Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

Title: Scaling of the SOL width in NSTX and extrapolation to NHTX		
OP-XP-709	**Revision:**	Effective Date: 02/09/07 *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

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Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

1. Overview of planned experiment

The goal of this experiment is to measure the I_p dependence and also the B_t dependence of the SOL n_e, T_e, particle and heat flux widths at the outer midplane. The first three quantities are measured by the reciprocating probe, and the latter one is obtained from the divertor IR camera data after field line mapping. The ultimate goal is to devise a physics-based technique to extrapolate the measured SOL widths for NHTX, to better predict the heat and particle flux footprints for PFC design.

2. Theoretical/ empirical justification

The biggest extrapolations from NSTX to NHTX are in: I_p (1.0 -> 3.5 MA), B_t (0.55 -> 2.0 T), and P_{heat} (7-10 MW -> 30-50 MW). Since a big part of the NHTX proposed mission is to test the boundary physics at extremely high heat and particle fluxes, there is a need to predict the plasma footprints at the divertor strike regions. Historically such predictions are made based on analytic, 1-D, or 2-D models, which are benchmarked against experimental data from various diagnostics. Specifically the heat flux width (λ_q) can be obtained from IR cameras measuring the divertor tile temperature and magnetic mapping, and the density, temperature, and turbulent particle flux widths (λ_n, λ_t, and λ_Γ) can be obtained from midplane reciprocating probes.

In NSTX, the heat flux widths have been measured[1] as a function of heating power and I_p. At $P_{NBI} \geq 4$ MW ($P_{loss} \geq 3$ MW), the heat flux width was rather insensitive to further increases in P_{NBI} and was in the range of 0.7-1.0 cm (see figure 1a). Also, the heat flux width decreased rapidly with increasing I_p (figure 1b). Neither

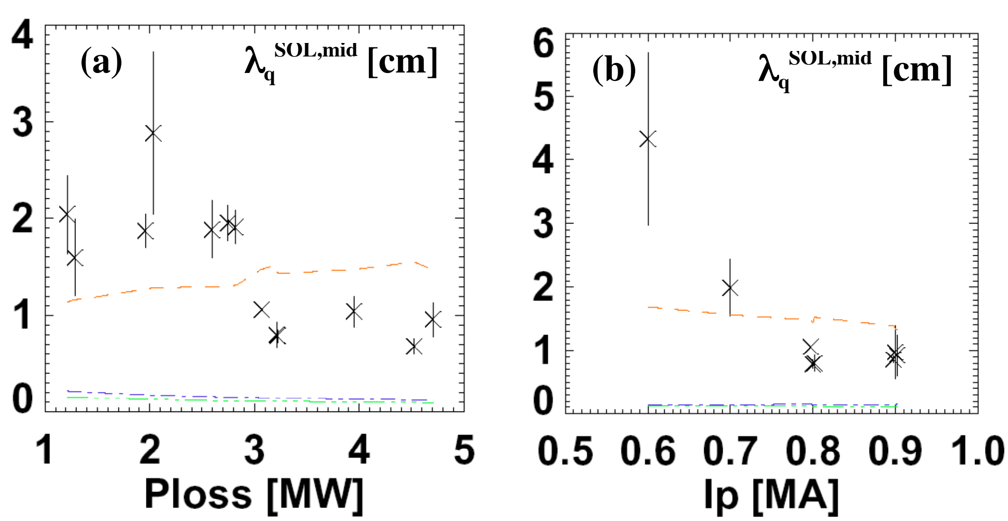

Fig. 1 – Dependence of midplane SOL heat flux width on (a) P_{loss}, and (b) I_p.

of these trends was well represented by three different models[2] of the SOL width (red, blue, and green curves in Figure 1), highlighting the need for the consideration of other models.

In addition, the n_e and T_e widths have been measured as a function of line-average density (figure 2a). Whereas the n_e width drops slightly with line-average density, the T_e width (curiously) does not have a monotonic dependence on line-average density. Also figure 2b shows that the density profile gets steeper with increasing input power, but the heating power range is limited to 1-2 MW.

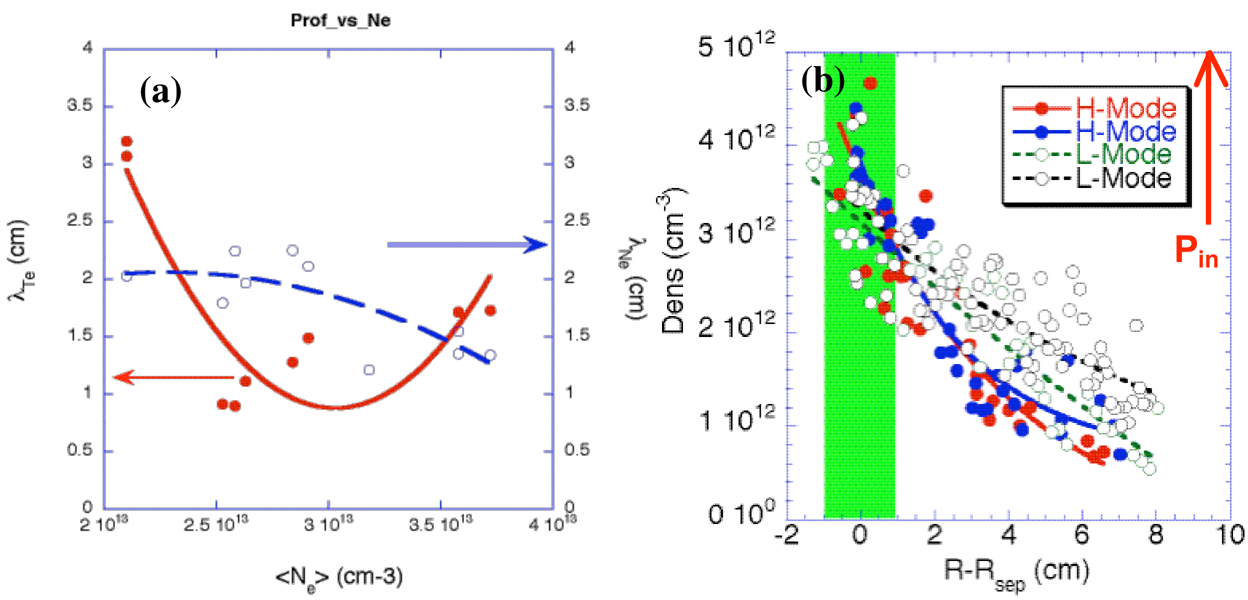

Fig. 2 – Dependence of (a) midplane SOL n_e and T_e flux width on line-average density, and (b) n_e profile changes during a P_{in} scan.

We note that, at present, the overlap between reciprocating probe data and IR camera data has been minimal. Thus, one of the deliverables of this experiment is to obtain a consistent dataset on which to test models of the SOL width. All fluctuation diagnostics are highly desirable to better connect the measured SOL widths to the underlying turbulence.

In terms of execution of the experiment plan, the reciprocating probe can plunge to near or at the separatrix for $P_{NBI} \leq 3$ MW, and so the baseline discharges uses that level of heating power. On the other hand, extrapolation to NHTX is best accomplished at higher β_N/P_{NBI}, and so at each I_p/B_t combination, an additional discharge at P_{NBI} =5 MW is included, mainly for IR camera data. The 3 MW base case will be accomplished by dropping source C voltage; this method is preferable to pulse-width modulation for a stable separatrix location, as needed for the reciprocating probe.

3. Experimental run plan (1 day, prioritized list below)

- Reproduce baseline PF2L LSN #119083 or newer version from 2007 with 1100-1200 Torr on CS to suppress large ELMs, and P_{NBI}=3 MW. Use source C at reduced voltage to get 3 MW. (3 shots)
- Repeat above with P_{NBI}=5 MW by adding source B. (2 shots)
- Perform I_p scan at approximately fixed q95 and at P_{NBI}=3 MW, 5 MW (15 shots)

  I. 1.0 MA, 0.55 T
  II. 0.6 MA, 0.35 T
  III. 1.1 MA, 0.55 T
  IV. 0.9 MA, 0.5 T
  V. 0.7 MA, 0.4 T

Time permitting: Perform B_t scan at I_p=0.8 MA (5 shots)

I. 0.8 MA, 0.55 T
II. 0.8 MA, 0.35 T

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

This XP requires a fully operational NBI system. We desire HeGDC between shots of ~ 6.5 minutes for a 12.5 minute repetition rate.

5. Planned analysis

The SOL widths will be analyzed from the data obtained, and relationships between the SOL widths will be investigated in the context of analytic cross-field transport models.

6. Planned publication of results

Data and analysis will be presented at ITPA SOL group meetings and published in J. Nucl. Materials from the 2008 plasma-surface interactions meeting.

PHYSICS OPERATIONS REQUEST

Scaling of the SOL width in NSTX and extrapolation to NHTX **OP-XP-709**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **63** Flattop start/stop (s): _____/_____

I_P (MA): **0..6-1.1** Flattop start/stop (s): **0.15/1.0 (max)**

Configuration: **Lower Single Null**

Outer gap (m): **10 cm** Inner gap (m): **5-10 cm**

Elongation κ: **2.0** Triangularity δ: **0.45**

Z position (m): **0.00**

Gas Species: **D**, Injector: **Inner wall Midplane**

NBI - Species: **D**, Sources: **A/B/C**, Voltage (kV): **90, 90, ~70**, Duration (s): **<1 sec**

ICRF – Power (MW): ____, Phasing: , Duration (s): _____

CHI: **Off**

Either: List previous shot numbers for setup: **119083 (LSN)**

Or: Sketch the desired time profiles, including inner and outer gaps, κ, δ, heating, fuelling, etc. as appropriate. Accurately label the sketch with times and values.

DIAGNOSTIC CHECKLIST

Scaling of the SOL width in NSTX and extrapolation to NHTX **OP-XP-709**

Diagnostic	Need	Desire	Instructions
Bolometer - tangential array		✓	
Bolometer array - divertor		✓	
CHERS	✓		
Divertor fast cameras		✓	
Dust detector			
EBW radiometers			
Edge deposition monitor		✓	
Edge pressure gauges		✓	
Edge rotation spectroscopy		✓	
Fast lost ion probes – IFLIP		✓	
Fast lost ion probes – SFLIP		✓	
Filtered 1D cameras		✓	
Filterscopes	✓		
FIReTIP		✓	
Gas puff imaging		✓	
High-k scattering		✓	
Infrared cameras	✓		
Interferometer – 1 mm			
Langmuir probes - PFC tiles		✓	
Langmuir probes - RF antenna			
Magnetics – Diamagnetism	✓		
Magnetics – Flux loops	✓		
Magnetics – Locked modes	✓		
Magnetics – Pickup coils	✓		
Magnetics - Rogowski coils	✓		
Magnetics - RWM sensors		✓	
Mirnov coils – high frequency	✓		
Mirnov coils – poloidal array	✓		
Mirnov coils – toroidal array	✓		
MSE		✓	
Neutral particle analyzer		✓	
Neutron Rate (2 fission, 4 scint)			
Neutron collimator			
Plasma TV		✓	
Reciprocating probe	✓		
Reflectometer - FM/CW		✓	
Reflectometer - fixed frequency homodyne		✓	
Reflectometer - homodyne correlation		✓	
Reflectometer - HHFW/SOL		✓	
RF antenna camera			
RF antenna probe			
Solid State NPA			
SPRED		✓	
Thomson scattering - 20 channel	✓		
Thomson scattering - 30 channel	✓		
Ultrasoft X-ray arrays		✓	
Ultrasoft X-ray arrays - 2 color		✓	
Visible bremsstrahlung det.		✓	
Visible spectrometers (VIPS)		✓	
X-ray crystal spectrometer - H			
X-ray crystal spectrometer - V			
X-ray PIXCS (GEM) camera			
X-ray pinhole camera			

1 R. Maingi, C.E. Bush, R. Kaita, H.W. Kugel, A.L. Roquemore, S.F. Paul, V.A. Soukhanovskii, and the NSTX team, et. al., *J. Nucl. Materials* (2007) at press.

2 G. F. Counsell, et. al., *Journal of Nuclear Materials* **266-269** (1999) 91.