# Issues Regarding Confinement and Transport Studies on NSTX

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## I. Introduction

The National Spherical Torus Experiment (NSTX) presents many unique scientific challenges from the point of view of confinement studies and understanding of local transport. This report represents an effort to outline key physics issues pertaining to global confinement, local transport, and fluctuations that should be addressed by the NSTX research program in the first two to three years of operation. The issues were discussed at the NSTX Research Forum, held on February 5 - 7, 1997, at the Princeton Plasma Physics Laboratory. As a result of these discussions, recommendations have come forth with respect to a research program outline and identification of work needed in the near term with respect to diagnostic development and theoretical modeling. The last item is not a purely academic exercise: many of these modeling efforts are needed to help experimentalists make judgments for diagnostic systems based on a consistent set of underlying assumptions.

This report is organized as follows. First, an outline of the major physics themes pertaining to confinement is given. Second, issues pertaining to diagnostics are outlined, both with respect to the schedule of bringing these items on-line, and with respect to technical issues that must be addressed aggressively in order to meet the physics goals. Third, theory-related issues are highlighted, most of which bear either on diagnostic development in the near term or on influencing early experimental programmatic choices.

## II. Physics themes

It is recommended that the near-term (2 - 3 year) confinement studies program on NSTX first focus on issues for which aspect ratio plays a particularly strong role in the underlying physics. Highest priority is given to those topics for which this characteristic might be used to illuminate underlying commonalities with normal aspect ratio tokamaks.

A. *Contribute to the confinement scaling database.* This issue will likely be performed in the early days of operation of NSTX, when diagnostics are just coming on-line. Global confinement scaling with average electron density $\langle n_e \rangle$, plasma current, RF heating power, and aspect ratio would be explored.

Even consideration of these early studies highlights the importance of early diagnostic coverage. Sensible contributions to even the global database requires knowledge of the confinement regime that has been accessed. This points to the need for edge diagnostics to look for signatures of an H mode transition ($H_\alpha$ detectors, for example), and edge density measurements that might be made by a Thomson scattering diagnostic to detect H mode edge pedestals.

Further efforts in confinement scaling studies should quickly move from the global to the local, including characterization of thermal, momentum, and particle transport coefficients from power and particle balance considerations. Such a campaign will demand more extensive profile coverage than the "Day 1" diagnostic set lists. This issue is highlighted by the simplest consideration of the desired programmatic elements, and is revisited in the discussion of the individual measurements that are needed (Section III).

B. *Aspect ratio scaling*. Results from past scaling studies suggest a dependence of confinement on toroidicity (strong dependence on major radius, weaker dependence on minor radius [Grisham *et al.*, Phys Rev. Lett. 67 (1991) 66]) that serves as part of the motivation to perform confinement studies that focus on variations in aspect ratio. A second motivation is born from the work of Rewoldt *et al.* [Phys. Plasmas 3 (1996) 1667], where it has been suggested that partial or complete stabilization of certain microinstabilities might be expected for $A < 1.5$. Results from such a study will serve to illuminate issues basic to the viability of an ST as a reactor concept. Again, global studies can be performed initially, but rapidly the scientific need for profile diagnostics, including core fluctuation measurements, will become urgent.

The most relevant aspect ratio studies will be those in which other parameters important to core confinement are kept constant. Pertaining to this, we note that for scans in which neutral beam heating is applied, there is an apparent difficulty in keeping the ratio of the heating profile width to the plasma height constant as A is varied. This is a fundamental limitation owing to the height of the TFTR heating beams. The possibility of introducing an insertable mask at the grids of the neutral beam ion source might be investigated as a means of altering this height, and keeping the heating profile self-similar during such a scan.  Of course, RF-only aspect ratio scans could be performed, and with sufficiently narrow deposition profiles would not be compromised by an analogous issue.

C. *Dimensionless scaling.*  NSTX can make significant contributions to this topic as a result of the large values of $\rho^*$ that will be present. Such studies will put conclusions reached in dimensionless scaling studies to an extreme test.

Two emphases are suggested. First, the dimensionless scaling studies should be designed to make contact with the results obtained on tokamaks with more typical aspect ratio. It should be determined whether it is possible to obtain matches in dimensionless parameters expected on NSTX on other devices. The possibility of enlisting the support of other tokamak devices, such as DIII-D, should be explored. This support might come in the form of experiments in which the expected dimensionless parameters of NSTX are matched as closely as possible. Second, connection should be made with other small aspect ratio devices. It is noted that the Pegasus device (University of Wisconsin) will connect with the available aspect ratios for NSTX (1.25 ~ 2) from the *lower* end, making a comparison of confinement scaling results (in any sense, not just dimensionless scaling) from that device to NSTX important.

A concern for these studies is the difficulty of keeping the Mach number constant while varying $\rho^*$. With unidirectional injection, the role of and the dominant terms in the E∞B flow shear may change as heating power is varied. This issue and others related to other transport studies underscores the desirability of adding flexibility with respect to rotation by adding counter neutral beam injection, as is discussed below. In addition, keeping the heating profile width to plasma height constant in such a scan would be of value, as pointed out above.

D. *H mode transitions: L-H mode transitions and the edge pedestal width*. Predictions of the performance of small aspect ratio devices include the possibility that the power threshold for H modes will be quite low on NSTX. The wide ranging possibilities regarding this phenomena include the prospect that transitions to enhanced confinement might not be observed at all, and that the normal state of operation might always be one of strong suppression of edge turbulence without the onset of an edge barrier. The speculations regarding this issue are wide-ranging. NSTX power threshold studies will complement those performed on Alcator C-MOD, as both devices have small major radius compared to most of the contributors to this issue, but have B fields that differ by as much as two orders of magnitude at the edge.

In addition, the ST may shed light on edge pedestal width issues. This is an issue of great interest both from the fundamental physics point of view, i.e. what are the physical mechanisms responsible for it, and from the practical scaling point of view, i.e. how will the pedestal scale to an ITER size machine and will that make H-modes easy or difficult to obtain? NSTX can serve a valuable role in potentially elucidating the relevant physics for the following reasons. Among the possible factors controlling the pedestal width are $\rho_i$, the density gradient scale length, the intrinsic mode widths and packing of low order rational surfaces. NSTX is in a very new regime because of the high edge q, and therefore has dense packing of the rational surfaces at the edge. In addition, the low field strength and resultant large $\rho_i$ yields the possibility that the instability dynamics may lead to different mode widths. The flexibility built into NSTX should allow the investigation of some of the parametric dependencies and hopefully can elucidate what the dominant parameters are.

E. *Core transport barrier studies.* It has been suggested that small aspect ratio devices might easily promote the onset of reduced transport by the formation of core transport barriers [Stambaugh, IAEA 1996, Montreal; T.S. Hahm, synopsis contribution to the Forum] Contributing factors include the expected reduction in growth rates at low A, and the large pressure gradients permitted by the high beta limits that are expected in ST's.

We note that this issue might be complicated by the unidirectional injection, in the direction parallel to the plasma current, that is planned for NSTX. Application of a toroidal flow in this direction naturally opposes the pressure gradient in establishing large values of the radial electric field and its shear. In fact, on TFTR, pressure-gradient-driven transport barriers in Enhanced Reverse Shear plasmas collapse when unidirectional co-injection is applied. While transport barriers are known to be present in NCS plasmas on DIII-D, they are sustained in spite of the steep pressure gradients. Rotational shear overwhelms the opposing  p contribution. With this in mind, the flexibility obtained with balanced injection capability (simultaneous co- and counter-injection) would significantly enhance the flexibility of core transport barrier studies on the NSTX device. In addition, pellet injection should be examined as a potential tool for accessing enhanced confinement regimes. Its value in this regard has been illustrated on many devices.

F. *Perturbative transport, and comparison to steady-state properties*. One of the most powerful means of revealing the underlying dependencies of particle and thermal fluxes is through the application of perturbations, and the comparison of perturbed fluxes to those inferred from steady-state particle and power balance techniques. Such perturbations include working gas and impurity gas puffing, pellet injection, neutral beam blips, and the application modulated or pulsed RF. Such studies are particularly relevant to NSTX, as a result of the unknown scaling of fluctuation behavior to small A, and the predictions that instabilities dominant in normal aspect ratio devices such as TFTR ought to be stabilized at the smallest A values. As such, the response of fluxes to perturbations ought to illuminate any fundamental changes between normal and small A. These perturbation studies should be part of any of the aspect ratio and dimensionless scaling programs on NSTX.

The relation between particle and energy transport should also be a focus of both perturbative and steady-state transport analysis. In particular, the viability of any reactor concept hinges in part on the relationship between impurity (helium) transport and thermal flows. Helium transport studies, performed with spectroscopy with gas puffing and neutral beam injection, can be used to assess this important issue.

G. *Local transport and correlation with fluctuations*. A challenge for the NSTX program is to ascertain a means for characterizing core fluctuations. Some diagnostic issues are pointed out in Section III. The importance to the underlying physics understanding of ST confinement cannot be overstated, especially in light of the predictions of microinstability suppression at low A. We also point out that, due to the low B field, the prospect of instabilities in the Alfven range of frequencies is strong, and that possible coupling of these instabilities with ion acoustic waves might make for a fascinating merger of what are normally treated as separate issues, i.e. MHD-type instabilities and microinstabilities. Whatever the chosen diagnostic or diagnostics, a first choice should be to optimize the system for the search for long wavelength instabilities, owing to the expectation that $0.1 < k_{\perp}\rho_i < 1$.

## III. Diagnostic Implementation and Considerations

A significant concern of the Working Group pertained to the planned implementation of profile diagnostics. As such, two strong conclusions were reached:

1. Urgent consideration should be given to making multipoint, multipulse Thomson scattering a Day 1 diagnostic.
2. The implementation of neutral beam-based diagnostics should not be delayed.

It is recognized that measurements of some quantities, such as the current profile, requires careful consideration and development.

With the refocused emphasis of the fusion effort as a science-based plasma physics program, and with the opportunity to use the spherical torus concept as a test bed for obtaining leverage with respect to many fundamentally important physics issues, it is strongly felt that developing the means of measuring local thermodynamic quantities early in the NSTX program should be made a high priority. Given the vigor and increasing sophistication of the dialogue between experiment and theory, and the possibly profound physics issues that may be illuminated by examination of the ST concept, a physics-based national program of ST research cannot survive long without both temporal and radial documentation of quantities such as electron and ion temperature, flow velocities, and magnetic field.

Issues pertaining to the measurement of various quantities, and possible diagnostic development issues and recommended tasks, are highlighted below.

A. *Electron temperature measurements*. Time-dependent measurements of electron temperature are of high value on both TFTR and DIII-D. Thomson scattering is the only electron temperature diagnostic which is guaranteed to work for NSTX. The value of multiple time point radial coverage with Thomson scattering systems has been demonstrated in the community on the DIII-D device. The alternative of a single time-point system is deemed unacceptable when considering the exploratory nature of early plasma operation on any device, and the potential importance of performing studies of time dependent and non-linear behavior on NSTX. In addition, the diagnostic cost of implementing of a multiple time point system has to be weighed against the cost of compiling time histories from multiple shots, and the possible physics studies that might be compromised if the program is forced to rely on a single time point system.

Such systems have proven their worth not only in terms of temperature measurements, but density measurements as well. This may be particularly important in assessing the behavior of the edge region in H mode plasmas. The value of configuring multipoint systems in "burst" modes in order to characterize plasma density and temperature behavior on fast time scales will also be of value in the study of nonlinear plasma phenomena.

It is also proposed that the technique of using the Electron Bernstein Wave emission for electron temperature and electron temperature fluctuation measurements be explored. This promising technique must be examined from the point of view of wave propagation physics and launch. A possible test bed for this technique might be the CDX-U device at PPPL.

Use of soft x-ray measurements to get the central electron temperature and a measure of the profile shape through filtered soft x-ray arrays is also suggested. The arrays may also be useful for MHD instability identification, as well as a measure of the equilibrium flux surface shape as demonstrated on PBX-M [[E.T. Powell, R. Kaita, and R.J. Fonck, Rev. Sci. Instrum. 61 (1990) 3301]

Recommendations for near term action:

1. pursue the allocation of resources for a multiple time point Thomson scattering system
2. encourage the examination of an Electron Bernstein Wave based diagnostic, including proof-of-principle demonstration on a low field device such as CDX-U.

B. *Ion temperature and ion rotation measurements*. Assessing local transport on any auxiliary heated plasma device requires separation of the roles of the ion and electron channels. Charge exchange recombination spectroscopy (CHERS) has proven to be invaluable throughout the community as a means for measuring ion temperature, impurity ion density profiles and fluxes, and plasma rotation. In addition, CHERS measurements provide many of the elements required to measure the radial electric field through solution of the force balance equation for the observed impurity. This will be of central importance to NSTX in the study of transport barrier formation and sustainment. Both of these issues underscore the desirability of having the TFTR heating beam installed as quickly as possible. New high throughput transmission grating spectrometers may be considered for this measurement system.

As a result of relatively cool edge temperatures and the proximity of the sight line paths to impurity sources, it is quite likely that edge emission of hydrogen-like impurities will compete with charge exchange emission from the neutral beam volume. Given the relatively good diagnostic access on NSTX, it is urged that a viewing location be allocated to CHERS to install a fiber optic array that has a similar orientation as that viewing the neutral beam, but does not view the neutral beam directly. This will enable a direct measure of background light, a problem that plagues CHERS measurements on every toroidal device where they are attempted. Access to a vertical view of the heating beam also is not available as the vacuum vessel is presently envisioned. It is strongly recommended that modifications be made soon to allow for future flexibility, even if it is decided that the installation of vertically view optics should be delayed.

Although data interpretation is more complicated for a vertical view than a horizontal view, installation of such a view early is highly desired. Poloidal rotation ($V_\theta$) represents a critical component of the impurity force balance equation, and its measurement will be a key element of E∞B flow shear studies in both the edge and the core.

Note also that there is concern over the interaction of fast ions injected by neutral beams and RF applications on NSTX. This concern underscores the potential value of an X-ray crystal spectrometer to measure ion temperature in the event that neutral beam heating is not desired for a particular experiment (or before the beam is available) , such as one employing RF heating.

Recommendations for near term action:

1. Identify viewing locations for background light measurements
2. Plan for modification of the vacuum vessel hardware to anticipate the installation of vertical CHERS views for $V_\theta$ measurements.

C. *Electron density measurements*. While a multiple time point Thomson scattering system might be used, interferometry must seriously be considered for this needed measurement due to its superior time response. The existing TFTR MIRI system is a candidate for this measurement. However, it is pointed out that while vertically oriented chordal measurements provide the possibility of being combined with Faraday rotation measurements of the current density, their inversion requires knowledge of the flux surface geometry. The inversions of interferometry data might be aided by constraints on the flux surfaces provided by x-ray imaging (Powell *et al.*; see section D below).

This difficulty can be avoided by making measurements on the horizontal midplane, for which the assumption of toroidal symmetry is particularly useful. This approach also allows determination of the toroidal magnetic field profile through a simultaneous Faraday rotation measurement. The roles of paramagnetic and diamagnetic effects in a high beta device like NSTX are exaggerated compared to higher aspect ratio tokamaks, and measurement of $B_T$ may supplement or surpass the finite beta corrections made possible by kinetic profile measurements. Of course, measurements of the current profile are not possible with this geometry.

Development of the Imaging Second Harmonic Interferometer (ISHI) system on Alcator C-Mod should be followed closely, and possible application to NSTX should be considered. The potential for spatial resolution of ~2 mm at the edge is attractive, as is the system's inherent immunity to vibration. Due to the short wavelengths used, however, it is not well suited for the dual purpose of Faraday rotation measurements. Reflectometry can also provide edge profile data at a variety of poloidal locations. On DIII-D spatially resolved edge profiles have been obtained with subcentimeter spatial resolution and temporal resolution of 100μs.

Recommendations for near-term action:

1. Study the uncertainties of a measurement of the toroidal field through midplane interferometry. Assess whether these uncertainties lead to a measurement of the toroidal field that will be more accurate than can be obtained through measured kinetic profiles and calculations of fast ion populations. This work is related to that recommended for the poloidal field measurements, discussed below.

D. *Poloidal magnetic field measurements.* Owing to the low toroidal field on NSTX, the applicability of standard techniques for measuring $B_\theta$ and the q profile is highly questionable. In fact, NSTX may be a device for which a combination of core $B_\theta$ profile measurement techniques and magnetics must be used in order to constrain the plasma equilibrium. Regarding the Motional Stark Effect technique, separation of $\sigma$ and $\pi$ components of $D_\alpha$ emission will be greatly reduced as compared to higher field devices. At best, long integration times (~ 100 ms) might be needed. At worst, usable accuracy will not be obtainable. It has been suggested that this problem may be improved by the use of laser-induced fluorescence with the MSE diagnostic. Additionally, if ST plasmas are characterized by strong radial electric fields, it is of considerable concern as to whether the plasma's own electric field will dominate in at least some portions of the plasma over the electric field experienced by beam neutrals as they traverse the plasma's magnetic field. Regarding Faraday rotation, concern centers over the fact that its application requires two inversions, as well as knowledge of the plasma equilibrium profile shapes.

It is also suggested that measurement of the pitch angle of pellet ablation clouds be considered for q profile measurements in the core. However, the required pellet injection would of course destroy the plasma properties of interest. Finally, equilibrium reconstruction aided by measurements of flux surface geometry via pinhole camera images has been demonstrated on PBX-M [E.T. Powell, R. Kaita, and R.J. Fonck, Rev. Sci. Instrum. 61 (1990) 3301]. The viability of this technique should be assessed for NSTX plasmas.

Recommendations for near term action:

This items are interconnected and sufficiently complex that an open examination of these issues with an expert group may be warranted.

1. Examine the q profile accuracy required from the point of view of MHD stability studies. This exercise and item (1) should be directed at assessing if it is possible at all to obtain the desired accuracy in the plasma edge with MSE or Faraday rotation.
2. Continue examination of signal-to-noise of pitch angle measurements. Examine the accuracy required to obtain useful q profile measurements.
3. Examine the value of a direct $B_T$ measurement, discussed above. It may be valuable component in obtaining the q profile, in conjunction with angle measurement.
4. Assess whether suggested laser fluorescence techniques can be applied to MSE measurements. This includes a realistic estimate of the required laser power and duty cycle.
5. Consider the application of a heavy ion beam probe for the measurement of poloidal magnetic field.

E. *Core fluctuations*. Predictions of the suppression of turbulence as low aspect ratios are approached [Rewoldt, '96] underscores the strong desirability on scientific grounds of measuring characteristic core fluctuations on NSTX. In existing devices, dialogue with the theory community is becoming increasingly dependent on such measurements.

In the expected parameter range in NSTX electron cyclotron emission-based scattering techniques will not be possible. O-Mode reflectometry in the 20 - 60 GHz range may provide a means of making core measurements, as it is well suited to the small poloidal wave numbers expected. This technique's utility is limited to density profiles with some degree of peaking. Also, launch issues pertaining to the pitch angle of the magnetic field need to be assessed. In the event that flat density profiles are dominant on NSTX, collective FIR scattering can be performed, but little spatial and k resolution will be possible.

A potential difficulty of fluctuation measurements by Beam Emission Spectroscopy (BES) was identified in this workshop, namely, the presence of large poloidal pitch angles, especially near the plasma edge. On TFTR and DIII-D, advantage is taken of the fact that midplane sightlines view along a field line within the neutral beam volume, thus providing poloidal spatial resolution. On NSTX, such a midplane view would result in poor resolution, since the pitch angle of the field lines will be many tens of degrees. Core measurements with BES appear to be more tractable using midplane views.

Note that, although long wavelength modes are expected, the program should be prepared to examine the shorter wavelength regions as well. This issue may be of particular importance to the understanding of the anomalously high electron transport observed on larger aspect ratio devices even when the ion channel is suppressed. The essential point is that, while informed speculation about fluctuation properties exists, ST's represent such a radical departure from existing experiments that the program should be prepared for deviations from expectations, which will undoubtedly occur.

In the Working Group discussions, it became evident that more discussion is required to come to a recommendation regarding the best approach for core fluctuation measurements. Further discussion, with the possible inclusion of others experienced in fluctuation measurements in the plasma core, seems in order.

Recommendations for near term action:

1. Form a core fluctuation expert group to examine and recommend a core fluctuation diagnostic approach.
2. Examine the possibility of off-midplane views for BES measurements.

F. *Radial electric field measurements*. Turbulence suppression and E∞B shear flow are central to the issue of advanced tokamak operation. Direct $E_r$ measurements would be of high value to the NSTX program. Supplementing the determination of $E_r$ through solution of the impurity force balance equation may be more than a luxury, since the potential accuracy of needed $B_\theta$ measurements is in question. Also, the accuracy of $V_\theta$ by CHERS has yet to be assessed, and at present hinges on up-down symmetry of impurity emission that may well be violated at low aspect ratio. The viability of using the $D_\alpha$ emission from different energy components of the neutral beam should be assessed.

The implementation of a heavy ion beam probe should also be considered for this application.

Recommendations for near term action:

1. Using plausible $E_r$ magnitudes and expected line brightness, assess the diagnostic requirements for a direct measurement of $E_r$ using $D_\alpha$ emission.
2. Explore the possibility of using an existing HIBP for measurements of the local plasma potential.

G. *Edge transport diagnostics*. The topic of fluctuations and transport is of utmost importance at the plasma edge as well. As Langmuir probes are relatively inexpensive, and the edge of ST devices is unexplored territory, they should be implemented in such a way to permit poloidal coverage as well as midplane coverage. Reciprocating probes should also be considered. As mentioned above, reflectometry techniques should also be considered for edge electron density measurements. They also can provide poloidal coverage.

Multilayer mirror spectroscopy is also suggested as a possible means for obtaining edge temperatures and impurity information, and its potential for characterizing edge MHD activity has been demonstrated.

## IV. Need for a standardized set of NSTX profiles

Discussion of diagnostic and other programmatic issues would be greatly facilitated by the widespread use of standardized profiles.

Forward modeling with a self-consistent equilibrium, under some agreed-upon set of assumptions, should be performed to generated standardized profiles of electron density, electron and ion temperature, impurity concentration, q profile, and toroidal rotation profile. Three sets of conditions were identified as being potentially useful:

1. L mode
2. H mode
3. High performance (neoclassical ions)

Availability of profiles under these classes would serve to give the community a broad sense of the possible ranges of plasma operation on NSTX, and at least as importantly would give physicists a standardized set of profiles with which diagnostic system development can be guided. Profiles generated with reasonable assumption regarding momentum transport (e.g. $\chi_\phi = \chi_i$, as is often observed on TFTR, or $\chi_\phi = \chi_e$, as is often seen on DIII-D) would also be of practical value to those considering fluctuation diagnostics, for example, as it might help the user decide for which frequencies a fluctuation diagnostic should be optimized.

While some profiles do exist that have been optimized with respect the to beta limits and the plasma pressure, they are not widely available in general. Also, since the future performance of NSTX is such an unknown, the availability standardized profiles over a wide range of confinement possibilities is highly desirable.

## V. Needs from theory

Examination of a number of theory-related issues should be pursued in the near term.

A. *Kelvin-Helmholtz instabilities*. Due to the presently envisioned unbalanced beam injection, attention should be paid to the possible onset of Kelvin-Helmholtz instabilities for NSTX-like plasmas in gyrokinetic simulations. This can be examined as a matter of course in gyrokinetic studies of microinstabilities in general, but only if rotation is explicitly included in the assumed profiles. This again points to the need for a self-consistent estimate of a range of obtainable toroidal rotation velocities. The issue is potentially of concern for NSTX, owing to the stronger toroidicity of small aspect ratio plasmas.

B. *Neoclassical performance of NSTX plasmas.* A related issue was pointed out above, but the importance of understanding the implications of neoclassical transport for NSTX is emphasized here by pointing out that there may be issues for MHD stability if somehow neoclassical transport is realized. Is neoclassical transport, and the accompanying pressure gradients, consistent with the stability requirements of NSTX? What is the beta limit with the available power if neoclassical theory dominates?

Related to this issue is an assessment of the applicability of neoclassical theory to ST's in general. Does neoclassical theory exist in sufficient sophistication to cope with the large orbit sizes that will occur in ST's, especially in light of the possibly steep pressure and electric field gradients? Will the neoclassical transport really be small, given the large orbits

C. *Nonlinear neoclassical viscosity regimes.* Strong damping of poloidal flows is expected in NSTX, due to the large gradient in the toroidal magnetic field. However, due to large orbit and drift orbit widths and the expected high beta limit, significant orbit squeezing is expected. Do these effects lead to the possibility of approaching a nonlinear neoclassical viscosity regime in which the damping is overcome?

D. *Microinstability and nonlinear analysis of standardized profiles*. The standardized profiles discussed above should be checked with microinstability calculations and nonlinear simulations to determine whether they are reasonably self-consistent. Preliminary work in this area has begun [Rewoldt], but the profiles should be varied in a way consistent with the expected input power.