Counter Current Drive With ECH and NBI

by
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in collaboration with
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M. Murakami,† P.A. Politzer, R. Prater,
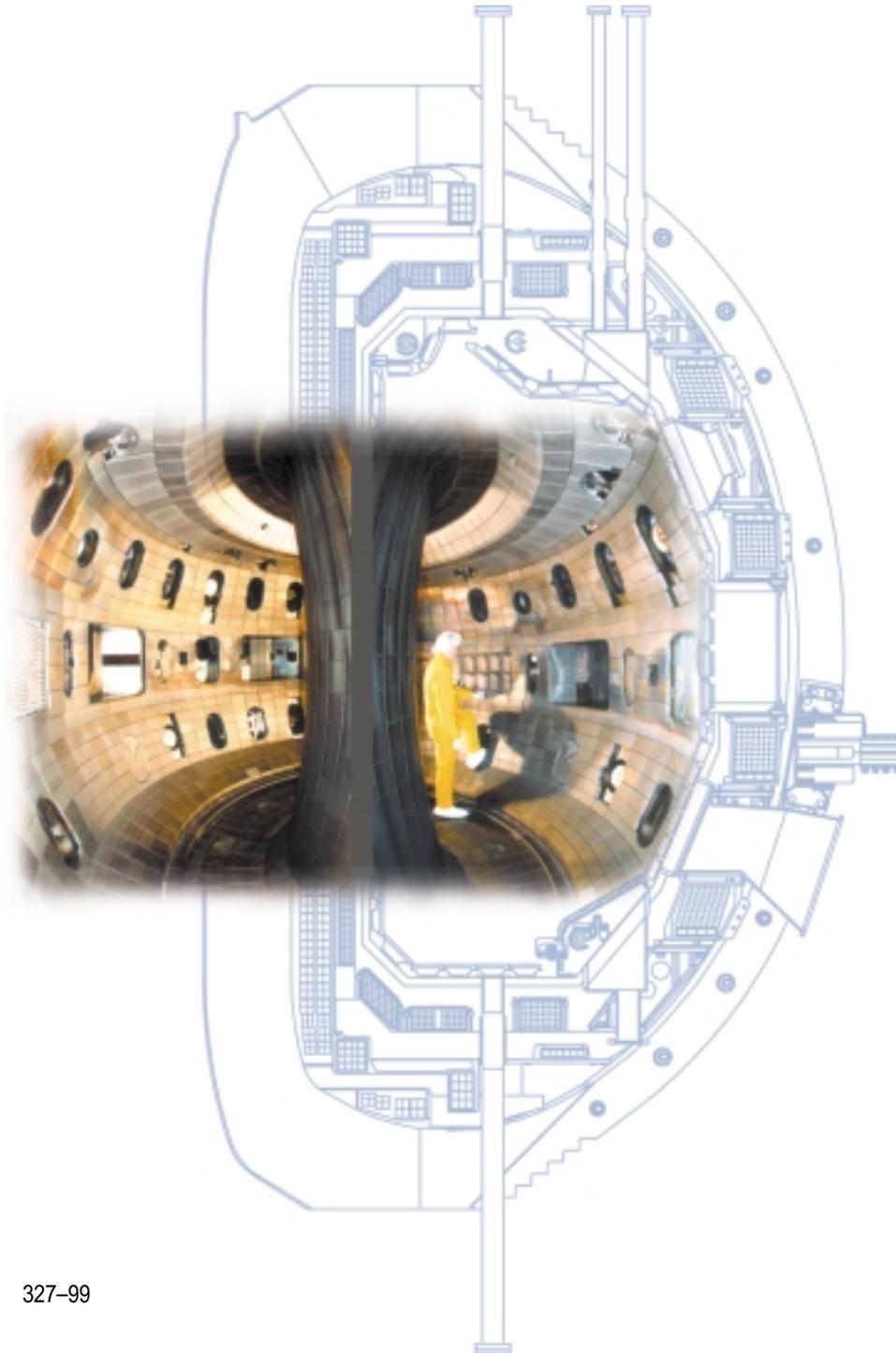B.W. Rice,* D.I. Schuster,‡ and M.R. Wade†

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Presented at
the American Physical Society
Division of Plasma Physics Meeting
Seattle, Washington

November 15–19, 1999

327–99

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Counter Current Drive with ECH and NBI[1] C.C.
PETTY, T.C. LUCE, Y.R. LIN-LIU, J. LOHR, R. PRATER, General
Atomics, B.W. RICE, Lawrence Livermore National Laboratory — In
experiments on the DIII-D tokamak, the non-inductive current profiles
resulting from counter current drive using electron cyclotron heating
(ECH) and neutral beam injection (NBI) have been measured. The
evolution of the poloidal magnetic flux as measured by motional Stark
effect polarimetry was the basis for experimentally determining the non-
inductive current profiles. The counter current drive from ECH at $q \approx 3$
was found to be radially localized with the peak of the driven current
near the power deposition location. Although the measured radial profile
was broader than theoretical predictions (a similar result to that found
for co current drive with ECH), the magnitude of the experimental and
theoretical counter current drive were in good agreement. Even though
current drive from NBI is not expected to be as localized as that from
ECH, the measured radial profile of the NBI driven current was found
to be even broader than theoretical predictions. Comparisons have been
made between the non-inductive current profiles for co and counter NBI
for plasmas with similar bootstrap currents.

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X	Prefer Oral Session
	Prefer Poster Session

Special instructions: DIII-D Contributed Oral Session, immediately following TC Luce

Date printed: July 15, 1999

Electronic form version 1.4

NBI AND OFF-AXIS ECH ALLOW CURRENT PROFILE CONTROL IN ADVANCED TOKAMAK (AT) MODELING FOR DIII-D

- **Example of AT scenario modeling with $q_{min} \geq 1.5$ for more than 10 s**

  P_{ECH} = 3.0 MW P_{NBI} = 6.2 MW

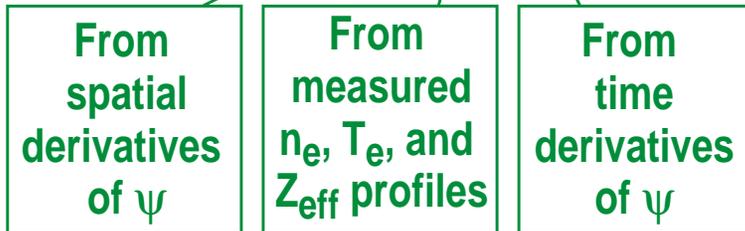 B_T = 1.6 T β_N = 2.7

  I_P = 1.1 MA f_{BS} = 53%

- **Models of NBI and ECH current drive need to be tested experimentally to validate modeling and to interpret future experiments**

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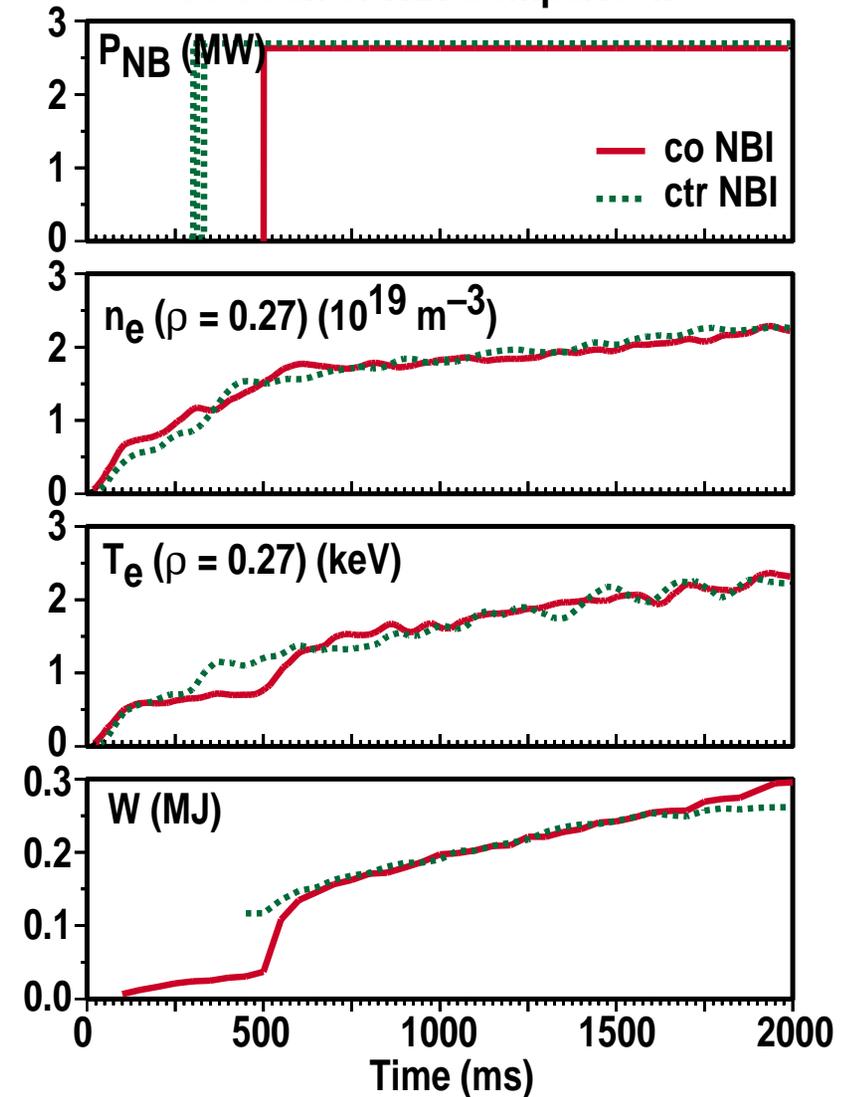SAN DIEGO

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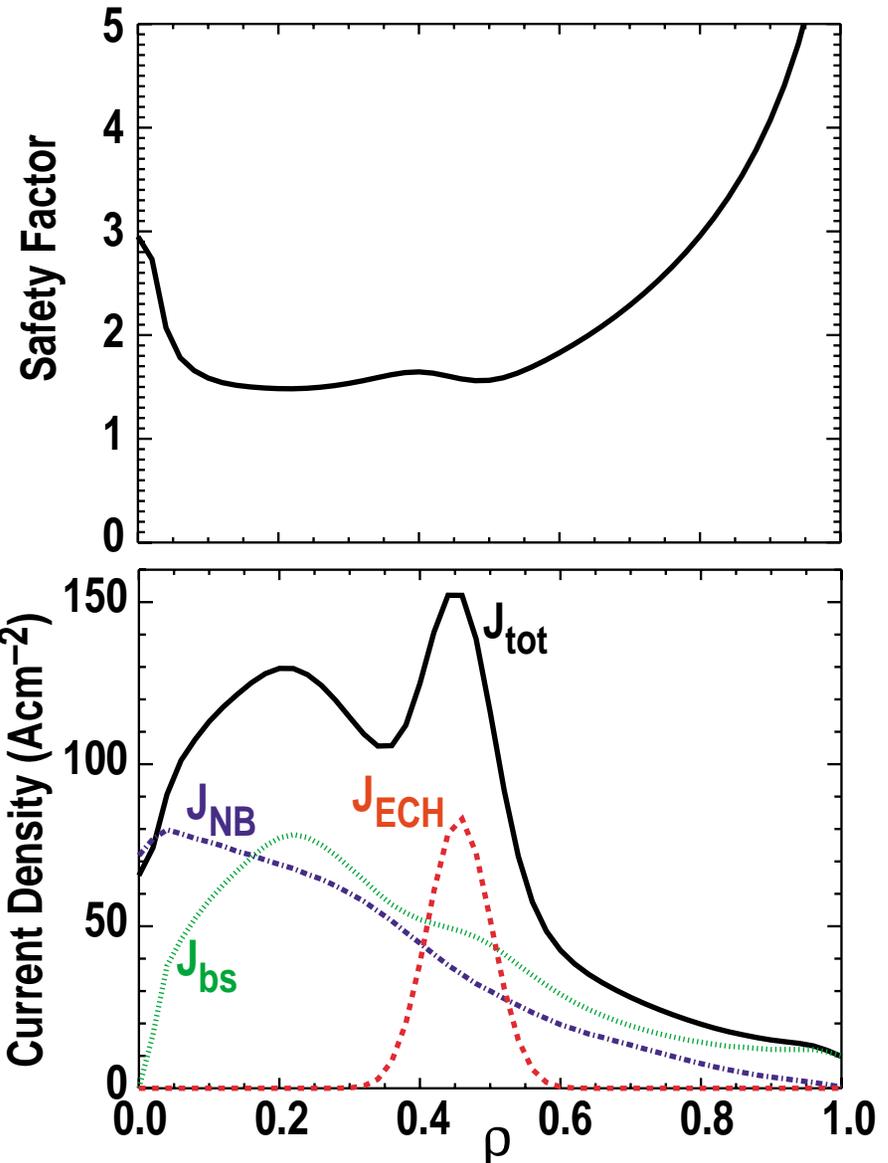
CURRENT DRIVE IS MEASURED FROM CHANGE IN NONINDUCTIVE CURRENT PROFILE FOR CO/COUNTER NBI OR WITH/WITHOUT ECH

- **Bootstrap current profile is kept fixed for co/counter NBI**

- **Poloidal flux ψ is obtained from magnetic reconstructions with high resolution MSE spectroscopy**

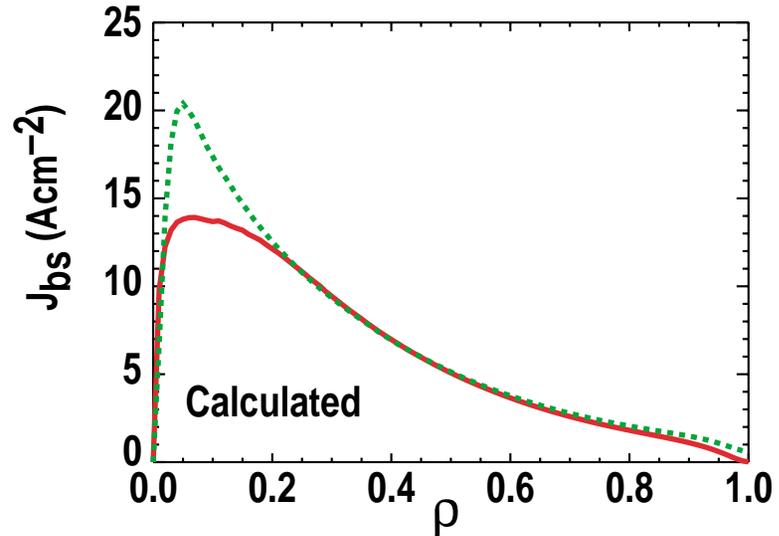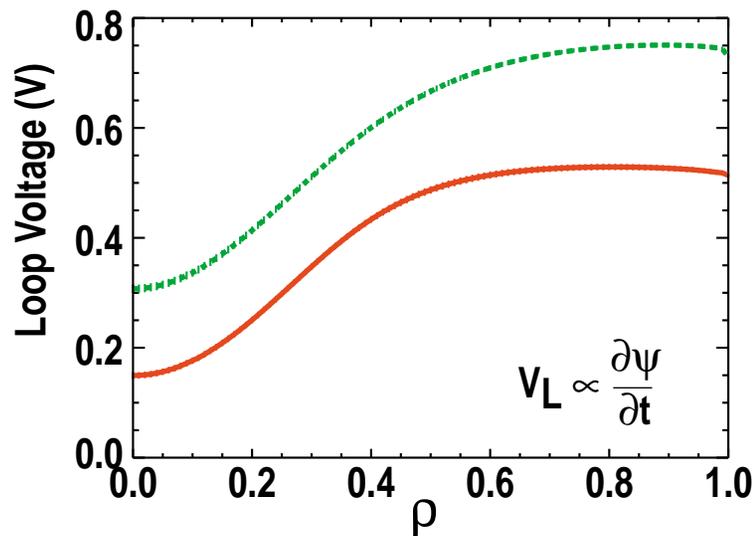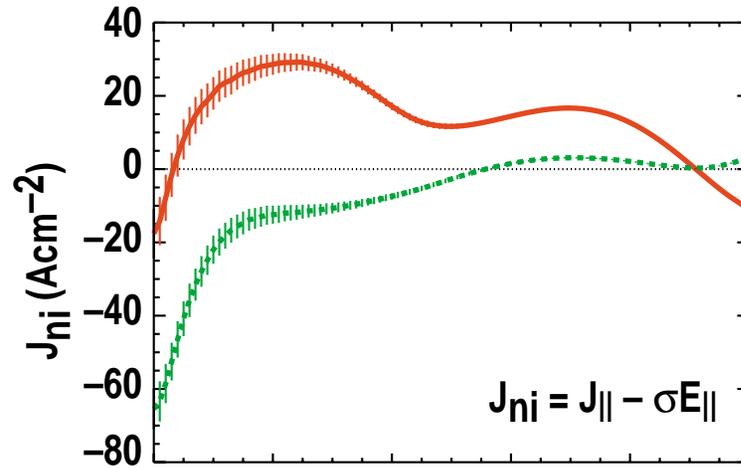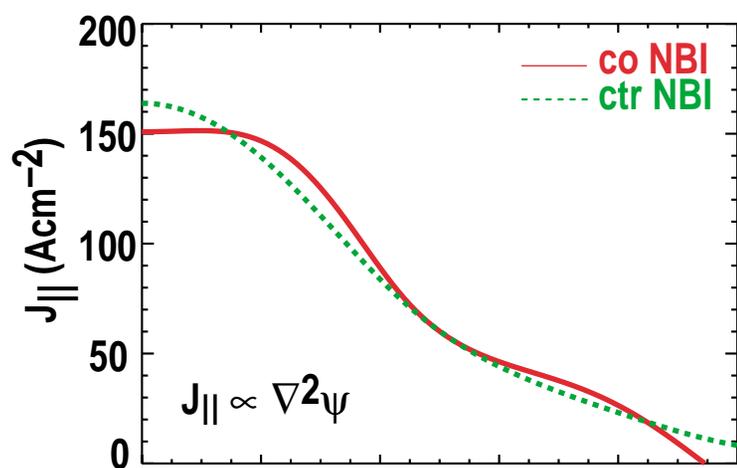- **Noninductive current profile is determined from parallel Ohm's law**

$$J_{ni} = J_{\parallel} - \sigma_{neo} E_{\parallel}$$

From spatial derivatives of ψ	From measured n_e, T_e, and Z_{eff} profiles	From time derivatives of ψ

Co/Counter NBI Comparison

Co/Counter NBI Comparison

- P_{NB} (MW)
- co NBI
- ctr NBI
- n_e ($\rho = 0.27$) (10^{19} m^{-3})
- T_e ($\rho = 0.27$) (keV)
- W (MJ)

Time (ms)

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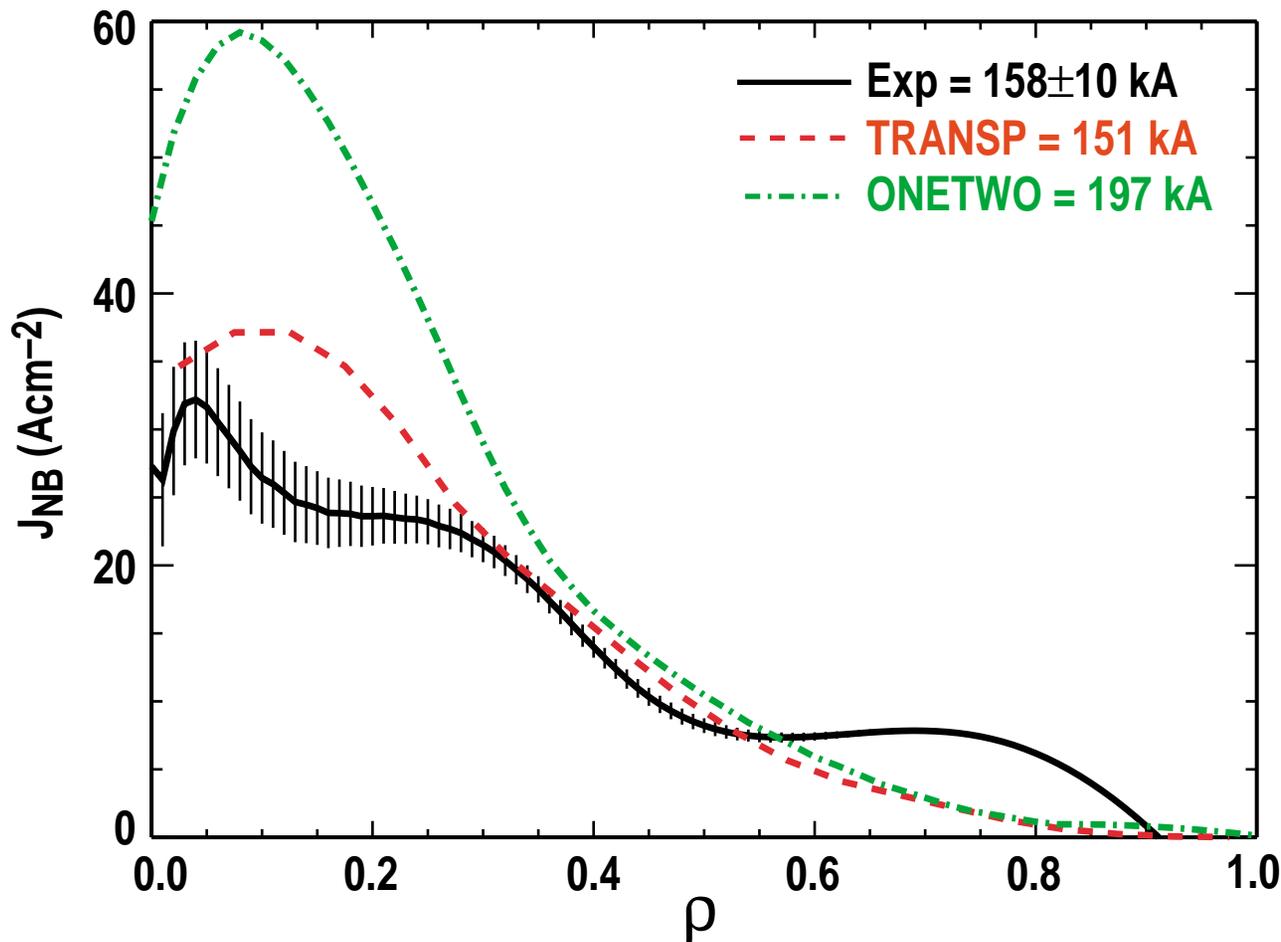SAN DIEGO

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SWITCHING NBI FROM CO TO COUNTER REVERSES
# THE DIRECTION OF MEASURED NONINDUCTIVE CURRENT

All quantities averaged over 0.4 s

MEASURED NBCD PROFILE IS SLIGHTLY BROADER THAN THEORETICAL PROFILE FROM TRANSP, BUT INTEGRATED CURRENTS AGREE

Exp = 158±10 kA
TRANSP = 151 kA
ONETWO = 197 kA

J_{NB} (Acm^{-2})

ρ

- **TRANSP uses an orbit following Monte-Carlo calculation of fast ion distribution function**

- **ONETWO uses an asymptotic solution of fast ion distribution function starting with orbit-averaged birth profile**

- **Orbit following Monte-Carlo calculation of NBI is being implemented in ONETWO**

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COUNTER ECH CURRENT DRIVE IS ALSO MEASURED, ALTHOUGH APPARENTLY WITH A PROFILE BROADER THAN THEORY
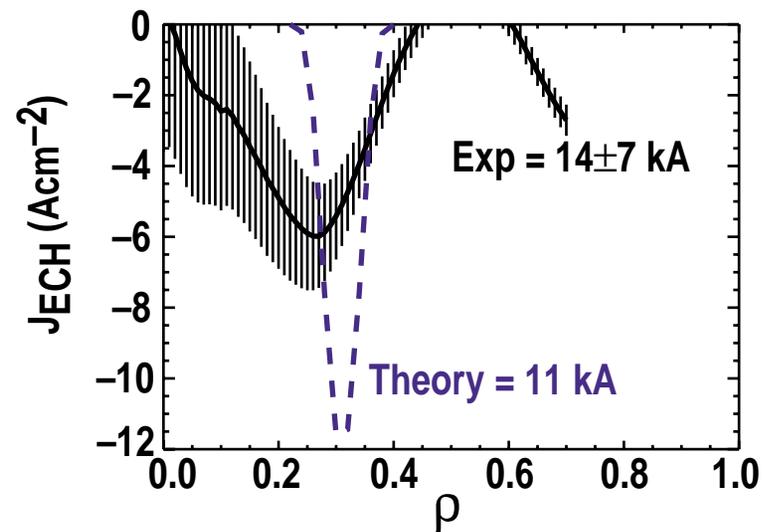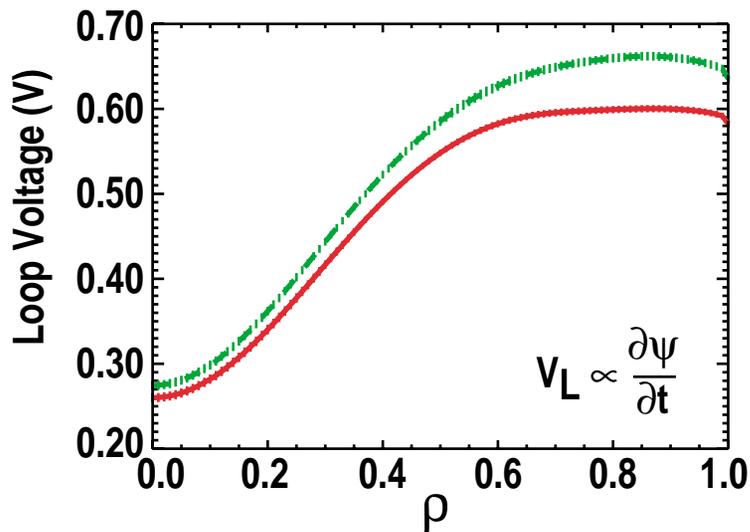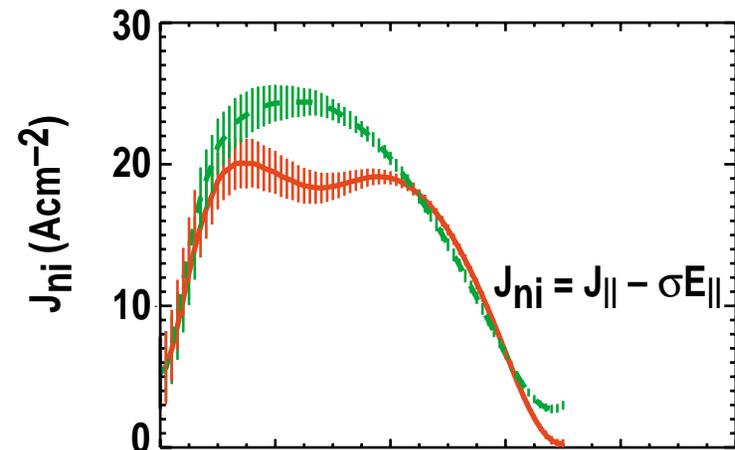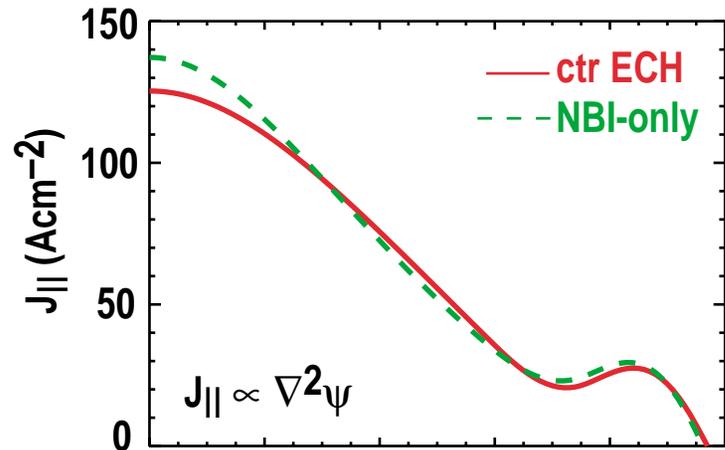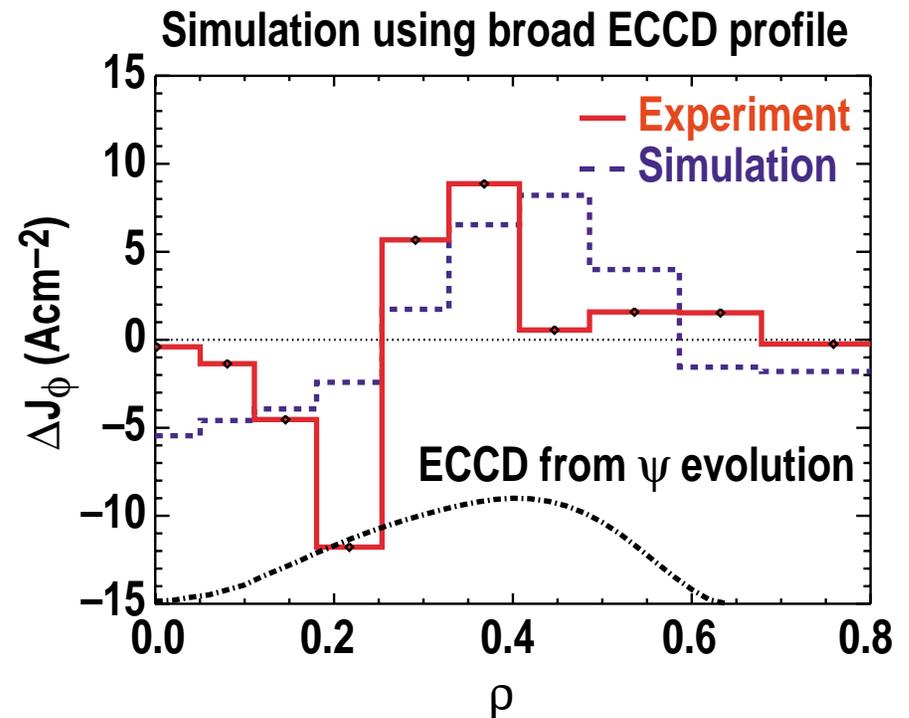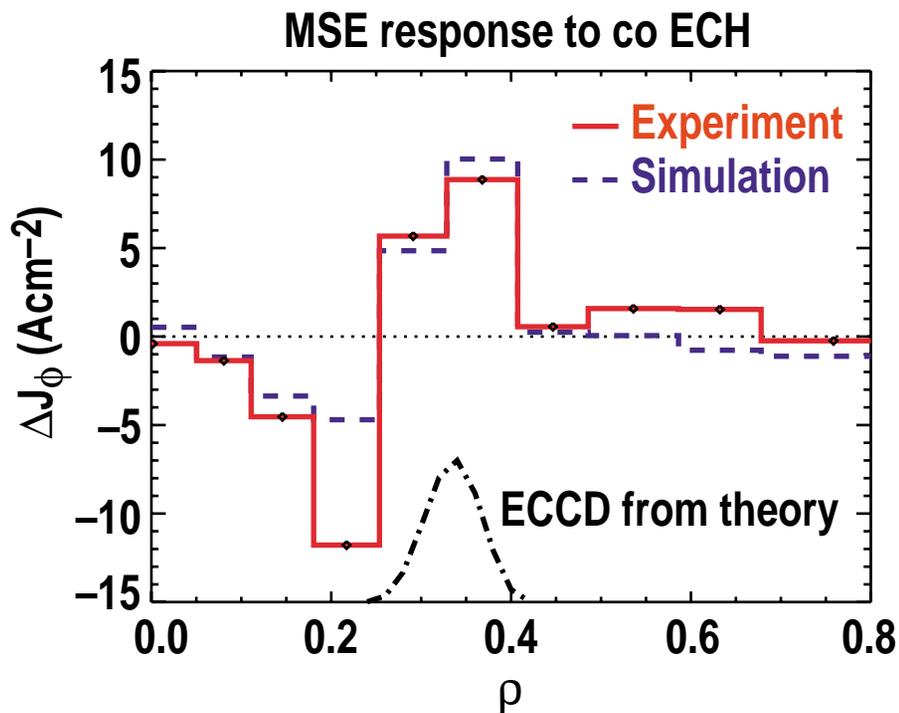

- **Counter ECH experiments use a single gyrotron (0.6 MW)**

SIMULATION OF THE MSE DATA USING THE THEORETICAL ECCD PROFILE AGREES WITH THE MEASURED RADIAL PROFILE

- **Change in J_ϕ during ECH is proportional to local change in B_Z measured by the MSE diagnostic:**

$$\Delta \mu_o \, J_\phi \approx - \Delta \frac{\partial B_Z}{\partial R}$$

- **See poster GP1.35 by D.I. Schuster this afternoon for more information**

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SUMMARY

- **Measured radial profile of NBI current drive derived from co/counter comparison is slightly broader than theoretical models (e.g., TRANSP), but the integrated currents agree**

- **Experimental MSE signals show that ECH current drive is at least as localized as theoretical predictions**

- **Magnitude of experimental ECH current drive is at or above the level predicted by Fokker-Planck calculation**

- Next year, current drive experiments with 2.5 MW of ECH power and new launcher will help remove any remaining ambiguity in the results

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