Strongly Curved Superconducting Magnets and their Effects in a Compact Synchrotron for Hadron Therapy

H X.Q. Norman[1,2,3], R.B. Appleby[1,2], S.L. Sheehy[3,4]
[1]*University of Manchester, Manchester, UK*
[2]*Cockcroft Institute, Warrington, UK*
[3]*University of Melbourne, Melbourne, Australia*
[4]*ANSTO, Australia*

Superconducting, curved magnets can reduce accelerator footprints by producing strong fields (3T) and reducing the number of magnets required, making them an attractive choice for applications such as heavy ion therapy. There exist two problems: the effect of strongly curved harmonics and fringe fields on accelerator beam dynamics is not fully understood. Also, the usual way of describing the field using cylindrical multipoles breaks down for curved magnet geometries and when the field has longitudinal dependence near the magnet ends. These issues are especially important to rectify when placing such magnets in compact accelerators, where off-axis fields and fringe fields can significantly affect beam quality and long-term beam stability. We investigate the impacts of utilising a curved canted-cosine-theta (CCT) superconducting magnet in a compact medical synchrotron. We develop a method to analyse and characterise the curved fields of an electromagnetic (EM) model of the CCT, and apply this method to study their effects on the beam dynamics and long-term beam stability in a compact medical synchrotron model. The method is general and can be applied to any magnet configuration to be studied in any compact accelerator. Here it is demonstrated on a curved CCT EM model developed for the main bending magnets in a 27 m circumference carbon ion therapy synchrotron, designed within the Next Ion Medical Machine Study (NIMMS) and the Heavy Ion Therapy Research Integration Plus European project. The method provides insights allowing for the optimisation of both the magnet and synchrotron lattice designs before potential implementation in a future treatment facility.