Comparison of Resonant Field Amplification in High Beta Plasmas in DIII–D and JET

by

H. Reimerdes,

in collaboration with

M. Bigi[1], R.B. Buttery[1], M.S. Chu[2], A.M. Garofalo, M.P. Gryaznevich[1], T.C. Hender[1], D.F. Howell[1], G.L. Jackson[2], R.J. La Haye[2], Y.Q. Liu[3], G.A. Navratil, M. Okabayashi[4], S.D. Pinches[5], J.T. Scoville[2], E.J. Strait[2], and EFDA-JET Workprogramme Collaborators

[1]EURATOM/UKAEA Fusion Association
[2]General Atomics
[3]Chalmers University
[4]Princeton Plasma Physics Laboratory
[5]Max-Planck-Institut für Plasmaphysik

Presented at
46th Annual Meeting
American Physical Society
Division of Plasma Physics
Savannah, Georgia

November 15–19, 2004

DIII–D NATIONAL FUSION FACILITY SAN DIEGO

EFDA EUROPEAN FUSION DEVELOPMENT AGREEMENT JET

Columbia University

316-04/HR/rs

Resonant field amplification important for operation above the no-wall beta limit

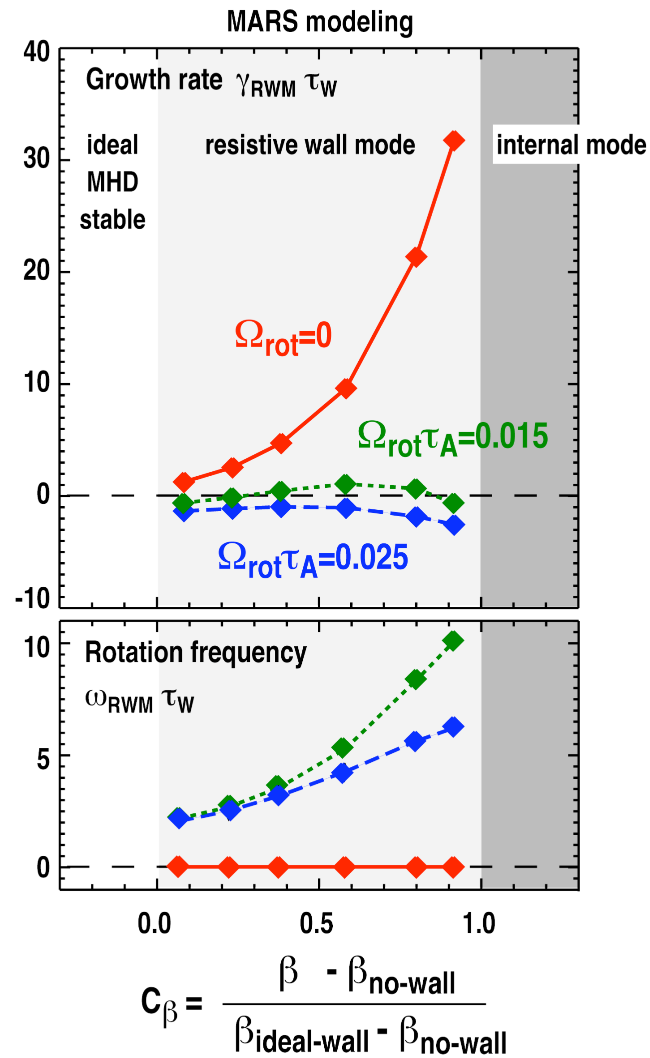
- **Resonant field amplification** (RFA)
  [Boozer, *Phys Rev Lett* **86** (2001) 1176]

  Externally applied resonant fields can excite a weakly damped mode

$$A_{RFA} = \frac{\text{plasma response}}{\text{externally applied field}}$$

- The **resistive wall mode** (RWM) in a fast rotating plasma can be weakly damped
  - Damping caused by plasma rotation Ω_{rot} and some dissipation in the plasma
    [Bondeson and Ward, *Phys Rev Lett* **72** (1994) 2709]

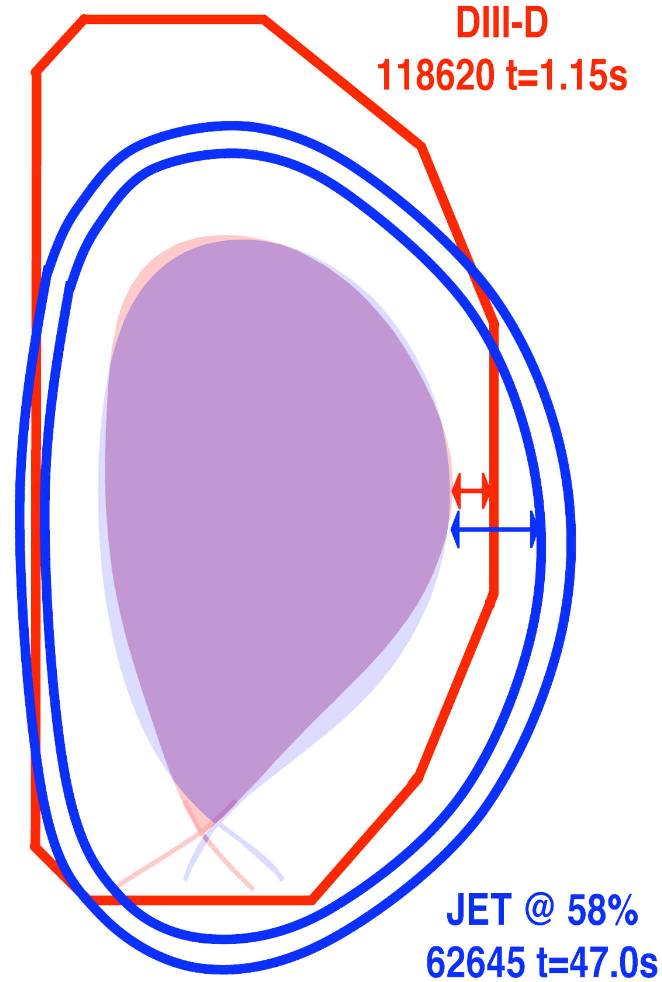
- Extrapolation of stabilizing effect of Ω_{rot} to future experiments requires detailed understanding of the dissipation mechanism



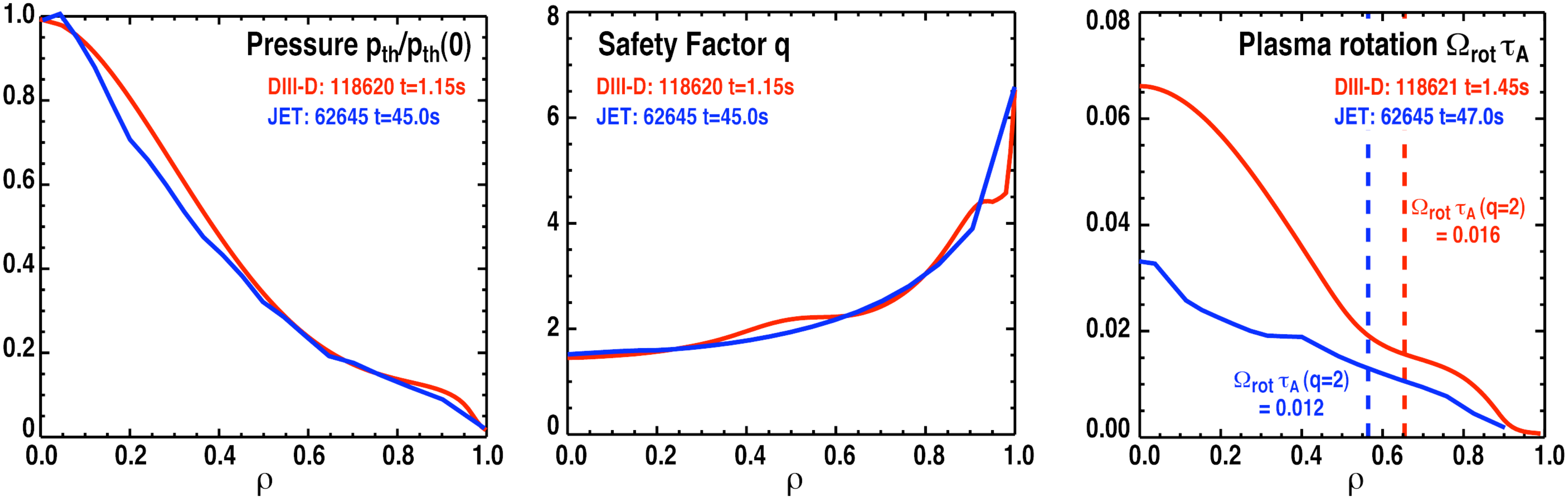
Cross-machine comparison helps to identify the important elements for RFA and RWM stabilization by plasma rotation

Similar discharges in DIII-D and JET

- Match **ideal MHD properties** of the plasma
  - Plasma shape
  - Safety factor profile
  - Pressure profile
- Match **dissipation properties**
  - Plasma rotation normalized to the inverse of the Alfvén time τ_A
- Experiments differ in the **wall properties**
  - Wall position $r_W/a \sim 1.2$ (DIII-D) versus ~ 1.35 (JET)
  - Characteristic wall time $\tau_W \sim 3.5$ ms (DIII-D) versus $\tau_W \sim 5.0$ ms (JET)



Match equilibrium profiles in DIII-D and JET



Ideal MHD properties

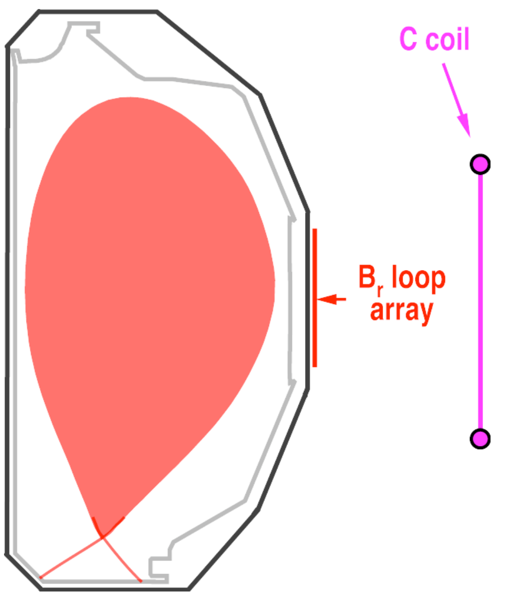
➔ Calculated $\beta_{no\text{-}wall}/l_i$ agree within 15%

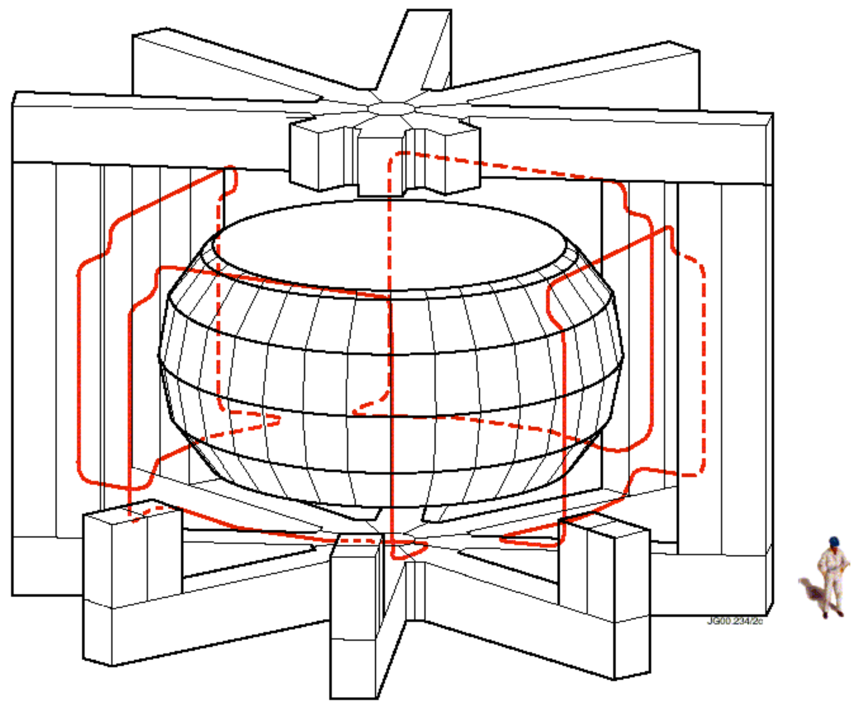
➔ While in DIII-D $\beta_{ideal\text{-}wall}$ exceeds $\beta_{no\text{-}wall}$ by ~60%, the greater wall distance in JET reduces this gain to ~30%

➔ Decrease Ω_{rot} in DIII-D by superposing n = 1 magnetic braking

RFA measurement on DIII-D and JET using external error field correction coils with similar geometry

- **Apply resonant field:**
  - One pair of the error field correction coils (C-coil in DIII-D and EFCC in JET) ➔ apply **pulses** with a large n = 1 component
- **Detect plasma response:**
  - Toroidal arrays of external B_r loops measure the magnitude and toroidal phase of the n = 1 perturbation

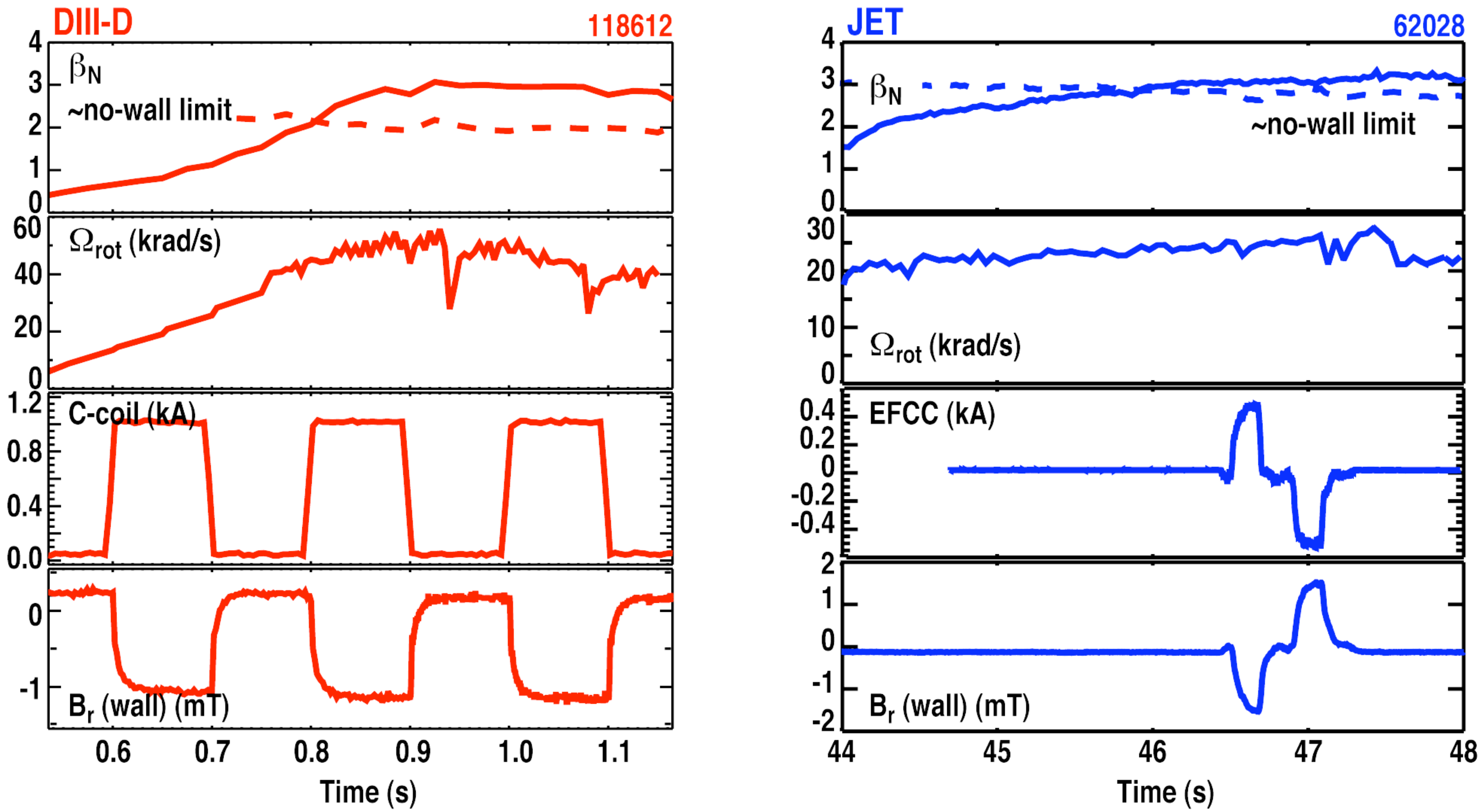




DIII-D NATIONAL FUSION FACILITY

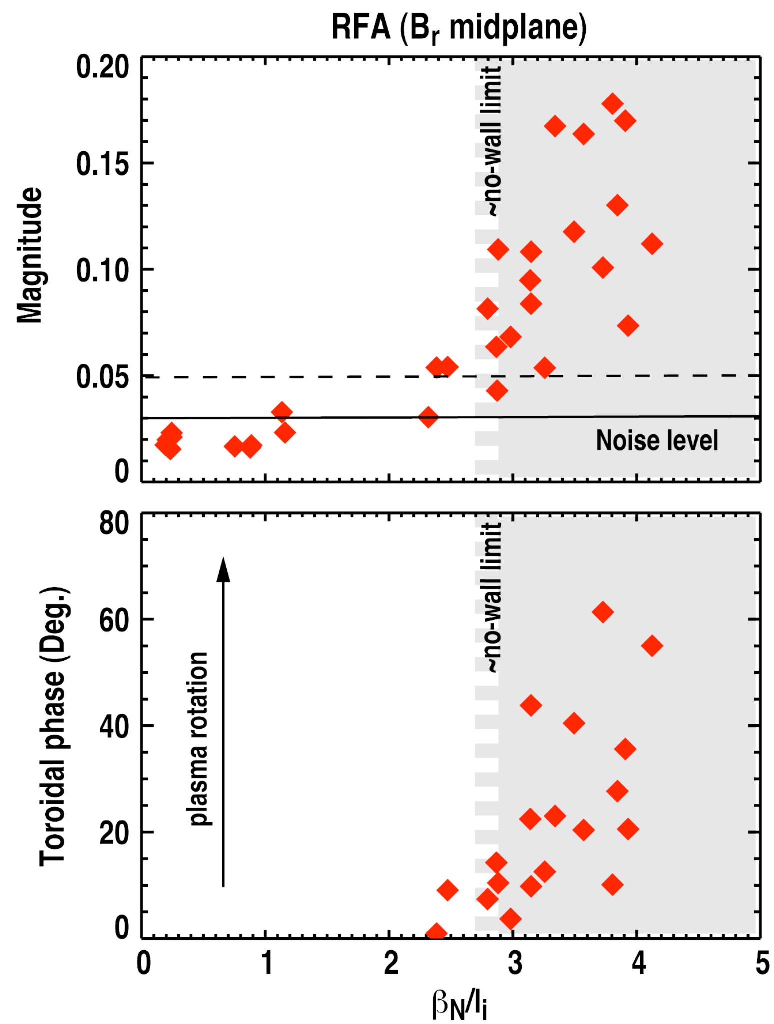
EFDA EUROPEAN FUSION DEVELOPMENT AGREEMENT JET

Apply external magnetic n = 1 perturbations when β exceeds no-wall limit



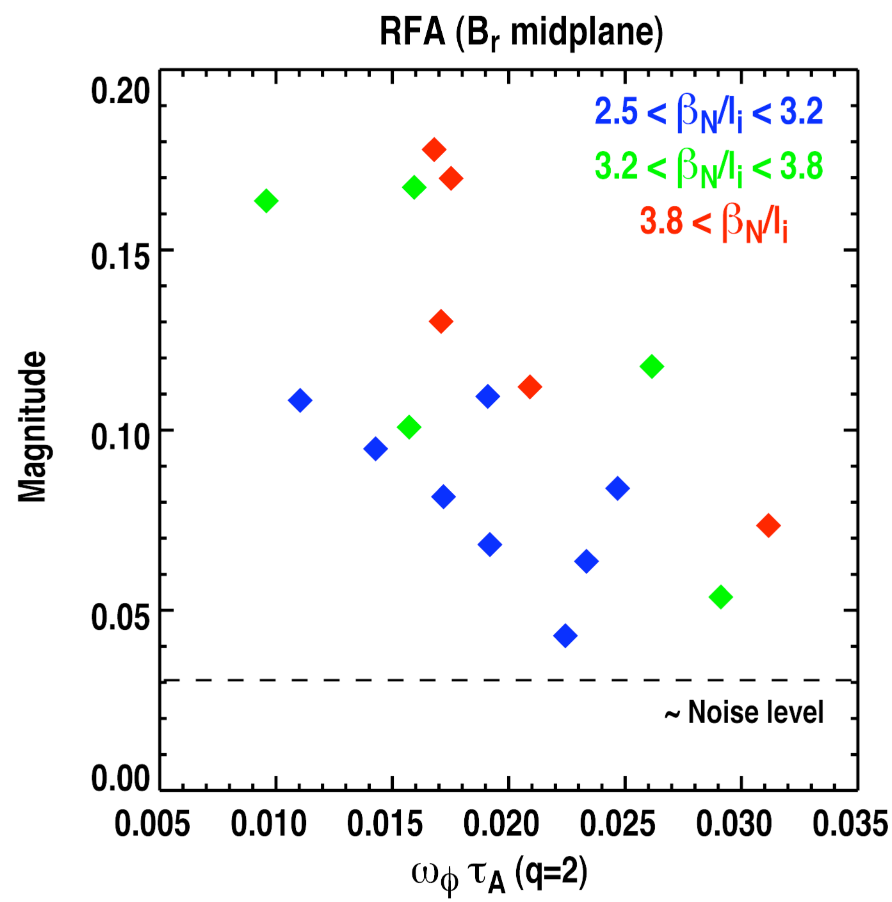
In DIII-D RFA increases significantly when β exceeds the no-wall limit

- Increase of the RFA when β_N exceeds the calculated $\beta_{N,no\text{-}wall}$ similar to previous DIII-D results
  [Garofalo et al, Phys. Plasmas **10** (2003) 4776]
- Large scatter in the RFA magnitude and phase



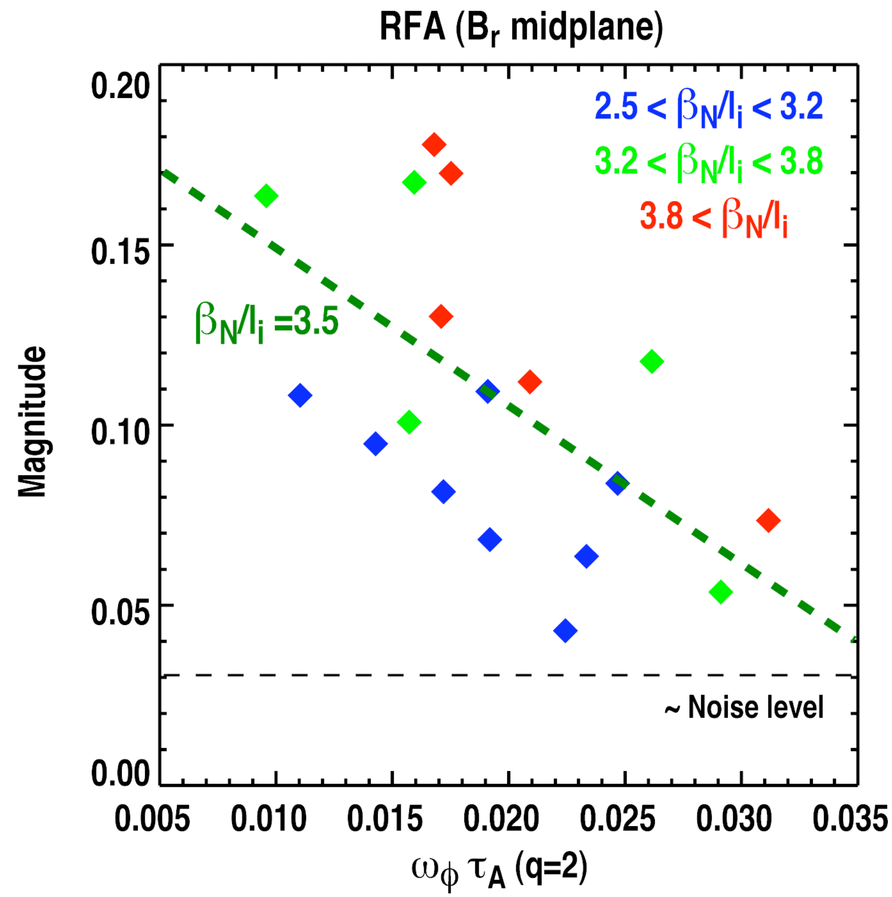
RFA depends on plasma rotation

- While the RFA magnitude increases with β, it decreases with increasing rotation
- No obvious dependence of the toroidal phase on Ω_{rot}



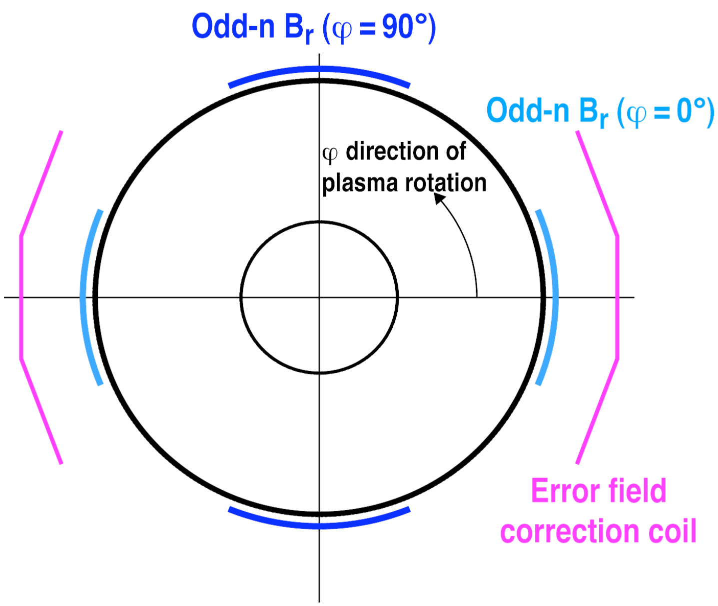
RFA depends on plasma rotation

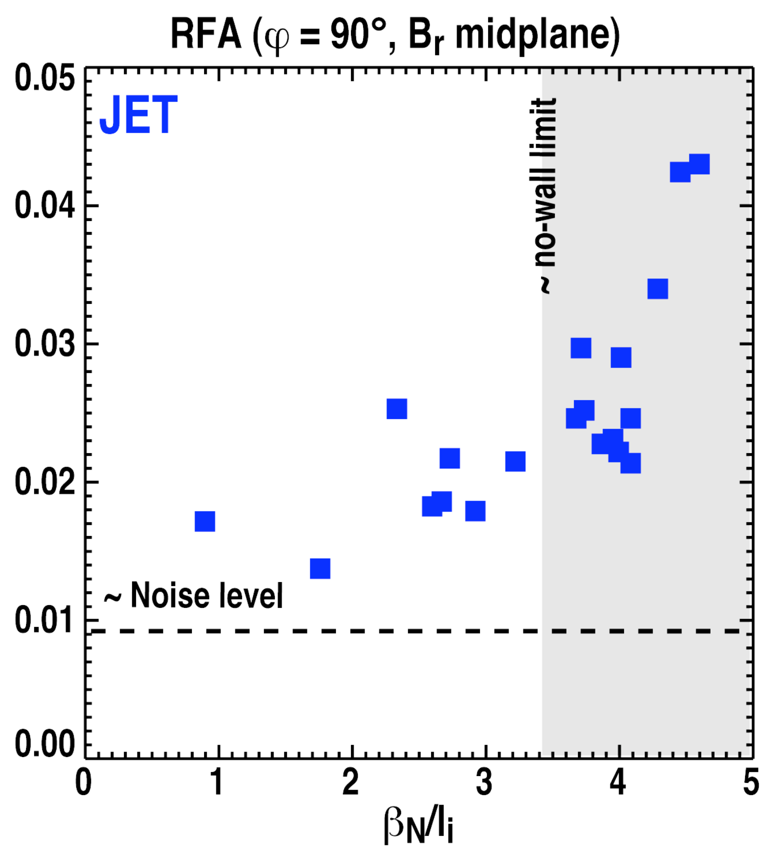
- While the RFA magnitude increases with β, it decreases with increasing rotation
- No obvious dependence of the toroidal phase on Ω_{rot}
- Linear correction for Ω_{rot} dependence reduces the scatter of the RFA magnitude



In JET RFA also increases significantly when β exceeds the no-wall limit

- 0° probe dominated by direct coupling
  ➔ use only probe at 90°



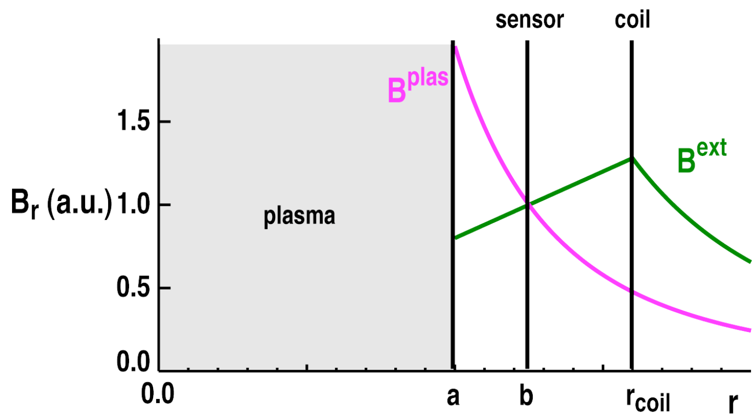


RFA magnitudes at the plasma boundary in DIII-D and JET are in quantitative agreement

- Location of conducting wall determines RWM drive

$$C_\beta = \frac{\beta - \beta_{no-wall}}{\beta_{ideal-wall} - \beta_{no-wall}}$$

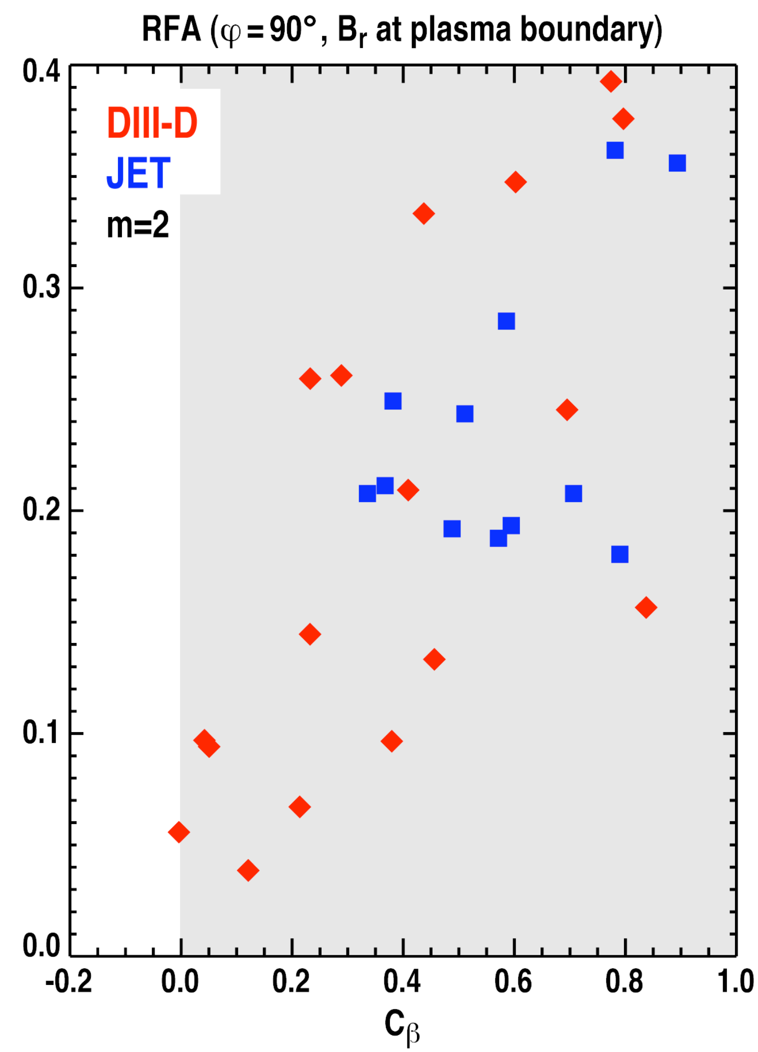
- Radial decay of external and plasma field introduces a radial dependence of $|A_{RFA}|$



  – Cylindrical approximation

$$|A_{RFA,a}|/|A_{RFA,b}| = (b/a)^{2m}$$

	DIII-D	JET
$(b/a)^4$	3.8	8.4



Summary

- In DIII-D and JET the resonant field amplification increases significantly once β is close or above $\beta_{no\text{-}wall}$
- In DIII-D the RFA magnitude increases with decreasing plasma rotation consistent with larger amplification closer to marginal stability
- Evaluating the RFA in both devices in plasmas with the same normalized plasma rotation (➔ dissipation) at the plasma boundary (➔ external kink) and at the same value of C_β (➔ ideal MHD) results in quantitative agreement