Electromagnetic Characterization of Big Aperture Magnet Used in Particle Beam Cancer Treatment

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Abstract

Resistive magnets are one of the principal components of ion medical accelerator systems used in heavy ion cancer treatment. To fulfill medical requirements, like the size of irradiation field and an uniform dose distribution, some magnets of the transport beam line may require large aperture and a large region where the integrated magnetic field is within specifications (good field region). Very precise magnetic field simulations are needed to fulfill the stringent magnet design parameters. After a validation benchmark between COMSOL simulations and measurements of a dipole magnet used in the Centro Nazionale di Adroterapia Oncologica (CNAO), COMSOL Multiphysics has been used to characterize the magnetic field quality of a very large 90° bending magnet. This dipole is a 1.81 T iron dominated magnet and it is used in the vertical line of the hadrontherapy facility to deflect carbon or proton beams. An important characteristic of this magnet is the integrated field quality, which must be better than ±2x10-4 in a 20 x 20 cm^2 good field region. The magnet yoke is subdivided in six parts for ease of construction and handling. A stiffening frame has then been foreseen to preserve the mechanical rigidity of the magnet and its impact on the field quality has been investigated. Simulations show an increment of 0.5% in the magnetic field strength due to the structural elements but this effect does not affect the requested field quality in the magnet aperture. 2D dynamic simulations have been made that foresee a time constant of 1.13 s for the eddy currents decay at the end of the current ramp. The feeding current ramp used for this magnet is slow and the transitory effects vanish while the beam is accelerated, such that when the beam is extracted the magnetic field is already stable. A similar magnet, with eventually an improved stiffening frame, will be used in the design of a carbon ion gantry, which is a rotating transfer line that allows patient irradiation from any direction.