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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

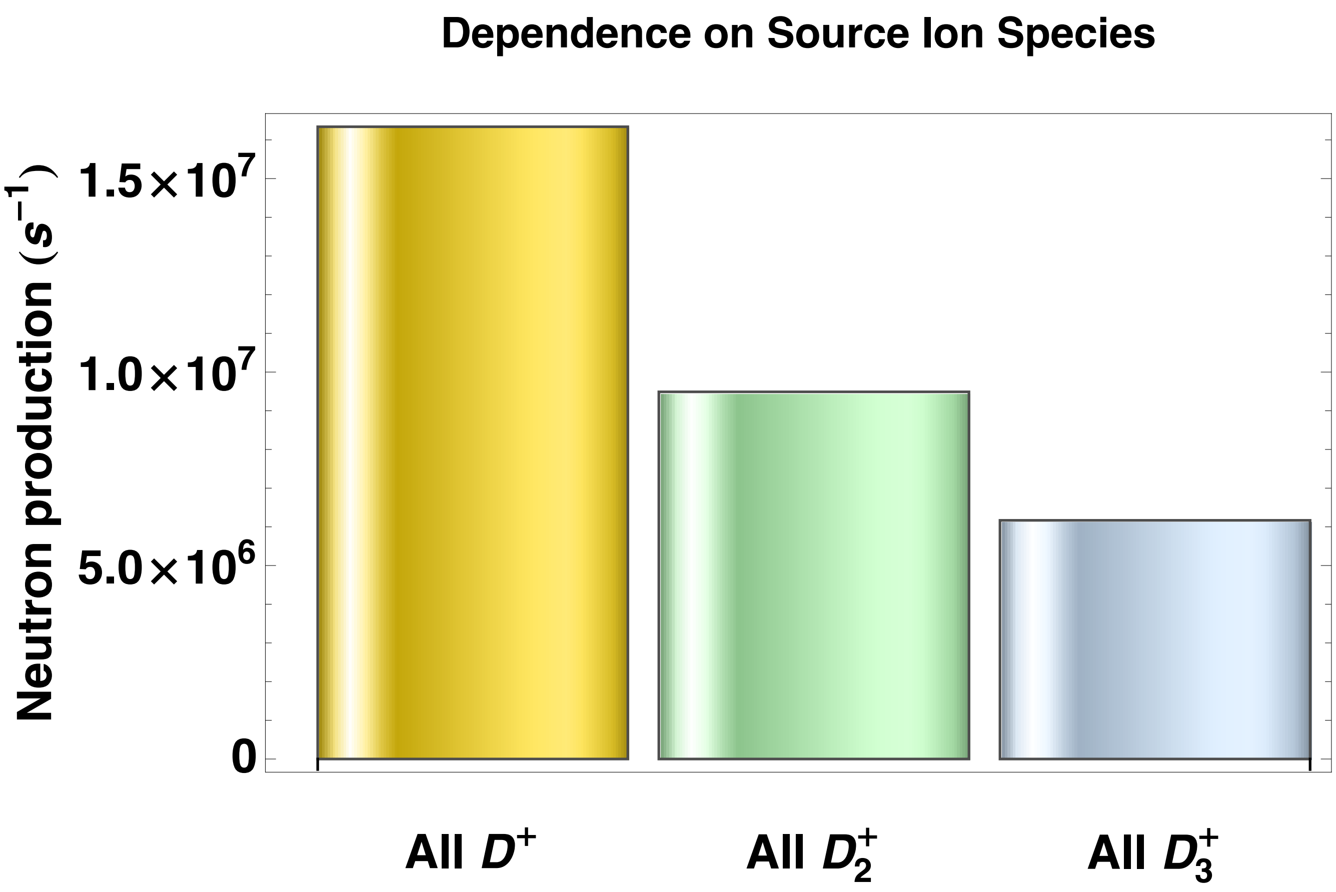
Cathode Current	30 mA
Gas pressure	2 mTorr

Ion energy at anode	0.01 keV
Gas density	6.400e+19 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

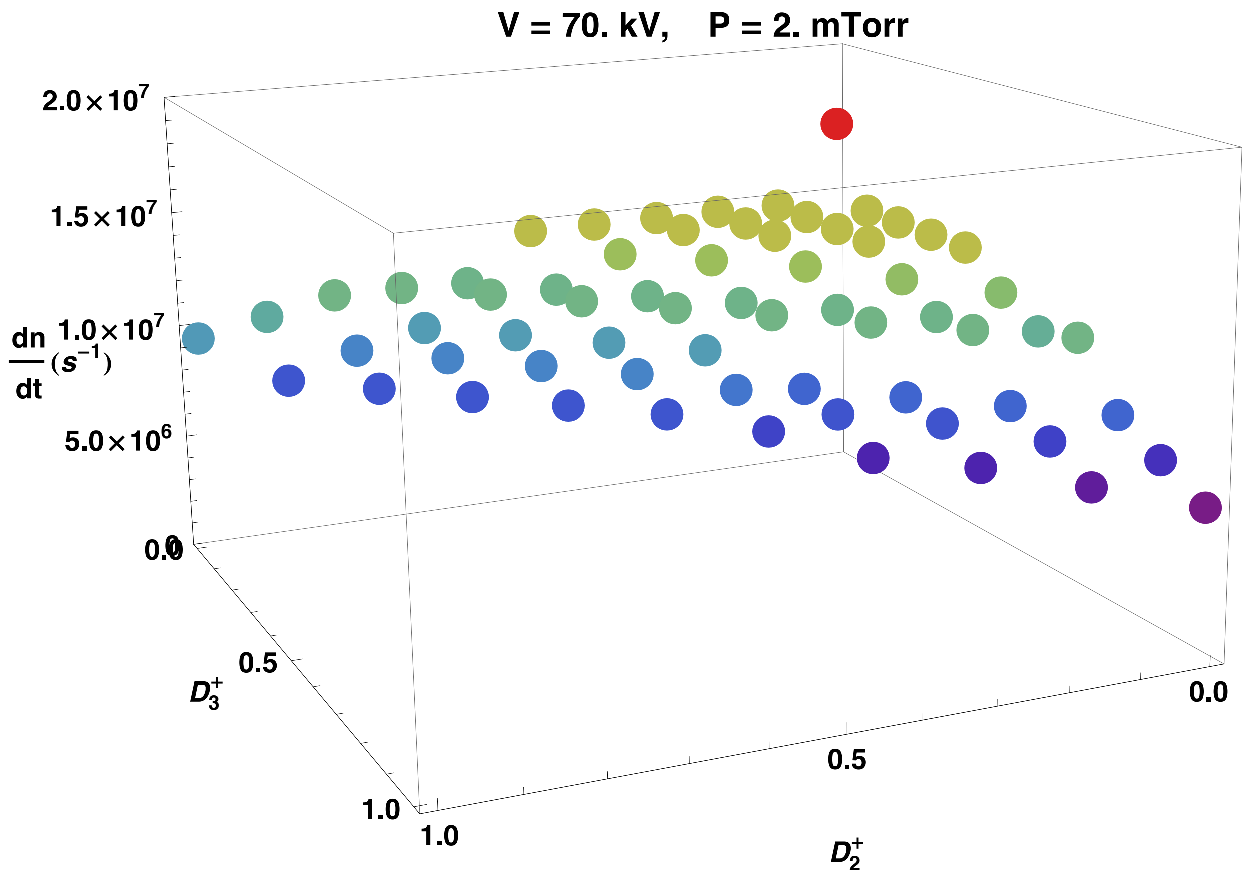
D^+ Somewhat Favored for Source Species



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

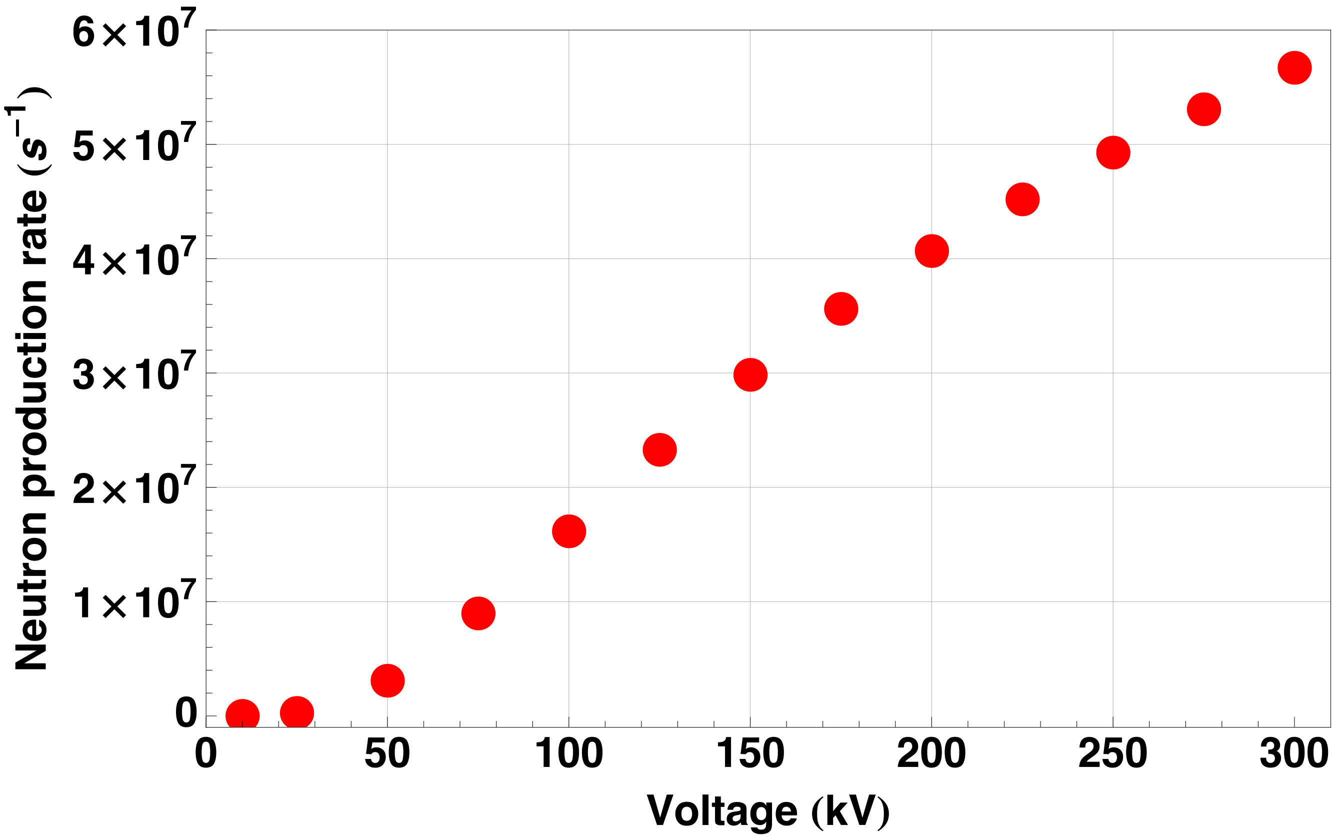
D$^+$ Slightly Favored for Source Species

- 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

1^{st} generation fuels:

D + T → n (14.07 MeV) + ^{4}He (3.52 MeV)

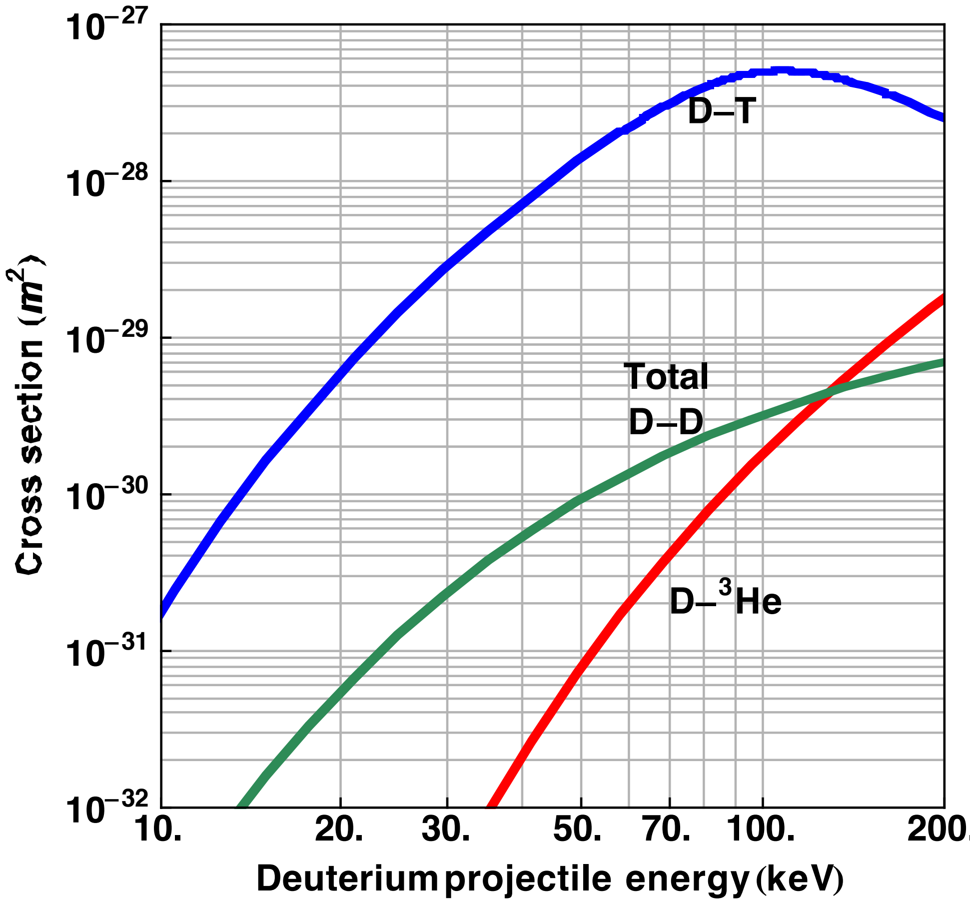
D + D → n (2.45 MeV) + ^{3}He (0.82 MeV)

→ p (3.02 MeV) + T (1.01 MeV)

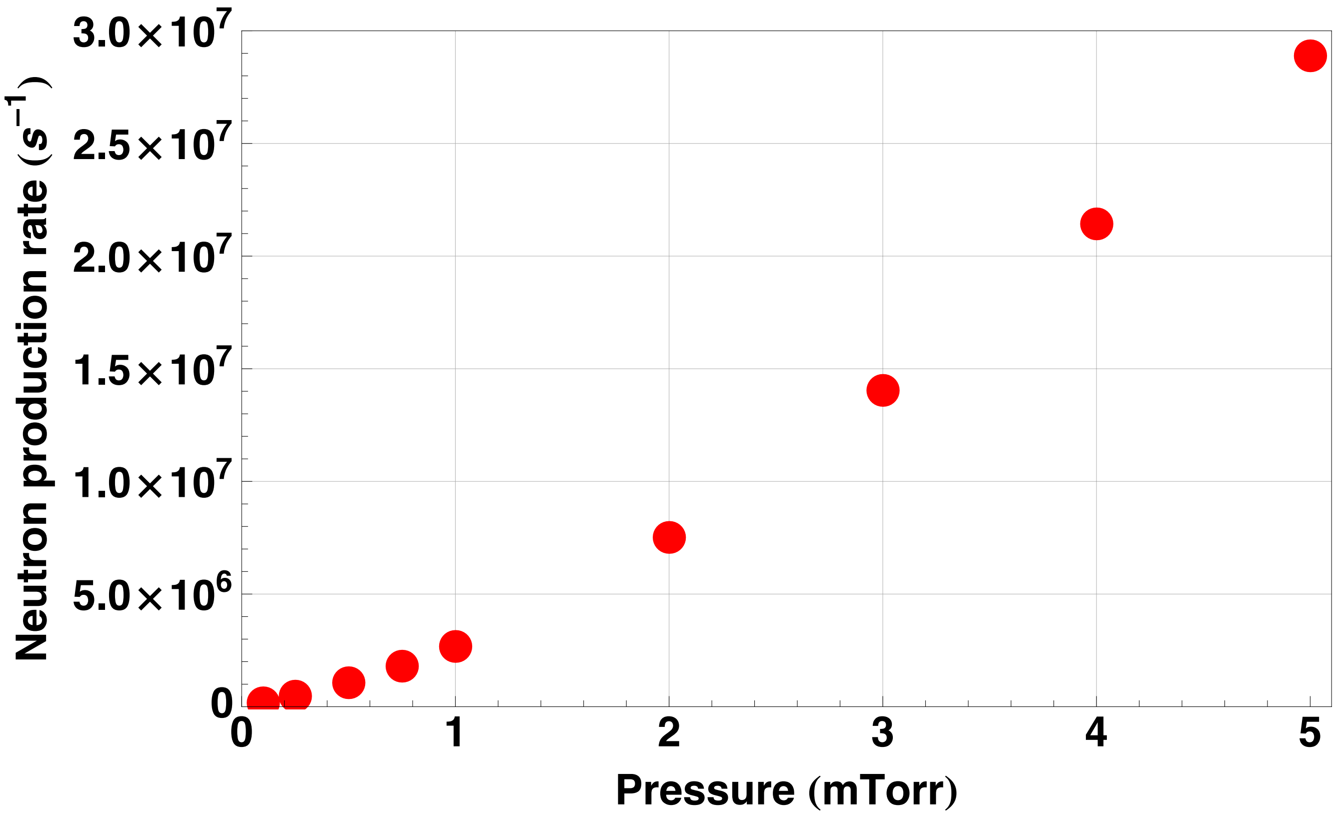
{50% each channel}

2^{nd} generation fuel:

D + ^{3}He → p (14.68 MeV) + ^{4}He (3.67 MeV)



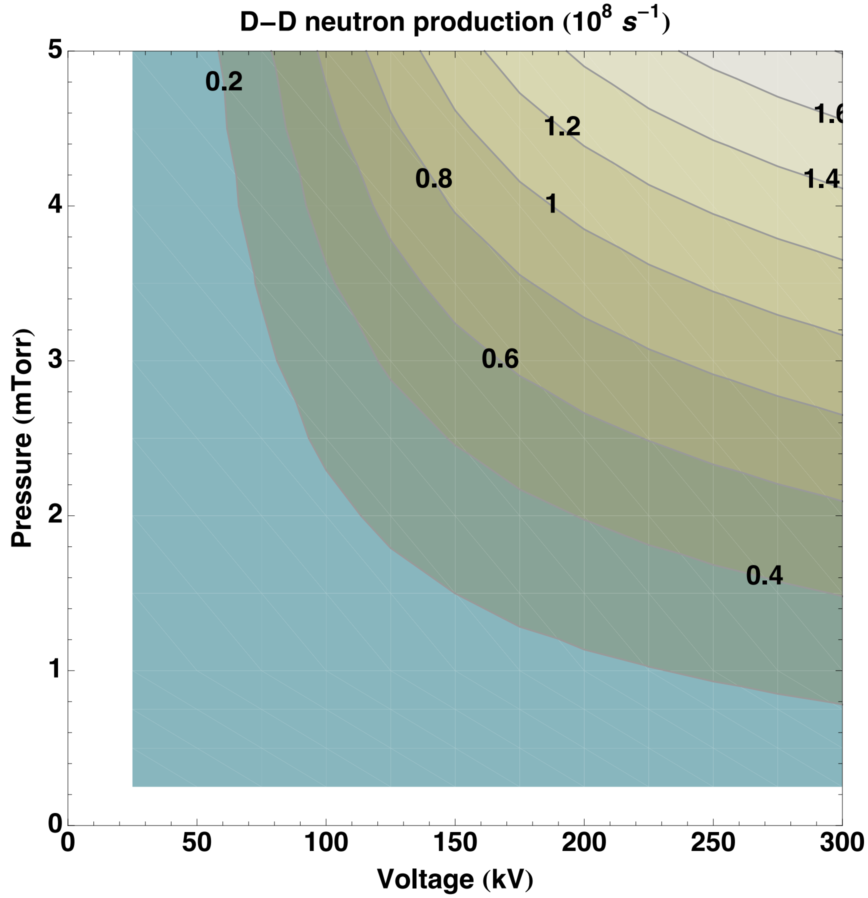
Increasing the Pressure Strongly Increases Neutron Production

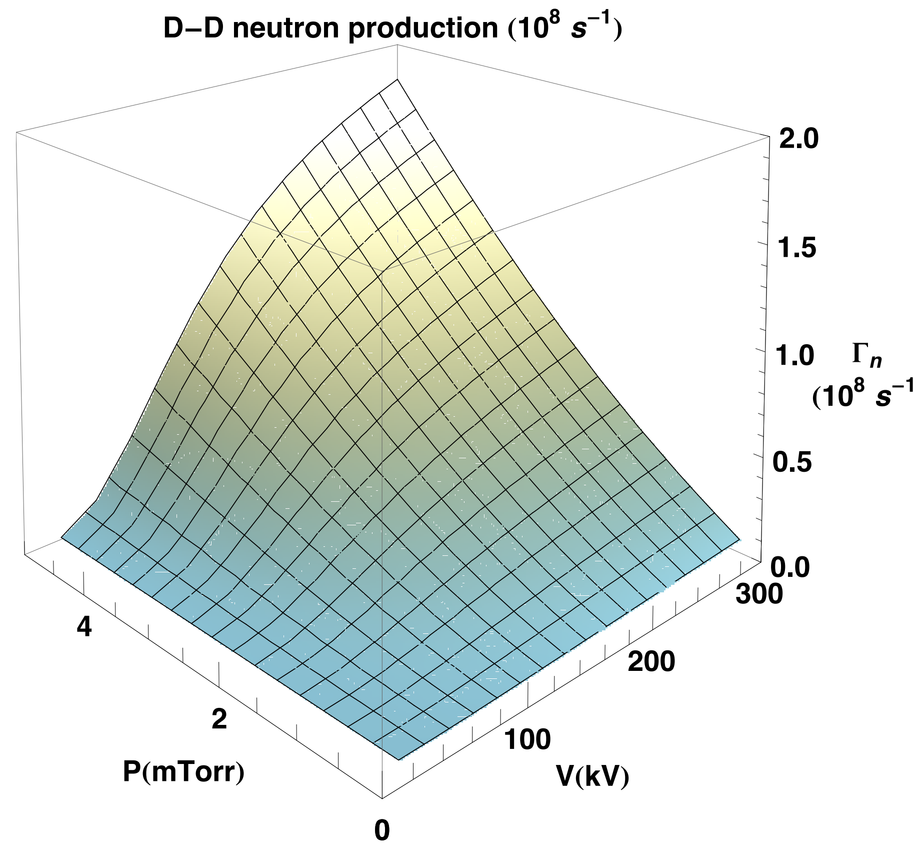


2 mTorr (0.27 Pa), 30 mA, 70 kV, r_c=0.1 m, r_a=0.2 m

Higher Voltage and Pressure Increase Neutron Production Strongly

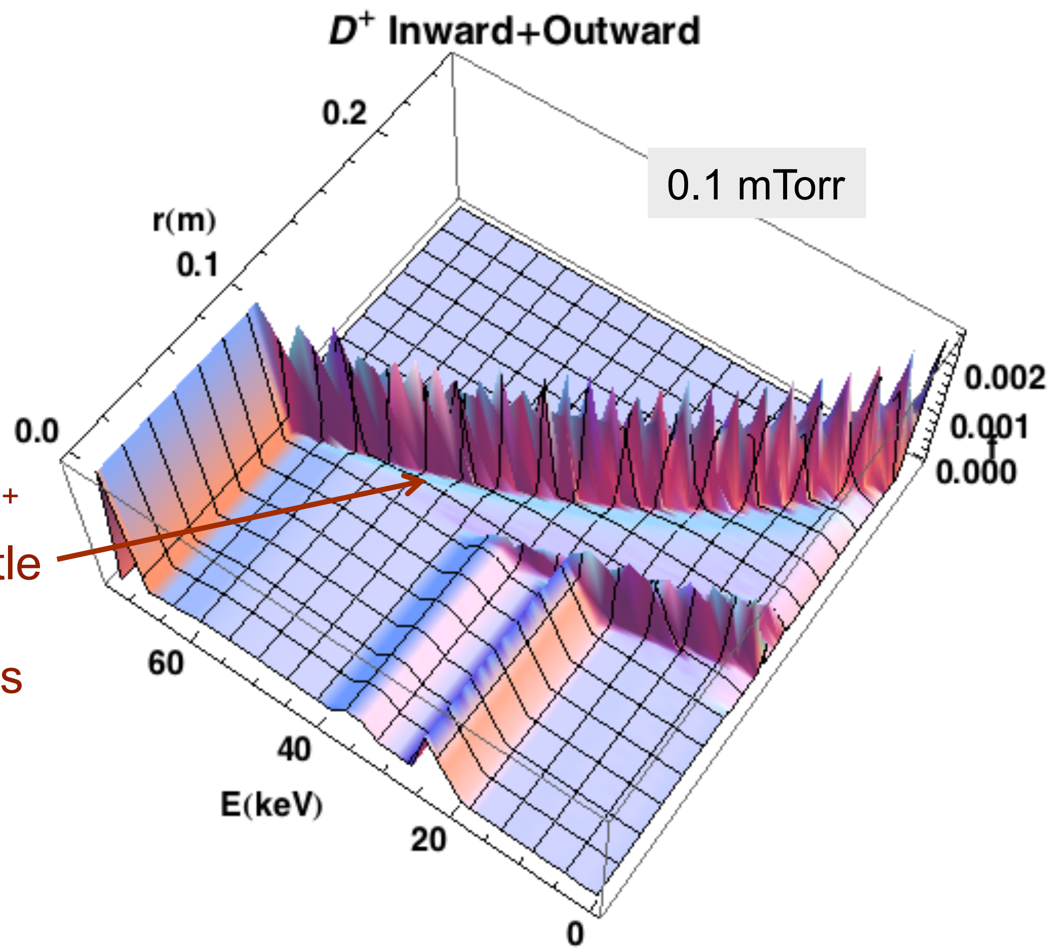
30 mA, r_c=0.1 m, r_a=0.20 m, Source: 0.06 D^+, 0.23 D_2^+, 0.71 D_3^+





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^+

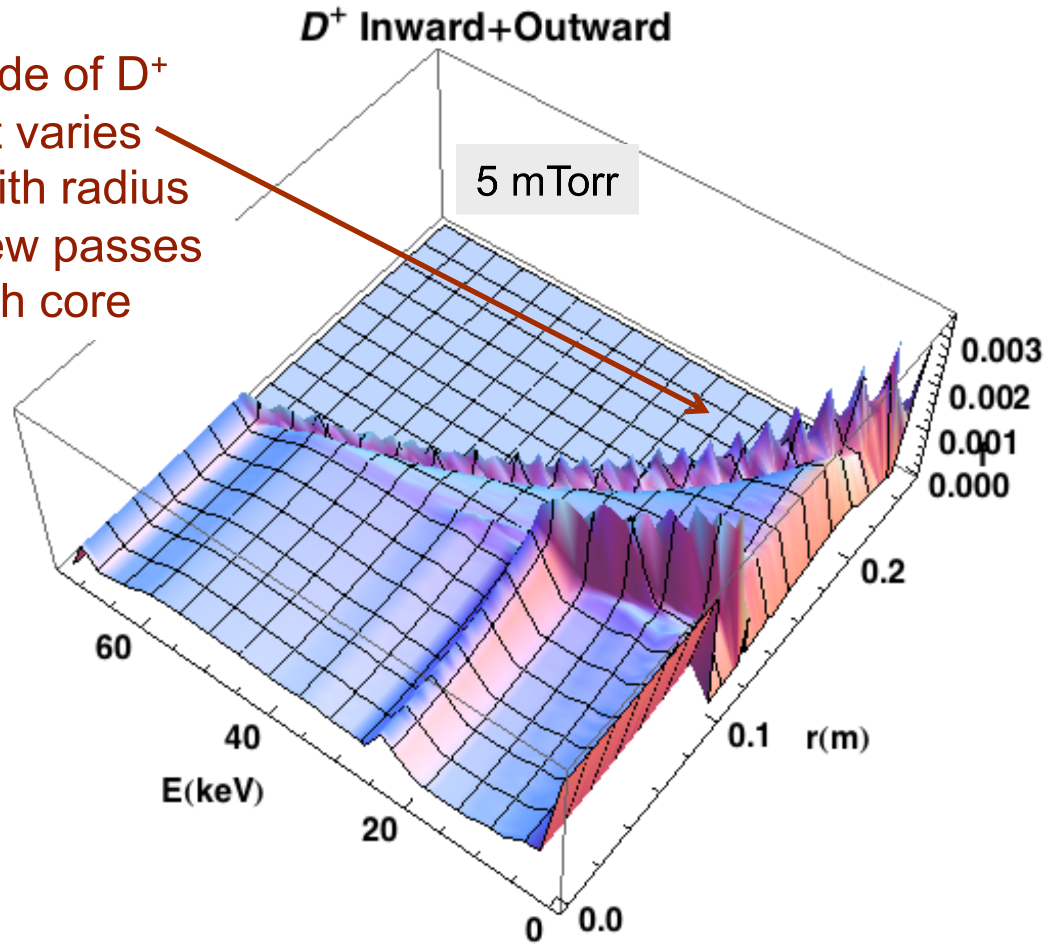


Magnitude of D^+ current varies little with radius => many passes through core

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^+

Magnitude of D^+ current varies greatly with radius => very few passes through core



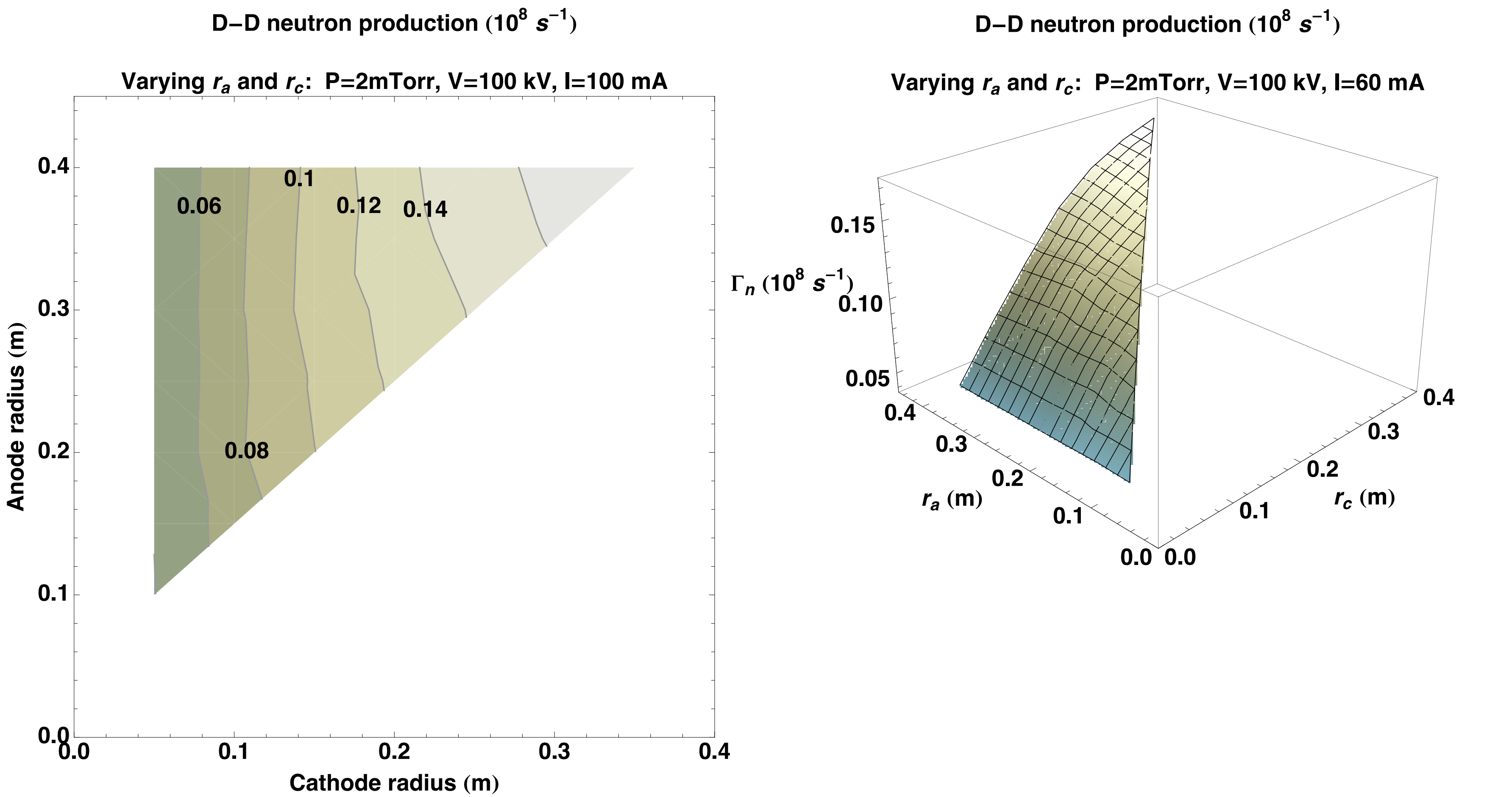
Increasing Pressure Increases Neutron Production Rate and Affects the Origin of the Fusion Neutrons

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^+

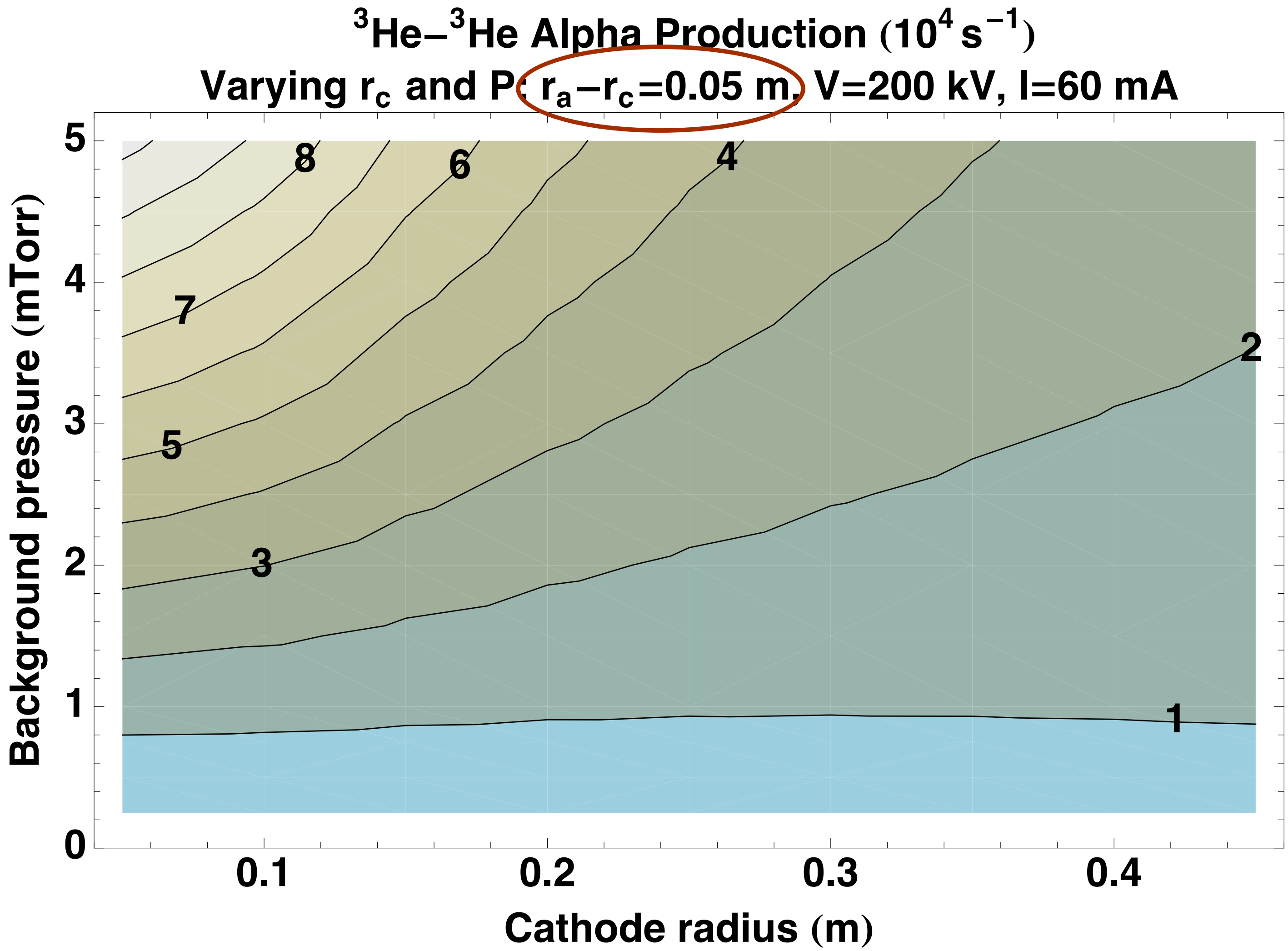
Units of 10^5 n/s	0.1 mTorr	1 mTorr	5 mTorr
D^0 - Gas	0.09	8.7	166
D_2^0 - Gas	0.03	2.5	31
D^- - Gas	0.003	1.1	45
D^+ - Gas	0.60	7.7	33
D_2^+ - Gas	0.49	3.6	8
D_3^+ - Gas	0.51	3.2	7
Total neutrons	1.7	26.8	299

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

70 kV, 30 mA, 2 mTorr, Source: 0.06 D^+, 0.23 D_2^+, 0.71 D_3^+



^{3}He-^{3}He 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-^{3}He 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 ~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.