NSTX-U

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Plans / collaboration discussion – disruption prediction and avoidance (Columbia U. group)

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NSTX-U Macrostability TSG meeting

October 25th, 2013

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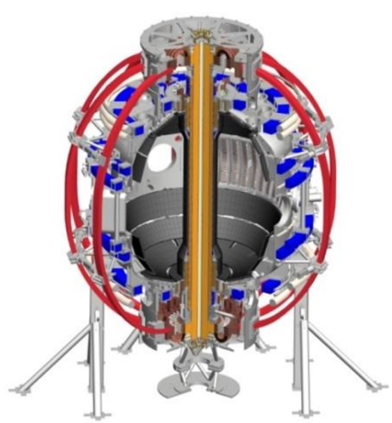

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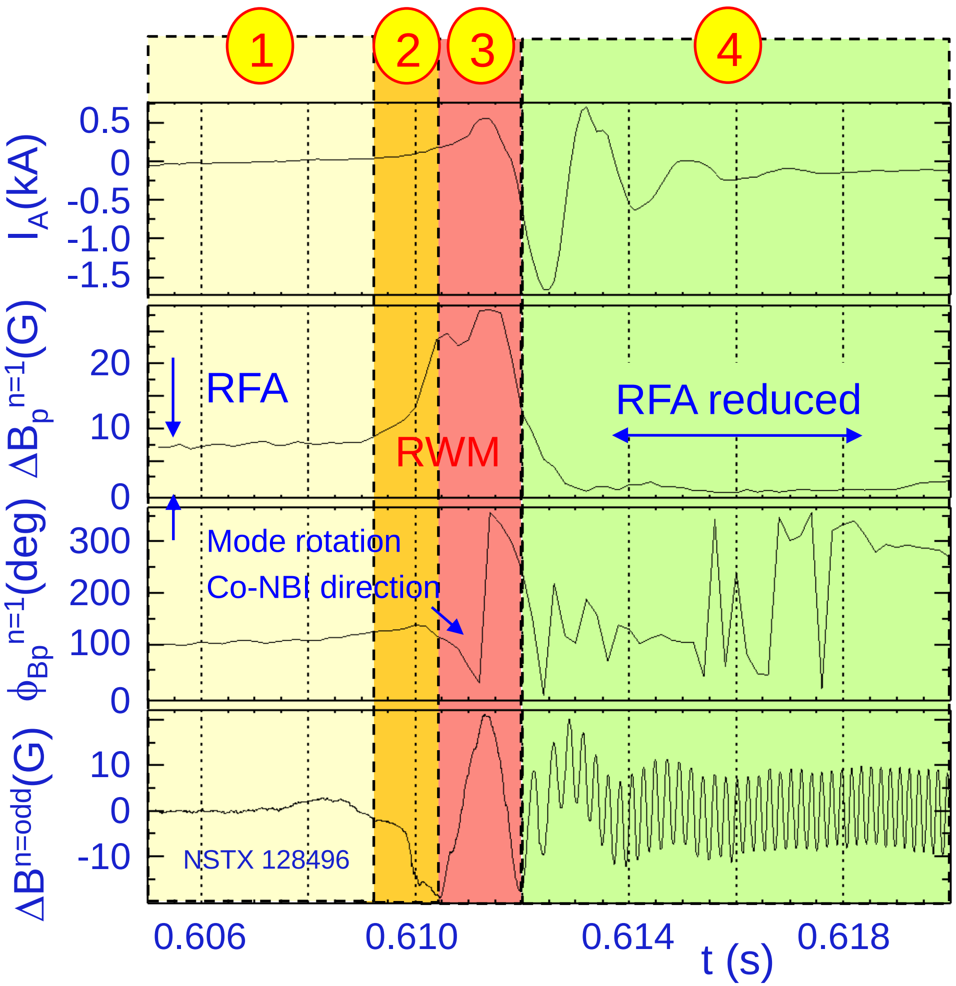
Columbia U. NSTX-U grant proposal research plans – drive suggestions for theory/simulation collaboration ideas

- Near-complete disruption avoidance in long-pulse devices is a new "grand challenge" in tokamak stability research
- CU physics research areas on NSTX-U include a focus on disruption prediction and avoidance
  1. Global MHD mode active control
  2. Global MHD mode stabilization physics (incl. kinetic RWM physics)
  3. Non-resonant plasma rotation alteration / physics / control (NTV)
  4. MHD spectroscopy for disruption avoidance

  Brief discussion here on how theory could help us address these topics (also avoid duplication of effort)
- Subject of new ITPA Joint Experiment/Analysis effort
  - MDC-21: "Global mode stabilization physics and control for disruption prediction and avoidance"

Highly successful disruption P&A needs to exploit several phases to avoid mode-induced disruption

Active RWM control in NSTX



S.A. Sabbagh, et al., Nucl. Fusion **50** (2010) 025020

1. Pre-instability
   - RFA to measure stable γ
   - Profile control to reduce RFA
   - Real-time stability modeling for disruption prediction
2. Instability growth
   - Profile control to reduce RFA
   - Active instability control
3. Large amplitude instability
   - Active instability control
   - Controlled plasma shutdown
4. Instability conversion or saturation
   - Profile control to damp mode
   - Handoff to other mode controller

1. Discussion topics related to global MHD control

- Stability in the presence of a toroidal resistive wall
  - Much experimental experience in NSTX - test non-linear MHD codes using existing data
  - M3D-C^1: resistive wall model is (almost) ready
    - Ferraro: thick shell model ready – beta testing after APS; Jardin: thin shell model almost completed
  - NIMROD: collaboration with S. Kruger / A. Becerra
    - Model recently fixed, first tests on NSTX equilibria underway, will be presented at APS DPP 2013
  - Differential rotation between wall and mode is highly desired
    - Should already be available in M3D-C^1, NIMROD
- NSTX-U model-based RWM state-space control
  - Real-time plasma / response model works well (Boozer model), but can it be expanded?
    - More explicit plasma parameters describing kinetic effects, rather than lumped into the α parameter?

2. Discussion topics related to kinetic RWM stabilization

- Kinetic stabilization physics should be implemented in non-linear codes and compared to results from MISK, etc.
  - NSTX cases sent to Kruger/Becerra (NIMROD) to test with resistive wall. Is physics in NIMROD code of kinetic effects "complete"?
  - S. Jardin indicted kinetic effects are being implemented in M3D-C^1
- Major task with theory: develop improved model of the plasma response near key rationals.
  - Perhaps M3D-C^1 / NIMROD models can guide this?
- Stabilization physics due to fast particles should be further addressed and implemented in linear/non-linear MHD codes
  - What are destabilization mechanisms (linear, or non-linear) that can be caused by fast particles? (hark back to D. Brennan 2012 MCM talk)
  - Is stabilization effect modeling due to Maxwellian distributions complete in the present theory of codes – linear, or non-linear?
- Influence of profile details not typically addressed
  - SPEC code: SAS sent two classes of NSTX equilibria to SH for testing

3. Discussion topics related to non-resonant plasma rotation alteration / physics / control (NTV)

- Significant progress with PPPL student over past 6 months on rotation control algorithm (w/ Sabbagh, Gates, Rowley)
  - First closed-loop state-space feedback (linear and non-linear, with observer) now demonstrated with one NTV actuator (spectrum), SAS expanding present quantitative NTV control model for generality

- Major task with theory (again!): develop improved model of the plasma response near key rationals
  - M3D-C^1 code produces overall field amplification close to experiment
  - A key difference for NTV vs. global stability – the effects of NTV on rotation are local
  - Is present M3D-C^1 model sufficient for realistic local resonant field component amplification/shielding near key rationals?

4. Discussion topics related to MHD spectroscopy for disruption avoidance

- Is M3D-C[1] presently capable of simulating low frequency MHD spectroscopy?
  - Code already shows plasma amplification of static applied field
  - Are more trivial (but needed) code capabilities available?
    - Ability to apply a toroidally propagating AC field? Synthetic sensors?
  - (With resistive wall) could the present physics model simulate amplification / phase shift of a low frequency AC field?
    - Why needed? In our high β_N NSTX experiments, the resonant field amplification (RFA) phase dynamics is important. Can it be modeled for better physics understanding / dependence on plasma parameters?
  - This capability in a non-linear MHD code would tie together several important physics aspects of disruption avoidance
    - Dependence of RFA on kinetic stabilization, mode dynamics, differential rotation between plasma and mode, etc.