1. Purpose of Experiments

We were asked to combine two sets of experiments that shared a common diagnostic and overlapped significantly in discharge requirements. The goals are:

- Measure the response of the ion temperature pedestal width to changes in collisionality. Specifically, determine whether the decoupling of $T_i$ from $T_e$ at low collisionalities changes the $T_i$ pedestal width as compared to that for $T_e$.

- Measure the response of the boron velocity (both toroidal and poloidal) to changes in stored energy and magnetic topology. Determine the relationship of the velocity, and momentum, in the pedestal to that in the core and SOL.

2. Background

Pedestal Width Measurements

Characterization of the H-mode pedestal and its scaling is an active area of research due to the pedestal’s connection to global energy confinement and thus its importance to future fusion devices. Neo-classical predictions indicate that the width of the pedestal ought to scale as $\Delta \sim T_i^{1/2} / B_T$ [1], while ion orbit loss theories predict a scaling with $\rho$, $\Delta \sim \rho_{pol}^{1/2} / B_p \times T_i^{1/2} / I_p$ [2]. Experimental results from JT-60 demonstrate a $\Delta \sim 1/B_T$ scaling in both the $T_e$ and the $T_i$ pedestal widths, thus lending support to ion orbit loss theories, while the same
parameters on DIII-D showed no variation with either $B_T$ or $I_p$. [3] Results from DIII-D do demonstrate wider ion pedestal widths and steeper $T_i$ pedestal gradients than their corresponding electron counterparts. [4] Work done on ASDEX Upgrade showed no systematic variation of pedestal width with plasma current, though there seems to be a slight scaling with $B_T$. [3]

On Alcator C-Mod the Thomson scattering diagnostics were used to measure the $T_e$ and $n_e$ pedestal widths as a function of both toroidal field and plasma current. The field was varied between 3 and 8 Tesla and the current between 0.4 and 1.6 MA. The resultant pedestal widths were between 2mm and 6mm wide and showed little dependence upon operational parameters. [5, 6]

With the installation of the new edge toroidal CX systems on C-Mod we have the ability to make edge measurements of the boron temperature and density pedestal widths to complement the electron measurements. On C-Mod it is generally assumed that $T_e=T_i$, however, this is not necessarily the case for all areas of operation space. Therefore, to confirm the C-Mod pedestal width’s lack of response to toroidal field and plasma current, we’d like to measure the relative $T_e$ and $T_i$ pedestal widths as a function of collisionality. If the pedestals do in fact differ, than it would be interesting to revisit several points in the previously surveyed parameter space to observe the $T_i$ pedestal scaling and compare it various theoretical scalings.

**Velocity Measurements**

Previous research on core and SOL velocities has indicated that in the core the toroidal velocity scales with stored energy, but outside the separatrix the magnetic topology is the dominant factor controlling the velocity’s direction and magnitude. [7,8]. In light of these discoveries, momentum transport in the pedestal region has become an active area of study. Previous experiments on Alcator C-Mod using x-ray spectroscopy have found, for certain regimes, that the transport is anomalous. [9] Studying the toroidal and poloidal velocity in the pedestal along with the core (and, if possible, the SOL) measurements will provide a better understanding of how momentum is transported through the pedestal region. This MP will concentrate on steady-state profiles of velocity/momentum during ICRF heated plasmas. Other experiments are needed using Ohmically heated plasmas so that the probe measurements of the SOL flows can be properly compared. In addition, research is needed on time-dependent transport to extract momentum transport coefficients.

**3. Approach**

The above goals can be obtained using the same shots and the charge-exchange recombination spectroscopy (CXRS) diagnostics. On Alcator C-Mod we focus on the $B^{\perp+4}$ n=7-6 spectral line located at $\lambda=494.467$nm. This choice of line is due to boron being a dominant impurity in C-Mod, the line being in the
optical range and hydrogen-like. We will employ the DNB at the outer wall and the GPI at the inner wall to actively stimulate the charge-exchange reactions. Injecting neutrals allows us to localize the measurement to the intersection of the beam (or puff) and the viewing chord. Analysis of the spectra produced in this manner provides profiles of the boron velocities and temperatures, derived from Doppler shifting and broadening, respectively.

This experiment will vary RF power both during a shot and from shot to shot in order to cover a range of stored energies and collisionalities. We will explore these effects at two currents, $I_P = 0.6$ and 1.0 MA, trying, in both cases, to get H-modes at low densities. Besides providing various stored energies and a wider range of collisionalities, the two cases will be a preliminary two-point survey of the parameter space covered by prior TS pedestal experiments. We will also make contact with standard collisionality with $I_P = 1.0$ MA, $n_{l_04} = 1.2 \times 10^{20}$ m$^{-2}$.

Discharges will be primarily run in LSN forward field. However, we will attempt to achieve H-modes with USN forward field in order to study the role of topology on velocity flows independent of stored energy. RF power will be varied to provide control of the stored energy and collisionality, through the temperature. The boronization conditions will need to be good for the higher current discharges and to reach the highest stored energy, and thus probe the widest range of the velocity’s dependence on $W_{\text{TOT}}$. Other parameters such as elongation and triangularity should remain as constant as possible. Because the CXRS periscopes have fixed views at the edges, minimizing any changes in the size of the gaps is necessary. Two successful shots will be acquired for each configuration to provide better statistics.

The pedestal will be viewed via the poloidal CX periscope and the new edge toroidal periscope. The data will be collected using the new PhotonMax cameras. Data can be taken every 12 ms. The B V spectra will be analyzed for temperature and velocity. Profiles will be constructed using data collected along several chords that are tangent to various flux surfaces. Pedestal widths and heights will be determined from these profiles.

4. Resources

4.1 Machine and Plasma Parameters

Toroidal Field: 5.4T  
Plasma Current: 0.6 / 1.0 MA  
Working Gas Species: $D_2$  
Density: $n_{l_04} = 0.4 / 0.6 / 1.2 \times 10^{20}$ m$^{-2}$  
Equilibrium configuration (if possible, refer to database equilibria): 1050428003 can be used as reference case but with low density.
4.2 Auxiliary Systems

RF Power, pulse length, phasing: 1-4MW @ 80 MHz, tiered pulse 0.8-1.0s long heating
Pellet Injection (species): none
Impurity blow-off injection: none
Diagnostic Neutral Beam: Yes
Special gas puffing: Ninja 10psi D₂ for innerwall CXRS
Ar, Ne puffs for core impurity rotation
Non-axisymmetric Coils (Connections, Current): Standard locked mode compensation on A-coils
Other: n/a

4.3 Diagnostics

All CXRS (DNB/GPI), Edge and Core TS, ECE, scanning probes for SOL flows during L-mode, bolometry, Hirex family, NeSox

5. Experimental Plan

5.1 Run sequence Plan

This experiment requires one forward field run day. Adequate operation of RF is required. Recent boronization would be good as well. Between shot boronization may be required if plasma performance calls for it.

5.2 Shot sequence plan

Program RF to increase in power 0.4s after initially turning on. Pre-H-mode densities as specified below, but increase to higher densities if H-modes prove elusive.

B = 5.4T

1) LSN, Ip=1.0MA, nl₀₄=1.2*10²⁰ m⁻² RF power at ~ 1 MW and 2MW above H-mode threshold (2 shots)
2) LSN, Ip=1.0MA, nl₀₄=1.2*10²⁰ m⁻² RF power at ~ 2MW and 3MW above H-mode threshold (2 shots)
3) LSN, Ip=1.0MA, nl₀₄=0.8*10²⁰ m⁻², RF power at ~ 1 MW and 2MW above H-mode threshold (2 shots)
4) LSN, Ip=1.0MA, nl₀₄=0.8*10²⁰ m⁻², RF power at ~ 2MW and 3MW above H-mode threshold (2 shots)
5) LSN, Ip=0.6MA, nl₀₄=0.4*10²⁰ m⁻² RF power at ~ 1 MW and 2MW above H-mode threshold (2 shots)
6) LSN, Ip=0.6MA, nl₀₄=0.4*10²⁰ m⁻² RF power at ~ 2MW and 3MW above H-mode threshold (2 shots)
7) USN, Ip=1.0MA, nl₀₄ = 1.2*10²⁰ m⁻² RF power at ~ 1 MW and 2MW above H-mode threshold (2 shots)
8) USN, Ip=0.6MA, nl_04 = 0.4*10^{20} m^{-2} RF power at ~ 1 MW and 2MW above H-mode threshold (2 shots)

We will need the DNB to have an ‘on-time’ that will encompass the anticipated L-H transition. Also we will need it to have on/off periods before and after the transition to H-mode. Set DNB for 12ms on and 12ms off pulses, 6.5-7.0A. Should H-modes prove too difficult to obtain at low densities, we will consider alternate methods such as JFT-2M shaped plasmas or obtaining certain data during cryopump focused runs.

6. Anticipated Results

- Determine where ion temperature pedestal width decouples from the electron pedestal width. Determine if it broadens with power crossing the separatrix.
  - Further experiments may be proposed depending on results. Correlate with the Thomson scattering diagnostic

- Derive a scaling of the toroidal velocity in the pedestal with stored energy.
  - Explore the dependence of both toroidal and poloidal velocities on other factors such as magnetic topology and pressure gradient.
  - Correlate with other flow diagnostics such as Hirex, Jr. and the inner wall scanning probe.

7. References