THE ASIAN REGIONAL PROPOSAL FOR A SINGLE-TUNNEL CONFIGURATION FOR THE CONVENTIONAL FACILITY

A. Enomoto, M. Miyahara, K. Hosoyama, S. Fukuda, S. Imamura, H. Itoh, Y. Sugimoto, T. Tauchi, and M. Yoshioka, KEK, Tsukuba, 305-0801, Japan

Abstract

The International Linear Collider (ILC) is an ambitious international project at a planning stage moving towards approval and construction under the supervision of the International Committee for Future Accelerators (ICFA). Thus far, a double-tunnel configuration has been considered as a possible option whereby the accelerator cavities and the power supplies would be housed separately. On the contrary, the single-tunnel configuration has been recently proposed for the baseline case, where the power supplies would also be housed in the accelerator tunnel or shifted to surface facilities. Although different aspects such as availability and safety need to be carefully studied, it offers significant advantages, particularly with respect to construction costs. In this paper, we propose the Asian regional single-tunnel configuration in conjunction with a compact high-level RF scheme.

INTRODUCTION

It was in 2004 when, in an attempt to reduce the number of design propositions and conclude an agreement about the unified design of the ILC, ICFA chose a superconducting (SC) RF technology for its accelerating system. A year later, ICFA established a global design effort (GDE), headed by Barry Barish and comprising three regional teams in Americas, Asia, and Europe. In February 2007, the GDE reached a significant milestone with the release of the reference design report (RDR) for a 31-km long electron-positron linear collider [1]. Currently, the GDE is in a transition stage, as it proceeds from a reference design to a technical design phase (TDP), aiming to establish a robust funding proposal, which could be presented to governments.

The ILC conventional facilities and siting (CFS) group consists of engineers and scientists at accelerator laboratories such as FNAL, CERN, DESY, and KEK. In RDR the most important task of this group was to provide sufficient evidence that the ILC could be constructed in three regions. For this purpose, the three regional teams chose their own "sample site." These "sample sites" need not necessarily coincide with the final accelerator site but should provide realistic settings for evaluating the various design proposals. In RDR all three regional teams reported deep tunnel solutions. Further, for the tunnel configuration, as in the case of most existing electron linacs, a double tunnel scheme was chosen after a significant number of discussions.

However, during the TDP, a single-tunnel configuration is coming up. Although such a tunnel configuration could apparently reduce the construction costs, there are concerns about the availability of the accelerator and the safety of life. The availability issue is being addressed with the use of numerical simulations. It needs to be balanced against the construction costs. On the other hand, the safety issue requires a different approach because we cannot weigh the construction costs against the safety of life. This issue is being discussed further in a later section.

ILC LAYOUT

The ILC will be an electron-positron beam collider composed of seven individual systems: an electron (e-) and a positron (e+) source, damping rings (DRs), ring-to-main-linac (RTML) beam transport, the main linacs (MLs), beam delivery system (BDS), and an interaction region (IR). The RTML and MLs, will be installed in each e- and e+ accelerator sides. The e- source, (part of) the e+ source, DRs, BDS, and IR will be located at the central region of the ILC. The total length of the accelerator will be approximately 30 km and will be operating at a center-of-mass collision energy of 500 GeV. However, it will need to be extended to some 50 km in length in order to achieve so high center-of-mass energies as 1 TeV. The baseline layout of the ILC, as this is described in the RDR, is shown in Fig. 1(a).

New ILC Layout under Discussion (SB2009)

In 2009, a new baseline layout was proposed for the ILC, which is referred to as the "Strawman" baseline (SB2009). Among the most important layout changes proposed is to shift the e+ source to the end of the e- ML, the DR lattice to have a race-track shape and place the DRs at the same level next to the BDS tunnel. The newly proposed layout is shown in Fig. 1(b). The major changes are summarized below: The injection line of the e- source will be changed to match that of the DRs. The positron source will be shifted to the edge of the e- ML. The undulator length will be increased from 200 m to 300 m. The total length will be approximately 3.34 km, including the injection line towards the DRs, which will be 170 m long. The DR circumference will be changed to 3.2 km. The length of the downstream RTML will be reduced from 1123 to 570 m. The two stages of the bunch compression system (BCS) will also be reduced to just one, and subsequently, 24 RF units will be shifted to ML. The RF units housed in the ML tunnels will be increased from 560 to 584 (294 on the e- side and 290 on the e+ side). The ML length will also be increased by 920 m. Because of the shift of e+ source, the total length of BDS will become 5876 m.

#atsushi.enomoto@kek.jp

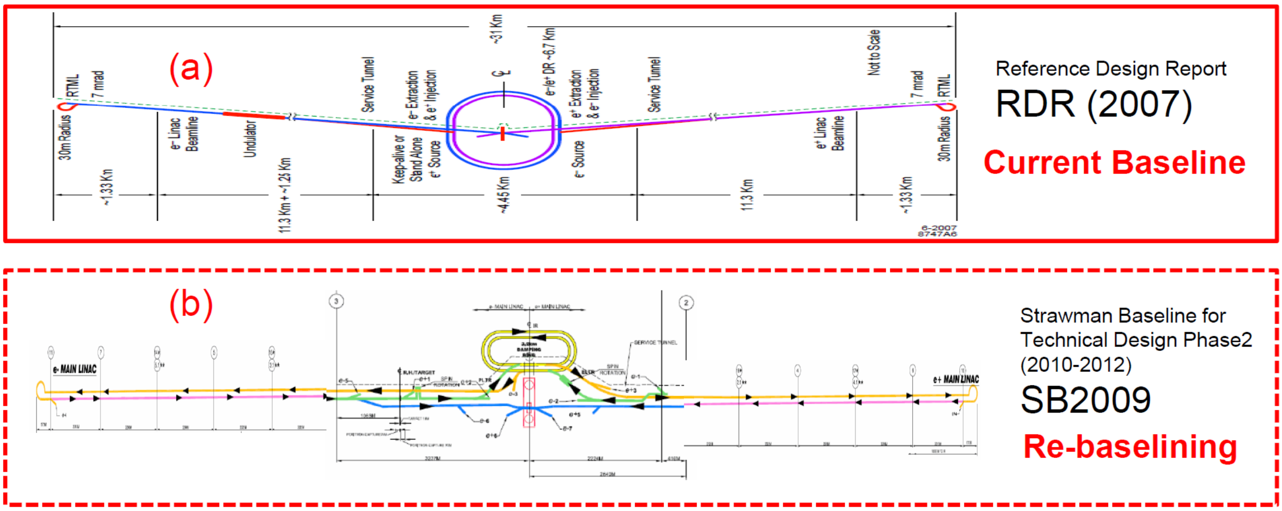

Figure 1: Overall ILC layout: (a) The upper layout was the RDR layout. (b) The lower layout is a new layout proposed in the “Strawman” baseline in 2009.

ML Single-tunnel Configuration

(1) Safety issue

In the double-tunnel configuration proposed in the RDR, one would be able to escape from the tunnel where an accident would have occurred to the adjacent tunnel through a connection passage located every 600 m. In the case of a single-tunnel configuration, all three regional design teams in America, Europe, and Asia have made different proposals based on their own safety regulations or guidelines:

<u>Americas solution</u>: Egress rooms will be located every 600 m along the ML tunnel. The egress room will be isolated from the tunnel by a door and in case of fire or helium (He) leak accident, fresh air will be provided through special ducts.

<u>European solution</u>: The ML tunnel will be separated into compartments ~600 m long by walls and doors. In the case of a fire accident, the compartment where the accident has occurred will be isolated by closing the doors of both ends, while air ventilation will be ceased by means of air dampers. In the case of a He leak accident, the gas will escape through ventilation ducts installed on the ceiling.

<u>Asian solution</u>: An auxiliary tunnel with a relatively small diameter will be excavated parallel with the accelerator tunnel. The two tunnels will be connected by passages located every 600 m. However, the egress tunnel will be build at a lower level to avoid the penetration of He gas or smoke.

(2) Single-tunnel accelerator configuration

Several possible solutions have been proposed for the single-tunnel accelerator configuration. These solutions are all variants of the high-level RF (HLRF) distribution scheme.

<u>RDR-type solution</u>: First, it is proposed to house the accelerator modules and their RF sources in just one tunnel. More specifically, two tunnels with a diameter of 4.5 m proposed together with a tunnel approximately 6.5 m in diameter that could house this double-tunnel configuration.

<u>Distributed RF system (DRFS)</u>: To improve the space factor of the RF source, the RDR design was modified. The 10-MW multi-beam klystron was replaced by 13 klystrons of a relatively small size. This modification simplified the waveguide system and eliminated the need for a high-voltage step-up transformer. The tunnel diameter was also reduced to 5.7 m.

<u>TESLA/EuroXFEL scheme</u>: To further reduce the tunnel size and eliminate the need for high-power equipment in the tunnel, it was proposed that both the accelerator modules and the high power klystrons would be installed in the underground tunnel. However, the high voltages needed for the klystrons would be provided through long cables by DC power suppliers located at the ground level. The tunnel diameter was further reduced to 5.2 m

<u>Klystron cluster system (KCS)</u>: High-power klystrons are also shifted up to the surface. In other words, only the accelerator modules remained housed in the underground tunnel. The tunnel diameter was now reduced to 4.5 m.

(3) Variation of the single-tunnel configuration and choice

From a civil engineering aspect, the volume of the underground tunnel that is necessary to accommodate the accelerator equipment decreased most in the KCS scheme, while its surface area increased. To mention from a mechanical engineering (cooling and ventilation) aspect, the heat loads in the tunnel, which would be produced by the HLRF system were least in the KCS scheme. However, for a long-distance high-power transmission, more R&D will be necessary in the KCS case.

For an accelerator with a flat surface supported by a substantial number of surface plants, a single-tunnel configuration with KCS may prove to be more effective. However, in the case of an accelerator site with a non-flat surface or which will be occupied with residents, because of difficulties that may be encountered in building large surface plants, the KCS solutions may not be suitable.

The Asian Proposal for a Single-tunnel Scheme

(1) The characteristics of the Asian sample site

In RDR, the Asian regional team proposed a sample site on the Japanese mountainous areas which had surveyed sites of uniform geology spreading over areas wider than ~50 km. The mountainous topography was dominant in the sample site, where the accelerator underground tunnel would be located at a depth ranging from 40 m to ~600 m.

(2) Tunnel configuration in the Asian sample site

Figure 2 shows a cross section of ML tunnel. A single-tunnel configuration was proposed to house all of the accelerator equipment. There will however be an additional tunnel of smaller diameter parallel to the main tunnel as shown on the left side in Fig.3. The concept design for this facility was developed in 2009 by a working group of the “Advanced Accelerator Association promoting science and technology (AAA)” through the collaboration between academic, industrial, and political communities in Japan.

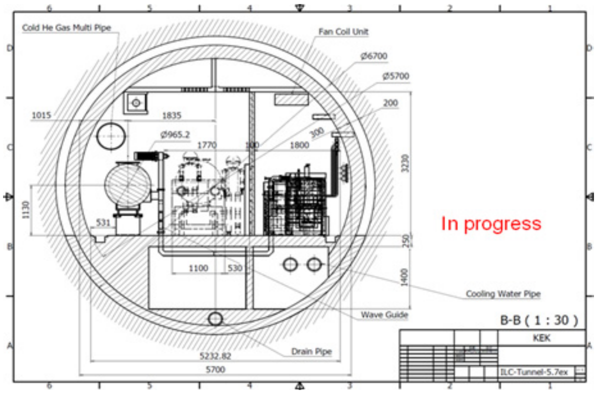

Figure 2: Single-tunnel ML accelerator configuration.

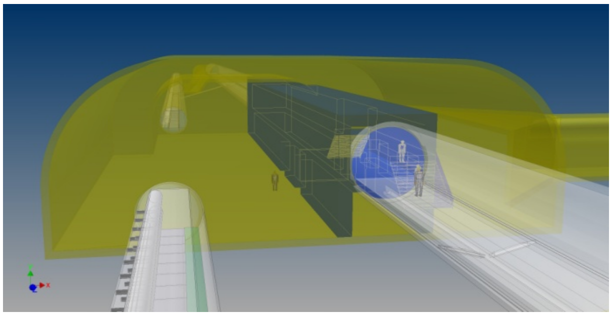

Figure 3: Asian regional tunnel configuration. The right side tunnel houses ML, while the left side tunnel is a pilot tunnel in the construction phase and used for purposes of egress and dranage after construction.

(3) The role of the sub tunnel

The auxiliary tunnel would serve the following purposes: As it has already described in the previous section, it could be used as an escape passage in case of emergency. The proposal of the Asian regional team for a single-tunnel configuration with a DRFS or an RDR type RF source includes more fire loads than the TESLA/EuroXFEL scheme or the KCS. It also includes longer access paths to the ground level. In other words, it has been formulated after careful consideration of all the safety issues.

The auxiliary tunnel could be used as a pilot tunnel, which would help in the excavation of the main tunnel. Another issue that will need to be addressed is the case of a serious accident that could occur when the tunnel boring machine (TBM) was trapped because of the subsurface geological patterns. To avoid such a risk, the meticulous geological survey around the pilot tunnel would be invaluable, especially if the auxiliary tunnel was excavated several months in advance. The reduced cost of its construction when compared to the main tunnel diameter of significantly larger diameter should also be noted.

Lastly, the auxiliary tunnel could be used for the drainage of ground water during the construction as well as the operation of the accelerator. The ground water could flows down to the auxiliary tunnel in order to keep the main tunnel dry at all times. And the ground water flowing along the main tunnel could be gathered and transferred through the auxiliary tunnel to a river not far away by taking advantage of the mountainous topography.

SUMMARY

In this paper, we investigated the single-tunnel configuration, which has been proposed by the Asian regional team for the ILC ML. This underground tunnel would house both the superconducting accelerator modules and their high-power RF sources. For the RF source, in particular, an RDR-type baseline and a DRFS-type alternative were evaluated. According to the Asian regional team, a small auxiliary tunnel could be excavated parallel with the main accelerator tunnel to accommodate safety requirements, a geology survey, and the treatment of ground water. On the basis of this proposal, the design of the ML tunnels and underground structures accommodating the electric, mechanical, and cryogenic systems is under development. Once the concept design for the entire accelerator system would have been completed, the construction costs would be estimated in detail.

REFERENCES

[1] International Linear Collider Reference Design Report 2007, ILC-REPORT-2007-1, and KEK Report 2007-2.