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, J. Menard et al	Date
ATI – ET Group Leader: S. Kaye, D. Stutman (co-leader)	Date
RLM - Run Coordinator: J. Menard	Date August 8, 2005
Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

R. Bell, S. Kaye, D. Gates, 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 near 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).

Recent progress in long pulse H-mode plasmas established conditions for, such as in 116318:

- Plasma current up to 1.5 s, with flat top starting before 0.2 s.
- MHD relatively quiescent conditions for 0.5 – 1.0 s, during which the iITB properties are likely to be dominated by transport mechanisms. This duration is more than an order of magnitude larger than the time scales of mechanisms that determine the iITB evolution.
- This highly desirable condition requires full beam power before t = 0.5 s to create.
- The NBI energy and power scan can therefore be carried out most effectively via power step down during the quiescent period.

The table below indicates the maximum range of NBI energies and powers to be used in this XP [Case: NBI Source-Energy (kV); approximate Power (**MW**)], providing also the maximum range of NBI momentum input.

Case	Src-kV/MW	A+B+C; MW	A+C; MW	A+B; MW	A; MW
I	A-90/2.2; B,C-100/2.4	7.0	4.6	4.6	2.2
II	A-90/2.2; B,C-90/2.2	6.6	4.4	4.4	2.2
III	A-90/2.2; B,C-80/1.7	5.6	3.9	3.9	2.2
IV	A-90/2.2; B,C-70/1.1	4.4	3.3	3.3	2.2
V	A-80/1.7; B,C-70/1.1	3.9	2.9	2.9	1.7
VI	A-70/1.1; B,C-70/1.1	3.3	2.2	2.2	1.1
VII	A-65/0.8; B,C-65/0.8	2.4	1.6	1.6	0.8

Initial progress in this study was obtained on NSTX in ‘04, via XP435, at 3 kG in field and 800 kA in current. The test produced 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 near 4.5 kG and 750 kA in 116318 increased this duration to 500 ms, when significant MHD activities were avoided.

The shots will be carried out in the sequence shown in following Table to take full advantage of 116318 and for reliable NBI operation. Some flexibility is built in to accommodate the plasma conditions obtained. To ensure the desired long pulse plasma conditions, all shots will use sources A, B, C early during current ramp-up and through and beyond t = 500 ms, as in the case of 116318, though at varied beam energies and subsequent durations.

	Source energy (kV)			Source on-times (ms)			Shade = Priority
C-S	A	B	C	A	B	C	Comment
I-1	**90**	**100**	**100**	100-1000	60-1000	160-1000	
I-1a	**90**	**100**	**100**	Same on-time	60-650, 800-1000	160-1000	On-off hysterisis
I-2	**90**	**100**	**100**	for all shots ↓	60-650	160-800	
#**I-2-CHERS**	**90**	**100**	**100**		60-600, chop 600-740	160-800, chop 800-940	Chop: 10-ms off & 10-ms on
I-2a	**90**	**100**	**100**		60-800	160-650	Tangency effect
II-3	**90**	**90**	**90**		60-1000	160-1000	
II-3a	**90**	**90**	**90**		60-650, 800-1000	160-1000	
II-4	**90**	**90**	**90**		60-650	160-800	
II-4a	**90**	**90**	**90**		60-800	160-650	
III-5	**90**	**80**	**80**		60-1000	160-1000	Best MSE ↓
III-6	**90**	**80**	**80**		60-650, 800-1000	160-1000	
III-7	**90**	**80**	**80**		60-650	160-800	
III-8	**90**	**80**	**80**		60-800	160-650	
IV-9	**90**	**70**	**70**		60-1000	160-1000	MAST similarity ↓
IV-10	**90**	**70**	**70**		60-650, 800-1000	160-1000	
IV-11	**90**	**70**	**70**		60-650	160-800	
IV-12	**90**	**70**	**70**		60-800	160-650	Best MSE ↑
V-13	**80**	**70**	**70**		60-1000	160-1000	A → 80 kV
V-13a	**80**	**70**	**70**		60-650, 800-1000	160-1000	
V-14	**80**	**70**	**70**		60-650	160-800	
V-14a	**80**	**70**	**70**		60-800	160-650	
VI-15	**70**	**70**	**70**		60-1000	160-1000	A → 70 kV
VI-15a	**70**	**70**	**70**		60-650, 800-1000	160-1000	
VI-16	**70**	**70**	**70**		60-650	160-800	
VI-16a	**70**	**70**	**70**		60-800	160-650	
VII-17	**65**	**65**	**65**		60-1000	160-1000	A → 65 kV
VII-17a	**65**	**65**	**65**		60-650, 800-1000	160-1000	Likely require more source conditioning
VII-18	**65**	**65**	**65**		60-650	160-800	
VII-18a	**65**	**65**	**65**		60-800	160-650	

To aid CHERS data interpretation; 7 times of 10-ms off & 10-ms on for the indicated duration before turning beam off.

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, V_ϕ, 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 fluctuations 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 affecting the fast ion and hence rotation behavior.

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

j) Fast-ion driven 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 fluctuation data bandwidth to 200 kHz for these will be highly desirable.

l) "Two-color" USXR tomography is high desirable, if possible.

m) EBW radiometer is desirable; the signals received may corroborate location of ITB .

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): **0.0/1.3**

I_P (MA): **~0.75** Flattop start/stop (s): **0.16-0.14/1.2**

Configuration: **LSN**

Outer gap (m): **12-14 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 116318**

NBI - Species: **D_2**, Sources: **A/B/C** Voltage (kV): **100, 90, 80, 70, 65 in groups**

Duration(s): ≤ **1.0**

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

CHI: **Off**

Either: List previous shot numbers for setup: **116318 for all Cases (see above)**

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		✓	Strongly desired
Neutron Rate (2 fission, 4 scint)		✓	
Neutron collimator		✓	
Plasma TV		✓	Strongly desired
Reciprocating probe		✓	
Reflectometer - FM/CW		✓	Strongly desired
Reflectometer - fixed frequency homodyne		✓	Strongly desired
Reflectometer - homodyne correlation		✓	Strongly desired
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		✓	