STATUS OF THE ISAC-II ACCELERATOR AT TRIUMF

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Abstract

A heavy ion superconducting linac is being installed at TRIUMF to increase the final energy of radioactive beams at ISAC. A first stage of 20MV consisting of five medium beta cryomodules each with four quarter wave bulk niobium cavities and a superconducting solenoid is being installed with initial beam commissioning scheduled for Dec. 2005. The initial cryomodule has met cryogenic and rf performance specifications. In addition we have demonstrated acceleration of alpha particles in an off-line test. A 500 W class refrigerator system has been installed and commissioned in Jan. 2005 with cold distribution due for commissioning in Sept. 2005. A transfer beamline from the ISAC accelerator and beam transport to a first experimental station are being installed. The status of the project is presented.

INTRODUCTION

TRIUMF is now preparing a new heavy ion superconducting linac as an extension to the ISAC facility [1], to permit acceleration of radioactive ion beams up to energies of at least 6.5 MeV/u. The superconducting linac is composed of two-gap, bulk niobium, quarter wave, rf cavities, for acceleration, and superconducting solenoids, for periodic transverse focussing, housed in several cryomodules. The linac is grouped into low, medium and high beta sections.

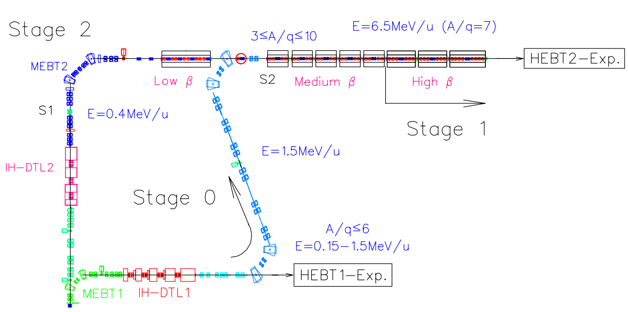

Figure 1: Stages 0, 1 and 2 for the ISAC-II upgrade.

Due to experimental pressure and budget limitations the installation of the linac has been grouped into three stages highlighted in Fig. 1. The initial Stage 0 to be completed in 2005 includes the installation of a transfer line from the ISAC DTL ($E = 1.5$ MeV/u) and the medium beta section to produce 20 MV of accelerating voltage for initial experiments. Stage 1 to be completed three years later includes the installation of the three high beta modules for a further 20 MV. The ISAC-II accelerator final Stage 2 is foreseen after 2010.

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CAVITIES

The cavities, originally developed at INFN-LNL[2], are two-gap bulk niobium quarter wave cavities. The first eight have a design velocity of $\beta_o \sim 5.7\%$ while the remaining twelve have a design velocity of $\beta_o = 7.1\%$. The cavities were fabricated at Zanon in Italy. The initial four were chemically polished at CERN and the remaining sixteen were chemically polished at JLab. Recently two cavities received additional electro-polishing in a collaboration with Argonne. The cavities are equiped with a mechanical damper which limits microphonics to less than a few Hz rms. A demountable flange on the high field end supports the tuning plate. Rf coupling is done through a side port. To date fifteen cavities have been characterized via cold test. Typical treatment involves a 30-40 minute high pressure water rinse and twenty four hour air dry in a clean room, followed by vacuum pumping and bakeout at 95C for 48 hours, then an LN2 pre-cool to 160K over 48 hours followed by helium transfer and test.

The ISAC-II medium beta cavity design goal is to operate up to 6 MV/m across an 18 cm effective length with $P_{cav} \leq 7$ W. The gradient corresponds to an acceleration voltage of 1.1 MV, a challenging peak surface field of $E_p = 30$ MV/m and a a stored energy of $U_o = 3.2$ J and is a significant increase over other operating heavy ion facilities. A distribution of the cavity performance is shown in Fig. 2 for both the characteristic fields at 7 W cavity power and at maximum power. Four cavities out of the fifteen have not met specification with at least one cavity being very poor. However recent studies have shown that the cavities can have Q-disease that makes them susceptible to slow cooldowns. One cavity has recently been retested with a fast cooldown with Q_0 rising from 0.8×10^9 to 2×10^9. The other poor performers will be retested with a fast cooldown.

CRYOMODULES

The engineering description and cryogenic tests are reported in a separate article.[3] The vacuum tank consists of a stainless steel rectangular box and lid. All services and feedthroughs are located on the lid. A serial LN2 piping circuit cools both the copper panels formed into a thermal shielding box and the rf coupling loops. Magnetic shielding in the form of high μ sheet is suspended between the warm wall and the cold shield. Cavities and solenoids are

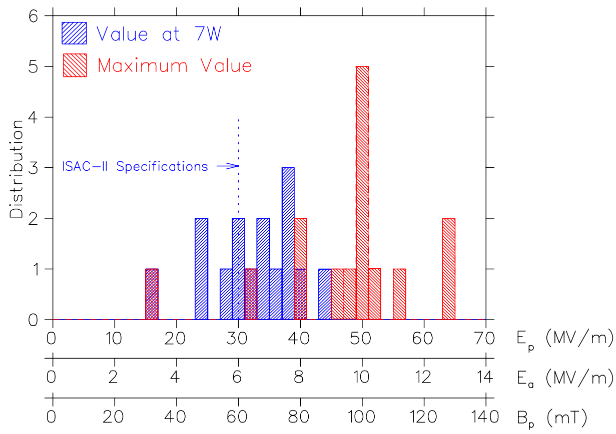

Figure 2: Histogram summarizing cavity performance for fifteen tested cavities. Shown are the numbers of cavities achieving a certain gradient at 7W helium load (blue) and the numbers of cavities achieving a certain maximum field (red).

suspended from a common support frame itself suspended from the tank lid. Each cryomodule has a single vacuum system for thermo-isolation and beam acceleration. Assembly is done in the new ISAC-II clean room.

The third cryomodule, SCB3, served as the prototype and is now fully commissioned[3]. Three separate cold tests have established the alignment of the cold mass, the cryogenic characteristics and the rf performance. In addition alpha particles from a radiaoactive source were accelerated to an energy of 9.4 MeV with an average cavity gradient of 5.6 MV/m, within 6% of the design goal of 6 MV/m for each cavity. SCB3 is now installed in the ISAC-II vault (Fig. 3. Presently SCB1 is being cold tested and SCB2 is in assembly. All cryomodules are due for installation by Nov. 2005.

CRYOGENICS

The ISAC-II Phase I cryogenic system was specified for tender in early 2003. Initially a complete turn key system including refrigerator, warm and cold piping, buffer tank, helium dewar, compressors, gas management and oil removal system were requested. All returning bids were overbudget. TRIUMF decided to take on a larger role in the project in order to reduce the capital costs. The scope of the initial contract was restricted to the major refrigerator components: refrigerator, main and recovery compressor and ORS/gas management. TRIUMF assumed the responsibility for installation of the Linde refrigerator components as well as the management of the contract for the installation of the warm piping by a local installer. In addition TRIUMF acquired and installed the buffer tank and helium dewar. The cold distribution, specified by TRIUMF, is being built and installed by Demaco.

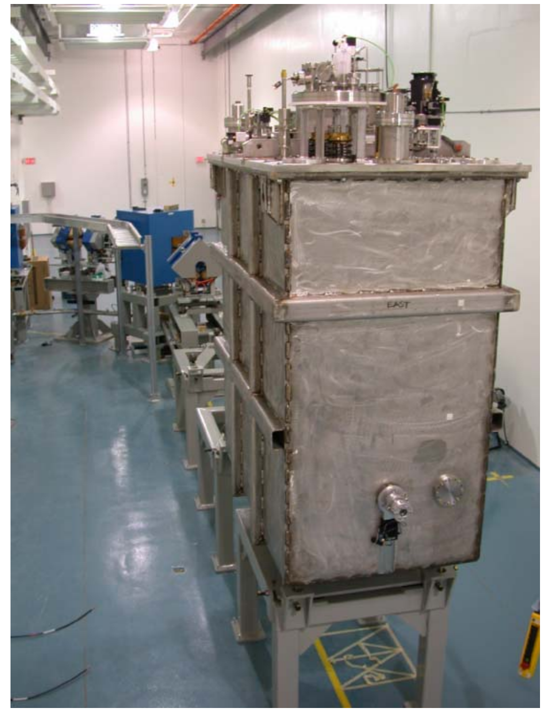

Figure 3: Cryomodule SCB3 installed in the ISAC-II vault.

Refrigerator

In the first phase, to be completed by Dec. 2005, five medium beta cryomodules will be installed. The linac cryomodules will be cooled by 4.5K LHe at 1.4 Bar. The measured static heat load for a single cryomodule is 13 W with a LN2 feed of 6 ltr/hr. Together with estimated thermal losses from the cold distribution of 72 W this gives a total static load of 137 W. The budget for active load component is 8 W per cavity giving 160 W for the twenty medium beta cavities for a total estimated heat load of 297 W. A TC50 cold box complete with oil removal and gas management system, main and recovery compressors was purchased from Linde, installed by TRIUMF and commissioned with Linde in Feb. 2005.

The contract specifications require a demonstrated refrigeration power of 530 W with a simultaneous liquifaction load of 0.7 gm/sec and a demonstrated pure liquifaction of 150ltr/hr (5.2gm/sec). The commissioning and acceptance tests utilized a 500 ltr dewar outfitted with immersion heaters, transfer lines, gas vent lines and gas meters for measuring gas flow. The measured refrigeration power with LN2 precooling is 610 W at 0.7gm/sec liquifaction. In addition three turn down modes were established by utilizing the variable frequency drive on the main compressor corresponding to peak refrigeration power of 375 W, 280 W and 190W and fractional wall power of 0.7, 0.59 and 0.53 respectively compared to the full output. The peak liquifaction is measured based on a rising level. The displaced vapour in the measurement enhances the liquifaction giving a calculated expected liquifaction of 180 ltr/hr (6.3 gm/sec). The demonstrated liquifaction rate was 225 ltr/hr. The required helium pressure stability is ±10Torr with flucuation limited to 1 Torr/sec. The measured stability in normal mode is a few Torr but at lower modes a periodic breathing at 0.025 Hz is observed with a maximum amplitude in the lowest mode of ±8 Torr with rate 1 Torr/sec. Linde is looking into the problem.

Cold Distribution

The refrigerator supplies liquid helium to a dewar via a Linde supplied transfer line. The main trunk supply line is fed LHe from the dewar. The cryomodules are fed in parallel from a helium supply trunk line through variable supply valves and field joints. The cold return from the cryomodules comes back to the trunk cold return line through open/close valves and field joints. During cooldown, when warmer than $20°$K, the returning gas is sent back to the suction side of the compressor through the warm return piping. Keep cold sections with proportional valves are required at the end of the trunk lines to join the trunk supply and the trunk cold return. Future expansion will involve demounting the keep cold sections, extending the trunk and cryomodule feed lines and remounting the keep cold sections. A second refrigerator will be added in two years. Pipe sizes and expected mass flows for the cold distribution are given in Table 1. Valves specified for the middle of the two trunk lines are for future installations to divide flows between two refrigerators. They can be installed as just valve seats with the stems left out, and run continuously open for Phase 1. In addition to the branch lines supplying the five cryomodules a secondary line off the main trunk supply is required to deliver LHe to the ISAC-II test/assembly area. All supply and cold return piping is vacuum jacketed and except for the short cryomodule feed lines is cooled with LN2.

Table 1: Cold distribution specifications.

Pipe	Supply ID (mm)	Return ID (mm)	Mass Flow (gm/sec)
Dewar to Trunk	18	45	25
Trunk	18	45	25
Cryomodule	13.8	32	5
Clean Room	13.8	32	5
Keep Cold	-	13.8	2

A cross-section of vault and refrigerator room is shown in Fig. 4.

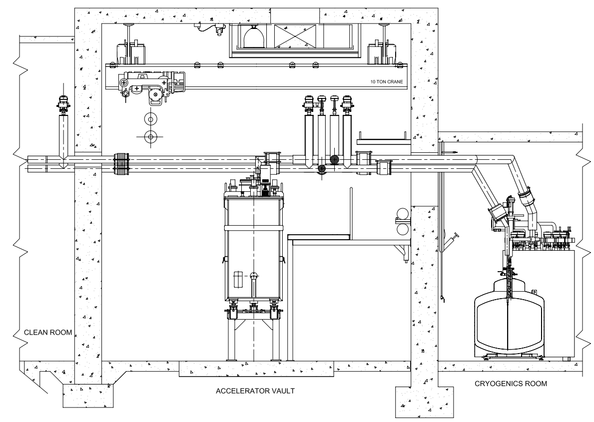

Figure 4: Vault and refrigerator room cross-section showing cryomodule, cold piping, service platform, helium dewar and cold box.

BEAMLINES

The S-bend transport line from the ISAC-I hall to the superconducting linac is almost complete. The line consists of two achromatic bend sections of $\sim 120°$ with two 4Q straight segments between. A 35 MHz buncher between straight segments matches the beam from the ISAC-I DTL to injection into the SC linac.

The high energy beamline is designed with a removeable section to be compatible with the installation of the high beta cryomodules. This represents a full length of 8.84 m so two 4.42 m long 4Q sections are used. This periodicity is maintained to the end of the vault with in all five 4Q sections. The sections can be tuned to unit cells with double focus poits at the end of each section or to periodic doublet sections with a phase advance of $\sim 90°$ for multicharge transport. Previous studies have shown that the accelerator can accomodate multicharge beams up to $\Delta Q/Q = \pm 10\%$. The present beamline design will accomodate such beams with some emittance growth due to the mismatch at the first cell after the linac.

At present the plan is to use existing dipoles from Chalk River to deliver beam up to three experimental stations. The installation of these beamlines will be staged over the next several years.

VAULT INSTALLATION

The cold distribution piping is scheduled for installation and commissioning in Nov. 2005. Installation of five cryomodules and the vault section of the high energy beam line is scheduled for completion in Nov. 2005. The goal is to achieve an accelerated beam to the end of the vault by Dec. 2005. An interim beam test using the S-bend tranfer line from ISAC-I injecting into the first cryomodule, SCB1, is scheduled for July 2005.

REFERENCES

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