Recent Progress in Steady State Fusion Using D-^{3}He

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ABSTRACT

The University of Wisconsin (UW) inertial electrostatic confinement (IEC) facility has made significant progress since 2000. The operating voltage has doubled to 160 kV. The neutron production rate has increased by a factor of 2, from 4.9 x 10^7/s to 1.1 x 10^8 s^{-1}. The D-^{3}He proton production rate has increased by, a factor of over 40. In addition new diagnostics have been developed, including a method to determine the spatial distribution of fusion reactions A new water cooled stainless steel chamber for higher power and lower pressure has been put into operation. Medical isotopes have been produced in an IEC device for the first time.

INTRODUCTION

The IEC device relies on the potential difference between the inner and outer grid to produce energies necessary to produce fusion reactions.[1,2] The cross sections for advanced fuels, e.g., D-^{3}He, require voltages of at least 100 kV in order to produce significant rates. Therefore, substantial effort was made to increase the operational voltage above 150 kV (Figure 1). A 200 kV power supply capable of 70 mA output was put into operation. This required a new high voltage cathode support design utilizing boron nitride for the insulator material. An oil filled interface between the 200 kV supply and the chamber was implemented. All these new features contributed to the increase of performance of the UW IEC device.

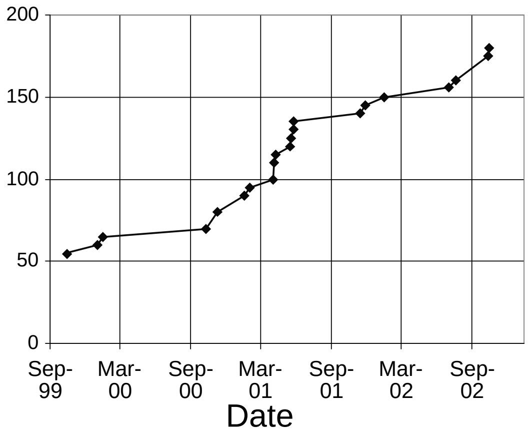

Figure 1. The UW device has tripled the operating voltage in the last three years.

EXPERIMENTAL PROGRESS

The diagnostics currently in use detect the 2.45 MeV neutron from the D-D reaction, the 3 MeV proton from the D-D reaction, and the 14.7 MeV proton from the D-^{3}He reaction.[34] A schematic of the operation of the proton detector is shown in Figure 2. A Si thickness of 700 µm allows both the 3 MeV proton and the 14.7 MeV proton to be detected at the same time. A 25 µm thick lead foil is placed in front of the detector to block x-rays, which create unwanted signals in the detector. Figure 3 shows some typical data from the proton detector, which can detect both the D-D and D-^{3}He protons.

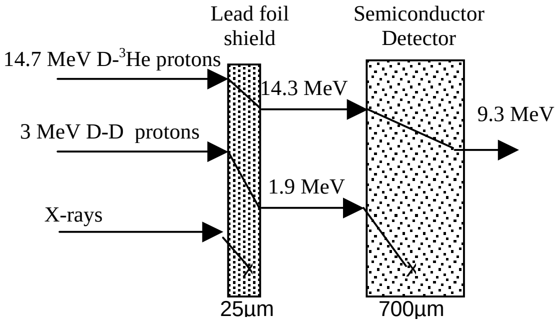

Figure 2. The Si detector used on the UW-IEC device detects the 3 MeV DD protons at 1.9 MeV and the D-^{3}He protons deposit 5 MeV before they exit the detector.

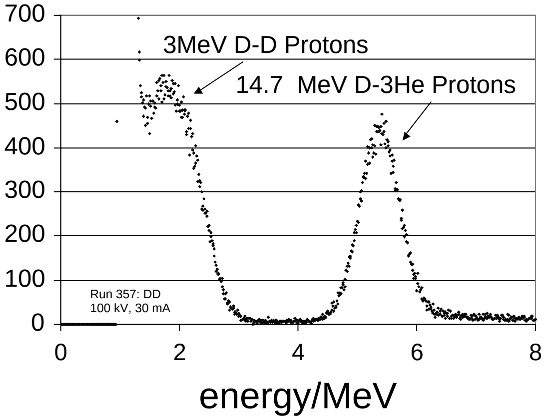

Figure 3. Typical energy spectrum of proton detector counts from D-^{3}He and D-D protons.

The proton production shows a substantial increase with voltage (Figure 4). The progress of proton and neutron production (Figures 5,6) is a direct result of the increased voltage capability of the UW IEC facility.

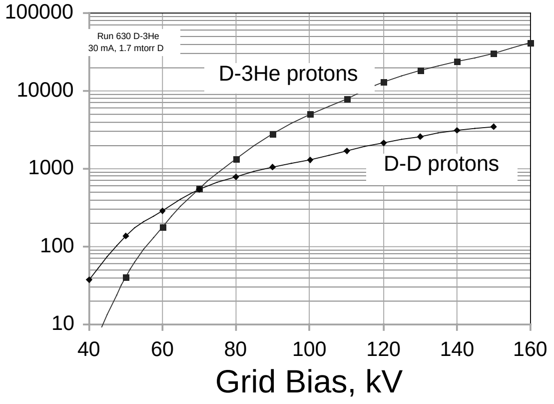

Figure 4: Both the D-^{3}He and D-D fusion reactions increase dramatically with cathode voltage.

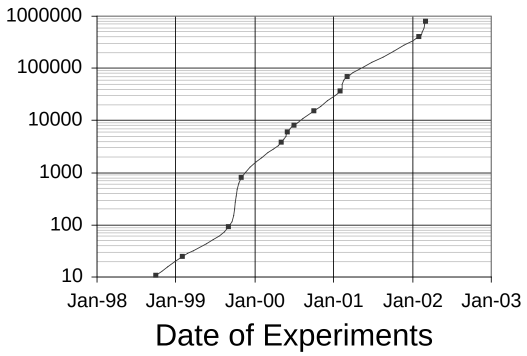

Figure 5. Significant progress in the production of protons in the UW IEC device has occurred over the past four years. Nearly a factor of 10^5 has occurred over that time period.

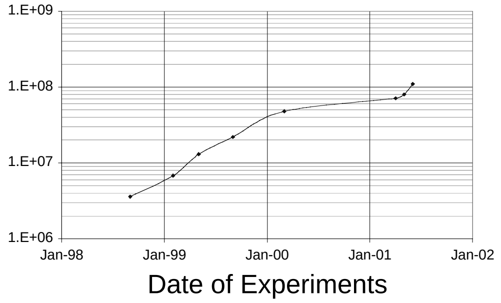

Figure 6. Significant progress in the production of D-D neutron has occurred over the past 3 years with a factor of 30 increase.

FUSION REACTION SPATIAL DISTRIBUTION

A new diagnostic has been developed to determine where the fusion reactions take place inside the chamber. The diagnostic consists of three aluminum discs of different diameters which are placed between the cathode and the proton detector. These eclipse the protons observed by the detector as shown in Figure 7.

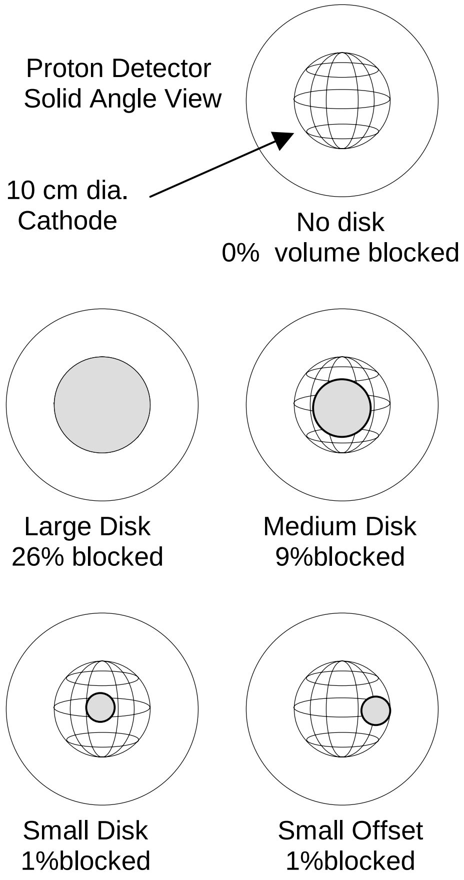

Figure 7. By placing solid discs between the cathode and proton detector, the location of D-^{3}He and D-D reactions can be determined.

The proton detector counts will be reduced when a disk is moved into place. The amount of the count reduction depends on the size of the eclipse disc used and the spatial distribution of fusion reactions. By comparing the percentage of the volume eclipsed to the percentage that the counts are reduced, the relative spatial distribution of the reactions can be determined.

Preliminary data for D-D fuel shows that a higher density of reactions in the center of the cathode is occurring, indicating a converged core mode of operation for D-D fusion. The data also shows a uniform reaction density across the cathode area for the D-^{3}He reactions Since there is strong evidence of embedded fusion[5] in this IEC device, it is possible that the D-^{3}He reactions are dominated by embedded fusion in the cathode grid wires. Future studies will be conducted to increase understanding of this spatial difference.

MEDICAL ISOTOPE PRODUCTION

The production of PET isotopes is one near-term application for the IEC devices.[6] A solid molybdenum cathode was installed and embedded D-^{3}He fusion on the surface created about 1 nCi ^{94m}Tc from the reaction ^{94}Mo(p,n)^{94m}Tc.[5] Another experiment aimed at producing ^{13}N from water has been conducted. To produce ^{13}N, a water-filled aluminum panel has been installed inside the chamber (Figure 8). The D-^{3}He protons will pass through the thin walls (100 microns) and create the isotope ^{13}N using the ^{16}O(p,γ)^{13}N reaction.[7]

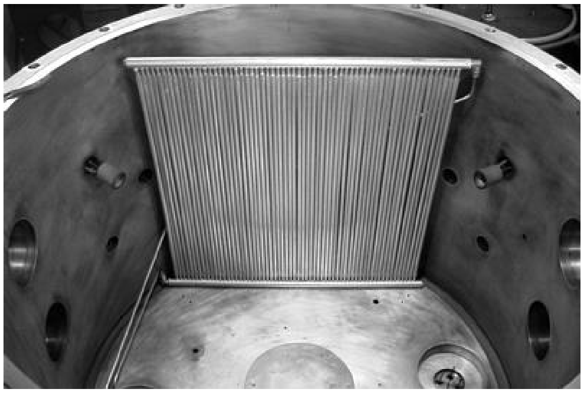

Figure 8. Water circulator in IEC chamber used to create ^{13}N.

CONCLUSIONS

Advances in the performance of the University of Wisconsin's inertial electrostatic confinement fusion device has produced a substantial increase in the production of protons using advanced fuels. This has allowed the production of proof of principle levels of PET isotopes. The medical isotope ^{94m}Tc has been produced using protons from a steady state D-^{3}He fusion reaction, and is the first known non-electrical application of D-^{3}He fusion energy.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Dr. Wilson Greatbatch and the Grainger Foundation who funded this work. The authors would also like to acknowledge support from the University of Wisconsin-Madison.

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