Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**		
Title: Neoclassical Tearing Mode Threshold Studies		
OP-XP-427	**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)

1. Overview of planned experiment

The experiment has two goals. The first, and primary, goal is to document the "β_{pol}" threshold for onset of neoclassical tearing modes (NTM). The approach will be to perform a beta scan in a sawtoothing target plasma. If there is the ability to modify the sawtooth parameters, e.g., using a TF or Ip scan to change the q=1 radius, that would provide further useful information. As these will be, for the most part, sawtoothing plasmas, they should provide a nice data set for an initial study of sawtooth induced heat pulse propagation. Additionally, a scan of plasma collisionallity would be valuable, either through density (lower temperature) or impurity puffing.

2. Theoretical/ empirical justification

Low aspect ratio (ST) reactors, perhaps more so than conventional aspect ratio tokamak reactors, rely on a large bootstrap fraction to support the confining plasma current. As it is this current which is believed to non-linearly drive tearing modes, NTMs are potentially a problem for STs. This experiment is the first in, hopefully, a series of experiments to study NTMs on NSTX, possibly culminating in tests of a system for feedback control of the NTM.

3. Experimental run plan

The object is to create a target plasma which sawtooths as early as possible (at least near the start of the current flattop). In the normal course of events, the beta would rise (and collisionality drop?) during the subsequent evolution of the plasma. Thus, the bootstrap fraction should increase throughout the discharge.

I would imagine that such a target discharge would be relatively high current (0.8 – 1.0 MA), would utilize early NBI to encourage current penetration and possibly would include some type of plasma expansion with current ramp. M. Bell has developed one form of such plasmas, shots *ca.* 103270, which might provide a starting point. The plasma cross-section was kept relatively small during the current ramp, clearly to help the current penetrate. Beams were also injected from nearly t=0, so that on-axis beam driven current would push q(0) down?

In the previous experiment each sawtooth crash excited an n = 2 mode which subsequently decayed before the next sawtooth. The damping rate evolved in the course of the discharge, suggesting that the critical island size was decreasing. This experiment was performed very early in NSTX operation with limited diagnostic coverage.

In a one-day experiment, I would expect a largish part would be spent in developing the target plasma. There would then be a few shots to ensure good diagnostic coverage and perhaps some modification of the beam heating power. Time permitting, a second target would be explored, either higher current or a different toroidal field.

Bootstrap current fraction might be controlled through collisionality, also. This may also affect NTM onset physics if we are fortunate to be in the relevant NTM-collisionality regime.

The previous target plasma was 700 kA, 33 kA. It was a diverted, lower single null plasma with kappa ≈ 2 and very early beam injection. With the improvements in machine control and reduction in error field, it might be desirable to make this a limiter plasma (to avoid H-mode) and possibly ohmic. The flattop could be stretched to 0.4 s (or longer), providing more data per shot. Finally, the current could be increased towards 1 MA (at a TF current of 33 kA) to push q(0) down. Suitable starting target plasmas may be identified in the course of this run.

0) **Prepare target, 1000 kA, TF 33 kA.** **(5-10 shots)**
This phase will adjust target plasma parameters to create a reproducible sawtoothing plasma. It is likely that the start-up evolution will need to be tweaked and the target plasma parameters adjusted (e.g., aim for a lower Ip as in the original experiment). Starting point will result from discussion with operators.

A) **beta scan** **(2-5 shots)**
The initial target will use 1 beam sources, or about 3 MW of heating power. The first change would be to increase beam power (two, then three sources), assuming that the NTMs excited were stable as before. Adjustments in beam timing and notching may also be required to fine-tune beta evolution.

B) **Ip 'scan', Itf = 33 kA** **(2-5 shots)**
It is the poloidal beta which enters the bootstrap equations, so the first parameter to vary would be the plasma current. First step down to 700 kA (unless part 0 was already there) and then decide whether a further scan was desirable. Would also affect polarization drift term.

C) **TF 'scan', Itf = 47 kA, Ip = 1 MA?** **(2-5 shots)**
The object here is to decrease the sawtooth inversion radius by increasing the toroidal field. Start with 47 kA [constant q(a) vs. 0.7 MA and 33 kA] and adjust up or down accordingly. Adjust beam power to scan beta.

D) **density/impurity scan, (as time permits)** **(2-4 shots)**
change collisionality to reduce bootstrap current (decoupled from beta).

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

This XP requires an operational NBI system. As it will rely heavily on the diagnostic capability to detect internal modes, the high-n and high-f Mirnov arrays should be functional as well as the JHU soft x-ray cameras. (High n array is desired for mode analysis of lower frequency modes.) Analysis of the results, beyond simple empirical scaling, will require detailed profile data; thus, Thomson scattering, CHERS are required and MSE would be highly desirable.

5. Planned analysis

Plasma analysis requires EFIT and TRANSP. Higher level analysis requires TRANSP to feed parameters to codes such as PRIME, possibly PEST-III.

6. Planned publication of results

The initial results will likely be suitable for a Journal article. If more extensive data on plasma parameters is available, allowing for more extensive analysis and simulations, further articles could be written.

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **53 kA** Flattop start/stop (s): **0.0/0.5**

I_P (MA): **1.1 MA** Flattop start/stop (s): **0.2/0.5**

Configuration: **Inner Wall / Lower Single Null / Upper SN / Double Null**

Outer gap (m): _____, Inner gap (m): _____

Elongation κ: _____, Triangularity δ: _____

Z position (m): **0.00**

Gas Species: **D / He**, Injector: **Midplane / Inner wall / Lower Dome**

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

ICRF – Power (MW): ____, Phasing: **Heating / CD**, Duration (s): _____

CHI: **On / Off**

Either: List previous shot numbers for setup: **(103270) or as suggested by operators.**

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	**Need**	**Desire**	**Instructions**
Bolometer – tangential array			
Bolometer array - divertor			
CHERS	✔		
Divertor fast camera			
EBW radiometer			
Edge pressure gauges			
Edge rotation spectroscopy			
Fast lost ion probes		✔	
Filterscopes			
FIReTIP		✔	
Gas puff imaging			
H□ camera - 1D			
Infrared cameras			
Interferometer - 1 mm			
Langmuir probe array			
Magnetics - Diamagnetism	✔		
Magnetics - Flux loops	✔		
Magnetics - Locked modes		✔	
Magnetics - Pickup coils	✔		
Magnetics - Rogowski coils	✔		
Magnetics - RWM sensors		✔	
Mirnov coils – high frequency	✔		
MSE		✔	
Neutral particle analyzer			
Neutron measurements		✔	
Plasma TV	✔		
Reciprocating probe			
Reflectometer – core	✔		
Reflectometer - SOL			
SPRED			
Thomson scattering	✔		
Ultrasoft X-ray arrays	✔		
Visible bremsstrahlung det.			
Visible spectrometer (VIPS)			
X-ray crystal spectrometer - H			
X-ray crystal spectrometer - V			
X-ray GEM camera			
X-ray pinhole camera			