(Original: October 28, 2006)
Rev. November 2, 2006

To: Distribution
From: GDE Change Control Board
Subject: Response to the Change Request (October 7, 2006) for the BCD Parameter/Layout Section – CCR#18

Preamble

This is the CCB response to the proposed changes to apply to the Parameter/Layout section of the September 2006 version of GDE ILC Baseline Configuration Document [1]. CCB received the change configuration request (CCR) from J.M.Paterson on October 7, 2006 and CCB forwarded it to GDE the next day [2]. This Change Request was treated as Class-2. D.Schulte, S.Mishra, K.Kubo and N.Toge were assigned as the CCB reviewers. CCB requested remarks from the GDE Cost Engineers concerning cost implications, who responded in the CCB hearing that was held on October 23, 2006 [3].

Summary

Requester proposed:

To redefine the ILC layout in which both the electron and positron damping rings (DRs) are to be contained in a single, common tunnel which is situated centrally around the interaction regions (IRs). Consequently,

- While the fundamental designs of the electron source, positron source, damping rings and bunch compressors are maintained “as they have been”, the so-called “positron insert” will be eliminated.
- The positrons produced with photons from the undulator section in the electron linac will be boosted to 400MeV then to 5GeV for injection into the positron damping ring located around the IR. Thus, the 400MeV low energy e+ transport is substantially shortened and it would no longer go across the interaction point.
- The RTML section is redefined so as to include the beam transport lines for damped yet longitudinally uncompressed 5GeV e- and e+ beams, now extending from the DRs (around IR) over 12km along the main linacs (MLs), towards the entrance of the bunch compressors near upstream ends of the MLs.

The main motivation behind this change request is to slash the construction cost of the ILC by eliminating the need for civil construction for one of the tunnel housing and by consolidating the conventional facilities for the damping rings. Although new beamline elements have to be introduced for the 5GeV beam transport, the elimination of one of the DR tunnels results in a significant net cost reduction.

CCB response:

1. **CCB agrees that the cost change (in this case, reduction) expected from this change request is substantial, such that it qualifies as Class-2. Consequently, CCB assumes that its role concerning this change request is to assess its merits and make a recommendation to EC, rather than to make a final configuration change decision.**
2. **CCB recommends EC to adopt this change request, with small refinements on illustrations and the text (Appendix A), for reasons detailed below in the Discussion section.**
3. **CCB will encourage the relevant parties, and will work with them, to update the "RTML" and "Damping Ring" sections of BCD in accordance with the updated layout.**
4. **CCB wishes to take this opportunity to urge the parties responsible for the "e+ source" and "Conventional Facility" sections to update their BCD descriptions which are long over due.**

Discussion:

General Layout Issues:

1. This CCR represents a proposal of the new "outline" of the beamline ILC topology based on the "centralized injector/damping-ring complex". Most of the fundamental building blocks for the required beamlines are identified and their concise descriptions are given. An elevation offset of 10m is introduced to maintain DR off the BDS plane so as to avoid certain interference in terms of installation and operation (radiation safety aspects). The injection/extraction lines for DRs are associated with service tunnels to house the power supplies, modulators, RF sources and control electronics.

   However, many details need to be still worked out. An outstanding example is the transverse offsets of the DRs relative to the IR, which is likely to be site-dependent. The chicane beamlines for fine timing-adjustment need to be also incorporated.

2. The DR tunnel now will have to accommodate two rings (one for the electron, the other for the positron) from the beginning. Thus their installation, commissioning and concurrent operation are new issues that have to be an integral part of detailed planning and examination on the construction and operation of ILC, and their implications need to be fully understood. The existence of these issues are noted, yet many of the details are still there to be worked out.

3. The cross section views of the ML tunnels indicate that the electron-ML, 5GeV transport and low-energy e+ transport can be reasonably comfortably contained within tunnels with 5m diameter, and possibly within tunnels with 4.5m diameter. However, again, many engineering details are yet to be fully worked out, including transportation of their components and their installation order construction, as well as their alignment sequence, maintenance and service procedures.

4. The cross section of the DR tunnels which is currently under active study by the RDR group is 4m which is considered sufficient for accommodating one electron-DR and one positron-DR simultaneously, but is deemed insufficient for adding one more positron-DR when needed. It is considered that 4.5m diameter is necessary to do the latter. CCB also notes that details of the component installation, including that of RF cavities, are yet to be completed even with the case of "absolutely two rings only". CCB's understanding is that at this point of time the DR group is seeking to redefine the baseline layout topology of its system so as to be able to proceed with the first round of refined engineering design efforts.

5. CCB assessment
   - CCB concurs with the requesters that the engineering issues identified so far are all fundamentally solvable, if not thoroughly having been solved yet. Given this notion, and with the nature of BC at this point of time in mind, the current level of perceptions by the requesters on these issues, in CCB's viewpoint, warrant GDE to proceed with reasonable confidence that full engineering design be worked out.
   - The present baseline definition (September, 2006) of the DR system is to build one electron DR and one positron DR but to allocate the room for the second positron DR in case of need at later time. CCB understands that the preference of the DR Area Group leaders, in their consultation with the RDR management board, is to eliminate provision for the second positron DR. CCB assumes that this topic shall be treated as a separate, another CCR matter, with more concrete inputs on the subjects, including beam dynamics, installation and costing implications.
   - CCB feels that in this section of BCD some refinements of illustrations for the layout are worth for helping the readers. The beam paths as a result of this CCR would become substantially more complex than before. Some textual description of other parts of the BCD, in particular in relation to the path length constraints stemming from bunch timing considerations, will be also helpful. A suggested replacement text, which supersedes the version submitted by the requesters, is attached as Appendix A.

Beam Dynamics Issues with RTML:

1. This change request requires long transport of low emittance 5GeV beam and vertical bending in RTML. An important point to note in evaluating the beam dynamics issues here is that while the emittance and emittance ratio is extremely small, the energy spread is also small, since the beams to be transported are not yet longitudinally compressed. The requester's (P.Tenenbaum) statements in the change request and during the CCB hearing [3] are summarized as follows.

   - Filamentation is not an issue, because while long 5GeV beamlines have been added, their focusing strengths are weak (weaker by factors 1/2~1/3, compared to the 400MeV e+ transnport which immediately follows the positron production target) and the beam energy spread also being small.
   - Synchrotron radiation in the "escalator arcs" is not an issue. The bends are weak and focusing is strong there.
   - Higher-order dispersion from "escalator arcs" is not an issue.
   - Electron cloud effect is not an issue, since the bunch spacing is sufficiently large.

- Studies by L.Wang have shown that ion instabilities is at the tolerable level if the vacuum 20nTorr is maintained. This vacuum level is considered achievable with in-situ baking of the vacuum chambers.
- Beam jitter from fast changing stray fields will be probably OK. Studies by K. Kubo [5] have shown that stray fields of 7.5 nT RMS cause 5% emittance growth after turnaround. Measurements in End Station B at SLAC indicated about 2 nT field. The position jitter itself (at turnaround entrance) can be corrected by feed-forward at the exit of the turnaround.
- Studies have shown that emittance growth from misalignments is characterized as only an incremental issue compared to the present baseline RTML.
- Beam-gas scattering will make 2×10^{-6} of beam into halo, assuming 20 nTorr, which is tolerable if we collimate before the turnaround. (For comparison, present Baseline RTML has 9×10^{-8} halo generation.)
- The specifications for the vacuum quality, stray field and stability of magnet support should be carefully examined.

2. CCB assessment
   - CCB notes that the statements given by the proponents on the emittance dilution issues across the 5GeV transport have been mostly only qualitative. However, the work by Kubo [6] who has independently evaluated the emittance growth issues in the 5GeV beam transport has become available during the CCB review process. The numerical results given by [6] support the claim by the proponents of this change request.
   - CCB notes that the required tolerance on the accuracy of beta- and dispersion-matching across the long beam transport have not been fully numerically documented. CCB also notes that the 5GeV line is relatively spacious, longitudinally, so that additional beamline elements or instrumentation are relatively easily implemented, if determined to be necessary. However, CCB wishes to point out that very careful simulation and engineering studies are still required to examine the needs for such additional instrumentation and other beamline elements in more “crowded” parts such as “getaway” lines.
   - Overall, CCB agrees with the proponents that beam dynamics issues with the extended RTML, including the long 5GeV transport, are not of the nature to cast fundamental doubt over the feasibility of this new layout scheme.
   - Consequently, CCB considers that, from the beam dynamics viewpoint, the proposed new layout scheme is acceptable as a new baseline for proceeding with further design and engineering efforts.

Timing Control Issues:

1. Issues: The system-wide timing control, especially for the self reproduction for the positrons, in which the fresh positron bunch is made by electron bunch of collision partner of the ex-positron bunch, demands that a general condition be satisfied on the path lengths on ILC, as long as the ILC system topology is unchanged. One of the possible solutions that was identified by a task force [4] was to maintain the following condition:

$$L_4 + \Delta_1 + L_3 - L_2 = nC. \qquad (1)$$

Here, L_2 is the distance from the positron production target to the IP, L_3 is the distance from the positron damping ring extraction point, to the IP, L_4 is the distance from the positron production target to the positron damping ring injection point, and Δ_1 is the distance from the injection kicker to the extraction kicker in the positron damping ring. Basically, there is no major impact to this condition from the proposed configuration change, since L_4 and L_3 are increased and decreased by the same amount, respectively. L_2 is not changed at all. Depending on the beam injection and extraction positions, Δ_1 can be varied up to C/2. Injection and extraction positions are almost fixed by the longitudinal position of the DR respect to the IP.

2. CCB assessment: CCB does not observe any new serious problems on the configuration change from the standpoint of beam timing issues. However, preservation of the timing constraint is a must at ILC[1]. It is mandatory to conduct very careful accounting of path lengths of all relevant beamlines in forthcoming design efforts. The required capability of timing adjustment measures (for instance, with chicanes) should be determined based on these studies.

Cost Issues:

1. The cost impact associated with this configuration change has been presented to the CCB in three blocks: a) changes to the low-energy positron transport and the positron booster (reduction of 400MeV e+ transport), b) introduction of 5GeV beam transport, and c) elimination of one of the two DR tunnels. They are quoted, as normalized by the previous DR system construction cost (i.e. September 5, 2006 version of BCD) as:
   - a) –10.9%
   - b) +14.5%
   - c) –26.2%

   Thus, the net impact is cost reduction by –22.6% and this qualifies as Class-2 change request.

2. CCB understands that an effect of potential variation of the DR tunnel diameter in the range of 4 ~ 4.5m is of the order of ~1% or less, in the terminology above.

Overall CCB Assessment:

1. CCB finds that this CCR brings in a substantial cost reduction while maintaining a good likelihood of achieving a workable ILC design.

2. In the spirit of present definition of BCD, which reads “A forward looking configuration which we are reasonably confident can achieve the required performance *and* can be used to give a reasonably accurate cost estimate by late-2006/early-2007 in a ‘Reference Design Report.’”, CCB finds that this CCR to be acceptable, and recommends EC to adopt it.

3. CCB, however, emphasizes the need for a substantial amount of tightly coordinated engineering

1 According to the report of the task force [4], the condition (1) is a special case within a set of more generalized solutions. Actually we will have some freedoms to change the harmonic number of DR if we allow to relax implicit constraints on equidistant bunches in the linac bunch train. There are step-solutions which give much more flexibilities in the choice of the DR circumference, where the pass length constraints in (1) may be relaxed. Development of specific cases of such refined solutions are subject to work by relevant area and global system groups.

efforts in the areas of beamline designs, vacuum, magnet, instrumentation, CF/S together with installation and alignment.

4. CCB also emphasizes that implications of this new layout on commissioning and maintenance aspects of ILC must be carefully examined and the results must become part of the shared understanding among all within GDE.

5. CCB finds that suitable updates of BCD text for the DR and RTML sections are called for.[2]

6. Likewise, CCB notes that suitable updates of BCD text for the e+ sources and conventional facilities are highly desirable.

7. As referred to in the part under "General Layout Issues", a set of small refinements are suggested for the replacement text for the BCD section in question. It is attached in Apendix A.

Additional Notes:

Handling of Cost-Related Information:

The "Hearing" on the cost impacts was held via Webex and telephone connection on October 23, 2006. The minutes of the hearing are available at [3]. However, as announced by GDE EC and reported at the Vancouver GDE meeting all public communication from CCB will have all "raw" cost numbers withheld (replaced by fractional numbers wherever possible and adequate).

E N D

References

[1] http://www.linearcollider.org/wiki/doku.php?id=bcd:bcd_home .

[2] http://lcdev.kek.jp/ML/PubCCB/msg00092.html

[3] Minutes of CCB Hearing, Oct. 23, 2006. http://www.linearcollider.org/wiki/lib/exe/fetch.php?=cache=cache&media=bcd:layouthearing20061023.pdf .

[4] H. Ehrlichmann, S. Guiducci, K. Kubo, M. Kuriki, A. Wolski, "Recommendations for ILC Configuration Satisfying Timing Constraints", 2006 http://www.linearcollider.org/wiki/lib/exe/fetch.php?cache=cache&media=bcd:timingrecommendations-revapril17.pdf . Also, M.Kuriki, K.Kubo, E.Ehrichmann, S.Guiducci and A.Wolski, "Timing Constraints on ILC", ILC-Asia Note 2006-03, http://lcdev.kek.jp/ILCAsiaNotes/2006/ILCAsia2006-03.pdf .

[5] K.Kubo, "Rough estimation of effects of fast-changing stray field in long transport of RTML", ILC-Asia Note 2006-05, October 12, 2006.

[2] CCB acknowledges that a change request for the RTML section in this context has been submitted on October 25, 2006.

http://lcdev.kek.jp/ILCAsiaNotes/2006/ILCAsia2006-05.pdf
[6] K.Kubo, "Simulation of low emittance transport in long straight line of ILC RTML", ILC-Asia Note 2006-06A, Revised October 20, 2006.
http://lcdev.kek.jp/ILCAsiaNotes/2006/ILCAsia2006-06A.pdf

Appendix A

Suggested replacement text for the new Parameter and Layout section of BCD is attached in the following 10 pages.

1. Baseline Parameters and Layout

This section outlines the essential aspects of the ILC baseline parameters and the layout of the ILC accelerator complex.

1.1 Baseline Parameters

The tentative parameter set for the ILC [1] was distributed in February 2005. It consisted of two parts:

- Linac parameter set
- Beam parameter range

The working groups suggested possible changes, in particular during the Snowmass workshop. Not all proposed changes were supported by compelling arguments, and were rejected (see “Justification” section, below). The following changes are needed, based on recommendations mainly from WG2 and WG5:

- The nominal operating accelerating gradient should be 31.5 MV/m for the 500 GeV stage, and 36 MV/m for the upgrade stage, with $Q_0=10^{10}$ for both cases. The RF system should be designed so as to be able to provide 35 MV/m and 40 MV/m, respectively.

- One RF unit for the baseline design for 500GeV stage should consist of one 10MW klystron and 3 cryomodules each containing 8 cavities.

Taking into account these changes, slightly revised parameter sets are given in Table 1.1 The spirit of the parameter sets however, do not change and are described below.

The proposed beam parameters are grouped within 5 sets rather than one. In the past a collider project in most cases used to provide a unique set of parameters which were tuned to give the highest luminosity. In actual machine operations, however, unexpected or underestimated difficulties require the adoption of operating conditions different from those assumed in the initial design. It is desirable to provide for such changes in the initial design. Since these changes are not very predictable, an operating plane is defined, rather than an operating point. Requiring to accept a wide range of parameters may introduce challenges in the design, but the resulting machine operational flexibility is deemed to be more valuable. If the machine, as built, works for a wide range of parameters within the operating plane, then it should be easier to reach the design luminosity.

The five sets are:

- Nominal set — used as a reference to scale to the other sets
- Low bunch charge — (low Q) reduction in bunch charge by a factor of two
- large σ^*_y(large Y) — increased vertical beam size due to factor two larger emittance growth in LET
- Low power (low P) — reduced number of bunches (n_b) by factor of two
- High luminosity (high L) — smaller IP beam size and shorter bunch. (**This is not a part of the `baseline' but is added just for reference**.)

Among these, the first four sets give the same luminosity -- $L = 2\times10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$, to be compared with the TESLA TDR peak luminosity $L = 3.4\times10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$, while the high L parameter set gives $L = 5\times10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$.

As described above the parameter sets are not intended to be considered as fixed sets, but as an indication of the degree of flexibility intended to be built into the machine. Hence each sub-system should accommodate – where possible – the most demanding parameters. The final ‘operating point’ is almost certainly going to be within the space defined by these parameter sets, but will not necessarily correspond to any one of them. The sets of important parameters, which bound the operating plane, are (they are of course related) given in Table 1.1 below:

		min	nominal	max	
Bunch charge	N	1	2	2	$\times10^{10}$
Number of bunches	n_b	1330	2820	**5640**	
Linac bunch interval	t_b	**154**	308	461	ns
Bunch length	σ_z	**150**	300	500	μm
Vertical emitance	$\gamma\varepsilon_y$	**0.03**	0.04	0.08	mm.mrad
IP beta (500GeV)	β_x	**10**	21	21	mm
	β_y	**0.2**	0.4	0.4	mm
IP beta (1TeV)	β_x	**10**	30	30	mm
	β_y	**0.2**	0.3	0.6	mm

Table 1.1 Baseline Parameter

The alternative of designing to a single ‘default’ parameter set – while appealing from the point of view of the sub-system designers – would effectively remove the margins and flexibility outlined above. Since limiting factors in machine performance are not yet known, it is extremely desirable to maintain all such options in the parameter plane. In addition, allowing for the overhead also keeps open the option of achieving a luminosity greater than the nominal $2\times10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ if not as high as High L.

Justification of the choice

A few problems associated with the baseline parameter sets and some possibilities of different parameter sets were pointed out from working groups during the Snowmass workshop.

1. **Short bunch**

Low Q and High L parameter sets demand a bunch length as short as 150 μm, to be compared with 300 μm in the nominal set. WG1 concluded that, though a single-stage bunch compressor is just enough for compressing a 6mm bunch from the damping ring to 300 μm, a two-stage compressor is mandatory for a shorter bunch length or for a DR bunch longer than 6mm.

Obviously a two-stage compressor is more expensive and requires a longer site. However, exact cost and length differences are not yet known. A shorter two-stage compressor is still under consideration. A two-stage compressor may be desirable even for the nominal parameter set. Thus, it is recommended that the possibility of a shorter bunch be retained.

2. **Long Pulse Length in the Main Linac**

H. Padamsee and B. Foster suggested a longer beam pulse length (accordingly a longer klystron pulse length) in the main linac with the same pulse charge. If, for example, the beam pulse length is doubled (2ms), the beam current and, therefore, the number of modulators/klystrons would be halved, which reduces the cost of the RF system.

The cost of the cryogenics system, on the other hand, increases due to the higher duty factor. Taking into accout all the above, the proposers of this idea expect the total cost to decrease. It was also pointed out a longer pulse would ease the demand on the MPS and is also better for the detector performance. However, according to C. Adolphsen, the total cost increases slightly. A more detailed study of the cost is needed.

In addition to the cost uncertainty, a longer pulse requires a longer modulator/klystron pulse which is not currently available. Thus, this possibility is ranked as an `alternative' configuration.

3. **Larger Number of Bunches**

The Low Q parameter set demands a number of bunches as large as about 6000. This is particularly demanding for the design of the Damping Ring, including the need for development of very fast kickers. At this moment we retain the operating condition with up to 5640 bunches per pulse as part of our baseline configuration.

4. Very Low Q Parameter Set

J. Gao proposed a `Very Low Q' parameter set in which the bunch charge is 0.6×10^{10} (40% lower than the nominal). This demands more bunches (6000), a shorter bunch (120 μm), a higher repetition rate (8 Hz) together with a tight focusing at the IP. The main motivation is to reduce the space-charge effect in the Damping Ring (it eliminates the need for a coupling bump) and a smaller disruption (D_y=9). With this parameter set the smaller IP spot size (horizontally and vertically) and the shorter bunch length is very demanding. It is necessary to evaluate if these demands outweight the benefits of relaxing the space-charge and the disruption. Accordingly, this option has been rejected.

5. Smaller Number of Bunches with Higher Rep Rate

S. Guiducci suggested reducing the number of bunches by 2 (as in the low P set), but maintaining the 1ms pulse. Luminosity is recovered by increasing the repetition rate to 10 Hz, requiring a factor of two reduction in the damping time (possible with a factor two shorter ring, assuming the same kicker rise time). The resulting factor two drop in linac beam current halves the peak beam power and could potentially halve the number of the 10MW klystrons; but the fill time also increases, thus reducing the efficiency and increases the dynamic cryoload by a factor of two. Increasing the vertical emittance by a factor of two, while reducing the horizontal emittance by the same factor was also discussed (Guiducci); this option increases the beamstrahlung by a factor of four, however, this assumes that no modifications to the demagnification in the final focus are made. Accordingly, this option has been rejected.

6. High L

A. Seryi pointed out a difficulty in designing the IR region for the High L set especially at 1TeV. The disrupted beam has a long low-energy tail due to the strong beamstrahlung. The lowest energy that the dumpline can accept is about $0.3E_0$. The integrated power below this energy which the detector system can tolerate is less than 10 W. With the present 1TeV High L set, this limit is greatly exceeded. To solve this problem, the beamstrahlung (especially the Upsilon parameter) has to be reduced. A longer bunch (300 μm), larger β_x and β_y, a lower vertical emittance 0.023 mm.mrad coupled with an increased bunch charge (2.4×10^{10}) has been proposed. This set tightens vertical tolerances (smaller DR emittance and a smaller emittance growth budget) and a larger disruption (kink instability). The requirements can be a little relaxed by choosing the nominal bunch charge but with a slightly decreased luminosity from the High L set.

The required change is within a reasonable range from the standard set and may be feasible by the time when the 1 TeV upgrade is implemented. This option is not listed in the standard parameter sets since the High L set itself is not the baseline.

Required R&D for the Baseline

- The performance of the proposed two-stage bunch compressor needs to be confirmed, including errors. It is also desirable to see if a shorter two-stage compressor is feasible.

- A Damping Ring design capable of storing 6000 bunches need to be established.

Required R&D for the Alternative Parameters

Long Pulse with 5 Hz or 10 Hz

- The technical feasibility and cost of a long-pulse RF system needs to be investigated.

1.2 Layout of the ILC Accelerator Complex

1.2.1 Overview

Figure 1(a) shows a schematic view of the baseline layout for ILC in its phase-1 configuration which supports physics experiments at center-of-mass energies up to 500 GeV. The site footprint is dominated by two main linacs, for accelerating electrons and positrons, respectively, each of which extends over a length of approximately 10 km. Together with the electron sources, damping rings and the beam delivery systems, the total site length is expected to be approximately 31 km.

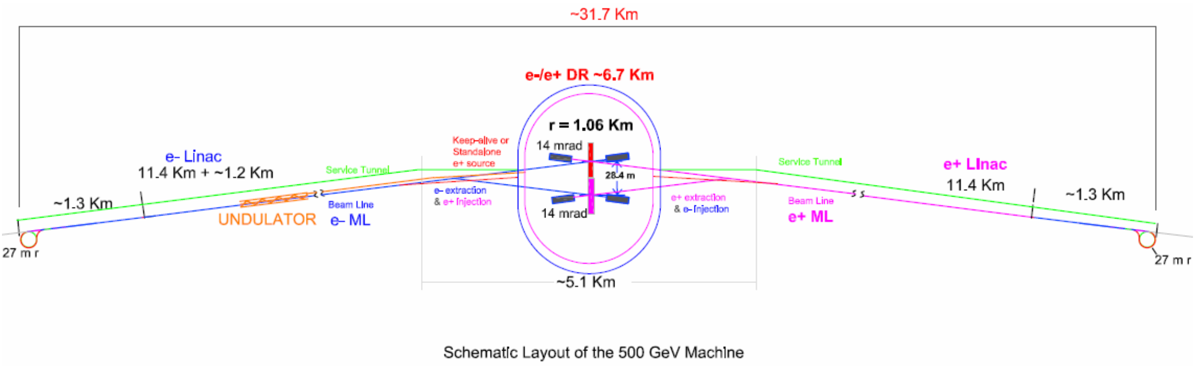
Figure 1(b) shows a scaled, closed-up view in a 3-dimensional perspective which focused on the positron injection and electron extraction from the damping ring complex.

Figure 1(c) gives a possible layout of the conventional facilities which correspond to the beam lines shown in Figure 1(b), for illustration purposes. Details of the exact topologies are subject to changes through further engineering design efforts.

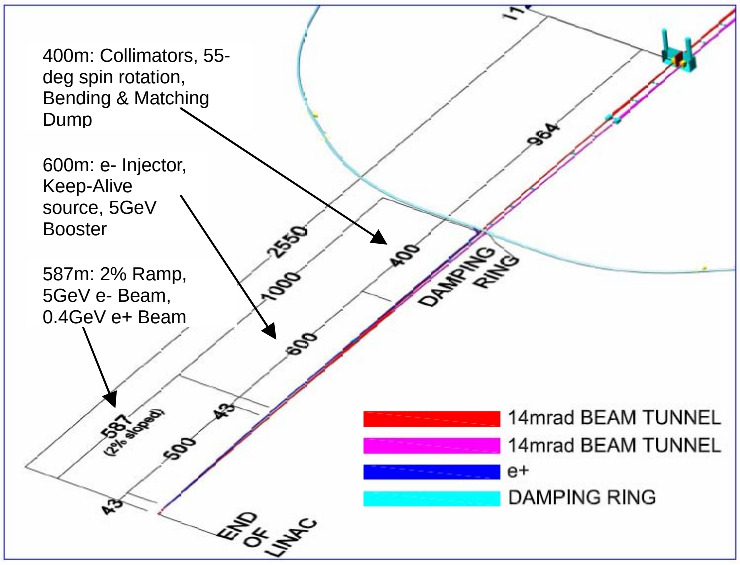
1.2.2 Electron Source

The electron source is the point of origin of all ILC beams in normal operation. The positron beam in normal operation will be generated by photons produced by the passage of electron beams through the undulators. The electron source will be part of the Central Injector/Damping Ring complex (see Fig.1(a)). It is located on the e+ linac side of the the Damping Ring which has an electron and a positron ring in the same tunnel. The exact location of the electron source will be determined through optimization of the injection beam line into the damping ring. The polarized electron source system includes one 5GeV linac to inject the beam into the electron damping ring.

(a)



(b)



(c)

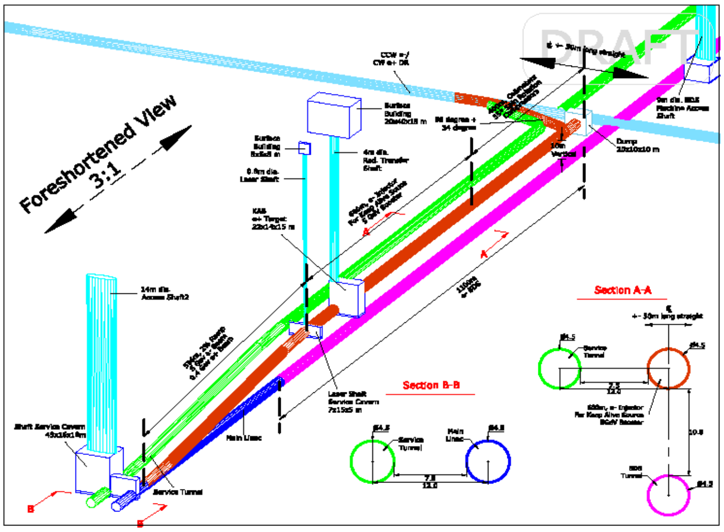


Figure 1: (a) Schematic view of the ILC baseline layout for phase-1; (b) Scaled 3-D schematic view on one side of the damping ring injection/extraction; (c) A possible layout topology of conventional facilities for the area shown in (b).

1.2.3 Damping Rings

The damping rings (DRs), operated at the beam energy of 5 GeV, will reduce the beam emittance to the level required by the specifications discussed in Section 1.1. The rings are approximately 6.7 km in circumference. The baseline layout has the damping rings located centrally between the linacs and above the level of the beam delivery system. The elevation difference will give adequate shielding to allow operation of the injector/damping-ring (INJ/DR) complex with other ILC systems in open access. One electron and one positron ring in the same tunnel are assumed in this baseline configuration. A study on timing issues at ILC [2], where positrons are produced with undulator photons from electrons of previous bunches, gives the following constraint: The difference in path length, from the production point to collision point, between the positrons and the electrons, including the distance between injection and extraction points in the damping rings, should be an integer multiple of the damping ring circumference. It is noted that simple longitudinal (parallel to the main linacs) relocation of the damping rings does not affect this timing constraint. Consequently, the exact locations of the damping rings may be site-dependent to a certain extent. However, other changes to the layout of ILC systems, such as relocation of the damping rings transverse to the main linacs, the lengths of the linacs or the beam delivery systems will change timing requirements and solutions.

1.2.4 Ring-to-Main-Linac

The RTML beam line begins at the damping ring and transports the damped beam through the linac tunnel to the low energy end where it turns through 180 degrees. The RTML includes a suitable set of beam diagnostics, bunch compression and spin manipulation sections. The 180˚ turn-around allows the application of a feed-forward beam stabilization system. After the turn-around, in the bunch compressor, the beam is accelerated up to 13-15 GeV before injection into the main linacs. These 10 km, 5 GeV beam transport lines from the central complex to the beginning of the RTML bunch compressors are required to maintain the low emittance of the damped yet longitudinally uncompressed beams. They are therefore more complex in instrumentation and correction than the e+ transport lines that they replace in the previous ILC layouts.

1.2.5 Main Linacs

The main linacs receive the beams from the RTML at 13-15 GeV and accelerate them up to 250 GeV in normal phase-1 operation. As discussed below, the main linacs on the electron side are interlaced by undulators to incorporate the positron production system, or segments associated with beam diagnostics, and tune-up dumps for ensuring good operability.

The angle between the two main linacs is irrelevant to the design of most collider systems. An exception is that the Beam Delivery System requires this value for detailed optics design. The baseline design has two beam delivery transport lines leading to two interaction points where the beams interact with a 14 mrad crossing angle.

1.2.6 Positron Source

Positrons in normal operation are produced with photons originating from the electron beam from the main linac at an energy of 150 GeV. For that purpose a 200 m-long undulator system is incorporated in the electron main linac. The positron production target that converts these undulator photons to positrons is located on the “electron side” of the IR. After acceleration up to 400 MeV, the positron beam is brought to the central INJ/DR complex and accelerated to 5 GeV by a pre-accelerator before injection into the positron damping ring. The trajectory of the positrons upon extraction from the positron damping ring is essentially a mirror image of that of the electrons.

To allow commissioning or debugging of the positron damping rings, positron RTML and the positron main linac, an auxiliary (or keep alive) positron source will be provided at the entrance to the 5 GeV positron pre-accelerator.

1.2.7 Beam Delivery

The beam delivery system receives the beams of energies up to 250 GeV in phase-1 operation, collimates them, focuses them, collides them at the interaction points, and safely disposes of the exhaust beam at the beam dumps. In the baseline layout, the ILC supports two interaction regions which provide collisions at beam crossing angles of 14 mrad..

1.2.8 Elevation Layout

In the baseline configuration, the bulk of the main linacs will be built approximately following the “local horizontal” lines that are defined by the local gravity in its neighborhood. This is the preferred elevation layout from the standpoint of straightforward engineering implementation of the liquid He leveling within the main linac cryostats.

However, for sake of ensuring emittance controls and beam tuning, the entire beam delivery system beam line is to be built to stay in a single mathematical plane normal to the gravity vector at a point near the interaction regions. The INJ/DR complex will also be on a plane parallel to that of the BDS but displaced vertically from it by 10 to 20 meters.

1.2.9 Path Length Constraints

The fact that positrons are produced by undulator photons which are produced by electrons within previous machine pulses lead to special issues of timing controls. They lead to constraints or preferences on various aspects of the ILC design, including the choice of the circumference of the damping rings and all the beam line path lengths.

A detailed analysis of this issue has been reported by A.Wolski et al in [2]. It is understood that an integral relationship is highly desired between the circumference of e+ damping ring and the path length a new positron bunch travels in a round trip through the INJ/DR complex, the RTML, the main linac and the beam delivery.[1]

1.2.10 Hardware Layout within the Tunnels

Following the study presented in the Section 12.3 “Number of Tunnels” of GDE White Papers (http://www.linearcollider.org/wiki/doku.php?id=bcd:bcd_home), the hardware for the main linacs (and many of other subsystems) will be implemented in two parallel-running tunnels. More discussions are found in the “Conventional Facilities and Siting” section of BCD.

1.2.11 Energy Upgrade and the Accelerator Layout

The first phase (500 GeV centre-of-mass) will be constructed using a tunnel long enough to achieve 250 GeV final energy in each linac with an average gradient of 31.5 MV/m (~2×10 km assuming a 0.75 fill factor). A second phase (phase 2) upgrade to 1 TeV centre-of-mass will then require extending the tunnel (away from the IR) an additional ~2×9.3km assuming cavities capable of 36 MV/m operational gradient.

The Beam Delivery System will be configured so that it can support operation at 1TeV with only minor upgrades. The main dump systems will be configured for the 1 TeV option from the start.

Injectors will be configured for phase 1 so that there is a minimum impact on them when upgrading to phase 2. Prospective sites must be chosen with the TeV phase 2 machine in mind; specifically the availability of both the total required land and power.

References

[1] http://www-project.slac.stanford.edu/ilc/acceldev/beamparameters.html, http://www-project.slac.stanford.edu/ilc/acceldev/beampar/Suggested ILC Prameter Space.pdf

[2] “Recommendations for ILC Configuration Satisfying Timing Constraints,” by H.Ehrlichmann, S.Guiducci, K.Kubo, M.Kuriki and A.Wolski, submitted to GDE

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1 The previous baseline solution for these issues was the insertion of 1.2 km into the positron linac comparable to the positron production region in the electron linac. This insert would contain a few hundred meter path length adjuster which is no longer required as the interaction regions and detectors are now at the same longitudinal location. The whole 1.2 km insert in the e+ linac has been removed and the “Keep alive source” is now part of the central complex. See 1.2.6. The positrons now pass through an additional half turn in the damping ring between injection and extraction and this partially corrects the e+/- timing. Further correction will be required but the amount is dependent on the lengths of so many systems which are presently under review, that a decision on the optimum correction methodology will be delayed until some time in the future. There are many possible timing correction strategies which will be considered at this time.and compared with the cost of a 1 km insert in e+ linac.

Executive Committee on April 7, 2006. Available from:
http://www.linearcollider.org/wiki/lib/exe/fetch.php?cache&media=bcd:timingrecommendations-revapril17.pdf .