Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: Rotation Damping Physics in High β_N ST Plasmas		
OP-XP-408	**Revision: v1.0**	Effective Date: 2/4/03 *(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: Rotation Damping Physics in High β_N ST Plasmas **OP-XP-408**

1. Overview of planned experiment

Briefly describe the scientific goals of the experiment.

The overall goal of the experiment is to determine the plasma rotation damping physics of ST plasmas at high β_N exceeding the ideal no-wall beta limit. Particular attention will be placed on the toroidal rotation profile evolution, considering rotation damping theories connected to the high β_N modes observed.

Understanding of plasma rotation damping mechanisms at high β_N is important to optimize passive stabilization, to scale results to future devices, and to determine requirements for active mode stabilization. However, understanding of rotation damping physics at high β_N is not yet well understood in the advanced tokamak in this operational regime. While both experiments and theory exist on this topic, they have yet to be merged in high β_N ST experiments.

The present experiment will consider rotation damping from all relevant modes at the highest β_N possible. The modes expected to be generated in this study include the resistive wall mode (RWM), neoclassical tearing modes (NTM), and edge localized modes (ELM). Present theories to be investigated and compared to experiment include non-resonant neoclassical toroidal viscosity in the perturbed helical field, resonant electromagnetic coupling of rational surfaces to error fields or the conducting wall, and edge plasma viscosity. NSTX experiments have also generated results that may challenge or lead to expansion of present rotation damping theories.

This experiment will study

1) The observed global nature of toroidal rotation damping at β_N / $\beta_{Nno\text{-}wall}$ > 1
2) The observed dependence of rotation damping on toroidal field (q_{min}) and β_N / $\beta_{Nno\text{-}wall}$
3) Resonant vs. non-resonant damping mechanisms to explain the observed rotation damping profile
4) The dependence of rotation damping on boundary configuration (LSN vs. DND)
5) Comparison of rotation damping for different modes (RWM, NTM, ELM) where applicable

2. Theoretical/ empirical justification

Brief justification of activity including supporting calculations as appropriate

While rotation damping in tokamak plasmas is fairly well understood at lower β_N, it is not well understood for plasmas with β_N > $\beta_{Nno\text{-}wall}$. Present RWM theories have addressed the toroidal rotation evolution corresponding to the onset of the mode. However, there is no clear conclusion at present for the rotation damping mechanism, nor the dissipation mechanism leading to mode stabilization. Some theories (Fitzpatrick, et al.) link these two mechanisms.

Operation of NSTX in 2002 yielded plasmas with β_N exceeding $\beta_{Nno\text{-}wall}$, and in such plasmas, toroidal rotation damping was significantly more severe than when $\beta_N < \beta_{Nno\text{-}wall}$. The evolution of the rotation profile was significantly different in these plasmas with, being global in nature (Fig. 1). An additional interesting complication was the observation that the rotation evolution was altered by the magnitude of the toroidal field (Fig. 2).

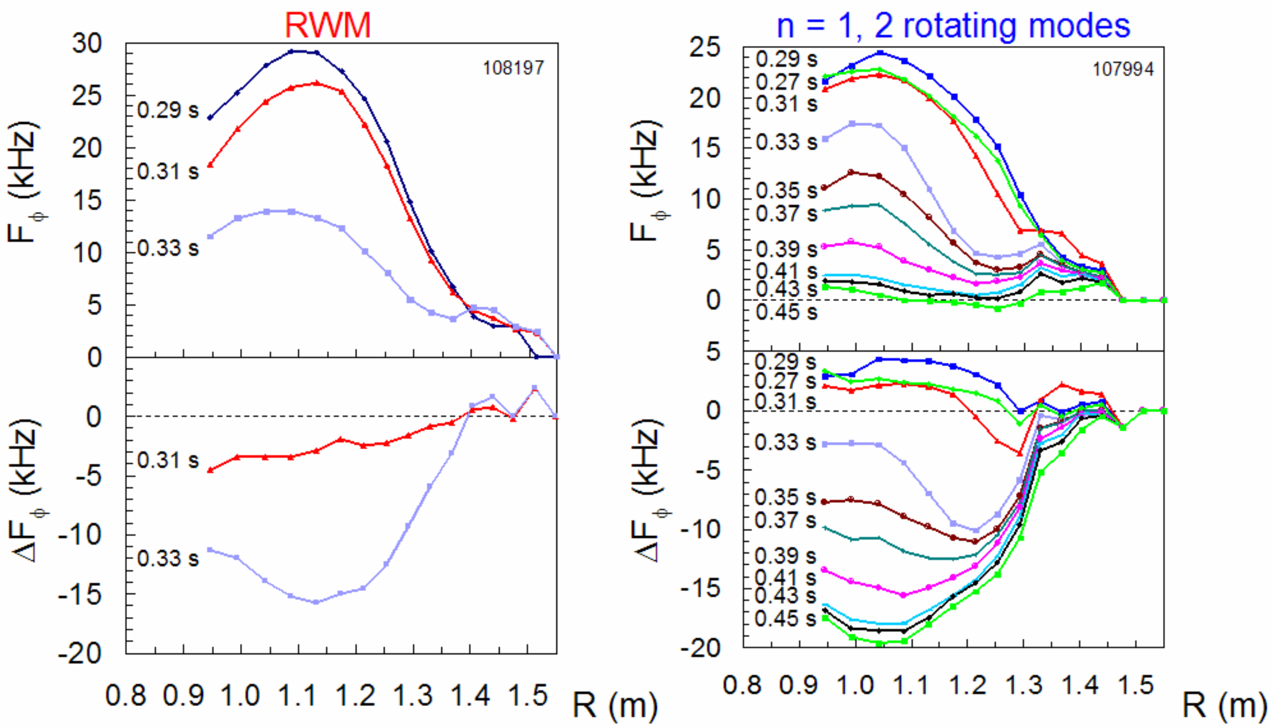

Fig. 1

Presently there are some theories addressing rotation damping physics. Ideal perturbation of RWM theory, base on non-resonant, neoclassical toroidal viscosity, is qualitatively consistent with observed global nature of rotation damping and qualitatively consistent with observed, relatively small damping at edge. We can compare quantitatively using computed mode eigenfunction. Resistive perturbation of magnetic islands theory, base on electromagnetic torque on island (induction motor model), is qualitatively consistent with observed, localized damping. Such perturbations have been observed above or below $\beta_{Nno\text{-}wall}$ and can follow global damping events. Part of the proposed analysis is to make quantitative comparisons between theory and experiment. Edge perturbation of ELMs theory, base on viscosity induced by edge perturbation, can be investigated with new CHERS capability.

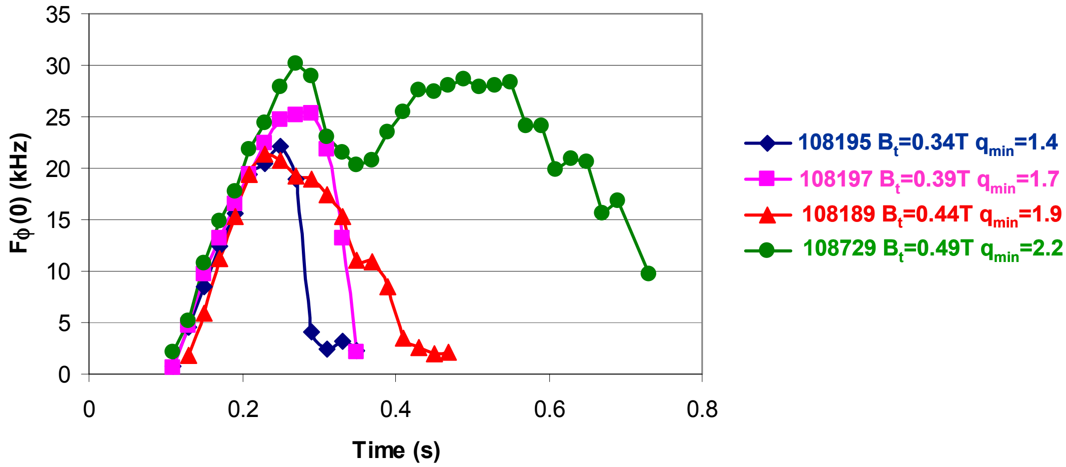

Fig. 2

3. Experimental run plan

Describe experiment in detail, including decision points and processes

The present passively stabilized operational regime in NSTX at high β_N lies between 4.5 < β_N < 6.5, established in lower single null (LSN) plasmas. The experiment would operate at the higher end of this regime. Operating in a passively stabilized space with the largest range of β_N is preferred. The DND is useful in altering the ELM characteristics.

Task		Number of Shots
A) Control Shots		3
($\beta_N < \beta_{N\ \text{no wall}}$, B_t>0.4T, β_p<0.4, $\tau_{\text{flat top}}$>0.3s)		
❑ B_t=0.45T, 1 NBI source (source B), I_p=0.8MA, LSN		
❑ If significant rotating modes exist, increase I_p=1MA		
B) Rotating mode alone plasmas		8
($\beta_N < \beta_{N\ \text{no wall}}$, alter position of island w.r.t. passive plates)		
❑ Repeat A, B_t=0.35, 0.4T		
❑ Change Gap_{in}, Gap_{out}		
❑ 3-NBI step-down to track rotation		
C) Rotating mode plus RWM plasmas		18
(Produce plasmas with $\beta_N > \beta_{N\ \text{no wall}}$, 2 or 3 NBI sources)		
i. Highest β_N		
❑ 3 NBI sources, B_t=0.45T for calculating source term (reference 112093/112094 with constant B_t)	1	
❑ Slow B_t ramp down (0.45 → 0.29T) to vary rotation evolution	1	
❑ Reproduce with constant B_t = target B_t for RWM (0.30, 0.35T?) (q scan with B_t)	2	
❑ Slow B_t ramp up (0.30? T0.40T) to delay rotation damping	2	
ii. Lower β_N		
❑ 2 NBI sources (A+B) (reference 112088), constant B_t=0.45T	1	

- Slow B_t ramp down ($0.45 \rightarrow 0.29$T) to vary rotation evolution — 1
- Reproduce with constant B_t = target B_t for RWM (0.30, 0.35T?) — 2
  (q scan with B_t)
- Vary NBI source input (sources B+C, C+A) — 4
  (Possibly change T_i profile (?))
  - Slow B_t ramp up to vary rotation evolution

iii. Density scan with "pure" RWM (if we have) or higher β_N plasmas — 4
(Change T_i profile)

D) Vary fuel rate and configuration to produce ELMy or ELM-free H-mode plasmas — 6
(β_N< β_N no wall, B_t>0.4T, β_p<0.4)

- Fueling rate (plenum pressure) scan
- Run DND to produce large ELMs

Total shots: 35

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

Describe any prerequisite conditions, development, XPs or XMPs needed.
Attach completed Physics Operations Request and Diagnostic Checklist

As usual, standard magnetic diagnostics are essential. Diamagnetic loop and Thomson scattering are required since partial kinetic EFIT reconstructions will be essential for this experiment. Since the experiment needs to have complete diagnosis of the resistive wall mode, both standard and edge CHERS diagnostics are required, as well as the locked mode detector. The new internal locked mode sensors are highly desired, but are not required for the setup phase of the XP.

5. Planned analysis

What analysis of the data will be required: EFIT, TRANSP, etc.

Partial kinetic EFIT will be crucial for this experiment, and will be run for each shot of interest. DCON stability analysis will be performed during the experiment as required. TRANSP will be useful to examine the evolution of the bootstrap current, fast ion pressure, and momentum input and diffusion.

6. Planned publication of results

What will be the final disposition of the results; where will results be published and when?

Reaching a firm conclusion on quantitative and qualitative agreement between theory and experiment of a non-resonant, global damping mechanism for plasmas with $\beta_N > \beta_{Nno\text{-}wall}$ would warrant initial publication in Phys. Rev. Letters. Greater detail of the full experiment would be appropriate for publication in Physics of Plasmas.

PHYSICS OPERATIONS REQUEST

Title: Rotation Damping Physics in High β_N ST Plasmas **OP-XP-408**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **3-4.5 kG** Flattop start/stop (s): _____/_____

I_P (MA): **<1.2** Flattop start/stop (s): _____/_____

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

Outer gap (m): **5+/-2**, Inner gap (m): **2+/-3(diverted)**

Elongation κ: **1.9+/-0.2**, Triangularity δ: **0.7+/-0.1**

Z position (m): **0.00**

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

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

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

CHI: **On / Off**

Either: List previous shot numbers for setup: **109025(Ip ramp LSN), 110073 (DND)**

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

Title: Rotation Damping Physics in High β_N ST Plasmas **OP-XP-408**

Diagnostic	**Need**	**Desire**	**Instructions**
Bolometer – tangential array		X	
Bolometer array - divertor			
CHERS	X		Also require edge CHERS
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			
FIReTIP		X	
Gas puff imaging			
Infrared cameras			
Interferometer - 1 mm		X	
Langmuir probe array			
Magnetics - Diamagnetism	X		
Magnetics - Flux loops	✔		
Magnetics - Locked modes	X		Internal sensors needed to complete XP
Magnetics - Pickup coils	✔		
Magnetics - Rogowski coils	✔		
Magnetics - RWM sensors	X		
Mirnov coils – high frequency		X	
Mirnov coils – poloidal array		X	
Mirnov coils – toroidal array		X	
MSE			
Neutral particle analyzer		X	
Neutron measurements		X	
Plasma TV	✔		
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	
X-ray crystal spectrometer - H			
X-ray crystal spectrometer - V			
X-ray PIXCS (GEM) camera			
X-ray pinhole camera			
X-ray TG spectrometer			