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XP 619: RWM Passive Stabilization Physics in NSTX

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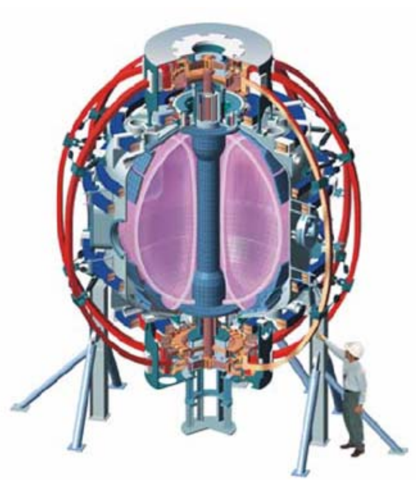

2006 NSTX Results Review
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PPPL

XP619 explores RWM passive stability physics

- Motivation:
  - Resistive wall mode (RWM) passive stabilization physics still not conclusively determined
- RWM Stabilization:
  - Alteration of instability drive
    - for example, p’ reduction by other MHD modes
  - Leading models invoke stabilization by energy dissipation related to plasma rotation (e.g. by resistivity, viscosity)
    - defines a critical plasma rotation (Ω_{crit}) for RWM stability
- Experiment:
  - scan parameters which are predicted to affect dissipation
  - observe effects on critical rotation

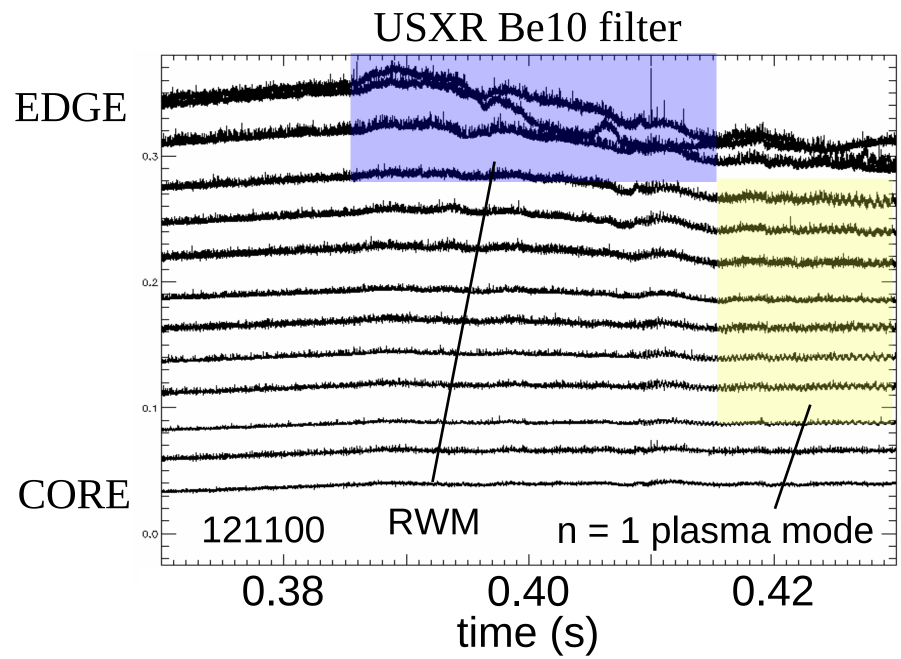
Examine several models used to predict RWM stability

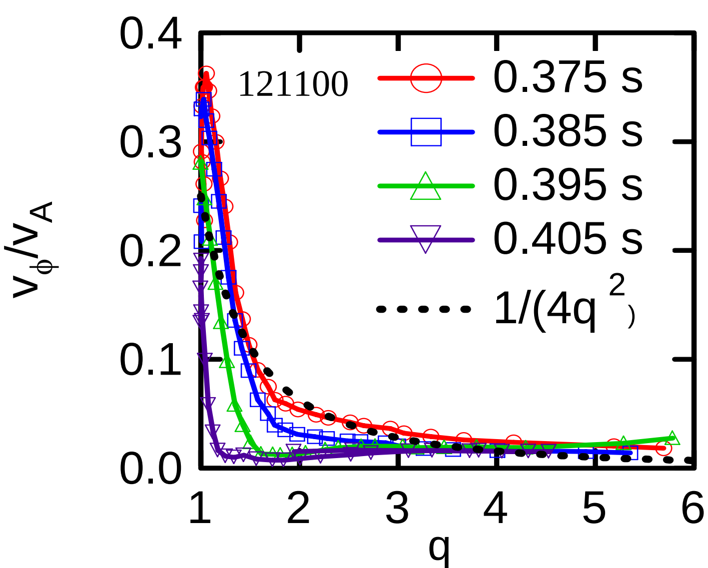
Stability Theory	Relevant Physics	Key Scalings
cylindrical tearing mode (Fitzpatrick)	rotation bifurcation mode interacting w/error field	bifurcation when: $\omega = \omega_0 / 2$
resistive layer (Finn/Gimblett-Hastie)	resistive layer dissipation + JxB torque on island	$(\gamma\tau_L)^{5/4} = \frac{1-\delta\gamma\tau_w}{-\varepsilon+\gamma\tau_w}$
"simple" RWM model (Fitzpatrick)	empirical perpendicular fluid viscosity	high ν_* limit: $\Omega_{crit} = \frac{1-md}{2\nu_*}$
semi-kinetic (Bondeson-Chu)	Alfven continuum coupling / ion Landau damping	stabilizing inertial enhancement: $\omega > \omega_A / 4q^2$
sound wave (Hammet-Perkins)	sound wave coupling / ion Landau damping	$F_{SD} = -\kappa_{\parallel}\sqrt{\pi}\lvert k_{\parallel} v_{th}^i \rvert \rho v_{\parallel}$
neoclassical effects (Shaing)	neoclassical perpendicular fluid viscosity	$T_{\mu\perp} \propto \varepsilon^{1/2} \nu_{ii}$
NTV (Shaing)	fluid-field viscosity	$T_{NTV} \propto \frac{p_i}{v_{th}^i} \frac{\omega}{\nu_{ii}}$

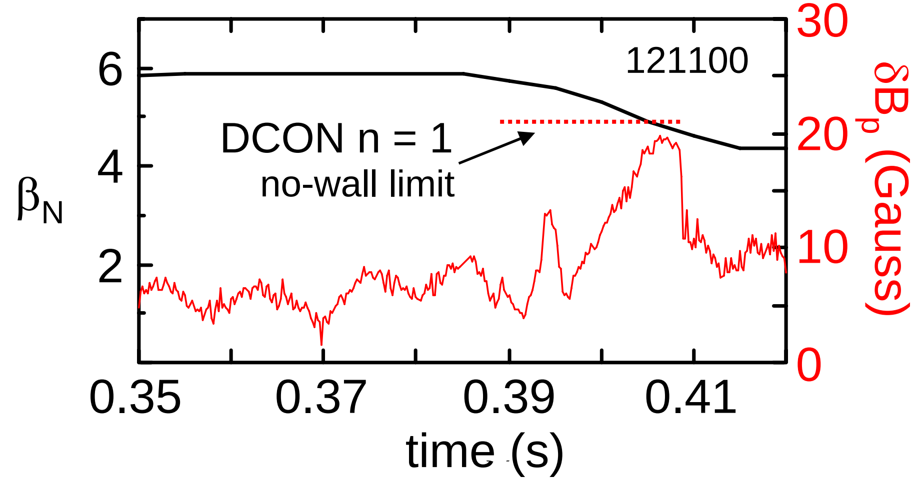
- experimentally varied ω_A & ν_{ii} to examine alteration of Ω_{crit}

Fast rotating plasma mode growth halts RWM growth

- rotation braking leads to unstable RWM growth
- appearance of large n=1 plasma mode coincides with reduction of RWM
- discharge suffers loss of β, but no disruption

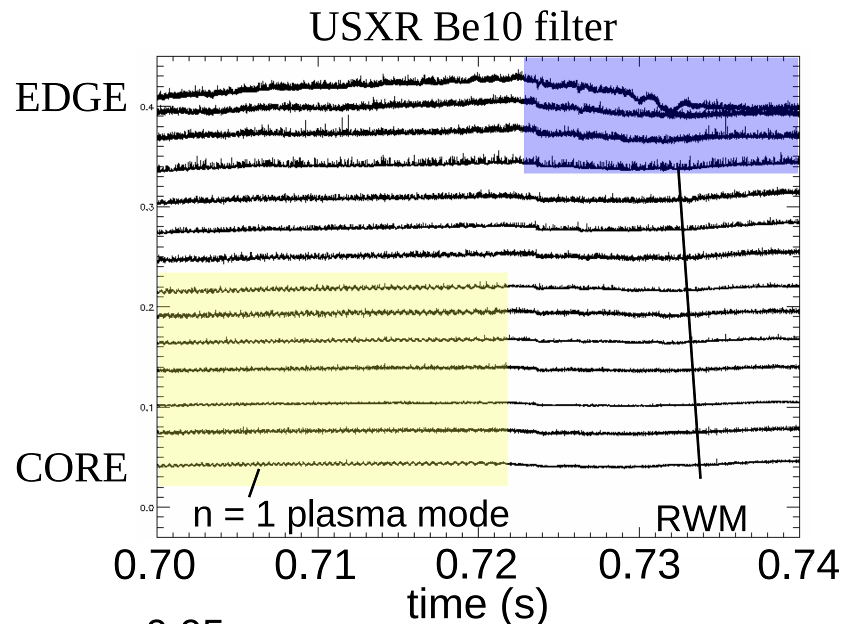


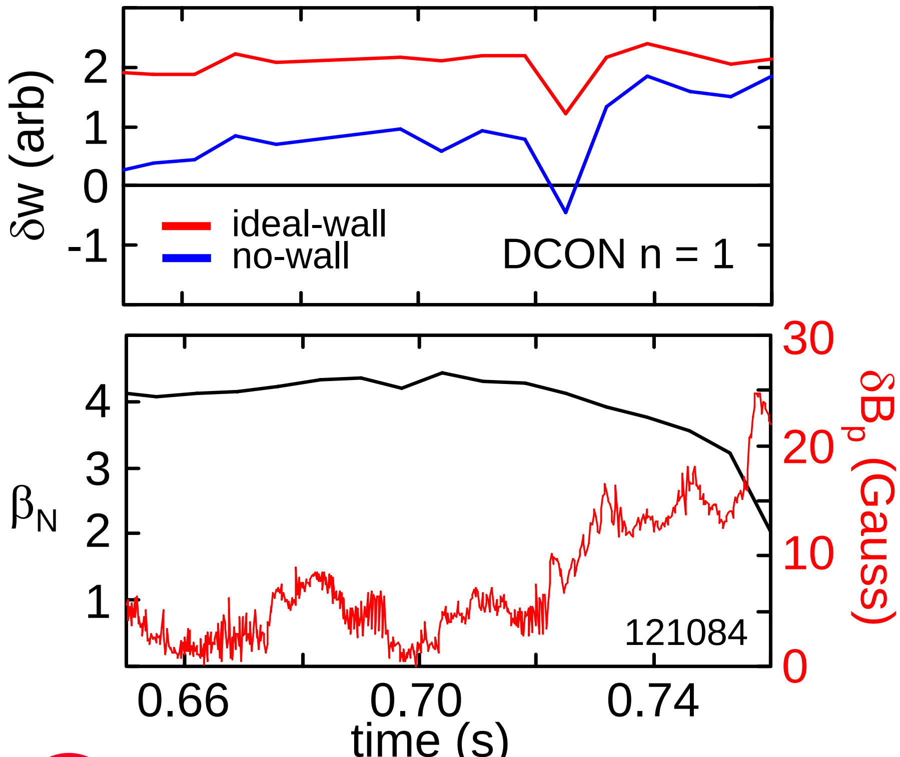


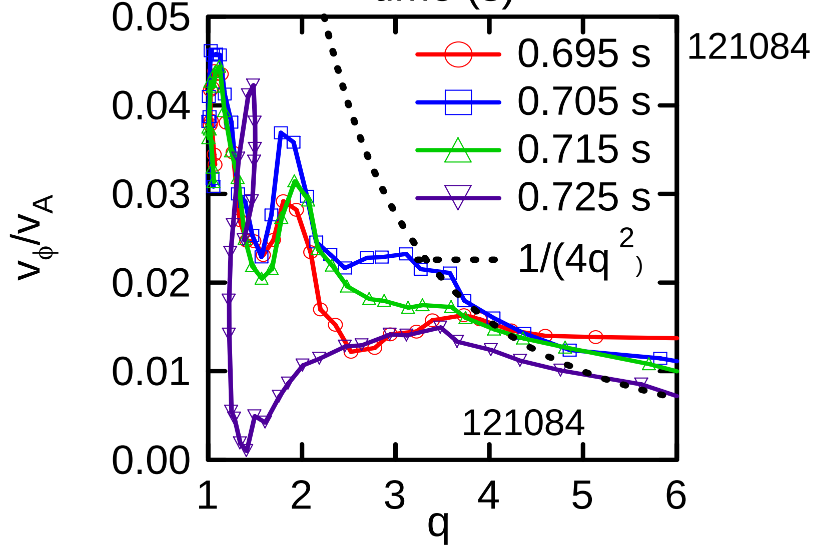


End of core n=1 plasma mode leads to RWM growth

- core mode keeps rotation low, RWM marginally stable
- DCON n = 1 no-wall near marginal stability as RWM starts growth

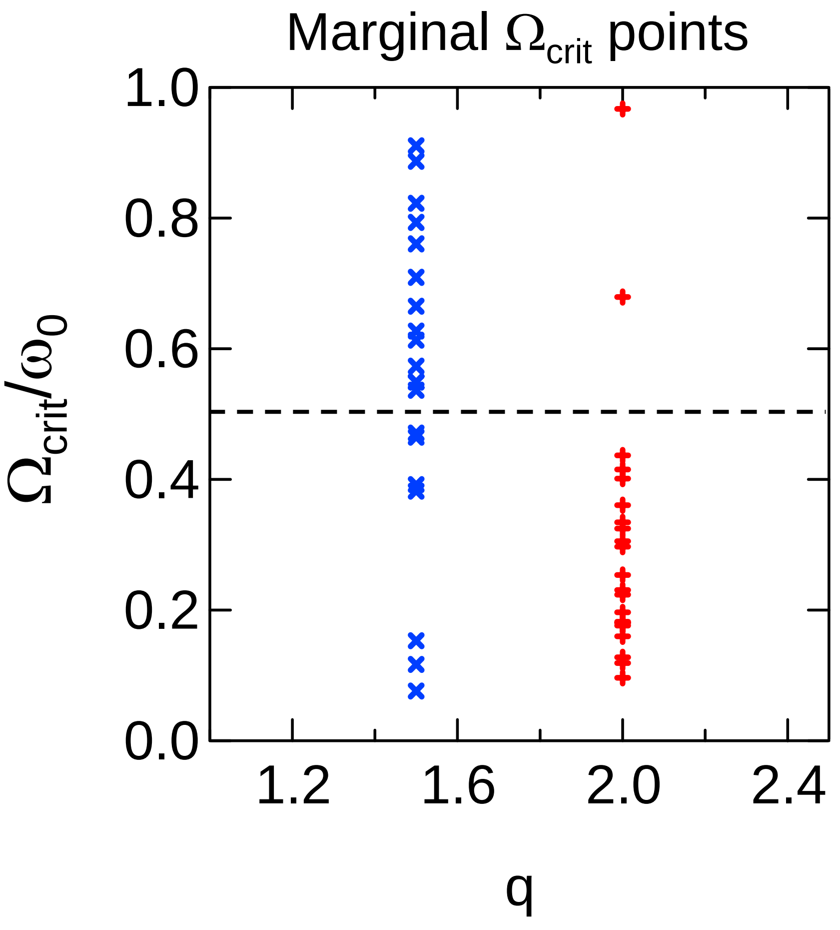






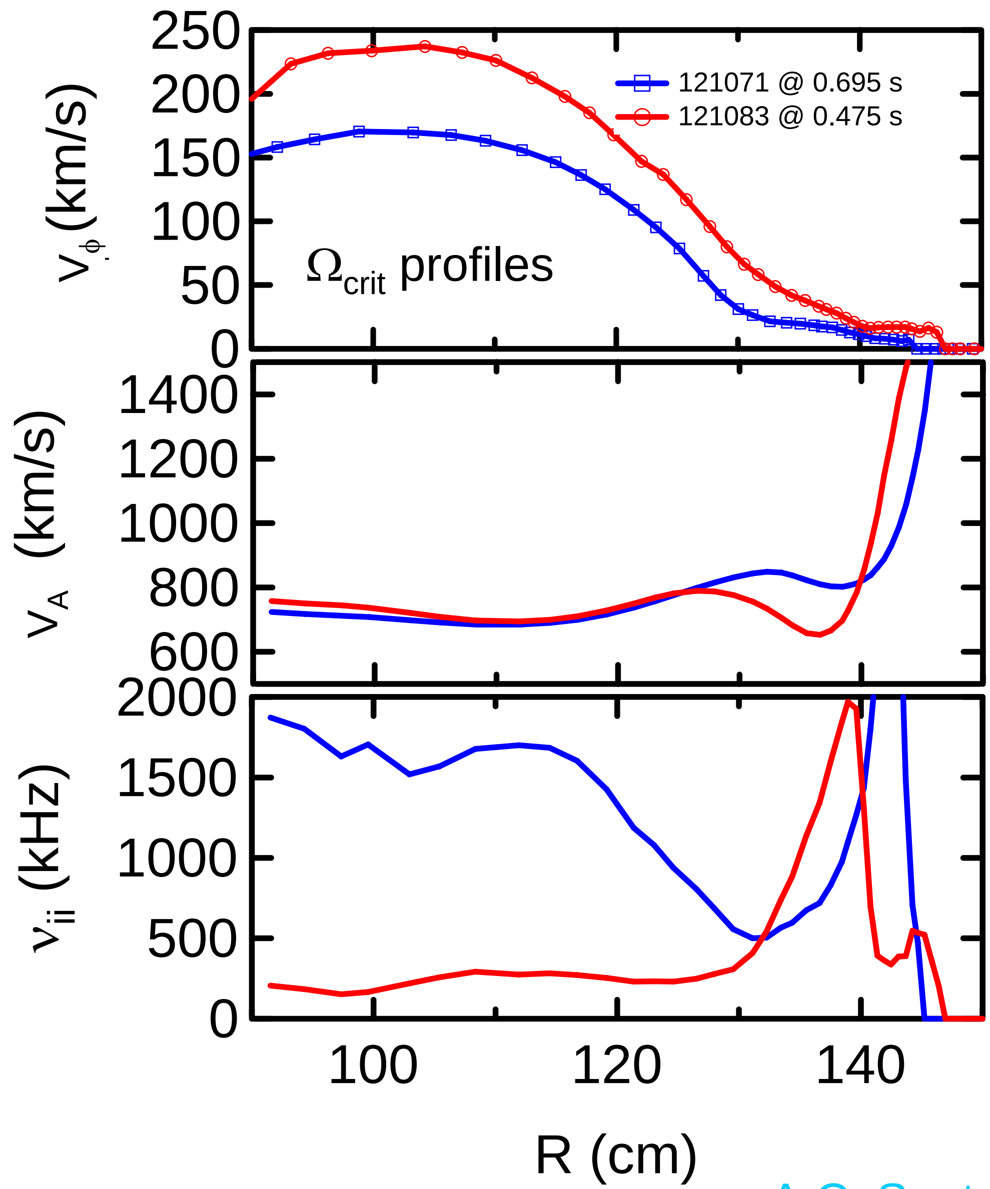
NSTX data inconsistent with Fitzpatrick mode locking model

- Model based on tearing mode interaction with error field
- Rotation bifurcation when rotation slowed to 1/2 steady-state value
- Data at q = 2 shows plasma stable at much lower rotation
- Data closer to core shows no correlation



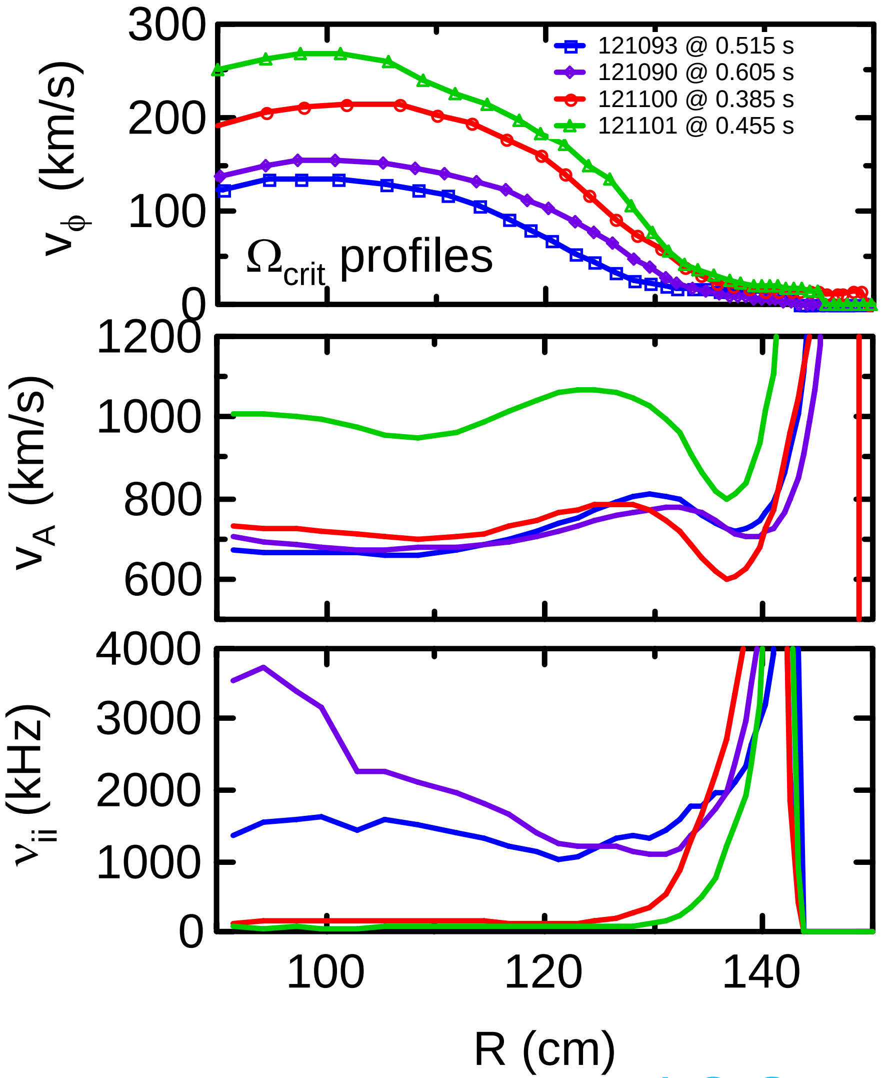
Increased ion collisionality leads to lower Ω_{crit}

- Comparison of two constant-q discharges with varying collisionality
  - Similar v_A across plasma cross-section
- Other shot pairs with similar v_A give similar result
- Continued analysis to determine profile dependence of dissipation
  - NTV torque strongest near R = 130 cm
  - other models have different spatial distribution of dissipation



Ω_{crit} may have weak v_A dependence

- V_A scan at constant q performed
  - no clear scaling of Ω_{crit} with v_A
- Variations in ν_{ii} complicate analysis
  - ν_{ii} effects must be included to isolate v_A dependence
- Profile effects can help determine dissipation physics
  - Compare localization of dissipation, plasma parameter dependence to experiment
  - MARS-F analysis to fully test dissipation profile for semi-kinetic and sound wave models



XP 619 data provides path to understanding RWM passive stabilization

- Faster rotating MHD shown to affect RWM stability
  - appears to alter unstable mode drive
- Fitzpatrick tearing mode model inadequate to describe NSTX RWM critical rotation
  - NSTX stable to much lower rotation than $\omega_0/2$ prediction
- Apparent dependence of Ω_{crit} on ν_{ii} observed
  - NTV and other calculations will determine profile effects
- Initial indication is weak variation of Ω_{crit} with v_A but analysis is ongoing
  - MARS calculations will test semi-kinetic and sound wave models
  - ν_{ii} dependence must be included to isolate any v_A effects