NSTX

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Discussion of ASC Milestones in 2011 and 2010

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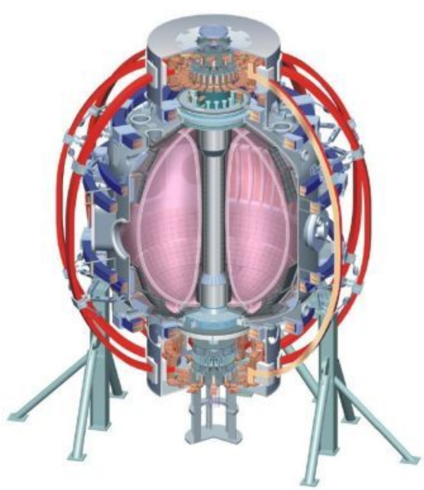
SPG leading the discussion
Thanks to M. Bell for contributions

B318, Wednesday the 24th of 2010



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Agenda

- Review R(11-2)
- Discussion of Potential New Milestones for FY-11
  - High-A and κ proposal
  - Improved ramp-up proposal
- Discussion of FY-12 Milestones Related to ASC
  - Advanced Divertors
  - Rotation Physics and Control.

Not here for word-smithing!

FY-11

R(11-2): Assess the dependence of integrated plasma performance on collisionality.

The high performance scenarios assumed for next-step ST devices such as NHTX and ST-CTF are based on operating at lower Greenwald density fraction and significantly lower pedestal collisionality than NSTX. Building on the research of the FY2010 boundary physics milestone R (10-3), Milestone R(11-2) would extend research on high- performance plasmas toward lower density and collisionality and systematically assess integrated performance (such as non-inductive current fraction, confinement, core and pedestal stability, pulse-duration, impurity content) of long-pulse H-modes. *Two possible tools for accessing reduced plasma collisionality are the Liquid Lithium Divertor (LLD) and the upgraded HHFW system capable of higher power and with resilience to ELMs*. Based on a successful demonstration of particle pumping in FY2010, the LLD would be utilized to vary plasma density and temperature by varying its pumping through control of parameters such as the strike-point position, flux expansion, the temperature, and thickness of the lithium layer. Further, the plasma integrated performance would be assessed as a function of boundary shape, in particular the strike point location and triangularity, to assess the possible trade-off between improved MHD stability (higher triangularity) and increased pumping efficiency (lower triangularity). Building upon recent successful electron heating by HHFW in low neutral beam power H-modes, the upgraded HHFW system will be used to heat electrons in order to decrease the collisionality and to increase non-inductive currents in high-power, long-pulse H-mode scenarios. The influence of these advanced pumping and heating capabilities on NSTX high-performance plasmas will be compared to time-dependent simulation codes such as TSC and TRANSP to develop a predictive capability for advanced ST operating scenarios.

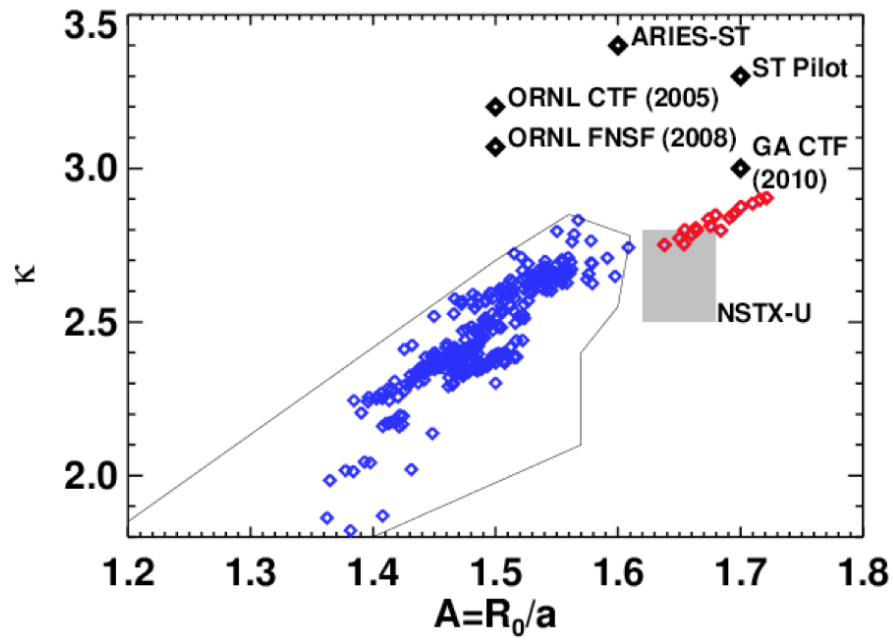
Two Alternative Milestones Have Been Discussed

- Not clear how to meet this milestone.
  - Neither tool for reducing collisionality worked properly in last run.
  - No certainty they will work next run.
- SPG recommendation:
  - Defer this milestone to FY-12, pending results in FY-11
  - Consider new milestones.

1: Scenario physics at high aspect ratio and very high elongation.

2: Redevelopment of the plasma startup for reduced density and lower collisionality.

- Notes:
  - There are likely combinations of the two.
  - They would likely be "joint" with MS TSG.
  - MS TSG discussion Tuesday was very positive toward the former



These are both worthwhile…we should do both.

Proposed Milestone For High Aspect Ratio/NSTX-U Support (I)

- Designs for next-step STs typically call for very high elongation (3<kappa<3.5), often at aspect ratios exceeding A=1.65. These parameters are beyond those which optimize performance in NSTX, where, due to considerations such as the vacuum chamber shape and coil design, the optimal parameters for high-beta, long-pulse discharges are closer to $2.4<\kappa<2.8$ and A=1.45. While the difference in these parameters may seem modest, these changes can triple the n=0 mode growth rate, while dropping the n=1 no-wall β_N limit by an entire unit. In this milestone, we will systematically study the modifications to plasma integrated performance as previously developed high-performance targets are modified to this next step regime. The maximum sustainable β_N will be determined vs. aspect ratio and (high) elongation, and compared to ideal stability theory; RWM stability will be assessed both experimentally and theoretically, and the viability of previously developed control techniques will be assessed. The vertical stability margin will be determined, and any necessary improvements to the controller implemented. The transport will be compared to expectations from lower aspect ratio and elongation plasmas, and simulated with gyrokinetic codes. These transport dynamics, including H-mode pedestal transport and it's impact on ELM stability, will be used to understand the non-inductive current sources. The results will be compared to free-boundary integrated modeling codes such as TSC and recently upgraded TRANSP. Overall, these results will help guide both design studies for next-step STs and determine many of the integrated performance issues these devices will face.

Proposed Milestone For High Aspect Ratio/NSTX-U Support (II)

- These scenario are not “optimal” for NSTX.
  - But need to be studied for next-step STs.
- Equilibrium control can be challenging with small top/bottom gaps.
  - Use of PF-2 through 5 as “pushing” coils for boundary control.
- Higher aspect ratio will deleteriously impact n=0 stability.
  - Improved controller, additional sensors, better models.
- Higher aspect ratio will deleteriously impact n=1 stability.
  - Experimental β_N limit vs. A & κ, comparison to ideal theory.
  - utility/adaptation of the LQG RWM controller.
- High aspect ratio and elongation may change the transport.
  - Modeling of ETG/MT growth rates vs. A and κ.
  - Experimental observation of confinement changes vs. these variables.
- Pedestal stability:
  - Contribute to the JRT.
- Divertor physics
  - Low-X-points lead to natural high flux expansion…connection to R(12-2)?

Milestone Idea For Improved Ramp-Up

- NSTX has established an inductive startup prescription from which it rarely deviates
- We ramp the current rapidly, V_{loop}=2-3 V, almost always with lots of pre-heating.
- Very high gas flow rates are used to cool the plasma edge so as not to produce very unstable current profiles.
  - Not "low-density locked modes"…they occur well after the start of flat top, in H-mode.
  - May be related to i) pressure peaking, ii) low-li, iii) tearing & locking,…
- This minimizes time spent in the ramp-up, allowing the longest flat-top, *but ….*
- *The large quantity of gas injected (typically 4 - 6 times what ends up in the plasma) produces a plasma density higher than we want and depletes edge pumping provided by lithium*
  - *CHI experiments have shown that we can achieve reliable inductive ramp-up at lower density with reduced loop voltage and still obtain H-mode…(also at low-l_i).*
- We should/could investigate changing our startup prescription to produce the flat-top conditions we want (l_i, n_e, β_N) reliably and with less gas fueling to optimize conditions for NICD and continued pumping by lithium
- Need to assess whether there are benefits or adverse impacts on achievable f_{NI}, stability, confinement and flat-top duration

Tools For This Study…and some Comments.

- Vary the fuelling (with SGI), pre-heating, I_P ramp-rate, diverting time.
  - How do these variables map to the flat-top collisionality and f_{NI}?
  - How much flat-top do we sacrifice (may not matter as much for NSTX-U…)?
  - Pedestal/ELM dynamics during flat-top…any change in the impurity accumulation?
- Role of Li in this process?
  - Move S.P. onto/off of LLD to modify pumping? What LITER rate?
- Realtime density feedback should be made very high priority if we are serious.
  - rt-SGI?
- Role of CHI?
  - Can provide an interesting comparison.
  - I^2t limit of OH coil prohibits routine use unless:
    - CHI current can be made much higher.
    - CHI will work with pre-charged OH.

    } ***Not ASC***
- Carbon accumulation will likely result in ramping n_e.
  - The proposed research solves "half" the n_e problem…but is still clearly worth doing.
- "Analysis" will be difficult…mainly an operational task.
  - Highly transient phase…G.-S. reconstructions are challenging.
  - Diagnostic data is often incomplete.
  - Tearing stability is essentially incalculatable.

FY-12

R(12-1) Assess very high flux expansion divertor operation (I)

The exploration of high flux expansion divertors for mitigation of high power exhaust is important for proposed ST and AT-based fusion nuclear science facilities and for Demo. In this milestone, *the controllability and plasma response* to advanced divertor concepts including the "snowflake" and "x-divertor" configuration will be assessed. Divertor heat flux handling, pumping with the liquid lithium divertor, impurity production, SOL turbulence and their trends with engineering parameters will be studied. Edge pedestal stability, ELM characterization, core transport and confinement, as well as edge transport and turbulence will also be studied. Measurements will be compared to analytic and numerical code predictions. This research will provide a significant impact on the present PMI concept development for both the ST and tokamak.

R(12-1) Assess very high flux expansion divertor operation (II)

- Divertor physics is not ASC task.
- Control and global stability may be…
  - n=0, high-m “instability” in the snowflake configuration.
    - Hopping between “+” and “-” configuration.
  - For high-κ & A (and l_i) , the snowflake divertor may deleteriously impact the m=1, n=0 (vertical) stability.
  - Reduction in average triangularity may impact n=1 stability, especially at higher-A.
- Do we want to commit to snowflake “control”?
  - May be difficult given that the PCS programmers are new, and there is (essentially) no gap between 2011 & 2012 runs.
- Can this be connected to (proposed) high-A work in 2011?

Research Milestone R(12-4): Investigate magnetic braking physics and develop toroidal rotation control at low collisionality (I)

- Plasma rotation and its shear affect plasma transport, stability and achievable bootstrap current, all needed for advanced operation scenarios, through the plasma poloidal beta and local profile shapes. In order to explore the role of rotation in transport and stability, **the physics governing the plasma rotation profile will be assessed over a wide range of collisionality and rotation by exploiting the tools of NBI momentum input and resonant and non-resonant braking from externally applied 3D fields. The plasma collisionality will be varied using density control with the Liquid Lithium Divertor and electron heating by High Harmonic Fast Waves.** Key aspects of this study include the behavior of the Neoclassical Toroidal Viscosity at low collisionality and rotation, and the detailed modeling of the plasma response to applied non-axisymmetric fields, including self-shielding. **To accomplish this milestone, real-time rotation measurements will be developed in FY2011. The effectiveness of various inputs in achieving controllability of the rotation profile will be assessed in order to develop and implement optimized real-time rotation control algorithms in FY2012.** In support of these goals, the IPEC code will be further developed to examine the impact of 3D fields on the plasma, and the more general theory will be converted to simpler models for the real-time rotation control. MISK code analysis will be used to determine rotation profiles that are optimized for plasma stability, and these profiles in turn will be used as targets for the rotation control system. This research will provide the required understanding of rotation control and plasma stability critical for NSTX-U, ITER and future burning STs.

Research Milestone R(12-4): Investigate magnetic braking physics and develop toroidal rotation control at low collisionality (II)

- IPEC/MISK modeling can & should be done.
- "System-ID" experiments for NTV and NB torque can be done, in preparation for control.
- Need to revisit the collisionality verbiage (another time).
- Progress in rt-V_{phi} has been slow.
  - Hardware engineers busy with 2^{nd} SPA.
  - Software engineers are both brand new…also working on 2^{nd} SPA.
  - Implementation of rt-V_{phi} in 2011 (or even 2012) run appears to be in serious risk.
  - Control must follow the measurement…appears more and more unlikely.
  - Resource conflict with divertor control task?
- Possible recommendation: Further de-emphasize the control tasks, more emphasis on plasma torque models and optimal rotation profiles. Should involve T&T (W. Solomon) more?