A Feasibility Study of Heavy Higgs boson detection by the $\gamma\gamma$ Collider at JLC

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Abstract

We studied a feasibility of Heavy Higgs boson detection. By use of **FULL JIM** detector simulator for JLC, the Higgs mass in this study is greater than 200GeV. The Higgs decay mode used is $H^0 \to Z^0 + Z^0 \to e^+ + e^- + q + \bar{q}$. The information we used mainly in this analysis is the Electro-Magnetic part and Hadronic part of the calorimeter. We found a efficiency of identification of Higgs boson to be 26% and background is smaller than 1/15 of signals.

1 Introduction

There are two simulator tools which have names of "JIM", which are FAST JIM[1] and FULL JIM[2]. FAST JIM is the simple simulator using the smearing algorithm, and FULL JIM is the FULL simulator which uses GEANT[3]. FULL JIM should be used for R&D for JLC detector studies in the future, so the features of FULL JIM are;

1. The whole system is working on UNIX system.
2. We can generate events in the system by switching.

$$\begin{aligned} e^+ + e^- &\to q + \bar{q}(u, d, s, c, b) \\ e^+ + e^- &\to t + \bar{t} \\ e^+ + e^- &\to H^0 + X \end{aligned}$$

   Furthermore we can put events into FULL JIM from outside.
3. An EVENT DISPLAY(fig1,2) is equipped in the system.
4. A speed to calculate one event is about 4 min/event (on HP9000/755)

In this paper, we analyzed a detection procedure of Higgs boson by FULL JIM.

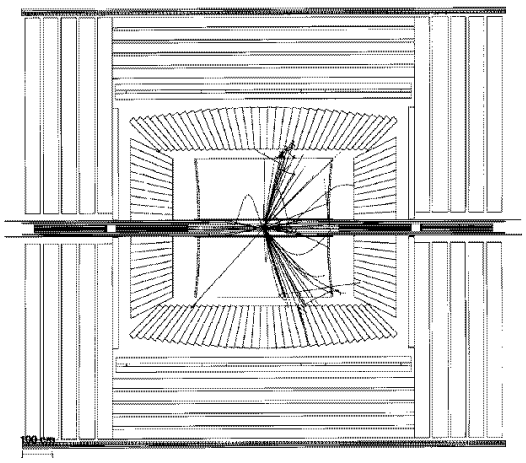

Figure 1: An event display(y-z plane) by FULL JIM($H^0 \rightarrow Z^0 + Z^0 \rightarrow e^+ + e^- + q + \bar{q}$).

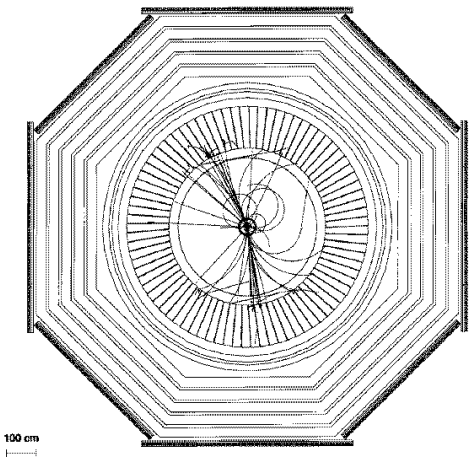

Figure 2: An event display in x-y plane of the same event shown in fig1

2 FULL JIM

FULL JIM consists of three main parts. They are the event generator, BANK system and GEANT. The event generator consists of PYTHIA and JETSET[4]. GEANT is a tool for the calculation of particle's interaction in the detector. Event generator and the GEANT exchange their data each other through the BANK system. A user must specify a number of events to generate, energy cut value for event display and others when the use starts FULL JIM. Outputs of FULL JIM are put in the BANK system as the calculated data. Then FULL JIM is started, GEANT is started up and calculates the detector geometry by the JLC-I detector parameters. Then, an event generated according to a user switch is put into the BANK system (when external events are used, events are fed to the BANK system at this moment). When GEANT gets the event from the BANK system, GEANT calculates the signals arisen from the detector in the event, and writes them to the BANK system.

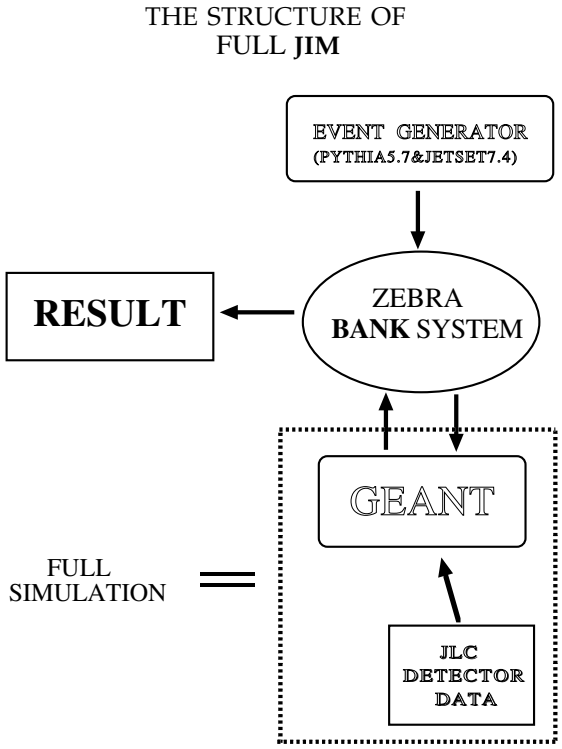

Figure 3: Structure of FULL JIM

3 Decay mode of heavy Higgs boson

This time we assume that Higgs mass is m_H=200Gev. We generated stationary Higgs bosons (we assume the Higgs bosons were generated by $\gamma\gamma$ collision (CMS=200GeV)). To reconstruct the Higgs boson, we use the Higgs decay mode $H^0 \to Z^0 + Z^0 \to e^+ + e^- + q + \bar{q}$. The use of $Z^0 \to e^+ + e^-$ decay mode makes the reconstruction of Z^0 bosons easy and simple. In this Higgs mass region, the $H^0 \to W^+ + W^-$ Higgs decay mode is dominating(fig4). But we can't use this decay mode, because the main background is $\gamma + \gamma \to W^+ + W^-$ and that cross

section is much larger than of the Higgs production. This time we made 5000 events of the Higgs decays. It took 4 days for that 5000 events generation and the amount of generated events is 1.2GB.

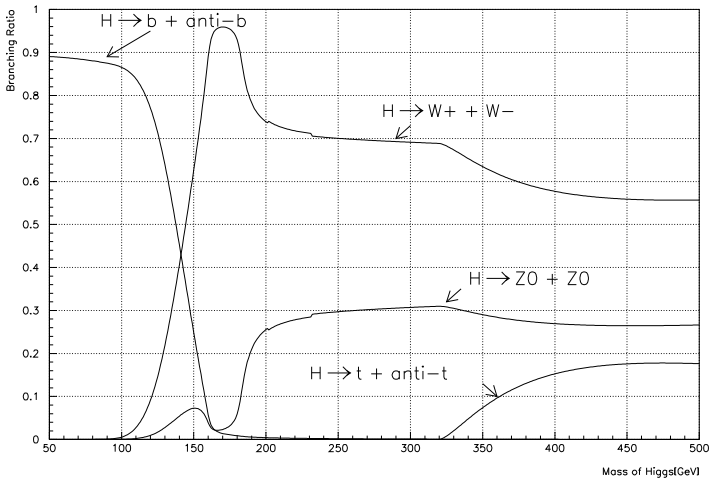

Figure 4: Higgs boson branching ratio

4 Z^0 reconstruction

The data we used for Higgs reconstruction are signals from electro-magnetic calorimeter (EM calorimeter), hadronic calorimeter (HAD calorimeter) and CDC (Central Drift Chamber). First we reconstruct Z^0 through $Z^0 \to e^+ + e^-$ decay mode. The deposit energy of $e^+(e^-)$ in the EM calorimeter is much larger than that in the HAD calorimeter. We required $e^+(e^-)$ to deposit it's energy in the EM and HAD calorimeter in that way. Then we make a corn (opening angle of 0.024str) whose direction is the EM calorimeter position the energy of $e^+(e^-)$ is found and we define that integrated energy in the corn is net $e^+(e^-)$ energy (E_{tot}),

$$E_{tot} = \int_{corn} E_{cal} ds$$

where E_{cal} is energy in the corn. Farther more we reconstruct Z^0 through $Z^0 \to q + \bar{q}$ decay mode. The deposit energy (>1.0GeV) of quark jets on the HAD calorimeter is much larger than that of the EM calorimeter. We required $q(\bar{q})$ to deposit it's energy in the EM and HAD calorimeter in that way. So we searched most energetic and 2nd energetic HAD calorimeter cluster should be more than 1.0GeV. A corn (opening angle of 1.298 str) is made and their energy is calculated. We take account of number of hits on the CDC. The CDC has 100 layers, single stable particles like $e^+(e^-)$ has about 100 hits on CDC, quark jet has much over 100 hits.

We generated 58 signal events ($H^0 \to Z^0 + Z^0 \to e^+ + e^- + q + \bar{q}$) to Z^0 reconstruction, and got fig5. Then we generated 4942 background events, and got fig6. In fig6, number of events misidentified as $H^0 \to Z^0 + Z^0 \to e^+ + e^-$ is 426.

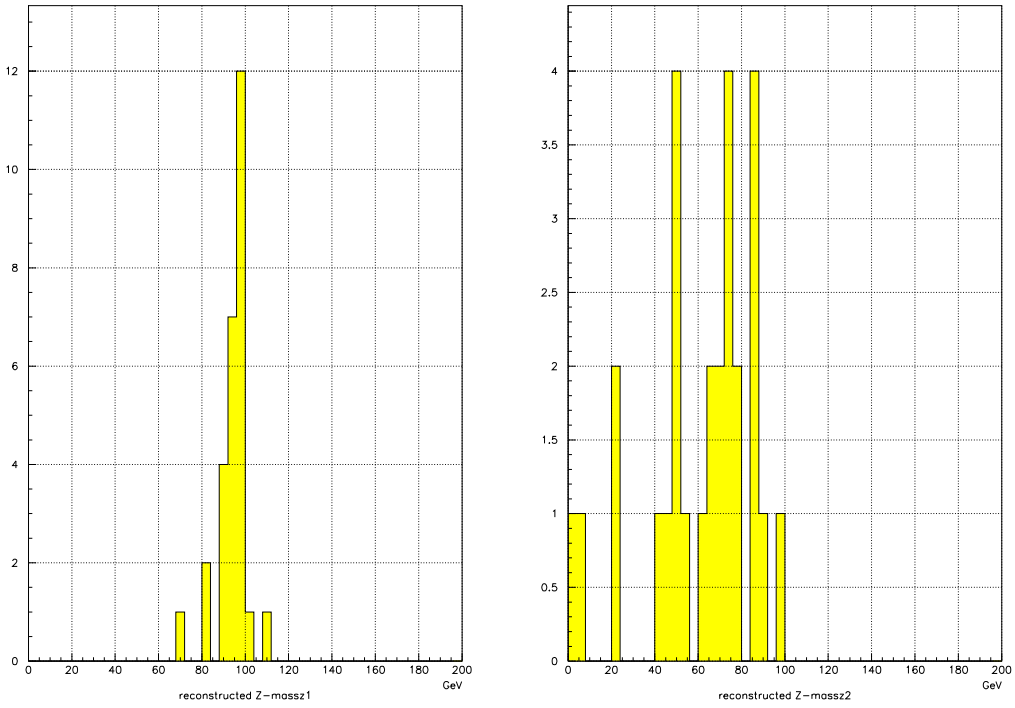

Figure 5: Signal event reconstruction. Left plot shows reconstructed Z^0 from electron. Right one shows that from quark jets.

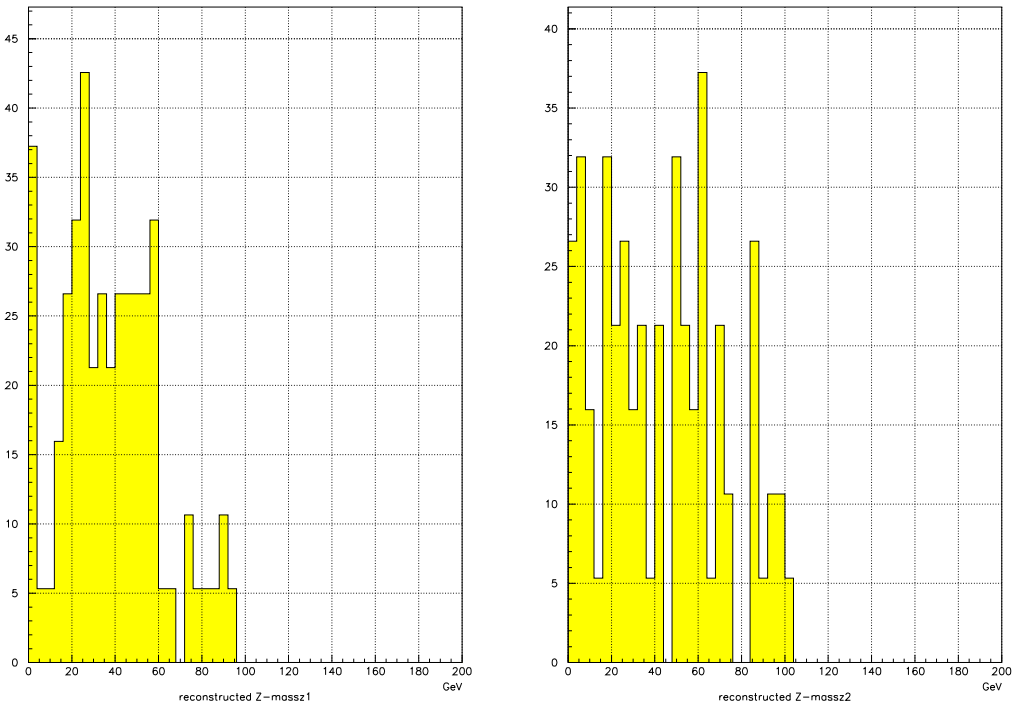

Figure 6: Background event reconstruction. Left plot shows misreconstructed Z^0 from electron. Right one shows that from quark jets.

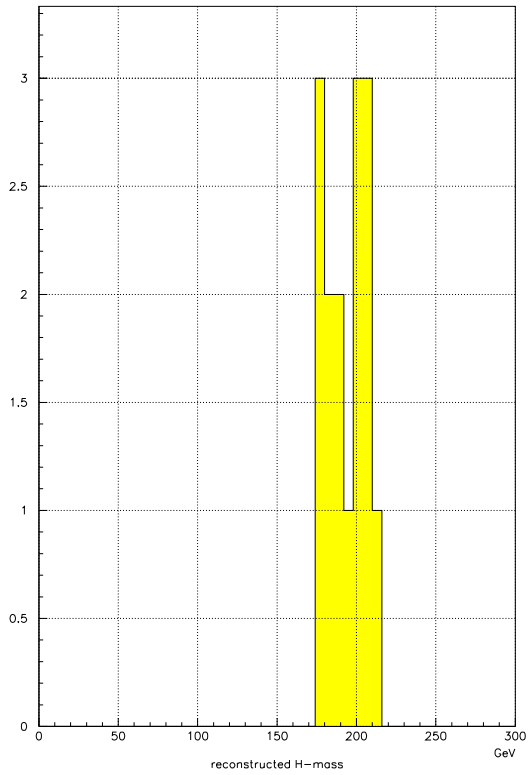

Figure 7: H^0 reconstruction after Z^0 mass cut.

5 H^0 boson reconstruction

For a Higgs boson reconstruction, we set conditions on reconstructed Z^0 bosons. The conditions are $80 \leq m_{Z^0} \leq 100$GeV for Z^0 which decay to $e^+ + e^-$, $63 \leq m_{Z^0} \leq 120$GeV for decay to $q + \bar{q}$. We reconstruct Higgs bosons from those Z^0 bosons in signal events, and got fig7. In fig7, there are 15 entries and all entries are $H^0 \to Z^0 + Z^0 \to e^+ + e^- + q + \bar{q}$ events. After setting condition, there are no Z^0 boson candidates from the background event. In the following table, results are summarized.

m_H	193 ± 12 GeV
Eff	26%
BGR	under 1/15 of signals

m_H : reconstructed Higgs mass
Eff : Efficiency of Higgs reconstruction
BGR : Background ratio

6 Conclusion

According to various simulations, total luminosity of $\gamma\gamma$ collider is 10 fb^{-1}/yr[6]. We can estimate number of Higgs boson we can reconstruct from this luminosity and our result.

$$N=390/yr$$

It follows from what has been said that the study of heavy Higgs boson can be executed in $\gamma\gamma$ collision in JLC.

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