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Abstract

The collaborative development of an optimised cavity/cryomodule solution for application on ERL facilities has now progressed to final assembly and testing of the cavity string components and their subsequent cryomodule integration. This paper outlines the verification of the various cryomodule sub-components and details the processes utilised for final cavity string integration. The paper also describes the modifications needed to facilitate this new cryomodule installation and ultimate operation on the ALICE facility at Daresbury Laboratory.

INTRODUCTION

Preparations for the assembly of a new Superconducting RF (SRF) cryomodule, which has been developed for long-term high Q_{ext} and CW operation for application on Energy Recovery Linac (ERL) accelerators, is well underway at Daresbury Laboratory.

Table 1: Cryomodule Design Parameters

Parameter	Value
Frequency (GHz)	1.3
Number of Cavities	2
Number of Cells per Cavity	7
Cryomodule Length (m)	3.6
R/Q (Ω)	762
E_{acc} (MV/m)	> 20
E_{pk}/E_{acc}	2.23
H_{pk}/E_{acc} (Oe/MV/m)	46.9
Cryomodule Energy Gain (MeV)	> 32
Q_o	$>1 \times 10^{10}$
Q_{ext}	4×10^6 - 10^8
Maximum Beam Current	100 mA
Max. Cavity Forward Power (kW)	25 SW

To date, the international partners who have participated in this collaborative development (Cornell and Stanford Universities, Lawrence Berkeley Laboratory, FZD Rossendorf, DESY and Daresbury Laboratory) have identified appropriate sub-system solutions to achieve the fundamental requirements for this new cryomodule, which have been reported previously elsewhere [1]. Table 1 highlights the primary cryomodule design parameters, which will be installed on the ALICE ERL accelerator at Daresbury Laboratory and validated with beam in 2010.

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CAVITY DESIGN AND FABRICATION

Two 7-cell Nb cavities have been provided by DESY. These cavities were originally fabricated and tested together in TTF-I as a superstructure [2]. Subsequently the cavities were sent to Cornell for modification. LBNL, Daresbury and Cornell have developed a new design for the cavity end cells and associated beam-pipes, in order to propagate higher order mode power to ferrite-lined beam-pipe loads, similar to the HOM load used in the Cornell Injector Cryomodule [3]. Figure 1 shows a schematic of the cavity string assembly.

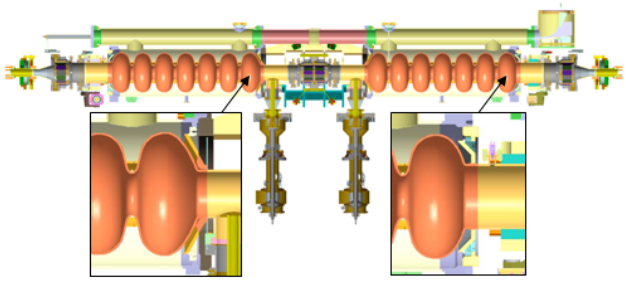

Figure 1: ERL Cavity String Assembly

The two half-end cells of the 7-cell cavities have been successfully removed and new end cells and beam-pipe have been fabricated (see Figure 2). The final electron-beam welding is imminent. We plan to use BCP final treatment since the operating gradient is of the order of 20 MV/m. All flange designs were changed to knife-edge conflat interconnections, with brazing to Nb beam tubes similar to that used for the Cornell Injector cryomodule. The Ti-helium vessel and gas return pipe designs were

modified to conform to the FZD Rossendorf cryomodule discussed below. The blade tuner used for the TTF superstructure test was changed to the modified Saclay II tuner design so that it would fit in the chosen cryomodule envelope. The input couplers and HOM loads were chosen to be identical to the ones used in the Cornell Injector module. The design of the cavity string is carefully laid out to fit inside the module.

Figure 2: Cavity Components at Cornell

CRYOMODULE ASSEMBLY PROCESS

Wherever possible, existing assembly procedures and tooling fixtures have been employed from the original ALICE cryomodule, fabricated by ACCEL GmbH under license from FZD Rossendorf [4]. All of the major internal cryomodule components have however been modified including; cavities, input couplers, tuners, HOM absorbers, magnetic shields and cryogenic cooling circuits.

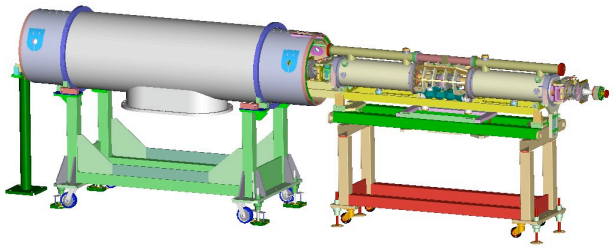

Figure 3: Cavity String Assembly into Outer Cryomodule

By utilisation of a cantilevered rail system, the sealed cavity string assembly can be rolled into the outer cryomodule vessel (see Figure 3). Once positioned, the cavity string is then locked in place by a single titanium locking fixture, which then provides a longitudinal constraint on the mechanical component contraction when the cryomodule is cooled to cryogenic temperatures (see Figure 4). In this way, the contraction occurs from both ends of the cryomodule towards this central, locked position. This ensures that the input couplers (which are positioned very close to the central locked reference position) do not get exposed to excessive lateral stresses during cool-down.

The cryomodule incorporates three layers of magnetic shielding in order to try and maximise the achievable Q_o and thereby minimise the cavity dynamic heat load; two mu-metal magnetic shields are attached to the outer 80 K skeleton and a third cryoperm magnetic shield covers each cavity helium vessel.

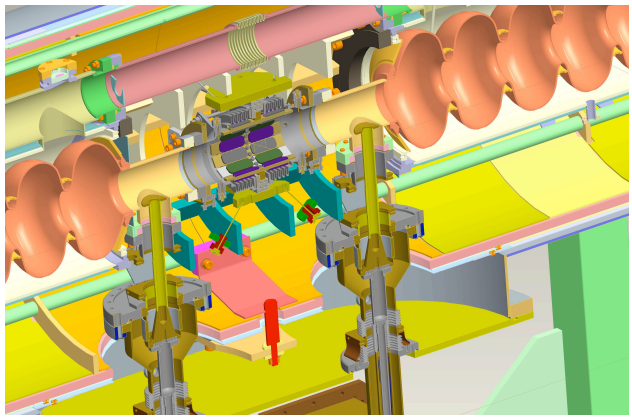

Figure 4: Central Cavity String Locking Position

INPUT COUPLER PREPARATIONS

The input couplers employed are modified versions of the Cornell ERL injector design [5], which have been shortened to facilitate installation into the smaller diameter ALICE cryomodule. They have been fabricated by CPI Inc. under licence from Cornell University. Prior to assembly of the couplers into the cavity string, they must be rigorously cleaned and inspected, before being baked and high power RF processed. To date, both couplers have been assembled onto their respective cold and warm baking stations (see Figure 5 a) and b)) in preparation for a high temperature bake at 150 C for 24 hours.

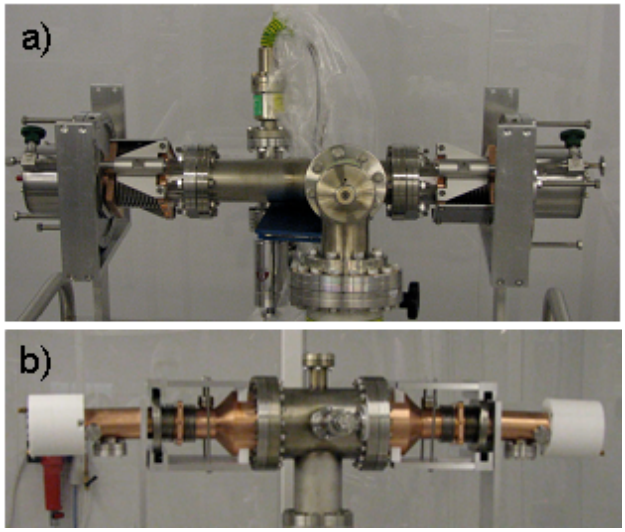

Figure 5: a) Cold and b) Warm Coupler Bake Assemblies at Daresbury

Once a successful bake has been completed, the coupler assemblies will be re-assembled, in a back-to-back configuration, onto a high power coupling box to allow for high power conditioning. The RF power will be

limited to ~10 kW CW during conditioning, as we will not have gaseous helium (GHe) cooling available. Pulsed conditioning will then be performed up to the 30 kW limit of the test IOT (see Figure 6).

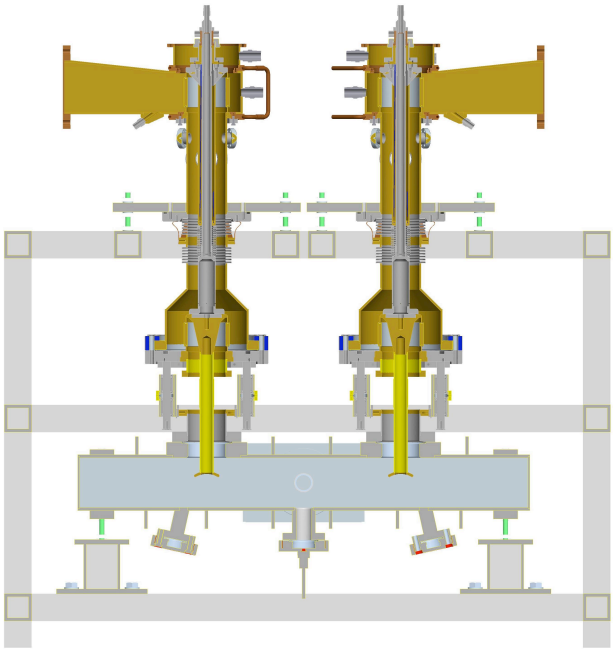

Figure 6: Input Coupler RF Conditioning Assembly

ALICE CRYOPLANT MODIFICATIONS

Presently on ALICE the cryomodule 80 K skeleton is cooled using liquid nitrogen (LN2), however for this new cryomodule GHe will be used, which will have the anticipated benefit of reducing turbulent pressure fluctuations, leading to a lower cryomodule microphonics sensitivity. In addition, both the input couplers and all three beam-pipe HOM absorbers have 5 K cooling intercepts, which the existing ALICE cryogenics system does not currently provide (see Figure 7).

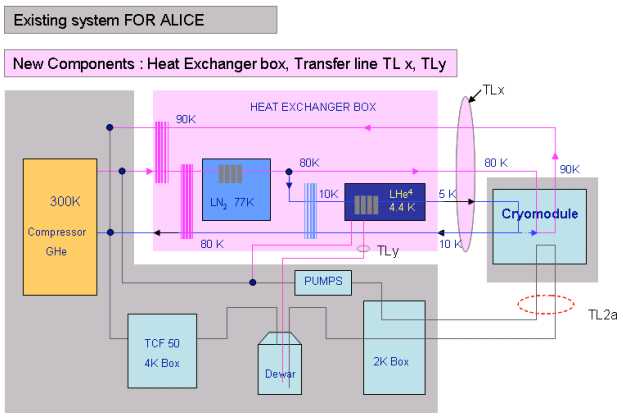

Figure 7: ALICE Cryoplant Modifications

A secondary heat exchanger system (designated COOL-IT; COOLing to Intermediate Temperatures) has therefore been developed which taps off available 300 K, high pressure GHe from the main compressor, plus an additional LHe feed from the 4 K reservoir dewar. The high pressure GHe circuits at 80 K and 5 K are then generated via the heat exchanger box, which will be located close to the ALICE ERL cryomodule as shown in Figure 8.

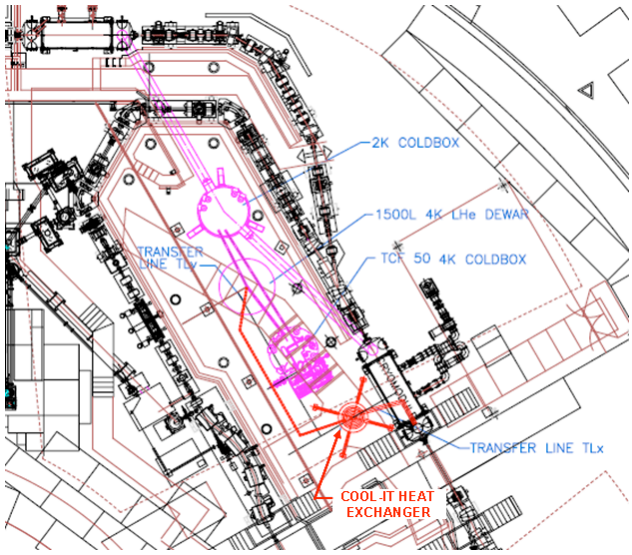

Figure 8: COOL-IT System Installation on ALICE

SUMMARY AND OUTLOOK

The vast majority of the cryomodule hardware is now either available or under fabrication. We anticipate having both couplers RF conditioned and cavities available at Daresbury by late June 2009. All tooling and fixtures required for the cryomodule assembly are complete and therefore cleanroom assembly of the cavity string is expected to start by early July. The COOL-IT system will be installed on ALICE in late 2009 in readiness for connection to the new cryomodule when installed in 2010.

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