A Proposal to Initiate Research and Development for a Vertex Detector at the Future e^+e^- Linear Collider

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Linear Collider Flavour Identification (UK) Collaboration
(LCFI Collaboration)

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Abstract

The LCFI Collaboration has been formed in order to study all aspects of heavy flavour identification at future e^+e^- linear colliders in the TeV energy region. Over several years of work it has become clear that this environment, characterized by multi-jet events potentially rich in new physics processes, will provide unprecedented opportunities and challenges for detectors in general, and for vertex detectors in particular. Fortunately, as already seen at SLC, the linear collider environment lends itself to extremely powerful pixel-based vertex detectors. The particular characteristics of the TeV-scale machine will permit an extremely small diameter beam-pipe at the interaction region. This, coupled with ongoing developments which will lead to even greater reduction in detector thickness, should permit the very high efficiency and purity for heavy flavour identification (charm and bottom quark jets) required to satisfy the most challenging physics requirements. These topics have been studied on paper since 1991. Meanwhile, the accelerator R&D has moved forward with impressive speed, so that a running machine by 2008-2010 now appears to be feasible. In order to build one of these adventurous detectors on the required timescale, it is now necessary to move from paper designs to detector R&D. We propose to set up two complementary test stations (one at Liverpool University and one at RAL) and to obtain a small supply of 'setup grade' CCDs with which to carry out the appropriate device and system studies. In addition, we propose to carry out mechanical studies, possibly using the ATLAS (UK) metrology system being set up for the measurement of SCT modules. The present request covers approximately three years, and comprises 2.6 SY of RAL Technology Department effort, plus an equipment budget of £127K, running costs of £5K per annum and £5K per annum travel. In parallel, we are discussing the design of custom CCDs suitable for the second phase of this project. It is hoped that this may be funded jointly with users in the astronomy community, where there is a considerably overlapping area of interest. Plans for design and production of detectors for specific experiments will follow after the formation of international collaborations 4 or 5 years from now. The present programme is aimed at establishing a proven base from which such detectors can be seriously proposed for physics at the startup of the new machine. We intend to maintain close contact with colleagues in Japan and the USA who are also beginning R&D in this area.

This document is organised as follows. In Section 1, we discuss briefly the physics goals, and indicate how these lead naturally to a number of challenging requirements for the vertex detector. The rather complex design issues, and implications for the overall detector R&D programme are discussed in Sections 2 and 3, in sufficient detail to explain the magnitude of the task to those readers needing the full picture. Those who prefer to omit these details are invited to skip to Section 4, where we summarise the short-term goals and describe the proposed test facilities, with cost estimates. The long term plans and overall schedule are outlined in Section 5, with brief conclusions in Section 6.

1. Introduction

1.1 Electroweak symmetry-breaking

The origin of electroweak symmetry-breaking (EWSB) is one of the most pressing issues in high energy physics today. Experimentally the focus is on searches for the Higgs boson, the single remaining missing component of the Standard Model (SM), as well as on searches for beyond-SM particles. The latter are predicted by various models which provide explanations for the observed EWSB, such as those based on Supersymmetry (SUSY) principles. Current searches will continue at LEP2, which will run through the year 2000, and will be continued and extended at the Tevatron Run II until the startup of the LHC. HERA will also be running in the same period and has discovery potential complementary to LEP and the Tevatron. The mass reach for, for example, the SM Higgs boson is expected to be about 120 GeV with these facilities. From 2006 onwards the LHC will spearhead these searches and will have a mass reach for many Higgs/SUSY channels up to ~1 TeV.

However, the global SM fits to world EW data imply, via radiative corrections, that the SM Higgs boson exists and has a mass below ~ 300 GeV at 95% C.L. The situation is hence analogous to that in the years just before the direct observation of the *W* and *Z* bosons at CERN: the data strongly imply that a (SM) Higgs is 'around the corner', or that, in its absence, there must be new dynamics that reproduces the role played by the SM Higgs in radiative corrections. The case for an e^+e^- collider 'Higgs factory', operating initially at c.m. energies in the range 300-500 GeV to exploit Higgs production via $e^+e^- \to HZ$, is hence very powerful. Furthermore, in addition to providing the capability for precision measurements of the Higgs production cross-section and decay branching ratios, such a facility would represent a 'factory' for production of $t\bar{t}$, W^+W^- and Z^0Z^0 events, allowing comprehensive studies of the heaviest particles now known. Finally, increasing the c.m. energy to 1, and ultimately 1.5 TeV, would give the e^+e^- collider a complementary 'discovery reach' to that provided by the LHC. The opportunity to have *both* the e^+e^- collider and the LHC operating in parallel, maximising our ability to search for, and measure precisely, new dynamics at the heart of EWSB, is very attractive for the advancement of our fundamental understanding of particle physics.

1.2 High energy e^+e^- colliders: current world view

In the past decade the proof of principle of e^+e^- linear colliders (LC) has been demonstrated by the ever-more-successful operation of the SLC at SLAC, which has (so far) delivered more than 0.5M Z^0 decay events to SLD. In parallel, a series of £10M-scale test facilities in Europe, the USA and Japan has demonstrated the feasibility of an e^+e^- collider with beam energies up to 0.5 TeV and luminosity in excess of $5\times10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. Novel ideas such as the two-beam accelerator offer a path towards even higher beam energies of 1 TeV or more.

A series of international LC accelerator workshops has taken place since 1988 and the proceedings document the enormous progress that has been made. Two viable RF technologies have emerged, based on X-band and superconducting cavities, and are being pursued by consortia centred around SLAC/KEK and DESY, respectively. In the USA the recent Gilman Panel report highlighted the X-band e^+e^- linear collider as a desirable future facility, and encouraged a vigorous phase of engineering R&D in collaboration with KEK. A similar process, supported by ECFA, is taking place for the DESY superconducting RF project, TESLA. In both cases engineering design reports will be presented to the respective funding agencies in 2001, with requests to initiate the funding process. The outcome of this process, as well as the timing, are impossible to predict a priori, but it seems likely that one e^+e^- linear collider will be approved, hopefully