NSTX

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LLD Physics Survey XP, Rev. 1

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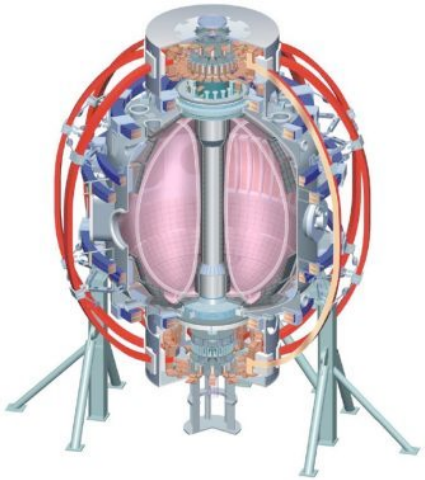

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Intro.

- Goals
  - Establish operation with a ***pumping LLD*** over a wider range of conditions than in commissioning XPs.
    - Get more info about how to run NSTX with a pumping LLD.
  - Establish some key physics trends.
    - Important to do this early, since LLD may or may not work as well at the end of the run as the beginning.
  - Gather data for further XP planning…first glance at interesting physics.
    - Not a surrogate for devoted XPs within the TSGs.
- Assumptions
  - Sufficient profile, pedestal, SOL and fluctuation diagnostics are functioning to make a cross-cutting XP worthwhile.
    - Assume "standard" B_P-based RWM/DEFC + n=3 correction is available and used.
  - NSTX is reasonably well conditioned, with early H-mode and at least 400 msec MHD-free I_P flat-top in the 900 kA/0.45 T reference.
  - The commissioning XP has demonstrated a shape with good LLD pumping + suggested fuelling scheme.
    - Henry's XP has this an an explicit goal.
- Dilemma
  - We have 2 days of run-time.
  - TSGs requested many more shots than can be accommodated in 2 run days.
  - Look for common physics themes among the groups.

ASC Group Wish-List

- Start with “warm” LLD, shape chosen as indicated before, run in priority order.
  - Load I_P=700 kA, B_T=0.48, P_{inj}=4MW (7 shots)
    - Repeat, raising/lower power to pin approximate β-limit
    - Be sure to ramp down I_P.
  - Change to B_T=0.4 (I_P=700 kA), P_{inj}=4MW. (7 shots)
    - Repeat, raising/lower power to pin approximate β-limit
    - Optimize power & gas waveforms for long(ish) pulse.
  - Change to I_P=1100 kA (B_T=0.4), P_{inj}=4MW. (7 shots)
    - Repeat, raising/lower power to pin approximate β-limit
    - May need to reduce I_P given the lower elongation and (potentially) triangularity.
  - Change to I_P=1100 kA (B_T=0.48), P_{inj}=4MW. (7 shots)
- Braking/RMP pulses could be added to select cases.
  - or NB pulses to probe modifications of ideal stability.
- Repeat each (some) scenario(s) with a cold LLD.
  - In each case, repeat with 4MW power, then an additional shot matching the approximate β-evolution of the warm-LLD case (more or less power)

Shot counts could be wildly off pending difficulty of LLD operations.

Macrostability Wish List

- Targets / control use
  - Reduced ν^* H-mode target over a large range of plasma current (3 - 4 shots)
    - ASC shot list has plan for high κ, I_p scan, including low l_i target – should suffice, need to specify (coordinate) what strikepoint configuration(s) to use – all high delta should be ok for Macro XPs
  - Full range of NBI power in H-mode targets at low and high ν^* (2 - 3 shots)
    - ASC shot list has cold/warm LLD and power scan – more specific definition of the actual shots to take should be made as a group
    - Suggestion is to choose two configurations yielding large range of ν^*, and have 3 NBI source scan for each (6 shots). One purpose of NBI source scan is to produce NTM (ramp n = 1 field?)
  - Run with n = 3 braking (1 - 2 "long pulse" shots; low/high ν^* comparison shots (2))
    - Can re-run XP933 shot 133743 for comparison, or add to any new H-mode target. Use long pulse to allow different n = 3 braking steps, reaching steady-state V_ϕ. (part of ASC shot list)
    - Run in high/low ν^* comparison shots; Run at least one shot down to very low rotation to reproduce superbanana plateau regime conditions (as done in CY 2009)
  - Run RWM control, B_p sensors and CY2009 settings to compare (2+ shots)
    - Can be added to any shot, but best done for boundary configuration close to CY2009 fiducial, now with LLD – cover both high and low ν^*, and low l_i. (easily added to ASC shot list)
    - One of these shots should include a condition spun down to low rotation (see "braking" above)
  - Run RWM control with B_p and B_r sensors (~ 2 shots)
    - Can be added to any shot, but suggest a limited number; use settings from 128487
  - Reduced q_{95} target as starting point for ELM stability, other studies (3+ shots)
    - Can use XP818 reduced q_{95} ELMing target 127889 (or later equivalent). If allowed, run LSN and USN variants.
    - Looking for an ELMing case, may need to run off a cold LLD and/or use USN variant

T & T Wish List

- Scan at constant q most important for T&T
  - Keep B_t/I_p constant allows same pitch angle for direct comparison of fluctuations for GPI and BES
- Prefers maximal scan range in B_t at constant q
- 700kA/0.35T (or 800kA/0.4T)
- 900kA/0.45T (or 950kA/0.48T)
- 1100kA/0.55T (Power scan here)
- Power scan at 1 setting, highest I_p, B_t point at which scan is possible
- BES, GPI, reflectometer, high-k should be consulted to be available

Boundary Physics

- No specific requests, but a few reminders:
  - Need to maintain outer-gap for optimal pedestal resolution (10 cm)
  - Keep biased down, say dr-sep=-1 cm.
    - Important for diagnostics and LLD operations
  - Maintain optimal OSP location for pumping.

Highlights from Group Review of the LLD Commissioning XP

http://nstx.pppl.gov/DragNDrop/Topical_Science_Groups/Meetings/lithium_research/2010_XP_reviews/Kugel_XP1000_17Feb10.pdf

- Suggested references tend to be B_T=0.45 & I_P=900 kA
  - I_P/B_T=2000 kA/T
  - 129015 at intermediate-δ, 129061 at high-δ
- Main focus is on scanning the OSP radius (and hence δ_L) in order to develop shapes with good LLD pumping.
  - Will try some/all of $R_{OSP}\approx$0.55,0.64 (likely not 0.75, maybe not 0.35)
- Likely that $R_{OSP}\approx$0.55 (or 0.65) is required for significant LLD pumping.
  - Standard highest-δ configuration is not thought to be a good candidate.
- For R_{OSP}=0.65 (bull-nose tile), the pulse length and/or input power may be highly constrained.
  - Limited by energy on LLD.
- Develop cases with HFS & SGI fuelling.
- Compare warm (liquid lithium) and cold (solid lithium) LLD cases.

Observations

- Commissioning XP should provide the starting point.
  - "Starting Point"=shape with reasonable pumping and a recommended fuelling scenario.
  - Likely to be an intermediate-δ configuration (κ~2.2, δ_L~0.5-0.6), which are typically not as forgiving as high-δ.
- ASC would like a long-pulse demonstration with and without LLD.
- Both MS and T&T would like a collisionality scan.
- T&T wants the scan at constant q.
- MS wants to perturb individual shots (braking pulses and RWM control studies) within a collisionality scan.
- Need to keep I_P high enough that NB ions are held in…remember the 10cm gap!
- Don't want to try for too-challenging configurations at the start.
- n=3 fields applied for braking can also be used for:
  - Studies of the pedestal response to RMP at various collisionality.
  - S.P. splitting and striations.
- *Collisionality impact on core and pedestal physics is a common theme.*

Overall Proposal: Focus on a Constant-q Collisionality Scan
Repeat the Shot List Once with Warm LLD, Once With Cold LLD

- Develop a longish-pulse target at lower current and field.
  - Long pulse demonstration for ASC, low-field part of constant-q scan for T&T and mhd, long pulse for multiple braking steps for MS.
  - Apply various magnetic braking pulses.
- Develop a high-current, high-field target, with same q.
  - Will provide the collisionality scan for MS & T&T, high-current and field SOL width studies.
  - Repeat key braking pulses.
  - Power scan.

The order of the next 2 steps TBD:

- Develop the intermediate case in the constant-q scan.
  - Maybe repeat braking pulses as necessary.

- Develop a high-current, low-field target.
  - Low-q_{95}, low-l_i, high-β_T for ASC, MS.

VERY, VERY, VERY unlikely to finish all four major steps in 1 day.

Proposal, In Suggested Priority Order
Day 1 with Warm LLD, Day 2 with Cold LLD

- Configuration 1: 750 kA, 0.38 T (I_P/B_T=2000 kA/T)
  - Develop target to longest reasonable pulse length. (7 shots)
    - Likely start with 4 MW, increase/decrease power to most it can gracefully tolerate.
  - Apply n=3 fields. (7 shots)
    - See next slide.
  - Take a few lower-power points. (3 shots)
- Configuration 2: 1.0MA, 0.5 T (I_P/B_T=2000 kA/T)
  - Develop target to full TF waveform duration. (4 shots)
    - This shot should take all 6 MW, unless confinement is really good.
  - Repeat n=3 fields. (7 shots)
    - See next slide.
  - Do power scan. (3 shots)
    - 2,4 MW cases
- Configuration 3: 900 kA, 0.45 T (I_P/B_T=2000 kA/T)
  - Develop to reasonable length (3 shots)
    - braking pulses? (7 shots)
- Configuration 4: 1 MA, 0.38 T (like 134837)
  - Low-q_{95}, low(er)-l_i, high-β_T for ASC
  - Develop target to reasonable length (no braking pulses?) (5 shots)

Braking Pulses Must be Carefully Planed

- ~7 shots allocated in each configuration to study 3-D field effects vs. collisionality.
  - High-field case has only a short flat-top, and will not permit many steps.
- Suggested allocation:
  - 3 shots for NTV studies.
  - 2 shots for RMP studies.
  - 2 shots for momentum pinch.
- Leave that to Sabbagh, Kaye, Maingi (Berkery, Solomon, Canik, Ahn whoever else).

Backup

- TSG leaders - for the LLD physics survey XP, please think through which physics questions/scans each TSG should address, determine the plasma target shots you need, and consult with Dennis (out sick this week) and Stefan to begin putting together a list of shots to be developed. We will then try to consolidate/reduce the number of shot types needed, expecting to build off of whatever comes from initial shot development and Henry/Vlad LLD commissioning/pumping XPs.