1. Remaining Action Items on Dry Chamber Wall
2. "Overlap" Design Regions
3. Scoping Analysis of Sacrificial Wall

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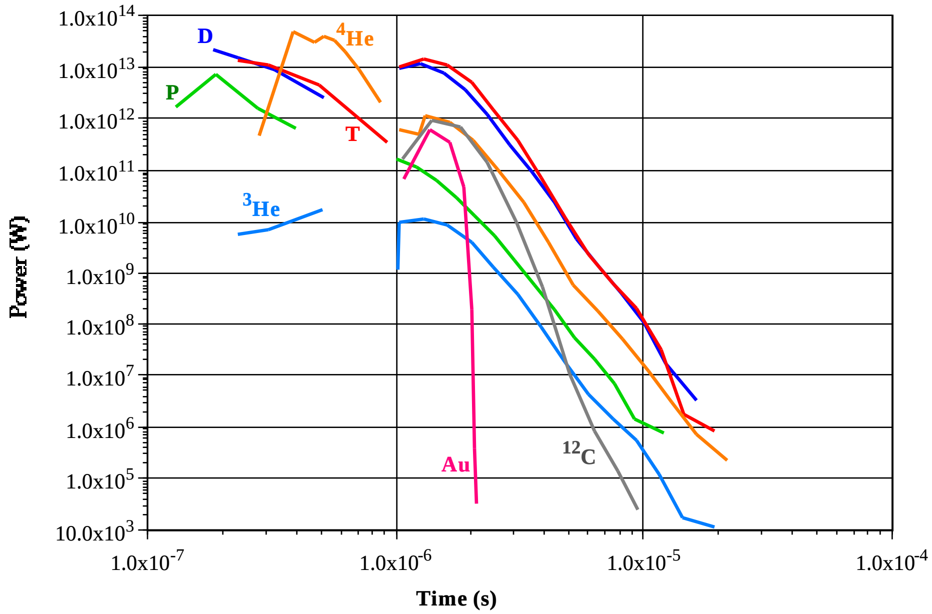
ARIES E-Meeting

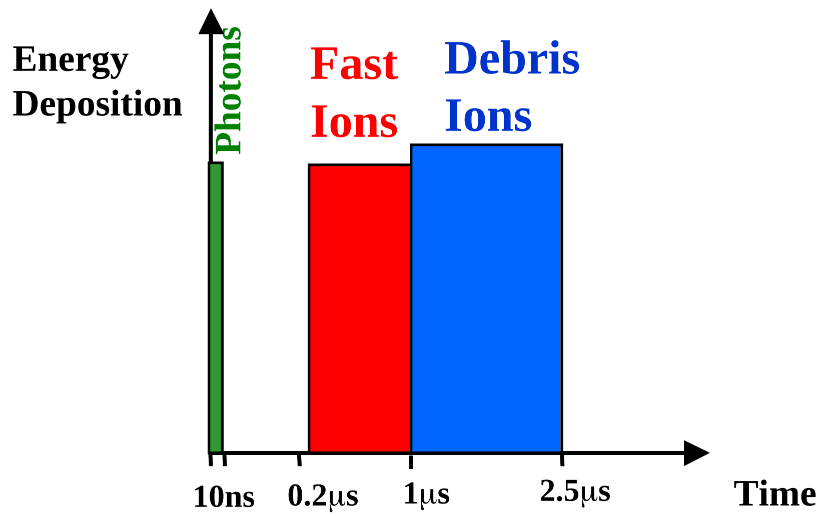
October 24, 2001

Accuracy of Simplified Assumption Used to Estimate Temporal Distribution of Energy Depositions

Temporal Distribution of Energy Depositions from Ions for Direct Drive Spectra and Chamber Radius of 6.5 m

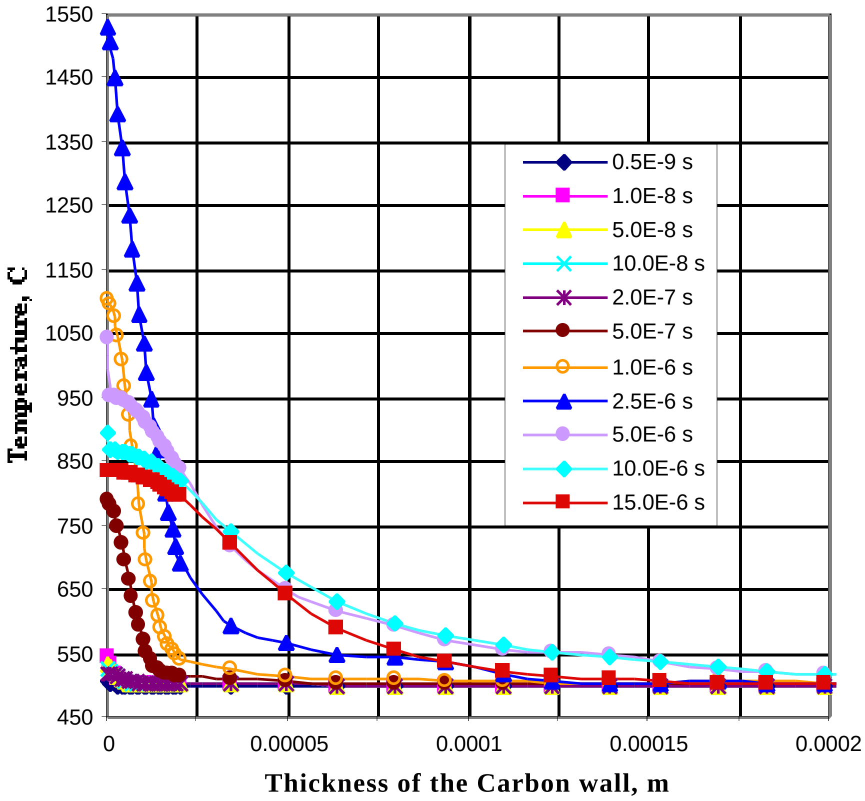


Simplified Temporal Distribution of Energy Depositions from Photons and Ions Assumed in Early Calculations

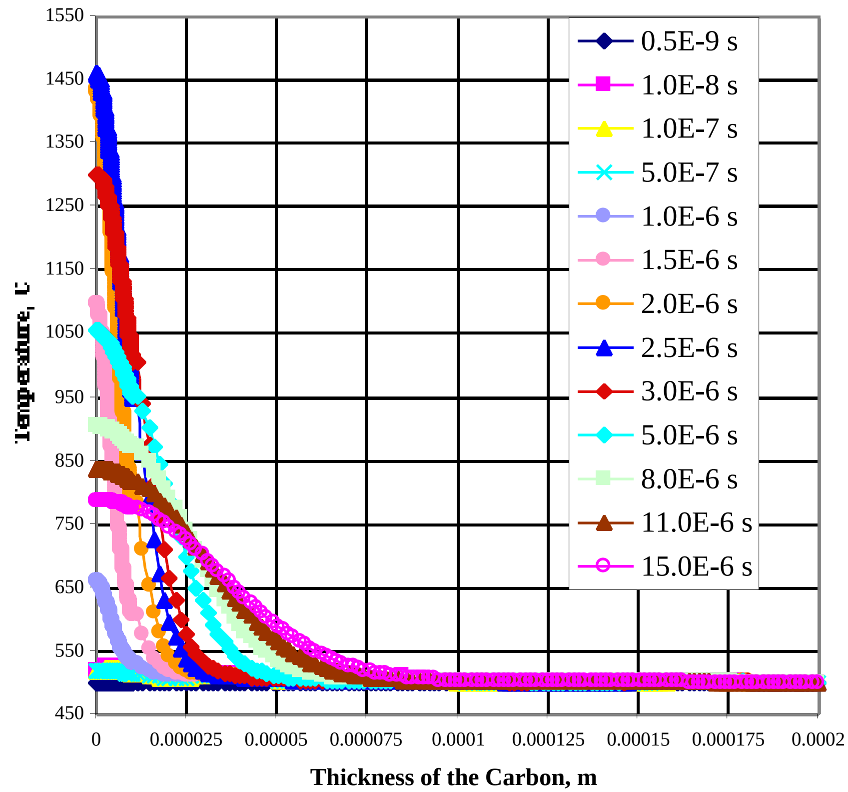


Spatial Temperature Profiles in Example Flat Carbon Wall at Different Times Under Energy Deposition from Photons and Ions for Direct Drive Target

Simple Assumption Case



Accurate Temporal Distribution Case



- **Temperature Profiles are Very Similar**
- **Max. C Temp. for Simple Assumption Case (~1530°C) > More Accurate Case (~ 1460°C)**
- **Simple Assumption Adequate for Scaling Analysis**

Reminder: Please Send Me Your Contributions on the Dry Wall Paper

ASSESSMENT OF IFE DRY CHAMBER WALL

(TO BE PUBLISHED IN FUSION ENGINEERING & DESIGN)

A. R. Raffray, R. R. Peterson, M. Billone, L. El-Guebaly, G. Federici, D. Goodin, A. Hassanein, D. Haynes, R. Moore, F. Najmabadi, D. Petti, R. Petzoldt, M.S. Tillack, X. Wang, M. Zaghloul

- **Last Reminder Sent on October 2, 2001, Including Latest Outline and Expected Contributions**
- **Contributions Due by the End of October**

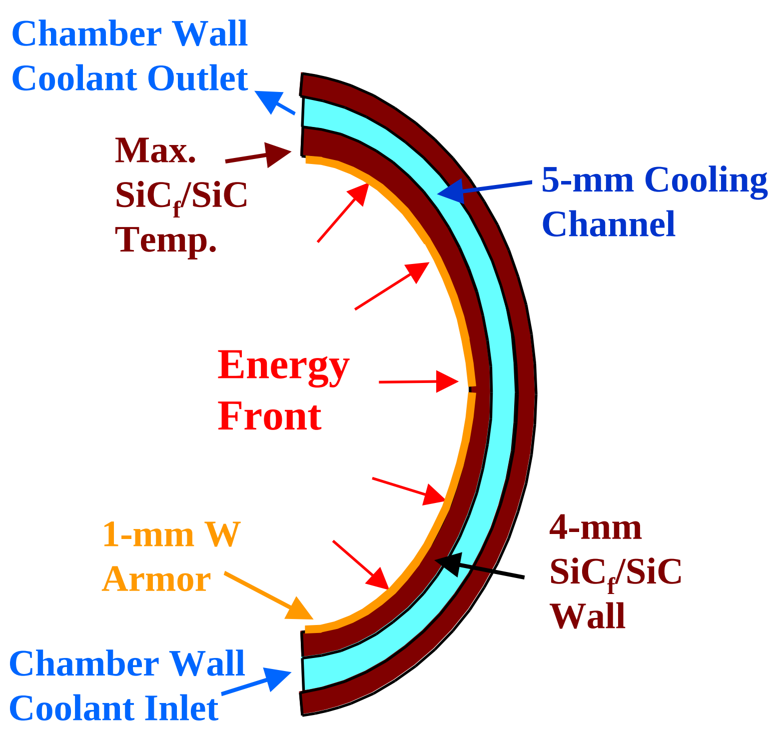
Overlap Points

Simple self consistent calculation

- **Driver parameters**
- **Chamber geometry and chamber wall design**
- **Power to chamber wall**
- **Coolant outlet temperature**
- **Cycle efficiency**
- **Thermal-hydraulic parameters**
- **Maximum temperature of chamber wall**
  - **Chamber wall power assumed to be spread over the complete period between successive shots (optimistic assumption)**
- **Run a few example cases with the goal of maintaining SiC_f/SiC T_{max} at the wall < 1000°C**
  - **Results will show acceptable combination of parameters (design window)**
  - **e.g. limit on chamber size for a given power output**

Example Temperature History for Tungsten Flat Wall Under Energy Deposition from Indirect-Drive Spectra

Assume Channel $L = \pi R$



Direct Drive:
Driver Energy = 1.2 MJ
Gain = 128
Yield = 153.6 MJ
Driver Efficiency = 0.07

Indirect Drive:
Driver Energy = 3.3 MJ
Gain = 139
Yield = 458.7 MJ
Driver Efficiency = 0.25

Parametric Studies for Dry Wall with Direct Drive Target Under Constraint: $T_{max,SiC/SiC} < 1000°C$

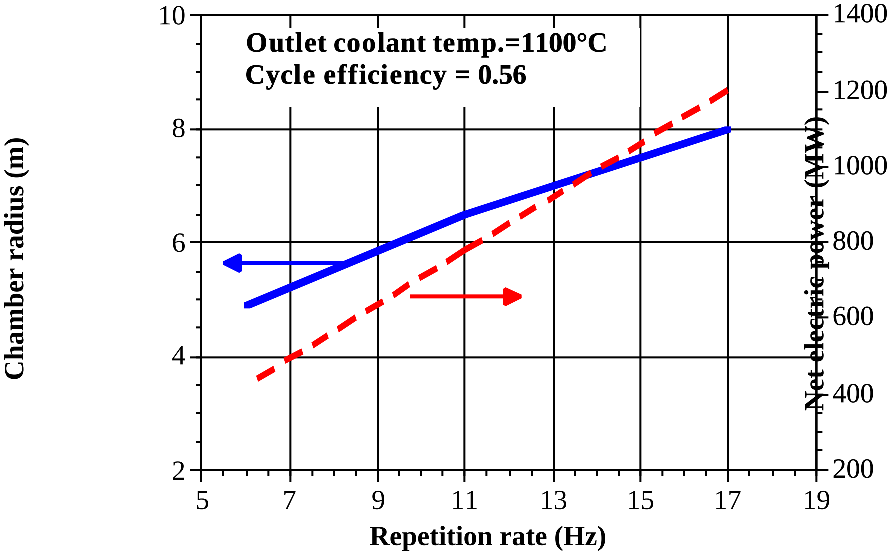
Driver									
Rep-rate (Hz)	**6**	**11**	**17**	**11**	**11**	**11**	**17**	**17**	**14.2**
Cycle									
Power cycle efficiency	**0.556707**	**0.556707**	**0.556707**	**0.453052**	**0.509046**	**0.399188**	**0.493217**	**0.25608**	**0.556707**
Power									
Fusion Power (MW)	921.6	1689.6	2611.2	1689.6	1689.6	1689.6	2611.2	2611.2	2182.12
Effective heat flux on first wall (MW/m2)	0.926467	0.965243	0.984781	1.698522	1.348149	2.013902	1.491739	2.624989	0.9879
Total thermal power (MW)	987.0336	1809.5616	2796.5952	1809.5616	1809.5616	1809.5616	2796.5952	2796.5952	2335.97
Gross electric power (MW)	549.48	1007.39	1556.88	819.82	921.15	722.35	1379.32	716.15	1300.45
Auxiliary Power (4%)	21.97	40.29	62.27	32.79	36.846	28.89	55.17	28.64	52.01
Laser power (MW)	102.85	188.57	291.42	188.57	188.57	188.57	291.42	291.42	243.42
Net electric power (MW)	**424.6516**	**778.5279**	**1203.18**	**598.4609**	**695.7328**	**504.8897**	**1032.725**	**396.0762**	**1005.009**
Thermal-Hydraulics (Pb-17Li)									
Inlet temperature (C)	529.9124	529.9124	529.9124	379.4173	451.8779	323.6784	429.5823	217.7744	529.91
FW outlet temp.(C)	715.45	715.45	715.45	526.06	617.25	455.92	589.19	322.64	715.45
Blanket outlet temperature (C)	**1100**	**1100**	**1100**	**830**	**960**	**730**	**920**	**540**	**1100**
Chamber Wall + Channel geometry									
Chamber radius (m)	**4.9**	**6.5**	**8**	**4.9**	**5.5**	**4.5**	**6.5**	**4.9**	**7.3**
FW channel length (m)	15.386	20.41	25.12	15.386	17.27	14.13	20.41	15.386	22.9
Thermo-mechanics									
Approx. SiC/SiC thermal stress (MPa)	177.4788	184.907	188.6498	325.3778	258.2585	385.7936	285.7654	502.8566	1.89E+02
Approx. quasi-SS SiC/SiC Tmax (°C)	**994.2947**	**995.0592**	**993.7092**	**992.0947**	**996.0095**	**998.7566**	**995.827**	**996.5873**	**9.97E+02**
Approx. quasi steady-state W Tmax (°C)	1003.657	1004.813	1003.661	1009.259	1009.633	1019.108	1010.902	1023.114	1.01E+03
Average W surface temp. (°C)	910.8846	912.041	910.8884	935.934	926.9446	952.9856	931.0942	970.6768	9.14E+02
Friction Factor									
Pressure Drop (MPa)	0.299996	0.631296	1.091047	1.214109	0.878241	1.605607	1.683574	5.132096	8.72E-01
FW Pumping Power (MW)	0.345398	1.332536	3.559145	3.116138	2.037178	4.504298	6.216648	27.30795	2.38E+00

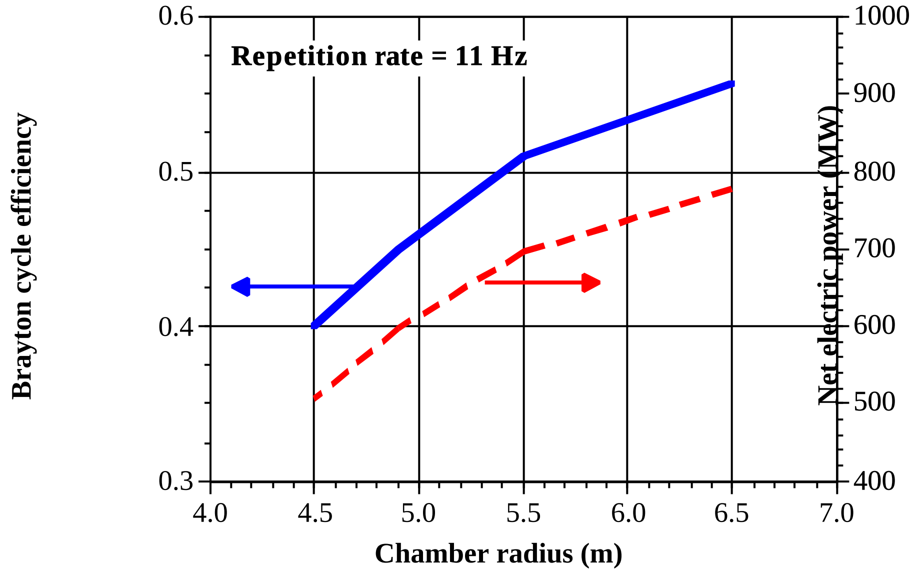
Combination of Parameters to Maintain $T_{max,SiC/SiC}$ < 1000°C for Direct Drive Target

Direct Drive:
Driver Energy = 1.2 MJ
Gain = 128
Yield = 153.6 MJ
Driver Efficiency = 0.07

Adjust coolant outlet temperature (and hence cycle eff.) as a function of chamber radius to maintain SiC_f/SiC Temp. < 1000°C

Fusion power = 1690 MW





Example trade-off - What is preferable: a 5.2-m chamber with 7 Hz rep rate and 500 MWe or a 7.3-m chamber with 14.2 Hz rep rate and 1000MWe?

Preferable to operate with higher cycle efficiency for given fusion power

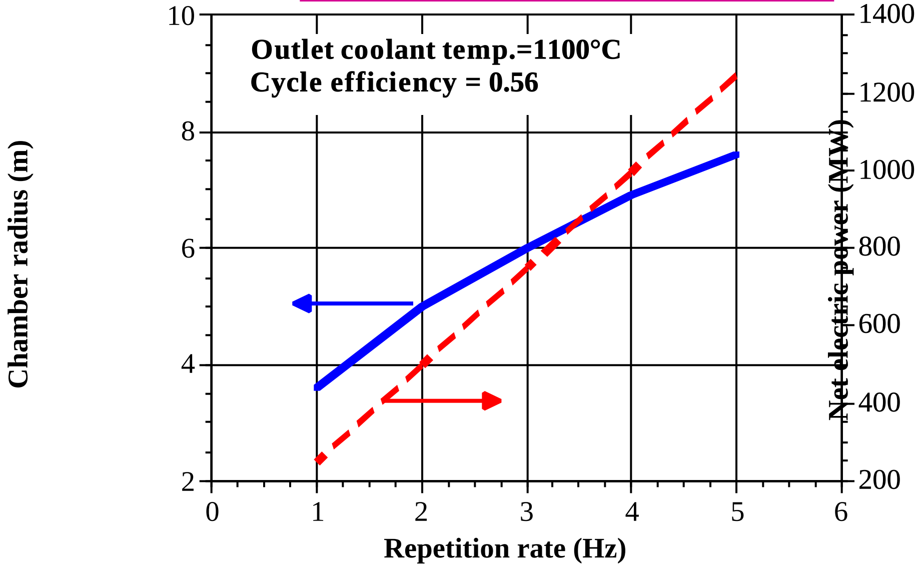
Parametric Studies for Dry Wall with Indirect Drive Target Under Constraint: $T_{max,SiC/SiC} < 1000°C$

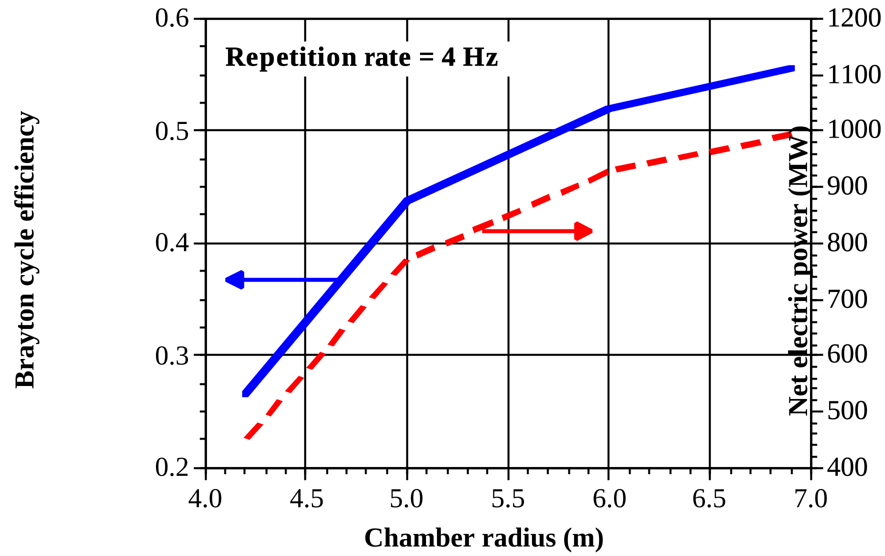
Driver								
Rep-rate (Hz)	**3**	**2**	**4**	**1**	**5**	**4**	**4**	**4**
Cycle								
Power cycle efficiency	**0.556707**	**0.556707**	**0.556707**	**0.556707**	**0.556707**	**0.520213**	**0.438038**	**0.265449**
Power								
Fusion Power (MW)	1376.1	917.4	1834.8	458.7	2293.5	1834.8	1834.8	1834.8
Effective heat flux on first wall (MW/m2)	0.942971	0.905252	0.950695	0.873121	0.97954	1.257295	1.810504	2.565907
Total thermal power (MW)	1471.05	980.70	1961.40	490.35	2451.75	1961.40	1961.40	1961.40
Gross electric power (MW)	818.94	545.96	1091.92	272.98	1364.90	1020.34	859.16	520.65
Auxiliary Power (4%)	32.75	21.83	43.677	10.91	54.59	40.81	34.36	20.82
Driver power (MW)	39.6	26.4	52.8	13.2	66	52.8	52.8	52.8
Net electric power (MW)	**746.5862**	**497.7241**	**995.4483**	**248.8621**	**1244.31**	**926.7321**	**772.0008**	**447.0252**
Thermal-Hydraulics (Pb-17Li)								
Inlet temperature (C)	529.91	529.91	529.91	529.91	529.91	468.59	362.69	223.34
FW outlet temp.(C)	725.59	725.59	725.59	725.59	725.59	647.56	512.79	335.46
Blanket outlet temperature (C)	**1100**	**1100**	**1100**	**1100**	**1100**	**990**	**800**	**550**
Chamber Wall + Channel geometry								
Chamber radius (m)	**6**	**5**	**6.9**	**3.6**	**7.6**	**6**	**5**	**4.2**
FW channel length (m)	18.84	15.7	21.666	11.304	23.864	18.84	15.7	13.188
Thermo-mechanics								
Approx. SiC/SiC thermal stress (MPa)	180.3032	173.0911	181.7802	166.9474	187.2956	240.4042	346.1821	490.6209
Approx. quasi-SS SiC/SiC Tmax (°C)	**1002.177**	**998.3648**	**999.7559**	**1001.545**	**1004.165**	**1001.249**	**1004.265**	**1004.088**
Approx. quasi steady-state W Tmax (°C)	1011.701	1007.508	1009.358	1010.364	1014.059	1013.948	1022.552	1030.005
Average W surface temperature (°C)	913.862	909.6692	911.5193	912.5252	916.2199	924.4646	947.5012	973.9444
Friction Factor								
Pressure Drop (MPa)	0.482377	0.293258	0.687569	0.129437	0.914802	0.892278	1.444223	3.13288
FW Pumping Power (MW)	0.828721	0.335877	1.574986	0.074124	2.619374	2.198347	4.125496	11.55705

Combination of Parameters to Maintain $T_{max,SiC/SiC}$ < 1000°C for Indirect Drive Target

Indirect Drive:
Driver Energy = 3.3 MJ
Gain = 139
Yield = 458.7 MJ
Driver Efficiency = 0.25

Adjust coolant outlet temperature (and hence cycle eff.) as a function of chamber radius to maintain SiC_f/SiC Temp. < 1000°C





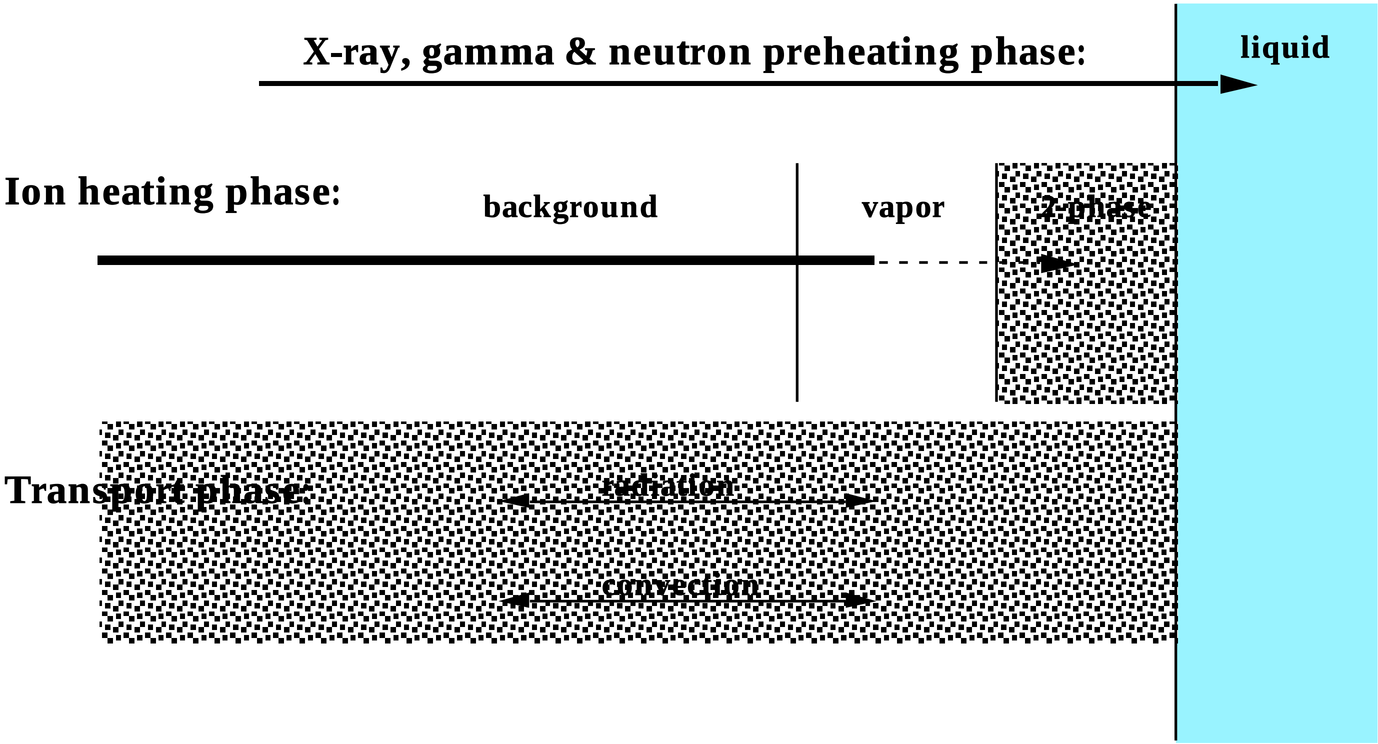
Example trade-off - What is preferable: a 5-m chamber with 2 Hz rep rate and 500 MWe or a 6.9-m chamber with 4 Hz rep rate and 1000MWe?

Choice of Strawman Parameters

See strawman file

- **Parameters correspond to 1000MWe**
- **It is not clear if a smaller chamber with lower electrical power would provide cost benefit**
- **However, if a smaller chamber size is required by other considerations (e.g. target injection) we should change the parameters to accommodate this**

Scoping Analysis of Chamber Recovery Time for Sacrificial Wall Concept



Concern about creating quiescent atmosphere in time for next shot:

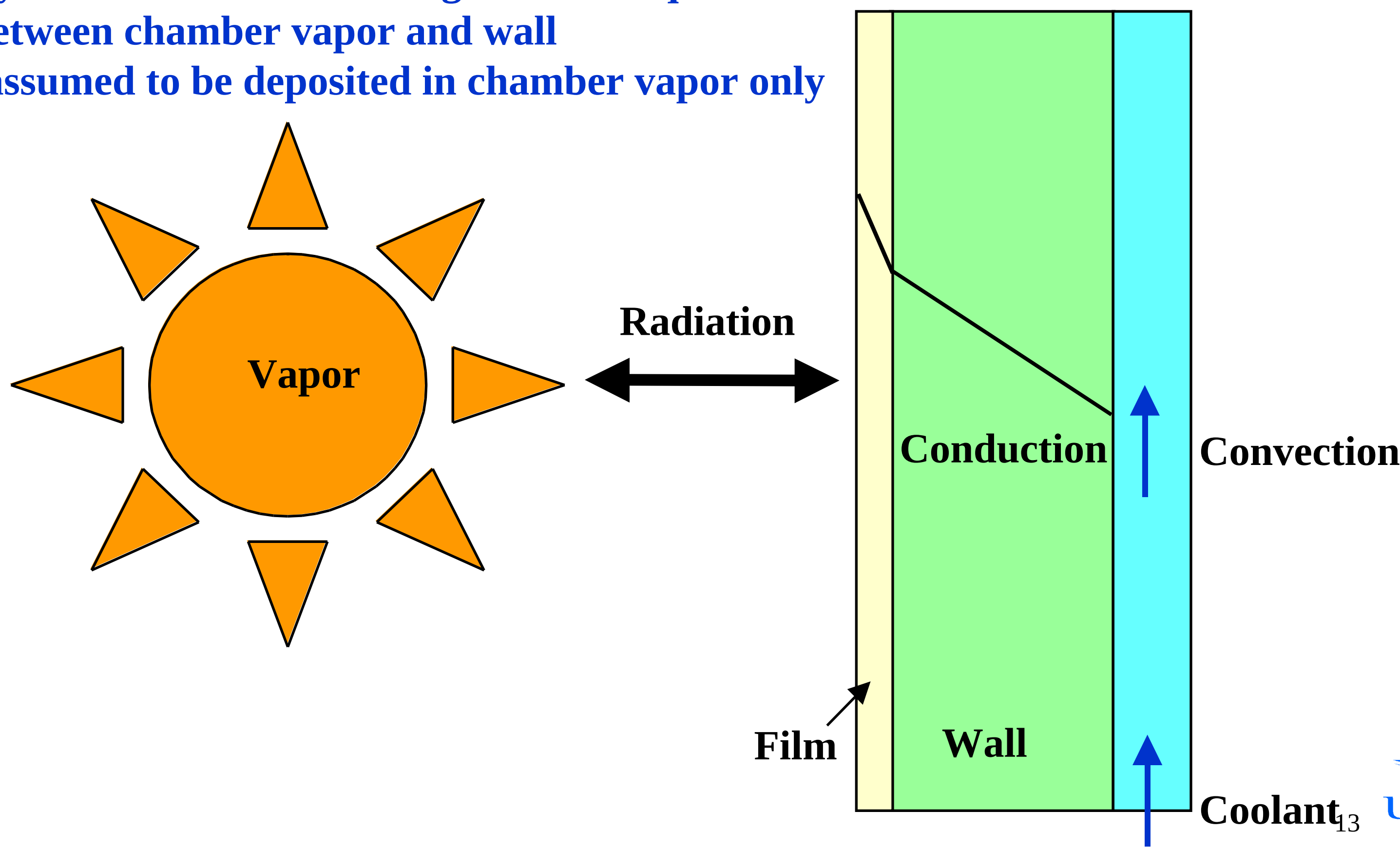
- **Time scale of recovery mechanisms, e.g:**
  - **Condensation**
  - **Clearing**
  - **Aerosol evacuation**

- **Initial effort on scoping analysis of time scale for recondensation**

UCSD

Schematic of RECON Model for Estimating Evaporation/Recondensation Following Chamber Micro-Explosion

- **Simple 1-D Model Initially Developed for PROMETHEUS Analysis (M. Tillack)**
  - **Conduction through wall and convection to coolant**
  - **Wall temperature estimated from quasi steady-state heat flux and coolant temperature**
  - **Evaporation/condensation at liquid wall surface**
  - **X-ray energy attenuated in chamber gas and in liquid wall**
  - **Radiation between chamber vapor and wall**
  - **Ion energy assumed to be deposited in chamber vapor only**



Using RECON to Help in Sacrificial Wall Analysis and Assessment

- **Major issue about "long term" chamber dynamics**
  e.g. How long does it take for chamber to return to desired pre-shot conditions

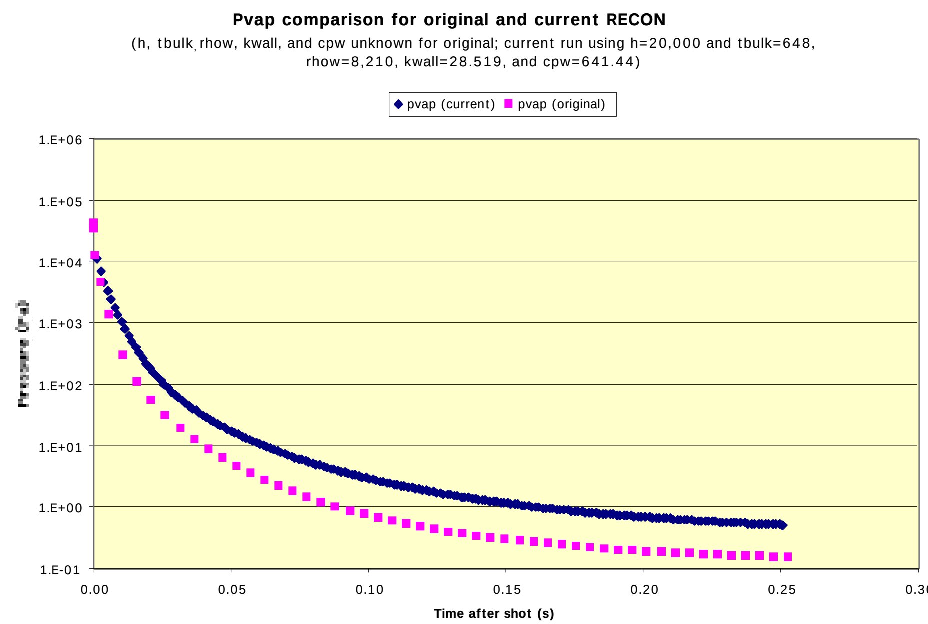
- **Key processes and parameters include:**
  - **vapor condensation**
  - **vapor radiation**
  - **heat transfer to coolant (influencing liquid wall temperature)**
  - **Pressure of chamber gas**
  - **Rep rate**
  - **Chamber size**
  - **Coolant temperature**

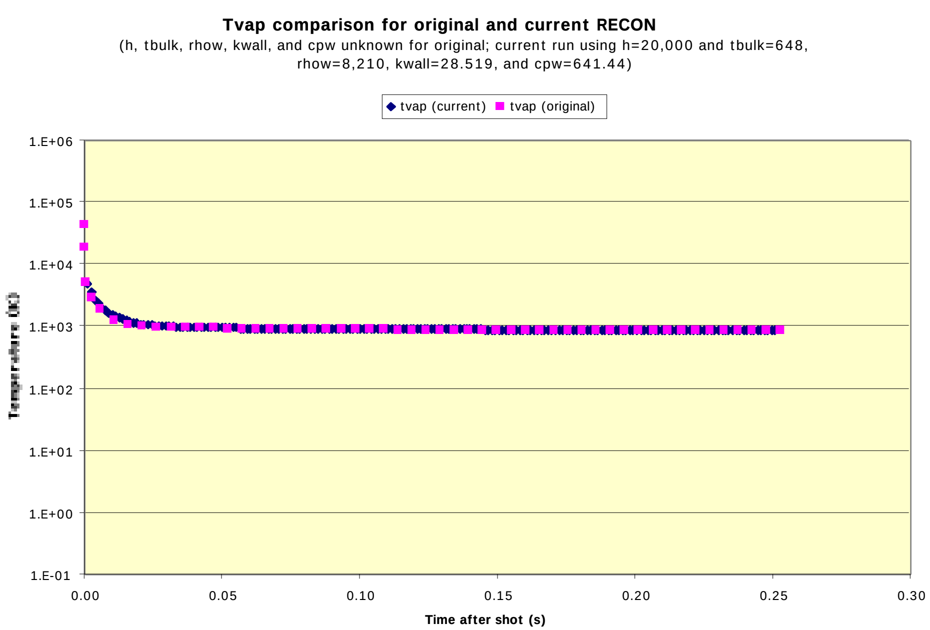
Proposed Action Plan

- **Validation case from one remaining run from PROMETHEUS**
- **Try to adapt RECON to provide solutions for the DD and ID target parameters**
- **Assess accuracy and usefulness of results**
- **Perform initial parametric analysis to assess relative importance of various parameters**
- **Make assessment of combinations of parameters (design window analysis)**

Comparison of RECON Run with PROMETHEUS Results for Pb

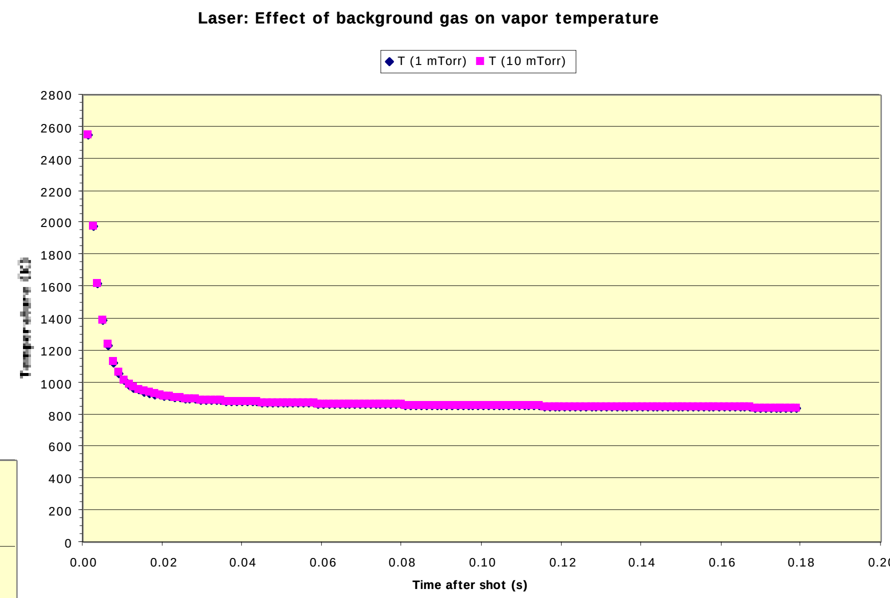
Pb vapor pressure history



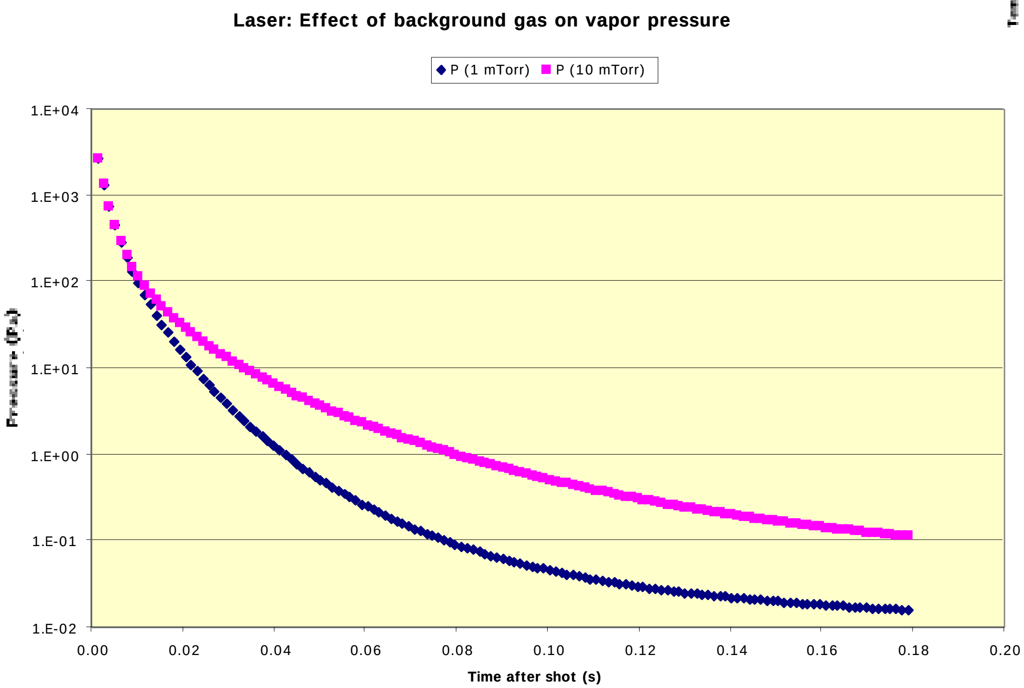


Pb vapor temperature history

Example Parametric Runs for Pb Film



Effect of background gas pressure on Pb vapor temperature history following shot

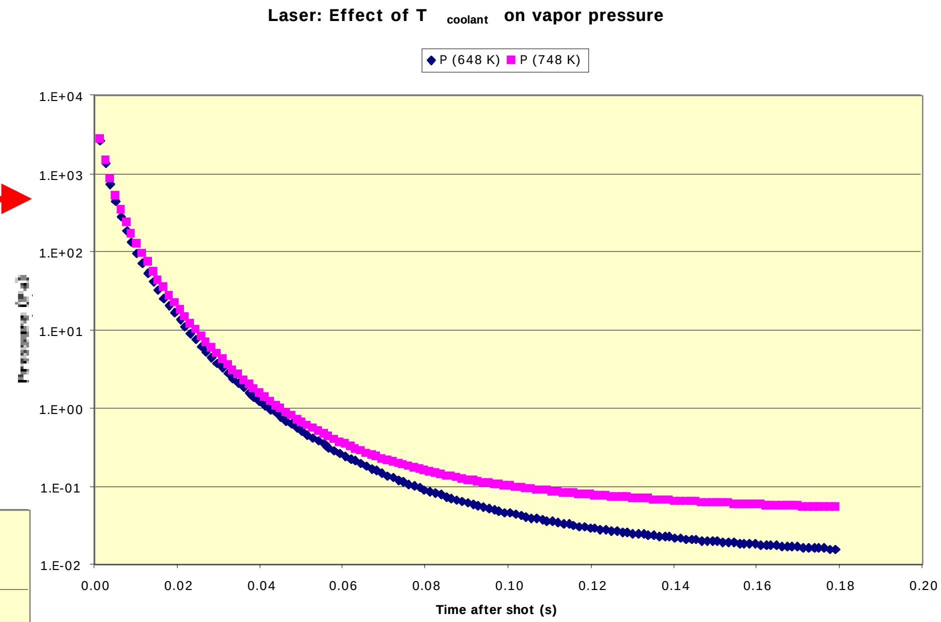


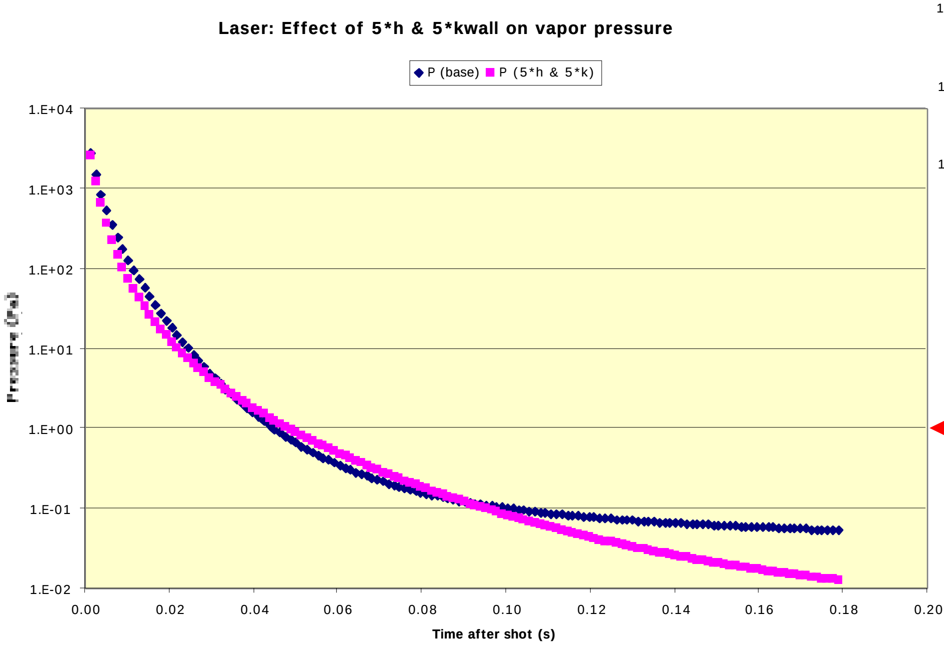
Effect of background gas pressure on Pb vapor pressure history following shot

- Affects vapor recondensation rate

Effect of Coolant Temperature and of Wall Heat Transfer Capability on Pb Vapor Pressure History Following Shot

Effect of coolant temperature on Pb vapor pressure history





Effect of wall conduction and convection to coolant on Pb vapor pressure history