Density and impurity control is goal of multi-year Li program on NSTX

Seven Impurity Control XPs Planned for 2010:

XPs:	Author:	Title:
XP1002 (LR)	Soukhanovskii	Core impurity density and radiated power reduction using variations in LLD divertor conditions.
XP1005 (ASC)	Menard	Modifications to the early discharge evolution to reduce late impurity content evolution
XP-1006 (ASC)	Gerhart	Development of High-Elongation Beam Heated Scenarios with Reduced Impurity Content and Increased Non-Inductive Fraction
XP-1007 (ASC)	Bell	Use of HHFW heating to increase the non-inductive current fraction in NBI-produced H-mode plasmas with triggered ELMs to control impurity buildup
XP-1024 (LR)	Skinner	Controlling Impurity Sources by Diffusive Lithium Injection <<<<
XP-1027 (ASC)	Canik	RMPs below the ELM triggering threshold for impurity screening.
XP-1056 (LR)	Mansfield	Can Li Aerosol Injection Mitigate High-Z Impurity Accumulation During ELM-Free H-modes?

XP 1024 Controlling Impurity Sources by Diffusive Lithium Injection

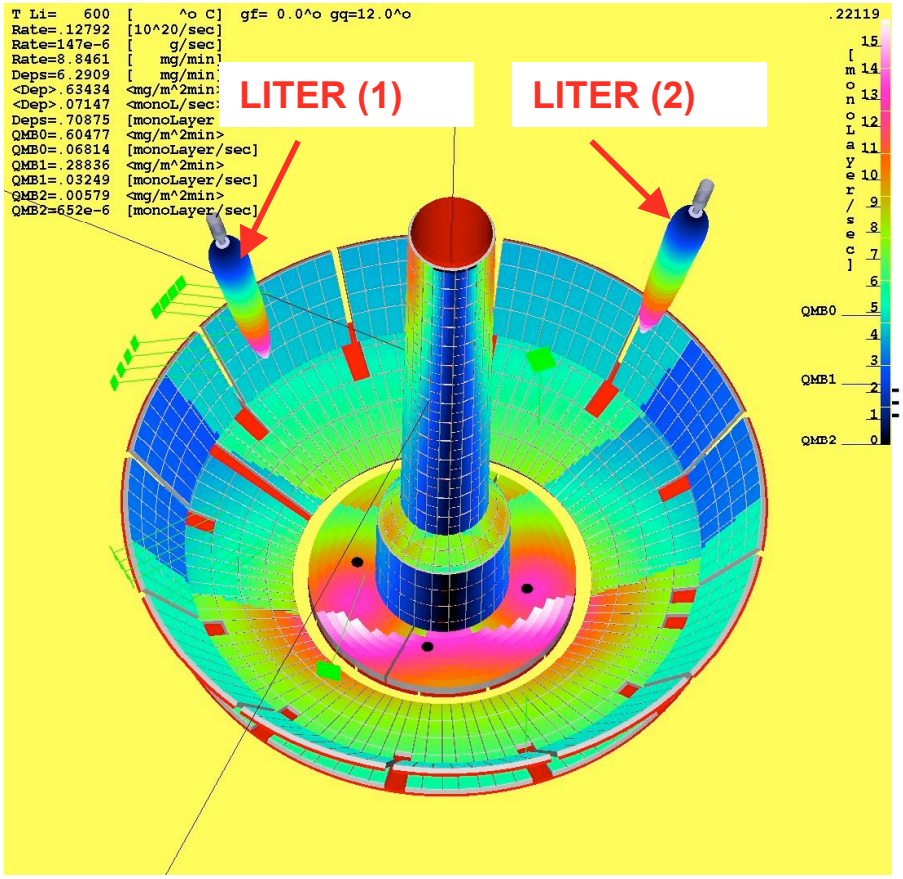
Charles H. Skinner, Daren Stotler and the NSTX team

- FY2011 Research Milestone R(11-3) "Understand and minimize the sources and accumulation of plasma impurities arising from lithium conditioning of the PFCs."
- Relevant to ITER ELM control: "further exploration of increased Li coverage using He neutral gas or dropper."

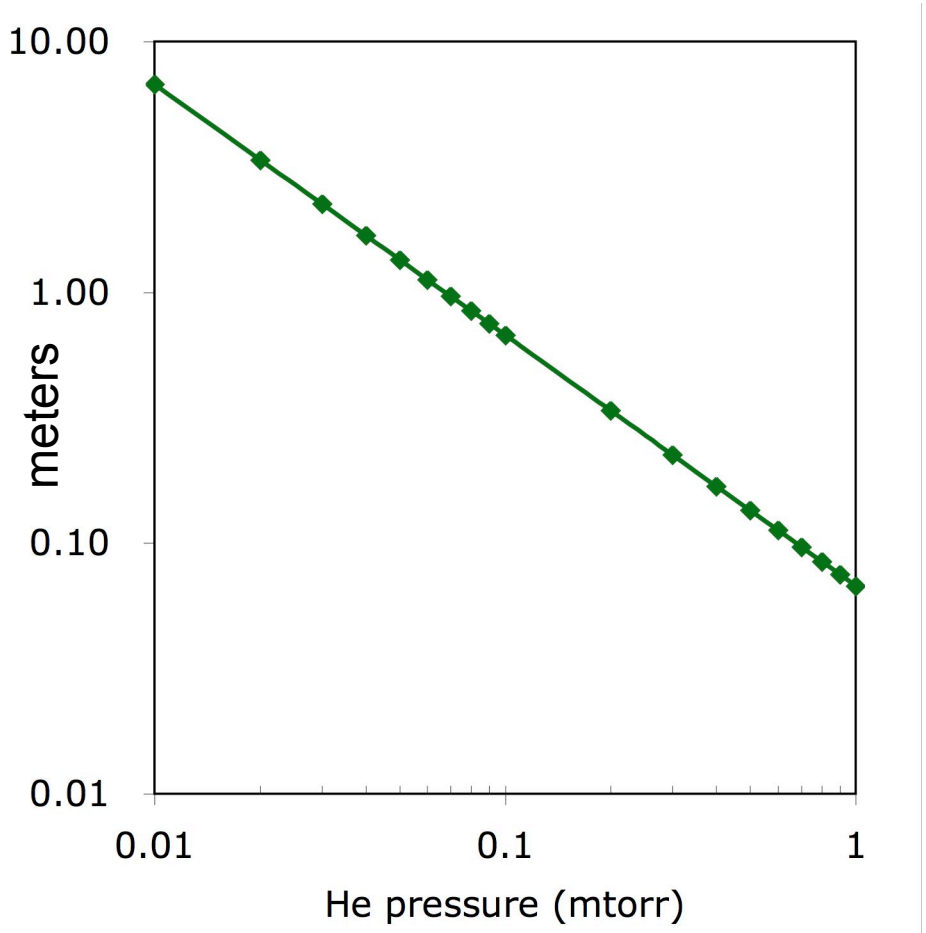
Motivation for XP1024:

- Tackles impurities at source on wall
- Asdex experience showed that carbon impurities were not reduced without complete W coating of C.
- Complete vessel coverage with a Li coating thicker than the erosion depth should, *by definition*, eliminate all non-Li influx.
- But need to control off-normal events that can remove Li coating and expose C and metals.

Li evaporation



Calculation of lithium deposition in NSTX lower vessel. Note Li poor coverage of centerstack shadow and some areas on passive plates. [L. Zakharov].



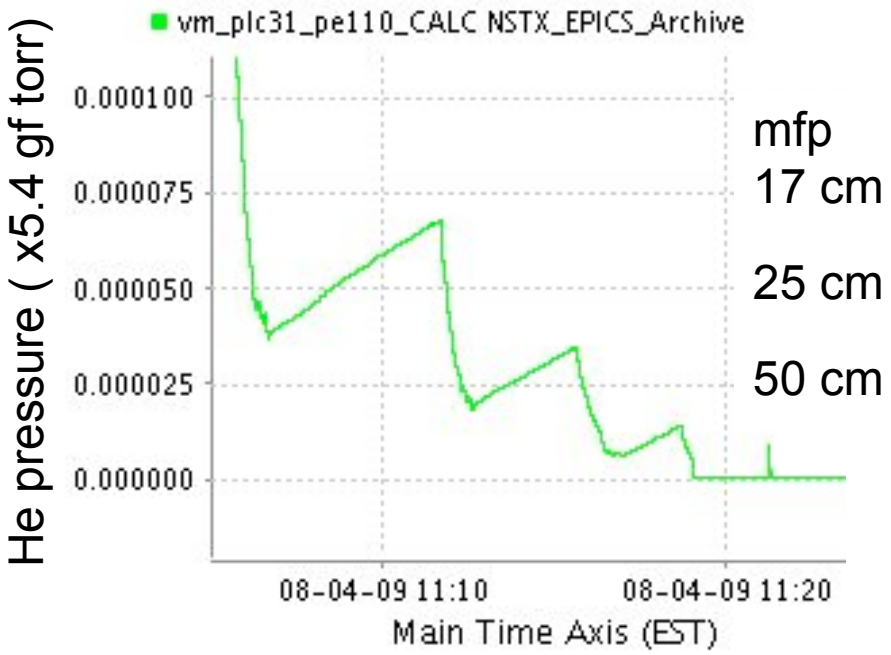
Mean free path of neutral lithium at 627 °C in helium gas at 27 °C
(J. Nucl. Mater., 390-391 (2009) 1005).

Li diffusion in He

Concept:

- Increase Li coverage of NSTX upper vessel wall by evaporating Li into low pressure helium.
- Adjust mean free path of Li in He by varying the helium pressure to produce a diffusive coating of the upper vessel, midplane and regions not in line-of-sight to LiTER.

Li diffusion in He (Aug 4, 2009)



Results from XP951 in 2009

Promising initial results June 11 '09:

- 134279: 187 mg Li no He
  134292: 183 mg Li with He.
- Fueling (gas+NB) 76↗ 88 torr-l

At 1.0 s:

- Same line electron density.
- Visible bremstrahlung Zeff ↘ 5%
- Rad power ↘ 20%
- Carbon Zeff (chers) ↘ 6%
- Zeff (metals) ↘ 33%

Mixed results Aug 4th 2009

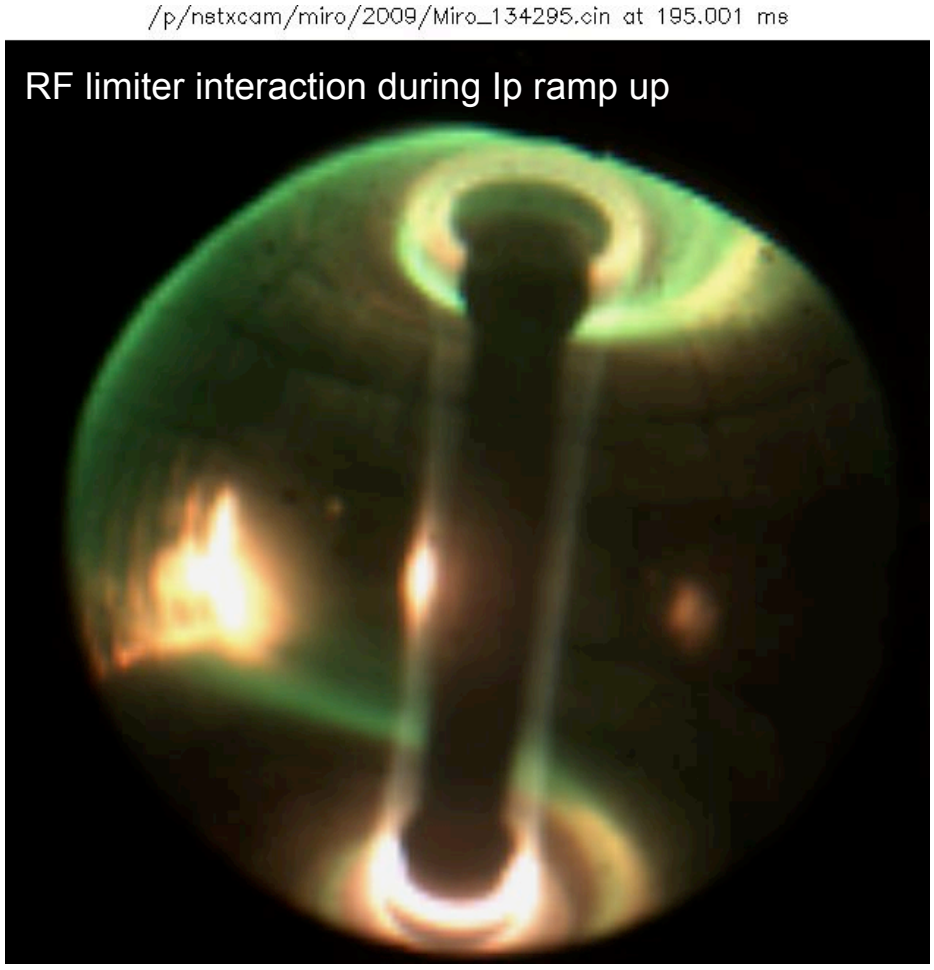
	no He	with He
• Li 'in Mach'	154 mg	↗ 1,212 mg
• Fueling (gas+NB)	82	↗ 134 torr-l

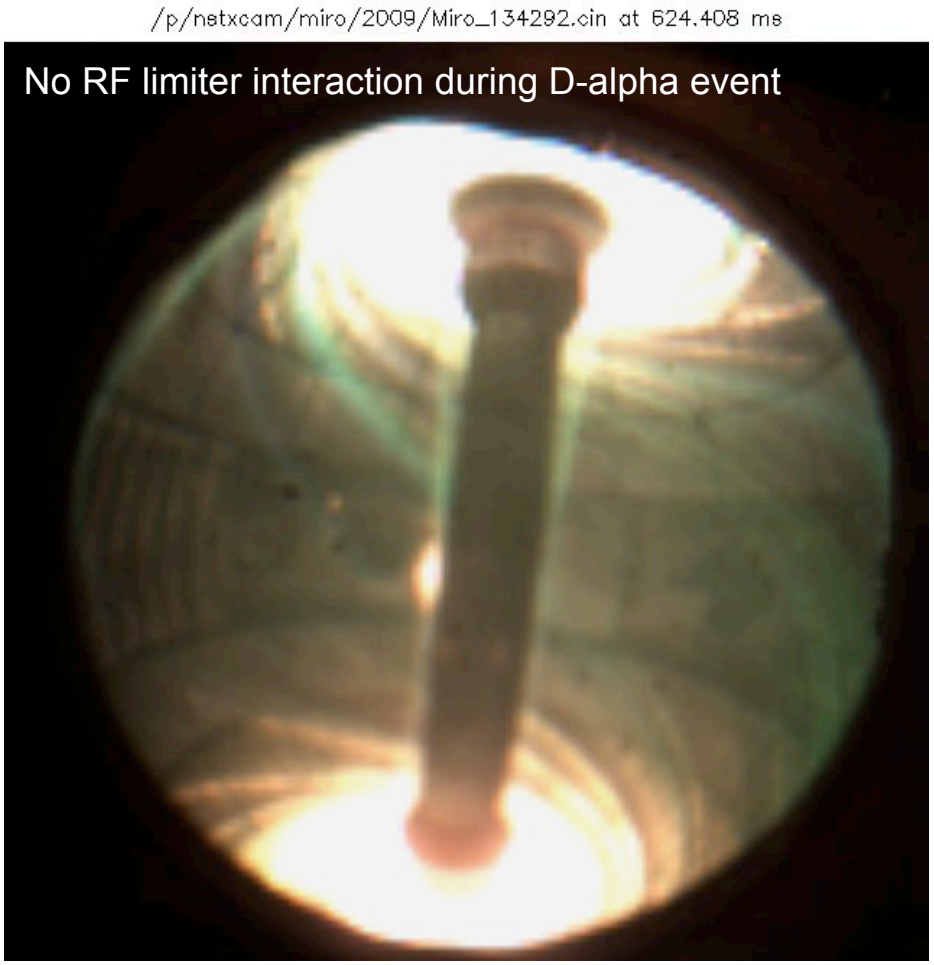
At 1.0 s:

- line electron density ↘ 12%
- Carbon Zeff (chers) ↘ 18%
  after event @ 0.76s
- Visible bremstrahlung Zeff ↗ 20%
- Rad power ↗ 5%
- Zeff (metals) ↗ 37%

Comparison to no-He case complicated by difference in D-alpha (ELM) behavior.

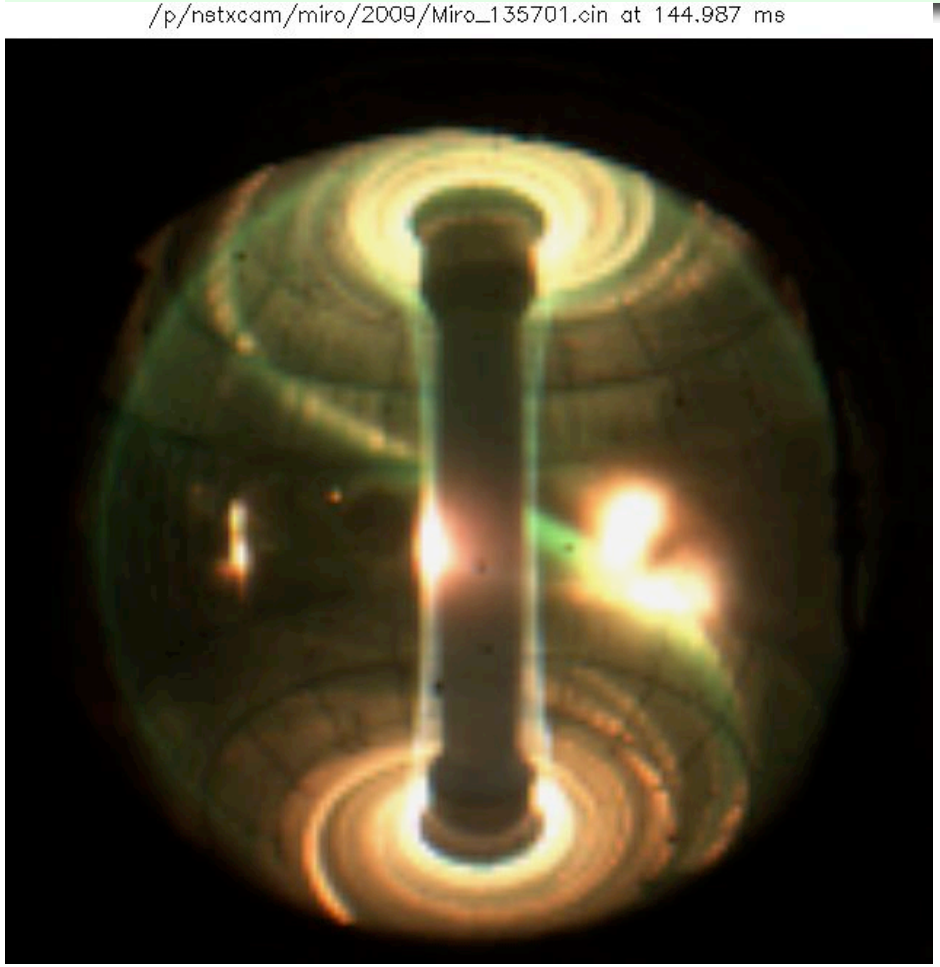
Jun 11th plasma-wall interactions

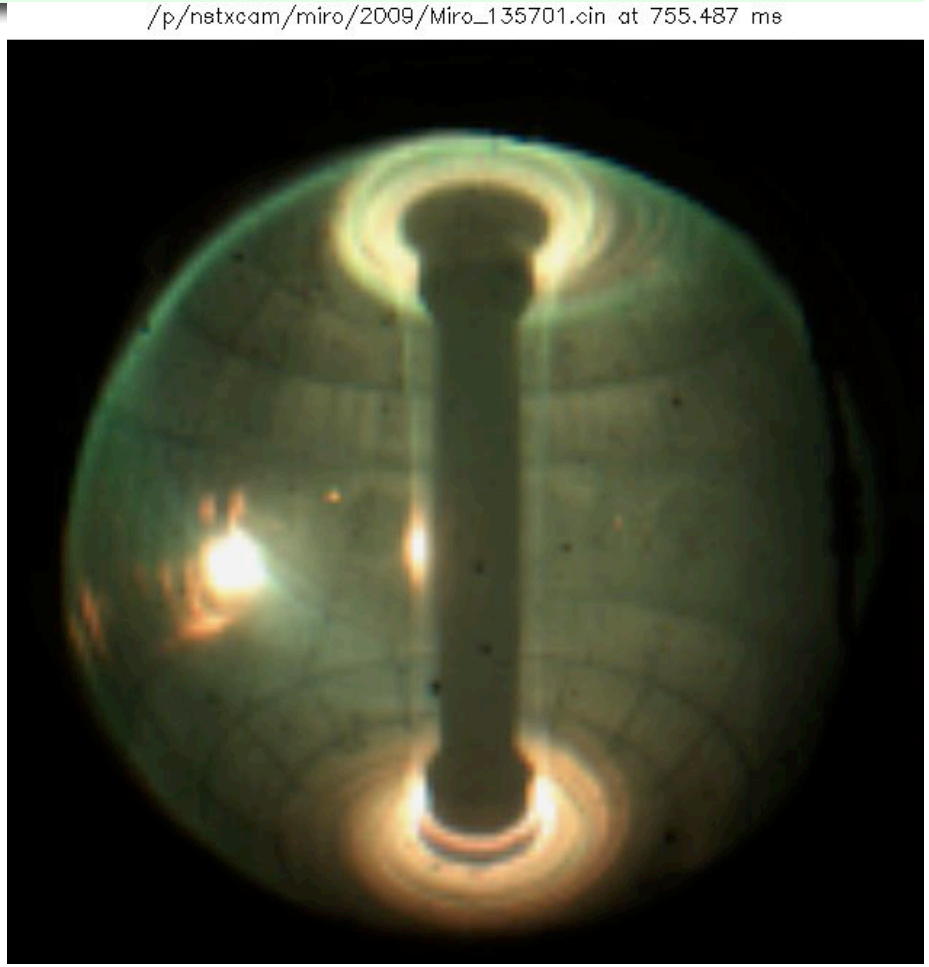




- Typically see RF limiter interaction with early 3 source NB (~130 ms) with- and without He but not during Ip flattop.
- See also event in 134292 @ 624 ms not due to RF limiter interaction.
- No consistent 'greening' of Miro image from LiII 5485Å line.

Aug 4th plasma-wall interactions



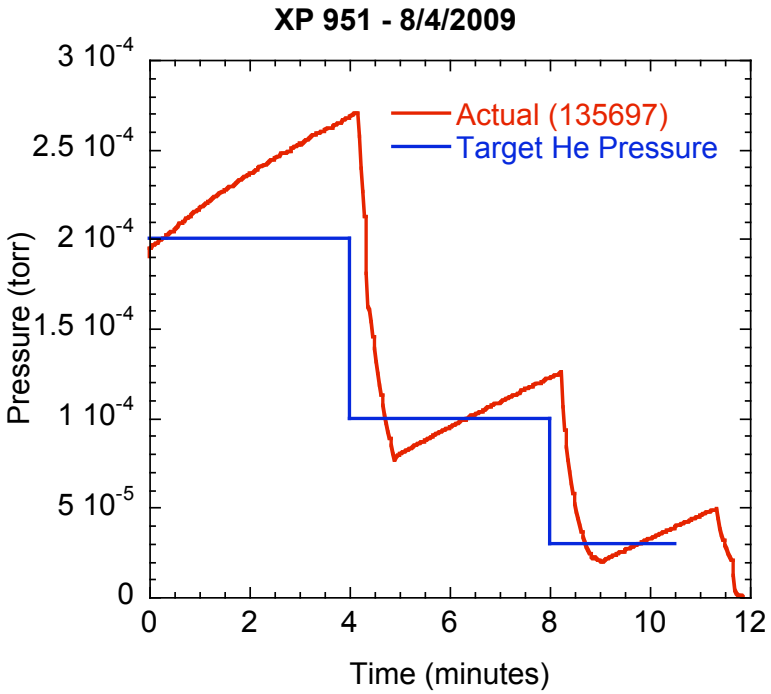


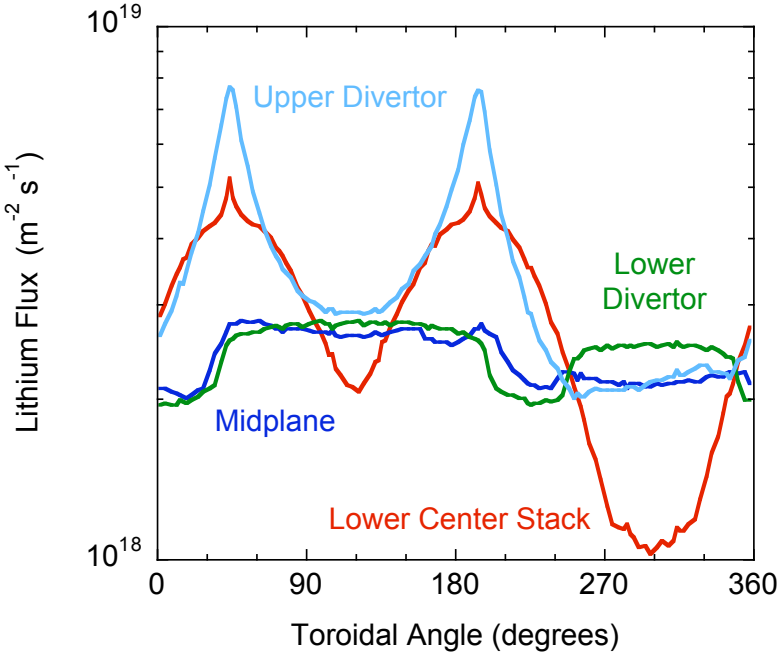
Strong interaction at Bay I @ 144 ms
Arcs …. ?

Strong interaction with RF limiter @ 755 ms.

Could Li lowered edge density increase beam ion loss and lead to more intense PMI that impeded attempt to reduce impurities ?

2009 helium pressure profile





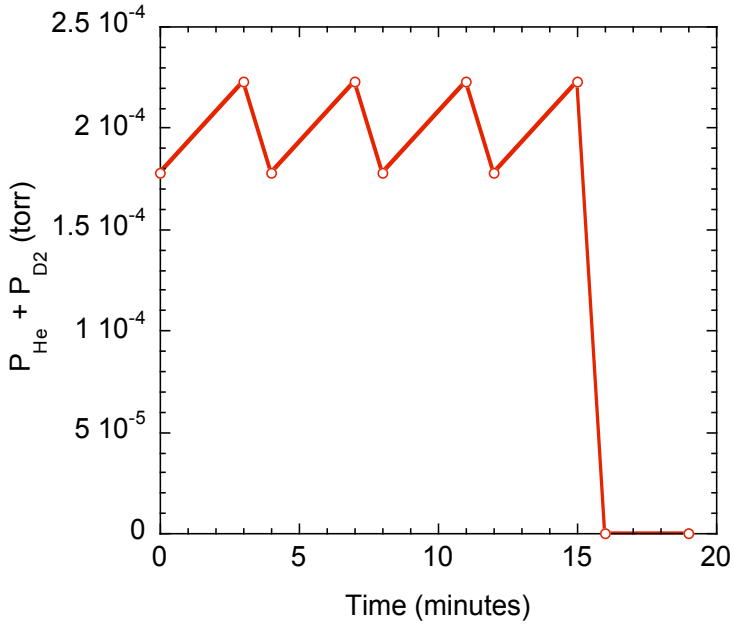
2009

- He pressures and relative intervals chosen to minimize toroidal nonuniformity,
- 8/4/09 implementation in Control Room complicated by:
  - Baratron problem
    - Pressure reconstructed from ion gauge IG110.
  - D_2 outgassing.

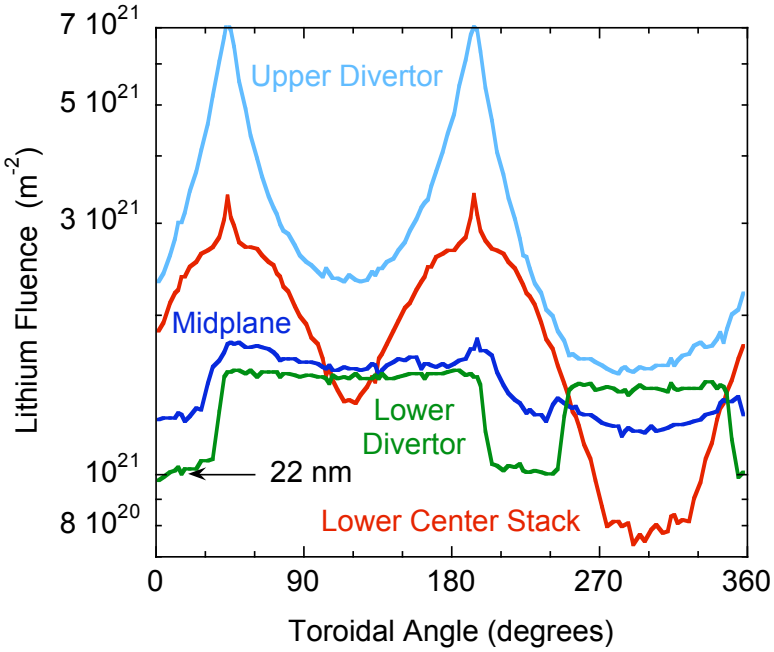
Considerations for 2010

- Renew divertor Li coverage each shot with 200 mg Li in vacuum.
- Coating > erosion depth
- Propose separate calibration XMP to benchmark MonteCarlo calculations: operate each LiTER into He separately - measure with Bay E top QMB

Revise He profile for 2010 to account for outgassing & obtain more uniform divertor coverage



16 min @ 0.2 mtorr / 3 min @ 0.0 mtorr; 60 mg/min



- Li + D_2 cross section similar to Li + He ⇒ use baratron total pressure.
- Outgassing rate estimated from XP-951.
- Include a vacuum evaporation using 200 mg ⇒ 3 min at 60 mg/min,
  - Corresponding fluence on most of lower divertor & CS ~10^{21} m^{-2}.
  - Obtaining similar deposition in shadowed regions ⇒ 16 min at 0.2 mtorr.
    - Divide into 4 intervals to counteract outgassing.
- Provides more than adequate coverage elsewhere:
  - D flux near midplane ~2 x 10^{20} m^{-2} s^{-1}.
  - Erosion over one shot @ 5% sputtering: 10^{19} m^{-2},
  - Li pumping of D: 2 x 10^{20} m^{-2}

FY10 plan:

- Minimize impurities and off-normal events by:
  - Increasing Ip from 0.93 in 2009 to 1.1 MA (per XP950)
  - ELM control ?
  - Improve plasma control ?
  - HFS or SGI fueling based on prior experience ?
  - Increase outer gap clearance ?
    - Some exposed in-vessel surfaces better covered this year.
  - Avoid 3rd NB source during ramp up to avoid lost beam ions ?
  - Aim for 800 ms flattop to reveal impurity rise.
    - *Help from ASC and Boundary groups appreciated…*
  - LLD unheated.
  - Benchmark Monte Carlo code with XMP.
  - Use revised He pressure vs. time profile to maintain Li on divertor.

Run time allotted: 0.75 d. First cut:

- 10 shots to develop quiescent discharge, 200 mg LiTER in vac., LLD unheated.
- 10 shots with He profile. Vary Li, vary fueling, tweak plasma control…

Diagnostics, Analysis, XMP:

Key Diagnostics:

- Spectroscopy
- Fast cameras
- VB - chord Zeff
- CHERS - carbon Zeff
- Bolometry - metals Zeff
- QMBs
- 0.1 torr Baratron

Analysis:

- Identify impurity sources and locations: Fe, Mo, C…
- Identify cause of PMI events - ELMS or MHD or …. ?
- MIST modeling of impurity transport ?
- UEDGE, WallPSI ?

XMP:

- Benchmark MonteCarlo calculations by evaporating Li into helium from one LiTER at a time.
- XMP needs LiTER + Vac operators - no plasmas