DRIFT TUBE CAVITY CRYOMODULE DESIGN FOR RIA

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Abstract

We present the current status of our Rare Isotope Accelerator (RIA) cryomodule development effort. The RIA driver and post accelerator linac drift tube sections require about forty reliable, low heat leak cryomodules, each containing from seven to nine drift-tube-loaded cavities. A proposed triple spoke option for RIA would increase this count to about seventy. We have developed a cryomodule featuring separated cavity and insulating vacuum spaces suitable for all classes of drift-tube-loaded cavities used in RIA. Issues include ease of assembly, cavity cleanliness, and subsystem interface (cryogenics, couplers, tuners, shields). We employ an innovative warm-to-cold beam line transition to reduce module-to-module dead space while preserving a top loading box design that minimizes the size of the cleanroom assembly. An AIP-funded upgrade to Argonne's existing ATLAS heavy ion linac will allow us to gain valuable operating experience by qualifying the prototype cryomodule in a real machine.

INTRODUCTION

Existing heavy ion accelerators make use of drift-tube-loaded SRF cavities capable of reaching accelerating gradients of a few MV/m [1]. Fabrication techniques at the time did not include the low particulate, clean handling methods used in modern cavity production. The associated cryomodules housing the cavities were of simple "common vacuum" design where the cavity interior vacuum space was common with the cryomodule insulating vacuum space. The inevitable result is particulate contamination on the RF surfaces of the cavities which limit performance. Tests at ANL [2] have confirmed that application of techniques such as high pressure water rinsing (HPWR) and clean handling can improve the performance of existing cavities. The drift-tube cavities proposed for the RIA driver and post accelerator linacs will take advantage of the latest production and handling techniques to yield high accelerating gradients. Cryomodules must be designed to preserve a low particulate environment for these cavities to ensure peak performance. The primary feature of this design is isolation of the cavity vacuum space from the insulating vacuum.

CRYOMODULE DESIGN

Figure 1 shows one of the cryomodules used in the positive ion injector (PII) used in ANL's ATLAS heavy ion accelerator. Although it features common vacuum, it differs from the older cylindrical, end-loading ATLAS cryomodules in its top-loading, box layout.

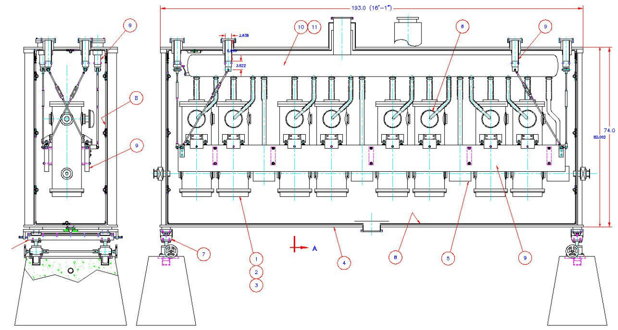

Figure 1: ATLAS PII cryostat.

The RIA cryomodule extends this successful design to include separate vacuum spaces while preserving its positive features. The box geometry is appropriate for quarter-wave, half-wave, and spoke-loaded cavities while the top-loading design simplifies assembly. Figure 2 shows a version of the cryomodule containing eight quarter-wave cavities operating at 115 MHz together with a focusing solenoid.

Cavity Vacuum Space

Cavity vacuum is isolated from the insulating vacuum. The beam ports of adjacent cavities are tied together with Conflat-flanged bellows sections. The cavities are evacuated via a high conductance manifold connecting all cavities to a clean pumping station. RF input couplers attach to the undersides of the cavity and feed out through ports in the bottom of the vacuum vessel. Beam valves attach to the ends of the structure at the cold-to-warm interface.

A novel cryomodule end wall design minimizes the distance between adjacent cryomodules. The end wall uses a dogleg design which allows the complete cavity assembly to drop into the vacuum vessel while sealed and under vacuum. The beam valves pass through holes in the angled end walls where a flanged adapter plate seals against the vacuum vessel. Figure 3 shows a detail view.

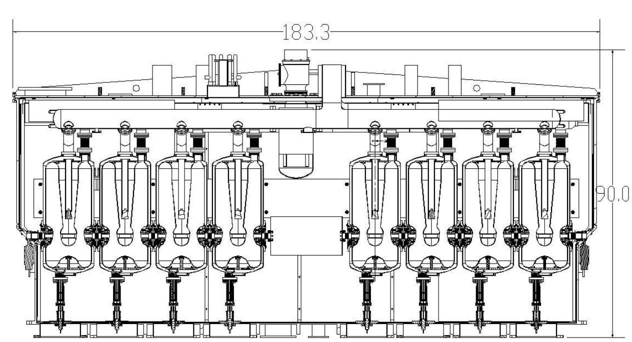

Figure 2: RIA drift-tube cavity cryomodule.

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Shields

Both magnetic and thermal shielding are provided. The magnetic shield is a single layer of 0.040" thick Co-Netic operating at room temperature. The material is attached to the inside wall of the vacuum vessel in 30" wide sections using a system of threaded studs and batten strips to ensure positive contact at overlapping seams. This low cost technique eliminates welding and subsequent annealing of large shield subassemblies.

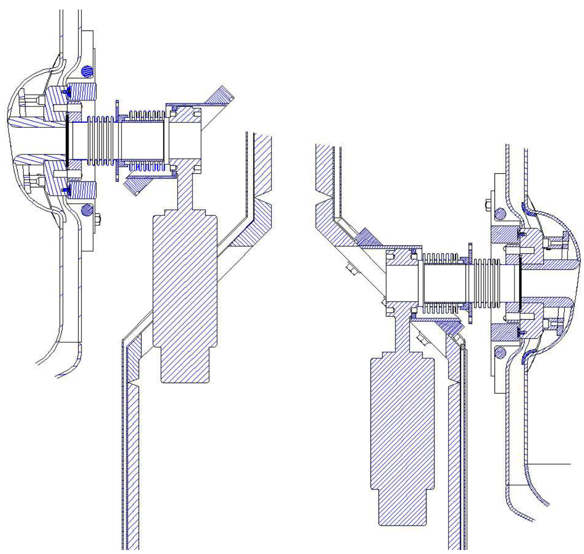

Figure 3: Module-to-module interface showing beam line warm-to-cold transitions, valves, angled vacuum box end walls and module top-loading.

The thermal radiation shield consists of multiple sheets of 0.065" thick copper suspended from a liquid nitrogen manifold located at the top of the cryomodule. The shields are conduction cooled and wrapped with multilayer insulation (MLI). They are designed for ease of installation and provide a peak shield temperature < 90 K.

Cavity Support Structure

The cavities are supported within the cryomodule using a modification of the technique used in the PII cryomodules. Two aluminum beams form a rigid rail system upon which the individual cavities and focusing elements are mounted and aligned. The rails hang from the cryomodule top plate by heat-stationed stainless steel members. The support system is designed with the goal that there be no net shift in cavity elevation upon cooldown. At the same time the structure should be adequately stiff to prevent swaying of the cold mass. The support members are angled from the rails in towards the center of the module in such a way that the longitudinal shrinkage of the rails offsets the vertical shrinkage of the members and of the stainless steel cavity helium vessels. Figure 4 shows the geometry schematically.

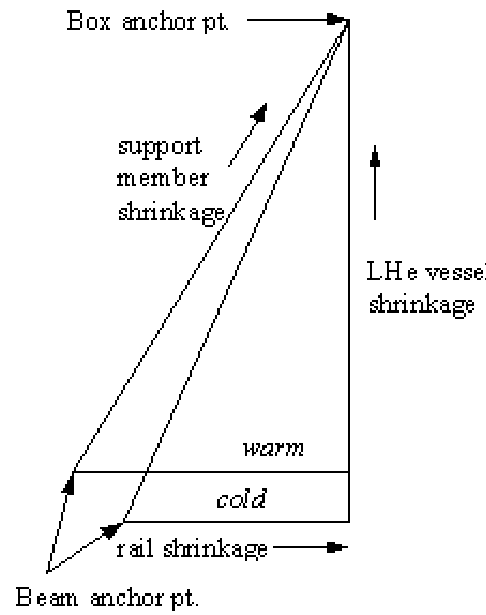

Figure 4: Support geometry.

CRYOMODULE ASSEMBLY

The cryomodule is designed for ease of assembly. Cavities, couplers, inter-cavity spools, beam valves, vacuum manifold and alignment rails are assembled using clean handling techniques. These components represent the particulate-sensitive elements of the module together with the support frame (Figure 5). Once they are assembled and hermetically sealed the subassembly is removed from the clean assembly area and suspended from the module top plate (Figure 6). At this point subsystems such as cryogenic connections, mechanical tuners, and instrumentation are added. The vacuum vessel is prepped with magnetic and thermal shields. Finally the top plate/cavity subassembly is lowered into the vacuum vessel (Figure 7).

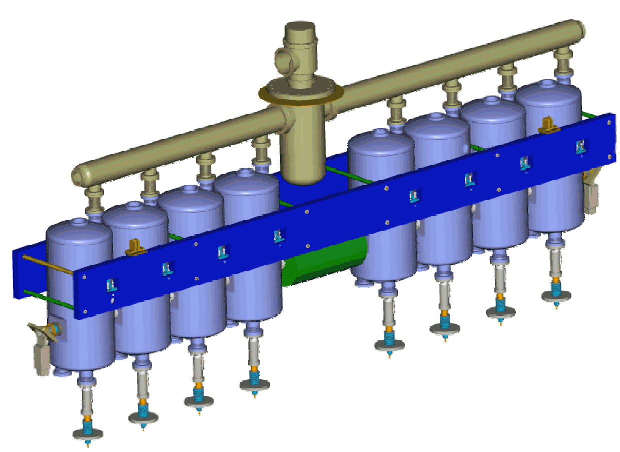

Figure 5: Clean subassembly.

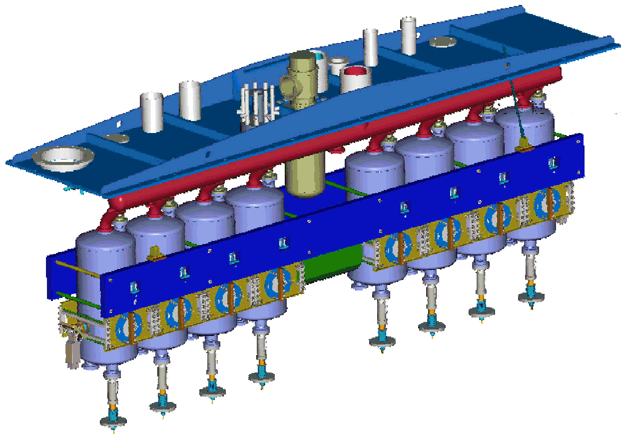

Figure 6: Clean subassembly suspended from top plate.

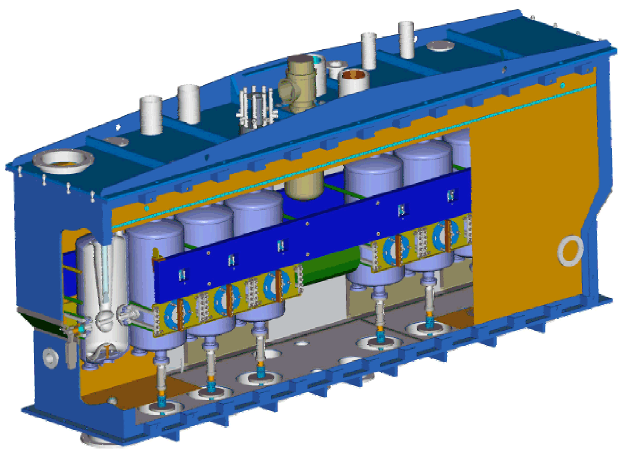

Figure 7: Cutaway of complete assembly.

ATLAS PROTOTYPE

ANL plans to install a prototype box cryomodule containing quarter-wave and half-wave cavities at the end of the existing ATLAS accelerator. This will provide the opportunity to test RIA – class drift tube cavities in a realistic operating environment complete with cryogenic refrigerator, vacuum and RF subsystems, and particle beams. The initial configuration will contain one quarter-wave and one half-wave cavity. Eventually the module will be completely populated with eight quarter-wave cavities providing a substantial energy increase for ATLAS users. Construction has begun on this prototype.

CONCLUSIONS

A cryomodule suitable for all classes of RIA drift tube cavities has been designed. The key feature is isolation of the cavity vacuum space to maintain a low-particulate environment. This is necessary for maximum performance with cavities fabricated and handled using state-of-the-art techniques. Other features of the design include a versatile box geometry with top-loading capability for ease of assembly. The beam line warm-to-cold transitions have been designed to minimize the space between cryomodules. They also permit separate clean assembly and isolation of the particulate sensitive components prior to final insertion into the vacuum box. Magnetic and thermal shields have been designed for low cost and ease of assembly while the cavity support structure provides a zero-net elevation shift for the cavities upon cooldown. The prototype module will be installed in ANL's ATLAS complex for tests with beam as part of a real accelerator.

REFERENCES

[1] Shepard, K.W., "Superconducting Heavy-Ion Accelerating Structures," NIM in Phys. Rev. A 382, 1996, p. 125-131.

[2] Kelly, M.P. et al, "Cold Tests of a Spoke Cavity Prototype for RIA," PAC2001, p. 1047.