Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

Title: **LLD Core Physics Survey**

OP-XP-1066	Revision: **0**	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: S.P. Gerhardt, et al.	Date
ATI – ET Group Leader:	Date
RLM - Run Coordinator:	Date

Responsible Division: Experimental Research Operations

RESTRICTIONS or MINOR MODIFICATIONS
(Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

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1. Overview of planned experiment

There are three overlapping goals for this XP:

1: Establish operation with a pumping LLD over a wider range of current, field, and power than in the commissioning and pumping XP.

This will provide additional information about how to run NSTX with a pumping LLD.

2: Establish key trends for core physics.

Important to establish these trends early in the run, as the continued efficacy of LLD as a pump may decrease through the run, either as a result of component failures or surface contamination.

3: Gather data for further XP planning.

However, this XP is not a surrogate for any devoted XP within the TSGs.

To meet these goals, the XP will expand on the LLD commissioning and pumping XPs. It is assumed that those XPs have provided:

1: A recommended shape that provides pumping. Operation with the largest triangularity consistent with pumping is desirable. The shape must be compatible with long pulse operation at 4-6 MW of injected power.

2: A fueling scheme that provides reliable H-mode access and discharge performance. It would be desirable for this to be based on SGI; otherwise the standard HFS injector will be used.

3: Recommended LITER evaporation rate and LLD temperature.

4: Examples of discharges in the chosen shape at 900 kA & 0.45 T, for I_P/B_T=2000 kA/T

This XP will expand those results to a wider range of field and current as follows, with a key focus on the physics of varied collisionality at constant-q.

Step 1: Develop a long-pulse configuration with I_P=750 kA and B_T=0.38 T. Some limited studies of the effect of n=3 fields will be executed.

Step 2: Develop a configuration with I_P=1 MA and 0.5 T. Some limited studies of the effect of n=3 fields will be repeated.

Contingency: extend discharge to 1.1 MA and 0.55 T. This combination matches the I_PB_T product limit of 6 MA·T while keeping a ratio of 2 MA/T

Step 3: Develop a high-β_T configuration, at 900-1000 kA and B_T=0.38.

2. Theoretical/ empirical justification

The liquid lithium divertor is the major upgrade to NSTX for the 2010 experimental campaign. It should, in principal, provide significantly greater pumping capability than the solid lithium coatings that have been previously applied, provided that the strike-point is sufficiently near the plate.

The boundary and lithium research topical science groups have many experiments devoted to understanding the details of LLD pumping and its impact on the physics of the plasma boundary. However, LLD may have a profound impact on the behavior of the core plasma. For instance, if reduced core plasma density is achieved with constant or increased plasma temperature,

* it may lead to increased neutral beam current drive,

* it may, depending on the collisionality scaling of NTV, lead to enhanced braking due to 3-D fields,

* it may modify the intrinsic stability of the RWM,

* it may modify core turbulence, potentially resulting in improvements in confinement.

A common element of these physics topics is the variation of plasma performance with collisionality. Hence, the variation of collisionality at constant-q will be the primary physics focus of the XP. If additional time is available, a low-q, high-β_T scenario will be examined.

3. Experimental run plan

Notes:

N1: These discharges will operate at intermediate triangularity. This may have a deleterious impact on the global stability, and may make the discharges more difficult to run at higher values of I_P/B_T.

N2: The shot list below is to be repeated twice, first with a warm LLD, then with a cold LLD. However, a priority is to be placed on the warm LLD portion of the shot list. See Decision Point #2.

N3: If mode locking early in the shot at low density is a problem, consider the addition of early error field correction. Example RWM category, smf algorithm, to load is 135779.

3.1 Low current and field, long pulse discharge development.

3.1.1 Load recommended discharge from LLD commissioning or pumping XPs. Lower field & current to 0.38 T and I_P=750 kA. Injected power will likely be 4MW, (1 shot)

3.1.2 Adjust beam power, fuelling, other parameters to achieve >1 sec pulse. (4 shots)

3.1.3 Repeat the shot in 3.1.2 with either/both larger or smaller power. (3 shots)

3.1.4 If steps 3.1.1-3.1.3 took less than 9 shots, then do n=3 braking studies described in 3.5. (4 shots)

3.2 High current and field

3.2.1: Using the same shape, increase the current and field to 1.0 MA and 0.5 T Adjust gas and input power to achieve >700 msec of I_P flat-top. (4 shots)

3.2.1: Repeat with shot in 3.1.2 with either larger or smaller power. (2 shots)

3.1.3 If steps 3.2.1 and 3.2.2 took less than 9 shots, then do n=3 braking studies described in 3.5. (4 shots)

Decision Point #1: Proceed to yet higher I_P and B_T values (3.3), or to higher normalized current (3.4)

3.3: Highest current and field contingency

3.3.1 Increase the current to 1.1 MA and 0.55 T. Adjust gas and beam power. Should be a minor perturbation to the previous condition. These will be short discharges, so skip magnetic braking. (4 shots)

3.4 High-β_T discharge development contingency

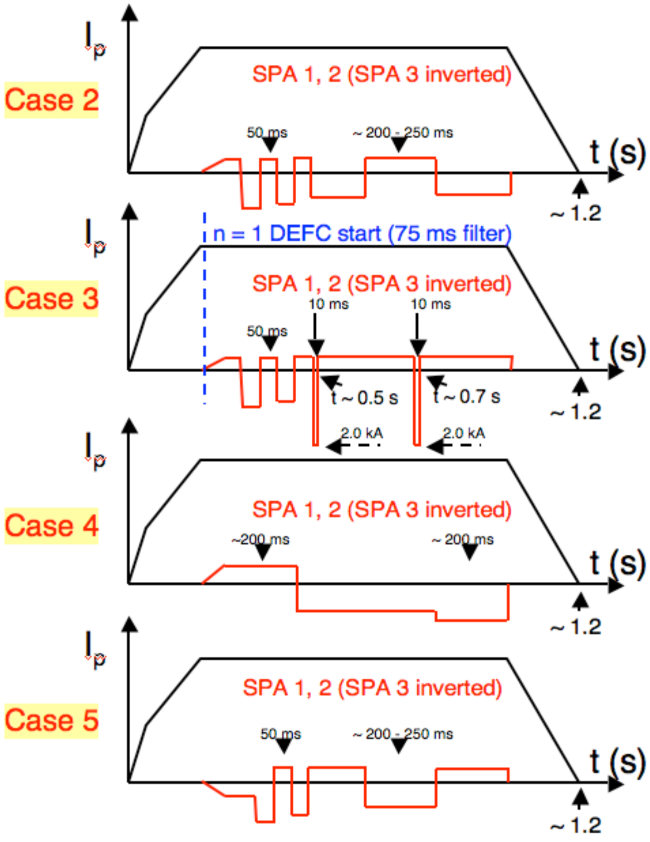
3.4.1: Set I_P=1 MA and B_T=0.4 T. Adjust power and fuelling to achieve longest possible pulse. (4+ shots)

Note that this development is likely to be the most challenging, and so is last in the list.

Decision point #2: at end of day #1 with warm LLD:

If steps 3.1 and 3.2 are complete and the lithium surface of a “cold” LLD is not liquefied by plasma exhaust heat in this scenario, the then use day 2 for a repeat of discharges these discharges with a cold LLD.

If steps 3.1 and 3.2 are not finished, or if operation with a functionally “cold” LLD is not possible in this shape at the required power levels, then use day 2 to finish outstanding cases.



3.5: n=3 braking studies.

(This step may be repeated at various values of field and current).

Note that it is anticipated that most discharges in this XP will use the standard n=3 correction waveform developed in the past few years;

this is called the “Case 1” n=3 field application. In addition, four additional n=3 waveforms will be tested. They are shown above and listed below in propriety order.

Case 2: Begin with correction, the move through a series of braking pulses. The first few pulses are of intermediate amplitude and duration, followed by a longer braking phase, correcting phase, and braking again. Short n=3 pulses are imposed on the final correcting phase.

Case 3” Initial pulses for momentum transport studies, followed by two more widely spaced pulses to look for EPH mode triggering.

Case 4: Initial correction, followed by braking in order to achieve low rotation.

Case 5: Inverted version of Case 2.

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

Warm LLD + dual Liters.

RWM control with B_P sensors and pre-programmed EF correction. Coils must be anti-series connected.

6 MW NBI.

No RF or CHI.

Full profile diagnostics (bolometry, MSE, CHERS, MPTS).

It is assumed that a shape with “good” LLD pumping, with a recommended fuelling scenario, and consistent with long pulse, has been developed in the LLD commissioning and pumping XPs.

5. Planned analysis

MSE constrained reconstructions with EFIT and LRDFIT. TRANSP runs for some cases. NTV calculations.

6. Planned publication of results

Results will be presented at meetings such as IAEA and ITPA, as part of the overall LLD summary. Similarly, LLD overview papers may include results from this XP.

PHYSICS OPERATIONS REQUEST

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Brief description of the most important operational plasma conditions required:

The most important operational condition is to run in a shape where LLD pumping has been demonstrated, consistent with long(ish) pulse operation. A reduction in the flat-top density compared to a similar cold-LLD shot is the desired condition for this XP.

Previous shot(s), which can be repeated: To be provided by LLD Commissioning XP.

Previous shot(s) which can be modified: To be provided by LLD Commissioning XP

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

I_{TF} (kA): **3.8 kG-5.5 kG** Flattop start/stop (s): To I^2t limit of coil

I_P (MA): **0.7-1.1** Flattop start/stop (s): Longest consistent with rampdown for f_{dis}.

Configuration: **LSN**

Equilibrium Control: **Isoflux** (rtEFIT)**. S.P. control will likely be used.**

Outer gap (m): **0.1** Inner gap (m): TBD Z position (m): **-3cm <Z<0**

Elongation: **TBD** Triangularity (U/L): **TBD** OSP radius (m): **TBD**

Gas Species: **D_2** Injector(s): LFS + (SGI or HFS)

NBI Species: **D** Voltage (kV) **A:** 90 **B:** 90 **C:** 70-90 Duration (s): **full shot**

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

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

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

LLD: Yes Temperature (°C): 210-250

EFC coils: On Configuration: **Odd**

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		√