Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**		
Title: Develop Early H-mode Startup for Access to High qmin		
OP-XP-440	**Revision:**	Effective Date: *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*
PROPOSAL APPROVALS		
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ATI – ET Group Leader: J. Menard		Date
RLM - Run Coordinator: S. Kaye		Date
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 goal of this experiment is to develop the use of H-mode during the current ramp as a method for reliably tailoring the current profile evolution to obtain q_{min} >> 1 at the end of the current ramp. H-mode access during the current ramp is important in NSTX due to its small size and low electron temperature in Ohmic or L-mode operation. Early H-mode should allow higher electron temperature but could introduce a host of other challenges with regard to MHD stability. The purpose of this experiment is to empirically determine the optimal sequencing of H-mode, heating, and current ramp rate to reliably access q_{min} >> 1 at the end of the current ramp. This experiment will take advantage of experience on DIII-D of inducing a H-mode during the current ramp to reliably access current profiles with q_{min} >> 1 with weakly negative shear.

2. Theoretical/ empirical justification

Rapid penetration of the current density during the current ramp phase of a tokamak discharge can lead to monotonic q profiles that are unfavorable for obtaining high bootstrap current operation. Such rapid current penetration can be caused by either high plasma resistivity or plasma instabilities. The plasma resistivity is predominantly determined by the plasma electron temperature ($\eta \propto T_e^{-3/2}$). While this can be controlled by plasma heating, the extent to which this can be done in the current ramp is determined by electron transport. In a typical NSTX discharge, T_e < 400 eV throughout the current ramp which due to the small size of NSTX leads to rapid penetration of the current density. This typically leads to q_{min} ~ 1 at the end of the current ramp. Since the bootstrap current fraction scales as $f_{BS} \propto q\beta_N$, the low q_{min} is clearly unfavorable for high bootstrap fraction operation. The most effective means of raising T_e during the current ramp is to improve the plasma transport. While some gain in L-mode operation can be obtained by modifying the current profile evolution itself, the most effective means for improving transport is to change the confinement state from L-mode to H-mode. Experiments early in 2004 have shown that by diverting the plasma during the current ramp, H-mode is reliably obtained provided a clean method for controlling the L-H transition. The staging of the H-mode transition, plasma heating, and current ramp rate must be carefully adjusted to avoid gross MHD instabilities that would cause rapid current penetration. The early H-mode technique has been developed in DIII-D Advanced Tokamak operation and is now the preferred method for reliably accessing AT current profiles.

3. Plan

The experimental will be performed as follows:

1. Reproduce current ramp early phase of 111964 (or similar discharge). Induce L-H transition at end of current ramp. In all cases, run neutral beams long enough to observe MHD activity associated with rational order surfaces in order to assess current profile evolution (2 shots)

2. Establish best method for obtaining robust L-H transition during the current ramp. Use various combinations of limiter-divertor configuration change, power step up, brief reduction in current ramp rate to zero, and gas injection rate. Starting point will be to convert to divertor configuration, then program a 30 ms pause in current ramp at 2 NBI sources. On subsequent shots, adjust duration of current ramp pause and number of NBI sources as

dictated by results. If unsuccessful or unreliable, make adjustments to divertor configuration to lower L-H transition threshold and prior to power step/current ramp pause (6-10 shots)

3. Using best available method, vary H-mode timing (through timing of the change from limited to divertor configuration) to assess effect on plasma confinement and current profile evolution. Scan H-mode timing from start late in the current ramp (~ 120 ms) to technical limit in rough steps of 20 ms. During this step, maintain same current ramp rate as reference shot. (4 shots)

4. Post L-H transition Power Scan: At earliest achievable L-H transition, scan NB power following L-H transition in steps of 1/2 source to determine maximum limit on heating power before locked modes occur. (3 shots)

5. Current Ramp Rate Scan : Using earliest achievable L-H transition and highest possible NB power, scan current ramp rate following L-H transition up in 0.5 MA/s steps to determine maximum achievable ramp rate without locked modes. (4 shots)

6. Combined Current Ramp Rate/Power Scan: Scan current ramp rate down in steps of 0.5 MA/s. At each step, starting from maximum power point, scan power subsequent up in steps of 1/2 source to technical limit to determine limit on heating power at each current ramp rate level. (5 shots)

7. Repeat at best condition to ensure that access to obtained current profile is reliable (2 shots)

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

Machine: 3.5 - 4.5 kG
Beams: 60-90keV deuterium on source A, 90 keV on others
ICRF: None
Diagnostics: Toroidal mirnov array, multi-pulse Thomson scattering, and CHERS as well as information on general impurity level impurities are essential.

5. Planned analysis

EFIT, TRANSP, MPTS, and CHERS are essential for subsequent analysis of current profile evolution and stability (both global and edge-localized).

6. Planned publication of results

If successful, developed scenario will be used extensively by NSTX program focused on developing Advanced Tokamak scenarios with qmin >> 1 as well as long-pulse scenarios. A paper comparing and contrasting the results from NSTX and DIII-D should result from the obtained results.

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **41-53kA** Flattop start/stop (s): **-0.010s/1.0s**

I_P (MA): **0.8MA** Flattop start/stop (s): **0.18s/1.0s**

Configuration: **Lower Single Null**

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

Elongation κ: **2-2.4**, Triangularity δ: **0.55-0.75 (lower x-point)**

Z position (m): **0.00**

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

NBI - Species: **D**, Sources: **A,B,C** Voltage (kV): **80** Duration (s): **1s**

ICRF – Power (MW): **0MW**, Phasing: , Duration (s): _____

CHI: **Off**

Either: List previous shot numbers for setup: **111964**

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	Need	Desire	Instructions
Bolometer – tangential array			
Bolometer array - divertor			
CHERS	X		
Divertor fast camera			
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		X	
FIReTIP	X		
Gas puff imaging			
Infrared cameras			
Interferometer - 1 mm			
Langmuir probe array			
Magnetics - Diamagnetism	X		
Magnetics - Flux loops	X		
Magnetics - Locked modes	X		
Magnetics - Pickup coils	X		
Magnetics - Rogowski coils	X		
Magnetics - RWM sensors		X	
Mirnov coils – high frequency		X	
Mirnov coils – poloidal array		X	
Mirnov coils – toroidal array	X		
MSE		X	
Neutral particle analyzer			
Neutron measurements	X		
Plasma TV	X		
Reciprocating probe			
Reflectometer – core			
Reflectometer - SOL			
RF antenna camera			
RF antenna probe			
SPRED			
Thomson scattering	X		
Ultrasoft X-ray arrays	X		
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			
X-ray TG spectrometer			