Preliminary Results

from

XP-718: Investigate Effect of Li Pellets on H-mode Performance

and

XP-719: Investigate Effect of Lithium-coated Divertor on Plasma Performance with LITER-1d

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NSTX Physics Meeting
PPPL, April 30, 2007

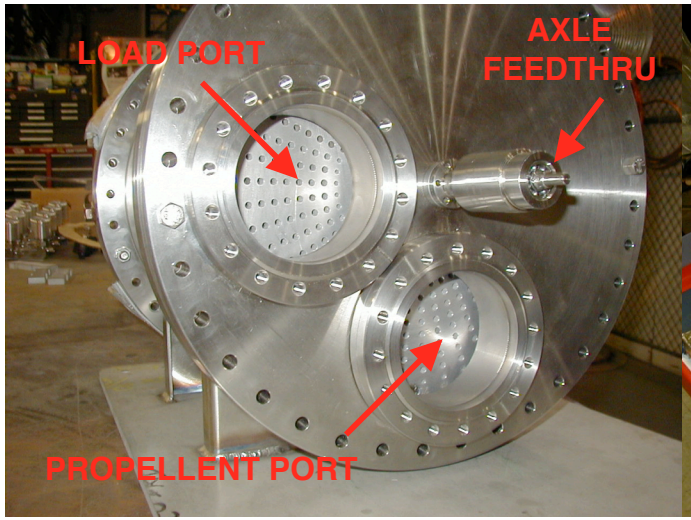
XP-718: Investigate Effect of Li Pellets on H-mode Performance

- ***Previous work***
- FY04 LPI into LSN D NBI tested only L-mode/intermittent H-mode conditions.
- FY05 LPI into He conditioning shots tested only L-mode at low density D LSN.

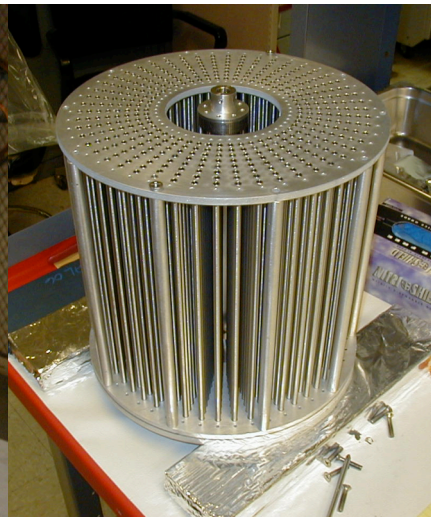
- ***The Experimental questions investigated by this XP***
- How will Li Pellet Injection into LSN He discharges affect subsequent D LSN H-Mode discharges?
- How will direct injection into ohmic phase of D LSN H-Mode discharges affect subsequent NBI phase?

- ***XP Overview***
- 10 Li pellets, 3.4 mg each were injected into either ohmic He LSN plasmas for lithium deposition, or directly into NBI D LSN plasmas run under similar conditions with or without 50ms NB notches for injection.
  - I_p = 1MA, B_T = 0.45T, P_{NB} = 4MW (2 NB sources)
  - No He Conditioning Discharges applied

LPI Reliably Injected Li Pellets for XP-718



OUTBOARD VIEW



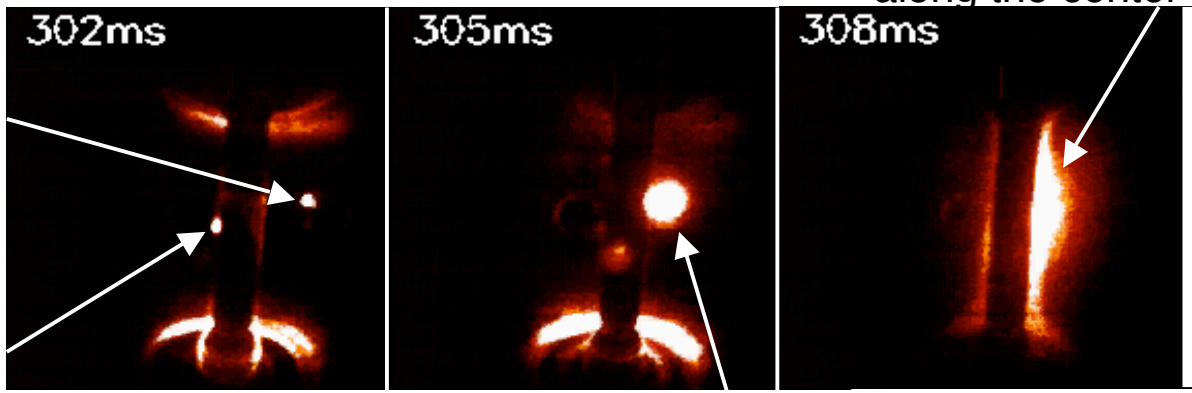
400 BARREL TURRET

- **Sabot (cartridge) style injector for injecting solid pellets (≤ 5 mg) & powder (micro-pellets)**
- **50 – 200 m/s radial injection**
- **1 – 8 pellets per shot capacity**
- **400 pellet capacity**

Lithium vapor spreading along the center-stack

FY04 Lithium pellet moving through ohmic He plasma after entering boundary

In-board gas injector

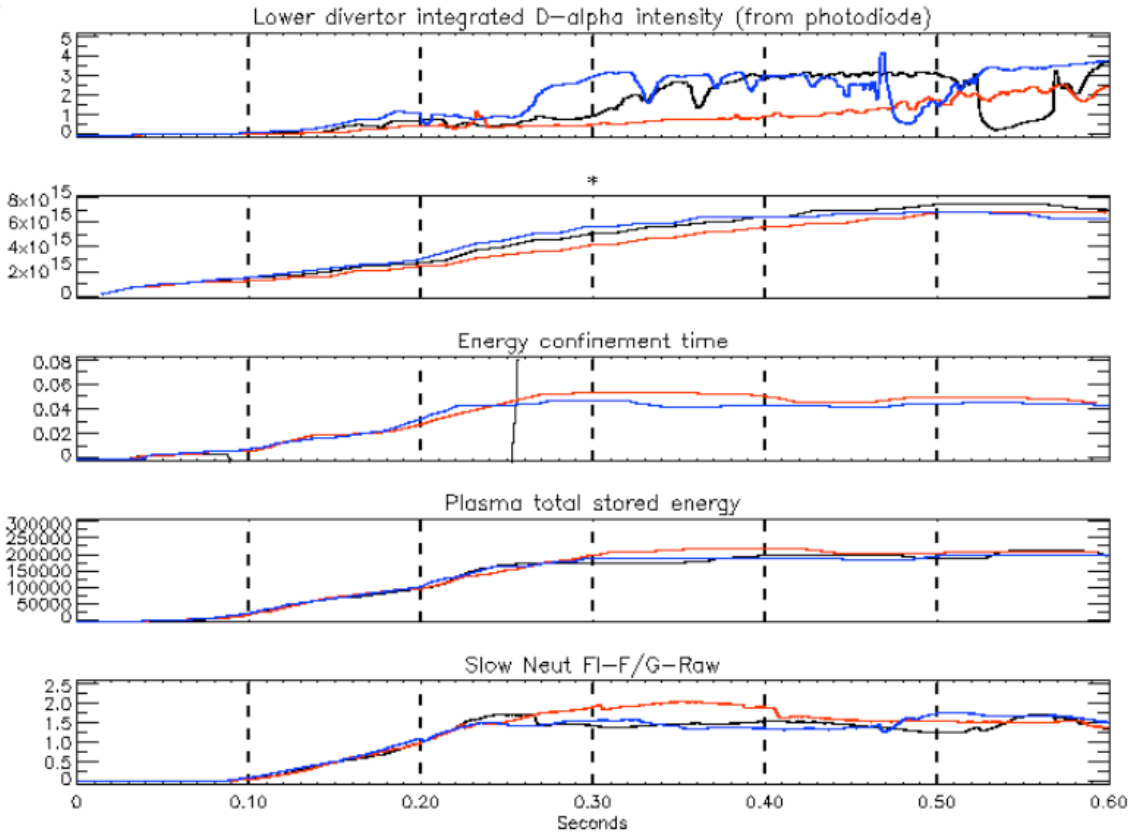


Li I Plasma-TV

Pellet plasmoid approaches center-stack

Part-I: After 1 Pellet, Measured a Change in n_e on First Shot and Return to Normal on Second

- 1st 2NBI D LSN reference plasma following a 3.4 mg Li pellet into an ohmic He plasma, exhibited:
  - decreased Dα (17% @350ms, 8%@550ms)
  - increase in τ_e, W_E, S_n
- The following D reference shot reverted to the pre-Li conditions.



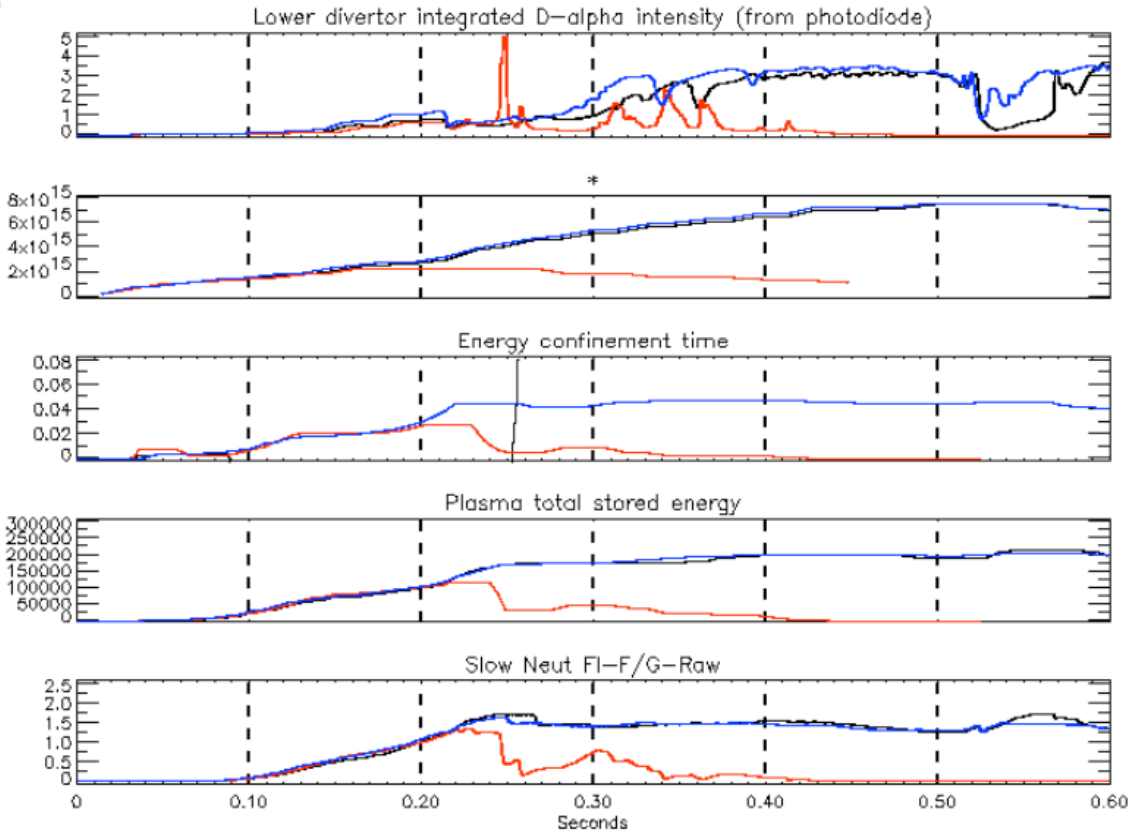
- ***This result is similar to FY06 LITER result which achieved H-mode n_e decreases without He Discharge Conditioning***

Part-II: After 4 Pellets, Measured a Large Change in n_e and a Collapse on First Shot and Return to Normal on Second

REFERENCE SHOT → Shots: 123148

1ST SHOT AFTER 3.4 MG LPI → 123159

2nd SHOT AFTER 3.4 MG LPI → 123160



- 1st 2NBI D LSN reference plasma following 4 LPI 3.4mg L pellets into 4 ohmic He plasmas (13.6g)

  - exhibited early decreased Dα and n_e decay (locked mode?)

- The following D reference shot reverted back to the pre-Li conditions.

- ***More Li may have changed start-up density and caused lock mode?***

Part-III: LPI Into NBI Notch of D LSN Discharge

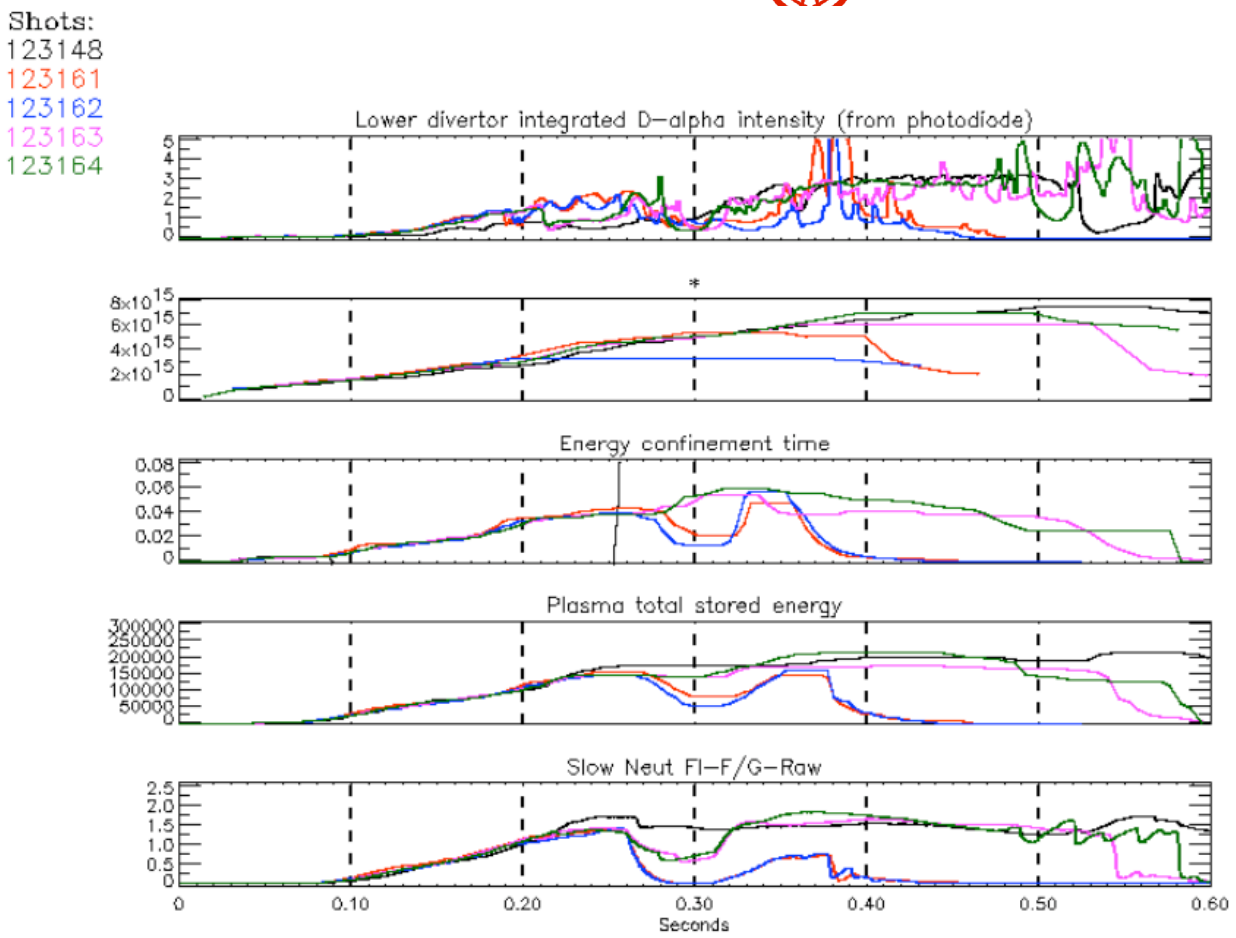
123148 - No Notch

123161- NBI-A&C
Notched 260-310ms
LPI ETA 300ms

123162- NBI-A&C
Notched 260-310ms
LPI ETA 290ms

123163- NBI-C
Notched 260-310ms
NBI-A No Notch
LPI ETA 290ms

123164- NBI-C
Notched 260-310ms
NBI-A No Notch
LPI ETA 280ms



• ***Adjusting LPI ETA and NBI heating in the notch varied profiles and yielded highest confinement and neutron yields in this sequence.***

XP-718 Summary and Conclusions

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

- After lithium pellet injection into each of 4 ohmic He plasmas, the following reference NBI plasma progressed until the neutron rate started to rise, and then deteriorated to a shortened discharge, possibly as a result of exceeding an MHD limit due to improving performance.

- Single lithium pellets were injected directly into reference plasmas with one or both NBI sources notched for 50ms. The pellet arrival time was decreased from 40, to 30, to 20 ms from the NBI turn-off time.

    - *Notching a single source yielded highest confinement and neutron rate during subsequent 2-source phase in this sequence*

XP-719: Investigate Effect of Lithium-coated Divertor on Plasma Performance with LITER-1d

Experimental Plan

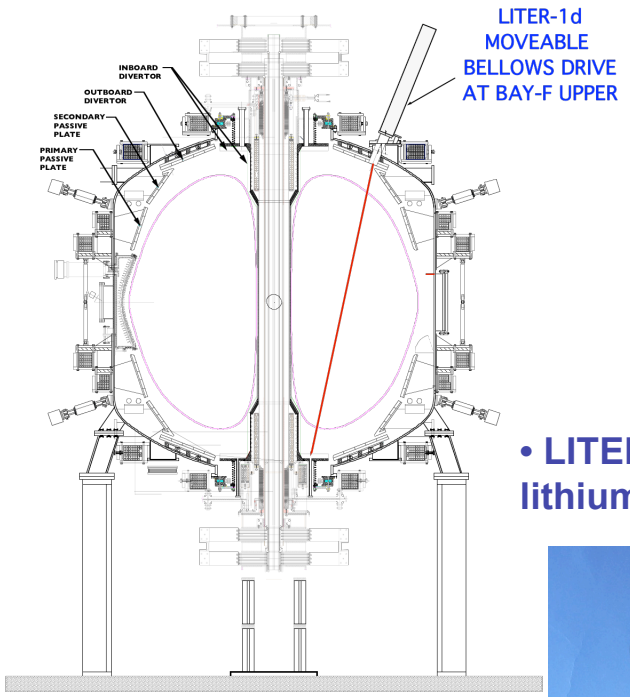
- Investigate the effect of a lithium-coated divertor on plasma performance using the LITER-1d evaporator.

- Start by evaporating small amounts of lithium comparable to pellets between and during shots, and then proceed to larger amounts of lithium until an effect on the spontaneous density rise is observed.

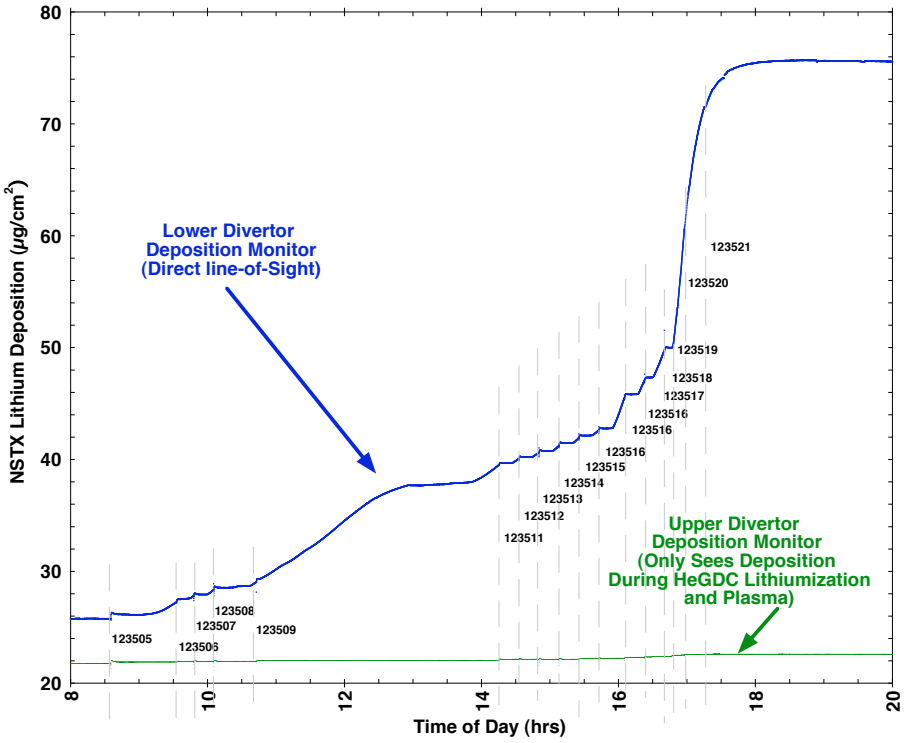
- Subsequent experimental steps would focus on optimizing the effectiveness of the lithium deposition in controlling the density for longer times.

LITER LIThium EvaporatoR Reliably Evaporated Lithium on NSTX PFC's

- LITER-1d Aimed at Lower Inner Divertor

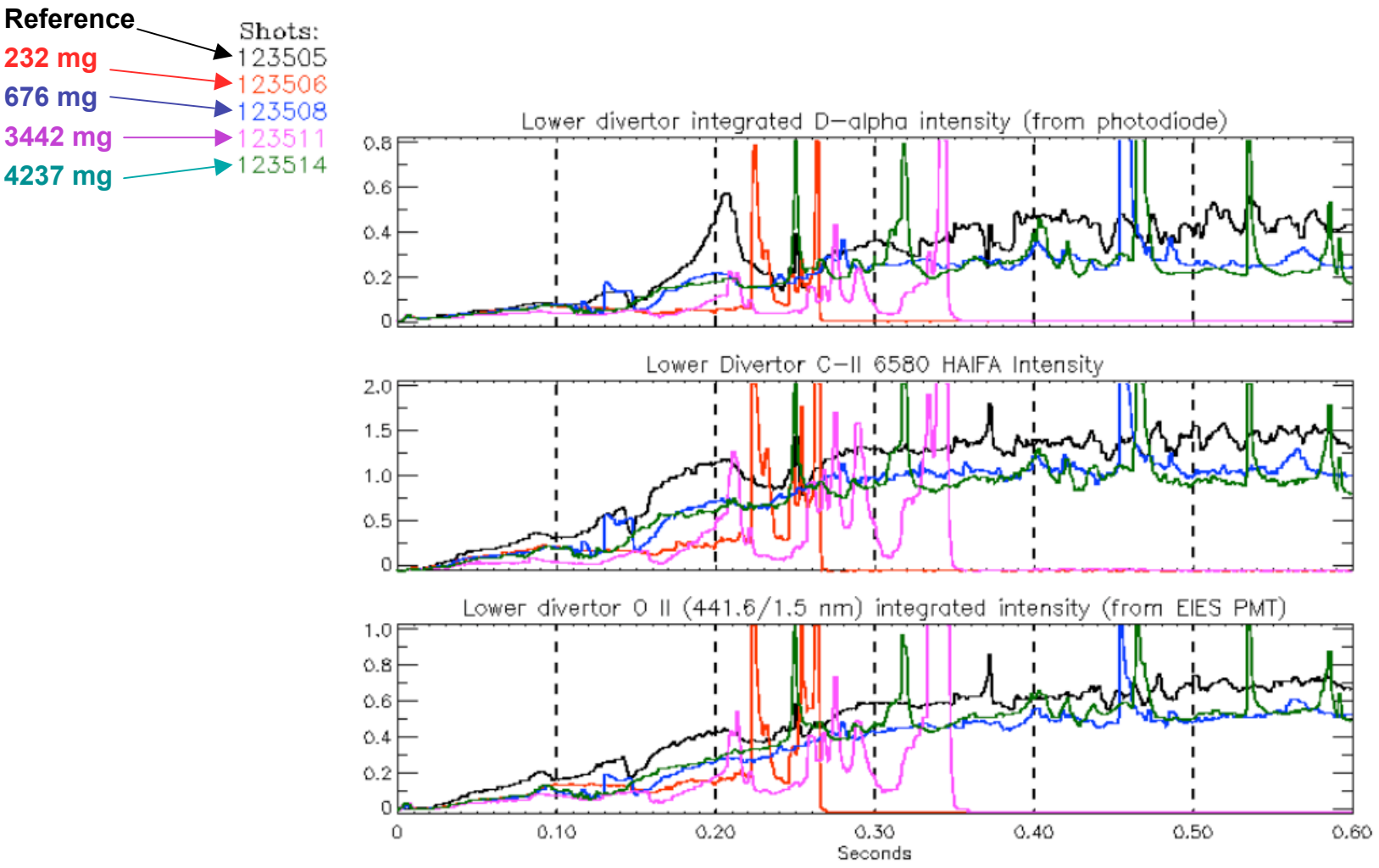


- LITER-1d loaded with lithium on probe

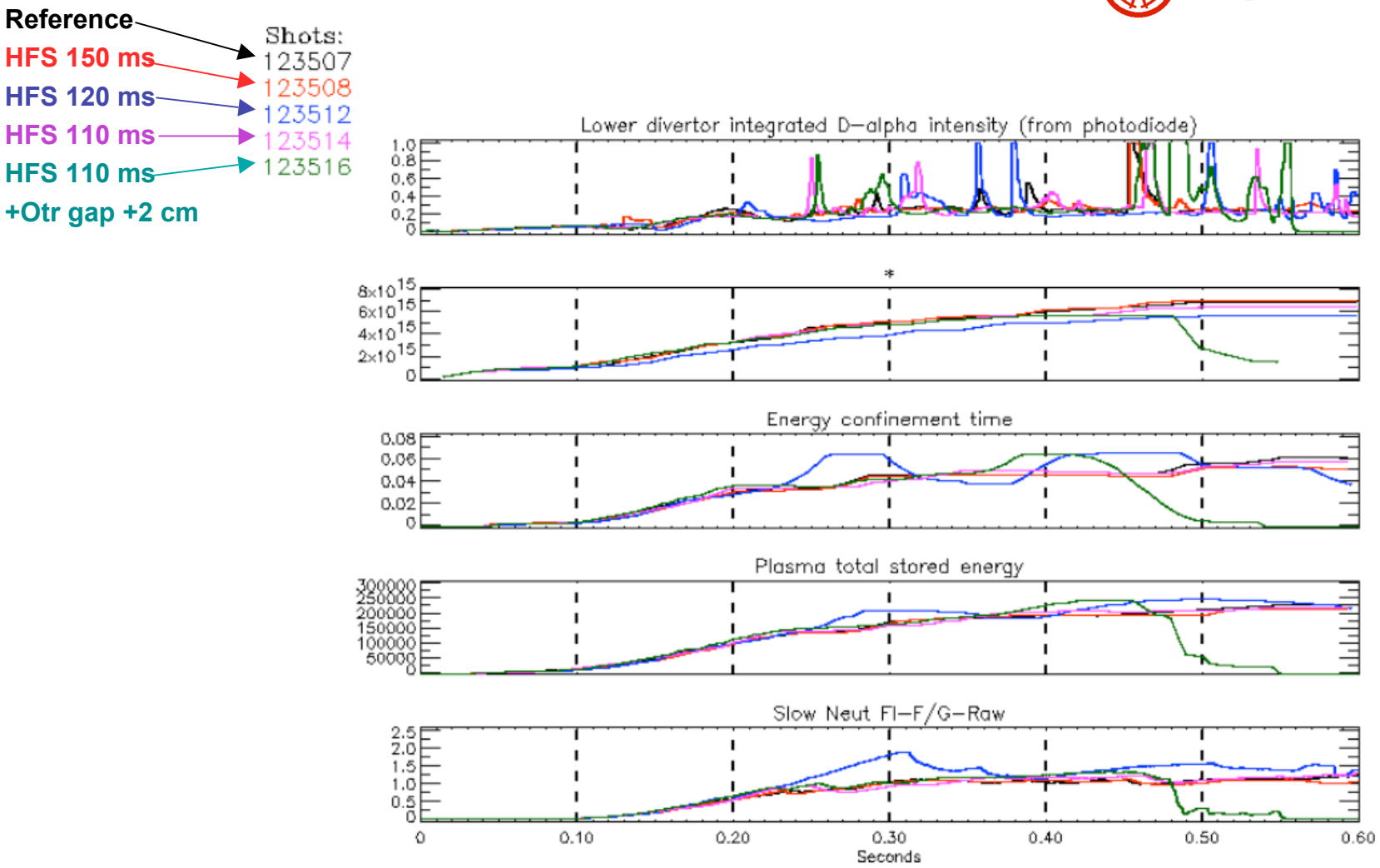


- Lithium Deposition on Divertor Region Quartz Deposition Monitors Increased with Shot Number

Lithium Evaporation On NSTX PFCs Decreased Dα, C II, and O II Luminosity

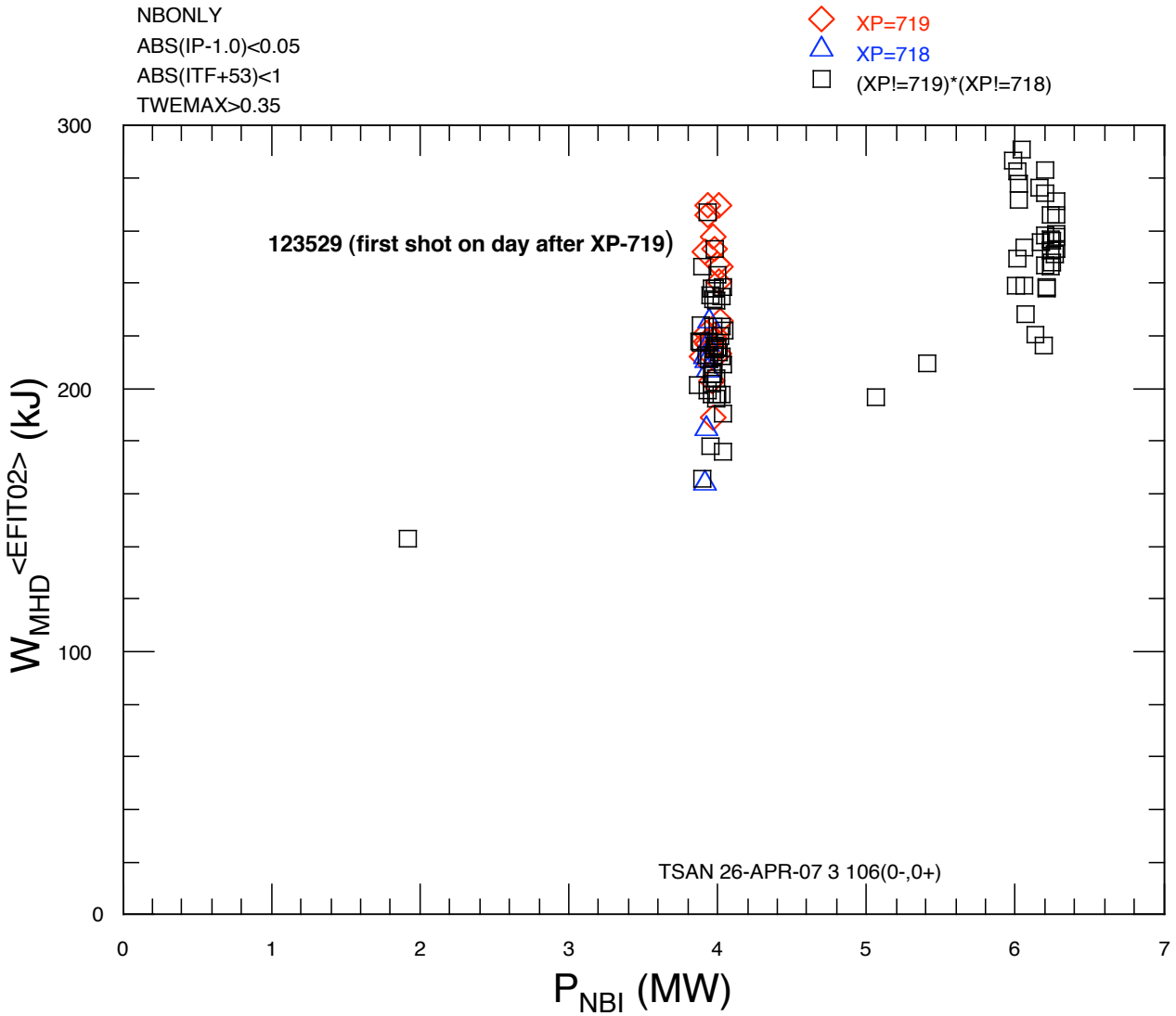


Increasing Pumpout Duration after HeGDC and Increasing Outer Gap Enhanced Effectiveness of Reducing HFS Gas Fueling



- 123512 performance improved with 9.5 min HeGDC and longer (~ 5 min) pumpout after HeGDC

Lithium Evaporation Increases Stored Energy at Constant NB Power



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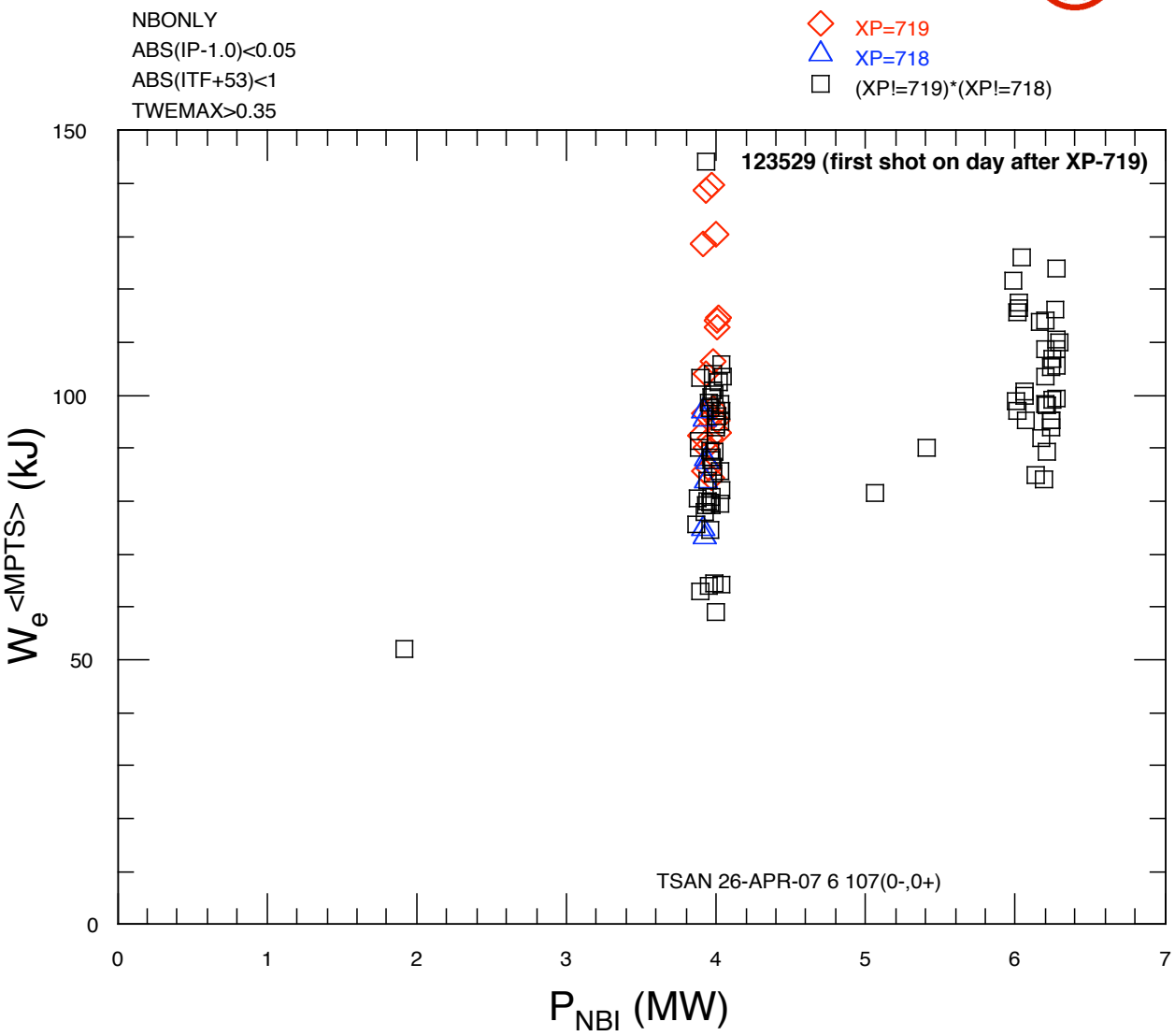
Lithium Evaporation Significantly Increases Electron Stored Energy at Constant NB Power



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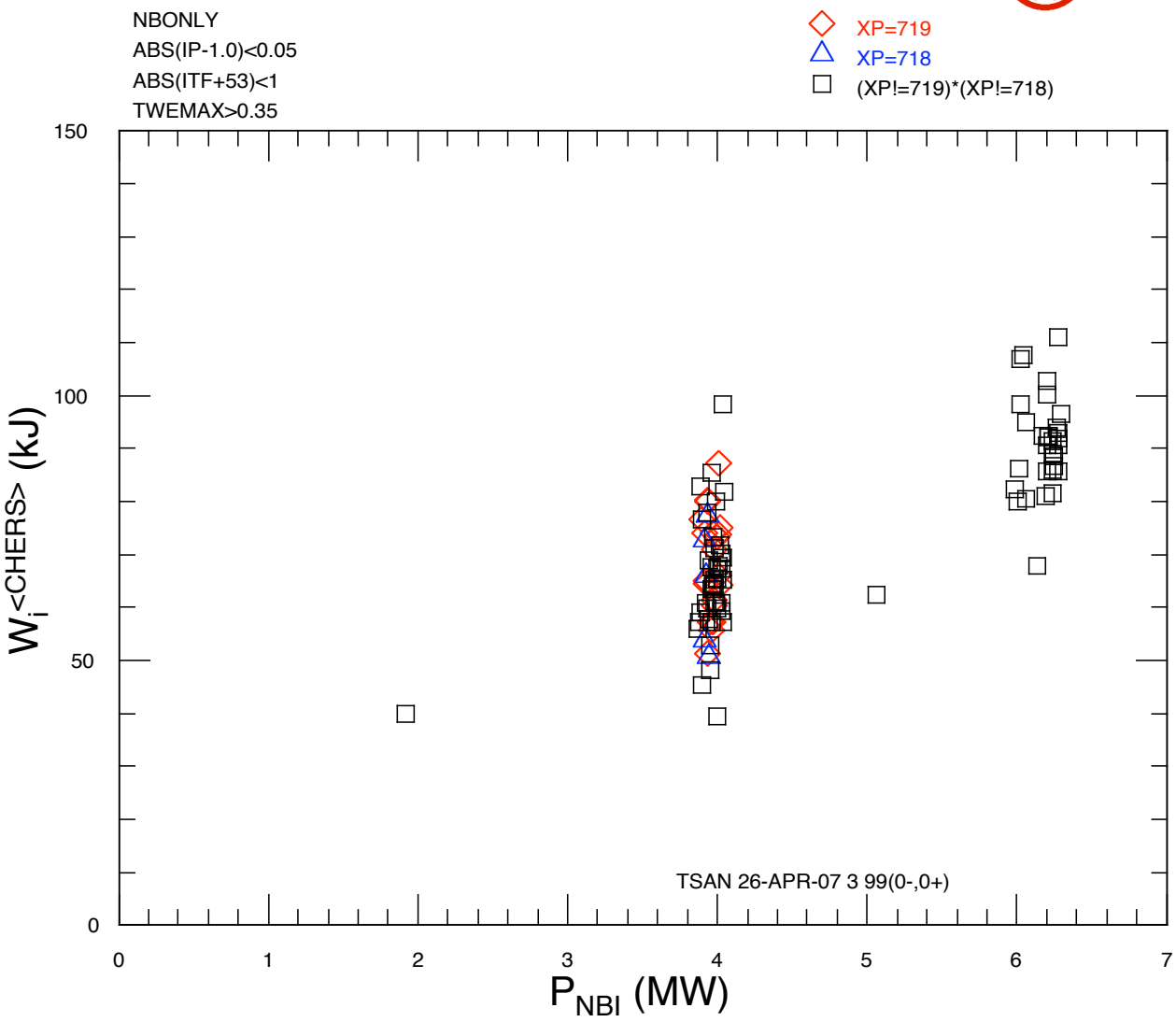
Lithium still effective on first shot on day after XP-719

Lithium Evaporation Affects Ion Stored Energy Only Slightly



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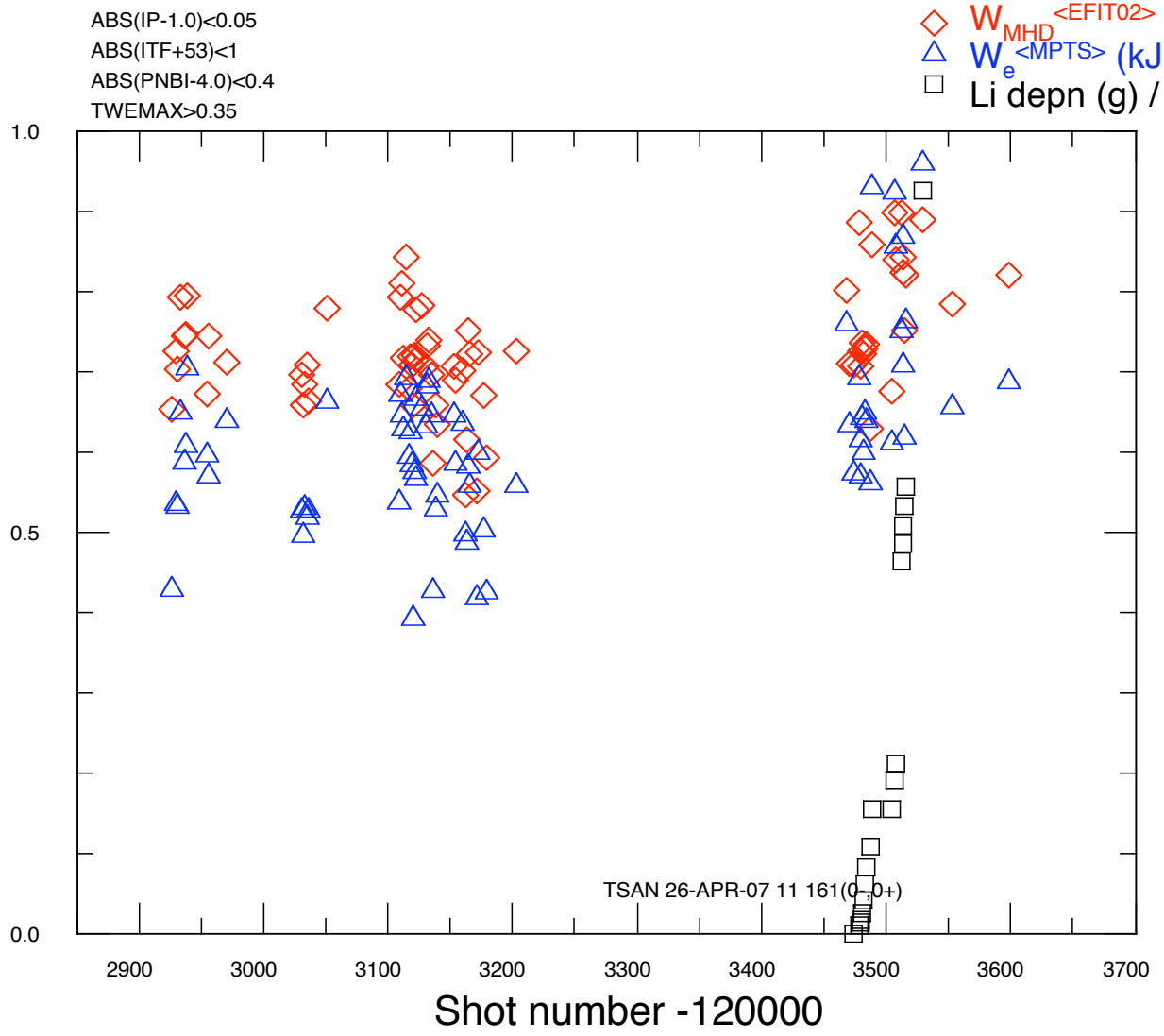
Lithium Evaporation Increases Electron Stored Energy and Stored Energy at Constant NB Power



τ_e, W_e, and Nominal Evaporated Lithium *versus* Shot Number

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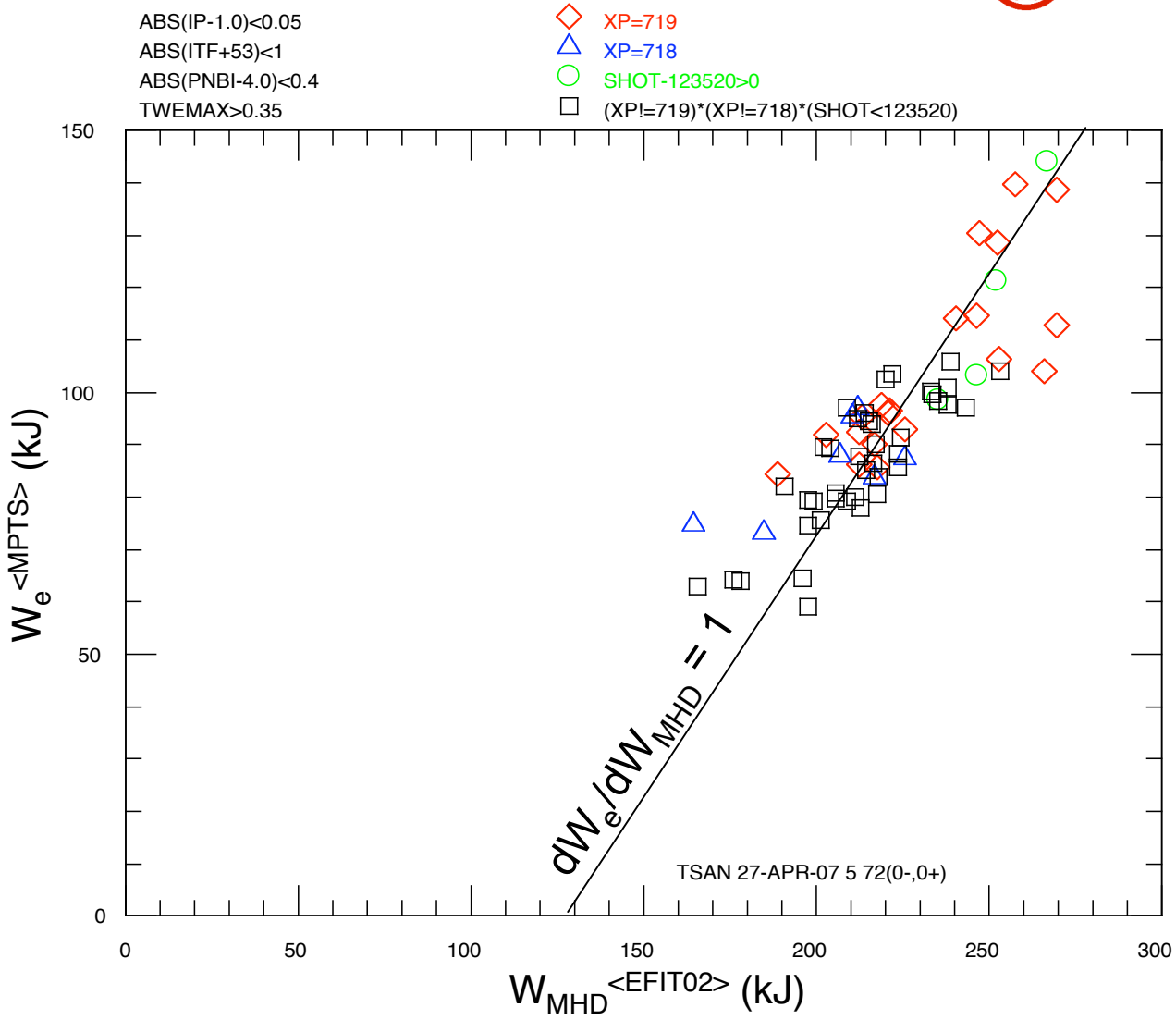
Effect on W_{MHD} Is Dominantly Through Increase in W_e



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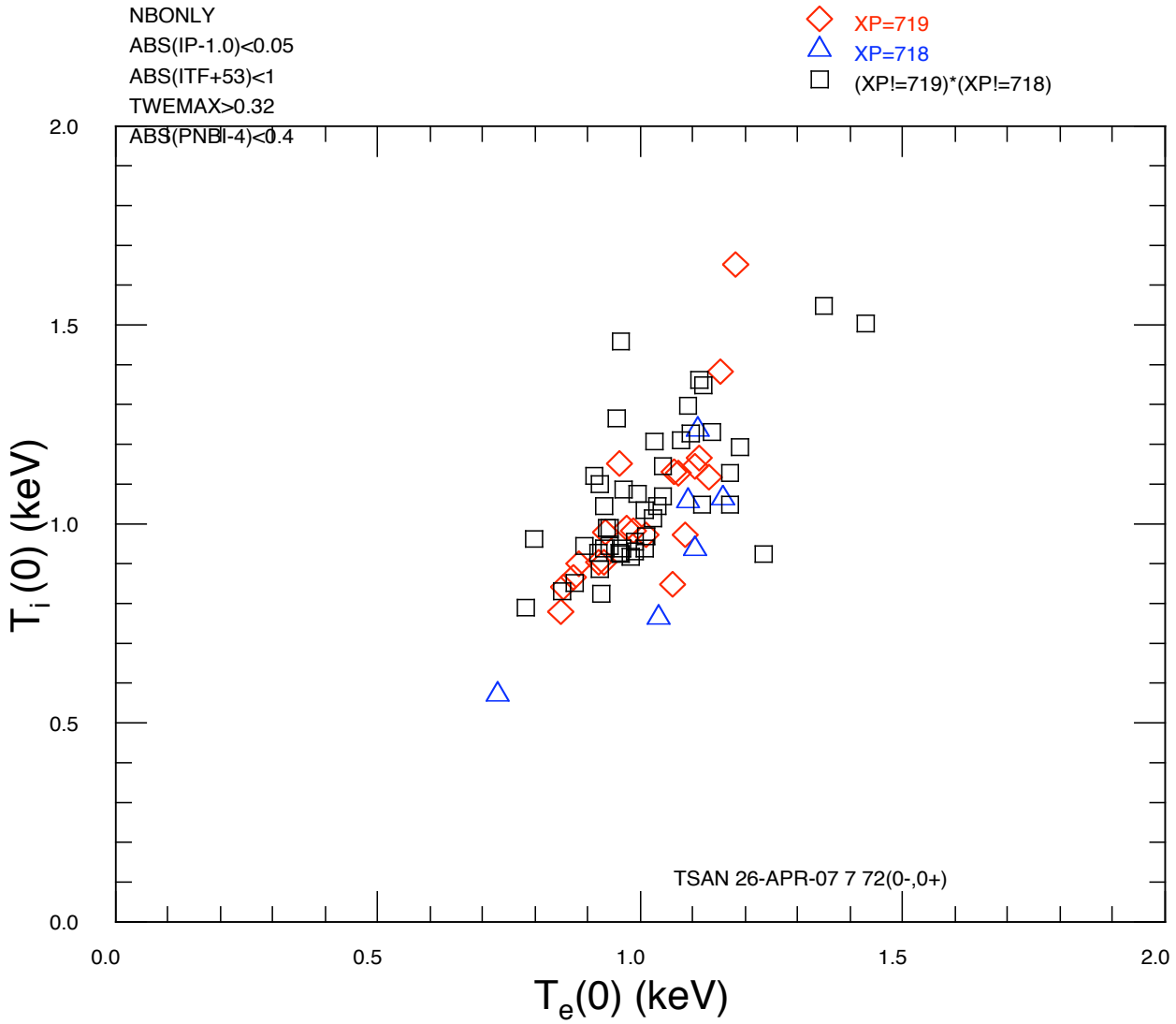
On Average, Central Temperatures Are Not Increased by Lithium



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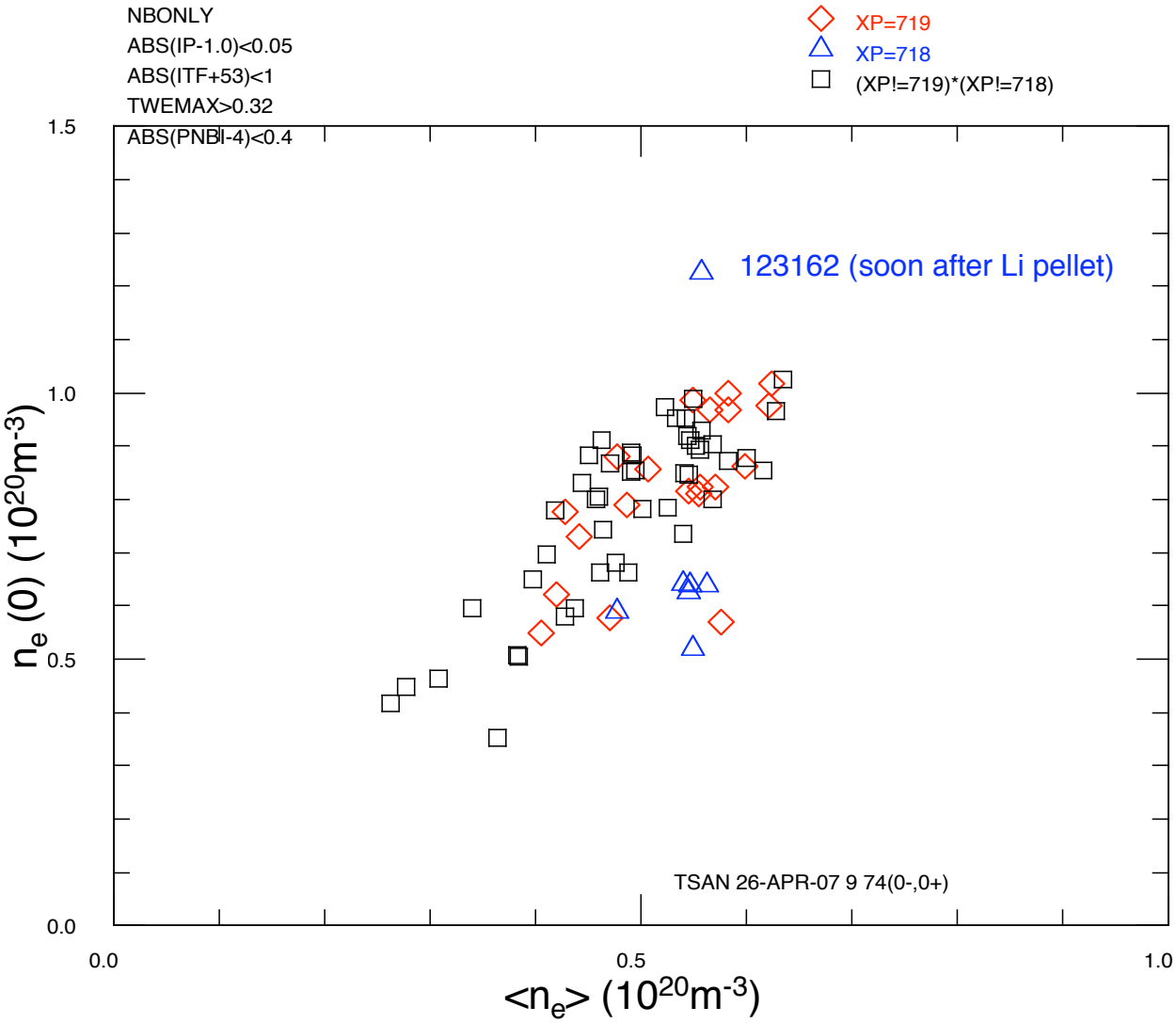
Density Peakedness Is Not Affected by Lithium



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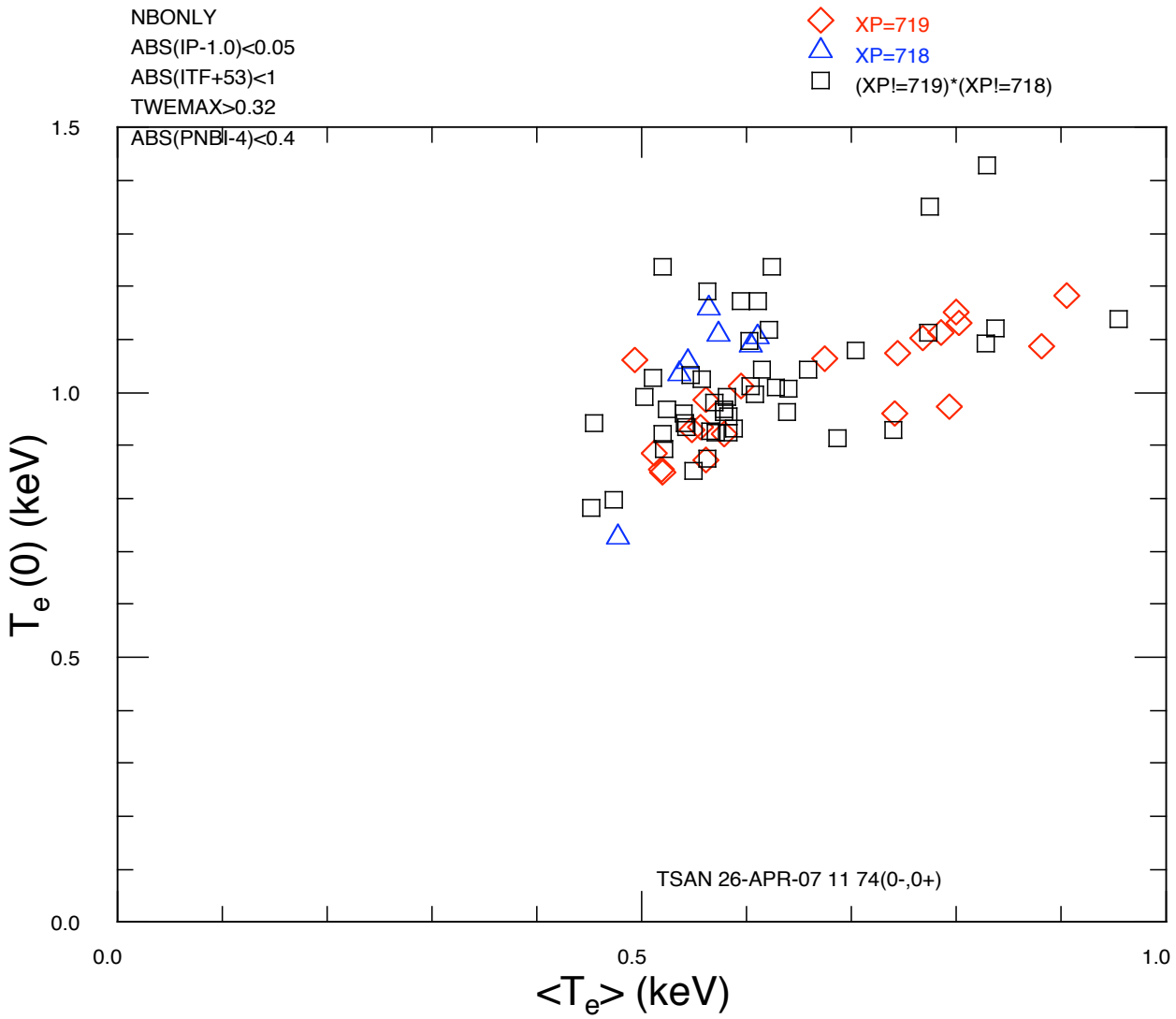
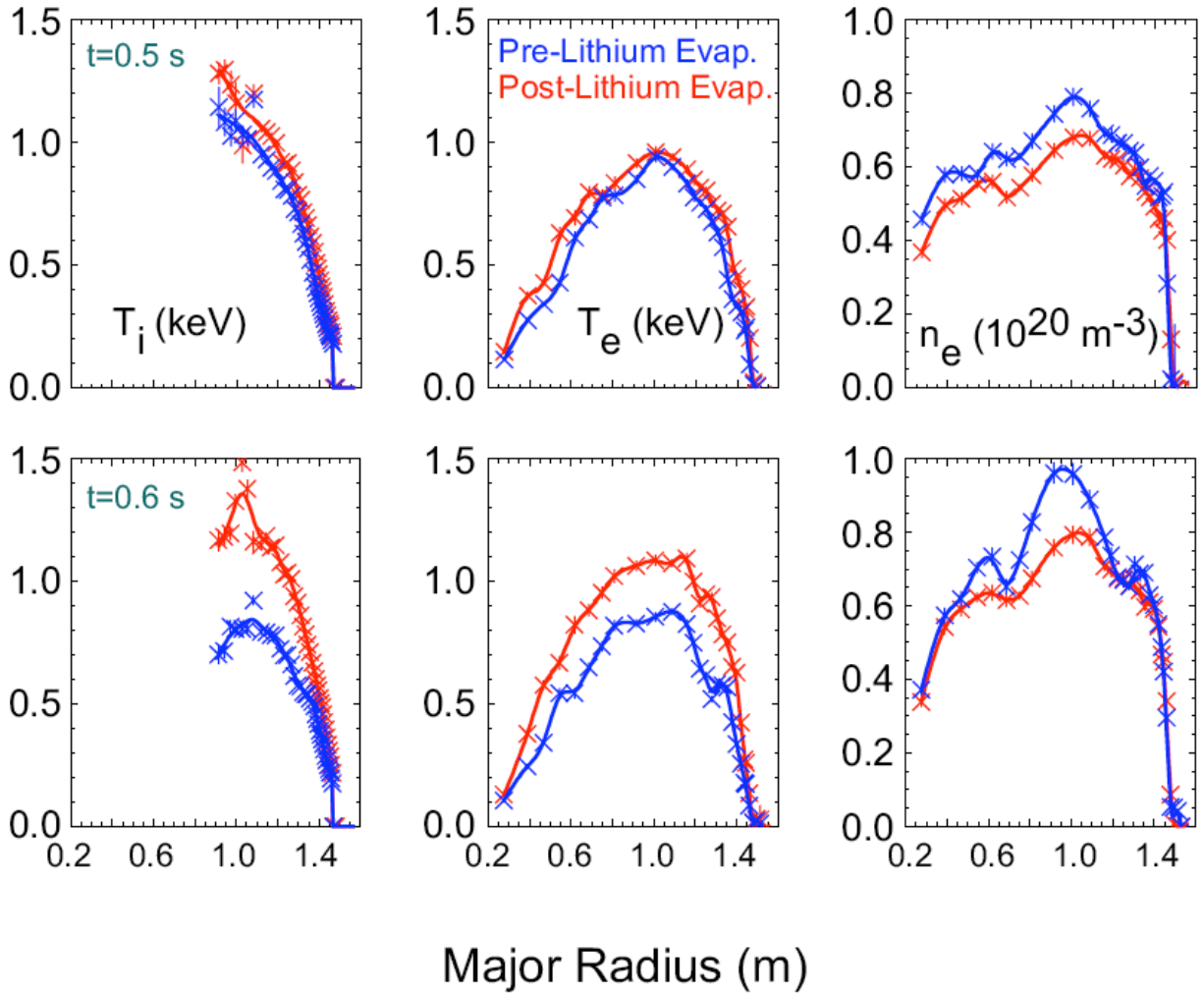
Broadening of T_e Profile Appears To Be Responsible for Improvements in W_e



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



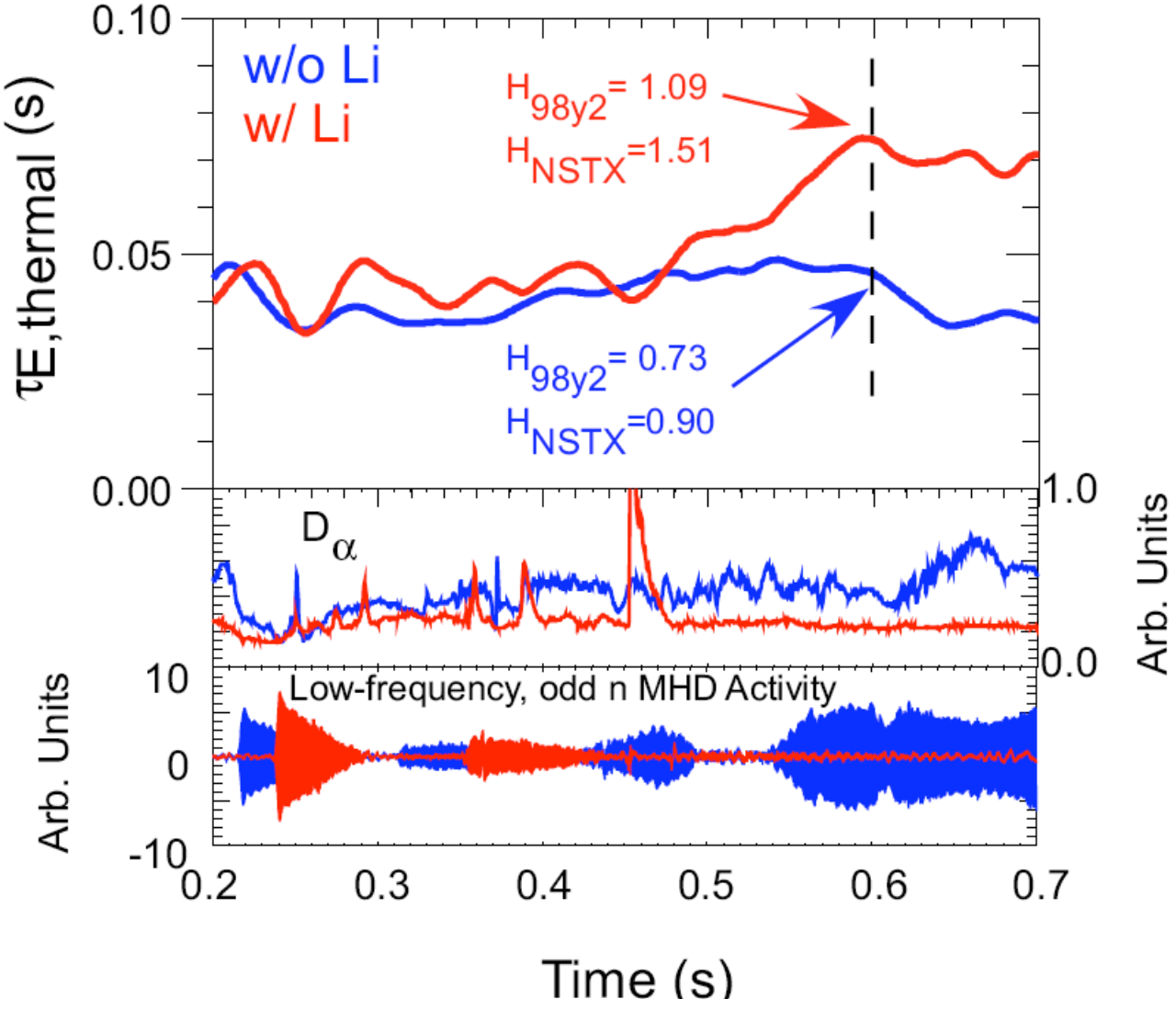
W/O Li

W/Li

- 123505 Before Li, 123507 was 2nd Shot after deposition started. 205 mg since previous shot, 437 mg total.

S. Kaye

TRANSP Analysis: H_{NSTX} = 0.90→1.51 post Li



- 123505 Before Li, 123507 was 2nd Shot after deposition started. 205 mg since previous shot, 437 mg total.

S. Kaye

Summary

- LITER-1d deposited 11.6g of Li over 2 day run between and during discharges.
- The same D LSN 2NBI reference discharge was used throughout the XP.
- HeGDC was necessary to remove fuel gas. Lithium evaporation continued during HeGDC, producing both direct divertor deposition and a global lithiumization.
- As the total evaporation increased with shot number, ELMs disappeared, recycling and OH consumption decreased, and $<T_e>$, W_{MHD}, τ_e and neutron yields increased; density either decreased modestly or continued to increase.
- Although D_α decreased, n_e continued to remain unchanged or continued to rise. This behavior suggested the conjecture that increased edge temperatures and improving confinement were allowing the density and stored energy to rise because of an improving fuel gas efficiency.
- A reduction of the HFS gas duration produced modest decreases in density and increases in performance. These improvements were enhanced by increasing the duration between the end of HeGDC and the suceeding discharge, and also increasing the outer gap.
- As the Li deposition continued and performance improved, discharges reached MHD stability limit and terminated prematurely.
- An attempt was made to slow the rapid ramp-up by delaying one of the sources but was not successful in the time available.

Conclusions

- Although understanding the affect of evaporated lithium on recycling in NSTX needs further work, there is a clear and reproducible effect on the energy confinement.
- This may be correlated with hotter edge temperatures and ELM-free H-modes (and changes in ELM characteristics) observed after lithium evaporation.
- A direct measure of the recycling coefficient would be useful (needs a sharp fueling cut-off *e.g.,* SGI, or single-pulse CTI_{RTAN} as a τ_p diagnostic)
- Prompt control (and monitoring) of HFS fueling appears to be important for controlling density as the energy confinement improves.
  - This should be included as an LLD preparation task for testing in FY08