Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**		
Title: **ELM stability dependence on plasma shape**		
OP-XP-942	Revision:**0**	Effective Date: **7/20/09** *(Approval date unless otherwise stipulated)* 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: **ELM stability dependence on plasma shape** No. **OP-XP-942**

AUTHORS: **A. Sontag, J. Manickam, T. Osborne, P. Snyder, R. Maingi** DATE: **5/19/09**

1. Overview of planned experiment

The goal of this experiment is to expand the operational shape space in NSTX to low triangularity (δ) discharges where ballooning modes have been predicted to limit edge stability. Calculation of stability in NSTX plasmas with $\delta \geq 0.4$ using the ELITE code indicates that the plasmas should be marginally stable to peeling-ballooning modes, even in discharges where ELMs are observed. The calculations show the plasma closer to the peeling boundary, but farther away from the ballooning boundary. On the other hand, calculations with PEST have shown that ballooning modes may indeed be playing a role in those discharges. Decreasing δ should decrease ballooning stability and allow a better comparison of the two codes in a shape where ballooning modes are predicted.

Specifically, the relative importance of upper, lower and average δ will be examined by independently varying upper and lower δ. Results from C-mod are consistent with the idea that the lowest value of δ limits edge stability, rather than just the top, bottom, or the average, but this result has not yet been verified. This experiment would try to create various shapes to test the hypothesis that it is the lowest value of δ that determines stability.

This XP will address the following questions:

1) Does the calculated peeling-ballooning stability agree with experimental observations as the ballooning stability boundary is approached?
2) Can it be determined which value of δ determines ballooning stability?

2. Theoretical/ empirical justification

Increased δ leads to increased pedestal pressure and width [1], and is important in accessing small ELM regimes [2-4]. Calculations have shown the importance of δ in setting the edge pressure limit, particularly at low R/a [5]. Fig. 1 shows a prediction of the pedestal pressure limit (from ELITE) of a major radius scan at fixed minor radius, i.e. an R/a scan, at two different values of average δ. At low $\delta \sim 0$, ballooning modes mainly limit the edge pedestal pressure to a value

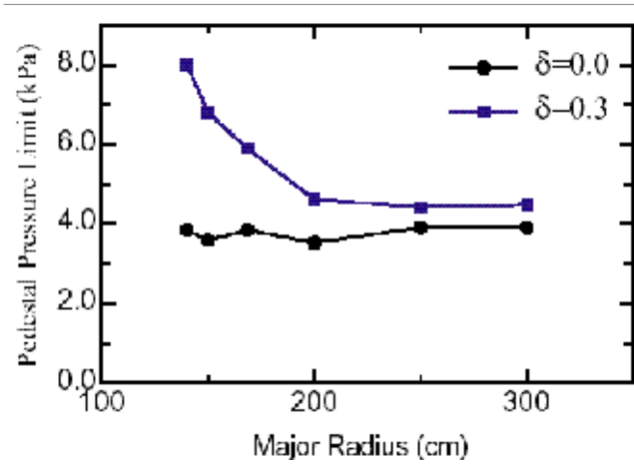

Fig. 1. Dependence of pedestal pressure limit in major radius at fixed minor radius, i.e. an aspect ratio scan, from [Snyder PPCF 2004].

invariant with R/a. For higher values of $\delta \geq 0.3$, the ballooning mode limit increases rapidly with decreasing R/a, and the edge stability becomes more limited by the kink/peeling branch.

The diamagnetic drift is thought to have a significant effect on the stability of peeling-ballooning modes in the pedestal [6]. MHD instabilities are predicted to be stabilized by diamagnetic effects when $\omega_*/2 > \gamma_{MHD}$, where γ_{MHD} is the growth rate of the mode and ω_* is the diamagnetic drift frequency. Peeling-ballooning stability calculations using the ELITE code without toroidal flow have been performed for DIII-D discharges during the period leading up to an ELM. The observation of unstable ELM growth on DIII-D is consistent with the calculated growth rate of the mode exceeding $\omega_*/2$.

NSTX plasmas have been observed to be unstable to ELMs at calculated mode growth rates an order of magnitude below the threshold for stabilization due to diamagnetic effects [7] as shown in Figure 2. By decreasing δ, it is believed that the NSTX operating point can be moved closer to the ballooning limit.

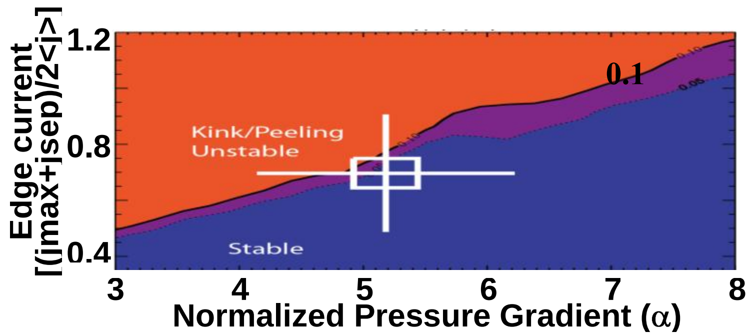

Figure 2*: NSTX peeling-ballooning stability as calculated by ELITE for a discharge with Type I ELMs {Maingi, APS08].*

The value of δ quoted in these studies is typically the average of the upper and lower values. Recent work proposes that pedestal stability is strongly affected by the degree of up-down symmetry [8]. Shown in Figure 3 is a PEST calculation of ballooning stability where δ_{upper} is scanned at several fixed values of δ_{lower}. The maximum stable β_N is proportional to the average triangularity. By developing configurations with low $\delta_{average}$, it should be possible to increase the ballooning drive of the ELMs. This should change the ELM characteristics such as size and helicity.

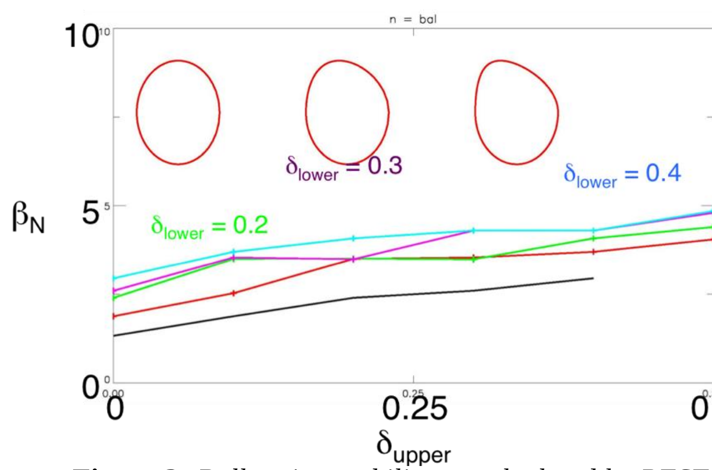

Figure 3: *Ballooning stability as calculated by PEST for several fixed values of δ_{lower}, varying δ_{upper}.*

[1] Leonard, *et al.*, Phys. Plasmas, **15** 056114 (2008)
[2] Stober, *et al.*, Nucl. Fusion, **41** 1123 (2001)
[3] Kamada, *et al.*, Plas. Phys. Cont. Fusion, **44** A247 (2000)
[4] Saibene, *et al.*, Nucl. Fusion, **45** 297 (2005)
[5] Snyder, *et al.*, Plas. Phys. Cont. Fusion, **46** A131 (2004)
[6] Snyder, *et al.*, Phys. Plasmas, 9 2037 (2002)
[7] Maingi, APS 2008

[8] Manickam, personal comm. (2009)

3. Experimental run plan

This experiment will begin by establishing a LSN fiducial based on shot 133886, and then independently modifying upper and lower δ to achieve a variety of shapes. The reference discharge has 4 MW of early NBI and used strike point control. q_{95} is high in the reference discharge, so will be decreased by raising I_p to 800 kA from 700 kA. This experiment will also use strike point control, with manually adjusted PF1s. Early NBI is required to maintain low ℓ_i for more ease in shape development. A balanced double-null shape will also be tested by altering the drsep request of the fiducial discharge. Enough NBI power should be put in to make sure the ELMy limit is accessed. Standard HeGDC between shots of 6.5 min will be used with a 12.5 min shot cycle. Low levels of Li may be used to ensure shot reproducability.

Run plan:

Task	# of shots
1) Establish fiducial	5
• 133886 as template	
Ip = 0.8 MA, Bt = 4.5 kG, 4 MW NBI	
adjust Ip and Bt to get lower q95 than 133886 for proper ELM regime	
2) Reduce δ_{upper} at fixed δ_{lower}	
use negative PF1AU current to push δ_{upper} down	5
vary PF1AU slowly to avoid conflicts with strike point control algorithm	
3) Reduce δ_r^{sep} to ~ 0 to make balanced DN shape	5
4) Reduce δ_{lower} at fixed δ_{upper}	
use negative PF1AL current to push δ_{lower} down	15
vary PF1AL slowly to avoid conflicts with strike point control algorithm	

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.

All standard magnetic diagnostics are required as well as diamagnetic loop and Thomson scattering for partial kinetic EFIT reconstructions. MSE is highly desirable to constrain the current profile for good PEST runs. D_α diagnostics to monitor the ELM bursts are required. Any additional constraints to the edge profiles that will be available will increase the certainty of the stability boundary mapping.

5. Planned analysis

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

EFIT will be used to reconstruct the plasma profiles, with multiple time slice averaging used for the edge pressure profiles. ELITE will be used to calculate peeling-ballooning stability including the effects of rotation. PEST-I will be run to calculate low-n and ballooning stability.

6. Planned publication of results

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

Determination of the affect of upper vs. lower triangularity on ELM stability would be a new result and be suitable for publication in Physical Review Letters.

PHYSICS OPERATIONS REQUEST

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(use additional sheets and attach waveform diagrams if necessary)

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

ELMy H-mode without disruption-inducing MHD.

Previous shot(s) which can be repeated: 133886

Previous shot(s) which can be modified:

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

I_{TF} (kA): 4.5 kG Flattop start/stop (s):

I_P (MA): 0.8 Flattop start/stop (s):

Configuration: **LSN/DN**

Equilibrium Control: **strike-point**

Outer gap (m): Inner gap (m): Z position (m):

Elongation κ: 2.1 Upper/lower triangularity δ: 0-0.35

Gas Species: Injector(s):

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

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

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

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

EFC coils: On Configuration: **Odd**

DIAGNOSTIC CHECKLIST

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Note special diagnostic requirements in Sec. 4

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

Note special diagnostic requirements in Sec. 4

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