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Plan of the Japan Linear Collider

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Abstract

This paper gives an outline of the Japan Linear Collider(JLC) project, especially JLC-I. The status of the various R&D studies is briefly presented. Finally, the status of the construction and design studies for the Accelerator Test Facility(ATF) is summarized.

I. INTRODUCTION

As one of the post-TRISTAN projects, the R&D of the JLC project was started from 1987 aimed at constructing the machine by the end of this century[1]. During the following five years the JLC R&D has been making remarkable progress and the studies are now shifting to the design of an advanced machine beyond the conceptual one[2]. It is presently expected that many sub-accelerator systems will reach the design goal within three years. The ATF has been designed to test the experimental feasibility of the many sub-accelerator systems. The ATF comprises a 1.54-GeV S-band injector linac, a damping ring, a bunch compressor, a positron generation system and a computer control system[3]. Construction of the ATF will be completed in 1996. KEK has also been a part of the international collaboration for the Final Focus Test Beam (FFTB) project of SLAC to focus a beam to $60nm$ in vertical beam size. Beam commissioning has recently started.

Many high-energy physicists have urgently requested the construction of an e^+e^- linear collider which can cover the center-of-mass energy range of 300 to $500GeV$ with a peak luminosity of $5 \times 10^{33} cm^{-2} sec^{-1}$, as the phase-I machine of the JLC project(JLC-I). We are thus investigating the technical feasibility to construct the JLC-I. The JLC-I is a necessary step toward future TeV linear colliders[4]. We hope to submit a technical design proposal for the JLC in 1996. Figure 1 shows the desirable time schedule of the JLC project based on our over-all R&D scenario.

II. RECENT STATUS OF THE JLC-I

The performance of the accelerator required in the startup stage of the JLC-I is to provide a 'bottom-line' luminosity of $5 \times 10^{32} cm^{-2} sec^{-2}$ at a center of mass energy of $300GeV$ so as to achieve the discovery of a Higgs particle. The key point of the JLC is to operate in a multi-bunch, flat-beam mode. In order to prevent beam break-up, a new concept of a damped accelerating cavity, named "Choke Mode Cavity", was proposed, which might play an important role in killing dangerous higher order modes(HOM) during multi-bunch operation[5]. We can fairly say that world-wide progress concerning key RF technologies has basically been achieved, and we may be in a technically favorable position to propose the JLC-I. In the Linear Collider Workshop of Emittance'93, a physicist from KEK proposed a single-stage bunch compressor scheme without Arc to simplify the complicated double-stage one which has the sections of $\sim 1500m$ Arc[6]. Figure 2 shows a schematic diagram of the JLC-I.

III. COMPONENT R&D AND DESIGN

A thermionic gun having a fast grid pulser for multi-bunch beam generation has been developed[7]. Multi-bunch electron beams of relativistic energies ($\sim 0.9MeV$) and comprising 175 bunches per pulse at an interval of $5.6nsec$ and 2.3×10^{10} electrons per bunch, have also been obtained by a laser-triggered RF gun. However, the lifetime of the cathode is now a few hours[8]. Polarized electron guns have also been developed in collaboration with a group from Nagoya University. The final target of the R&D is polarization higher than 80% and a cathode-lifetime of 1 week[9]. On the other hand, the JLC requires an intense positron source of 8×10^{11} particles per rf-pulse. A computer simulation has revealed the possibility of such an intense positron source using conventional technology, assuming that the beam loss is 50%[10].

The S-band RF components have almost been tested in the ATF linac. We have achieved a accelerating gradient of $84MV/m$ with a bunched beam. The S-band klystrons was developed so as to produce an RF peak power of $100MW$ for $1\mu s$ and $85MW$ for $4.5\mu s$ pulse duration. We designed an energy doubler(SLED) with two coupling irises. A stable peak power of $380MW$ was obtained from the SLED output for an input power of $80MW$ with a $4.5\mu s$ pulse width. R&D on the RF windows has been carried out with a resonant ring. It has been shown that alumina windows could be built to survive up to 310 MW of S-band RF power[11].

1.98-GeV damping rings have a normalized emittance of $\gamma\epsilon_x \leq 3.0\mu$radm and $\gamma\epsilon_y \leq 30$nradm. The damping times are $\tau_x \leq 6.13$msec and $\tau_y \leq 8.0$msec. All components of the damping ring will be tested in the ATF damping ring[12].

The X-band klystron generated a peak RF power of $79MW$ for $50nsec$ pulses[13]. A constant impedance disk-loaded structure was developed for a high-gradient experiment at X-band frequencies. By using the $30MW$ X-band klystron, the average accelerating gradient was obtained to be $85MeV/m$. Preliminary measurements of the cold model for the choke-mode cavity showed good damping properties, while maintaining a high-Q accelerating mode. A hot model of the S-band structure with a choke will be made and tested in the ATF injector linac. The technical R&D of machining and brazing has started for 1/4-scale structures of S-band frequency. The accuracy of machining for the diameter dimension is $\pm 4\mu m$ and for the off-center is less than $3\mu m$. The surface roughness was estimated to be on the order of $0.1\mu m$[14].

The design study of the final focus has almost been completed[15]. At present, the study is concentrating on the R&D of the quadrupole magnets, as well as the support and alignment system. An important issue is the resistive wake fields on the poles of the final quad. To avoid any beam breakup due to this effect, the aperture of the quad is made as large as

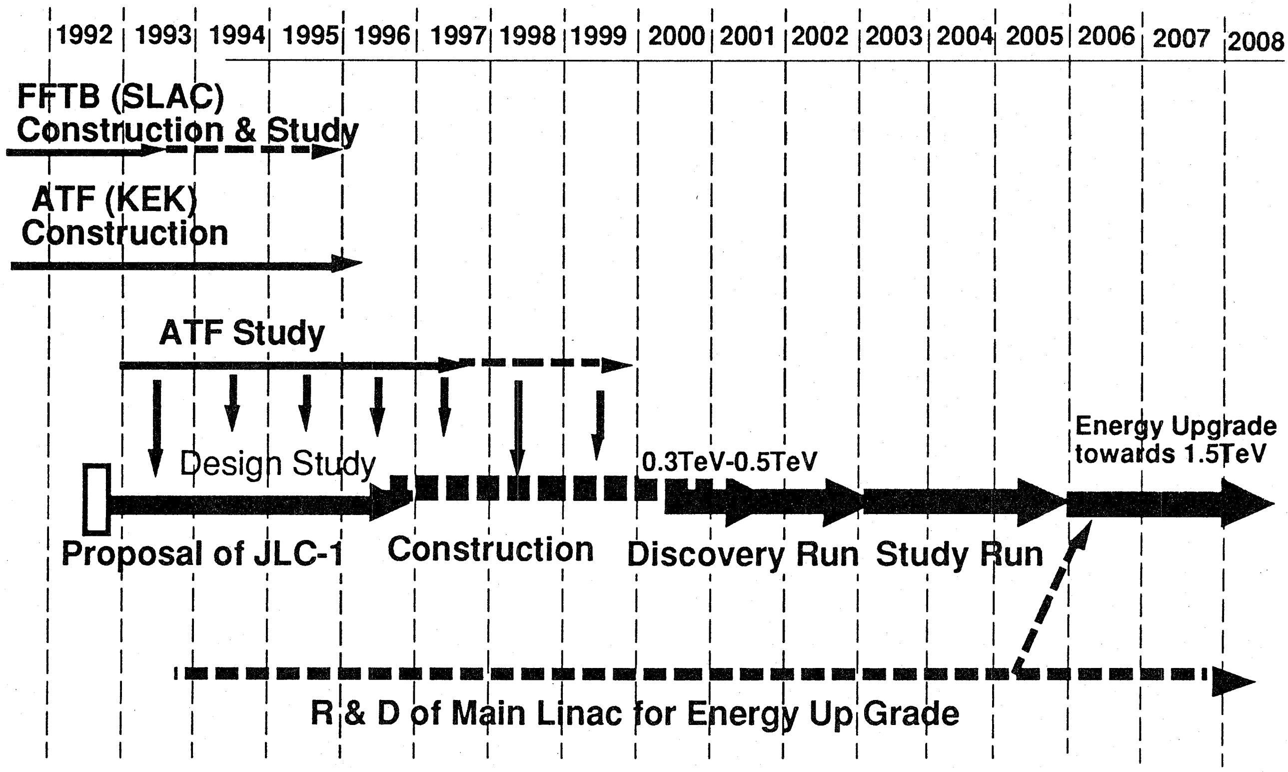

Figure 1. Time schedule of the JLC project.

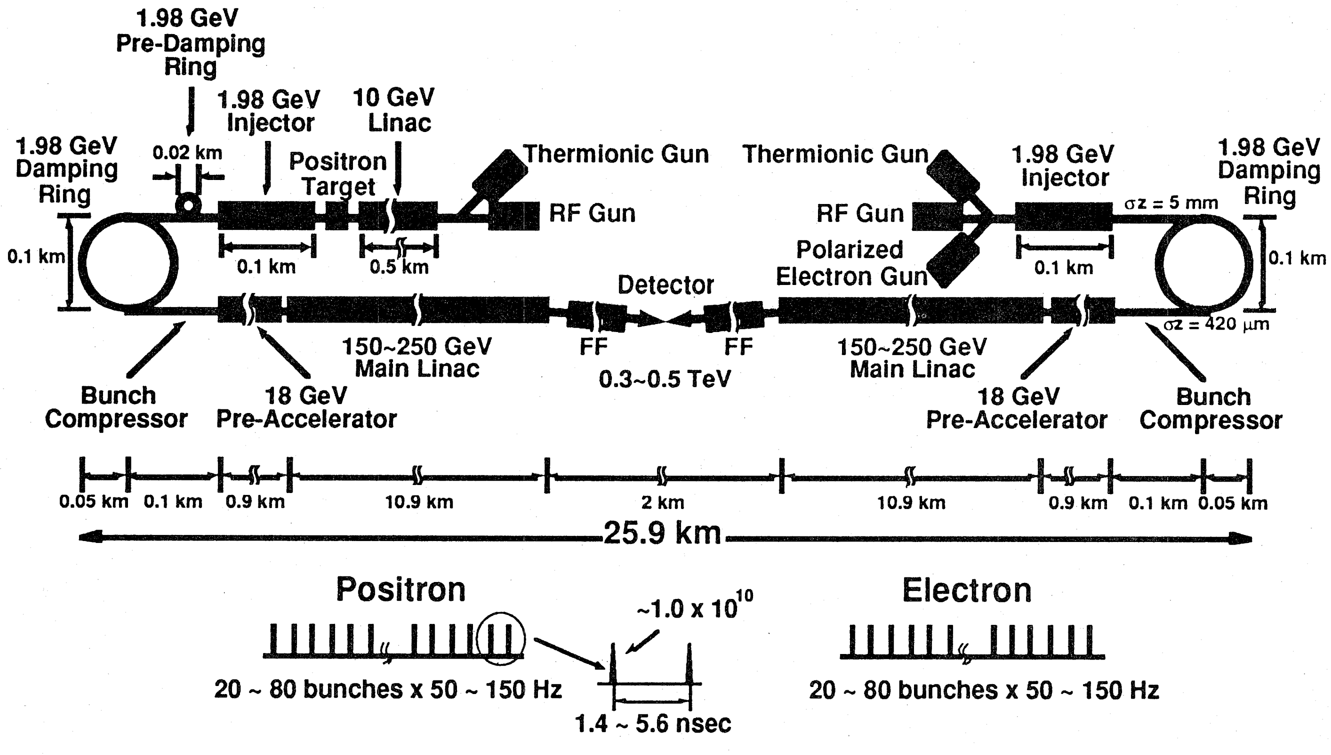

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Figure 2. Schematic Diagram of JLC-I.

6.6mm in diameter.

IV. ATF PROJECT AT KEK

The ATF is being constructed at KEK. The ATF has been designed to investigate the feasibility of the linear-collider operation scheme and to accumulate beam-control techniques for the linear collider. In the case of the best schedule, the ATF damping ring will be completed by the end of 1995.

We will use sixteen 3m-accelerating structures to accelerate electron multi-bunch beams up to $1.54GeV$, and two 3m-accelerating structures with a slightly different RF in order to compensate for any bunch-to-bunch energy spread of $\pm3\%$ due to multi-bunch beam loading until the energy spread is less than $\pm1.0\%$. The entire 1.54-GeV linac will be completed in early 1995.

The target values of the damping ring were chosen as follows: number of bunches per train, 20; number of trains, 5; number of particles per bunch, 1×10^{10}; maximum total current, 600mA; natural emittance, 1.2nradm; bunch length, 5mm; energy spread, 0.08%; normalized emittance with intra-beam, 5×10^{-6} and $5 \times 10^{-8} radm$. The results of a tracking simulation(SAD(KEK original code)) indicate that the dynamic aperture is sufficient for beam injection. Also, the tolerances of the quadrupole misalignment and rotational misalignment, the sextupole misalignment, the magnetic field error and the monitor setting error are less than $30\mu m$ vertically, $50\mu m$ horizontally, 0.5mrad rotationally, 0.1% and 0.1mm to obtain the required emittance, respectively.

The vacuum chamber design has been refined so as to reduce the impedance of the entire vacuum system, including the beam-diagnostic devices. Synchrotron photon absorbers are arranged so that they are not directly seen by the beam. The design value of the longitudinal impedance(0.1Ω) appears to be possible[16].

Instabilities caused by the higher-order modes will be suppressed by using a damped cavity and a bunch-to-bunch betatron tune spread of about 1×10^{-3} generated by an RFQ device. To ease the multi-bunch instabilities due to the wake of the rf cavities and a shift of the bunch positions due to beam loading, an rf freq. of 714MHz was adopted. A cold model of the RF cavities is now being tested. We will construct a hot model of the damped cavity in order to test the performance during the next year[17].

The support table has three legs with movers. Each leg has a vertical mover and a horizontal mover with a stepping resolution of $1\mu m$. All of the magnets in one normal cell are supported and firmly fixed by a table, which is 2.4m long and 1.0m wide.

Considering the transverse wake in the main linac, stabilization of the extracted beam from the damping ring is extremely important. In order to achieve this stabilization, we need to use a double kicker system, separated by a phase advance of π, in order to cancel the jitter. We have obtained an estimation of the jitter range as being from 10^{-4} to 5×10^{-4} on the double kicker system.

Development efforts are being made on beam instrumentation devices, such as wire scanners, beam-profile monitors, fast signal-processing electronics, beam-position monitors. The wire scanner and a few other new instruments were tested earlier this year in collaboration with a group from Tohoku University, using their electron linac facility[18]. A synchrotron radiation monitor to be used at the damping ring will be developed with a group at the Institute for Nuclear Study, University of Tokyo.

V. CONCLUSION

We have already achieved 5 years of R&D since our JLC study started in 1987. We are now proceeding in a new phase of R&D to construct the ATF and JLC-I. The immediate goal of the JLC development group is to construct the ATF and to demonstrate the feasibility of a multi-bunch flat beam with adequately low emittance.

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