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Discussion of NSTX Contributions to ITER-ITPA: Macroscopic Stability – pre-Forum

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Macroscopic Stability Topical Science Group

NSTX Macrostability Topical Science Group Meeting
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How can NSTX Macro TSG best contribute to ITER/ITPA?

- Actions for Meeting
  - Summary of "joint experiment" discussion at Lausanne ITPA mtg
  - Discuss topics – experimental / theoretical / modeling perspectives
  - Suggest experiment/analysis, priority given present resources
  - Identify personnel interested in leading ITPA related experiments

- Guidance : Recall Program Director's Questions
  - "Which ITER and ITPA high priority areas should NSTX focus on?"
  - "Which joint experiments should NSTX contribute to or lead?"
  - 20 – 30% experiments for ITER support
    - improve follow-through and reporting to ITPA

High Priority ITPA MHD Stability Research Areas

- Largest single problem: disruptions (and runaways)
  - Suggest that NSTX research approach this several ways: (i) database/empirical, (ii) causal mode physics, (iii) control/avoidance
    - Embodied in different joint experiments
- Priority areas noted and discussed
  - Vertical stabilization for ITER
  - Disruptions (control, mitigation, and loads)
    - e.g.: address runaway issue – with RMPs as a possible technique to avoid mode locking during dusruptions, which leads to worse heat loss issues
    - Disruption database – further development
  - NTMs (many subtopics)
  - Error field effects
    - Quantify effects of error fields, specify multi-mode error correction requirements and error field thresholds at medium to high beta (note: present EFCCs are only n = odd capable)
  - RWM control
    - Mode stabilization physics
    - Control system: need specifications for noise, voltage/current required for power supplies, frequency response, control of large transient events
    - first priority is dynamic correction of error fields; second priority is correction of RFA and RWM control at higher beta
  - Magnetics diagnostics for ITER (J. Lister - special presentation)
    - Focus on compensation of ferromagnetic materials, effective positioning, redundancy

ITPA MHD Stability Group - Joint Experiments (NSTX contact)

- MDC-1: Disruption mitigation by massive gas jets (none)
- MDC-2: Joint experiments on resistive wall mode physics (SAS)
- MDC-4: NTM Physics – aspect ratio comparison (SPG)
- MDC-5: Comparison of sawtooth control method for NTM suppression (SPG)
- MDC-12: Non-resonant magnetic braking (SAS)
- MDC-13: Vertical stability physics and performance limits in highly elongated plasmas (DAG)
- MDC-14: Rotation effects on NTMs (SPG)

new

- MDC-15: Disruption database development (SPG)
- MDC-16: Runaway electron generation, confinement, and loss (none)
- MDC-17: Physics-based disruption avoidance (SPG)
- - MHD risks associated with the Test Blanket Modules (none)

- Three talks given in Lausanne for NSTX Macro TSG on four subjects
  - Effective: NSTX results appeared in summary report under 5 joint experiments

"Joint Experiments" - Individual Discussion (1)

- What is a "joint experiment" (JEX)?
  - "joint experiment" to be viewed more generally – "joint analysis", etc.
    - analysis of multi-machine data
    - coordinated multi-machine experiments on a common topic
    - "identity experiments" to determine scaling vs. size, aspect ratio, etc.
  - Involves common scientific personnel, analysis tools
  - Provides results beyond what is possible in a single machine
- MDC-1: Disruption mitigation by massive gas jets
  - No proponent for NSTX at present
  - Compact Torus (CT) injection slide by R. Raman shown
    - ITPA interested in CT injection research if sufficient density to suppress runaways can be reached
    - No runaways at present on NSTX – should we try to produce them?
    - Significant effects on disruption characteristics due to Li pellets, Li wall?

"Joint Experiments" - Individual Discussion (2)

- MDC-2: Joint experiments on resistive wall mode physics
  - Presentation given by S. Sabbagh for NSTX on RWM research
  - Report given by H. Reimerdes
    - MDC2.1: critical velocity for RWM stabilization – abolish this concept?
      - greater complexity than perhaps first imagined
      - DIII-D identifies their mode as TM not RWM
    - should benchmark linear stability models (MARS-K, MISK)
      - (SAS: comments that this has been done for Solov'ev equilibrium)
    - JT-60U EWM – EPM trigger of RWM, similar in DIII-D
      - (SAS: has also been seen in NSTX – suggests this to be ideal joint analysis/experiment between devices)
    - coupling mechanism between instabilities (ELM/fishbone trigger)
    - MDC2.2: cross-machine comparison of resonant field amplification
      - IPEC RFA mentioned, should be further justified in experiments – in the plasma; near rational surfaces.

"Joint Experiments" - Individual Discussion (3)

- MDC-4: NTM Physics – aspect ratio comparison
  - Presentation given by S. Sabbagh for NSTX on NTM research
  - S. Gerhardt identified as NSTX contact
  - NTM discussion basically reserved for MDC-14
    - Focus on aspect ratio effects has come through most explicitly in LaHaye's marginal island width XP
    - Suggest that NSTX should revive this JEX, as it focuses on aspect ratio effects
- MDC-5: Comparison of sawtooth control method for NTM suppression
  - Sauter: JET's old conclusion of shear stabilization of sawteeth now possibly changed to fast particle stabilization
  - Investigation of fast particle stabilization and how this might scale to ITER is important
    - Should NSTX pursue research on this?
  - S. Gerhardt named as NSTX contact

"Joint Experiments" - Individual Discussion (4)

- MDC-12: Non-resonant magnetic braking
  - Presentation given by S. Sabbagh for NSTX on NTV research
  - NSTX non-resonant n = 2 braking success shown
  - NSTX observation of stronger braking at higher T_i, consistent with NTV theory (analysis continues); lower ν_i results of interest to ITER
  - Ted Strait suggested the need for a joint experiment here, SAS agrees (joint XP submitted to MAST; XP submitted to DIII-D last year)
- MDC-13: Vertical stability physics and performance limits in highly elongated plasmas
  - C-Mod, DIII-D, JET, NSTX: typical noise levels in the control systems are equivalent to delta-Z/a~0.5-1%
    - Modes such as ELMs can create larger perturbations (3% in DIII-D)
  - Z-dot noise a problem on JET – AC losses associated with this
  - Gribov: noise levels of n = 0 AND n = 1 need specification for ITER; on DIII-D, he has seen an order of magnitude noise variation
  - More to do re: performance limits at high elongation?

“Joint Experiments” - Individual Discussion (5)

- MDC-14: Rotation effects on NTMs
  - Summary presentation by R. Buttery included NSTX results
    - NSTX and other devices show that the threshold for onset of NTMs decreases with decreasing toroidal rotation
    - experimental results most consistent with a modification of stability by variation of flow shear
    - NSTX and other devices show that the metastability threshold scales as ρ^*, and marginal island width scales with the ion banana width
  - More to do in the area of error field thresholds and marginal island width?
  - Suggest that cause of NTM stabilization in NSTX Li wall experiments should be determined and reported

New “Joint Experiments” - Individual Discussion (1)

- MDC-15: Disruption database development
  - Activity “promoted” to joint experiment to best insure priority for it
  - S. Gerhardt named as NSTX contact
  - Update present disruption database – emphasis on halo current data
  - Some variables: $I_p(t)$, $I_{halo}(t)$, $TPF_{1,2}$ at Ihalo-max, $TPF_{1,2}(t)$ optional, Z_current_centroid(t), q(t), (TPF_1 = max/avg, TPF_2 = <n=1>/n=0)
    - would like 100+ datapoints
    - include low A/high q data (ITER scaling, future STs)
  - target date – approximately 6 months (tight timescale)
  - J. Wesley will send the variable list to interested ITPA members, along with a suggested timeline
- MDC-16: Runaway electron generation, confinement, and loss
  - No runaways in NSTX at present - would need to use (risk) run time to develop an operating regime with runaways

New “Joint Experiments” - Individual Discussion (2)

- MDC-17: Physics-based disruption avoidance
  - S. Gerhardt named as NSTX contact
  - Based on recent ECH results from FTU and ASDEX-Upgrade; goals have been broadened
  - Goals
    - Quantify the requirements for postponement of disruptions with ECRH
    - Explore other means of disruption avoidance, such as feedback stabilization or forced rotation of disruption precursors with non-axisymmetric coils
    - Investigate the combination of mode stabilization and fast current ramp-down
  - NSTX could contribute to the 2nd or 3rd stated goal

New “Joint Experiments” - Individual Discussion (3)

- MHD risks associated with the Test Blanket Modules (TBM)
  - TBMs will be installed for Day 1 operation of ITER
    - Considered the raison d’etre for ITER by TBM engineers
    - Considered critical that TBMs be constructed from ferromagnetic metal
    - MHD risks associated with significant error field magnitude; spectrum
  - Decision post-ITPA meeting not to declare this a new JEX (yet)
  - Input to this research task could come from
    - Basic: connect to more general error field related research
    - Moderate: specific experiments using non-axisymmetric coil set
    - Detailed: simulate TBM on NSTX with a hunk of iron
      - Suggested by R. LaHaye for DIII-D research
  - Significant task to address at “detailed” level
    - Modeling of field in non-saturated material; simulating TBM field spectrum

Which ITER/ITPA High-priority Topics Should Macro Focus On?

- Disruption characteristics, mitigation
  - Halo currents, peaking; power deposition, vessel forces, runaways (possible?)
    - Understand effect of disruptions(+ ELMS?) on divertor/first wall ('09 XP by SPG)
    - ??Interest in joint disruption modeling effort (NIMROD/M3D, halo currents; EU has program)
  - ??Future: possible use of CT injection for mitigation (Raman, et al.)
- Disruption avoidance: plasma and mode control
  - Plasma control requirements (vertical stability, shape, position) – joint w/ ISO?
    - Magnetic Diagnostics for ITER (SPG mentioned interest by JEM)
  - NTM mitigation, avoidance of mode locking, role of error fields
  - RWM active control – focus on low V_ϕ?; increased $<\beta_N>_{pulse}$ and control reliability
  - Resonant field amplification, multi-mode EF reduction, IPEC vs. vacuum
  - ??ELM control (NTM/RWM seeding?, effect on V_ϕ, joint w/ boundary group)
  - Rotation damping; control
    - Effects of 3-D fields/modes (NTV vs. δB, collisionality; INTV; resonant damping, etc.)
- Mode physics and stabilization
  - NTM stability physics vs. A, marginal island width, ρ^* effects, V_ϕ, V_ϕ shear
  - RWM stabilization physics – V_ϕ, collisionality, q; focus on low V_ϕ?