Princeton Plasma Physics Laboratory

NSTX-U Experimental Proposal

Title: **Correlation of SOL turbulence with SOL heat flux width**		
OP-XP-1514	Revision:	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: TK Gray	Date
SG, TSG or TF Leader (assigned by RC): V Soukhanovskii	Date
Run Coordinator (RC): J Menard	Date
Responsible Division: Experimental Research Operations	

RESTRICTIONS or MINOR MODIFICATIONS

(Approved by Experimental Research Operations)

NSTX- EXPERIMENTAL PROPOSAL

TITLE: **Correlation of SOL turbulence with SOL heat flux width** No. **OP-XP-1514**

AUTHORS: **TK Gray, S Zweben** DATE:

1. Overview of planned experiment

The goal in this experiment is to measure the reduction in scrape-off layer (SOL) width observed with the addition of lithium and correlate that with measurements of SOL turbulence at the midplane and in the divertor as a function of increasing injected beam power.

2. Theoretical/ empirical justification

The use of lithium wall conditioning in NSTX resulted in a reduction of SOL width, λ_q as measured by divertor infrared (IR) cameras. Modeling performed by the Lodestar group suggests this contraction is due to reduced interchange turbulence, which is brought about because of the reduced pedestal density gradient that occurs with the addition of lithium. This experiment seeks to correlate SOL turbulence as measured by Gas Puff Imaging (GPI), Beam Emission Spectroscopy (BES) and Reflectometry at midplane with Langmuir probes and visible imaging, both tangential and perpendicular, in the divertor as the turbulence is expected to decrease with the addition of lithium and repeat at several injected beam powers.

3. Experimental run plan

If the XMP "High-Z reference discharge development" is successful in developing a medium triangularity discharge that can maintain the outer strike point at a given radius on the outboard divertor target, then the preference for this experiment is to run in medium triangularity in the "High-Z Reference Discharge" to take advantage of the increased divertor Langmuir probe coverage on the outboard target. The outer strike point should be positioned near the Langmuir probe at r = 0.7 m. Otherwise, the NSTX-U fiducial high triangularity discharge shape will be used.

This proposal is separated into two parts. The first part using minimal Li wall conditioning with evaporation rates between 10 – 50 mg of Li and the injected power is increased from low to high power. The second part of the proposal repeats the scan of injected power but substantially increases the amount of pre-discharge Li evaporation to ~ 300 mg. The actual amount of Li evaporation used will depend on the machine conditions on the day of experiment. Likewise,

<u>Part 1</u>

1. Establish low P_{NBI} discharge with little to no pre-discharge Li evaporation (10 – 50 mg) and the following discharge characteristics (1 shot):
    a. I_p = 0.9 MA, B_T = 0.45 T

b. I_p and B_t may be altered according to Table 3 if machine and administrative limits allow at the time of the experiment.

c. No Midplane GPI puffing

2. Repeat this low power, low Li discharge for repeatability and to obtain GPI data (1 shot).

   a. Midplane GPI puffing at t = XXX

3. Increase beam power to the pre-defined medium power with low Li evaporation and take 2 shots at these conditions (2 shots)

   a. Maintain GPI puffing on the 2nd shot and follow the same timing as step 2 and follow for all subsequent shots.

4. Increase beam power to the pre-defined high power with low Li evaporation and take 2 shots at these conditions (2 shots)

5. Increase beam power to the pre-defined highest power with low Li evaporation and take 2 shots at these conditions (2 shots)

Part 2

6. Repeats steps 1 – 4 with a large amount (~ 300 mg) of pre-discharge Li evaporation (8 – 10 shots)

   a. Allow 2 – 4 shots to adjust centerstack fueling when the Li evaporation is first increased

   b. At the highest beam powers, disruptions due to β_N limits are likely and should be reserved for the end of the day or contingency

Table 1 describes the matrix of desired shots for this proposal with 4 left as contingency to adjust center stack fueling and to achieve the highest power discharges when greater amounts of Li evaporation is begun.

Table 1: Proposed Shot Matrix

	Li evaporation	
P_{NBI} (MW)	**Low (10-50 mg)**	**High (300 mg)**
Low Power	2	2 - 4
Medium Power	2	2
High Power	2	2
Highest Power	2	2?

4. Required machine, NBI, RF, CHI and diagnostic capabilities

Needed XMPs: High-Z reference discharge development, CHERS Assessment, Commission ISOFLUX and rtEFIT
Needed XPs: “Controlled introduction of Lithium into NSTX-U” (1529)
Desired, but not necessary XPs: “Investigating small-scale edge turbulence with GPI”

Error! Reference source not found. lists the state of various diagnostics that will be used during the experiment. Diagnostics such a Thomson Scattering, visible cameras, IR cameras and all other diagnostics listed in the diagnostic checklist but not listed in **Error! Reference source not found.** are expected to be available on every shot.

Table 2: Diagnostics status for each part of the experiment. Diagnostics not listed, but listed as needed, are assumed to be available on every shot.

Shot	P_{NBI}	CHERS	GPI	SOL Refl.	Probes
1	Low	X		Swept	Swept
2	Low		X	Fixed Freq.	i_{sat}
3	Medium	X		Swept	Swept
4	Medium		X	Fixed Freq.	i_{sat}
5	High	X		Swept	Swept
6	High		X	Fixed Freq.	i_{sat}
7	Highest	X		Swept	Swept
8	Highest		X	Fixed Freq.	i_{sat}

GPI requires a ratio of I_p (MA) / B_T (T) = 2 for optimal viewing. Table 3 is a list of viable I_p and B_T combinations to optimize the GPI view. The XP title, "Investigating small-scale edge turbulence with GPI" will seek to optimize view in NSTX-U. During operation of NSTX, GPI was typically operated with I_p = 0.9 MA and B_T = 0.45 T. While this is still an option in NSTX-U, machine and administrative conditions allowing, I_p and B_t may be increased up to 1.5 MA and 0.75 T respectively.

Table 3: Viable I_p and B_T for optimal GPI view.

I_p (MA)	B_T (T)
0.9	0.45
1.1	0.55
1.3	0.65
1.5	0.75

5. Planned analysis

EFIT, SOLT, XGC1 and SOLPS

6. Planned publication of results

Results allowing, this will be published at the next PSI and IAEA meetings.

7. Estimated Neutron Production

Based on the number of shots, plasma current levels, and expected durations, estimate the maximum neutron production of this experiment. See calculator in Appendix #2 for this calculation.

# of Shots used in Estimate: 18 Estimated Total Neutron Production: 7.2E15 – 1.44E16*

*Assuming 1 – 2 second discharges at 1.1 MA

PHYSICS OPERATIONS REQUEST

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Brief description of the most important operational plasma conditions required and any special hardware requirement:

Previous shot(s) which can be repeated:

Previous shot(s) which can be modified:

Machine conditions *(specify **ranges** as appropriate, strike out inapplicable cases)*

B_T Range (T): **0.45** Flattop Duration (s): **1 sec**

I_P Range (MA): **0.9** Flattop Duration (s): **1 sec**

Configuration: **LSN, drsep <= -10 mm**

Equilibrium Control: **Outer gap / Isoflux** (rtEFIT) **/ Strike-point control** (rtEFIT)

Outer gap (m): **10 cm** Inner gap (m): Z position (m):

Elongation: **2.2** Triangularity (U/L): **0.5-0.6** OSP radius (m): **0.7**

Gas Species: **D** Injector(s):

NBI Species: **D** Heating Duration (s):

Voltage (kV) 50 cm (1C): 90 60 cm (1B): 90 70 cm (1A): 90

Voltage (kV) 110 cm (2C): 90 120 cm (2B): 0-90 130 cm (2A):

ICRF Power (MW): **0** Phase between straps (°): Duration (s):

CHI: **Off** Bank capacitance (mF):

LITERs: On Total deposition rate (mg/min) or dose per discharge (mg): **Varies. See run plan for Li deposition amounts for each discharge.**

EFC coils: Off

DIAGNOSTIC CHECKLIST [1]

TITLE: **SOL Turbulence** No. **OP-XP-1514**

AUTHORS: DATE:

Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
Beam Emission Spectroscopy	✓	
Bolometer – midplane array	✓	
CHERS – poloidal		✓
CHERS – toroidal	✓	
Divertor Bolometer (LADA)		
Divertor visible cameras	✓	
Dust detector		
Edge deposition monitors [2]		
Edge neutral density diag.		✓
Edge MIGs [2]		
Penning Gauges [2]		
Edge rotation diagnostic		✓
Fast cameras – divertor [2]	✓	
Fast ion D_alpha - poloidal		
Fast ion D_alpha - toroidal		
Fast lost ion probes - IFLIP		
Fast lost ion probes - SFLIP		
Filterscopes [2]		✓
FIReTIP		
Gas puff imaging – divertor		
Gas puff imaging – midplane	✓	
Hα cameras - 1D [2]	✓	
Infrared cameras [2]	✓	
Langmuir probes – divertor	✓	
Langmuir probes – RF		
Langmuir probes – RF ant.		✓
Magnetics – Diamagnetism		
Magnetics – Halo currents		
Magnetics – RWM sensors		

Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
MAPP		
Mirnov coils – high f.		
Mirnov coils – toroidal array		
MSE-CIF		
MSE-LIF		
Neutron detectors [2]		
Plasma TV		
Reflectometer – 65GHz		✓
Reflectometer – correlation		✓
Reflectometer – FM/CW		✓
Reflectometer – fixed f	✓	
Reflectometer – SOL	✓	
SSNPA [2]		
RF edge probes		
Spectrometer – divertor		✓
Spectrometer – MonaLisa		
Spectrometer – VIPS		✓
Spectrometer – LOWEUS		
Spectrometer – XEUS		
TAE Antenna		
Thomson scattering	✓	
USXR – pol. Arrays		
USXR – multi-energy		
USXR – TG spectr.		
Visible Brems. det. [2]		

Notes:

[1] Check marks in this table do not guarantee diagnostic availability. Check with diagnostic physicists or research operations management to ensure diagnostic coverage.

[2] In some cases, a given line represents multiple diagnostics. For instance, there are multiple SSNPAs, multiple IR cameras, multiple neutron detectors, and multiple Langmuir probe arrays.

Appendix #1: Allowed Neutral Beam Power vs. Pulse Duration

Heating of the primary energy ion dump limits the beam duration to that given in the following table[1]:

Acceleration Voltage [kV]	MW per Source	MW per Beamline	Pulse Length [s]
65	1.1	3.2	8
70	1.3	3.8	7
75	1.5	4.5	6
80	1.7	5.1	5
85	1.9	5.8	4
90	2.1	6.4	3
95	2.4	7.1	2
100	2.6	7.7	1.5
105	2.8	8.4	1.25
110	3.0	9.0	1

Table A1: Beam power and pulse length as a function of acceleration voltage

Appendix #2: Table for neutron rate estimations:

Change only the blue cells					
I_p Range [kA]	Center of I_p Range [kA]	Number of Discharges	Typical Discharge Time [s]	Assumed Neutron Rate [N/s]	Fluence at this I_p [N]
$0<I_p\leq400$	200	0	0	0.00E+00	0.00E+00
$400<I_p\leq600$	500	0	0	1.00E+14	0.00E+00
$600<I_p\leq800$	700	0	0	2.00E+14	0.00E+00
$800<I_p\leq1000$	900	0	0	3.00E+14	0.00E+00
$1000<I_p\leq1200$	1100	18	2	4.00E+14	1.44E+16
$1200<I_p\leq1400$	1300	0	0	5.00E+14	0.00E+00
$1400<I_p\leq1600$	1500	0	0	8.00E+14	0.00E+00
$1600<I_p\leq1800$	1700	0	0	1.30E+15	0.00E+00
$1800<I_p\leq2000$	1900	0	0	2.00E+15	0.00E+00
Total # of Discharges		18	Total Fluence		1.44E+16

Table A2: Neutron Emission Rate Calculator. Double click to open in excel for automatic calculation. Change only the blue cells.

[1] J.E. Menard, et al., Nuclear Fusion **52**, 2012 (83015)