NSTX
Control System Modeling and PCS Support

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Overview

- **Collaboration Goal:**
  - **Accurate shape control, integrated control of other parameters**
- **Collaboration Approach:**
  - **Digital plasma control system (PCS)**
  - **Real time reconstruction (rtefit)**
  - **Modern control design methods:**
    - **modeling of system to control**
    - **modern design/analysis tools**
    - **Near term (model) applications:**
      - **understand vertical instability**
      - **understand OH-less startup**
    - **Long term applications:**
      - **Accurate advanced controllers**

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Summary of Recent Results

- PCS development and support
- Modeling, simulation, and validation:
  - tools, experimental analysis
  - power supplies
  - diagnostic Green functions
  - vacuum (coils/vessel) circuit response
  - plasma VDE
- OH-less startup scenario support
  - data to Khayrutdinov/Choi
  - DINA development
  - scenario design

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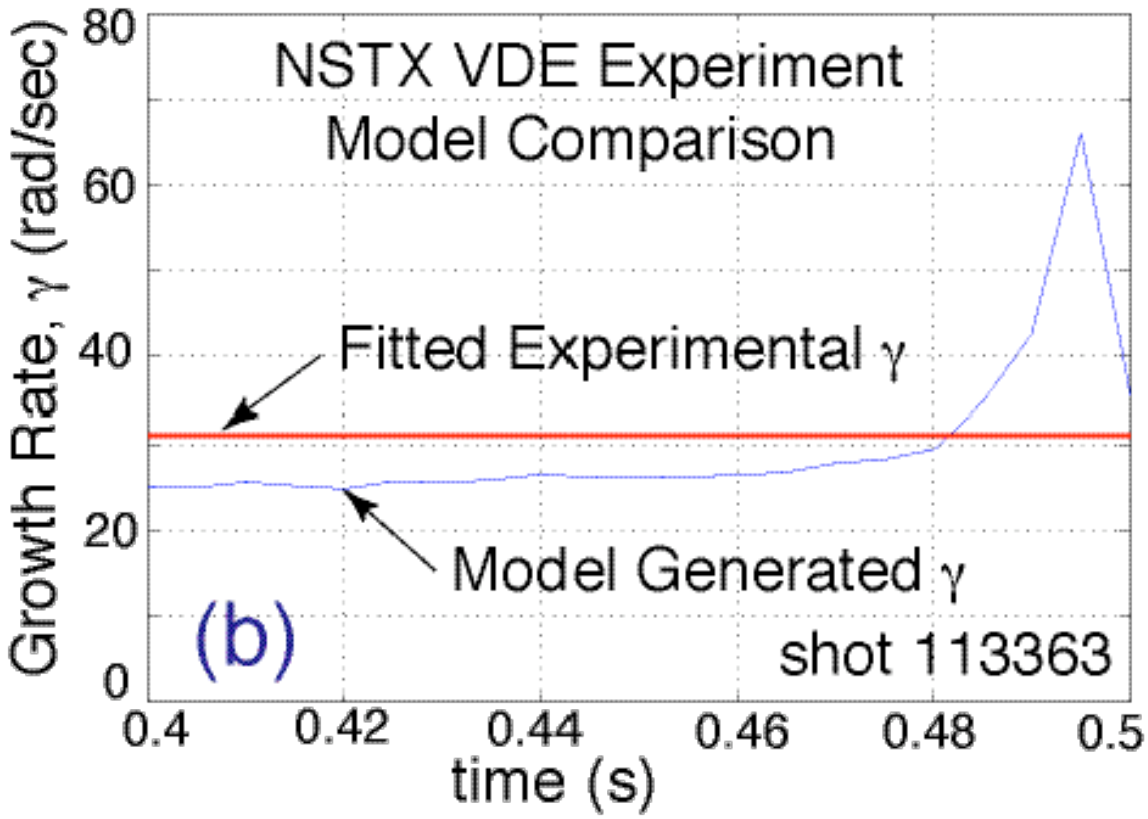
PCS Development and Support

- Upgraded software versions to most recent PCS and rtefit/isoflux algorithm
- Supported rtefit/isoflux use in experiment during initial learning curve
- rtefit/isoflux use became more routine
- Enabled scans of double null shape up/down symmetry
- Enabled exploration of more strongly shaped single and double null plasmas

Modeling, Simulation, and Validation

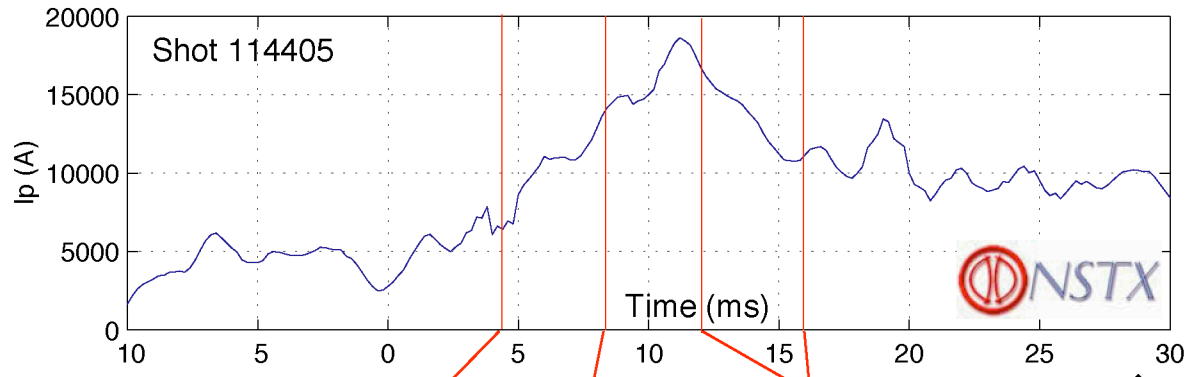
EXPERIMENT/MODEL COMPARISON OF CONTROL-DISABLED VDE PROVIDES VALIDATION OF PLASMA/PASSIVE STRUCTURE MODEL

- **Vertical control is disabled at t= 0.4 s and unstable plasma evolves through a Vertical Displacement Event (VDE).**
- **Sequence of EFIT resonstructions (previous slide) provide time history of vertical position and allow fitting of overall growth rate, γ.**
- **Model calculations of γ, based on a linearized model calculated from each EFIT, compare favorably with growth rate fitted to experiment.**

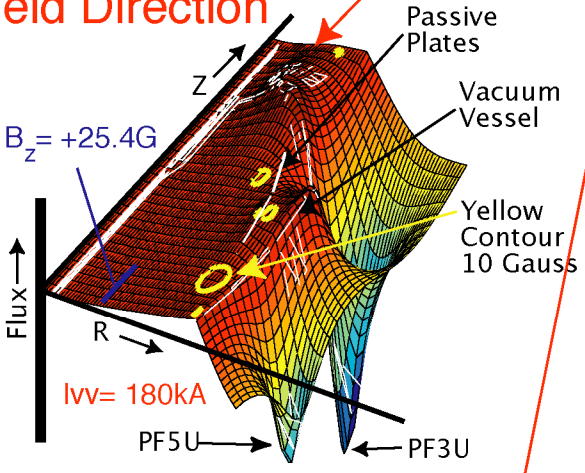


OH-less Startup Scenario Support

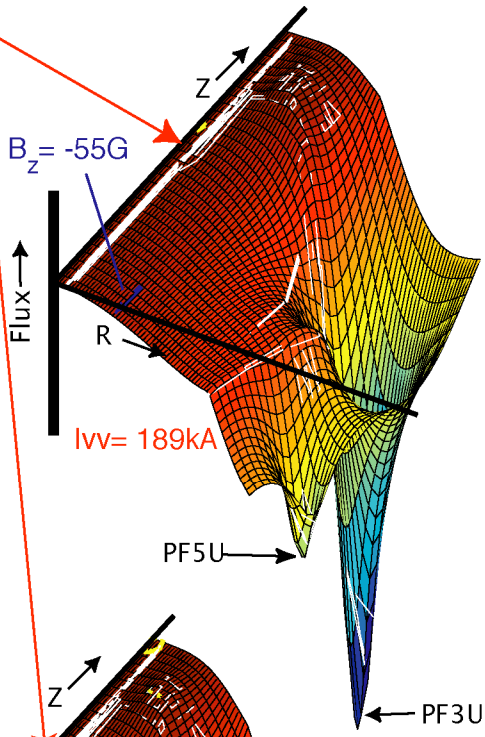
Vacuum Field Simulation for OH-Less Initiation



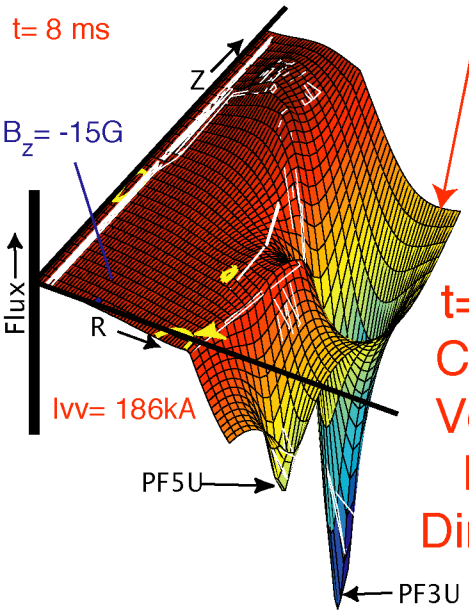
t= 4ms
Wrong Vertical
Field Direction



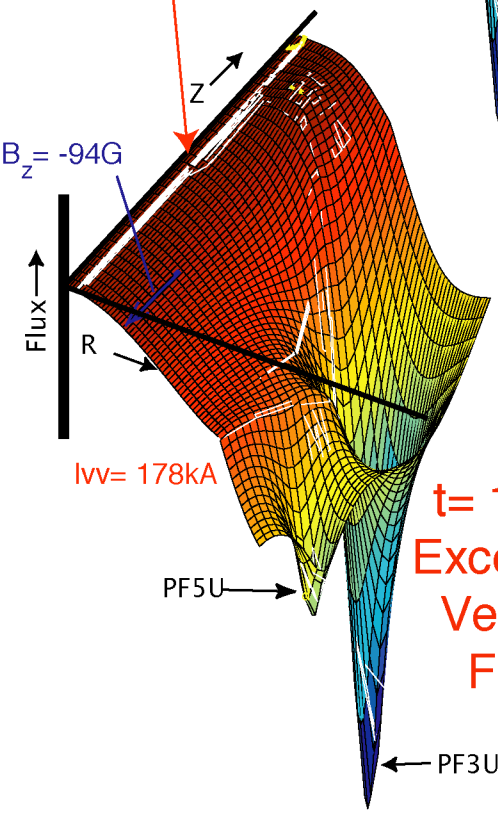
t= 12ms
Moderate
Vertical
Field



t= 8 ms



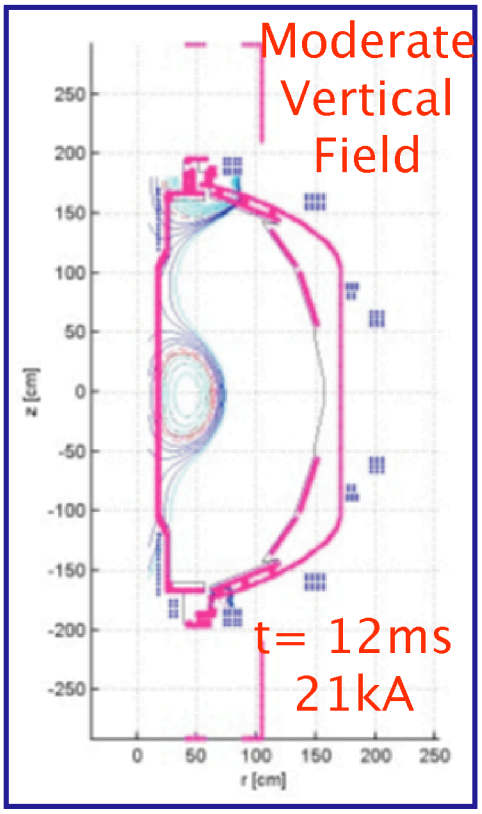
t= 8ms
Correct
Vertical
Field
Direction

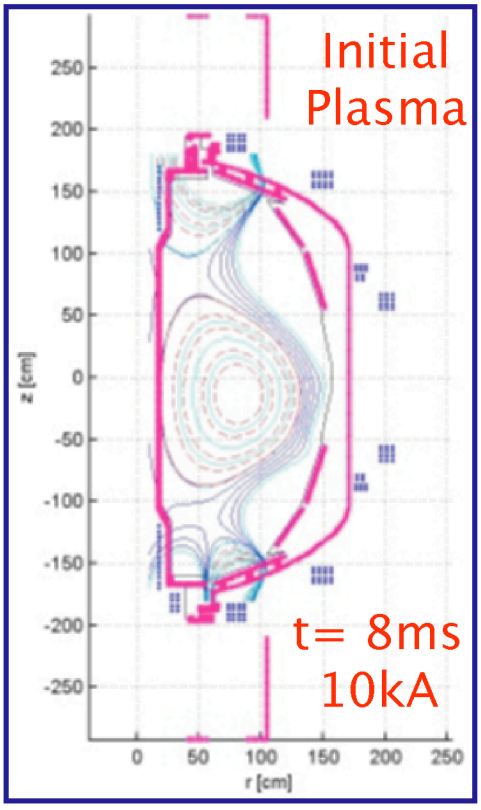


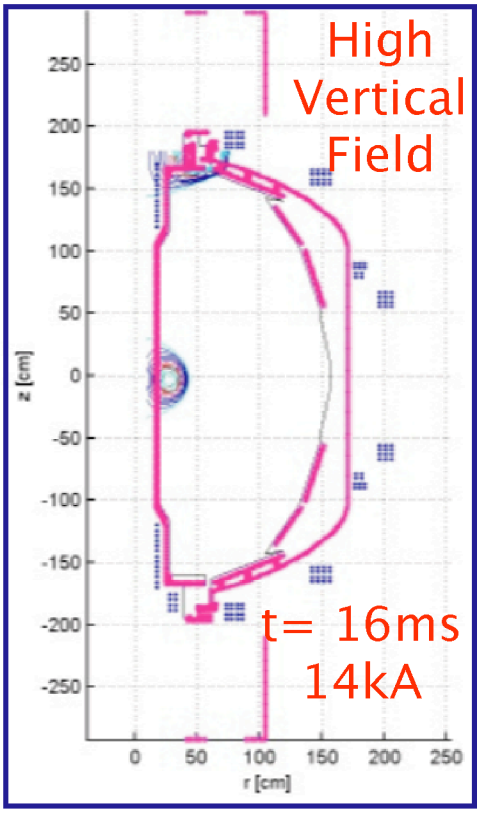
t= 16ms
Excessive
Vertical
Field

DINA Simulation is Consistent With the Plasma Initiation Sequence

No plasma possible prior to ~8ms because of positive vertical field







Future plans - Present Collaboration

- Support engineering analyses
  - experimental needs
  - ongoing modifications
- Complete detailed system validation (all coils, vacuum vessel, VDEs)
- Simulink NSTX plant model
- Design vertical controllers
- Get ready for advanced shape control design
- Continued support OH-less startup
  - DINA development/simulations
  - scenario calculations

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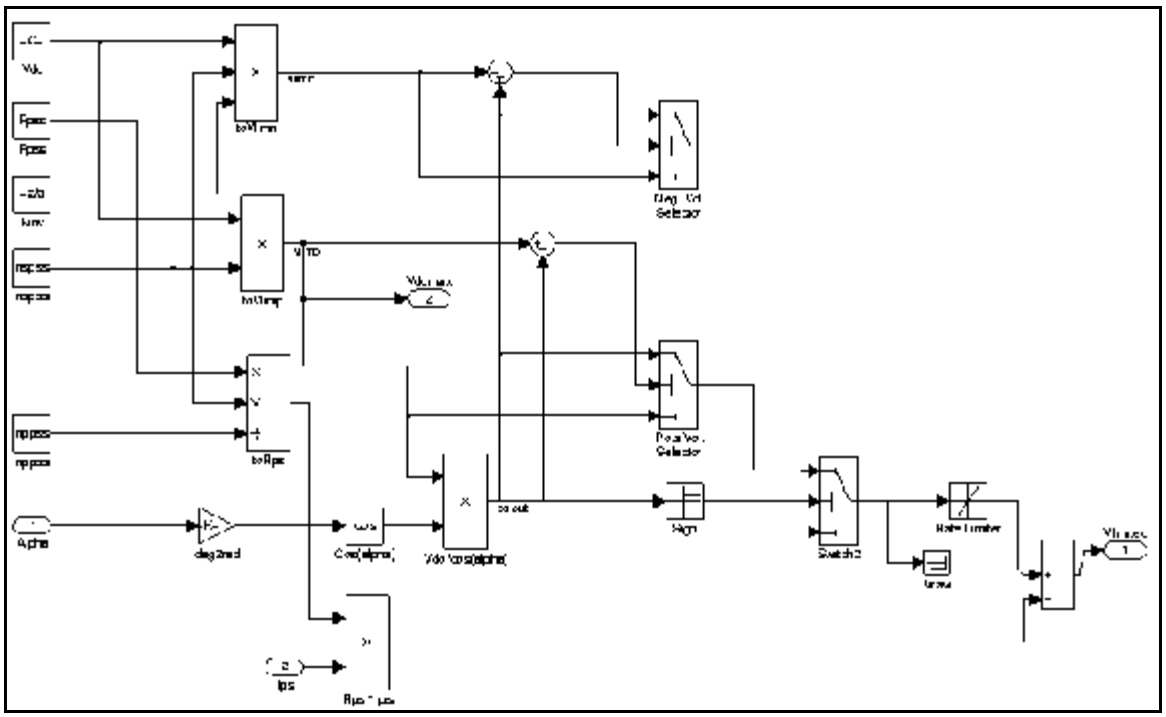
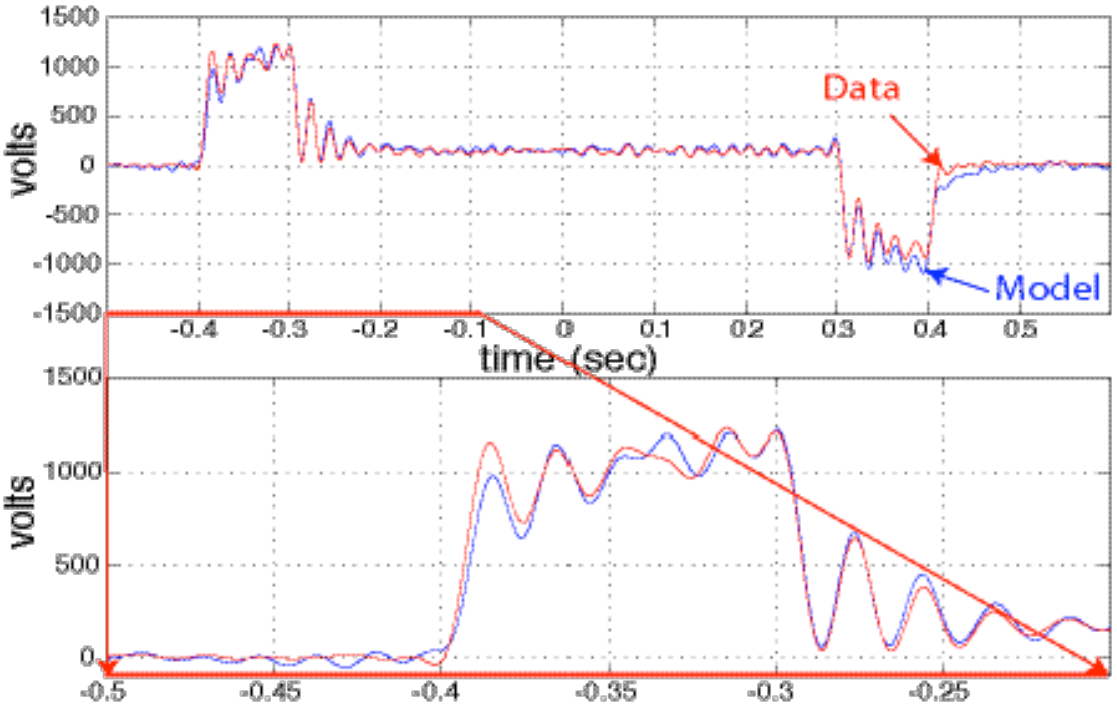
Backup Slides

EXAMPLE POWER SUPPLY MODEL VALIDATION

- **NSTX 12 pulse power supply model (R.Hatcher):**

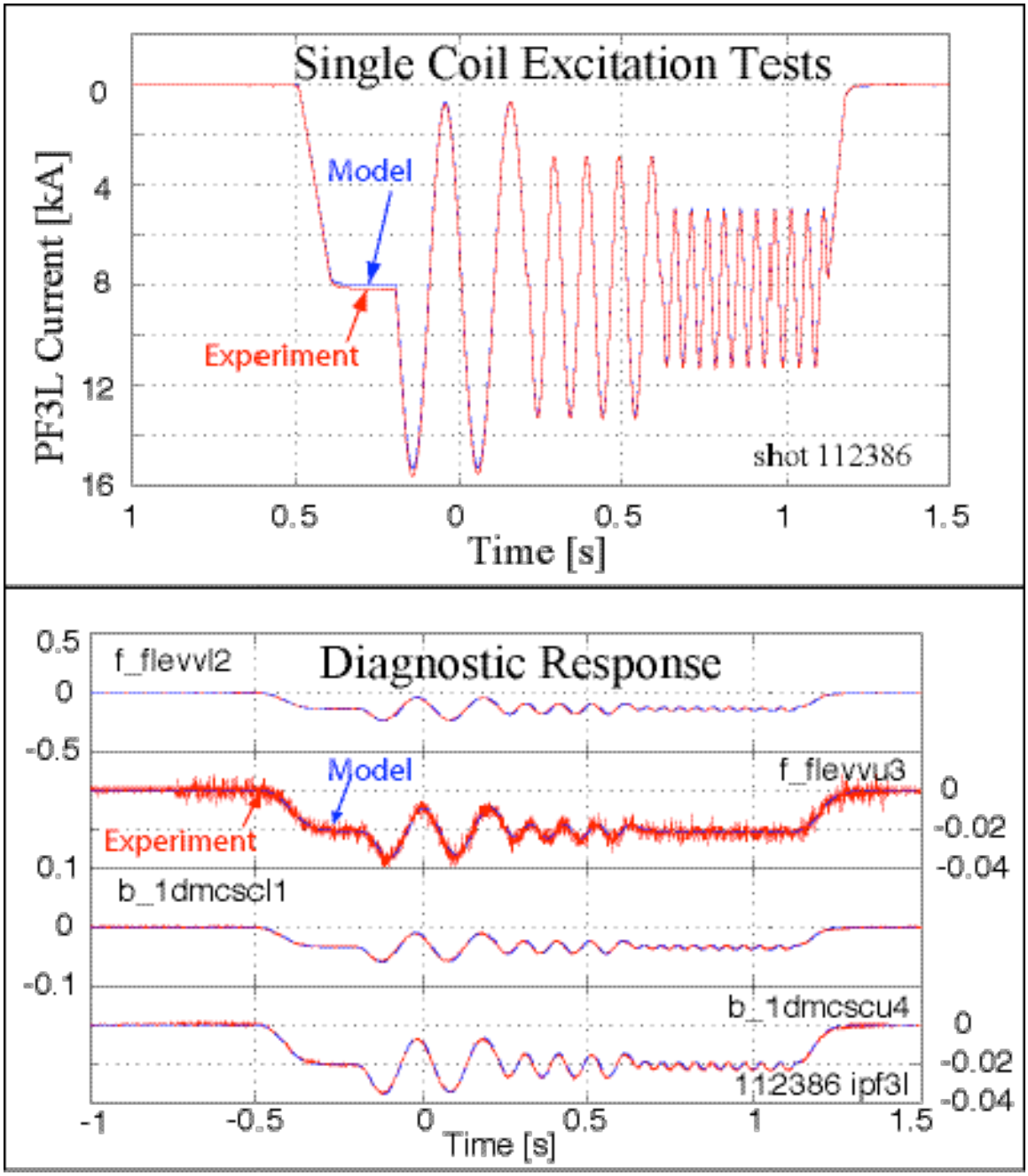


- **Typical validation results (OH, PF2u,l, PF3u,l, PF5u,l):**



SINGLE COIL EXCITATION TESTS VALIDATE MODEL

- **Single coil voltage waveforms from experiment excite model and results are compared with experiment.**



Future plans - New Collaboration (2005-2008)

- Proposal in preparation
- Support PCS upgrades for experimental needs
- Support OH-less startup experimental efforts, analysis (including DINA/Simulink)
- Validate and apply nonrigid linear plasma models
- Design/implement advanced multivariable (MIMO) controllers

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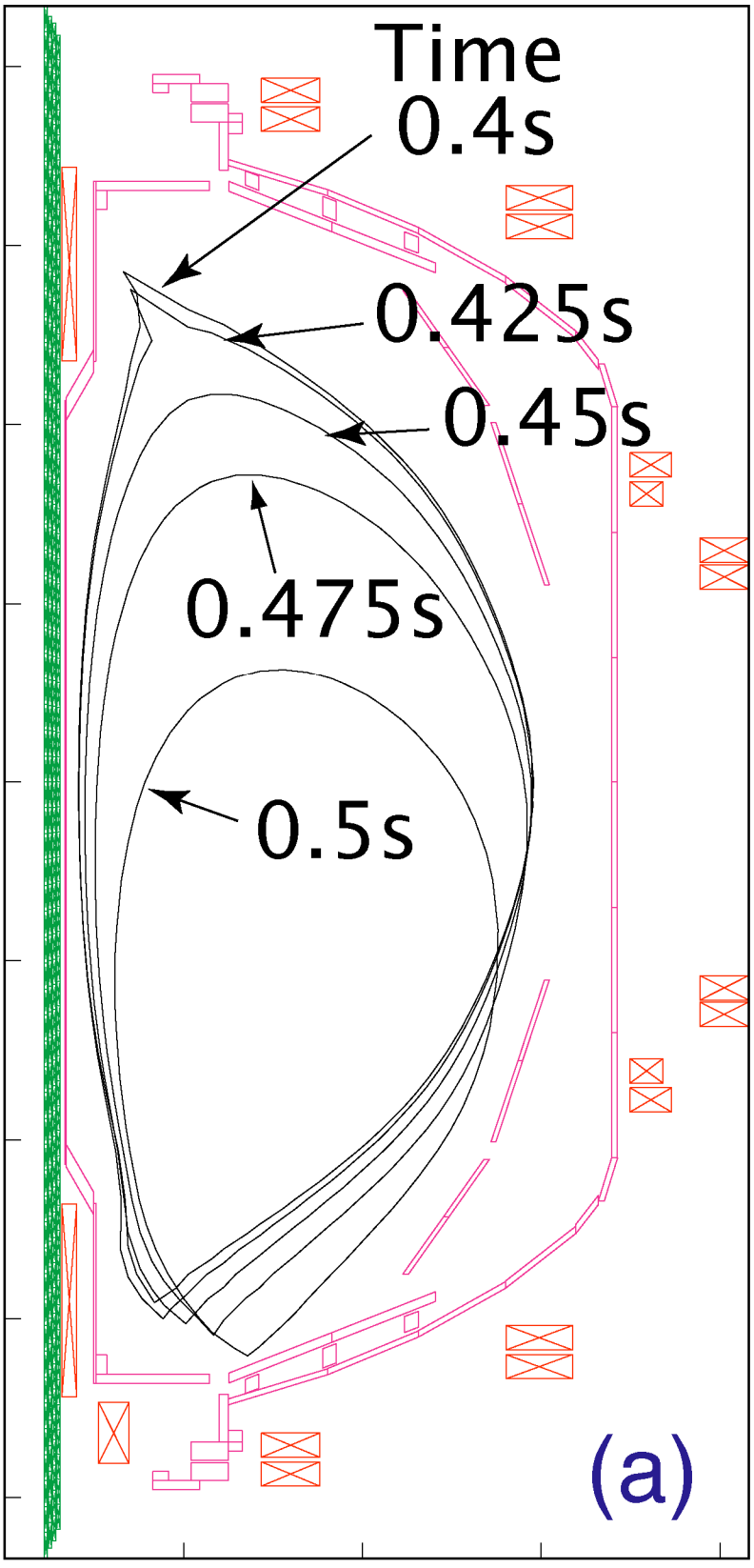
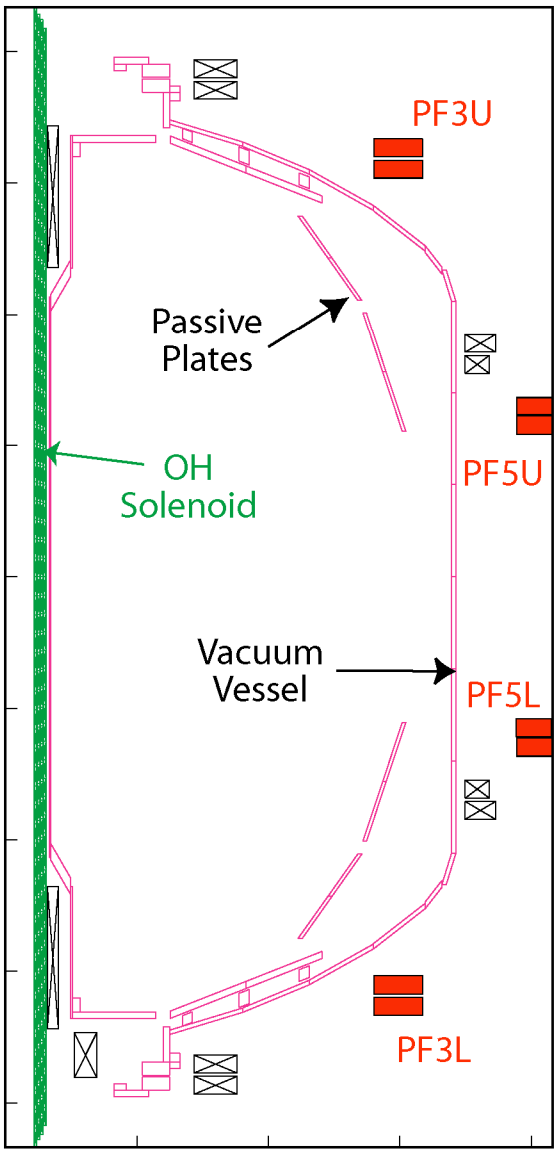
NSTX GEOMETRY AND VERTICAL DISPLACEMENT EVENT (VDE)

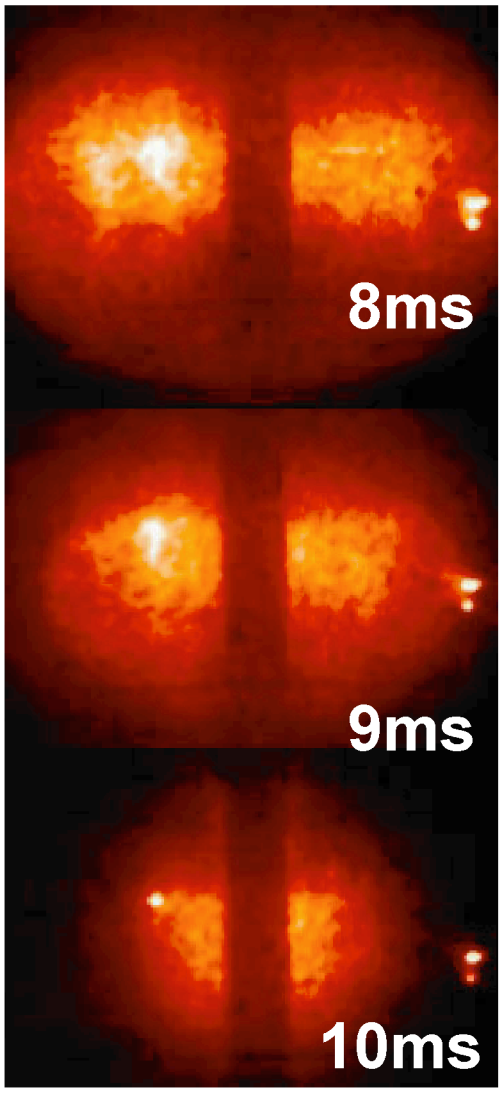


Initial Successful Solenoid-Less Operation in NSTX Used Outside Coil Pairs

- Analysis provides guidance for NSTX experment
- Allows validation of models under very severe accuracy requirements.



RF pre-ionization provides initial breakdown near outer extremes of chamber. At ~8ms vertical field switches sign and plasma is formed over a major part of the chamber. Vertical field continues to rise above that required for full bore plasma and compresses the plasma onto the centerpost.



NSTX

Goals of Present Collaboration (2002-2005)

- Support PCS development
- Model/validate NSTX axisymmetric system
- Support high kappa operation
  - Analyze vertical stability
  - Design controllers
- Prepare for advanced shape controller implementation
- Support OH-less startup scenario
  - Analysis
  - Design
  - DINA simulation

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