KA–TP–16–96
May 1996

HIGGS PARTICLES*

Conveners:

A. Djouadi[1,2], H.E. Haber[3], P. Igo–Kemenes[4], P. Janot[5] and P.M. Zerwas[1]

Working Group:

A. Arhrib[6], T. Binoth[7], E. Chopin[8], V. Driesen[2], W. Hollik[2], C. Jünger[2], J. Kalinowski[9], W. Kilian[1], B.R. Kim[10], M. Krämer[1], G. Kreyerhoff[10], G. Moultaka[6], S.K. Oh[11], P. Ohmann[12], J. Rosiek[2] and J.J. van der Bij[7].

[1] Deutsches Elektronen–Synchrotron DESY, D-22603 Hamburg, Germany.

[2] Institut für Theoretische Physik, Universität Karlsruhe, D-76128 Karlsruhe, Germany.

[3] Physikalisches Institut, Universität Heidelberg, D-6900 Heidelberg, Germany.

[4] Santa Cruz Institute for Particle Physics, University of California, Santa Cruz, CA 95064, USA.

[5] PPE Division, CERN, CH–1211, Geneva 23, Switzerland.

[6] Physique Mathématique et Théorique, E.S.A. du CNRS N° 5032, Université Montpellier II, F–34095 Montpellier, France

[7] Albert–Ludwigs–Universität Freiburg, Fakultät für Physik, Hermann–Herder–Strasse 3, D–79104 Freiburg, Germany.

[8] Laboratoire de Physique Théorique ENSLAPP B.P.110, 74941 Annecy-Le-Vieux Cedex, France

[9] Institute of Theoretical Physics, Warsaw University, PL–00681 Warsaw, Poland.

[10] III Physikalisches Institute A, RWTH Aachen, D–52056 Aachen, Germany.

[11] Institute for Advanced Physics, Kon–Kuk University, Seoul 143–701, Korea.

[12] Department of Theoretical Physics, Oxford University, OX1 3NP Oxford, UK.

* To appear in the Proceedings of the Workshop *Physics with e^+e^- Linear Colliders*, Annecy–Gran Sasso–Hamburg, Feb. 4 – Sept. 1, 1995, P.M. Zerwas (editor).

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Introduction and Summary

A. Djouadi[1,2] and P.M. Zerwas[1]

[1] Deutsches Elektronen–Synchrotron DESY, D-22603 Hamburg, FRG.

[2] Institut für Theoretische Physik, Universität Karlsruhe, D-76128 Karlsruhe, FRG.

The search for scalar Higgs particles and the exploration of the mechanism which breaks the electroweak symmetry, will be one of the major tasks at future high–energy e^+e^- colliders. In previous studies it has been shown that e^+e^- linear colliders operating in the energy range $\sqrt{s} \sim 300$ to 500 GeV with a luminosity of $\int \mathcal{L} \sim 20$ fb^{-1} are ideal machines to search for light Higgs particles.

In the Standard Model (SM) the Higgs mass range $M_H \lesssim 200$ GeV is easy to cover at these energies. This intermediate Higgs mass range is one of the theoretically most favored ranges, allowing the particles to remain weakly interacting up to the GUT scale $\Lambda \sim 10^{16}$ GeV [a prerequisite for the perturbative renormalization of the electroweak mixing angle from the GUT symmetry value 3/8 down to the experimentally observed value at low energies]. The search of intermediate-mass Higgs bosons can be carried out in three different channels: the Higgs–strahlung process $e^+e^- \to ZH$ and the fusion mechanisms $WW/ZZ \to H$. The cross sections are large and the properties of the Higgs boson, in particular spin–parity quantum numbers and couplings to gauge bosons and fermions, can be thoroughly investigated, allowing for crucial tests of the Higgs mechanism.

In the Minimal Supersymmetric Standard Model (MSSM) the Higgs sector is extended to three neutral scalar and pseudoscalar particles h/H, A and a pair of charged particles $H^\pm$. The lightest Higgs boson h has a mass $M_h \lesssim 140$ GeV and can be detected in the entire MSSM parameter space either in the Higgs–strahlung process, $e^+e^- \to hZ$, or by the complementary mechanism of associated production with the pseudoscalar particle, $e^+e^- \to hA$. Moreover, there is a substantial area in the MSSM parameter space where the heavy Higgs bosons can be also found; for a total energy of 500 GeV this is possible if the H, A and $H^\pm$ masses are less than 230 GeV. Similar to the SM, various properties of these Higgs bosons can be investigated.

Higher energies are required to sweep the entire mass range of the SM Higgs particle, $M_H \lesssim 1$ TeV. The high energies will also be needed to produce and to study the heavy scalar particles in extensions of the SM, such as the MSSM, if their masses are larger than ~ 250 GeV. Masses of the heavy Higgs bosons in this range are suggested by grand unified supersymmetric theories. In e^+e^- collisions, these experiments can be performed in the second phase of the colliders with a c.m. energy up to 1.5 to 2 TeV. In this report, we analyze the potential of a 1.5 TeV e^+e^- linear collider, with an integrated luminosity of $\int \mathcal{L} \sim 200$ fb^{-1} *per annum* to compensate for the drop of the cross sections at high energies. We will study the heavy Higgs particles in the Standard Model, in the minimal supersymmetric extension and in other more speculative scenarios.

In the Standard Model, the main production mechanisms of Higgs particles, $e^+e^- \to HZ$ and $e^+e^- \to \nu\bar{\nu}H/e^+e^-H$, will be discussed and the cross sections, including the interference between the Higgs–strahlung and the fusion processes, will be given [2]. The double Higgs production process, in which the trilinear Higgs coupling can be determined [therefore leading to the first non–trivial test of the Higgs potential], will be discussed in Ref.[3]. Finally, possible effects of New Physics beyond the SM on production cross sections and angular distributions of Higgs bosons, will be summarized in Ref.[4]. Consequences of a model in which the Higgs boson interacts strongly with scalar singlet fields in a hidden sector, are described in Ref.[5].

Subsequently, we will investigate the properties of the heavy Higgs particles in supersymmetric extensions of the SM. We will restrict ourselves first to the minimal extension which is highly constrained, parameterized by only two free parameters at the tree–level: a Higgs mass parameter [generally the mass the pseudoscalar Higgs boson M_A] and the ratio of the vacuum expectation values of the two doublet fields responsible for the symmetry breaking, tgβ, which in grand unified supersymmetric models with Yukawa coupling unification is forced to be either small, tg$\beta \sim 1.5$, or large, tg$\beta \sim 50$.

The various decay modes of the heavy CP–even Higgs boson H, the pseudoscalar boson A and the charged Higgs particles $H^\pm$ will be analyzed in Ref.[6], in particular the decays into supersymmetric particles, charginos, neutralinos, squarks and sleptons. The production of the heavy Higgs particles, primarily through the channels $e^+e^- \to HA$ and H^+H^-, will be also discussed in Ref.[6] and the complete one–loop electroweak radiative corrections of the cross sections will be summarized [7,8]. We will finally discuss the multiple production of the SM and the light MSSM Higgs bosons in Refs.[9,10]. Some of these processes will allow us to determine the fundamental Higgs trilinear couplings.

A brief discussion of the Higgs sector in the next–to–minimal supersymmetric extension of the Standard Model, Ref.[11], concludes this report.

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