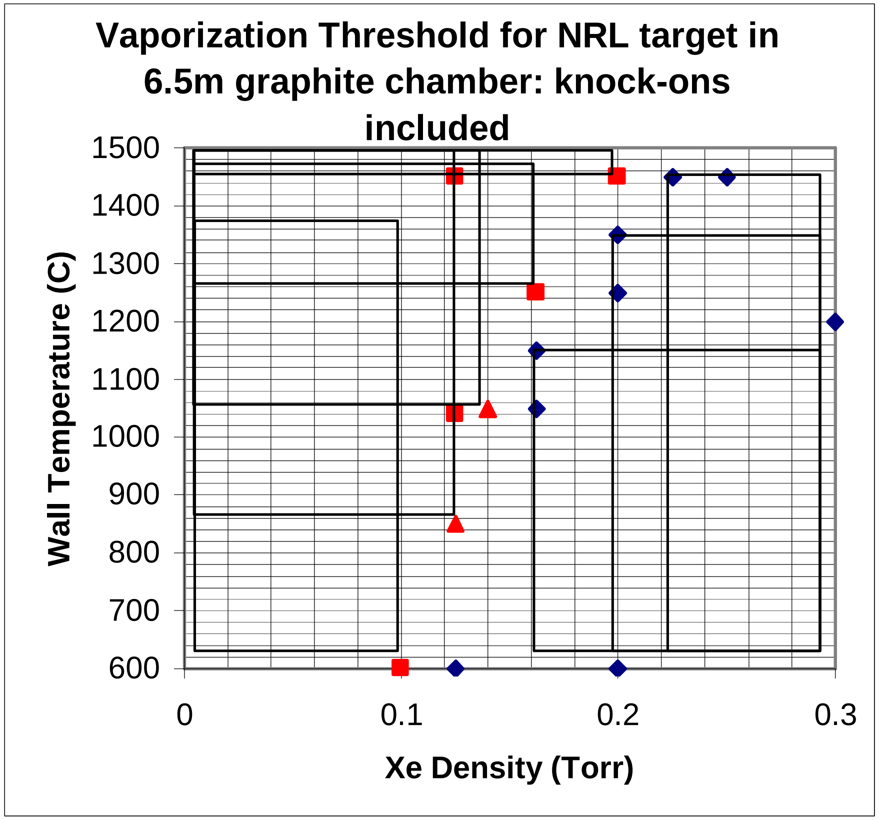
Parametric Results from Gas-Filled Chamber Analysis

D. A. Haynes, Jr.

and R. R. Peterson

University of Wisconsin

Fusion Technology Institute



Summary and Outline

A series of BUCKY simulations have been performed to study target chamber dynamics for dry wall IFE designs using the NRL 160MJ direct drive laser target. For example, a two-fold decrease in Xe pressure from the 500 millitorr required to protect the chamber from the 400MJ SOMBRERO target output is possible with no reduction in operating temperature.

- Wall Temperature & Xe Density Wall Survival Criteria
- Effect of Knock-ons (energetic ions from Perkins' calculation)
- Chamber Radius Scan
- Replacement of Xe with Kr
- Alternative Wall Materials: BeO, alternative graphites
- Wall Temperatures and Heat Flux as a function of position and time

Chamber Dynamics Status Update

Target Output

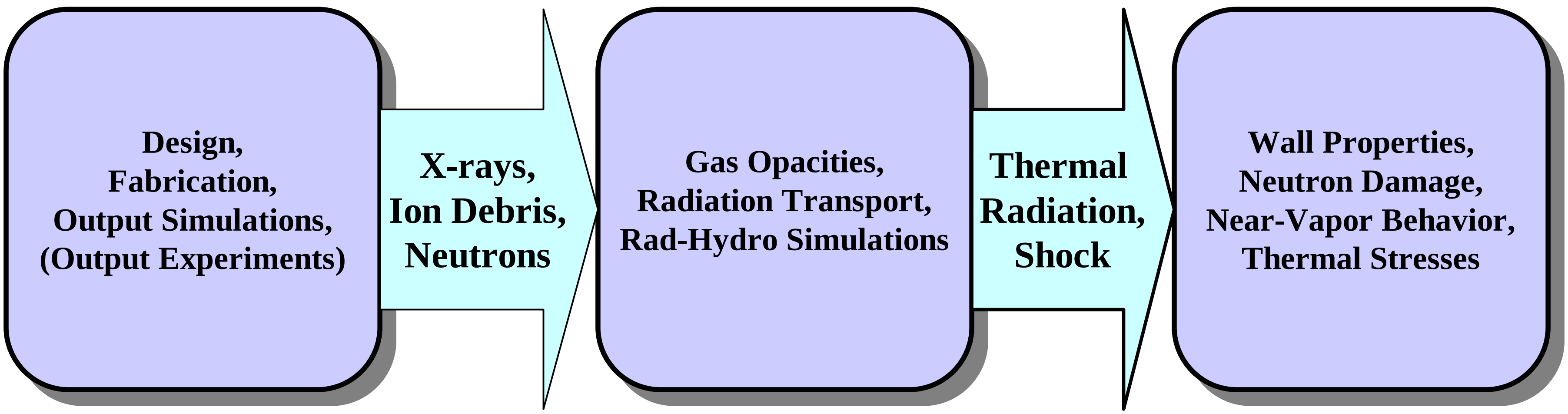
NRL DD laser target

Gas Behavior

Xe, and Kr

Wall Response

Graphite, T dependence BeO, Alternative Graphites



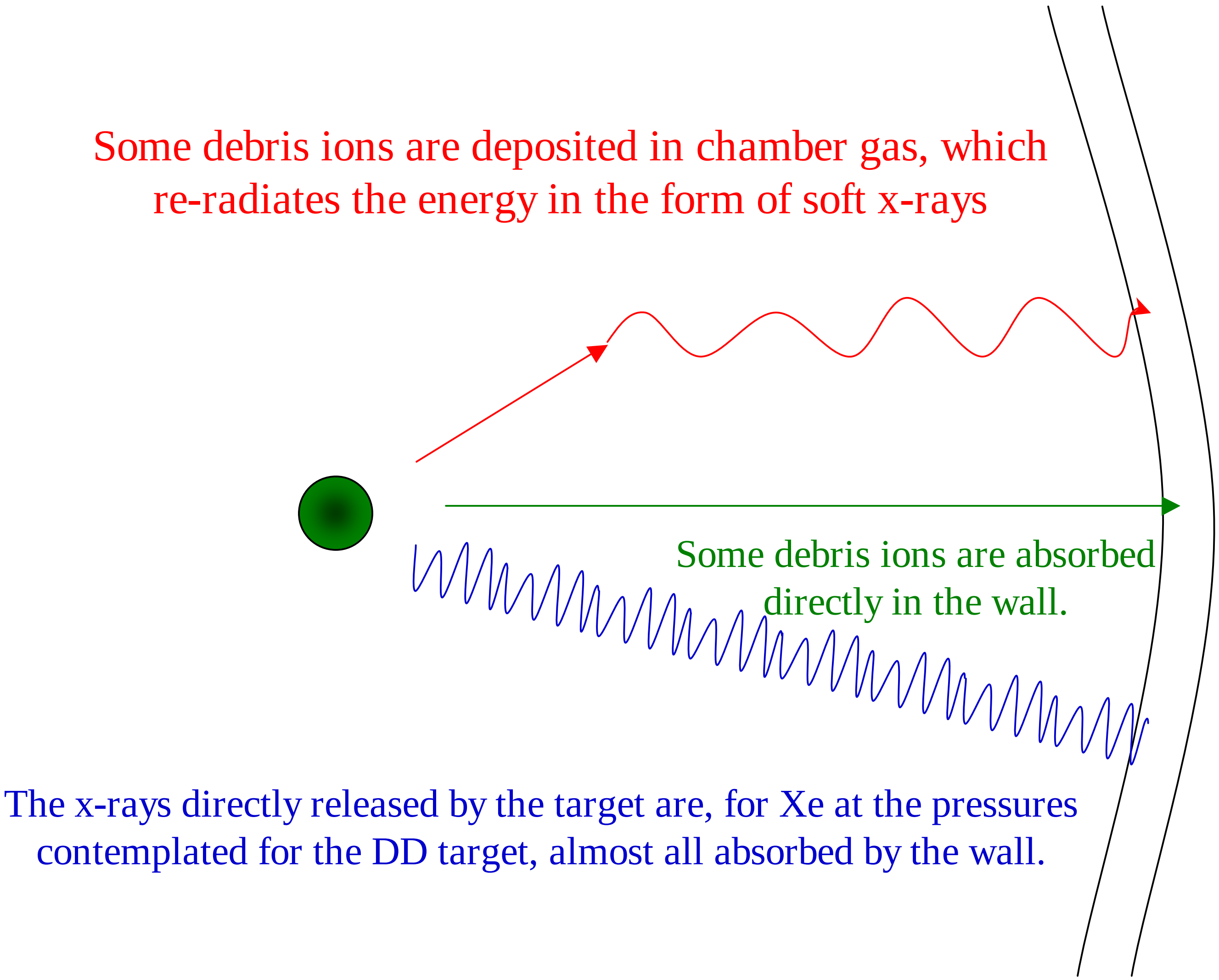
X-rays, Ions

(hydro and knock-on)

Chamber Radius

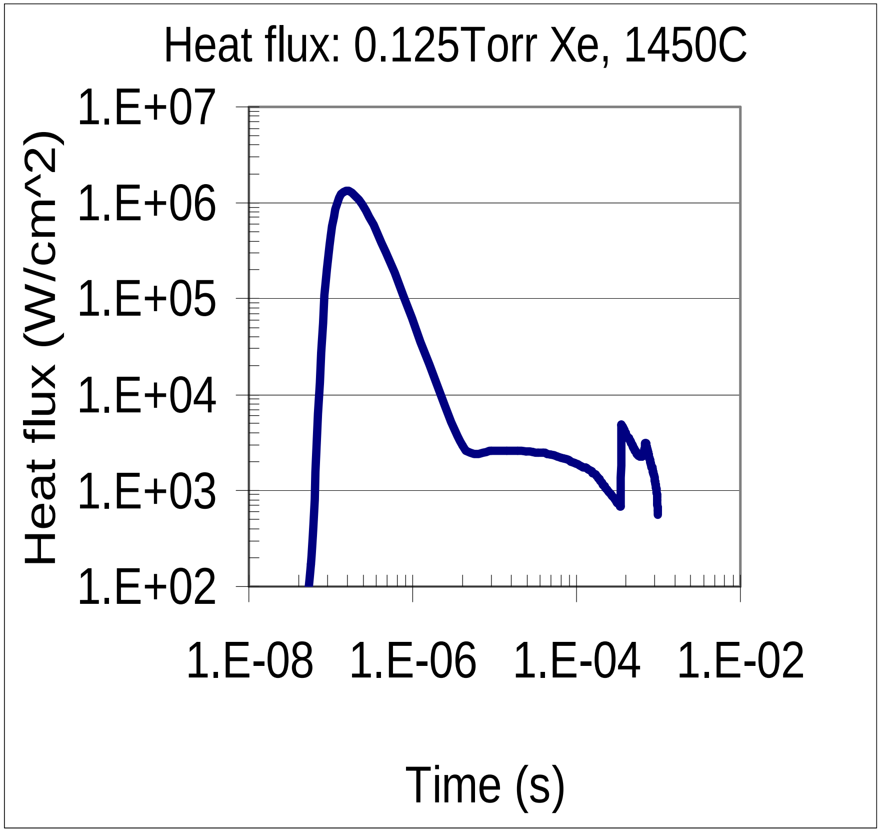
UW uses the BUCKY 1-D Radiation-Hydrodynamics Code to Simulate Target, Gas Behavior and Wall Response.

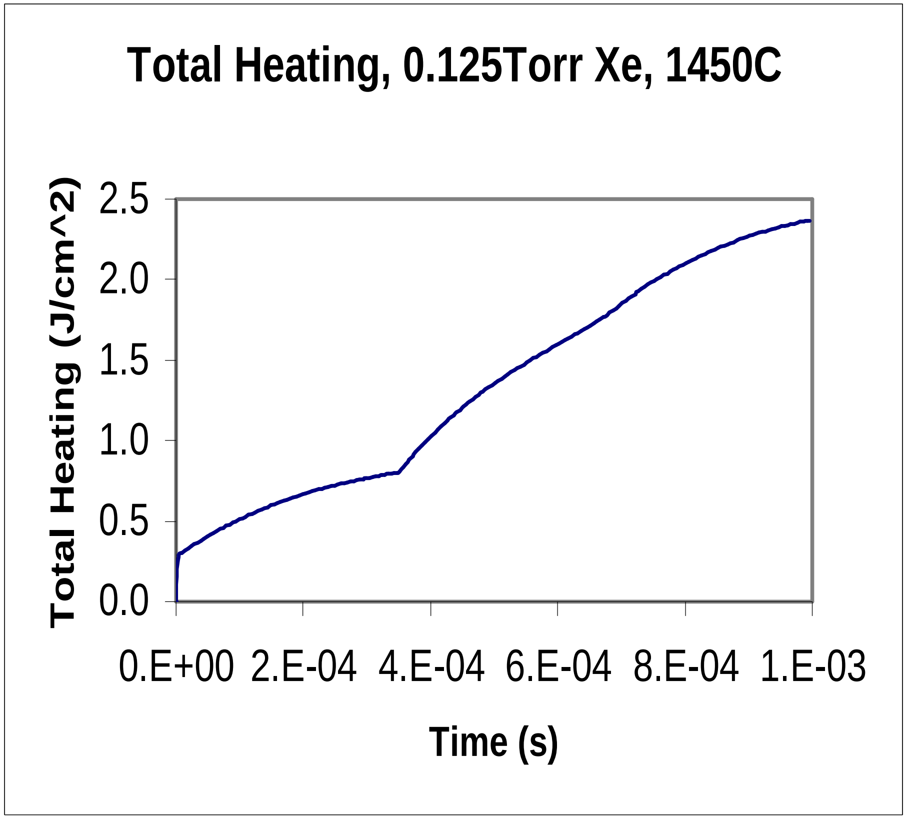
The threat spectrum can be thought of as arising from three contributions: fast x-rays, unstopped ions, and re-radiated x-rays



The wall (or armor) reacts to these insults in a manner largely determined by it's thermal conductivity and opacity.

The threat spectrum heats the first wall





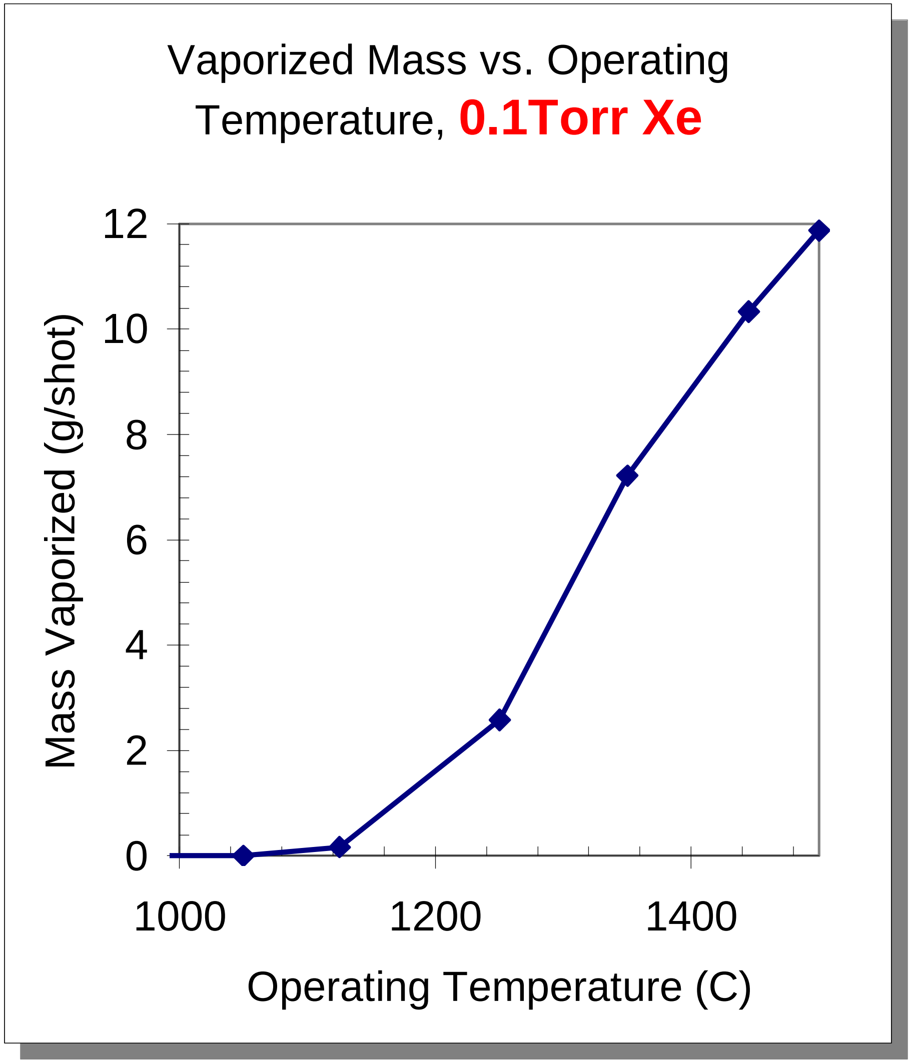
The effect of lowered wall temperatures on first wall survival has been investigated for 50 and 100 mT Xe densities.

•For a Xe density of 50 milliTorr, lowering the wall operating temperature to 600C from 1445C had little effect on first wall evaporation, reducing the per shot vaporized mass from 307g to 298 g.

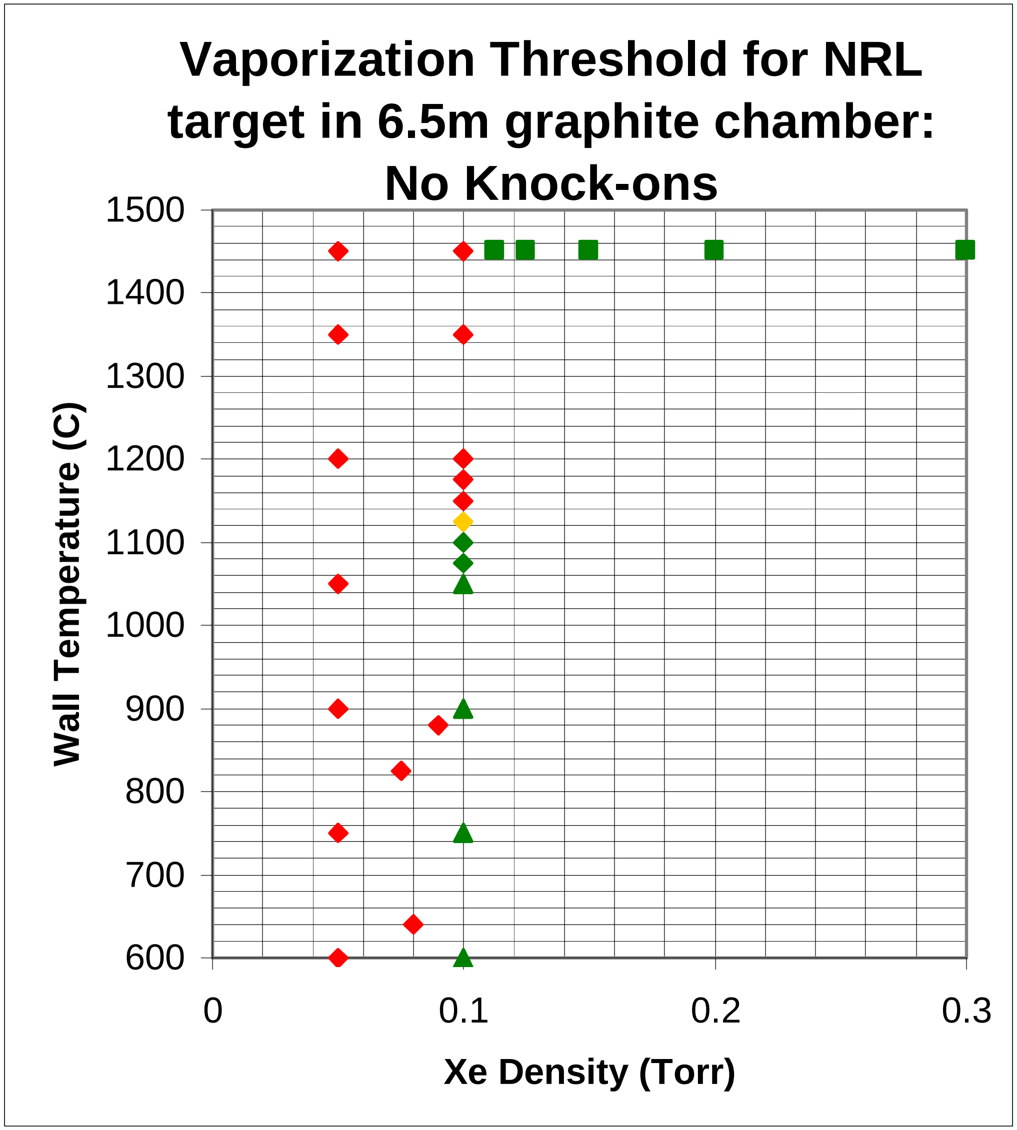
•600C to 1455C ~ 1710 J/g

•1455C to Vaporization~2835J/g

•Sublimation : 59370 J/g

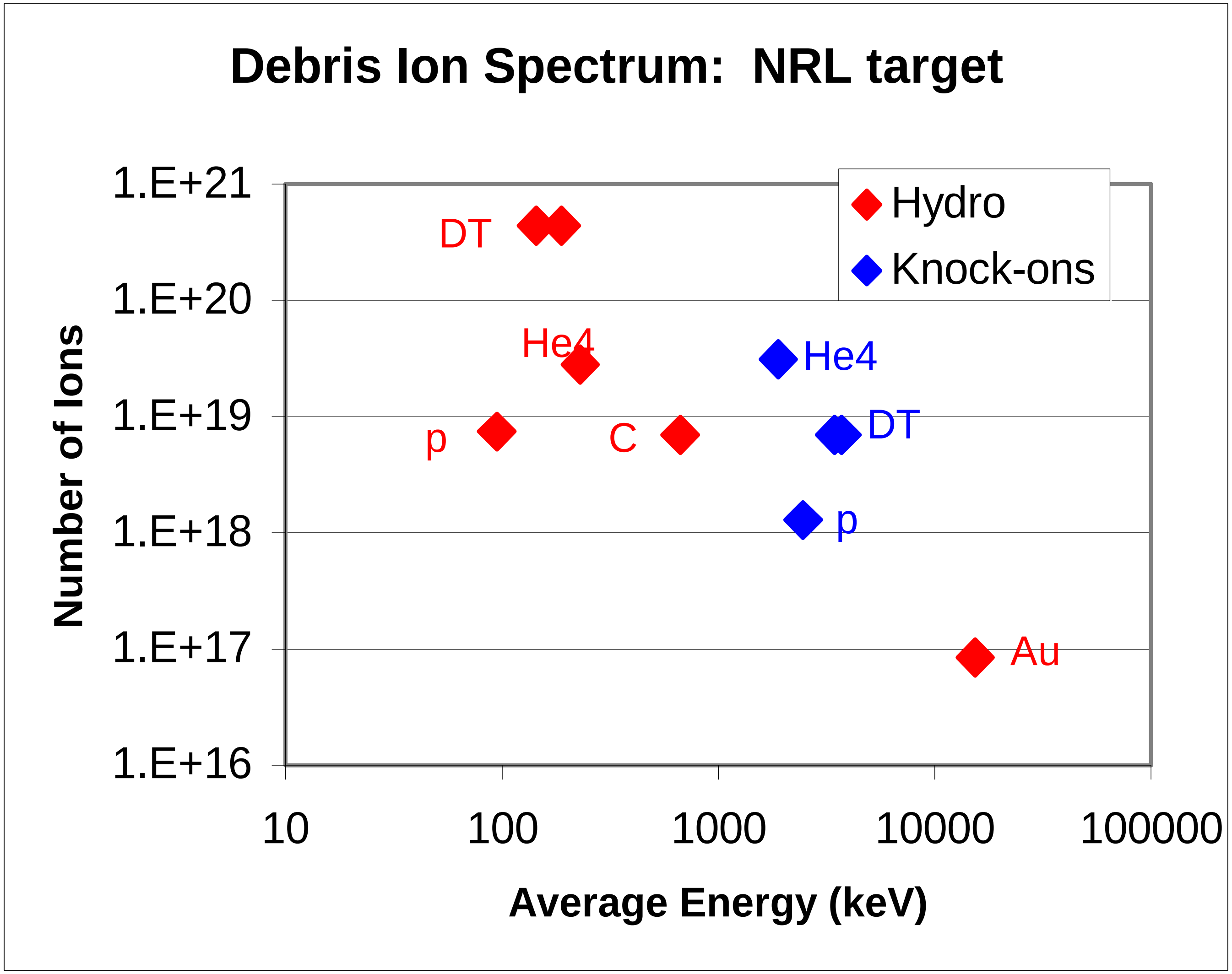


Wall temperature is considerably less important than Xe pressure in determining first wall survival.

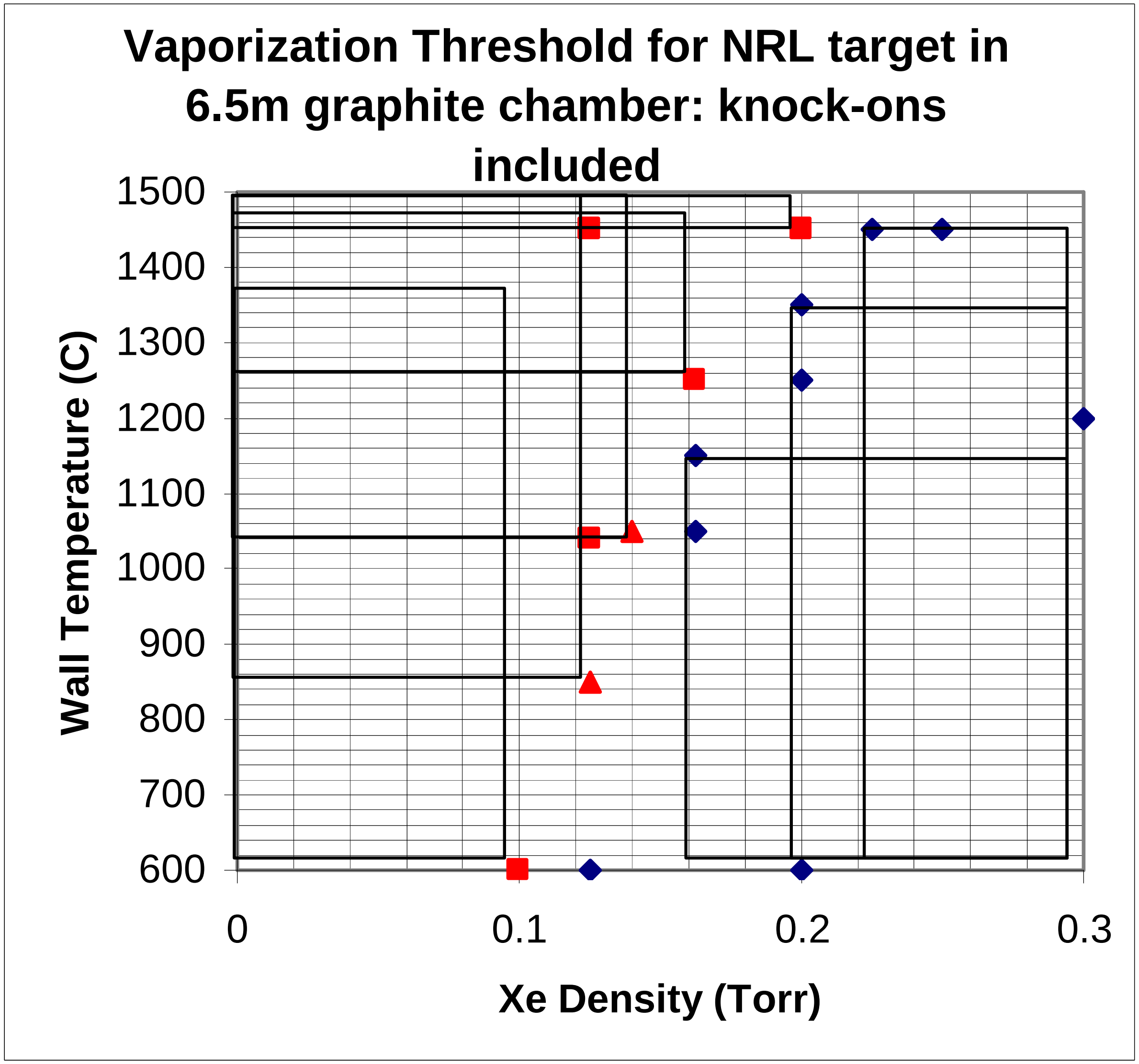


N.B.- No Knock-ons were included in this series of calculations. The effect of knock-ons is considered next.

“Knock-ons” contribute 18MJ to the total of 43MJ of ion debris. (Knock-on spectrum from Perkins)

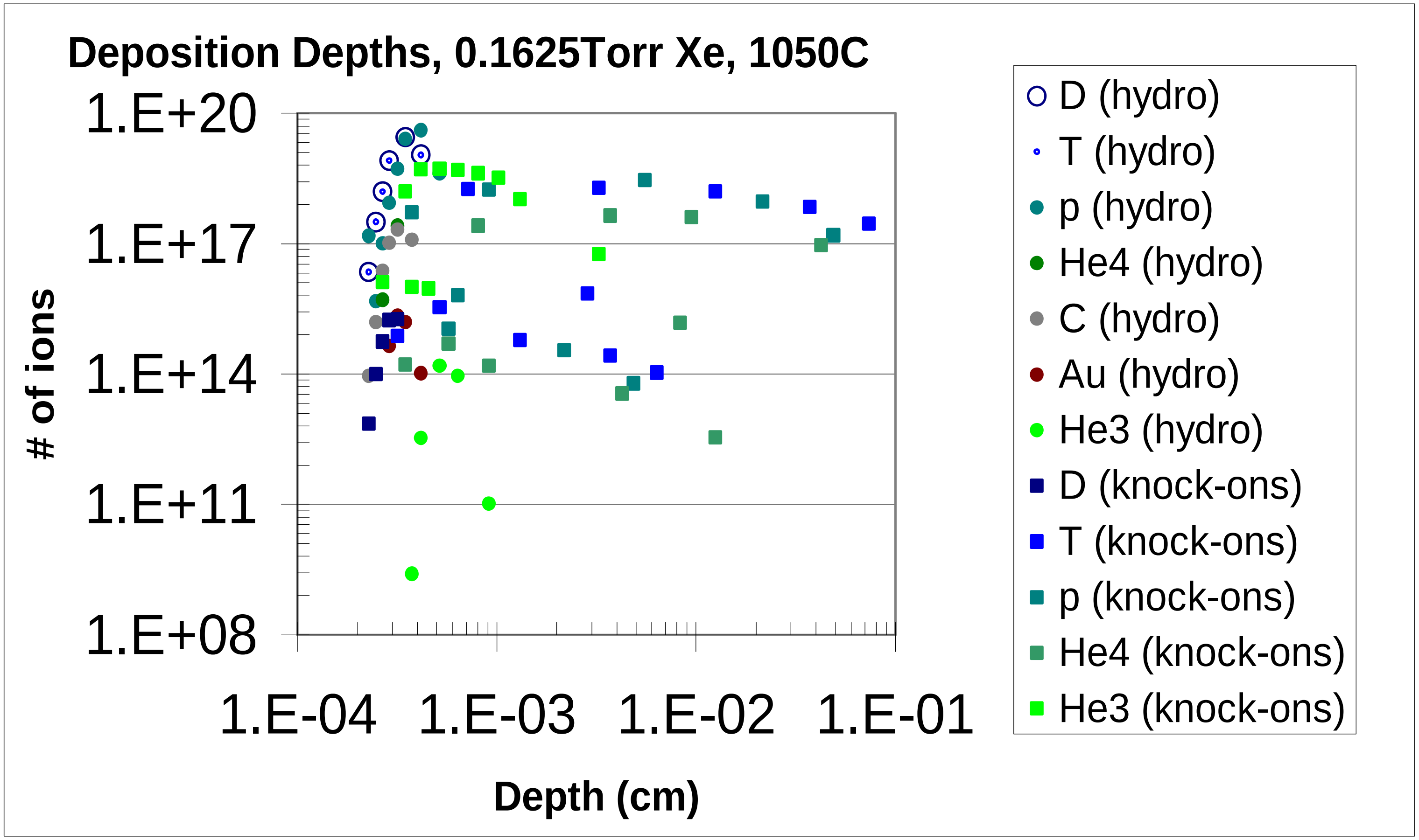


The inclusion of knock-on ions leads to an increase in the amount of Xe required to protect the first wall, and a somewhat stronger wall temperature dependence.



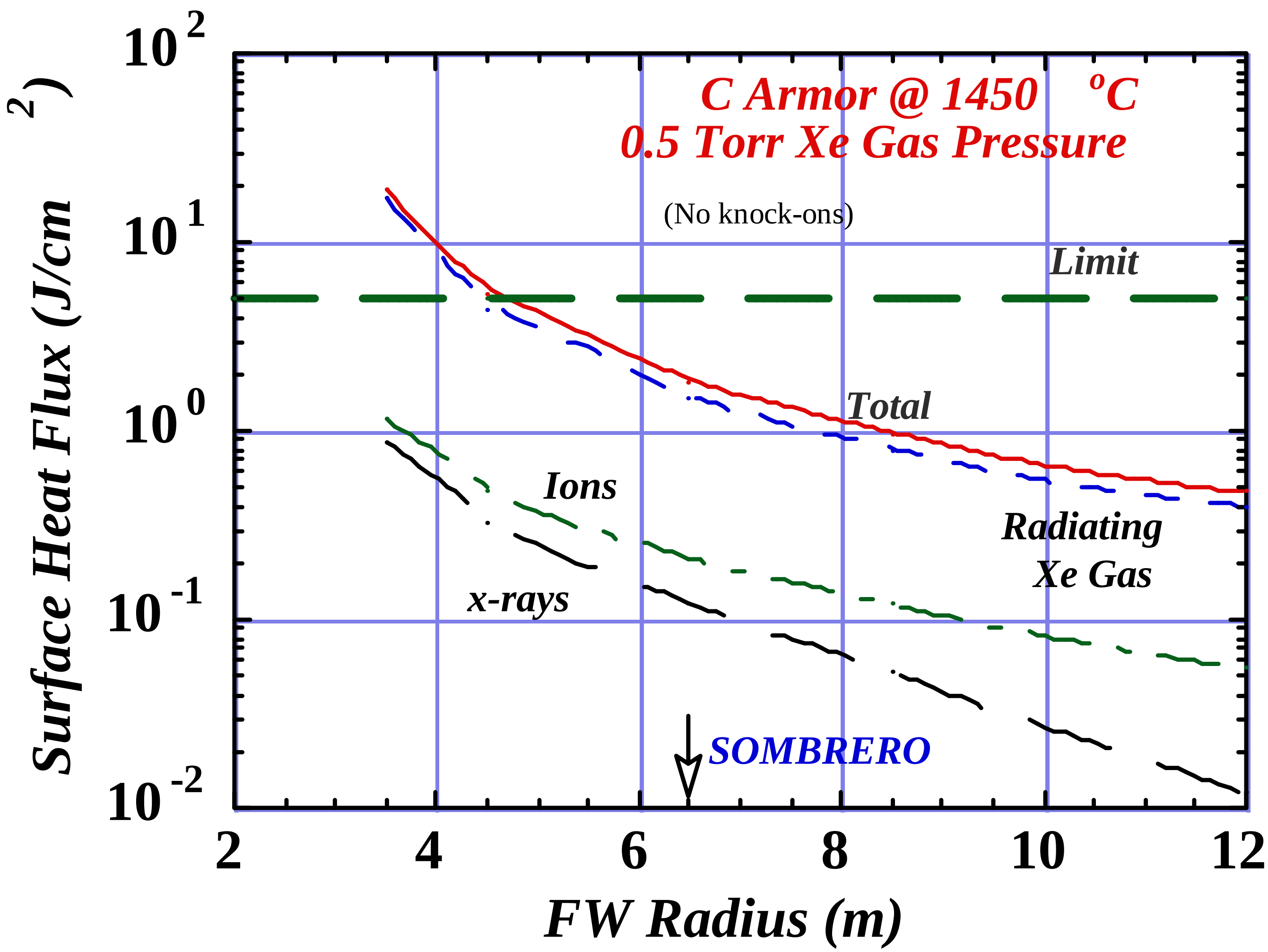
N.B.- ion deposition model needs finer time resolution before conclusive results can be given. Will report on final results at next project meeting.

Perkins spectrum leads to shot by shot modification of the armor composition



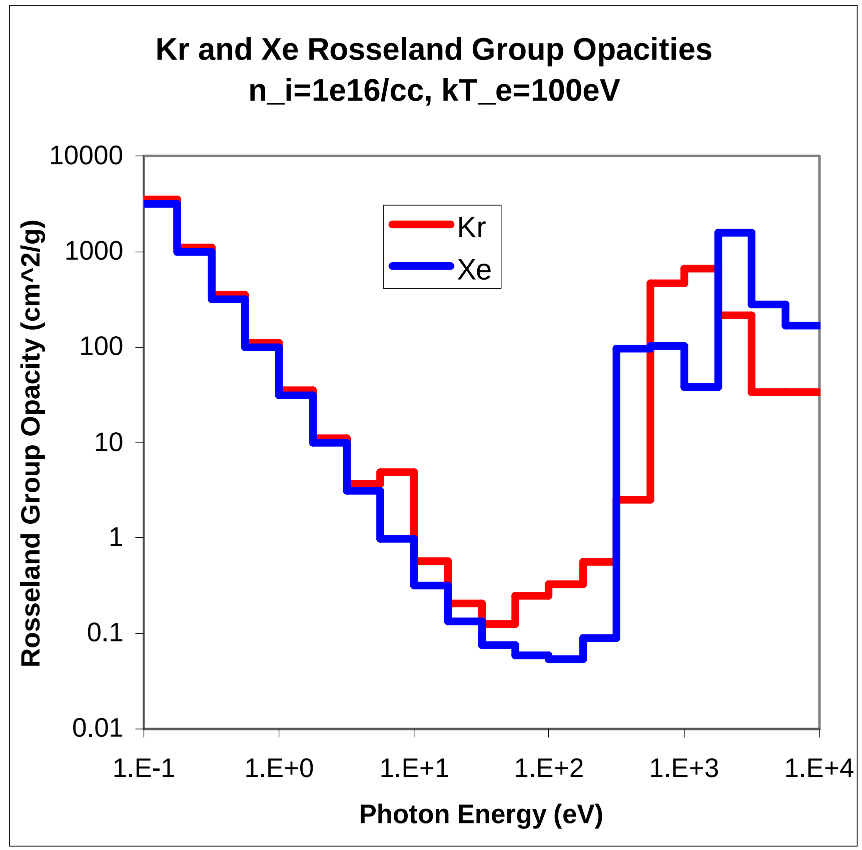
• The cumulative effect of this modification of the armor is a potentially important outstanding issue.

Chamber radius scan @ 1450C and 0.5Torr Xe: Surface Heat Flux Limits Minimum FW Radius with C Armor to 4 m (w/o knock-ons, 4.5m with knock-ons)



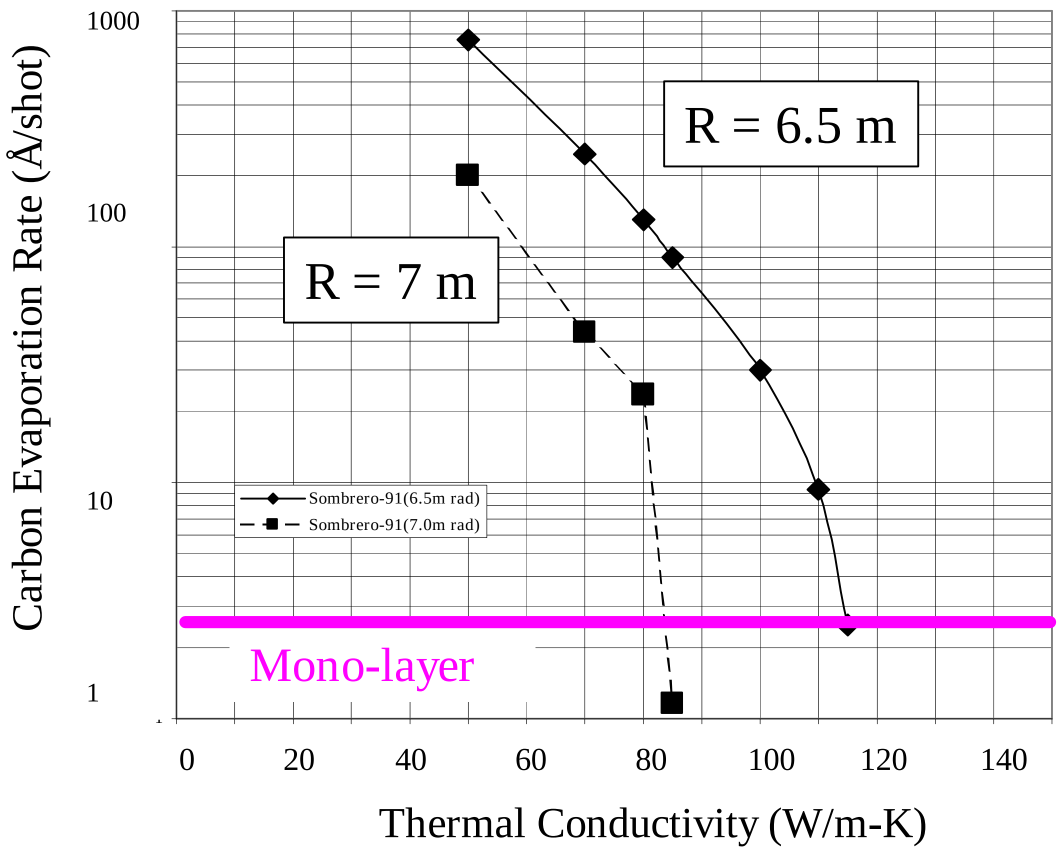
In the event that Xe activation should prove problematic, we have studied the possibility of using Kr

- The Kr equation of state and opacity have been calculated using IONMIX.
- A series of BUCKY simulations in which Xe was replaced by Kr was performed to discern the effect of the differing opacities, stopping powers, and equations of state.
- At an operating temperature of 1125C, 12.5% more Kr is needed to protect the first wall.

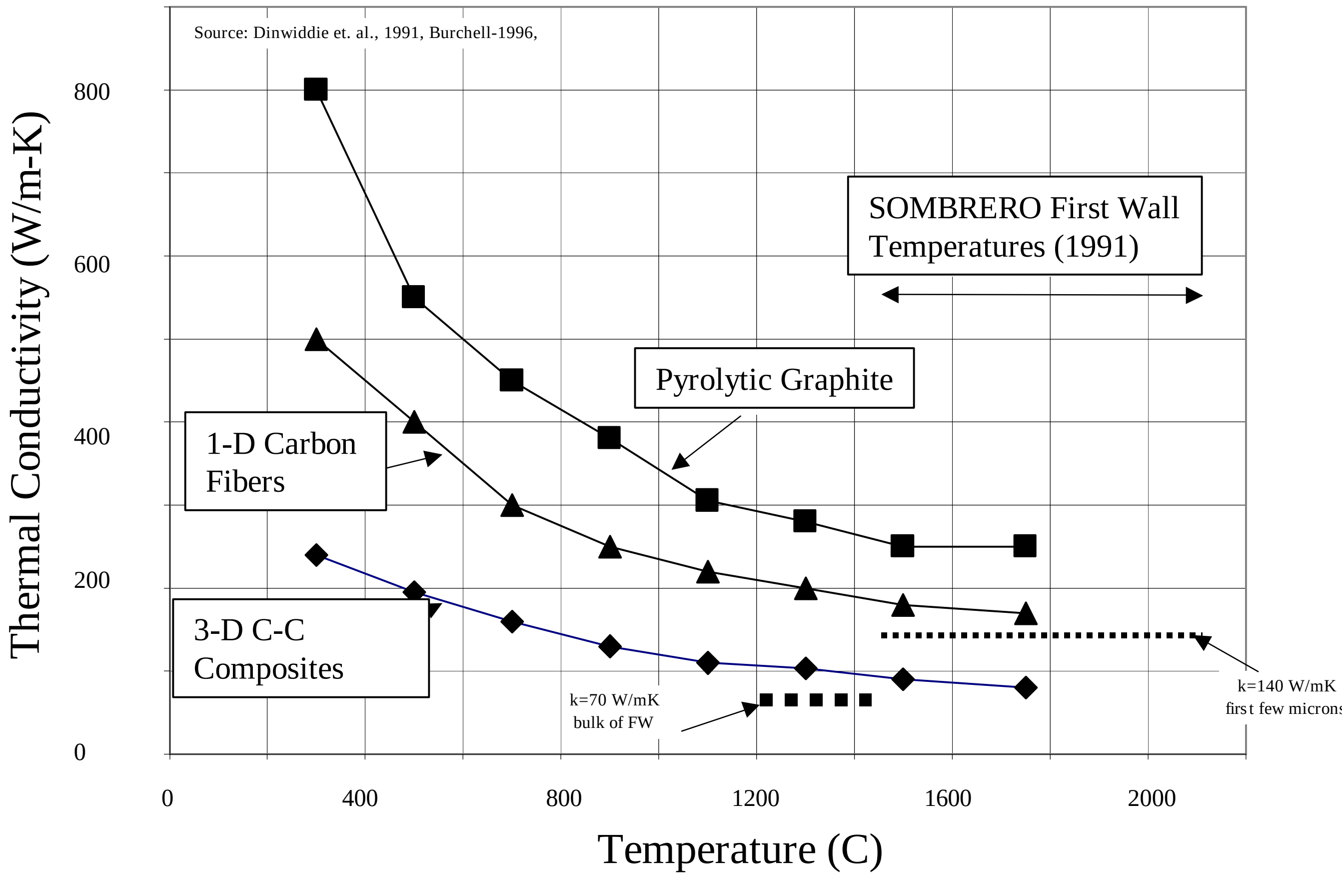


The SOMBRERO study demonstrated the importance of thermal conductivity on first wall survival

BUCKY Simulation: SOMBRERO target output, 1.8×10^{16} cm^{-3} Xe, 650 cm radius graphite wall

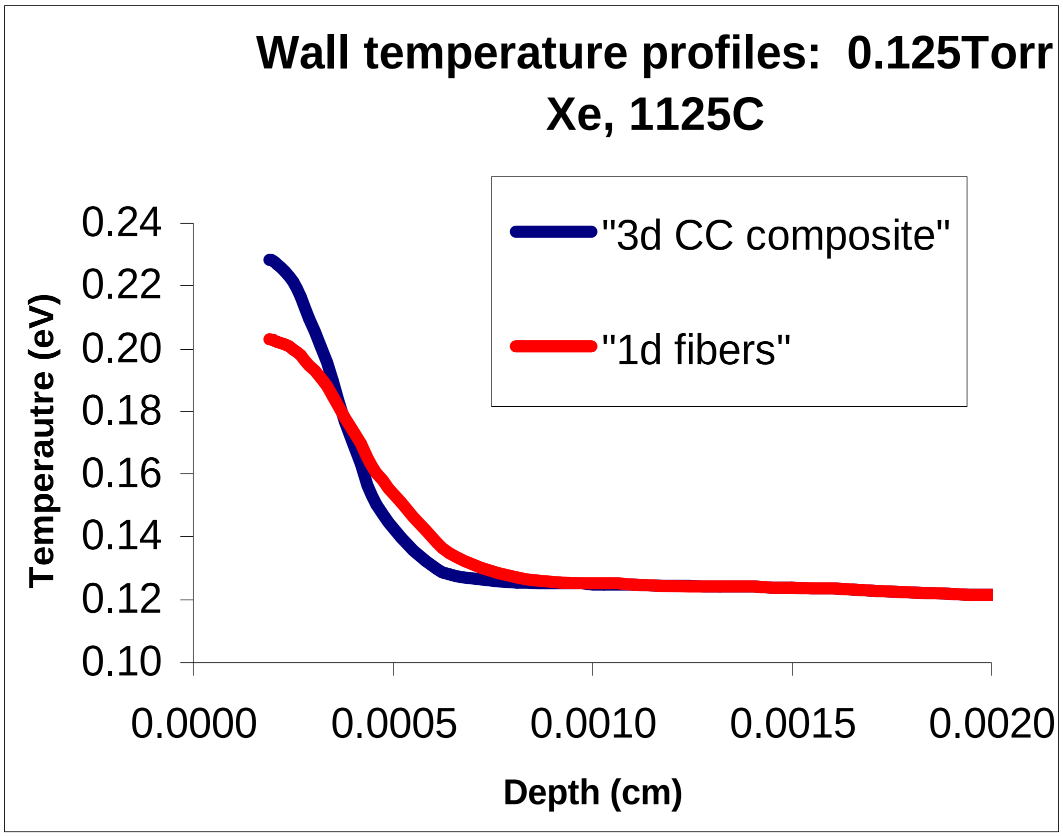


Differing forms of graphite have widely varying thermal conductivities



Keeping all else fixed and doubling the thermal conductivity (from 3d composites to 1d fibers) allows less Xe gas.

•For the case of no knock-ons, 0.125Torr Xe and an operating temperature of 1125C, the increased conductivity leads to avoidance of wall vaporization, where the composite conductivity led to threshold amounts of vaporization



As a low-Z material with interesting thermal properties, a few runs with a BeO armor have been conducted. For example, a chamber with 0.225Torr Xe operating at 1450C achieves a surviving first law As for the SOMBRERO material, BeO vaporizes at 0.2Torr Xe and 1450C.

	SOMBRERO Graphite	BeO
Mass Density (g)	2.26	3.01
T_{vap} (eV)	0.338	0.349
Heat Capacity (J/g-eV)	23200	26700
Thermal Conductivity (W/g-eV)	13344	1845[1]
Latent Heat of Vaporization (J/g)	59730	56700[2]

1. Beaton and Hewitt, "Physical Property Data for the Design Engineer", p.362 (Hemisphere, 1989).
2. "Designing with Beryllium", a publication of "BRUSH WELLMAN, Inc., Cleveland, OH.

N.B. Lower thermal conductivity leads to qualitatively different T(depth) profiles, the consequences of which are still being investigated

Summary and Conclusions

•Several excursions from the SOMBRERO baseline chamber have been investigated in light of the new threat spectrum:

- •Xe pressure and Armor temperature parameter space has been segregated into those values which cause the first wall to evaporate and those which do not.
- •The detailed debris ion spectra from Perkins has been incorporated into the simulations. Most of the gold ends up being deposited in the wall.
- •Kr can be used instead of Xe, though approximately 10% higher density is required for first wall protection at an operating temperature of 1125C.
- •BeO has been investigated as an example of an alternative armor material, and the effects of armor thermal conductivity have been investigated.

A series of BUCKY simulations have been performed to study target chamber dynamics for dry wall IFE designs using the NRL 160MJ direct drive laser target. For example, a two-fold decrease in Xe pressure from the 500 millitorr required to protect the chamber from the 400MJ SOMBRERO target output is possible with no reduction in operating temperature.

Future work on chamber dynamics

- Follow-up for NRL target in SOMBRERO-like chambers?
- Alternative Wall Materials: Operating parameter scans:
  - W + SiC
  - Boron Carbide
  - BeO
- Confirm results for knock-on ions with finer time resolution for deposition.
- HI target: Threat spectrum still needed.
- Other NRL DD target concept?
- Begin work on wetted wall

HIF Target Chamber Issues

Fusion Technology Institute University of Wisconsin - Madison

- **Target Output Spectra:** **HIF target output energy partition has a much higher fraction in x-rays, which requires more gas to stop. Capsule ions are all stopped by hohlraum.**

- **Chamber Clearing:** **in the 5-Torr regime, the fractional build-up of gaseous impurities is slower.**

- **Debris from Hohlraum:** **hohlraum mass is high enough that significant build-up on chamber wall is possible.**

- **Target Survival During Injection:** **might not be a big issue because hohlraum protects target.**

- **Gas Turbulence:** **turbulent density variations are likely to be not important to channel formation as long as the gas does not have a turbulent speed greater than 1 km/s. The relatively large mass of the target might make deflection of the target by turbulence less likely.**

- **Gas Temperature:** **channel formation will not be hurt as long as gas temperature is low enough to avoid ionizing the gas. Heating of the target is likely not an issue.**

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

Fusion Technology Institute University of Wisconsin - Madison

- 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