Abstract
Gridded inertial-electrostatic confinement (IEC) devices accelerate and focus ions using voltage differences between nearly transparent concentric grids in spherical or cylindrical geometry. High voltages can be produced partially easily between the grids, giving the accelerated ions energies (~50 keV) suitable for positioning plasmas of advanced fuels, such as D, He. The resulting fusion products potentially can produce radioisotopes useful for position emission tomography and other applications. Research will be reported on the modeling effort for the UW IEC device and diagnostics, including comparison to experiments. The following physics effects will be discussed: charge exchange; ionization; neutralization for hydrogen and lithium isotopes; spherical Child-Langmuir radial electrostatic potential profile; attenuation by the cathode grid; multiple-pass ion and electron production due to charge exchange and ionization of the initial current; subsequent rotations of the resulting streams of particle-electron currents due to ionization, thermonic emission, and secondary electron emission; and fusion reactions, due to several phenomena in the plasma.

Inertial-Electrostatic Fusion Depends on Creation of a Radial Electrostatic Well and Spherically (or Cylindrically) Convergent Ion Flow
1. Inner grid (cathode) is biased to a high negative potential.
2. Fuel gas flows into the chamber and pressure is maintained.
3. Positive ions are created around the outer grid (anode).
4. Ions accelerate toward inner grid, gaining fusion-relevant energies.
5. Ions and electrons ionize neutral gas.
6. Ions charge-exchange with neutrals, fuse with other ions or neutrals, or hit grid.
7. Charge-exchange neutrals fuse with background gas.
8. Particle detectors monitor reaction rates.

Basics of IEC Model
- UW code includes the key atomic physics and fusion reaction rates for deuterium and helium-3.
  - Species included are D⁺, D, D⁺, D₂, D₃, He, H, H⁺, H⁺, He⁺.
  - Calculations presented here are for deuterium fuel only.
- Radial electrostatic potential profile will be nearly Child-Langmuir (balancing ion flow with adiabatic electrons), accelerating ions inward and electrons outward.
- Average ion will make only a few radial passes before being absorbed by the inner grid or undergoing charge exchange or ionization.
- Spattering, secondary electron emission, and thermonic electron emission can be important.
- Ionization will drain a small amount of energy from an ion, and will create an ion-electron pair that will contribute to the measured current.
- Charge exchange will create a hot neutral plus a cold ion that will subsequently be accelerated by the electrostatic field.
- Resulting ions and charge-exchange neutrals can undergo fusion with background gas or oscillating ions.
- Converged core physics remains uncertain and is not yet implemented.

Analysis Tracks Deuterons and Electrons during Multiple Passes through Core
- Only pure deuterium/electron plasmas have been modeled so far.
- Charge exchange dominates moderately collisional plasma.
- Child-Langmuir potential continues above in red.
- Neutral gas density outlined by red, 4.4 x 10^13 m⁻².
- Cathode radius 0.25 m.
- Grid potential difference 80 kV.

Results
- “Production” Due to Charge Exchange Plus Ionization Can Be Substantial
  - Production by second-generation ions that started at radius rₐ.
- Two-Generation Calculation of Proton Production Falls Short of Experimental Value
  - Experimental D-D proton production at 80 kV and 30 mA is 2 x 10^10 protons/s.
  - Two-generations of the present computational method give ~10^9 protons/s total.
  - Main contribution stems from charge-exchange neutrals and radially moving ions reacting with background gas.
  - Converged-core and counter-streaming-ion fusion terms give very small contributions.

Summary
- Gridded IEC device models have been developed.
  - Atomic physics.
  - Fusion reactions.
- Fusion product production as a function of radius has been estimated.
  - Using only the initial current plus first and second generations of created ions gives values ~20 times lower than those found in the UW IEC experiments.
  - Preliminary indications are that following several more generations of ion production may reconcile these differences, but much work remains.
- Neglected effects, particularly embedded ions, can be important. Work on including these is in progress.