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NSTX 5 Year Plan – Initial Ideas for MHD

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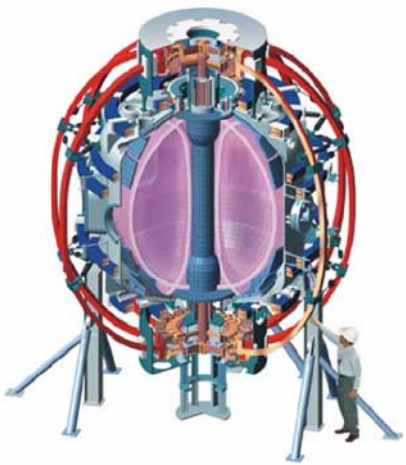
NSTX 5 Year Plan Meeting - MHD
February 14th, 2007
PPPL



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Our opportunity to establish NSTX MHD research for the next 5 years

- Motivation
  - Define 5 year plan for MHD research in an open, group format
- Goals for today's meeting
  - Begin presentation of these ideas / research interests
  - Discussion to prepare for strawman plan
- All ideas welcomed!

Focused 5 year planning effort requires target goals

- General assumptions for 5 year plan goals
  - Support for NHTX: steady-state, high performance (β_N), reduced aspect ratio plasma
  - Support for ITER (ITPA), USBPO, CTF (ST development)

- Bridge from present (07-08) to next 5 years (2009-2013)
  - Initial RWM active control to “optimized” RWM control
  - RWM “critical rotation” to full understanding of stabilization physics
  - Plasma rotation physics/initial control to full study, active control
  - Initial NTM studies to full characterization, mitigation (stabilization?)
  - NSTX config. to targeted NHTX configuration (shape, stabilizers)
  - Disruption database studies to possible expanded disruption studies

Near-term plans (2007 – 2008) for MHD research build upon present results

(From DOE Mid-term Review Meeting, 2006)

- Investigation of extreme elongation regime for CTF, stability studies with greater detail of J(r) from expanded MSE
- RWM / DEFC research targeting active stabilization needs for USBPO, ITER, CTF, KSTAR
- RWM research program leveraging joint experiments (ITPA) for needed physics understanding of kink/RWM stabilization
- Further attention to ITPA / ITER disruption needs (e.g. B, q scaling of locked mode threshold, thermal quench and halo current peaking studies)
- Characterization of NTM at low A, high β and assessment of current drive needs for stabilization

MHD ETG 2007 XP Prioritization: 2007-08 Plans Addressed

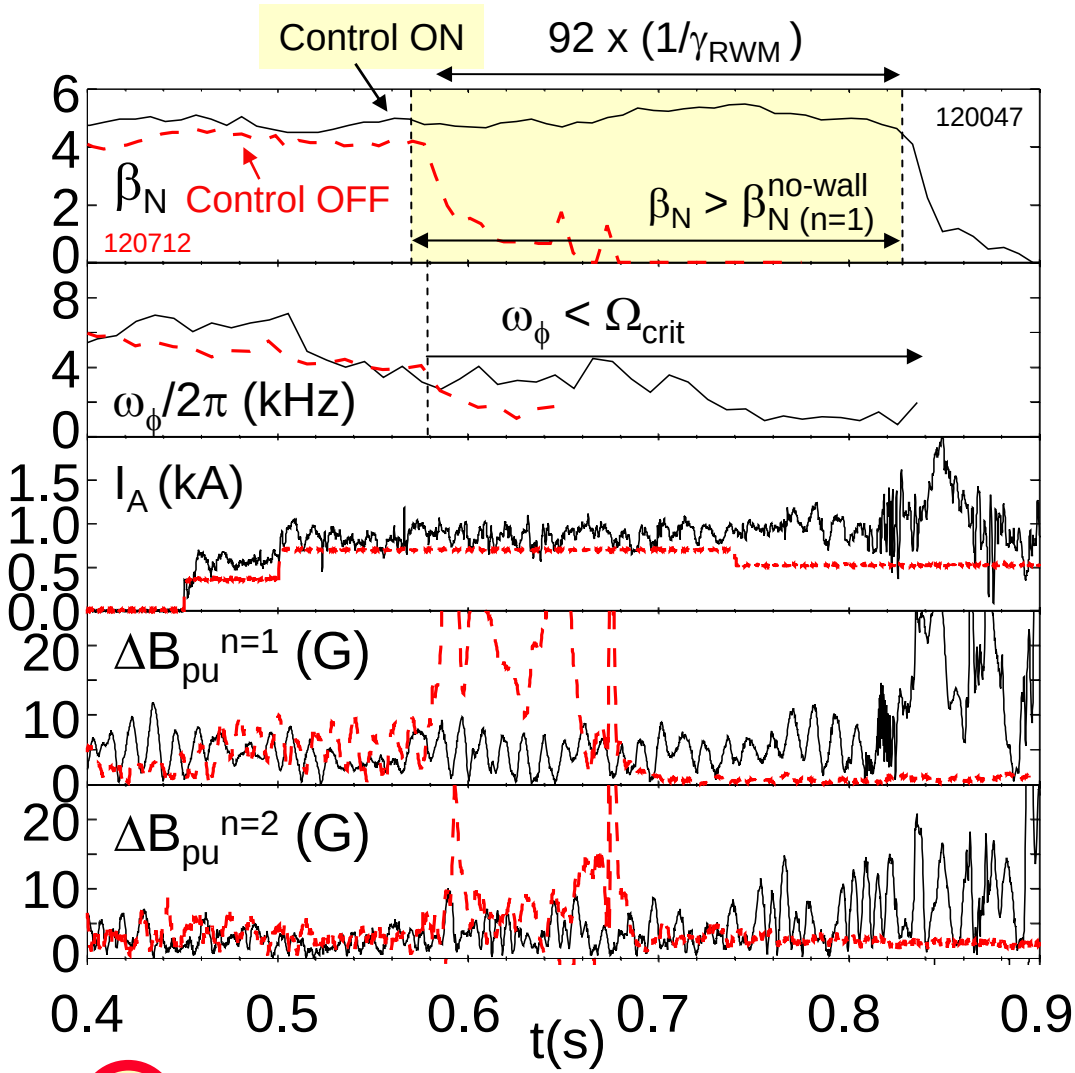
- MHD XP Presentations requesting run time

	Assessment of intrinsic error fields after TF centering (Menard)	1.0 days
	RFA detection optimization during dynamic EF correction (Menard)	1.0 / 1.5 days
	RWM active stabilization and optimization – ITER scenario (Sabbagh)	1.5 days
	• Assessment of RWM mode stiffness (Okabayashi)	-- days
	• n = 3 magnetic braking w/ optimal n = 1 error field correction (Garofalo)	0.5 days
5	Fast Soft X-ray Camera (FSXIC) Imaging of MHD (Bush)	piggyback
days	Exploration of stability limits at high l_N with strong shaping (Gates)	1.0 days
	B and q scaling of low-density locked-mode threshold at low-A (Menard)	1.5 days
	• Measurements of plasma boundary response to applied 3D field (Park)	-- days
	RWM suppression physics at low aspect ratio (Sabbagh)	1.0 days
	• RWM D3D+ joint experiment – ε, β, $V_\phi(\psi)$ effects on $\Omega_{crit}(\psi)$ (Sabbagh)	1.0 days
	NTV dissipation physics: n = 2 perturbations and ν_i (Sabbagh)	0.5 days
	• Toroidal flow damping by island-induced NTV (Shaing)	-- days
10	Marginal island width of NTMs in NSTX (LaHaye)	0.5 days
days	NTM threshold at low plasma rotation (Strait/Buttery/LaHaye)	0.5 days
	Exploration of stability limits at high l_N with n=1 control (Gates)	1.0 days
	Measurement of scrape-off layer current during MHD (Takahashi)	PB / 0.5 days
	RWM resonant field amplification, destabilization of n > 1 (Sabbagh)	1.0 days

Run time guidance: 5 – 10 run days (16.0 - 21.0 run days originally requested)

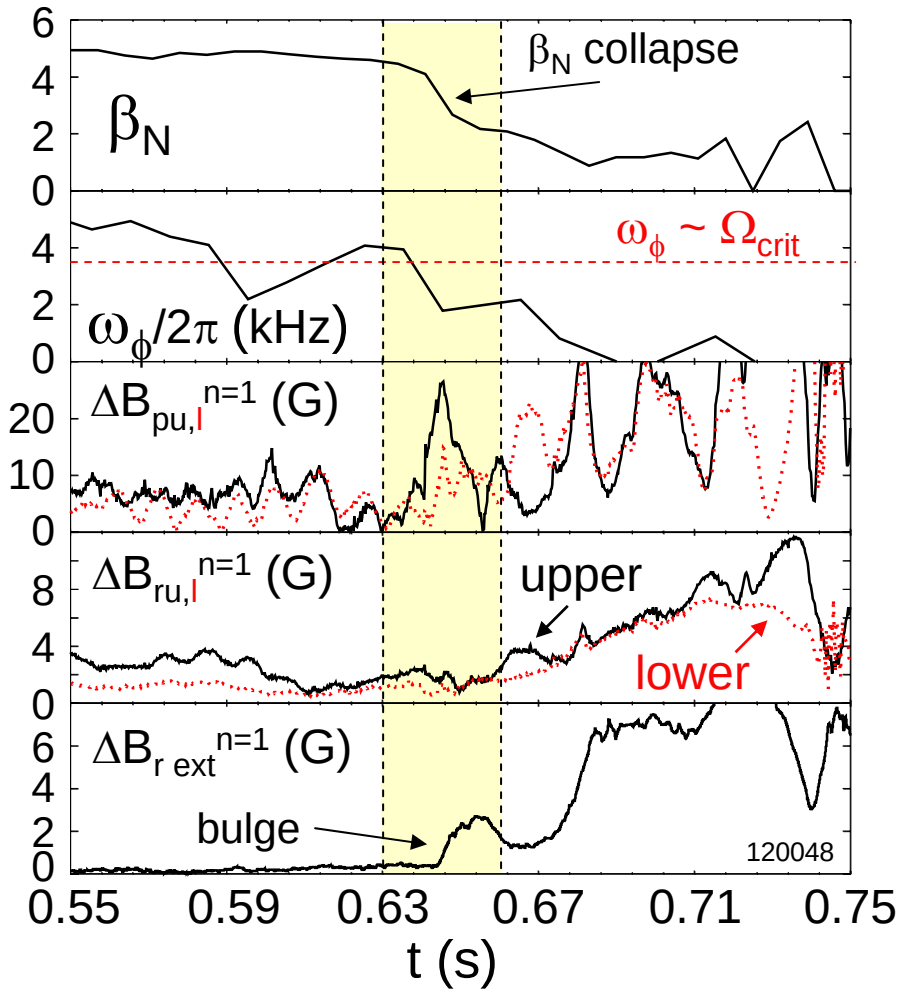
CU group will expand present RWM studies through 5 years

RWM active stabilization at low rotation



- Active stabilization
  - Follows stabilization at low rotation research (Sabbagh, et al., PRL **97** (2006) 045004.)
  - Define optimized feedback algorithms
- RWM stabilization physics research
  - Key for extrapolation to future devices (Sontag, et al., IAEA 2006 paper EX/7-2Rb.)
- Plasma rotation physics and control
  - Follows neoclassical toroidal viscosity observation (Zhu, et al., PRL **96** (2006) 225002.)

RWM may change form and grow during active control

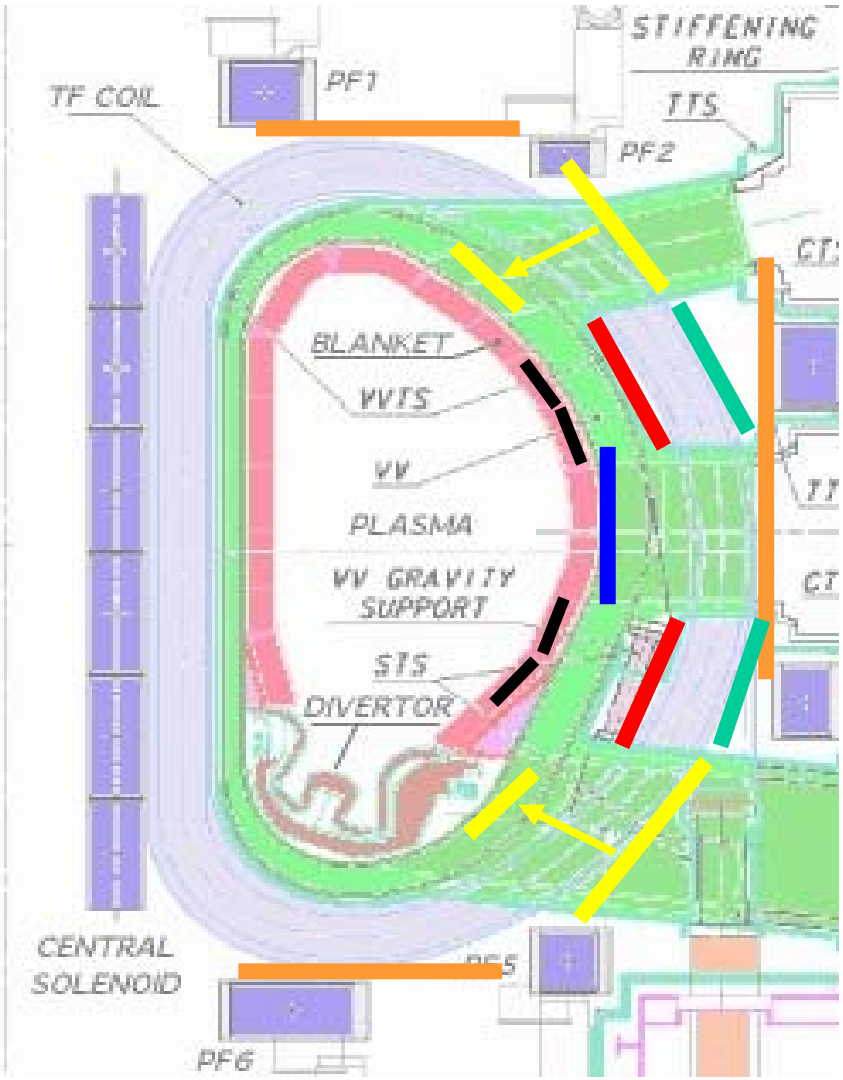


(Sabbagh, et al., PRL **97** (2006) 045004.)

- Poloidal *n* = 1 RWM field decreases to near zero
  - Radial field increasing
- Subsequent growth of poloidal RWM field
  - *Asymmetric* above/below midplane
- Radial sensors show RWM bulging at midplane
  - midplane signal increases, upper/lower signals decrease
  - Theory: may be due to other stable ideal *n* = 1 modes becoming less stable (multimode analysis next step)

2007 research will assess using combined sensors for optimization

ITER non-axisymmetric coil designs being studied by USBPO for combined ELM, RWM, error field control



J. Menard, USBPO MHD group leader

- RWM: G. Navratil, J. Bialek (CU)
- ELM: T. Evans (GA)
- Error field: M. Schaffer (GA)

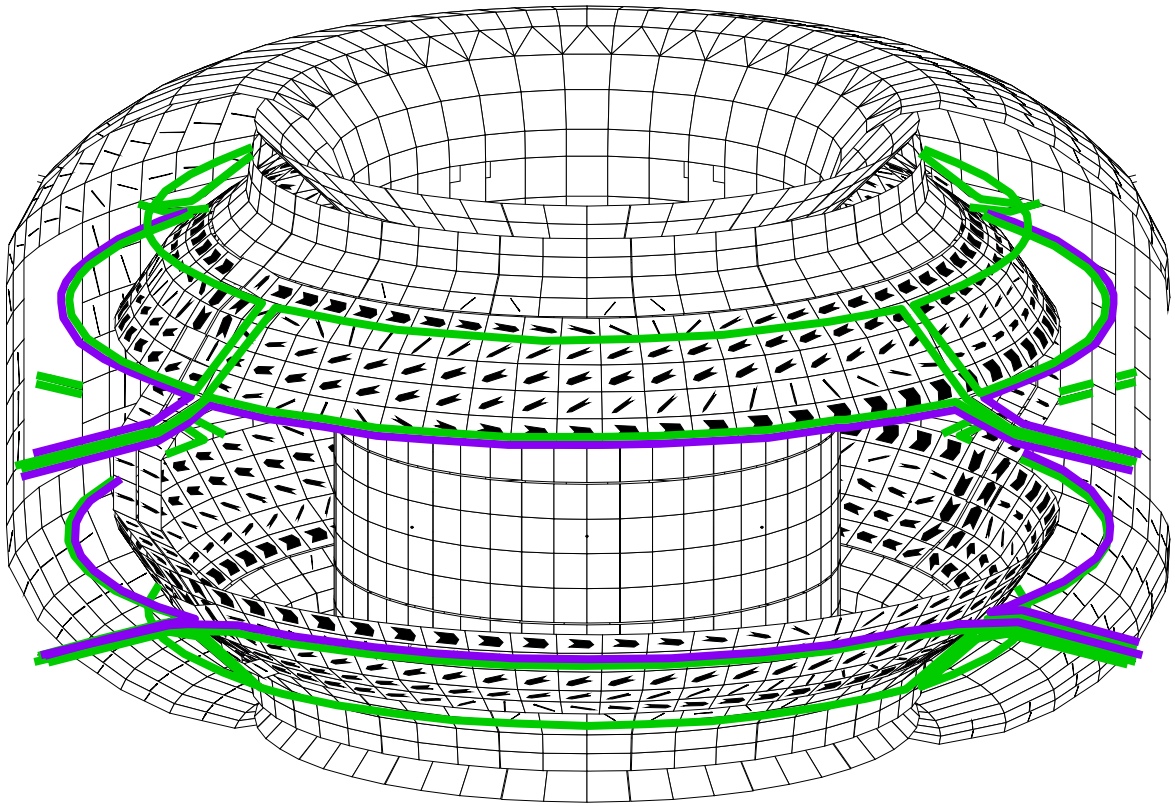
Coil position considerations

1. **Present error field correction coils**
2. **Mid-plane port-plug RWM coils**
3. ~~**ELM coils on vessel, inside TF**~~
4. **ELM coils in blanket modules**
5. **ELM coils on TF, near mid-plane**
6. **ELM coils on upper/lower ports**

Future NSTX non-axisymmetric coil upgrades should consider support for ITER and other devices

NSTX supports RWM stabilization calculations conducted for KSTAR

n = 1 RWM passive stabilization currents (VALEN)



IVCC (RWM) control coils
(upper,middle,lower)

- Conducting hardware modeled
  - Vacuum vessel
  - Center stack backplates
  - Divertor backplates
  - Passive stabilizer (PS)
  - PS Current bridge
- Follows similar calculations for NSTX, DIII-D, ITER, JT-60SA, several others

Initial ideas to establish 5 year plan goals stem from present research (I)

- RWM control
  - Test optimized techniques offline ‘07, implement ’08-’09, use ’09+
  - Possible sensor upgrade for optimal control
  - Possible passive plate modification to test control; NHTX support
  - Need for multiple mode stabilization? Internal coils?
- Plasma rotation
  - Resonant damping, islands, damping mitigation for steady-state ops
  - Real-time rotation evaluation for active rotation control; fast CHERS
  - Density control (ion collisionality) to support physics study (ITER, etc.)
- RWM stabilization physics
  - NSTX well-equipped for study – analysis/’07 run determine upgrades
  - Rotation/profile, ν_i , RWM active control beneficial (required) tools for study

Initial ideas to establish 5 year plan goals stem from present research (II)

- NTM
  - Approaches for study constrained by hardware upgrades
    - "Committed" to analysis of current drive needs for stabilization
    - Suggest that NSTX leverage low A, high β for physics contribution
    - Suggest focus on physics, and what is needed for steady-state operation
    - Will an active stabilization system be supported? Passive studies only?
  - Improve diagnostics for mode determination / stability analysis
    - MSE (in plan), SXR (mode diagnosis may alter plan), etc.
- Shaping / configuration
  - Self-consistent current profile (β dependent) for steady-state ops
    - Any possible "real-time" alteration? β, MSE, rotation (E_r) feedback?
  - Possible NSTX device alteration to support NHTX? (plates, divertor)
- Disruptions
  - What role (percentage effort) will NSTX take in disruption studies?

Several ideas discussed in preliminary fashion at "kickoff" meeting 12/20/2006 (I)

- NTM active stabilization
  - need to state a full plan of what we want to do, from characterization to a decision point of either mitigation, or possible active control
    - what can be done? what can be funded?
    - is this important enough to pursue?
  - EBW might not work for stabilization, due to problems with current drive localization and changes the localization you might actually get
- Furth-Hartmann coils
  - Application of some amount of external transform – for MHD, ELM, general transport and divertor studies
- Additional RWM coils
  - Useful for RWM stabilization, rotation control, ELM mitigation, etc.
  - greater poloidal spectrum of applied field, test effect of penetration of passive plates and how active stabilization can be improved with optimal control algorithms (for ITER, KSTAR, NHTX, CTF)

Several ideas discussed in preliminary fashion at "kickoff" meeting 12/20/2006 (II)

- Optimized RWM passive stabilization
  - Calculate possible optimized plate jumper configuration, and wiring the passive plates to test these configurations
- Targeted RWM passive (+active) stabilization configurations
  - Possible configuration changes to support NHTX, other devices
  - Evaluate effect of eliminating plates; replacing certain plates with internal RWM active stabilization coils
  - Boundary group also suggests possible changes to secondary PP geometry
- Improved error field correction
  - using this greater coil set – again, to support steady-state operation, but also influences boundary, ELM, NTM, RWM physics