

# On Including Electron Effects In VICTER

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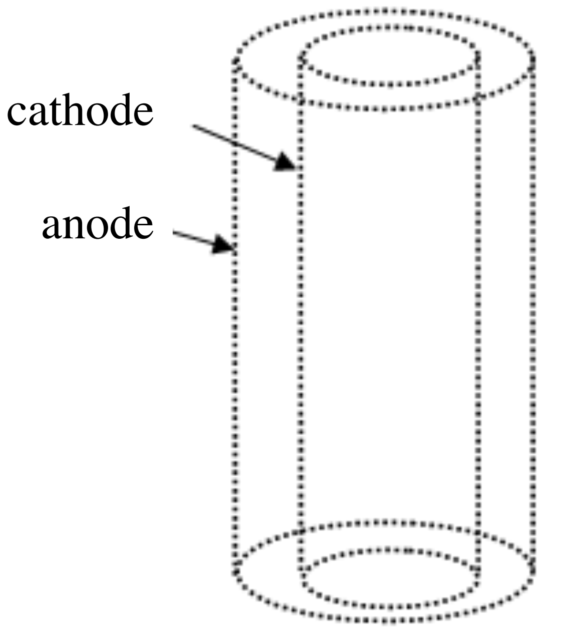
# Review of VICTER 2.0

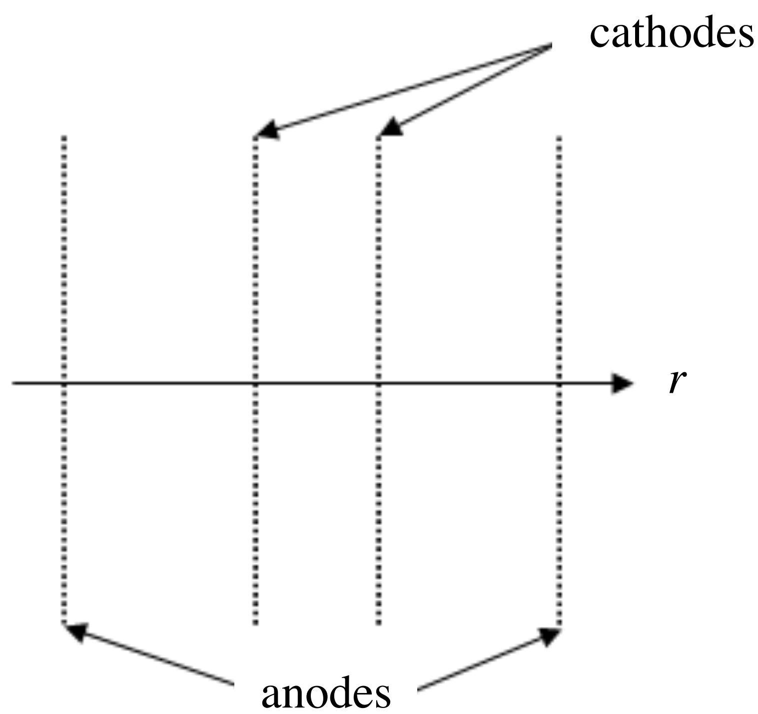
- Focuses on atomic and molecular physics of $D^0$, $D_2^0$, $D^+$, $D_2^+$, $D_3^+$, $D^-$, and $D_2^-$ .
- $D^+$, $D_2^+$, and/or $D_3^+$ ions enter from the source region outside the anode.
- Ion – neutral interactions dominate over ion – ion interactions.
- Ions and neutrals, except $D_3^+$, can be created in the intergrid and cathode regions by impact ionization, charge exchange, electron capture, stripping, and dissociation of fast ions in collisions with the background gas.
- Interactions occur without momentum transfer between nuclei; $v \neq 0$ daughter products travel at the same speed as parent.
- Collisionless ion motion occurs between interactions.

# Non-Spherical, 1-D Geometries are Treated

Code can model planar, cylindrical, or spherical geometry (all 1D; quantities vary with “radius”).

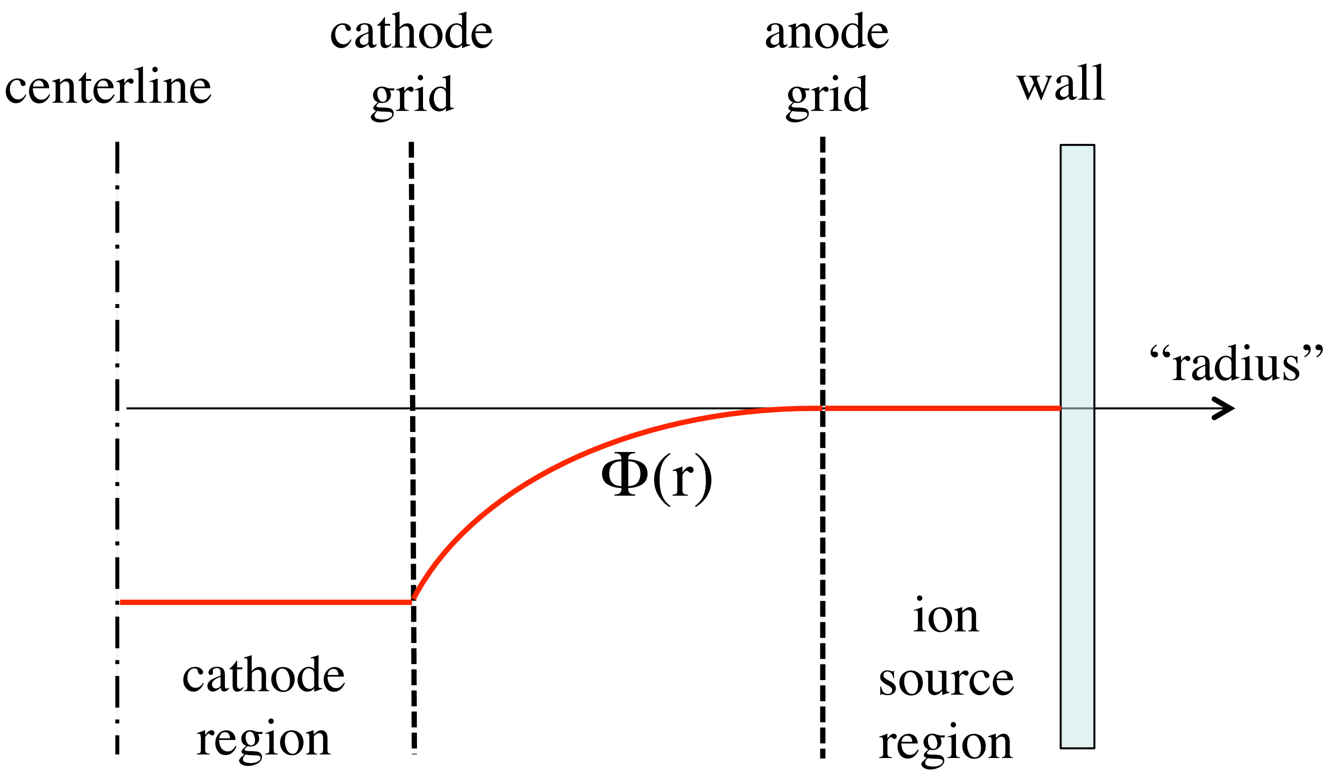



Cylindrical geometry




Planar geometry (edge view)

# Vacuum or Child-Langmuir Electrostatic Potentials Are Assumed between Grids




- Flat potential assumed in the cathode and source regions.

# Deuterium Atomic and Molecular Processes Included in VICTER 2.0

| | |
|---|---|
| $D^+ + D_2 \rightarrow D + D_2^+$ | charge exchange of $D^+$ |
| $D^+ + D_2 \rightarrow D^+ + \ldots$ | stationary $D^+$ production |
| $D^+ + D_2 \rightarrow D_2^+ + \ldots$ | stationary $D_2^+$ production |
| $D_2^+ + D_2 \rightarrow$ various products | destruction of $D_2^+$ |
| $D_2^+ + D_2 \rightarrow D^+ + \ldots$ | fast $D^+$ production |
| $D_2^+ + D_2 \rightarrow D^+ + \ldots$ | stationary $D^+$ production |
| $D_2^+ + D_2 \rightarrow D_2 + D_2^+$ | charge exchange of $D_2^+$ |
| $D_3^+ + D_2 \rightarrow$ various products | destruction of $D_3^+$ |
| $D_3^+ + D_2 \rightarrow D^+ + \ldots$ | fast $D^+$ production |
| $D_3^+ + D_2 \rightarrow D_2^+ + \ldots$ | fast $D_2^+$ production |
| $D_3^+ + D_2 \rightarrow D^+ + \ldots$ | stationary $D^+$ production |
| $D_3^+ + D_2 \rightarrow D_2^+ + \ldots$ | stationary $D_2^+$ production |

- Some of these processes are sums over various reaction channels.
- Negative ions, fast neutral atoms and molecules form by analogous processes.

# Now What's New

- Adding electron kinetics to VICTER
- Computing the electron energy spectra
- Including the feedback of the electrons on the ion kinetics

# Modeling Electron Kinetics

- Free electrons generated at the cathode by secondary emission.

$$S_c = \sum_{species} \int F_s(E)\gamma_{\text{sec}}(s,E)\,dE$$

- Additional electrons generated at v = 0 in the intergrid region by ion impact and electron impact ionization.
- Electrons are accelerated outward by the electrostatic potential.

# Electron Kinetics - II

The electron source term in the intergrid region satisfies a Volterra equation

$$S_e(r) = A_e(r) + \int_{cathode}^{r} K_e(r,r')S_e(r')dr'$$

where

$$K_e(r,r') = n_{gas}\sigma_{ei}\left(E_e(r,r')\right)$$

$$E_e(r,r') = -e\varphi(r) + e\varphi(r')$$

and $A_e(r)$ = electron source due to ionization of background gas by secondary electron and ion impact ionization.

# Electron Energy Spectrum

From the electron source term we generate the electron energy spectrum,

$F_e(r, E)dE$ = number of electrons passing through the radius $r$ per second with kinetic energy between $E$ and $E+dE$.

# Electron Ionization Affects the Ion Kinetics

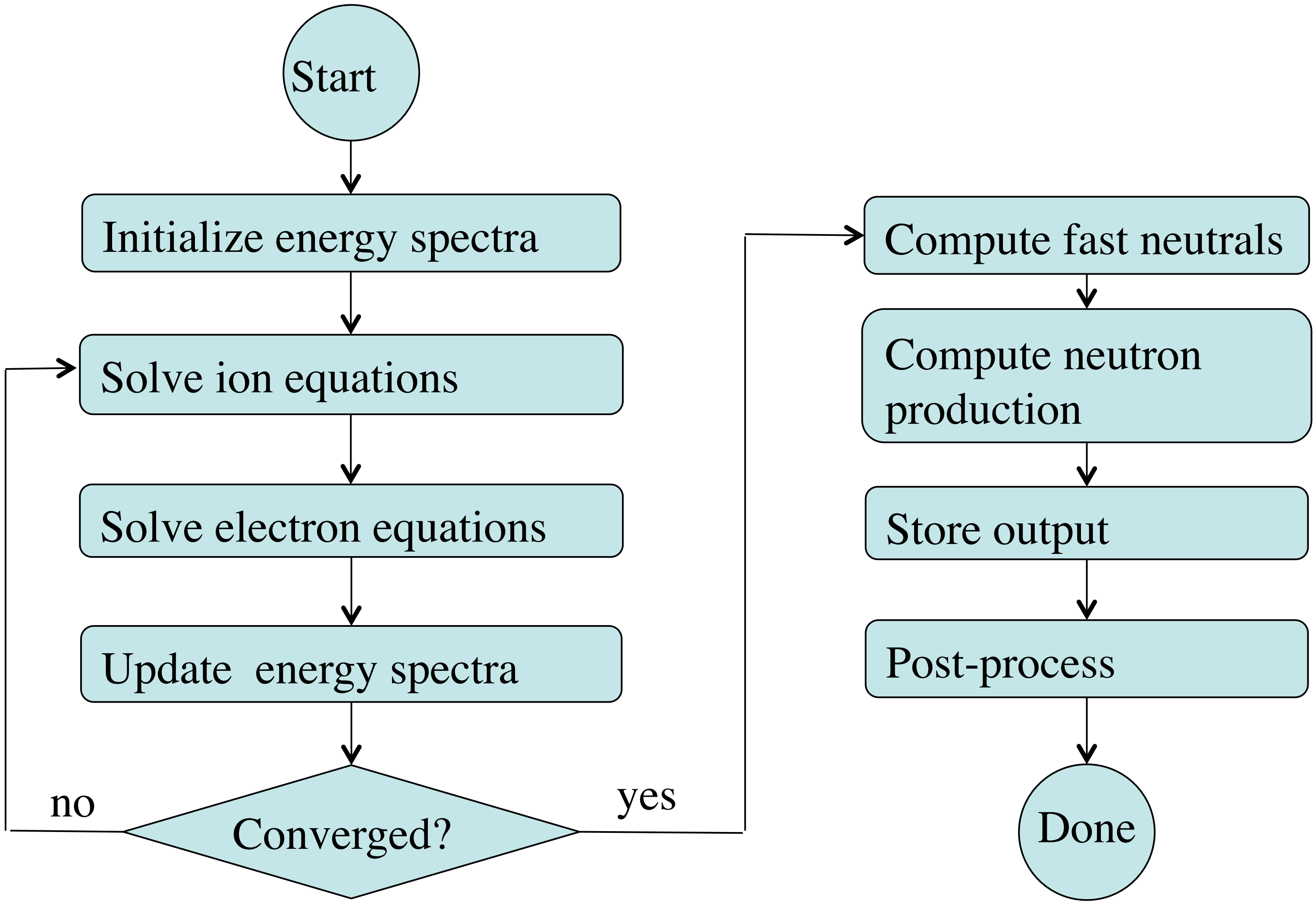
- Electron ionization creates more ions in the intergrid region

$$A_s(r) = \text{old value } + n_{gas}\int F_e(r,E)\,\sigma_{es}(E)\,dE$$

where $A_s(r)$ is the inhomogeneous term in the ion Volterra equations.

- Consequently, the ion and electron kinetic equations have to be solved simultaneously

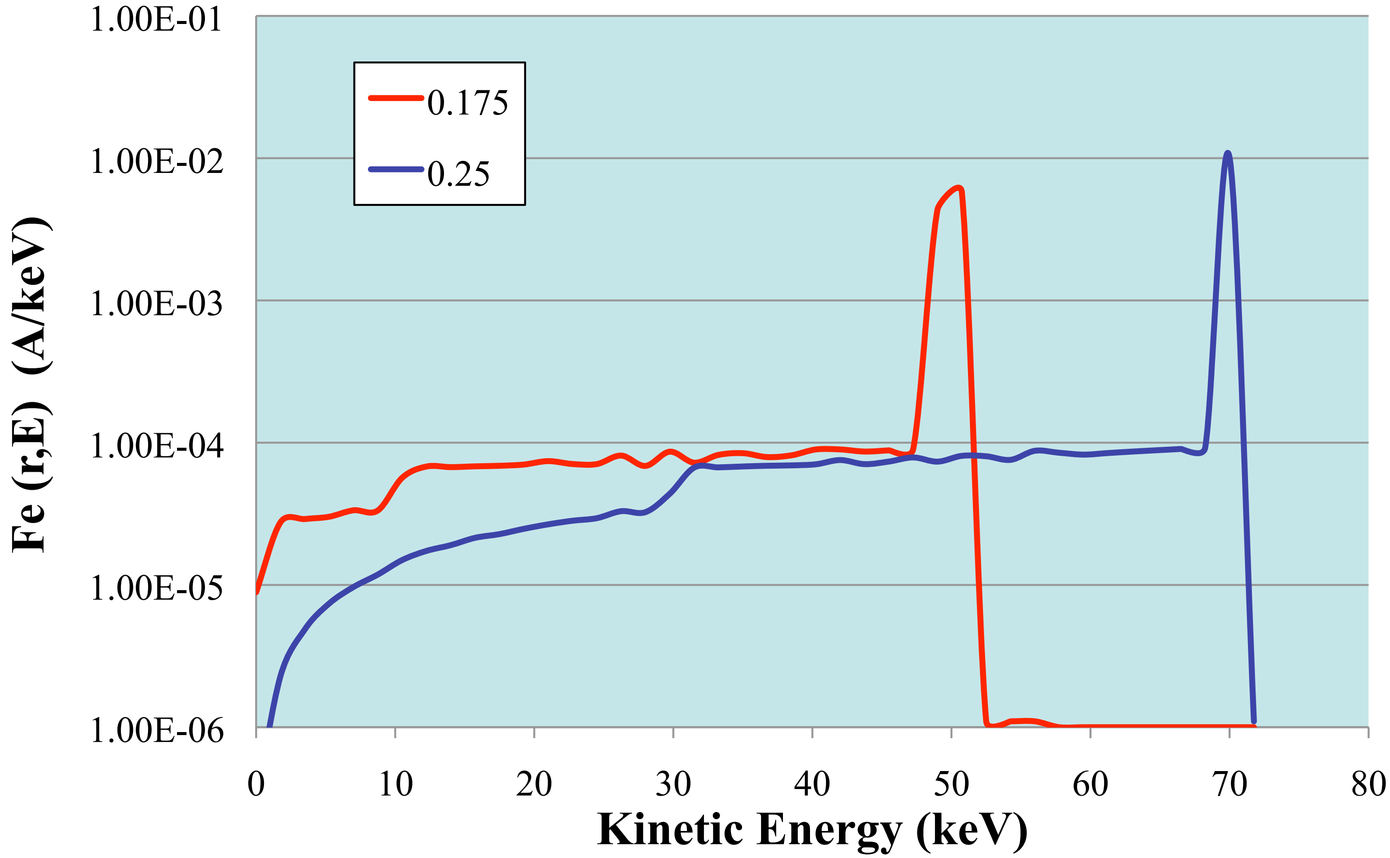
# Iterative Numerical Solution Procedure



# Parameters for a Sample Calculation

- Spherical geometry
- Cathode radius = 10 cm
- Anode radius = 25 cm
- Cathode potential = -70 kV
- Deuterium gas at 2.5 mTorr
- Cathode current = 30 mA

# Electron Energy Spectrum (at two different radii)

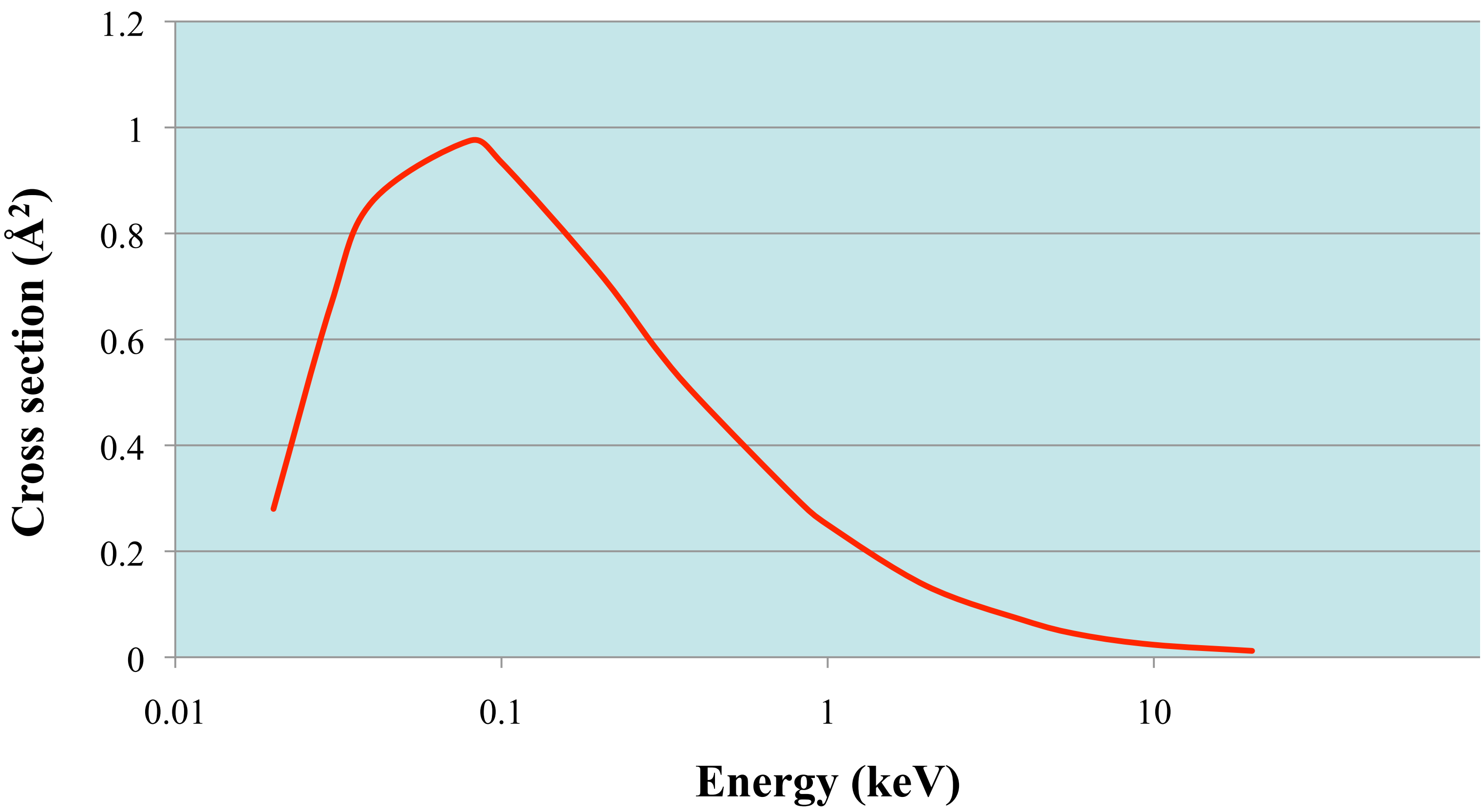


# Electron Current at the Anode Radius

| | |
|---|---|
| • From secondary emission at cathode | 17.5 mA |
| • From ion impact ionization in the intergrid region | 3.5 mA |
| • From electron impact ionization in the intergrid region | 4.3 μA |

Conclusion – for typical Homer IEC parameters, electron impact ionization in the intergrid region is negligible.

# Electron Ionization of $D_2$



# Electron Mean Free Path at 2.5 mTorr

$$\lambda_e = \frac{1}{n_{gas}\sigma_{ioniz}}$$

At 100 eV, $\lambda_e$ = 1.25 m

At one grid point from the cathode (1.5 mm away), the electron energy is 1.7 keV and their mean free path is 100 m.

# Summary

- Electron ionization in the intergrid region has been added to VICTER.
- Initial results show that ionization by electrons in the intergrid region is not important at typical IEC parameters.
- A difficulty with the approach so far is that the peak in the electron impact ionization cross section is not well-resolved. A non-uniform energy mesh for the electrons is needed.

Produced by University Communications

# Thank you for your attention.

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