Simulation of the electron dynamics in non-ideal Penning traps

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The work proposes a new method to study the dynamics of the electrons confined in a non-ideal Penning trap, in which diocotron, bouncing and Larmor frequencies are of the same order of magnitude and electron-neutral collisions are important. The method is based on the use of the time average of the trajectories, instead of following exactly the electron motion. In absence of collisions, the electron trajectories are characterized by three parameters: two of them are the total energy and the canonical angular momentum, which are constants of the motion and determine, for each electron, a region in (r,z) domain where the trajectory is constrained. In fact, the trajectory is confined in a subset of that domain, and its shape depends on a third parameter (in the case of a separable potential, this parameter is simply the ratio between energies in r and z directions, and the electron moves in a rectangular region). Therefore, to each electron is associated a space density, which represents the time average of the positions spanned during the motion. Collisions with neutral atoms or molecules cause a suitable variation of the three parameters, and, consequently, of the shape of the region that is associated to each electron.
In practice, the determination of the exact density is rather time consuming; for that reason, two different approaches are here proposed:
1) the use of the ergodic distribution. As it depends only on the total energy and on the canonical angular momentum, it represents a useful tool for a simplified description of the electron density;
2) a three-parameter description that approximates the accessible region of the electron by using a simple procedure for decoupling the real potential. Comparisons with the exact space (obtained by calculating numerically the trajectory and sampling it at constant time intervals) density have proved that the method provides an excellent approximation for the density associated to each particle.
The simulation of time evolution of the electron distribution is performed using a procedure in which, after loading a suitable number of computational particles, at each time interval the calculation is divided in three steps:
(I) using a Monte Carlo technique, a small fraction of the particles is chosen to collide with neutral atoms;
(II) the new parameters for the colliding particles are updated (considering elastic collisions, ionizations and cathode secondary emissions due to positive ions impact);
(III) the self-consistent electrostatic potential is updated by solving the Poisson's equation.
In the presentation, results obtained with the two different approaches will be presented and discussed.