Supported by

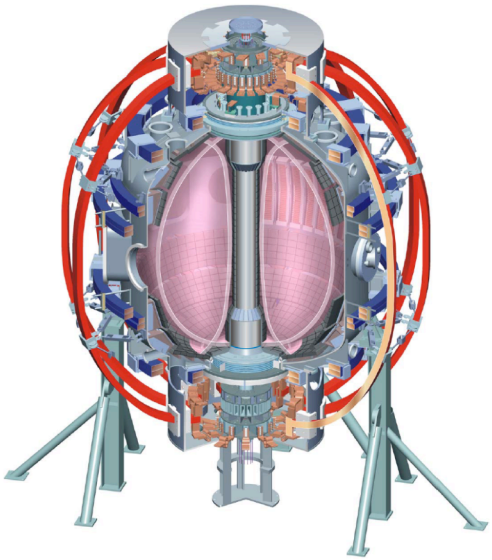
# Review of NSTX Lithium Experiments: XP-718 (Pellet Injection) and XP-719 (Surface Coatings)


H. W. Kugel and NSTX Team


NSTX Results Review
July 23-24, 2007
PPPL, Princeton, NJ


College W&M
Colorado Sch Mines
Columbia U
Comp-X
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
ORNL
PPPL
PSI
Princeton U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Maryland
U Rochester
U Washington
U Wisconsin

Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAERI
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
KBSI
KAIST
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

# Motivation


- NSTX research on lithium-coated plasma facing components is the latest step in the decade-long, DOE multi-institutional research program to develop lithium as a plasma-facing system that can withstand the high heat and neutron fluxes in a DT reactor.

- NSTX lithium research is also aimed towards sustaining the current non-inductively in H-mode plasmas which requires control of both wall recycling and impurity influxes.

- The 3 Phase NSTX 5-Year Lithium Plan for Particle Control and Power Handling is moving aggressively toward the 3rd Phase:

  *I. Lithium Pellet Injector (2005-2007)* ⇐ *07 results this talk*

  *II. Lithium Evaporator (2006-2007)* ⇐ *07 results this talk*

  *III. Liquid Lithium Divertor (Installation 2008)*

# XP-718: Lithium Pellet Injection Results

NSTX

- In FY05, LPI was done into LSN Helium conditioning shots, and the subsequent D LSN L-mode exhibited a strong density reduction effect lasting 1-2 shots, but *NO* effect seen without the Helium conditioning shots.

- In FY07, following a 3.4 mg Li pellet into an ohmic He plasma, the reference NBI D plasma exhibited a decrease in density and an increase in neutron rate. The following reference plasma reverted back to the pre-Li conditions.

- Single lithium pellets were injected directly into reference plasmas with one or both NBI sources notched for 50ms. Pellet arrival time varied

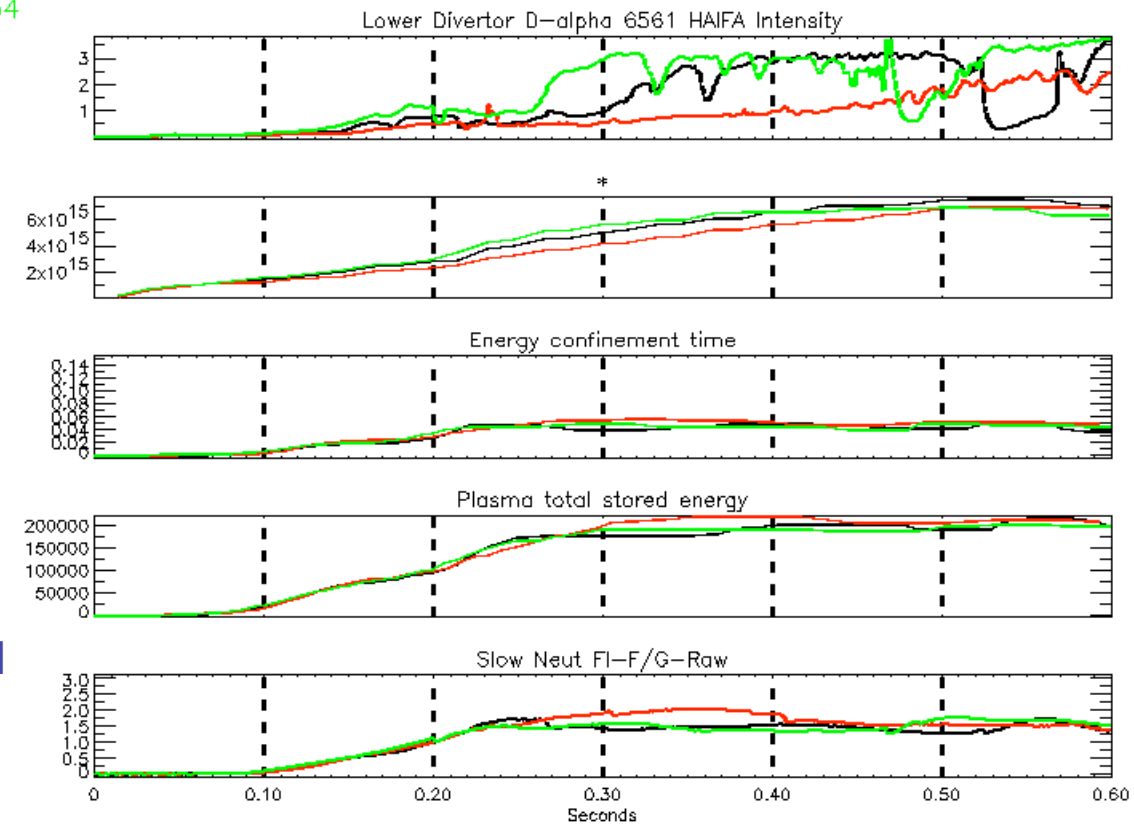
  - *Notching a single NBI source yielded small early decrease in $n_e$ and improvements in confinement and neutron rate during subsequent 2-source phase in this sequence before locked mode termination*

# After 3.4 mg LPI into Ohmic He Shot, $n_e$ changed on the 1st Ref D LSN H-Mode Shot and a Returned to Normal on the 2nd

NSTX

REFERENCE SHOT — Shots: 123148
1st SHOT AFTER 3.4 MG LPI — 123153
2nd SHOT AFTER 3.4 MG LPI — 123154

- 1st 2NBI D LSN reference plasma following a 3.4 mg Li pellet into an ohmic He plasma, exhibited:
  - decrease in Dα and $n_e$(25% @300ms)
  - increase in $\tau_e$, $W_E$, $S_n$
- The following D reference shot reverted to the pre-Li conditions.




- *This result is similar to FY06 LITER result which achieved H-mode $n_e$ decreases without He Discharge Conditioning*

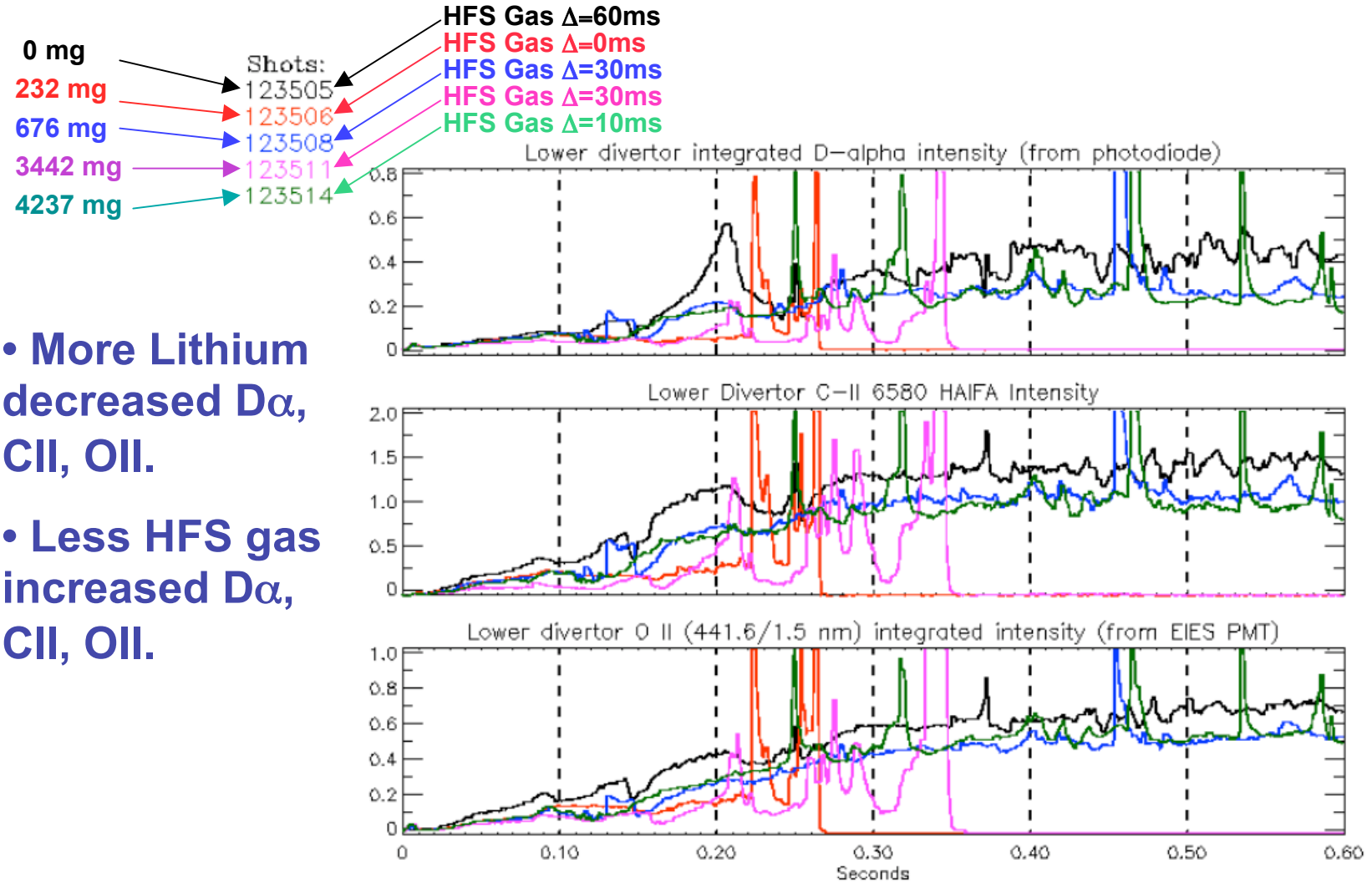
PPPL PRINCETON PLASMA PHYSICS LABORATORY

# Summary of LPI Results 2004-2007

| He Ω Conditioning Discharges | HeGDC Between Discharges | LPI Application | Reference Deuterium Discharge | Density Effect | Other Effects |
|---|---|---|---|---|---|
| NO | Yes | Directly into D Reference Discharges | CSL L-mode<br>LSN L-mode<br>DND L-mode | None | Impurity Reduction |
| 6-8 Conditioning Discharges | Yes | Into He Ω discharge of same shape | CSL L-mode<br>LSN L-mode | X3 decrease<br>X2 decrease @$5\times10^{12}$ $cm^{-3}$ | Lasted 2-3 shots |
| No | Yes | Into He Ω discharge of same shape | LSN H-mode | $n_e$ decreased 25%@$5\times10^{13}$ $cm^{-3}$ | Lasted 1 shot<br>Increase in $\tau_e$, SE, $S_n$ |
| No | Yes | Directly into NBI pwr notch | LSN L-mode | None | Penetration sensitive to NBI off time |
| No | Yes | Directly into NBI pwr notch | LSN H-mode | Small early $n_e$ decrease | Terminated by Locked Mode |

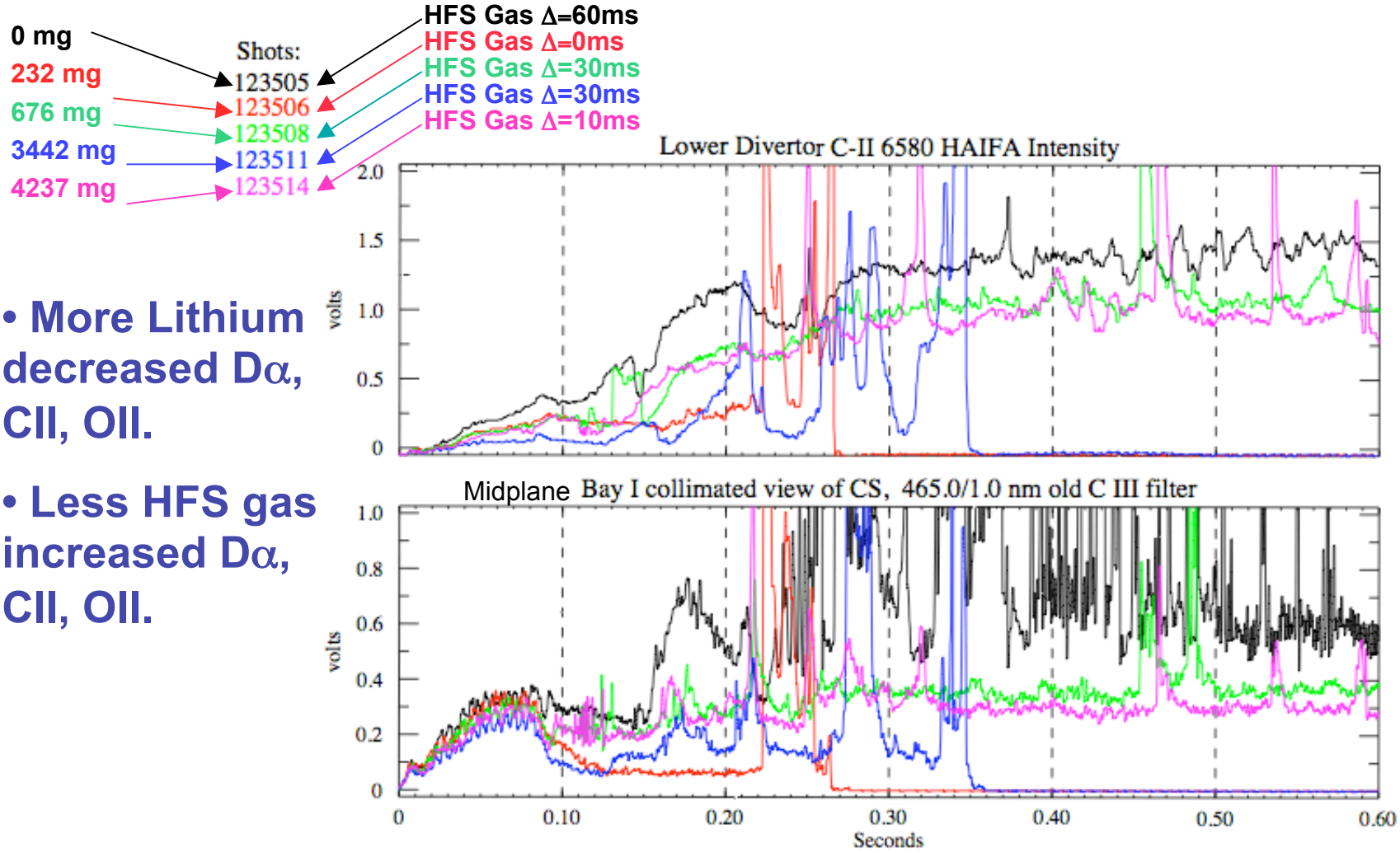
- **Surfaces *pre-coated with lithium* pumped diverted deuterium plasmas**
- **H-mode plasmas even without wall conditioning sensitive to lithium deposition**

# XP-719: Increasing Lithium Evaporation On NSTX PFCs Decreased Dα, C II, and O II Luminosity



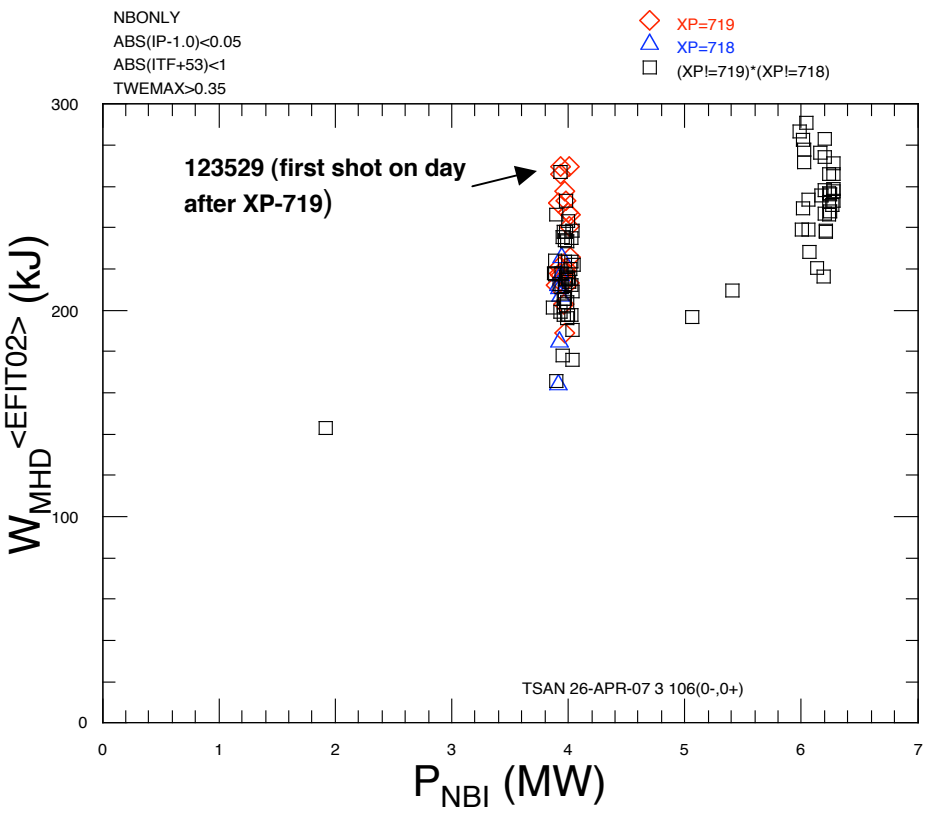

- More Lithium decreased Dα, CII, OII.
- Less HFS gas increased Dα, CII, OII.

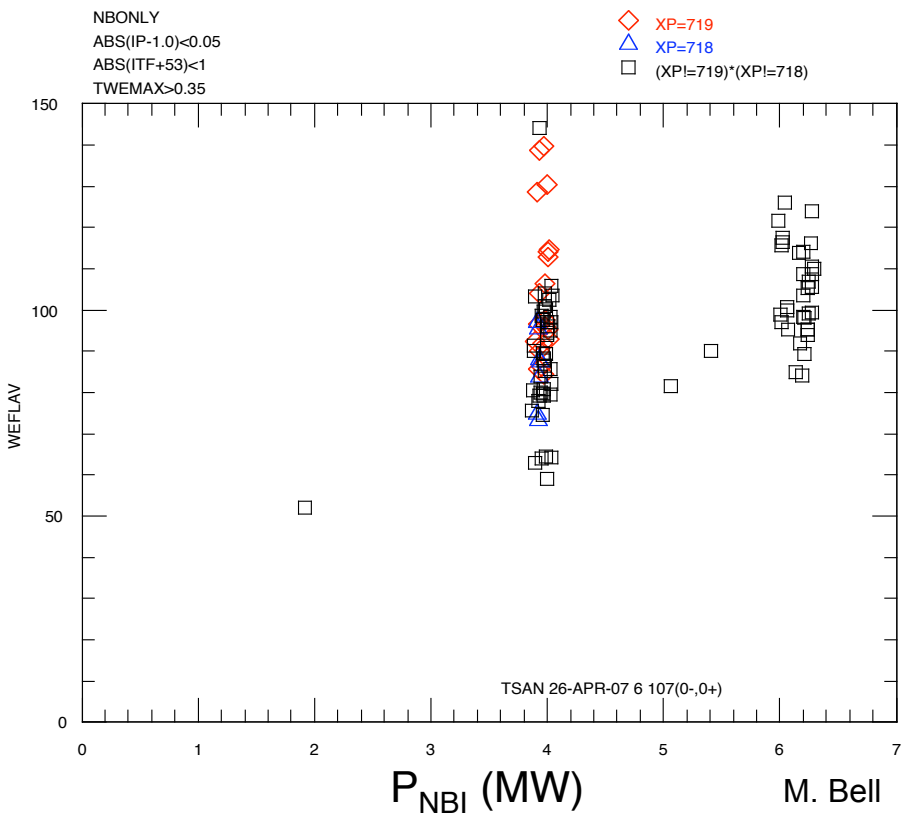
# C II Luminosity Decreased on Lower Divertor and on Midplane




- More Lithium decreased Dα, CII, OII.
- Less HFS gas increased Dα, CII, OII.

# Lithium Evaporation Effect on Stored Energy

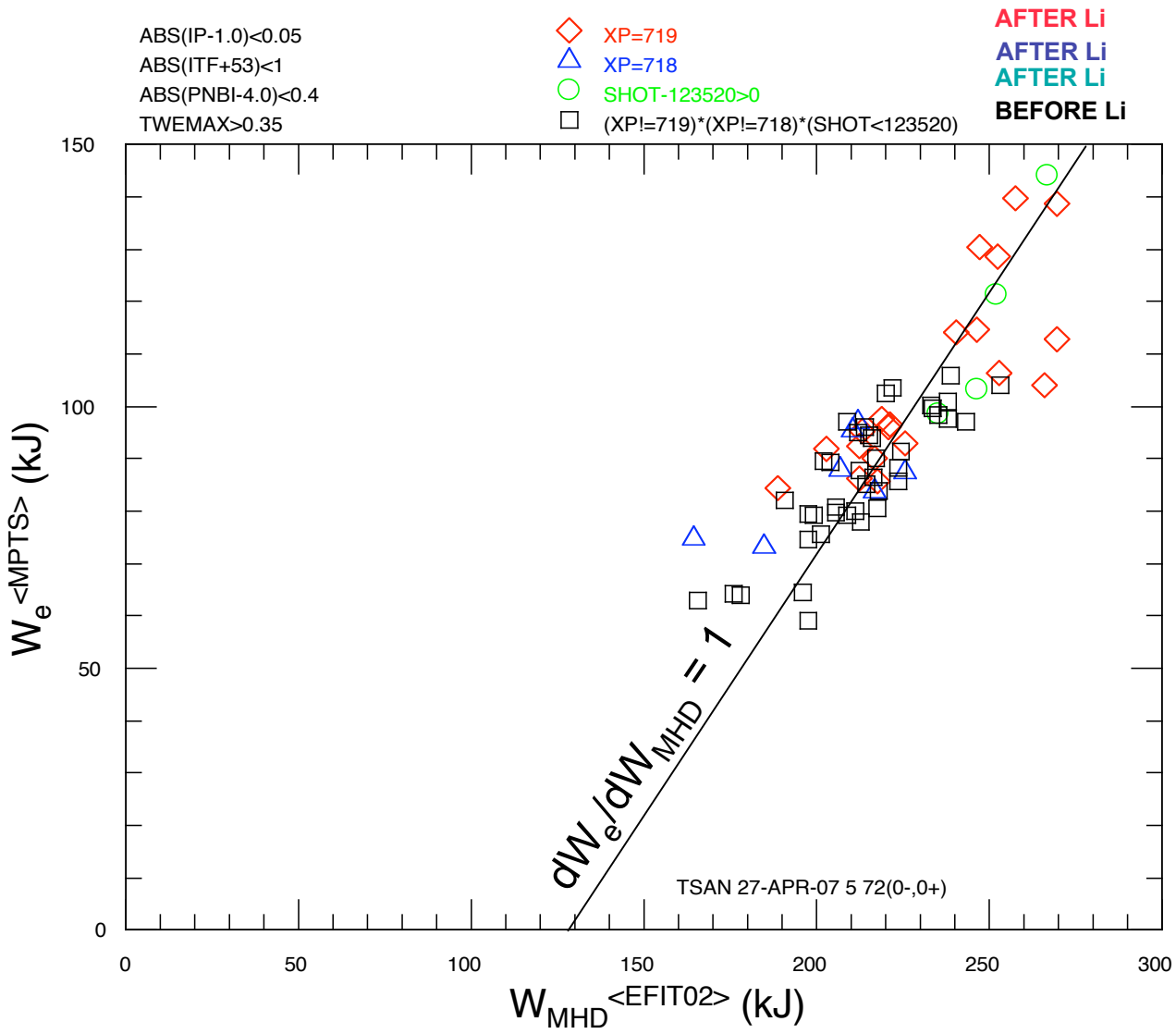



- Lithium Evaporation Increases Stored Energy at Constant NB Power

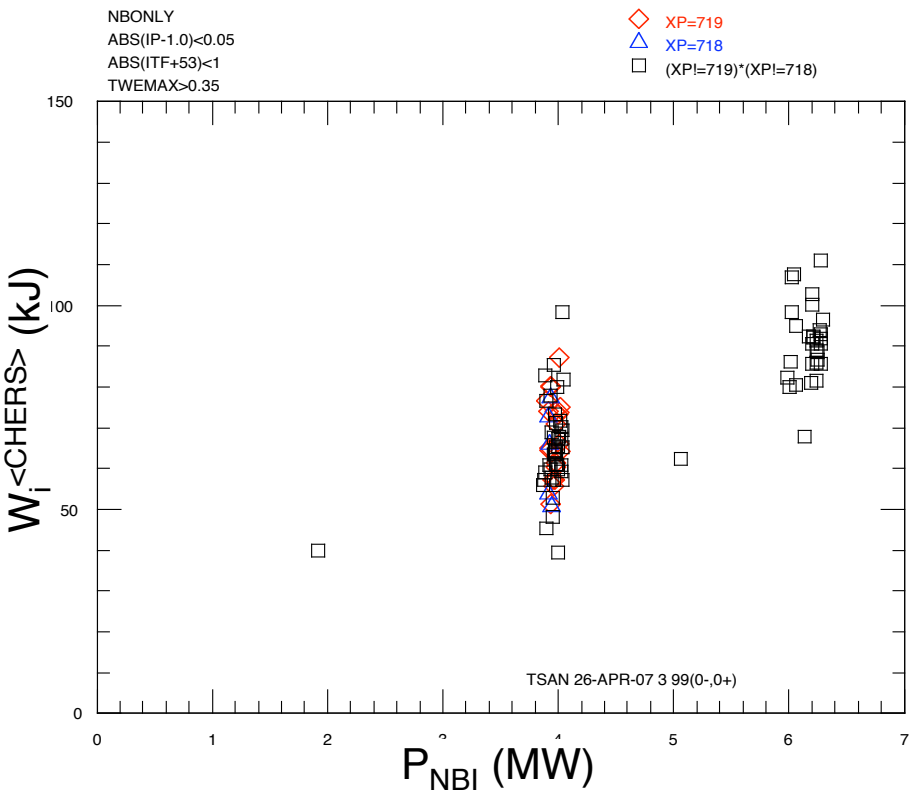
- Lithium Evaporation Significantly Increases Electron Stored Energy at Constant NB Power

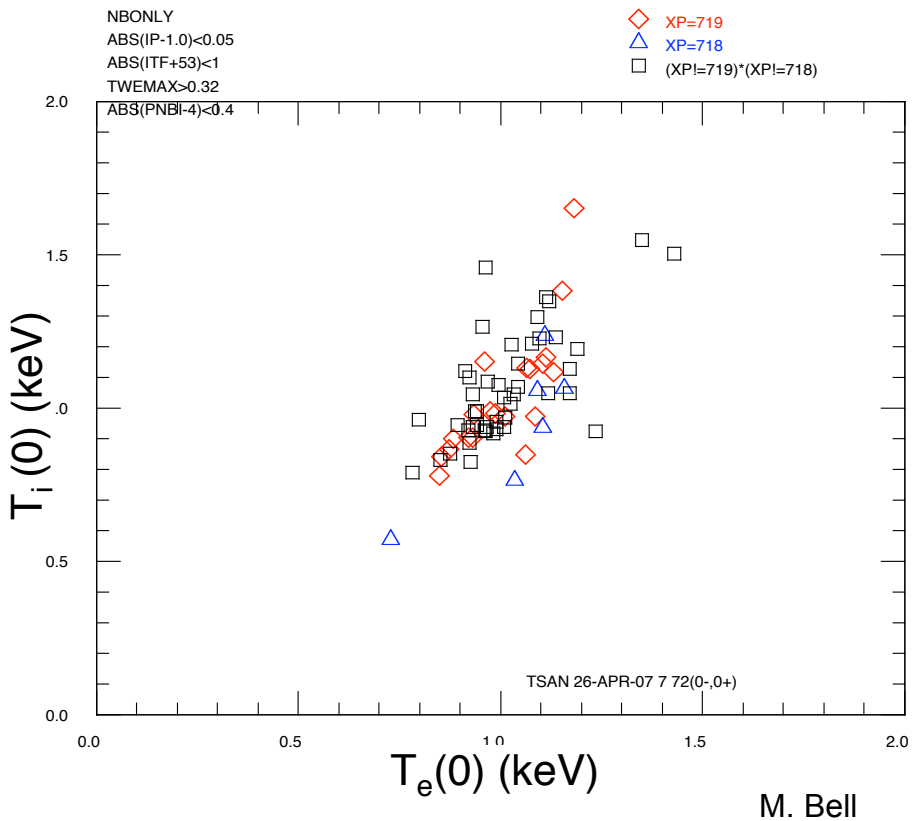
# Effect on $W_{MHD}$ Is Dominantly Through Increase in $W_e$




M. Bell

# Lithium Evaporation Effect on Ions

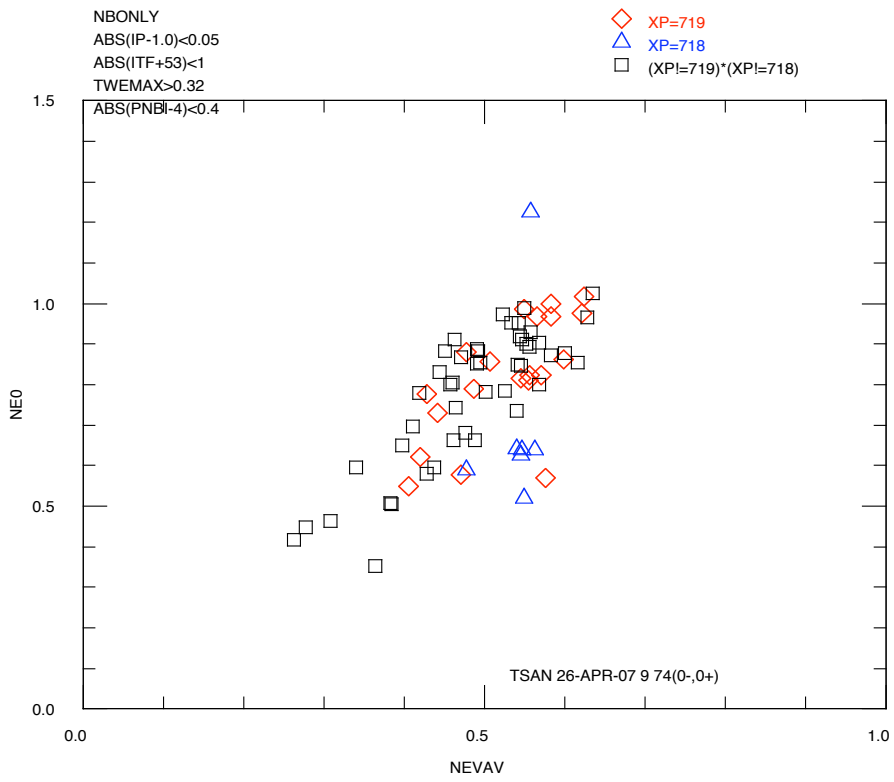


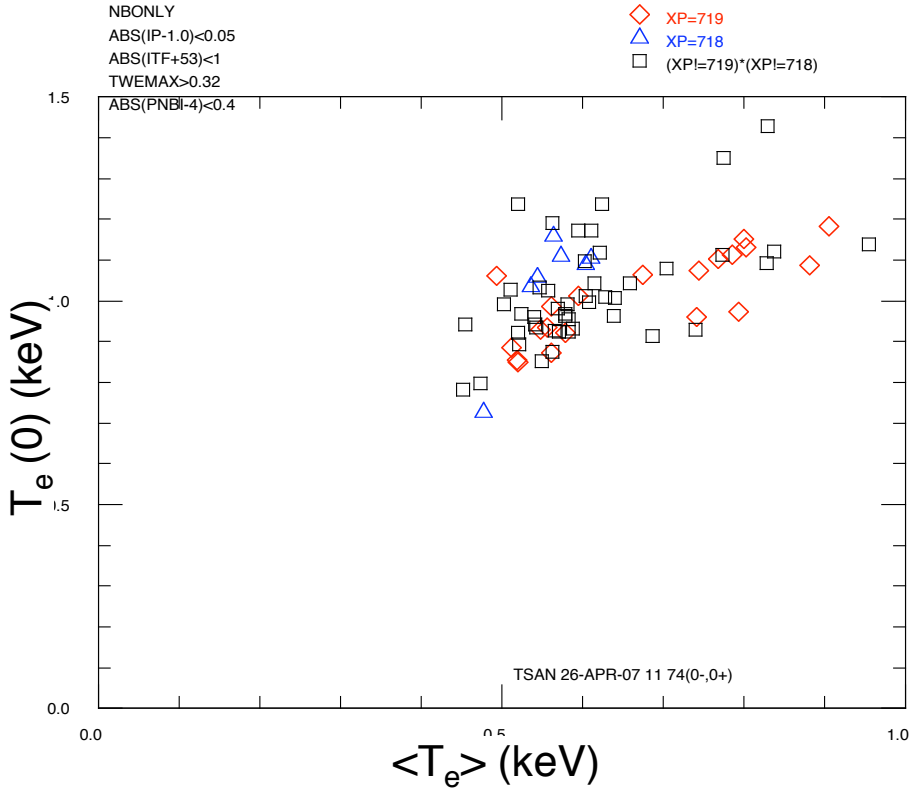




M. Bell

- Lithium Evaporation Affects Ion Stored Energy Only Slightly
- On Average, Central Temperatures Are Not Increased by Lithium

- **Density Peakedness Is Not Affected by Lithium**
- **Broadening of $T_e$ Profile Appears To Be Responsible for Improvements in $W_e$**

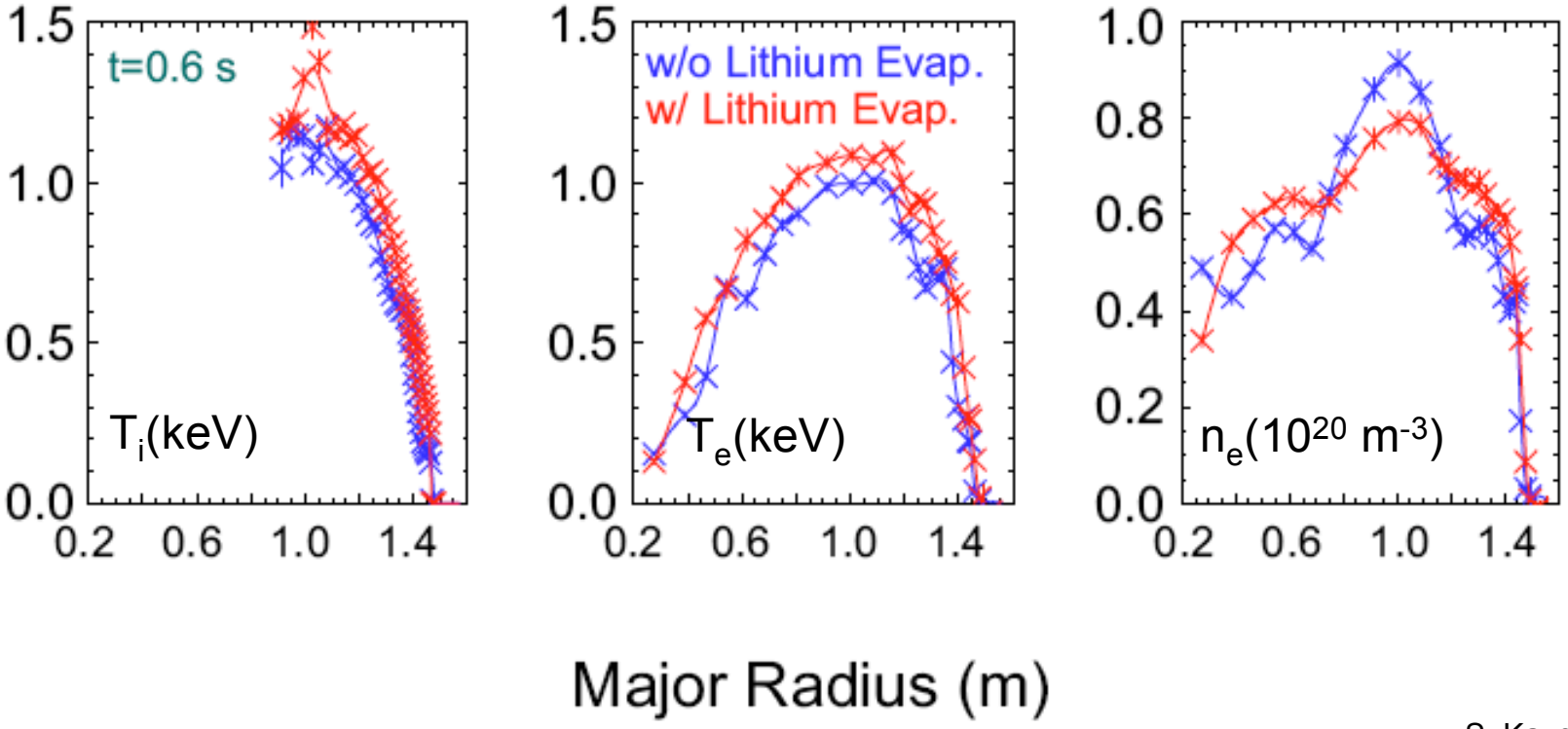



**M. Bell**

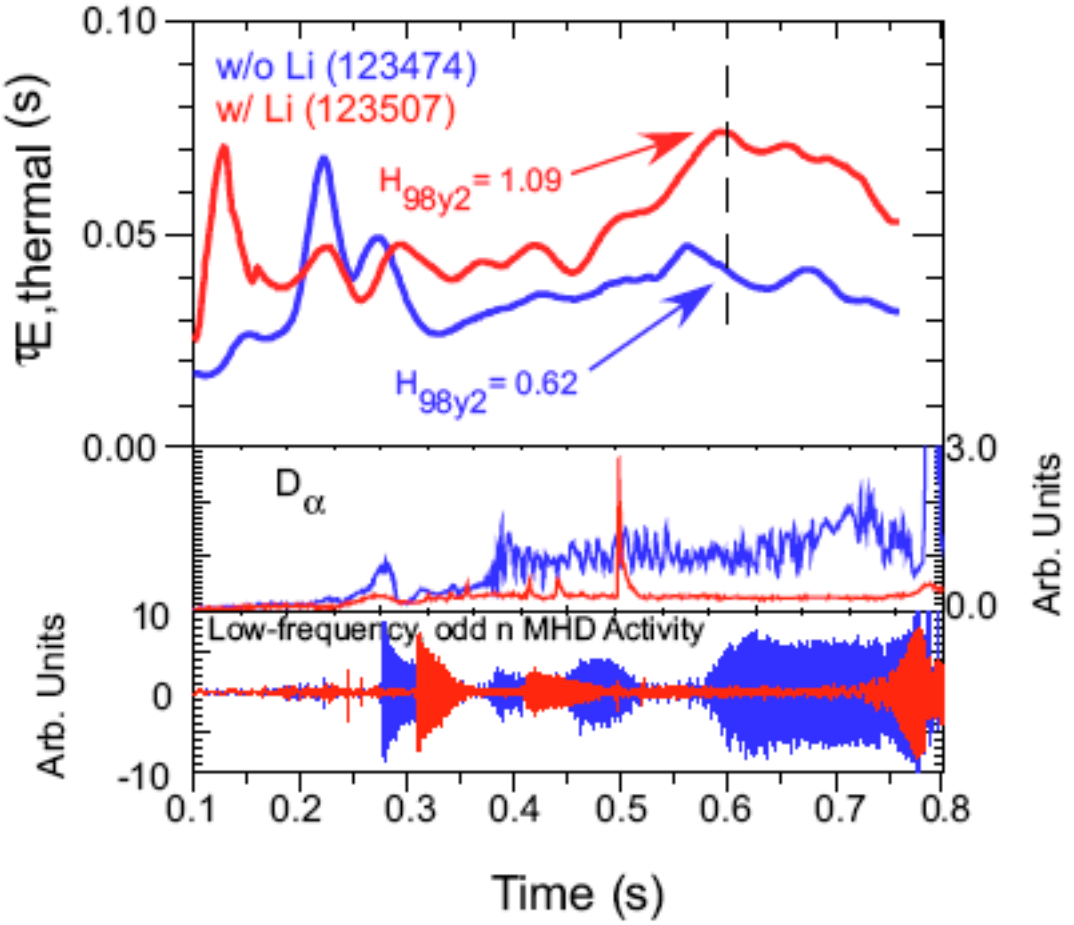
# TRANSP Analysis Finds Performance Enhancement Obtained in H-mode Discharges with Lithium

w/o Lithium 123474
w/ Lithium 123507




S. Kaye

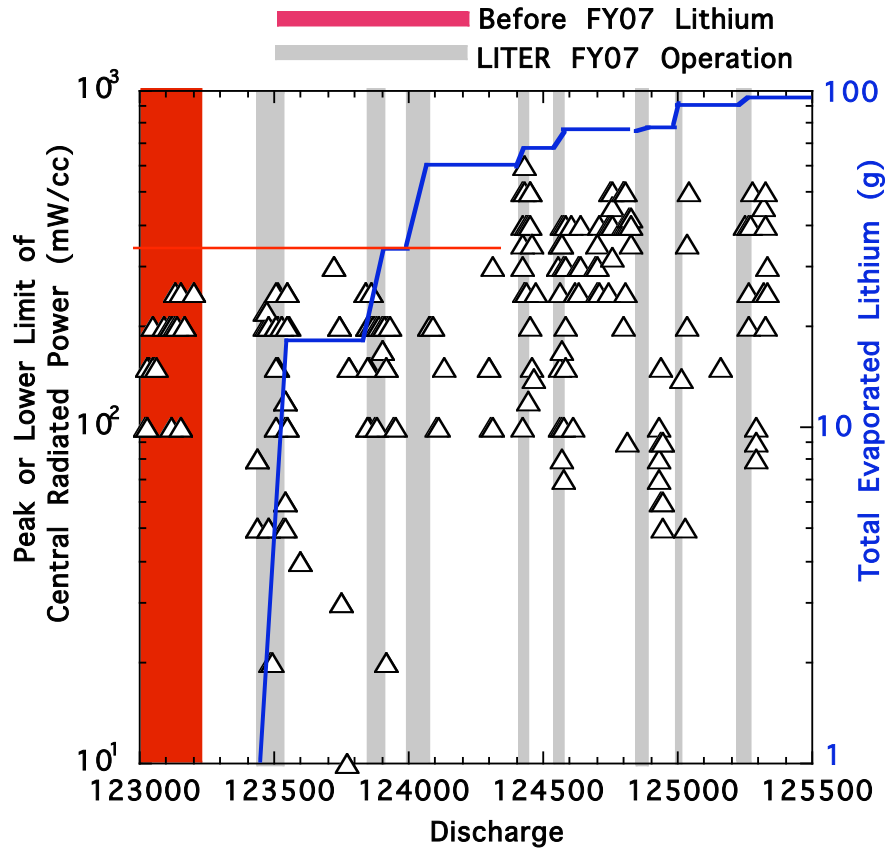
# TRANSP Analysis: $H_{NSTX}$ = 0.62 →1.09 post Li




S. Kaye

- *Typical $H_{NSTX}$ Enhancements ~1.3-1.8*

# Discharges With High Central Radiated Power Occurred More Frequently and With Increasing Intensely with Shot Number




- L-mode
  - low Prad
- H-mode Short
  - low Prad
- H-mode ELMy
  - low Prad
- H-mode ELM Free
  - high Prad

**Issue: Is the behavior of the central radiated power due to**

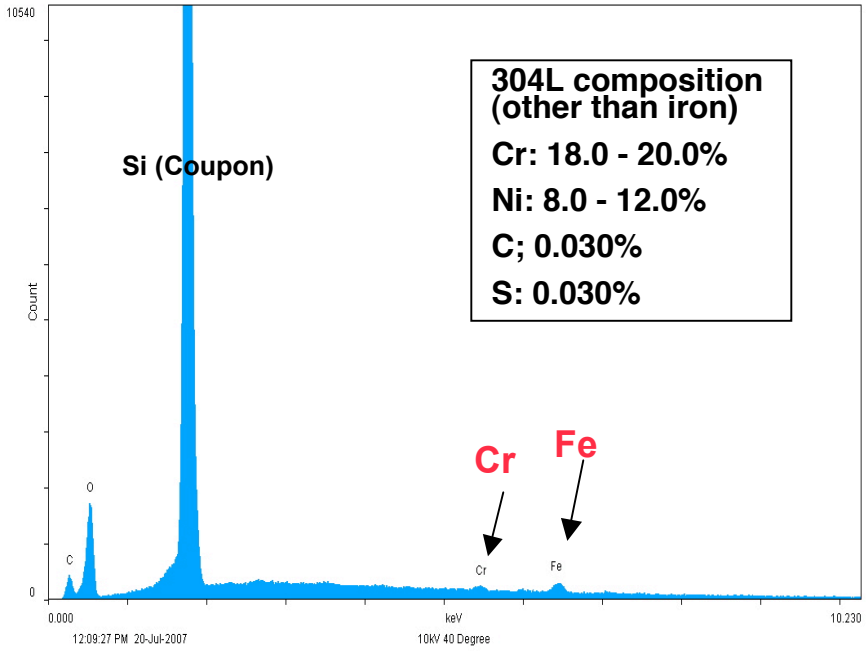
- improving fuel and impurity confinement?
- machine operations, LITER operation?

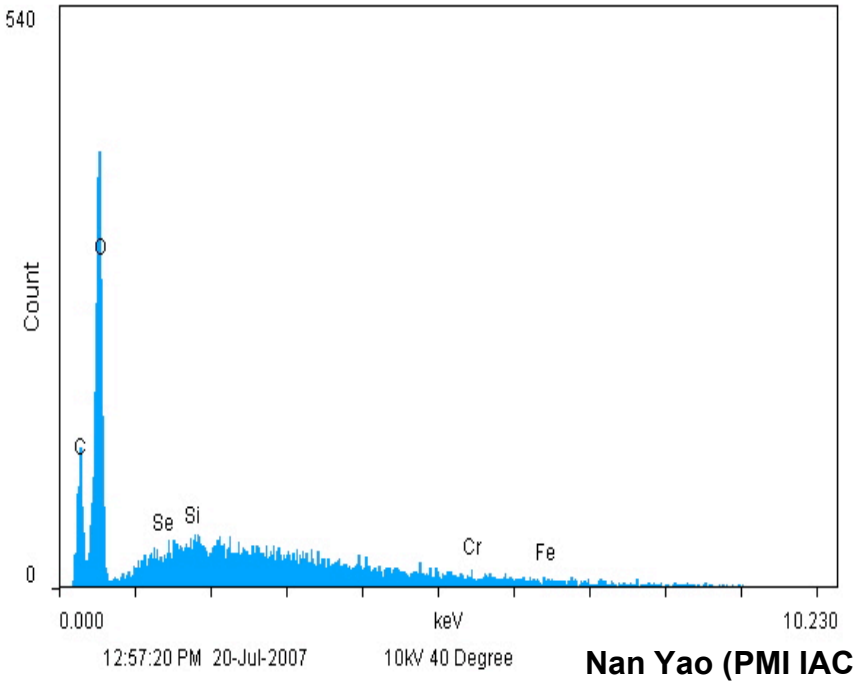
# • Bay I-J Midplane Coupon Exhibits Fe and Cr Deposition
# • Thick Flake Sample at LITER Output Shows No Metals

NSTX

• The K-Xray spectrum of the Bay I-J Midplane Silicon Coupon exhibited C, O, Si (coupon) and small amounts of Cr and Fe. No Ti Ni, or Mo were observed.

• Bay F Upper Divertor thick flake obtained from the local lithium HeGDC buildup near the output of LITER exhibited only C, O, and no Si (coupon) and no Cr, Fe, or other metals.




Nan Yao (PMI IAC)

• This result is consist with the deposition of typical plasma impurities on the Midplane Coupon and no metal output from LITER.

PPPL PRINCETON PLASMA PHYSICS LABORATORY

# Summary and Conclusions

- Although understanding the affect of evaporated lithium on recycling in NSTX needs further work, there is a clear and reproducible effect on
  - *decreases* in oxygen impurities, plasma density, inductive flux consumption, and ELM frequency (including their complete suppression in H-mode plasmas)
  - *increases* in electron temperature, ion temperature, energy confinement, and DD neutron rate.

- Additional phenomena and observations, such as the below need additional work:
  - the continued density rise,
  - the duration of the lithium coatings,
  - spatial distribution of the lithium coatings,
  - increases in core metal impurity radiation,
  - Helium retention following HeGDC and HeGDC requirements,
  - diagnostic window depositions and operational issues.