Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: Effect of ρ* and rotation on non-H-mode NBI-heated plasmas in NSTX

OP-XP-???	**Revision:**	Effective Date: *(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

Title: Effect of ρ* and rotation on non-H-mode NBI-heated plasmas in NSTX **OP-XP-???**

1. Overview of planned experiment

The goal of this experiment is to establish a baseline understanding of ion and electron transport in MHD-quiescent long-pulse NSTX NBI-heated discharges after successful machine bake-out and error field reduction and lay the grounds for further dimensionless scaling experiments. First, the **toroidal field dependence** of the transport will be investigated **at fixed q** by simultaneously varying the applied magnetic field and plasma current at **fixed heating power and electron density**. Assuming the transport will be reduced at higher field, the maximum stored energy will increase with magnetic field. Thus, operating at fixed q should allow operation at roughly fixed β, β_N, and β_P as ρ^* is varied. (The electron density being held fixed, ν^* will however vary as $1/T^2$). Fixed q operation should also aid avoidance of ideal and NTM stability limits for all configurations. Finally, another important reason to keep the q profile fixed is that, if a good confinement region enclosed within a rational surface exists (as impurity injection results suggest with respect to q=2), its volume is kept unchanged in this way.

Second, the **effect of rotation on transport** will be investigated by varying the applied torque again at fixed heating power and density by modifying the NBI source voltage and mixture.

Thirdly, a **density and power scan** will be performed to gain additional data **at the lowest and highest possible rotation speeds**. Higher density should enable keeping T_i/T_e fixed (presumably around 1) and minimize the impact of Zeff changes, both important conditions for future dimensionless scaling experiments. The high density shots will also probe operation near the Greenwald limit in high performance discharges. Finally, Neon will be injected in some of these discharges, in an attempt to separately study impurity ion transport.

2. Theoretical/ empirical justification

Toroidal magnetic field scans at moderate density

Although ν^* will vary, one can view this as a preparatory stage towards true ρ^* scaling experiments. Thus, the growth rates computed by microstability analysis will give us a first insight on whether the transport is gyro-Bohm or not. Indeed, since one can expect that the growth rates will remain reasonably unchanged during a B_T scan at moderate density, any confinement improvement would indicate a finite Larmor radius effect on transport. Furthermore, if electron losses will continue to dominate at moderate density, the confinement enhancement (or lack thereof) can be attributed to the electron channel.

Effect of rotation shear

Rotation shear can stabilize the long wavelength Temperature Gradient (ITG) and Trapped Electron (TEM) modes, which are believed to drive the anomalous ion transport. The microstability analysis predicts however, that these modes are intrinsically stable in the inner two thirds of the NBI heated NSTX plasma, due the strong effect of beta-prime at low aspect ratio, as well as the (anomalously) high T_I/T_e ratio. Thus, although a large ExB shearing rate is

also present in these plasmas, according to this prediction its effect on ion transport should be secondary.

The anomalous electron transport on the other hand, is believed to be caused by the short wavelength Electron Temperature Gradient (ETG) modes, predicted to be strongly driven by the high T_I/T_e ratio in NSTX NBI plasmas. Due to their short wavelength however, these modes are not stabilized by ExB shear.

In conclusion, this experiment will help discriminate between two explanations for the good ion confinement assessed in NSTX: T_i/T_e and β' stabilization, versus ExB shear stabilization. If the microstability expectations are right, the former mechanism would prevail and one should not see a significant change in either the electron or ion confinement properties while the shearing rate is varied.

Power and density scan at different rotation conditions

These are exploratory experiments, with the aim of learning to control parameters important for further transport studies (e.g., T_i/T_e, ExB shear and Z_{eff}), as well as attempting to obtain long-pulse, 'transport grade' discharges at high density. Indeed, in the perspective of true ρ^* and β' scaling, as well as of a tentative to isolate the stabilizing impact of β', it is important to first control parameters as rotation shear, T_i/T_e, or Z_{eff} impact. A simple way to control T_i/T_e would be keeping it fixed (presumably around unity) by operation at high density. The high density operation would also minimize the eventual impact of variations in the impurity density (Z_{eff}) on transport.

Scanning the density will also provide a few (B, n_e, T_e) points closer to satisfying the criterion for true ρ^* scaling ($n_e \sim B^{4/3}$, $T_e \sim B^{2/3}$).

Finally, concerning the neon injection, preliminary experiments have established this as a viable technique for the study of particle transport on NSTX

Another more basic motivation for this proposal is that so far, the dependence of the thermal transport on magnetic field and rotation has not been systematically investigated with full diagnostic coverage and with time-dependent ion temperature analysis in long-pulse discharges suitable for transport studies. Both the poloidal magnetic field and velocity are expected to play a role in the E×B shearing rate, and the magnetic field strength plays an obvious role in determining the neoclassical transport, so a controlled scan of magnetic field is well justified. Several additional transport experiments have been proposed to investigate the dependence of NSTX transport on the thermal profile gradients and plasma beta. These experiments would benefit from the prior execution of this experiment, which would establish baseline plasmas suitable for transport studies and elucidate the possibly dominant influence of magnetic field strength and plasma rotation on transport in NSTX.

3. Experimental run plan

1. NBI setup: Source A at 80kV, sources B and C at 60kV, each injecting from t ≈ 80 ms until shortly before beginning of current ramp-down. 200 ms or longer flat top will be attempted.
2. The plasma current and shaping time-evolution will be that used in shot 107227. The elongation will be fixed at 1.9 and X-point triangularity at 0.6-0.7 by using the PF1A coils. The plasmas should initially be center-stack limited and then become double-null diverted during the flat-top for the duration of the discharge flat-top.
3. H-mode should be systematically avoided by controlling the inner gap during the diverted phase as needed. Outboard gas puffing will also be used to prevent the H-mode.
4. The experiments will be run at fixed q, using four paired values of plasma current and vacuum toroidal magnetic field:
   a. I_P = 800kA at B_t= 3kG
   b. I_P = 1MA at B_t = 3.75 kG
   c. I_P =1.2MA at B_t = 4.5 kG
   d. I_P =1.6MA at B_t = 6 kG

   The 6 kG points will be attempted at the end of the present campaign.
5. The baseline line-average density used will be $4\times10^{19}m^{-3}$ to avoid locked modes and the Greenwald limit.
6. The systematic scan in the table below will be used to vary the B-field and rotation. At least 2 shots should be obtained for each configuration and MPTS and CHERS data for each shot must be acquired. A third shot with Ne injection will be added for several of the B/rotation scan conditions. The number of shots needed to complete this XP is **33**. (Without counting the 6 kG shots at the end of the campaign). Assuming most shots are successful/useful this XP can be executed in *1 run day*.
7. The prioritization of the shots is as follows. We will first perform the B_t scan with source A. After that we will first run the 1 MA/0.375 kG/4x10^{19} cm^{-3} point with sources B and C and *assess in between shots* if changing the sources makes a difference in the rotation profile. If not, we abandon the B_t scan and proceed to the power/density scan.
8. No beam blips will be used for improved CHERS background subtraction, since sometimes they appear to cause confinement changes. For an additional background measurement the beam will be turned off shortly before the end of the current flat top. In other words, we will trade off accuracy in the *absolute* CHERS measurement for increased reliability of the *relative* measurement and assessment of transport changes.

		Beam Injection and Density Parameters					
B_T scan at two rotation conditions							
I_P (MA)	B_T (T)	Source	Voltage	n_e-bar ($10^{19}m^{-3}$)	Neon puff		
0.8	0.30	A	80kV	4	x	x	x
1.0	0.375	A	80kV	4	x	x	x
1.2	0.45	A	80kV	4	x	x	x
1.6	0.6	A	80kV	4	x	x	x
0.8	0.30	B, C	60, 60kV	4	x	x	x
1.0	0.375	B, C	60, 60kV	4	x	x	x
1.2	0.45	B, C	60, 60kV	4	x	x	x
1.6	0.6	B, C	60, 60kV	4	x	x	x

Power and density scan at different rotation conditions							
1.0	0.375	C	60kV	6	x	x	
1.0	0.375	C	60kV	8	x	x	x
1.0	0.375	B, C	60, 60kV	6	x	x	
1.0	0.375	B, C	60, 60kV	8	x	x	x
1.0	0.375	A, C	80, 60kV	6	x	x	
1.0	0.375	A, C	80, 60kV	8	x	x	x

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

The XP requires an operational NBI system and the capability of generating double-null diverted discharges with the plasma control system. No CHI will be used.

In between shots toroidal velocity profiles will be needed to assess the value of the repeating the B_t scan with sources B and C instead of A.

For the Neon injection experiments one of the new fast injectors at Bay J midplane will be used to better define the evolution of the neutral Ne source. This mandates the **preliminary calibration of the gas puff** (plenum pressure and duration) before execution of the above proposed XP. This calibration can be performed in piggyback mode using the end phase of discharges from other XPs.

A **visible filterscope for neutral neon** emission is also desired for the injection experiments.

Density fluctuation amplitudes and correlation lengths obtained with microwave reflectometry/interferometry are also highly desirable.

5. Planned analysis

The analysis includes EFIT, TRANSP output, gyrokinetic microstability analysis with GS2, NCLASS for the ExB shear evaluation, and MIST for impurity transport

6. Planned publication of results

EPS, APS conferences.

PHYSICS OPERATIONS REQUEST

Title: Effect of ρ* and rotation on non-H-mode NBI-heated plasmas in NSTX **OP-XP-???**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **24-70** Flattop start/stop (s): _____/_____

I_P (MA): **0.8-1.6** Flattop start/stop (s): **0.2/0.5**

Configuration: **Double Null Diverted**

Outer gap (m): **5-10 cm**, Inner gap (m): **1-5 cm**

Elongation κ: **1.9**, Triangularity δ: **0.6-0.7**

Z position (m): **0.00**

Gas Species: **D**, Injector: **Inner Wall and Outer Midplane**

NBI - Species: **D_2**, Sources: **A/B/C**, Voltage (kV): 80/60/60 ,Duration (s): **<0.5**

ICRF – Power (MW): **0**, Phasing: **N/A**, Duration (s):

CHI: **Off**

Either: List previous shot numbers for setup: **107227**

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

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