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A SCRF Infrastructure for Europe

Abstract

This document reflects the recent discussions on the proposed infrastructure at "Electron Accelerator R&D for the Energy Frontier" at Orsay and has been edited by E. Elsen, N. Walker, L. Lilje.

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A SCRF Infrastructure for Europe

Introduction

Over the last decade, the TESLA Collaboration has reduced the cost per gradient of SCRF by approximately a factor of 20 over the then existing facilities. This was due in part to an increase in achievable gradient from ~5 MV/m to ~25 MV/m. The R&D programme centred at the TESLA Test Facility (TTF) infrastructure at DESY has ultimately led to a proposed major new facility at DESY (the European XFEL) and the adoption of the technology for the International Linear Collider (ILC).

The current global effort for the ILC has set itself the goal of achieving an operational gradient of 31.5 MV/m, requiring mass-production of some 15,000 cavities achieving ≥35 MV/m with a yield in excess of 90%. Although several proof-of-principle of these gradients exists, the current limited statistics of the DESY production fall significantly short of this ambitious goal. It has been recognised by the international ILC community (GDE) that new state-of-the-art production infrastructure is required, and that each region (Americas, Europe and Asia) should endeavour to set up such infrastructure within a globally coordinated and focused effort in a timely manner.

In this document, we briefly outline the scope and programme of the installation of a new infrastructure for Europe, as proposed by the recent Letter of Intent (LoI) sent to the C.E.R.N. Council Strategy Group by Prof. Albrecht Wagner on behalf of the European Partners of the TESLA Technology Collaboration. In accordance with the LoI, we investigate the use of existing and suitable infrastructure at CERN as the host for the proposed central production facility supported and complemented with existing installations in the national labs.

Programme of facility

The primary justification for the SCRF facility is the ILC. However, the facility can be built as a generic infrastructure to develop high performance cavities with a view to supporting other projects such as leptons, protons, neutrinos, muons and light sources. It would enable R&D, industrialisation and tests of SCRF technology with many possible applications beyond the ILC.

The ILC programme and goals will be integrated in the world-wide effort of the project under the guidance of the GDE. Specific requests related to other projects for different kinds of particles and extension to other cavity types will have to be investigated and adequately integrated. The infrastructure defined for ILC is based on a highly modular detailed design that is expected to cover a large part of these requests.

It is understood that in the unlikely event that repairs are needed on a LHC cavity, it will take the highest priority for the use of the shared infrastructure.

ILC Request (in order of priority)

- New generation cavity production facility including auxiliaries
  - leading to processes transferable to industry
- Production of a 4th generation module
  - Integration of components (cavities, couplers, tuners, magnets, BPMs) in a 4th generation cryostat
  - Instrumentation for modules (alignment)
- Production of one or two complete ILC RF units

Other Projects (proton, muon, neutrinos, light sources)

- Capability of preparing and testing cavities with state-of-the-art infrastructure
- Implementation of other SCRF R&D requests in accordance with the overall programme of the facility

Detailed program

The production of high-performance SC cavities requires state-of-the-art surface preparation. An integrated facility will allow significant improvement of the current preparation steps towards an industrial production-like level, with a large enough throughput (~100 cavities/year). After cavities have passed the acceptance test in a low-power RF test, a fraction of the produced cavities will be integrated into accelerator modules (cryomodules). A scheme for this process is shown in figure 1. The two large building blocks are the cavity preparation infrastructure and the module assembly clean room with their associated test infrastructure.

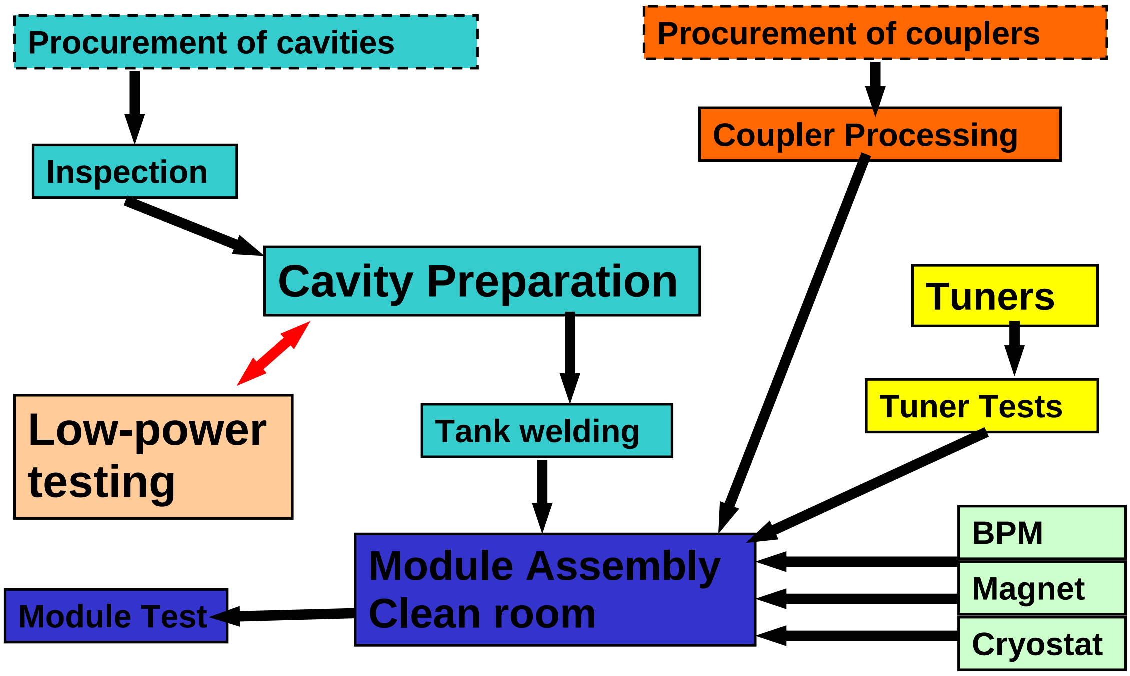

Figure 1: Sketch of the work-flow during an accelerator module assembly.

Cavity Preparation Infrastructure

General description of cavity process

- Step 1 Inspection of incoming cavities
  - optical inspection
  - tuning of cell for field flatness (frequency)
  - mechanical measurements (length/ eccentricity)
  - optical inspection of surface
- Step 2 Preparation for acceptance/ vertical test
  - damage layer removal
  - annealing
  - final surface treatment
  - assembly in class 10 clean room
  - high pressure rinsing with ultra-pure water @ 100bar
  - assembly of variable input power antenna for vertical test
  - assembly to test insert
- Step 3 Vertical test
- Step 4 Preparation for Module
  - tank welding
    - installation of in situ field measurement device
    - welding of Nb to Ti connections
      (EB/ Bellows & Inter-connection ring)
    - tuning of field profile and frequency
    - helium vessel welding (TIG)
  - final preparation of dressed cavities
    - removal of in situ field profile device
    - assembly of HOM coupler pickup antenna
    - high pressure rinsing
    - assembly of power coupler
  - on a few cavities:
    - horizontal test of cavity and all accessories (CHECHIA-like)
- Step 5 Module assembly
  - cavity string assembly
  - module assembly
  - module test

Sketch for the layout of the cavity preparation infrastructure

The newly setup infrastructure should improve over existing infrastructures in several ways. Typical infrastructures today are still single-line processing R&D infrastructures. A failure of one process in the chain leads to unacceptable delays in schedule. Therefore, redundancy in the layout is a necessity. In addition, the processes should be modularised, which makes the overall scheme more maintainable and flexible. It allows also implementing changes in the overall production scheme that might be identified by the ongoing worldwide R&D efforts. This flexibility can also accommodate other projects interested in making use of this infrastructure.

A sketch of this infrastructure can be found in figure 2. The centrepiece is the clean room, where all critical assembly takes place. The needed cavity preparation processes are attached to this in a modular manner, which also enhances the flexibility. Apart from the implementation of state-of-the-art cavity preparation processes, quality assurance / control processes will be implemented. In the same manner mass production issues are addressed e.g. cleaning of parts like screws etc.

The clean room for the cavity preparation and for the module assembly need to be independent to avoid conflicts in resources and space.

The goal is to achieve an equivalent production rate[1] of ~100 cavities/year. A total cavity production of 50-100 cavities is expected over the funding period (to be determined).

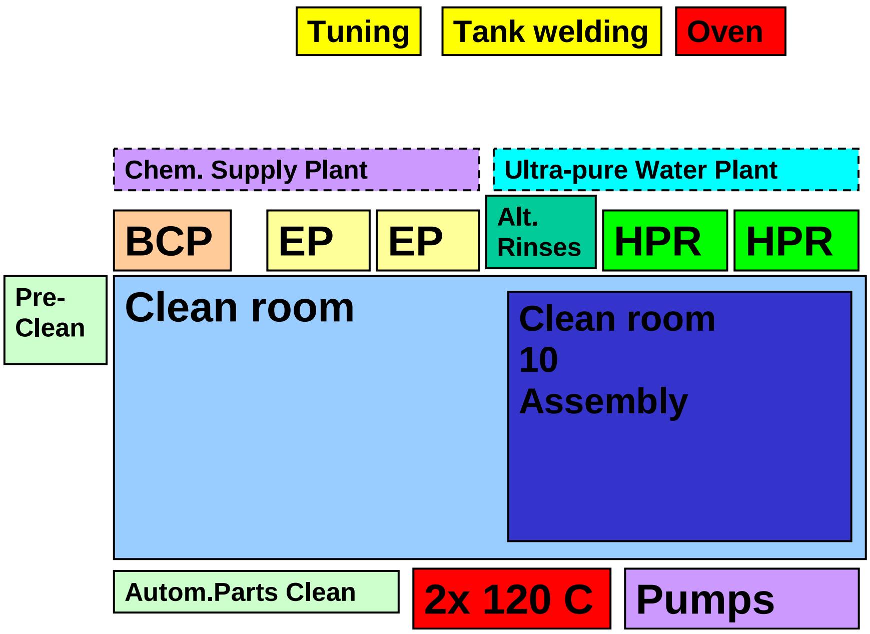

Figure 2: Sketch of the cavity preparation infrastructure.

[1] This is not necessarily the cavity manufacturing rate. It may include re-cycled cavities excluded during the production process.

Testing capabilities

The ultimate quality control step is the low-power RF test of the cavities and the high-power RF test on the module. It is assumed the facility provides:

- Vertical low-power tests (VT): max. 100 tests/year
- High-power pulsed horizontal tests (HT): a few test/year
  - critical assembly of main power coupler
  - existing infrastructure in European partner laboratories probably sufficient (e.g. cryostats available are CryoHoLab (CEA), CHECHIA (DESY), HOBICAT (BESSY)).
- Module tests: 2 Modules/year
  - includes re-assemblies
- Coupler tests
  - this should match module testing (2/year)
  - the LAL coupler test facilities are well suited to provide this
- Tuner tests
  - the need for a dedicated infrastructure requires evaluation
    - could be liquid nitrogen
    - can be tested during cavity HT
- BPMs
  - Stage I: beam test independent of module (standalone beam test stand at some test beam – to be determined)
  - Stage II: Eventually ship full modules to ILC beam test facility as part of the international programme (to be determined)
- Magnets
  - Alignment
  - Field quality

Possible Implementation at CERN

A central facility at CERN will make use of existing infrastructure[2]. It will be complemented by a network of facilities coordinated to take advantage of the existing facilities in the national laboratories (CEA, DESY, IN2P3, INFN…). CERN general services are available as a support for several activities within the SCRF facility. Some of the specific installations are covered in the following.

Cryogenic

The general infrastructure exists in building SM18. Priorities need clarification (i.e. with future LHC requirements, coming for example from the magnet test stands or from RF tests for LHC cavity repairs.) with regard to the sharing of the installed 4K capacity. The 2K pumping capacity would need a significant upgrade of the gas purification system, while the RF cryogenic infrastructure would need a general upgrade for operation at 2K.

Vertical Test

4 x 4.5m pits available (see figure 3). Two pits are equipped with cryostats sufficient to handle nine-cell 1.3 GHz cavities. The diameter should also be largely sufficient for cavities of other frequencies. Historically, LEP and LHC cavities have been tested without compensating for the earth magnetic field. This is mandatory for niobium cavities and seems easily achievable. A test capacity for the LHC in case of repairs will be maintained.

Horizontal Test

The horizontal high-power testing is assumed not to be at CERN central facility. Several facilities are available for this task: Cryholab, Hobicat, DESY.

Module

Shielded areas for module testing (Bunkers) exist capable of handling LEP- or LHC-type cryomodules. The size is believed to be sufficient for ILC modules of about 12m length.

Figure 3: Vertical test cryostat area. Visible are only the concrete 'hats' for radiation protection. These can be rolled away on rails, uncovering below a test cryostat sunk into the ground; two with sufficient depth to contain a LEP 352 MHz cavity of 2.4 m length and the (heat) radiation shields above it, and one of lesser depth used for single cell cavity tests. The 300 W solid-state RF power amplifiers with their circulator and load are housed behind the concrete wall (for low power cavity/module tests)

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[2] Sergio Calatroni, Bruno Vullierme, Joachim Tückmantel, "CERN Facilities for Superconducting RF", Presented at "Electron Accelerator R&D for the Energy Frontier", Orsay, 2006

Space

About ~1000 m^2 will probably be made available after 2007(old magnet test stand). This space will be ideally suited for the cavity preparation facility. Some additional space will be needed for the cryostat assembly.

Surface Preparation

This will require refurbishing to meet the goals set above and have the desired redundancy.

Clean rooms

Ideally a new clean room for cavity preparation should be built in the free space mentioned above, although less optimal solutions might still be identified making use of old existing facilities. A large clean room for string assembly exists from the LEP and LHC production runs (see figure).
Parts cleaning/preparation exists.

RF Testing

Low-power RF exists (for VT), some refurbishment and upgrades are needed.

Figure 4: Picture of cleanroom for LEP- and LHC-module assembly. It is divided in two parts of equal size, each 15 m long and 4 m wide, separated by a large double door. The dust-filtered air is blown from the ceiling towards the floor. The entry part is in class 1000, and the working part is in class 1÷10, exceptional for an installation of this size. An object enters the front part, letting the dust settle, and is only then transferred into the main working part. Right of the main doors, the personnel entry door to a small space for the operators to change into special garments, with another exit door into the class 1000 zone. The 'front court' allows modules to be mechanically assembled or disassembled (critical volumes remaining closed, only opened inside) and set onto rails; these lead along the whole clean-room for easy transport.

Missing Infrastructure (tentative)

- Integrated surface preparation with clean room.
- Module test High Power RF
- Cryogenic pumping capacity

Cost and Resources

The exact cost and resource requirements still require study. The following list should be taken as an indication of the expected scope.

- Infrastructure setup
- Cryogenic operation
- Cavity fabrication
- Coupler fabrication
- Cryostat fabrication
- Manpower 10 – 30 FTE (to be determined)

Possible Schedule

- 2007 Cavity and coupler order
- 2008 Infrastructure setup and commissioning
- 2009 Operation

References:

Sergio Calatroni, Bruno Vullierme, Joachim Tückmantel, ”CERN Facilities for Superconducting RF”, Presented at “Electron Accelerator R&D for the Energy Frontier”, Orsay, 2006