DIII-D ohmic current driven RWM experiments with feedback stabilization

by
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for
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DIII-D NATIONAL FUSION FACILITY

GENERAL ATOMICS

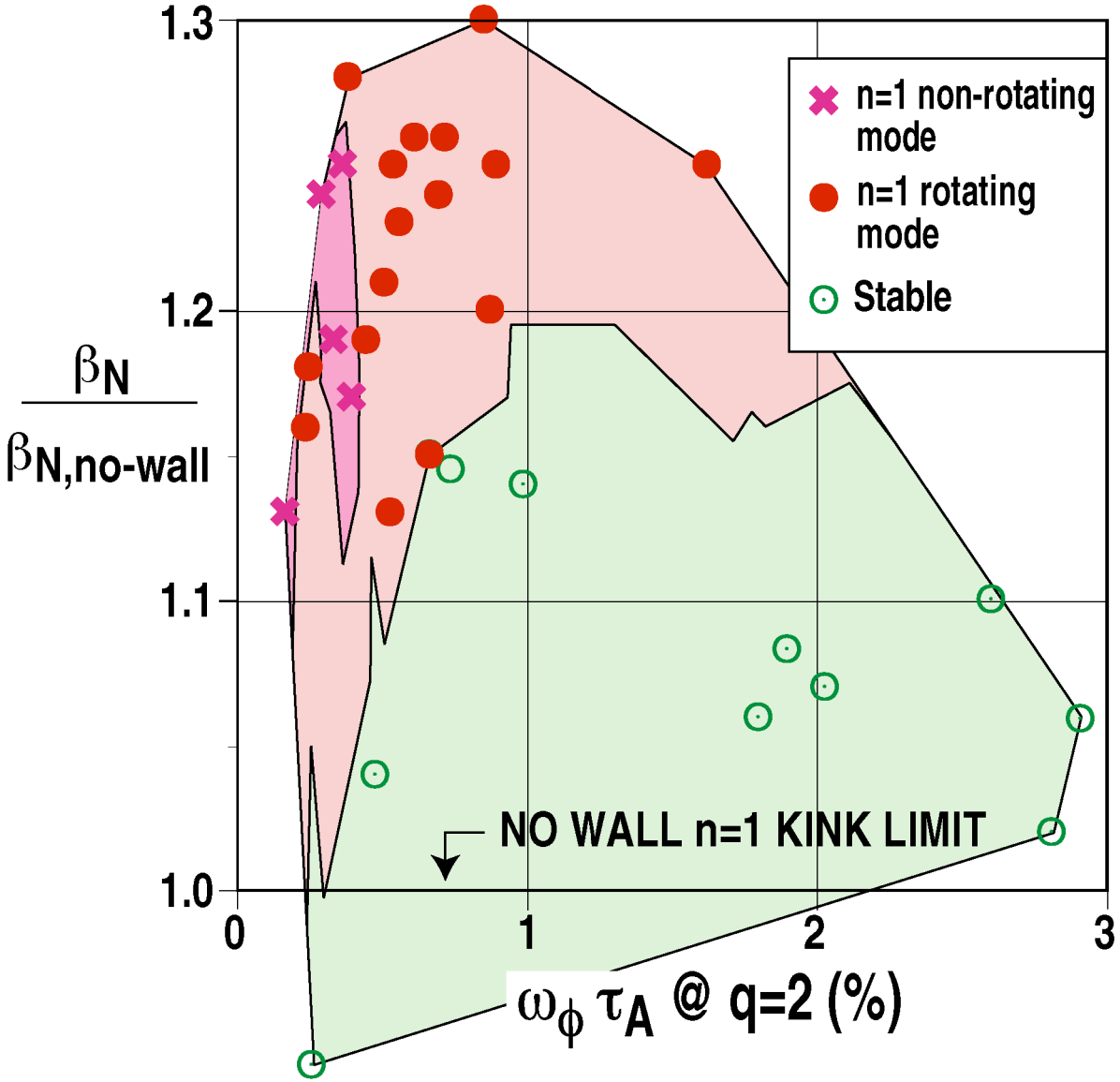
OUTLINE

- Motivation
- Temporal behavior of current driven ohmic RWMs
- Characteristics of current driven RWMs
  - q, j profiles
  - poloidal m number
  - Te profiles
- Feedback control
- Summary

CURRENT DRIVEN RWMs CAN BE USEFUL FOR STUDYING RWM PHYSICS AND FEEDBACK CONTROL

- Ohmic plasmas
  - Kinetic stabilization is negligible
- Low Beta and low rotation
  - Bootstrap current effects are minimized (no NTMs)
- Connect with RFP studies
  - Multimode feedback stabilization
- Current driven RWMs (q=3) have been previously observed in JT-60U and HBT
  - (Matsunaga, et. al, PPCF 2007)
- Useful for optimizing RWM feedback stabilization
- Initial experiments in DIII-D showed RWM-like behavior
- ITER relevent

HIGH β_N, LOW ROTATION DIII-D DISCHARGES OFTEN SHOW A MIX OF MHD MODE ACTIVITY



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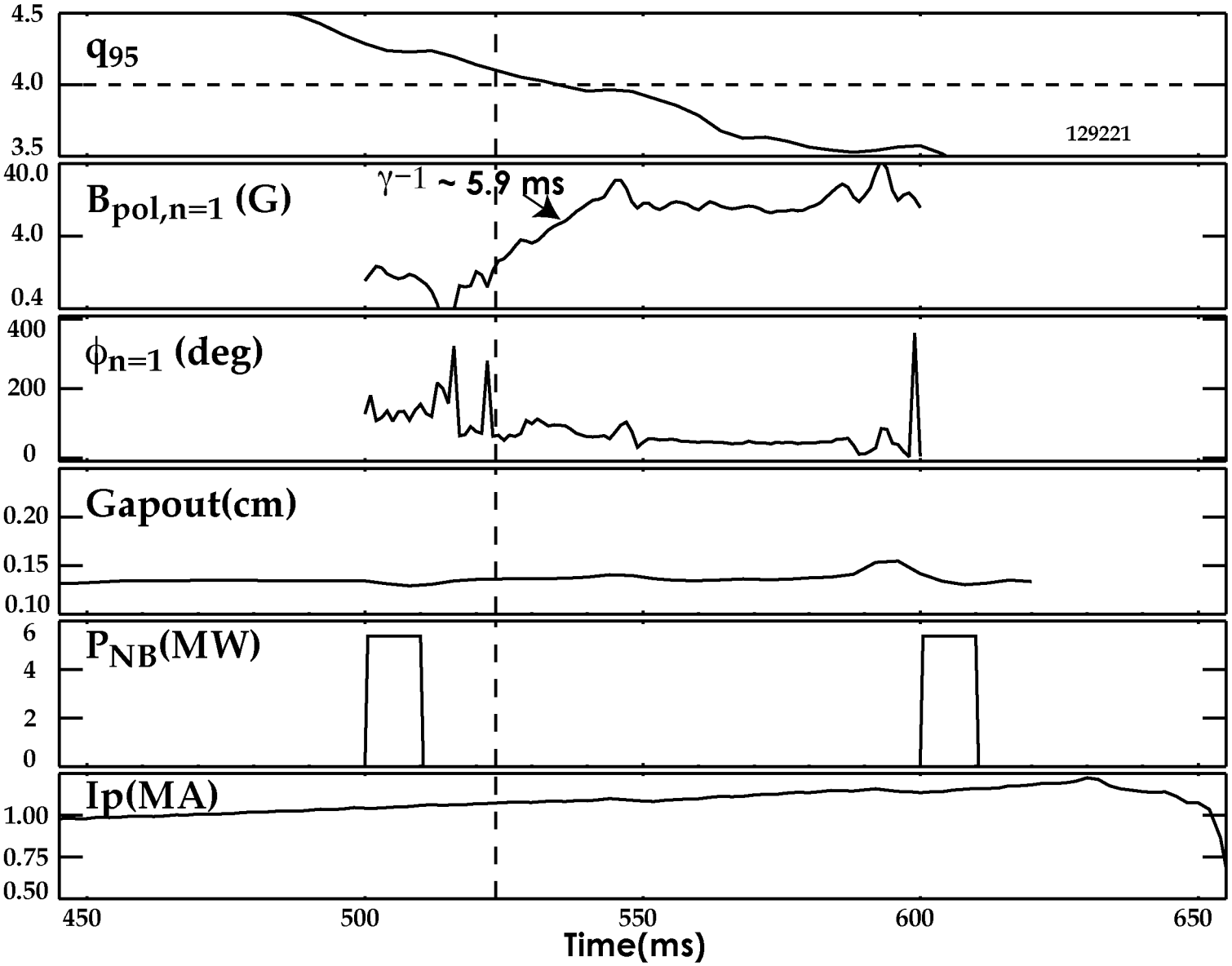
RWM BEHAVIOR OBSERVED DURING CURRENT RAMP AT q95 ~ 4 IN LOW β OHMIC PLASMA DISCHARGES



- Growth rate is comparable to DIII-D wall time
- Phase is constant (non-rotating mode)
- Beam 'blips' for diagnostics. Beam torque is zero

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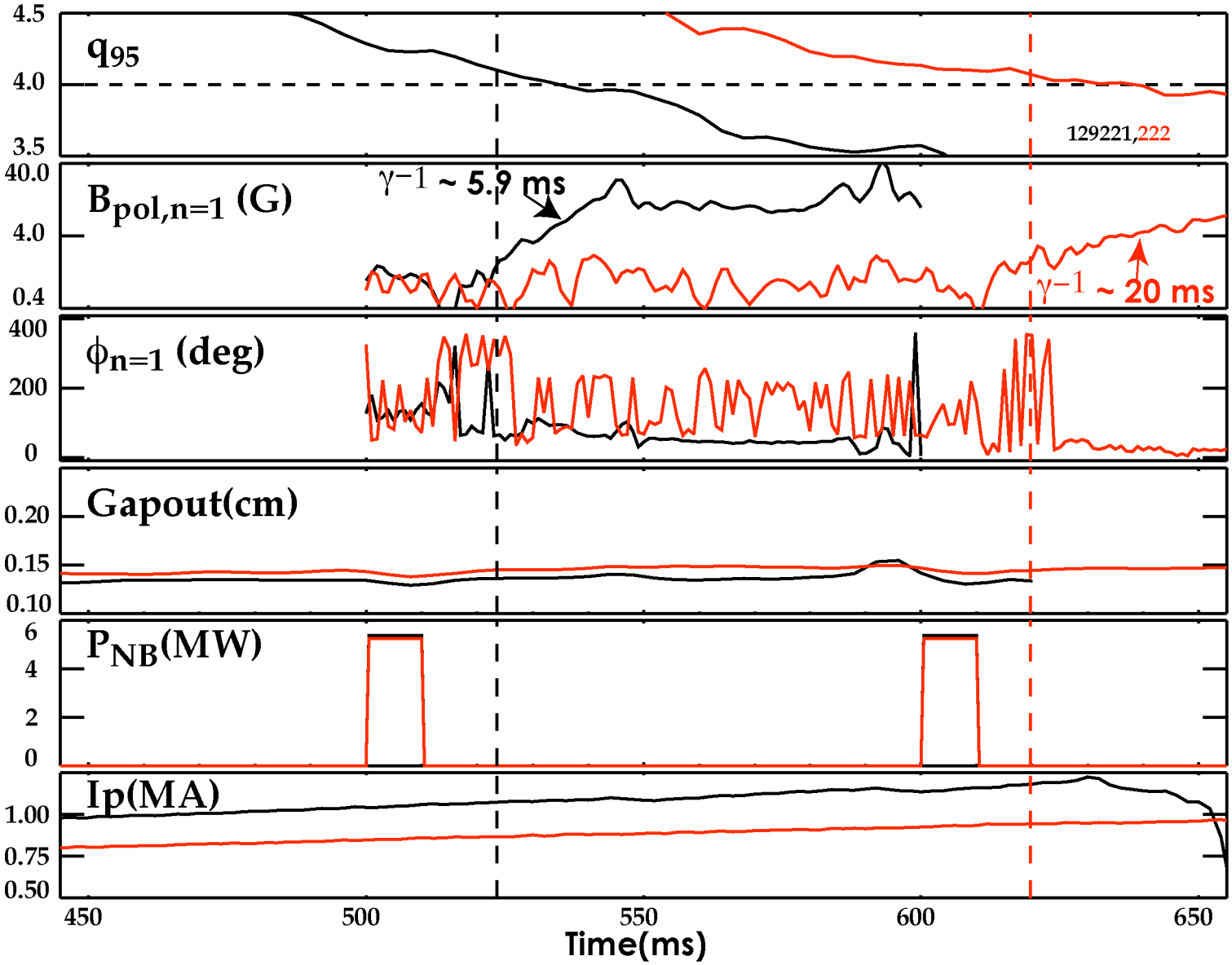
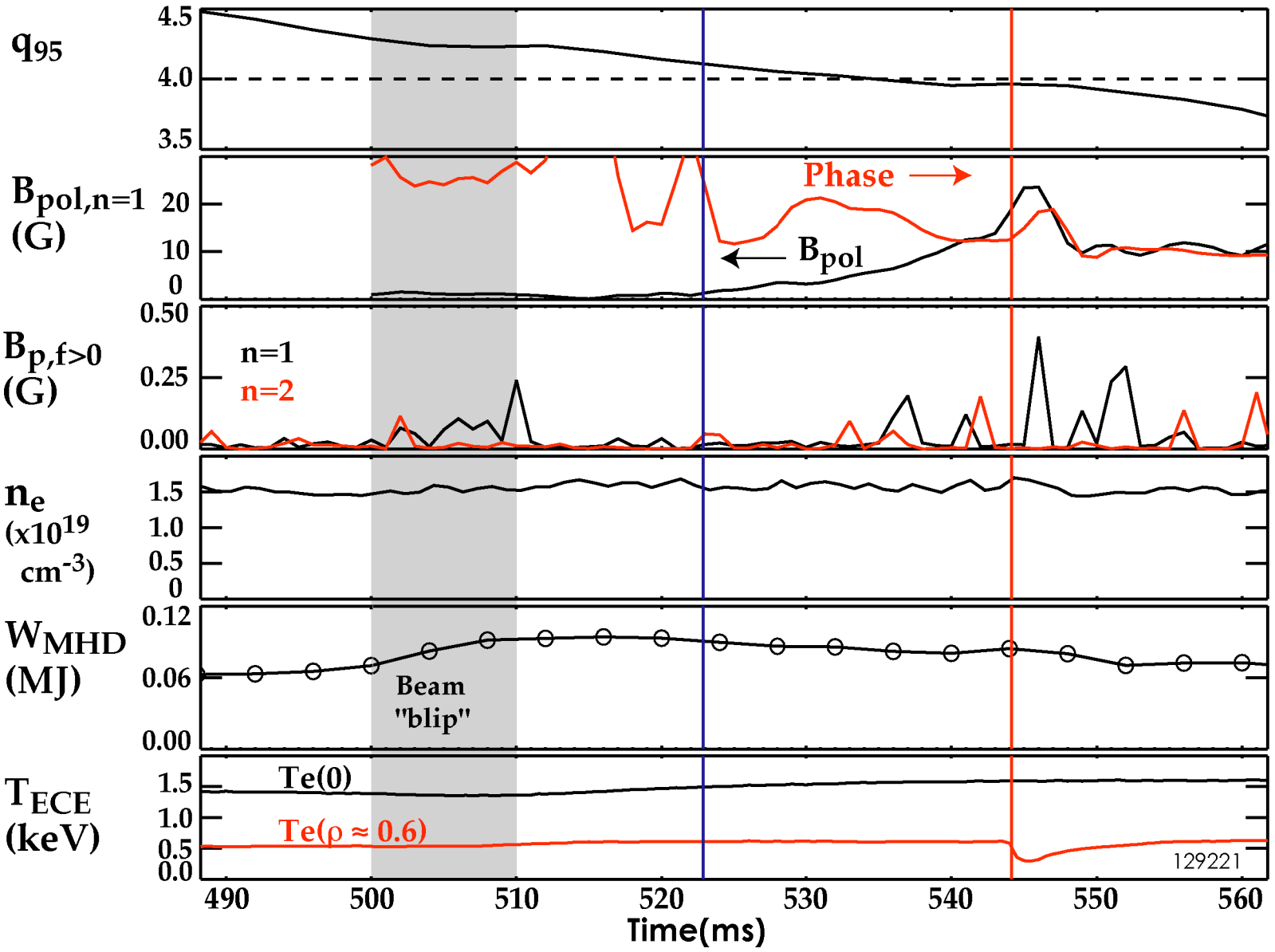


- RWM onset is delayed when Ip ramp is slower
- Growth rate is comparable to DIII-D wall time
- Growth rate is slower at lower dIp/dt
- Phase is constant (non-rotating mode)

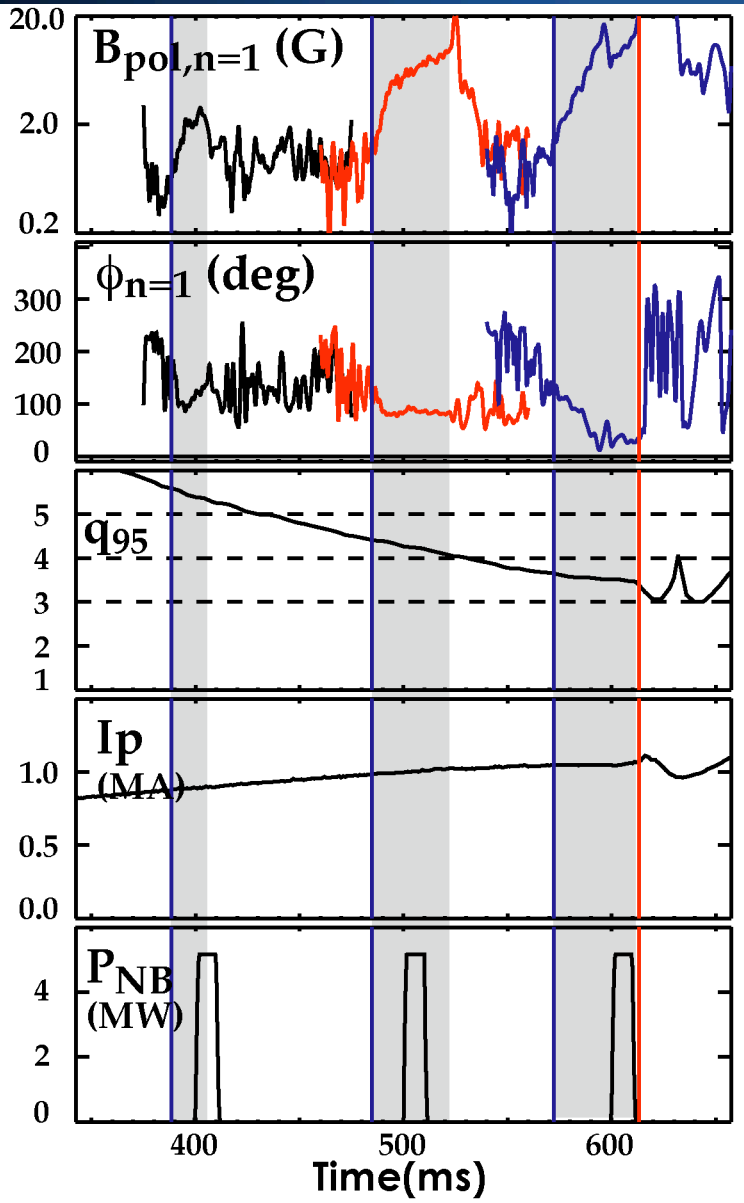
- Beam 'blips' for diagnostics. Beam torque is zero

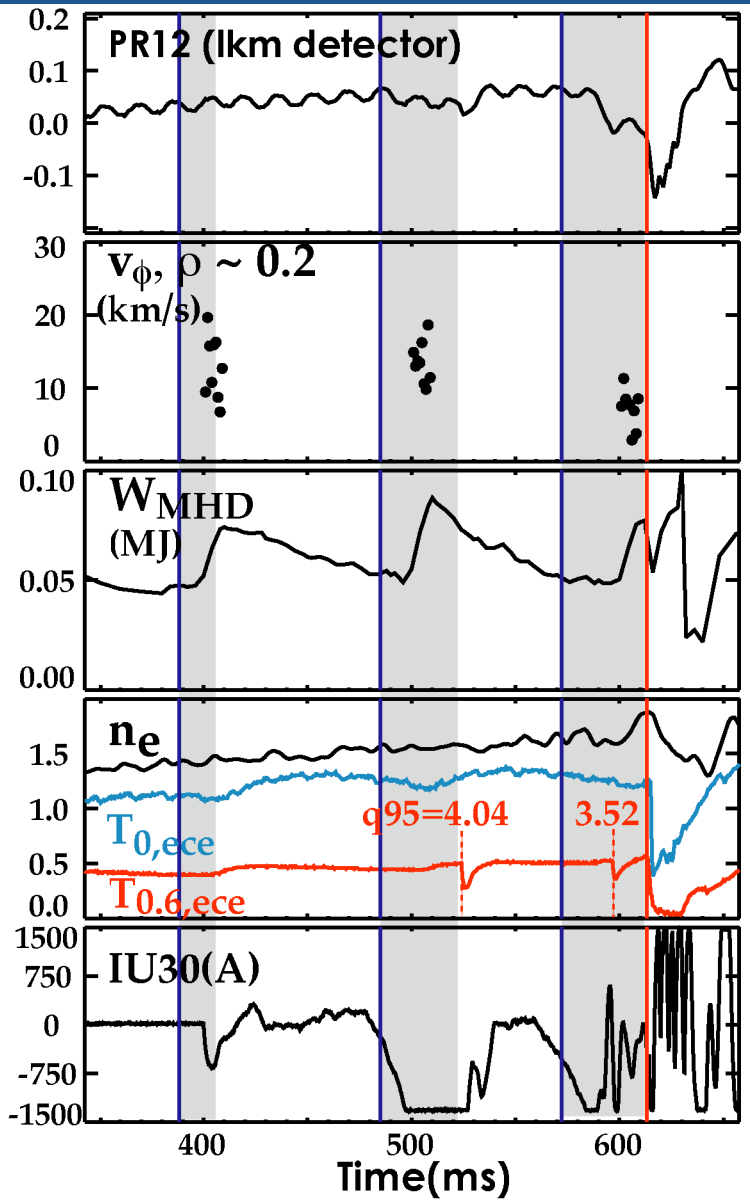
RWM BEHAVIOR OBSERVED DURING CURRENT RAMP AT q95 ~ 4



- Rotating MHD is not observed (< 0.5 G)
- No decrease in ne (locked mode signature)
- W_{mhd} response correlated with the beam 'blip
- Sharp decrease in Te(0.6) ~20 ms after mode onset

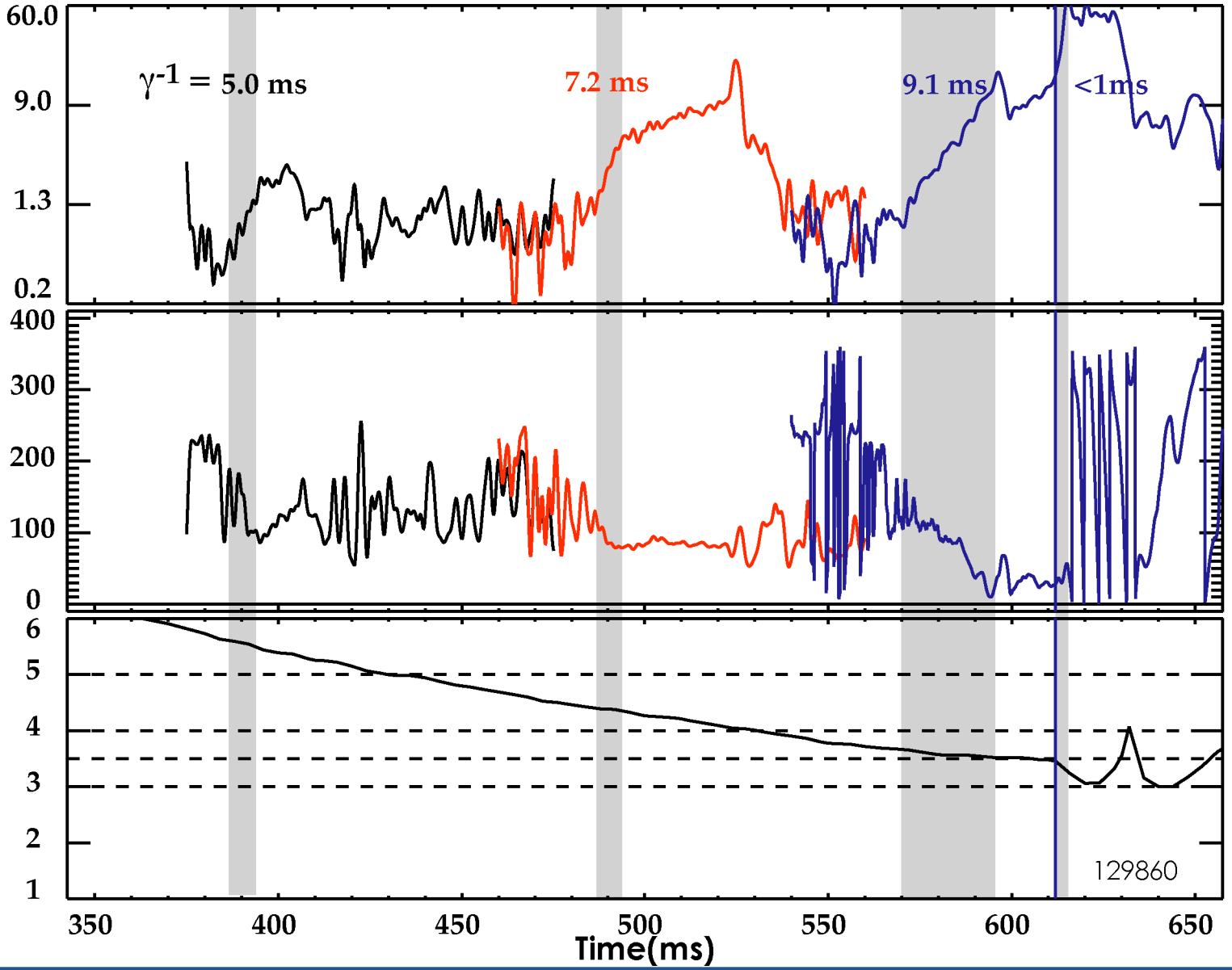
RWM BEHAVIOR OBSERVED DURING CURRENT RAMP AT q95 ~ 5, ~ 4, and < 4





- Temperature drop is observed 20 ms after start of RWM (near q=4 and 3.5)
- Although feed-back is applied by Icoils, gain is too low to stabilize the RWM

RWM BEHAVIOR OBSERVED DURING CURRENT RAMP BEGINNING AT q95 ~ 5+Δ, 4+Δ , and 3.5+Δ, WHERE Δ ~ 0.2-0.5



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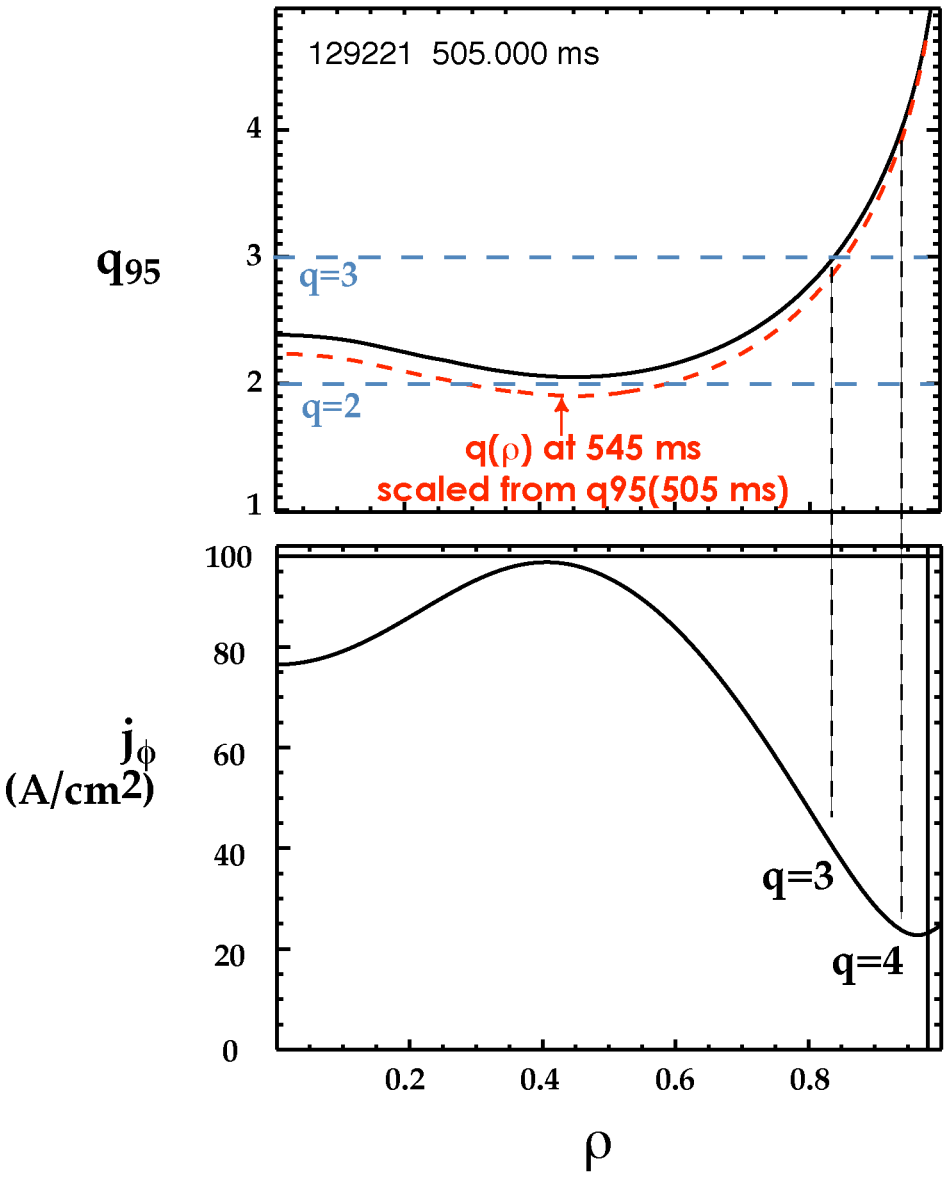
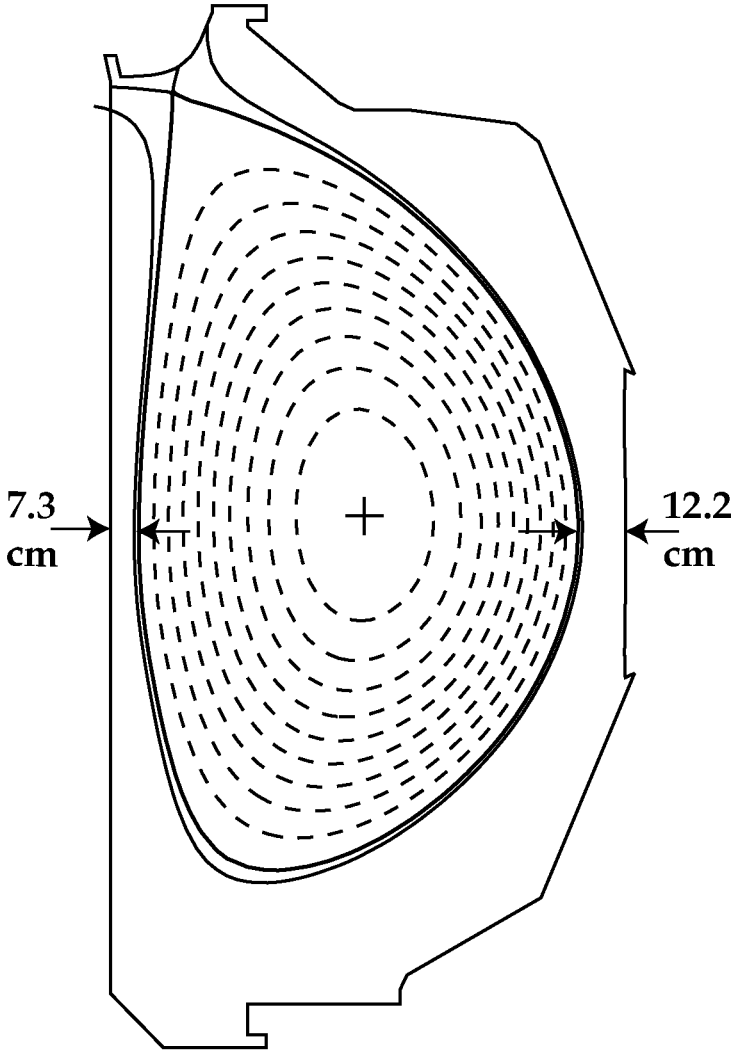
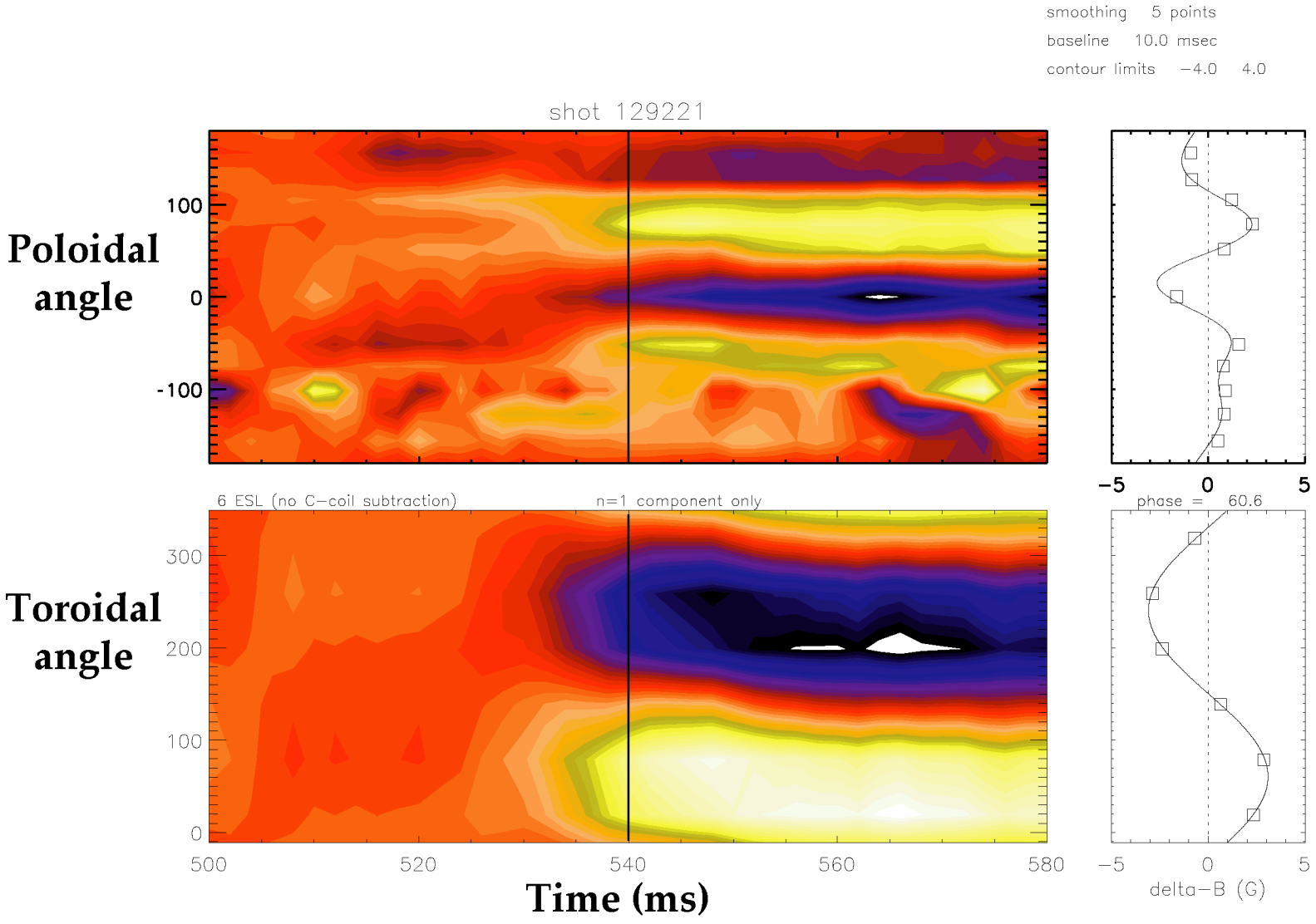
PROFILES BEFORE AND DURING THE RWM



- Is 'event' at 545 ms associated with q < 2?



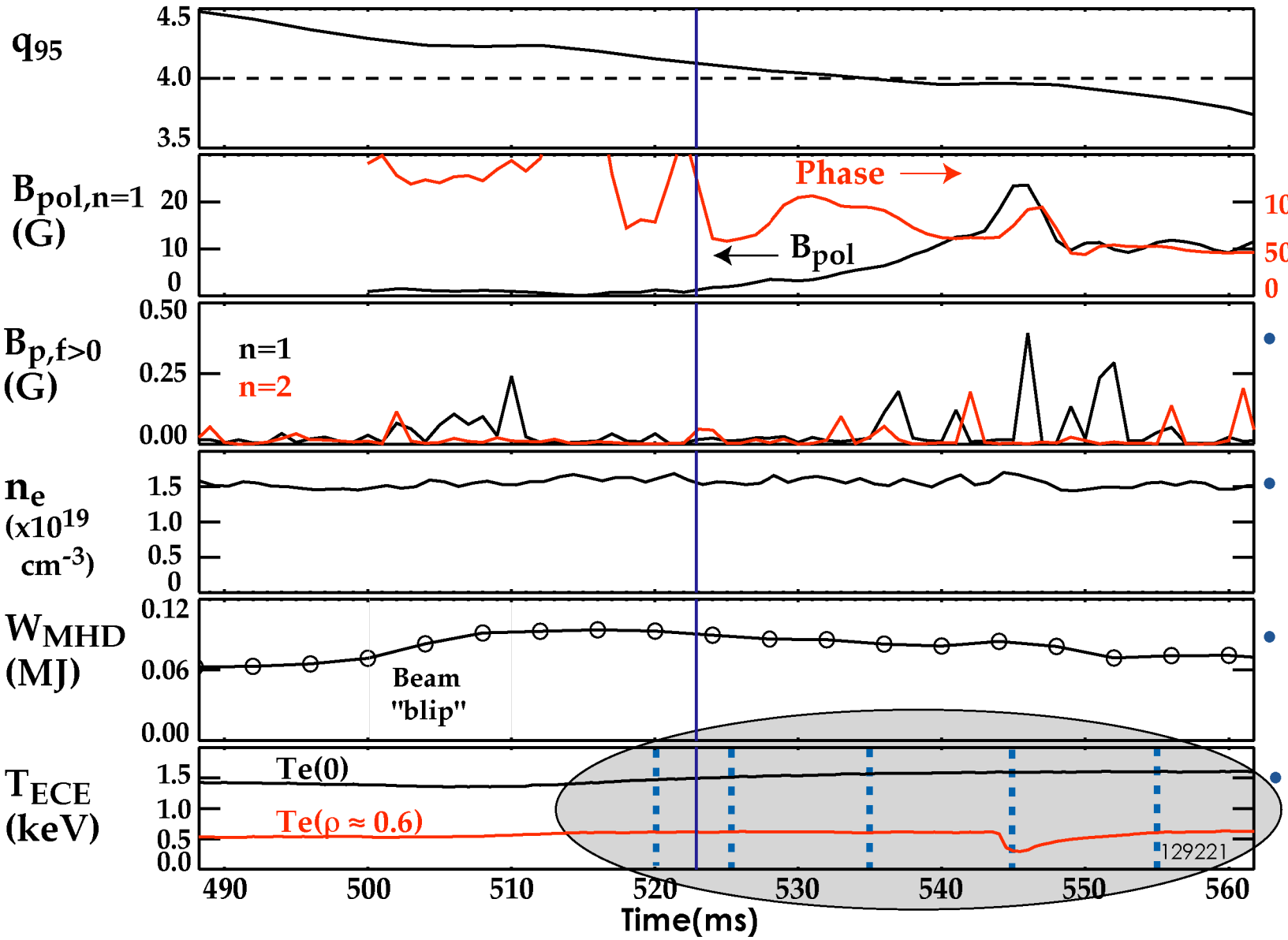
ANALYSIS FOR q95 ~ 4 INDICATES n=1 AND PRIMARILY m = 2 and 3 GLOBAL MODES



$B_{m=1} = 0.27$
$B_{m=2} = 1.3$
$B_{m=3} = 1.1$
$B_{m=4} = 0.33$

Mode is predominantly n=1

RWM BEHAVIOR OBSERVED DURING CURRENT RAMP AT q95 ~ 4



- Rotating MHD is not observed (< 0.5 G)
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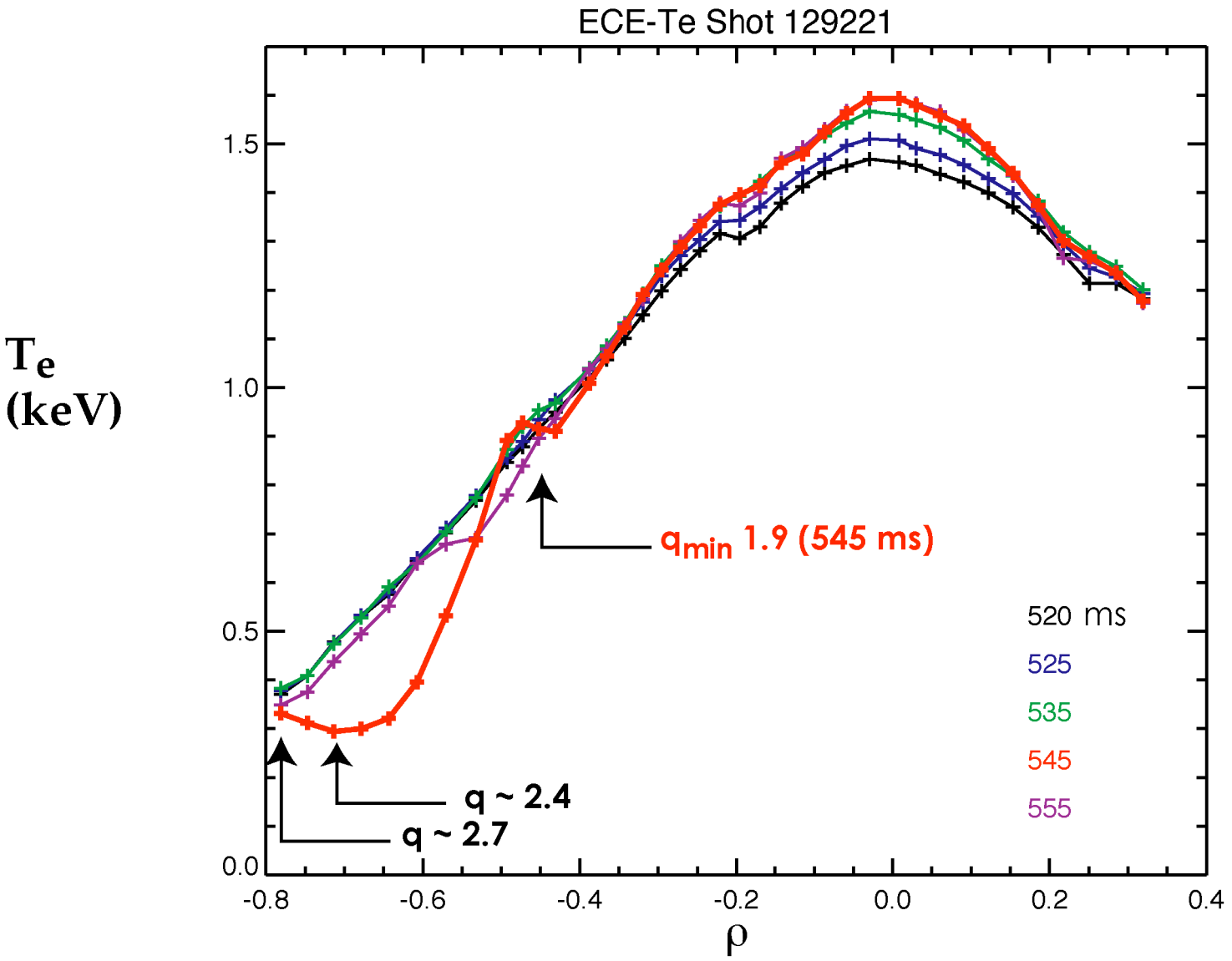
Te BEHAVIOR AT q95 = 4 IS TRANSIENT



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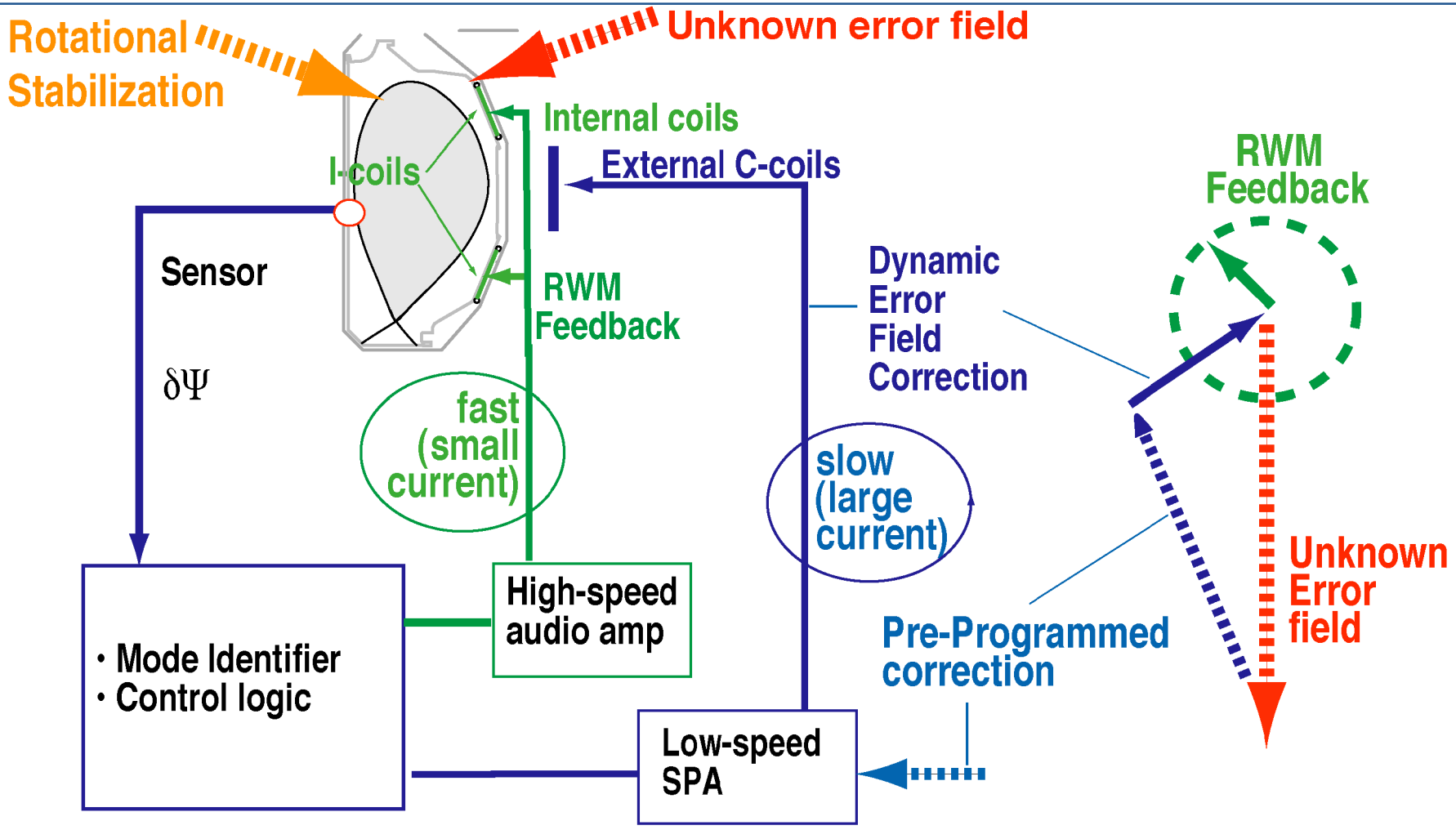
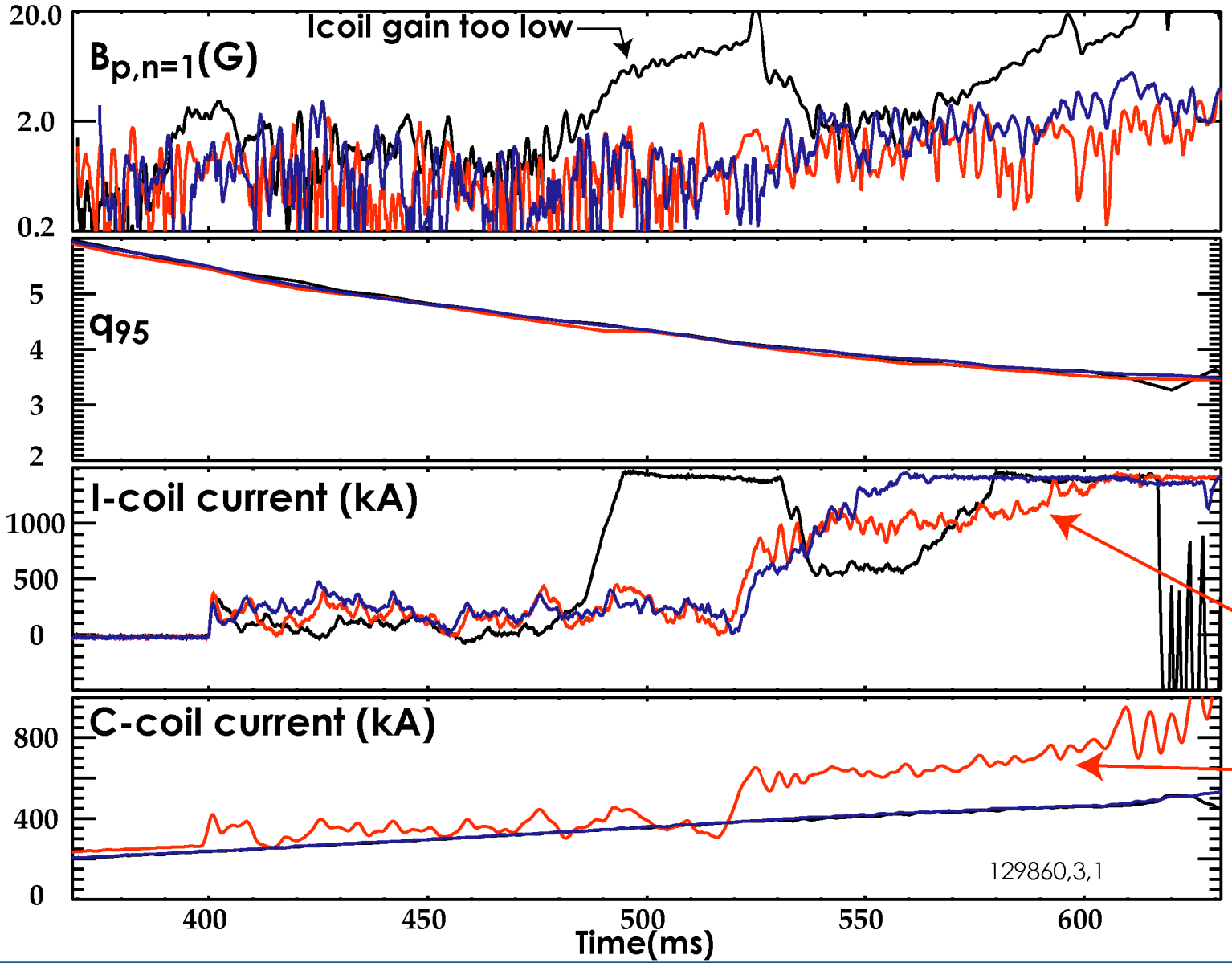
DYNAMIC ERROR FIELD CORRECTION, DEFC, (C-coils) WITH FAST FEEDBACK (I-coils) CAN STABILIZE RWMs



FEEDBACK STABILIZATION OF CURRENT DRIVEN RWMs HAS BEEN DEMONSTRATED



- Higher feedback gain and Dynamic Error Field Correction (DEFC) can stabilize the RWM

Gp=40

Gp=80

Gp=80 + C-coil DEFC

- Dynamic Error Field Correction (DEFC) reduces demand for Icoil current

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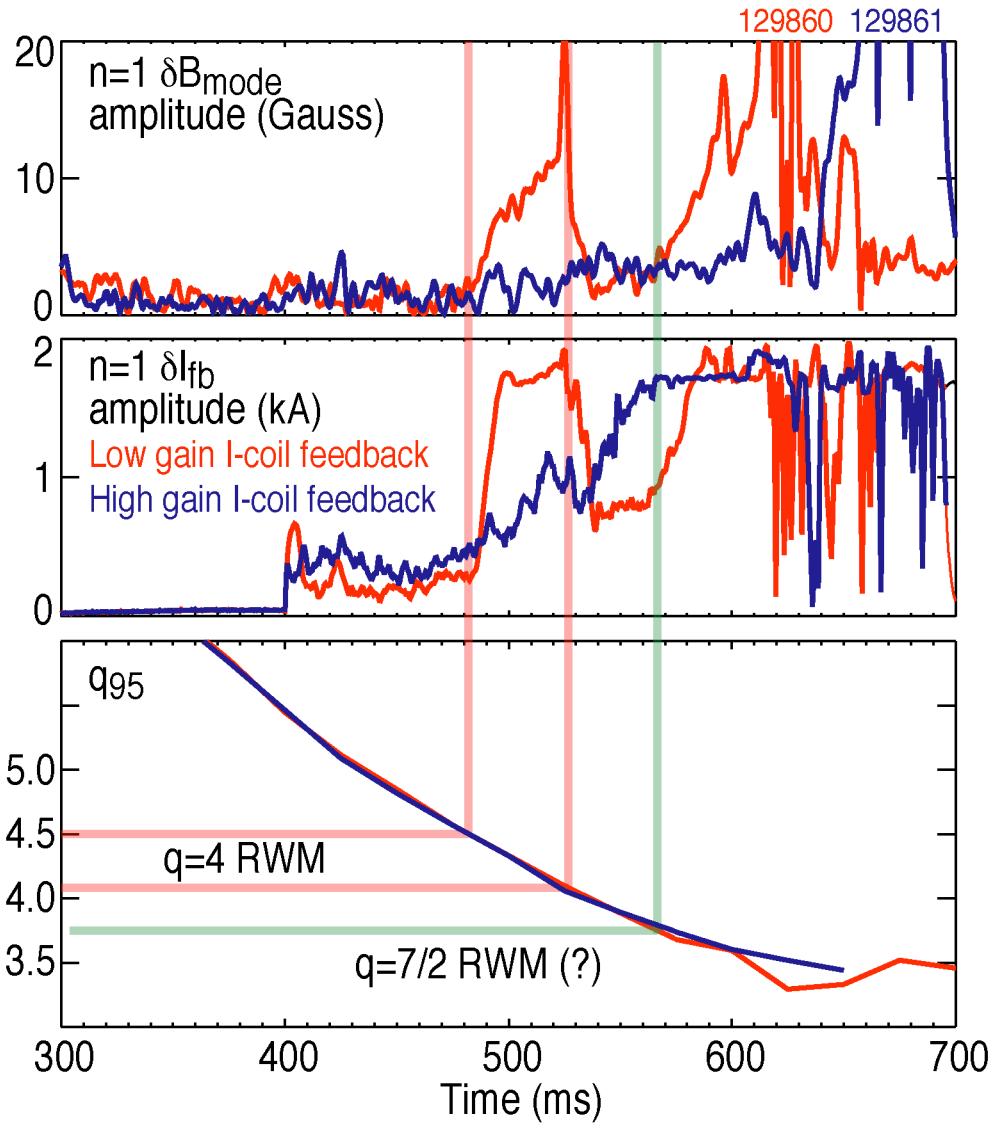
WITH HIGH GAIN, I-coil FEEDBACK CAN STABILIZE CURRENT DRIVEN RWM ACTIVITY



- I coil Gp = 80 (stable)
- I-coil Gp = 40 (unstable)

SUMMARY

- n=1 RWM-like behavior has been observed in DIII-D ohmic discharges at q_{95} ~ 5, 4, 3.5
  - In general, other MHD is not observed
  - Growth rate, γ^{-1} is comparable to the DIII-D wall time
  - γ^{-1} decreases when dIp/dt decreases
- RWM mode m=2 and 3 components are dominant even though q_{95} ~ 5, 4, 3.5
  - JT-60U RWM was excited at q_{95} ~ 3 and m/n=3/1
- Transient T_e drop is observed, but well after the RWM has been excited
  - Seems to correlate with q_{95} passing through 4 and 3.5
- I-coil feedback has successfully stabilized the RWM mode
  - C-coil DEFC has reduced currents in I-coil circuit
- MYSTERIES/QUESTIONS
  - Why is the mode triggered near rational surfaces?
  - What is the significance of activity at q=4.0 and 3.5?
  - Why are only m=2,3 observed?
- Future work will expand on the initial results
  - Gap scan to further document RWM behavior
  - Characterize poloidal mode structure
  - Model comparisons (DCON?)
  - Compare with other tokamak and RFP studies
  - Optimize feedback (test advanced control schemes?)
  - Expand parameter range where the current driven RWMs are observed