Advanced Chamber Concept with Magnetic Intervention:
- Ion Dump Issues
- Status of Blanket Study

A. René Raffray

UCSD

With contributions from:

M. Sawan, G. Sviatoslavsky, I. Sviatoslavsky

UW

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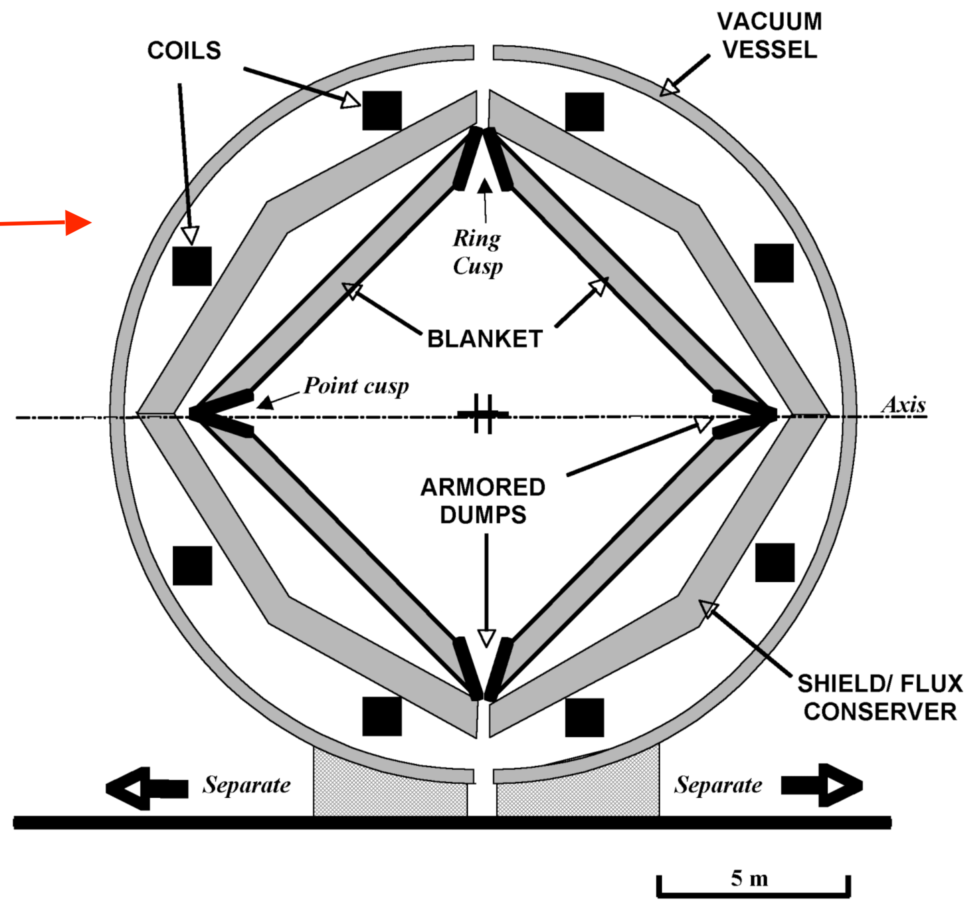
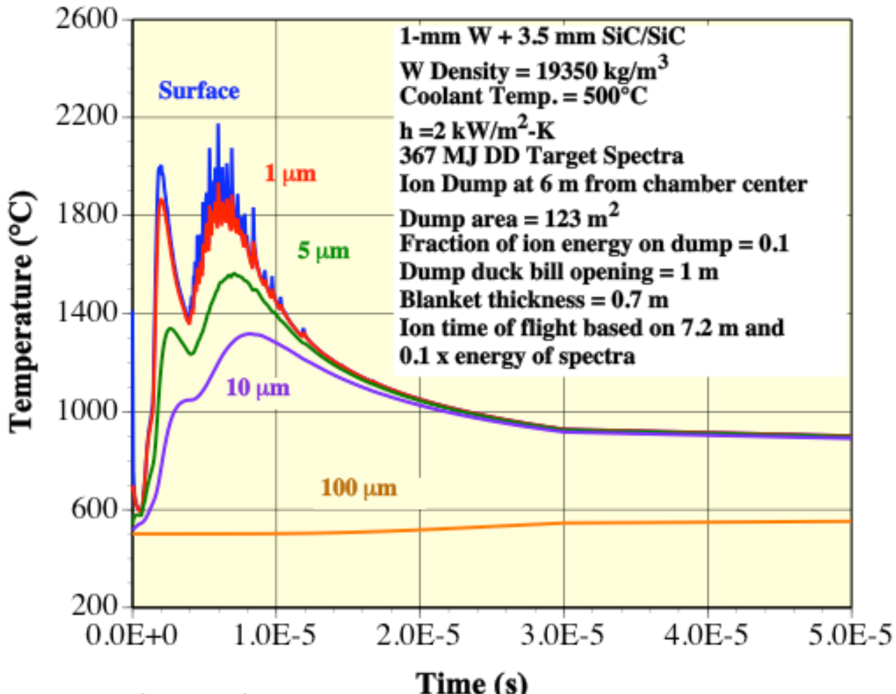
Advanced Chamber Based on Magnetic Intervention Concept Using Cusp Coils (from last time)

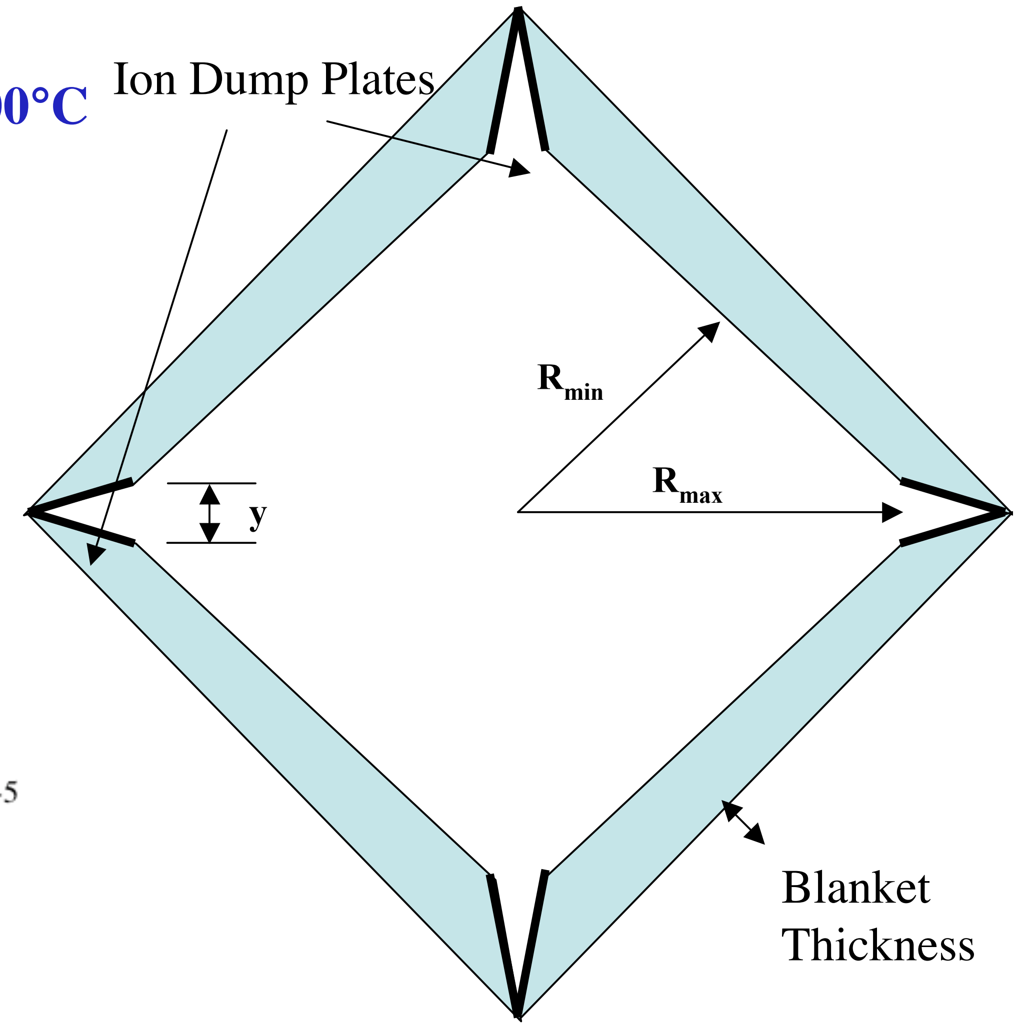
- **Use of resistive wall (e,g SiC) in blanket to dissipate magnetic energy *(>90% of ion energy can be dissipated in the walls).***
- **Initial chamber schematic from Bertie Robson (with cone-shaped chamber blanket concept).**
- **The initial configuration was rotated 90° for the blanket analysis as this seems to favor the maintenance scheme.**
- **Dump plates to accommodate all ions but at much reduced energy *(<10%).***
- **Dump plates could be replaced more frequently than blanket.**



Ion Energy Deposition and Thermal Response of Dump Plates Estimated for Cone-Shaped Chamber

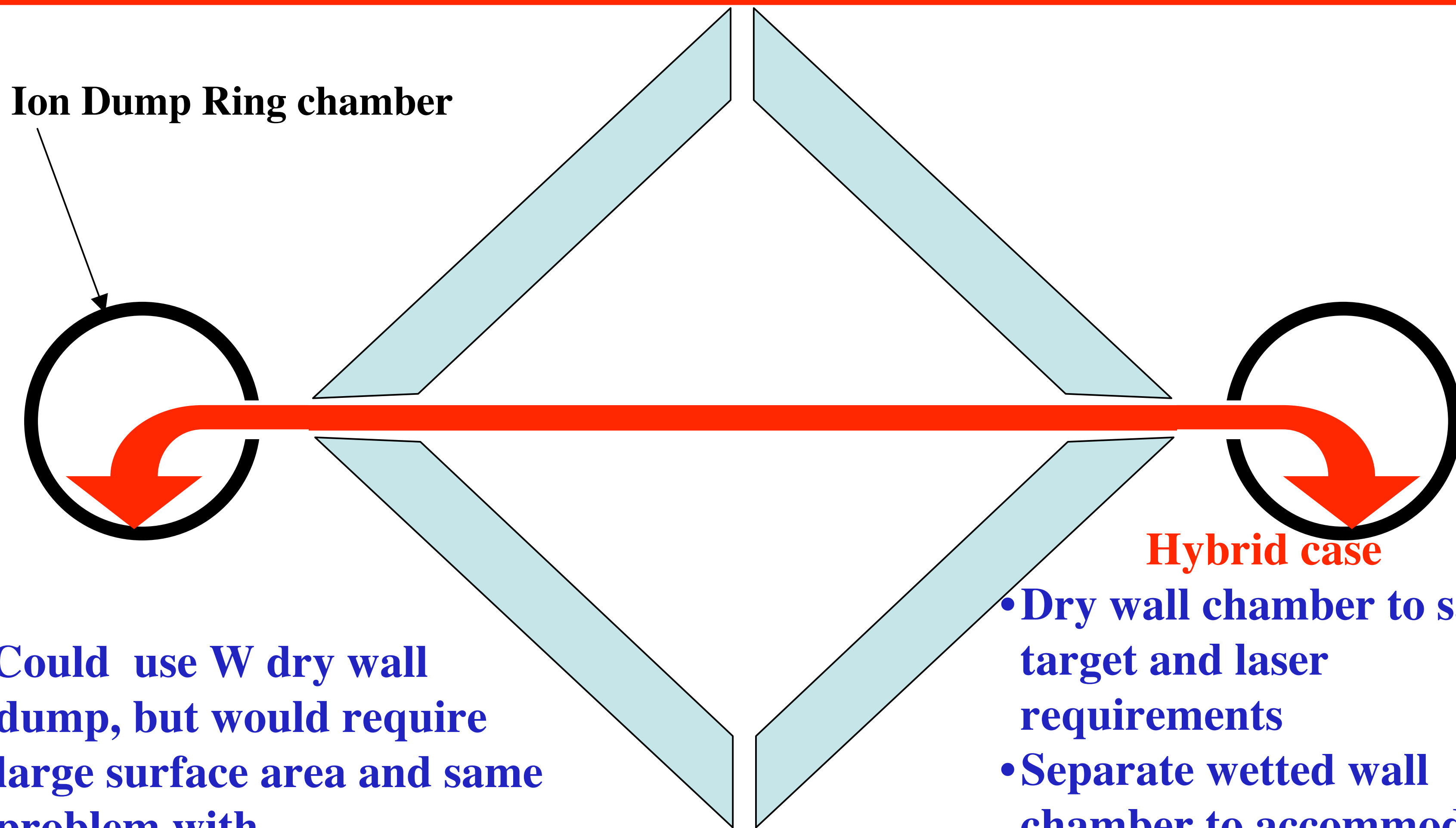
- **For example case with ~10% of ion energy on plate, max. W temp. ~ 2200°C**





- **Revised ion energy on dumps:**
  - **~7.7% within 0.5 □s**
  - **~23% over 0.5-1.5 □s**
- **Major change, ~30% ion energy on dumps**
- **If dry wall dump within chamber, need ~30% of chamber area for dump**
- **Then, why not design whole chamber the same way?**

Seems More Advantageous to Position Dump Plate In Separate Smaller Chamber



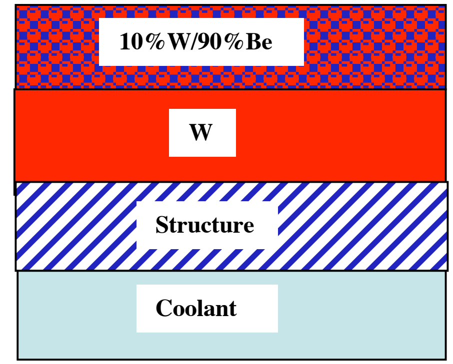
Hybrid case

- Dry wall chamber to satisfy target and laser requirements
- Separate wetted wall chamber to accommodate ions and provide long life
- Have to make sure no unacceptable contamination of main chamber

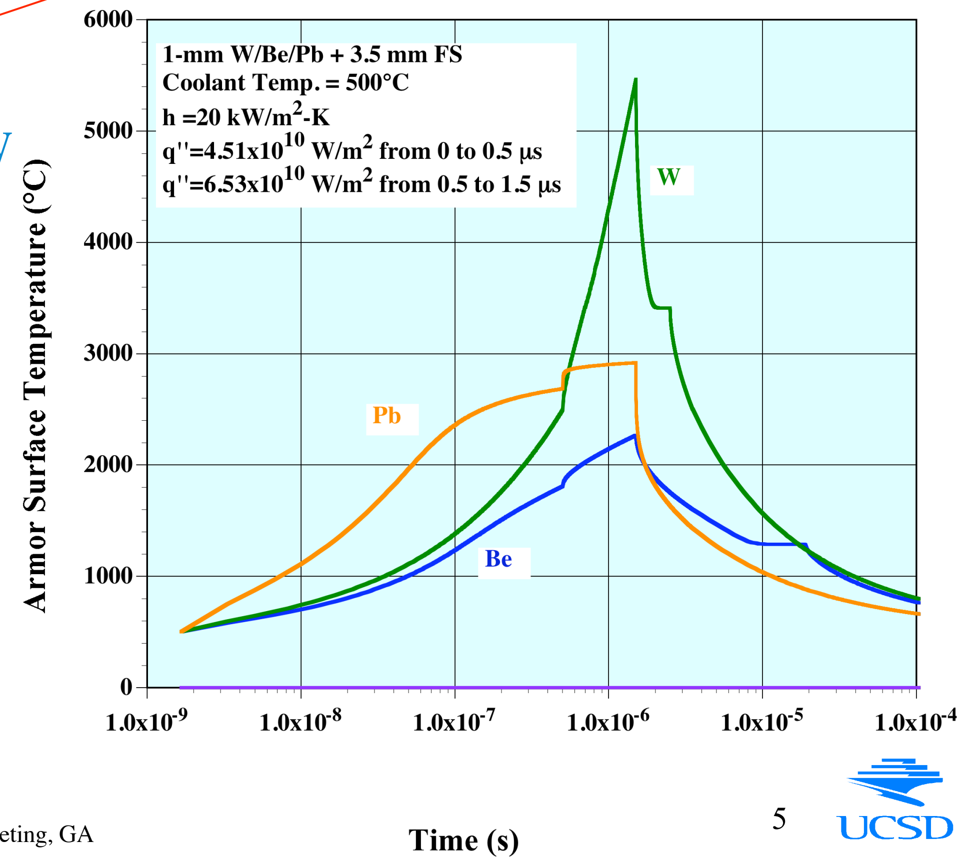
- Could use W dry wall dump, but would require large surface area and same problem with thermomechanical response and He implantation
- Could allow melting (W or low MP material in W)

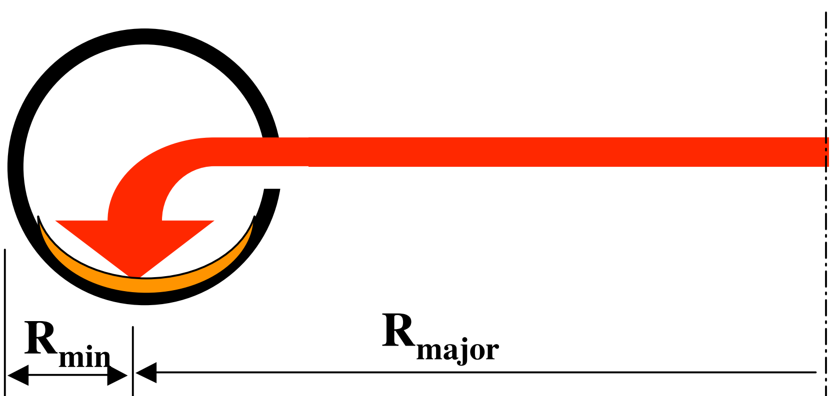
Scoping Analysis of an Example Ring Chamber

- Some flexibility in setting chamber major and minor radii so as not to interfere with laser beams
- e.g., with R_{major}/R_{minor} =8/2.7 or 9/2.4 m, and assuming 35% of wetted wall area sees ion flux with a peaking factor of 1:
  - Ion dump area = 300 m^2
  - From 0 to 0.5 μs, q'' = 4.53x10^{10} W/m^2
  - From 0.5 to 1.5 μs, q''= 6.56x10^{10} W/m^2



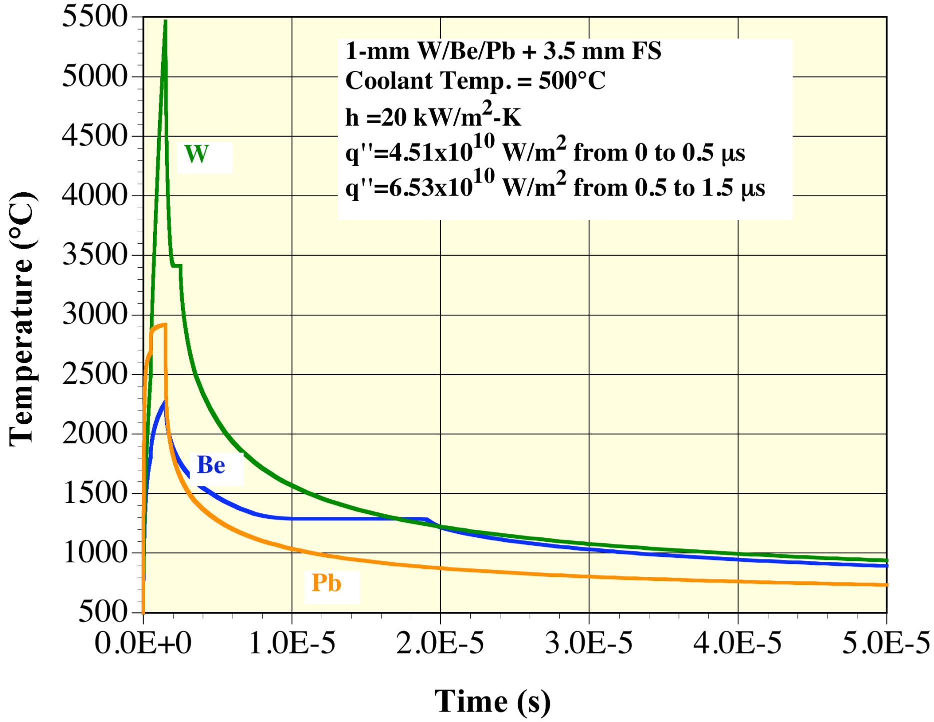
- Three cases:
  - W with phase change
  - Low MP metal (e.g. Be) in high porosity W (~80-90%) which provides integrity and could help retain Be melt layer
  - Wetted wall chamber with Pb as example material

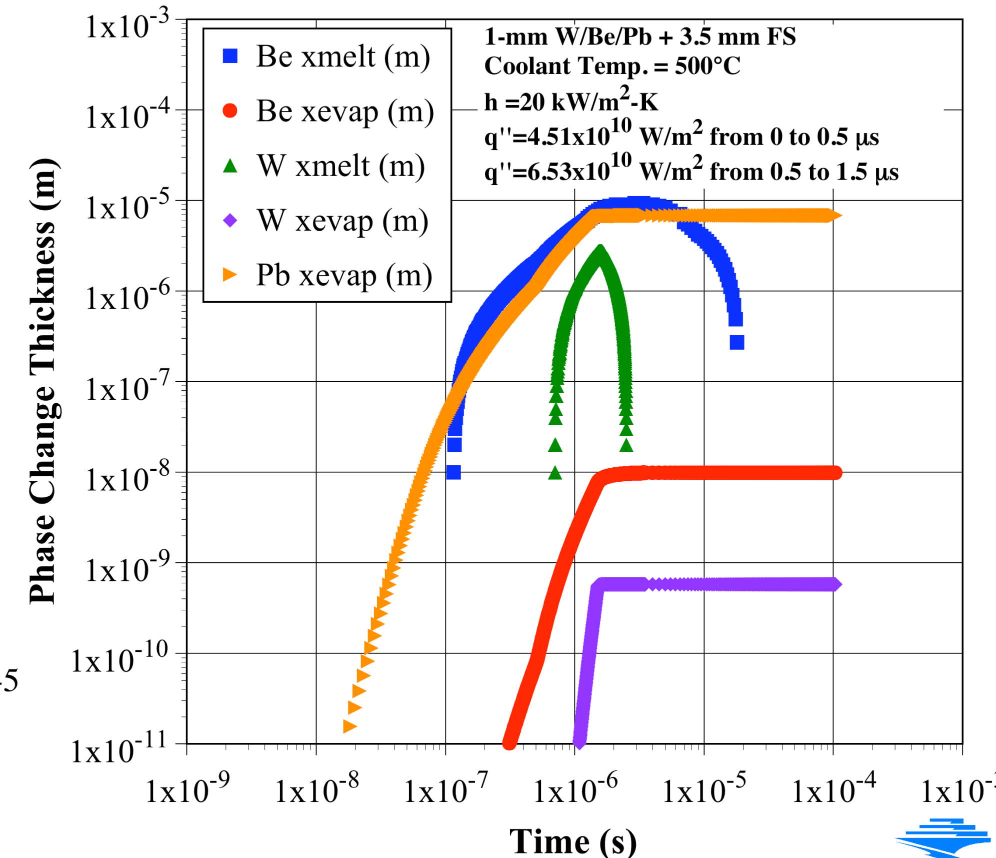




Temperature and Phase Change Thickness Histories for W, Be and Pb for Example Case

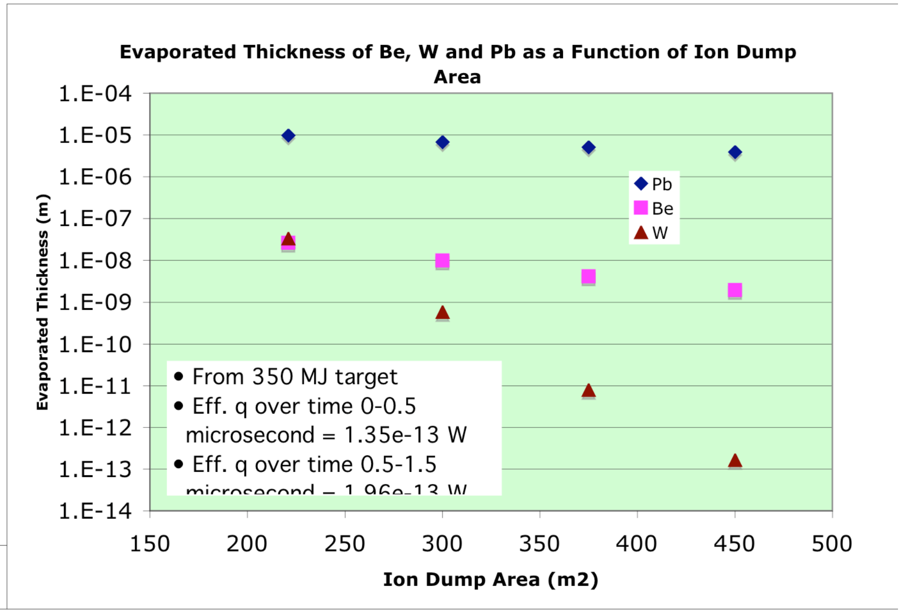
- 350 MJ target (ion energy = 87.8 MJ)
- Ion dump area = 300 m^2
- From 0 to 0.5 □s, q'' = 4.53x10^{10} W/m^2 (7.7% of ion energy)
- From 0.5 to 1.5 □s, q''= 6.56x10^{10} W/m^2 (22.3% of ion energy)

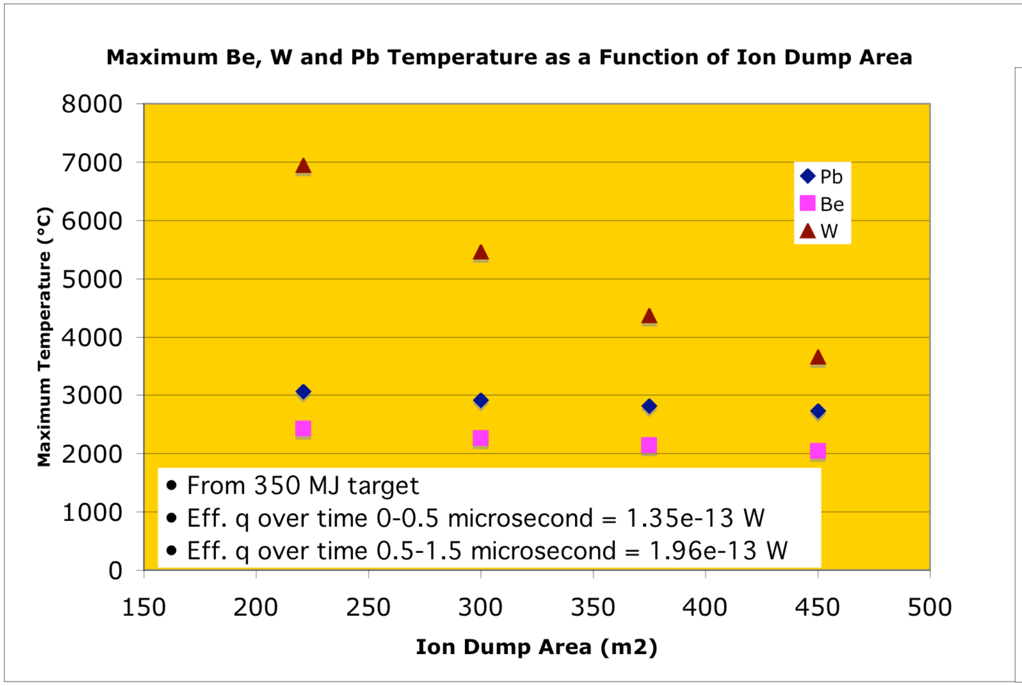


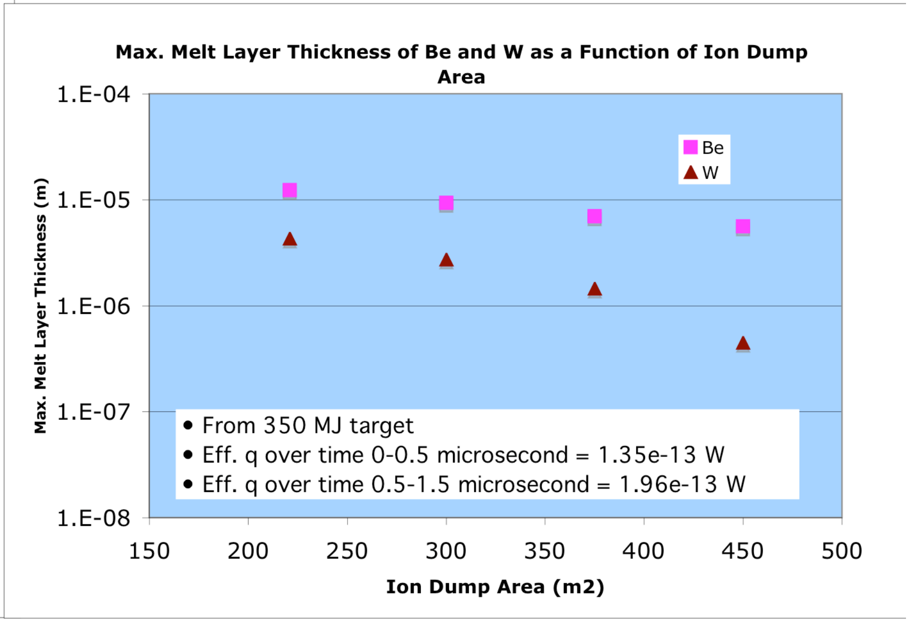


Maximum Temperature and Phase Change Thicknesses for W, Be and Pb as a Function of Ion Dump Area

- 350 MJ target (ion energy = 87.8 MJ)
- Evaporation loss per shot relatively modest for W but could be a concern for Be (1 nm/shot ~ 0.43 mm/day)
- Stability of melt layer is a concern
- Would Be in a porous W matrix be more stable?
- For wetted wall in particular, the evaporated material (e.g.Pb) must recondense within a shot and not contaminate main chamber

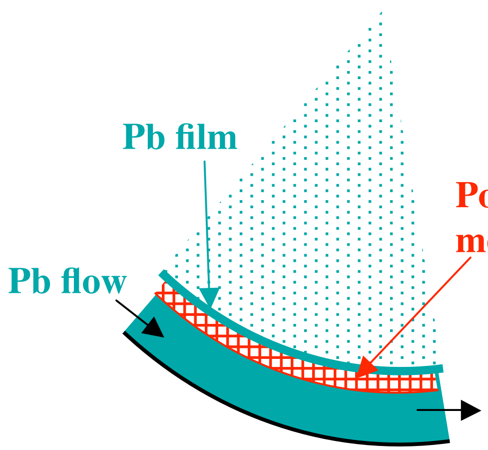


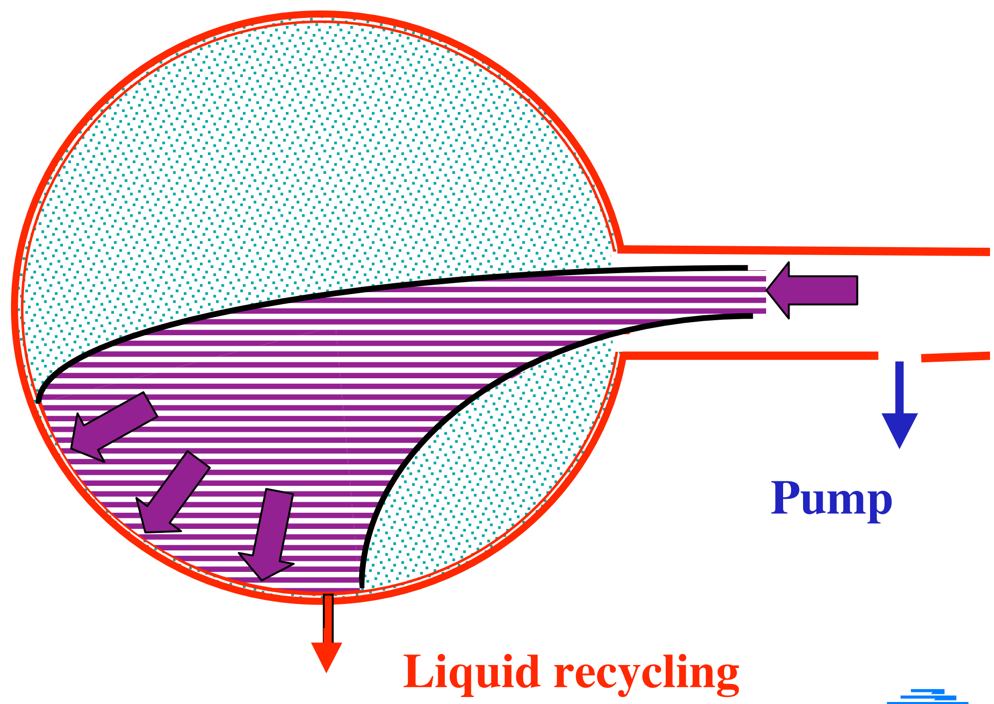




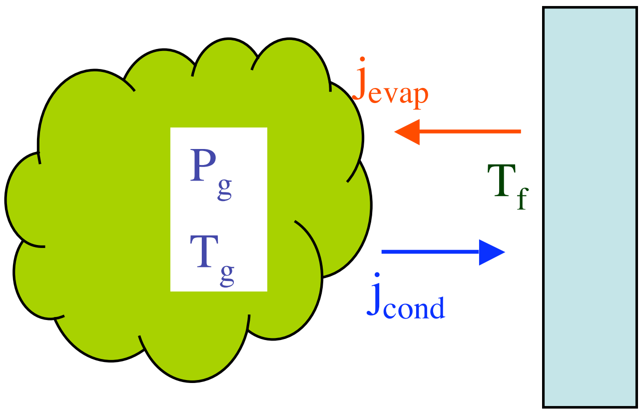
Wetted-Wall Concept Could Consist of a Porous Mesh Through Which Pb Oozes to Form a Protective Film

- **Need to make sure that protective film is reformed prior to each shot**
  - **radial flow through porous mesh**
  - **circumferential flow of recondensed Pb**
  - **no concern about any droplets falling in chamber**





Film Condensation in Ion Dump Chamber



$$j_{net} = \left(\frac{M}{R2\pi}\right)^{0.5}\left[\Gamma\alpha_c \frac{P_g}{T_g^{0.5}} - \alpha_e \frac{P_f}{T_f^{0.5}}\right]$$

j_{net} = net condensation flux (kg/m^2-s)

M = molecular weight (kg/kmol)

R = Universal gas constant (J/kml-K)

Γ = correction factor for vapor velocity towards film

α_c, α_e = condensation and evaporation coefficients

P_g, T_g = vapor pressure (Pa) and temperature (K)

P_f, T_f = saturation pressure (Pa) and temperature (K) of film

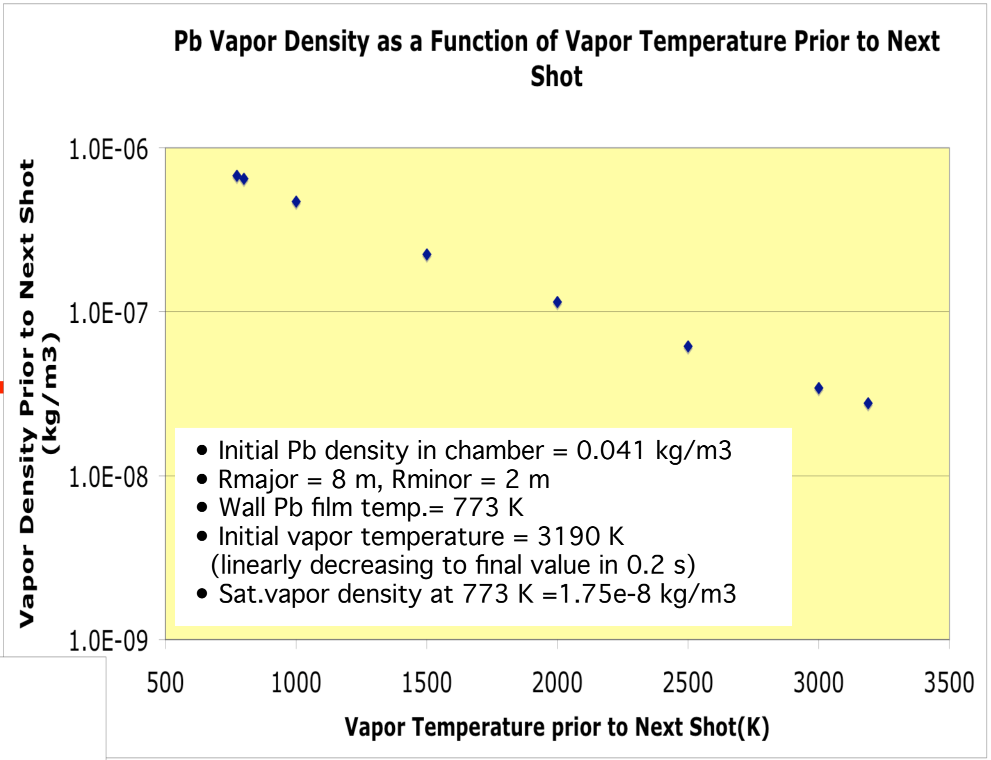
Example Scoping Calculations

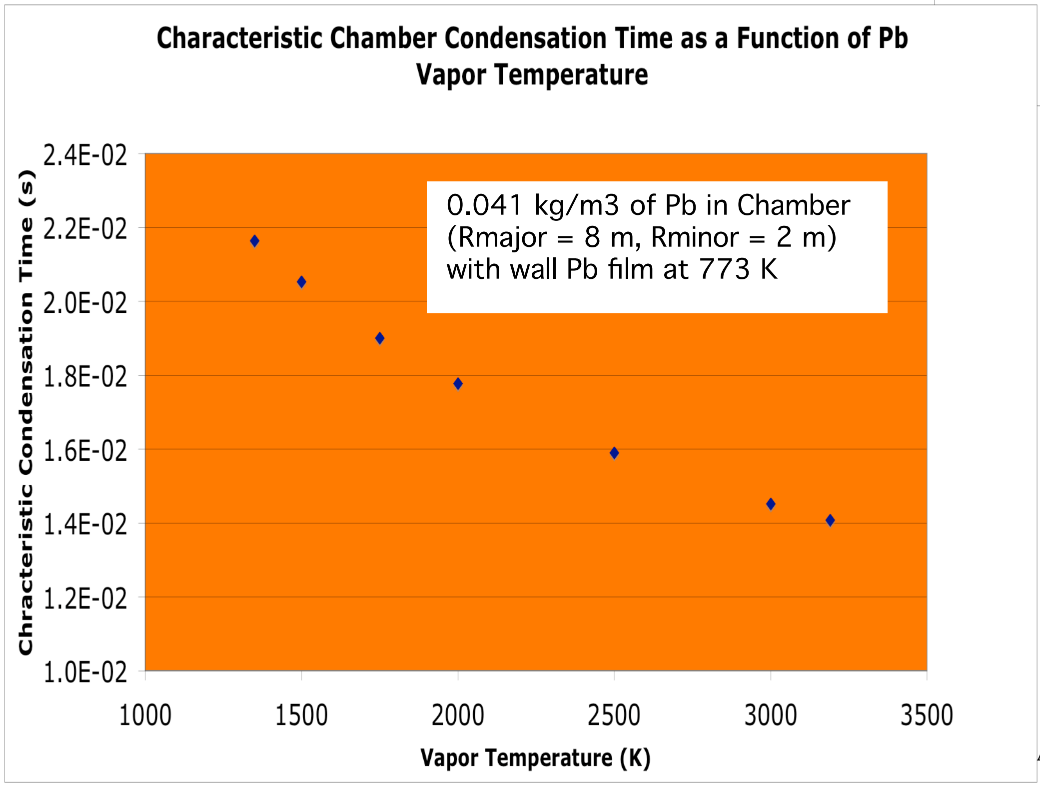
- Ion energy from 350 MJ target = 87.8 MJ
  - 7.7% of ion energy to dump over 0-0.5 μs
  - 22.3% of ion energy over 0.5-1.5 μs
- Evaporated thickness and vapor temperature rise from ion energy deposition in ion dump chamber
- Liquid Pb as film material
- Conservatively small ion deposition area = 220 m^2

  e.g. 35% of chamber with R_{major} = 8 m and R_{minor} = 2 m

Scoping Analysis of Pb Condensation in Example Ring Chamber

- **Characteristic condensation time very fast, ~0.01-0.02 s**





- **Depending on final vapor temperature, vapor density prior to next shot is about 1-10 times higher than saturated vapor density at assumed wetted wall temperature of 773 K (1.75×10^{-8} kg/m^3 or ~0.01 mTorr at ST)**

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Status of Blanket Study for Magnetic Intervention Chamber

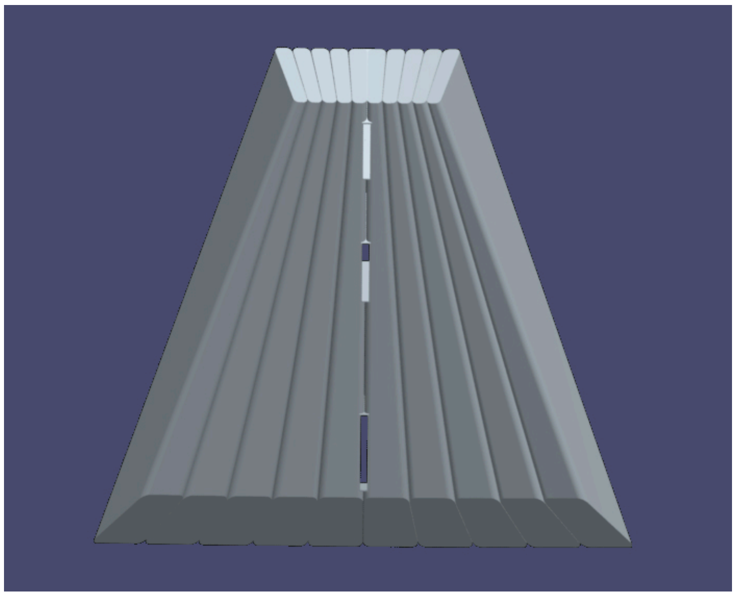
- **More detailed study of blanket using Pb-17Li and SiC_f/SiC**
  - Neutronics
  - Fabrication
  - Assembly and maintenance
  - Thermal-hydraulics

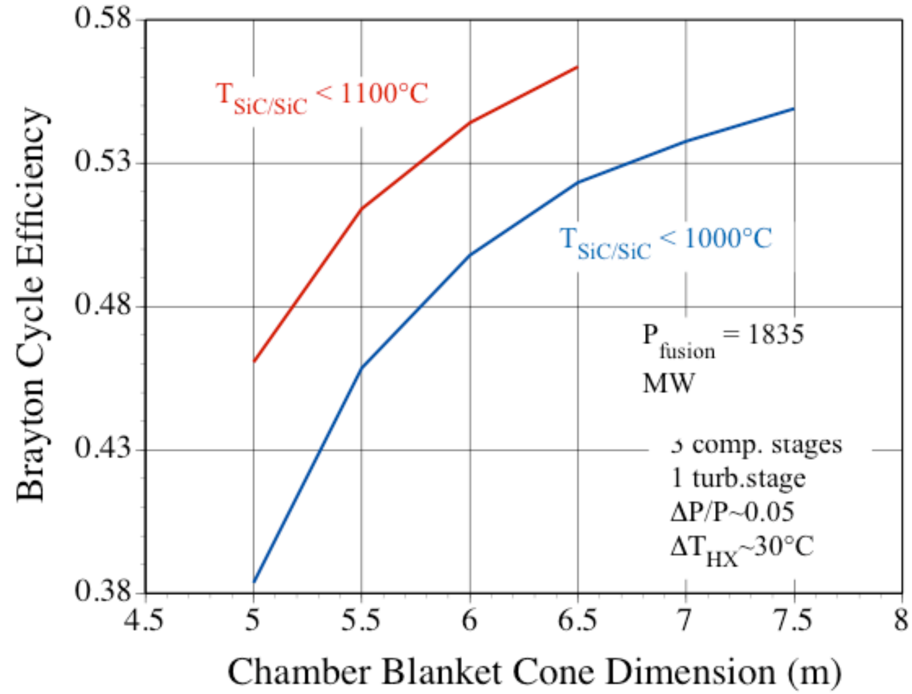
- **Initial study of blanket using flibe and SiC_f/SiC**
  - Possible configurations
  - Neutronics

To be reported by M. Sawan and G. Sviatoslavsky

Self-Cooled Blanket Concept Coupled to a Brayton Cycle (Pb-17Li + SiC_f/SiC and Flibe + SiC_f/SiC)

Blanket	Rchamber	Max. SiC T	Max. SiC/Cool T	Coolant Tin	Coolant Tout	Coolant DP	Cycle eff.
Pb-17Li	6 m	1000°C	900°C	483°C	799°C	~0.3 MPa	50%
Pb-17Li	6 m	1100°C	950°C	580°C	930°C	~ 0.3 MPa	55%
Flibe	6 m	1000°C	912°C	519°C	700°C	~1 MPa	46%
Flibe	6 m	1100°C	1010°C	590°C	790°C	~1 MPa	50%





- **From simple estimate for flibe with same blanket configuration as Pb-17Li:**
  - **Flibe low Re and poor heat transfer properties result in lower cycle η and higher ΔP for given SiC_f/SiC T_{max} constraint.**
- **Need to perform analysis for optimized flibe configuration**

Summary

- Scoping study of self-cooled Pb-17Li + SiC_f/SiC blanket concept for use in the magnetic-intervention cone-shaped chamber geometry completed

- Initial study of flibe + SiC_f/SiC blanket started, needs to be completed based on neutronics calculations and optimized configuration

- Separate dump chamber with melted solid wall or wetted wall assessed for magnetic intervention case
  - Much relaxed atmosphere requirements for separate dump chamber
  - Encouraging results as condensation is very fast
  - Need to ensure no unwanted contaminants in main chamber
  - Need more detailed design of dump chamber configuration including how to recycle liquid for wetted wall concept

- Future work
  - Complete flibe+SiC_f/SiC blanket scoping study
  - More detailed design of separate dump chamber