Overview of University of Wisconsin Inertial-Electrostatic Confinement Fusion Research

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Fusion Technology Institute, University of Wisconsin

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Objectives of UW IEC Research

1. Optimize fusion reaction rate in an IEC device:
   a. 14.7 MeV protons from D-^{3}He, and
   b. 2.45 MeV neutrons from D-D.
2. Use fusion-product protons and neutrons for industrial applications, such as:
   a. creating radioisotopes for nuclear medicine, and
   b. detecting clandestine materials.
3. Understand and optimize gridded IEC device physics and engineering.

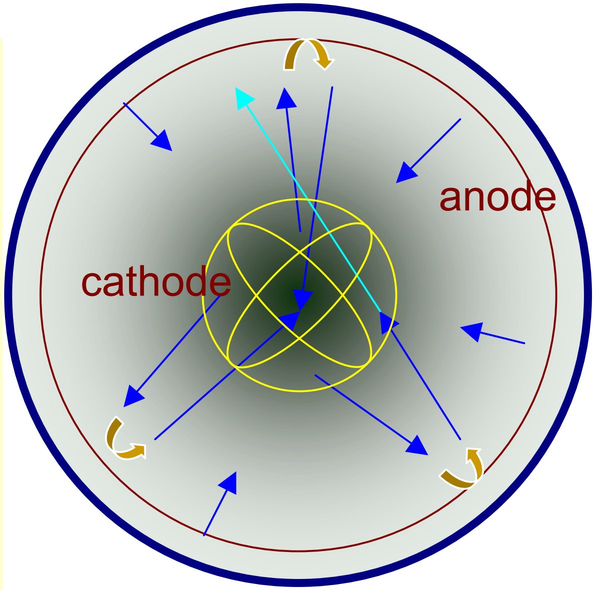
FESAC Non-Electric Applications Panel Recommended Investigating Near-Term Applications

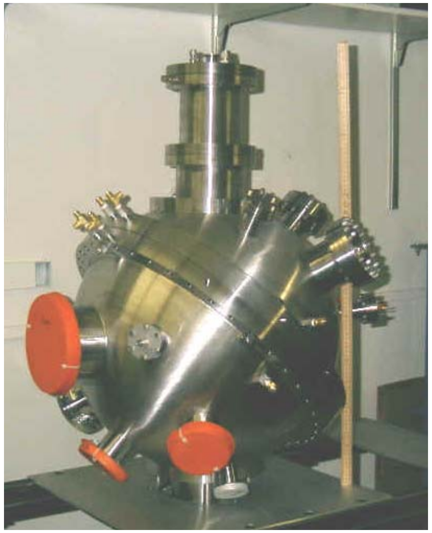
"The DOE-OFES should identify a small, but steady, source of funding to specifically look at near-term applications that are not related to electricity production."

Non-Electric Applications of Fusion
Final Report to FESAC
July 31, 2003

Inertial-Electrostatic Fusion Depends on Creation of a Radial Electrostatic Well and Spherically (or Cylindrically) Convergent Ion Flow

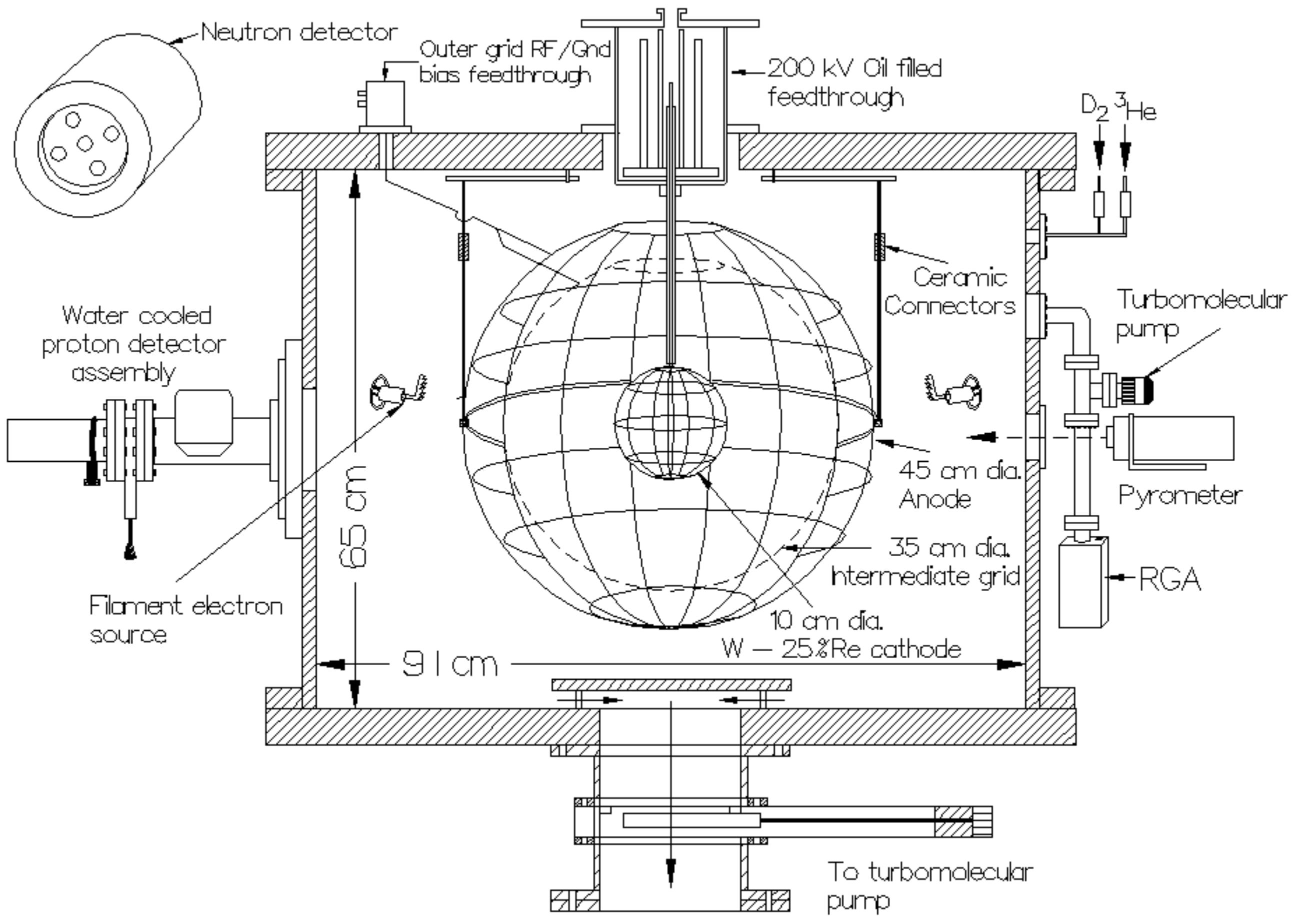
1. Inner grid (cathode) is biased to a high negative potential.
2. Fuel gas flows into the chamber and pressure is maintained.
3. Positive ions are created around the outer grid (anode).
4. Ions accelerate toward inner grid, gaining fusion-relevant energies.
5. Ions and electrons ionize neutral gas.





5. Ions charge-exchange with neutrals, fuse with other ions or neutrals, or hit grids.
6. Charge-exchange neutrals fuse with background gas.
7. Particle detectors monitor reaction rates.

Present UW Aluminum Chamber Provides a Large Volume Reaction Region

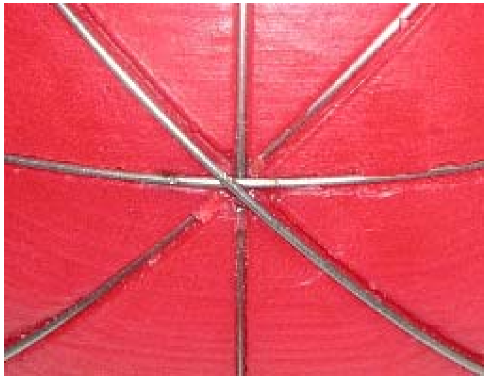


Fabrication System for Standardized Grid

1. Mold produced from rapid prototype model

2. Wax poured into mold

3. Wires wound around wax form

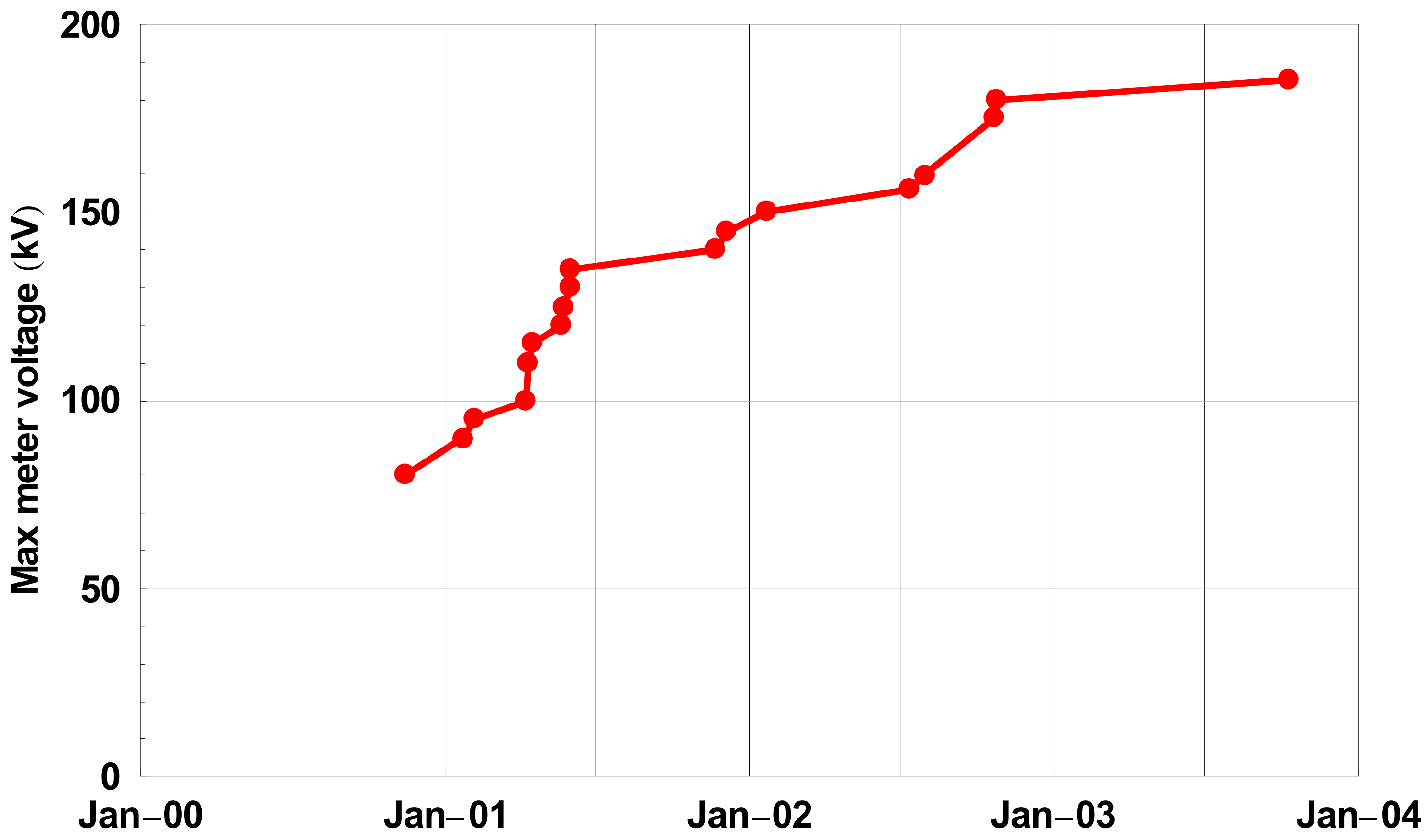


4. Wires spot welded at junctions

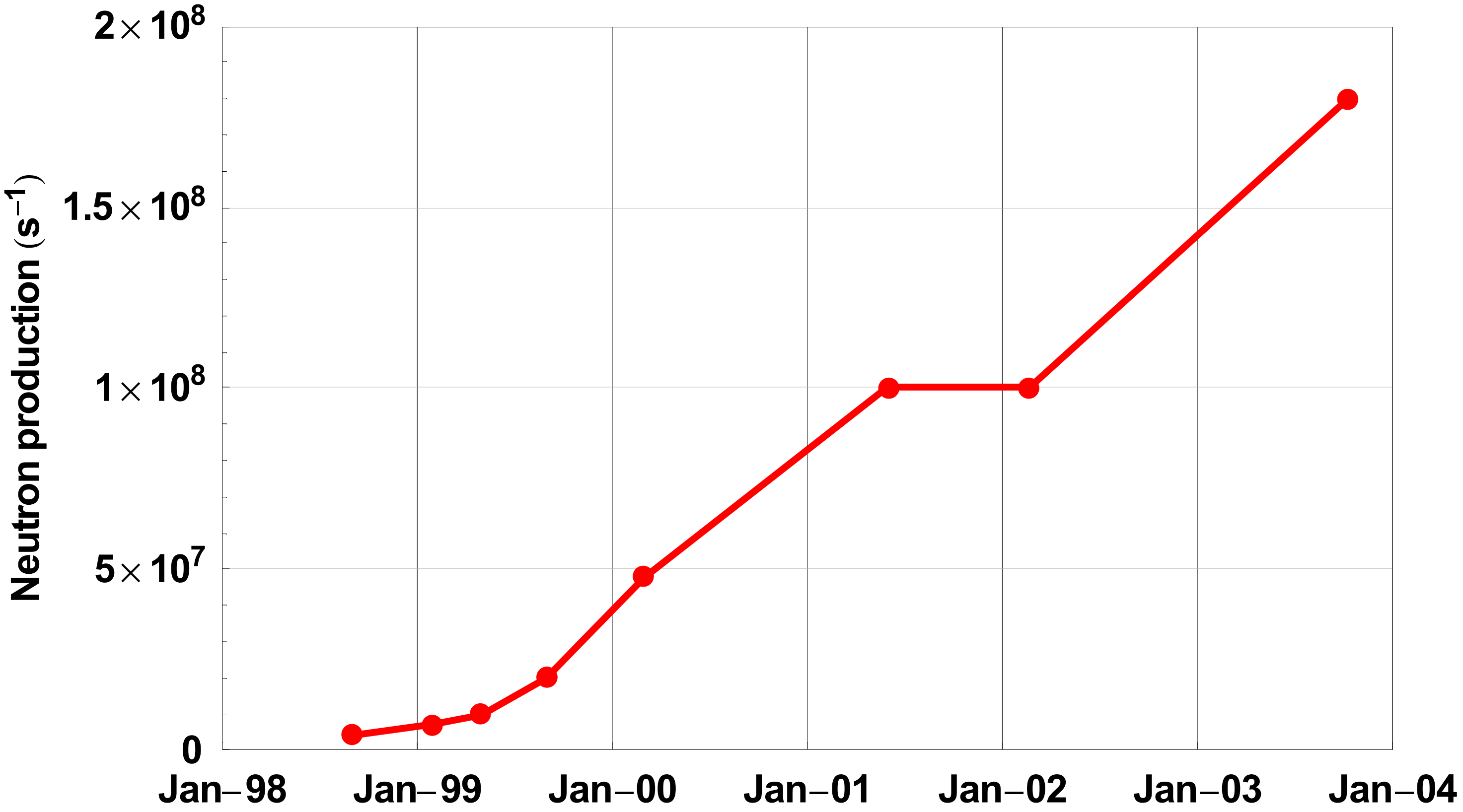
5. Wax form melted away at ~80 °C

6. Finished grid cathode

Significant Progress Has Been Made in Achieving High-Voltage Operation

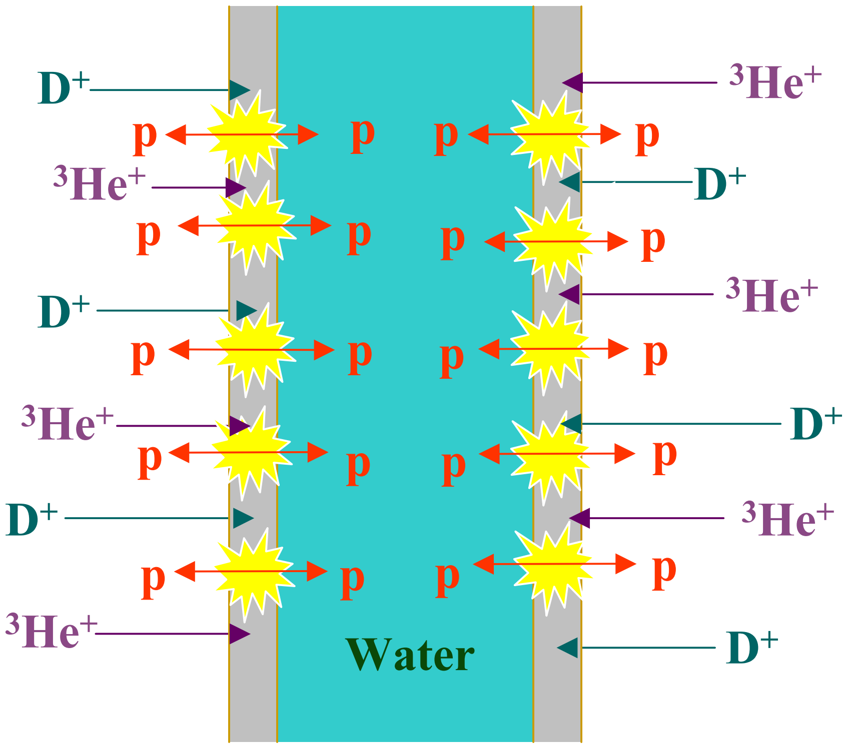


Maximum UW IEC D-D Neutron Production So Far is 1.8×10^8 per Second



- See related poster P-II-25 by Alex Wehmeyer, et al. (Wed afternoon).

D-^{3}He Fusion Protons Can Produce ^{13}N from a Water Target

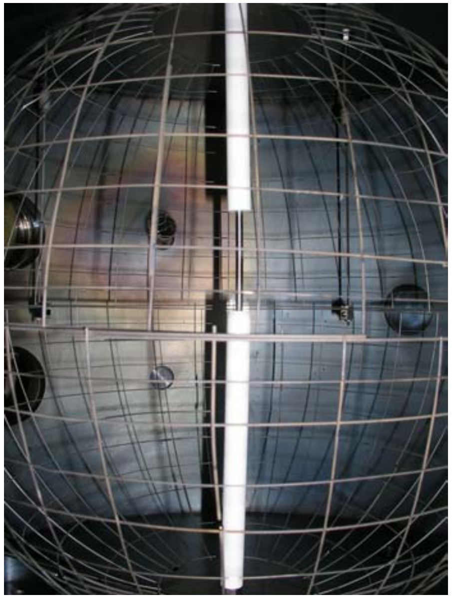


Thin-Walled Stainless Steel Tube

- Replace the cathode with a thin-walled stainless steel tube.
- Embedded fusion occurs in the tube wall:
  $D + {}^{3}He \rightarrow$
  $p\ (14.7\ MeV) + {}^{4}He\ (3.7\ MeV)$
- Half of the 14.7 MeV protons travel into the water, creating ^{13}N through the reaction
  $^{16}O(p,\alpha)^{13}N$

PET Isotopes Have Been Created in the UW IEC Device

- On Feb 19, 2003 the PET isotope ^{13}N was made by John Weidner in an IEC device by bombarding water in thin SS tubes with D-^{3}He protons born in the central cathode region.
  - J. Weidner, et al., *FS&T* **44**, 539 (2003).
- On June 13, 2003 the PET isotope ^{13}N was made by Ben Cipiti in an IEC device by bombarding water in a thin SS tube (acting as a cathode) with D-^{3}He protons born in the cathode.
- See poster P-II-15 by Ben Cipiti (Wed afternoon).



Fast He Ions Can Produce Significant Damage in Materials

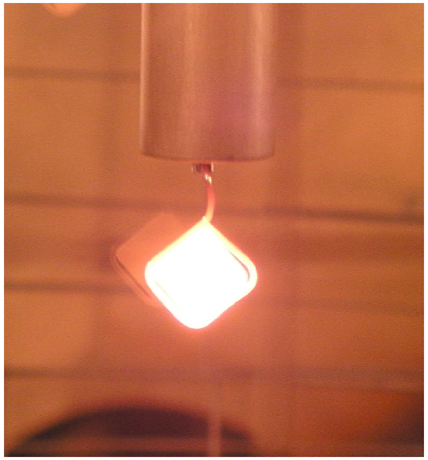
Wire grid cathode was replaced by a sample target.

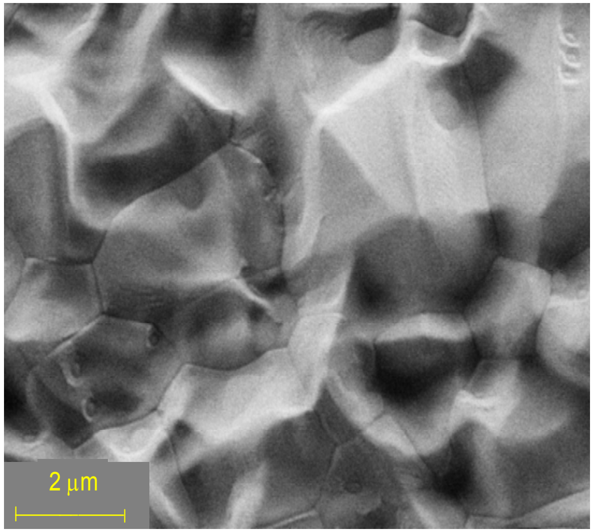
Deuterium bombardment did little damage.

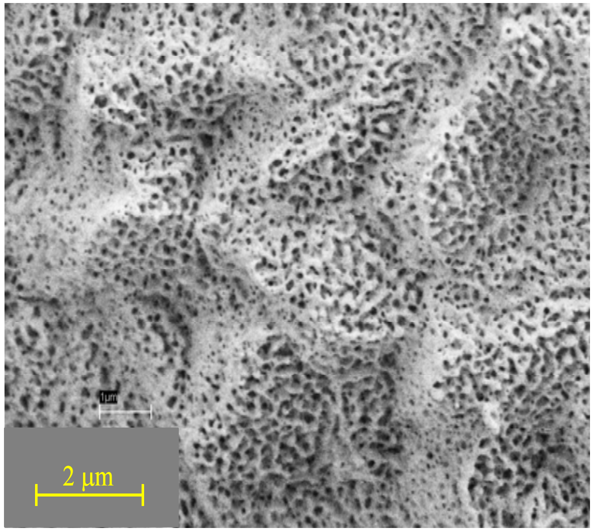
TaC irradiated at 830 °C with >6x10^{17} D/cm^2.

Helium bombardment did significant damage.

HfC irradiated at 775 °C with >6x10^{17} He/cm^2.



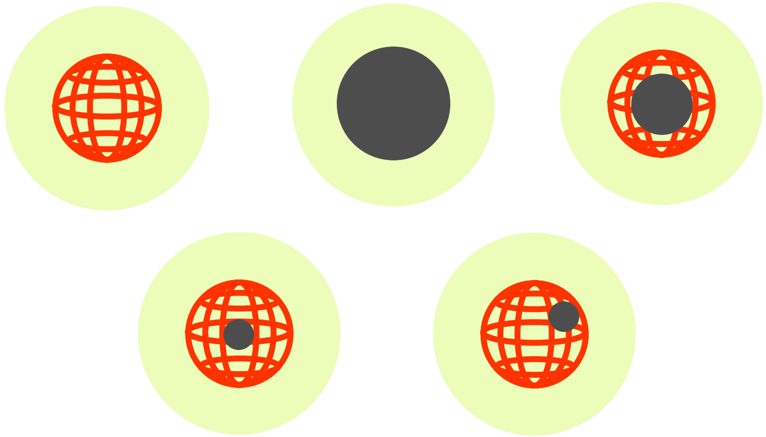




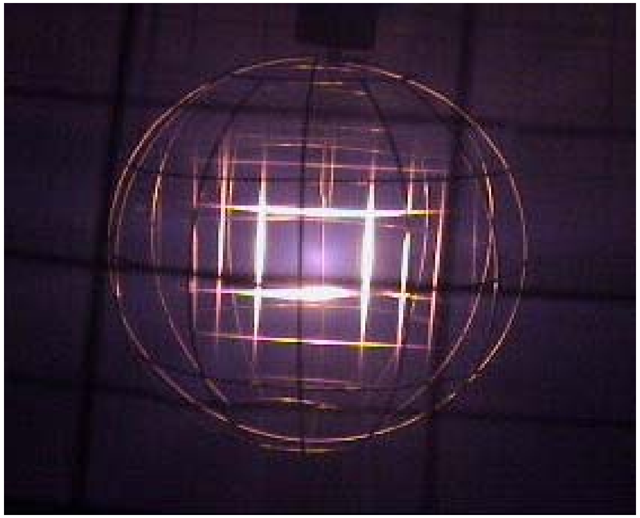
- See poster P-II-24 by Ross Radel, et al. (Wed afternoon) for further info.
- Initial work on W by Ben Cipiti (submitted to J. Nucl. Materials, 2004).

Two New Diagnostics Help Us Analyze the Location of Fusion Reactions and Ion Flow

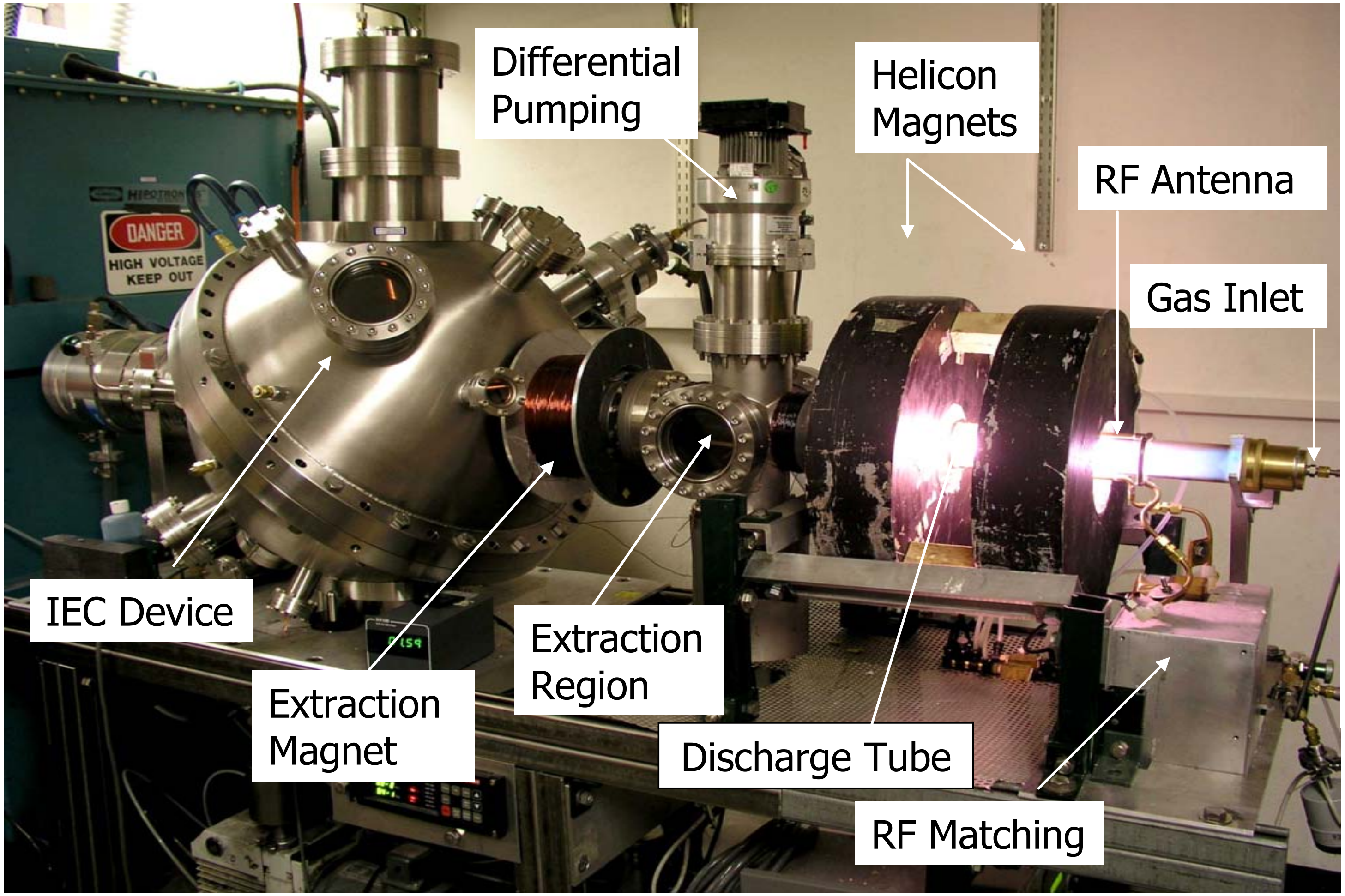
- Eclipse discs block some D-3He protons and shift their energies.
  - Bob Ashley, S. Krupakar Murali, Ben Cipiti
  - See R.P. Ashley, et al., *FS&T* **44**, 539 (2003).



- Chordwires use power balance to analyze ion flows.
  - S. Krupakar Murali (UW dissertation, 2004)



Helicon Ion Source Operating with UW's Spherical IEC Chamber



- See poster P-II-27 by Greg Piefer, et al. (Wed afternoon).

Summary

- UW IEC experiments have made significant progress in
  1) producing the PET-scan radioisotope ^{13}N,
  2) investigating ion damage to first-wall materials,
  3) optimizing neutron production for detecting clandestine materials,
  4) creating a helicon ion source,
  5) developing IEC diagnostics, and
  6) fabricating high-voltage grids and stalks.
- For further information, see http://fti.neep.wisc.edu/research/iec.html and TOFE 2004 posters P-II-15, 24, 25, and 27.