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XP1134: Comparison of Diverted Plasmas Incident on Lithiated LLD, Molybdenum, and Graphite Surfaces

For Research Milestone R(12-1) and NSTX-U Planning

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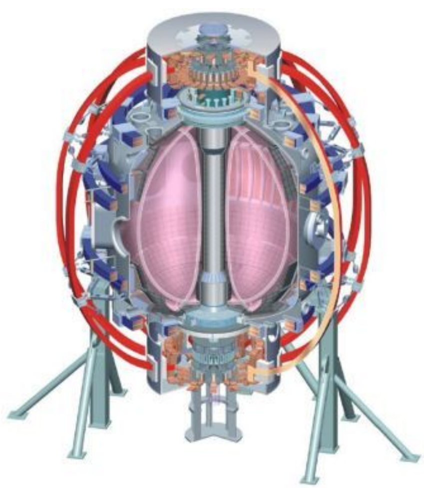
LRTSG

May 24, 2011



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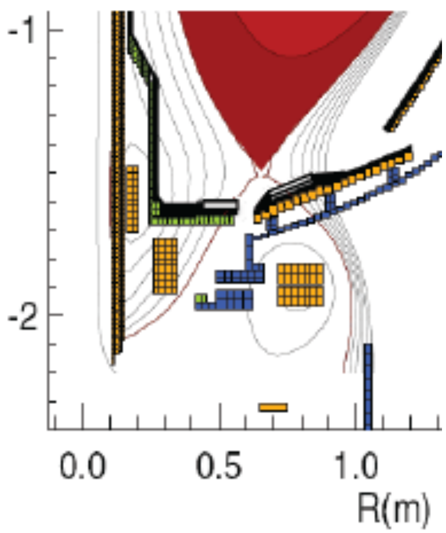
Goals

- Comparison of diverted plasmas incident on lithiated -LLD, -molybdenum tile, and -graphite tile surfaces

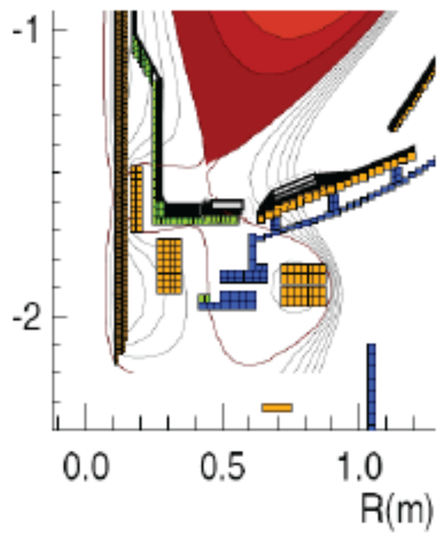
- Resolution of LLD 2010 open issues for completion of analysis
  - described in IAEA2010, ISFA2011 papers,
  - referred to in following slides

Early in the Run, with Impurity-free LLD, with Constant Fueling, and Minimal but Sufficient LITER for ELM-free H-modes: *XP to Compare 4 LSN Plasmas Incident on Lithiated –LLD, -Molybdenum and -Graphite Divertor*

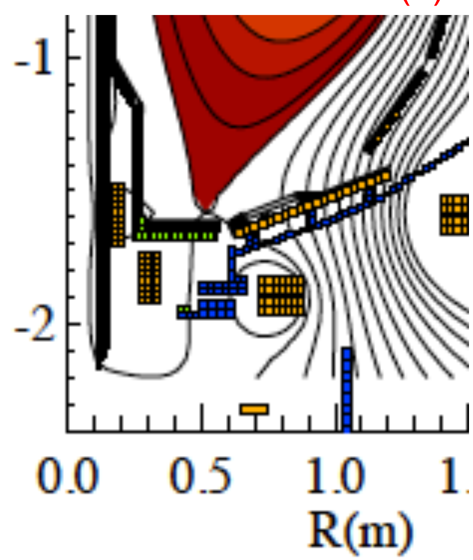
1. LSN SP on Mo-LLD and Mo (IBD-tile)
REF: 142505 (16)



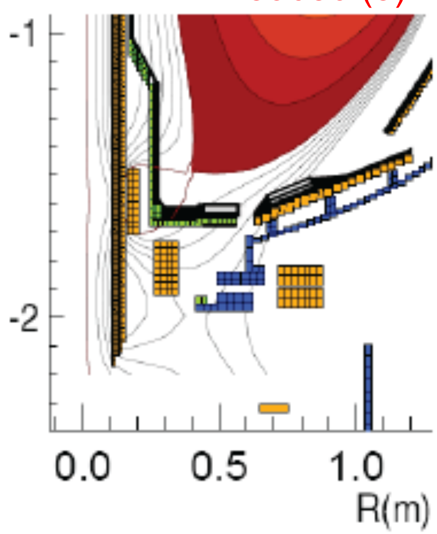
2.OBSP Mo-tile, IBSP on ATJ
REF: 139571 (10)



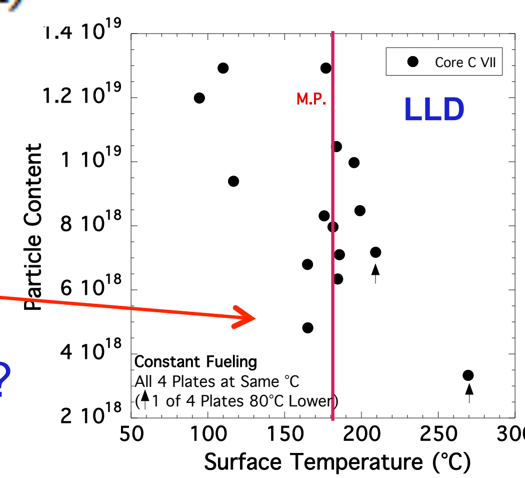
3.Snowflake-minus OBSP on Mo tile
REF: 139497 (3)



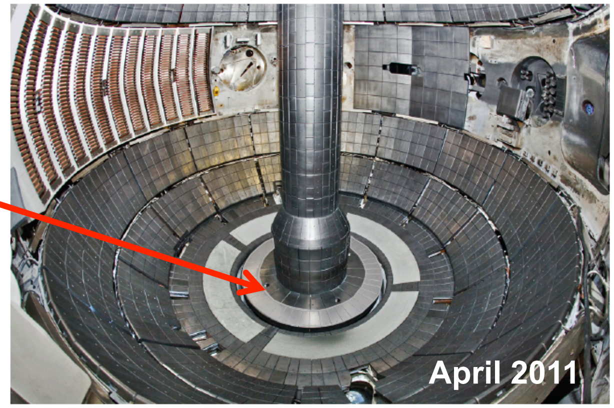
4.Standard IBD SPs on ATJ
REF: 139630 (3)



- Immediate Deliverables:
  - How does core D^+ change?
  - How does electron density rate of rise change?
  - How does core C^{6+} change?
  - How do the edge C source terms change, Prad?
  - How do edge conditions (ELMs, quiescence) change?
  - How does SGI tau p* change?

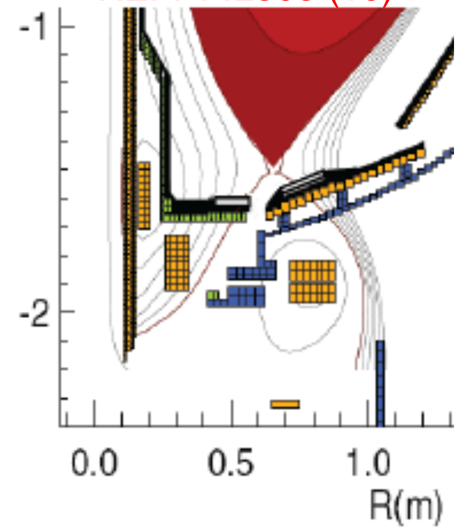


Day-1 (16 shots) : Begin with Both LSN Strike Points on Lithiated -LLD and -Mo (IBD-tile)

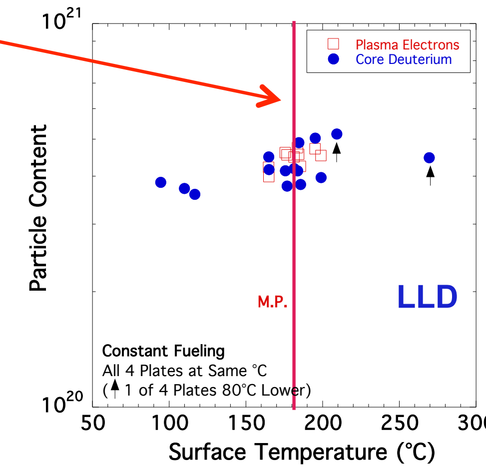


1. Both LSN SPs on Mo-LLD and Mo (IBD-tile)

REF: 142505 (16)

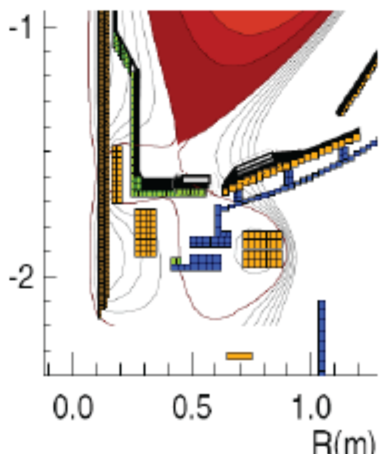


- Day-1 Measurement Plan (16 shots)
  - Early in Run, LITER 20 mg/min, constant fueling
  - Let LLD plasma auto-heat 10°C per shot
  - SGI for selected tau p* measurements
  - As FF transitions through Li melting (180°C) measure:
    - Waveform of Core D and C^{6+} particle content
    - Electron density rate of rise
    - Li, CII, OII, Mo, Prad waveforms
    - Fast IR front face temperature waveforms
    - LP array and edge turbulence measurements
    - ELM characteristics
    - Global wall pumping characteristics

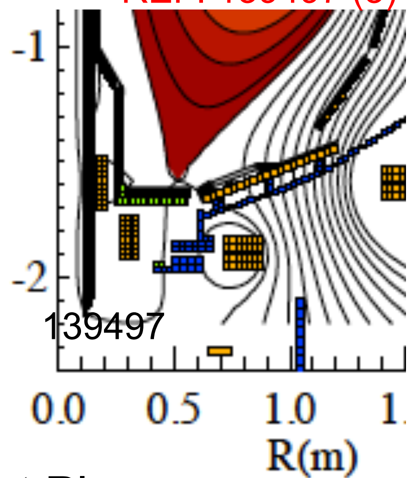


Day-1 (cont.): Move Strike Points Inward and Repeat
(while LLD cools down and LLD Li solidifies)

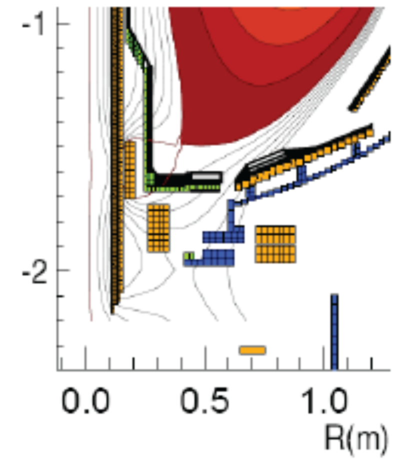
2.OBSP Mo-tile, IBSP on ATJ
REF: 139571 (10)



3.Snowflake-minus OBSP on Mo tile
REF: 139497 (3)



4.Standard IBD SPs on ATJ
REF: 139630 (3)



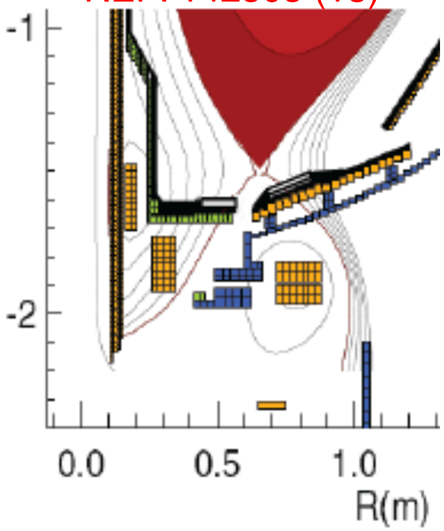
- Day-1 (cont.) Measurement Plan
  - Early in Run, LITER 20 mg/min, constant fueling
    - Waveform of Core D and C^{6+} particle content
    - Electron density rate of rise
    - Li, CII, CIII, OII, Prad waveforms
    - Fast IR front face temperature waveforms
    - LP array and edge turbulence measurements
    - ELM characteristics
    - Global wall pumping characteristics

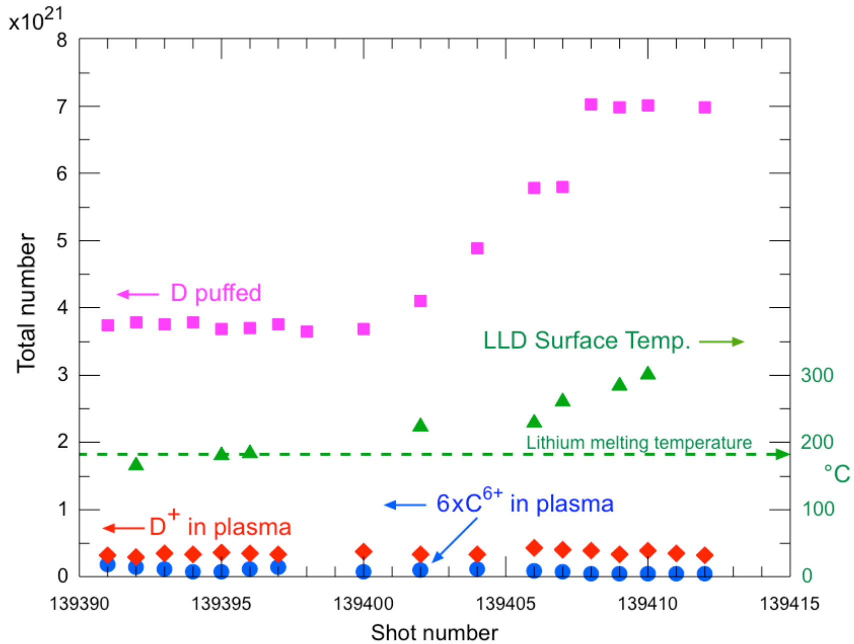
Day-1.5 (16 shots): Strike Points on Lithiated -LLD and –Mo

Goal: Resolve the Fueling Pathways

1. Both LSN SPs on Mo-LLD and Mo (IBD-tile)

REF: 142505 (18)





• The difference between the deuterium gas input and the plasma deuteron content reached very high values in this experiment without disrupting the plasma, but there was little change the plasma deuterium content.

• This suggests that the added deuterium, after becoming ionized in the scrape-off layer flowed to the divertor and was absorbed by the liquid lithium rather than recycling and eventually increasing the plasma density.

• But this is not definitive because the cooling the LLD to the lithium solidification temperature to allow the solid lithium to saturate and restore deuterium recycling was not performed.

Summary of Questions to Be Investigated by this XP as D OSP is Diverted from Lithiated Mo to Lithiated Graphite

- How does the core D content change as the divertor substrate is changed?
- How does the core C^{6+} content change as the carbon sputtering term is changed?
- How much of the electron density rate of rise is due to the divertor sputtering source?
- How do Li, CII, CIII, OII, Mo, Prad waveforms vary during the discharge as the surface heats?
- How do the Fast IR front face temperature waveforms change for the different lithiated substrates?
- Under quiescent $D\alpha$ conditions, can local recycling coefficients be measured using LP array Isat/$D\alpha$ ratios?
- How do ELM stability characteristics change as sputtering and edge fueling change?
- How do the global wall pumping characteristics change as the lithiated substrate changes?

Prerequisites

1. LITER-F and K able to evaporate at 5-20mg/min.
2. The 2-color IR camera monitoring LLD Tsurf using previous calibrations if necessary to provide between discharge measurements.
3. The slow IR camera using the previous 2-color and other calibrations to provide between discharge measurements.
4. The LLD viewing 1D-CCD-Dα and 1D-CCD-Li cameras operating for radial and time dependent documentation.
5. The LLD viewing fast cameras operating with carbon and oxygen filters operating for radial and time dependent documentation.
6. The DIMS spectrometer shall be centered on the oxygen and carbon luminosities for impurity time dependent documentation.
7. ZEUS, LOEUS, SPRED, JHU, and Fiberscope systems operating and monitoring metals.
8. Apply 10 ms SGI pulses for Tau p* measurements as requested.

XP1134 Shot Sequence

Day-1

Run Day	Shot No.	Estimated Bulk T°C	Estimated FF T°C	ISP	OSP	Fueling
1	1	35		Mo (50cm)	LLD (77cm)	constant
1	2	45		Mo (50cm)	LLD (77cm)	constant
1	3	55	166	Mo (50cm)	LLD (77cm)	constant
1	4	65		Mo (50cm)	LLD (77cm)	constant
1	5	75	181	Mo (50cm)	LLD (77cm)	constant
1	6	85	224	Mo (50cm)	LLD (77cm)	constant
1	7	95	261	Mo (50cm)	LLD (77cm)	constant
1	8	105	301	Mo (50cm)	LLD (77cm)	constant
1	9	115		Mo (50cm)	LLD (77cm)	constant
1	10	125		Mo (50cm)	LLD (77cm)	constant
1	11	135		Mo (50cm)	LLD (77cm)	constant
1	12	145		Mo (50cm)	LLD (77cm)	constant
1	13	155		Mo (50cm)	LLD (77cm)	constant
1	14	165		Mo (50cm)	LLD (77cm)	constant
1	15	175		Mo (50cm)	LLD (77cm)	constant
1	16	185		Mo (50cm)	LLD (77cm)	constant
1	17			ATJ	Mo(50cm)	constant
1	18			ATJ	Mo(50cm)	constant
1	19			ATJ	Mo(50cm)	constant
1	20			ATJ	Mo(50cm)	constant
1	21			ATJ	Mo(50cm)	constant
1	22			ATJ	Mo(50cm)	constant
1	23			ATJ	Mo(50cm)	constant
1	24			ATJ	Mo(50cm)	constant
1	25			ATJ	Mo(50cm)	constant
1	26			ATJ	Mo(50cm)	constant
1	27			Snowflake-	Mo(50cm)	constant
1	28			Snowflake-	Mo(50cm)	constant
1	29			Snowflake-	Mo(50cm)	constant
1	30			AJT	ATJ	constant
1	31			AJT	ATJ	constant
1	32			ATJ	ATJ	constant

Day-1.5

Run Day	Shot No.	Estimated Bulk T°C	Estimated FF T°C	ISP	OSP	Fueling
1.5	1	35		LLD (77cm)	LLD (77cm)	increase
1.5	2	45		LLD (77cm)	LLD (77cm)	increase
1.5	3	55	166	LLD (77cm)	LLD (77cm)	increase
1.5	4	65		LLD (77cm)	LLD (77cm)	increase
1.5	5	75	181	LLD (77cm)	LLD (77cm)	increase
1.5	6	85	224	LLD (77cm)	LLD (77cm)	increase
1.5	7	95	261	LLD (77cm)	LLD (77cm)	increase
1.5	8	105	301	LLD (77cm)	LLD (77cm)	increase
1.5	9	115		LLD (77cm)	LLD (77cm)	increase
1.5	10	125		LLD (77cm)	LLD (77cm)	increase
1.5	11	135		LLD (77cm)	LLD (77cm)	increase
1.5	12	145		LLD (77cm)	LLD (77cm)	increase
1.5	13	155		LLD (77cm)	LLD (77cm)	increase
1.5	14	165		LLD (77cm)	LLD (77cm)	increase
1.5	15	175		LLD (77cm)	LLD (77cm)	increase
1.5	16	185		LLD (77cm)	LLD (77cm)	increase

Options for this afternoon time slot:

- include 3 shots of X-point fueling (how does the above plasma response change versus fueling location)
- or, revisit above issues
- or, start other inboard XP

After LLD Cooldown and Lithium Solidifies

After cool	17	55	166	LLD (77cm)	LLD (77cm)	Ibid #16
	18	65		LLD (77cm)	LLD (77cm)	Ibid #16
	19	75	181	LLD (77cm)	LLD (77cm)	Ibid #16

Backup

2010 Lithium Results Summary

- Early work by McCracken, Erents, and others found fast deuterium retention in clean solid lithium and liquid lithium to be close to unity *for a clean lithium surface*.
- Results from laboratory studies after TFTR and NSTX 2006-2009 for solid Li on graphite, suggested that the retention of D in solid NSTX Li might be limited to less than unity due to: (1) Li intercalation in graphite, (2) Li interactions with impurities in graphite, (3) Li reactions with vacuum gases, and (4) D saturation of the Li, surface layers, *and that probably liquid Li would provide more retention for longer durations.*

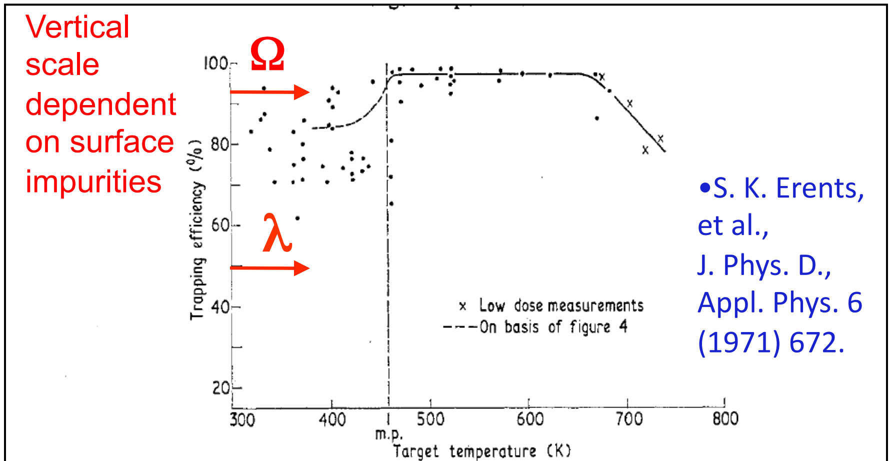


Figure 3. Trapping efficiency of lithium for 18 keV deuterons as a function of temperature for constant dose of 5×10^{17} ions/cm^2.

- However, the 2010 LLD results based on the <u>required fueling for stable discharges</u> imply comparable solid and liquid Li pumping under NSTX conditions.
- Question: In NSTX, are the 2010 D retention percentages in solid Li and liquid Li both near unity (Ω), or both much less than unity (λ)?