CY 02+ XPs Supporting Proposed MHD Stability and Mode Control Research

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MHD Stability ET Group - 2001 Experimental Plans Session

Princeton Plasma Physics Laboratory

Mode Control Topics to address in CY 2002+

- Study long duration wall-stabilized plasma (many τ_{wall})
  - Continue analysis of RWM physics in ST magnetic field geometry
  - Compare RWM physics between low and moderate A devices
- Sustain operation significantly above present beta limit
  - Study of instabilities above no-wall limit, and $\beta_N > 6l_i$
- Analyze modes in diamagnetic plasmas ($\beta_N \sim > 5.5$)
  - Present plasma strongly paramagnetic ($B_t(0)/B_{t\_vac} = 1.41$)
    - Even though paramagnetic, present β_t = 26% => $\beta(0)$ = 48% !
  - Study modes in plasma with unity central beta (and above)
- Design active feedback system based on this study
  - Re-design of present passive feedback configuration

Experimental Proposals: CY 2002+

MHD

- XP20 Characterization of the resistive wall mode in the ST
  - Sabbagh, et al., pending final review
- XP: Aspect ratio effects on resistive wall mode stability (NSTX/DIII-D similarity experiment)
  - Garofalo / Sabbagh, et al., also Submitted to GA group Thrust #4
  - Pressure-driven mode/wall coupling and beta limit comparison
- XP: Physics of ballooning mode stabilization at low A
  - Awaiting availability of internal magnetic measurements
  - Will examine second stability regime at low aspect ratio

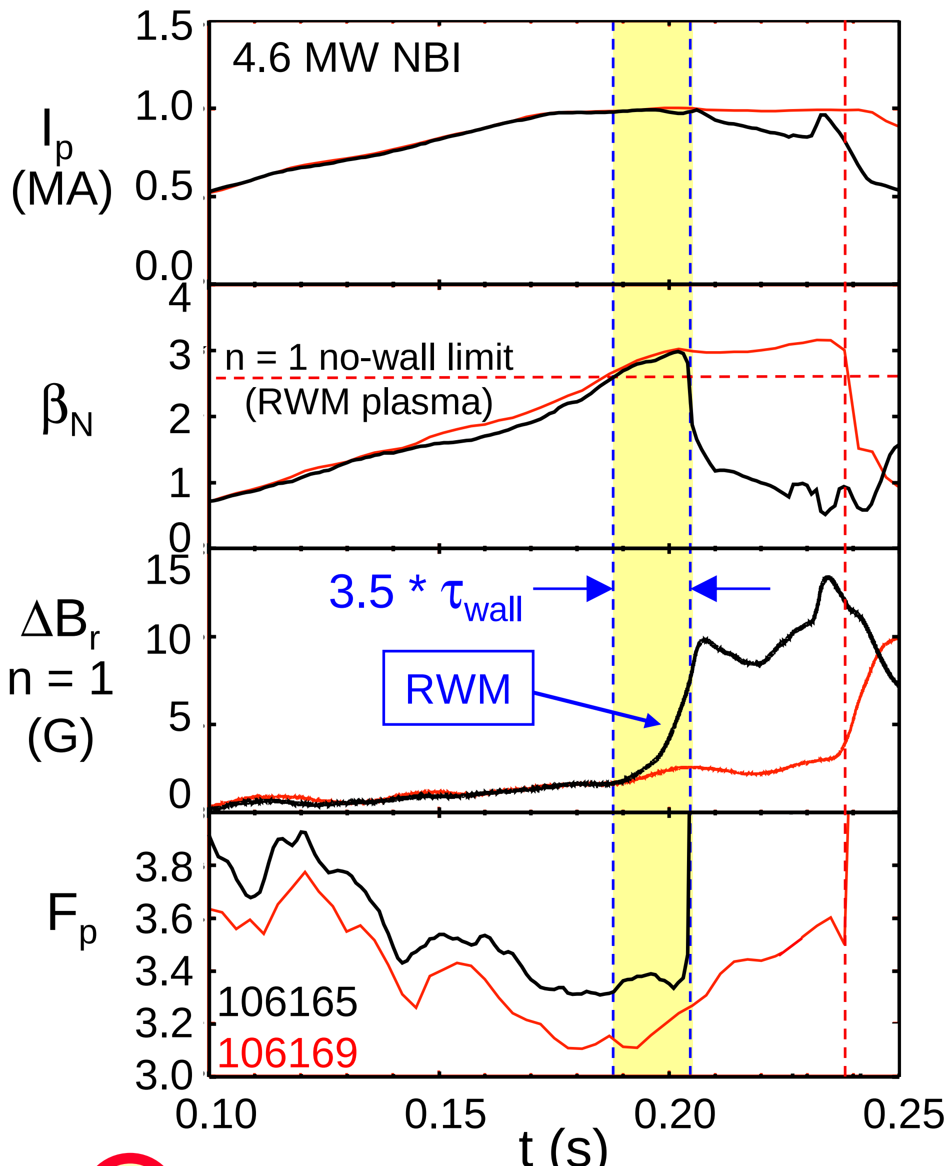
ISD

- XP: Dependence of resistive wall stabilization on equilibrium configuration
  - Paoletti, et al., submitted to the ISD Experimental Task Group

XP20 Characterization of the Resistive Wall Mode in the ST

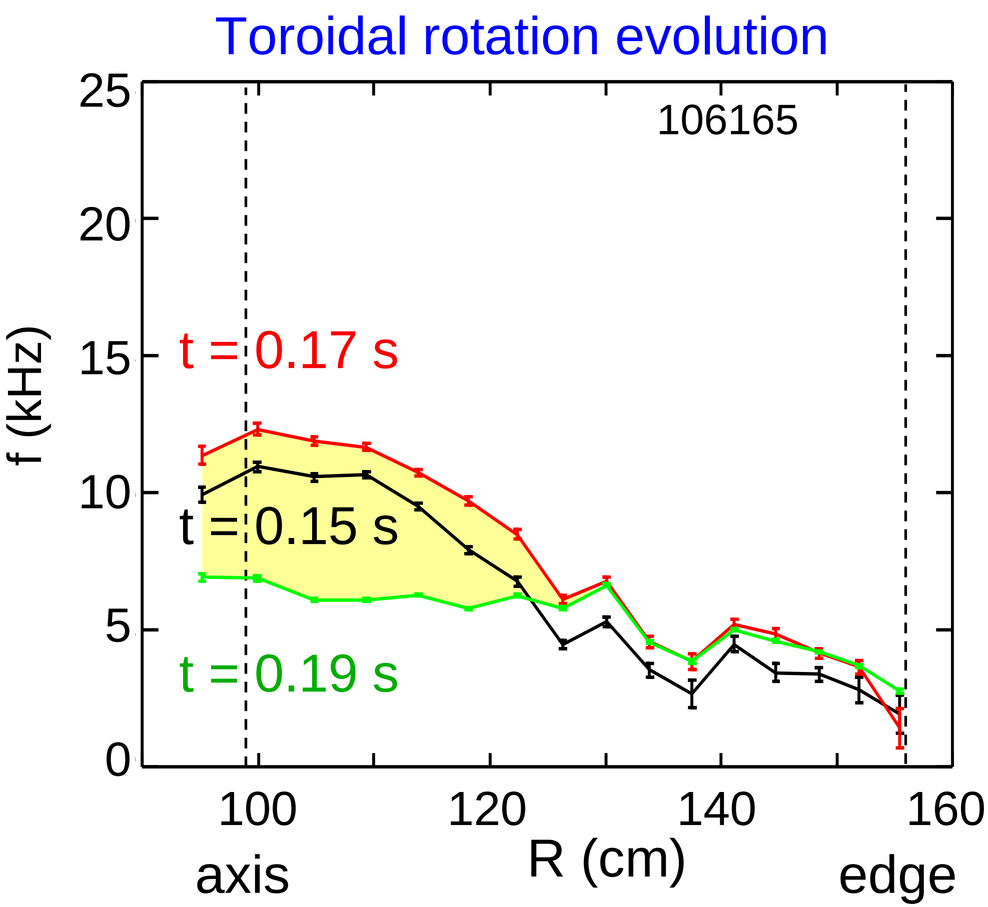
- Motivation
  - Determine / analyze RWM characteristics in spherical torus geometry
- Goals
  - Stabilize RWM for longer duration (t ~> 10 τ_{wall})
    - Operate with reduced error field to reduce rotation damping
      - PF5 coil centering, and/or operate plasma closer to upper passive plates
    - Use less rapid change of NBI heating; allow V_{ϕ} to reach high levels
    - Sustain low l_i with divertor operation, and/or H-mode, and/or HHFW
  - Attempt operation significantly above β_N ~ 6l_i
  - Determine critical rotation frequency for RWM growth
  - Analyze dependence of critical rotation frequency on Alfven speed
  - Measure δT_e due to RWM using unequal TS pulse interval
  - Vary localization of toroidal rotation damping and correlate radial variation of mode amplitude
    - Possible through equilibrium profile variation

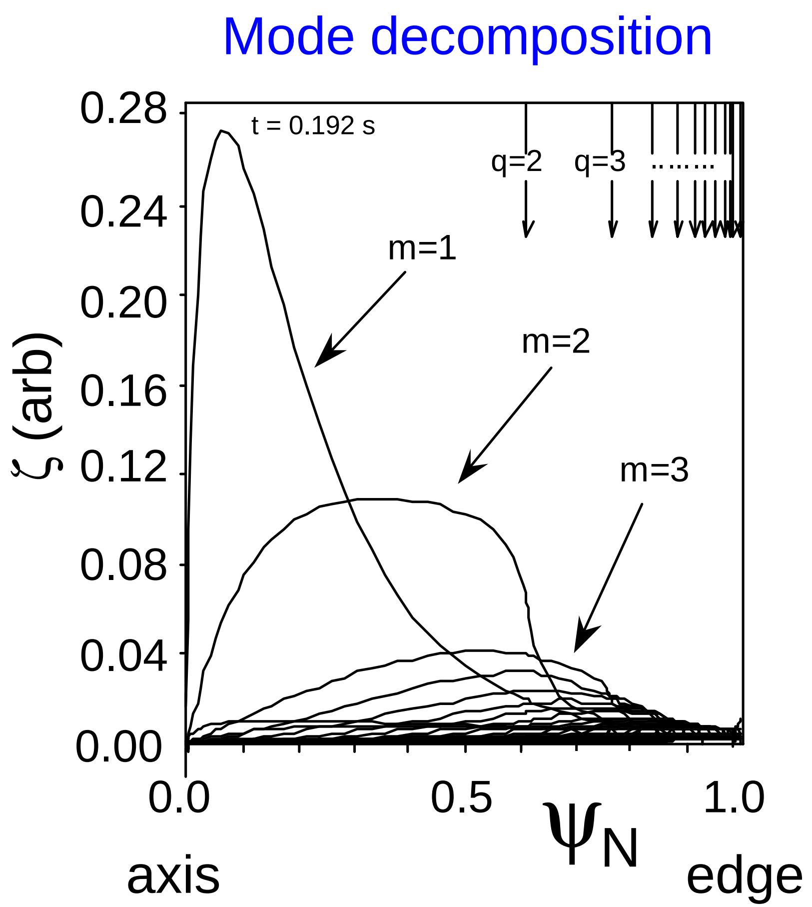
Resistive wall mode observed on locked mode detector



- Observed when ideal no-wall limit violated
  - Not observed with low NBI power
- Observed in locked mode signal
  - when mode computed to be coupled to wall
  - after toroidal rotation decrease
- Growth rate ~ 1 / τ_{wall}
- Grows while plasma is rotating and β_N increasing
- Unique rapid rotation decrease across plasma core
- No clear precursor in Mirnov signals
- USXR shows kink perturbation

Toroidal rotation damping strongest where mode amplitude is largest in RWM





GATO

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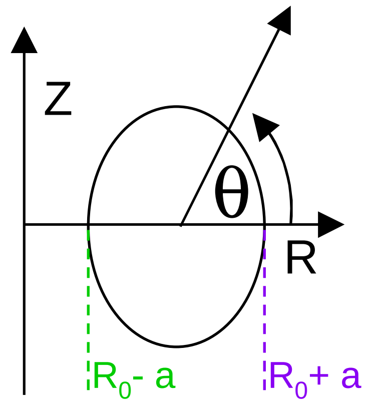
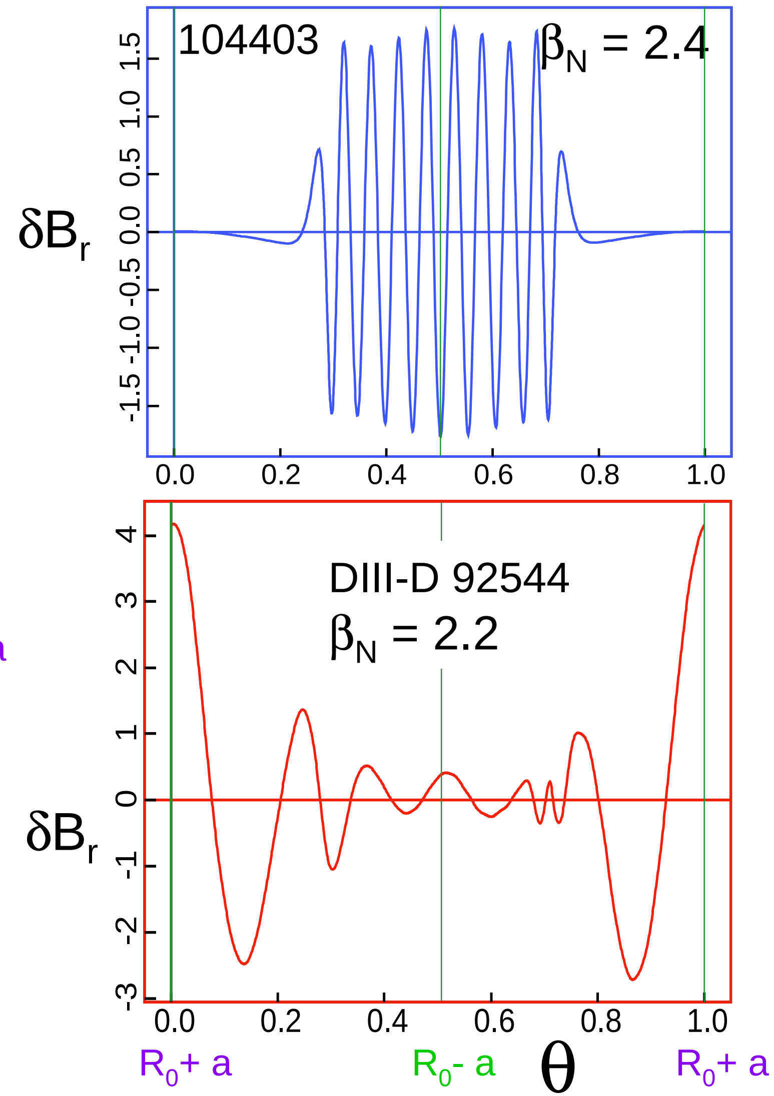
Aspect ratio effects on resistive wall mode stability (NSTX/DIII-D similarity experiment)

- Motivation
  - Compare RWM physics between low and moderate A devices
- Goals
  - Create similar discharges with different aspect ratios
    - Match poloidal cross-section, β_N, proximity to no-wall limit
  - Compare RWM physics for similar and different edge q
    - Plasma / wall coupling
    - Rotation damping rate and critical rotation frequency
    - Radial variation of mode amplitude (rotation damping profile)
    - RWM growth rate
  - Determine key equilibrium differences producing RWM differences
    - Can ideal MHD explain differences in RWM behavior by difference in aspect ratio and q?

Edge δB_r significantly different in ST magnetic field geometry relative to advanced tokamak

- δB_r n = 1 at edge: NSTX at β_N ~ 2.4
  - Minimum amplitude on outboard side
  - short poloidal wavelength on inboard side
  - Weak wall coupling



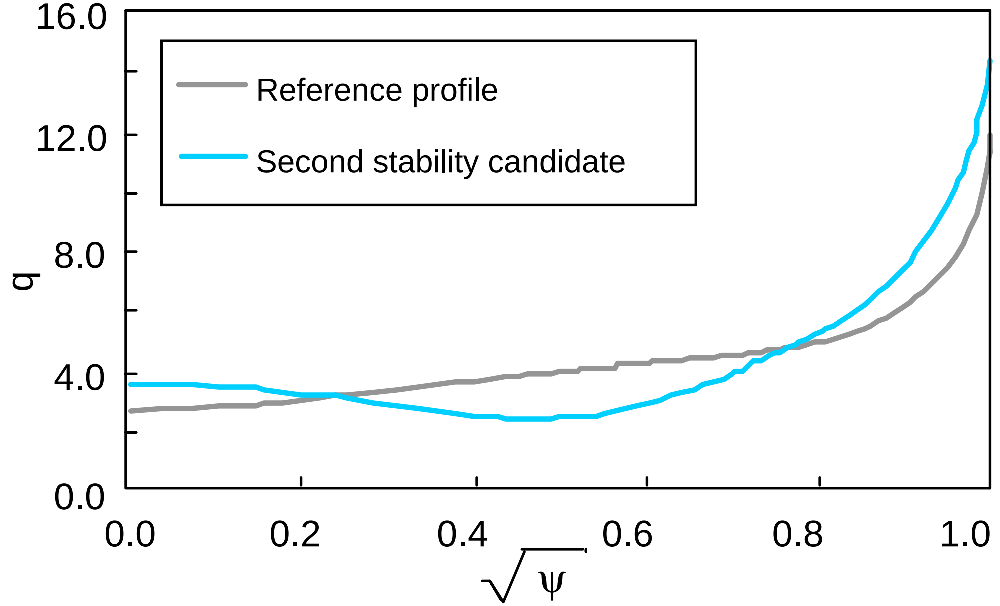


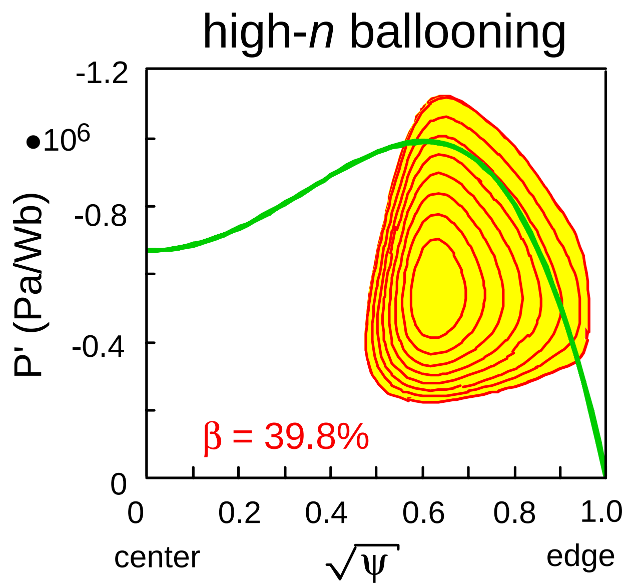
- δB_r n = 1 at edge: DIII-D at β_N ~ 2.2
  - Maximum amplitude on outboard side
  - relatively long poloidal wavelength
  - Strong wall coupling

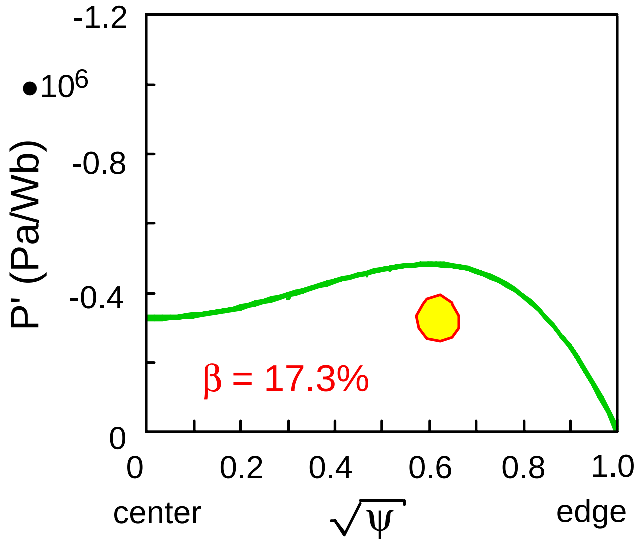
Physics of ballooning mode stabilization at low A

- Motivation
  - Exploit synergistic effects of geometric magnetic well at low A and current profile shaping to increase high-*n* stability
  - Examine the experimental balance of stabilizing effects and destabilizing poloidal field curvature
  - Examine role of FLR effects on high-*n* stabilization
- Goals
  - Operate plasmas with flux surfaces in the second stable region
  - Quantify influence of geometric well and poloidal field curvature
  - Demonstrate plasma behavior when quickly thrust into high-*n* unstable region
  - Demonstrate unique characteristics of second region boundary behavior expected at low A
- Note: requires internal magnetic data to determine q

Low A yields unexpected second stability behavior







- As P profile is scaled down
  - Closed unstable region shrinks and disappears
  - As β increases, marginally stable to high-n at β = 32.2%
- Due to higher order 1/A effects such as poloidal field curvature (destabilizing)

Required and Desired Diagnostics

- Required
  - Flux loops and integrated poloidal Mirnov coil data
  - CHERS toroidal rotation measurement
  - Locked mode detector measurements
  - Thomson scattering
  - Diamagnetic loop
  - USXR
- Desired
  - Second toroidal position USXR array
  - Toroidal Mirnov array
  - Measurements of currents in passive conducting structures
  - Mirnov coils measuring radial field perturbation
  - Fast camera