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Review of XP-827: LITER Characterization and ELM Mitigation

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H. W. Kugel, D. Mansfield, R. Maingi, et al

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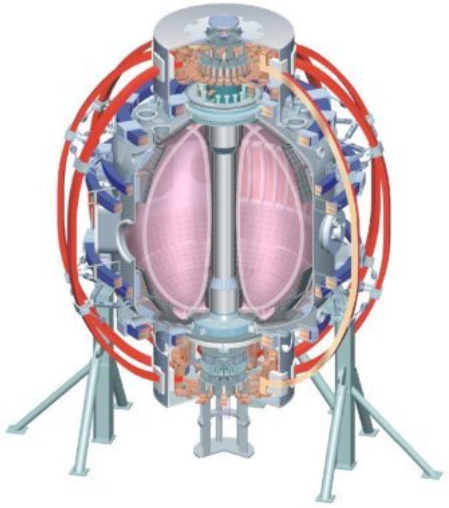
NSTX Results Review
PPPL, Princeton University, Princeton, NJ
August 06, 2008

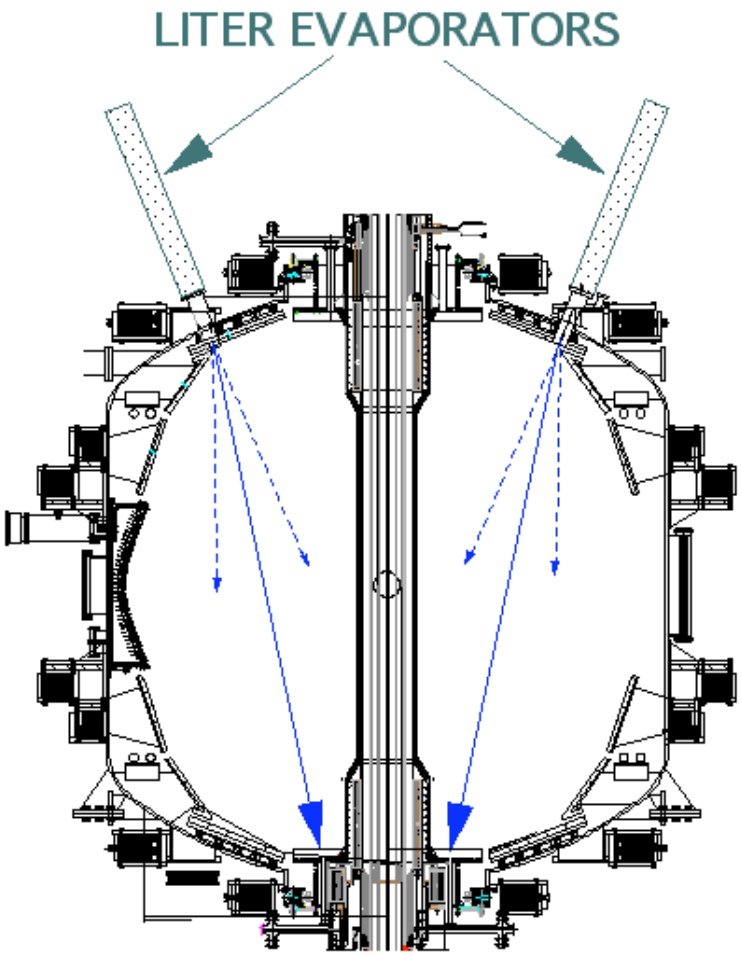


Overview of XP-827: LITER Characterization and ELM Mitigation

- **Sequence**
  - Day-1: High Recycling, Low Triangularity Shots
  - Day-2: High Triangularity Shots (9.5min HeGDC)
  - Day-3: High Triangularity Shots (0-9.5min HeGDC)

- **Procedure**
  - During XP-827, the 2 LITER system evaporated a total of 20.6 g into the vessel between discharges.
  - Prior to the discharge, the LITERs were withdrawn behind special shutters,
    - LITERs stayed behind shutters during discharges, and
    - LITERs stayed behind shutters during subsequent HeGDC (up to 9.5 min)
  - After HeGDC, the LITERs were reinserted for 10 minutes, and deposited Li at 10-70 mg/min, prior to the next discharge.

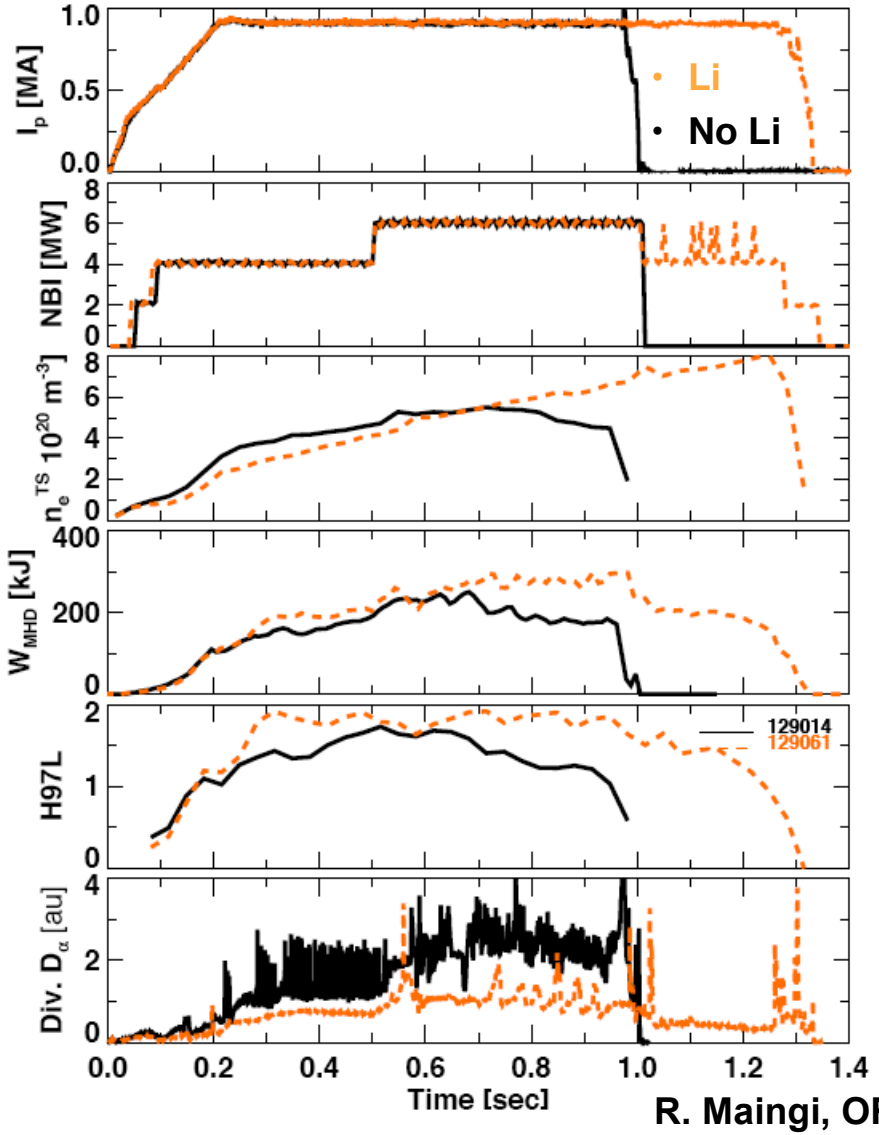
Dual LIThium EvaporatoR (LITER) Configuration Used for XP-827 and Subsequent Experiments



- LITER central aiming axis to graphite divertor and gaussian angle at 1/e (dashed)
- During 2008 LITER evaporated 120 g of Li into vessel and 43 g on each LITER shutter

Solid Lithium Surface Coatings Increase Confinement, Stored Energy, and Pulse Length

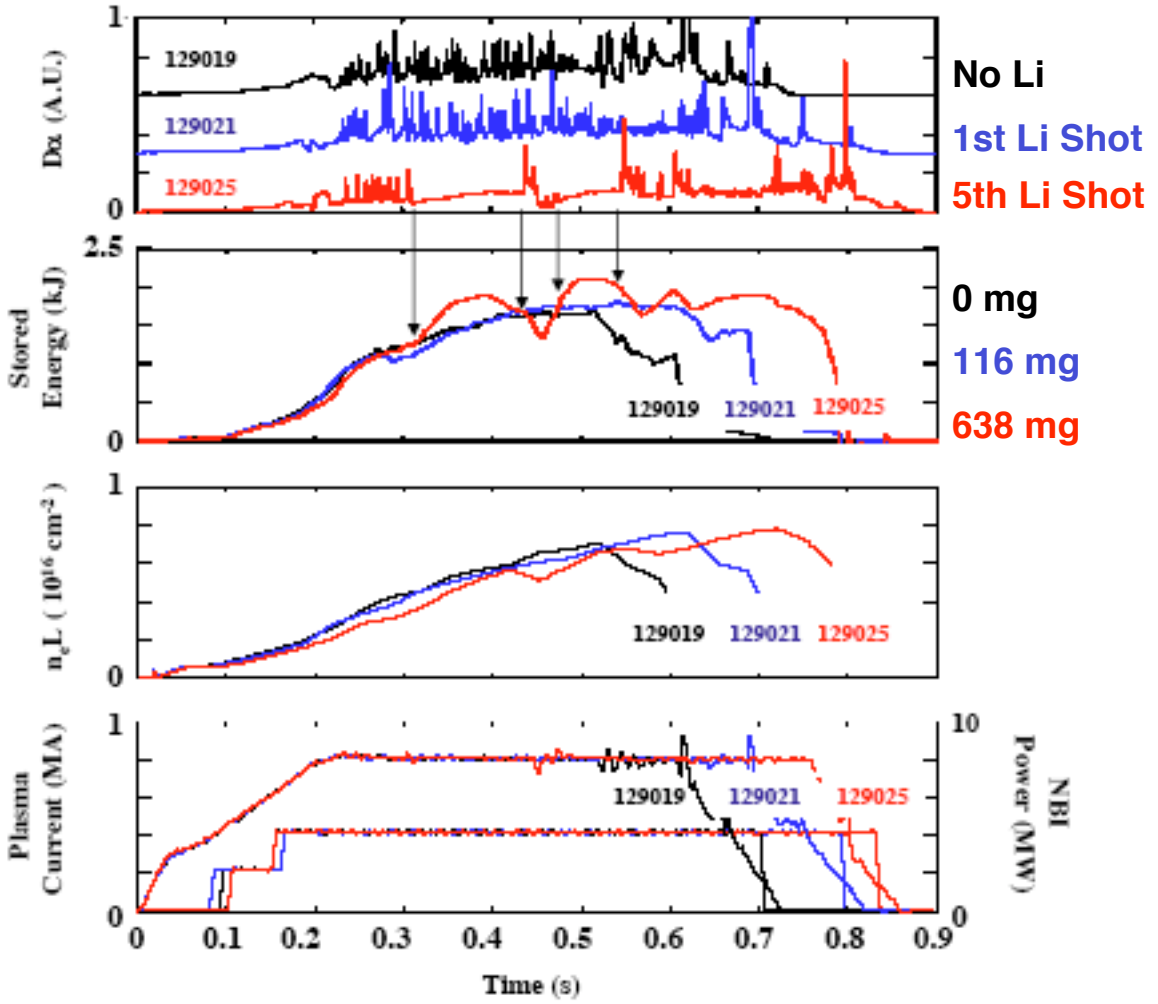
- Comparison for pre-Li and post-Li reference shots with constant NBI, constant external gas, etc.
- Lithium (188 mg) reduced density in initial period up to 0.6s
  - pre-Li discharge was ELMy
  - ELMs were absent on Li shot
- In time, the lack of ELMs causes the density in the discharge with Li to overtake the shot without Li.



R. Maingi, ORNL

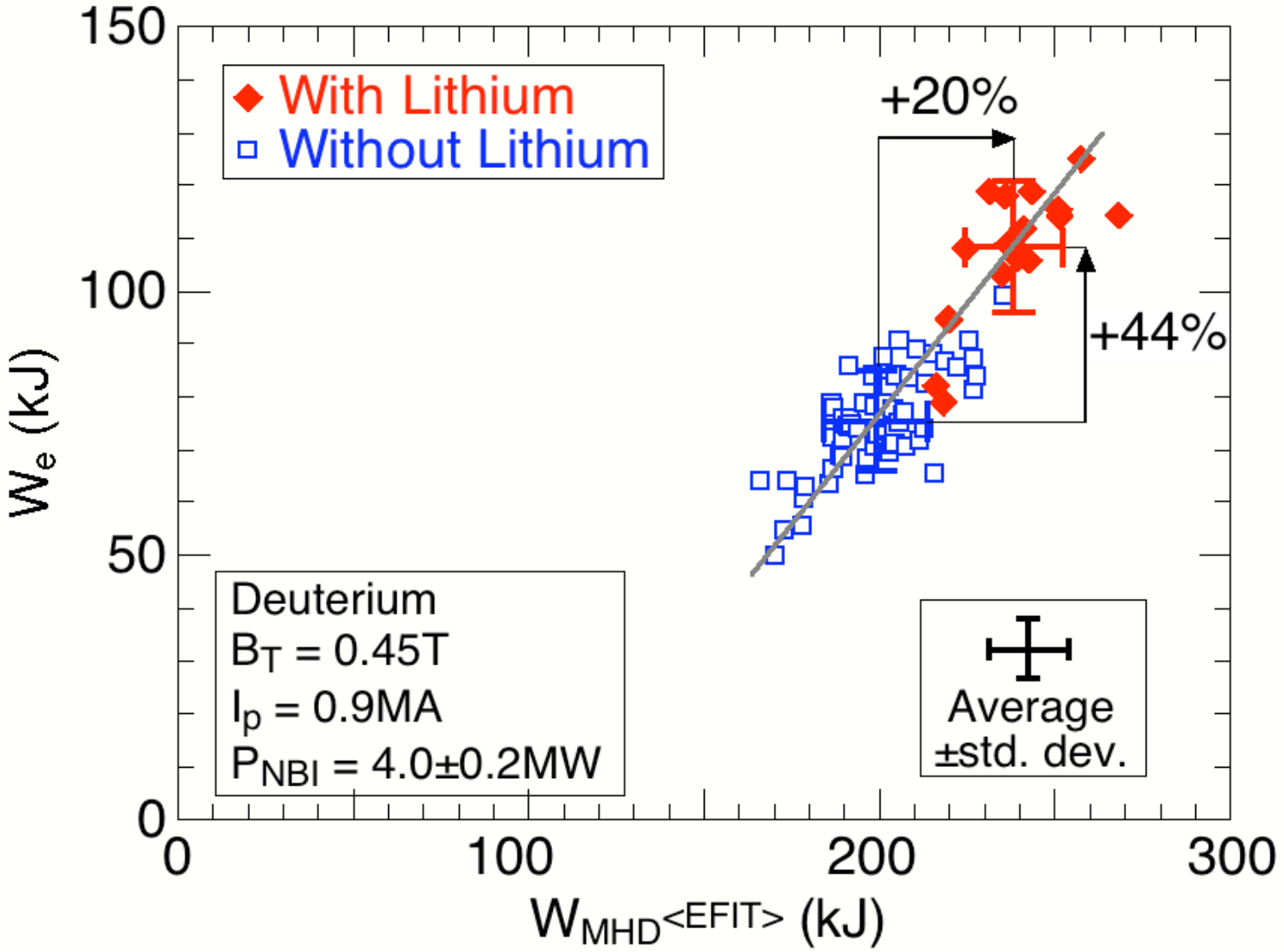
ELM Suppression by 5th Discharge With Li
No ELMs ⇒ Immediate Increase in Stored Energy

- As Li increases
  - ELMs decrease
  - Stored energy increases
  - Pulse lengthens
- At higher Li evaporation rates and higher PFC accumulations, complete ELM suppression occurs
  ⇒ higher confinement*



*** D. Mansfield, PSI08, O-28**

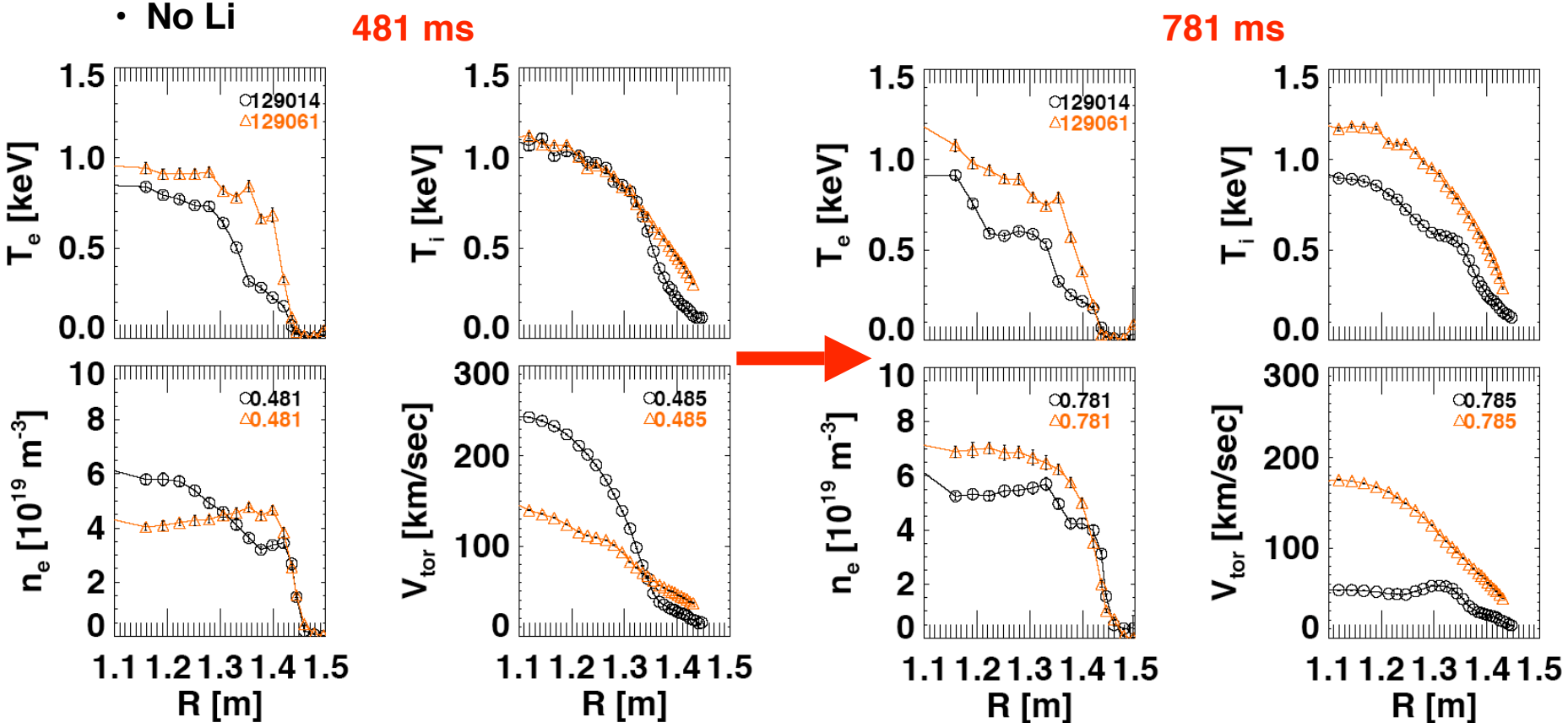
Stored Energy (W_{MHD}) Increases After Li Deposition Mostly Through Increase in Electron Stored Energy (W_e)



G. Bell

Lithium Edge Conditions Increased Pedestal Electron and Ion Temperature

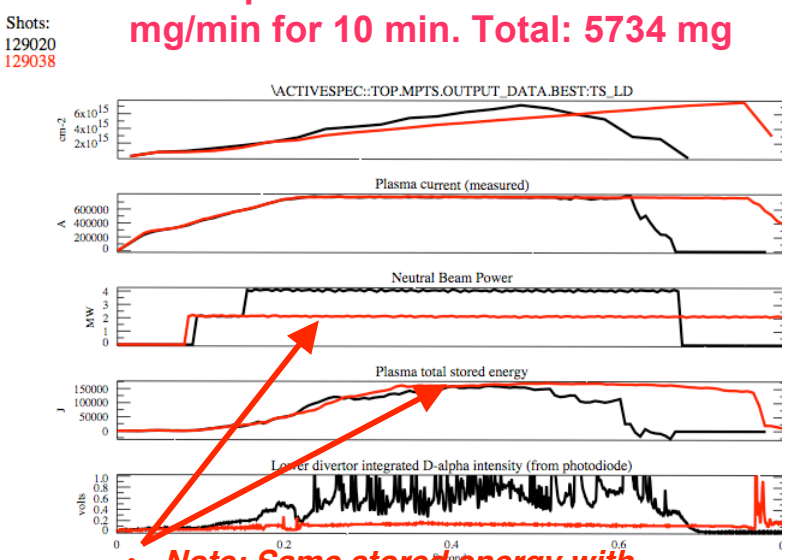
- Li
- No Li



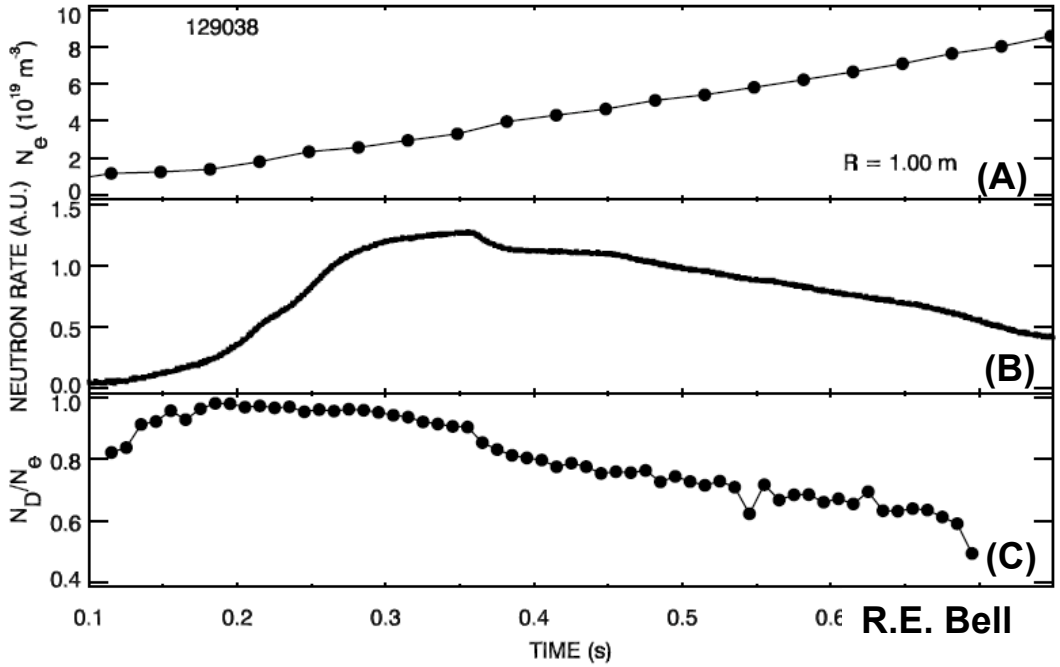
R. Maingi, ORNL

Uncontrolled Density and Impurity Rise Due to Increasing Confinement: Deuterium-to-Central Density Ratio Decreases, Neutron Rate Decreases

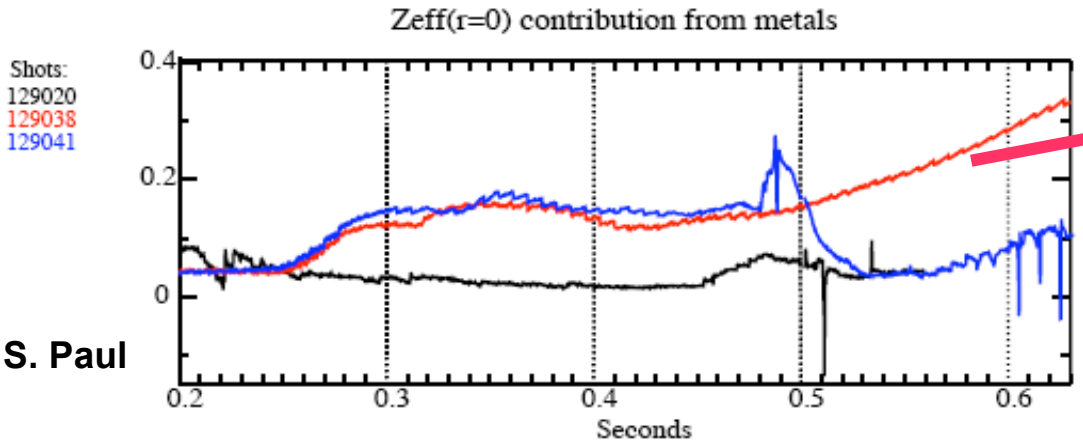
- Li Deposition Before Shot: 70 mg/min for 10 min. Total: 5734 mg



- *Note: Same stored energy with half the Input power*

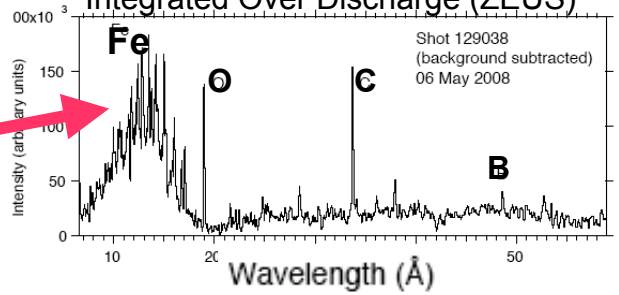


R.E. Bell



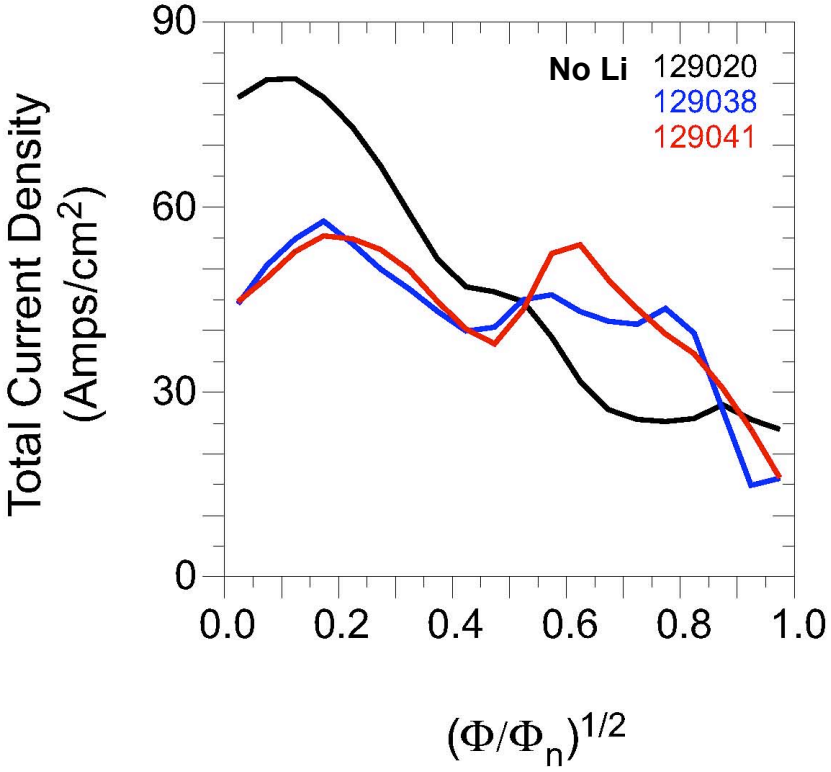
S. Paul

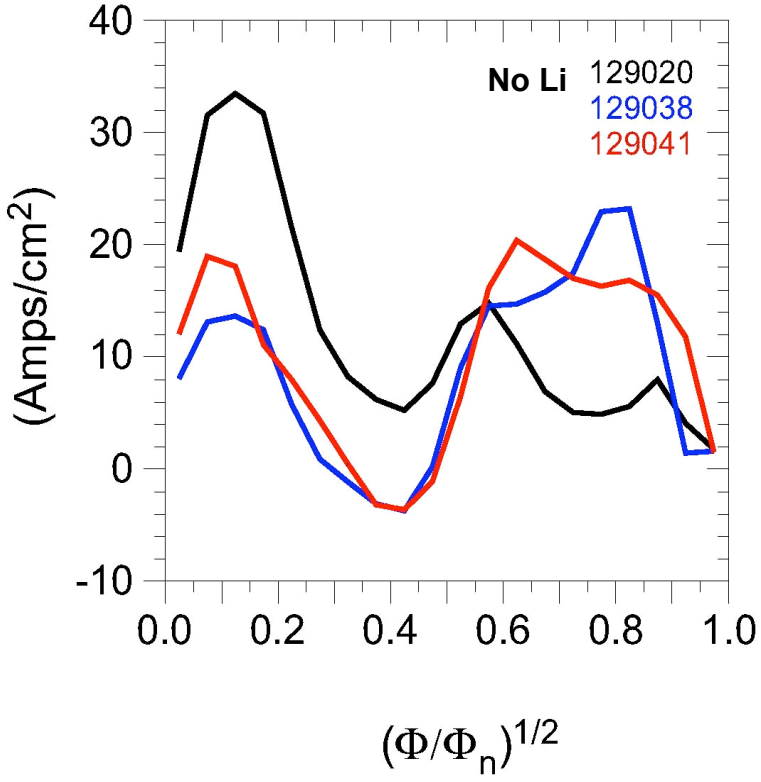
Integrated Over Discharge (ZEUS)



J.K.Lepson, UCB SSL
P.Beiersdorfer, LLNL

Lithium Edge Conditions Yield ELM Suppression
TRANSP Analysis Finds Increase in Edge Current

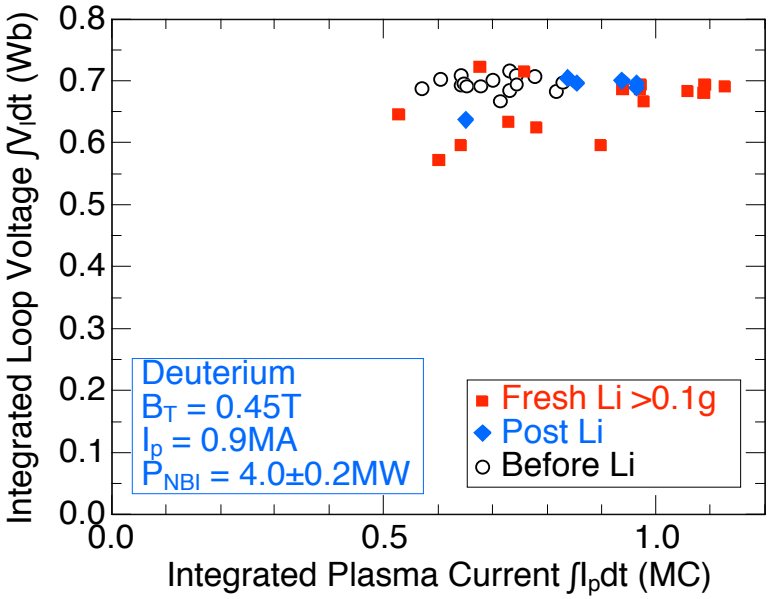


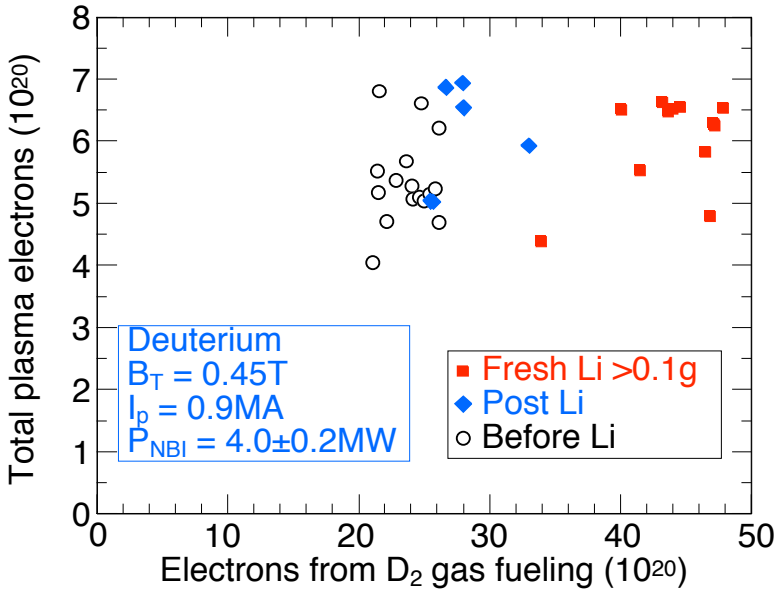


Stability Analysis in Progress

S. Kaye

Lithium Edge Conditions Reduce OH Flux Consumption and Require Large Fueling Increases to Maintain Density





- **Reduced OH Flux Consumption**
- **Large Fueling Increases to Maintain Density**

M. G. Bell

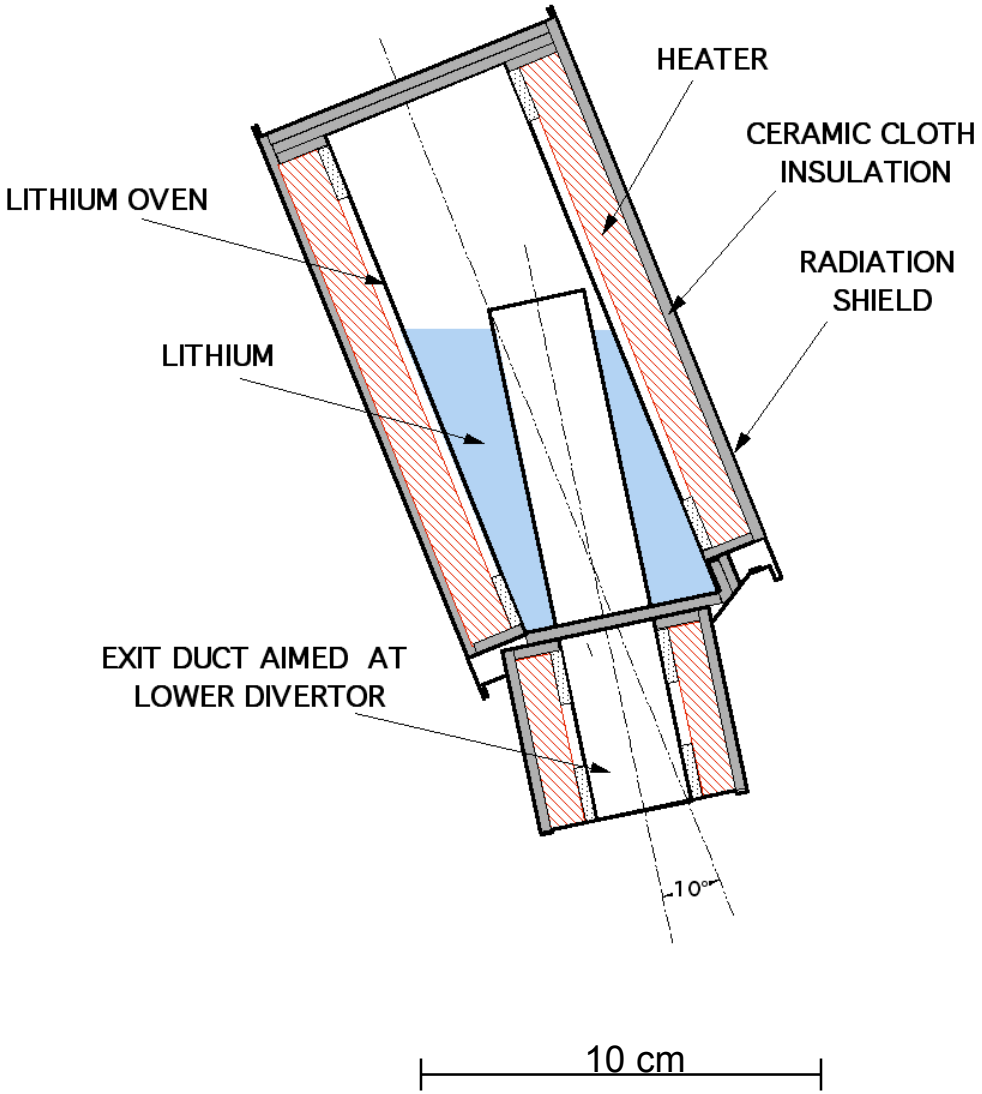
Summary and Conclusions

- In recent experiments, the dual LIThium EvaporatoR (LITER) evaporated 120g of Li into NSTX
  - The LITERs deposited lithium on the lower divertor target for 10 min, at combined rates of 10-70 mg/min
  - Prior to each discharge, the LITERs were withdrawn behind shutters
  - The shutters remained close during a subsequent period of HeGDC
  - The shutters were then reopened and the deposition cycle repeated

- The effects of the lithium on standard discharge scenarios include:
  1. Reduced plasma density in the early phase of the discharge
  2. Suppression of ELMs
  3. Improved energy confinement
  4. Reduced flux consumption and increased pulse length for standard, high-triangularity discharges
  5. Reduced HeGDC time between discharges to maintain the H-mode
  6. Increased pedestal electron and ion temperature
  7. Reduced SOL plasma density and edge neutral density
  8. Discharges after lithium also benefited from n=1 and n=3 mode control by the external non-axisymmetric coils to reduce deleterious MHD activity.

Backup

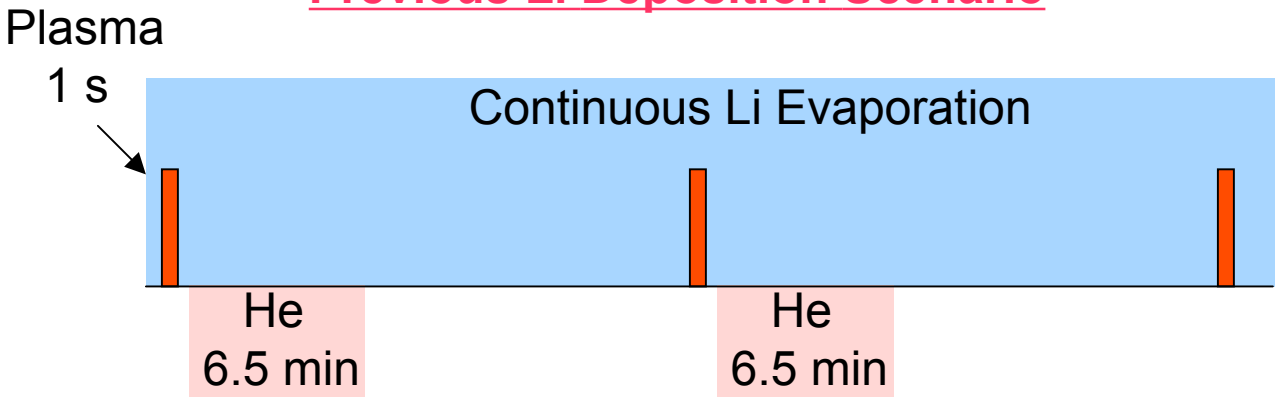
Design of LIThium EvaporatoR Shown in Operating Orientation



- LITER on probe & loaded with Li under argon
- Typical Operating Conditions
  - Capacity: 90 g Li
  - Oven Temp: 600-680°C
  - Rate: 1mg/min - 80mg/min

Newly-Installed LITER Shutters Allow More Flexible Lithium Wall Conditioning

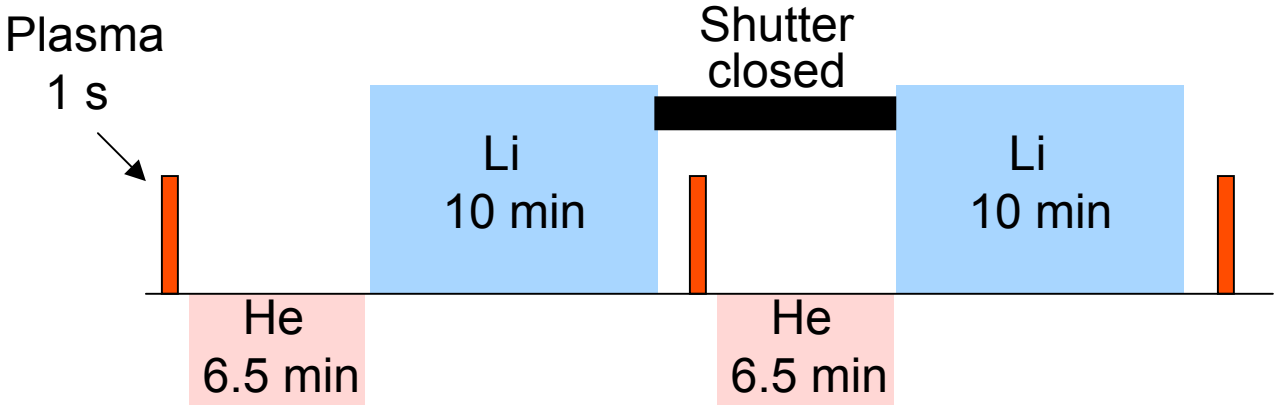
Previous Li Deposition Scenario



Disadvantages

- Window coating during discharge
- Codeposition of Li and He during HeGDC
  - Causes He dilution of D plasma

New Li Deposition Scenario Using Li Shutters

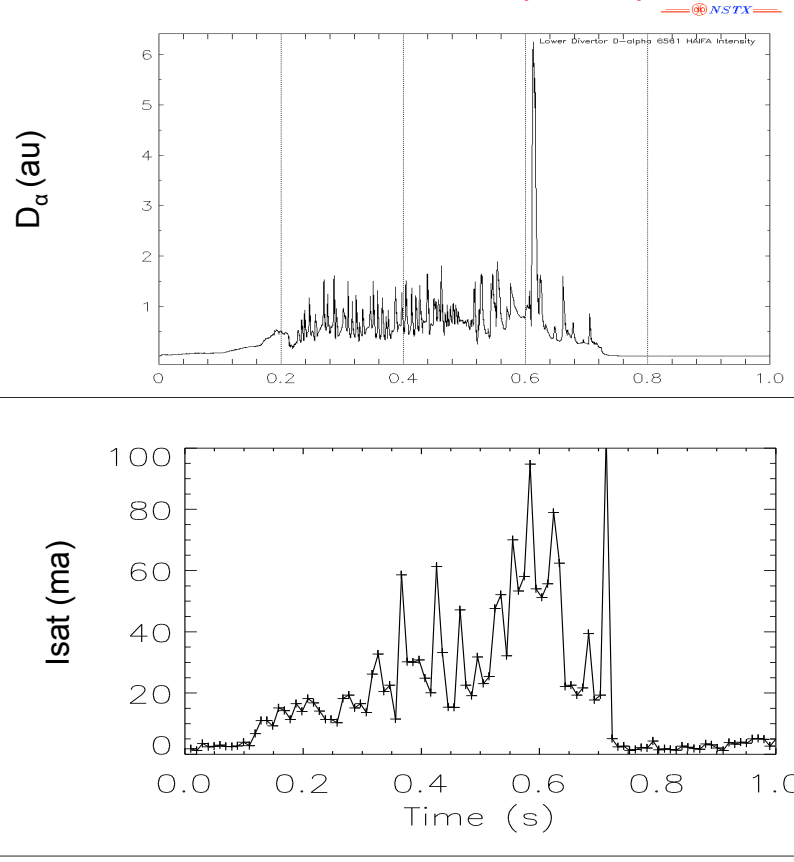


Advantages

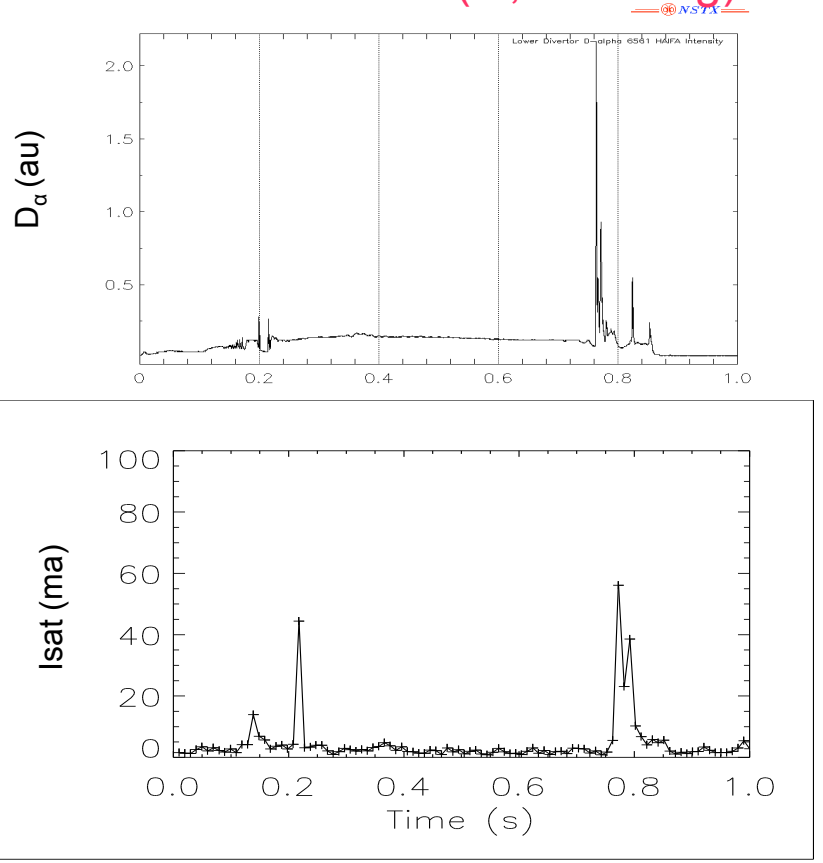
- No window coating during discharge
- No codeposition during HeGDC
  - Avoids He dilution

During Lithium Edge Conditions ELM Suppression Reduces Flux to Divertor Langmuir Probe Outside Separatrix

Shot 129019 (no Li)



Shot 129038 (Li, 5734 mg)

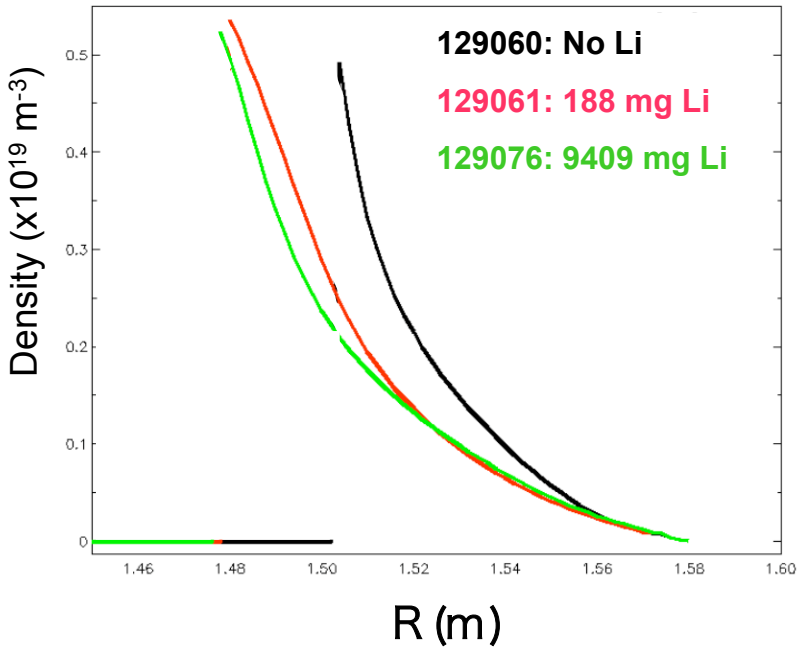


- **Tile mounted Langmuir probe is located at r = 0.91 m, z =- 1.52 m, on lower outer divertor. Radius of outer strike point is ~0.8 m.**

J. Kallman

Lithium Edge Conditions Reduce SOL Density and Edge Neutral Density

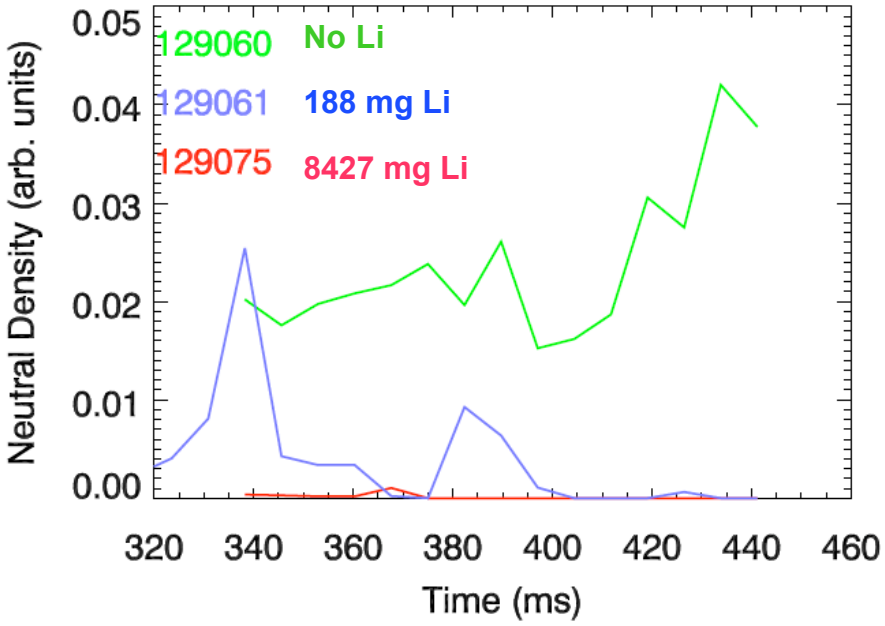
SOL Density



J. Wilgen, ORNL

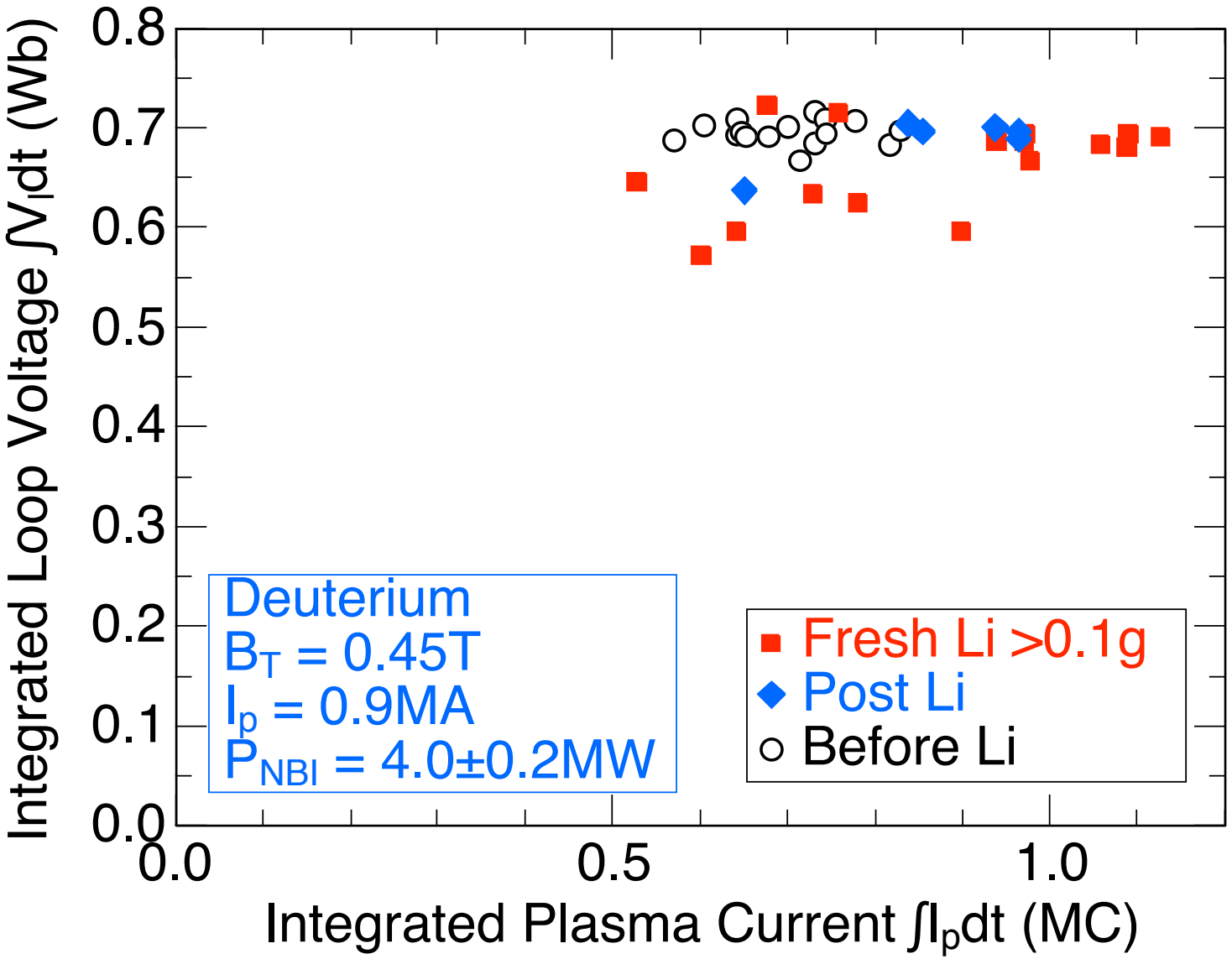
*J. B. Wilgen et al., Rev. Sci. Instrum. **77,** (2006) 10E933.

Edge Neutral Density



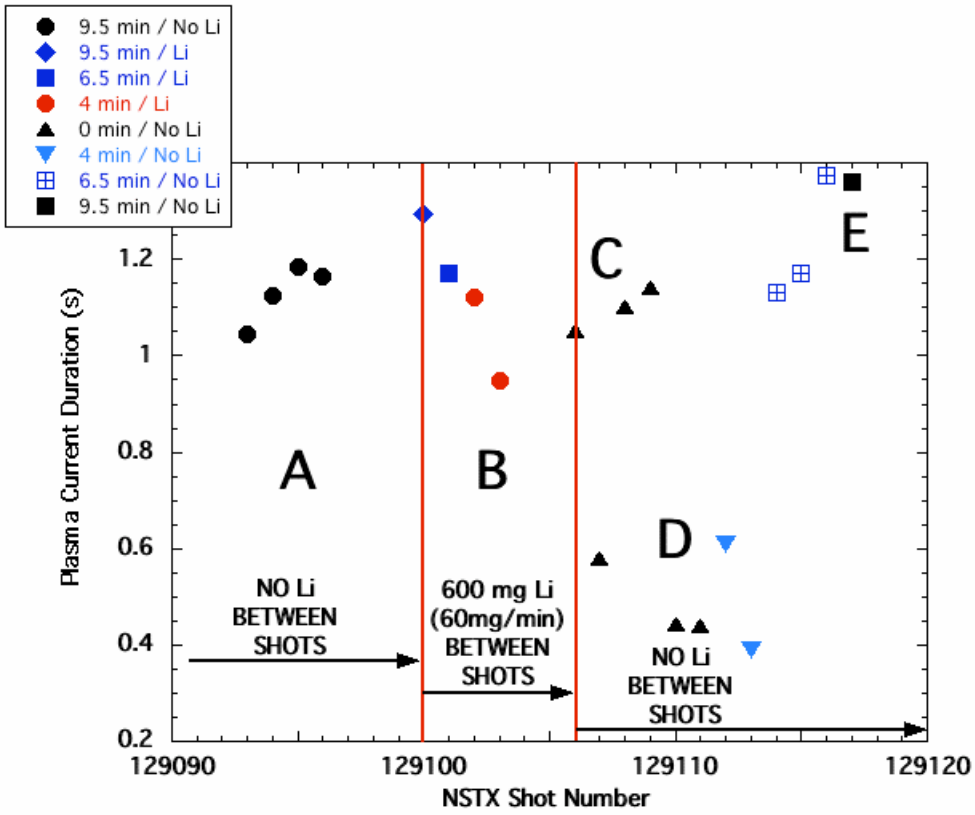
P. W. Ross

Lithium Edge Conditions Reduce OH Flux Consumption



M. G. Bell

Lithium Edge Conditions Allowed Long H-mode Plasmas with Reduced or No HeGDC



- A - Reference shots with 9.5 min of HeGDC and no Li between shots.
- B - HeGDC shortened from 9.5 to 4 min followed by 10 min Li deposition.
- C - No HeGDC followed by no Li deposition.
- D - Initially at C no change, but by D conditions degrade.
- E - Reapplication of HeGDC restored and exceeded initial conditions (A).