Liquid Wall Chamber Dynamics

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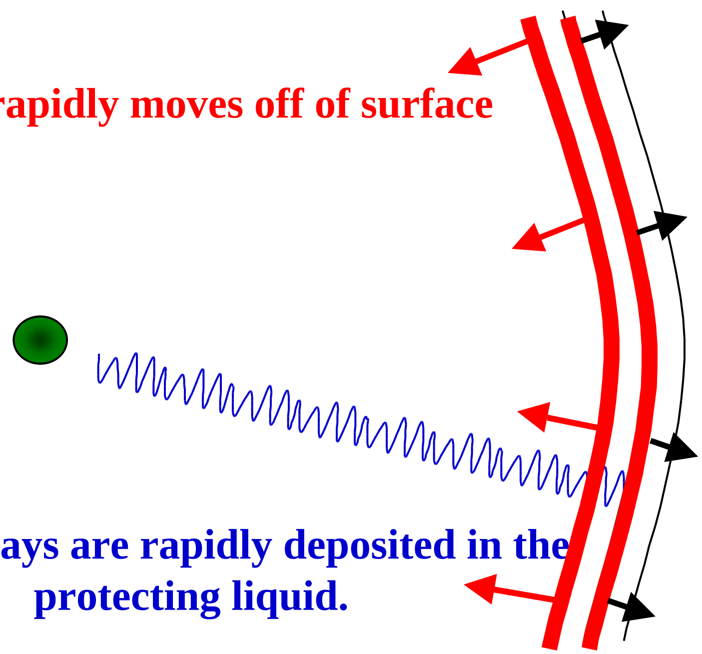
Outline

- **Phenomenology**
- **Analysis Methods**
- **Examples**

The Vapor Produced from Liquid Protection by Target X-rays can Protect material from Subsequent Ions

t ~ 1-10 ns

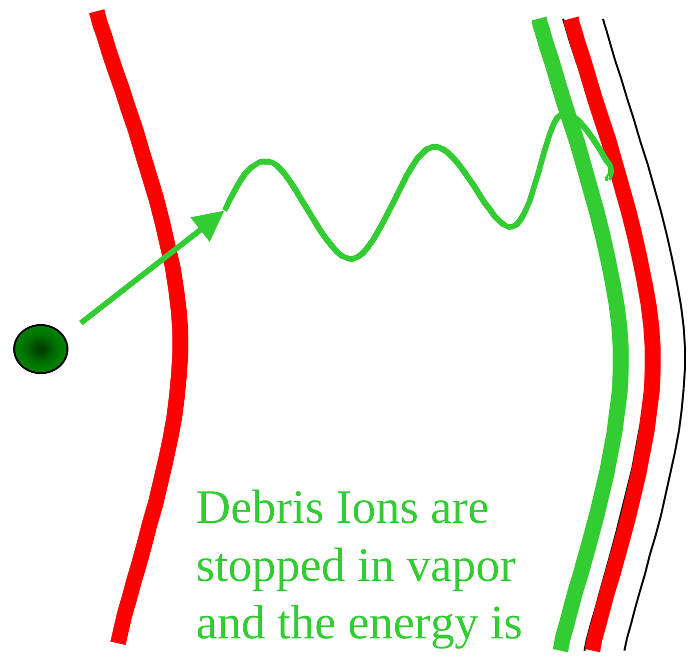
Vapor rapidly moves off of surface



Target x-rays are rapidly deposited in the protecting liquid.

Impulse launches shocks that might damage substrate and/or splash liquid.

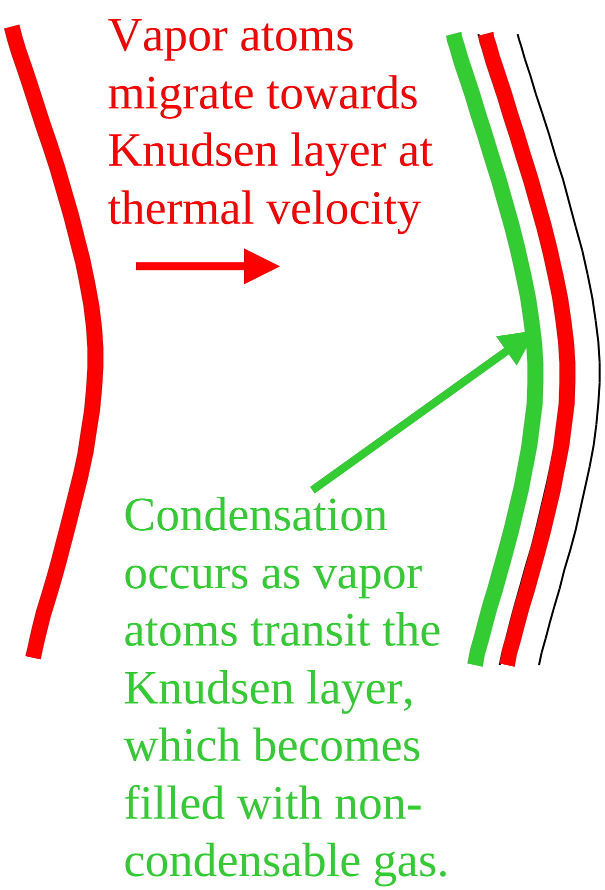
t ~ 1-10 μs



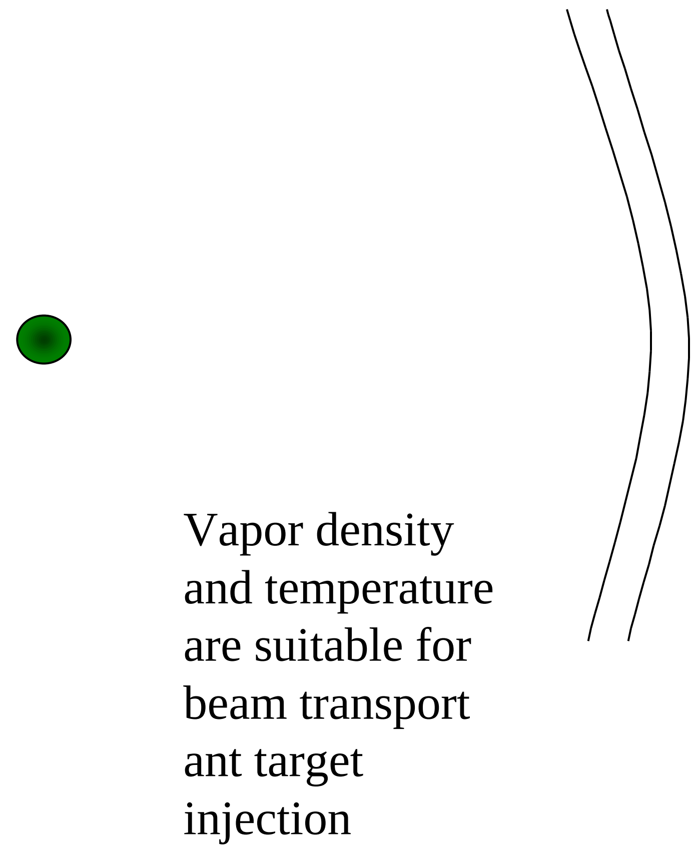
Debris Ions are stopped in vapor and the energy is re-radiated, some of it going to the liquid causing more vaporization.

Re-establishment of Chamber Vapor and Liquid Protection Conditions Set Rep-Rate

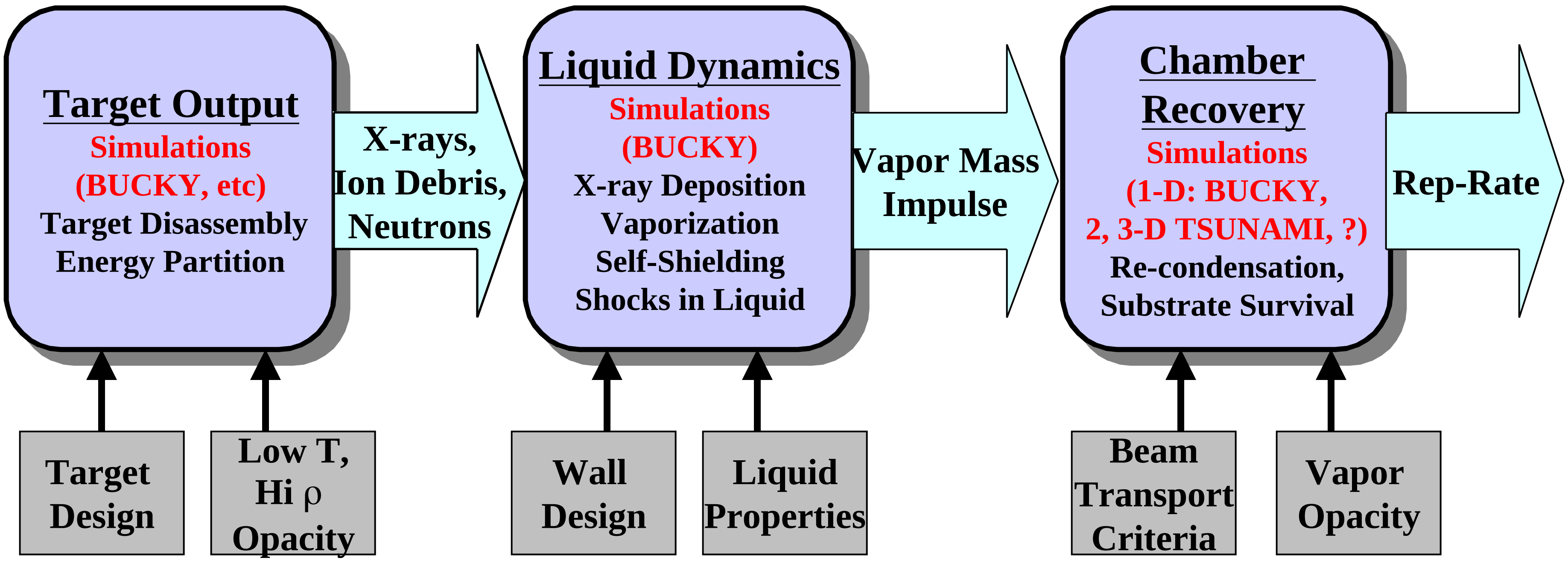
t ~ 1-100 ms



t ~ 100-500 ms



Wetted-Wall Chamber Physics Critical Issues Involve Target Output, and First Wall Response



BUCKY, a Flexible 1-D Lagrangian Radiation-Hydrodynamics Code; Useful in Predicting Target Output and Target Chamber Dynamics

- **1-D Lagrangian MHD (spherical, cylindrical or slab).**

- **Thermal conduction with diffusion.**
- **Applied electrical current with magnetic field and pressure calculation.**
- **Equilibrium electrical conductivities**

- **Radiation transport with multi-group flux-limited diffusion, method of short characteristics, and variable Eddington.**
- **Non-LTE CRE line transport.**
- **Opacities and equations of state from EOSOPA or SESAME.**

BUCKY, a Flexible 1-D Lagrangian Radiation-Hydrodynamics Code; Useful in Predicting Target Output and Target Chamber Dynamics

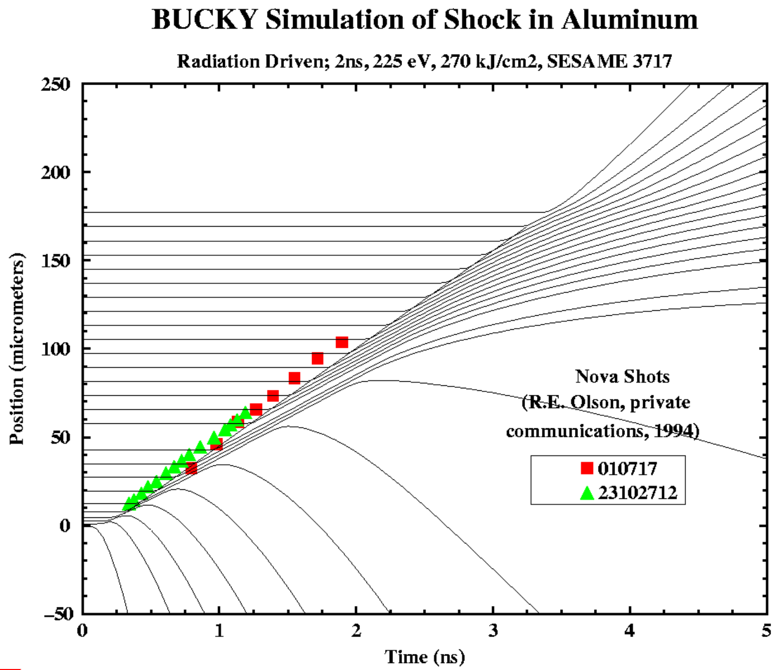
- **Thermonuclear burn (DT,DD,DHe^3) with in-flight reactions.**
- **Fusion product transport; time-dependent charged particle tracking, neutron energy deposition.**

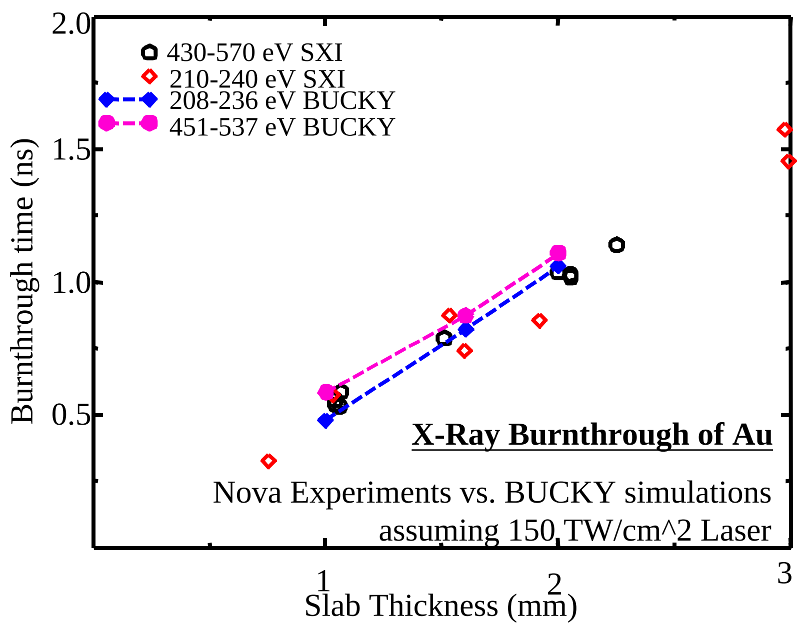
- **Applied energy sources: time and energy dependent ions, electrons, x-rays and lasers (normal incidence only).**
- **Moderate energy density physics: melting, vaporization, and thermal conduction in solids and liquids.**

- **Benchmarking: x-ray burn-through and shock experiments on Nova and Omega, x-ray vaporization, RHEPP melting and vaporization, PBFA-II K_α emission, …**
- **Platforms: UNIX, PC, MAC**

Radiation Transport and Hydrodynamics are Crucial to IFE Fill-Gas Calculations: Validated for BUCKY and EOSOPC

- EOSOPC represents an improvement over IONMIX for LTE plasmas:
  - Atomic Physics: multi-electron wavefunctions (UTA)
  - Degeneracy lowering: Hummer-Mihalas formalism is implemented
  - Additional effects in EOS: (partial degeneracy, modified Debye-Hückel interaction)
  - Results from EOSOPC have been benchmarked against burnthrough experiments, and compared with other major opacity codes, such as STA.

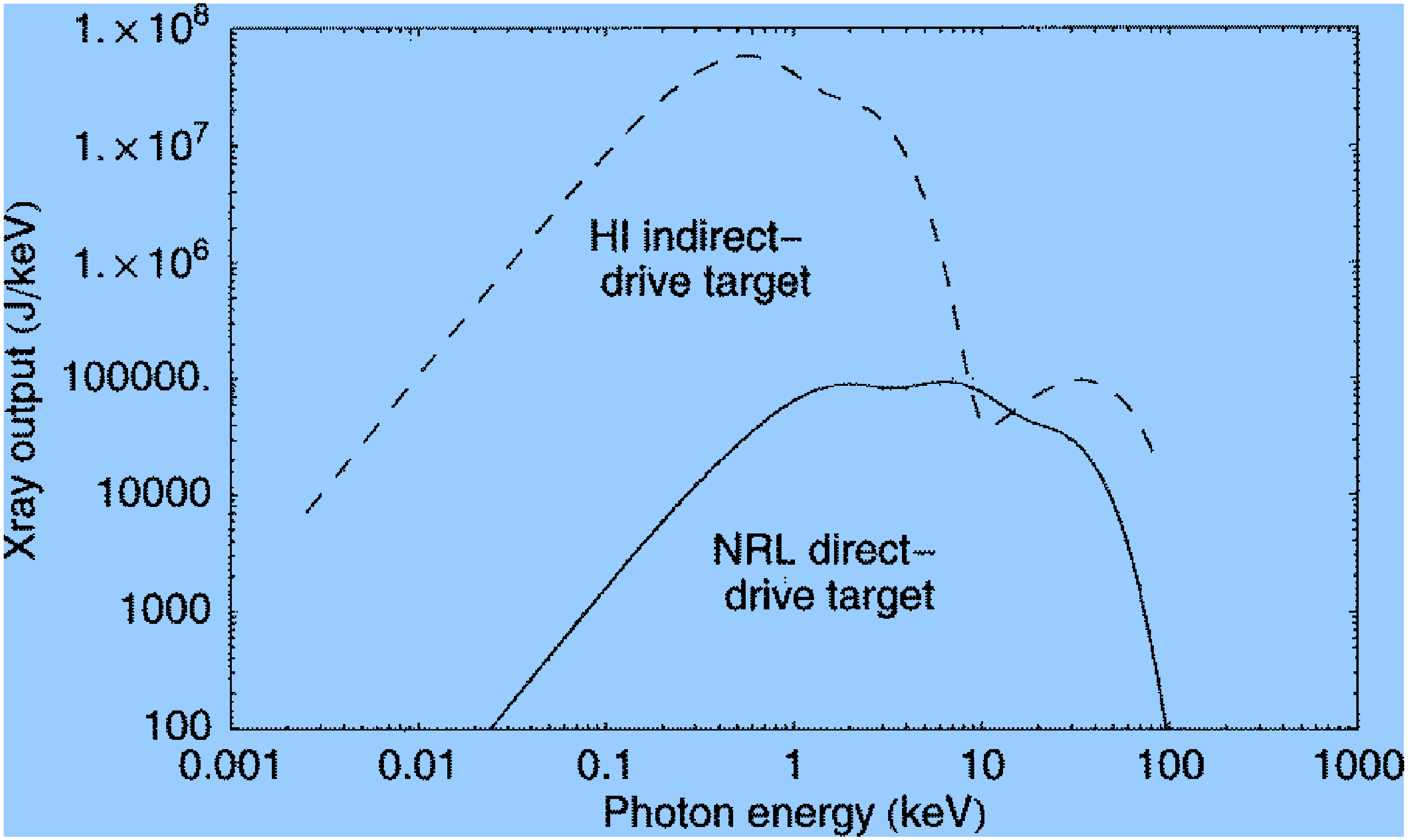




Direct and Indirect-Drive Differ in Spectra and Energy Partition

Spectra and Energy Partition will effect Vaporization of liquid walls.

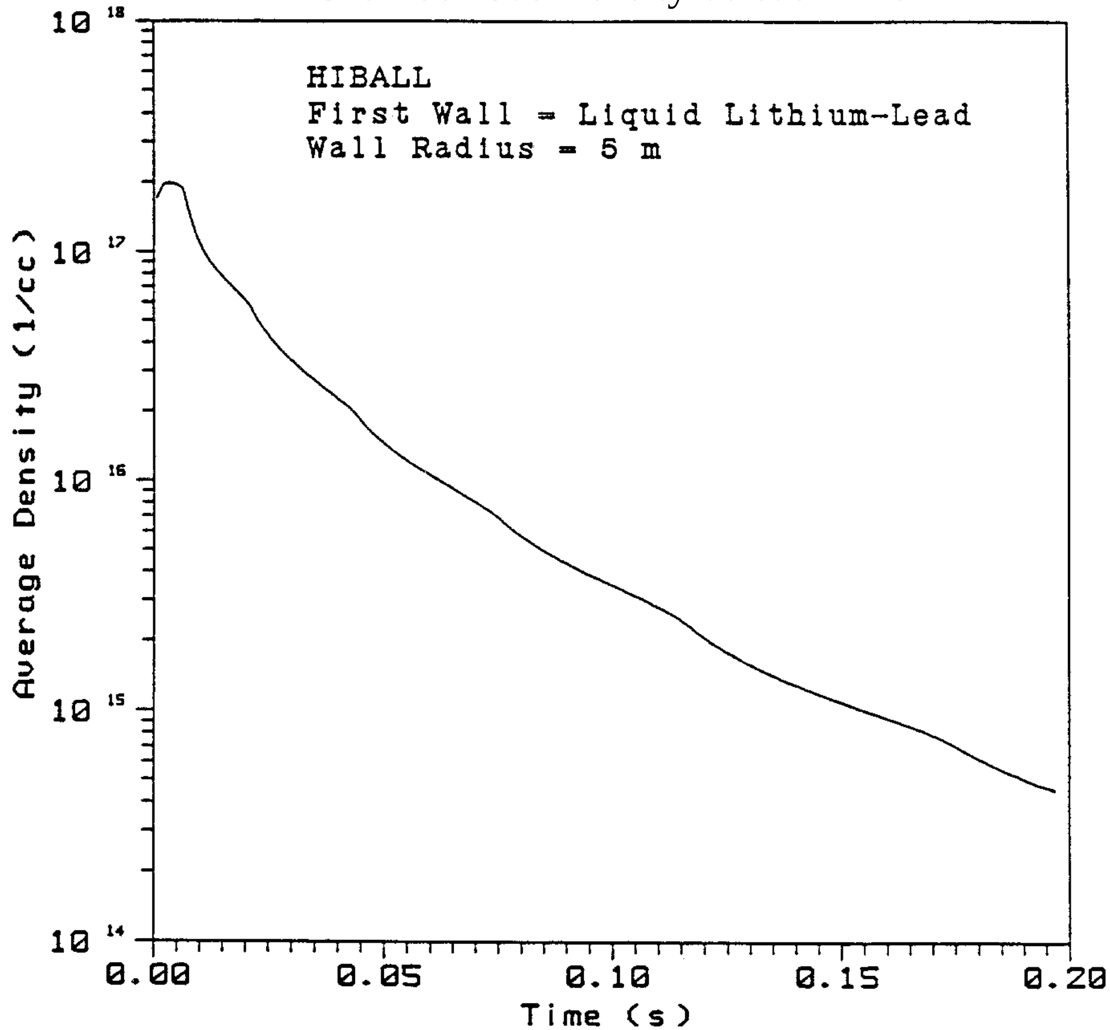
LLNL Predictions of X-ray spectra



Chamber Clearing Dominates Rep-Rate Considerations in Low Chamber Gas Density Wetted-Wall Chamber Concepts

- In Low Chamber Gas Density Wetted-Wall and Thick-Liquid Concepts, the Re-Condensation of Chamber Vapor Can Limit the Rep-Rate.
- BUCKY Models the Vaporization and Subsequent Re-Condensation of Vapor.
- Calculation is 1-D and Only Considers Condensation on Walls (No Nucleate Condensation).
- In HIBALL, Ballistic Focusing of Ion Beam Required a Very Low Gas Density and a Low Rep-Rate.
- This is Not Nearly as Important for Concepts Such as SOMBRERO, Where Vaporization of the Wall is Avoided and the Ambient Gas Density is Much Higher.

BUCKY Calculation of HIBALL Target Chamber Gas Density versus Time



Recoil from Rapid Vaporization Applies a Large Impulse to Surviving Liquid and Substrate

Typical Liquid Wall Parameters

X-ray Fluence	10-100 J/cm^2
X-Ray Deposition Pulse Width	1-10 ns
Pulse Width of Recoil Pressure	~ 100 ns
Peak Pressure	~ 1 GPa
Impulse	100 Pa-s