Particle Beam Tracking with COMSOL Multiphysics®

Oleg Karamyshev[1], Lee J. Devlin[1], Carsten P Welsch[1]

1. University of Liverpool, UK;.

Introduction: Accurate and efficient tracking is important for designing particle accelerators as well as many other applications which use electromagnetic fields to control particles. We have developed a tracking code in MATLAB® Simulink® which uses electric and magnetic fields calculated in COMSOL Multiphysics®. Existing tracking codes often appear to the user as a black box and their performance is limited. We have developed the code to be flexible, allowing us to solve different types of problems for different particles from electrons to heavy ions.

Figure 1. Scheme of the code

Computational Methods:

Equation of charged particle motion in electro-magnetic field:

$$\frac{\partial \vec{V}}{\partial t} = \frac{q}{m}\sqrt{1-\frac{V^2}{c^2}}\left\{\vec{E}+\left[\vec{V}\vec{B}\right]-\frac{1}{c^2}\vec{V}(\vec{V}\vec{E})\right\}$$

The code can use electro-magnetic fields from COMSOL, analytical solutions and measurements.

Figure 2. Integration block, the "heart of the code"

Features of the code:

- ability to combine different electric and magnetic field maps
- MATLAB® environment is easy and powerful for pre and post processing
- Add-ons such as "space charge", residual gas scattering, loss conditions.

Figure 3. example of particle velocities and coordinates distribution commonly used in accelerator physics - "phase space ellipse"

Results:

We have used the code for different studies, for example tracking of electrons from cathode through a combination grids to the detector. Combination of 2D and 3D field maps calculated in COMSOL were used.
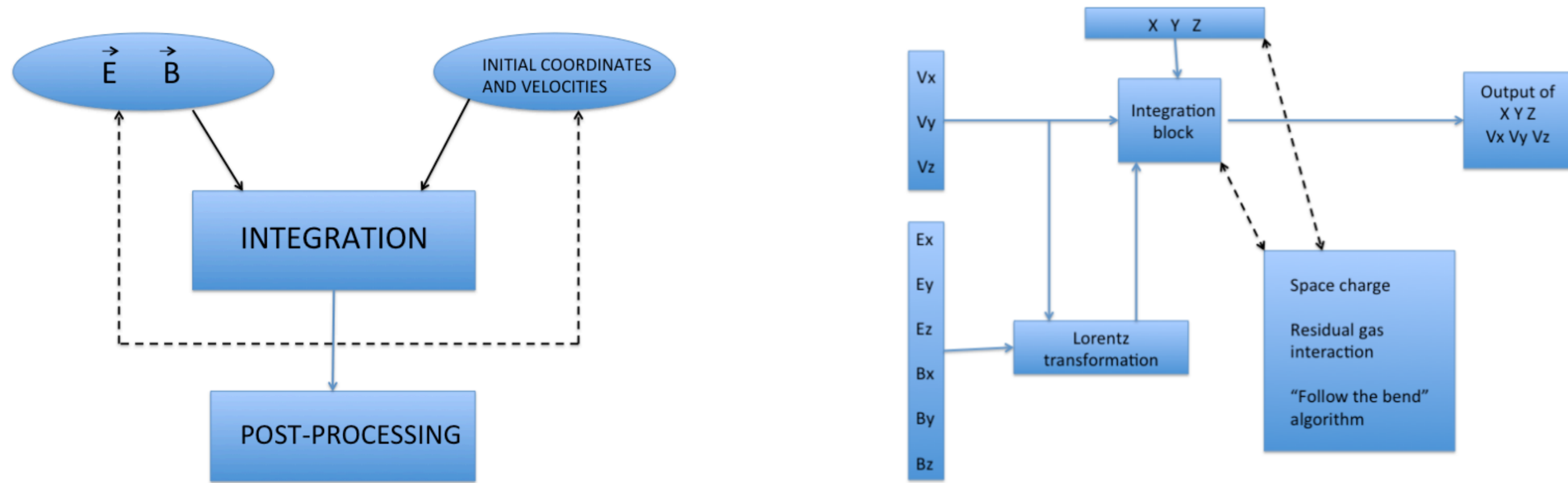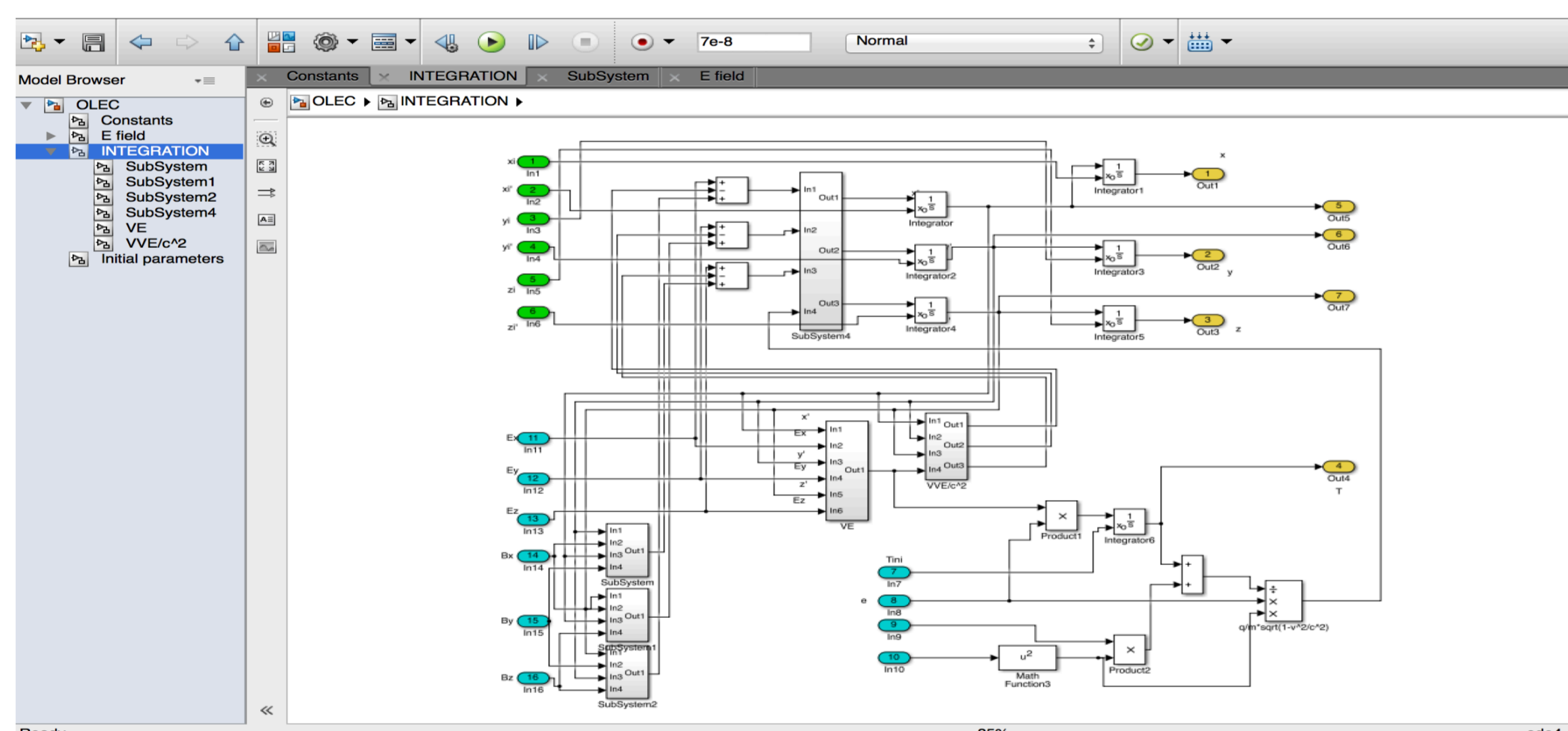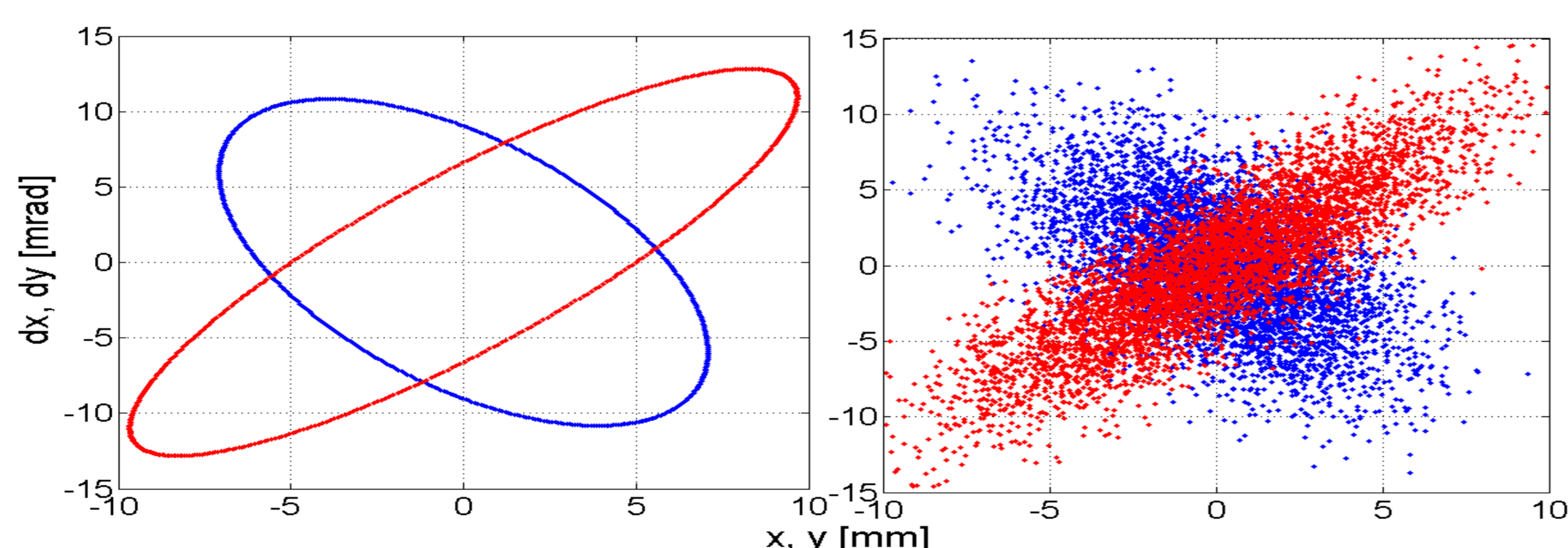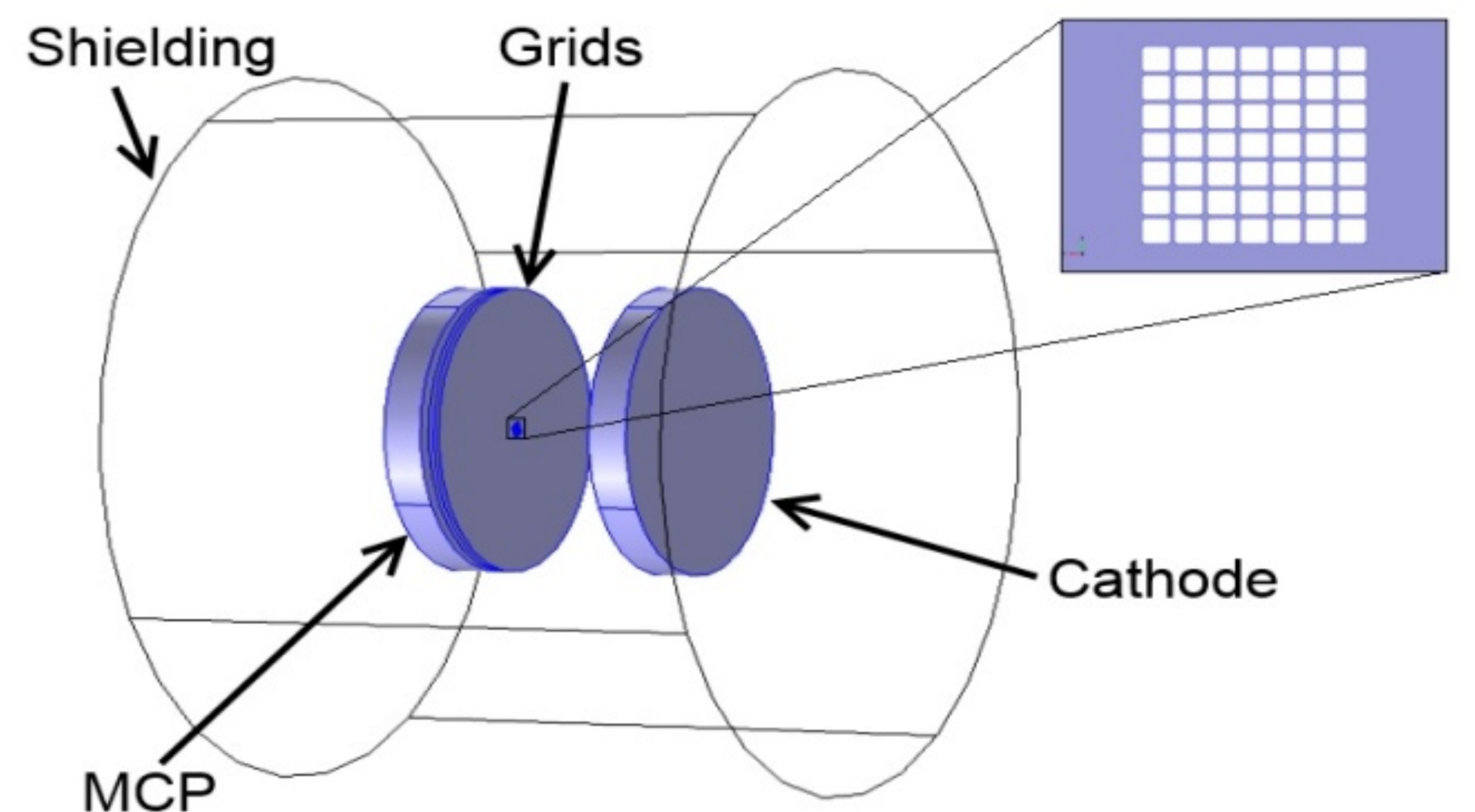

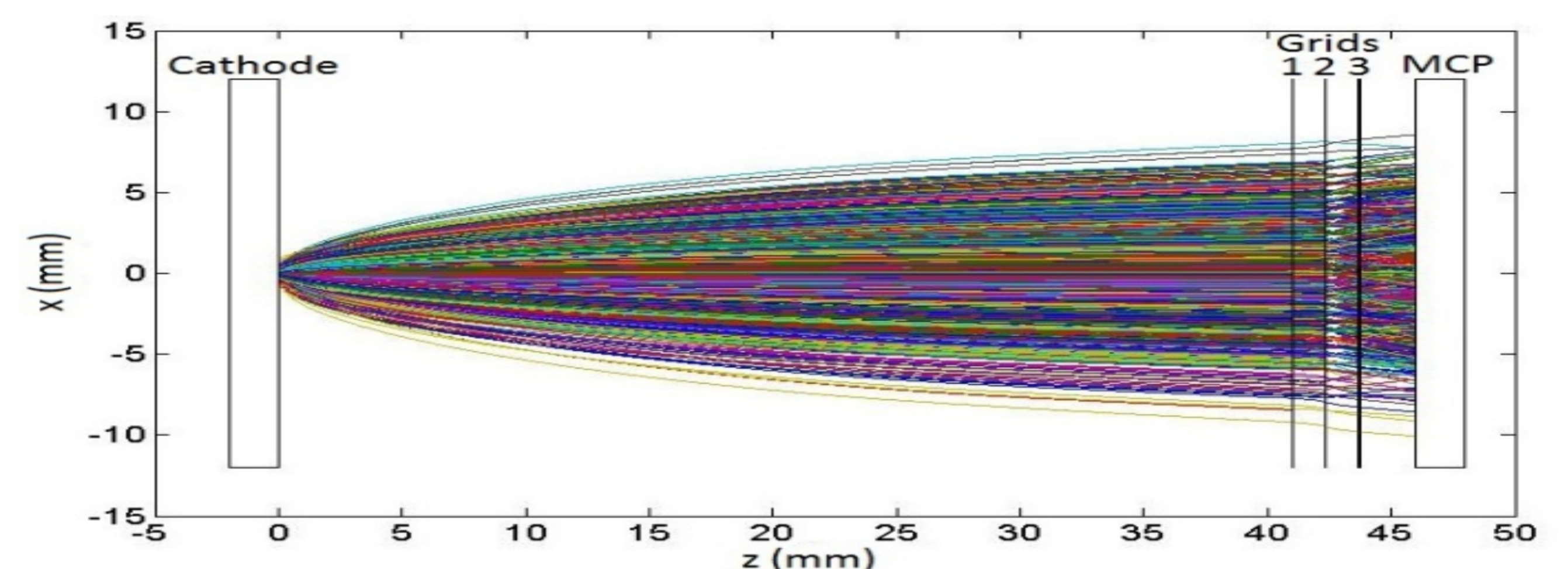**Figure 4.** COMSOL model of a photocatode [1]

Figure 5. Tracking results

Another example, an accelerating beamline[2]. Combination of measured magnetic field and 3D electrostatic field from COMSOL:
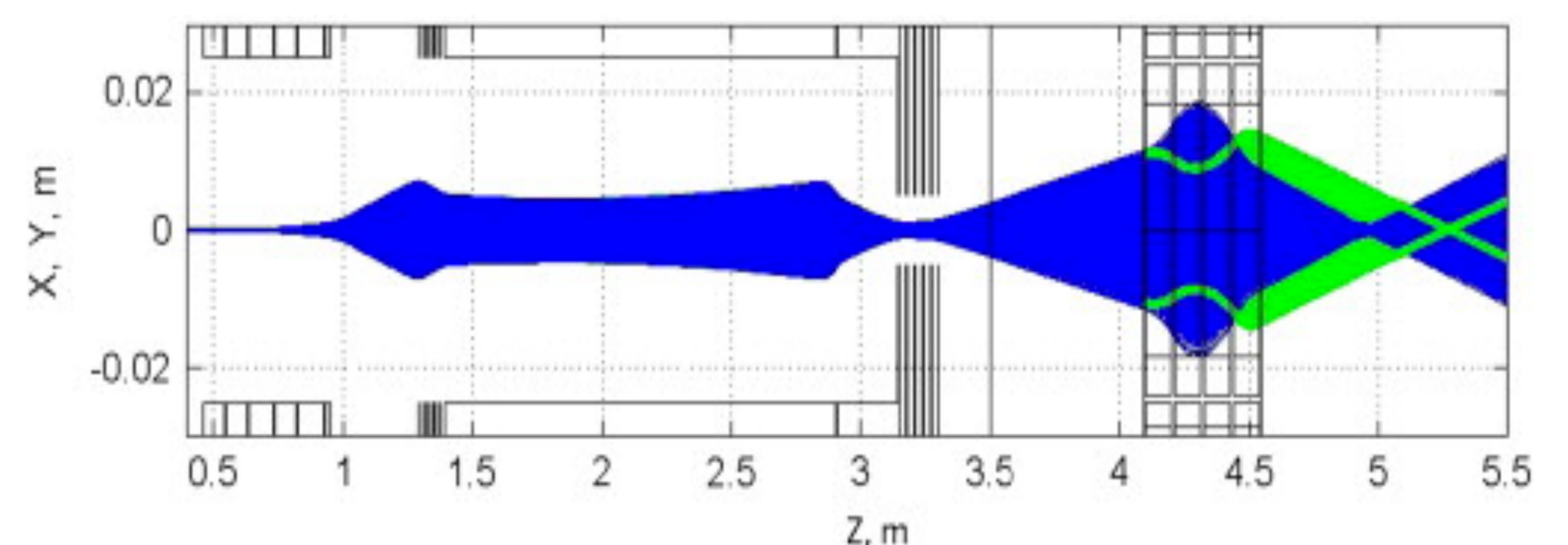

Figure 6. Tracking through an accelerating beamline

References:
1. J.Devlin et al., "Measurements of the Longitudinal Energy Distribution of Low Energy Electrons", Proc. IPAC14, MOPRI051, Dresden, Germany (2014).
2. O. Karamyshev, "Design of the injector for a small recycling ring on the CERN-AD", Nucl. Instr. Meth.A, 700 (2013) 182–187. Author, Article Title, Journal, Volume, Page numbers (year)