BAW-1: ML Accelerator Gradient
Summary of Discussions and Proposal

Proposal submitted by ILC GDE Project Managers for consideration as a Baseline Change Request, 28 September, 2010.

Summary

We discussed the optimum Main Linac (ML) operational field gradient based on the current status of the global R&D effort and the evaluation of achieving the milestone cavity performance of 35 MV/m, with $Q_0 \geq$ 8E9, and a second pass production yield of 56% in the middle of TDP.

As a result of the workshop discussions, we propose keeping our best effort to realize a ML accelerator operational gradient of $\geq$ 31.5 MV/m with $Q_0 \geq$ 1E10, on average, with a gradient spread of not larger than ±20%.

To accommodate the operation of cavities with the proposed range of gradients, additional installed RF power capacity of 10-15% (for 31.5 MV/m ±20%) is required over that stated in the RDR. (The additional overhead will be smaller if, after further R&D, the gradient spread can be reduced.) This provides adequate power for the statistically likely possibility of a sequence of high-gradient cavities in a given RF unit. It is assumed that this additional cost is more than offset by the cost-effectiveness of accepting a gradient spread (in terms of mass-production yield and its impact on cavity costs).

Discussions:

1. Cavity gradient TDP2 R&D goal:

We discussed the global status of cavity gradient R&D as reflected in the production yield database. The interim TDP1 R&D milestone of cavity production yield, >50% at 35 MV/m (including cavities which have undergone a 2nd surface treatment and test process), has been achieved.

We discussed strategies for gradient improvement, categorizing and prioritizing tasks leading toward the Technical Design Report (2012) and further effort beyond 2012. These are listed as:

- Short term R&D topics:
  - manufacturing process including quality control, preparation with surface treatment including a time/cost effective process such as "vertical EP", and further studies towards the understanding and (further) reduction of field emission.
- Long term R&D topics:
  - seamless hydro-forming, large-grain with Chemical Polishing (CP), alternative cavity shapes, etc.

During the discussions, it was suggested that the current results indicate that an R&D target of 80% at 37 MV/m could be more practical; this was provoked in-part by the observation that recent cavity results indicate either gradients exceeding 35 MV/m, or much lower gradients (<25 MV/m), indicative of mechanical fabrication problems. Although the result is encouraging, it was felt that the statistics for these observations were still less sufficient to justify adopting this as the primary R&D goal. In addition, it is quite likely that the two goals listed in the table below for vertical test, (50% at ≥38 MV/m, 90% at 35 MV/m), will prove to be reasonably consistent once more statistics are gained during TDP2. For this reason, it was decided to keep the original TDP2 R&D goal of 90% at 35 MV/m (including second-pass processing). Keeping this goal underscores our emphasis on implementing quality control to sustain the high yield.

2. ML accelerator cavity operational gradient: Project specification

Based on the above, the ML accelerator cavity gradient specification has been discussed with the goal to produce a project specification which balances: 1) the required minimum cavity and cavity-string observed gradient limits and 2) the ML accelerator minimum operational gradient performance requirements. The discussion concluded as follows:

1) Observation

The current balance of cavity performance (35 MV/m) and ML accelerator operational performance of 31.5 MV/m is very challenging. However, we propose to keep this guideline, on a best effort basis, with forward looking spirit, based on the progress in the last few years.

2) Proposal for the strategy:

- We propose to revise our major cavity performance guidelines to have two categories, as follows:

  - R&D goal for nine-cell cavity gradient in vertical test: ≥35 MV/m with 90% yield (with Q_0≥8E9) including 2nd pass processing and test (as needed). This infers an average gradient reasonably higher than 35 MV/m, and may be considered equivalent to ≥38 MV/m on average.
  - Project specification for nine-cell cavity gradient in vertical test: ≥35 MV/m on average with total gradient spread, of no more than ±20%.

- We propose to keep our best effort to realize a ML accelerator operational gradient of 31.5 MV/m, on average, with a gradient spread of no more than ±20%. An additional HLRF power margin of 10-15% will be required to support the proposed gradient spread, it may be balanced by the cost-effectiveness of accepting a gradient spread.
  (underlined part is our core recommendation).

- The summary of the discussion and proposal is given in Table 1.

Table 1: Technical Design Cavity Performance Specification and R & D Goal.		
Cost-relevant design parameter(s) for TDR	**ML cavity gradient Project Specification**	**9-cell Cavity R&D Goal**
9-cell Cavity Gradient in Vertical Test, including 2nd pass, with $Q_0 \geq$ 8E9	35 MV/m, average w/ Spread: 28–42 MV/m ($\leq \pm$20 %)	35 MV/m at 90 % yield (equivalent to $\geq$ 38 MV/m, average)
9-cell Cavity Gradient in Cryomodule Test	34 MV/m, average	34 MV/m, average. CM Gradient Test $\leq$ 3 % below Vertical Test
ML Operational Gradient with $Q_0 \geq$ 1E10	**31.5 MV/m average, w/** Spread: 25–38 MV/m ($\leq \pm$20%)	31.5 MV/m, average. Operational gradient limit $\leq$ 1.5 MV/m below Cryomodule Test. Controls margin $\leq$ 3 %
Required RF power overhead for control (see RF Power Table link, below)	~10-15% (TBD)	

In Table 1, both the Specification and the R & D Goal are described in terms of an average cavity gradient to be achieved with an allowance for peak-to-peak gradient spread. Cavity performance is listed for two test stages, Vertical Test and Cryomodule Test, corresponding to tests done with single cavities and tests done after a cavity has been connected to a cavity string and inserted into a cryostat, respectively. The Main Linac (ML) Operational Gradient refers to the gradient at which the cavity can operate indefinitely following installation in the main linac. The table lists an R & D Goal of not more than 3% deterioration of cavity gradient from Vertical Test to Cryomodule Test, assuming the 35 MV/m with the 90 % yield to 34 MV/m on average, respectively. It also lists an R & D goal operational limit of not more than 1.5 MV/m below the limit seen in the Cryomodule Test and an operational Controls Margin gradient of not more than 3%.

Links for further information presented at the Baseline Assessment Workshop:
http://ilcagenda.linearcollider.org/conferenceOtherViews.py?view=standard&confId=4593

Summary
R & D Status and ILC Cavity Database record
General terminology describing gradient performance
Cavity performance from Vertical Test to Cryomodule Test
RF Power – installed capacity table