1. Purpose of Experiments
Include immediate goal of the experiments, scientific importance and/or programmatic relevance. Refer to any relevant program milestones or ITER R&D commitments.

The purpose of this experiment is to further study parametric decay instabilities, and energetic particle generation at the edge during ICRF injection. Using the new fast-scanning RF probe and the charge-exchange neutral particle analyzer, the spatial structure of decay waves that accelerate the ions will be probed. These measurements have not been made on other tokamaks and may be valuable in extending theories of parametric decay instabilities from slab models to toroidal geometry.

2. Background
Discuss Physics basis of the proposed research, Prior results at Alcator or elsewhere, and any related work being carried out separately.

Measurements by the perpendicular neutral particle analyzer routinely show that there is edge ion heating during ICRH on Alcator C-Mod. This is believed to be caused by a nonlinear decay of the RF heating wave. Measurements with RF probes on Alcator have shown that one such decay, the Parametric Decay Instability occurs frequently.

In most standard operating regimes, such as $B_T$ of 5.3 or 6.5 T show a threshold in RF power of $\approx 500$kW. The threshold for edgeheating, though, is observed to go below 10kW when the ICRF wave is an exact harmonic of the local ion cyclotron frequency at the plasma outer edge.

A dedicated experiment was run on 960223 to examine some issues regarding this phenomenon. In particular, the experiment was expected to quantify the relationship between the PCX and RF probe measurements, give a pitch angle spectrum of the energetic particles, and determine if these particles generate impurities. The particle spectra had a strong pitch angle dependence, and were peaked between perpendicular and 45 degrees, the trapped/passing boundary. Another result is that the decay waves detected by the RF probes were found to be generated at the probe radius, rather than in the plasma edge. Because of power supply delays and difficulty achieving repeatable, low-field plasmas there
was only time to attempt three toroidal fields. It is worth noting that for these low-field plasmas the RF single pass absorption is very low.

A new fast-scanning RF probe has been installed, which will enable measurement of RF field strength profiles on a single shot, up to the LCFS.

Measurements after the above run made at $B_T = 5.3T$ show that escaping energetic particles also have significant structure in $z$. With current data, it is not clear where these particles are heated. Energetic particles observed at the midplane may be being accelerated purely perpendicularly, but off the midplane and away from the resonance. They would be observed after a bounce orbit takes them to the PCX sightline and changes the pitch angle. Or the particles may accelerated with a finite parallel component at the resonance at the outer midplane LCFS. Resolution of this issue is key to understanding the structure of the accelerating field.

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.

A significant gap in the previous experiment will be addressed by running at a toroidal field of 4.72T. Since boronization, the RF single pass absorption for off axis heating is quite good (see e.g. shot 960124009). In this case the plasma heating will be via hydrogen minority heating at $R=.60m$. There is also the third harmonic of deuterium just at the edge of the LCFS at this field, which will give edge heating at low, highly repeatable RF power. Once the shot is obtained, the CX analyzer can be scanned in both toroidal direction and poloidally. Toroidally, key will be pinpointing the peak in the flux. Scanning in both directions will require up to 8 shots. The RF fast-scanning probe will measure profiles of the pump wave and PDI decay waves. New moveable probes will give some measurements of the poloidal and toroidal variation of these profiles.

Changing the toroidal field to 4.82T will move the deuterium third harmonic to just behind the limiter, and so should remove any effect it’s having on the plasma. We expect the CX analyzer to see no edge heating at this field, and the RF probes should record a large difference at the LCFS, as the decay waves would no longer be strongly interacting with the particles.

To compare the bulk heating of the plasma with and without the strong particle interaction at the edge, we will want at least one shot at 4.72T and one at 4.82T to have above 1MW of RF power. This comparison was not possible during the previous run (960223), which did not include a shot with significant single pass absorption of the RF heating wave.

After we have the flux surface geometry for our standard shot-of-the-day, we will want to calculate a field that puts the deuterium 3$^{rd}$ harmonic at the radius where the RF probe intersects the LCFS, somewhat off the midplane. This is around 4.6T.

Slow toroidal field ramps, say from 4.5 to 5.0T at constant RF power are the most efficient way to look at the effect of small changes in the location of the resonance. Long
RF pulses at constant field give better counting statistics on the PCX, but a ramping field gives a more complete qualitative picture. The ramp should be repeated for at least 2 RF power levels, about 20kW and 100kW, for at least 3 different PCX poloidal sightlines.

The fill should include small amount of hydrogen, around 4%, in order to reduce the shot-to-shot variation.

H-modes are a complication and best avoided. The low RF power levels involved and \( I_P = 600\text{kA} \) should keep the heating low enough to avoid strong H-modes.

Only relatively low RF powers will be required, so for simplicity we will use only one antenna, E-port if available.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

Toroidal Field: 4.72T and variable
Plasma Current: 600kA
Working gas species: D, with approx. 4% H in plenum.
Density: \( n_l_{04} \) of \( 7 \times 10^{19} \text{ m}^{-2} \).
Equilibrium configuration a simple single-null diverted plasma
Outer Gap: around 1cm.

Pulse length, typical current & density waveforms, etc.: The requested field should be available for a 300ms flattop. Breakdown should be achieved by the most convenient method.

4.2 Auxiliary Systems

RF Power, pulse length, phasing: One antenna, pulses of variable height.
Pellet Injection (species): none
Impurity blow-off injection: none
Special gas puffing:
Other:

4.3 Diagnostics

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

RF probes, PCX, TCX, Moly Monitor, bolometers, reflectometer, TS, edge FSP, usual core diagnostics, Chromex, \( 2\pi \) bolometer.
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.)

minimal

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.

This run can be accomplished in one day.

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.

Obtain a reproducible shot with $B_T = 4.72T$, using a small field scan, 4.6–4.9T with 100kW RF to locate the neutral flux maximum if necessary. The RF power will be fired in four pulses, 120ms wide, with 40ms between pulses. Power levels will be approximately 10kW, 20kW, 50kw, 100kW, and with 1MW on at least one shot.

The PCX will be scanned toroidally to at least two more locations, trying to bracket the flux maximum, and scanned poloidally for at least 2 more shots.

The repetition of shots will be used to get detailed profiles with the scanning probe of the various decay waves of interest, and coarser shot-to-shot scans with the other moveable probes.

A small change in $B_T$ to 4.82T puts the resonance outside the limiter. Approximately three shots with different positions and configurations of RF probes are needed to diagnose the expected change in the RF edge field profile.

Three shots at a field calculated to place the resonance at the point where the fast-scanning RF probe approaches the LCFS, $\sim 4.6T$, will shed light on the issue of whether PDI in the plasma is a local effect, as it is outside the plasma.

Next, we will set up a shot with a TF ramp during plasma flattop, $B_T = 5.0 \rightarrow 4.0T$, and the RF on throughout the flattop at 100kW. The PCX will be scanned poloidally for at least 2 sightlines below the midplane. This will take at least 3 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.

Data for further validation of PDI theory will be generated.

A novel diagnostic, the fast-scanning RF probe will be used to measure wave profiles in the plasma edge in various conditions.

In general, see Background section for a discussion of the experimental goals.

The data acquired will form significant portions of two doctoral theses.
7. References

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

1995 APS posters, Rost et al, Reardon et al.