CO-TOROIDAL ROTATION WITH ELECTRON CYCLOTRON HEATING IN DIII–D

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Co-Toroidal Rotation with Electron Cyclotron Heating in DIII-D

- Background
  - RF electron heating (EC or Fast Wave) added to NBI driven target discharge is observed to generally reduce the toroidal rotation velocity, V_{tor}. J.S. deGrassie et al Proc. 26th EPS Conf. Maastricht, **23J**, 1189 (1999).
  - These target discharges have $T_i > T_e$. Other measurements on DIII-D show that transport of momentum and ion thermal energy increase with increasing T_e/T_i.

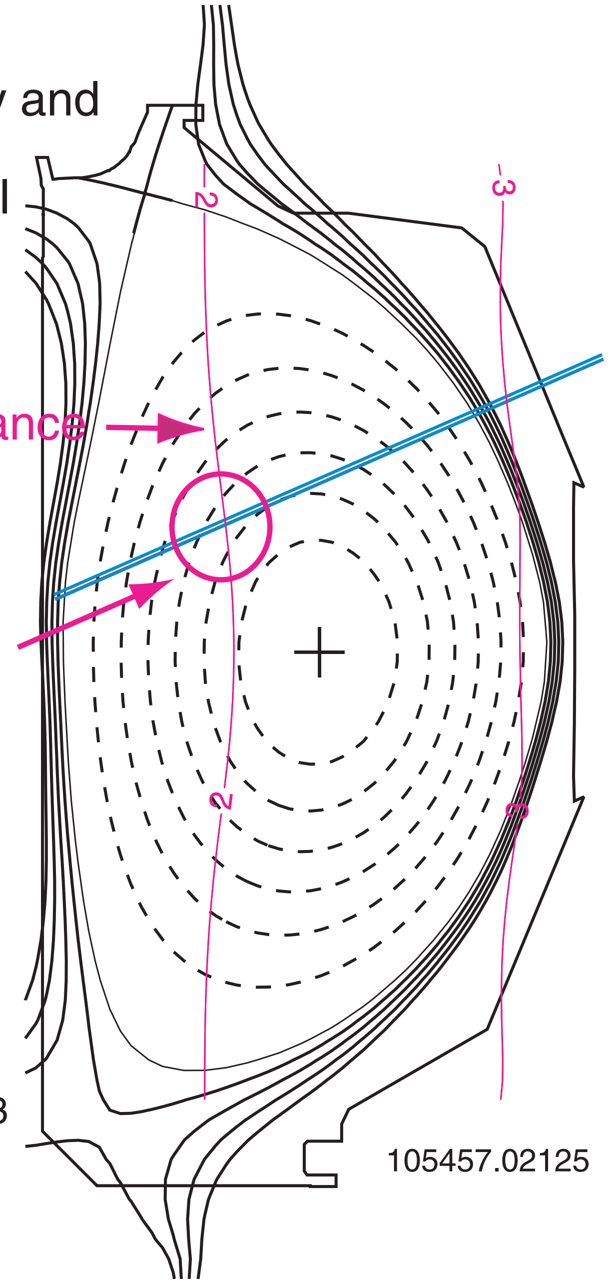
- This experiment used only very short NBI 'blips', with minimal momentum and energy input, for diagnostic purposes.
  - ECH was essentially added to an Ohmic target discharge.
  - The experiment was done to look for evidence of a heat pinch.
  - It is observed that with the addition of ECH, the discharge develops a significant toroidal rotation in the core, ~ 40km/sec.

Co-toroidal rotation develops in the core with ECH applied to an essentially Ohmic target discharge

- Neutral beam blips must be used to measure C ion velocity and temperature. But comparisons with and without ECH indicate that the first blip does not drive a dominant toroidal rotation in the core.

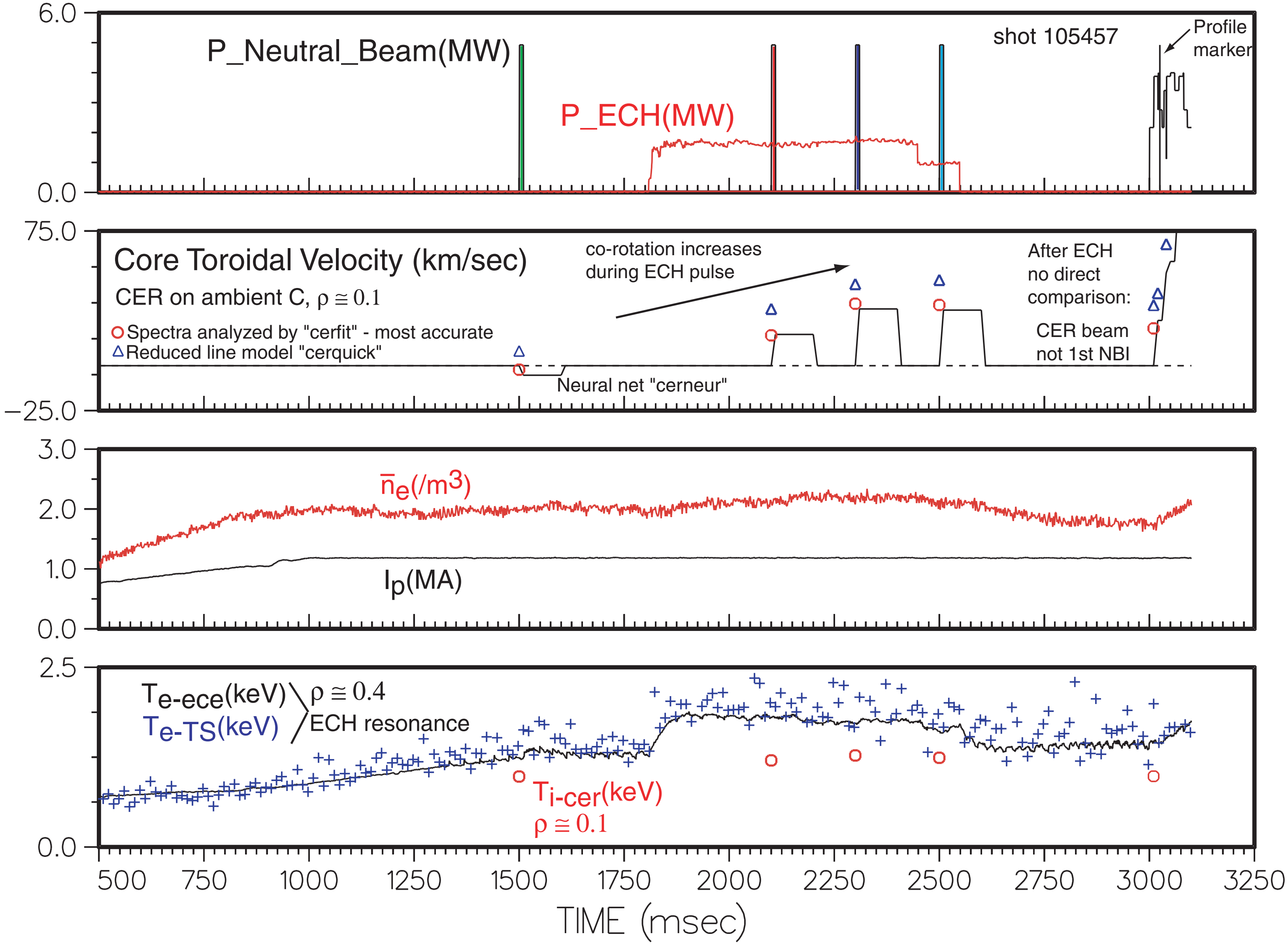
- The experiment being performed was to investigate a heat pinch accompanying off-axis ECH - radial launch so that there is negligible **k•B**

- Is this an ECH effect, or a heating effect, or something else? Still TBD.



The "Effect"

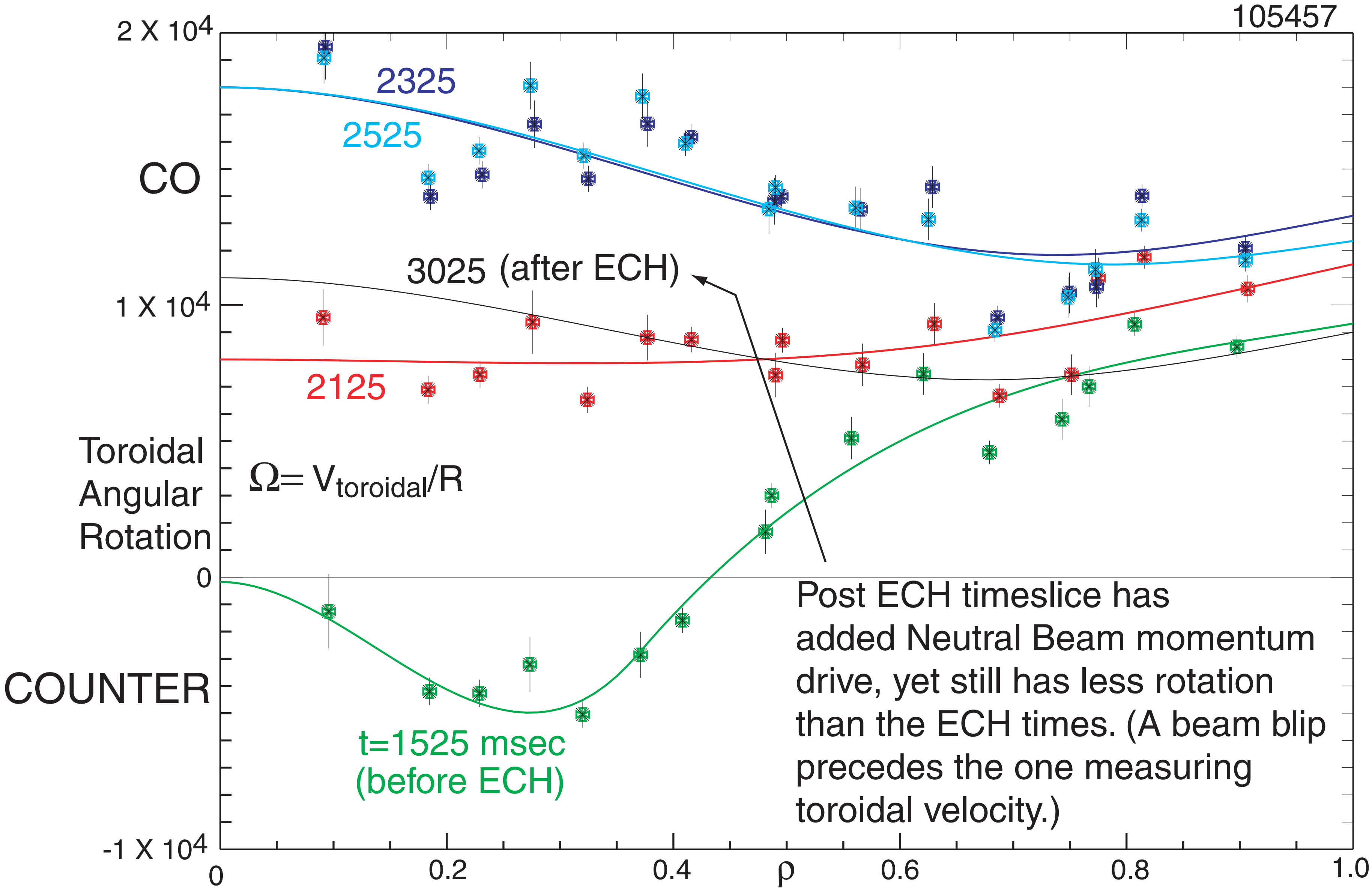
Co-toroidal rotation accompanies ECH in a steady sawtoothing Ohmic target discharge. Neutral Beam (NB) blips (10 msec) for CER measurement begin to 'spin' the discharge, but comparison is before and during ECH. After ECH there is more NBI torque on the first slice since the core CER beam is not delivered first.



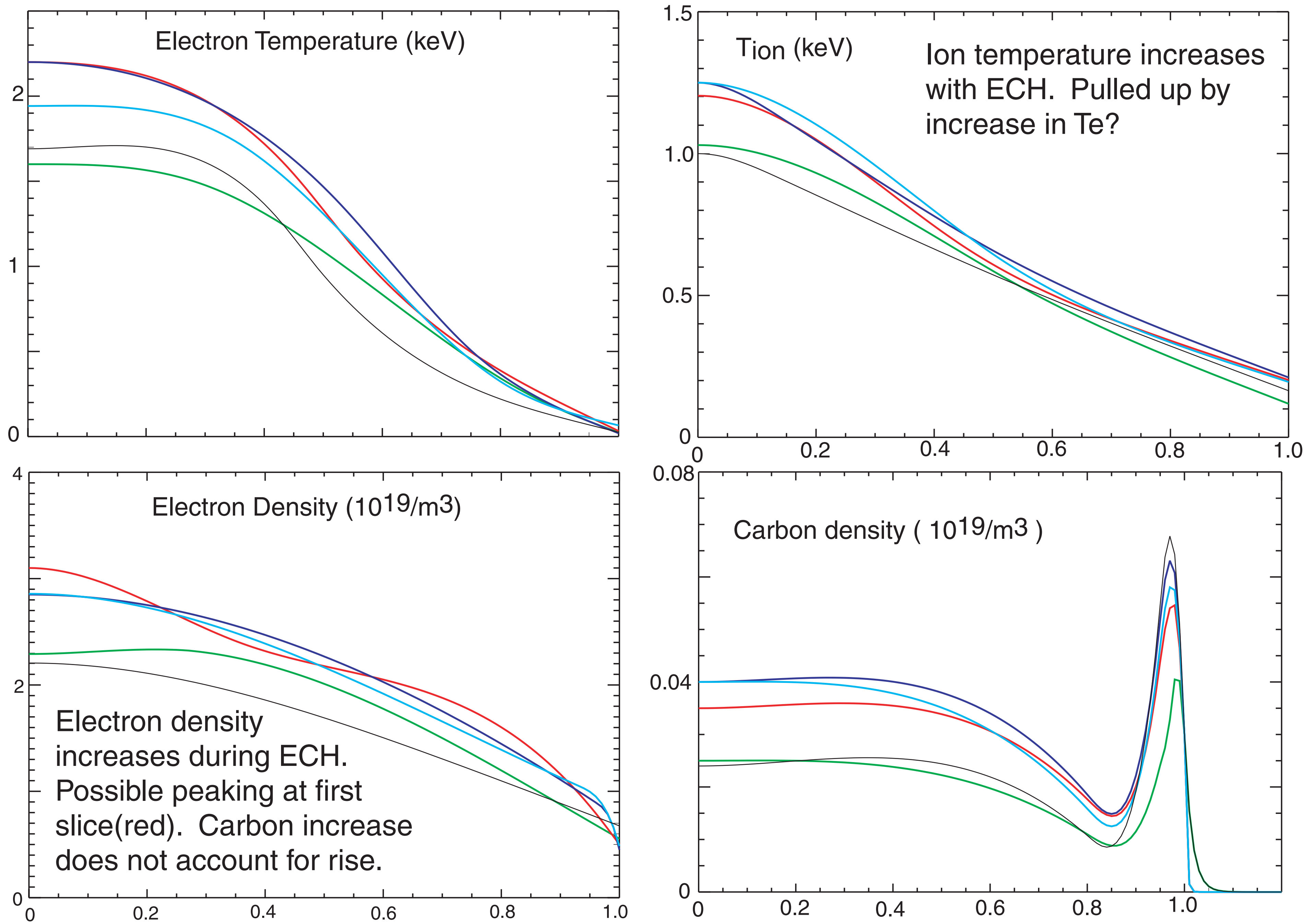
Toroidal Rotation Profiles

Significant co-toroidal rotation develops with ECH power

Essentially Ohmic target discharge; sawteeth at all time slices.



Profiles for the same time slices in shot 105457

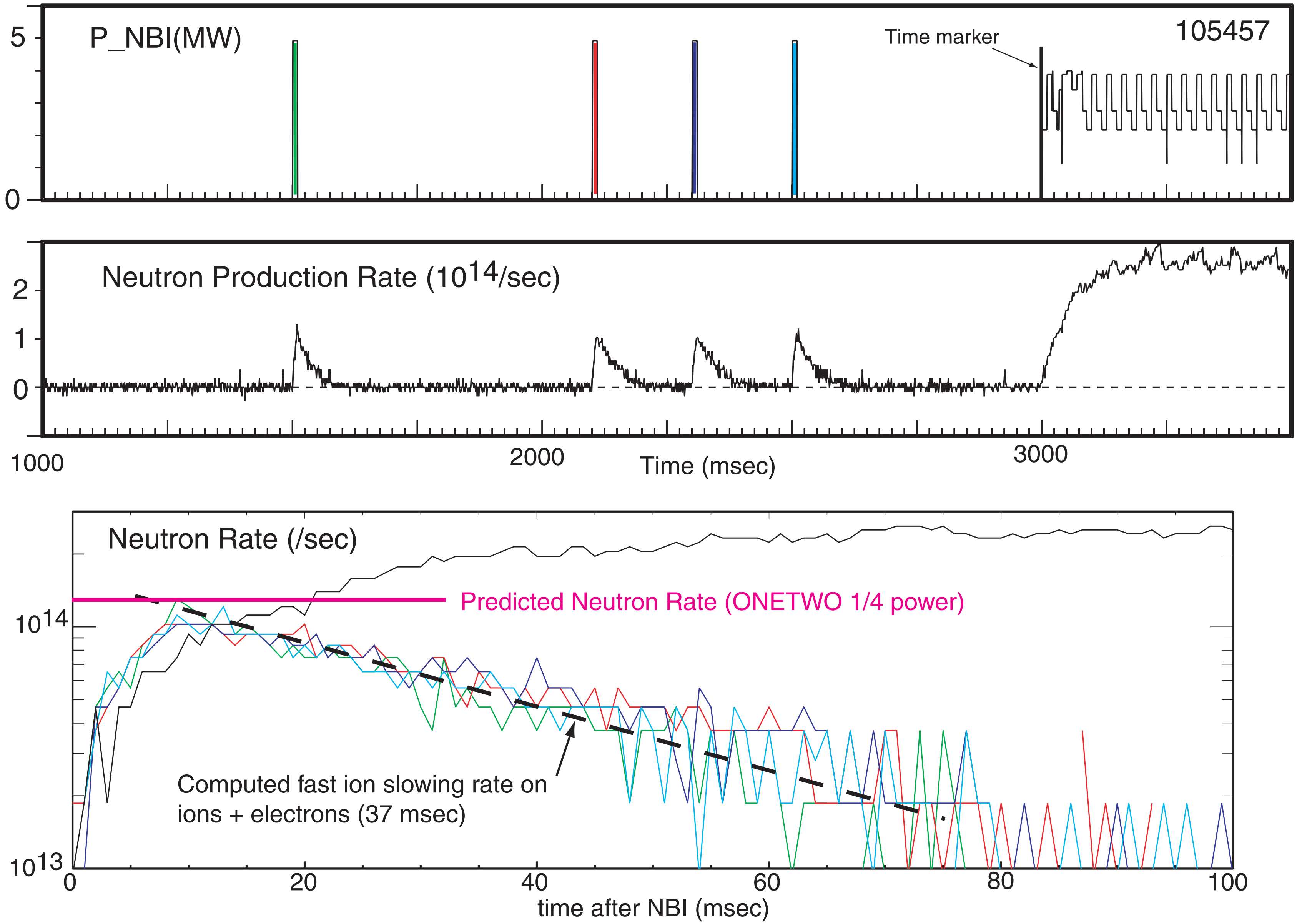


Use neutron rate, R_n, to guide computation of NBI torque from beam blips:

Computed, and measured (R_n) fast ion slowing time is 37 msec.

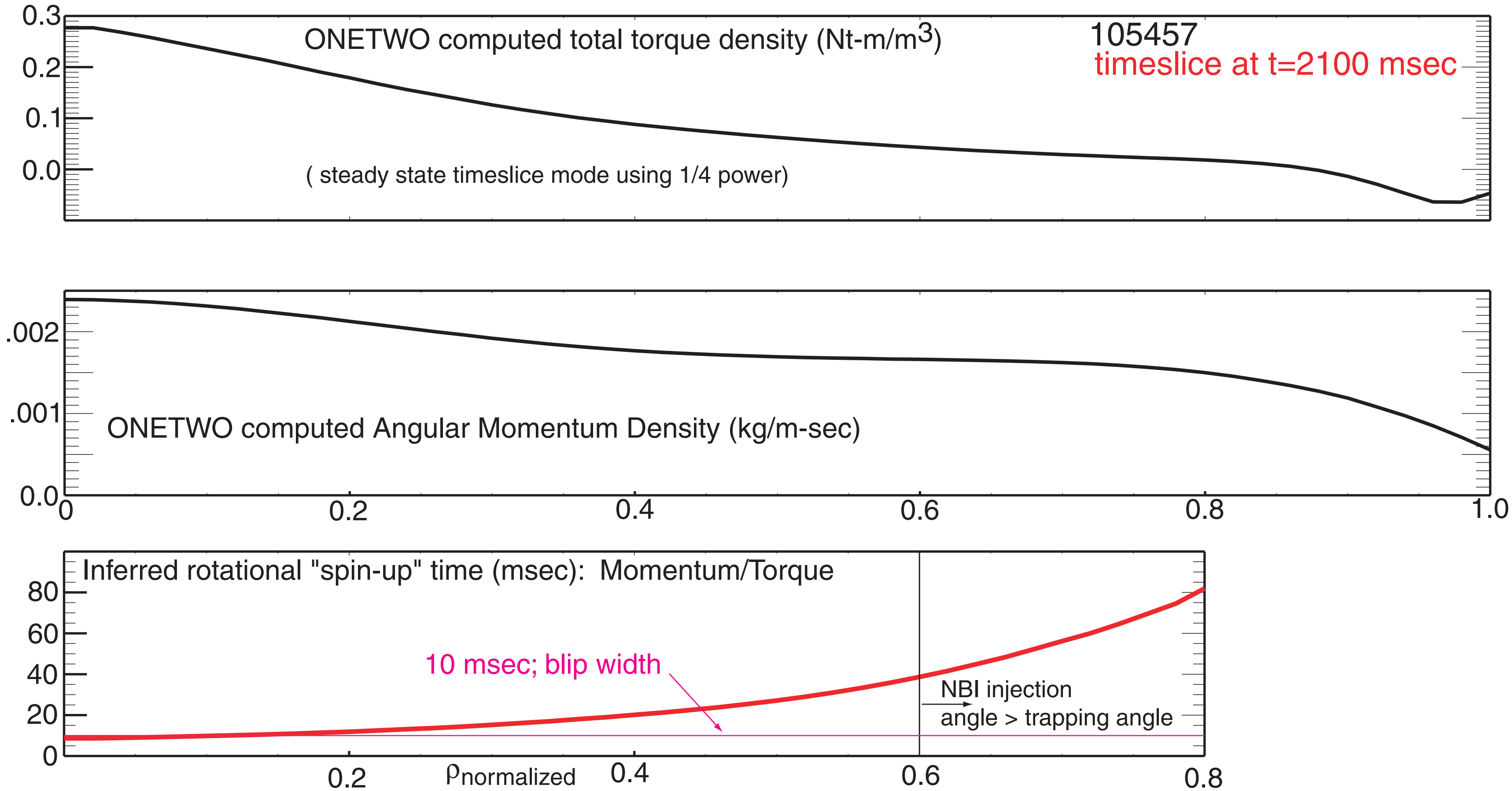
=> scale beam power by $(1. - e^{-10msec/37msec}) = 0.24$ for the blip torque estimate.

Beam ions born into trapped orbits will deliver full toroidal momentum in one bounce time, but we are interested in the core where the prompt orbits are dominated by passing ones.



Estimate time required for NBI to spin-up plasma to measured rotation.

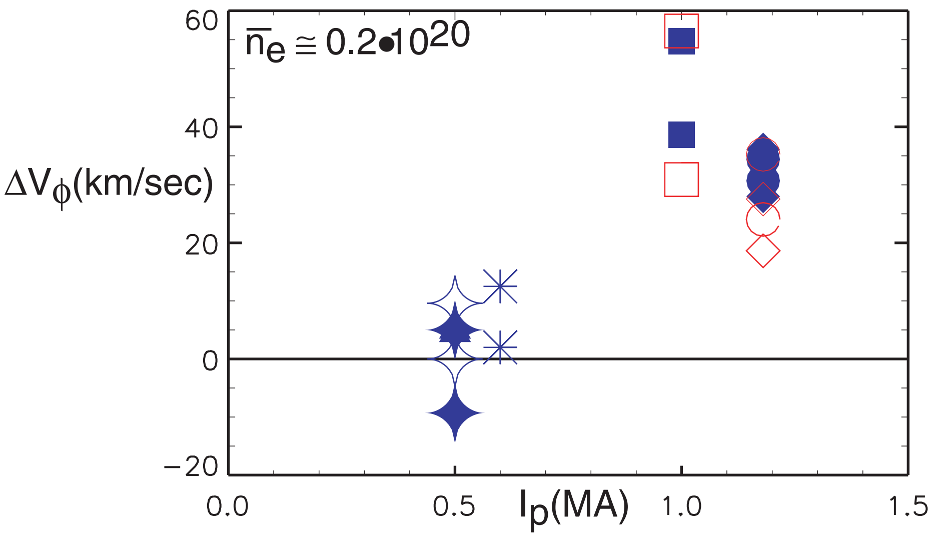
- Use ONETWO in steady state analysis mode - 1/4 NBI power to allow for blip time less than slowing down time.
- Result: Only near the axis is the Torque predicted to be able to spin-up the rotation to that measured in 10 msec. (This seemingly contradicts the pre-ECH measurement at 1500 msec.) => the large rotation changes at rho= 0.3 -0.4 are not expected to be possible due to NBI.
- However, marginality of the timescale separation dictates that the experiment be repeated with even shorter NBI blips.



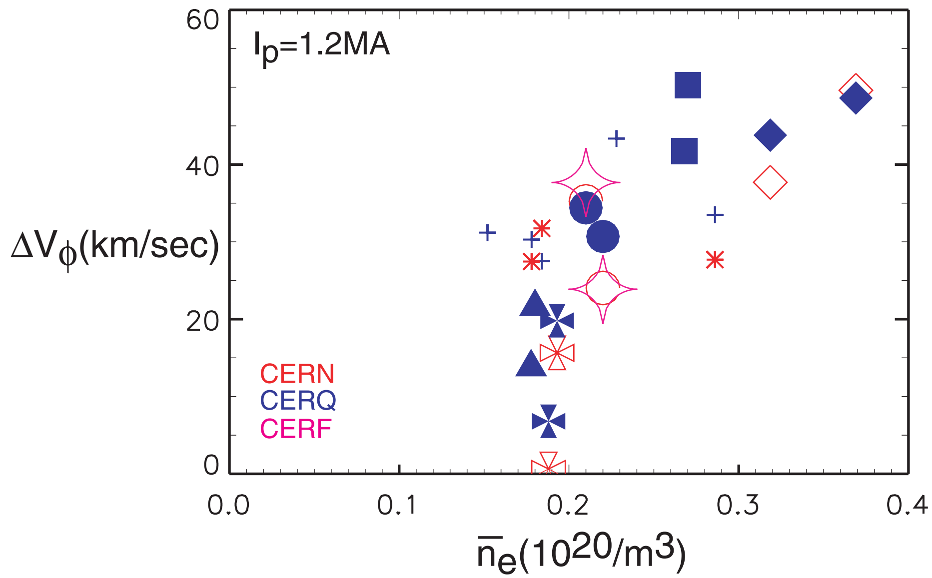
Scaling with plasma current and electron density

$\Delta V_\phi = V_\phi(\text{ECH}) - V_\phi(\text{before ECH})$ core channel

"Effect" only at higher I_p in experiments

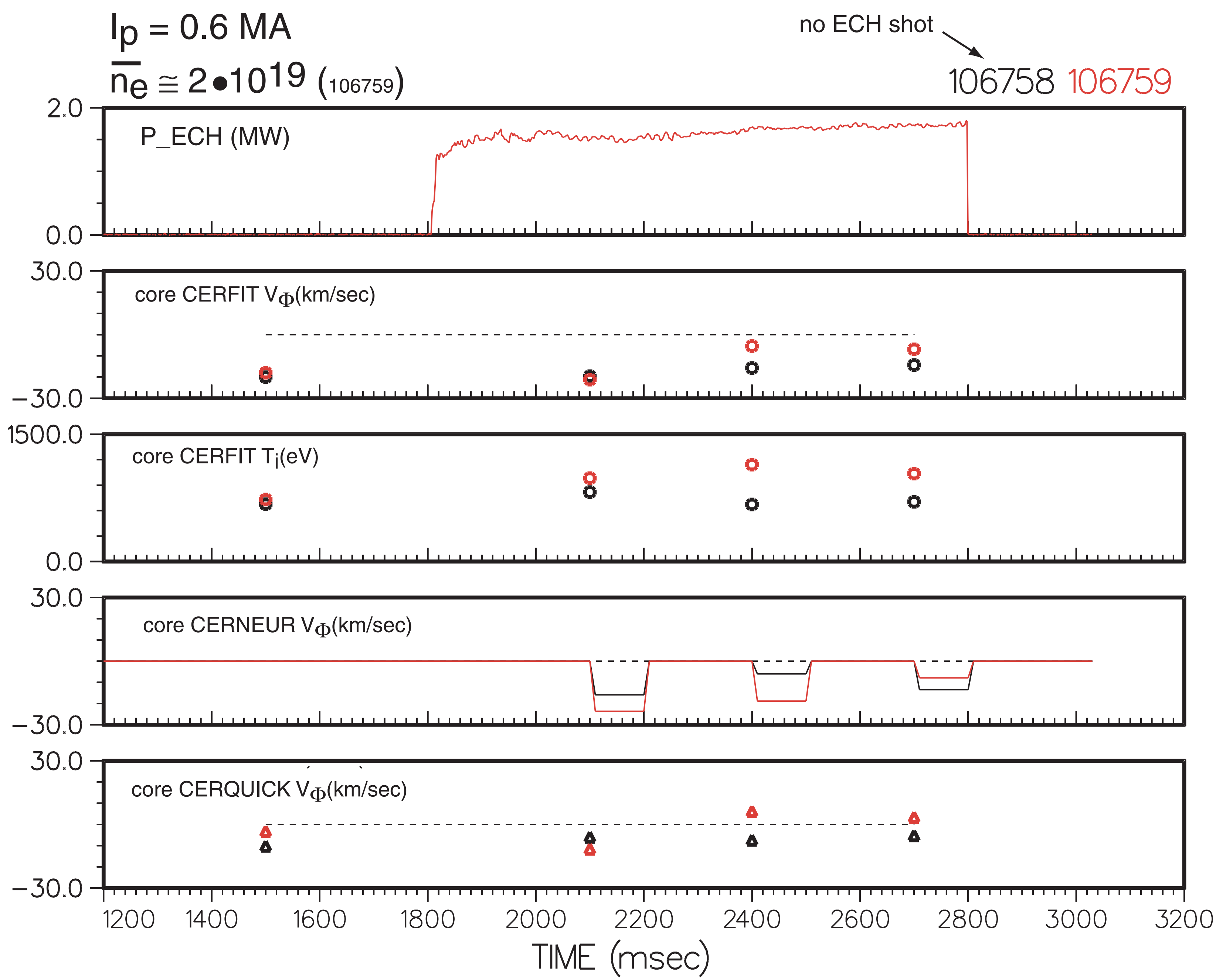


and may have a density threshold



Only direct comparison w/wo ECH done at low plasma current

Small difference in toroidal velocity in the core



Summary

- Electron Cyclotron Heating may result in toroidal rotation.

- The experiment must be done carefully
  1) With shorter CER integration time to measure the spin up during the NBI blip.
  2) With comparisons of discharges with/without ECH.
  3) To measure any scaling with I_p, n_e, and P_{ECH}.

- Preliminary indications are that it is not an RF specific effect, in that higher electron density and stronger poloidal field (I_p) enhance the effect.