Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: **Scaling of heat flux profiles and edge turbulence in NSTX discharges with li-coated PFCs for the FY2010 Joint Research Milestone**		
OP-XP-1043	Revision:	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: R. Maingi	Date **June 1, 2010**
ATI – ET Group Leader: V.A. Soukhanovskii	Date
RLM - Run Coordinator: E.D. Fredrickson	Date
Responsible Division: Experimental Research Operations	

RESTRICTIONS or MINOR MODIFICATIONS

(Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: **Scaling of heat flux profiles and edge turbulence in NSTX discharges with li-coated PFCs for the FY2010 Joint Research Milestone** No. **OP-XP-1043**

AUTHORS: **R. Maingi, J-W. Ahn, T.K. Gray, R.J. Maqueda, A.G. McLean** DATE: **June 1, 2010**

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1. Overview of planned experiment

The primary goal of this XP is to measure the divertor heat flux profile (peaks, widths) in discharges with li-coated PFCs to compare with pre-li discharges, which represents NSTX's contribution to the FY2010 Joint Research Milestone. We will investigate a comprehensive set of variations: I_p, B_t, P_{NBI}, and a few different plasma shapes. The secondary goal is to obtain midplane tutbulence measurements with GPI and reflectometry to correlate with the measured SOL heat flux widths.

2. Theoretical/ empirical justification

The research proposed here is motivated partly by the FY 2010 Joint Facilities Milestone: "Conduct experiments on major fusion facilities to improve understanding of the heat transport in the tokamak scrape-off layer (SOL) plasma, strengthening the basis for projecting divertor conditions in ITER. Divertor heat flux profiles and plasma characteristics in the tokamak scrape-off layer will be measured in multiple devices to investigate the underlying thermal transport processes. The unique characteristics of C-Mod, DIII-D, and NSTX will enable collection of data over a broad range of SOL and divertor parameters (e.g., collisionality, beta, parallel heat flux, and divertor geometry). Coordinated experiments using common analysis methods will generate a data set that will be compared with theory and simulation." In addition, the plan will give more information on how to project the heat flux footprint for NSTX-Upgrade ($I_p \leq 2$ MA, $B_t \leq 1$ T, $P_{NBI} \leq 10$ MW, pulse length < 5 sec).

Previously, we have observed that that the divertor heat flux in non-lithium discharges increases linearly with P_{NBI}, faster than linearly with I_p (e.g. figure 1), and decreases in going from single-null to double-null and also with flux expansion (Maingi, JNM 2007; Gates PoP 2006; Gray, JNM 2010 submitted; Soukhanovskii EPS 2009). Correspondingly the midplane-mapped widths are independent of P_{NBI} and flux expansion, but decrease sharply with I_p. The Bt

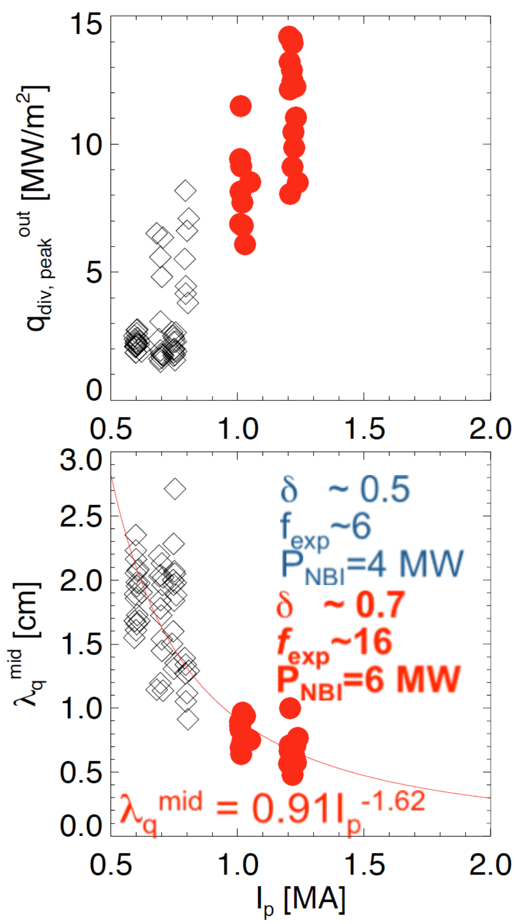

Fig. 1: dependence of peak outer divertor heat flux and midplane-widths on plasma current, I_p.

dependence has not been well-documented, but piggyback experiments have indicated no strong B_t dependence.

We now propose to measure the heat flux footprints as a function of I_p, B_t, P_{NBI}, δ_r^{sep}, and in a common scaled poloidal cross-section shape common to DIII-D and C-Mod, in NSTX discharges with lithium coated PFCs. Preliminary indication is that the heat flux width shrinks as the ELMs are suppressed with lithium, thus increasing the divertor loading and requiring a thorough characterization for the NSTX-Upgrade. Note that active mitigation techniques (gas puffing/detachment, snowflake divertor - see Soukhanovskii PoP 2009; Soukhanovskii NF 2009; Soukhanovskii JNM 2010 submitted) are being investigated in separate XPs.

3. Experimental run plan (3 days)

GPI will always be on, but will only be optimized at the right field line pitch of ~ 35^0 (e.g. 0.8 MA-0.9 MA, 0.45 T). in general we want 2 good discharges per condition, but will settle for that at the endpoints only if time is constrained.

Day 1:

• Develop baseline 1.2 MA, 0.45 T (based on pre-li 128797)

- –Vary fueling +/- 100 torr with 100-200 mg Li between shots to set up target. Desire a deischarge that's mostly ELM-free, although that's not required. Probably means ~ 200mg lithium between every discharge. (6)
- –P_{NBI} scan: 2-max MW (1 MW increments). The upper limit will be set by β limit. (8)
- –Drop I_p=0.8 MA; P_{NBI} scan: 2-max MW (1 MW increments). The GPI will be most effective during this scan. Take repeat shots as needed. (10)

Day 2:

Highest priority is the easily achievable end points of the I_p scan: 1.2 MA and 0.8 MA. We'll hit the other end points, and then the middle points. This fine scan is desired since the SOL width narrows faster than linear with I_p. The NBI value will be selected from the previous day, based on the achievable input without exceeding the β limit.

• I_p scan at 3 or 4 MW NBI: 1.2 MA, 0.8 MA, 1.3 MA, 0.7 MA, 1.0 MA, 1.1 MA, 0.9 MA (18)

• B_t scan from 0.35-0.55 T (0.05 T increments) – run at 0.8 MA, high δ (8)

Day 3:

• Scaled poloidal shape match to C-Mod and DIII-D to match ν^*, κ, δ: (e.g. from XP721: δ ~ 0.5, κ=1.8, large δ_r^{sep}). A candidate shot is 124657/124662 from XP 721 (see Figure 2; DIII-D has also made the same shape). This will have to be re-run with lithium. A few different gas puff rates to get a ν^* scan are desired. (6)

• δ_r^{sep} scan: -6mm, -3mm, 0mm, -10mm, -20 mm, at high δ ~ 0.7 and repeated for medium δ ~ 0.5. The high δ discharges will be started from the 0.8 MA, 0.45 T discharge above. The medium δ discharges can be started from 137613, although we should move the strike point onto the LLD earlier, if possible. Use the same P_{NBI} as for the I_p scan above at high δ, and reduce down to 3 MW for the low δ part. (20)

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

Strike point control will be used in this XP. NBI up to 6 MW, no CHI or rf.

5. Planned analysis

The IRTV profiles will be analyzed for integral heat flux widths (Loarte, JNM 1999), and the GPI data will be analyzed for blob characteristics. This dataset will be the basis for SOLPS and UEDGE modeling, as well as possible BOUT, XGC, and SOLT modeling.

6. Planned publication of results

The results will contribute to the Joule milestone report, IAEA and APS papers.

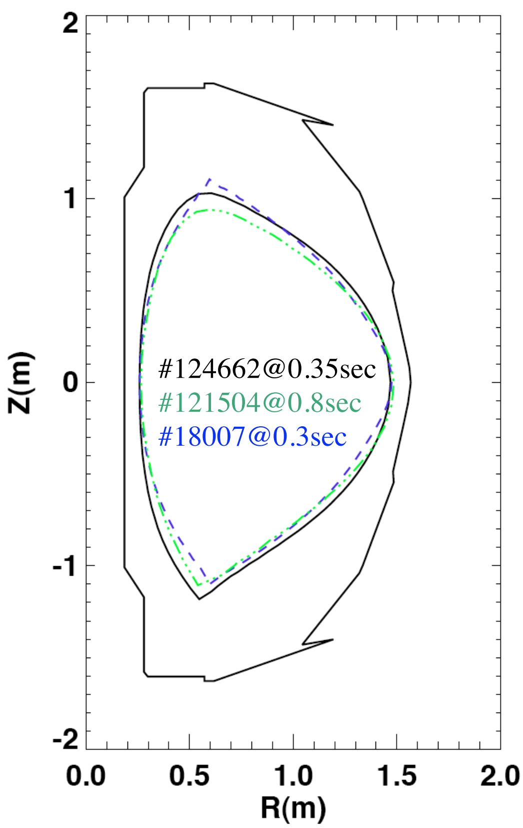

Fig. 2. Common shape developed for experiment. Color code: NSTX (black), MAST (blue: dashed), and C-Mod (green: dash-dot). The NSTX and C-Mod plots are scaled by 0.96 and 2.8 respectively, and the C-Mod boundary is shifted inward by 0.19 m.

PHYSICS OPERATIONS REQUEST

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(use additional sheets and attach waveform diagrams if necessary)

Brief description of the most important operational plasma conditions required:

Relatively constant OSP radius; ability to scan I_p and B_t over wide range

Previous shot(s) which can be repeated:

Previous shot(s) which can be modified: 128797, 137613, 24662

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

I_{TF} (kA): **0.35-0.55 T** Flattop start/stop (s):

I_P (MA): **0.7-1.3 MA** Flattop start/stop (s):

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

Equilibrium Control: Outer gap / Isoflux (rtEFIT) / **Strike-point control (rtEFIT)**

Outer gap (m): **10cm** Inner gap (m): **varies** Z position (m): **varies**

Elongation: **1.8-2.4** Triangularity (U/L): **0.5-0.7** OSP radius (m): **40cm, 70cm**

Gas Species: D_2 Injector(s):

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

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

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

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

LLD: Temperature (°C): **210 for drsep scan; else unheated**

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**
Beam Emission Spectroscopy		
Bolometer – divertor		√
Bolometer – midplane array		√
CHERS – poloidal		√
CHERS – toroidal	√	
Dust detector		√
Edge deposition monitors		√
Edge neutral density diag.		√
Edge pressure gauges	√	
Edge rotation diagnostic		√
Fast cameras – divertor/LLD		√
Fast ion D_alpha - FIDA		
Fast lost ion probes - IFLIP		
Fast lost ion probes - SFLIP		
Filterscopes	√	
FIReTIP		√
Gas puff imaging – divertor		√
Gas puff imaging – midplane	√	
Hα camera - 1D	√	
High-k scattering		
Infrared cameras	√	
Interferometer - 1 mm		
Langmuir probes – divertor		√
Langmuir probes – LLD		√
Langmuir probes – bias tile		
Langmuir probes – RF ant.		
Magnetics – B coils	√	
Magnetics – Diamagnetism	√	
Magnetics – Flux loops	√	
Magnetics – Locked modes		√
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 detectors		√
Plasma TV		√
Reflectometer – 65GHz		√
Reflectometer – correlation		
Reflectometer – FM/CW		
Reflectometer – fixed f		
Reflectometer – SOL		√
RF edge probes		
Spectrometer – divertor		
Spectrometer – SPRED		√
Spectrometer – VIPS		
Spectrometer – LOWEUS		
Spectrometer – XEUS		
SWIFT – 2D flow		
Thomson scattering	√	
Ultrasoft X-ray – pol. 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 tang. pinhole camera		