NSTX

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Strike Point Control

& Contributions to

XP 919: Intermediate δ discharge with lithium PFC coatings, J. Kallman

XP 924: “Snowflake” divertor in NSTX, V. A. Soukhanovskii

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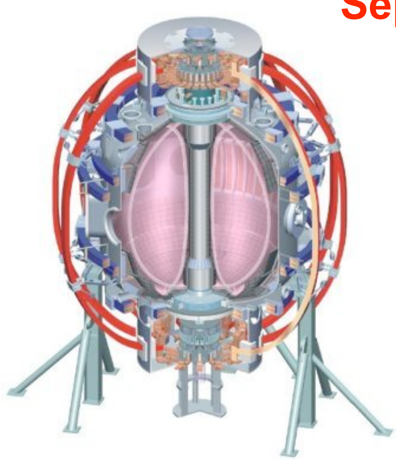
2009 NSTX Results and Theory Review

Room B-318

September 15th, 2008



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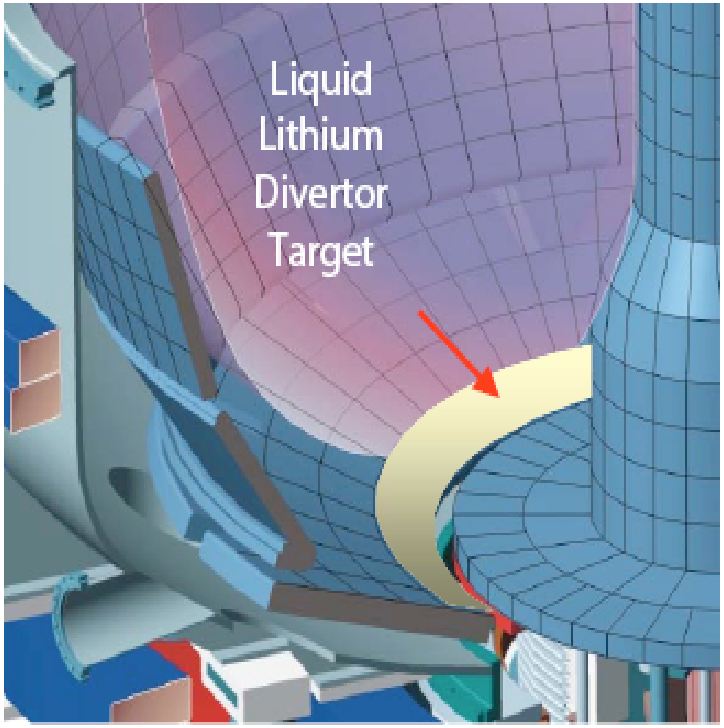
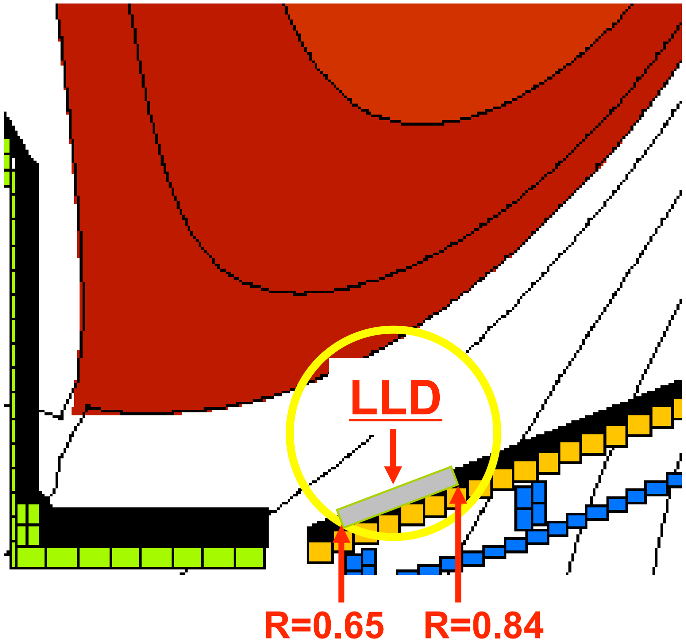
Background: Planned Liquid Lithium Divertor Requirements n Strike Point Control



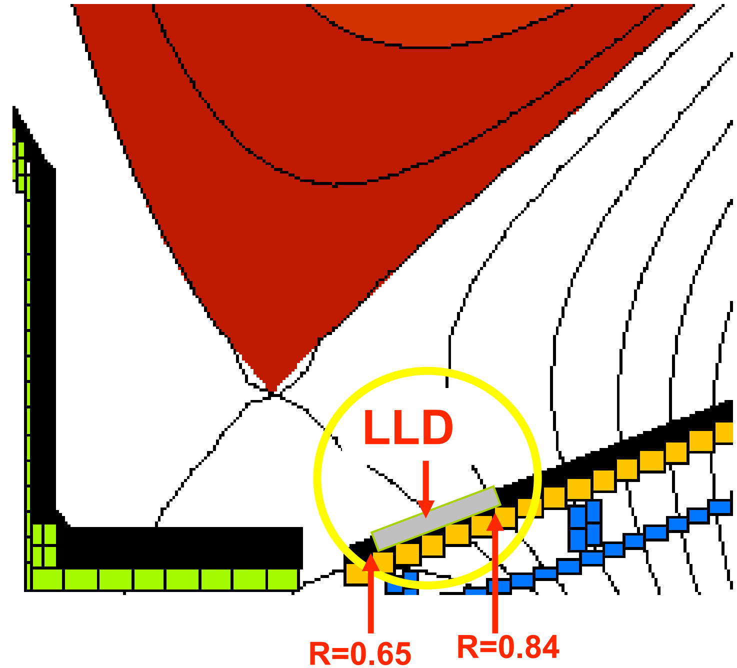
Schematic of NSTX showing location of LLD inside vacuum vessel

- Liquid lithium divertor (LLD) on NSTX, will enable experiments with the first complete liquid metal divertor target in a high-power device in 2009.
- The location in the vacuum vessel is shown schematically in the figure.
- Reduced recycling with LLD.
- To get better and consistent density reduction and to avoid contact with the LLD and the CHI gap, the most important parameter is strike point position.

Motivation: Density Reduction via Strike Point Control



High δ : n_e reduced by 25%

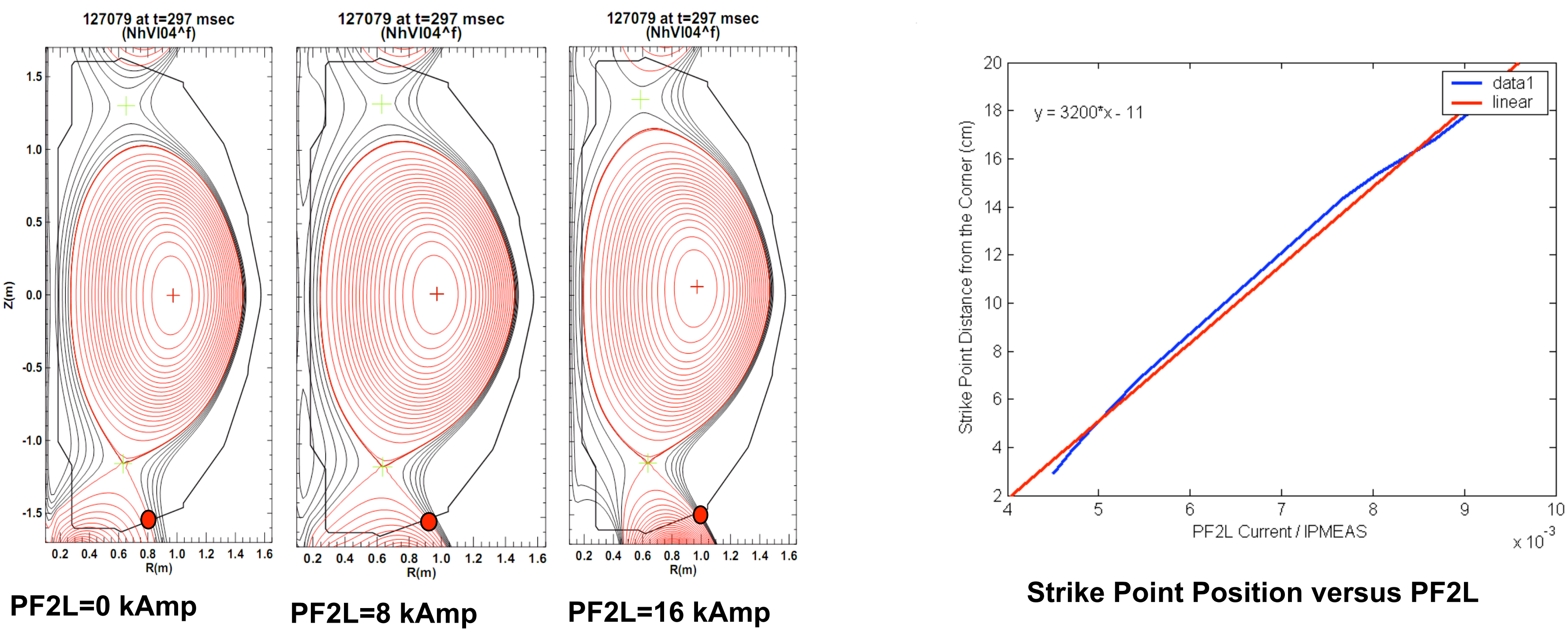


Low δ : n_e reduced by 50%

- Density reduction depends on proximity of outer strike point to LLD
- To get better and consistent density reduction, the strike point has to be closely controlled.

Preliminary Study: ISolver Analysis

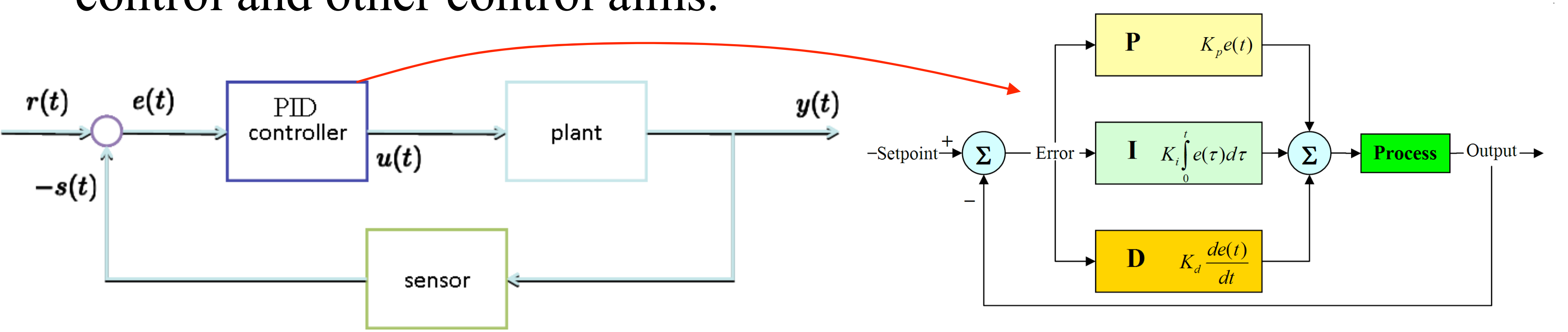
- Using ISolver showed that
  - The outer strike point predominantly depend on PF2 .
  - Analyzed the effect of PF2L in ISolver.
  - The dynamics of Single Input Single Output (PF2L current to Strike Point change) can be modeled as a first order system with time delay.



The change in the strike point with different PF2L current

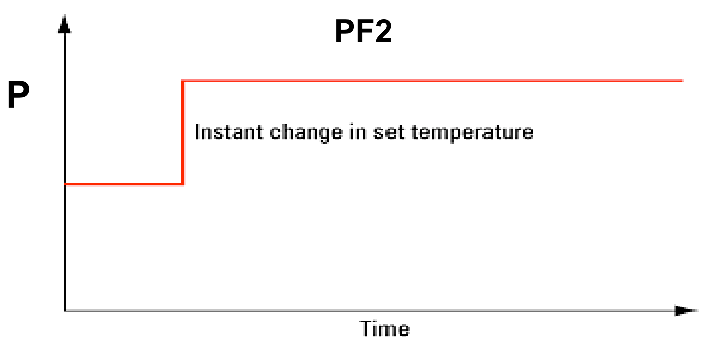
Aim: Design a Real Time Controller for the Strike Point Motion

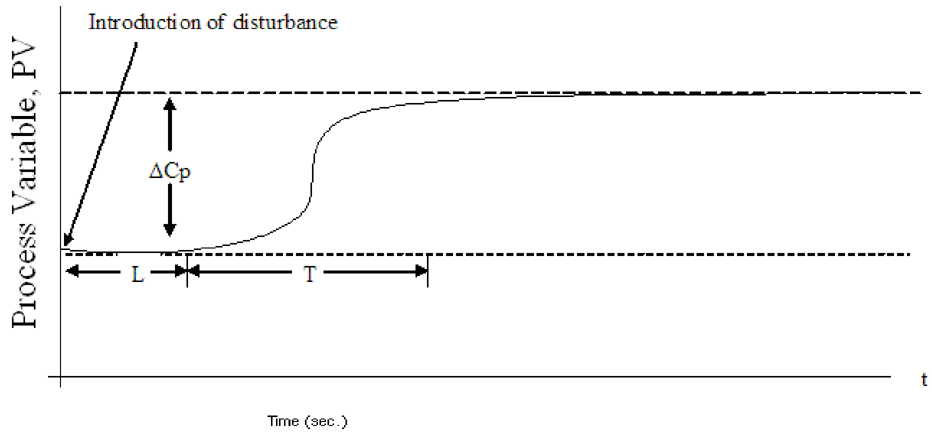
- Use the insight from the ISolver equilibrium code to design a PID controller to keep the strike point at the center of LLD, with ~1 cm variation from the reference value.
- Why PID? Current PCS only accepts PID controller.
- Experiment:
  - Put perturbations in the PF1/PF2 requests & measure the strike point response.
  - Test and tune the strike point controller.
- Study the compromise with respect to the loss in control for shape control and other control aims.



- In this case, s=position and r=reference position of the strike point.

Experiment Analysis: Step Response and PID Controller





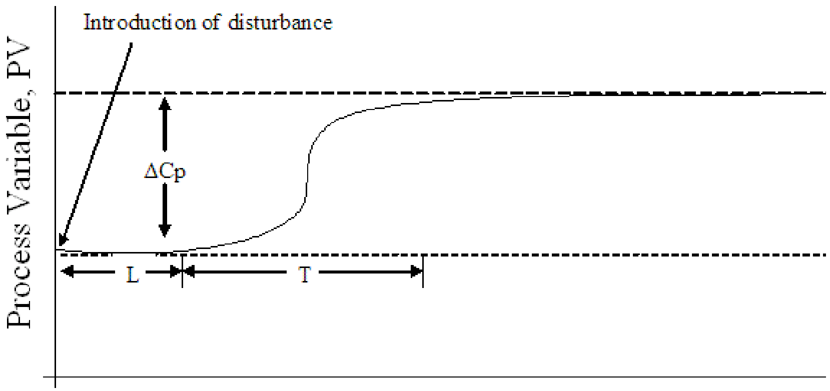
- For this system of First Order ODE with time lag we can model it using these constants
- L = lag in time response
- ΔCp (%) = the percentage change in output signal in response to the initial step disturbance
- T = the time taken for this change to occur
- N = $\frac{\Delta C_p}{T}$; where N is the reaction rate
- Given these we define $K = \frac{P}{(NL)}$

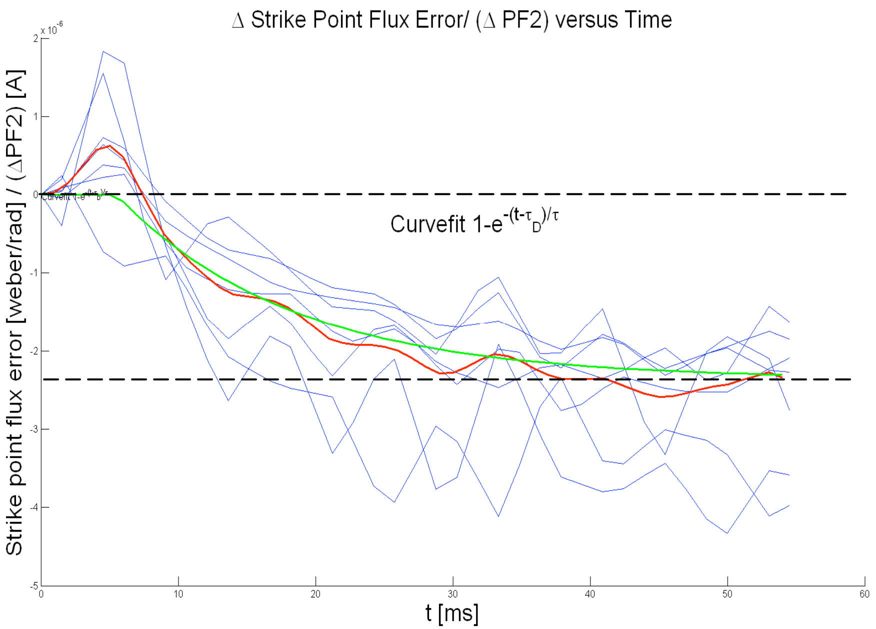
Experiment Analysis: Step Response and PID Controller

- The point of "tuning" a PID loop is to adjust how aggressively the controller reacts to errors between the measured process variable and desired setpoint.
  - If the controlled process happens to be relatively sluggish, the PID algorithm can be configured to take immediate and dramatic actions whenever a random disturbance changes the process variable or an operator changes the setpoint.
  - Conversely, if the process is particularly sensitive to the actuators that the controller is using to manipulate the process variable, then the PID algorithm must apply more conservative corrective efforts over a longer period.
- The essence of loop tuning is identifying just how dramatically the process reacts to the controller's efforts and how aggressive the PID algorithm can afford to be as it tries to eliminate errors.
- Ziegler and Nichols developed a heuristic sub-optimal but robust first guess for PID controller gains for a 1st order ODE with time lag, based on their expertis

	K_c	T_i	T_d
P	K		
PI	0.9K	3.3L	
PID	1.2K	2L	0.5L

Experiment Analysis: Step Response and PID Controller

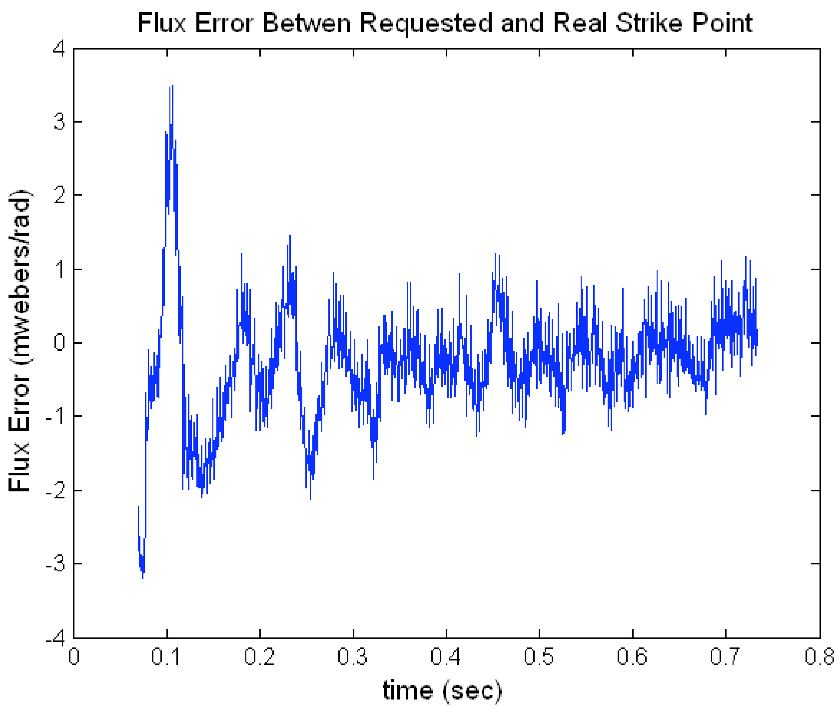


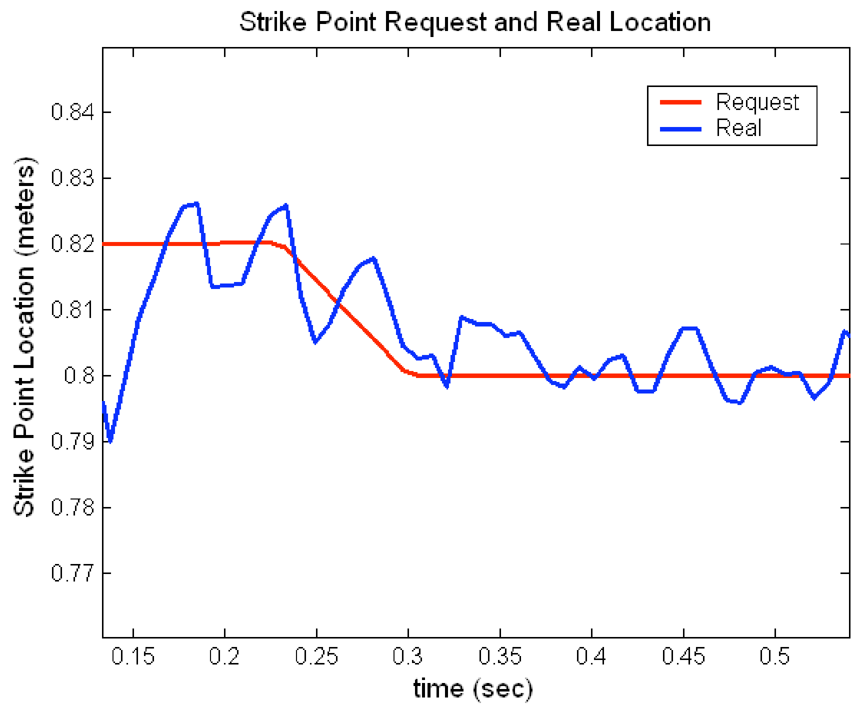


Calculated PID controller | P: 170 – 550 (mean 360)

P-I has 1-2 ratio | I: 340 – 1100 (mean 720)

Results: PID Controller Performance





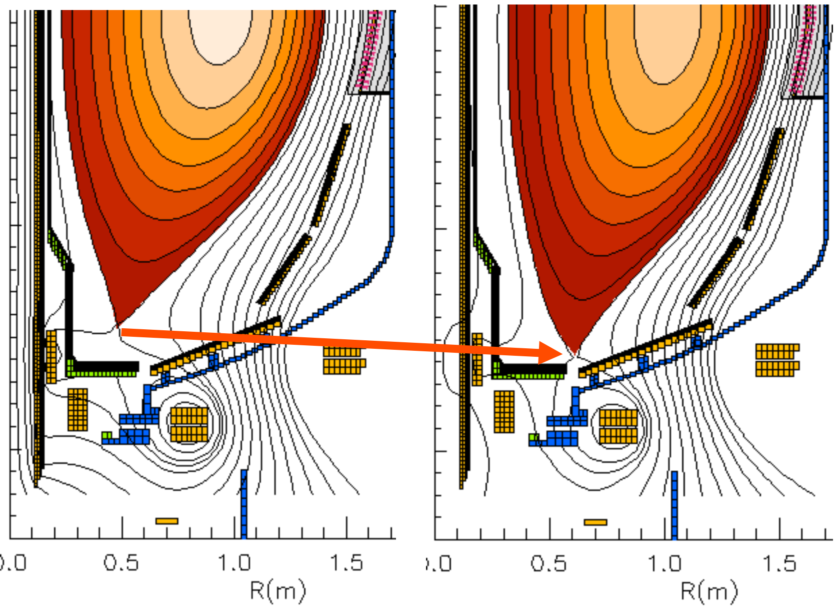
- Shot 133886:

  Calculated PID controller P: 170 – 550 (mean 360)

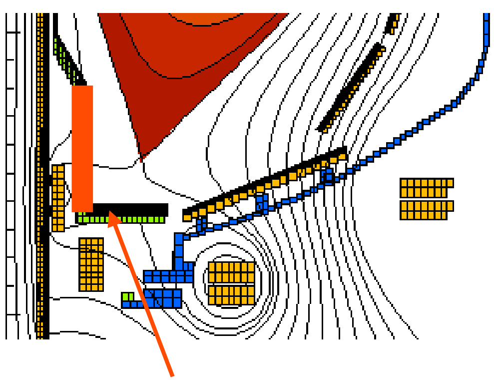
  P-I has 1-2 ratio I: 340 – 1100 (mean 720)

  Tuned these values in experiment to P: 400 and I: 800.

Inner Strike Point Control

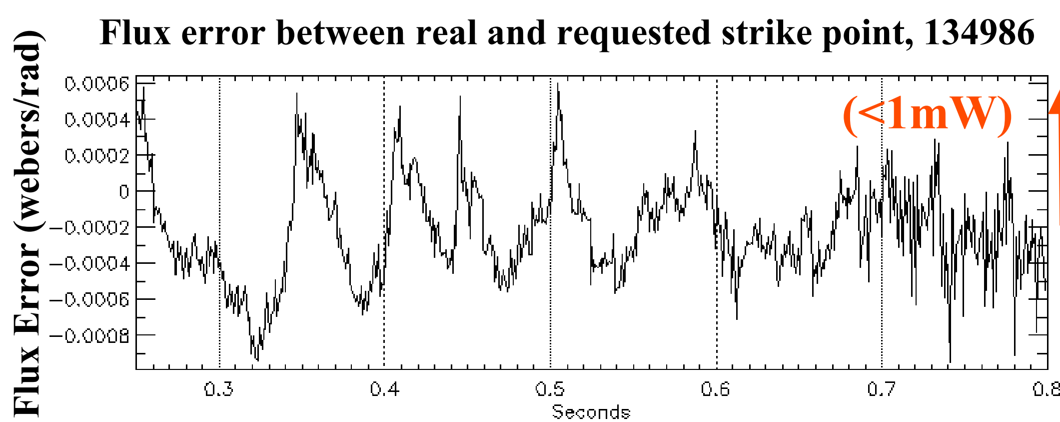


X-points bifurcation

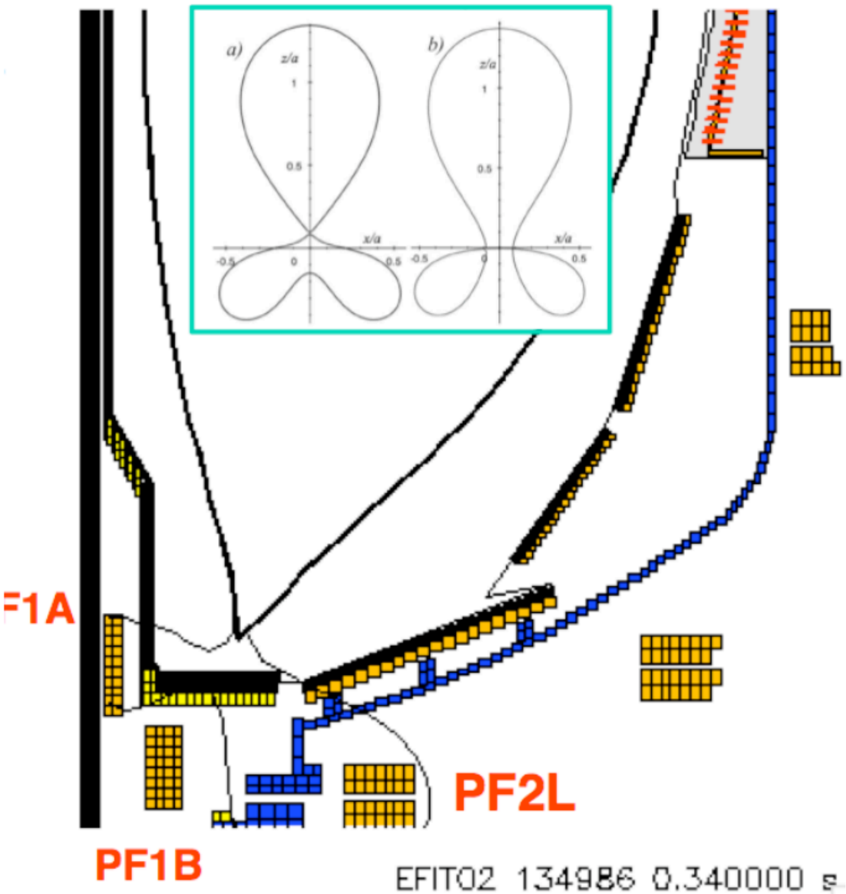


Segment to control inner strike point

- The outer-strike point controller kept the controller at requested position but problems during the transition
- During the transient phase of the discharge, equilibrium bifurcated to a nearby solution with a low X-point.
- Algorithm was jumping from one solution to the other one.
- To make more stable plasma: Added inner strike point controller.



Contribution: Snow Flake Experiment

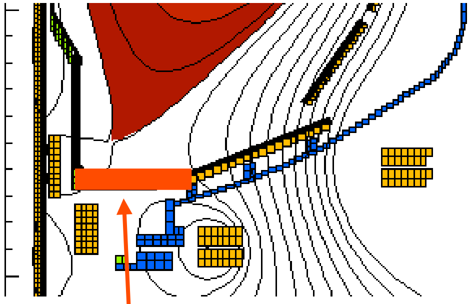


Vlad Soukhanovskii

Example "snowflake" divertor configuration in NSTX.

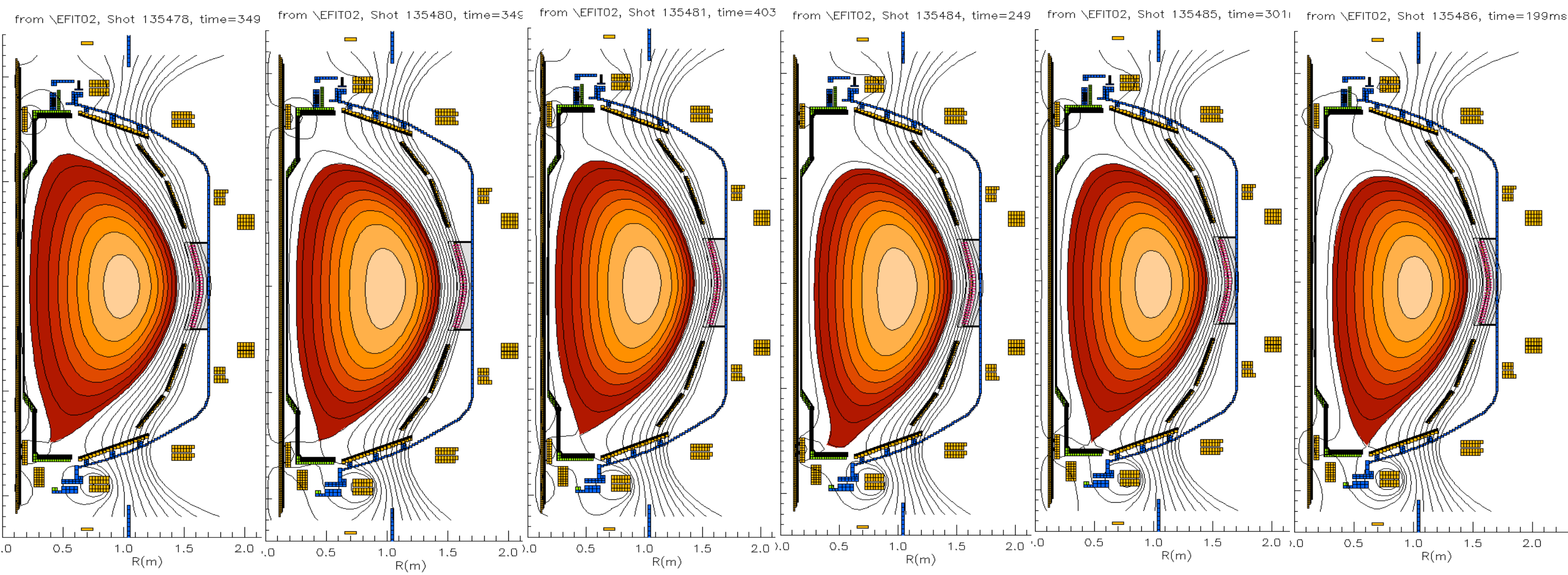
- "Snowflake" divertor configuration, a second-order null is created in the divertor region by placing two X-points in close proximity to each other.
- This configuration has higher divertor flux expansion and different edge turbulence and magnetic shear properties, beneficial for divertor heat flux reduction, and possible "control" of turbulence and ELMs.
- Implemented and used inner/outer strike point control to test the "snowflake" configuration.

Expanded Outer Strike Point Control



Segment to control outer strike point on the inner divertor plate

- Developed outer strike point controller for the inner divertor plate.
- Used inner and outer strike point controller to achieve “snowflake”.
- Scanned the outer strike point from 44 cm to 73 cm.



Snowflake scan from 44 to 73 cm

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