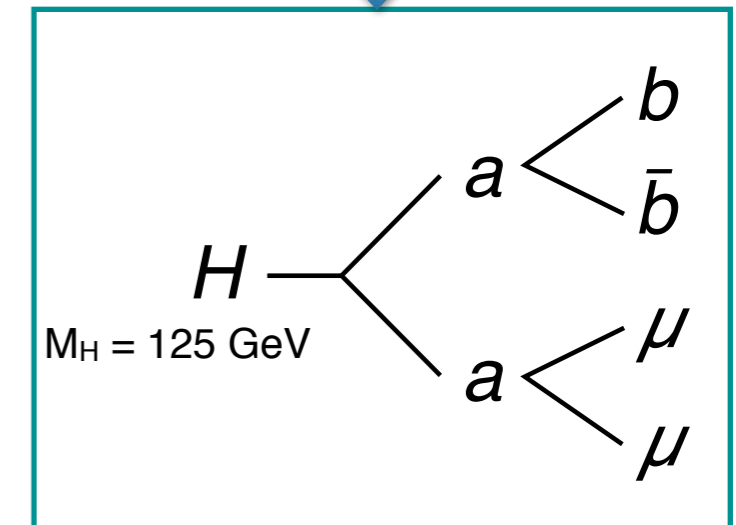
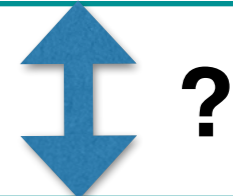
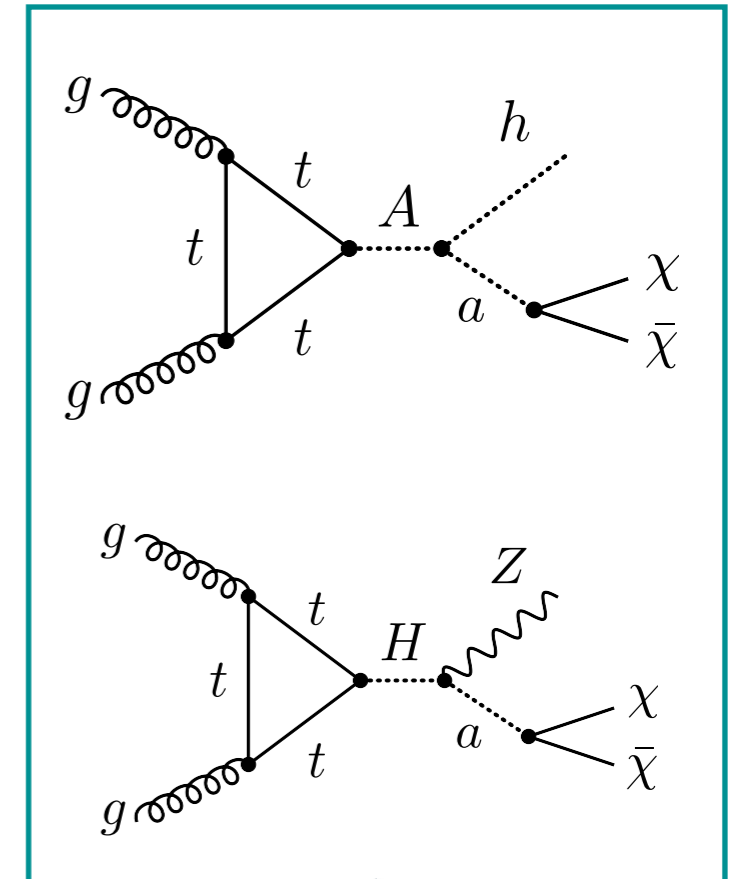
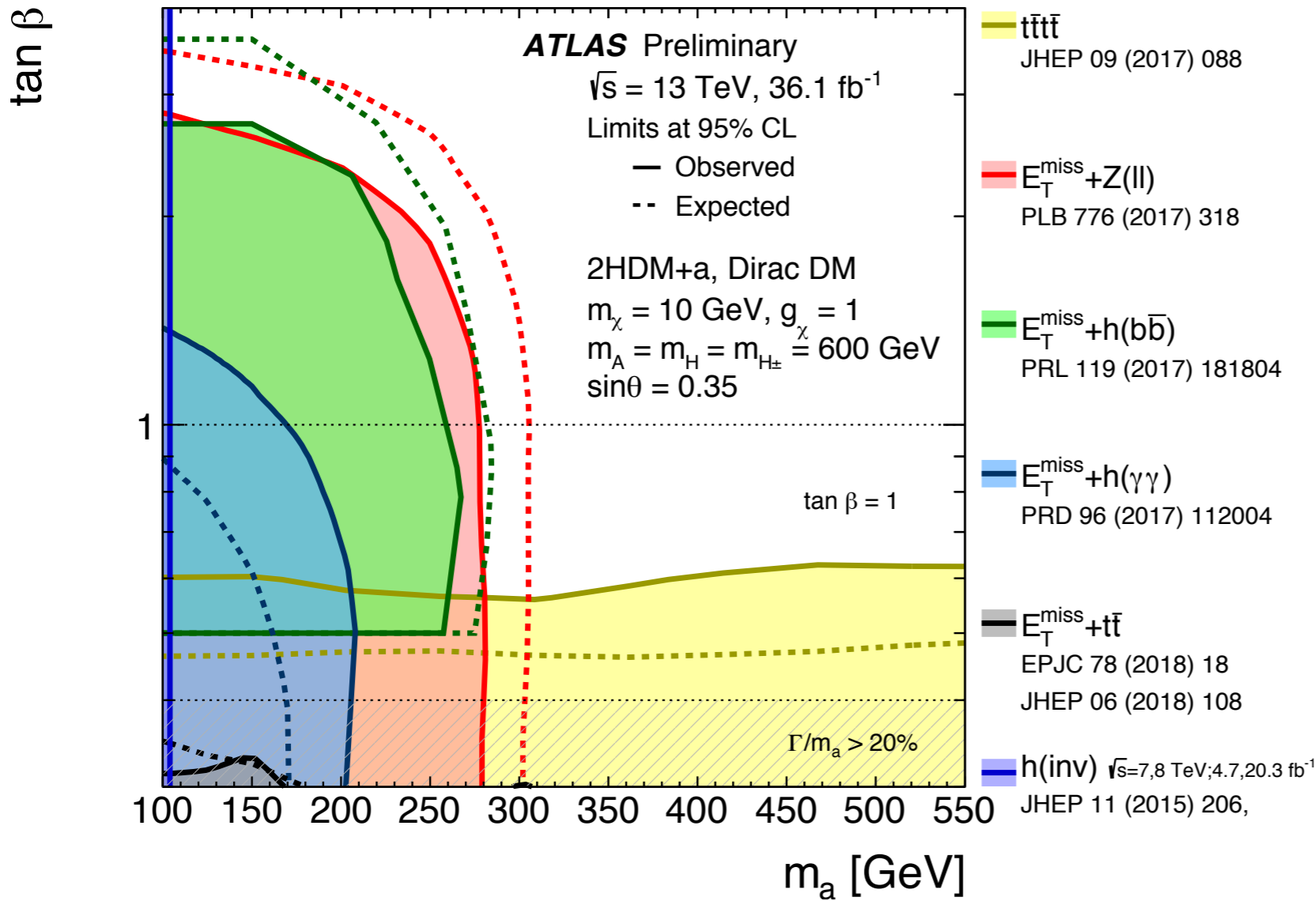
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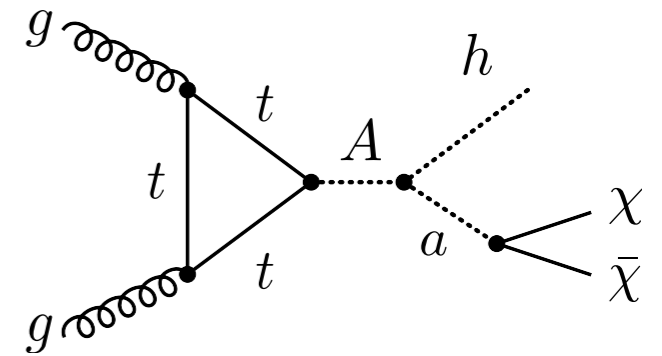
# 2HDM+a limits

Using 2015+2016 data results in ATLAS.



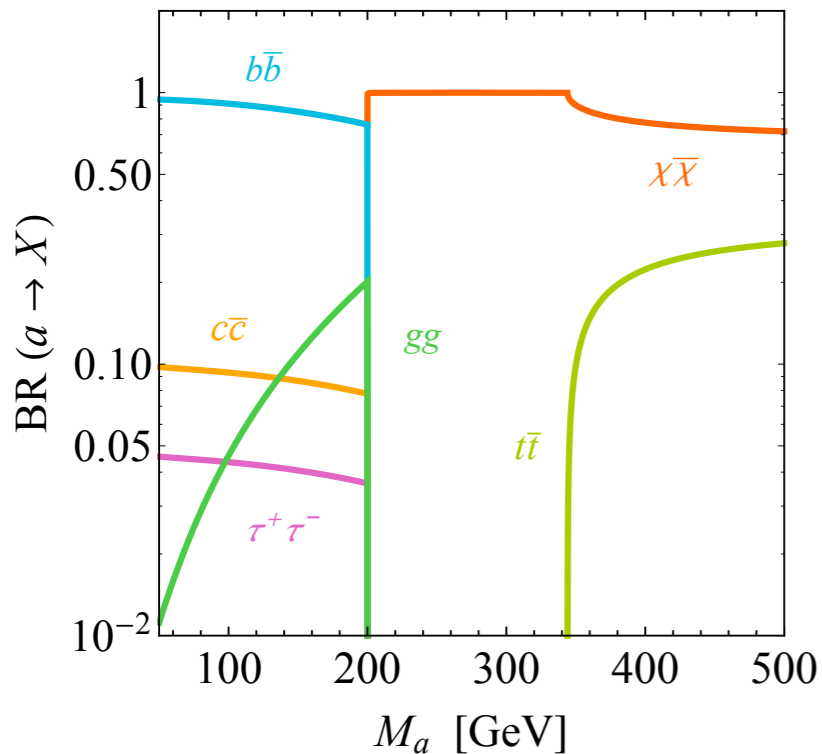


- 2HDM+S vs 2HDM+a
  - Similar, but in 2HDM+S no coupling between a and DM
    - ➔ All the decays go to SM
  - 2HDM+a assumes  $g_{\text{DM}} \sim 1$ , used for interpretations of mono-X DM searches

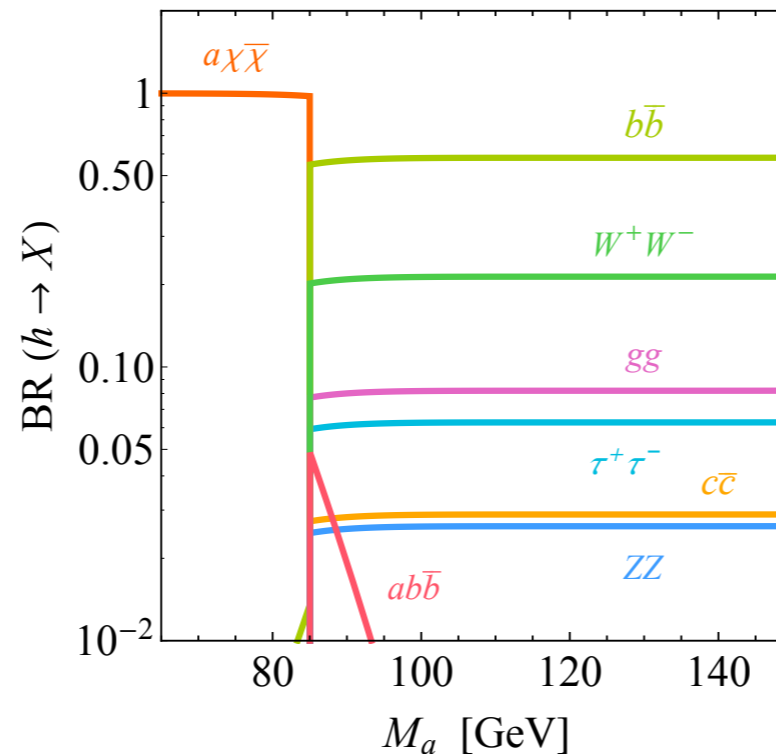


arXiv:1701.07427

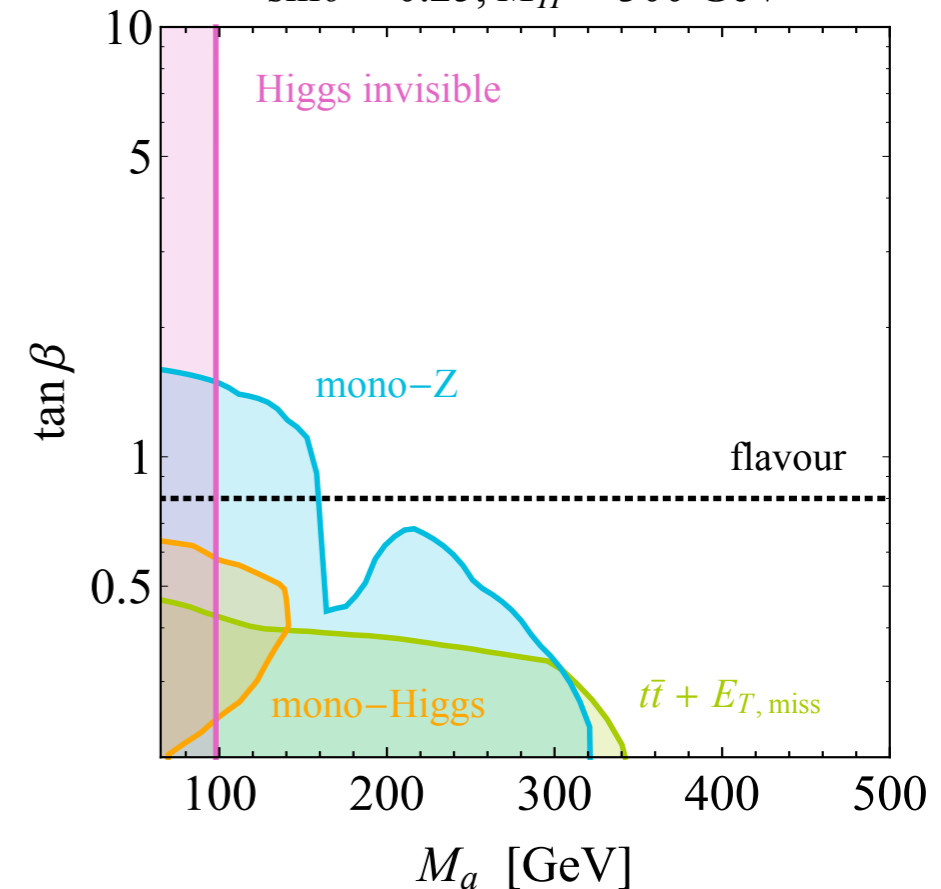
$\sin\theta = 1/2, m_\chi = 100 \text{ GeV}$



$m_\chi = 20 \text{ GeV}$



$\sin\theta = 0.25, M_H = 300 \text{ GeV}$

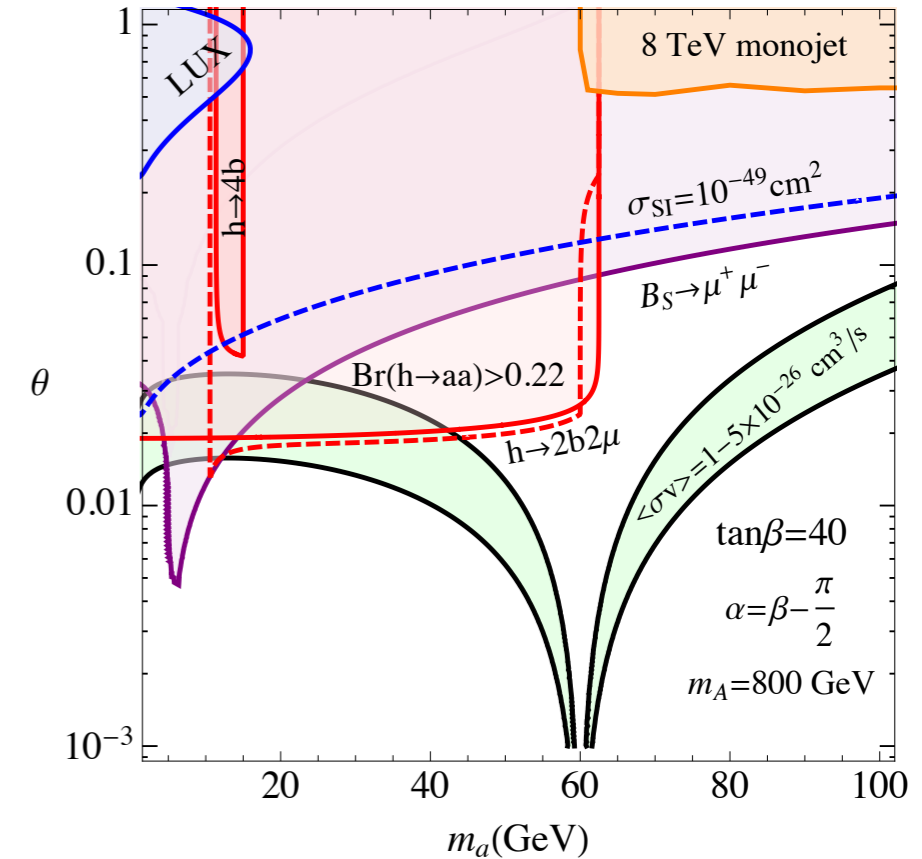




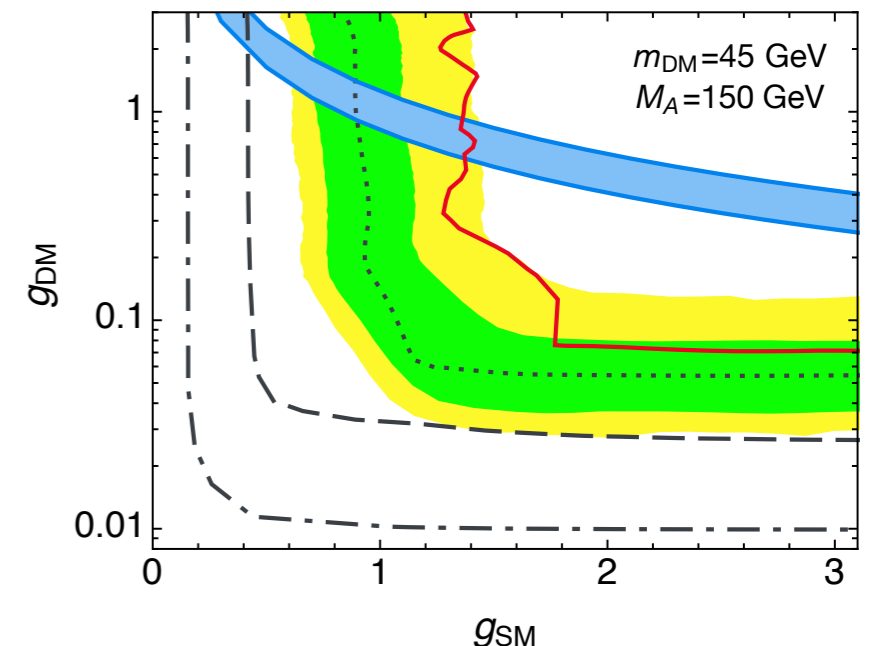
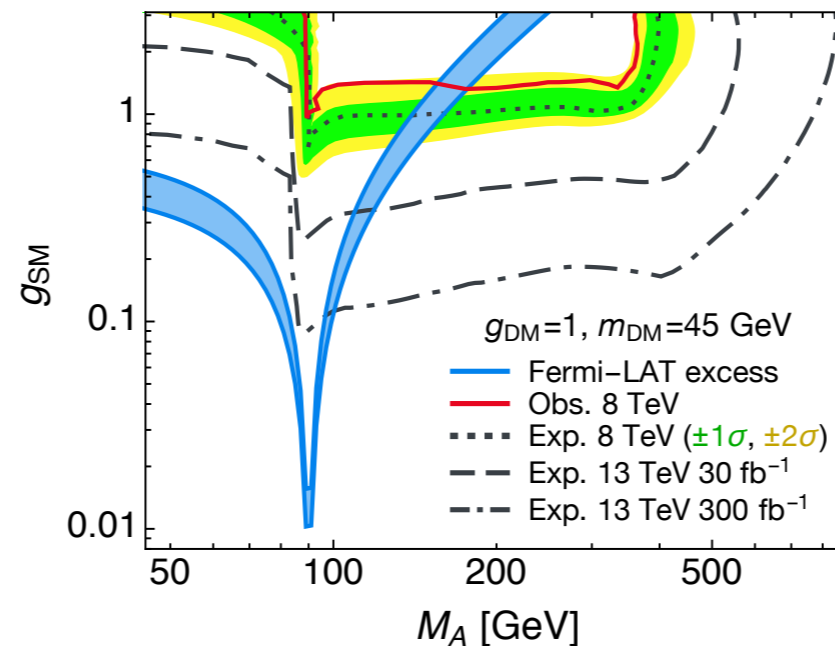
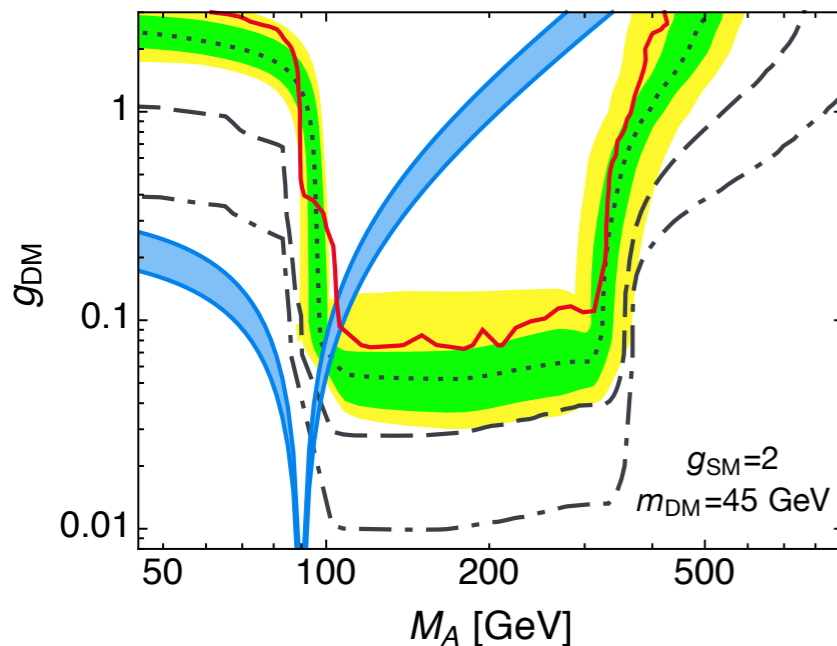
# 2HDM+s/a?

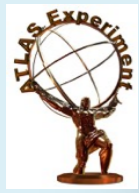
\* Can we come up with a model where a could decay to both DM and SM fermions and then show all the constraints together?

arXiv:1404.3716



arXiv:1505.07826v2





# H- > displaced

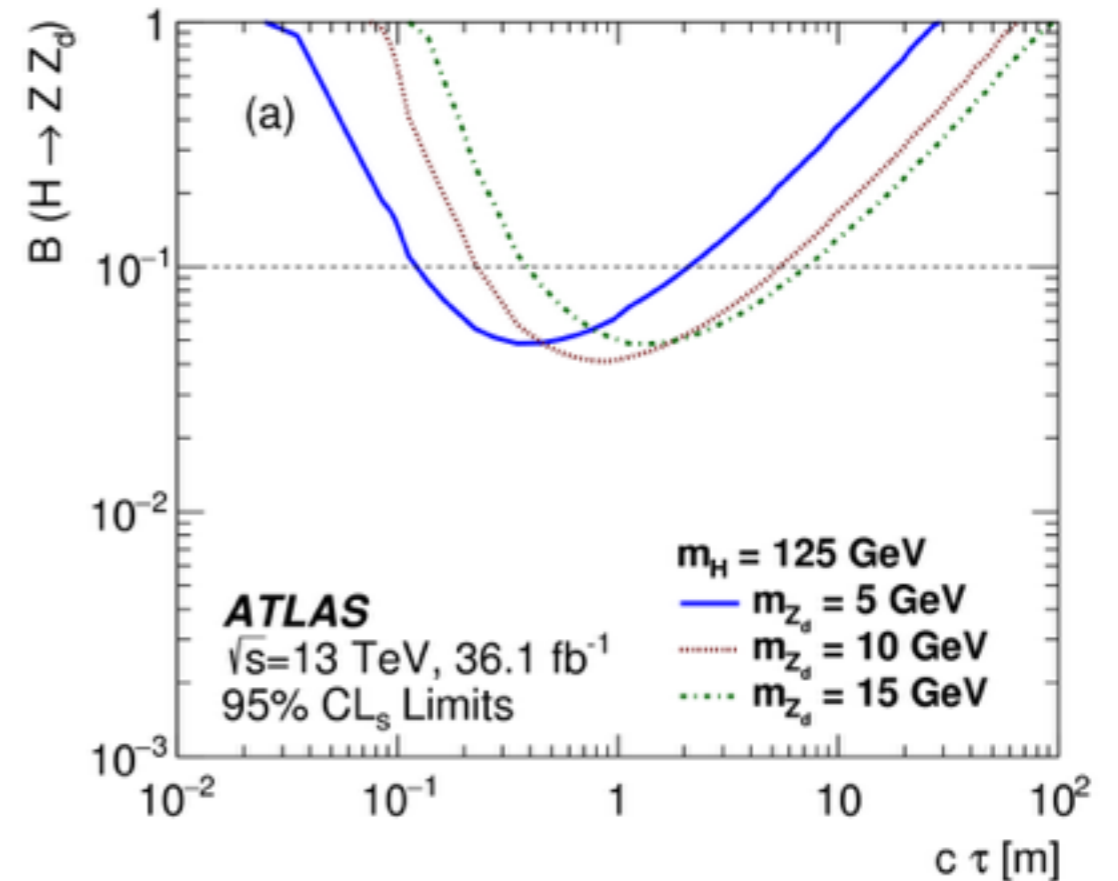
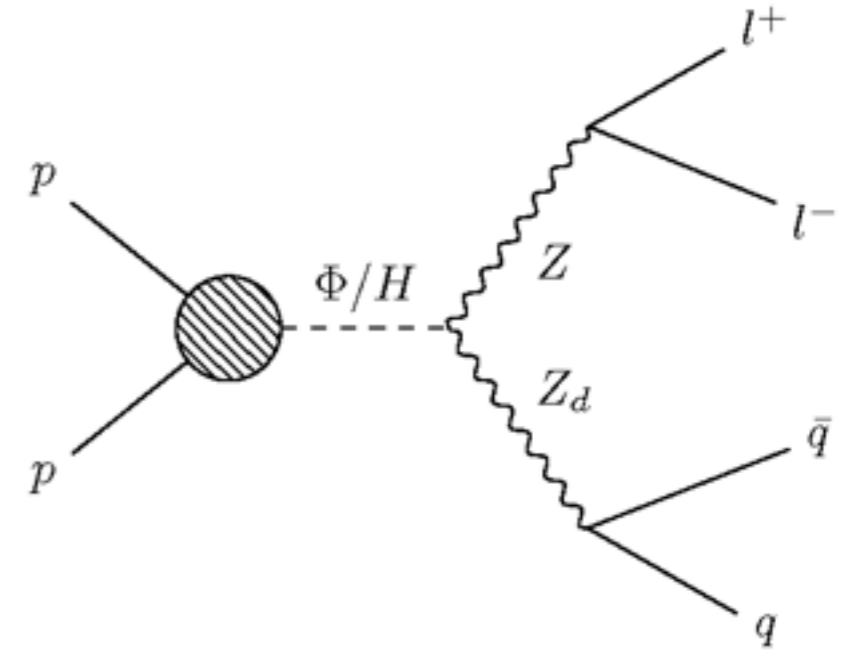
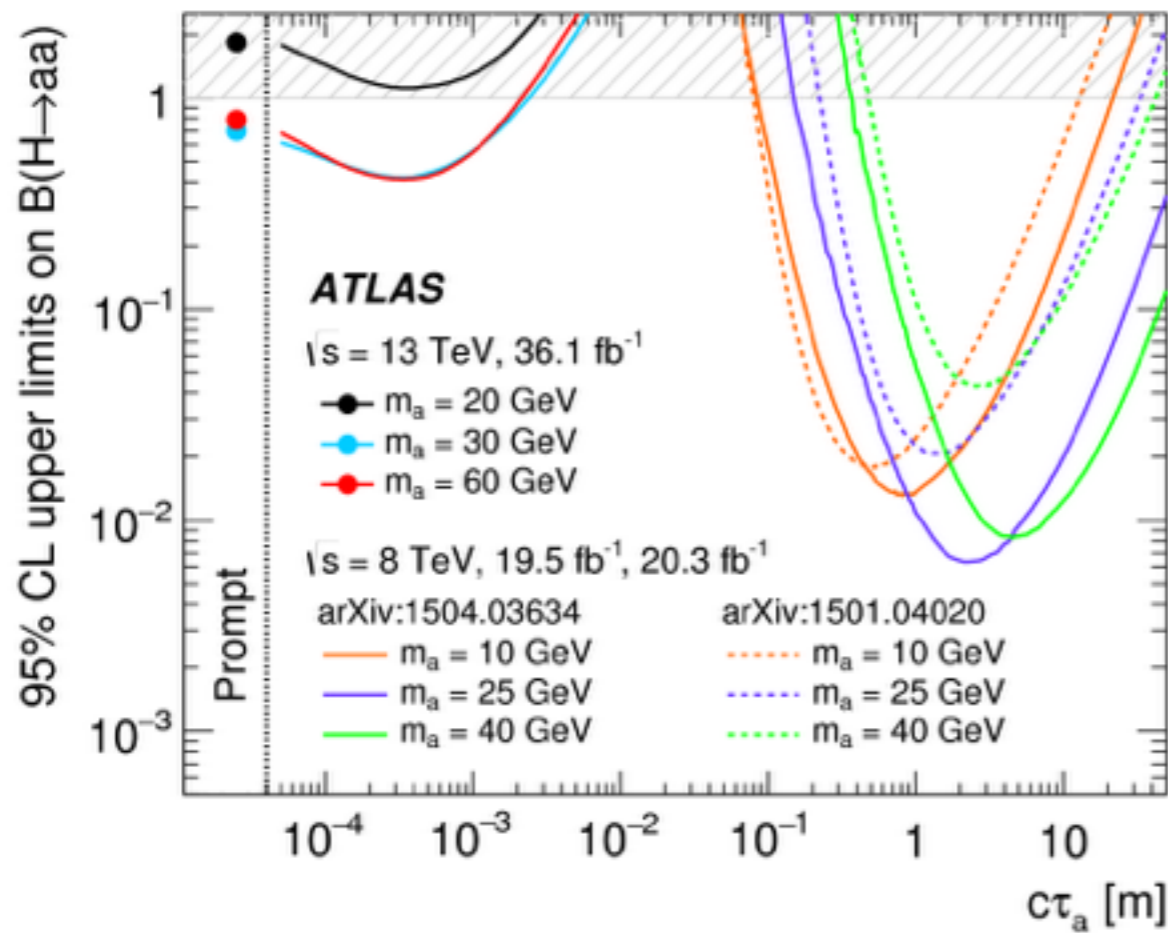


# H → displaced jets

• 36 fb<sup>-1</sup> @ 13 TeV

EXOT-2017-24

**h → aa → 4b**

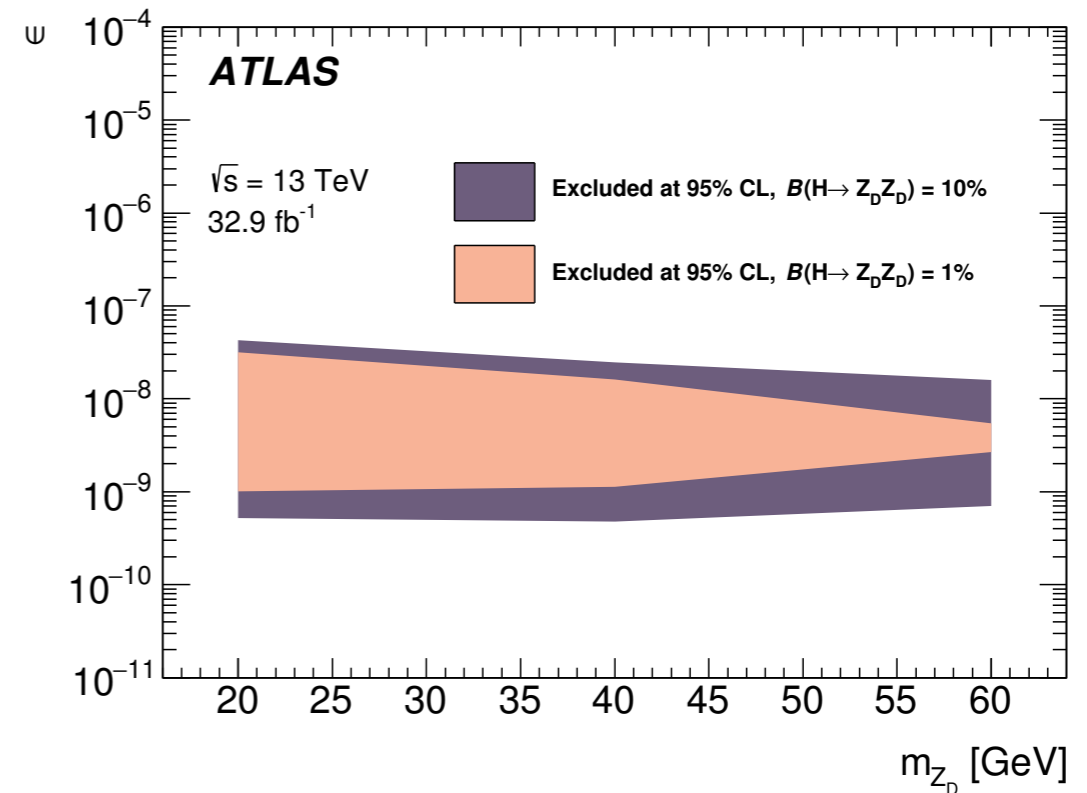
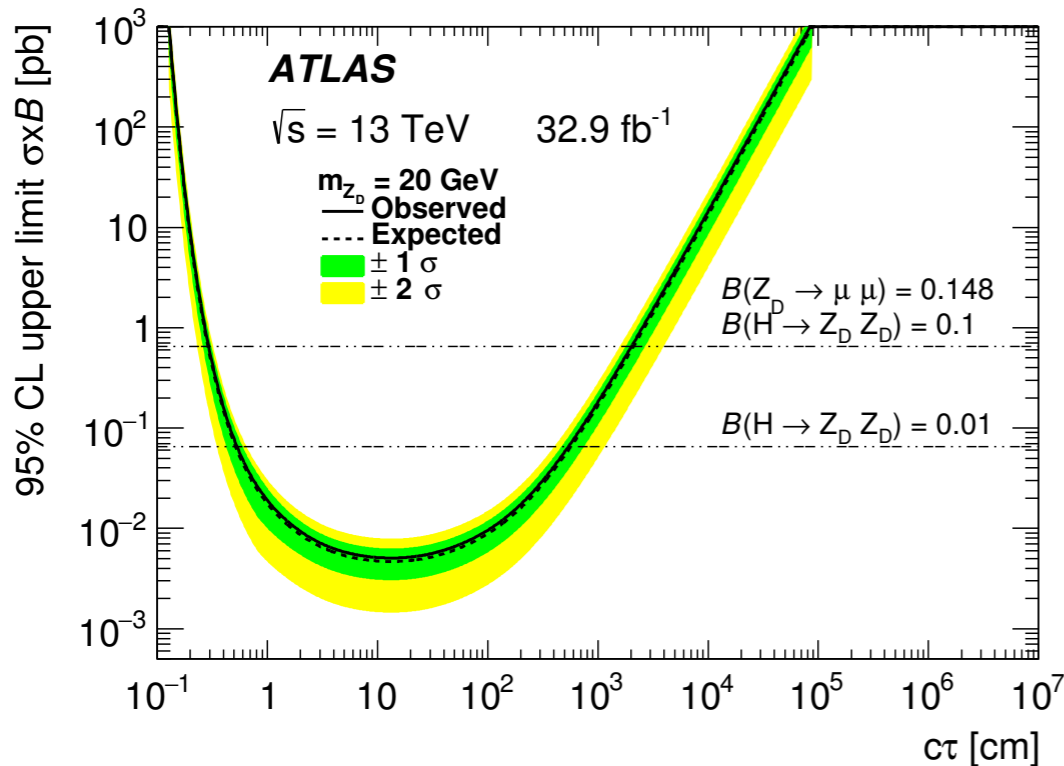
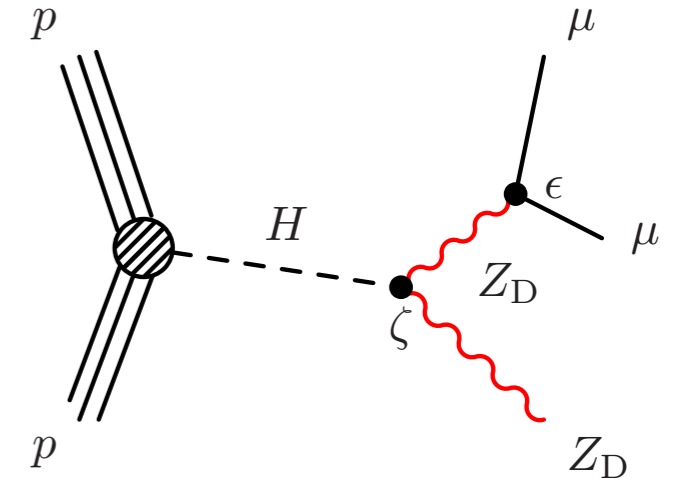




# H → displaced muons

• 32 fb<sup>-1</sup> @ 13 TeV

[arXiv:1808.03057](https://arxiv.org/abs/1808.03057)





# H $\rightarrow$ mesons $\gamma$



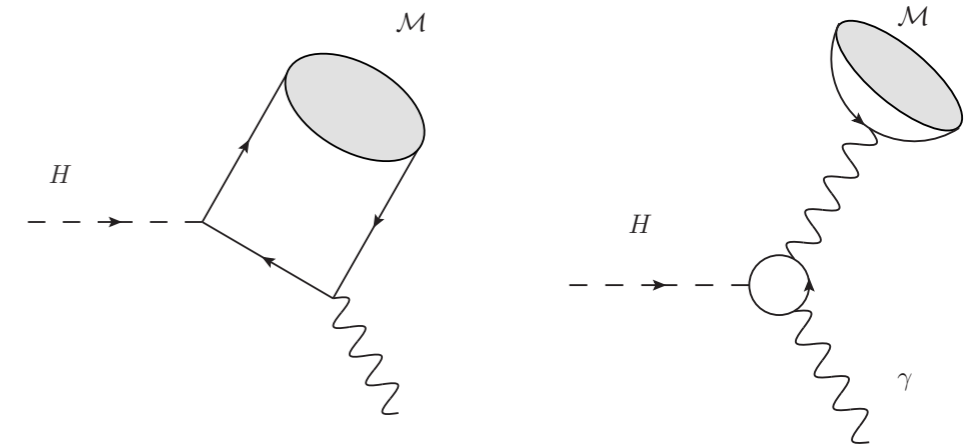
# $H \rightarrow J/\psi\gamma, \psi(2s)\gamma, \Upsilon(nS)\gamma$

• 36 fb<sup>-1</sup> @ 13 TeV

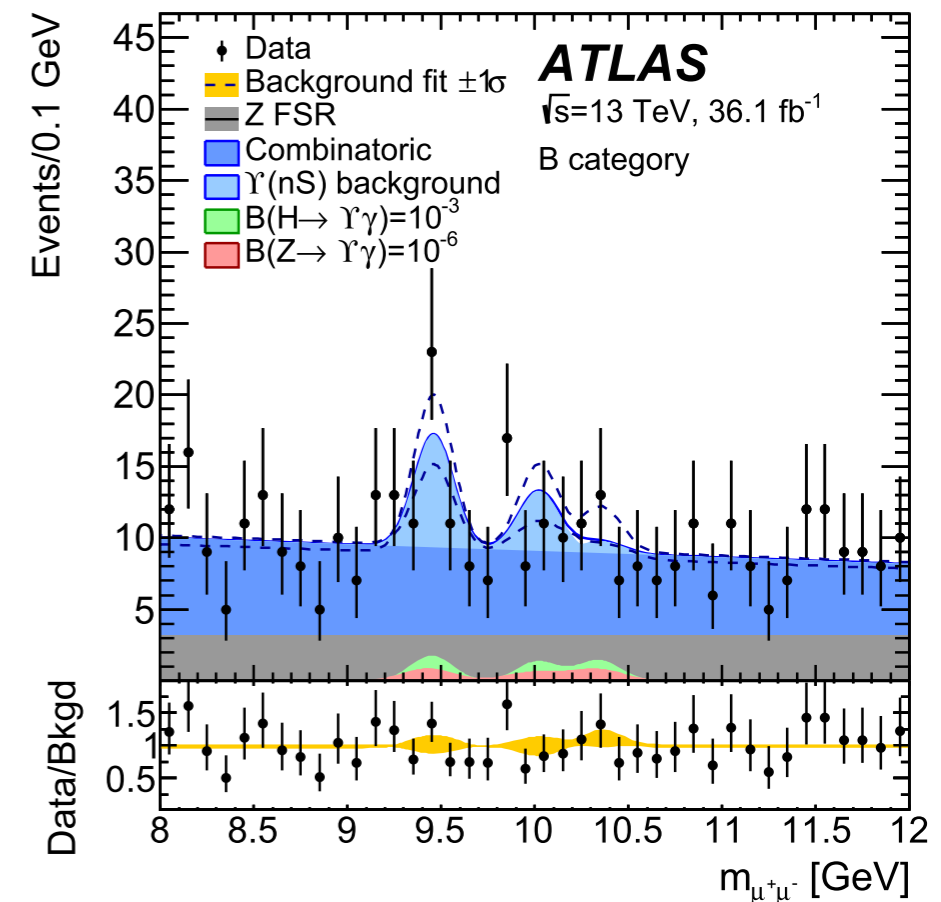
*Phys. Lett. B 786 (2018) 134*

• Standard Model Predictions:

- ▶  $\mathcal{B}(H \rightarrow J/\psi\gamma) = (2.99 \pm 0.16) \times 10^{-6} \dagger$
- ▶  $\mathcal{B}(H \rightarrow \psi(2S)\gamma) = (1.03 \pm 0.06) \times 10^{-6} \dagger$
- ▶  $\mathcal{B}(H \rightarrow \Upsilon(1S)\gamma) = (5.2^{+2.0}_{-1.7}) \times 10^{-9} \dagger$



Branching fraction limit (95% CL)	Expected	Observed
$\mathcal{B}(H \rightarrow J/\psi\gamma) [10^{-4}]$	$3.0^{+1.4}_{-0.8}$	3.5
$\mathcal{B}(H \rightarrow \psi(2S)\gamma) [10^{-4}]$	$15.6^{+7.7}_{-4.4}$	19.8
$\mathcal{B}(Z \rightarrow J/\psi\gamma) [10^{-6}]$	$1.1^{+0.5}_{-0.3}$	2.3
$\mathcal{B}(Z \rightarrow \psi(2S)\gamma) [10^{-6}]$	$6.0^{+2.7}_{-1.7}$	4.5
$\mathcal{B}(H \rightarrow \Upsilon(1S)\gamma) [10^{-4}]$	$5.0^{+2.4}_{-1.4}$	4.9
$\mathcal{B}(H \rightarrow \Upsilon(2S)\gamma) [10^{-4}]$	$6.2^{+3.0}_{-1.7}$	5.9
$\mathcal{B}(H \rightarrow \Upsilon(3S)\gamma) [10^{-4}]$	$5.0^{+2.5}_{-1.4}$	5.7



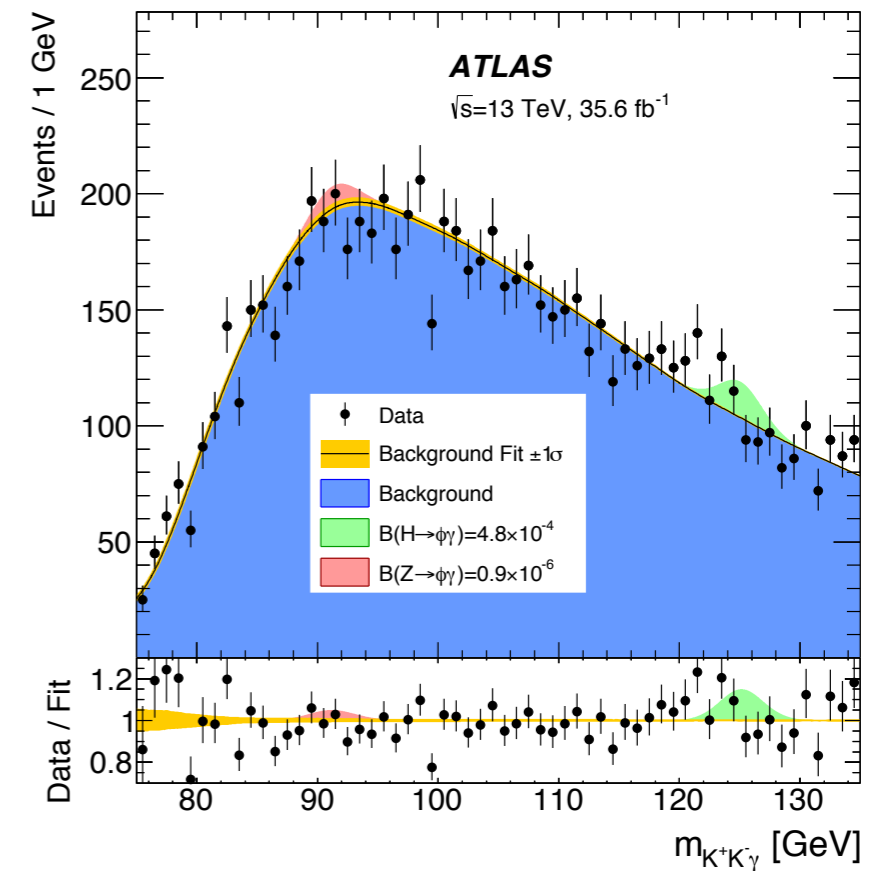
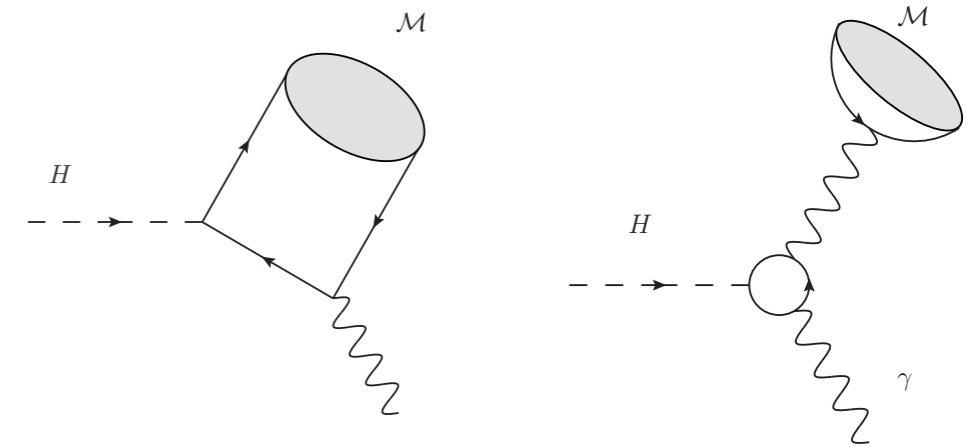
• 36 fb<sup>-1</sup> @ 13 TeV

*JHEP 07 (2018) 127*

• SM predictions:

- ▶  $\mathcal{B}(H \rightarrow \phi\gamma) = (2.31 \pm 0.11) \times 10^{-6}$
- ▶  $\mathcal{B}(H \rightarrow \rho\gamma) = (1.68 \pm 0.08) \times 10^{-5}$

Branching Fraction Limit (95% CL)	Expected	Observed
$\mathcal{B}(H \rightarrow \phi\gamma) [10^{-4}]$	$4.2^{+1.8}_{-1.2}$	4.8
$\mathcal{B}(Z \rightarrow \phi\gamma) [10^{-6}]$	$1.3^{+0.6}_{-0.4}$	0.9
$\mathcal{B}(H \rightarrow \rho\gamma) [10^{-4}]$	$8.4^{+4.1}_{-2.4}$	8.8
$\mathcal{B}(Z \rightarrow \rho\gamma) [10^{-6}]$	$33^{+13}_{-9}$	25



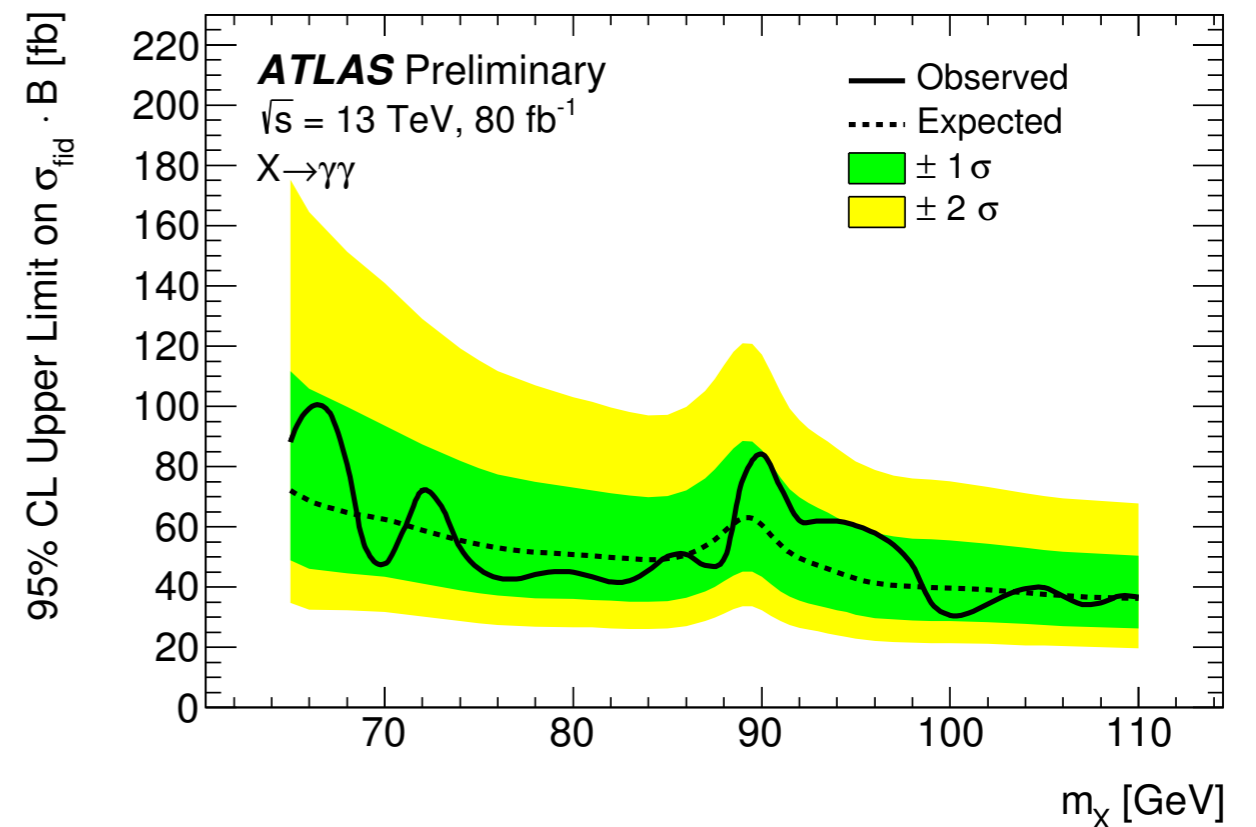
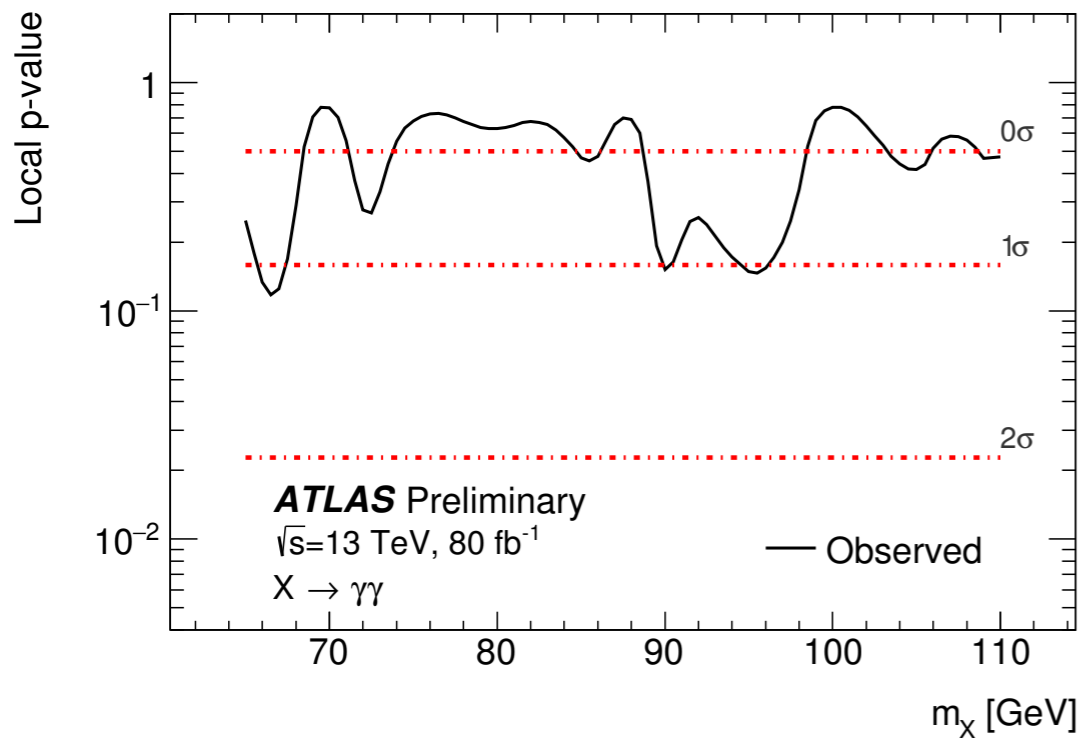




# Low-mass $\gamma\gamma$

- 80 fb<sup>-1</sup> @ 13 TeV

**ATLAS-CONF-2018-025**





# Backup



# H → e/μ τ

[1604.07730](https://arxiv.org/abs/1604.07730)

