# ILC R&D Board Task Force on High Gradients (S0/S1) Charge and Definition of Goals

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#### 1.1 Introduction

The need of making the accelerating gradients in the superconducting cavities more reproducible is a top priority. The current status as has been measured at DESY and KEK is not yet satisfactory. 35-40~MV/m at a high  $Q_0$  has been achieved in 9 cavities in low-power tests as proof-of-principle. In a production-like mode of cavity processing not enough cavities achieve the performance specification of the ILC: 35~MV/m at  $Q_0 = 10^{10}$ .

On the positive side single-cell cavities in various labs have obtained even higher performance. Nonetheless, the yield rates vary between labs. Still, the single-cell cavities indicate that the current treatment is not far away from the good parameter set even when taking into account the variations in the laboratories.

Looking at the history of TTF some significant effort is needed to transfer results on the simpler single-cell cavities to multi-cells. Three cavity productions (20-30 each) were done to improve the gradient from the level of 5-10 MV/m to 25 MV/m with classical etching. This included especially the training of companies to provide the required niobium and electron beam weld quality, but also some significant learning curve in the surface preparation of cavities for testing.

To date, the first real production run on multi-cells with the goal to achieve ILC gradients using electropolishing (EP) as a surface treatment has been undertaken at DESY. So far the results show a comparable performance to the etched (BCP) cavities (average maximum gradient with  $Q_0$  below  $10^{10}$  for BCP:  $26.6 \pm 4.5$ , for EP:  $28.5 \pm 4.4$ ) with the advantage of avoiding the time-consuming  $1400^{\circ}$ C heat treatment. The original goal of ILC-like gradients has not been achieved in a sufficiently reproducible manner. To improve the yields for 35 MV/m in production quantities the R&D board has been asked by the ILC executive committee to set up a task force which addresses this issue.

The module performance has been tracking vertical tests performance quite well. The average module gradient improved to 26 and 28 MV/m in the two cryomodules built with the most recent cryostat concept and etched cavities.

# 1.2 Gradient Task Force Charge

The RDB is asked to set up a Task Force to carry out a closely coordinated global execution of the work leading to the achievement of the accelerating gradient specified in the ILC Baseline.

A definition of the R&D goals for the cavity performance in terms of gradient and yield and a plan for achieving them should be proposed by this group, which should take account of the global resources available and how they may be used most rapidly and efficiently.

The accelerating gradient performance and yield should be specified for cavity production, and treatment process (S0), and for cryomodules (S1), and the plan should cover the demonstration of this performance in all cases.

The GDE will facilitate the coordination at the global level to achieve this vital goal as soon as possible.

#### 1.3 Definition of Goals

## 1.3.1 Cavity Production and Treatment: S0

#### 1.3.1.1 S0 Ultimate Goals:

The cavity performance is influenced by both the fabrication process and the surface preparation process. Due to the ongoing effort in all the regions to qualify further vendors for cavities the S0 goals are two-fold:

- The preparation process and vertical test yield for 35 MV/m at  $Q_0 = 10^{10}$  should be greater than 90% for a sufficiently large number (greater than 100) of preparation and test cycles. There should be a complete description of the preparation and testing processes so that these can be reproduced in qualified facilities located in other places. The time scale for this goal should be commensurate with the completion of the TDR (middle of 2009).
- After a viable cavity process has been determined through a series of preparations and vertical tests on a significant number of cavities, achieve 35 MV/m at Q<sub>0</sub> = 10<sup>10</sup> in a sufficiently large final sample (greater than 30) of ninecell cavities in the low-power vertical dewar testing in a production-like operation e.g. all cavities get the same treatment. The yield for the number of successful cavities of the final production batch should be larger than 80% in the first test. After re-processing the 20 % underperforming cavities the yield should go up to 95%. This is consistent with the assumption in the RDR costing exercise.

The original goal in the BCD was a distribution of cavity gradients of 37 +/- 5% MV/m. This corresponds to a 95% yield assuming the cavities have to perform at more than 35 MV/m in the low-power test before being assembled to accelerator modules. As the yield is a more important number from project point-of-view, the task force prefers to use the yield number as opposed of aiming at a certain shape of the distribution. The realistic shape of the distribution is unknown. Most likely, it will be non-gaussian (opposed to what was assumed in the BCD) with an asymmetry due to the hard physical limit at high field

To give more confidence in the plan described below and to define a more refined set of milestones the following intermediate goals are set.

#### 1.3.1.2 S0 Intermediate goals:

A large confidence in the cavity gradients can be gained by making two sets of experiments:

- 'Tight-loop' processing of a few (1-4) cavities over and over again. This should be started right away on existing cavities.
  - o The goal is to demonstrate gradients after new 10 preparations are within less than 10% of the average gradient of each cavity.
- Production'-like processing of batches of at least 20 cavities each (with some time delay between them) in a state-of-the-art processing facility.
  - O The staging of these batches should allow for process improvements obtained from parallel R&D programs, such as single-cell preparations, or 9-cell studies equipped with diagnostics, and other materials and process evaluations.
  - O Whereas during the setup of the first production run some more re-testing (up to 3-4) would be expected, in the second and the following ones, the maximum number of re-test should be progressively lower (a total of 1-2 tests per cavity) until the goals above are achieved.
- All the above mentioned preparations and tests can serve to fulfil the first of the
  ultimate goals. The production and preparation of the cavities can be dispersed
  over the regions provided the processes are well enough defined to make them
  comparable. Different cavity shapes might be acceptable for this goal provided
  sufficient confidence has been achieved for each shape under consideration.

For the final production mentioned in the ultimate goals, the cavities should be again collected from the various regions (e.g. to qualify different niobium vendors and cavity manufacturers). The cavity shape needs to be defined by this date. In case of the surface preparation in each region (and not in one central facility), before this preparation series it is mandatory to establish that the processing facilities are equivalent in their performance. A method of achieving this could be to exchange qualified 'standard' cavities across the regions.

## 1.3.2 Cryomodule Production: S1

Achieve 31.5 MV/m at a  $Q_0$ = $10^{10}$  as operational gradient as specified in the BCD in more than one module of 8 cavities including e.g. fast tuner operation and other features that could affect gradient performance

## 1.3.2.1 Final goal (following the BCD definition):

All cavities built into modules perform at 31.5 MV/m including enough overhead as described in the BCD. The cavities accepted in the low-power test should achieve 35 MV/m at  $Q_0 = 10^{10}$  with a yield as described in the S0 definition (80% after first test, 95% after re-preparation). At least three modules should achieve this performance. This could include re-assemblies of cryostats (e.g. exchange of cavities). It does not need to be final module design. An operation for a few weeks should be performed.

## 1.3.2.2 Intermediate goals

Achieve 31.5 MV/m average operational accelerating gradient in a single cryomodule as a proof-of- existence. In case of cavities performing below the average, this could be achieved by tweaking the RF distribution accordingly.