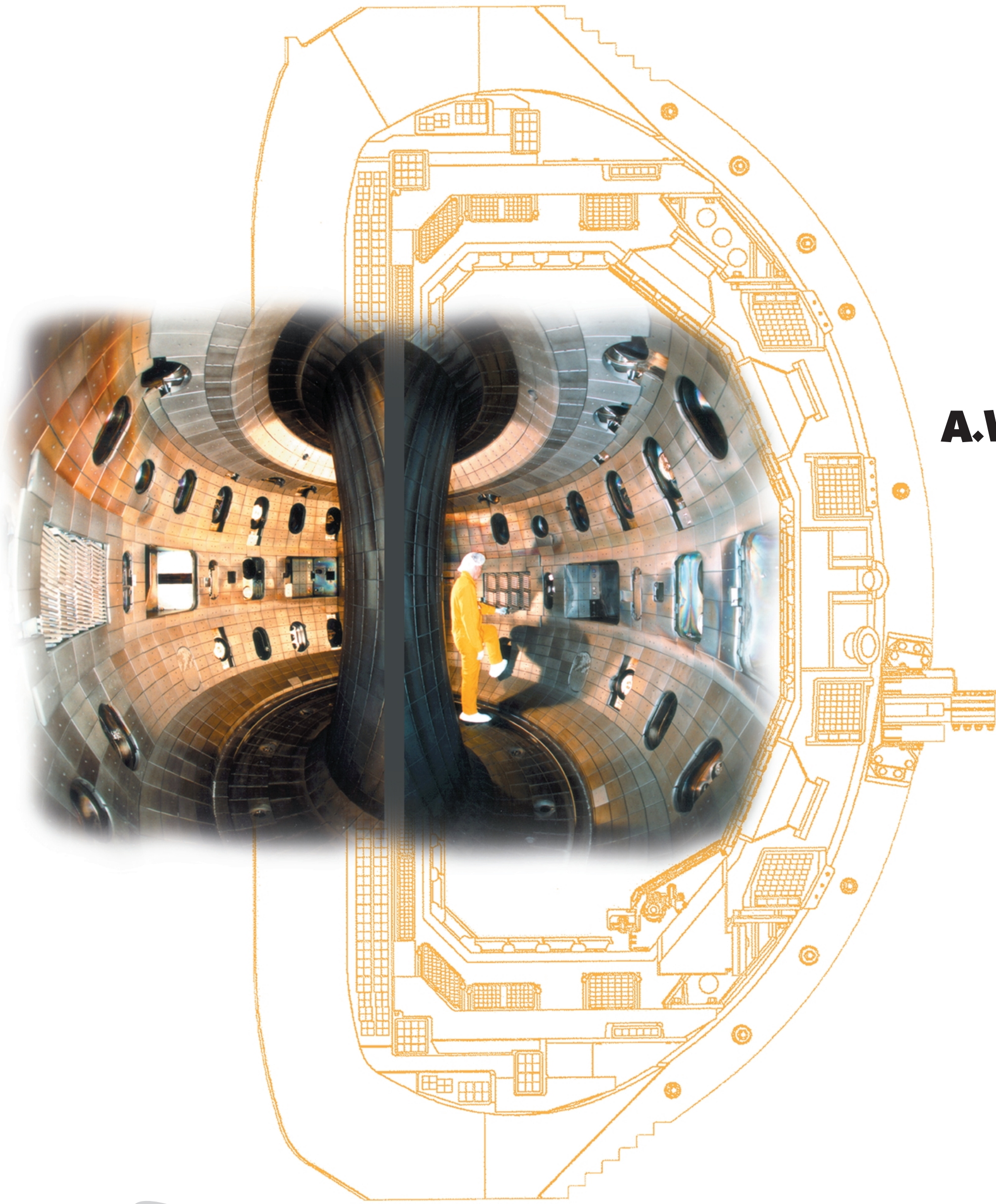

Stability of Advanced Tokamak Plasmas in DIII–D

by
E.J. Strait
for D.P. Brennan, M.S. Chu, J.R. Ferron,
A.W. Hyatt, R.J. La Haye, Y.R. Lin-Liu, T.C. Luce,
T.H. Osborne, P.A. Politzer, R. Prater,
J.T. Scoville, T.S. Taylor, A.D. Turnbull,
E.D. Fredrickson,* L.C. Johnson,*
M. Okabayashi,* A.M. Garofalo,†
G.A. Navratil,† E.A. Lazarus,‡ M.R. Wade‡

*Princeton Plasma Physics Laboratory
†Columbia University
‡Oak Ridge National Laboratory

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280-00/EJS/wj

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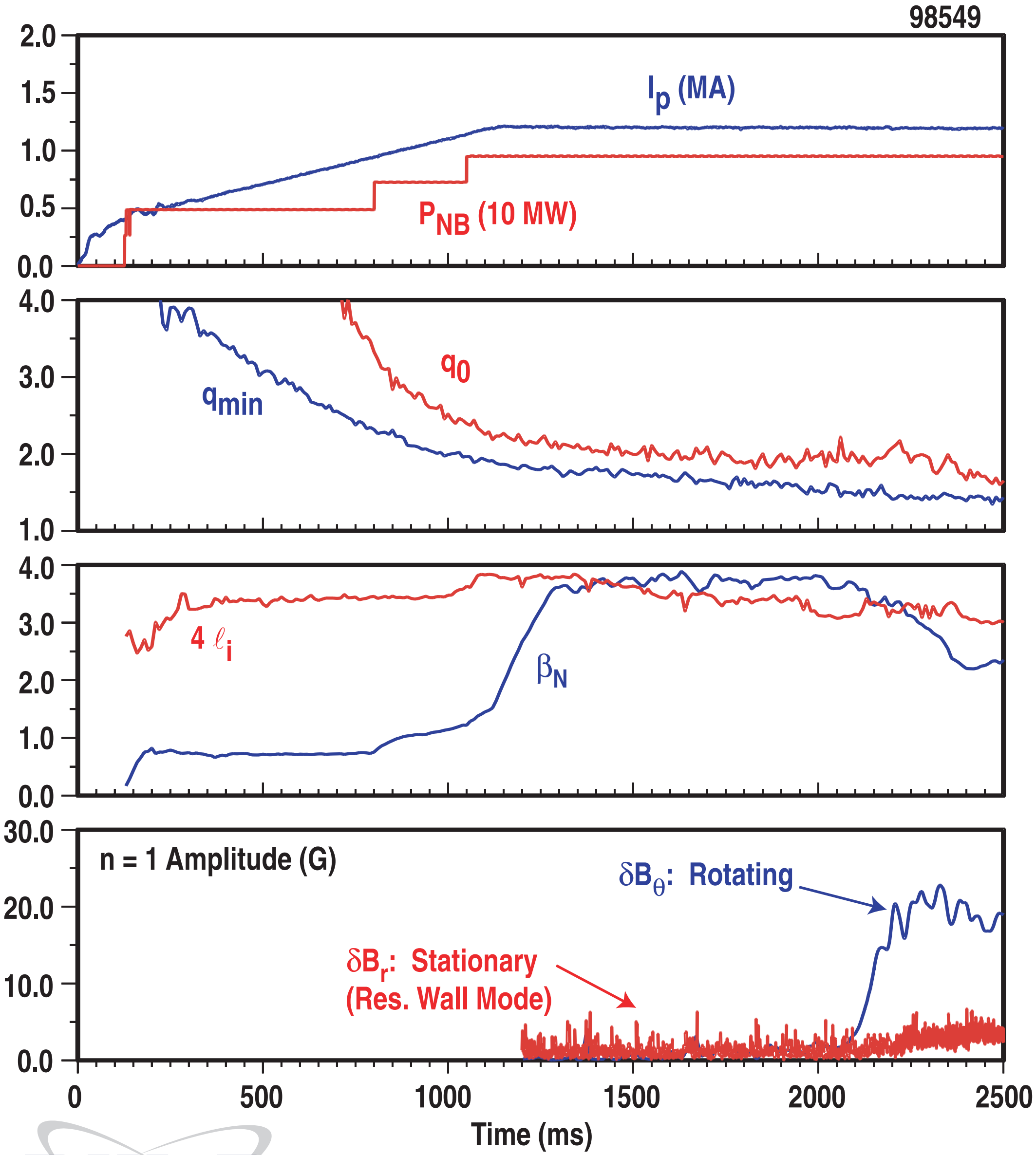
MHD STABILITIES LIMIT THE PERFORMANCE OF DIII–D ADVANCED TOKAMAK PLASMAS



- Discharge shaping improves stability limit
- Ideal kink/resistive wall mode limits maximum beta
  - Feedback stabilization with external coils
- Tearing mode limits high beta duration as current density profile evolves
  - Current profile control for avoidance
  - Localized current drive to stabilize neoclassical tearing mode

T.C. Luce (preceding talk)
M.R. Wade (CI2.001)

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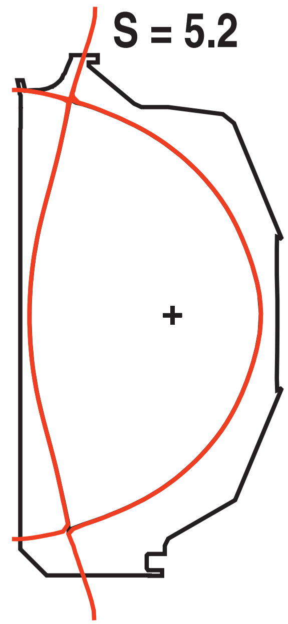
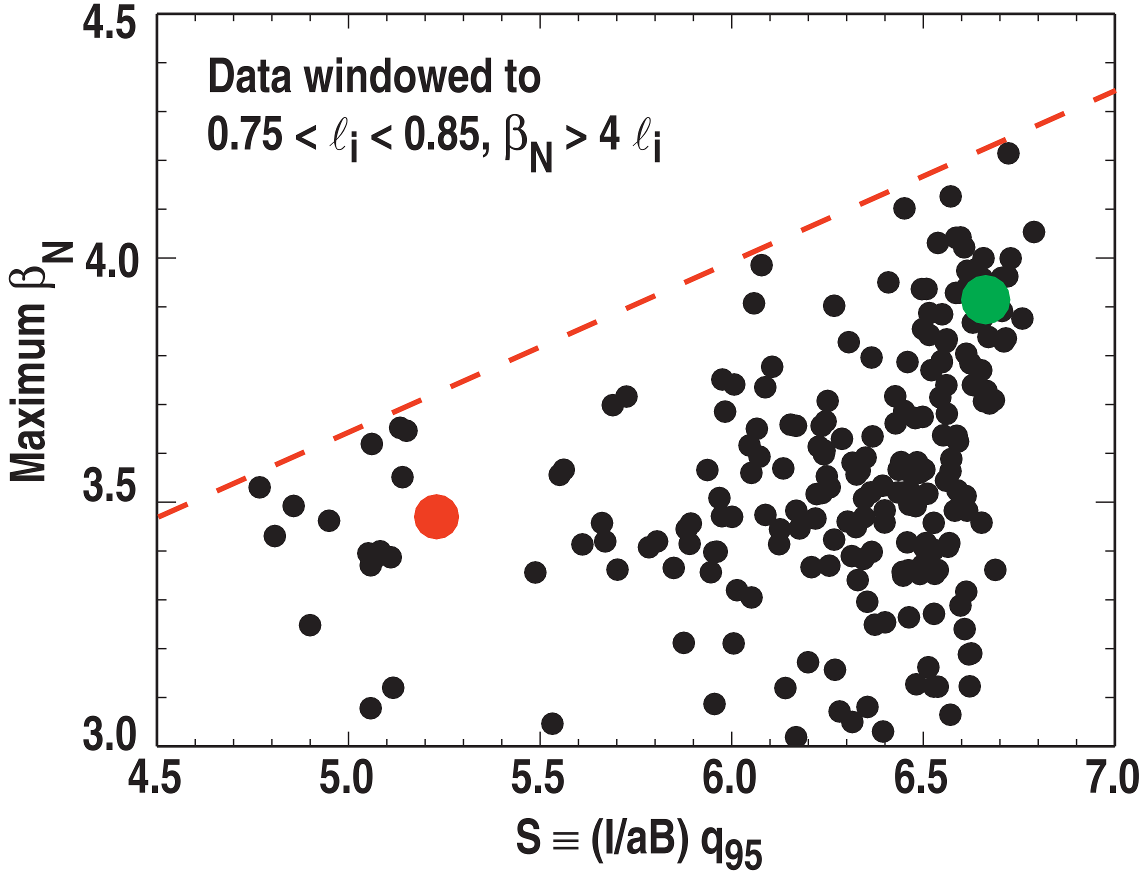
OBSERVED STABILITY LIMIT INCREASES WITH SHAPING

- Reduced triangularity for pumping affects maximum β_N
- Highest β_N cases are cauculated to require wall stabilization
  - Resistive wall modes are observed

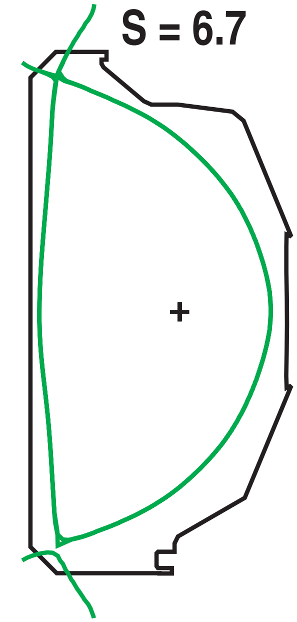


Pumping Shape

$\kappa = 1.8; \delta = 0.6$



$$\propto \varepsilon \left(\frac{1 + k^2}{2}\right) f(\kappa, \delta, \beta, ...)$$



Optimized Shape

$\kappa = 2.0; \delta = 0.9$

M.R. Wade (CI2.001)
T.C. Luce (IAEA 2000)

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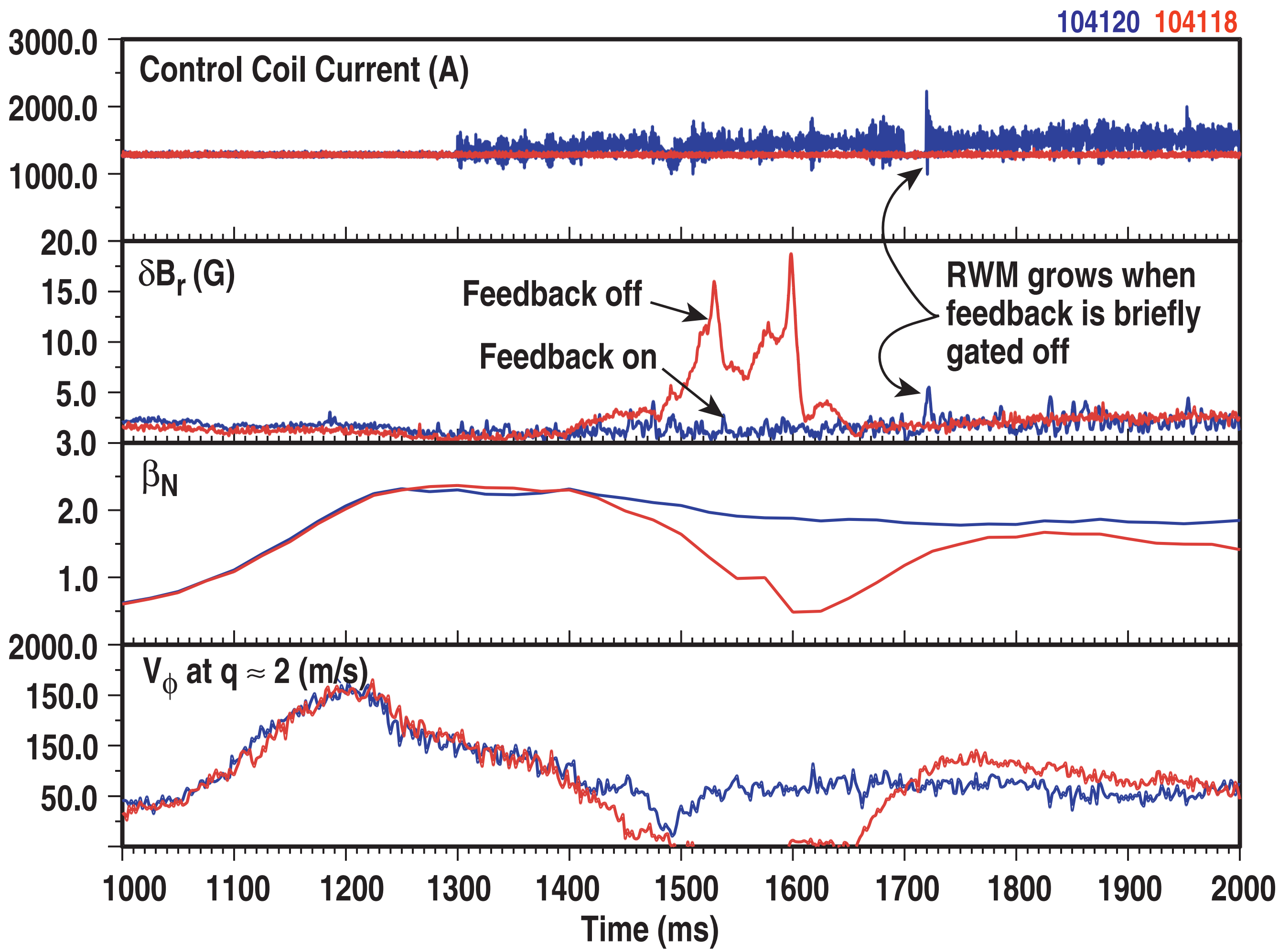
FEEDBACK CONTROL STABILIZES RESISTIVE WALL MODE FOR $\gtrsim 10^2\ \tau_{wall}$

- Weakly unstable plasma created by slow plasma current ramp
- Feedback control extends stable duration by more than 500 ms (to end of I_p ramp)



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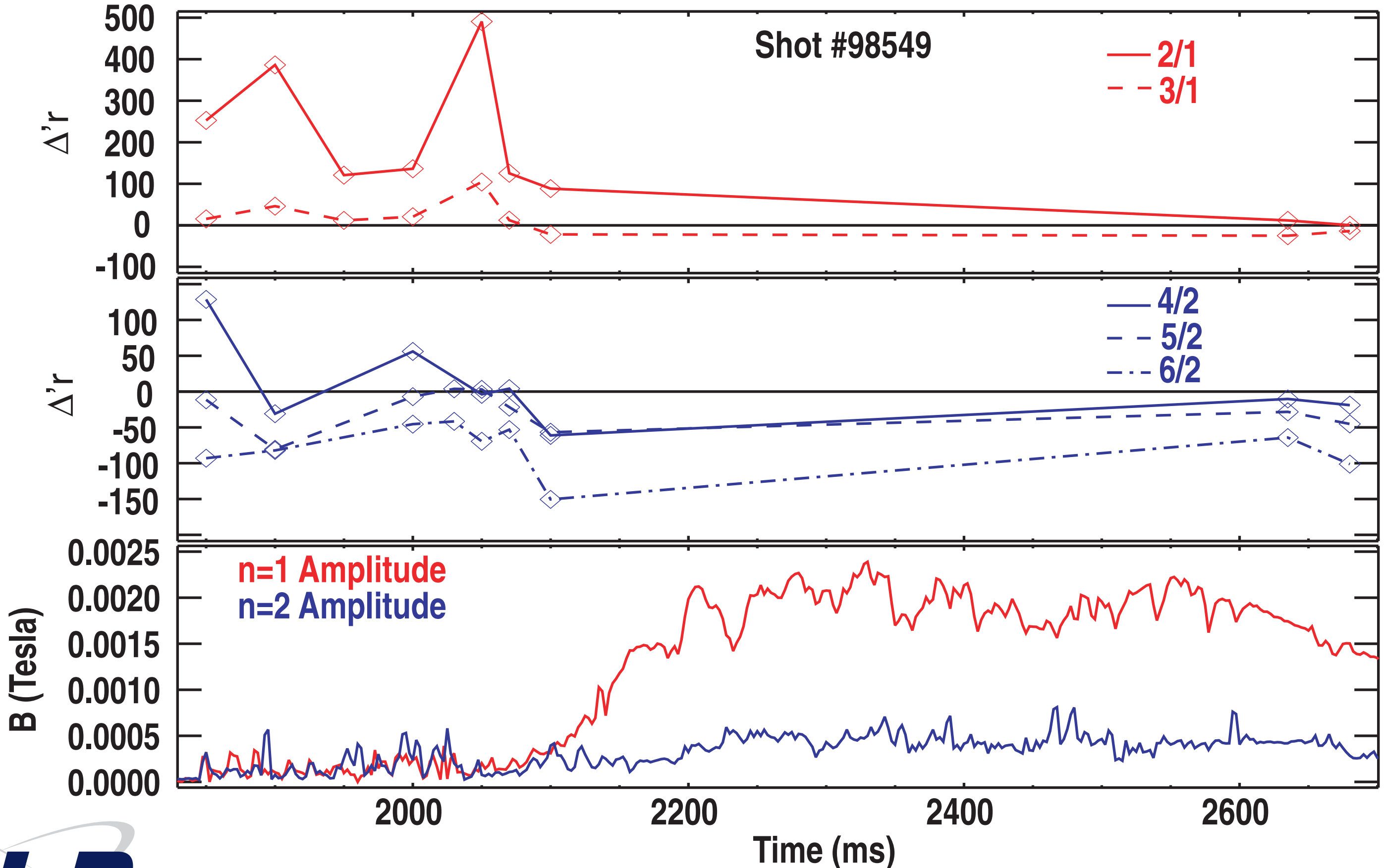
A. Garofalo (next talk)
M. Okabayashi (GI1.005)

L. Johnson, G. Navratil, T. Scoville, M. Chu, D. Edgell
(Poster session NP1)

280-00/jy

TEARING MODES INDICATE A NEED FOR CURRENT PROFILE CONTROL

- Preliminary analysis suggests a "classical" ($\Delta' > 0$) tearing mode onset in this Advanced Tokamak plasma
- Saturated state may include a neoclassical contribution (helically perturbed bootstrap current)



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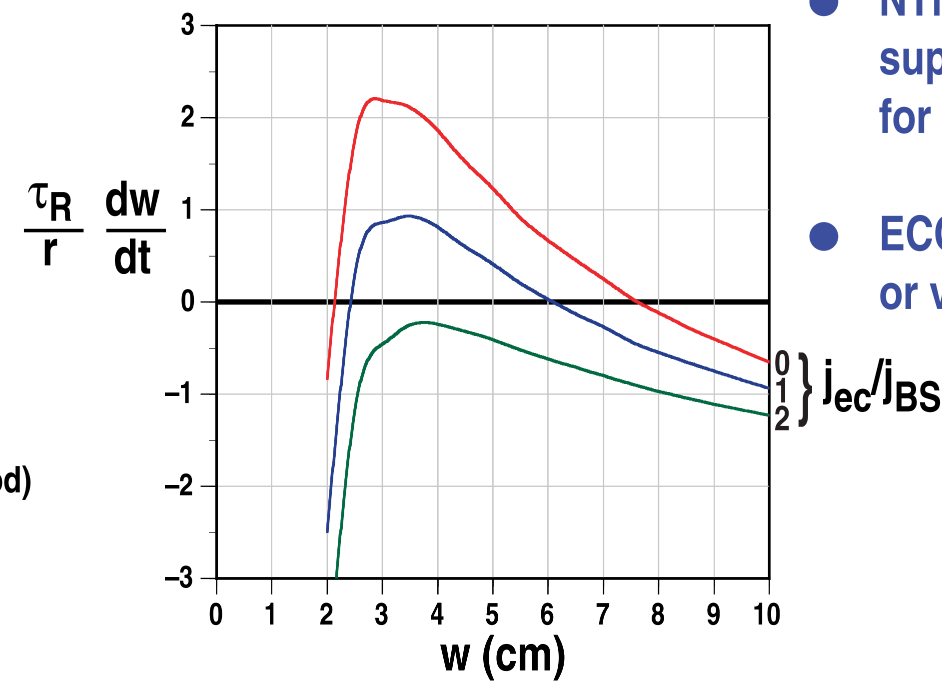
D.P. Brennan (poster session NP1)

280–00/EJS/wj

CO-ECCD RADIALLY LOCALIZED AT ISLAND CAN REPLACE THE "MISSING" BOOTSTRAP CURRENT AND COMPLETELY STABILIZE THE NEOCLASSICAL TEARING MODE

$$\frac{\tau_R}{r}\frac{dw}{dt} = \Delta' r + \varepsilon^{1/2}\left(\frac{L_q}{L_p}\right)\beta_\theta\left[\frac{r}{w} - \frac{r w_{pol}^2}{w^3} - \frac{8qr\delta_{ec}}{\pi^2 w^2}\left(\frac{\eta\, j_{ec}}{j_{bs}}\right)\right]$$

$m/n = 3/2$
$\beta_\theta = 0.9$
$\Delta' r = -3$
$r = 0.36$ m
$\varepsilon^{1/2} = 0.5$
$L_q/L_p = 1.5$
$w_{pol}/r = 0.05$
$\delta_{ec}/r = 0.08$
$\eta_0 = 0.4$ (no mod)



- NTM amenable to complete suppression because $\gamma < 0$ for $w < w_{seed}$
- ECCD must lie within island or very near rational surface

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R.J. La Haye, F.W. Perkins (poster session NP1)

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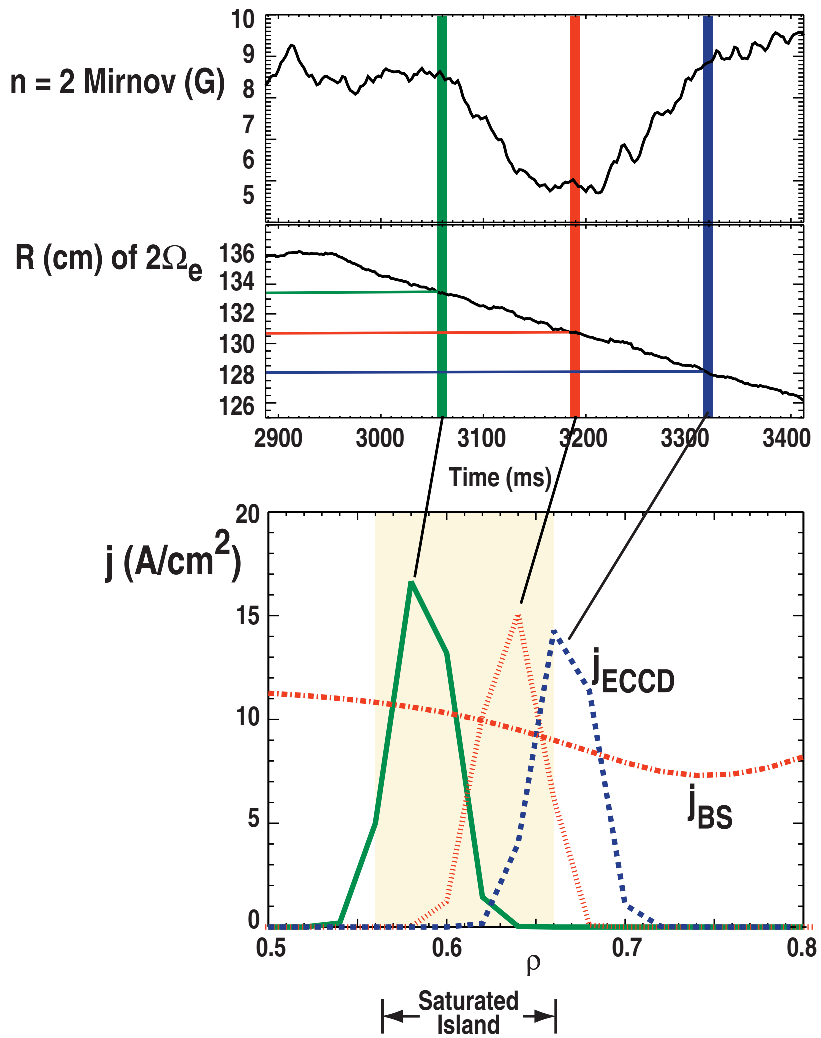
THE LOCATION OF ECCD IS CRITICAL TO FULL STABILIZATION



- Toroidal field was ramped down to scan ECCD past the island
- Alignment within 2 cm is required
- $j_{ECCD} > j_{BS}$ is satisfied
- Sensitivity of effect to location implies that the width of the ECCD is less than the island size, in agreement with ray tracing calculation
- These results show that modeling is accurate even in ELMing H–mode with sawteeth and a tearing mode, at large ρ

- Results similar to those obtained on ASDEX-U and JT-60U

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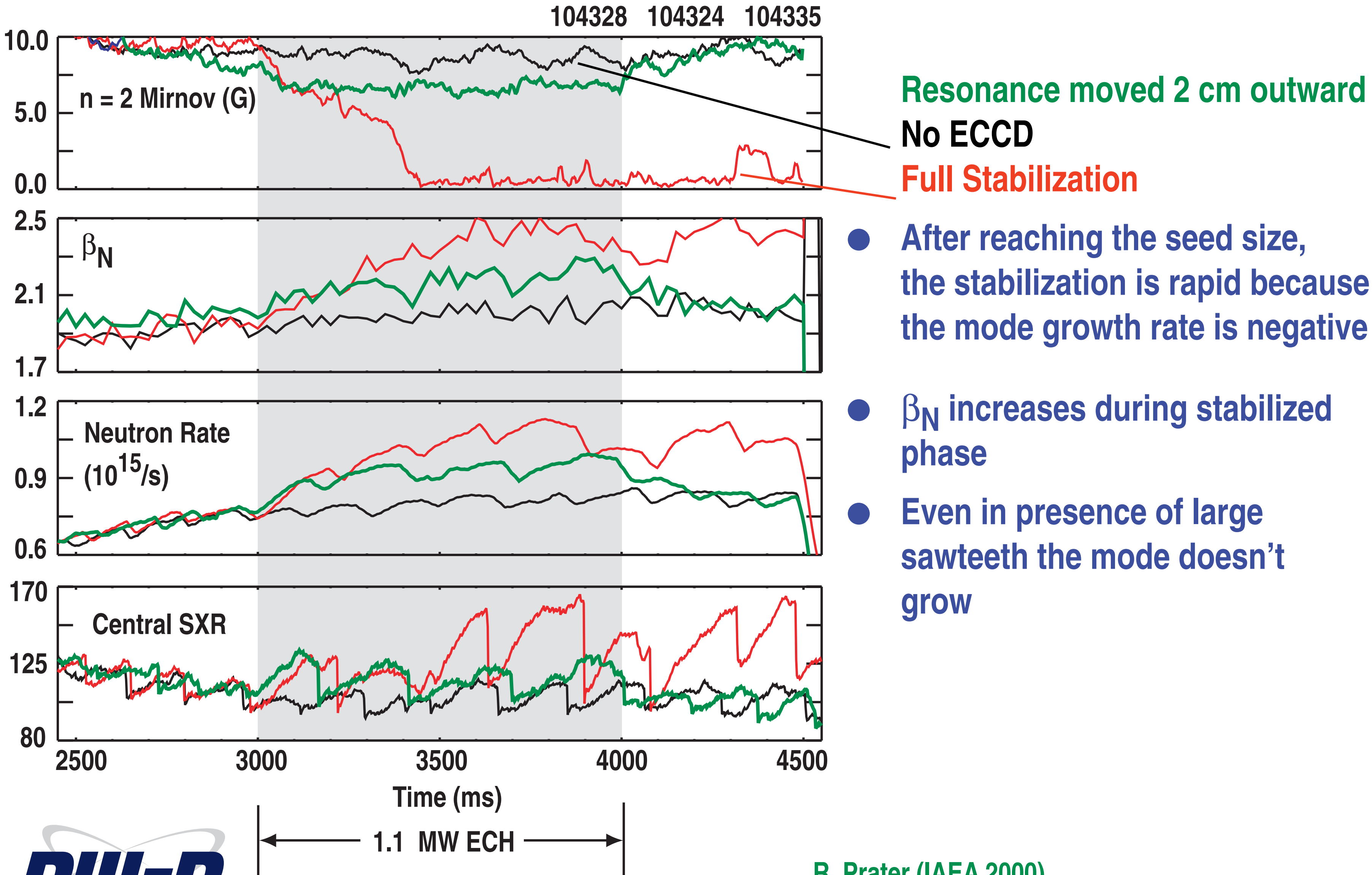
R. Prater (MO1.006)

226-00/rs

FULL STABILIZATION OF NTM OBTAINED WITH MODEST ECH POWER



- After reaching the seed size, the stabilization is rapid because the mode growth rate is negative
- β_N increases during stabilized phase
- Even in presence of large sawteeth the mode doesn't grow

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R. Prater (IAEA 2000)

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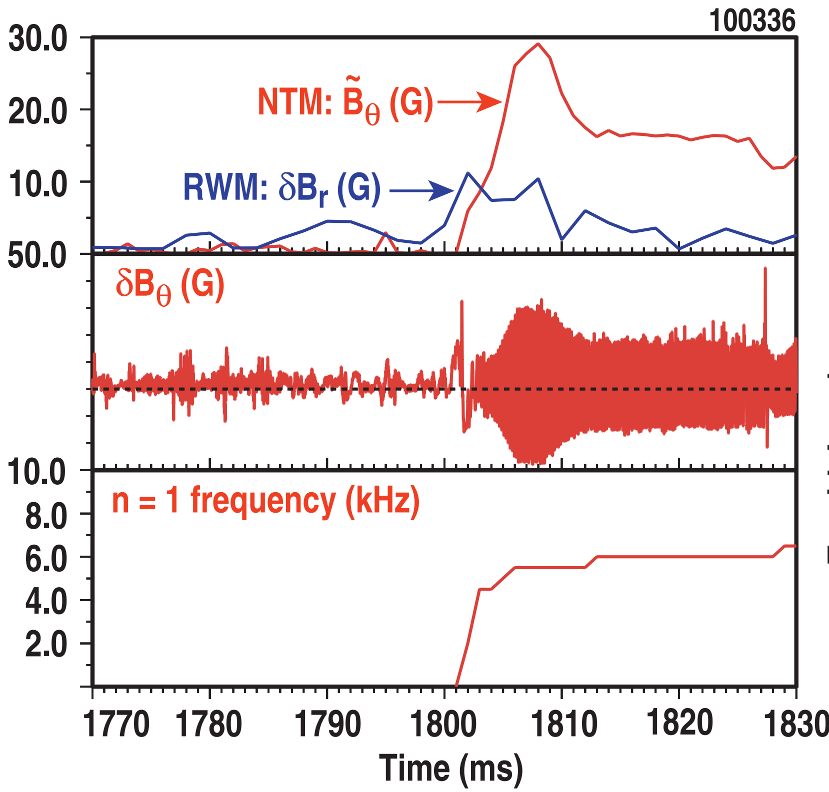
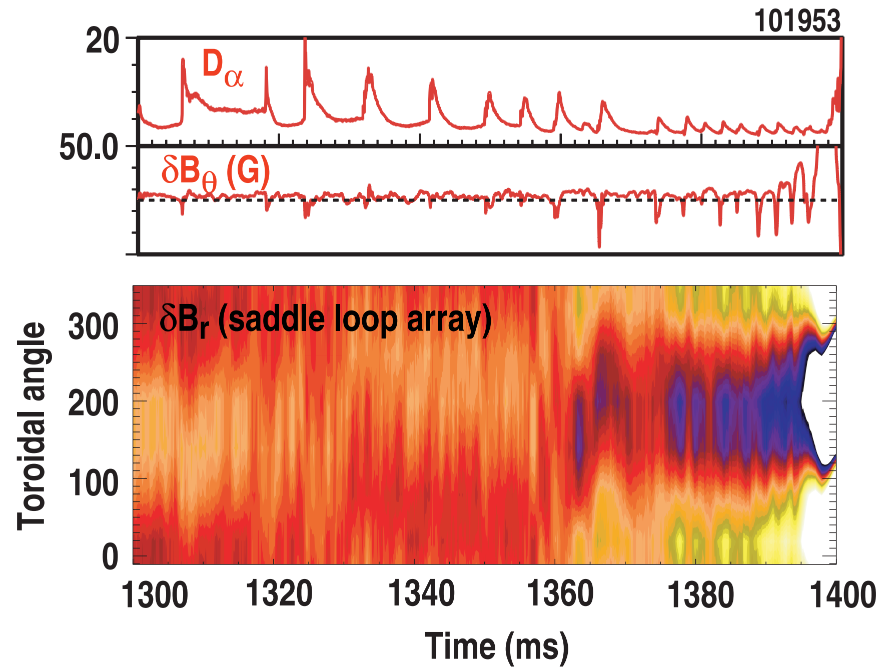
COUPLING OF MHD MODES IS LIKELY TO BE IMPORTANT IN ADVANCED TOKAMAK PLASMAS

- Optimized discharges are marginally stable to several modes
- Resistive wall mode triggers neoclassical tearing mode
- ELMs induce transient resistive wall mode response





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SUMMARY

- Performance of Advanced Tokamak plasmas is limited by low-n MHD instabilities
  - Ideal kink/resistive wall mode limits maximum beta
  - Tearing modes limit duration as J(r) evolves
- Strong shaping improves the beta limit
- Feedback control improves the stabilizing effect of a resistive wall
  - High β duration extended by $>10^2\ \tau_{wall}$ in weakly unstable cases
- Localized ECCD stabilizes neoclassical tearing modes
  - Precise placement of modest ECH power allows complete stabilization
- Coupling of MHD modes near instability thresholds represents both a challenge and an opportunity
  - Complicates understanding of stability limits
  - May enhance benefits of active stabilization

SUMMARY

- Performance of Advanced Tokamak plasmas is limited by low-n MHD instabilities
  - Ideal kink/resistive wall mode limits maximum beta
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- Localized ECCD stabilizes neoclassical tearing modes
  - Precise placement of modest ECH power allows complete stabilization
- Development of these new tools for stabilization should lead to reliable high-beta operation