STATUS OF CH CAVITY AND SOLENOID DESIGN OF THE 17 MeV INJECTOR FOR MYRRHA*

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Abstract

The multifunctional subcritical reactor MYRRHA (**M**ulti-purpose **hy**brid **r**esearch **r**eactor for **h**igh-tech **a**pplications) will be an accelerator driven system (ADS) located in Mol (Belgium). The first accelerating section up to 17 MeV is operated at 176 MHz and consists of a 4-rod-RFQ followed by two room temperature CH cavities with intertank quadrupole triplet focusing and four superconducting CH structures with intertank solenoids. Each room temperature CH cavity provides about 1 MV effective voltage gain using less than 30 kW of RF power. The superconducting resonators have been optimized for electric peak fields below 30 MV/m and magnetic peak fields below 30 mT. For save operation of the superconducting resonators the magnetic field of the intertank solenoids has to be shielded towards the CH cavity walls. Different coil geometries have been compared to find the ideal solenoid layout.

INTRODUCTION

Transmutation of long-lived radioactive waste and advanced technologies for future power generation will be investigated with the MYRRHA ADS [1]. The IAP of Frankfurt University is responsible for the development of the 17 MeV injector, a 13 meter long front end of the 600 MeV MYRRHA linac. To achieve the extremely high reliability of the beam supply for the reactor, two injectors will be driven at the same time. With this parallel redundancy the beam can be provided even during a failure of one injector. Because of thermal stress in the reactor not more than 11 beam trips of $t > 3s$ per year are allowed. The following accelerating structures up to 60 MeV are using the concept of serial redundancy [2].

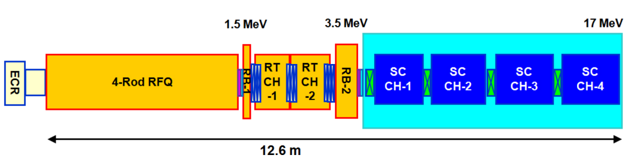

Figure 1: Overview of the MYRRHA injector.

A 4-rod-RFQ will bunch and accelerate the proton beam up to 1.5 MeV [3]. After a five gap CH rebuncher the proton bunches will be accelerated to 3.5 MeV with room temperature CH structures. Quadrupol triplets for focusing and phase probes for diagnostics are placed between the structures. 3 MV/m will be provided by the superconducing accelerators. Four bulk niobium CH cavities are assembled together with four 4.5 Tesla solenoids with coils made of NbTi in one cryomodule [Figure 1].

CH CAVITY DESIGN

Crossbar H-mode (CH) cavities are excellent candidates for acceleration of ions in the low and medium energy range. These resonators driven in the TE_{211}-Mode will be used for all accelerating and rebunching cavities after the 4-rod-RFQ from 1.5 to 17 MeV.

Room temperature CH cavities

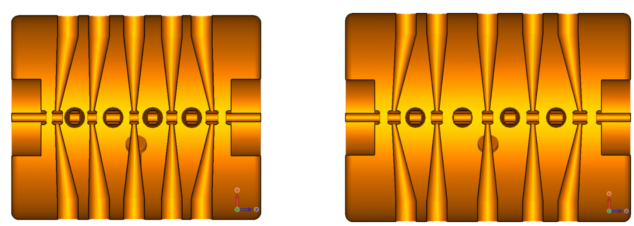

Figure 2: Scheme of the two room temperature CH structures.

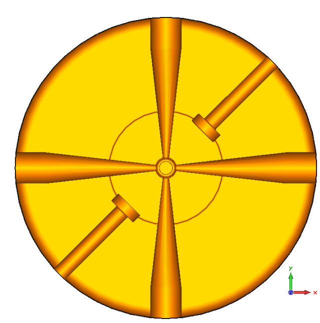

Figure 3: The diagonal tuners act mainly capacatively and provide a total frequency shift of 1 MHz.

CH-1 consists of three and CH-2 of two inclined stems [Figure 2]. Together with the extra volume around the vaults the inclination of the stems increases the induction on the outer stems. This flattens the gap voltage distribution and consequently the thermal load on the stems. The vaults at the resonator ends create additional space outside the cavity and are used for the quadrupole triplet lenses.

Each CH structure is tuned by two mainly capacitively acting tuners that provide a total frequency shift of 1 MHz.

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The tuners are mounted on the cavity wall under 45 degree to the horizontal plane [Figure 3].

Table 1: Parameter list of the room temperature CH-1 and CH-2 of MAX.

Parameter	RT CH-1	RT CH-2
Frequency [MHz]	176	176
Q-Factor (85% MWS)	14539	14964
P_{sim} [kW]	16.5	18.5
P_{real} (85% MWS) [kW]	19.4	21.8
$Z_a(\beta\lambda - def.)$ [MΩ/m]	113.5	100.6
U_0 [MV]	1.26	1.37
U_a [MV]	1.03	1.14
β_{avg}	0.066	0.077
No. of Gaps	10	10
Energy Range [MeV]	1.5 – 2.5	2.5 – 3.5
$E_a(\beta\lambda - def.)$ [MV/m]	1.8	1.6
L [mm]	715.2	833.6
$L(\beta\lambda - def.)$ [mm]	568.7	699.3
Diameter [mm]	584	608
Aperture [mm]	25	25

Superconducting CH cavities

One cryo-module will contain all cold parts of the injector. For manufacturing and transportation reasons the superconducting CH structures are not longer than 1.2 m. For this reason the number of gaps decreases with higher β_{avg} from 10 to 7.

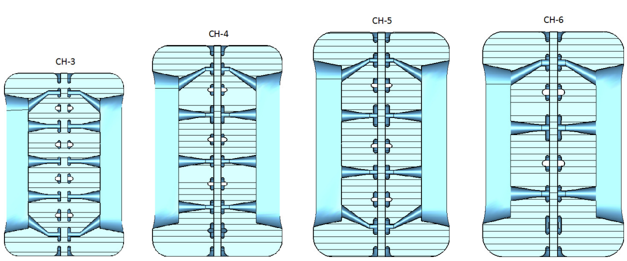

Figure 4: The four superconducting CH cavities in scale relatively to each other.

All superconducting cavities will be made of bulk Niobium and are optimised for an acceleration gradient between 3.5 and 3.9 MV/m and for a flat electric peak field distribution along the gaps. Low electric peak surface fields below 30 MV/m minimise the risk of quenching and ensure a safe operation [Table 2].

SC SOLENOID DESIGN

Superconducting solenoids driven at a maximum magnetic field of 4.5 T are used in the cold part of the injector for transversal focusing. The current densitiy of 300 A/mm^2 in the main coil is ten times smaller than the critical current density, where the solenoid is quenching [4].

Four superconducting solenoids of the same type will be placed between the accelerating cavities. The main coil

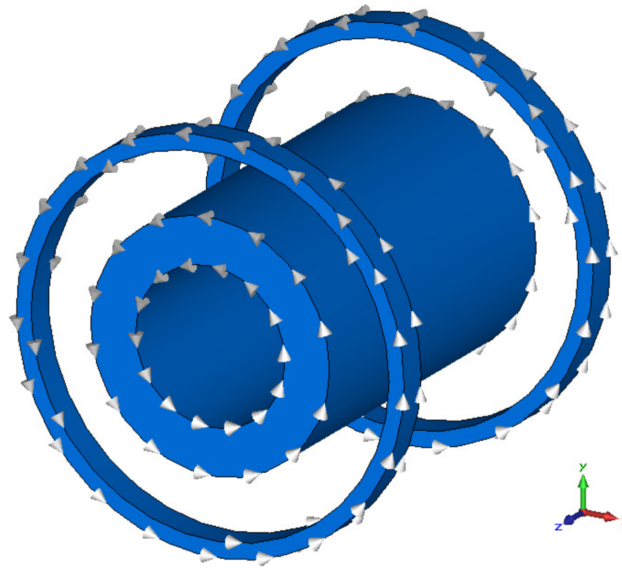

Figure 5: Main and bucking coils of the superconducting solenoid.

of the solenoid is 120 mm long and has 4300 windings of Niobium-Titanium in a copper matrix. To avoid quenching of the neighbouring accelerators the magnetic field of the solenoid has to be reduced. Two bucking coils with 420 windings at the ends of the main coil [Figure 5] minimise the fringe field [Figure 6 and 7]. All multi-filamentary superconducting wires in the solenoid can carry a total current of 120 A.

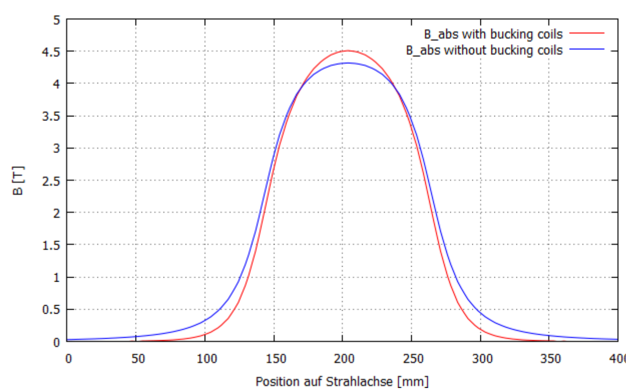

Figure 6: A solenoid with bucking coils has a lower fringe field in comparison with a simple solenoid. Both solenoids are normalized to the same focusing strength.

OUTLOOK

The new tuning concept of superconducting CH structures with static and dynamic tuners on the girders between the stems will be applied for the four sc injector cavities for MAX after a successful demonstration of this concept with a 325 MHz cavity at IAP [5].

The effects of the solenoids fringe field on the CH cavity are under investigation. Further simulations to shield the magnetic flux are necessary.

Table 2: Parameter list of the superconducting CH-3 to CH-6 of MAX.

Parameter	SC CH-3	SC CH-4	SC CH-5	SC CH-6
Frequency [MHz]	176	176	176	176
U_0 [MV]	4.25	4.72	4.93	4.78
U_a [MV]	3.50	3.98	4.18	4.09
β_{avg}	0.102	0.131	0.157	0.178
No. of Gaps	10	9	8	7
Energy Range [MeV]	3.5 – 6.7	6.7 – 10.4	10.4 – 14.2	14.2 – 17
$E_a(\beta\lambda - def.)$ [MV/m]	3.9	3.7	3.6	3.5
Geometry Factor [Ω]	62.6	67.6	70.2	73.2
$R_0/Q_0[\Omega]$	2216	2165	1817	1577
$R_0 R_S[\Omega^2]$	138849	146345	127558	115473
E_{max} [MV/m]	29.27	28.06	30.59	28.92
$B_{max}[mT]$	27.8	29.7	35.27	31.35
E_{max}/E_a	7.5	7.6	8.5	8.3
L [mm]	915.9	1075.3	1129.0	1126.9
L $\beta\lambda - def.$ [mm]	901.1	1071.1	1162.1	1178.8
Diameter [mm]	600	650	684	708
Aperture [mm]	30	30	40	40

Additional measurements with a test solenoid close to a CH structure at 4.2K will be performed together with GSI in the demonstrator experiment [6]. A main focus in this layout is to put on high safety margins to reach the specified reliability.

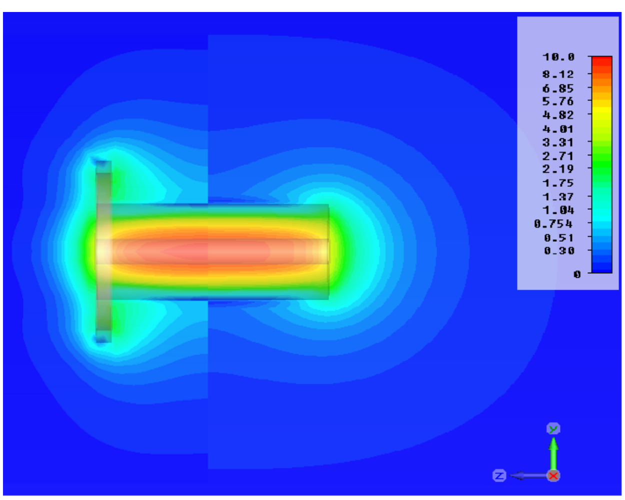

Figure 7: In this graphic two pictures with the magentic flux of a solenoid are merged. On the left side the solenoid with bucking coils is shown. The simple solenoid without bucking coils on the right side creates more spacious magnetic flux. The coloured scale is normalized to the highest field level of the left solenoid (4.5T). Both solenoids would have the same focusing strength, so the simple solenoid would have a less peak field (compare with figure 5).

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