Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

Title: NSTX/MAST Identity Experiments on iITB Formation and Evolution (ITPA TP-8)

OP-XP-513	**Revision:**	Effective Date: Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Authors: M. Peng, A. R. Field et al, R. Bell, E. Synakowski, J. Menard, D. Gates, B. LeBlanc, S. Sabbagh, S. Kaye, M. Bell, L. Baylor, E. Fredrickson, D. Stutman, K. Tritz, K.C. Lee, F. Levinton, L. Roquemore, M. Redi, Dave Mikkelsen,	Date
ATI – ET Group Leader: S. Kaye, D. Stutman (co-leader)	Date
RLM - Run Coordinator: J. Menard	Date
Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

R. Bell, D. Johnson, S. Kaye, D. Stutman, E. Synakowski, Mike Bell

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL-XP513

Title: NSTX/MAST IDENTITY EXPERIMENT ON iITB FORMATION AND EVOLUTION

Goals

- Document the evolution of the ion-ITB region, where $\chi_i \sim \chi_i^{NC}$, which is observed to form in the core and then evolve outwards in H-mode plasmas in both NSTX and MAST.
- Study the dependence of the driven toroidal flow and ExB flow shear on the injected momentum from the NBI, including cases matched to MAST 'identity' plasmas and cases where the injected momentum is stepped during the flattop of the discharge.
- Document the effect of the E×B flow shear and q-profile evolution on the iITB and correlate with the measured level of low-k turbulence, if available.

1. Background

Transport analysis of both NSTX and MAST plasmas reveals a broad region in the core of both L- and H-mode plasmas where χ_i is suppressed to the neo-classical level. Micro-stability analysis indicates that low-k turbulence may be at least partially stabilized in the iITB zone due to the E×B flow shear.

On both NSTX and MAST the tangential NBI systems drive strong toroidal flow with $M_\phi \sim 1$. This strong flow is expected to make the dominant contribution to the E×B flow shear rather than the pressure gradient. In this limit ω_{SE}/γ_m scales as M_ϕ rather than ρ^* with a critical toroidal Mach number required for ITB formation. As well as the E×B flow shear, the micro-instability growth rates also depend on the magnetic shear $s = r/q \cdot dq/dr$ as well as the temperature and density gradients, $\varepsilon_{n,T} = L_{n,T}/R$, and temperature ratio, $\tau = T_e/T_i$.

The aim of these experiments is to document the formation and evolution of the iITB and its dependence on the ExB flow shear and q-profile evolution through transport analysis of H-mode discharges over a range of heating, torque, temperature, and rotation conditions. The NBI heating power and energy will be scanned to vary both the heating power and the applied torque (at fixed power) to study the dependence of the driven flow and flow shear on the applied power and torque. Step changes in beam power during the flattop on NSTX will be carried out to shed additional light on the physics of iITB evolution. The evolution of the iITB and toroidal flow $V_{i\phi}$ is to be diagnosed using the high resolution CHERS systems now available on both NSTX and MAST together with the evolution of the electron profiles from the NdYAG TS systems. As well as the kinetic diagnostics and others required for transport analysis, any available turbulence and q diagnostics, e.g. reflectometry and MSE (on NSTX) should be important.

These experiments are to be performed on 'identity' discharges with similar configuration and parameters on both NSTX and MAST (M5/005, M5/047), which form the ITPA Joint Experiment TP-8. The first NSTX part was run in July '04 as XP-435 at reduced TF of 0.3 T, and will be repeated at 0.45 T in '05.

2. Experimental shot list

On NSTX and MAST, the iITB dynamics can be changed by changing the NBI momentum (and hence the plasma flow and flow shear), the plasma current (and hence the q and q shear), the NBI power (and hence the plasma beta and bootstrap current, which in turn affects q), the rate of density rise (and hence T_i/T_e), and the H-transition time (and hence the density profile evolution and momentum deposition, particularly at lower NBI energies).

The table below maps out the range of NBI energies and powers to be used in this XP, organized in nine cases [Case: NBI Source/Energy, flattop Shots + NBI stepping shots]:

~4.4 MW	~3.3 MW	~2.2 MW
I: B, A/90, 2+1	II: 0.5B, A/90, 2+1	III: B→A/90, 2+1
IV: B, 0.67A, C/80, 2+1	V: B, A/85, 2+1	*VIII: B, A/70, 2+1*
VI: B, A, C/70, 2+1	*VII: B, A, C/70, 2+1*	*IX: B, A, C/60, 2+1*

Initial progress in this study was obtained on NSTX in '04, via XP435, at 3 kG in field and 800 kA in current. Cases I – VI were tested in '04 at 3 kG field, producing conditions appropriate for the goals of the XP, though with appropriate flattop durations limited to 2-3 times the energy confinement times (100-150 ms). Factors of 2 and 4 in the ranges of NBI power and torque were demonstrated, respectively. Operation at 4.5 kG is expected to more than double the flattop duration to up to 400-500 ms, avoiding large MHD activities.

These shots will be carried out in the following manner, subject to improvements based on up-to-date results of the '05 campaign:

A) Carry out the described power-momentum scan at ~4.5 kG field, which should ensure appropriate flattop durations comparable to the current redistribution times. Cases VII – IX, with beam energies near 70 kV or lower, can be reproduced on MAST, as indicated below:

NSTX	**Power**	**MAST**
VII: C, B, A/70, 2	*3.3 MW*	SW: 50 keV, 1.5 MW SS: 60 keV, 1.8 MW
VIII: B, A/70, 2	*2.2 MW*	SS: 70 keV, 2.2 MW
IX: C, B, A/60, 2	*2.2 MW*	SW: 35 keV, 0.7MW SS: 60 keV, 1.5 MW

B) Use source A at 90 kV for Cases I – III for ~1s to allow proper MSE measurement in 8 chords, as 90 kV (with ≤ ±100 V accuracy) energy from this source will provide the "cleanest" data for this measurement.

C) All cases will aim for H-transition at around ~80 ms and sustained H-mode for greater than 400 ms ms without dominating MHD activities.

D) All shots will chose a shape and divertor configuration (DND or LSN) best suited for the XP. 4 MA/s current ramp rate, density $\bar{n}_e \sim 1\text{-}2\times10^{19}$ m^{-3} at H-mode transition, $\kappa \sim 2.0$ – 2.2, and $\delta \sim 0.4\text{-}0.6$ are some of the expected conditions.

E) Beam timing is expected to be 50 ms for source B, 70 ms for source A or C, and 130 ms for the third source if specified. Beam energies, durations, and source combinations will be varied in groups of constant energy, to ensure NBI reliability and minimize beam shot cycles required by energy change.

F) A NBI power stepping shot will immediately follow the flattop NBI shots in each case, at 200-300 ms into the flattop, for the remainder of the flattop. This will allow documentation of the iITB evolution properties prior to and following the stepping.

G) He glow discharge cleaning for 11.5 min is expected to be required for each shot. Short morning boronization can be appropriate dependent on the wall condition of the preceding day.

H) The above approach so far has allowed sustained moderate ELM conditions for up to ~400 ms at 4.5 kG, with absence of large MHD activities for ~400 ms.

I) The shot sequence is determined by the following considerations:

Cases I – III with 90-kV beam energy (±100 V) should be carried out first to take advantage of maximum beam reliability at the start of experiment, and to enable reliable MSE measurements; energy will vary in subsequent shots.

The remaining cases will be carried out in sequence of decreasing NBI energy to maximize the reliability of NBI operation.

All cases will maintain inner/outer gaps of 6-8 cm/12 cm to minimize the fast ion interactions with the HHFW launcher system and help ensure good plasma quality during NBI injection.

3. Required machine, NBI, and diagnostic capabilities

a) The XP requires operational NBI and the capability of generating sustained H-mode diverted discharges with the plasma control system, as indicated in the above descriptions and table.

b) Fresh boronization may be required.

c) MSE measurement to constrain q_0 values is required for shots using 90 kV beam energy from source A.

d) Magnetics for EFIT reconstruction is required, with EFIT accounting for plasma rotation and MSE.

e) TS required in all cases.

f) CHERS diagnostic of Ti, Vϕ, C-IV, and Z_{eff} profiles is required for analysis and TRANSP calculations. Carbon profiles are further important in helping to clarify particle transport properties.

g) In-vessel B_R and B_p measurements up to ~200 kHz are required to document potentially relevant mode signatures.

h) High frequency digitized Mirnov signals are desirable as TAE's and CAE's are expected to play a significant role in determining the fast ion behavior.

i) NPA in the “ion temperature” configuration and neutron measurements are highly desirable.

j) Fast-ion drive mode measurements are encouraged as these are expected to be likely prevalent in these shots, per NPA and neutron measurements of shots from XP435.

k) FIR interferometry is highly desirable, particularly for H-mode plasmas with broad or even edge peaked density profiles. Increased data bandwidth for these will be highly desirable.

l) “Two-color” USXR tomography is high desirable.

m) Techniques to reduce the magnitude of H-mode “ears” at edge are highly desirable. These include possibly beneficial effects of Li coating via pellets, and Supersonic Gas Injection (SGI).

n) EBW radiometer is desirable, aimed at a mid-plane location (R ~ 130 cm) where the evolving iITB zone is expected to sweep through.

o) Tangential XR camera is desirable, as it corroborate the presence or absence of large Te variations due to various modes.

4. Planned analysis

The analysis includes EFIT, TRANSP output, gyrokinetic microstability analysis with GS2 and GYRO, NCLASS including rotation effects for the ExB shear evaluation. Detail of this part of the effort is being developed.

5. Planned publication of results

Conferences paper, refereed journals, and ITPA meetings.

PHYSICS OPERATIONS REQUEST

Title: **OP-XP-513**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **(~4.5 kG)** Flattop start/stop (s): **0.6/1.0**

I_P (MA): **0.8** Flattop start/stop (s): **0.16-0.14/1.0**

Configuration: **LSN or DND**

Outer gap (m): **12+ cm**, Inner gap (m): **6 – 8 cm**

Elongation κ: **~2.2** Triangularity δ: ~**0.4 – 0.6**

Z position (m): **0.00/-0.05**

Gas Species: **D** Injector: **H-mode gas puff for 113699**

NBI - Species: **D_2**, Sources: **A/B/C** Voltage (kV): **90, 85, 80, 70, 60 in groups**

Duration(s): ≤ **0.9**

ICRF – Power (MW): **0** Phasing: Duration (s):

CHI: **Off**

Either: List previous shot numbers for setup: **113699 for all Cases**

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: NSTX-MAST Identity Experiments on iITB in Co-NBI H-Mode Plasmas OP-XP-513

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		✓	
High-k scattering			
Infrared cameras			
Interferometer – 1 mm		✓	
Langmuir probes - PFC tiles		✓	
Langmuir probes - RF antenna			
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 Rate (2 fission, 4 scint)		✓	
Neutron collimator		✓	
Plasma TV	✓		
Reciprocating probe		✓	
Reflectometer - FM/CW	✓		
Reflectometer - fixed frequency homodyne	✓		
Reflectometer - homodyne correlation	✓		
Reflectometer - HHFW/SOL		✓	
RF antenna camera			
RF antenna probe			
Solid State NPA	✓		
SPRED		✓	
Thomson scattering - 20 channel	✓		
Thomson scattering - 30 channel	✓		
Ultrasoft X-ray arrays		✓	
Ultrasoft X-ray arrays - 2 color	✓		
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	✓		