Chapter 1

Project Overview

The JLC project is the post-TRISTAN high energy physics program recommended by the High Energy Committee in 1986. The project consists of the construction of a linear collider, and the experiments therewith, at an initial center of mass energy around 500 GeV which will eventually reach 1.5 TeV, along with successive machine upgrades[1, 2, 3]. The recommendation initiated a systematic R&D program, which has been producing many remarkable results. On the other hand, the recent precision measurements at LEP have greatly enhanced the importance of an e^+e^- linear collider to explore the energy region just above LEP II[4].

We propose the construction of JLC-I, which is an e^+e^- linear collider to cover the center of mass energy range of up to 500 GeV with a peak luminosity of 5×10^{33} cm^{-2}sec^{-1}, as the phase-I machine of the JLC project.

1.1 Physics

The main purpose of JLC-I is to discover and study the Higgs boson and the top quark, which are the two missing constituents of the Standard Model.

The most exciting possibility is the discovery of a Higgs particle with a mass less than 200 GeV. This mass range is particularly interesting from the viewpoint of grand unified models with the grand desert hypothesis, which naturally explain charge quantization, anomaly cancellation, strengths of the gauge interactions, *etc.* Moreover, the Weinberg angle $\sin^2\theta_W$, which has been precisely measured at LEP, agrees well with the prediction of its simplest supersymmetric extension originally introduced to solve the naturalness problem. Grand unified models with weak-scale supersymmetry predict at least one light Higgs boson, which cannot be missed at JLC-I with $\sqrt{s} = 300$ GeV.

If the weak-scale supersymmetry is indeed the case, JLC-I has a good chance to find heavier Higgs bosons as well as supersymmetric particles. JLC-I, being an e^+e^- collider, will provide a unique opportunity to carry out detailed studies of these particles and will possibly allow us to get insight into physics on the Planck scale.

On the other hand, if no Higgs boson exists within the reach of JLC-I, one is forced to abandon the weak-scale supersymmetry and simple grand unification scenario. The JLC-I project thus has the potential of guiding the future direction in particle physics.

The analysis results of precision electroweak measurements strongly indicate the existence of the top quark in the reach of JLC-I. The study of the top quark properties is a necessary step to establish and go beyond the Standard Model. The top quark has rich physics in itself distinct from the spectroscopy of other quarkonia. The strong coupling constant α_s can be measured with little ambiguity, since perturbative QCD is applicable to the threshold region. It is also possible to detect the Yukawa interaction. Furthermore, the accurate determination of its mass, possible only at an e^+e^- collider, will fix the radiative correction parameters. This enables us to look for new physics effects, when combined with the W- and Z-boson parameters to be precisely determined by JLC-I, making full use of its high luminosity and beam polarization.

The experiment at JLC-I will reveal the nature of the two missing constituents of the Standard Model. We believe that it will possibly probe the physics up to Planck scale and uncover the secrets of the creation and evolution of our Universe.

1.2 Starting the JLC-I Accelerator Construction

We consider here the technical feasibility of construction of the JLC-I accelerator. The key specification we impose upon the accelerator in its startup stage is to provide a 'bottom-line' luminosity of 5×10^{32} cm^{-2}sec^{-1} at $\sqrt{s} = 300$ GeV to achieve the initial physics goals.

The main linac was conceived to be of X-band, in which multi-bunched beams are accelerated at very high gradients. Therefore the key issues in the full scale R&D program started in 1987 have been to develop klystrons capable of emitting peak powers as high as about 100 MW and to experimentally verify high acceleration gradients as high as 100MV/m in linac structures, both of which were far beyond the state of the art of linac technology in 1987. Furthermore an accelerator test facility ATF was founded, where we first started to construct a test S-band linac, planning to later annex to it a test damping ring of extremely small beam emittances. All-around R&D studies have also been intensively carried for other topics such as electron/positron sources and final focus systems. In parallel with those studies, we have been making every effort to optimize parameters of the JLC for its various phases. Of particular concern is the RF frequency choice among S-, C-, or X-band for JLC-I, since the X-band technology is still in a developing stage. R&D work at overseas institutes such as SLAC, CERN, INP-Protovino/Novosibirsk and DESY has been more or less on similar lines and there have been frequent exchanges of informations between KEK and those institutes.

The results of the R&D work are very promising. We were able to achieve an output power of 41 MW for the X-band klystron, which is about the same level as achieved at SLAC and INP. Accelerating gradients well higher than 50 MV/m have been achieved successfully for S-band and X-band structures. A novel idea of the choke cavity was proposed which might play an important role to kill dangerous higher order modes in the mult-bunch operation. Those results suggest that we have caught up with the world-wide progress of key RF technologies. Hence it is fair to say that major technological difficulties have been basically resolved and we may be in a technically favorable position to propose the collider construction as far as JLC-I is concerned for which technological requirements are still not so stringent. There remain, of course, many difficult problems to be solved: attaining high reliability of various components, their mass production in the industry, system design of the whole accelerator complex, site problem, etc. The most important may, however, be that we can assert the JLC-I construction only on condition that we promote the international technical collaboration as before or more.

A very brief résumé about the present status of R&D work might be appropriate here in order to review the whole range of our activities.

Electron/positron sources: A large enough number of electrons is shown extractable from conventional thermionic gun. An RF gun with a laser triggered photocathode is successfully providing low emittance beams at a relativistic energy. World-record polarizations have been obtained by use of special crystal structures of gallium-arsenic alloys. A thorough simulation study has been carried out for positron production.

Damping ring with its injector: Construction of a test damping ring at the ATF is in preparation to verify the possibility of achieving very low emittances required for linear colliders. An S-band injector linac is being constructed to provide 1.5 GeV electrons.

X-band klystron: High power tests of the JLC XB-72K klystron are being carried on and a peak power of 41 MW has already been obtained. The beam power was as high as 234 MW which is just as large as that achieved at SLAC.

Accelerating structure: An acceleration gradient of 80 MV/m was obtained for conventional structures at both S- and X-bands. Basic studies for precision machining of structure components are intensely pursued with convincing results at the KEK machine shop. Simulation studies for damped structures and detuned ones are also providing affirmative results. The choke cavity, a new idea for damping higher order modes, has been proposed.

Final focus system: A achromatic line with a fairly large momentum acceptance has been designed. A couple of final quads which must provide precise field distribution in a very small aperture were manufactured successfully and will be tested at the FFTB facility of SLAC. The compton beam profile monitor which was proposed at KEK is being manufactured and will be tested at the FFTB too to survey the possibility of measuring beam sizes of nanometers. Careful simulation studies are continued to clarify the background noise problem at the interaction region.

Construction cost estimation: A resonable estimation of boring the tunnel is obtained. Regarding the machine cost, the R&D work described above is still limited to proof-of-principle studies for each components. The cost reduction critically depends on mass-production effects, which we have to pursue seriously henceforth.

The proposed JLC-I project is, in a sense, a pilot project for the entire JLC program. The project aims at exploring a new frontier of e^+e^- collider physics with a modest extension of technologies at hand. We believe that the construction of JLC-I is a necessary step for future TeV linear colliders.

Following the operation as an energy-frontier machine, JLC-I will remain active not only as a top factory but also, automatically, as a Z-factory(b-factory) and a W-factory with polarized beams and with a two-orders-of-magnitude higher luminosity than those of existing facilities.

Bibliography

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