PLANNING FOR THE NEW LINEAR COLLIDER TEST FACILITY AT FNAL & PROGRESS ON 3.9GHz SRF*

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Abstract

With the decision by the ICFA International Technology Recommendation Panel (ITRP) to endorse superconducting technology for the International Linear Collider, Fermilab has been moving ahead on plans to develop a collider test facility with infrastructure to carry out R&D and test on SRF cavities, modules, and systems that comprise the main linac. This paper outlines the long-term R&D goals, the planned stages of development, the involvement of collaborators, and the development of infrastructure that is underway. It also gives a short report on progress on the ongoing 3.9GHz SRF program.

ILC AMERICAS REGIONAL PLAN AND EXPRESSED DOE SUPPORT

It is understood that the US ILC Linac responsibilities will be broadly split between the two lead labs, FNAL and SLAC. Fermilab's main area of responsibility will be in the area of superconducting RF technology, modules, and rf control. SLAC's main area will be in rf power. Fermilab's role is more clearly defined in the JLab-Fermilab MOU as quoted below.

"The ILC Americas regional plan is for FNAL to assume the role of lead laboratory for ILC SRF technologies, working in close partnership with other US SRF centers, including TJNAF, Argonne and Cornell." (To name just three) This phrase clearly indicates the desire and the need for close collaboration by experienced US SRF laboratories in order to successfully carry out the SRF R&D in this country. It goes without saying that international collaboration is essential as well.

Equally important is the US Department of Energy statement that it "has expressed its interest in the possibility of hosting a linear collider, at Fermilab, subject to the machine being affordable and scientifically validated by physics discoveries at the LHC." [1]

These words make it clear that Fermilab should vigorously move ahead at establishing a coordinated effort of SRF cavity and module development with the broader vision of being able to carry out integrated systems tests of a main linac unit as defined in the ILC Technical Review Committee 2nd Report (2003) [2]. Under Ranking 2 Energy one finds "To finalize the design choices and evaluate reliability issues it is important to fully test the basic building block of the linac. For TESLA, this means several cryomodules installed in their future machine environment, with all auxiliaries…The test should as much as possible simulate realistic machine operating conditions, with proposed klystron, power distribution system and with beam… The cryomodules must be run at or above their nominal field for long enough periods to realistically evaluate their quench and breakdown rates. …" Thus the general R&D goals have been laid out.

LONG TERM R&D GOALS FOR ILC MAIN LINAC WORK

As indicated in the last paragraph, development and test of cavities, modules and components and subsystems is a key goal. And there are other important goals, not the least of which are developing Fermilab's expertise and capabilities in SRF systems, strengthening US and US industry SRF capabilities, and forming strong collaborations with other US labs and international partners to make the best use of existing capabilities.

A specific goal of the plan is to be able to have a module string of order 4 modules and a photoinjector to supply appropriate beam and beam structure. There should be the capability for iterative process and test of cavities and modules. Infrastructure must be developed to support this concept.

Cavities at reproducible high gradient performance are the all important ingredient of the R&D program. It will be necessary to development processing procedures that can reliably provide cavities of the TESLA shape with gradients above 35MV/m and for more recent shapes (re-entrant or low loss) gradients of 40. These acceptance goals are based on a model developed at ILC Snowmass that proposes the average realistic achievable gradient will be 90% of critical field and that spread about that average should be not greater than 5% rms. The expected operating gradient in the linac is then 10% lower or 31.5 and 36MV/m respectively. In order to meet these ambitious goals cavity processing must attain much better reproducibility than at present.

COLLABORATION

The best way to approach the issue of cavity performance high gradient reproducibility in the US in the immediate future is avail ourselves of expertise and facilities that exist. To this end there are a number collaborative efforts underway. For EP processing Fermilab will collaborate with JLab and their system will be commissioned with TESLA cavities and we can begin to get statistics there on the processing success rate. Cornell will also work on processing, both BCP and EP. Vertical dewar tests will be carried out at both JLab and Cornell. The joint ANL/FNAL Chemistry Facility will be commissioned early in 06 for BCP. After experience is gained at JLab as well as at DESY and KEK, consideration will be given to the development of a state

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of the art EP system to be implemented at the ANL/FNAL Facility. Design of this system will be a collaborative effort including expertise at ANL and LANL as well as experience from DESY and KEK. The importance of this EP development will depend to a large extent on the success of single crystal or large grain research with BCP processing, as it appears that this direction could be much less difficult and more economical.

The joint ANL/FNAL chemical processing facility collaboration has been started in recognition of the convergence of interests over the past decade between the two labs and between low and high beta SRF cavity communities. The techniques to achieve state of the art performance are converging and new cavity types are filling the gaps between low and high beta.

Fermilab has been a collaborator in TESLA since its inception. Present bilateral activities relate to development of 3.9GHz 3rd Harmonic cavity systems at FNAL for TTF-VUV-FEL. DESY is providing individual TESLA cavities for the FNAL photoinjector upgrade and chemical processing development as well as parts for a TESLA cavity string for a first module at Fermilab. Cavities will have been tested in CHECHIA. The string and module will be assembled at Fermilab, It is hoped that INFN will participate in the cold mass for this module and in development of a "4th generation module". The 4th generation module would incorporate shorter cavity slot length and the quadrupole package mounted at the center of the module.

Fermilab is also collaborating with KEK in the areas of cavities through the mechanism of Japan US Accord. KEK will provide 4 cavities for a second module in the US. Cavities will also be available from Accel, JLab, and AES.

MODULE TEST FACILITY SCHEDULE

The Superconducting Module and Test Facility Proposal (SMTF) describes the steps toward infrastructure and module implementation [3].

A proposed schedule for implementing the ILC Test Facility at Fermilab has for 06-07 (Phase 1a) the installation and commissioning of one (8 cavity) module and the injector to be followed in 08 (Phase 1b) by an upgrade of the injector and preparation for a 2nd module. During this time 06-08 it is expected that of order 3 modules will be assembled for test, but it will be unlikely that they will all meet gradient specifications, as the learning experience is of greater importance than ideal final results. Phase 2 in 08-09 should see two modules in operation with the upgraded injector. Finally in Phase 3 four modules would come into operation. During all this time both cavities and modules would be built, processed, and recycled as improvements in performance and better designs are implemented.

INFRASTRUCTURE DEVELOPMENT

Considerable infrastructure development must be undertaken at Fermilab and heavy reliance must be made of the existing infrastructure throughout labs in the US. Specifically in the near term Fermilab must rely on others with respect to e-beam welding, chemical processing and vertical dewar testing. Fermilab is proceeding as fast as funding allows: to establish a Cryo Module Assembly Facility, to continue on the implementation of the ANL/FNAL Cavity Processing Facility, to construct a Horizontal Test Dewar, and to establish two module test areas at buildings that have been historically used for physics experiments. These Fermilab buildings go under the names of Meson Hall and NewMuon Building.

The Cryo Module Assembly Facility will be in a building of 60x200ft (Building MP9). Class 10 and Class 100 areas 60x12ft will allow for cavity string assembly. Other areas are devoted to cold mass and vacuum vessel assembly much in the way as done at DESY. It is expected that this area with assembly tooling will be available in summer 06.

A Horizontal single cavity test cryostat (similar to CHECHIA) is under design and should be operational in spring of 06.

The east side of Meson Hall has been cleared of old equipment and experimental magnets and new infrastructure and shielding caves assembled. The Cryo Test Facility will be used to provide helium in the Meson Hall. This system has begun operating at 4K in fall of 05 and will be able to supply 60W of useful 2K helium in the coming winter. Originally it was planned to have both ILC and Proton Driver (PD) module strings in Meson, but this appears to be too tight. Now Meson will hold the PD test string area and an area for individual cavity tests (Horizontal test dewar, HTD) or individual 8 cavity modules. The first cavity operation here will be a one-TESLA-cavity module destined in the longer run for the photoinjector upgrade. This cavity (Capture Cavity 2) and vacuum vessel from DESY and Saclay is being assembled at Meson for commissioning at 4K in November 05 and at 2K in January 06. Technical support infrastructure is being developed including rf power, low level rf and controls. The controls are presently a mix of DESY DOOCS and EPICS; the llrf is from the DESY effort. In spring to summer 06, it is planned that single 3.9GHz cavity tests will take place at Meson using the infrastructure that has been developed and the Horizontal Test Dewar. At a later date tests of TESLA style cavities will start in the HTD.

Because of space limitations in the Meson Hall, especially in the longitudinal direction it has been decided that the ILC module test are will be located in the NewMuon building which is a building of about 27x78m. This building can be easily extended when the need arises. In 06 a very large experimental magnet will be removed and a second temporary cryosystem will be installed here. This system will have the capability of about 40W useful at 2K. In the long run it is hoped that a larger system with ~300W capability can be procured. In 06 technical infrastructure will be installed to support an eight cavity module and the Photoinjector. By the beginning of 07 there should be a module installed as well as the PhotoInjector that will be moved from its present location at the A0 building. Extensive systems tests can then begin.

THE PHOTOINJECTOR

The PhotoInjector, which is very similar to that that has been used at DESY, will be upgraded and become the injector for the ILC modules. Presently it consists of a normal conducting rf gun, drive laser and single TESLA cavity to provide 15MeV beam with a 1 μsec bunch structure and bunch charge variable up to about 10nC. With the addition of the second TESLA cavity the beam energy will be increased from 15 to 40 MeV. The bunch spacing can be easily modified for the closer bunch spacing of 337 ns now required for the ILC. The laser has been recently improved and pulse to pulse fluctuation reduced to 5% rms. The gun can now operate to provide beam bunches for 0.15ms and the rf modulator that drives the gun can provide rf pulses of 0.6ms. In the long run (after a year or so of module commissioning) the gun should be replaced with one that can provide 1ms beam macropulses and the modulator upgraded to 1 ms.

The injector presently provides a round normalized emittance of typically $5x10^{-6}$m, and in the "flat" configuration this becomes $0.41/41x10^{-6}$m in x/y. This flat profile reproduces the shape of the linear collider beam if not its size. (TESLA TDR normalized emittances at collision are $0.03/10x10^{-6}$m. [4]) The injector compressed beam is presently of order 550 μm where as in the TDR it is 300 μm.

With the addition to the injector of a second TESLA cavity it will be much easier to control space charge blowup. The 3rd Harmonic cavity that provides linearization to the bunch energy profile will allow even better compression, higher peak currents and better exploration of HOM excitation. Thus the PhotoInjector should be well suited as an injector to the module tests.

3.9 GHz DEVELOPMENTS

Two types of 3.9GHz SRF cavities are under development. The accelerating mode type (3rdHarmonic) will be used for a four cavity module at DESY VUV-FEL and at the upgraded PhotoInjector for bunch compression. The deflecting mode cavity will be used as a bunch slice diagnostic in the upgraded PhotoInjector. These two cavity types are Fermilab's first entry into SRF cavity design and fabrication and have been invaluable as engineering learning experiences. To date vertical dewar testing has been carried out on 3 cell cavities. The accelerating mode cavity has achieved E_{acc} of 19MV/m (~105mT) and a R_{res} of 6 to 10 nOhm. The design value is 14MV/m. It is possible that the field is limited by global thermal effects. The deflecting mode cavity has achieved E_{trans} of 7.5 MV/m (~120mT), but the residual resistance continues to be a problem with the best value to date of R_{res} ~60nOhm. Here the design value is 5MV/m deflecting. Papers in this workshop are TuA09, TuP14, Th50, and ThP29.

MATERIALS RESEARCH WITH UNIVERSITIES

Materials research is getting underway at Fermilab. This includes the implementation of an eddy scanning machine from SNS, surface analysis with SEM and EDX that can be used on a routine basis, and RRR measurements. Collaborative efforts with the universities include efforts with the Applied Superconductivity Center (ASC) University of Wisconsin, and Northwestern. These investigations include grain boundary flux penetration, magneto optical study of flux penetration and atom probe tomography. Papers in this workshop are TuP01, TuP47, TuP48, ThP01, TuP06, TuP54, and TuP55.

CONCLUSION

Fermilab is gearing up to take on the challenges of superconducting R&D for ILC. However this program must rely heavily on collaboration both with the US and internationally. Effort is being directed both toward cavity performance and toward module assembly and systems tests with beam. Work is continuing on 3.9GHZ development and materials research working with universities has been initiated.

REFERENCES

[1] From DOE for inclusion in S. Holmes EPP2010 talk.

[2] International Linear Collider Technical Review Committee Second Report 2003, SLAC-R-606

[3] SMTF Proposal Final Draft, http://ilc-dms.fnal.gov/Workgroups/SMTF/

[4] TESLA Technical Design Report, DESY 2001-011 March 2001, TESLA Report 2001-23 http://tesla.desy.de/new_pages/TDR_CD/start.html