Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

Title: Characterize NBI driven current evolution

OP-XP-608	**Revision:**	Effective Date: *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

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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)

Prior to execution of this XP locate a more recent shot that is similar to 117541.

NSTX EXPERIMENTAL PROPOSAL

Characterize NBI driven current evolution ***Assess the effects of supra-Alfvénic fast ion driven instabilities on driven current in the plasma core*** **OP-XP-608**

1. Overview of planned experiment

Experiments will be carried out where the neutral beam driven current is maximized, such as in moderate density, high electron temperature plasmas. The goal of this year's experiments is primarily to identify a target plasma fit for more extensive experiments. In previous experiments it was found that Toroidal Alfvén eigenmodes (TAE) and energetic particle modes (EPM) were stable below a fairly sharp threshold in beam voltage. This may reflect a dependence on power, fast-ion velocity, or a more subtle change in the fast ion distribution. By scanning the beam voltage from above to below this threshold, the current profile evolution can be compared in otherwise very similar discharges, correlated with the presence and absence of these modes. The Motional Stark Effect (MSE) diagnostic will be used to measure current profile evolution. Mirnov coils, soft x-ray cameras, heterodyne reflectometers, and far infrared tangential interferometers will be used to characterize the mode activity. The scanning and solid-state neutral particle analyzer (NPA) diagnostics will be used to monitor fast ion transport, assisted by the fast-lost-ion probes (FLIP) and neutron diagnostics. Analysis will be carried out using TRANSP, which calculates the fast ion distribution and beam driven currents, and EFIT, which ensures MHD equilibrium consistency with measured plasma density, temperature, rotation and current profiles.

It is fortuitous for this experiment that the beam driven current fraction depends only weakly on the beam voltage so that the experiments may be done where the effects of MHD on the beam driven current and the bootstrap contribution to the current are minimized. Further, the shots should be at moderate beta and toroidal rotation, minimizing complexities resulting from mapping of the ion and electron kinetic data to flux surfaces. These lowest voltage shots should provide the cleanest experimental data for benchmarking the TRANSP beam driven current calculation.

The results will be used to benchmark the Alfvén eigenmode mode theory of mode structure and evolution that can affect on the fast ion distribution and the core plasma current densities in NSTX as well as future burning plasmas such as ITER.

2. Theoretical/ empirical justification

Supra-Alfvénic fast ion driven instabilities and fast ion loss and dispersion may play a strong role in the determination of NB heating and current drive efficiencies in NSTX. These processes may affect the sustainable current density profiles in high-performance NBI-heated NSTX plasmas and the long-pulse "hybrid" plasmas projected in ITER. Enhanced losses of fast ions have been observed in the presence of a broad range of fast ion driven MHD activity on NSTX. This research will therefore aim to develop a basis for predictive understanding to advance long-pulse high performance plasma research on NSTX, and to strengthen the scientific basis for the ITER hybrid mode operation.

3. Experimental run plan

The approach is based on ’04 low neutral beam voltage shots where low frequency MHD was weak or non-existent. An example is shot 113114 with a single 60 kV beam from 0.05s. Current drive is more efficient at low voltage, which will help in the analysis. However, even in this example the bootstrap current is calculated to be roughly twice the beam driven current, with the total beam and bootstrap current of 150 kA compared to the total current of 800 kA. Because a long pulse is desirable to allow the current profile to equilibrate, the actual target plasma will be a long pulse shot, 117541, from 2004. This shot had all three neutral beam sources at 65 kV, vs. source C at 60 kV for shot 113114 and had considerable MHD activity. It is hoped that reducing the number of sources, and possibly the beam voltage will result in a quiescent discharge.

The parameters for the two shots are compared in Table I. Shot 113114 was from May 28, 2004 and had a morning boronization (30 min glow followed by 45 min He GDC). Shot 117541 was from Aug. 8, 2005. The previous boronization was May 19, 2005, ca. Shot 115876. Probably the most important difference between these two shots, apart from the beam heating power, was that 113114 was an L-mode plasma, shot 117541 was in H-mode. Assuming that L-mode operation is key to avoiding fast ion MHD, the starting point will be to use He puffing to keep the plasma in L-mode. In that case, time from the last boronization is probably not too important.

shot	113114	117541
shot date	5/28/04	8/8/05
LSN	L-mode	H-mode
Boronization	same day	5/19/05
He glow	9.5 min	?
kappa	1.90	2.10
Btor (kG)	3.84	3.80
Ip (MA)	0.87	0.69
Te (keV)	1.21	0.74
ne (10^13)	2.50	2.97

P_beam (MW)	2.54	3.25
V_beam (kV)	60	65

The run plan will be to start the day with source A conditioned to 90 kV for the MSE diagnostic. It will be used to provide pulses during the discharges for the measurement of the q profile. The remaining sources (B &C) will begin at 65 kV. If fast ion instabilities are present, the density or beam voltage will be lowered, if possible, to reduce ratio of fast ion velocity to Alfvén velocity. If fast ion instabilities are absent at 65 kV, raise density or beam voltage to find additional conditions with and without fast ion instabilities. If a set of conditions with similar plasma parameters is found where fast ion instabilities can be controlled, the current profile evolution will be documented with MSE by varying the source A on time.

The NPA will be used for a mini-documentation of the fast ion profile in target plasmas of interest Following this, the beams (B&C) will be conditioned back up to 85 kV and a set of data will be collected with strong fast ion MHD. (Note: shot 113114 used LFS gas feed as in 112814, but reduced by 20%.)

1. Start day with source A conditioned to 90 kV, B & C at 65 kV.
    a. Reproduce long pulse shot 117541, but with only sources B&C at 65 kV
    b. Repeat, but now introduce He to keep in L-mode. These two shots will provide the basis for later decisions as to whether to continue He puffing to keep in L-mode.
    c. Finally, replace B&C during current ramp phase (up to 200ms) with Source A. This will provide an initial measure of the current profile. If no deleterious effects result from this substitution, continue for rest of experiment.
2. If TAE/EPM activity, then try single source shots with only B or C, else goto 7.
3. If TAE/EPM activity persists, raise field to 5+ kG, else goto 7.
4. If TAE/EPM activity persists, drop beam voltage to 60 kV, repeat steps 1-3, else goto 7.
5. If TAE/EPM activity persists, try density scans up or down, else goto 7.
6. if TAE/EPM activity persists, increase and decrease current 650 kA and 850 kA, else goto 7.
7. Document current profile evolution with MSE, fast ion transport with NPA.
    a. Scan source A ontime in 50 ms intervals from 200 ms. Scan NPA tangency radius.
8. Document current profile evolution, fast ion transport with TAE/EPM in best comparison shot.

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

Toroidal field of 5 kG or 5.5 kG should be available. MSE is required.

5. Planned analysis

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

Extensive TRANSP analysis to calculate fast ion distribution. Benchmark TRANSP resistive current diffusion modeling against MSE data. As much useful data as possible will be used to benchmark M3D-k and NOVA simulations.

6. Planned publication of results

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

Target would be Physics of Plasmas Journal article.

PHYSICS OPERATIONS REQUEST

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Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **34-52** Flattop start/stop (s): **0.0/1.0**

I_P (MA): **0.750** Flattop start/stop (s): **0.2/0.9**

Configuration: **117541**

Outer gap (m): _____, Inner gap (m): _____

Elongation κ: _____, Triangularity δ: _____

Z position (m): **0.00**

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

NBI - Species: **D**, Sources: **A/B/C**, Voltage (kV): **90/65/65**, Duration (s): **0.90**

ICRF – Power (MW): **0**, Phasing: **Heating / CD**, Duration (s): _____

CHI: **On / Off**

Either: List previous shot numbers for setup: **117541**

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

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Diagnostic	**Need**	**Desire**	**Instructions**
Bolometer – tangential array			
Bolometer array - divertor			
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	✔		
Gas puff imaging			
Infrared cameras			
Interferometer - 1 mm			
Langmuir probe array			
Magnetics - Diamagnetism	✔		
Magnetics - Flux loops	✔		
Magnetics - Locked modes	✔		
Magnetics - Pickup coils	✔		
Magnetics - Rogowski coils	✔		
Magnetics - RWM sensors			
Mirnov coils – high frequency	✔		
Mirnov coils – poloidal array	✔		
Mirnov coils – toroidal array	✔		
MSE	✔		
Neutral particle analyzer	✔		
Neutron measurements	✔		
Plasma TV	✔		
Reciprocating probe			
Reflectometer – core	✔		
Reflectometer - SOL			
RF antenna camera			
RF antenna probe			
SPRED			
Thomson scattering	✔		
Ultrasoft X-ray arrays	✔		
Visible bremsstrahlung det.			
Visible spectrometers (VIPS)			
X-ray crystal spectrometer - H			
X-ray crystal spectrometer - V			
X-ray PIXCS (GEM) camera			
X-ray pinhole camera			
X-ray TG spectrometer			