Negative Ion Generation in an IEC Fusion Device

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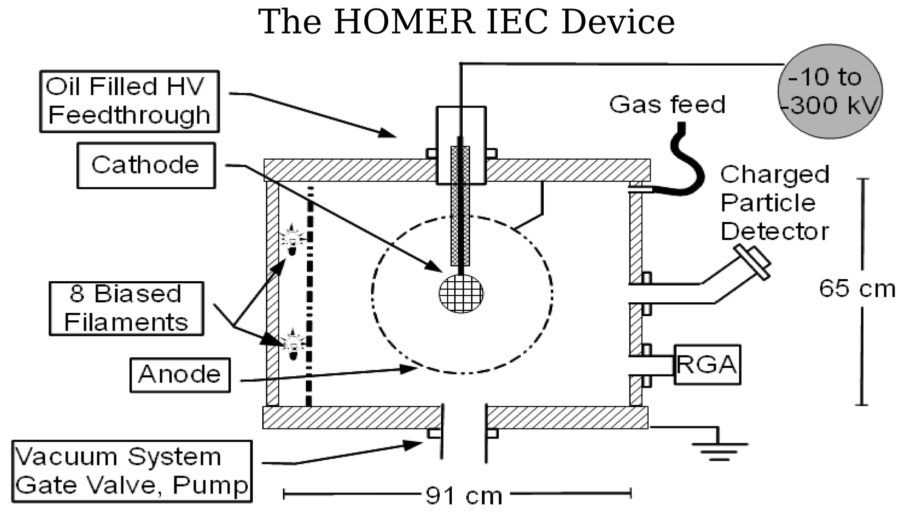
The discovery of negative ion generation in Inertial Electrostatic Confinement (IEC) devices [1] has prompted a campaign to extend understanding of negative ion phenomena in IEC devices. Theoretical studies include modeling negative ion physics in IEC devices by adding negative ion generation and propagation to a 1-D computational model of ion and fast neutral currents in IEC devices [2], to produce negative ion spectra that can be compared with experiment. Experimental studies of negative ions in an IEC device focus on examining negative ion current spatial profiles, generated by a mobile Faraday Cup in the IEC device source region. This study explores the relationship between negative ion production and cathode geometry, and looks for evidence of negative ion focusing. The improved understanding of IEC physics from this work will be presented and the viability of the IEC as a negative ion source will be evaluated.

Inertial Electrostatic Confinement Apparatus

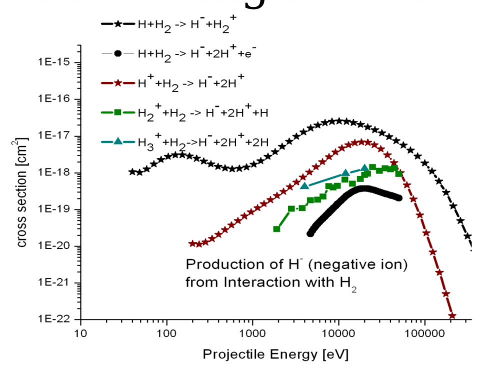
The HOMER IEC Device



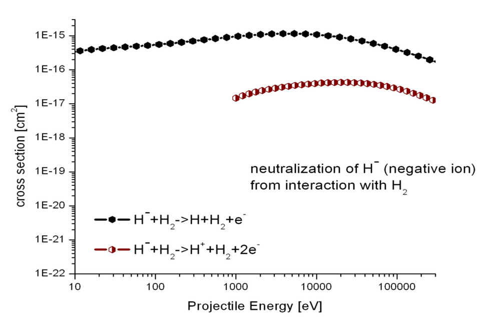
The IEC produces an unique environment for the production of negative ions. Electrostatic fields accelerate nuclei to an energy relevant for negative ion production via (dissociative) charge exchange reaction. At the center of the cathode a focusing of ions produces an electrostatic well that traps cold electrons where a population of excited neutral molecules occur, producing a region where negative ions are likely to form via electron attachment.

Negative Ion Reaction Cross Sections

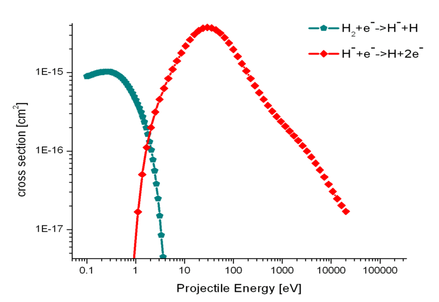
Negative Ion Charge Exchange Producing Reactions



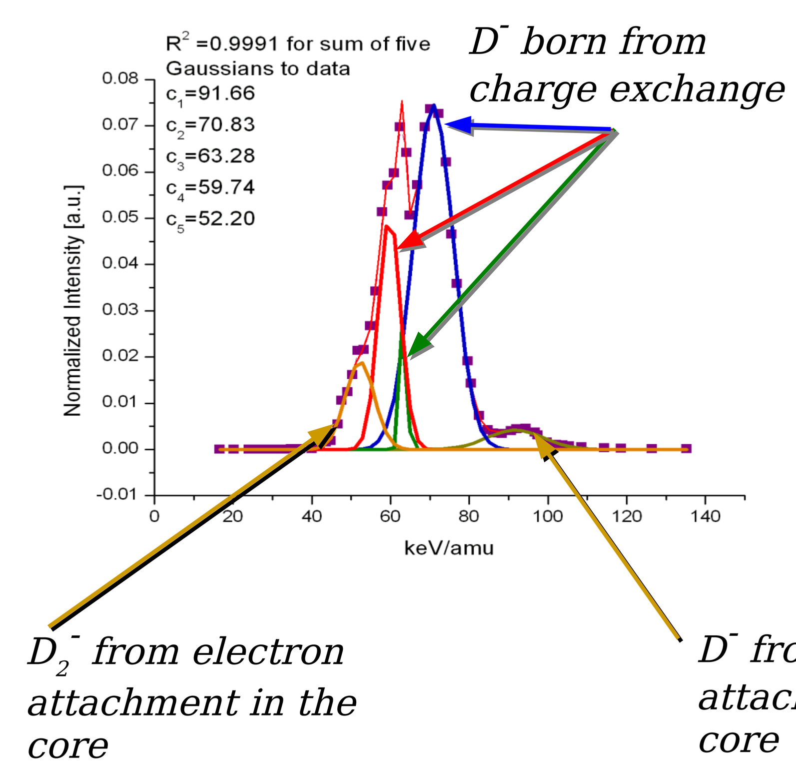
Negative Ion Stripping Reactions



Electron Attachment Production and Electron Stripping of Negative Ions



Negative Ion Energy/Mass Spectrum

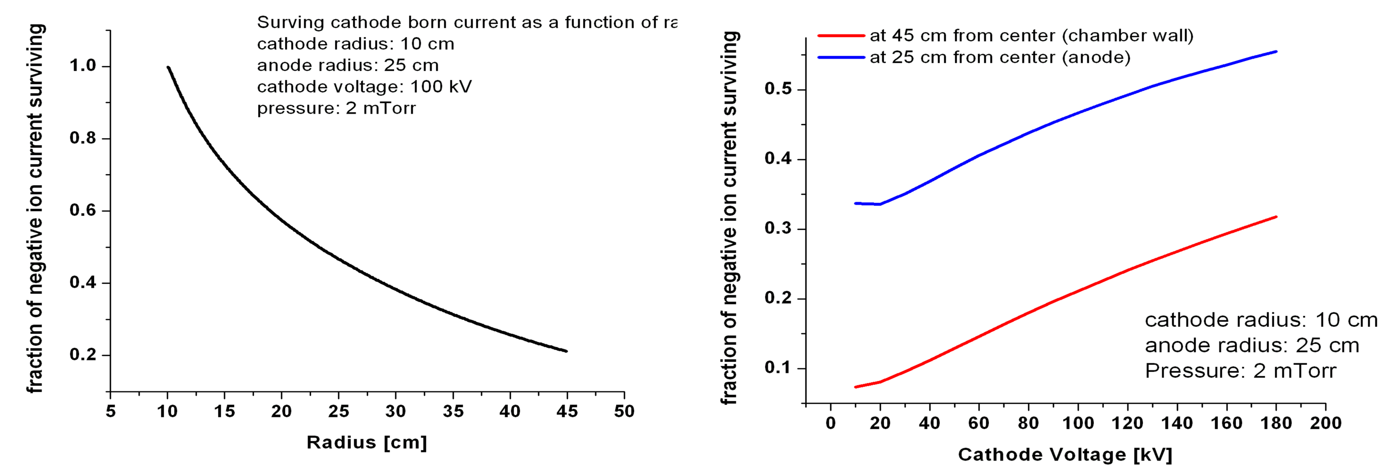


By bending negative ion current through a magnetic field the current is spread into a spectrum according to the energy/mass ratio. The resulting spectrum at 100 kV on the cathode is best fit to the sum of five Gaussian peaks [1].

Negative Ion from Core Attenuation Simulation

It is possible to model the attenuation of negative ion current born from electron attachment in the IEC cathode as it travels out, as the radial dependence of kinetic energy for these negative ions is the difference between the cathode potential and vacuum potential,

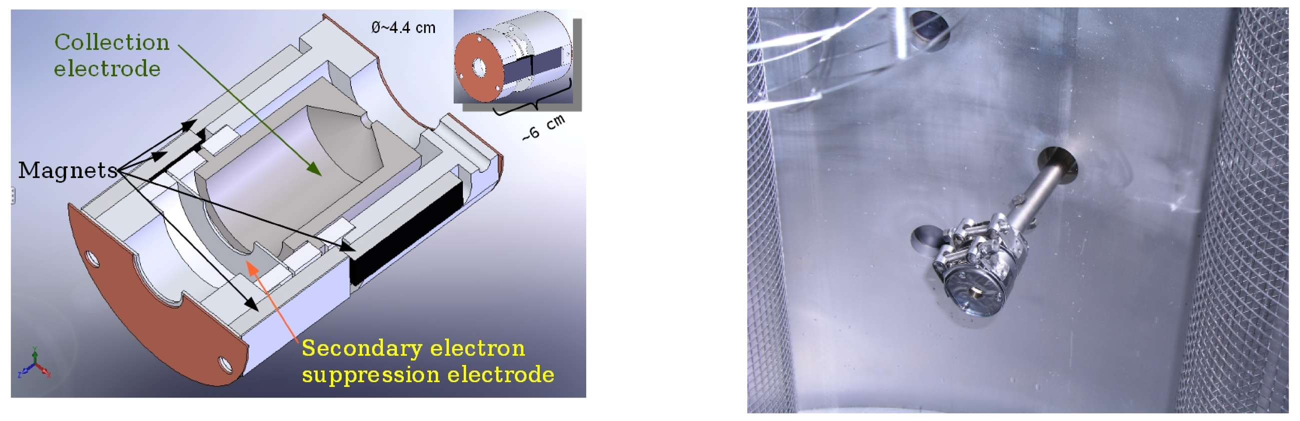
Results



Simulation of attenuation of negative ion current born from electron attachment leaving cathode. System simulated was 20-50 cathode-anode diameter, at 100 kV on the cathode, 2 mTorr.

The model results show that ~80% of the negative ions leaving the cathode are attenuated before the reach the wall to be measured.
A cathode voltage parametric show how the negative ion attenuation responds at an anode 15 cm from the cathode, and 20 cm beyond that in a2 mTorr environment

Negative Ion Radial Profile Apparatus

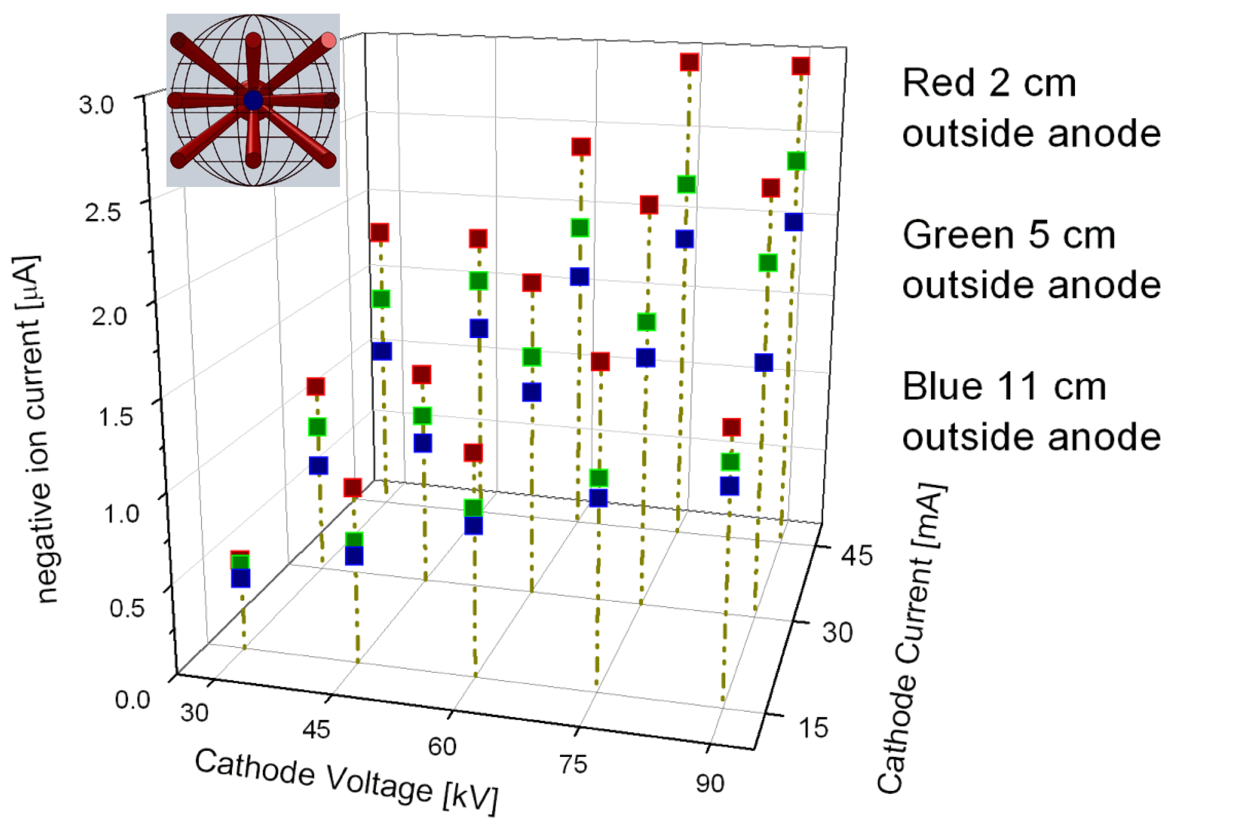


Design and installed enclosed Faraday cup

An enclosed Faraday Cup has been developed to produce negative ion current measurements for parametric studies. The enclosed system is shielded against interference from thermal plasma and energetic electrons, so only energetic negative ions are measured. This Faraday cup can be moved in the region outside the anode to produce radial and longitudinal scans of the negative ion current for profile measurement.

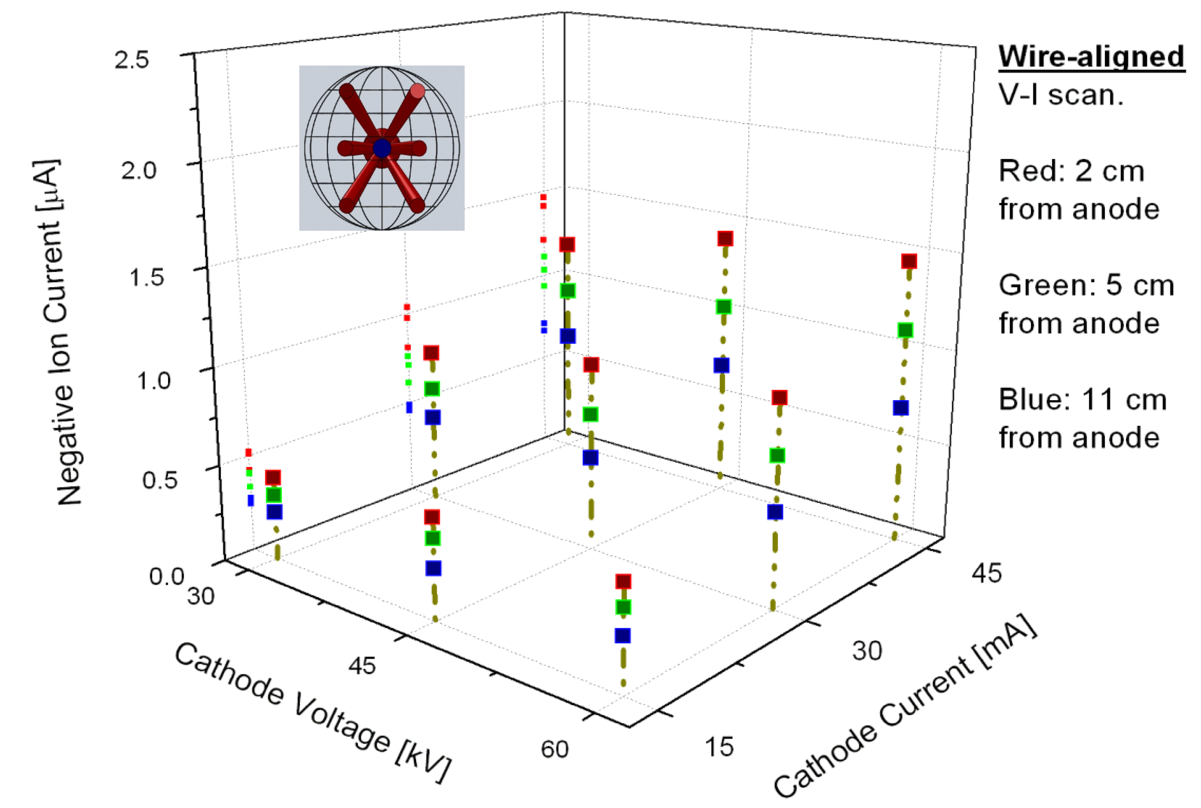
Negative Ions Form a Substantial Fraction of the Ion Current

Negative Ion Current Parametric at Three Radii – Aligned with Hole on Cathode



Results aligned with cathode jet in a system with a 20 cm diameter cathode and 50 cm diameter anode, in 2 mTorr chamber pressure.
The measured negative current continues to increases with voltage and current at 5 cm and 11 cm outside the anode, while at 2 cm outside the observed current plateaus or rolls over above 75 kV on the cathode.

Negative Ion Current Parametric at Three Radii – Aligned with Wire on Cathode



Results aligned with cathode wire (off jet) in a system with a 20 cm diameter cathode and 50 cm diameter anode, in 2 mTorr chamber pressure.
These results show:
the off jet negative ion current is lower than on jet
the measured negative ion current plateaus between 30 and 45 kV on the cathode and behavior is largely the same at all radial observations.

Conclusions:

- The IEC provides a unique environment for the formation and acceleration of negative ions.
- Theoretical studies of negative ion current attenuation show that significant attenuation occurs, but further modeling will clarify creation and attenuation.
- Parametric and profile studies show that observed negative ion current is not only dependent on IEC parameters, but also distance and orientation with respect to the cathode.

[1] D.R. Boris, et al., Phys. Rev. E. 80, 036408 (2009).
[2] G.A. Emmert and J.F. Santarius, Phys. Plasmas 17, 013503 (2010).

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