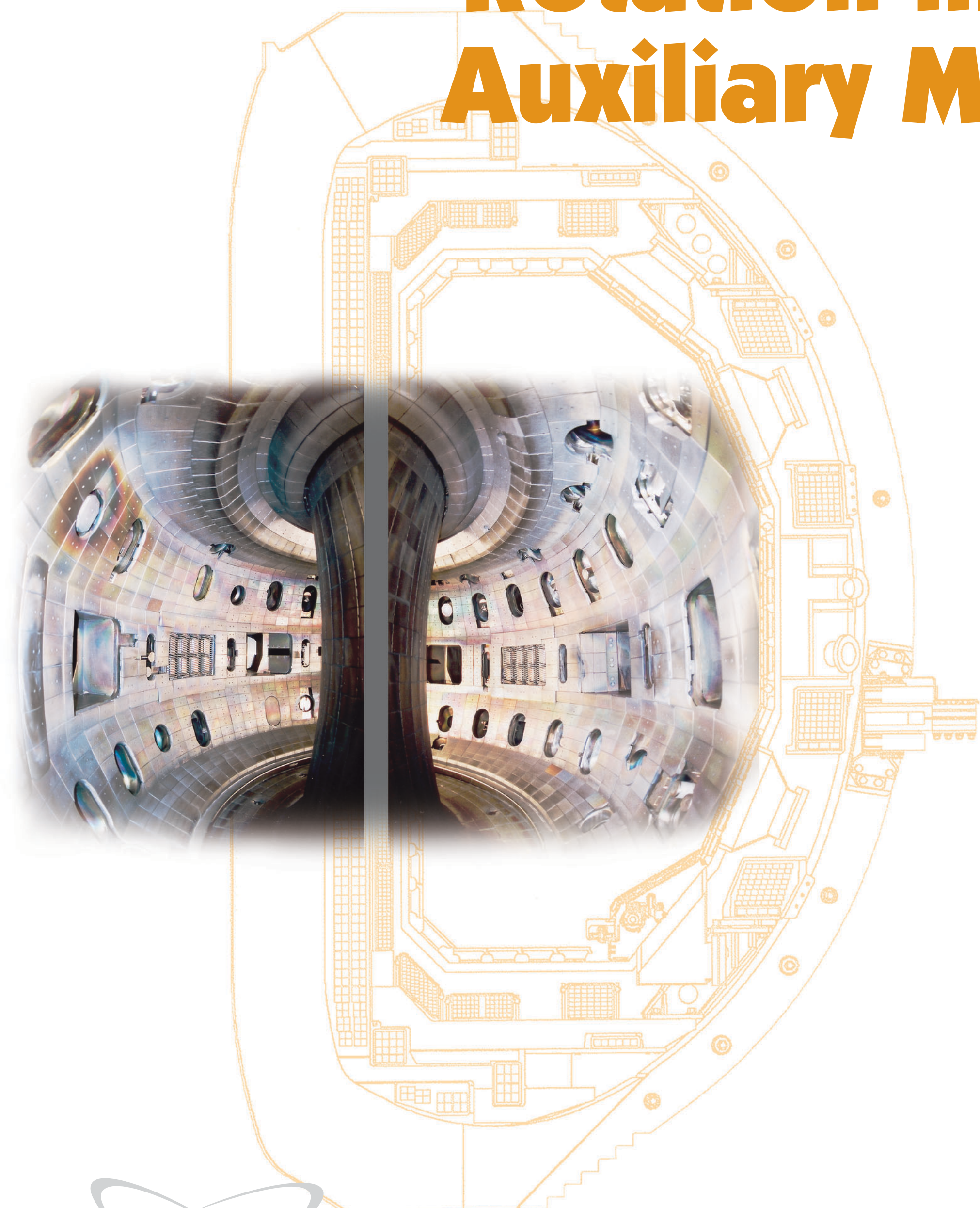
Rotation in DIII–D without Auxiliary Momentum Input



by
J.S. deGrassie,
in collaboration with

K.H. Burrell, J. Lohr,
L.R. Baylor[1], W. M. Solomon[2]

[1]Oak Ridge National Laboratory
[2]Princeton Plasma Physics Laboratory

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

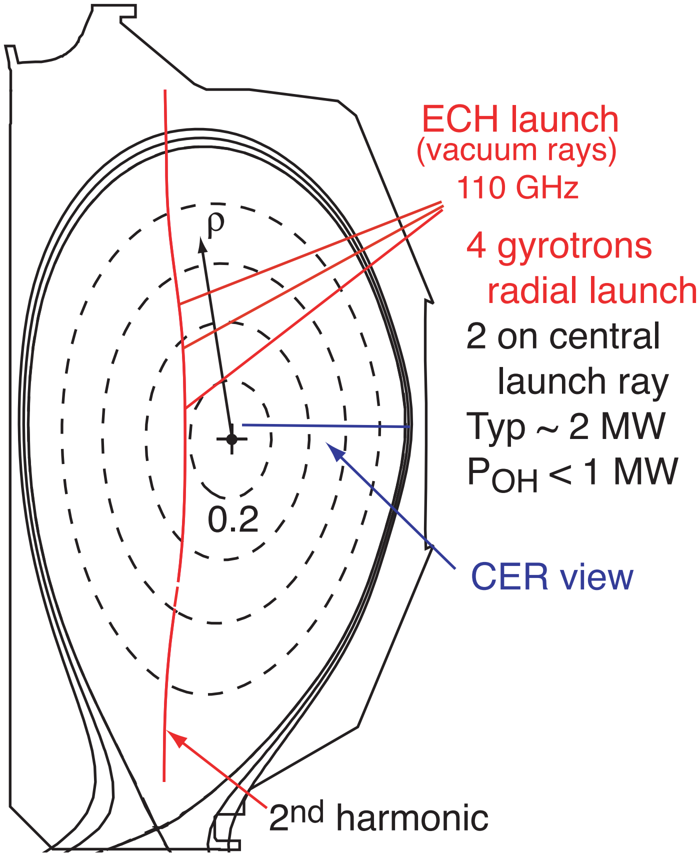
November 15–19, 2004

GENERAL ATOMICS

302-04/JSD/rs

DIII–D
NATIONAL FUSION FACILITY
SAN DIEGO

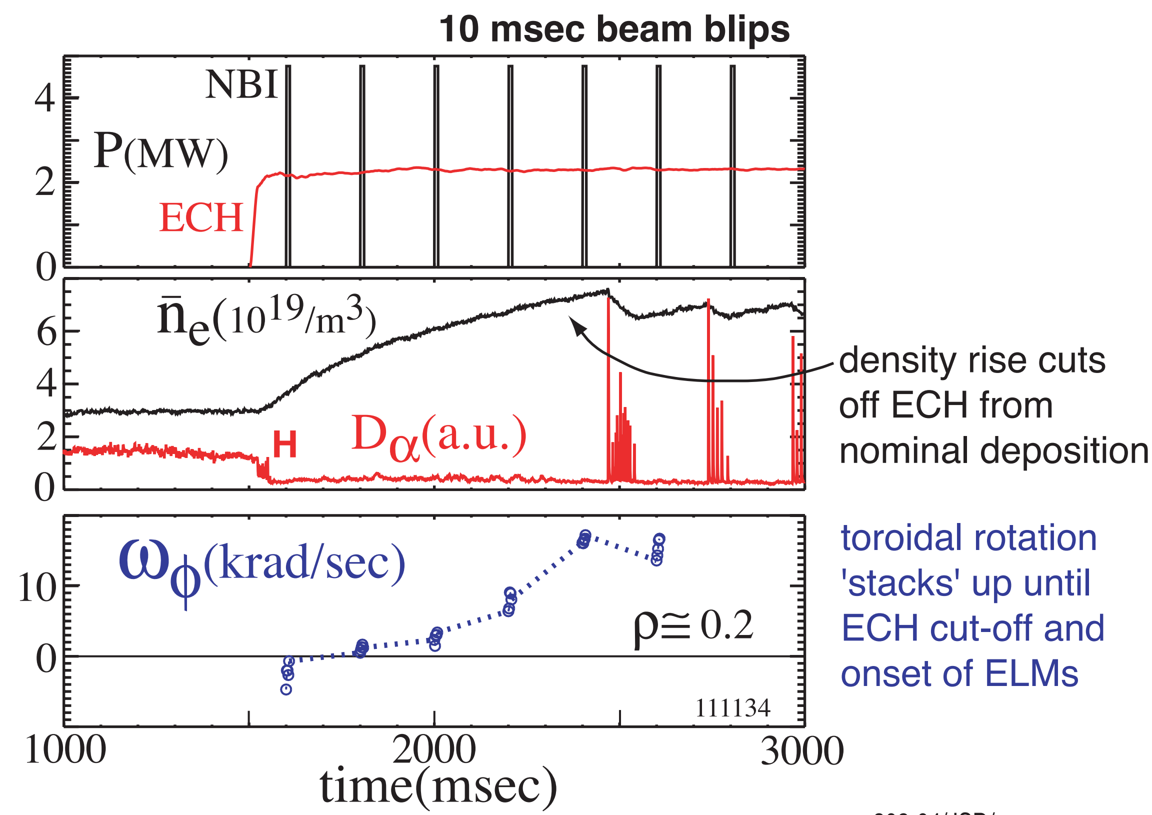
Toroidal Rotation Measurements in DIII-D in ECH H-mode Discharges*



- Lower Single Null Discharges; inboard ECH resonance
- Steer launch poloidally to vary ECH power deposition
- 1-4 gyrotrons; ~ 500 kW each
- CER: C^{+6}, He^{+2} (bulk) Requires NBI
- Use < 4msec of NBI 'blip' to obtain unperturbed state
- Move time of first blip for temporal evolution

"Interior" ECH generates long ELM-free period.

=> typicaly one timeslice per shot



302-04/JSD/rs

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

Rotation profiles for all ECH power deposition profiles are hollow, In contrast to a flat rotation profile in Ohmic H-modes.

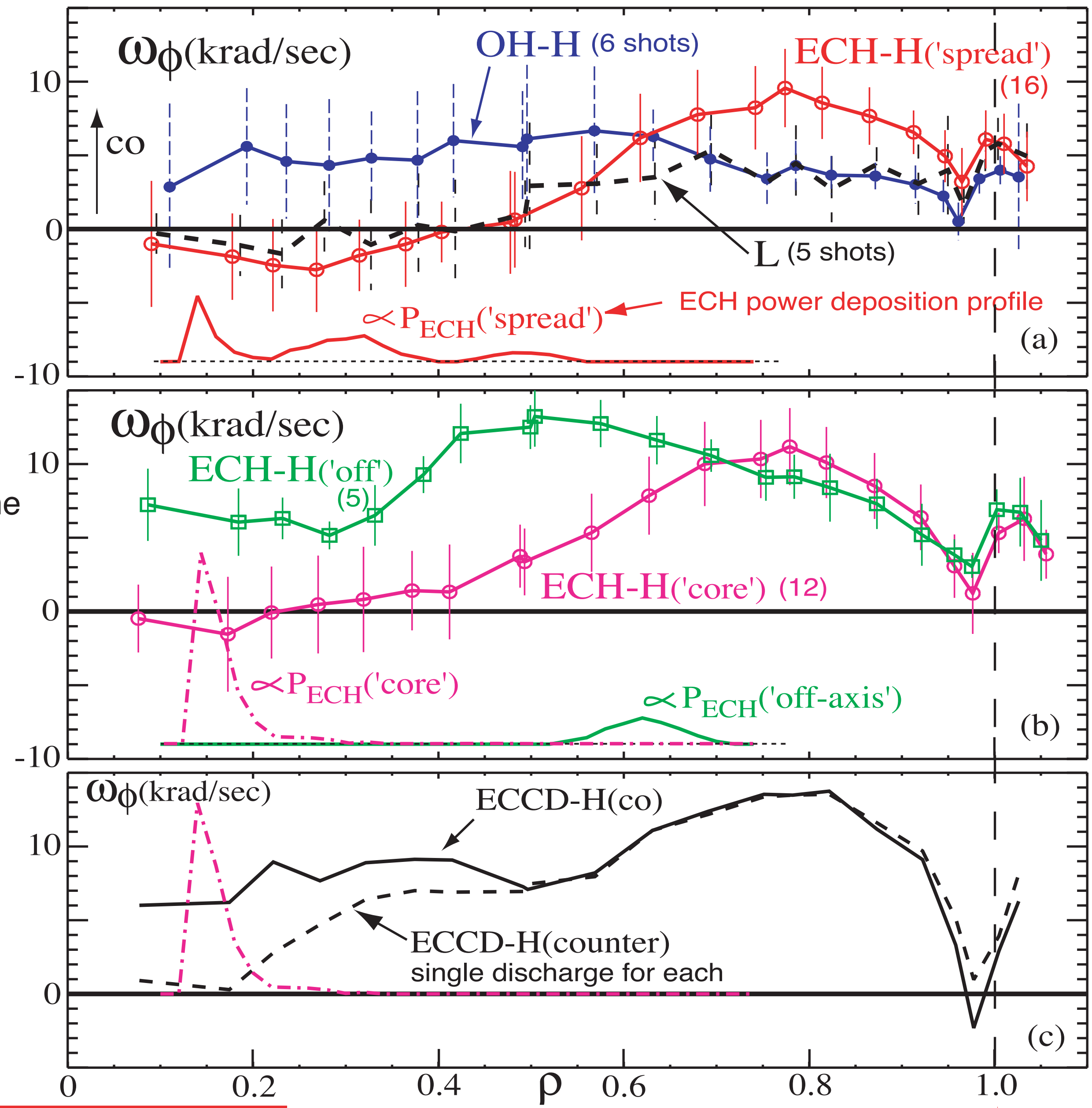
(a) Plotting rotation frequency:

$\omega_\phi = U_\phi/R \quad \text{vs} \quad \rho$

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

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

302-04/JSD/rs

The magnitude of the boundary rotation velocity is consistent with a simple loss cone in velocity space.

- We interpolate the edge rotation value when the CER channels overlap the LCFS on the outboard midplane, as determined by EFIT.
- We find $\overline{\omega_\phi(\rho=1)}$ = 4.8 ± 1.6 krad/sec, or $\overline{\omega_\phi(\rho=1)}$ = 5.8 ± 1.8, depending upon the EFIT reconstruction details
- The magnitude of this boundary value for C^{+6} is commensurate with a loss-cone.

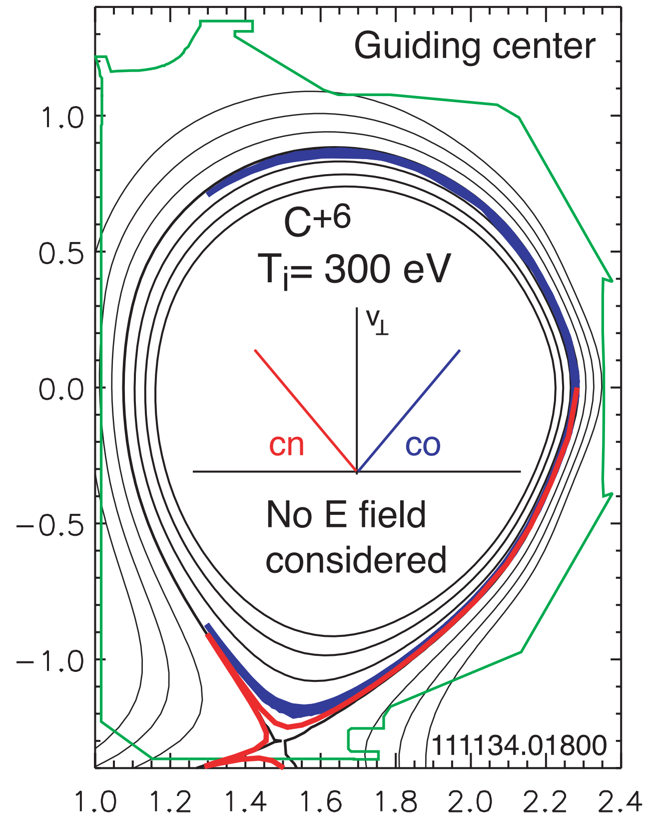
Loss cone origin: collisionless loss of counter going ions (at $R_{boundary}$)

Could $V_\phi(lcfs) = R_{boundary}\omega_\phi(lcfs)$ be due to the loss cone in velocity space? Collisionless co-orbits are confined while counter are lost. With the loss cone pitch ~ 45 degrees & T_i = 300eV,

$\langle\omega_\phi(lcfs)_{C+6}\rangle$ = 4.4 krad/sec

$\langle\omega_\phi(lcfs)_{D+}\rangle$ = 11 krad/sec

However, it is unlikely that there is much of a hole in velocity space for C^{+6} because of large collisionality near the edge. This is not the case for D^+ which is less collisional.

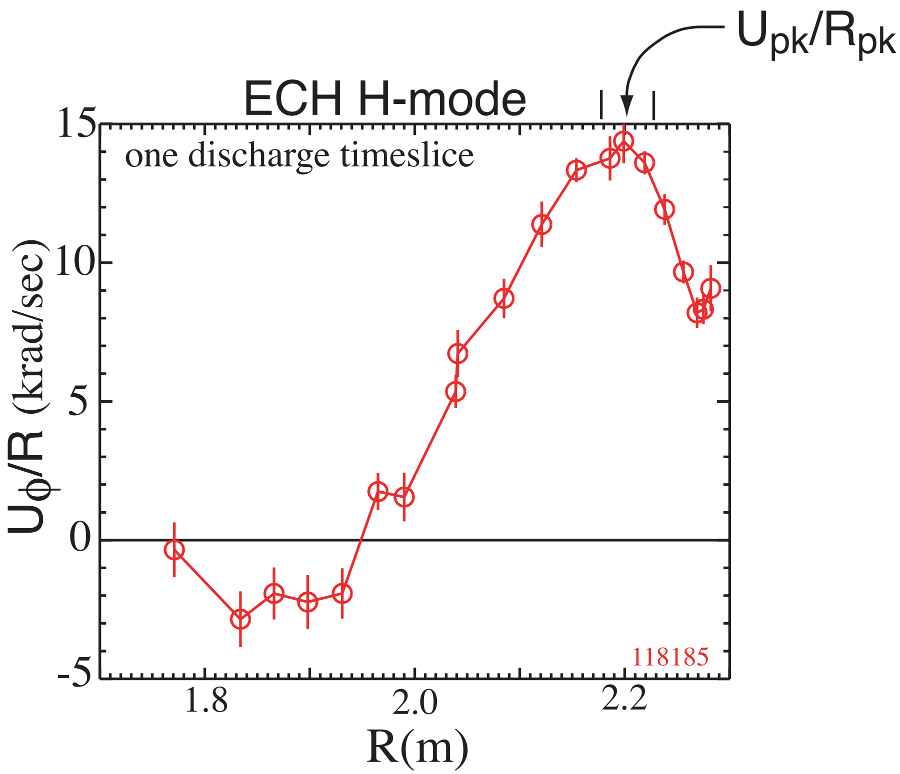


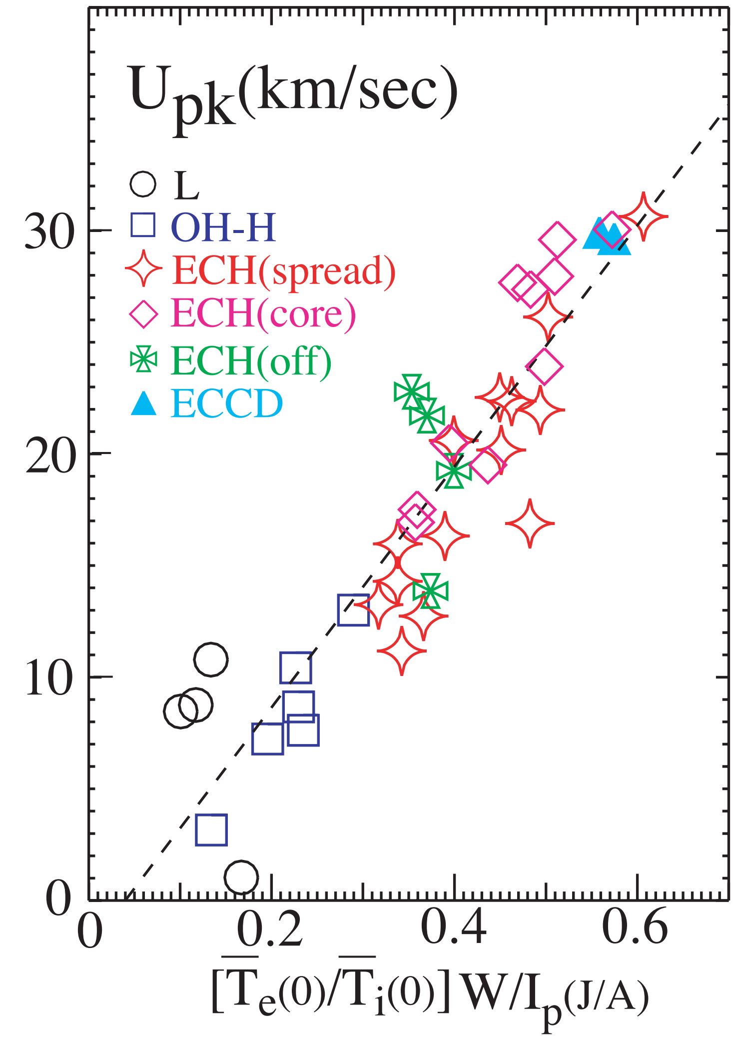
DIII-D NATIONAL FUSION FACILITY SAN DIEGO

302-04/JSD/rs

Toroidal rotation velocity at $\rho \sim 0.8$, 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

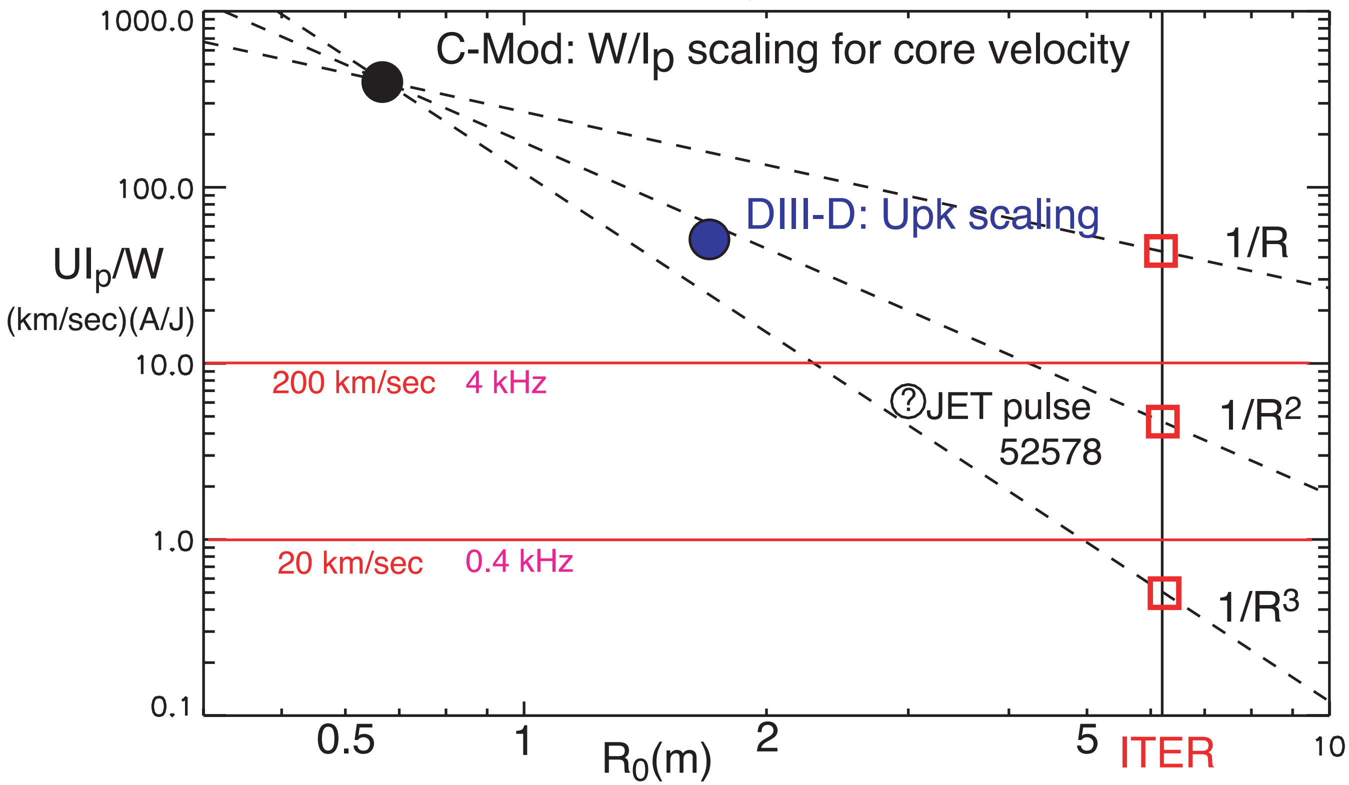
DIII-D NATIONAL FUSION FACILITY SAN DIEGO

302-04/JSD/rs

Can we use the U_{pk} scaling for "non-driven" discharges to make a prediction for ITER?

Maybe. This requires knowing a size scaling.

U scaling with W/I_p vs major radius



For the absolute U values given for the ITER projection lines we use W = 300MJ and I_p = 15MA.

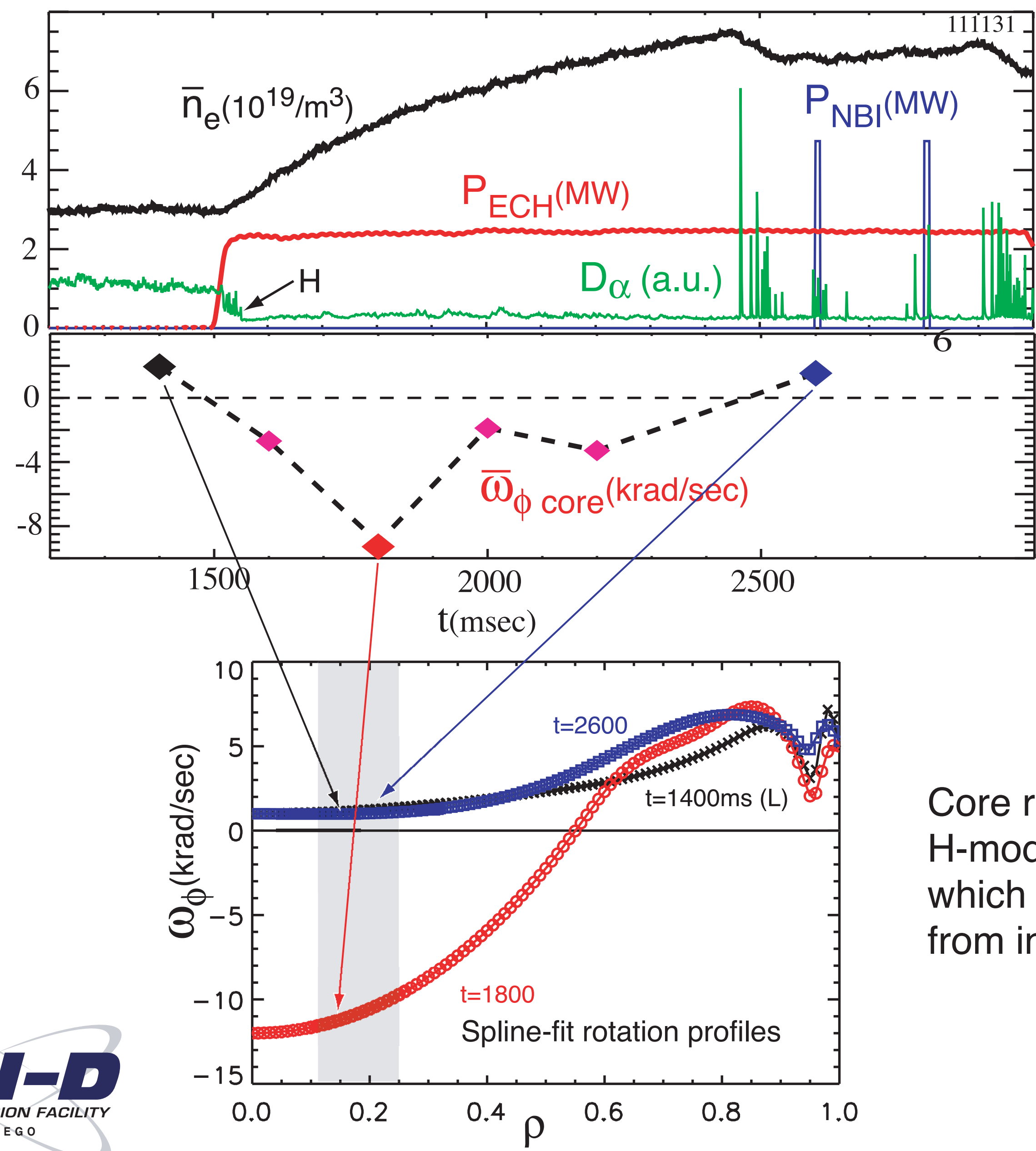
The equivalent radius in ITER would be R_{pk} = 7.8 m, which has been used to convert V to a frequency, in kHz.

For the JET pulse we have taken a ~ "pedestal" rotation frequency at R ~ 3.65 m.

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)

=> it has not diffused in from the boundary



$\overline{\omega}_{\phi\ core}$= spatial average over three inner channels.

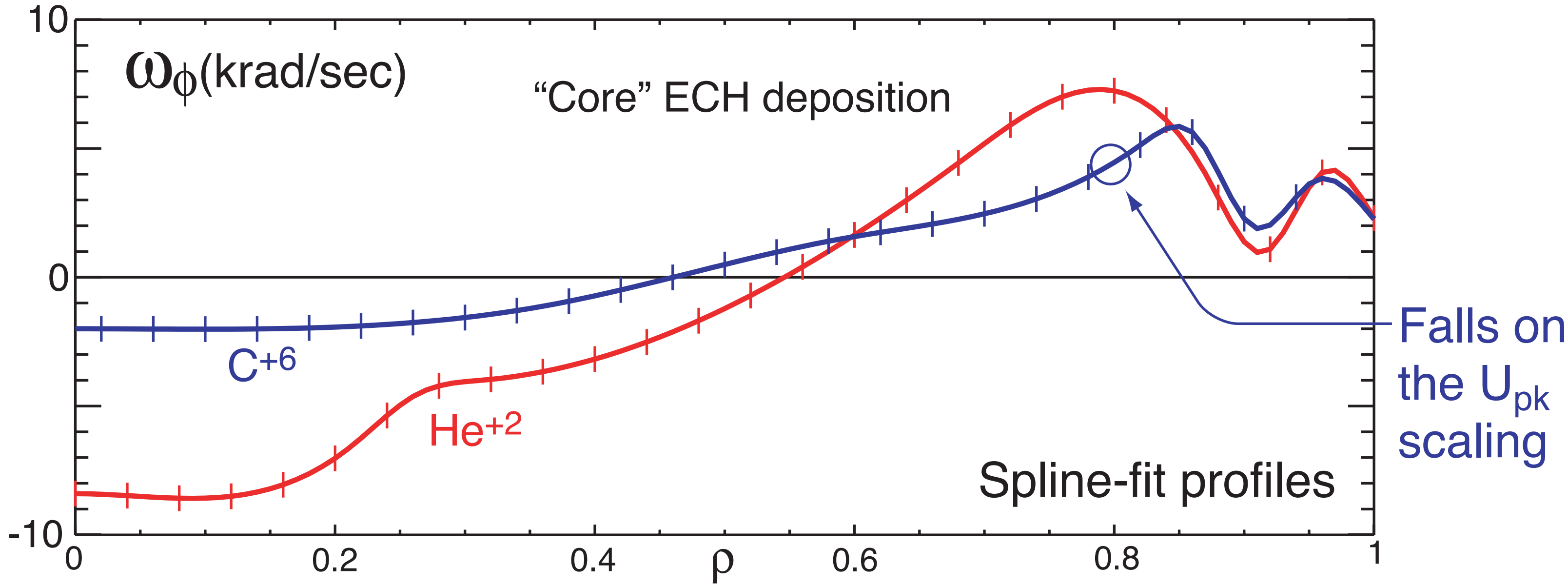
Core rotation returns to pre-ECH H-mode state after ELMs start, which is also after ECH cut-off from interior deposition.

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

302-04/JSD/rs

Main ions also exhibit the hollow, reversed rotation profile in ECH H-modes

- Helium ECH H-modes. He^{+2} core rotation more strongly counter than C^{+6}
- ELMing => hollow rotation profile does not require ELM-free state



Measured He^{+2} and C^{+6} rotation profiles are from different shots of a pair of nominally identical repeat discharges.

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

302-04/JSD/rs

Rotation in DIII-D without Auxiliary Momentum Input
Summary

- Rotation profiles in ECH H-mode are hollow; co-I_p outside, depressed or counter- I_p in the interior. In contrast, OH H-modes have a relatively flat, co-rotation profile.

- The boundary rotation is nonzero. It is in the co-direction, $\langle\omega_\phi(\rho=1\rangle\sim$ +5 krad/sec averaged over this set. The effect of an ion velocity loss cone is under investigation.

- All these discharges with non-driven toroidal rotation show a co-rotation peak near $\rho\sim 0.8$. The velocity here scales as $[T_e(0)/T_i(0)](W/I_p)$.

- Combining this U_{pk} scaling with the core velocity scaling from C-Mod we can form a size scaling to ITER, predicting $f_\phi\sim 2$ kHz. Such scaling should be sought in JET.

- The temporal history of the core rotation shows that the counter-rotation can develop in time. It is not due to a remnant of the pre-ECH (L) state, nor does it diffuse in from the edge.

- Mechanism?
  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 rotation results from nonambipolar currents, with presumably an integrated net zero torque over this interior region.

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

302-04/JSD/rs