NSTX Experiments with Evaporated Lithium Coatings on Plasma-Facing Surfaces

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M.G. Bell, H.W. Kugel, R. Kaita, R. Majeski, D.K. Mansfield, L.A. Roquemore, C.H. Skinner, J.R. Timberlake, L.E. Zakharov

Princeton Plasma Physics Laboratory

on behalf of the

NSTX Research Team

Culham Sci Ctr
Univ St. Andrews
York Univ
Chubu Univ
Fukui Univ
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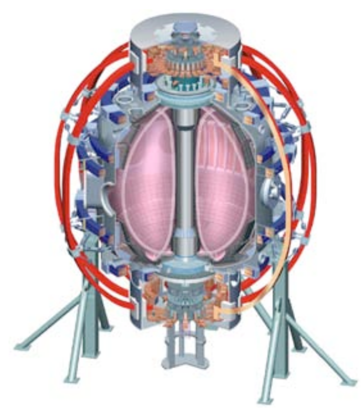


Supported by Office of Fusion Energy Sciences — Office of Science

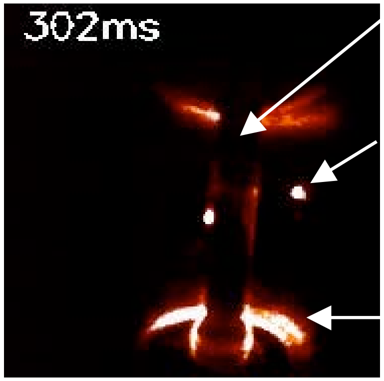
Investigating Lithium on Plasma-Facing Surfaces for Density Control and Improving Confinement

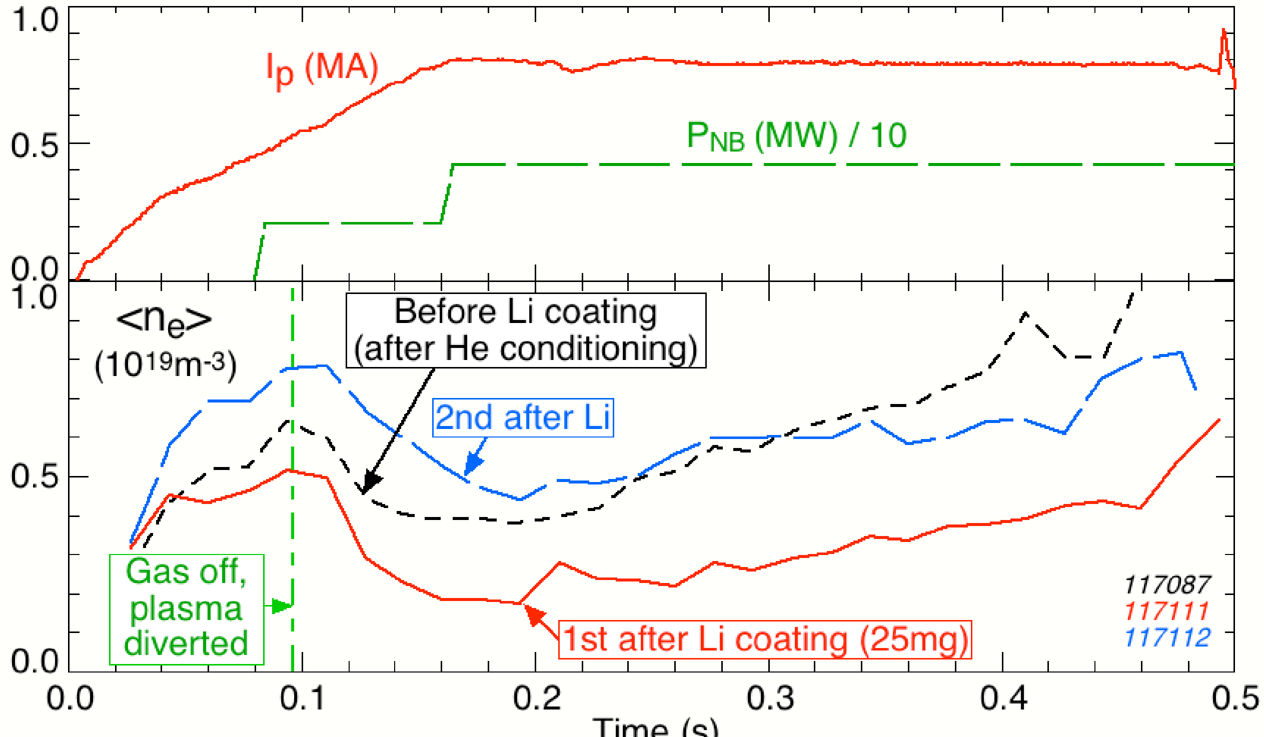
- Continuous density rise in NSTX H-mode plasmas limits efficiency of NB and RF current drive
  - Improve NB penetration, reduce edge collisionality
- TFTR produced dramatic reductions in recycling and increases in “supershot” confinement through lithium coating
  - Pellet injection, evaporation, laser-ablated droplets (DOLLOP)
  - Similar observations in T-11, CDX-U, FTU
  - Subsequent experiments in divertor tokamaks have not reproduced this behavior for H-mode plasmas

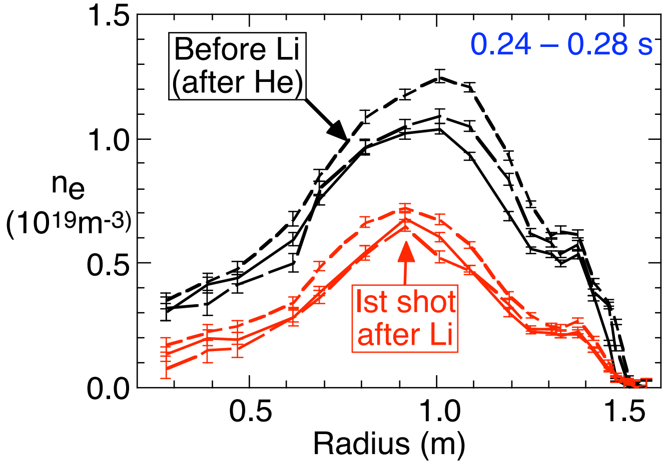
In 2005, Coating Inner Wall and Divertor Using Lithium Pellets Reduced Recycling Significantly

- “Pre-condition” graphite divertor surface with OH helium discharges
- Run reference deuterium L-mode divertor discharge with NBI heating
- Inject Li pellets (2 – 5 mg) into OH helium discharges: 25 mg total
- Repeat deuterium L-mode divertor discharges with NBI to assess effects on recycling

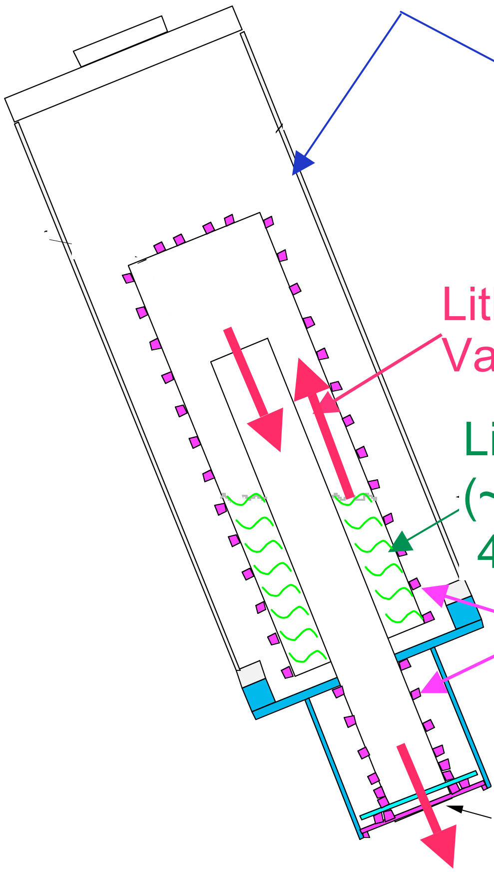
Image in Li I light

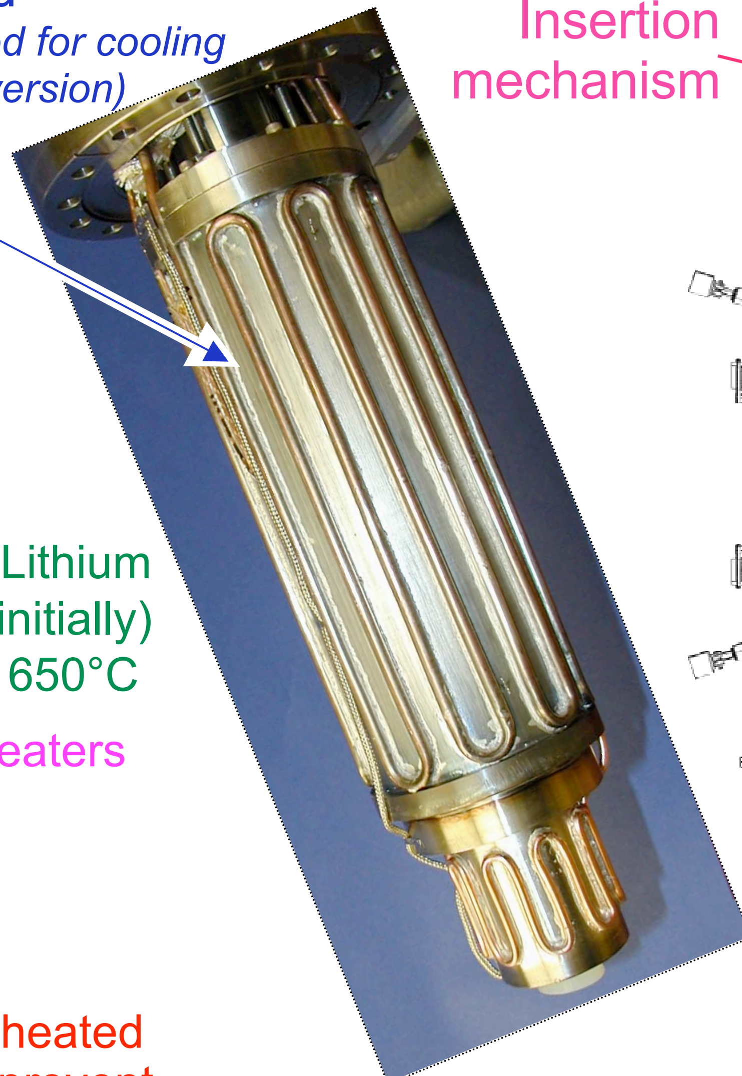


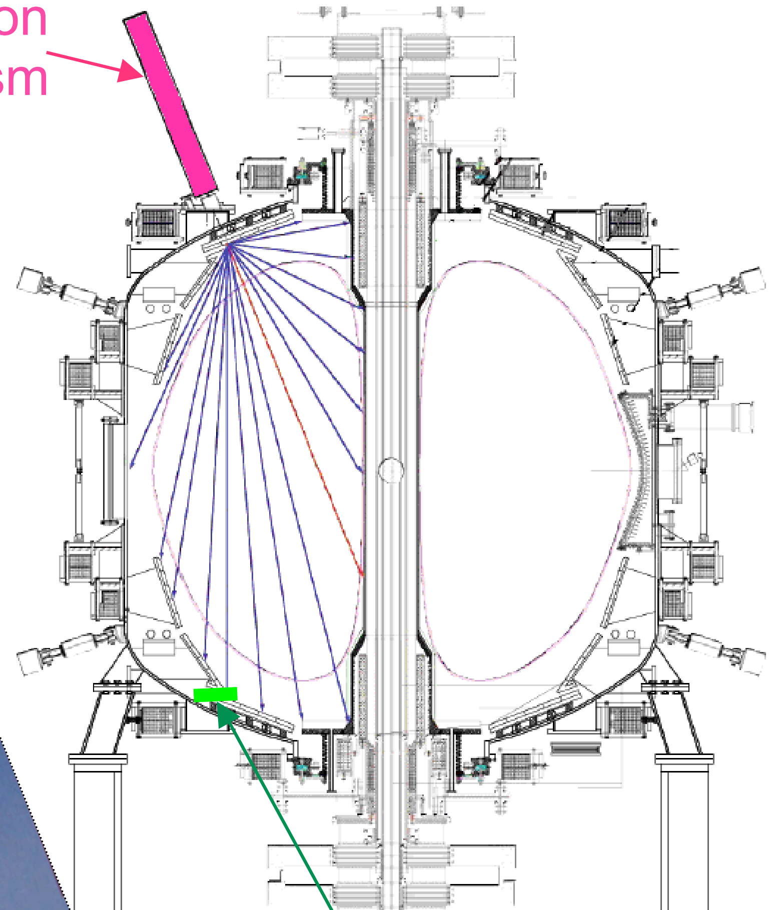




Developed Lithium Evaporator LITER-1 for *In-Situ* Coating of Plasma Contact Areas on Carbon Tiles







Performed 12 Lithium Evaporation Cycles and Examined Effects on Standard NB-Heated Plasmas

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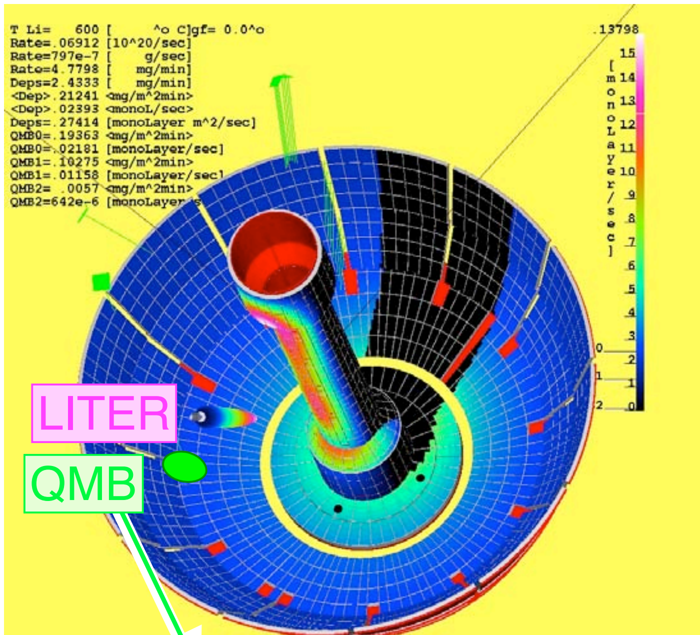
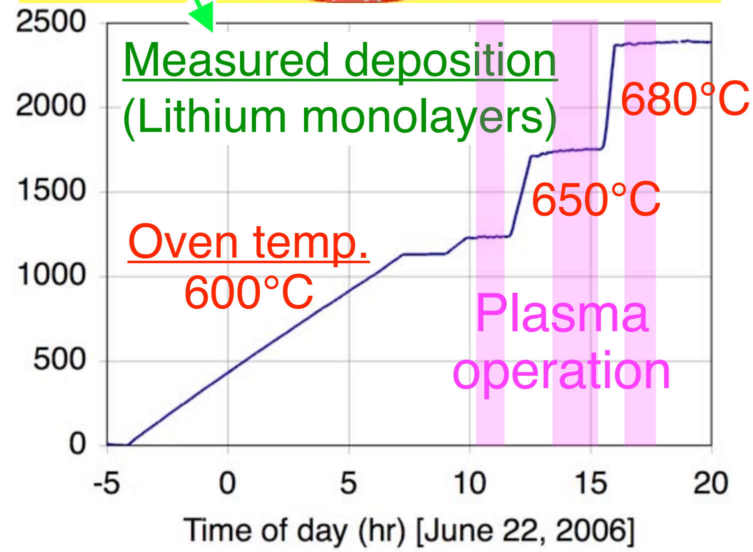
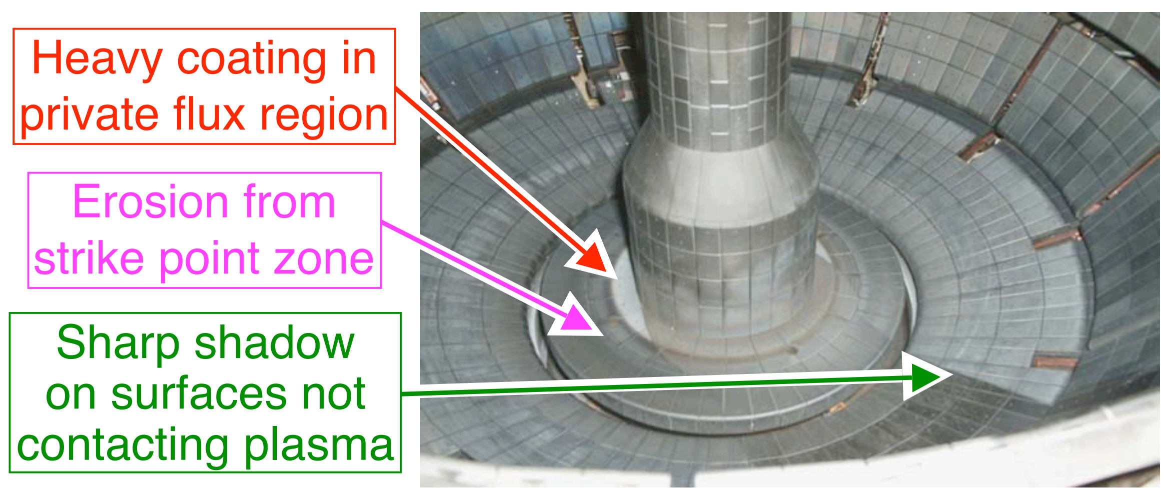
Modeled deposition pattern



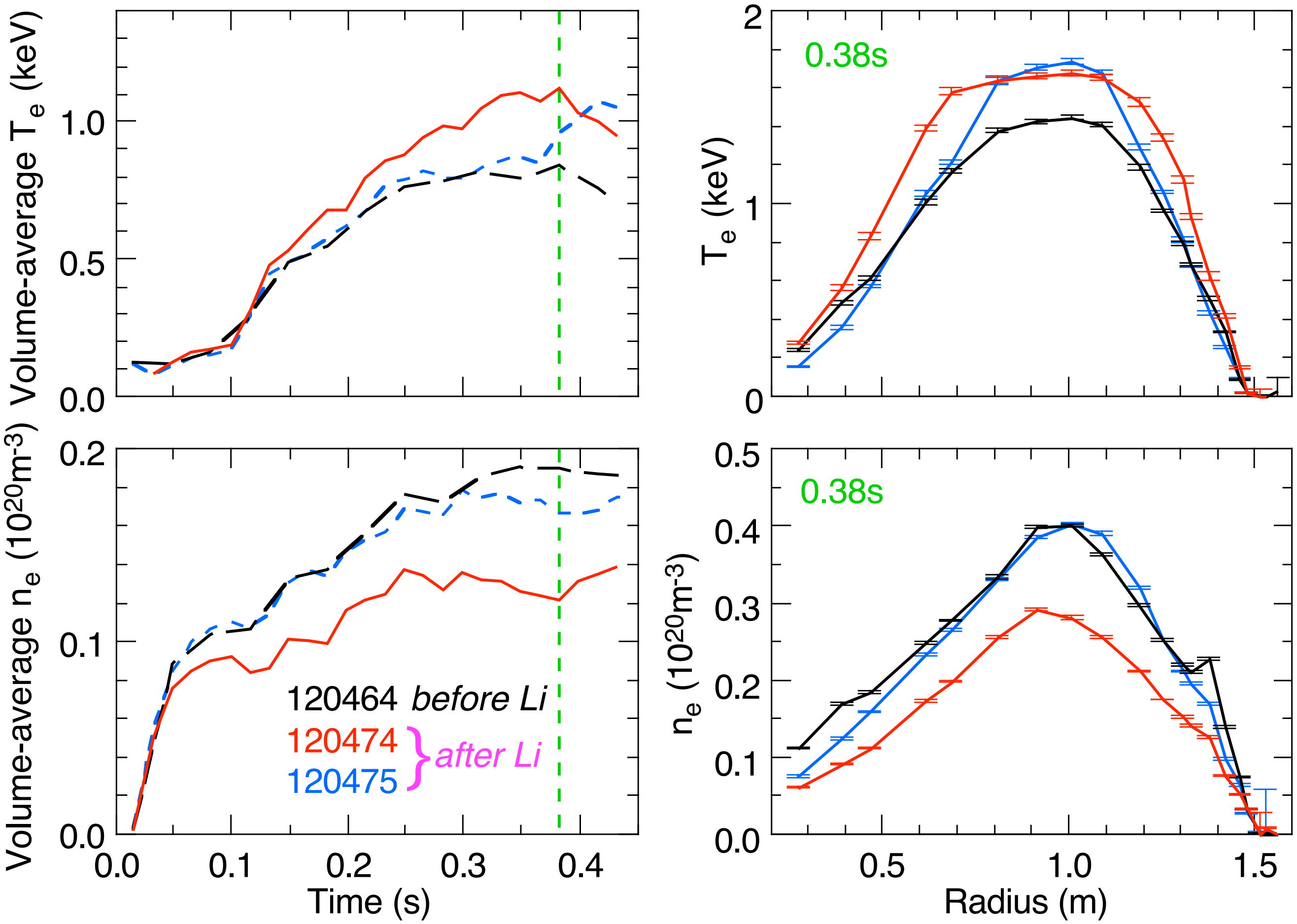


- Evaporation rates up to 35mg/min
- Deposited 14 – 4800 mg over periods 60 – 740 min
- Little effect on subsequent discharges until 400mg lithium deposited
  - Oxygen emission was reduced after depositing smaller amounts of lithium

$LiOH/Li_2CO_3$ layer formed after air exposure



Evaporated Lithium Coating Provides Transient Reduction in Recycling Similar to Pellets



- NB-heated **L-mode** divertor discharges *with same gas puffing*
- Intervening shots were OH helium plasmas
  - May account for part of density reduction
- ~400mg lithium evaporated in about 1 hr

- Reduction in density disappeared on second discharge, *but*
- There were significant reductions in D_α and oxygen impurity radiation
  - *oxygen reduction persisted over several subsequent days of operation*

In H-mode Discharges, Evaporated Lithium Coating Affects Core with Small Change in Pedestal

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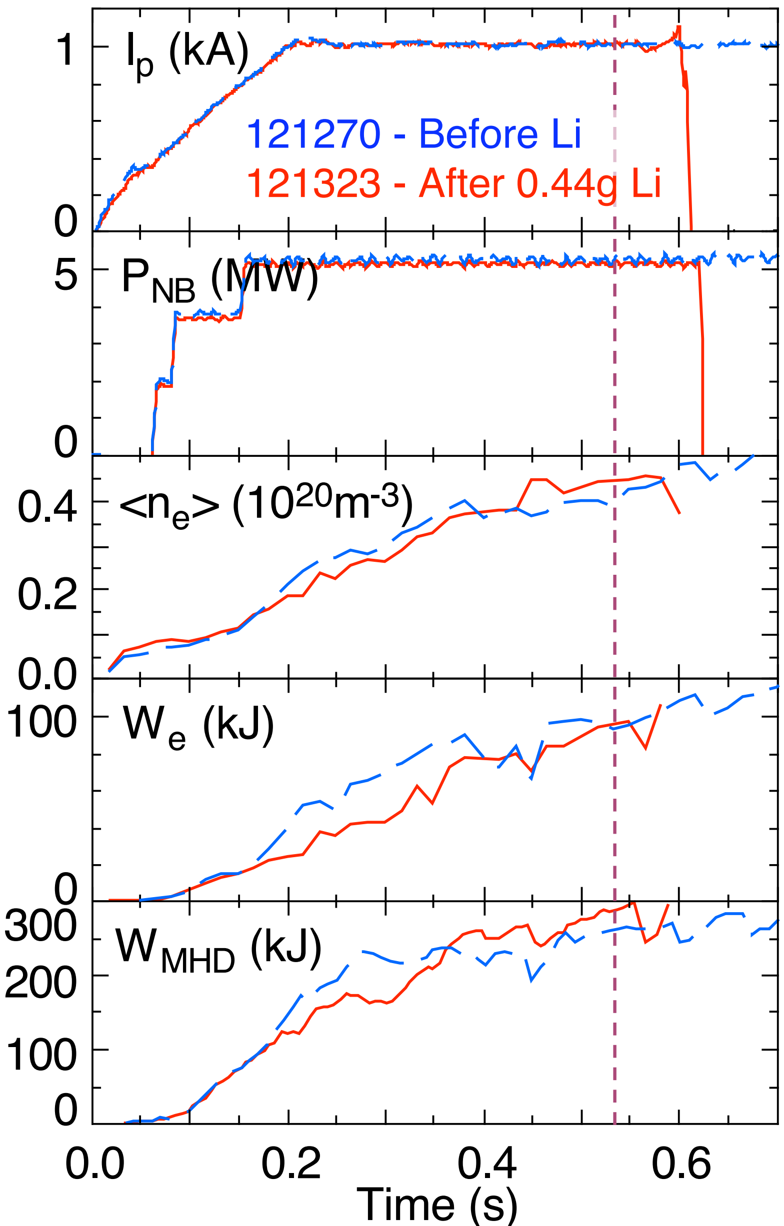
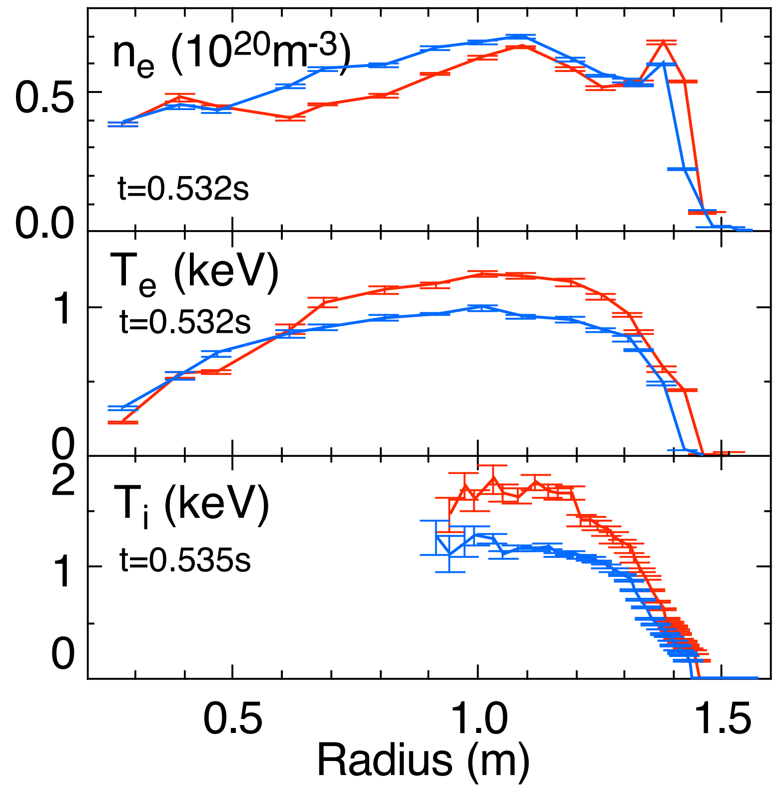


- Both shots *without* helium conditioning
  - Similar gas puff on both shots
- H-mode transition delayed 20ms and dithered for ~50ms on post-Li shot
- Significant effect only on *first* shot



Similar central n_e

Higher central T_e

Much higher central T_i

Evaporated Lithium Produced Benefits but had Less Effect than Anticipated on Basis of Pellet Results

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- Improvements in H-mode plasmas without extensive pre-conditioning
  - Higher *central* T_e, T_i; global τ_E improved 10 – 20%
  - Reduction in density for same gas input: 5 – 25%
  - Reduced D_α and persistent reduction in oxygen emission
  - Reduced poloidal flux consumption
- Similar improvements also occurred in reverse-shear discharges
- Benefits not apparent until ~400mg deposited in one application
  - Reduction in density lasted only one shot
  - Thicker films neither more effective nor longer lasting
- Evaporated films thicker than from pellets but deposited more slowly
  - Passivation by residual H_2O, CO_2; intercalation into graphite
  - Evidence for migration of lithium away from divertor strike points

Plans for Lithium PFC Research

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- In 2007
  - Install evaporator with two angled nostrils for better coverage
  - Compare evaporated and pellet-deposited lithium directly
  - Develop specifications for a liquid lithium divertor module
    - Build on CDX-U, T-11, FTU experience and NSTX data
- In 2008
  - Install liquid lithium divertor module
  - Begin investigation of low-recycling regime with high peak power flux

Lithium-Related Presentations at this Conference

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NI1.4 "Achievement of Low Recycling and High Power Density Handling in CDX-U with Lithium Plasma-Facing Components"- Kaita

QO2.3 "Experimental Study of the Effects of Lithium Coated Plasma Facing Components on Energy Confinement Time in the CDX-U Device" - Spaleta

QP1.5 "The Development of LITER - a Lithium Evaporator for Use in Fusion Devices" - Mansfield

QP1.6 "Effect of Evaporated Lithium PFC Coatings in NSTX" - Kugel

UI1.4 "Ignited Spherical Tokamaks as a Reactor Development Facility" - Zakharov

UI1.5 "FTU experimental results using a lithium liquid limiter" - Mazzitelli

VP1.10 "Overview of Final CDX-U Experiments with Lithium Plasma-Facing Components" - Kaita

VP1.11 "Particle Confinement Times for Discharges with Lithium Plasma-facing Surfaces in CDX-U" - Gray

VP1.12 "Status of the Lithium Tokamak eXperiment (LTX)" - Majeski

VP1.13 "Diagnostics for Experiments with Liquid Lithium Plasma-Facing Components in LTX" - Strickler

VP1.14 "Design and Fabrication of the Lithium Tokamak Experiment" - Kozub