Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

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PROPOSAL APPROVALS

Responsible Author: R.J. La Haye	Date 6/1/09
ATI – ET Group Leader: S.A. Sabbagh	Date 6/1/09
RLM - Run Coordinator: R. Raman	Date 6/1/09
Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: NSTX and DIII-D Aspect Ratio Comparison of NTM Physics — No. **OP-XP-914**

AUTHORS: R.J. La Haye, R.J. Buttery, S. Gerhardt, S.A. Sabbagh

DATE: **5/7/09**

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1. Overview of planned experiment

It is planned to destabilize an m/n=2/1 neoclassical tearing mode in each discharge during the rise in beta and switch phases to beta ramp down. While information on the beta for destabilization is useful (to be coordinated with XP-915 R. J. Buttery et al), the key points here are the conditions for the saturated NTM (before power and thus beta ramp down) and the marginal point at which self-stabilization occurs. The effect of rotation on the saturated condition will be obtained by varying the rotation with n=3 magnetic braking. The saturated island width in the low aspect ratio NSTX can be compared to data in the large aspect ratio DIII-D (more just done in February 2009); this allows evaluation of delta' and DR terms. The marginal island width comparison will help check the physics of the small-island stabilizing effects, important both for destabilization, and for stabilization by radio frequency current drive. For the marginal island width to be successfully measured, the plasma must stay in H-mode and the island must not lock. Thus some shape development is needed before the experimental day and/or at the beginning of the day to get a shape that keeps the plasma in H-mode at low power. Also the best possible n=1 and 3 error field correction will be needed in the ramp down to keep the NTM rotating and not lock to the wall.

2. Theoretical/empirical justification

Small island stabilizing effects (transport, polarization current, etc.) set the marginal beta above which neoclassical tearing modes (NTMs) can be excited. The marginal full island width is the value of w at which growth is largest. This island size plays an important role in determining the electron cyclotron current drive (ECCD) requirements for stabilization in ITER. In "high" aspect ratio devices (ASDEX-Upgrade, DIII-D, JET and JT-60U), the marginal island width for m/n=3/2 is found to be about twice the ion banana width. [R.J. La Haye, R. Prater, R.J. Buttery, N. Hayashi, A. Isayama, M.E. Maraschek, L. Urso and H. Zohm, "Cross-machine benchmarking for ITER of neoclassical tearing mode stabilization by electron cyclotron current drive", Nuclear Fusion 46, 451 (2006).]

The purpose of this experiment, in NSTX, is to investigate if this scaling occurs at low aspect ratio. As m/n=3/2 is difficult to routinely produce in NSTX, the m/n=2/1 mode will be studied in conjunction with new experiments on DIII-D at both similar and lower q95. XP-739 in May 2007 got only one good 2/1 shots (#123873 and was analyzed; the polarization threshold fitted better than the transport threshold, and the ratio of 2/1 marginal island width to ion banana width was about 2, as in the 3/2 high aspect ratio data base. More cases are desirable in NSTX for analysis and confirmation. Further experiments in 2008, XP-801, could not keep the m/n=2/1 NTM from locking (February) or H-mode dropped out (June) in the ramp down. The problem in DIII-D has not been locking but dropping out of H-mode as the power is lowered, In experiments in 2008 and 2009, 3 good cases each for analysis of 2/1 modes at q95~4 and 7 respectively were obtained and 2 good cases of 3/1 modes at q95~7.

3. Experimental run plan (0.75 DAYS)

Baseline condition: 1.0 MA, 4.4 kG, deuterium gas (~123873 to be modified in shape). Sources A and B at 90 keV; Source C at 68 keV for half power, best n=1 and 3 EFC. A reliable H-mode at ~3 MW with frequent ELMs is needed (may require brief beam blip to >3 MW). Not too close or too much Li so no evolution of plasma conditions during the operating day. Development of higher elongation with reduced drsep, lower triangularity, lower X-point shape may be needed to keep plasma in H-mode at low power; this will tentatively be done for XPs 914 and 915 on 15 May and further development may be needed on the XP 914 run day June 4, per step (1).

1) **Baseline**. Develop the routine 2/1 NTM excitation in an ELMing H-mode at q95~7. Pre-program ramp down NBI power and look for staying in H-mode and 2/1 stabilization. A lower L to H threshold that implies a lower H to L might be advantageous for the ramp down phase. However in DIII-D the counter intuitive way of success was to raise density raising the H to L threshold power; the H to L occurred earlier but the marginal point occurred even earlier (due to lower Ti?). Some guessing as to the pre-programmed ramp down will be made based on 123873 . If desired conditions are met repeat and move to step (2). Otherwise if H-mode is lost first or 2/1 locks first before stabilization continue development of shape for lowering L to H threshold power.

(6~12 shots)

2) **Ramp Down Optimization:** Adjust timing of beginning of ramp down and rate of ramp down assuming step (1) successfully achieved desired conditions. Volt-sec limit of concern here.

(4 shots)

3) **Sat Mode Rot Scan:** Vary n=3 magnetic braking in beta ramp up and saturation (turn back to n=3 EFC at start of NBI ramp down) with one shot each at n=3 currents at saturation before ramp down of 0, 530 A, 750 A, 1061 A, or as possible such as to avoid 2/1 mode locking and stay in ELMing H-mode before ramp down.

(4 shots)

4) **Marg Mode Rot Scan Assuming steps (1) to (3) successfully obtained data**, try moderate n=3 braking in ramp down and hope for mode stabilization before mode locking.

(4 shots)

TOTAL (18 ~24 shots in 0.75 days to be coordinated with 0.75 days in XP915)

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

Machine: need to operate with clean machine before substantial Li used so as to get frequent ELMs and routine reproducible conditions for destabilization of m/n=2/1 mode.

Toroidal Field: B_T=-4.4 kG

Plasma Current : I_P=1.0 MA

Shape: NSTX 123873 with variation

Beams: Enough power to excite 2/1 mode. 2 needed but 3 desirable for finer tuning of power ramps.

ICRF: not needed.

Diagnostics: Magnetics (fast and slow), RWM detectors
CHERS for core Ti and rotation
Thomson scattering
SXR for island width

5. Planned analysis

In each case of a "break" in the n=1 Mirnov amplitude to self-stabilization, the island width and the "bootstrap drive" at this marginal point, the island width to ion banana width, rotation, etc to compare to DIII-D. Time-dependent modeling will be done for some key shots with either or both the polarization and the transport threshold models. The analysis of the saturated widths (well beyond the marginal widths?) is also of interest particularly as to rotation dependence. Both delta' and DR will be evaluated from the MRE at both the saturated and marginal points. DCON for DR evaluation to use in the MRE.

6. Planned publication of results

Results would be most valuable in combination with data on DIII-D for publication as a paper in Nuclear Fusion, for example. This would be input for the ITPA MHD stability group 2009-2010 joint experiments MDC-4 on aspect ratio and MDC-14 on rotation effects. Note that data is in hand on DIII-D at q95~4 from 2008 to match yet older JET data: new JET experiments to be done in 2009 for better comparison to DIII-D (high aspect ratio, q95~4 comparison versus size).

PHYSICS OPERATIONS REQUEST

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Describe briefly the most important plasma conditions required for the experiment:

Schedule before much Li so as to get frequent ELMs that can routinely destabilize the m/n=2/1 NTM. Coordinate with XP-915 to be run June 4.

Best n=1 and n=3 EFC in ramp down of beta so as to keep rotation up and prevent locking of the 2/1 mode before self-stabilization.

Expect to modulate beams (10msec on 10 off) as previous for finer power ramps in some intervals of shots. Last beam in ramp down will be A for MSE and CHERS.

Previous shot(s) which can be repeated:

Previous shot(s) which can be modified: 123873

Machine conditions *(specify ranges as appropriate, strike out inapplicable cases)*

I_{TF} (kA): -53 [BT(0)=-0.44] Flattop start/stop (s): 0/0.75

I_P (MA): 1.0 Flattop start/stop (s): 0.25/0.5

Configuration: DND (low X-pt and reduced triangularity for frequent ELMs)

Equilibrium Control: Operator's preference

Outer gap (m): 0.07 Inner gap (m): 0.04 Z position (m): 0

Elongation κ: 2.03 Upper/lower triangularity δ: 0.50

Gas Species: D Injector(s): Some will be modulated in part of shots.

NBI Species: **D** Voltage (kV) A: 90 B: 90 C: 68 Duration (s):

ICRF Power (MW): 0 Phase between straps (°): Duration (s):

CHI: **Off** Bank capacitance (mF):

LITERs: Off Total deposition rate (mg/min):

EFC coils: On Configuration: **Odd / Even / Other** *(attach detailed sheet*

DIAGNOSTIC CHECKLIST

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Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
Bolometer – tangential array		x
Bolometer – divertor		x
CHERS – toroidal	x	
CHERS – poloidal		x
Divertor fast camera		x
Dust detector		
EBW radiometers		x
Edge deposition monitors		x
Edge neutral density diag.		x
Edge pressure gauges		x
Edge rotation diagnostic		x
Fast ion D_alpha - FIDA	X	
Fast lost ion probes - IFLIP		X
Fast lost ion probes - SFLIP		X
Filterscopes	x	
FIReTIP		X
Gas puff imaging		X
Hα camera - 1D		X
High-k scattering		X
Infrared cameras		X
Interferometer - 1 mm		X
Langmuir probes – divertor		X
Langmuir probes – BEaP		X
Langmuir probes – RF ant.		X
Magnetics – Diamagnetism	X	
Magnetics – Flux loops	X	
Magnetics – Locked modes	X	
Magnetics – Pickup coils	X	
Magnetics – Rogowski coils	X	
Magnetics – Halo currents		x
Magnetics – RWM sensors	X	
Mirnov coils – high f.	X	
Mirnov coils – poloidal array	X	
Mirnov coils – toroidal array	X	
Mirnov coils – 3-axis proto.		x

Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
MSE	x	
NPA – E||B scanning		X
NPA – solid state		X
Neutron measurements		X
Plasma TV		X
Reciprocating probe		X
Reflectometer – 65GHz		X
Reflectometer – correlation		x
Reflectometer – FM/CW		X
Reflectometer – fixed f		X
Reflectometer – SOL		x
RF edge probes		X
Spectrometer – SPRED		X
Spectrometer – VIPS		X
SWIFT – 2D flow		X
Thomson scattering	X	
Ultrasoft X-ray arrays	X	
Ultrasoft X-rays – bicolor		X
Ultrasoft X-rays – TG spectr.		X
Visible bremsstrahlung det.		X
X-ray crystal spectrom. - H		X
X-ray crystal spectrom. - V		X
X-ray fast pinhole camera		X
X-ray spectrometer - XEUS		X