CY03 XPs Supporting Proposed MHD Stability and Mode Control Research

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MHD Stability ET Group - Experimental Planning Session

Princeton Plasma Physics Laboratory

Fulfilling proposed research on global mode stabilization

- Past Columbia research grant objectives fulfilled
- Present NSTX plasmas are well advanced
  - Long duration, wall-stabilized plasma (many τ_{wall})
  - Operation significantly above no-wall β_N limit
  - Diamagnetic ST plasma
- Future research supporting three year DoE grant
  - Passive stabilization (including conducting plate re-design)
  - Resistive wall mode physics
  - Wall-stabilized high β_N equilibrium resilience
  - Active feedback (including design – GMS working group)

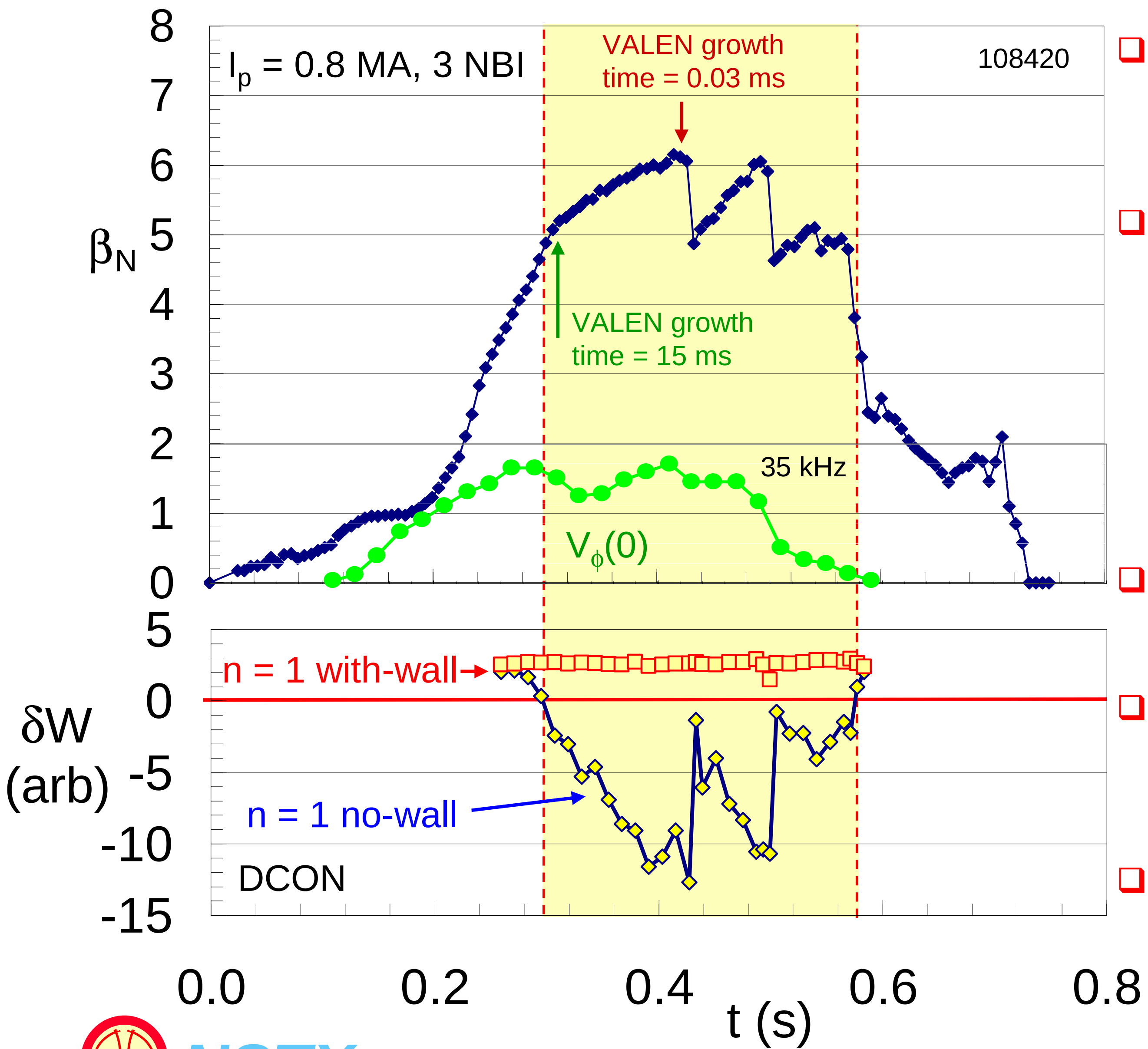
Experimental Proposals: CY 2003+

- XP: Stabilization physics of resistive wall mode in high β_N ST
  - Sabbagh, et al., aimed to utilize CY03 enhanced RWM diagnostic set
  - Passive/active stabilization physics of the sustained, high β_N RWM
- XP: Aspect ratio effects on resistive wall mode stability (NSTX/DIII-D similarity experiment)
  - Sabbagh/Garofalo/Reimerdes et al., to be resubmitted to GA group Thrust #4 (Dec. 2002)
  - Pressure-driven mode/wall coupling and beta limit comparison
- XP: Rotation damping physics of the resistive wall mode
  - Zhu, et al., supporting graduate student thesis
- XP: Resilience of low A plasmas to kink/ballooning modes
  - Determine high/low-n kink/ballooning physics by crossing boundaries

Stabilization physics of resistive wall mode in high β_N ST

- **Motivation**
  - Determine / analyze high β_N RWM stabilization in ST geometry
- **Goals**
  - Stabilize RWM for long duration (t >> 10 τ_{wall}) at various $\beta_N > \beta_{N\ no\text{-}wall}$
    - Choose configuration with high V_ϕ
    - Operate at lowest sustainable l_i to maximize $\beta_N / \beta_{N\ no\text{-}wall}$
  - Determine dependence of rotation sustainment on q_{min}
  - Determine effectiveness of passive stabilization on $\beta_N / \beta_{N\ no\text{-}wall}$
  - Determine dependence of critical rotation frequency on $\beta_N / \beta_{N\ no\text{-}wall}$
  - Measure δT_e *evolution* during RWM using unequal TS pulse interval
  - Utilize initial active feedback system (when available)
  - Utilize RWM advanced diagnostic set to be available in 2003
    - RWM sensors, 2D USXR, MSE, etc.

Passive stabilization less effective at highest β_N



- Plasma sustained at 30% over no wall limit for 18 τ_{wall}
- Passive stabilizer loses effectiveness at maximum β_N
  - VALEN growth time now much shorter (0.03 ms) at collapse time
- $V_\phi(0)$ increases as $\beta_N >> \beta_N$ no-wall
- Stabilizer regains effectiveness after β_N collapse
- Operation above no-wall limit ceases when $V_\phi(0)$ small

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 present RWM stability theory explain differences in behavior by difference in aspect ratio and q?

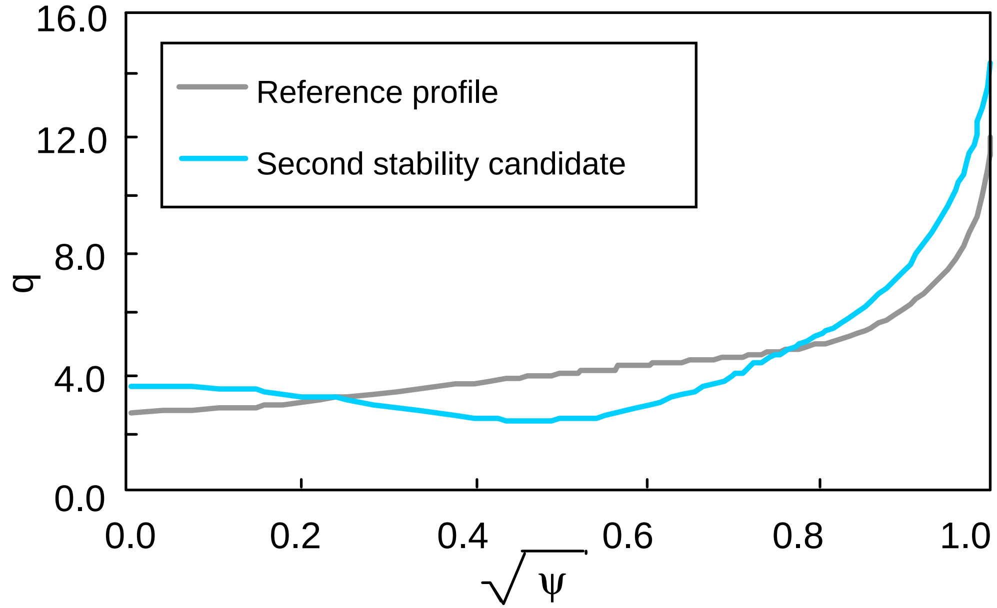
Rotation Damping Physics of the Resistive Wall Mode

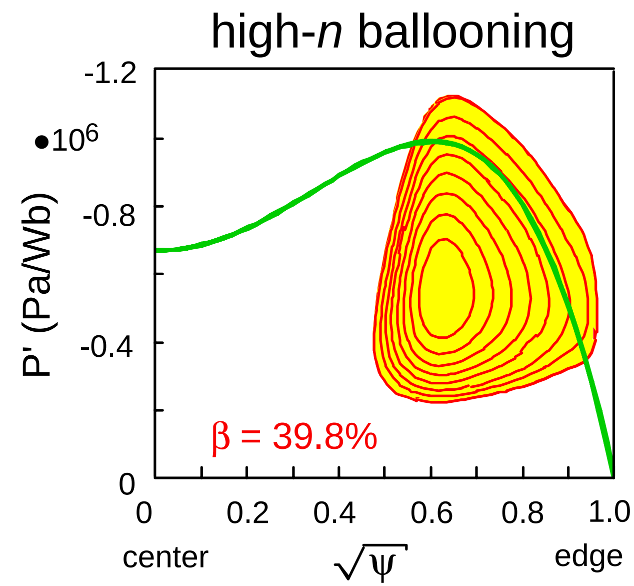
- Motivation
  - Determine the physics of rotation damping by the resistive wall mode
    - Present theories include sound wave damping, Alfven wave resonances, ion Landau damping, TTMP
- Approach / Goals
  - Conduct experiment that will vary key physics parameters in RWM rotation damping theories
    - Present NSTX RWM data indicates that disappearance of low-order rational surfaces (by B_t scan) can alter rotation damping
  - Compare experimental results to all applicable theories
    - Including numerical models, if need be
  - Work with proponents of the most promising theories to determine alterations needed to match experiment
    - Aspect ratio effects and poloidal mode coupling are neglected in many models. NSTX might clarify the role of these effects.

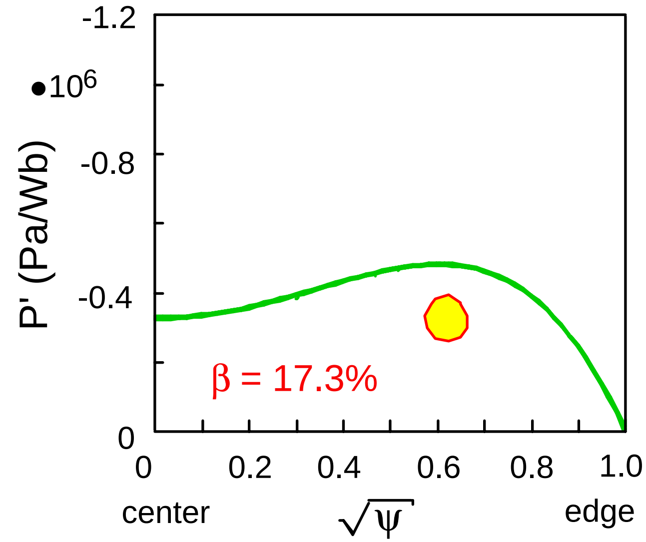
Resilience of low A plasmas to kink/ballooning modes

- Approach
  - Cross ideal low-n, high-n, and resistive wall mode stability boundaries and determine plasma dynamics in stability space
    - does plasma return to a new equilibria, or suffer β collapse?
- Goals
  - Determine key physics of observed dynamics in stability space
  - Operate plasmas with flux surfaces in the high-n second stable region
    - Exploit synergistic effects of magnetic well at low A and current profile shaping to increase high-*n* stability
  - Demonstrate plasma behavior when quickly thrust into high-*n* unstable region
  - Demonstrate unique characteristics of second region boundary behavior expected at low A
  - Examine role of FLR effects on high-*n* stabilization
- Note: internal magnetic data to determine *q* required for high-n stability diagnosis

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)

Duration and Required / Desired Diagnostics

- Each XP could be completed in 1 – 1.5 run days
- Required
  - Flux loops and integrated poloidal Mirnov coil data
  - CHERS toroidal rotation measurement
  - Locked mode detector measurements
  - Thomson scattering
  - Diamagnetic loop
  - USXR
- Desired
  - MSE
  - Advanced RWM sensors
  - Advanced USXR diagnostics
  - Toroidal Mirnov array
  - Fast camera