Generation of X-ray and Ion Threat Spectra for the Fusion Test Facility using the BUCKY 1-D Radiation Hydrodynamics Code

THE UNIVERSITY of WISCONSIN MADISON

T.A. Heltemes and G.A. Moses

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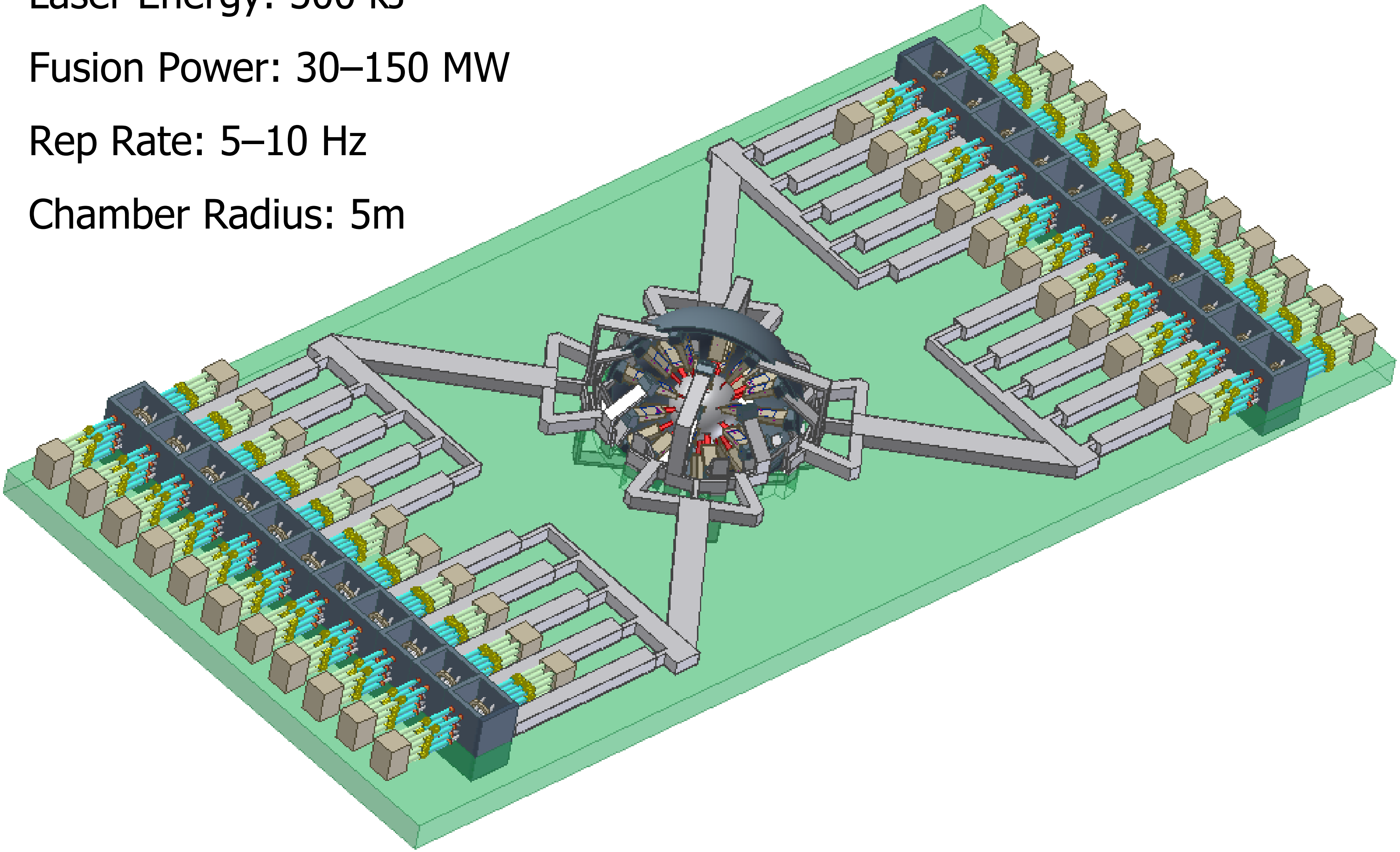
FTF Facility Overview

Laser Energy: 500 kJ

Fusion Power: 30–150 MW

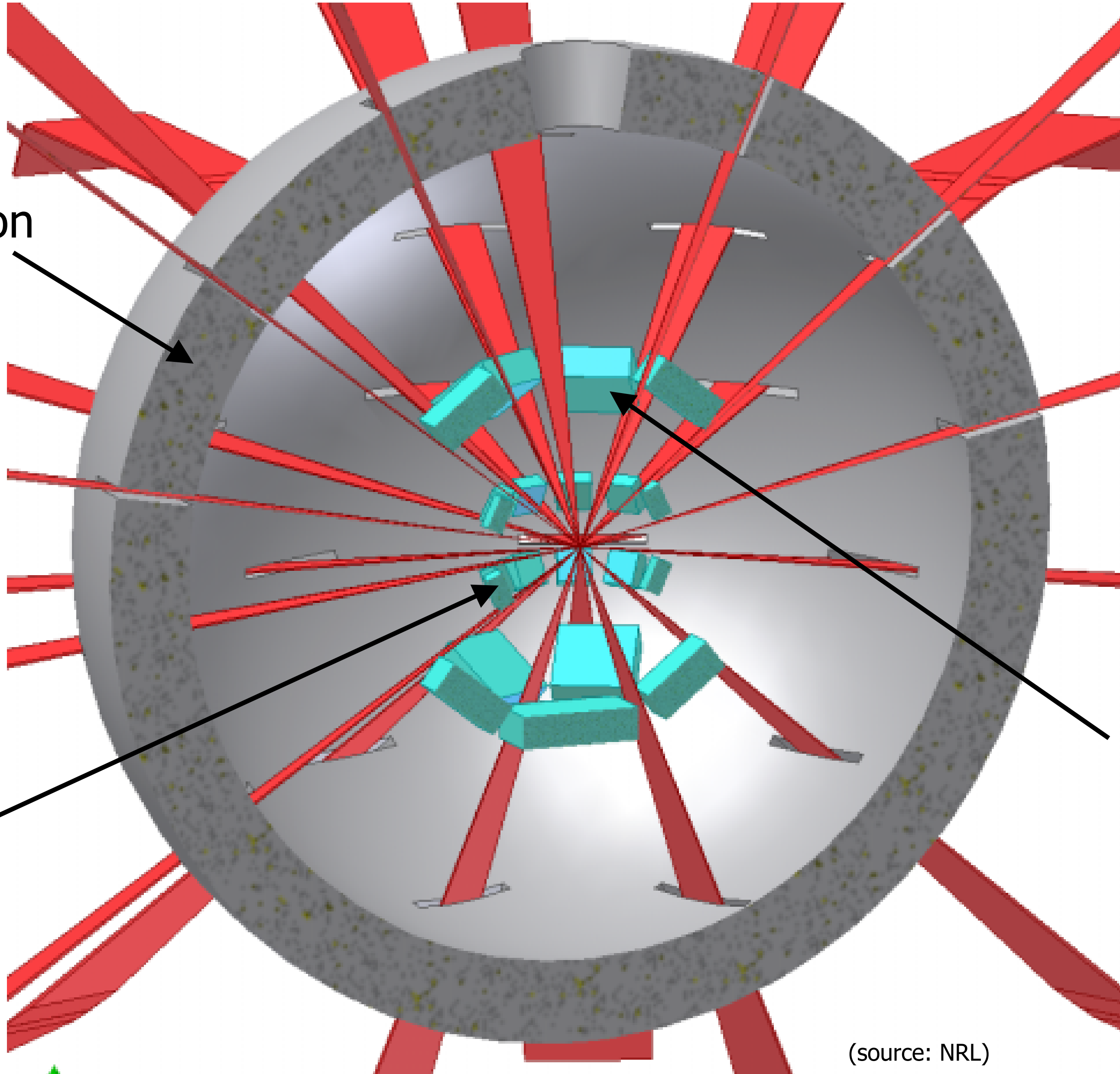
Rep Rate: 5–10 Hz

Chamber Radius: 5m

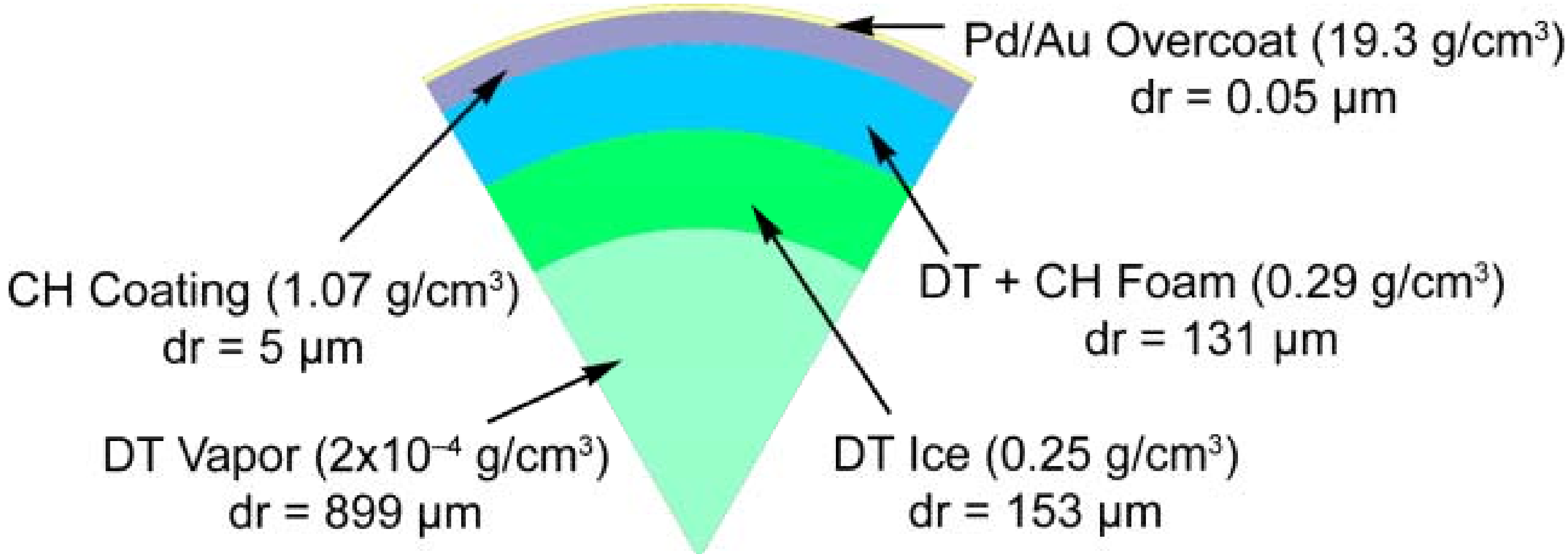


(source: NRL)

FTF Target Chamber

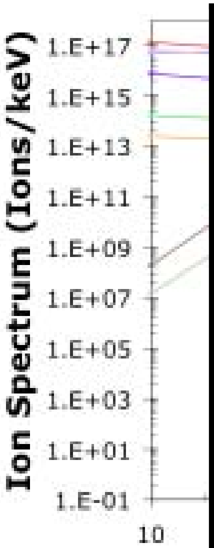


FTF Target Specifications

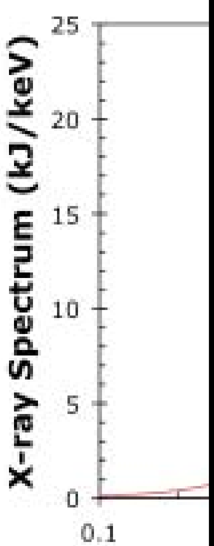


- KrF Driver: 500 kJ at 5 Hz
- Hot Spot Conditions
  - $T = 10$ keV
  - $\rho R = 0.3$ g/cm^2
  - $V_{max} = 4.1\times10^7$ cm/s
- Target Gain: ~60
- Target Yield: 29.75 MJ
- Total target mass: 1.167 mg

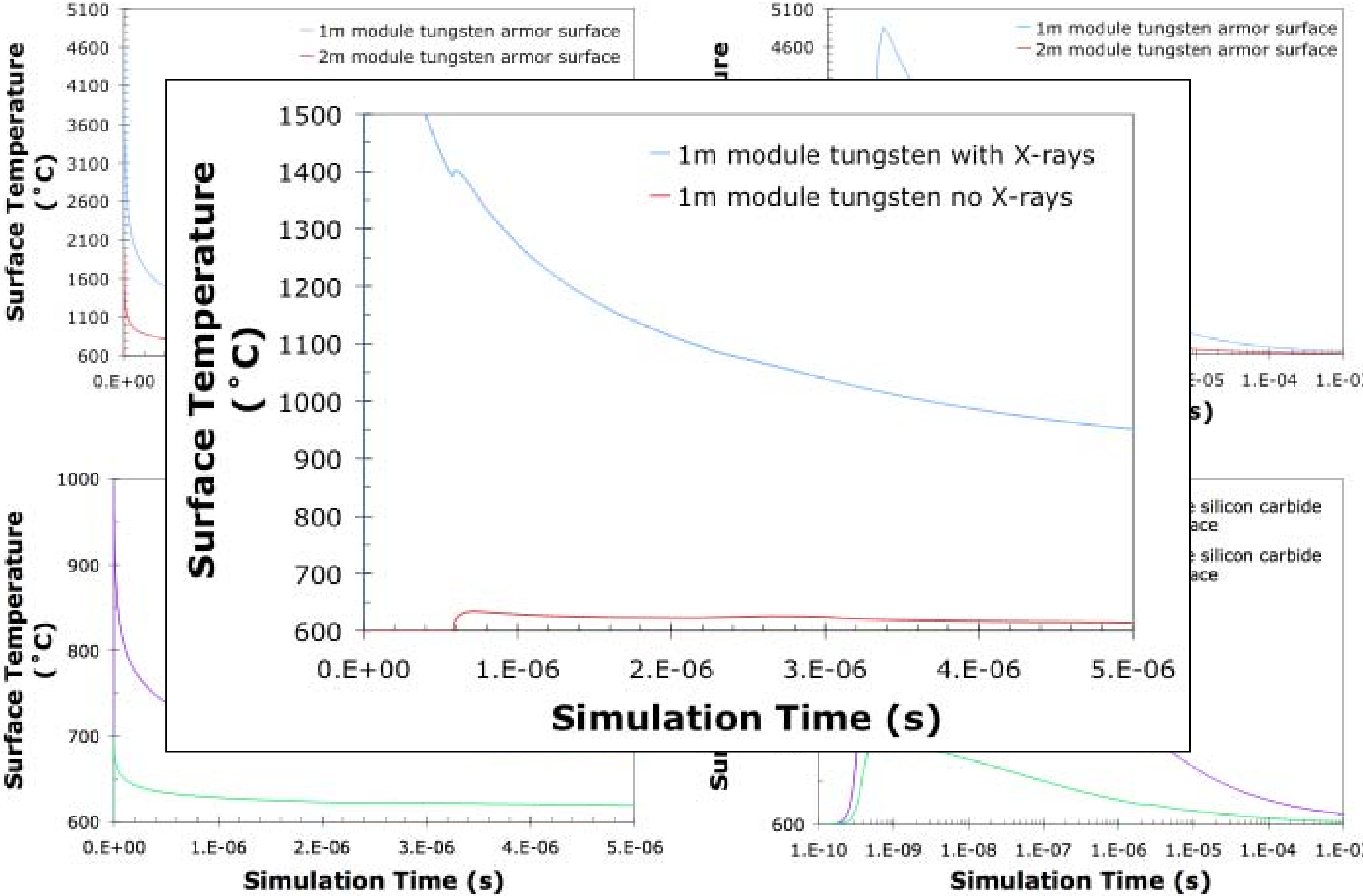
BUCKY was used to simulate the thermal response of the test module armor materials using a scaled-down 365MJ HAPL Target



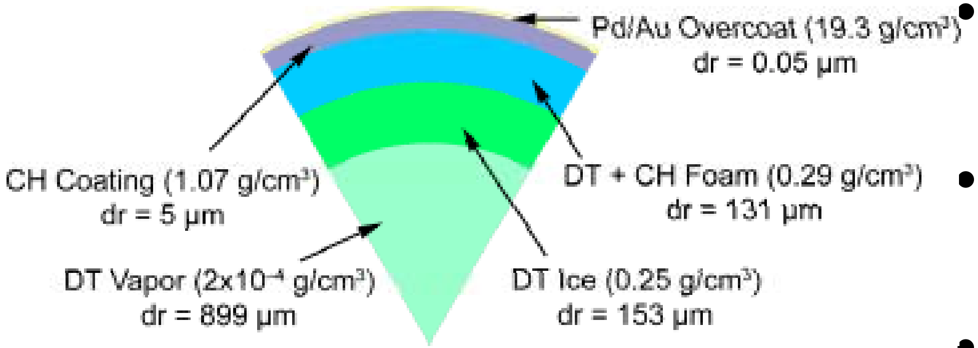
Parameter	HAPL target, full scale	HAPL target with 0.0815 multiplier
Driver Energy (MJ)	2.459 MJ	
Target Gain	148.3	
Charged Particle Yield (MJ)	87.854	7.160
Neutron Yield (MJ)	274.3	22.355
X-ray Yield (MJ)	4.937	0.402
X-ray Pulse FWHM (ps)	170	

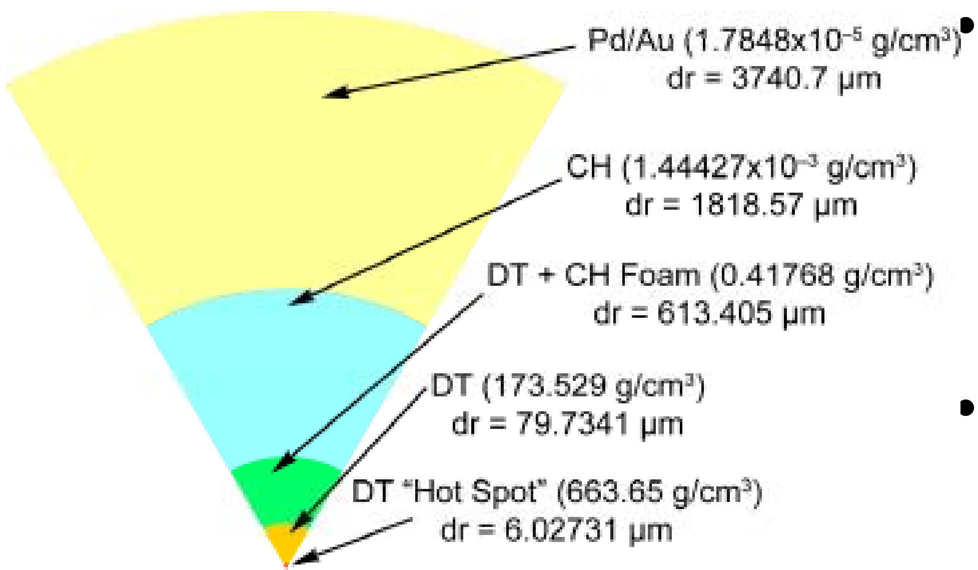


Results of the scaled HAPL target give us a baseline to compare our target simulation results against



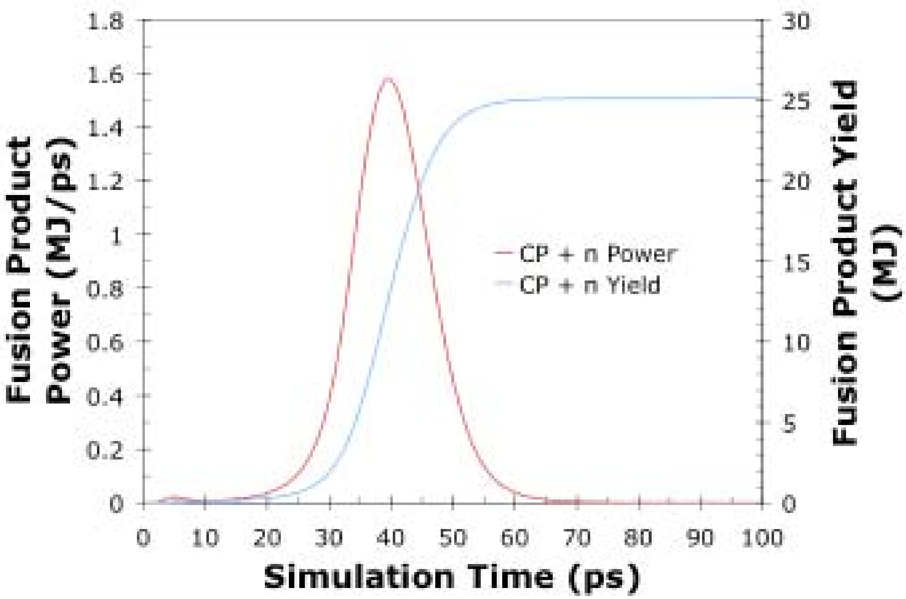
BUCKY was used to simulate the FTF target at the point of ignition with an estimated set of initial conditions

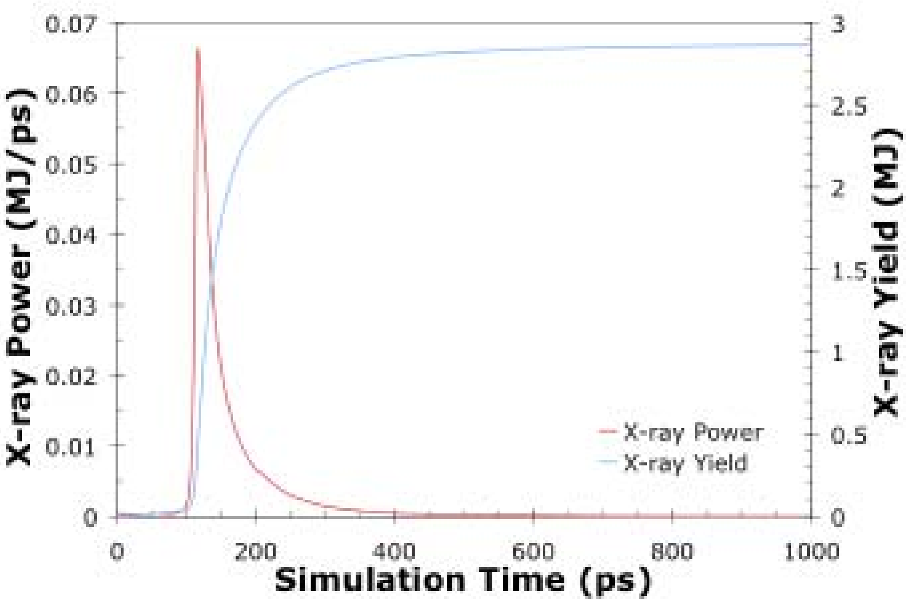




- A radial build was created using densities at the ignition point of the HAPL target
- The hot spot density was determined using an initial condition of $\rho R = 0.4$ gm/cm^2
- The pure DT zones were assigned an inward velocity of 6.4×10^7 cm/s and all other materials were assigned and outward velocity of 6.4×10^7 cm/s
- Ignition temperatures were assigned
  - Hot spot DT = 4 keV
  - DT = 800 eV
  - DT+CH Foam = 600 eV
  - CH = 400 eV
  - Au = 200eV
- The target was bounded by a global temperature condition of 1 eV and pressure condition of 6.67 mtorr to represent the xenon chamber gas (0.5 mtorr at 0˚C)

The BUCKY simulation was able to achieve ignition using the specified initial conditions



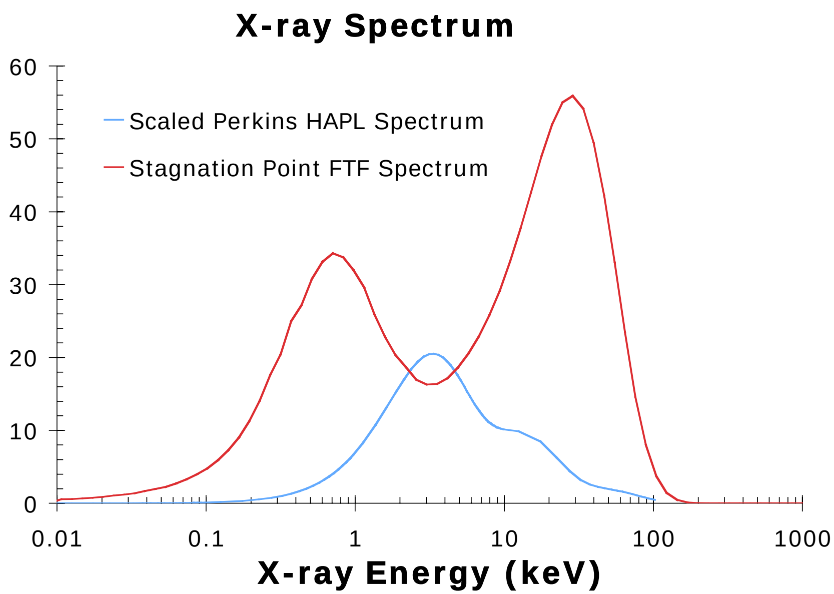


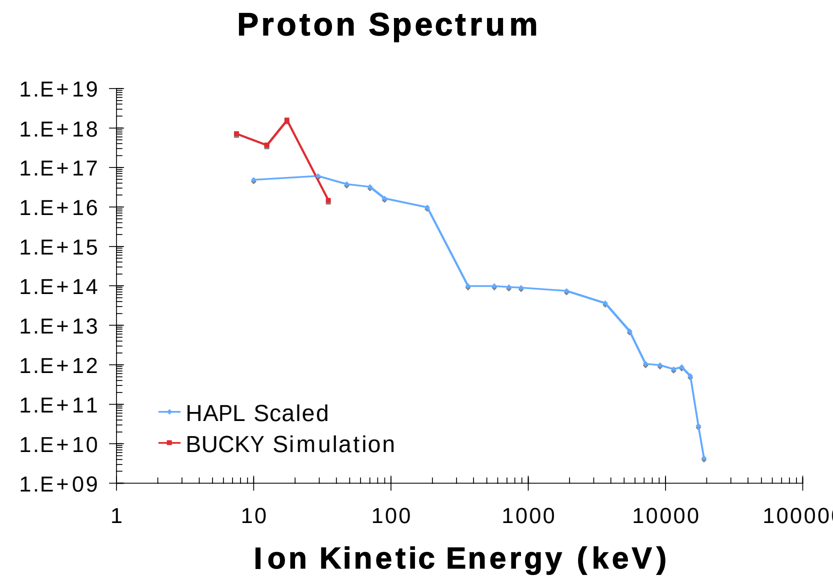
- The compressed FTF target achieved the following yields:
  - Total CP: 5.003 MJ
  - Total n: 20.124 MJ
  - Total X-ray: 2.885 MJ
- The fusion pulse FWHM was:
  - Charged particles: 22 ps
  - Neutrons: 22 ps
  - X-rays: 24 ps

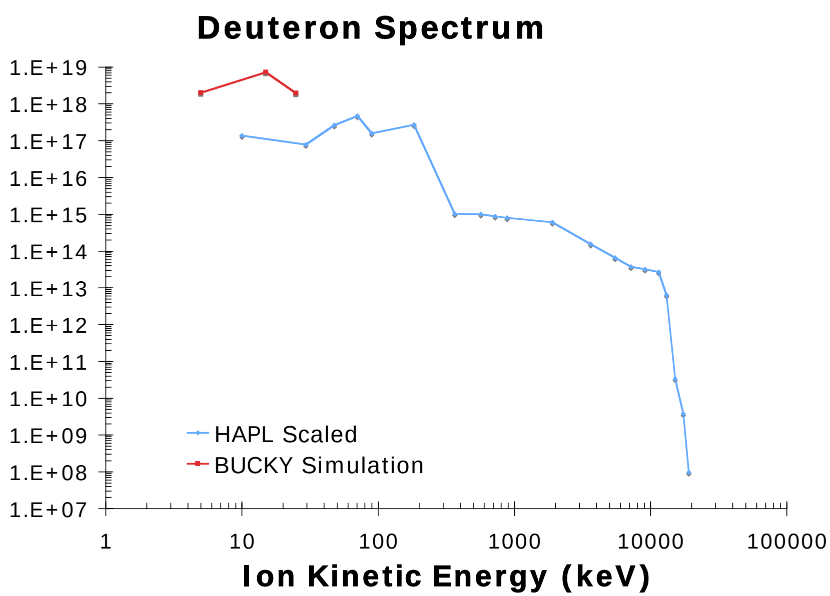
Does the FTF target scale well from the HAPL target?

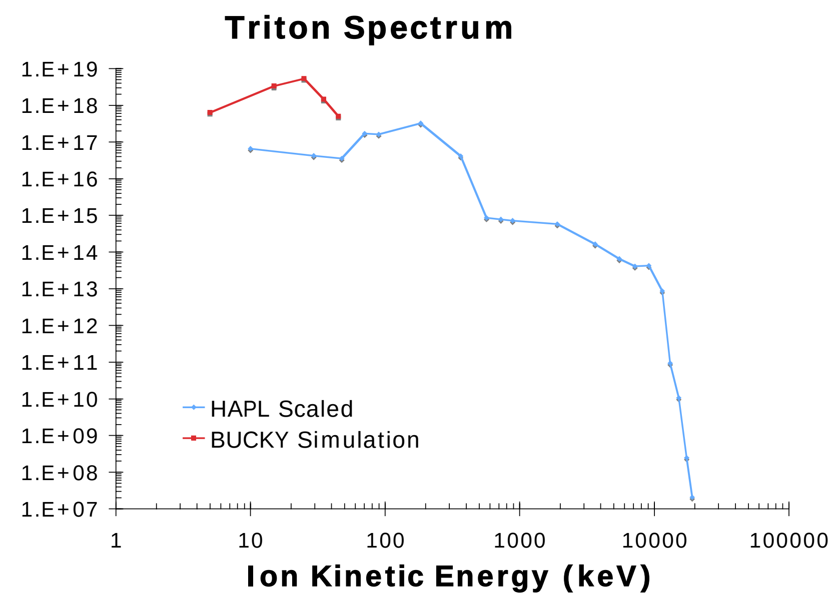
Parameter	HAPL 365 MJ Target	FTF 29.75 MJ Target
Target mass (mg)	8.002	1.167
Driver energy to mass ratio (MJ/mg)	0.307	0.428
Target gain to mass ratio (1/mg)	18.533	25.493
Charged particle yield to mass ratio (MJ/mg)	10.979	4.287
Neutron yield to mass ratio (MJ/mg)	34.279	17.244
X-ray yield to mass ratio (MJ/mg)	0.617	2.472
X-ray pulse FWHM to mass ratio (ps/mg)	21.2	20.6
Total yield to mass ratio (MJ/mg)	45.625	25.493

How well does the BUCKY spectra compare with the scaled HAPL target spectra?

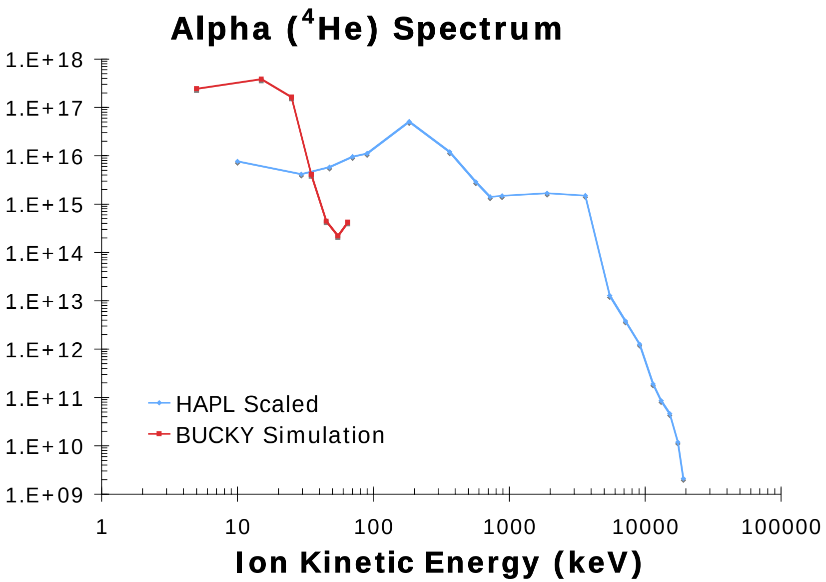


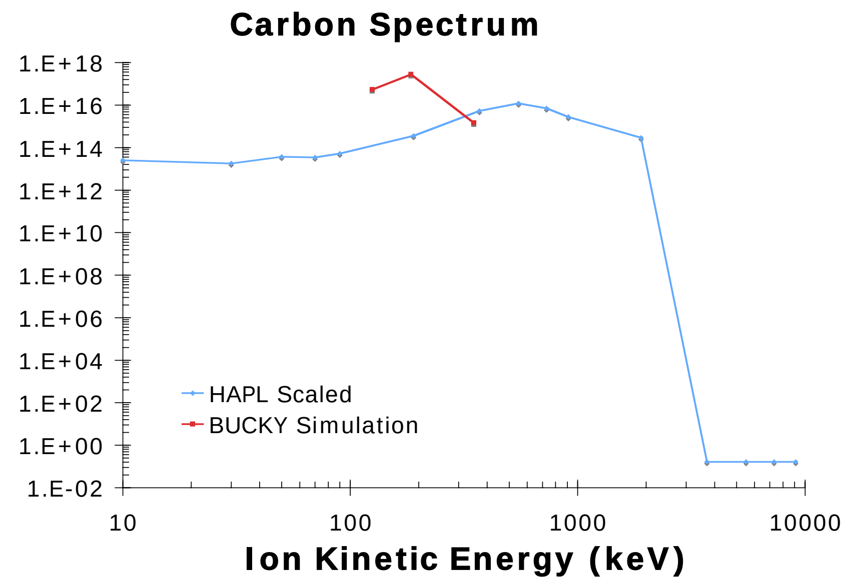


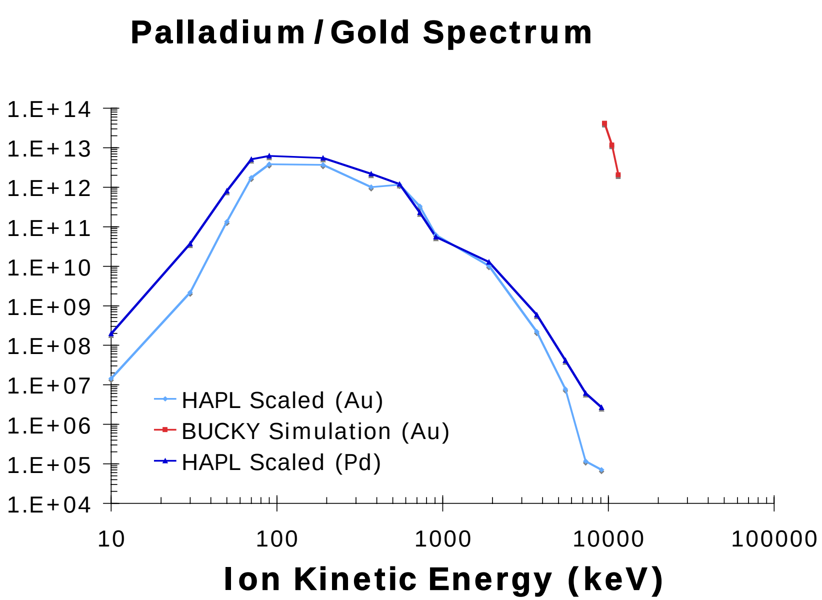




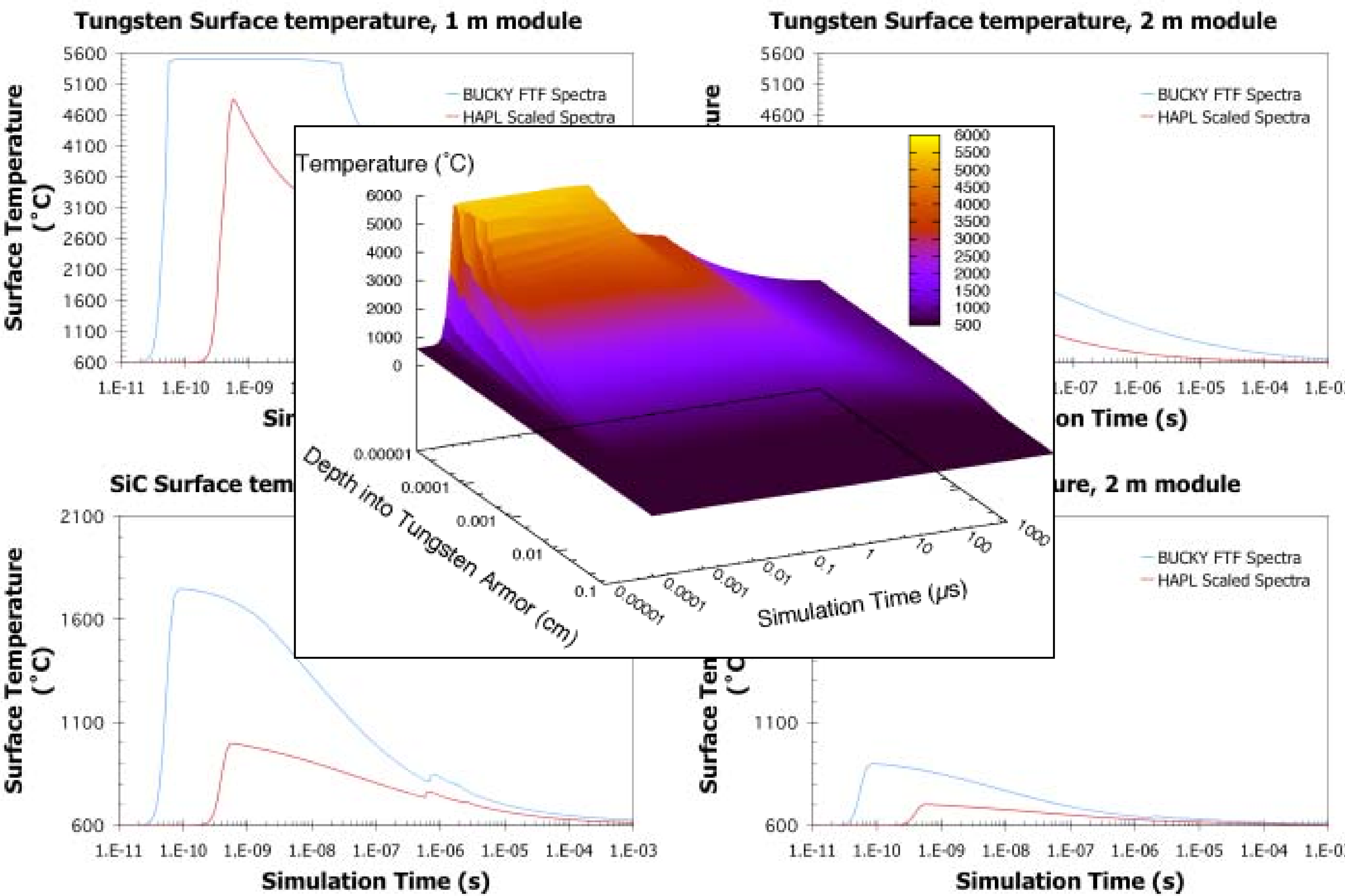
How well does the BUCKY spectra compare with the scaled HAPL target spectra?







The resulting spectra were used in the chamber simulation to find the temperature rise on the surface of the module armor materials



Conclusions and Future Work

- The Compressed FTF target simulations carried out using the BUCKY 1-D radiation hydrodynamics lead to some insights about the FTF target
  - ♦ Linear scaling of the HAPL target spectra may not be a valid assumption to apply to the FTF target design
  - ♦ The FWHM of the X-ray pulse for the two target designs are comparable on a per milligram basis, about 21 ps/mg for both designs
- Comparison between the scaled HAPL target (29.75/365 ≈ 0.0815) and FTF target ion and X-ray spectra show
  - ♦ The ion spectra from the BUCKY FTF simulation have narrower range of ion kinetic energy and lower average energy compared to the scaled HAPL target spectra
  - ♦ The X-ray spectrum from the BUCKY FTF simulation has a wider range of X-ray energy and has two distinct peaks
- Comparison between the scaled HAPL target and FTF target module armor heating show
  - ♦ For the 1m module, tungsten is not desirable as an armor material
  - ♦ For the 2m module, either tungsten or silicon carbide may be used

Conclusions and Future Work

- Change the gold opacity data from the LTE model to the non-LTE model
- Run a BUCKY simulation of the “cold” FTF target with the proposed KrF laser driver power profile
- Modify the output to include ^{3}He ion information
- Modify the outer high-Z layer to a 50/50 Pd/Au mixture
- Run the cold FTF target simulation integrated with the chamber simulation
  - Run for three inert buffer gases: Helium, Argon and Xenon
  - Run with tungsten, silicon carbide and graphite as armor materials
- Compare the results of the cold 1D BUCKY target simulation to a cold 2D target simulation