Challenges for the ILC SCRF R&D

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The challenges for the ILC R&D program are noted and progress in meeting them described. Despite technical, organizational and resource difficulties the program results are positive. indicating that our goals are within reach.

1 Introduction

Good progress in meeting the goals set by the GDE Directorate is being made although there remains considerable work to do. The rate of progress is increasing through recently adapted infrastructures coming on line for ILC SCRF. Work is underway for a further, very significant speed up of that rate with additional infrastructure around the world being put into place.

The "high level" goals set by the GDE leadership are cast in terms of the groups defining the challenges. We adopt their nomenclature here for describing those goals: S0 – Demonstrate high yield of 35 MV/m cavities in vertical test; S1 – Assemble and test several cryomodules with average accelerating gradient > 31.5 MV/m; S2 – Demonstrate an RF Unit with ILC parameters, design gradient and ILC-like beam at full pulse rate. An RF unit is one klystron plus modulator, two cryomodules with 9 cavities and one cryomodule with 8 cavities plus a quadrupole. [1] Some results are already in hand

In the interests of meeting these global goals as well as various regional and national goals, infrastructures for manufacture, processing and test are being outfitted in the three regions. This effort will soon increase the pace at which results relevant to the S group goals are produced and put our community in a position to publish an EDR with confidence.

2 S0 - Where are We?

Proof of principle for 35 – 40 MV/m exists but the yield is low for 35 MV/m in 9 cell cavities. Single cell gradients of 40 - > 50 MV/m show that the baseline procedures being used are capable of good results. Controlled preparation and tests are underway at several labs in an effort to discover the sources of the poor reproducibility. It is widely agreed that many coordinated tests will be required. Basic R&D with single cells is also underway to find even better treatments.

An idea of the reproducibility challenge can be gained from Fig. 1 showing that there are significant instances of good results but they had to be selected from a large number of tests on a large number of cavities. Fig. 2 shows the typical spread in results now being obtained. This relatively small yield implied by these figures is the focus on an increasingly coordinated international program to understand the sources of the scatter and devise methods to narrow it

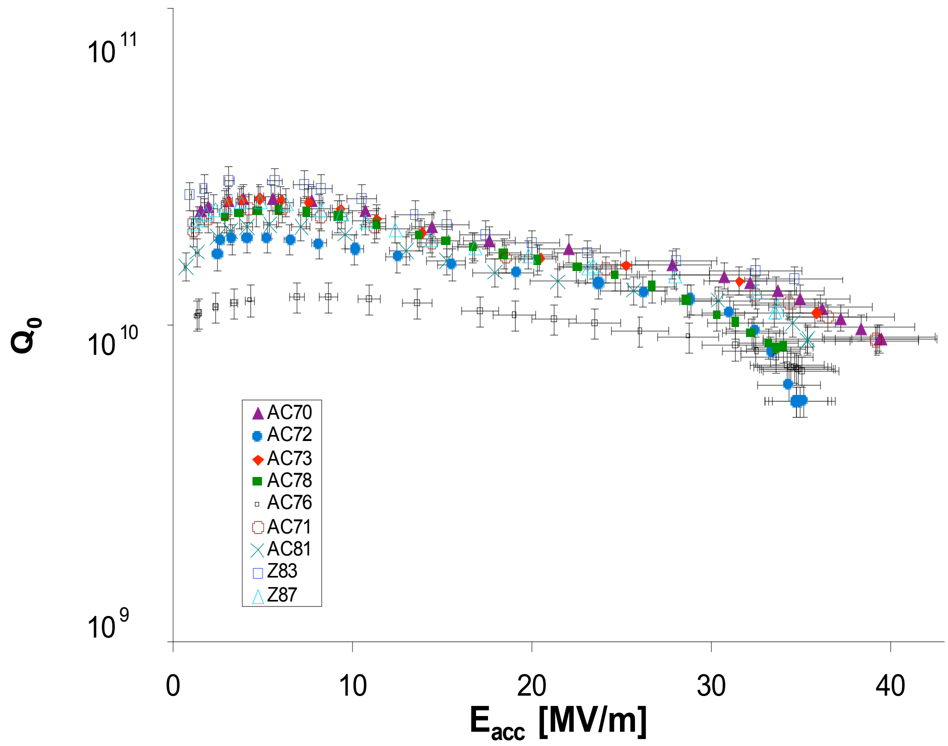

Fig. 1 TESLA 9 cells; best tests of 9 best cavities in vertical tests (courtesy Lutz Lilje)

significantly.

I am very pleased to report that there is already in indication of progress in this regard. Colleagues at KEK, using a limited sample of cavities to contrast with the usual processing results report a narrowing of the spread in single cells to less than 10 MV, centered at 46 MV. A key step in the improved process is believed to be a final, light, electropolish using freshly prepared acid. Of course, it is imperative to check these results using a commonly agreed upon protocol in the three regions and then, if good results are forth coming to begin applying the method to 9 cell cavities.

3 Upgraded and New Infrastructures

In order to make a significant increase in the rate at which cavities can be processed and tested as required by the S0 and other S activities, all three regions are bringing more infrastructure into operation.

In the Americas, JLAB has modified existing EP, HPR and Vertical test apparatus to deal with 9 cell 1.3 GHz cavities. Cornell has installed a vertical EP apparatus to see if this potentially more economical method of EP suffices. At FNAL/ANL vertical test capabilities

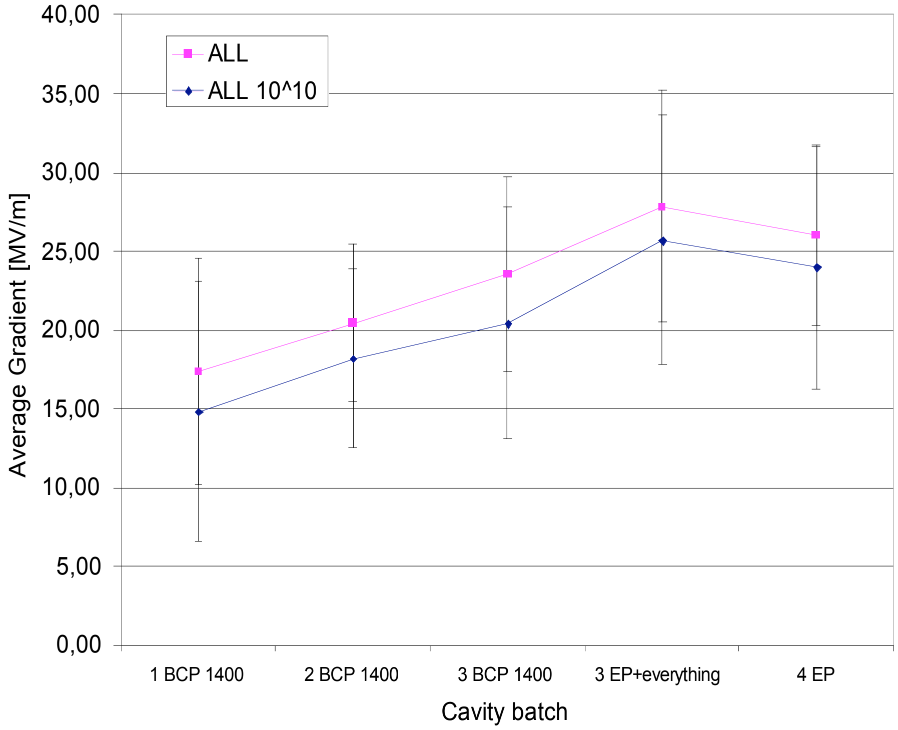

Fig. 2 Recording of all cavity tests prior to mid 2007. The notations along the bottom refer to processing methods: BCP – buffered chemical polish; EP – electropolish (courtesy Lutz Lilje)

for up to three pits and processing facilities are being installed for high test throughput. In Japan at KEK a new facility is also being constructed that will contain new processing apparatus and a clean room for assembly work.

Taking into account the existing facilities and the new ones coming on line, Table 1 shows the potential for processing and test throughput by year.

Year	Jlab	Cornell	ANL/FNAL	KEK	DESY	Total
2007	30	10	20	30	50	140
2008	40	10	50	40	50	190
2009	50	10	50	40	50	200

Table 1 The physical infrastructure limited number of cavity individual processing and test cycles that could be carried out in the three regions.

Whether the other resources required to fulfill this potential will be available remains to be seen. It is hopeful that the total of orders for new cavities from industry, needed for testing, is 60 in 2007.

4 S1 – Where are We?

In this area there is significant progress to report. A new module test stand has been completed at DESY and is now in operation. Modules 6 and 7 of the TESLA Test Facility/FLASH assembly have been successfully tested there. This is a big advance in that this facility is independent of the accelerator so that features of the cryomodules can be studied without interrupting beam operation of the accelerator. Fig. 3 shows the steady progress being made towards the ILC goal for S1.

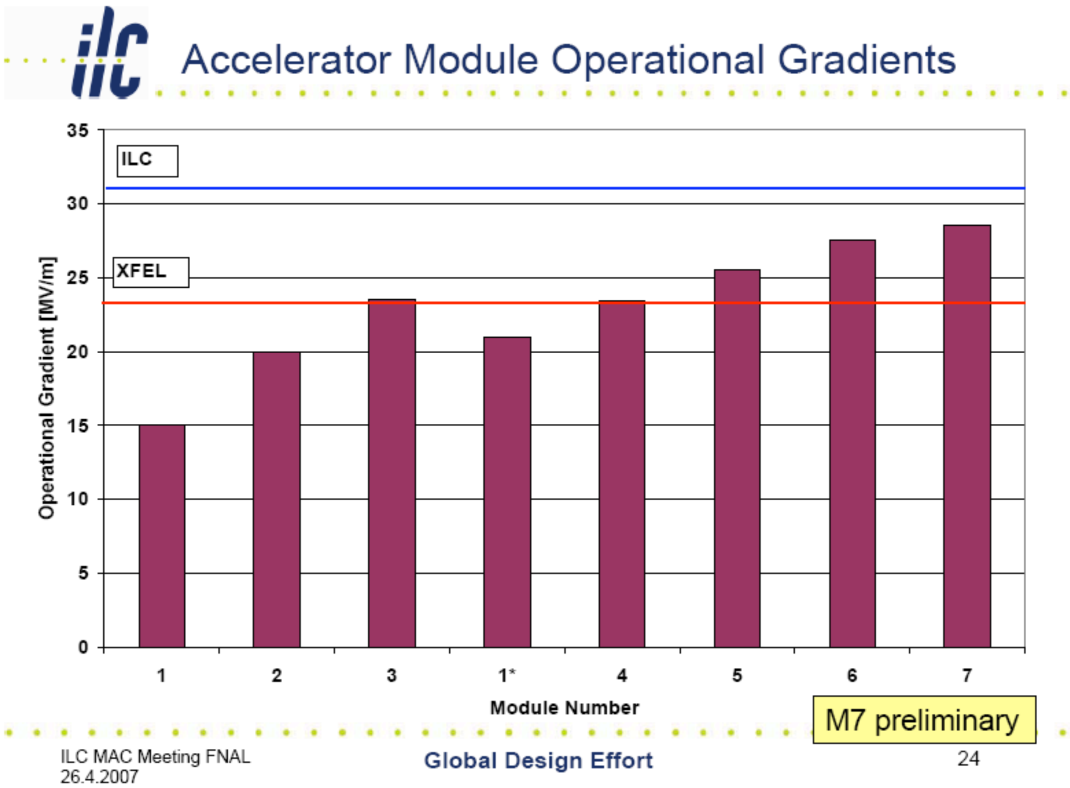

Fig. 3 Showing the improvement with module number of the achievable operating gradient

ILC module assembly and test facilities are being installed at KEK and Fermilab. When complete we will have powerful means for making rapid progress provided that we can arrange for coordinated programs – a challenge.

5 S2 – Where are We?

We anticipate that soon there will be three facilities capable of contributing to the carrying out of this charge. Currently the FLASH/TTF facility serves as the premier facility for this work and is committed to test as many ideas and components as possible. A Superconducting Test Facility (STF) is under construction and early use at KEK. An ILC Test Facility is under construction at Fermilab too. As the S0 and S1 activities bear fruit we will have the means for making system tests of these sections of accelerator to solidify system requirements and introduce industry to the requirements. We hope that it will be possible to have significant enough participation from industries that ultimately we can depend on them for production of rf units meeting all requirements for the ILC.

While it is true that many issues for the ILC rf units have been addressed, at least partially, by TTF, many remain, particularly those having to do with operation at full ILC beam parameters and operation with those parameters for significant periods of time.

6 Alternate Concepts R&D – Long Range

While a number of suggestions have been made, three are receiving most of the attention: i) alternate cavity shapes; ii) alternate material form; iii) alternate fabrication methods.

6.1 Alternate shapes

The approach taken for the alternate cavity shapes is to minimize the ratio of surface magnetic field to accelerating gradient. This rests on the fact that the superconducting state is magnetic field limited. Shapes designed in somewhat different ways to achieve this end are referred to as the “low loss” shape, the “Ichiro” shape and the “reentrant” shape. Using the reentrant shape accelerating gradients in excess of 50 MV/m have been achieved in single cells. Implementing this achievement in 9 cell cavities with high yield remains for the future after we have been successful in this with the standard “Tesla” cavity shape.

6.2 Alternate Material Form

Here the idea is to use niobium material with large crystals to minimize the number of grain boundaries in a single cavity. An extension is to fabricate cavities from single crystals, grown large in the initial ingot formation and then sawed our and rolled into sheets large enough for drawing of cavity halves. Both of these approaches have been explored to some extent with encouraging results. Further tests are planned. The need for altering the manufacturing process at the niobium vendor should one of these approaches prove to be superior is an additional barrier to wide adoption on a short time scale.

6.3 Alternate Fabrication Methods

Electron beam welding is one of the most expensive steps in the currently employed manufacturing process. This has led to the trial of hydroforming or spinning for complete cavity shapes. Single cavities or groups of cavities can then be electron beam welded to the end groups where one 9 cell cavity is fastened to the next. Both of these methods have been developed to a significant extent. So far, however, the net simplification to the manufacture of 9 cell cavity unity has not warranted a switch to either of these approaches. Development continues.

7 Organizational Infrastructure for ILC SRF R&D

GDE R&D coordination in SRF has been progressing steadily. It is significantly strengthened by the existing, worldwide linkages of SRF workers as SRF applications expand, applications such as x-ray and neutron sources as well as heavy ion accelerator.

This broader perspective in encompassed by the Tesla Technology Collaboration (TTC) which comprises 52 member institutions in 12 countries. It holds meetings twice a year which deal will all aspects of SRF. This information exchange is of great benefit to ILC as well as to the other applications. A rich source of primary information on the subjects introduced above can be found in the proceedings of the most recent TTC meeting which was held at FNAL April 23-26, 2007 [2] In addition there are the triennial International SRF Workshops. The next TTC meeting will take place at DESY in January 2008; the next International Workshop in October 2007 in Beijing.

8 Acknowledgments

Grateful acknowledgment is hereby made of the information and illustrations furnished by many collaborators in the 3 regions. Much of the material was taken from the just completed TTC and ILC – MAC meetings. Particular thanks to Hasan Padamsee for his essential help in preparing the slides.

9 References

[1] ILC RDR Vol III, p. 80, www.linearcollider.org/cms/?pid=1000025
[2] TTC April 23 – 26 program, https://indico.desy.de/conferenceDisplay.py?confId=200