FIRE/PHYSICS
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ERROR FIELDS AND ROTATION - FIRE

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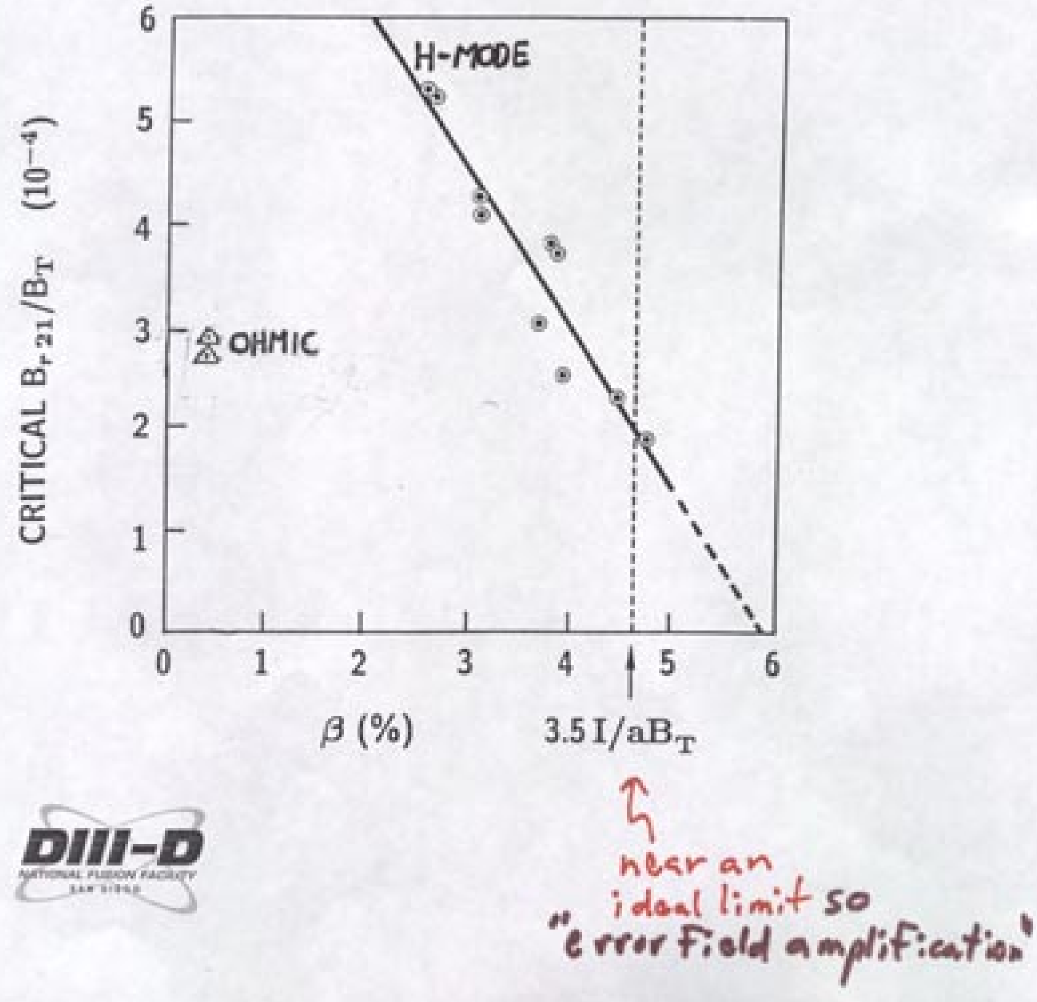
NON-LINEAR STABILITY DECREASES WITH β, *i.e.* SENSITIVITY TO ERROR FIELDS INCREASES

(H–MODE, LEFT OR LEFT/RIGHT BEAMS)

- ONSET OF LOCKED MODE, NO ROTATING 2/1 BEFORE



DIII-D NATIONAL FUSION FACILITY SAN DIEGO

TABLE I: CONVENTIONAL TOKAMAK

Relative critical m/n = 2/1 resonant error field for locking in ohmic target discharges in I_p flattop at $G = \bar{n}_{20}\,\pi a^2 / I_p = 0.2$ with neo-Alcator confinement. All quantities evaluated at q = 2
Note $\Delta'_0 r_{21} \equiv -2$ m = —4, parabolic, parabolic squared T_e and D_2 assumed.

	DIII—D*	JET	IGNITOR	FIRE	ITER
$\omega_0 \equiv \omega_{*e}$ (10^4 rad/s)	0.83	0.26	0.96	0.72	0.082
τ_A (µs)	0.34	0.32	0.11	0.16	0.35
τ_R (s)	0.54	2.4	6.2	4.0	58
τ_E (s)	0.030	0.091	0.22	0.21	0.96
$\tau_v \equiv 4\,\tau_E$ (s)	0.12	0.36	0.86	0.84	3.8
τ_{rec} (s)	0.0063	0.018	0.024	0.019	0.17
$\tan^{-1}(\omega_0\tau_{rec})^{-1}$(deg)	1.1	1.2	0.2	0.4	0.4
$B_{r21}/B_{\phi 0}$ (10^{-4})	3.0	0.9	0.9	0.9	0.3

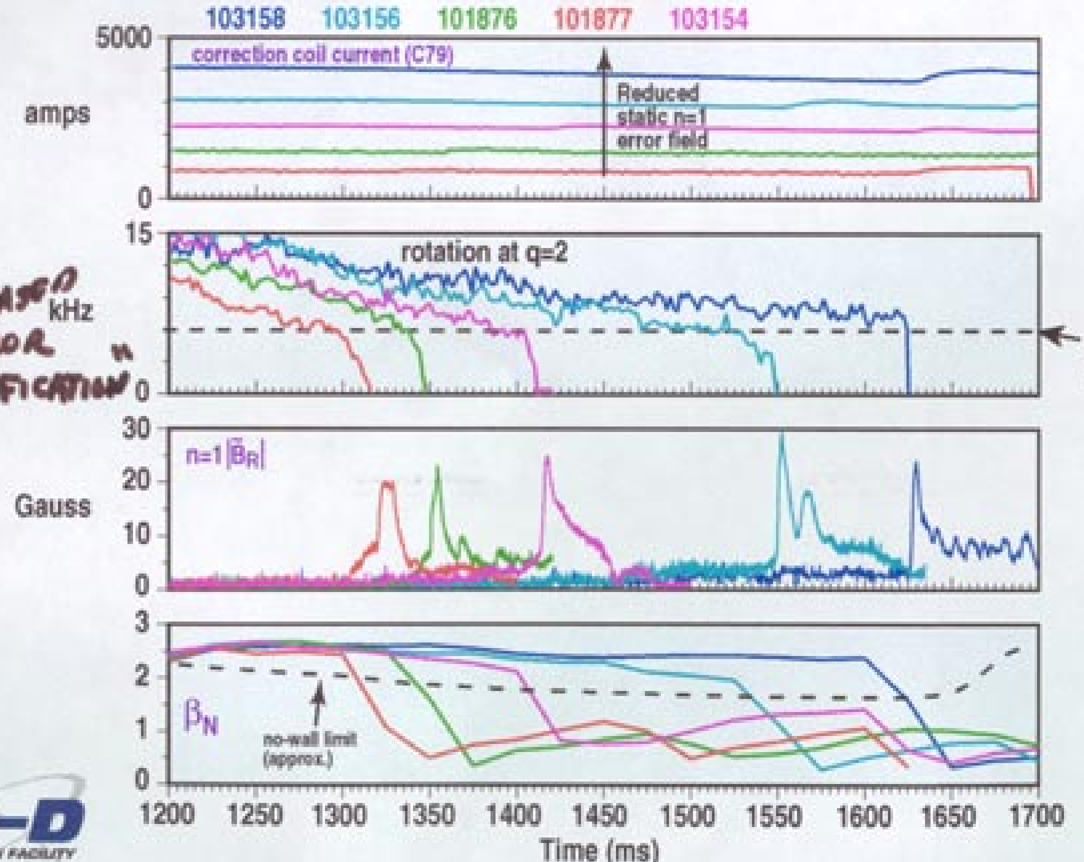
*$B_{\phi o}$ = 1.3 T, I_p = 1.0 MA, R_0 = 1.7 m, a = 0.6 m, LSND, q_{95} = 3.5, $\bar{n}_{20}$ = 0.18.
$B_{\phi o}$ = 2 T, I_p = 2 MA, R_0 = 3.0 m, a = 1.0 m, LSND, q_{95} = 3.5, $\bar{n}_{20}$ = 0.13.
$B_{\phi o}$ = 13 T, I_p = 11 MA, R_0 = 1.32 m, a = 0.47 m, LSND, q_{95} = 3.6, $\bar{n}_{20}$ = 3.2.
$B_{\phi o}$ = 8.5 T, I_p = 5.7 MA, R_0 =2.0 m, a = 0.53 m, DND, q_{95} = 3.5, $\bar{n}_{20}$ = 1.3.
$B_{\phi o}$ = 5.3 T, I_p = 15 MA, R_0 = 6.2 m, a = 2.0 m, LSND, q_{95} = 3.8, $\bar{n}_{20}$ = 0.24.

- $\omega_0 \equiv \omega_{*e}$, $\omega_0/2\pi \approx 1$ kHz
- $\Rightarrow B_{r21}/B_{\phi 0} \approx 9\times10^{-5}$ is not a problem
  - ★ Comparable to JET
    . . . uncorrected JET $\approx 6\times10^{-5}$
  - ★ increases w/ density
  - ★ FIRE has good errorfield correction coil

CED TOKAMAK

BETTER CORRECTION OF THE m/n=2/1 ERROR FIELD REDUCES ROTATION DECAY AND POSTPONES THE ONSET OF THE RWM

- RWM onset when rotation drops to ~6 kHz ($\omega\tau_A$ =0.02)
  - ★ Eventual growth rate of RWM increases
  - . . . ℓ_i lower, β_N closer to $\beta_{N,\ ideal\ wall}$



DROPS
D INCREASED
OF "ERROR "
AMPLIFICATION

CORRE
INCR

$\beta_N > \beta_{N,}$

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TABLE II: ADVANCED TOKAMAK

Relative critical m/n = 2/1 resonant error field for locking or RWM in $1.5 < q_{min} < 2$ discharges with $\beta_{N,\,no\,wall} < \beta_N < \beta_{N,\,ideal\,wall}$. High dissipation regime assumed with $\omega_c\,\tau_A$ at q=2 ≡ 0.019 from DIII—D experiments.

	DIII—D*	JET	IGNITOR	FIRE′	ITER-FEAT′
ω_c (10^4 rad/s)	5.0	—	—	3.2	0.5
τ_A (μs)	0.4	—	—	0.34	0.70
$\omega_c\,\tau_A$	0.020 ≥ 0.019	—	—	0.011 < 0.019	0.0035 < 0.019
τ_R (s)	18	—	—	14	2000
τ_E (s)	0.12	—	—	0.30	3.0
τ_v (s)	0.24	—	—	0.60	6.0
τ'_{rec} (s)	0.11	—	—	0.072	3.8
$\tan^{-1}\left[\left\lvert\frac{\Delta'_{0\,21}r}{4}\right\rvert(\omega_0\,\tau'_{rec})\right]^{-1}$ (deg)	61	—	—	77	28
$B_{r21}/B_{\phi 0}$ $(10^{-4})_{RWM}$	0.3	—	—	No RWM stab.	No RWM stab.
$B_{r21}/B_{\phi 0}$ $(10^{-4})_{locking}$	0.6	—	—	0.2	0.1

*$B_{\phi 0}$ = 2.1 T, I_p = 1.6 MA, R_0 = 1.7 m, a = 0.6 m, LSND, q_{95} = 3.6, 9.5 MW tan beams, $\bar{n} = 0.4\ \bar{n}_{GR} = 0.53\times10^{20}\ m^{-3}$.

Experiments planned for 2003 campaign.

No AT operation planned.

′$B_{\phi 0}$ = 8.5 T, I_p = 5.4 MA, R_0 = 2.0 m, a = 0.53 m, DND, 34 MW rf, $\bar{n} = 0.65\ \bar{n}_{GR} = 4.0\times10^{20}\ m^{-3}$, q_{95} = 3.7, q_{min} = 1.4.

′$B_{\phi 0}$ = 5.3 T, I_p = 10 MA, R_0 = 6.2 m, a = 1.86 m, 35 MW rf, q_{95} = 4.6, q_{min} = 1.6, $\beta_N/4\,l_i$ = 1.5, $\bar{n} = 1.0\ \bar{n}_{GR} = 0.9\times10^{20}\ m^{-3}$.

- $\omega_0 \equiv \omega_{*e}$, for rf only, $\omega_0/2\pi \approx 5$ kHz, $B_{r21}/B_{\phi 0} \approx 2\times10^{-5}$ — for locking is difficult assuming rotation at electron diamagnetic drift freq.
  - ★ No RWM stabilization even if zero error field
    - . . . RWM active feedback coils provided in design
- Possible use of 8 MW/120 kV tan TFTR beam studied (Bob Budny, TRANSP)
  - ★ $\omega_0/2\pi \approx 2$ kHz at $\rho = 0.6$ for 8 MW/120 kV tan beam is too little rot.
    - . . . Need ≈4x to get $\omega \geq \omega_c$ for RWM stabilization at 3×10^{-5}?