HIGGS AT JLC PHASE-I

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Higgs physics at JLC phase-I at $\sqrt{s}$=250–500 GeV is reviewed. Situation of Higgs boson searches at present and in near future towards the JLC experiment is also introduced.

The Higgs boson is the key to open the future generation of the particle physics. The couplings and their evolutions of Higgs are significantly sensitive to the fundamental structure of interaction and contents of particles up to GUT scale. There are strong indications that the mass of the lightest Higgs boson is lower than 250 GeV where the first phase of JLC project (E_{cm} =250–500 GeV) covers very well. The indirect measurements at LEP/SLC/Tevatron give an upper mass bound of about 200 GeV at 95% CL [1] for the SM Higgs. In the MSSM, the mass of the lightest CP-even Higgs must be lower than 150 GeV, and even in more general scheme in SUSY the bound does not exceed 210 GeV [2] assuming the finite Higgs coupling up to GUT scale.

So far the experimental lower mass bound of the SM Higgs is around 110 GeV and about 90 GeV for the MSSM Higgs (h^0, A^0) at 95 % CL obtained at LEP-II [1]. The LEP-II this year is sensitive to Higgs with mass up to 115 GeV for the SM-like Higgs. Although the remaining time is limited in the current LEP running schedule, the recent LEP preliminary results may indicate the Higgs at around 113–115 GeV [1]. In the LEP combination, we observed a 2.6σ excess there from background expectation, which is consistent with the SM Higgs yield. Here we do not describe the detail of the observation, but apparently we need at least double the statistics to discuss the Higgs existence from scientific point of view. This situation will become clearer by the publication of this document since CERN has already decided to extend LEP running by one month. If the observation goes further to a signal side, CERN might extend LEP running more. Tevatron run2 in the following years has search potential to the SM Higgs up to higher than 120 GeV with 3σ significance provided the integrated luminosity exceeds 10 fb^{-1} per experiment. Hence even if LEP stops running in this year, LEP and Tevatron combination would yield more than 5σ discovery in several years, if Higgs is around 113–115 GeV. The best way to clarify the situation would be to extend LEP running next year. Final decision may come from CERN on November this year. At forthcoming LHC, there are varieties of channels in the SM and MSSM in which we have enough discovery potential in wide mass range, while the detectable channels are limited due to huge backgrounds in the *pp* collisions, and also the production yield could be much lower if nature is further beyond the MSSM.

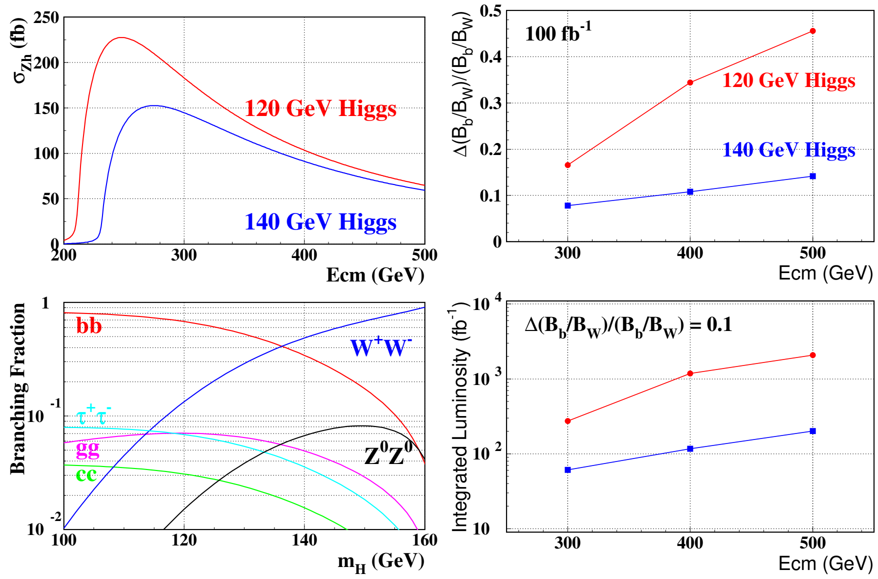

Figure 1. (Left) Production cross-section (for M_H=120 and 140 GeV) as a function of $\sqrt{s}$ and decay branching ratio of the SM Higgs: (Right-top) expected measurement error in $Br(h^0 \to b\bar{b})/Br(h^0 \to W^+W^-)$ for 120 and 140 GeV SM Higgs as a function of $\sqrt{s}$. Luminosity of 100 fb^{-1} (roughly one year JLC running) is used (plot by I.Nakamura): (Right-bottom) necessary luminosity for measurement of $Br(h^0 \to b\bar{b})/Br(h^0 \to W^+W^-)$ to achieve 10% error which correspond to 5% error in Yukawa-coupling strength for down-type quarks.

At JLC, with the clean experimental environment of the e^+e^- collision and with the design luminosity, we have enough sensitivity even to the worst case with the lowest cross-section in models. The physics background processes which have event topologies similar to those of Higgs signals have cross-section just one or two orders of magnitude higher than the signal. The most severe backgrounds are the W and Z-pair production, for which the precise prediction of the background has been established. The Higgs discovery itself is relatively easy at JLC provided that we establish luminosity of order of 10^{34} $cm^{-2}s^{-1}$ at $\sqrt{s} = 250 - 500$ GeV. We need only "one day" running to discover the SM-like Higgs [3], which is extremely different situation from other experiments like LHC. One can say, in other words, it is really a "big discovery" when we find no Higgs at JLC. And our purpose of the experiments at JLC is not only to judge the existence of the light Higgs, but also to measure the Higgs properties precise enough if it exists. We would measure the cross-section and the branching ratio in percent order or less in its error at JLC based on more than 10^5 Higgs events in a few years running (see fig 1 left), which results in the precise measurements of the Higgs gauge coupling and Yukawa-coupling, and furthermore derivation of Higgs self-couplings in multi-Higgs production. Varieties of discoveries are yet waiting for us. For instance, if $\mathrm{Br}(\mathrm{h}^0 \to \mathrm{b\bar{b}})/\mathrm{Br}(\mathrm{h}^0 \to \tau\tau)$ is found to be different from m_b^2/m_τ^2, all models belonging to SM or type-II 2HDM, such as SUSY models, are excluded (Note that the precise running mass of b-quark is to be provided from theoretical side). If the measured cross-section is smaller than the minimum cross-section [2] expected in SUSY models, it means new physics further beyond SUSY between EW and GUT scale. When we combine the $\mathrm{Br}(\mathrm{h}^0 \to \mathrm{W}^+\mathrm{W}^-)$ with the measured cross-section σ_{h^0}, the total width of the Higgs Γ_{h^0} can be deduced by a simple equation; $\Gamma_{\mathrm{h}^0} = \Gamma^{\mathrm{SM}}_{\mathrm{h}^0} \times \frac{\mathrm{Br}^{\mathrm{SM}}(\mathrm{h}^0 \to \mathrm{W}^+\mathrm{W}^-)}{\mathrm{Br}(\mathrm{h}^0 \to \mathrm{W}^+\mathrm{W}^-)} \times \frac{\sigma_{\mathrm{h}^0}}{\sigma^{\mathrm{SM}}_{\mathrm{h}^0}}$, where $\Gamma^{\mathrm{SM}}_{\mathrm{h}^0}$ is the total width for the SM Higgs and $\sigma^{\mathrm{SM}}_{\mathrm{h}^0}$ is the production cross-section for the SM Higgs. In a similar manner, the absolute strength of the Higgs Yukawa-couplings to fermions can be deduced in a model independent fashion from measured cross-section and $\mathrm{Br}(\mathrm{h}^0 \to \mathrm{f\bar{f}})/\mathrm{Br}(\mathrm{h}^0 \to \mathrm{W}^+\mathrm{W}^-)$. Fig 1 right plots shows the sensitivity expected at JLC for the measurement of the Yukawa-coupling strength. All of those, which are expected to be done only with the next $\mathrm{e}^+\mathrm{e}^-$ Linear Collider, are essential to give definite answers to physics models and to determine the fundamental structure of the interaction in nature up to GUT scale. Obviously, the future Linear Collider is the best and necessary project in order to definitely answer the question whether we live in SUSY world or SM-like world, or completely new unexpected world.

References

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