XP 512: RWM Critical Rotation Profile and Comparison to DIII-D

A. C. Sontag

Department of Applied Physics and Applied Mathematics, Columbia University

NSTX Results Review - 12/12/05

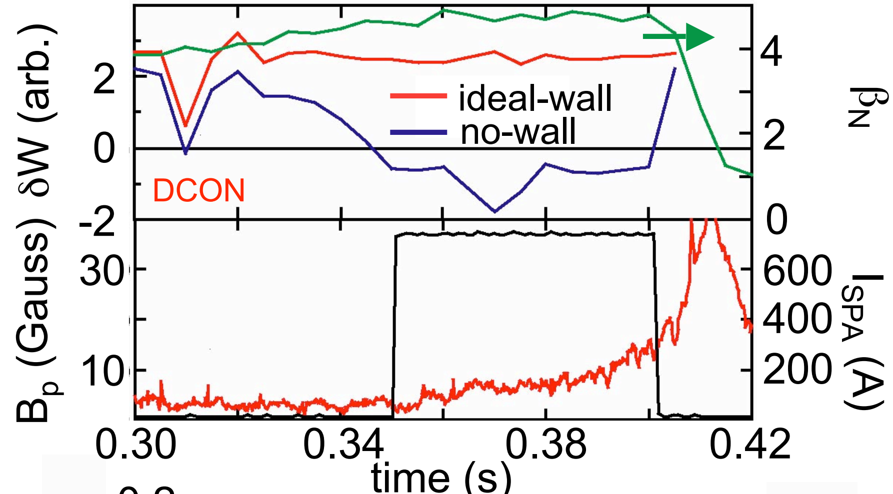
Princeton Plasma Physics Laboratory

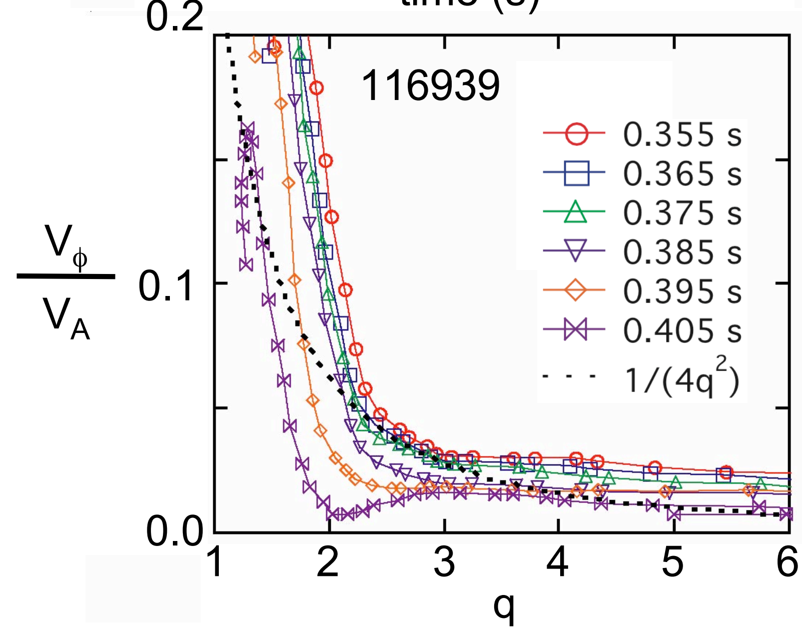
Active Rotation Braking Allows NSTX to Examine Rotation Profile Effects on RWM Stability

- Previous work on NSTX relied on ‘natural’ RWM destabilization
  - most cases were rotationally stabilized
  - rotation braking due to n = 1 MHD interferes with RWM identification
- 2004 data indicated $1/q^2$ dependence for Ω_{crit}
  - high rotation across entire profile guarantees stability
  - in-between cases difficult to diagnose
- Application of n = 1 & 3 external perturbations allows controlled rotation braking to induce RWM
  - can induce RWM by dropping rotation from edge inward
  - also gives resonant field amplification (RFA) observations to characterize mode

Application of External n = 1 Causes RFA & Rotation Braking Until Unstable RWM Growth

- Resonant field amplification (RFA) when $\beta_N > \beta_{N\ no\text{-}wall}$
  - amplification of external perturbations by *stable* RWM
  - predicted by theory*
  - Ideal MHD stability δW from DCON (A.H. Glasser)
- RFA observed until rotation braking destabilizes mode
  - unstable growth after significant rotation damping
  - edge rotation remains stabilizing
  - low rotation at multiple low-order rational q surfaces

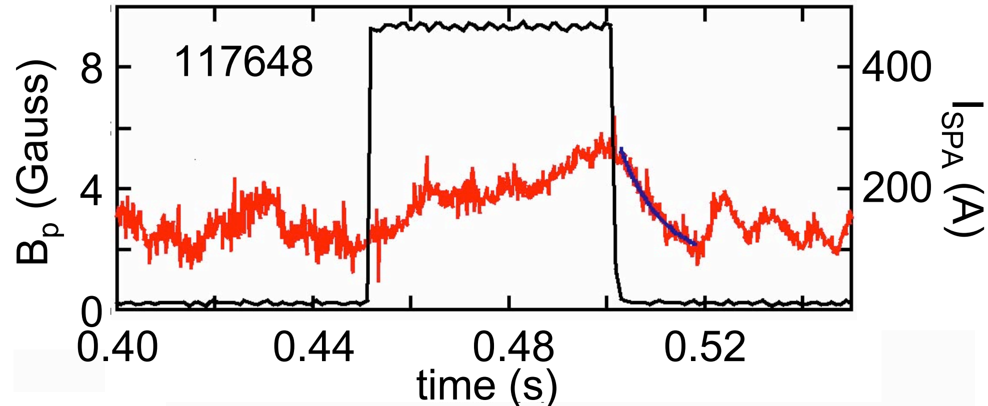


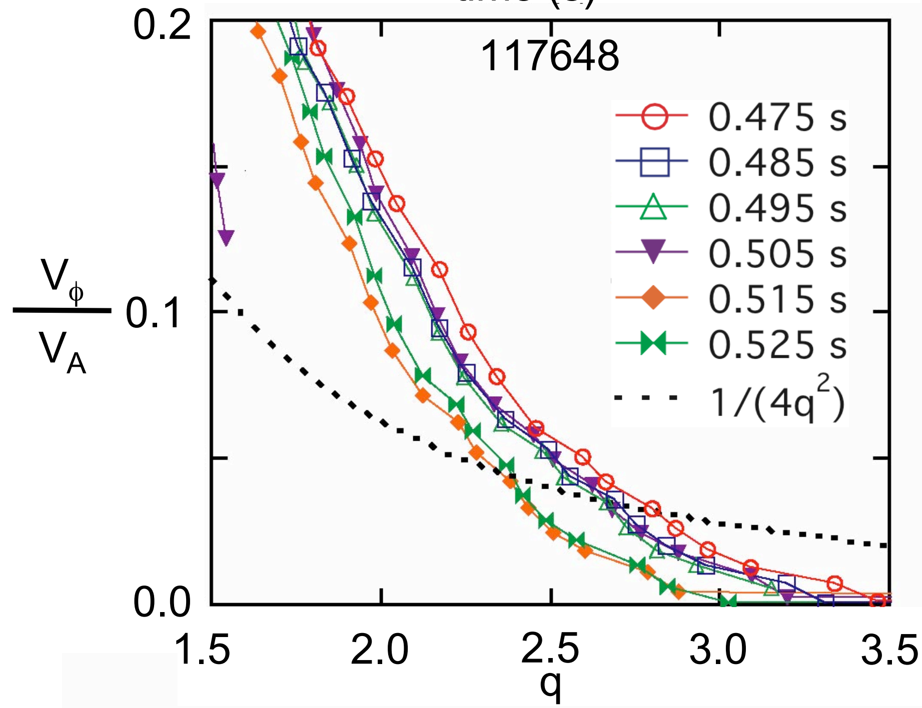


*Boozer, A.H., Phys. Rev. Lett., **86** 5059 (2001)

RFA Decays When External Field Turned Off Before RWM Destabilization

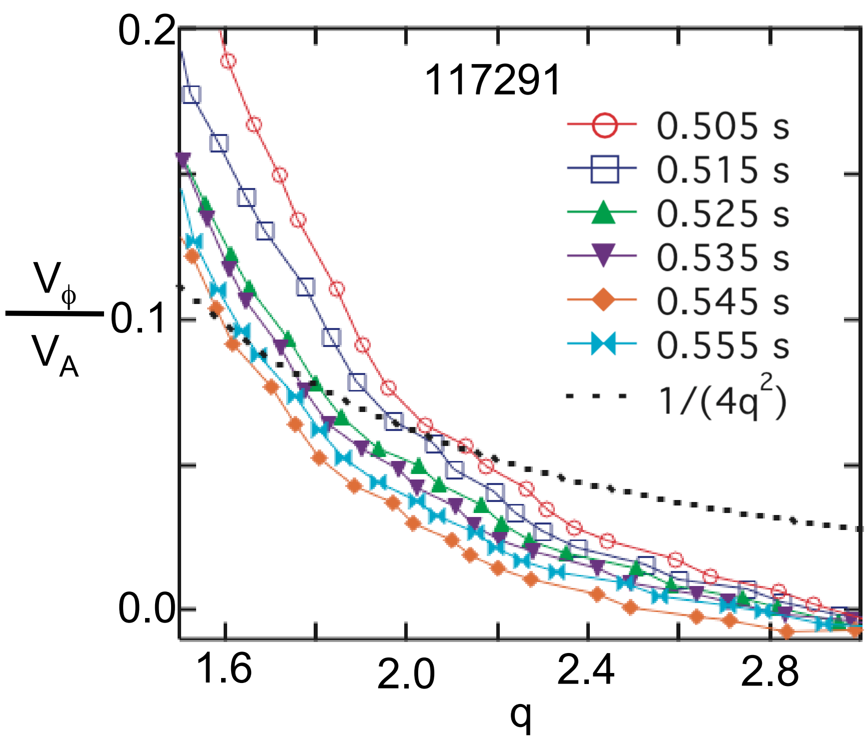
- rotation remains high at some low-order rational q surfaces
  - near zero rotation outside q = 3 (ψ_N ~ 0.65)
- field amplitude below threshold
  - ~20 Gauss causes unstable mode growth and disruption
- 9.1 ms decay time measured

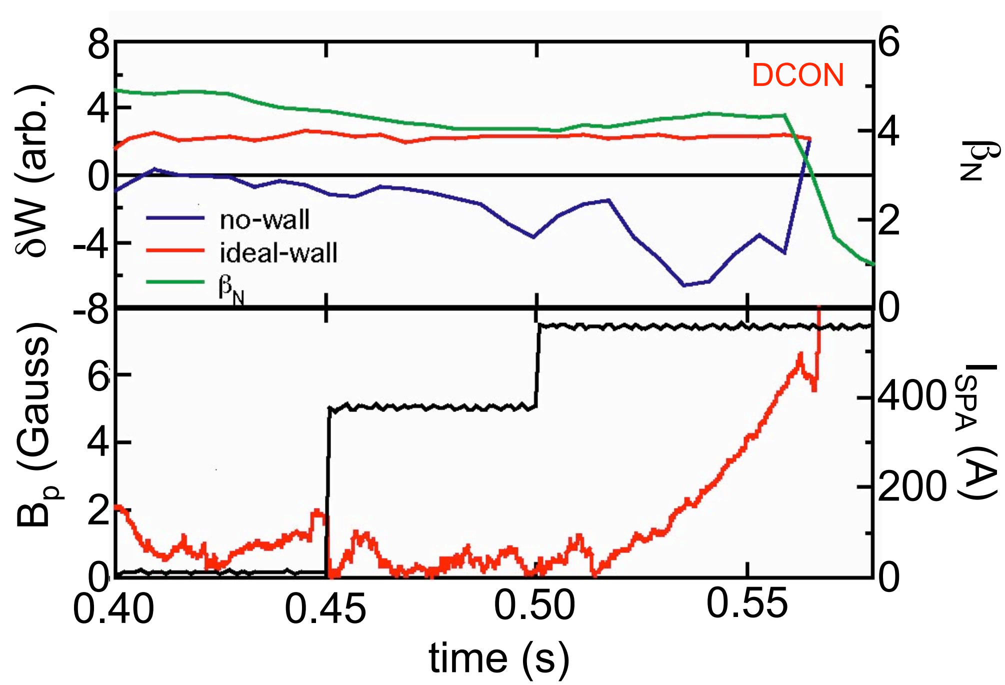




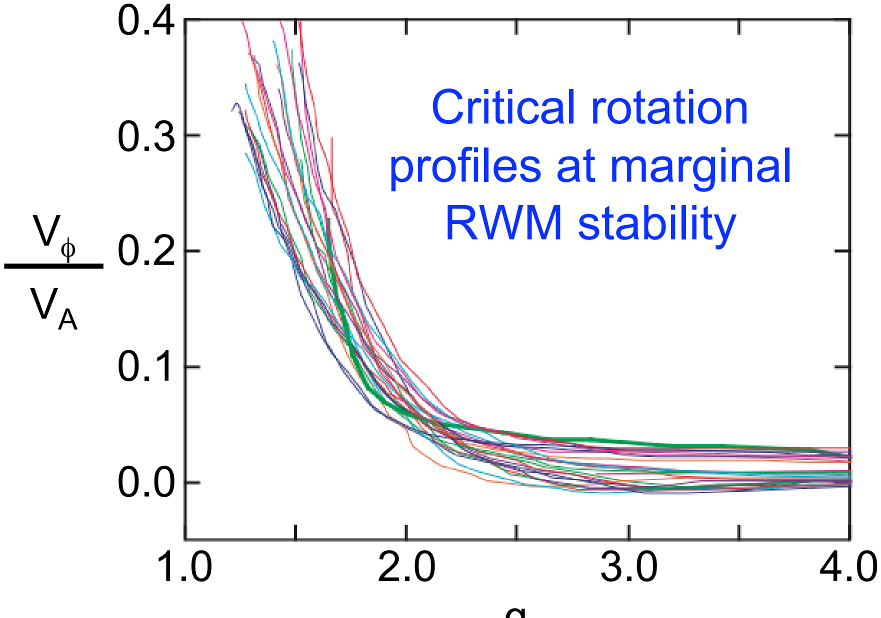
Rotation on Higher Order Rational Surfaces Not Required for RWM Stabilization

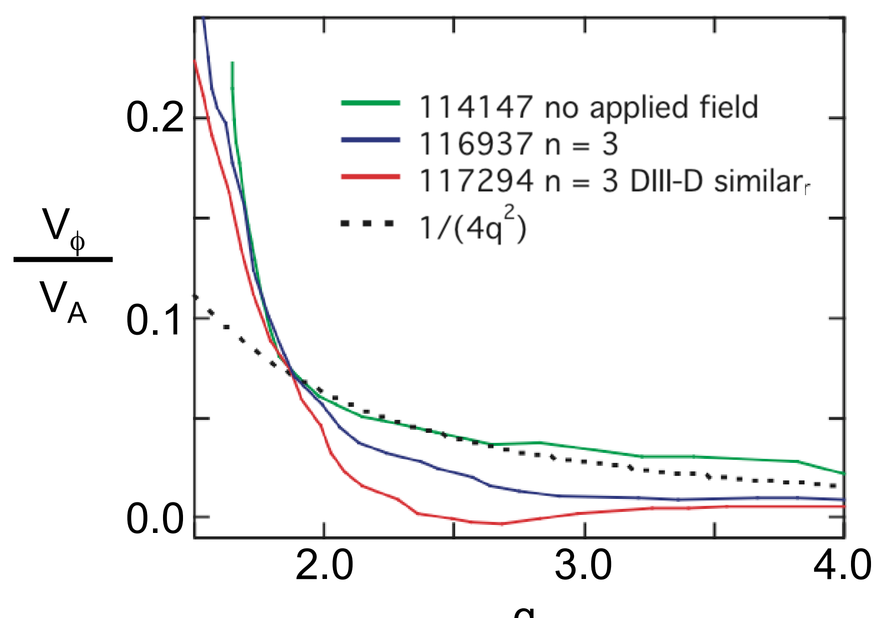
- Plasma remains RWM stable with near zero rotation outside q = 3
  - Stable with near zero rotation outside ψ_N = 0.62
  - growth coincides with low rotation inside of q = 2





Significant Variation Observed in Marginal Rotation Profiles

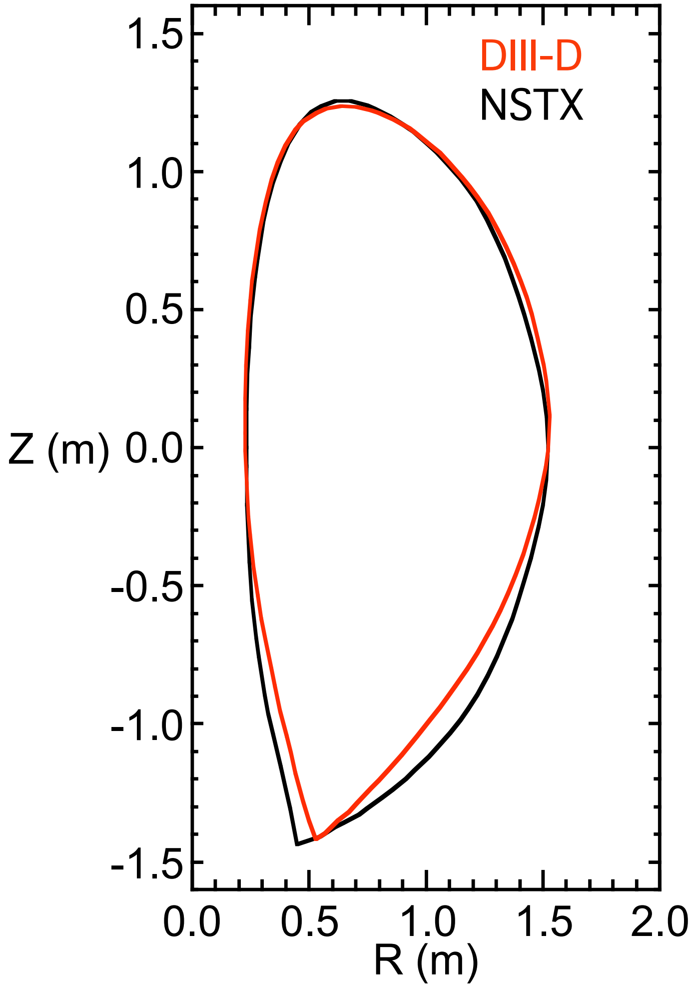




- Each case is last profile before unstable RWM growth observed
- Shot with no applied field has entire profile near or above $1/4q^2$
- n=3 applied field used to alter rotation profile
  - rotation in edge of plasma suppressed
- q = 2 region appears significant but not definitive

DIII-D Shape Reproduced to Examine A Scaling of Ω_{crit}

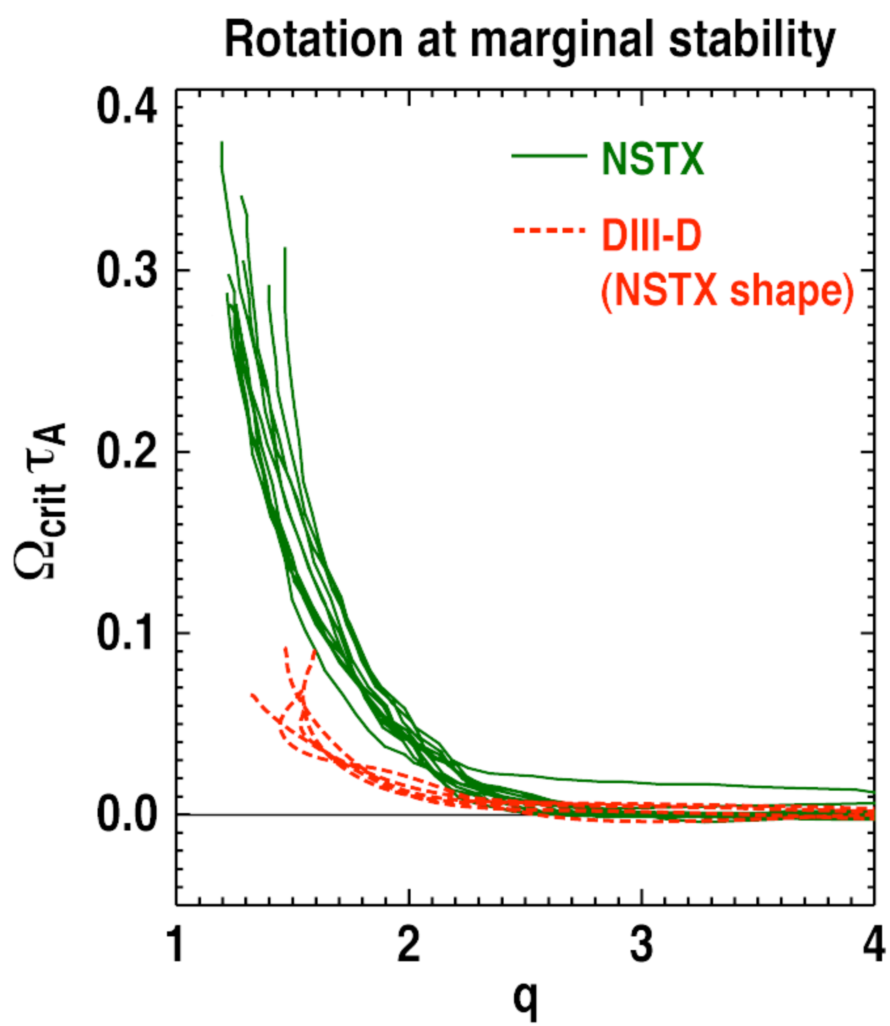
- Including neoclassical viscous dissipation in RWM dispersion relation* leads to inverse aspect ratio dependence of Ω_{crit}
- Previous comparisons used different techniques to determine Ω_{crit}
  - Active braking on NSTX allows more straightforward comparison
- DIII-D shape matched in NSTX with $\beta_N > \beta_N^{no\text{-}wall}$
  - q & β scans performed



*Shaing, K.C., Phys. Plasma **11** 5525 (2004)

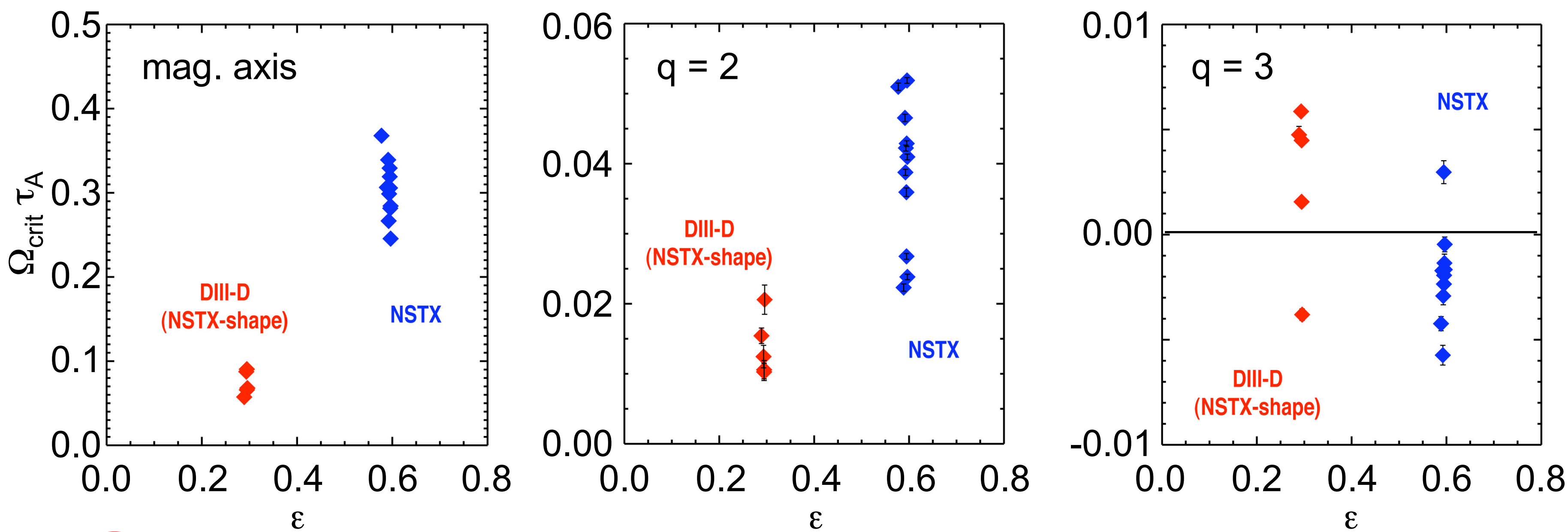
More Rotation Required for RWM Stability in NSTX

- Comparison of marginal profiles in similar shaped discharges
- Low rotation edge doesn't affect stability
- NSTX has higher rotation throughout region which determines stability



Similarity Experiment is Examining RWM Stability Variation with A

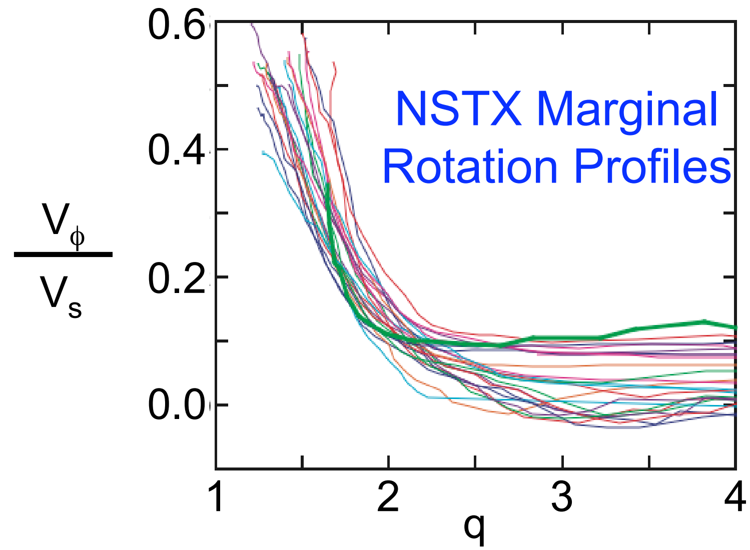
- Profile effects being studied
  - NSTX has higher rotation at q = 2 and in the core
  - very low rotation at q = 3 ⇒ Ω_{crit} cannot depend on q = 3
- Large data spread (especially NSTX)
  - subjectivity in determining start of unstable growth
  - 10 ms averaging time for rotation measurement



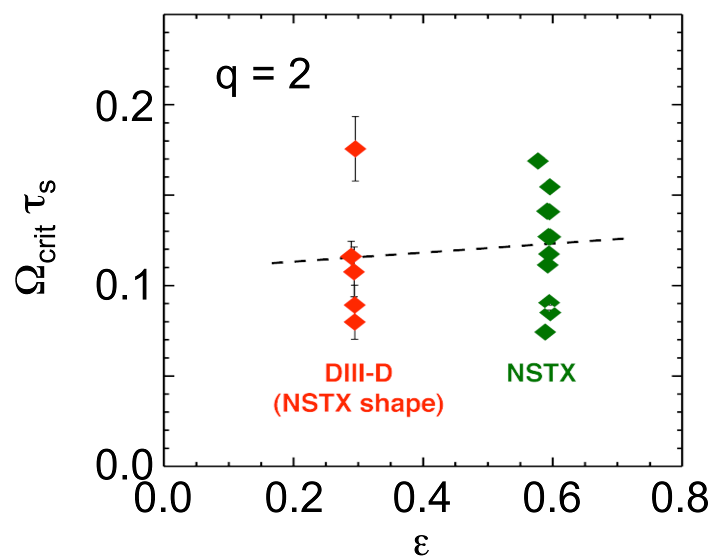
Sound Speed Normalization Removes Aspect Ratio Dependence

- Coupling to sound waves is one possible dissipation mechanism
  - depends on sound speed

$$V_s = \sqrt{\frac{kT_e + \gamma k T_i}{m_i}}$$



- Critical rotation variation at q = 2 reduced with V_s normalization
  - consistent with significant dissipation due to sound waves



Numerical calculations of relative magnitudes of sound and Alfven wave dissipation needed

Summary

- Active coils allow detailed study of RWM physics
  - rotation control
  - RFA studies - MHD spectroscopy
- Examining rotation profile effects indicates rotation at outer q surfaces not required for RWM stability
  - RWM stable discharges produced with low or negative rotation outside q = 3
  - core rotation (inside q = 1.5) alone cannot stabilize RWM
- DIII-D similarity study under way to determine aspect ratio effects on RWM stability
  - low-A requires higher rotation
  - V_s normalization removes aspect ratio dependence