STUDYING HIGGS BOSONS BY TOP PAIR PRODUCTION AT PHOTON COLLIDERS

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We study the effect of heavy neutral Higgs bosons on the $t\bar{t}$ production process at photon linear colliders. The interference patterns between the resonant Higgs production amplitudes and the continuum QED amplitudes are examined. The patterns are sensitive to the phase of the $\gamma\gamma$-Higgs vertex which is a good probe of new charged particles.

1 Introduction

New physics contribute to the Higgs production at photon colliders via radiative corrections from the new charged particles. When the photon-photon-Higgs vertex is written by

$$L_{\phi\gamma\gamma} = \frac{1}{m_\phi} \left( b^H_\gamma A_{\mu\nu}A^{\mu\nu} + b^A_\gamma \tilde{A}_{\mu\nu}A^{\mu\nu} \right) \phi,$$

(1)

where $\phi$ denotes a spinless boson $H$ or $A$ ($H$ and $A$ are the CP-even and CP-odd Higgs bosons respectively.), the $\gamma\gamma\phi$ vertex parameter $b^\phi_\gamma$ generally has complex phase even in CP invariant theories of the Higgs sector. Because the imaginary part of $b^\phi_\gamma$ is a sum of the contribution from the $\phi$ decay modes into charged particles whereas the real part receives contribution from all the charged particles, we expect that $\text{arg}(b^\phi_\gamma)$ is a good probe of heavy charged particles.

In this report, we study the interference patterns of the resonant and the continuum amplitudes for the $\gamma\gamma \rightarrow t\bar{t}$ process by using the circularly polarized colliding photons [1]. It will be shown that these interference effects allow us to observe the complex phase of the $\gamma\gamma$-Higgs vertices, as has been shown in $WW$ and $ZZ$ production processes [2].

2 Observables For The Process $\gamma\gamma \rightarrow t\bar{t}$

The helicity amplitudes for the process $\gamma\gamma \rightarrow t\bar{t}$ can be expressed as

$$M^{|\sigma|} = |M_0\rangle + |M_1\rangle,$$

(2)

$^a_{\text{based on the work in collaboration with K. Hagiwara [1].}}$
where the first term $M_\phi$ stands for the $s$-channel $\phi$-exchange amplitudes and the latter term $M_t$ stands for the $t$- and $u$-channel top-quark-exchange amplitudes. By considering the decay angular distribution of $t\bar{t}$ pairs, we can derive the convoluted four observables, $\Sigma_1$ to $\Sigma_4$,

$$
\Sigma_i \left( \sqrt{s}_{\gamma\gamma} \right) = \int d\sqrt{s}_{\gamma\gamma} \sum_{\lambda_1, \lambda_2} \left( \frac{1}{L_{0.8}} \frac{dL_{\lambda_1\lambda_2}}{d\sqrt{s}_{\gamma\gamma}} \right) \left( \frac{3\beta}{32\pi s_{\gamma\gamma}} \right) \int S_{\lambda_1\lambda_2}(\Theta, \sqrt{s}_{\gamma\gamma})d\cos\Theta,
$$

for $i = 1 - 4$ where the functions $S_{\lambda_1\lambda_2}$ contain all the information about the $\gamma\gamma \rightarrow t\bar{t}$ helicity amplitudes:

$$
S_{1\lambda_1\lambda_2} = |M_{1\lambda_1\lambda_2}^{RR}|^2, \quad S_{2\lambda_1\lambda_2} = |M_{1\lambda_1\lambda_2}^{LL}|^2,
$$

$$
S_{3\lambda_1\lambda_2} = 2\Re \left[ M_{1\lambda_1\lambda_2}^{RR} (M_{1\lambda_1\lambda_2}^{LL})^* \right], \quad S_{4\lambda_1\lambda_2} = 2\Im \left[ M_{1\lambda_1\lambda_2}^{RR} (M_{1\lambda_1\lambda_2}^{LL})^* \right].
$$

$\Theta$ is the polar angle of the top momentum in the $\gamma\gamma$ CM frame, and the normalized luminosity distribution for each $\gamma\gamma$ helicity combination is expressed by $(1/L_{0.8})dL_{\lambda_1\lambda_2}/d\sqrt{s}_{\gamma\gamma}$ where $L_{0.8} \approx 0.1 L_{geom}$. In this report, the luminosity distribution is derived by assuming $\sqrt{s}_{ee} = 500$ GeV, $x = 4.8$, $P_t = -1.0$ and $P_e = 0.9$.

### 3 Effects Of The $\gamma\gamma\phi$ Phase On The Observables

We study the $\arg(b^A_\phi)$ dependence of the four observables defined in the previous section. These observables are sensitive to the interference effects between the resonant $\phi$-production and the continuum QED amplitudes. Fig. 1 shows the observables $\Sigma_1$ to $\Sigma_4$ for the $A$ boson production in the left, and for the $H$ boson production in the right-hand side. We adopt a MSSM prediction for calculating the magnitudes of the $\phi$-production amplitudes. The MSSM parameters used here are as follows: $m_A = 400$ GeV, $\tan\beta = 3$, $m_\tau = 1$ TeV, $M_2 = 500$ GeV, $\mu = -500$ GeV. The solid and dashed curves indicate the case of $\arg(b^A_\phi) = 0$ and $\pi/4$, respectively.

When we compare the $\arg(b^A_\phi) = 0$ observables and the $\arg(b^A_\phi) = \pi/4$ observables in Fig. 1(a), we notice that the magnitudes of all the observables decrease, that is, the negative interference becomes stronger for $\arg(b^A_\phi) = \pi/4$. This statement can also be applied to the observables for the $H$ boson production in Fig. 1(b) except for $\Sigma_2$. As to $\Sigma_2$, the magnitude increases and the positive interference effect is enhanced for $\arg(b^H_\phi) = \pi/4$, because of the sign relation for the $\phi$-production amplitudes which is useful for probing CP parity of Higgs bosons [3]; $[M_H]_{\lambda\lambda} = -[M_H]_{\lambda\lambda}$ while $[M_A]_{\lambda\lambda} = [M_A]_{\lambda\lambda}$.  


4 Conclusion

We have studied the effects of heavy Higgs bosons in $t\bar{t}$ production process at photon colliders. We have introduced observables by considering the angular correlation of decay products of top quarks, and found that the $\arg(b^L)$ dependence of the four observables are significant enough that the phase of the $\gamma\gamma\phi$ vertex function may be measured experimentally by a careful study of all the observables.

References

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