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Nobu Toge
Chair, ILC GDE Change Control Board

Dear Toge-san,

Proposal for Change in ILC Damping Rings Baseline Configuration

We wish to propose a change in the baseline configuration for the ILC damping rings. Briefly, the change is to eliminate the second positron damping ring, so that the damping rings system would consist simply of two rings with circumference roughly 6.7 km (one ring for electrons, and one for positrons) and the associated injection and extraction lines. All other specifications would remain the same.

The main purpose of the configuration change is to reduce the costs of the damping rings; though there are also technical benefits, particularly to do with the injection and extraction (which no longer have to divide the injected beams between two rings, or combine the beams extracted from two rings), and with the alignment and support systems. There is some increase in technical risk, mainly to do with the electron cloud effect that was the original motivation for specifying two positron damping rings; however, studies since the original baseline decisions were made indicate significant progress with the development and understanding of techniques that may be used to prevent build-up of the electron cloud. The important results are summarised in the attached documentation. It is now believed that, with continued R&D, techniques can be applied that will allow the positron damping ring subsystem to meet its performance goals with a single positron ring.

In our view, because of the cost and technical impact of this configuration change, the appropriate classification is “Class 2” according to the CCB scheme. We should like to emphasise two important points associated with this change: first, R&D into mitigation techniques for the electron cloud should be continued as a very high priority; second, design of the damping rings complex should not preclude installation of a second positron damping ring as a later upgrade, should electron cloud effects be found to be a limitation on performance.

We attach the documentation requested by the CCB to support this change request:

1. Requester's contact details.
2. Concise summary of the change request.
3. Replacement text for relevant parts of the baseline configuration descriptions.
4. Classification in requester's view.
5. Reasonably detailed descriptions and reasons for the change request.
6. Assessment of the impacts of the change.
7. Supporting materials.

If you require further information or clarification of any details, please let me know.

Yours sincerely,

Andy Wolski
for the ILC Damping Rings Area System Leaders.

Change in Baseline Configuration for ILC Damping Rings

Replacement of two positron rings by a single positron ring

3 August 2006

1. Requester's contact information.

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2. Summary of change request.

The present baseline configuration for the damping rings includes two identical rings for the positrons; each ring is approximately 6.7 km in circumference. The two rings would be stacked one above the other, with a vertical separation of order 1 m, in a single tunnel. The injection systems must be capable of directing bunches from a single beamline coming from the positron source alternately into the upper and lower rings. Similarly, the extraction systems must be capable of combining bunches coming alternately from the upper and lower rings into a single beamline connecting to the RTML.

The proposed change will eliminate one of the positron damping rings, so that the damping rings system would consist simply of two rings, each with circumference roughly 6.7 km (one ring for electrons, and one for positrons), and the associated injection and extraction lines. The systems for separating alternate bunches in the injection line and combining alternate bunches in the extraction line would not be included in the baseline. All other specifications would remain the same.

Eliminating the second positron damping ring would lead to a significant cost reduction in the damping rings subsystem, and would also have technical benefits resulting from the simplification of the injection and extraction systems, and the alignment of the upper positron ring. However, there are technical risks associated with removing the second positron ring, particularly in connection with the electron cloud effect. Design and construction of the baseline configuration should not preclude an upgrade to the two-ring configuration (including the required modifications for the injection and extraction lines) should electron cloud effects be found to limit the operational performance of the positron damping ring. R&D into mitigation techniques for electron cloud effects must be continued as a very high priority.

3. Replacement text for relevant parts of Baseline Configuration Document

The text for the Damping Rings section of the Baseline Configuration Document has been substantially revised and simplified. Instead of the detailed discussion and justification for the configuration choices, a reference is given to the report from which this text was originally taken. Only the initial summary, updated to reflect changes from the original baseline configuration, has been retained. This will make it much easier to maintain an accurate current version in the case of future changes. The proposed new version of the Damping Rings section of the Baseline Configuration (version 27 July 2006) is attached.

4. Classification of change request.

We believe that the change request should be "Class 2" in the CCB classification. The cost implications (a reduction) is likely to exceed $100M. There is potentially a significant impact on technical issues in the damping rings, with R&D for mitigation of electron cloud effects having increased urgency.

Technical impact of the change configuration in itself is limited to the damping rings system. There are potential operational impacts on downstream systems if electron cloud effects make it difficult to achieve the levels of beam stability and/or intensity necessary for luminosity production.

5. Detailed description and reasons for the change request.

The present baseline configuration specifies two positron damping rings: these would be located in the same tunnel, with one ring positioned vertically above the other, with a vertical separation of order 1 m. The injection systems would direct bunches alternately between the two rings; thus the bunch separation would be doubled, compared to that in a single ring, and the average current would be halved. The extraction systems would combine bunches extracted alternately from the two rings and direct them down a single beamline to the RTML and subsequent systems.

The two-ring configuration was chosen for the baseline because of concerns over electron cloud. Studies reported in [1,2] indicated that with the nominal beam parameters (bunch charge and number of bunches) in a single 6 km ring, the electron cloud would reach densities sufficient to drive beam instabilities. Simulations showed that reducing the average current by dividing the beam between two positron damping rings would reduce the build-up of the electron cloud to levels that should not impact operational performance, with a relatively large margin of confidence. The mitigation techniques considered included: coating the chamber surface with a low SEY material, and use of solenoids in field-free regions. We note in particular that the use of solenoids would not be particularly effective in the damping rings, where the bend and wiggler sections dominate the average density of the cloud around the ring; the solenoid field is very weak compared with the wiggler field. This situation is in contrast to the B factories, where the cloud density in the field-free regions makes a significant contribution to the average; solenoid fields in this case are highly effective at suppressing the electron cloud. Comparisons of the configuration options for the damping rings were based on use of solenoids together with optimistically low values for the peak secondary electron yield.

Using two rings instead of one for the positrons has a clear cost impact. Although the two rings can be located in the same tunnel, the costs of the magnets, power supplies, vacuum system, RF system and instrumentation and diagnostics are doubled or nearly doubled over the costs for a single ring. Present estimates suggest a reduction in cost of the order of 20% of the entire damping rings system by eliminating the second positron damping ring. There are also technical considerations: the injection and extraction systems become simpler in the case of a single ring; and the alignment issues are more complex for vertically stacked rings. Although the original assumption was that the vertical separation of the rings would be only 1 m, the size of the cryostats for the RF cavities and the wigglers will require a separation significantly larger than this, with potential implications for the tunnel diameter, at least in local sections. Insofar as we intend to preserve the option of two vertically stacked positron damping rings, the initial support system must already be designed with this in mind. The need to support and align additional loads will mean that the support system cost will not reflect all of the savings that would be associated with a single-ring baseline.

Since the configuration studies in 2005, studies of electron cloud suppression in the damping rings have continued. In particular, two new techniques have been the focus of attention:

- use of grooved chamber surfaces;
- use of clearing electrodes.

Some laboratory-based measurements have already been made of the effective secondary electron yield of grooved chamber surfaces in field-free conditions; the results support simulation studies that show significant reduction in the secondary electron yield [3,4,5,6]. Experiments have not yet been carried out to demonstrate the effectiveness of this technique in dipole fields, for example in the damping wigglers, but simulations suggest that the presence of the magnetic field should not significantly impair the suppression of the electron cloud, though there is some dependence on the shape of the grooves [6]. There are also concerns regarding an enhancement of the impedance of the vacuum chamber from the grooved surface: this has been studied by Bane and Stupakov [7]. Experimental tests are planned at PEP-II of the effect of grooved chamber surfaces on secondary electron yield; for the geometry proposed for these tests, the expected enhancement of the impedance is approximately 50%.

Clearing electrodes have long been used for ion clearing, but it is also expected that they should be effective at clearing the electron cloud. Some simulation studies have already been performed [6], and possible electrode designs have been considered [6,8,9]. Concerns include the possible RF heating of the electrodes from the beam [10], the additional impedance that may come from the electrodes, and the generation (or absorption) of higher-order modes. If these concerns can be addressed, then use of clearing electrodes could be an effective technique for preventing electron-cloud build up inside strong magnetic fields.

We note that the electron cloud studies performed for the configuration studies in 2005 generally assumed a narrow chamber aperture in the wiggler (approximately 18 mm full gap). Since the decision was taken to specify a superconducting wiggler for the baseline configuration, the aperture can be much larger (up to 50 mm [11]). The larger aperture in the superconducting wiggler itself has some effect on reducing the build-up of the electron cloud, and also allows space for use of mitigation techniques (grooved chamber or clearing electrodes).

New results on electron cloud studies, including simulation and experimental results were presented and discussed at VLCW06 [12]. As a result of the discussion, the following points were agreed:

- The baseline configuration should be changed to specify a single positron damping ring, as opposed to the pair of positron damping rings presently in the baseline.
- The design of the damping rings systems should not preclude later installation of a second positron ring, which will provide a possible fallback solution if electron cloud effects turn out to limit performance.
- R&D on the full range of electron cloud mitigation techniques, including experimental demonstration in test facilities, must be a very high priority for the ILC Damping Rings program.

We note that, in addition to the grooved chamber surfaces and the clearing electrodes discussed above, further R&D is necessary on coatings with low secondary yield to understand fully their vacuum properties and possible impact on impedance. Use of solenoids, at least in the field-free regions may also be necessary to achieve good suppression of the electron cloud around the ring. Opportunities for experimental studies on suppression techniques are provided by the B factories, and (possibly from the middle of 2008) by CESR-TF [13].

6. Assessment of the impacts of the change.

The main impact of the change in configuration will be a reduction in cost of the damping rings system of roughly 20%. There will be some simplification in the design, construction and operation, particularly regarding the injection and extraction systems. The change should not impact other systems, either upstream or downstream of the damping rings.

We emphasize that eliminating the second positron ring would place new emphasis and urgency on R&D aimed at suppressing the electron cloud. While the various suppression techniques look sufficiently promising to justify the change in the baseline configuration, there are still technical problems to be overcome and demonstrations to be made. Thus, as long as there remains uncertainty regarding the impact of the electron cloud on the positron damping ring, a configuration with two positron damping rings should remain an alternative, or a potential upgrade.

7. Supporting materials.

Copies of the slides presented on electron cloud at VLCW06 are available at:

https://wiki.lepp.cornell.edu/ilc/bin/view/Public/DampingRings/ConfigStudy

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