Study of RWM Stability and RWM Feedback Control in Reactor Relevant Low-Rotation Discharges in DIII-D

by
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with
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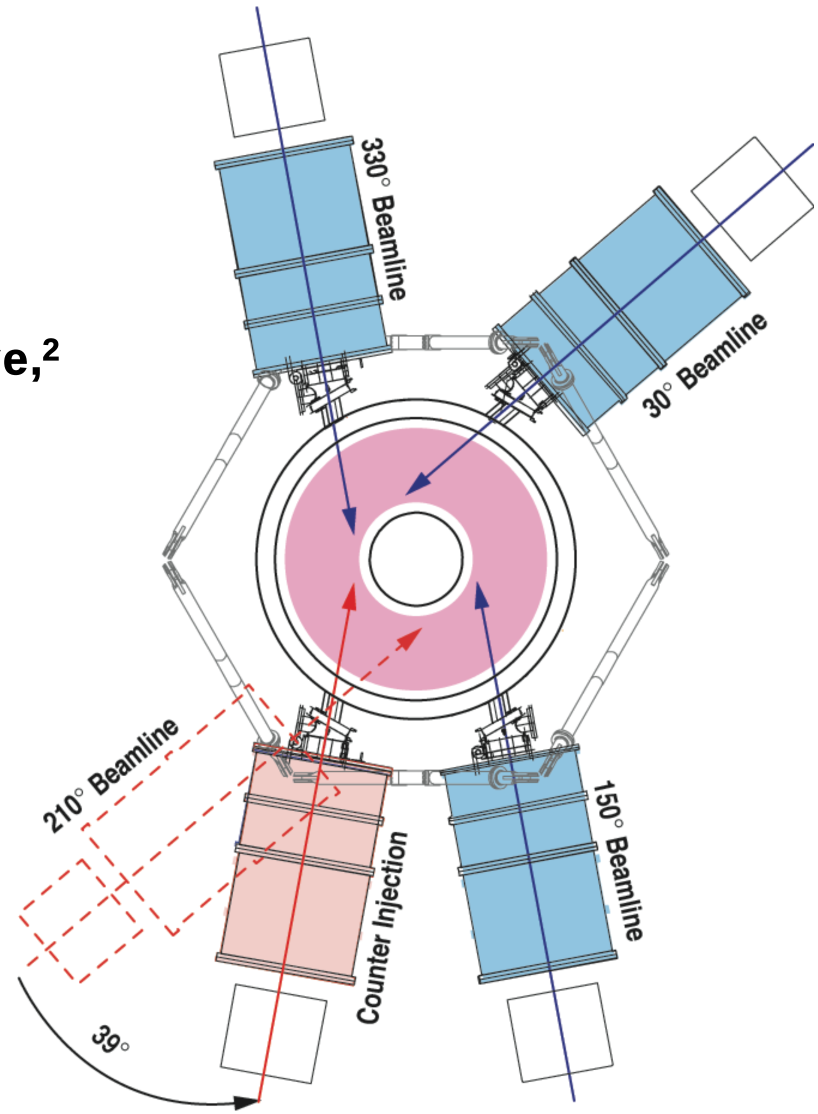

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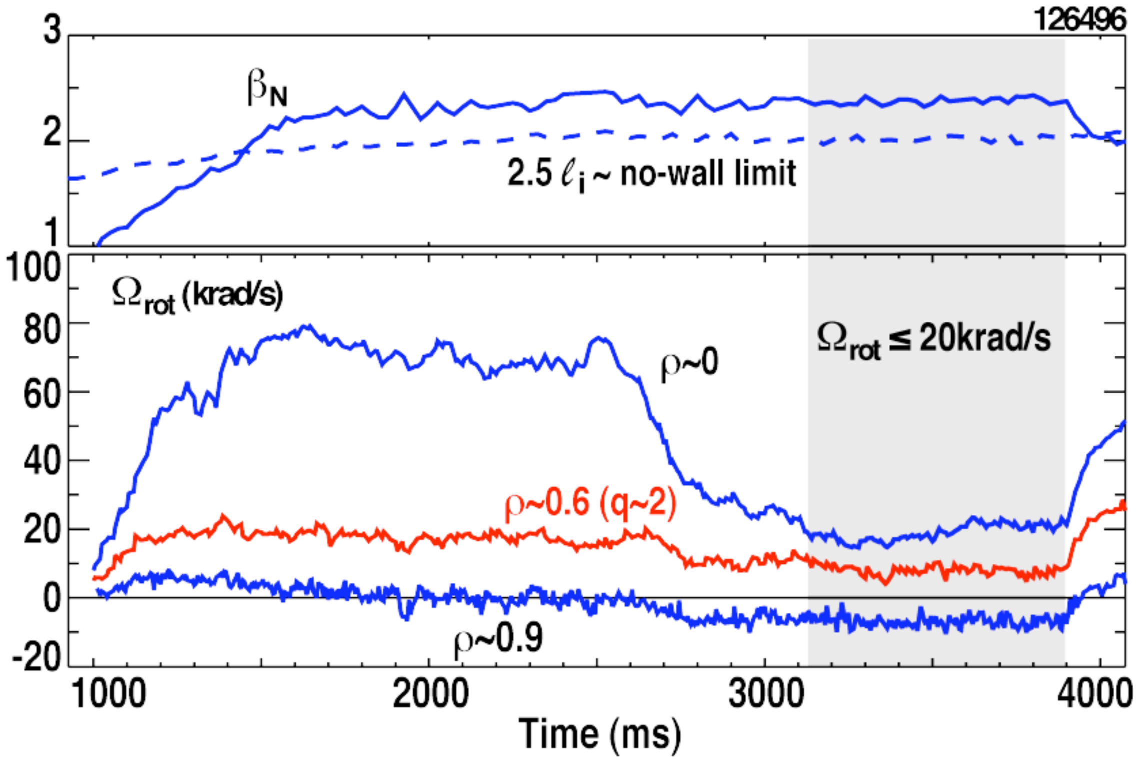
Columbia University

Sustained Resistive Wall Mode (RWM) Stabilization Obtained With Very Low Plasma Rotation



- **Rotation of $\Omega_{rot}\tau_A$= 0.3% at the *q*=2 surface is sufficient to stabilize RWM**
  - Rotation at ρ=0.6 the same as prediction for ITER steady-state scenario 4
  - RWM stability at low rotation requires good *n*=1 error field correction
  - Critical rotation 2-10 times lower than previous measurements in DIII-D

➜ **E.J. Strait, post-deadline invited talk (ZI1.06), Friday 12:00PM**

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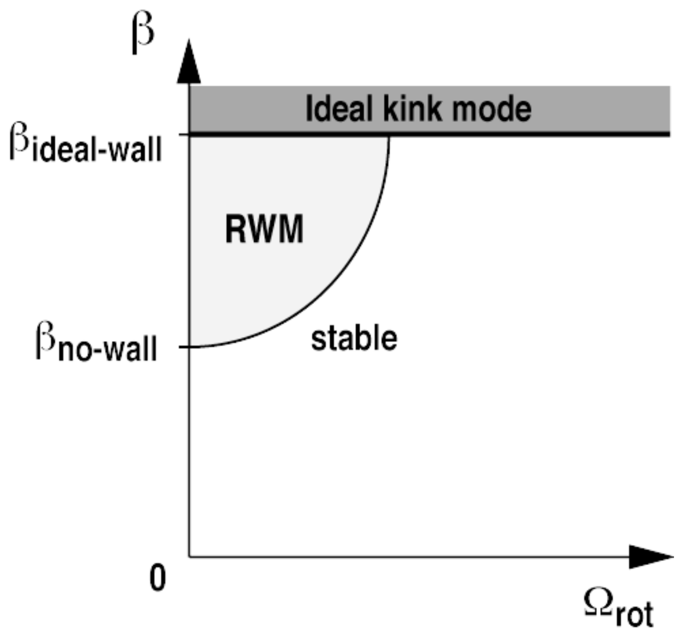
Re-Orientation of Neutral Beam Injection (NBI) Beam-Line Decouples Beta and Toroidal Plasma Rotation

- **RWM stability depends on beta and plasma rotation**



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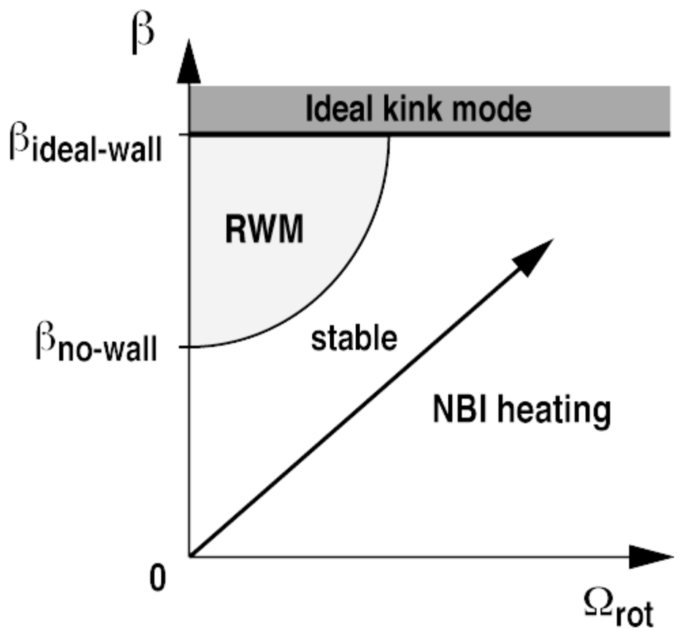

- **Uni-directional NBI requires "magnetic" braking to study RWM stability and RWM feedback**
  - Apply n=1 magnetic field ↔ decrease n=1 error field correction

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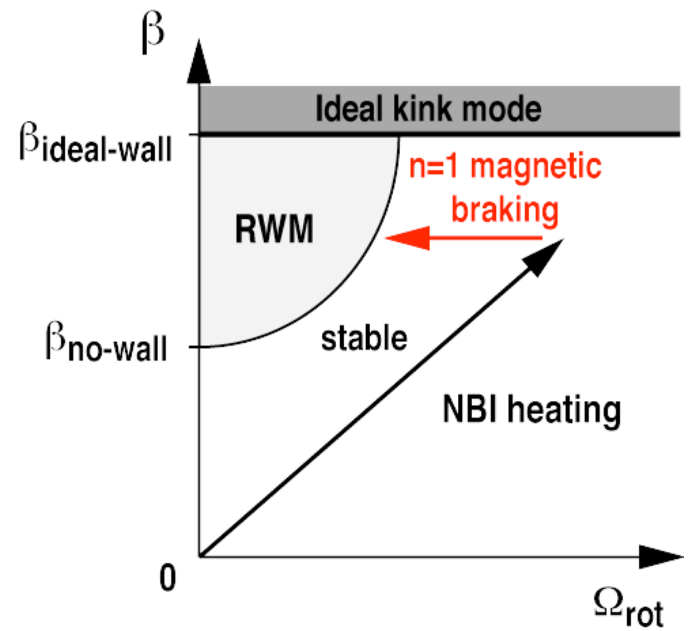

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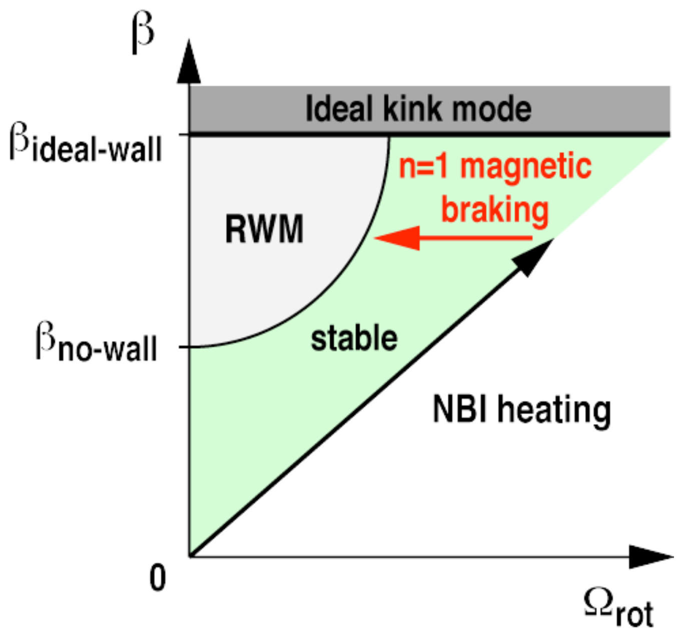

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- **Balanced NBI allows access to high β, low rotation regime with minimum non-axisymmetric fields**

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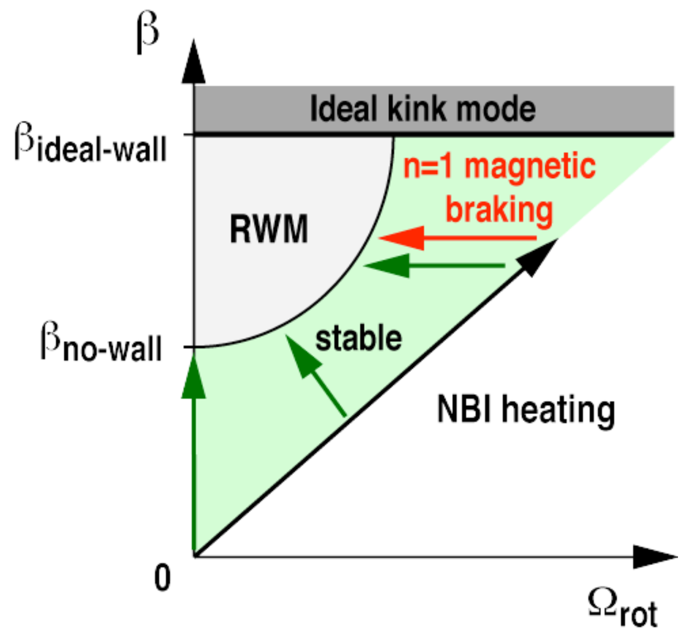

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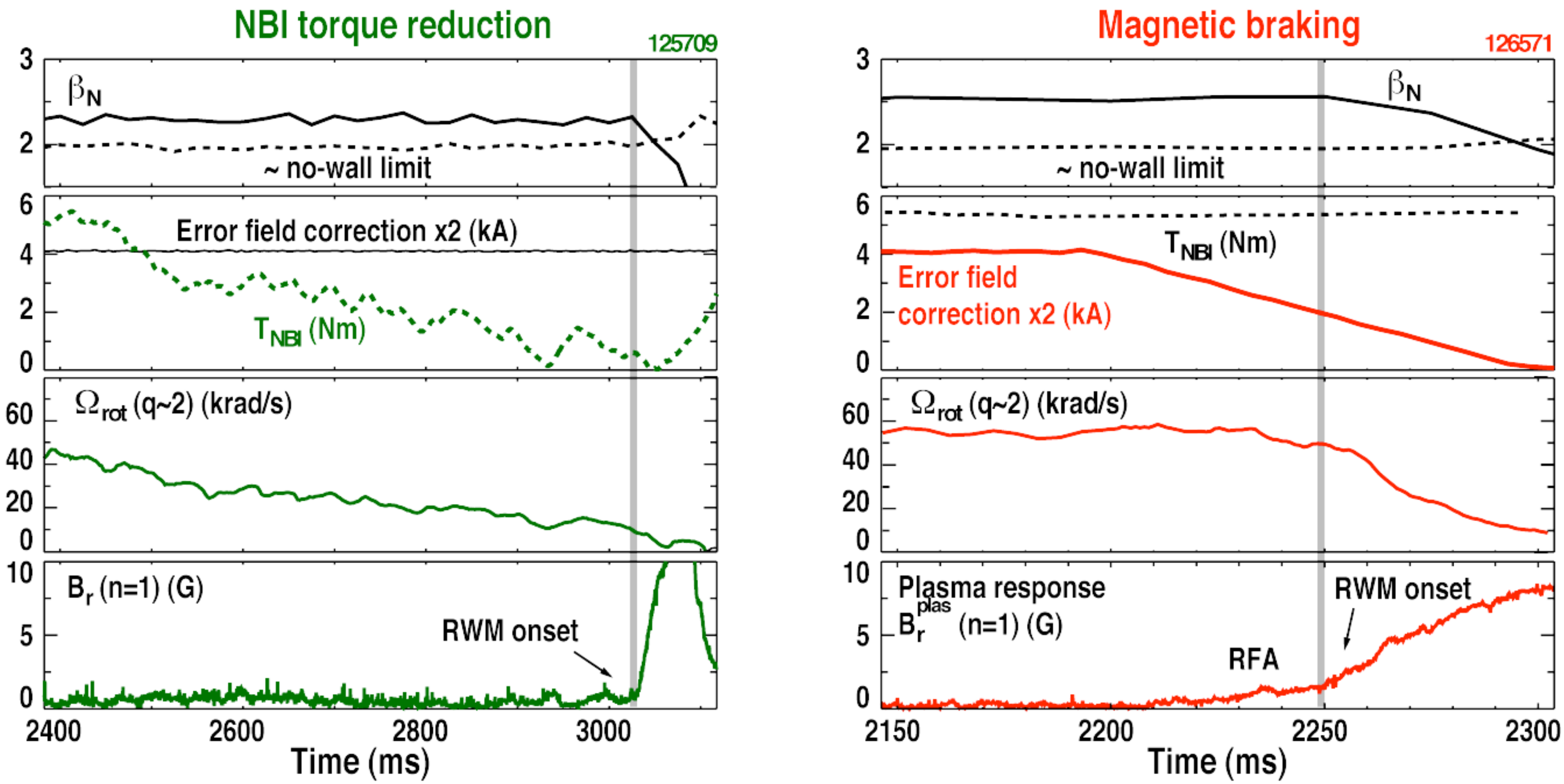
Reducing NBI Torque and *n*=1 Magnetic Braking Yield Very Different Rotation Thresholds



- **NBI torque reduction and correction of *n*=1 error field yield RWM onset at low rotation**
- **Magnetic braking by removing correction of *n*=1 error field yields RWM onset at high rotation**

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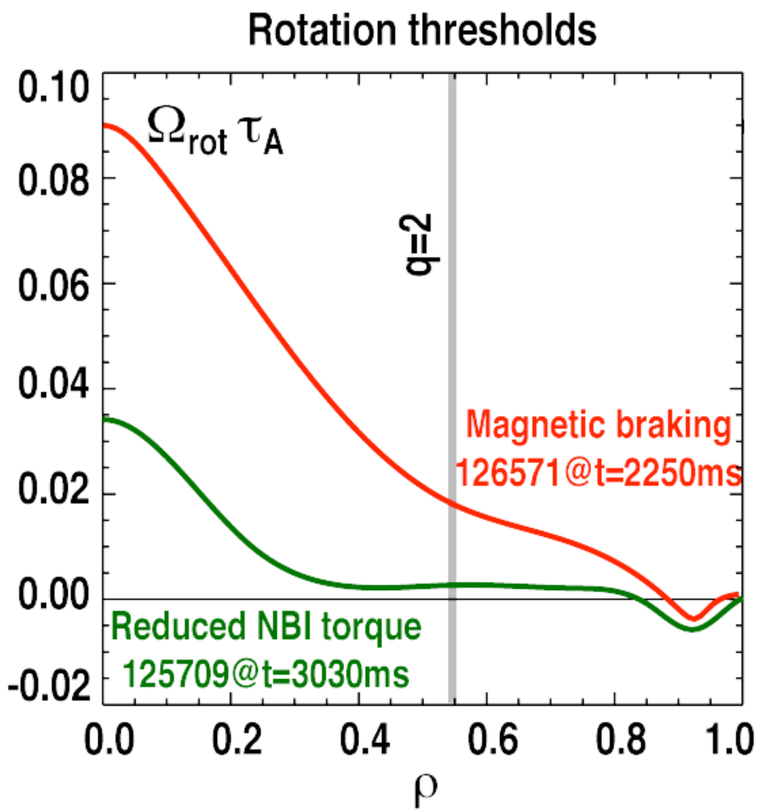

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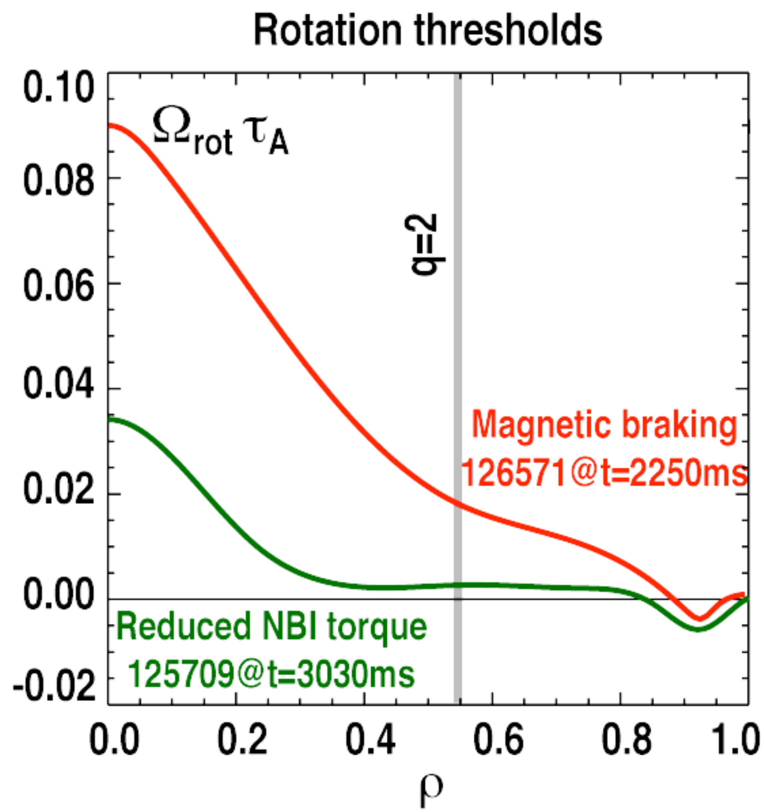

- **Charge exchange recombination diagnostic measures carbon impurity rotation**
  - Correction for deuterium expected to be important

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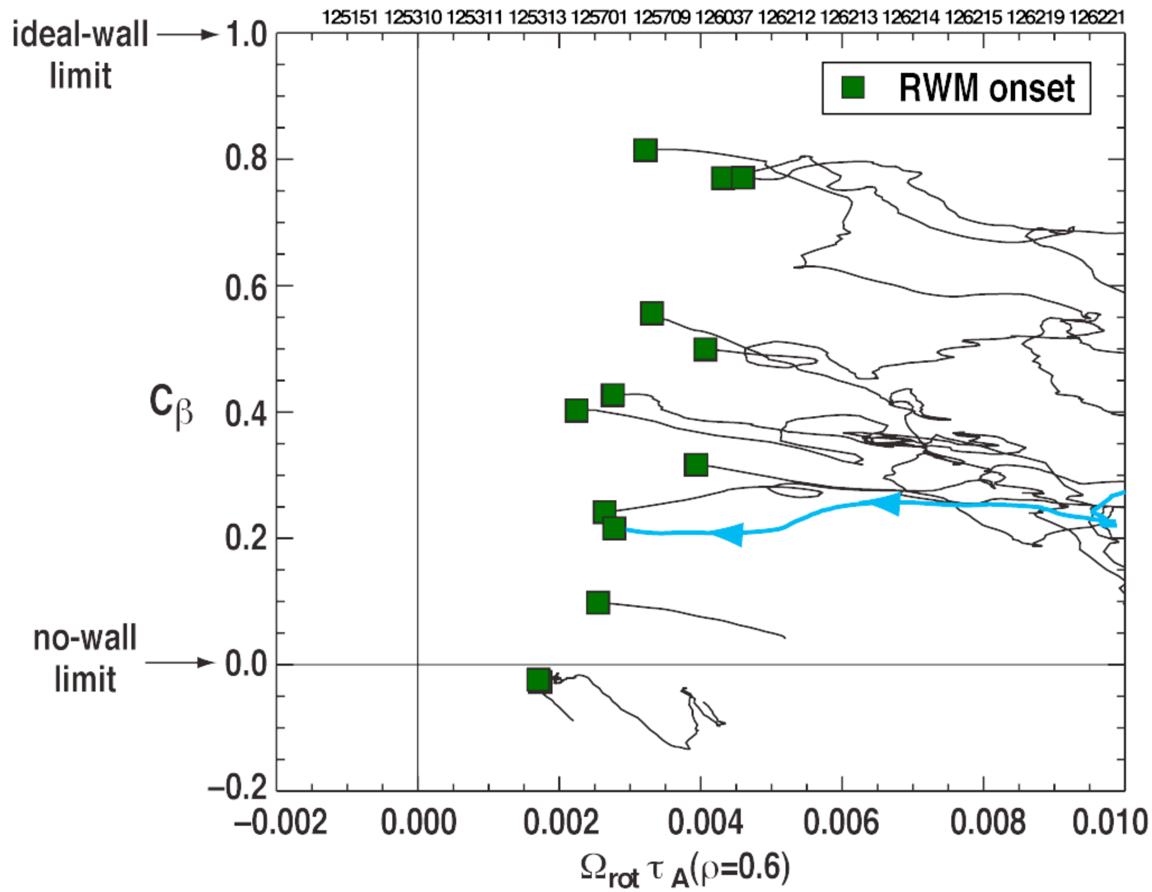
Rotation Threshold With Reduced NBI Torque and Corrected Error Field Has Only a Weak β-dependence



- **RWM onset occurs when rotation at ρ=0.6 (*q*~2) reduced to $\Omega_{rot}\tau_A$=0.2-0.3%**

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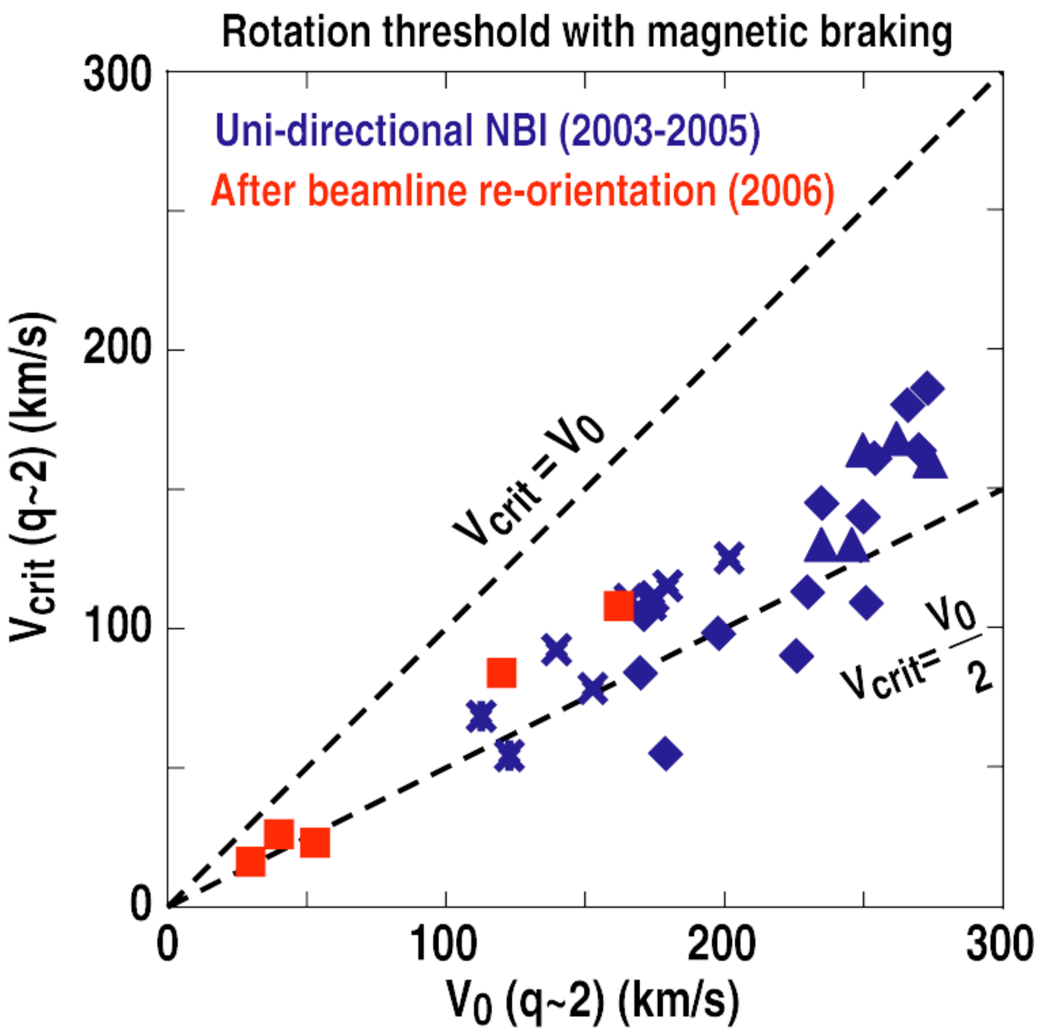
Resonant Magnetic Braking May Lead to an Overestimation of the Linear RWM Stabilization Threshold

- **Increasing a resonant non-axisymmetric field can lead to bifurcation in the torque balance**
  - Rapid rotation decrease from high value to essentially locked
- **Threshold V_{crit} is related to rotation before magnetic braking V_0**
  - "Induction motor" model predicts: $V_{crit} \sim V_0/2$
- **If bifurcation occurs at high rotation, the linear RWM threshold is overestimated**



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➜ A.M. Garofalo, UP1.02, Thursday 9:30AM-12:30PM

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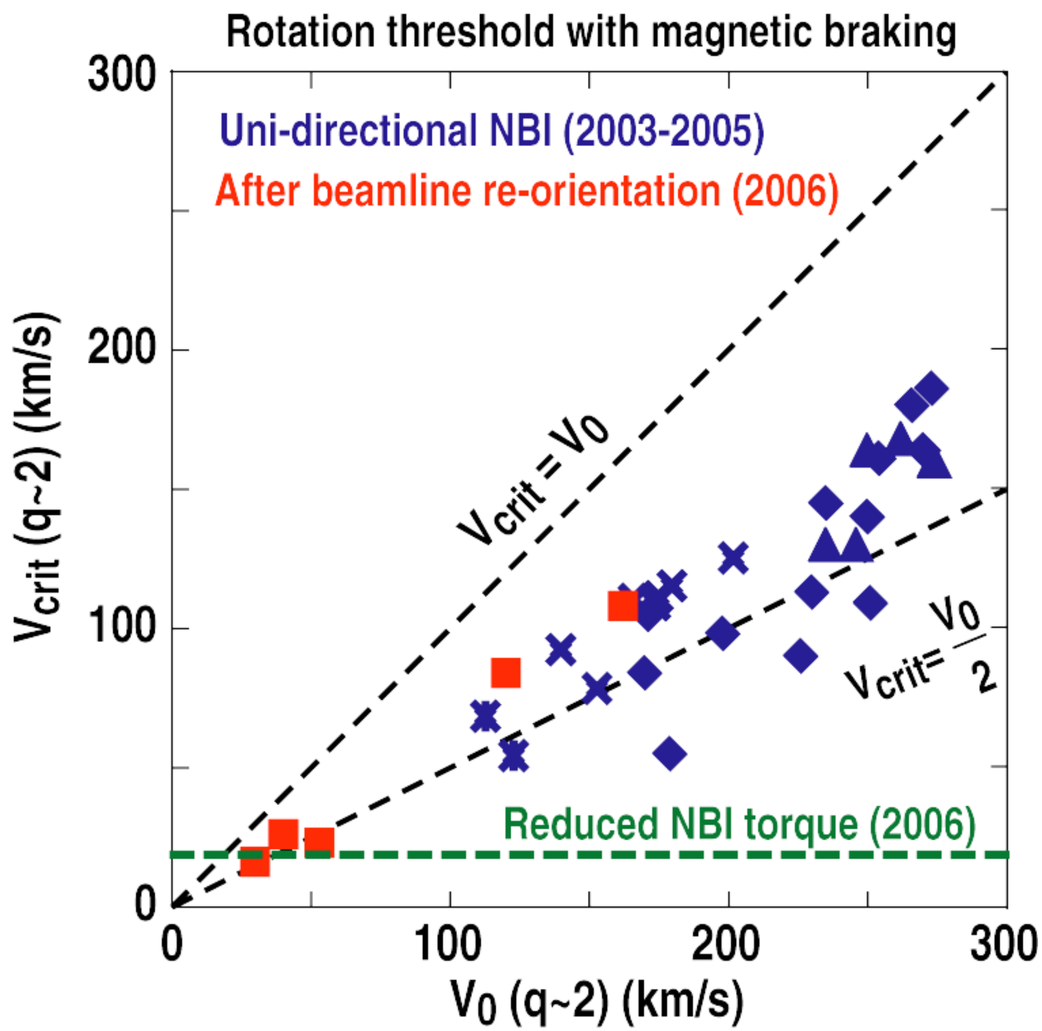
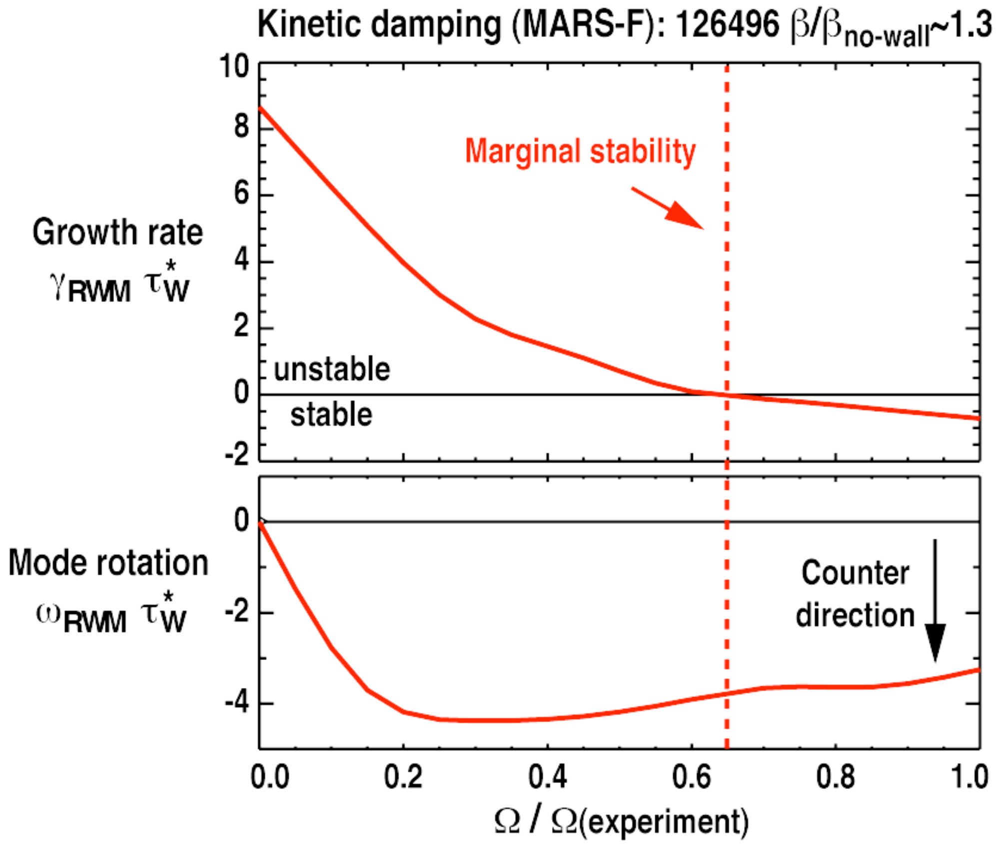
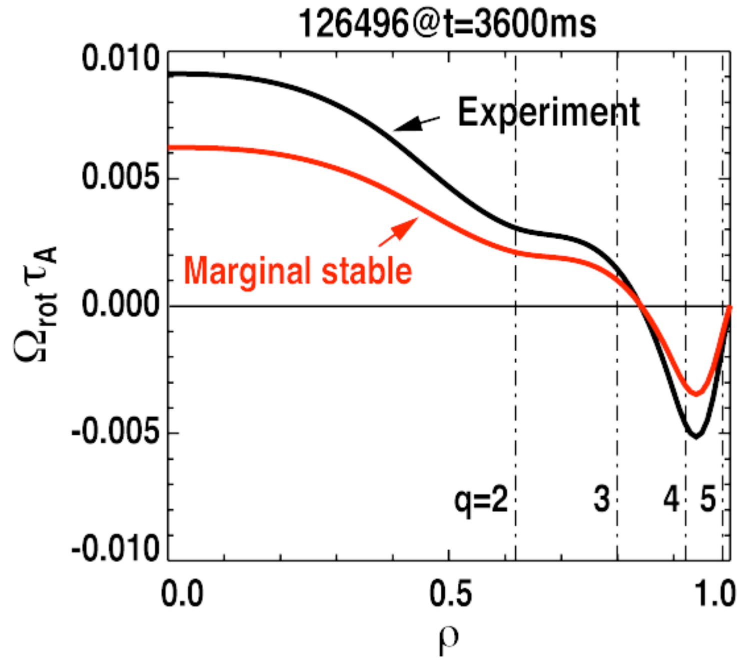


→ **A.M. Garofalo, UP1.02, Thursday 9:30AM-12:30PM**

Kinetic Damping Model Consistent With Observed Low Rotation Threshold

- **Marginal stability predicted with ~65% of the experimental rotation**
  - Corresponds to $\Omega_{crit}\tau_A$=0.2% - similar to experimental results





- **Negative mode rotation suggests strong interaction near plasma edge (e.g. *q*=4)**

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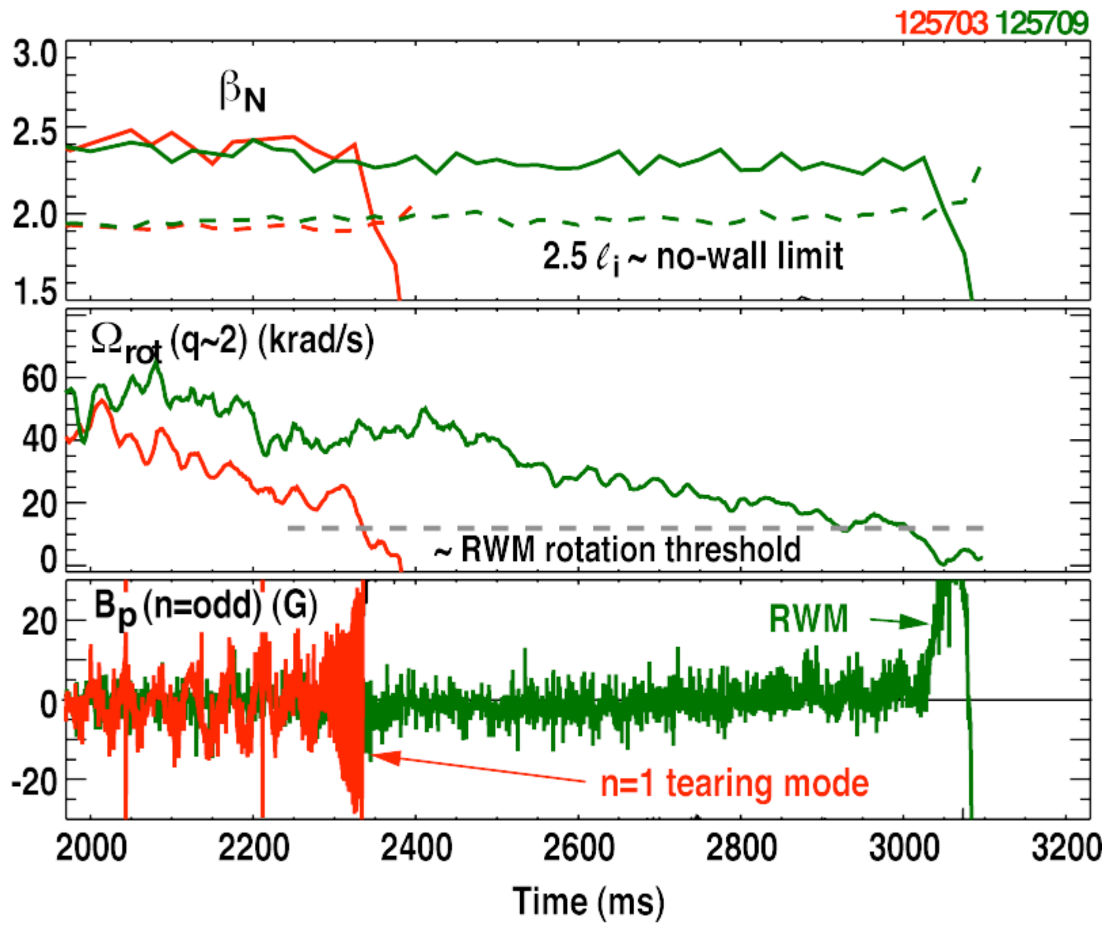
RWM Feedback at Low Rotation More Difficult Than Anticipated

- **First attempts of RWM feedback not yet conclusive**
  - **➜ M. Okabayashi, UP1.03, Thursday 9:30AM-12:30PM**

- **Onset of 2/1 tearing mode frequently observed above RWM rotation threshold**
  - High susceptibility to tearing in the vicinity of an ideal MHD stability limit



Sustained RWM Stabilization Obtained with Very Low Plasma Rotation

- **With low NBI torque and *n*=1 error field correction the rotation threshold for RWM stabilization at the *q*=2 surface is found as low as $\Omega_{rot}\tau_A$=0.2-0.3%**
  - Rotation threshold is 2 to 10 times lower than suggested by previous experiments using *n*=1 "magnetic braking"

- **Resonant magnetic braking may cause a bifurcation in the torque balance and lead to an overestimation of the linear RWM rotation threshold**

- **"Kinetic damping" model (calculated with MARS-F code) found consistent with the observed low rotation threshold**
  - Rotation at higher *q*-surfaces (*q*>2) predicted to be important

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Contributions of the DIII-D RWM Group at This Meeting

Post-deadline invited talk - Friday 12:00 PM -12:30 PM

- *RWM Stabilization by Slow Plasma Rotation in DIII-D Tokamak Discharges with Balanced Neutral Beam Injection*(ZI1.06) - E.J. Strait

Poster session UP1 - Thursday 9:30 AM - 12:30 PM

- *Tokamak MHD Stability at High Beta and Low Plasma Rotation* (UP1.02) - A.M. Garofalo
- *Feedback Control of RWMs in Slowly Rotating DIII-D Plasmas* (UP1.03) - M. Okabayashi
- *Measurement of Plasma Displacement Due to RFA in High Beta DIII-D Plasmas Using CER Spectroscopy* (UP1.07) - M.J. Lanctot
- *FAR-TECH RWM Identification Via Kalman Filter and Implementation of Model-Based Feedback Control* (UP1.09) - J.-S. Kim
- *RWM Identification and Feedback Control Using Eigenmode-Based DIII-D/RWM Model* (UP1.11) - Y. In
- *n>1 RWM Identification* - (UP1.12)- J. Kim

Poster session ZP1 - Friday 9:30 AM - 12:30 PM

- *Investigation of RWM internal structure* (ZP1.11) - I.N. Bogatu