

Transitions to Improved Core Transport in DIII-D L-mode NCS Discharges

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Transitions to Improved Core Transport in DIII-D L-mode NCS Discharges¹ M.E. AUSTIN, K.W. GENTLE, University of Texas, K.H. BURRELL, C.C. PETTY, General Atomics, C.L. RETTIG, University of California, Los Angeles — Spontaneous increases in core electron and ion temperature and ion rotation velocity have been observed in DIII-D L-mode discharges with low density and early neutral beam injection. A reduction in turbulent fluctuation level is usually seen coincident with the changes. Many times these improvements in core confinement correlate with a low order rational q value coming into the plasma, but at other times they do not. We explore the possibility of a threshold for this transition by comparing integer q and non-integer q cases. We also investigate in this class of discharges the case with q_{\min} near 1, just before the onset of sawteeth. These discharges exhibit a state that lacks a well-defined layer of reduced thermal diffusivity as seen in higher q transitions but instead exhibits a broad overall improvement in confinement.

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Abstract

Discharges with spontaneous increases in core electron and ion temperature and ion rotation velocity have been observed in DIII-D L-mode discharges with low density and early neutral beam injection. A reduction in turbulent fluctuation level is usually seen coincident with the changes. Many times these improvements in core confinement correlate with a low order rational q value coming into the plasma, but at other times they do not. We explore the possibility of a threshold for this transition by comparing integer q and non-integer q cases. We also investigate in this class of discharges the case with q_{\min} near 1, just before the onset of sawteeth, a state that lacks a well defined layer of reduced thermal diffusivity as seen in higher q transitions but instead exhibits a broad overall improvement in confinement.



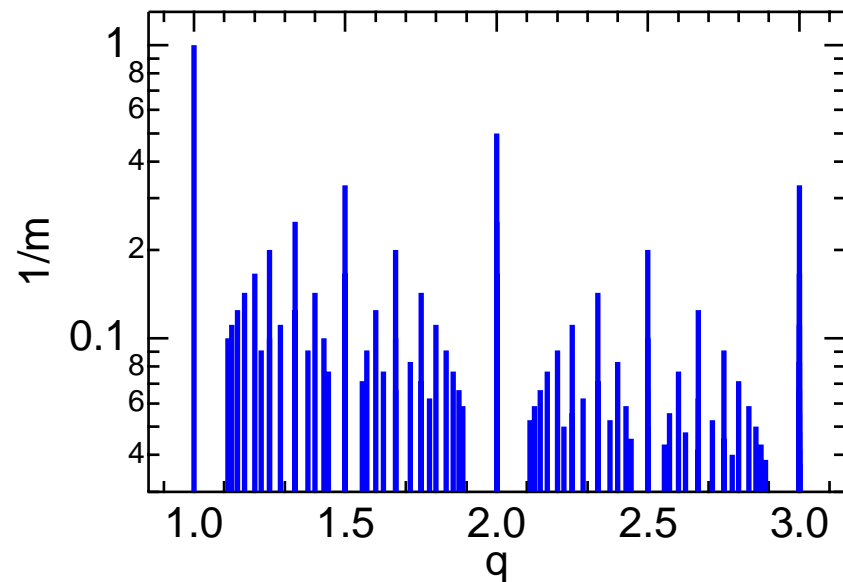
Motivation

In low density L-mode negative central shear discharges (NCS), changes in transport are observed that correlate with the emergence of low-order rational q surfaces in the plasma.

These observations evoke the following questions:

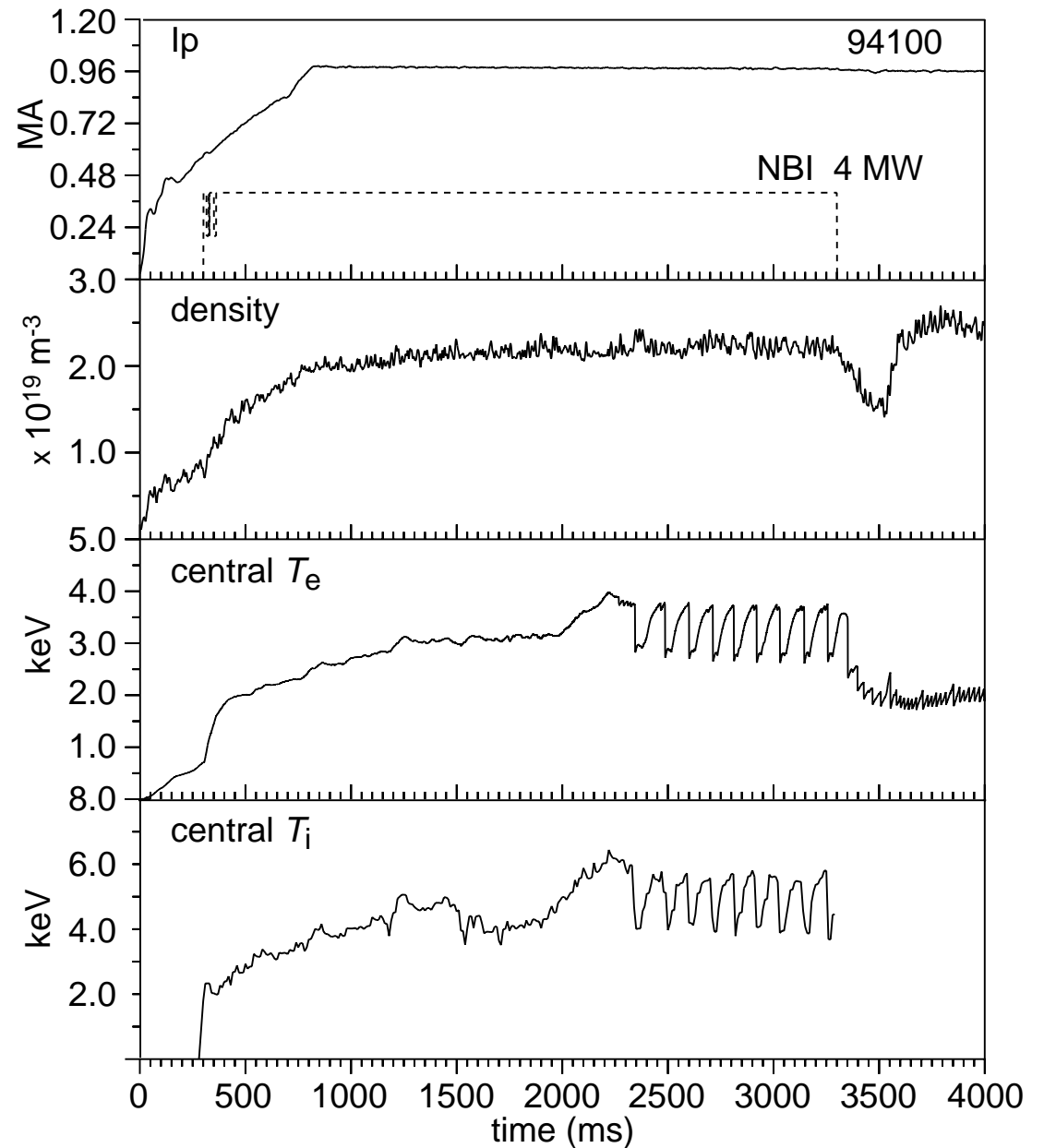
Are the transport changes related to the “good” surfaces near low-order rational q surfaces — or, are the changes instead related to some sort of convective phenomenon associated with rational q values?

Plot of low-order rational $q=m/n$ with $n \leq 9$.



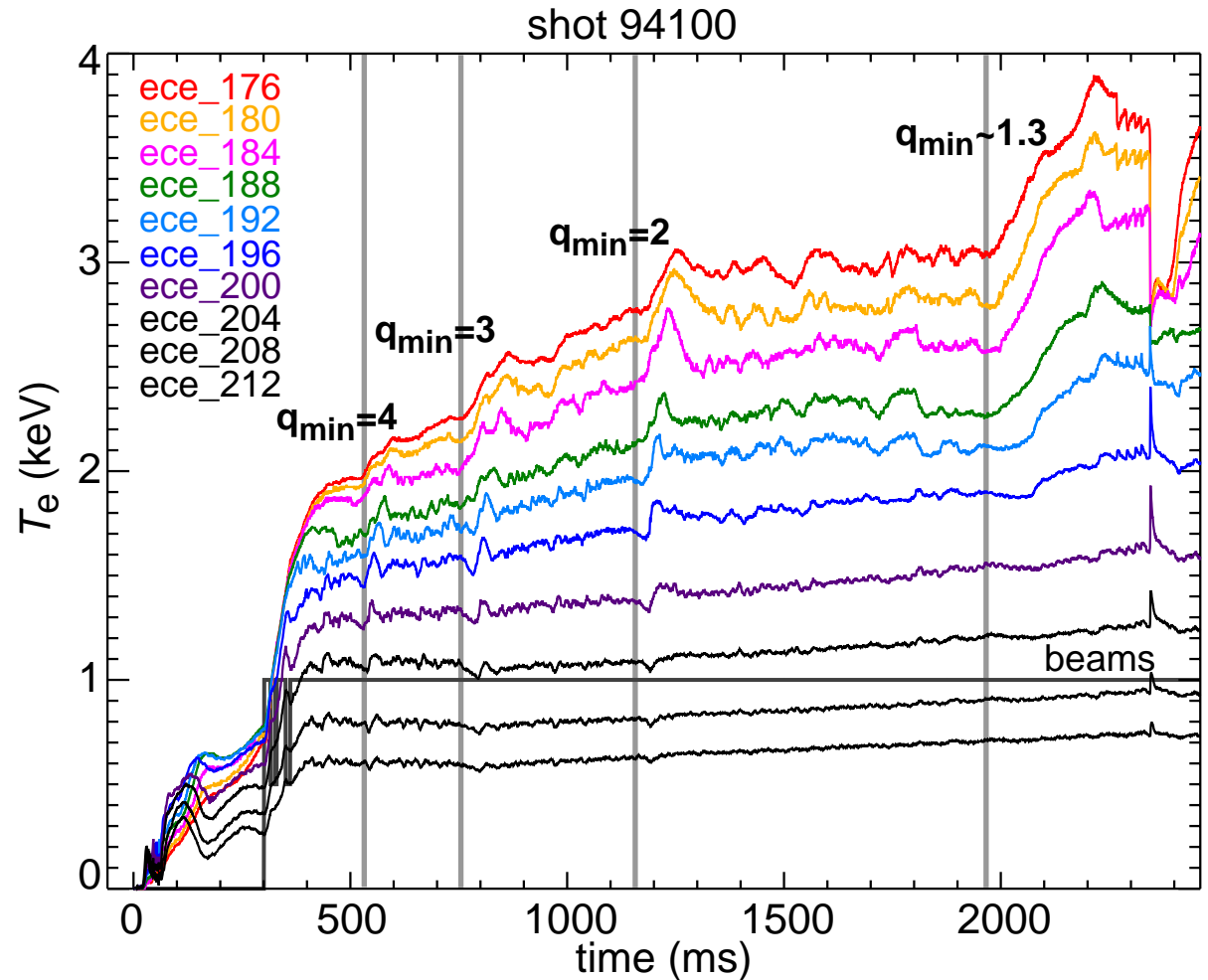
Characteristic Discharge

- moderate NBI power
- L-mode
- low density
- neg. central shear (NCS)



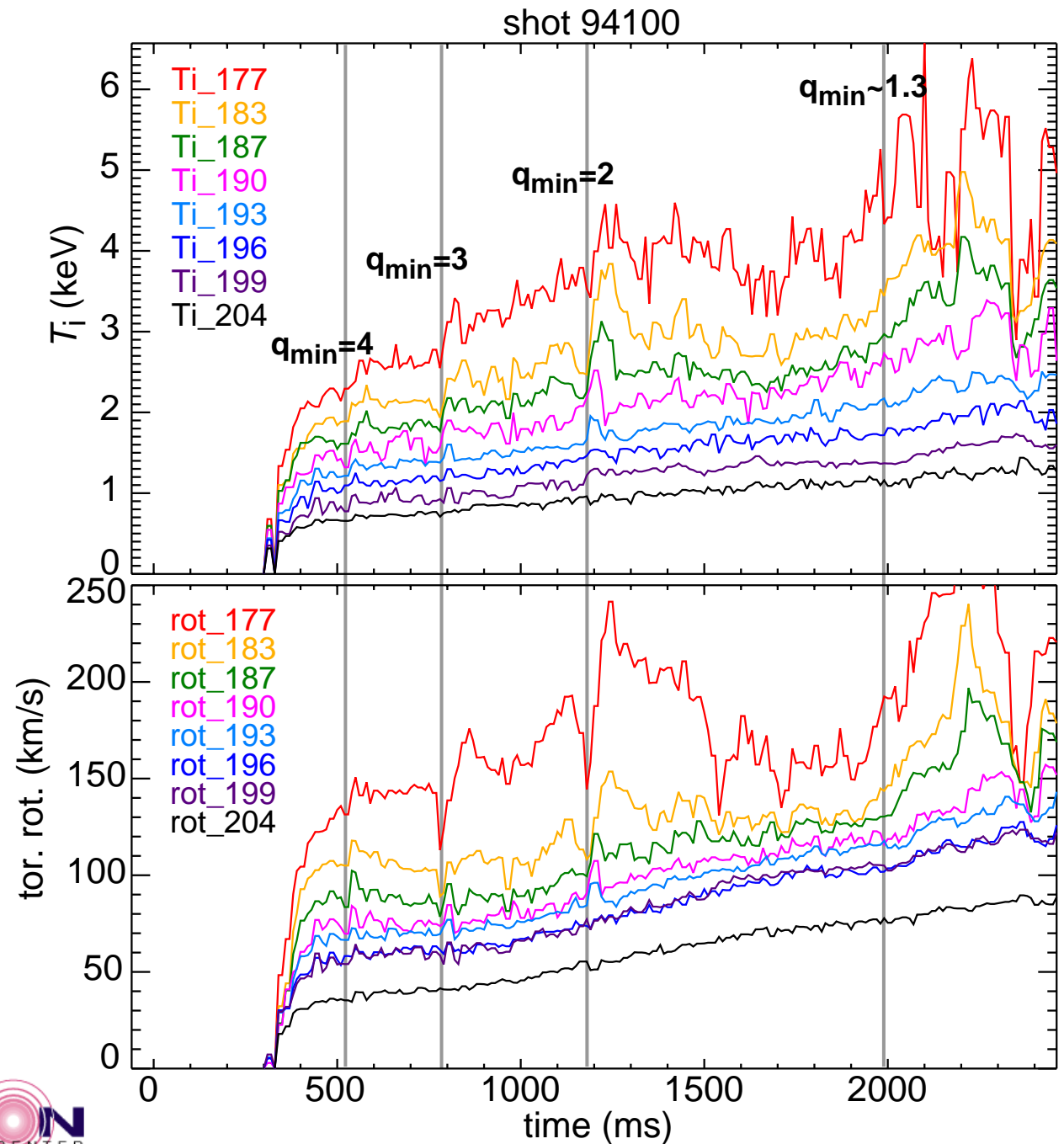
q-related changes seen in T_e at constant heating power

Electron temperature data from a typical L-mode NCS discharge with transient transport changes.



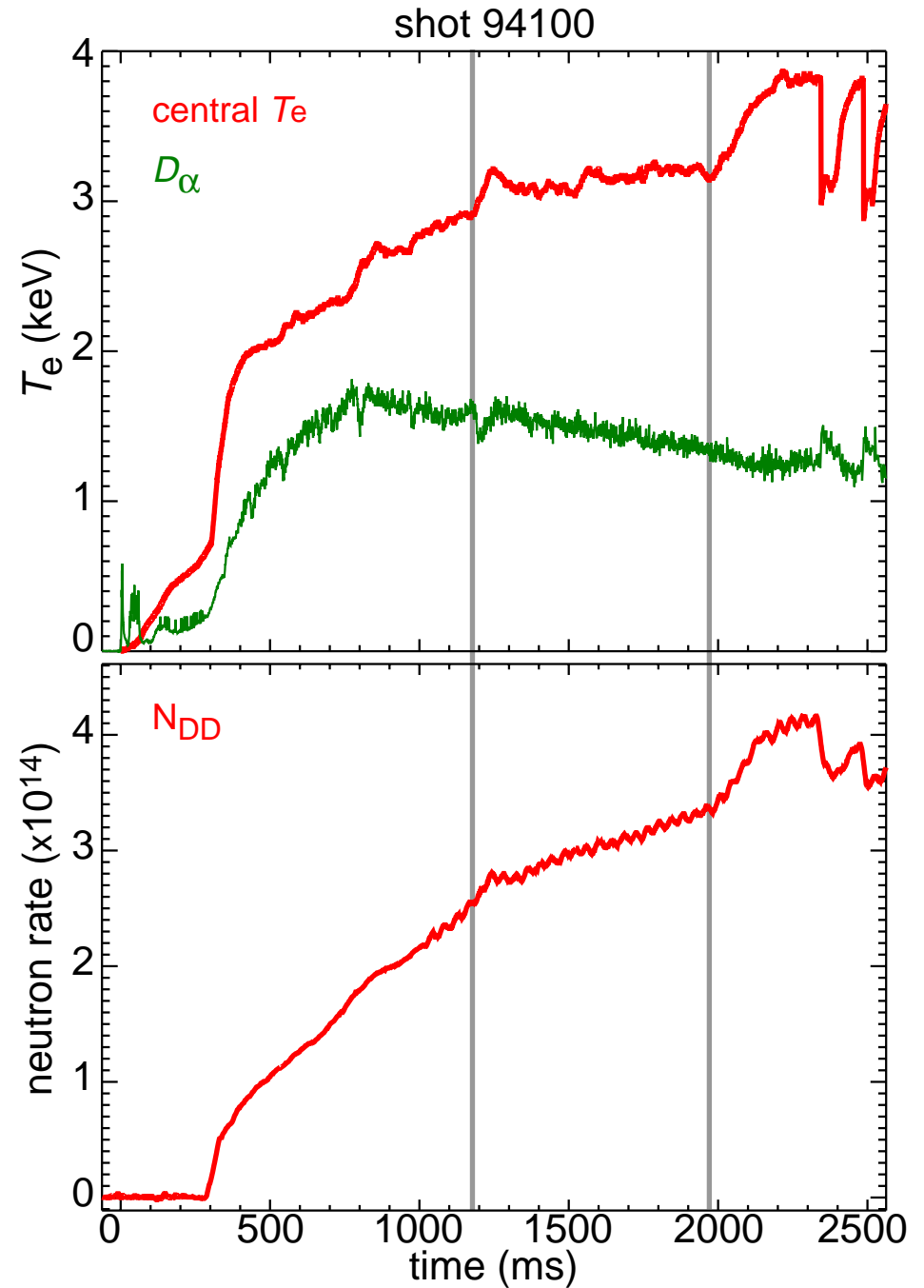
q-related changes
also seen in T_i , v_ϕ .

- Dips in central ion temperature and toroidal rotation are seen just before jumps
- Similar dips do not occur in central electron temperature

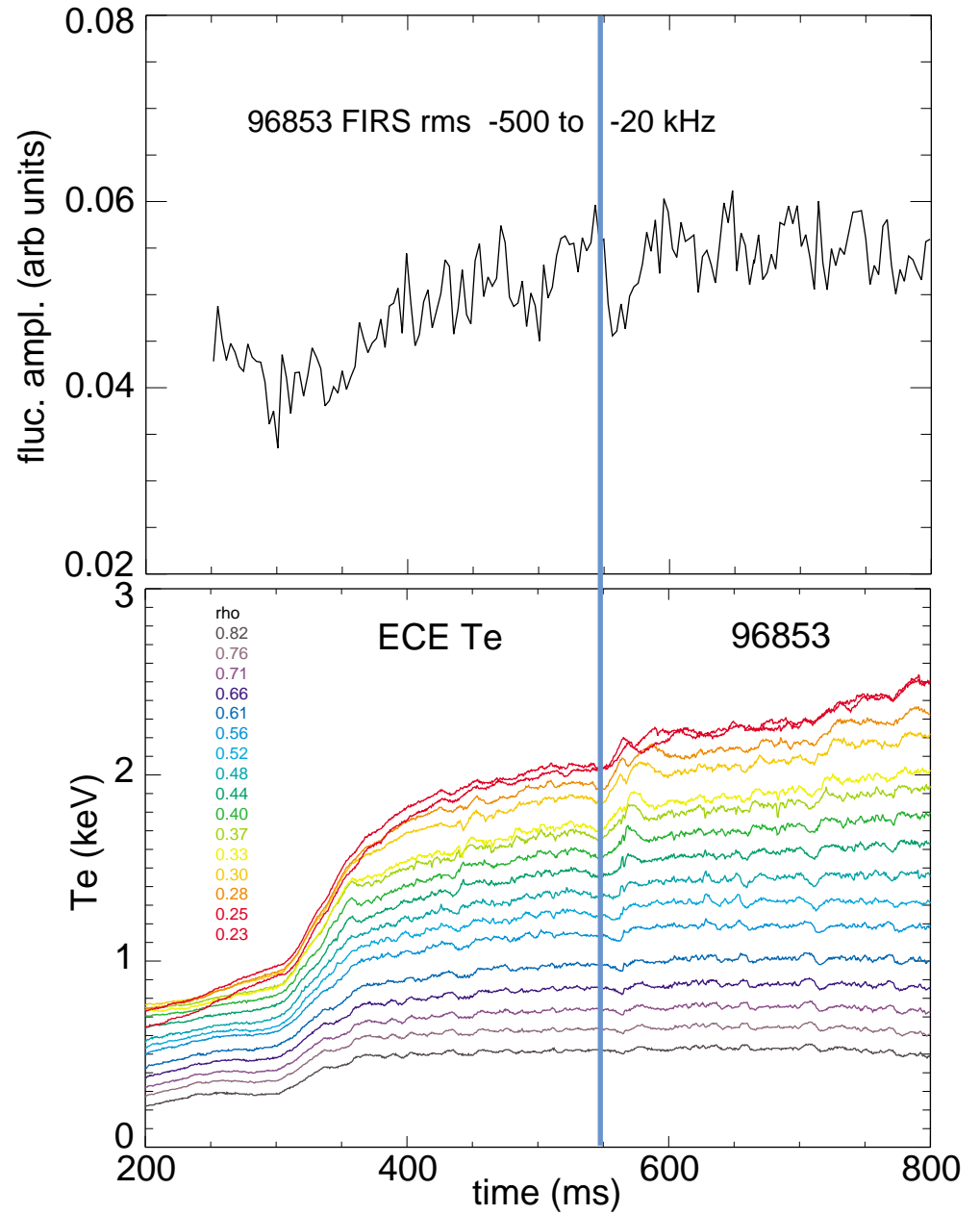
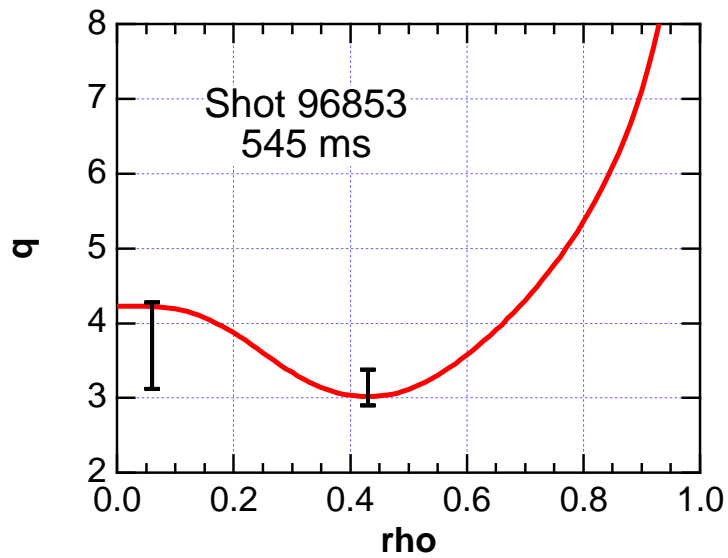


Other indicators of improved transport

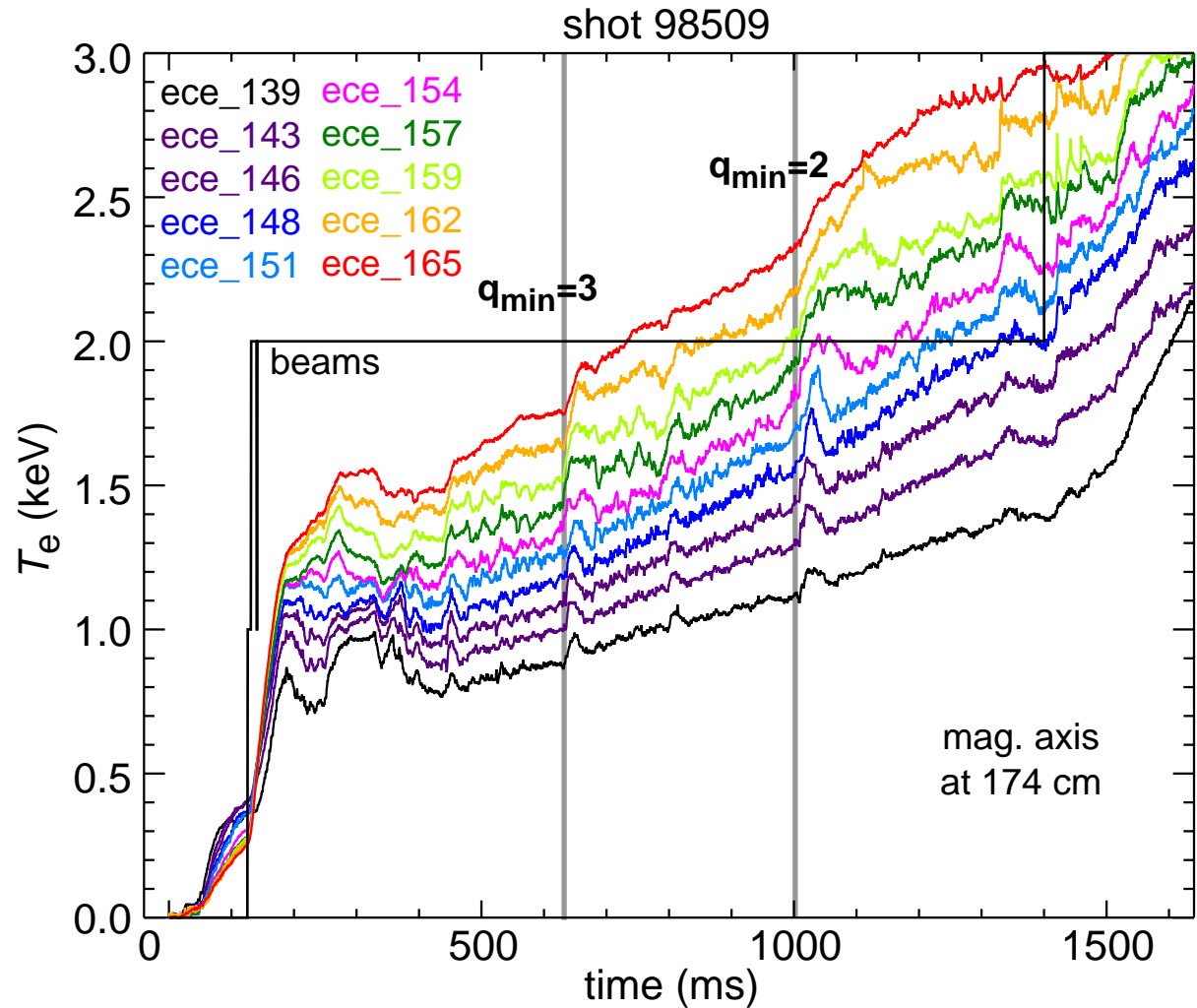
- Besides the jumps in temperature, improved confinement is indicated in the changes in neutron rate and plasma β .
- A drop in edge heat/particle flux (D_α) is also a common feature of the transient jumps.



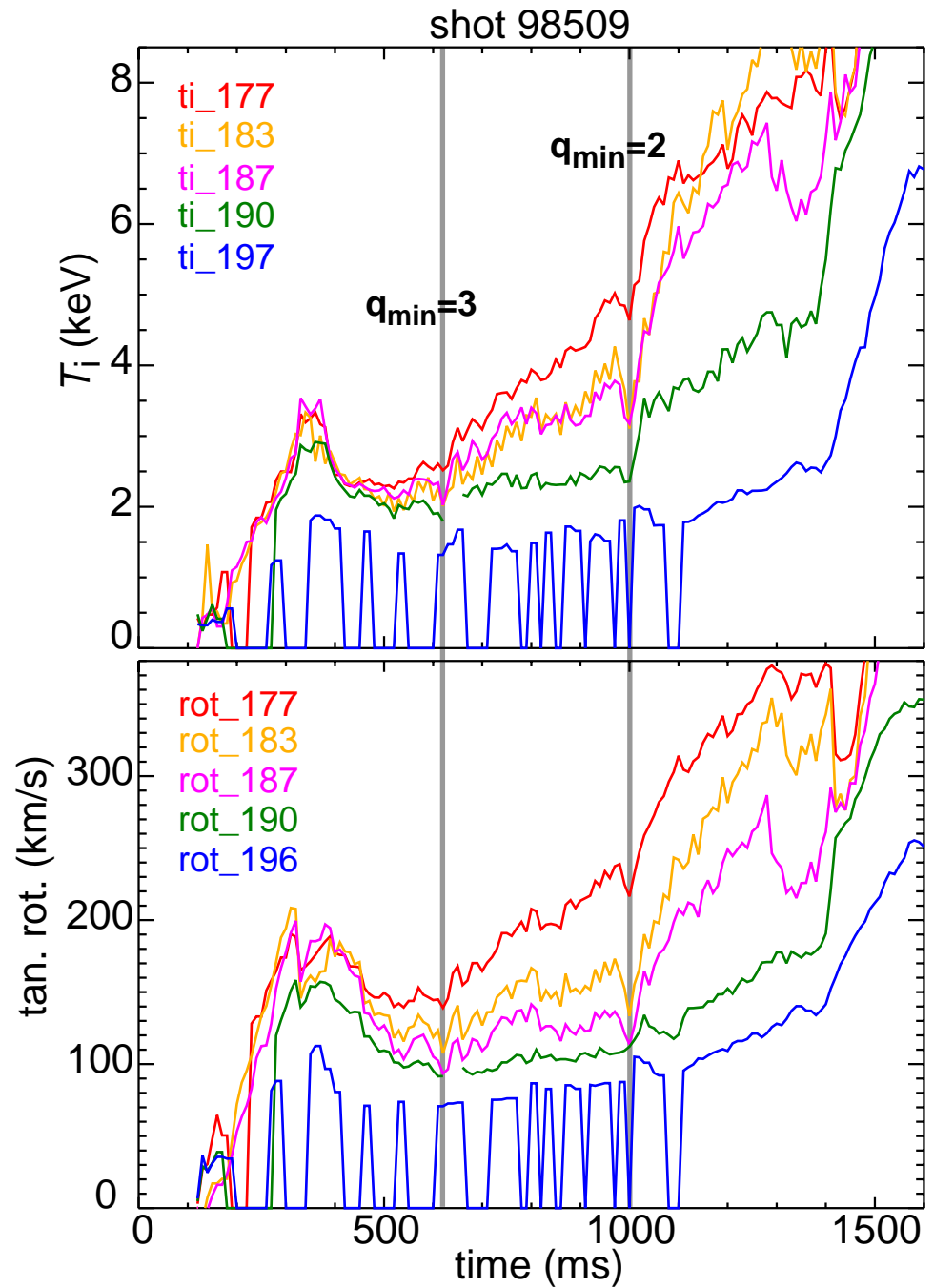
- Transient reductions in turbulent fluctuations are seen coincident with temperature jumps



- Another example of transient transport changes near integer q_{\min}
- Changes visible near half integer also
- Low B_t shot (1.6T)–ECE T_e measurements are from high-field side

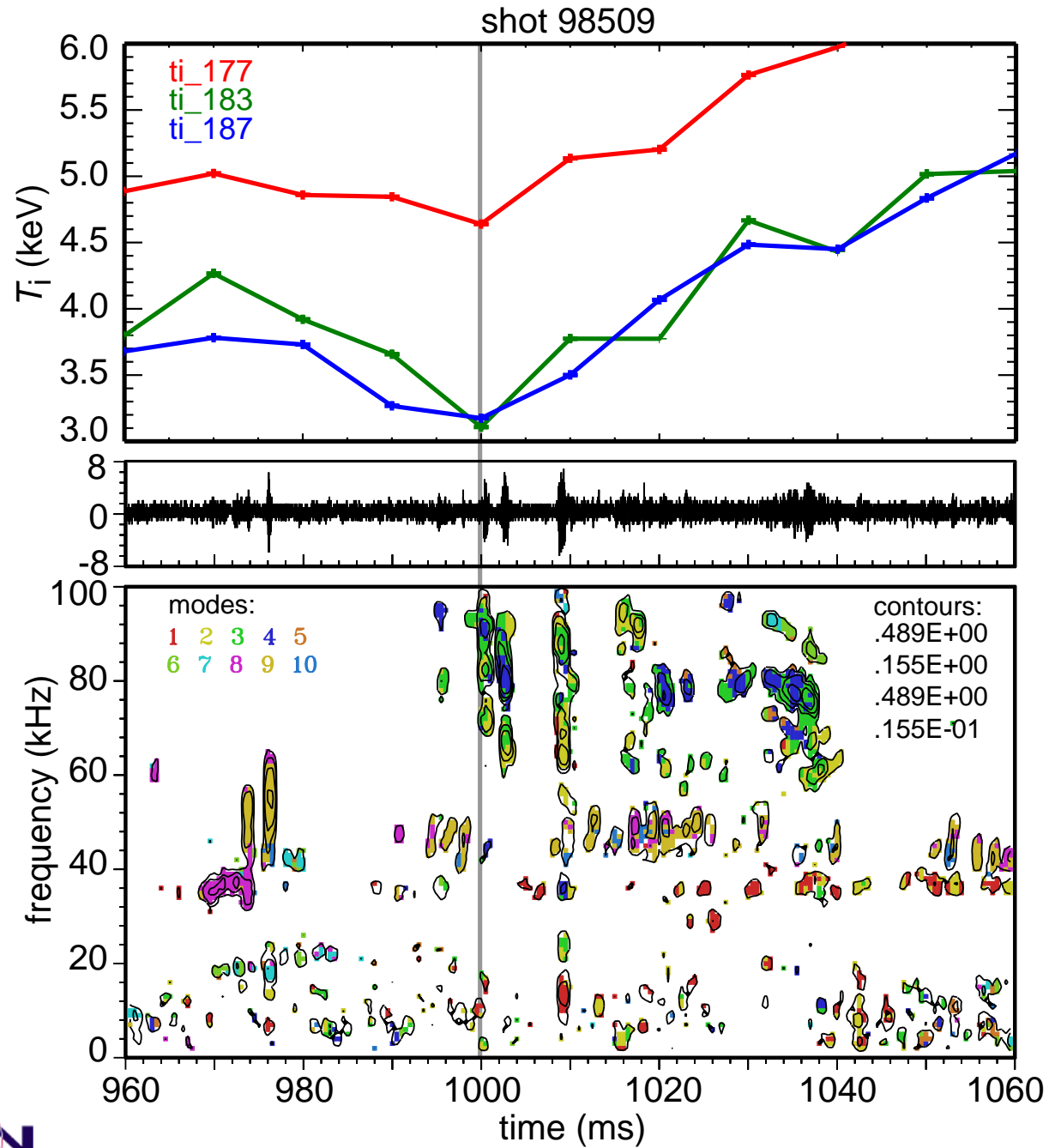


- Ion temperature and toroidal rotation traces for the same shot
- T_i and v_ϕ show signs of an internal transport barrier



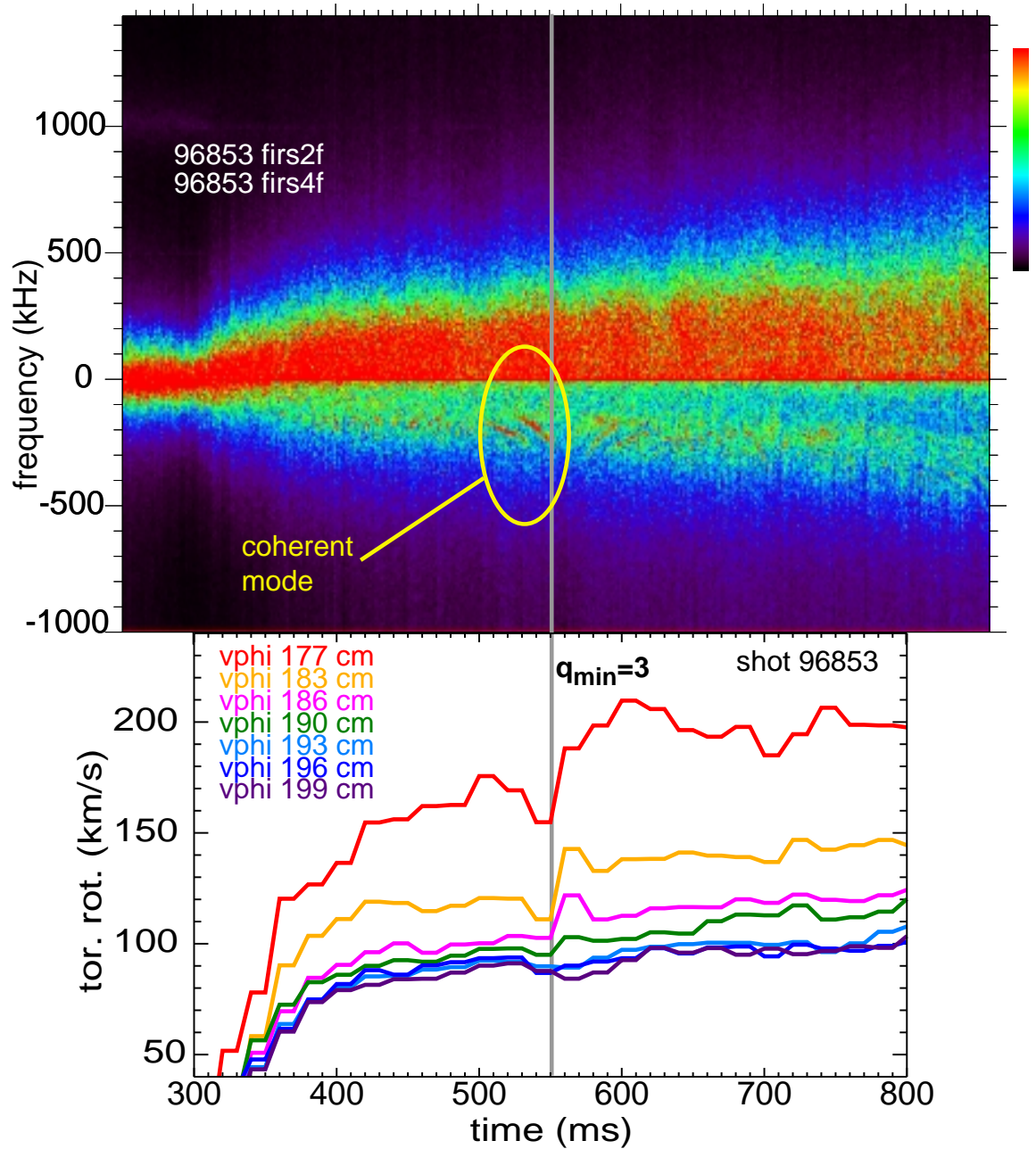
Dips in T_i , v_ϕ —what is the cause?

- High-n modes with a bursting nature often appear
- Have not been able to identify the m-number



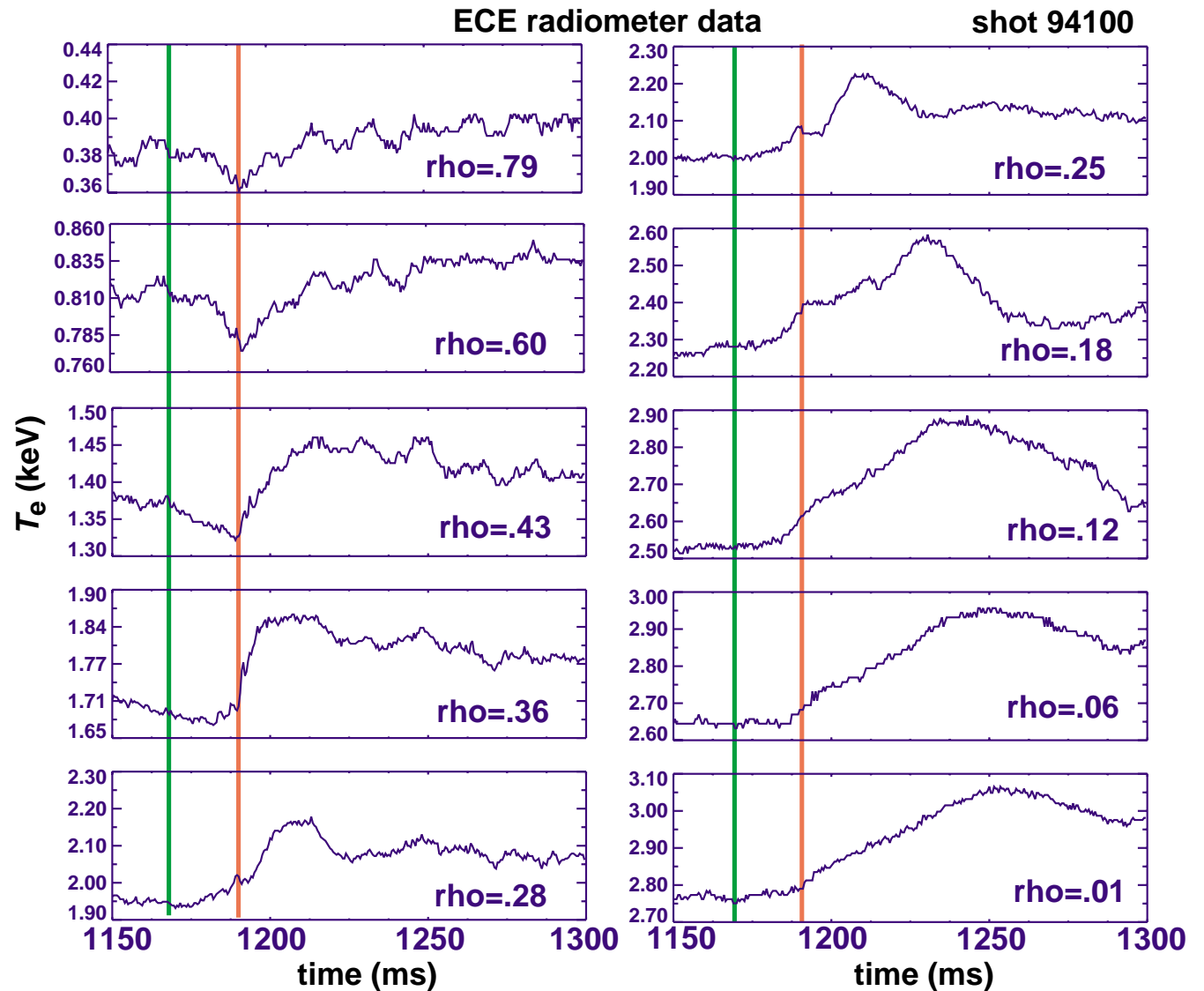
Ion losses may be due to high frequency modes

- High frequency “chirping” modes are often seen just before jumps.
- May be related to Alfvén eigenmodes.



A close look at the electron temperature

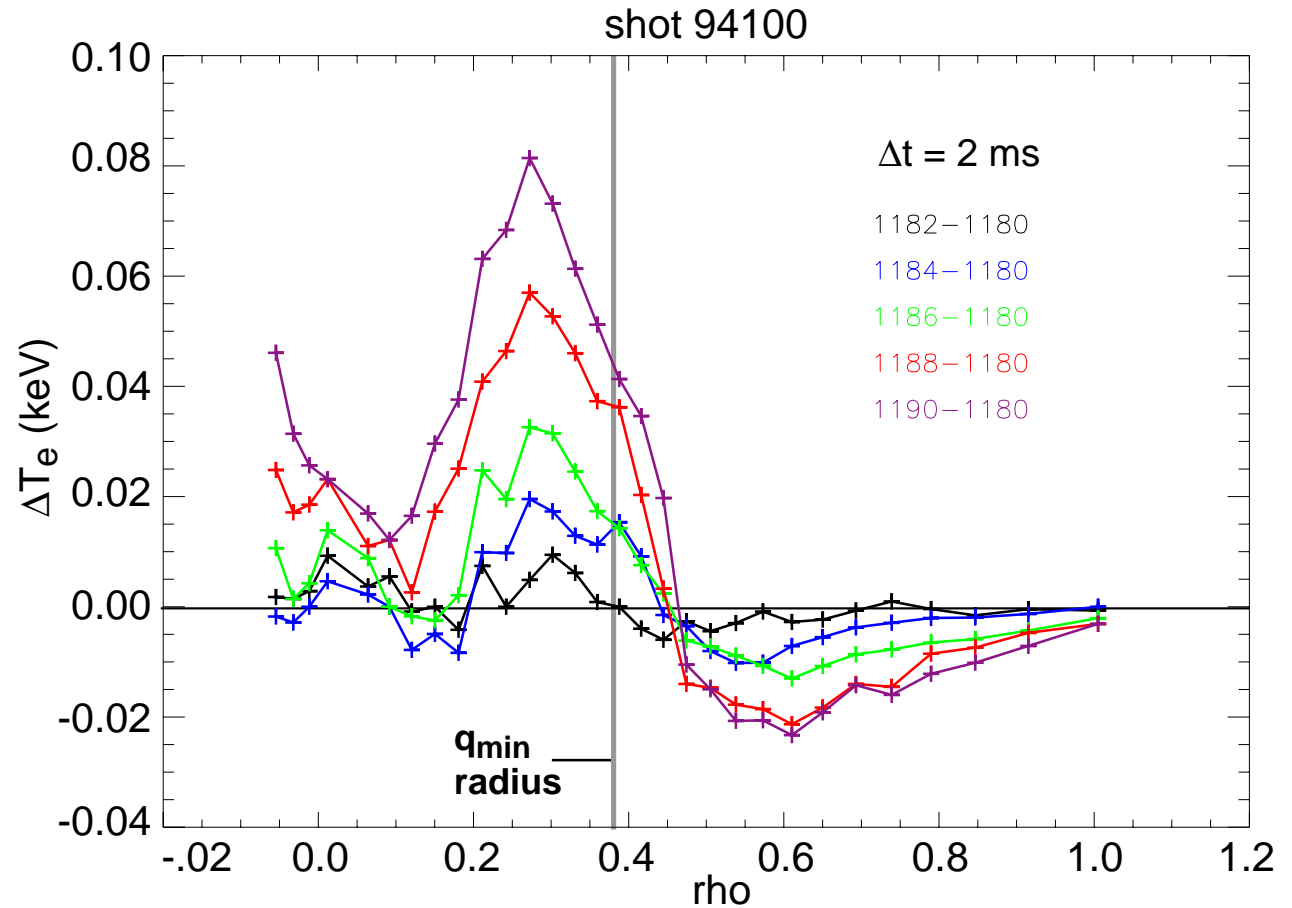
- In the early stage of the transition, outer radii see decrease in T_e as inner radii see increase
- In latter stage, the increase occurs on all channels and propagates inward



Change in T_e near

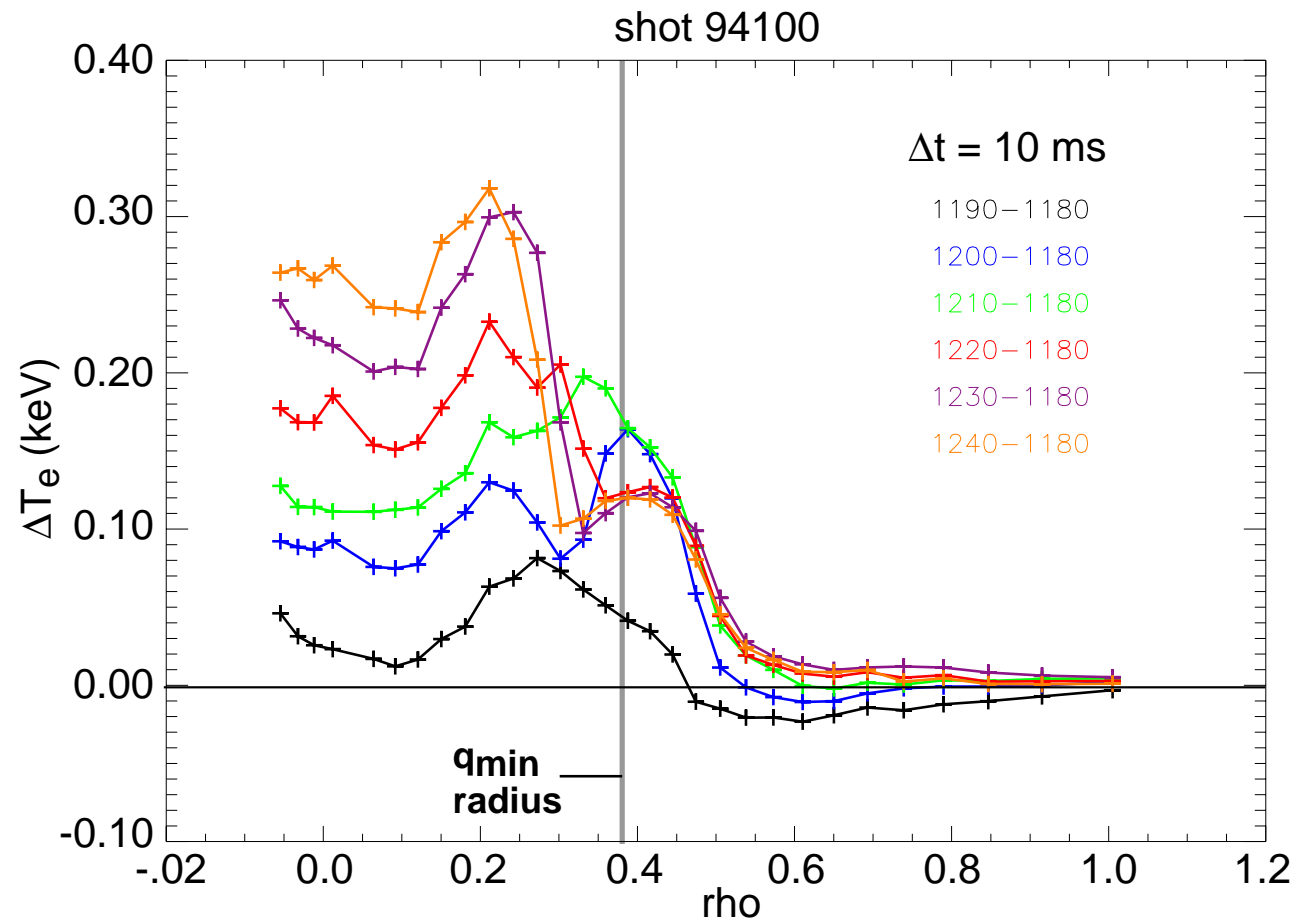
$$q_{\min} = 2$$

- ΔT_e profile exhibits peaking-up in early stage— increase inside of $\rho_{q_{\min}}$ and decrease outside



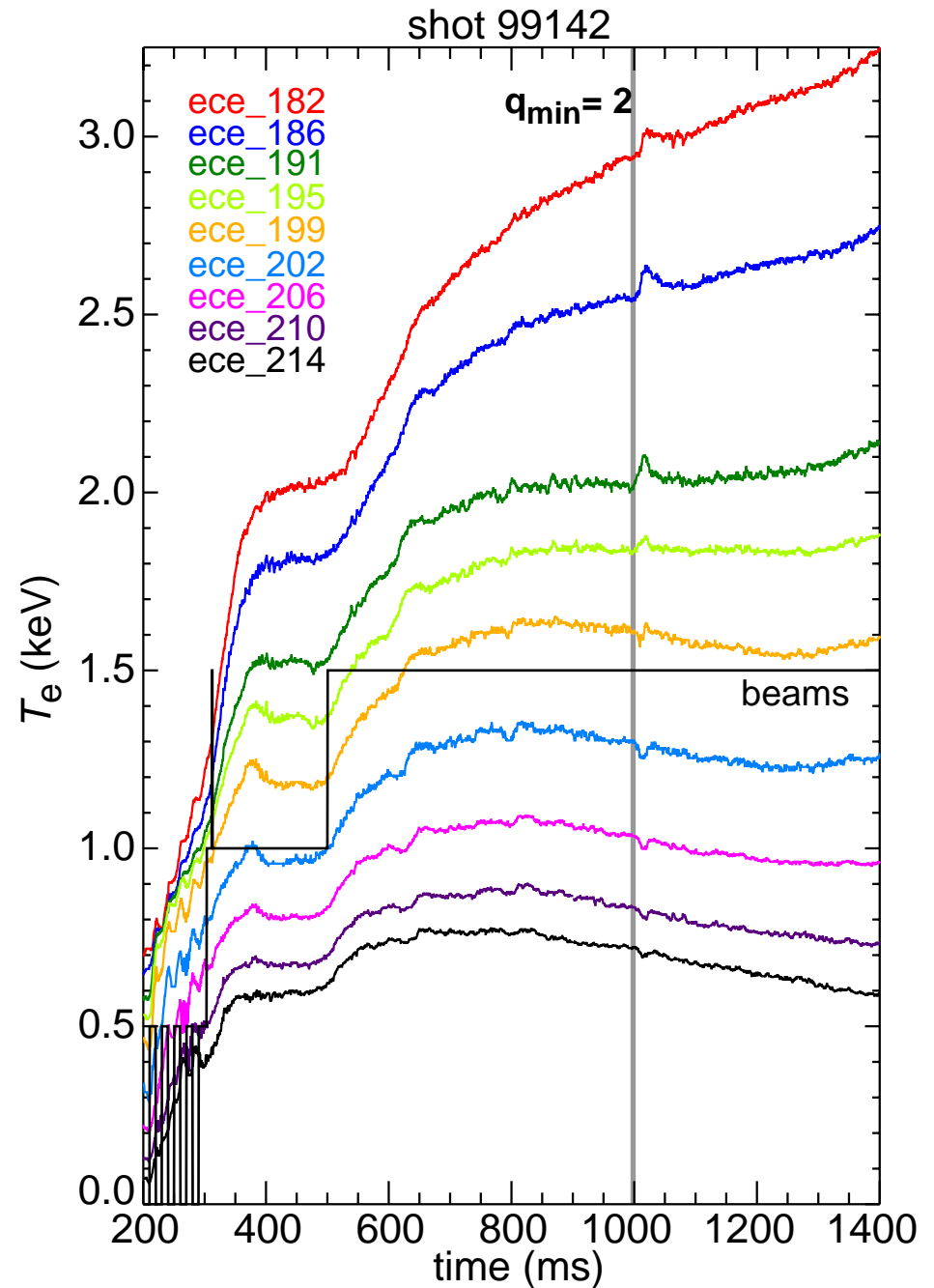
Change in T_e near $q_{\min} = 2$

- In later stage, ΔT_e profile shows only increase at inner radii with dips near $\rho_{q_{\min}}$ — possible reconnection?



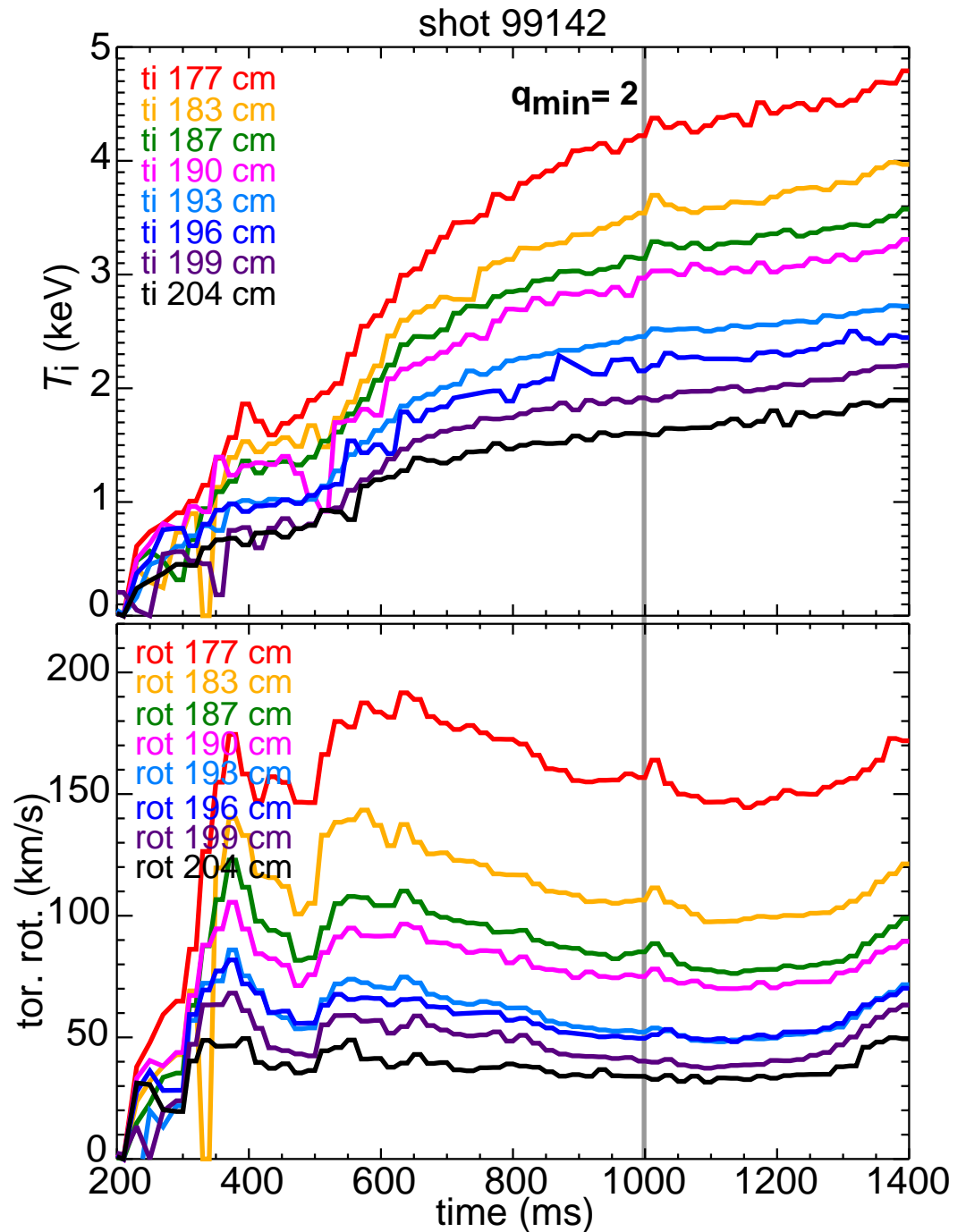
T_e near integer q_{\min} in counter-injection discharges

- Jumps in temperature have also been seen in counter-NBI discharges
- Effect tends to be smaller and shorter lived



T_i and v_ϕ near integer q_{\min} in counter injection discharges

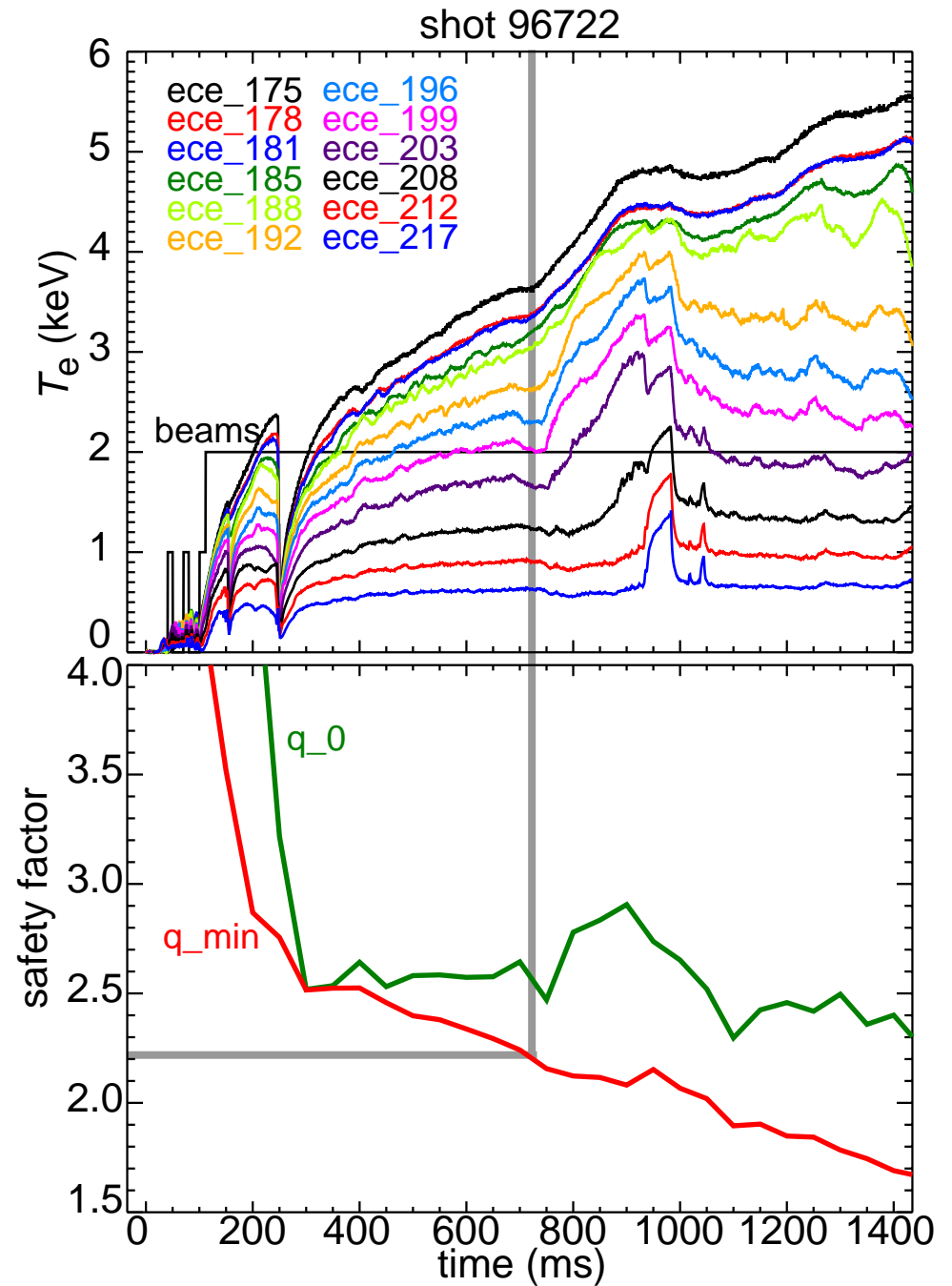
- Change in ion temperature and rotation is nearly imperceptible in counter-NBI
- Injected power level is higher than comparable co-injection shots



Temperature steps seen at non-integer

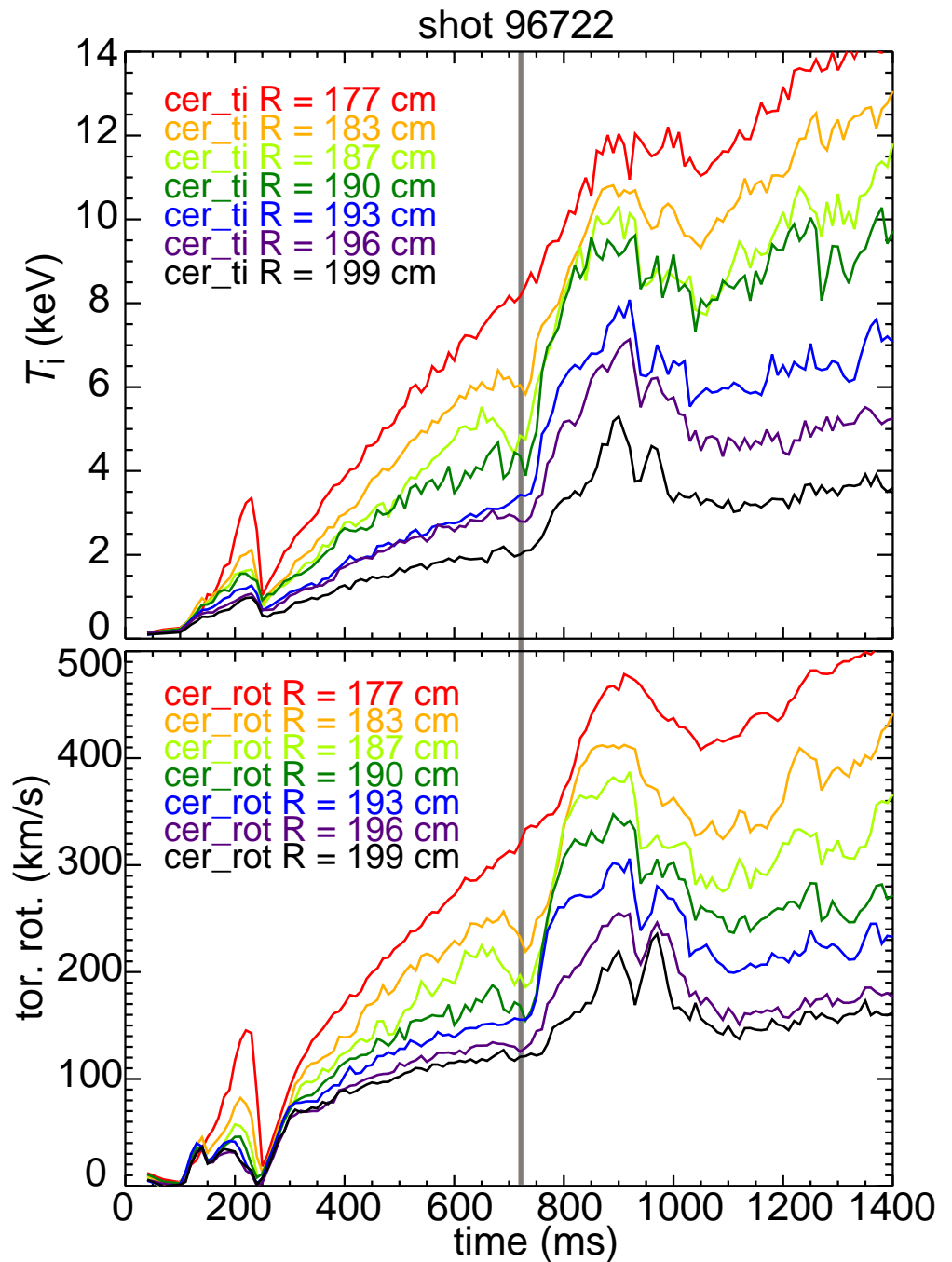
q_{\min}

- Temperature jumps are sometimes observed in discharges at values of q_{\min} that are not integer or half-integer
- T_e behavior is similar to integer q_{\min} case
 –decrease at outer radii,
 increase near core



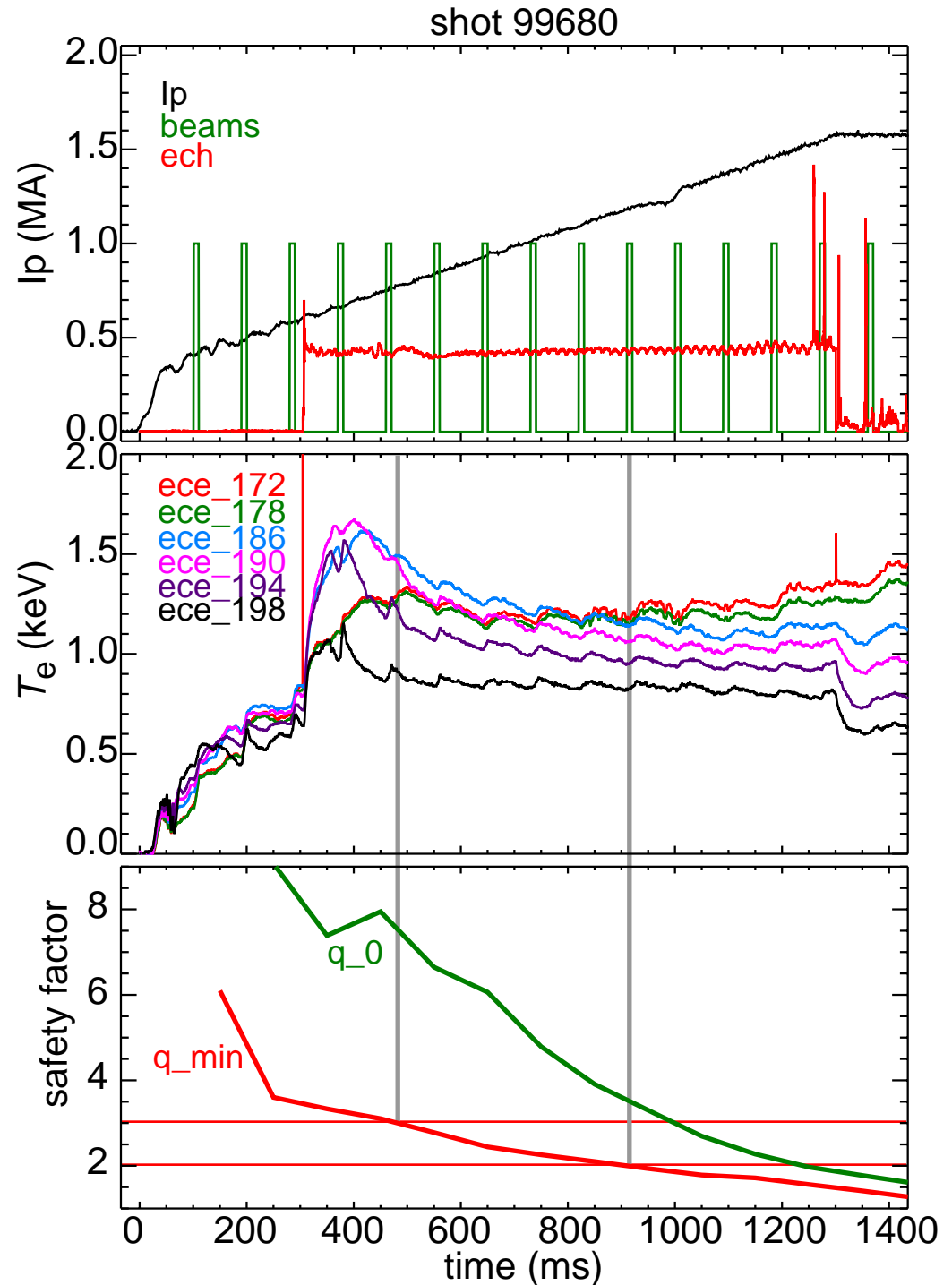
T_i steps seen at non-integer q_{\min}

- Increase in T_i , v_ϕ is due to formation of internal transport barrier
- Again, similar behavior as integer q_{\min} case—dips in T_i and v_ϕ just before jumps



NCS discharge without temperature jumps

- An L-mode, low density, negative central shear discharge with ECH & beam blips
- No temperature jumps observed as q_{\min} passes through integer values
- May implicate fast ions playing a role in transient transport changes



Summary

- Jumps in temperature that occur near low-order rational q_{\min} in DIII-D NCS discharges are transient changes to a state of improved confinement.
- Some aspects of the transitions or steps show that the transport changes are not entirely diffusive—reconnection-like events are seen.
- Observation of the phenomenon only in NBI discharges may indicate that fast ions play a role.
- No consistent MHD mode has been observed with the transitions but very high frequency coherent modes (Alfvenic modes?) seem to be linked to them.
- The transient changes that occur for q_{\min} values ≥ 2 are similar to the more robust changes at $q_{\min} \sim 1.3 \Rightarrow$ same mechanism.
- Cases of temperature jumps seen without integer or half-integer q_{\min} values present may imply a mechanism that does not *require* proximity to low-order rational q but simply occurs more readily there.

