Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**			
Title: **Fast ion transport induced by Alfvén avalanches**			
OP-XP-819	Revision:	Effective Date: Expiration Date: *(2 yrs. unless otherwise stipulated)*	
PROPOSAL APPROVALS			
Responsible Author: E.D. Fredrickson			Date
ATI – ET Group Leader:			Date
RLM - Run Coordinator:			Date
Responsible Division: Experimental Research Operations			
MINOR MODIFICATIONS (Approved by Experimental Research Operations)			

NSTX EXPERIMENTAL PROPOSAL

TITLE: **Fast ion transport induced by Alfvén avalanches** No. **OP-XP-819**

AUTHORS: **E. Fredrickson, M. Podestà, W. Heidbrink, D. Darrow** DATE: **Feb 14, 2008**

1. Overview of planned experiment

This experiment combines ideas from five proposals and provides target plasmas to address several goals. The highest priority is to investigate the scaling with density, toroidal field, beam voltage, and current profile of the TAE and Avalanche onset thresholds. A second goal is to document the fast ion loss due to fishbone-like energetic particle modes as seen with sFLIP. The third goal is to expand the quiescent operational space to higher beam power and H-mode plasmas. A final goal is to validate FIDA diagnostic with both quiescent plasmas and plasmas with strong energetic particle driven instabilities.

The target plasma (e.g., 124781) developed for TAE and TAE-avalanche studies in the 2007 campaign includes a quiescent period, followed by a period with TAE or TAE avalanches and ends, typically, with a period of multiple, fishbone-like modes. This target plasma will be systematically varied to provide longer quiescent periods, quiescent periods with beam blips (if required), quiescent periods at higher beam power, as well as scans of beam voltage and power to determine onset threshold scaling of TAE and TAE avalanches. An attempt will be made to extend the quiescent regime to H-mode plasmas. Attempts will be made to optimize the fishbone phase for fast ion transport studies. High-k scattering studies of TAE interactions with the continuum will also be included.

2. Theoretical/ empirical justification

Fast-ion redistribution or losses due to fast ion modes in ITER or other fusion reactors is expected to be through multi-mode transport, *e.g.*, Alfvén avalanches. NSTX is well situated to the study of Alfvén avalanches. Avalanches have been observed [Fredrickson, NF 06], but in plasmas prior to routine availability of MSE. To simulate the effect of avalanches on fast ion confinement, we need to measure the amplitude (and confirm the radial eigenmode structure) of each mode involved in the avalanche. We need the q-profile and other equilibrium data for NOVA calculations of mode structure. The new FIDA diagnostic, together with NPA, ssNPA and sFLIP may also help confirm the details of the predicted affect on fast ion transport.

3. Experimental run plan

The goal is to reproduce target plasma with quiescent period similar to 124764, then extend quiescent regime to parameters. Introduce source A to 150 ms to provide early measurement of q-profile and after 300 ms.

Two activities will proceed in parallel with main experiment. The first will to look for TAE coupling to Kinetic Alfvén waves in the continuum with the high-k scattering diagnostic. Without the capability for remote steering, this will have to be done at some fixed radius.

The second activity will be to study HHFW suppression of Angelfish in the early period of these discharges, assuming HHFW is available and assuming Angelfish are present. A 20 ms blip of HHFW will be applied approximately from 150 to 170 ms. And from shot-to-shot the RF power will be scanned in roughly 0.5 MW steps up to the highest power.

Main experiment

1. Reproduce density, current, beams, neutron rate evolution for shot 124764.. Source A from 85 to 150ms, 300ms to 500ms, source C from 150ms to 300ms. Depending on results from FIDA-XMP, might interchange source B and source C throughout XP.

    IF (plasma quiescent) THEN GOTO 2.

2. Delay source C-to-A swap from 300 ms to 400 ms to determine length of quiescent period, for subsequent plasmas, set source C/A swap accordingly for subsequent shots.

c…Optimize length of quiescent period

3. Skip at discretion of Heidbrink/Podesta

    DO I=1,3

        Start FIDA beam-blip experiments.

c…Make fast ion distribution measurements, optimize FIDA

    ENDDO

4. Switch to deuterium operation. This step may also be skipped if similar shots were attempted in FIDA XMP-54.

c…Can we get quiescent D shot for FIDA (improves neutron accounting)

c…Will D shot go into H-mode? (avalanche threshold in H-mode, different gap structure)

        IF (plasma quiescent) THEN GOTO 5

        ELSE

            Raise density

            IF (plasma quiescent) THEN GOTO 5

        ELSE

            increase toroidal field

IF (plasma quiescent) THEN GOTO 5

ELSE

lower beam power

IF (plasma quiescent) THEN GOTO 5

ELSE

Skip quiescent deuterium operation (5)

GOTO 6

ENDIF

5. Skip at discretion of Podesta/Heidbrink

DO I=1,3

Repeat beam blip experiments in Deuterium.

c…Make fast ion distribution measurements, deuterium for (absolute) neutron measurements.

ENDDO

6. IF (quiescent D plasmas H-mode) THEN go back to Helium L-mode plasmas

Adjust density to optimize reflectometer data, if req'd

Sources B & C should be nominally at 65 kV.

Use B at nom. 65 kV for quiescent period (until ≈240ms), then source C.

Start voltage/power scan for C to avalanche threshold

DO I=1,4

IF (no avalanche) THEN

Increase beam voltage by 10 kV increment

c…Scan of β_{fast} to determine TAE and TAE avalanche threshold.

c…Similar to XP705, but using beam voltage/power instead of power

ELSE IF (avalanche) THEN

Decrease beam voltage by 5 kV

GOTO 7

ENDIF

ENDDO

7. Start documentation of TAE avalanche condition (from either part 6 or 7)

6-shot NPA scan (tangency radius nominally 50cm, pitch ≈0.6)

8. q-dependence of avalanche threshold. change C-B swap back to 220 ms

c…is avalanche threshold dependent on q_{min}?

DO WHILE(MHD)

Delay swap in 10 ms steps

ENDDO

IF(no MHD AND avalanches)THEN

Reduce C voltage in 5 kV steps

ELSE IF (no avalanche) THEN

Increase C voltage in 5 kV steps

ENDIF

c…NPA/ssNPA/FIDA documentation of fast ion transport

c…high-k scattering gets radial scan here

9. Increase toroidal field to 5.5 kG

c…low-Vfast/Valfven scaling of avalanche threshold

c…try for lower density? Find threshold with ≈ 65 kV beams?

IF(no avalanches)THEN

DO WHILE(no avalanches; max steps 3)

Increase source C voltage by 5 kV, repeat

ENDDO

ELSE

DO WHILE(avalanches; max steps 3)

Decrease source C voltage by 5 kV, repeat

ENDDO

ENDIF

10. Reduce toroidal field to 3.5 kG, source C at avalanche threshold for 7.

c…high-Vfast/Valfven (CTF) scaling of avalanche threshold

c…add higher density point?

IF(no avalanches)THEN

DO WHILE(no avalanches; max steps 3)

Increase source C voltage by 5 kV, repeat

ENDDO

ELSE

DO WHILE(avalanches; max steps 3)

Decrease source C voltage by 5 kV, repeat

ENDDO

ENDIF

11. Switch to D prefill/puffing, attempt H-mode

c…Look for threshold in H-mode plasma

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

MSE is a must.

The voltage on sources B and C will be scanned from 65 kV up to 90+ kV. They should be started at 65 kV for the first shots.

5 channel reflectometer diagnostic.

FIDA/NPA/ssNPA/sFLIP(w/PMT)

Capability for vertical scan of NPA is highly desired. Alternatively, radial scan might be done.

High-k scattering desired. Should be set for scattering volume as close to core as reasonable (≈110 to 115 cm).

5. Planned analysis

Benchmarking TRANSP beam, bootstrap and fast ion deposition calculations will require extensive TRANSP analysis/simulations.

Study of TAE onset, TAE avalanche threshold will require extensive NOVA-k and M3D-K simulations.

6. Planned publication of results

The results should be publishable in several specialist articles as well as contributing to general publications from NSTX

PHYSICS OPERATIONS REQUEST

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Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **34-65** Flattop start/stop (s): **0.0/1.0**

I_P (MA): **0.8** Flattop start/stop (s): **0.2/0.9**

Configuration: **124764**

Outer gap (m): Inner gap (m):

Elongation κ: Upper/lower triangularity δ:

Z position (m):

Gas Species: **He,D** Injector(s): Midplane/Inner wall

NBI Species: **D** Sources: **ABC** Voltage (kV): **90/60-90/60-90** Duration (s): **0.9s**

ICRF Power (MW): **2-3 MW** Phasing: **180º** Duration (s): **0.02**

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

LITER: Off

Shot numbers for setup: **124764**

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 – ExB 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		✓