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Plan

Asian Plan for the ILC Development in the Near Future

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1 Introduction

It is a general consensus among high energy physicists to build an electron-positron linear collider of the energy range up to about 1TeV as the next program after the LHC. It is also a general consensus that there should be only one linear collider of TeV range in the world. Two technologies for linear collider had been competing since more than 15 years ago. ICFA issued a statement in August 2004 during ICHEP at Beijing that the collider, now named ILC (International Linear Collider), is to be based on the superconducting technology. Following this statement, the first ILC workshop was held in November 2004 at KEK, where the remaining technological issues for the superconducting collider were discussed together with the organizational issues of international collaboration.

ILCSC published a report in March 2004 on the organization and timeline of the linear collider development, aiming at the machine completion in mid 2010's. According to the report, the world collaboration is to be coordinated by Central GDI (Global Design Initiative) with three regional GDIs (Asia, North America, Europe) under it. The GDI should complete the CDR (Conceptual Design Report) by the end of 2005 and the TDR (Technical Design Report) by 2007, envisaging the start of construction around 2009.

In the ILCSC meeting right after the workshop at KEK it was decided to hold the second ILC workshop in August 2005 at Snowmass in USA in parallel with the already scheduled physics workshop. There, the technical outlines of the CDR are to be essentially frozen such as the accelerating gradient, the number of tunnels (one or two), damping ring shape (dogbone or smaller ring), positron production scheme (conventional or undulator-based), and so on.

The purpose of this document is to summarize our present consideration towards the design and advanced-stage development efforts on the ILC, in the hope of facilitating accelerated collaborative efforts among the colleagues from Asia and from throughout the world.

2 Critical Research Areas

We would like to contribute to the world collaboration for the ILC putting emphasis on the following three fields.

(A) Establishment of the technology for accelerating gradient 35MV/m

(B) Pursuit of possible higher accelerating gradient

(C) Beam technology development using KEK-ATF

It is likely that the Snowmass workshop will adopt 35MV/m as the baseline accelerating gradient. The item (A) is to establish the industrial technology for this gradient. TESLA-TTF has proved the feasibility of 35MV/m. What has actually been done, however, was a test of a few individual cavities in vertical and horizontal cryostats and in addition a beam acceleration test of one cavity with other lower-gradient cavities in the same cryostat. It will still take some time before reaching the final design which is fit for industrialization. To this end we think we need an all-in-one facility for superconducting technology, albeit many considerations are needed concerning its scale and scope. We realize that TTF2 at DESY and SMTF at FNAL are currently being pursued for similar purposes in addition to STF. We believe that concurrent establishment of three regional test centers at this stage of development is much needed and should be supported for facilitating the build-up of regional research and industrial activities, which in the end will become our critical asset for constructing the ILC through a global collaboration.

It is desirable that the Central GDI (or something equivalent) coordinates the international collaboration in order to avoid excessive duplication of the R&D expenses. However, it will still take time for such an organization to become fully functional. It must also be taken into consideration that participation by industries of many countries plays an important role in large scale projects like ILC. Nurturing the industrial level of participating countries should also be within the scope of the coordination by the GDI.

The item (B) is to develop cavities for higher gradient and to establish related technologies. The electro-polished cavities of TESLA type can reach the maximum gradient around 40MV/m. If these cavities are to be used at 35MV/m in actual operations, the margin does not necessarily seem to be enough. It is more desirable to have a larger margin by using cavities that are durable under higher gradient. Another reason for higher gradient is the site length. The ultimate collision energy of the ILC will be 1TeV. To reach this energy by the gradient 35MV/m, a site longer than 45km is required. There are a few site candidates in Japan that satisfy this requirement but, if one takes into account other conditions such as access convenience, it is desirable to make the total length shorter than $\sim$40km by using higher accelerating gradient.

It has been pointed out that the maximum accelerating gradient is influenced by the surface treatment process and quality control. However, recent data seem to show that the present technology of electro-polished cavities is already reaching the theoretical limit of super-conductivity breakdown due to the surface magnetic field. Therefore, a development of cavity shapes different from TESLA type is necessary for exceeding the present values of the accelerating gradient. This is a very urgent subject because the baseline gradient will be decided in the Snowmass workshop. The completion of the whole technology associated with the new cavity by August 2005 is obviously impossible. What we aim at is that the possibility of a higher gradient is to be mentioned in the CDR and to establish the technology by the time of TDR.

In the following we adopt 45MV/m as the figure of the target gradient for the consistency of the document. The actually achievable value might be a little different. Also one should note that 45MV/m is the gradient for operation with the margin taken into account rather than the maximum gradient. The latter is somewhat higher.

The main linacs are of course the largest and the most cost-driving components in the ILC, but they are not everything. The item (C) aims at the establishment of beam handling technology needed for other components such as the damping rings and the beam delivery system, which also require advanced technologies. KEK-ATF is the only storage ring that can realize the beam emittance for the ILC. It was designed as a prototype damping ring for the linear collider with warm technology. It cannot be called the model damping for the cold technology by design, since the positron beam is not readily available and the space charge effects there is very weak. Nevertheless, since it is impossible to build a new prototype ring by the time scale of CDR/TDR, it is our duty to make use of full capabilities of the ATF. An extension of the ATF is desirable within the limited time and budget.

3 Facility Plans

With the critical research areas identified in the previous section, our specific plans are outlined below. The topics 3.1, 3.2 and 3.3 address the areas (A) and (B), while 3.4 and onward correspond to the area (C).

3.1 Test of 45MV/m at Existing Facilities

There are a few cavity shapes that are expected to give higher accelerating gradients. One of them, the reentrant type cavity, has already recorded 46MV/m (maximum gradient) in a single-cell testing at Cornell university in November 2004. This fact proves that a higher gradient is actually possible by choosing a proper cavity shape. However, handling issues may remain with surface rinsing and polishing in mass production due to its concaved cavity shape. As a better candidate of the cavity shape for higher gradient we choose the so-called LL (Low Loss) type designed at Jefferson Laboratory. The first step tests of 45MV/m LL cavities are being planned as

- Single-cell test in December 2004
- Vertical test of four 9-cell cavities in September 2005

All these can be done using existing facilities. The purpose of these tests is to give an impact to the CDR which is to be completed by the end of 2005. In case that we cannot obtain the expected performance in these tests, we will cancel the plan for 45MV/m in the following years and replace it with a slower plan aiming at possible usages in the far future, such as the second phase of ILC and other accelerator applications.

3.2 STF Phase 1

We are planning to build a facility STF (Superconducting RF Test Facility) in an existing building in KEK. The building itself has been used for the development of a proton linac of the J-PARC project and will be emptied by summer 2005. The basic purpose of the STF is the following.

- Establish the industrial technology for the linac unit (35MV/m and 45MV/m) ready for mass production.
- Promote industrial level of Asian region for the component production.
- Form a base station in Japan for international collaboration.
- Enlist and educate new human resources particularly the young scientists.

We divide the whole plan of STF into two phases. Phase 1, which is to be build in JFY2005 and 2006 (Japanese fiscal year starting in April), includes the following items:

- Fabricate a cryostat to accommodate the four 45MV/m 9-cell cavities mentioned in the previous subsection.
- Fabricate four TESLA-type 9-cell cavities (nominal 35MV/m) and a cryostat to accommodate them.
- Construct the RF power system and the cryogenic system needed for the simultaneous operation of the above two cryomodules. (These are mostly reuse components and will be prepared in the last quarter of JFY2004.)

- Create an electron beam source and the diagnostics devices for the beam test.

- Test the above system, including both 35MV/m and 45MV/m, by the end of JFY2006.

This phase will establish the feasibility for the gradient 45MV/m and will be the first step towards the industrial design. The Phase 2 is still needed for the full industrialization.

We consider that the electron beam is needed in this facility. By using a beam we can measure the higher modes excited by the beam, can check the alignment accuracy using these modes, and can develop beam monitors. In addition, if we have an intense beam of ∼10mA (full current of ILC), change of Lorentz detuning by the beam loading can be tested and the control of phase and amplitude variation can be established. Thus, we believe, using a beam we can establish various technologies at a relatively small amount of additional investment compared with that for the linac system itself. In the Phase 1 of the STF we are going to use a laser-driven DC gun which current will be somewhat lower than the full current of the ILC. An RF gun will be installed in later stages.

There is another subject for industrialization, namely the cost reduction, which is a key for the realization of ILC. The technologies of Nb/Cu clad cavity and seamless cavity are expected to bring about considerable cost reduction. The development of these technologies can be done in parallel with the program listed above. If the cavities produced by the conventional technology perform well and if the new technology of fabrication is completed separately, there will be no additional technology needed in combining the two.

We have a facility of electro-polishing which has been in use for many years and is by now substantially aged. We can still use this facility for the 8 cavities (35MV/m and 45MV/m) in Phase 1. For further production of electro-polished cavities, however, a drastic reinforcement of the facility is indispensable, regardless what actually goes with Phase 2. We plan to build a new facility in JFY2006. This facility will make it possible to electro-polish cavities produced abroad, too.

3.3 STF Phase 2

Phase 2 of STF is being scheduled in JFY2007 to 2009. What we are now thinking of as Phase 2 is:

- Three cryostats each containing 12 cavities of 35MV/m (or 45MV/m if its development is successful).

- Associated reinforcement of the RF power and refrigeration systems.

- Synthetic test of all the systems with the beam.

At of this writing, with the GDI yet to be launched, it is difficult to present a concrete plan of STF at this stage of development nor is adequate to do so, since the coordination of international tasks by the GDI will be functional by the time to design Phase 2 in detail. In any case, nevertheless, tests with a few long cryomodules with a beam will be necessary somewhere in the world for the completion of the TDR.

3.4 Studies Using ATF

- Beam dynamics studies such as the fast ion instability and the dynamic aperture in the presence of wigglers.

- Continuation of the R&D of diagnostics devices such as the laser wire and the cavity BPM.

- Stabilization and coupling correction of ATF extracted beam.
- Development and beam test of fast kickers. (It is also possible to test a kicker developed somewhere else.)

Although the ATF emittance is close to that for the ILC, the extracted beam is still fluctuating and the emittance is considerably larger than in the ring due to the x-y coupling. Stabilization and coupling correction are important issues for satisfying the ILC requirements. They are also indispensable for making use of the extracted beam for other study such as the development of diagnostics system.

The last item, fast kickers, is a particularly urgent issue. There are two different ideas on the damping ring, i.e., the so-called dogbone ring which has been studied for TESLA for many years and a small ring which does not share the tunnel with the main linac. The choice is going to be made in the Snowmass workshop in summer 2005. The small ring idea demands especially severe specifications. Obviously it is impossible to develop a kicker that satisfies all the requirements for the small ring by the time of the workshop. What is necessary by summer 2005 is to show a data that can convince us of the technology completion within additional few years. We are going to test a stripline kicker in this time scale. The test consists of kicking the stored beam (multiple bunches) and observing the oscillation of the bunches.

The development of fast kickers also has a longer-term purpose. A fast kicker will make it possible to get an ILC-type beam (bunch interval around 300ns) from ATF, which can be used for the development of various diagnostics devices. For this end several kickers are necessary for actually extracting the beam from the ring.

3.5 Extension of ATF

The ILC requires a collision of tightly focused beams with the height as small as 5nm (the first stage). Fundamental issues are whether we can produce such small sizes and maintain them for long time and whether we can stabilize the center-of-mass position of the two beams.

On the first issue, FFTB at SLAC succeeded in obtaining ~60nm beam by 1997. We can extend the extraction beamline from the ATF, which we tentatively call ATF2, to include a prototype of the ILC final focus system. In spite that the beam energy is factor 40 lower in ATF2 than in the FFTB, we expect to get a beam size ~35nm owing to the small emittance of the ATF. The improvement of the size from the FFTB is not quite remarkable compared with the ultimate ILC target 5nm. However, efforts to maintain the size for long period were not made in the FFTB.

For the second issue, i.e. the stabilization, the ILC requires an accuracy down to a few nanometer. The minimum beam size ~35nm expected in ATF2 is order of magnitude larger. Nonetheless, we can perform a stabilization test to a few nanometer using the 'nanoBPM' which is under development at the ATF.

In order for these studies to be useful, the extracted beam from the ATF must satisfy several requirements. The present emittance increase should be minimized, though this is not an absolute requirement. More important is the position jitter of the extracted beam. It must be less than $\sim 0.3\sigma$ (random components) for the demonstration of the small beam size and is even severer $\sim 0.05\sigma$ for the stabilization study.

When the stable extraction from ATF by fast kickers becomes ready, we can obtain an ILC-type beam (several bunches with the interval a few hundred nanosecond). With this beam we can perform tests of the bunch-to-bunch feedback system, which is indispensable for the ILC.

There are many accelerator and experimental physicists in the world who are interested in this plan. It is quite desirable that it is constructed by international collaboration in the sense both of manpower and budget. We hope the cost, except those for the floor construction and shielding, be shared by the three regions. If this be done, ATF2 will be a miniature of ILC with respect to the world collaboration.

Study items concerning ATF2 are not matters of CDR. In this sense they are not very urgent compared with CDR-related issues such as 45MV/m and kickers. It should also be in mind that the design work for the final focus system, except for a few parameters such as the crossing angle and the total length of the beam delivery section, will still continue even after the start of machine construction. Thus, studies after TDR can also have influence on the final beamline design. Training of beam tuning using ATF2 will also be useful for minimizing the actual commissioning period of the real machine.

3.6 Miscellaneous

There are a few individual items that are not included in (A)(B)(C) listed in Section 2, such as

- Target damage test in KEKB for positron production.
- Development of polarized electron gun.

There are two candidates for the scheme of positron production, the undulator-based method which has been investigated for TESLA and the conventional method by bombarding electron beam. The latter has an advantage of the absence of interference between electron and positron operations but a problem is the possible destruction of the target material. The abort beam from KEKB can be used for a test of target damage theory albeit the beam pulse length is short compared with the ILC beam (10μs vs. 1ms). This is one of the most urgent issues to be decided in summer 2005.

We have described our plan for the ILC project with the emphasis on the next two years. It will also be useful for understanding our stance to know what we are not thinking of or what we have eliminated or postponed since the initial plan.

The initial plan included a development of super-structure of 45MV/m cavity after the vertical test of 9-cell cavities. Thus, the cavities to be installed in the horizontal cryostat in this plan were 2 super-structures rather than 4 9-cell cavities. Since this process might cause a delay of the technology establishment though it potentially gives higher effective gradient and a lower cost, and since it requires a long cryostat for vertical test in the first step, we postponed it to a later stage. We think to get a 4-cavity cryomodule is more urgent than a super-structure. We shall later discuss which should have higher priority, super-structure or a cryomodule with more than 4 cavities.

There are two possible schemes for fast kickers, one is the stripline kicker, the other the so-called Fourier kicker. We decided to develop the former only, since we judged we would not be convinced by summer 2005 with the performance of the Fourier kicker in the real ILC damping ring even if the proposed program is successful.

We will not try to test a positron production nor to develop the related components, although we plan a test of the target damage as mentioned above because we cannot expect a significant contribution in this field within the required time scale.

4 Scope for International Collaboration

The proposed plans in this letter are aimed to be realized through fully international efforts. How successfully we collaborate strongly affects the rate at which how we boost the R&D and complete necessary design works towards TDR under GDI which will be founded soon. In this consideration from the perspective of the Asian team that the following three points are of particular relevance:

- On the basis of the recent past emittance performance of, and of its unique position as a facility entirely dedicated to development of the LC low emittance systems, ATF can continue playing a critical role in addressing numerous injector issues in the near future. In addition, with the extension into ATF2, the ATF can play a vital role in advancing the technologies required at the beam delivery and final focus systems. KEK is committed to maintaining this hardware complex for these applications. We would strongly like to invite active and creative participation in these programs by all in the world who are interested in any phases of the planning, construction, operation and analysis efforts.
- In the area of superconducting cavities, we would like to contribute to the world efforts by developing a solid fabrication and preparation technologies for the high gradient operation as well as by aggressively exploring cost reduction possibilities. Pending negotiations with interested parties, we may be able to deliver some number of cavity units to be tested overseas, in addition for those to be operated at STF. KEK is committed to developing ways to promote an international collaboration where critical technical information can be openly shared.
- In the area of STF Phase-1, while KEK has a reasonable pool of expert human resources, we consider it vital to invite a certain influx of technical and engineering information from our colleagues around DESY and elsewhere. This allows us to make a jump start which in turn would be sure to produce technical outcome that would help all who are involved in the world towards TDR and construction of ILC. Thus, we would like to bring attentions of all lab and community leaders in the world to the fact that very active exchanges of visitors in this area will be indispensable, and a world agreement on how to share and protect engineering information in both research and industrial sectors would be absolutely essential.

Through discussions that this document would hopefully initiate and with your valuable inputs we wish to start an active and productive international collaboration work as soon as possible and boost the design work towards CDR and TDR under GDI.

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