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Cavity R&D for HBS Accelerator

N. F. Petry #, K. Kümpel, M. Schwarz, S. Lamprecht, O. Meusel, H. Podlech[1]

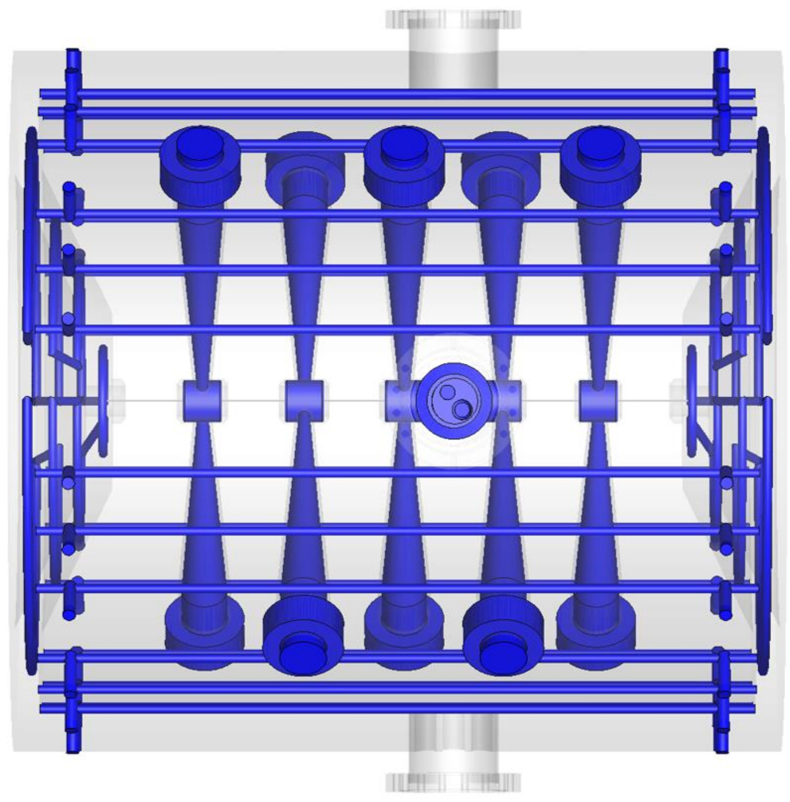
IAP, Goethe Universität, Frankfurt am Main, Germany

[1]also at Helmholtz Forschungsakademie Hessen für FAIR, Darmstadt, Germany

Abstract

The demand for neutrons of various types for research is growing day by day worldwide. To meet the growing demand the Jülich High Brilliance Neutron Source (HBS) is in development. It is based on a high power linear proton accelerator with an end energy of 70 MeV and a proton beam current of 100 mA. The main part of the accelerator consists of about 45 CH-type cavities. As the current beam dynamic layout is still work in progress the number of cavities can change for the final design. For this beam dynamic layout the design of the CH-type cavities was optimized to handle the high accelerating gradient. The results of the performance of the CH-type cavities will be presented in this paper.

CH-type Cavities



Side view of the cooling design from the CH-type cavities.

The expected thermal load for the cavities will reach a maximum value of 25 kW/m. Therefore a cooling design was initially developed for the CH-type cavities and has been improved to handle the high acceleration gradient. The cooling design consists of one cooling channels for each stem, one for each tuning device, one for the power coupler, two for the lids and 24 for the tank. The highest thermal load and thus the most cooling effort will be on and around the stems, since those are the regions with the highest current inside the cavity. Hot spots are also in the middle section of the tank possible due to the mode used for acceleration, which is the TE_{211}-Mode. To account for the high acceleration gradient changes to the cooling design of the stems were made. The optimization of the cooling design lead to an additional water volume inside the tank at the beginning and the end of each stem, which can be seen in the view of the side of the cavity, shown in the figure to the left.

Table 1: Estimated Parameters of CH cavities

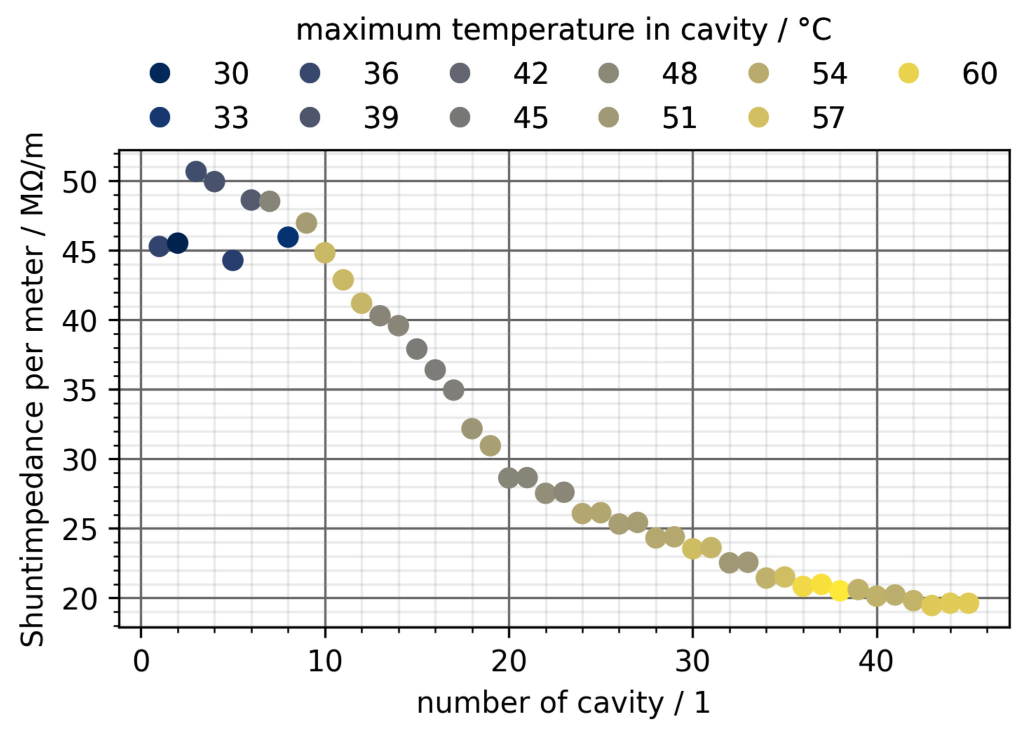
Parameter	Specifications
Frequency	176.1 MHz
Input energy of first cavity	2.5 MeV
Output energy of last cavity	70 MeV
Shunt impedance	19 – 51 MΩ/m
Aperture diameter	35 mm
Voltage	0.5 – 2.4 MV
Gradient	1.5 – 2.4 MV/m
Amplifier power	100 – 500 kW
Total power per cavity	70 – 405 kW
Thermal load	8 – 25 kW/m
No of cavities	≈ 45

Program for Design Iteration

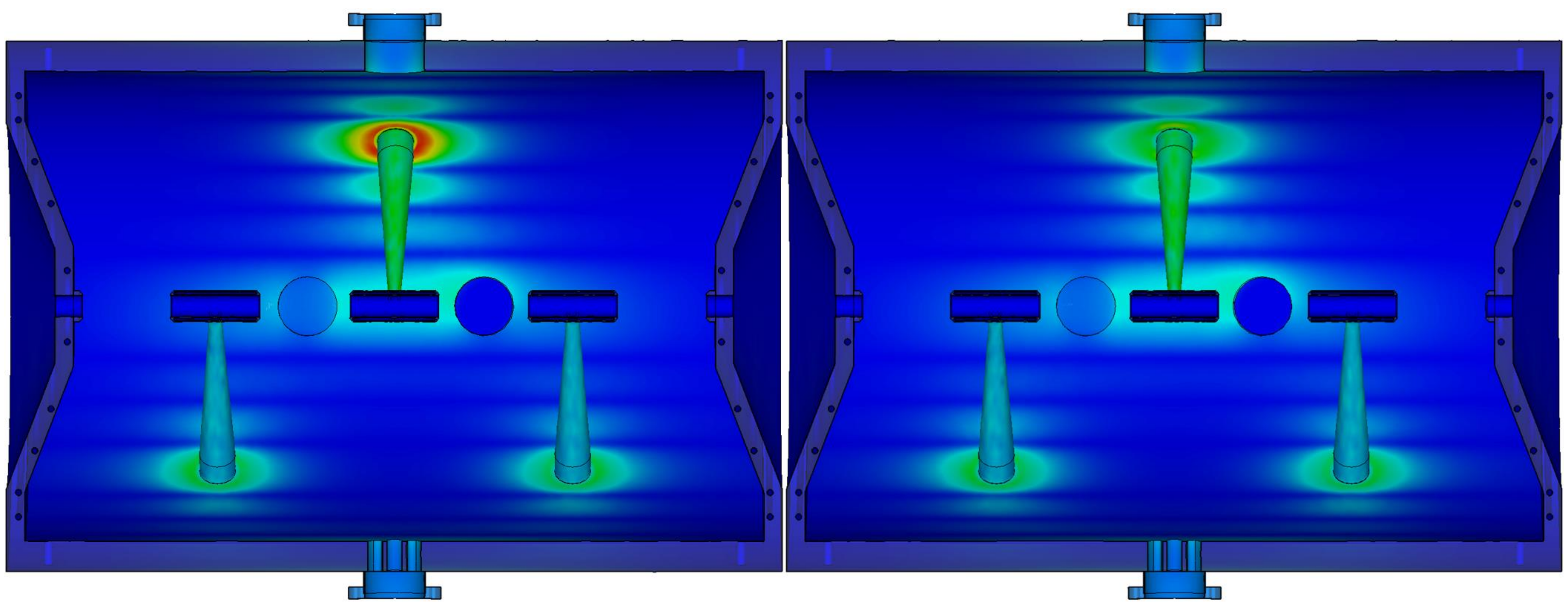
A python program is in development to handle the design of over 45 CH cavities. After designing a first version of the beam dynamic simulation one will get an ideal gap voltage distribution as a result. This gap voltage distribution acts as input file for the program. In this case the program LORASR, a multi-particle tracking code for beam dynamic designs, is used. For the output files of LORASR the python program can automatically create an input file from which one can generate the designs for the approximate 45 CH cavities required. The CH cavity designs are created as CST Studio Suite files, from which the program will start first the RF simulations and afterwards the thermal simulations. As a result one will get the real gap voltage distribution of the CH cavities which then can be used to correct and modify the beam dynamic simulation. This iterative process will converge at some point and one will get the final design for manufacturing. Besides the real gap voltage distribution the program will calculate several other key parameters which are important for the design process for the CH-type cavities.

Results

After the RF simulations have finished one will get several relevant RF properties of the cavities from the program, for example the shunt impedance Z_{eff}. The values of Z_{eff} used in this poster are 90 % values to include imperfections from manufacturing. The shunt impedance of the 45 cavities along with the corresponding temperature of the hottest spot inside the cavity is plotted in the figure to the left. The following thermal simulations are calculated with a duty cycle of 20 % and additional power safety margin of 20 %. The results are summarized in Table 1. For a better comparison between the new design and the old design the enhanced design was applied only on the stem in the middle of the cavity. Due to the enhanced design the hot spot around the stems disappeared and the highest temperature reached inside the cavity has dropped by around 20 °C, shown in the figure above. The WIP design from mid 2022 needs 45 CH-type cavities to reach 70 MeV, of which 3 cavities are rebuncher cavities.



Results of the WIP mid 2022 design with 45 CH-type cavities. To include imperfections from manufacturing the plotted shunt impedance are 90 % values of the simulation results.



Results of thermal simulation of the enhanced cooling design for the stem in the middle in comparison to the old cooling design of one CH cavity. Low temperatures are displayed in blue and the highest temperatures are displayed in red. The hot spots around the stems have disappeared and the highest temperature inside the cavity has dropped by around 20 °C.

Nils Petry - Institute of Applied Physics - Max-von-Laue Str. 1 - 60438 Frankfurt am Main - petry@iap.uni-frankfurt.de - www.linac-world.de