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SUPPRESSION OF m=2/n=1 NEOCLASSICAL MODES BY LOCALIZED ECCD IN DIII–D

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GENERAL ATOMICS

CompX

PPPL PRINCETON PLASMA PHYSICS LABORATORY

SUPPRESSION OF m=2/n=1 NEOCLASSICAL TEARING MODE BY LOCALIZED ECCD IN DIII–D

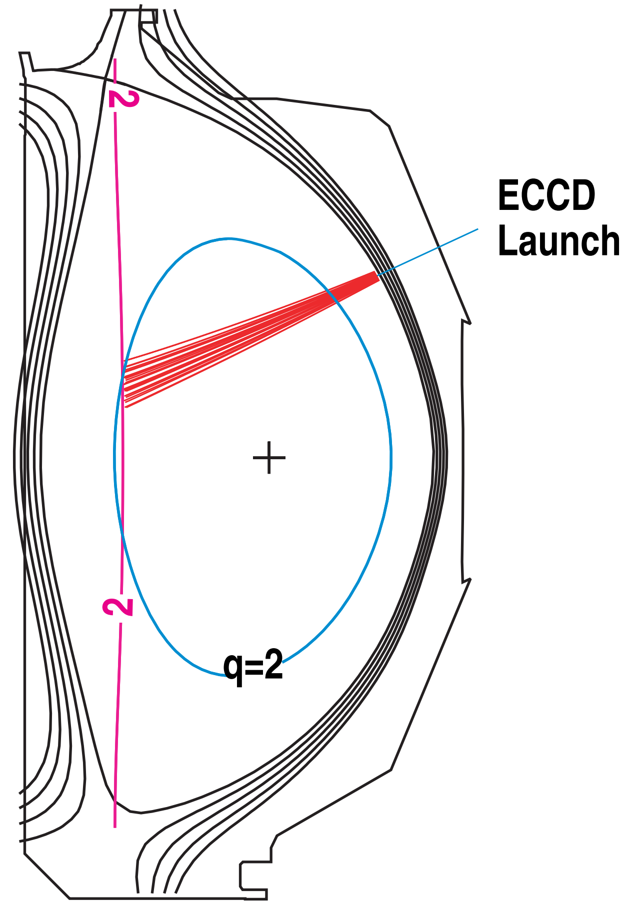
- m=2/n=1 mode has been suppressed by ECCD
  — Suppression more difficult than for m=3/n=2 mode due to larger growth rate
- Accurate placement of ECCD is critical
  — Automated control of B_t used to determine optimum location
  — Illustrated by analysis of 3/2 stabilization
- Improved confinement found when 2/1 mode is stabilized
  — Improvement of stability limits not tested yet, but plasma rotation increases

MOTIVATION

- The m=2/n=1 tearing mode is dangerous because it often locks to the wall and grows until a major disruption occurs

- Radially localized ECCD should stabilize the m=2/n=1 tearing mode by replacing the "missing" bootstrap current in the island
  - Similar to m=3/n=2 stabilization by ECCD on AUG, JT–60U, and DIII–D

- These experiments on DIII–D use five gyrotrons to inject 2.7 MW of ECCD aimed at the q = 2 surface



MODIFIED RUTHERFORD EQUATION SHOWS EFFECTS OF ECCD

- $$\frac{\tau_R}{r}\frac{dw}{dt} = \Delta' r + \frac{128}{3\pi}\frac{j_{BS}}{j_q}\frac{r}{s}\frac{1}{w}\left[1 - \frac{w_{pol}^2}{w^2} - K_1\left(\frac{w}{\delta_{EC}}, \frac{\Delta R}{\delta_{EC}}\right)\frac{j_{EC}}{j_{BS}}\right]$$

  — j_{EC}/j_{BS} is figure-of-merit

  — K_1 represents the effectiveness of the ECCD, including effects of finite width δ_{EC} of the ECCD and displacement ΔR from the rational surface

  — K_1 modeled by Perkins and Harvey

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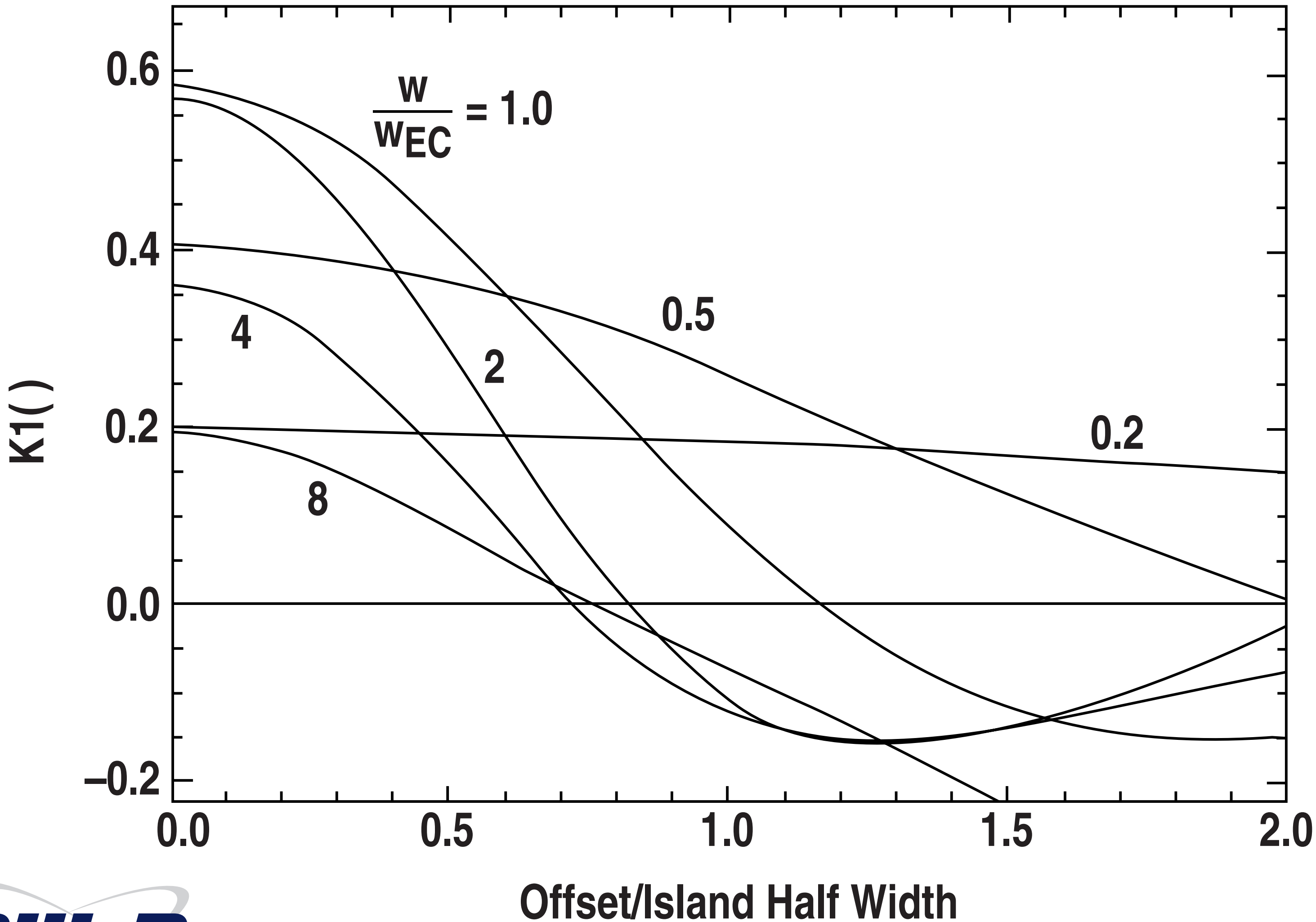
EFFECTIVENESS OF ECCD IS MAXIMUM WHEN THE ISLAND SIZE AND THE ECCD WIDTH ARE COMPARABLE



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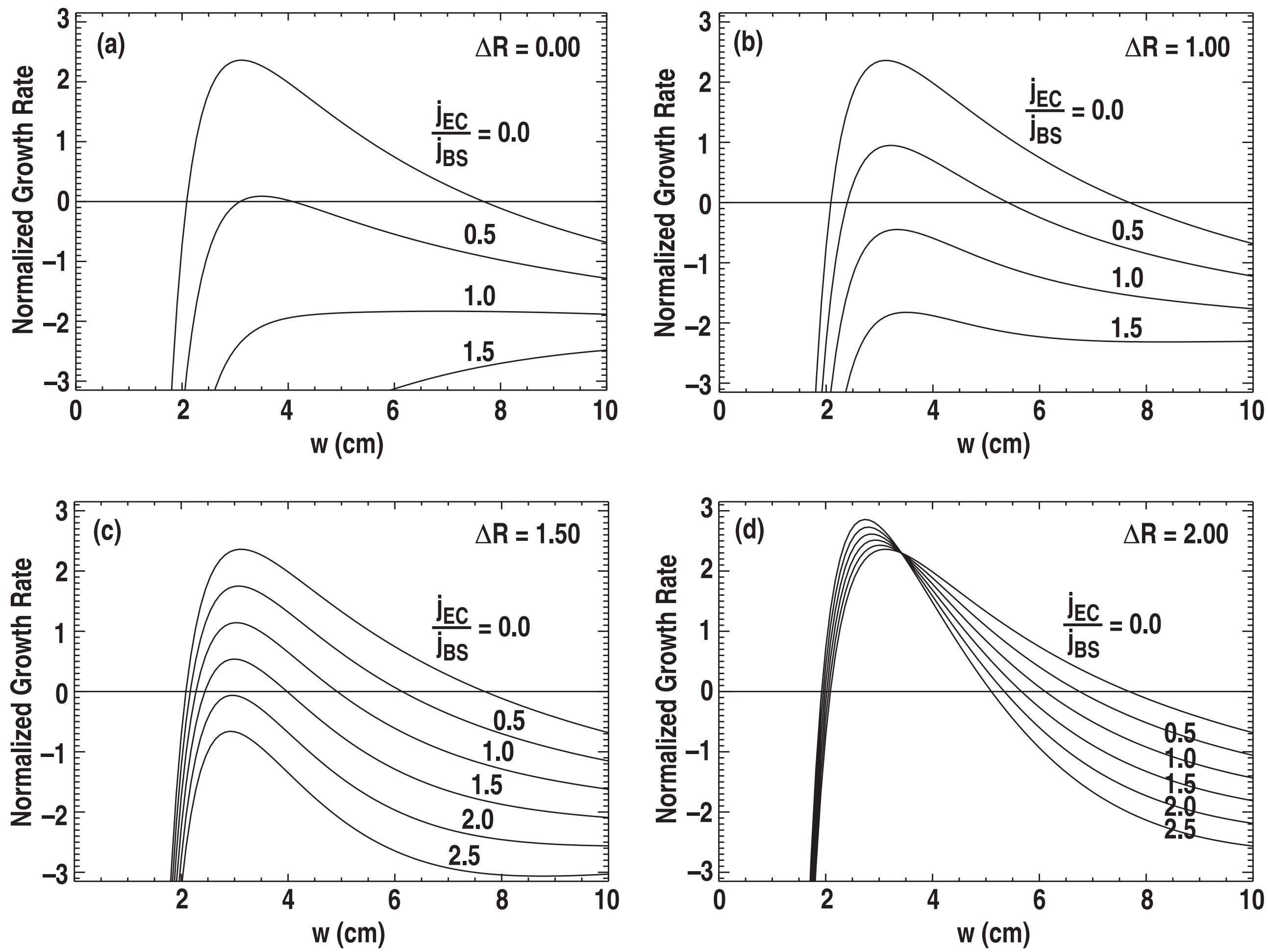
STABILITY SHOWS STRONG SENSITIVITY TO OFFSET OF THE ECCD FROM THE RATIONAL SURFACE



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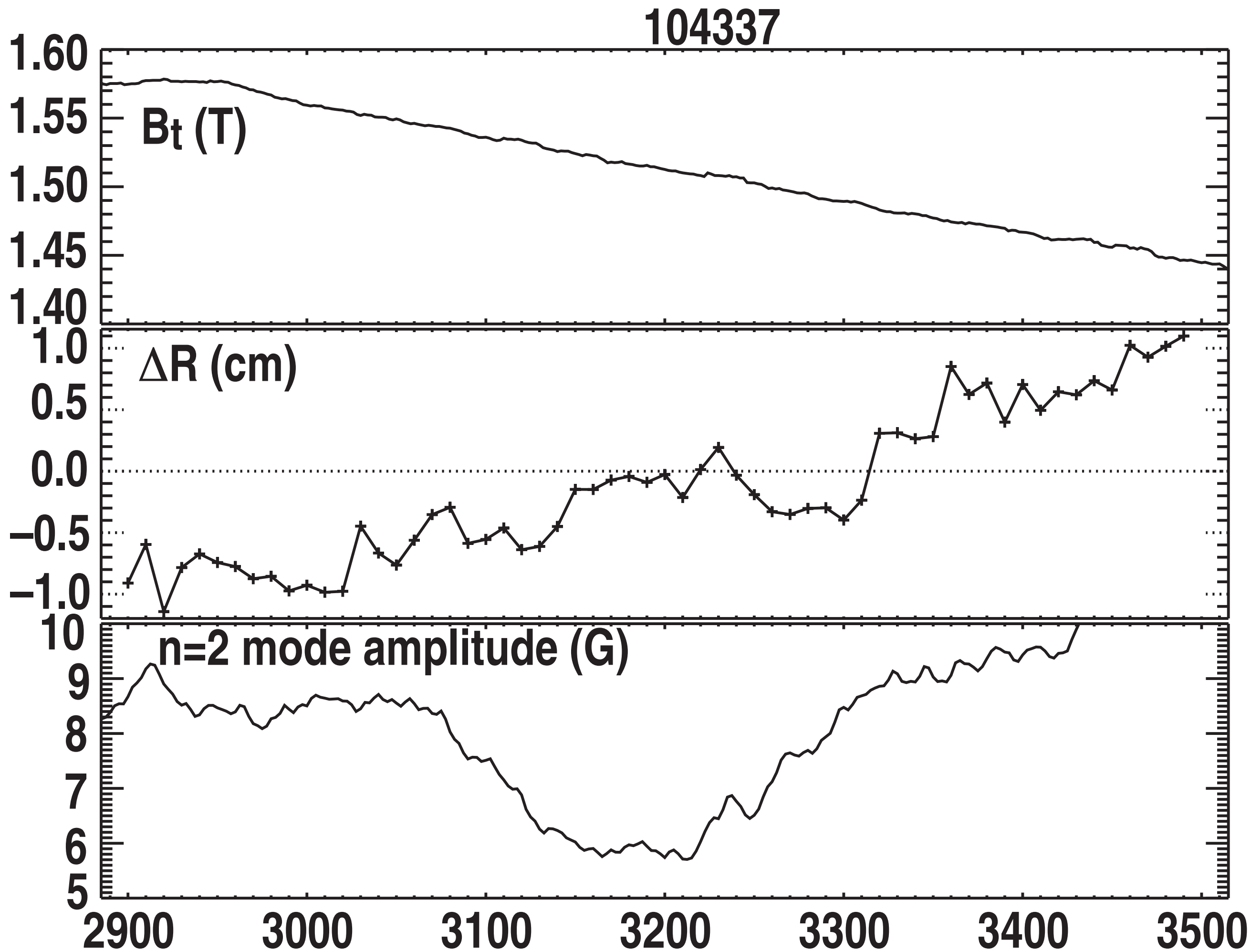
B_T RAMPDOWN FOR m=3/n=2 NTM ILLUSTRATED THE SENSITIVITY OF THE LOCATION OF ECCD



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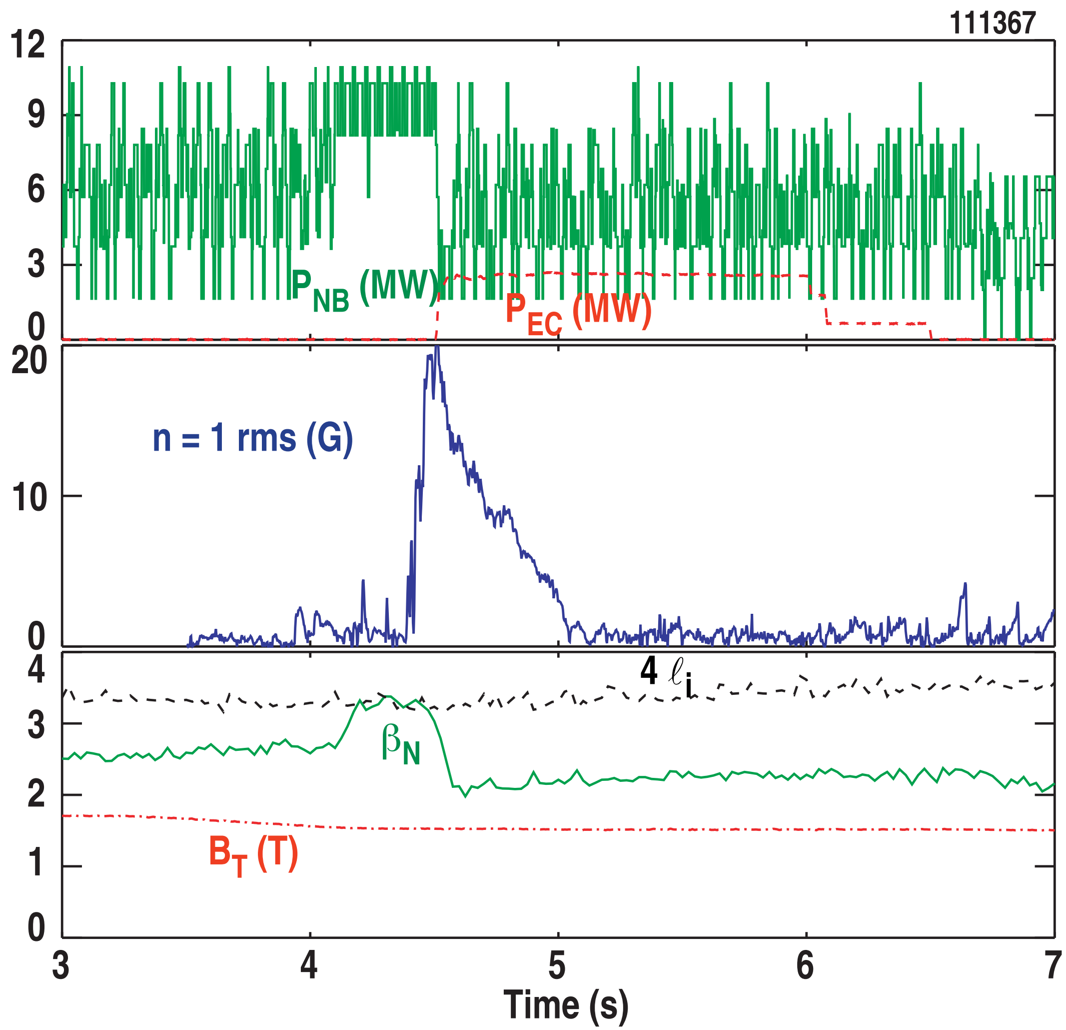
FIRST DEMONSTRATION OF COMPLETE SUPPRESSION OF THE m = 2/ n = 1 TEARING MODE



- β_N is held constant using NBI power feedback
- Energy confinement increases by 25% after m = 2/ n = 1 mode stabilization
- Location of ECCD optimized by toroidal field feedback

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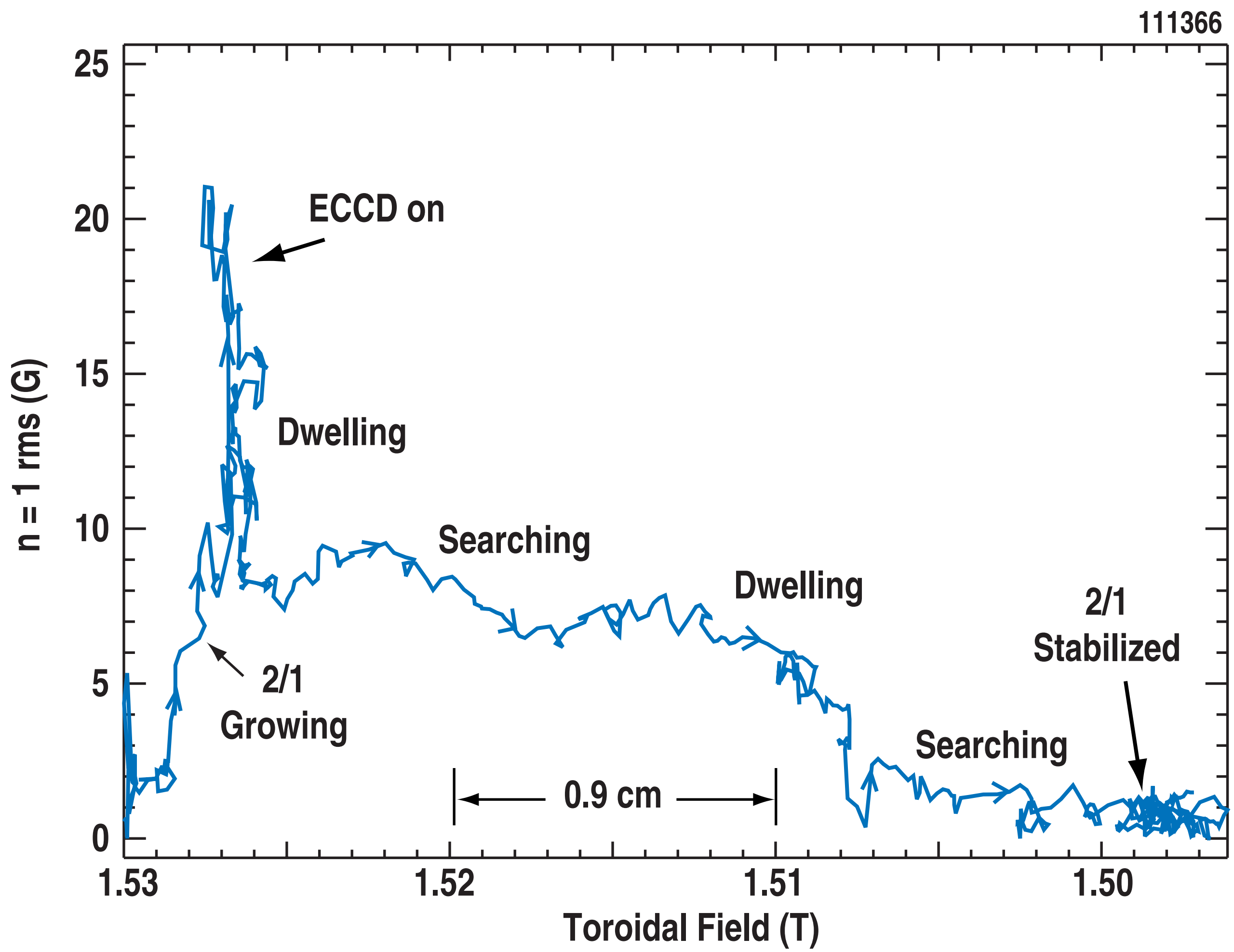
PLASMA CONTROL SYSTEM DETERMINES OPTIMAL B_T VALUE FOR ECCD SUPPRESSION IN REAL TIME



- PCS makes two steps of ≈0.01 T, each equivalent to moving ECCD position by 0.9 cm

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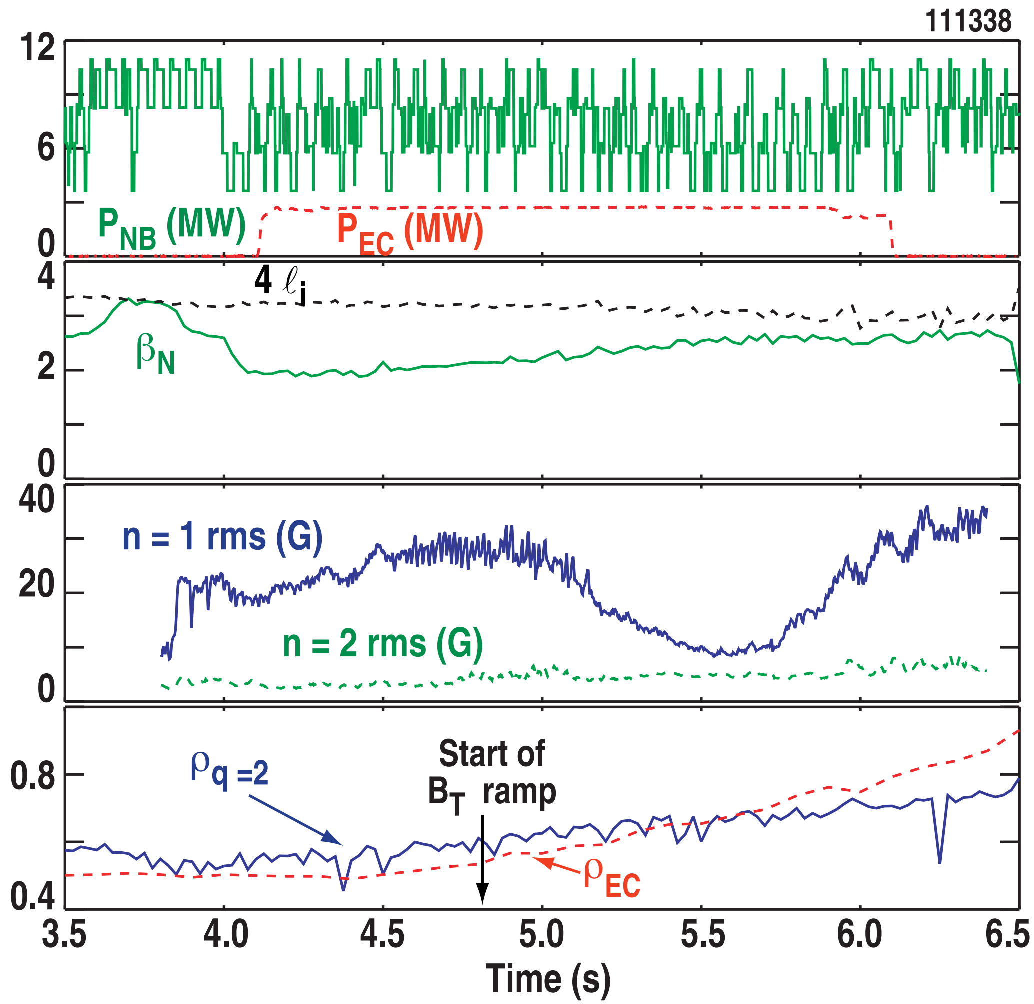
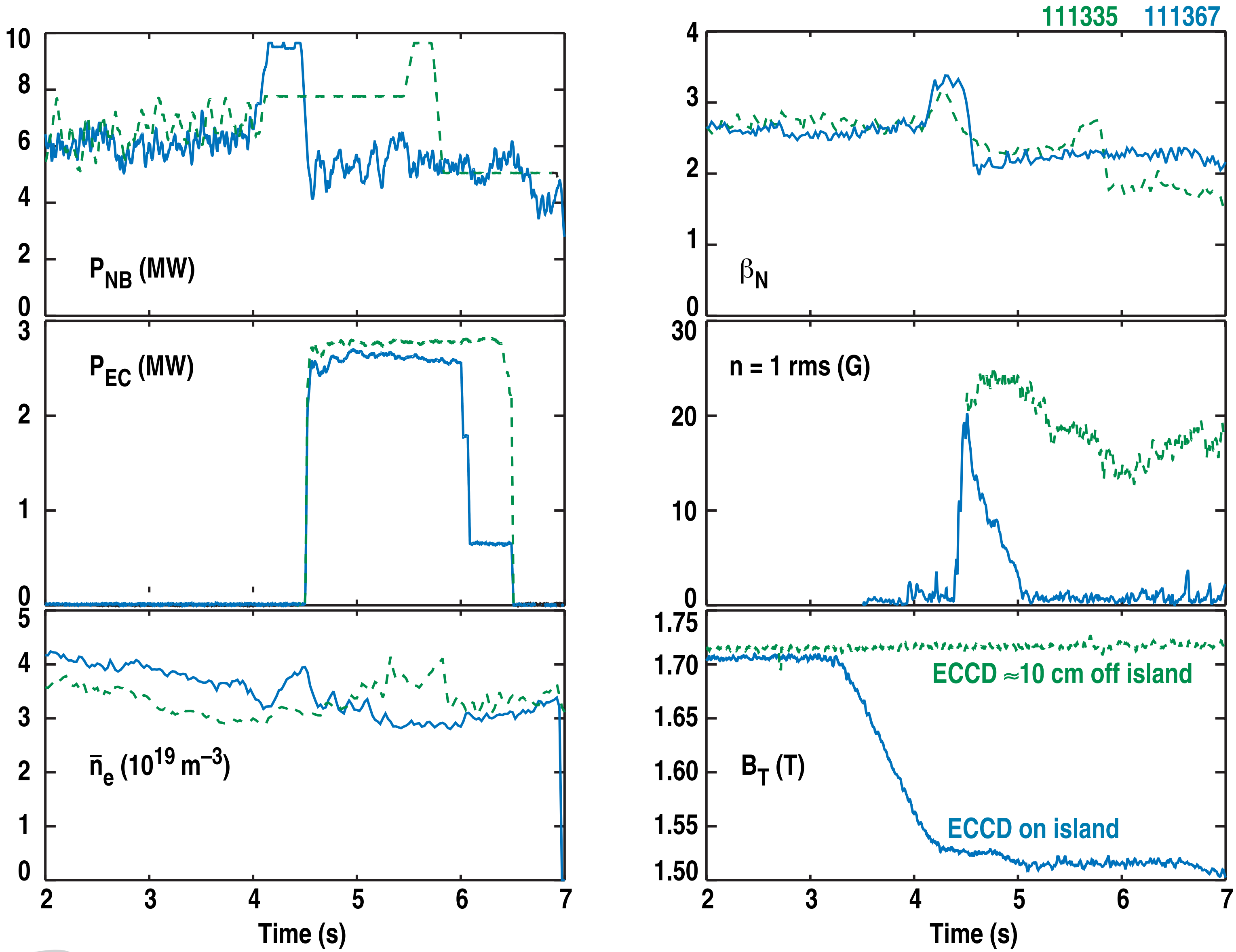
OPTIMAL SUPPRESSION OF m = 2/n = 1 ISLAND OCCURS WHEN ECCD IS ALIGNED WITH q = 2 SURFACE



- Constant diamagnetic flux maintained by NBI power feedback
- m = 2/n = 1 island grows when beta reaches ideal no-wall limit
- Relative locations of ECCD and q = 2 surface are scanned past one another using B_T ramp down

WHEN ECCD POSITION IS MOVED AWAY FROM ISLAND, m = 2/n = 1 TEARING MODE PERSISTS DESPITE LOWER β_N



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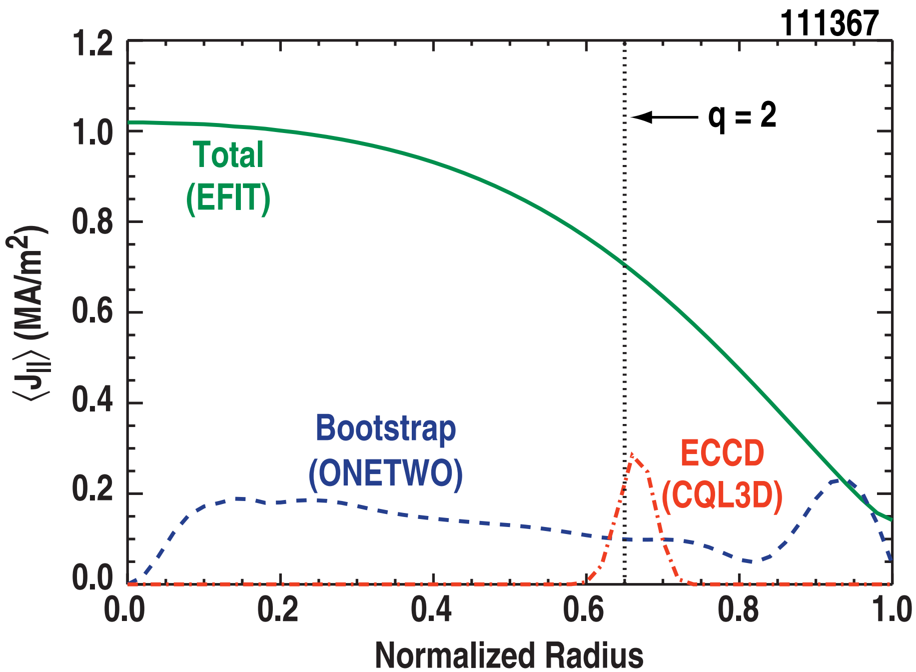
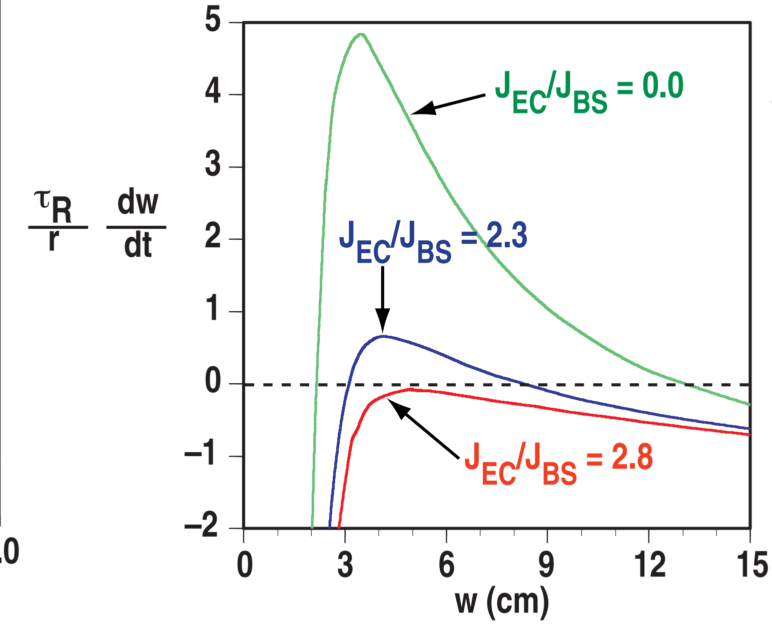
MODELING PREDICTS m = 2/ n = 1 TEARING MODE STABILIZATION REQUIRES $J_{EC}/J_{BS} \geq 2.8$, IN AGREEMENT WITH EXPERIMENT

Calculated current densities for complete suppression case



Normalized growth rates from modified Rutherford eq. assuming ECCD located within island



- Parameters adjusted to match measured island width in absence of ECCD

- 40 kA of ECCD is ≈ 3% of total current

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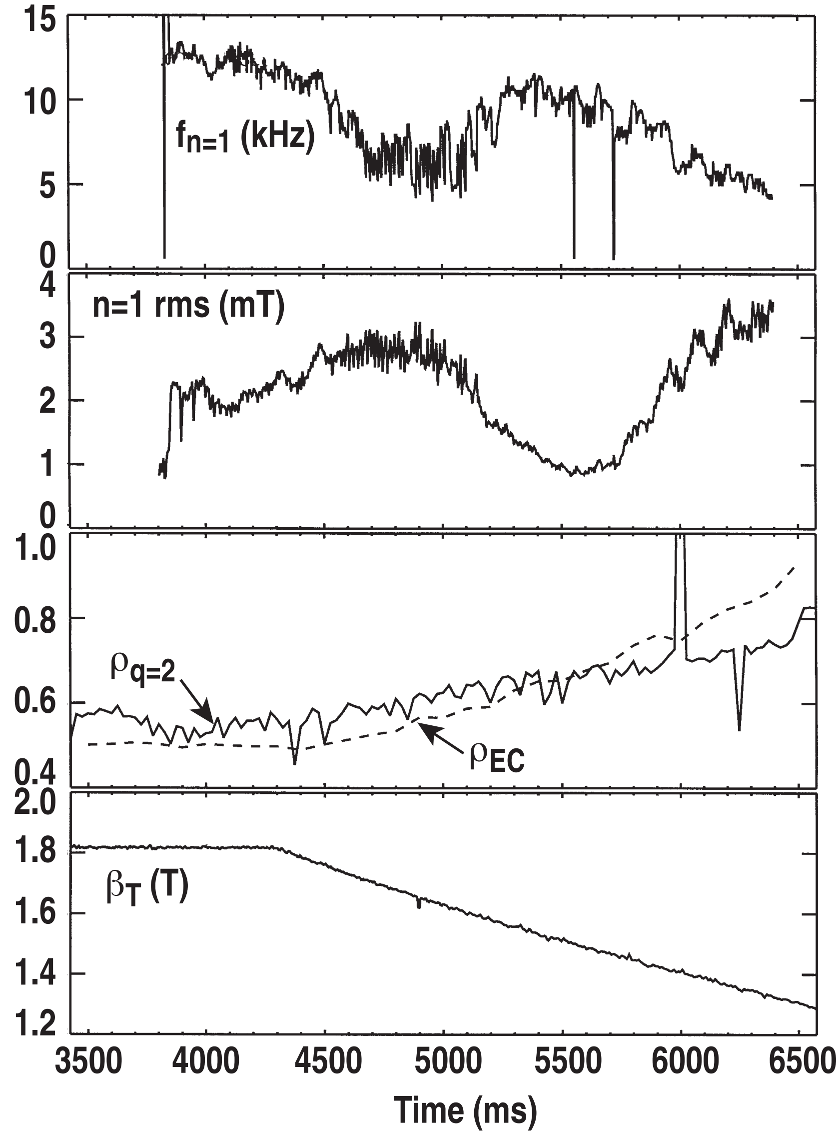
REDUCTION OF n=1 MODE AMPLITUDE LEADS TO INCREASED PLASMA ROTATION



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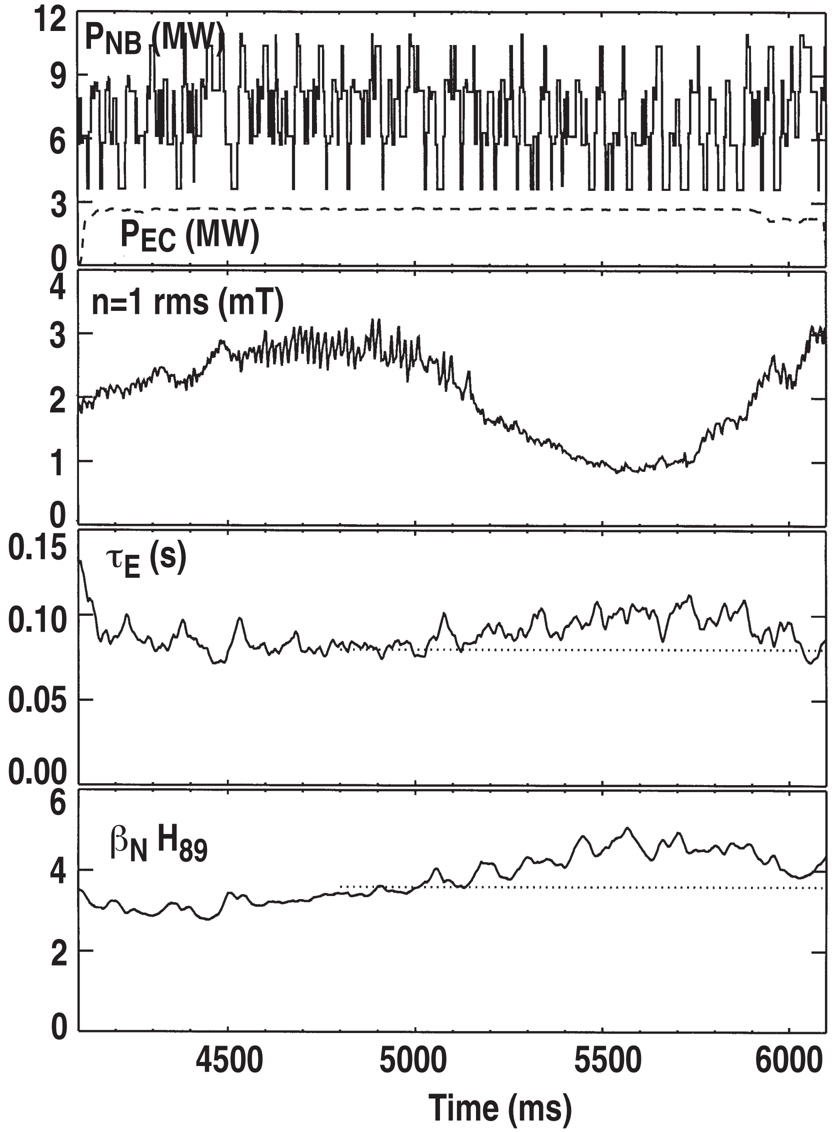
REDUCTION n=1 MODE AMPLITUDE LEADS TO IMPROVED CONFINEMENT AND PERFORMANCE



CONCLUSIONS

- Reduction of the amplitude of 3/2 and 2/1 NTMs is a robust effect
- Important benefits to the performance of the discharge accrue when NTMs are reduced
- Adaptive control of the ECCD location is necessary and effective
- Calculations of the needed ECCD are in good agreement with NTM theory