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XP935: Search for multiple RWM behavior at high β_N

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NSTX Results and Theory Review

September 15-16, 2009

Princeton Plasma Physics Laboratory

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v1.1

XP935: Search for multiple RWM behavior at high β_N

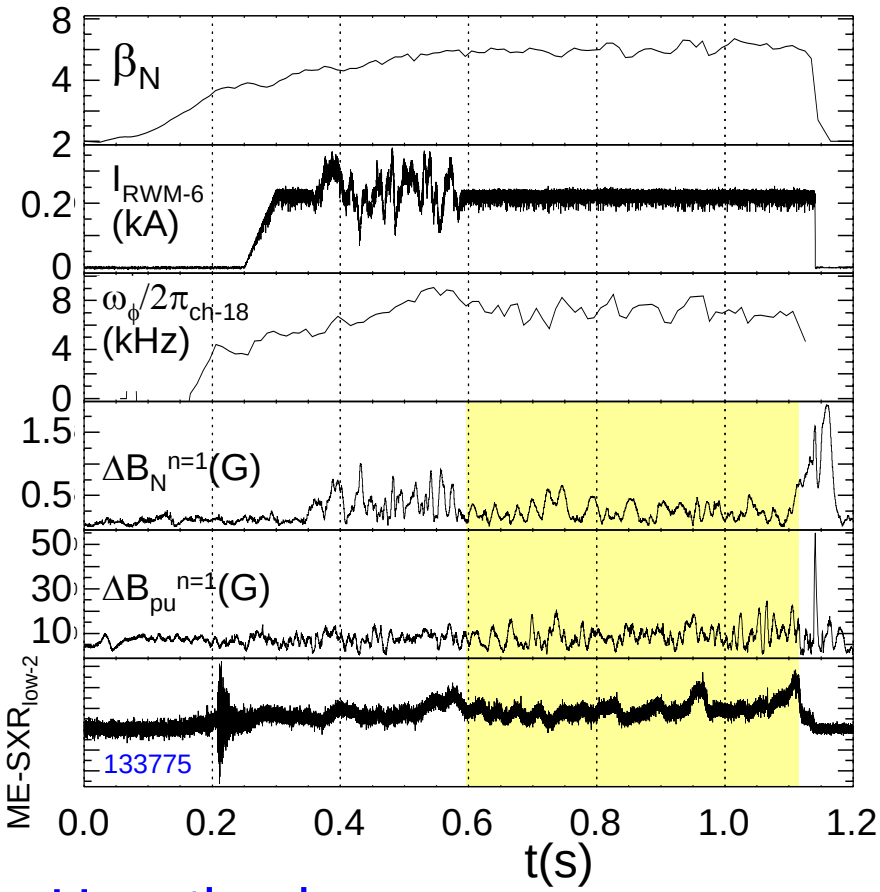
- Goals
  - Determine if unstable RWM is born from observed, stable RWM (with frequency near peak resonant field amplification – XP931), or a 2nd mode
    - Provides understanding to best minimize stored energy fluctuations at high β_N (e.g. through RWM active control improvement)
    - If same mode, supports single mode physics model; key conclusion for RFA control of NBI
    - If second mode, supports multi-mode theory, key conclusion for RWM control in ST, also, key conclusion for RFA control of NBI
  - Determine β_N dependence of RFA for these modes
  - Determine effect of ω_ϕ on these modes as marginal stability approached
  - Determine effect of active n = 1 control for these modes near marginal stability
- Addresses
  - NSTX R(09-1) and IR(10-1) milestones
  - ITPA joint experiment MDC-2.1, MDC-2.2

Direct approach to investigate multiple RWMs

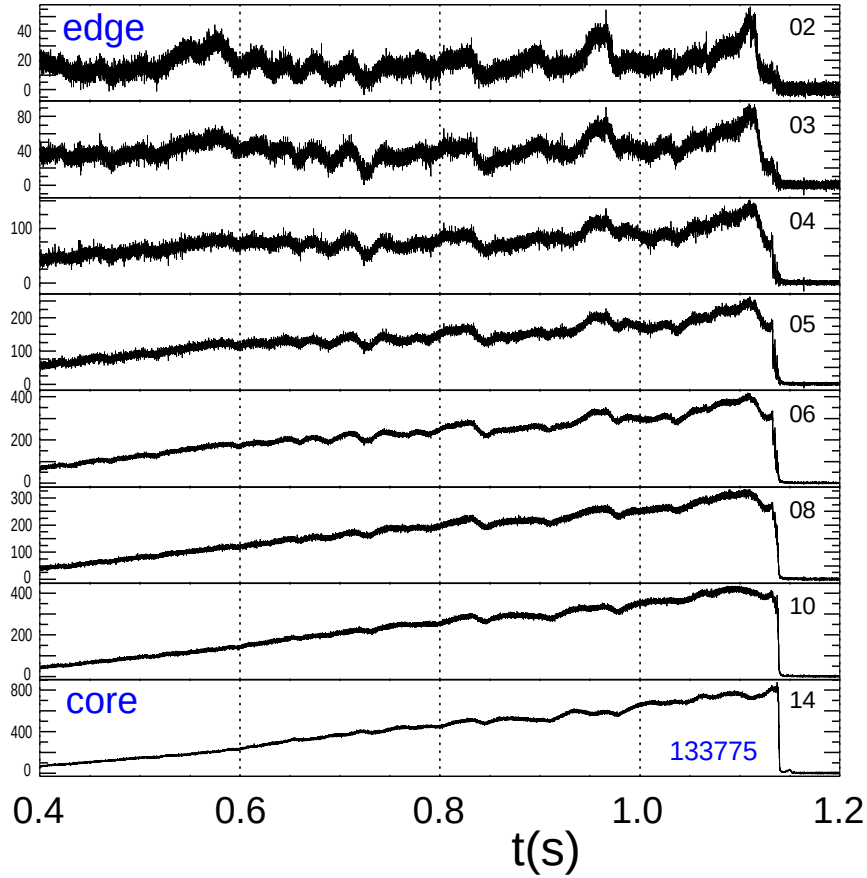
- Approach
  - Past approach: determine ideal mode structure and compare to external magnetics
  - ME-SXR allows direct approach to finding mode
    - direct observation of stable, rotating RFA as RWM is driven unstable
    - RFA to be compared with results from XP931 (ME-SXR)
  - Unstable RWM will either
    - Grow from stable, rotating RFA as marginal stability is approached
    - Grow independent of stable RFA as instability threshold is crossed
- Status
  - Scan in normalized beta completed, with MSE data
    - Notable: six shots with $\beta_N > 6$, reduced $I_p = 0.52$ MA reached $\beta_N = 7.4$
  - Rotating 30Hz seed fields show resonant field amplification, and "by eye" correlation with SXR measurements
    - several long-pulse (~ 1.3s) shots with RFA seed fields
  - ~ 30 Hz SXR activity shown to increase in radial extent as β_N increases
  - Observed growing RWM apparently independent of the 30 Hz activity

High β_N shots exhibit low frequency activity in magnetic/kinetic diagnostics

I_p = 0.8 MA shot (programmed termination)

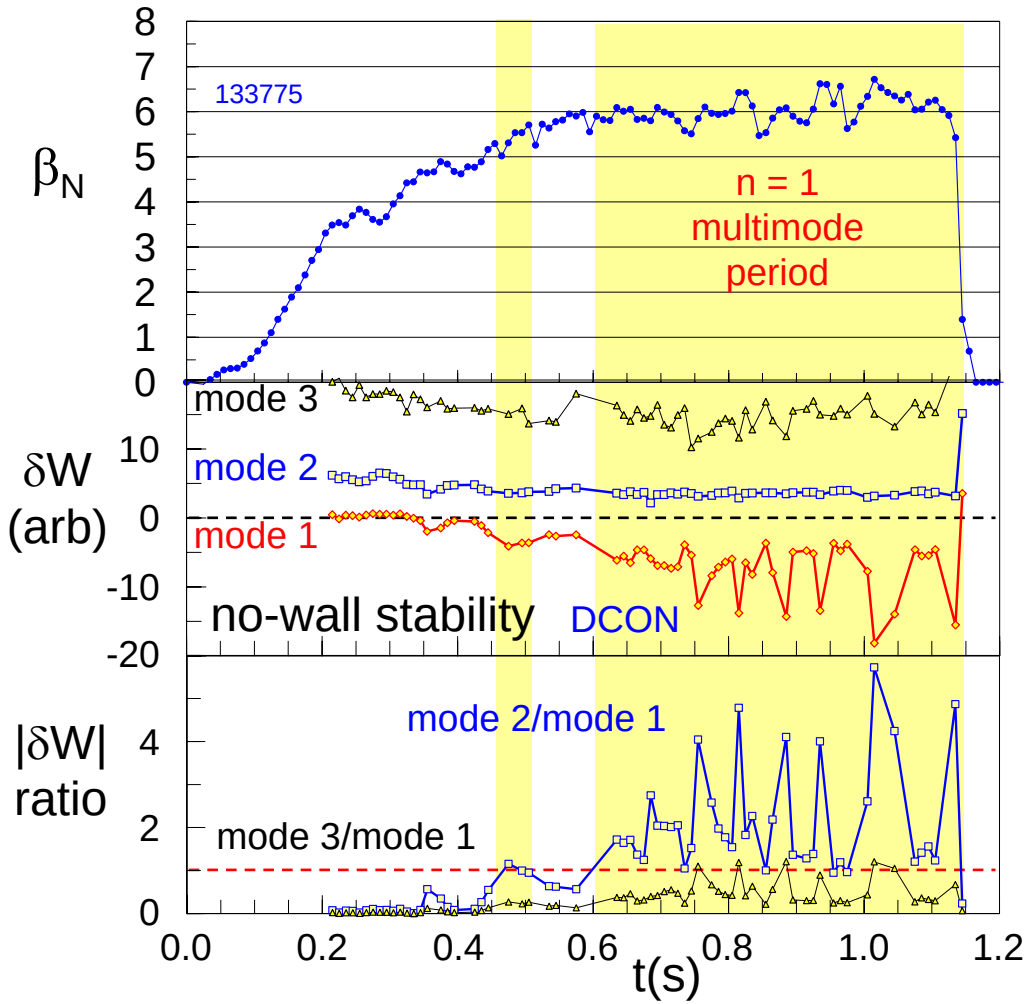


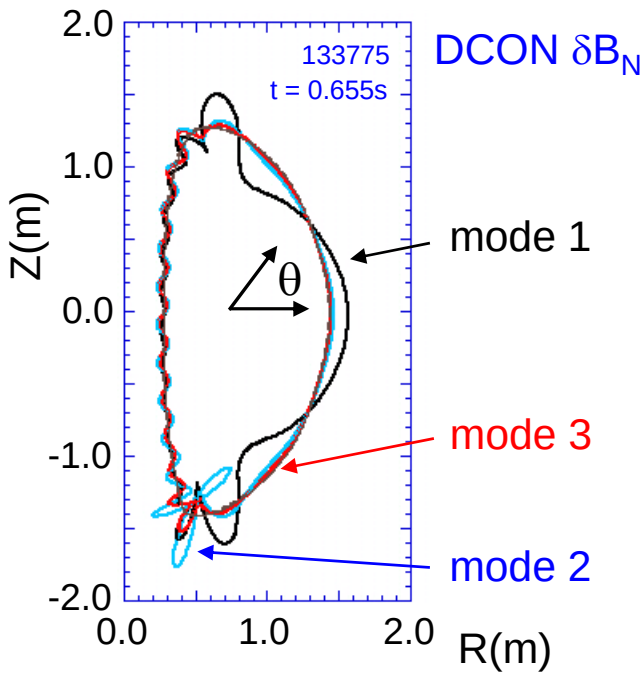
Multi-energy SXR data shows ~ 30 Hz mode activity

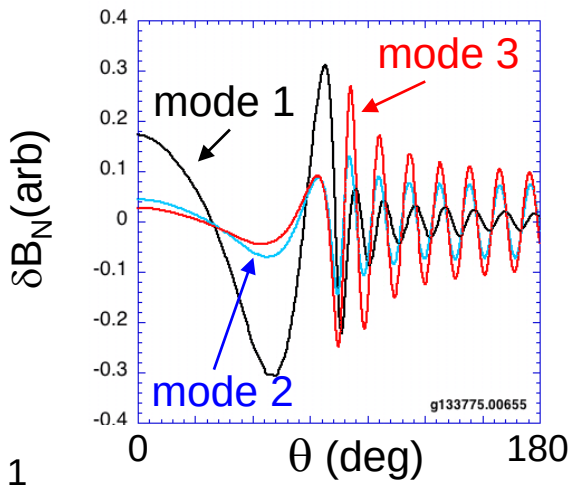


- Hypothesis
  - Mode that eventually goes unstable is locked and stabilized
  - Mode that is observed in magnetic RFA and kinetics is stable 2nd mode

Multimode response theoretically expected to be significant at high β_N

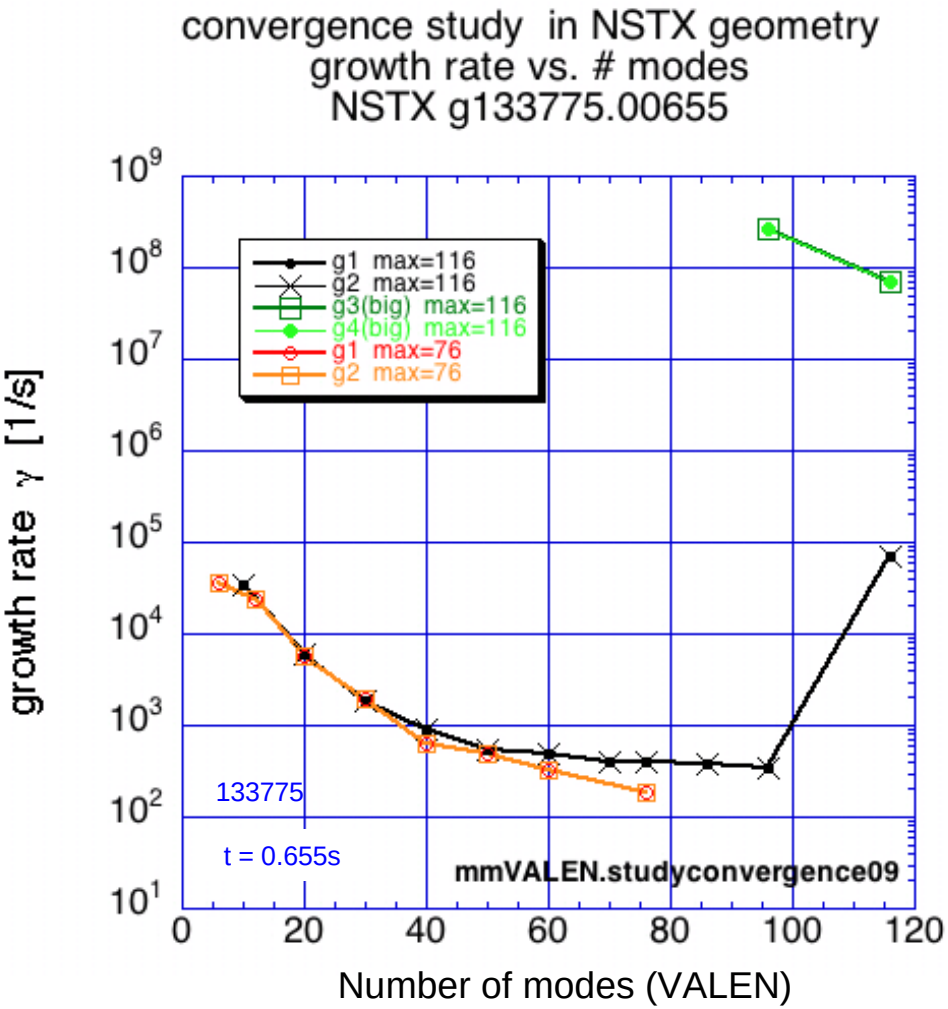


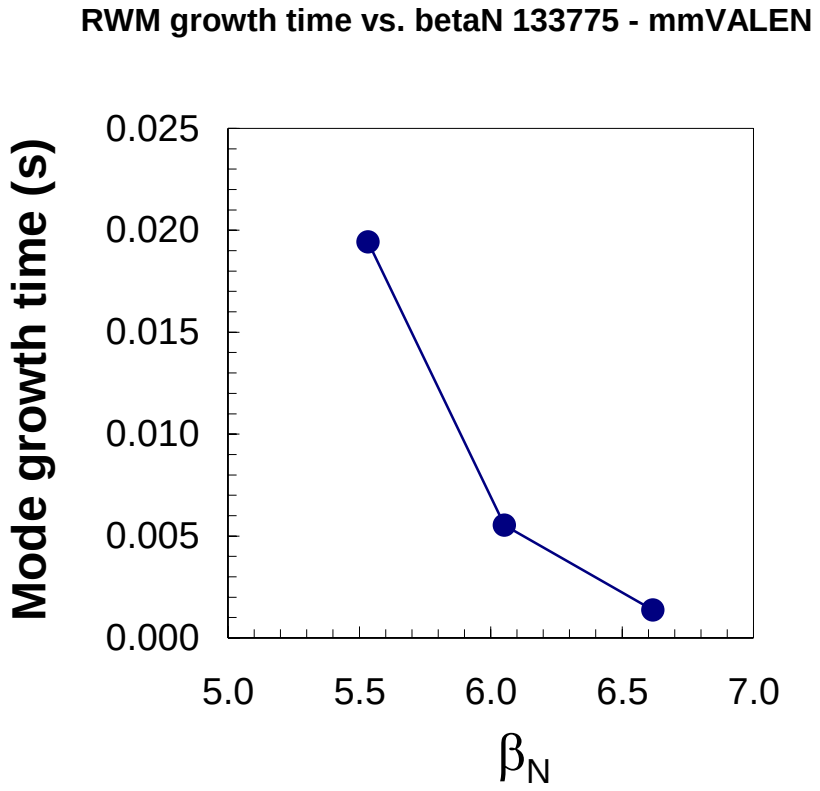




- Boozer multimode criterion for n = 1 met at high β_N (PoP 10 (2003) 1458.)
  - $|\delta W|$ smallest for 2nd n = 1 eigenfunction
  - Ratio of $|\delta W|$ for 3rd vs. 1st least stable mode sometimes also > 1

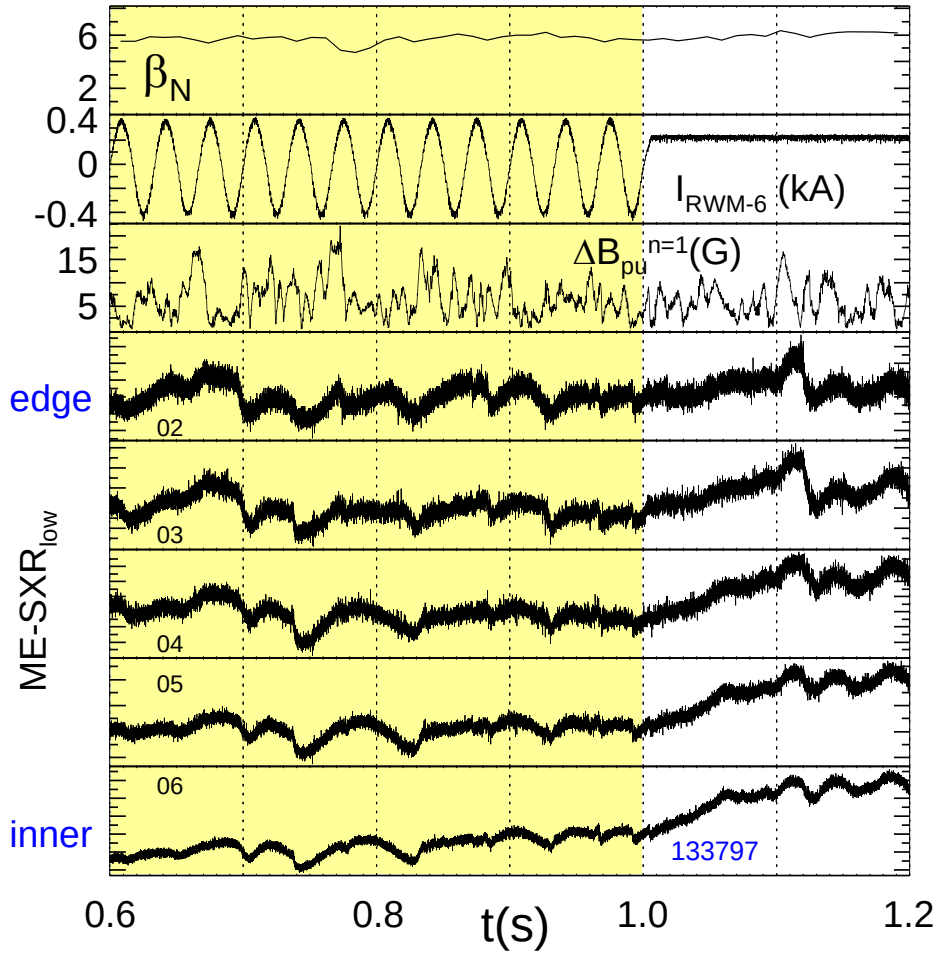
Multi-mode VALEN code testing successfully on high β_N cases



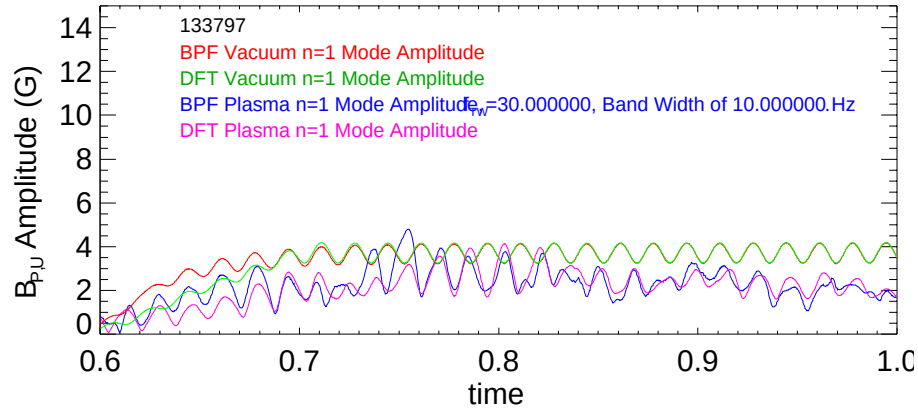


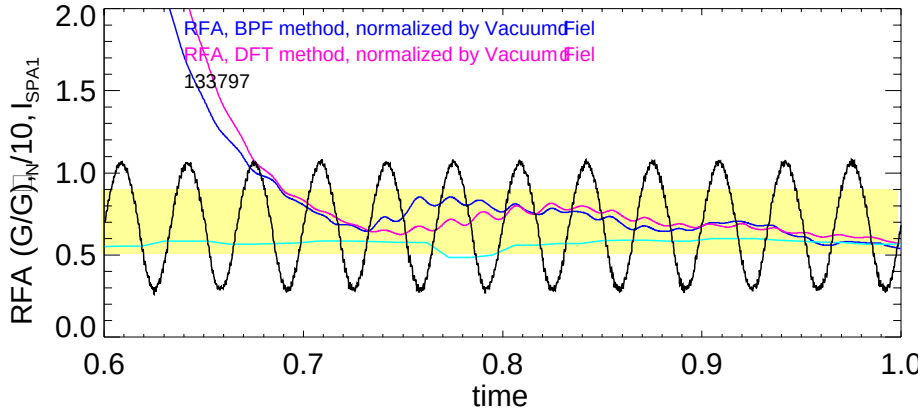
- Talk by Jim Bialek gives further detail on multi-mode VALEN
- To be used to determine response of 2nd mode to feedback, error field

RFA of co-rotating applied field observed, along with oscillations in ME-SXR signals



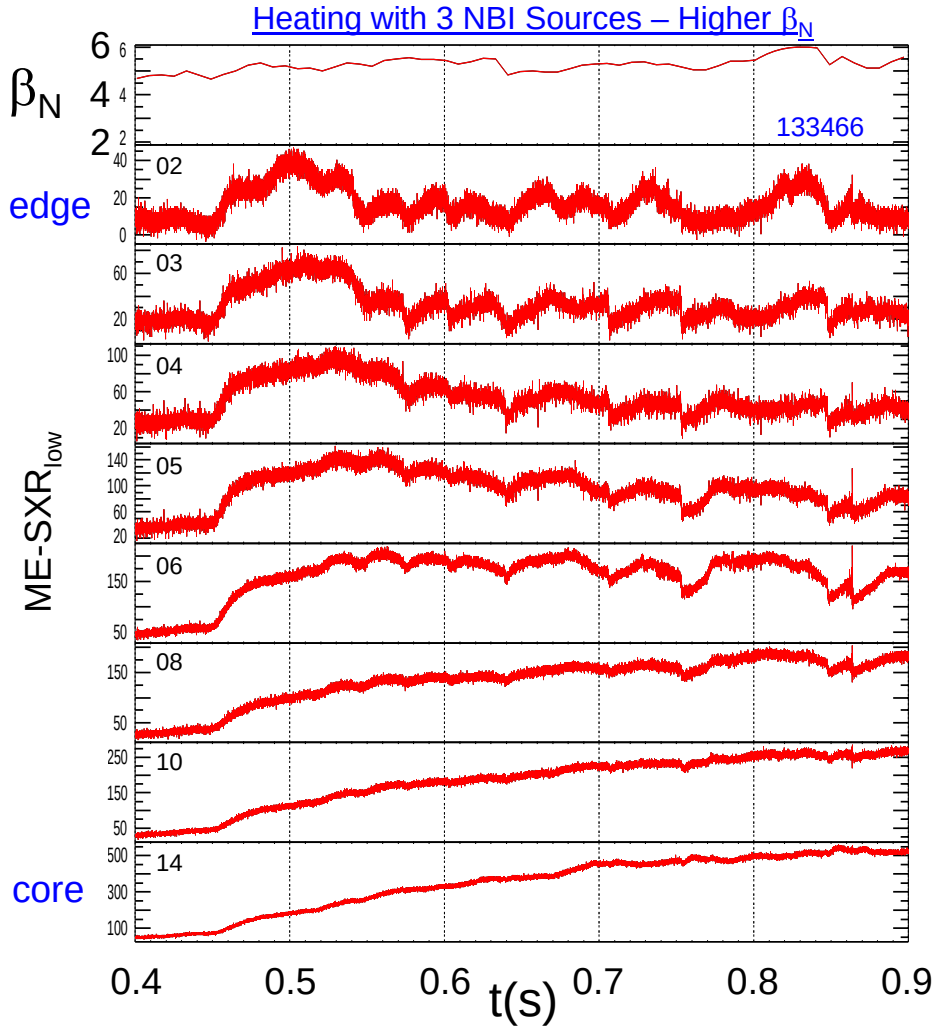
Resonant Field Amplification (RWM B_p sensors)

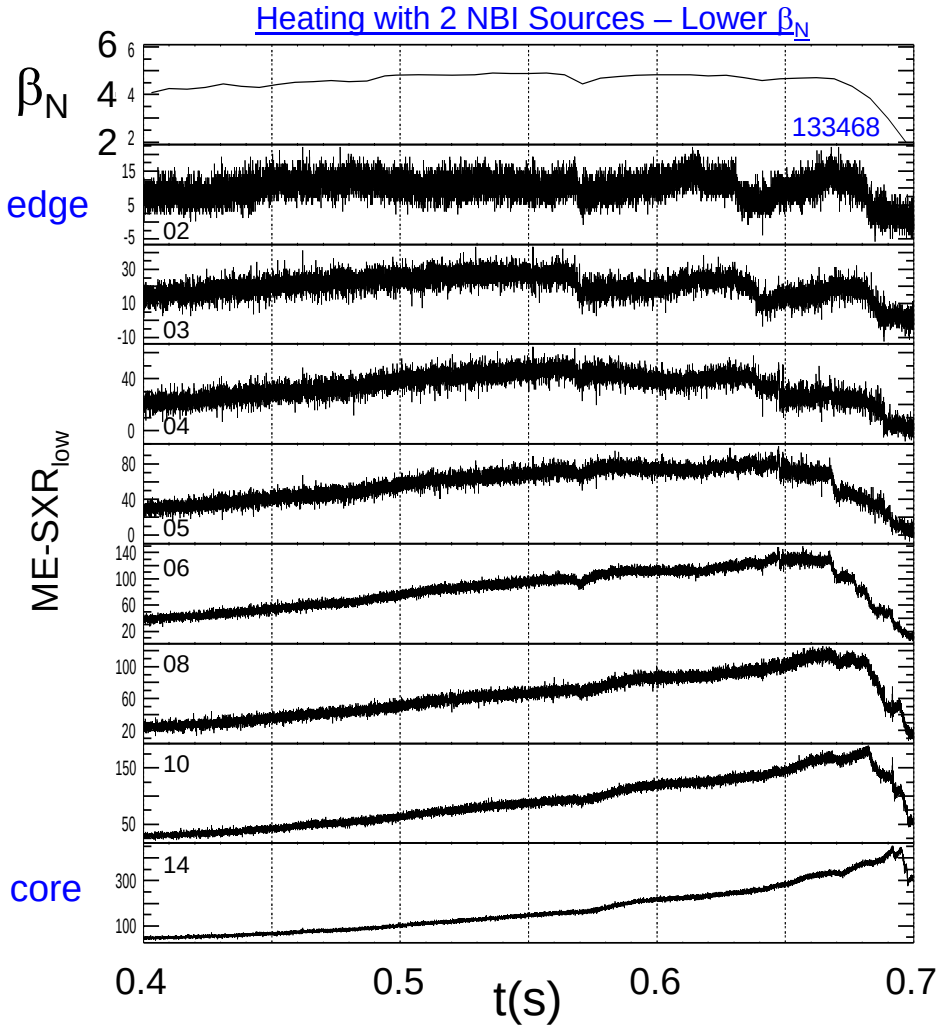




- ME-SXR oscillations also before / after pre-programmed AC
  - Apparent correlation with n = 1 B_p sensor amplitude
  - Need to quantify amplitude of ME-SXR vs. β_N, compare to magnetic RFA

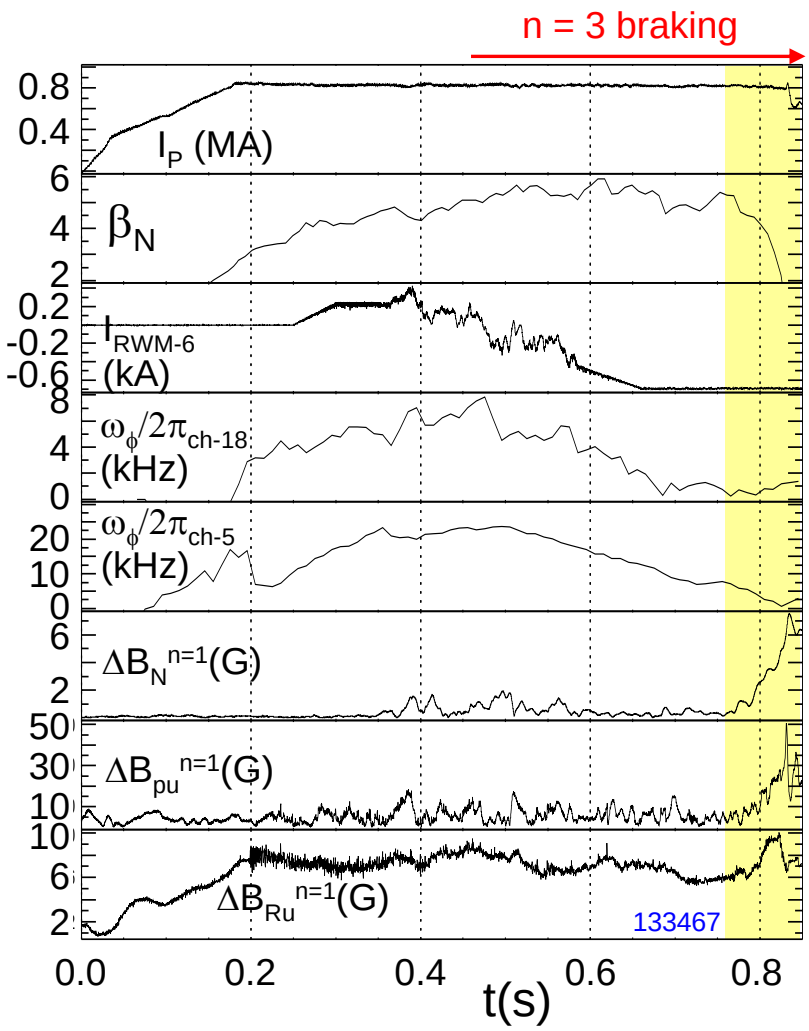
Mode observed in ME-SXR at ~30Hz covers greater radial extent as β_N increased

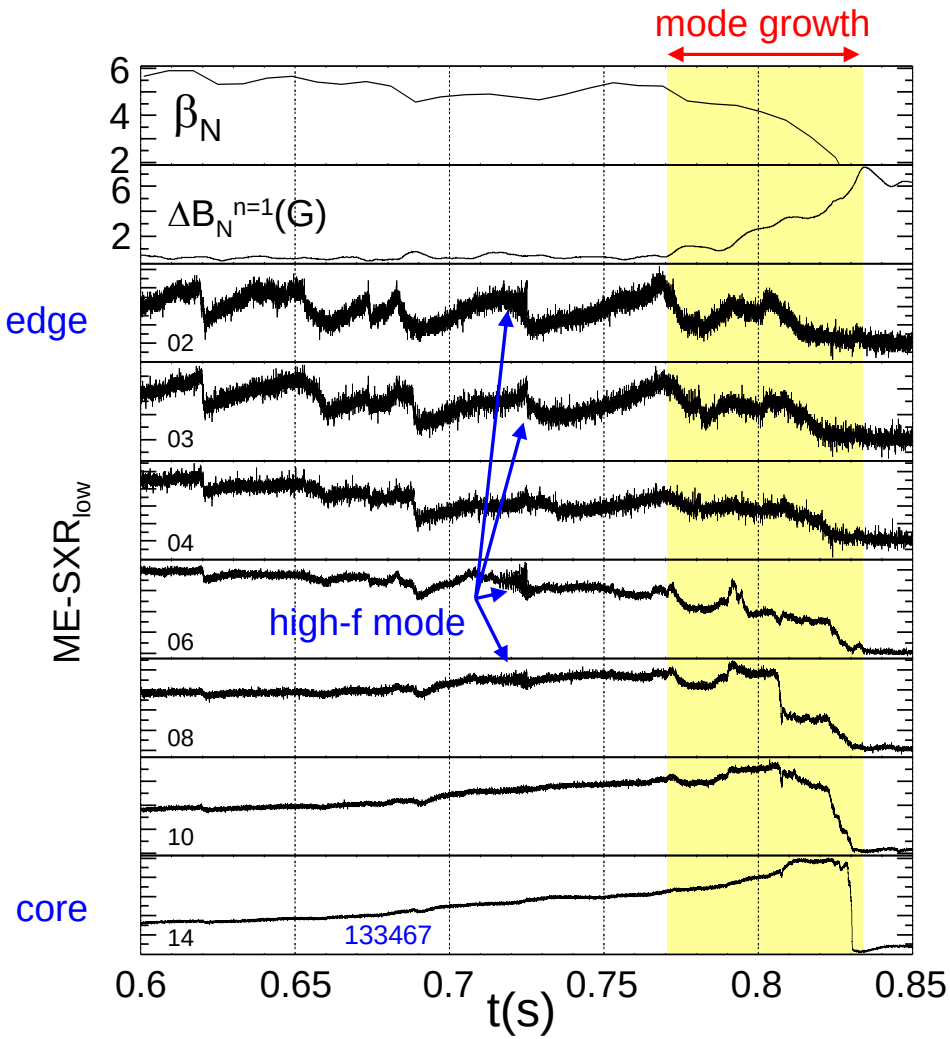




- Note: proximity to marginal stability (e.g β_N plus ω_ϕ level) may be key
  - Some high β_N ~ 6 shots show less mode activity (e.g. 133478) – need to quantify

The observed growing RWM appears to be independent of the stable, ~30 Hz activity





- Unstable mode is locked; ME-SXR mode apparently co-rotating
- Greater radial extent of ~ 30Hz during RWM growth, but appears superposed

XP935 Search for multiple RWMs at high β_N: Next Analysis Steps

- Make correlation between magnetic and kinetic measurements of mode activity (lot of signal processing)
- Analyze/quantify ME-SXR amplitude increase with β_N ; correlate with magnetic RFA
- Examine radial extent of mode activity
  - Data inversions
  - Compare to theoretical expectations
- Examine larger number of shots to distinguish mode activity
  - Also consider RWM unstable shots from the larger database (as ME-SXR ~ 30 Hz mode activity appears in many high β_N shots).