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

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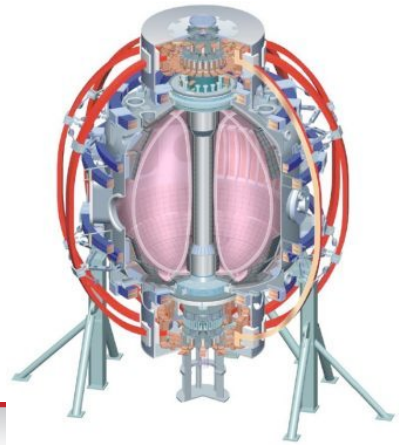
Li TSG Meeting
April 14, 2010



Do we understand the LLD surface?

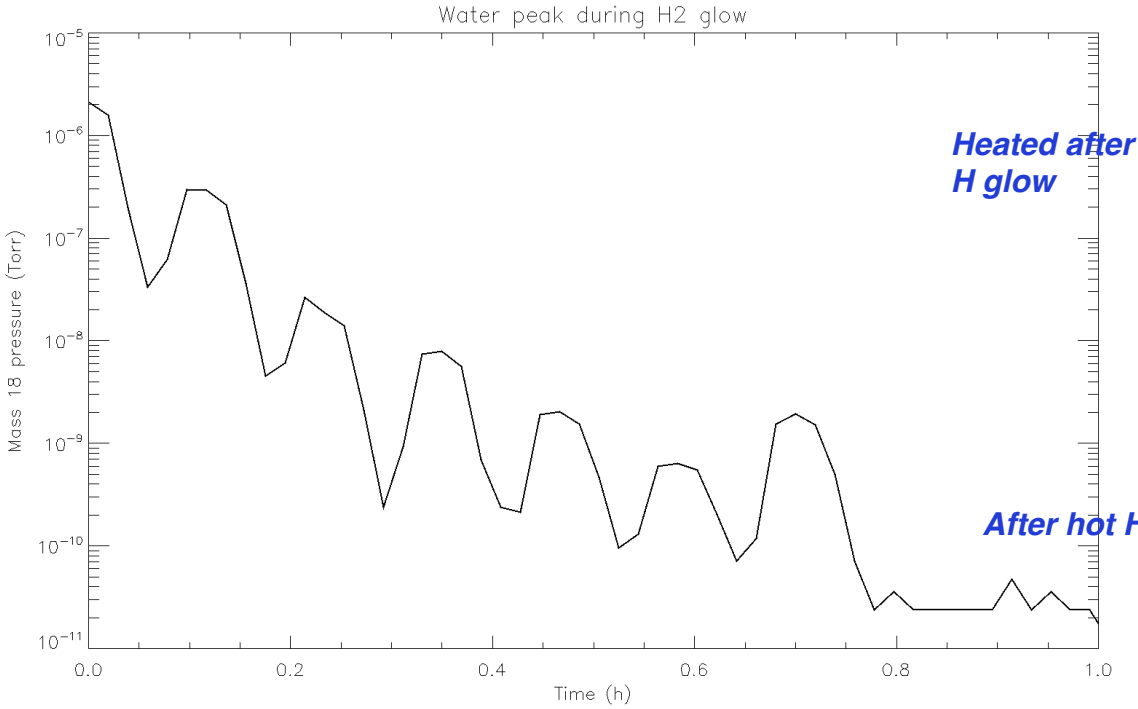
To pump at predicted levels, we need an active lithium surface of sufficient thickness with a sufficient plasma flux

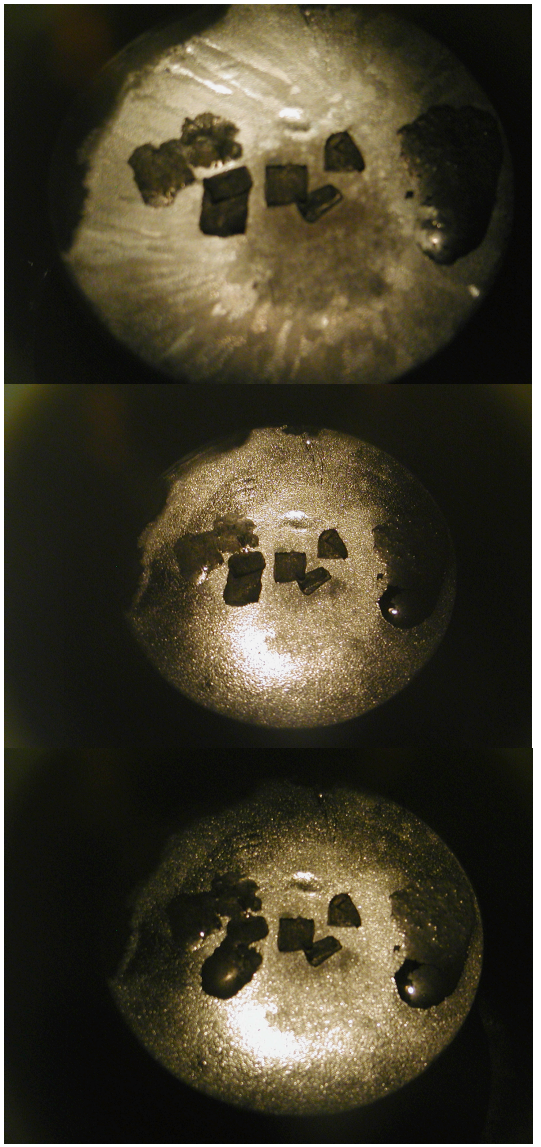
Is it:

- 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

- H_2 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
  - 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





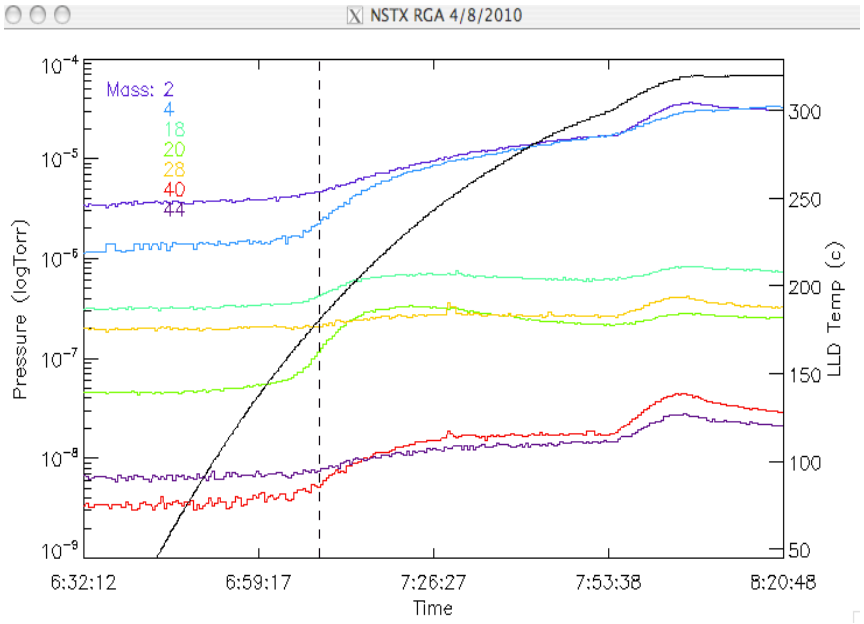
Before cold H glow

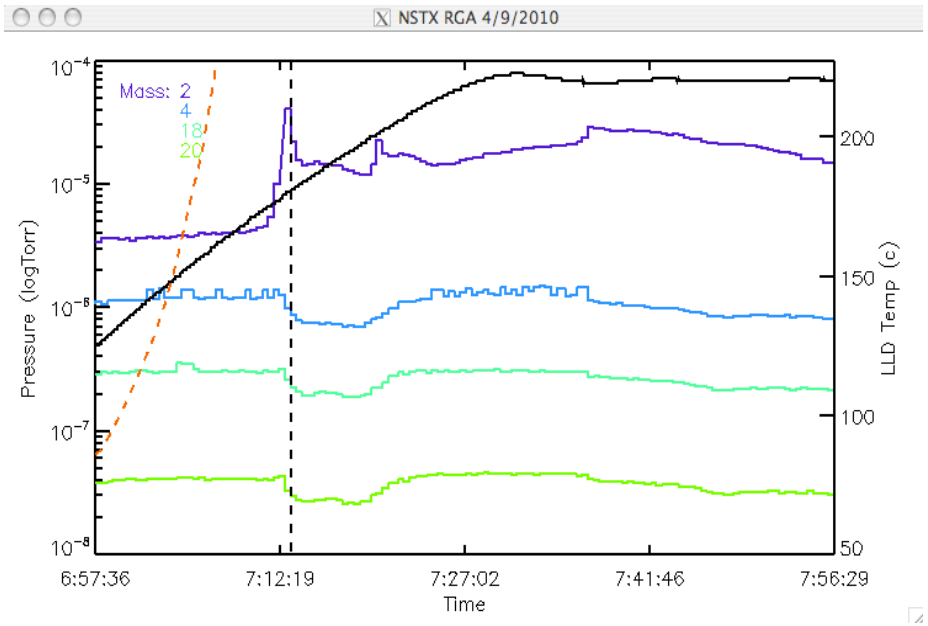
Heated after cold H glow

After hot H glow

Preliminary Outgassing Data

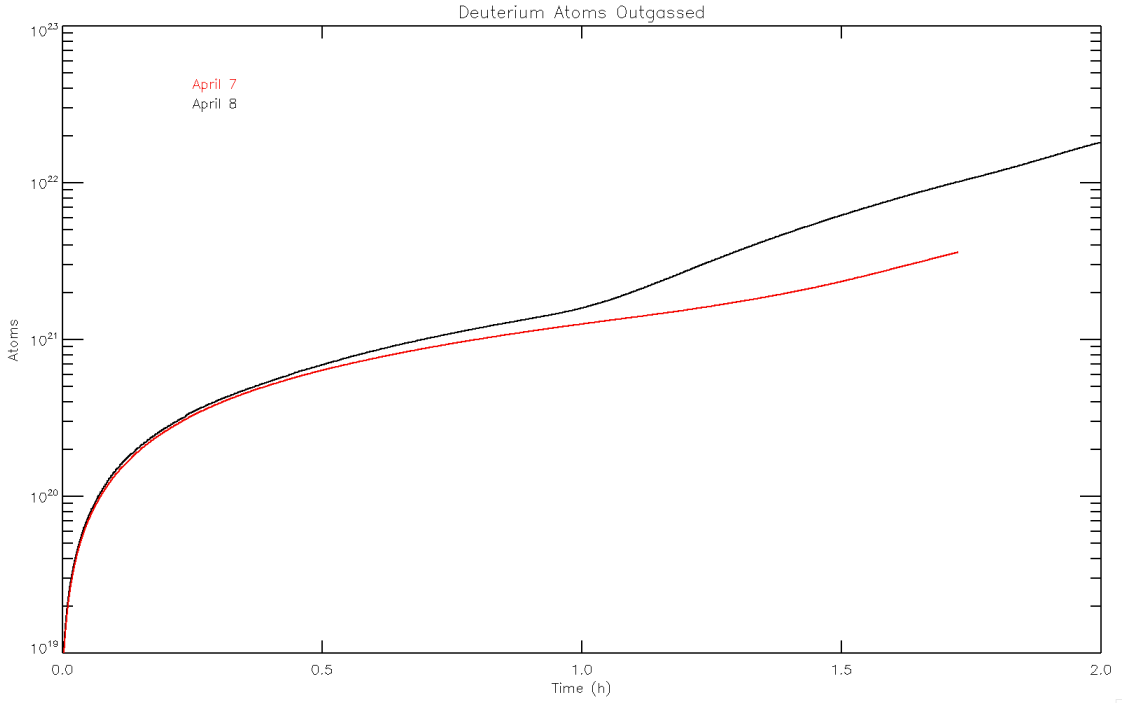
- RGA shows that deuterium, hydrogen entrained in LLD
- Lab experiments showed rise in H_2, drop in H_20 when lithium 'active' – not observed conclusively on NSTX
- Although mass 2 seems to saturate and decrease during heating, mass 4 continues to increase (4/8)
- On 4/9, water drop and H rise observed, 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 ~10^{22} atoms/hr @320 C



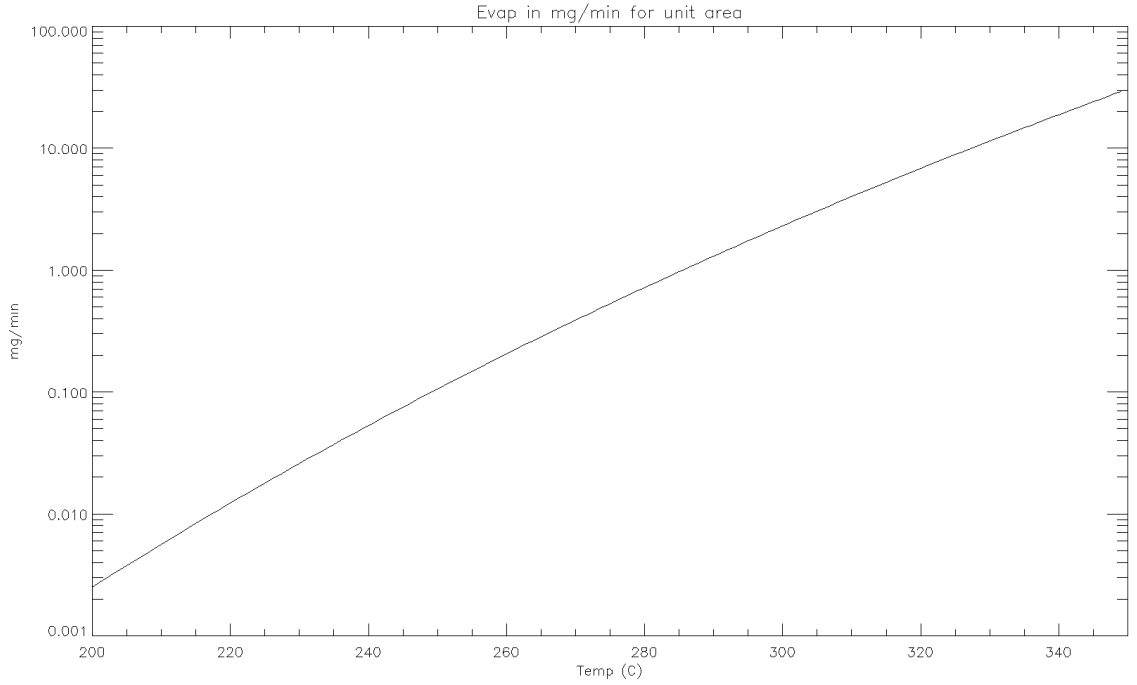
LLD Theoretical Maximum Evaporation

- 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

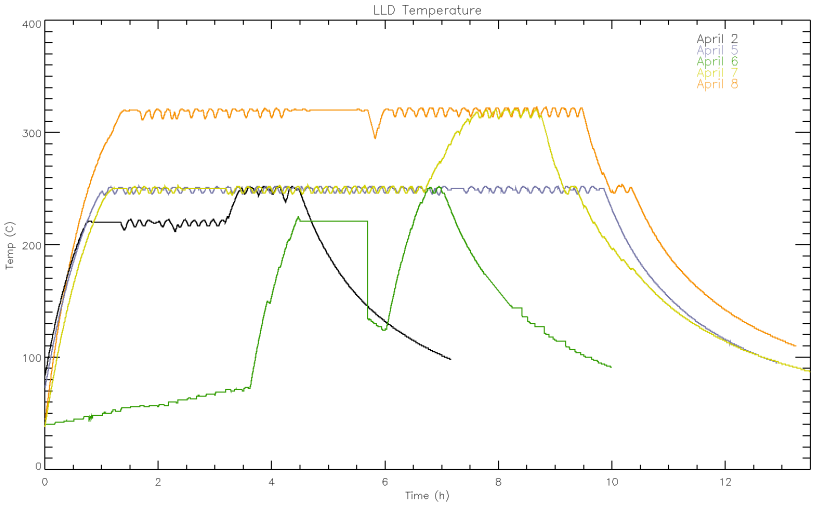
$$J = \frac{n\bar{v}}{4} \qquad \bar{v} = \sqrt{\frac{8kT}{\pi m}} \qquad n = \frac{P}{kT}$$

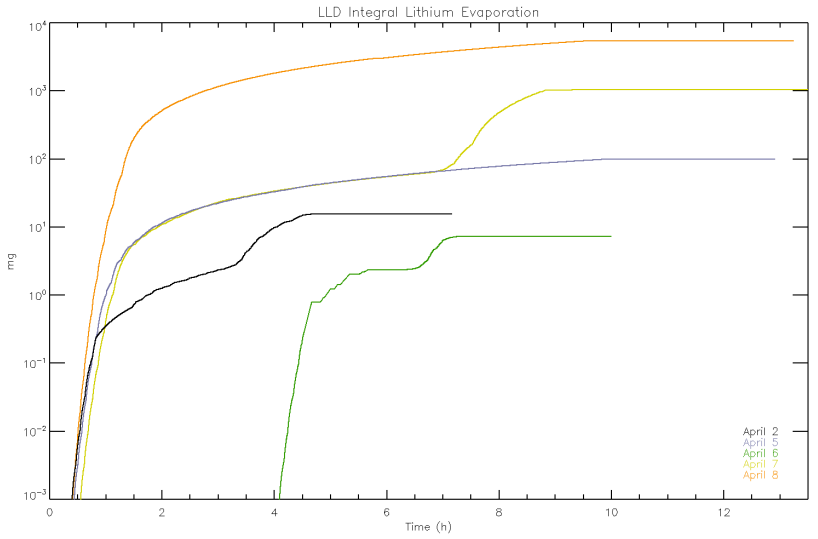
$$J = \frac{P}{kT}\sqrt{\frac{kT}{2\pi m}}$$

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



LLD Lithium Inventory



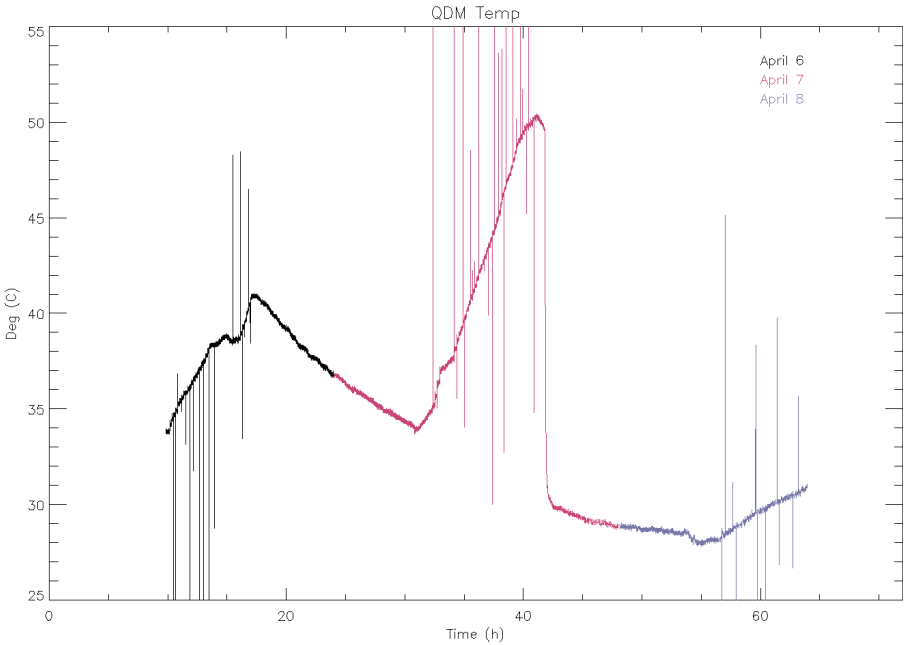


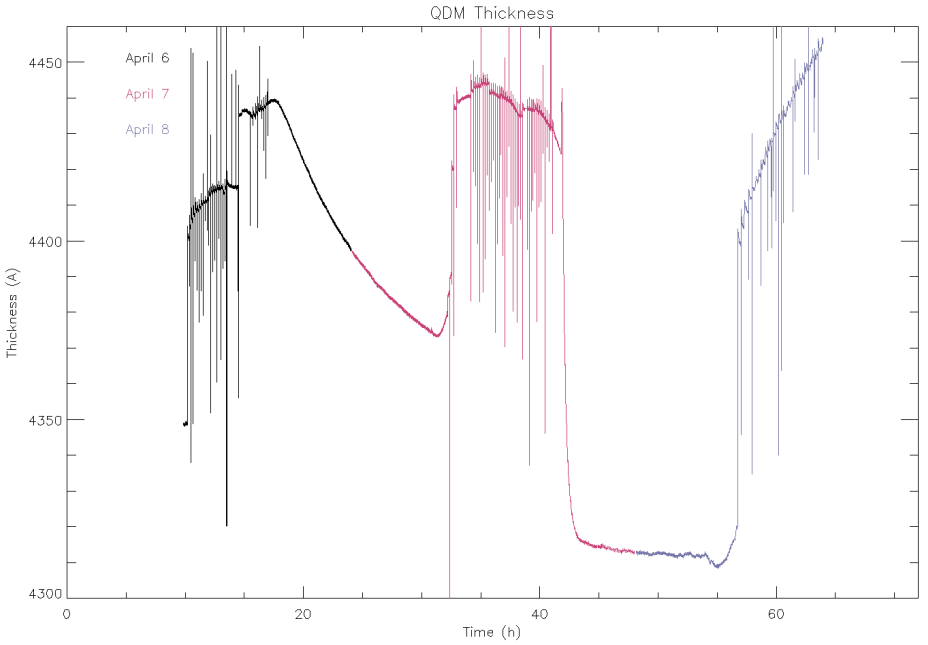
- LLD temperature data from EPICS (plate averaged from bulk TCs) used in previous equation (with 'effective' surface area correction of 1.33) to calculate evaporation
- LITER rates account for 3 functioning plates – from Hans spreadsheet
- Leonid estimates only 4.5% LITER efficiency!

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	?

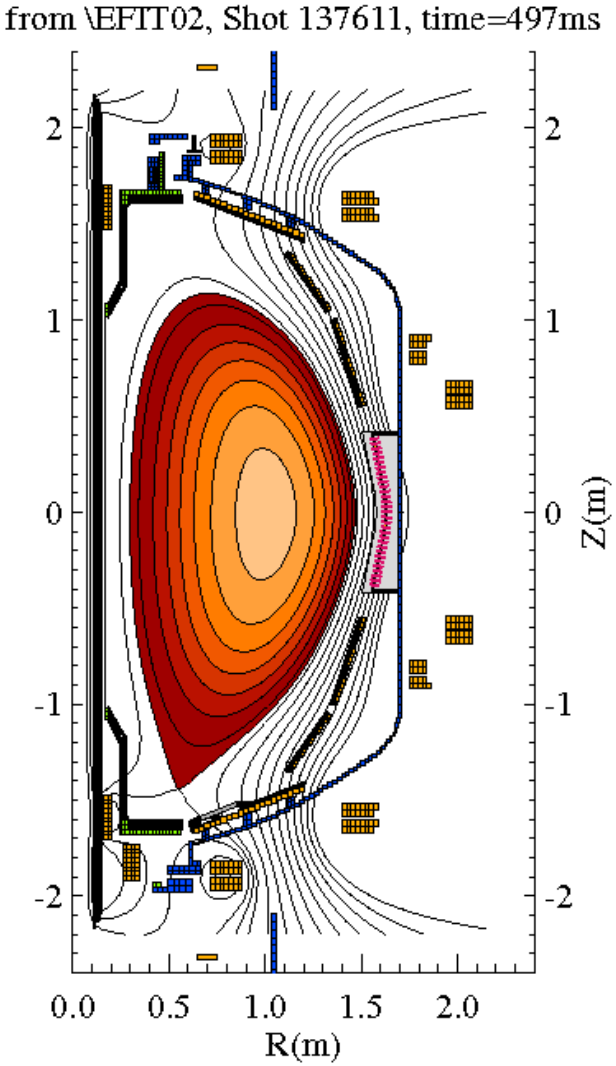
QDM Data

- 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

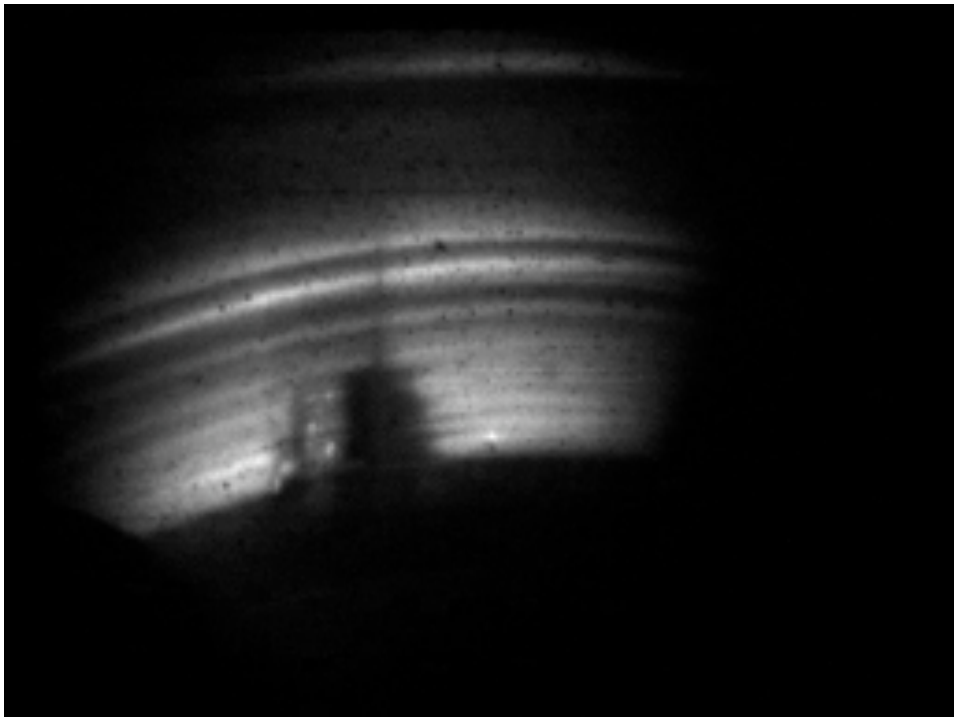




We're getting the divertor part right



- 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 ~ 11 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
  - 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?