# CONSTRUCTION OF THE MYRRHA INJECTOR

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*Abstract*

A collaboration of SCK•CEN, IAP and BEVATECH GmbH is currently constructing the room temperature CH section of the 16.6 MeV CW proton injector for the MYRRHA project. The elaboration of all the construction readiness files for the construction of the accelerating cavities of the first CH section (1.5 to 5.9 MeV) is ongoing. In parallel, the planning, development and fabrication of all further components of this accelerator section is in progress, while the full study for the remaining section is under preparation. This contribution is documenting the most recent status.

## INTRODUCTION

The MYRRHA Injector is a room temperature linac and accelerates a 4 mA CW proton beam to 16.6 MeV. The protons achieve its final energy of 600 MeV in the following superconducting linac. Then they are deflected to the spallation target inside the MYRRHA reactor core [1][2]. For the operation of MYRRHA a high reliability and availability of the proton beam is required [3]. To demonstrate the acceleration of the linac in compliance with the reliability requirements the injector will be constructed to an energy of 5.9 MeV in a first stage (see Fig. 1). Meanwhile the design of the second stage up to 16.6 MeV will be finalized [4].

The Ion source and the LEBT of the MYRRHA Injector were tested at LPSC Grenoble and now have been moved to UCL Louvain-La-Neuve for extensive beam tests together with the 4-Rod-RFQ. BEVATECH is working on the technical design and the construction of the linac section behind the RFQ from 1.5 MeV up to 16.6 MeV. The technical design includes the mechanical design of the RF cavities, the steering and focusing magnets, the power couplers, various beam diagnostic elements, the alignment system, the vacuum system, the support structure, and the cabling and wiring of all accelerator components.

The compact beam dynamics design of the CH section is merged with a technical concept, which allows an easy setup and alignment [4]. The RF cavities and the focusing magnets are aligned separately and are connected on the beam line with QCF connections. The precision surfaces of all components are protruding on the top of the accelerator cavities. Hence, at least four precision markers per RF cavity and focusing magnet are visible for the tacheometer. Furthermore the linac components are designed to be easily exchangeable. Although the intertank space between two CH cavities amounts less than 20 cm a magnet can be removed without moving adjacent RF cavities and vice versa.

## TIMELINE AND PROJECT ORGANISATION

The Project has been organized as a requirements engineering approach with about 120 different work packages managed by SCK•CEN and BEVATECH.

The technical design phase for the first stage of the MYRRHA Injector (5.9 MeV) is scheduled to be completed in autumn 2017, while in parallel already the first cavities for the injector have gone into production since April 2017. This will be followed by construction, testing and commissioning of the injector. In Q1/2021 the handover of the first stage of the injector will mark the closing of the project (see Fig. 2).

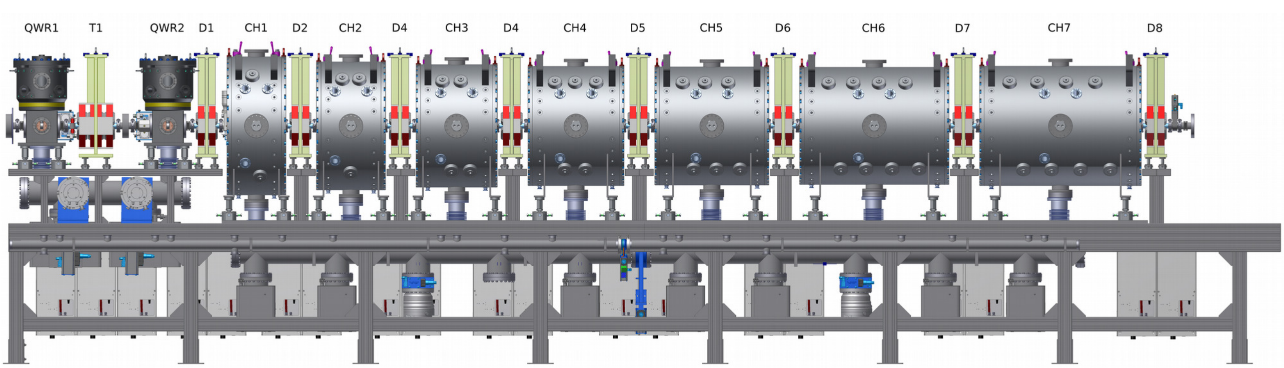


Figure 1: MYRRHA Injector construction scheme up to 5.9 MeV.

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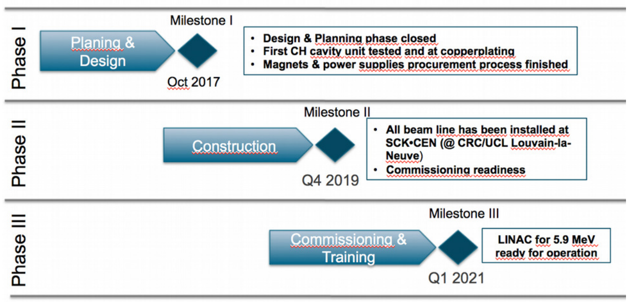


Figure 2: Long term scope estimated schedule.

## INJECTOR SETUP

The CH-Section of the MYRRHA Injector is divided into the four subsections MEBT-1, CH-Section-1, MEBT-2 and CH-Section-2. The MEBT-1 section is 1.4 m long and consists of two QWR rebuncher cavities, two steering magnets, a quadrupole triplet magnet, a quadrupole doublet magnet, a BPM and an ACCT. In the adjacent CH-Section-1 seven CH cavities with an increasing length and a decreasing diameter are located. A phase probe and a quadrupole doublet magnet are integrated in the intertank space between two CH cavities. The MEBT-2 section contains a drift section for a tomography tank, two doublet magnets and a CH rebuncher cavity. CH-Section-2 is structured in a similar way like CH-Section-1. Six CH-Cavities with doublets and phase probes in the intertank sections accelerate the proton beam to 16.6 MeV.

## RF CAVITIES

The technical design of all RF cavities up to 5.9 MeV is finalized. CH cavity 1 and 2 are already in construction and will be ready for the factory acceptance tests at the end of 2017 (see CH cavity 1 in Fig. 3). The two QWR rebuncher cavities of MEBT-1 are currently in the final technical design phase, so that the first four RF cavities behind the 4-Rod-RFQ can be commissioned in 2018. From the third CH cavity it is planned to deliver a CH cavity for commissioning every three months.

All 16 CH cavities of the injector are based on the same construction principle. The cavity lids are conically formed and allow the integration of beam diagnostic elements, gate valves, bellows and the focusing magnets. For the vacuum sealing of the cavity lids a proven and reliable double gasket concept is used. It consists of a metal gasket on the UHV side, followed by a pre-vacuum notch and an O-Ring. With such a system, the accelerator can continue the operation until the next maintenance period in case the metal gasket with a circumference of 2.5 m (± 0.2 m, depends on cavity diameter) has a leakage. Another important measure to increase the reliability is to minimize the mechanical stress on the structure caused by thermal gradients. This is why all inner surfaces of the MYRRHA CH cavities are well water-cooled. The temperature of the cavity components will be adapted by controlling the rate of flow of the respective cooling channel.

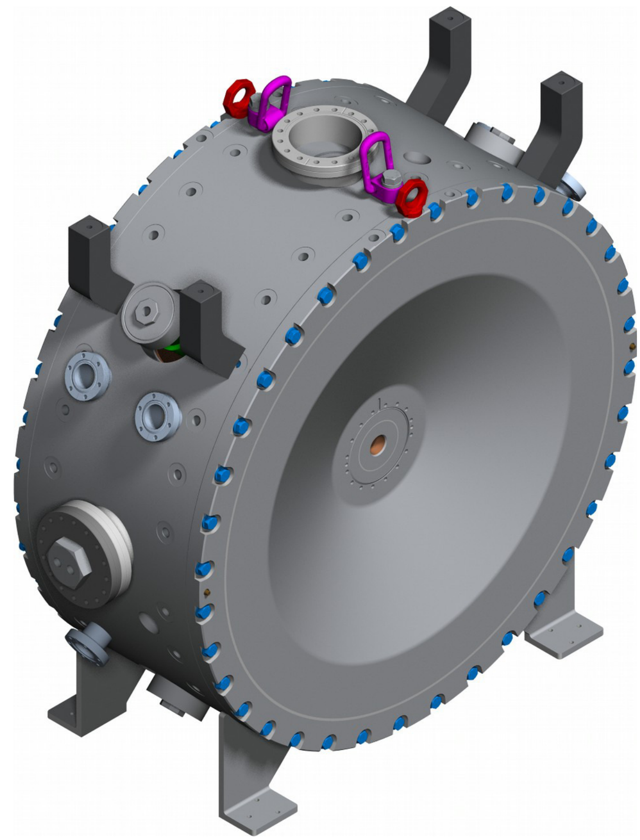

Figure 3: Technical design of CH cavity 1.

The same concepts for improving the reliability are considered for the construction of the QWR rebuncher structures. Both QWR cavities are optimized for a low space consumption on the beam axis and are structurally identical [5]. The power couplers for the QWR rebuncher are integrated in a ceramic vase and hence are cooled by the surrounding air.

## MAGNETS

In total the MYRRHA Injector consists of 4 steering magnets and 18 quadrupole lenses. A quadrupole triplet lens, a quadrupole doublet lens and a pair of steering magnets is located in the MEBT-1 followed by six quadrupole doublet magnets in the CH-Section-1. All doublet lenses in the first stage of the injector are identical. The second type of doublet magnets with an increased beam pipe aperture is installed from 5.9 MeV.

The design phase of all magnets is completed and the delivery of the first magnets is planned for 2018.

### *Quadrupole Magnets*

The quadrupole magnet design is a tailored solution for the intertank space between two CH cavities. The design facilitates an accurate alignment and an easy exchange from the intertank area.

Table 1: Key Parameters of the Quadrupoles of the Triplet Lens in MEBT-1

| Parameter | Outer quad. | Inner quad. |
|---|---|---|
| Max. Gradient | 26 T/m | 29 T/m |
| Ampere turns | 3936 At | 4400 At |
| Effective length | 54.3 mm | 81.5 mm |
| Power Loss | 2.2 kW | 2.9 kW |

The quadrupole magnets have an octagonal iron yoke with tapered poles mounted in the quadrants. The aligned quadrupoles of the triplet and the doublet magnets are integrated into a frame. This frame stands on adjustable feet and protrudes over the diameter of the adjacent CH cavities for a better visibility of the precision surfaces. All quadrupoles are specified for gradients up to 40 T/m and have a power consumption up to 3.2 kW. The main parameter of the quadrupole magnets are listed in Table 1 and Table 2.

Table 2: Key Parameters of the Quadrupoles of Both Doublet Types

| Parameter | Doublet I | Doublet II |
|---|---|---|
| Max. Gradient | 40 T/m | 30 T/m |
| Ampere turns | 4672 At | 4736 At |
| Effective length | 53.9 mm | 71.0 mm |
| Power Loss | 2.7 kW | 3.1 kW |

### *Steering Magnets*

The design of the steering magnets needs to meet the space restrictions of the specific position in the beam line. The first steerer is integrated into the end flange of the 4-Rod-RFQ whereas the other steering magnets are mounted on the beam pipe of a quadrupole magnet. This safes valuable space, which can be used for beam diagnostic elements.

The design of the window frame yoke and the air-cooled coils is identical for a pair of steerers in their respective MEBT section. To achieve the specified deflection angle of 15 mrad, the steerers in the MEBT-2 section are increased in length. The parameters of the steering magnets are specified in Table 3.

Table 3: Key Parameters of the Steerer Type I (MEBT-1 and Steerer Type II (MEBT-2)

| Parameter | Steerer I | Steerer II |
|---|---|---|
| Deflection angle | > 15 mrad | > 15 mrad |
| Ampere turns | 1848 At | 2310 At |
| Integrated B | 2.8e-3 Tm | 5.4e-3 Tm |
| Power Loss | 160 W | 410 W |

## BEAM DIAGNOSTICS

For the reliable beam operation of the MYRRHA Injector the specified stability parameters in Table 4 need to be measured and verified with various beam diagnostic elements. An ACCT and a BPM are integrated in both MEBT sections. MEBT-2 has an additional space reserved for an emittance measurement device (tomographic tank or slit-grid-scanner). On the end flange of each CH cavity a phase probe is mounted.

During the commissioning phase a movable diagnostic bench will be positioned behind every new mounted pair of a cavity and a magnet.

Table 4: Stability Parameters for Stable Beam Operation and the Appropriate Beam Diagnostic Device

| Parameter | Tolerance | Device |
|---|---|---|
| Energy stability | < ± 1% | Phase probe |
| Current stability | < ± 2% | Current transformer |
| Position deviation | < ± 10% | BPM |
| Beam size var. | < ± 10% | Tomographic tank |

## CONCLUSION

The first stage of the MYRRHA Injector (5.9 MeV) is planned to be ready for use in the first quarter of 2021. In a cooperation of SCK•CEN, IAP and BEVATECH the injector section from 1.5 MeV to 5.9 MeV will pass the technical design phase, the construction phase and the commissioning phase within 40 months. Currently the first accelerator components are already in fabrication and the procurement of the accelerator components with a long production time will be completed soon.

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