Extended Scalars

ATLAS+CMS

Xiaohu SUN
on behalf of ATLAS+CMS

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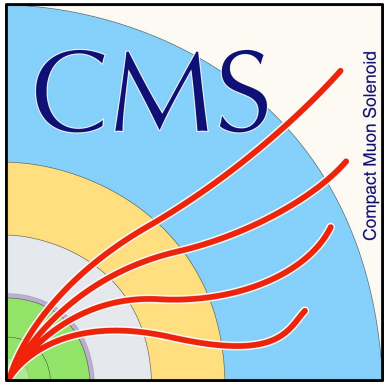
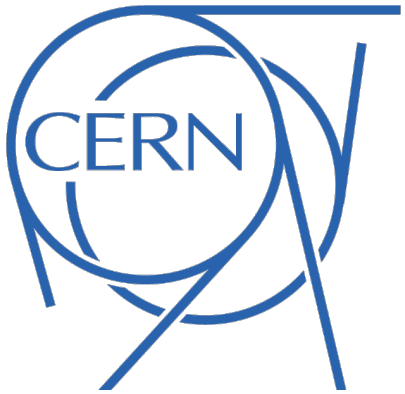
15-07-2015
IHEP





Relevant searches in ATLAS + CMS

- *Only results with interpretations are presented*
- *ALTAS*
  - **A→Zh**, PLB 744 (2015) 163-183 2HDM
  - **H→hh→bbbb**, arXiv:1506.00285 2HDM
  - **SM Higgs couplings**, ATLAS-CONF-2014-010 2HDM, EW singlet
  - **$H^{\pm}$→WZ**, PRL 114, 231801 (2015) “LHCHXSWG-2015-001 (2015.05.05)” Triplet
- *CMS*
  - **H→hh & A→Zh** PRD 90, 112013 2HDM
  - **A→Zh** arxiv:1504.04710 2HDM
  - **H/A→Z A/H** CMS-PAS-HIG-15-001 2HDM

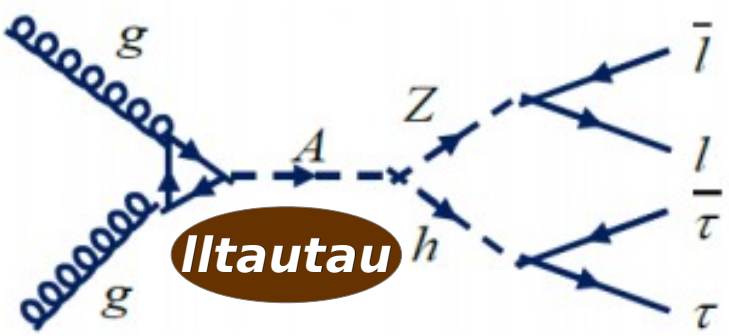
2HDM specification

- In the context of the ***CP-conserving*** 2HDM
- Yukawa coupling arrangements define **four** different 2HDM types: T*ype I, II, Lepton-specific, Flipped*
- Xsec is calculated with ***SusHi*** version 1.3.0 (ATLAS), 1.2.0 (CMS)
- BRs calculated with ***2HDMC*** version 1.6.4 and with the assumption of $m(A) = m(H) = m(H^{\pm})$, $m(h) = 125$ GeV and $m_{12}^2 = m_A^2 \tan\beta/(1 + \tan^2\beta)$
- The ***width*** effects are taken into account, for example, up to 5% of m(A) in A→Zh and 15% of m(H) in H→hh→bbbb (ATLAS)
- ***b-associated*** production is considered and contributes in high tanβ

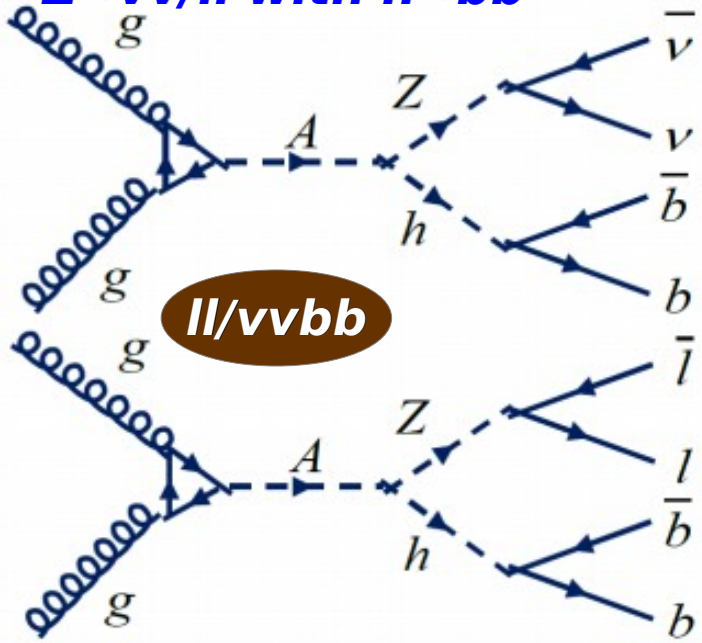
ATLAS A→Zh

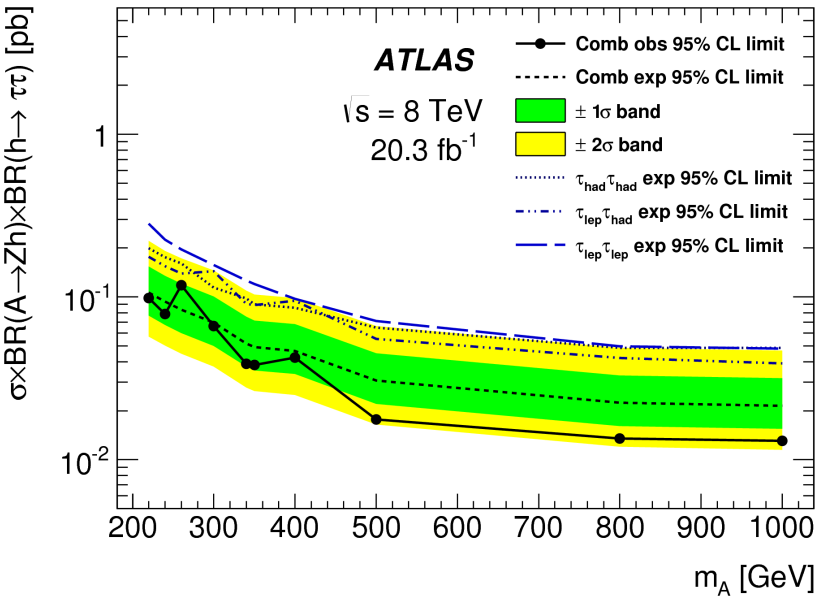
- Look for a CP-odd Higgs boson A decaying to Zh

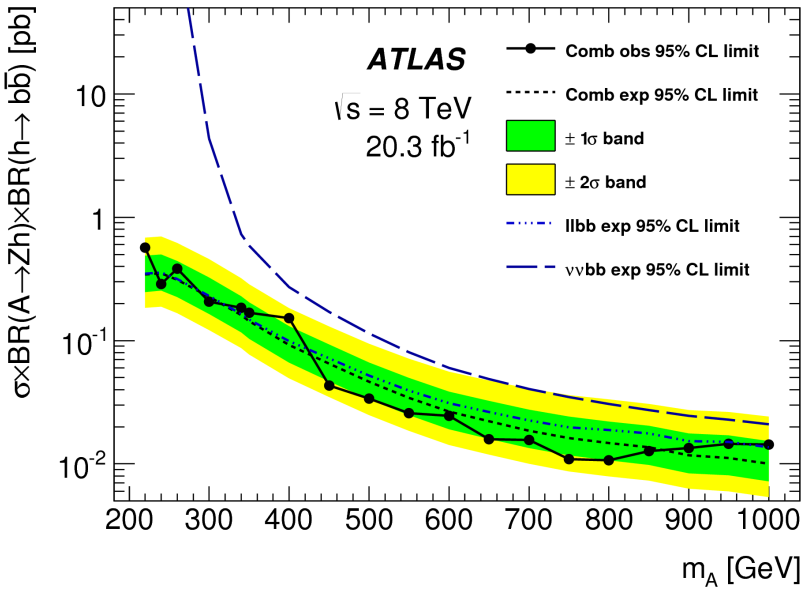
Three channels including Z→ll, hadronic and leptonic tau decays



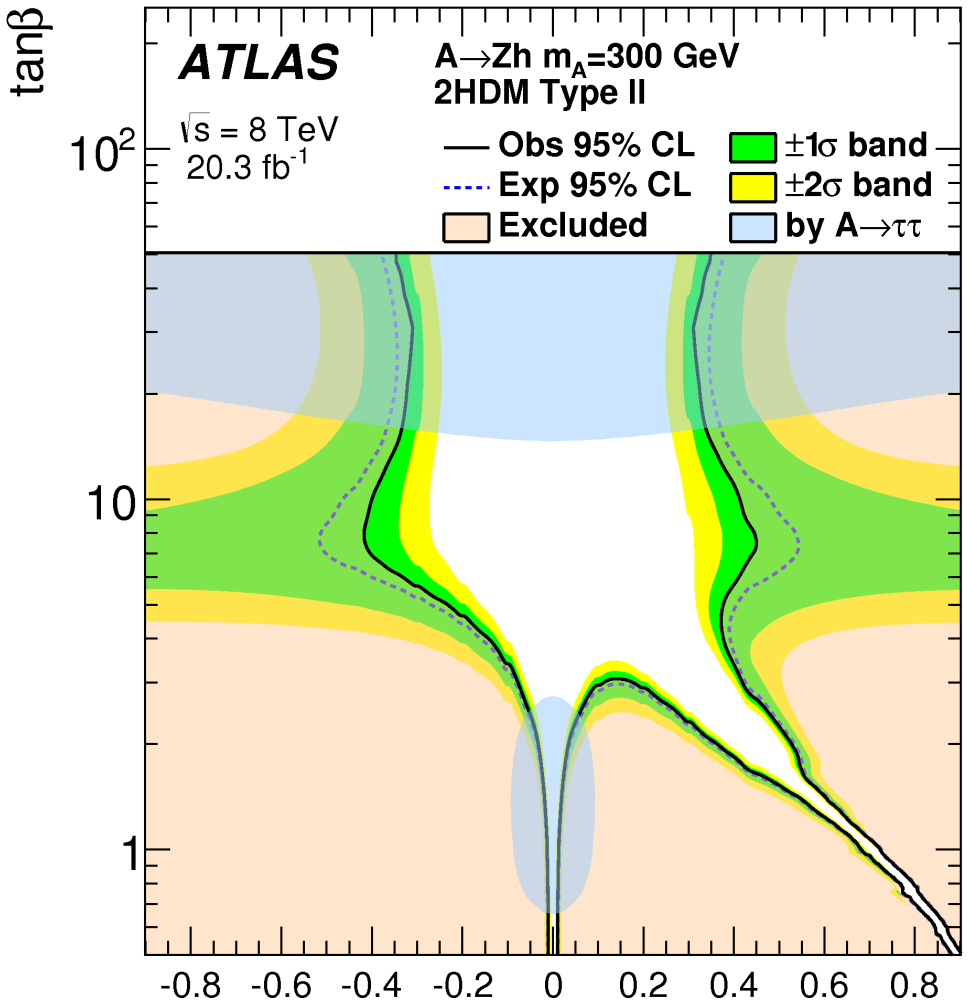
Two channels including Z→vv/ll with h→bb



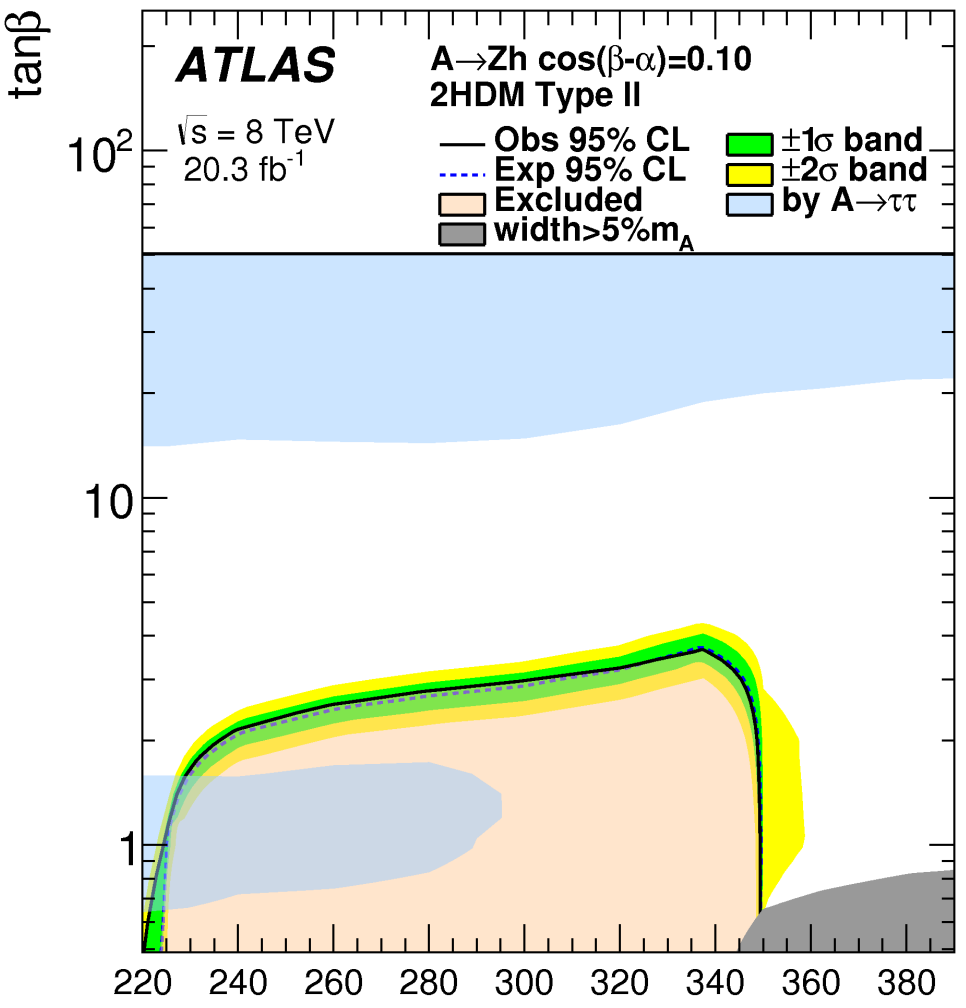




ATLAS A→Zh Type II 2HDM



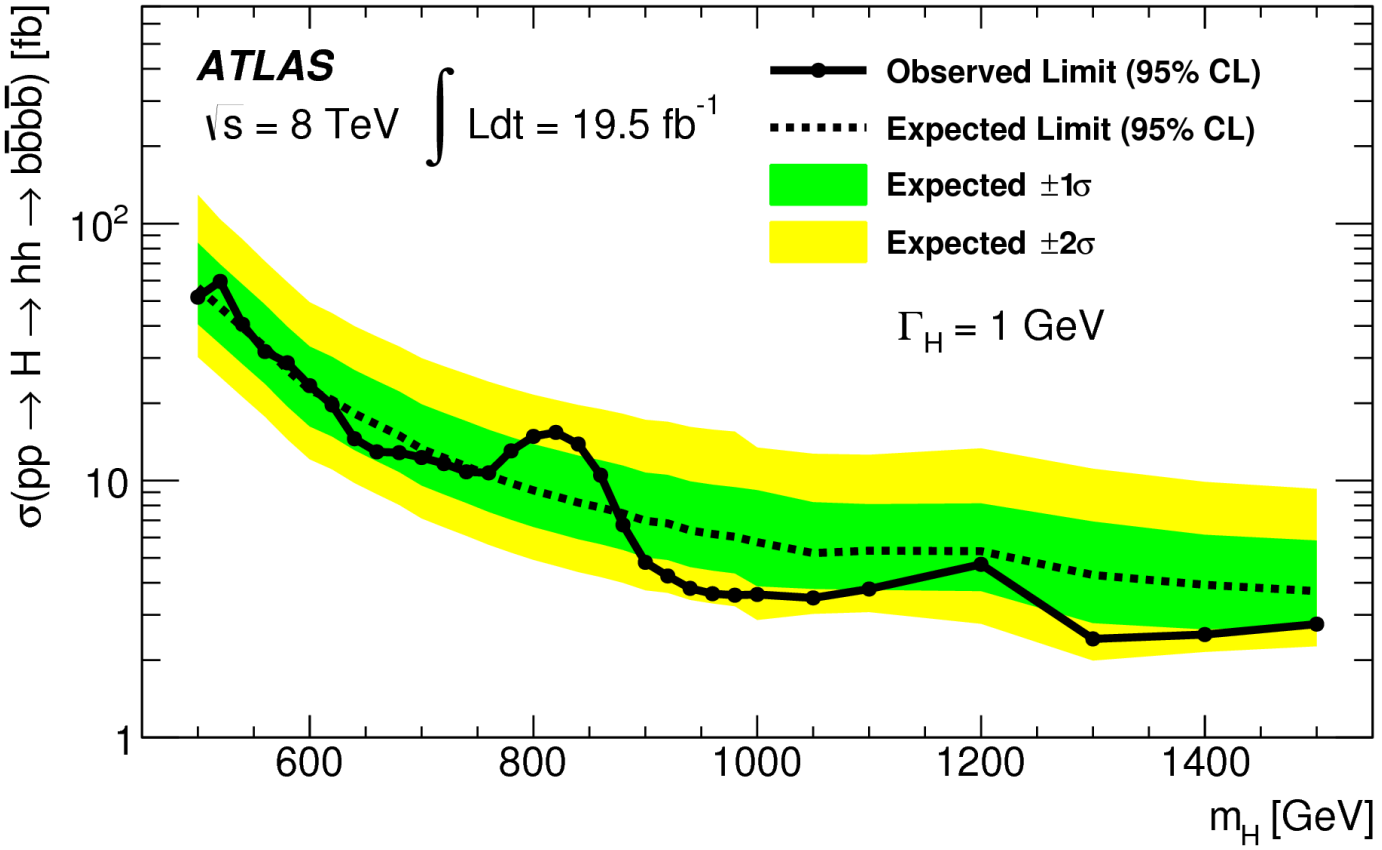
Type II
m(A) = 300GeV



Type II
cos(β-α) = 0.10

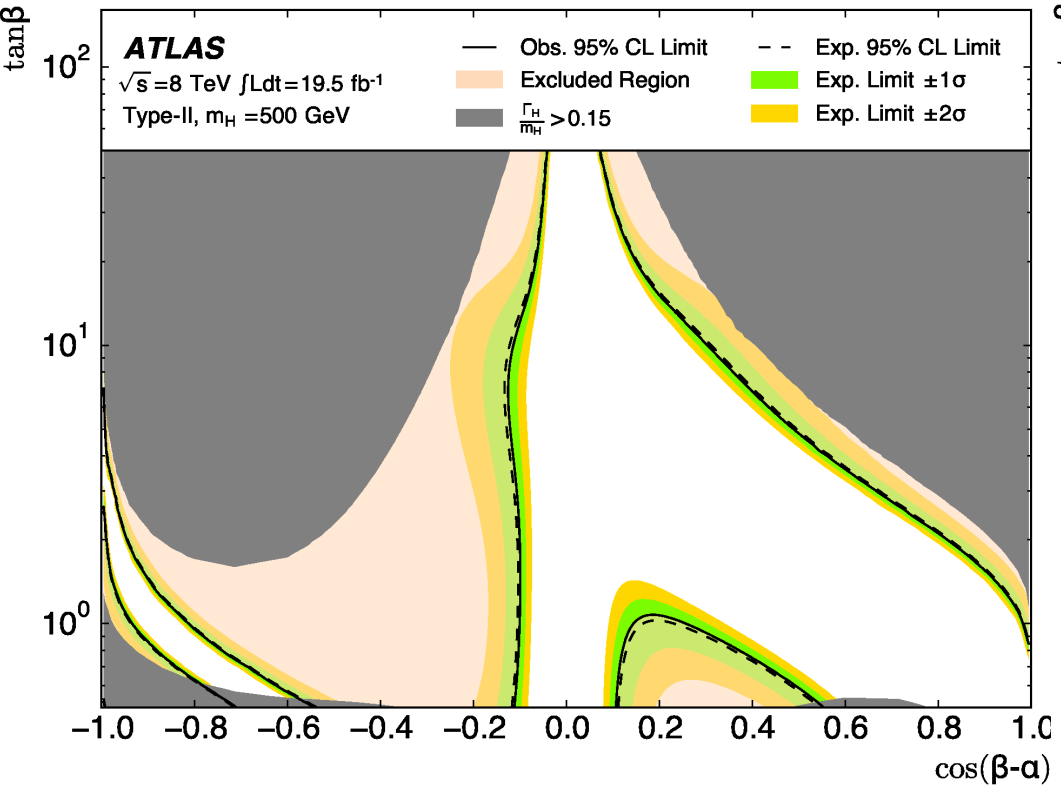
ATLAS H→hh→bbbb

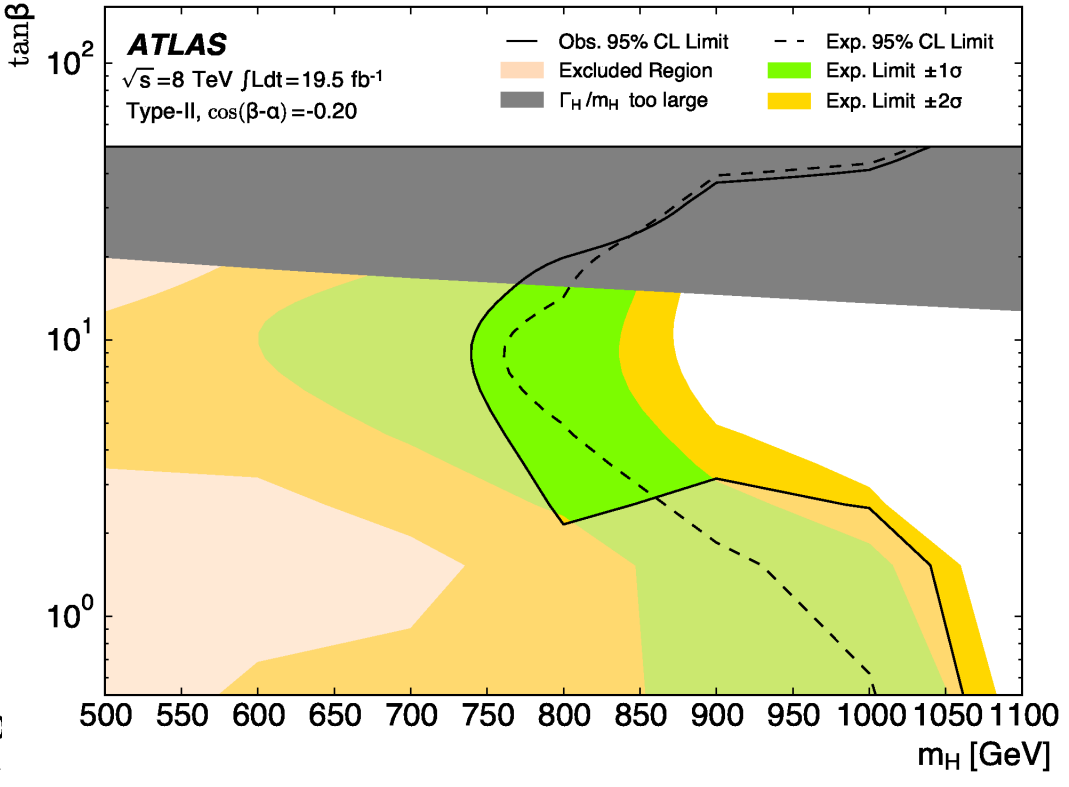
- Look for a CP-even Higgs boson H decaying to **hh→bbbb**
- Sensitive in high mass regime



- Width effects are taken into account up to 15%*m(H) and more

ATLAS H→hh→bbbb Type II 2HDM





Type II
m(A) = 500GeV

Type II
cos(β-α) = -0.20

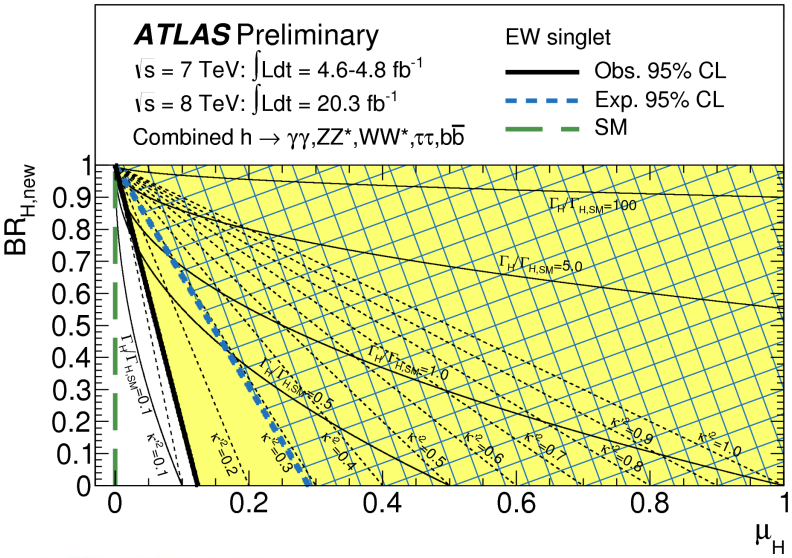
width/m(H)
within 15% for m(H)=500GeV
up to 23% for m(H)=1000GeV

ATLAS SM Higgs couplings

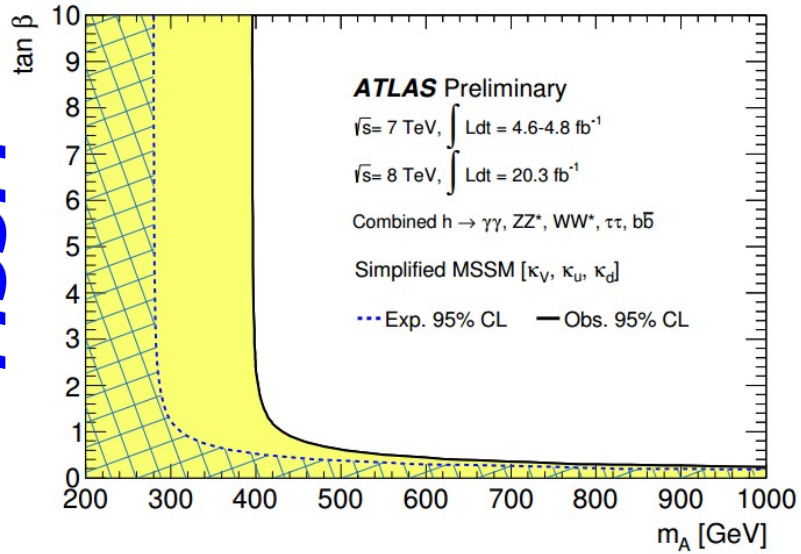
to be updated

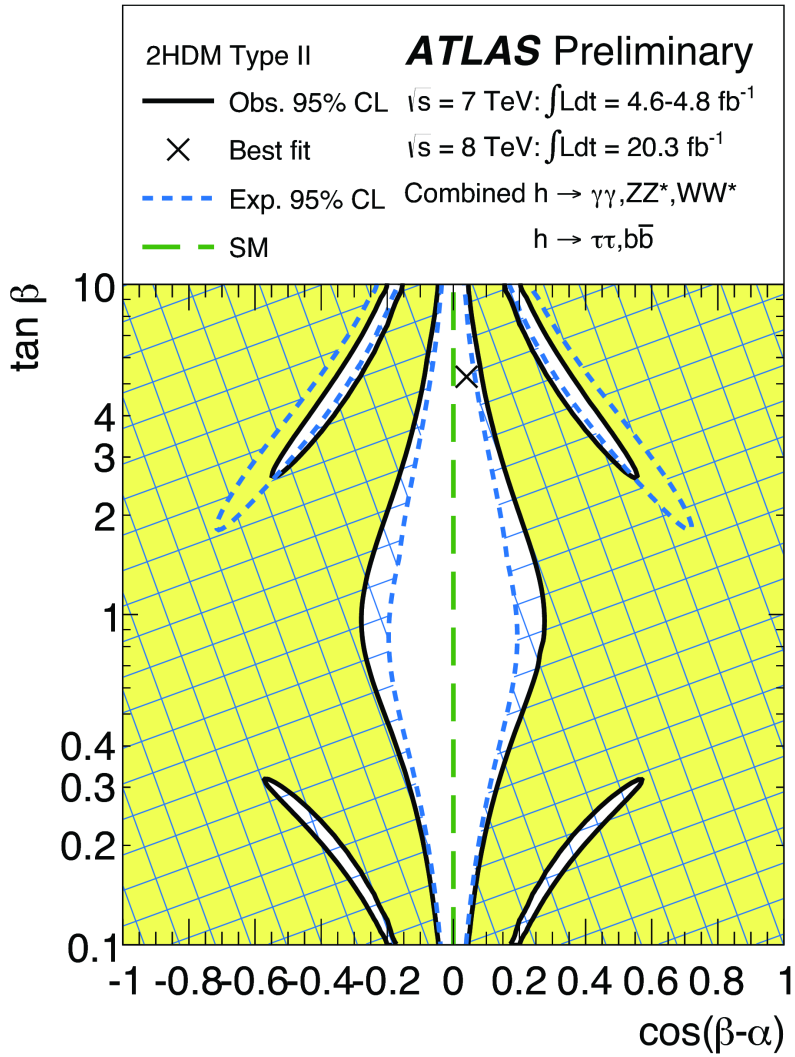
- Indirect constraints on BSM physics via SM Higgs couplings including h→γγ, ZZ, WW, ττ, bb

EW singlet



Simplified MSSM

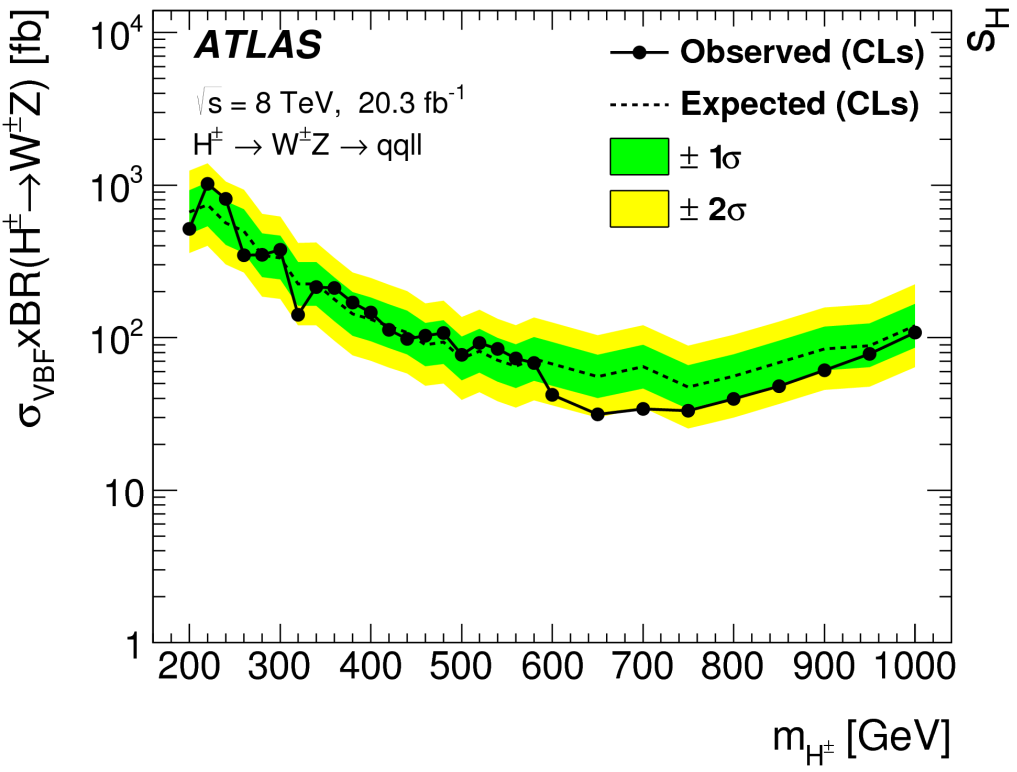


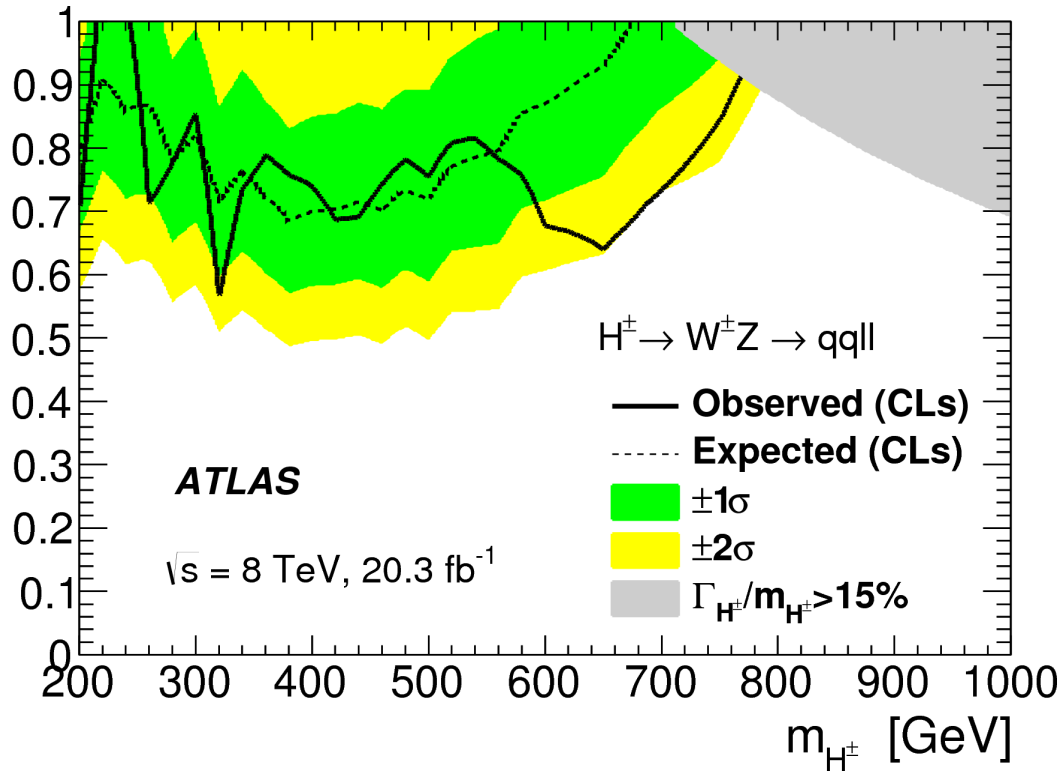


2HDM Type II

ATLAS $H^{\pm}\rightarrow WZ$

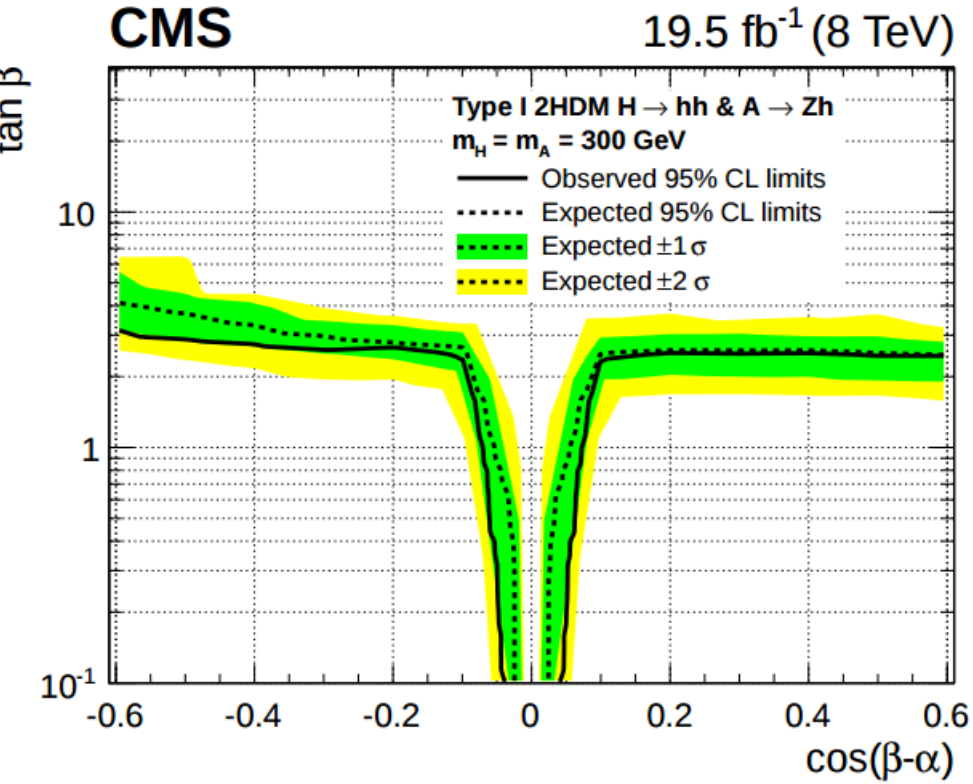
- Search for a charged Higgs boson produced in the VBF Mode with decay of $H^{\pm}\rightarrow WZ$, $W\rightarrow qq$ and $Z\rightarrow ee/\mu\mu$
- The data are compared with the Georgi-Machacek Higgs triplet model (GMHTM)

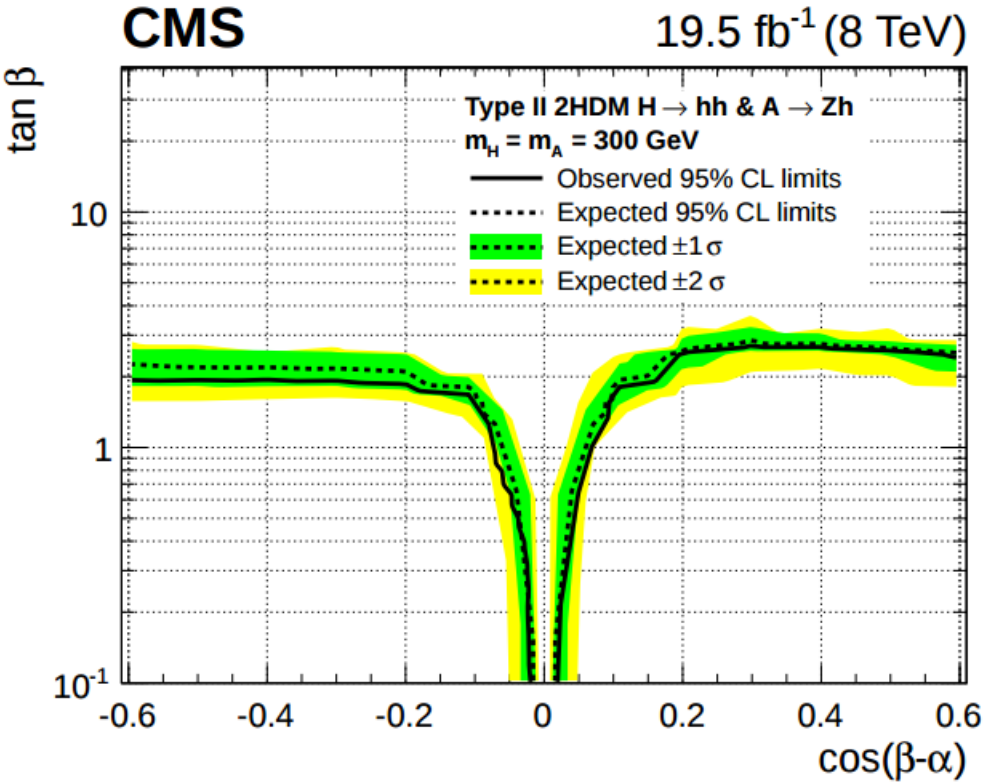




CMS H/A→multilepton/diphoton

- Inclusively search final states with three or four charged leptons and a resonant pair of photon + at least one leptons, for H→hh or A→Zh



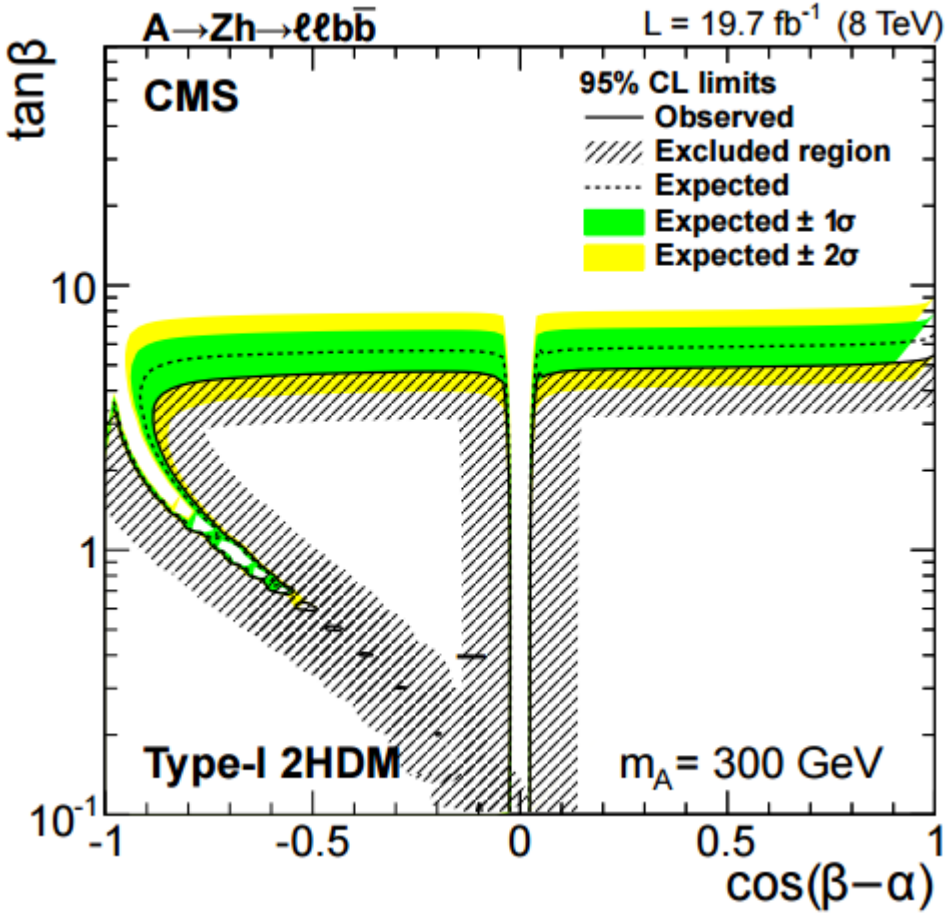


2HDM Type I m(H)=m(A)=300GeV

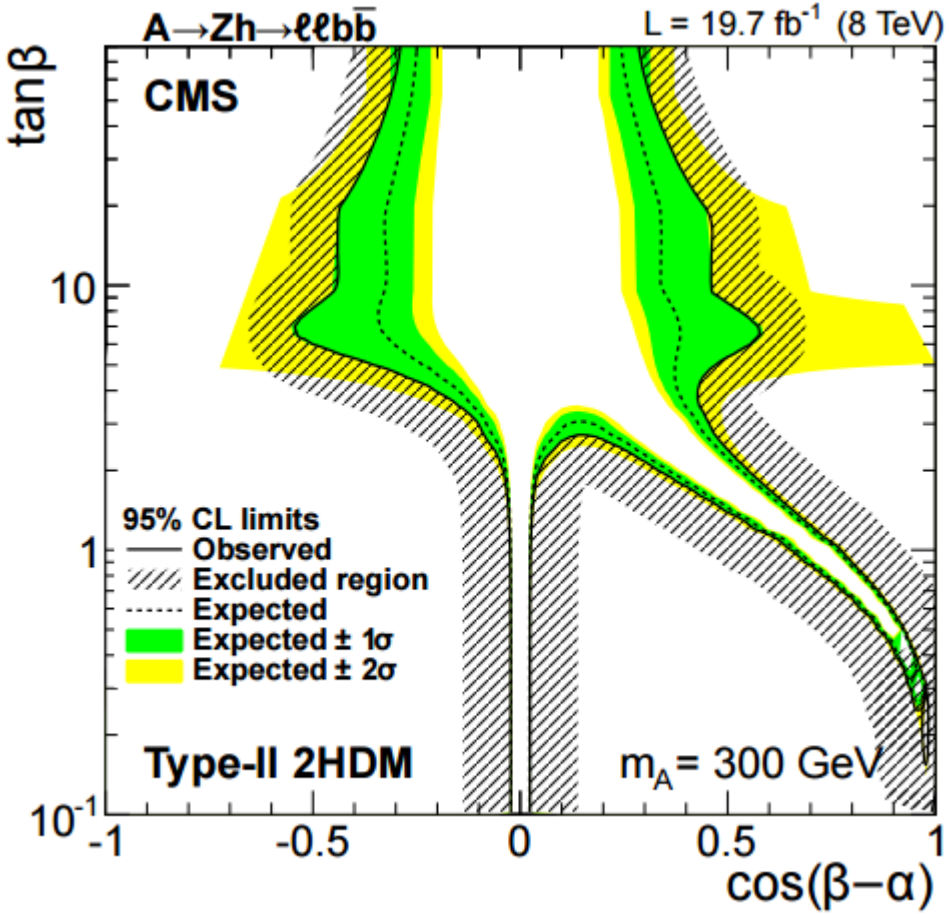
2HDM Type II m(H)=m(A)=300GeV

CMS A→Zh

- Look for CP-odd pseudoscalar A to Zh→llbb



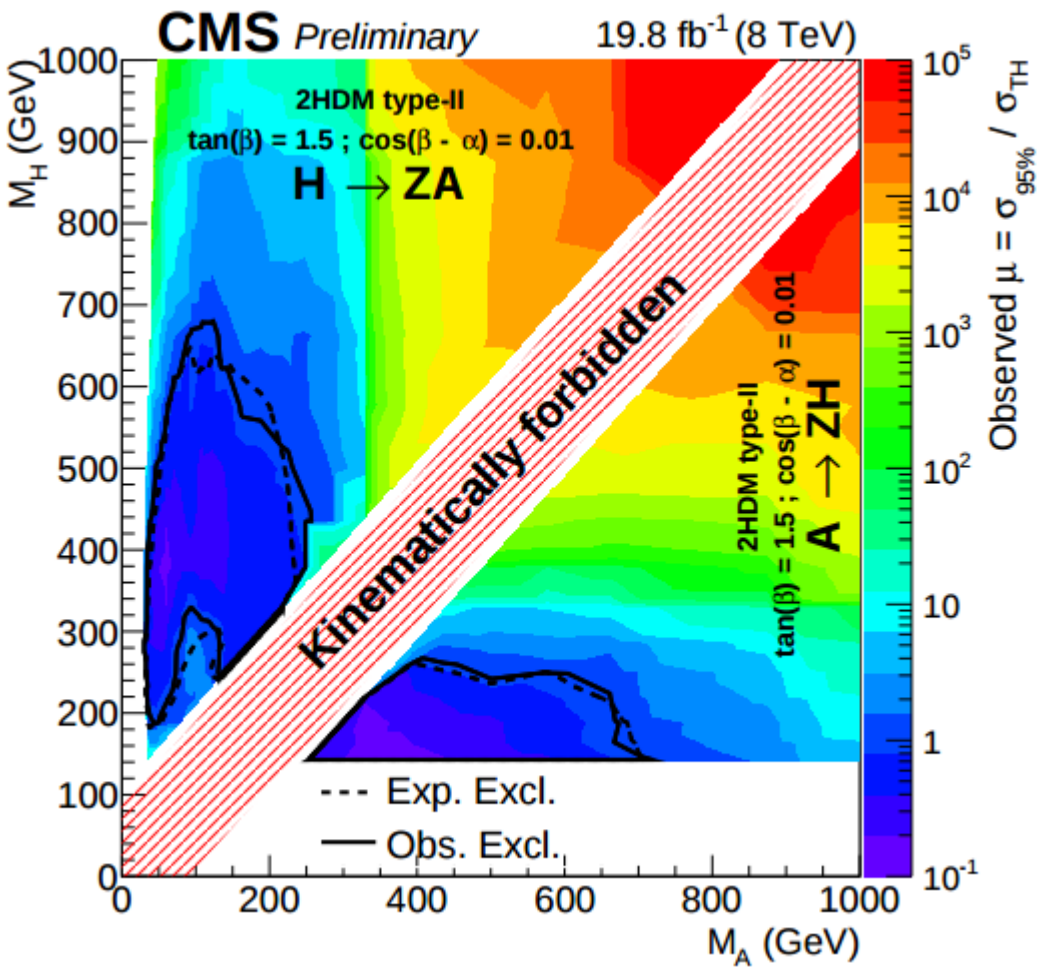
2HDM Type I
m(A)=300GeV



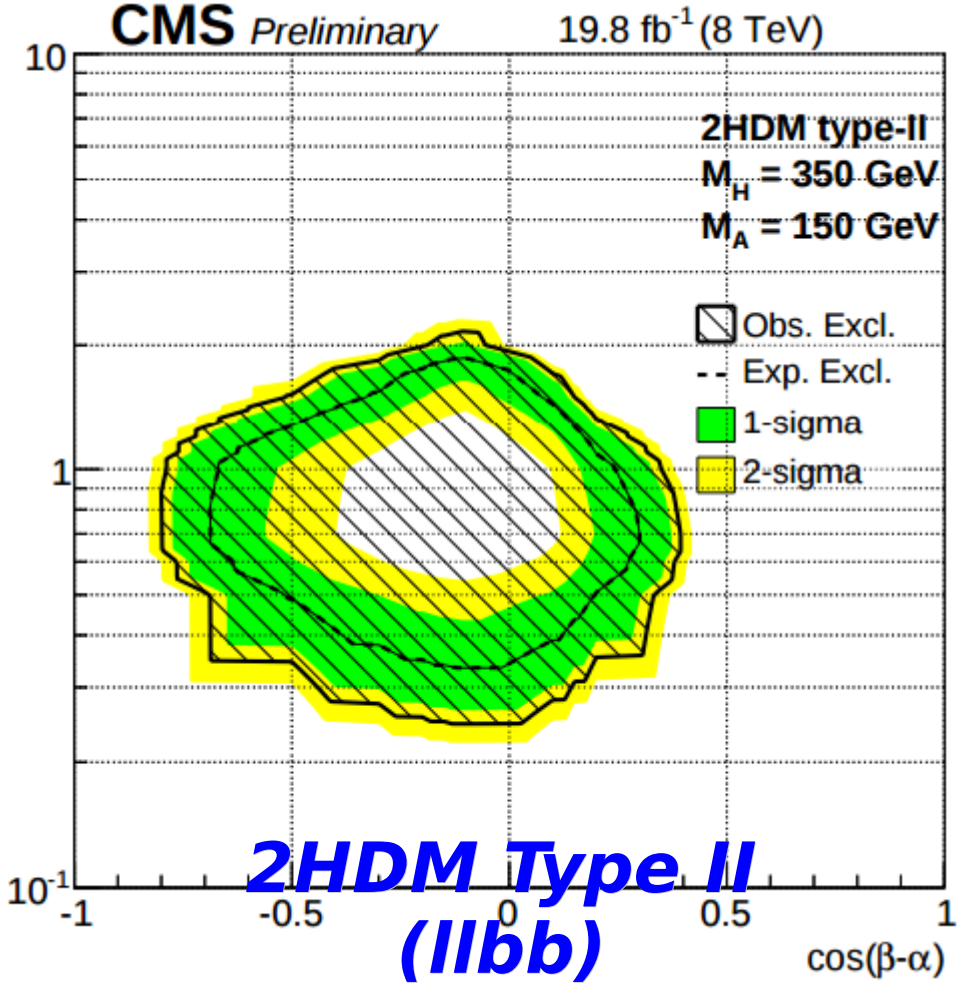
2HDM Type II
m(A)=300GeV

CMS H/A→Z A/H

- Search for H/A→Z A/H →llbb or llττ



2HDM Type II (llbb)



2HDM Type II (llbb) m(H)=350GeV m(A)=150GeV

Interpretations in ATLAS + CMS

- Various searches targeting extended scalars were implemented in ATLAS and CMS with 7 and 8 TeV

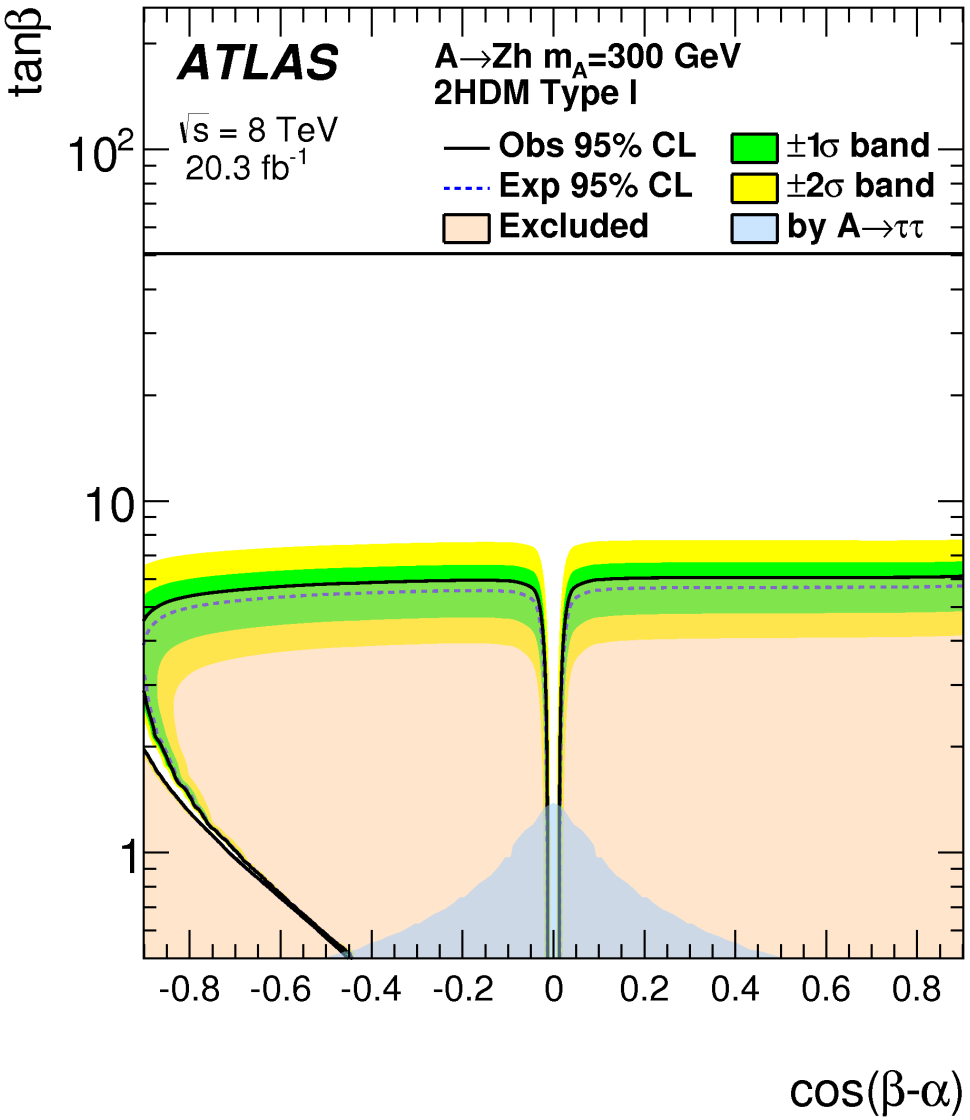
- No significant excesses were found in data, while interpretations were performed trying to make exclusions in 2HDM, additional electroweak singlet and Georgi-Machacek Higgs Triplet Model

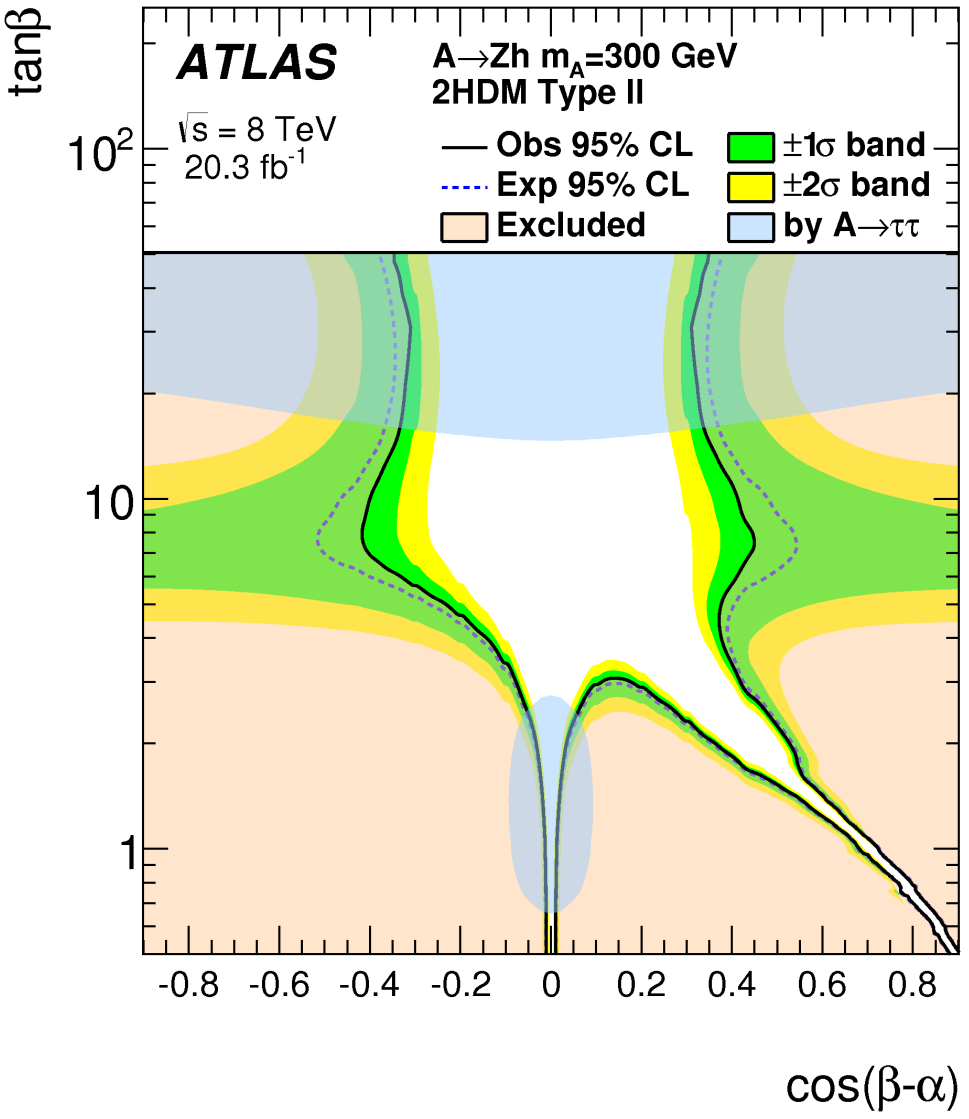
- Promising further searches are coming in 13TeV and beyond

backup

2HDM A->Zh type I and II

- In the plane of tanb vs cos(b-a)

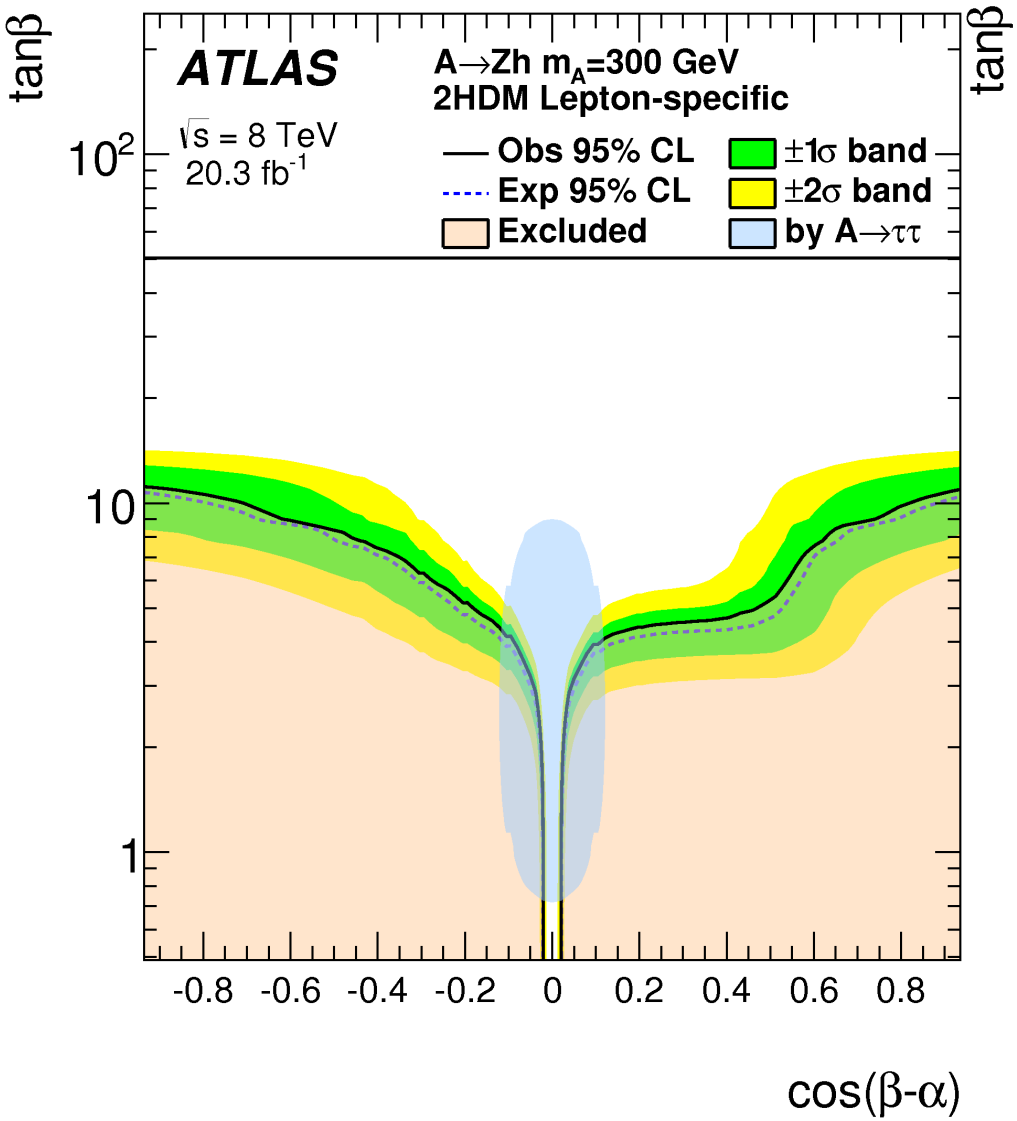


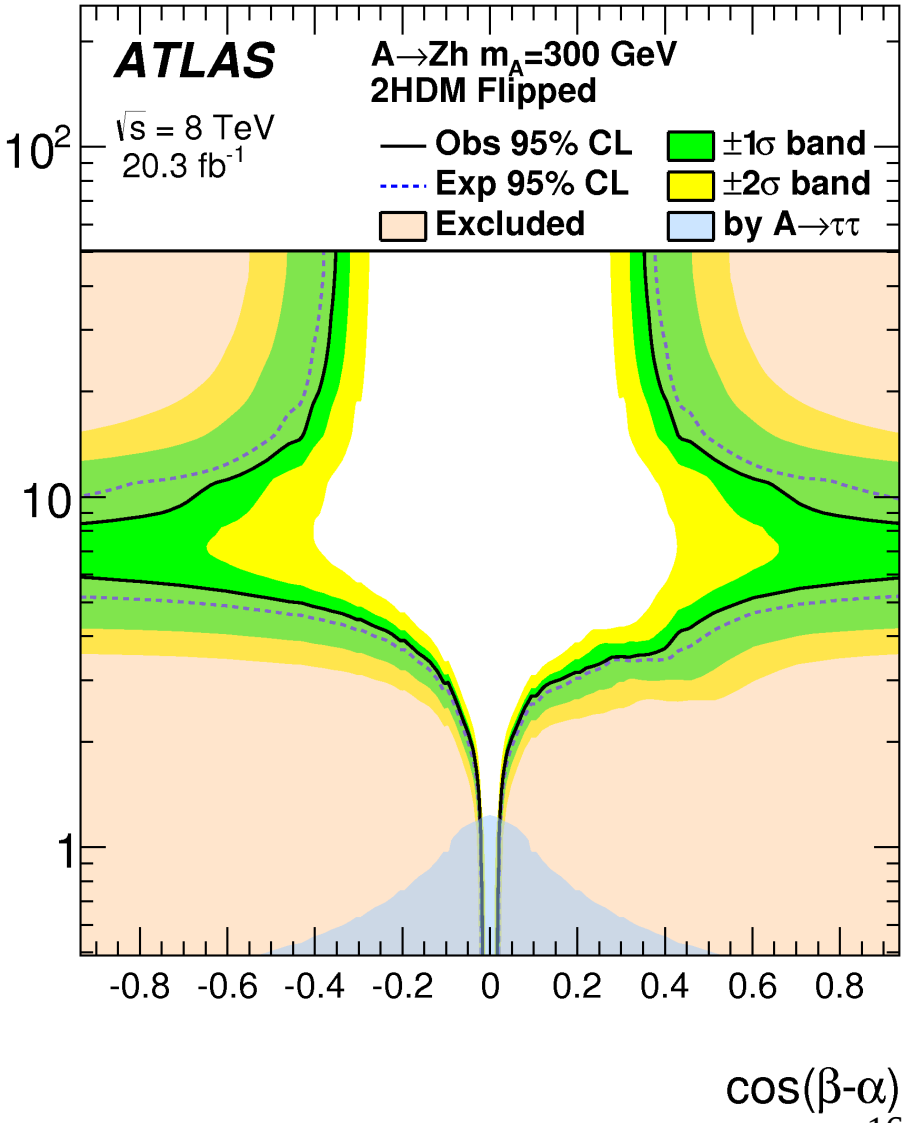


- ATLAS result on A->tautau is overlaid on top

2HDM A->Zh type III and IV

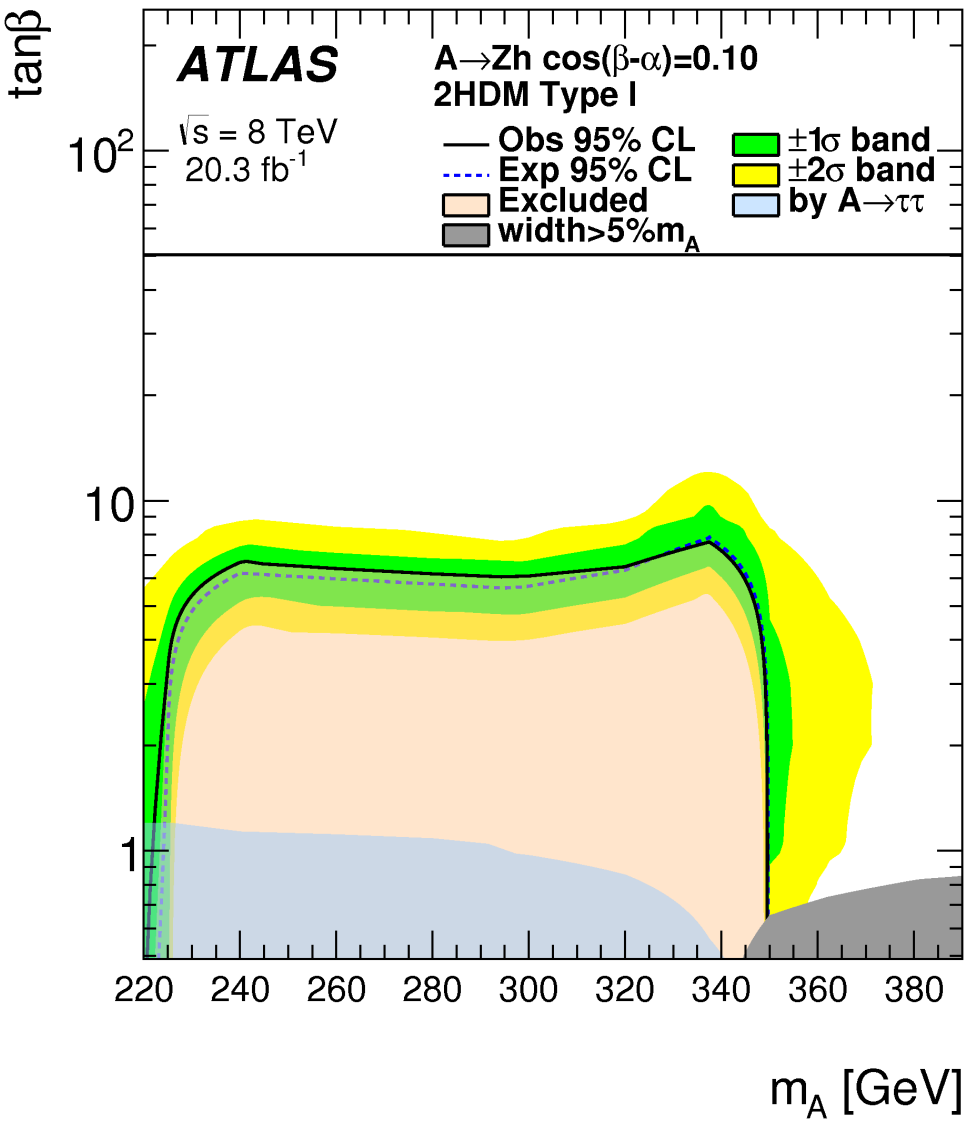
- In the plane of tanb vs cos(b-a)

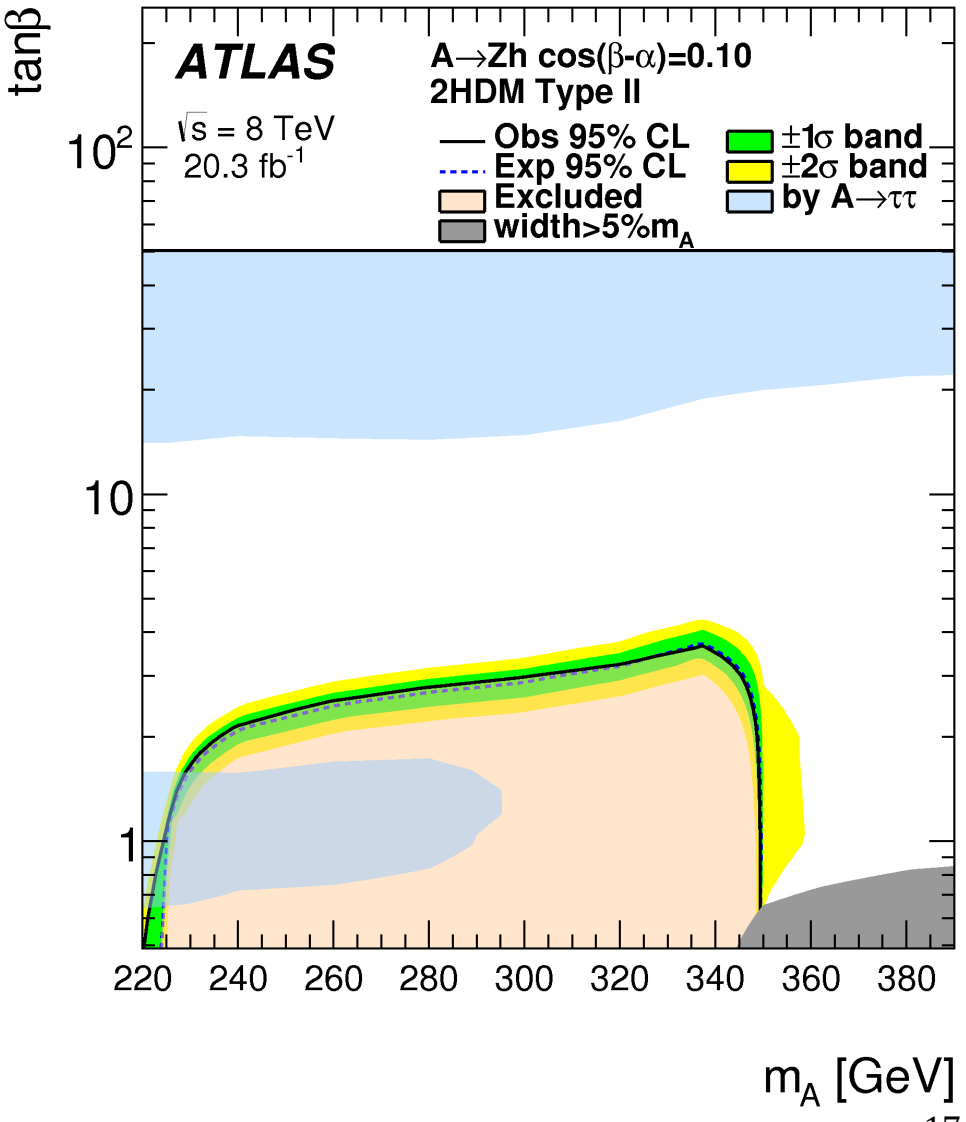




2HDM A->Zh type I and II

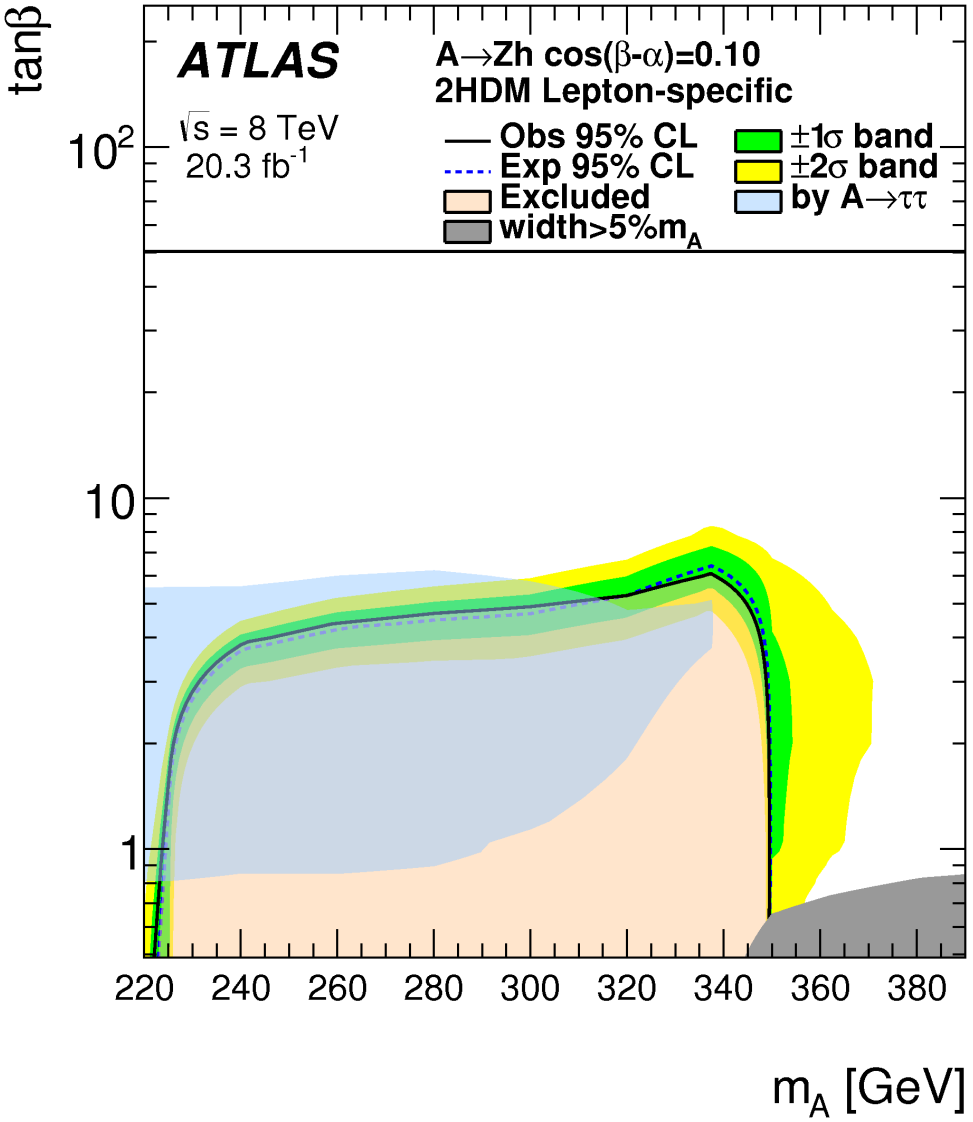
- In the plane of tanb vs mA

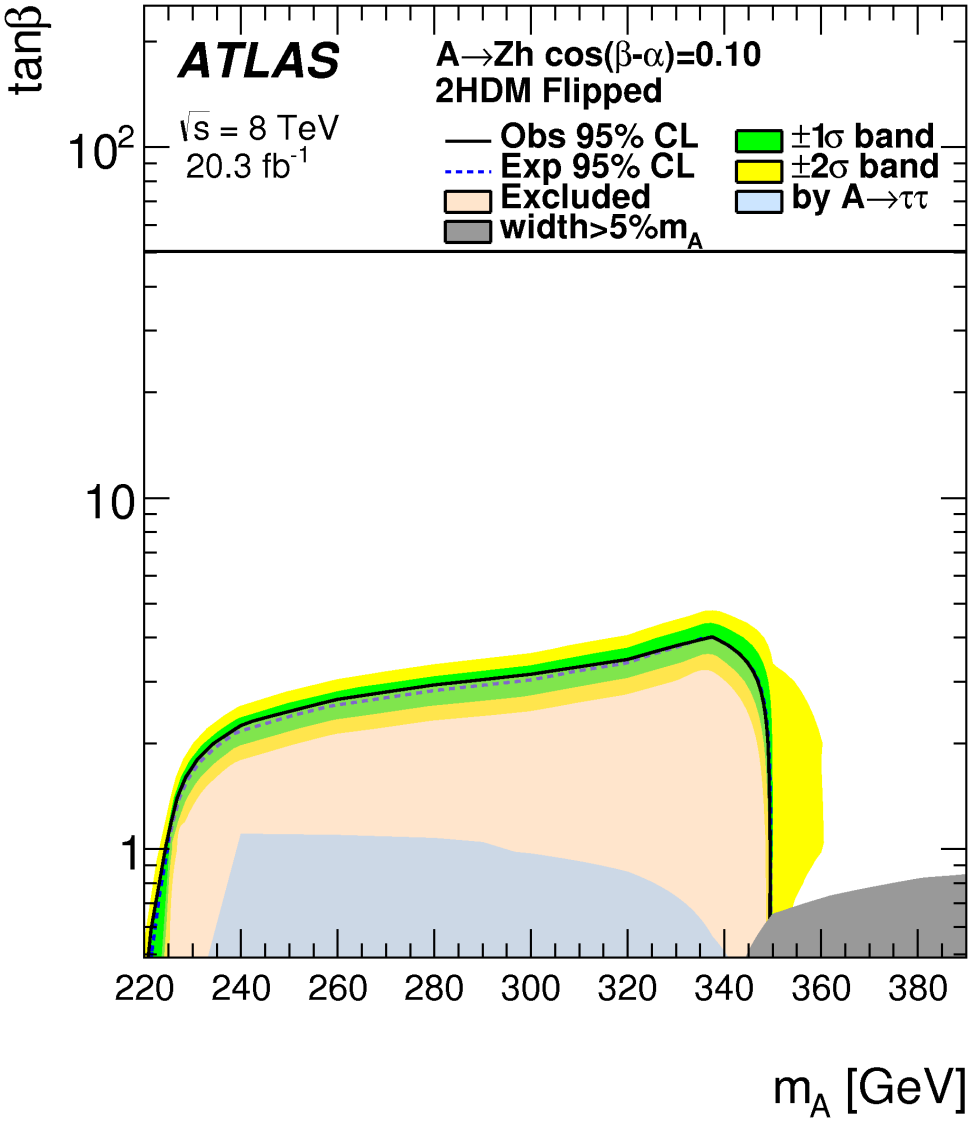




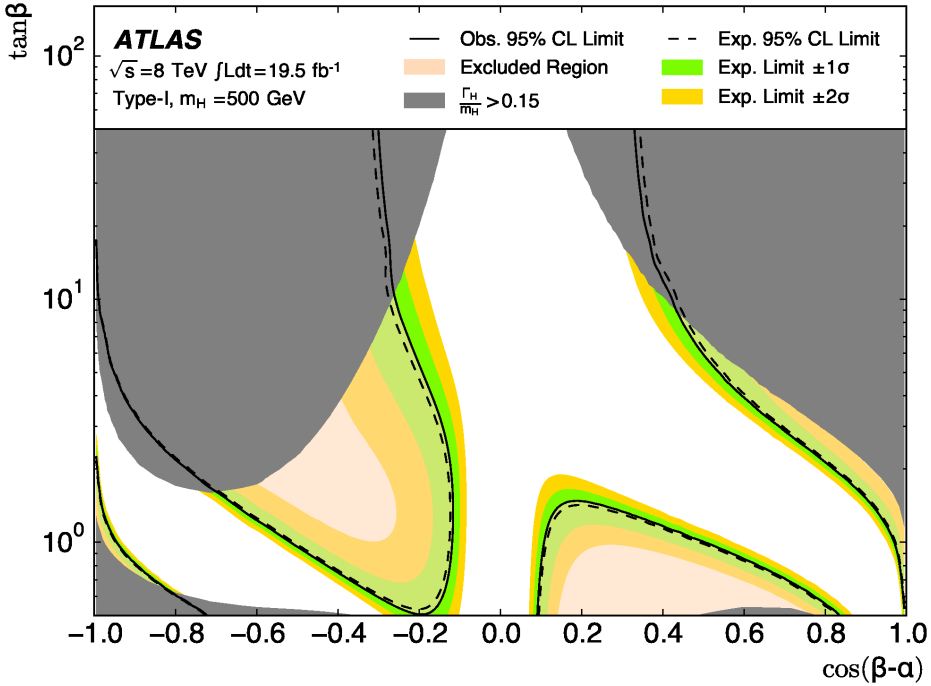
2HDM A->Zh type III and IV

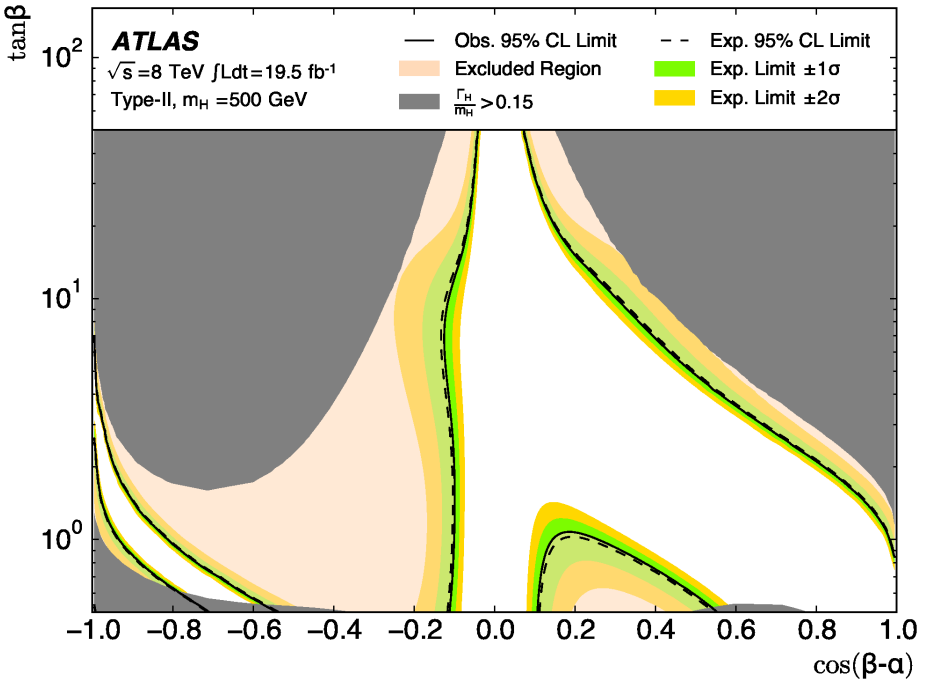
- In the plane of tanb vs mA

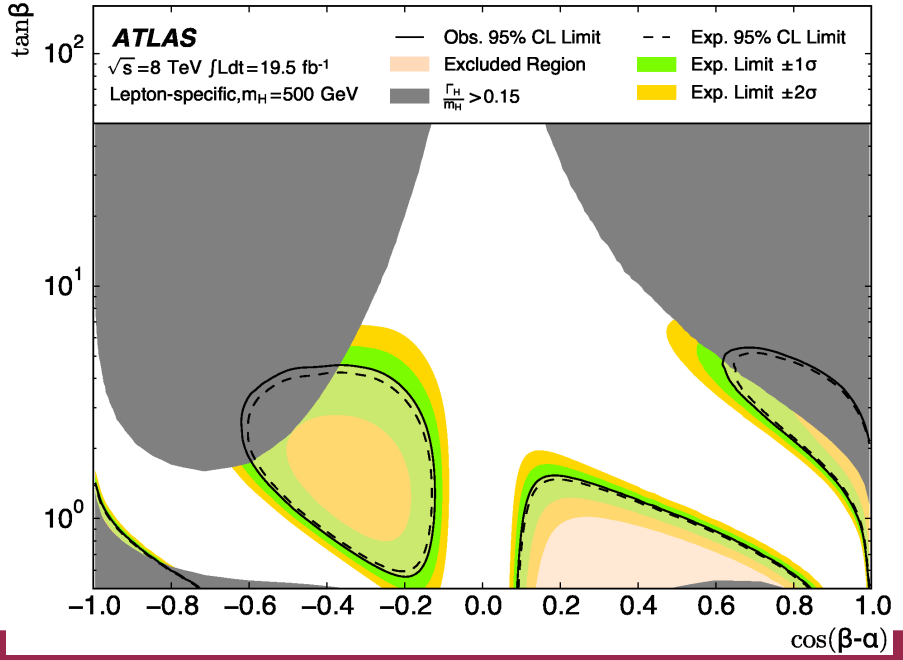


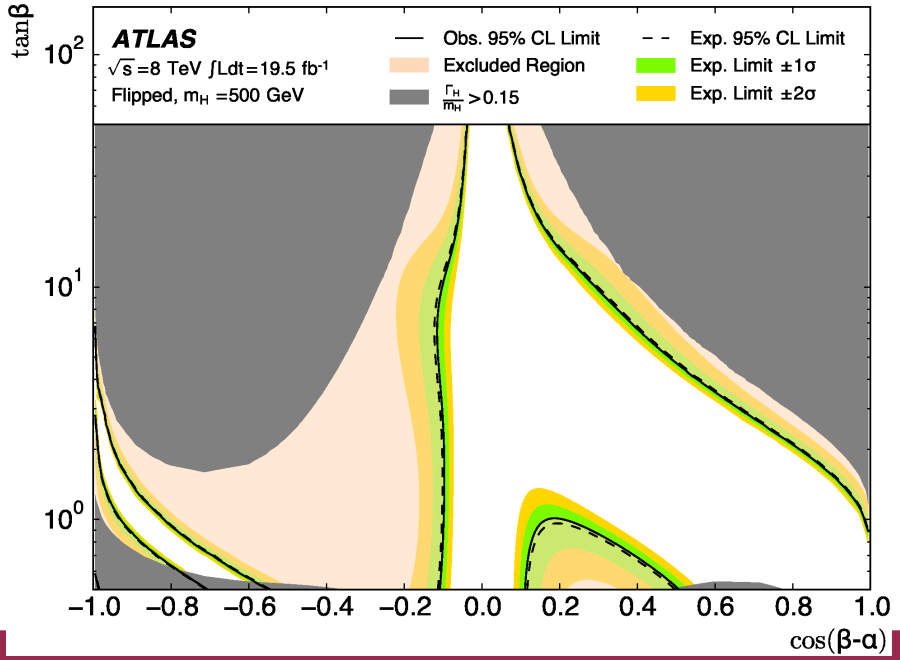


2HDM interpretation - tanb vs cos(b-a)

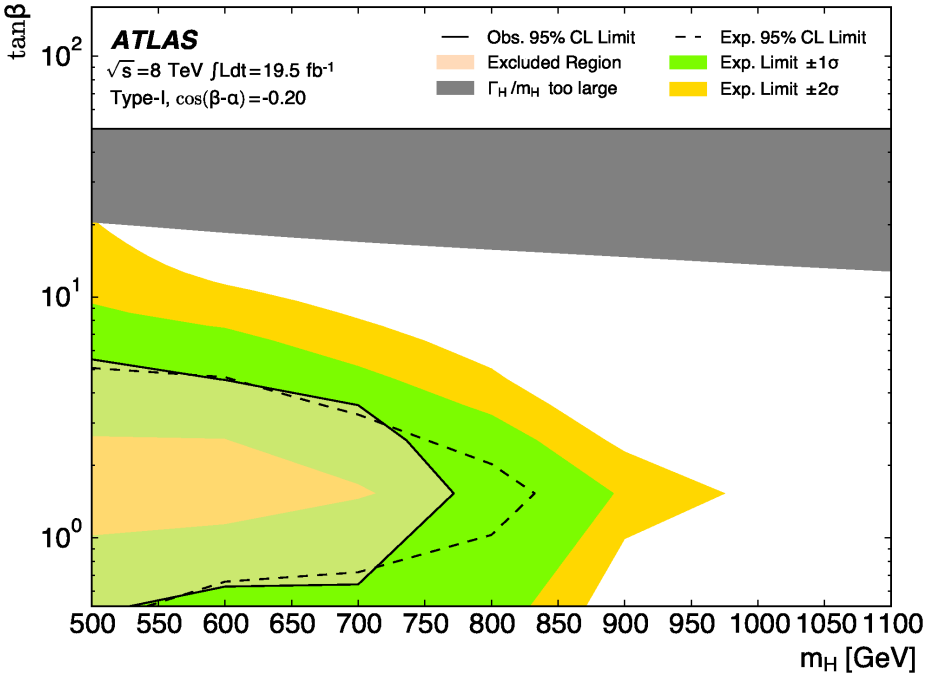


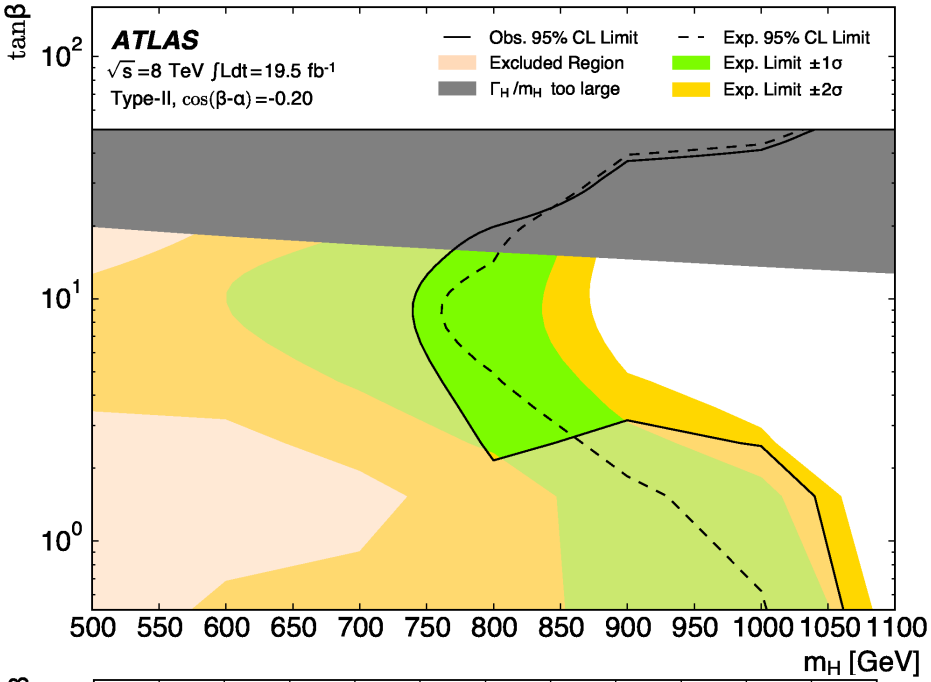


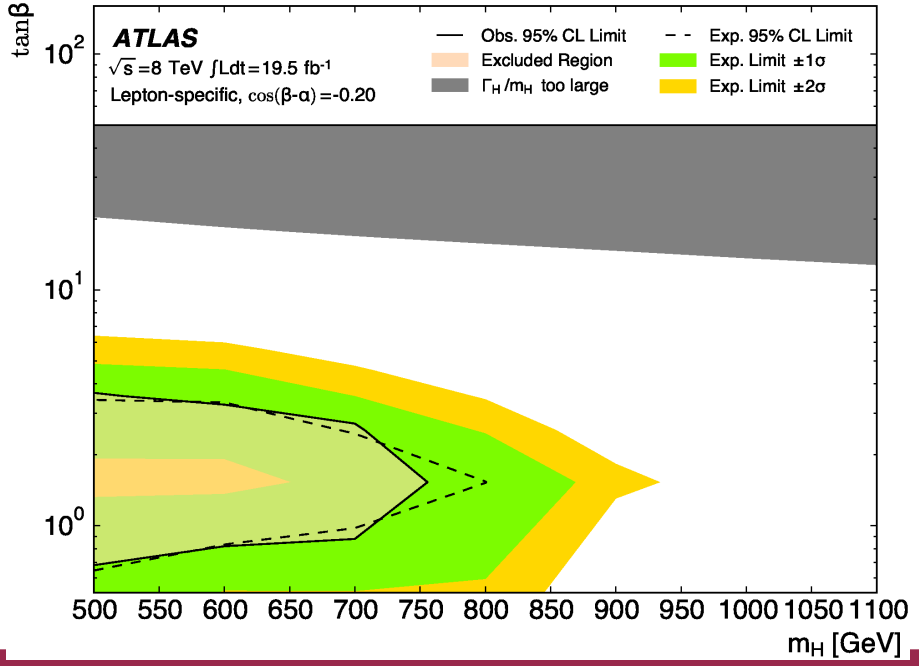


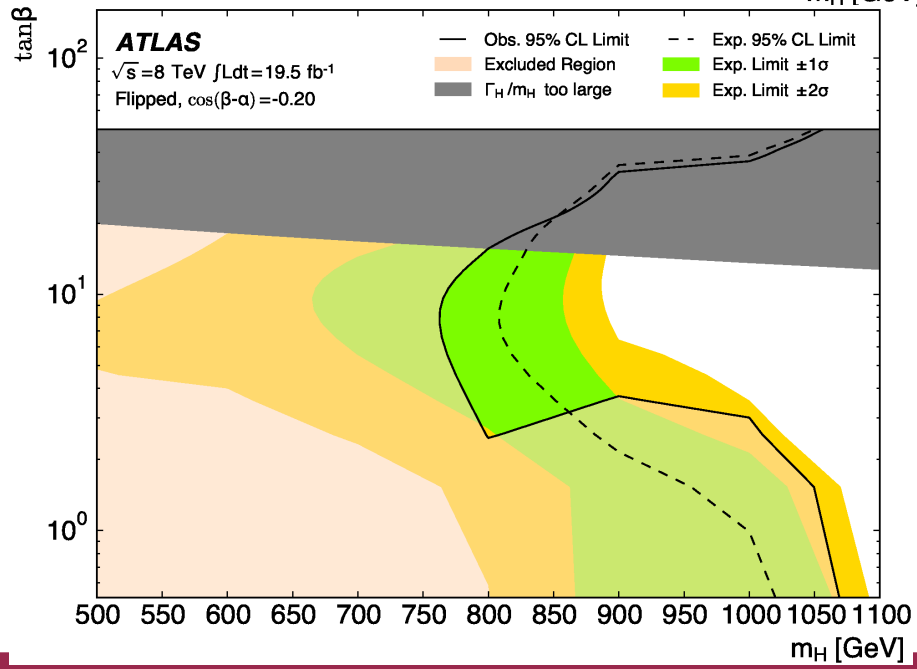


2HDM interpretation - tanb vs mH









ATLAS SM Higgs couplings

- EW singlet parametrization

$$\kappa^2 + \kappa'^2 = 1$$

$$\sigma_h = \kappa^2 \times \sigma_{h,\mathrm{SM}} \qquad \sigma_H = \kappa'^2 \times \sigma_{H,\mathrm{SM}}$$

$$\Gamma_h = \kappa^2 \times \Gamma_{h,\mathrm{SM}} \qquad \Gamma_H = \frac{\kappa'^2}{1 - \mathrm{BR}_{H,\mathrm{new}}} \times \Gamma_{H,\mathrm{SM}}$$

$$\mathrm{BR}_{h,i} = \mathrm{BR}_{h,\mathrm{SM},i}, \qquad \mathrm{BR}_{H,i} = (1 - \mathrm{BR}_{H,\mathrm{new}}) \times \mathrm{BR}_{H,\mathrm{SM},i}$$

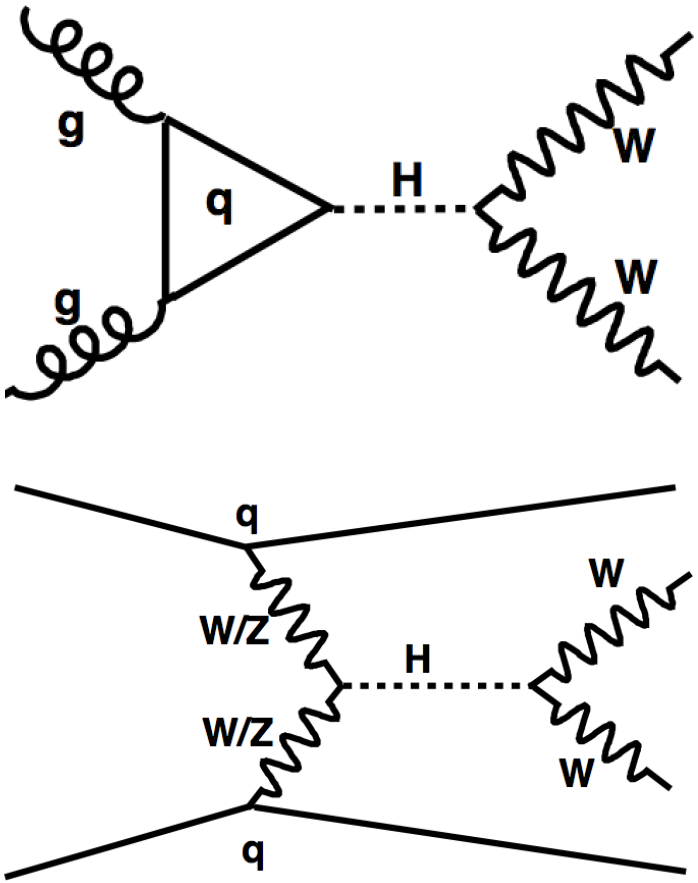
$$\mu_h = \frac{\sigma_h \times \mathrm{BR}_h}{(\sigma_h \times \mathrm{BR}_h)_{\mathrm{SM}}} = \kappa^2$$

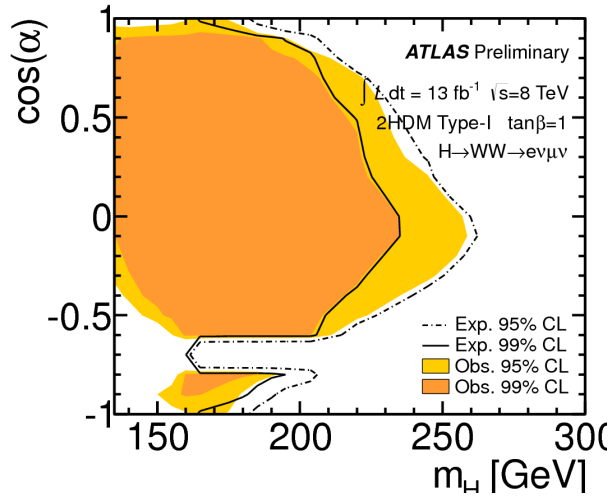
$$\mu_H = \frac{\sigma_H \times \mathrm{BR}_H}{(\sigma_H \times \mathrm{BR}_H)_{\mathrm{SM}}} = \kappa'^2 (1 - \mathrm{BR}_{H,\mathrm{new}})$$

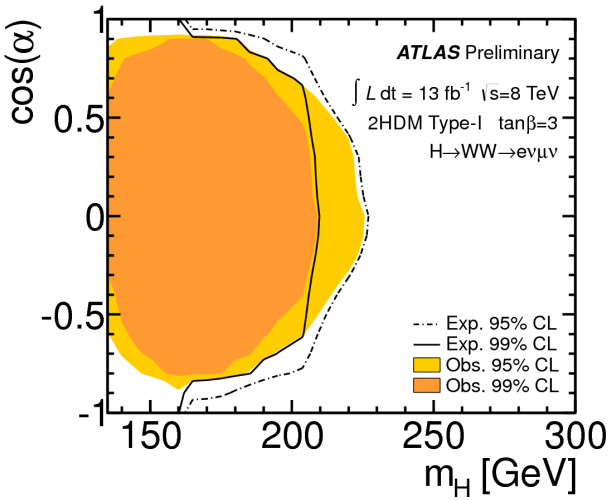
ATLAS HWW(eνμν)

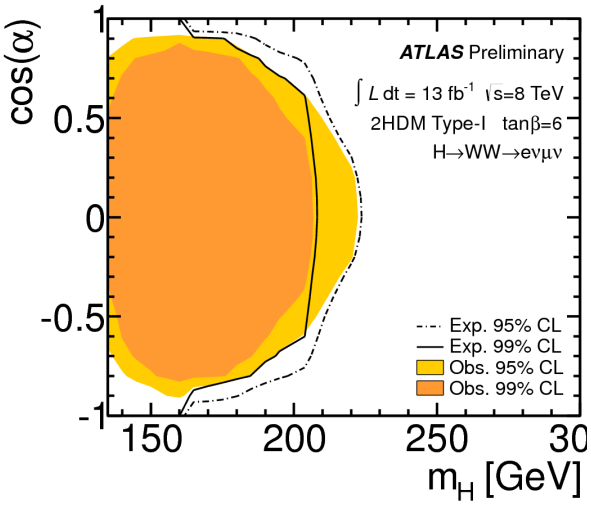
ATLAS-CONF-2013-027
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/ATLAS-CONF-2013-027/

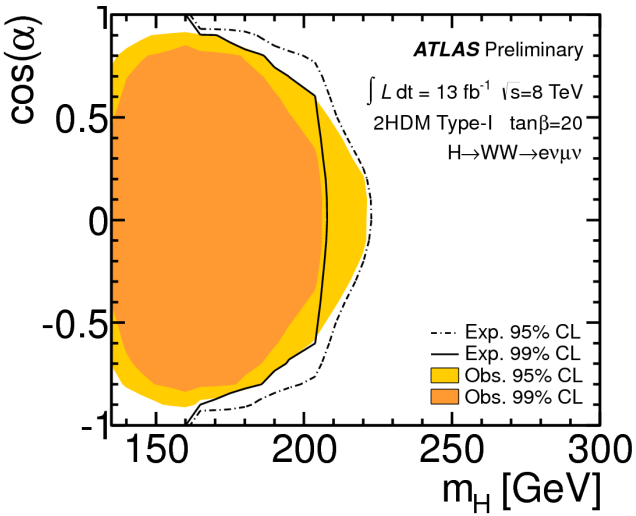
- Search for $H \to WW^{(*)} \to e^- \bar{\nu}_e \mu^+ \nu_\mu \,/\, e^+ \nu_e \mu^- \bar{\nu}_\mu$





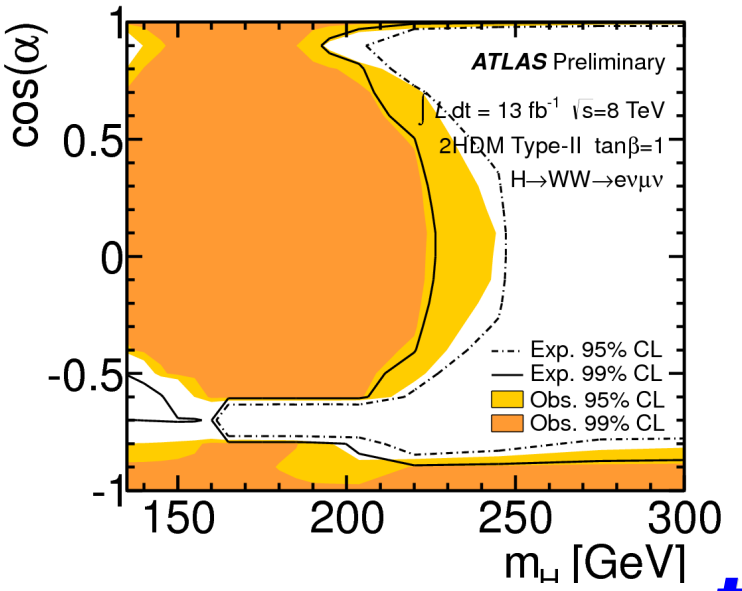


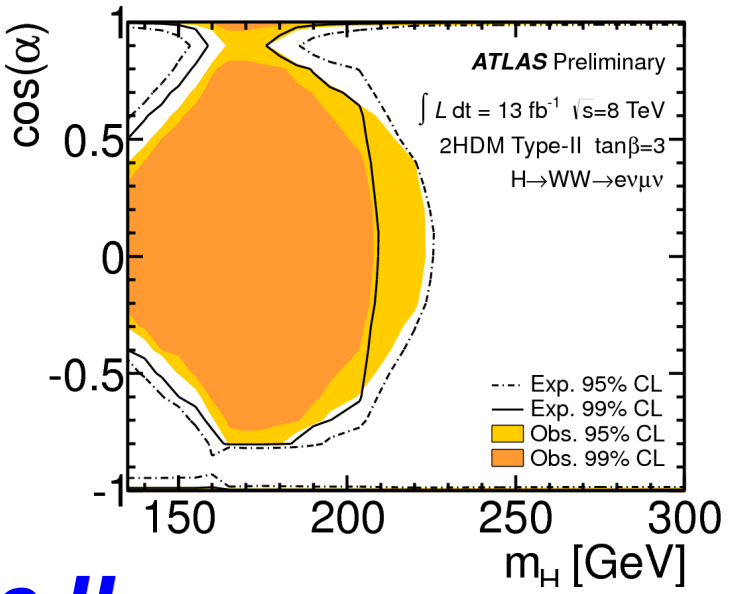




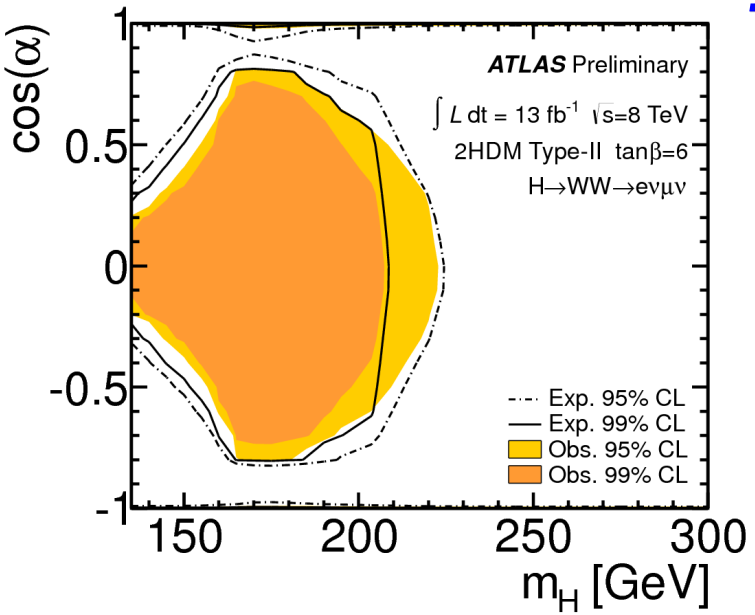
type I

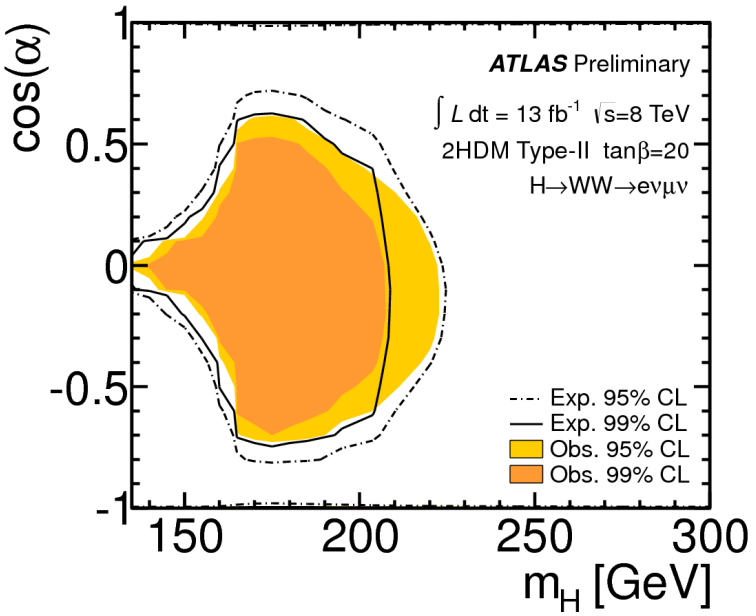
2HDM type II





type II

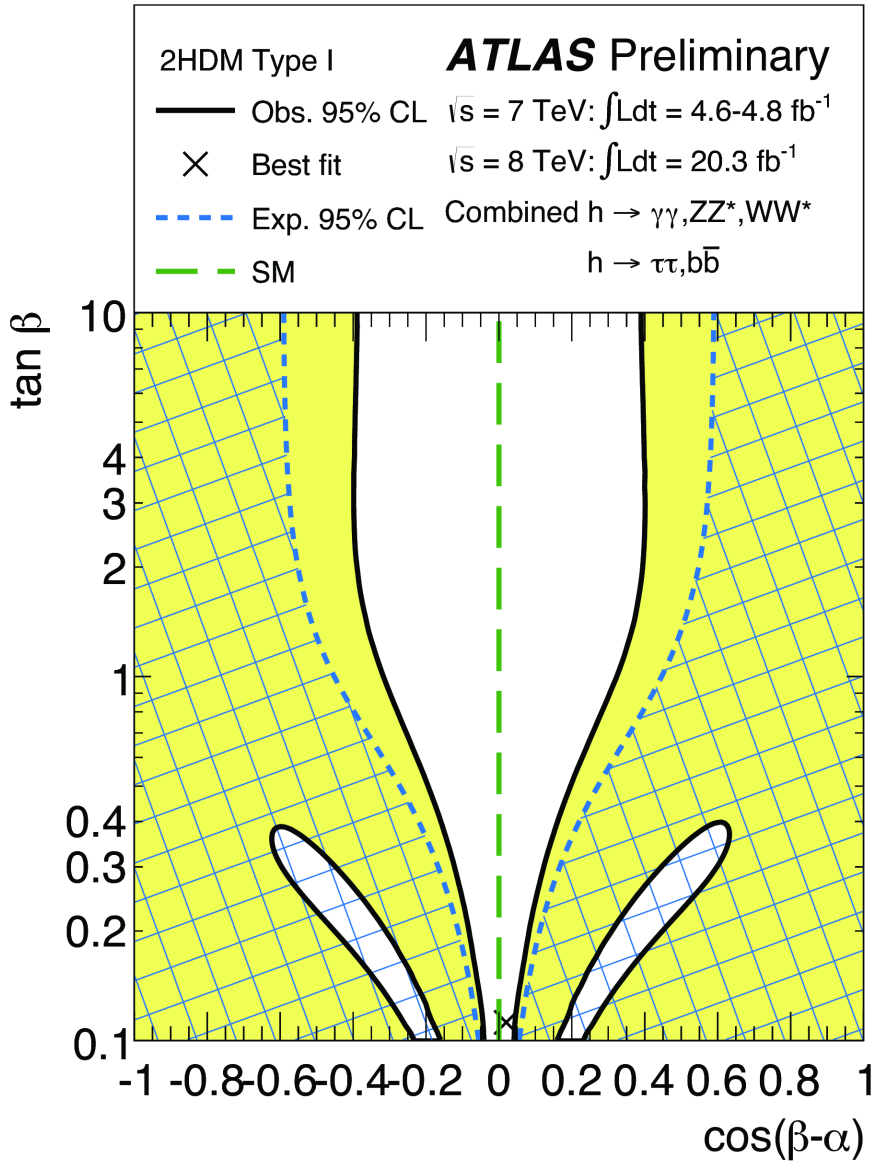


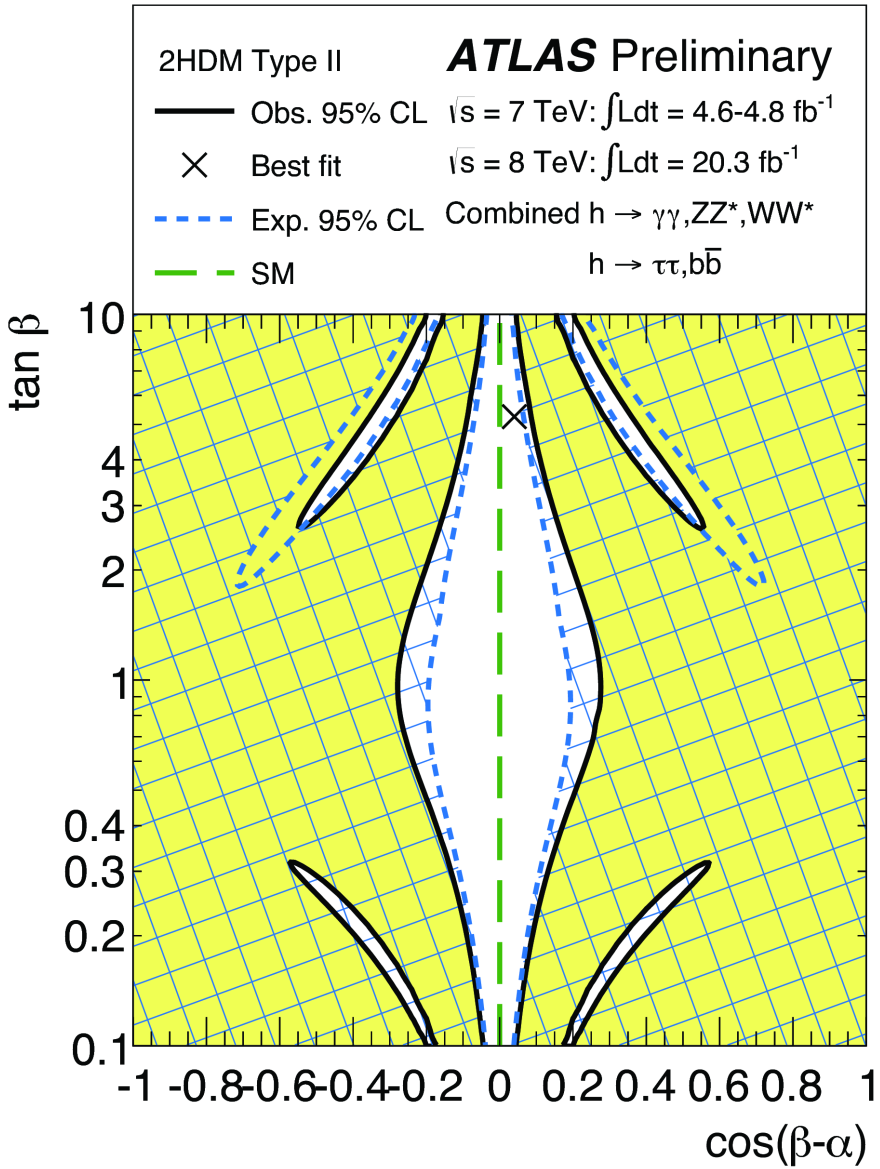


ATLAS SM H

ATLAS-CONF-2014-010
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/ATLAS-CONF-2014-010/

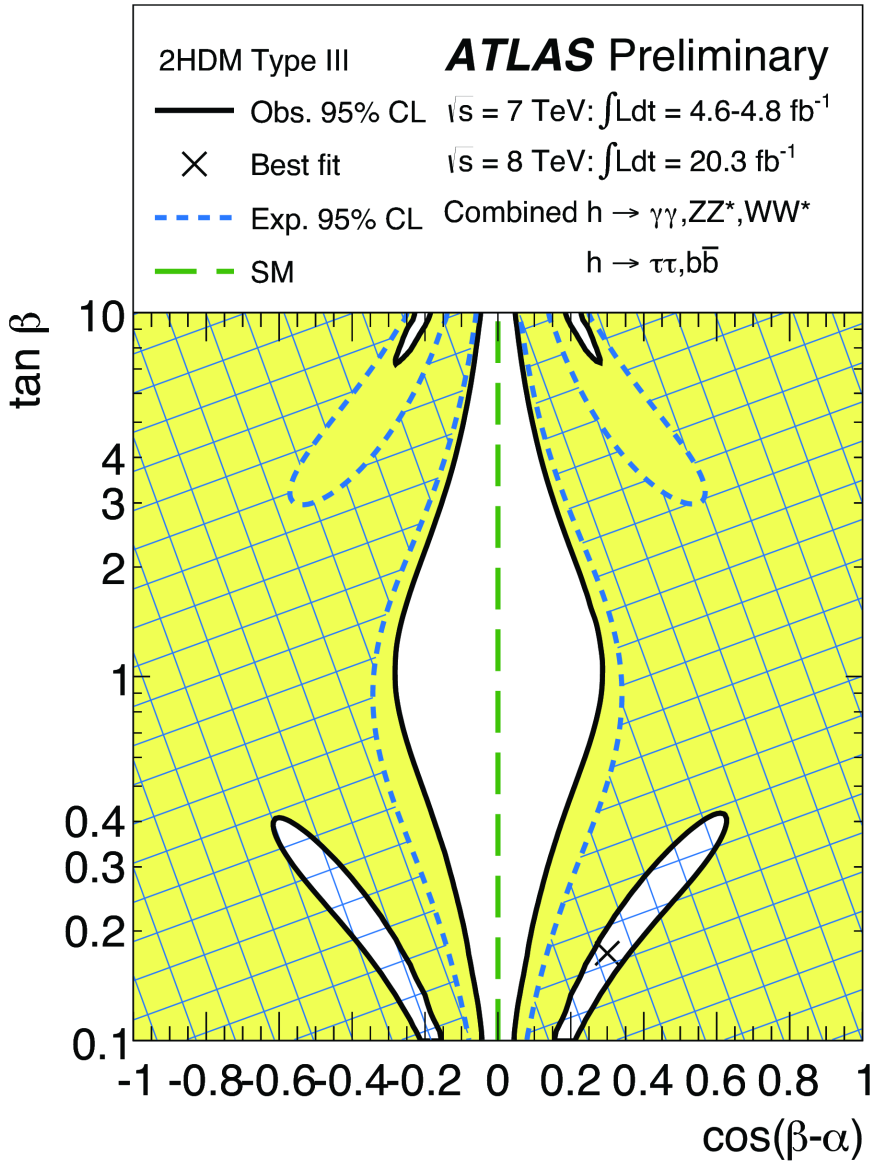
- With the constraints from SM Higgs Coupling Measurements

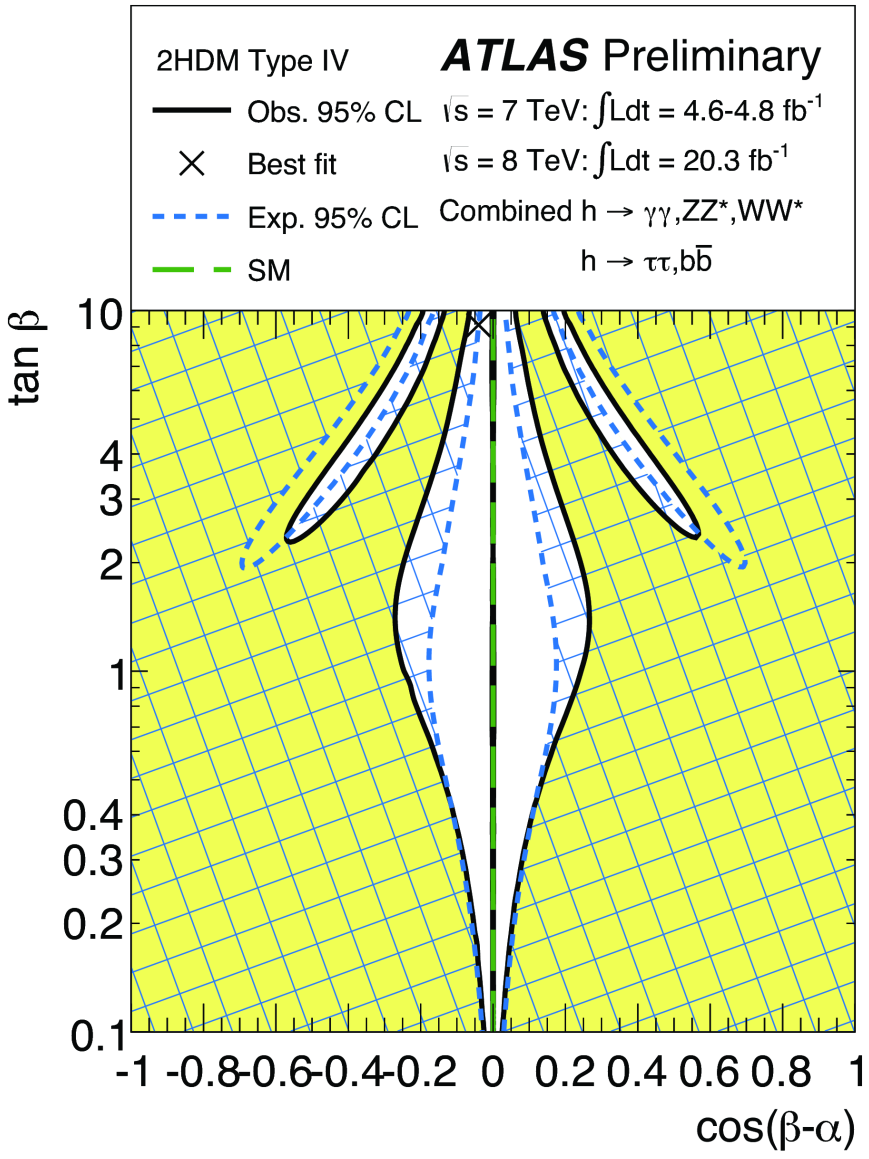




ATLAS SM H constraints

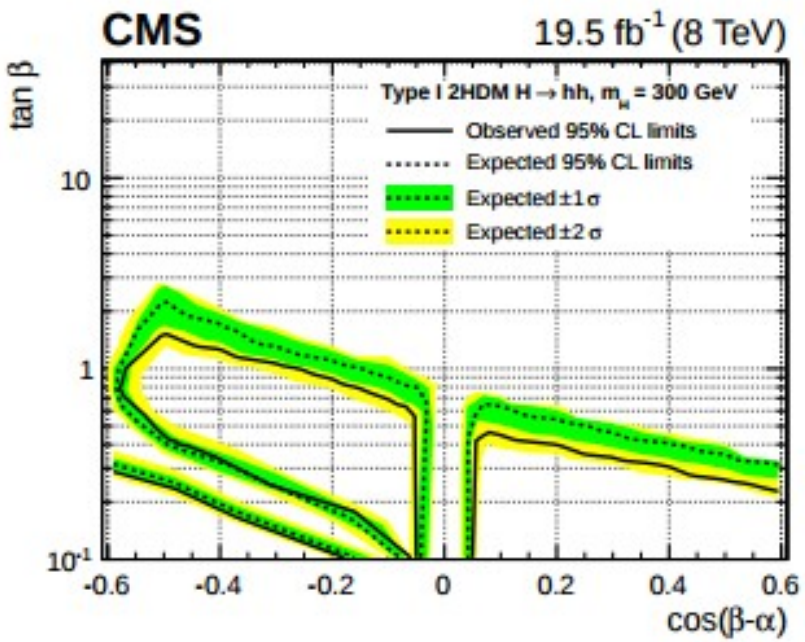
- With the constraints from SM Higgs Coupling Measurements

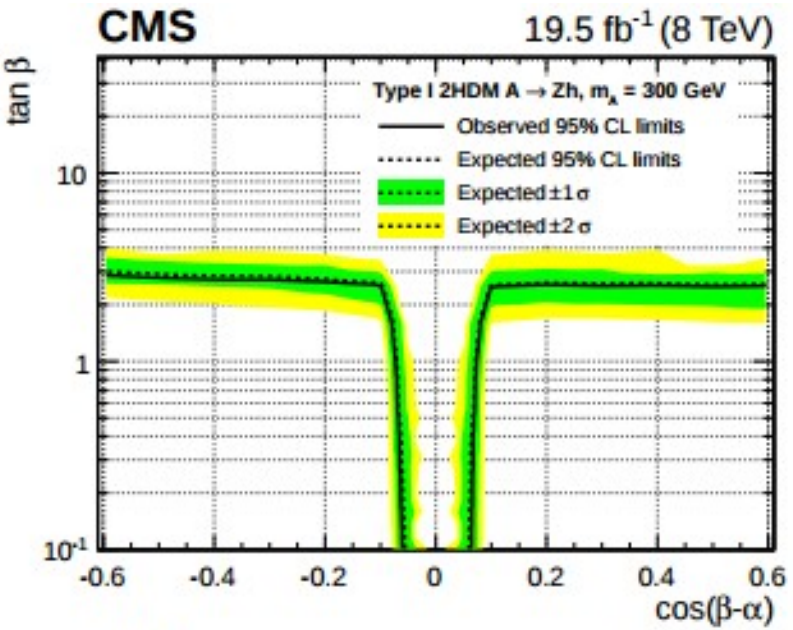


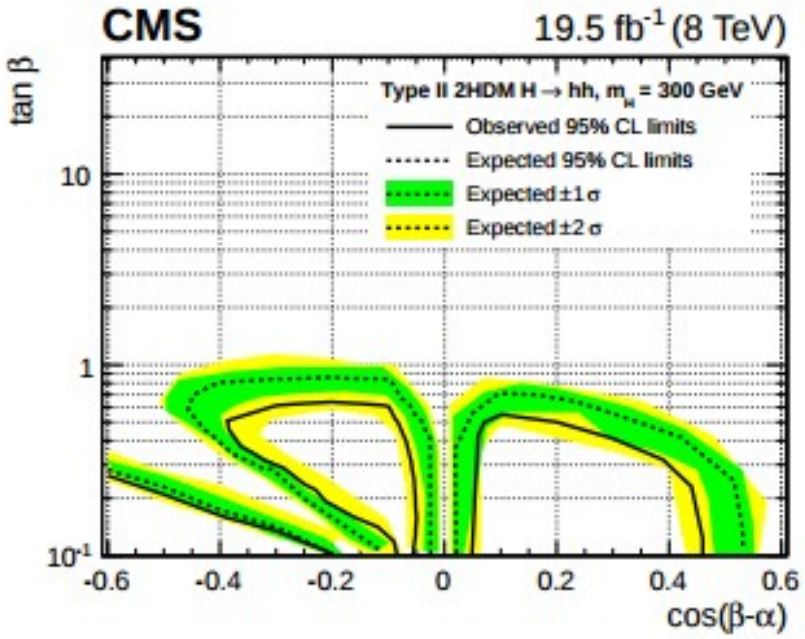


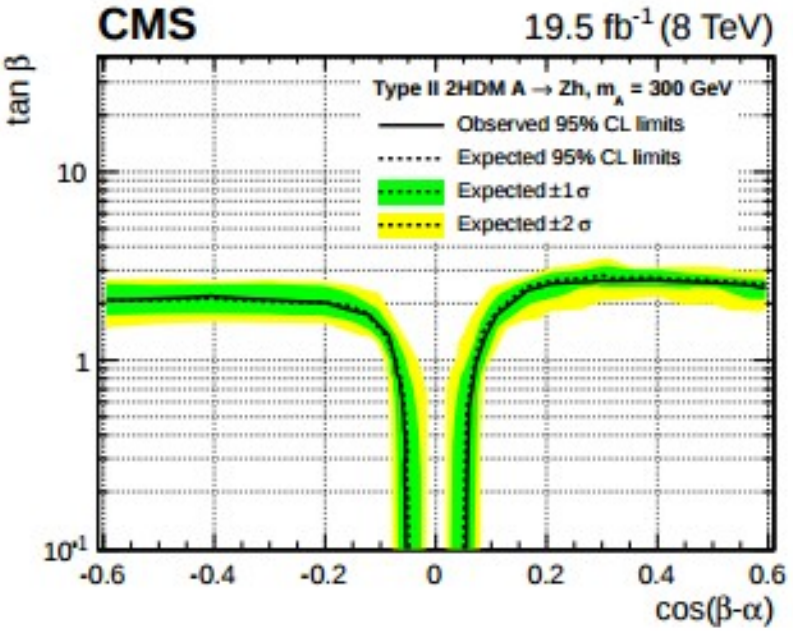
CMS H/A→multilepton/diphoton

A

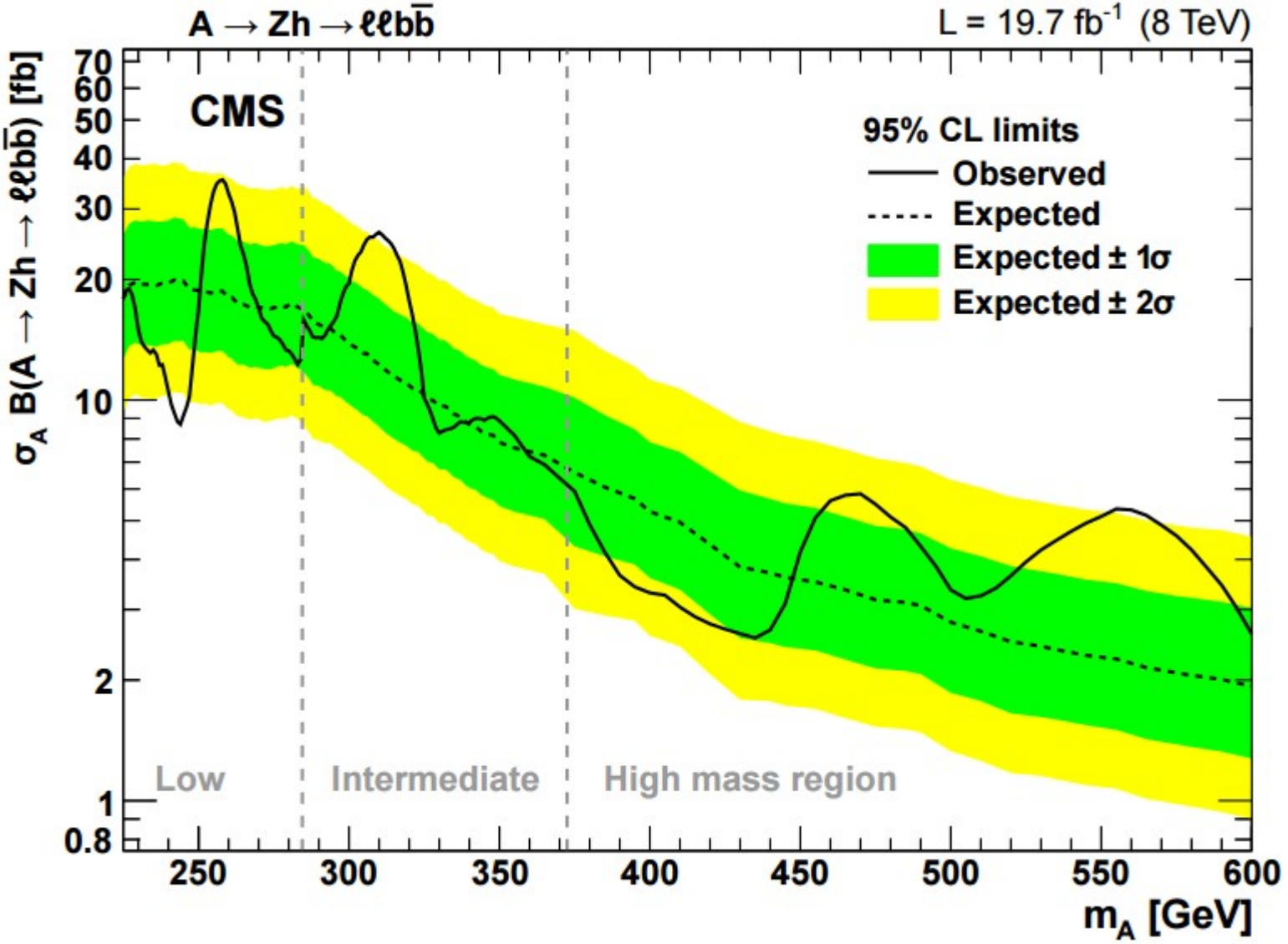








CMS A→Zh


A → Zh → ℓℓbb̄
L = 19.7 fb-1 (8 TeV)
CMS
95% CL limits
Observed
Expected
Expected ± 1σ
Expected ± 2σ
σA B(A → Zh → ℓℓbb̄) [fb]
70
60
50
40
30
20
10
2
1
0.8
Low
Intermediate
High mass region
250
300
350
400
450
500
550
600
mA [GeV]

CMS H/A→Z A/H (llττ, shape-based)