# 805 MHz $\beta$=0.47 Elliptical Accelerating Structure R&D
## (R&D Category: Driver Linac)

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**Summary**
The RIA driver linac will accelerate heavy ions over the same velocity range as the proton linac of the Spallation Neutron Source (SNS). It was decided to use the superconducting six-cell elliptical 805 MHz cavities of SNS for the high-energy portion of the RIA linac, thereby saving the non-recurring development and engineering costs, and reducing technical risk. For additional savings, it was decided to extend the elliptical multi-cell cavity design to lower velocity, v/c=0.4, using the same cryostat and RF systems. Elliptical cavities will thus constitute about three-quarters of RIA's total accelerating voltage, and most of that voltage will be provided by cavities already developed for SNS. The development program for the 805 MHz $\beta$=0.47 six-cell cavities began in 2000 as a collaboration between MSU, Jlab and INFN Milan, and should be completed in 2004. Vertical tests of prototype $\beta$=0.47 six-cell cavities have significantly exceeded required quality factors and accelerating electric fields. The large beam aperture (77 mm) reduces beam loss, relaxes alignment criteria, and eliminates the need for additional higher-order-mode couplers. A horizontal cryomodule is presently under construction for testing two six-cell cavities in realistic operating conditions. In the tests, issues such as attainable gradient, cryogenic load and control of microphonics will be addressed, and performance of the mechanical tuners, power coupler, and RF systems will be checked. By the end of 2004 elliptical cavity R&D will be complete (assuming FY2004 funding of $550k) and driver linac designs and production plans can be finalized.

### 1. Elliptical Cavities for RIA
A four-year R&D plan for FY2001-FY2004 is underway to develop a $\beta$ = 0.47 elliptical accelerating structure suitable for the Rare Isotope Accelerator (RIA) driver linac. Michigan State University (MSU) will continue to take the lead on the development of a $\beta$ = 0.47 six-cell structure in collaboration with Thomas Jefferson National Accelerator Facility (JLAB) as their priorities allow. In any case, information gained at JLAB on the $\beta$ = 0.61 and $\beta$ = 0.81 SNS cavities will be closely followed and incorporated.

The RIA driver linac design uses elliptical cavities to supply about 75% of the required accelerating voltage (heavy ions accelerated from about 85-400 MeV/u) [1]. A significant synergistic advantage was realized with the decision to utilize the 805 MHz elliptical, axisymmetric, 6-cell cavities with geometric $\beta$ (=v/c) values of 0.61 and 0.81 developed for the Spallation Neutron Source (SNS) project [2]. In addition, the RIA

R&D program substantially benefits from SNS activities for the associated elliptical cavity's cryomodule, power coupler, and tuner. To complete the RIA acceleration lattice, a β=0.47 cavity is being developed specifically for RIA and is the basis of this research [3, 4]. The cavity cross sections are shown in Figure 1.

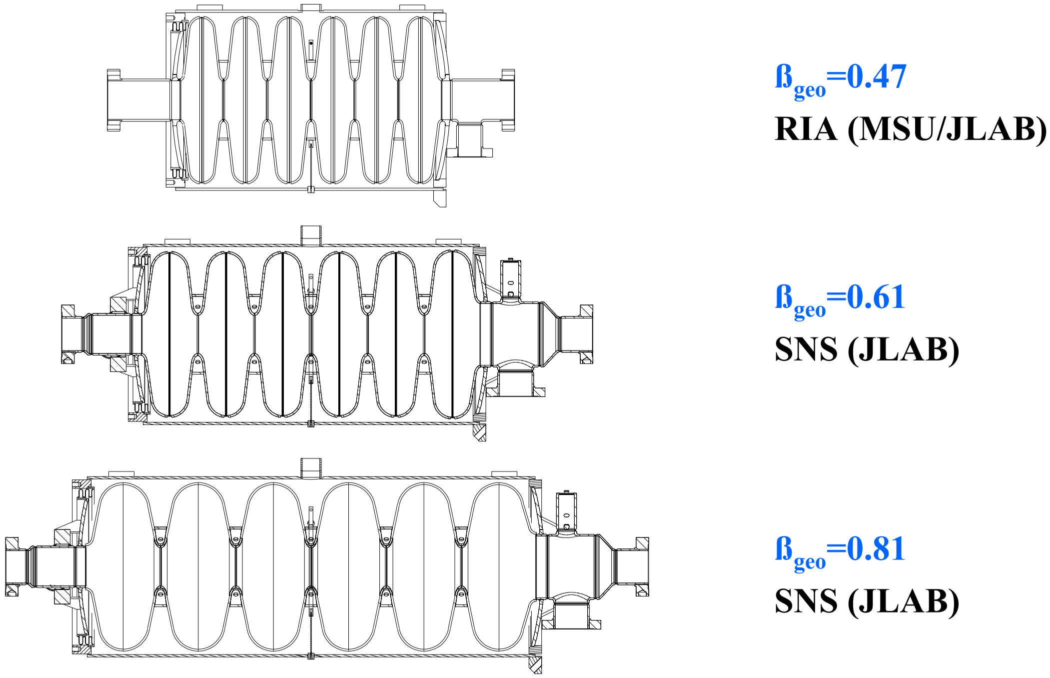


**Figure 1**. 805 MHz six-cell elliptical cavities for RIA.

Given the limited RIA R&D funds, it is of paramount importance that they be allocated to the most critical, long-lead items whose demonstration is required to confidently design and cost RIA. In this context, the 1999 Marx Committee recommended as the two key research areas the superconducting rf cavities and cryomodules for the driver linac, and the gas catcher [5]. These remain the most critical items, even more so today, with the reduced window of opportunity for definitive R&D before construction. A primary R&D element in this context is the development of 805 MHz, β=0.47, elliptical cavities. While significant progress has been made in the development program, it is extremely important to bring this effort to its final conclusion as expediently as possible to provide the technical foundation necessary to design and cost RIA.

**2. β=0.47 Cavity R&D Program**

The cavity development proceeded in three phases as shown in Figure 2. The single-cell prototyping was the first hardware element of the R&D program. Two single-cell units were made following the design of Barni et al [6] and tested in a vertical cryostat configuration with the Q vs. accelerating gradient performance significantly exceeding that specified for RIA (8 MV/m with Q = 5 x $10^9$). There was no evidence of multipacting problems. With these promising results the work proceeded to the multi-cell structures.

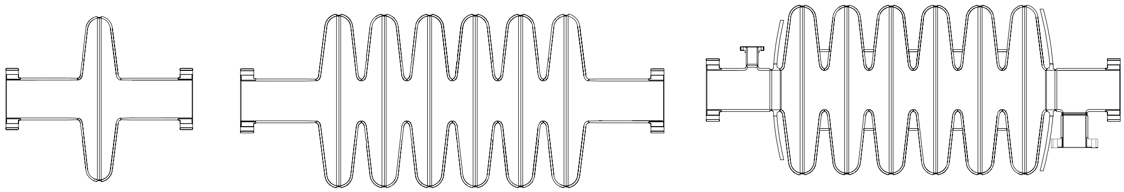


**Figure 2.** β=0.47 R&D program showing phases of cavity development.

Next a six-cell prototype with no radial couplers, stiffeners, tuner or helium vessel was fabricated that allowed testing of the cup shapes as they relate to electromagnetic performance, frequency, field flatness, and microphonic response. The cavity was mechanically tuned to ~10 % field flatness before processing and assembling in a Class 100 cleanroom. Figure 3 shows the Nb prototype after installation on the insert for the first vertical test. The six-cell prototype was tested in September 2002 with the quality factor, Q, versus accelerating gradient shown in Figure 4. The design gradient of 8 MV/m corresponds to peak electric fields of 27.5 MV/m and peak magnetic fields of <60 mT. These are the same peak design values used for the SNS elliptical cavities. The design accelerating gradient and a Q of $5 \times 10^9$ would generate 21 W of heating per six-cell cavity. As can be seen from Figure 3, the design values have been exceeded by more than a factor of two. The excellent test results for RIA and SNS show that a higher design value of 32.5 MV/m could be acceptable.

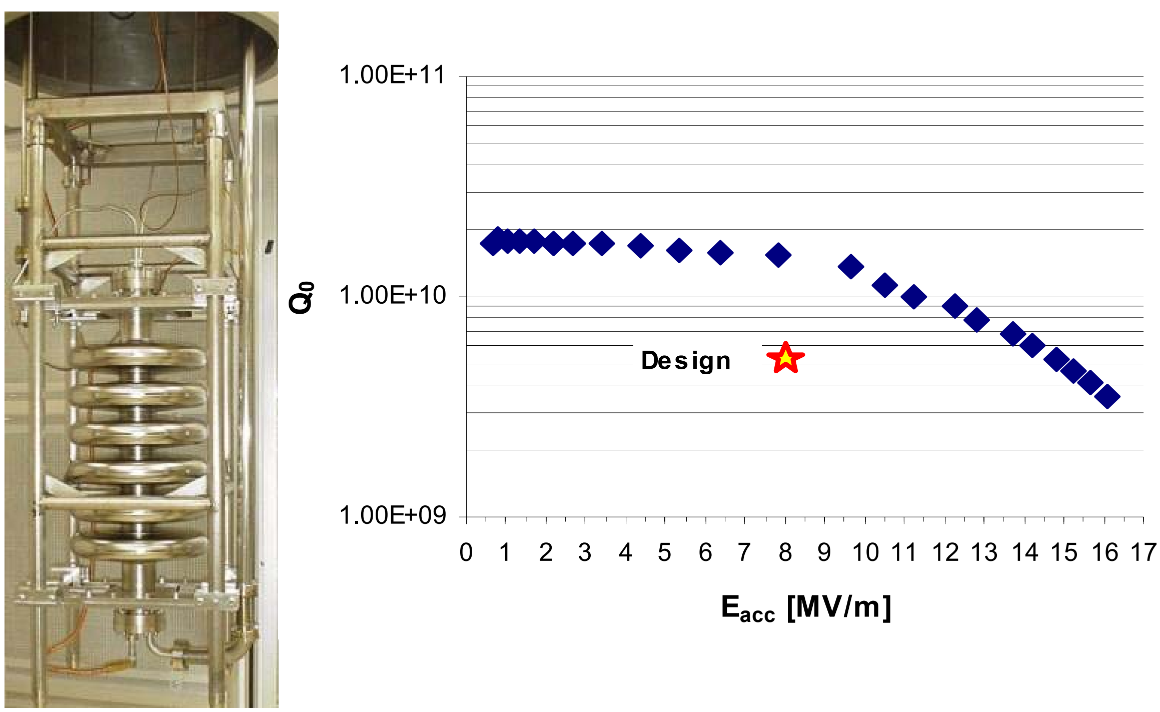


**Figure 3.** Six-cell Nb β = 0.47 prototype in cleanroom ready for vertical Dewar testing, and measure quality factor versus accelerating gradient.

The final R&D phase for cavity fabrication was two six-cell prototypes with stiffening rings, coupler ports, and He vessel dishes. (See right panel of Figure 2.) Testing of these units in a vertical cryostat configuration was completed in May 2003 with results comparable to the simple six-cell.

**3. β=0.47 Cryomodule R&D Program**

A rectangular cryomodule design with cryogenic alignment rail that can accommodate all of the superconducting cavity and magnet types is proposed for RIA [7]. This type of module has been used at MSU, TESLA, INFN Legnaro and ANL. Beam dynamics simulations show that four β=0.47 cavities per module are acceptable. The cryomodule design is shown in Figure 4. A prototype cryomodule is under construction with two cavities. The cavities with helium vessel, power coupler and tuner have been completed and are shown in Figure 5. While the SNS has already developed a cryomodule that could be used for the elliptical cavities of RIA, it would be inappropriate for the drift tube cavities, and significant simplifications and cost savings are possible with the rectangular cryomodule due to RIA's continuous, relatively low power beam.

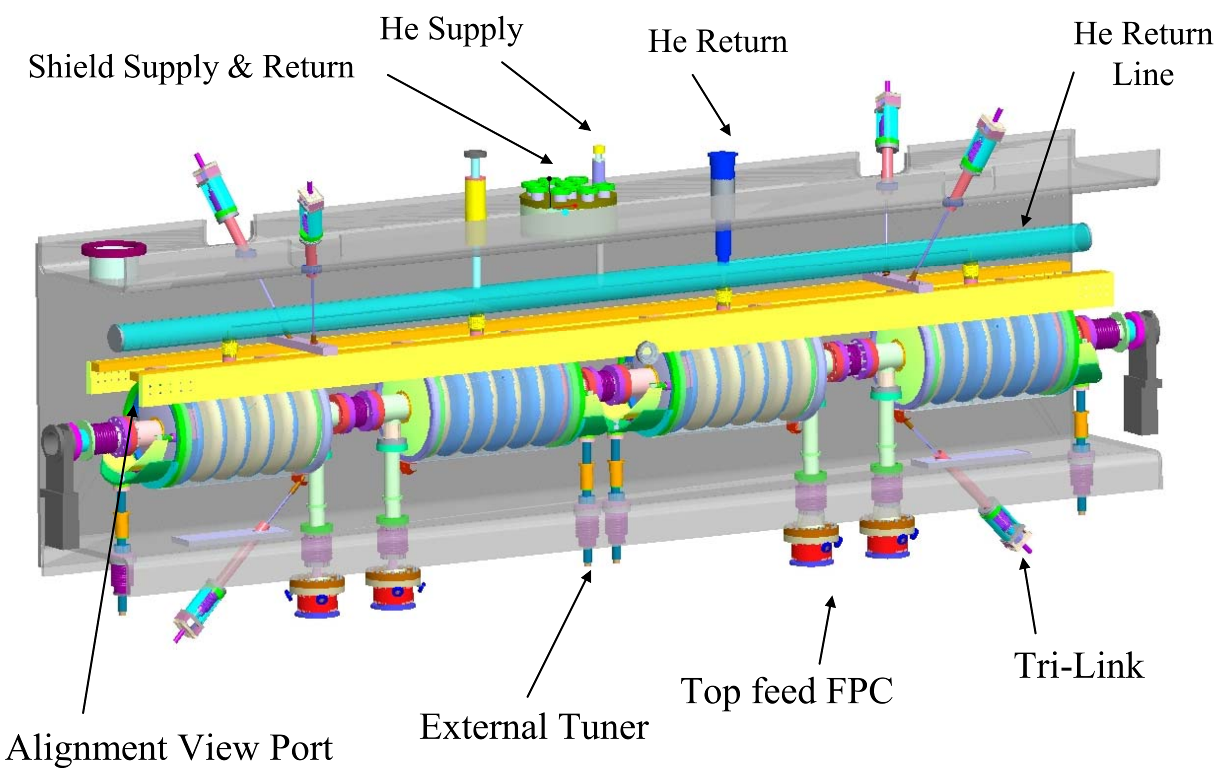


**Figure 4.** The β=0.47 cryomodule design.

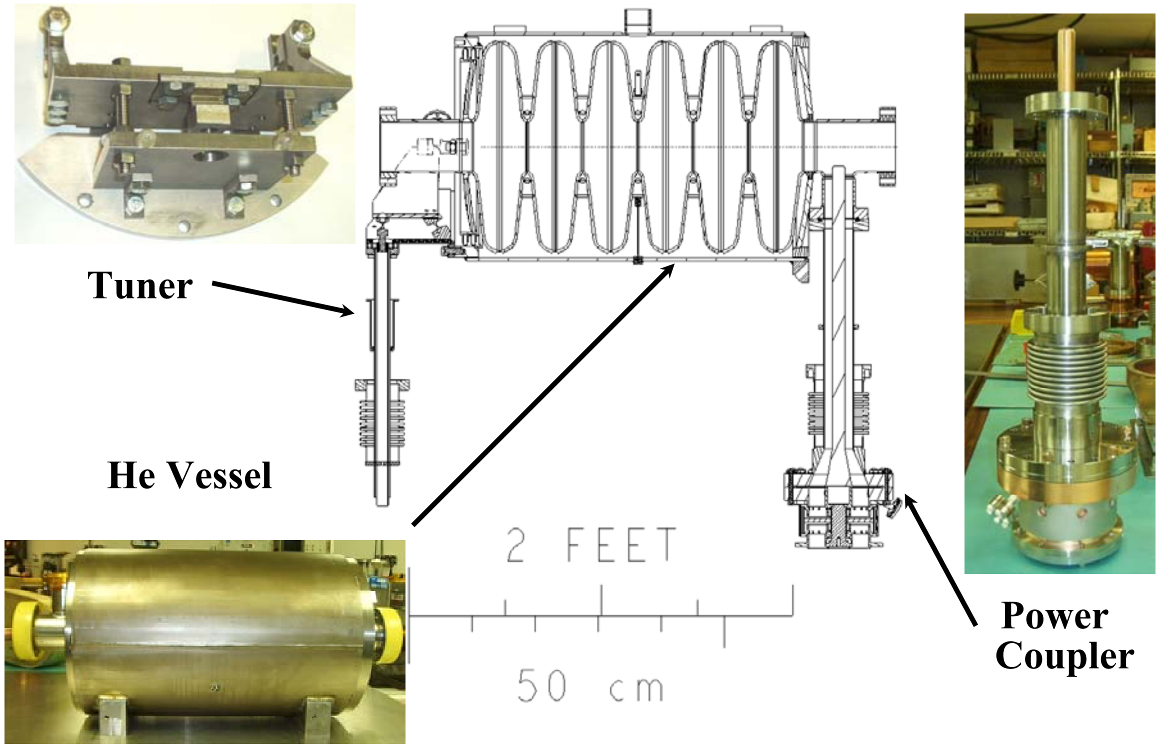


**Figure 5.** Six-cell β=0.47 cavity with radial coupler ports, stiffening rings, He vessel, tuner and input power coupler.

Given RIA beam loading and an estimated required microphonic-driven bandwidth, a Qext value of approximately $2x10^7$ was determined. MAFIA and ANALYST simulations of possible coupler configurations were confirmed with tests using the single-cell and multi-cell copper models. The coupler has been designed following the strategy of modification of the SNS coupler. An analysis was done and a determination made that no HOM dampers will be required for the RIA driver application [8]. A major focus of the cryomodule testing is the microphonic response, as RIA and the CEBAF upgrade have comparable levels of beam loading. Passive and active control schemes are being explored. The cryomodule assembly should be complete in 2003. Provided that FY2004 funding of $550k is received, testing under realistic operating conditions will take place in 2004. By the end of 2004 elliptical cavity R&D will be complete. At that time, RIA linac design and production plans, which are critical long-lead items, can be finalized.

**Table 1.** β = 0.47 R&D funding from DOE to MSU and JLAB.
** Requested funding to complete elliptical structure R&D.

| | |
|---|---|
| **FY2001** | **$400k** |
| **FY2002** | **$690k** |
| **FY2003** | **$500k** |
| **FY2004** | **$550k**** |

## 4. References

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