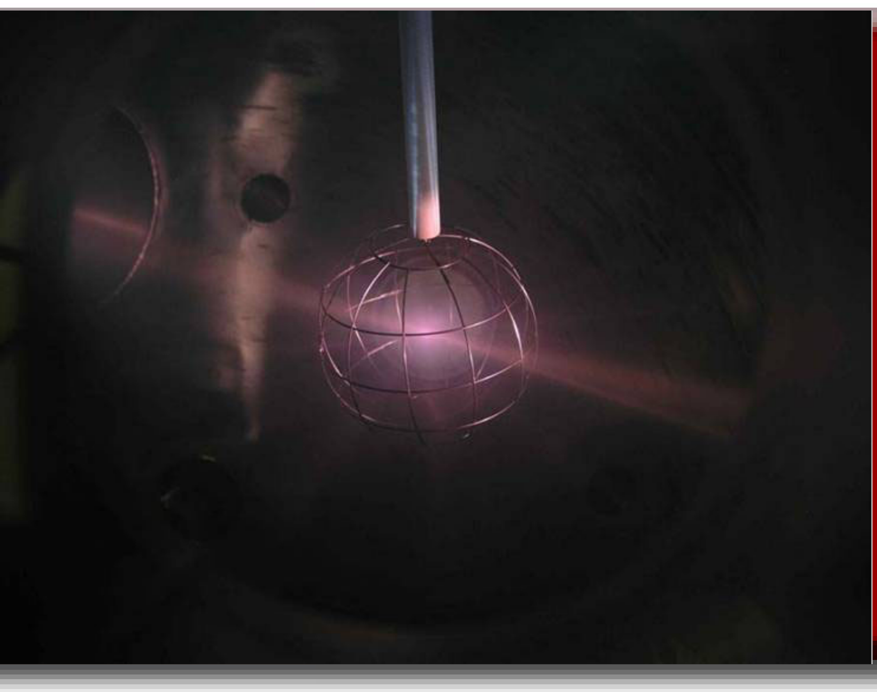

Optimization and Characterization of a Helicon Ion Source on an Inertial Electrostatic Confinement Device for Helium-3 Fusion

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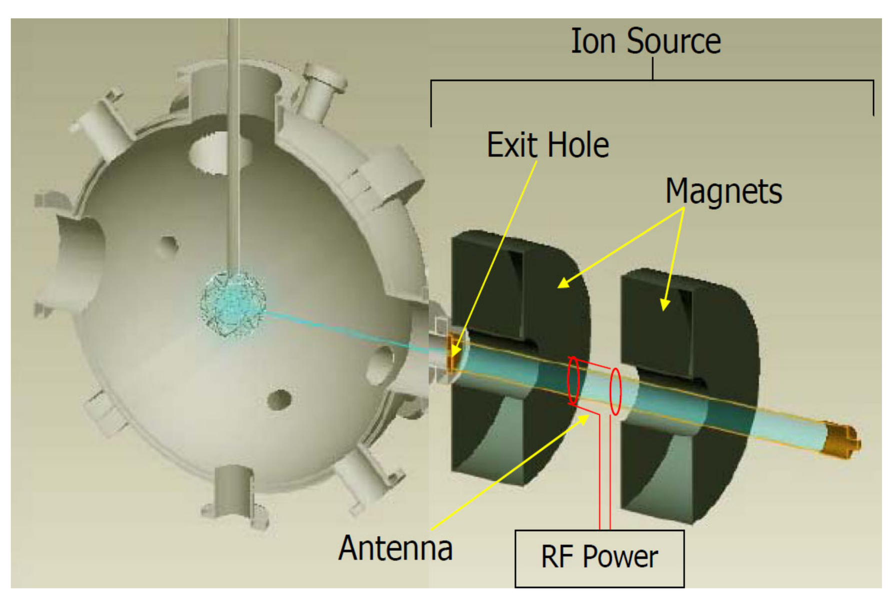
Summary

- The HELIOS inertial electrostatic confinement device is undergoing several upgrades to increase ^{3}He-^{3}He fusion rates to allow for diagnostic studies and benchmarking a numerical code on spherically convergent ion flow.
- The ion source is being optimized to maximize the extractable ion current via magnetic field and rf antenna geometries. A double probe has been constructed as the first step in characterizing the helicon plasma.

Inertial Electrostatic Confinement

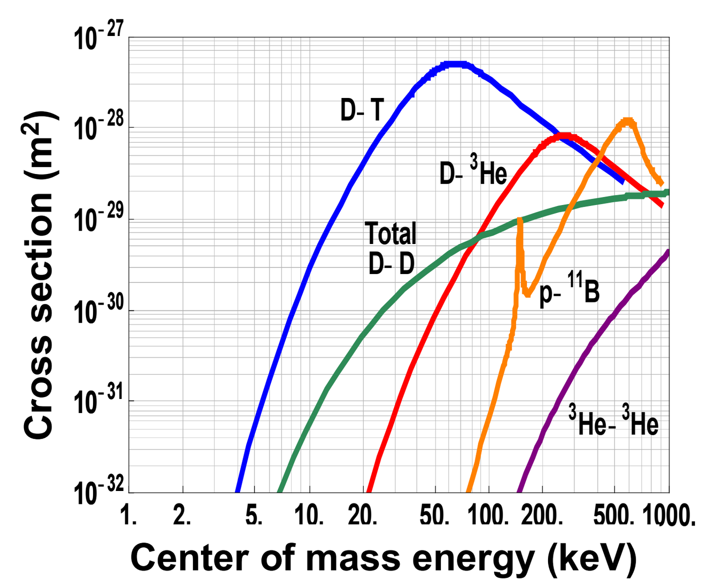
- IEC devices are well suited for studying advanced-fuel fusion reactions requiring higher ion energies, since ions are accelerated directly to fusion-relevant energies.
- Ions are accelerated radially due to the electrostatic field between two concentric electrodes or semi-transparent grids. Atomic and molecular interactions with background neutral gas greatly degrade the ion energy spectrum.



Helium-3 Fusion

Neutron rate per watt of fusion (from fuel only)	
Reaction	Neutrons/s (MeV)
D-T	4×10^{11} (14.1)
D-D	9×10^{11} (2.45)
D-^{3}He	2×10^{10} (2.45)
^{3}He-^{3}He	~0

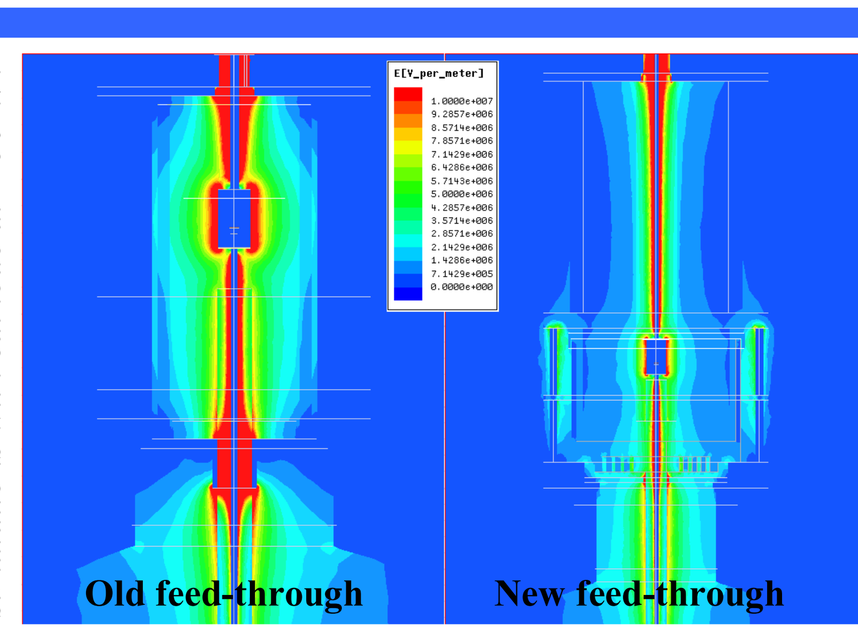
- The ^{3}He(^{3}He,2p)^{4}He reaction produces virtually no high-energy neutrons, plus all nuclei are stable. → very reduced radioactivity levels and material damage to the walls due to neutrons.
- Research of IEC operation with ^{3}He can yield better understanding of the reaction, with relevance to nuclear and solar physics.
- Experiments can benchmark the VICTER code on spherically convergent ion flow in its single-atomic-species formalism [1].



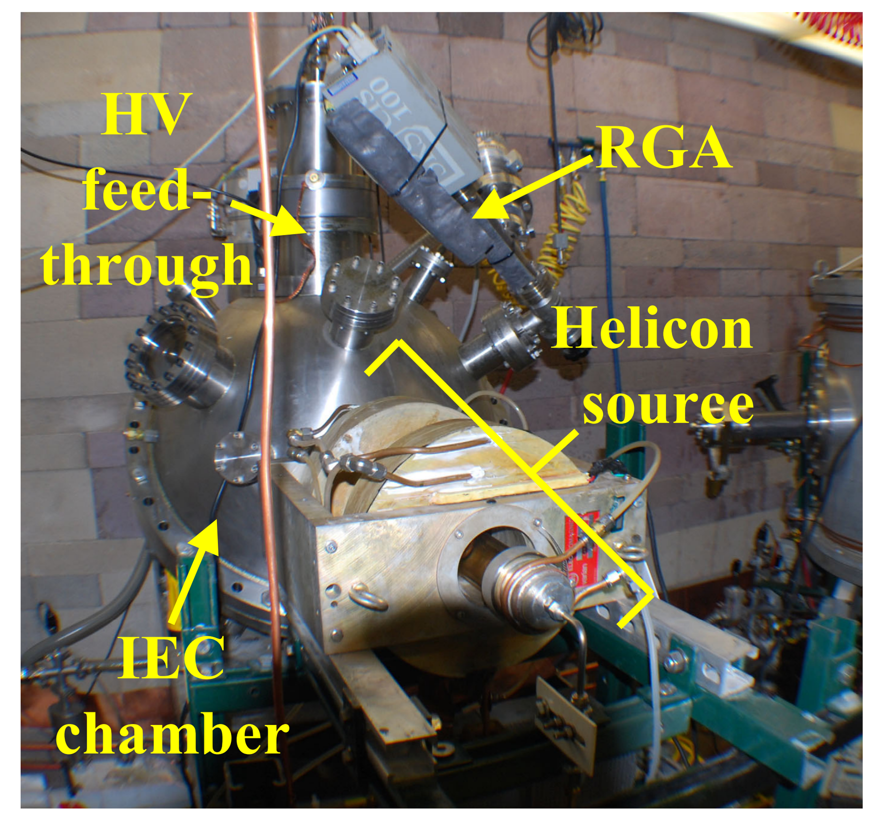
High Voltage

- A new high-voltage feed-through has been designed and built to take advantage of a new 300 kV power supply.
- The new design increases surface paths to ground by using non-conducting materials, significantly reducing electric fields, particularly near the vacuum interface, where stalk failures typically happen.

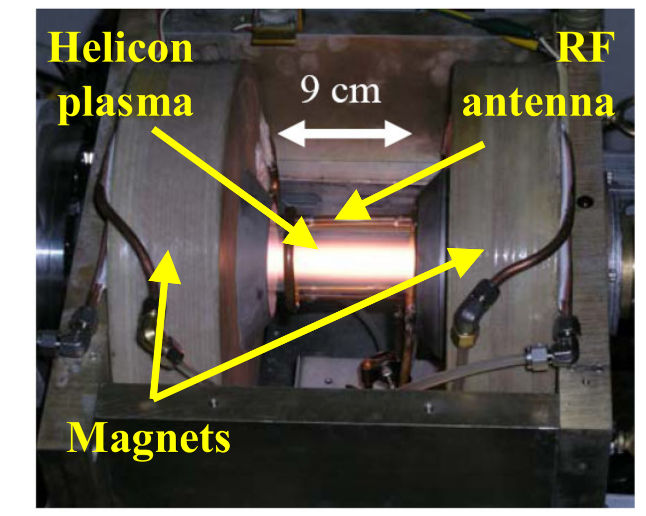
Ansoft Maxwell vacuum electrostatic simulations with cathode at -250 kV.



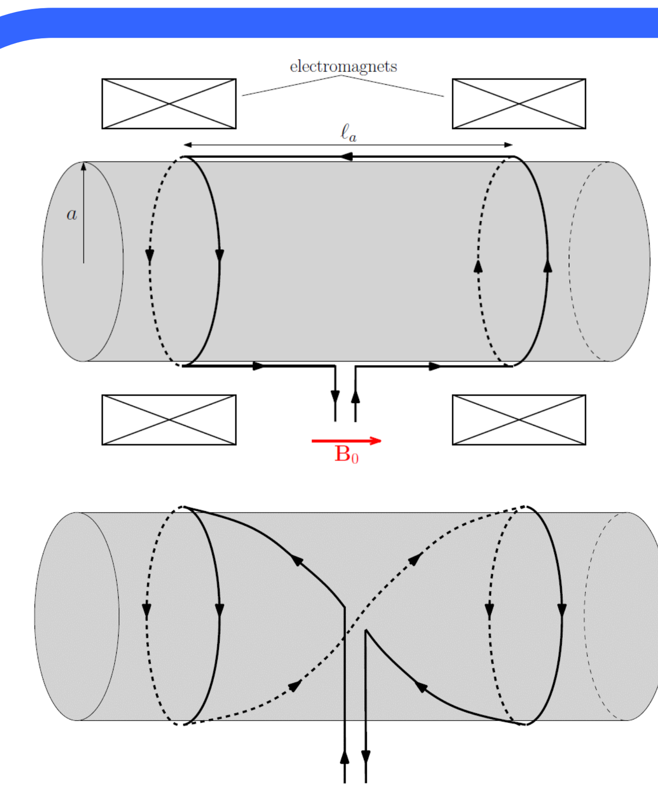
Experimental Setup: the HELIOS IEC Device



- HELIOS is a spherical IEC device with an external helicon ion source, allowing for lower background pressure in the vacuum chamber to minimize the ion energy spectrum softening by charge-exchange reactions with neutrals.
- HELIOS was built specifically for helium-3 experiments, with a record fusion rate of ~10^3 reactions/s at -134 kV cathode voltage and 7 mA ion current [2], too low for diagnostic investigations of reactant ion energy distributions and spatial profiles of fusion events.
- A campaign is underway to enhance the ion current extracted from the helicon ion source, as well as the high/voltage capabilities of the system.

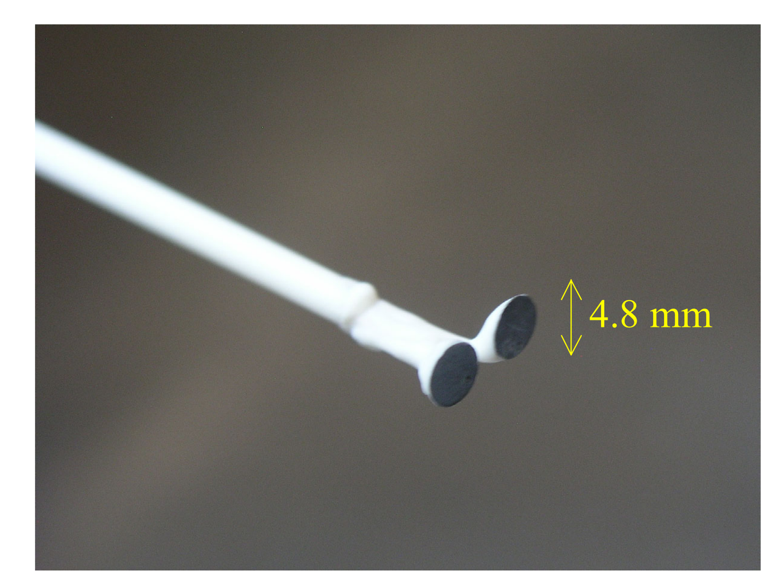


Helicon Ion Source



- The main way of increasing the extractable ion current (emission-limited to the Bohm current $I_B \sim n_0 T_e^{1/2}$) is to make a denser plasma. Plasma densities in helicon sources can be increased by over 50% by changing the rf antenna from a Nagoya type III to a twisted Nagoya geometry [3].

- An additional factor of 3-4 can be achieved by applying a non-uniform magnetic field instead of a uniform axial one [4]. These modifications will be tested in the near future to increase the extractable ion current.
- The discharge chamber has been upgraded to include a quartz-to-molybdenum seal, in order to avoid o-rings and a ceramic heat shield and decrease impurity levels, which is crucial for helium plasmas.
- Proper measurements of n_0 and T_e are important because they would confirm any progress in increasing these parameters and would give information on the plasma parameters for designing a new extraction system, currently a single grounded electrode with an aperture only.
- Previous attempts at characterizing this source with helium have not been successful. A spectroscopic study based on a collisional-radiative model [5], which was only valid for hydrogen and low power levels, which yielded $n_0 \sim 3$–7×10^{11} cm^{-3} and $T_e \sim 4$–6 eV for up to 1.5 kW rf power and 1.2 kG magnetic field.
- An effort is taking place to characterize the plasma with a double probe, due to its intrinsic compensation for rf oscillations and its decreased heat load relative to a single Langmuir probe.



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