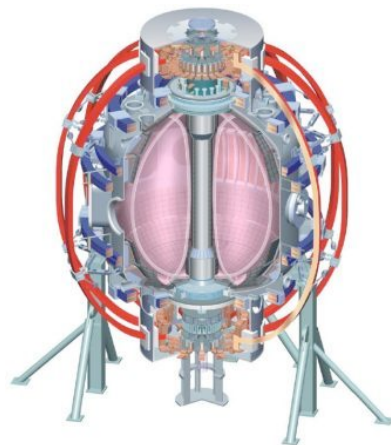


L? L? D? – Outgassing Studies and Lithium Inventory

College W&M
Colorado Sch Mines
Columbia U
Comp-X
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
ORNL
PPPL
PSI
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Maryland
U Rochester
U Washington
U Wisconsin

Josh Kallman

**Li TSG Meeting
April 14, 2010**



Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
KBSI
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

Do we understand the LLD surface?

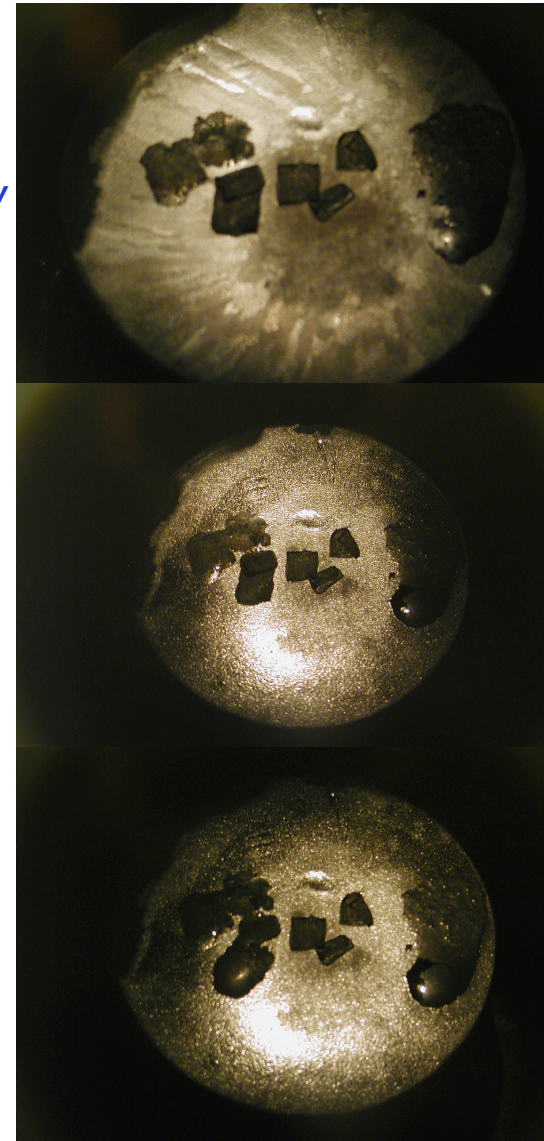
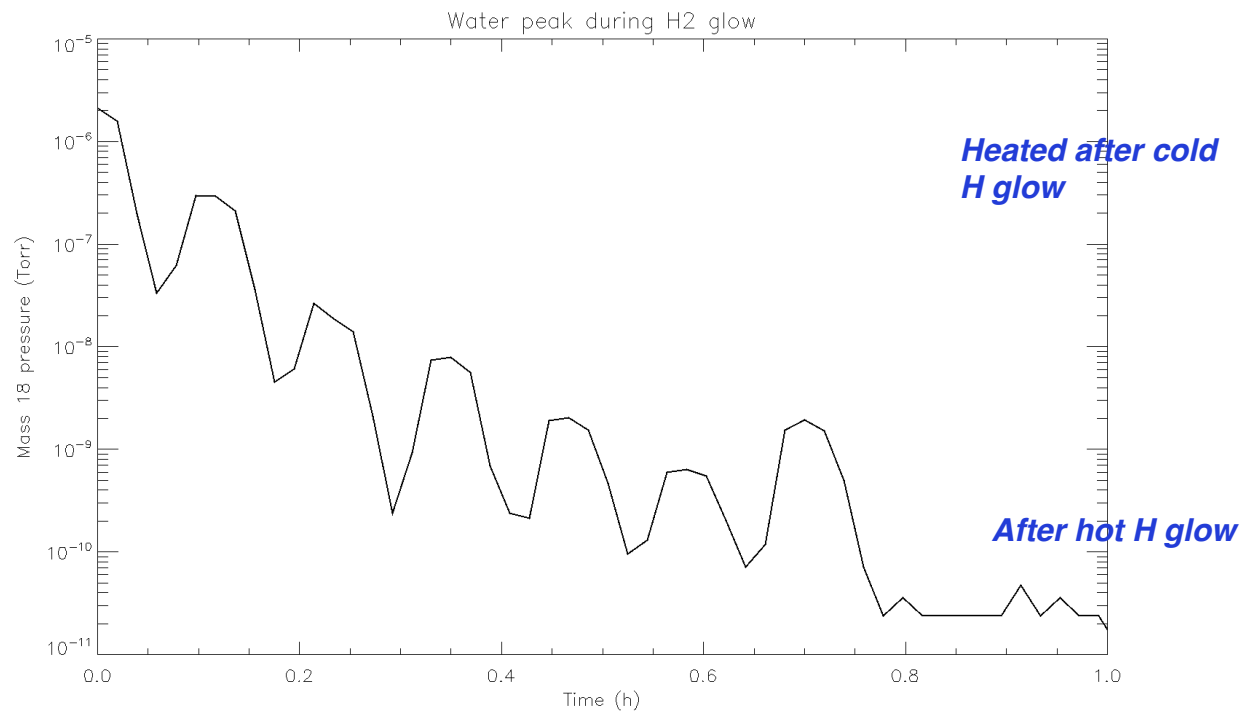
To pump at predicted levels, we need an active lithium surface of sufficient thickness with a sufficient plasma flux

Is it:

- Liquid (active)?
 - laboratory experiments?
 - ‘shininess’?
 - outgassing studies?
- Lithium (of the requisite thickness)?
 - balance between evaporation and deposition?
 - necessary thickness? (in M. Jaworski)
- a Divertor?
 - is there sufficient particle flux to the pumping region?

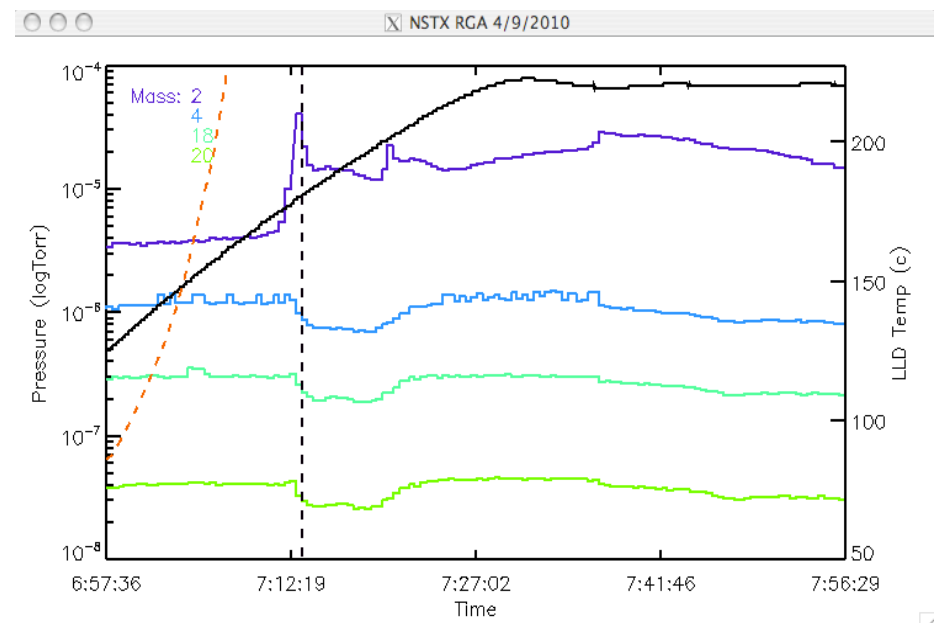
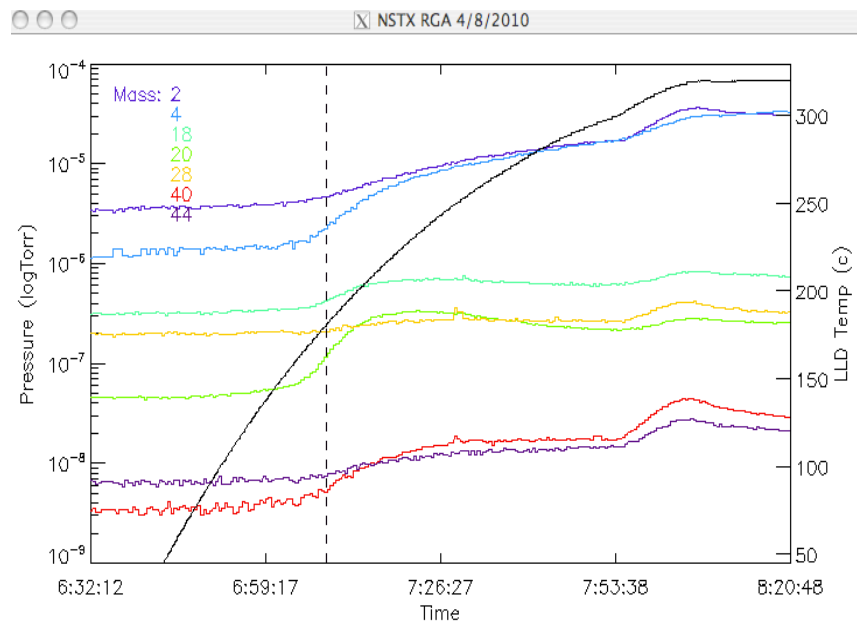
L245 Tests

- H₂ and He glows performed on cold passivated Li surface for 1 hr each
- Recovery in pumping observed for H glow
 - water peak drops by factor of 1000 *Before cold H glow*
 - for He glow drop in water peak factor of 2-3
- Surface recovered 'shininess' when reheated the next day after cold H, and hot H glow helped further remove surface contamination



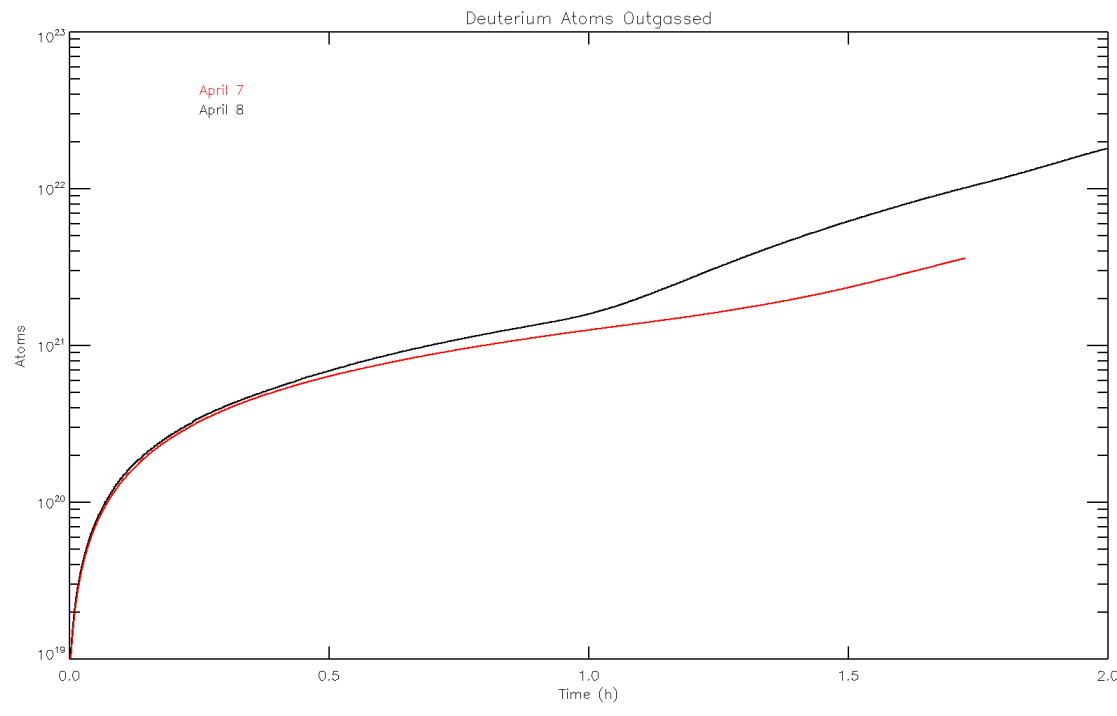
Preliminary Outgassing Data

- RGA shows that deuterium, hydrogen entrained in LLD
- Lab experiments showed rise in H_2 , drop in H_2O when lithium 'active' – not observed conclusively on NSTX
- Although mass 2 seems to saturate and decrease during heating, mass 4 continues to increase (4/8)
- On 4/9, water drop and H rise observed, but very close to LITER crossing lithium melt threshold
- Longer experiment necessary to more fully outgas LLD and measure various species inventories
 - effects of various glows?



Deuterium outgassing on 4/7 and 4/8

- Ideal gas law and RGA pressure/actual pressure ratio (with orifice correction) and pumping rate can give one total amount of deuterium atoms escaping from surface and being pumped
- Now compare to Li rate – D reference is $\sim 10^{22}$ atoms/hr @320 C



LLD Theoretical Maximum Evaporation

- Partial pressure taken from Moir, APEX meeting 1999 – same as are used to calculate LITER deposition.
- These represent the theoretical maximum rate, not accounting for any impurities in the material or other obstructions to surface evaporation

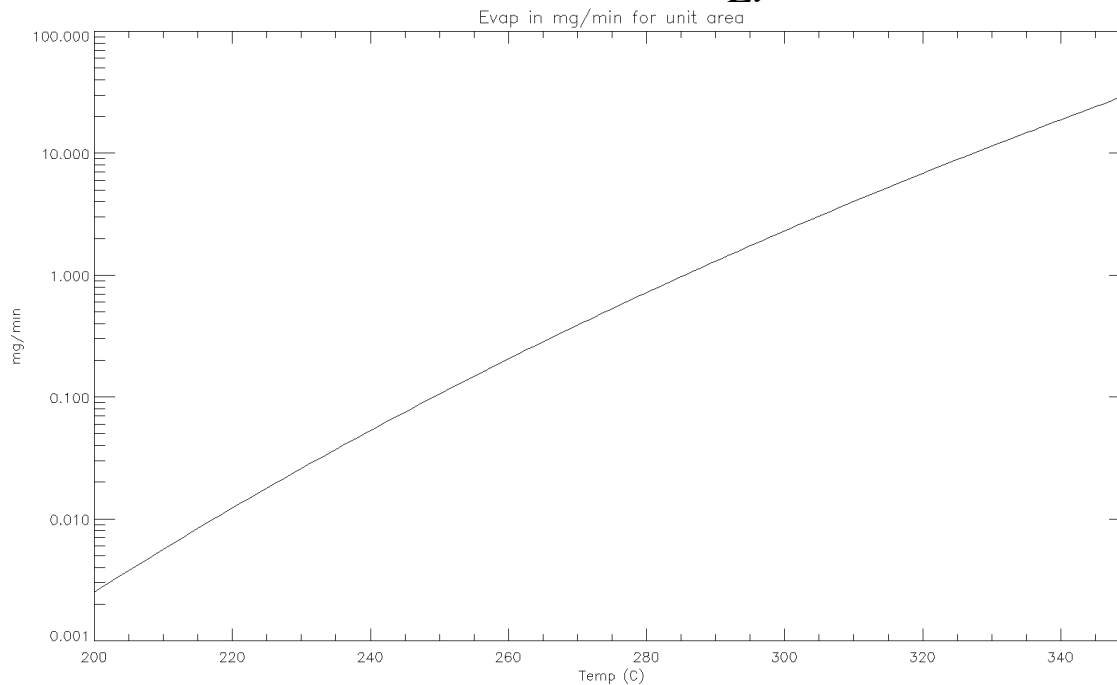
$$J = \frac{n\bar{v}}{4}$$

$$\bar{v} = \sqrt{\frac{8kT}{\pi m}}$$

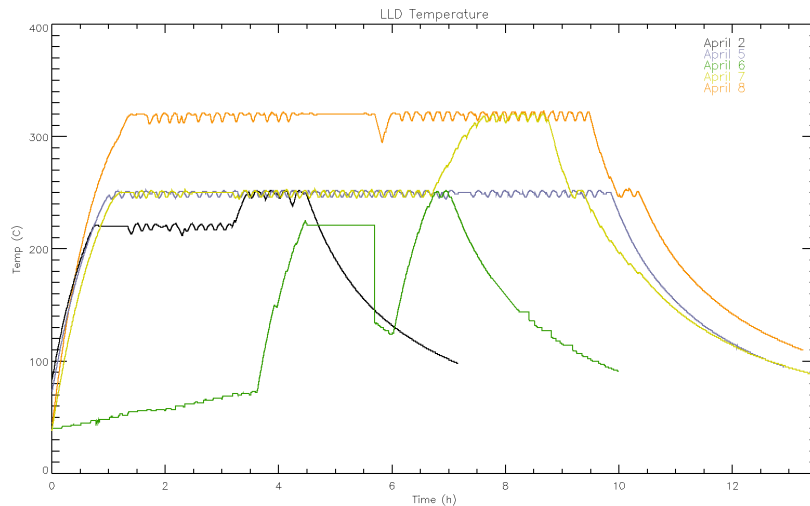
$$n = \frac{P}{kT}$$

$$J = \frac{P}{kT} \sqrt{\frac{kT}{2\pi m}}$$

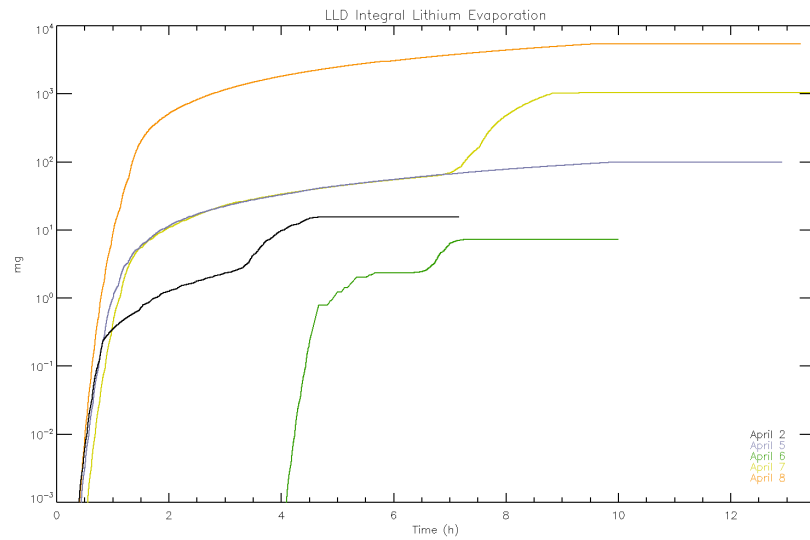
$$P_{Li} = \exp(18.4 - 18750/T)$$



LLD Lithium Inventory



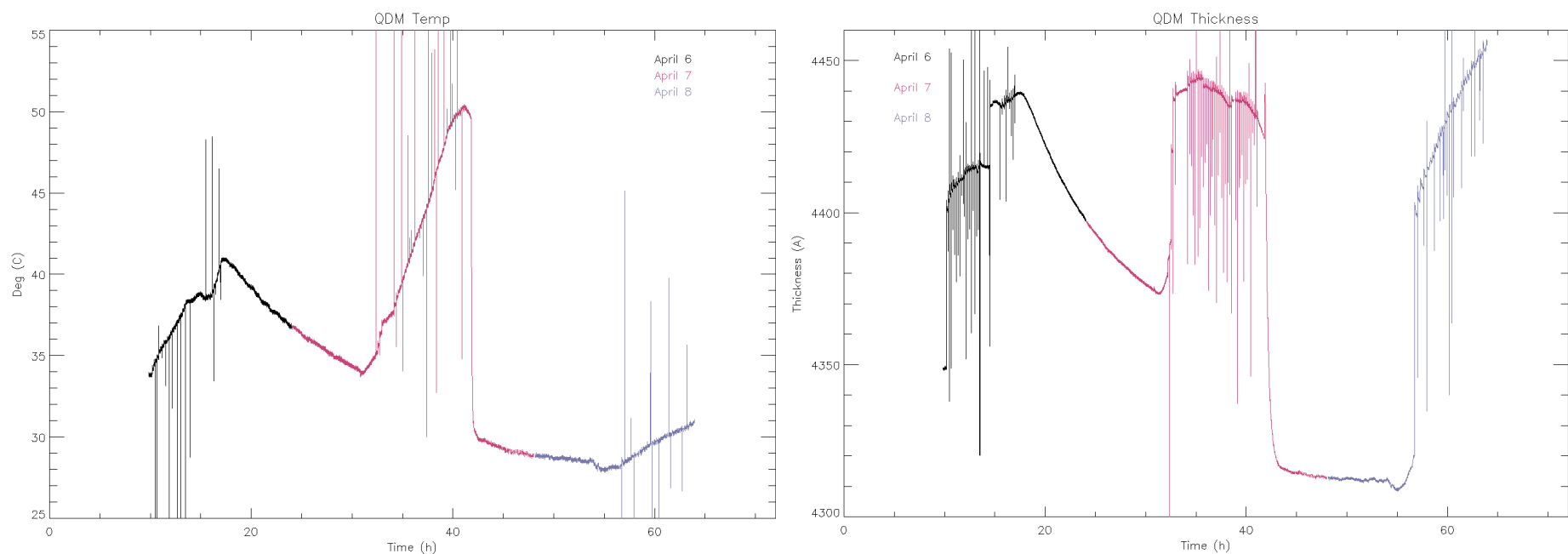
- LLD temperature data from EPICS (plate averaged from bulk TCs) used in previous equation (with 'effective' surface area correction of 1.33) to calculate evaporation
- LITER rates account for 3 functioning plates – from Hans spreadsheet
- Leonid calculates only 4.5% LITER efficiency!



Date	LITER	LLD	Net	Total
Pre	2310	0	2310	2310 mg
4/2	237	15	232	2542
4/5	425	100	325	2867
4/6	268	7	261	3128
4/7	396	1036	-640	2488
4/8	306	5441	-5135	?

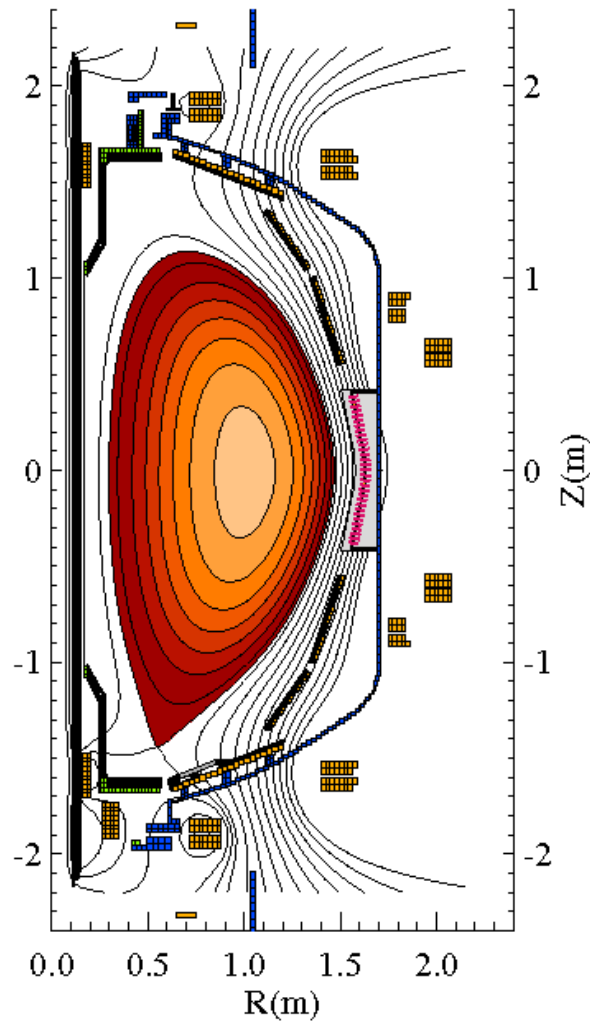
QDM Data

- Downward facing QDM shows evaporation from LLD
- Cooling air turned on at 6 PM on 4/7, accounts for large drop in signal
- Large rise during morning of 4/8 coincides with first plasma shot of the day
- Large upward trend on 4/8 during high temp, heavy evap

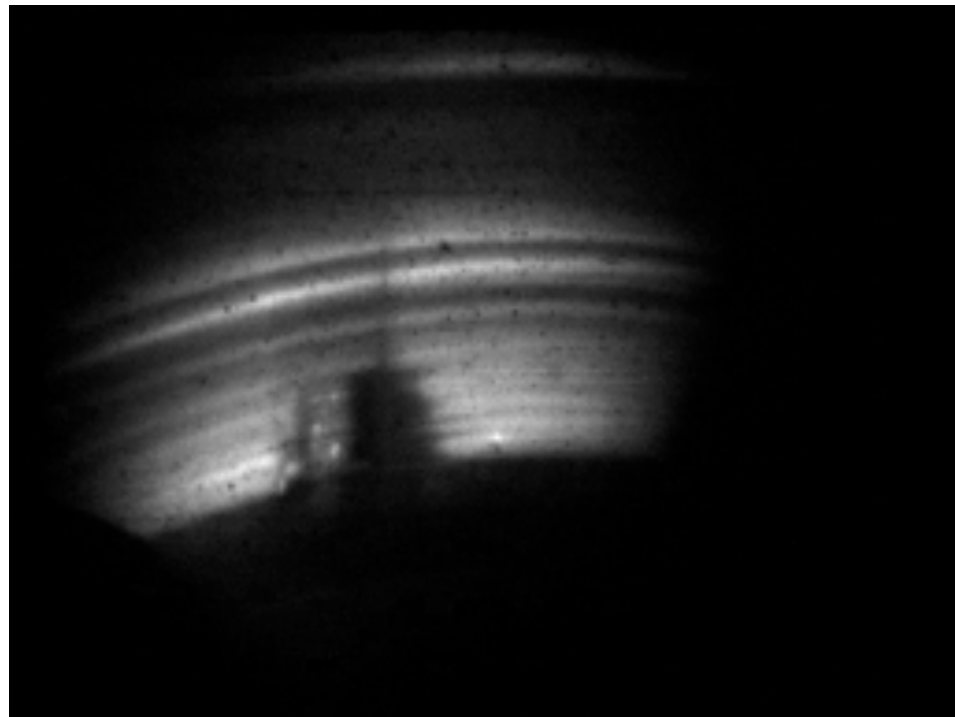


We're getting the divertor part right

from \EFIT02, Shot 137611, time=497ms



- Efit shows the strike point on the LLD
- Fast cameras show the probes glowing from strike point interaction
- Probes show fluxes of 10^{22} - 10^{23} particles per shot (Monday physics meeting)



Assesment

- Liquid?
 - we have yet to see a conclusive RGA spectrum with the drop in the water peak
 - things are happening at the melting point
 - the fact that we are retaining deuterium is a good sign
- Lithium?
 - yes at first, but running too hot for too long tips the balance
 - need better calibrated QDM and LITER data
 - a larger sustained evaporation will help ensure this
- Divertor?
 - probes, visible and IR cameras, and EFIT all say that we are putting flux on the LLD

Complementary Offline Lab Studies

- We can do, and are doing, more in the lab
 - earlier results were of a qualitative flavor
 - it would be nice to have a quantitative method for determining surface activation
- C128 will perform Li deposition studies to
 - help calibrate LITER
 - measure reflectivity of surface
 - we could use a real camera for this! any volunteers?
- C128 will eventually perform glows to quantify surface conditions as a function of fluxes of various species
 - Lithium Conductivity Diagnostic (LCD) calibration opportunity
 - more thorough degassing studies at various temperature ranges and after differing types of glows (cleaning and contaminating)
- L112 is nearing readiness to perform heat flux studies onto sample LLD chunk with MSE-LIF beam
 - close to NSTX heat flux $\sim 11 \text{ MW/m}^2$ peak power density
 - will use thermocouples and IR data for 30 Hz temperature response

Suggestions, areas for improvement

- Before vent: bake LLD to 320 C to remove pure lithium, run plasmas while hot to clean impurities and improve lithium removal
 - watch RGA spectra during process, will inform on eventual 4th plate procedure
- Re-bake after vent to further clean surface, asses contamination during bake
- Fill with lithium after vent to specified depth, as suggested by Mike Jaworski and discussed here
- Run hydrogen glow after deposition to remove surface oxides
 - monitor RGA during and after glow, look for changes in hydrogen/water ratio
 - Ashikawa NIFS results concur with effectiveness of hydrogen glow
 - possible pre-heating before plasma ops to 320 for 0.5 hr to help clean oxides
- Assess effects of vent and deposition on probes, think about cleaning methods
 - as this directly relates to my thesis, it will probably end up higher on my priority list
- General
 - data flow: why aren't the EPICS data in MDS yet?