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

Verify Nb can be observed spectroscopically and investigate necessary conditions.

Verify localization of impurity source to active antenna using Nb marker tiles magnetically connected to J antenna.

Verify erosion rate of B coating by RF enhanced sheaths.

Test hypothesis that the impurities penetration is enhanced by convective cells resulting from radial gradient in RF enhanced sheath potentials.

Investigate whether low single pass absorption increases erosion rate/impurity production.

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

Despite the danger of stating the obvious, this experiment continues the investigation of the role ICRF plays in boronization erosion and impurity production. Previously, we have identified RF sheaths as the primary culprit for enhanced (compared to ohmic heated discharges) Mo production and boronization erosion where the most important source/erosion location is on the top of the outer divertor. These conclusions were deduced from a series of experiments.

During the last machine opening, Nb tiles were installed on the outer divertor module at C-D tile 79. These tiles are magnetically connected to the J antenna under typical, LSN
fiducial discharges. With these marker tiles, we should be able to directly demonstrate the location of the impurity source and that it is connected to the active antenna.

Furthermore, an outstanding question is why is this location more important than other locations where sheaths should be present, for example the antenna protection limiters. One possible explanation is convective cells resulting from the resulting radial electric field from the RF sheath rectification.[1,2] In normal field operation, the ExB convection will transport impurities from the outer divertor shelf to the plasma mid-plane. In reverse field configuration, the impurities from the outer divertor shelf should be transported back to the shelf/divertor. By monitoring the core Nb in similar discharges, we should be able to determine the Nb content varies with normal versus reverse magnetic configuration.

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.

We would like to further investigate the results of previous experiments that suggested the Mo production and B erosion is linked to enhanced sputtering from rectified fields connected to the active antenna. We would like to use the first set of discharges to establish that we can detect the Nb in the plasma and document Nb concentration with J antenna power. We will also utilize a set of D and E antenna heated discharges to investigate the level of Nb in the plasma for antenna operation without magnetic connection to the antenna. In standard LSN operation, we would like to establish a set of discharges in H-mode to be used for later comparison with reverse field and low single pass absorption discharges for both over night and between discharge boronization. We will also obtain information on B erosion and subsequent Nb levels as a function of injected RF energy and lifetime of the between discharge boronization. The reverse field discharges will be compared to the normal field orientation discharges to test the hypothesis that the RF convective cells influence the impurity penetration into the plasma. Finally, we will compare erosion rate and impurity production for discharges with weak single pass absorption with the standard strong single pass absorption obtained in the first set of discharges. In these experiments, we are of course assuming that the impurity source and erosion rates will be similar in all discharges.

4. Resources

4.1 Machine and Plasma Parameters
Give values or range for:

- Toroidal Field: 5.2 T
- Plasma Current: 1 MA
- Working Gas Species: D
- Density: $n_l_{04} = 0.8 \times 10^{20}$
- Equilibrium configuration (if possible, refer to database equilibria):

4.2 Auxiliary Systems
RF Power, pulse length, phasing: <4 MW, heating phasing  
Pellet Injection (species): no  
Impurity blow-off injection: no  
Diagnostic Neutral Beam: no  
Special gas puffing: some $^3$He  
Non-axisymmetric Coils (Connections, Current): normal [+Dtop -Dbot -Jtop +Jbot]  
Other: Between shot boronization.

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

Standard set with particular emphasis on radiated power, Nb and Mo monitoring, and $Z_{eff}$.

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.

3.5 days if time permits and results are good.

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.

5.2.1 (1/2 day) Verify Nb can be observed and related to J antenna operation.

Using a standard discharge (5.4 T, 1 MA, nl_04~0.9 m$^{-2}$, 1 cm outer gap) in a poorly conditioned machine (little or no B remaining), ramp J power to 3 MW. (2-3 shots)
Repeat with D+E antennas without J (2-3 shots).
Repeat with D+E+J antennas at 3.5 MW and 4 MW total (2.5 MW from J and remainder from D+E). (2 shots)

5.2.2 (1 day) Establish discharges for comparison with reverse field and low single pass discharges.
Following overnight boronization, use standard, LSN discharge with J @2.5 MW and D+E @1.5 MW. Track Nb and Mo concentration and $P_{rad}/P_{input}$ versus discharge and integrated Joules till Nb concentration saturates or discharge performance degrades. (20 shots)

Perform between shot boronization limited to 0.6-0.7 m and run consecutive discharges with J @2.5 MW and D+E @ 1.5 MW (4-5 shots)

Time permitting, another between shot boronization limited to 0.6-0.7 m and run consecutive discharges @2.5 MW first with J then D+E followed by J (3 shots).
Repeat with D+E first then J followed by D+E. (3 shots)

5.2.3 (1 day) Test hypothesis convective cells increase impurity penetration. Using LSN discharges in reverse field, repeat shot sequence from 5.2.2.

Following overnight boronization, use standard, LSN discharge with J @2.5 MW and D+E @1.5 MW. Track Nb and Mo concentration and $P_{\text{rad}}/P_{\text{input}}$ versus discharge and integrated Joules till Nb concentration saturates or discharge performance degrades. (20 shots)

Perform between shot boronization limited to 0.6-0.7 m and run consecutive discharges with J @2.5 MW and D+E @1.5 MW (4-5 shots)

5.2.4 (1 day) Investigate weak single pass absorption (J at 50 MHz) versus strong with same antenna.
Following overnight boronization, use standard, LSN discharge with J @2.5 MW and D+E @1.5 MW. Track Nb and Mo concentration and $P_{\text{rad}}/P_{\text{input}}$ versus discharge and integrated Joules till Nb concentration saturates or discharge performance degrades. (20 shots)

Perform between shot boronization limited to 0.6-0.7 m and run consecutive discharges with J @2.5 MW and D+E @1.5 MW (4-5 shots)

Time permitting, another between shot boronization limited to 0.6-0.7 m and run consecutive discharges J @2.5 MW first till Nb saturates

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.

Confirm previous identification of RF sheaths as the primary culprit for enhanced (compared to ohmic heated discharges) Mo production and boronization erosion where the most important source/erosion location is on the top of the outer divertor.

Provide some evidence for role of convective cells in making the outer shelf the primary impurity source.

Results will be included in future publications and potential APS invited presentation.

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