A PRELIMINARY ALIGNMENT PLAN FOR RIA AT MSU*

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1. INTRODUCTION

The Rare Isotope Accelerator (RIA) is a new laboratory proposed for heavy ion research in the US. The accelerator will provide beams of isotopes outside the valley of stability.[1] The U.S. Department of Energy's Office of Science has given RIA third priority in major research facilities over the next twenty years. This is a preliminary plan for alignment if the lab is sited at Michigan State University (MSU).

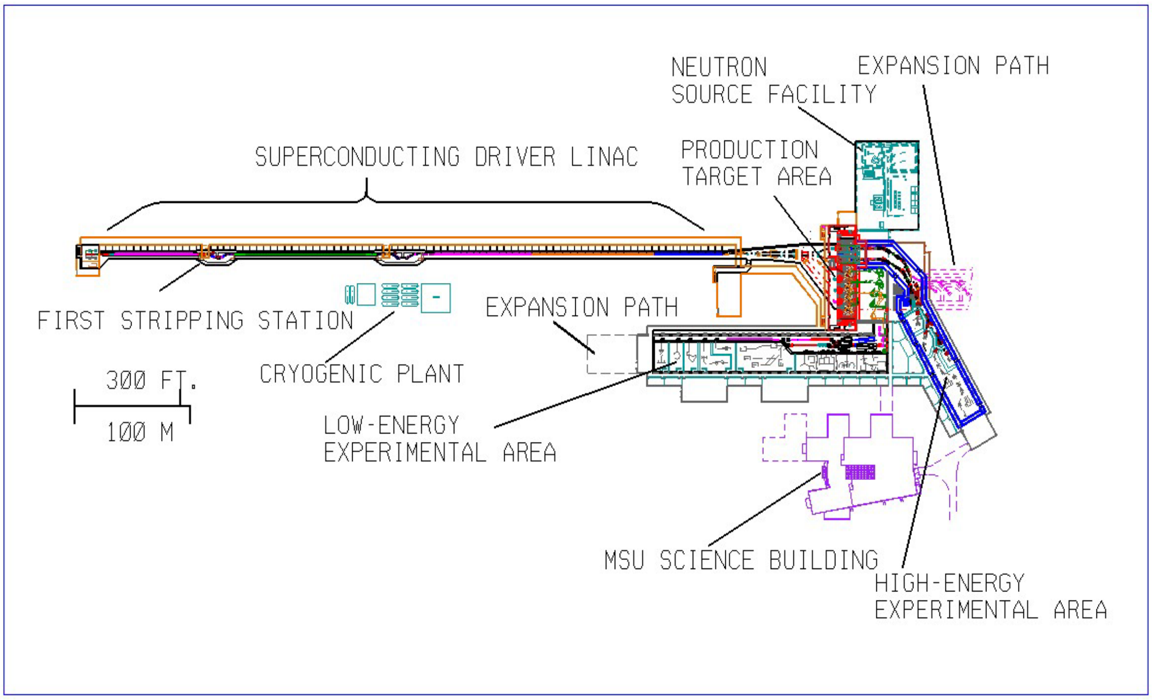

Figure 1. The Rare Isotope Accelerator Laboratory

The RIA accelerator system, shown in Figure 1, begins with two Electron-Cyclotron Resonance (ECR) ion sources, either of which can inject elements ranging from hydrogen to uranium into a Radio-Frequency Quadrupole (RFQ). The beam is accelerated to energies of 900 MeV for protons and 400 MeV per nucleon for uranium by a linear accelerator using superconducting cavities. The beam transport system serves either an isotope separation online

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(ISOL) target or a fragmentation target. The ISOL target produces a low energy beam while the fragmentation production target produces secondary beams which have velocities of the primary beam.

A large variety of beamline components must be aligned to the beam axis. These include ion sources, electrostatic focusing elements, room temperature magnets, superconducting accelerator modules with internal magnets, superconducting focusing and bending magnets, beam diagnostic devices, and experimental apparatus. At the National Superconducting Cyclotron Laboratory (NSCL), optical metrology is used to set the beamline components to their theoretical positions. The telescopes have been set with their optic axis on the beam axis and each magnet has fiducials on that axis. The superconducting dipoles have room temperature pole tips with the targets mounted directly to the steel. The superconducting quadrupoles have links adjusted during magnetic mapping to align the magnetic axis to the line formed by the centers of the two end flanges. The advantage of such a system is the "beam's eye view" of the fiducials.

2. OVERALL PLAN FOR RIA

An overall plan using features from several laboratories will produce an accelerator system with the required precision. Using modern laser trackers, a laboratory as large as RIA can have its components placed to their theoretical coordinates with high precision.[2,3] A monument grid in the floors with a 10 meter maximum spacing extends the range of the coordinate measurement machines (CMM) to the whole laboratory. This spacing ensures that a tracker with a 35 meter range can view more than three monuments from any position. A master monument which defines the origin of the coordinate system and the direction of the X, Y, and Z axes can be arbitrarily chosen. By comparing other monuments to this master, the settlement and flexing of the floor can be monitored. For monuments, a "nest" for a spherically mounted retroreflector (SMR) is embedded in the floor with a steel cover (See Figure 2). Nests typically use a small magnet in the center to clamp the SMR to the precision machined nesting surface. In order to keep the unit cost low, the nest is designed to be machined by a programmable lathe in one operation. The monuments will be installed with non-shrink grout after the floors have cured.

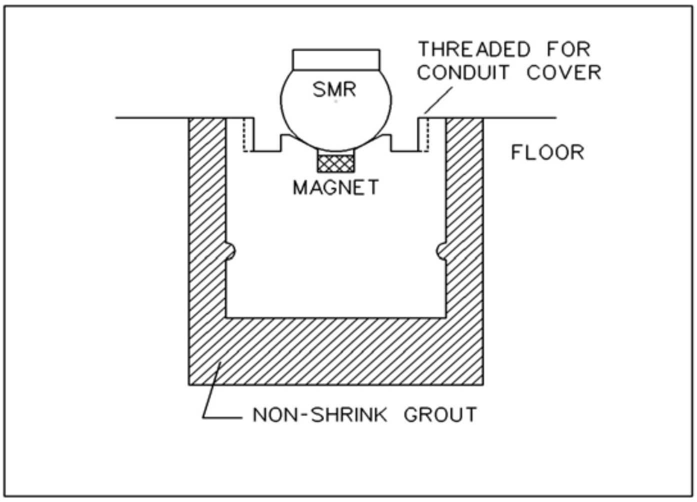

Figure 2. A floor monument SMR nest.

At the NSCL, vertical monuments are tooling dock scales mounted to the permanent cast concrete walls. These are well suited to the jig transits with optical micrometers. At RIA, since the floor monuments are known in elevation, a post of fixed length mounted to a monument can raise the reference to the height of the beamline for optical levelling.

3. FIDUCIALIZATION OF INDIVIDUAL COMPONENTS

The position in space of a rigid object can be referenced by a minimum of three non-collinear SMR targets. The task of positioning that object is easier if the three targets are mounted close to the position adjusters.

3.1. ECR Ion Sources and Injection Line

The central beam axis of an ECR ion source is collinear with the steel return yoke of the dipole coils. Figure 3 shows the ARTEMIS ion source at NSCL. SMR nests can be installed on the outer surface of this thick cylindrical tube. For the electrostatic quadrupoles and dipoles, the surfaces of interest are mounted to a framework of insulators inside a long tube. The best way to map those surfaces to external nests on the vacuum jacket is with an “ARM” style coordinate measurement machine (CMM). These have been used elsewhere[4] to measure and align experimental equipment in tight quarters.

Figure 3. The ARTEMIS ECR Ion Source at NSCL.

3.2. RFQ and Linac

The RFQ is easy to fiducialize since it is a room temperature device. SMR nests can be mounted to the outside and referenced to the end flanges.

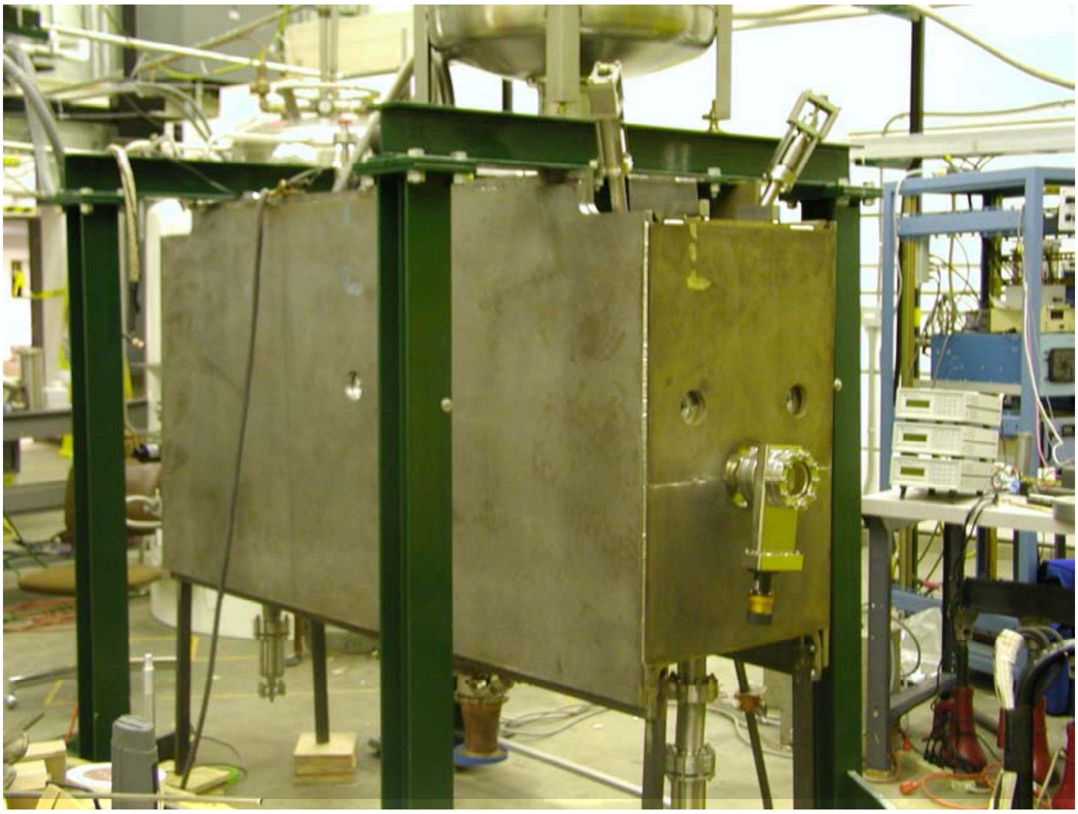

Figure 4. A linac test cryomodule.

The linac module consists of groups of cavities with superconducting solenoids between them. Figure 4 shows the prototype test module containing eight elliptical cavities during construction. Figure 5 is a drawing of the β=0.47 prototype cryomodule that could be used in RIA. The alignment ports are used to measure the motion of the cavities during cooldown. The interior of the superconducting linear accelerator cavities cannot be accessed outside a class 10,000 clean room. Because of this, the small bore, and the length of the module, all position measurements have to be taken on the outside of the cavities and magnets. An additional complication is the tight packing of other beamline components on each end of the linac cryomodule once it is in the beamline. The cavities and solenoids are rigidly attached to a large titanium rail inside the helium container near the top. Using an ARM style CMM, the cavities and solenoids can be aligned to each other with high precision. Three invar rods extending from the top of the rail to SMR nests on the outside of the vacuum vessel would provide fiducialization for the entire assembly. In order to trust the fiducials, the mechanical connections to these rods need to be flexible and the temperature distribution between the helium container and the room temperature vacuum vessel needs to be well defined by flexible thermal clamping at the shields. The major drawback to such a system is the high heat load from the fiducial rods, but the RF cavities will dominate the heat load during operation.

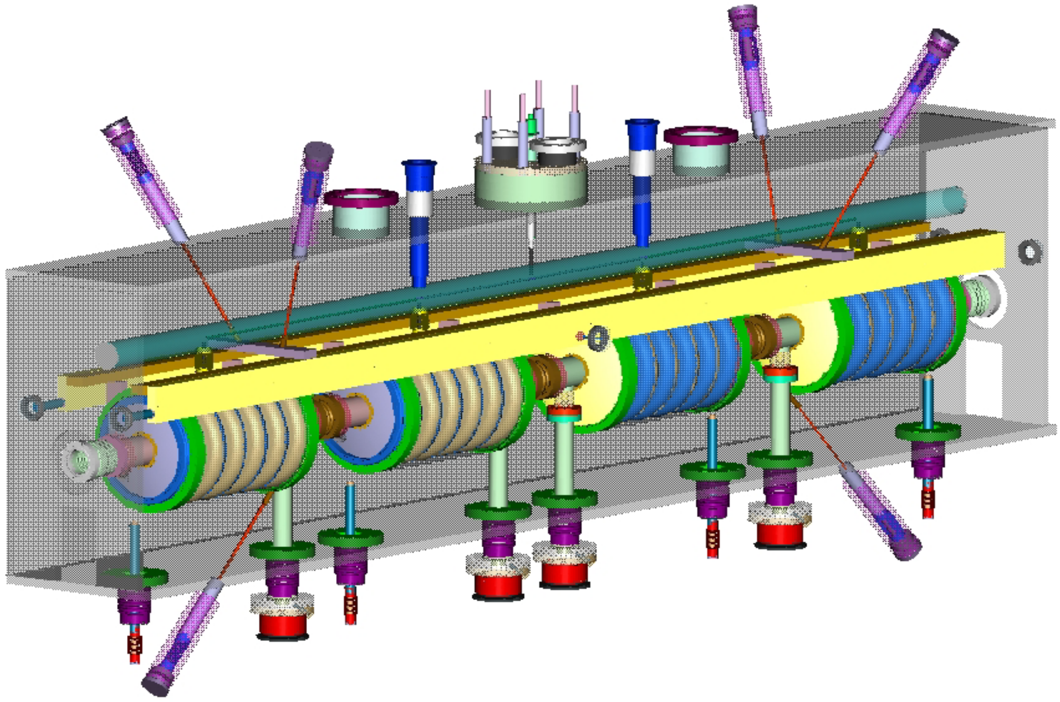

Figure 5. A design for a full size β=0.47 linac cryomodule.

3.3. Superconducting Quadrupoles and Dipoles

The planned high energy transport system is very similar to the magnets in use at NSCL. The quadrupoles have low carbon steel pole tips and return yokes inside the liquid helium container (Figure 5). The vacuum cryostat has a warm bore. For the quadrupoles, the links are adjusted to put the magnetic central axis on the line formed by the centers of the two end vacuum flanges. The magnet mapper and fiducials are clamped to the cryostat with ball transfers for repeatability. In order to avoid opening the beamline when checking the positions, additional SMR nests will be mounted on the sides of the cryostats and calibrated to the central axis during the mapping operations.

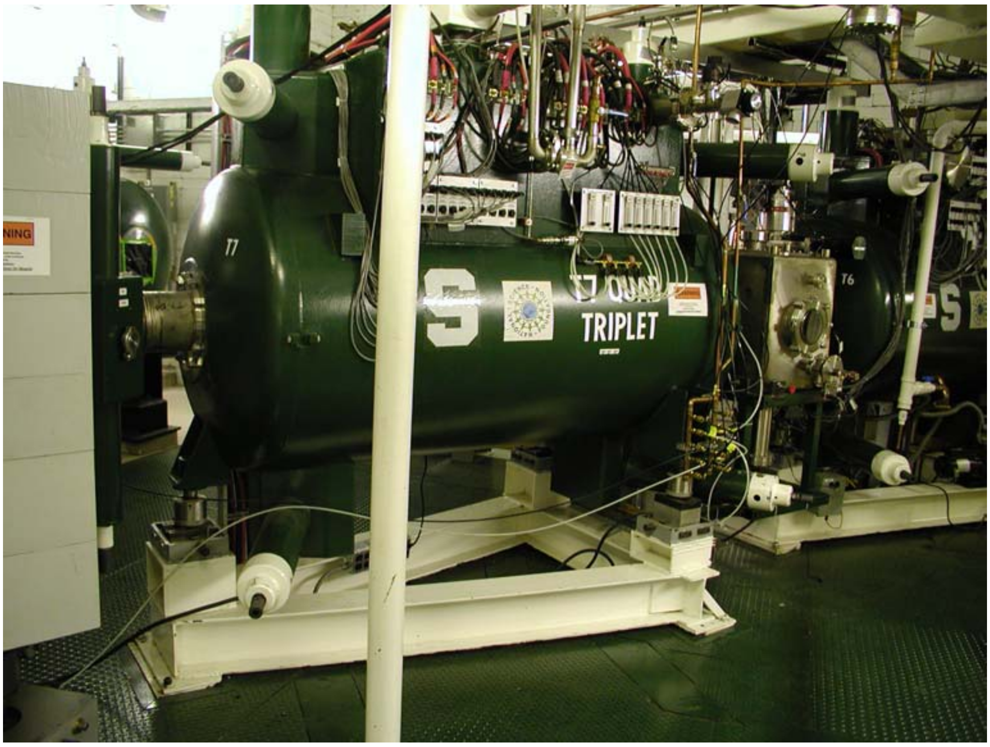

Figure 5. A superconducting quadrupole triplet magnet at NSCL.

The 45,000 kg superconducting dipoles (Figure 6) have room temperature steel pole tips that penetrate into the beam vacuum space. The pole tips have small precision dowel pin holes at each end for the alignment fixturing. Finally, SMR nests are to be added to the outside of the cryostat and calibrated to the holes.

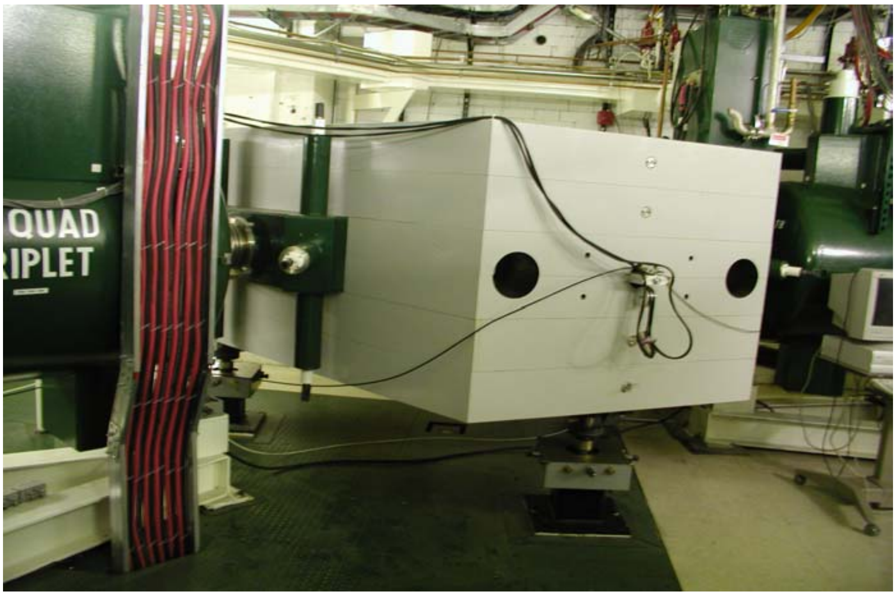

Figure 6. A superconducting 45 deg. dipole magnet at NSCL.

3.4. Room Temperature Magnets

The low energy transport systems after the Gas Stopping Stations are simple, water cooled, small room temperature magnets. The fiducialization of such magnets is accomplished by a high precision fabrication of the return yoke and pole tips with either built-in SMR nests or dowel holes for drop-in nests.

3.5. Beam Diagnostics and Experimental Equipment

Beam diagnostic devices do not lend themselves to the installation of SMR nests. They are typically gas filled detectors with thin aluminized mylar windows. Figure 7 shows a typical diagnostic chamber with its associated gas handling system and nuclear electronics. One option is to use the same optical methods presently being used at NSCL: The jig transit or alignment telescope is installed in the beamline referenced to the end flange fiducials on a previously aligned quadrupole magnet. The detector window is viewed with a machinist's scale laid across its frame to center it on the beam axis. A second option is to use an ARM-style CMM and compare the coordinates of the corners of the frame with the theoretical values referenced to local monuments.

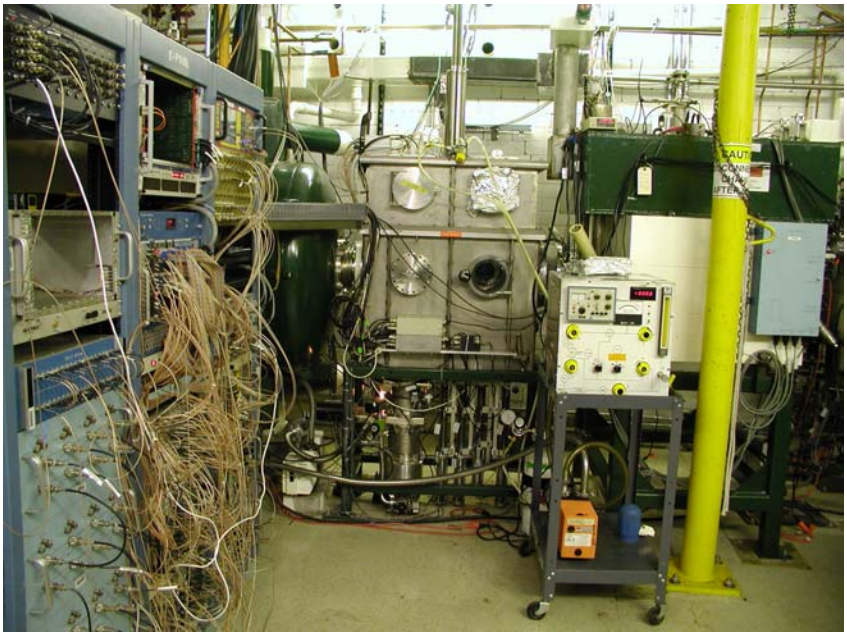

Figure 7. The A1900 focal plane detector box at NSCL.

3.6. High Radiation Areas

The ISOL and Projectile Fragmentation target areas will both be highly radioactive after a short period of operation. In order to minimalize the personnel time spent in the area, magnets and chambers can be set on kinematic mounts, with a spare pre-aligned to an identical mount in a separate storage room. The spare would be dropped into place and the position checked from 30 meters away by a laser tracker.

4. SUMMARY

This paper has presented a preliminary proposal to the accelerator alignment community for comment on the installation of the Rare Isotope Accelerator at Michigan State University. The technique of treating the accelerator and beamlines as a large single object to be measured with a coordinate measuring machine, developed at synchrotron light sources and other large accelerators, is well suited to the installation and later maintenance of this facility.

References

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