Increasing chamber armor lifetime with the tamped target design and low-pressure buffer gas

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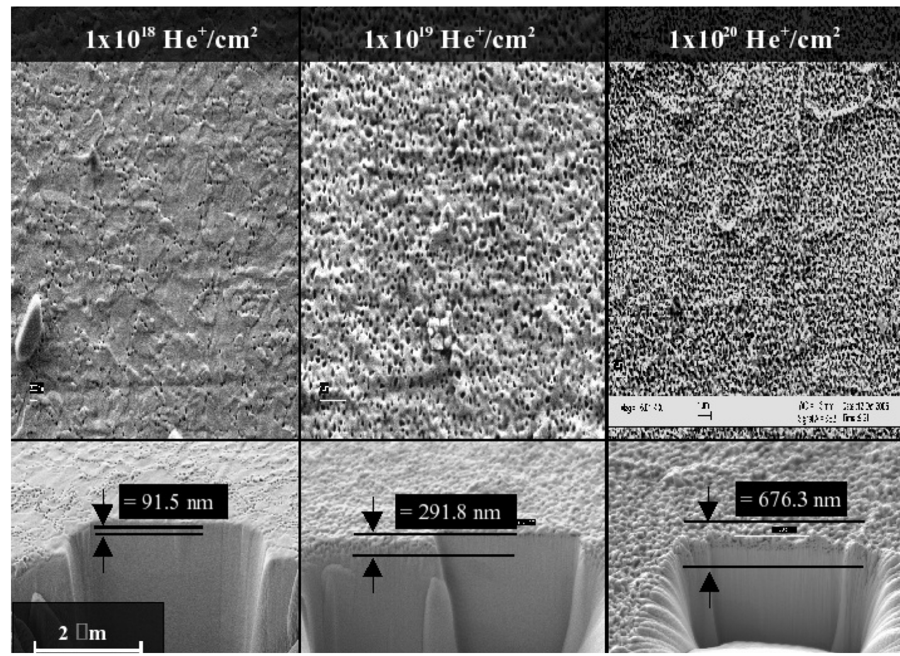
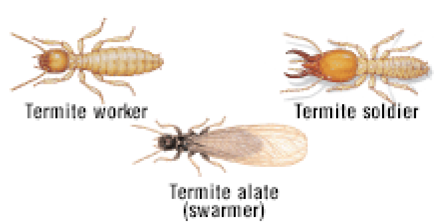
Two first-wall assembly lifetime limits are approximately 2 FPY

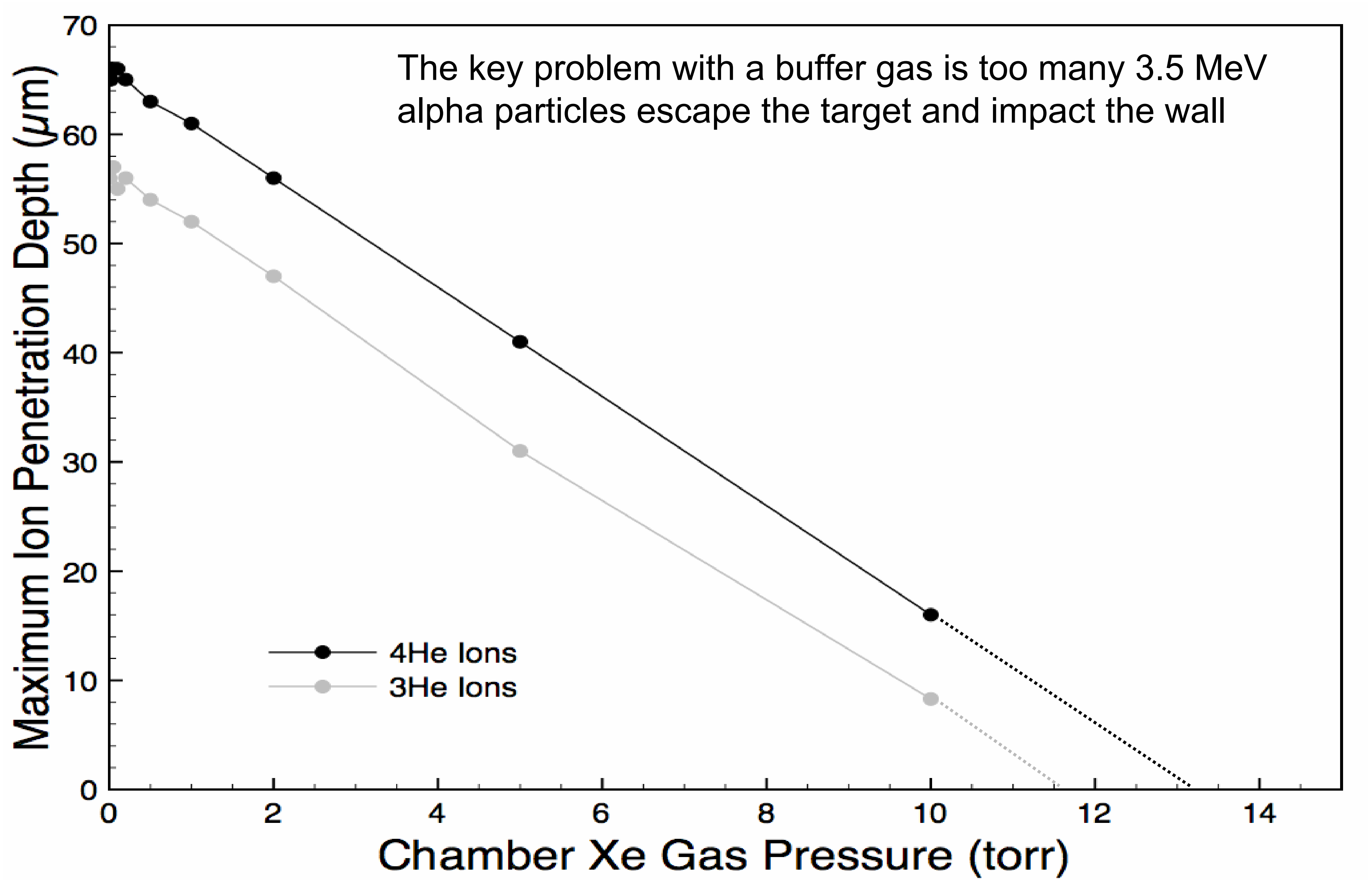
- Neutron damage (100 DPA).
  - 3 FPY lifetime
- Thermal stress due to rapid cyclical temperature rise.
  - 2400˚C for tungsten or 1000˚C for silicon carbide limits.
  - 2 FPY lifetime
- Morphology change and armor erosion due to alpha implantation.
  - Onset at ~10^{17} ions/cm^2
  - 7.5 FPD to onset
  - Low-energy alpha erosion of tungsten armor ~1 μm per 10^{19} ions/cm^2.
  - 2 FPY lifetime
  - Significant uncertainty in tungsten armor lifetime.

IEC Helium Ion Implantation Experimental Results



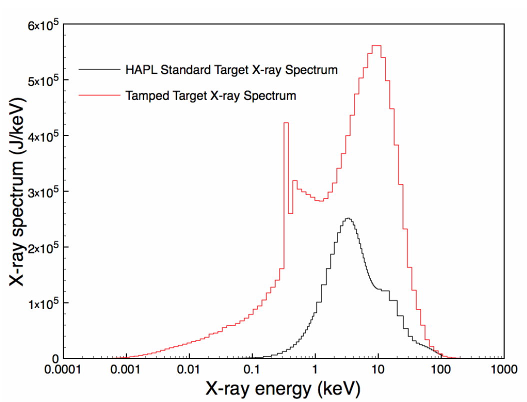


Preventing alpha induced morphology change by increasing buffer gas pressure is impractical

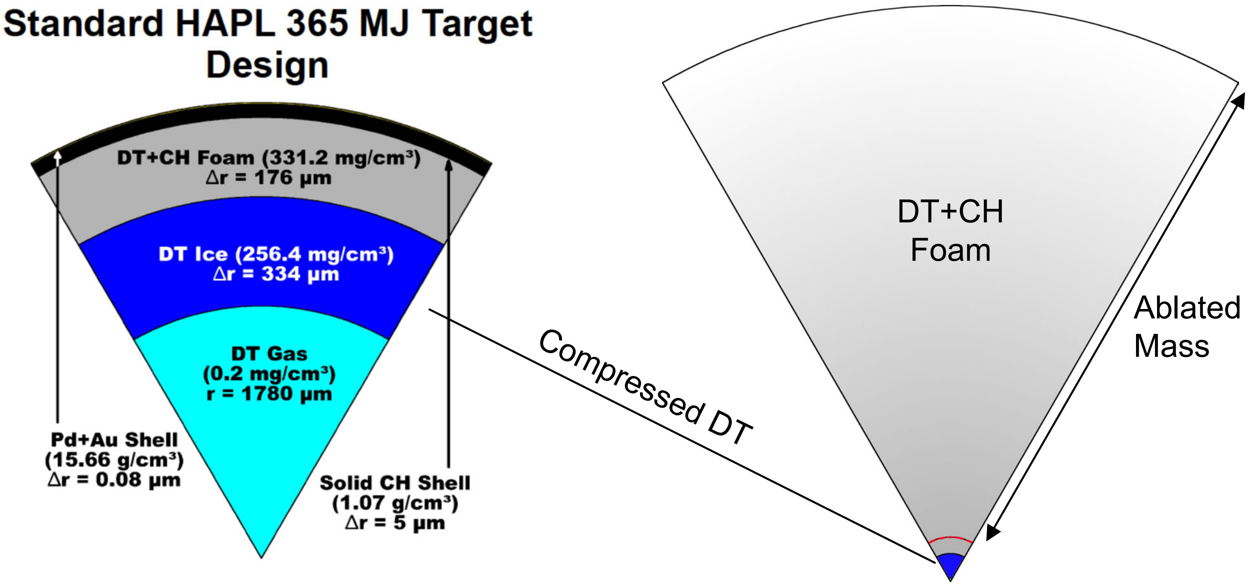


Target configurations at time of ignition demonstrate the effect of the tamper on alpha confinement

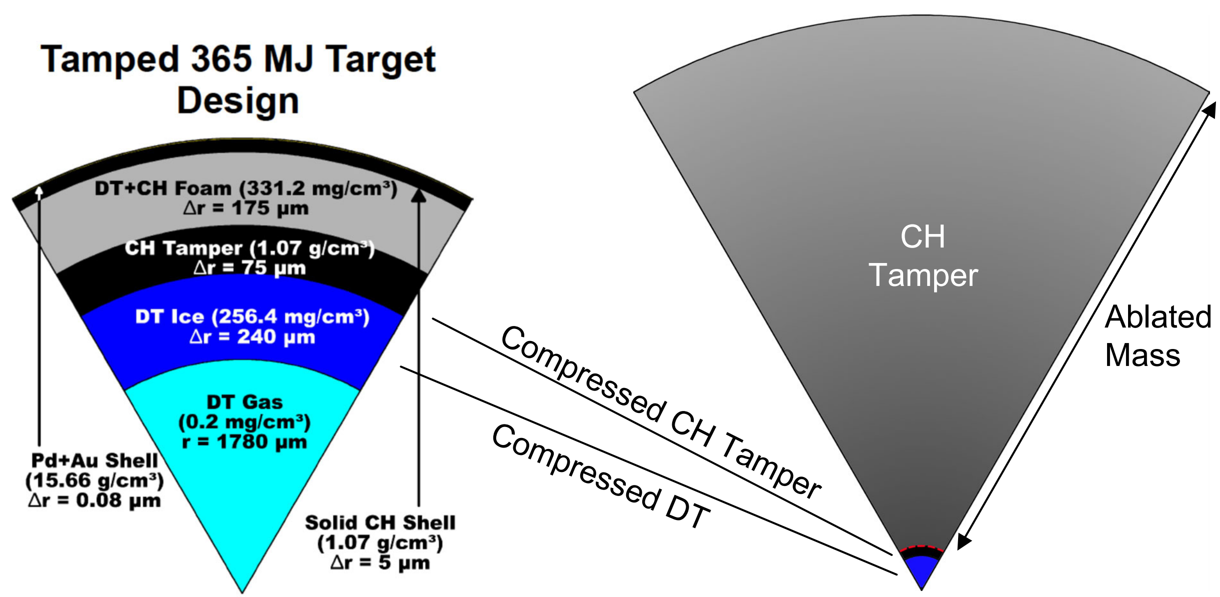
- The tamper traps 99.5% of the fusion alphas inside the debris plasma
- Alpha particle kinetic energy is partially converted to x-ray energy by interaction with the debris plasma



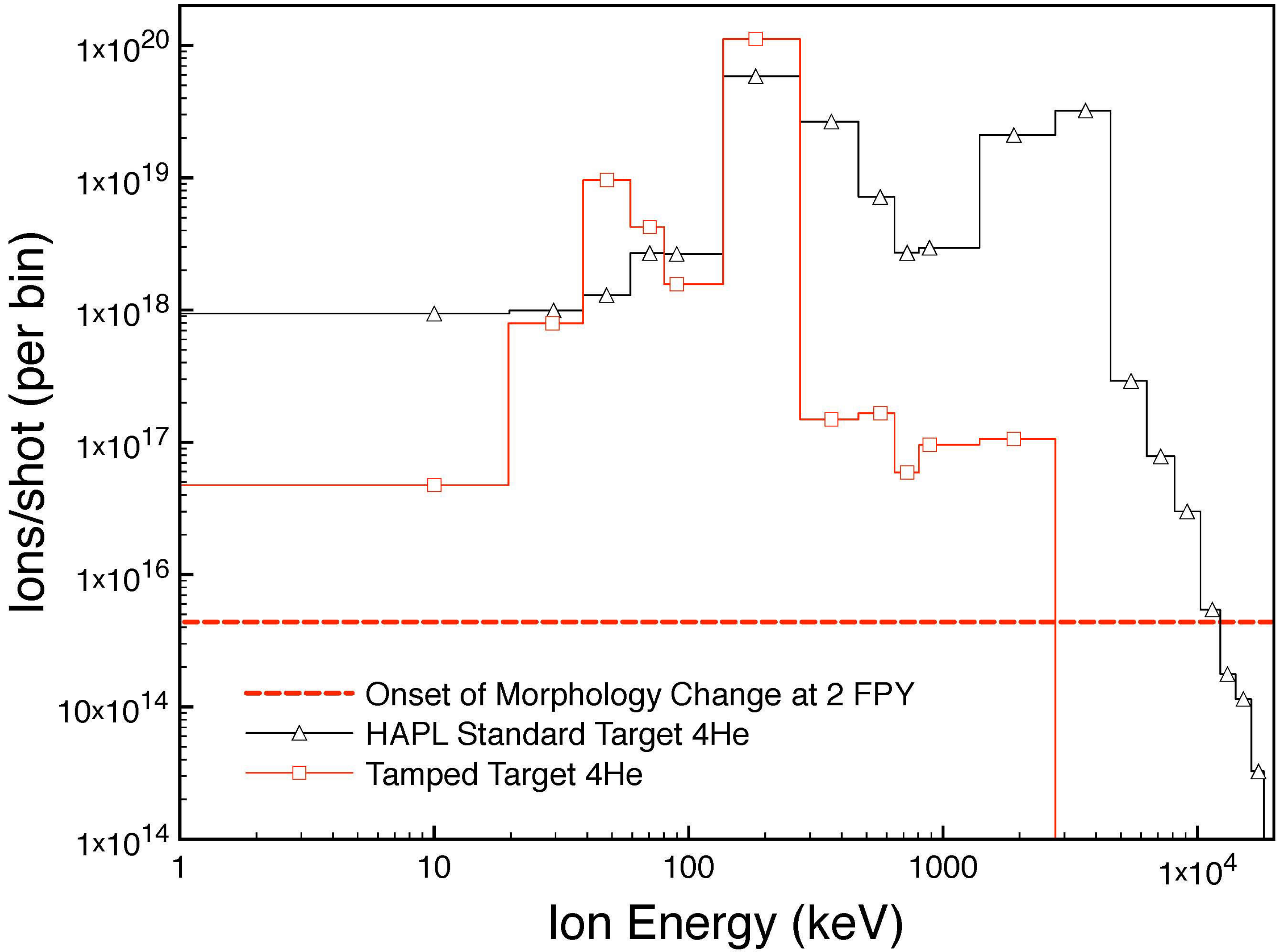
Standard HAPL 365 MJ Target Design



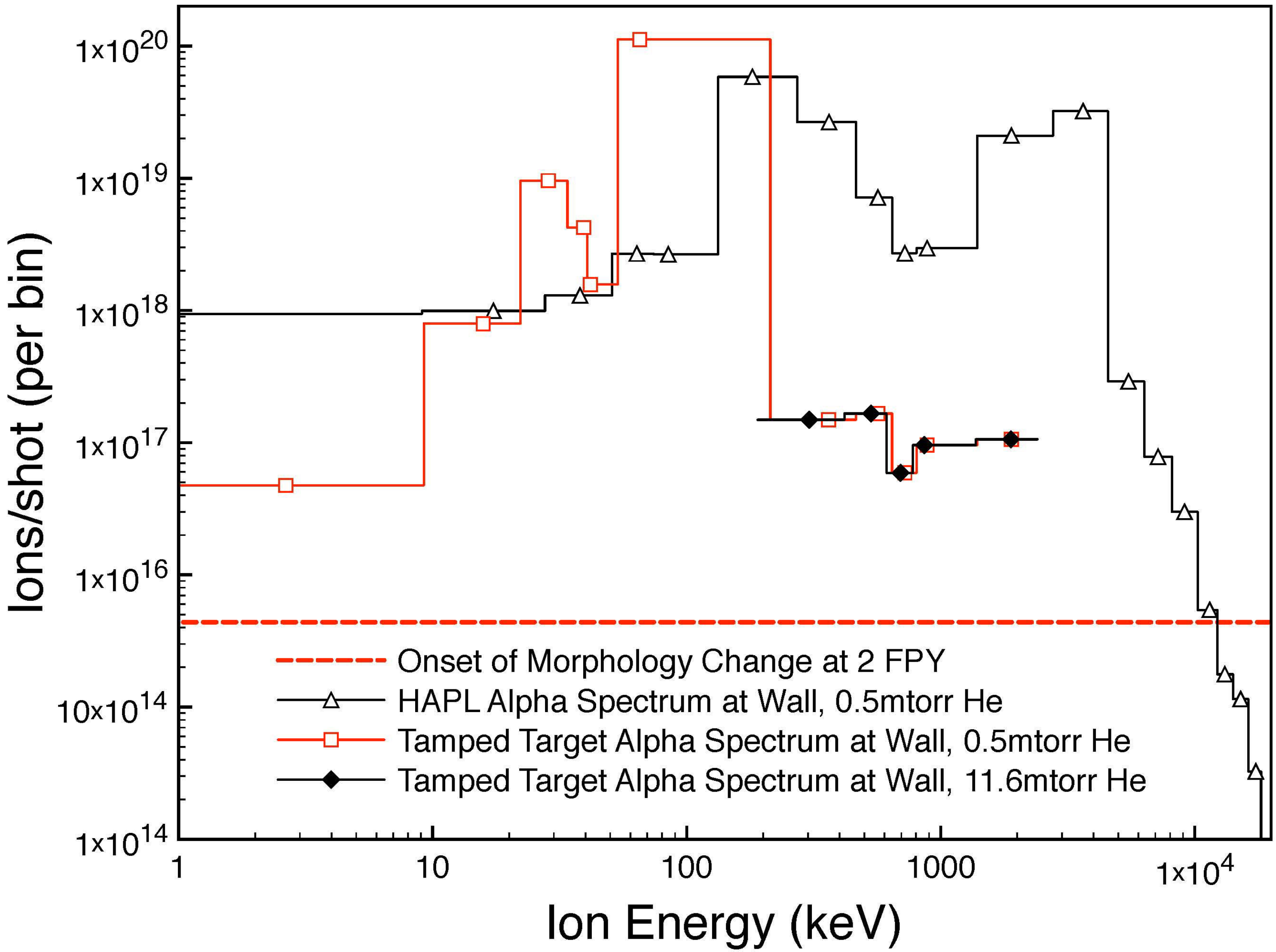
Tamped 365 MJ Target Design



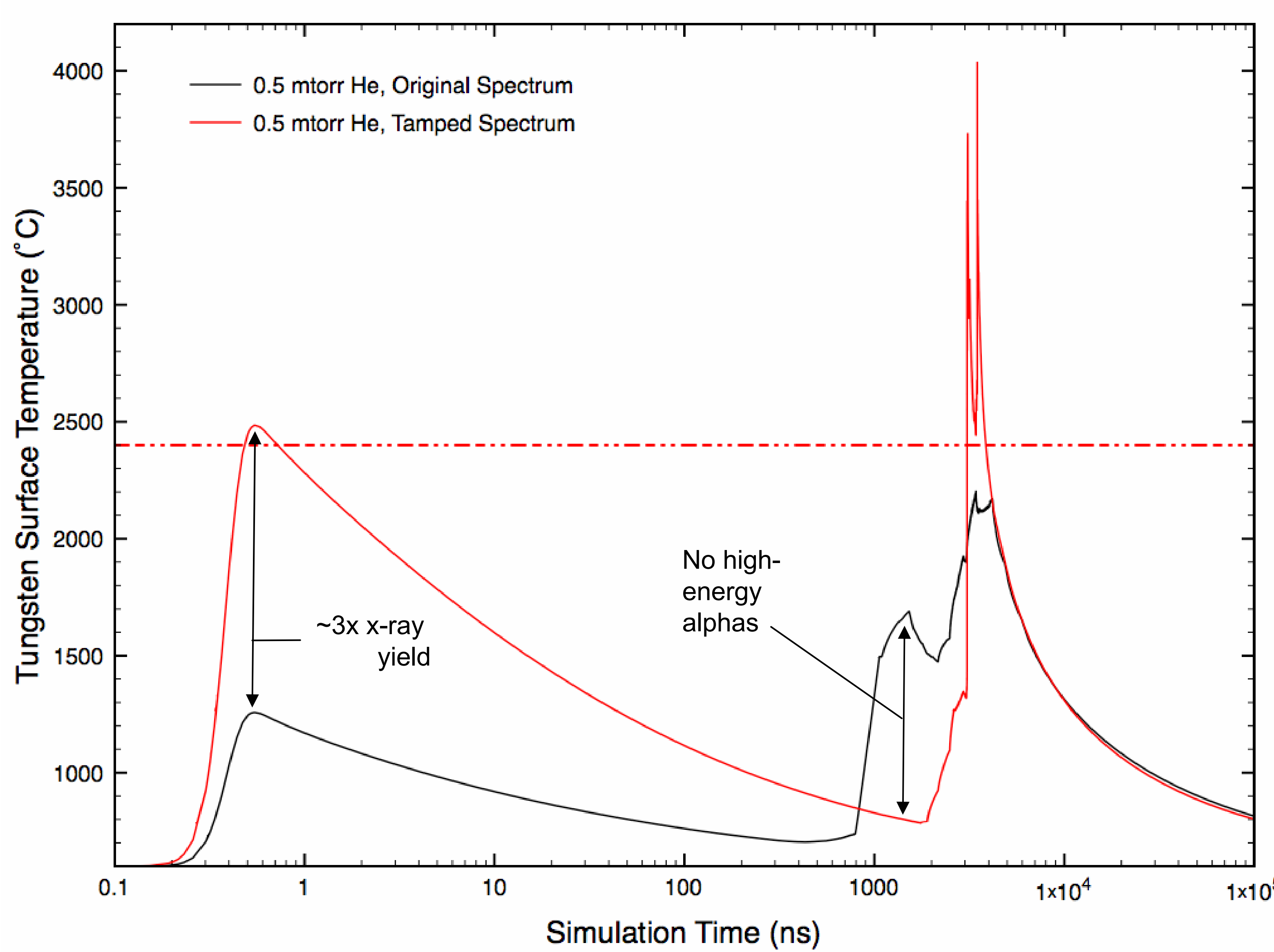
Alpha spectrum comparison of standard HAPL and tamped targets



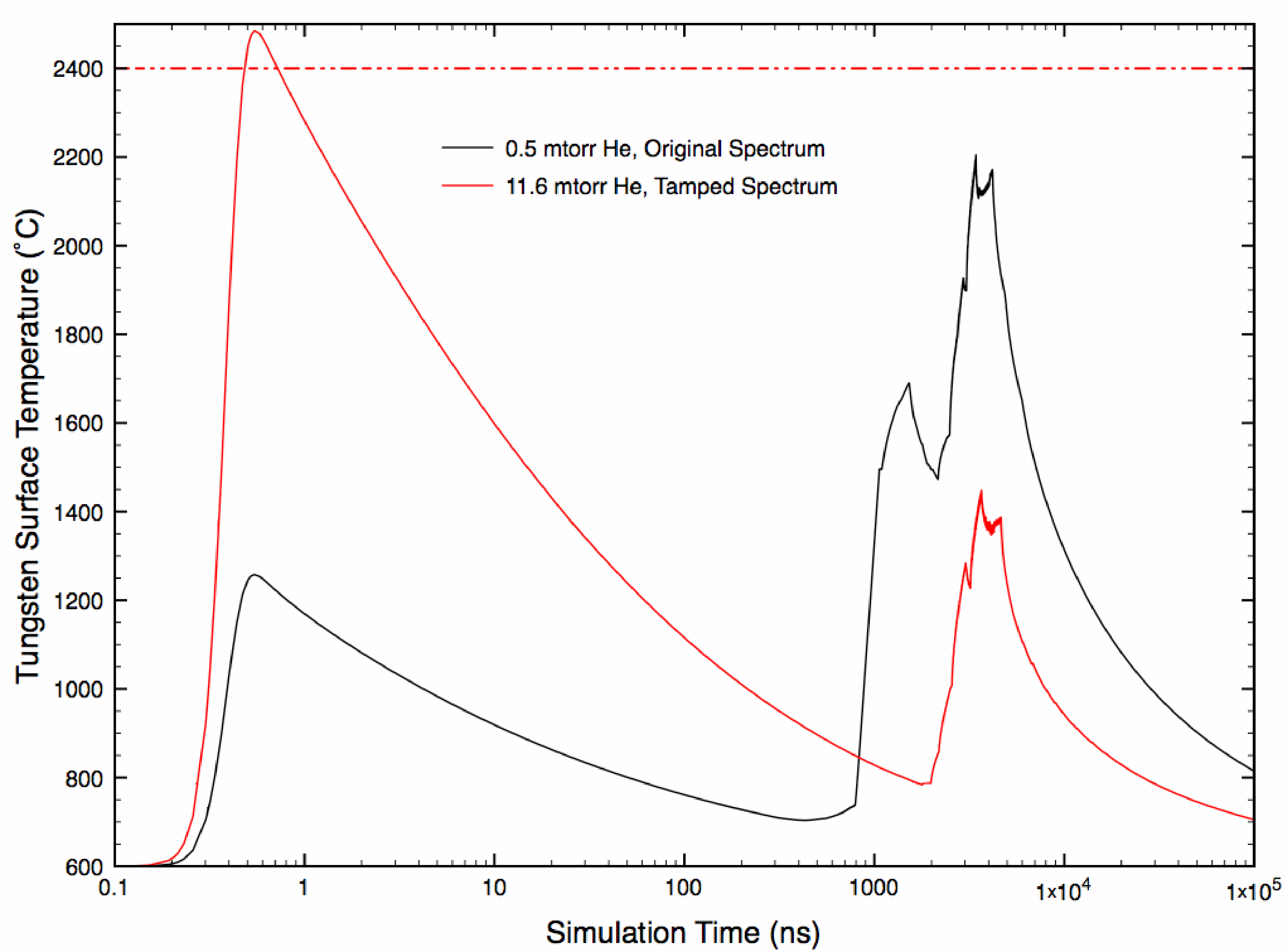
Alpha spectrum at the wall demonstrates the effect of the buffer gas on reducing alpha fluence into the tungsten armor



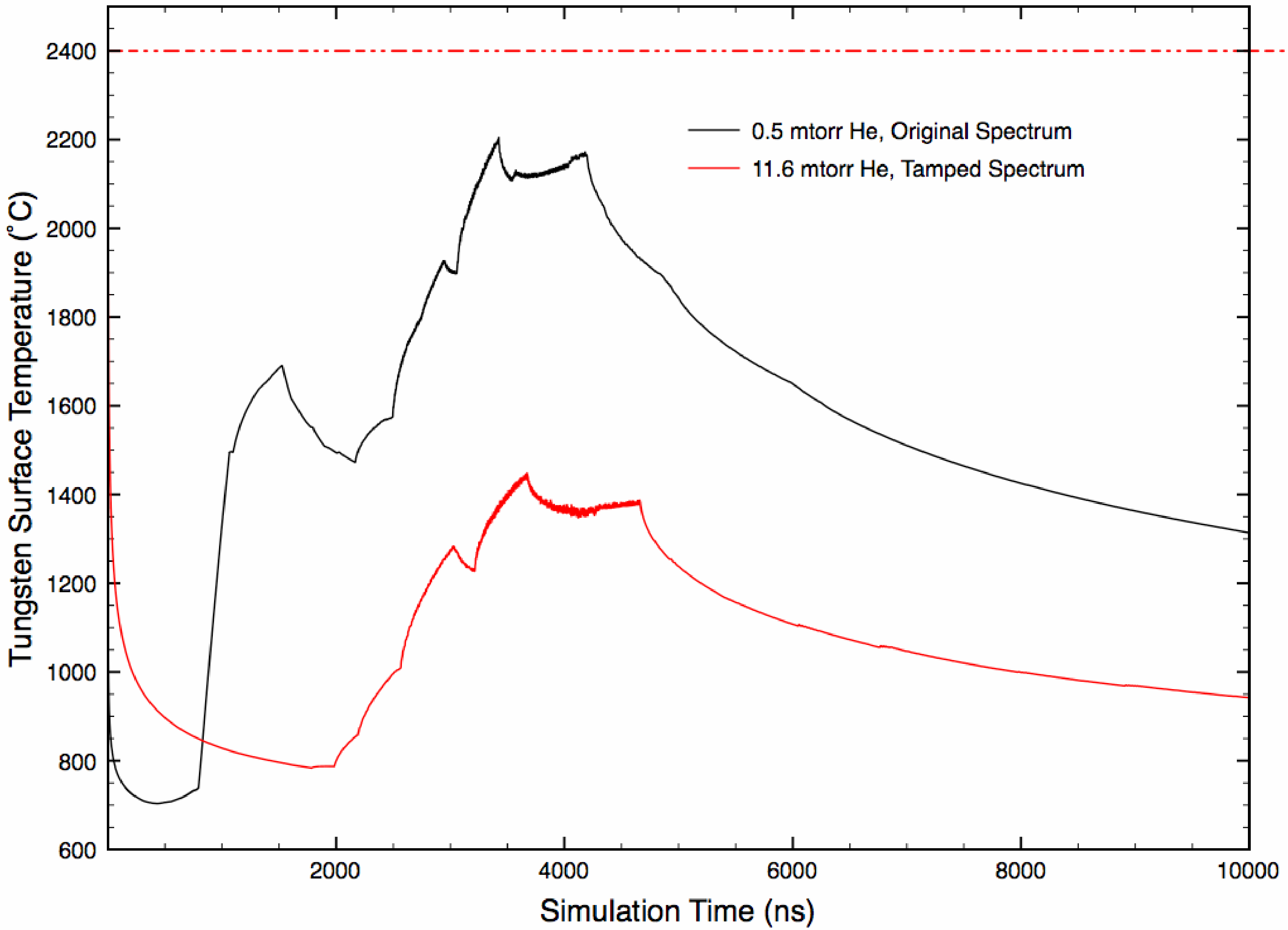
Tamped target exacerbates tungsten surface temperature response when combined with minimal buffer gas.



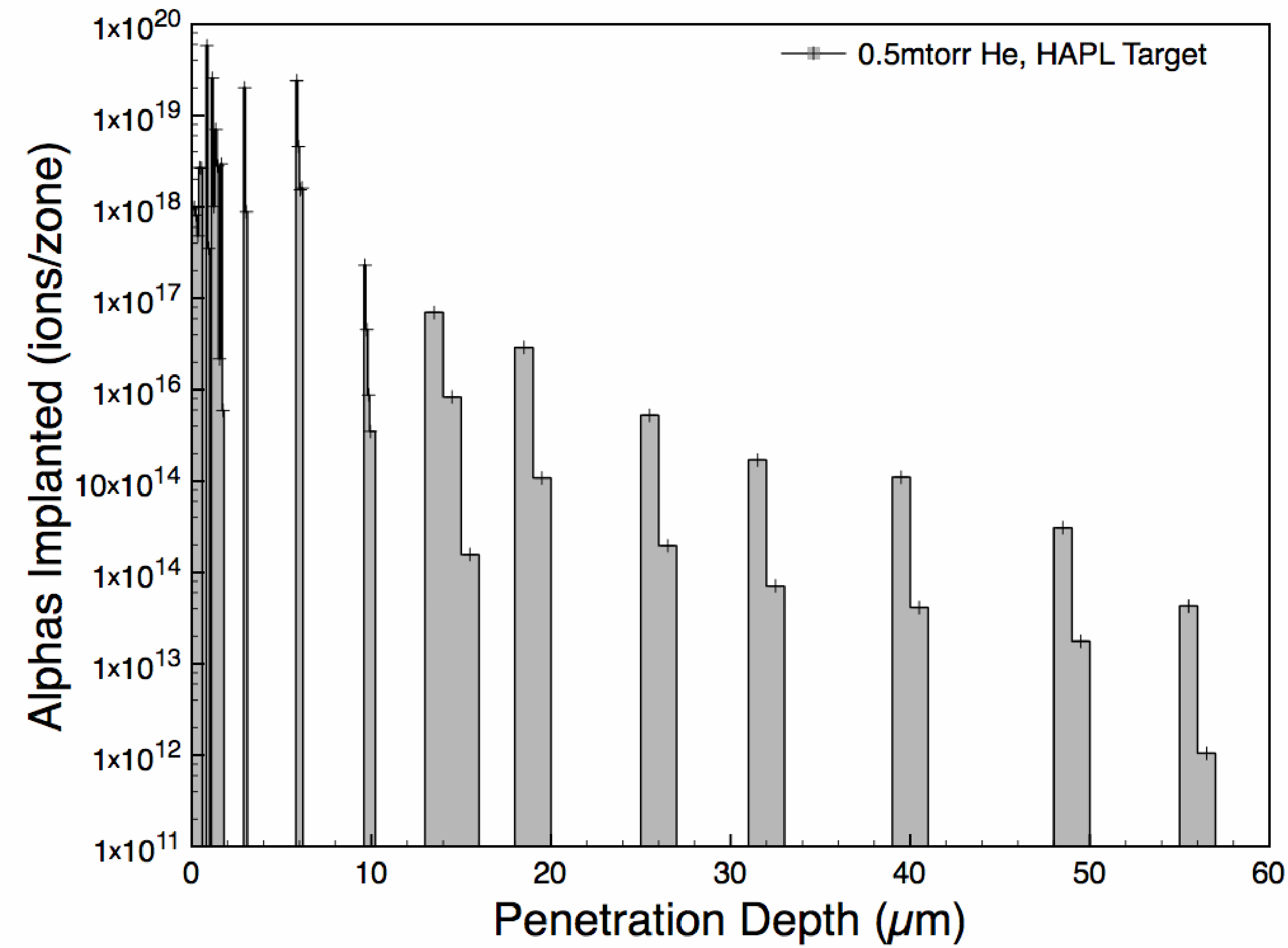
Tungsten surface temperature comparison of standard HAPL target with no buffer gas and the tamped target with sufficient gas to stop low-energy alphas



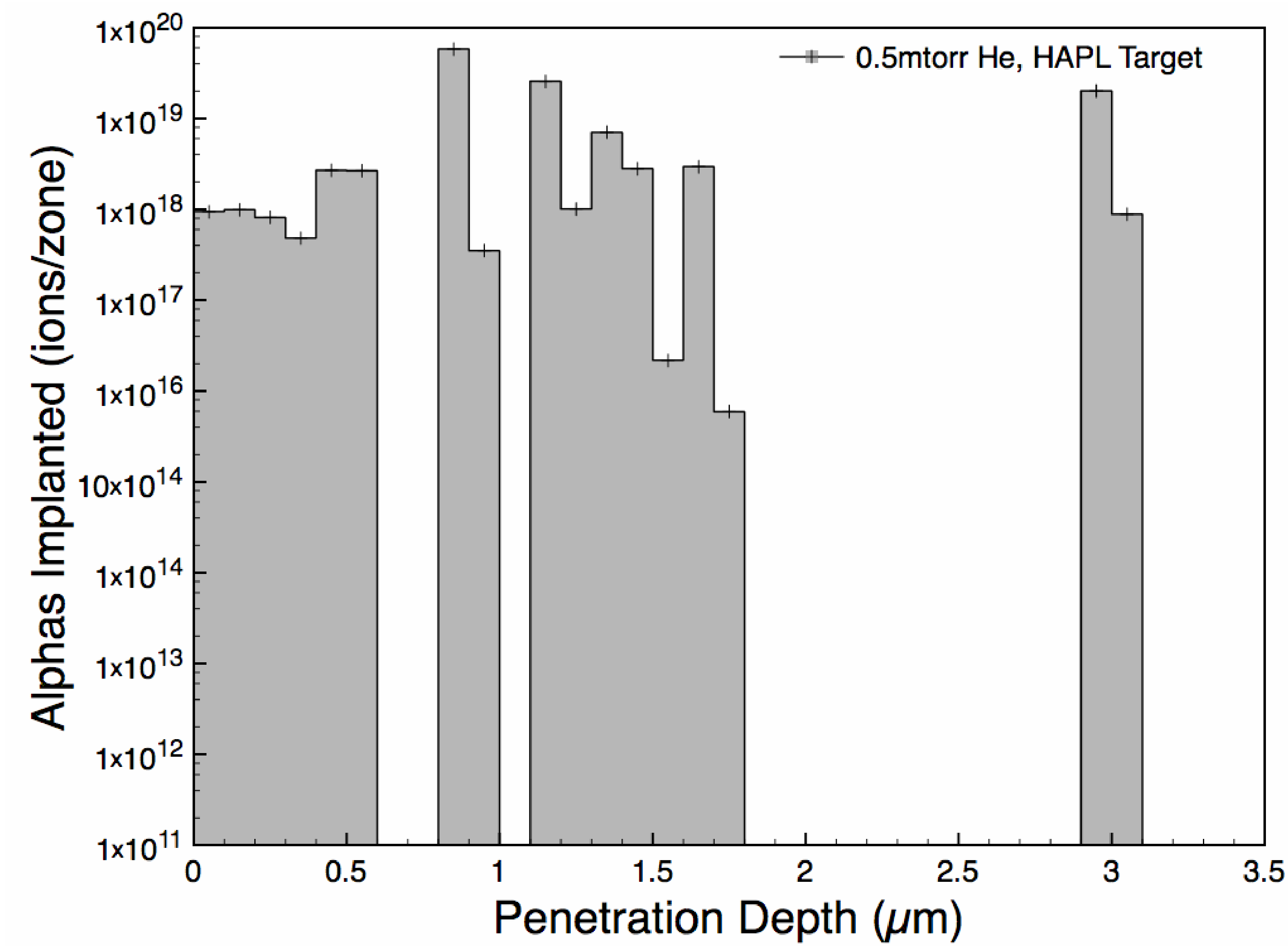
Tungsten surface temperature comparison of standard HAPL target with no buffer gas and the tamped target with sufficient gas to stop low-energy alphas



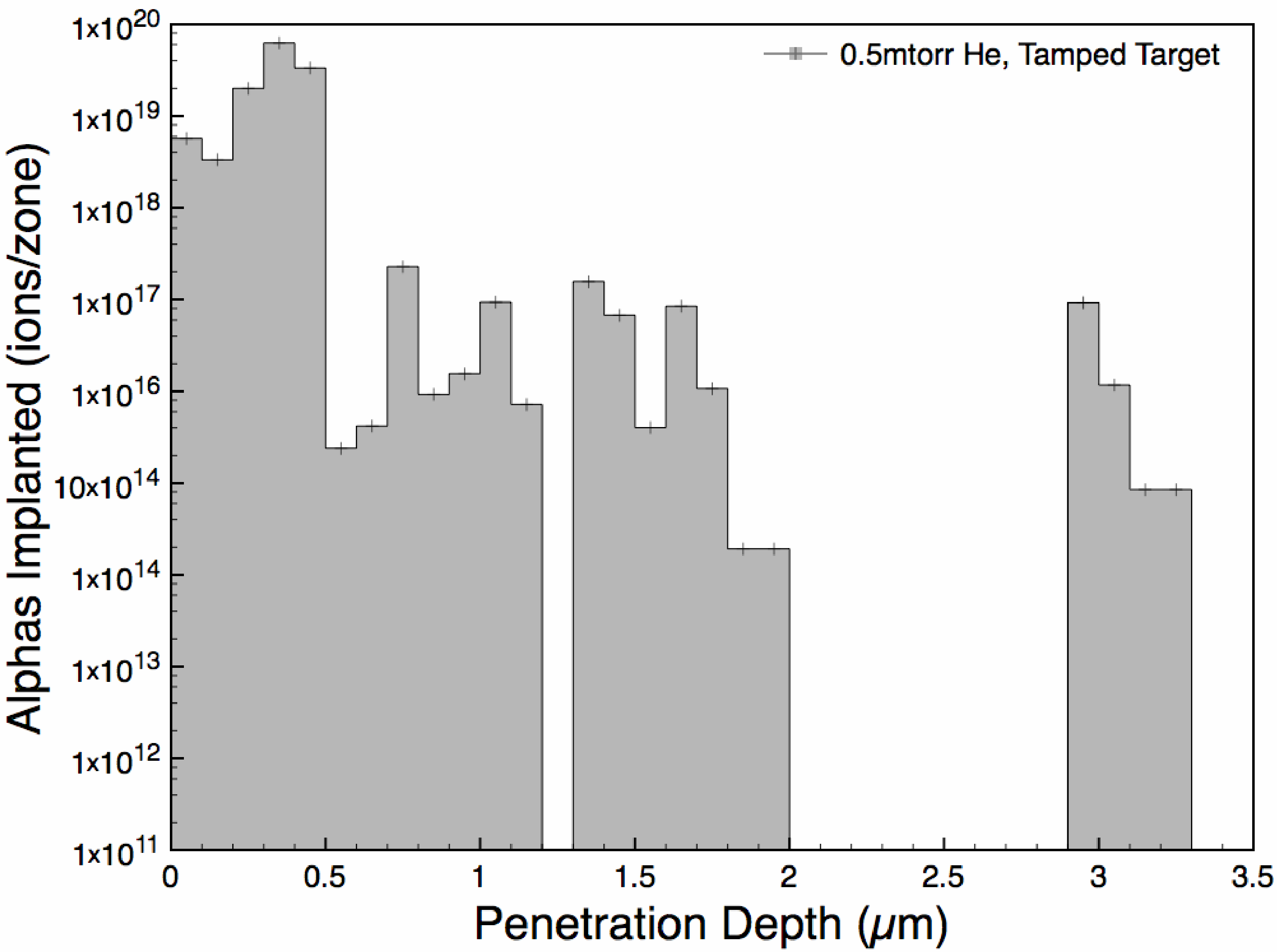
Alpha penetration into tungsten for the HAPL standard target with 0.5 mtorr helium buffer gas



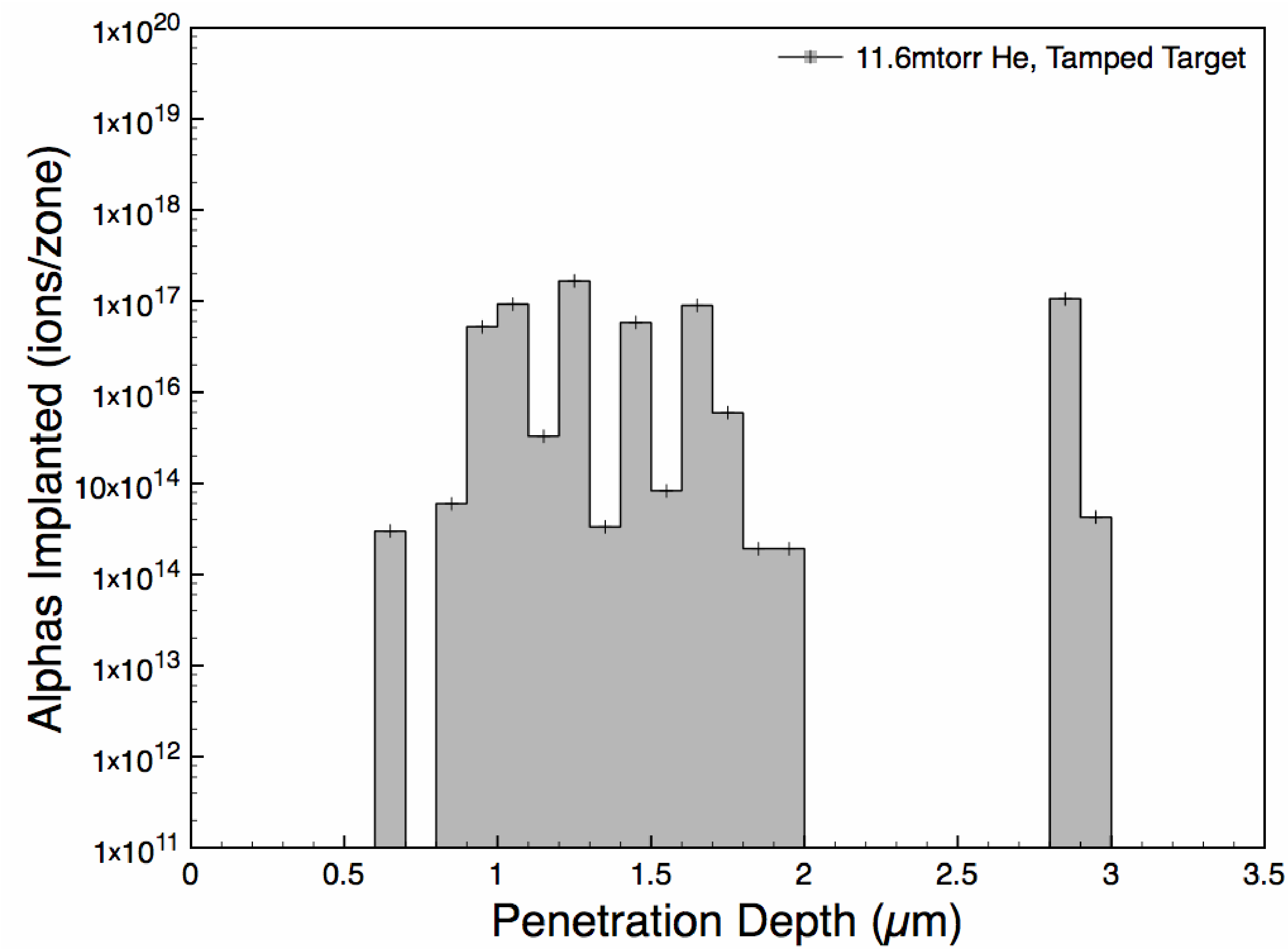
Alpha penetration into near-surface tungsten for the HAPL standard target and 0.5 mtorr helium buffer gas



Alpha penetration into tungsten for the tamped target and 0.5 mtorr helium buffer gas



Alpha penetration into tungsten for the tamped target and 11.6 mtorr helium buffer gas



Conclusions and future work

- A tamped target with no buffer gas increases the temperature transient of the tungsten armor surface to both x-rays and debris ions to unacceptable maxima.

- A tamped target along with He buffer gas meets the thermal constraints of the tungsten armor surface but does not sufficiently reduce the alpha particle fluence to the tungsten armor to avoid the onset of morphology change.

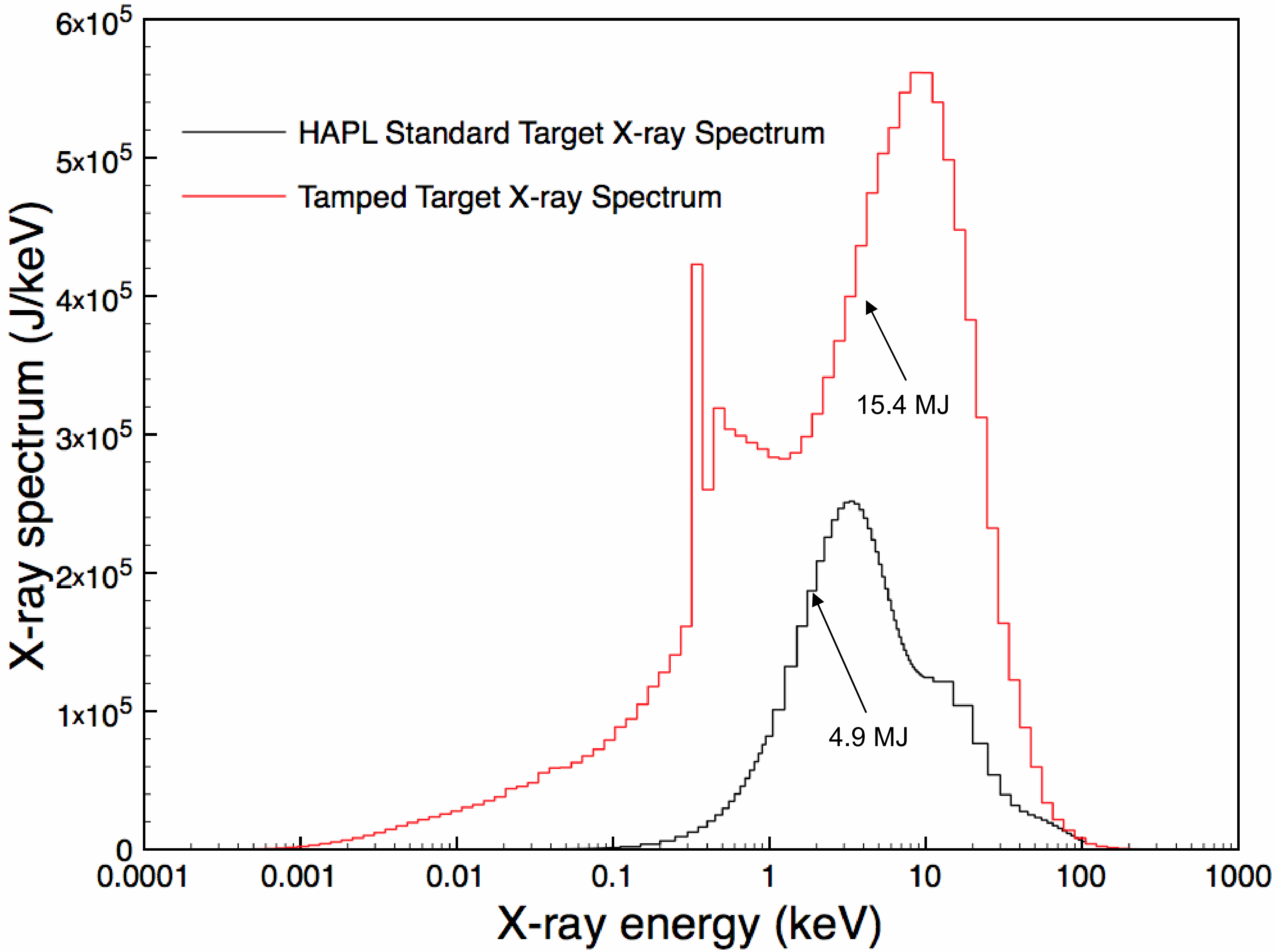
- The onset of morphology change in tungsten armor is a limiting parameter in this design option. Trace numbers of alphas lead to morphology change.

- What is the cross field alpha particle leakage in the magnetic protection approach?

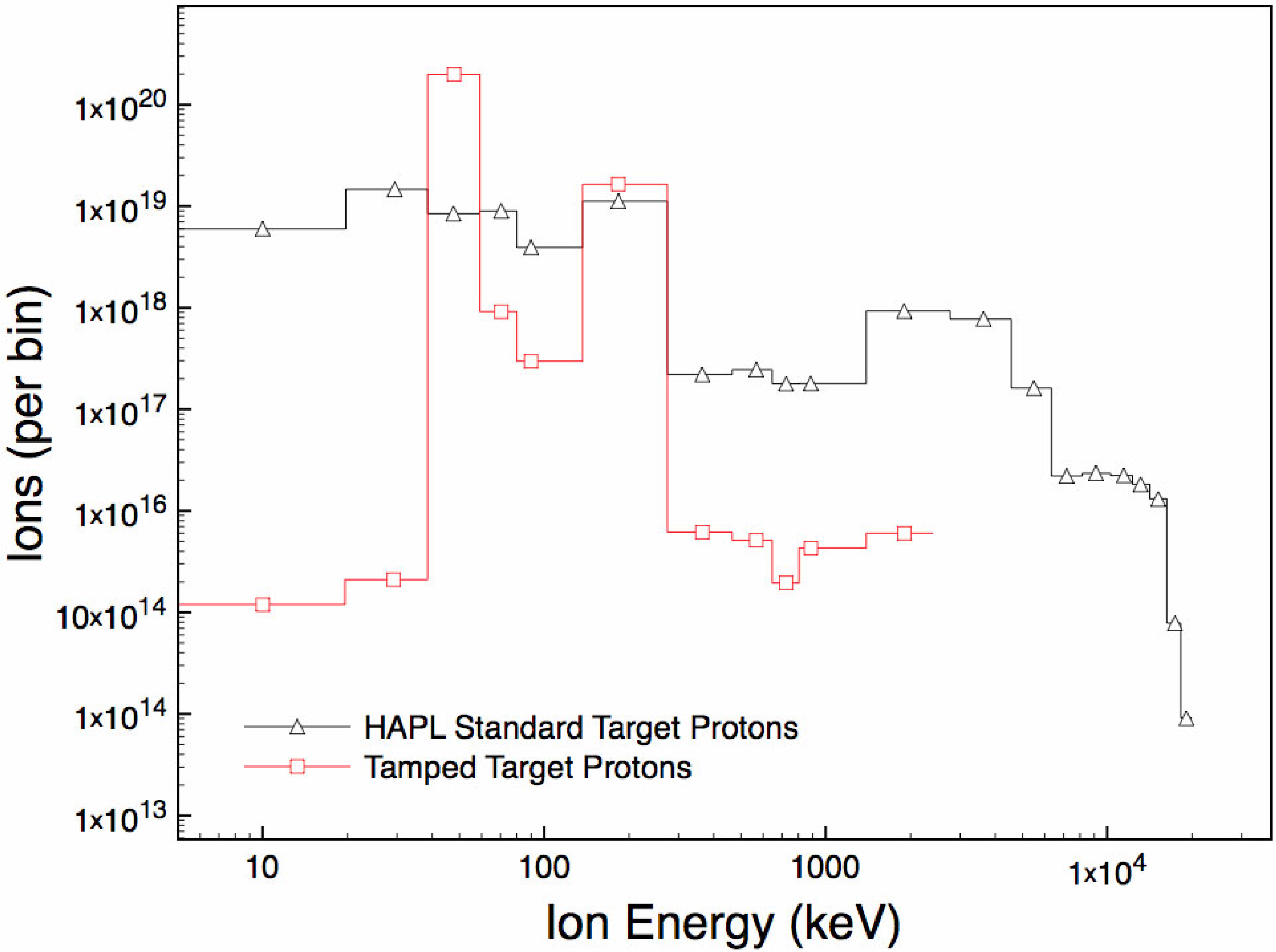
Extra slides

X-ray yield of tamped target is ~3x larger than the HAPL standard target

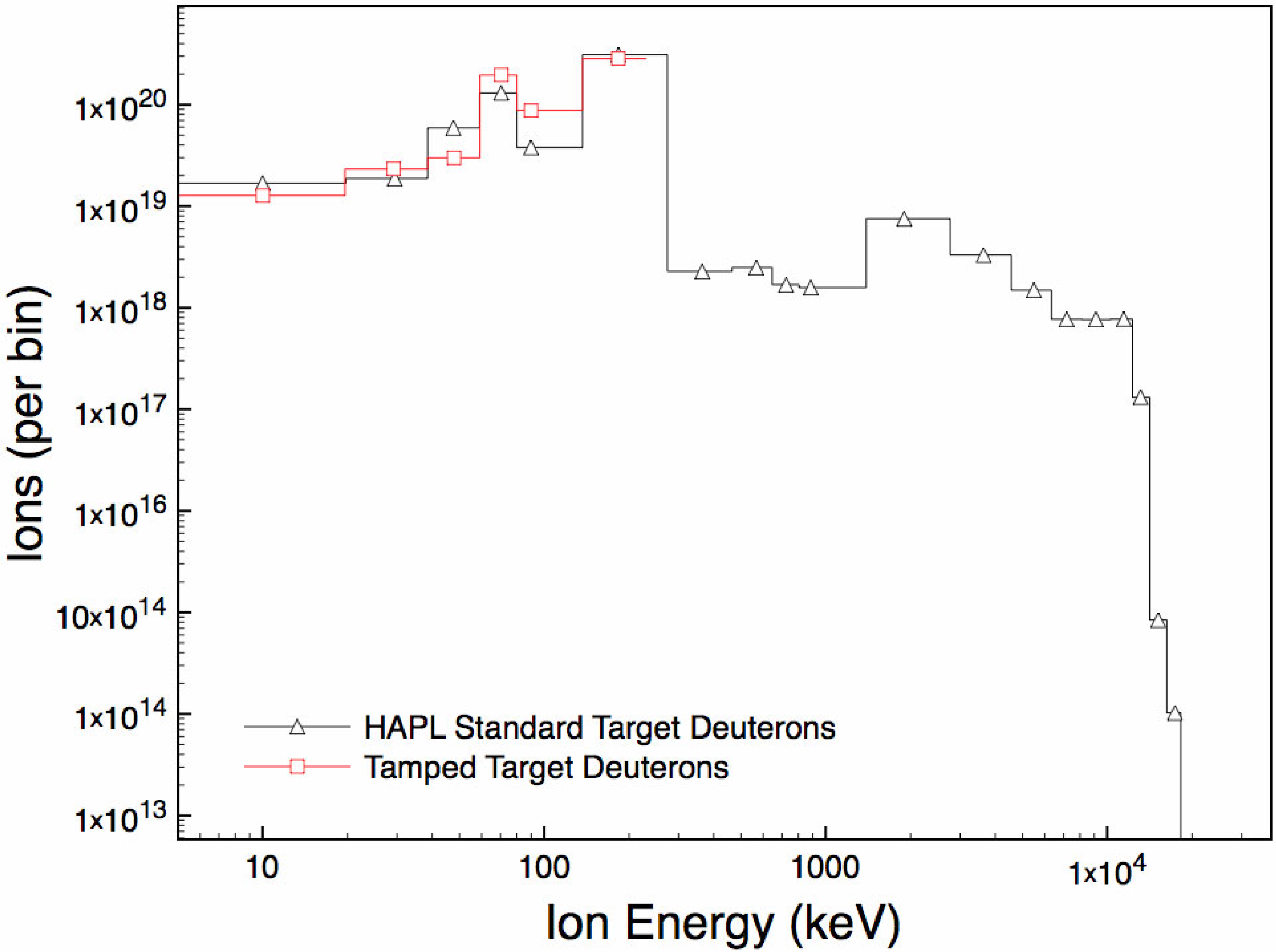
A note of caution: we are comparing the x-ray yield of a tamped target simulated with the BUCKY code to the standard HAPL target simulated by LLNL.



Proton spectrum comparison, 365 MJ Fusion Yield



Deuteron spectrum comparison, 365 MJ Yield



Trition spectrum comparison, 365 MJ Fusion Yield