Progress Report on SPARTAN Simulation of IFE Chamber Dynamics

Farrokh Najmabadi and Zoran Dragojlovic

HAPL Meeting

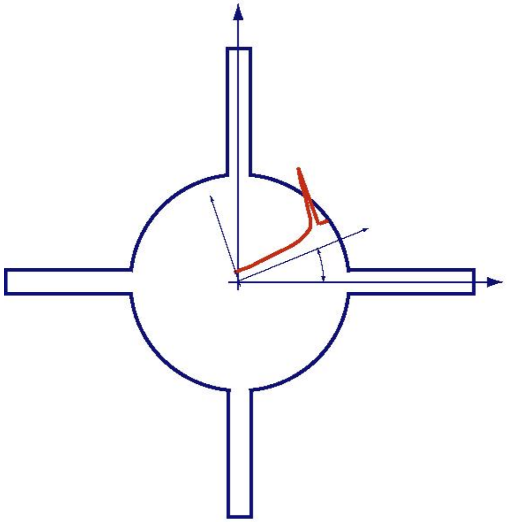
March 3-4, 2005
Naval Research Laboratory
Washington DC

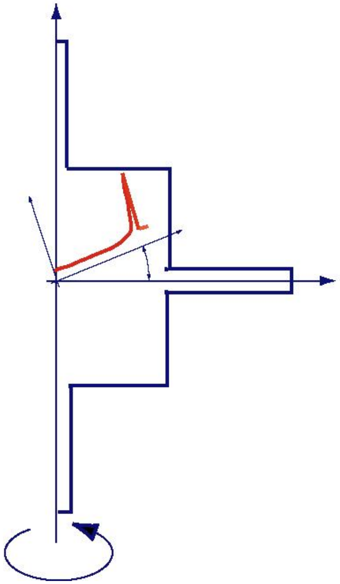
Electronic copy: http://aries.ucsd.edu/najmabadi/TALKS
UCSD IFE Web Site: http://aries.ucsd.edu/IFE

Thermo-Mechanical Response of Chamber Wall Can Be Explored in Simulation Facilities

SPARTAN features:

- Physics: Navier-Stokes equations with state dependent transport properties; Coronal model for radiation.
- Numerics: Godunov solver; Embedded boundary; and Adaptive Mesh Refinement
- Two-Dimensional: Cartesian and cylindrical symmetry
- Use results from rad-hydro codes (BUCKY) as initial condition.

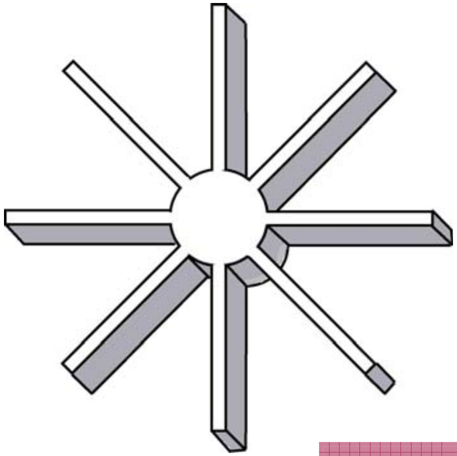




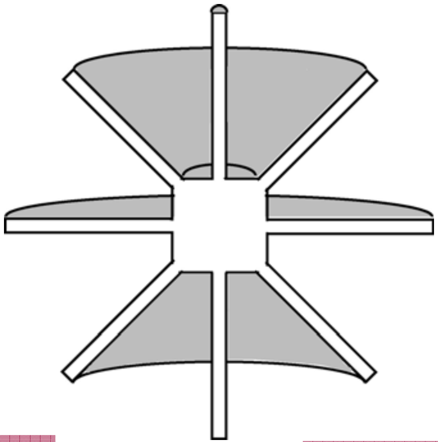
- All previous results were based on a Bucky run provided by Don Haines

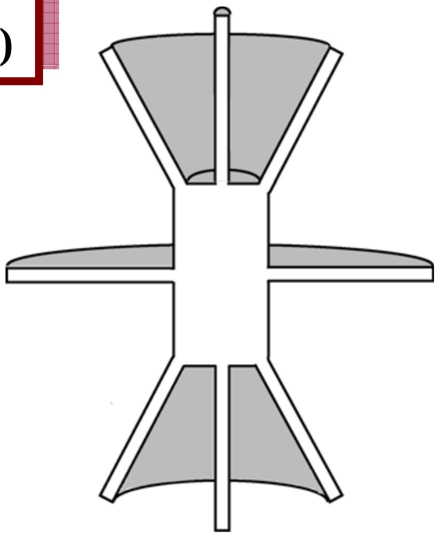
A variety of chamber geometries has been considered

Infinite cylinder
(Cartesian symmetry)

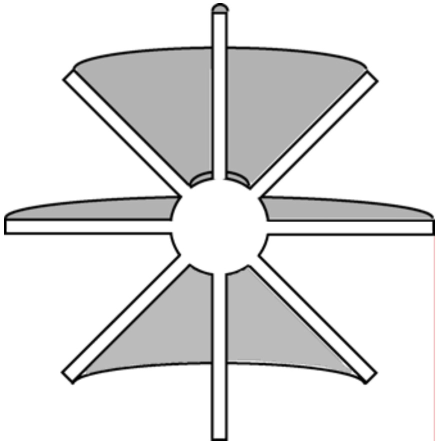


Finite cylinder
(Cylindrical symmetry)

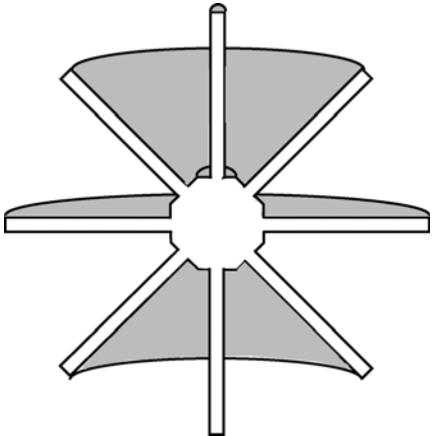




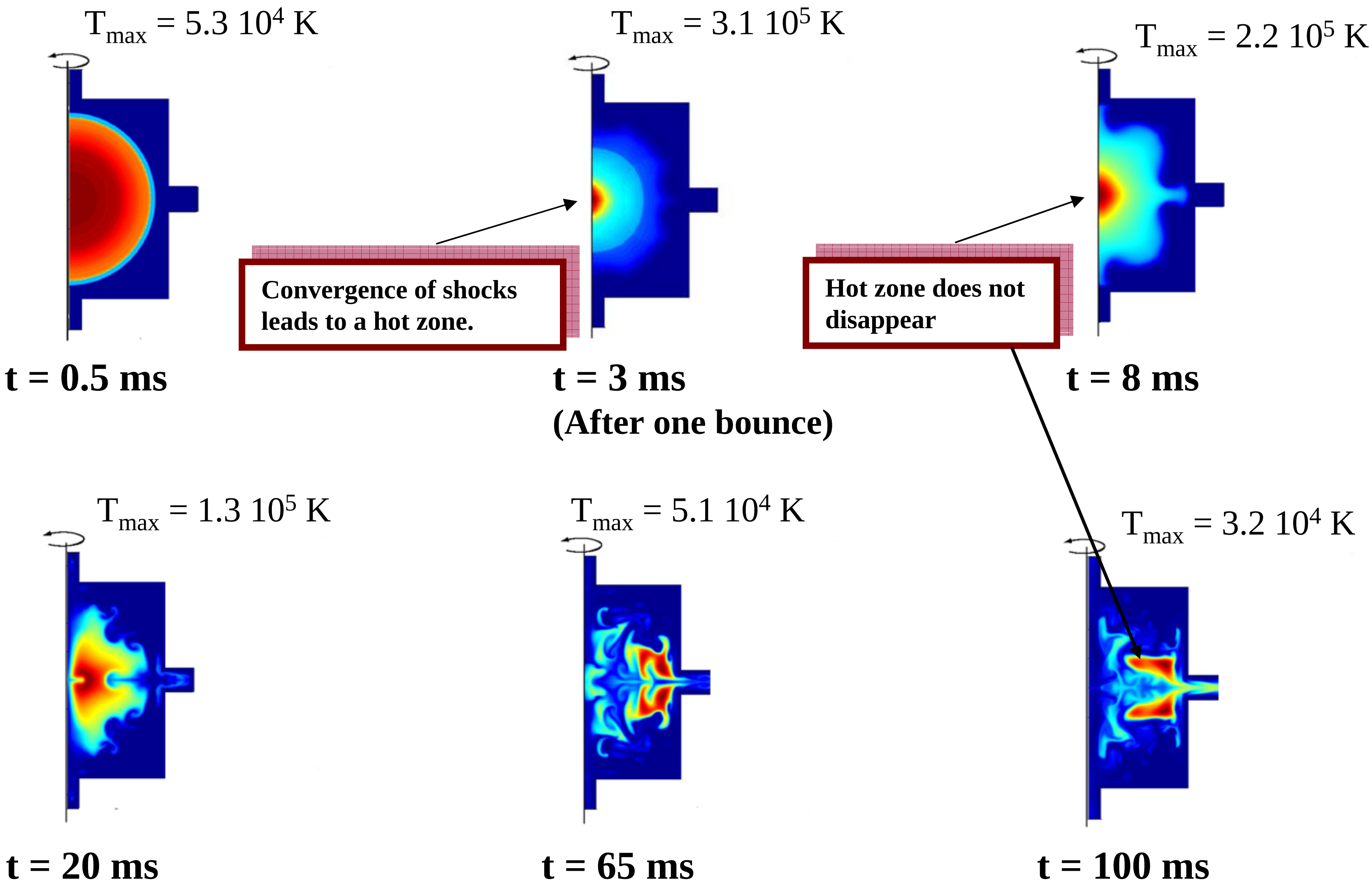
Sphere
(Cylindrical symmetry)



Octagon
(Cylindrical symmetry)

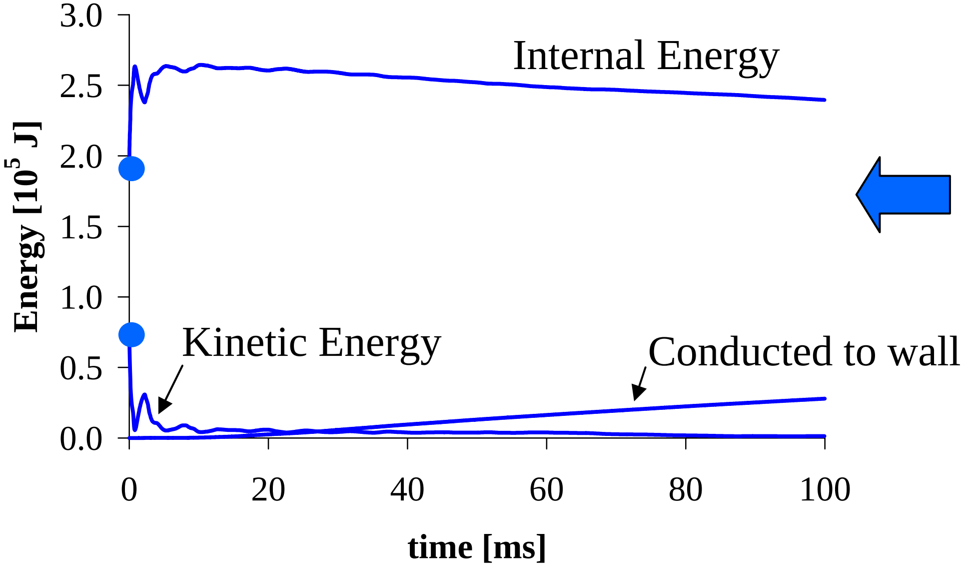


Without Radiation, a high temperature zone would be developed in the chamber



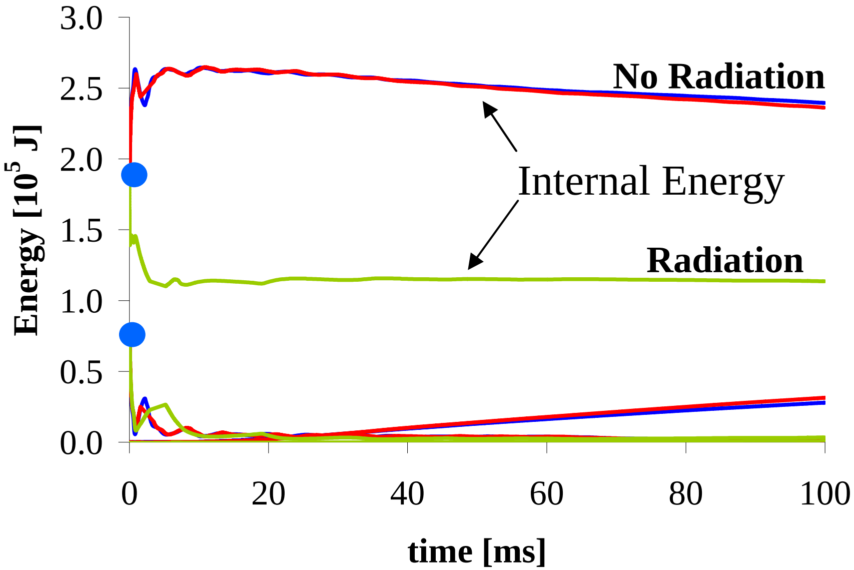
Without Radiation, a high temperature zone would be developed in the chamber

Case I: No Radiation



After the first "bounce" kinetic energy of gas is converted into internal energy (hot zone). Conduction to the wall is too slow.

Case II: With Radiation



The energy is dissipated by radiation. The gas temperature is effectively pinned by radiation (~5,000K for Xe)

Dynamic Evolution of Xe-filled Chambers

A large number of cases with different geometries were simulated:

- 3-D effects can be observed and sufficiently described by using a combination of Cartesian and axisymmetric cylindrical 2-D models.
- Shape of the chamber makes little difference in peaks and averages of the temperature (< 10%).
- Peak Xe temperature is set by radiation at about 5,000K.
- A Journal article was written but is currently shelved. (see below)

Status of Plans from Previous HAPL Meeting

- **Separate radiation step from the fluid dynamics in order to shorten the run time with the full radiation source term.**
  - ✓ Done! (only a factor of ~2 reduction in run time).
  - ✓ We purchased a two-processor 64-bit (native) computer with fast memory access: Drastic reduction in run time.
  - ✓ Developed MATLAB based GUI for post-processing of the data.
  - ✓ Developed a program to construct the problem geometry from simple geometrical shape.

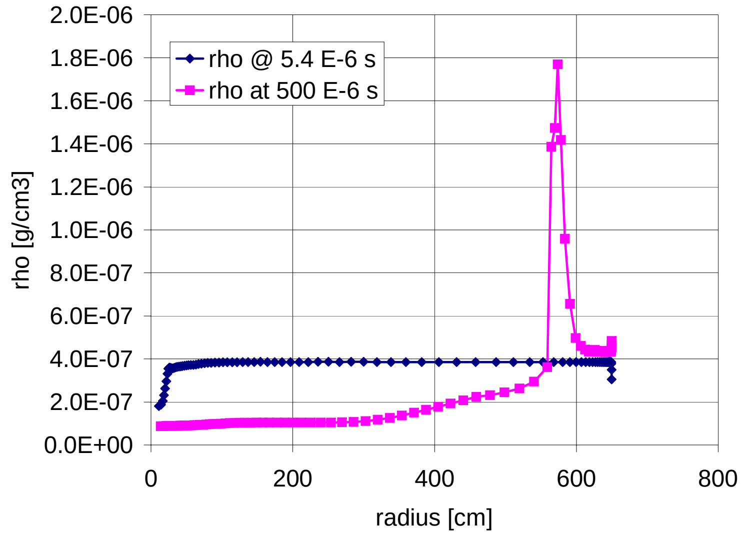
- **Parametric study of different gases (Xe, He, D, T) and initial pressures in the chamber:**
  - ✓ We received Bucky runs for chambers filled with D, T, and Xe at 10, 30, and 50 mTorr.
  - ✓ There are significant differences between new Bucky runs and one received from Don Haines.

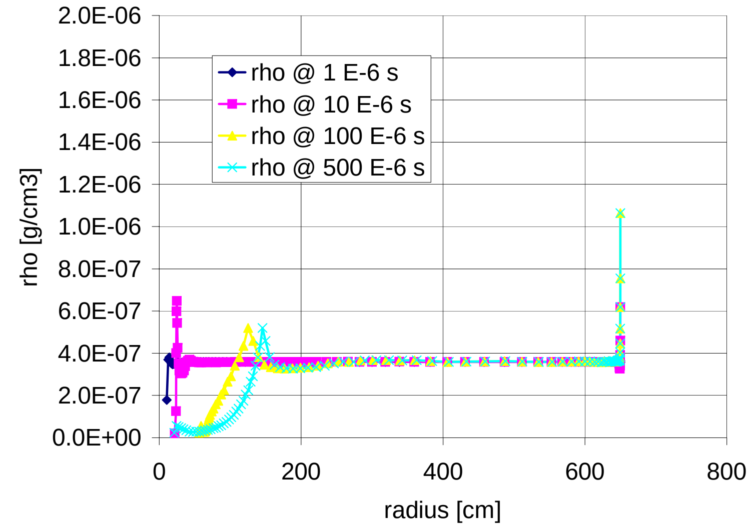
Differences between Old and New Bucky Runs (50 mTorr Xe)

Data from Don Haynes, 2001

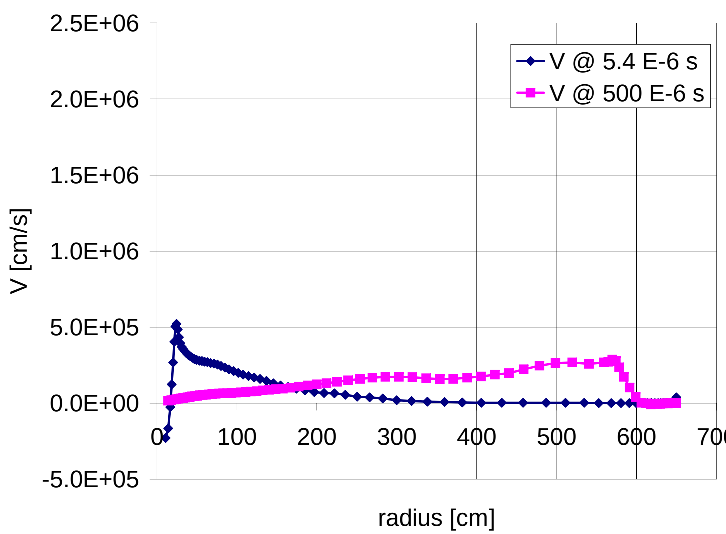
Data from Greg Moses, 2004

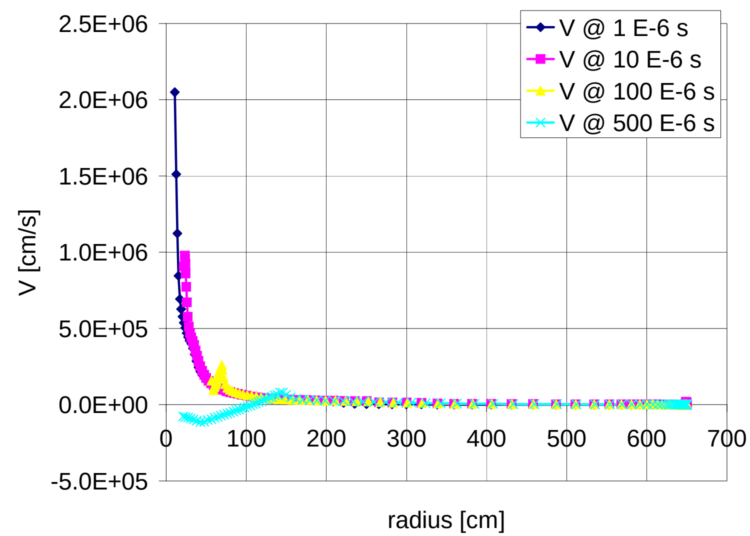
Density





Velocity

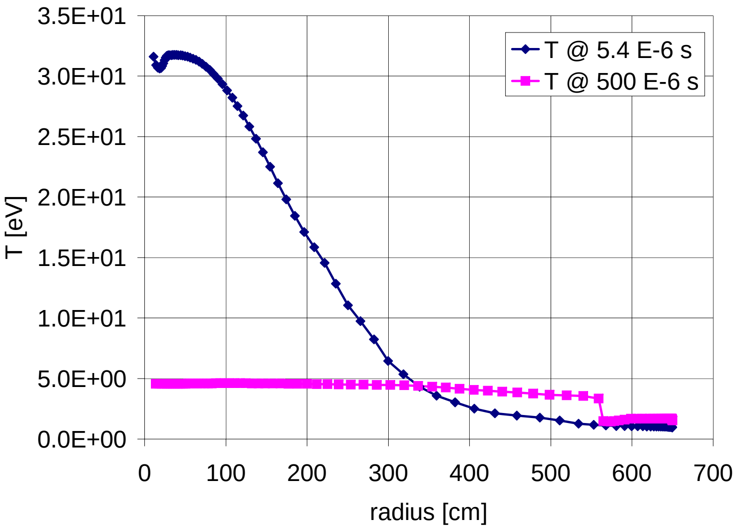




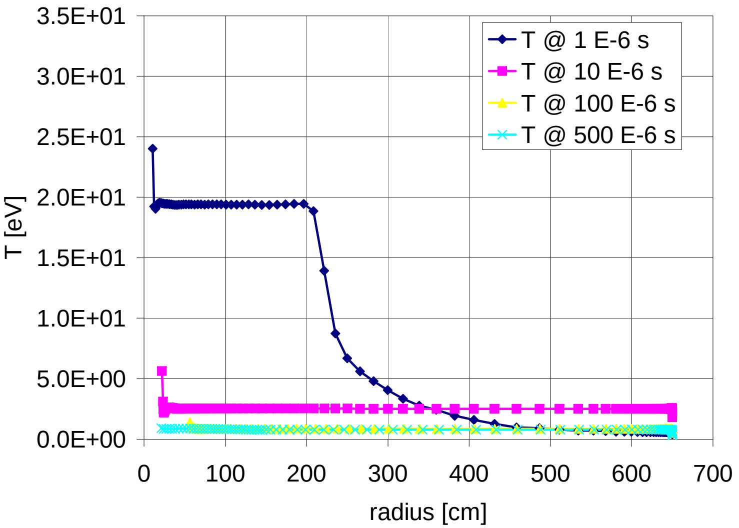
Differences between Old and New Bucky Runs (50 mTorr Xe)

Temperature

Data from Don Haynes, 2001



Data from Greg Moses, 2004

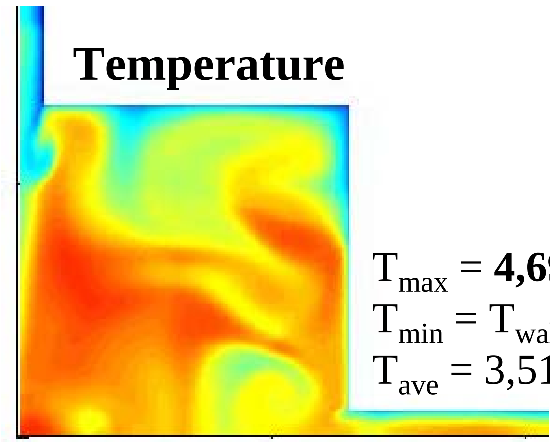


Comparison of SPARTAN runs using Old and New Bucky Runs as initial conditions

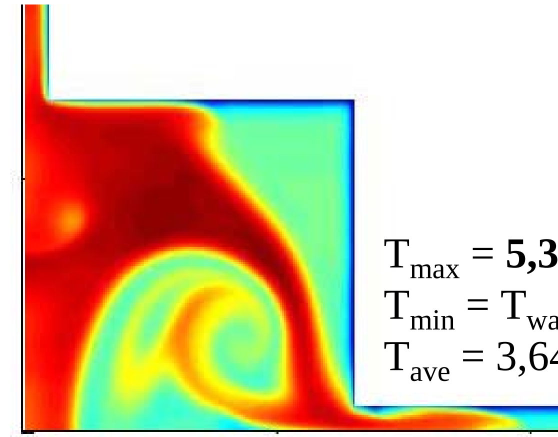
Data from Don Haynes, 2001

Data from Greg Moses, 2004

Temperature

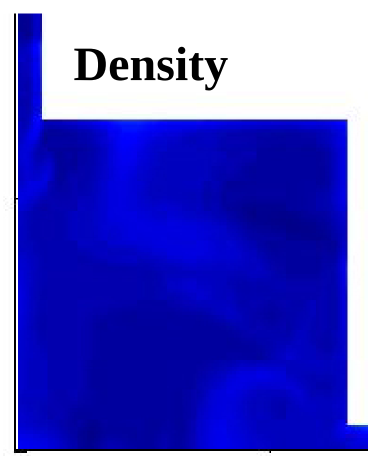


T_{max} = **4,690 K**
$T_{min} = T_{wall}$ = 973 K
T_{ave} = 3,510 K

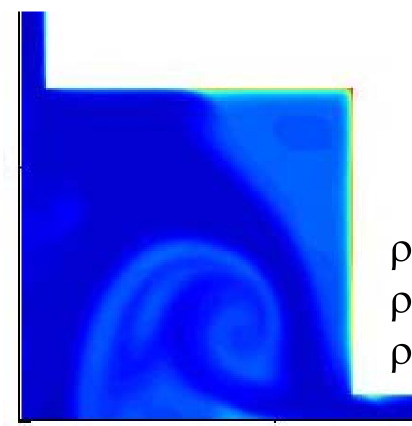


T_{max} = **5,370 K**
$T_{min} = T_{wall}$ = 973 K
T_{ave} = 3,640 K

Density

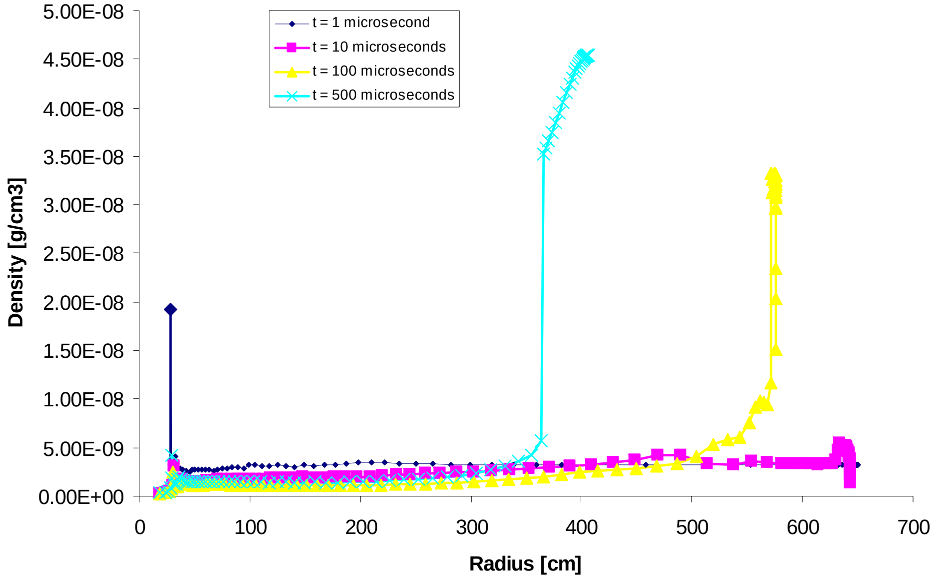


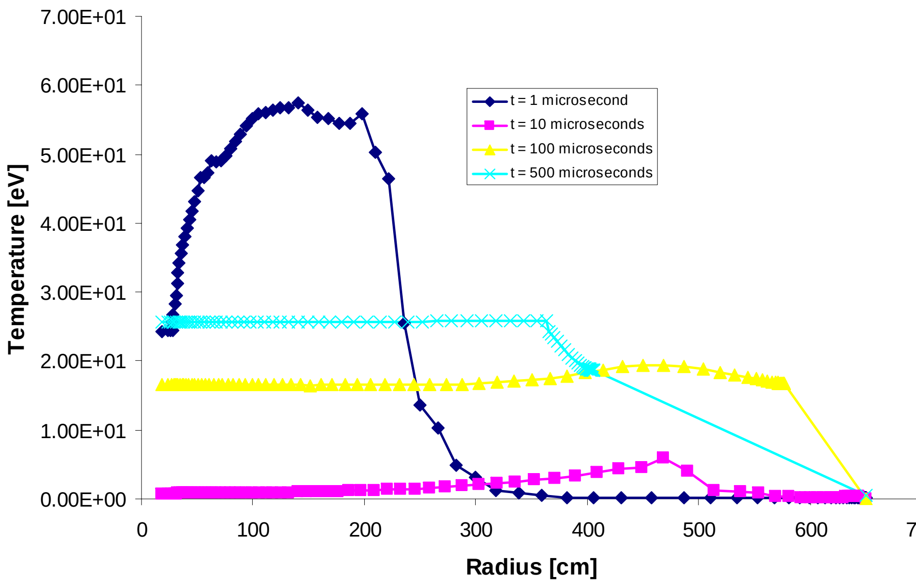
$\rho_{max} = 1.2\ g/m^3$
$\rho_{min} = 0.3\ g/m^3$
$\rho_{ave} = 0.4\ g/m^3$

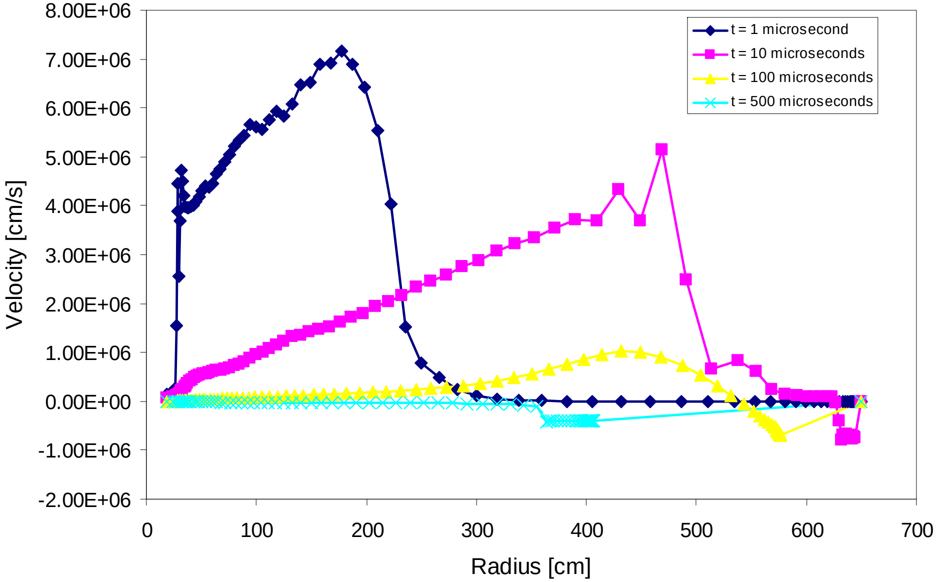


$\rho_{max} = 2.9\ g/m^3$
$\rho_{min} = 0.5\ g/m^3$
$\rho_{ave} = 0.7\ g/m^3$

30m Torr D
Initial Condition from Bucky







Temperature increases with time.

Final Words…

- **Parametric study of different gases (Xe, He, D, T) and initial pressures in the chamber:**
  - ✓ Whenever Bucky initial conditions becomes available.

- **Regime of validity of SPARTAN:**
  - ✓ $Ku = \lambda/L < 0.01$ Valid
  - ✓ $Ku \sim 1$ Molecular flow, not valid
  - ✓ $0.01 < Ku < \sim 0.2$ Transition (transport coefficients should be modified) but in IFE chambers transport is dominated by radiation

  - ✓ 50 mTorr: $\lambda_D = 2$ cm $\lambda_{Xe} = 1$ cm **OK**
  - ✓ 5 mTorr: $\lambda_D = 20$ cm $\lambda_{Xe} = 10$ cm Transition (**probably OK**)
  - ✓ 0.5 mTorr: $\lambda_D = 2$ m $\lambda_{Xe} = 1$ m Molecular flow (**NO**)