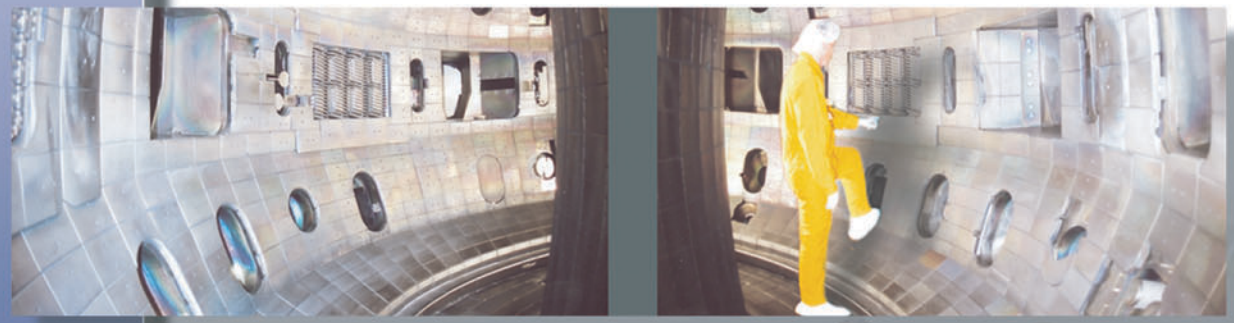

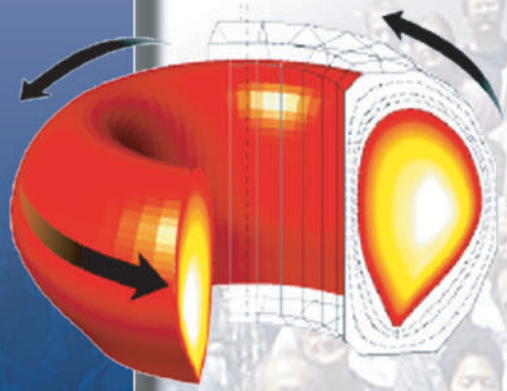

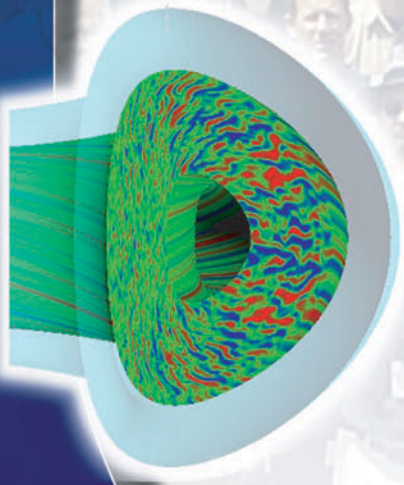

"PLASMA ROTATION IN ELECTRON CYCLOTRON HEATED H-MODES IN DIII–D"

by

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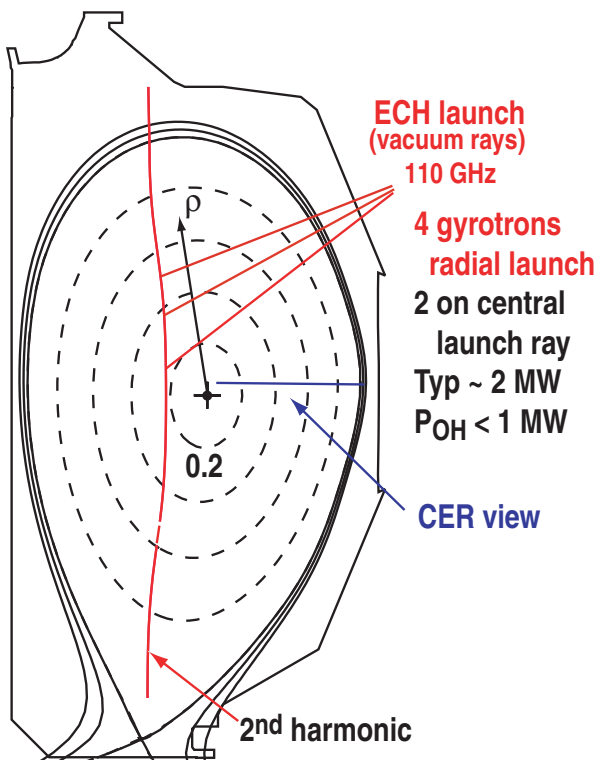
GENERAL ATOMICS

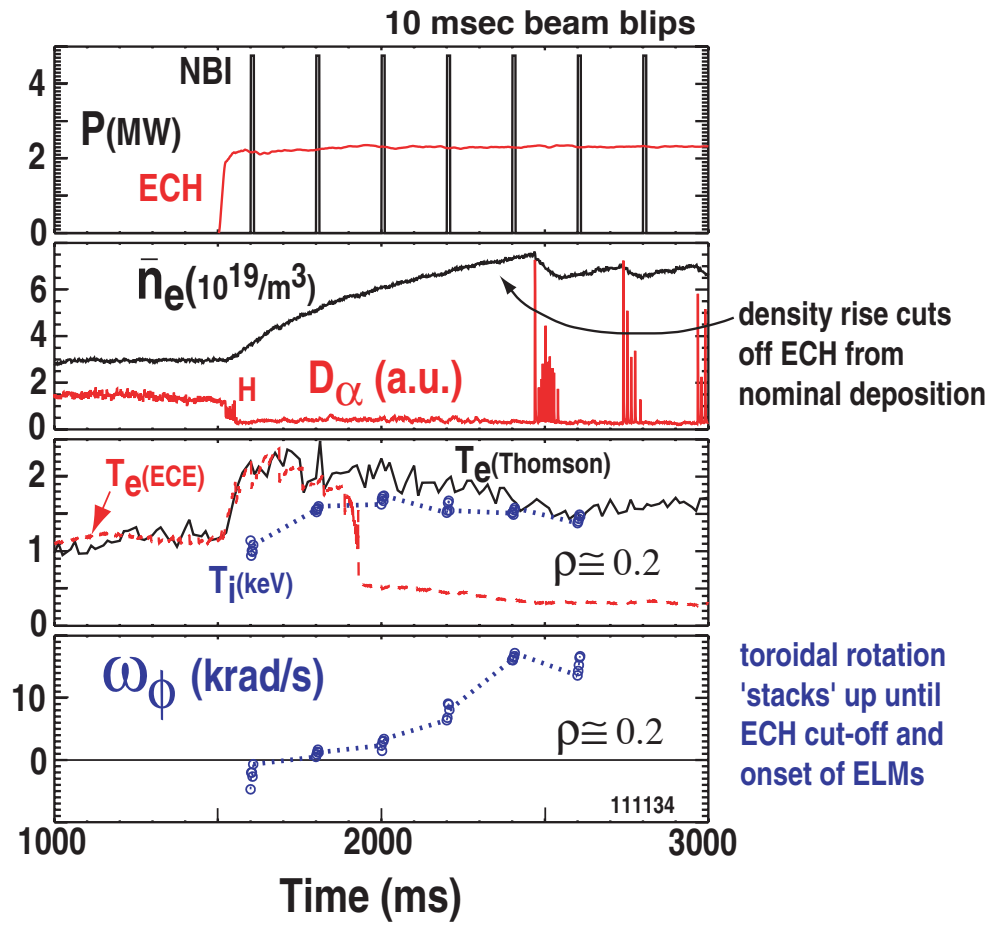
279-04/TST//jy

285-04/JSD/rs

TOROIDAL ROTATION MEASUREMENTS IN DIII–D IN ECH H-MODE DISCHARGES

- Charge Exchange Recombination Spectroscopy: C^{+6} Bulk ion D^{+}; (and CER of bulk He^{+2})
- Requires NBI. Beam torque limits measurement interval to < 4 ms to have an unperturbed state
- Toroidal momentum from short beam 'blip' injection is well confined, → typically one timeslice/shot
- Move the timing of the first beam blip shot-to-shot to obtain a time sequence
- Generally these ECH H-modes have long ELM-free periods, → evolving conditions





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* deGrassie et al, PoP, **11** 4323 ('04)

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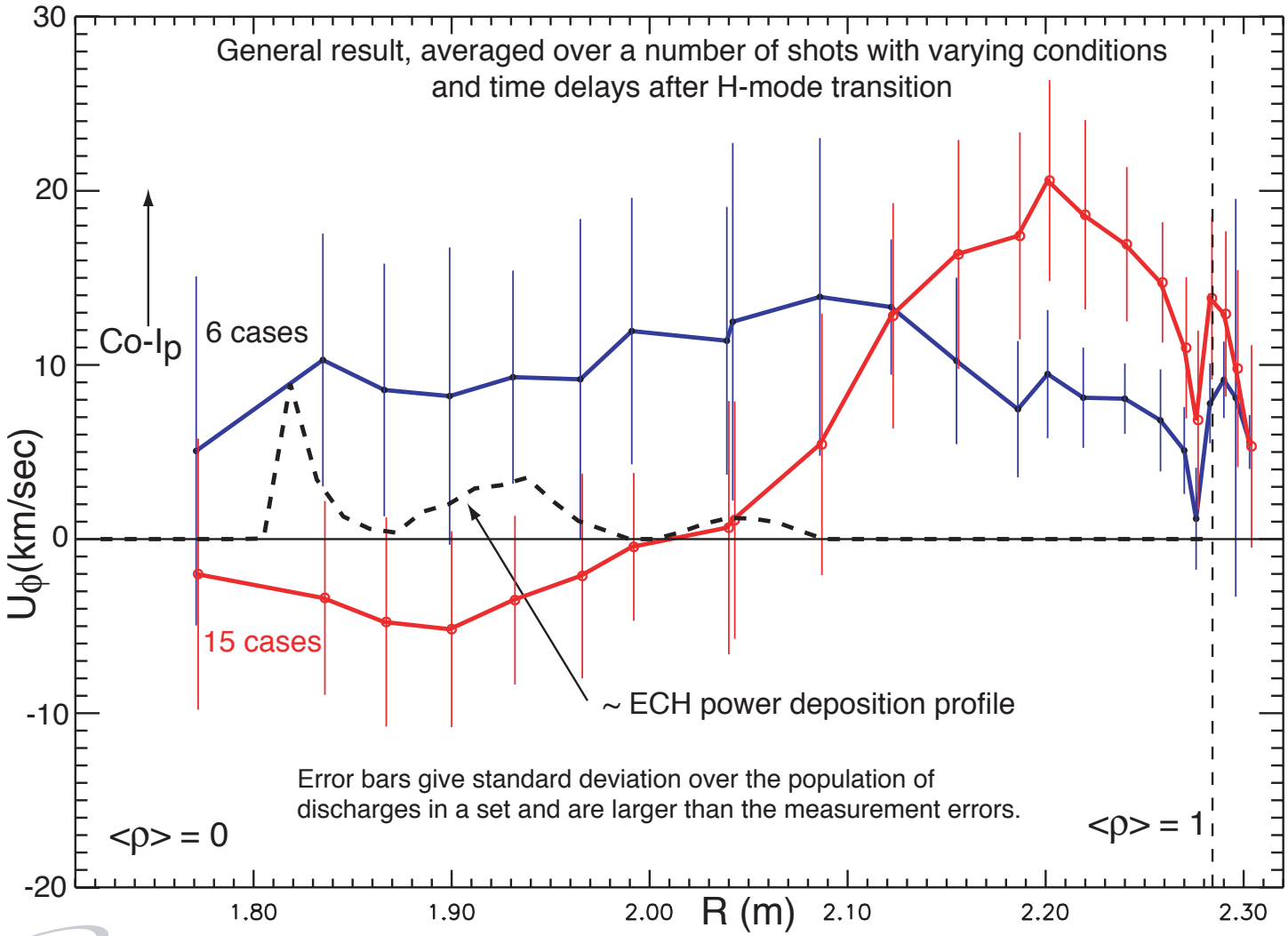
ECH H-MODES IN DIII–D SHOW A HOLLOW TOROIDAL ROTATION PROFILE IN CONTRAST TO OH-H MODES, WHICH HAVE A RELATIVELY FLAT PROFILE

No auxiliary momentum input

- **Rotation profiles measured for bulk He+2 are also hollow and reversed**



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ROTATION PROFILES FOR ALL ECH POWER DEPOSITION PROFILES ARE HOLLOW

The core (near central) rotation profile depends only weakly upon ECH deposition, while there is no discernable effect on the outer region profile

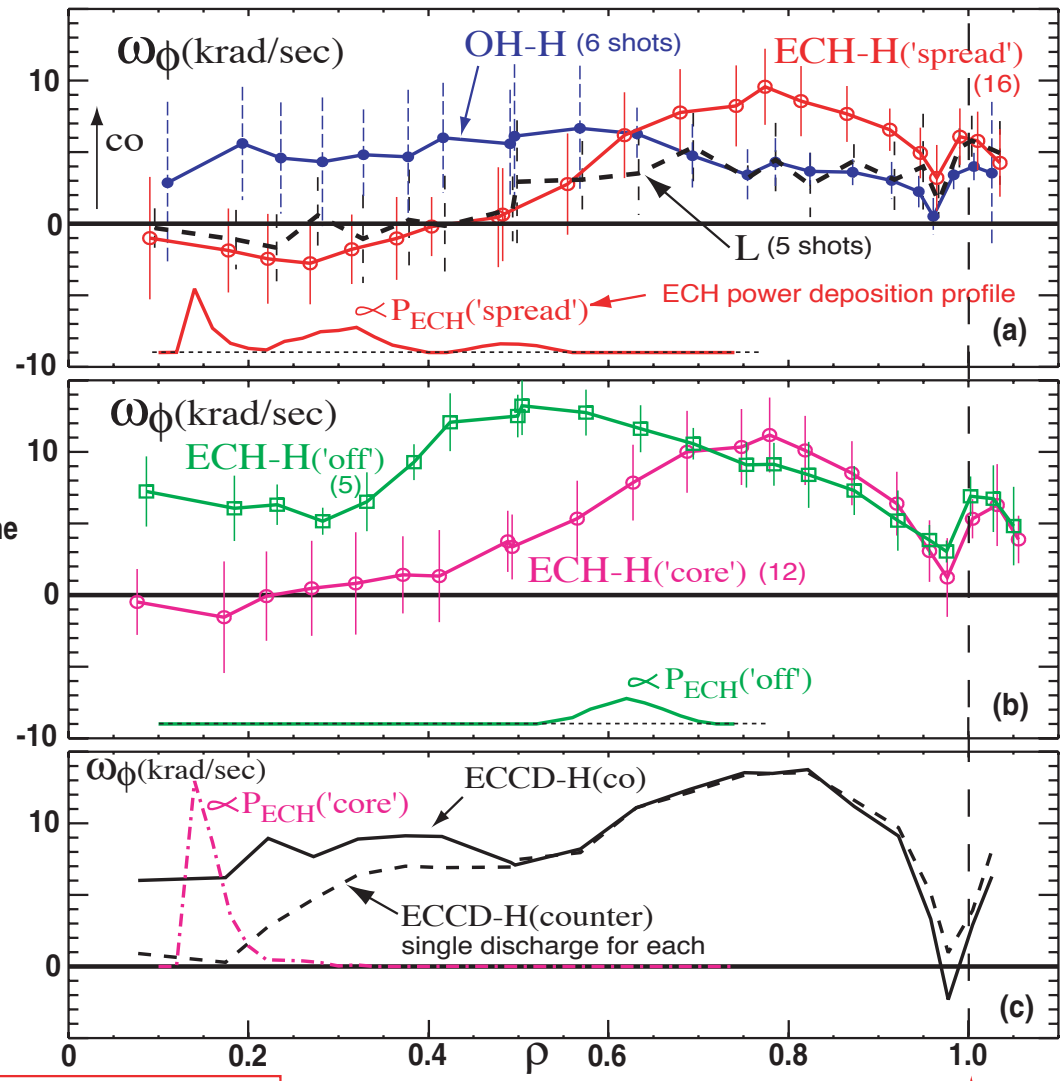
(a) Same data for ECH-H and OH-H, now plotting rotation frequency:

$\omega_\phi = U_\phi/R$ vs ρ

The pre H-mode slices (L) are hollow also, but to a lesser extent.

(b) ECH H-mode profiles are hollow for all power deposition profiles used. Off-axis heating is most unique; yet the rotation profile details are not highly sensitive to the P_{ECH} deposition.

(c) The ECCD database is limited. Here an example profile for a co- and a counter-ECCD H-mode with core deposition shows an interesting variation in the core.



Boundary rotation value is nonzero

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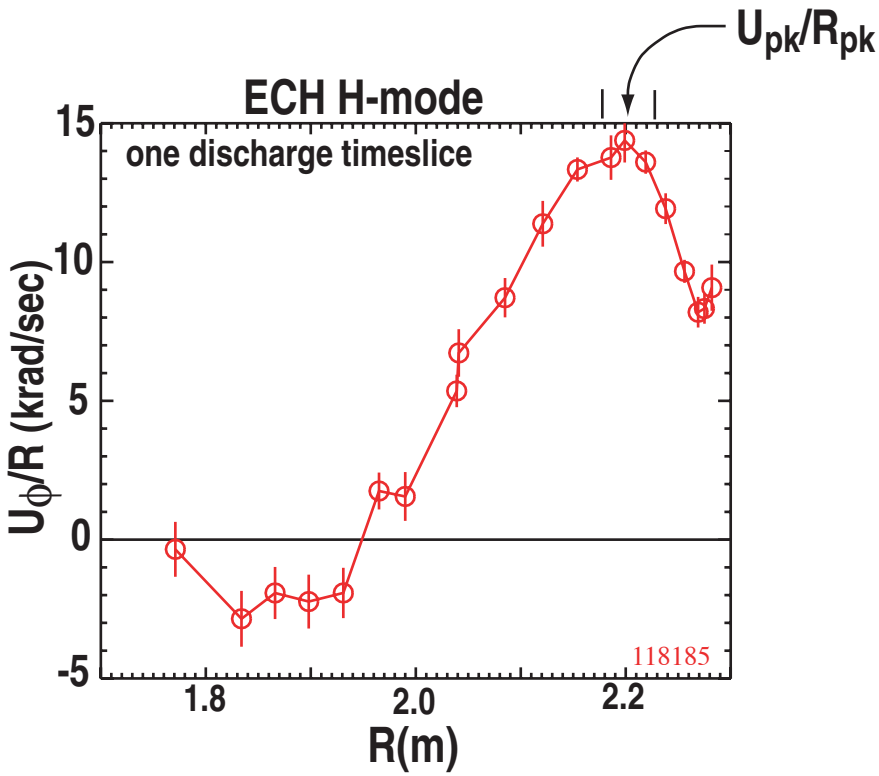
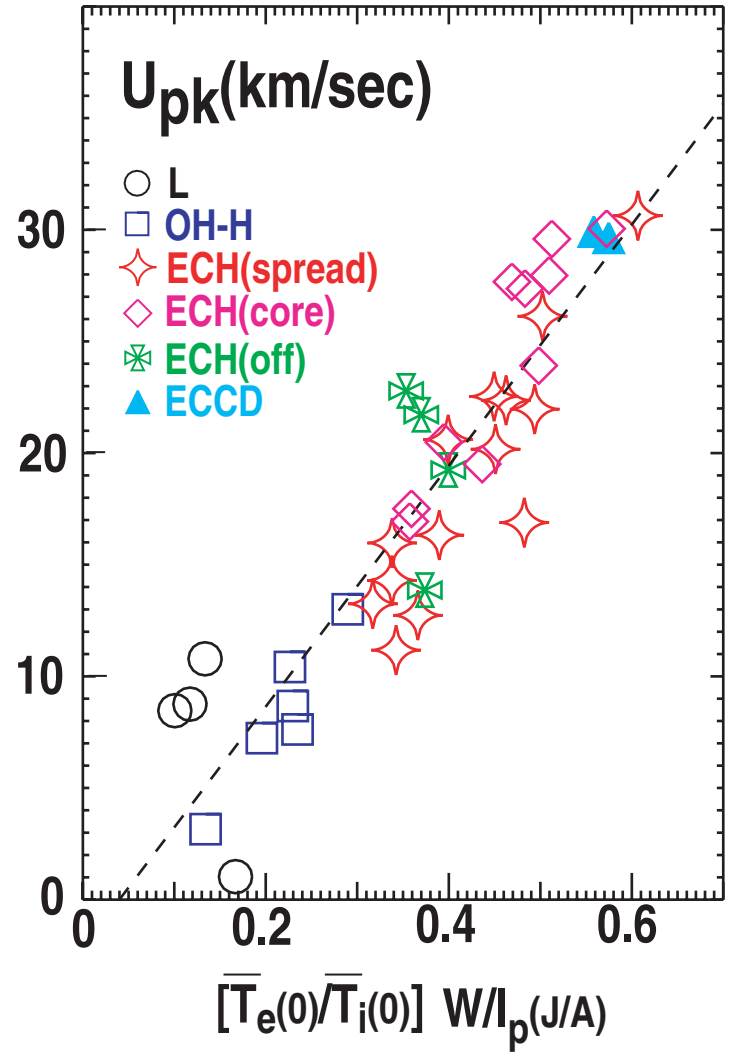
TOROIDAL ROTATION VELOCITY AT $\rho \sim 0.77$, U_{pk}, SCALES AS $[T_e(0)/T_i(0)][W/I_p]$

- Common to all 'non-driven' cases is co-Ip directed rotation near $R_{pk} \sim 2.2$ m





$\overline{T}_e(0)$ = near central, averaged electron temperature

$\overline{T}_i(0)$ = near central, averaged ion temperature

W = plasma thermal energy

I_p = plasma current

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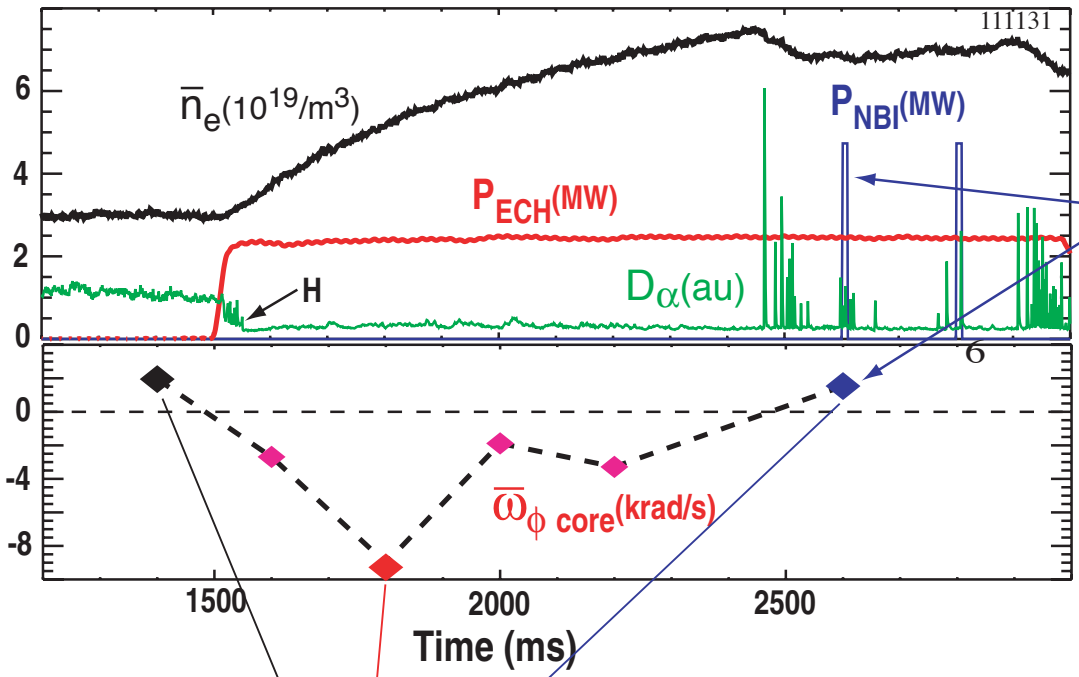
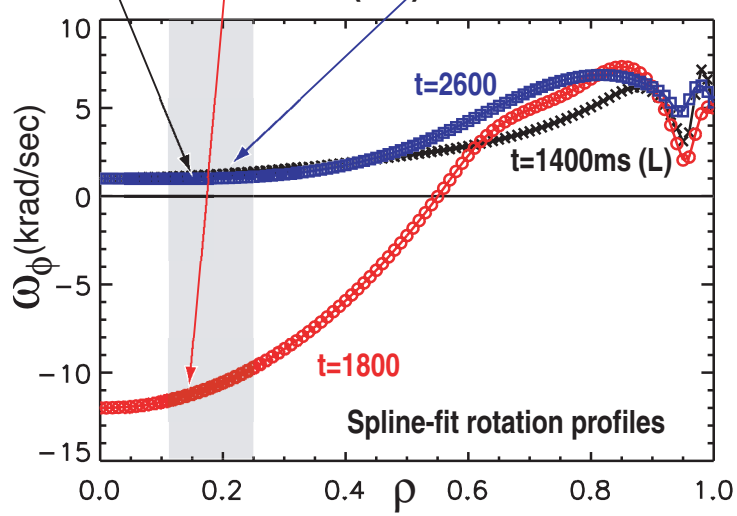
TEMPORAL HISTORY FOR CORE ROTATION SHOWS THAT COUNTER-ROTATION CAN DEVELOP IN TIME; IT IS NOT A RESIDUAL FROM THE L-MODE STATE (pre-ECH)



Shot in sequence with latest first blip

$\bar{\omega}_{\phi\ core}$= spatial average over 3 inner channels.



Core rotation returns to pre-ECH H-mode state after ELMs start, which is also after ECH cut-off from interior deposition.

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PLASMA ROTATION IN ECH H-MODES IN DIII–D SUMMARY

- Rotation profiles in ECH H-mode are hollow; co-Ip outside, depressed or counter- Ip in the interior. OH H-modes by contrast have a relatively flat, co-rotation profile
- All ECH power deposition profiles used result in a hollow rotation profile the 'off-axis' deposition results in less depression of the core co-rotation
- The boundary rotation is nonzero. It is in the co-direction, $\langle\omega_\phi(\rho=1)\rangle$ ~ +5 krad/s averaged over this set. The effect of an ion velocity loss cone is under investigation
- All discharges with non-driven toroidal rotation show a co-rotation peak near ρ ~ 0.77. The velocity here scales as $[T_e(0)/T_i(0)](W/I_p)$
- The temporal history of the core rotation shows that the counter-rotatoin can develop in time. It is not due to a remnant of the pre-ECH ('L') state
- Mechanism? (speculation!)
  (a) Outer region driven by an edge co-source with momentum diffusion and an inward pinch, as in the C-Mod model for the ELM-free H-mode rotation profile
  (b) Interior results from nonambipolar currents, but with an integrated net zero torque, analogous to models explaining nonzero toroidal rotation with ICRH