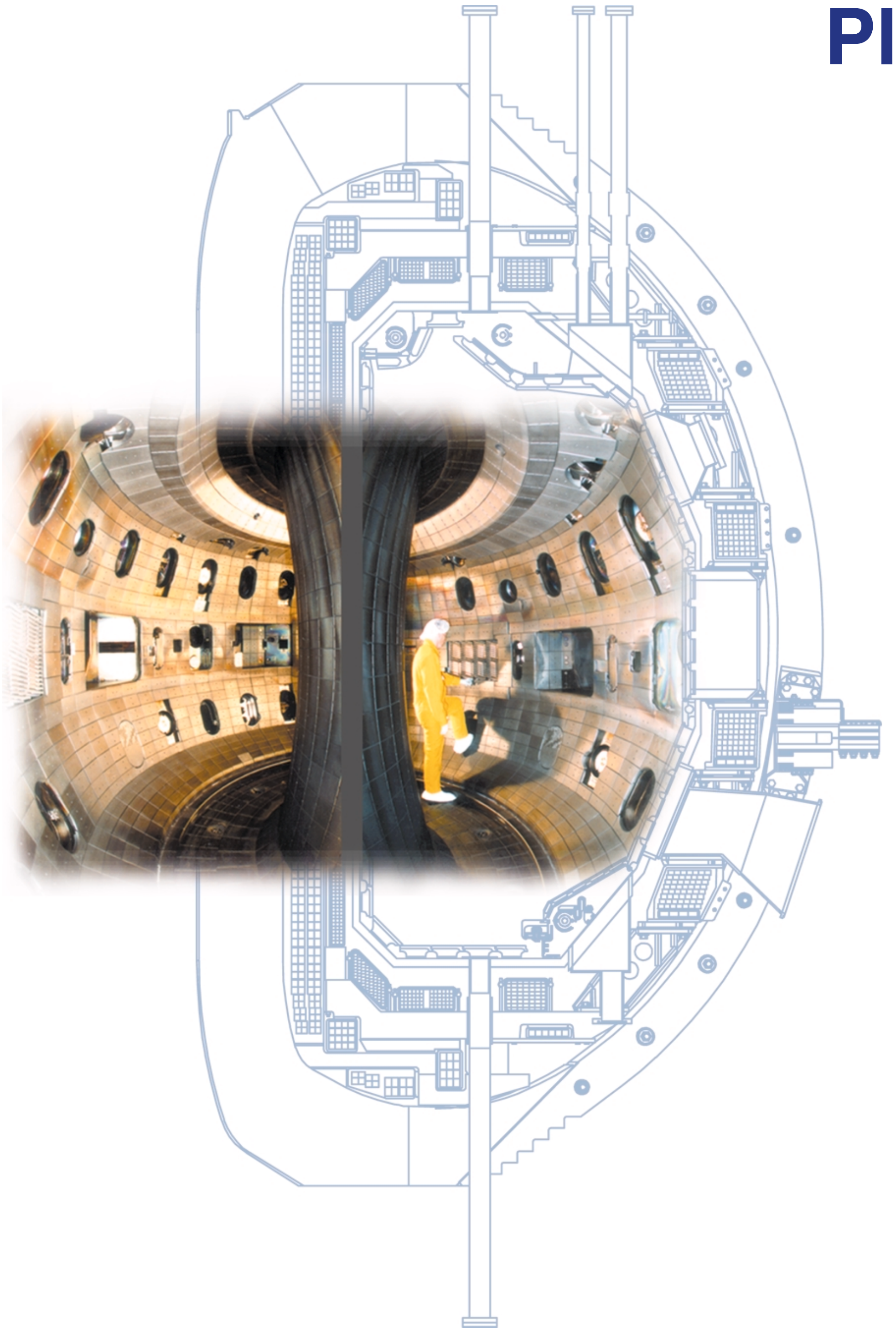

Plasma Profile Behavior in DIII-D Discharges with Counter NBI

by

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Abstract Submitted
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Plasma Profile Behavior in DIII-D Discharges with Counter NBI[1] J.C. DEBOO, C.M. GREENFIELD, K.H. BURRELL, General Atomics, E. SYNAKOWSKI, Princeton Plasma Physics Laboratory, B.W. STALLARD, Lawrence Livermore National Laboratory, E.J. DOYLE, C.L. RETTIG, L. ZENG, University of California, Los Angeles — Internal transport barriers, ITBs, have been observed in electron and ion temperature profiles and in electron density profiles with counter neutral beam injection into 1.6 MA discharges limited on the inside wall of the vacuum vessel. The profiles exhibited peak values a factor of 2 or more above values outside the barrier. A neutral beam power scan was performed to search for a threshold for the formation of an ITB. No clear threshold was found, however, it was found that for the lower power levels applied, 7–9 MW, a barrier region transiently formed near $\rho \sim 0.4$ and then collapsed to the plasma center. The cause of the collapse is under investigation. At the larger powers, up to 15 MW, the barrier region formed near $\rho \sim 0.5$ and was usually terminated by the onset of a locked mode during the current ramp phase of the discharge. At the larger powers a transient H–mode phase or dithering occurred which inhibited or destroyed profile peaking and ITB formation. ITB formation resumed following return to an L–mode phase.

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☐ Prefer Oral Session
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Special instructions: DIII-D Poster Session 1, first poster

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Internal Transport Barriers Were Studied With Counter Neutral Beam Injection

- **Motivation**
  - Counter-NBI drives current opposite in direction to the core plasma current causing the central q value to increase, producing negative central magnetic shear in the core, and extending the sawtooth-free period required to maintain internal transport barriers (ITBs)
  - The direction of the toroidal rotation is reversed, causing the rotational shear and ∇p terms in the shearing rate equation to aid each other rather than oppose each other as in the co-injection case:
    $\omega_{ExB} = \omega_{\nabla p} + \omega_{rot}$

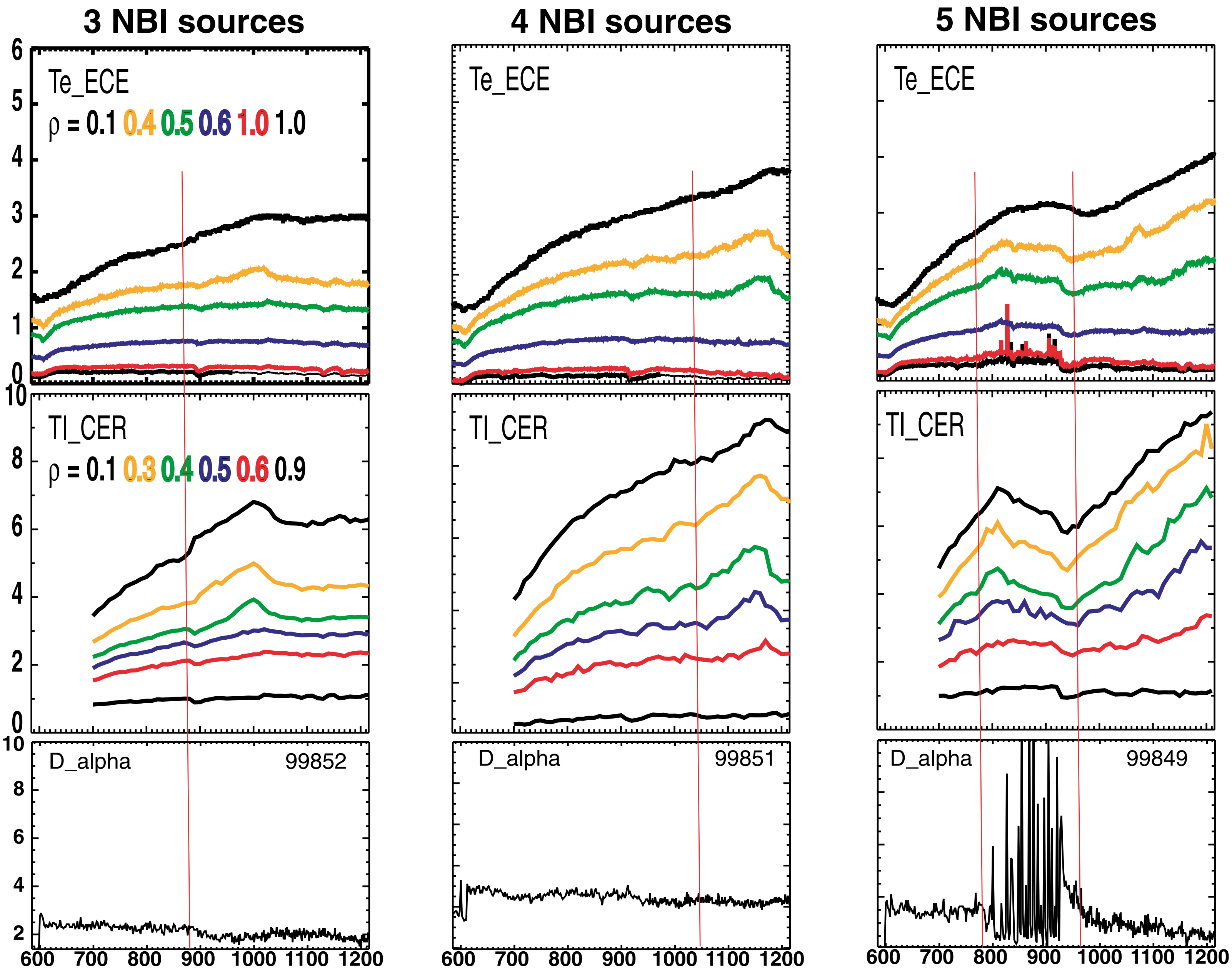
- **L-mode discharge configuration**
  - limited on the inside wall of the vessel
  - employed ECH preheat to help form ITB
  - apply NBI during I_p ramp phase

- **Power scan in steps of one NB source (~ 2.4 MW)**
  - search for threshold for ITB formation with 3 – 7 sources

Summary of Results

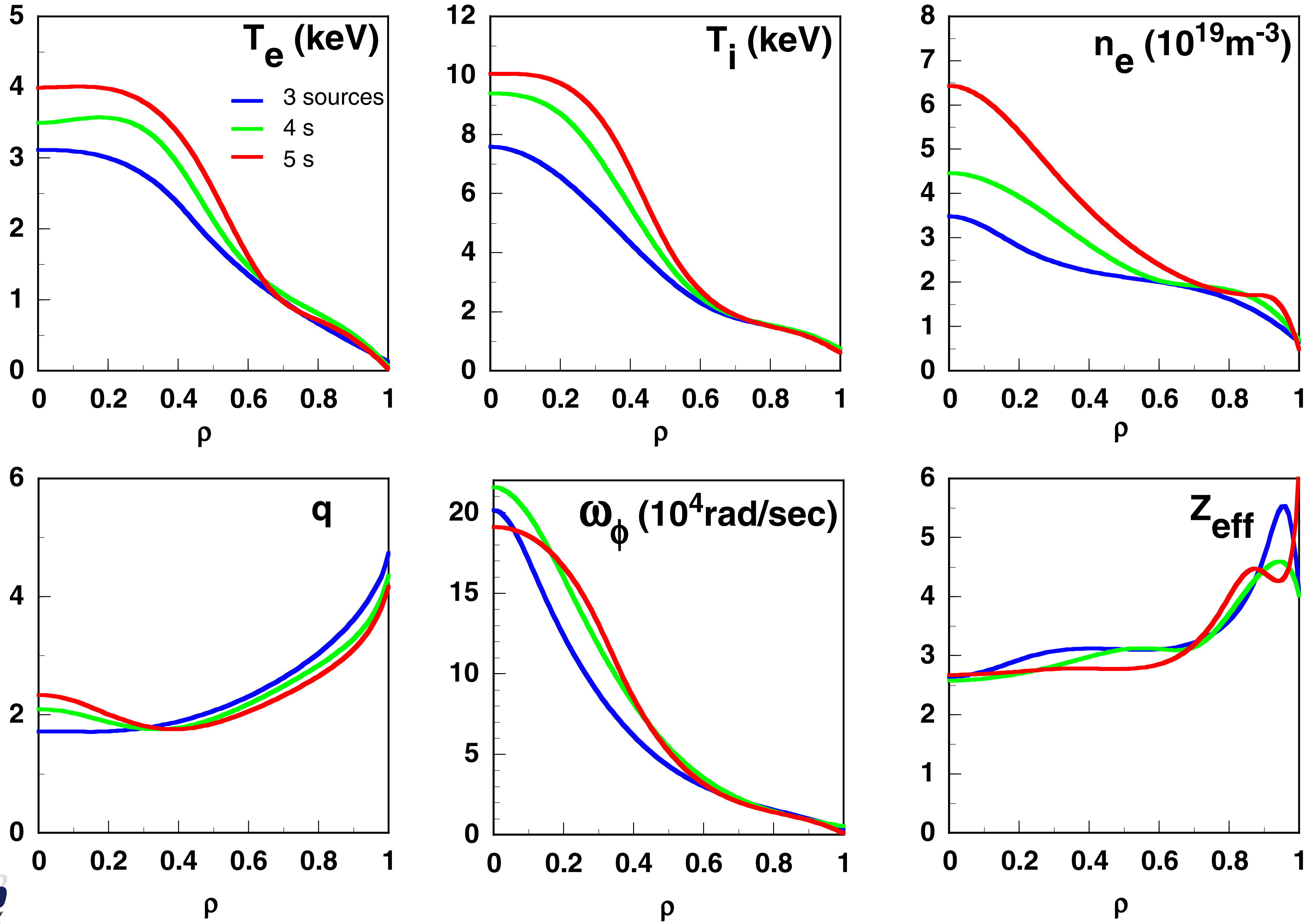
- ITBs observed in temperature, density and toroidal rotation profiles
- Found weak, transient ITB formed with 3 NBI sources (7.2 MW)
  - core barriers broaden with increasing heating power
- For $P_{NBI} \geq 11.2$ MW (5 sources) dithering, H-mode-like activity appeared at the plasma edge and destroyed or inhibited formation of a core barrier
- ECH preheat pulse not necessary for ITB formation

ITB Threshold is Exceeded Transiently with 3 NBI Sources (7.2 MW)



The Core Barriers Broaden With Increasing Heating Power

- Times of analysis chosen at peak performance during local barrier formation (3s at 997 ms, 4s at 1122 ms, 5s at 1197 ms)



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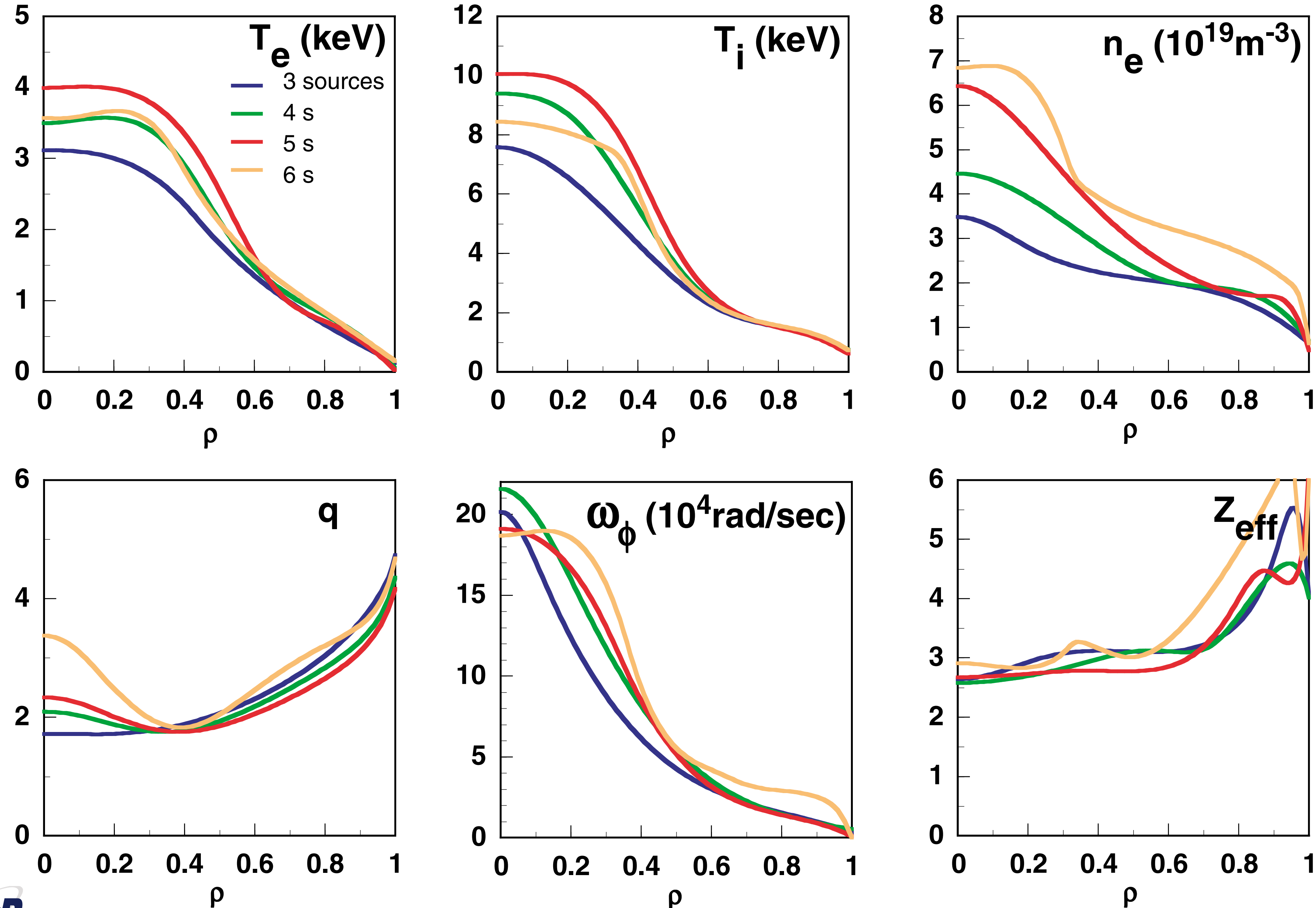
The Barriers Weaken for $P_{NBI} \geq 13.6$ MW (6 sources)

- MHD activity and locked modes weaken barrriers with 6 and 7 sources



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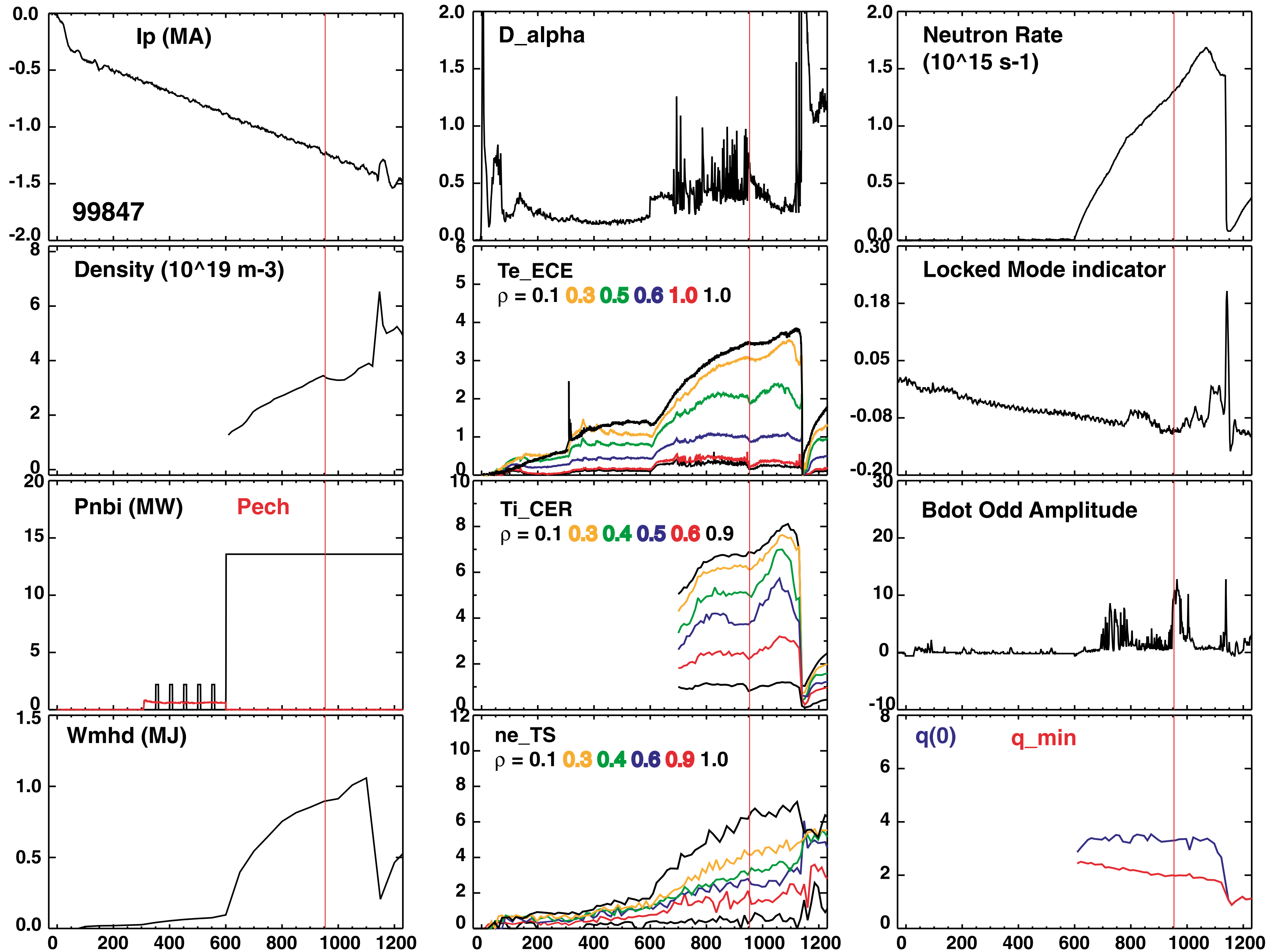
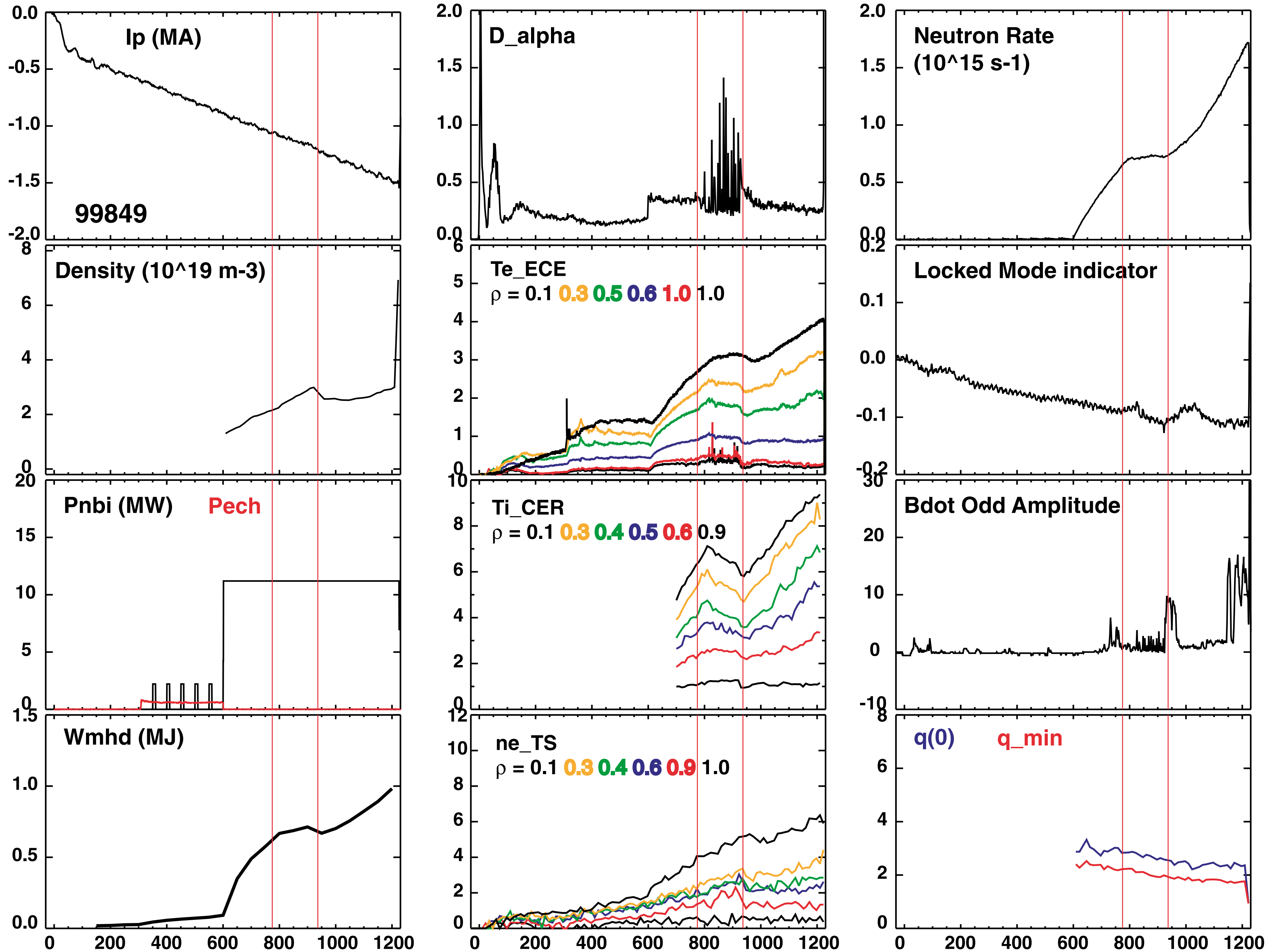
Formation of ITB is Inhibited by Dithering H-mode-Like Activity at Edge



- **The ITB forms following termination of the dithering activity**
- **Barrier formation begins off-axis**
- **At the higher power levels, the ITB is often terminated by a locked mode**

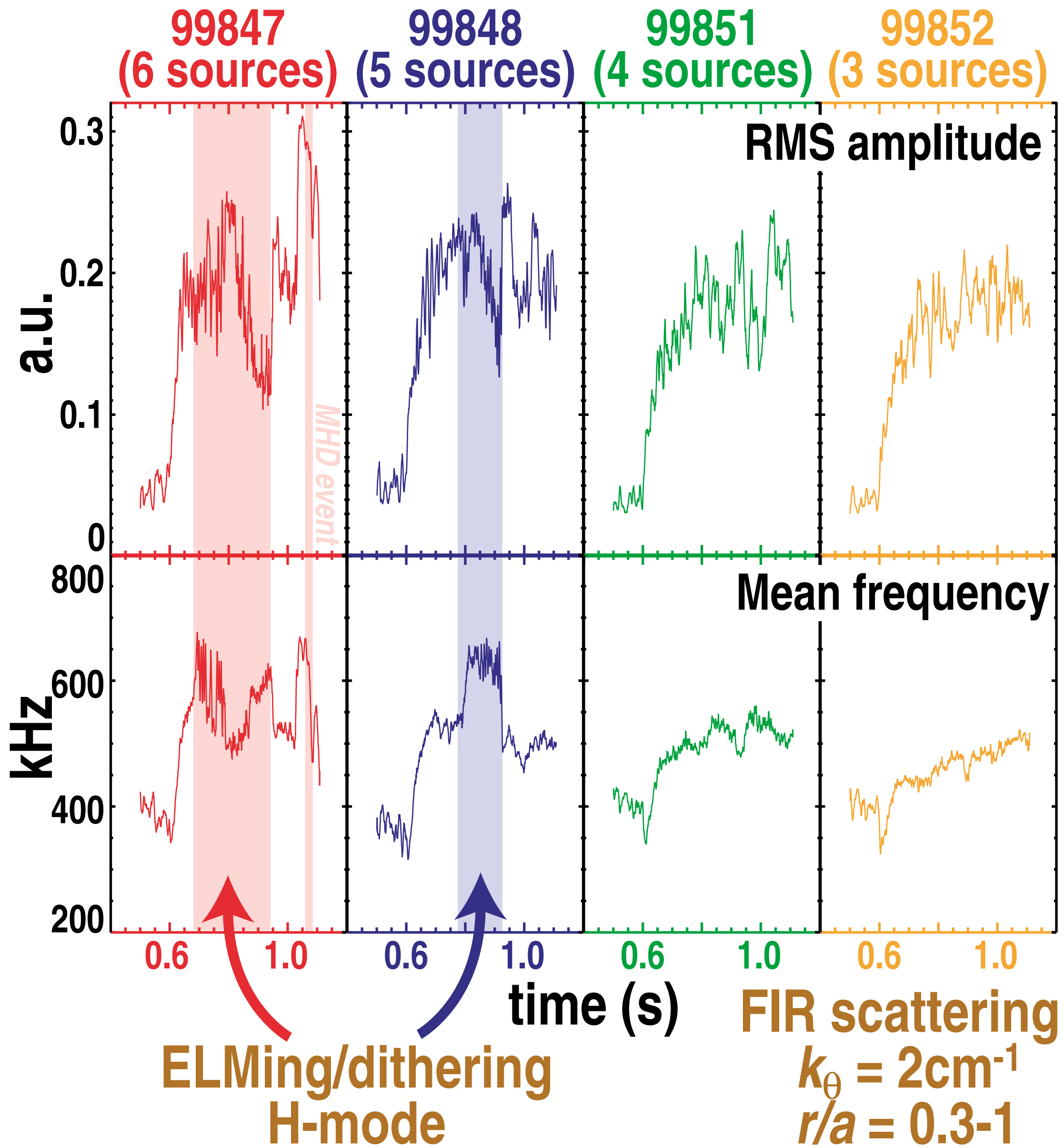
The Core Barrier Can Be Destroyed by Dithering H-mode-Like Activity



- **The ITB reforms when the dithering activity ceases**

Spatially Integrated Turbulent Fluctuations Decrease During Dithering Activity in Higher Power Cases

- Decrease in fluctuations preceeds observation of core barrier in the profiles
- FIR scattering integrates from $0.3 \le \rho \le 1.0$



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Temporal Evolution of Profiles

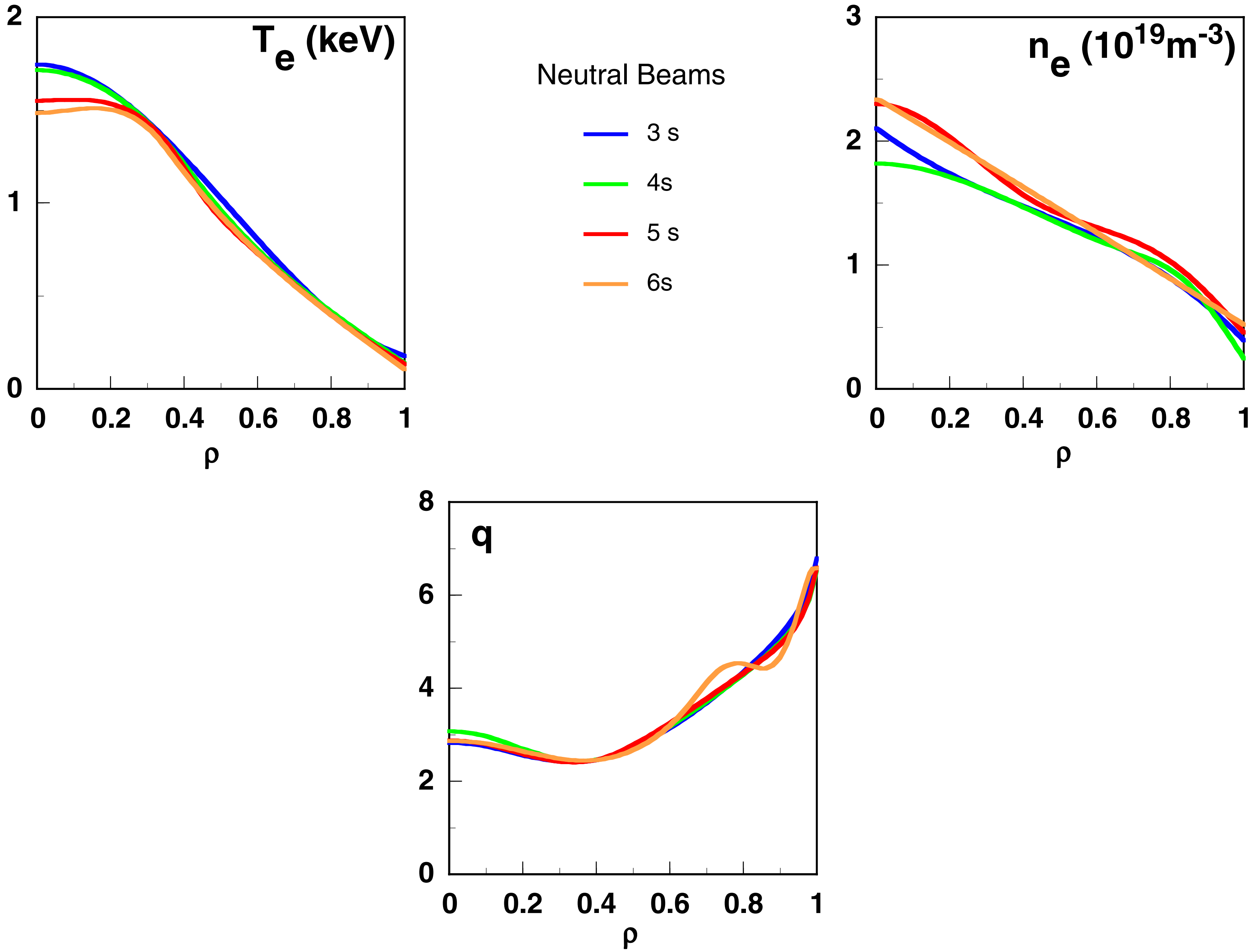
- Discharges have very similar profiles before high power phase of power scan begins at 600 ms.
- q_{min}>1 is sustained for over 0.5 sec in high power phase. More power produces stronger reversed shear in core.
- T_e profile develops a broad, flat region in core, $\rho \leq 0.3$
- Differences in profiles due to varying NB power levels is more pronounced in T_i, ω_ϕ and n_e than in T_e.
- Power threshold for producing dithering H-mode activity at edge is between 4 and 5 NBI sources. Profiles during dithering period are plotted as dashed lines.
- Early in the high power phase, ω_ϕ and T_i profiles increase with each neutral beam source but by 900 ms the profiles

at all powers are very similar due to the impact of the dithering activity on the 5 and 6 source cases.

- During the dithering, H-mode-like phase the edge density increases, consistent with typical H-mode behavior, but the density profile remains peaked in the core, more like an ITB characteristic.

Profile Comparisons for NBI Power Scan

Comparison at 609 ms, beginning of high power phase



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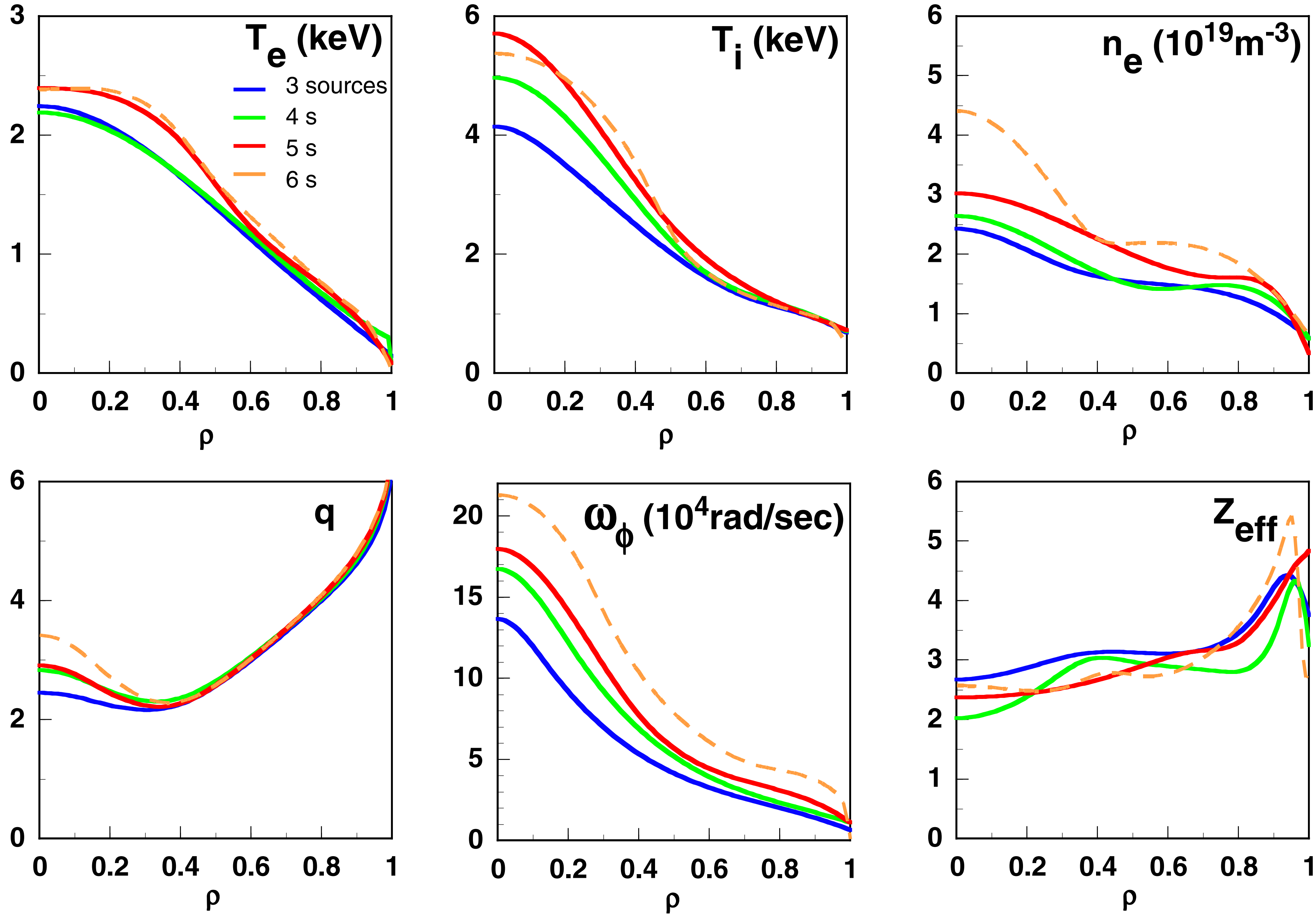
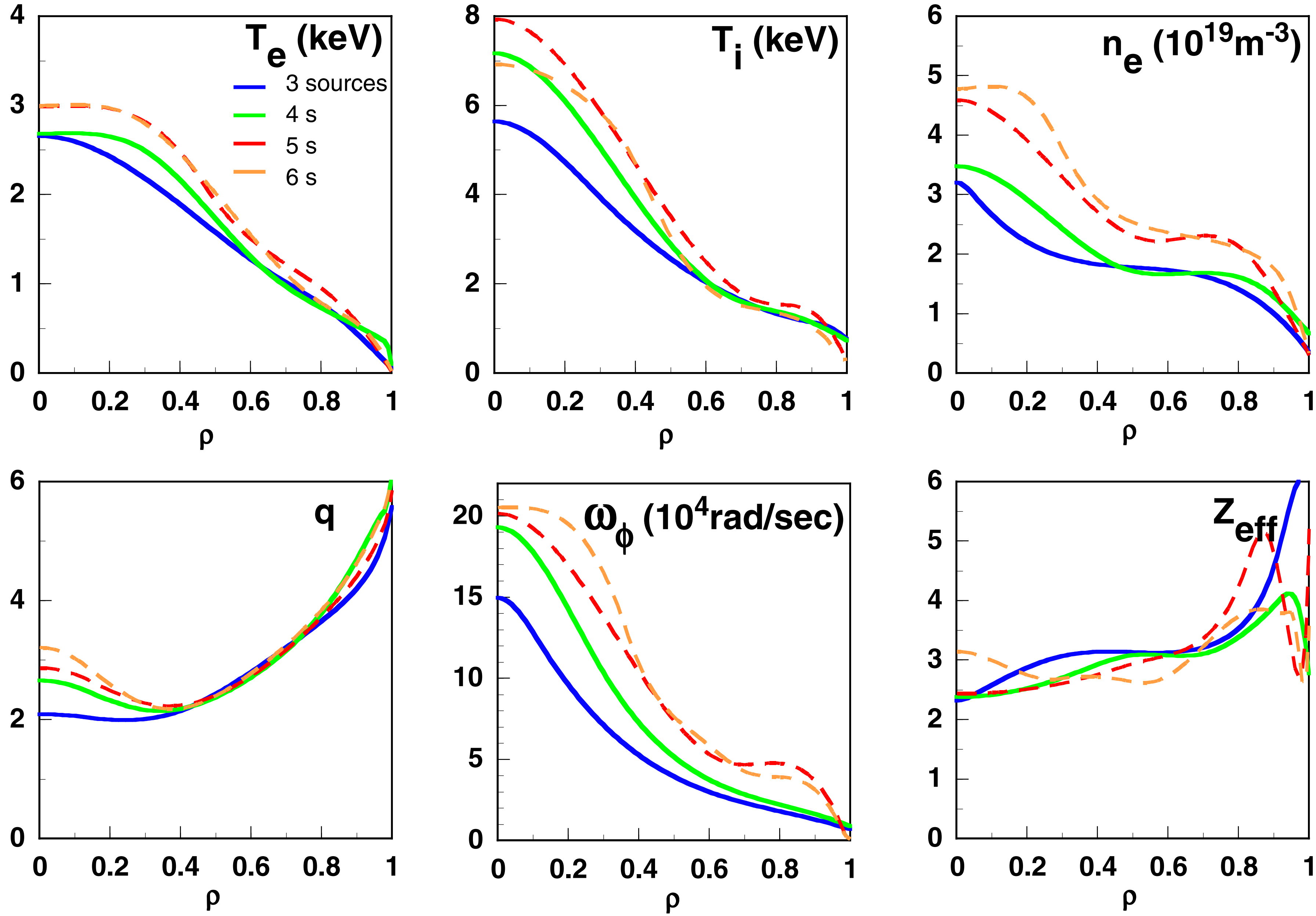
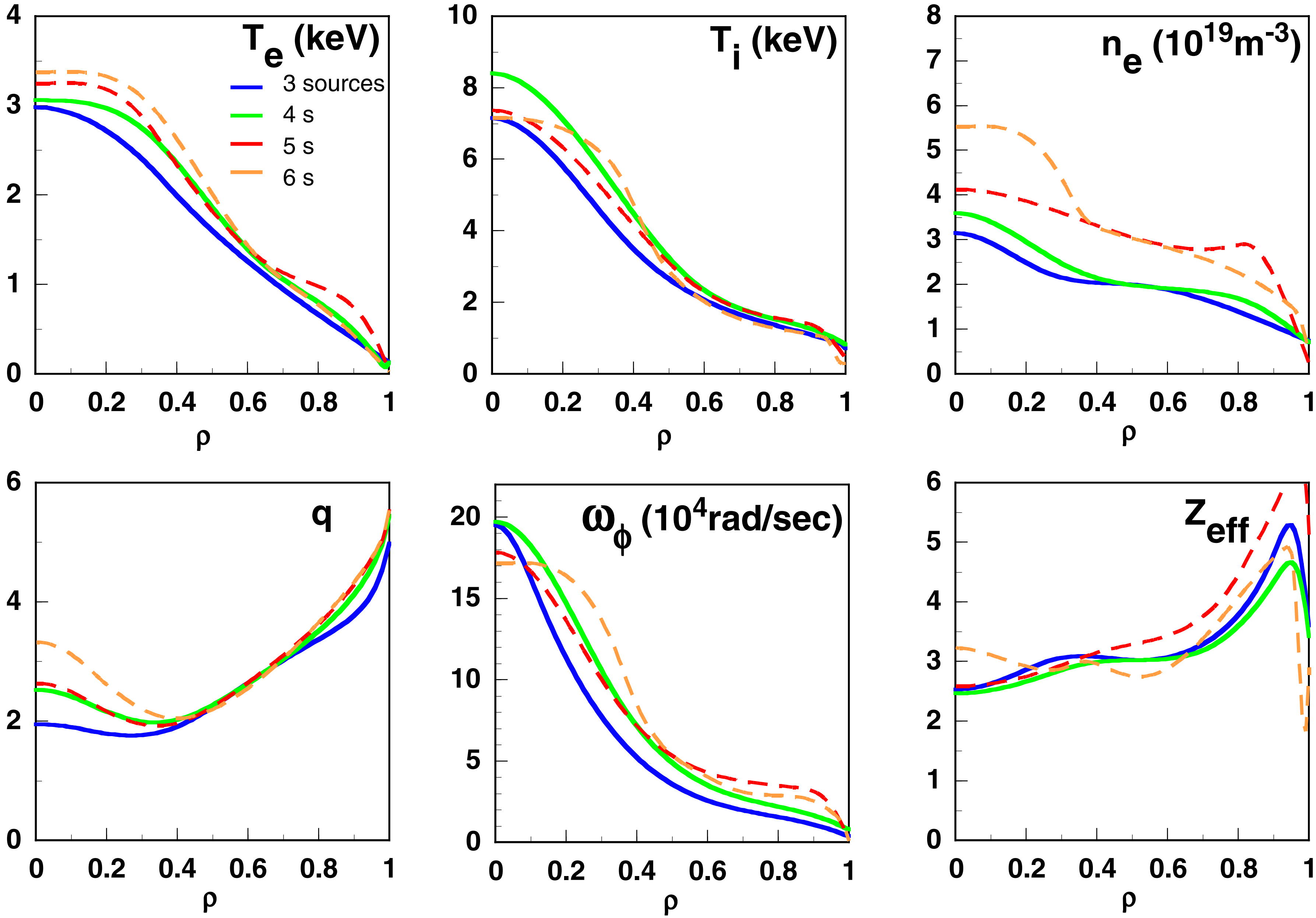
Profile Comparisons at 709 ms



Profile Comparisons at 809 ms



Profile Comparisons at 909 ms



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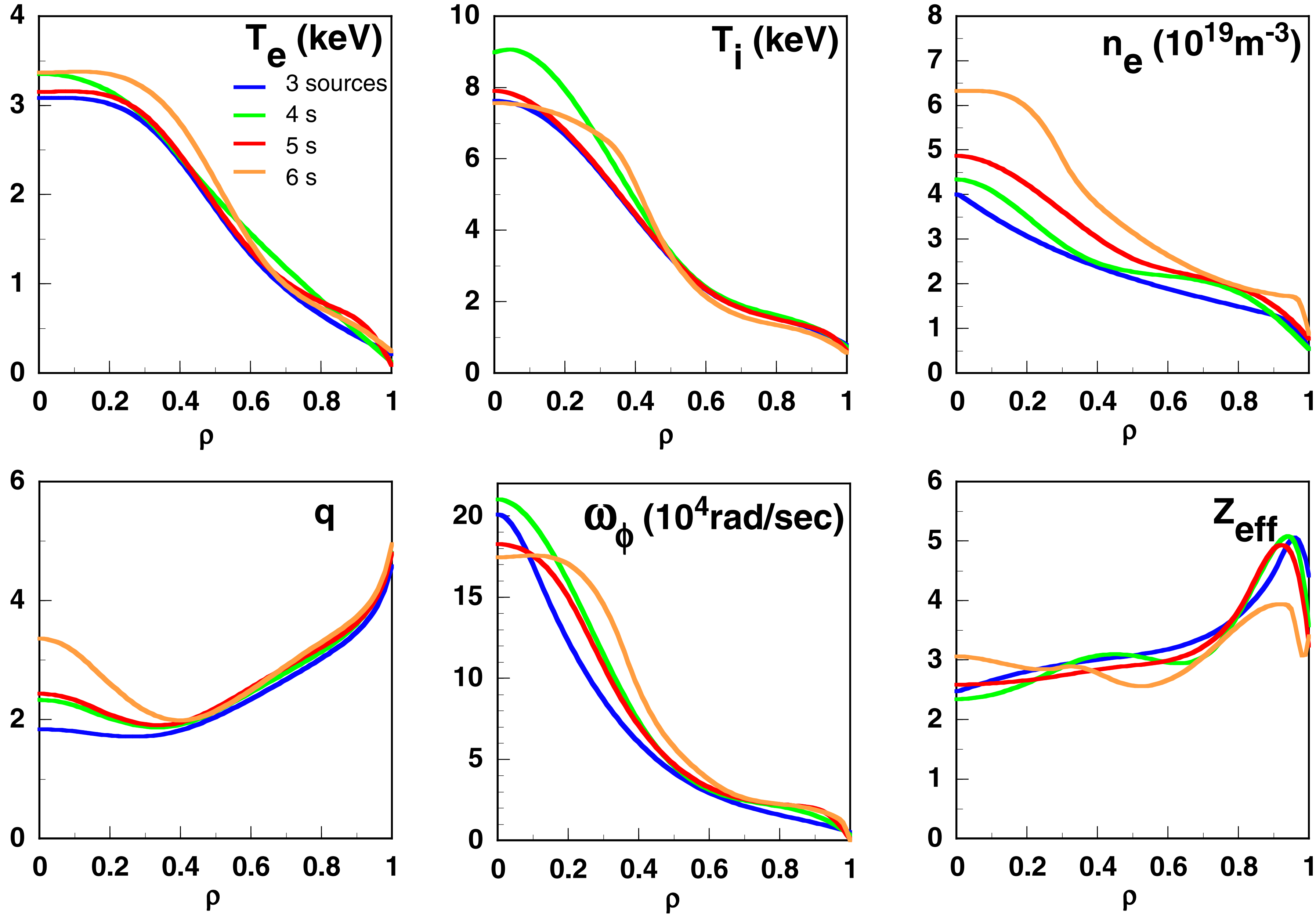
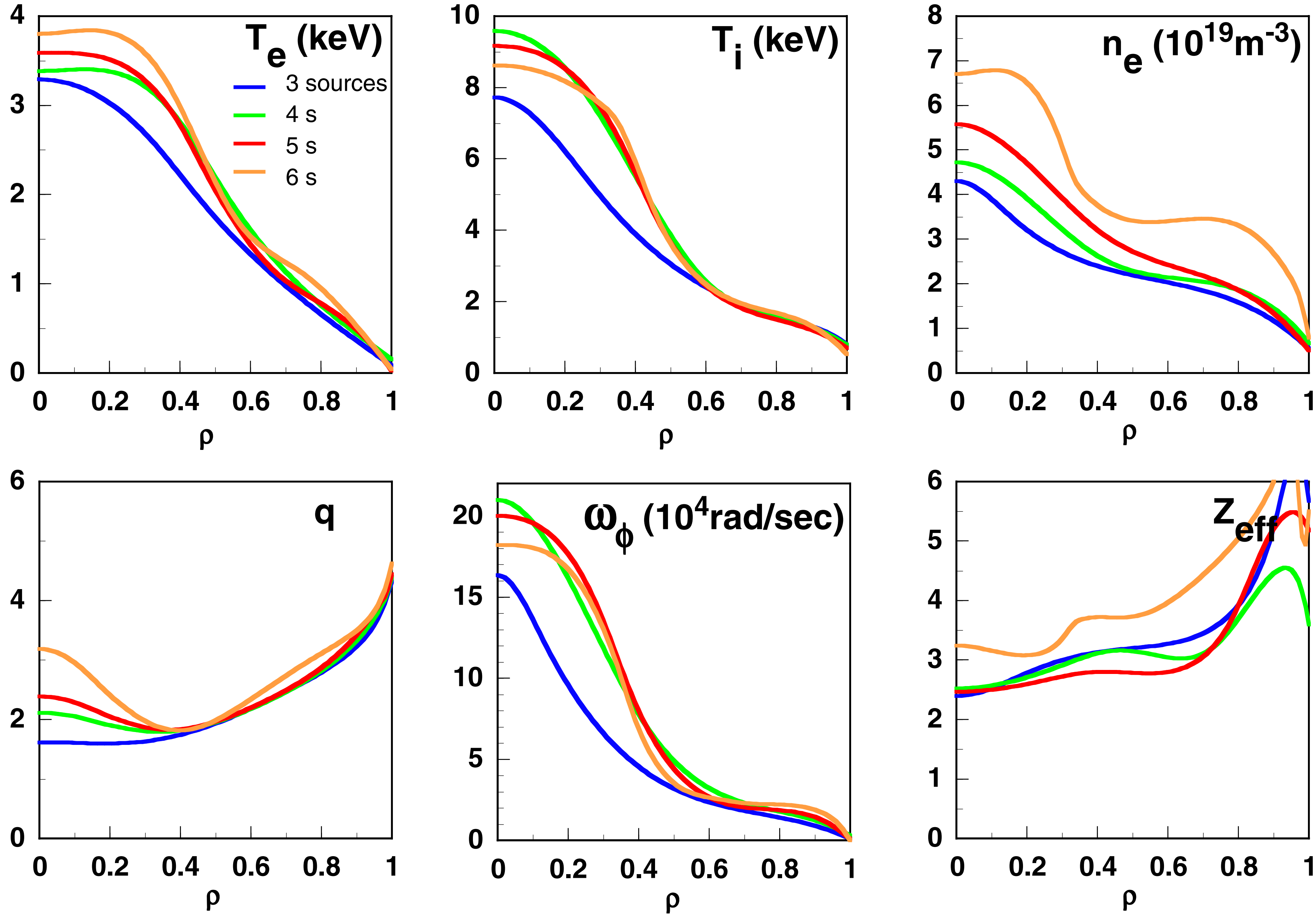
Profile Comparisons at 1009 ms



Profile Comparisons at 1109 ms



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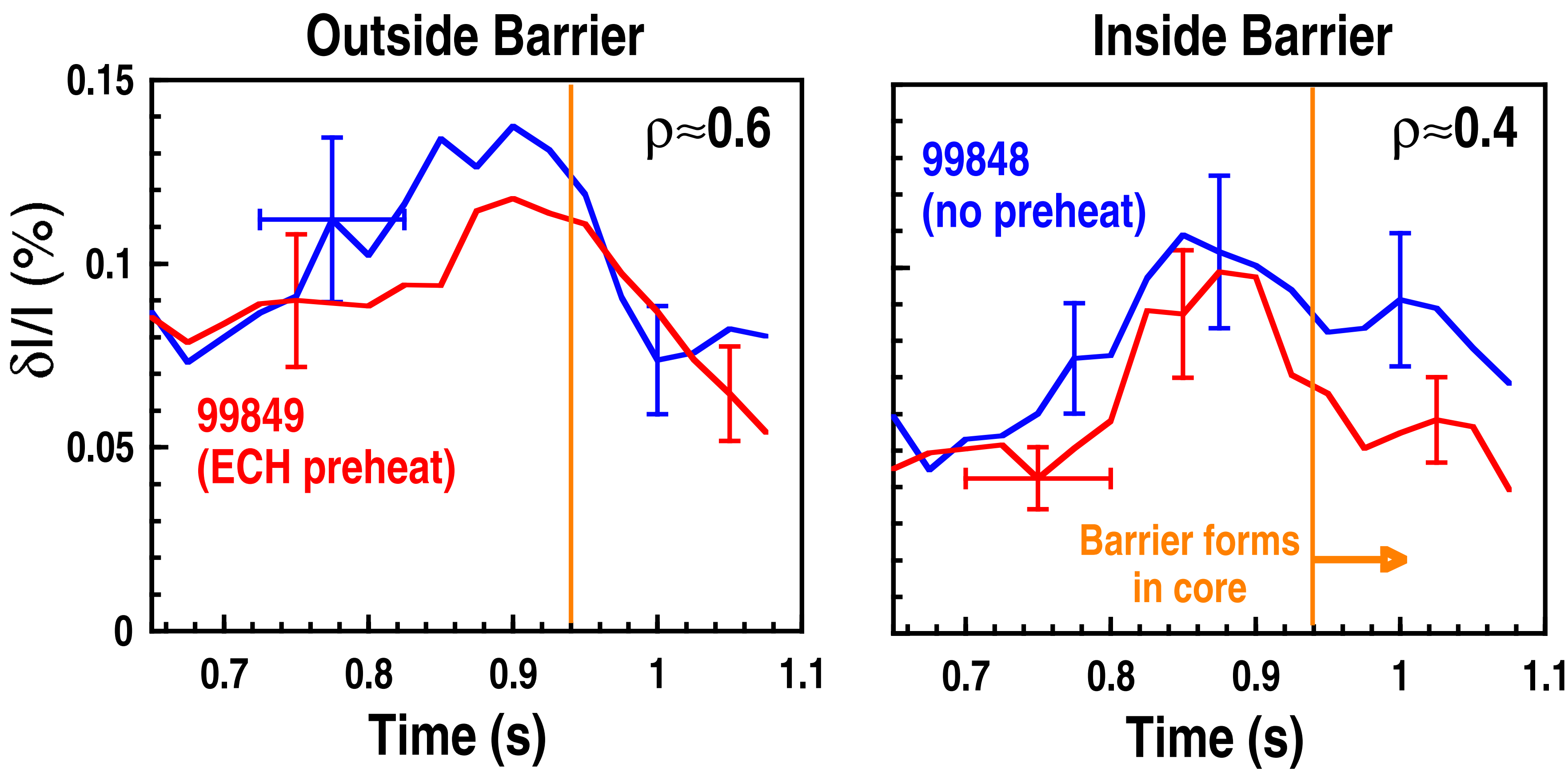
BES Fluctuations Are Lower Inside the Core Barrier for ECH Preheat Case

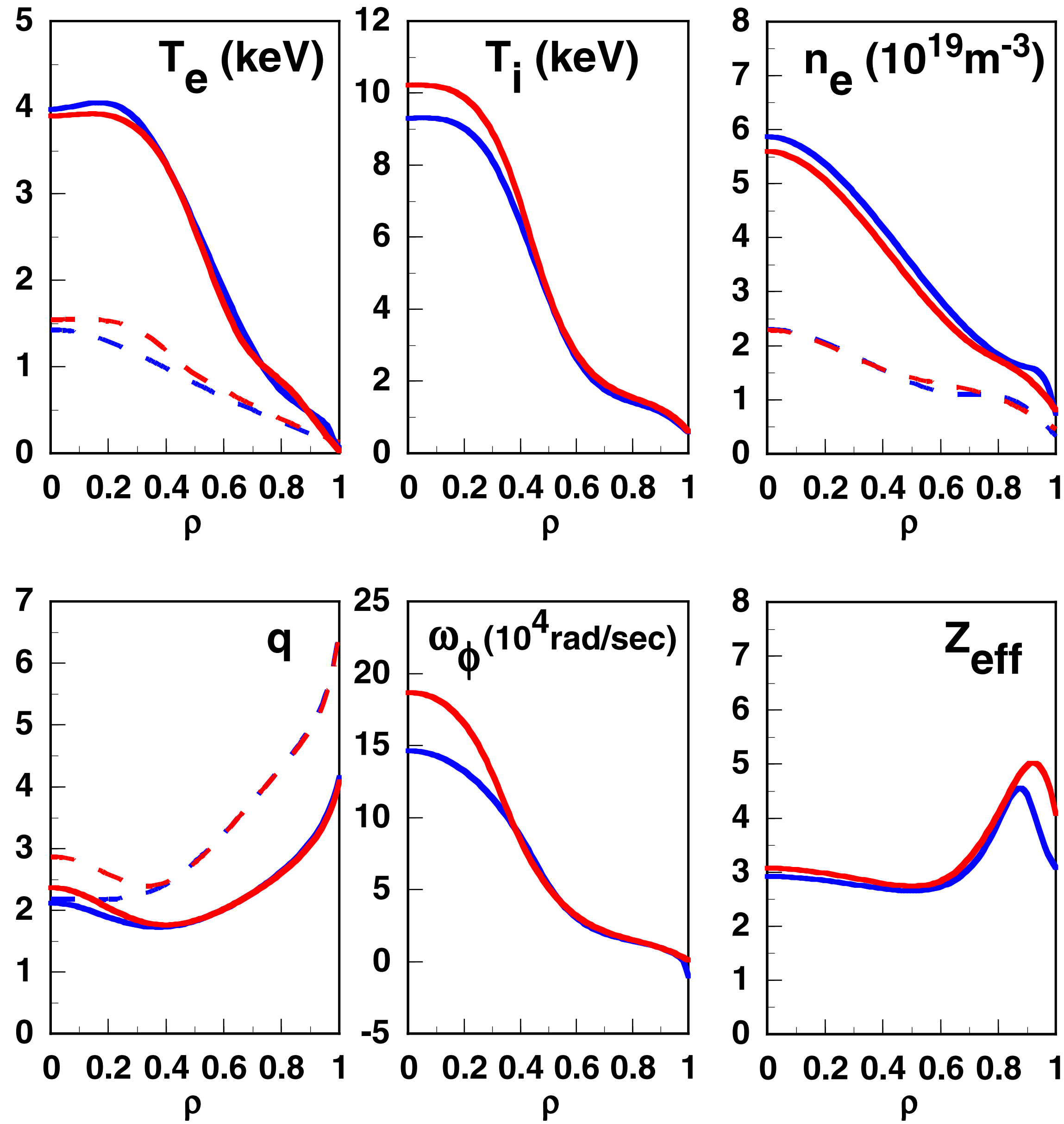
- long wavelength fluctuations $k_\theta \leq 1\ cm^{-1}$



ECH PREHEAT IS NOT A NECESSARY CONDITION FOR ITB FORMATION

99849 with ECH preheat
99848 without preheat

- At the end of the ECH pulse (dashed lines, 0.6 s) profiles are similar except the shear is reversed in the core and the Te profile is slightly broader due to ECH resonance at ρ=0.15
- At 1200 ms (solid lines, 1.2 s), near peak performance, the Ti and rotation profiles are slightly more peaked. The other profiles and overall performance are very similar



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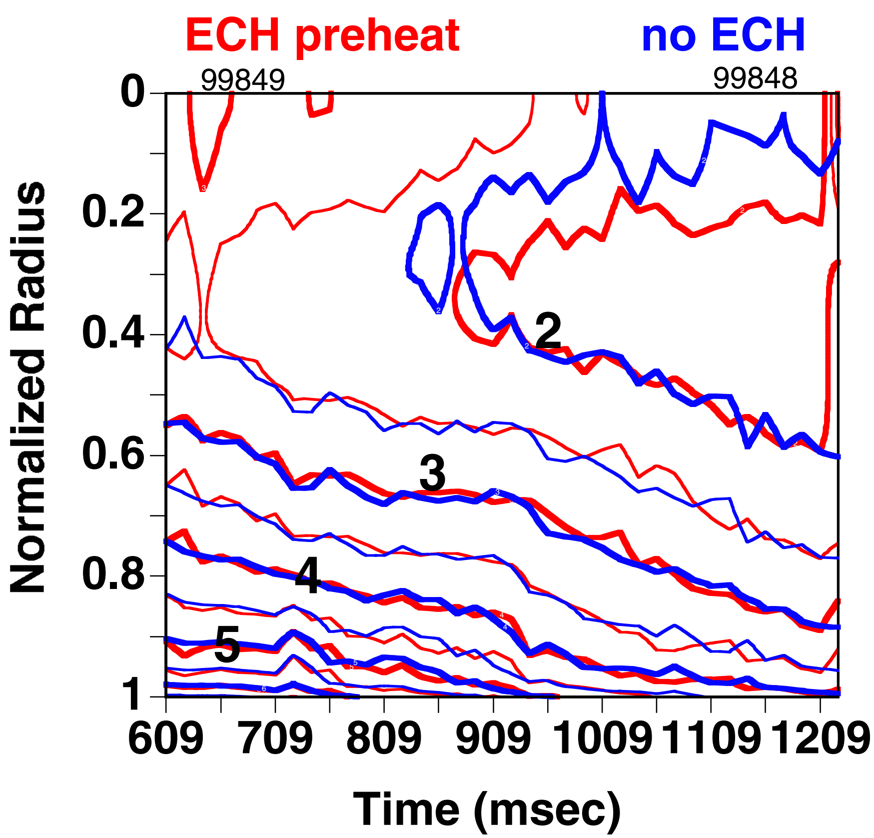
ECH Preheat Pulse Produces Slightly More Reversed Shear in the Plasma Core

- Contours of constant q differ primarily in the core $\rho \leq 0.4$



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Summary of Results From ITB Studies with Counter NBI

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