# Effects of Lithiumization on Electron Temperature and Density Profiles*

*B.P. LeBlanc and the NSTX Team*

**49th Annual Meeting of the Division of Plasma Physics**

November 12-16, 2007
Rosen Centre Hotel
Orlando, Florida

**This work is supported by DOE Contract No. DE-AC02-76CH03073.*

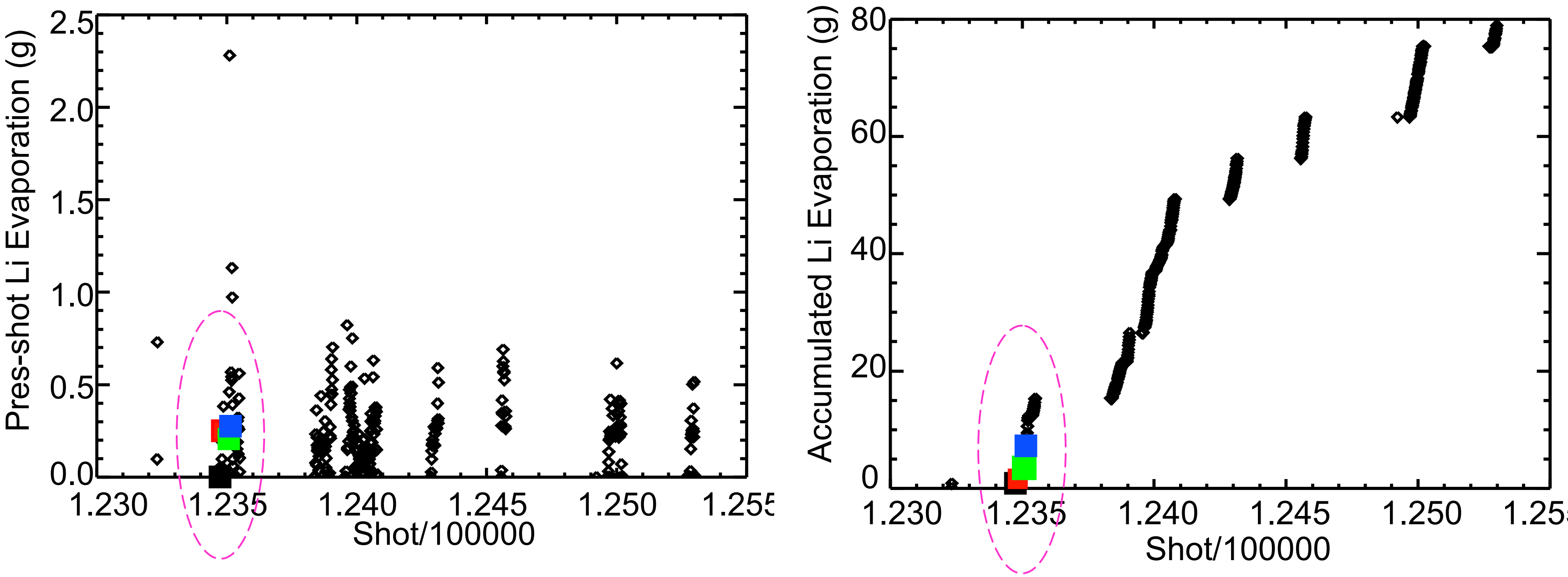
# Abstract

NSTX conducted an aggressive first wall conditioning campaign during which up to 100 g of lithium was evaporated progressively inside the vacuum vessel. This work will search for change in the behavior of *ne* and *Te* profiles measured by Thomson scattering. Casual observation during the earlier phase of the lithiumization did not reveal significant changes, but a systematic search will be done for the preparation of this paper. Contrary to last year's results, the effects of this more aggressive lithiumization appear to last longer; increase in stored energy and reduction of ELM activity have been observed, sometimes accompanied by core impurity accumulation. Further analysis will attempt to correct the part of the Thomson scattering data which was affected by window coating during the last month of plasma operation. This work is supported by United States DOE contract DE-AC02-76CH03073.

# Outline

- Ascertain effects of lithiumization based on a set of 44 discharges ( 1MA, 0.45 T, NBI)
  – 31 fiducial discharges obtained prior to, during and after lithiumization
  – 16 discharges obtained during a dedicated evaporation experiment
- Search for effects on profiles' shape and $W_e$
  – time dependent effects
  – shot average effects
- MPTS (Thomson scattering system) upgrades

# Lithium Deposition for 2007 Run




The maximum pre-shot deposition was 2.3g, but most non-zero values were below 0.5g.The estimated time resolved evaporation was 79g, but in excess of 90g was actually used by evaporator.

The four data points marked with colored squares are part of a controlled Li evaporation scan, and will be used within the rest this poster.

*The evaporation data was provided by Hans Schneider.*

# Dedicated Li Evaporation Scan

*Select 4 discharges – 0.45T, 1.0MA, NBI – part of a carefully executed evaporation scan, which is marked with magenta ovals in the previous slide.*

| Shot | Pre-shot (g) | Accrued (g) |
|---|---|---|
| 123474 | 0.0 | 0.82 |
| 123483 | 0.25 | 1.60 |
| 123507 | 0.21 | 3.47 |
| 123514 | 0.28 | 7.25 |

# Search for Time Dependent Effects

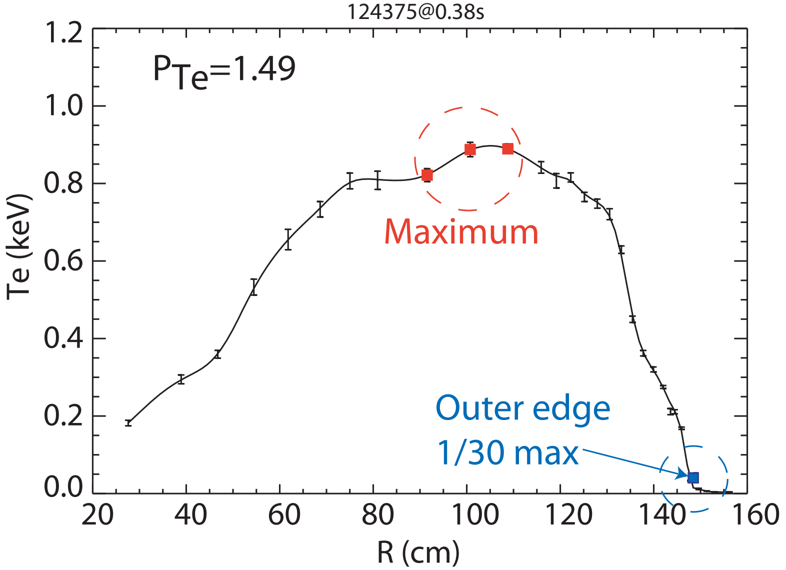
NSTX

- Define peakedness parameter for $T_e(R)$, $n_e(R)$ and $p_e(R)$
- Follow peakedness evolution for discharges with different amounts of lithium coating
  - Evolution against time
  - Trajectories against central profile values
  - Overlay of different plasma shots

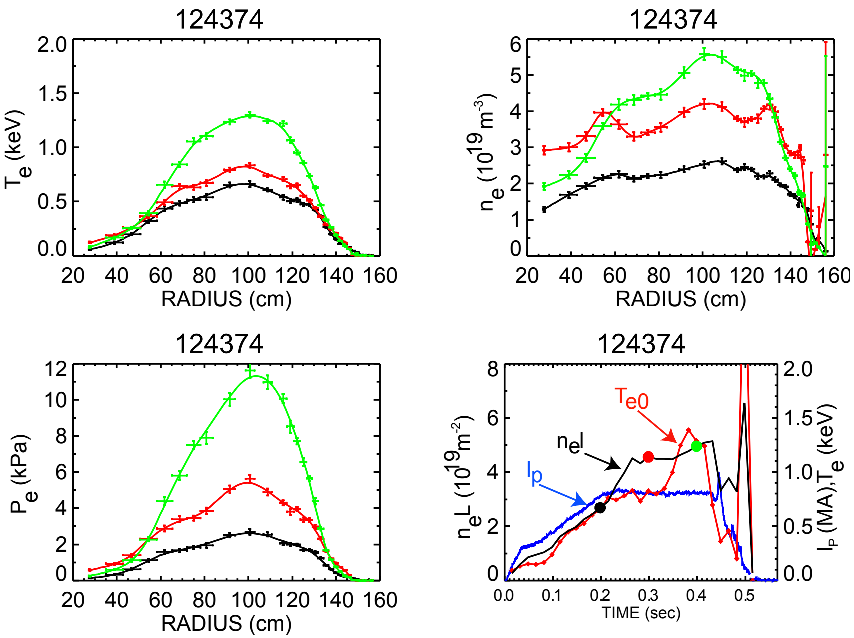
# Peakedness parameter

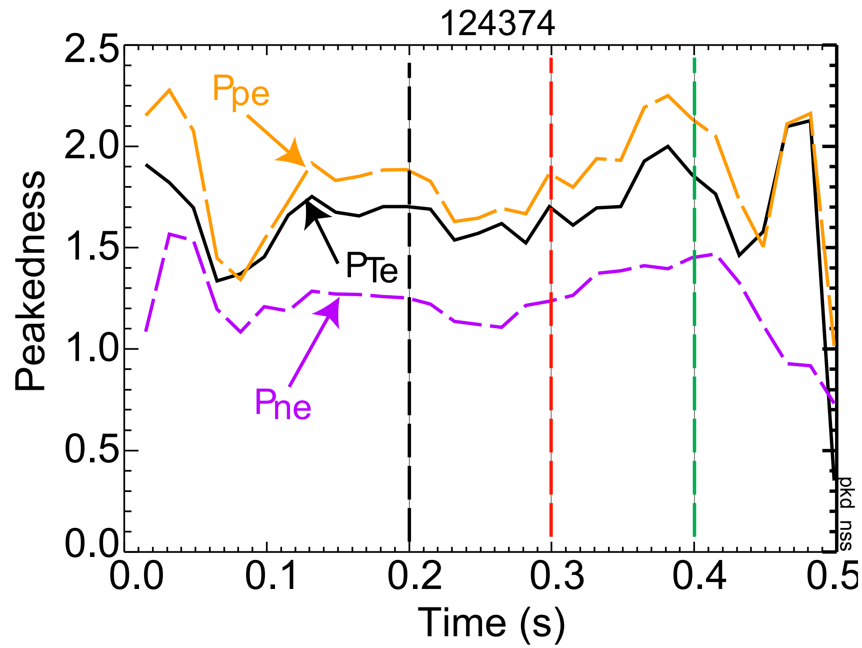
- Use MPTS data to define a peakedness parameter e.g. $P_{Te}$
- *Take average of 3 central points divided by average of profile data points from inside to R corresponding to 1/30 of profile maximum*
- *Similar calculation for electron density and pressure*

$$P_{Te} = \frac{\frac{1}{3}\sum_{center-1}^{center+1} Tef}{\frac{1}{n}\sum_{inside}^{outside} Tes}$$



# Peakedness Variation over Time



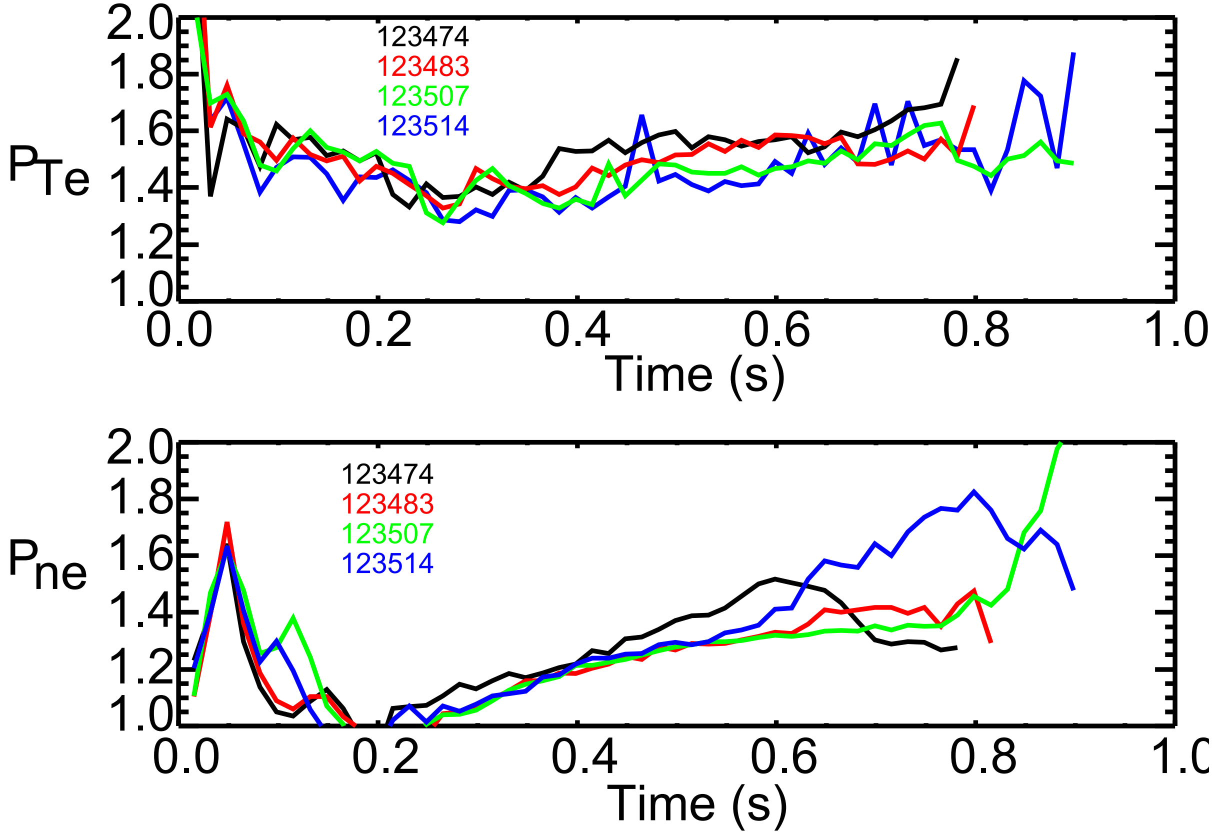




*Left panel:* MPTS profile $T_e(R)$, $n_e(R)$, $p_e(R)$ output at 0.2, 0.3, 0.4 s, along with nel, and central Te. Ip trace is also shown.

*Right panel:* Time evolution of the peakedness parameters $P_{Te}$, $P_{ne}$, $P_{pe}$. Dashed vertical lines indicate the times corresponding to the profiles seen on the left.

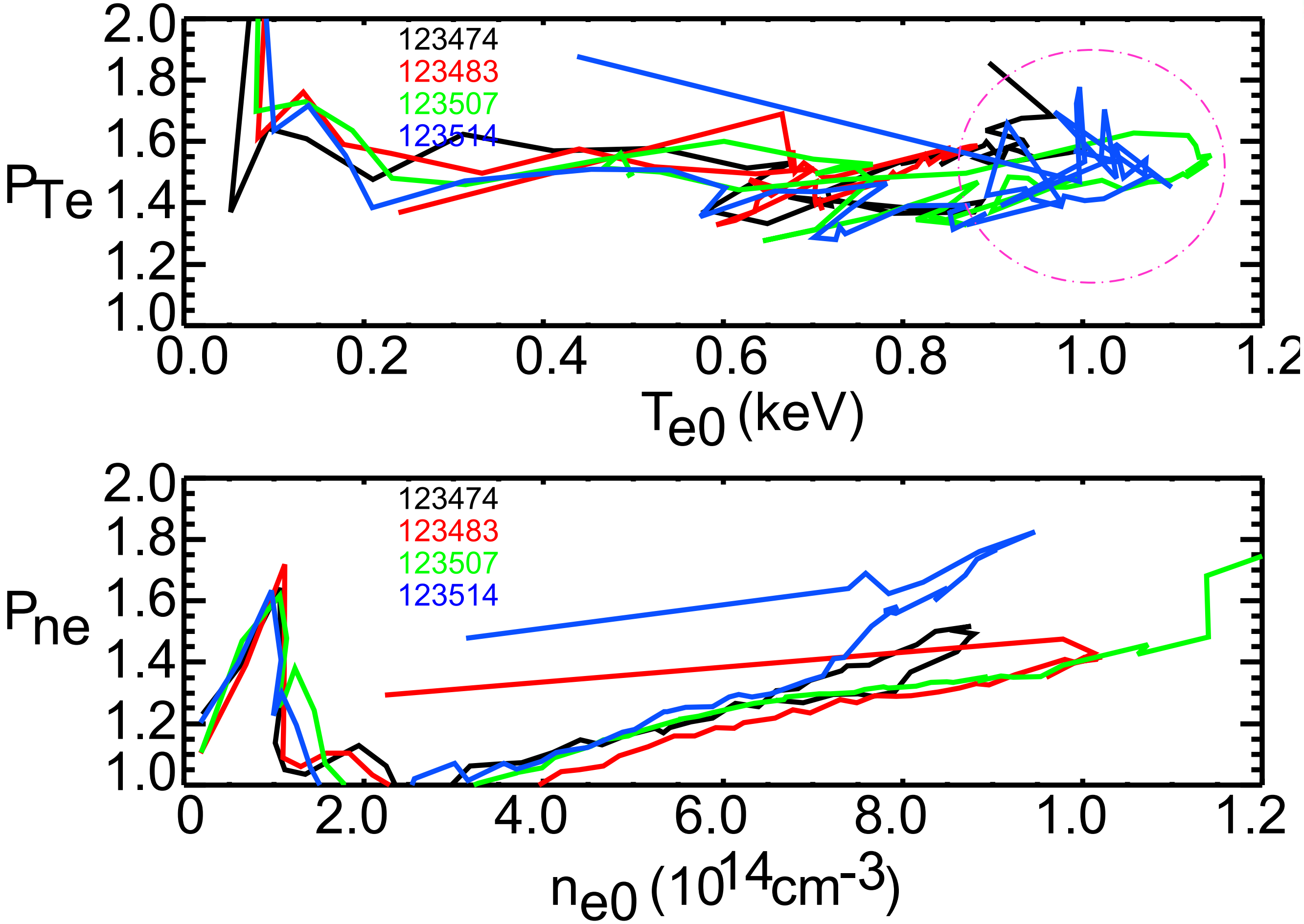
# Peakedness Time Evolution for Three Plasmas
## *Part of Dedicated Li Scan*

NSTX




The shots with largest Li accumulation – green and blue traces – have a consistently lower $P_{Te}$ over time.

# Peakedness Trajectories for Three Plasmas
## *Part of Dedicated Li Scan*

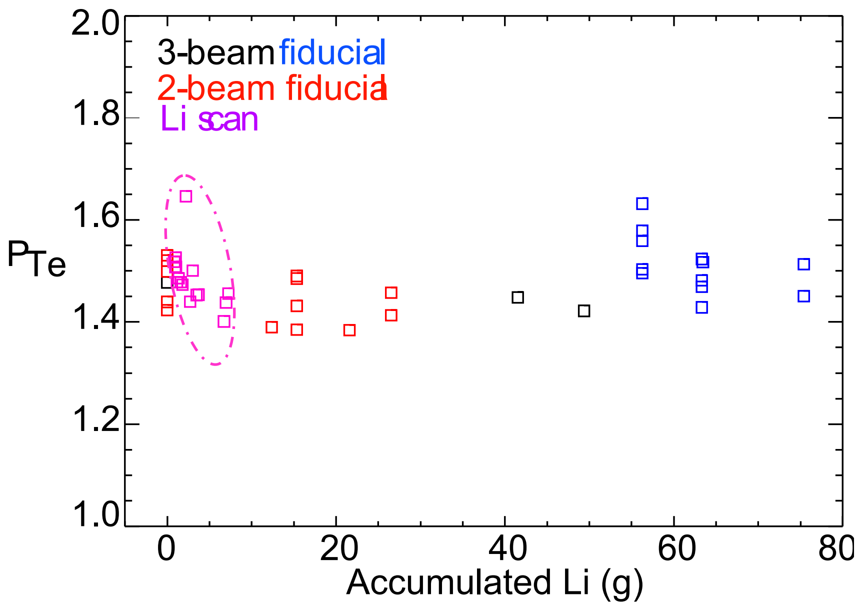


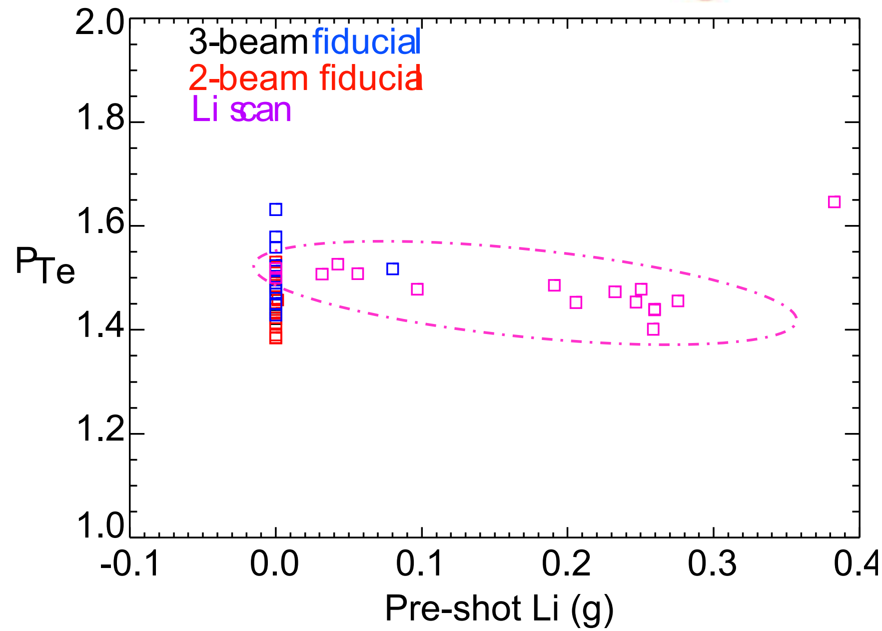

The shots with largest Li accumulation – green and blue traces – spend more “time” at high $T_e$.

# Search for Shot Average Effects

- Take average from $t_1$=0.2s to a time $t_2$ before Ip drop-off or NBI stop, typically $_{t2}$ =0.75s
- Time average made of the peakedness' $P_{Te}$, $P_{ne}$, and $P_{pe}$, and also the electron stored energy We and the total stored energy $W_{mhd}$
- Similarly MPTS' $T_e(R)$, $n_e(R)$, and $p_e(R)$ are also averaged over time

# Effects on Te(R) peakedness
# $P_{Te}$ vs. prompt and accumulated Li



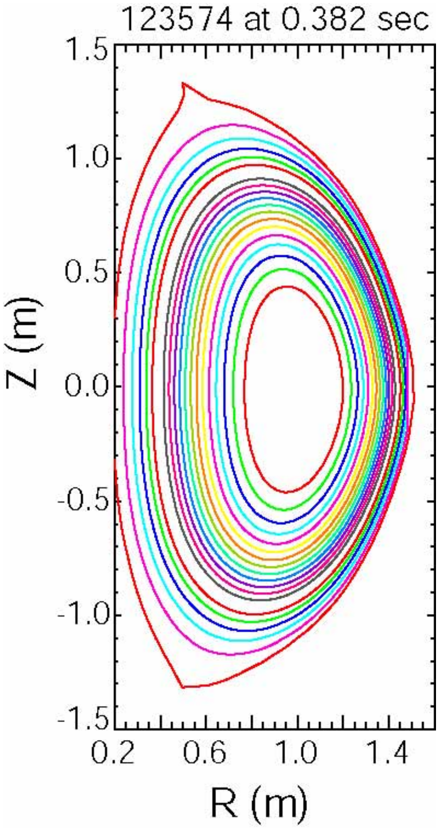



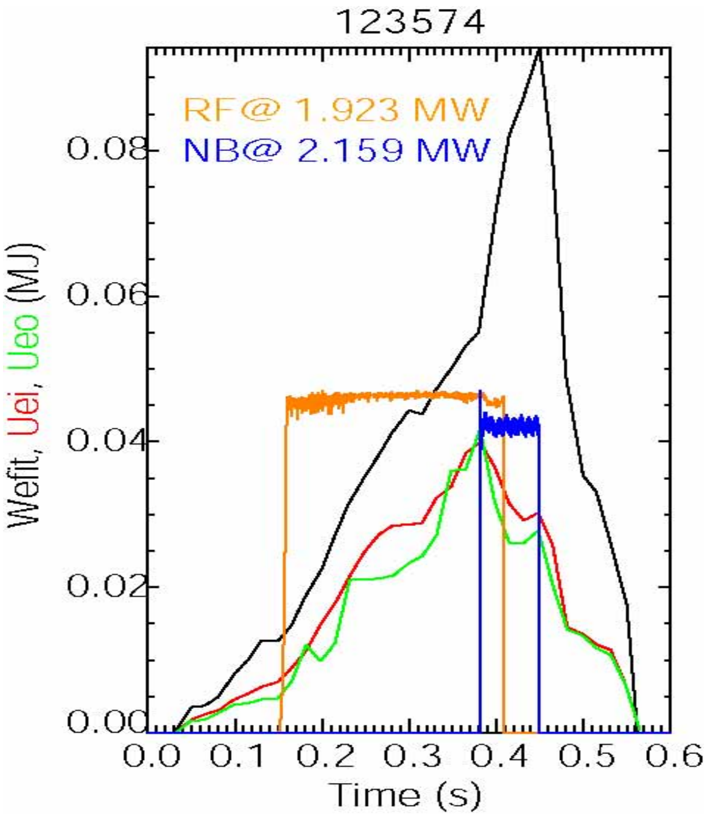

- Long term – days – effects of lithiumization not observed on peakedness
- A $P_{Te}$ reduction — $T_e(R)$ profile broadening — is visible for the dedicated Li evaporation scan data set

# Electron Stored Energy Calculation
## *Using EFIT and MPTS data*

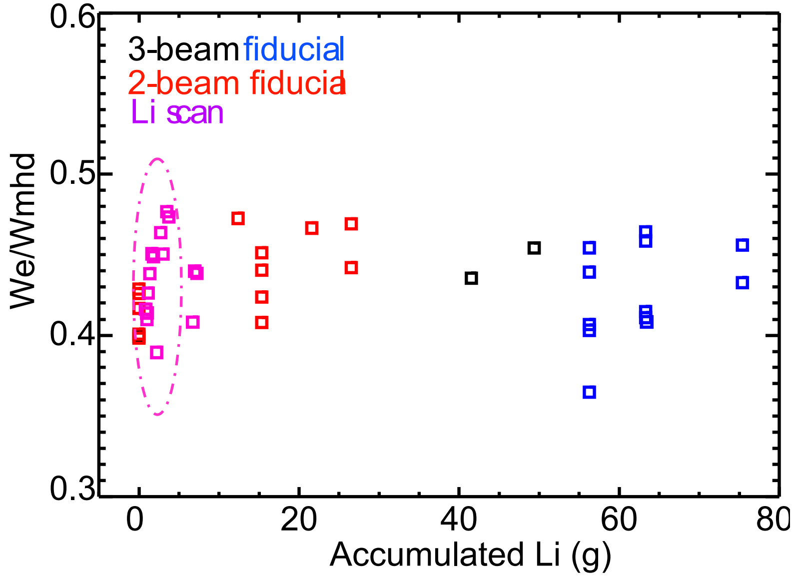
The inner and outer $P_e(R)$ is mapped over the poloidal cross-section based on EFIT's equilibrium. Two outputs:

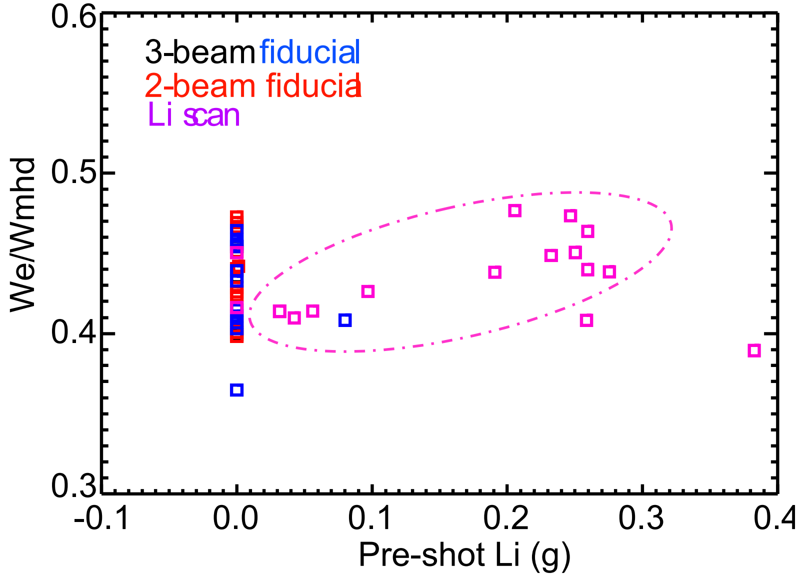
- *uei* (inside/high-field side) is computed using high-field side of $P_e(R)$
- *ueo* (outer/low-field side) is computed using low-field side of $P_e(R)$



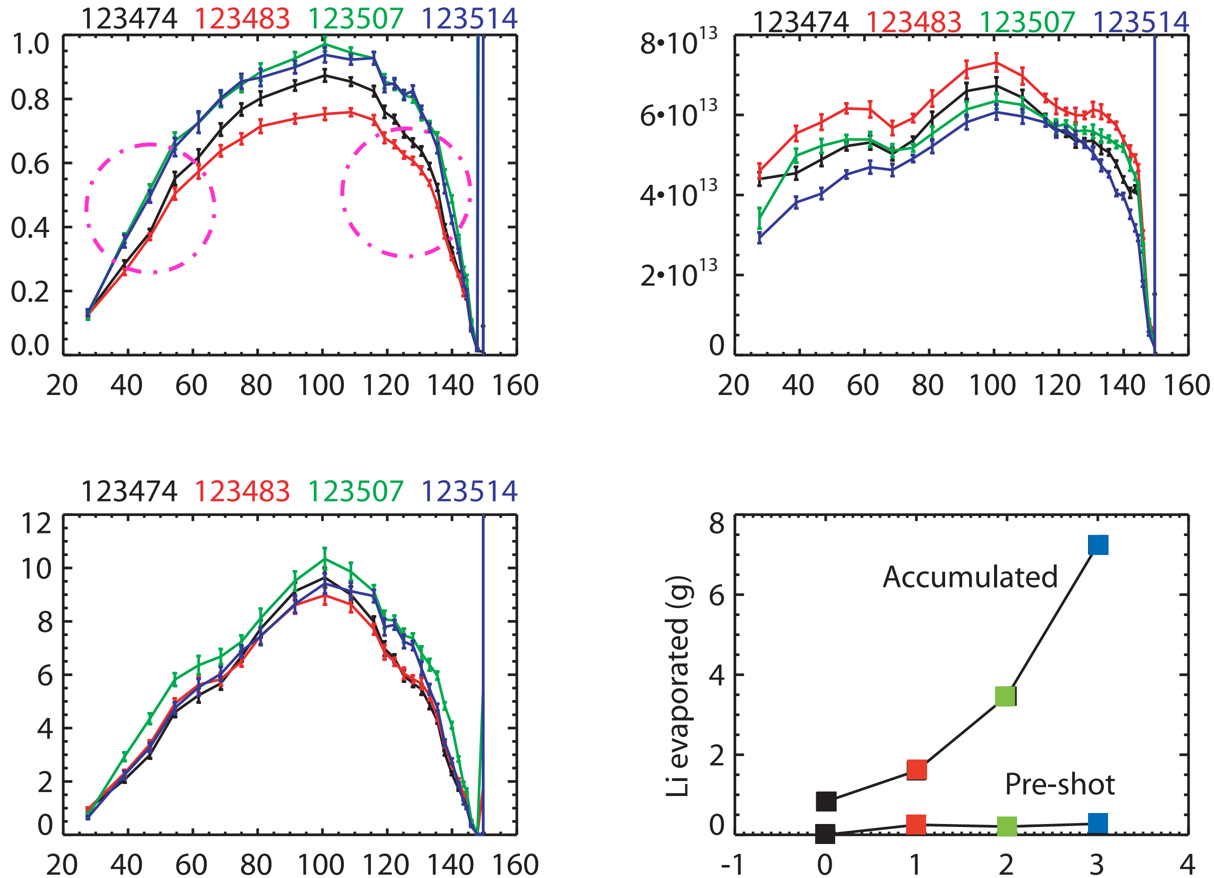
# We/Wtot vs. Lithiumization
## Pre-shot and accumulated Li




- An increase of the ratio We/Wmhd occurs for the Li evaporation scan data set

# Shot Averaged Profile Effects Observed
## *Dedicated Li evaporation scan*




A broadening of $T_e(R)$ is seen for larger amount of evaporated lithium

# Early Times $n_e l$ *vs.* Li Evaporation
## *Comparative numbers*

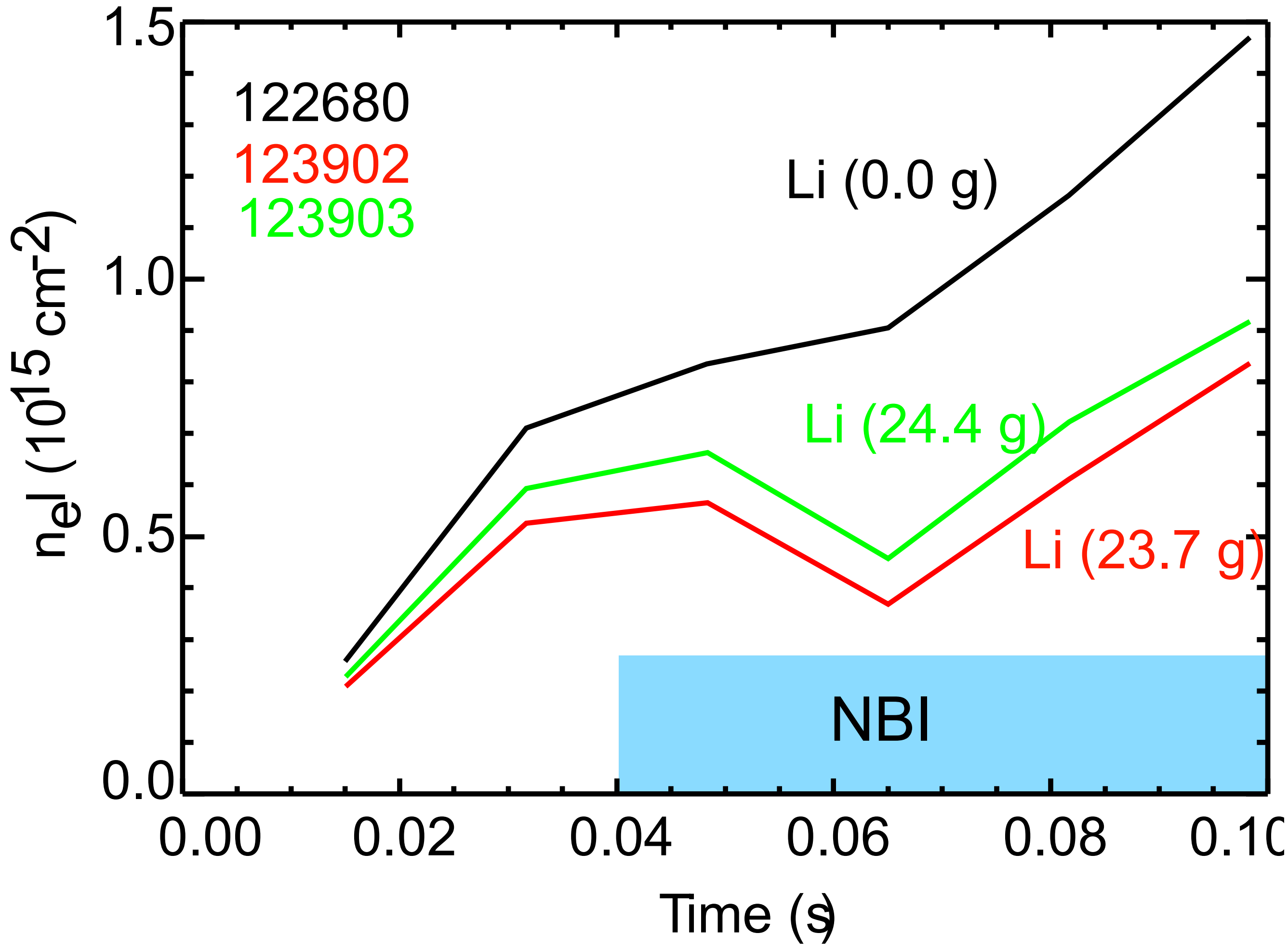
NSTX

**$I_p$ = 0.8MA, TF= 0.45 T, NBI @4MW**

| | Pre-shot Li | Accum. Li | Nel @0.1 s |
|---|---|---|---|
| SHOT # | (g) | (g) | ($10^{15}$ $cm^{-2}$) |
| 122680 | 0.0 | 0.0 | 1.47 |
| 123902 | 0.58 | 23.72 | 0.84 |
| 123903 | 0.64 | 24.36 | 0.92 |

# Early Times $n_e l$ *vs.* Li Evaporation
## *Lower pre-NBI density with Li coating*

NSTX



# MPTS Upgrades
## *Polarizer and in-situ window Calibration*

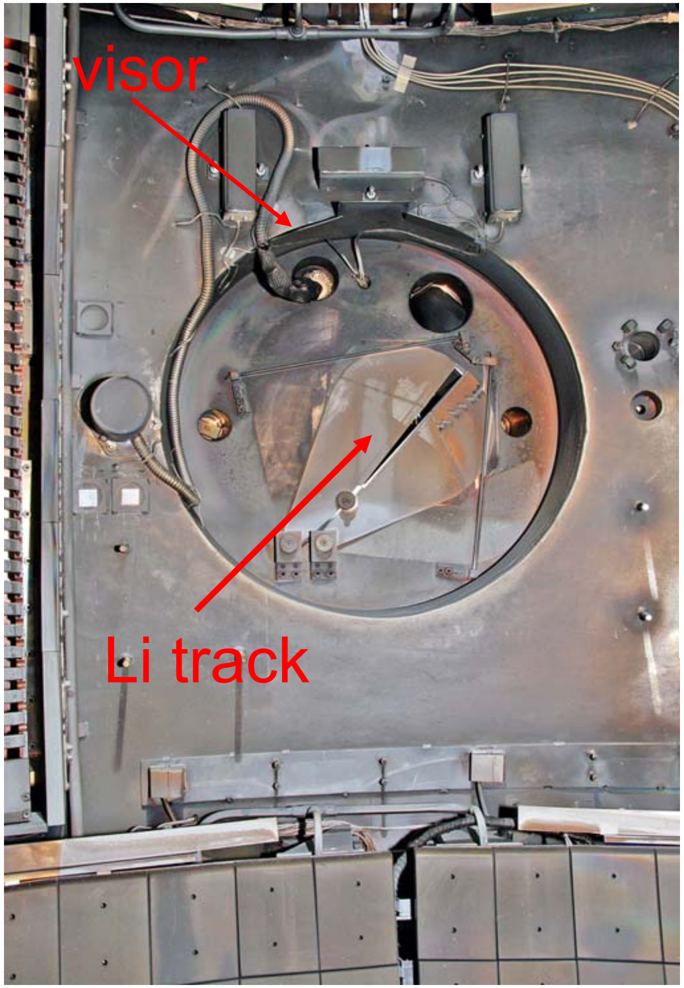
NSTX

- A polarizer has been installed on the viewing optics in order to reduce plasma radiation
  - Metallic accumulation, observed during last experimental campaign, generated high plasma radiation often saturating the MPTS detection system
- An in-situ retractable viewing optics illumination system is being installed to permit spectrally resolved measurement of the window transmission under vacuum condition
  - Window coating was unusually large last year with part of the optics losing around 45% transmission

# Viewing Window Protection Measures

NSTX

- The window shutter assembly comprises 2 blades:
  - S217 and S218
  - Slightly open because of air drive shutdown
- Visor installed at top of port
  - Liter in line of sight with MPTS window
- Lithium evaporation track from previous year visible at window center

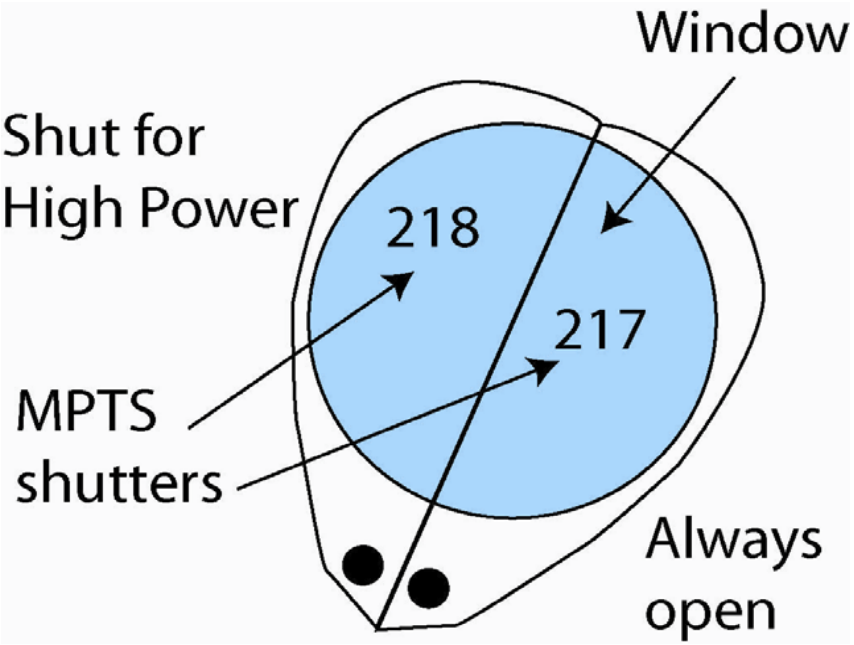



Lane Roquemore

# Nevertheless Strong Window Coating Observed
## *Area Exposed during High Power Most Affected*



- Two shutters protect the viewing window
  - S217 is always open during plasma operation
  - S218 is shut during high power discharge
- Coating occurred mostly in the S217 area
  - Coating appears consistent with plasma operation rather than Liter evaporation



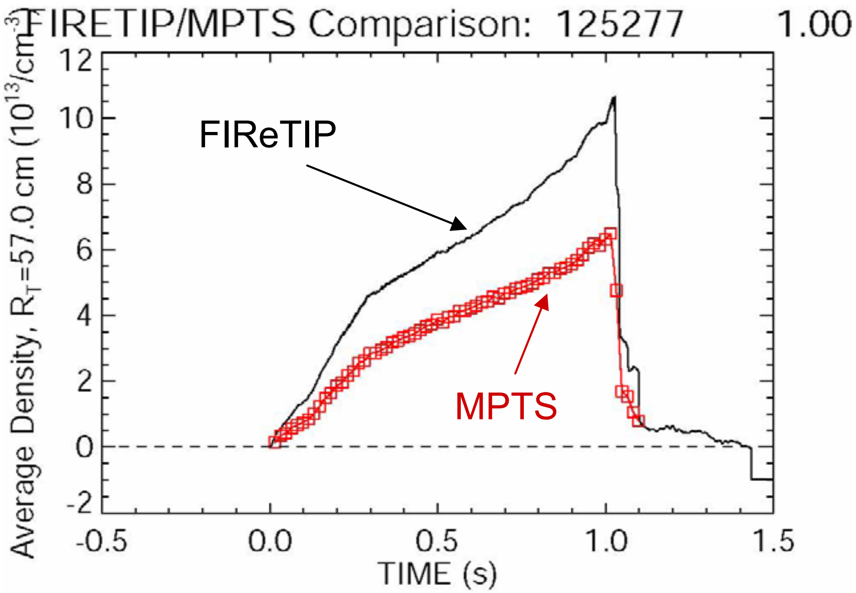
# Unusually Large Window Coating Observed

- Window coating was unusually large this year, with a section of the window losing 45% transmission
- Coating is not uniform over the window area
  - Consistent with exposure during plasma operation
- End-of-run transmission loss was around 5% in the past

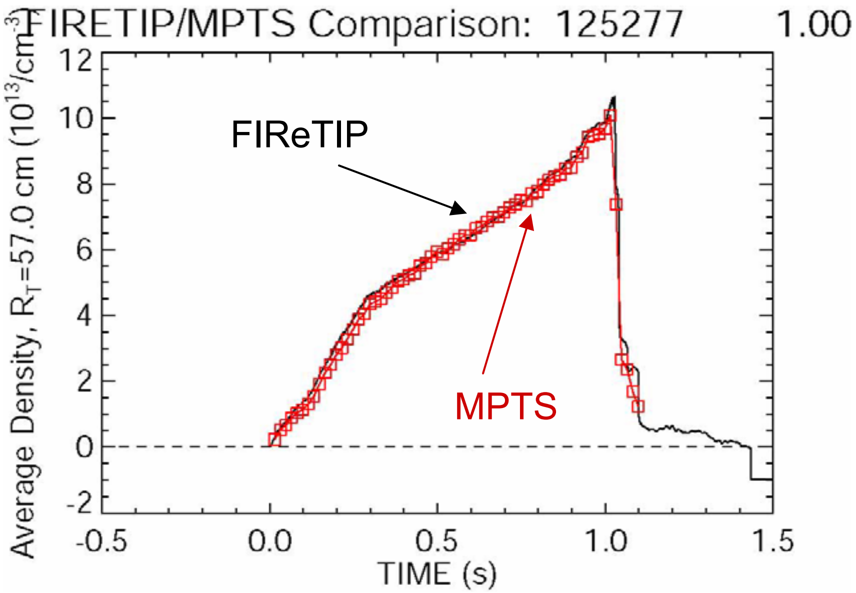
Photograph of the MPTS viewing window after the end of the 2007 run campaign

# Comparison to Laser Interferometer $n_e l$ Consistent with MPTS Window Transmission Loss

Original Analysis




Window Correction Applied



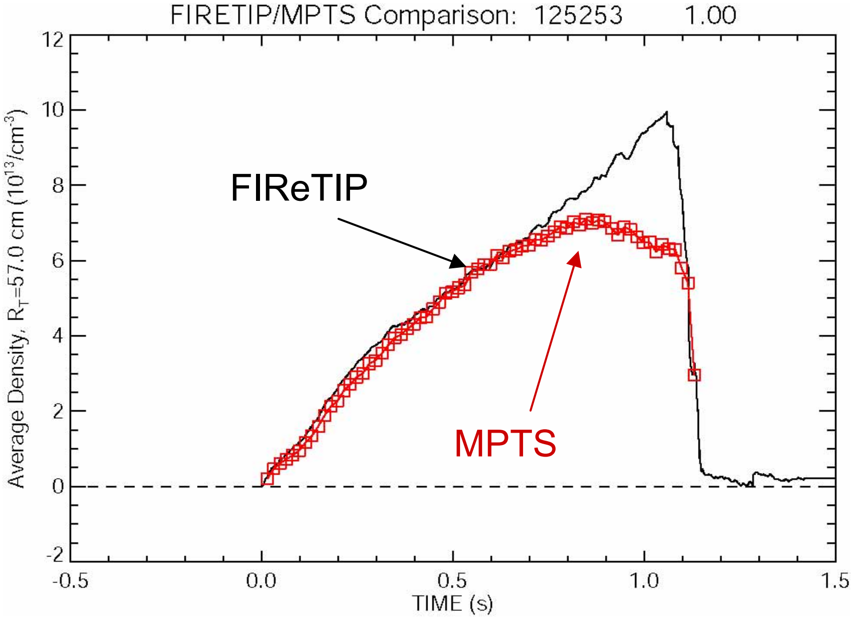

MPTS' *nel* normally agrees to within 5% with FIReTIP' – laser interferometer. Thomson scattering is sensitive to window coating, while laser interferometry is not. Correction to $n_e(R)$ was made based on end-of-run Rayleigh and Raman scattering calibrations and FIReTIP reference shots.

*The FIReTIP data was provided by K.C. Lee.*

# Detector Saturation Observed

- While MPTS' *nel* normally tracks well Firetip' – laser interferometer – such is not the case during detector saturation
- Consistent with saturation of avalanche photodiode
- Saturation caused by high plasma background radiation

Severely Saturated Data

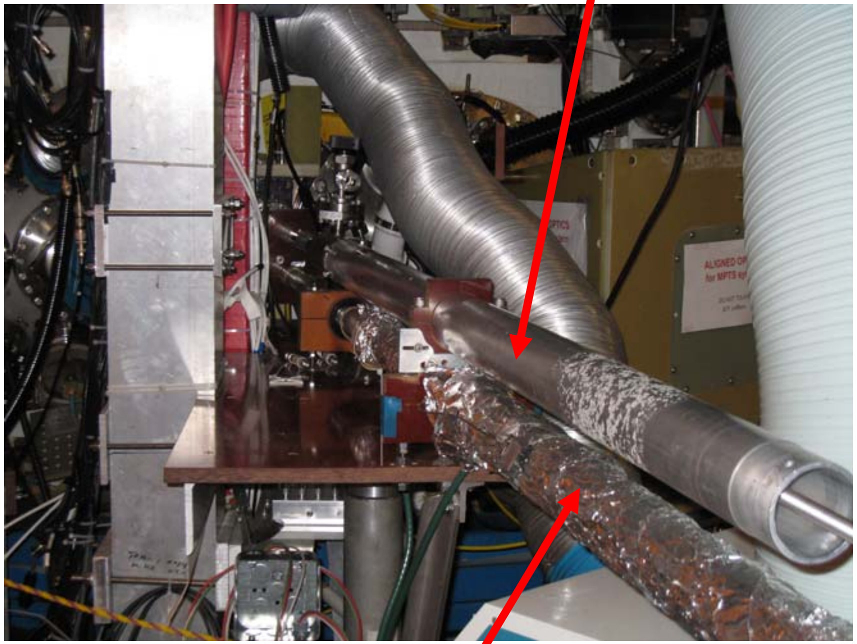


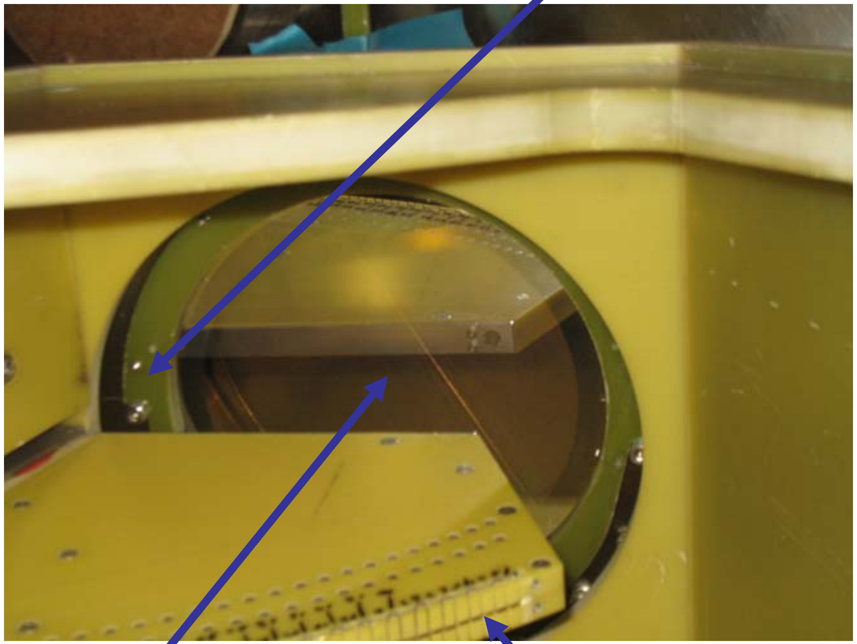
# NEW MPTS HARDWARE
## *Polarizer and in-situ window calibration*

NSTX

Illumination probe assembly

Polarizer in frame assembly





Laser flight tube

Window & closed shutters

Fiber bundle holder

# Conclusion

NSTX

- A broadening of $T_e(R)$ profile appears during carefully executed lithium evaporation, resulting in larger $W_e/W_{mhd}$
- These effects subside possibly because of lithium coating passivation
- There is some indication that Li coating reduces pre-NBI density
- Unusually strong window coating occurred during last experimental campaign
- Metallic accumulation caused large plasma background radiation conducive to detector saturation
- MPTS system is being upgraded with viewing polarizer and in-situ illumination system