L-Mode NCS Discharges with Expanded $\rho_{q_{\text{min}}}$

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Poster CP1.87
Motivation

• The motivation of the experiment was to expand the radius of the various ITBs while maintaining high $q_{\text{min}}$ and obtain higher $\beta$ and better bootstrap alignment

• Discharges with Negative Central (magnetic) Shear (NCS) are of interest due to their improved stability against a variety of MHD phenomena
Motivation (Con’t)

• High $q_{\text{min}}$ leads to a large bootstrap current, important for AT scenarios
• L-mode is also attractive for AT scenarios as it reduces the divertor heat fluxes
• Another motivation is to study whether large $\rho_{q_{\text{min}}}$ influences the characteristics of the ITBs
Overview

• Analysis for a single high performance shot is presented

• Key points:
  – Improved performance obtained
  – Little or no correlation of the barrier location with $q_{\text{min}}$ in particular and q-profile in general
  – Discharge is stable to ideal modes, but strong MHD activity is still observed
Peak Performance is Twice that of a Standard L-mode Discharge

- Peak Performance
  - $\beta_N \cdot H_{89} = 8$
  - $\beta_N = 2.8$
  - $\rho_{q_{\text{min}}} = 0.55$
  - $q_{\text{min}} = 2.3$
  - $q_0 = 4.3$
  - $\dot{N} = 3.1 \times 10^{15}$ n/s
- Duration $\sim 0.75$ s

- L-mode
- ITBs in
  - $T_e (\rho \sim 0.6 - 0.7)$
  - $T_i (\rho \sim 0.45 - 0.55)$
  - $n_e (\rho \sim 0.45 - 0.6)$
  - $\omega_{\text{ExB}} (\rho \sim 0.45 - 0.5)$
Discharge Evolution

- Note: H-mode transition at \( t = 1153 \) ms
Profile Evolution (0-1200 ms)

- $n_e \times 10^{19} \text{ m}^{-3}$
- $T_e \text{ (keV)}$
- $T_i \text{ (keV)}$
- Toroidal Rotation (kHz)
- Impurity Density \( \times 10^{19} \text{ m}^{-3} \)
- Radiated Power (W/cm$^3$)
Equilibrium is Highly Shifted with Low Current in Core

Safety Factor

\[ q_0 = 4.32 \]
\[ q_{\text{min}} = 2.38 \]

\[ B_z \]

\[ x^2 = 10.3 \]

\[ P_0/\langle P \rangle = 4.16 \]

Shot: 98482  Time: 1140 ms
Barrier Locations are not Well Correlated with $q_{\text{min}}$
Comments

• Barrier location is determined from profiles
• $\rho_{Ti} < \rho_{q_{min}} < \rho_{Te}$
• Temporal location of the $T_e$-barrier is independent of $q_{min}$
• Location of the $T_i$-barrier is strongly correlated with the location of the gradient in the toroidal rotation
• Location of the $T_i$-barrier is not well correlated with $q_{min}$
Transport

- Discharge was modeled both with TRANSP and CORSICA
- Ion power balance is dominated by flow from the ions to the electrons, as is typical of L-mode discharges
- Electron power balance is dominated by conduction
- Ion transport analysis is compromised by the presence of MHD activity
Profile Barrier Locations Consistent with Transport Calculations

- Barriers as found from profile fits correspond to locations of large gradients in transport coefficients
Strong MHD Activity Perturbs Equilibrium and Profiles

- Large amplitude (~80 G at wall) bursts of $n = 1$ MHD activity are observed late in the L-mode phase
- Bursts are well correlated with shifts in equilibrium and profiles
- Activity is associated with gross plasma displacements
- The bursts appear to flatten the profiles and may increase the radius of the ITBs
Spatial Structure of Mode

- Mode is peaked at $\rho \sim 0.55$
- SVD analysis compliments of Tim Luce
Good Ideal Stability is Obtained

- The broad pressure profile contributes to the good ideal stability and allows access to the high achieved $\beta$
- Also contributing to the stability is the lower than usual peaking factor: $P_0 / \langle P \rangle = 4.1$
- Observed activity is likely either an $n = 1$ resistive interchange mode or a resistive kink
- Growth rate is $\sim 1$ ms, consistent with resistive modes
- No evidence of TAE modes
GATO Results

- Stability analysis consistently shows that ideal modes are stable in the presence of a wall and unstable with no wall.
L-mode Phase Terminates with an MHD triggered transition to H-mode

• As the discharge evolves, the central pressure rises due to the transport barriers
• MHD activity increases, which at first marginally increases the radius of the barriers
• Finally, a very large amplitude MHD event triggers a transition to H-mode
• Despite the MHD activity, the discharge does not disrupt
Comments & Conclusions

• Shot is similar to previous NCS L-mode discharges but with generally improved performance
• Due to the small central poloidal field, energetic ions are not well confined.
• Multiple barriers exist (T_e, T_i, Toroidal Rotation) at differing values of \( \rho \)
• Ideal stability is consistent with calculations
Comments & Conclusions (Con’t)

• The location of the ITBs is not well correlated with $q_{\text{min}}$
• MHD activity is varied and very complex
• The presence of the strong MHD activity compromises the transport analysis