1. Purpose of Experiments

The goal of this proposal is to measure the q-profile with MSE during current ramp with ICRH experiments, and to further study edge stability, and in particular, the Elmy H-mode regime obtained last year (MP. 324 A). In addition, we will use the PCI and MHD loops to characterize the fluctuation spectra (including ELMs and internal tearing modes) as the discharge evolves during the current ramp and beyond. We will look for tearing modes with the GPC ECE diagnostic as in 1996. We also want to see if the ELMy H-mode obtained last year with simultaneous central and off-axis ICRH will persist with central, or off-axis ICRH only, at comparable total power levels. We would also like to determine the threshold conditions for ELMy H-mode as a function of input power, in particular as a function of edge collisionality. These experiments would also provide further input into forming suitable AT target plasmas for LHCD next year.

2. Background

Last year we carried out a set of current ramp experiments using two ICRF frequencies that were available for simultaneous off-axis and on-axis heating. The goal was to see if we could produce ITBs without EDA, but with current ramp, and presumably non-monotonic q-profiles [1]. The plan was to vary the ratio of the off and on axis power until ITBs were formed, and then attempt to increase the central power, hopefully without collapse of the ITBs. However, instead of ITBs, we found ELMy H-modes, presumably due to the high edge electron temperatures ($T_{ped} = 1 \text{ keV}$), and possibly strong edge bootstrap currents. ITBs were not observed, presumably due to the low densities. In addition, with the
PCI diagnostic we observed rich phenomena of fluctuations as the ramp evolved, before sawteeth set in. TAE modes near the plasma center may also have been observed on the PCI, with frequency evolutions similar to those observed on JET, presumably due to the strong ICRH tail at the relatively lowish densities ($1 \times 10^{20} \text{m}^{-3}$). In principle, by measuring the TAE mode numbers with magnetic loops, the q-profile could be determined from the temporal evolution of the TAE frequency (A. Fasoli, private communication). Unfortunately, attempts to measure the q-profile with MSE were not successful last year, presumably due to lack of reliable calibration of the MSE diagnostic. This problem is solved now, and we should be in a better position to measure the q-profile during the ramp and beyond, thus providing valuable data to H. Yuh to finish his Ph.D. thesis.

3. Approach

Describe the methodology to be employed; explain the rationale for the choice of parameters, etc. Describe the analysis techniques to be employed in interpreting the data, if applicable. If the approach is standard or otherwise self-evident, this section may be absorbed into the Experimental Plan.

The present method would be similar to that used in the 1996 campaign [2] when only a single ICRF frequency (or two frequencies but near each other as available now) was used yet 5 keV central temperatures were obtained with powers less than 2 MW. Unfortunately, neither MSE nor edge Thomson measurements were available in 1996. We would have up to 4 MW of ICRF available now, or twice as much power as in 1996, and comparable power to what was injected last year (= 3 MW typically). Nevertheless, if we get ELMy H-mode, or high edge pedestal temperatures at intermediate power levels, (2.5 - 3 MW), it is more important to carry out scans with the MSE rather than push the power beyond 3 MW. We should also explore dependence of the edge pedestal on the magnetic field, (on and off axis heating) to see which ICRH location is more efficient to produce ELMy H-modes and/or reversed shear. It is important that the plasma be clean, hence we propose to carry out this experiment on the second day after boronization. Low H-fraction (less than 10%) in a clean deuterium plasma is desirable with low $Z_{\text{eff}}$ to maintain as long skin times as possible during the ramp. During ramp, the ECE emission will be monitored for the presence or absence of internal tearing modes (in contrast to the 1996 experiments, they were not seen in 2002 two-frequency experiments). The experiments will be analyzed with TRANSP and GS2, for the APS meeting (end of October). There are special requests for collecting MSE data, owing to background light coming from the D and E part antennas during RF injection. Howard recommends that we maximize power from the J port antenna to the extent possible for his data. Since the edge MSE channels look at E antenna, he would prefer to use D port for additional power rather than E port. Since the DNB pulse duration is 50ms, MSE needs 3 shots at each RF power to map out the q-profile evolution in time. If we use a second field besides 5.4T, Howard would like 4 field only (no plasma, beam in gas only) shots to calibrate MSE for that TF. These shots can be referenced via 1030521013.
4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

**Toroidal Field:** $B = 5.3\,T$, $4.5\,T$

**Plasma Current:** Ip ramp to 800 kA in 0.24 sec, followed by flat-top up to 1 sec.

**Working gas species:** Deuterium, with $< 10\%$ H minority

**Density:** $1 \times 10^{20}\,\text{m}^{-3}$ target

**Equilibrium configuration** *(if possible, refer to database equilibria):* similar to shot 1021025026

**Pulse length, typical current & density waveforms, etc.** Refer to database or sketch desired waveforms; see shot 1021025026 at $5.4\,T$, and 1021025032 at $4.5\,T$

4.2 Auxiliary Systems

**RF Power, pulse length, phasing:** $3.0 \,(4.0)\,\text{MW}$, heating phase, E, D and J port antennas

**Pellet Injection (species):** none

**Impurity blow-off injection:** none

**Special gas puffing:** none

**Other:** DNB; Ar if time allows

4.3 Diagnostics

List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

Standard set; in addition, ECE, MSE, Edge Thomson, PCI

4.4 Neutron Budget

Estimate the neutron dose rate at the site boundary. Give basis for estimate. *(Once some experience has been gained a standard formula will be provided for estimating dose rates.)*

Level seen last year

$1 \times 10^{13}$

5. Experimental Plan

5.1 Run sequence plan

Specify total number of runs required, and any special requirements, such as consecutive days, no Monday runs, extended run period (10 hours maximum), etc.

One good day required, long day if possible; A suitable date for this experiment may be July 8, Tuesday, assuming the machine was boronized over the weekend and run for other experiments on Monday, July 7, for clean up, with ohmic (or moderate ICRF powers) without major disruptions.
5.2 Shot sequence plan

For each run day, give detailed specification for proposed shot sequence: number of shots at each condition, specific parameters and auxiliary systems requirements, etc. Include contingency plans, if appropriate.

1. 8 shots: establish required discharge at 5.4T, ramp current to 0.8 MA and inject RF power; raise total RF power to 3.0 MW. Maximize J port power to the extent possible

2. Repeat for 3 shots with no RF for MSE background calibration

3. Repeat with 3 shots with J port antenna only for MSE

4. Repeat with 3 shots with 1.3 MW from D added to J port for MSE

5. Repeat 3 shots with 1.3 MW E-port, 1.3 MW D-port, 2.0 MW J-port for MSE

6. 3 shots for ramp at 4.5 T, up to 3.0 MW to check ELMy H mode behavior; if results are favorable, and if time allows, give 7 shots for MSE, including 4 shots for calibration at 4.5T without plasma.

Comment: If ELMy H-mode is not obtained in step 1, switch to step 6 instead of step 2. If ELMy H-mode is obtained at 4.5T, then continue with steps 3-5 for MSE.

6. Anticipated Results

Discuss possible experimental outcomes and implications. Indicate if the program may be expected to lead to publications, milestone completions, improved operating techniques, etc. Indicate if the experiments are intended to contribute to a joint research effort, or an external database.

We expect the following outcome: Satisfactory database for H. Yuh’s thesis so he can graduate; further data on ELMy H-mode in C-Mod and further understanding of edge stability during transition from resistive to collisionless pedestals; data on TAE modes in C-Mod during ICRF at low density operation; confinement data at low densities and the role of ICRF tails; further insight into suitable target plasma formation for AT scenarios with MCCD and/or LHCD; PCI data on low frequency modes (up to 0.5 MHz) during transition to the collisionless edge pedestal regime; APS meeting poster(s); Publication(s).

7. References

Include references both to external and internal literature or communications which bear on this proposal. See Section 2.
