

Liquid wall chambers for HIF

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[Updates contribution to chamber discussion for Accelerators for HIF, May 23-26, 2011]

Liquids are useful to mitigate effects of microexplosions

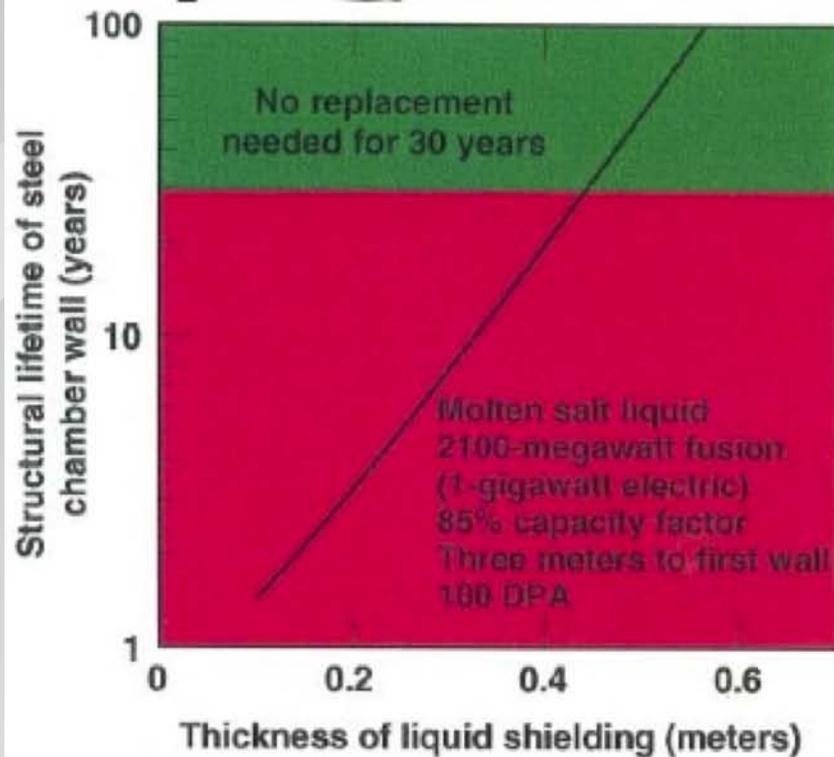
- *X rays & debris—evaporation and impulse*
- *Neutrons—isochoric heating impulse & mat'l damage*
- *Gas filled chambers handle x rays and debris for low yield high pulse rate long standoff from final optics*
- *Neutrons with gas filled chambers result in short chamber lifetime*

3000 MW = 3000 MJ/s = yield(MJ) x shot rate (#/s)

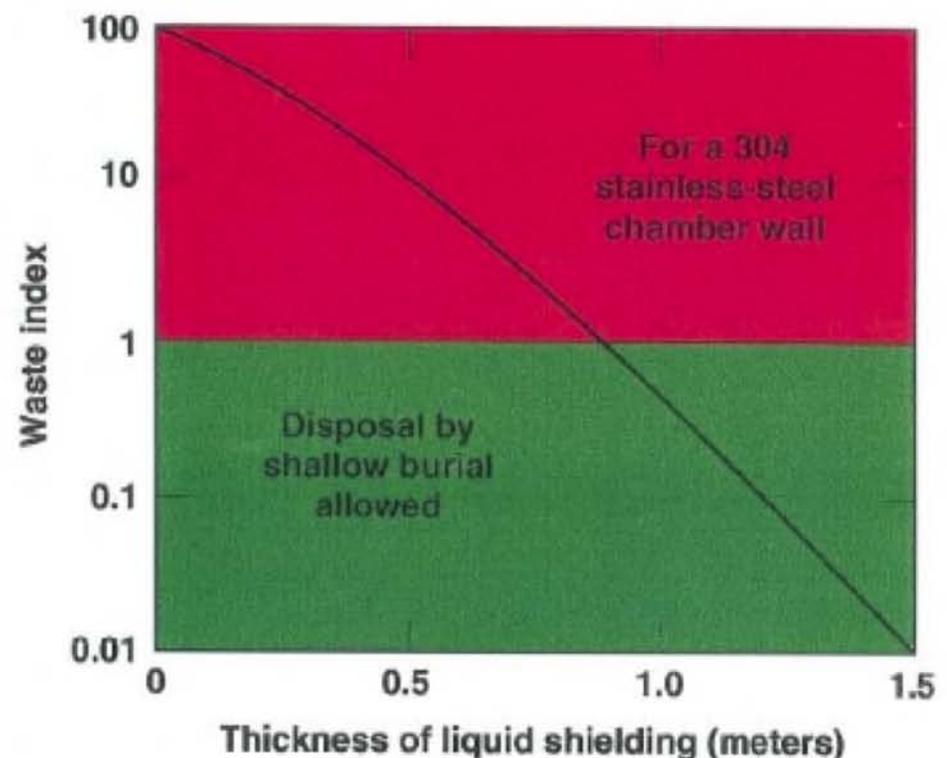
3000 MW = 3000 MJ/s; >3000 MJ; <1 shot/s); gravity clearing
<300 MJ; >10 shot/s); active clearing

Rationale for thick liquid walls

Liquid candidates: Li_2BeF_4 , Li, LiPb



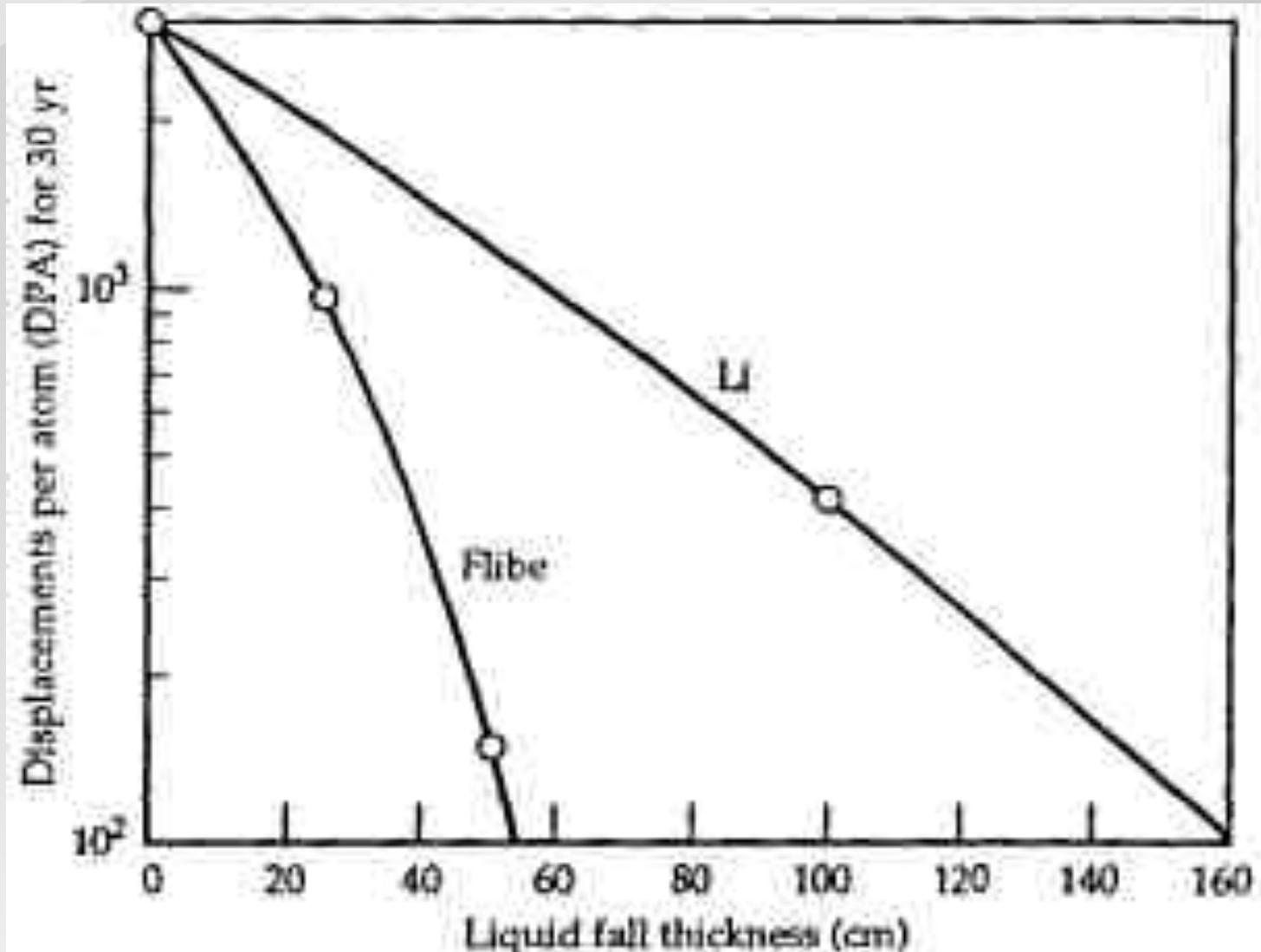
Sumer Sahin, R. W. Moir, A. Sahineslan, and H. M. Sahin, "Radiation damage in liquid-protected first-wall materials for IFE-reactors," *Fusion Technology*, 30, 1027-1035 (1996).



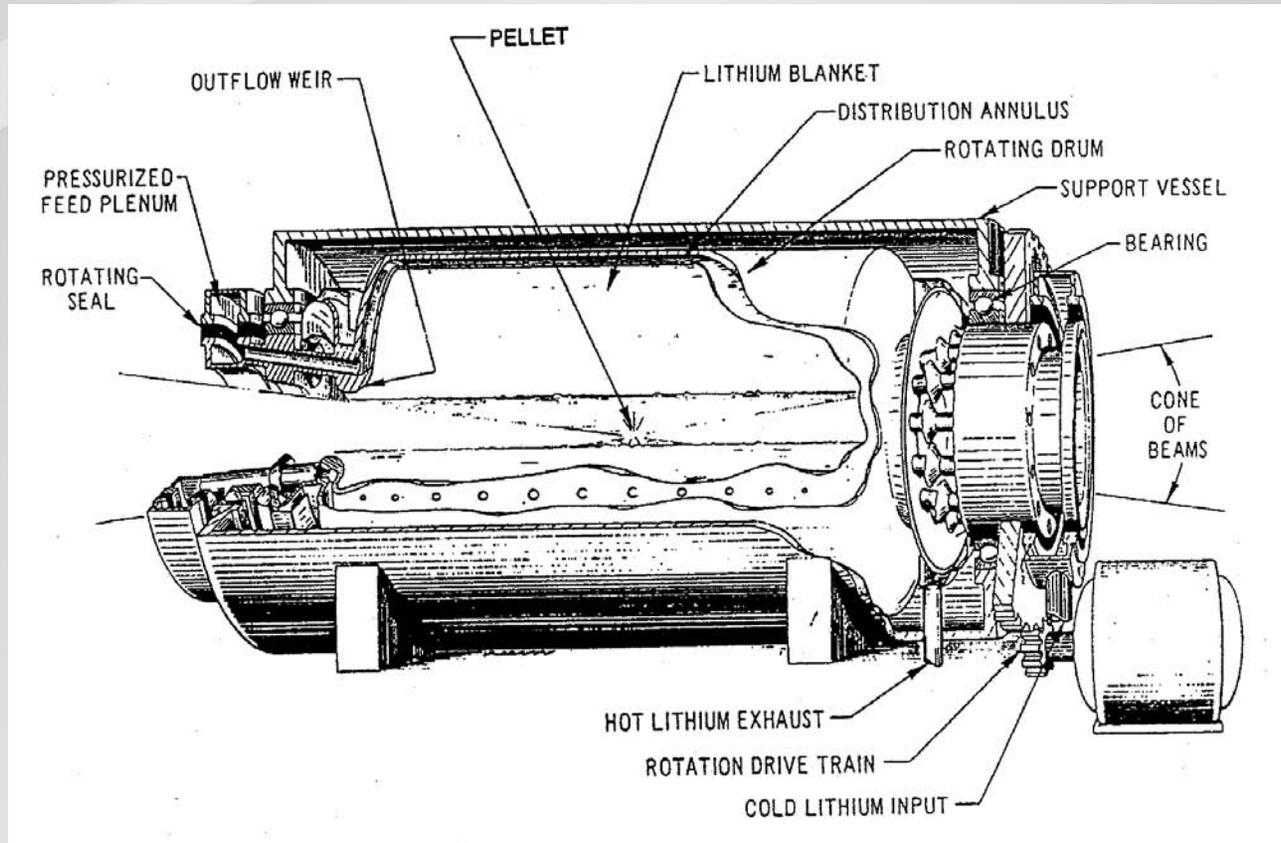
J. D. Lee, "Waste Disposal Assessment of HYLIFE-II Structure," *Fusion Technology*, 25, 74 (1994).

- 1-Life of the plant wall material
- 2-Shallow burial of plant structures at end of life

For the same damage liquid lithium being 3 times less dense must be about 3 times thicker than Li_2BeF_4

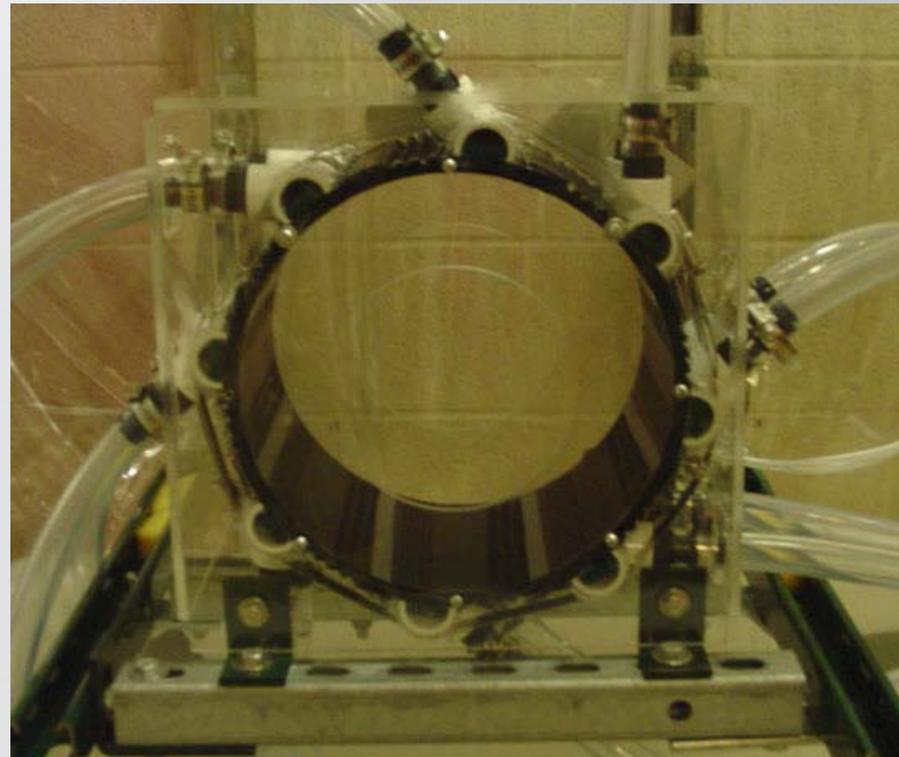
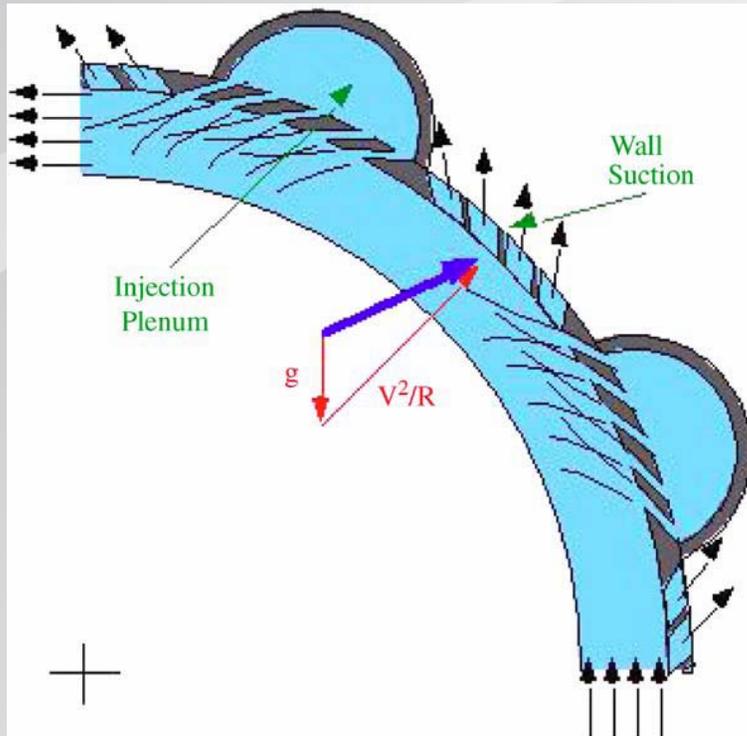


Burke proposed a spinning liquid apparatus for flowing liquid showing motors, seals, etc,



R. Burke, "The Argonne heavy-ion-beam reactor using a centrifugal blanket," in Heavy Ion Fusion (Proc. Workshop Argonne, 1978, Rep. ANL-79-41, Argonne National Laboratory, II. (1979) 5.

UC Berkeley worked on modeling and experiments in support of vortex chamber concept (no moving parts)

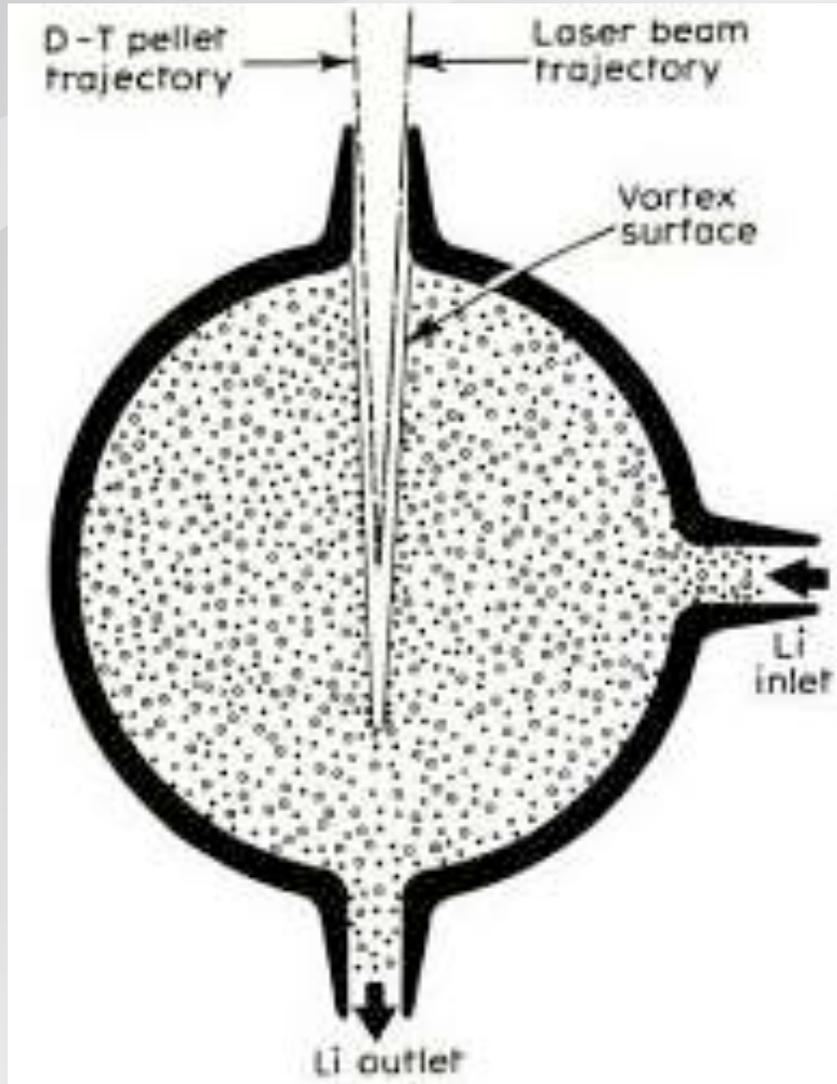


Per F. Peterson, Philippe M. Bardet, Christophe S. Debonnel,
Grant T. Fukuda, Justin Freeman, Boris F. Supiot

Vortex chamber exp
Dia. = 20 cm

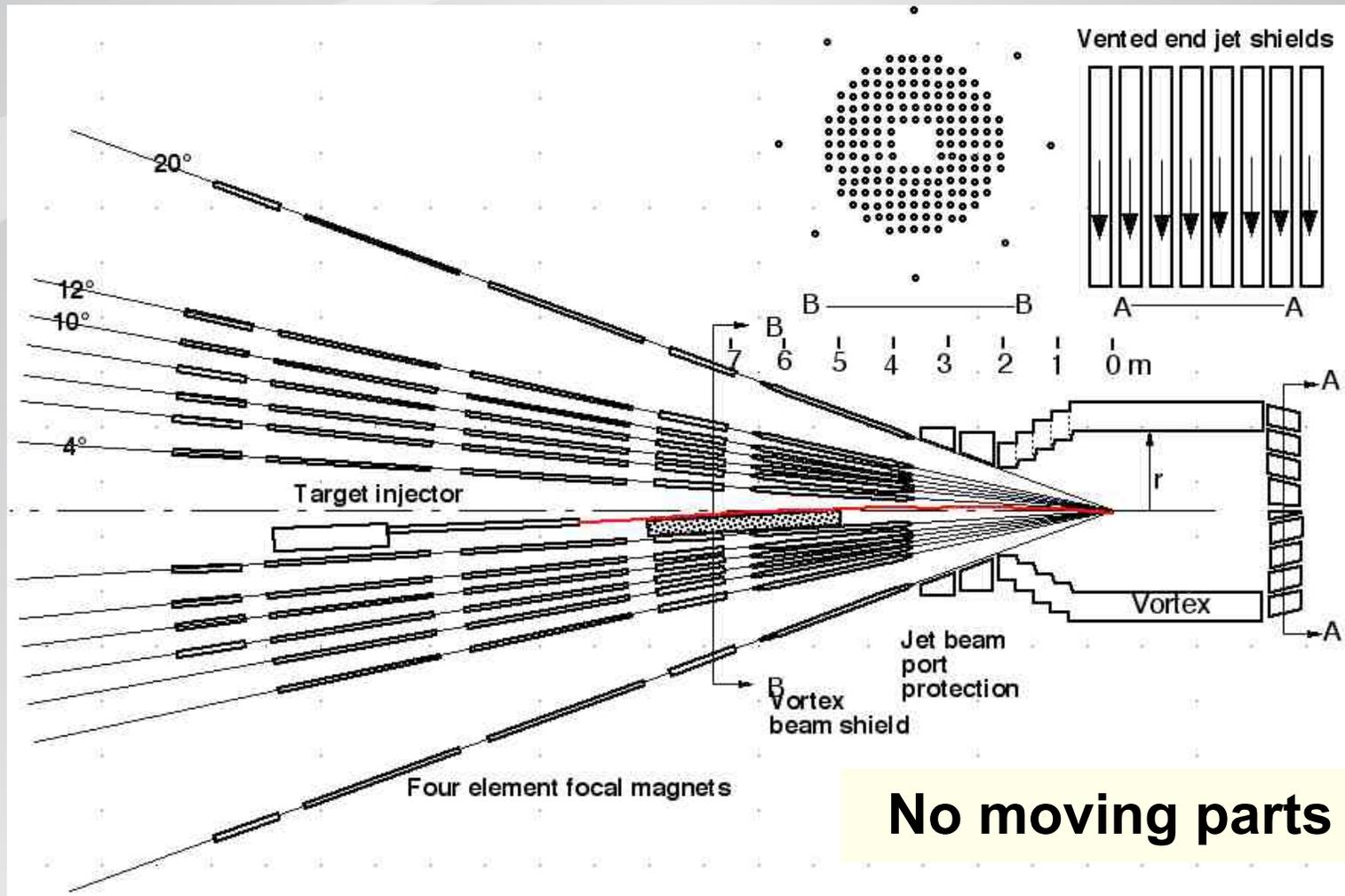
Blascon, a liquid lithium vortex chamber

Art Fraas



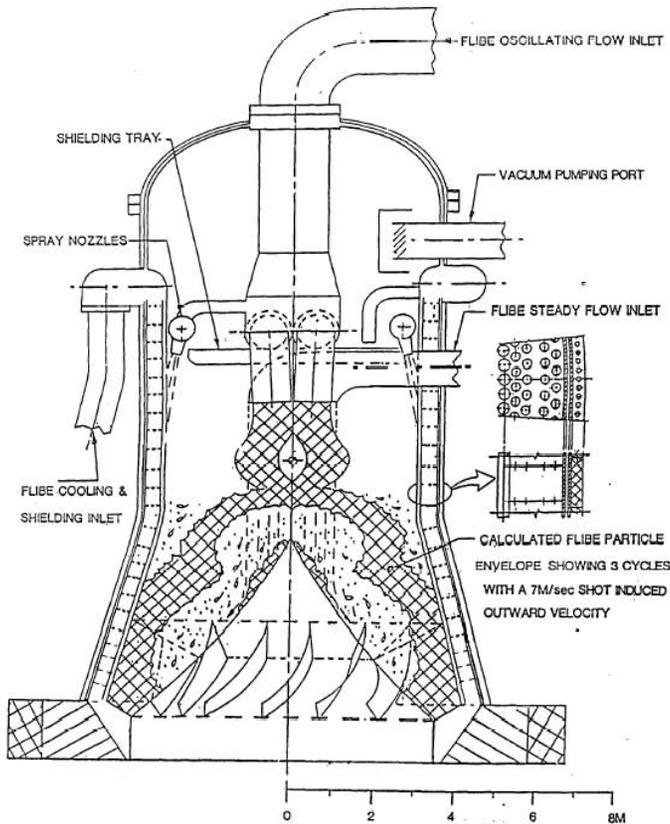
- ❑ Gas bubbles reduce water-hammer effect, stress on outer wall is reduced.

Liquid jets and a vortex chamber protect solid structures for the life of the plant



Final optics protection is important

HYLIFE-II is a thick liquid wall chamber design for heavy ion fusion (HIF)

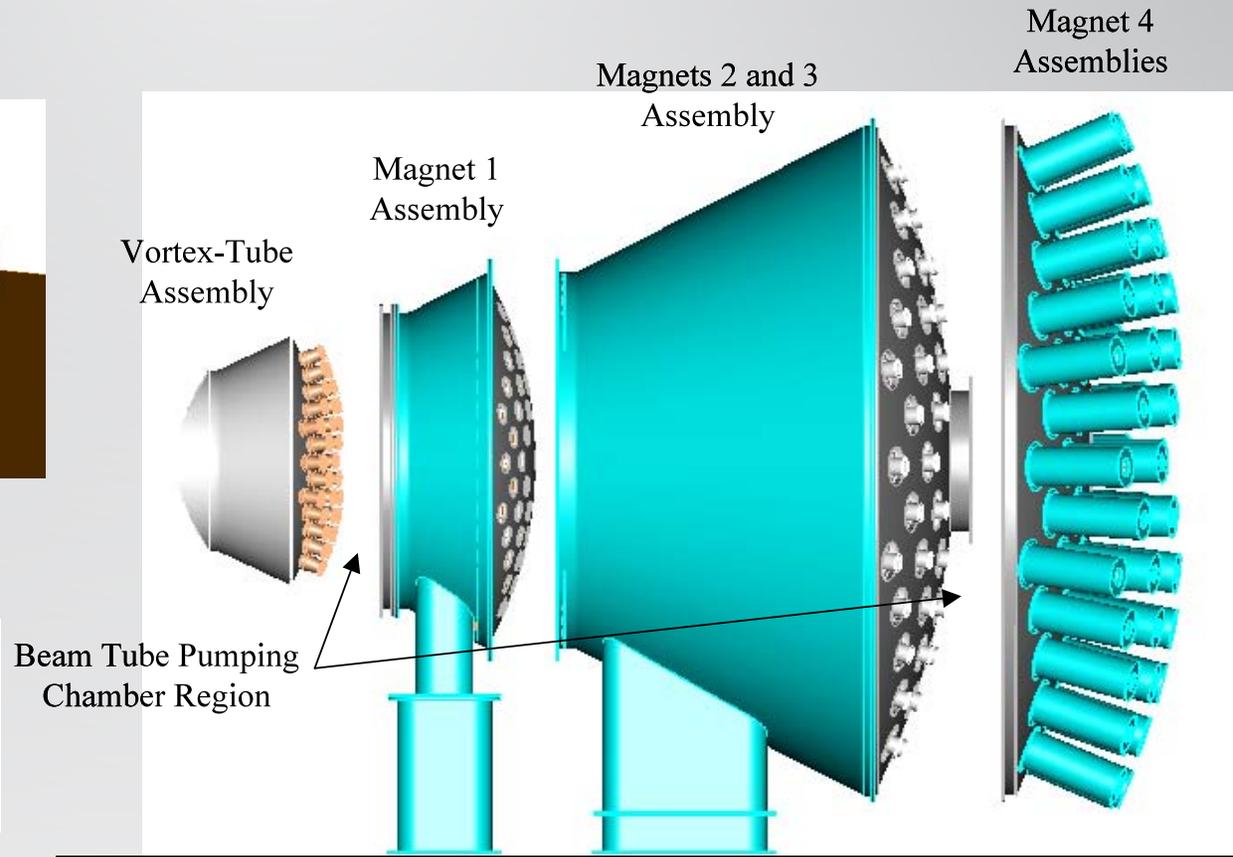
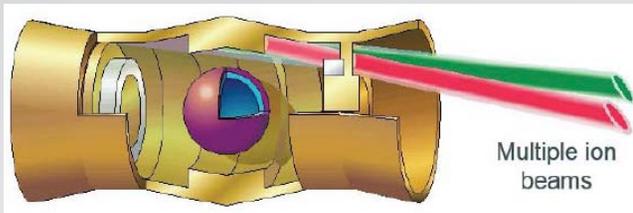
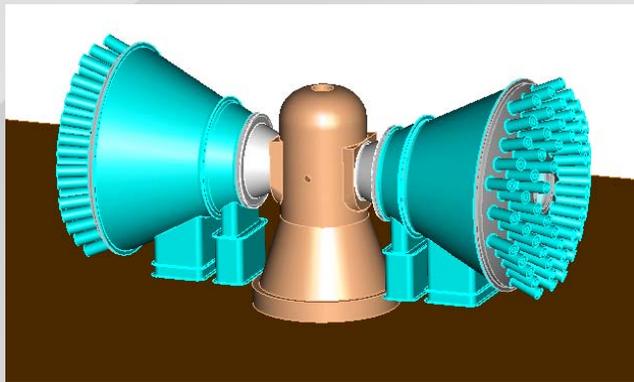


Cross section of HYLIFE-II chamber
FW radius = 3 m

Indirect drive targets, multi-beam
induction linac driver
Liquid is molten salt – flibe or flinabe
Effective shielding thickness is 56 cm
Chamber is lifetime component
Oscillating jets dynamically clear droplets
near target (clear path for next pulse).
Allowed compact chamber, short beam
propagation distance
High temperature molten salt coolant
gave good thermal efficiency (44%)
Final focus magnets shielded from
neutrons and predicted to be lifetime
components

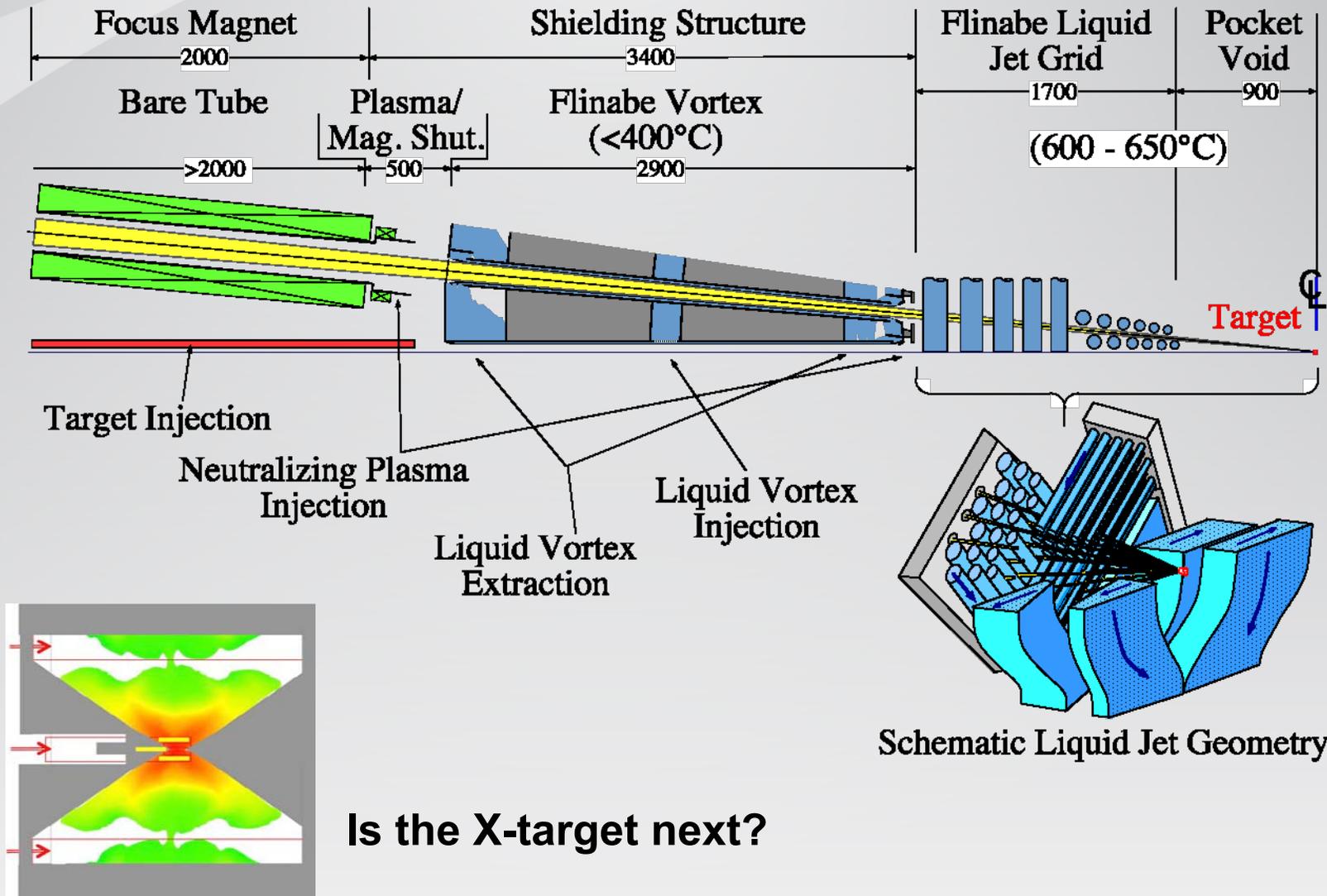
Ref. - S.S Yu et al., Fusion Science and Technology, 44,
No.2, 266 (2003).

Integration of the chamber, target and final optics is a big deal!



Robust Point Design did this.

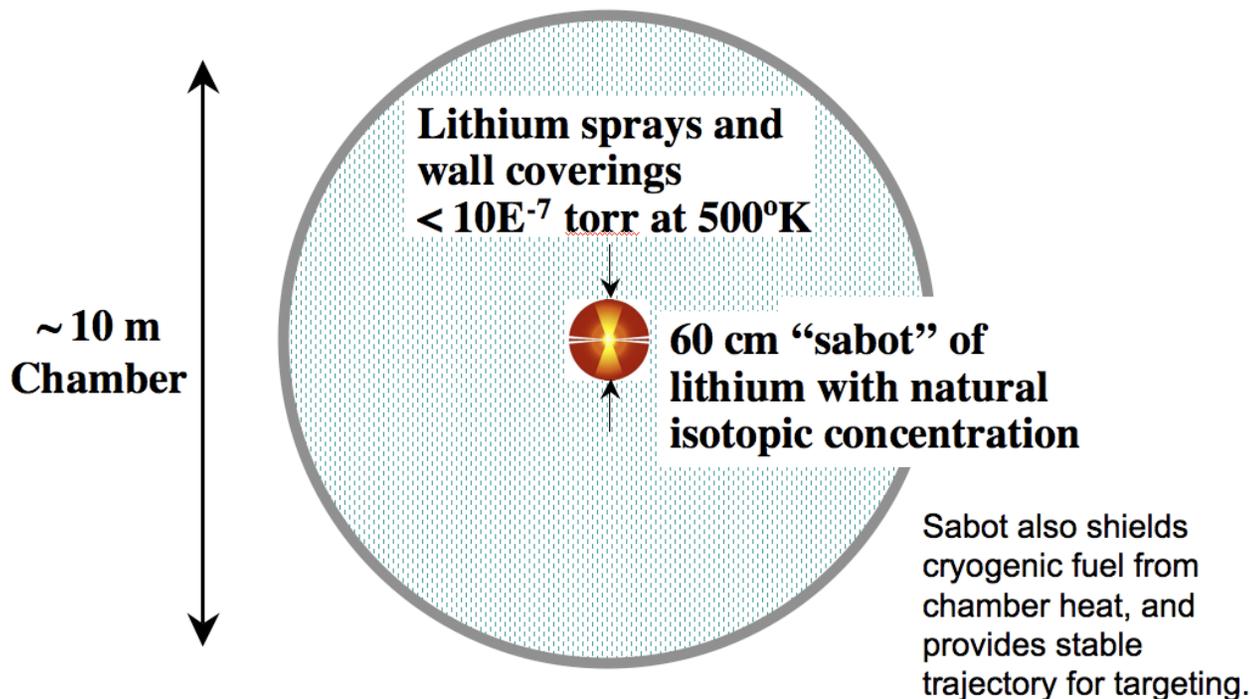
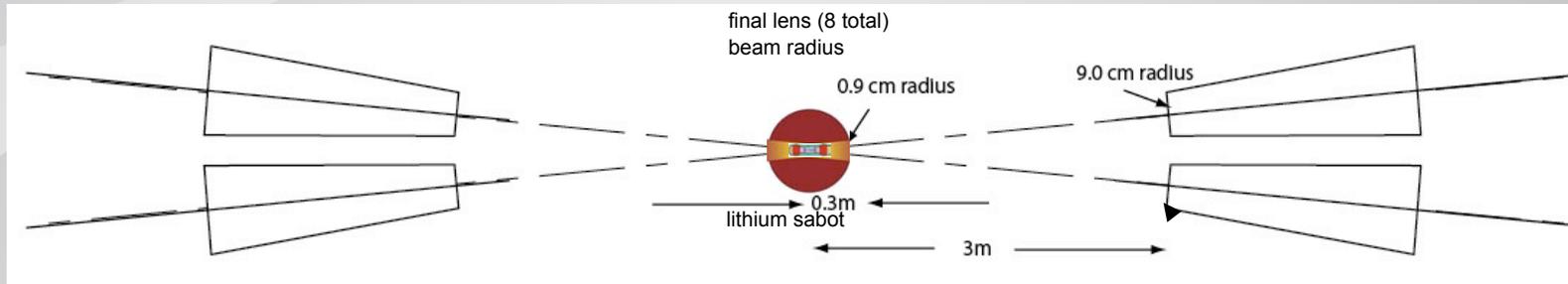
Liquid protected final optics needs small half-angle



Burke's Fusion Power Corp design uses liquid Li

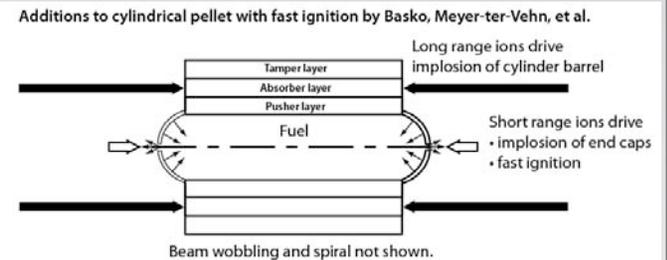
Final optics shield at 3 m

30 cm of Li around target



**Shield
at only 3 m!**

Sabot also shields cryogenic fuel from chamber heat, and provides stable trajectory for targeting.



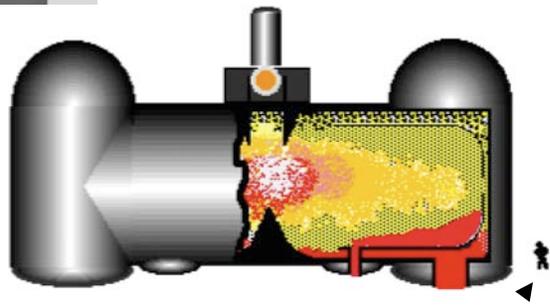
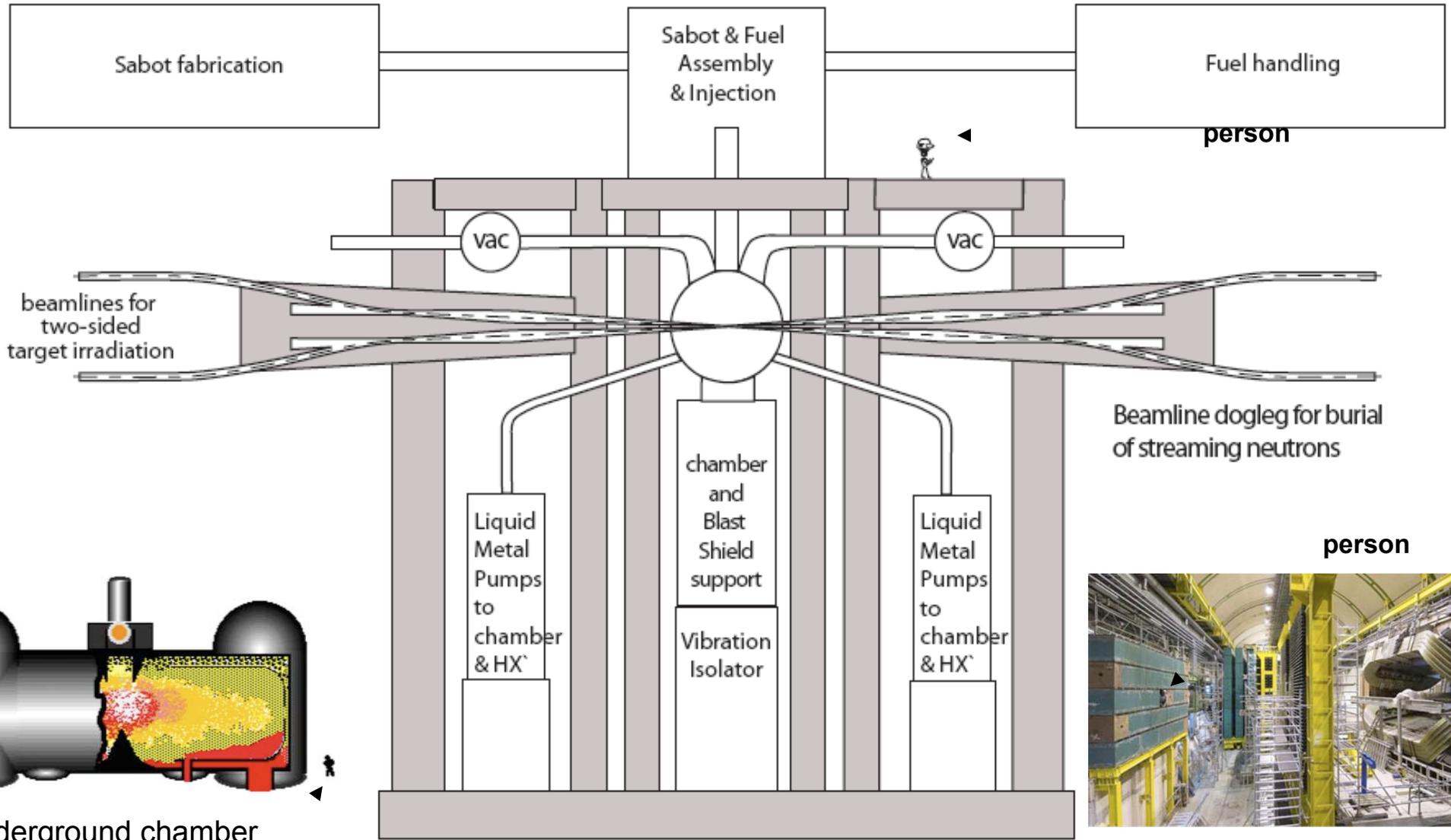
Short-range ions burn through blow-off (or casing on axis) to assist penetration for Fast Ignition.

Additional features use beams with substantially different stopping ranges, which is enabled by Telescoping Beams of Multiple Isotopes.

R. Burke and J. Cutting, Argonne National Laboratory, 1974
Transactions IEEE, Spring 1974

Chamber Vault

design factors: Neutrons, Fire, Availability, Maintenance



Underground chamber

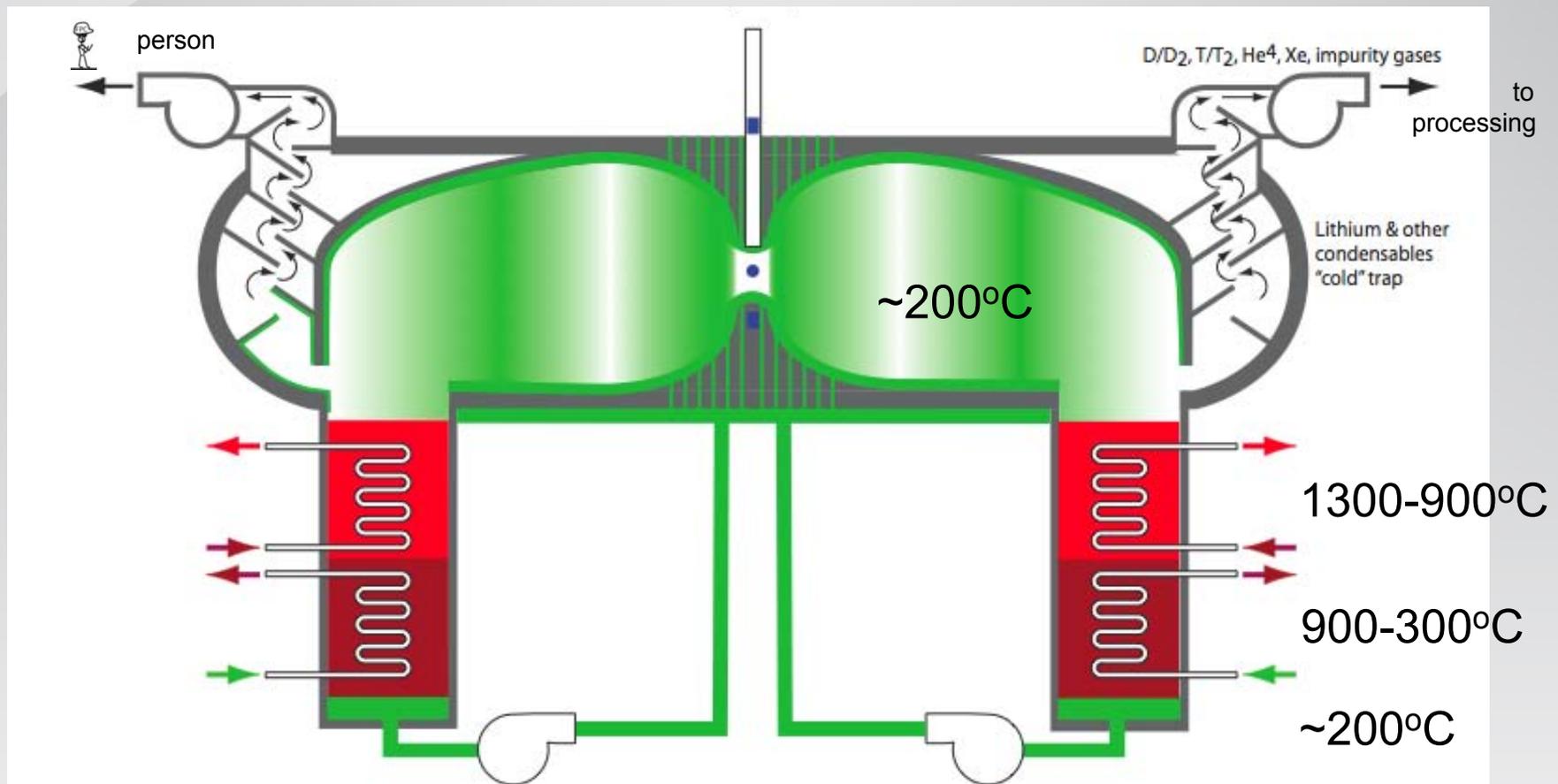
person



High energy physics detector vault
CERN - LHC

Chamber Functions: Ready to Pulse

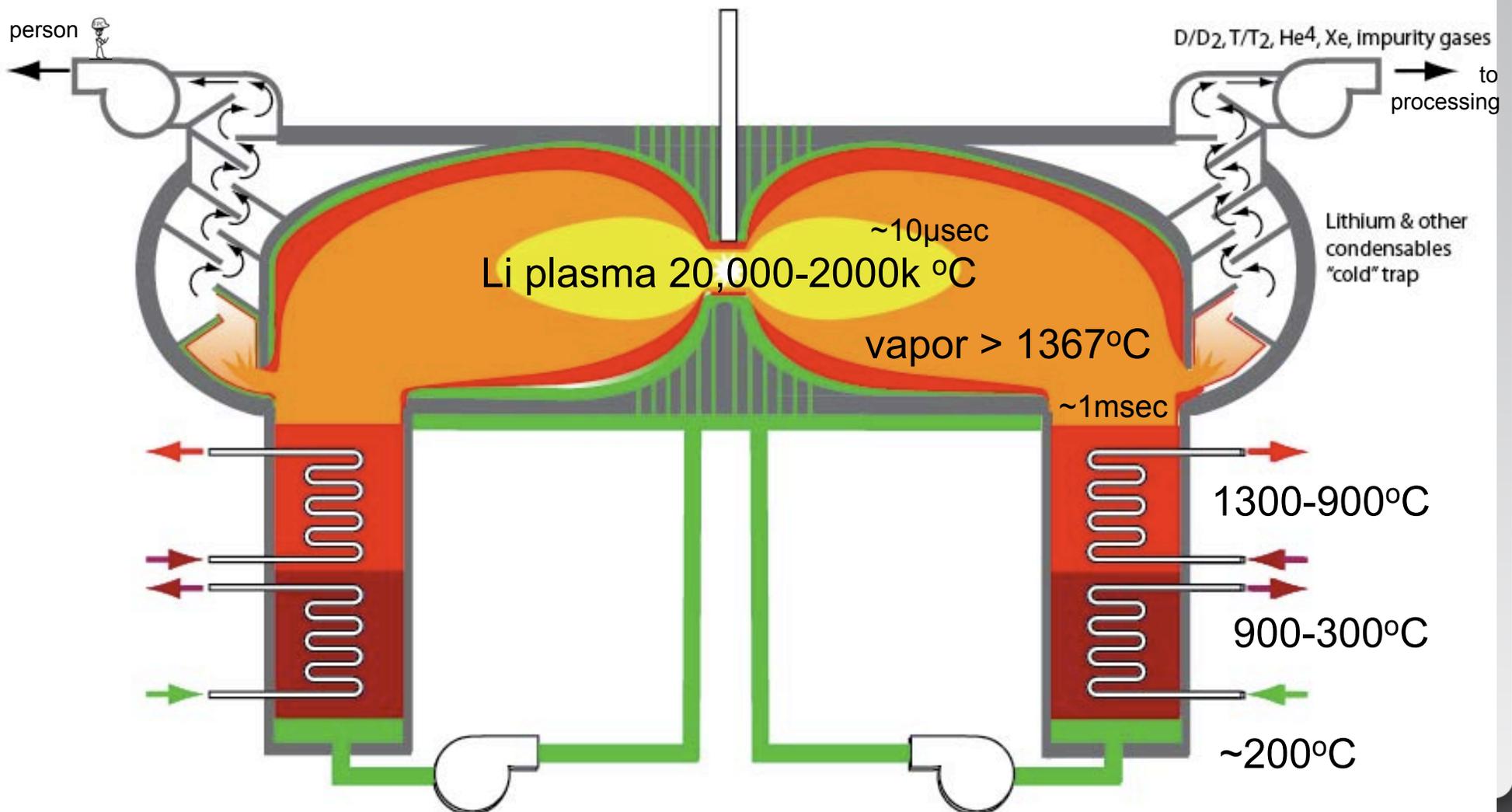
- Vacuum restored for ion beam
- Lithium deployed to handle neutrons and blast
- Fuel charge in position



Chamber Functions: Handling energy

- Conducting high temperature heat to exchangers
- Maintaining low wall temperature
- Evacuating gases
- Starting injection of next fuel assembly

energy propagation to heat exchanger



FPC Chamber Functions

- Safe confinement of fusion energy and tritium
- Protect vessel materials from neutrons
- Reestablish vacuum for ignition beam propagation
- Deliver high temperature heat* to heat exchangers
- Chamber materials at low temperature*
 - Cooled by lithium incoming $\sim 20^{\circ}\text{C}$ above 185°C melt point
 - Low chamber erosion
 - Push HX per normal engineering and economics practice
 - Nb-Zr tubing good for 1300°C lithium¹
- Unique to FPC concept

1. "Development of Advanced High Temperature Heat Exchangers", proposal to U.S.D.O.E., Office of Nuclear Energy, Science & Technology, by University of Nevada, Las Vegas Research Foundation July 11, 2003

Conclusions

- **Liquid wall chambers are there for HIF**
- **They require demanding integration of target and final optics with chamber**
- **Final optics stand-off distance is a super important parameter**
- **Multiple options exist: vortex, droplets, oscillating and stationary jets,**
- **Hydraulic design called for**

HIF needs a target design and integrate with chamber and final optics