CP Violation of Higgs Particles

CP properties of Higgs particles are determined by their interactions with other particles.

1) Interactions with Gauge bosons.

Tree level couplings in the SM has the form:

$$Z^\mu Z_\mu H \ , \ \ W^{-\mu} W^+_\mu H \ , \tag{1}$$

where Z, W and H are the Z-boson, W-boson and Higgs particles, respectively. The Higgs particle is CP even eigenstate (scalar).

At loop level, other types of interactions may be generated,

$$\begin{aligned} &Z^{\mu\nu} Z_{\mu\nu} H \ , \ \ W^{-\mu\nu} W^+_{\mu\nu} H \ , \\ &F^{\mu\nu} F_{\mu\nu} H \ , \ \ G^{\mu\nu} G_{\mu\nu} H \ . \end{aligned} \tag{2}$$

Here $F_{\mu\nu}$ and $G_{\mu\nu}$ are the field strengths for the photon and gluon, respectively. If CP is conserved, Higgs particles with such couplings are CP even states. For a CP odd Higgs particle, the interactions will have the following forms

$$\begin{aligned} &Z^{\mu\nu} \tilde{Z}_{\mu\nu} H \ , \ \ W^{-\mu\nu} \tilde{W}^+_{\mu\nu} H \ , \\ &F^{\mu\nu} \tilde{F}_{\mu\nu} H \ , \ \ G^{\mu\nu} \tilde{G}_{\mu\nu} H \ . \end{aligned} \tag{3}$$

If CP is violated, a Higgs particle can have mixed interactions.

2) Interactions with fermions.

In general, a spinless particle can coupl to fermions in the following form

$$\bar{f}(a + ib\gamma_5) f H \ , \tag{4}$$

where f is a fermion which can be a lepton or a quark. a-term is a CP even interaction and b-term is CP odd one. If both a and b are not zero, CP is violated. In the SM, the Higgs particle is a CP even state, it only has a-term type of coupling. For a pesudascalar, it only has b-term type of coupling. The A^0 Higgs in the MSSM is such a particle.

3) Interactions among Higgs particles.

These interactions are very model dependent. Not practical to use these interactions to determine the CP properties experimentally.

There have been some theoretical studies to determine the intereactions of Higgs particles with gauge bosons and fermions.

Reveiws:

1) The Higgs Hunter's Guide, J.F. Gunion, Howard E. Haber, Gordon L. Kane and Sally Dawson.

2) Weakly-Coupled Higgs Boson, J.F. Gunion, A. Stange and S. Willenbrock, Preprint, UCD-95-28, hep-ph/9602238.

Specific discussions:

1) $\gamma\gamma$ collider. Using photon polarization asymmetries in $\gamma\gamma \to H$ to determine the CP property was discussed by J.F. Gunion and J.G. Kelly, Phys. Lett. B333, 110(1994).

2) Study CP property of Higgs using $gg \to H$ was discussed by B. Grzadkwoski, J.F. Gunion and T.C. Yuan, Phys. Rev. Lett. 71, 488(1993).

3) Study of ZZH coupling at e^+e^- collider was discussed by A. Skjold and P. Osland, Nucl. Phys. B453, 3(1995).

4) Study of $t\bar{t}H$ coupling at LHC was discussed by J. F. Gunion and Xiao-Gang He, Preprint, UCD-96-5, hep-ph/9602226.

5) Study of $t\bar{t}H$ coupling at NLC was discussed by J.F. Gunion, B. Grzadkowski and Xiao-Gang He, preprint, UCD-96-14, hep-ph/9605326.

CP violation study by S. Bar-Shalom, D. Atwood, G. Eilam, R. Mendel, and A. Soni, Phys. Rev. D53, 1162(1996)

6) Study of $\mu^+\mu^-H$ coupling at muon collider was discussed by V. Barger, M.S. Berger, J.F. Gunion and T. Han, Preprint, UCD-96-6, hep-ph/9602415.

CP violation study by D. Atwood and A. Soni, Phys. Rev. D52, 6271(1995).