September 23, 2006

To: **Distribution**

From: **GDE Change Control Board**

Subject: **Response to the Change Request (September 8, 2006) for the BCD Beam Delivery Section**

Preamble

This is the CCB response to the proposed changes to apply to the Beam Delivery System (BDS) section of the 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 September 8th, 2006 and CCB forwarded it to GDE the same day. This Change Request was treated as Class-1. T.Markiewicz and G.Blair were assigned as the CCB reviewers. CCB requested remarks from the GDE Cost Engineers concerning cost implications (Appendix 1) and from BDS AG Leaders concerning the amount of iron to use for the spoilers (Appendix 2).

Summary

The current BCD has a total of eight magnetized iron muon spoilers; one 18m and one 9m spoiler per beam-line.

Requester proposed:

1. To reduce all four 18m muon spoilers to 5m and to eliminate the four 9m muon spoilers completely.
2. To retain the caverns for all eight muon spoilers at their current dimensions to accommodate future upgrades if proved necessary by the eventual beam halo population. Such an upgrade would take about 3 months assuming a schedule of 3-shifts, 7-days a week.

This change request is motivated by the reduction in the mass of iron required for the shorter spoilers and by the notion that such reduction of the spoiler mass would be still acceptable in terms of detector background and personnel safety.

CCB response:

1. **CCB agrees that the cost change (in this case, reduction) expected from this change request qualifies it as Class-1.**
2. **CCB agrees to adopt the proposed change request as is, for reasons detailed below in the Discussion section.**
3. **CCB approval of this change request is contingent upon continuation of detailed detector studies on their whole system, including both charged particle trackers and calorimeters, to ensure that the occupancy due to muons does not affect the high precision physics measurements.**

Discussion:

Technical Issues:

1. Muons are produced in electromagnetic showers in the beam-halo collimation system. A small but significant fraction of these can then travel the extent of the BDS tunnel to reach the detector halls. The issues to consider are detector background and personnel protection in the detector hall and in any access tunnels.
2. The need for 18m and 9m spoilers previously considered was based on the duty factor of the NLC and a conservative assumption (from SLC experience) of a beam halo whose occupancy is 0.1% of the core beam. Because of the $\times 70$ $[(n_bQ)_{Xband}/(n_bQ)_{Lband}]$ better ILC duty factor for "fast detectors" and the conservative assumption of 0.1% lost halo, the change proponents point out that simulations exist that predict the halo population to be about three orders of magnitude smaller [1,3] in perceived ILC operation conditions. The lengths and placement of the spoilers were determined to best minimize detector backgrounds within the constraints of the optics. The result has been found to provide an adequate shielding capability which satisfies the personnel protection requirements for occupants of the IR hall.

Implications to the Physics Programs:

1. The muons will contribute to the background occupancy of the tracking detectors. The TPC occupancy due to the muons is now estimated to be of order 0.15%. The occupancy of the TPC, from all sources, should be kept below a total of 1%; so the change request is consistent with the TPC requirements. However this needs to be checked with detailed simulations for the very high precision ($\sim 10^{-5}$) physics measurements.
2. The background level should be low enough so that work can be carried out on the detectors during machine operation, together with sufficient protection in the case of machine failure. This appears to be the case after the proposed change, provided the beam-halo estimates are correct.

Cost Issues:

1. The main impact of the change in configuration will be an 81% reduction in the cost of the muon spoiler system.
2. The cost saving is approximately 3.1 %, normalized to the total BDS construction cost.
3. The cost saving is dominated by the reduction in the amount of iron in the muon spoiler system from 19,628 tons to 3,635 tons.

CCB Assessment:

1. Appendix 3 summarizes CCB's understanding on presently known detector background implications. Likewise, Appendix 4 summarizes CCB's understanding on presently known radiation safety implications of muon spoilers, as derived from the materials provided by the BDS AG Leaders and by L.Keller.
2. Given the continually changing configuration of the ILC together with the difficulty in obtaining quantitative limits of detector performance, in addition to the newness of any real installation plan, CCB finds the following issues while assessing the merit of the proposed change:

- A change request for a 14mrad/14mrad configuration has been recently endorsed by CCB. For this new configuration, no documentation other than the ray trace plot provided is yet available on the muon background issues, although basic geometry implies that the new configuration will be better for personnel protection. It is understood that this work is in progress. Furthermore, while some of the 20 mrad/ 2 mrad documentation mentions 3m concrete neutron shields, these do not appear to be in the BCD. These studies should be adequately documented.
- As Appendix 3 shows, with 0.1% halo population, the physics analysis with TPC is considered very likely to withstand muon background with 5m magnetized iron (5m muon spoilers) in 500GeV operation. While the muon background situation becomes marginal in 1TeV operation, if the halo population is factor 1/10 ~ 1/1000 smaller, as estimated in the references quoted by this change request, this will be a non issue, also.
- While the detector scheme based on TPC is used to benchmark the performance of the muon spoiler system, we note that presently there are other detector concepts under consideration as well. For instance, silicon tracking is probably more robust against muon backgrounds. We also note that the calorimeters are considered to be less of a problem, because of the higher time resolution which allows us to decipher the signals on the bunch-by-bunch basis. However, detailed, quantitative simulation studies of their performance against muon backgrounds have not yet been completely done.
- True optimization of the muon wall issue requires cooperation from the detector community over and beyond the estimation of total occupancy in one of several kinds of detectors. This has been sought by the BDS group in the past and currently as well. The response to this change request should warn the detector community that they may need to indeed plan for this in their tracking, calorimetry, and muon detection systems, both from the point of view of hardware tagging and the impact on event reconstruction, a level of detail no one has had the manpower to address to date.
- As Appendix 4 shows, the radiation safety requirements in the collider hall are well cleared with 5m muon spoilers in nominal beam operation with 0.1% halo, whether in 500GeV or 1 TeV operation. This, together with Appendix 3, indicate that if the halo population is indeed substantially (say, 1/1000) smaller than 0.1%, and if the understanding of the detector background and their impact on physics analysis are correct, the ultimate factor that determines the required thickness of muon spoiler is the so-called "worst case" accident, not the detector background.
- The statement is made that the "worst case" accident scenario is well covered (25× less than SLAC Radiation Safety limit) by a 5m magnetized wall. While no documentation, for this statement existed at the time this change request was submitted, simulations were repeated at the request of the CCB. The results are summarized by the 2nd part of the table in Appendix 4 and will be presented in the near future to the BDS group. The accident examined is failure of the kicker system that brings the beam to the tune-up dump; the IRs are protected by copper stopper-burn-through monitors which are the source of the muons; the 5m wall protects against these muons. The role of the 5m wall as part of the beam containment system for the primary beam is mentioned in the documentation provided but not developed as part of the change request.
- The installation plan is a reasonable first start as an estimation of the impact to ILC, if an upgrade of 5 to 18m is determined necessary. However, more studies seem necessary to

accurately evaluate the schedule impact, for instance, by taking into account the conflicts that may occur once the detector is on beamline and other beamline components are already in the tunnel. This also applies to new installation of 9m units.

3. With all the caveats that we note in conjunction with this change request as outlined above, the CCB's concludes its assessment as follows:
   - Technically, this change request is acceptable in the sense that the proposed reduction and simplification of the muon spoiler system appear still acceptable from the viewpoint of presently known simulation results, and that a provision is still maintained to revert to the more conservative configuration as laid out in the original baseline.
   - This change request brings in a certain cost reduction.
   - Consequently, CCB accepts this change request as is, provided,
     ① The alcoves in the tunnel, with their original dimensions, are maintained so that the muon spoilers can be extended after ILC startup, if found necessary, as stated in the change request proposal document, and.
     ② Organized, coordinated and detailed detector studies are carried out on their whole system, including both charged particle trackers and calorimeters, to ensure that the occupancy due to the muons does not affect the very high precision physics measurements.

Additional Notes:

Handling of Cost-Related Information:

1. As 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).

References

[1] http://lcdev.kek.jp/ML/PubCCB/msg00079.html , http://www-project.slac.stanford.edu/ilc/acceldev/beamdelivery/rdr/docs/CCR_muon/CCR_muon_walls.doc and references therin.

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

[3] "Estimation of beam halo in TESLA", R. Brinkmann, http://acfahep.kek.jp/BDIR2000/proceedings/brinkmann.pdf

Appendix 1: Response from GDE CE on Cost Impacts of Muon Spoiler CCR

- *Subject*: [CCB-661] RE: Cost Implications of BDS Change Request - Sep.9, 2006
- *From*:Tetsuo Shidara
- *To*: CCB
- *Cc*: A.Seryi, D.Angal-Kalinin, H.Yamamoto, P.Garbincius, W.Bialowons, N.Walker
- *Date*: Thu, 14 Sep 2006 23:45:07 +0900

Dear Toge-san,

Here is a very brief reply from CEs for the BDS change request of the muon spoiler system.

Cost saving: Cost difference BEFORE and AFTER the change is approximately 3.1 %, normalized to the total BDS construction cost.
CCR Class: This cost saving corresponds to Class 1.

Note 1: Due to our ILC-GDE confidentiality protocols, actual cost numbers are not shown here. With your knowledge you have gained in the past, this form of fractional cost difference might be sufficient for CCB.

Note 2: Assessment is based on the file "BDS_WBS_v1.7" prepared by the BDS AS leaders. We only consider the cost difference of 5-, 9-, 18-m muon spoilers without changing the related CF&S design.

Note 3: The amount of iron, BEFORE and AFTER this change, was reported by Andrei as 19628 tons and 3635 tons, respectively, based on the file "muon_spoiler_updated" prepared by Jin-Young Jung, et al. Unit cost ($/kg) might be higher than usual if the cost difference is dominated mainly by this iron weight difference.

Tetsuo Shidara for CEs

Appendix 2: Response from BDS AG Leaders on the amount of iron before and after applying the proposed CCR

- *Subject*: [CCB-657] RE: Cost Implications of BDS Change Request - Sep.9, 2006
- *From*: Andrei Seryi
- *To*: N.Toge, CCB
- *Cc*: D.Angal-Kalinin, H.Yamamoto, P.Garbincius, W.Bialowons, N.Walker
- *Date*: Tue, 12 Sep 2006 09:50:55 -0700

Dear Nobu,

For the amount of steel: the presentation by Jin-Young Jung, which is referenced in supporting materials, tells that single 5m long muon spoiler have the following volume and mass of iron (slide 11):

116m^3 of iron, which is 908.7 ton (lbs converted to tons)

For single set of 9m and 18m muon walls, one would have 626.4m^3 of iron, which is 4907 ton

For four branches of beamlines one would multiply the numbers by four.

So, amount of iron before: 19628 ton after : 3635 ton.

Best regards
Andrei

Appendix 3: CCB's understanding of the Detector Background Evaluations in Relation to BDS Muon Spoilers.

TPC Background Evaluation **Simulation: 15% of 0.1% of 200 bunches of 2E10 e-,e+ on PC3, both sides of BDS = 1.2E9** **Count: Number of Muons entering TPC (=2.5m diameter area at IP)** **Uncertainty 1: Contribution from other elements of collimation system: Action: Multiply ×6** **Uncertainty 2: Number of TPC "hits" per muon: Assume 1 hit/entering muon** **Note 200 muons correspond to 61.6 usec @ 308ns bunch spacing** **Assumption: TPC can accept ~2500 hits corresponding to 1% Occupancy**		
Muon Spoiler Layout	250GeV beam	500GeV beam
18m magnetized	$24 \times 6 = 144$	$122 \times 6 = 732$
5m magnetized	$64 \times 6 = 384$	$536 \times 6 = 3216$
zero	$1276 \times 6 = 7656$	$3045 \times 6 = 18270$

This table is derived from L.Keller's presentation of Summer, 2006, plus FNAL-FN-07890-AD, and H.Yamamoto's WWS/MDI remark in response to A.Seryi, all quoted in BDS AG's CCR memo.

Notes:

1. The quoted hit rates (per 200 crossings) account for contributions from both the electron and positron sides.
2. FNAL-FN-07890-AD (quoted in CCR) says that 1% occupancy is OK for trackers and calorimeters. Yamamoto in his WWS/MDI letter says that 384-hit corresponds to 0.15% occupancy. If we take those numbers, 1% TPC occupancy means 2560 hits.

Appendix 4: CCB's understanding of the Radiation Safety Evaluations in Relation to BDS Muon Spoilers

Radiation Safety Evaluation: Regular Operation

Simulated Muon Dose in IR2 when IR1 has beam (20mrad/2mrad config)

Total Beam Loss rate of 0.1% from two nom. ILC beams distributed on spoilers, absorbers and protection collimators according to TURTLE runs done when calculating efficiency of the collimation system

Safety Goal is <0.05 mRem/hr, corresponding to 100 mRem/year

[3m Concrete added for neutron protection (little effect on muons)]

Muon Spoiler Config	Max rate in any 80cm x 80cm area in mRem/hr	
	500GeV ECM	1TeV ECM
5m magnetized Fe	< 0.01	0.04
18m unmagnetized Fe	0.03	0.12
No shielding	0.09	1.5

Radiation Safety Evaluation: Worst Case Accident

Case: Failure of Kickers bringing beam to Linac TuneUp Dump

100% ILC Beam (nominal parameters) hits either of two stoppers in front of collimation system (14mrad/14mrad config)

Safety Goal = <25 Rem/hr and 0.1 Rem Total

Shielding: 5m Magnetized Fe

Calculated Dose Rate at IP-side of Fe Wall (Z=340 m) and in IR Hall

Dose Rate (mrem/hr) = (muons/cm^2/sec)(0.13)

Private Communication: Lew Keller: To be presented at a 2 Oct 2006 BDS meeting

Target	Max Simulated Muon Dose rate in any 50cm x 50cm area in Rem/hr			
	500GeV ECM		1TeV ECM	
	Z = 340 m	IR Hall	Z=340 m	IR Hall
STL1, z=1490m	1.53	0.042	3.1	0.43
STL2, z=1197m	0.49	0.013	1.7	0.13

Most part of this table, unless otherwise noted, is derived from L.Keller's presentation of Summer, 2006, as quoted in the CCR documented provided by the BDS AG leaders.