First Wall Response to Several ~400MJ Targets' Threat Spectra

<u>New meeting, same conclusion:</u>

The remarkable differences between the ~400MJ NRL and SOMBRERO targets lead to marked difference in first wall survival. The target output calculations for the ~400MJ NRL target indicate a large fraction of non-neutronic yield in high energy, highly penetrating ions and x-rays, resulting in less threat to the first wall, requiring less buffer gas than SOMBRERO.

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for the staff of the
Fusion Technology Institute
University of Wisconsin

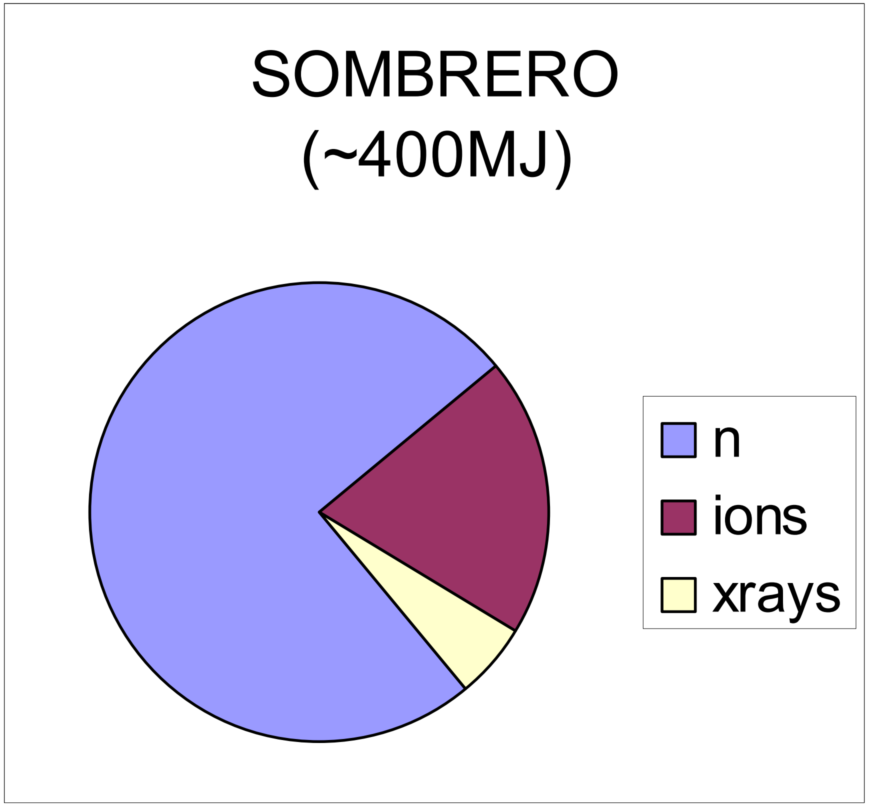
HAPL WORKSHOP
20011114

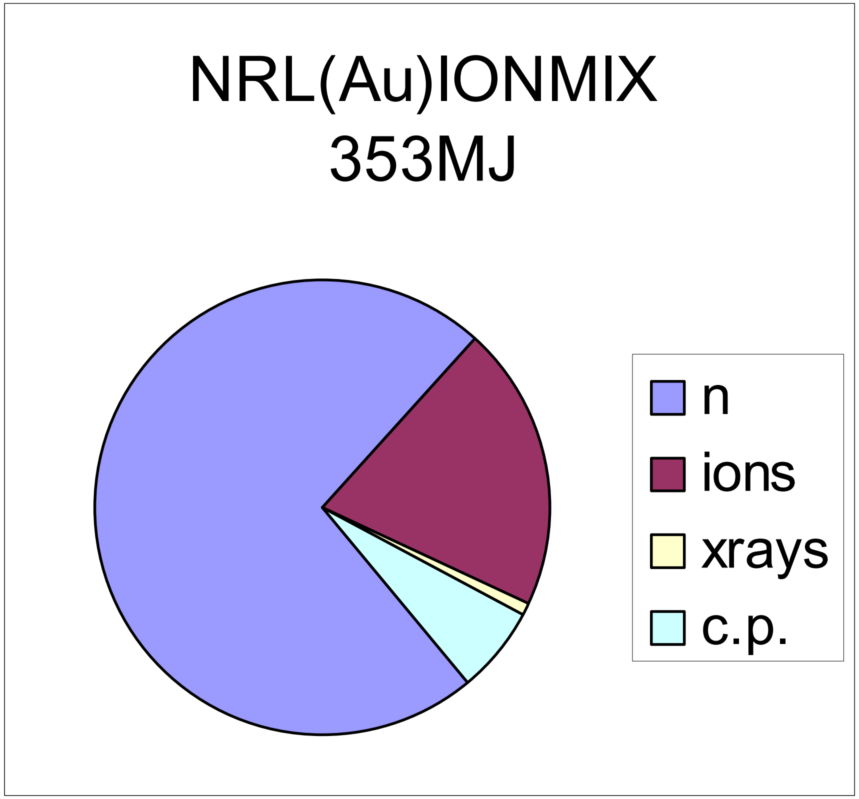
Summary/Outline

We have performed a series of BUCKY chamber response simulations to gauge the effect of the threat spectra from the high (~400MJ) yield NRL direct-drive laser target. Both graphite and tungsten first walls survive (no per shot vaporization) at 6.5m with little chamber gas (< 25mTorr). This is in stark contrast to SOMBRERO results. The difference stems from differences in threat partitioning and especially x-ray spectra.

- Comparison of SOMBRERO and NRL chamber response
- Effect of replacing Au with Pd in target
- Effect of Opacity models used in target output calculation on first wall response
- Variations on a theme: armor material, wall radius
- Indirect-drive target considerations

The recently calculated target output from the radiatively-smoothed direct-drive laser targets differs markedly from the legislated SOMBRERO output.

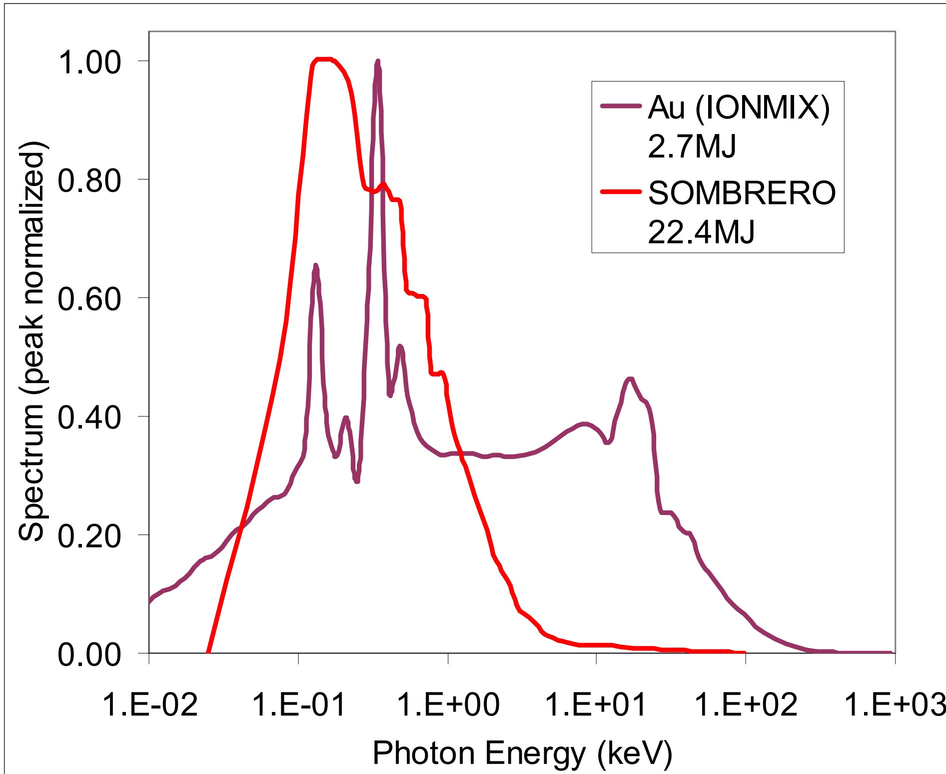


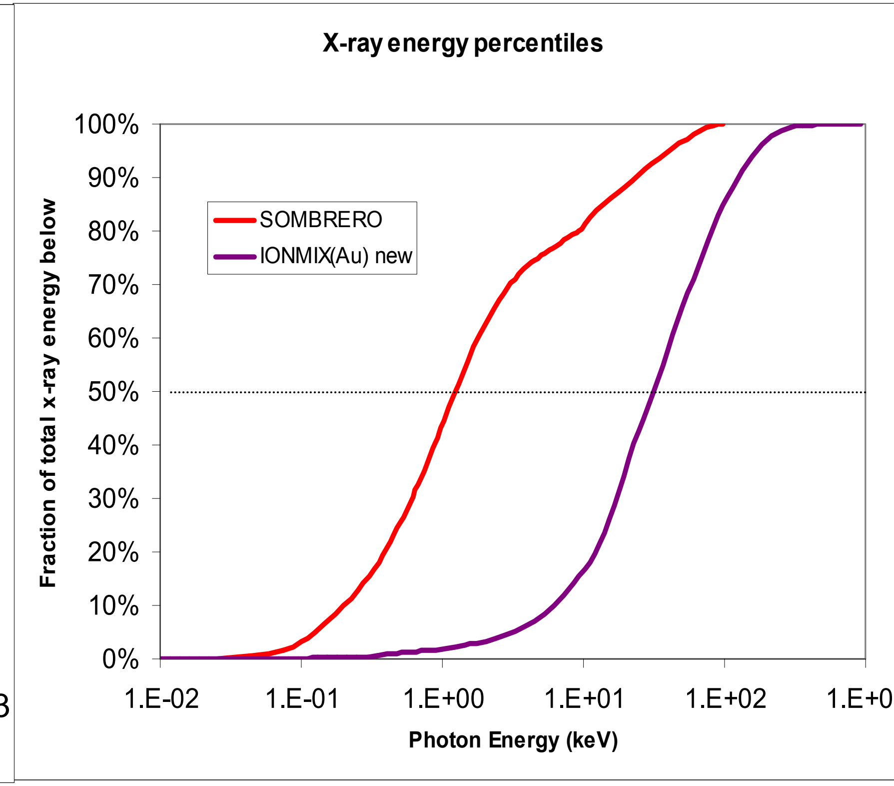


5.3% of total yield in x-rays

0.8% of total yield in x-rays

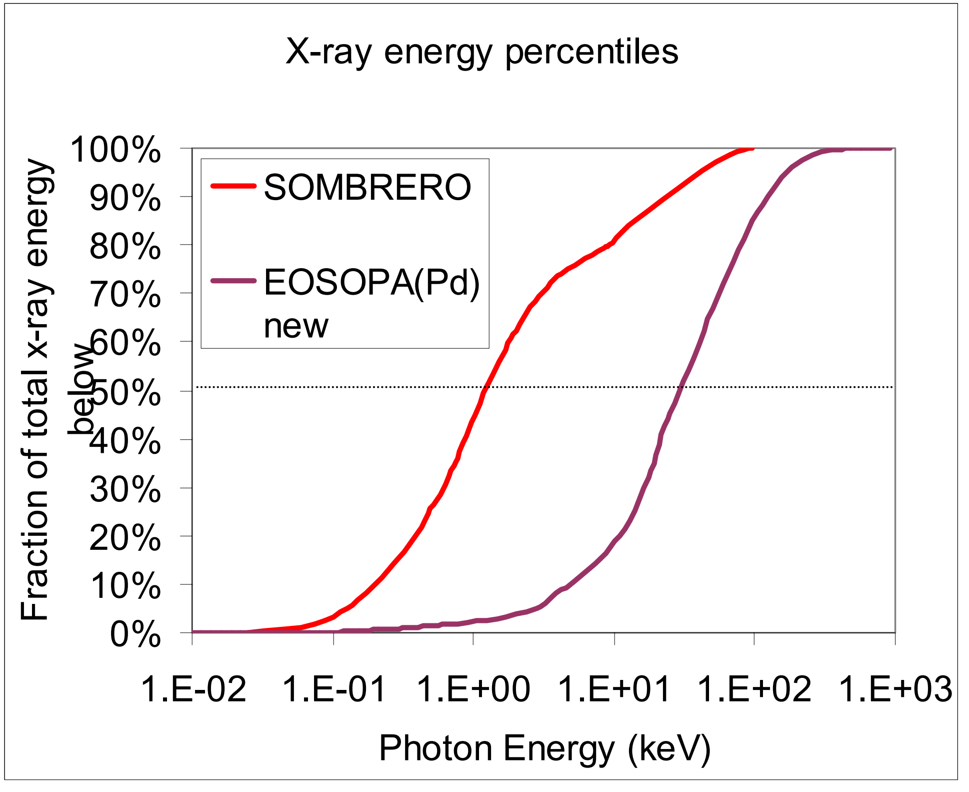
The difference in total x-ray yield is not as striking as the difference in spectra.

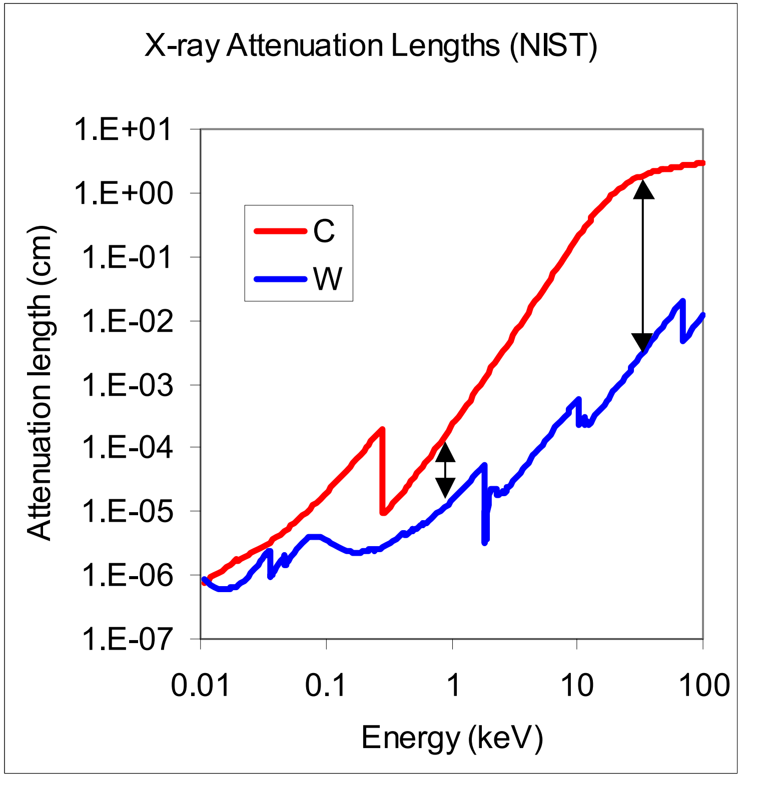




- Half of SOMBRERO’s 22.4MJ x-ray energy was emitted below a keV.
- Half of NRL(Au)’s 2.7MJ x-ray energy was emitted above 31keV.

SOMBRERO x-rays heated a thin layer of the first wall, while the NRL target's x-ray heat the first wall almost volumetrically.

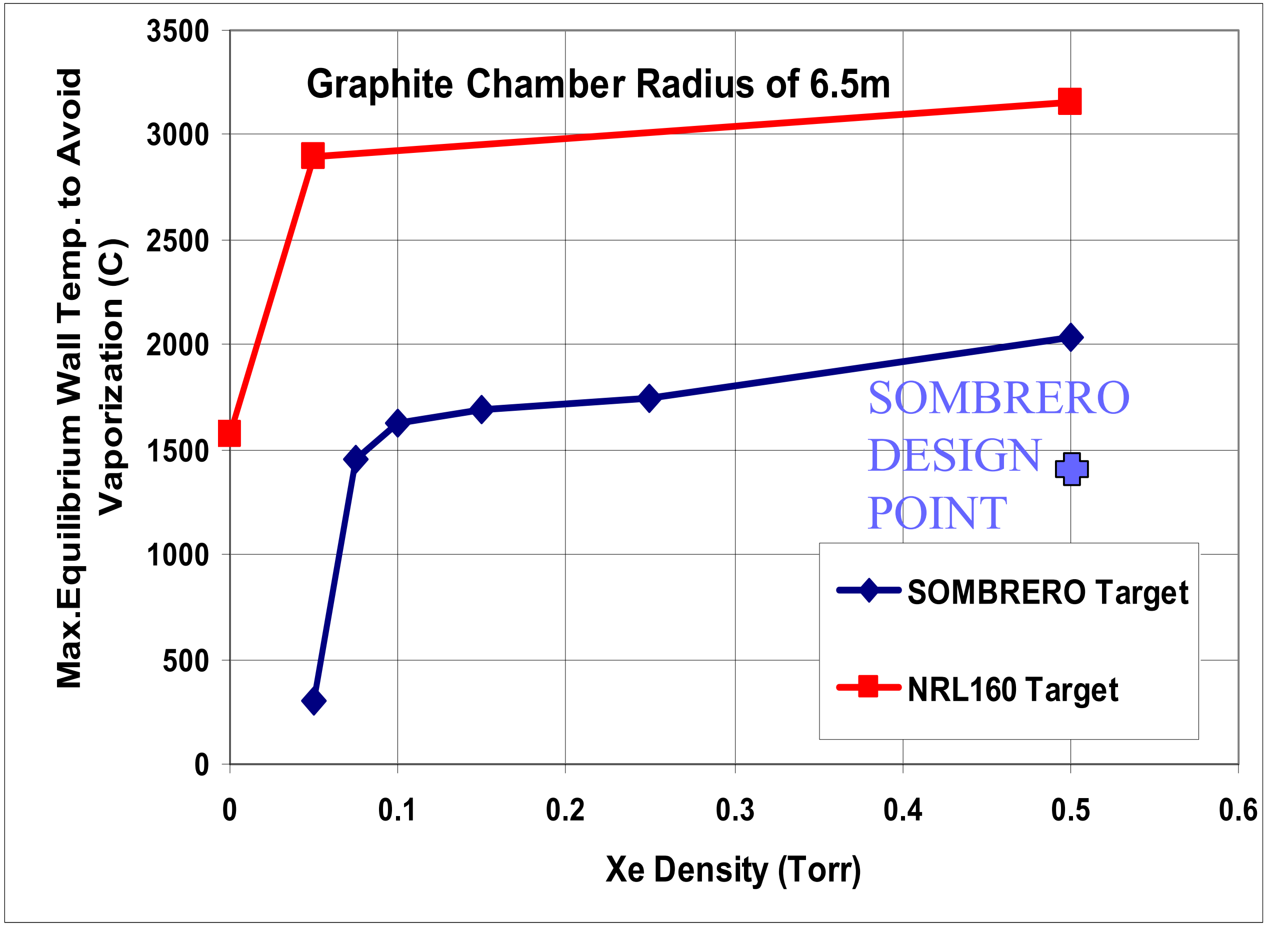




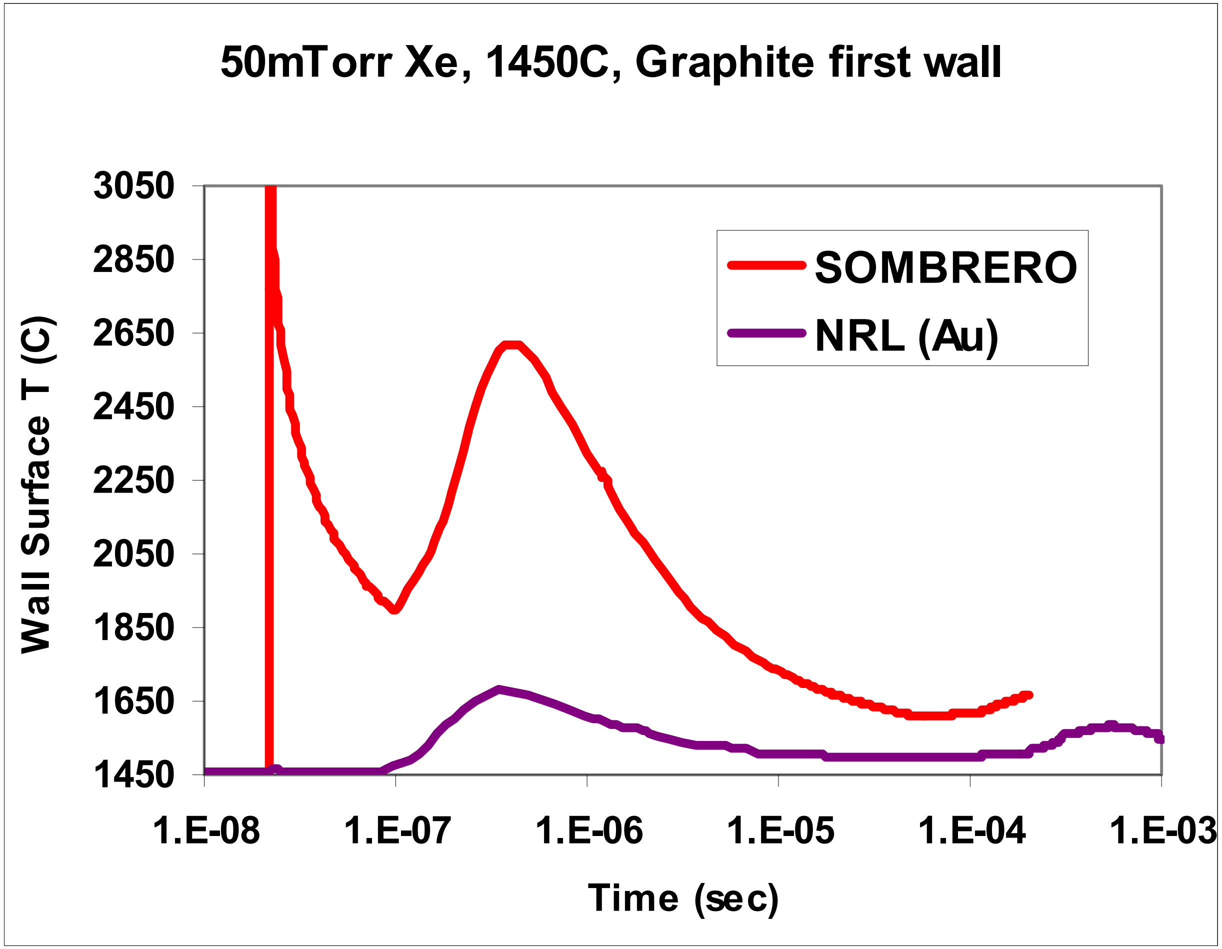
In graphite, the SOMBRERO characteristic attenuation length for x-rays was approximately 1 micron. For the NRL target it is 1cm.

An old slide waved for context. As part of ARIES-IFE we exercised BUCKY to study the Xe density required to prevent first wall vaporization for a 6.5m C chamber.

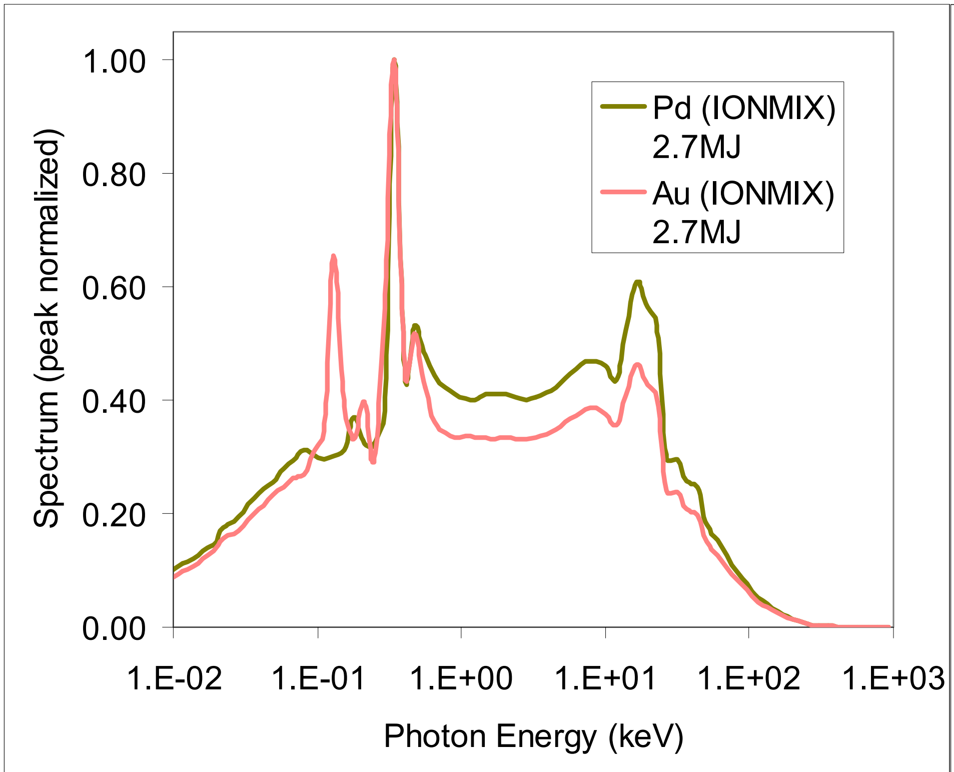
- The gas density and equilibrium wall temperature have been varied to find the highest wall temperature that avoids vaporization at a given gas density.
- Vaporization is defined as more than one mono-layer of mass loss from the surface per shot.
- The use of Xe gas to absorb and re-emit target energy increases the allowable wall temperature substantially.

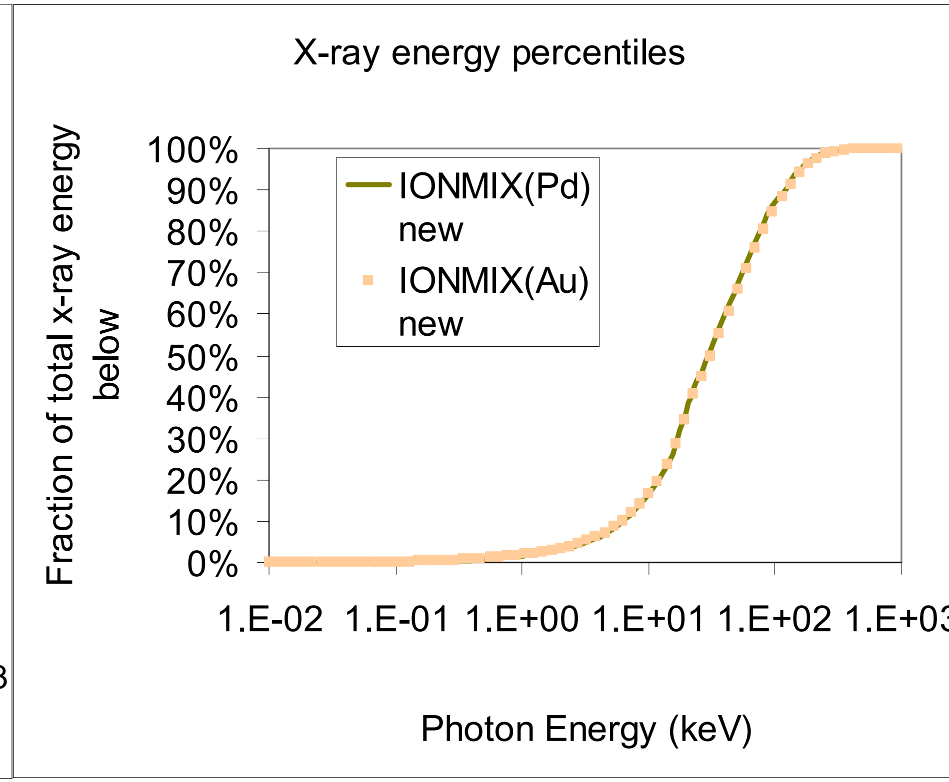


The SOMBRERO target caused over 6 grams of C to vaporize each shot at the case study point, whereas the NRL target does not vaporize the wall.



Variations in target output associated with changing the target's patina from Au to Pd does not substantially effect target output, it has no practical effect on per shot first wall vaporization.





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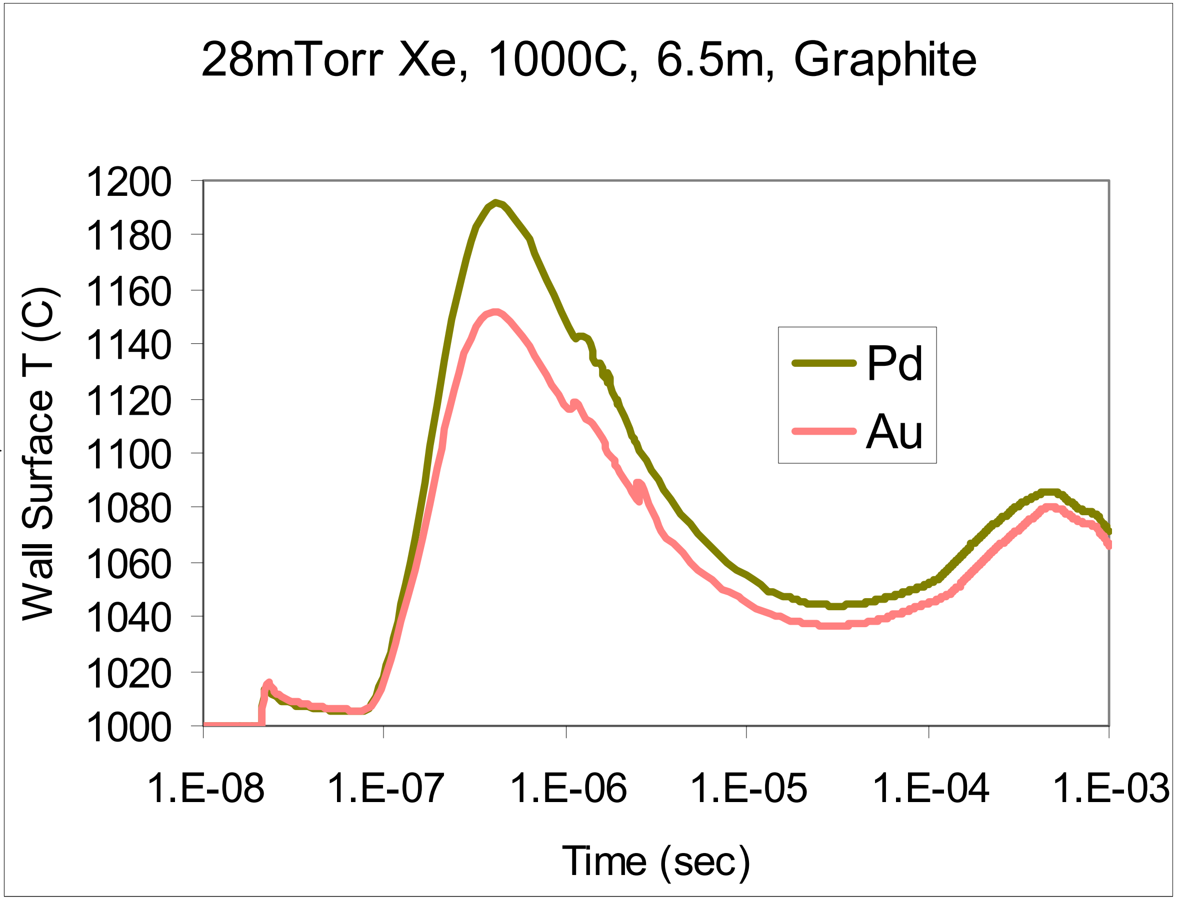
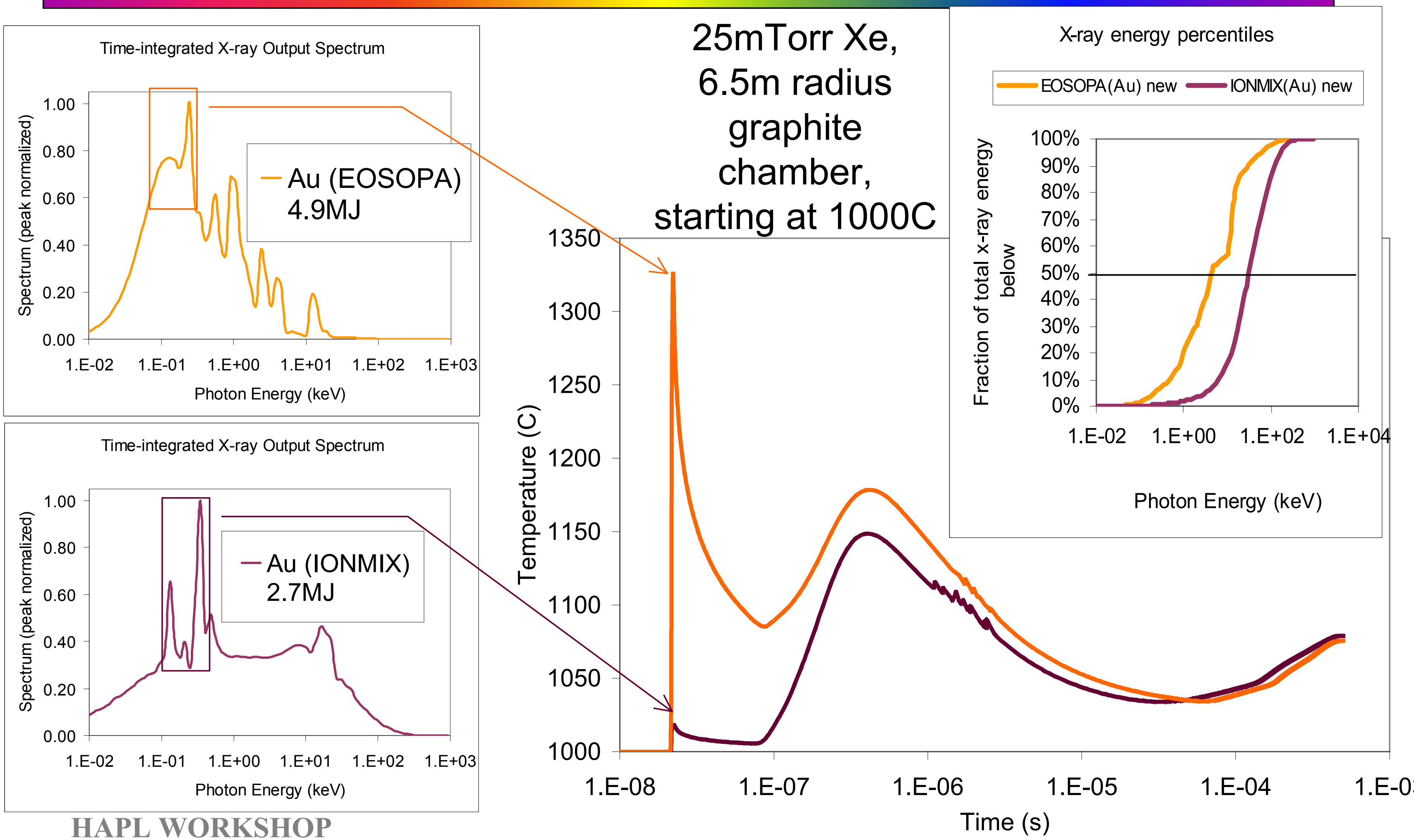
Note the scale.
The peak difference is ~ 40C

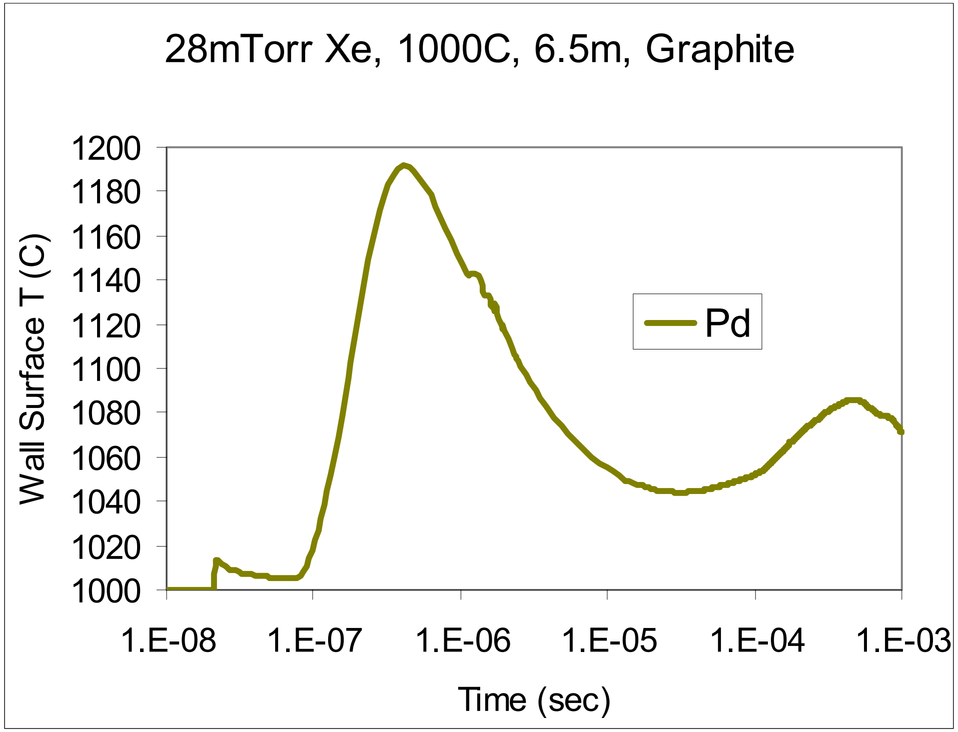


The difference stems from details of ion deposition in the wall, and on charge state of patina remnants, thus it is only as certain as are the calculations of the charge state.

Different EOS/Opacity models used in the calculation of the 0.03 micron Au later in the NRL radiatively pre-heated target lead to vastly different x-ray output, and thus to significantly different chamber response.

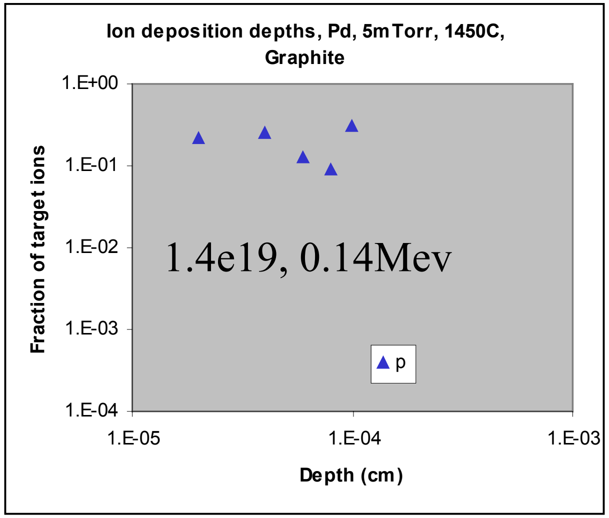


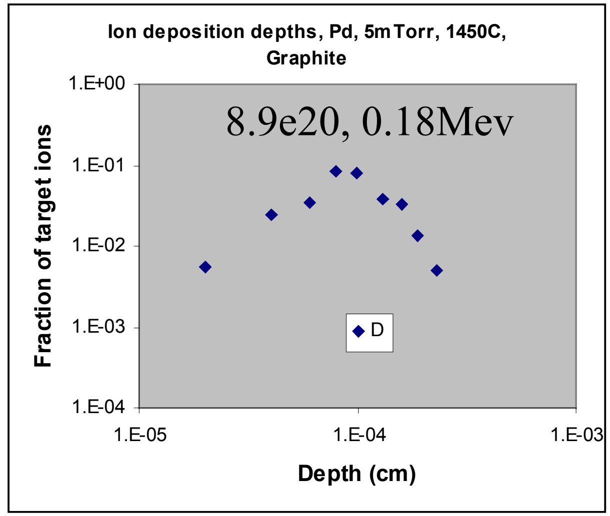
Less than 25 mTorr of Xe is required to prevent per shot vaporization, at temperatures of less than 1450C, for a graphite chamber of 6.5m radius: what is the practical limit of chamber gas density?

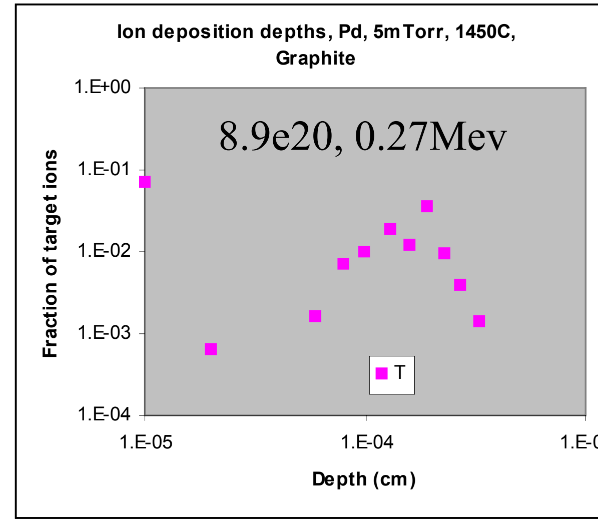


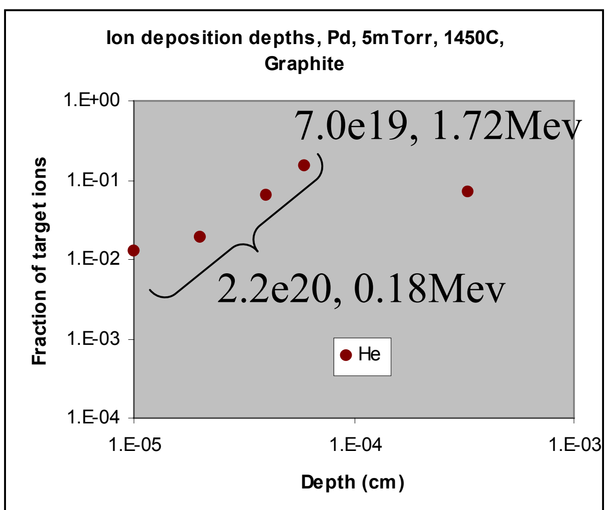
- This conclusion holds regardless of:
  - Au/Pd
  - IONMIX/EOSOPA
- Without significant gas protection in a dry wall chamber, the ions will embed in the wall.

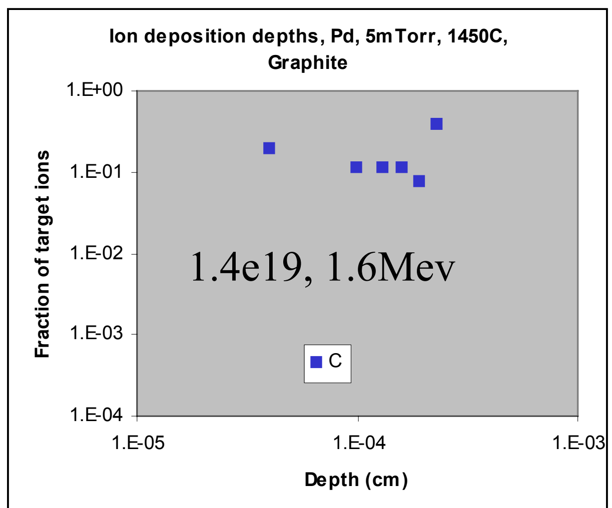
Thus, if amounts of Xe are determined through per-shot vaporization, we will have to deal with the ions depositing in the wall

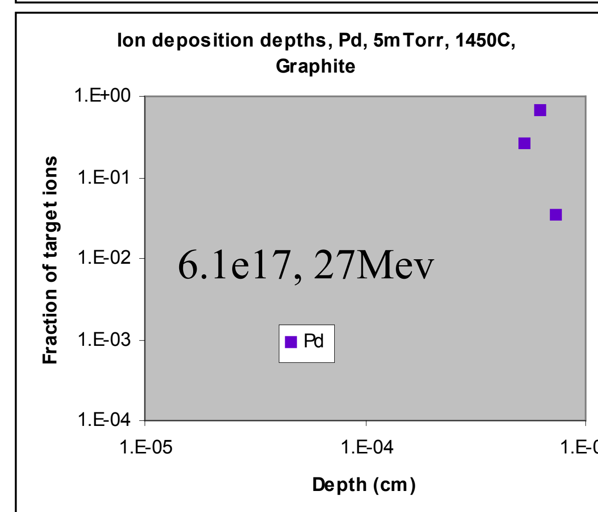






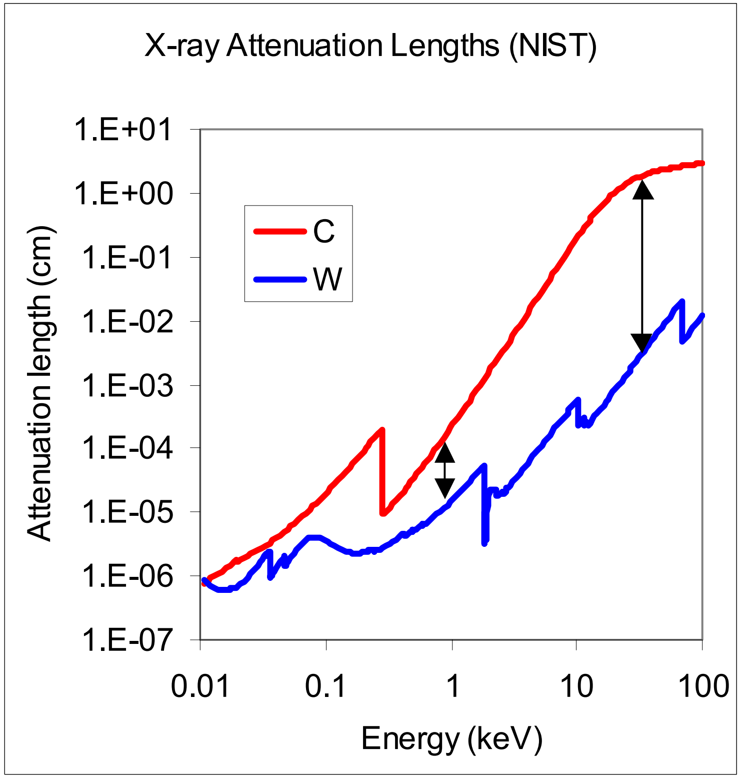


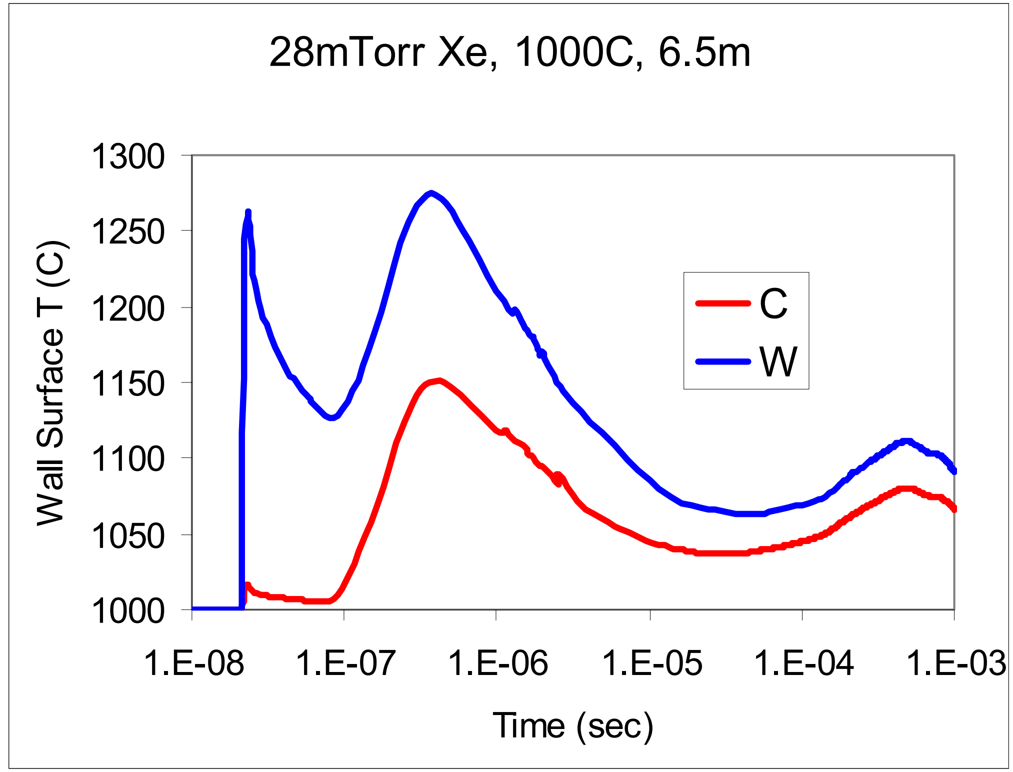




N.B. – Deposition depths depend strongly on charge of the ions. These results assume no neutralization with transit through Xe. BUCKY can track charge state during transit.

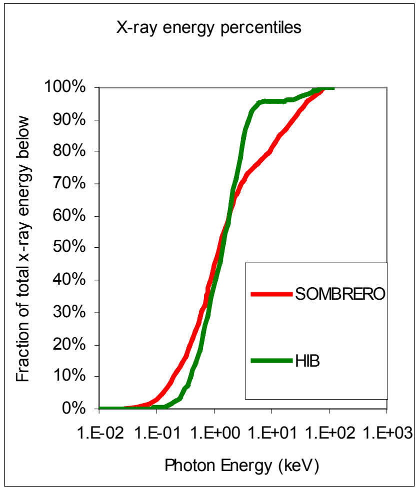
Miscellany 1: The hard x-ray spectrum from these targets (compared to SOMBRERO, ID HIB targets, *e.g.*) allows the use of armor material with higher Z than C, W for instance.

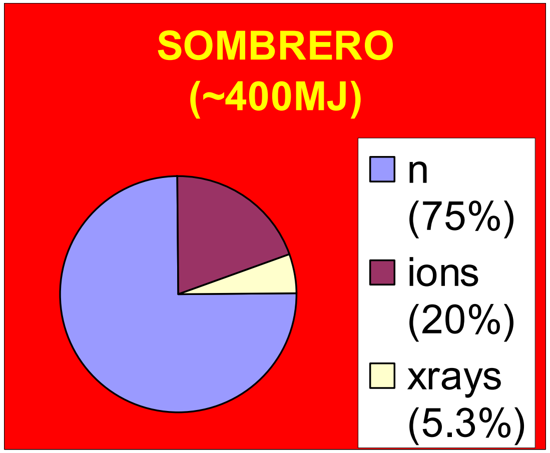


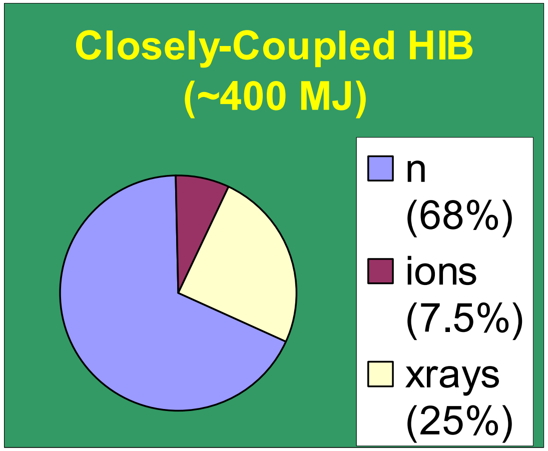


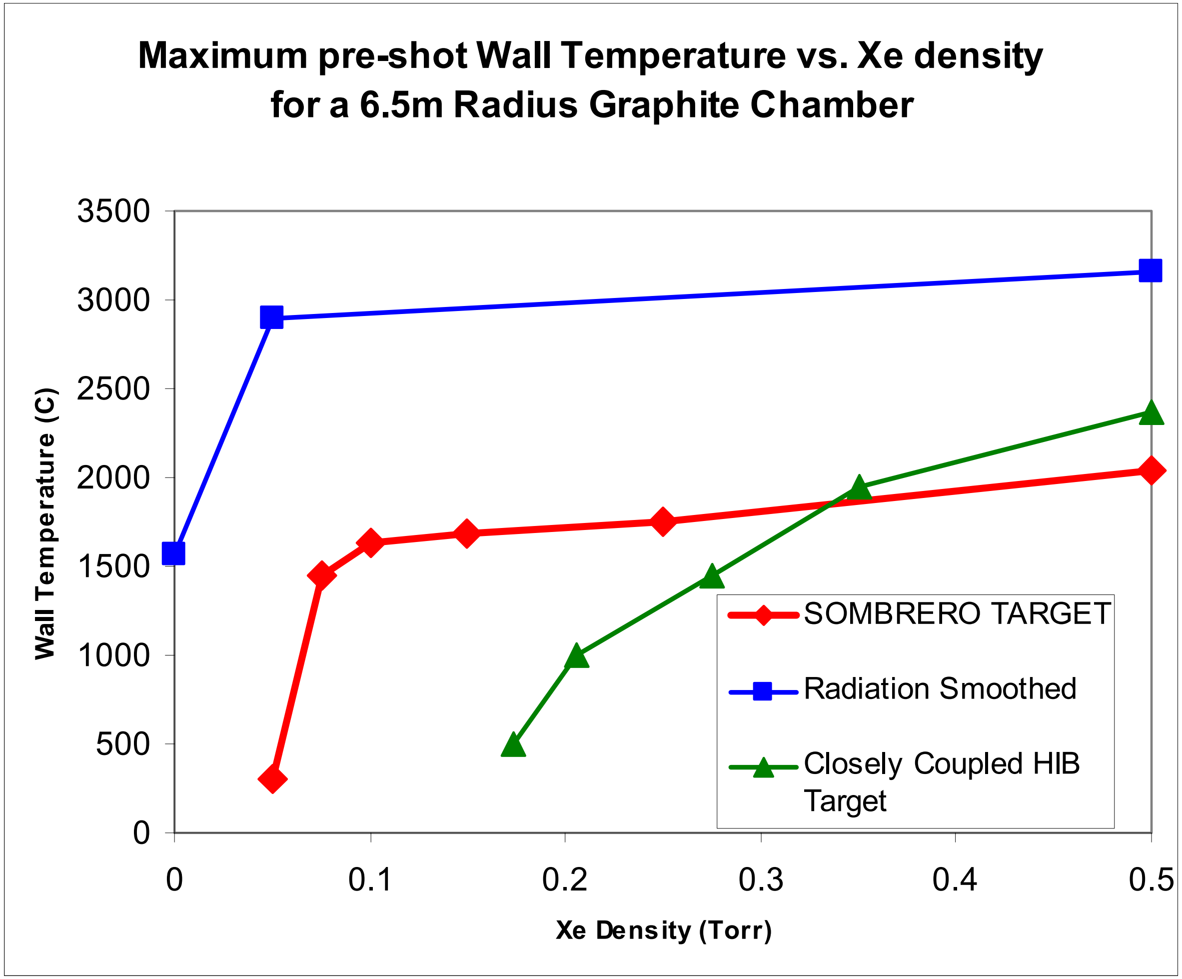
Miscellany 2: Preliminary calculations indicate that a graphite chamber radius can be significantly reduced keeping Xe density low, though an operating window remains to be established.

Miscellany 3: If the spectrum from an indirectly-driven laser target resembles that of the C/C HIB target SOMBRERO magnitude Xe densities are required to protect a dry first wall









The calculations in the figure above were performed under the ARIES aegis.

Summary/Future Work

We have performed a series of BUCKY chamber response simulations to gauge the effect of the threat spectra from the high (~400MJ) yield NRL direct-drive laser target. Both graphite and tungsten first walls survive (no per shot vaporization) at 6.5m with little chamber gas (< 25mTorr). This is in stark contrast to SOMBRERO results. The difference stems from differences in threat partitioning and especially x-ray spectra.

•Past judgments about maximum x-ray loading were based on a soft x-ray spectrum. We may need to produce a thick shell, no patina target design to understand how a >10keV burning core's x-rays end up spectrally redistributed.

•True operating window searches for one of these NRL targets, both T_eq. vs. Xe density and Xe density vs. radius. What are the (non-vaporization related) constraints as to minimum ambient density and minimum radius?

•At the end of these simulations (1ms) the bulk of the low density chamber gas is still very hot (>10000K). We may want to hand-off late-time chamber conditions to a higher dimensional, lower energy density code than BUCKY to judge re-establishment of pre-shot quiescence. (winds, turbulence, beam ports, etc.)