NSTX

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Measurements of Halo Currents With Improved Diagnostics, Including the Effects of a Liquid Lithium Divertor

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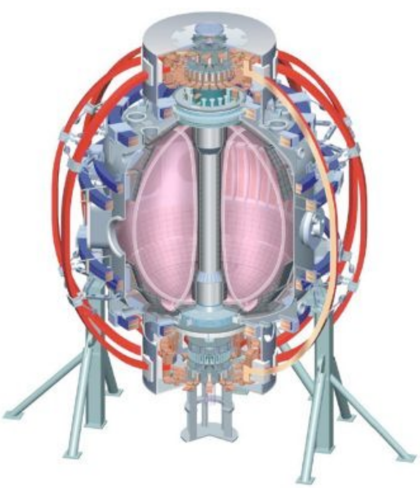
NSTX 2010 Research Forum
MS TSG Breakout Session
Dec. 1st, 2009



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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 JxB force that can break the tokamak.
    - Sideways forces also observed (not presently measurable in NSTX).
  - New halo current diagnostics in 2010 should allow improved measurements.
    - Fast IR thermography is a side benefit.
  - 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
- Goals
  - Measure halo current distribution in scans over q_{95} and/or downward velocity.
  - 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.
  - 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)

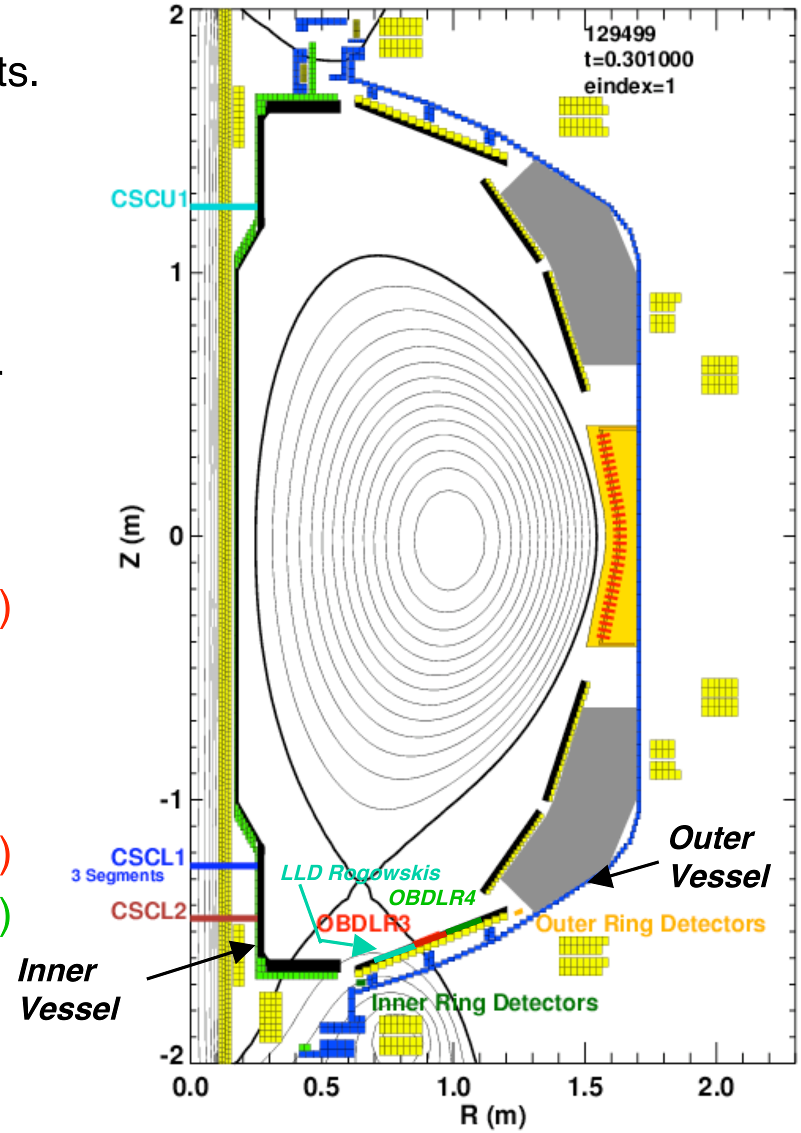
Arrays of Instrumented Tiles (2009)

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

Improved Instrumented Tiles and LLD (2010)

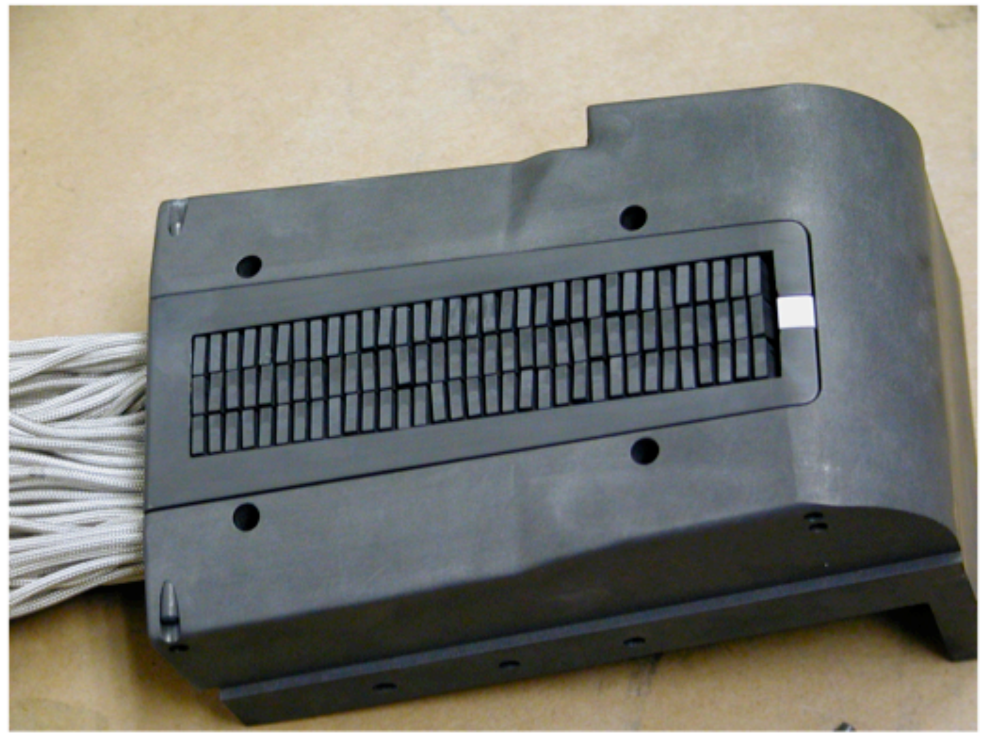
- 6 Tiles in row 3 of the outboard divertor (OBDLR3)
- 6 Tiles in row 3 of the outboard divertor (OBDLR4)
- 4 Rogowskis on the LLD centerposts
- Bias Electrodes in LLD Diagnostic Gap Tiles

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

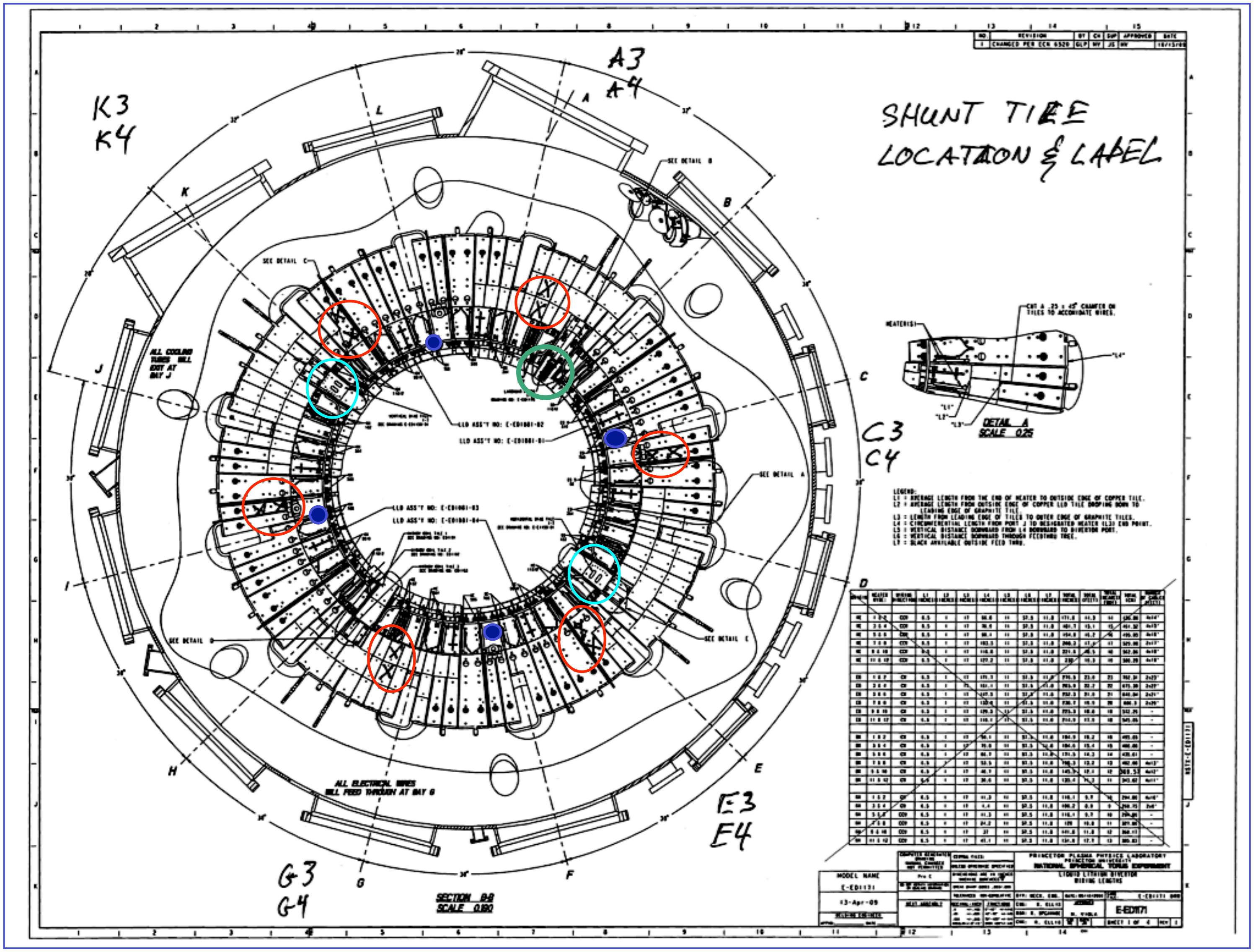


"Super-Tile" May Also Provide Important Data for HC and CQ Studies

- 99 Pins
  - 33 Rows
  - 3 Columns
- Configurable at 33 triple probes.
- Estimate T_e and n_e in the halo?



Expanded Toroidal Coverage in 2010



Super Tile

Shunt Tiles

LLD

Centerpost Rogowski

LLD Gap Bias Tiles

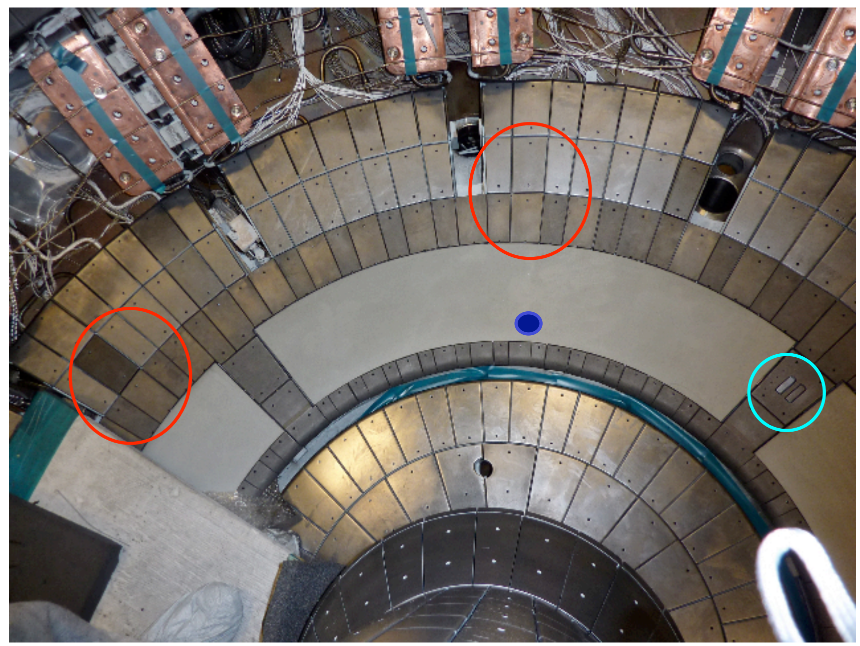
Expanded Toroidal Coverage in 2010

Super Tile

Shunt Tiles

LLD Centerpost Rogowski

LLD Gap Bias Tiles

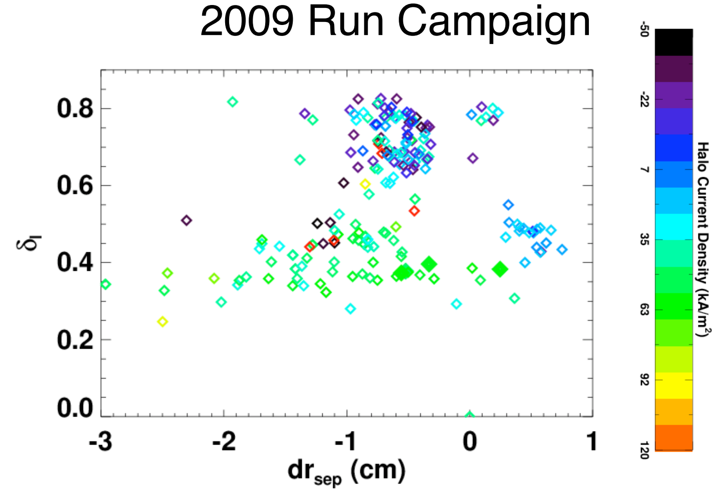


LLD Will Collect Substantial Halo Currents from Inadvertent VDEs

- 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}

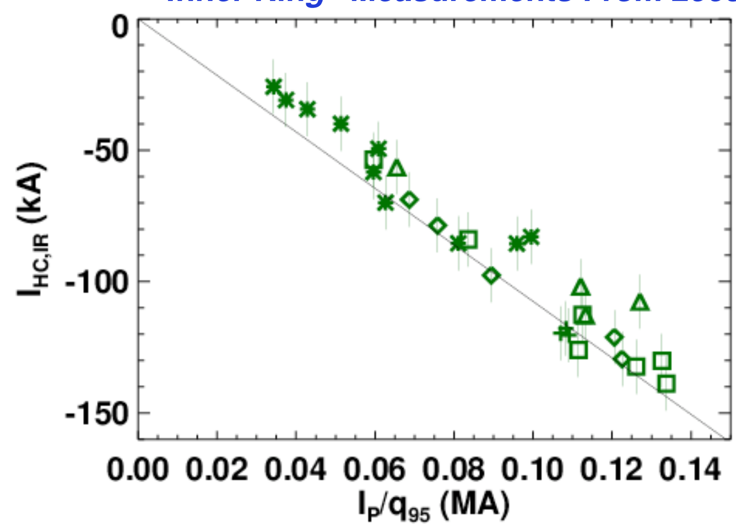
2009 Run Campaign



Strategy for this XP:

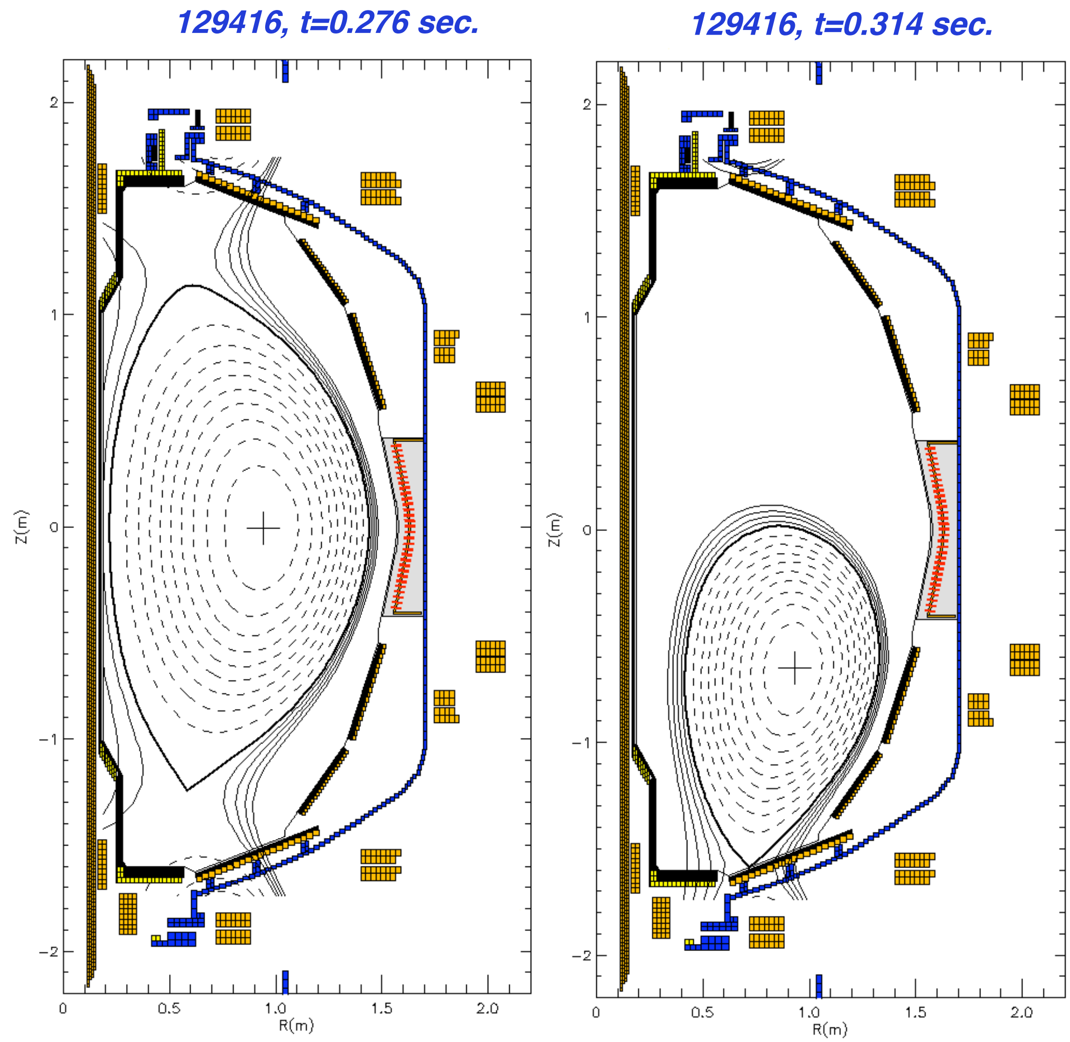
- ***Compile statistics for disruption/VDE dynamics during the 1st half of the run.***
- ***Develop baseline for "worst-case" disruptions in 2010.***
- ***Find I_p & B_T combinations that lead to HCs less than the worst case bounds.***
- ***Scans only in this range!***

"Inner Ring" Measurements From 2008



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.



Run Plan (Cold LLD), 1/2 day

- Establish reference discharge: Ohmic 129416 is a template (3 shots)
  - Switch to D_2 in order to be compatible with LLD pumping.
  - Reduce the plasma current to fit in the allowed HC limits
- 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)
- May also try a few shots with NBI (3 shots)
  - Test observation in many devices that NB shots have lower HCs than Ohmic.
- Goal: Characterize the HCs
  - 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.
- This data is useful even without step 2.

Run Plan (Warm LLD), 1/2 day (?)

- Repeat 2-3 chosen configurations from day 1, see how Li changes things.
  - "configuration"={Shape,I_P, B_T, Offset Voltage}
- Repeat each case in D_2 vs. He.
  - Recycling surface vs. pumping surface.
  - Will pumpout result in a hotter plasma in the D_2 case?
- Check the standard things:
  - 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?
- Operations/diagnostics issues:
  - How much evaporation required between shots?
    - Can we measure/estimate Li leaving the tray?

Backup

Diagnostics

- Halo current detection.
- Fast equilibrium reconstruction.
- Fast visible camera viewing divertor region.
- Fast IR camera viewing the divertor region.
  - New fast TCs?
- USXR (horizontal and a vertical cameras) viewing the lower divertor.
- Triple Langmuir probes in the super-tile for T_e, n_e measurements.