Measurement and theory advances needed to achieve long range ST goals

J.E. Menard, PPPL

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Please attempt to assess MHD needs in the context of the IPPA goals:

- IPPA - ST 5 year goal: Make a preliminary assessment of the attractiveness of the ST regarding confinement, ***stability, and high beta operations***, and non-inductive operations (to be achieved early in the 2004 - 2008 time frame)
- IPPA – ST 10 year goal: Assess the attractiveness of extrapolable, ***long-pulse operation*** of the spherical torus for time scales much greater than the current penetration time scales (to be achieved in the 2009 timeframe)
- IPPA Science Goal 1: Advance the fundamental understanding of plasmas... and enhance predictive capabilities through comparison of experiments, theory, and simulation

Caveats

- The following list is not complete, and is merely a starting point for discussion
- Please add to this list as needed and make suggestions for improvement

Measurement Needs

- Mode identification:
  - Islands - tearing modes, double TM, NTM
    - Toroidal mode numbers, poloidal mode numbers
    - Internal structure, emission profile, tangential images
    - Local temperature and density perturbations
      - Can EBW substitute for ECH for internal T_e measurement?
  - Resistive wall modes, kink modes
    - What diagnostics are needed to distinguish between kink and tearing signatures, or convincingly prove absence of tearing?
    - Sound wave and/or viscous damping and RWM stabilization physics
      - What are the fluctuation signatures? Can we measure them?
  - Locked modes/error fields
    - Sensors closer to plasma, higher-n needed (some planned)
  - How exactly to we assess the need for active MHD control tools and systems – either for RWM or NTM?

Measurement Needs

- Internal profile diagnostics:
  - Kinetic density and temperature
    - Required for kinetic reconstructions, non-ideal physics
  - Rotation – toroidal, poloidal, edge
    - Direct effect on force-balance and equilibrium
    - Needed to assess rotational shear stabilization?
  - B_P and E_r
    - Required for accurate q profile
    - Er for consistency check of force balance
  - Fast ion pressure profile
    - Required to complete kinetic pressure, drive terms for MHD
    - Assess role of MHD in transporting fast ions

Analysis Needs/Goals

- EFIT:
  - Incorporate as much kinetic data into EFIT as possible.
- Stability analysis
  - Comparison of EFITs to TRANSP
    - Are profiles reasonable?
    - Consistent with classical beam slowing down?
    - Required for kinetic reconstructions, non-ideal physics
  - Goal should be rapid comparison of mode structure signatures to theory – move beyond stability thresholds
  - Execute TM/NTM analysis between shots, or at least more frequently
    - What are codes available to do this?
    - Does theory need further development for ST geometry?

Analysis Needs/Goals

- Non-linear/resistive MHD physics:
  - Understand role of rotation, rotational shear, and conducting structure on RWM and TM stability, structure, and non-linear saturation
    - RWM - Compare growth rates & structure to experiment
      - Is the linear, nearly-ideal treatment of RWM physics a decent approximation to a more realistic non-linear treatment – can we figure this out in the next 5 years?
      - **Will NIMROD or M3D be able to do RWM physics?**
    - TM/NTM – Is standard treatment o.k. for low-A, high β?
  - Error field penetration, amplification, and operational impact may be altered by low-A, high β
    - How does rotation modify EF & locked-mode physics?

Analysis Needs/Goals

- Fast particle MHD:
  - Fishbone, TAE, CAE, EPM
  - Predictions of mode frequency, toroidal and poloidal mode numbers, radial structure
    - Understand drive physics, thresholds, growth rates, impact on fast ion distribution
  - How do these instabilities impact performance?
    - Unwanted fast ion loss?
    - Broadening of fast ion pressure profile?
    - Anomalous ion heating?

Summary

- Machine performance presently outpacing diagnostic (and hence modeling) capabilities
  - This will improve significantly over next 5 years
  - But, will we understand significantly more in 5 years?
- Multiple MHD diagnostic, modeling, and theory advances are needed:
  - To fully utilize NSTX and meet its design objectives
  - To meet the IPPA goals
  - To support a possible NSTX CS upgrade (or other?)