# Shutdown Handler and Non-Inductive Current Calculations

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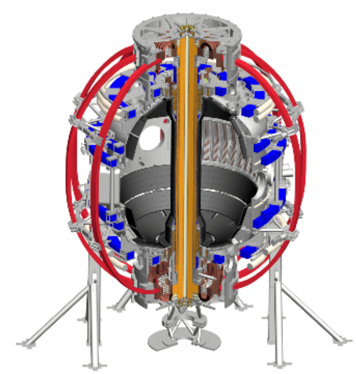


# Shutdown Handler Designed to Gracefully End the Plasma

- State machine implementation
- Coding of the state machine is largely free of detailed plasma physics/control.
- Why do this?
  - Want to limit control transients at the end of the discharge.
  - Want to support critical research in disruption detection/avoidance.

“SS” = “Shutdown State”

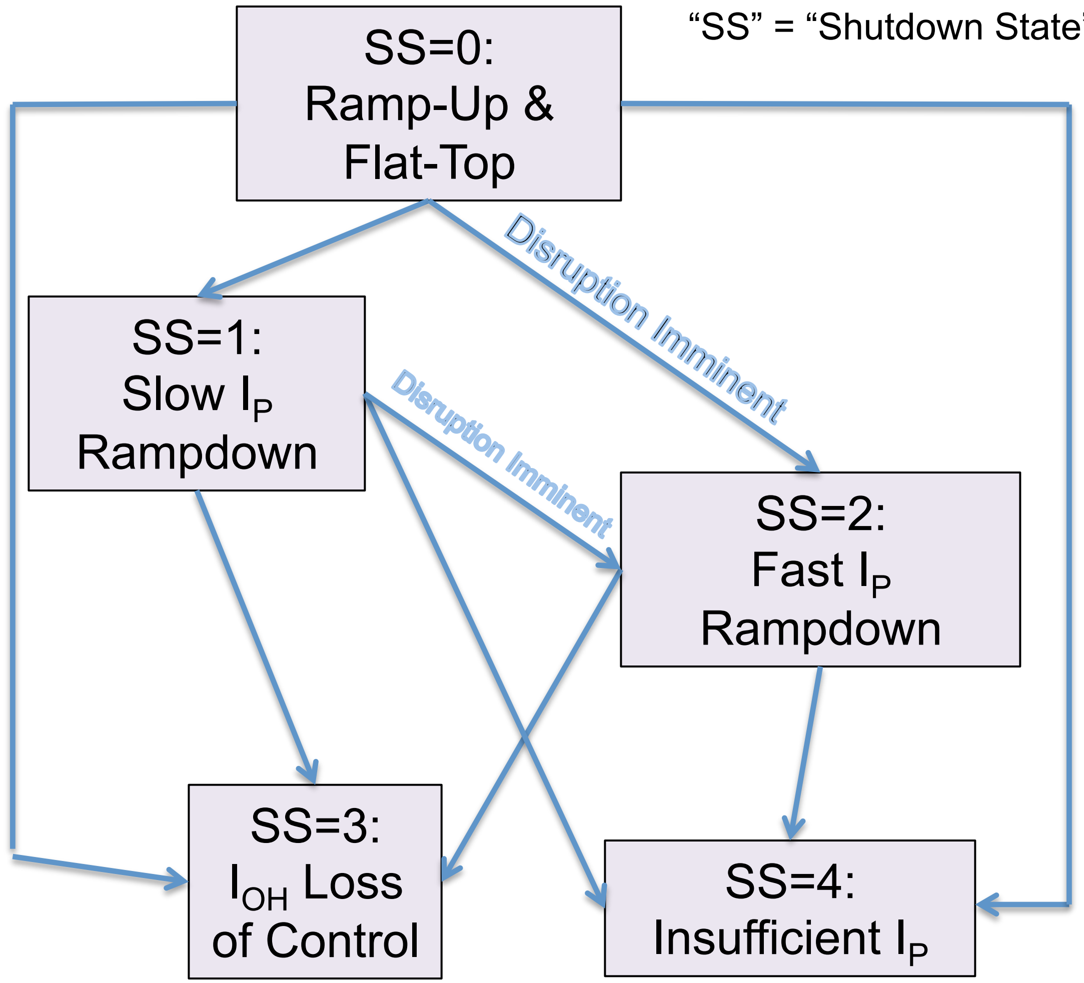



*Diagram of the State Machine Presently Implemented in PCS*

# What Controls, and is Controlled By, the Shutdown Handler?

**Controls It**

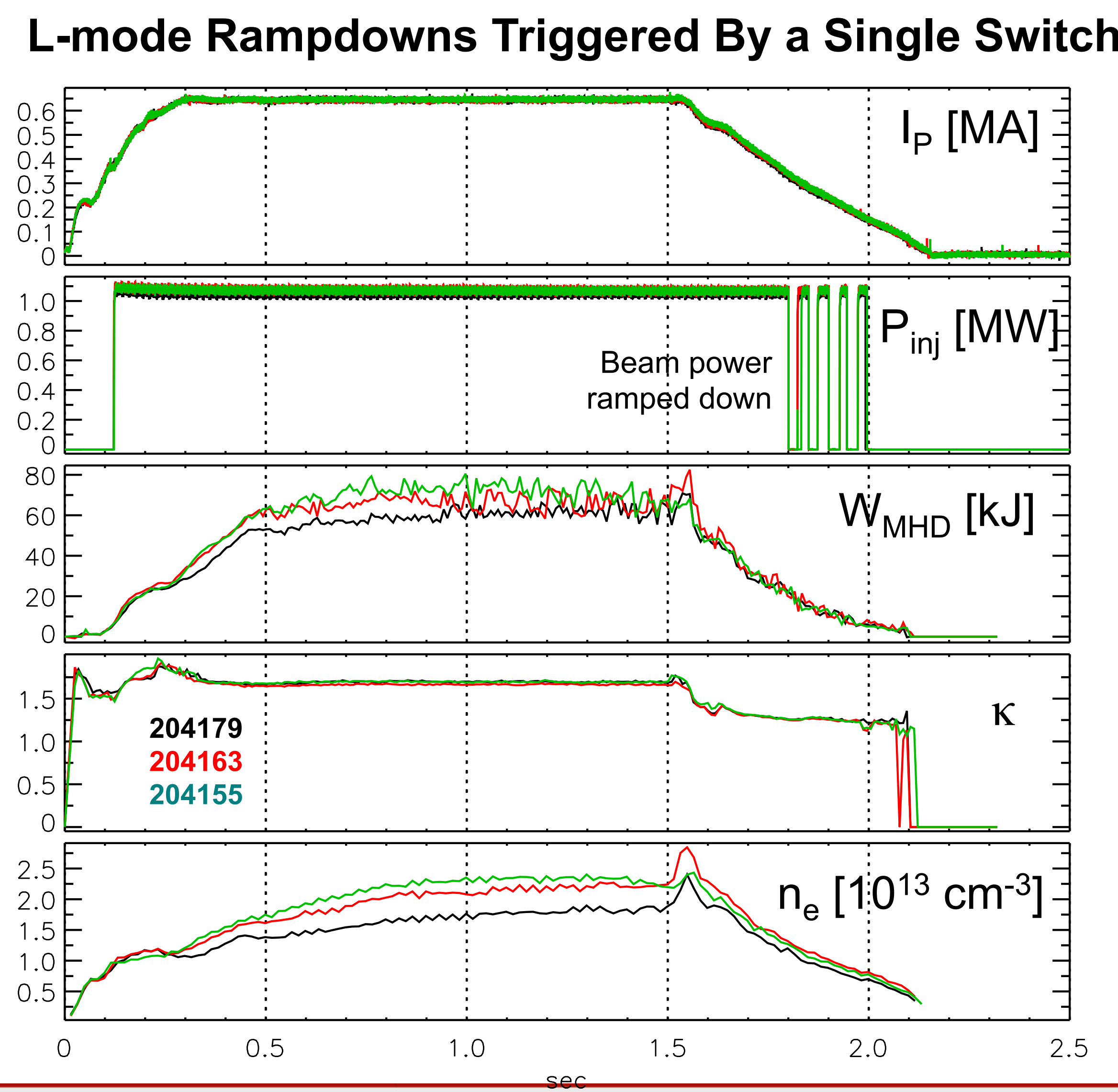
- Can go into fast rampdown by:
  - Detection of large n=1 mode.
  - Detection of large loss of plasma current.
  - Detection of excessive vertical motion.
  - $I_P$ drops beneath value required for rtEFIT while using ISOFLUX
  - Operator request
- Can go into slow rampdown by:
  - Detection that OH coil is approaching a heating limit.
  - Detection that OH coil is approaching a current limit.
  - Operator request

**It Controls**

- At each state change, can change the control algorithm used by the shape & position, TF, OH, gas, NBI, LGI, ModeID & RWM control codes.

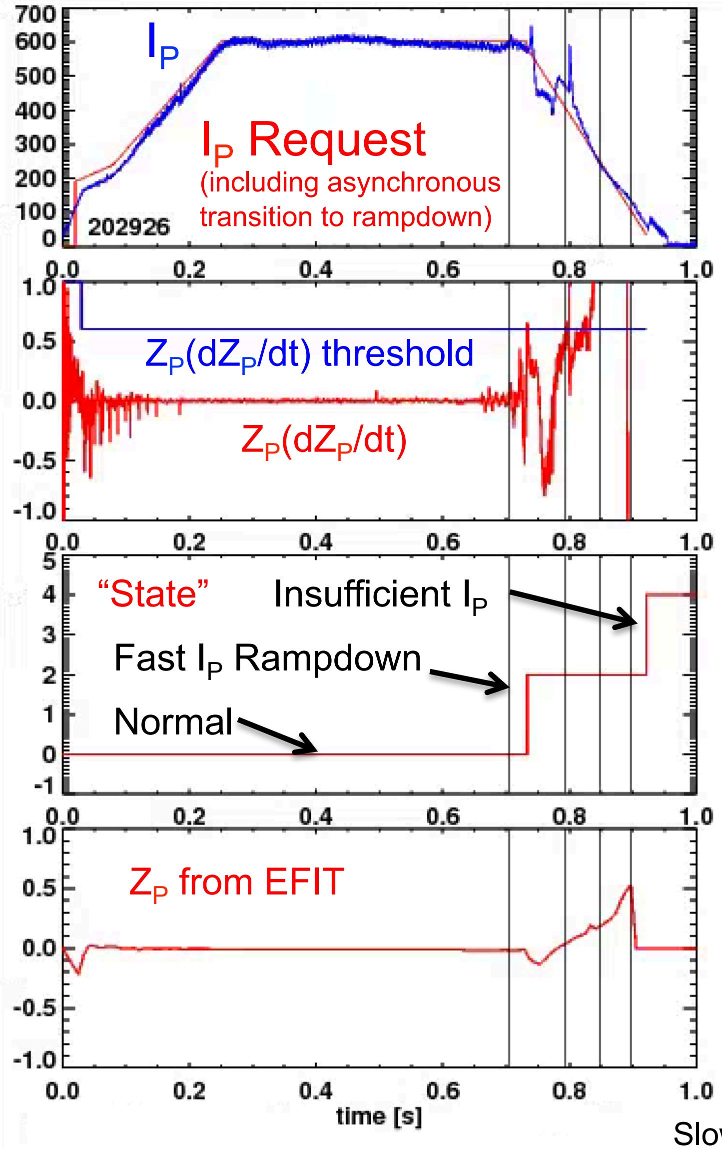
# Shutdown Handler Used to Create Smooth L-Mode Rampdown

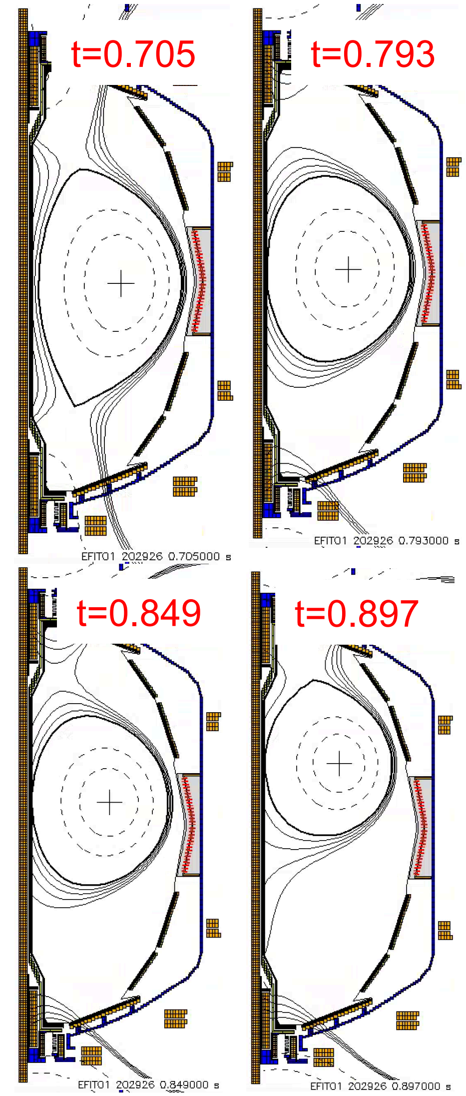
- Three AM fiducial shots from week of 4/4/2016.
- Single operator waveform modified at t=1.5 to start the rampdown.
- Rampdown is IWL, with power and $I_P$ slowly ramped off.



# Shutdown Handler Also Used to End Failing Discharges

- Shot requested to go longer, but vertical motion detected.
- Rampdown initiated.
- Plasma inboard limited, only slowly drifts up.



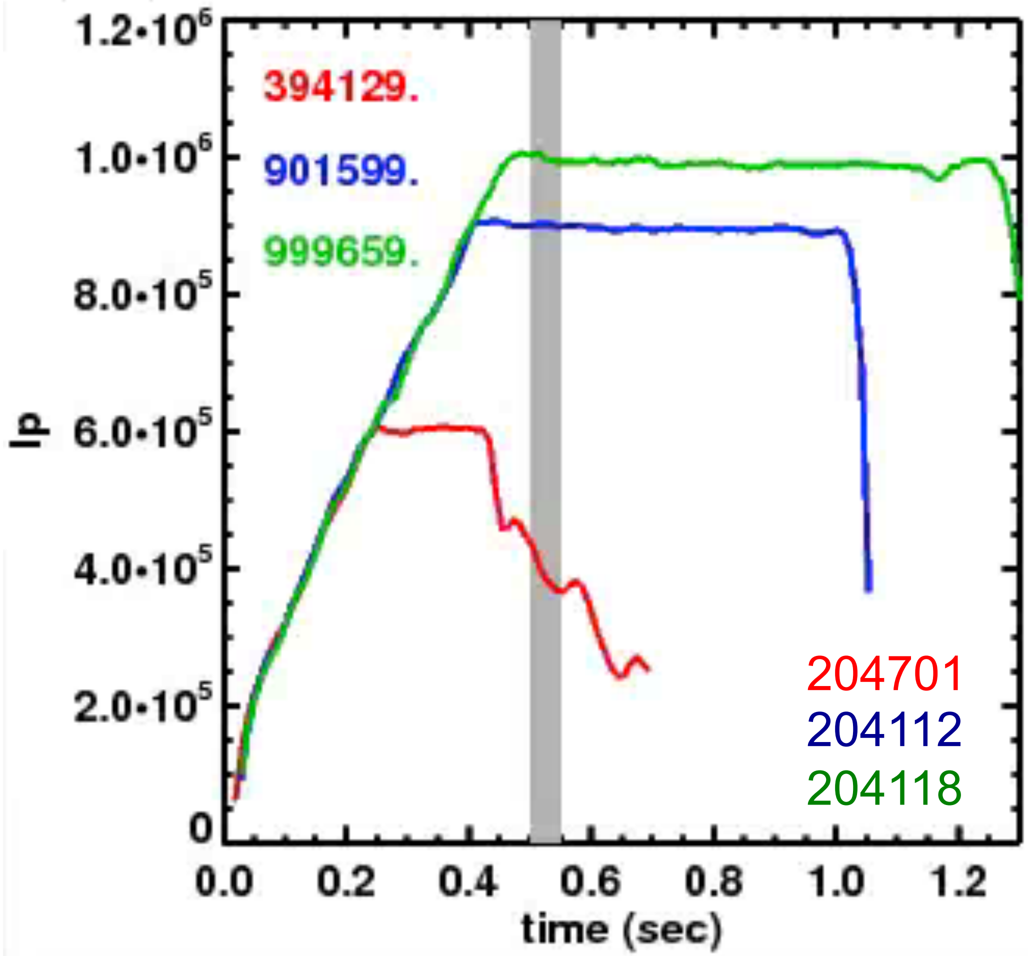

Slow Drift Up, But No VDE or Disruption

# Next Steps

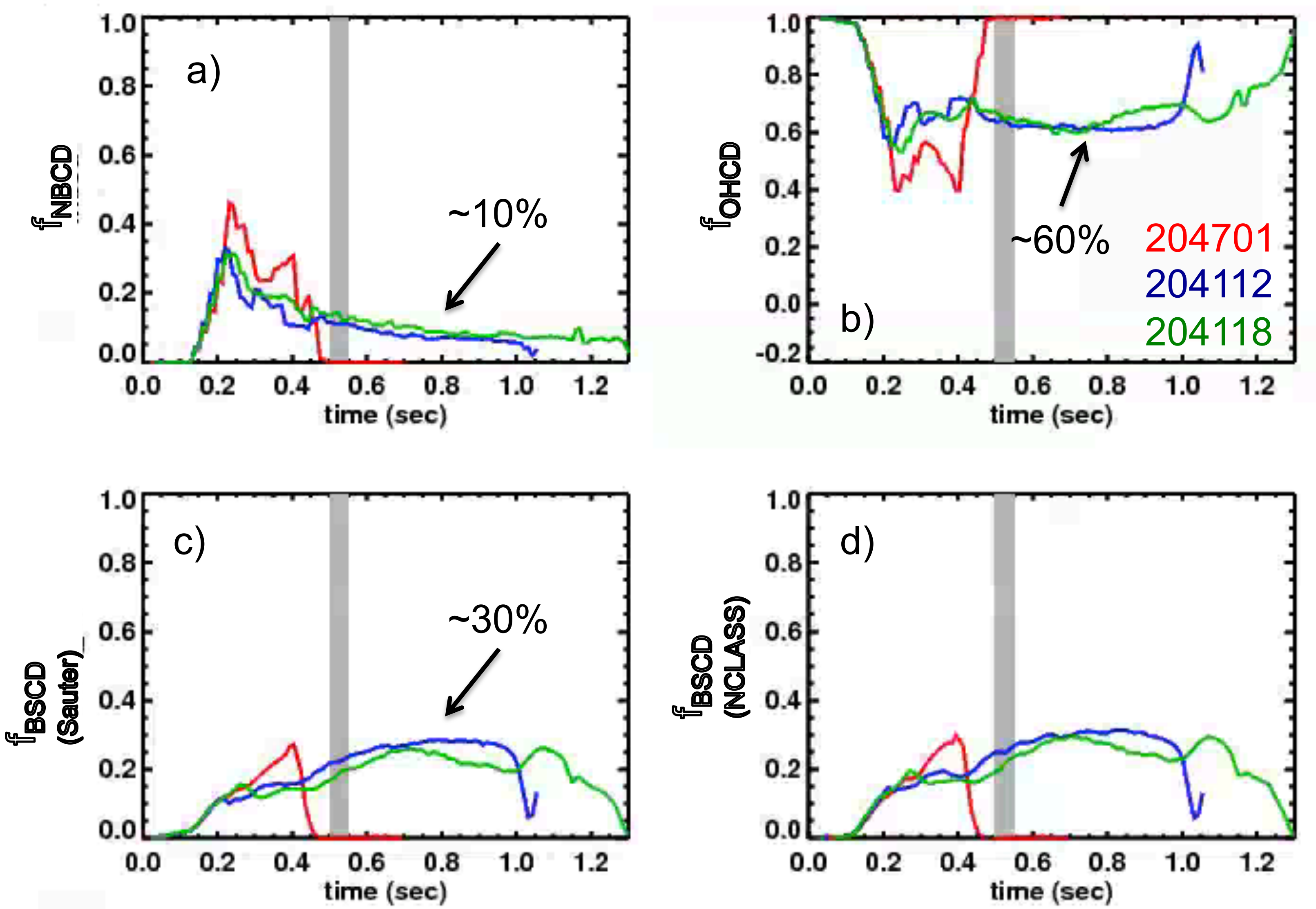
- During this run, we never activated the part of code allowing a transition from slow to fast rampdown:
  - Noticed on May 16th that reason was the settings in the system category during the slow rampdown phase.
  - Tried it on May 20th, but had a code bug.
  - Fixed the bug, but didn't get a chance to test it.
- Need to allow the RWM sensors to trigger the rampdown
  - Clayton Myers had them running great, never flipped the switches.
- Need to see if some other configuration of the vertical position sensing code can be less sensitive to n=1 modes.

# Non-Inductive Current Fraction Overview

- Operations with high non-inductive fraction ($f_{NI}$) is a prominent goal of NSTX-U.
- This quantity, and its sub-components, are typically computed with TRANSP.
- Don't have good $T_i$ data for the shots under consideration, so simply using BEAST runs.
  - Recognize that these are approximations/estimates



# Best Shot has (Transiently) $f_{NI}$~60%, More Sustained Shots Have $f_{NI}$~40%



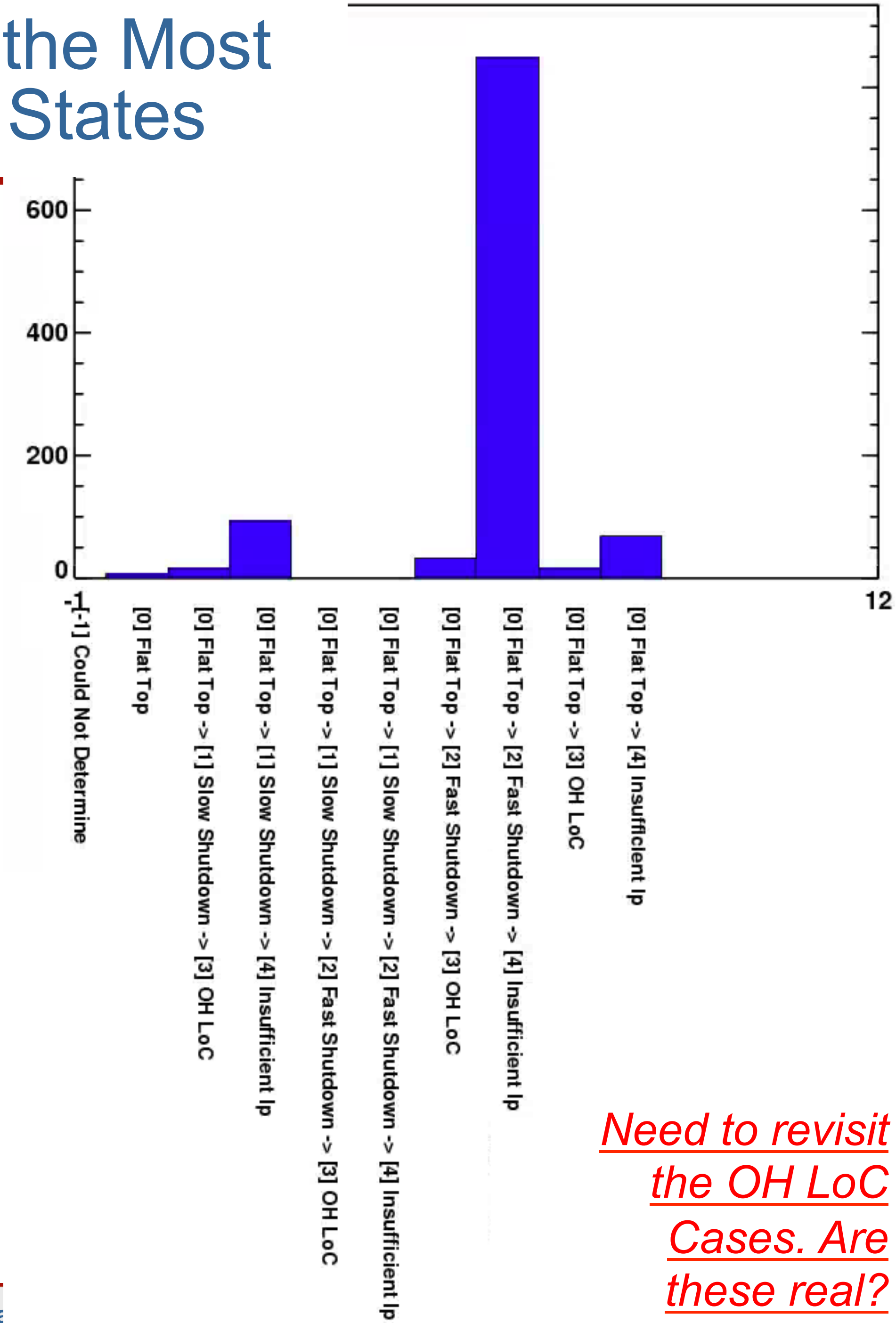
# Next Steps

- Not a lot of new analysis jumping out at me.
- Primarily, continue the scenario development tasks:
  - Early H-mode
  - Higher elongation
  - Error field correction
  - RWM control for higher $\beta_N$
- Get more routine $T_i$ data
  - Use the modulation tricks that Ron has recommended

# Backup

# Database Analysis Shows the Most Common Path Through States

- Most likely the go from Flat-Top through Fast Shutdown to Insufficient $I_P$.
  - These are all the failing plasmas.
- Somewhat likely the go from Flat-Top through Slow Shutdown to Insufficient $I_P$.
  - These were the L-mode rampdowns.
- Last common case was Flat-Top directly to Insufficient $I_P$.
  - These are shots that failed to ramp-up…fizzles.




*Need to revisit the OH LoC Cases. Are these real?*

# Database Analysis Shows the Causes of Leaving Flat-Top

- By far the most common is Vertical Position Loss of Control (LoC)
  - But beware, those sensors are sensitive to n=1 modes as well as n=0,
- OH Near LoC triggers shutdown based on OH current or heating limit.
- $I_P$ LoC looks for large values of the $I_P$ error.
- We never activated the BP & BR n=1 LoC.
  - Therefor don't read anything into its having no instances…wait till next year.