Below-threshold CP-odd Higgs boson search via A $\rightarrow$ Z*h at the LHC

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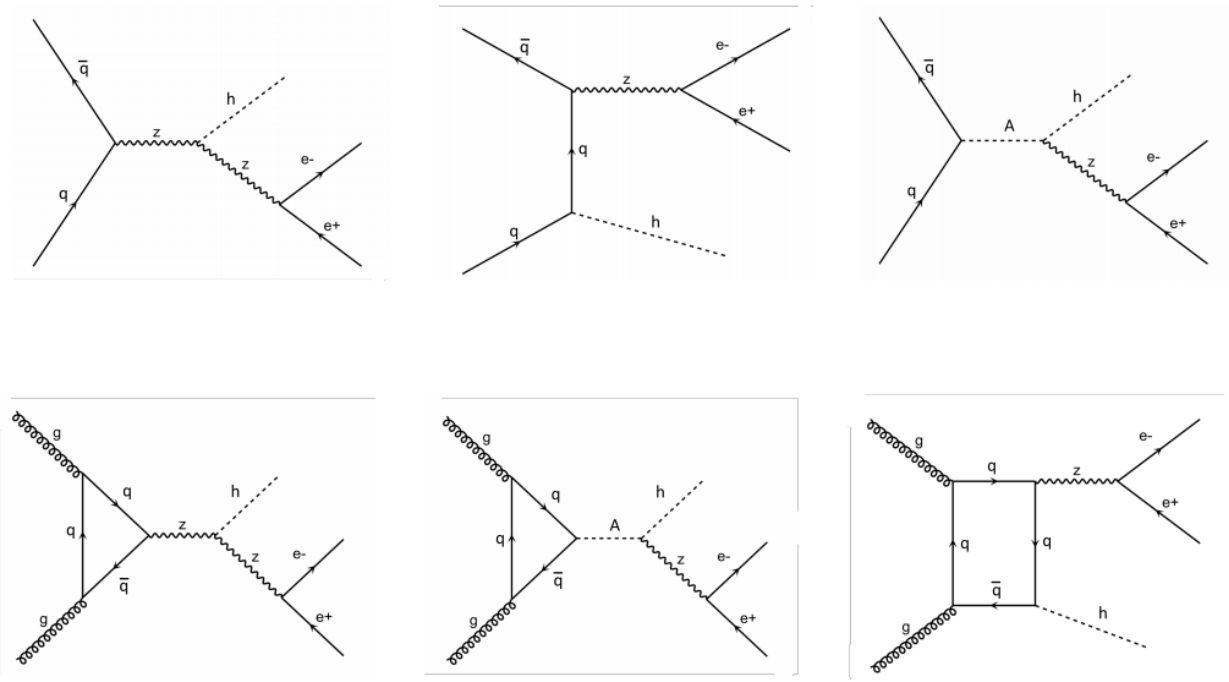
Project Overview

- The Two-Higgs Doublet Model (2HDM) is a well motivated BSM theory, in that it is the simplest extension of the SM relying only on the doublet structure already observed in nature.
- In a 2HDM there are five manifest bosons; two CP-even neutral Higgs (including the Standard Model h), two charged Higgs and the CP-odd Higgs 'A'.
- Experimental evidence from the LHC has pushed the lower mass bound for m_A into the hundreds of GeV range.
- Previous searches have considered only the region in which both the Z and h remain on-shell, i.e. $m_A > m_Z + m_h \approx 215 GeV$.

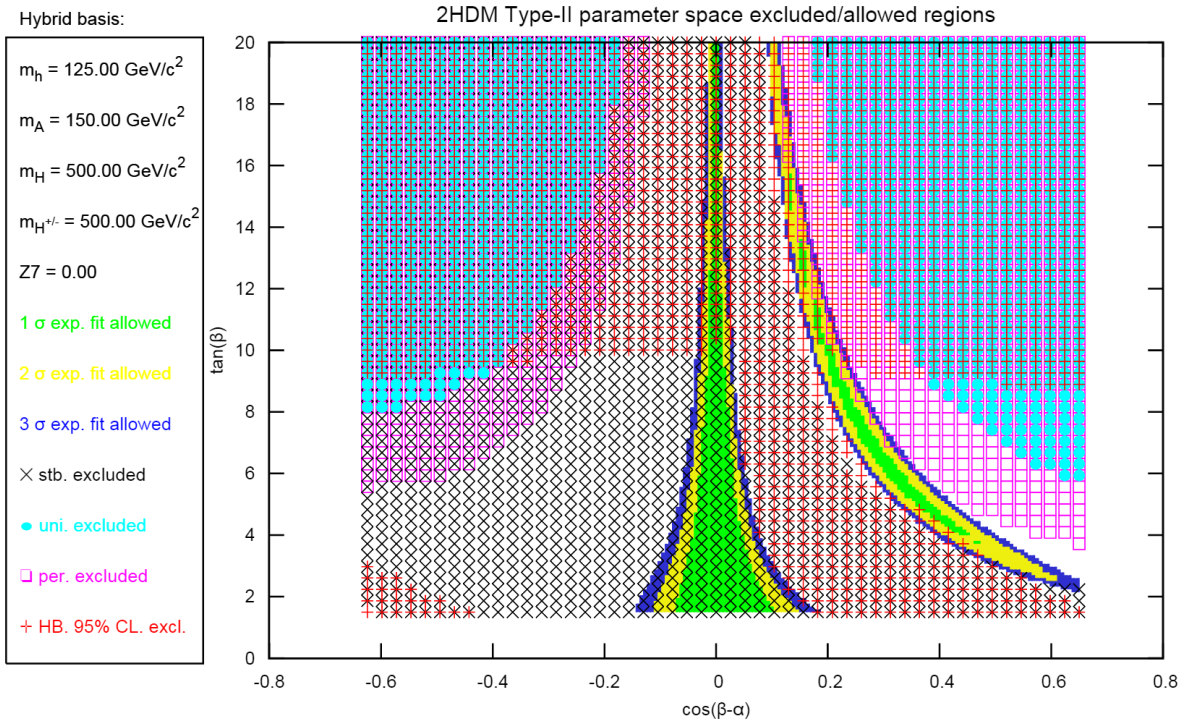
Sub-processes



Feynman diagrams for the process under consideration. We consider Z boson decays to a lepton pair, and adopt the narrow width approximation for the Higgs. Our analysis then considers the channel $Z^*h \to l^+l^- b\bar{b}$

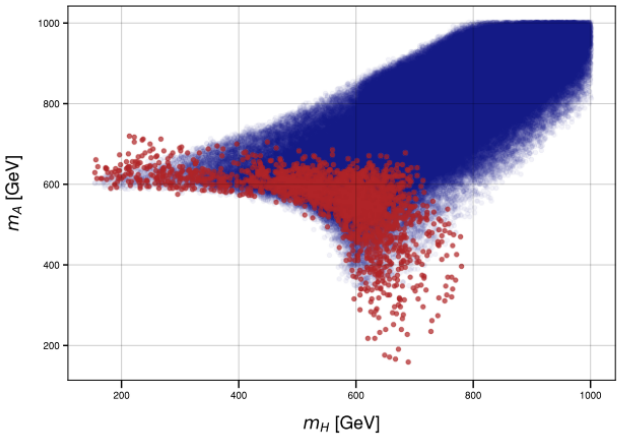
Parameter Space

- Seven parameters are required to fully define the 2HDM; the masses of the Higgses, mixing angle α, ratio of vacuum expectation values tan(β), and self-coupling Z_7.
- The parameter space is strongly constrained by theory (unitarity, perturbitivity, stability) and experimental exclusion bounds.

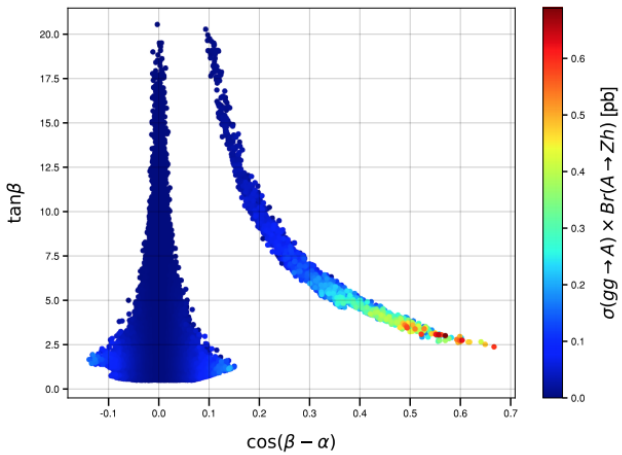


Below-threshold viability

- The 'right-arm' region of the type II 2HDM can access the below-threshold A
- Regions where the A cross-section is significantly greater than the SM background, in total or differentially, have the potential to be observed at the LHC.

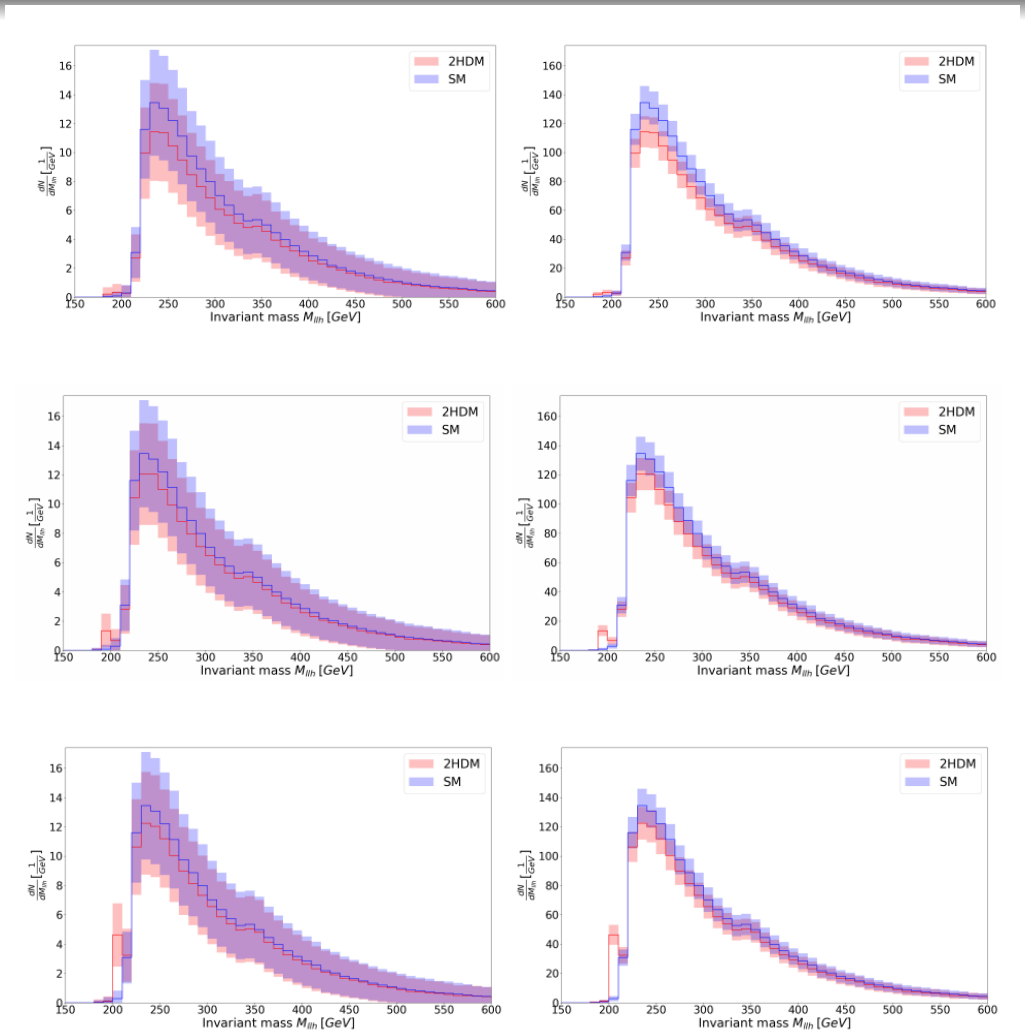


Parameter space points from the central and right-arm region recast in the mA/mH plane. Red points are from the 'right-arm' region.



Calculated cross-sections for the process gg $\rightarrow$ Zh in the tan(β) - cos($\beta - \alpha$) plane

Numerical results



Differential cross sections for (top to bottom) $m_A = 190, 200, 210 GeV$. The left figures have a luminosity of $100 fb^-1$ while the right figures correspond to a luminosity of $1000 fb^-1$.

Conclusions

- The resonant peaking structure for $m_A = 190, 200 GeV$ is visible and separated from the SM background.
- Even an analysis performed on run 2 data could provide evidence of a below-threshold A, and near discovery significance at close to the 215 GeV threshold.
- At the projected luminosity of the HL-LHC a discovery would be possible over the full mass range considered here.

bin	N(SM)	$N(m_A = 190$ GeV)	$N(m_A = 200$ GeV)	$N(m_A = 210$ GeV)
180	0.2	2.1 ($\sigma = 2.6$)	0.2 ($\sigma = 0$)	0.4 ($\sigma = 0$)
190	0.8	3.2 ($\sigma = 3.2$)	13.5 ($\sigma = 16.7$)	1.0 ($\sigma = 0$)
200	2.8	2.7 ($\sigma = 0$)	6.5 ($\sigma = 2.3$)	46.2 ($\sigma = 25.7$)
210	30.8	27 ($\sigma = 0.7$)	28 ($\sigma = 0.5$)	32.4 ($\sigma = 0.3$)

Number of events in each 10 GeV bin for three benchmark scenarios at L $= 100 fb^{-}1$.

Thank you! Questions?

More details can be found in the paper:

Below-threshold CP-odd Higgs boson search via $A \rightarrow Z * h$ at the LHC, E. Accomando, M. Chapman, A. Maury, S. Moretti, Phys. Lett. B, 818(2021)