Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: Characterization of turbulence in the NSTX boundary

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PROPOSAL APPROVALS

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MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: Characterization of turbulence in the NSTX boundary NUMBER: Rev 1

AUTHORS: J. Boedo, K. C. Lee, H. Kugel, S. Zweben, R. Maingi DATE: 13-FEB-2004

0.0 Overview of the Planned Experiments

A basic characterization of the properties of turbulence in the NSTX edge is required to develop an elementary knowledge of the cross-field transport, benchmark NSTX against other devices and eventually, advance basic understanding by comparing measurements to BOUT predictions. Further experiments will eventually allow a systematic survey of the dependence of turbulence on heating power, shape, and density. We will start with L-mode since the signal/noise ratio is higher. The GPI camera and the edge reciprocating probe were repositioned during the last vacuum opening and are now set for a 30-35° pitch angle. Consequently, the experiments should be performed at ~800-900 kA plasma current and a ~4.5 kG toroidal field, conditions that also have been shown to have long duration H-modes.

A density scan will be first priority since the edge turbulence is predicted to depend crucially on a combination of Ballooning/Resistive X-point interplay as can be seen in Fig. 1. The simulations indicate that as the density is increased (at constant pressure), the turbulence peaks more strongly on the LFS midplane and its intensity increase. Although NSTX does not have poloidally resolved turbulence diagnostics yet, the changes in turbulence intensity should be clearly observable. Further data will be obtained in H-mode, where the predictions hold, although at lower intensity levels due to the stabilization of turbulence by velocity shear. The key diagnostics for this XP will be:

- Fast Probe for edge fluctuations and profiles
- Reflectometers
- GPI edge camera for edge fluctuations
- H_α/D_α cameras and diodes particle inventory/transport analysis
- Divertor Langmuir probes for divertor electron density, temperature, and particle flux

The basic L-mode experiments should be performed with fairly low NBI power, just below the L-H transition threshold, to assure probe penetration past the LCFS. For true LSN, (800 kA, 0.45 T) the L-H transition power threshold should be ~650 kW unless LFS fueling is used. The plasma should be run so that ~4 density values ranging from 1.5 to ~4.5 $\times 10^{13}$ cm^{-3} (high density values may be too high for low power conditions) can be achieved. Particular attention will be paid to detecting MARFEs and the effects of plasma detachment. The diagnostics can take data at various times during the discharge to have the desired density.

The power levels will be obtained by using derated NBI sources, instead of modulated, to avoid separatrix oscillations. There are two possible ways of heating these plasma.s The higher power discharges can be kept in L-mode if desired by strong outboard gas fueling.:

- Run with very low power sources (de-rated ~40-45 kV kV) or ~350 kW and add sources for total power levels of 350, 700 and 1050 kW

- Run with higher power sources (de-rated ~ 60 kV) or 750 kW per source and add sources for total power levels of 750, 1500 and 2250 kW.

The experiments can start with the lowest power set (~350 or 750 kW, whichever alternative is chosen) and fuel the plasma so that it is kept in L-mode and the lowest desired density is achieved. The density increase in NSTX will naturally provide higher densities. The gas puff can be increased to achieve higher densities if needed.

After the first density scan, the power should be increased to the next step and if possible, kept in L-mode by gas puffing and the density scan repeated. A third power point at (~1050 or 2250 kW) will follow, obtaining H-mode, and a density scan will be performed.

The second data set concentrates on comparing the LSN configuration to a double null diverted (DND) plasma at two NBI power levels conducing to L and H-mode. The physics basis for this comparison is the addition of a second X-point and the corresponding resistive mode. The expectation is that a second X-point not only would increase the source but also pin down the existing mode and thus the fluctuation levels should increase on the LFS

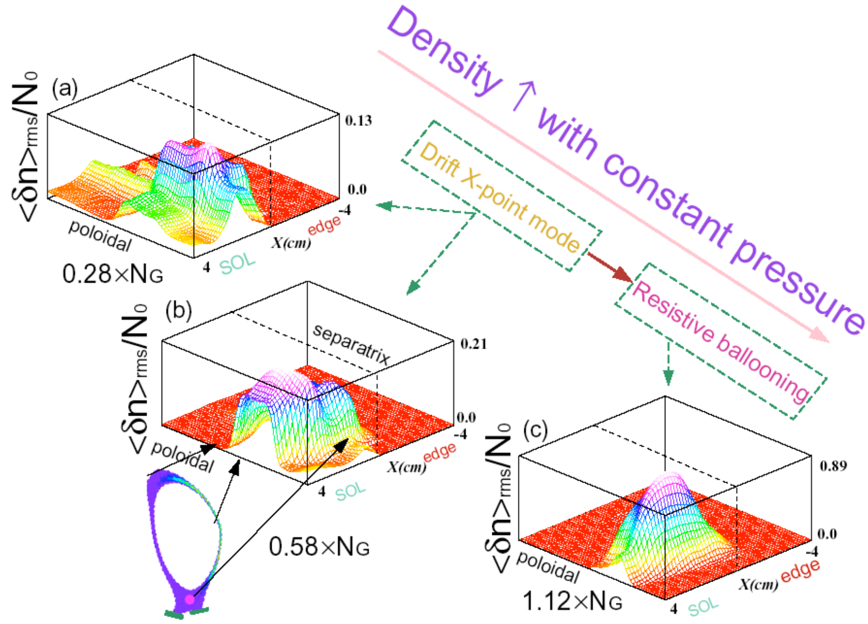

Figure 1. BOUT-predicted poloidal/radial variation of normalized density fluctuations with Greenwald factor (DIII-D simulation).

. Another BOUT prediction is that the ExB velocity shear levels will change substantially when the configuration is shifted from LSN to DN. An example of changes induced by modifying the grad-B direction (or the location of the X-point) is shown in Fig. 2, where the turbulent radial particle flux varies by factors of ~2 inside the LCFS.

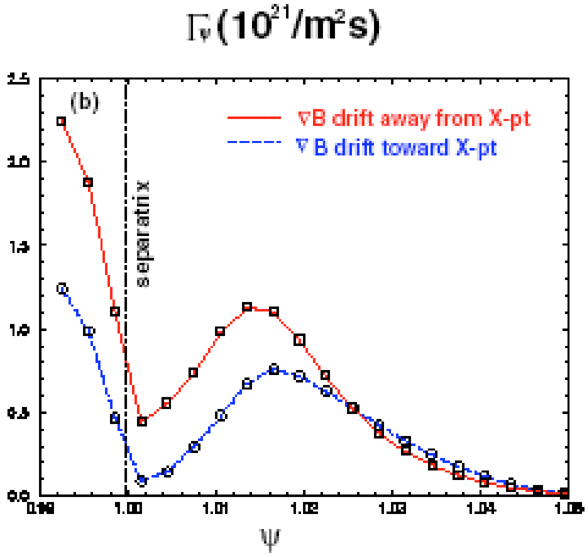

Figure 2. BOUT-predicted variation of the surfaced-averaged particle flux with change in the direction of the Grad-B drift. Factors of ~2 at the LCFS.

2.0 Conditions and Requirements

The main mode of operation is in lower single null divertor geometry, with some shots in DN for comparison. Operations are design to be a compromise between having enough flux-swing to maintain a 200-300 msec current flat-top and running in H-mode with I_p~ 800 kA and B_t = 4.5 kG. Note that ELM free H-mode are to be avoided because they are transient in nature. H-modes with continuous ELM's are acceptable, especially if shots with and without transitions can be taken for comparison. A shots such as 110194, 111543 and 111902 are a good reference.

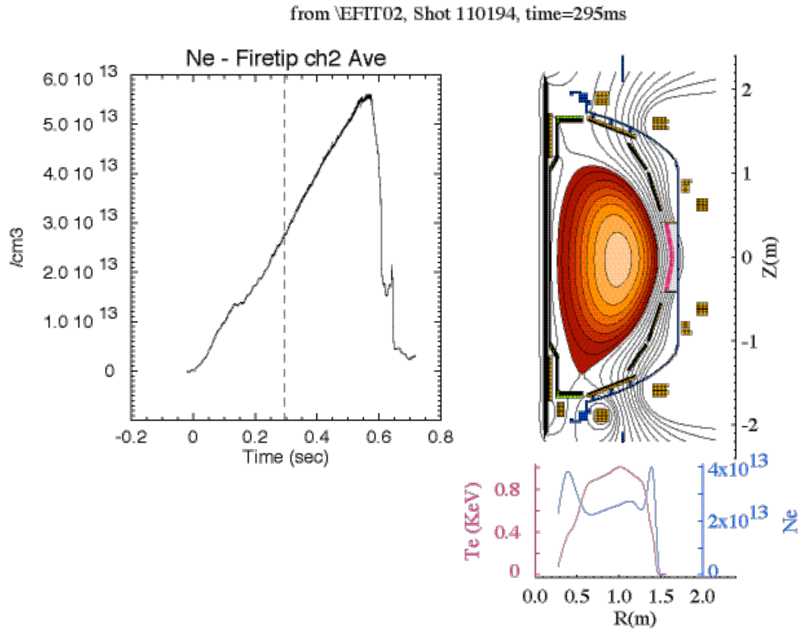

Figure 3. Configuration for reference shot 110194 (other references 111543 and 111902).

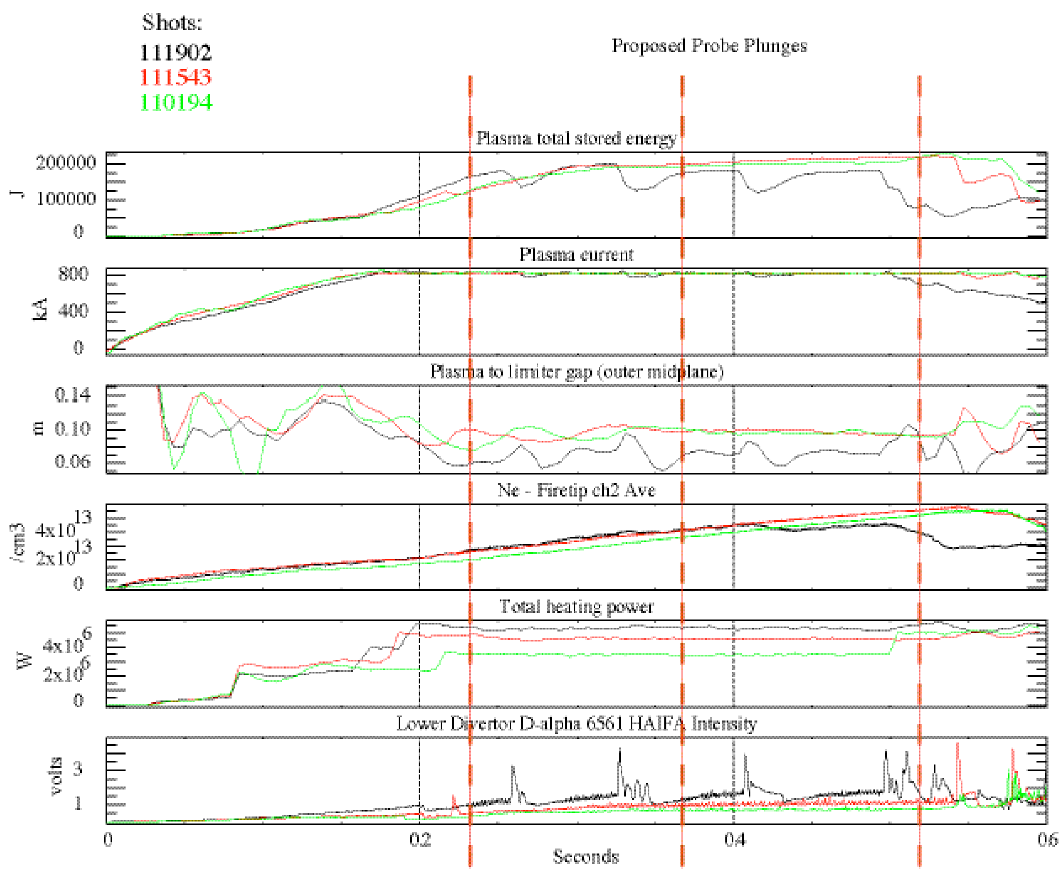

Figure 4. Timeline for reference shots 110194, 111543 and 111902. Proposed discharges have lower power levels. H-mode transition will be avoided by LFS gas puff. The probe will plunge at various times during the discharge to sample different densities.

Shots will be NBI heated ranging from ~1/3 source to nearly a full source. Planning is for 24 shots per day and He glow between discharges to maintain some density control. All shots are with deuterium prefill with deuterium beams. Helium GPI will be used in conjunction with the Edge TV system on every shot unless the gas puffing is found to be too perturbative. Typically each ***series*** requires at least one setup shot to verify the geometry for the scanning probe, no significant shape changes are expected by modifying the density unless instabilities are excited.

Experimental Run Plan (2 days)

He glow will be required between discharges to keep the density under control. The density series will be stared at a medium value (~2.5 or 3.5 e 13) to avoid locked modes or density limit events related to too low or too high densities.

<u>FIRST DAY</u>

1 Conditioning:

Perform 30 minutes of He GDC.

2 L-mode, LSN low power (~300 kW) ne scan (1 good setup shot+ 4 good shots)

Establish discharges with I_p~ 800 kA with a 200-300 msec flat top, B_t = 4.5 kG. Scan sensity $<n_eL> = 2 \times 10^{15}$ cm^{-2}, 4×10^{15} cm^{-2}, and 5×10^{12} cm^{-3}, make sure to check for signs of plasma detachment. Use #110194 or 111902 (a LSN with NBI, but I_p is not to be ramped down) as a reference discharge. Lowest density is to be determined by locked mode limit, i.e. execute discharges with density high enough to avoid locked modes, nominally with $< n_e> = 2.5 \times 10^{13}$ cm^{-3}. Attempt to keep l_p as constant as possible during the flat top.

3 L-mode, LSN Threshold power (~600 kW) ne scan (1 good setup shot+ 4 good shots)

Stack another de-rated NBI source into plasma with above conditions (using shot #110194 as a reference discharge) so that the injected power is varied from 300 to 600 kW. Shots may have helium puffs for the edge camera. Avoid operations near disruption limit to prevent damage to edge probe. D_a cameras will be used to judge if there are transitions to H-mode. Reduce power a bit is needed to stay in L-mode.

4 H-mode LSN (0.90 MW) ne scan (1 good setup shot+ 4+ 6 good shots)
Repeat ne scan in H-mode (4 shots)
Study L-H transition physics. Find transition time and place GPI and scanning probe on it. Fist 3 shots with GPI, then add the probe. (6 good shots)

TOTAL GOOD SHOTS: 21

SECOND DAY

5 H-mode LSN LCFS scan (1 good setup shot + 9 good shots)

Place separatrix at ~ 150 cm. Then scan separatrix +- 6 cm in 1.5 cm steps in shot to shot basis

6 LSN to DN L and H mode

DN Configuration power and ne scan: (2 good setup shot + 8 good shots)

Convert to DND configuration with same operating conditions, injecting with NBI sources as detailed below. To the extent possible, keep □, □, q, l_i as similar as possible to the LSN case. Scan density $<n_e L> = 2 \times 10^{15}$ cm^{-2}, 4×10^{15} cm^{-2}, and 5×10^{12} cm^{-3}, make sure to check for signs of plasma detachment.

L-mode 600 kW (4 shots)
H-mode 1 MW (4 shots)

7 DN H-mode 1 MW LCFS scan (4 shots)

TOTAL GOOD SHOTS: 24

TOTAL XP GOOD SHOTS: 45

4.0 Required machine, beam, ICRF and diagnostic capabilities:

1. NSTX will need to operate with plasma currents principally at 800 kA and toroidal field at 4.5 kG
2. No RF is required.
3. NBI is required throughout
4. The following diagnostics are required: scanning probe, interferometer, magnetics, filterscopes, mid-plane bolometers, plasma TV, and VB emission, Thomson Scattering, divertor/wall probes, divertor bolometer, thermal helium injector/edge camera sytem, IRTV cameras.
5. The following diagnostics are useful: VIPS, PHA, and SXR.

5.0 Planned Analysis

- Characterize turbulence levels of density and potential in NSTX
- Calculate cross-field turbulent transport from turbulence levels
- Separate broadband and intermittent fluctuations
- Characterize intermittent fluctuations vs radius
- Scale all of the above with density and confinement (L or H mode)
- Provide enough data for UEDGE and BOUT
- Compare data with BOUT results
- Calculate radial particle and heat transport (perpendicular and parallel flows)
- D_{α} emission from lower divertor will be used to calculate particle balance

6.0 Experimental Results Summary

1. Electrostatic cross-field transport measurements will be obtained. Scaling of rms levels and intermittency levels with density will be calculated. Basic properties of intermittency will be deduced.
2. Initial results will be included in the upcoming meeting abstracts such as APS and PSI.

PHYSICS OPERATIONS REQUEST

Title: Characterization of the Boundary Layer and Power Flow to the Divertor **XP No.: XXX**

Machine conditions (indicate range where appropriate):

TF: Flattop (kG) __4.5___ Flattop start/stop (s): throughout_

I_p: Flattop (kA) ___800__ Flattop start/stop (s): see 110194

Position:R (m) 1.45-1.5m__Z (m) __0____**Inner wall / Single null** / **Double null**

Gas: Prefill: ______D2____ Puff: __ He for edge camera______

NBI: Power (MW) 0.3 MW__ Start / stop (s) __varies___ Voltage (kV) __~60__

RF: Power (MW) _none___Start / stop (s) ________Frequency (MHz) ______

CHI: **Off** / Start-up / Ramp-up / Sustainment

If this is a continuation of a previous run or if shots from a previous run are similar to those needed, provide shot numbers for setup

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If shots are new and unique, sketch desired time profiles and shapes. Accurately label the sketch so there is no confusion about times or values. Attach additional sheets as required.

DIAGNOSTIC CHECKLIST

Characterization of the Boundary Layer and Power Flow to the Divertor   No. 217

Diagnostic system	**Need**	**Desire**	**Requirements** (timing, view, etc.)
Magnetics	✓		
Fast visible camera	✓		
VIPS-1		✓	
VIPS-2		✓	
SPRED	✓		
GRITS		✓	
Visible filterscopes	✓		
VB detector	✓		
Midplane bolometer	✓		
Diamagnetic flux		✓	
Density interferometer (1mm)		✓	
FIReTIP interf'r/polarimeter		✓	
Thomson scattering	✓		
CHERS	✓		
NPA		✓	
X-ray crystal spectrometer		✓	
X-ray PHA		✓	
EBW radiometer			
Mirnov arrays	✓		
Locked-mode detectors		✓	
USXR arrays		✓	
2-D x-ray detector (GEM)		✓	
X-ray tangential camera		✓	
Reflectometer (4 ch.)	✓		Scanning mode
Neutron detectors	✓		
Neutron fluctuations	✓		
Fast ion loss probe	✓		
Reciprocating edge probe	✓		
Tile Langmuir probes	✓		
Edge fluctuation imaging	✓		
H-alpha cameras (1-D)	✓		
Divertor camera (2-D)	✓		
Divertor bolometer (4 ch.)	✓		
IR cameras (2)	✓		
Tile thermocouples	✓		
ERD	✓		

ORNL Reflectometer	✓		
UCLA Reflectometer Kubota	✓		