Alcator C-MOD

Mini-Proposal

Subject: ICRF Heated Dimensionless Scaling (C-MOD / ASDEX-UG)  
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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.

This mini-proposal is similar to MP085A Dimensionless Scaling (C-Mod/DIII-D) by Greenwald, et al. The goal is to test dimensionless scaling by producing discharges in C-Mod and ASDEX-UG which have identical nondimensional parameters, but have different dimensional parameters. This experiment is proposed as part of C-Mod/ASDEX-UG collaboration.

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

Dimensionless scaling experiments have started during Phase II-B operation. A power scan at $n_e = 1.5 \times 10^{20} \text{ m}^{-3}$ was completed on C-Mod, which was reproduced on DIII-D. However, in the DIII-D comparison different heating methods are used (ICRF for C-Mod, NBI for DIII-D). We propose to do the ASDEX-UG comparison using the same heating method (ICRF H minority heating) with similar heating profiles. This discharge can also be reproduced on DIII-D when the 30 MHz ICRF operation becomes possible.

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 set of operating points for the comparison have been identified. The heating scenario will be H minority heating in D majority plasma. With the presently operating transmitters (80 MHz for C-Mod, ≥ 30 MHz for ASDEX-UG), it is not possible to obtain on-axis resonance while maintaining the scaling constraint $B \propto R^{-5/4}$. However, acceptable off-axis resonance conditions (20% of minor radius toward the low field side in C-Mod, 20% toward the high field side in ASDEX-UG) can be achieved.
The H minority concentration may have to be adjusted to obtain similar power deposition profile and power split between electron and ion heating. C-Mod should operate at low H concentration ($\simeq 1\%$) and ASDEX-UG at high concentration (10\%) to compensate for the different densities. Because the comparison is more straightforward in L-mode plasmas, this experiment should be done with the ion $\nabla B$ drift away from the X-point to avoid H-mode transitions. Future extensions of this experiment include H-mode comparison and $\rho_s$ scaling. Of particular interest is size scaling (C-Mod vs. A-UG) at the same field (2.6 T), same RF frequency (80 MHz) and same heating scenario (second harmonic H minority heating).

The plasma shape parameters will be matched as closely as possible: $R/a = 3.3$, $\kappa_x = 1.7$, $\delta_x^a = 0.1$, $\delta_x^l = 0.3$ (it may not be possible for C-Mod to get $\delta_x^l$ much below 0.4). Scaled parameters are:

<table>
<thead>
<tr>
<th></th>
<th>$R$ (m)</th>
<th>$a$ (m)</th>
<th>$B_T$ (T)</th>
<th>$I_p$ (MA)</th>
<th>$n_e (10^{20} \text{ m}^{-3})$</th>
<th>$P_{tot}$ (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-Mod</td>
<td>0.68</td>
<td>0.21</td>
<td>5.60</td>
<td>1.00</td>
<td>2.06</td>
<td>3.89</td>
</tr>
<tr>
<td>ASDEX-UG</td>
<td>1.65</td>
<td>0.50</td>
<td>1.85</td>
<td>0.80</td>
<td>0.35</td>
<td>2.00</td>
</tr>
</tbody>
</table>

A power scan (ohmic, $P_{tot}/2$, $P_{tot}$) will be performed at the specified density. This density was selected to be in the middle of normal operating density range for the two tokamaks.

If time allows, power scans at lower density (0.25 for A-UG, 1.47 for C-Mod) and higher density (0.45 for A-UG, 2.65 for C-Mod) should be performed.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

**Toroidal Field:** 5.6 T

**Plasma Current:** 1.0 MA

**Working gas species:** D (majority) and H (minority)

**Density:** $n_e = (1.5–2.7) \times 10^{20} \text{ m}^{-3}$

**Equilibrium configuration** (if possible, refer to database equilibria): Lower single-null, with the ion $\nabla B$ away from the X-point

**Pulse length, typical current & density waveforms, etc.** Refer to database or sketch desired waveforms: current flat-top to 1.2 sec.
4.2 Auxiliary Systems

RF Power, pulse length, phasing: Up to full power
Pellet Injection (species): none
Impurity blow-off injection: possibly
Special gas puffing: Ar for HIREX, possibly H puff from a separate valve
Other:

4.3 Diagnostics

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

All available diagnostics, especially \( n_e, T_e, T_i \), and \( Z_{eff} \) profiles.

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.)

Less than \( 10^{13} \) per shot.

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.

1 run.

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.

Some discharge development is needed to setup the slightly non-standard plasma. A power scan (ohmic, \( P_{tot}/2, P_{tot} \)) will be performed first at \( = 2.1 \). Shots will be repeated until satisfactory profile data \( (T_i(r) \) in particular) are obtained. Power scans will be repeated at \( = 1.5 \) and at \( = 2.7 \). Some adjustment of the H concentration may be necessary.

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.

This experiment will provide a test for dimensionless scaling of tokamak transport. The results will provide critical information to ITER, and will lead to a joint publication.

7. References

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