Princeton Plasma Physics Laboratory
NSTX-U Experimental Proposal

Title: **Ip/Bt scaling**		
OP-XP-	Revision:	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: S.M. Kaye, J. Berkery, M. Podesta, …………	Date **3/2/15**
SG, TSG or TF Leader (assigned by RC): W. Guttenfelder	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: **Ip/Bt scaling** No. **OP-XP-**
AUTHORS: **Kaye et al.** DATE: **3/2/15**

---

1. Overview of planned experiment

The goal of this XP is to perform Ip/Bt scans in NSTX-U boronized and lithiated H-mode plasmas. This is a multi-TSG XP whose objective is to see how confinement and transport, pedestal characteristics, divertor characteristics and stability are impacted by changing plasma current and toroidal field. Scans will be performed that include plasma current variation at fixed toroidal field, toroidal field variation at fixed plasma current, and finally, a coupled current and field scan (at fixed Ip/Bt), which can result in a large variation in collisionality at relatively constant beta and rhostar. The experiment will be performed during the boronized phase of NSTX-U operation, as well as repeated later on with lithium wall conditioning. The first part of the scans will cover Ip and Bt parameter space that generally overlap with that from NSTX, giving a direct connection back to NSTX to assess differences due to differences in aspect ratio. In order to compare directly to NSTX results, this XP will by run at fixed injected power (4 MW) using only the 1A and 1B beam sources. Other XPs will explore power scans and other combinations of beam sources. During the later stage of first-year NSTX-U operation, the current and field scans will be extended up to the maximum first year targets as facility operations allow. The discharges from this XP will be used by a number of TSGs, as mentioned above.

2. Theoretical/ empirical justification

In NSTX, it was found that the scaling of confinement and transport with Ip and Bt differed in boronized and lithiated plasmas. The former showed strong field and weak current dependences, while the scaling in the latter was well described by the ITER98y,2 scaling (strong current, weak field). The two seemingly contradictory scalings could be reconciled through studying the collisionality dependence, which pulled both datasets together. The collisionality scaling was strong, with normalized confinement increasing almost inverse linearly with collisionality (i.e., a strong increase in normalized confinement with decreasing collisionality). This would have positive ramifications for future, FSNF-scale devices. It is the purpose of this XP to explore the Ip/Bt scalings and to assess whether the collisionality scaling remains strong or starts to weaken at the lower collisionalities accessible on NSTX-U. The sources of transport in both the electron and ion channel will be explored as well. Specifically for electrons, will microtearing, ETG, TEM, KBM be important for controlling electron transport, and in which regimes? For ions, will the ions remain at the neoclassical level, or will they become more anomalous due to low-k and/or KBM turbulence as collisionality is reduced? Other issues will be addressed by the other TSGs. This XP addresses directly the R15-1 research milestone.

3. Experimental run plan

The experimental plan will cover Ip and Bt ranges in the matrix given below. The numbers in the boxes indicate the priority order in the shot plan. It is envisioned that the bottom row plasma current scan to 1.6 MA (at 0.75 T) will be performed later in the run, when these field and current values will be allowed. This will no doubt occur in lithiated plasmas. The scans up to 0.65 T and 1.3 MA will be performed in both boronized and lithiated plasmas. A list view of the shot plan is given below table (in the list view, the shots typed in red indicate the diagonal of the table, which would serve as the collisionality scan at fixed Ip/Bt (q). Priority 1-8 shots are required. Priority 9 will be obtained if time allows. At least two shots per condition are required. The first priority will be to run at 4 MW using NB sources 1A and 1B. These discharges are indicated in the shot list by the suffix "A". However, an additional source mix (at 4 MW) will be used as well for some of the conditions. This mix will consist of 1A and 2A (70, 130 cm), and are designated "B".

I_P (MA)/ B_T (T)	*0.7*	*1.0*	*1.3*	*1.5*
0.35 (or 0.4)	*7*	*1*	*9 ??*	
0.5	*4*	*2*	*5*	
0.65	*8*	*3*	*6*	
0.75	*10*	*11*	*12*	*13*

The actual shot list is given below, indicating source mix. It is envisioned that the shot list can be separated into five half-days of differing priority. Priority 1 discharges will be run first in each of the boronized and lithiated phases. The shot list is given in the five half-day segments. The shots along the matrix diagonal are indicated in red.

Priority	Ip (MA)	Bt (T)	Ip/Bt
1	1.0	0.35 (or 0.4)	2.9 (or 2.5)
2	1.0	0.5	2
3	1.0	0.65	1.5
4	0.7	0.5	1.4
5	1.3	0.5	2.6
6	1.3	0.65	2
7	0.7	0.35 (or 0.4)	2 (or 1.8)

8	0.7	0.65	1.1
9	1.3	0.35 (or 0.4)	3.7 (or 3.3)
10	0.7	0.75	0.9
11	1.0	0.75	1.3
12	1.3	0.75	1.7
13	1.5	0.75	2

Shot #/1/2 Day	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
First (B)	1A	1A	2A	2A	3A	3A	4A	4A	5A	5A	6A	6A
Second (B)	7A	7A	8A	8A	9A	9A	2B	2B	6B	6B	7B	7B
Third (Li)	1A	1A	2A	2A	3A	3A	4A	4A	5A	5A	6A	6A
Fourth (Li)	7A	7A	8A	8A	9A	9A	2B	2B	6B	6B	7B	7B
Fifth (Li)	10A	10A	11A	11A	12A	12A	13A	13A	13B	13B		

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

Easy access to H-mode is required. Pulse lengths long enough to give quasi-steady conditions are required. ELM activity should be similar among all discharges, either grassy or Type V ELMs, or Type 1 ELMs that are "infrequent" (so as to be able to assess "steady" transport and confinement, etc. within the ELM cycle). Two beam sources, 1A and 1B at ~4 MW total will be required. No RF or CHI is required. Profile diagnostics, BES and other diagnostics specifically requested by other TSGs will be required. If shown to be non-perturbative, some Neon puffs to monitor impurity transport, and possibly GPI puffs for edge turbulence studies, can be considered for some of the shots.

5. Planned analysis

EFIT/LRDFIT, TRANSP, gyrokinetic analyses will be performed for assessing the confinement and transport properties of the plasmas.

6. Planned publication of results

It is hoped that the first confinement/transport results can be shown at the APS 2015 meeting. An IAEA presentation/Nuc. Fusion paper in the transport area is envisioned once the entire dataset is obtained and analyzed. It is also expected that a number of other presentations and publications will come out of other TSGs making use of these discharges.

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:__*58*__ Estimated Total Neutron Production:___*3.4e16 N*___

PHYSICS OPERATIONS REQUEST

TITLE: **Ip/Bt scaling** No. **OP-XP-**
AUTHORS: **Kaye et al.** DATE: **3/2/15**

Brief description of the most important operational plasma conditions required and any special hardware requirement: *Quasi-steady and reproducible H-mode conditions*.

Previous shot(s) which can be repeated:

Previous shot(s) which to modify:

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

B_T Range (T): **0.35-0.75** Flattop Duration (s): **~1.5**

I_P Range (MA): **0.7-1.6** Flattop Duration (s): **~1.5**

Configuration **LSN**

Equilibrium Control: **Outer gap / Isoflux** (rtEFIT)

Outer gap (m): Inner gap (m): Z position (m):

Elongation: **~2.3** Triangularity (L): **~0.6** OSP radius (m):

Gas Species: **D^+** Injector(s): **easy H-mode access**

NBI Species: **D^0** Heating Duration (s): **~1.5**

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

Voltage (kV) 110 cm (2C): **90** 120 cm (2B): **90** 130 cm (2C): **90**

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

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

LITERs: Off (early scan) / On (later scan) Total deposition rate (mg/min) or dose per discharge (mg): **TBD**

EFC coils: On for EF control, etc.

DIAGNOSTIC CHECKLIST [1]

TITLE: **Ip/Bt scaling** No. **OP-XP-**

AUTHORS: **Kaye et al.** DATE: **3/2/15**

Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
Beam Emission Spectroscopy	x	
Bolometer – midplane array	x	
CHERS – poloidal		
CHERS – toroidal	x	
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		x
Fast ion D_alpha - toroidal		x
Fast lost ion probes - IFLIP		
Fast lost ion probes - SFLIP		
Filterscopes [2]		
FIReTIP		x
Gas puff imaging – divertor		
Gas puff imaging – midplane		
Hα cameras - 1D [2]	x	
Infrared cameras [2]		
Langmuir probes – divertor		
Langmuir probes – RF		
Langmuir probes – RF ant.		
Magnetics – Diamagnetism		
Magnetics – Halo currents		
Magnetics – RWM sensors	x	

Note special diagnostic requirements in Sec. 4

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

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, and multiple neutron detectors, multiple Langmuir probe arrays.

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

Heating dump that of the primary energy ion limits the beam duration to 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	18	1.5	2.00E+14	5.40E+15
$800<I_p\leq1000$	900	0	0	3.00E+14	0.00E+00
$1000<I_p\leq1200$	1100	22	1.5	4.00E+14	1.32E+16
$1200<I_p\leq1400$	1300	14	1.5	5.00E+14	1.05E+16
$1400<I_p\leq1600$	1500	4	1.5	8.00E+14	4.80E+15
$1600<I_p\leq1800$	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		58	Total Fluence		3.39E+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)