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Exploration of IEC Device Operating Regimes*

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Outline

- Key physics effects for a selected (base) case
- Exploration of parametric dependencies
- Future directions
- Summary and Conclusions

How IEC Theory Code Modeling Works

$$S_i(r) = A_i(r) + \sum_{j=1}^{2} \int_r^{\text{anode}} K_{ij}(r, r') S_j(r') dr', \quad i = 1,2$$

It's

Turtles (= current)

All

the

Way

Down!

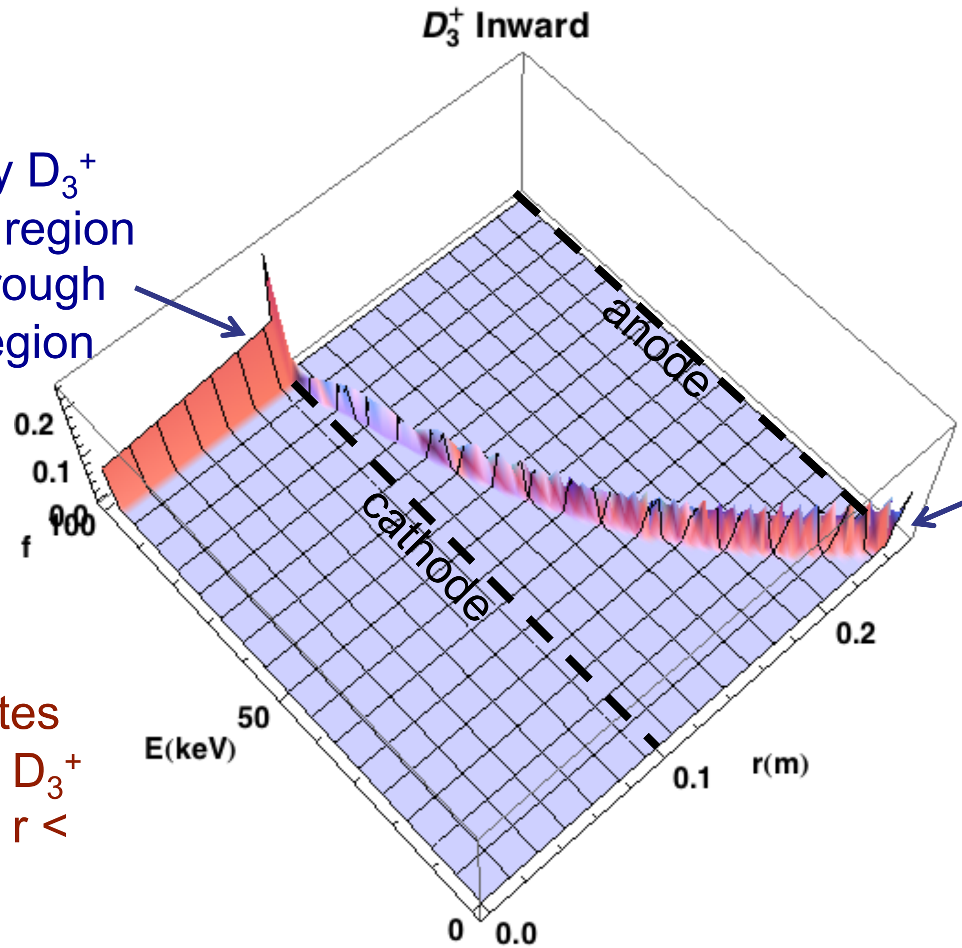
Base Case Input Parameters

Cathode Radius	0.100 m
Anode Radius	0.250 m
Wall Radius	0.456 m
Cathode Voltage	300 kV
Potential Model	vacuum potential
No cold ions in cathode region	
Source ion fractions:	
D+	0.060
D2+	0.230
D3+	0.710

Cathode Current	100 mA
Gas pressure	2 mTorr
Ion energy at anode	0.01 keV
Gas density	6.400e+19 m^-3
Cathode transparency	0.95
Anode transparency	1.00
Number of zones:	
Intergrid region	100
Cathode region	50
Source region	50
Energy grid	50

Ion Currents Show Effects of Source Species Mix and Electrostatic Potential Profile

Full energy D_3^+ from source region passing through cathode region

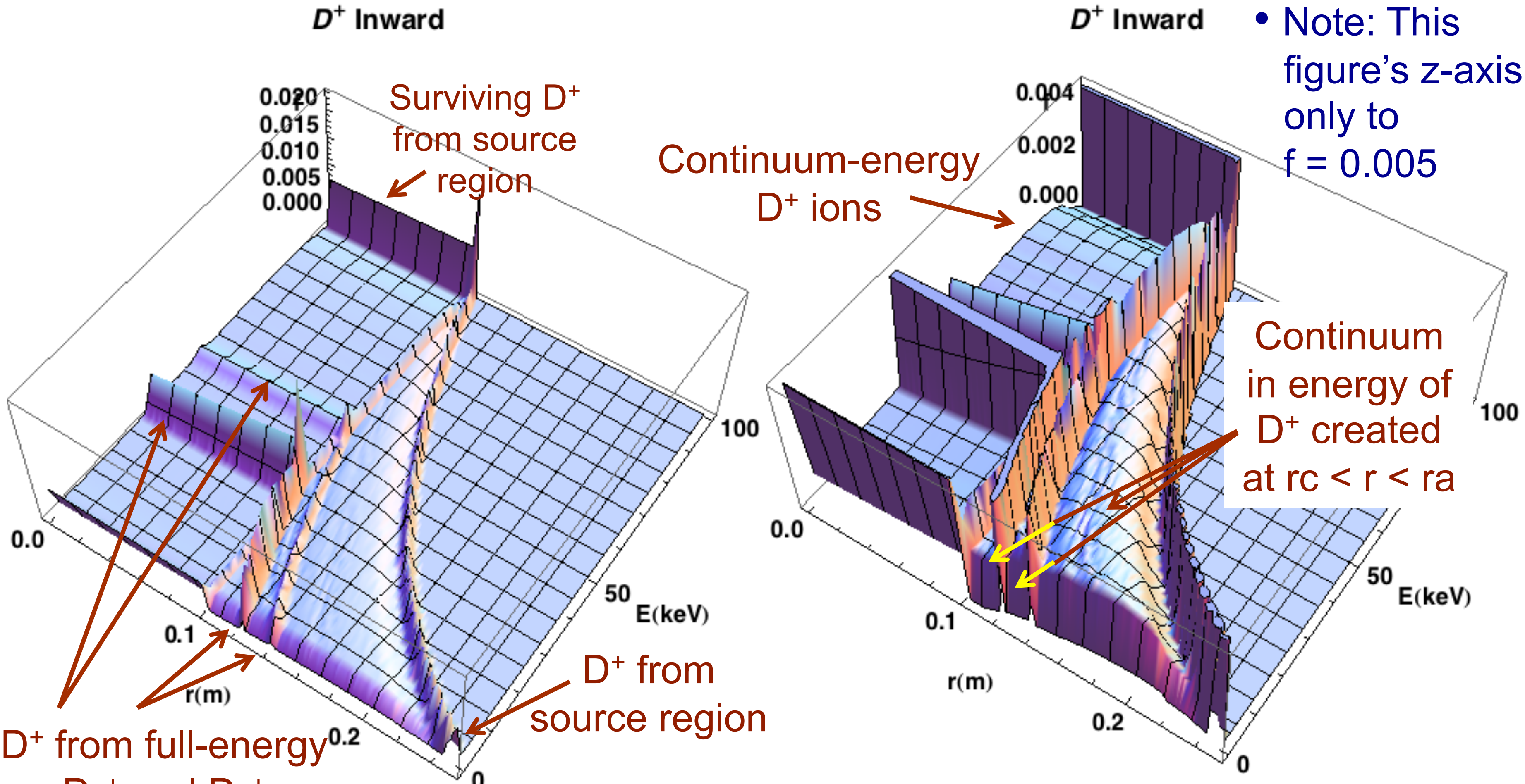


D_3^+ from source region

- Note that D_3^+ creates D^+ and D_2^+, but no D_3^+ gets created for r < anode radius.

100 kV, 100 mA, P=2 mTorr, rc=0.1 m, ra=0.25 m, source D^+:D_2^+:D_3^+=0.06:0.23:0.71

Ion Currents Show Effects of Source Species Mix and Electrostatic Potential Profile

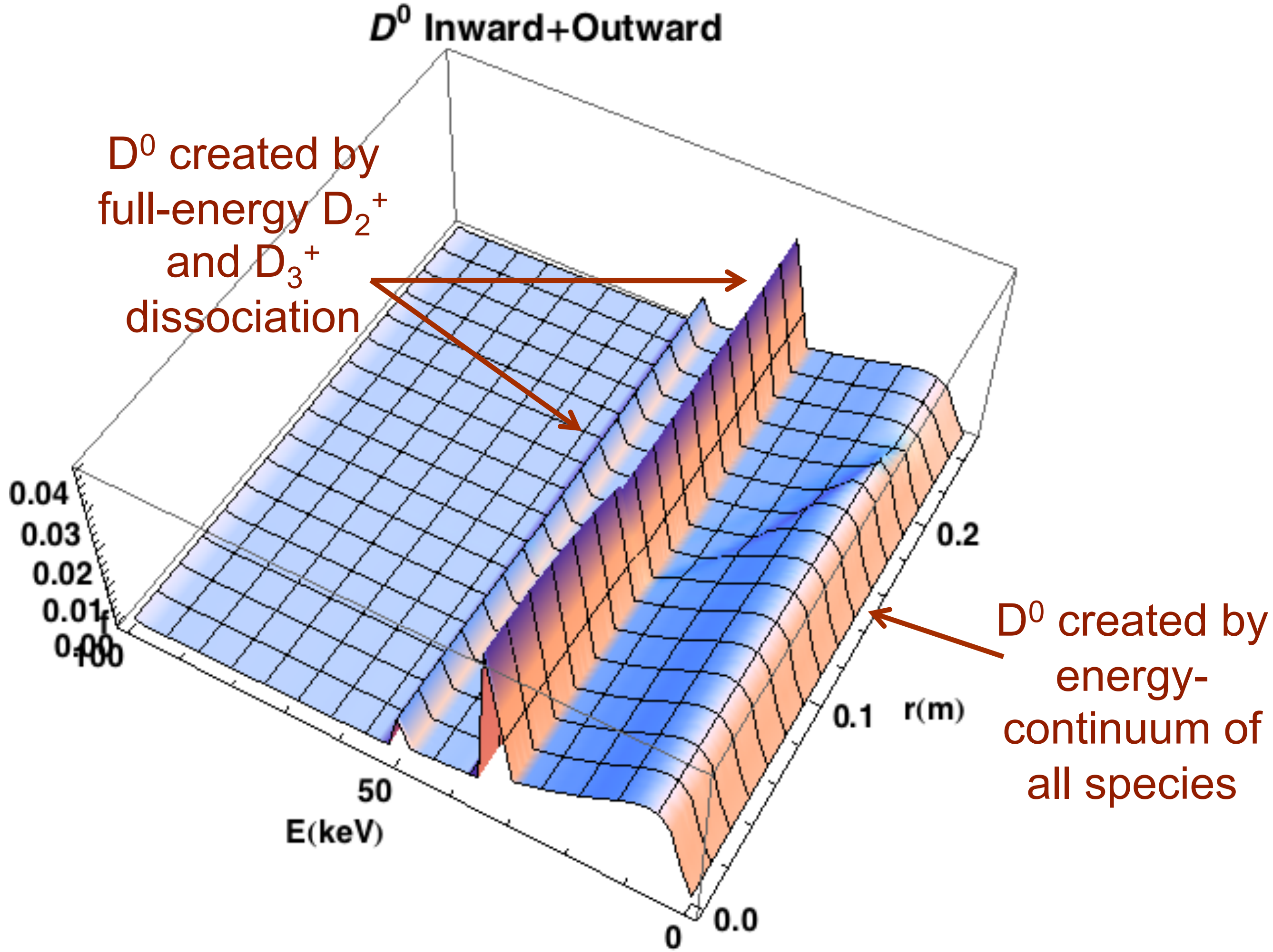


- Note: This figure's z-axis only to f = 0.005

100 kV, 100 mA, P=2 mTorr, rc=0.1 m, ra=0.25 m, source $D^+:D_2^+:D_3^+=0.06:0.23:0.71$

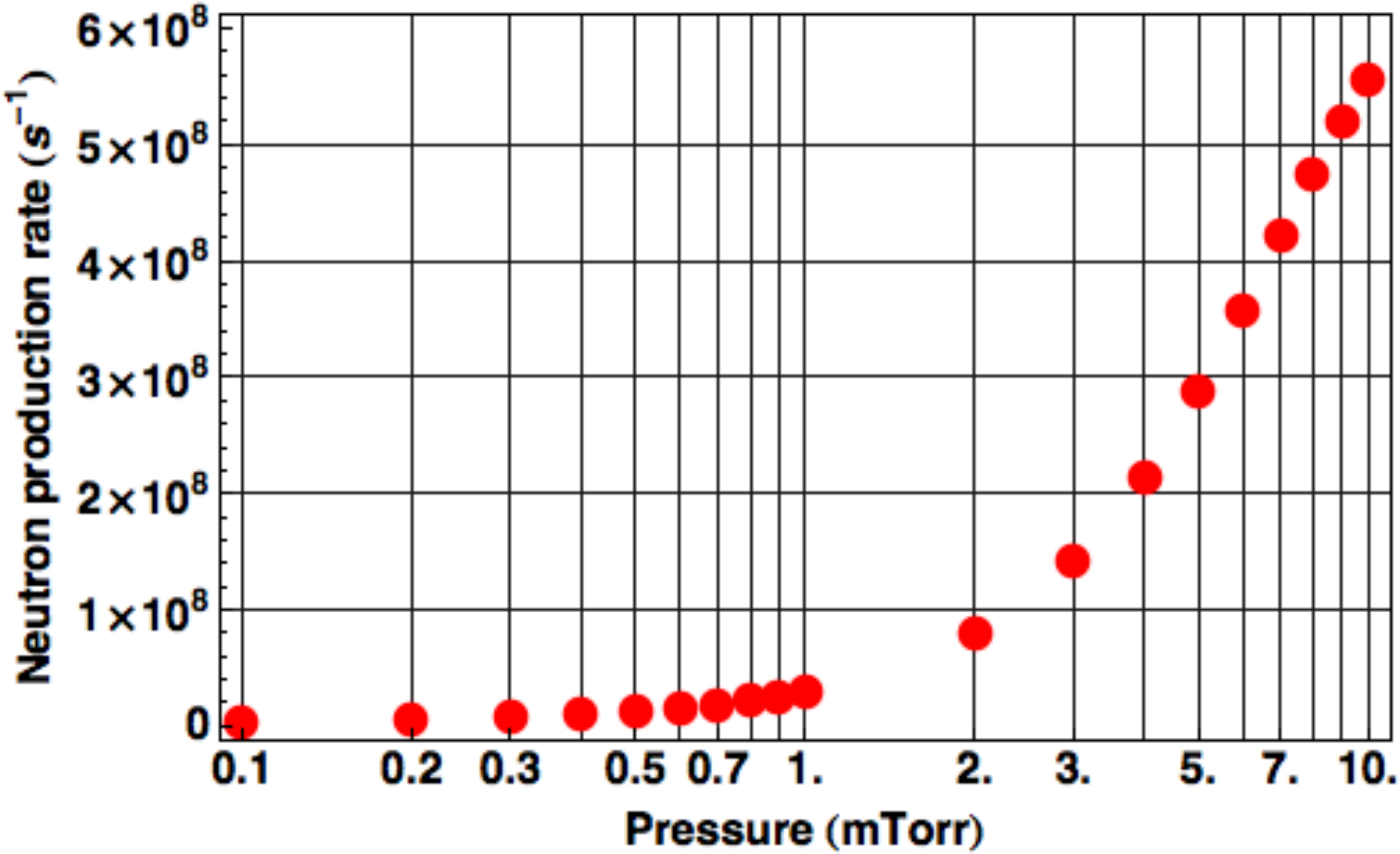
Neutrals Show Analogous Effects

100 kV, 100 mA, P=2 mTorr, rc=0.1 m, ra=0.25 m, source $D^+:D_2^+:D_3^+=0.06:0.23:0.71$



Higher Background Gas Pressure Increases Neutron Production Strongly

- Note: filament-assisted discharge; model is not valid for a glow discharge.

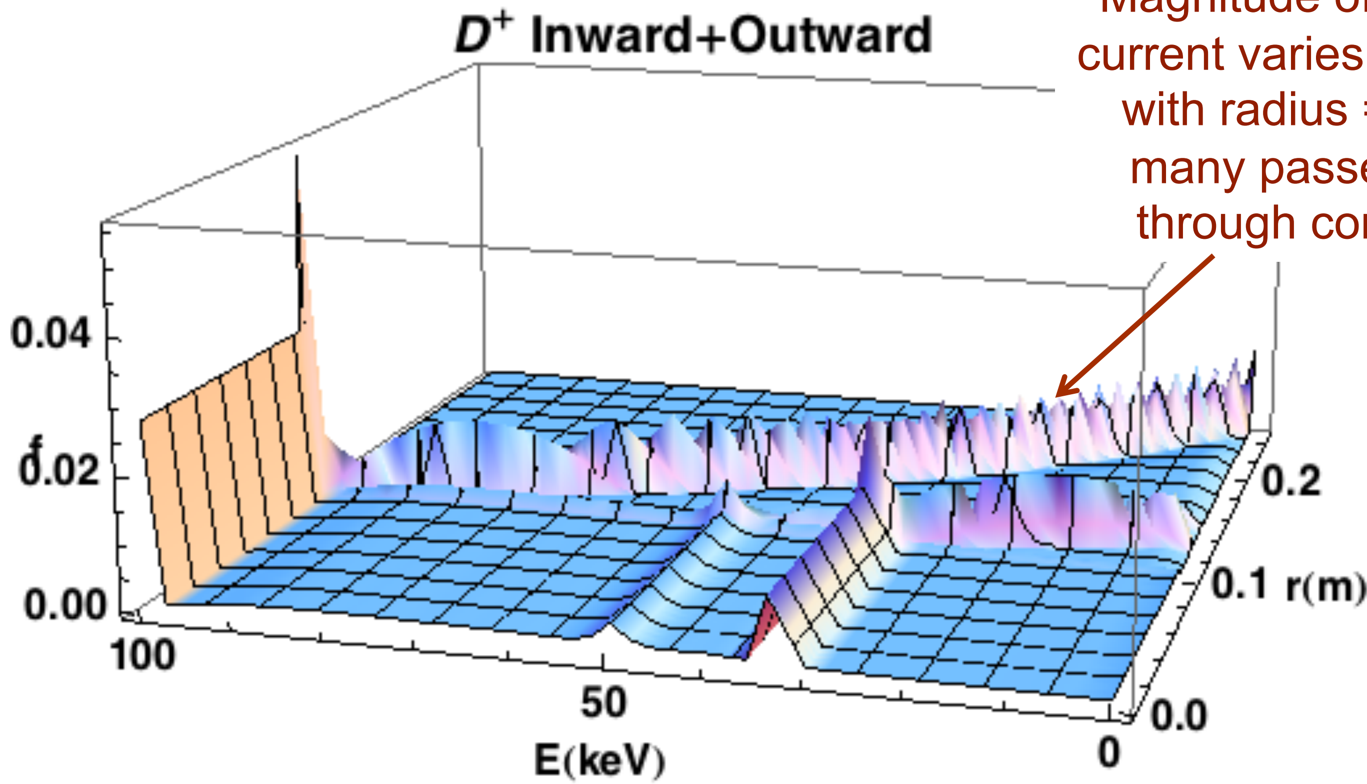


100 kV, 100 mA, r_c=0.1 m, r_a=0.25 m, Source: 0.06 D^+, 0.23 D_2^+, 0.71 D_3^+

At Low Pressure, Atomic Physics Effects Are Relatively Small

100 kV, 100 mA, r_c=0.10 m, r_a=0.25 m, Source: 0.06 D^+, 0.23 D_2^+, 0.71 D_3^+

0.1 mTorr



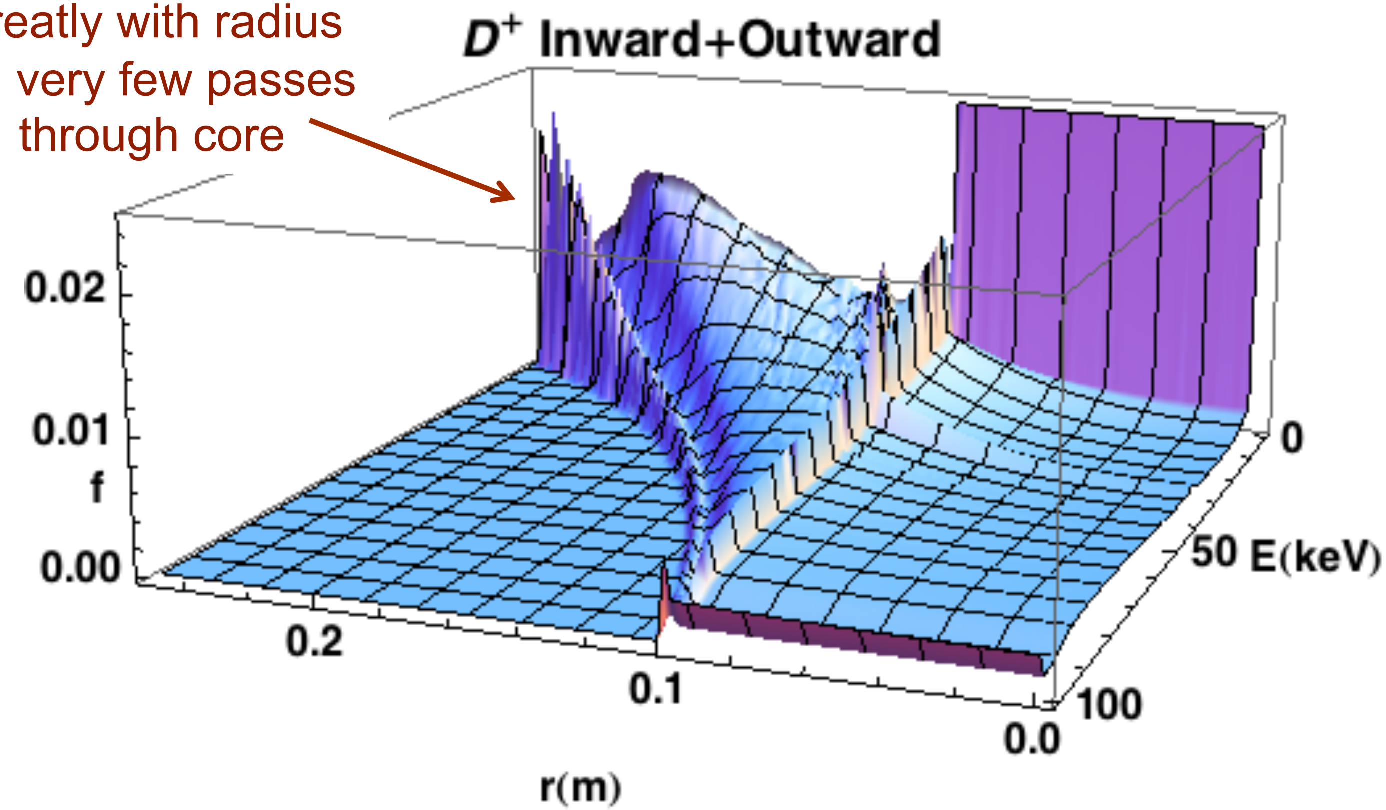
Magnitude of D^+ current varies little with radius => many passes through core

At Higher Pressure, Atomic Physics Effects Are Strong

100 kV, 100 mA, r_c=0.10 m, r_a=0.25 m, Source: 0.06 D^+, 0.23 D_2^+, 0.71 D_3^+

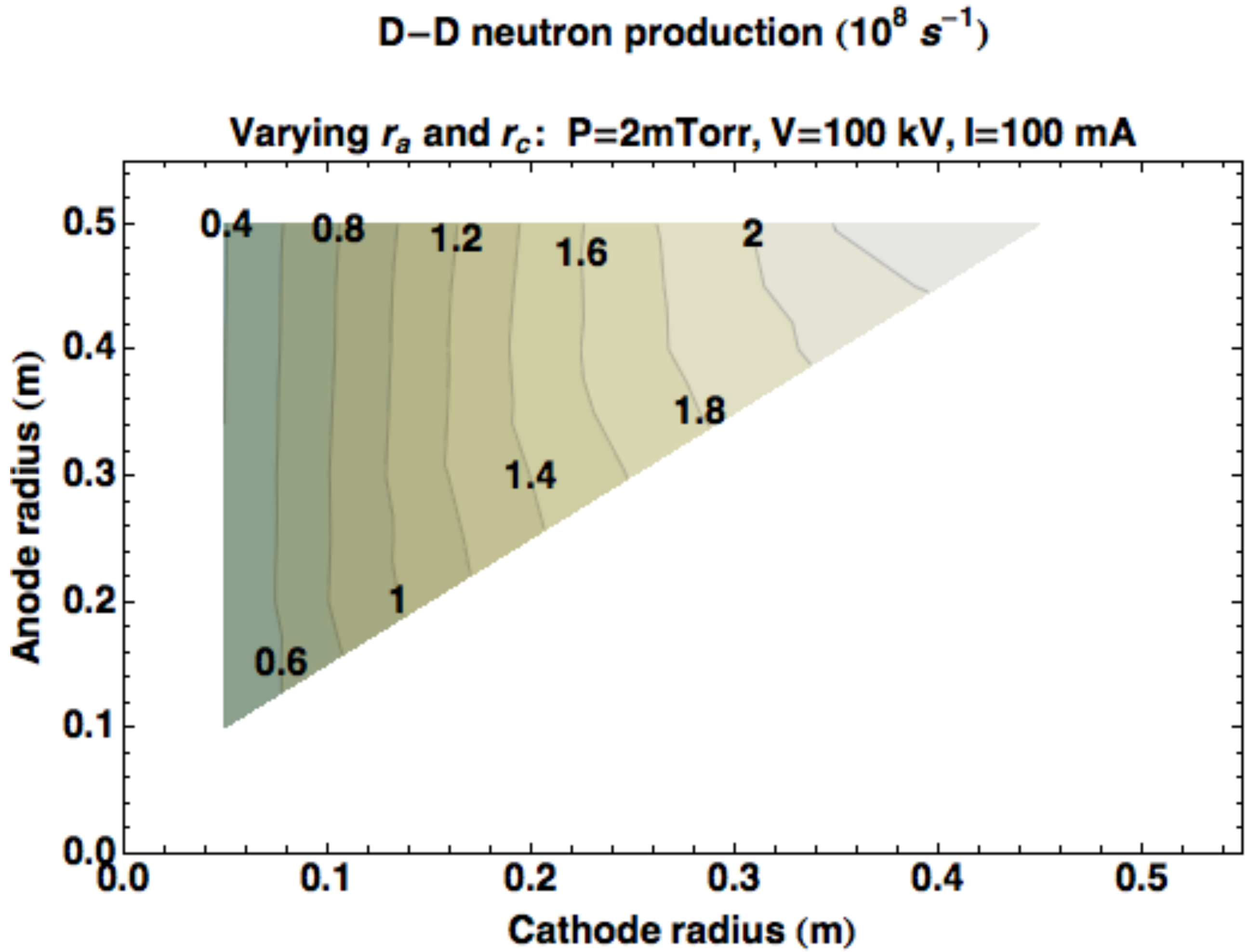
Magnitude of D^+ current varies greatly with radius => very few passes through core

10 mTorr



D-D Performs Better at Larger Radii for Constant Cathode-Anode Spacing

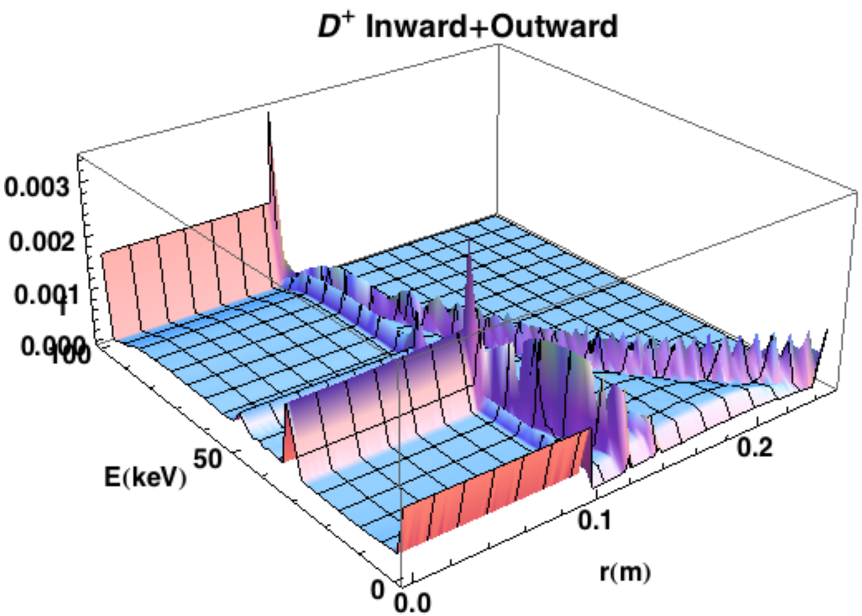
100 kV, 100 mA, P=2 mTorr, Source: 0.06 D^+, 0.23 D_2^+, 0.71 D_3^+



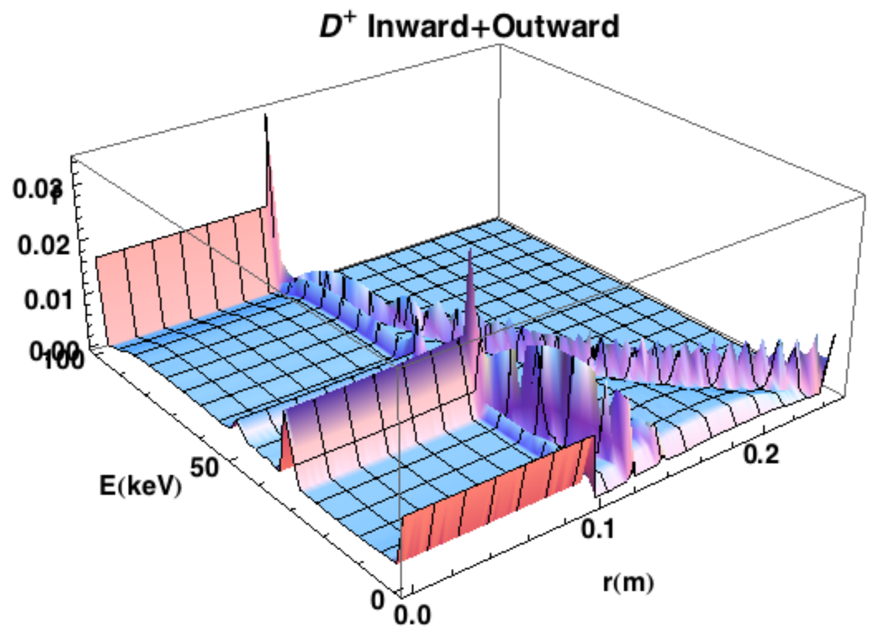
Parameters Scale Linearly with Ion Current

100 kV, 2 mTorr, r_c=0.10 m, r_a=0.25 m, Source: 0.06 D^+, 0.23 D_2^+, 0.71 D_3^+

10 A



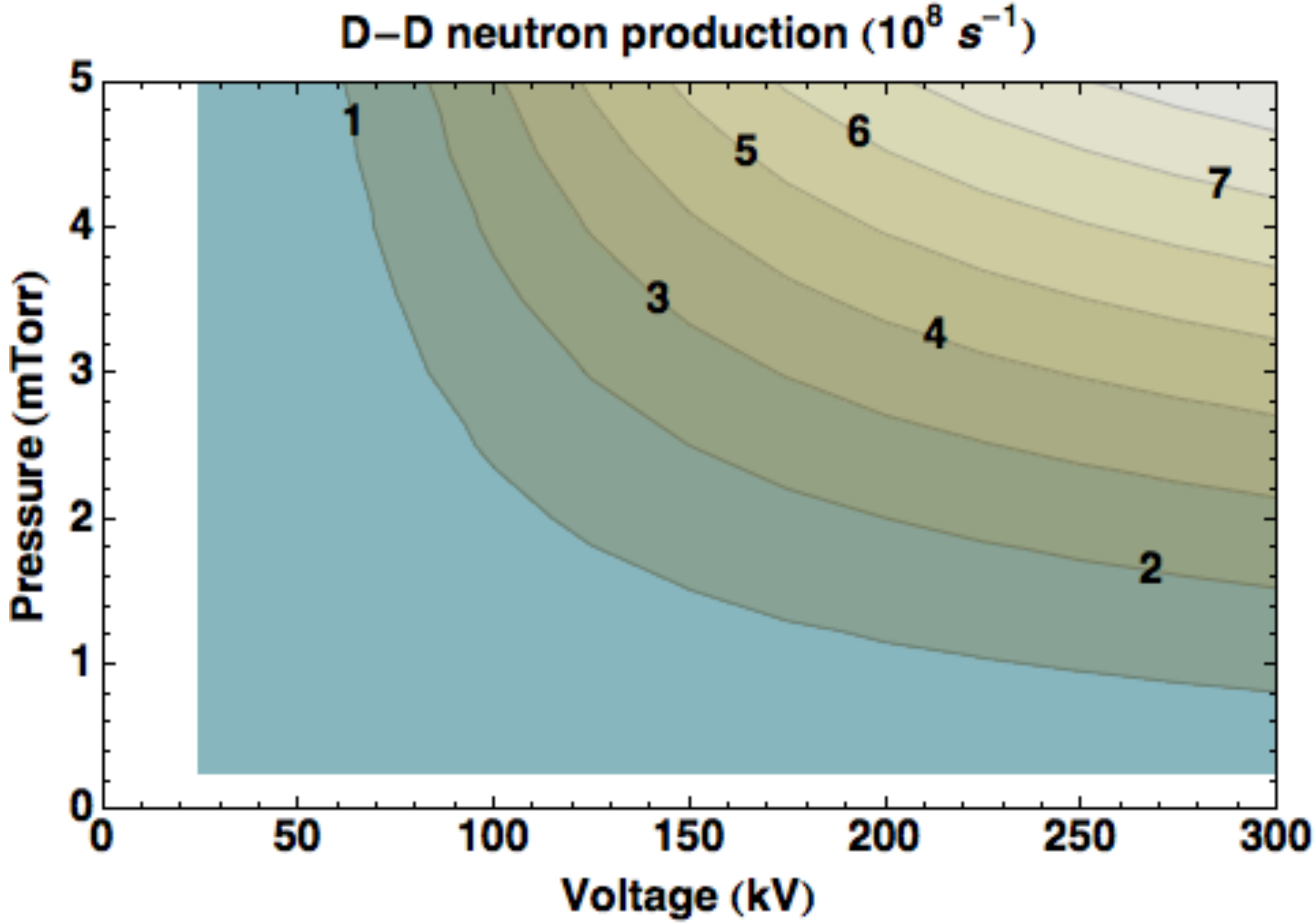
100 A



- Ion-impact ionization increases slightly in the cathode region.
- Note: the analysis does not include core space-charge effects.

Higher Voltage and Pressure Increase Neutron Production Strongly

100 mA, r_c=0.1 m, r_a=0.25 m, Source: 0.06 D^+, 0.23 D_2^+, 0.71 D_3^+



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
  - add negative ions (Eric Alderson),
  - include D-^{3}He and p-^{11}B fuels,
  - refine cross section data,
  - allow a glow discharge ion source distribution,
  - implement electrons as a separate species, and
  - optimize the configuration and plasma parameters

Summary and Conclusions

- UW's integral equation code now creates files with detailed output for all species as functions of r and E.
- We have developed a reasonable understanding of the key active processes in moderate pressure (0.1-5 mTorr) plasmas.
  - Caveat: negative ions remain to be implemented.
- The integral equation code predicts that the neutron production rate depends:
  - strongly on voltage and pressure,
  - moderately on anode radius and current, and
  - very little on cathode radius.