Google: [Leonid Zakharov] $\longrightarrow$ http://w3.pppl.gov/~zakharov

Operational and design space of LLD,

Li/Mo Capillary Porous System (CPS) and Li/SS/Cu plate

Leonid E. Zakharov

Princeton Plasma Physics Laboratory, MS-27 P.O. Box 451, Princeton NJ 08543-0451

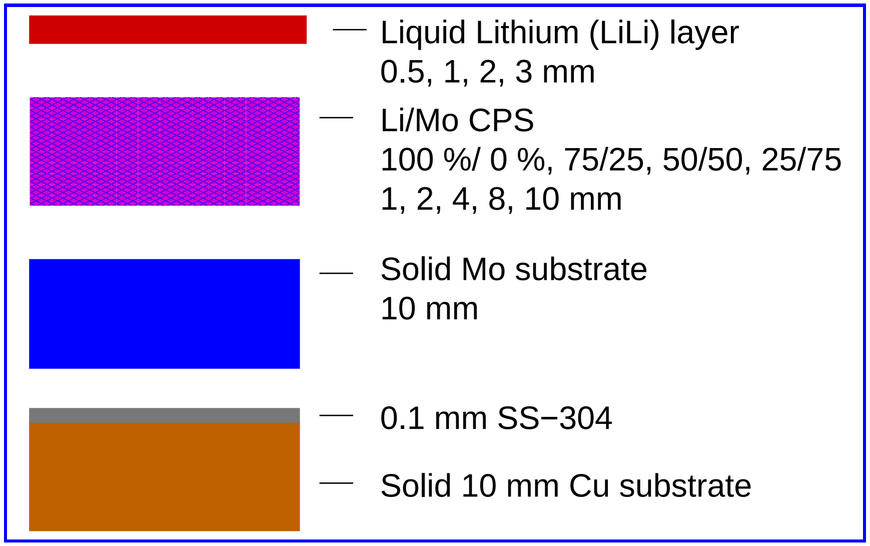
NSTX Meeting,

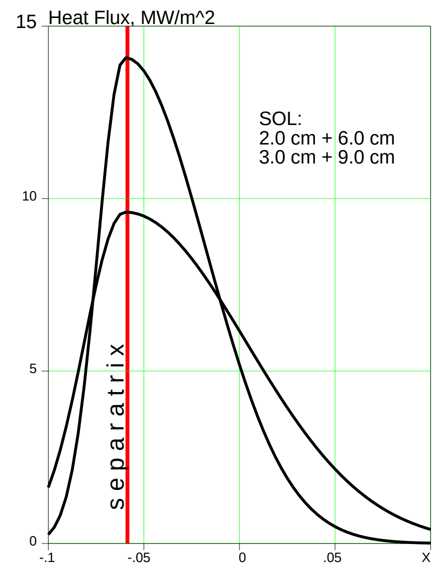
May 29, 2007, PPPL, Princeton NJ

[1] This work is supported by US DoE contract No. DE–AC020–76–CHO–3073.

Contents

Both Liquid Lithium (LiLi) and Li/Mo CPS were considered





Heat flux profile from the SOL

$$Q_{SOL} = Q_0 \exp\left[-\left(\frac{x - x_0}{d(x)}\right)^2\right], \quad \begin{cases} d = d_{out}, & x \geq x_0 \\ d = d_{in}, & x < x_0 \end{cases} \qquad (1.1)$$

Characteristic scale lengths, mm

d_{in}	d_{out}	Δ_{LiLi}	$\Delta_{Li/Mo}$	Δ_{SS}	$\Delta_{Mo,Co}$	Li/Mo CPS
20,30	60,90	0.5, 1,2,3	1,2,4,8,10	.1	10	4/0, 3/1, 2/2, 1/3, 0/4

Lowest NBI energy (20-30 keV) is the most appropriate for the LiWall regime in NSTX

The Reference Transport Model (RTM)

$$\chi_e = \chi_i = D_{i,e} = \chi_i^{neo} \tag{1.2}$$

predicts $\tau_E \simeq 0.3$ sec for 0.6 MW NBI at 25 keV.

Expected $\tau_E \simeq 0.1 - 0.15$ sec

The expected working range of $P_{NBI} \simeq$0.75-1.5 MW.

The range of P_{NBI} considered: 0-2.5 MW deposited to LLD.

RTM seems to be consistent with CDX-U results

Initial temperature is very important for limits by evaporation

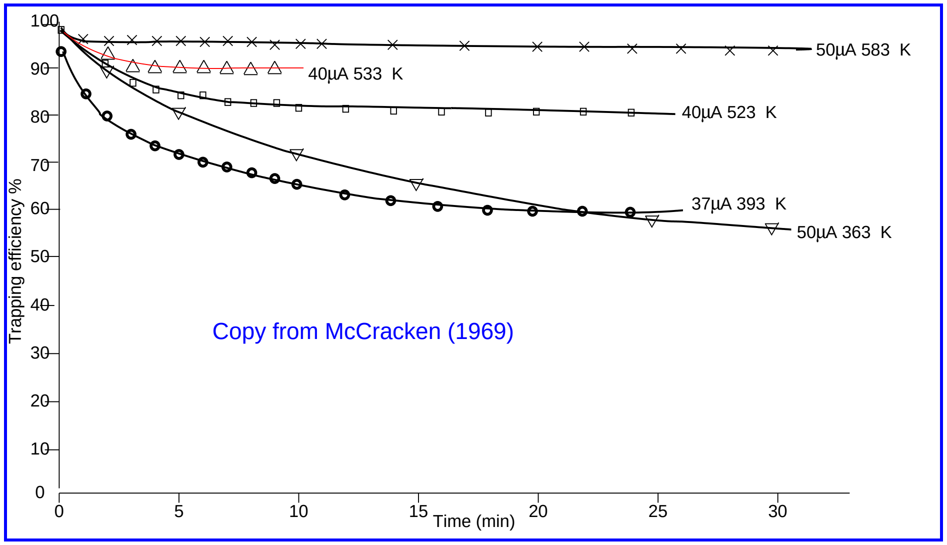
Initial temperatures:

- 100^{o}C, solid lithium, although
  heat losses for melting of Li have been neglected (!) (additional reserve of $\Delta T \simeq$100^{o}C for the Li/SS/Cu plate).
- 200^{o}C, liquid lithium.

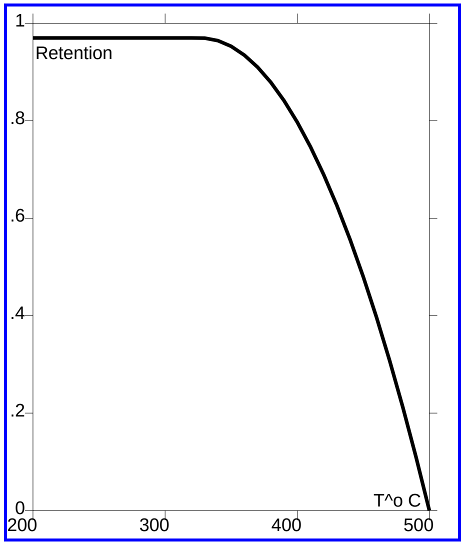
Surface area 0.7 m^2 contains 10^{19} Li particles/monolayer, or $3 \cdot 10^{26}$ Li particles/mm of thickness.

1 working mm of Li is sufficient for pumping 10^4 of $3 \cdot 10^{21}$ D,
more than sufficient for 2 weeks of NSTX operation

Lithium retains Hydrogen in a limited window of temperatures



McCracken retention curves



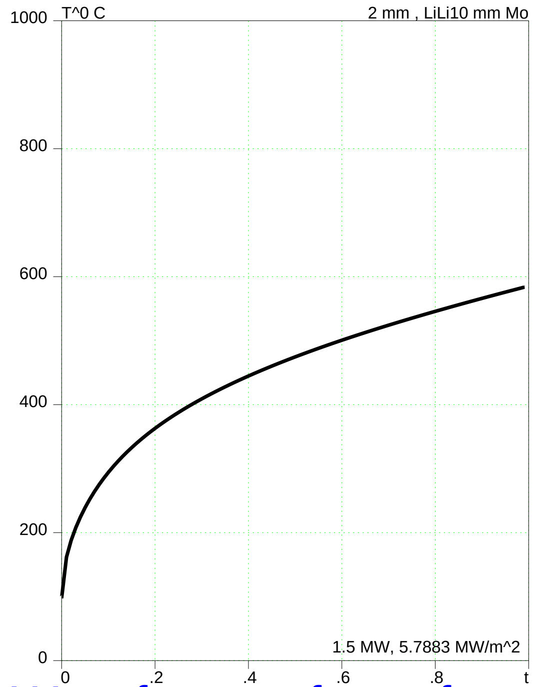
Short term retention curve used in calculations

Probably short lasting retention allows temperatures above 350^{o}C (R.Majeski)

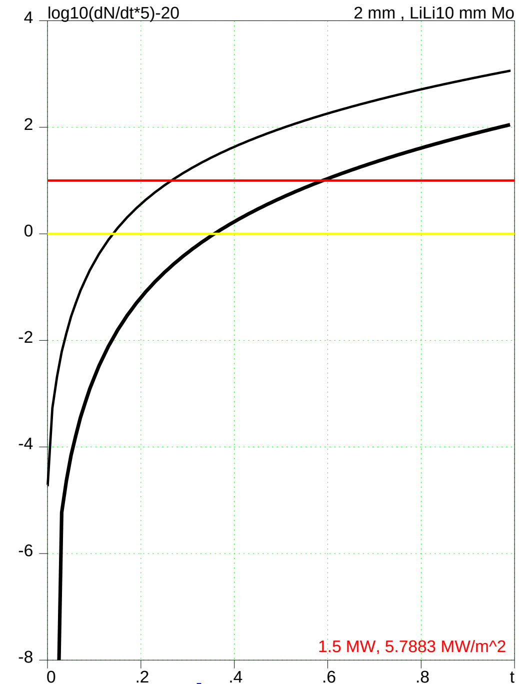
Short term retention curve was taken arbitrarily

Requires special technology studies

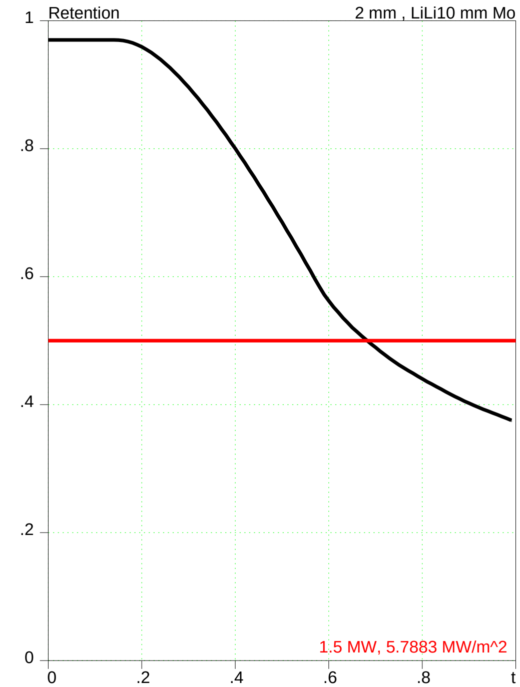
3-D Cbebm code (written for Marangoni effect) is used to simulate heating of Li surface



Waveform of surface temperature T_{Li}



Evaporation $\log_{10}(dN/dt) - 20$

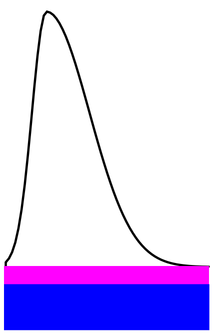


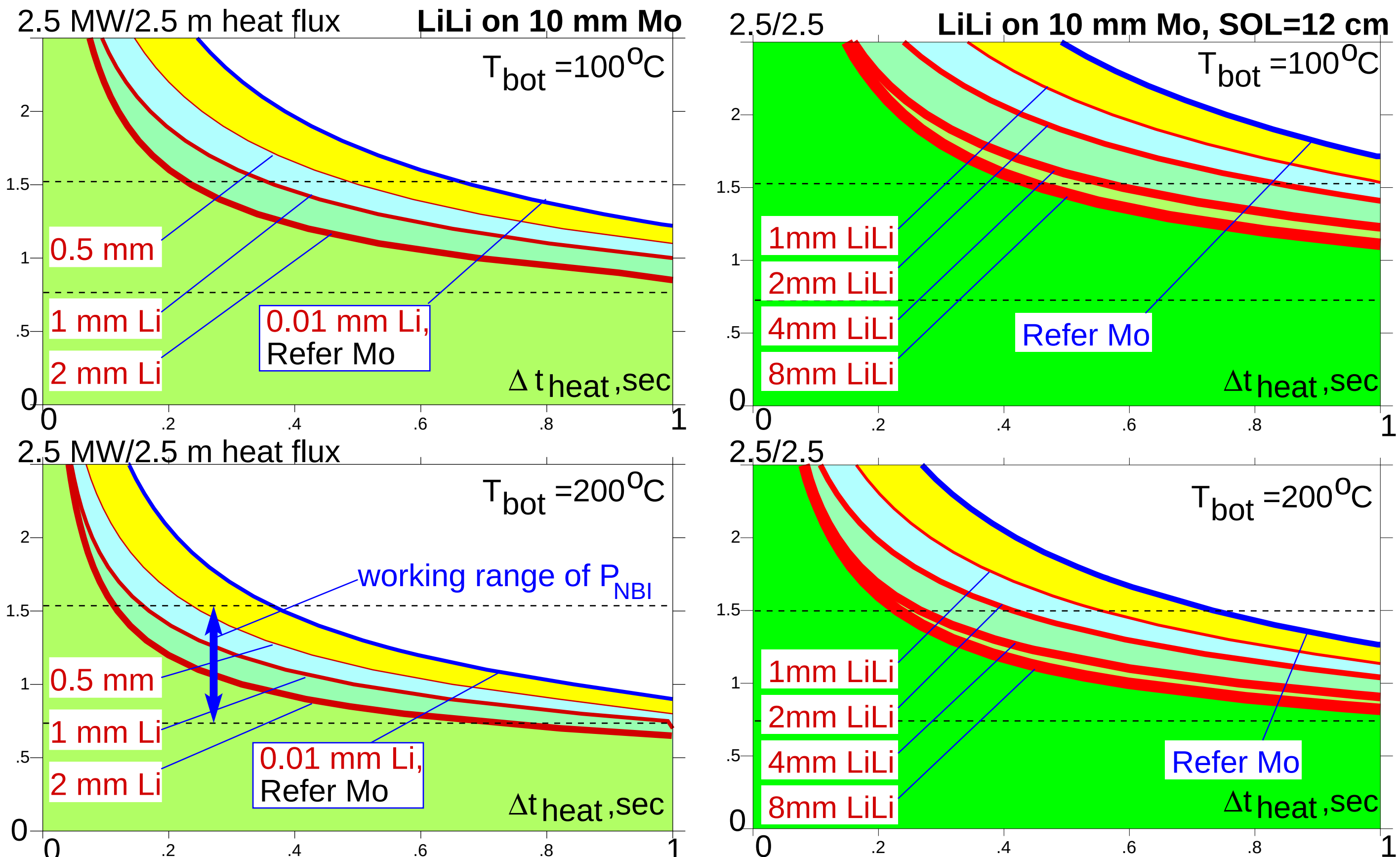
Overall retention

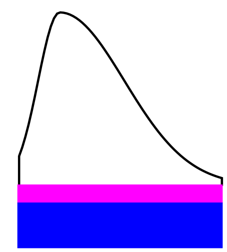
Evaporation limit was set to $10^{21}\ 1/sec$

The role of reduction in retention after 350^o is unknown

Operational space is limited by evaporation limit





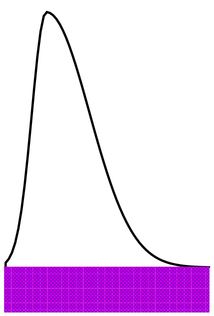


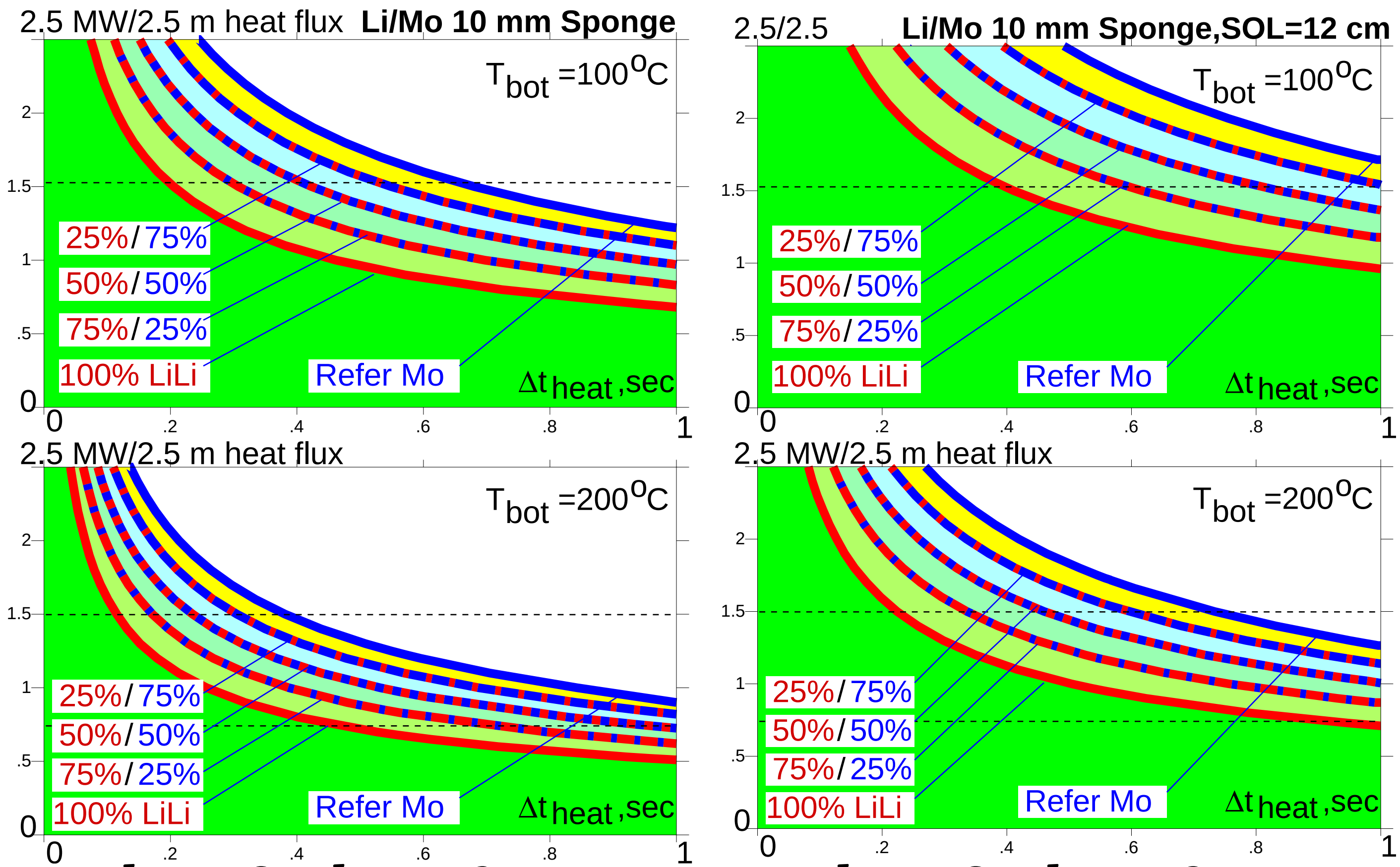
$d_i = 2, d_e = 6$ cm $\qquad$ $d_i = 3, d_e = 9$ cm

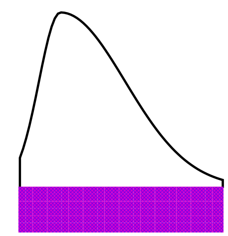
Operational space is situated between the axis and the curve for each case.

100^o of initial ΔT is equivalent to 3 cm of d_{SOL}

Regarding the thermal regime, CPS has advantage over LiLi



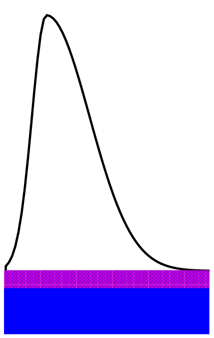


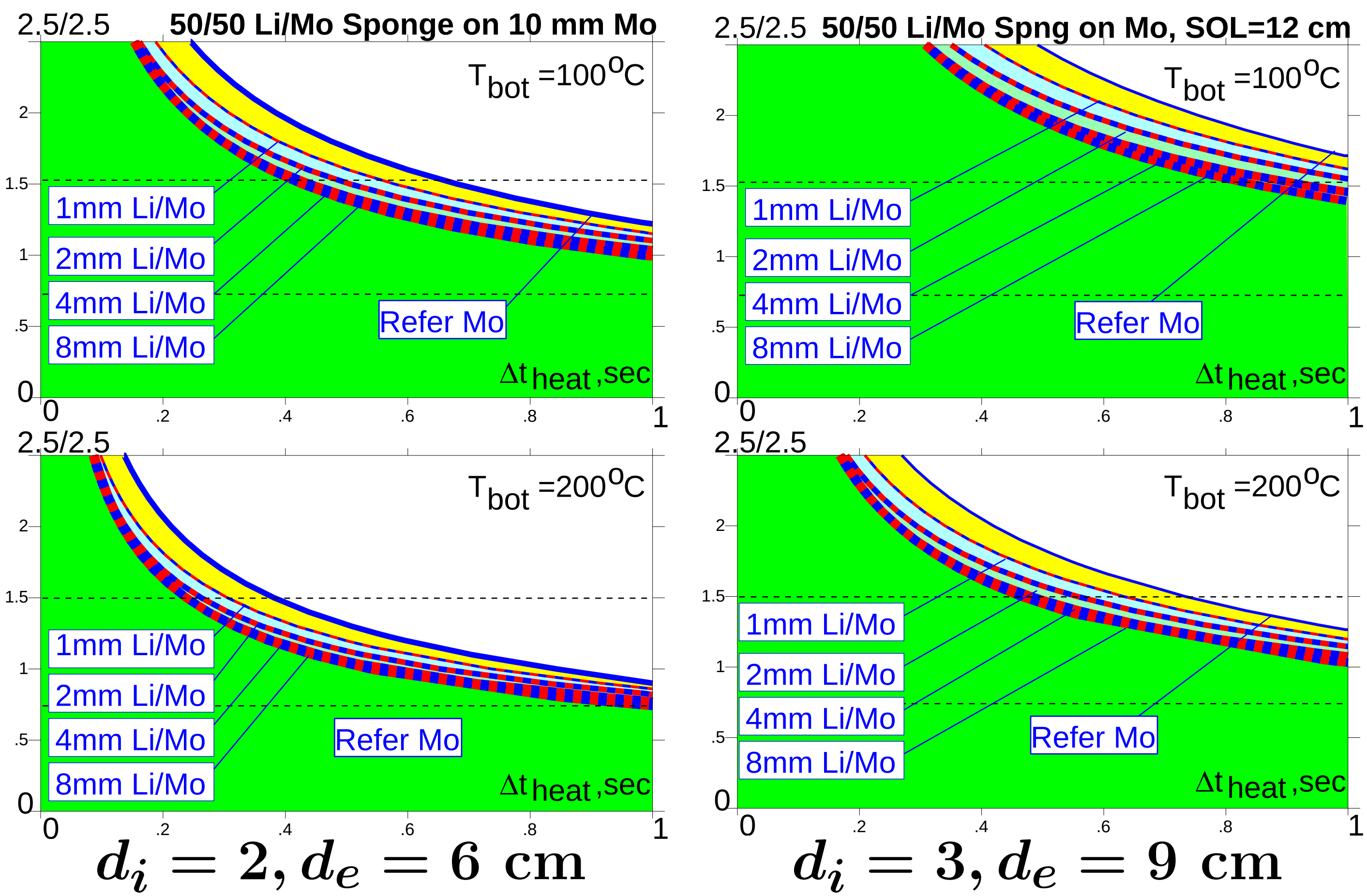


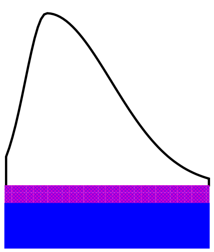
$d_i = 2, d_e = 6$ cm $\qquad$ $d_i = 3, d_e = 9$ cm

$\chi_{Li/Mo} = C_{Li}\chi_{Li} + (1 - C_{Li})\chi_{Mo}$ **requires technology test**

50/50 Li/Mo CPS may have the best characteristics

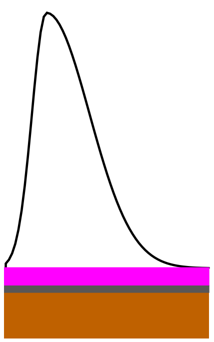


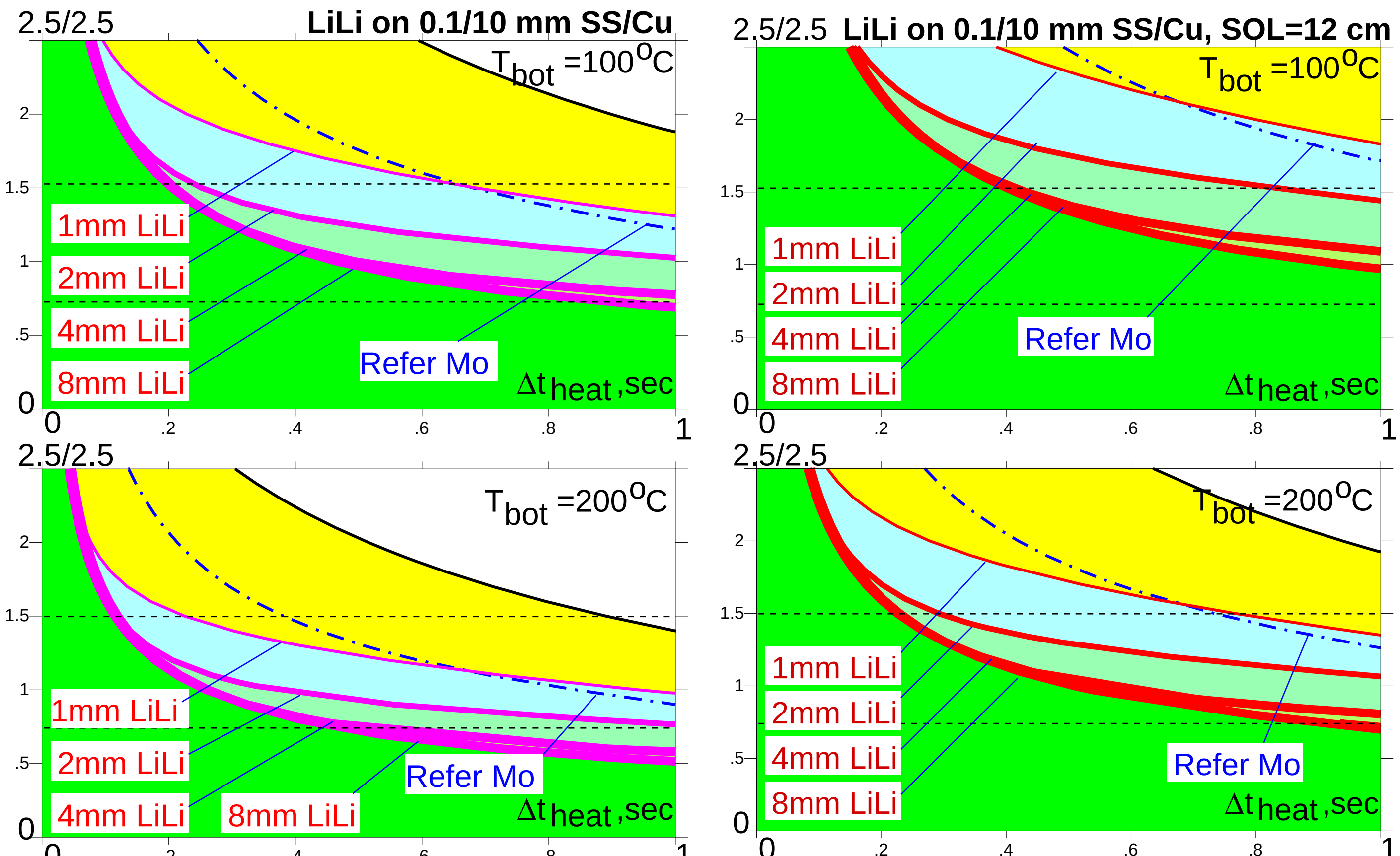




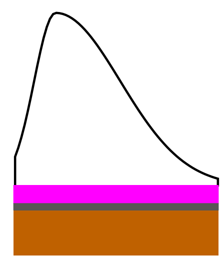
Potential clogging by LiOH, LiD, etc requires technology studies

The plate 0.1-1 mm of Li on 0.1/10 SS/Cu provides the operational space for LiWall regime in NSTX



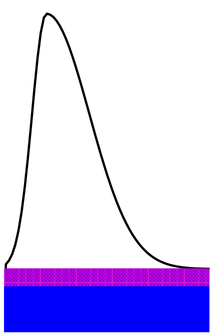


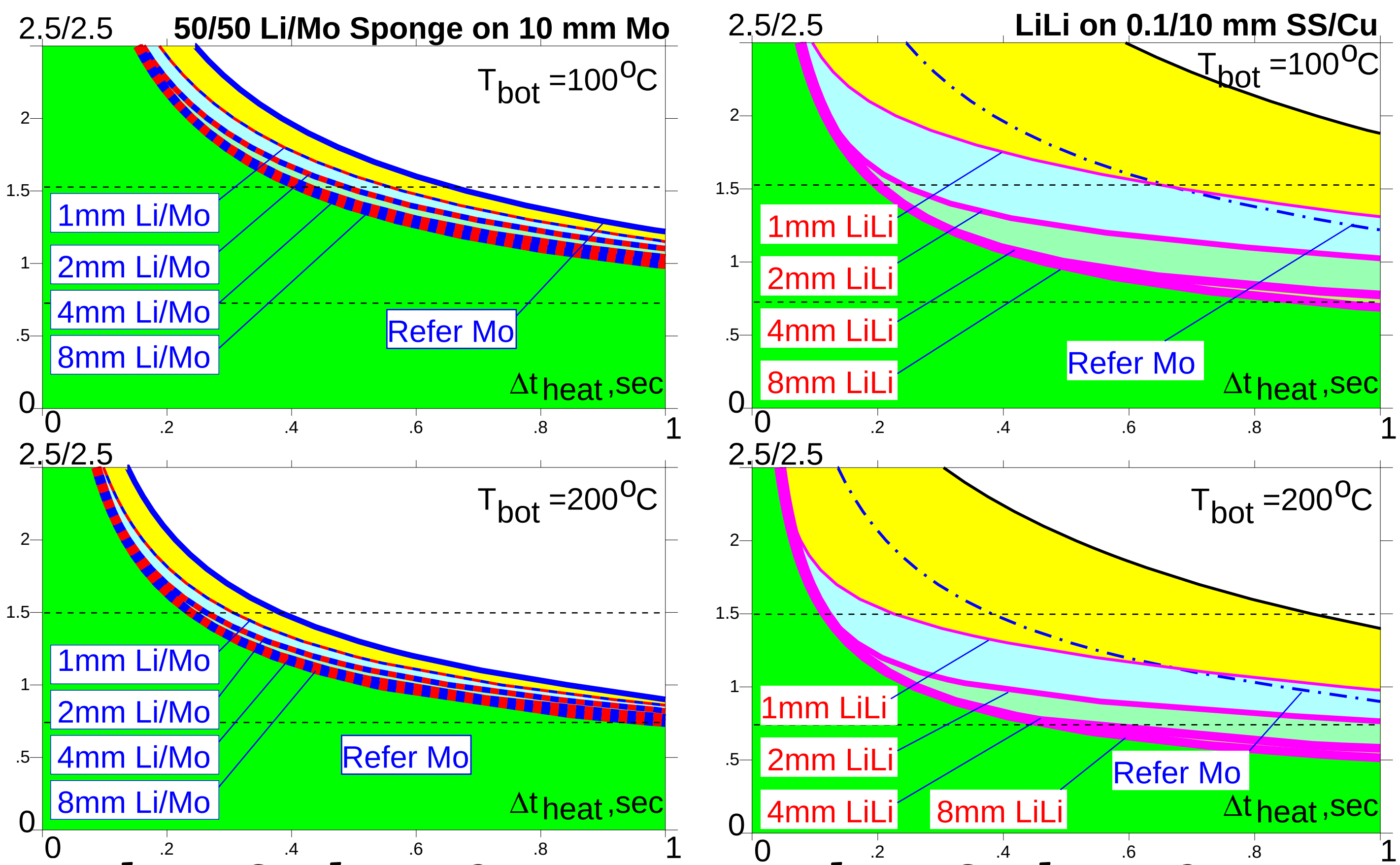
$d_i = 2, d_e = 6$ cm $\qquad$ $d_i = 3, d_e = 9$ cm

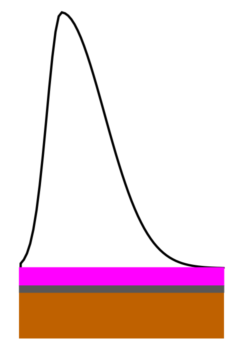


The heat flux profile in the SOL is a crucial unknown

1/0.1/10 mm Li/SS/Cu plate outperforms 10 mm Li/Mo CPS



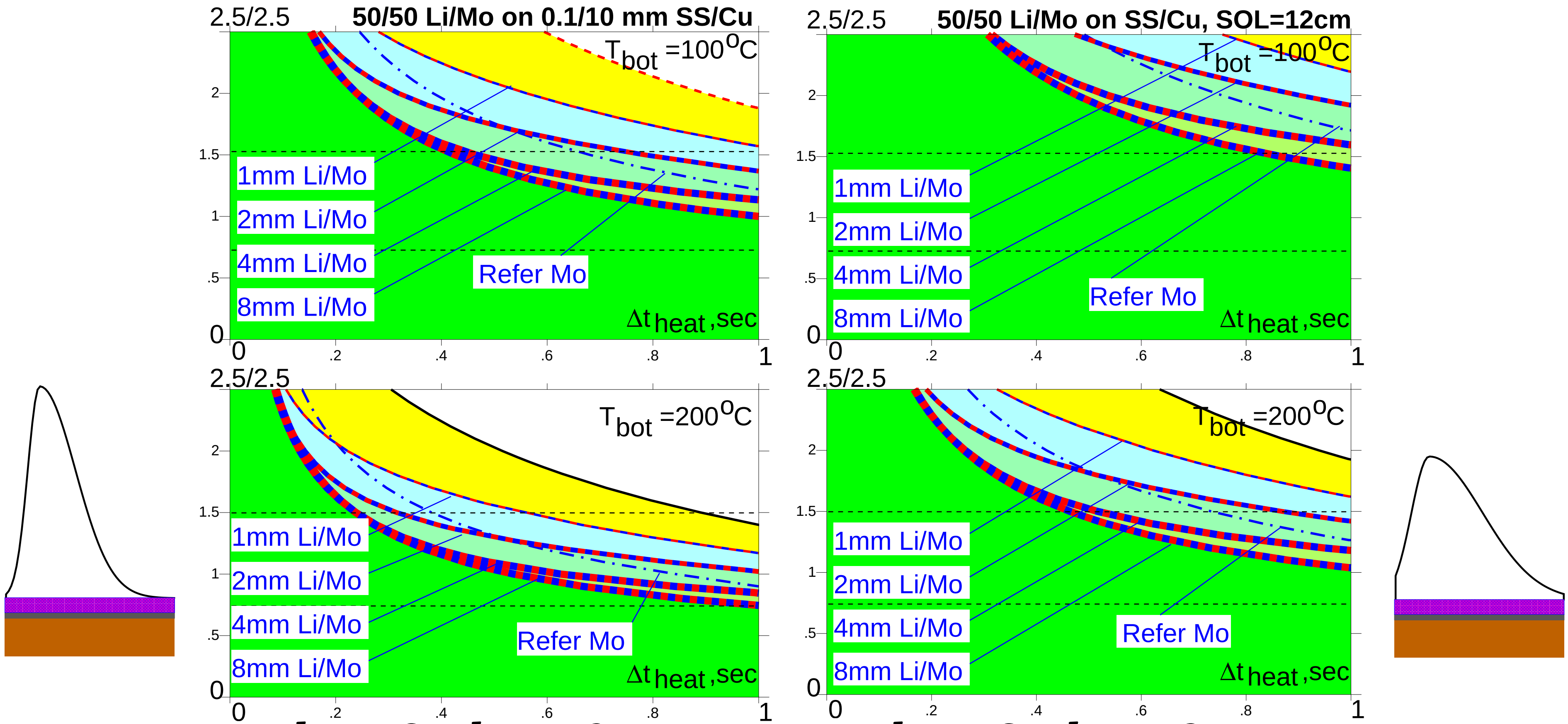




$$d_i = 2, d_e = 6 \text{ cm} \qquad d_i = 2, d_e = 6 \text{ cm}$$

The plate also has fewer technology unknowns

1 mm Li/Mo CPS on 0.1/10 mm SS/Cu plate is the best



$d_i = 2, d_e = 6$ cm $\qquad$ $d_i = 3, d_e = 9$ cm

1 mm Li/Mo CPS on 0.1/10 mm SS/Cu is similar to T-11M,FTU

LLD design faces many unknowns from plasma physics and technology sides

Leaving aside plasma physics unknowns, which are important for both Li/SS/Cu plate and LLD, the plate is more capable than Mo-based CPS:

1. larger design (LiLi or CPS) and operational space
2. well-known physical properties
3. possibility of solid/liquid back and forth transitions
4. simpler overall maintenance
5. no need of additional heating (cooling might be necessary ?)

Everything is simplified because of the plate limited life expectancy.

1/0.1/10 mm Li/SS/Cu plate outperforms the Mo-based CPS in all aspects

The Li/SS/Cu plate is sufficient for the first LiWall regimes on NSTX

Installation of Li/SS/Cu plate will be the turning point for PPPL toward relevance to the energy R&D, lost at present

Do we need

to install it

before Li/Mo-CPS ?