Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

Title: **Current Profile Modifications and Fast Ion Loss from BAAEs/EPMs**

OP-XP-905	Revision: **2**	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: D. Darrow	Date 4/14/09
ATI – ET Group Leader: G. Taylor	Date
RLM - Run Coordinator: R. Raman	Date
Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: **Current Profile Modifications and Fast Ion Loss from BAAEs/EPMs** No. **OP-XP-905**

AUTHORS: **D. Darrow, N. Crocker, E. Fredrickson, N. Gorelenkov, W. Heidbrink, S. Kubota, K. C. Lee, M. Podestá, K. Tritz, H. Yuh** DATE: **4/14/2009**

1. Overview of planned experiment

Alfvénic modes driven by beam ions in NSTX are known to redistribute and expel fast ions and are thought to alter the current profile. The goal of this experiment is to visit plasma conditions in NSTX where bursts of beta-induced Alvfén acoustic eigenmodes (BAAEs) or energetic particle modes (EPMs) have previously occurred, measure the mode radial structure, and make detailed measurements of the changes in the current profile produced by these bursts, along with any redistribution and loss of fast ions resulting from the bursts. In addition, eternal braking fields will be applied to slow the toroidal rotation of the plasma in order to obtain more details of the mode radial structure and frequency vs minor radius to allow more detailed comparison with NOVA predictions of BAAE eigenfunctions. Comparison with calculated BAAE eigenfunctions will improve understanding of the exact nature of these bursting modes in NSTX and whether they are strictly ideal MHD modes (BAAEs) or whether they are EPMs which can only exist when the fast ions are present.

2. Theoretical/ empirical justification

Previous measurements of EPM/BAAE bursts have shown drops in the neutron rate of ~10% with clearly observable beam ion losses at the edge of the plasma. [D. Darrow, *et al. Nucl. Fusion* **48** (2008) 084004.] There is anecdotal evidence [H. Yuh, private communication 2009, S. Gerhardt, private communication, 2009] that bursting MHD modes, especially during intervals of reversed shear during the plasma current ramp up (when EPM/BAAE bursts are often observed), have caused significant changes in the MSE pitch angle profile in NSTX plasmas. These observations warrant a more systematic investigation.

3. Experimental run plan

A. Start the experiment by reloading the machine settings for shot 127393 (900 kA, 0.44 T, 3 beam sources at 90 kV). This is a discharge which had 5 bursts during the current flattop, between 610 and 710 ms. The bursts were ~15-20 ms apart, not far enough separated to obtain MSE data before and after each one.

B. Confirm presence of EPM/BAAE bursts in the discharge. If bursts are absent, reduce plasma current in steps of 100 kA until bursts are observed again.

C. (Permit a maximum of 2 hours for this step.) Try to diminish the fast ion drive for the bursts by incrementally increasing the gas puff rate in order to increase the plasma density shot by shot, in steps of ~$1\text{x}10^{19}\text{m}^{-3}$ in order to increase the separation in time between the bursts. An MHD-free interval of at least 50 ms is sought before and after a single burst in order to acquire MSE data with a reasonable signal-to-noise ratio. Try up to 5 steps in gas puff rate. If that is successful, then the new gas puff rate will define the baseline condition.

D. (Permit a maximum of 2 hours for this step.) If the desired 50 ms interval for MSE is not attainable, then increase the plasma current in 100 kA steps as an alternative method to lengthen the interval between bursts. If the higher current results in bursts with the desired quiescent interval between, then use this as the baseline condition for the XP. If higher current eliminates bursts entirely, then step back downward in current in smaller steps. If this proves unsuccessful, then the experiment will revert to the original plasma condition as the baseline discharge and attention will be focused on measuring the accumulated effect on the current profile of several bursts in succession. In this event, a quiescent interval of at least 50 ms on both ends of the set of bursts is sought, which will allow characterization of the effect of the set of bursts on the current profile.

E. Repeat the baseline discharge 5-10 times to obtain at least 30 burst events. Confirm that good quality data has been acquired with MSE, Mirnov coils, USXR arrays, CHERS, reflectometers (if possible), neutron detectors, FIDA, sFLIP, SSNPA, NPA, FIReTIP and the high-k scattering system. If the initial discharges in this sequence produce a reasonable signal level on the E||B NPA, then conduct a vertical scan with that diagnostic on successive shots in order to gather additional information on the effect of the bursts on the radial profile of the beam ions.

F. (Reserve at least 2 hours for this step.) Once the desired number of burst events have been obtained and good data has been acquired on the requisite diagnostics, repeat the discharges and add n=3 braking. Increase the current in the braking coils until the central rotation frequency is less than 5 kHz. Obtain 5-10 well-documented discharges under this condition, paying careful attention to the quality of the SXR camera data for fitting of the mode radial structures.

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

A prerequisite for the running of this XP is that long pulse discharges have been reliably obtained previously within the same campaign.

5. Planned analysis

A. TRANSP runs for each shot.

B. LRDFITs for each shot

C. Detailed analysis of MSE profiles, comparing before and after the set of bursts in order to define the degree to which current density changes from before to after the bursts as a function of minor radius in the discharge.

D. Assessment from NPA, SSNPA, and FIDA data of the amount of beam ion redistribution within each burst and over the set as a whole.

E. Determination of the beam ion loss fraction from the neutron rate, and the lost beam ion pitch angle distribution from sFLIP.

F. Analysis of the Mirnov coil data for mode frequency, amplitude, and n number composition in each burst.

G. Fitting of mode amplitude radial profiles to the SXR array, FIReTIP, and reflectometer data.

H. Calculation of ideal BAAE eigenfunctions and frequencies for some typical bursts with NOVA, and comparison with the measured profiles and frequencies.

I. Look for changes in toroidal rotation profiles after bursts to evaluate radial transport of fast ions.

6. Planned publication of results

Results will be published in PPCF or Nuclear Fusion, within 1 year of the experiment.

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:

The most important condition for this XP is the occurrence of the EPM/BAAE bursts

Previous shot(s) which can be repeated: 127393

Previous shot(s) which can be modified: 127393

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

I_{TF} (kA): 53 Flattop start/stop (s): -0.02 / 1.35

I_P (MA): 0.9 Flattop start/stop (s): 0.21 / 0.87

Configuration: **LSN**

Equilibrium Control: **Isoflux** (rtEFIT)

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

Elongation κ: Upper/lower triangularity δ:

Gas Species: Injector(s):

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

ICRF Power (MW): none Phase between straps (°): Duration (s):

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

LITERs: On Total deposition rate (mg/min): **TBD**

EFC coils: On Configuration: **Odd** (n=3) *(attach detailed sheet*

DIAGNOSTIC CHECKLIST

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Note special diagnostic requirements in Sec. 4

Diagnostic	Need	Want
Bolometer – tangential array		
Bolometer – divertor		
CHERS – toroidal	X	
CHERS – poloidal		X
Divertor fast camera		
Dust detector		
EBW radiometers		
Edge deposition monitors		
Edge neutral density diag.		
Edge pressure gauges		
Edge rotation diagnostic		X
Fast ion D_alpha - FIDA	X	
Fast lost ion probes - IFLIP		X
Fast lost ion probes - SFLIP	X	
Filterscopes		
FIReTIP	X	
Gas puff imaging		
Hα camera - 1D		
High-k scattering		X
Infrared cameras		
Interferometer - 1 mm	X	
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	X	
Mirnov coils – high f.	X	
Mirnov coils – poloidal array	X	
Mirnov coils – toroidal array	x	
Mirnov coils – 3-axis proto.		

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		
Reciprocating probe		
Reflectometer – 65GHz	X	
Reflectometer – correlation		
Reflectometer – FM/CW		
Reflectometer – fixed f		
Reflectometer – SOL		
RF edge probes		
Spectrometer – SPRED		
Spectrometer – VIPS		
SWIFT – 2D flow		
Thomson scattering	X	
Ultrasoft X-ray arrays	X	
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		