Particle Beam Tracking with COMSOL Multiphysics®

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Abstract

In this contribution we present a custom-made tracking code developed in MATLAB® Simulink® which uses electric and magnetic fields calculated in the COMSOL Multiphysics® software. Accurate and efficient tracking codes are an important tool for designing particle accelerators as well as many other applications which use electromagnetic fields to control particles. Commercially developed tracking codes are often expensive, may appear to the user to be a black box and their performance is limited. The code is flexible as the initial particle position and velocity distributions can be defined by the user, as well as the particle type and the physics of beam interaction. The code we have developed has already been applied to simulate different types of beams from low energy electrons and antiprotons used in fundamental physics research to ions used for medical treatment. It also allows beam tracking to be performed through a combination of fields such as 2-dimensional and 3-dimensional field maps calculated by COMSOL or from other sources such as measurements or analytical calculations.

We have used COMSOL software to calculate electric fields of various elements of accelerators, such as elements of medical, industrial and research cyclotrons, injection/extraction systems from low-energy electrostatic rings, transport beam lines, experimental setups for electron emission studies Figure 1. As the code was developed to perform accurate tracking of low-energy particles, the accuracy of the field map is crucial. Each model requires a different approach and sets a number of challenges. We use 2D models wherever possible to decrease simulations times and apply different approaches for meshing the model in 3D models in order to achieve necessary accuracy in important regions. Figure 2.
Our code allows us to improve those field maps by applying smoothing techniques and use of symmetries when possible.

We have used the combination of COMSOL Multiphysics and our code to simulate a wide range particle of accelerators and beam lines parts and in this contribution we present the most challenging problems that we have solved, such as particle tracking through several grid electrodes of an electron gun and accurate tracking through various parts of accelerators and beam lines. Figure 3.

Our code in combination with COMSOL provides very accurate tracking through different electromagnetic fields. Its flexibility allows us to solve different types of problems for different particles from electrons to heavy ions. For low-energy particles our code provides great accuracy and efficient in terms of simulation times, therefore allows us to use it on regular

workstations and laptops.

Figures used in the abstract

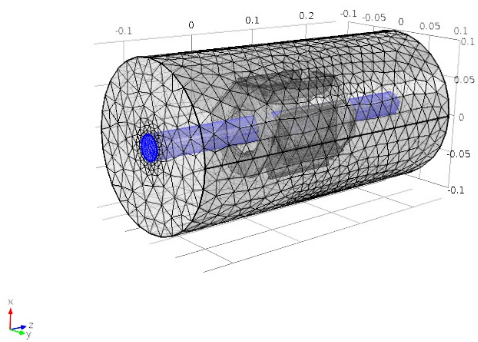

Figure 1: Overview of the electrostatic quadrupole model

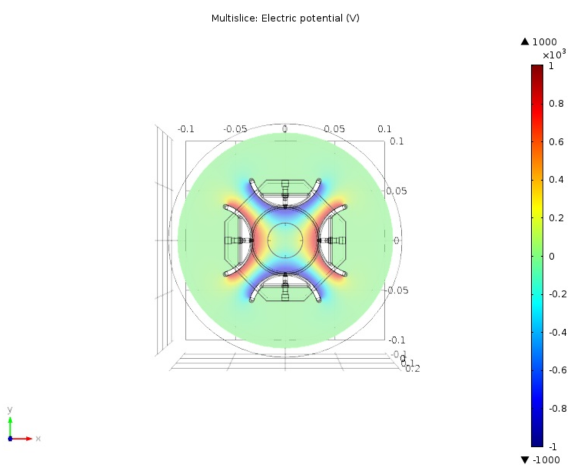

Figure 2: Electric field inside the quadrupole

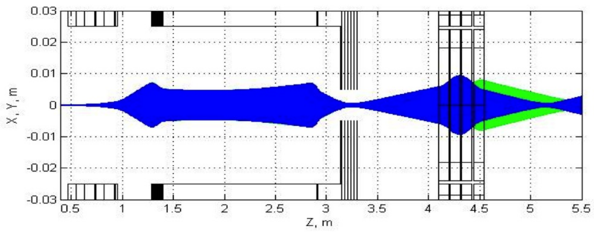

Figure 3: Particle tracking through an injection beamline