Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: **Thermal transport in the NSTX boundary**		
OP-XP-923	Revision:	Effective Date: **27-Mar-09** *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: R. Maingi	Date
ATI – ET Group Leader: V. Soukhanovskii	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: Thermal transport in the NSTX boundary | No. **OP-XP-923**

AUTHORS: R. Maingi, J. Ahn, J. Kallman, R. Maqueda, S. Paul, V. Soukhanovskii, D. Stotler, S. Zweben | DATE: **27-Mar-09**

1. Overview of planned experiment

The goal of this experiment is to assess SOL thermal transport by measuring midplane and divertor profiles and turbulence and comparing with 2-D fluid and turbulence codes. The experiment is the main implementation of the FY 2010 Joint Research Target (formerly "Joule" milestone) between Alcator C-Mod, DIII-D, and NSTX, although additional experiments are also expected to contribute.

2. Theoretical/ empirical justification

The transport of heat in the scrape-off layer, coupled with the magnetic geometry, sets the heat flux footprint at the target and wall. The observed ~ cm scale decay lengths at the midplane are the result of the competition between parallel and perpendicular transport. While experiments have suggested that parallel heat transport is classical and dominated by electron conduction near the separatrix [Ahn, PoP 2008], the radial transport is intermittent and convective, i.e. non-diffusive, and thought to be determined by turbulence. The goal of this XP is to simultaneously measure the power balance and turbulence characteristics, while varying parameters that are known to affect the measured heat flux profiles.

The outer divertor peak heat flux was shown to increase strongly with input power, particularly after burning through a radiative divertor regime and going to a high recycling regime [Maingi, JNM2007]. The heat flux width mapped to the midplane was not strongly dependent on the heating power. In addition, the peak heat flux increased strongly with I_p, with the width narrowing rapidly, indicating a reduction in cross-field transport. The power accountability in those discharges was ~ 70%, and was limited partly by inability to measure power to the upper divertor and the coarse spatial resolution of divertor bolometer channels [Paul, JNM 2005]. In addition, gas puffing has been shown to strongly affect the divertor heat flux profiles, leading to partial detachment [Soukhanovskii, JNM 2007].

The new 20 channel divertor bolometer and fast IR camera are being commissioned and will improve the power accounting capability, both averaged over and between ELMs. In addition the gas-puff imaging system [Maqueda, RSI2001, Zweben NF 2004] was upgraded and a new divertor imaging system was commissioned, enabling improved measurements of the turbulence. Hence these two parametric variations (P_{NBI} and I_p) are the most important ones to repeat with the new diagnostics.

There is also substantial interest in comparing NBI and RF heating, since NBI leads to a fast ion population that may set a minimum for the SOL width. NSTX and DIII-D have discussed doing an explicit heating method comparison to address this effect, and to more closely tie to the C-Mod results. Finally L-mode operation substantially changes the turbulence characteristics and has broader SOL widths in general. Hence there is much interest in comparing the divertor characteristics in L-mode vs. H-mode. While a substantial power scan in L-mode is unlikely with the favorable grad-B drift direction, a sequence of discharges with unfavorable grad-B drift is suggested to allow a power scan up to 3-4 MW.

To model the results with 2-D fluid and neutrals codes (e.g. SOLPS, UEDGE, DEGAS-2), and turbulence codes (e.g. SOLT, BOUT), good divertor profile data is needed. Thus an important aspect of this experiment is outer strike point sweeping over existing divertor Langmuir probes. For the low-δ discharge, such a sweep is built-in across R_{LP}=0.8 m. For the high-δ discharge, a strike point sweep across R_{LP}=0.5m would need to be implemented. In addition, data from the 1-D CCD cameras is needed to obtain D_α, D_γ, and C-III emission profiles.

3. Experimental run plan

The main scans in this XP are a power (NBI) scan, I_p scan, fueling scan to change density, an NBI vs. RF comparison, and an L-mode vs. H-mode comparison. There is a desire to obtain as much of a power scan in L-mode as possible, which would be facilitated by running reversed-B_t or developing upper-single null H-modes. For completeness, data in both lower $\delta \sim 0.4$-0.5 and higher $\delta \sim 0.7$ (fiducial-like) discharges is desired.

Shot sequence (2 days FY 2009):

1. Re-run lower $\delta \sim 0.4$-0.5 discharge #132209 but with I_p=0.8 MA, B_t=0.44 T, δ_r^{sep}=-2cm, P_{NBI}=4 MW. (4)
2. Perform an NBI scan from 1-6 MW after L-H transition: 2 MW, 3 MW, 1 MW, 5 MW, 6 MW. Turn down voltage on source C to get to 1 MW power level. (10)
3. Repeat baseline discharge and start I_p scan: 0.7 MA, 0.6 MA, 0.9 MA, and 1.0 MA at 4 MW NBI. Try to keep edge pitch constant by fixing B_t/I_p = 0.55 T/MA. If P_{LH} increases too much, then do the higher I_p at fixed B_t=0.5T or 0.44 T. Monitor the edge field line pitch in real time. (18)
4. Repeat baseline discharge and perform fueling scan +/- 200 torr in HFS fueling rate (6)
5. Time permitting: Repeat steps 2-4 for a high triangularity discharge, shot #132208. The highest priorities are abbreviated versions of a power scan (4, 6 MW) and I_p scan (0.9, 1.2 MA). (30)

There are a couple of additional desired datasets. It is possible that these would be run at the beginning of the FY 2010 run. They are listed here for completeness, with details to be supplied later.

1. Explicit comparison of RF and NBI at 1, 2, 3 MW power levels at 0.8 MA, 0.44 T.
2. Using reversed B_t to increase P_{LH} and doing an L-mode power scan in LSN at 0.8 MA, 0.44 T.

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

H-mode access at reasonable power is required. HeGDC between shots will be adjusted according to need, probably ~ 9 min for a 15 minute rep rate.

5. Planned analysis

EFIT/LRDFIT needed, along with simulation of diagnostic data with SOLPS and/or UEDGE. Neutrals analysis will be done with DEGAS-2. Turbulence data and measured SOL widths will be used as input to various turbulence codes, e.g. SOLT and BOUT.

6. Planned publication of results

Nuclear fusion papers, along with an overall write-up of the milestone experiments.

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:

Need to maintain shape as best as possible during NBI and I_p scans.

First starting case: lower $\delta \sim 0.4$-0.5, δ_r^{sep}=-2cm, P_{NBI}=4 MW.

Second starting case: higher $\delta \sim 0.75$, δ_r^{sep}=-2cm, P_{NBI}=4MW.

Previous shot(s) which can be repeated:

Previous shot(s) which can be modified: 132209 (low δ), 132208 (high δ)

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

I_{TF} (kA): 40-67 (0.34-0.55 T) Flattop start/stop (s):

I_P (MA): 0.6-1.0 MA Flattop start/stop (s): 140-200 ms

Configuration: Limiter / DN / **LSN** / USN

Equilibrium Control: **Outer gap / Isoflux** (rtEFIT): Isoflux

Outer gap (m): **0.1** Inner gap (m): **varies** Z position (m):

Elongation κ: ~2 Upper/lower triangularity δ: 0.4-0.5; 0.7-0.8 high δ

Gas Species: **D** Injector(s): any

NBI Species: **D** Voltage (kV) **A: 90** **B: 90** **C:** 65-90 Duration (s): <1 sec

ICRF Power (MW): 0 Phase between straps (°): Duration (s):

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

LITERs: Off / On Total deposition rate (mg/min):

EFC coils: Off/On Configuration: **Odd / Even / Other** *(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	√	
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 – E‖B 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		