Development of Comprehensive Integrated Model for IFE Chamber Wall Interaction

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Presented at the High Average Power Laser Meeting
Pleasanton, Ca, Nov. 13-14, 2001

OUTLINE

- **Identify all processes for wall response/erosion:**
  - **Energy deposition from laser, photons, and ions**
  - **Spatial heat generation in wall**
  - **Phase change: melting, evaporation/sublimation**
  - **Physical sputtering by various target debris**
  - **Chemical sputtering and RES**
  - **Macroscopic erosion**
- **Assess relative importance of these processes for IFE chamber wall conditions**
- **Identify key processes for inclusion in the computer module during first year effort.**
- **Develop mathematical models and independent computer module based on these models**
- **Plans for future upgrade to add more detailed models and cover a wider range of chamber conditions**

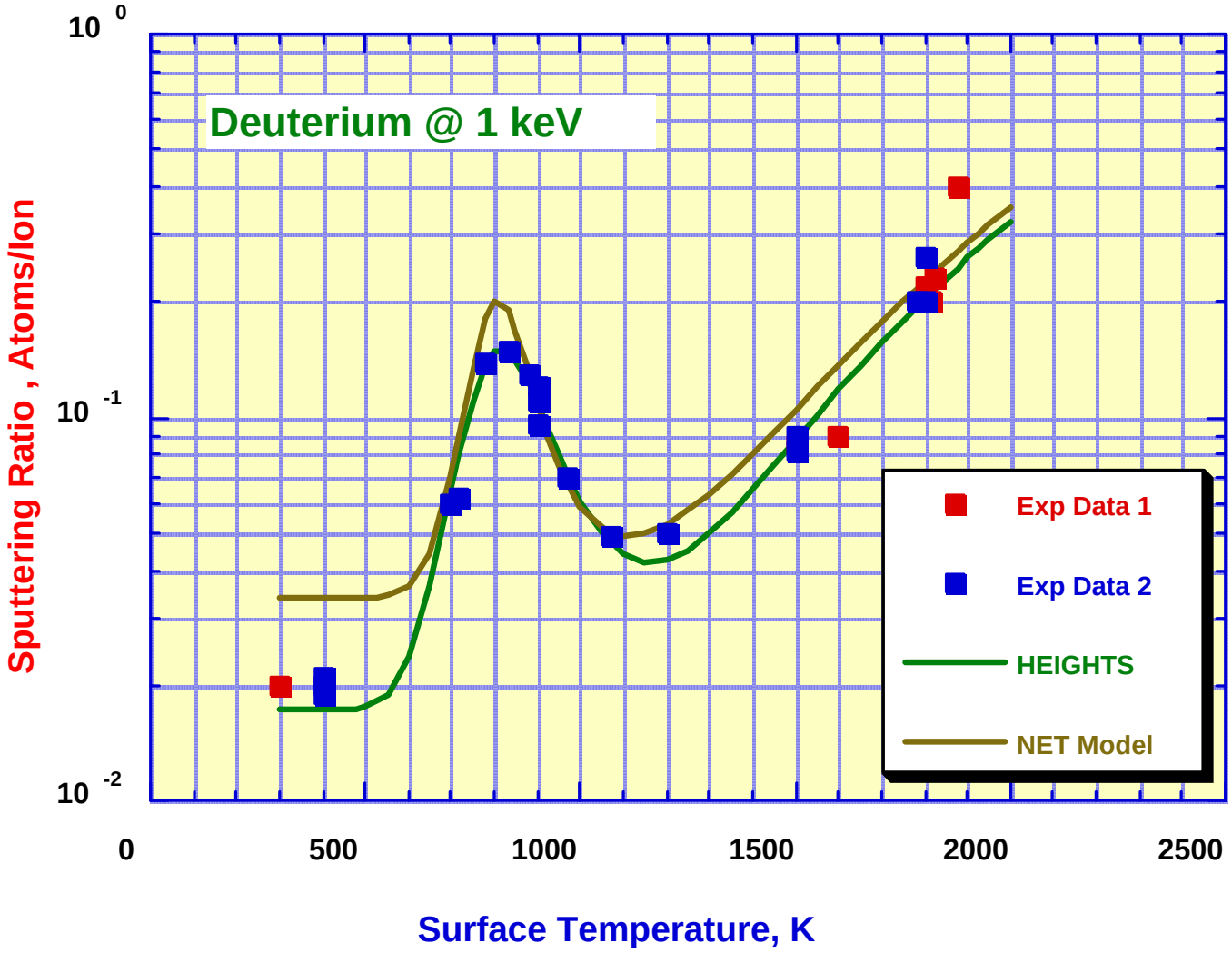
Physical Sputtering Model

Physics	Physical model depends on wall material, energy of ion debris incident particle angles (normal in this case).
Model	Developed model is based on semi empirical formula and on 3-D Monte Carlo models that depends on energy of ion debris and burn products and their spectra. • The sputtering yield Y is calculated from the semi empirical formula: $$Y = \frac{C_Y}{u_0} Z_1^{0.75} (Z - 1.8)^2 \left(\frac{M_1 - 0.8}{M_2} \right)^{1.5} \frac{(E_0 - E_{th})}{\left(E_0 - E_{th} + 50 Z_1^{0.75} Z_2\right)^2}$$ where C_Y is a constant, u_o is surface binding energy, and E_{th} is threshold energy for sputtering.
Key Parameters	Energy of incident ion debris, wall material, long term radiation effects.
Key Uncertainties	Energy of ion debris spectra reaching the wall , characteristics of surface modified layer during operation.
Relative Importance	Tends to be a threshold mechanism and to peak at a certain ion energy; e.g. for C, it peaks at ion energy of ~ 1 keV. Possibly not a major mechanism for chamber wall erosion and mass evolution, in particular for cases with no or very low protective gas pressure and high energy incident ions (~1 MeV)

Physical Sputtering Model (cont)

Time-Scale	**Comparable to energy-deposition time-scale.**
Spatial Location	**Wall surface and in particular near surface modified layer.**
Inter-relation with Other Processes	**All processes affecting particle transport and energy deposition with or without gas.**
Inclusion in Model	Could be included from the start particularly for cases with gas protection and low evaporation and low macroscopic erosion regime, but with lower priority

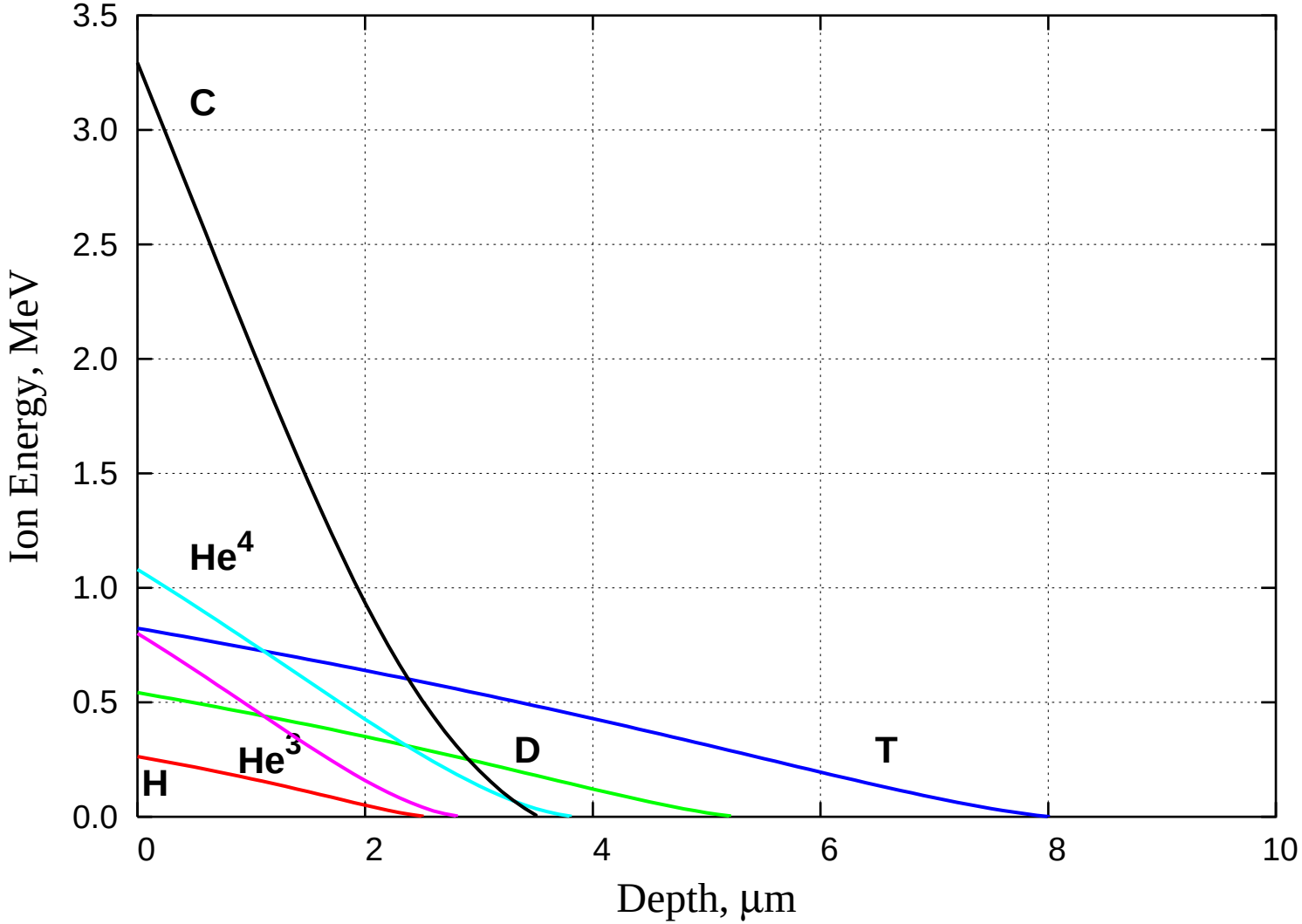
Chemical Sputtering and Radiation Enhanced Sublimation of Graphite



HEIGHTS CALCULATION of DEBRIS ION RANGES

Debris Ions - NRL Direct Drive Target

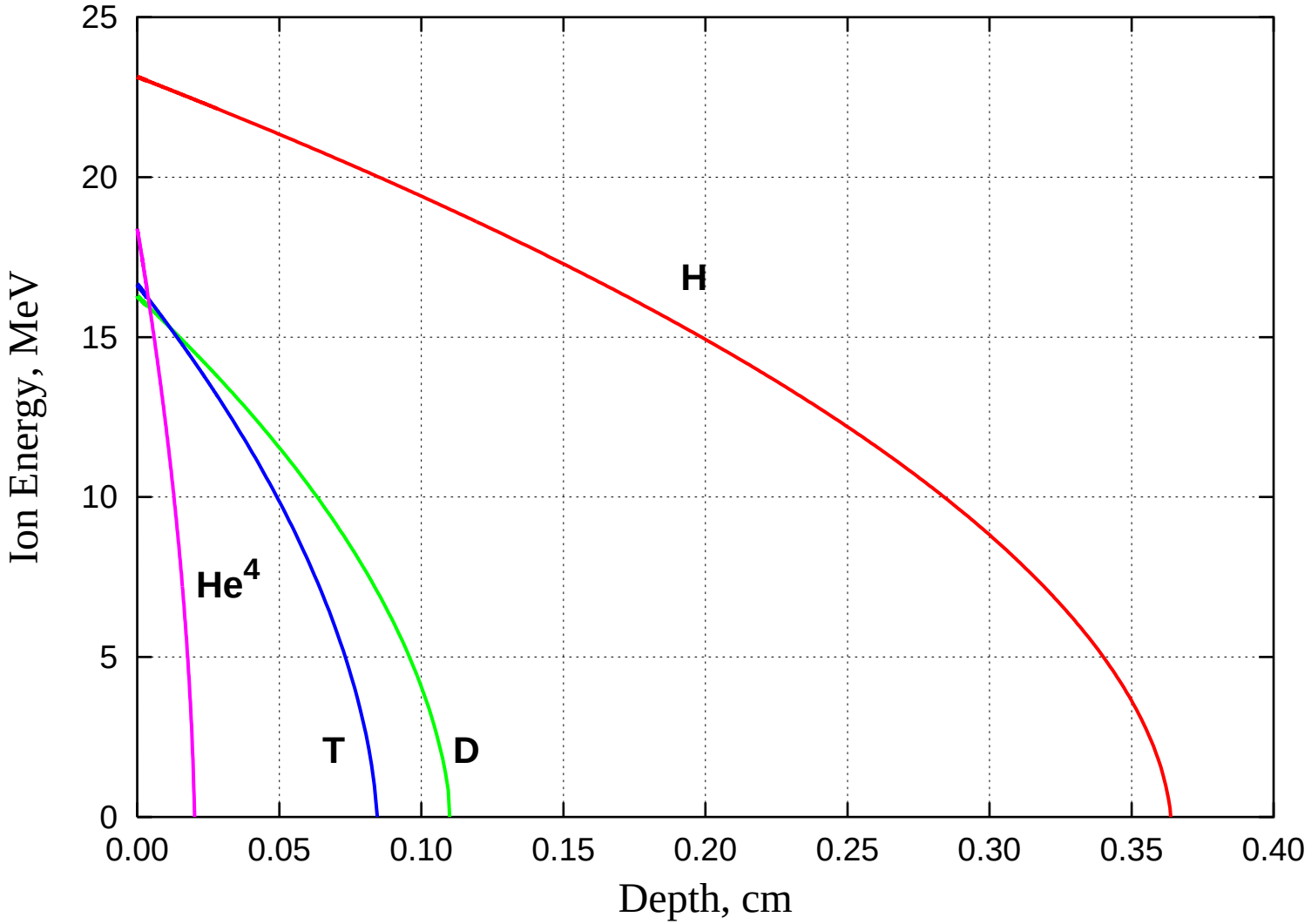
CFC cx-2002u Wall



HEIGHTS CALCULATION of FAST ION RANGES

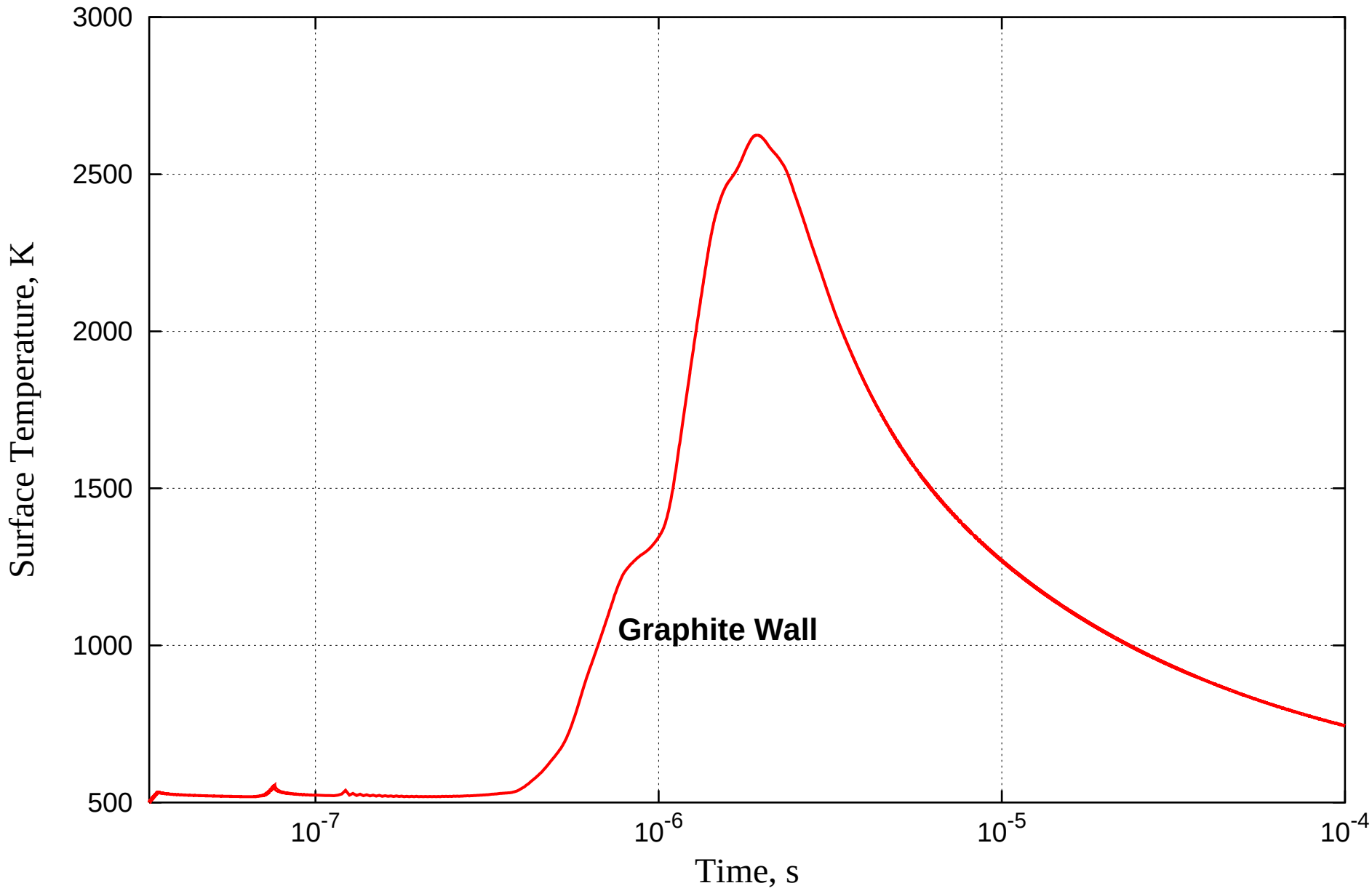
Fast Ions - NRL Direct Drive Target

CFC cx-2002u Wall



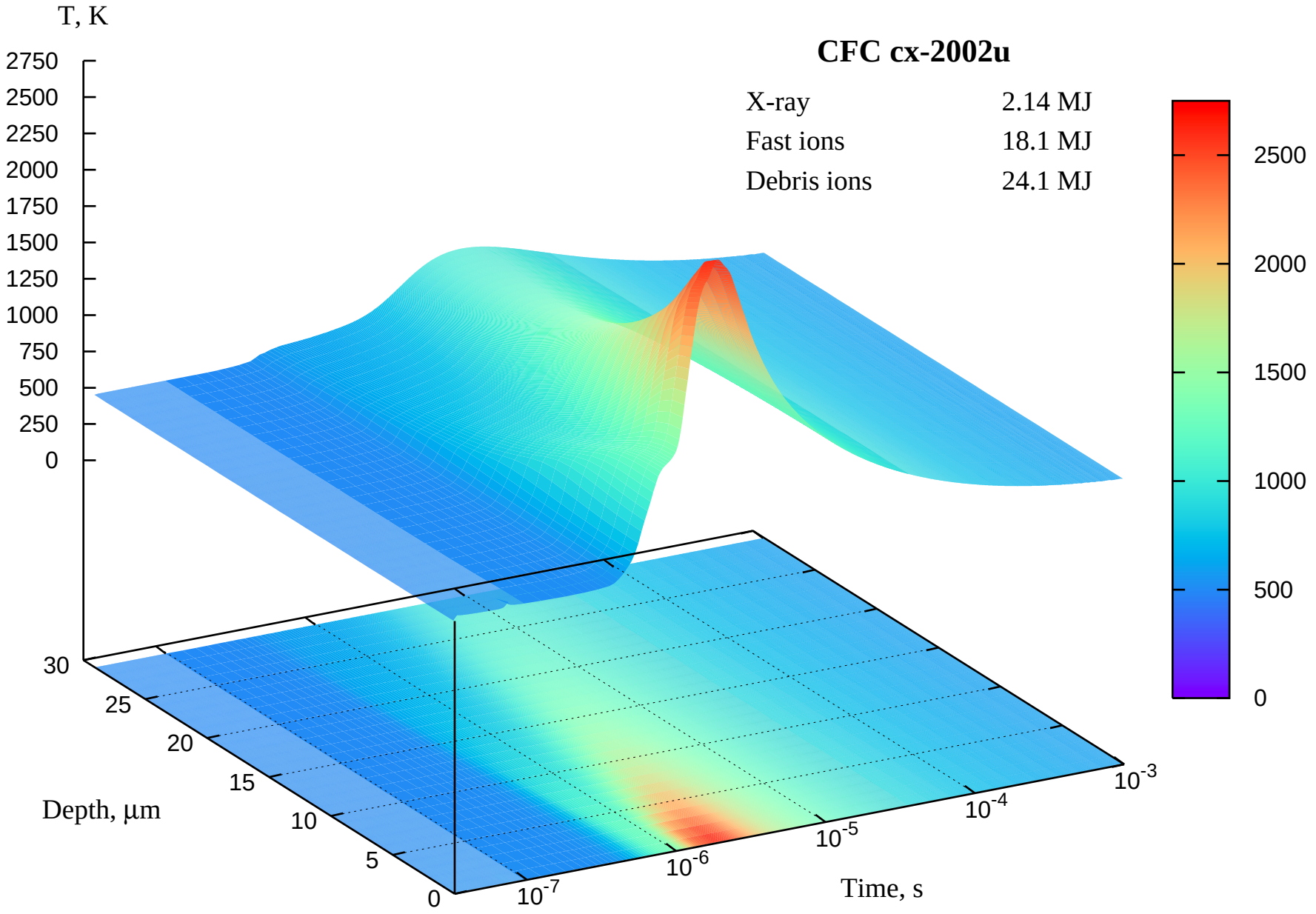
HEIGHTS CALCULATION of SURFACE TEMPERATURE

NRL Direct Drive Target



HEIGHTS SIMULATION of NRL DIRECT TARGET

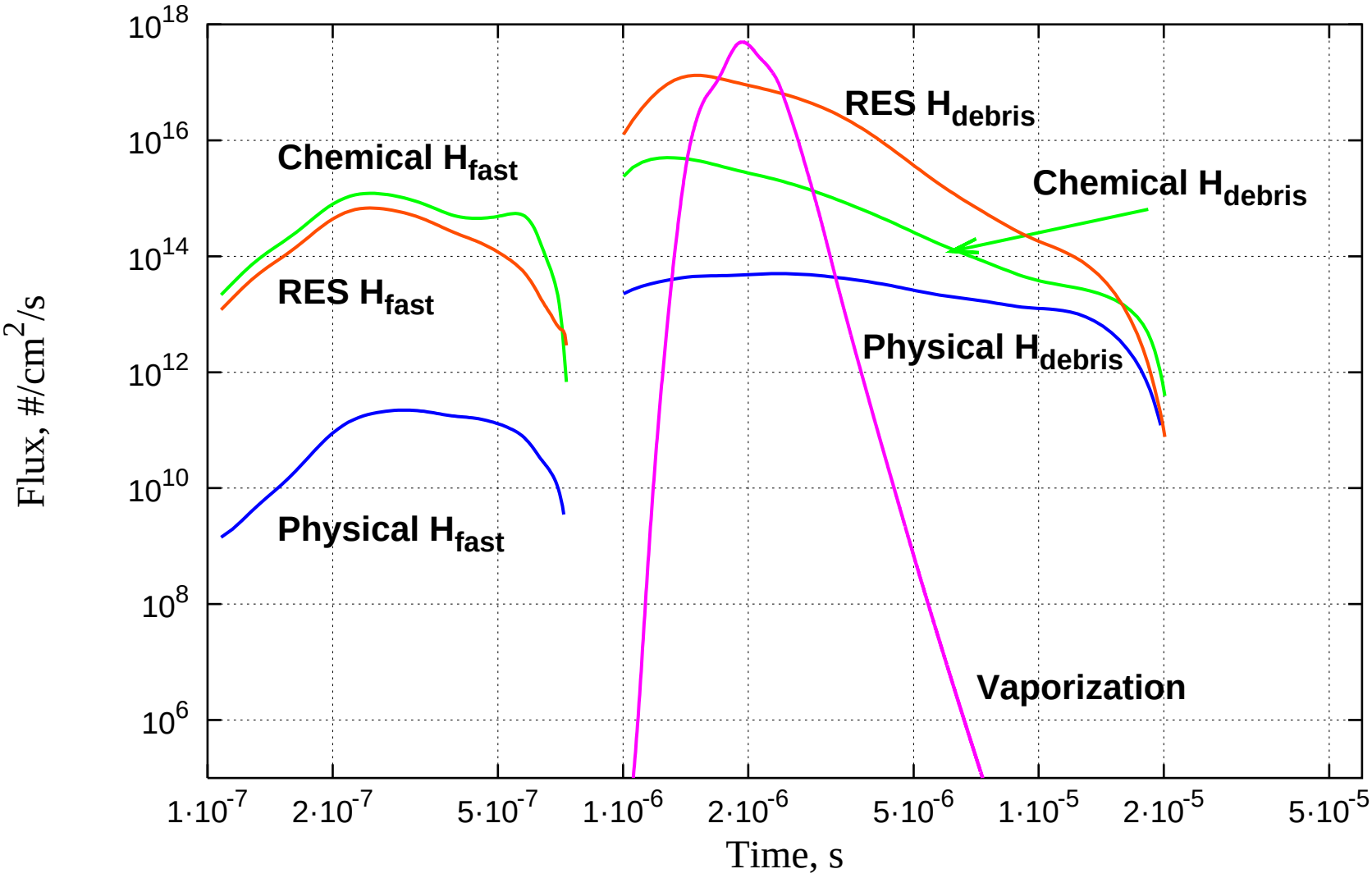
Temperature rise due to laser, X-ray, and ion depositions



HEIGHTS CALCULATION of SPUTTERING-VAPORIZATION

NRL Direct Drive Target

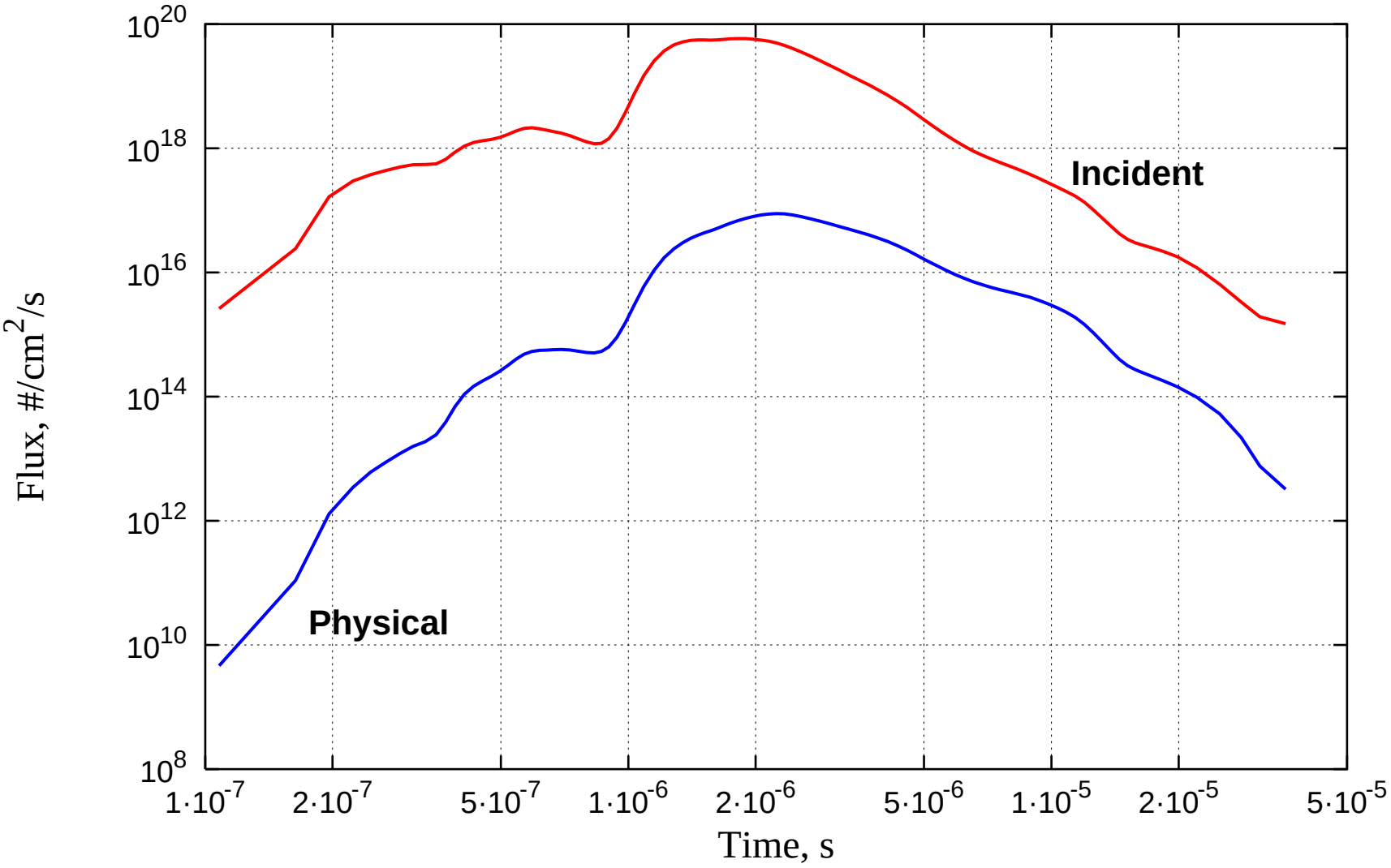
CFC cx-2002u Wall



HEIGHTS CALCULATION of WALL EROSION

NRL Direct Drive Target

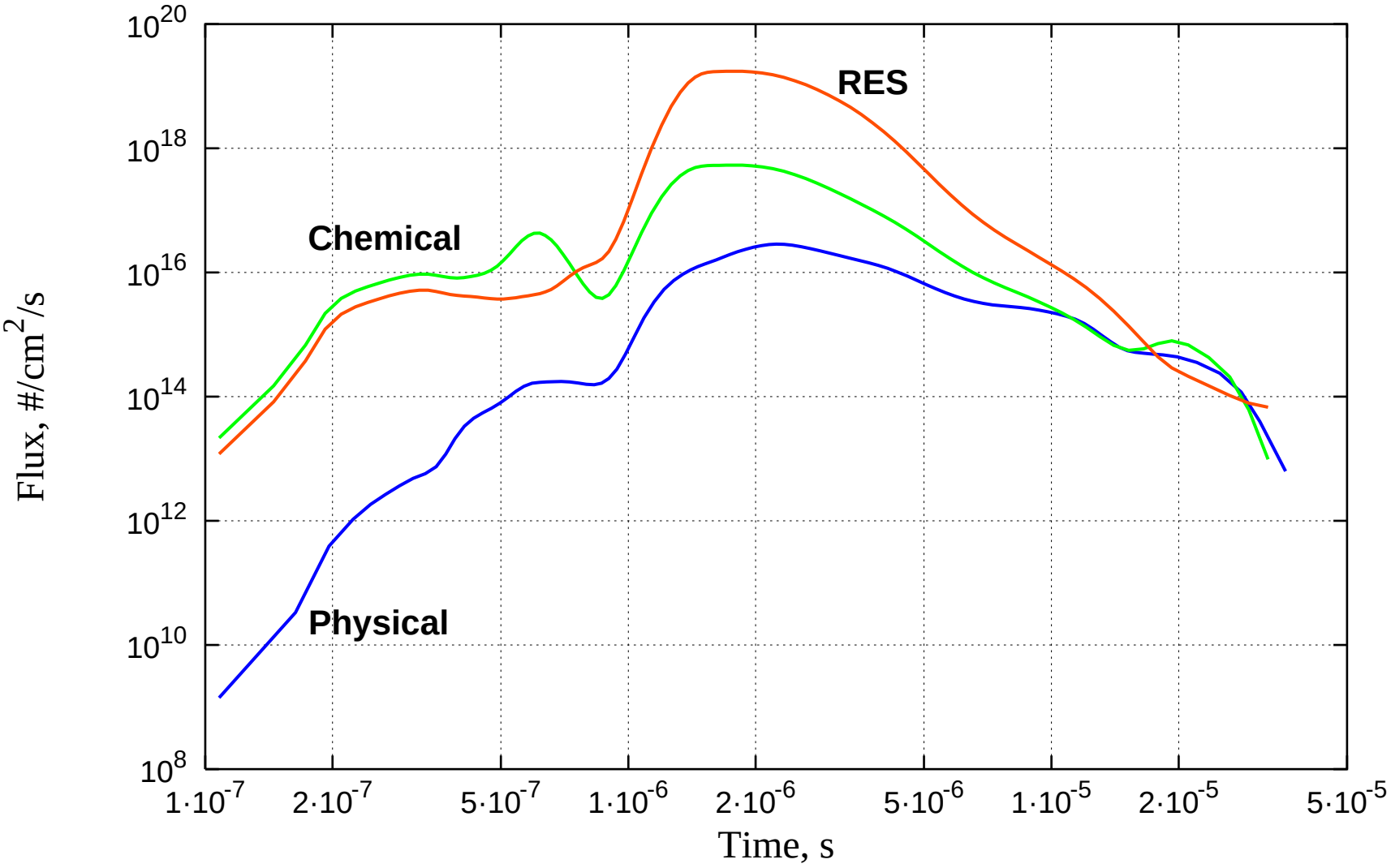
Tungsten Wall



HEIGHTS CALCULATION of WALL EROSION

NRL Direct Drive Target

CFC cx-2002u Wall



HEIGHTS CALCULATION of WALL EROSION

NRL Direct Drive Target

6 Hz @ 85% availability

	GRAPHITE	TUNGSTEN
Vaporization	**30 μm**	**15 μm**
Chemical	**20 μm**	—
RES	**600 μm**	—
Physical	**2 μm**	**6 μm**

HEIGHTS CALCULATION of WALL EROSION

NRL Direct Drive Target

6 Hz @ 85% availability

	CFC cx-2002u	CFC MKC-1PH
Vaporization	**30 μm**	**<1 μm**
Chemical	**20 μm**	**130 μm**
RES	**600 μm**	**15 μm**
Physical	**2 μm**	**2 μm**

The proposed tasks and deliverables are summarized below:

- **Identify all potentially important processes for IFE chamber wall interaction.**

  These processes include:

  - **Spatial heat generation in wall from photons and ions** — **INCLUDED**
  - **Phase change for melting, evaporation/sublimation** — **INCLUDED**
  - **Physical sputtering by target debris** — **INCLUDED**
  - **Chemical sputtering by target hydrogen products** — **INCLUDED**
  - Macroscopic erosion of Carbon materials — BEING DEVELOPED

- **Assess the importance of these processes for IFE chamber wall interaction by performing preliminary parametric estimates.** — **BEING DONE**

- Identify key processes for inclusion during the first year. — BEING DONE

- Evolve mathematical models and equations of these key processes**.** — BEING DONE

- **Write an independent computer module based on above models.** — BEING DONE

- **Perform preliminary comparison of module results with existing codes for selected cases.** ----------