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Comparison of Spherical and Cylindrical Geometries in Inertial Electrostatic Confinement Devices

Brian J. Egle

John F. Santarius, Gerald L. Kulcinski

Fusion Technology Institute – University of Wisconsin-Madison

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WISCONSIN IEC ^{3}HeCTRE

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Overview

Objectives

- Compare the newly constructed 3rd UW Inertial Electrostatic Confinement (IEC) device to UW's original IEC device
- Investigate performance differences between spherical and cylindrical geometries
- Develop a simple and fast modeling technique to estimate the relative performances of various designs

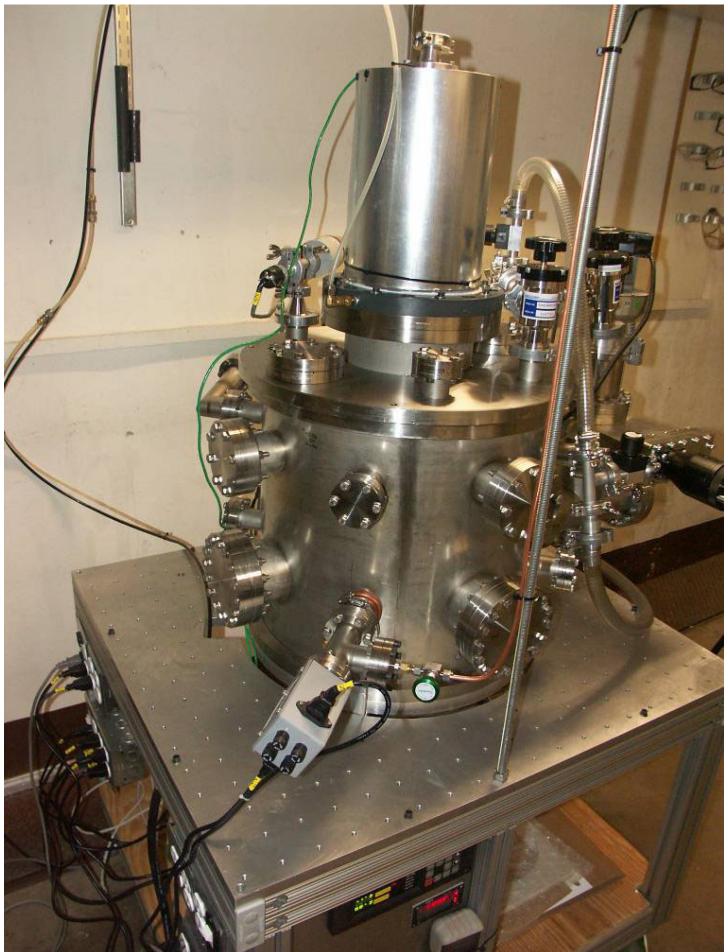
Overview

Outline

- New chamber construction
- Reaction rate comparison to the original IEC
- Modeling technique
- Experimental results compared to modeling
- Discussion

New Chamber Construction

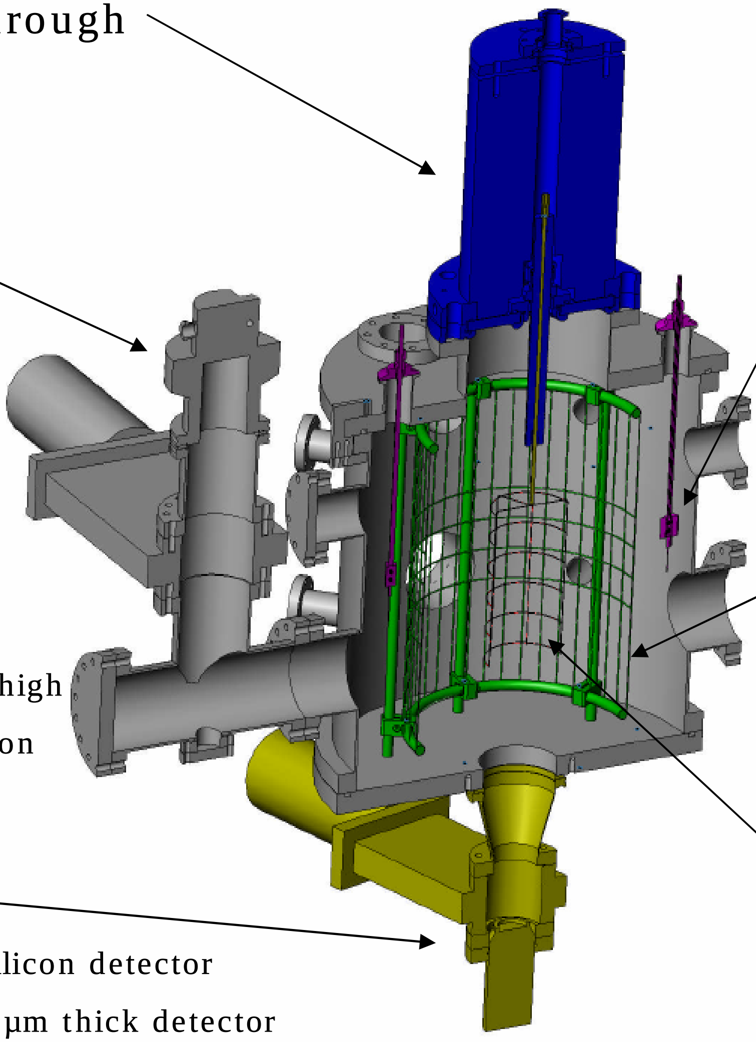
Helium-3 Cylindrical Transmutation Reactor → ^{3}HeCTRE



Goals of ^{3}HeCTRE

- Cylindrical geometry experiments
- Medical isotope production experiments

Features of ^{3}HeCTRE



High Voltage Feed Through

- Tested to -150 kV

Vacuum System

- 250 liters/sec turbo-molecular pump
- Base Pressure 2×10^{-4} Pa (1.5×10^{-6} Torr)

Main Chamber

- 75 liters
- 46 cm diameter x 46 cm high
- Stainless steel construction

Proton Detector

- Ortec Ultra 1200 mm^2 silicon detector
- 400 µm of lead foil, 700 µm thick detector
- 44.8 cm from center of chamber

Ion Source

- Tungsten light bulb filaments
- 4 filaments (maximum of 6) 60° apart around perimeter of Chamber
- Adjustable along Z-axis, currently aligned with the midpoint of the chamber and cathode

Anode

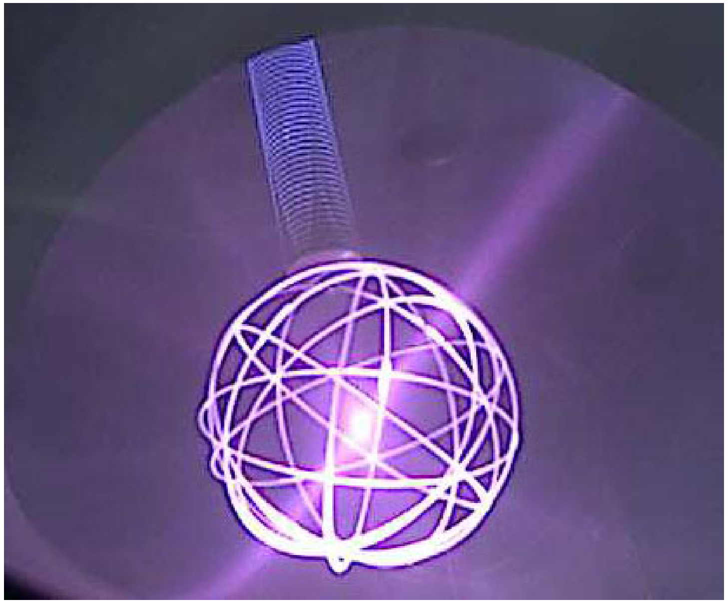
- Cylindrical
- 27 cm diameter x 38 cm high
- Stainless steel wire mesh

Cathode

- Tungsten-Rhenium wire
- Shown: 10 cm diameter by 19 cm high cylindrical

New Chamber Construction

Milestones



- Began construction July 2005
- First D-D reactions April 2006
- Best neutron rate as of Oct 18, 2006
  2.7×10^{7} neutrons/sec at 145 kV,
  35 mA, and 0.3 Pa (2 mTorr)
- First D-^{3}He reactions Oct 18, 2006
- Best proton rate as of Oct 27, 2006
  2.0×10^{7} protons/sec at 130 kV,
  30 mA and 0.3 Pa (2 mTorr)

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Cathode/Anode Geometries

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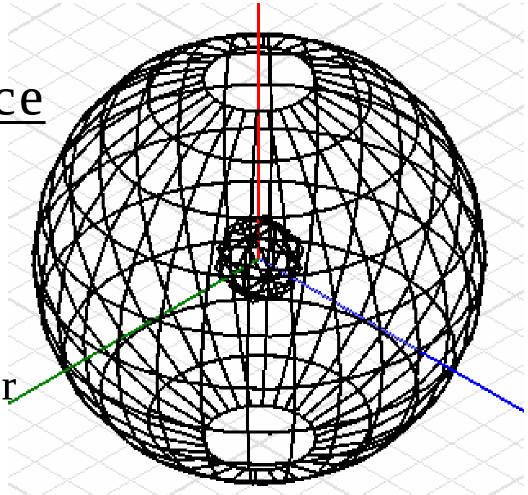
1st UW-IEC Device

Chamber Details

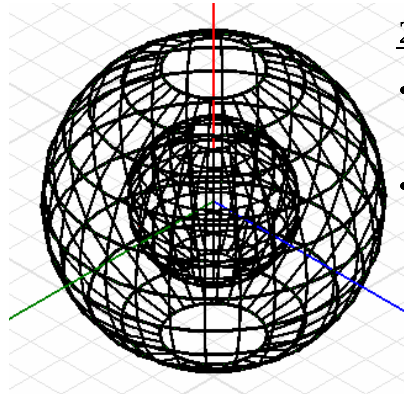
- 470 liter volume
- 95 cm diameter x 66 cm high chamber
- Aluminum



Baseline of Comparison

10S-50S

- 10 cm Spherical Cathode
- 50 cm Spherical Anode



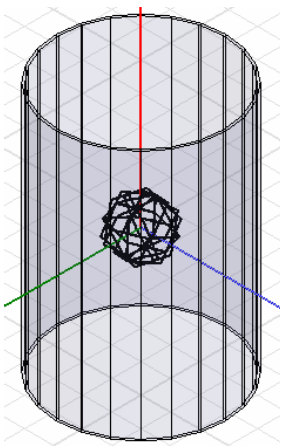
20S-40S

- 20 cm Spherical Cathode
- 40 cm Spherical Anode

^{3}HeCTRE

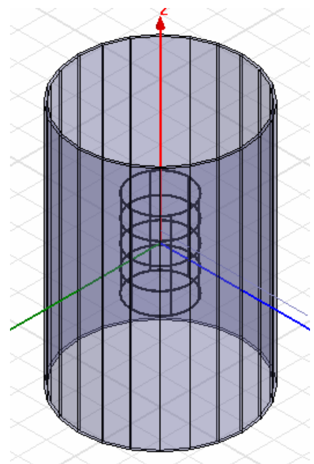
Chamber Details

- 75 liter volume
- 46 cm diameter x 46 cm high chamber
- Stainless Steel



10S-27C

- 10 cm Spherical Cathode
- 27 cm x 43 cm Cylindrical Anode

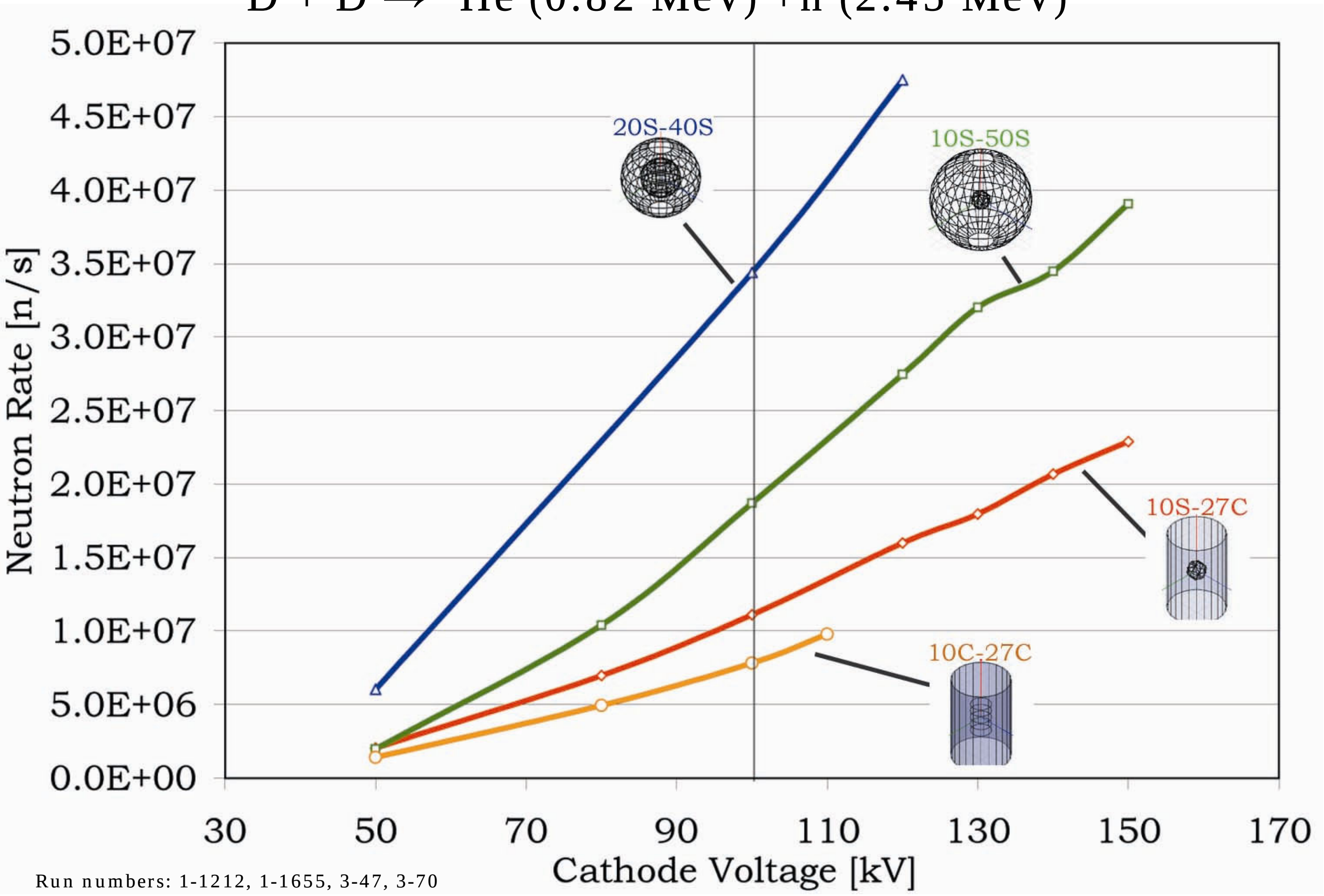


10C-27C

- 10 cm x 19 cm Cylindrical Cathode
- 27 cm x 43 cm Cylindrical Anode

Experimental Results

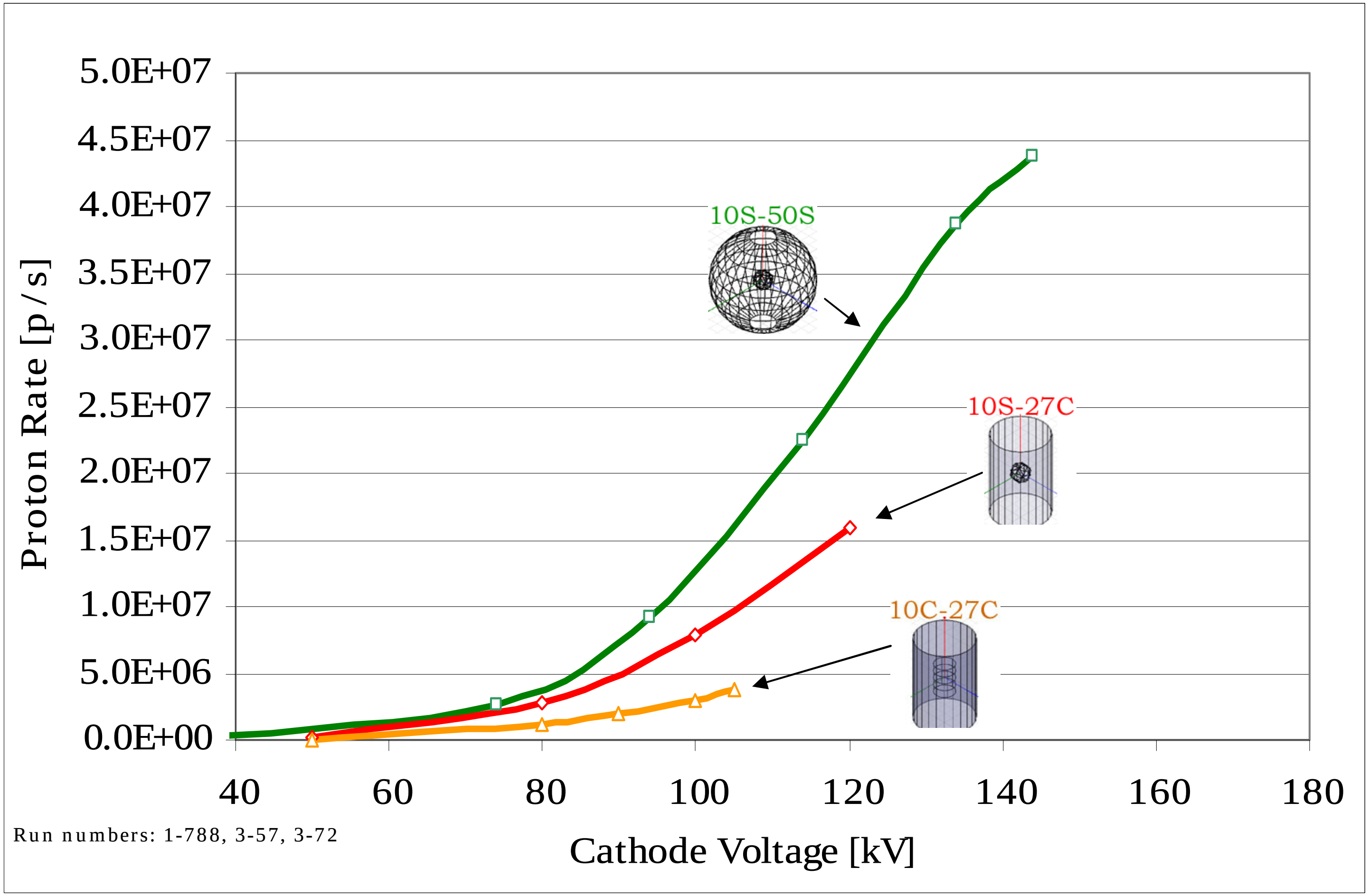
$D + D \rightarrow {}^3He\ (0.82\ MeV) + n\ (2.45\ MeV)$



0.3 Pa of D gas, 30 mA meter current, steady state

Experimental Results

$D + {}^3He \rightarrow {}^4He\ (3.7\ MeV) + p\ (14.7\ MeV)$



0.3 Pa of D and ^3He gas mixture, 30 mA meter current, steady state

Modeling Technique

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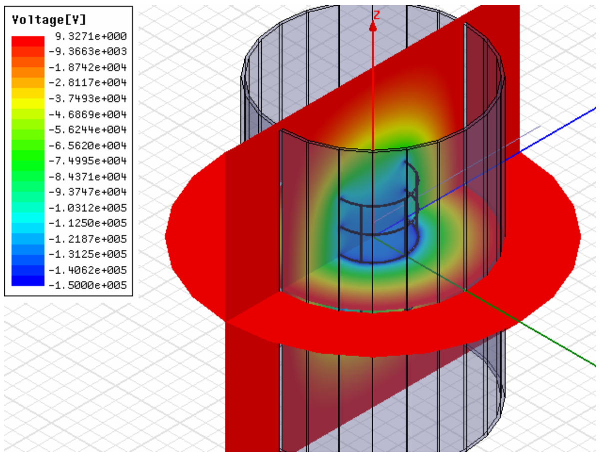
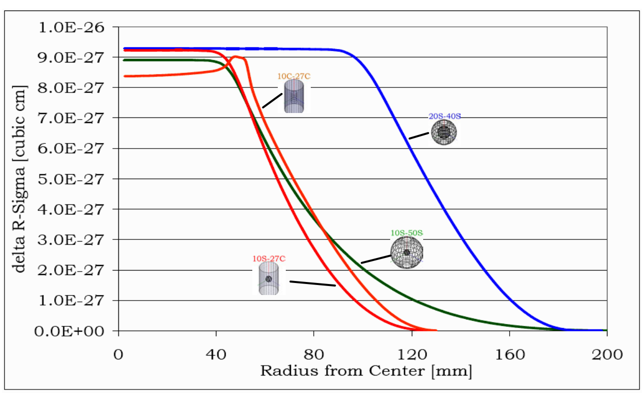




Purpose of Model

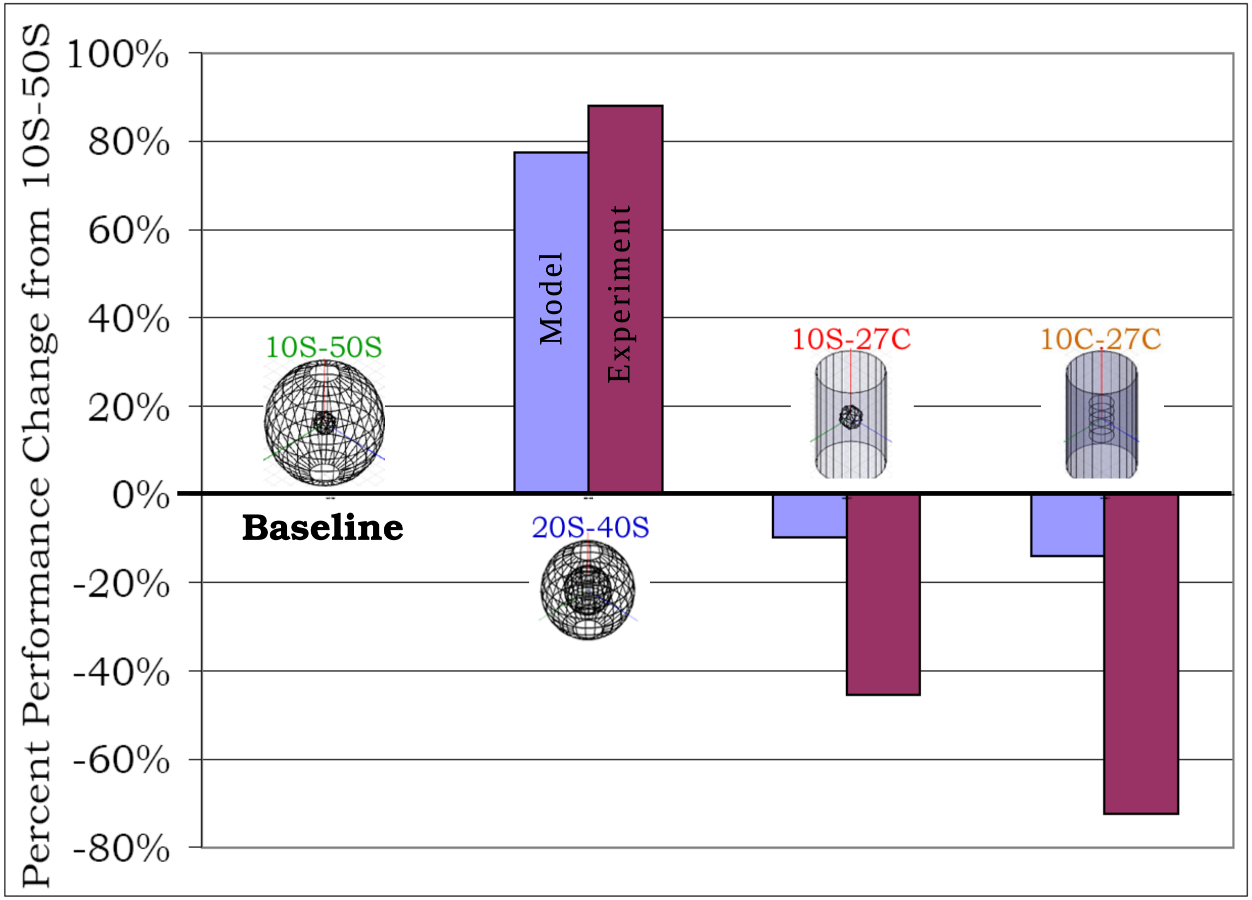
- To optimize new cathode-anode designs before investing significant time into experimentation and advanced modeling techniques

Modeling Method

- The vacuum electrical potential was found as a function of radius along the X-axis using Maxwell 3D™
- Fusion cross-sections, σ[v(r)], were calculated for individually shells of width Δr using the vacuum potential and the center of mass energy
- The relative performance of each design was predicted by the sum of Δr * σ[v(r)] for each shell

Comparison of Model to Experimental Performance

D + D → ^{3}He (0.82 MeV) +n (2.45 MeV)



0.3 Pa of D gas, 30 mA meter current, steady state

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Conclusions

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D-D and D-^{3}He reactions have been observed in the newly constructed cylindrical IEC Chamber

Best D-D rate at 145 kV, 35 mA, 0.3 Pa

2.7x10^{7} neutrons / sec

Best D-^{3}He rate at 130 kV, 30mA, 0.3 Pa

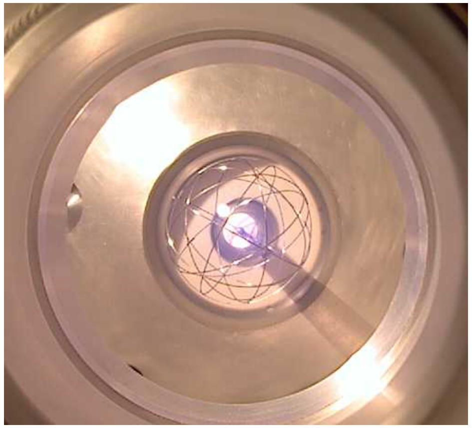
2.0x10^{7} protons / sec

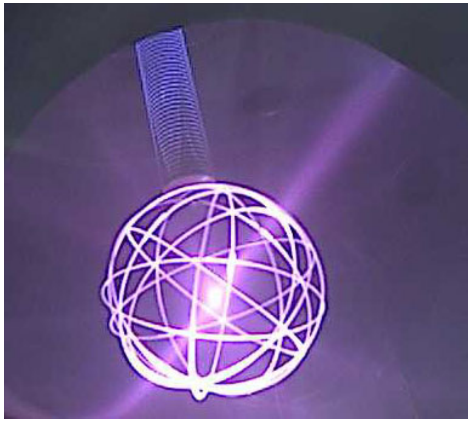
Conclusions

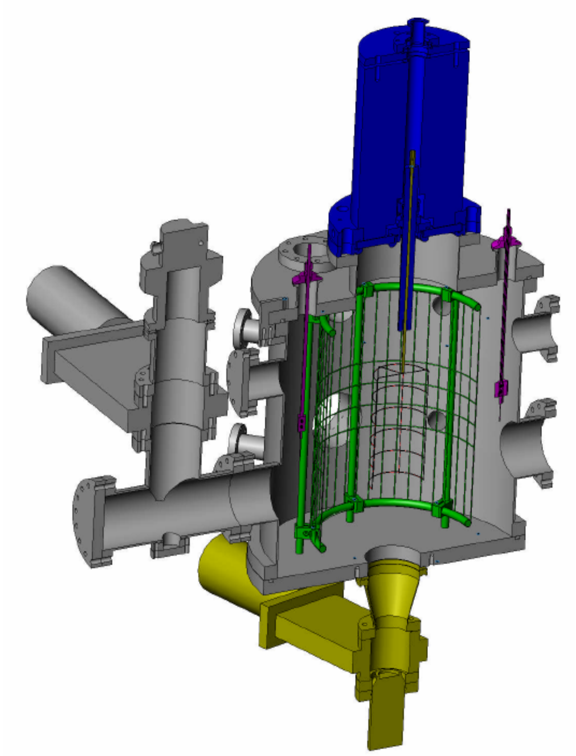
At this early stage of experimentation, D-D and D-^{3}He reaction rates are lower in ^{3}HeCTRE than in the original UW IEC chamber.

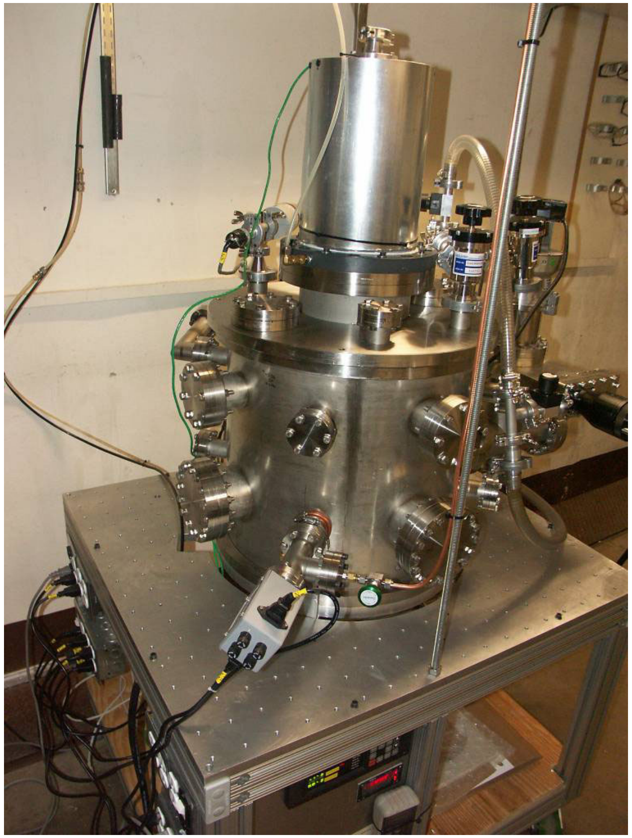
Further experimental work is required to optimize ^{3}HeCTRE to the same performance levels as the previous chamber

Questions?







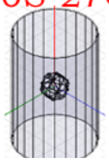


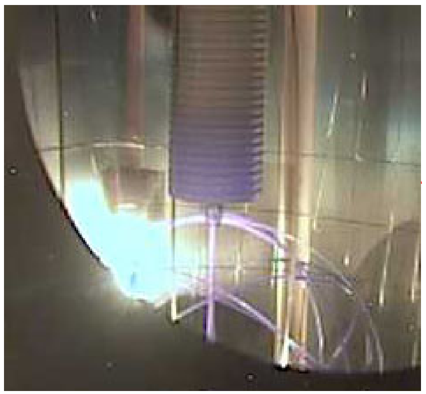
Brian J. Egle
egle@wisc.edu

Additional Slides

Observations

10S-27C





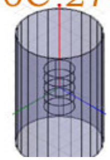
With Filaments
120kV 30mA

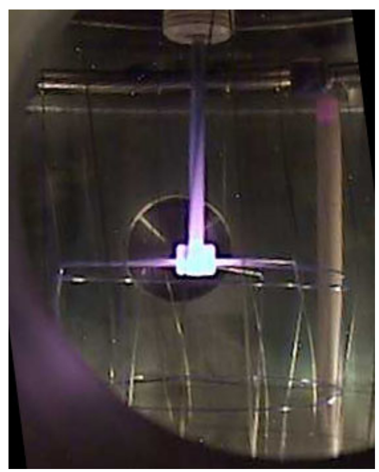
Glow Discharge Mode

Asymmetric heating of cathodes along Z-axis of ^{3}HeCTRE

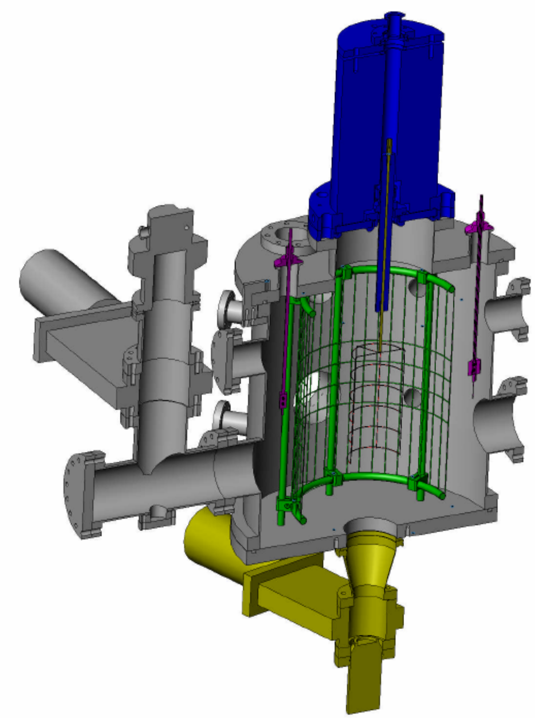
- May indicate ion-electron channeling along the z-axis of the anode

10C-27C





With Filaments
80kV 30mA

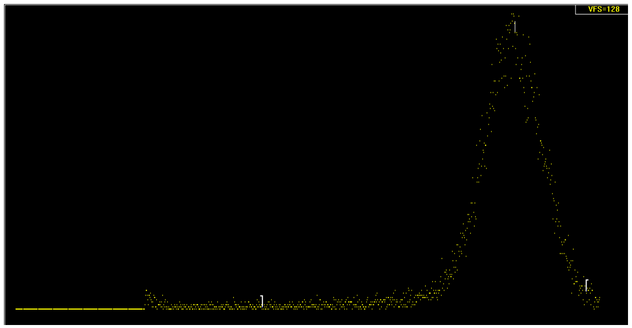


Model Assumptions

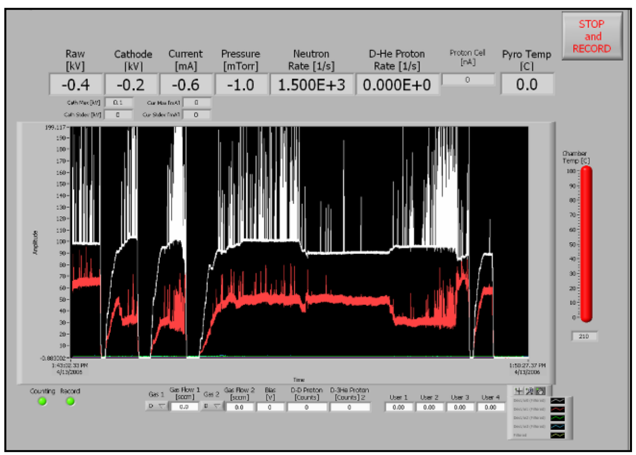
Model Assumptions

- Vacuum fields only – no plasma
- Single value of ion energy equal to electrical potential in each shell. *Does not include the work done at UW by Emmert and Santarius to evaluate the detailed ion energy spectrum*
- Singularly ionized monatomic ions. *Does not include work done by Emmert and Boris that shows the ion source region is mainly* D_3^+
- Beam – stationary target reactions only

Experimental Data



D-^{3}He Proton Spectrum 10/23/06



LabView Operation Screen

- Data Collection
  - Operation conditions and neutron and proton counts are digitally recorded using LabView™
  - Neutron and proton counts are also monitor using MCA software to control noise
- Experimental conditions
  - -50 to -150kV cathode voltage
  - 30mA total current through cathode
  - 0.3Pa (2mTorr) background pressure of Deuterium and/or Helium-3 gas