



# Strongest signal for $pp \rightarrow A \rightarrow ZH$ in the 2HDM

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September 23, 2019

Working in the Two Higgs Doublet Model, what might be found? For the process;

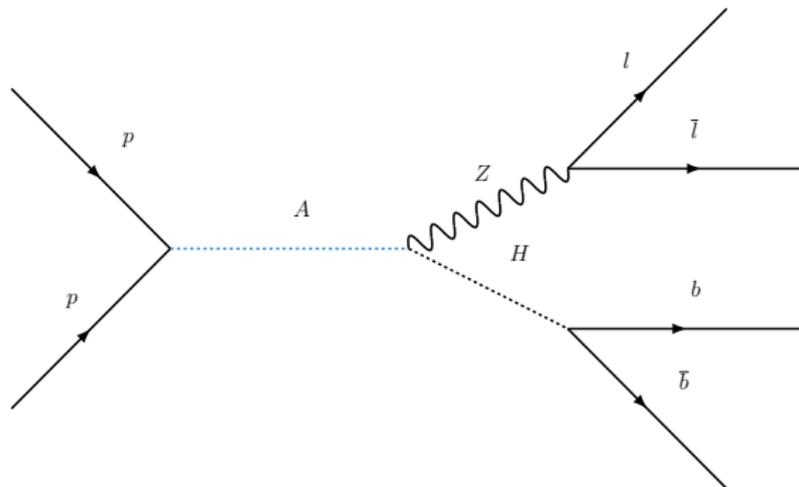


Figure:  $A$  is the CP odd Higgs,  $H$  is the neutral heavy Higgs.

Would it be visible above background? Has it been excluded by current observations?

# Model parameters

This could exist with a range of input parameters, we work in the physical bases;

- ▶  $m_h$  - mass of the neutral light Higgs (normally the SM Higgs)
- ▶  $m_H$  - mass of the neutral heavy Higgs
- ▶  $m_A$  - mass of the CP odd Higgs
- ▶  $m_{H^\pm}$  - mass of the charged Higgs (we chose this to be  $= m_A$ )
- ▶  $\tan(\beta)$  - the ratio of the vacuum expectation values, diagonalizes the squared-mass matrices of CP-odd and charged scalar.
- ▶  $\sin(\beta - \alpha)$  -  $\alpha$  diagonalises the neutral CP-even Higgs mass-squared matrix.
- ▶  $\lambda_6$  and  $\lambda_7$  - the sixth and seventh quartic couplings (we chose these both to be  $= 0$ )
- ▶  $m_{12}^2$  (we chose this to be  $= m_A^2 \tan(\beta)/(1 + \tan^2(\beta))$ )

We are closely following the work in;

*"Search for a heavy Higgs boson decaying into a  $Z$  boson and another heavy Higgs boson in the  $\ell\ell b\bar{b}$  final state in  $pp$  collisions at  $\sqrt{s} = 13$  TeV with the ATLAS detector"*,

from the **Atlas collaboration**.

They share their data for observed limits and background levels on [hepdata.net](http://hepdata.net).

To obtain the strength of the expected signal for some chosen model parameters we multiply;

1. Cross section of the production process. At tree level we have  $b$  assisted production and gluon production for the CP odd Higgs  $A$ .
2. The branching ratio of the first decay;  $A \rightarrow ZH$ .
3. The branching ratio of the secondary decay  $H \rightarrow b\bar{b}$ .

No need to include  $Z \rightarrow \bar{l}l$  as it is not dependent on the model we are studying.

All these values come together from various programs; To start with we can use HiggsBounds and HiggsSignals to check theoretical limits and older observed limits respectively.



Figure: HiggsBounds and higgs signals are twinned programs

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1. To get the production cross section there is a program called SusHi.



Figure: SusHi is written in Fortran.

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3. sadly nobody made 2HDMC a logo...

# Signal strength

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And the whole lot sits on top of LHAPDF and FeynHiggs.



Figure: Feynhiggs is supporting software.

It doesn't really stop there....



Docker can get us out!

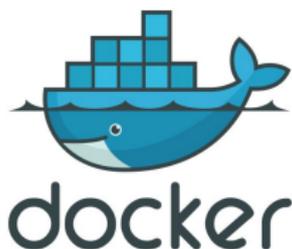


Figure: Docker is a container

```
https://hub.docker.com/r/henrydayhall/higgspheno  
docker pull henrydayhall/higgspheno
```

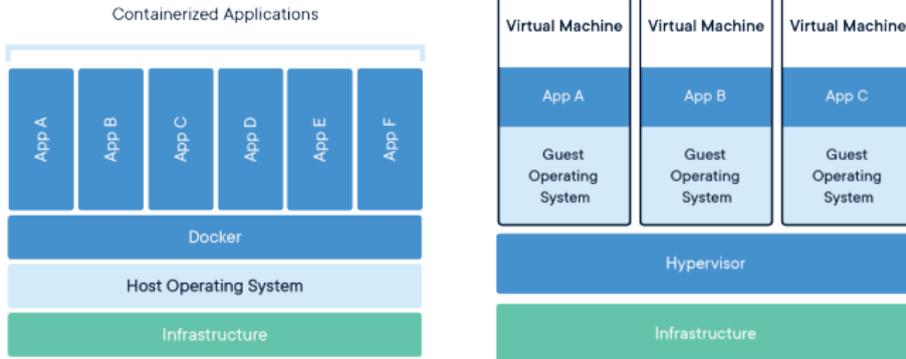


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<https://hub.docker.com/r/henrydayhall/higgspheno>

- ▶ Please tell me if you get an error, I will try to fix things.
- ▶ Please tell me if you have ideas from improvements.
- ▶ Please share if you make extensions/improvements.

**<https://hub.docker.com/r/henrydayhall/higgspheno>**



Figure: Singularity is a container architecture that doesn't require super user privileges.

The Singularity can be built straight from the Docker.

```
sudo singularity build my_higgspheno.simg docker://henrydayhall/higgspheno
```

# Does it work?

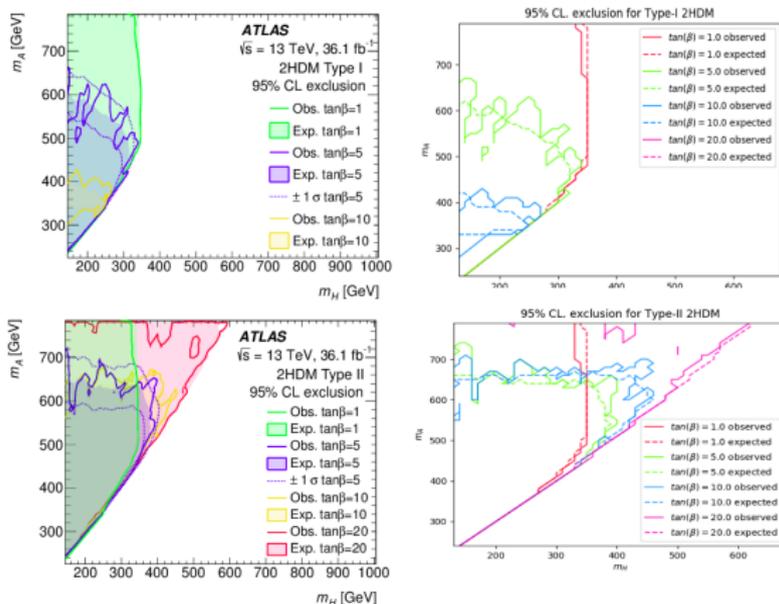


Figure: Results produced in the container agree well with the paper we are following

Craft a bridge to madgraph 2HDM model.

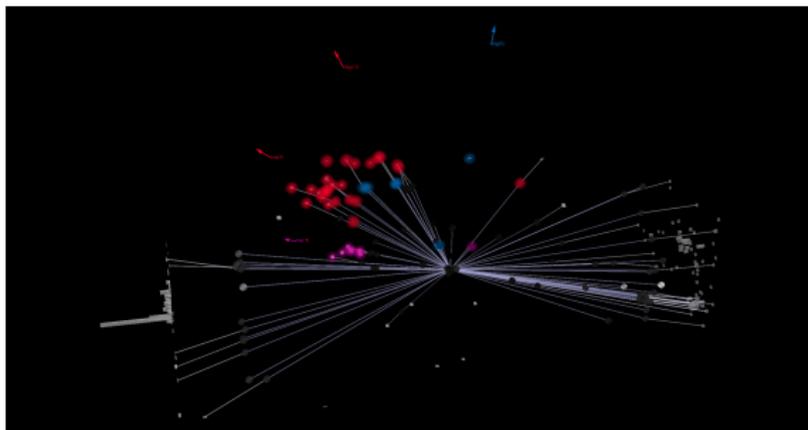


Figure: A visualised simulation of a Heavy Higgs decay in madgraph.

Thank you!

**Thank you for listening.**