Radioactive Ion Beam (RIB) Production with a Forced Electron Beam Induced Arc Discharge (FEBIAD) ion source.

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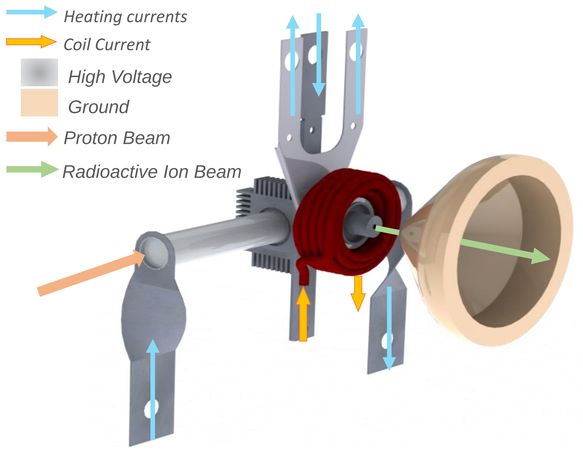


ISAC's Target Ion-Source unit to produce radioactive ion beams. Some of the elements are present only in a FEBIAD ion source.

Introduction

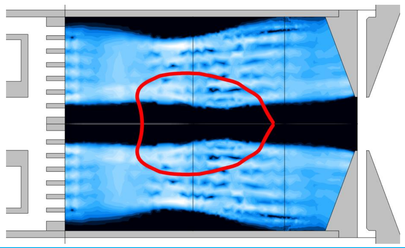
RIBs are used for medicine, study nuclear structure and fundamental symmetries.
TRIUMF produces RIBs utilizing the Isotope Separation On-Line method, in which an ion source is a key component.
The FEBIAD ion source is typically used for noble gases, molecular and halogens RIBs, and is a baseline ion source for TRIUMF's new Advanced Rare IsotopE Laboratory (ARIEL).

In a FEBIAD ion source, a hot hollow cathode generate electrons that are accelerated into the anode volume via a grid. Thermalized nuclear reaction products from the target are ionized by electron impact inside the anode. A magnetic field provides focusing/confinement of the electrons.
So far, different facilities seem to exhibit different ionization regimes with no clear explanation on how, therefore limiting how we can exploit. the best regime for the future facilities.

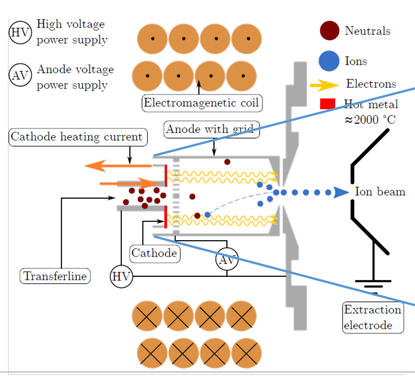
To investigate this source, simulation and experimental studies, are ongoing for the ISAC and ARIEL FEBIAD ion sources. COMSOL Multiphysics software is being used in order to investigate the FEBIAD source parameters and the influence onto each other. To our knowledge this is the first simulation approach taking the magnetic field into consideration.

Ionization Maps

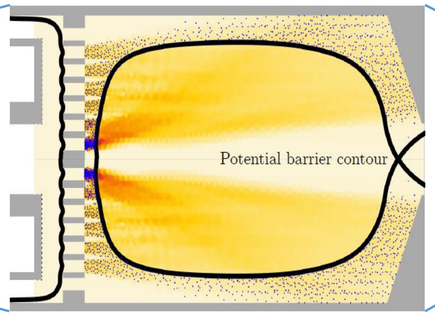
- Electron transport simulations define the ion current inside the anode volume.
- For each parameter combination, a potential well defines the of effective volume from which ions can be extracted .
- By integrating the ionization rate in the volume outside the potential well, we obtain the ion current.



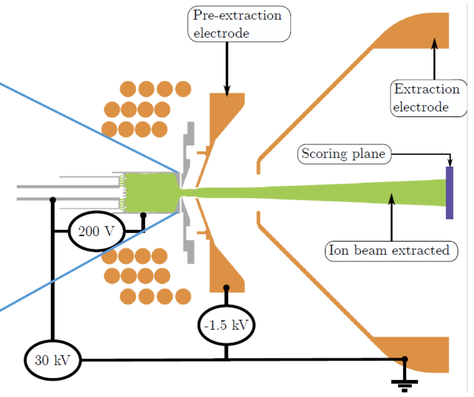
Multi-physics simulations



- A joule heated cathode emits electrons.
- A voltage accelerates the electron into the anode volume.
- An electromagnetic coil current generates a magnetic field that confines the electrons.
- Depending on the electron energy, there is a chance for an ion to be created by electron impact.

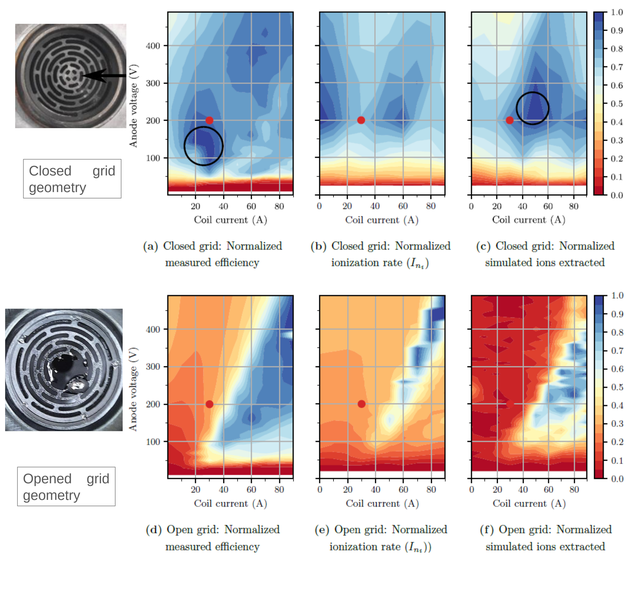


- The ionization map (left box) is computed from electron impact ionization cross section and helps initialize the ion position.
- The equipotential line defines the potential barrier, and the blue dots corresponds to the ion initialization as computed from the ionization rate per unit volume.



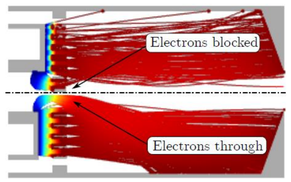
- Simulated ion extraction reflect the parameters imposed and allow experimental comparison
- Relative intensity, emittance, and energy spread are compare to experiments and show good agreement.

Experimental campaign



- Ionization efficiency measurements for two different grid geometries (column 1)
- Ionization rate as found from the ionization map (middle column)
- Fraction of ions extracted as found from the ion tracking simulations (third column)

- For the closed grid case, an island of efficiency is observed and most of the ionization efficiency is above 0.6.
- For the open grid case, there is a simultaneous increase with both coil current and anode voltage
- Both trends can be understand based on the electron trajectories. Beam can be either blocked or let through on specific voltage-current combinations.



Conclusion

- ✓ **A numerical model has been developed** comprising the relevant operational parameters of the FEBIAD ion source and from fundamental principles. The FEBIAD numerical model has **included the magnetic field for the first time** in these types of studies.
- ✓ The FEBIAD ion source is **driven by electron impact ionization under strong space charge effects.**
- ✓ Ionization efficiency measurements confirm that most of the **ions observed experimentally are created just beside the grid** as predicted from the simulation..
- ✓ With the simulation based-optimization obtained, the **geometrical changes can potentially increase the ionization efficiency ten-fold**.

Discovery, accelerated