EFFECTS OF CHAMBER GEOMETRY AND GAS PROPERTIES ON HYDRODYNAMIC EVOLUTION OF IFE CHAMBERS

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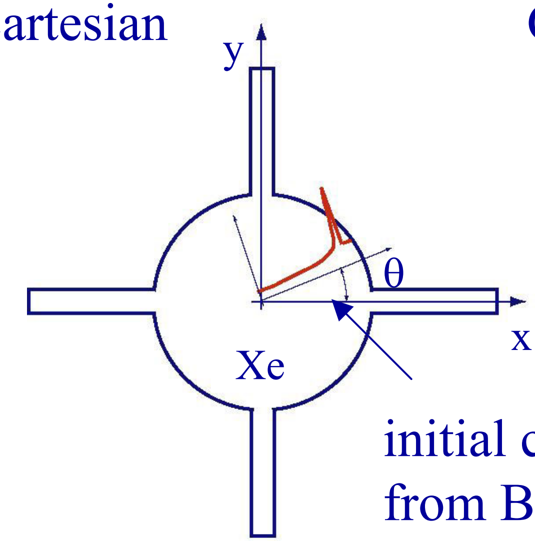
Motivation

- The focus of our research effort is to model and study the chamber dynamic behavior on the long time scale, including:
  - the hydrodynamics;
  - the transfer mechanisms such as
    - photon and ion heat deposition
    - chamber gas conduction, convection and radiation;
    - chamber wall response and lifetime;
    - cavity clearing.
- In order to investigate these phenomena, a fully integrated numerical code SPARTAN is being developed as assembly of well documented algorithms.
- This talk is concerned with
  - multidimensional geometry effects which arise as fluid interacts with the vessel wall containing various beam access ports.
  - Effect of molecular diffusion and background plasma on chamber state evolution.

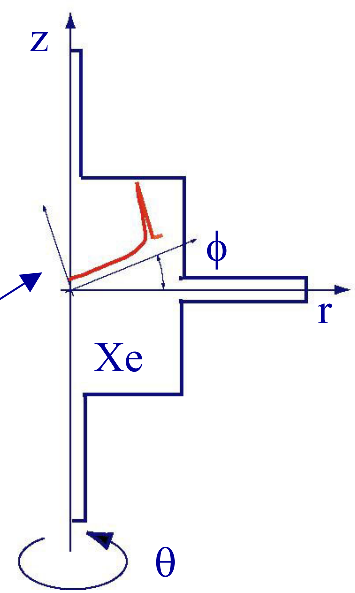
IFE Chamber Models

- SPARTAN numerical algorithms:
  - –Godunov solver of Navier-Stokes equations with state dependent transport properties.
  - –Embedded boundary
  - –Adaptive Mesh Refinement
- Two different aspects of the cylindrical chamber given here:
  - –Cartesian geometry (everything along chamber axis is constant)
    - Arrays of beam lines along chamber axis replaced by 4 beam sheets.
  - –Cylindrical Geometry: (everything along polar angle θ is constant).
    - Arrays of beam lines around chamber perimeter replaced by a single beam sheet.
    - A beam line placed on top and bottom.

Cartesian



Cylindrical



initial conditions from BUCKY

chamber dimensions:

radius: 6.5 m

height: 13 m

beam sheet dimensions:

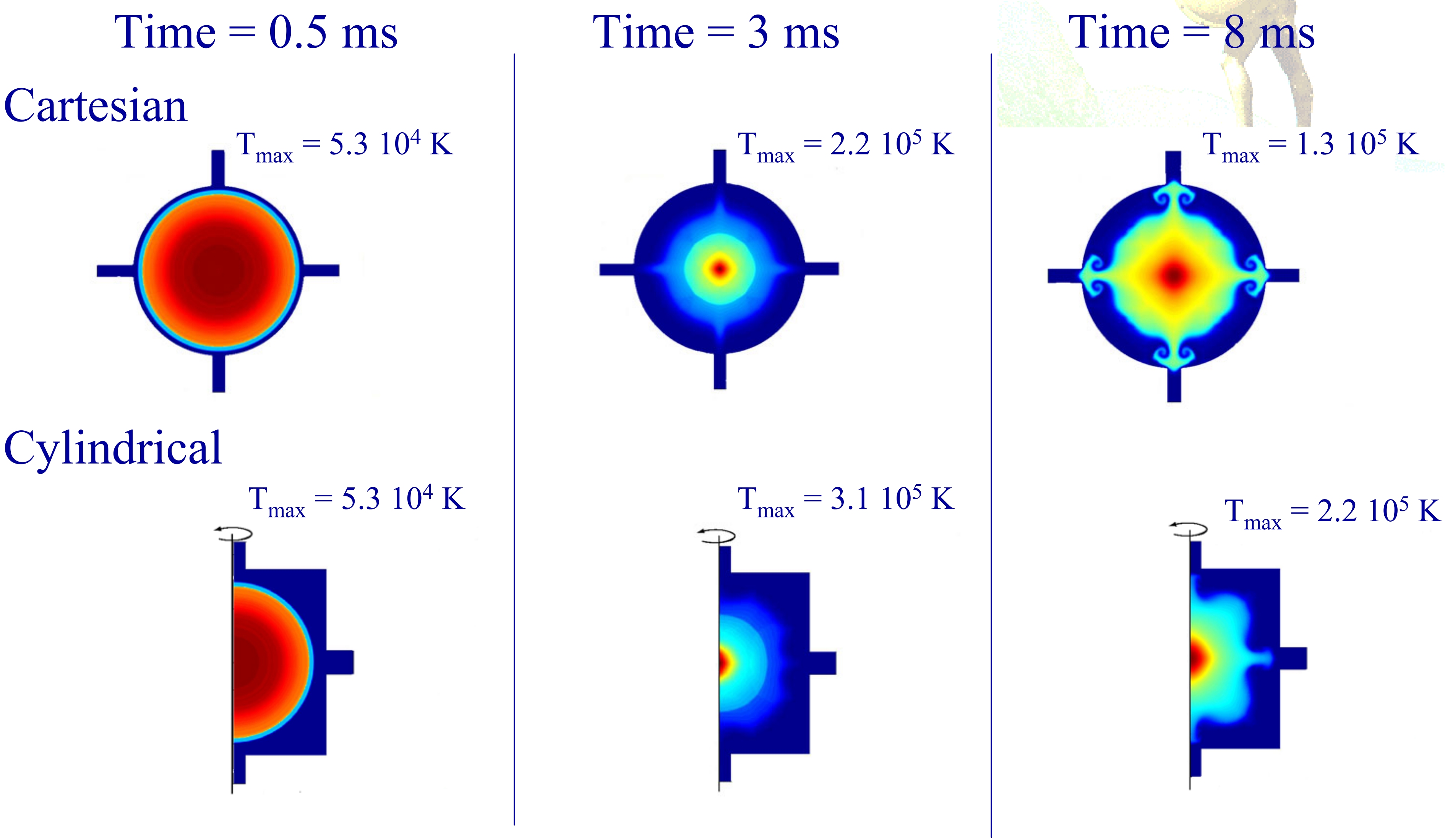
length: 20 m

width: 1 m

Effects of Chamber Geometry on Evolution of Chamber State

- Details are given for neutral gas.
- Impact of background plasma will be addressed separately.

Effects of Chamber Geometry



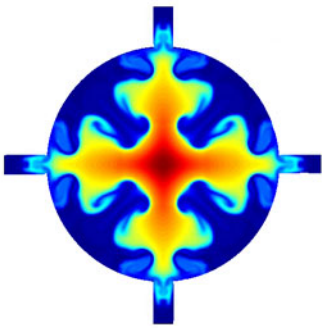
For all cases: $T_{min} = T_{wall}$ = 973.16 K

Effects of Chamber Geometry

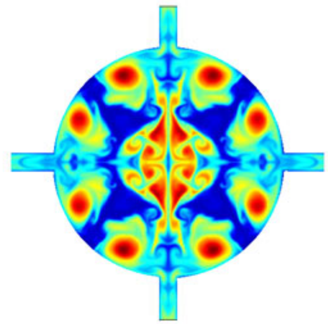
Time = 20 ms | Time = 65 ms | Time = 100 ms

Cartesian

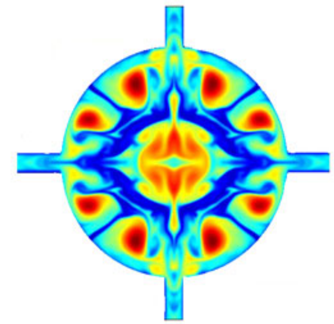
Time = 20 ms: $T_{max} = 1.2\ 10^5$ K



Time = 65 ms: $T_{max} = 2.8\ 10^4$ K

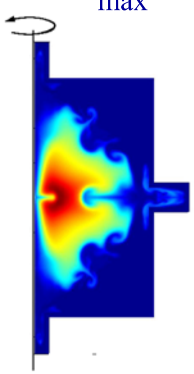


Time = 100 ms: $T_{max} = 2.3\ 10^4$ K

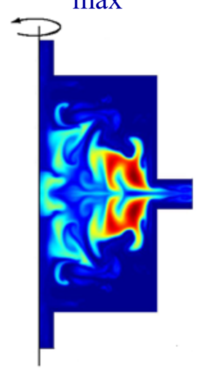


Cylindrical

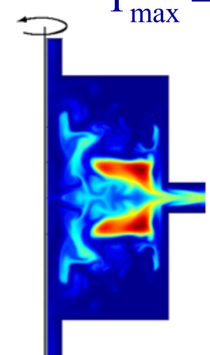
Time = 20 ms: $T_{max} = 1.3\ 10^5$ K



Time = 65 ms: $T_{max} = 5.1\ 10^4$ K



Time = 100 ms: $T_{max} = 3.2\ 10^4$ K

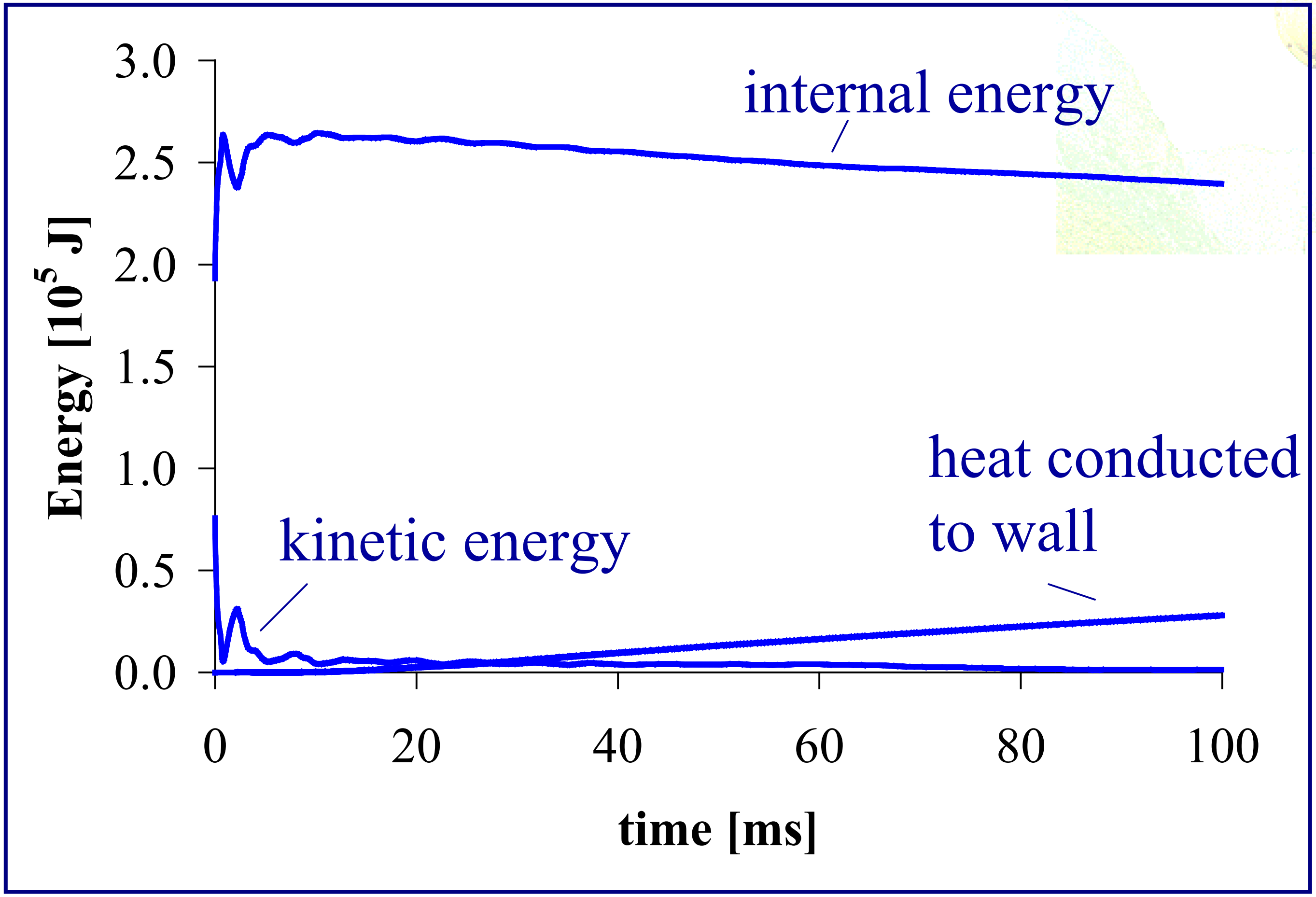


For all cases: $T_{min} = T_{wall} = 973.16$ K

Evolution of Gas Energy from 0-100 ms

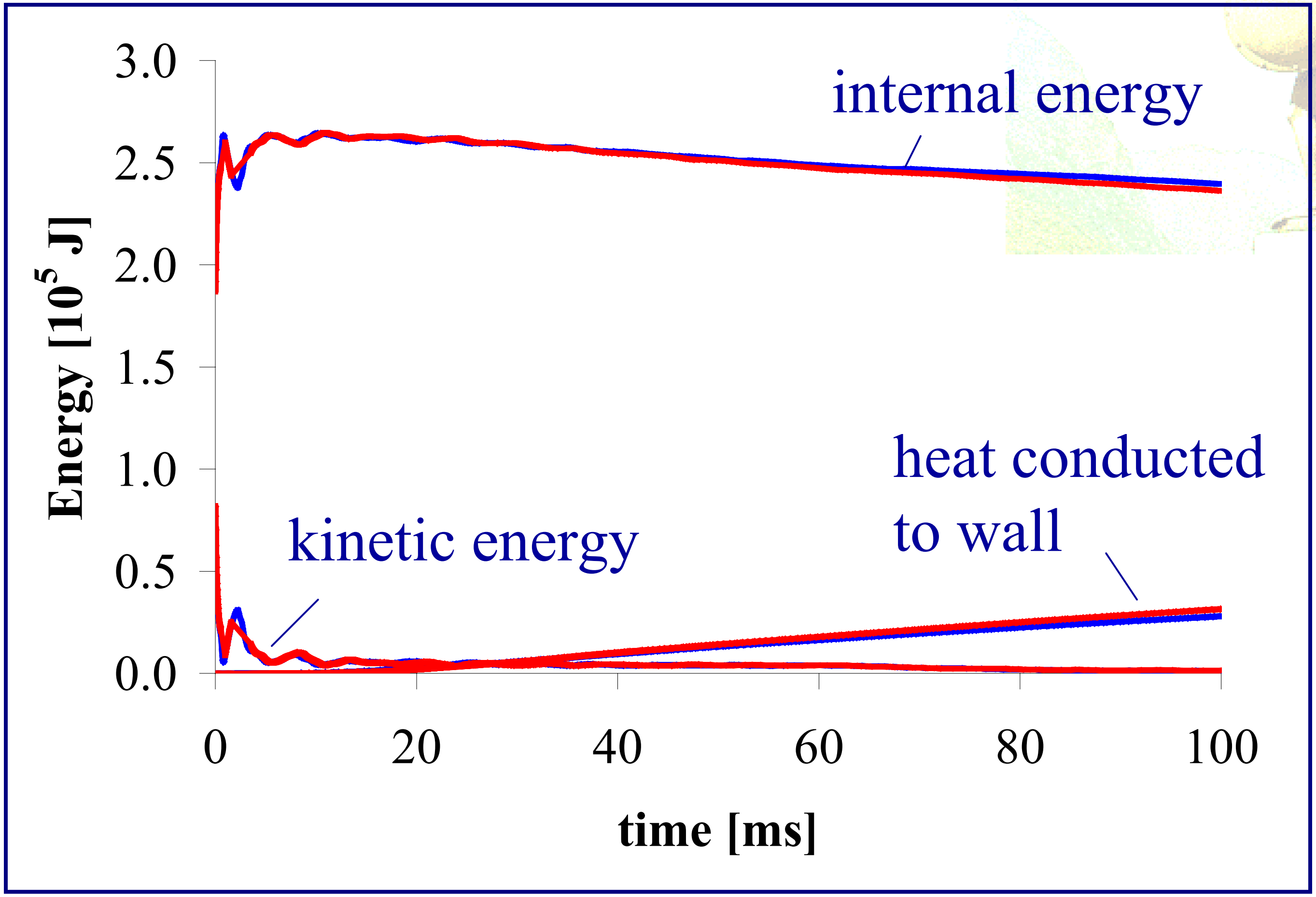
- Impact of transport phenomena on chamber system, such as:
  - Molecular conduction of neutral gas.
  - Conduction due to free electrons of background plasma.
  - Volumetric heat loss due to radiation of background plasma.

Gas Energy from 0-100ms



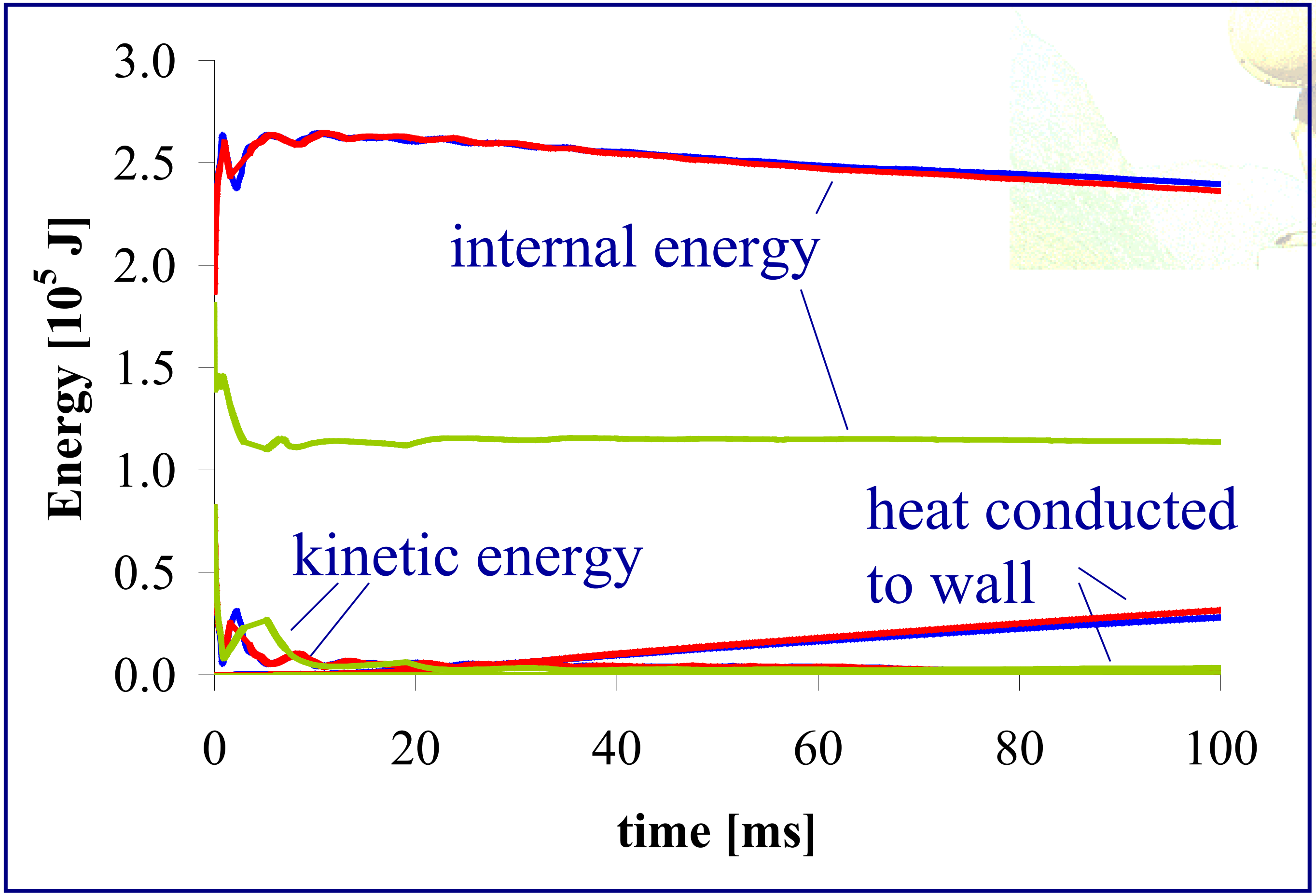
- Case I: Neutral Gas

Gas Energy from 0-100 ms



- Case I: Neutral Gas
- Case II: Neutral Gas + Electron Conductivity

Gas Energy from 0-100 ms



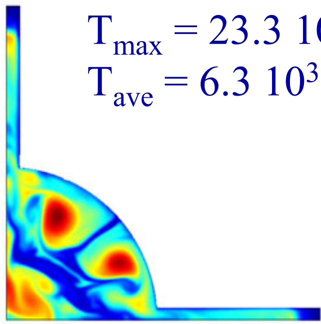
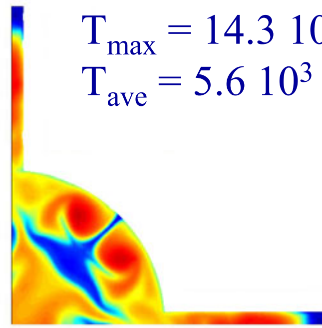
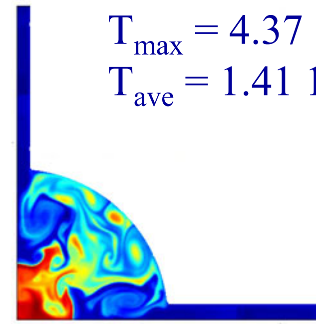
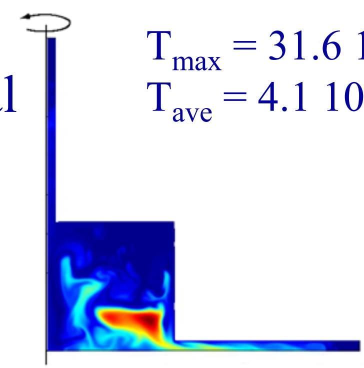
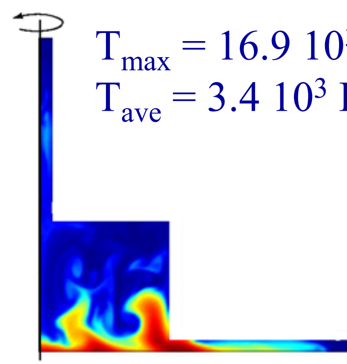
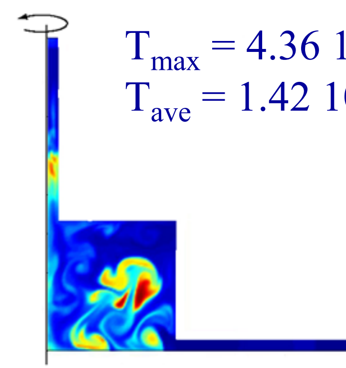
- Case I: Neutral Gas
- Case II: Neutral Gas + Electron Conductivity
- Case III: Neutral Gas + Electron Conductivity + Radiation

Chamber State at 100 ms

- Impact of electron conductivity.
- Impact of radiation.

Chamber State at 100 ms

	Case I: Neutral Gas	Case II: Neutral Gas + Electron Conductivity	Case III: Neutral Gas + Electron Conductivity + Radiation
Cartesian	T_{max} = 23.3 10^3 K T_{ave} = 6.3 10^3 K	T_{max} = 14.3 10^3 K T_{ave} = 5.6 10^3 K	T_{max} = 4.37 10^3 K T_{ave} = 1.41 10^3 K
Cylindrical	T_{max} = 31.6 10^3 K T_{ave} = 4.1 10^3 K	T_{max} = 16.9 10^3 K T_{ave} = 3.4 10^3 K	T_{max} = 4.36 10^3 K T_{ave} = 1.42 10^3 K

For all cases: $T_{min} = T_{wall}$ = 973.16 K

Conclusions

- SPARTAN simulations of the hydrodynamic evolution of the IFE chamber indicate:
  - Multi-dimensional effects of chamber geometry are critical in assessing the chamber dynamics.
  - Radiation of background plasma is the most important mechanism of heat transfer.
- Is 2-D modeling good enough?
  - Maybe.
    - Present simulations with Cartesian and cylindrical geometry show similar trends in flow and heat transfer.
    - To fully answer this question, more different aspects of geometry to be probed by 2-D simulations, such as spherical chamber wall, different configuration of beam lines, etc.
    - Doing at least a few 3-D simulations might be a good idea.