Structural Optimization of the AISHa Ion Source

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The AISHA source for hadrontherapy facilities is designed for high brightness multiply charged ion beams with high reliability, easy operation and maintenance. AISHa has been designed to meet the above-cited requirements by means of high field He-free superconducting magnets, while the radial confinement will be provided by a Halbach-type permanent magnet hexapole structure (Figure 1). [1]

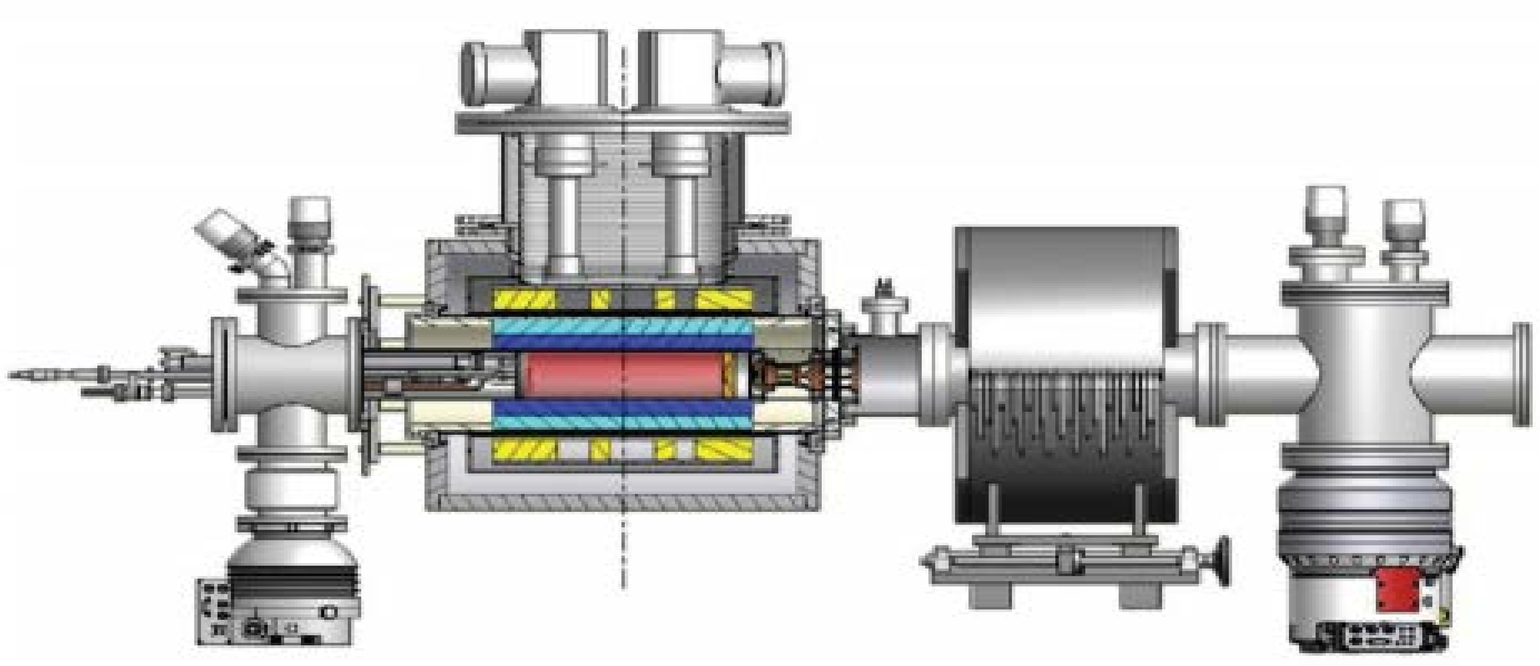

Figure 1. Layout of the AISHa source

In the development of this new source some improvements of mechanical and structural type have been introduced, in particular the optimization has involved two important parts of the source: the containment chamber and the plasma chamber. The optimization of these components has focused on two aspects: structural mechanics and fluid dynamics; both of these aspects have been optimized by using the COMSOL code. Permanent water flow in the plasma chamber is required to provide the expected low temperature. Therefore, the goal of our study was to optimize the design of the groove.

This optimization of the particular was done starting from a model of the chamber used in other sources. The model was designed considering four cylinders: φ=92 mm (chamber inner diameter), φ=94 mm (water flow internal diameter), φ=102 mm (water flow outside diameter) and φ=104 mm (chamber external diameter), each divided in two half cylinders. For each of the two half-cylinders an input, an output and three septa were designed. The domains considered were two, one for water and one for the metal (AISI 316L and aluminum 3003-H18) (Fig. 2).

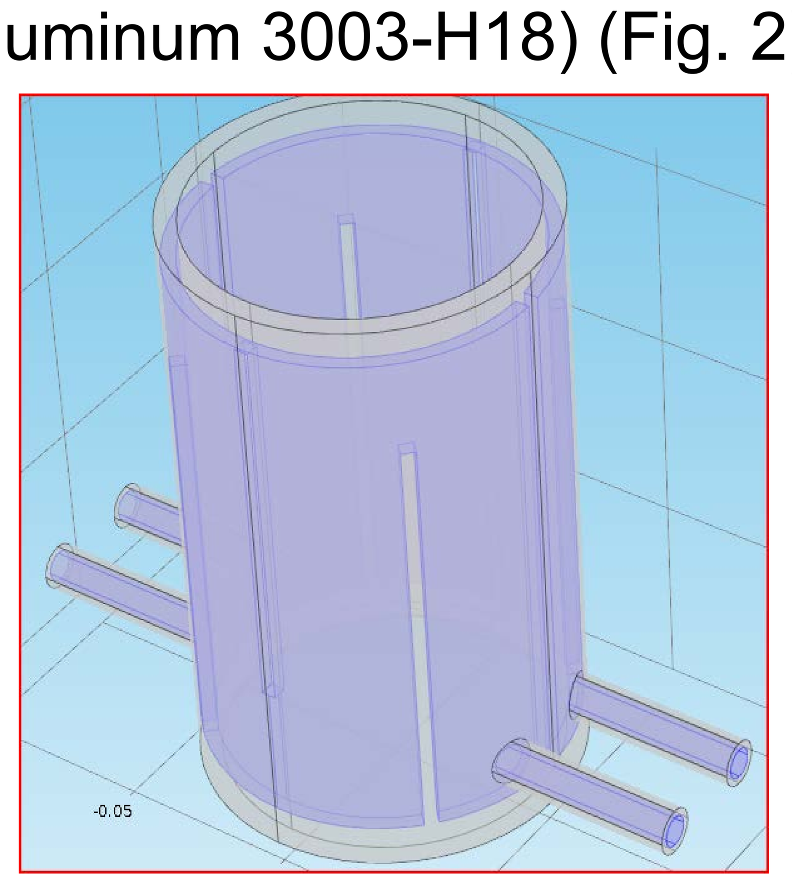

Figure 2. In gray the metal domain and in purple the water domain

The results obtained in the case of aluminum 3003-H18 show that the temperature reaches the maximum value of about 300 ° K at the output of water, that is, after the water has traveled the half cylinder, it is heated and has lost in part its cooling capacity. Nevertheless, this temperature is satisfactory, as we must have a maximum surface temperature of the lower chamber of 50° C in order not to damage the magnets that are in contact with it. The flow obtained is substantially laminar. Calculating the Reynolds number with the expression:

$$\mathrm{Re} = \frac{v * D}{\mu}$$

and assigning the values: v=0.35 m/s (the highest in the flow), D = 0.004 mm and assuming the value 1.01 *10-6 m2/s for the kinematic viscosity μ of the water, we get a Reynolds number equal to 1386 so we are in the field of laminar flow (Re less than 2300 is laminar flow) (Figures 3 and 4).

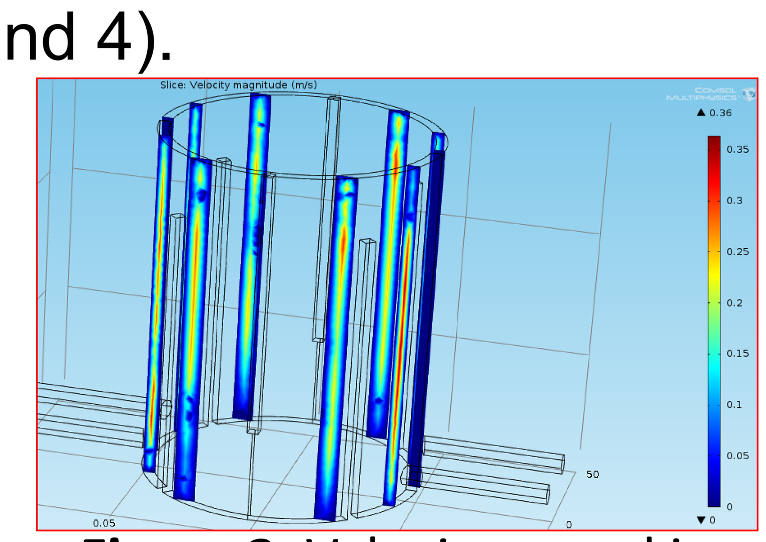

Figure 3. Velocity speed in the aluminum case

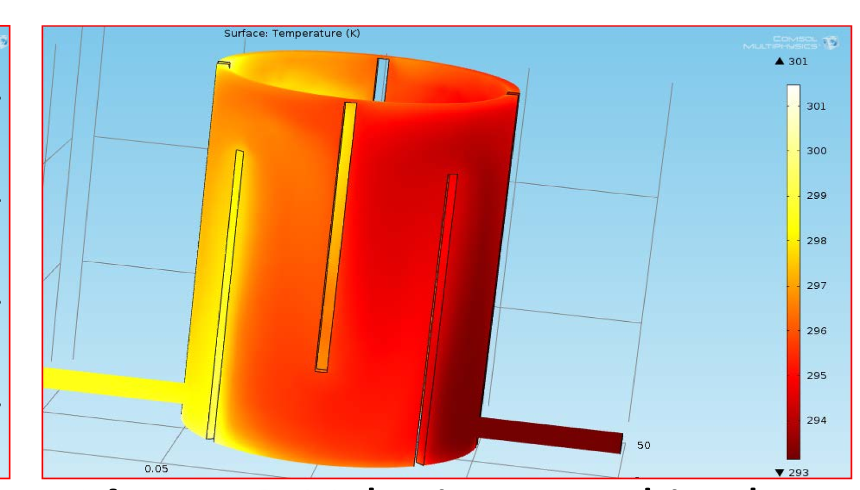

Figure 4. Velocity speed in the aluminum case.

This temperature decrease is due to the characteristics of the two materials: in fact the thermal conductivity of steel (14.6 W/m*K), is lower than that of aluminum (155 W/m*K); it is a measure of the ability of a material to transmit heat (i.e. the lower the value of k, the more insulating is the material). The first step has been developed considering a length of the chamber of 155 mm. Then the simulation was performed for the actual size of the chamber, that is 655 mm, but as the plasma formation takes place within 360 mm it has been decided to simplify the simulation, and then the calculations, considering a total length of 360 mm. Another simplification was to divide the plasma chamber into 4 equal sectors each with an input and an output.

In conclusion, our goal was to optimize the design of the plasma chamber. Starting from a simplified model and with subsequent iterations we are able to optimize the plasma chamber of the source AISHa.[2]

References:

1. [1] L. Celona, G. Ciavola, S. Gammino, L. Andò, D. Mascali - DESIGN OF THE AISHA ION SOURCE FOR HADRON THERAPY FACILITIES - Proceedings of ECRIS2012, Sydney, Australia, ISBN ISBN 978-3-95450-123-654

2. L. Celona al. ECR IONS SOURCE DEVELOPMENT AT INFN-LNS – Proceedings of ECRIS2014