Multiphysics Simulations for the Design of a Superconducting Magnet for Proton Therapy

C. Calzolaio[1], H. Carolin[1], S. Stephane[1]

[1]Paul Scherrer Institut, Villigen, Switzerland

Abstract

The use of proton therapy for cancer treatment shows a growing trend, since the radiation dose delivered to the target volume is maximized and the dose to the surrounding healthy tissues is minimized. To direct the proton beam from all directions to the tumor in the patient, the last part of the beam transport system is mounted on a gantry rotating 360° around the patient. This system consists of conduction cooled superconducting magnets operating at 4.2 K, thus reducing the weight and the footprint of the whole machine and enabling new treatment scenarios.

This contribution focuses on COMSOL Multiphysics® simulations of the electro-thermal and mechanical behavior of the main magnet during several phases. First, the cool-down from room temperature to 4.2 K considering the corresponding thermal stress in the assembly will be presented. After that, the magnet operation will be discussed. This includes transient simulations involving Joule and inductive heating and mechanical calculations under different load conditions. The stress management is particularly important for the design of the coils that are wound with a Rutherford cable made of brittle Nb3Sn strands.

After creating a complex magnet geometry using the COMSOL Multiphysics® built-in CAD system, the AC/DC, the Heat Transfer and the Structural Mechanics Modules have been coupled as the physical properties of the superconducting materials are non-linear functions of B-field, temperature and strain.