Internship in plasma physics for ion sources

Modelling the transport and the heating of electrons inside the plasma confined by the magnetic-field structure of an electron-cyclotron resonance ion source within the GEANT4 framework

Electron-cyclotron resonance ion source (ECRIS) works on a multi-step mechanism to produce highly-charged ions, which can then be injected into an accelerator beam line:

1. Absorption of the heating high-frequency electromagnetic wave injected into the ECRIS inner volume, which accelerates the electrons and realises first ionisations of the atoms;
2. The obtained high-temperature electrons are partially confined by the magnetic field of the source in order to maximize the absorption of the electromagnetic wave as well as the probability for the accelerated electrons to ionise further the gas;
3. The obtained ions are extracted from the ECRIS plasma with the help of dedicated electrostatic fields.

The modelling of the transport of electrons and ions is necessary in order to design sources as well as to understand their performances or the measurements performed with precise plasma diagnostics. Such a modelling is handled in two regimes:

- The first instants of the ECRIS heating by the electromagnetic wave, when the plasma is sufficiently cold to reduce drastically the probability of electron or ion collisions;
- The permanent regime where the hot plasma is present inside the ECRIS.

In parallel with an on-going work with our collaborators of the LAPLACE lab in Toulouse to develop a particle-in-cell model of the permanent regime, we propose here to develop a code for calculating the charged-particle transport of the first instants, using Monte-Carlo methods of particle tracking inside both the confining magnetic field map and the electric field of the electromagnetic wave within the CERN/GEANT4 libraries. This C++ environment has proven to be accurate to compute charged-particle tracks over decades of particle kinetic-energies through matter and electromagnetic-field maps and is widely used.

This work is being done within the framework of an on-going project started a few years ago in a collaboration between GANIL and the company Pantechnik (Bayeux, Normandie, France) to develop an original ECRIS equipped with an exactly axisymmetric magnetic field map aiming at optimising the transport efficiency from the source to the first beam transport stages of the accelerator, named PK-GANESA.

The internship will have as a goal the development of the C++ model and the different classes and methods necessary for the calculation, the numerical tests and the prediction of spectra (ions and electrons) at the locations of ECRIS diagnostics to be mounted for planned experiments. A minimum time of four months is required. This internship will come after a first one in 2022, which permitted to design and test accurate 2D and 3D field-interpolation schemes for the raytracing of the electrons within the field maps. It will be more oriented on the heating of the electrons by the microwave in the collisionless regime of ECRIS and more specifically on the volume mapping of the source where the electron resonant heating is achieved.

Expected skills
plasma, nuclear and particle physics, Monte-Carlo simulations, C++ and object-oriented programming

This work cannot be pursued by a PhD-thesis

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