THE SM HIGGS-BOSON PRODUCTION IN $\gamma\gamma \rightarrow h \rightarrow b\bar{b}$ AT THE PHOTON COLLIDER AT TESLA

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Abstract

Measuring the $\Gamma(h \rightarrow \gamma\gamma)\text{Br}(h \rightarrow b\bar{b})$ decay at the photon collider at TESLA is studied for a Standard Model Higgs boson of mass $m_h = 120$ GeV. The main background due to the process $\gamma\gamma \rightarrow Q\bar{Q}(g)$, where $Q = b, c$, is estimated using the NLO QCD program (G. Jikia); the results obtained are compared with the LO estimate. Using a realistic luminosity spectrum and performing a detector simulation, we find that $\Gamma(h \rightarrow \gamma\gamma)\text{Br}(h \rightarrow b\bar{b})$ can be measured with an accuracy better than 2% after one year of photon collider running.

A photon collider option of the TESLA $e^+e^-$ collider offers a unique possibility to produce the Higgs boson as an s-channel resonance and to determine its properties with a high accuracy. The neutral Higgs boson couples to the photons through a loop with the massive charged particles, thus $h\gamma\gamma$ coupling is sensitive to contributions of new particles. The SM Higgs boson with a mass below $\sim 140$ GeV is expected to decay mainly into the $b\bar{b}$ final state. Here we consider the process $\gamma\gamma \rightarrow h \rightarrow b\bar{b}$ for a Higgs-boson mass of $m_h = 120$ GeV at a photon collider at TESLA. Both the signal and background events are generated according to a realistic photon–photon luminosity spectrum. A simulation of the detector response is incorporated as well.

In the analysis we use the CompAZ parametrization of the spectrum to generate energies of the colliding photons. For the energy of primary electrons
$\sqrt{s_{ee}} = 2E_e = 210$ GeV, we obtain a peak of the $J_z = 0$ component of the photon–photon luminosity spectrum at the invariant mass of the two colliding photons $W_{\gamma\gamma}$ equal to 120 GeV. We assume the integrated luminosity of the primary $e^-e^-$ beams equal to $L_{ee}^{geom} = 502$ fb$^{-1}$.

A generation of signal events was done with PYTHIA 6.205, with the parameters for a Higgs boson as in HDECAY. A parton shower algorithm, implemented in PYTHIA, was used to generate the final-state particles. The background events due to processes $\gamma\gamma \rightarrow b\bar{b}(g), c\bar{c}(g)$ were generated using the program written by G. Jikia, where a complete NLO QCD calculation for the production of massive quarks is performed within the massive-quark scheme. For a comparison we generated also the LO background events as implemented in PYTHIA. The fragmentation was performed using the PYTHIA program. A fast simulation for a TESLA detector (SIMDET 3.01) was used to model a detector performance. The jets were reconstructed with the Durham algorithm ($y_{cut} = 0.02$). The double $b$-tag was required to select the signal $h \rightarrow b\bar{b}$ events ($\varepsilon_{bb} = 70\%$ and $\varepsilon_{cc} = 3.5\%$ were assumed). The following cuts were used to select reconstructed $b\bar{b}$ events: (1) a total visible energy $E_{vis} > 90$ GeV; (2) the ratio of the total longitudinal momentum of all observed particles to the total visible energy $|P_z|/E_{vis} < 0.1$; (3) a number of jets $N_{jets} = 2, 3$; (4) for each jet we require $|\cos \theta_{jet}| < 0.75$. The obtained distributions of the reconstructed $\gamma\gamma$ invariant mass $W_{rec}$ are shown in Fig. 1 (left). The expected relative statistical error of $\Gamma(h \rightarrow \gamma\gamma) \text{Br}(h \rightarrow b\bar{b})$ is equal to $\sqrt{N_{obs}}/(N_{obs} - N_{bkgd})$. If estimated from the selected mass region, it is equal to 1.9%. We introduce the corrected, reconstructed invariant mass as: $W_{corr} \equiv \sqrt{W_{rec}^2 + 2P_T(E_{vis} + P_T)}$. The distributions of the $W_{corr}$ are shown in Fig. 1 (right). In the selected $W_{corr}$ region one achieves an relative accuracy $\Delta \left[\Gamma(h \rightarrow \gamma\gamma) \text{Br}(h \rightarrow b\bar{b})\right] / \left[\Gamma(h \rightarrow \gamma\gamma) \text{Br}(h \rightarrow b\bar{b})\right] = 1.7\%$.

Assuming $\text{Br}(h \rightarrow b\bar{b})$ will be measured to 1.5%\footnote{Other background contributions, from the resolved photon(s) interactions and the overlaying events, were found to be negligible.}, Higgs-boson partial width $\Gamma(h \rightarrow \gamma\gamma)$ can be extracted with accuracy of 2.3%. Using in addition the result from the $e^+e^-$ Linear Collider for $\text{Br}(h \rightarrow \gamma\gamma)$, one can extract $\Gamma_{tot}$ with a precision of 10%.

References

[1] B. Badelek et al., TESLA TDR, DESY 2001-011, hep-ex/0108012.

[2] P. Nieżurawski, A.F. Żarnecki, M. Krawczyk, hep-ph/0208234, accepted by Acta Phys. Polon. B.
Figure 1: Reconstructed invariant mass $W_{\text{rec}}$ (left) and corrected invariant mass $W_{\text{corr}}$ (right) distributions for the selected $b\bar{b}$ events. Contributions of the signal, due to the Higgs boson with a mass $m_h = 120$ GeV, and of the heavy-quark background, calculated in the NLO QCD, are indicated. For comparison, the LO background estimate is also plotted (dots). Arrows indicate the mass window optimized for the measurement of the $\Gamma(h \rightarrow \gamma\gamma)\text{Br}(h \rightarrow b\bar{b})$. 