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# Reduced Recycling from Lithium Coatings: Recent Results and Plans

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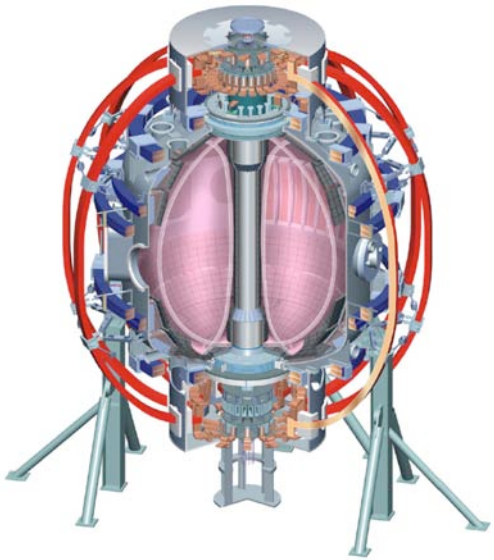


# Lithium Research Motivation and Goals


- TFTR demonstrated benefit of partial Li coating on graphite PFCs
  - Strong edge pumping (reduction of recycling)
  - Improvement in energy confinement (x2)
- CDX-U found liquid lithium limiter yielded
  - ~30% recycling coefficient
  - up to an order of magnitude increase in confinement times (exceeded ITER98P(y,1) scaling by 2 - 4×)
  - very high power handling capability (~50 MW/m$^2$, 300 s)
- NSTX in FY05 used Lithium Pellet Injection (LPI) to create coatings that significantly pumped neutral-beam-heated plasmas
- NSTX is preparing for FY06 run a Lithium Evaporator for routine thick lithium coatings over a significant fraction of the PFCs
  - Aim to provide density control for long-pulse operation

# NSTX Lithium Research Applications to ST, ITER and Demo

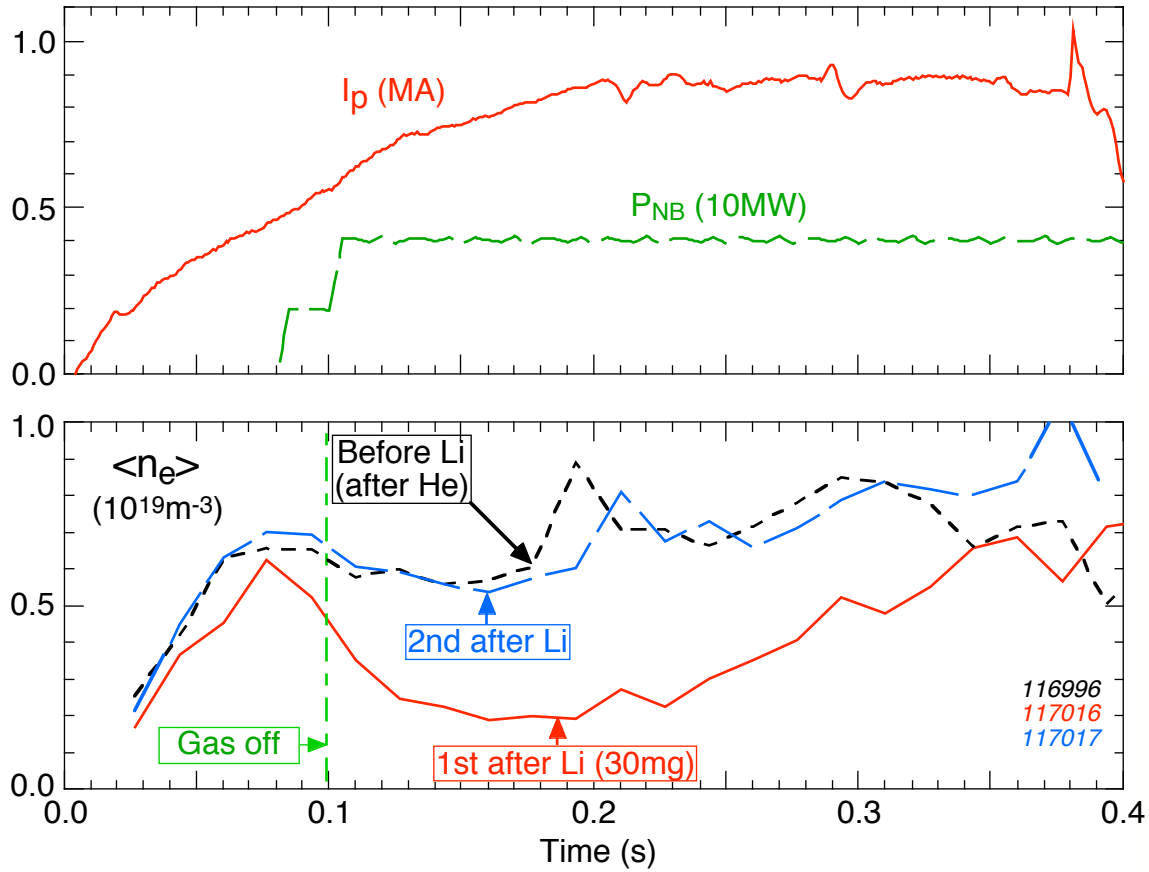

- Lithium PFCs for High Power ST
  - Very high power handling capability for high P/R divertors
- Lithium PFCs for ITER and DEMO
  - ITER and DEMO continued long pulse operation is not possible with planned Be, C and W PFCs
  - Lithium flow concepts could:
    - Remove tritium,
    - Handle high power, and
    - Avoid issues associated with Be, C and W PFCs

# NSTX Lithium Experiments Guided by TFTR Experience

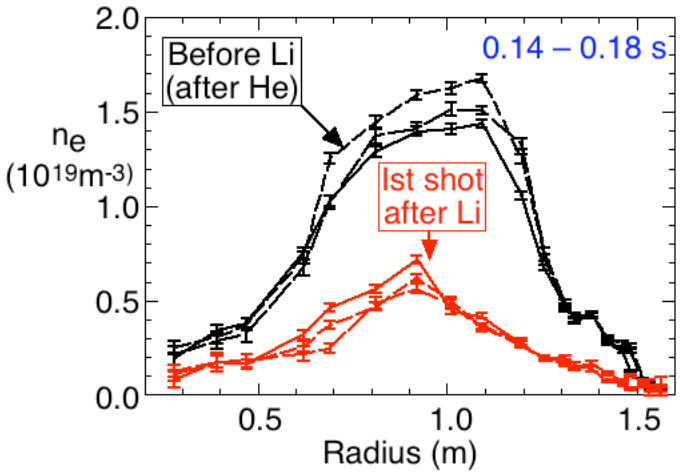
- Both Center Stack Limited (CSL) and Lower Single Null (LSN) discharges were studied in separate NSTX experiments

1) Ohmic Helium discharges were used to *degas* the Center Stack (Exp-1 & Exp-2) and the Lower Divertor (Exp-3)
2) Lithium Pellets were injected into repeated CSL and LSN Ohmic Helium discharges to coat the plasma wetted surfaces and *prevent lithium saturation by the fuel gas*
3) CSL and LSN deuterium NBI reference plasmas were run to measure changes due to lithium pumping of the edge plasma
   - Deuterium puffing was limited in reference plasmas to avoid saturating the available lithium pumping capacity

# Exp-1: First CSL NBI Deuterium Shot After 30mg of Lithium Deposition Exhibited Factor ~3 Decrease in Density

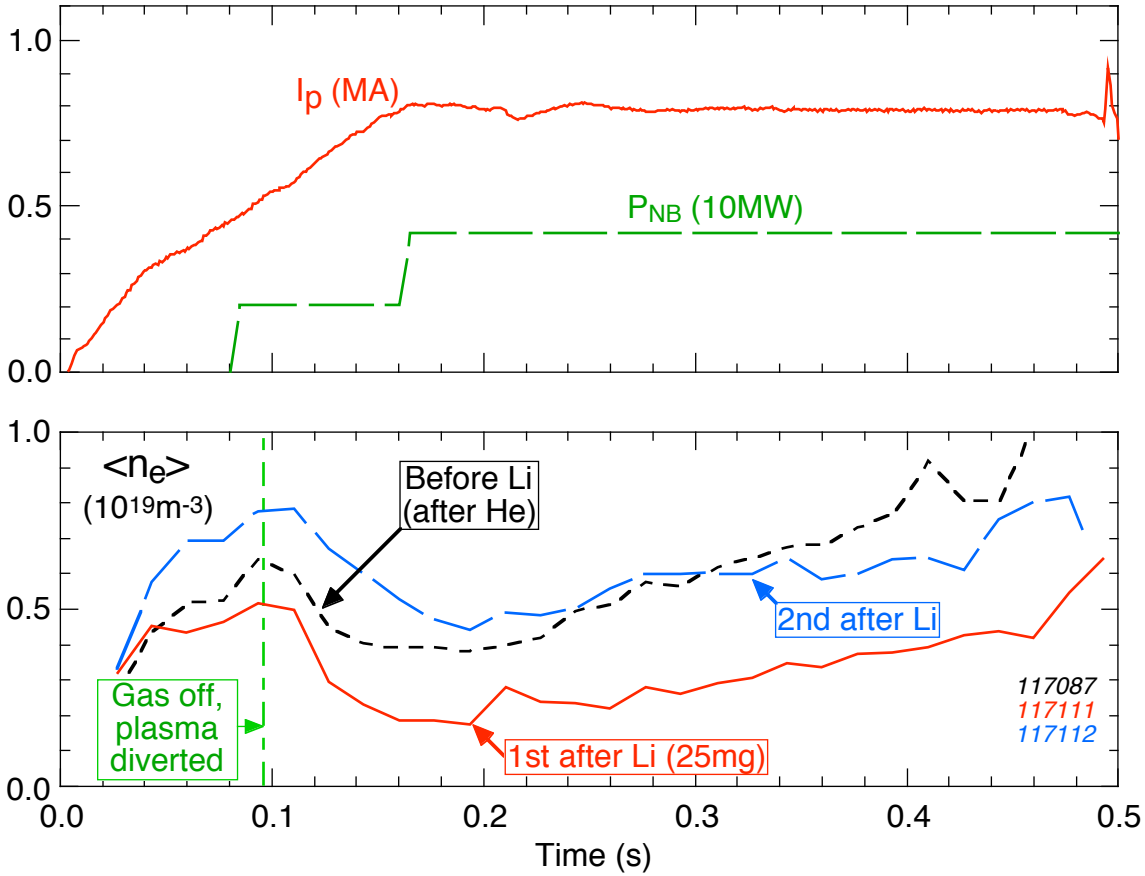



Center-stack limiter discharges,
0.9 MA, 0.45T,
$D_2$ gas fueling 3.5mg

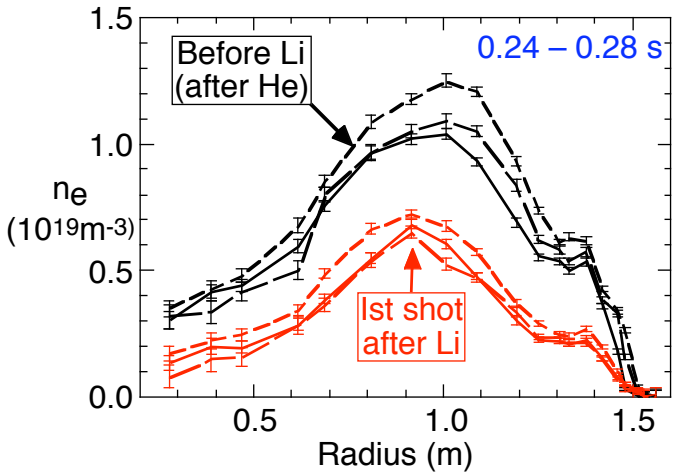



- Li pumping of edge density saturated after the 3 similar D discharges consistent with the consumption of the deposited lithium.
  ~30 mg Li = $2.6 \times 10^{21}$ Li atoms available to react with $2.6 \times 10^{21}$ D
  ~$9 \times 10^{20}$ D/Shot, and Li pumping stops in 2-3 shots ($1.8\text{-}2.7 \times 10^{21}$ D removed)

# Exp-3: First LSN NBI D Shot After 25 mg of Li Deposition Exhibited Factor ~2 Decrease in Density

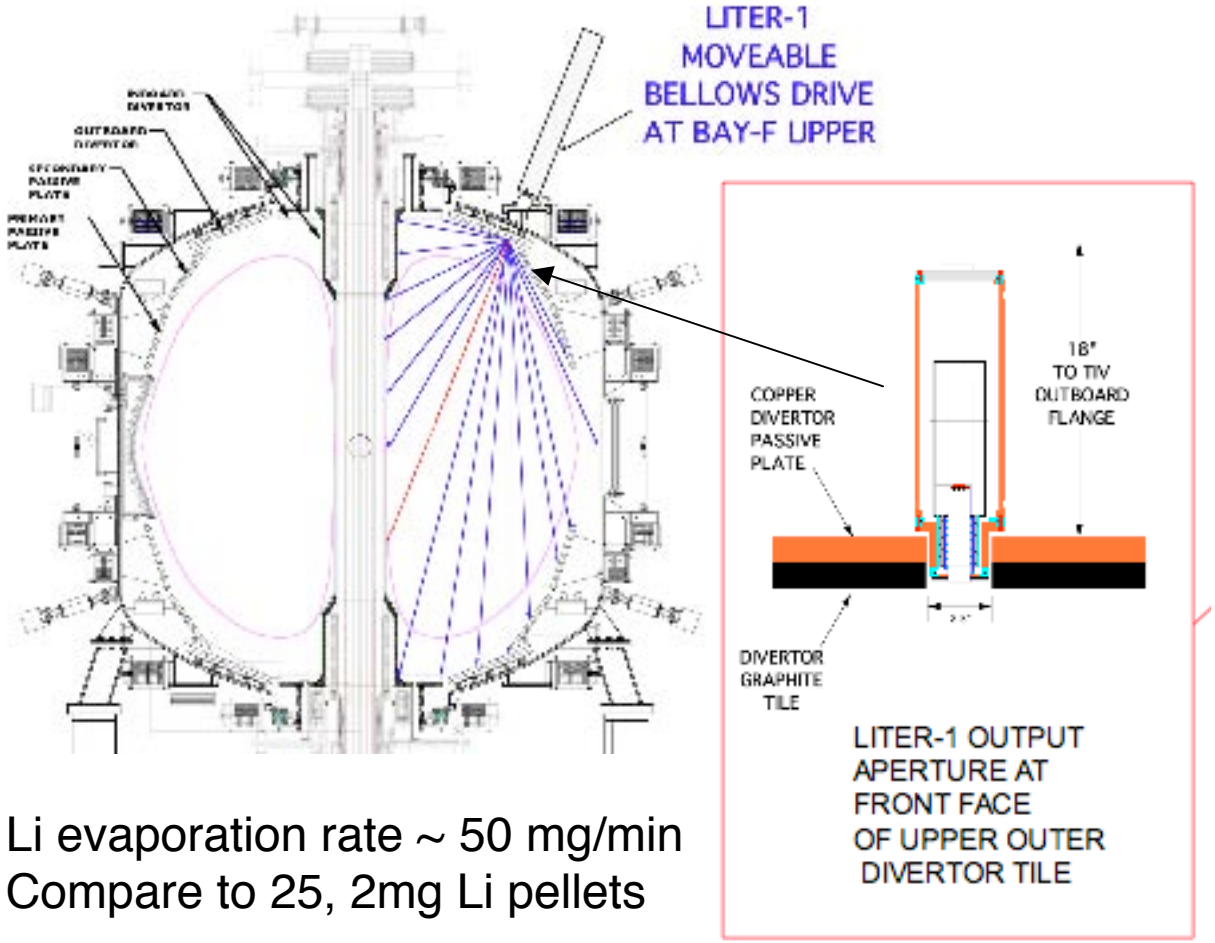


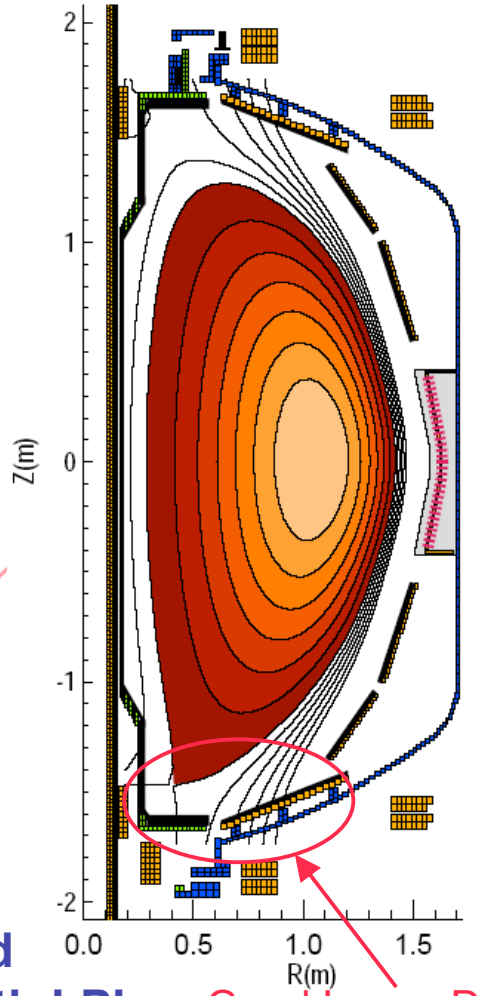

Lower single-null divertor discharges, 0.45T, $D_2$ gas fueled 3.5mg




- 25 mg of lithium pumping of edge density saturated after the 3 similar D discharges and returned to pre-Li wall conditions
- Expected if most injected gas reacts with the deposited lithium

# The Next Step: Lithium Evaporator LITER-1 Being Readied for Density Control for Long-pulse Operation




Li evaporation rate ~ 50 mg/min
Compare to 25, 2mg Li pellets

- **Evaporated lithium films should reduce recycling and improve particle control beyond levels achievable with LPI**

Good Lower Divertor Region Coverage

# LITER-1 Status: Off-line Testing & Calibration in Progress for Installation During Week of 2/27/06

EXIT APERTURE
("SNOUT")

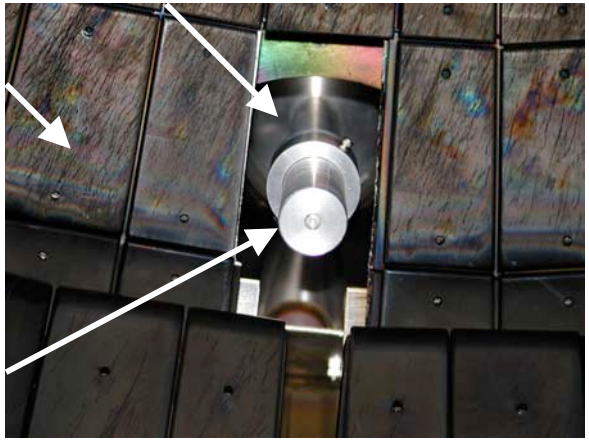
BAFFELED
LITHIUM
RESERVOIR

LITHIUM OVEN

GAP IN COPPER DIVERTOR BACKPLATE
AND CARBON TILES

GRAPHITE PLASMA-
FACING TILE

LITER-1 TIP



LITER-1 "MOCKUP"
INSIDE NSTX

- Rate of lithium deposition on NSTX plasma facing components controlled by varying temperature of lithium oven

# Experimental Proposal (XP) for Investigation of Density Control Using Evaporated Coatings

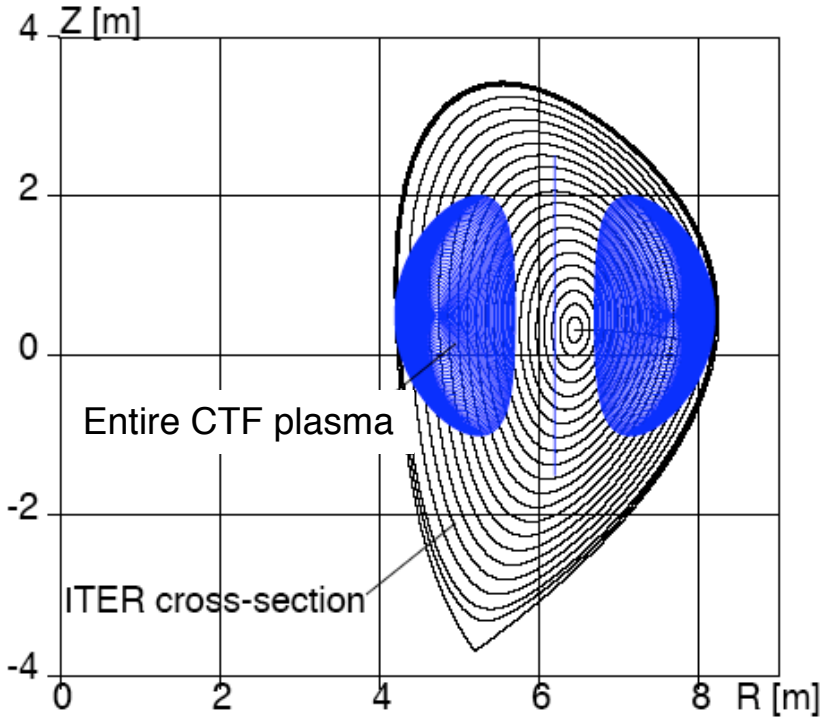
- XP601: "Effect of Evaporated Lithium PFC Coatings on Density Control" will investigate the effects of evaporated lithium coatings on density control prior to its application in other XP's.
- First, this XP will make contact with the LPI thin coating results, and then proceed to thicker coatings and long pulses.
- The basic sequence of XP601 will characterize:

1. Thin coatings on conditioned & unconditioned surfaces for comparison with LPI coatings – L-mode (day 1)
2. Thin coatings to achieve H-mode, same shape as above (day 2)
3. Thick coatings to achieve H-mode, same shape as above (day 2)
4. Thin/thick coatings for density controlled long pulse, LSN H-mode (day 3)
5. Thin/thick coatings for density controlled L-mode for transport and turbulence experiments (day 3)

# Preparations for Upgrading Fueling Capability to Accommodate Lithium Edge Pumping

- Gas Injection System Fueling
  - Test present Low Field Side gas injection systems at higher pressures
  - Test High Field Side-midplane gas injection system at the same higher pressure and increase its plenum capability x4-5
  - Install 3 injectors in parallel at Bay-J top
- Supersonic Gas Injector Fueling
  - SGI on a movable probe commissioned and operated on NSTX
  - Used to fuel ohmic and 2 - 6 MW NBI-heated L- and H-mode plasmas
  - Measured fueling efficiency 0.1 - 0.3
  - New larger plenum and multi-pulse capability installed
  - May install separate dedicated fueling line for high pressure operation

# Lithium Tokamak With Core Fueling Leads To a Simple, Compact Component Test Facility




CTF with TF, PF and blanket comparable in volume to present-day light water fission reactor pressure vessel (~100 $m^3$)

- PFC: 0.1-0.5 mm "creeping" lithium film in porous moly or tungsten surface
- Required lithium replacement rate: ~10 liter/hr (flow rate < 1 cm/s) for ITER
- $R_0$ = 1.25m, a = 0.75m, A = 1.66, $\kappa$ = 2, $B_T$ = 3T, $I_p$ = 11 MA
- Plasma volume = 26 $m^3$ (3% of ITER)
- Small size = access for core fueling with low voltage NBI
- At 40% $\beta$, $P_{fusion}$ = 400 MW (~ITER)
- Manageable tritium requirements for reactor development

L. Zakharov

# NSTX lithium research is unique and has applications to high power ST, ITER, and Demo

- NSTX thin coating Li Pellet Injection experiments demonstrated that surfaces *pre-coated with lithium* edge pumped a diverted plasma
  - Results are consistent with consumption of the deposited lithium
- A Lithium Evaporator is in preparation for routine thick lithium coating over a significant fraction of the PFCs for experiments in early 2006 to provide density control for long-pulse operation
- Lithium coating has potential for significant performance improvement in NSTX
- The results will be used for Decision Analysis on edge pumping (e.g., enhanced lithium capability and/or cryopumping) and core fueling (e.g., D Pellet Injection and/or Compact Torus Injection)