Alcator C-Mod

Mini-Proposal

MP No. 529

Subject: Toroidal field dependence of the L-H transition at low density in Ohmic and ICRF heated plasmas

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Group: Transport, H-mode Scenarios

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Approved by: **Date Approved:**

1. Purpose of Experiments

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

The input power required to enter H-mode has been found to depend nonlinearly on the density where it increases rapidly below some critical density that varies from machine to machine. On C-Mod, at $B_T = 5.4$ T, the observed critical density is about 8×10^{19} m^{-3}, which is significantly higher than the L-mode target density foreseen in ITER. Other machines find a substantially lower critical density, but they operate at substantially lower toroidal field. The purpose of these experiments is to try to determine how this critical density scales with toroidal field to better predict what the critical density might be in ITER. This has been approved as an ITPA joint experiment together with DIII-D, JET, and ASDEX-Upgrade, now called CDB-11.

2. Background

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

The critical density in C-Mod below which the power required to achieve H-mode increases dramatically was found to be about $\bar{n}_e = 8 - 10 \times 10^{19}$ m^{-3} [1]. In other machines at substantially lower toroidal field, the critical density was found to be considerably lower at about $\bar{n}_e = 2.5 \times 10^{19}$ m^{-3} [2]. Since ITER intends to run with an L-mode target density of $\bar{n}_e = 5 \times 10^{19}$ m^{-3} [3], if the critical density in ITER is as high as in C-Mod at the same toroidal field, then ITER may have difficulty achieving H-mode with the presently foreseen auxiliary heating power if the H-mode threshold power scaling correctly predicts the threshold power for nominal low threshold conditions [4]. While there is considerable uncertainty both theoretically and experimentally in the threshold power, the critical low density limit has been reproduced in C-Mod in recent experiments varying the plasma current (Fig. 1). So, it is a robust result and it remains to determine how this critical density depends on toroidal field to see how it will scale to ITER. This experiment has been approved as a joint ITPA experiment CDB-11 and there is interest on DIII-D, JET, and ASDEX-Upgrade to perform joint experiments to address this important physics issue for ITER.

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.

Achieving reproducible low density target plasmas for H-mode threshold studies should now be straightforward with the new cryopump. To make best use of the cryopump, reversed field upper single null plasmas may be required, but the miniproposal could be run with the normal field direction even if the cryopump is not as effective. For the first half run day, the L-mode target density will be scanned from nl04 of 2×10^{19} m^{-2} to 6×10^{19} m^{-2} from shot to shot during an decreasing ramp in toroidal field from 5.4 T down to 2.2 T. We will begin at 0.6 MA to keep $q_{95} > 2.5$. We may try increasing the current slightly to increase the Ohmic input power, but we want to avoid low q disruptions. For the second half run day, we will instead use ICRF heating at 50 MHz and operate with H minority heating at 3.3 T and 0.75 MA. Then, we will scan the density from shot to shot over the same range as before but now with an increasing ramp in ICRF power from 0.5 MW to as high as achievable or necessary to obtain the H-mode at each density. In addition to the basic power threshold parameters, this experiment should also determine how the core and edge plasma rotation, edge temperature and density, turbulence and other MHD activity, radiated power, and Z_{eff} change with the critical density to see if any of these parameters give some insight into the changes in physics near the critical density.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

Toroidal Field:	5.4 T – 2.2 T
Plasma Current:	0.6 MA – 0.75 MA
Working Gas Species:	Deuterium
Density:	2×10^{19} m^{-2} – 6×10^{19} m^{-2}

Equilibrium configuration (if possible, refer to database equilibria): 1080124028

4.2 Auxiliary Systems

RF Power, pulse length, phasing:	ICRF at 50 MHz up to at least 3 MW
Pellet Injection (species):	None
Impurity blow-off injection:	None
Diagnostic Neutral Beam:	Yes
Special gas puffing:	No special puffing

Non-axisymmetric Coils (Connections, Current); Standard configuration
Other: Cryopump for density control

4.3 Diagnostics

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

Core and edge Thomson for temperature and density profiles. HIREX for ion temperature and rotation profiles. CXRS with DNB for ion temperature measurements. Bolometry for radiation profile measurements. Visible Bremsstrahlung for Z_{eff} measurements. Fast scanning probes for SOL flow measurements. Fast magnetic pick-up coils, PCI, and Reflectometry for fluctuation measurements.

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.

Two half run days are required.

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.

For the first half run day, we will start with shot 1080124028 and reduce nl04 from shot to shot down to 2×10^{19} m^{-2} while we ramp the toroidal field down from 5.4 T to 2.2 T at 0.6 MA. We will continue to reduce density until H-mode cannot be achieved. Then, we may try increasing the plasma current up to 0.75 MA if we can still avoid low q disruptions to have more Ohmic input power.

For the second half run day, we will run at 0.75 MA, 3.3 T with 50 MHz H minority ICRF heating. We will ramp up the ICRF power from 0.5 MW to as high as possible, at least 3 MW to scan the threshold power, ramping from 0.5 s to 1.5 s. Then, we will scan the target density shot to shot from nl04 = 6×10^{19} m^{-2} to 2×10^{19} m^{-2}. In this way we will map out the H-mode power threshold at each density to see if the low density limit is lower at 3.3 T than the values previously observed at 5.4 T between 0.8 – 1.0×10^{20} m^{-2}.

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 should indicate if there is a dependence of the critical low density for the H-mode power threshold on toroidal field or not. Based on the threshold scaling, we might expect the L-H threshold to occur sooner in time (higher B_T) as we lower the density for moderate densities and then to happen later in time (lower B_T) or not at all as the critical density is approached. This will also help to test Guzdar's L-H threshold model [5], depending on how the edge pressure gradients respond. If a clear toroidal field dependence of the low density limit is found, this would suggest that ITER may not be able to operate at its prescribed L-mode target density and achieve H-mode with the power level that is presently intended to be installed. If the critical density is found to be independent of toroidal field, then more experiments will be required together with other machines to attempt to determine how the critical density scales with other plasma parameters. We may also find that core or edge flows, edge temperature and density, radiation, Z_{eff}, turbulence, or other fluctuations play a key role in the critical low density for the H-mode threshold. These results are important for a paper at the upcoming EPS meeting in June 2008.

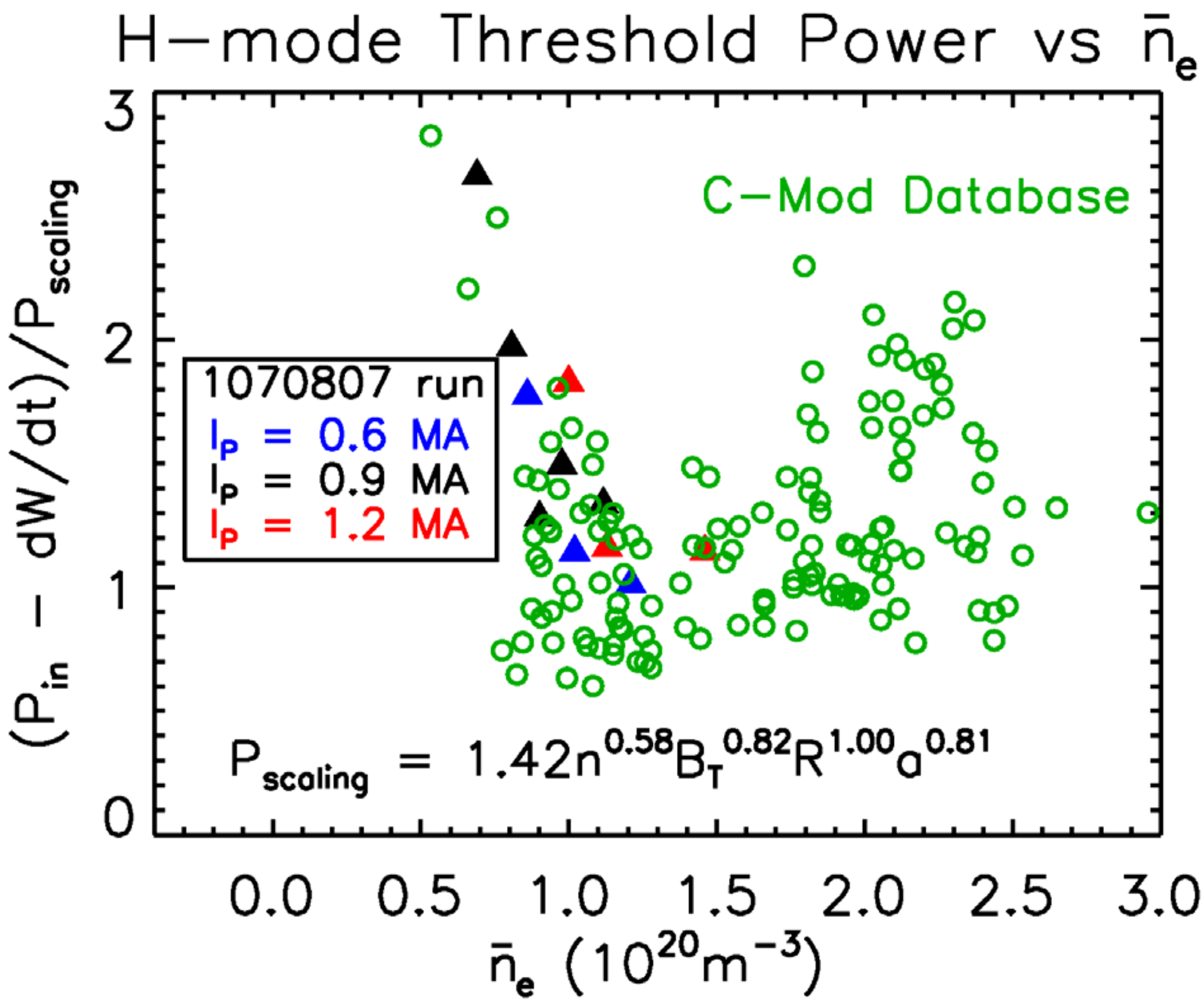

Fig. 1. Data from the 1070807 run indicates that the low density limit to the H-mode threshold lies at about 1×10^{20} m^{-3} independent of the plasma current. Previous results over a broad range of conditions in the C-Mod database indicate a limit perhaps as low as 0.8×10^{20} m^{-3}.

7. References

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

[1] J A Snipes, et al, *Plasma Phys. Cont. Fus.* **38** (1996) 1127.

[2] H-Mode Database Working Group, *Proc. 21st EPS Conf. on Controlled Fusion and Plasma Physics (Montpellier)* **18B** Part I (1994) 334.

[3] E J Doyle, et al, *Nuclear Fusion* **47** (2007) S18.

[4] J A Snipes, et al, *Plasma Phys. Cont. Fus.* **42** (2000) A299.

[5] P N Guzdar, et al, *Phys Rev. Lett.* **89** (2002) 265004.