Production of heavy neutral MSSM Higgs Bosons in $\gamma\gamma$ collisions in $b\bar{b}$ final states

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We have studied the production of heavy neutral Higgs in high energetic collisions of polarised photons. It turned out that for one polarisation state of the photons the production of heavy neutral Higgs boson is possible. The analysis of diferent parameters both for the signal and for the background lead us to suggest several cuts in order to increase the significance of the signal. Applying this cuts to the generated events lead us to consistent results.

1 Introduction

The Higgs bosons are required by the Standard Model and the supersymmetric extension of it. The minimal supersymmetric extension of the Standard Model (MSSM) contains two charged ($H^{\pm}$) Higgs bosons and three neutral Higgs bosons: the light $\mathcal{CP}$-even Higgs particle (h), and the heavy $\mathcal{CP}$-even (H) and the $\mathcal{CP}$-odd (A) Higgs states. The MSSM Higgs sector can be described in leading order by two independent parameters, which are in general chosen as the pseudoscalar mass M_A and tanβ=v_2/v_1, *i.e.* the ratio of the two vacuum expectation values of the scalar Higgs fields. While the mass of the lightest $\mathcal{CP}$-even Higgs boson h is bounded to $M_h \lesssim 130$ Gev, the masses of the heavy Higgs bosons $H, A, H^{\pm}$ are expected to be of the order of the electroweak scale up to about 1 TeV. The heavy Higgs bosons are nearly mass degenerate. The negative direct search for the MSSM Higgs particle at LEP2 yields lower limits $M_{h,H,A} \gtrsim$ 90 GeV for the neutral Higgs masses.

In our work we studied only the uncharged state H, which is produced in high energetic $\gamma\gamma$ collisions. We assumed a large value for the A mass. The properties of the light $\mathcal{CP}$-even Higgs boson h are similar to those of the light SM Higgs boson, and can be detected in the $b\bar{b}$ decay mode just as the SM Higgs. The WW and ZZ decay modes are suppressed for the heavy H case. We considered a moderate value of tanβ so the dominating decay mode for H is $b\bar{b}$. This seems to be the most interesting process because of the heavily supressed background in the helicity state coresponding to the production of Higgs particle. We considered a future linear e^+e^- collider, which can use each bunch for collisions only once. Due to this fact, it is posible to polarise the electrons up to 80%. Next to the interaction point we considered a long wave length laser to produce high energetic photons through Compton scattering. Due to the polarisation of the incoming electrons one gets also polarised photons. We will denote by $+$ the right handed polarisation of the photons and and by $-$ the left handed polarisation of the photons. The beam polarisation is in such a way that the most frequently produced state is $+$ state. Because we collided two photons, we have 4 helicity states: $++$, $+-$,$-+$ and $--$, where two of them are equivalent ($+-$,$-+$). We differentiate the two helicity states J=0 and J=$\pm$2 which coresponds to $++$ and $--$,respectively $+-$ and $-+$ polarisation states of the incoming photons. We have generated both background and signal and searched for significant cuts.

2 Event generation

We used the program PYTHIA 6.2 to generate the signal and the background events and for computing the cross sections. We also used the program SIMDET 4 to simulate the detector. Then we applied different cuts to produce a signal with more significance. We have considered

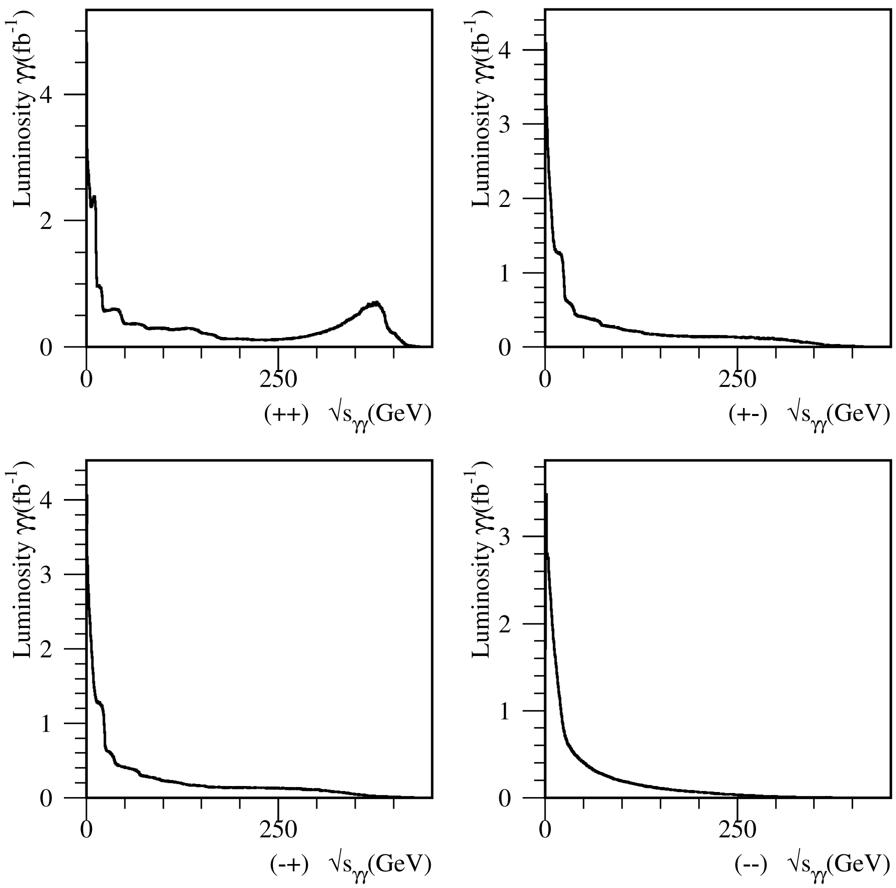

Fig. 1: *Luminosity Spectra*

the beam energy in such a way , that the Higgs mass is equal to the energy corresponding to the luminosity peak in the interesting helicity channel.

2.1 Luminosity

In order to compute the luminosity we have used the program CIRCE 2.0. This program provided the distribution of luminosity and the integrated luminosity. The luminosity spectra for the four helicity configurations are shown in Fig.1

2.2 Signal

For generating the signal we have used PYTHIA 6.2. Due to the fact that the Higgs particle is a very narrow resonance we run PYTHIA 6.2 in the fixed energy option and after that we boost the events. The boost was considered in the direction of the pipe. It has been done in the following way: we have generated random values of the momentum from the distribution of momenta; with this value we computed the Lorentz factor. Working in the MSSM scenario we used as input parameters $M_A = 375$ GeV and tanβ=7. Due to the fact that the heavy Higgs boson has spin 0 it can only be produced in J=0

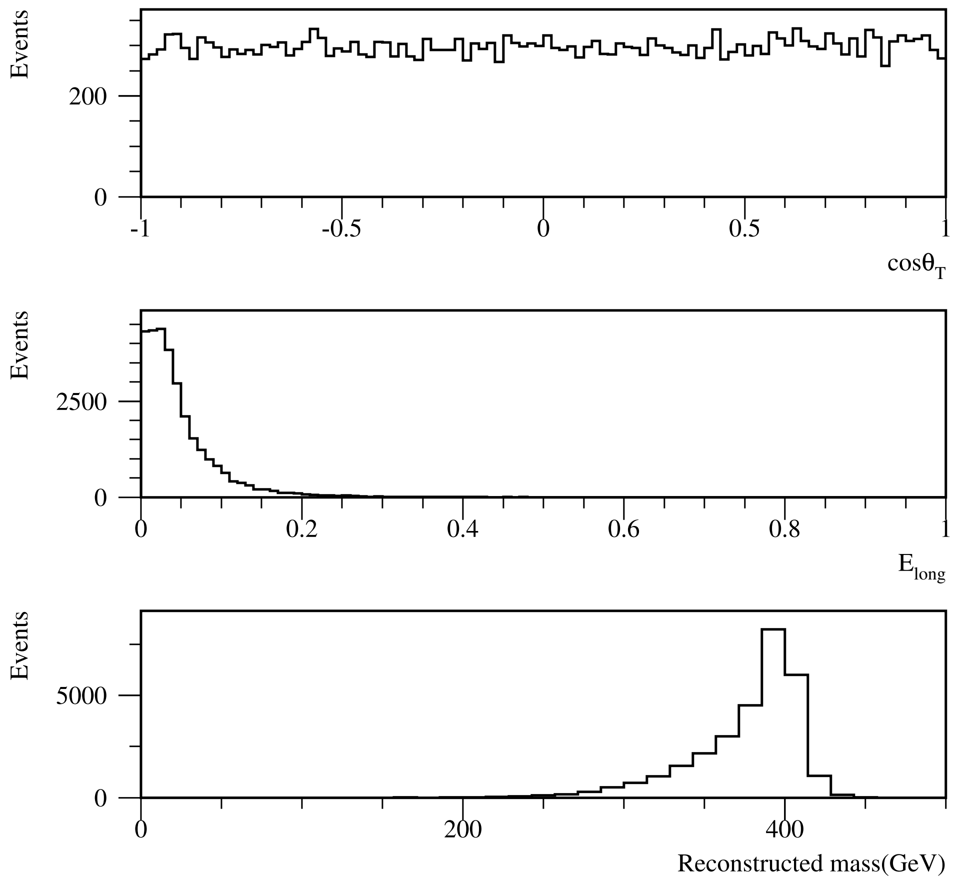

Fig. 2: *Trust cosinus, longitudinal energy imbalance and reconstructed mass for Higgs boson*

configurations, *i.e.* only in ++ and −− scenarios. The helicity state −− is neglected due to the low production of photons in the interesting energy region. In this scenario the dominant decay of the heavy Higgs boson is $H \to b\bar{b}$ which has a specific signature in the detector, namely a 2-jets event. The thrust cosinus ($cos\theta_T$) longitudinal energy imbalance ($E_{long} = \frac{|\sum p_z|}{\sum |p|}$) and reconstructed mass distributions of the signal can be seen in Fig.2.

We will estimate expected events in one year of running with the following formula:

$$N_S(\gamma\gamma \to H \to b\bar{b}) = \quad (1)$$

$$= \frac{dL\gamma\gamma}{d\sqrt{s_{\gamma\gamma}}}\bigg|_{M_H} \frac{4\pi^2\Gamma(H \to \gamma\gamma)BR(H \to b\bar{b})}{M_H^2}$$

where $\Gamma(H \to \gamma\gamma)$ is computed in the following way:

$$\Gamma_{tot} = \frac{\Gamma(H \to \gamma\gamma)}{BR(H \to \gamma\gamma)} \quad (2)$$

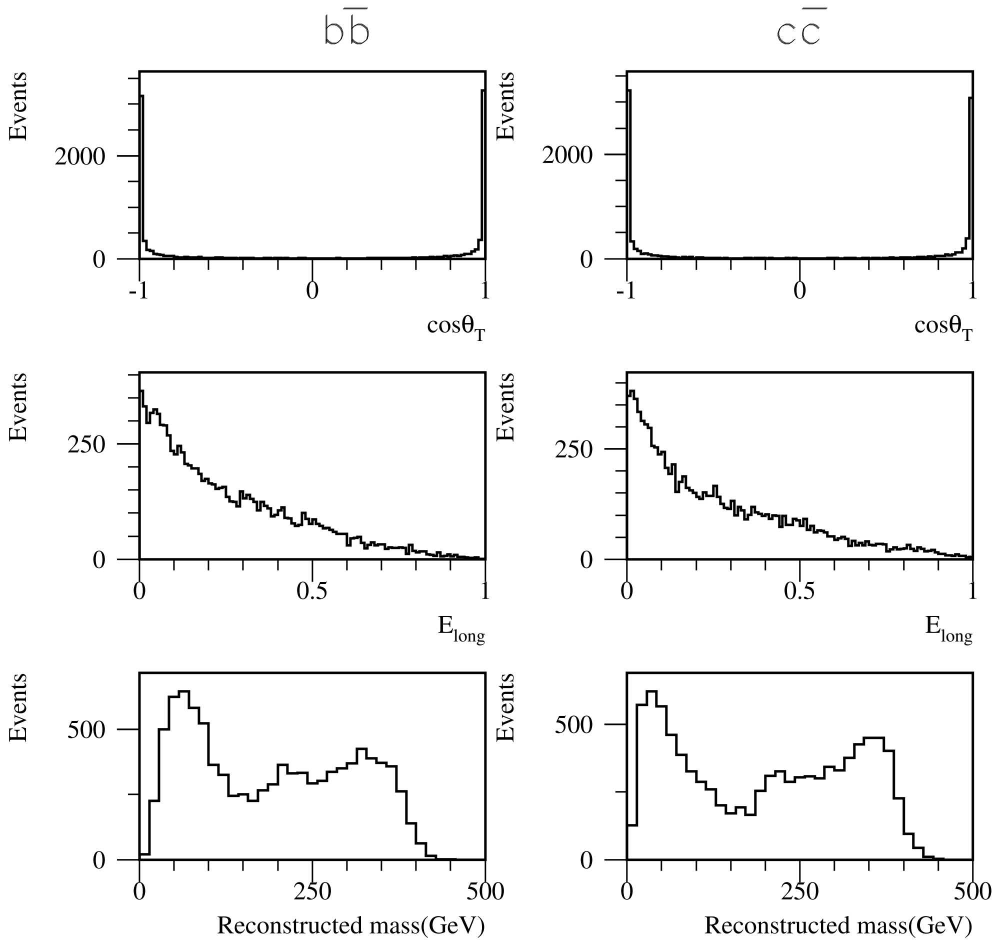

Fig. 3: *Trust cosinus, longitudinal energy imbalance and reconstructed mass for background*

For computing the total width of the Higgs boson and the branching ratio of the process $H \rightarrow \gamma\gamma$ we used the program HDECAY.

2.3 Background

We also used PYTHIA 6.2 for generating the background. We considered the two most important background processes, *i.e* $\gamma\gamma \rightarrow b\bar{b}$ and $\gamma\gamma \rightarrow c\bar{c}$. For computing the background we run PYTHIA 6.2 in variable energy option.The thrust cosinus ($\cos\theta_T$) longitudinal energy imbalance (E_{long}) and reconstructed distributions of the background can be seen in Fig.3.

For computing the number of events expected we used the following formula:

$$N_{b\bar{b}/c\bar{c}} = \sigma \cdot \mathcal{L} \tag{3}$$

3 Results

It is easy to see differencies between signal and background distributions. The thrust cosinus for the signal has a isotropic distribution while for the background we have a peaked distribution in the pipe direction. The longitudinal energy imbalance for the signal is in the first chanels while for the background it has a long tail in the upper channels. The reconstructed mass distribution for the mass presents

Tab. 1: *Selection efficiency*

	$c\bar{c}$(%)	bb(%)	signal(%)
(++)	5.9	4.9	67.2
(+−)	1.5	1.3	−
(−+)	1.6	1.0	−
(−−)	0.3	0.3	−

a peak around 50 GeV due to the jets lost in the pipe. These lead us to use the following cuts in our analysis: $|cos\theta_T| < 0.7$, $E_{long} < 0.2$ and $M > 300$GeV. The efficiency of this selection can be seen in Tab. 1.

The expected number of events in one year for a total luminosity of $126.59 fb^{-1}$ (corresponding to energies above 300 GeV) is shown in Tab.2. The background number of events are computed by (3) with the mention that we have scaled down the cross section for the state (++) by a factor of 4. This is due to the fact that PYTHIA 6.2 does not give a good cross section for this state. The scaling factor we assumed to be the same as at 120 GeV. The signal number of events is computed by (1) where the parameters are given by HDECAY :

BR(H→ $b\bar{b}$)=0.2356

BR(H→ $\gamma\gamma$) $= 8.66 * 10^{-6}$

Γ_{tot}=1.142 GeV

At this stage of our work we have obtained the next result for the invariant mass of the Higgs boson compared with the $b\bar{b}$ (see Fig.4).

Hence we consider that we succed to do significant cuts of background making use only of 3 parameters.

4 Outlook

In future we have to compute more accurately the cross sections for the background events. In future we have also to consider that the A boson cannot be sepparedet from the H boson experimentaly. We have to study the distribution of more parameters both for the background and for the signal in order to make future cuts. Also we have to include into our analysis the b tagging in order to reduce the $c\bar{c}$ background.

Tab. 2: *Number of events*

	Luminosity($fb^{-}1$)	$c\bar{c}$	$b\bar{b}$	signal
(++)	101.5	564800	32100	178.4
(+−)	12.1	354600	22100	−
(−+)	12.0	352400	22000	−
(−−)	1.0	33500	2100	−
Total	126.6	1305300	78300	178.4

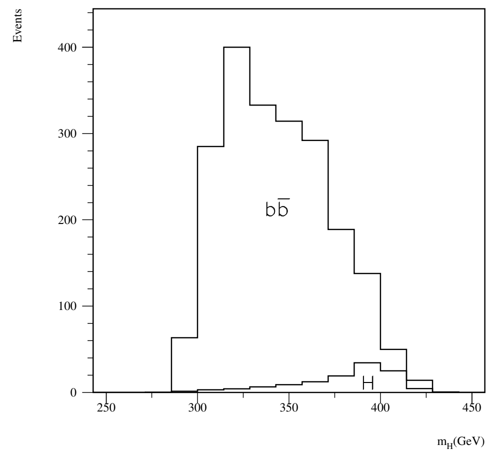

Fig. 4: *Invariant Mass Spectrum*

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