Probing Higgs Couplings in Gluon Initiated Z-Pair Production at the Large Hadron Collider

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Introduction

The discovery of the Higgs Boson at the Large Hadron Collider (LHC) brought about the completion of the Standard Model of Elementary Particles (SM), describing every interaction mediated by strong, weak, and electromagnetic forces [1,2]. The Higgs was found at the LHC via proton-proton collisions at 7 TeV. When colliding protons, one of the most viable methods for Higgs production is through gluon fusion:

\[
\mathcal{M} (gg\rightarrow H) = \frac{\lambda \phi^2}{4\pi^2} \int \frac{d^4q}{(2\pi)^4} \int \frac{d^4p}{(2\pi)^4} \frac{1}{p^2 - M^2} \frac{1}{q^2 - M^2} \frac{1}{(p+q)^2 - M^2} \frac{1}{(p+q)^2 - M^2}
\]

The broken symmetry of the vacuum is what gives rise to the mass of the elementary matter particles and intermediate vector bosons.

Scattering Cross-Section

Using the mathematical framework of quantum field theory (QFT), the amplitude of the \(gg\rightarrow H\) process is given by

\[
\mathcal{M} = \left(\frac{i}{2\pi^2}\right) \left[\chi_{\phi^2}(\vec{p},\vec{q},\vec{r})\right] \left(\chi_{\phi^2}(\vec{l},\vec{m},\vec{n})\right) \left(\chi_{\phi^2}(\vec{r},\vec{p},\vec{q})\right)
\]

which takes into account the production of the Higgs in the first line and the Higgs decay in the second line. The top quark loop is given by

\[
p = \int d^4q \left[\chi_{\phi^2}(\vec{q},\vec{r})\right] \left(\chi_{\phi^2}(\vec{r},\vec{p})\right) \left(\chi_{\phi^2}(\vec{p},\vec{q})\right)
\]

The number of candidates observed in data as well as the expected yields for background and signal are used to estimate the initial fit values for the signal and background yields.

The mass of the Higgs Boson was measured to be 125.62 ± 0.67 GeV [3]. The cross section will be highest in the region above 2 TeV, where a deviation is observed in the lower region. Given that the neutral Higgs signal falls within the current uncertainty of the CMS Higgs measurement and appear as a single SM Higgs signal.

Conclusions

The scalar fields in the neutral Higgs sector of the general two Higgs doublet model can occupy nearly identical masses. Our simulations have shown that there are scenarios where the neutral Higgs signal falls within the current uncertainty of the CMS Higgs measurement and appear as the SM Higgs. This would place the neutral Higgs masses as:

- \(M_H = 125.954 \pm 0.246 \text{ GeV}\)
- \(M_{h^0} = 125.247 \pm 0.246 \text{ GeV}\)

and make their signals nearly impossible to distinguish. We can assume that the \(A^0\) and \(H^0\) masses are heavy enough not to interfere with the neutral scalar Higgs. Under the condition that \(b = \pi/4\) the two vacuum expectation values would be degenerate at:

\[
t_f = v_f = 173.948 \text{ GeV}
\]

Future work includes analyzing how our model will change under restrictions imposed by the Minimal Supersymmetric Extension.

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