Lithium Research Topical Science Group Mid-run Assessment 17 June 2009

Charles Skinner for LR TSG

Outline:

- List of accomplishments
  - XP837 Recovery of Lithium Wall Conditions
  - XP911 Li pumping and retention in NSTX.
  - XP950 Dependence of metallic impurity generation.
  - XP951 Diffusive Li injection.
- Remaining hi-priority XPs
- Reversed TF XPs.

XP827(2009), Recovery of Lithium Wall Conditions and ELM Mitigation in High-δ Discharges

H. Kugel et al.,

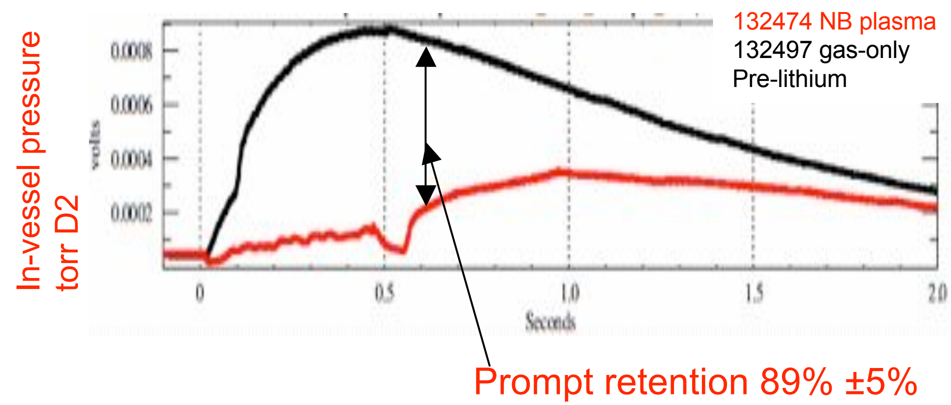
- Rerun of 2008 XP (previously dedicated to low-δ discharges) restored good wall conditions.
- With introduction of lithium:
  - Longer pulse duration,
  - Earlier H-mode transitions,
  - significant density reduction in the early part of discharges
  - increased electron temperature, electron stored energy and confinement time
  - oxygen reduced.
- As the net lithium deposition increased
  - transition to ELM-free discharges.
  - pulse duration increased to about 1.2 sec,
  - oxygen approached the 2008 levels.
  - a high-δ, H-mode, discharge was obtained with 1 MW NBI (1.8 MW total) with Tau-E of about 100ms.
  - eventually the HeGDC was reduced to 0 minutes, allowing an increased duty cycle.
  - 2008 low-δ discharges were reproduced

XP911 Retention Preliminary results.

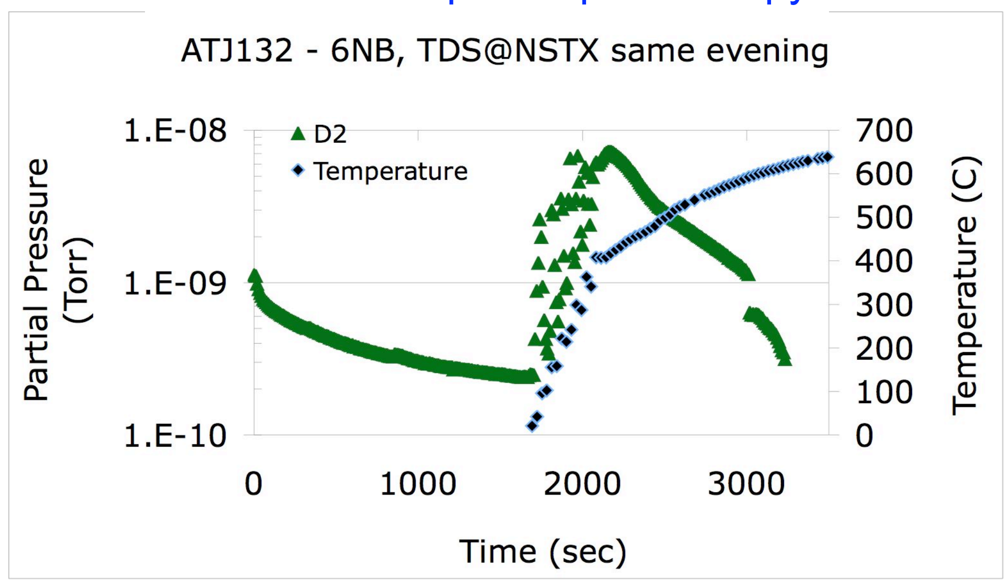
C. H. Skinner et al.,

Joule Milestone:

- Gas balance measurements showed high (>90%) prompt retention, that decreased due to post-shot outgassing.
- Both ohmic and NB plasmas measured (NB calibrated).
- Sample probe for prompt surface analysis installed and commissioned.
- After exposure, thermal desorption spectroscopy was performed on an ATJ samples (collaboration with Purdue University).
- Further surface analysis in progress at Purdue.



Thermal Desorption Spectroscopy



XP911… X-ray Photo-electron Spectroscopy of ATJ graphite samples exposed on sample probe.

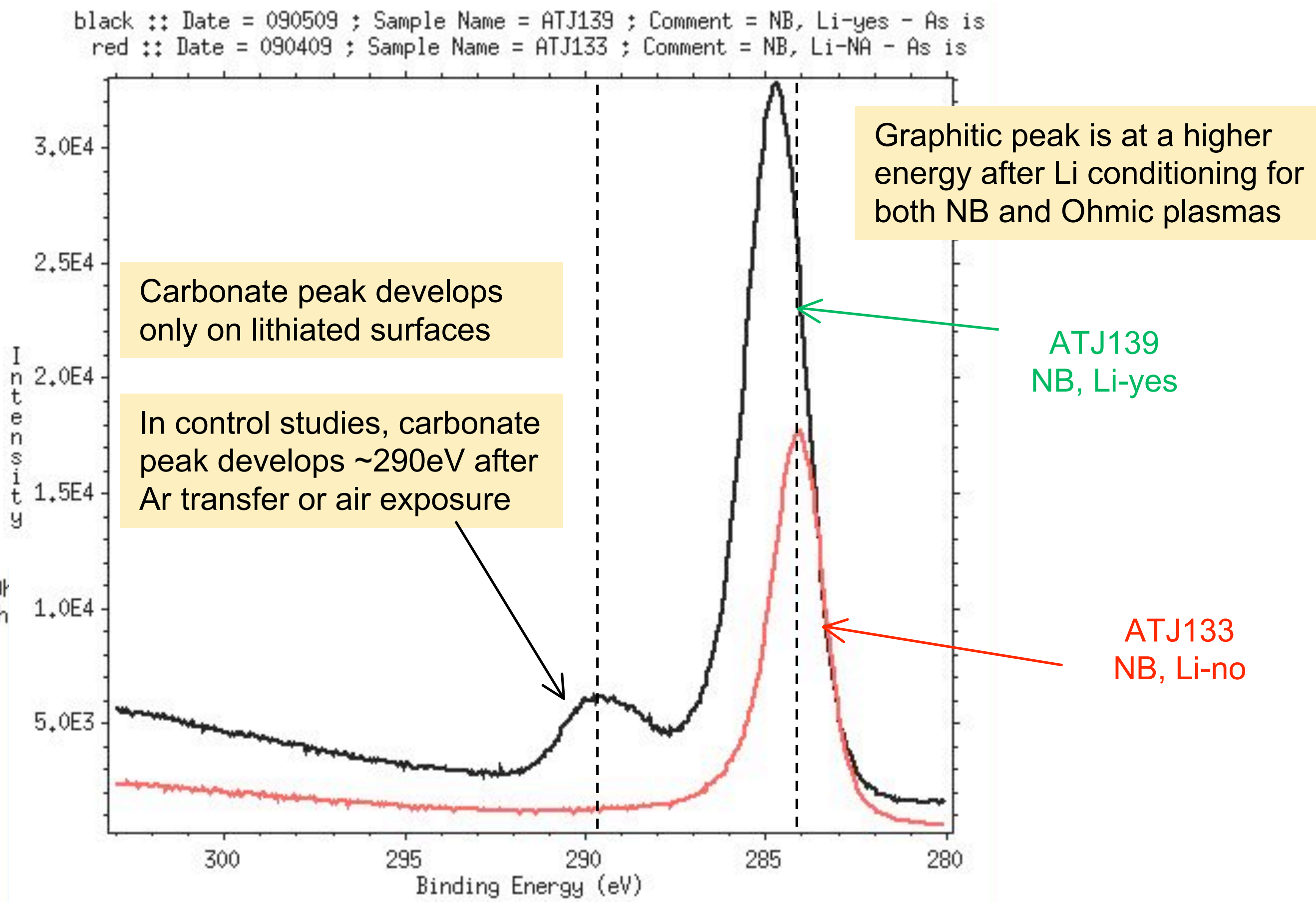
Sample of results: C1s peaks in lithiated vs. non-lithiated - NB

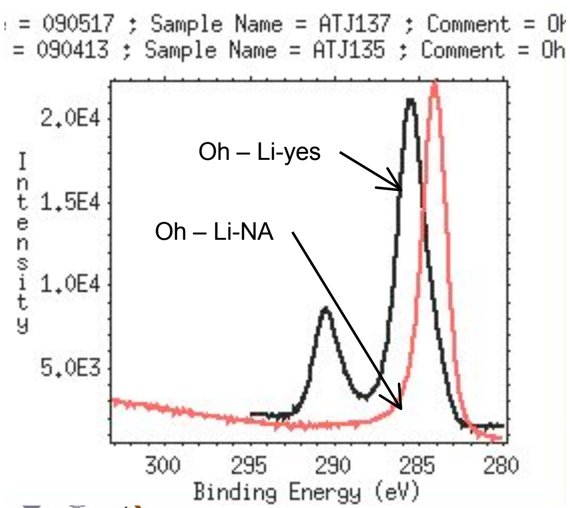
ATJ139

- Lithium conditioning
- 6 NSTX NB plasma shots
- Ar cleaning
- TDS performed at Purdue
- XPS at Purdue

ATJ133

- No lithium conditioning
- 6 NSTX NB plasma shots
- Shipped to Purdue under Ar
- TDS at Purdue





RSSEL

PURDUE UNIVERSITY

XP-950: Dependence of metallic impurity accumulation on I_p and the outer gap in the presence of lithium deposition

S. Gerhardt, S. Paul et al.,

Motivation:

- Li-conditioned ELM-free scenarios are known to suffer from massive radiated power if they achieve long pulse.
- Speculation/lore what that large outer gap or high I_p would limit the impurity accumulation, that source mix might matter.
  - Test this hypothesis with systematic scans.
  - Try, if possible, to diagnose the difference impurities, impurity sources, and provide operations/infrastructure guidance.

<u>Preliminary</u> results:

- Carbon Increases when the Outer Gap Became Large
- Total Radiated Power Reduced with Increasing Outer Gap At I_P=700kA
- For Fixed Gap of 20 cm, high-I_P Had Less P_{rad}, but Similar Rate of Rise, but ELMs may Complicate Analysis

XP-951 Diffusive Li injection.

Motivation:

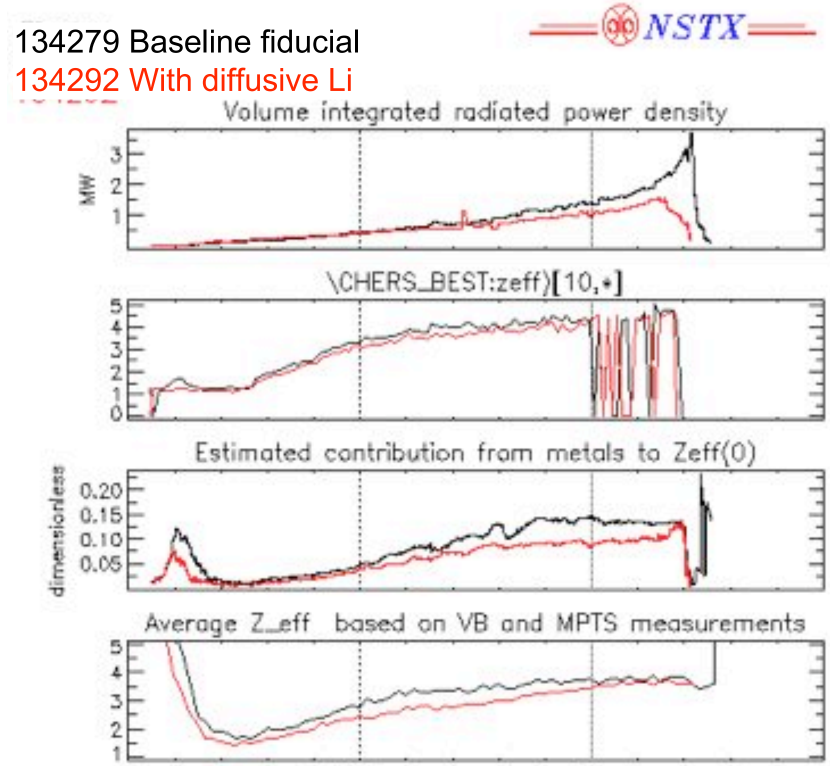
- Density and impurity control is goal of multi-year Li program on NSTX.
- But so far elimination of ELMs by Li has caused impurity accumulation late in discharge.

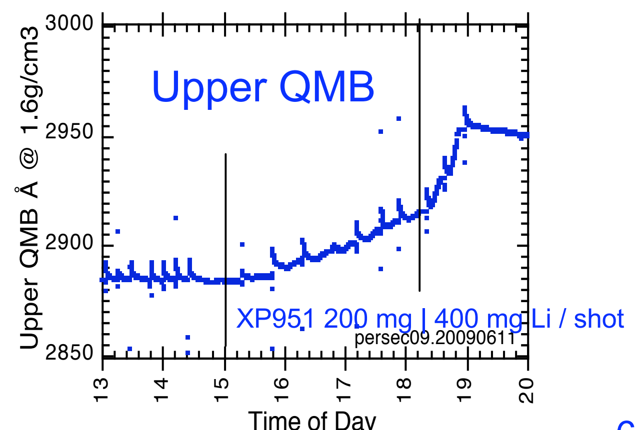
Plan to increase Li coverage:

- Inject Li into low pressure He gas.
- Collisions will scatter Li into previously shadowed areas on center stack and upper midplane.

Results

- More pumping (more gas needed) and up to ~20% lower Prad, lower Zeff (VB), Zeff (CHERS), Zeff (metals).
- See expected deposition on upper QMB.
- No large increase in He emission on SPRED.
- Notice 'enhanced' green emission on upper CS.
- DEGAS modeling in progress.





LRTSG XPs proposed for 2nd half of campaign

XP913 Initial use of Li Dropper

D. Mansfield

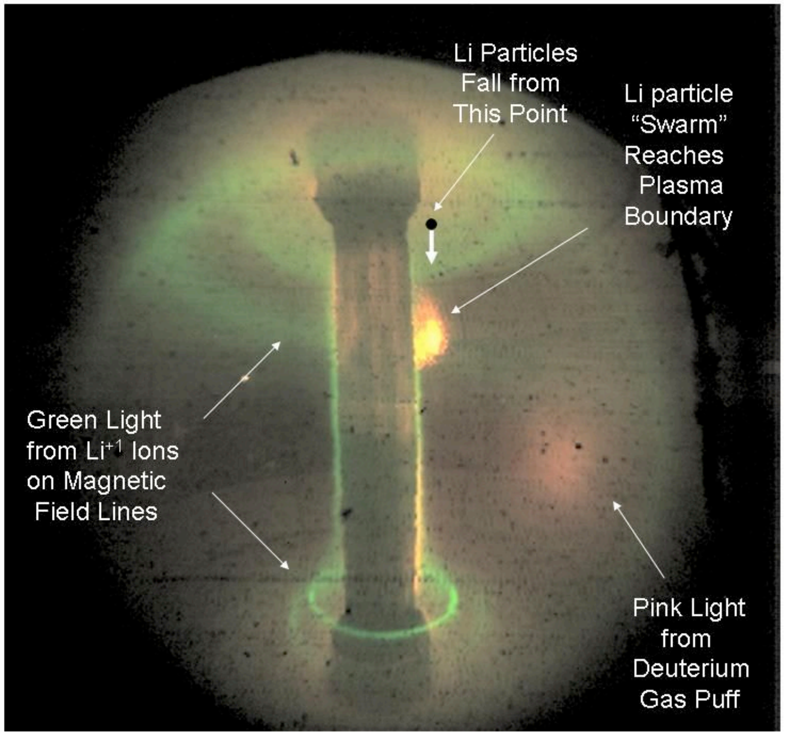
Goal(s) of the XP

- Establish whether or not the 2008 aerosol experiment is reproducible.
- Fiducials: H mode by early NBI overdrive - reduced CS gas
  - Early aerosol injection - before L-to-H transition
  - 10 mg/s and higher - probe the limit of Li aerosol mass flux
- Push plasma performance

Then:

- Investigate synergistic effects with LITER
  - Can aerosol injection suppress impurity influx?
  - If TF reversed, drop Li into X-point.

Camera View of Early Li Aerosol Injection Taken at t ~ 60 ms



Already prioritized by BP TSG 1 day 1st priority, 1/2 day 2nd priority.

Canik/Maingi + Soukhanovskii + Zweben

Combination of three XPs that will vary lithium conditioning and look for effects on:

1. **Energy confinement** -Does stored energy continue to increase with Li beyond what is required to suppress ELMs? A systematic study…. (Canik/Maingi).

2. **Pumping capability** - critical issue for comparison of lithium coatings and LLD. SGI-fueled LITER-conditioned H-mode discharges demonstrate that Ni is controlled and Ne rise is due to carbon. Plan to assess η_p , τ^*_p with UEDGE or 0D models…. (Soukhanovskii).

3. **Edge turbulence** in NSTX - SOL turbulence determines SOL transport, i.e. plasma parameters at separatrix, so an effect of lithium on SOL turbulence can be a mechanism through which lithium affects plasma as a whole. GPI measurements…. (Zweben).

1 - 1.5 run days

1. Dependence of energy confinement enhancement on lithium coating thickness

Canik/Maingi

A. Some evidence that the enhancement of energy confinement increases with the Li layer thickness

- Transport has been analyzed for many shots by S. Ding
- Some of the data shows an increase in the H-factor at very high Li evaporation
  - but some data shows the opposite trend !
- Need a controlled experiment to conclusively test this

B. Li layer thickness clearly affects the ELM behavior

- Does stored energy continue to increase with Li beyond what is required to suppress ELMs?

Basic Plan: Measure energy confinement as systematic fn. of quantity of Li evaporated.

Options:

- Add in a shot of RMP ELM triggering (at 50 or 60 Hz) at each Li level to test ELM size vs. Li layer thickness?
- Add a series of shots in L-mode to separate confinement enhancement and ELM suppression?

2. Assessment of Li pumping

Soukhanovskii

- Assessment of pumping capability is a critical issue for comparison of lithium coatings and LLD.
- This year- last opportunity to do measurements with lithium coatings on graphite. Do we understand it?
- How to assess pumping capability η_p? Global divertor recycling R?
  - Run UEDGE model, match measured edge and divertor parameters, conclude η_p, R,
  - Use simple 0D (or TRANSP) particle balance model and dN / dt=0 discharges
- Propose to do pumping capability assessment XP
  - Use several LITER rates and SGI fueling
  - Can use high-δ shape and LLD shape
  - Derive global η_p , τ^*p , etc using pulsed SGI fueling

- SGI-fueled LITER-conditioned H-mode discharges demonstrate that Ni is controlled and Ne rise is due to carbon.
- Used modest LITER rate (9 mg/ min), Nearly ELM-free, Gas fueling (LFS + SGI) during first 200 ms, NBI fueling ~ 8 x 10^{20} s^{-1}, Deutron inventory constant, Can vary constant N_d
- Electron inventory is rising due to 1) carbon source increasing? 2) confinement?
- Observed only in LITER discharges

3. Effect of Lithium Coatings on SOL Turbulence

Zweben et al.,

Goal: Look for the effects of lithium on SOL turbulence using GPI diagnostic, i.e. before vs. after lithium

Motivation: SOL turbulence determines SOL transport, i.e. plasma parameters at separatrix, so an effect of lithium on SOL turbulence can be a mechanism through which lithium affects plasma as a whole.

Physics Issues:

- No known mechanism for lithium coatings (or any surface coatings) to directly affect edge turbulence or transport (i.e. not in basic equations of edge turbulence theory)
- Several possible indirect mechanisms based on theory: - wall boundary conditions (~ within a Debye length) - edge pressure profiles (i.e. ne and/or Ti or Te) - edge neutral density, Zeff, and/or radiated power - edge flows and/or electric fields

⇒ need to measure these other things in addition to wall coatings and SOL turbulence.

Plan:

- Start with well conditioned lithium wall and 'de-condition' using D-GDC or other means (or reverse sequence)
- Keep external parameters (B,I, shaping, etc.) constant
- Use GPI and all other edge diagnostics to measure turbulence as fn. of lithium evaporated.

Measurement of SOL widths in ELM-free H-mode plasmas

Joon-Wook Ahn

Motivation: Previous SOL measurements in NSTX H-mode plasmas suggest that heat spread on the divertor tiles may be increased by ELMs.

- This comes from comparison of Te measurements from the probe and Thomson scattering, along with heat flux decay lengths.

Proposal: to conduct the same experiment in ELM-free H-mode plasmas. This will enable us to directly confirm the role of ELMs in setting Te and heat flux SOL widths.

- A successful SOLT modeling for an ELM-free H-mode plasma will be also a great advantage for deeper understanding of blobs behavior and its relation to SOL widths.

Plan:

- Compare MPTS Te (instantaneous) and scanning probe Te (can be affected by ELMs).
- Measure λ_q heat flux width with slow and fast IR camera
- Compare to SOLT model predictions

1/2 day

Retention XP revisited

Skinner

- Joule milestone language "… *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…*

- XP911 Retention (Joule Milestone) was run in the 2nd week after start of Li conditioning and saw little difference between pre-lithium and with-lithium retention.
- Wall conditions have changed after 124 g of lithium evaporation.

Plan: Repeat key shots of XP911 to see if the present heavy Li coating has made a bigger difference to the retention ± Li.

- Also use the sample probe to address long term Li exposure …

(1/2 day)

Potential XPs if TF reversed:

Potential XPs for reversed TF ranked in priority order:

- 0.5 day XP913 Li dropper into X-point (Mansfield)
  - Motivation: better access to strike point.
- 0.5 day High power L-modes (Maingi)
  - separate the effect of influx and confinement on core impurities
- 0.5 day USN H-modes (M.Bell)
  - understand performance dependence of Li location w.r.t X-point.

(Paragraph requested from authors)

Summary: LRTSG XPs proposed for 2nd half of campaign

Existing top priority:

XP913 1 day Li dropper (High potential for transformative technology for lithium conditioning)

New equal high priority XPs

1 long day (Tue/Thurs) combination Canik/Maingi + Soukhanovskii + Zweben.
Motivation: measuring energy confinement + pumping + edge turbulence as fn. of no Li and high Li conditioning.

1/2 day Joon-Wook, Motivation: measure SOL widths in ELM free H-mode with scanning probe.

1/2 day XP911 Retention with heavy lithium conditioning (Joule milestone). Motivation ±Li was not a big effect in early experiments.

Total 3 days.

Additional XPs if time allows:

additional 1/2 day XP913 combining 2 Li droppers and 2 LiTER.

additional 1/2 day for combination Canik/Maingi + Soukhanovskii + Zweben.

If TF reversed potential XPs ranked in priority order:

1/2 day XP913 Li dropper into X-point. Motivation: better access to strike point.
1/2 day Rajesh: High power L-modes (separate the effect of influx and confinement)
1/2 day Michael Bell: USN H-modes (understand performance dependence of Li location w.r.t X-point).