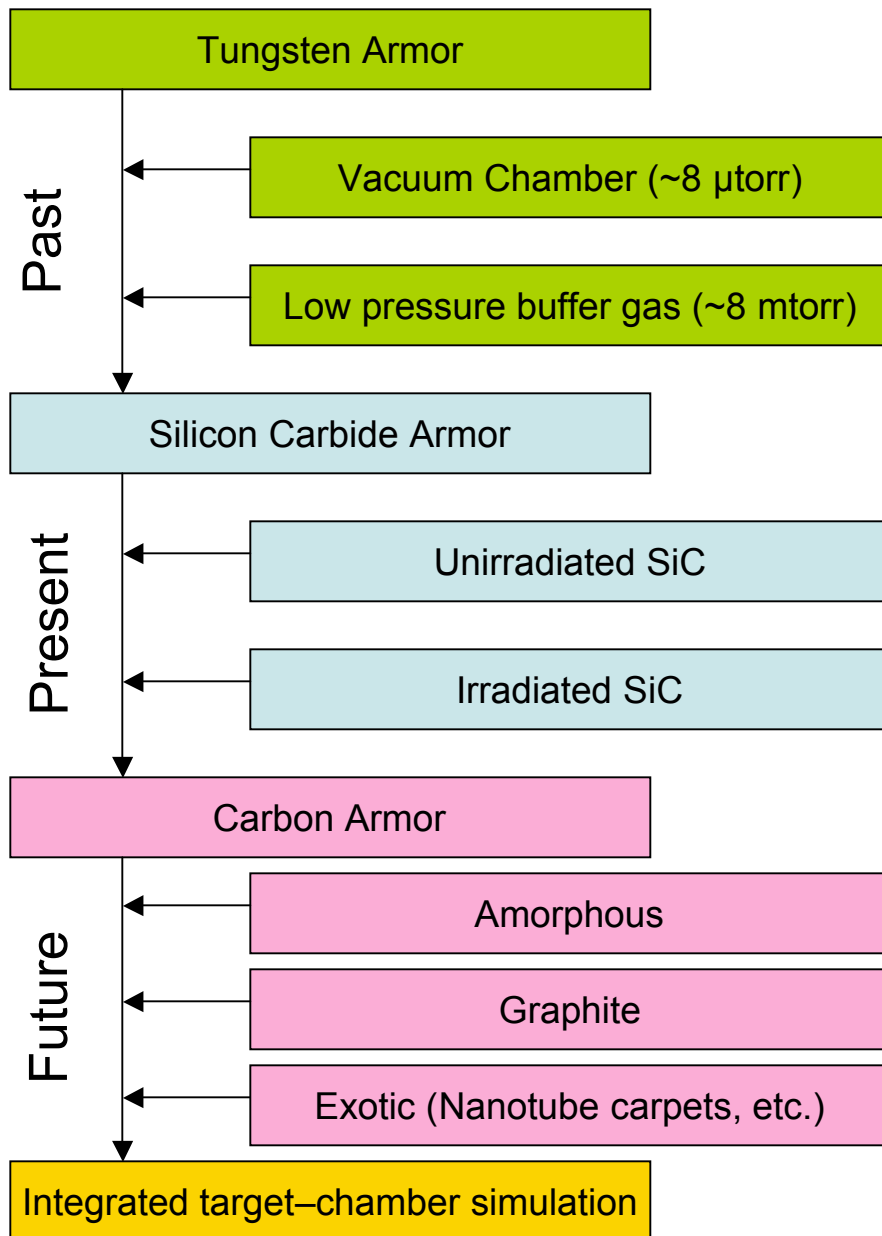


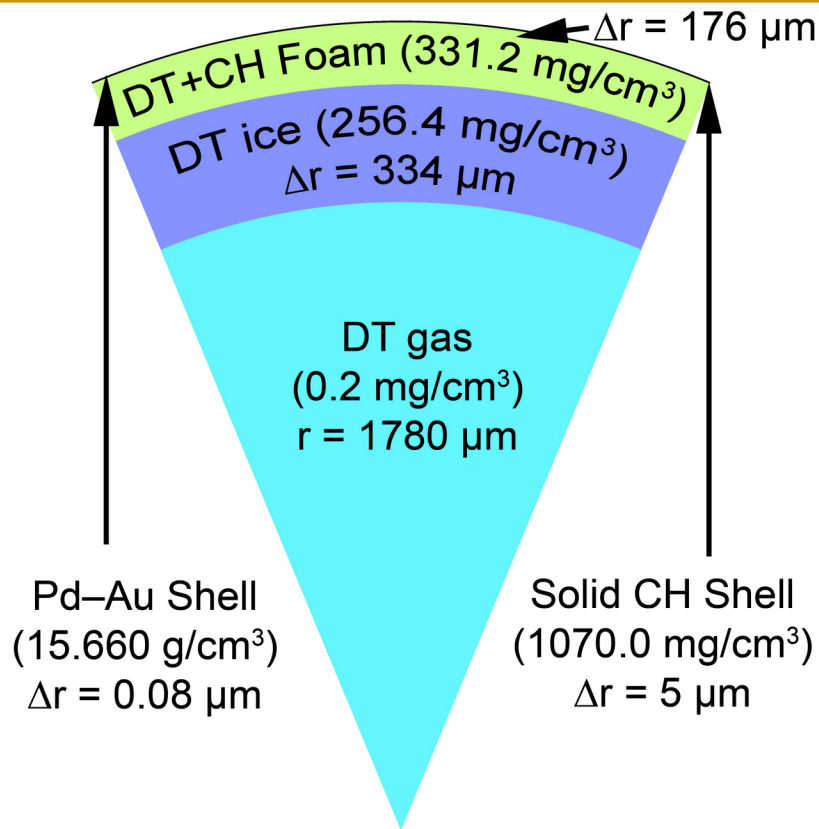
350 MJ Target Thermal Response and Ion Implantation in 1 mm thick silicon carbide armor for 10.5 m HAPL Chamber



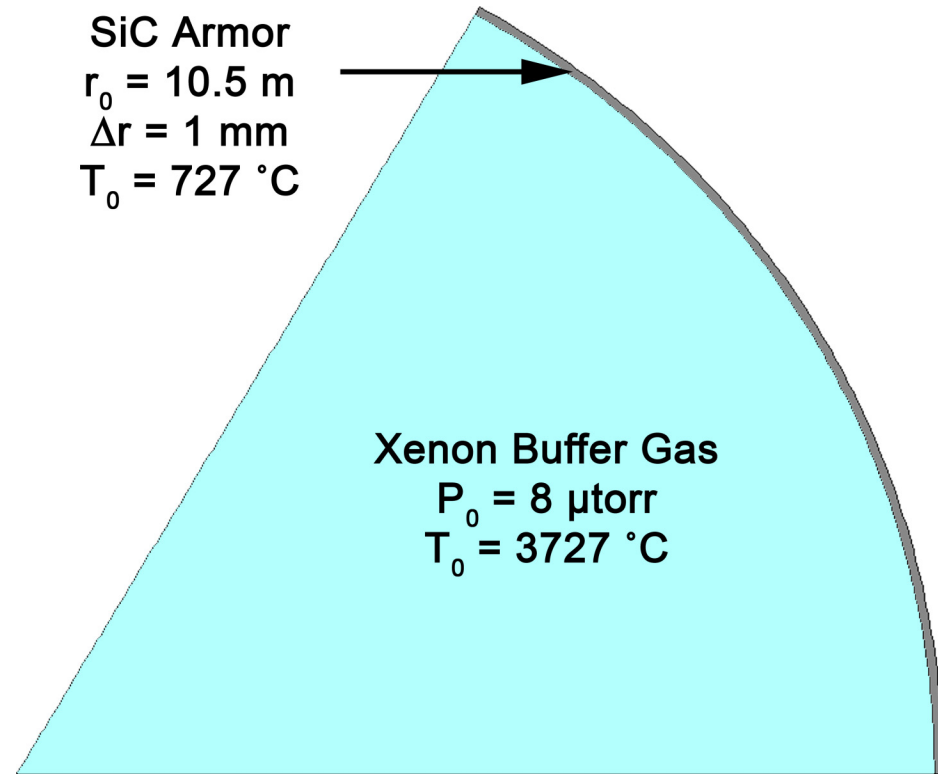
T.A. Heltemes and G.A. Moses
Fusion Technology Institute
High Average Power Laser Program Workshop
March 21–22 2006, ORNL



- Simulations will be added as required (porous tungsten, irradiated carbon, etc.)
- Ultimate goal is to produce a streamlined process to perform integrated end-to-end 1-D simulations for chamber thermomechanical performance



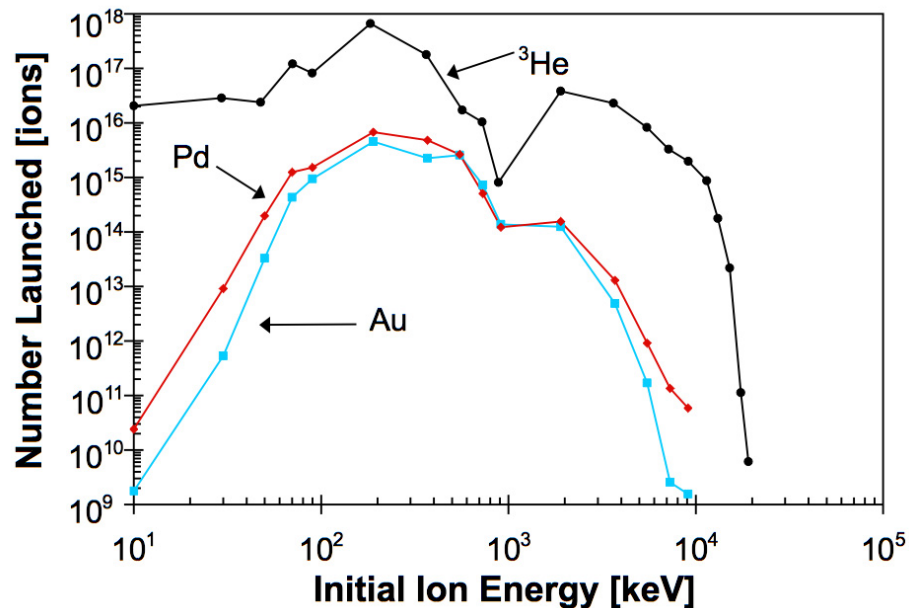
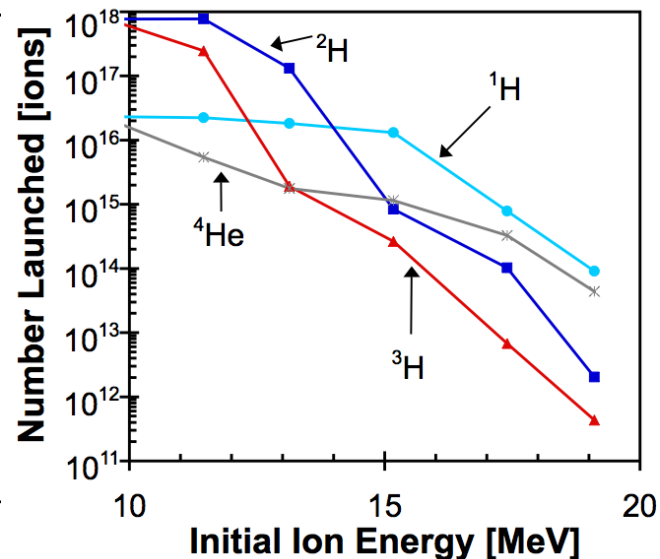
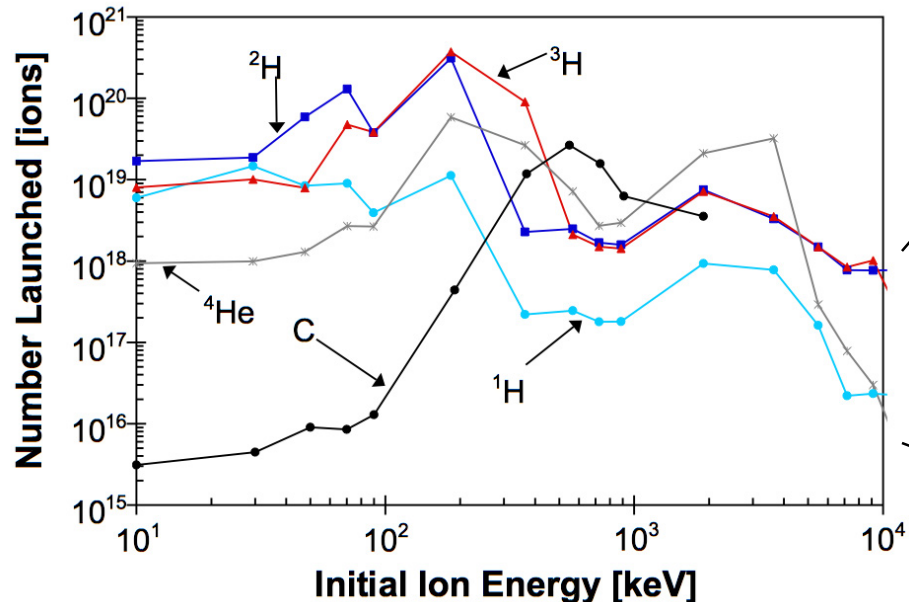
SiC Armor
 $r_0 = 10.5 \text{ m}$
 $\Delta r = 1 \text{ mm}$
 $T_0 = 727 \text{ }^\circ\text{C}$

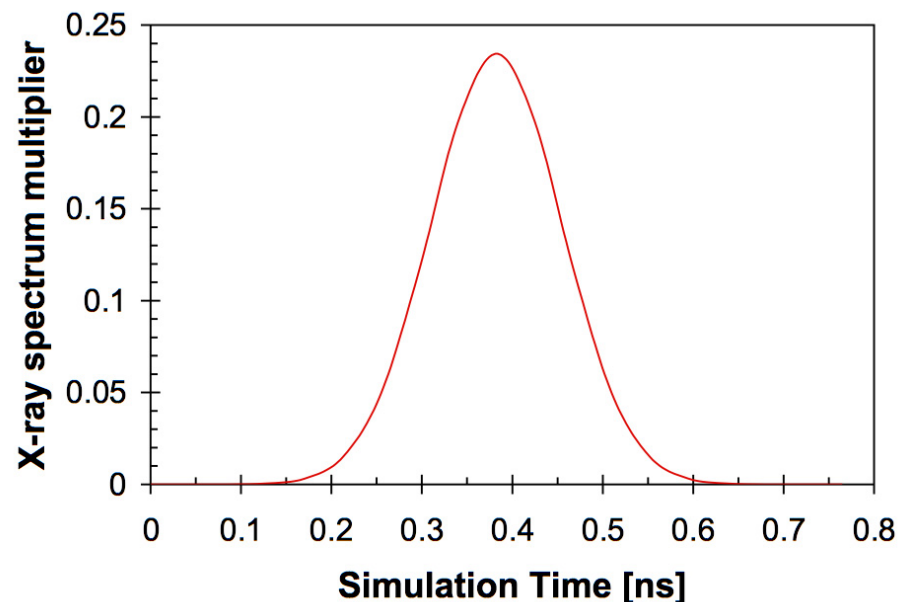
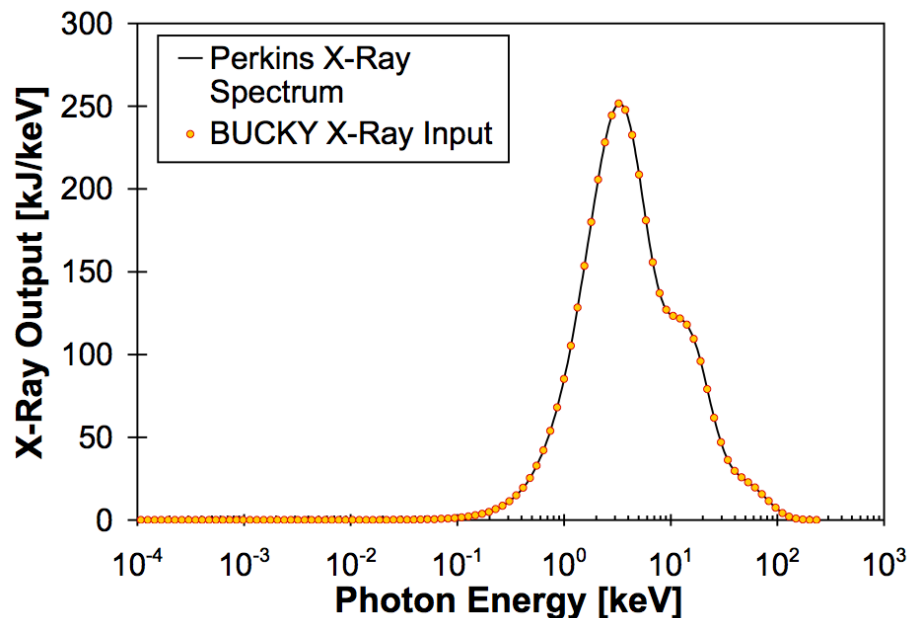


- HAPL baseline chamber geometry was used with a near-vacuum gas condition
- The high-Z (Pd/Au) coated target ion and x-ray spectra were used as inputs to the BUCKY simulation
- Initial armor temperature was set to 727°C (1000K) for the simulations

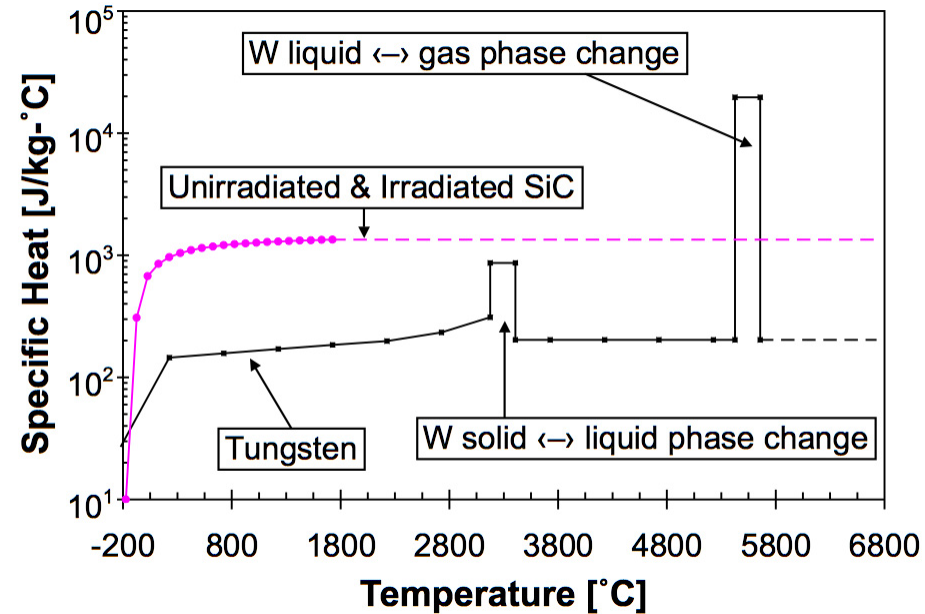
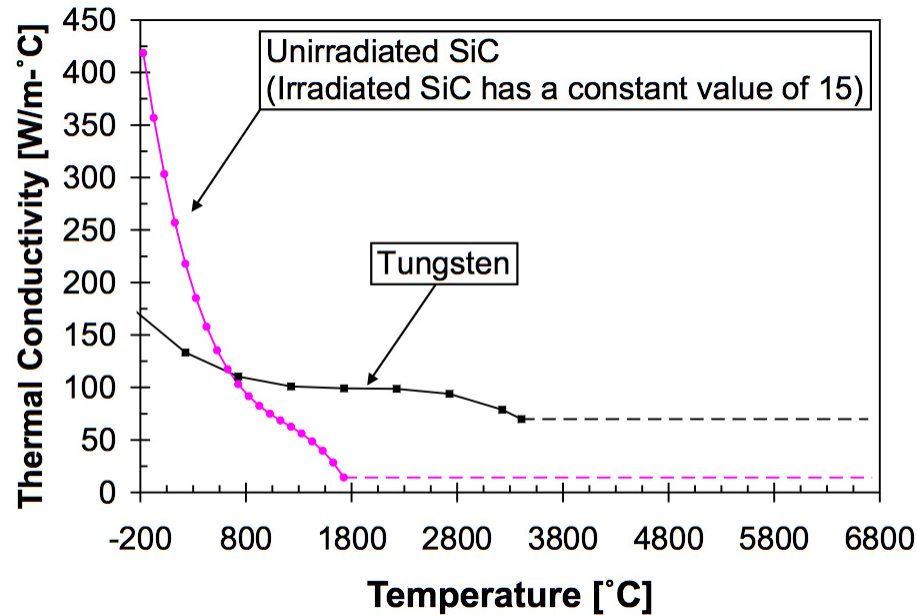
Perkins' 350 MJ target ion spectra were used as inputs for the BUCKY simulations.

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- Perkins' x-ray spectrum is time-integrated, which must be corrected for in the BUCKY simulation
- A Gaussian function was chosen to generate time-dependence based on results of BUCKY simulations of other direct-drive targets
- The time-integrated x-ray spectrum was multiplied by a Gaussian function with a FWHM of 170 ps



- Simulation uses a constant thermal conductivity of 15 $\text{J/kg}\cdot^{\circ}\text{C}$ for irradiated SiC
- Simulation uses a SiC sublimation temperature of 2760 $^{\circ}\text{C}$ (from CVD SiC spec sheet produced by Rohm and Haas, <http://www.cvdmaterials.com/silicon.htm>)

S.J. Zinkle & L.L. Snead (1998)

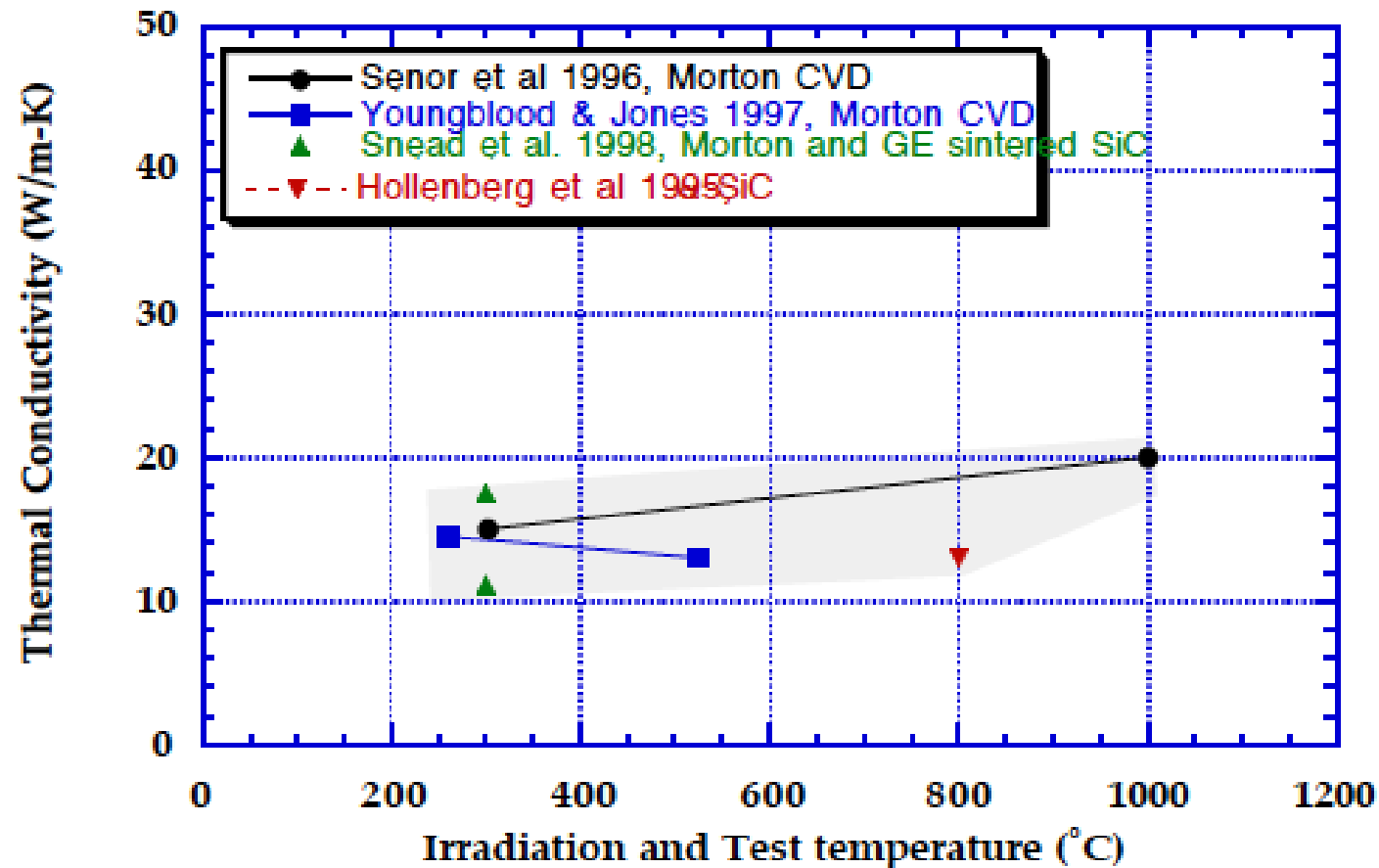
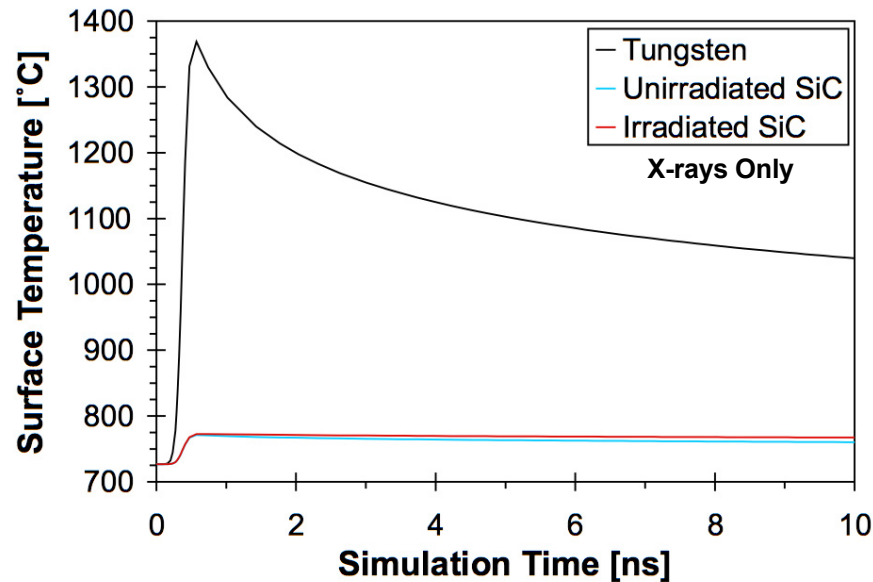


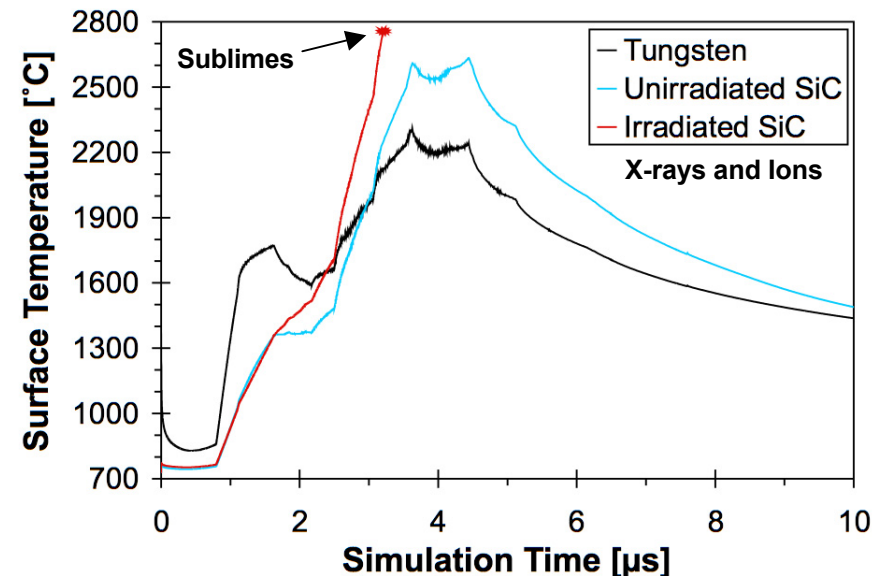
Fig. 2. Effect of neutron irradiation on the thermal conductivity of bulk SiC [9,20-22]. The studies in refs. [20-22] were performed on samples irradiated to 25-43 dpa, whereas the data by Snead et al. were obtained on samples irradiated to 0.1 dpa.

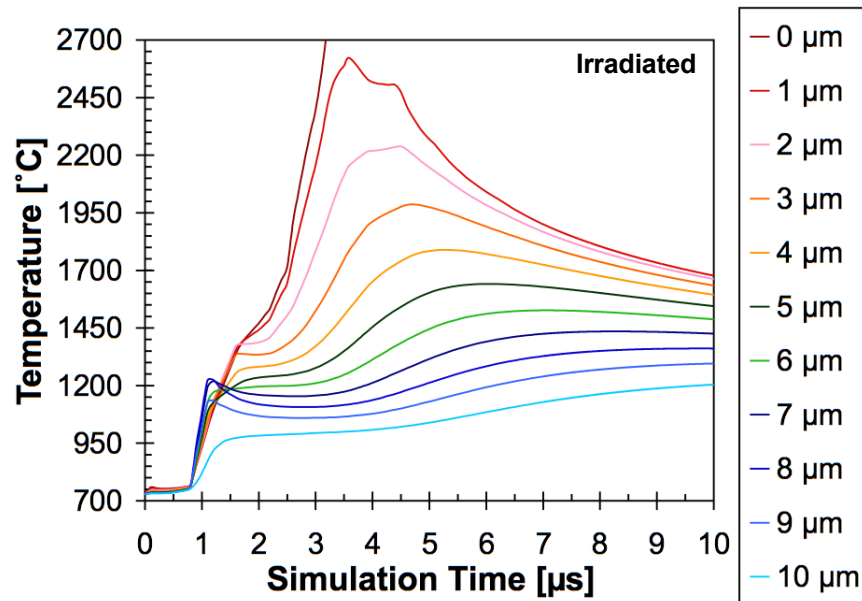
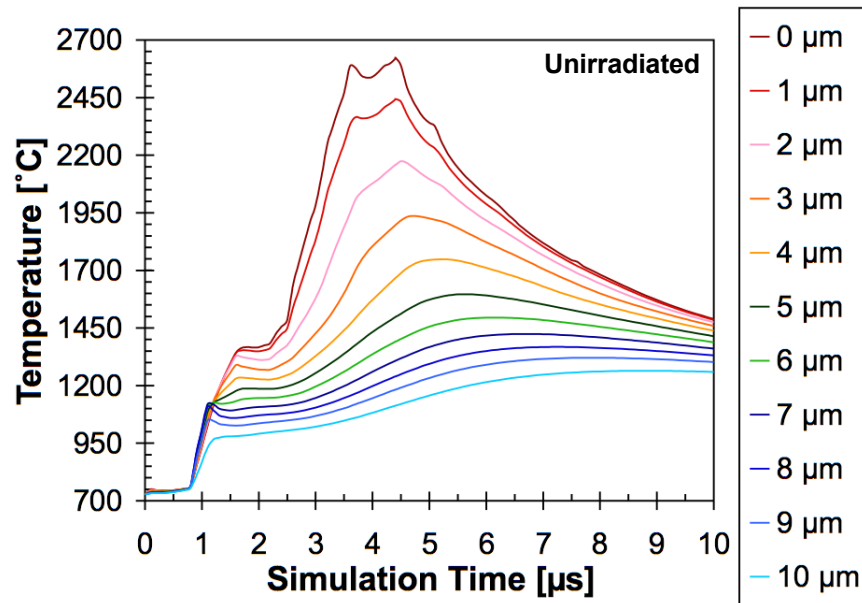
BUCKY simulations were run for both unirradiated and irradiated SiC and the results were compared to the previously conducted tungsten simulation

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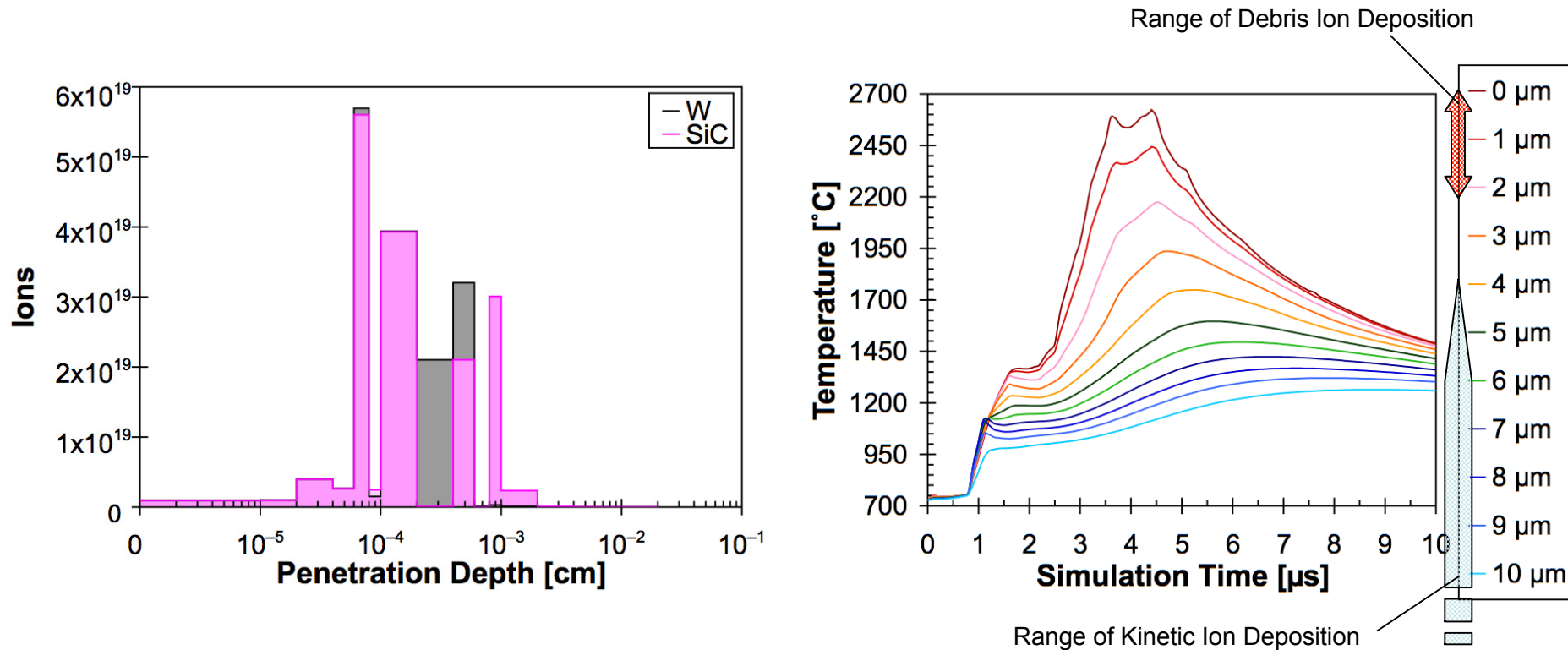


- Irradiation has a negligible effect on the temperature rise due to the x-ray pulse ($\sim 2^\circ\text{C}$ difference)
- Ion heating in the unirradiated SiC causes a greater peak temperature rise ($\Delta T_{\text{max}} = 1904^\circ\text{C}$) at 10.5 m than that of tungsten ($\Delta T_{\text{max}} = 1584^\circ\text{C}$)
- Every shot fired in an **irradiated** SiC armored chamber ablates due to the impinging ions to a depth of $0.5\ \mu\text{m}$ at $125\ \mu\text{s}$
- Summary of Results:
 - Irradiated SiC is unsuitable as an armor material without diversion or buffer gas
 - Unirradiated SiC does not ablate, but will exceed engineering limits of $1500\text{--}1700^\circ\text{C}$





- Both unirradiated and irradiated SiC show peak ion heating from the kinetic ions between 7–9 μm from the surface
- Largest temperature gradients are caused by the debris ions



- Debris ions deposit 0–2 μm into the SiC
- Kinetic ions deposit 4–200 μm into the SiC, with peak deposition from 4–20 μm

- **Irradiated** SiC is unsuitable for use as an armor material for the 10.5 m HAPL chamber without diversion of the ions or introduction of a buffer gas into the chamber
- Although **unirradiated** SiC does not reach its ablation temperature, the temperature rise from a target explosion does exceed the engineering limit of 1500–1700°C
- If magnetic diversion of ions is used for the HAPL chamber, silicon carbide is preferable to tungsten for mitigating the temperature rise due to the x-rays impinging on the armor

- Revise T_{sub} to 3008°C, which is the sublimation temperature listed in the NIST ceramics database
- More high-temperature thermal conductivity and specific heat data ($T > 1727^\circ\text{C}$) for **unirradiated** SiC are required
- Broader data set for **irradiated** SiC properties are required
- Need to more accurately model the behavior of silicon carbide near the sublimation temperature



