XP911 Li Pumping and Retention on NSTX

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Chase Taylor (Purdue U) and NSTX team.

- 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:

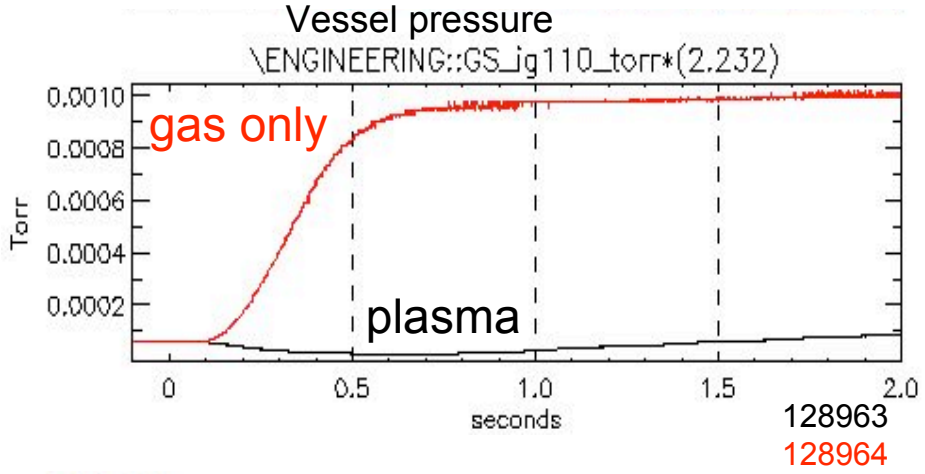
1. Particle balance of ohmic/RF shots (Static: valves closed, no pumping)
   a) Before and with Li, LLD.
   b) Time dependent data (sec - day)
   c) Measure D retained / D ion flux
   d) Quartz Microbalance data.
2. Particle balance of NBI shots (dynamic)
3. Surface analysis of 'fresh' samples using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

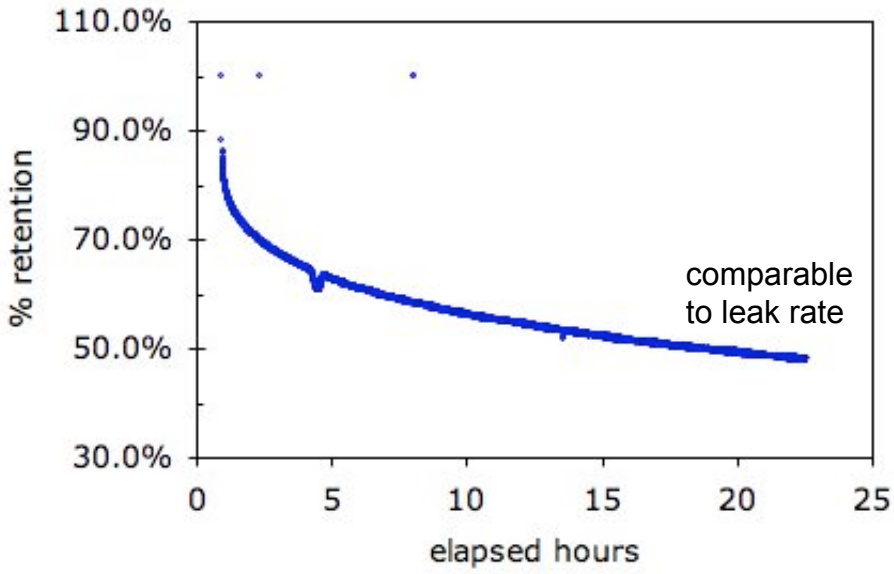
Coordinate with C-mod and DIII-D.

- 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.

Story so far….

- In 2008 XP824 run before-Li and with-Li
- Static pressure rise measured with all TIVs closed. Compare gas only and plasma shots.
- Ohmic/RF only (no NBI)
- Immediate retention 97% - 100%
  ~ similar before-Li and with-Li !
- Over 24 h retention drops to
  ~ 50% before-Li, 60% with-Li.





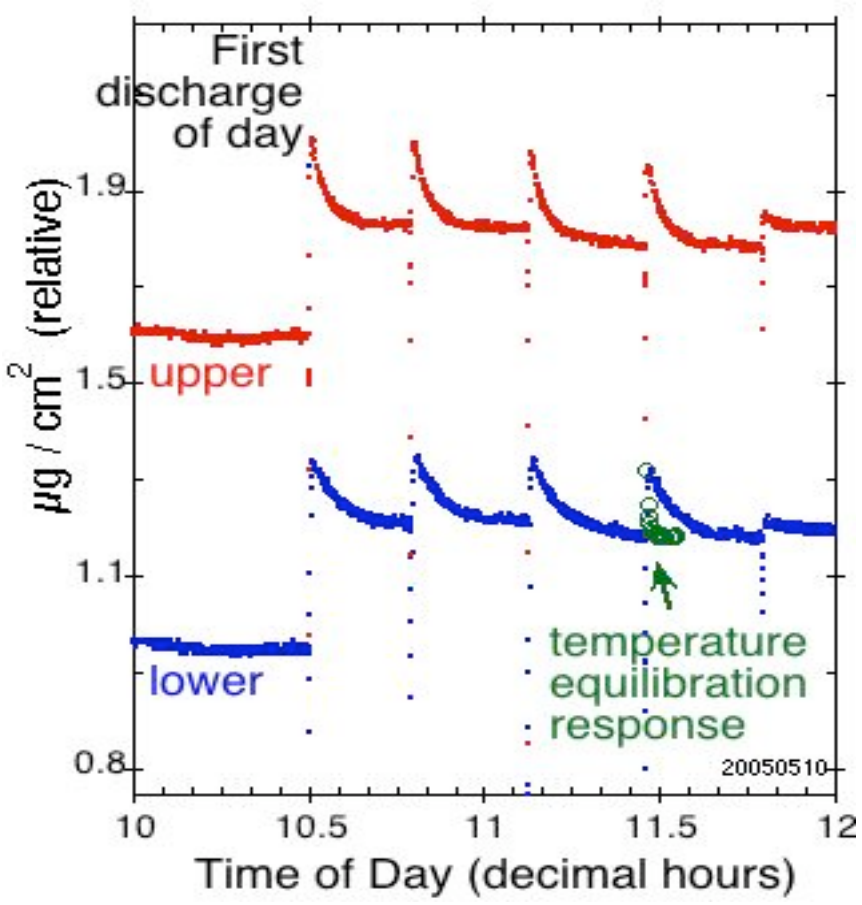
Above data is before Li,
with Li behavior is similar

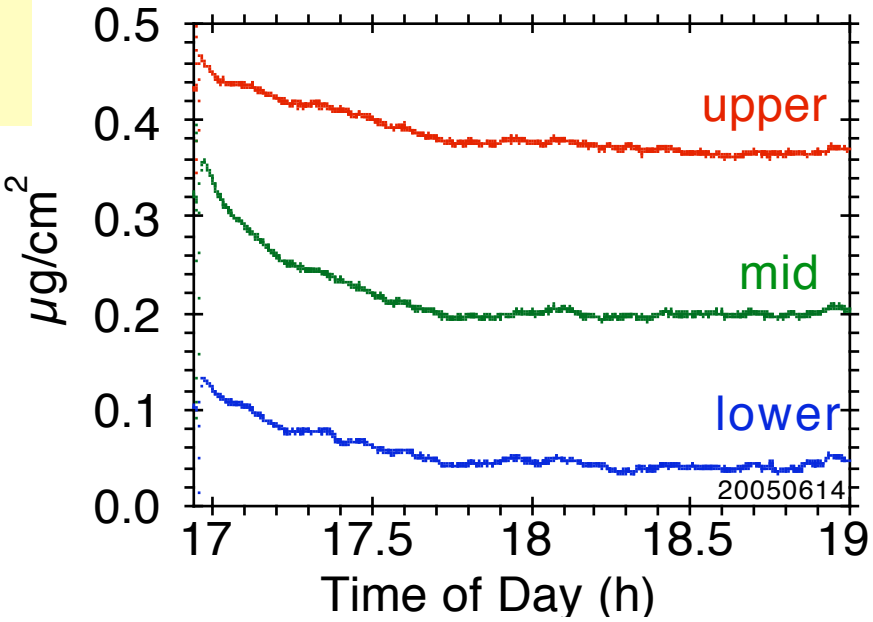
2008 Conclusions:

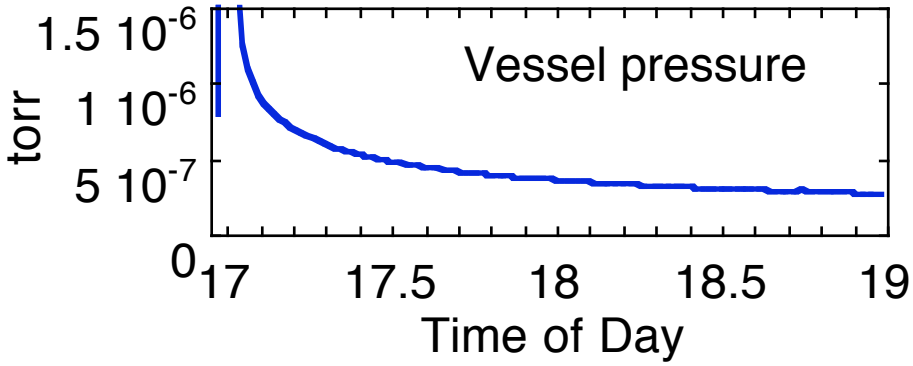
- Nearly all incoming gas ionized in SOL, transported on open field lines and implanted in divertor or wall.
- Short-term solute fractions > long-term value of H/C ~ 0.4
  (Andrew & Pick, J.Nucl.Mater., 220-222 (1995) 601)
- Outgassing from seconds - days

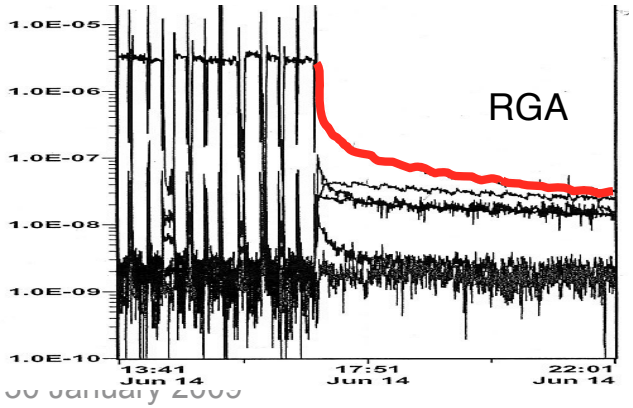
Retention also measured by Quartz Microbalance

QMB mass change









First shot of day always shows a step-up in asymptotic level.

What's new ?

Issues in 2008	Strategy for 2009
No measurements on NBI heated plasmas	Plan retention measurements with NBI (dynamic, w/cryopump)
No materials analysis data on state of D in carbon	Install sample probe. Plan exposure of C, Pd, Si samples followed by analysis either at Purdue or PPPL
No ion flux measurements of 'physics-based retention'	Plan strike point sweep over fixed Langmuir probes to measure (D retained / D incident)
Pressure calibration uncertain	New 0.1 torr baratron with stated 0.8% accuracy, NIST calibration Oct '08
RGA saturated	Calibrate RGAs in XMP. Use orifice
No modeling so far	Wall PSI (Pigarov) REDEP (Brooks)
He contribution ?	Unresolved ambiguity amu=4. Little He-GDC used with Li.

Analyse 'fresh' surfaces with new sample probe system

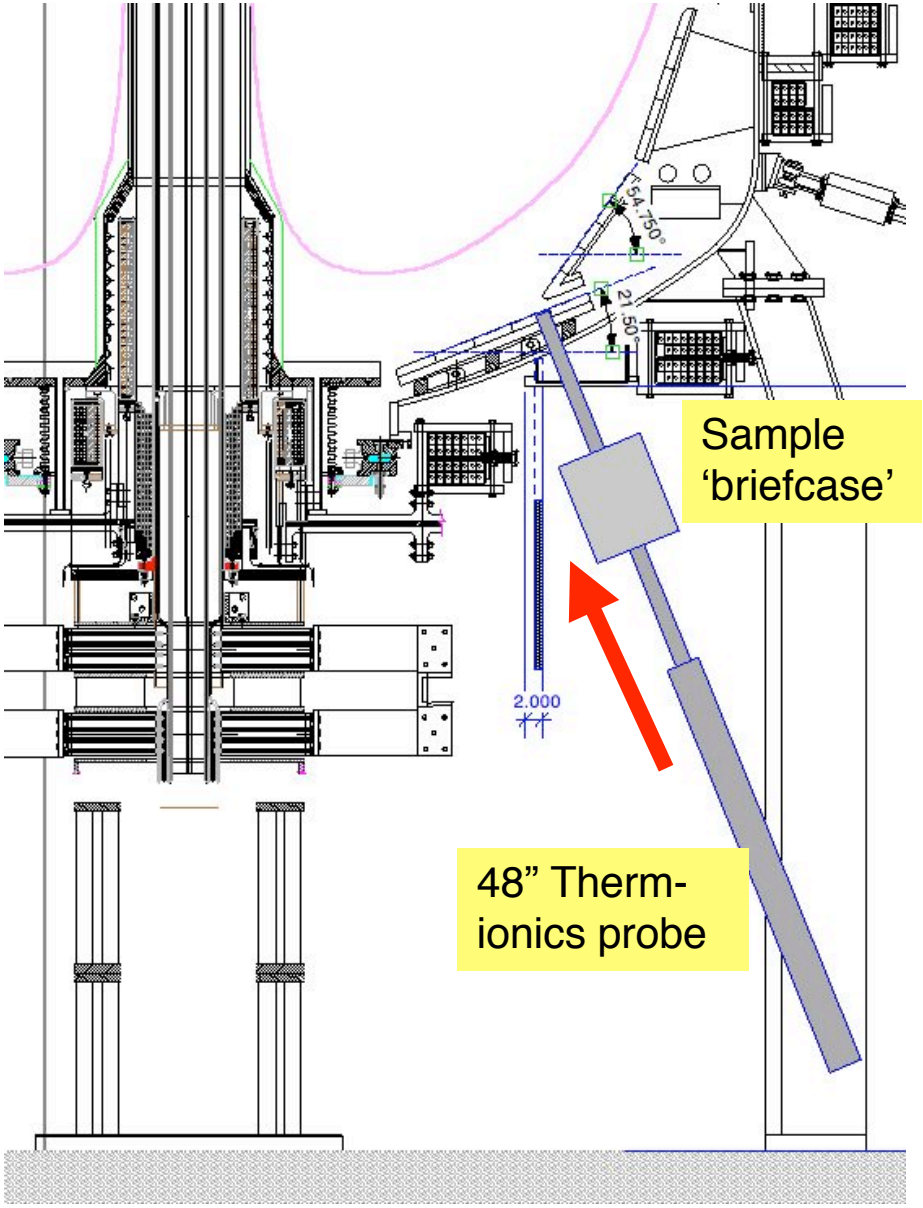
Stage Zero. Ability to introduce materials into SOL, expose them to plasma and then withdraw them behind gate valve during campaign. Remove under Ar and ship to Purdue for analysis (target March 15th)

Stage One. Plan for ex-vessel TDS (thermal desorption spectroscopy) in 'briefcase'. Then sample can be removed in vac. or Ar and shipped to Purdue U for extensive materials analysis (XPS, DRS, LEISS, HR-EELS, LEED, …).

Stage Two. Briefcase will have suite of surface analysis tools next to NSTX. (Purdue proposal under review).

Unique feature will be prompt TDS analysis ex-vessel for information on carbon / lithium / deuterium chemical bonding. No exposure to air and formation of $LiCO_4$.

1st stage of Purdue/PPPL collaboration to apply laboratory and tokamak studies to understand and exploit Li surface chemistry.



Surface Analysis before and with-Li

Aim is to analyse surfaces exposed to plasmas ± Li with negligible exposure to oxygen.

1. ATJ sample with TDS (thermal desorption spectroscopy) to get bond energies.
2. ATJ sample with XPS (X-ray photo-electron spectroscopy) for molecular state.
3. Pd sample for total D influx
4. Si to characterize deposition.

Staged approach:

Plan Zero:

Expose 4 samples for ~ 5 ohmic, then 5 NBI shots. Withdraw same evening. Retrieve under argon. Ship to Purdue for analysis using PHRISM, Omicron and KRATOS. Piggy-back commissioning when opportunities available.

Plan One:

As above but do ex-vessel TDS (thermal desorption spectroscopy) using electrical heater and built in RGA without breaking vacuum.

Plan Two:

As above with E-beam heater (potentially higher temperatures)

Plan Three

As above but with ex-vessel TDS, XPS, and DRS (direct recoil spectroscopy) etc…

Outline Plan :

1. XMP for Gas Calibrations:
   - Measure baseline NSTX pressure rise (to distinguish long term D_2 outgassing)
   - Cross calibrate ionization gauges, RGAs against new baratron
   - Measure NB cryopump response to gas-only pulse.
2. Repeat XP824 - ohmic/RF retention with improved diagnostics.
   - Use low triangularity to expose sample probe and compare to NB results.
   - Static measurement with TMP valves closed.
   - Before-Li half day ideally last Friday PM; track outgassing through Saturday
   - With-Li half day Friday PM; track outgassing through Saturday.
3. Present XP911 - retention of NB heated plasmas
   - Dynamic measurement with NB cryopumps open
   - Cross calibrate against static method using ohmic discharges.
   - Well-defined exposure of new sample probe with 2xATJ graphite, Pd, Si samples.
   - Ideally Friday PM half day before-Li and Friday PM half-day with Li; track outgassing over Sat.
   -

- Target discharge:
  - No disruption on rampdown
  - Low triangularity (for maximum flux to sample probe)
  - Long flattop (for maximum flux to sample probe)
  - Strike point scan over fixed Langmuir probe (for 'physics-based' D retained / D flux)
  - + info from D-alpha camera

Discharge Development:

Desire:

1. 1-3 NB sources, long pulse, H-mode,
   no minor disruptions on rampdown,
   low triangularity,
   Strike point scan over Langmuir probes.
   Strike point as close as possible to
   sample probe,
   NB cryopump operating normally.
   GDC @ discretion of operators.

2. Ohmic (650 kA?) version of the above

Candidate shots: (Rajesh)

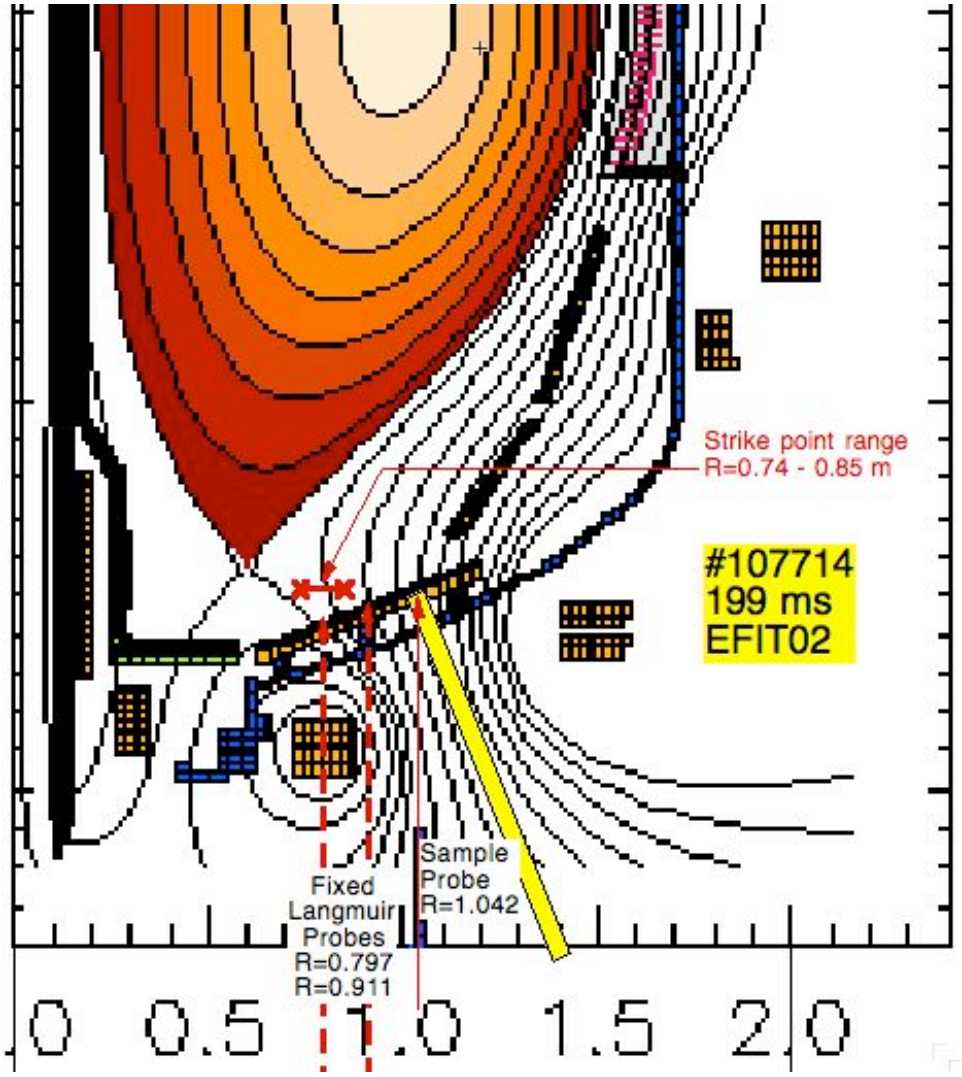
107714 890 kA, -53kA TF, LSN,
1.7 MW NB, type 5 ELMS,
0.35 s flattop (12 April 2002)

107317 up to 4.9 MW NBI same shape

107314 up to 4.8 MW NBI same shape

Ohmic/RF candidate:

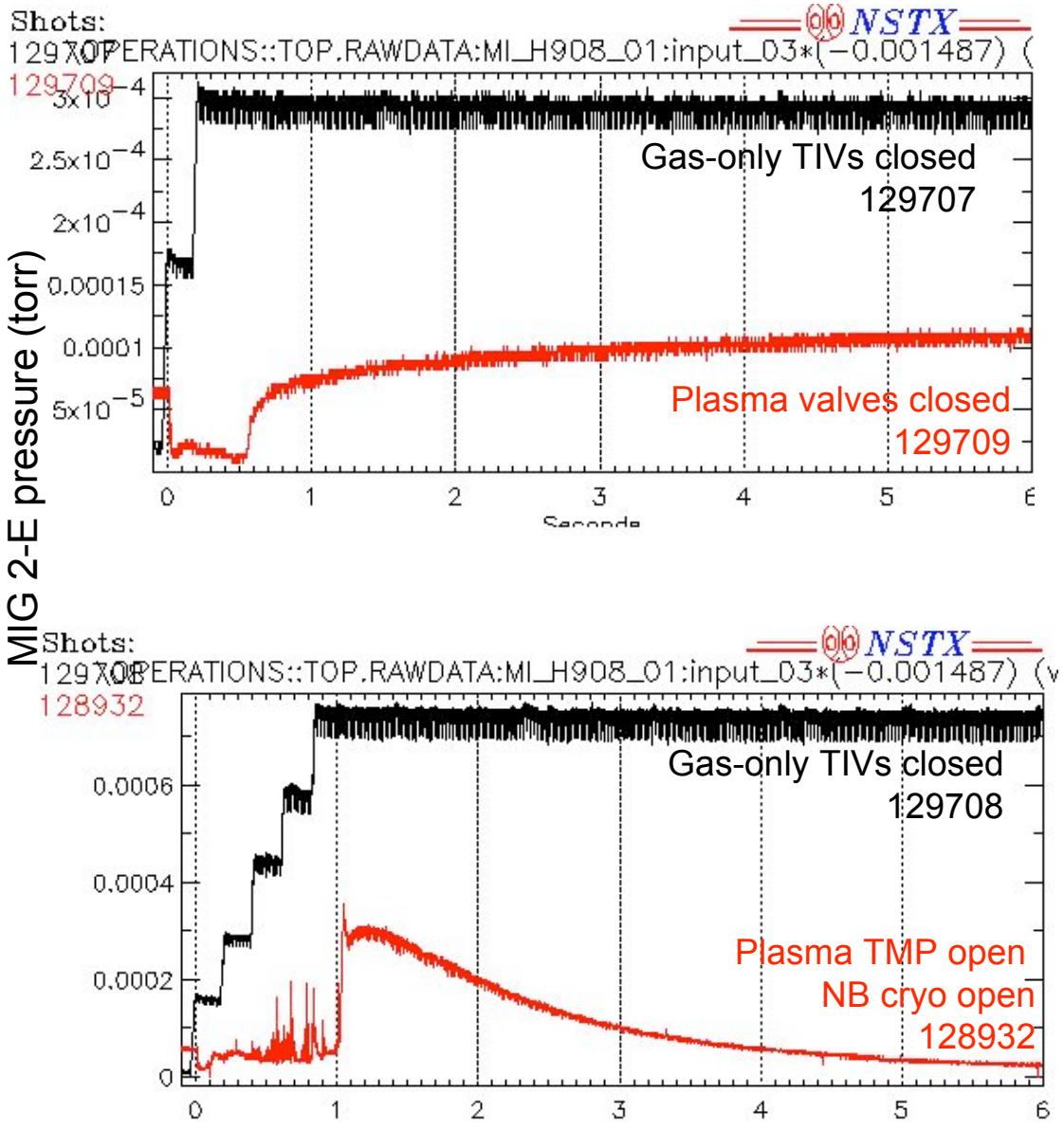
107714 with 650 kA and no beams.



Gas balance measurements

- Compare pressure after plasma with pressure from gas-only shot with all valves closed
- Straightforward to determine gas retained in wall for ohmic shots with all valves closed.
- NB shots need to allow for D on cryopanels:

  =∫pressure dt x cryopump speed.
- XMP measures cryopump speed.
- Close NB valves ~ t=10 s to measure longer term outgassing.
- Cross calibrate static/dynamic measurements - compare ohmic retention with cryopump open and closed.



Gas input different between shots

Draft XP911 shot list (1/2 day before LiTER operation)

Compare static and dynamic gas balance measurements.

4. Gas-only shot all valves closed (129708 from 5Jun08 5-puffs)
5. Ohmic shot all valves closed - low triangularity (000000 to be developed).
6. Gas only shot NB TIV open (but no NBI, same gas pulse as 000002)
7. Repeat gas-only shot NB TIV open (but no NBI) with more gas to check no gas-only retention.
8. Ohmic shot NB TIV open (but no NBI)

Dynamic retention measurements, expose sample probe

9. Controlled access to open sample probe TIV and raise sample probe into vessel
10. 1 source NB long pulse H-mode discharge (000001 with 1 NB source).
11. 2 source NB long pulse H-mode discharge. (000002)
12. repeat ~5 times to expose sample probe until ~ 4:30 PM
13. Repeat 2 source NB long pulse H-mode and close NB TIV @ 10 s to measure long term outgassing.
14. Withdraw sample probe, close sample probe TIV.
15. Remove samples under Argon or do ex-vessel TDS when available

Repeat above sequence (6-12) 1/2 day with two LiTERs operating 10 mg/min .

Run XP824 for 1/2 day before-Li and with-Li separately for ohmic/RF discharges.

Analysis and presentation:

Modeling including WallPSI code of Pigarov
and REDEP by Jeff Brooks.

Quarterly plan for 2009 agreed with DoE, C-mod, DIII-D, and NSTX :

First Quarter - Develop a list of the experiments and an outline of the research plan.

Second Quarter - Initial planned experiments will have been carried out on at least one of the three facilities.

Third Quarter - Experiments will have been carried out at multiple facilities. Experimental analysis and preliminary modeling will be in progress on results from multiple facilities. Make an initial evaluation of the results to date and adjust research plans as necessary.

Fourth Quarter: Complete the necessary experiments, analysis, and modeling. Prepare a joint report on the empirical understanding gained, the comparison to simulation and identify critical research areas to improve extrapolation to ITER.

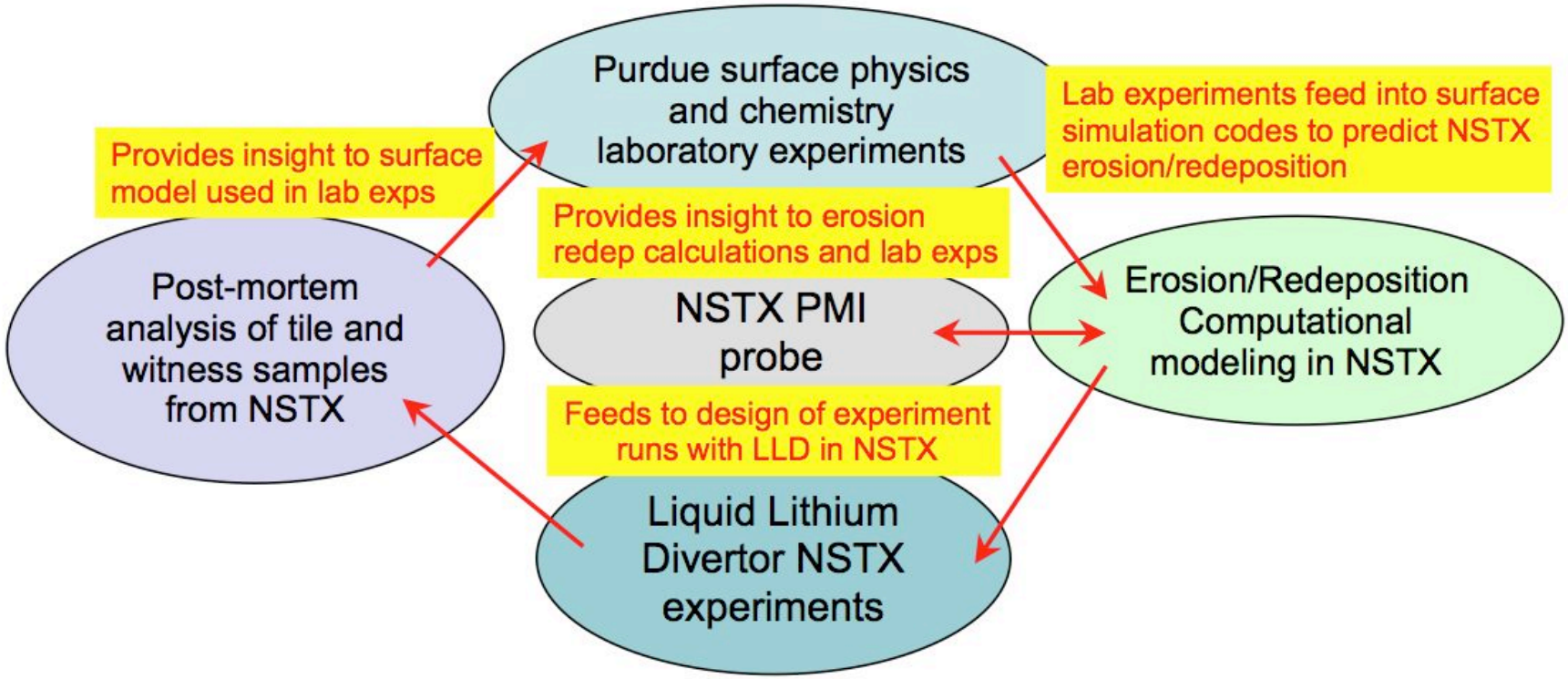
Presentation at Div/SOL ITPA mtg in Amsterdam 5-8 May 09 and 12th International Workshop on Plasma Facing Materials and Components for Fusion Applications Juelich on 11-14th May 2009.

Several publications…

Extras…

From Allain NSTX res forum 2008.pdf

Role of PMI probe on D retention studies



- At Purdue we're investigating the role lithium has on deuterium pumping and recycling of hydrogen and hydrogenous species (also to understand ELM suppression with Li surfaces)
- In addition we want to systematically study how lithiated surfaces can be modified with tunable recipes as input to NSTX shots
- **PMI Probe can help correlate shot-to-shot plasma performance to D retention by lithium-based surfaces: need *in-situ* measurements to dynamic nature of Li-D system**

PURDUE UNIVERSITY

J.P. Allain, D.L. Rokusek, et al. J. Nucl. Mat. accepted 2008