XP911 Li Pumping and Retention on NSTX

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- Density control via Li pumping of D is goal of multi-year Li program on NSTX.
- Retention is FY09 Joule Milestone - - >>

Four thrusts on NSTX:

1. Particle balance of ohmic/RF shots (valves closed, no pumping)
   a) Before and with Li, LLD.
   b) Time dependent data (sec - hours)
   c) Measure D retained / D ion flux
   d) Quartz Microbalance data.
2. Particle balance of NBI shots (with pumping)
3. Surface analysis of 'fresh' samples using sample probe *(Purdue collab.)*.
4. Modeling, including WallPSI code of Pigarov and REDEP by Jeff Brooks.

Coordinate with C-mod and DIII-D.

Joule Milestone

- Conduct experiments on major fusion facilities to develop understanding of particle control and hydrogenic fuel retention in tokamaks.
- In FY09, FES will identify the fundamental processes governing particle balance by systematically investigating a combination of divertor geometries, particle exhaust capabilities, and wall materials.
- Alcator C-mod operates with high-Z metal walls, NSTX is pursuing the use of lithium surfaces in the divertor, and DIII-D continues operating with all graphite walls.
- Edge diagnostics measuring the heat and particle flux to walls and divertor surfaces, coupled with plasma profile data and material surface analysis, will provide input for validating simulation codes.
- The results achieved will be used to improve extrapolations to planned ITER operation.

Calibrations:

First need to establish accuracy / reliability of NSTX pressure measurements (beyond existing (operational) needs).

Several days spent on calibrations/ linearity checks based on new NIST traceable 0.1 torr baratron.

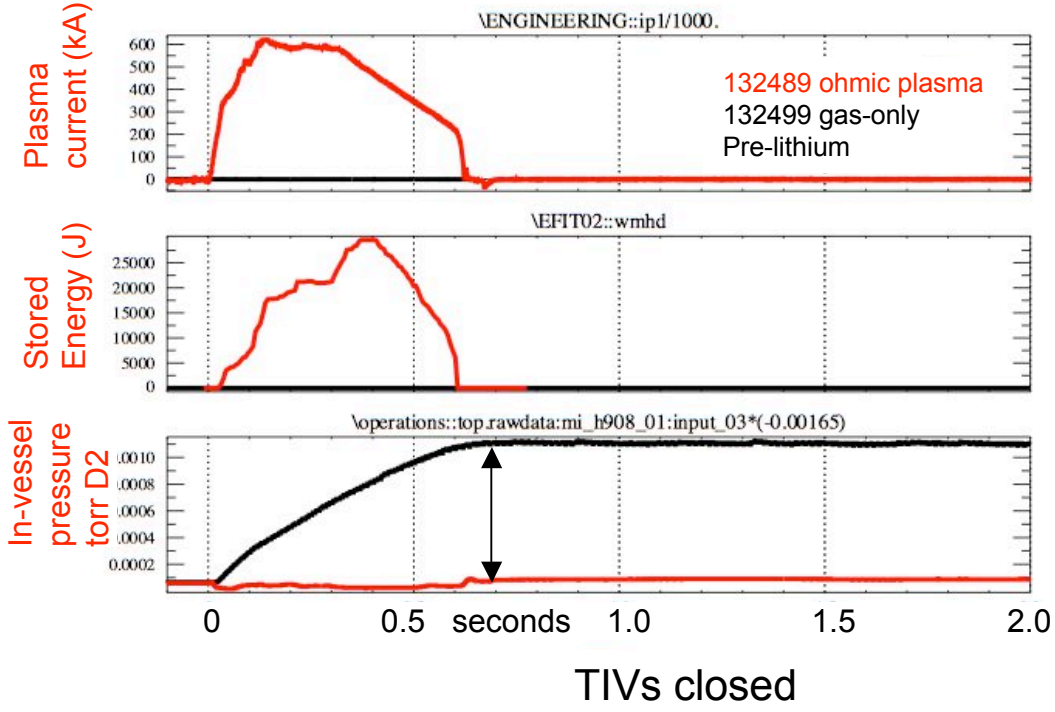
- Extensive N_2, D_2 calibrations of ionization pressure gauges (ig1, ig110, ig3).
- Trend RGA, Shot RGA calibrations.
- Orifice factor.
- Turbo pump and NB cryopanel pumping speed measurement.
- Cold gas input from NB measurement
- Vessel rate of pressure rise from leaks, outgassing measurement *(plan PPPL report with results).*

Four situations for D retention measurements:

1. Before-Li ohmic discharges (all TIVs closed)
2. Before-Li NB heated discharges.
3. With-Li ohmic discharges (all TIVs closed).
4. With-Li NB heated discharges.

Prompt retention before lithium (ohmic)

- Compare gas-only and ohmic discharge --- >>
- Discharge rampdown controlled to avoid minor disruptions.
- All pump valves closed (no neutral beam heating).
- Simple measurement of retention, independent of gauge calibrations.

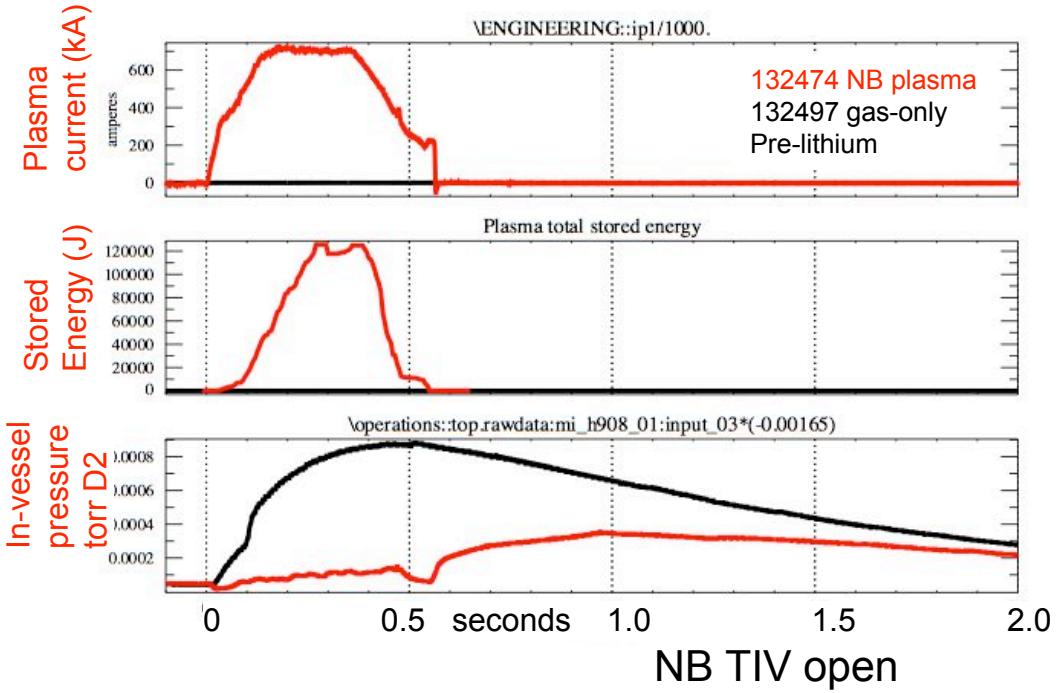


$$\text{Retention} = 1 - \frac{\text{pressure after discharge}}{\text{pressure after gas-only shot}} \times \text{ratio of gas input}$$

Preliminary prompt retention 93% ±5%

Prompt retention before lithium (NB heated)

- NB heated discharge.
- Discharge rampdown controlled to avoid minor disruptions.
- Neutral beam valve open,
  - need to account for gas pumped by cryopanels and from center stack gas injection.



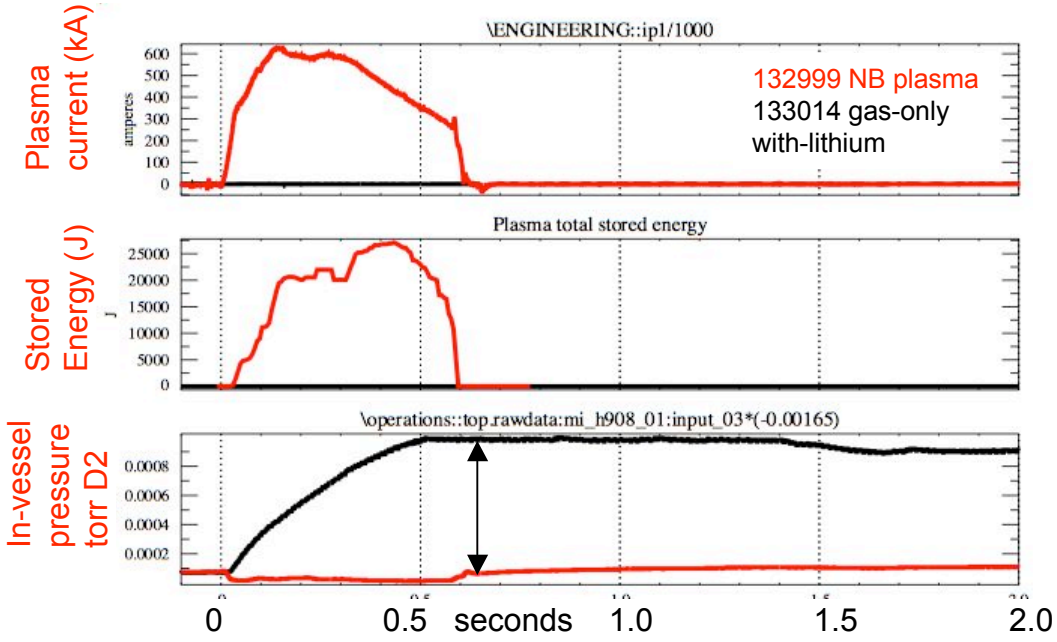
$$\text{Retention} = \frac{\text{Gas retained}}{\text{Gas fueled}} = \frac{\text{Gas input during Ip, less gas pumped, gas in VV}}{\text{Gas input (LF, CS, NB, + cold gas) during Ip}}$$

Preliminary prompt retention 89% ±5%

Comparison of methodology to ohmic case:
132493 ohmic retention with pumping: =90%
132490 ohmic retention valves closed: = 89%

Prompt retention with lithium (ohmic)

- Ohmic discharge
- Discharge rampdown controlled to avoid minor disruptions.
- All pump valves closed (no neutral beam heating).
- Simple measurement, independent of gauge calibrations.



$$\text{Retention} = 1 - \frac{\text{pressure after discharge}}{\text{pressure after gas-only shot}} \times \text{ratio of gas input}$$

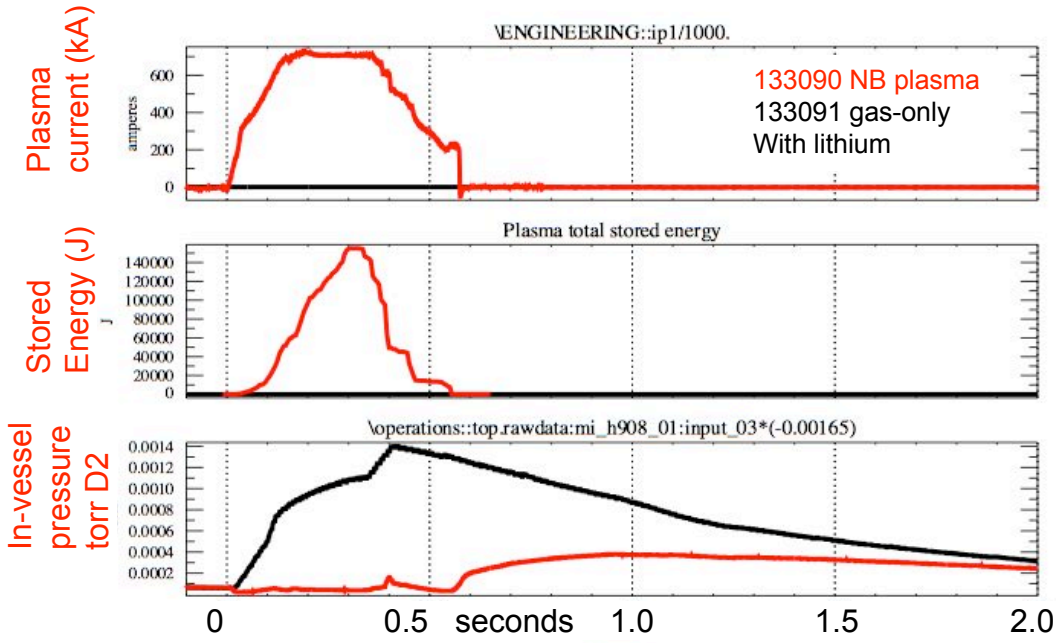
Preliminary prompt retention 94% ±5%

Prompt retention with lithium (NB heated)

$$\text{Retention} = \frac{\text{Gas input during Ip, less gas pumped, gas in VV}}{\text{Gas input (LF, CS, NB, + cold gas) during Ip}}$$

- NB heated discharge
- Discharge rampdown controlled to avoid minor disruptions.
- Neutral beam valve open, track gas on cryopanels and post shot fueling from center stack gas injection.

Preliminary prompt ret. 95% ±5%

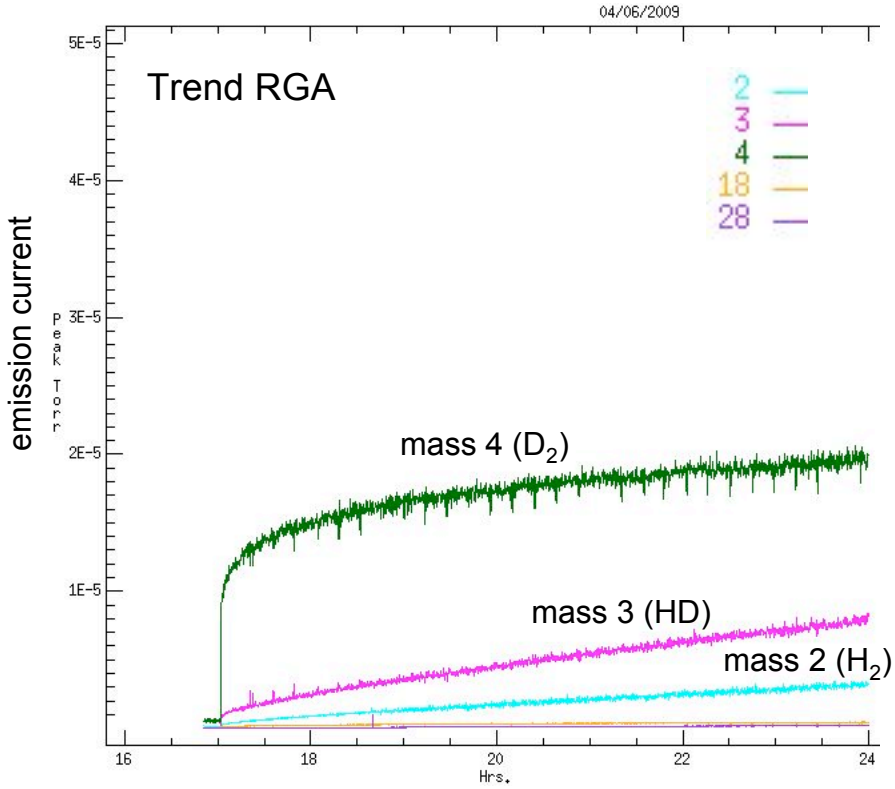


Preliminary prompt retention	Before Li	With Li
Ohmic	93%	94%
NB heated (increased tile temp.)	89%	95%

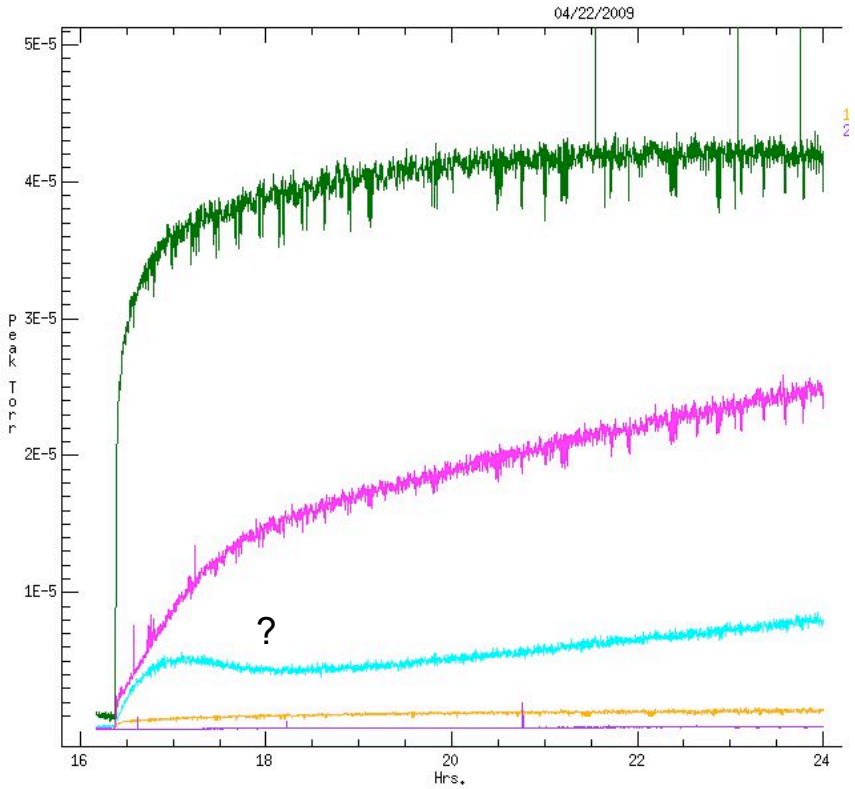
Effect of Li comparable to error bar.
More analysis needed to see if difference is significant

Deuterium outgassing reduces retention

Pressure rise evening after ohmic discharges pre Li
Last discharge had 29.7 torr-liters D fuel.



Pressure rise after ohmic discharges with Li
Last discharge 23.5 torr-liters D.



- Most SOL deuterium atoms and ions implanted promptly in graphite.
- Keep TIVs closed 12 - 72 h to integrate subsequent D outgassing.
- Some H outgassing also and isotope exchange between H and D.

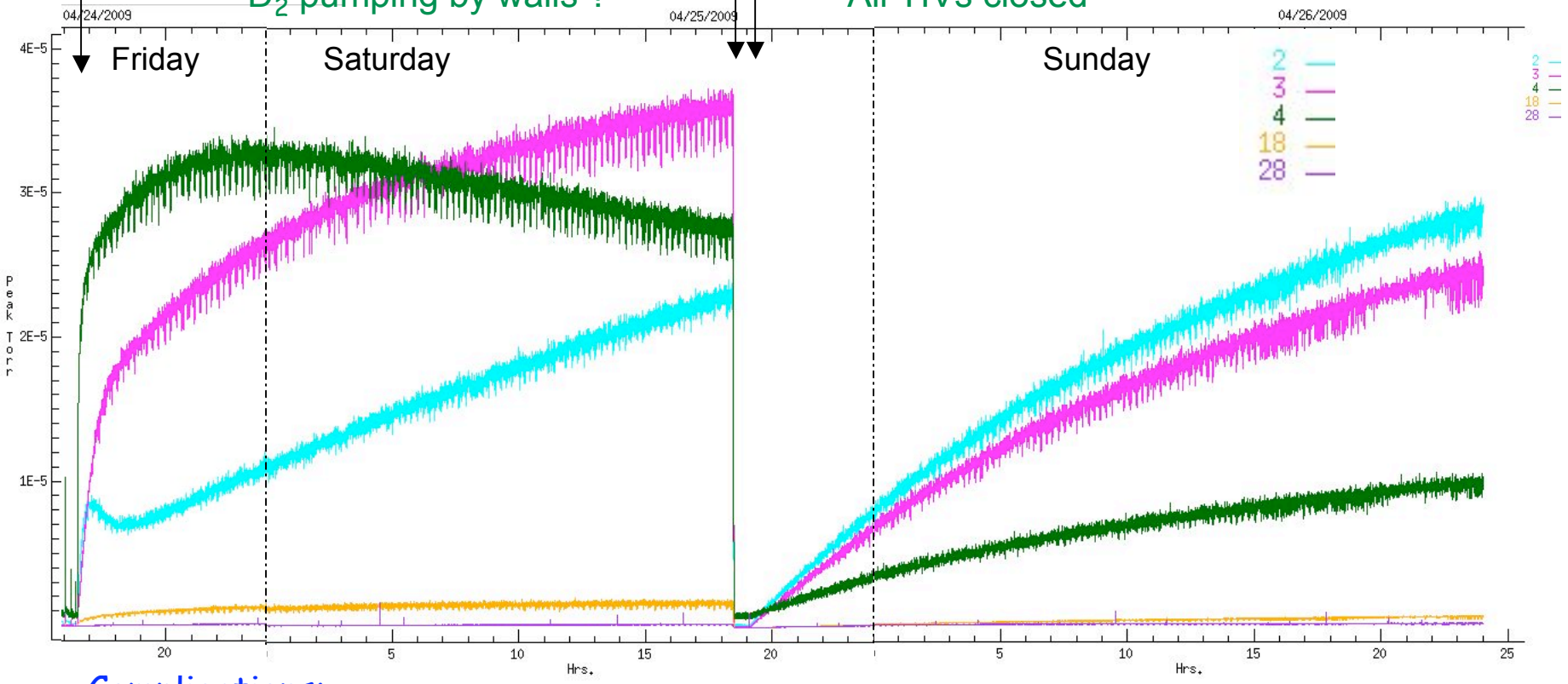
Long term retention ?

All TIVs closed after NB plasmas with Li

Open TMP TIV for pumpout

D_2 pumping by walls ?

All TIVs closed



Complications:

- Unexpectedly D_2 rate of rise is pressure dependent - implies wall pumping.
  - Isotope exchange
  - CS temperature decreases 29° to 22° on 4/25/09.
- How to account for outgassing from D implanted earlier in day /week / month?

Sample Probe

Specification:
4 samples on a 2" dia. probe (2xATJ graphite, Si and Si/Pd)

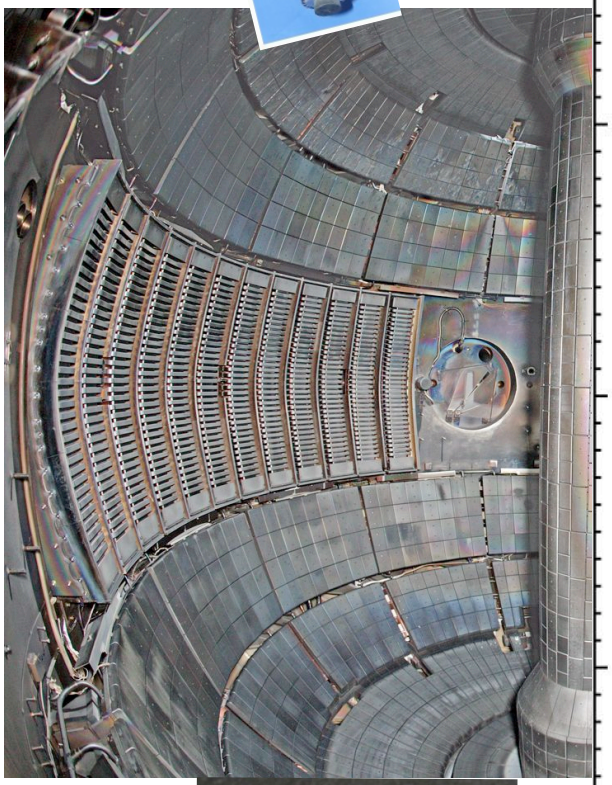
- Secure, disruption- proof mechanical attachment
- Thermal cooling,
- 16 thermocouple wires connections
- 2 Langmuir probes
- Heater connection(s).

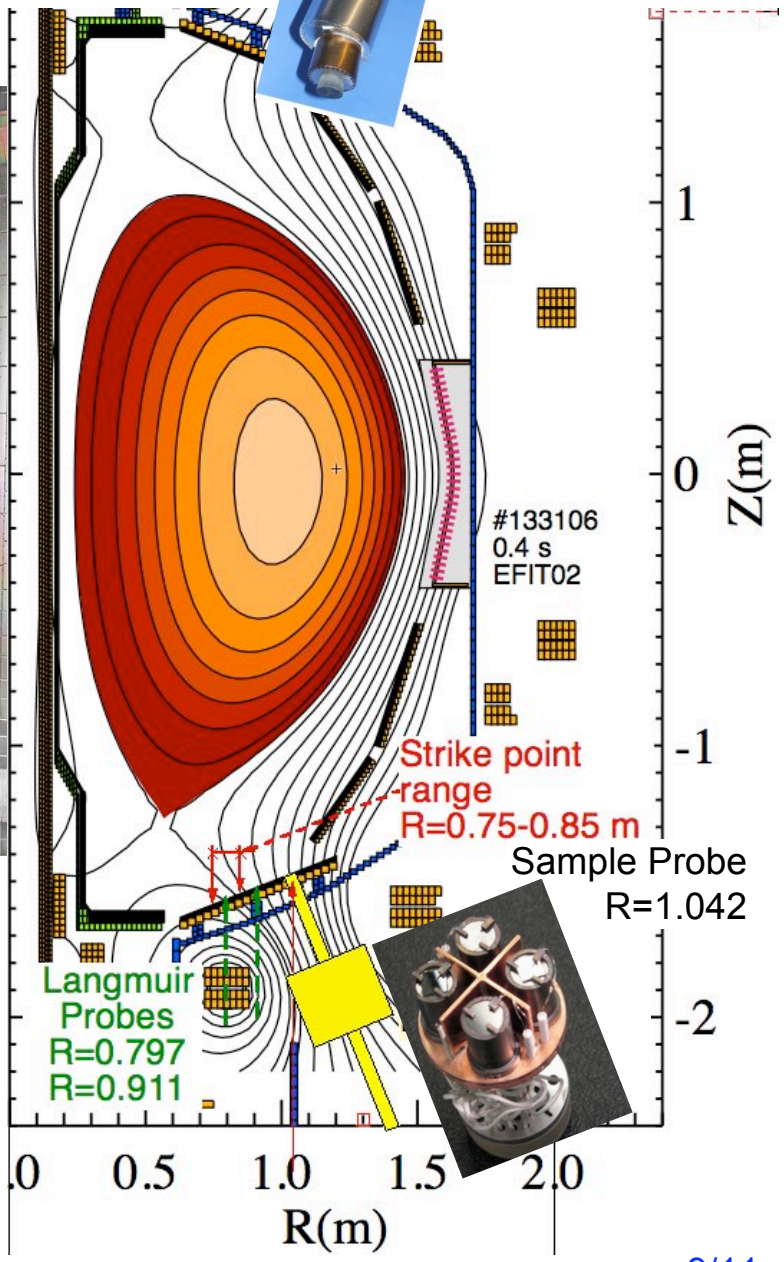
Must be installed and removed by one hand reaching through an argon-filled glove bag and through 4" diameter port and without using any tools.

The design met all the specifications and was installed in-time to get before-Li measurements

Credit: Lane Roquemore

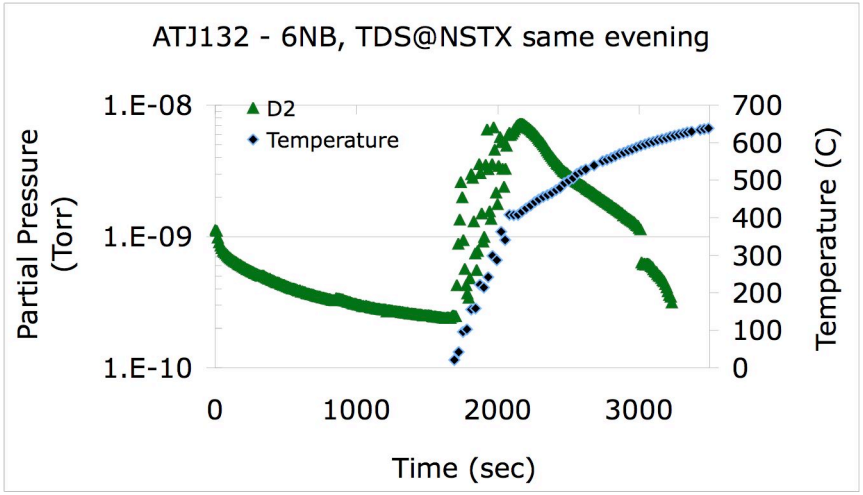
Lithium evaporators

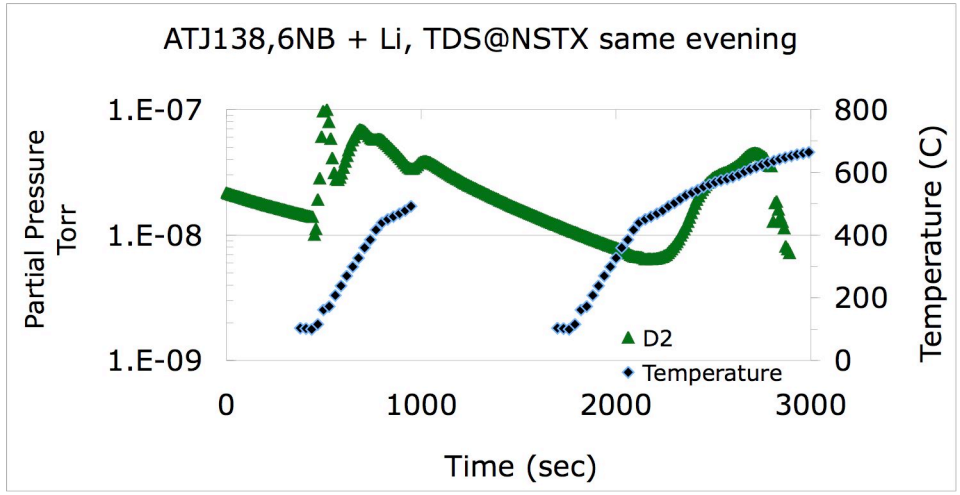




Sample Probe Results:

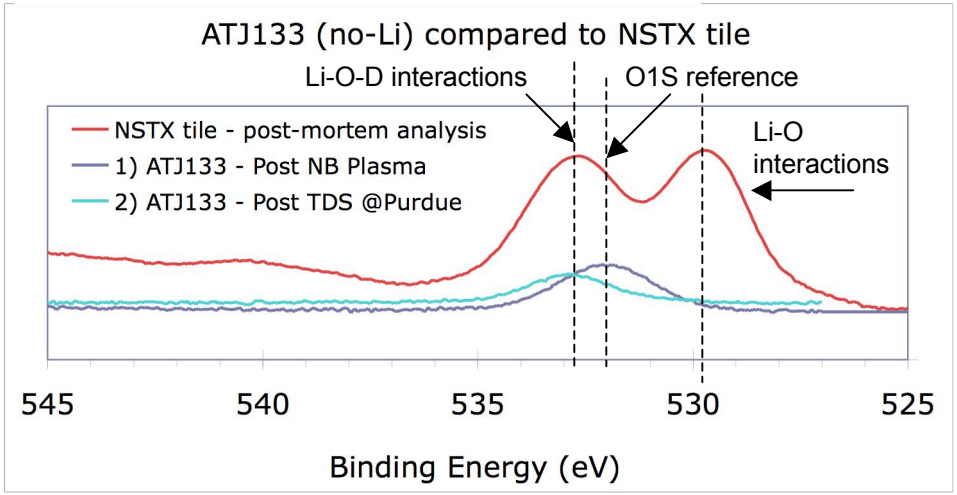
Thermal Desorption Spectroscopy before- and with- lithium





- Sample probe enabled prompt TDS measurements without any exposure to air.
- XPS measurements at Purdue showed shows the presence of lithium-oxygen and lithium-deuterium functional groups elucidating on possible hydrogen retention mechanisms.
- Analysis is on-going (next talk).

X-ray Photoelectron Spectroscopy



Future near term analysis:

PENDING:

- D retained / D ion flux from Langmuir Probe and D-alpha data.
- More error analysis: is Li retention difference significant ?
- Long term D_2 pressure from shot RGA data
- Correlation with tile temperatures ?
- More sample surface analysis including later high flux 'piggy back' samples.
- TDS: plot D_2 vs. temperature.
- 4th quarter report
- DPP APS oral
- PSI-19

Backup slide:

- Unexpectedly D_2 rate of rise is pressure dependent.
  - Isotope exchange + wall pumping