Chamber Gas Density Requirements for Ion Stopping

- It is necessary, but not sufficient, that a dry first wall chamber survive each shot without significant vaporization.
- It is also necessary, but not sufficient, that ion implantation be kept below some as yet to be determined level for each ion species in the target output.
- Towards the establishment of operating windows satisfying both requirements, a sequence of BUCKY chamber simulations have been performed.
- *E.g.*, for a 1000C, 6.5m radius graphite first wall, 80mTorr of Xe is required to prevent vaporization, while more than 1 Torr of Xe is required to prevent implantation of He ions.

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for the staff of the
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THE UNIVERSITY of WISCONSIN MADISON

HAPL WORKSHOP
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Summary/Outline

•80mTorr of Xe (not 25mTorr) is required to prevent first wall vaporization for a graphite wall at 6.5m from the threat of the Pd_EOSOPA target.

•An 8.1m radius graphite chamber wall does not sublimate for 25mTorr Xe and a starting temperature of 1000C.

•Ion implantation occurs up to remarkably high densities, with the He4 from the burn of the target requiring the most gas to prevent implantation.

•Updated lower gas density limit to prevent vaporization

- •80mTorr are required for the PD_EOSOPA target, graphite wall at 650cm, starting at 1000C.

•Threat partitioning, ion spectra

- •The 1.7MeV (average) He4 burn product is particularly threatening.

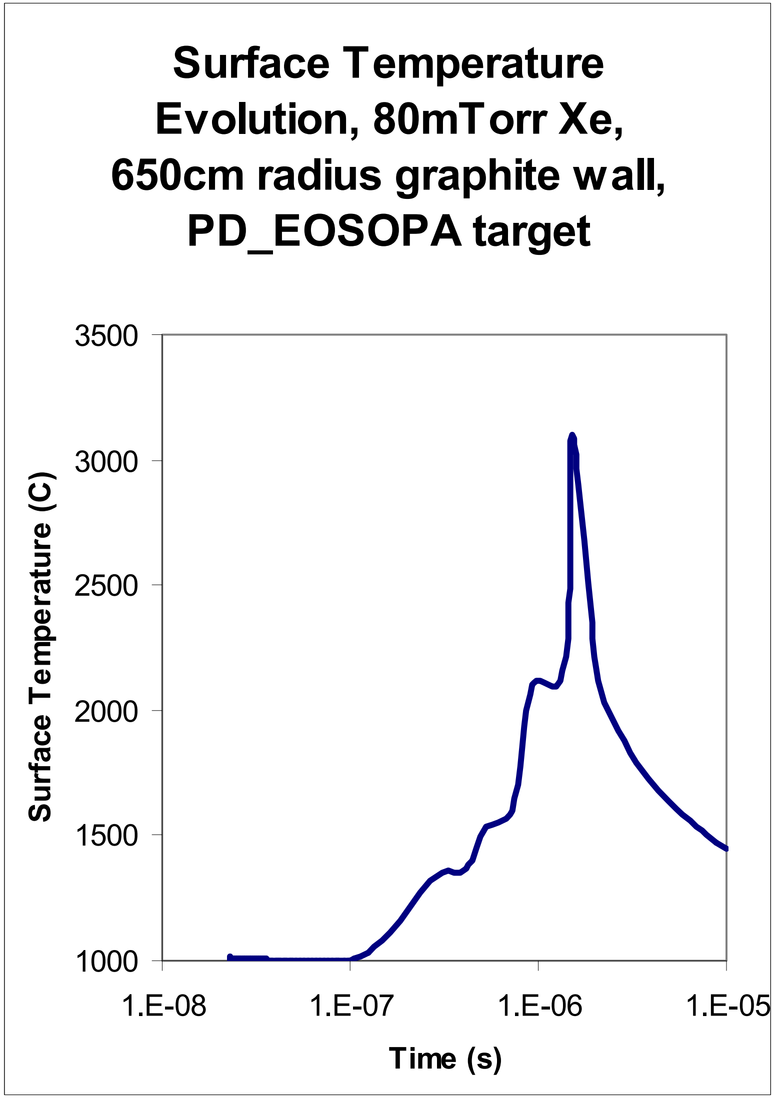
•Ion implantation as a function of Xe density

- •The amount of Xe required to prevent vaporization allows a significant (unacceptable?) amount of H isotopes, He4, and Pd through to the wall.
- •Prevention of all implantation requires <u>much more</u> Xe than SOMBRERO

•Grateful acknowledgments: Bob Peterson, Lance Snead, René Raffray

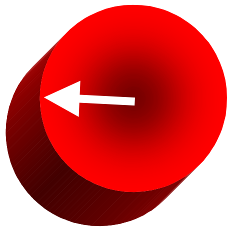
An improved treatment added to BUCKY allows more accurate treatment of high resolution time of flight spreading of the insult posed by target ions.

- As shown in the previous talk, BUCKY's treatment of fireball evolution had been validated.
- As will be shown, BUCKY's treatment of surface erosion due to nearly mono-energetic ion beams passing through a diffuse medium is being validated.
- In this particular application, the new treatment has led to a three-fold increase in Xe density required to prevent first wall vaporization for a graphite wall at 650cm, starting at 1000C.



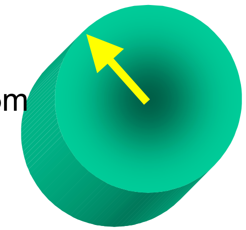
If He and Pd ion implantation should not pose an insurmountable problem for graphite, how can we get back down to 25mTorr Xe?

Initial Temperature



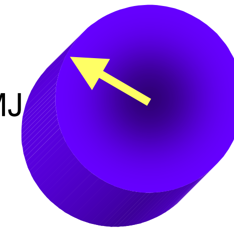
- 354MJ
- 25mTorr
- 600C
- 6.5m
- 372 g/shot

Chamber Radius



- 354MJ
- 25mTorr
- 1000C
- 8.1m
- 0 g/shot

Yield

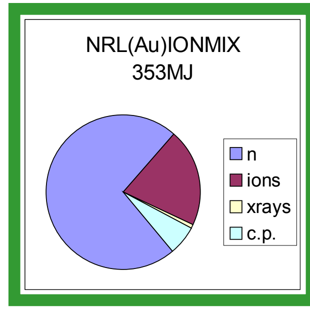


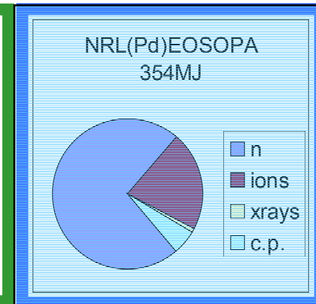
- 173.5MJ
- 25mTorr
- 1000C
- 6.5m
- 0 g/shot

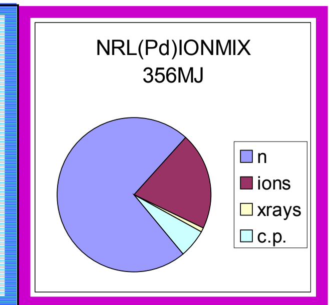
N.B.-None of these knobs will strongly effect the number of ions getting implanted in the wall. Yield variation is approximated here by varying ion flux, not energy spectrum. In this approximation, ion implantation dominated lifetime is inversely proportional to yield.

Three of the four BUCKY results, and Perkin's calculation, all show that a significant fraction of the ion threat comes from He4 fusion products.

Results from RRP, last meeting





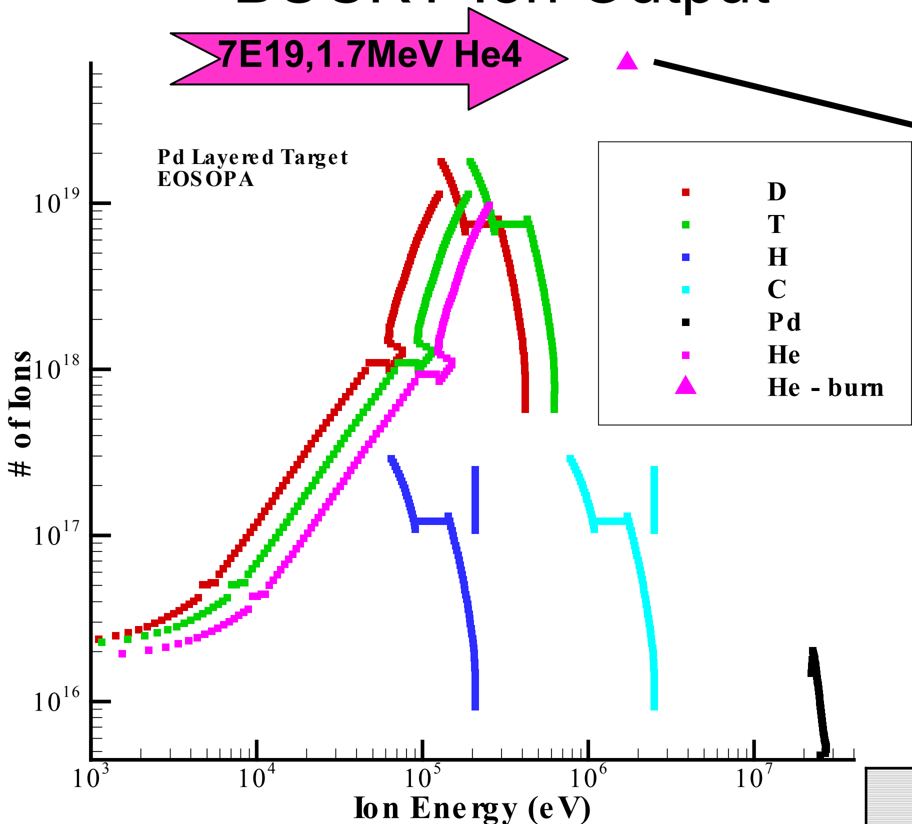


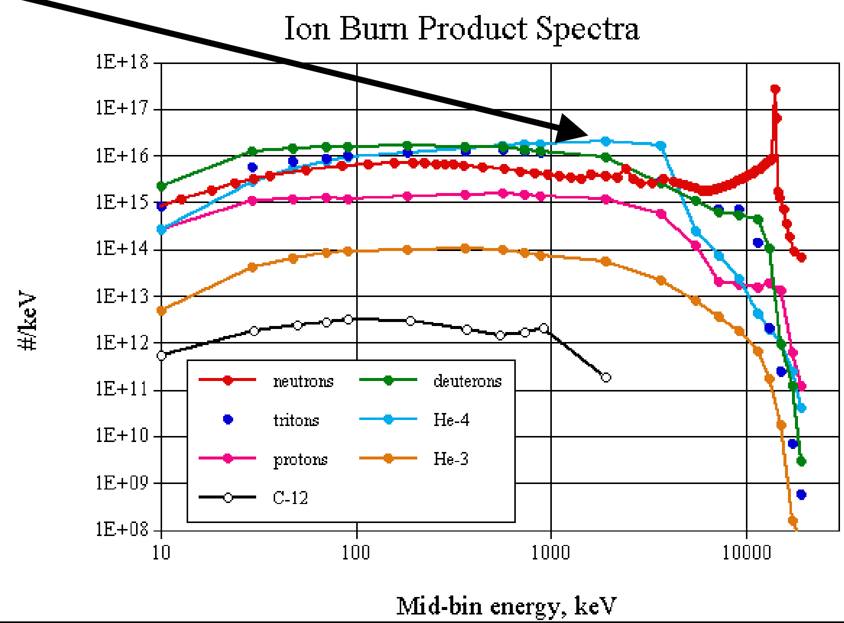
	Au IONMIX	Pd EOSOPA	Pd IONMIX
Yield (MJ)	353.1 (99.2 %)	353.7 (99.2 %)	355.7 (99.2 %)
Neutron (MJ)	257.0 (72.2 %)	256.7 (72.0 %)	260.1 (72.5 %)
X-ray (MJ)	2.66 (0.75 %)	2.68 (0.75 %)	2.71 (0.76 %)
Target Debris (MJ)	74.6 (21.0 %)	78.1 (21.9 %)	68.4 (19.1 %)
Charged Fusion Product (MJ)	21.7 (6.1%)	19.1 (5.4 %)	20.9 (5.8 %)

The BUCKY output spectrum did not have fine binning of the He4 burn products. To include the effect of time-of-flight spreading of the insult to the wall, the shape of Perkin's LASNEX spectrum was adopted for the burn He4 .

BUCKY Ion Output

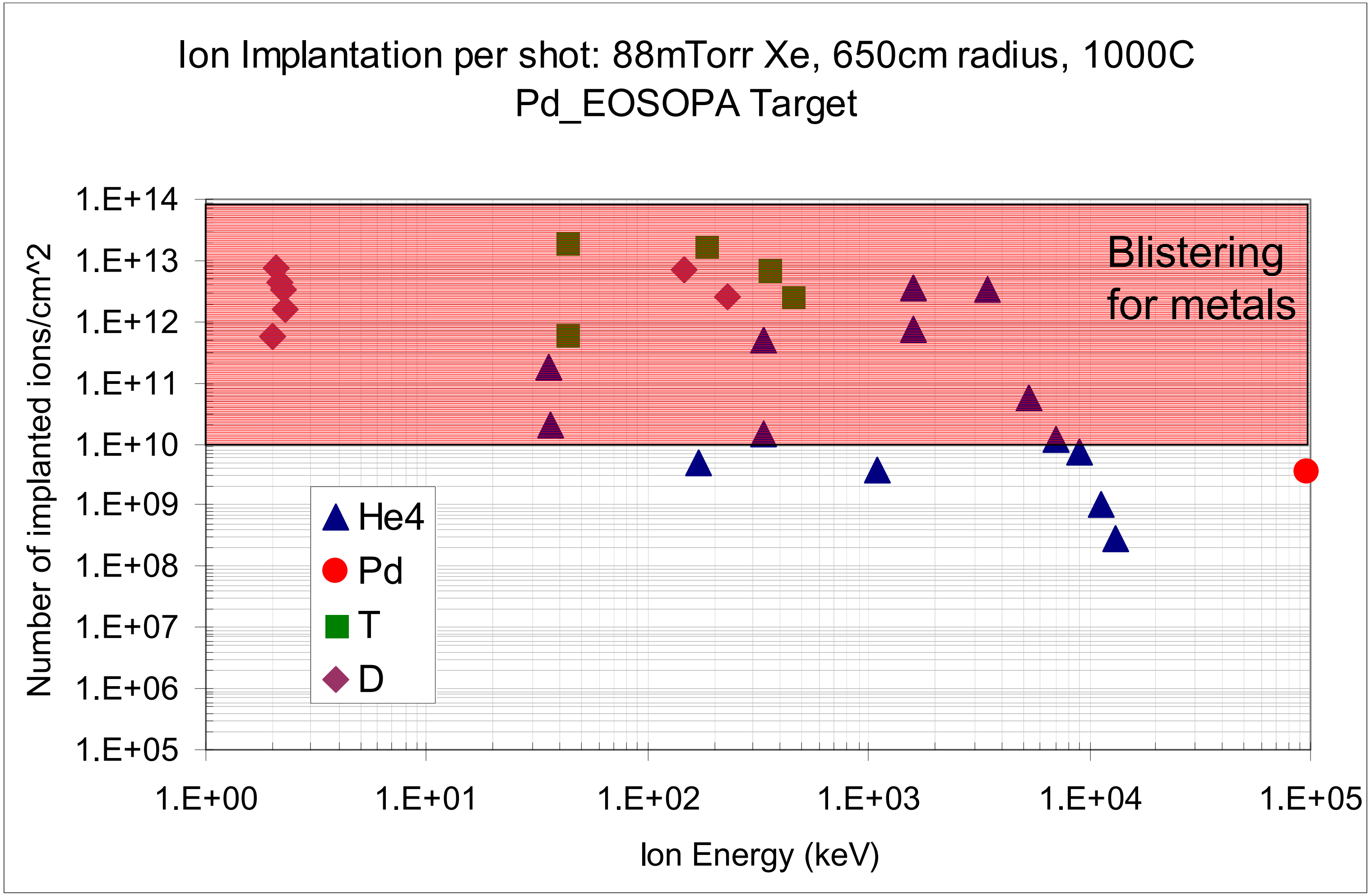
LASNEX Burn Ion Output





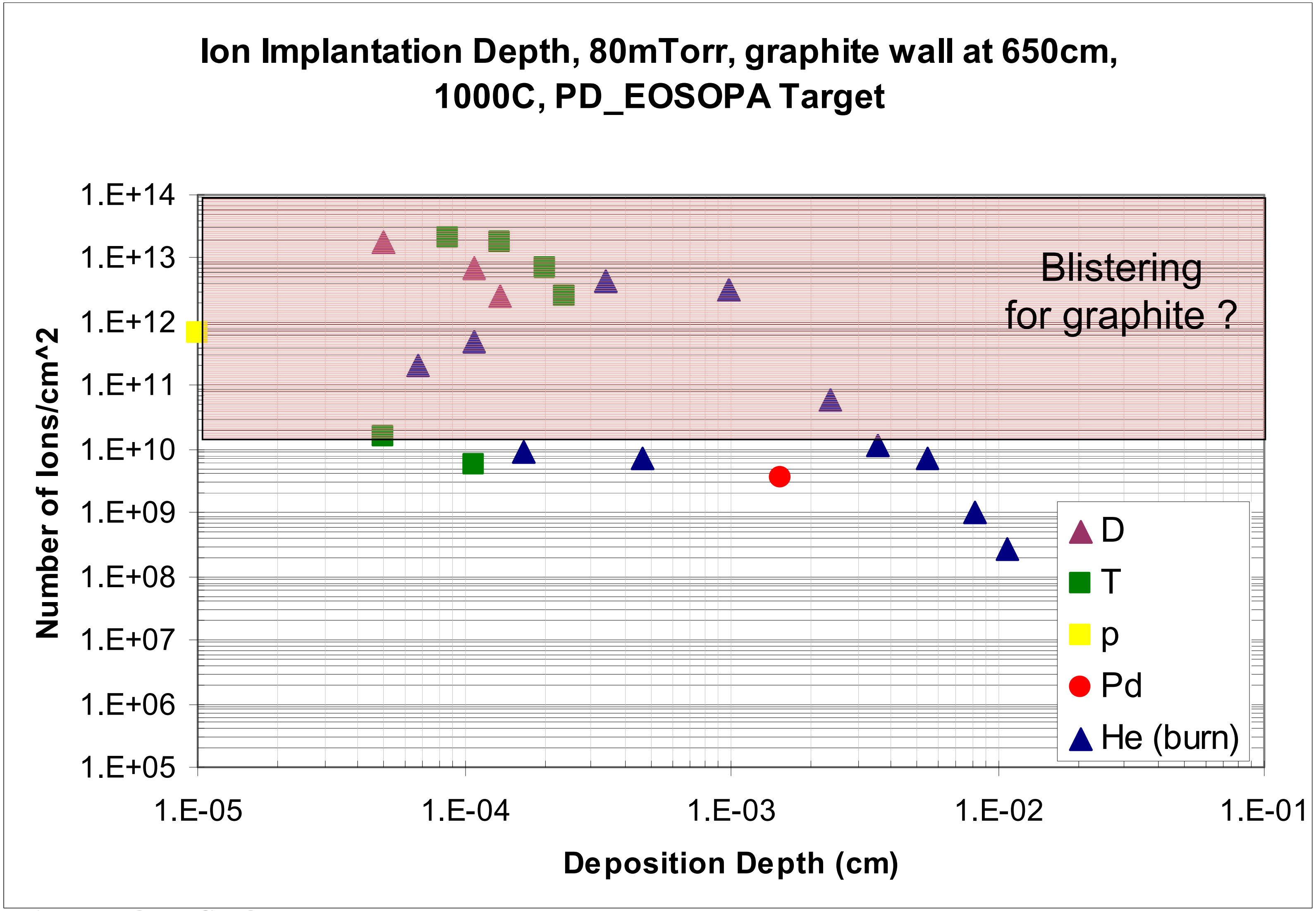
Ion	#	Total Energy (MJ)	Average Energy (keV)	Energy/amu (keV)	q/m
He4 (debris)	2.2E20	6	179	45	0.5
He4 (burn)	6.9E19	19.1	1700	425	0.5
Pd	6.1E17	2.6	27000	255	0.43
T	8.9E20	39	275	92	0.33
D	8.9E20	26	183	92	0.5
p	1.4E19	0.3	135	135	1
C	1.4E19	3.7	135	11.25	0.5

At a Xe density sufficient to prevent first wall vaporization (graphite, 6.5m, 1000C), Pd, He, T, and D ions implant in the wall.

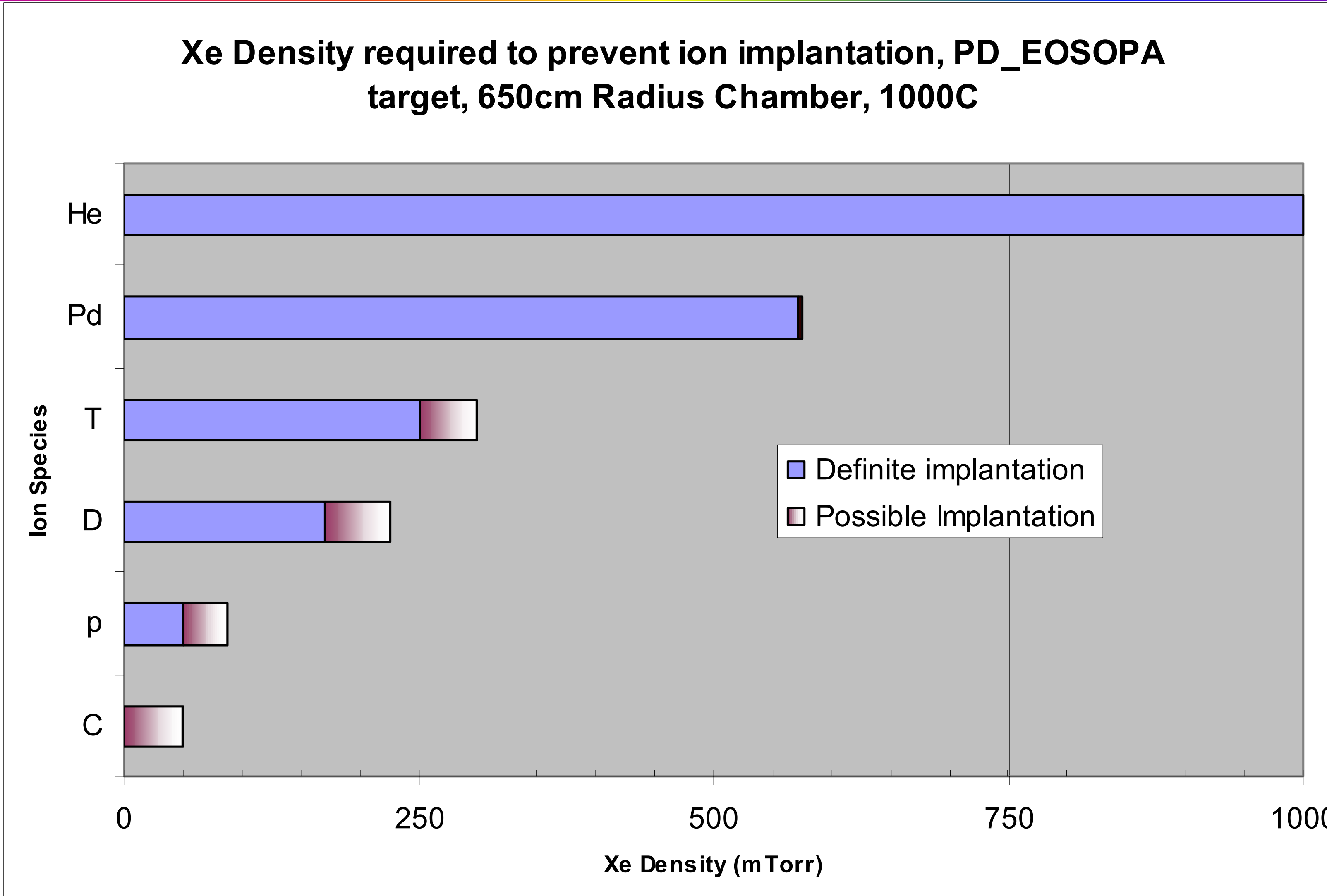


5Hz = 1.8E4/hr, 4.32E5/day, 1.3E7/month, 1.6E8/year

At the threshold Xe density for vaporization of a graphite wall at 650cm from the PD_EOSOPA target (80mTorr), ion deposition depth varies from 0.1 to 100 microns.



Different ions range out at different Xe densities.



Conclusions

- 80mTorr of Xe (not 25mTorr) is required to prevent first wall vaporization for a graphite wall at 6.5m from the threat of the Pd_EOSOPA target.
- An 8.1m radius graphite chamber wall does not sublimate for 25mTorr Xe and a starting temperature of 1000C.
- Ion implantation occurs up to remarkably high densities, with the He4 from the burn of the target requiring the most gas to prevent implantation.

Questions and Future Work

- Questions:
  - Are there other target designs that result in less energy in deeply penetrating ions, and/or are more thermally robust? A significantly thicker shell target would be one solution.
  - Can we afford to go down in yield and up in rep. rate?
  - What is the biggest size practical chamber?
  - Do H isotopes, He4 and/or Pd implantation in graphite pose a problem?
- Future Work:
  - Effect of initial wall temperature on required gas density.
  - BUCKY output calculation with finer binning of He4 burn products.
  - Radius and yield operating windows at Xe density fixed by target heating, injection constraints.

Options for Future Directions

- Assume the worst-blistering is a problem in both C-C and W
  - *Need ≈1000 mtorr of Xe which requires a more thermally robust target and/or a thicker ablator to modify burn atom spectra*
- Assume blistering is not a problem for C-C- at T> 1,000 °C
  - *Need ≈ 80 mtorr of Xe and a more thermally robust target*
- Assume blistering of C-C not problem and a ΔT>10°K possible for a 6.5 m radius chamber
  - *Then a 80 mtorr Xe gas is sufficient to protect the wall from ablation.*