

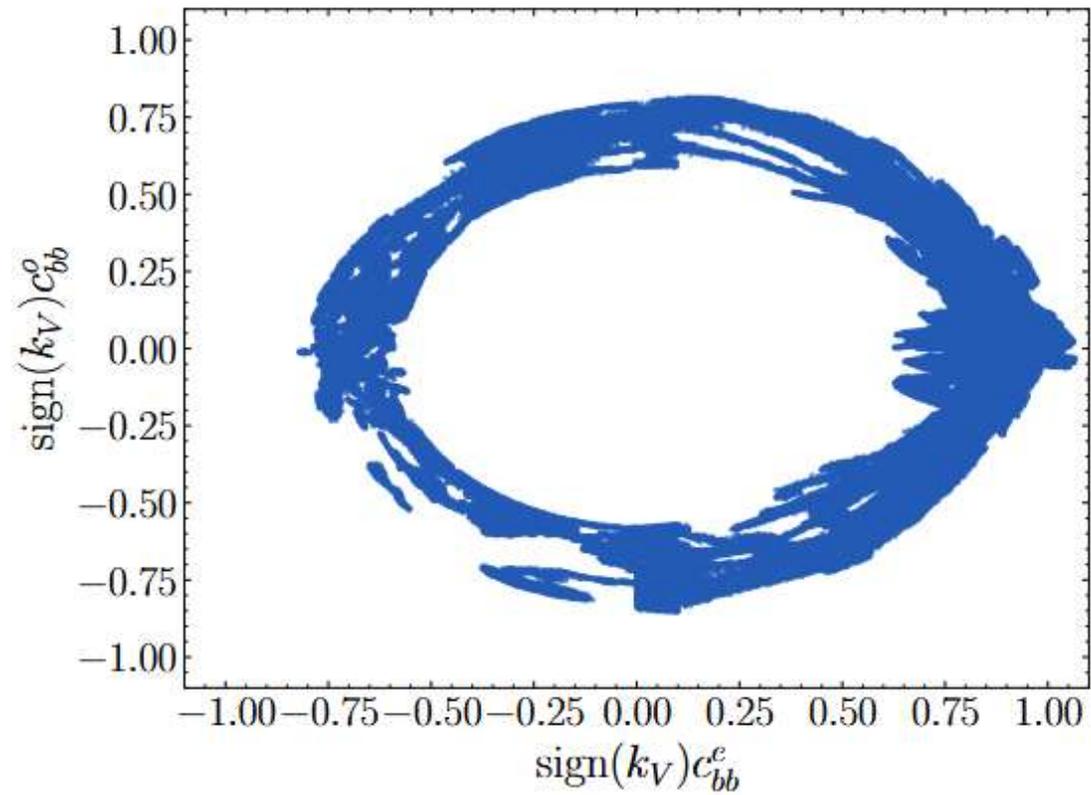
The background of the slide is a dark grey color with a repeating pattern of small, light-colored Feynman diagrams. These diagrams are scattered across the entire surface, creating a textured, scientific aesthetic. The diagrams include various types of vertices and lines, such as fermion lines with arrows, scalar lines, and interaction points.

Machine Learning Techniques to explore scalar-fermion couplings

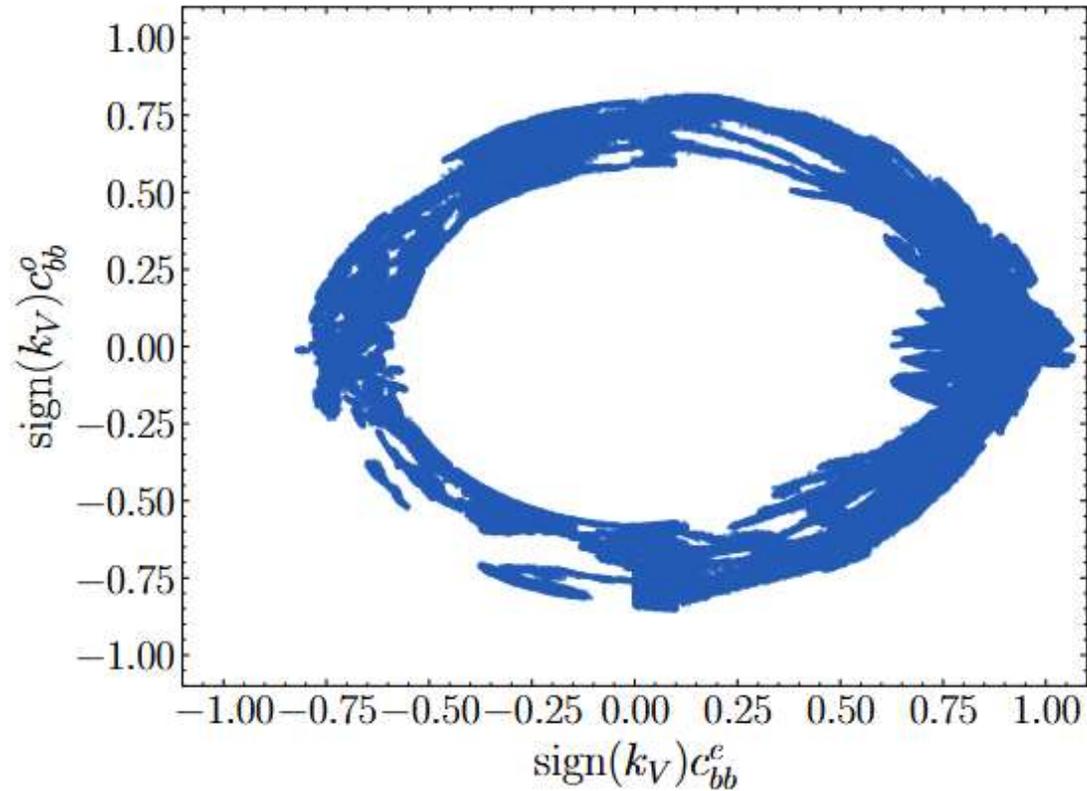
João António Costa Matos | [ist1103475](#)

Supervisors: Prof. João Paulo Silva, Prof. Jorge Romão

h_{125} couplings



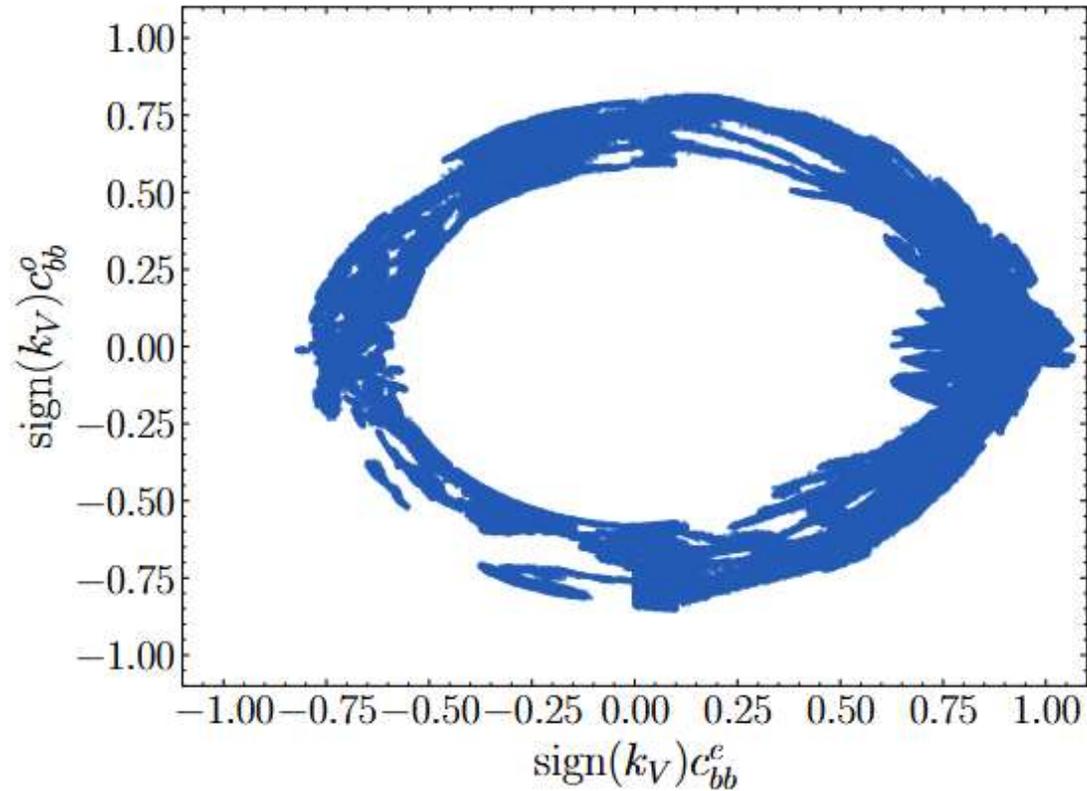
h_{125} couplings



Standard Model

$$-\mathcal{L}_{h_{125}ff} = \frac{m_f}{v} \bar{f}f h_{125}$$

h_{125} couplings



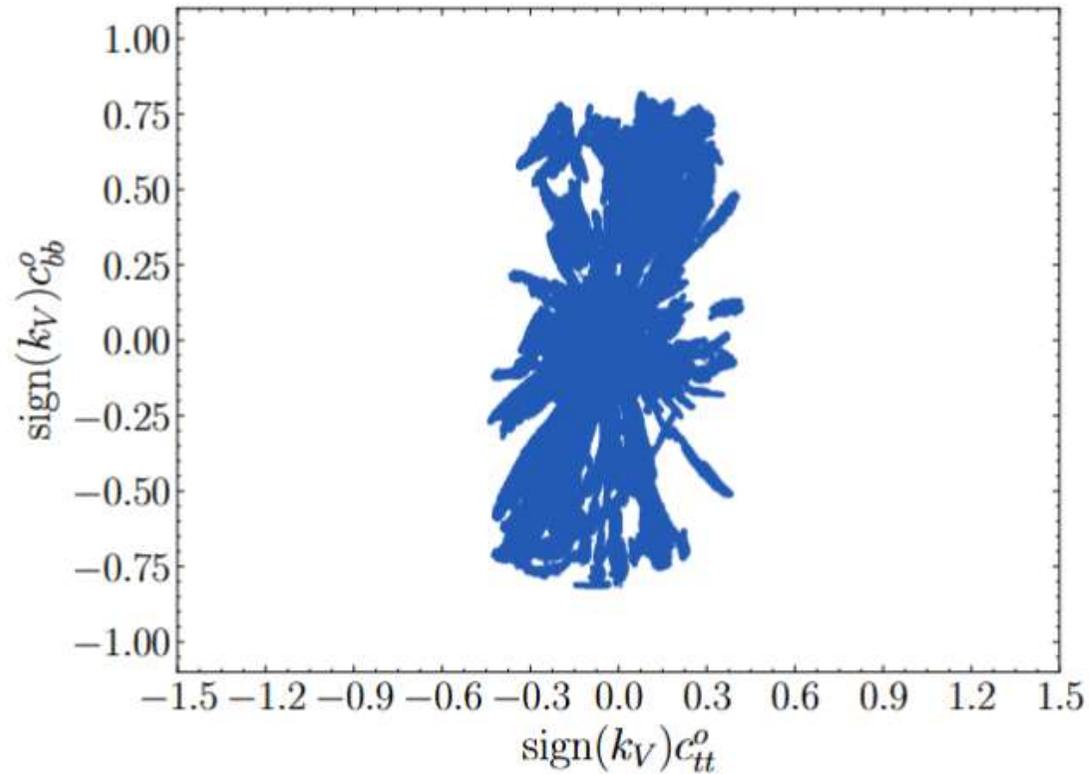
Standard Model

$$-\mathcal{L}_{h_{125}ff} = \frac{m_f}{v} \bar{f} f h_{125}$$

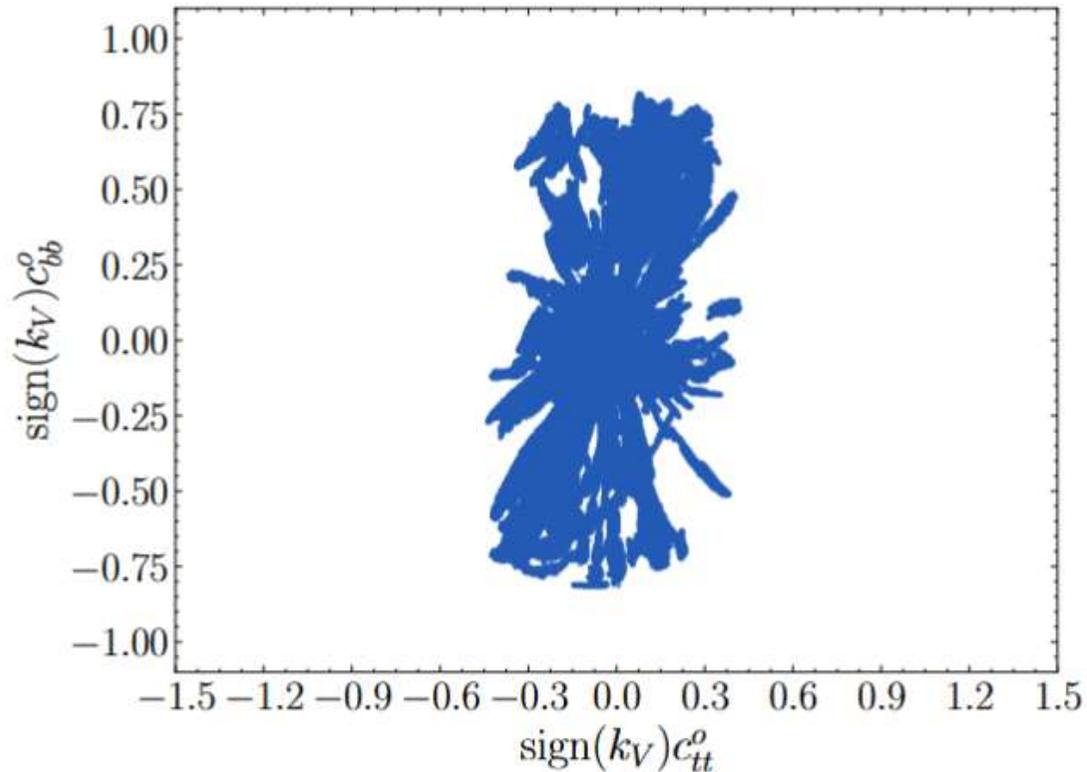
C3HDM

$$-\mathcal{L}_{h_{125}ff} = \frac{m_f}{v} \bar{f} (c_{h_{125}ff}^e + i\gamma_5 c_{h_{125}ff}^o) f h_{125}$$

Is h_{125} Scalar (S) or PseudoScalar (PS)?



Is h_{125} Scalar (S) or PseudoScalar (PS)?



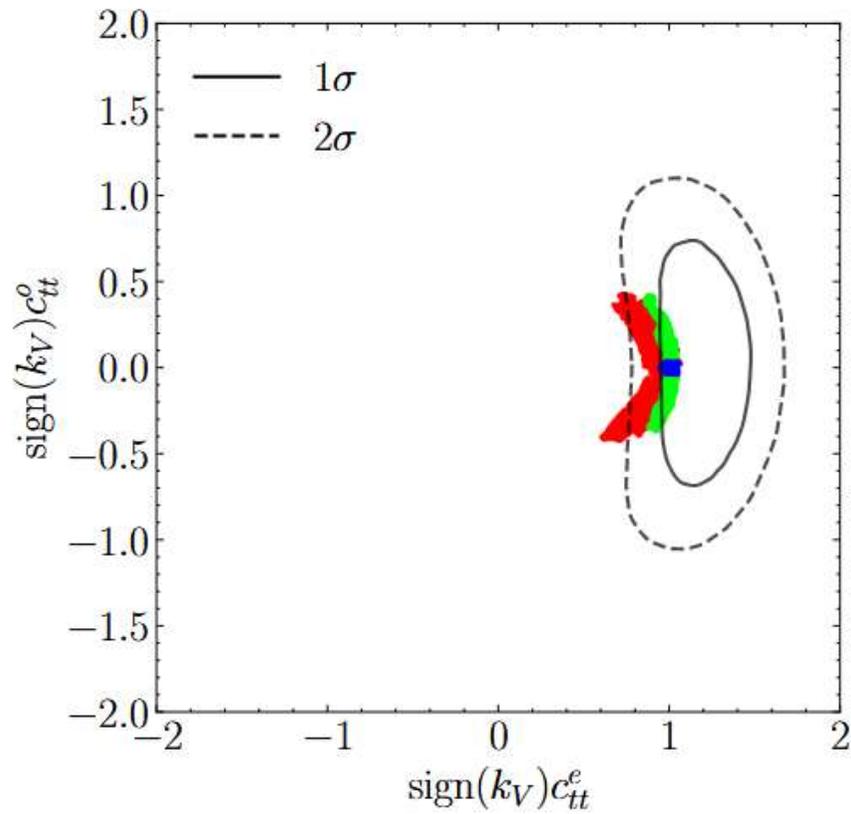
Pure S $h_{125}tt$ & Pure PS $h_{125}bb$

OR

Pure S $h_{125}bb$ & Maximally PS $h_{125}tt$

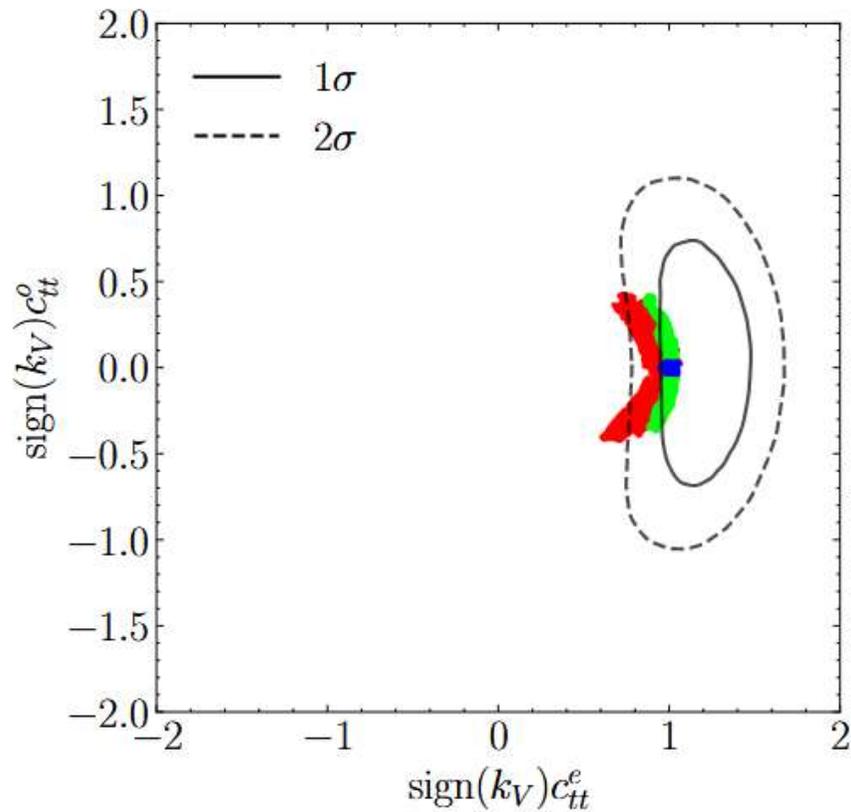
Or (almost) anything in between!

Machine Learning Capabilities



[R. Boto et. al., 2505.10625]

Machine Learning Capabilities



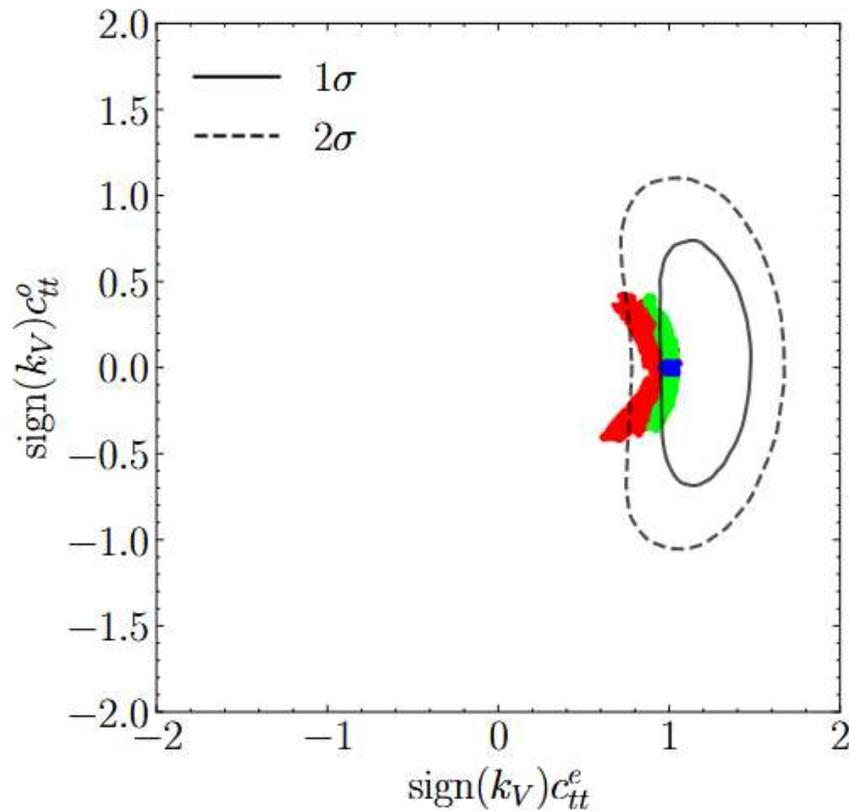
[R. Boto et. al., 2505.10625]

Informed traditional scanning methods



$$c_{tt}^o \approx 0$$

Machine Learning Capabilities



[R. Boto et. al., 2505.10625]

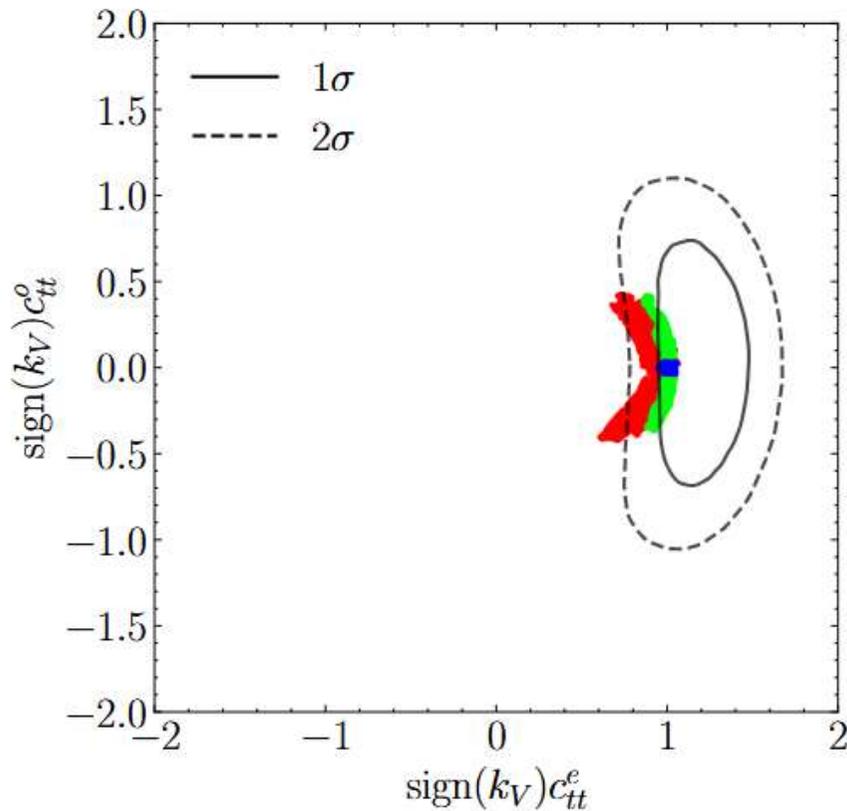
Informed traditional scanning methods

$$c_{tt}^o \approx 0$$

Machine Learning Techniques

$$|c_{tt}^o| \lesssim 0.5$$

Machine Learning Capabilities



[R. Boto et. al., 2505.10625]

Informed traditional
scanning methods



$$c_{tt}^o \approx 0$$

In 3 Months

Machine Learning
Techniques



$$|c_{tt}^o| \lesssim 0.5$$

In 3 Days

Monitoring Machine Learning

Type	I	II	X	Y	Z
$h_1 = h_{125}$	t, τ	τ	t	✓	✓
$h_2 = h_{125}$	t, τ	τ	t	✓	✓
$h_3 = h_{125}$	t, τ	τ	t	✓	✓
$h_4 = h_{125}$	t, τ	τ	t	✓	✓
$h_5 = h_{125}$	t, τ	<u>×</u>	t	<u>×</u>	<u>×</u>

Monitoring Machine Learning

ML

$\Gamma(B \rightarrow X_s \gamma)$ vs. STU

Type	I	II	X	Y	Z
$h_1 = h_{125}$	t, τ	τ	t	✓	✓
$h_2 = h_{125}$	t, τ	τ	t	✓	✓
$h_3 = h_{125}$	t, τ	τ	t	✓	✓
$h_4 = h_{125}$	t, τ	τ	t	✓	✓
$h_5 = h_{125}$	t, τ	<u>×</u>	t	<u>×</u>	<u>×</u>

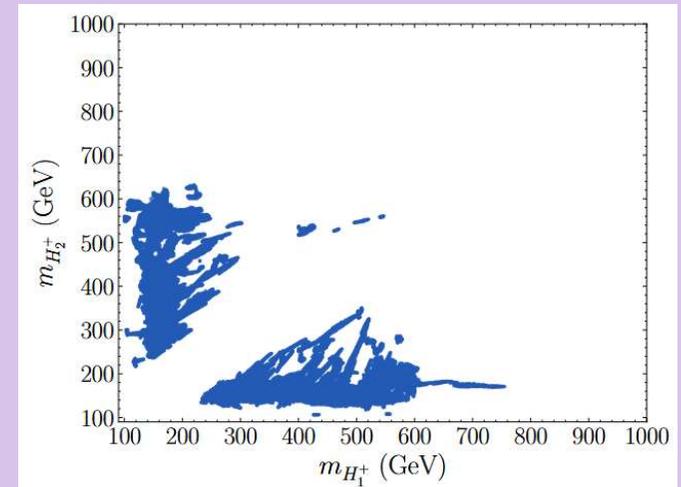
Monitoring Machine Learning

Type	I	II	X	Y	Z
$h_1 = h_{125}$	t, τ	τ	t	✓	✓
$h_2 = h_{125}$	t, τ	τ	t	✓	✓
$h_3 = h_{125}$	t, τ	τ	t	✓	✓
$h_4 = h_{125}$	t, τ	τ	t	✓	✓
$h_5 = h_{125}$	t, τ	✗	t	✗	✗

ML

$\Gamma(B \rightarrow X_s \gamma)$ vs. STU

Physics



$\Gamma(B \rightarrow X_s \gamma) + STU \Rightarrow m_{h_i} > 125 \text{ GeV}$

Ruled out by ordering: $m_{h_i} \leq 125 \text{ GeV}$

Conclusions

- Fully explored all 25 models within the C3HDM with Machine Learning Techniques
- Expanded the $|c_{bb}^o| > |c_{bb}^e|$ for Type Y and Type Z (excluding h_5 ordering)
- There can be 4 undetected scalar particles lighter than the h_{125}
- Monitored ML enabled us to understand h_5 failure in Types II, Y and Z
- Found the interesting possibilities:

Pure S $h_{125}tt$ & Pure PS $h_{125}bb$

Pure S $h_{125}bb$ & Maximally PS $h_{125}tt$

- **Help motivate precise experimental probes into the CP nature of h_{125}**
- **An article with these results has been sent for publication: [Boto, Matos, Romão, Silva, 2510.02445]**