U.S. Burning Plasma Organization draft prioritization of ITER physics tasks for MHD

J. Menard, **PPPL**
BPO MHD topical group leader
PPPL MHD SFG leader

PPPL SFG meeting
September 18, 2006
Director's Conference Room

Overview of initial prioritization activity

- Strong emphasis placed on issues/tasks that:
  - Could impact ITER design in the near term
  - Have a clearly defined deliverable - within 1-2 years
  - Represent U.S. interests and capabilities in ITER
  - other…
- Generated list of 70+ ITER issues
- For more info on MHD prioritization process, visit:
  - https://burningplasma.org/forum/index.php?showforum=15
- Descriptions of top 5 ITER MHD physics issues as prioritized by MHD topical group follow:

1. Active coil system for combined ELM suppression and RWM stabilization

- Description: Determine if a coil design exists that can provide both RWM stabilization and ELM suppression.

- Importance: ELM control is important for protecting the divertor in all ITER operating scenarios, and RWM stabilization is crucial for AT scenarios which operate far above the no-wall stability limit. However, the optimal control coils for these capabilities are not part of the ITER base design. It is necessary to determine which coil designs achieve robust control for ELM and RWM separately, and to determine if a common coil set can satisfy both needs. Such coils may also be beneficial for density pinch mitigation and ash removal.

- Deliverable: Determine optimal RWM and ELM control coil geometries. Form a joint task group between MHD and boundary groups to assess commonality of design and possibility of achieving robust RWM and ELM control with hybrid coil design.

- Delivery Date: 1 year

2. Requirements for (simultaneous) stabilization of (3,2) and (2,1) NTMs

- Description: Determine ECCD power, localization, and steering requirements for simultaneous stabilization of (3,2) and (2,1) NTMs in ITER. Explore expanded physics capabilities enabled by proposed "front steering" ECCD launcher.

- Importance: (2,1) NTMs are potentially disruptive to ITER plasmas and (3,2) NTMs could significantly degrade confinement. Both modes will be present in ITER (possibly simultaneously), so suppression of both low mode-number NTMs will be important for achieving high plasma beta and burning plasma conditions. The newly proposed "front steering" launcher for the ITER upper port greatly improves the achievable ECCD current density and the prospects for achieving simultaneous control of these modes, but additional physics assessment is required.

- Deliverable: Determine impact of "front steering" launcher on NTM control and improved operating scenarios, such as 2/1 NTM suppression in the hybrid scenario.

- Delivery Date: 1 year

3. Physics of noble gas injection disruption mitigation

- Description: Assess extrapolability of present mitigation techniques to ITER conditions.

- Importance: Significant progress has been made in reducing VDE halo currents (and other deleterious disruption side-effects) in existing devices through disruption mitigation techniques utilizing noble gas injection. The rapid penetration of radiating impurities is critical to the success of the technique. This penetration is presently interpreted as being facilitated by volumetric stochastization of the equilibrium magnetic field via induced MHD instabilities. At present, it is unclear if this process scales to the much larger size and magnetic Lundquist number (S) of ITER.

- Deliverable: Perform additional MHD modeling and experiments to assess scaling of MHD-induced penetration of impurities to ITER plasmas - for both standard operating and advanced tokamak scenarios with qmin > 2.

- Delivery Date: 1-2 years

4. RWM diagnostic and power supply requirements

- Description: Determine the RWM control requirements beyond optimal coil specification
- Importance: Significant progress has been made in understanding the stability benefits of placing control coils closer to the plasma in ITER, and in demonstrating RWM feedback control at low plasma rotation in existing experiments. However, the detailed power supply and diagnostic requirements for optimal RWM control in ITER remain unclear.
- Deliverable: Quantify the plasma noise characteristics in existing experiments, develop models for extrapolating to ITER, and assess impact on magnetic (or other) sensors for RWM detection and on power supplies powering RWM control coils.
- Delivery Date: 1-2 years

5. Locked-modes and error field correction specification

- Description: Determine the size-scaling of the locked mode threshold for extrapolation to ITER
- Importance: Error fields and associated low-density locked modes could impact the startup phase of ITER discharges and could also impact performance at high beta-N. Both resonant and non-resonant rotation damping is apparently important in determining the locking threshold. C-MOD data shows differences in br/Bt threshold scaling depending on whether n/nGW is fixed or an error field identity configuration is used. An unfavorable size scaling could impact the present error-field correction coil design for ITER.
- Deliverable: Finish/perform relevant experiments on C-MOD and other U.S. facilities, quantify the potential impact on the ITER error field correction coil set. Develop and test improved models of resonant and non-resonant rotation damping with application to locked-modes.
- Delivery Date: 1-3 years

Overview of 2nd prioritization process

- Narrowed list to top 14 across topical areas
  - Based on rankings/voting of all topical group leaders
    - https://burningplasma.org/forum/index.php?showforum=65

- 4 MHD topics made list of top 14:

  #1. Active coil system for ELM suppression and RWM stabilization

  #2. ITER disruption mitigation system design and physics understanding

  #4. Requirements for stabilization of (3,2) and (2,1) NTMs

  #14. Locked-modes and error field correction specification

Overview of 3rd prioritization process

- Goal is to develop ITER "issue cards" that document and justify desired changes to ITER design
  - Coordinated by Brad Nelson (ORNL), USIPO Engineering Manager
  - Prepare for December design review in Cadarache:
    - https://burningplasma.org/forum/index.php?showforum=58
  - Form BPO task groups as needed to provide input/support for issues

- Final critical assessment of previous lists of topics
  - Must clearly impact ITER design and be addressed within 0.5-1 year

- 3 MHD topics made "issue card" list:

  #1. Active coil system for ELM suppression and RWM stabilization

  #2. ITER disruption mitigation system design and physics understanding

  #4. Requirements for stabilization of (3,2) and (2,1) NTMs

Ideas for possible theory contributions

- Active coil system for ELM suppression and RWM stabilization
  - Use stellarator tools to better understand equilibrium, MHD stability, and transport response to 3D perturbations to tokamak edge
  - Study ITER RWM control with NMA code of Chu & Chance
  - Is there commonality in the desired coil sets for these control tasks?
- ITER disruption mitigation system design and physics understanding
  - Use M3D for noble-gas-injection induced disruption studies – does this physics extrapolate to ITER?
- Requirements for stabilization of (3,2) and (2,1) NTMs
  - Use PEST-3 to assess NTM stability changes from modifications of Δ' from more localized CD from “front steering” launcher
- Locked-modes and error field correction specification
  - Use stellarator codes (or perturbed equilibria from DCON) to study equilibrium response – address resonant vs. non-resonant damping mechanisms which control locking threshold and coil requirements

Ideas for possible NSTX contributions

- Active coil system for ELM suppression and RWM stabilization
  - Revisit ELM mitigation experiments with RWM/EF coils
  - Validate ITER RWM control models with NSTX RWM control tools
- ITER disruption mitigation system design and physics understanding
  - Perform/finish halo current studies, contribute data to ITPA
  - Attempt disruption mitigation w/ existing gas injection systems (SGI?)
- Requirements for stabilization of (3,2) and (2,1) NTMs
  - Study NTM seeding physics? Validate mod-Rutherford equation?
  - Not much we can do for NTM suppression with ECH/EBW….
- Locked-modes and error field correction specification
  - Finish locked-mode threshold experiments, contribute data to ITPA