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INTERFACE CHALLENGES FOR THE SRF CRYOMODULES FOR THE EUROPEAN SPALLATION SOURCE

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Abstract

The European Spallation Source is currently under construction in Lund in southern Sweden. The main part of the accelerator will consist of two different types of cryomodules housing three different types of cavities - double spoke cavities and two different elliptical cavities. The spoke cavities, as well as the cryomodules, will be provided by IPN Orsay, thus the external interfaces to the other accelerator systems have to be verified. While the procurement and assembly of the elliptical cryomodules will be performed by CEA Saclay, the cavities will be provided by INFN Milano and STFC Daresbury. Thus, in addition to the external cryomodule interfaces, also the internal interfaces between cavities and cryomodules have to be taken care of. This contribution presents the challenges related to this work.

INTRODUCTION

The proton accelerator of the European Spallation Source (ESS) [1] is composed of a warm section consisting of the proton source, low energy beam transport, radio frequency quadrupole, medium energy beam transport as well as the drift tube linac. The cold section will contain two types of SRF cryomodules, which will be described briefly in the following, and the main requirements of the cavities can be found in Table 1.

Table 1: Requirements on Superconducting Cavities

Requirement	**Spoke**	**medium-β**	**high-β**
Frequency / MHz	352.21	704.42	704.42
Optimum β	0.5		
Geometric β		0.67	0.86
E_{acc} / MV m^{-1}	9.0	16.7	19.9
E_{Pk} / MV m^{-1}	39	45	45
B_{Pk}/E_{Acc} / mT/(MV/m)	6.80	4.79	4.3
E_{Pk}/E_{Acc}	4.28	2.36	2.2
Iris diameter / mm	56	94	120
RF peak power / kW	335	1100	1100
G / Ω	130	196.63	241
maximum R/Q / Ω	425	394	477
Q_{ext} / 10^5	1.75-2.85	7.5	7.6
min $Q_0(E_{acc})$ / 10^9	1.5	5	5

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The 13 spoke cryomodules contain two double spoke cavities each with an operating frequency of 352.21 MHz. A picture of the cryomodule is shown in Fig. 1.

Figure 1: Picture of ESS prototype spoke cryomodule with its valve box, installed in the test pit at IPN-Orsay.

As the cavities and the cryomodules are provided by IPN Orsay, the internal interfaces between cavities and cryomodule are in the hand of one partner. The same holds for the helium supply for the operation of the cryomodule.

The 30 elliptical cryomodules, which will be provided by CEA Saclay, contain four elliptical cavities each with an operating frequency of 704.42 MHz. ESS requires 9 cryomodules containing medium-beta (β = 0.67) cavities, and 21 cryomodules housing high-beta (β = 0.86) cavities. It is to be noted that the cavities will be provided by different partner laboratories, in particular INFN Milano (medium-beta) and STFC Daresbury (high-beta). Thus, in comparison to the spokes, already the internal interfaces between cavities and cryomodule have to be well defined with a special attention to mechanical clashes that may occur during the assembly phase of the cryomodule. A model of an elliptical cryomodule is shown in Fig. 2.

As SRF cryomodules are complex systems, they have to rely on various auxiliary systems to allow appropriate operation. For example, the cavities have to be under vacuum, then are cooled down to cryogenic temperatures with the means of liquid helium before acceleration of the particle beam is possible. In order to define the interfaces between

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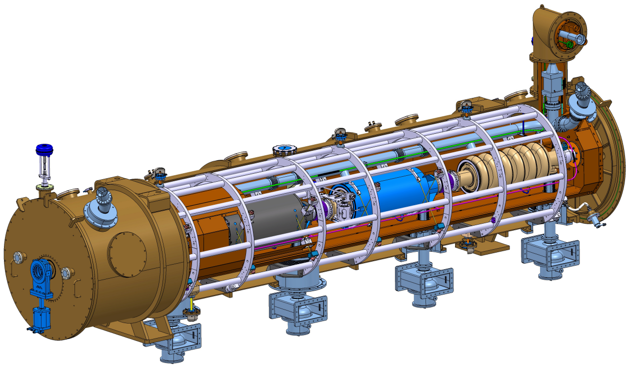

Figure 2: Model of ESS elliptical cryomodule.

the cryomodule and the various supporting systems is challenging at ESS, as possibly both sides of the interface are provided by in-kind partners, thus the coordination between those partners has to take place at ESS. Some of these interfaces are described in the following section, while most of them are valid for both types of cryomodules.

INTERFACE CAVITY CRYOMODULE

For the elliptical cavities, the interfaces towards the cryomodule are of importance, since the cavities are a contribution from a different partner and have to be suitable for installation and operation in the cryomodules to be assembled by CEA Saclay. Within the last year, some issues have been identified and mitigated. A picture of the dressed cavity highlighting the identified items is shown in Fig. 3.

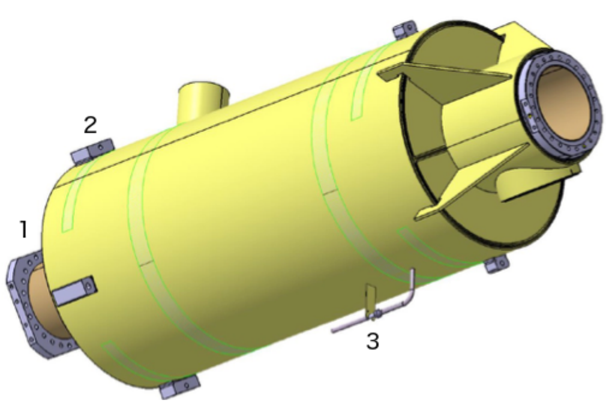

Figure 3: Model of dressed ESS elliptical cavity. 1: pickup antenna (hidden), 2: tuning blocks, 3: bimetallic joint.

The definition of the connector to the pick-up antenna (1) was important for the handling of the cavity during the installation into the cavity string. Its maximum dimensions had to be defined in detail for the cavity providing partners to allow an appropriate choice. Otherwise, clashes with the specialised tooling that is in use for the handling and assembly of the cavities at CEA Saclay would have occurred. Furthermore the mechanical tolerances of the location for the blocks (2) required to assemble the cold tuning system had to be revisited, as it became evident that the positioning required would be hard to achieve in the manufacturing process by the cavity vendors. In addition, the helium inlet is no longer a flanged connection, but a bimetallic weld (3) for longterm reliability.

CRYOMODULE INTERFACES

For the cryomodule interfaces, the disciplines vacuum, cryogenics and radio frequency, as well as the transportation and installation of the cryomodules will be reviewed in the following subsections.

Vacuum

The required cleanliness of the superconducting cavities imposes a clean assembly of all components connected to the beam line within the cryomodule. Thus, for the acceptance test, the pumping unit for evacuating the cryomodules' beam vacuum has to be assembled under clean room conditions. A local cleanroom is foreseen for the test stand TS2 [2] in Lund for the test of the elliptical cryomodules, while there are several options for the spoke cryomodules: assemble the pumping group before transportation from IPN Orsay to FREIA at Uppsala University [3] - this would keep the critical assembly steps in one hand - or under clean conditions at FREIA after arrival. Further, the definition of which vacuum components are assembled and provided by the partners was important. This includes the valves for beam and insulation vacuum, as well as the instrumentation.

Cryogenics

For the interface between cryomodules and cryogenics, the focus is on the elliptical cryomodules, as the spoke cryomodules and their valve boxes are both provided by IPN Orsay.

The so-called jumper connection connects the cryomodule with the corresponding valve box and it contains most of the helium supply and return lines. In addition a set of warm cryogenic auxiliary lines is needed for purging and purification purposes but also for pressure safety relief.The location and the mechanical tolerances associated with each interface have to be well defined to allow for the correct assembly. Moreover, the resultant thermo-mechanical stresses due to the various operating conditions also have to be derived for each system and for the interface. Finally, the choice of the flanges, gaskets, thicknesses and weld types have to be agreed for each mechanical interface between partners.

Radio-Frequency

For the radio-frequency system, i.e. the power coupler, the tuning system and the low-level RF system, several interfaces and equipment had to be defined, while the main challenge are the safety systems for the power coupler-cavity system. The descriptive model of a power coupler for the elliptical cryomodules is shown in Fig. 4.

The arc-detection system, consisting of photomultiplier tubes, used for the coupler conditioning as diagnostic component and the tests of the cryomodules at the partners cannot

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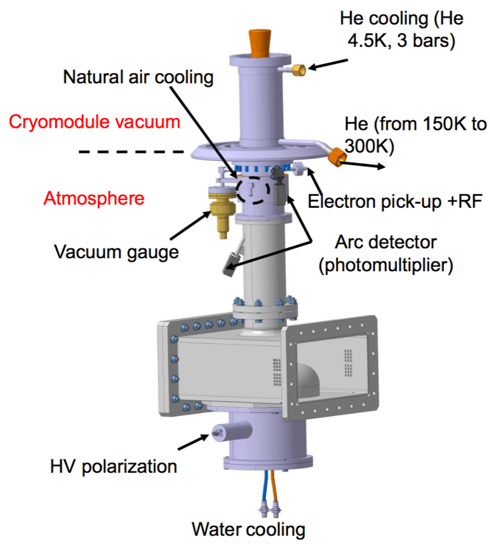

Figure 4: Model of ESS power coupler for elliptical cavities.

be used in the tunnel, since it would not withstand the radiation. Thus, a setup with fibre optics is under development, similar to the one in use at SNS [4]. To allow a good connection to the interlock system, the electronics for the electron pick-up systems has been developed at ESS in-house. Further, the way of implementation for the quench detection system is under discussion, special attention is given to which interlock systems shall be affected by a detected quench.

Transportation and Installation

The main challenge for the transportation is the movement and final positioning of the cryomodule in the accelerator tunnel. For the transportation of the cryomodules from France to Lund, special transport equipment will be used, similar to the applied frame that has been used for shipping the European XFEL cryomodules [5].

While the partner labs usually have the possibility to move the cryomodule using a crane, there is no such possibility in the test stand, as well as in the tunnel. In addition, further constraints regarding available clearance and tolerances for the final adjustment increase the complexity of the handling required.

SUMMARY

The definition of interfaces on cryomodules is of importance, especially when the provision of accelerator components is spread among various (in-kind) partners. Some of the major challenges for the ESS cryomodules have been summarised in this paper, but besides these ones there are way more to tackle. With the progression of the project, additional details show up that have to be addressed immediately.

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