Chapter 2

Detector for the Linear Collider

General Detector Concepts and Detector Performance

Conveners: M. Martinez, D.J. Miller, M. Piccolo

Working Group: A. Andreazza, M. Battaglia, G. Blair, G. Daskalakis, A. Juste, A. Kyriakis, C. Markou, H.U. Martyn, H. Nowak, I. Riu, M. Sachwitz, H.J. Schreiber, D. Schulte, R. Settles, R. Shanidze, C. Shepherd-Themistocleous, S. Shichanin, E. Simopoulou, R. Vuopionperä, C. Troncon

Detector Subsystems

Conveners: M. Mazzucato, D. Saxon, R. Settles

Working Group: S. Aïd, A. Andreazza, P. Bambade, T. Barklow, W. Bartel, M. Battaglia, R. Bellanzzini, S. Bertolucci, G. Blair, R. Brinkmann, I. Brock, R. Brown, J. Bürger, P.J. Bussey, M. Caccia, P. Checchia, G. Coignet, P. Colas, P. Clarke, C. Damerell, M. David, A. De Roeck, E. Elsen, E. Fernandez, Y. Giomataris, T. Greenshaw, R. Heuer, C. Heusch, N. Holtkamp, P. Hüntemeyer, P. Janot, L. Jönsson, F.P. Juster, B.J. King, F. Kircher, V. Korbel, U. Kötz, Y. Kurihara, P. Le Du, M. Leenen, W. Lohmann, C. Luci, L. Mandelli, M. Martinez, C. Meroni, J. Meyer, D. Miller, R. Nahnhauer, O. Napoly, R. Nania, R. Orava, M. Piccolo, M. Pohl, D. Reed, F. Richard, A. Rousarie, H.-G. Sander, U. Schneekloth, H.J. Schreiber, S. Schreiber, D. Schulte, C. Shepherd-Themistocleous, F. Simonetto, K. Sinram, A. Skillman, A. Sopczak, P. Steffen, H. Steiner, J. Steuerer, G. Tonelli, M. Tonutti, C. Troncon, C. VanderVelde, G. Vegni, A. Wagner, N. Walker, M. Weber, W. Wiedenmann, G.W. Wilson, K. Zapfe-Düren

Collider-Experiment Interface

Conveners: N. Holtkamp, M. Leenen, O. Napoly

Working Group: G. Bardin, R. Brinkmann, C. Cavata, S. Drozhdin, J.-P. Jorda, N. Mokhov, M. Sachwitz, H.J. Schreiber, S. Schreiber, D. Schulte, R. Settles, K. Sinram, N. Walker, K. Zapfe-Düren

Contents

2.5 Conclusion on Particle Physics and Experiments

The search for the fundamental constituents of matter and their interactions has led to a coherent picture of the structure of matter. This picture is known as the Standard Model. It encompasses the matter particles, leptons and quarks, classified in three families with identical symmetries. Their electroweak and strong interactions are successfully described by gauge theories in which the forces are carried by so called gauge bosons. These features are well established experimentally. A third component of the Standard Model is the still hypothetical Higgs mechanism through which the masses of the particles of the Standard Model may be generated.

This Standard Model has been tremendously successful in predicting the properties of new particles and the structure of their interactions. In many of its facets it has been tested to better than 1 %. However, no direct evidence for the Higgs mechanism has yet been seen.

Despite these important successes the Standard Model cannot be considered to be the ultimate theory of matter but rather as an empirical description of a part of physical reality which is itself part of a larger picture yet to be discovered. In the Standard Model none of the fundamental parameters, the masses and couplings or the symmetry patterns are derived from elementary principles but must be put in from observation. Furthermore, gravity, the interaction responsible for the large scale structures in the universe, is not included in the Standard Model. An ultimate theory should be able to predict the masses and couplings of all particles from one or a very few basic principles and it should include gravity in such a way that the evolution of the world from the time of the "big bang" to the present can be understood in detail.

Two strategies can be followed to gain insight into the physics beyond the Standard Model. First, the particles and forces of the Standard Model must be affected by the interactions at higher energies. Precision measurements can thus provide clues to this physics. Second, if the energies available in the laboratory are high enough to cross the thresholds, the new phenomena may be seen directly and thoroughly studied. These are the primary reasons for any new accelerator for particle physics research.

For several years the physics potential of a future Linear Collider has been studied in considerable detail. This work has been summarized in Chapter 1. Key elements of the research are the detailed study of the top quark, the understanding of the dynamics of the electroweak gauge bosons, the search for Higgs particles, and the search for signals of a more comprehensive and fundamental theory. Here, the next generation of colliders is certain to uncover striking new phenomena of fundamental interest. In comparing the physics programme of the LHC proton-proton collider and the e^+e^- collider, it became clear that their roles are complementary and both will be needed for a robust description of Nature that can extend far beyond the Standard Model of today. There exists a significant overlap in their capabilities but neither can gather the complete picture alone.

In Chapter 2 a high performance detector is presented which is needed to realize the full particle physics potential of the linear collider. Detailed studies have shown that a large, general purpose detector, incorporating the basic design features of typical e^+e^- collider detectors would provide the necessary performance and be able to deal with event and background rates associated with the projected luminosity.

The most essential components of such a detector are a very high resolution tracking detector close to the interaction point to measure the decays of short lived particles, a high resolution, large solid angle tracking detector to measure the topology and momenta of all charged particles, a high-field solenoid to provide the necessary magnetic field volume and bending power, a calorimeter to measure the energy and direction of neutral particles and to detect possible missing energy, and a segmented iron return yoke with embedded tracking detectors. While most of these features exist in current e^+e^- collider detectors, the challenge is to make them work at much higher energies and in the background environment characteristic of a linear collider. To meet this challenge intense R&D work is needed in a number of areas, such as high resolution solid state pixel detectors. Extensive work has gone into the study of all possible sources of background and methods to protect the experiment from it. In order to assess the physics capabilities of the detector, a few reference reactions have been analyzed in detail. It was found that the performance is fully adequate for the processes which were studied so far.

In conclusion, it should be emphasized that already today an experiment can be designed which would allow the full exploitation of the rich physics potential of a linear collider. Nevertheless, further research and development is needed to arrive at an optimized, robust technical design and an even better understanding of the physics reach.

LC DETECTOR GROUP: ADDRESSES

S. Aïd [15], A. Andreazza [22], P. Bambade [24], G. Bardin [14], T. Barklow [29], W. Bartel [15], M. Battaglia [16], R. Bellanzzini [12], S. Bertolucci [11], G. Blair [30], R. Brinkmann [15], I. Brock [7], R. Brown [10], J. Bürger [15], P.J. Bussey [13], M. Caccia [21], C. Cavata [14], P. Checchia [25], G. Coignet [2], P. Colas [14], P. Clarke [19], C. Damerell [10], G. Daskalakis [3], M. David [14], A. De Roeck [15], S. Drozhdin [9], E. Elsen [15], E. Fernandez [4], Y. Giomataris [14], T. Greenshaw [18], R. Heuer [12], C. Heusch [28], N. Holtkamp [15], P. Hüntemeyer [15], D. Jackson [29], P. Janot [24], L. Jönsson [20], J.-P. Jorda [14], A. Juste [14], F.P. Juster [4], B.J. King [31,15], F. Kircher [14], U. Kötz [15], V. Korbel [15], Y. Kurihara [17], A. Kyriakis [3], P. Le Du [14], M. Leenen [15], W. Lohmann [32], C. Luci [27], L. Mandelli [21], C. Markou [3], M. Martinez [4], H.U. Martyn [1], M. Mazzucato [25], C. Meroni [21], J. Meyer [15], D.J. Miller [19], N. Mokhov [9], R. Nahnhauer [32], R. Nania [6], O. Napoly [14], H. Nowak [32], R. Orava [16], M. Piccolo [11], M. Pohl [33], D. Reed [12], F. Richard [24], I. Riu [4], A. Rousarie [14], M. Sachwitz [32], H.-G. Sander [21], D. Saxon [13], U. Schneekloth [15], H.J. Schreiber [32], S. Schreiber [15], D. Schulte [15,a], R. Settles [23], R. Shanidze [32], C. Shepherd-Themistocleous [15,a], S. Shichanin [32], F. Simonetto [25], E. Simopoulou [3], K. Sinram [15], A. Skillman [19], A. Sopczak [32], P. Steffen [12,15], H. Steiner [5], J. Steuerer [15], G. Tonelli [26], M. Tonutti [1b], C. Troncon [22], C. VanderVelde [8], G. Vegni [22], R. Vuopionperä [16], A. Wagner [15], N. Walker [15], M. Weber [1b], W. Wiedenmann [23], G.W. Wilson [15], K. Zapfe-Düren [15].

---

[1]I. Physikalisches Institut, RWTH Aachen, Physikzentrum, D–52056 Aachen; [1b]III. Physikalisches Institut, RWTH Aachen, Physikzentrum, D–52056 Aachen; [2]Laboratoire d'Annecy le Vieux de Physique des Particules, LAPP, IN2P3-CNRS, BP-110, F–74941 Annecy-Le-Vieux CEDEX; [3]Institute of Nuclear Physics, NRCPS "Demokritos", GR–15310 Attiki; [4]I.F.A.E., Universidad Autónoma de Barcelona, E–08193 Bellaterra; [5]Lawerence Berkeley National Laboratory, USA–Berkeley, CA 94720; [6]Dipartimento di Fisica, Università degli Studi di Bologna, I–40126 Bologna; [7]Rheinische Friedrich-Wilhelms-Universität Bonn, Physik Inst., D–53115 Bonn; [8]Service de Physique des Particules Elémentaires, Univ. Libre de Bruxelles, B–1050 Bruxelles; [9]FNAL, Fermilab, P.O. Box 500, Batavia IL 60510; [10]Particle Physics, Rutherford Appleton Laboratory, Chilton, GB–Didcot OX11 0QX; [11]LNF, Istituto Nazionale di Fisica Nucleare (INFN), I–00044 Frascati; [12]CERN, CH–1211 Genève 23; [13]Department of Physics, University of Glasgow, GB–Glasgow G12 8QQ; [14]CE Saclay, F–91191 Gif/Yvette CEDEX; [15]DESY, Deutsches Elektronen-Synchrotron, D–22603 Hamburg; [16]Helsinki Institut of Physics, FIN–00114 University of Helsinki; [17]KEK, National Lab. for High Energy Physics, 1–1 Oho, Tsukuba-shi, Ibaraki-ken 305; [18]Department of Physics, University of Liverpool, GB–Liverpool L69 3BX; [19]Department of Physics and Astronomy, University College London, GB–London WC1E 6BT; [20]Physics Department, University of Lund, S–22362 Lund; [21]Institut für Physik, Johannes-Gutenberg-Universität, D–55099 Mainz; [22]Dipartimento di Fisica, Università degli Studi di Milano and INFN, I–20133 Milano; [23]Werner-Heisenberg-Institut, Max-Planck-Institut für Physik, D–80805 München; [24]LAL, Université de Paris–Sud, F–91405 Orsay Cedex; [25]Dipartimento di Fisica, Università di Padova, I–35131 Padova; [26]INFN, Sezione di Pisa, San Piero a Grado, I–56010 Pisa; [27]INFN, Sezione di Roma I and Dipartimento di Fisica, Università di Roma I "La Sapienza", I–00185 Roma; [28]Institute for Particle Physics, UC Santa Cruz, USA–Santa Cruz, CA 95064; [29]SLAC, Stanford University, USA–Stanford CA 94309; [30]Department of Physics, Royal Holloway and Bedford New College, University of London, GB–Surrey TW20 OEX; [31]Brookhaven National Laboratory, USA–Upton, NY 11973–5000; [32]Institut für Hochenergiephysik, DESY, D–15738 Zeuthen; [33]Labor für Hochenergiephysik, ETH, CH–8093 Zürich; [a]now at CERN.