Measurements of halo currents with the LLD and extended diagnostic capabilities

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MS TSG Meeting
XP review
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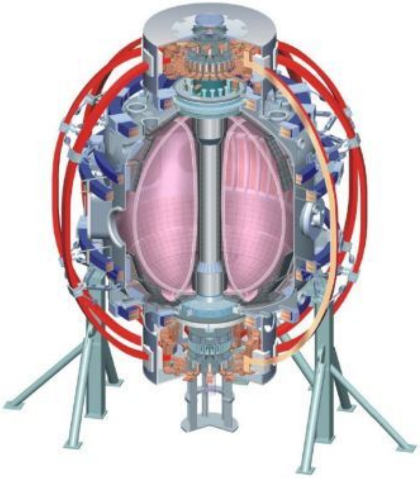

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Overview

- Background
  - Halo currents occur when the plasma comes in contact with the vessel/FW/divertor during a vertical displacement event (VDE).
  - These currents cause a vertical (and sideways) JxB force that can break the tokamak.
  - ITER task agreement started for the benchmarking of TSC halo models against NSTX.
  - Impact of liquid lithium surface on disruption dynamics is important for overall LLD understanding.
  - New halo current diagnostics in 2010 should allow improved measurements.

- Goals
  - Measure halo current distribution in scans over q_{95} and/or downward velocity.
  - Maximize use of new diagnostic capabilities, both fast and slow, to improve understanding of the effect of HCs on plasma facing materials (and vice-versa)
  - Determine how the presence of a hot Li surface impacts the disruption behavior.
    - Low ionization potential of Li may keep plasma cooler, speeding the I_P quench rates and increasing or reducing HCs.
    - Modifications to disruption behavior with recycling/pumping surface (He vs. D_2)
  - Potential side benefits (?): thermal loading, lithium expulsion measurements, evaporative barrier.
- Contributes to
  - ITPA halo current database development.
  - IPTA DSOL-4 disruption thermal loading, energy balance.
  - ITER Task Agreement.

Halo Current Diagnostics in NSTX Have Been Continually Upgraded

3 Rogowskis on the Center Column (pre-2008)

- One rogowski (CSCL1) broken into three segments.
- The other two (CSCL2 and CSCU1) continuous

Arrays of Toroidal Field Sensors (2008)

- Poloidal current flowing in vessel wall
- One array of 6 sensors near CHI gap (Inner Ring)
- One array of 6 sensors between outboard divertor (OBD) and secondary passive plate (SPP) (Outer Ring)

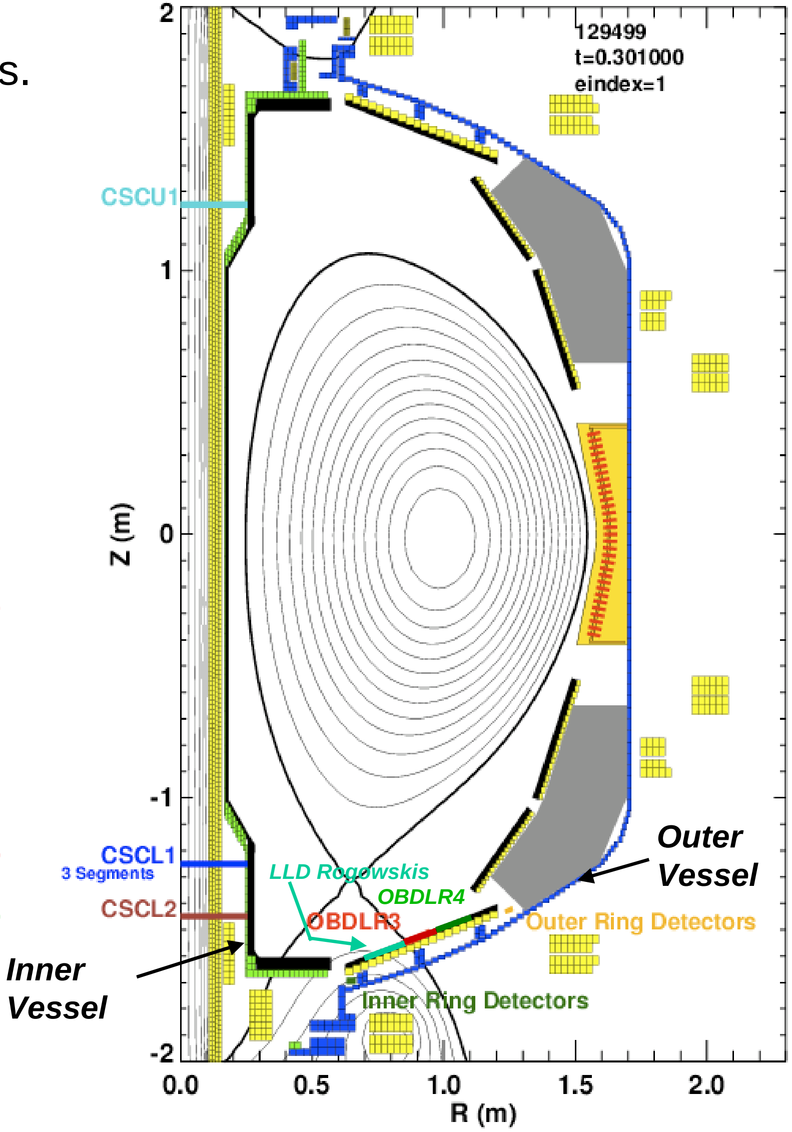
Arrays of Instrumented Tiles (2009)

- 4 Tiles in row 3 of the outboard divertor (OBDLR3)
- 90º Toroidal Separation
- Highly localized measurements of the current

Improved Instrumented Tiles and LLD (2010)

- 6 Tiles in row 3 of the outboard divertor (OBDLR3)
- 6 Tiles in row 3 of the outboard divertor (OBDLR4)
- 4 Rogowskis on the LLD centerposts
- Bias Electrodes in LLD Diagnostic Gap Tiles

NSTX has isolated inner and outer vacuum vessels.
Only connection between them is via buss-work at the vessel bottom.



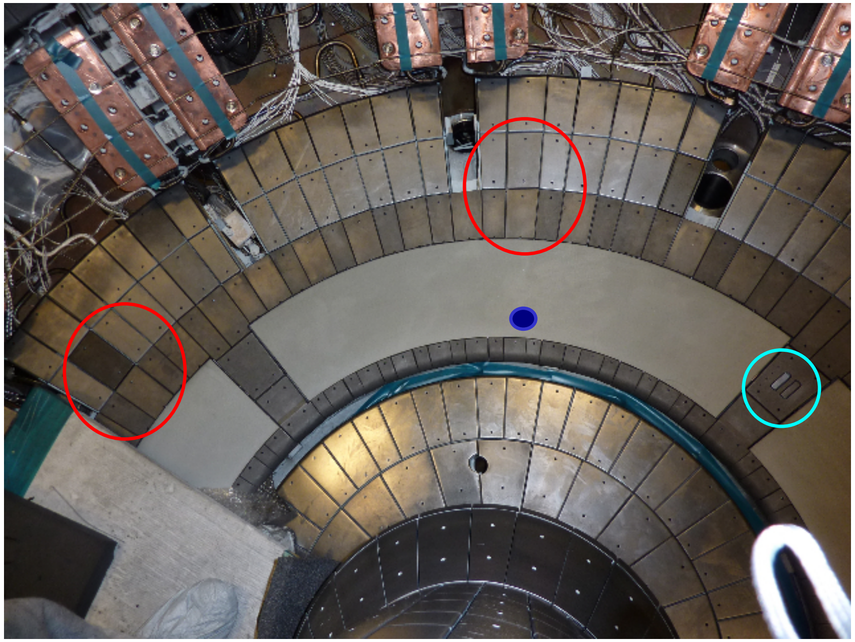
Expanded Toroidal Coverage in 2010

Super Tile

Shunt Tiles

LLD Centerpost Rogowski

LLD Gap Bias Tiles



New diagnostic capabilities to take advantage of

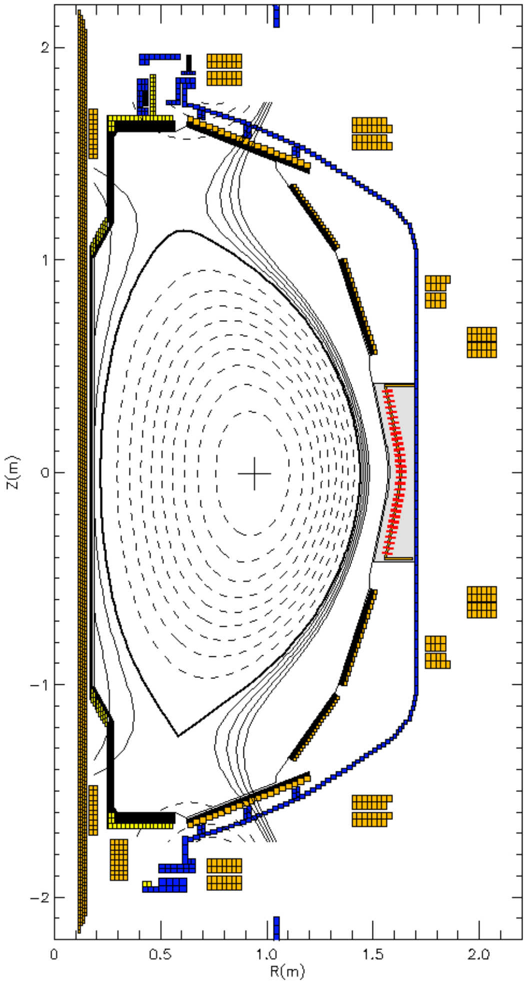
- Fast, filtered visible cameras viewing divertor region.
  - Two Phantom 7.3 cameras viewing nearly the complete lower divertor
  - C, Li emission filters
  - Operate with low gain/low integration time to maximize dynamic range
- Fast IR camera viewing the divertor region.
  - Two color operation to account for emissivity of Li vs. graphite
- Triple Langmuir probes for fast T_e, n_e measurements.
- Enhanced spectroscopy in medium and high resolution
  - DIVPSEC spectrometer (LLNL) and up to four Ocean Optics spectrometers (ORNL) monitoring D, He, Li, C, and molecular emissions simultaneously
  - Intensity calibration possible, plus synthesis with 2-D camera intensity profiles
  - Operate with low gain/reduced integration period to capture unsaturated emissions in HC (low time resolution likely)
- USXR (horizontal and a vertical cameras) viewing the lower divertor.

- Recommended diagnostic “Disruption capture mode” during some operations
  - As opposed to “SS capture mode” where gains/integration times are set higher to capture steady state emissions

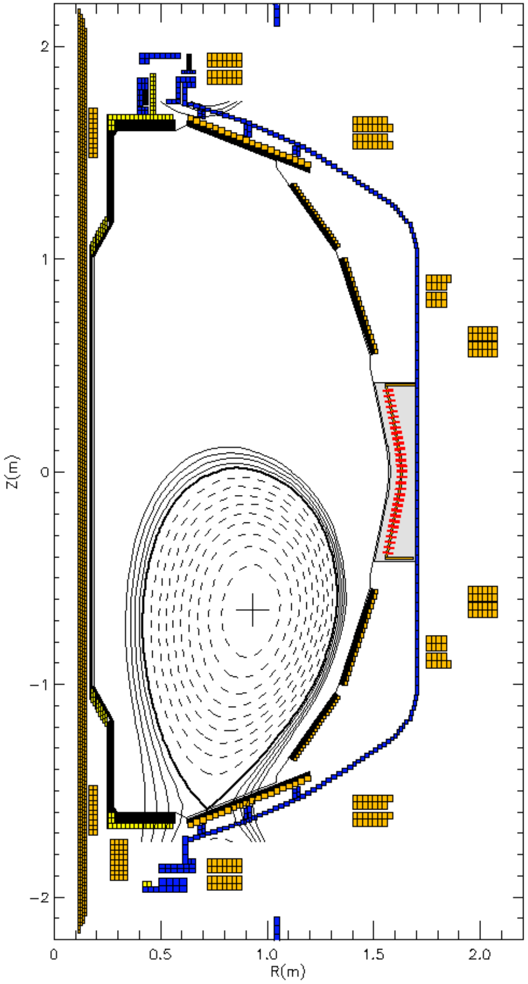
Suggested Discharge For These Studies

- Moderate triangularity Ohmic discharge.
- Induce VDE by turning off vertical position control.
  - Force down with an offset voltage on the radial field coils.
- Had been shown to be flexible:
  - Runs in D_2 or He
  - Runs over reasonable range of B_T and I_P (XP-833).
  - Takes 2-4 MW of NBI.
- Tends to land right on LLD.
  - Difficult to make downward VDEs that don’t do this.

129416, t=0.276 sec.



129416, t=0.314 sec.



Run Plan (Cold LLD), 1/2 day

1. Establish reference discharge: Ohmic 129416 is a template (6 shots)
   - Use D_2 in order to be compatible with LLD pumping.
   - Reduce I_p to fit in the allowed HC limits
   - Repeat for diagnostic coverage (filtered cameras, gain/T_{int} settings)
   - 10 or 12.5 minute cycle (10 minute litering)
2. Complete one or both of the following scans:
   - q_{95} scan via I_P and B_T variations. (5 shots)
   - Downward velocity scan via offset voltage variation. (3 shots)
3. Attempt to run HCs in shots with NBI (3 shots)
   - Test observation in many devices that NB shots have lower HCs than Ohmic (1, 2, 3 MW).

Goals: Characterize the HCs

- Attempt dynamic measurement of Li in the LLD
- Integrate results with data from unintended HC events.
- TPF vs. HCF for deliberate VDEs.
- I_P and B_T scaling with more diagnostics (limited in 2008 data set).
- Achieve good benchmark cases for ITER TA testing.

Run Plan (Warm LLD), 1/2 day

1. Repeat 2-3 chosen configurations from day 1 (6 shots)
    - See how Li changes emissions
    - “configuration”={Shape,I_P, B_T, Offset Voltage}
2. Repeat each case in D_2 vs. He. (6 shots)
    - Recycling surface vs. pumping surface.
    - Will pumpout result in a hotter plasma in the D_2 case?

Check the standard things:

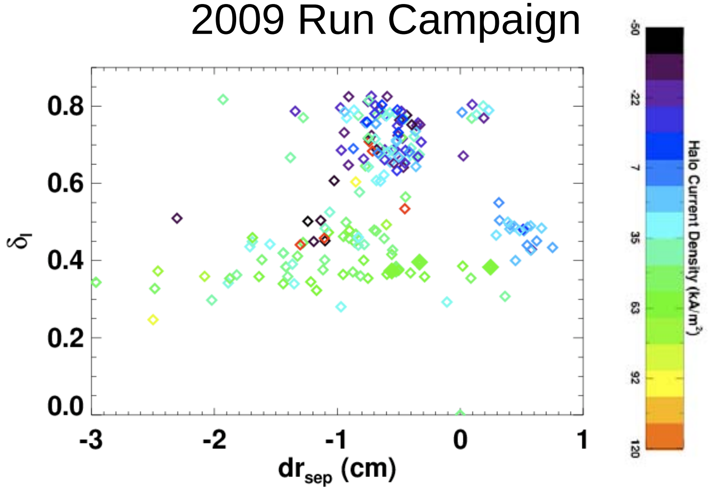
- How much erosion (Li, C) occurs, does the rate change?
- Effect of Li temperature on edge resistivity?
- Are halo currents larger or smaller?
- Has the current quench duration changed?
- How do the halo/boundary temperature and density change?
- Is the VDE growth rate the same?

LLD Will Be Subject to Substantial Disruptions and Halo Currents from Inadvertent VDEs

- Current density measured from shunt tiles in outboard divertor.
- LLD Area is ~1m^2, divided into four quadrants.
    - $A=2\pi R\delta R=2\pi\cdot 0.78\cdot 0.2=1m^2$
- Halo currents of 20-30 kA/segment should be assumed for the rare worst case.
    - Caveat, need to carefully look at the data for these worst cases

Halo Current Density vs. triangularity and dr$_{sep}$

2009 Run Campaign



Strategy for this XP:

• Compile statistics for disruption/VDE dynamics during the 1st half of the run.

• Develop baseline for "worst-case" disruptions in 2010.

• Find I_p & B_T combinations that lead to HCs less than the worst case bounds.

• Scans only in this range!

"Inner Ring" Measurements From 2008