INTERACTION OF TARGET DEBRIS WITH LIQUID-FILM-PROTECTED FIRST WALLS

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Modeled Phenomena

(HEIGHTS Package)

- X-ray (& reflected light) deposition in liquid film & underlying structure
- Thermal response and Evaporation of protective film
- Hydrodynamic-blowoff (transport) of vapor within the cavity
- Ion transport and energy deposition in ablated vapor, liquid film, and underlying structure
- Thermal and hydrodynamic response of vapor cloud and protective film to direct ion energy deposition
- Reradiation from vapor cloud
- Thermal and mechanical response of underlying structure to x-ray deposition, direct ion deposition, and radiation flux from vapor cloud.

OBJECTIVES

- **Develop an internally consistent, mechanistic model to determine the thermal-mechanical response of liquid-film-protected first walls to target debris.**

- **Parametric-study of key phenomena**

- **Define an operating window for reactor design**

PROBLEM DEFINITION

- First wall (porous or solid) covered with a thin liquid film of specified materials
- Specified cavity dimensions (chamber radius)
- Specified target yield & spectra (and reflected laser light, if any)
- Specified initial cavity condition (vacuum or pre-filled gas & vapor)

X-Rays Deposition in Liquid-Film and Solid-Wall

Assumptions:

- **Specified spectrum and energy density**
  - **Blackbody (0.1 keV and 1.0 keV) or given data**
  - **10 ns pulse duration**
  - **1-5 J/cm2**
- **Specified wall material, thickness, and porosity**
  - **1 cm thick solid graphite wall**
- **Specified film material, thickness, and initial temperature**
  - **1 mm Li or Pb**
  - **Li temp of 500 K and Pb temp of 700 K**
- **Specified chamber cavity radius**
  - **6.5 m radius**

Self-Consistent Kinetic Model

- **Optical properties are calculated for actual gas/vapor-plasma-debris conditions.**

- **During each time step, quantities such as density, temperature, and spectral radiation flux are used to calculate absorption and emission coefficients.**

- **This is achieved by solving the kinetic equations for ion concentration and for level populations of each charge state.**

- **Calculation of emission and absorption coefficients includes the three kinds of radiation:**
  - **Bremsstrahlung radiation**
  - **Recombination radiation**
  - **Line radiation.**

Atomic Physics Package

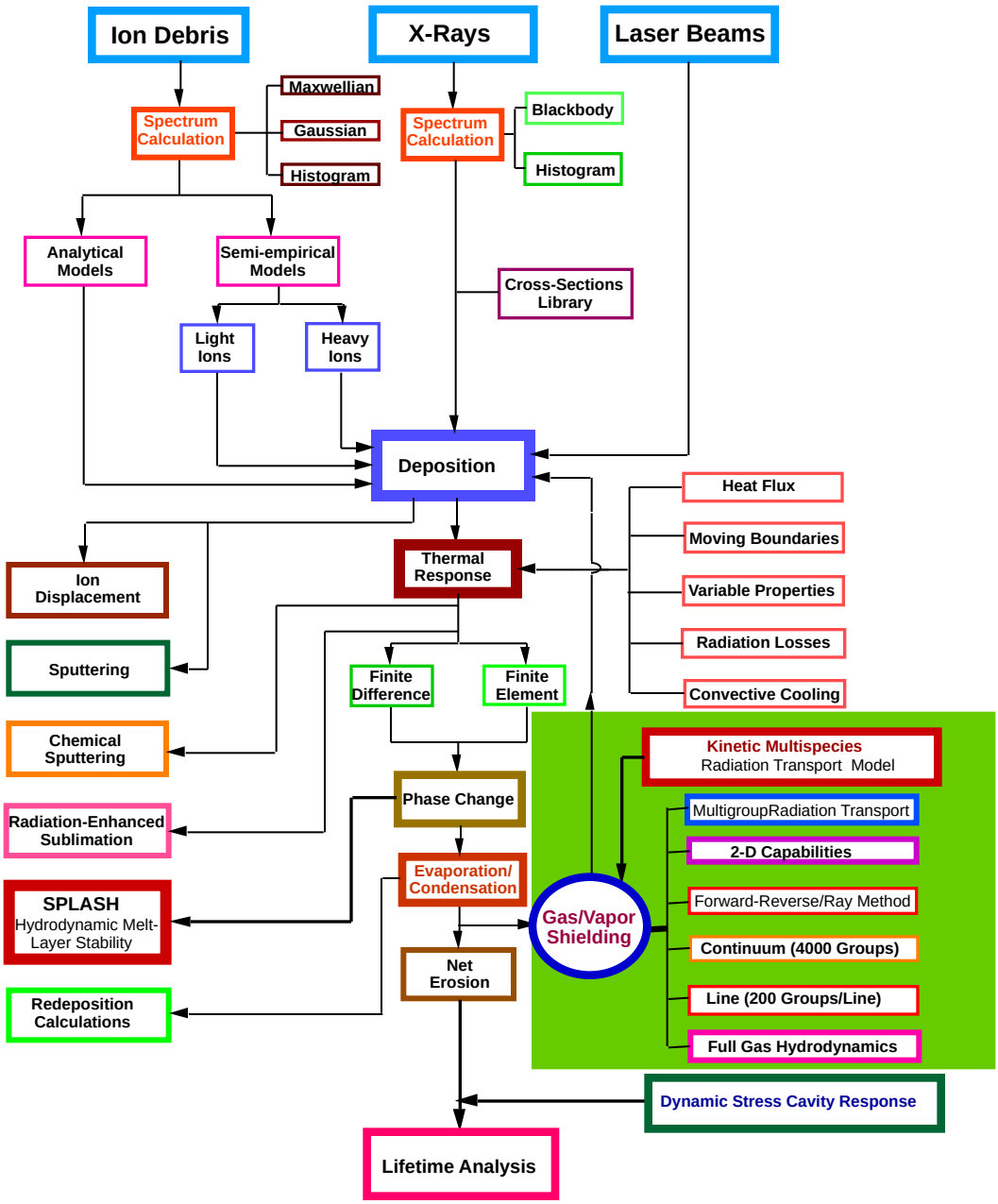
- **Atomic database implemented in the *SUPERATOM package* is used in these calculations.**

- **Some of the data includes:**
  - **Ionization potentials**
  - **Energy levels**
  - **Statistical weights**
  - **Quantum levels**
  - **Degeneracy levels**
  - **Oscillator force**
  - **Line transition probabilities**
  - **Ionization cross sections**

Photon Radiation &Transport Model

- Non-LTE Radiation Transport Model
- Both Continuum and Line Radiation are Included
- Up to 4000 Photon Energy Group for the Continuum Spectrum
- Up to 100 Separate Lines can be used for the Low-Z Materials and several 100's for Higher-Z Materials
- Each Single Line is treated as a Continuum Spectrum (Mini multi-group up to 200 groups/line)
- Doppler and Stark Broadening of Line Radiation
- Numerical Methods
  - Forward/Reverse for 1-1.5D model
  - Ray Tracing Techniques for 2-3D model

HEIGHTS-IFE Package



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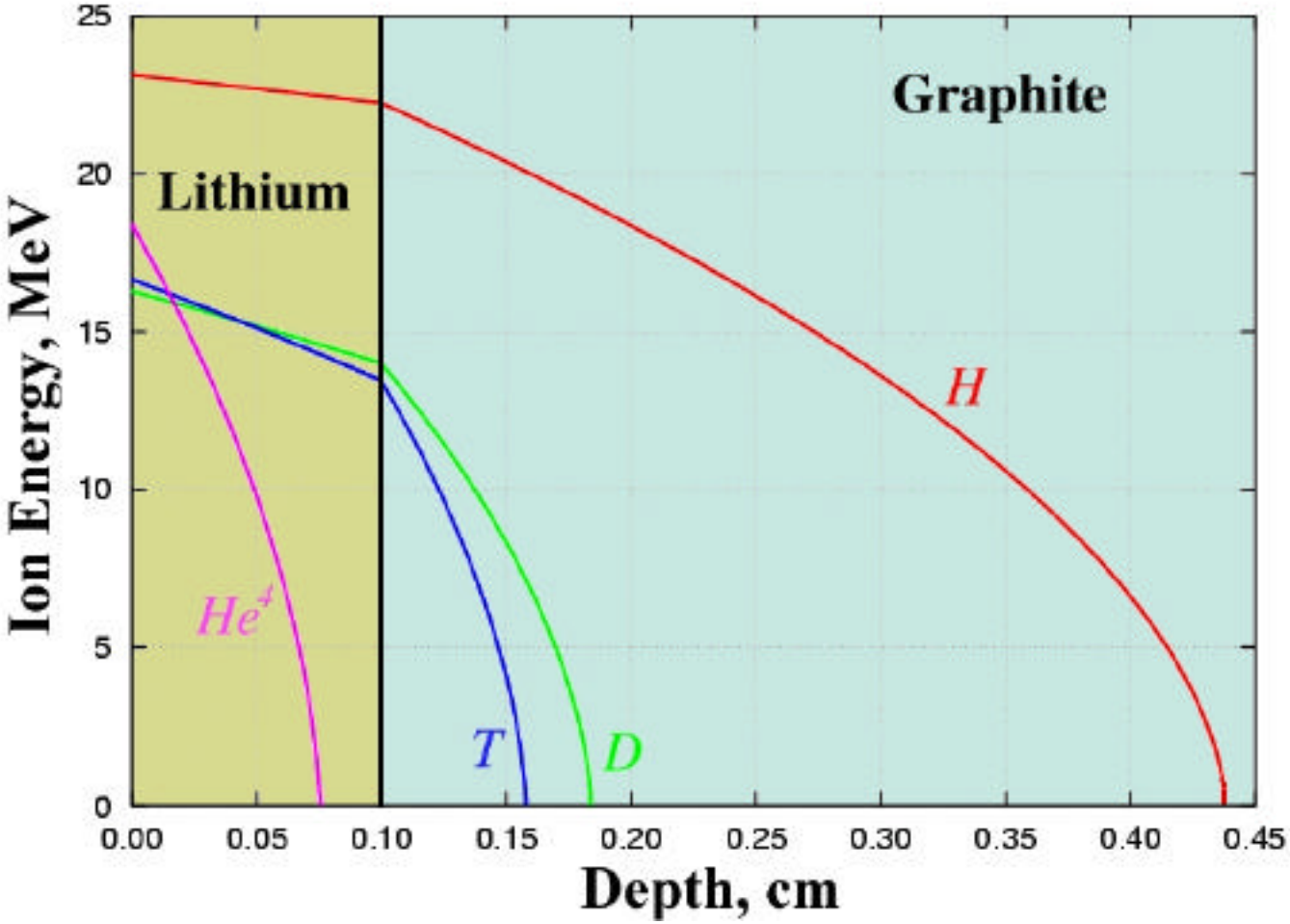
HEIGHTS CALCULATION OF FAST ION RANGES

Fast Ions - Direct Target

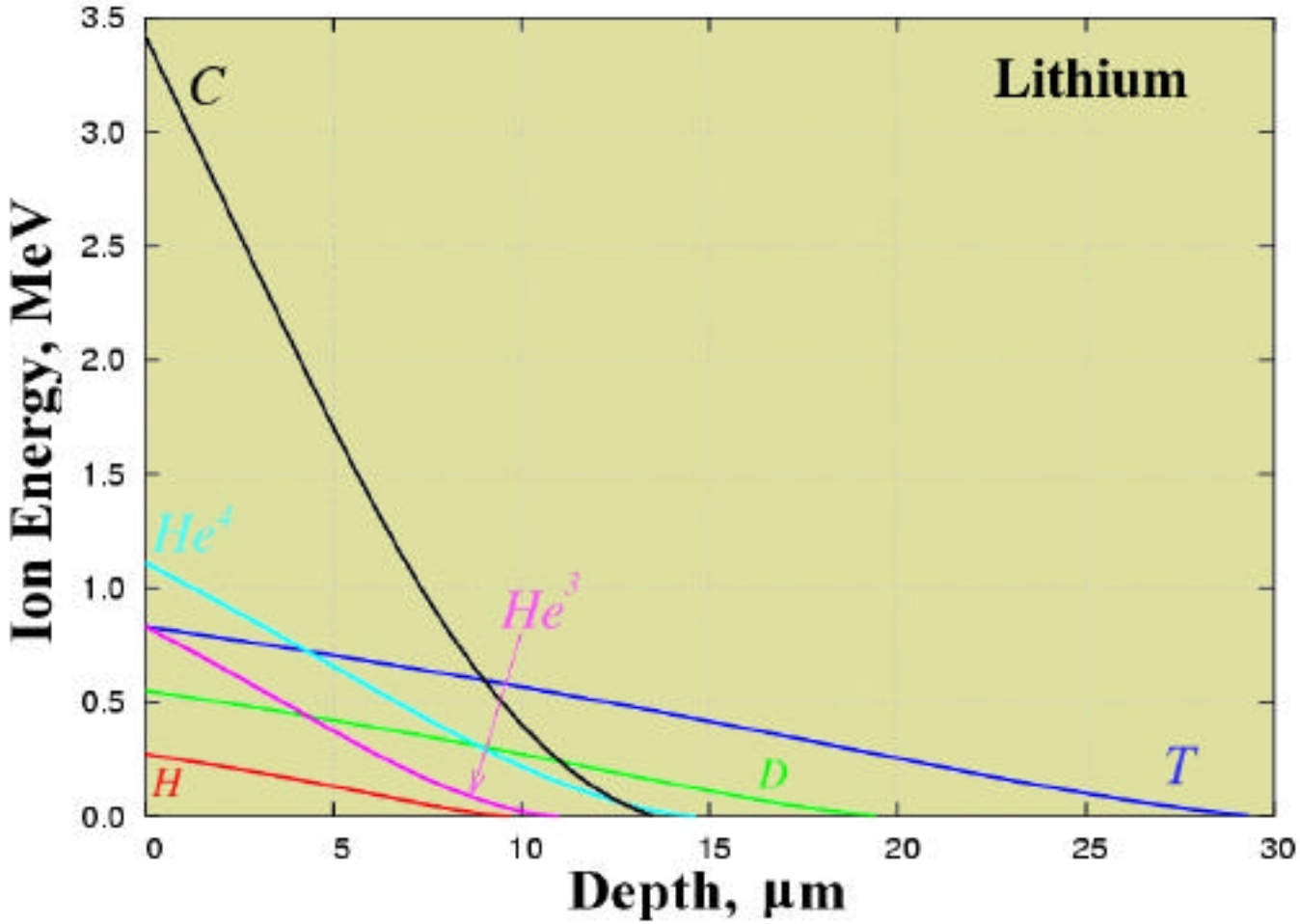
Li-Graphite Wall



HEIGHTS CALCULATION OF DEBRIS ION RANGES

Debris Ions - Direct Target

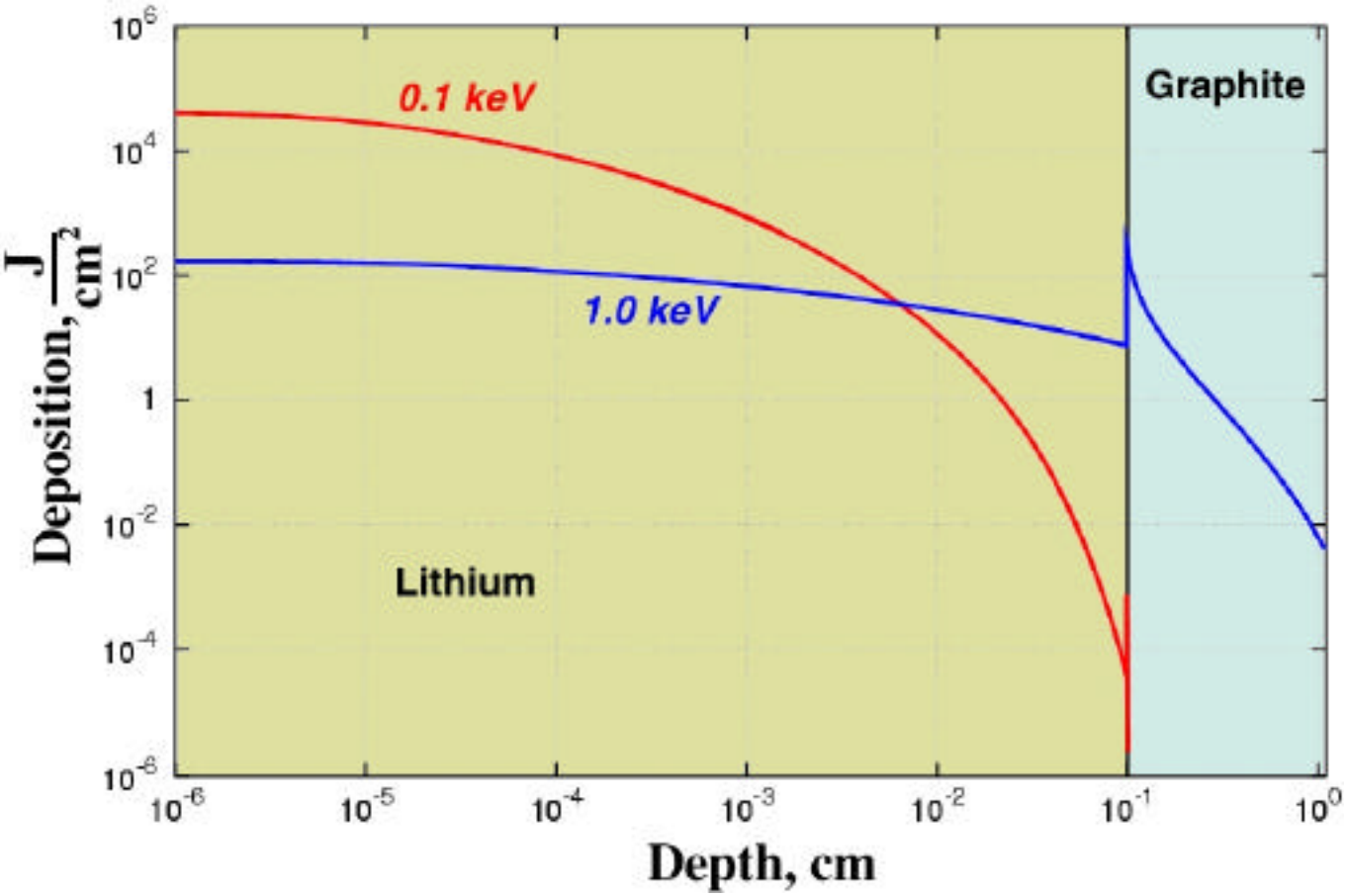
Li-Graphite Wall



HEIGHTS CALCULATION OF X-RAY DEPOSITION

1 mm Lithium / 1 cm Graphite

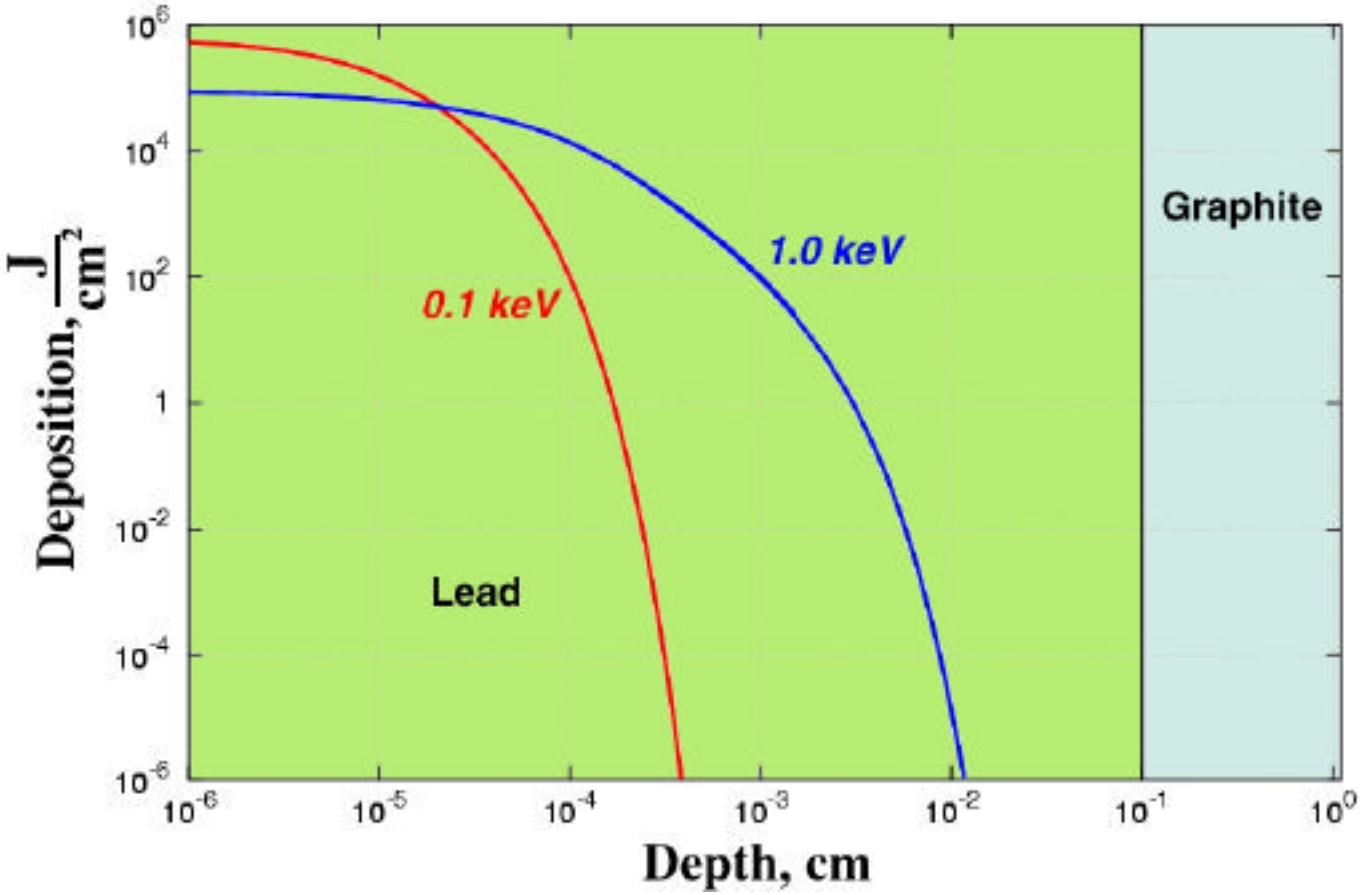
5 J/cm^2, 6.5 m Radius



HEIGHTS CALCULATION OF X-RAY DEPOSITION

1 mm Lead / 1 cm Graphite

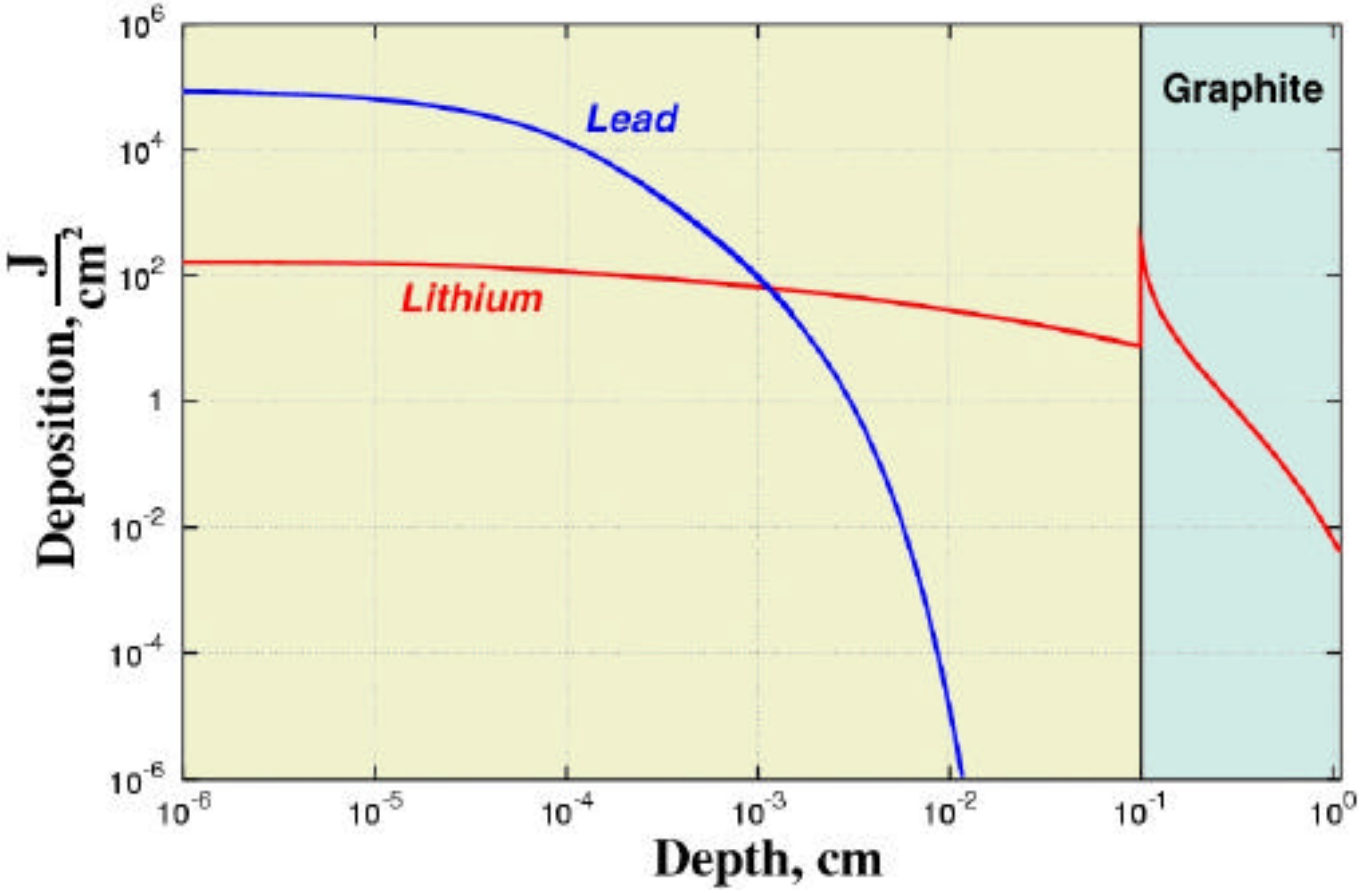
5 J/cm^2, 6.5 m Radius



HEIGHTS CALCULATION OF X-RAY DEPOSITION

1.0 keV Blackbody X-Ray

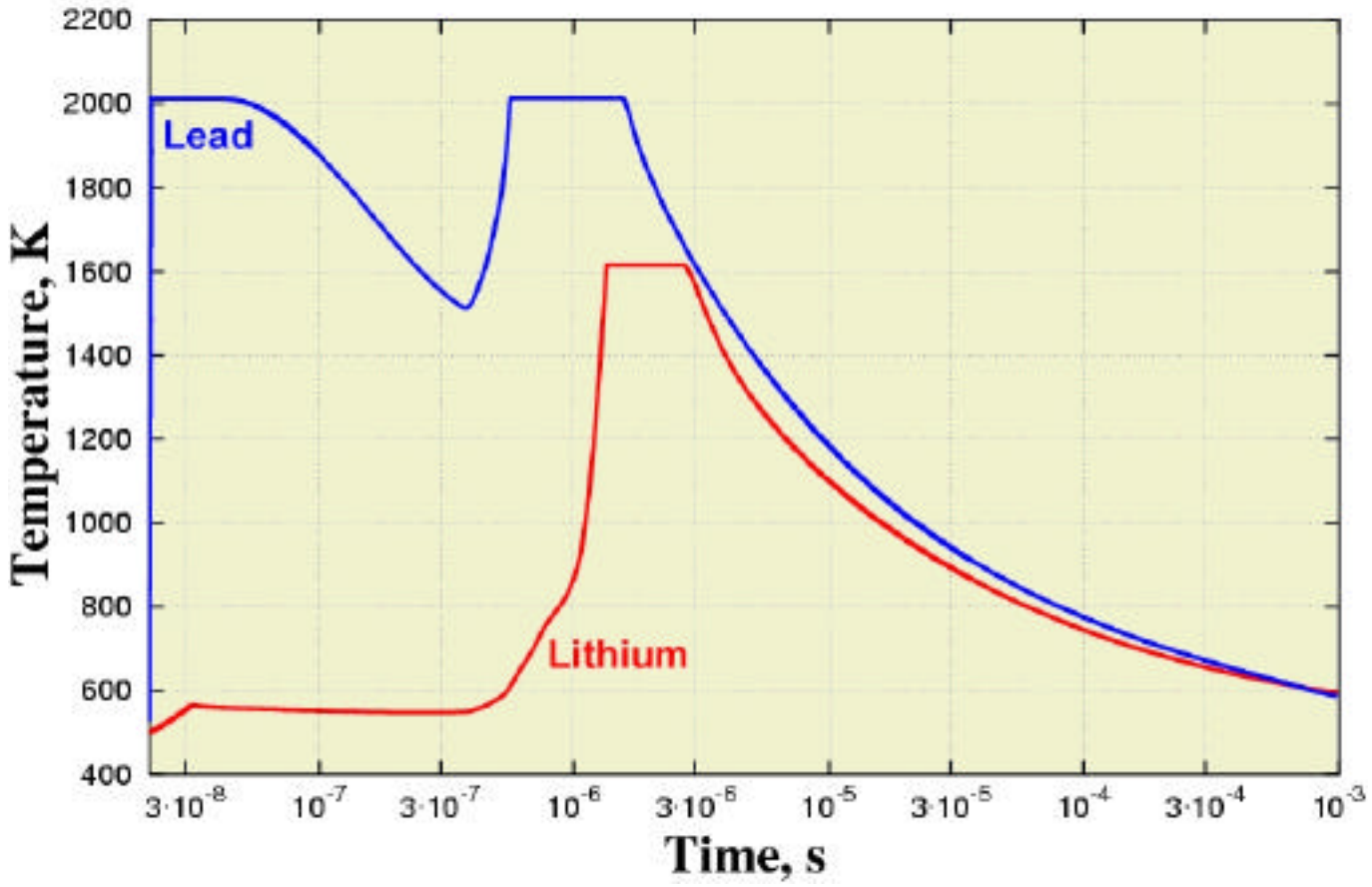
5 J/cm^2, 6.5 m Radius



HEIGHTS CALCULATION OF SURFACE TEMPERATURE

1.0 keV Blackbody X-Ray

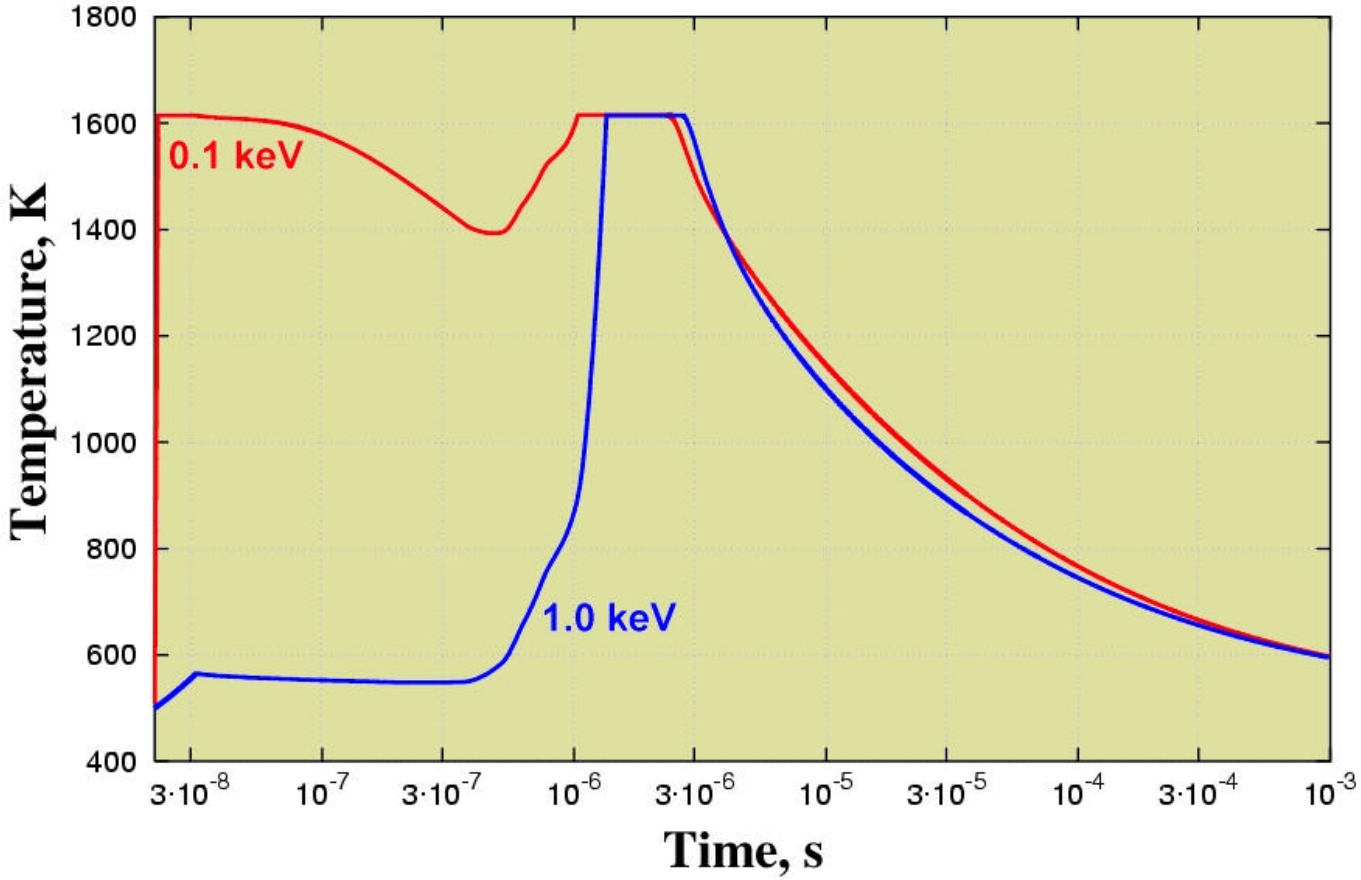
5 J/cm^2, 6.5 m Radius



HEIGHTS CALCULATION OF SURFACE TEMPERATURE

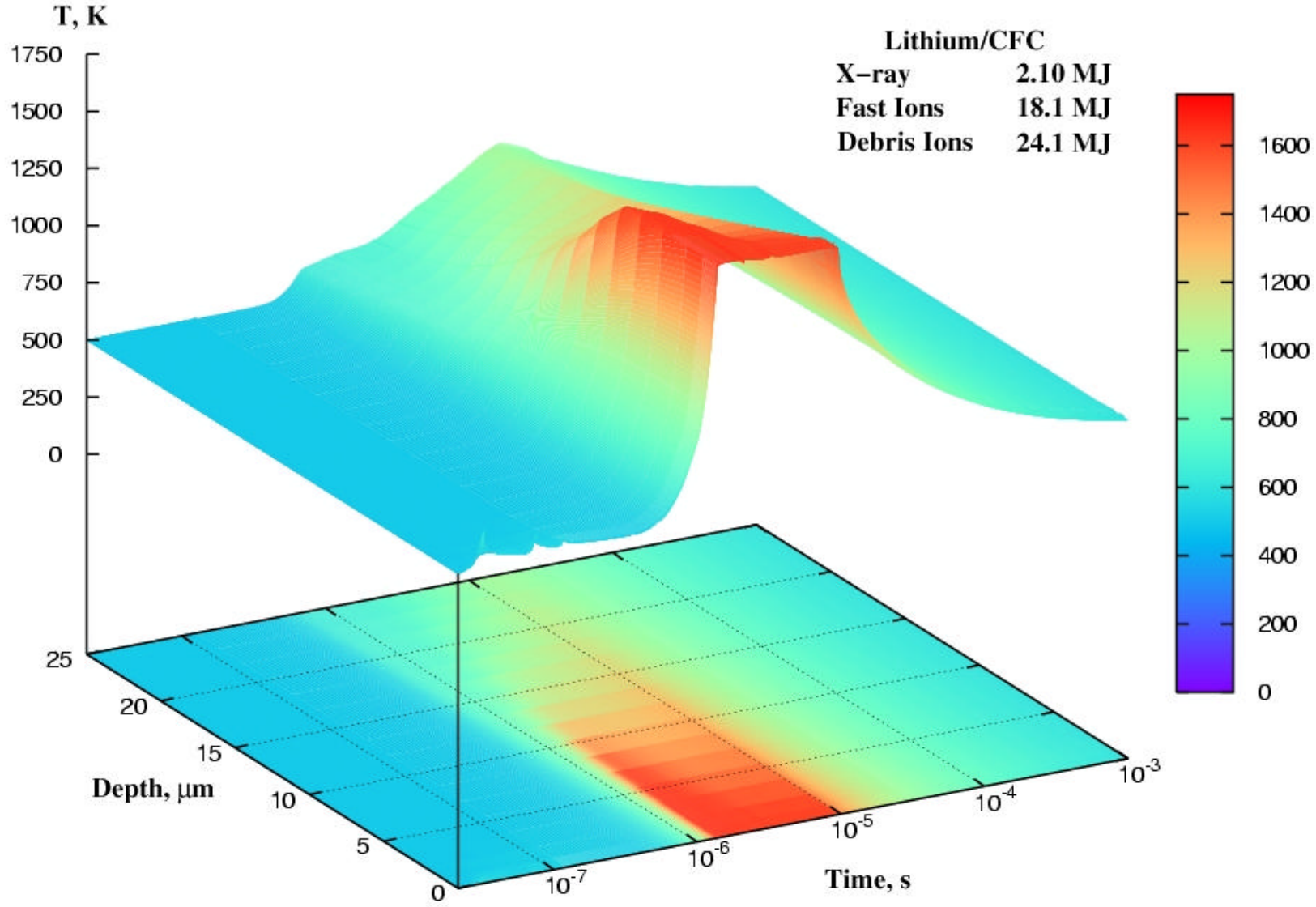
1 mm Lithium / 1 cm Graphite

5 J/cm^2, 6.5 m Radius

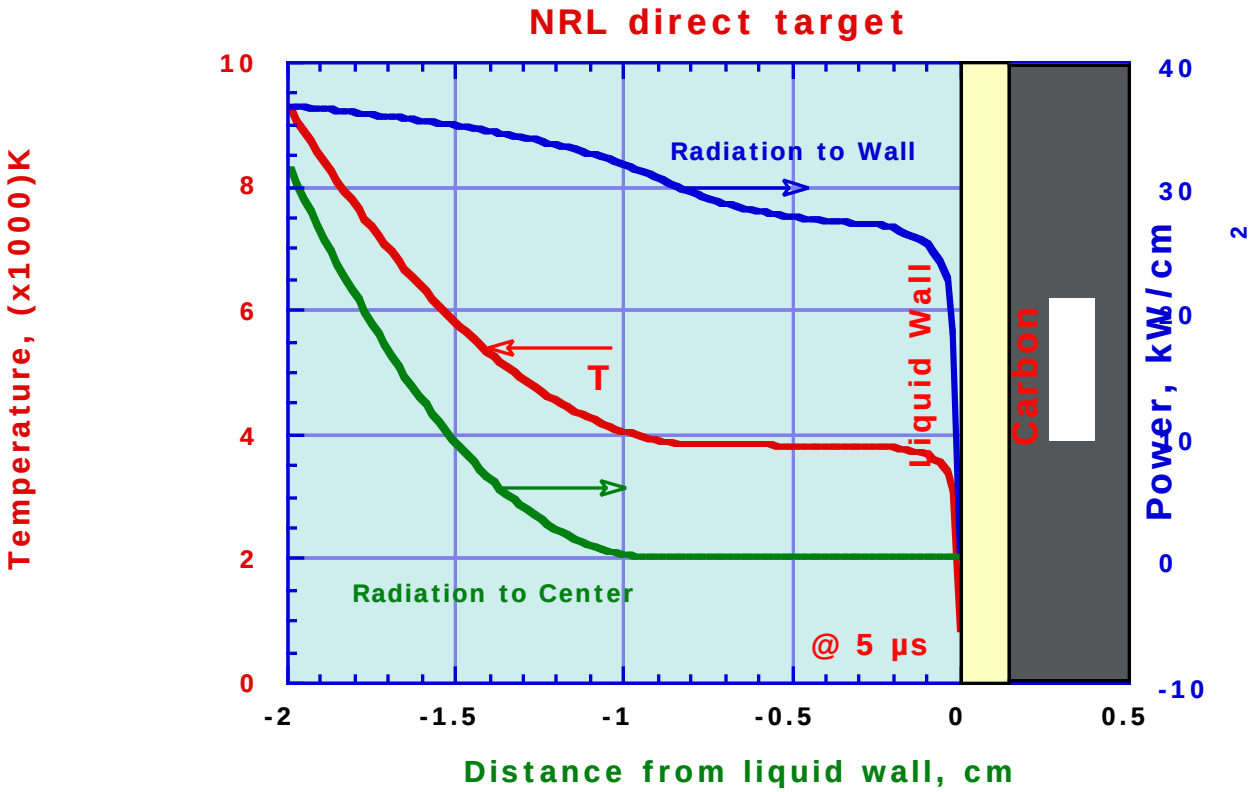


HEIGHTS SIMULATION OF NRL DIRECT TARGET

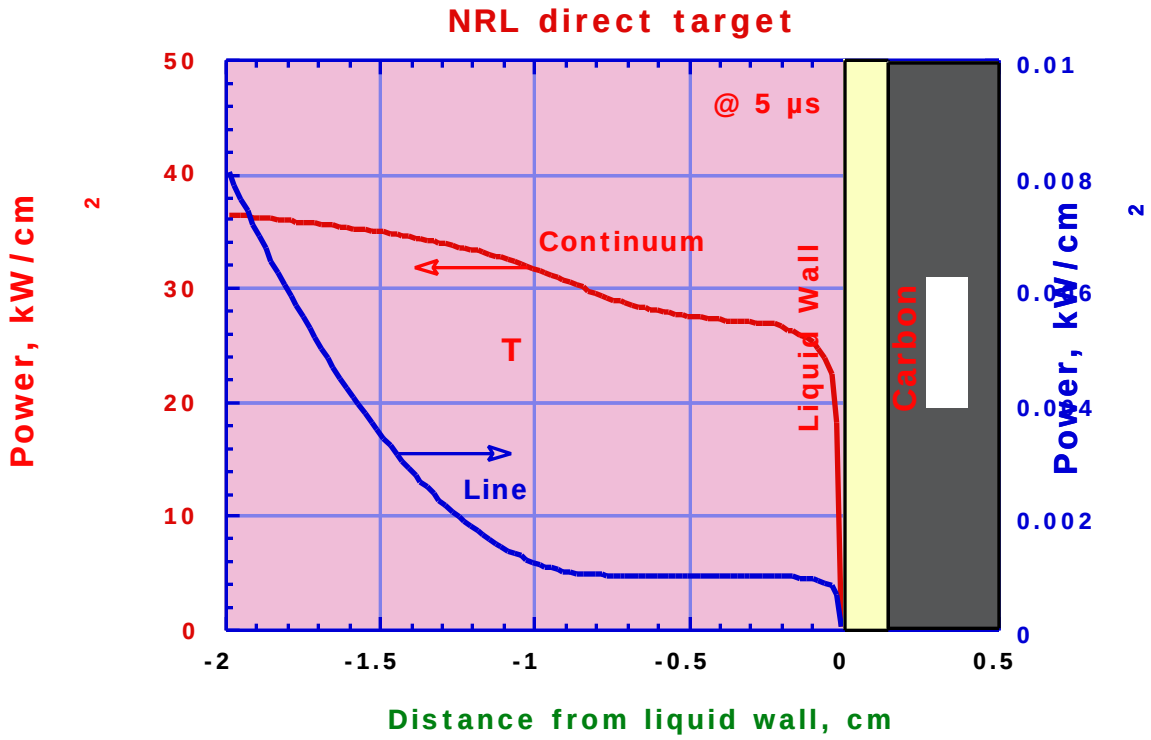
Temperature rise due to laser, X-ray, and ion depositions



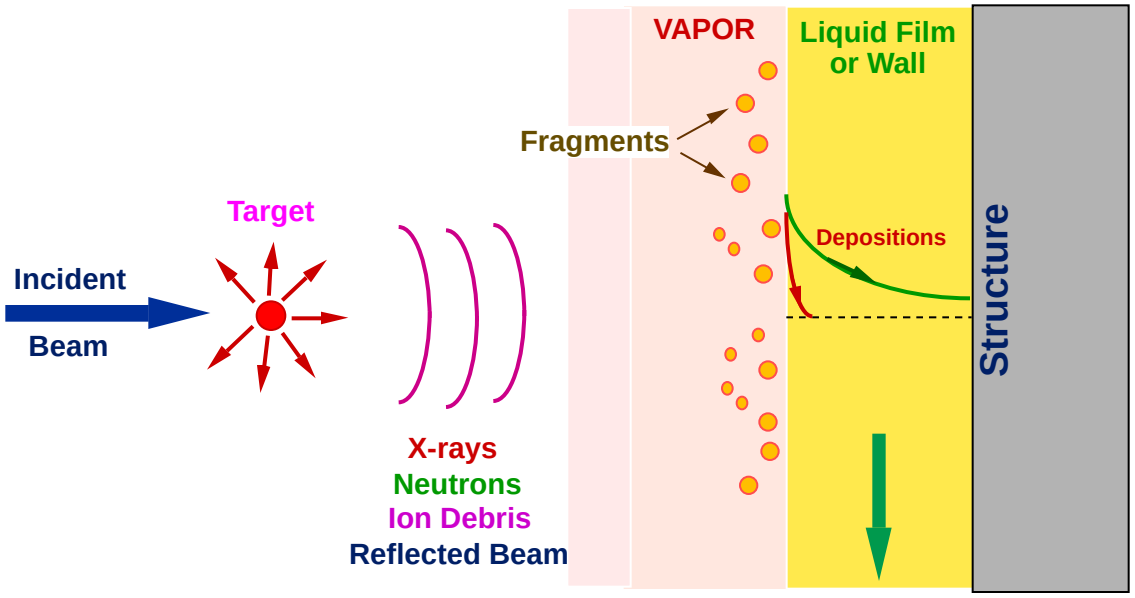
HEIGHTS Analysis of Vapor Evolution Dynamics and Radiation Power to Liquid Surface



HEIGHTS Analysis of Vapor Expansion and Continuum/Line Radiation Power to Liquid Surface



MODELING IFE CAVITY RESPONSE in HEIGHTS



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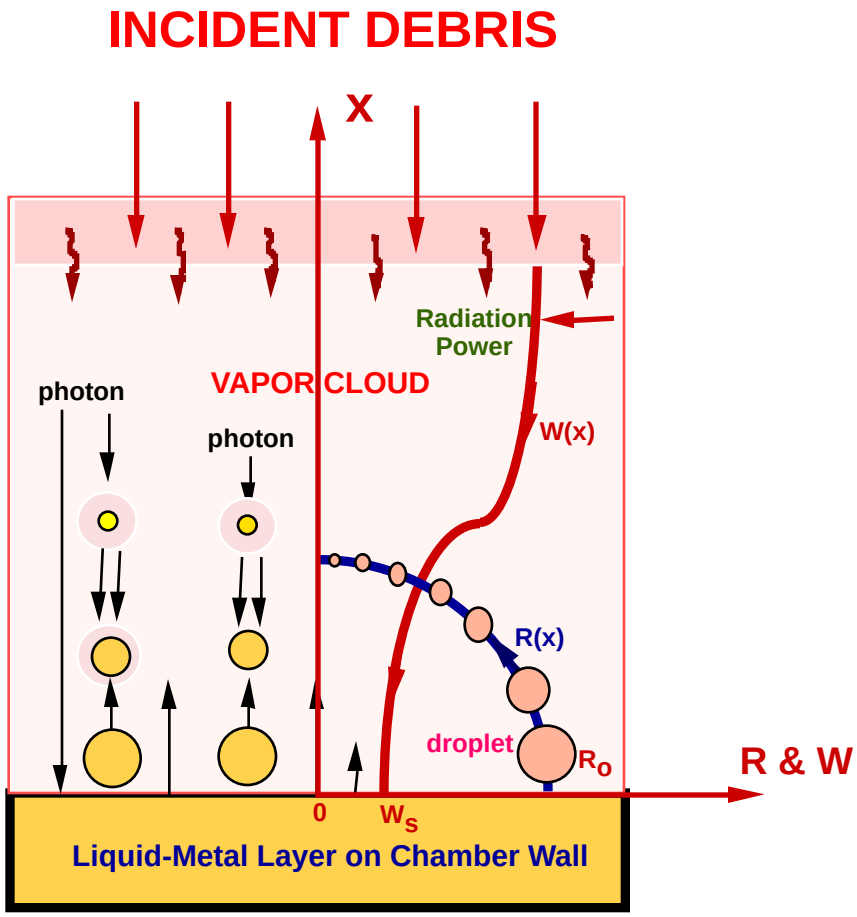
Macroscopic Debris Interaction with Vapor Plasma



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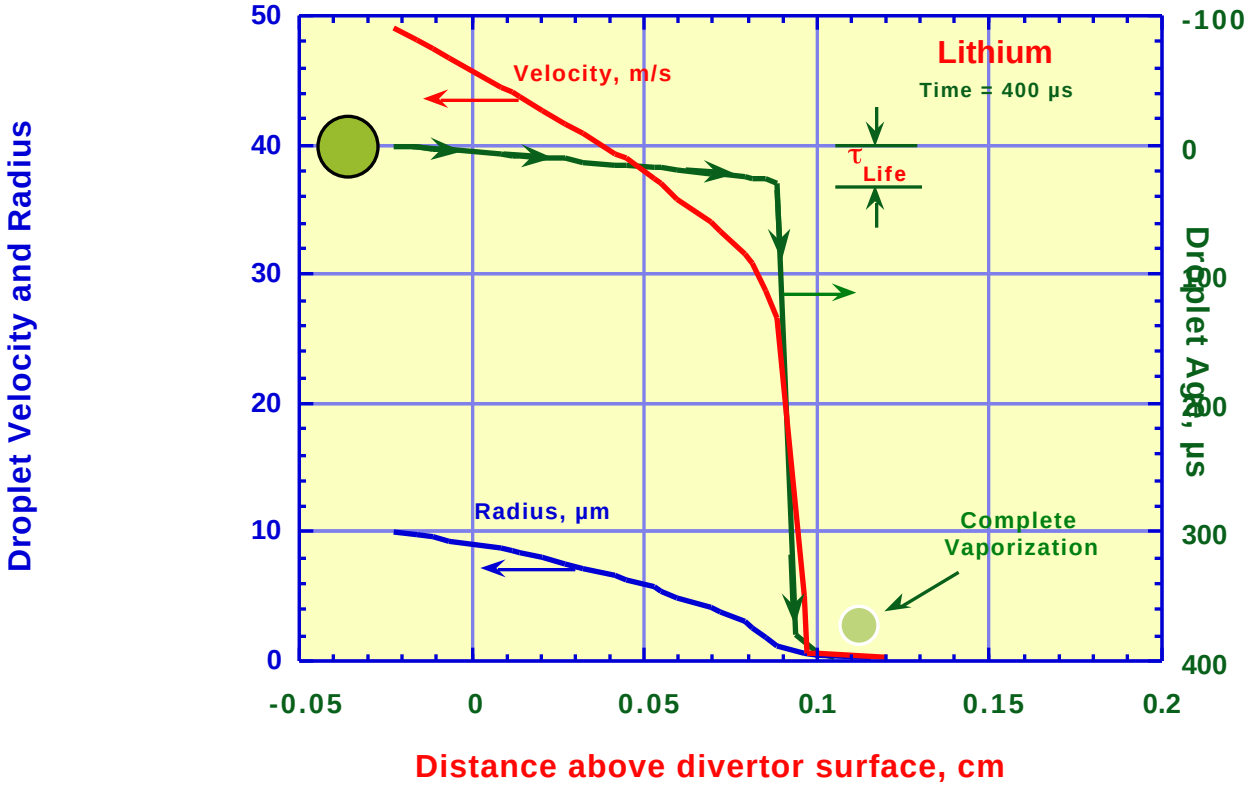
HEIGHTS Analysis of Spatial Dependence of Lithium Droplet Velocity and Radius



CONCLUSIONS

HEIGHTS Calculation Package Provide the Means to Mechanistically Evaluate Effectiveness of Thin Liquid Film or Thick Liquid Wall protection schemes Through an Integrated, Self Consistent Analysis of Coupled Physical Phenomena