

September 8, 2006

**To: Distribution**  
**From: GDE Change Control Board**  
**Subject: Response to the Change Request (July 29, 2006) for the BCD Beam Delivery Section**

## Preamble

This is the CCB response to the proposed changes to apply to the Beam Delivery section of the Dec. 2006 version of GDE ILC Baseline Configuration Document [1]. CCB received the change request from A.Seryi, who represents the leaders for the Beam Delivery System (BDS) Area Group, on July 29, 2006 and CCB forwarded it to GDE the same day [2]. This Change Request was treated as Class-2. T.Markiewicz, G.Blair, K.Kubo and N.Toge were assigned as the CCB reviewers. CCB requested remarks from the GDE Cost Engineers concerning cost implications [3] and MDI/WWS contacts concerning the physics impacts [4].

## Summary

### Requester proposed:

1. To revise the baseline beam crossing angles at the two IRs to be 14mrad/14mrad, from the previous 20mrad/2mrad, while maintaining support of beam collisions at two interaction points. The 20mrad/2mrad crossing angle is redefined as an alternative configuration, whose study will continue as such.
2. To have the two IRs located at  $Z=0$  (the same longitudinal coordinate) in the new baseline layout, instead of the longitudinally shifted layout.

This change request, according to the requesters, is motivated to reduce cost and improve performance; a large fraction of the cost saving is expected from adoption of 14mrad (instead of 2mrad) which reduces the power and cooling requirements of the extraction line magnets, and which reduces the technical difficulty and cost of the magnets in the 2mrad extraction beam line.

### 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, rather than making a final configuration change decision, based on an assessment on the technical and cost merits, CCB makes a recommendation to EC.**
2. **CCB recommends EC to adopt this change request as is, for reasons detailed below in the Discussion section.**
3. **CCB will encourage the relevant parties, and will work with them, to update the "Parameters and Layout" section of BCD in accordance with the new beam crossing angle (14mrad/14mrad) at the interaction point.**

## Discussion:

### Technical Issues:

1. Beam disruption at the interaction point and a flux of beamstahlung photons lead to the need for larger aperture extraction line magnets and other components (bore radii of 0.1 – 0.2m). For instance, the outgoing beam has to go through the final quadrupole magnets where low energy particles produced in beam collisions receive strong kicks. Then the quadrupole magnets downstream of the final quad have to be placed some distance away from the beam collision point so as to create a sufficient transverse separation of incoming and outgoing beams. This makes the aperture requirements even larger. These issues become more acute for a smaller crossing angle, e.g. 2mrad, because of the smaller transverse separation of incoming and outgoing beams.
2. The GDE Magnet Technical System (TS) Group responded [11] to CCB that in the present status of design development the following issues are noted:
  - Large Amp-Turns (>60,000 A-Turns) is needed for some of the extraction line magnets for 2mrad beam lines to create the required field in a large aperture.
  - For these magnets a large coil current (> a few thousand A) is needed to realize the required AT in with the winding that is squeezed in a small volume. This is necessitated by the requirement to avoid interference with the incoming beam.
  - Issues emerge with the technical design, fabrication, assembly, operation, safety and maintenance of such coil systems, which all lead to cost increases.
  - For these magnets substantial portion of iron core would saturate due the locally “pinched” geometry of the core, again to avoid interference with the incoming beam.
  - A larger iron core is needed for these magnets. The total weight of the magnets in the 2rad case will be >600t for extraction dipoles and >200t for quads, where 14mrad case demands only ~15% of these.
  - Ten quadrupole magnets and ten dipoles on each of the electron and positron beam extraction lines fall into this category in case of 2mrad beam crossing angle.
  - Larger power supplies and increased cooling are required for these larger magnets. (2mrad BDS beam line consumes approximately  $\times 6$  power of 20mrad BDS).
3. According to the analysis by the Magnet TS, the magnitude of technical issues is very similar for 14mrad and 20mrad cases. However, significant escalation of the challenge is observed when moving from 14mrad to 2mrad. The Magnet TS group considered that conventional magnet designs, with attempts to maintain separate magnets for the incoming and outgoing beams have proved to be functionally “impossible” or at best highly “infeasible”.
4. The Magnet TS noted the more recent efforts by magnet experts from different institutions to develop a conceptual design which combined the magnets for the two lines in one assembly. These were discussed at the Vancouver GDE Meeting (July, 2006) [5]. The Magnet TS states that with intense efforts these non-conventional solutions are considered to have a chance of being “feasible”. However, the Magnet TS emphasized that by the nature of the aperture requirements and the small beam line separation which arises naturally in the 2mrad layout, these magnets will always be very challenging that “many experienced magnet designers place at the cusp of feasibility”.
5. CCB considers that the statements by the Magnet TS Group should be given very serious weight.

Noting the present focus of GDE activities towards establishing a reasonably feasible and cost-effective design, CCB observes that the discussion by the Magnet TS group offers a substantial ground for supporting adoption of 14mrad/14mrad, as opposed to 20mrad/2mrad, as the new baseline.

6. The BDS Area Group leaders also pointed out the following: Compared with the 2mrad crossing angle, the 14mrad crossing angle design reduces the beam loss and relaxes the radiation condition in the beam extraction lines. Thus, the 14mrad case is expected to offer a better environment for beam collimation and beam diagnostic devices to improve the overall performance of the beam delivery system. CCB concurs that this is another point to note.

#### **Implications to the Physics Programs:**

1. The WWS accepts the 14mrad crossing as baseline at this stage, provided that R&D for small-angle crossing continues as an alternative configuration. It notes that the crab crossing technology still needs to be established.
2. The possible need for a low-angle IR is driven by scenarios (including the SUSY co-annihilation region) where very low energy particles may be the only visible final state; data from the LHC may indicate whether such scenarios are relevant in advance of ILC construction. Any loss to the low-angle detection efficiency may be offset by increased integrated luminosity. The benefits of additional low-angle coverage thus need to be weighed against the potential luminosity losses due to difficulty of machine operation.
3. Technological implications to the detector include the probable need for an anti-DID to reduce backgrounds; the WWS should continue such studies.
4. A single experimental hall containing two IRs is accepted as a baseline by the WWS, provided that reliable studies are performed of vibrations caused by activities on one IR reaching another IR. This may involve radiation safety issues. The operational assumptions such as detector assembly/upgrade and maintenance will have to be specified for such studies, where the WWS is eager to contribute.
5. CCB understands that 14mrad crossing is “large enough” that it would not exclude implementation of a future gamma-gamma option, although the gamma-gamma case is not presently explicitly included in the baseline. The CCB position concerning the gamma-gamma is found elsewhere [6].
6. CCB understands that the WWS concurs with adoption of 14mrad/14mrad layout as the new baseline for BDS. The WWS makes a provisional statement that it would like to see the R&Ds for small-angle crossing continue and be strongly encouraged. CCB assumes that such efforts, at the level dictated by available resources, are acceptable to the WWS.

**Cost Issues:**

1. Part of the cost studies on the BDS has been reported at Vancouver GDE meeting [7]. CCB received a general remark on the cost implications of this change request from the GDE Cost Engineers [3]. In addition, in the CCB hearing of the BDS cost implications associated with this change request [9], CCB learned the following:

- The ratio of the construction cost for the BDS based on the 14mrad/14mrad beam crossing angles, as opposed to the 2mrad/20mrad, at this moment is 0.843. The relative cost, cost reduction and estimated errors, at this moment, are tabulated below:

	Relative Initial Cost (2/20)	Relative reduction when 14/14 is adopted	Error(+)	Error(-)
Vacuum	7.1 %	1.4 %	1.4 %	-0.7 %
D&C	4.6 %	1.0 %	1.0 %	-0.5 %
Magnets	19.3 %	4.6 %	1.7 %	-0.6 %
CF/S	58.4 %	5.6 %	2.0 %	-2.5 %
Instr.	2.0 %	---		
Control	2.3 %	---		
Installation	6.0 %	---		
Cryogen	0.3 %	---		
Sum	100.0%	15.6%	6.2%	-4.4%

D&C: dumps and collimators

Magnets: this includes power supplies

Relative cost reduction is estimated to be 15.6 % + 6.2% - 4.4 %.

- Power consumption at 1TeV for a 2mrad BDS and 14mrad BDS beam lines are 60.9MW and 11.3MW, respectively.
2. CCB considers that these cost studies are still work-in-progress, although a substantial effort has been already put into them. Therefore, the numbers are subject to changes in the future, either through innovative hardware designs or inclusion and exclusion of some of the new or existing equipments for improved designs. However, CCB observes that adoption of the 14mrad/14mrad indeed would lead to a substantial cost reduction.

**CCB Assessment:**

1. CCB considers that the work done by the BDS Area Group and the related Technical System Groups, most notably those by the Magnet Technical System Group, on the design evaluation and their assessment of technical issues, are sound. The proposal to adopt 14mrad/14mrad beam crossing at the interaction point brings positive impacts in all aspects of the technical feasibility, reliability, operability and the cost.
2. CCB notes the issues of physics analysis in the area of slepton pair production studies. However, at this moment of understanding of physics, adoption of 14mrad/14mrad beam crossing angle does not have a fatal impact in this area.
3. Overall, this change request offers a BDS design baseline with good technical feasibility and

healthy physics potential for GDE to focus its detailed design studies during the forthcoming future. Consequently, CCB recommends adoption of this change request, as is.

4. The previous baseline based on the beam crossing angles of 2mrad/20mrad assumes to have the two main linacs pointing each other at 20mrad. This allows us to run the BDS line with the 20mrad beam crossing at energies higher than 1TeV in the future. This description is given in the "Parameters and Layout" section of BCD. CCB assumes that fundamentally the same logic applies for 14mrad/14mrad, and in this case, the two main linacs should be pointing each other at 14mrad, allowing one of the 14mrad BDS to run at higher energies in the future.

## **Additional Notes:**

### **Handling of Cost-Related Information:**

1. This Change Configuration Request is the first one that was submitted after the system-wide cost estimate was compiled by GDE based on the BCD. This is also the first Class-2 change request. After discussion among EC, GDE Cost Engineers and CCB chair, it was decided that the entire CCB will be given access to the detailed costing information, including the "raw" numbers, as found necessary, for each of the incoming Change Configuration Requests, in accordance with the GDE cost disclosure rules [8]
2. The "Hearing" on the cost impacts was held via Webex and telephone connection on August 25, 2006. It was attended by BDS Area Group Leaders, GDE Cost Engineers, EC contact (Barish, acting in place of Walker) and CCB members. The minutes of the hearing, while all "raw" cost numbers are removed are available at [9]
3. However, as reported at the Vancouver GDE meeting [10], all public communication from CCB will have all "raw" cost numbers withheld (replaced by fractional numbers wherever possible and adequate).

## References

- [1] [http://www.linearcollider.org/wiki/doku.php?id=bcd:bcd\\_home](http://www.linearcollider.org/wiki/doku.php?id=bcd:bcd_home) .
- [2] <http://lcdev.kek.jp/ML/PubCCB/msg00068.html>
- [3] Cost Engineers Remarks (with comments from A.Seryi):  
[http://www.linearcollider.org/wiki/lib/exe/fetch.php?cache=cache&media=bcd:reply\\_from\\_cest\\_o\\_ccb\\_for\\_bds-ccb\\_v.2.pdf](http://www.linearcollider.org/wiki/lib/exe/fetch.php?cache=cache&media=bcd:reply_from_cest_o_ccb_for_bds-ccb_v.2.pdf)
- [4] WWS/MDI Statements:  
[http://www.linearcollider.org/wiki/lib/exe/fetch.php?cache=cache&media=bcd:wwsmdi-bds-ccb\\_aug2006.pdf](http://www.linearcollider.org/wiki/lib/exe/fetch.php?cache=cache&media=bcd:wwsmdi-bds-ccb_aug2006.pdf)
- [5] <http://ilcagenda.cern.ch/getFile.py/access?contribId=121&sessionId=83&resId=0&materialId=slides&confId=316>
- [6] <http://www.linearcollider.org/wiki/lib/exe/fetch.php?cache=cache&media=bcd:ccb-com-bdsgg20060601.pdf>
- [7] <http://ilcagenda.cern.ch/getFile.py/access?contribId=75&sessionId=2&resId=1&materialId=slides&confId=316>
- [8] [http://www.linearcollider.org/newslines/pdfs/dc\\_20060831\\_cost-confidentiality.pdf](http://www.linearcollider.org/newslines/pdfs/dc_20060831_cost-confidentiality.pdf)
- [9] CCB Hearing on Cost Impacts of the BDS CCR:  
[http://www.linearcollider.org/wiki/lib/exe/fetch.php?cache=cache&media=bcd:bds\\_hearing20060825e.pdf](http://www.linearcollider.org/wiki/lib/exe/fetch.php?cache=cache&media=bcd:bds_hearing20060825e.pdf) ,  
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- [10] <http://ilcagenda.cern.ch/contributionDisplay.py?contribId=56&sessionId=2&confId=316>
- [11] Response to CCB inquiries from the Magnet Technical System Group:  
<http://www.linearcollider.org/wiki/lib/exe/fetch.php?cache=cache&media=bcd:magnettsreports.pdf>