



Theoretical Exploration of UW IEC Device Operation at Moderate Pressures*

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Outline

- Effect of changing parameters
 - Source species mix
 - Voltage
 - Pressure
 - Cathode and anode radii
- Future directions
- Summary and conclusions

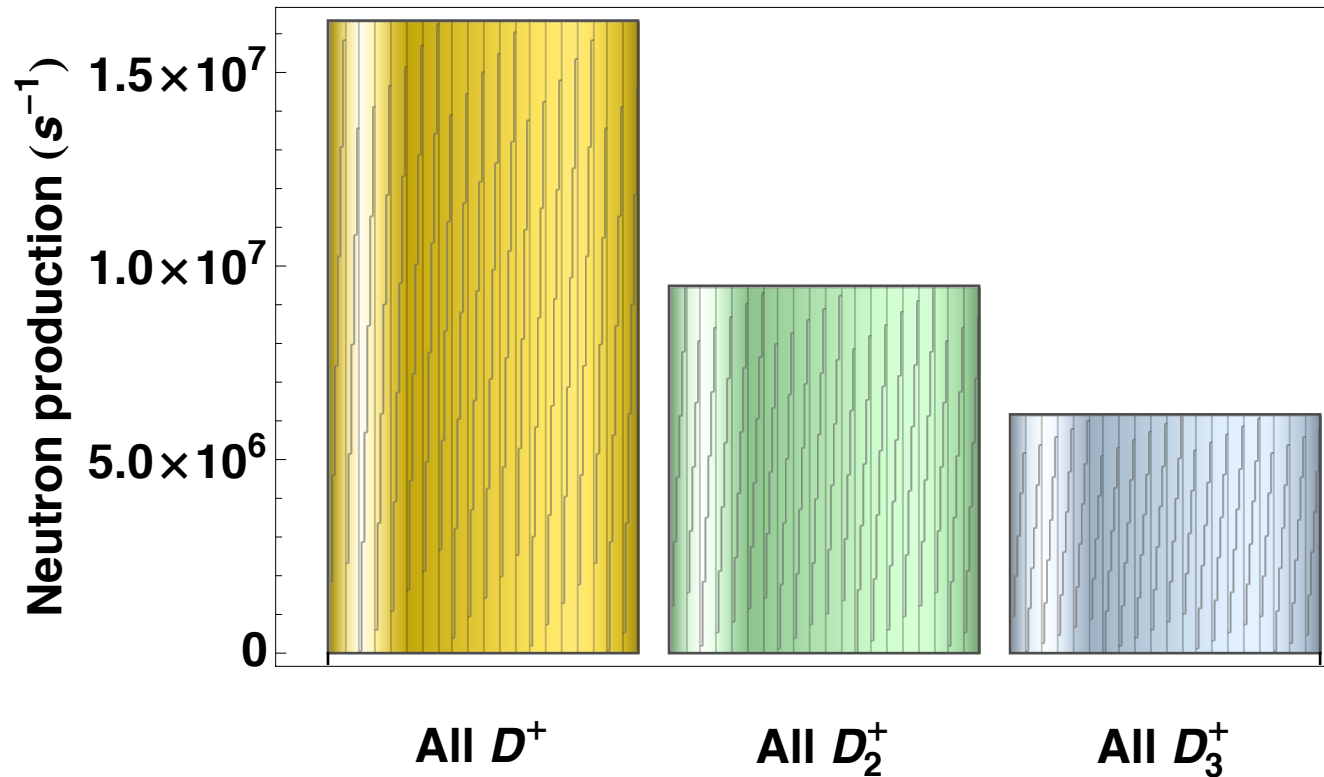
Base Case Input Parameters

Cathode Radius	0.10 m
Anode Radius	0.20 m
Wall Radius	0.45 m
Cathode Voltage	70 kV
Potential Model: vacuum potential	
No cold ions in cathode region	
Source ion fractions:	
D+	0.06
D2+	0.23
D3+	0.71

Cathode Current	30 mA
Gas pressure	2 mTorr
Ion energy at anode	0.01 keV
Gas density	$6.400\text{e}+19 \text{ m}^{-3}$
Cathode transparency	0.92
Anode transparency	1.00
Number of zones:	
Intergrid region	100
Cathode region	30
Source region	30
Energy grid	30

D^+ Somewhat Favored for Source Species

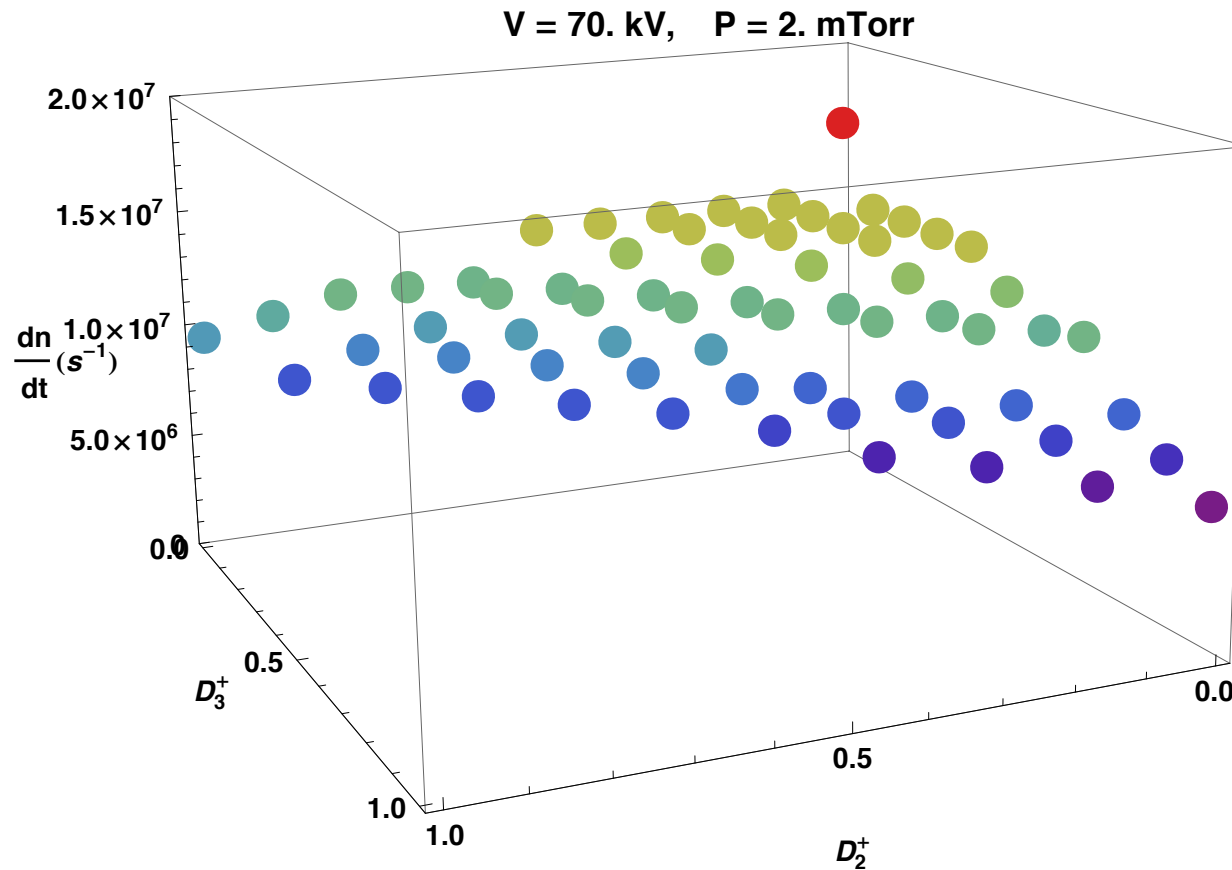
Dependence on Source Ion Species



2 mTorr (0.27 Pa), 30 mA, 70 kV, $r_c=0.1$ m, $r_a=0.2$ m

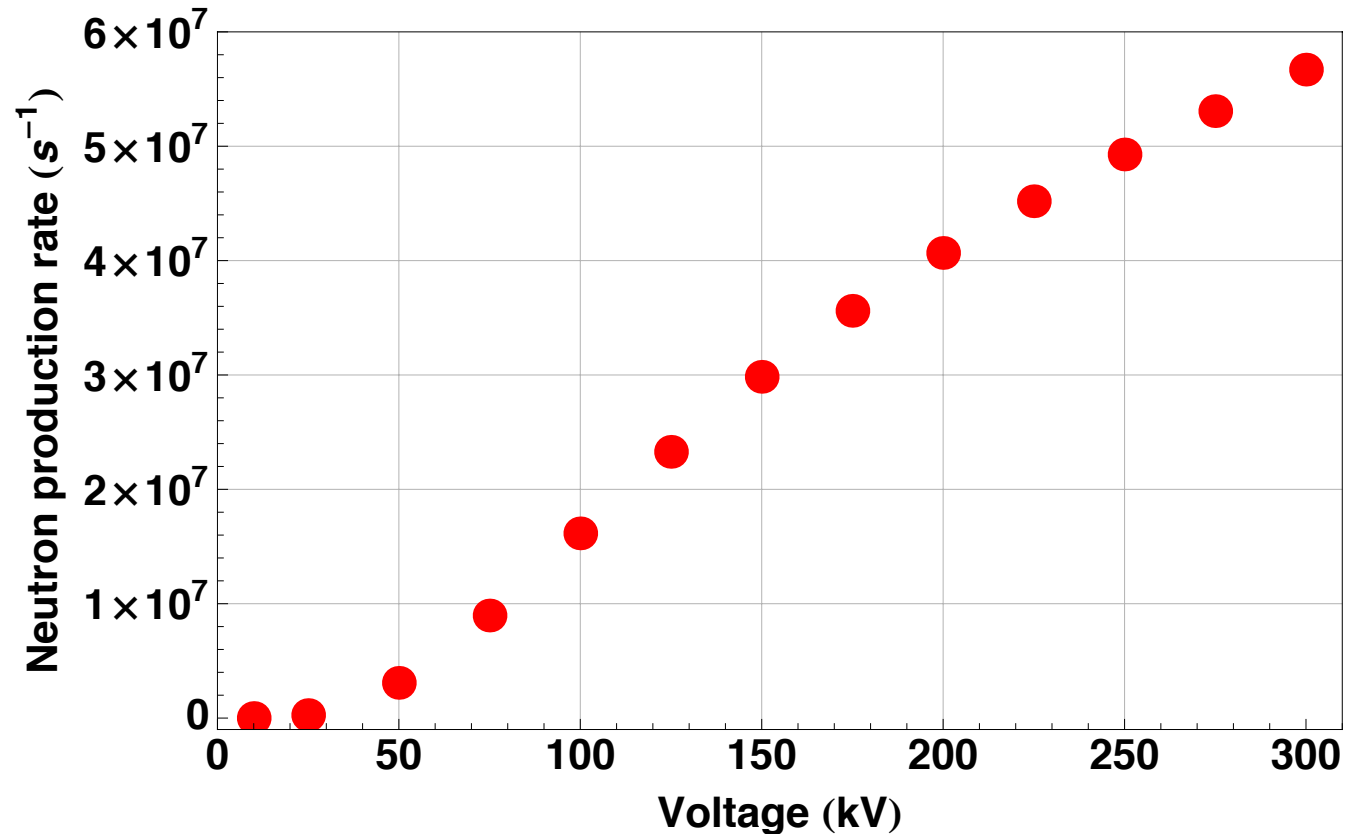
D⁺ Slightly Favored for Source Species

- Dots independently rainbow colored with purple low and red high.



2 mTorr (0.27 Pa), 30 mA, 70 kV, $r_c=0.1$ m, $r_a=0.2$ m

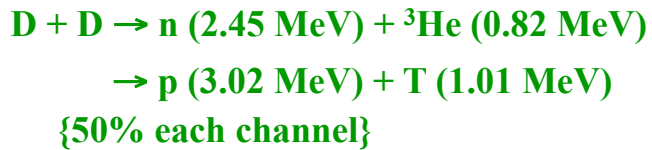
Increasing the Voltage Increases Neutron Production



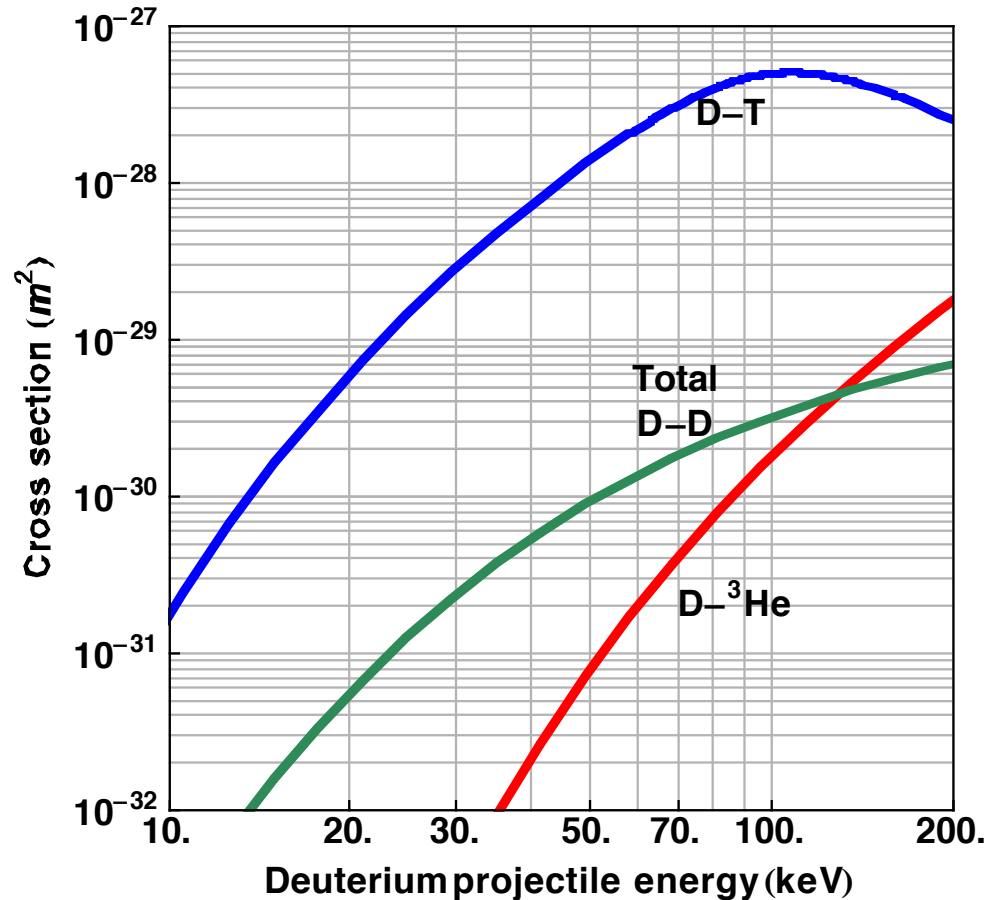
2 mTorr (0.27 Pa), 30 mA, 70 kV, $r_c=0.1$ m, $r_a=0.2$ m

Projectile-Target Cross Sections for Key Fusion Fuels

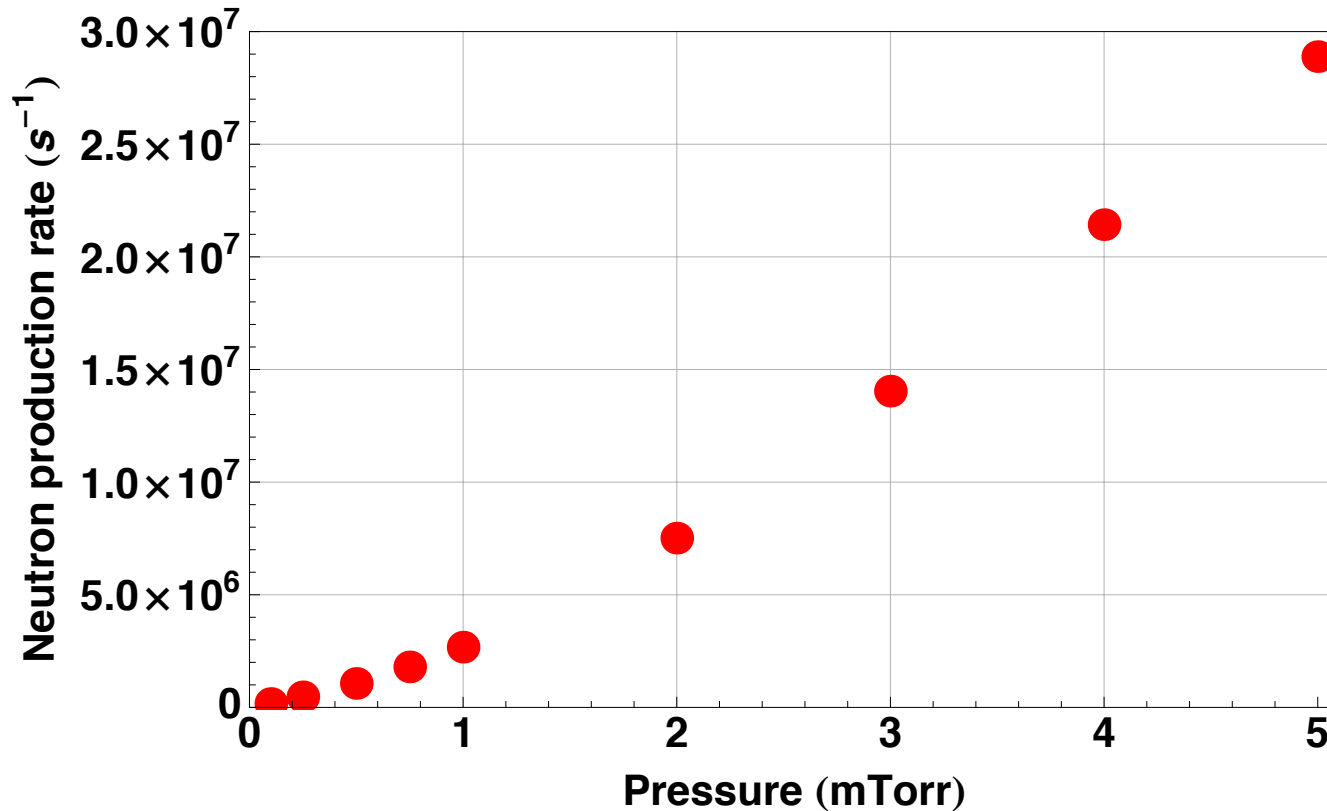
1st generation fuels:



2nd generation fuel:



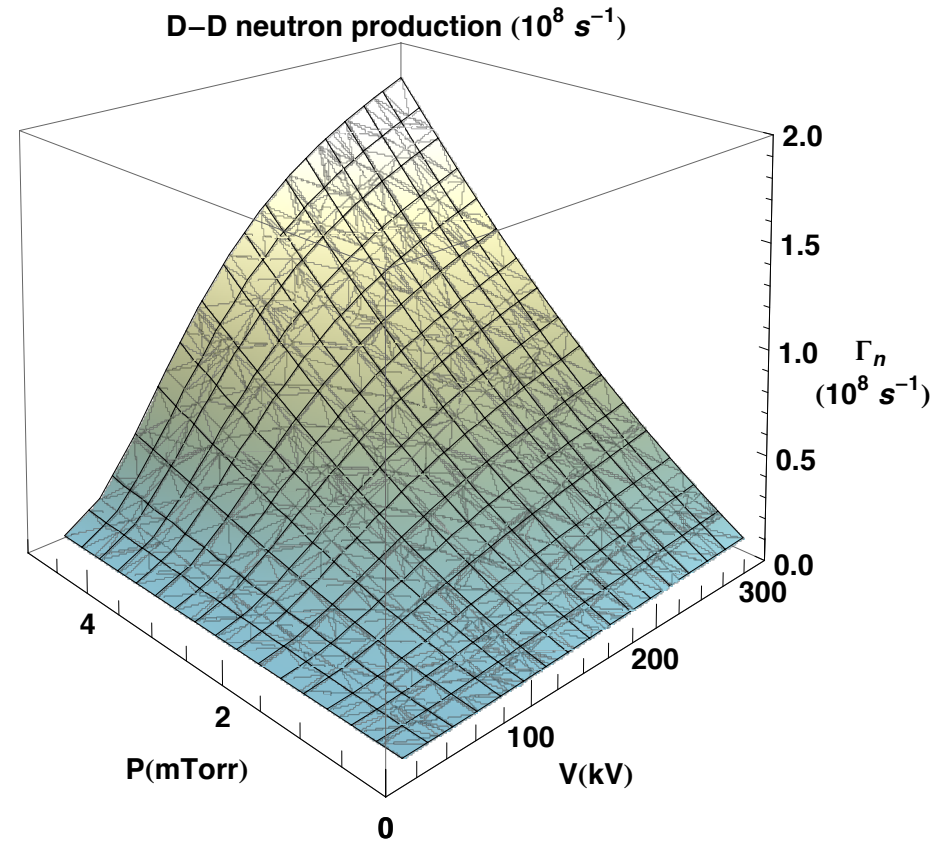
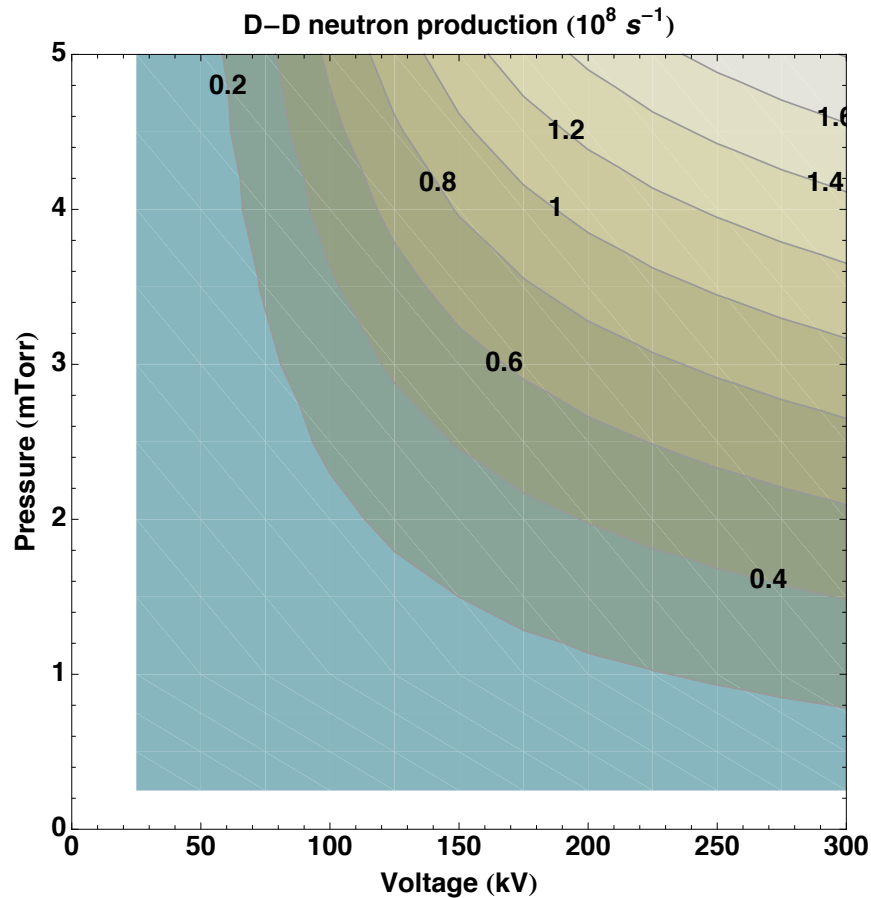
Increasing the Pressure Strongly Increases Neutron Production



2 mTorr (0.27 Pa), 30 mA, 70 kV, $r_c=0.1$ m, $r_a=0.2$ m

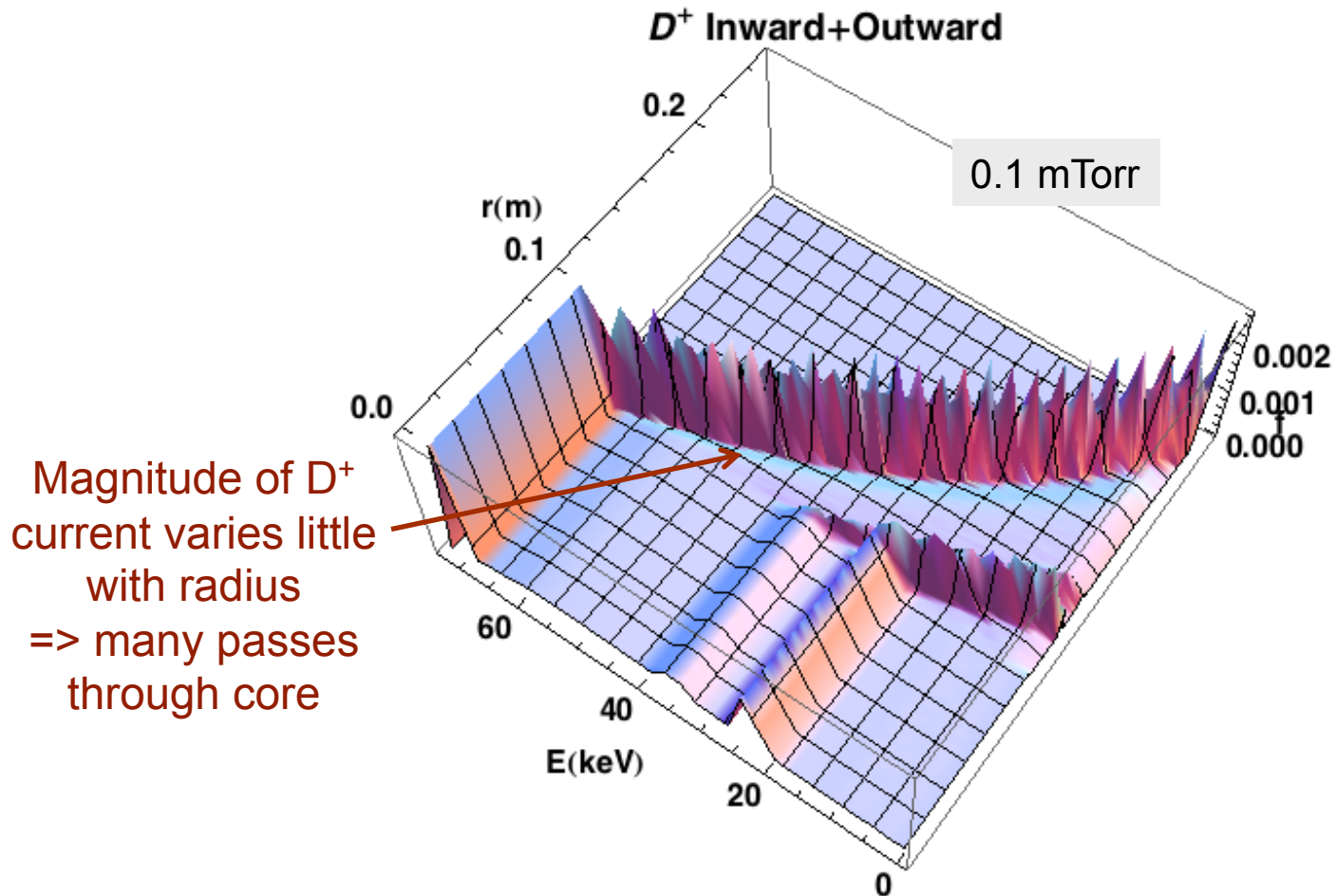
Higher Voltage and Pressure Increase Neutron Production Strongly

30 mA, $r_c=0.1$ m, $r_a=0.20$ m, Source: 0.06 D^+ , 0.23 D_2^+ , 0.71 D_3^+



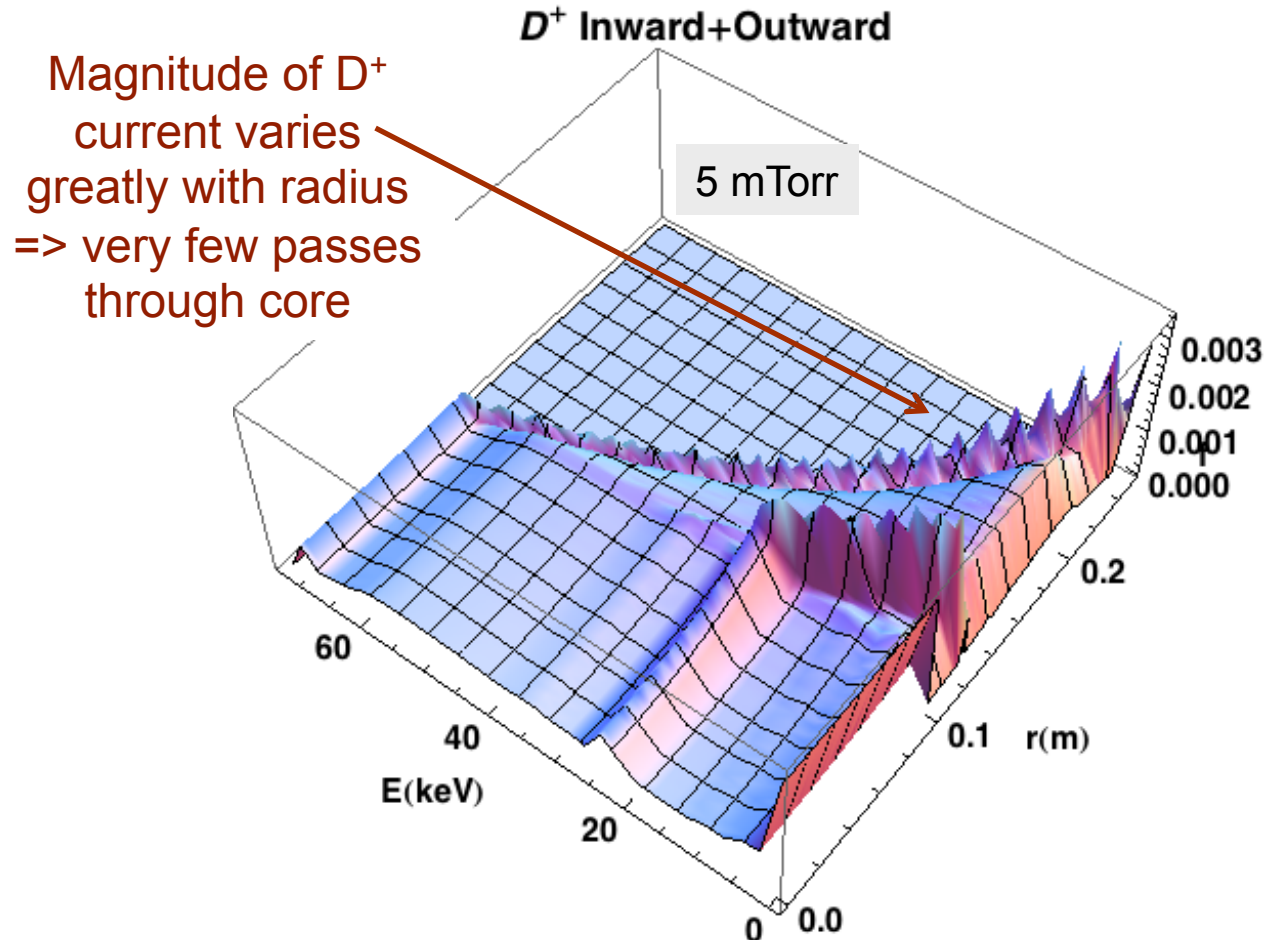
At Low Pressure, Atomic Physics Effects Are Relatively Small

70 kV, 30 mA, $r_c=0.10$ m, $r_a=0.20$ m, Source: 0.06 D^+ , 0.23 D_2^+ , 0.71 D_3^+



At Higher Pressure, Atomic Physics Effects Are Strong

70 kV, 30 mA, $r_c=0.10$ m, $r_a=0.20$ m, Source: 0.06 D^+ , 0.23 D_2^+ , 0.71 D_3^+





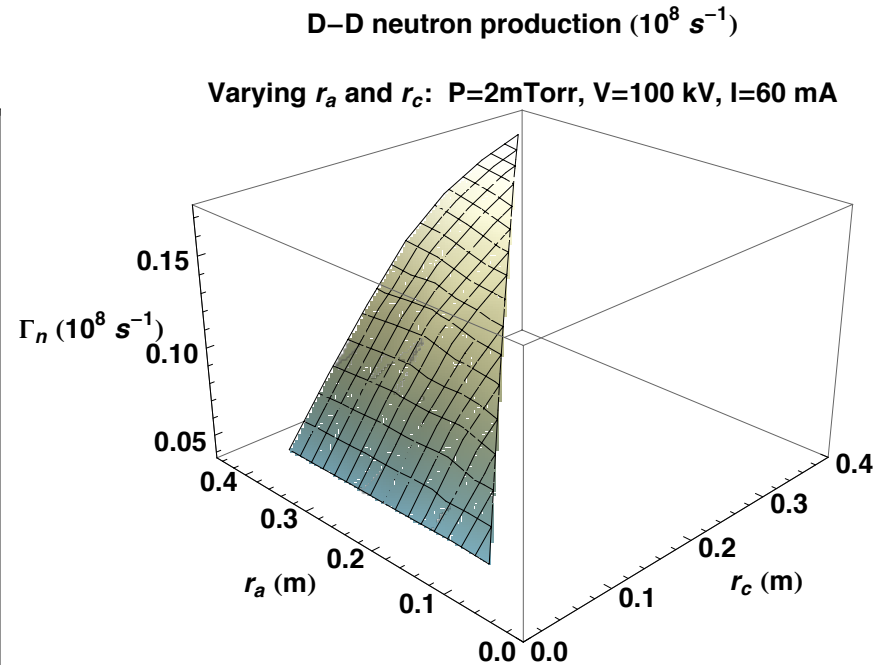
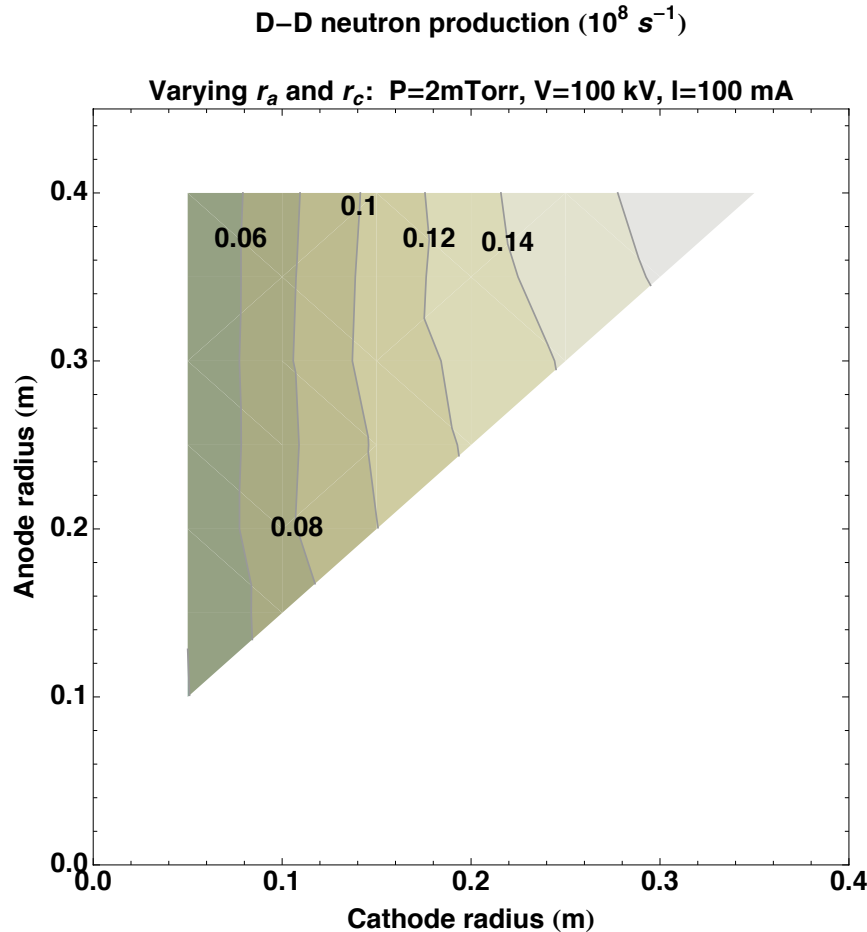
Increasing Pressure Increases Neutron Production Rate and Affects the Origin of the Fusion Neutrons

70 kV, 30 mA, $r_c=0.1$ m, $r_a=0.2$ m, Source: 0.06 D^+ , 0.23 D_2^+ , 0.71 D_3^+

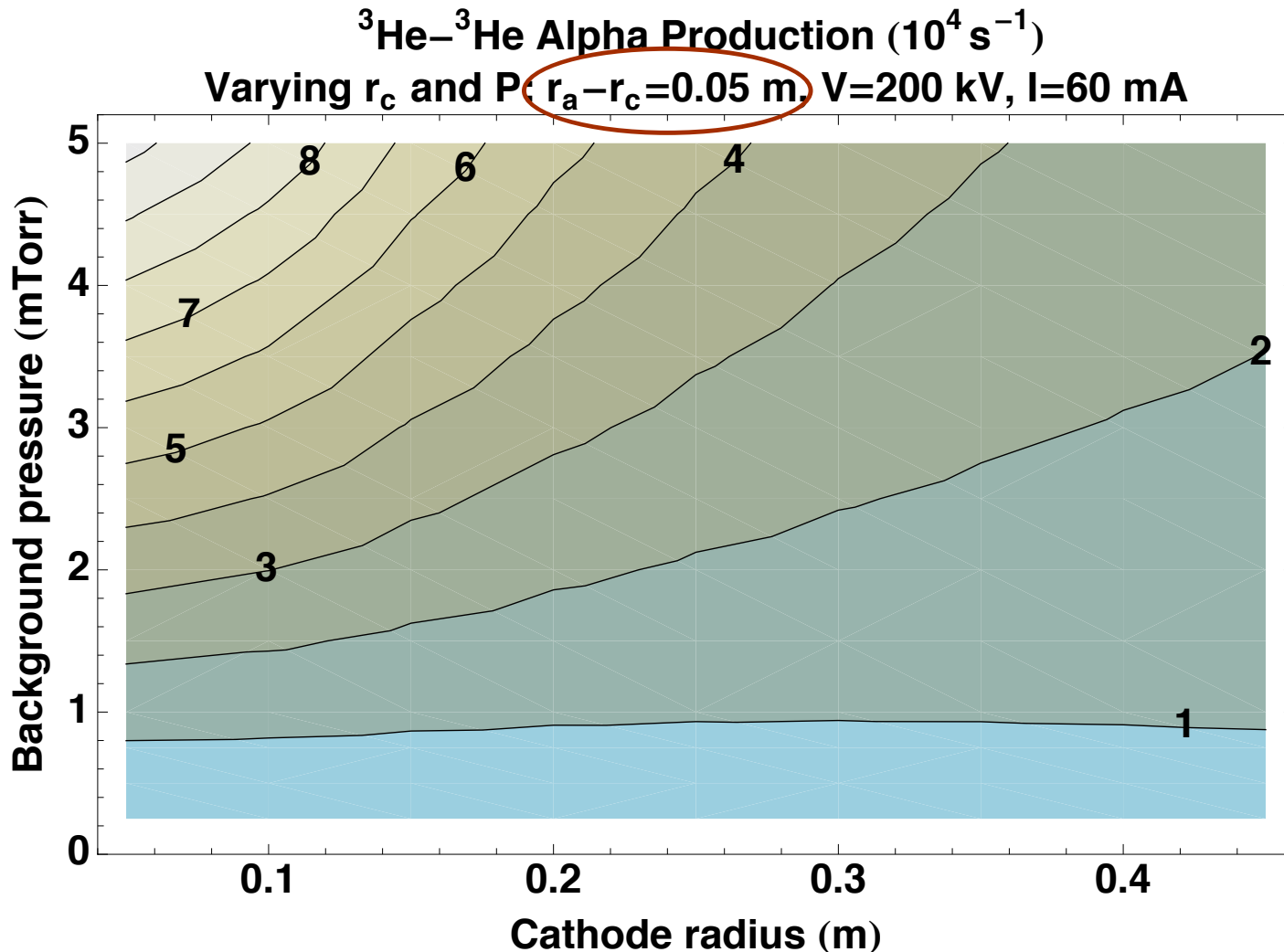
Units of 10^5 n/s	0.1 mTorr	1 mTorr	5 mTorr
D^0 - Gas	0.09	8.7	166
D_2^0 - Gas	0.03	2.5	31
D^- - Gas	0.003	1.1	45
D^+ - Gas	0.60	7.7	33
D_2^+ - Gas	0.49	3.6	8
D_3^+ - Gas	0.51	3.2	7
Total neutrons	1.7	26.8	299

Neutron Production Varies More Strongly with Cathode Radius than with Anode Radius

70 kV, 30 mA, 2 mTorr, Source: 0.06 D⁺, 0.23 D₂⁺, 0.71 D₃⁺



^3He - ^3He Fuel Performs Best at Small Radii and High Pressure



Future Directions

- Funded tasks during present 3-year DOE theory grant
 - implement planar and cylindrical geometries,
 - include D-T fuel and the He^{++} ionization state,
 - further benchmark against experimental data, and
 - scope space-charge effects of converging ions in core.
- Other tasks
 - include D- ^3He and p- ^{11}B fuels,
 - refine cross section data,
 - implement electrons as a separate species
 - allow a glow discharge ion source distribution, and
 - optimize the configuration and plasma parameters

Summary and Conclusions

- UW's VICTER integral transport code now creates files with detailed output for all species as functions of r and E .
- VICTER now includes negative ions, post-processed because they typically are a $\sim 10\%$ effect.
- We have developed a reasonable understanding of the key active processes in moderate pressure (0.1-5 mTorr) plasmas.
- VICTER predicts that the neutron production rate:
 - rises strongly with voltage and pressure,
 - rises moderately with cathode radius and wall radius,
 - depends linearly on current, and
 - depends very little on anode radius.