Study of H-mode Access in the Alcator C-Mod Tokamak: Density, Toroidal Field and Divertor Geometry Dependence

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Motivation: H-mode is envisioned as a potential baseline scenario for ITER plasma operation. Therefore, knowing the global H-mode threshold power and local plasma edge conditions for H-mode access is important. This poster presents a comprehensive study of H-mode access conditions on the Alcator C-Mod tokamak. All cases included in this study are deuterium plasmas, with the ion grad-B drift in the favorable direction for H-mode access, i.e., towards the active X-point. All H-mode transitions were induced with ICRF as the sole auxiliary heating power, configured in the fundamental hydrogen minority heating scenario.

1. Global H-mode threshold power ($P_{th}$)

- 1.5 Comparison to the RDZ model

$$\sin\alpha \approx 0.5-0.6 \ (\text{an 'L'-shaped boundary})$$

Motivation:

- C-Mod experimental results show reasonable experiments [2] conducted to study the effect of divertor geometry on $P_{th}$.
- Performed in vertical-plate vs. slot divertor (normally, C-Mod is operated with the vertical-plate divertor), by varying the outer separatrix strike point location.
- 5.4T/0.9-1.0MA, ICRF on-axis heating.
- Trigger L-H transition when plasma is operated with the slot divertor, at moderate and high density; this effect disappears at low density.

- Reduction in $P_{th}$ is U-shaped, with a local minimum at $P_{th} = 0.95$.
- Local $P_{th}$ increases sharply (stronger than linear) by ICRF power deposition or divertor geometry.
- A significant implication of the FM3 model: $P_{th}$ at sheath-to-conduction limited regime transition ($\eta_{sol} = 0.15$), this is also consistent with experiment.

- The FM3 model also reproduces the divertor geometry effects.
- Reason for the $P_{th}$ reduction in slot divertor: longer connection length. The FM3 model does not reproduce this.

2. Local edge conditions just before the L-H transition

- 3. Dependence of $P_{th}$ on divertor geometry

Divertor X-point configuration can strongly influence $P_{th}$, dedicated C-MOD experiments [2] conducted to study the effect of divertor geometry on $P_{th}$.

**Experimental Setup:**

- Performed in vertical-plate vs. slot divertor (normally, C-Mod is operated with the vertical-plate divertor), by varying the outer separatrix strike point location.
- 5.4T/0.9-1.0MA, ICRF on-axis heating.

**Key Results:**

- Significant ($>50\%$) reduction in $P_{th}$ when plasma is operated with the slot divertor, at moderate and high density; this effect disappears at low density.
- Density scaling of $P_{th}$ remains U-shaped with slot divertor.
- Reduction in $P_{th}$ best correlates with outer leg length, or LFS SOL connection length.

- The FM3 model gives asymptotic expressions for $P_{th}$.

**Dependence of $P_{th}$ on ICRF resonance location**

- An ITER-relevant aspect: ICRF will use combination of multiple heating methods, each may have different power deposition profiles.

**Experimental Setup:**

- Use two-frequency (80 and 70MHz) ICRF antennas. 80MHz ICRF waves injected in each discharge to induce H-mode.

**Key Results:**

- $P_{th}$ is not affected by ICRF power deposition location, unless ICRF resonance is placed in plasma edge near the inner wall.
- Significant inverse (90MHz) in $P_{th}$ probably due to a degradation in ICRF power absorption.

- 4. Comparison to the FM3 model for H-mode threshold power

- The FM3 model gives asymptotic expressions for $P_{th}$.
- The FM3 model predicts $P_{th}$ based on edge-SOL physics.
- No clear dependence on $P_{th}$, except for ICRF power deposition location.
- Consistent with experiment; quantitatively agreement also good.

- 3. Comparison to the RDZ model for the L-H transition

- Two key parameters of the RDZ model [3]:

$$\eta_{sol} = 0.9, 0.5 \ (\text{an 'L'-shaped boundary})$$

- C-Mod experimental results show reasonable agreement with the RDZ model predictions [1].
- Suggest: enhancement in finite-beta effect (due to increasing pressure gradient); stronger nonlinear interaction between ICRF waves and shear Alfven waves.

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