XP 428: Resistive Wall Mode Dissipation Physics

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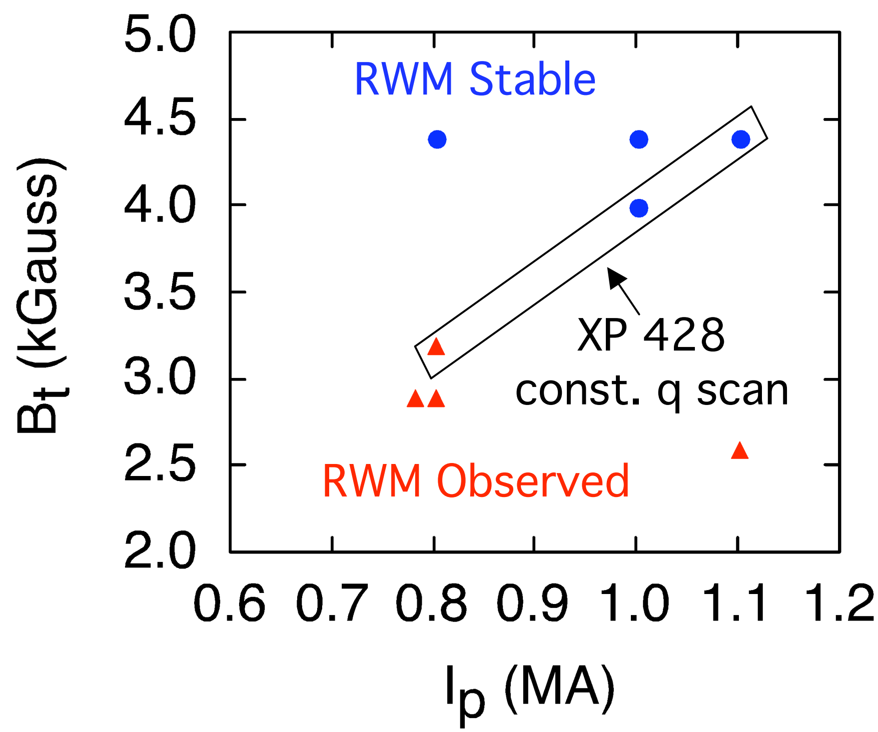
XP 428: Dissipation Physics of the Resistive Wall Mode

- ## Motivation
  - RWM stability when $\beta_N > \beta_{N\ \text{no-wall}}$ is allowed through a combination of toroidal rotation and energy dissipation
  - RWM energy dissipation mechanism(s) which allow stability above no-wall beta limit is (are) presently uncertain

- ## Goals
  - Examine q dependence of RWM stability boundary
    - $\omega_\phi/\omega_A > 1/4q^2$ observed as necessary condition in 2002 NSTX data
    - toroidal inertial enhancement limit from drift-kinetic energy principle
    - DIII-D observes $\Omega_{crit} \propto q^\alpha$ ($\alpha > 0$) dependence
  - Evaluate strength of dissipation mechanisms
    - sound wave dissipation $\propto k_{||} v_{ti} \rho$
    - ion Landau damping significant if $\omega_\phi > \varepsilon^{1/2} v_{ti}/qR$
    - numerical calculations → MARS-F
    - analytic theory → Fitzpatrick-Aydemir model
  - Determine relative importance of dissipation and inertia

Field Scan Attempts to Separate Inertia and Dissipation

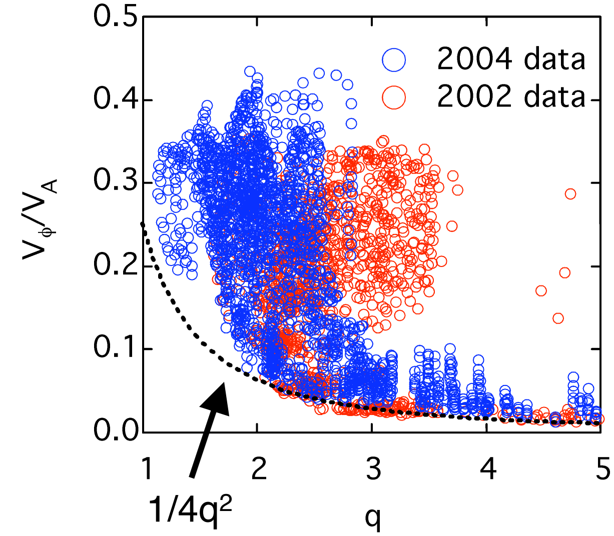
- If q not fixed: inertia and dissipation terms have similar scalings
  - want to separate effects in dispersion relation
- At fixed q_{95} scan B_t → vary inertial enhancement
  - $v_A \sim B/n^{1/2}$
  - $v_{ti} \sim T_i^{1/2} = n^{-1/2}$
  - vary I_p and B_t simultaneously
- One constant q scan completed
  - B_t scan at q_{95} ~5.8
  - high rotation in targets
    - mostly stable to RWM
    - performed before active coil available
      - no rotation control
  - lowest field shot unstable
    - 1/1 mode damps rotation
    - RWM onset when $\beta_N > \beta_{N\ \text{no-wall}}$



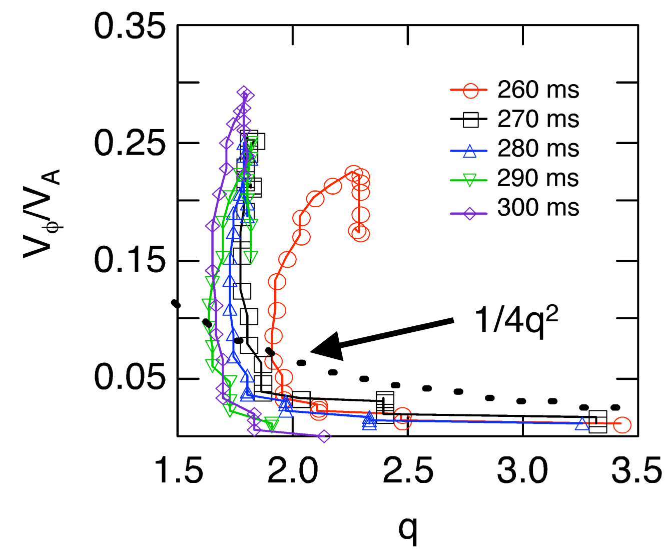
- Need more data to fully map out stability boundary
  - data from other XPs have variety of q_{95} values due to shaping variations, etc.

Inertial Enhancement Model Describes Observed Ω_{crit} Boundary in NSTX

- Shots with sufficient rotation survive for several τ_{wall}
  - several thousand shot*time*radius points from 2002 & 2004
  - $\beta_N > 5$ for all points
    - no-wall limit computed for 2004 data
  - all have $\beta_N > 5$ for at least 10 τ_{wall}



- Shots with insufficient rotation experience RWM collapse
  - usually in ~ 3 τ_{wall}
  - shot 114036 experiences RWM
    - growth after ~ 4 τ_{wall}

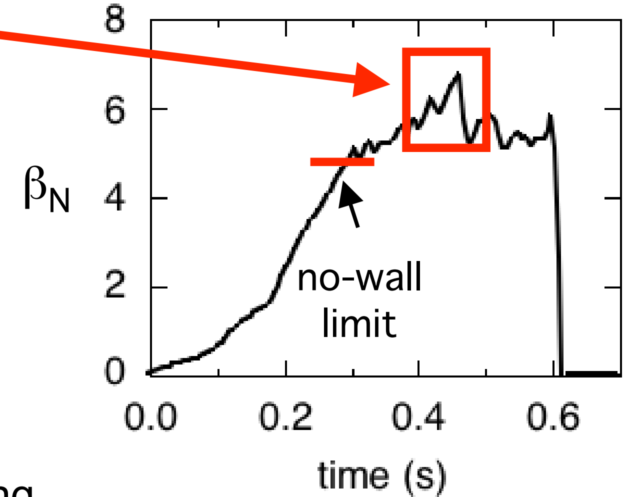


- $1/q^2$ dependence is contrary to observations on DIII-D

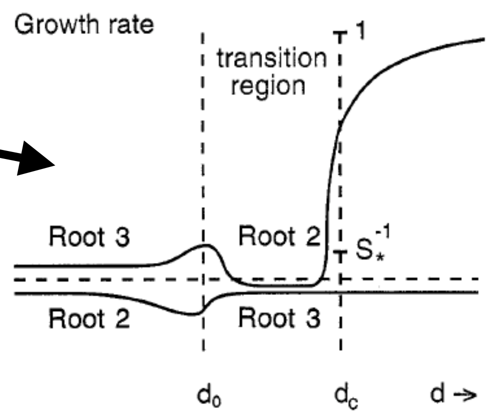
β Collapses on Ideal Time Scales Occur at Highest β_N in Wall Stabilized Regime

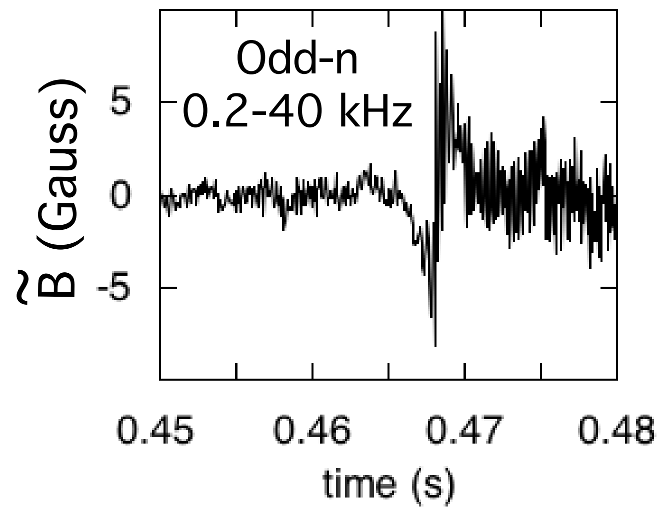
- Global collapse observed at high β_N
- Growth rate ~670 μs
  - Typical RWM growth rate ~ $O(\tau_{wall})$
  - DCON indicates ideal with-wall instability at peak β_N
  - growth rate indicates ideal time scale
    - in agreement with past VALEN calculations
    - VALEN calculations on present results pending
- Possible transition to external kink branch

Shot 112785



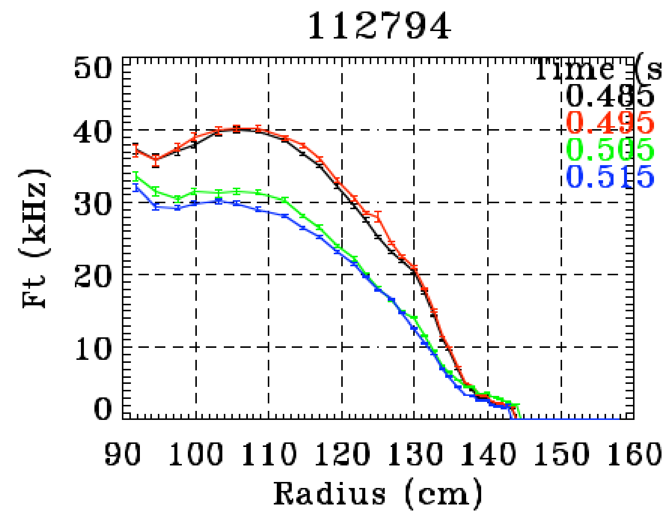
Fitzpatrick-Aydemir Dispersion Relation

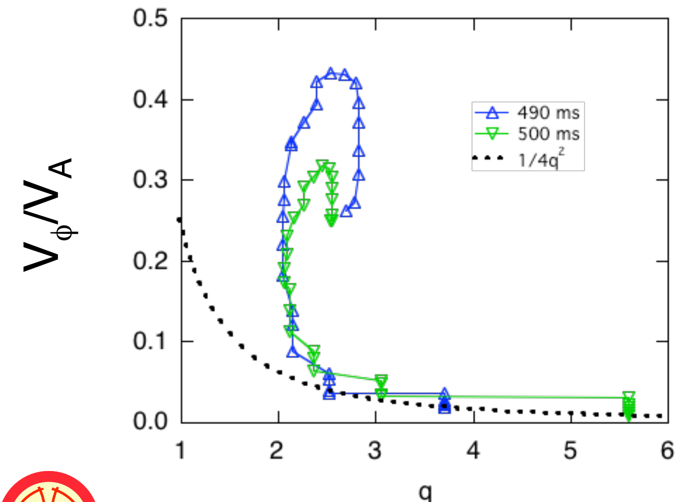


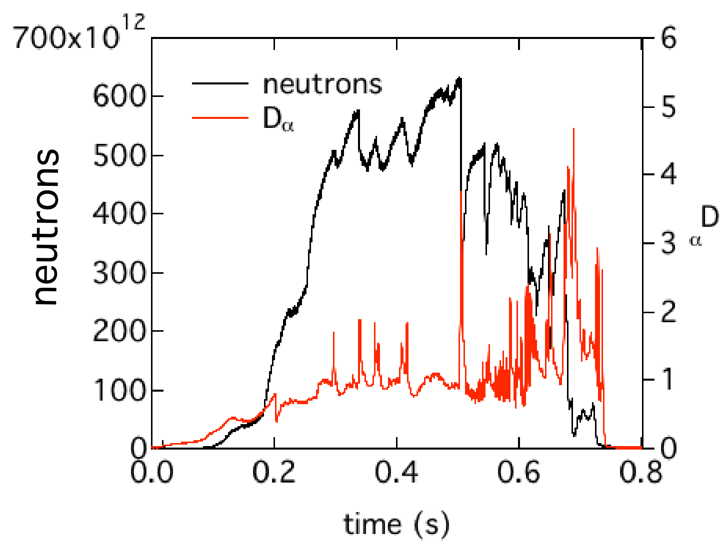


RWM Stability Restored During Fast Collapse

- Plasma remains above no-wall limit after fast collapse when with-wall limit is approached
- Rotation collapse is global
  - coincident D_α spike and neutron collapse confirm global nature of mode
- Rotation sufficient for RWM stability after collapse
  - similar to 108420 in previous run campaign

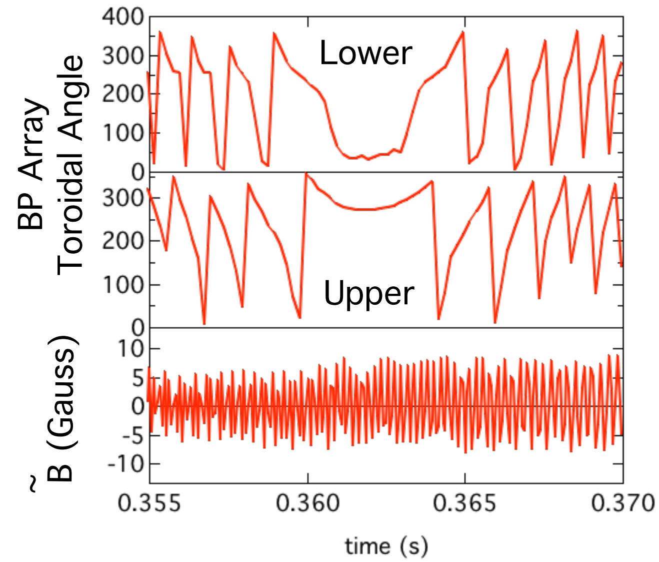


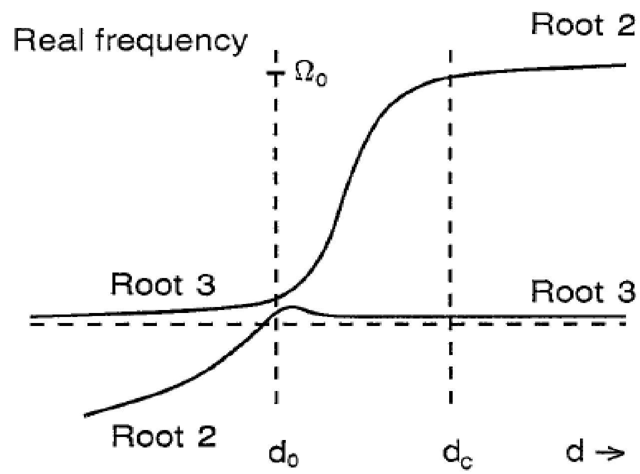




RWM/Kink Phase Velocity Reversal Observed

- 112804 has low plasma rotation due to 1/1 mode when no-wall limit is exceeded
  - $\omega_\phi < \Omega_{crit}$ throughout plasma
- RWM/kink appears with slow positive rotation when $\beta_N > \beta_{N\ no\text{-}wall}$
  - $\omega_{RWM} \sim 1$ kHz
  - $\omega_{1/1} \sim 5$ kHz
  - $\omega_{edge} \sim 3$ kHz
  - ⇒ $\omega_{RWM} < \omega_{edge}$ violates no-slip condition
- 1/1 mode continues high frequency rotation
- RWM/kink reverses phase
- F-A dispersion relation predicts phase reversal for external kink branch
  - theoretical calculations to determine required dissipation and other parameters for this behavior ongoing





Future Work

- Map out I_p-B_t stability space
  - determine if RWM stability dependent on q or B_t in NSTX
    - can discrepancy with DIII-D Ω_{crit} dependence be resolved?
  - New capabilities expand operating space
    - full TF allows wider range of q
    - active coil gives rotation control
- Continue evaluation of dissipation mechanisms
  - finish proposed scans to vary coupling to mechanisms
  - numerical calculations to determine relative magnitudes
  - compare with predictions of F-A analytic model
- Completion will give possibility of firm conclusions on nature of RWM dissipation mechanism