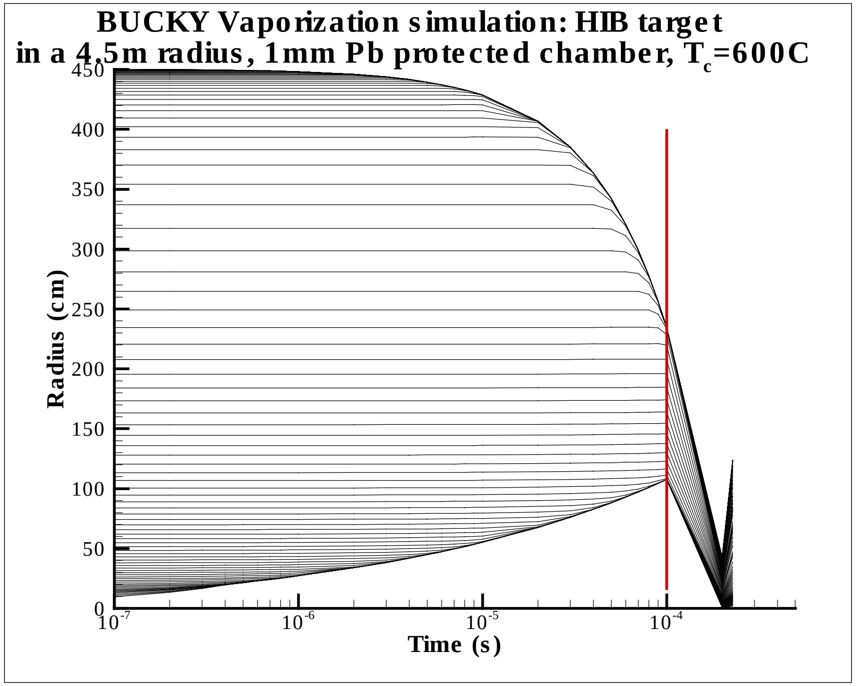
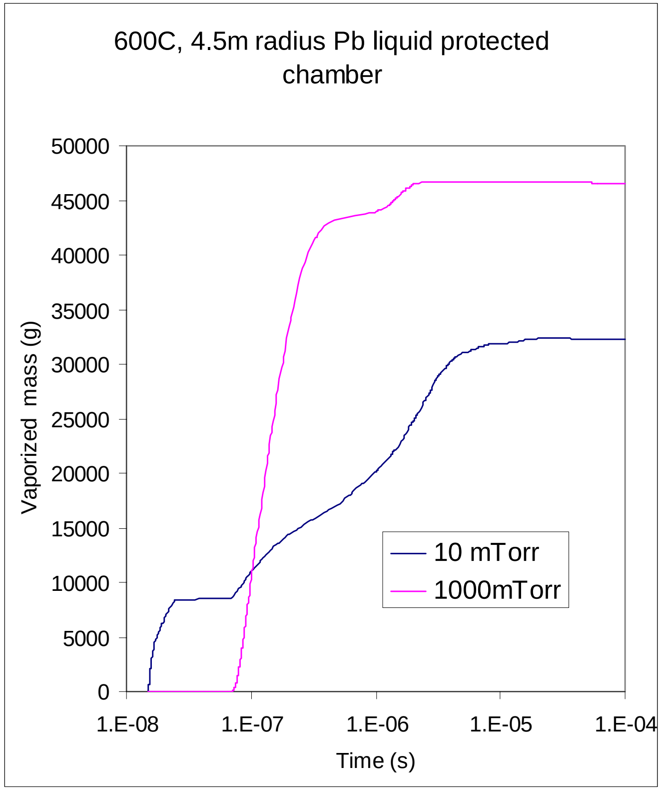
Results from parametric studies of thin liquid wall IFE chambers


BUCKY Vaporization simulation: HIB target in a 4.5m radius, 1mm Pb protected chamber, T_c=600C


600C, 4.5m radius Pb liquid protected chamber

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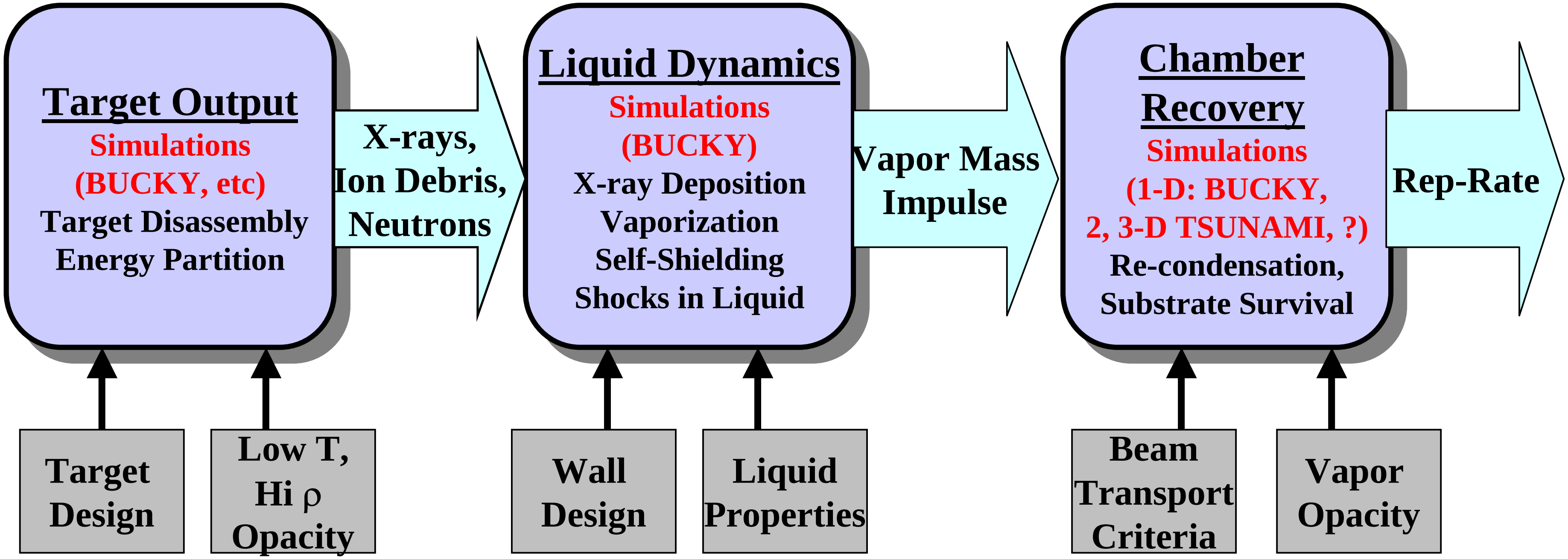
Summary/Outline

We present results from a set of BUCKY simulations of the response of a thin liquid wall chamber to the threat spectrum of the C/C HIB target. Parameters considered were wall material (Pb or FLiBE), vapor composition (Xe or vapor from the liquid) and vapor pressure. All variations considered lead to acceptable chambers from the point of view of ion deposition, vaporization thickness and condensation rates, though these simulations do not include the effects of splashing or aerosolization.

- Wall material (Pb or FLiBe)
- Vapor pressure (10mTorr or 1000mTorr)
- Vapor composition (Xe or wall material)
- Conclusions and future work
- Old business: dry wall strawman results

Wetted-Wall Chamber Physics Critical Issues Involve Target Output, and First Wall Response



Target Output
Simulations
(BUCKY, etc)
Target Disassembly
Energy Partition

X-rays,
Ion Debris,
Neutrons

Liquid Dynamics
Simulations
(BUCKY)
X-ray Deposition
Vaporization
Self-Shielding
Shocks in Liquid

Vapor Mass
Impulse

Chamber Recovery
Simulations
(1-D: BUCKY,
2, 3-D TSUNAMI, ?)
Re-condensation,
Substrate Survival

Rep-Rate

Target Design

Low T,
Hi ρ
Opacity

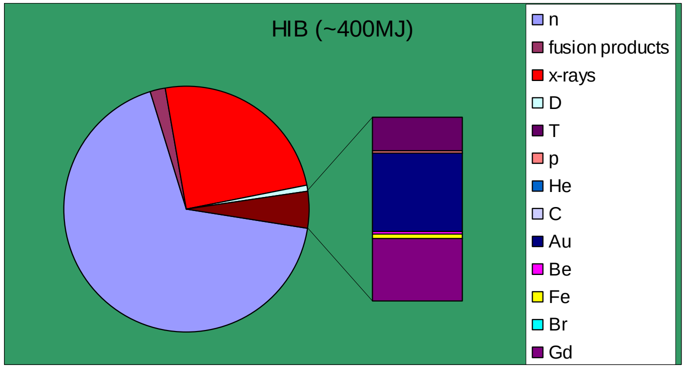
Wall Design

Liquid Properties

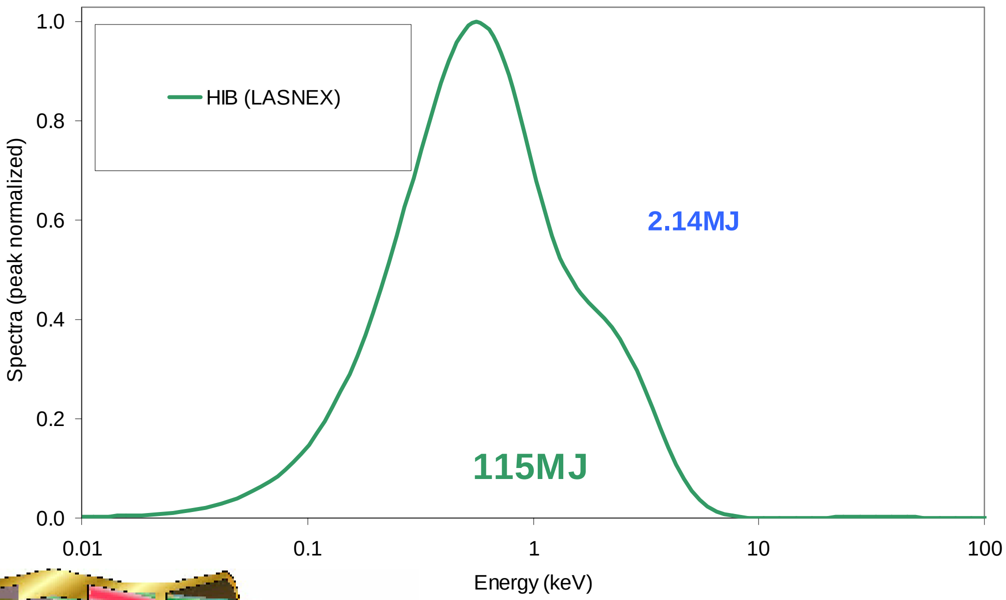
Beam Transport Criteria

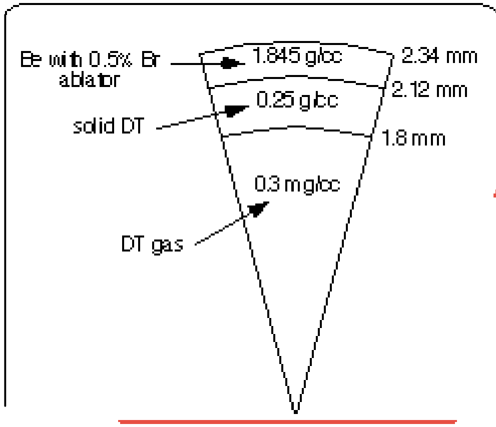
Vapor Opacity

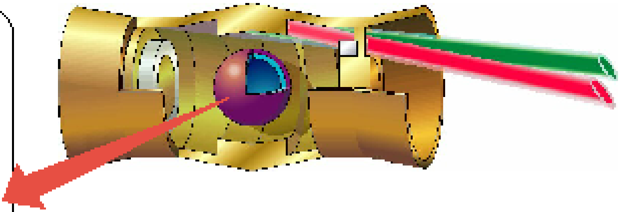
This talk concentrates on the effects of the threat from the closely coupled HIB target. The threat is predominantly from the soft x-rays produced by the interaction of capsule output and the massive hohlraum



Target output x-ray spectra





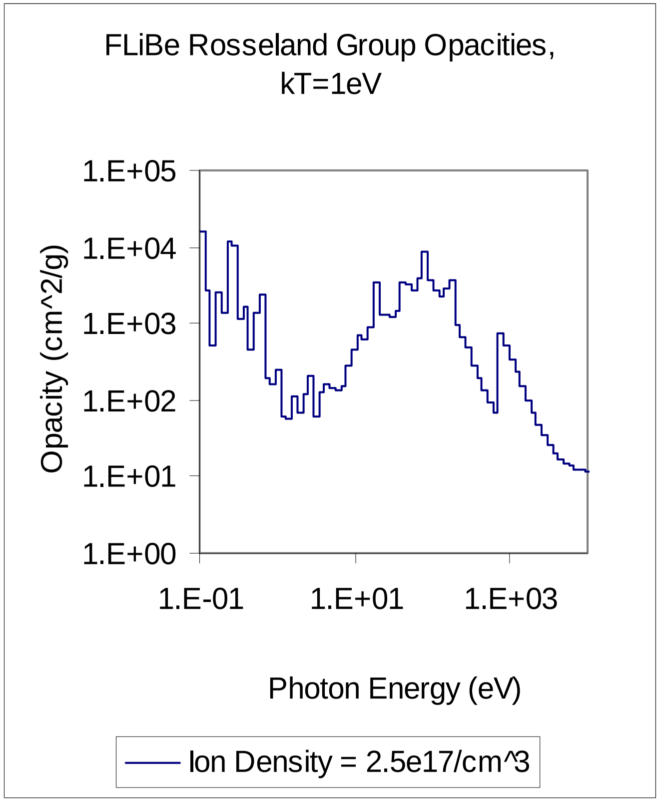


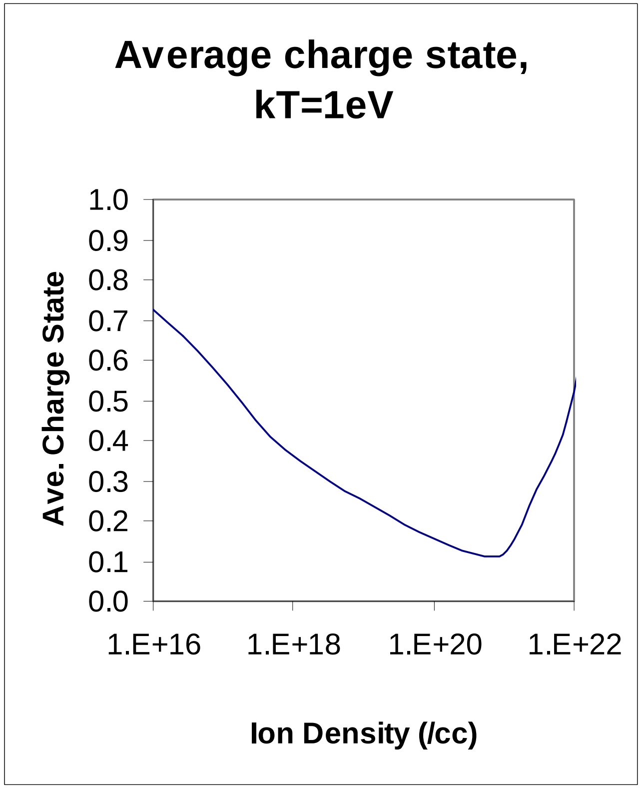
Ion beam characteristics:

- 3.5 GeV Pb+ ions
- 3.3 MJ input energy
- 1.7 mm effective radius spot

Though this target is not currently being emphasized by the HIB target community, its threat spectrum should be grossly similar to the more likely contenders. As this target is the only one for which we have detailed threat spectra, we use it a representative.

We have generated relevant FLiBE opacity and equation of state



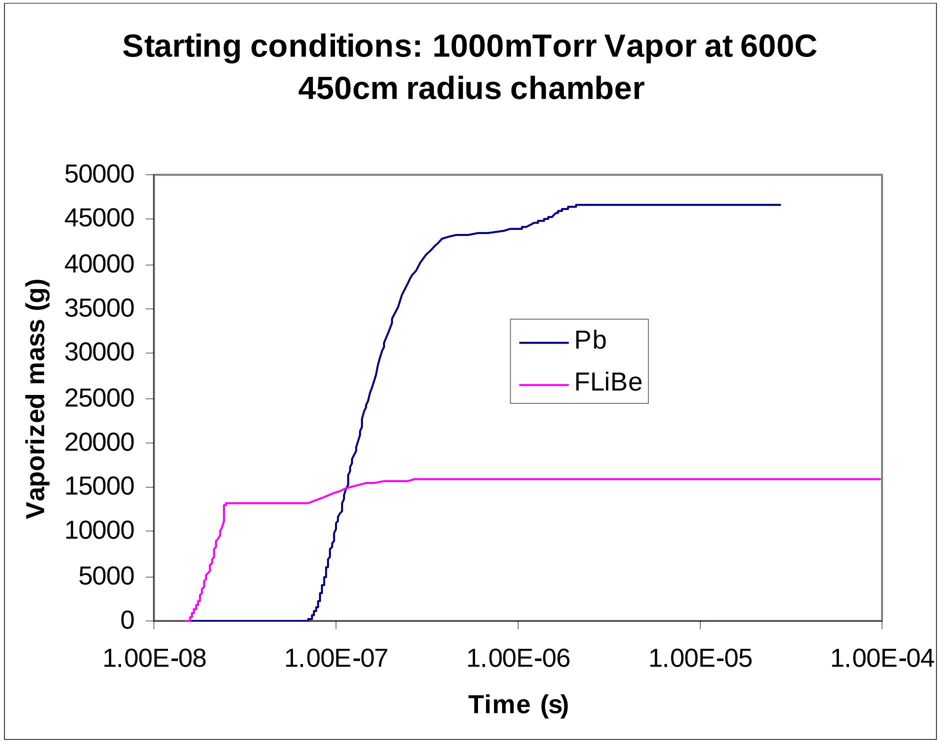


Calculations performed using DTAOPA, a detailed transition accounting, NLTE version of EOSOPA

FLiBe is considerably more transparent to the target x-rays than is Pb. This leads to more volumetric heating of the liquid, and less shielding by the chamber vapor and the superheated vapor.

As of 0.1ms after implosion:

- X-ray energy absorbed in vapor:
  - FLiBe: 36MJ
  - Pb: 114MJ
- Energy re-radiated to the wall:
  - FLiBe: 16MJ
  - Pb: 60MJ


Starting conditions: 1000mTorr Vapor at 600C
450cm radius chamber

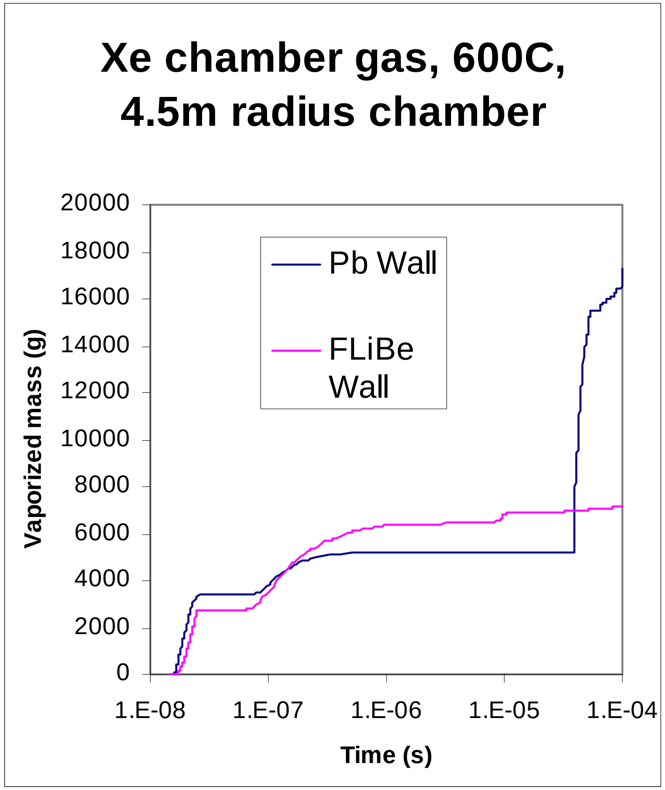
A hybrid design using both a chamber gas chosen for beam transport and a thin liquid wall chosen to protect the first wall is conceivable: 1000mTorr Xe

As of 0.1ms after implosion:

- X-ray energy absorbed in vapor:
  - FLiBe wall: 78MJ
  - Pb wall: 111MJ

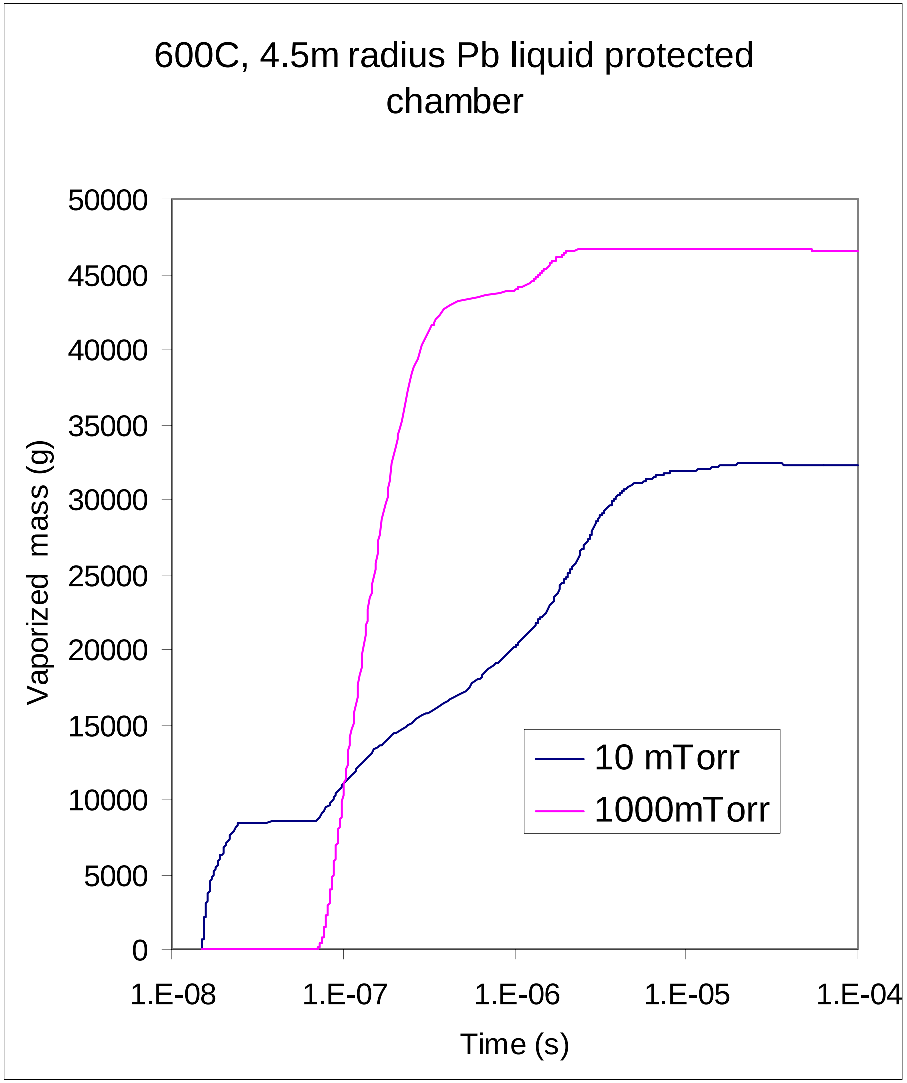
(Blow-off is treated as vapor for this purpose. Note that the Pb created early in the pulse better shields the wall from the end of the pulse.)

- Energy re-radiated to the wall:
  - FLiBe wall: 25MJ
  - Pb wall: 31MJ

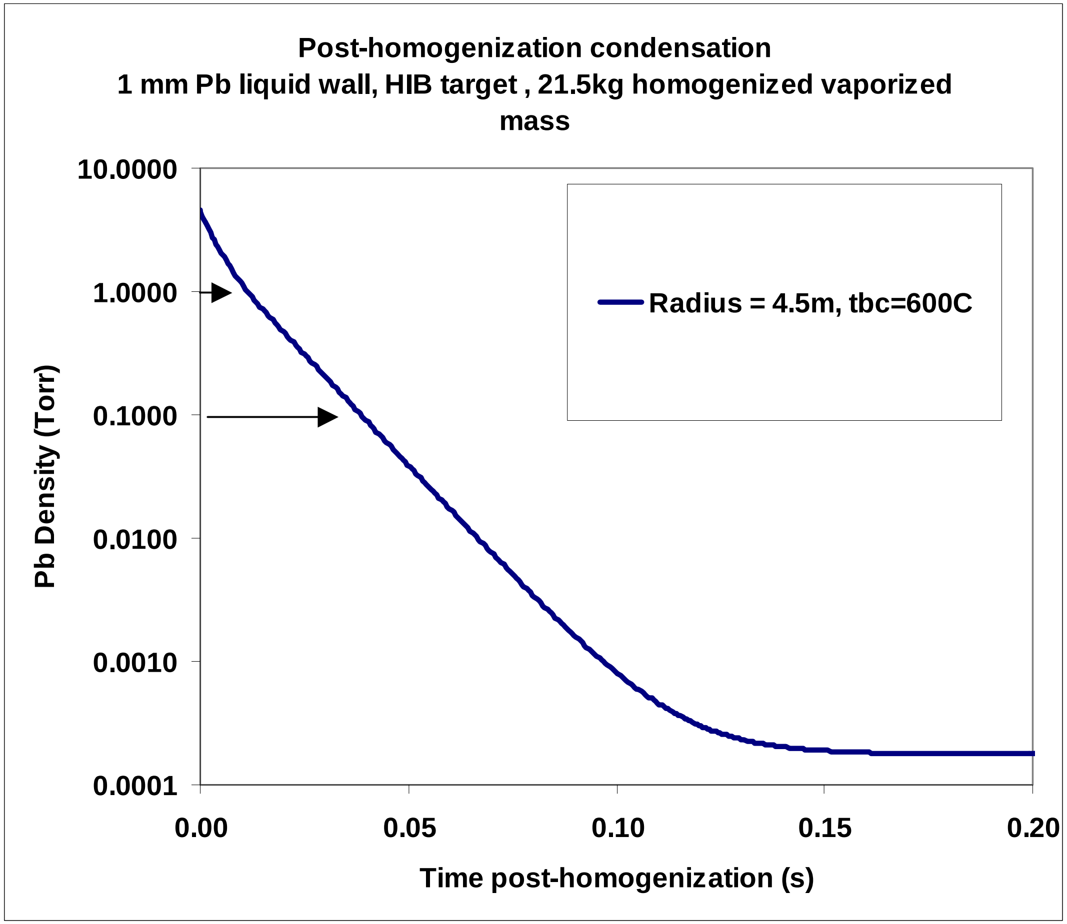


Different driver transport beam transport methods require different pressure of chamber gas. Last meeting we looked at 1mTorr. Here, we look at 10mTorr and 1000mTorr.

- The lower Pb chamber pressure actually results in less vaporized mass at the end of 0.1ms. This is due to the effect of soft, re-radiated energy due to ions and x-rays absorbed in the chamber gas.
- Re-radiated energy:
  - 10mTorr: 36MJ
  - 1000mTorr 60MJ



BUCKY does not include the effects of aerosol formation nor splashing. We have handed off early time, post flash chamber conditions to Phil Sharpe, who will report on his analysis of aerosol issues later this meeting.

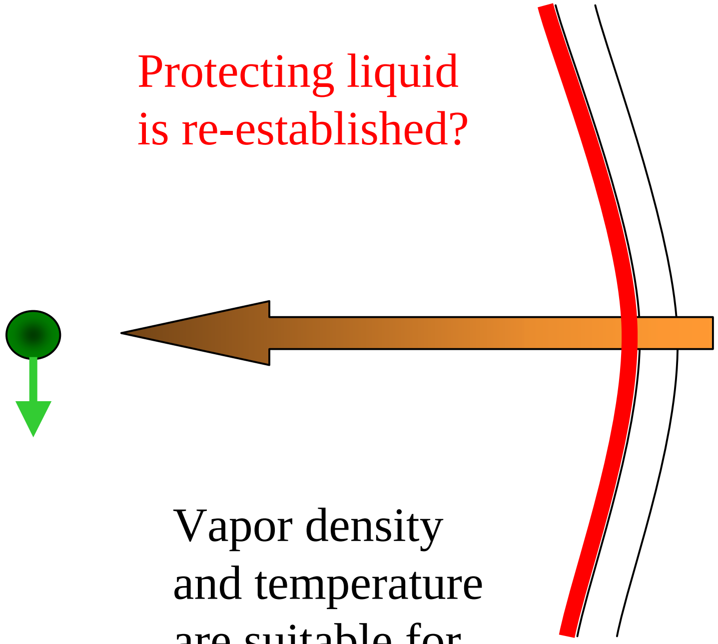


Plan of attack from last meeting:

- "Homogenize" chamber, converting bulk kinetic energy into thermal energy.
- Start condensation run from these conditions.
- Geometry dependent uncertainty: how long does it take to homogenize, and will there be any x-ray pulse produced by stagnation on axis?

Re-establishment of conditions suitable for target injection: do drops of aerosol remain?

t ~ 100-500 ms



Protecting liquid is re-established?

Vapor density and temperature are suitable for beam transport and target injection?

•We need to decide on the parameters space in which we want to identify operating windows, and what constitutes an acceptable design:

•Target Output

•Driver/Transport Method

•Radius

•Liquid

•Wall temperature

Summary/Conclusions

- For the 4.5m radius chamber assaulted by the C/C HIB target:
    - All of the combinations of chamber gas, pressure, and wall considered lead to 10s of kilograms of mass vaporized at the end of 0.1ms.
    - Based on results presented last time, and <u>absent splashing and aerosolization</u>, recondensation should proceed quickly enough to maintain a 5Hz rep. rate.
    - More vapor does not necessarily provide more protection to the first wall, due to soft re-radiation with no time of flight spreading.

We present results from a set of BUCKY simulations of the response of a thin liquid wall chamber to the threat spectrum of the C/C HIB target. Parameters considered were wall material (Pb or FLiBe), vapor composition (Xe or vapor from the liquid) and vapor pressure. All variations considered lead to acceptable chambers from the point of view of ion deposition, vaporization thickness and condensation rates, though these simulations do not include the effects of splashing or aerosolization.

Dry Wall Strawman Results

	DD Target (LY)	DD Target (HY)	ID Target 1	ID Target 2
Driver	KrF Laser	KrF Laser	Heavy Ion Beam	Heavy Ion Beam
Driver energy (MJ)	1.2	2.9	3.3	6
Driver efficiency (%)	7	7	25	47
Repetition rate (Hz)	14.2	5.3	4	4.9
Target	NRL Direct-Drive Target	NRL Direct-Drive Target	HI Indirect-Drive Target	HI Indirect-Drive Target
Gain	128	138	139	63
Target yield (MJ)	154	400	458	378
Spectra	From J. Perkins' calc.	From J. Perkins' calc.	From J. Perkins' calc.	N/A
Photon energy (MJ)	2.14	6.07	115	
Burn product fast ion energy (MJ)	18.1	52.2	8.43	
Slow ion energy (MJ)	24.9	60.0	18.1	
Neutron energy (MJ)	109	279	316	
Gamma energy (MJ)	0.0046	0.0169	0.36	
Injection velocity (m/s)	400	400	100	
Initial temperature (K)	18	18	18	
Calculated D-T temperature rise (K)	Š1.8	Š1.8	<<1	
Chamber				
Chamber radius (m)	7.3	7.2	6.9	6.9
Protective gas	Xe	Xe	Xe	
Gas density (mTorr)	10	10	(D.Haynes)	(D.Haynes)
Number of penetrations	100	100	(W. Meier)	(W. Meier)
Size of penetrations @ FW (m)	0.1	0.1	(W. Meier)	(W. Meier)
Conductance (liter/s)	36,420	36,420	(J.Pulsifer)	(J.Pulsifer)
Continuous pumping flow rate (mbar-liter/s)	1,141	1,141	(J.Pulsifer)	(J.Pulsifer)

	DD Target (LY)	DD Target (HY)	ID Target 1	ID Target 2
Chamber Wall				
Chamber armor	W	W	W	W
Armor thickness (mm)	0.1-1	0.1-1	0.1-1	0.1-1
Structural material	SiC_f/SiC	SiC_f/SiC	SiC_f/SiC	SiC_f/SiC
First wall thickness (mm)	4	4	4	4
First wall channel dimension (mm)	5	5	5	5
Coolant	Pb-17Li	Pb-17Li	Pb-17Li	Pb-17Li
Coolant inlet pressure (MPa)	~1.5	~1.5	~1.5	~1.5
Coolant inlet temperature (°C)	529	529	529	529
Coolant chamber wall outlet temperature (°C)	715	715	725	725
Coolant flow rate (kg/s)	$2.19x10^4$	$2.13x10^4$	$1.8x10^4$	$1.8x10^4$
Coolant pressure drop (MPa)	~1	~1	~1	~1
Maximum armor temperature (°C)	(D.Haynes)	(D.Haynes)	(D.Haynes)	(D.Haynes)
Armor evaporation per shot (µm)	(D.Haynes)	(D.Haynes)	(D.Haynes)	(D.Haynes)
Armor evaporation per year (µm)	(D.Haynes)	(D.Haynes)	(D.Haynes)	(D.Haynes)
Blanket	ARIES-AT	ARIES-AT	ARIES-AT	ARIES-AT
Structural material	SiC_f/SiC	SiC_f/SiC	SiC_f/SiC	SiC_f/SiC
Breeder	Pb-17Li	Pb-17Li	Pb-17Li	Pb-17Li
Total thickness (m)	0.4	0.4	0.4	0.4
^{6}Li enrichment (%)	90	90	90	90
Coolant (in series with FW)	Pb-17Li	Pb-17Li	Pb-17Li	Pb-17Li
Coolant inlet pressure (MPa)	~0.7	~0.7	~0.8	~0.8
Coolant inlet temperature (°C)	715	715	725	725
Coolant outlet temperature (°C)	1100°C	1100°C	1100°C	1100°C
Coolant pumping power (MW)	~5 MW	~5 MW	~4 MW	~4 MW

BUCKY simulations for the LY DD, HY DD, and ID Target 1 have been performed. Protective gas requirement, armor temperature and evaporation rates are reported.

Dry Wall Strawman Results

- ID1: 500mTorr
- DDLY: 10mTorr
- DDHY: 28mTorr
- N.B.: The effect of ion implantation is an important outstanding issue.
- Is brief melting acceptable? Desirable?
- No mass loss due to vaporization from thermal response.