THE NEW INJECTOR DESIGN FOR MYRRHA

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Abstract

The MYRRHA (Multi-purpose hYbrid Research Reactor for High-tech Applications) Project is a planned accelerator driven system (ADS) for the transmutation of long-living radioactive waste [1]. A critical passage for the beam quality and especially for the emittance is the injector. Therefore, a new injector design with improved beam dynamics has been developed, featuring low emittance growth rates while using only room temperature structures. The previous design consisted of a 4-Rod RFQ, 7 room temperature and 5 superconducting CH-DTL cavities and 2 rebuncher cavities [2], whereas the superconducting cavities in the new design have been replaced by 8 room temperature CH-cavities and an additional rebuncher. The main challenge during the development is achieving the required reliability to reduce the thermal stress inside the planned reactor [3]. Therefore, simulations with CST MICROWAVE STUDIO [4] have been made to compare several cooling concepts and to optimize the cavities, especially in terms of the shunt impedance.

BEAM DYNAMICS

The new MYRRHA Injector Design substitutes the superconducting CH-cavities of the previous Design presented in [2]. The low energy part until 5.87 MeV is still the same as in the previous design. After that a CH-rebuncher-cavity is foreseen. For the acceleration to 16.6 MeV another 8 room temperature CH-cavities will be used.

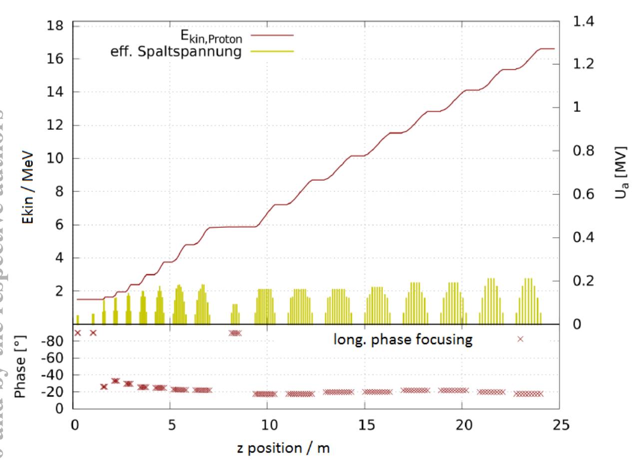

Figure 1: The estimated proton energy after the 4-Rod-RFQ is 1.5 MeV [5] and increases up to 16.6 MeV at the end of C H 15 (upper graph in red). The effective voltages of the gaps are plotted in yellow. The lower graph shows the constant phase configuration of the 15 cavities.

The main concern is the beam quality along the superconducting main linac, especially longitudinally. Therefore, the emittance growth in the injector had to be minimized by keeping the phase advance as constant as possible.

Table 1: The Number of Gaps and shunt impedances of the CH structures. For CH-cavity number 1 to 7 the shunt impedances have been simulated with CST whereas the other shunt impedances (*) have been estimated with previous designs (CH 8) and the assumption, of the decrease of the shunt impedance with 1/β.

Cavity	Number of Gaps	Shunt impedance [MΩ/m]
CH 1	3	22.18
CH 2	4	36.18
CH 3	5	48.38
CH 4	6	56.91
CH 5	7	61.50
CH 6	9	65.06
CH 7	9	61.06
CH 8	11	65.00*
CH 9	12	58.97*
CH 10	12	54.29*
CH 11	11	50.71*
CH 12	10	47.92*
CH 13	10	45.63*
CH 14	9	43.69*
CH 15	9	41.99*

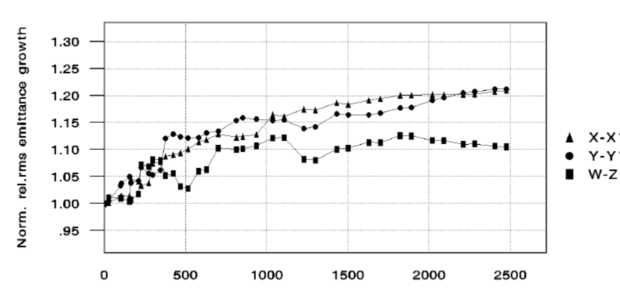

Figure 2: The growths of the transversal and longitudinal rms-emittance.

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COOLING SYSTEM

To ensure a high reliability of the CH-cavities the design of the cooling channels is important. The CH-cavities will be made of stainless steel and will be copper plated on the inside. Due to the poor thermal characteristics of steel in comparison to pure copper the layout of the cooling channels inside the cavity is very important. In comparison to the cooling system of the room temperature CH prototype [6] several improvements have been made.

Cooling System of the Lids

The previous design for the layout of the cooling channels for the lids of the CH prototype consists of 3 seperate cooling channels of which the two outer channels were wide concentrical channels with the problem that air pockets could occure which would impair the heat transport from the cavity material to the cooling water. The inner channel was designed as a maze of two concentrical channels without the risk of trapped air.

Thermal simulations have shown that the dissipated thermal energy on one lid is smaller than 1 kW for all cavities. That means that the limiting factor is not the amount of cooling water, but the position of the channels because of the bad heat transport inside the steel. Therefore inside one lid only one cooling channel is used. This channel consists of 5 concentrical cooling channels that are connected.

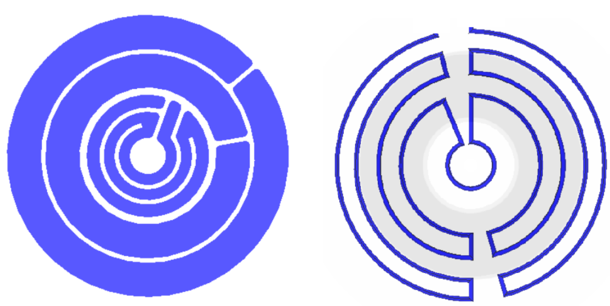

Figure 3: Comparison of the cooling channels inside the lids of the CH prototype (left side) and the MYRRHA CH cavities number 1 to 7 (right side).

Cooling System of the Tank

The cooling system of the tank of the CH prototype had 4 longitudinal cooling channels per quadrant. This design is easy to build for the manufacturer.

Because of the bigger outer dimensions and to make the tank as thermal stable as possible, another 2 channels per quadrant were added. The precise position of every channel was defined during several thermal simulations with CST.

Cooling System of the Stems, the Drift Tubes and the Plungers

The biggest part of the energy is dissipated on the stems and the drift tubes. Therefore, the thickness of the material between the surface and the cooling channels had to be as small as possible and was only limited by the needs of the manufacturing. The stems are milled from solid steel and the cooling channels are drilled afterwards. The shape of the channels consists of 8 sections with decreasing width.

The drift tubes are hollow on the inside, so that the cooling water can flow through two stems and a drift tube at once.

The plungers are equipped with coaxial water connectors and are hollow on the inside so that the plungers are lightweight for mounting and show very small heating during the simulations.

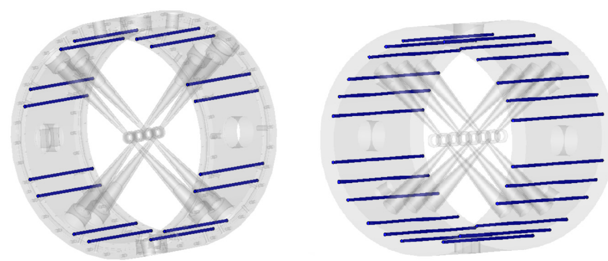

Figure 4: Comparison of the cooling channels inside the tank of the CH prototype (left side) and the MYRRHA CH-cavities number 1 to 7 (right side).

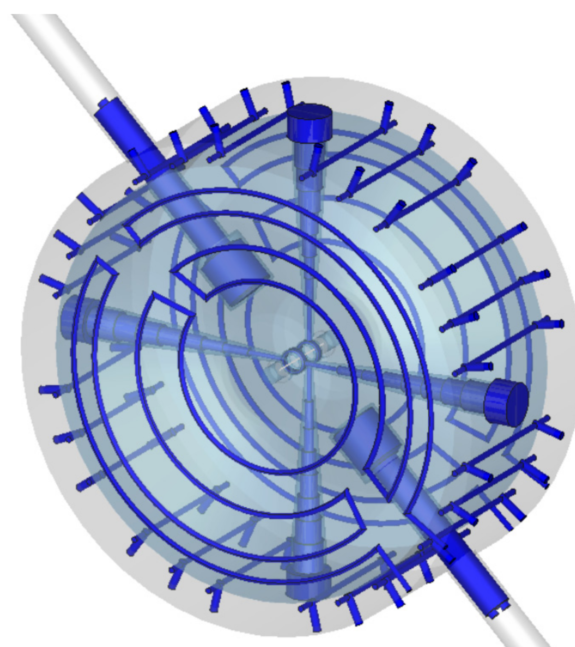

Figure 5: The complete cooling system of a MYRRHA CH-cavity.

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THERMAL SIMULATIONS

For the thermal simulations of the CH-cavities number 1 to 7 both the temperature of the cooling water and the surrounding air was assumed as 293 K. And a security margin of more than 15 % on the simulated power was implemented.

With the new cooling design the maximal simulated increase of the temperature of the CH-cavity was lower than 30 K.

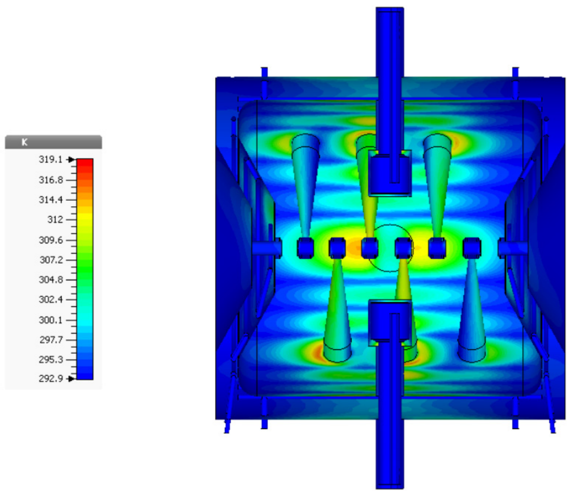

Figure 6: Result of a thermal simulation with the new cooling system inside MYRRHA CH-cavity number 5.

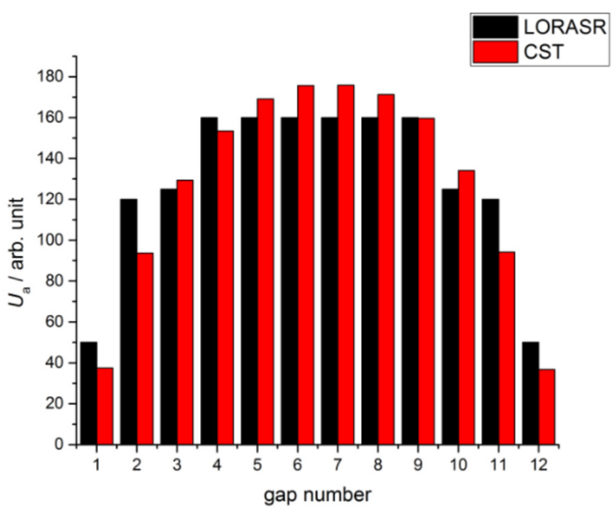

Figure 7: Comparison of the effective voltages of the CST and the LORASR simulation during the adjustment process.

RF-DESIGN

Currently the RF-design of CH-cavities number 8 to 15 is ongoing. Through minor changes on the overall mechanical design the effective voltages of the CST simulations should be adjusted to the effective voltages of the simulations of the beam dynamics.

Suitable for changing the ratios of the effective voltages is for example the lengths of the drift tubes or the depths of conical part of the lids. Also the influence of the position of the tuning plungers in beam and in radial direction on the voltages has to be considered.

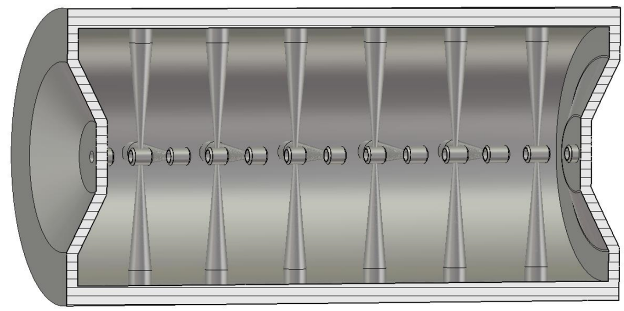

Figure 8: Sectional view of CH-cavity number 9.

CONCLUSION

The new injector design for MYRRHA consists of 15 room temperature CH cavities and accelerates the proton beam from 1.5 up to 16.6 MeV while using a constant phase configuration and low emittance growths rates.

For the cavities number 1 to 7 an improved cooling system has been designed and simulated. It has shown a temperaturestable behaviour with minor temperature rises.

The current voltage design of the remaining CH-cavities is still ongoing.

ACKNOWLEDGMENT

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