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HIGH-PERFORMANCE ACCELERATING CRYOMODULE FOR THE LINCE PROJECT

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Abstract

The linear accelerator of LINCE consists of 26 superconducting quarter-wave resonators with three different geometric betas working at 72.75 and 109.125 MHz and three types of SC solenoids. In this work we discuss the cryomodule design based on thermal and mechanical studies carried out using COMSOL Multiphysics.

INTRODUCTION

In the future LINCE facility [1] high-intensity stable ion beams should be accelerated to energies at and above the Coulomb barrier. For this purpose a compact CW linac is being design, for a range of Q/A=1-1/7 working at a fundamental frequency of 18.18 MHz and its harmonics. The linac is composed of 26 superconducting quarter-wave resonators with three betas 0.045, 0.077 and 0.150 working at 72.75 and 109.125 MHz. The superconducting cavities and solenoids are organized in four cryomodules (C1-C4), and a summary of the configuration is given in Table 1. In present paper we describe a design study of the first accelerating cryomodule C1.

DESCRIPTION OF C1 CRYOMODULE

The overall design of the facility was carried out using TRACK [2]. Positioning of the five superconducting QWR cavities and the three solenoids composing the C1 cryomodule is shown in Fig. 1. According to calculations, maximum field gradient of QWR is 1.39 MV, the length of the superconducting solenoids 21.9 cm and the working magnetic field between 5 - 6 T. To provide the needed acceleration voltages the SC QWR resonators must be built using pure Nb bulk material, working a T=4.5 K, as recently proven at ATLAS and SPIRAL2 project [3, 4]. The assembly must be placed in a dedicated cryostat at high vacuum, providing proper insulation for conductive and radiation thermal losses. Due to the high acceleration gradients and high-intensities, the choice has been to have independent vacuum for thermal insulation and for the beam pipe, to avoid possible surface contamination of the QWR cavities preventing field electron emission and multipacting effects.

The mechanical assembly of solenoids and cavities must be protected by a radiation shield of multilayer material, which will be placed close to the surface of the inox vessel. An additional radiation shield placed at intermediate distance between the external wall and the internal structure at T=4.5K (holding superconducting QWR and solenoids) will be maintained at T=77 K by LN2 cooling system. The conceptual design of the system

Table 1: Organization of QWR Resonators at LINCE in Cryomodules and their Main Working Characteristics

Cryomod. label	Freq. [MHz]	Beta	V acc. [MV]	Nº Cavities
C1	72.75	0.045	1.39	5
C2	72.75	0.077	2.38	7
C3	72.75	0.077	2.38	7
C4	109.125	0.15	3.30	7

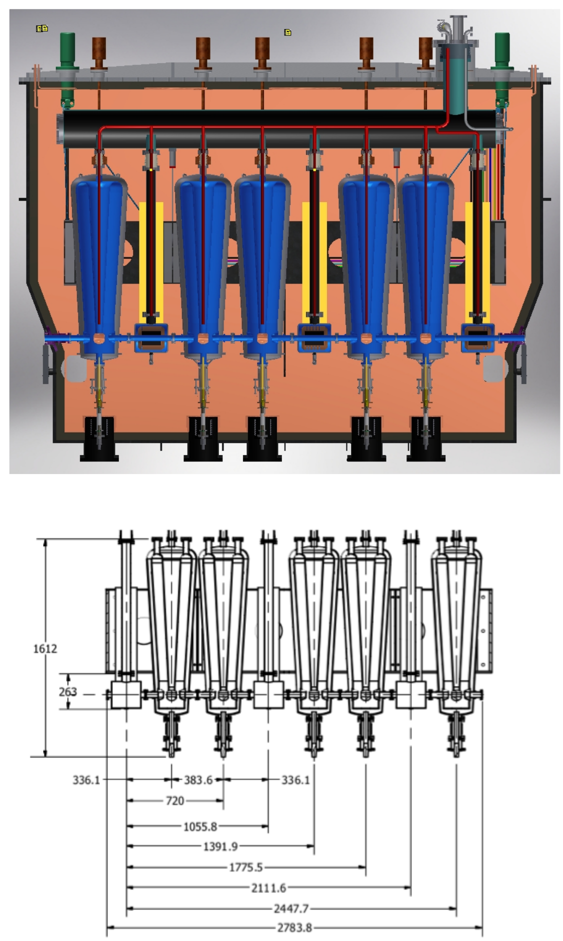

Figure 1: Positioning of cavities and solenoids in first cryomodule C1 for β = 0.045 and 72.75 MHz.

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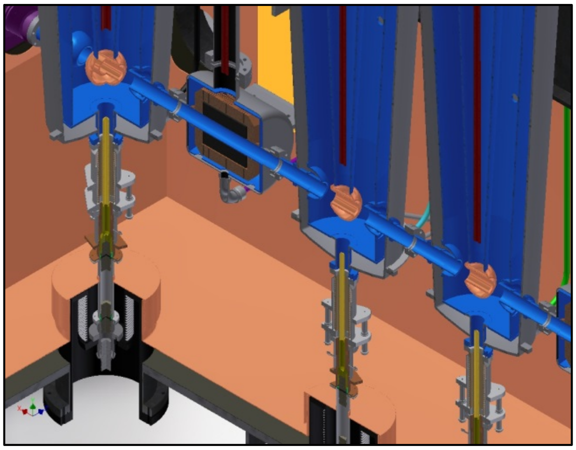

Figure 2: Detail C1 cryomodule assembly. See text for explanation.

is shown in Fig. 2: the assembly of SC cavities (blue), SC solenoids (brown) and RF couplers (yellow). The surface in light orange depicts the cooper radiation shield. The result of the design study of the assembly is shown in Fig. 3, where main components are indicated with arrows. The mechanical design has been carried out using the CAD software Autodesk Inventor [5], the cryomodule dimensions are 3.3 m (length) x 2.3 m (height) x 0.8 (width).

THERMODINAMIC, MECHANICAL AND MAGNETIC STUDIES

An important part of the cryomodule design is the structural stability of the vacuum vessel and its subsystems, since the complete assembly must stand extreme working conditions: a high pressure gradient - from atmospheric pressure to high-vacuum, and a extreme temperature gradient, from external T=300K down to T=4.5K at superconducting cavities and solenoids. In Fig. 5 we present the result of thermo-mechanical calculations performed with Comsol Multiphysics [6], where we have studied the thickness walls and reinforcements of the vessel structure. Thermo-mechanical calculations have been performed with the code COMSOL Multiphysics [4], including the proper mechanical and thermal boundary conditions (pressure and temperature boundaries and materials). In Fig. 4 it is shown the result of Von Miss stress for a tested configuration of vessel reinforcements.

From stationary thermal profile distributions we have analyzed the thermal losses associated to this cryomodule: 1) static heat losses due to radiation and conduction process in supports, cables and couplers, 2) dynamic losses, arising form RF losses in cavities, power couplers and current leads of solenoids. Altogether it is possible to estimate a static thermal load of 24.2 W. The dynamic heat load of C1 will depend on the power dissipated in the

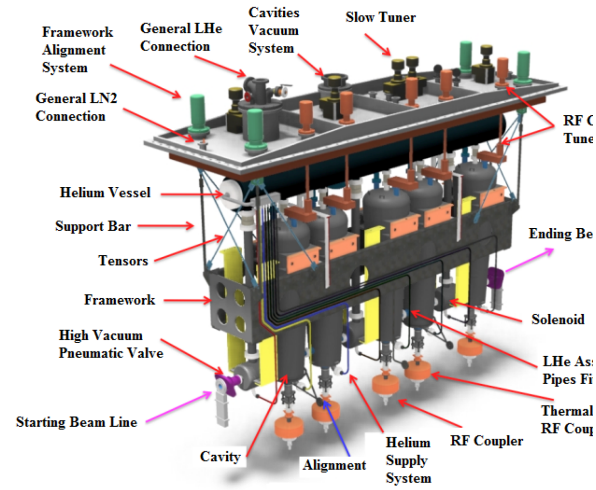

Figure 3: Mechanical design of the cryomodule showing main subsystems.

cavities and solenoids at operation. Estimates based on other projects at ANL (USA) and SPIRAL2 (France), give a value around 80 W for cryomodule C1 of LINCE.

A critical part of the design is the diamagnetic layer for shielding superconducting elements (cavities and solenoids) placed in the interior of the cryomodule, to avoid the formation of trapped currents in SC materials from the interaction of Earth magnetic fields during the cooling process. The optimization of the magnetic shielding was performed using the COMSOL AC/DC module. The full cryomodule was simulated with real dimensions, adding an inner foil of mu-metal material of variable thickness close to the wall of the main vessel. The results of the calculation are shown in Fig. 5. Final proposal for the magnetic shielding is a 1mm screen of MUMaterial placed close to the vessel wall.

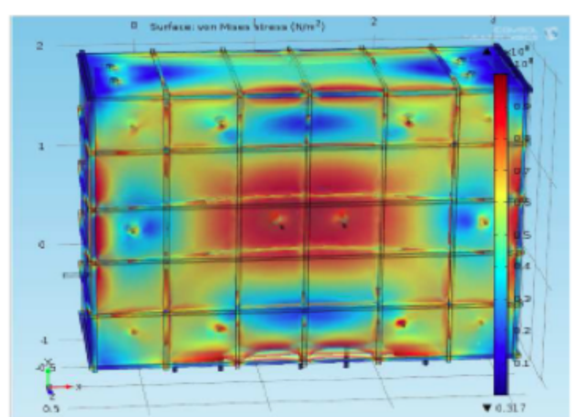

Figure 4: Surface Von Mises stress.

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SUMMARY AND CONCLUSIONS

In this work we discuss the design of cryomodule C1 of the LINCE facility. Main construction parameters have been obtained based on thermal and mechanical studies carried out using COMSOL Multiphysics. Further work will continue with the design of cryomodules C2-C4 and the corresponding inter-cryomodule matching sections, which should include dedicated beam diagnostic systems.

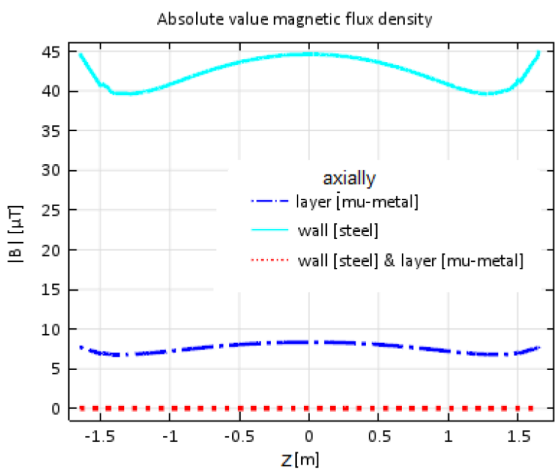

Figure 5: Earth Magnetic field attenuation after adding 1 mm shielding of MU-material.

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