2HDM $h^{\mathrm{SM}} \to Za_1$ benchmarks

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2HDM scan for $h^{\mathrm{SM}} \to ZA$ decays

We have investigate type I and type II 2HDM looking for exotic decay patterns of the SM-like Higgs boson such as

- $h^{\mathrm{SM}} \to ZA \to Z\mu^+\mu^-$
- $h^{\mathrm{SM}} \to ZA \to Z\tau^+\tau^-$
- $h^{\mathrm{SM}} \to ZA \to Zb\bar{b}$

This decay channels are novelty within ATLAS and CMS

Recent studies have focused upon decays of heavy $H/A \to Xh^{\mathrm{SM}}$
arXiv:1502.04478, arXiv:1504.04710, CMS-PAS-HIG-15-001

Exotic Higgs decays not excluded a priori

2HDM scan for $h^{\mathrm{SM}} \to ZA$ decays

We have scan the 2HDM in the physical basis

- $m_h = 122{,}128$ GeV $\quad m_{H,H^\pm} = 150{,}900$ GeV $\quad m_A = 1{,}100$ GeV
- $\tan\beta = 1.5{,}50 \quad m_{12}^2 =$ -4000,4000 GeV^2 $\sin(\beta - \alpha) = -1, 1$
- $\lambda_{6,7} = 0$

Tools used for the scan

- 2HDMC
- HiggsBounds+HiggsSignals
- SuperISO

2HDM scan for $h^{\mathrm{SM}} \to ZA$ decays

2HDMC v.1.6.5

- Generation of spectrum and decay tables
- Vacuum stability, Unitarity and Perturbativity constraints

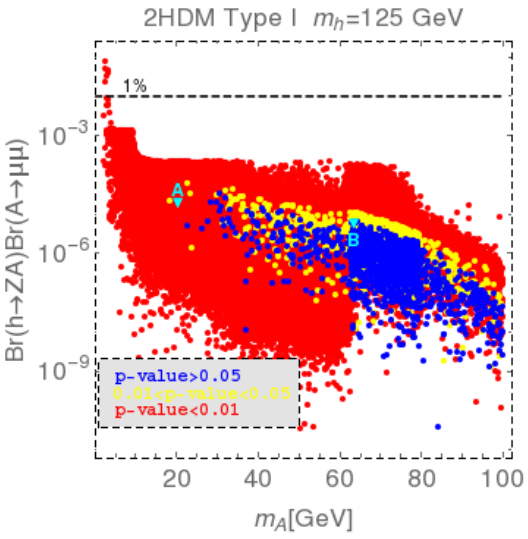
HiggsBounds v.4.1.3 + HiggsSignals v.1.6.5

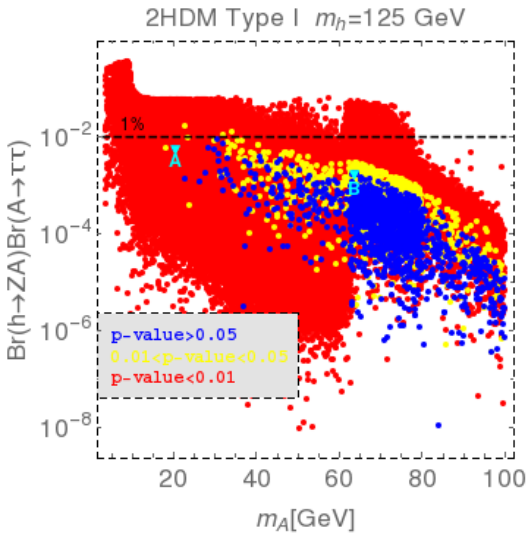
- Constraints from current measurements of the Higgs boson properties
- Constraints from non observation of further scalar in addition to h^{125}

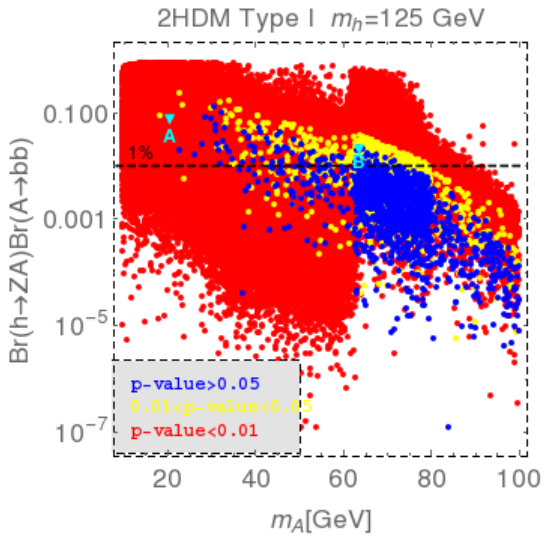
SuperISO v.3.4

- Constraints arising from flavour measurements

2HDM type I benchmarks







Red, Yellow and blue correspond to a p-value < 0.01, $\in (0.01, 0.05)$ and > 0.05 as compute by HiggsSignal

We select two benchmarks at $m_A \sim 20$ GeV and $m_A \sim 65$ GeV maximising the Br product

We call this benchmarks A and B respectively

2HDM type I

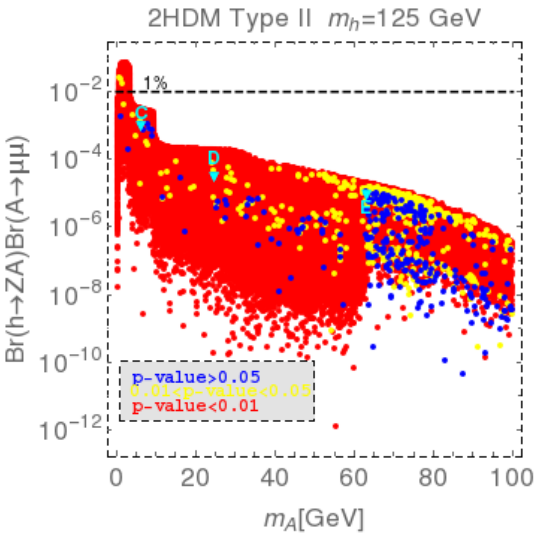
Benchmark A: $m_A \sim 20$ GeV

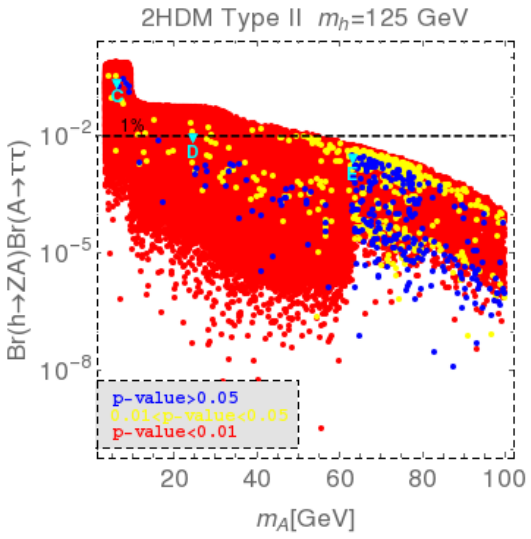
- $m_{H,H^\pm} \sim 165, 444$ GeV $\tan\beta \sim 1.86$ $m_{12}^2 \sim 3891$ GeV^2 $s_{\beta\alpha}$=-0.99
- $Br(h \to ZA)$ ~0.1 $Br(h \to \mu\mu) \sim 2{\cdot}10^{-4}$ $Br(A \to \tau\tau) \sim 6{\cdot}10^{-2}$
  $Br(A \to b\bar{b})$ ~0.85
- r_{hgg} =0.93

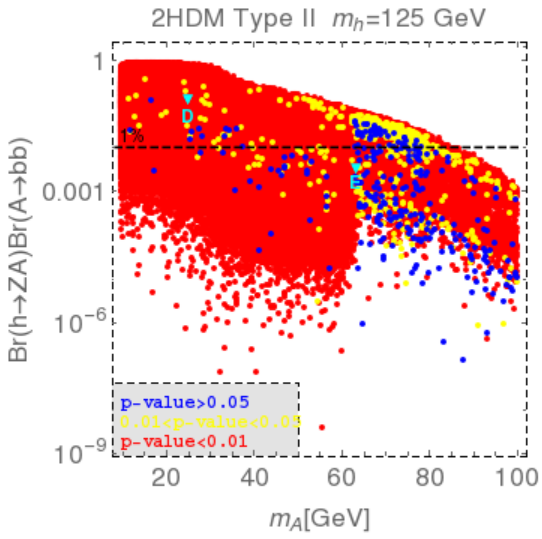
Benchmark B: $m_A \sim 63$ GeV

- $m_{H,H^\pm} \sim 154, 257$ GeV $\tan\beta \sim 6.20$ $m_{12}^2 \sim 2793$ GeV^2 $s_{\beta\alpha}$=-0.85
- $Br(h \to ZA)$ ~0.03 $Br(h \to \mu\mu) \sim 2{\cdot}10^{-4}$ $Br(A \to \tau\tau) \sim 7{\cdot}10^{-2}$
  $Br(A \to b\bar{b})$ ~0.79
- r_{hgg} =0.77

2HDM type II







Red, Yellow and blue correspond to a p-value < 0.01, $\in (0.01, 0.05)$ and > 0.05 as compute by HiggsSignal

We select three benchmarks at $m_A \sim 6$, $m_A \sim 25$ GeV and $m_A \sim 65$ GeV maximising the Br product

We call this benchmarks C, D and E respectively

2HDM type II

Benchmark C: $m_A \sim 6$ GeV

- $m_{H,H^\pm} \sim 263, 308$ GeV $\tan\beta \sim 1.89$ $m_{12}^2 \sim 2737$ GeV^2 $s_{\beta\alpha}$=0.99
- $Br(h \to ZA) \sim 0.3$ $Br(h \to \mu\mu) \sim 3{\cdot}10^{-3}$ $Br(A \to \tau\tau) \sim 0.78$
  $Br(A \to b\bar{b}) = 0$
- $r_{hgg} = 1.09$

Benchmark D: $m_A \sim 25$ GeV

- $m_{H,H^\pm} \sim 227, 226$ GeV $\tan\beta \sim 1.76$ $m_{12}^2 \sim 3406$ GeV^2 $s_{\beta\alpha}$=0.99
- $Br(h \to ZA) \sim 0.15$ $Br(h \to \mu\mu) \sim 2{\cdot}10^{-4}$ $Br(A \to \tau\tau) \sim 6{\cdot}10^{-2}$
  $Br(A \to b\bar{b}) \sim 0.91$
- $r_{hgg} = 0.10$

Benchmark E: $m_A \sim 63$ GeV

- $m_{H,H^\pm} \sim 210, 333$ GeV $\tan\beta \sim 2.38$ $m_{12}^2 \sim 4791$ GeV^2 $s_{\beta\alpha}$=0.7
- $Br(h \to ZA) \sim 0.04$ $Br(h \to \mu\mu) \sim 3{\cdot}10^{-4}$ $Br(A \to \tau\tau) \sim 7{\cdot}10^{-2}$
  $Br(A \to b\bar{b}) \sim 0.79$
- $r_{hgg} = 0.91$

Comments

On-shell Z boson scenario

Scenario A, C and D have an on-shell Z boson arising from the $h \to ZA$ decay $\to$ possibility to trigger onto the dimuon system

Scenario C has a very light pseudoscalar boson $\to$ heavily boosted decay products. Both ATLAS and CMS have analysis that tackle boosted μ and τ production from light boson decays
arXiv:1505.01609, CMS-PAS-HIG-13-010

Scenario A and D produces slightly boosted objects and for $A \to b\bar{b}$ decay standard reconstruction of b-jet might be inefficient. Possibility of using jet-substructure technique

Comments

Off-shell Z boson scenario

Scenario B and E have an off-shell Z boson arising from the $h \to ZA$ decay $\to$

No possibility to reconstruct clearly the Z peak

Still possible to trigger on one (or even both) muons from the Z decay

No boosted pseudoscalar boson, decay products well separated in the detector