The goal of this mini-proposal is to investigate mode conversion current drive using the J-port antenna.

2. Background

Initial experiments conducted during the last campaign were successful in establishing reliable antenna operation and obtaining reliable mode conversion scenario (mode conversion in D(3He) was more easily achieved than H(3He,D)). Although a quantitative measure the driven current is difficult to obtain from this data (RF power was 1.5-2 MW; plasma Z_{eff} ~4; discharges were dithering between L and H-mode; slower shot rate due to 8T operation; inability to place mode conversion on axis; and MSE had technical difficulties), modification of the sawtooth period was pronounced. For a ctr-current drive (+90 deg phasing) case (1030716016), the sawtooth period was extended to 15 msec and decreased to 5 msec for a co-current drive discharge (-90 deg) (1030716017). The measured power deposition profile is peaked near the q=1 surface. The sawtooth period modification is consistent with the MCCD modifying the local magnetic shear near the q=1 surface. Later discharges where the deposition essentially moved one GPC channel towards the core showed little sawtooth period modification.

Successful mode conversion electron heating has been demonstrated in D(3He), H(3He), and H(D) plasmas.[1-5] Recent modeling of PCI measurements of the mode conversion region have identified the ion cyclotron wave (ICW). Modeling has suggested mode conversion to the ICW can compete with mode conversion to the ion Bernstein wave. Although MCCCD was successfully demonstrated by Majeski et al.[1] mode conversion to ICW can significantly impact the current drive efficiency and driven current profile.
Calculations for C-Mod indicate up to 75 kA can be driven with 3 MW of power for near on-axis mode conversion ($r/a < 0.2$). For scenarios with the deposition further off-axis, the mode conversion scenario is complicated by the additional mode converted ICW that results in absorption in regions where trapping decreases the driven current and modifies the driven current profile.

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.

In order to optimize the driven current, target plasmas with high temperature and low density need to be prepared. In addition, near on-axis current drive will be pursued to minimize trapping effects. Some interesting upper single null target discharges achieved 4 keV with minimum impurity problems for ICRF power levels up to 4 MW. Another potential target discharge is early ICRF injection during the current ramp-up. In both cases, co-current, ctr-current, and heating discharges will be compared.

For the upper single null discharges, the MSE analysis may allow the reconstruction of the driven current profile. Comparing co-current, ctr-current, and heating discharges should improve confidence in the measured profiles. The expected current relaxation time should be 0.3-0.5 sec. Thus, comparing the surface loop voltage evolution for co-current, ctr-current, and heating discharges may provide an independent measure of the total driven current.

For the ramp-up discharges, the MSE analysis will be the primary method of determining the driven current. The expected current relaxation time is of order 0.6 sec while the ramp-up phase is $<0.3$ sec. In this case, current diffusion effects complicate the loop voltage analysis. Comparing the MSE measurements for co-current, ctr-current, and heating discharges should improve the confidence in the measured current profile.

Another means of inferring driven current is to attempt off-axis current drive near the q=1 surface and monitor changes to both the q-profile measured from MSE and sawtooth behavior. Again discharges with co-current, ctr-current, and heating phasing can be compared.

Although a variety of mode conversion scenarios are possible, the exact scenario depends on a number of other constraints. High resolution (spatial and temporal) ECE is available at 5.4 T with both the FRECE and GPC, important for measuring the electron power deposition. Furthermore the number of frequencies run in a single campaign is somewhat limited. Among the scenarios are:

$D(3^He,H)$ is a mode conversion scenario where the ion-ion hybrid layer can be located on axis for 50 MHz at 5.5 T (species mix is 65% D, 15% $3^He$, and 5% H). Using D and E-port antennas at ~80 MHz, central minority heating is available.

$D(3^He)$ is another mode conversion scenario similar to above except that the field required is 8 T at 78 MHz. At this field, the FRECE is unavailable, the number of discharges is typically less compared to a 5.4 T run, and the MSE requires additional calibration data.
H(\(^3\)He) is another mode conversion scenario similar to above except that the field required is 6.4 T at 78 MHz. At this field, the FRECE coverage is limited, the number of discharges is typically less compared to a 5.4 T run, and the MSE requires additional calibration data.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

- Toroidal Field: 5-6 T
- Plasma Current: 0.6-0.8 MA
- Working Gas Species: D with various levels of \(^3\)He
- Density: nl04<1.0 x 10\(^{20}\) m\(^{-2}\)
- Equilibrium configuration (if possible, refer to database equilibria):
  1) upper single null discharge like 1030509011 with 1 cm outer gap
  2) lower single-null ramp-up discharge like 1030709012

4.2 Auxiliary Systems

- RF Power, pulse length, phasing: J-port: 2 MW to full power at 50 MHz, co-, ctr- and heating phasing for 1 sec.
  D and E-port: 2.5 MW to full power for 1 sec.
- Pellet Injection (species): none
- Impurity blow-off injection: none
- Diagnostic Neutral Beam: yes
- Special gas puffing: \(^3\)He in B-side upper 16 psi

4.3 Diagnostics

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

FRECE, MSE, H/D, and Chromex/McPhearson monitoring \(^3\)He are particularly important.

5. Experimental Plan

Both sections must be filled in.

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 run is required for upper single null discharges and another for current drive during current ramp-up.

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.
Develop an upper single null plasma similar to 1031106017 where the central density was $1.5 \times 10^{20} \text{ m}^{-3}$ with at least 2.5 MW from D and E-port. Scan $^3$He concentration, density, and plasma current to maximize $T_e$ with minimum $Z_{eff}$. (5 shots)

Scan phase (co-, ctr- and heating phasing) under the optimum condition and measure q-profile evolution for each phasing. (15 shots)

Depending on the current drive success we would devote time to MSE calibration discharges (up to 5 shots).

Vary the B-field to place mode conversion near the q=1 surface (on the high field side).

Scan phase and evaluate effect on sawteeth. (5 shots)

Develop a lower single null plasma ramp-up discharge similar to 1030709009 where the central density was $1.0 \times 10^{20} \text{ m}^{-3}$ with at least 2.5 MW from D and E-port. Again scan target density and current to maximize $T_e$ with minimum $Z_{eff}$. (5 shots)

Scan phasing (co-, ctr- and heating phasing) will be carried out under the optimum condition. Measure q-profile evolution for each phasing. (15 shots)

Depending on the current drive success we would devote time to MSE calibration discharges (up to 5 shots).

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.

Quantify MCCD capabilities on C-Mod in support of 5 year plan objectives.

Provide data for experimental comparison to simulation. The MSE data may provide the first indication of the MCCD profile width. The characterization of this width could impact upon the suitability of using MCCD to stabilize MHD modes.

7. References

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


