ABSTRACT - PhD seminar - José Antonio Méndez Giono

Numerical and Experimental Study of multicharged ion beam extraction from electron cyclotron resonance ion source

Electron cyclotron resonance ion sources (ECR) are used to produce beam for particle and nuclear physics accelerators. The ion beam is formed from a magnetically confined plasma out of thermodynamic equilibrium. The goal of the thesis is to develop for the first time a set of three simulation codes able to reproduce the experimental beam emittance from ECR ion sources. Three simulation codes will be developed: (i) a self-consistent Monte Carlo simulation of the ECR plasma; (ii) a particle-in-cell (PIC) ion beam extraction simulation (ONIX-LPGP); and (iii) a beam transport simulation to characterize the ion beam through the low energy beam line (LEBT) until it reaches the beam emittance measurement instruments. An experimental section which will seek to validate the simulation through the installation of the PHOENIX V2 ECR ion source at LPSC on a low energy beam transport (LEBT) line for spectra, current, and emittance measurements. The ion beam considered is helium which light mass reduces the number of possible collisional processes.

For the beam transport simulation part of this study, a c code developed in site was adapted to the geometry and components on the LEBT. This software propagates macroparticles via the Boris algorithm, taking space charge effects into account. It also involves modelling of the corresponding magnets and extraction array.

The viability of using a guiding centre approach for particle propagation in a source plasma chamber was studied, this approach neglects the detailed electron's cyclotron motion, describing its trajectory through free motion of the centre of mass along the magnetic field lines and corresponding drifts. It's more expensive per propagation time-step than the widely used standard (Boris algorithm and other explicit integration schemes), but it could prove advantageous if it allows for the use of a large enough time-step as a product it not being constrained by the higher frequency cyclotron rotation, this was found to be the case in regimes with a low enough magnetic field gradient and particle energy.

The ECR plasma Monte-Carlo simulation under development implements a novel self-consistent approach for computing the ion and electron energy and spatial distribution through the source's plasma chamber. An advantage of this approach is that it is easily parallelizable. Collisional effects are considered in two groups. Elastic Coulomb collisions are implemented through an adapted Takizuka-Abe method. Inelastic collisions are to be implemented through a null-collision method. Ions and electrons are pushed independently on propagation loops until a time threshold is reached or the particles dies. Energy and density distributions from the propagations are used to iteratively compute the local electric potential in the plasma along with the electromagnetic field in the plasma chamber cavity. Once the MC simulation has converged, this would serve as an input to the ion beam extraction simulation. In this seminar I will introduce the physics of ECR ion sources and the simulation of such systems, as well as give an overview of the main results obtained so far and this project's prospects.