Study of the Process $\gamma\gamma \to \quad higgs \to b\bar{b}$ in SM and MSSM at the Photon Collider*

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Analysis of the precise measurement of the Higgs-boson production cross section $\gamma\gamma \to higgs \to b\bar{b}$ at the Photon Collider is presented. The study is based on the realistic luminosity spectra simulation. The heavy quark background is estimated on the NLO QCD level. Also other background processes and the contribution from overlaying events, $\gamma\gamma \to hadrons$, are taken into account. The non-zero beam crossing angle and the finite size of colliding bunches are included in the event generation. The detector simulation and realistic b-tagging are applied, and the criteria of event selection are optimized separately for each considered Higgs-boson mass. Our results indicate that for the SM Higgs boson with mass of 120 to 160 GeV the partial width $\Gamma(h \to \gamma\gamma)\mathrm{BR}(h \to b\bar{b})$ can be measured with the statistical accuracy of 2.1–7.7% after one year of the Photon Collider running. The systematic uncertainties of the measurement are estimated to be of the order of 2%. In case of the MSSM Higgs-bosons production we study the measurement assuming that parameter values correspond to the so-called 'LHC wedge'. For MSSM Higgs bosons A and H, for $M_A = 200$–350 GeV and $\tan\beta = 7$, the statistical precision of the cross-section measurement is estimated to be 8–34%, for four considered MSSM parameters sets. It is shown that in these scenarios the Photon Collider may discover heavy neutral Higgs bosons for lower values of $\tan\beta$ than the LHC limit.

A photon-collider option of the future e^+e^- linear collider offers the unique possibility to produce neutral Higgs bosons as s-channel resonances. The loop-induced $higgs\gamma\gamma$ coupling is sensitive to contributions from all massive charged particles. The precise measurement of the $\Gamma(higgs \to \gamma\gamma)$ can indicate existence of new particles, which may be too heavy to be produced directly. In case of the Standard Model we estimate the precision of the cross section measurement for the process $\gamma\gamma \to h \to b\bar{b}$, for $M_h = 120$–160 GeV. In case of the Minimal Supersymmetric extension of the Standard Model, for the heavy Higgs bosons, A and H, the precision of the corresponding measurement for the process $\gamma\gamma \to A, H \to b\bar{b}$ is evaluated. If MSSM parameter values are in the so-called 'LHC wedge', *i.e.* region of intermediate values of $\tan\beta \approx 4$–10, and masses $M_{A,H}$ above 200 GeV, these heavy bosons may not be discovered at the LHC [1, 2] and at the first stage of the e^+e^- linear collider [3]. Therefore, we also study the discovery potential of the Photon Collider. Detailed description of our analyses can be found in [4].

In our analysis all crucial experimental aspects of the measurement are taken into account. The analysis is based on the realistic $\gamma\gamma$-luminosity simulation for the Photon Collider at TESLA [5, 6]; the integrated luminosity corresponds to one year of Photon Collider running. We assume that the center-of-mass energy of colliding electron beams is optimized for the production of a Higgs boson with the given mass. Generation of all event samples took into account the Gaussian smearing of primary vertex and the beams crossing angle of 34 mrad in horizontal plane. Total widths and branching ratios of the Higgs bosons were calculated with the program HDECAY [7]. Event generation for Higgs-boson production process, $\gamma\gamma \to higgs \to b\bar{b}$, was done with the PYTHIA program [8]. A parton shower algorithm implemented in PYTHIA was used to generate the final-state partons. The fragmentation into hadrons was also performed using the PYTHIA program, both for Higgs-boson production and for all background event samples. The background events due to processes $\gamma\gamma \to b\bar{b}(g)$, $c\bar{c}(g)$ were generated using the program [9] which takes into account NLO QCD results. Other background processes, which were neglected in the earlier analyses, were also

*Presented by J. Ciborowski *(Institute of Experimental Physics, Warsaw University)* studied: $\gamma\gamma \to W^+W^-$, $\gamma\gamma \to \tau^+\tau^-$, and light-quark pair production $\gamma\gamma \to q\bar{q}$. From one to two $\gamma\gamma \to$ *hadrons* events are expected on average per bunch crossing in considered beam energy range. These so-called *overlaying events* were also taken into account in the signal and background events generation.

The detector performance was simulated by the program SIMDET [10]. Jets were reconstructed using the Durham algorithm. The low-angle tracks and clusters were not taken into account to minimize the influence of overlaying events. Two or three jet events were accepted. To reduce heavy-quark production background the lower cut on the polar angle for each jet and the upper cut on the total longitudinal momentum of the event were imposed. Additional cuts to suppress $\gamma\gamma \to W^+W^-$ background were also applied. For realistic b-tagging a dedicated package was used [11]. The criteria of event selection were optimized separately for each considered Higgs-boson mass. To compensate the energy loss due to escaping neutrinos we used the corrected invariant mass [12], $W_{corr} \equiv \sqrt{W_{rec}^2 + 2P_T(E+P_T)}$.

In case of the SM Higgs-boson production for $M_h = 120$ GeV the final W_{corr}-distributions for the signal and background events are shown in Fig. 1 (left). The systematic error of the measurement is estimated to be 1.8%. We have performed the full simulation of signal and background events for $M_h = 120$ to 160 GeV. Expected statistical precisions of $\Gamma(h \to \gamma\gamma)\mathrm{BR}(h \to b\bar{b})$ measurement are indicated in Fig. 1 (right).

We considered four MSSM scenarios I, II, III, and IV, corresponding to μ parameter values 200, -150, -200, and 300 GeV. The values of trilinear couplings were $A_{\tilde{f}} = 1500$ GeV and 2450 GeV for cases I–III and for case IV, respectively. The scenario IV is included for comparison with predictions presented by LHC experiments [2].

The result of the analysis for $M_A = 300$ GeV and $\tan\beta = 7$ is shown in Fig. 2 (left). From the number of signal and background events in the optimized W_{corr}-window the expected statistical precision of the cross-section measurement for $\gamma\gamma \to A, H \to b\bar{b}$ is 11%. We estimated statistical precision for $\gamma\gamma \to A, H \to b\bar{b}$ cross section measurement for all considered parameter sets. The most precise measurement is expected for parameter sets II and III — precision is about 10% and hardly depends on M_A. The worst measurement is expected for scenario IV.

For given M_A the precision weakly depends on $\tan\beta$ if parameter sets II or III are considered. In case of parameter sets I or IV the precise measurement will not be possible for $\tan\beta \lesssim 5$. For greater M_A values better precision of the cross section determination can be achieved in wider $\tan\beta$ range.

We studied the significance of signal measurement as a function of $\tan\beta$. Results obtained for different parameter sets for $M_A = 350$ GeV are compared in Fig. 2 (right). For all parameter sets the expected number of signal events for $M_A = 200$–350 GeV will be sufficient to cover most of the considered MSSM parameters space. We conclude that for $M_A \gtrsim 300$ GeV the Photon Collider should be able to discover Higgs bosons for much lower values of $\tan\beta$ than experiments at the LHC.

We acknowledge useful comments and suggestions of our colleagues from the ECFA working groups. This work was partially supported by the Ministry of Science and Information Society Technologies, project no. 115/E-343/SPB/DESY/P-03/DWM517/2003-2005, grant no. 1 P03B 040 26, and (P.N. only) grant no. 2 P03B 128 25.

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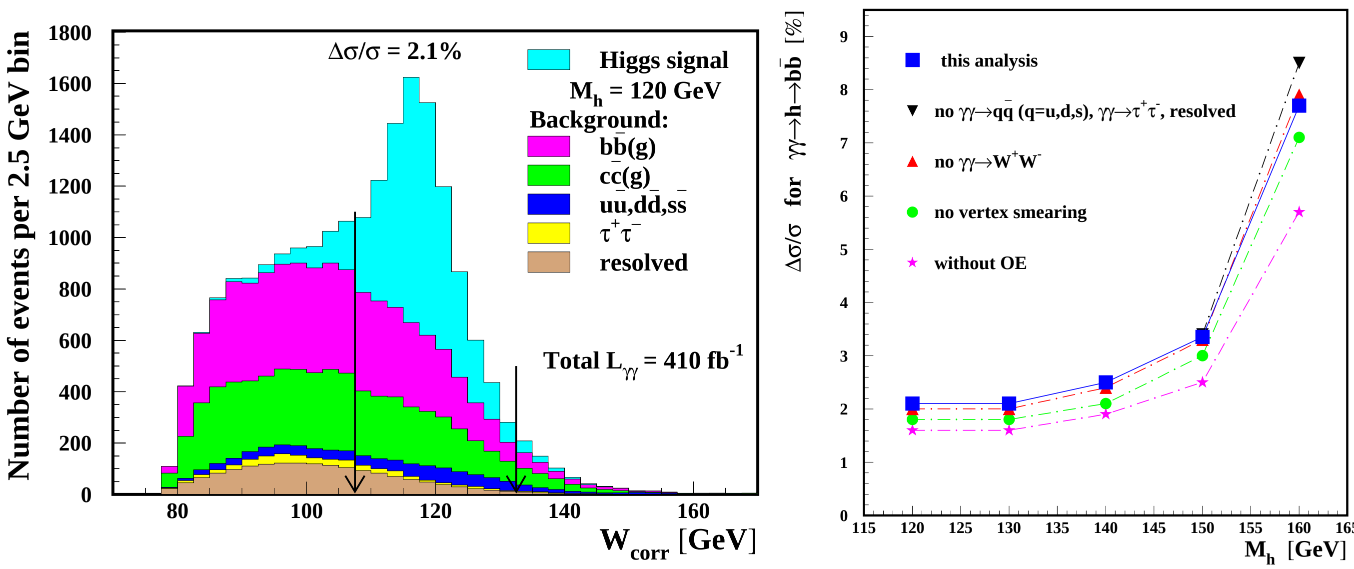

Figure 1: Distributions of the corrected invariant mass, W_{corr}, for selected $b\bar{b}$ events (left). Contributions of the signal, for M_h = 120 GeV, and of the background processes are shown separately. Arrows indicate the mass window optimized for the measurement of the $\Gamma(h \to \gamma\gamma)\mathrm{BR}(h \to b\bar{b})$, which leads to the statistical precision of 2.1%. Statistical precision of $\Gamma(h \to \gamma\gamma)\mathrm{BR}(h \to b\bar{b})$ measurement for the SM Higgs boson with mass 120–160 GeV (right). Final results of our analysis are compared with our earlier results, which did not take into account all aspects of the measurement.

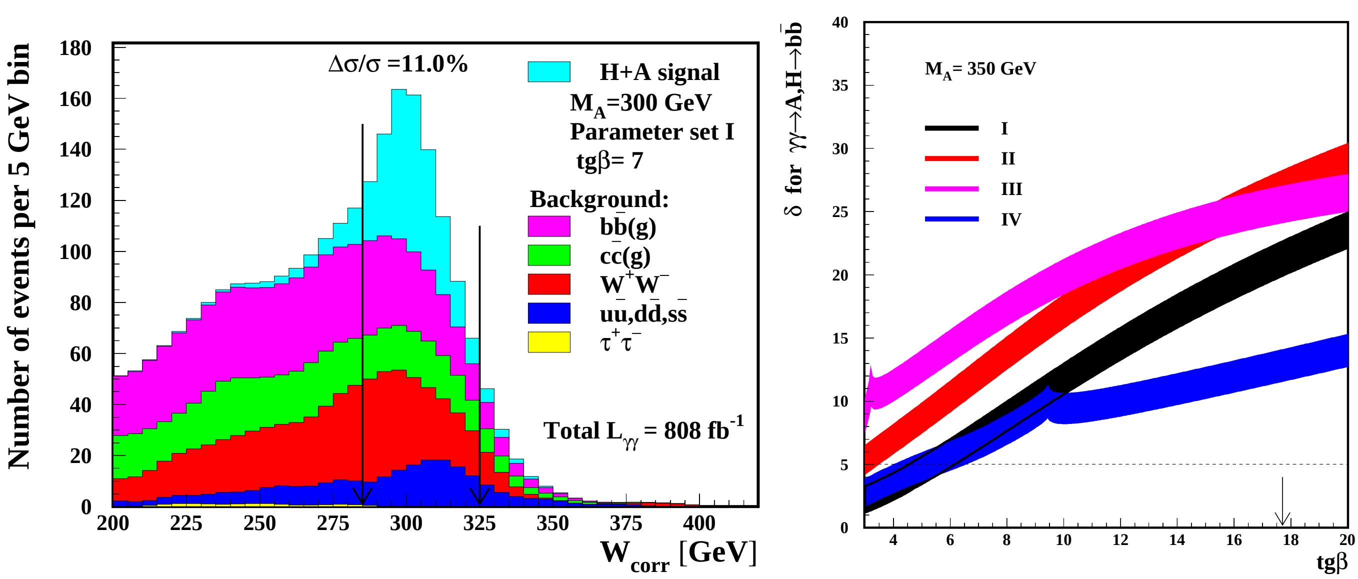

Figure 2: Distributions of the corrected invariant mass, W_{corr}, for signal (M_A = 300 GeV) and all considered background contributions (left). The precision of 11% for $\gamma\gamma \to A, H \to b\bar{b}$ cross section measurement is achieved. Statistical significances of $\sigma(\gamma\gamma \to A, H \to b\bar{b})$ measurement for M_A = 350 GeV (right). The band widths indicate the level of possible statistical fluctuations of the actual measurement. The estimated lower limit of the discovery region of LHC experiments [2] is indicated by an arrow.