GENERAL LAYOUT OF THE 17 MeV INJECTOR FOR MYRRHA*

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Abstract

The MYRRHA Project (Multi Purpose Hybrid Reactor for High Tech Applications) at Mol/belgium will be a user facility with emphasis on research with neutrons generated by a spallation source. One main aspect is the demonstration of nuclear waste technology using an accelerator driven system.
A superconducting linac delivers a 4 mA, 600 MeV proton beam. The first accelerating section is covered by the 17 MeV injector. It consists of a proton source, an RFQ, two room temperature CH cavities and 4 superconducting CH-cavities. The initial design has used an RF frequency of 352 MHz. Recently the frequency of the injector has been set to 176 MHz. The main reason is the possible use of a 4-rod-RFQ with reduced power dissipation and energy, respectively. The status of the overall injector layout including cavity design is presented.

THE MYRRHA-PROJECT

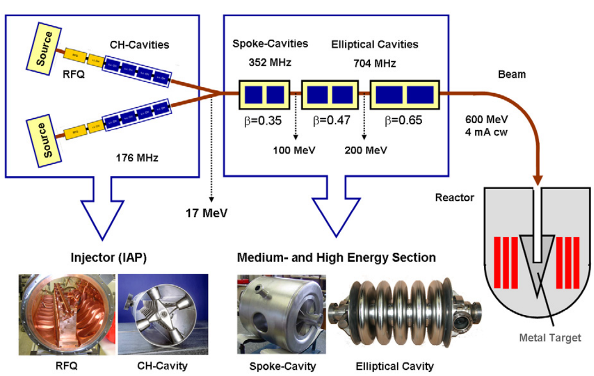

Figure 1: Overview of the MYRRHA-project.

Accelerator Driven Systems (ADS) for nuclear waste transmutation require proton drivers with energies between 600 and 1000 MeV and beam currents of several mA for demonstrators and up to several 10 mA for large industrial systems. Within the EUROTRANS project a baseline design for a 600 MeV linac has been carried out [1].
Recently a three year research period called MAX (MYRRHA Accelerator Experiment and Development) has been launched. The goal is the preparation of the construction of a 600 MeV transmutation demonstrator facility in Mol/Belgium (MYRRHA) [2]. A 600 MeV proton beam with a maximum power of 2.4 MW hits a spallation target. Because of the required cw operation a superconducting linac has been chosen.
The injector accelerates the beam to 17 MeV and the medium energy part, consisting of superconducting spoke-type cavities, delivers 100 MeV. The high energy section consists of two groups of superconducting elliptical 5-cell-cavities (Fig. 1).

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17 MEV INJECTOR

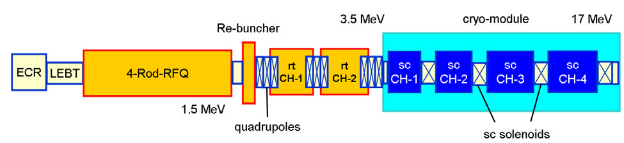

Figure 2: General layout of the 176 MHz, 17 MeV injector for MYRRHA. It consists mainly of a 4-rod-RFQ, two rt and four sc CH-cavities.

The injector (see fig. 2) consists of an ECR source, a Radio Frequency Quadrupole (RFQ), two rt CH-cavities and four sc CH-cavities. During the EUROTRANS project the RF frequency of the 17 MeV injector has been set to 352 MHz [3]. Recently it has been decided to investigate a frequency of 176 MHz for this part. The main reason is the possibility to use a 4-rod RFQ instead of a 4-vane-RFQ. The 176 MHz RFQ accelerates to 1.5 MeV. The energy gap between 1.5 MeV and the entrance of the first sc CH-cavity

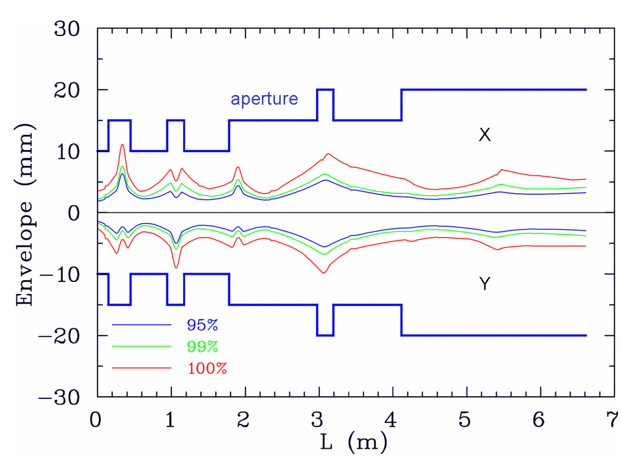

Figure 3: Beam envelopes along the DTL-part of the injector.

(3.5 MeV) is covered by two rt CH-cavities. The main acceleration of the injector is provided by 4 sc cavities with sc solenoids in between. It is planned to build two identical injectors to fulfill the stringent reliability requirements of the whole project. Beam dynamics simulations show good performance of the injector [4]. Figure 3 shows the 95%, 99% and 100% envelopes without errors along the DTL-part of the injector.

RFQ

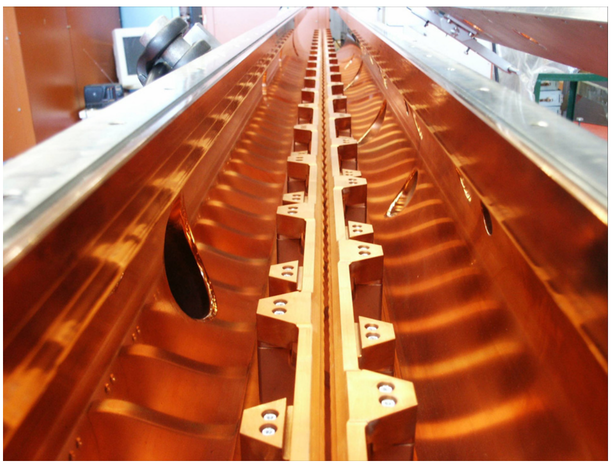

Figure 4: Typical 4-rod-RFQ at 175 MHz.

The previous design with 352 MHz asked for a 4-vane RFQ. The lower frequency makes a 4-rod-RFQ possible. Compared to the 4-vane-RFQ the 4-rod-RFQ has excellent tuning and access capabilities with a significant lower technological risk and capital investment.
The electrode voltage has been fixed to 40 kV to limit the thermal load of the cavity to 25 kW/m. This is only half the value which has been shown already for safe operation. Presently a short section of the RFQ is under construction to test the properties and the behavior under high average power. Figure 4 shows a typical cw 4-rod RFQ at 175 MHz and table 1 summarises the main design parameters.

Table 1: Design Parameters of the 4-rod-RFQ

Parameter	unit	value
RF frequency	MHz	176
Length	cm	400
Electrode voltage	kV	40
Impedance	kΩ m	67
RF power	kW	100
Thermal load	kW/m	25
E_{in}	keV	30
E_{out}	keV	1500

Room Temperature CH-Cavities

CH-cavities (Crossbar-H-mode) belong to the family of H-mode cavities. CH-cavities are multi-cell drift tube cavities using the H_{211}-mode [5]. The use of the KONUS beam dynamics reduces the transverse RF defocusing and makes long lense-free cavities possible. Beside a high shunt impedance at low and medium energies they have excellent capabilities for cooling because the water flows completely through the stems. Two rt CH-cavities are foreseen to cover the energy range from 1.5 to 3.5 MeV.
It has been decided to use multi-cell cavities up to 17 MeV to reduce the number of components and associated subsystems like LLRF, power couplers, tuners and amplifiers in this section. This will help to increase the reliability of the injector. Each cavity has to provide about 1 MV of effective voltage. Simulations have indicated that an RF power between 16 and 21 kW is required resulting in a thermal load of about 30 kW/m [6]. Table 2 summarises the main parameters of the rt CH-cavities. Figure 5 shows the layout of the first rt CH-cavity.

Table 2: Design Parameters of rt CH-cavities

Parameter	unit	value
RF frequency	MHz	176
Length ($\beta\lambda$)	cm	54/66
U_{eff}	MV	1.03/1.14
E_a	MV/m	1.91/1.71
Q_0	—	15000
$Z_{eff}\cos^2\varphi$	MΩ/m	124/93
P_c	kW	16/21
Thermal load	kW/m	30/32

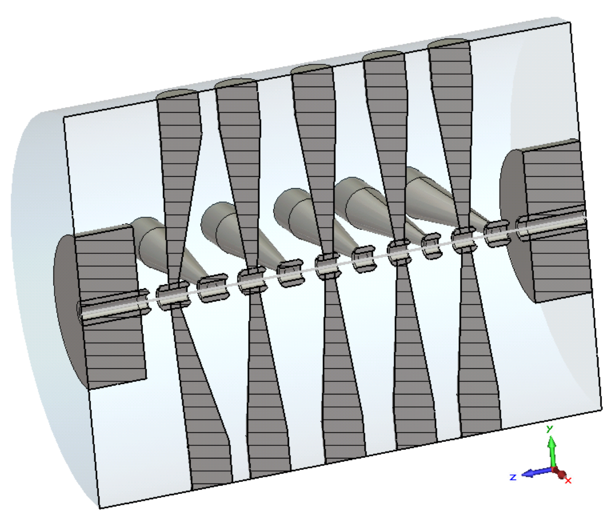

Figure 5: Layout of the first rt CH-cavity.

Superconducting CH-Cavities

Superconducting CH-cavities have demonstrated stable operation [7] with effective gradients of 7 MV/m [5]. The sc CH-cavities for the MYRRHA-injector will be operated at moderate gradients between 3.8 and 4 MV/m resulting in effective voltages between 3.5 and 4 MV. The electric peak field should be lower than 25 MV/m. The use of these multi-cell structures reduces the number of unwanted drift sections between cavities significantly compared to conventional spoke-type cavities. Each cavity will be equipped with a tuner system consisting of static tuners, slow bellow tuners and fast piezo based bellow tuners. A prototype cavity with such a tuner system is presently under construction and will be tested in a horizontal cryo-module with beam at GSI [8].

Figure 6 shows the layout of the first superconducting CH-cavity. To optimize the field distribution along the beam axis the cavity has inclined stems in the end cells. This increases the inductance and therefore the field in the end cell region. Depending on the cavity the required RF power (without beam) is expected to be between 20 and 30 W. The beam loading per cavity is between 14 and 16 kW. Table 3 shows the main parameters of the superconducting CH-cavities.

Table 3: Design Parameters of the sc CH-cavities

Parameter	unit	value
RF frequency	MHz	176
Length ($\beta\lambda$)	cm	87/101/107/107
U_{eff}	MV	3.50/3.98/4.18/4.09
E_a	MV/m	4.02/3.94/3.89/3.82
$Q_0@E_a$	—	$3{\cdot}10^8$
R_a/Q_0	Ω	3000
G	Ω	50-60
P_c	W	20-30
Gaps	—	10/9/8/7
Aperture diameter	mm	30/30/40/40

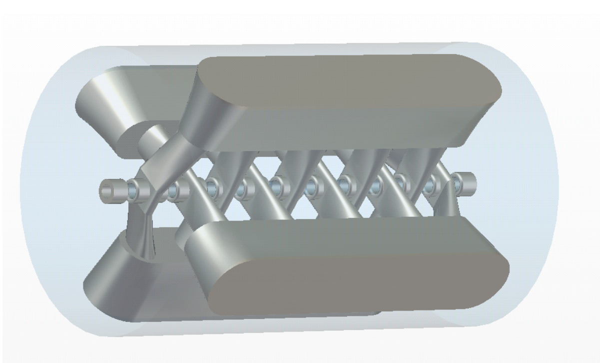

Figure 6: Layout of the first sc CH-cavity.

SUMMARY

A 17 MeV, 176 MHz injector for the MYRRHA project has been investigated. It is based on an ECR-source, a 4-rod RFQ, two rt CH-cavities and 4 sc CH-cavities. Extensive beam dynamics studies have been performed to optimise the lattice. All cavities are in the final design stage. For reliability reasons it has been decided to design the linac as conservative as possible. All major components have to be operated well below their physical limitations. In spite of this restriction the injector is very compact and efficient.

ACKNOWLEDGEMENT

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