Simulations of the CANREB Electron Beam Ion Source (EBIS)

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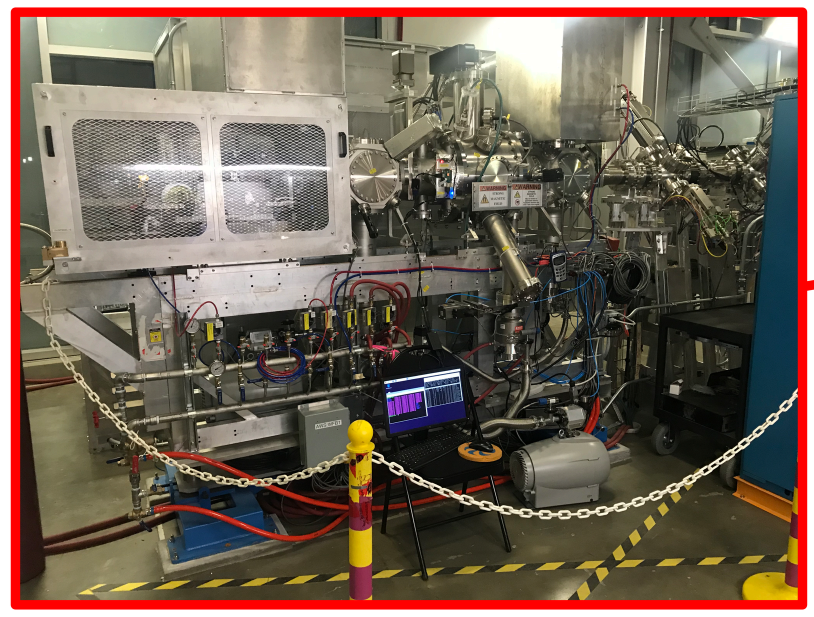
Introduction / Background

The newly commissioned ***CANadian Rare isotope facility with Electron Beam ion source*** **(CANREB)** at the ***Advanced Rare Isotope Experimental Laboratory (ARIEL)*** uses a cold-bore **EBIS** charge breeder (**Fig 1**) to produce **highly-charged Ions (HCI)** from bunched +1 RIB spanning the full mass-range up to uranium.



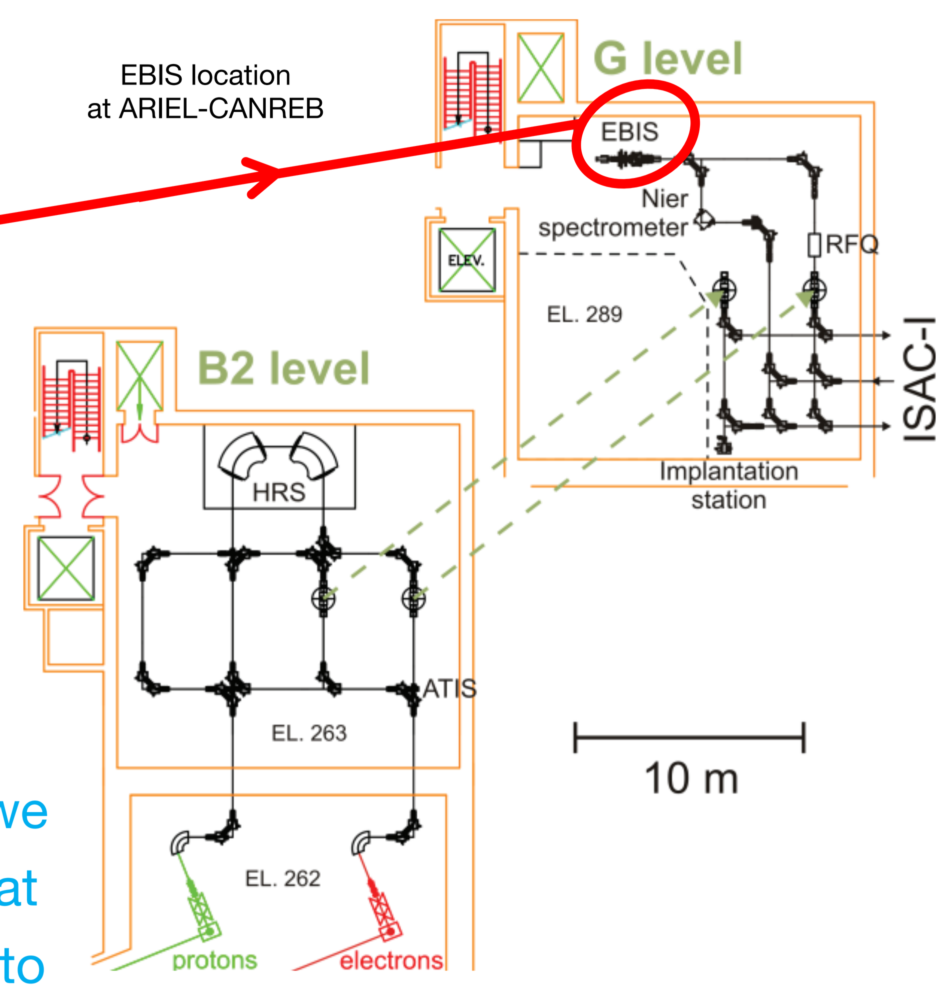


FIGURE 1 – EBIS (top-left) showing its location at ARIEL and setup at CANREB (right).

Following HV breakdown in 2019, we designed new PEEK feedthroughs at the 40^0K "temperature stop" (**Fig 2**) to bring HV (max 15 kV) from room temp to the drift-tubes at 4^0K in the B-field. Unfortunately, the breakdown persisted, leading to total failure of the PEEK feedthroughs at ~1 Tesla and ~7 kV (**Fig 4**). This chronic HV breakdown of the HV feedthrough in the B-field presents a severe issue in using the EBIS for HCI production.

Here we discuss simulations to understand the nature of the HV breakdown in the region shown in **Fig 2.**

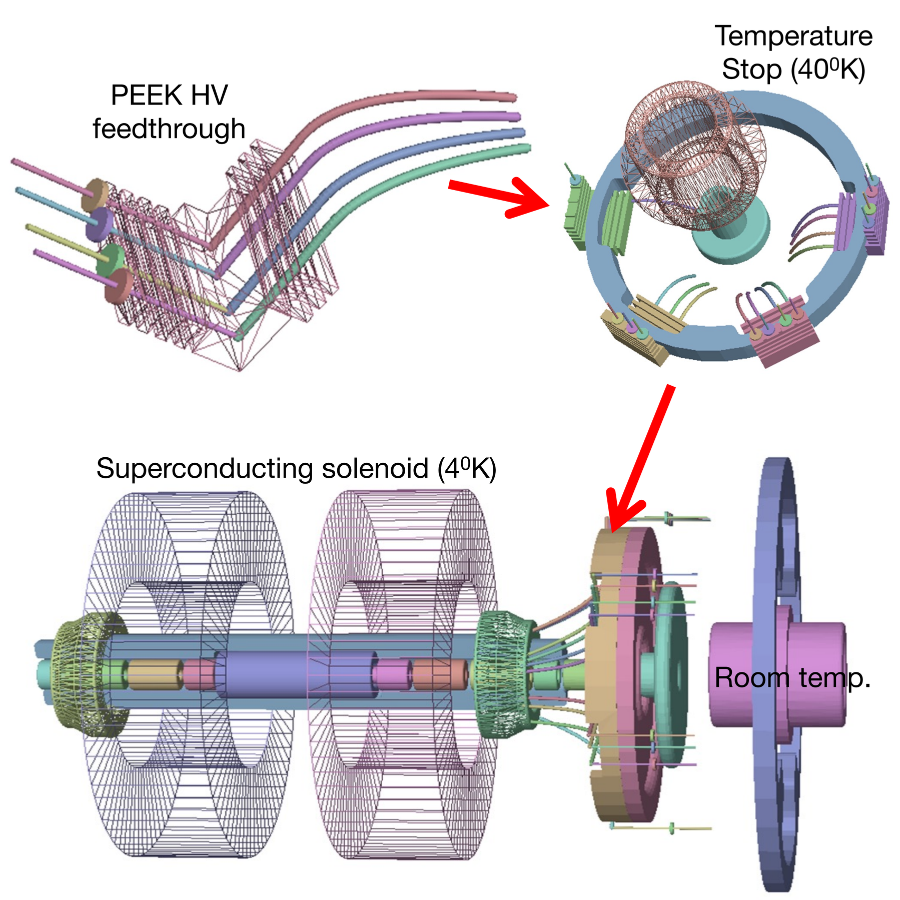


FIGURE 2 –OmniTrak simulation of the EBIS interior, including the superconducting solenoid, drift-tubes and the **problematic 4^0-40^0K "temperature stop"** region where the PEEK high-voltage feedthroughs and wiring (max +15 kV) are mounted.

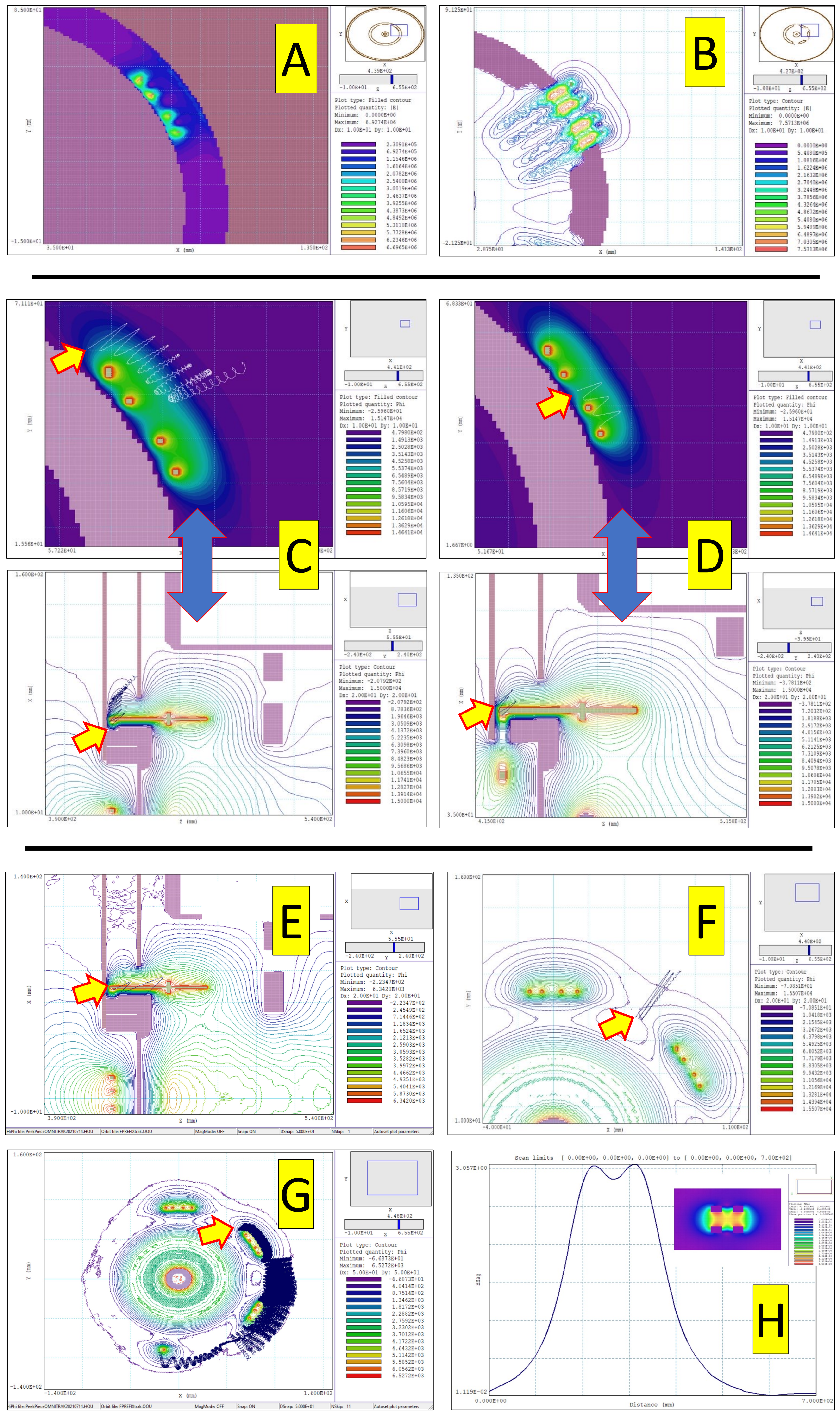


FIGURE 3 – (A and B) Electric field magnitudes (in V/m) surrounding bare stainless-steel wires in the region of the PEEK insulators (not shown). (A) between the 40^0K thermal shields in Fig 4(b), and (B) at the base of the "temperature stop" on the 40^0K thermal shield where the HV wires curve towards the drift tubes. Note the high electric fields surrounding all wires.

(C to G) electrons with 0 eV from an isotropic point source emitted at the arrows shown in the 3 Tesla solenoid magnetic field with +15 kV stainless steel wires, with (C to F) one single electron and (G) 2500 electrons.

Solenoid B-field simulation at 3 Tes;a used in all results A to G.

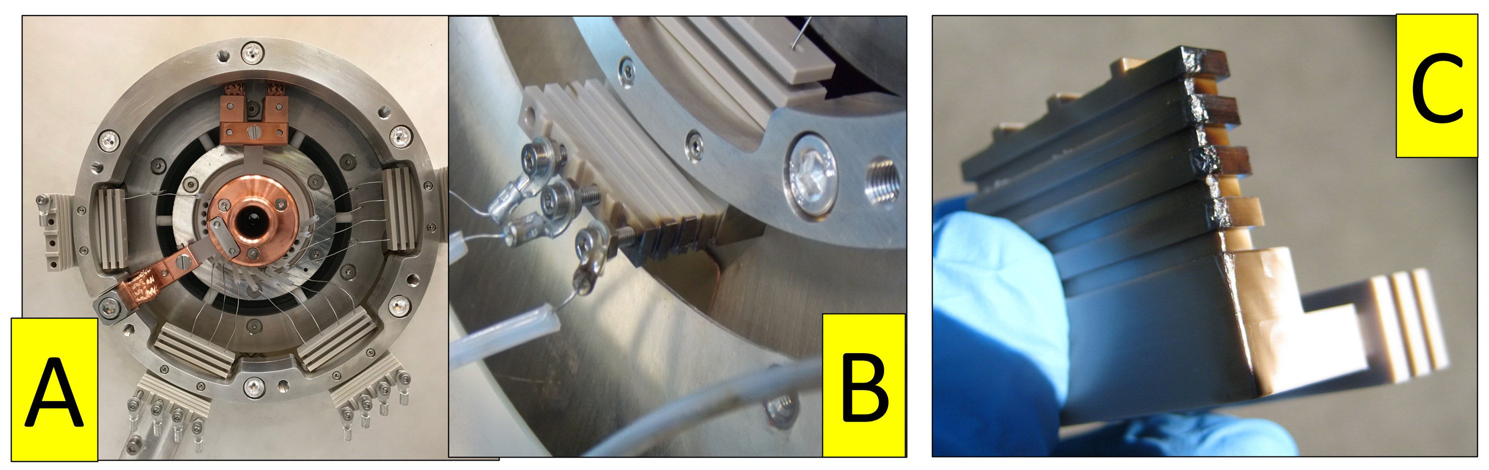


FIGURE 4 – Photos of (A) the PEEK insulators at the 40^0K "temperature stop" region; (B) close-up of the mounting with some damage visible; and (C) detailed view of the discharge/damage on the PEEK feedthroughs. Damage occurred at ~1 Tesla and ~7 kV (EBIS drift tubes should be able to reach 15 kV in a 6 Tesla B-field).

Quantifying the Breakdown

E-,B-fields & Electron Trajectory Simulations in OmniTrak:

OmniTrak Professional was used (**Fig 2 & 3**) to simulate the E- and B-fields, and the motions of electrons in the region of the PEEK feedthroughs (**Fig 4**) to gain insight to the physics of the breakdown.

Electric field strengths (**Fig 3AB**) are very high surrounding all bare wires (which should be eliminated in future designs). Electron trajectories follow a spiraling cyclotron motion in the B-field and orbit the +15 kV wires in the 40^0K region (**Fig 3 C to G**). Motion is complex but eventually terminates on the +15 kV wires or nearby metal surfaces at ground (**Fig 3 C to G**). One next solution is to replace all wiring with shielded Kapton or Teflon wires to eliminate the electric field in this region (**Fig 4**). Routing shielded wiring thru the magnet chamber may also be an option..

Discovery, accelerated