PROCEEDINGS OF SCIENCE

Radiative corrections for Higgs study at the ILC

Kiyoshi Kato[*]
Kogakuin University, Nishi-Shinjuku 1-24, Shinjuku, Tokyo 163-8677, Japan
E-mail: `kato@cc.kogakuin.ac.jp`

F. Boudjema

LAPTH[†]*, BP.110, Annecy-le-Vieux F-74941, France*

J.Fujimoto, T.Ishikawa, T.Kaneko, Y.Kurihara, Y.Shimizu

High Energy Accelerator Research Organization(KEK), Tsukuba, Ibaraki 305-0801, Japan

Y.Yasui

Tokyo Management College, 625-1 Futamata, Ichikawa, Chiba 272-0001, Japan

One of the most important goals of the International Linear Collider (ILC) experiments is the detailed study of Higgs particle. With the high-statistics data from devoted efforts by experimentalists, precise theoretical calculations are mandatory. The full electroweak radiative corrections require the large scale computation, so that the use of automated system for the perturbative computation is essential. Most of the radiative corrections for the important channels are already calculated for $e^+e^- \to ZH$[1], $\nu\bar{\nu}Z$[2, 3], e^+e^-H[4], $t\bar{t}H$[5, 6, 7], ZHH[8, 9]. Here, radiative corrections to a final 4-body state, $e^+e^- \to \nu\bar{\nu}HH$, is presented[10]. This channel is important for the study of Higgs potential in the high energy region. The calculated weak correction in G_μ scheme is small, less than 5% for $W > 600$GeV. In order to confirm the results, we have made the comparison between ZHH channel and $\nu_\mu\bar{\nu}_\mu HH$ channel, and also the estimation of the weak correction by assuming the dominance of $W^+W^- \to HH$ mechanism.

As one of the indispensable tools for the high-energy physics, the development of automated systems is another important item. Two new features in the `GRACE` system, the precision control and the factorization, are introduced. The former works to stabilize the numerical evaluation, and the latter accelerates the computation of matrix elements.

International Europhysics Conference on High Energy Physics
July 21st - 27th 2005
Lisboa, Portugal

---

[*] Speaker.

[†] URA 14-36 du CNRS, associée à l'Université de Savoie.

http://pos.sissa.it/

1. The results for $e^+e^- \to \nu\bar{\nu}HH$

The full electroweak radiative correction is done for the process $e^+e^- \to \nu\bar{\nu}HH$ by `GRACE` system for one-loop[11]. The input parameter set for the calculation is as follows: $M_W = 80.4163\text{GeV}$, $M_Z = 91.1876\text{GeV}$, $\Gamma_Z = 2.4952\text{GeV}$, $M_H = 120\text{GeV}$, $m_t = 180\text{GeV}$, $W = 2E_{beam} = 400 \sim 2000\text{GeV}$, $k_{cut} = 0.05E_{beam}$. The width of the Z only appears at the resonant poles. We have computed the radiative correction factor from the full set of electroweak one-loop diagrams and add the soft-photon correction factor to cancel the fictitious photon mass used for the regularization of infrared singularity. The QED factor, $\delta_{QED} = 2\alpha/\pi\left[(\log(s/m_e^2)-1)\log(k_{cut}/E_{beam}) + 4/3\log(s/m_e^2) + \pi^2/6 - 1\right]$, is subtracted to define the genuine weak correction, δ_W. The correction in the so-called G_μ-scheme, δ_W^G, is calculated by the value of $\Delta_r = 0.022674$.

The results are shown in Fig.1. The calculation is done by the extensive use of the `GRACE` system for the automated evaluation of Feynman diagrams. Since it is the large scale calculation, i.e., the number of tree(one-loop) diagrams is 12(3416) even if one neglects the scalar-electron couplings, the computation is checked by several methods built-in the system, including the UV and IR divergence cancellations, the invariance on the non-linear gauge[11, 12] parameters, and so forth.

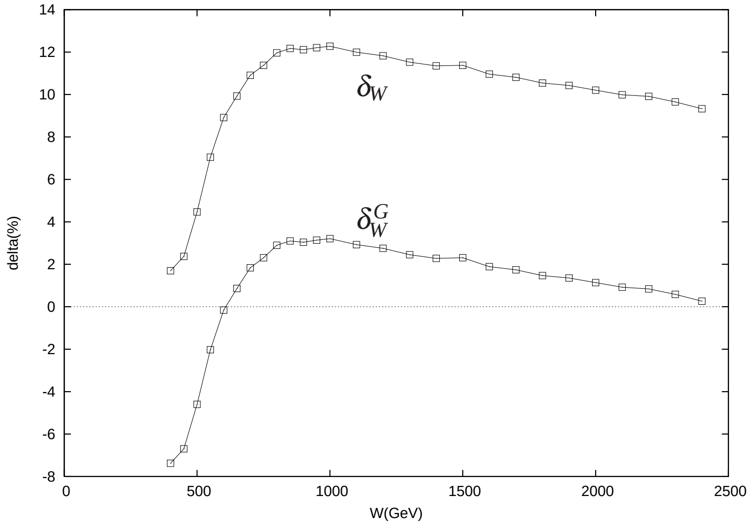

Figure 1: Energy dependence of the electroweak corrections, δ_W, for $e^+e^- \to \nu\bar{\nu}HH$. The lower curve is for those in G_μ-scheme.

In Fig.2, the electroweak radiative corrections for $e^+e^- \to \nu_\mu\bar{\nu}_\mu HH$ are shown. The process is dominated by the s-channel contribution which is similar to the process $e^+e^- \to ZHH$ studied in [8]. Though there is slight difference in the input parameter (mass of top quark), the values and the energy dependence of δ_W^G are similar. This consistency is another proof of the present computation.

In the high energy region, the t-channel mechanism, the WW-fusion, appears to be dominant. We have calculated the radiative correction for $W^+W^- \to HH$ as shown in Fig.3. The distribution of $M(HH)$, the invariant mass of Higgs pairs, can be obtained from the tree $e^+e^- \to \nu\bar{\nu}HH$. The convolution of the $\delta_W(WW \to HH)$ with the tree $M(HH)$ spectrum gives an approximated δ_W

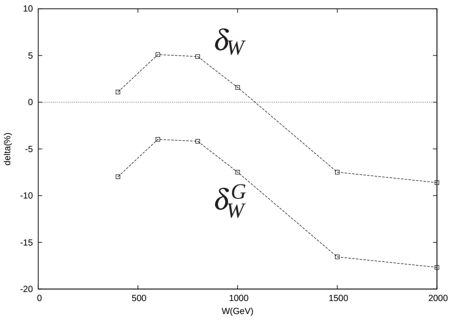

Figure 2: Energy dependence of the electroweak corrections, δ_W, for $e^+e^- \to \nu_\mu \bar{\nu}_\mu HH$. The lower curve is for those in G_μ-scheme. The lines are only for guiding.

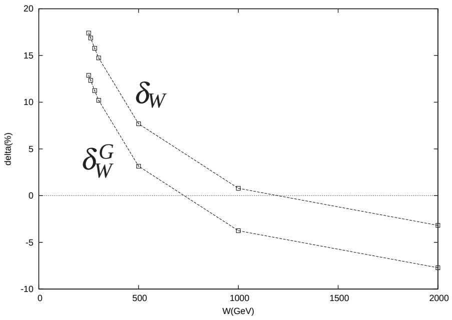

Figure 3: Energy dependence of the electroweak corrections, δ_W, for $W^+W^- \to HH$. The lower curve is for those in G_μ-scheme. The lines are only for guiding.

for $e^+e^- \to \nu\bar{\nu}HH$. For $W > 1$TeV, this convolution reproduces the value shown in Fig.1 within 1%. Taking into account of the fact that W's are spacelike off-mass-shell in $e^+e^- \to \nu\bar{\nu}HH$, this approximation proves that the result in Fig.1 is correct.

2. Recent development in `GRACE`

As is shown in the last sections, the large scale computation for the radiative corrections can only be possible by an automated system for the quantum field theory. The results already shown spawned from `GRACE` system[13]. In the followings, recent development in the system is briefly described.

(1) Precision control

The numerical computation always has a serious defect, i.e., the loss of accuracy due to numerical instabilities. An example is the Gram determinant that appears in the reduction of 5- or 6-point functions into the sum of lower point functions. Since the measure is infinitesimally small in the phase space region where the Gram determinant is zero, the zero should not affect the physical results. However, it appears as the problem in the practical computation because the number of digits for the computer calculation is limited. This defect can be eliminated if we perform the numerical computation with enough number-of-digit accuracy. We have developed the HMlib library for the high-speed multiprecision computation by the collaboration with Hitachi Ltd. Some examples are show where the conventional code gives a wrong value while the library calculates the value with enough accuracy.

(2) Factorization

Sometimes it is claimed that the computation of the cross section based by the Feynman diagram method is slower than that by the non-diagrammatic approach based on the Schwinger-Dyson equations[14]. This short can be improved when the repeated computation of the same function, a part of the amplitude, is avoided. The Feynman diagrams can be classified into subsets which have a common subdiagram in each subset. The iterated classification gives the optimized code, so that the computation time is accelerated. In the electroweak theory, the rate of acceleration is drastic and sometimes exceeds 100 for several processes.

3. Conclusion

The most of the one-loop full electro-weak radiative corrections for the Higgs production at the ILC have been completed including the tedious one, $e^+e^- \to \nu\bar{\nu}HH$, whose cross section is $O(100\text{ab})$ and δ_W^G is less than 5% for $W > 600\text{GeV}$.

The comparison between $e^+e^- \to \nu_\mu\bar{\nu}_\mu HH$ and $e^+e^- \to ZHH$, and the approximation using $W^+W^- \to HH$ are done to check the radiative corrections for $e^+e^- \to \nu\bar{\nu}HH$.

Two new developments are reported in the automated system, `GRACE`.

Acknowledgments

This work was supported in part by the Japan Society for Promotion of Science under Grant-in-Aid for Scientific Research B(No.14340081). This research is carried out under the auspices of Automated Calculations in Particle Physics (ACPP) - an International Research Group unit comprised of researchers from France, Russia and Japan (GDRI 397 of the French CNRS). We also thank IDRIS, *Institut du Dévelopement et des Ressources en Informatique Scientifique*, for the use of their computing resources.

References

[1] A. Denner, J. Küblbeck, R. Mertig, M. Böm, Z.Phys. C56 (1992) 687; B.A. Kniel, Z.Phys. C55 (1992) 605. See also, J.Fleischer, F. Jegerlehner, Nucl.Phys. B216 (1983) 469.

[2] G. Belanger, F. Boudjema, J. Fujimoto, T. Ishikawa, T. Kaneko, K. Kato, Y.Shimizu, Phys.Lett. B559 (2003) 252.

[3] A. Denner, S. Dittmaier, M. Roth, M. M. Weber, Nucl.Phys. B660 (2003) 289.

[4] F. Boudjema, J. Fujimoto, T. Ishikawa, T. Kaneko, K. Kato, Y. Kurihara, Y. Shimizu, Y. Yasui, Phys.Lett. B600 (2004) 65.

[5] G. Belanger, F. Boudjema, J. Fujimoto, T. Ishikawa, T. Kaneko, K. Kato, Y. Shimizu, Y. Yasui, Phys.Lett. B571 (2003) 163.

[6] You Yu, Ma Wen-Gan, Chen Hui, Zhang Ren-You, Sun Yan-Bin, Hou Hong-Sheng, Phys.Lett. B571 (2003) 85.

[7] A. Denner, S. Dittmaier, M. Roth, M.M. Weber, Phys.Lett. B575 (2003) 290.

[8] G. Belanger, F. Boudjema, J. Fujimoto, T. Ishikawa, T. Kaneko Y. Kurihara, K. Kato, Y. Shimizu, Phys.Lett. B576 (2003) 152.

[9] Zhang Ren-You, Ma Wen-Gan, Chen Hui, Sun Yan-Bin, Hou Hong-Sheng, Phys.Lett. B578 (2004) 349.

[10] Preliminary results were reported by Y.Yasui in ECFA 2004 at Durham, Sept. 2004.

[11] G. Belanger, F. Boudjema, J. Fujimoto, T. Ishikawa, T. Kaneko, K. Kato, Y.Shimizu, hep-ph/0308080 (2003).

[12] F. Boudjema, E.Chopin, Z.Phys. C60 (1996) 757.

[13] J.Fujimoto, to be published in the Proceedings of ACAT05(2005); T.Kaneko *ibid.*.

[14] F. Caravaglios, M. Moretti, Phys.Lett. B358 (1995) 332; F. Caravaglios, M.L. Mangano, M. Moretti, R. Pittau, Nucl.Phys. B539 (1999) 215.