

FIDUCIALIZATION OF THE CRYOMODULES FOR THE NSCL REACCELERATOR PROJECT*

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Abstract

The National Superconducting Cyclotron Laboratory is constructing a rare isotope beam stopping and reacceleration facility. This poster describes the proposed fiducialization and alignment plan for the superconducting RF linear accelerator modules.

INTRODUCTION

The National Superconducting Cyclotron Laboratory (NSCL)¹ is a national nuclear physics research laboratory on the campus of Michigan State University. The research programs at NSCL include nuclear astrophysics, nuclear structure, and the production of isotopes far from the valley of stability. In a typical experiment, heavy ions with masses ranging from hydrogen to uranium are created in an Electron Cyclotron Resonance (ECR) ion source and injected into the K500 cyclotron. The accelerated beam is transported to the K1200 cyclotron, where its electrons are stripped to a higher charge state before additional acceleration. After extraction, the beam has an energy of up to 200 MeV per nucleon. The extracted beam is focused onto a production target and the secondary beam from the fragmentation reaction is analyzed in a series of dipoles and quadrupoles/multipoles. A beam switchyard focuses the beam into one of six experimental stations. Superconducting magnets are found in the main coils of the two cyclotrons, one of the ECR ion sources, and in all of the high energy beam transport dipoles and quadrupoles/multipoles.

NSCL is developing a prototypical facility² to demonstrate the technical feasibility and performance characteristics for stopping and reaccelerating beams of rare isotopes produced and separated in flight, as an important step towards a next-generation rare-isotope facility in the United States. Beams of rare isotopes will be produced and separated in-flight at the NSCL Coupled Cyclotron Facility and subsequently stopped and reaccelerated efficiently and with minimal losses, in three steps:

- Stopping of exotic beams in a linear gas cell.

- Breeding the stopped ions to high charge states in a state-of-the-art Electron Beam Ion Trap (EBIT) ion source.
- Reaccelerating the ions in a Radio Frequency Quadrupole (RFQ) and a modern superconducting linear accelerator to beam energies of up to 3 MeV per nucleon.

The additional beamline installation for the Reaccelerator Project is shown in Figure 1. The exotic radioactive beams enter the experimental vault from the left and are stopped in the linear gas cell. The slow-moving singly charged ions are transported to the EBIT breeder, shown in blue, in the next room. After charge breeding, the beam is injected into an RFQ, shown in orange, for initial acceleration. The final acceleration is done by the three cryomodules of the superconducting linac.

NSCL will be the first facility worldwide to demonstrate and optimize the complete concept of creating fast exotic beams, stopping, breeding, and reaccelerating them. We apply innovative concepts to make the process more efficient and economical.

This paper describes the fiducialization and alignment plans for the linear accelerator cryomodules. It is difficult to fiducialize a superconducting beamline element due to the multiple layers of thermal shields. The cryomodules to be used in this project have the additional challenge of superconducting solenoid magnets interspersed with the RF cavities. By the use of rigid links the positions of the active elements can be transferred to the exterior of the module with an acceptable heat load and within the alignment budget for the module.

LINEAR ACCELERATOR CRYOMODULE

A typical linear accelerator cryomodule is shown in Figure 2. It consists of six superconducting RF cavities and three superconducting 9-tesla solenoid magnets. The β value ($=v/c$) of this unit is 0.041.

The helium containers of the cavities and solenoids are attached to a set of titanium rails. The rails are supported by vertical links at the top and are constrained by horizontal links on the sides and ends. A set of input

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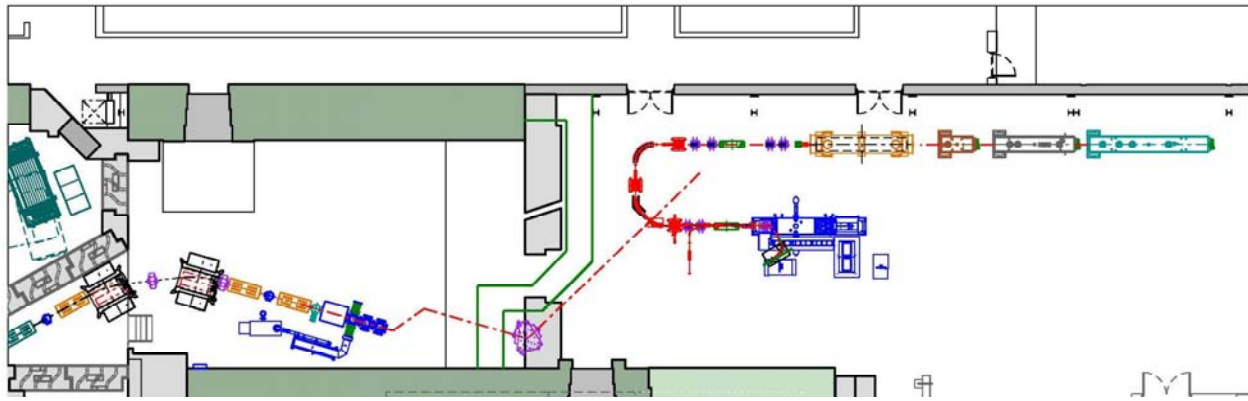


Figure 1. The Reaccelerator beamline.

couplers feed RF power in from the bottom through a flexible joint.

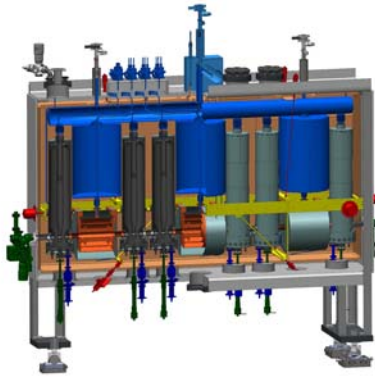


Figure 2. $\beta=0.041$ Cryomodule.

The cryostat box is supported by a three point stand. The vertical adjusters control height and level using ACME screws and 88.9 mm. diameter ball bearings. Each bearing slides in a horizontal concave slot. The horizontal adjusters are two ACME screws pushing the plate with the slot, riding on a set of 12.7 mm. ball bearings. Ball transfers constrain the motion of the plate in the direction perpendicular to the adjusting screws. The base of the steel box is clamped and grouted to the floor (see Figure 3).

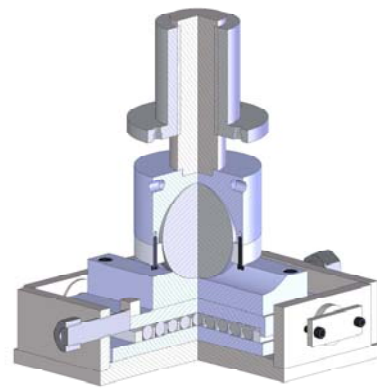


Figure 1. Orthogonal Adjuster

Cold Mass Assembly

The superconducting solenoid magnets are magnetically mapped by the vendor and the relationship between the central magnetic axis and reference dowel pin holes on the end flanges is provided. The flanges are specified with mounting holes for SMR pin nests. Using finite element analysis of the expected thermal motion of the mounting brackets during cooldown, the position of the reference points can be predicted at room temperature.

The RF cavities and solenoids are first mounted to the titanium rail structure in the clean room. The solenoids are attached to the RF cavities using bellows. The ends of the component string are sealed with gate valves and the dedicated vacuum pumping system. Once sealed, the assembly can be moved out of the clean room environment for alignment. The design of the cavities allows a measurement, with either the tracker or our Coordinate Measurement Machine (CMM) arm, (Romer Infinite model³) of the position of the central axis after the components have been attached to one another in the clean room and sealed. The titanium framework supports the elements and provides the attachment points for the horizontal links.

With the assembly out of the clean room, the alignment of the cavities to the titanium rails becomes much easier. The central beamaxis is defined by the theoretical location relative to the horizontal links, acting as fiducials. The cavities and solenoids are adjusted to their nominal positions relative to the rail framework and locked down. During operation, the rails are cooled with liquid helium to maintain a stable relationship between the components and the links. At this point, the relationship between the horizontal links and the central beam axis can be documented.

Link Details

The horizontal links serve to not only constrain the horizontal motion of the magnets and cavities, but also to transfer the position of the rail system to the outside of the cryostat. A cross-section of a typical horizontal link is shown in Figure 4.

The titanium rails support the superconducting RF cavities and the solenoids. The end of the Invar36 link is drilled to accept a spherically mounted retroreflector (SMR) pin nest. (This alloy was chosen for its small thermal expansion coefficient.) By measuring the positions of opposing links, the internal rail system can be known using a laser tracker.(FARO Tracker X⁴) The welded bellows is flexible enough to follow the movement of the internal components by squirming. By mounting paired links on opposing sides, the thermal contraction of the link rods can be eliminated from the alignment. Having six links available adds redundancy to the measurement.

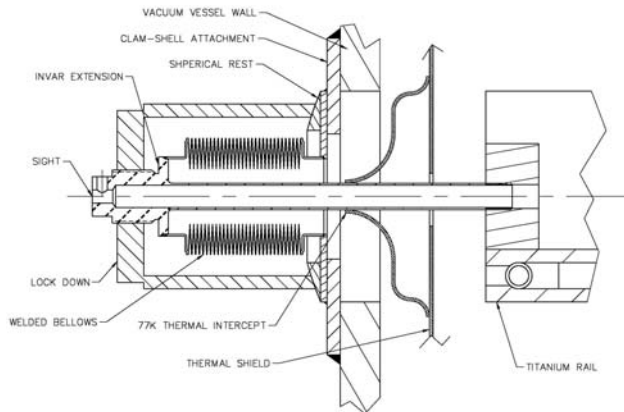


Figure 2. Horizontal link design.

Final Assembly

The cryomodule is assembled in layers. With the titanium rails hanging from the top lid of the module via adjustable vertical links, the copper liquid nitrogen shield can be assembled around the cavities and solenoids. This shield is thermally intercepted to the horizontal links to limit the heat load on the helium system. The 77K shield is wrapped in superinsulation on the outside and covered with aluminum tape on the inside. The vacuum jacket is

fabricated from steel plates, welded into a large rectangular box. The horizontal links protrude through holes in the side plates and a split disk with a central opening is welded between the vacuum vessel wall and the bellows flange.

During pumpout and cooldown, the lock down nuts are left off so the titanium rail assembly can freely move from thermal contraction. Once the cryomodule is cold, the nuts can be threaded on the ends of the links, pressing on the spherical washer, and adjusted by hand to horizontally center the cavity-solenoid string on an axis defined by the two beamline flanges. The vertical links on the top lid are adjusted to level the string and set the vertical height. Aligning the cavity-solenoid string to the end beamline flanges simplifies the attachment of the beamline elements which precede and follow the module.

As mentioned earlier, the cryomodule is mounted in the beamline on three support stands. Because of the absence of seismic activity near the laboratory, it is not necessary to constrain the module vertically. On the beamline support platform, the laser tracker can view three of the horizontal links, two on the side and one end, uniquely defining the cryomodule position. We have found that the commercial software (CAM2X⁴) that came with the tracker is sufficient to align beamline components to the planned beamlines in the laboratory.

SUMMARY

The NSCL is adding a stopped radioactive beam reacceleration facility, producing short lived isotopes at up to 3 MeV per nucleon. This poster describes the alignment plans for the superconducting linear accelerator component of the project.

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