Initial Simulations and Design of an Electron Collector for the Argonne Electron Beam Ion Source

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Background

An electron beam ion source (EBIS) being developed at the Argonne National Lab (ANL) will be used to charge breed rare isotopes from a 1 Curie ^{252}Cf source (CARIBU). These highly charged isotopes will then be accelerated via the Argonne Tandem Linear Accelerator System (ATLAS) to be used in nuclear and astrophysics experiments.

The main components of an EBIS are the electron gun, a drift region through a superconducting solenoid, and the electron collector, Figure 1. Ions are injected into the source and confined by the electron beam space charge. The ions are trapped within the drift region and can be subsequently ionized to very high charge states.

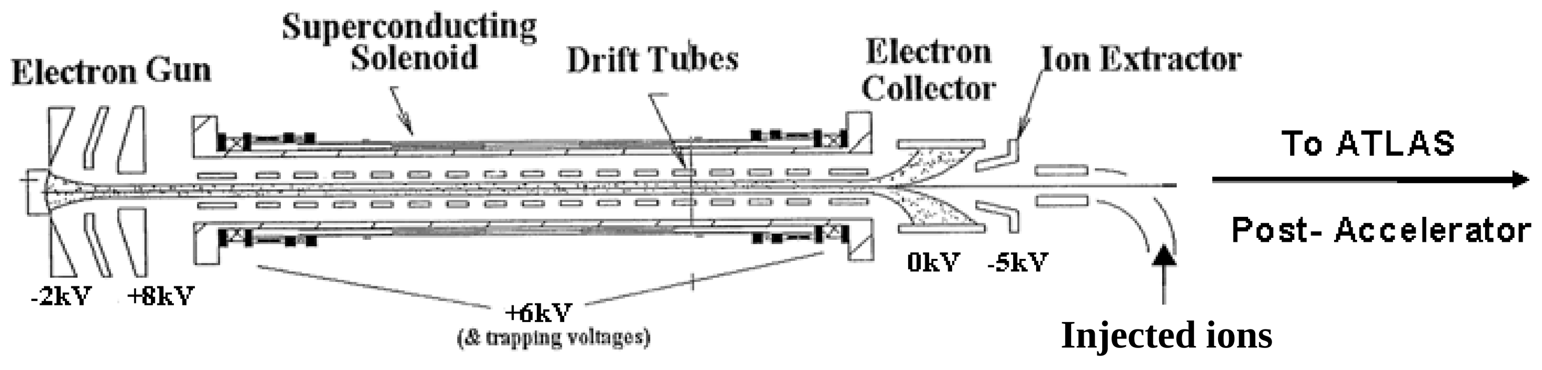

Figure 1: Schematic of an EBIS highlighting the main components

Goal

The proper design of the electron collector (EC) is critical to the efficient operation of the EBIS. Aside from its main function of dissipating the power from the electron beam, the EC is a key component during both the injection and extraction of ions. The main components of the EC are shown in Figure 2.

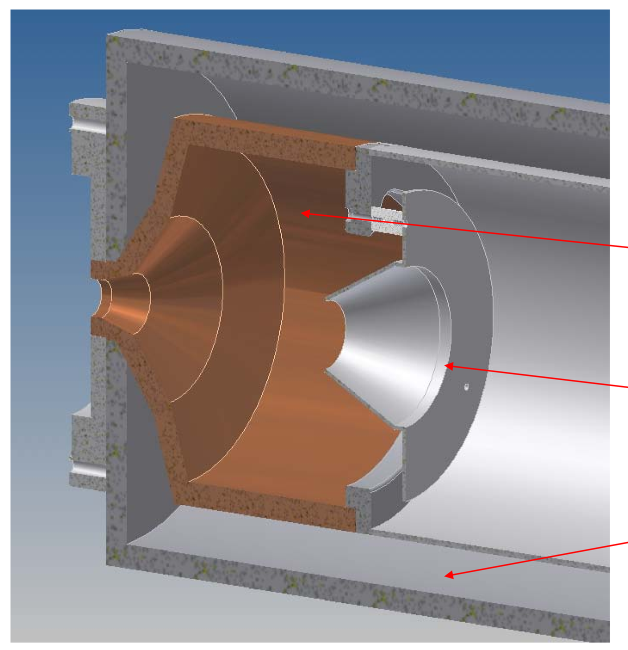

Figure 2: Solid model of the electron collector.

Simulations

Electron and ion beam simulations have been performed using the commercially available software package TriComp from Field Precision, LLC. The TriComp package includes programs which calculate 2D planar and axisymmetric electrostatic and magnetostatic fields, as well as self consistent charged particle trajectories within these fields.

Electron Beam Power Dissipation

An electron beam current of 2 A will be generated to achieve efficient charge breeding based on the maximum magnetic field in the trap, 6 T, the cathode radius, 2 mm, and the target current density in the trap, up to 500 A/cm^2. This 2 A electron beam will have a maximum energy of ~6 keV in the collector but a nominal energy of ~3.5 keV.

The uniformity and positioning of the electron distribution along the inside of the EC is mainly influenced by the magnetic field near the entrance and within the collector and the potential applied to the extractor electrode. Figure 3 shows the electron trajectories for various electron energies within the EC, while Figure 4 indicates the corresponding power density along the interior EC cylindrical surface.

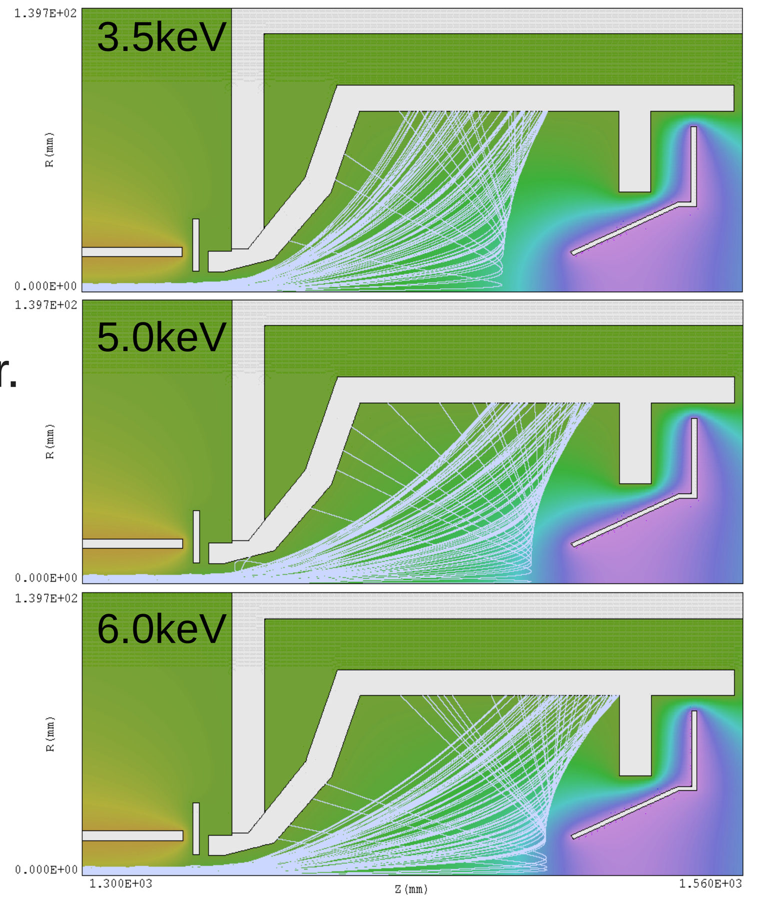

Figure 3: Simulated electron trajectories for 3 beam energies.

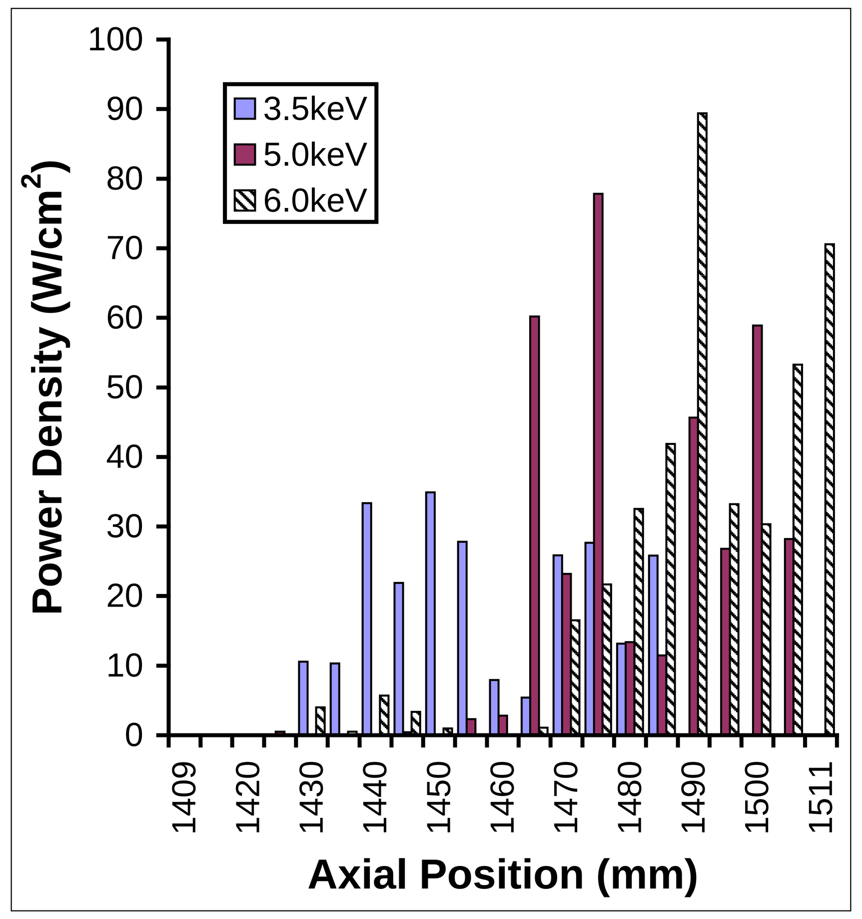

Figure 4: The power density calculated for the distributions in Figure 3.

Ion Injection and Electron Beam Acceptance

Besides a heat exchanger, the EC is an optical element which affects the interaction between the electron beam and injected ions. Properly matching the ion beam emittance to the electron beam acceptance is critical to achieving a high degree of overlapping of the two beams and, thus, efficient charge breeding.

The acceptance of the electron beam near the entrance of the collector was investigated by simulating the injection of a number of ion beam distributions from a starting position within the EC. The potential well created by the space charge of the electron beam is the key parameter influencing the ion beam confinement, so the ions were injected into the self consistent electric field solution from the electron beam simulations. The ions were considered to be accepted into the electron beam if their radial positions were within the electron beam envelope as they approached the trap. Figure 5 shows the phase space plots of injected and accepted ions, along with the acceptance value of the electron beam.

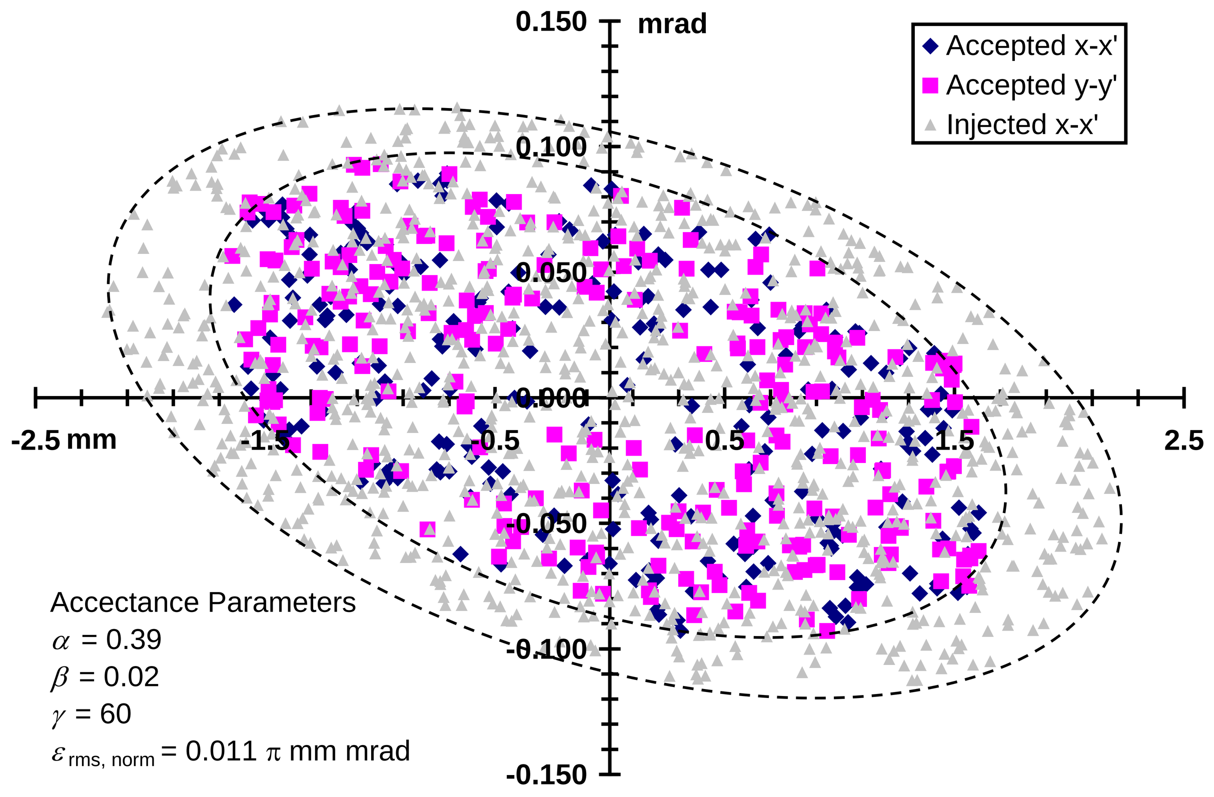

Figure 5: The phase space acceptance diagram of the electron beam within the EC.

Further Work

Modeling the extraction of highly charged ions from the EBIS trap through the EC, designing the injection/extraction beam line optics, and determining an adequate cooling configuration for the collector are the near term tasks.