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OVERVIEW OF RESULTS FROM THE ATF TORSATRON

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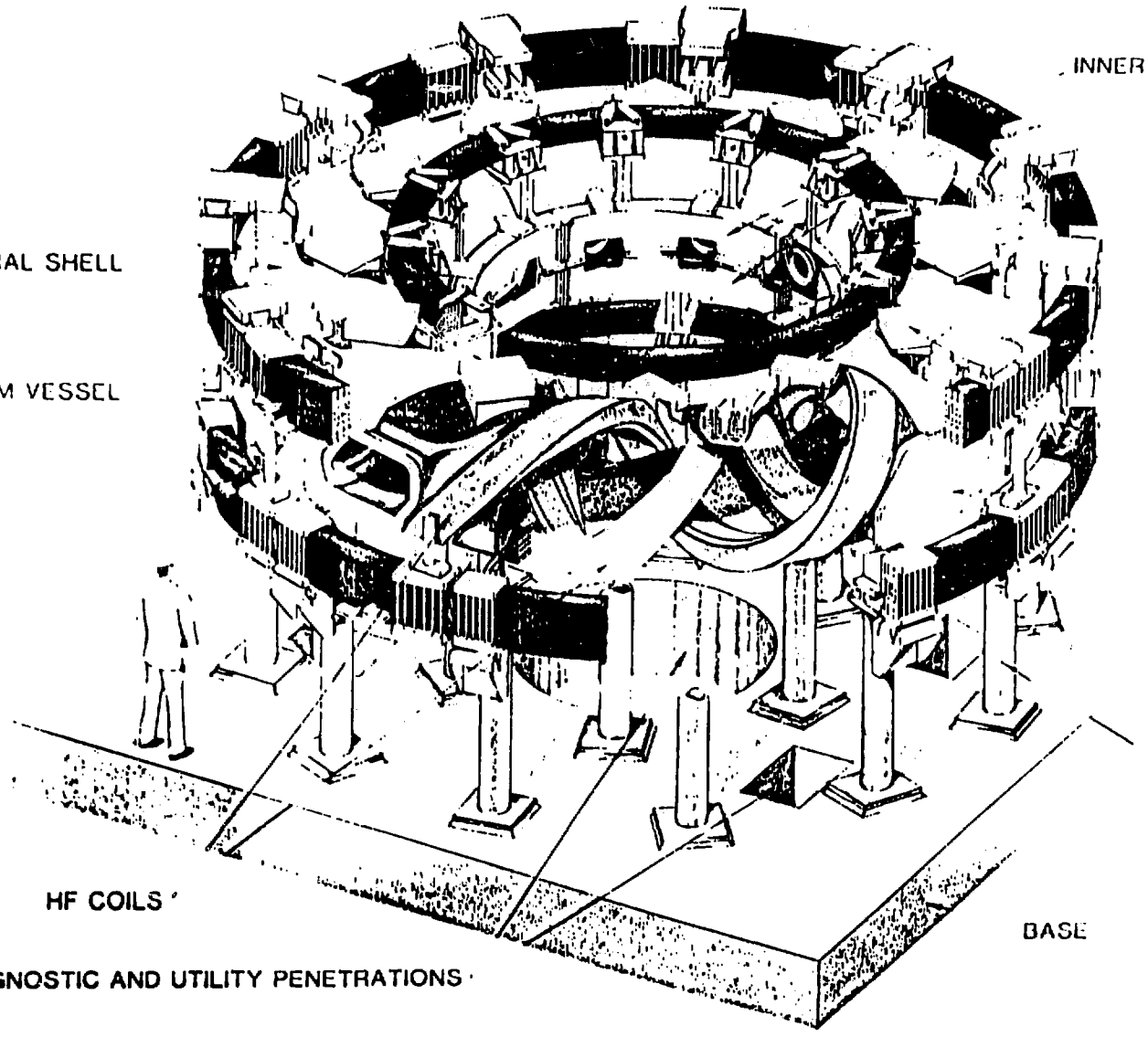
Physics Goals of the ATF Experiment

To gain a better understanding of toroidal confinement, and in particular of:

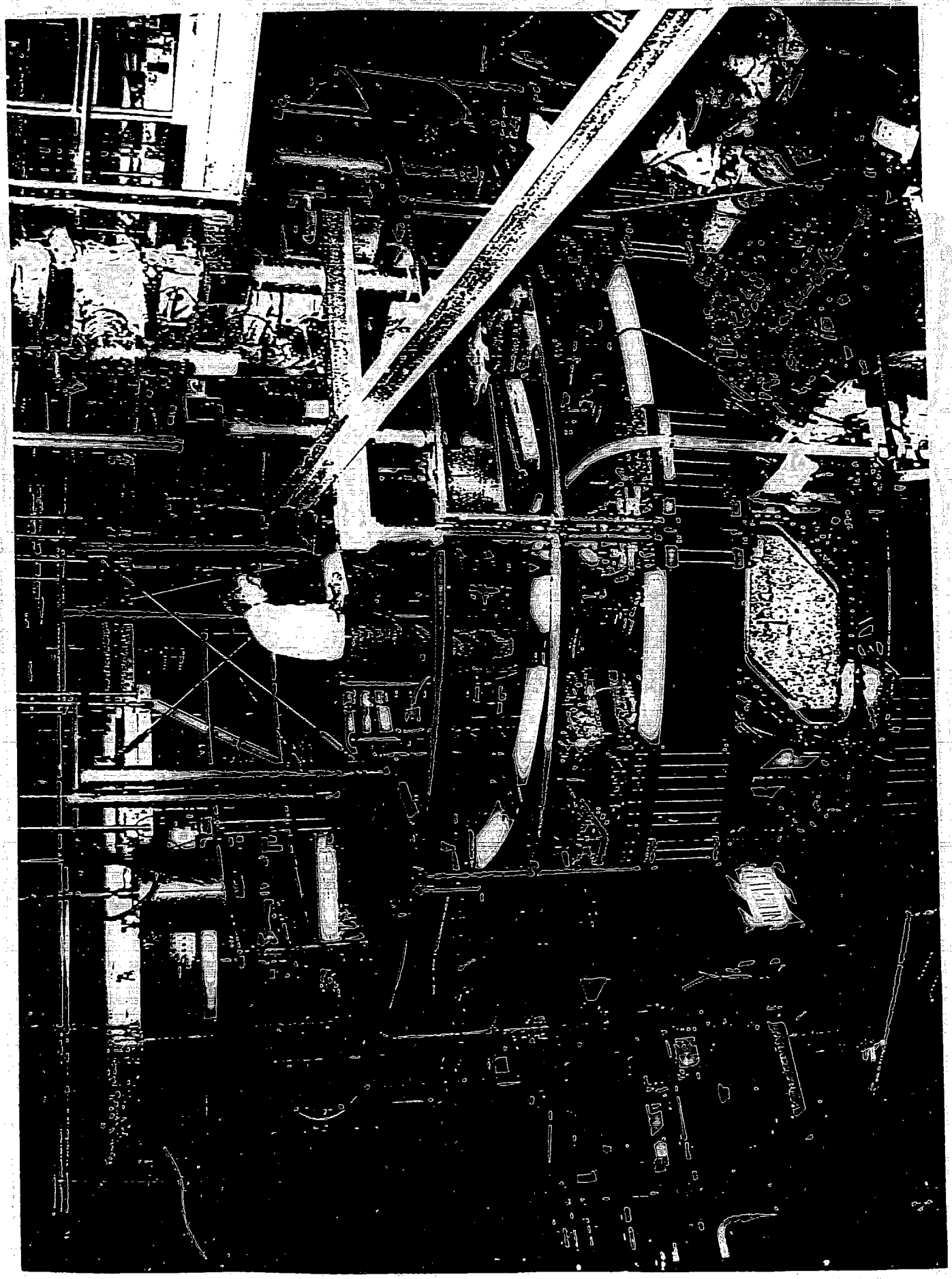
- Bootstrap and RF/NB Driven Currents
- Magnetic Configuration Optimization
- Particle and Impurity Control
- Beta Limits and Second Stability
- Low Collisionality Transport and the Role of the Electric Field
- Role of Plasma Current
- Plasma Profile Control

Topics to be Discussed

- Plasma Improvements Due to Improved Impurity Control
- Confinement Scaling
- Edge Fluctuations
- Bootstrap Currents



ATF
Advanced Toroidal Facility



ATF
DEVICE PARAMETERS

ATF: $\ell = 2$, m=12 Torsatron

$R_0 = 2.1$ m

$\langle a \rangle = 0.27$ m

$V_p = 3$ m^3

$B_0 = 0.95$ T (2nd harmonic ECH)

$B_0 = 1.9$ T (1st harmonic ECH)

$\iota(0) = 0.3$ $\quad$ $q(0) = 3.3$

$\iota(a) = 1.0$ $\quad$ $q(a) = 1.0$

ECH Power $\leq$ 400 kW (2 Gyrotrons)

NBI Power = 1.7 MW (2 Injectors)

ICH Power = 100 kW (1 antenna)

ATF PLASMA PARAMETERS

(NOT ALL PARAMETERS ACHIEVED SIMULTANEOUSLY)

$\bar{n}_e \leq 9 \times 10^{13}$ cm^{-3}

$\tau_E \leq 20$ ms

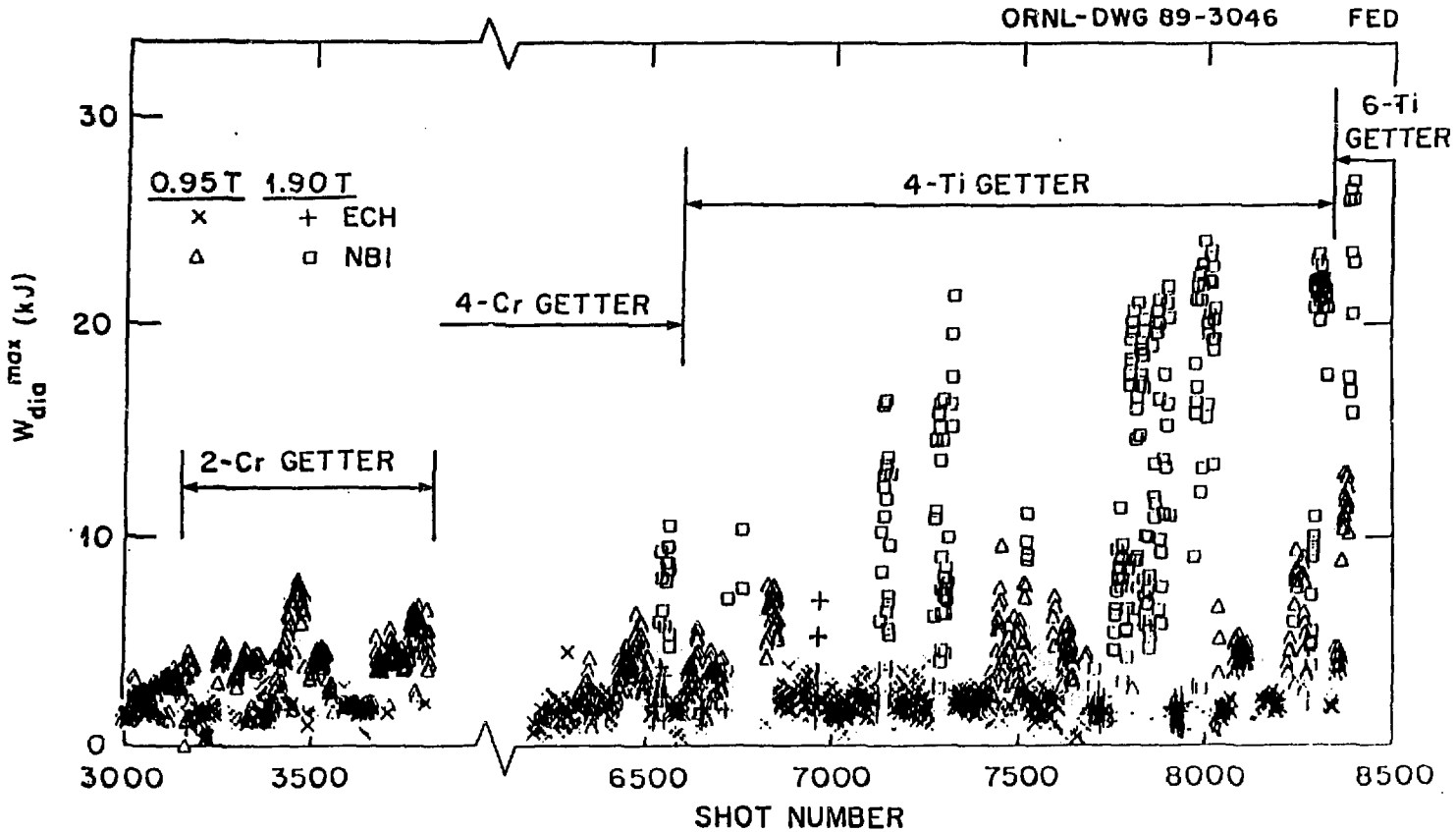
$W_p \leq 28$ kJ

$T_e \leq 1$ keV

$\beta_0 \leq 3\%$

$\langle\beta\rangle \leq 0.84\%$

STORED ENERGY INCREASES WITH IMPROVED GETTERING



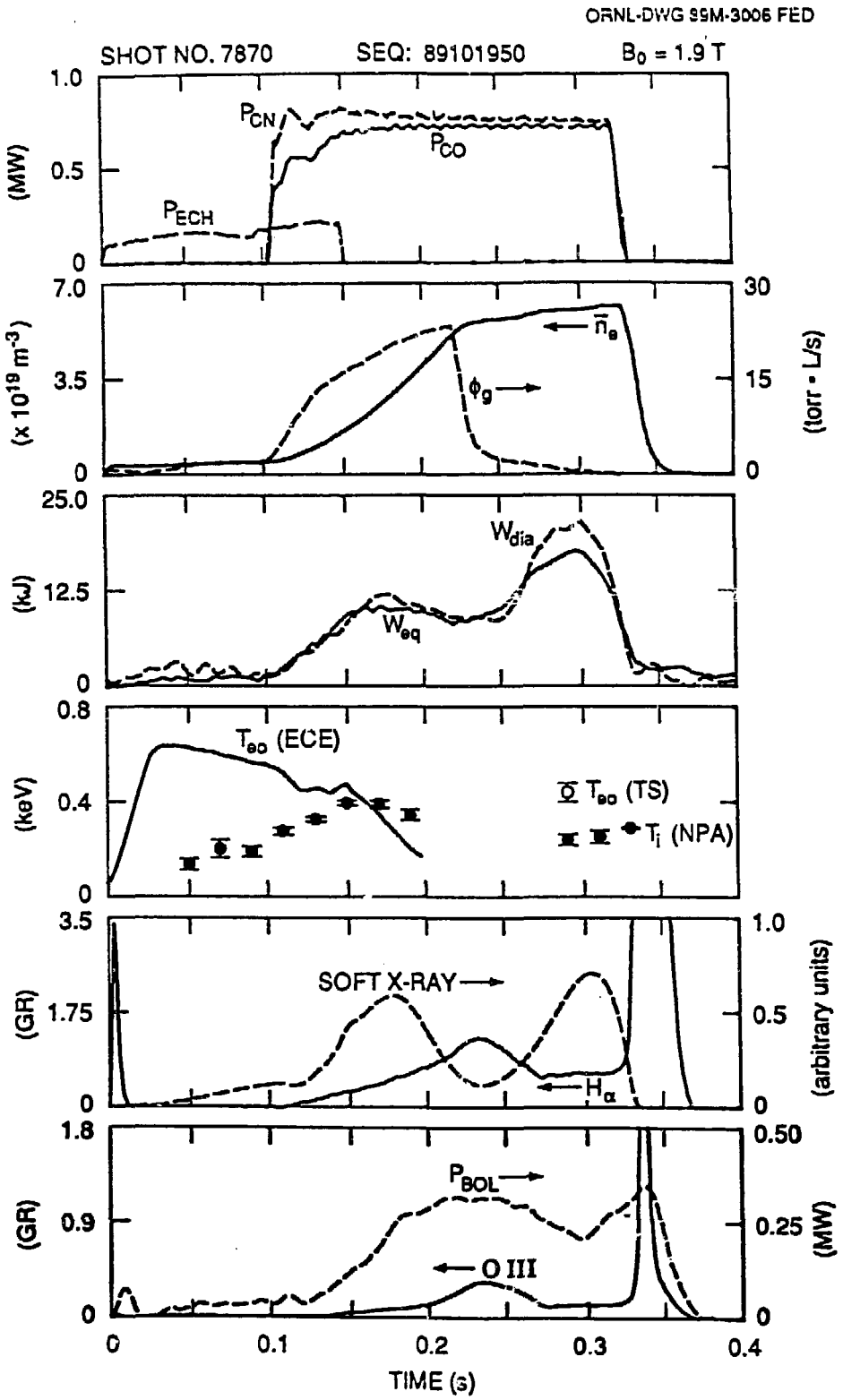
Recent Plasma Improvements Due to Improved Impurity Control

- Vacuum Vessel Baking + Glow Discharge Cleaning:
  - 1 sec. ECH Discharges @ 1 T.
  - NBI Discharges Suffered Thermal Collapse in Spite of Low $Z_{eff} \leq 2$, and Low Radiated Power Fraction ($P_{rad}/P_{input} \leq 40$ %) up to the Time of the Collapse.

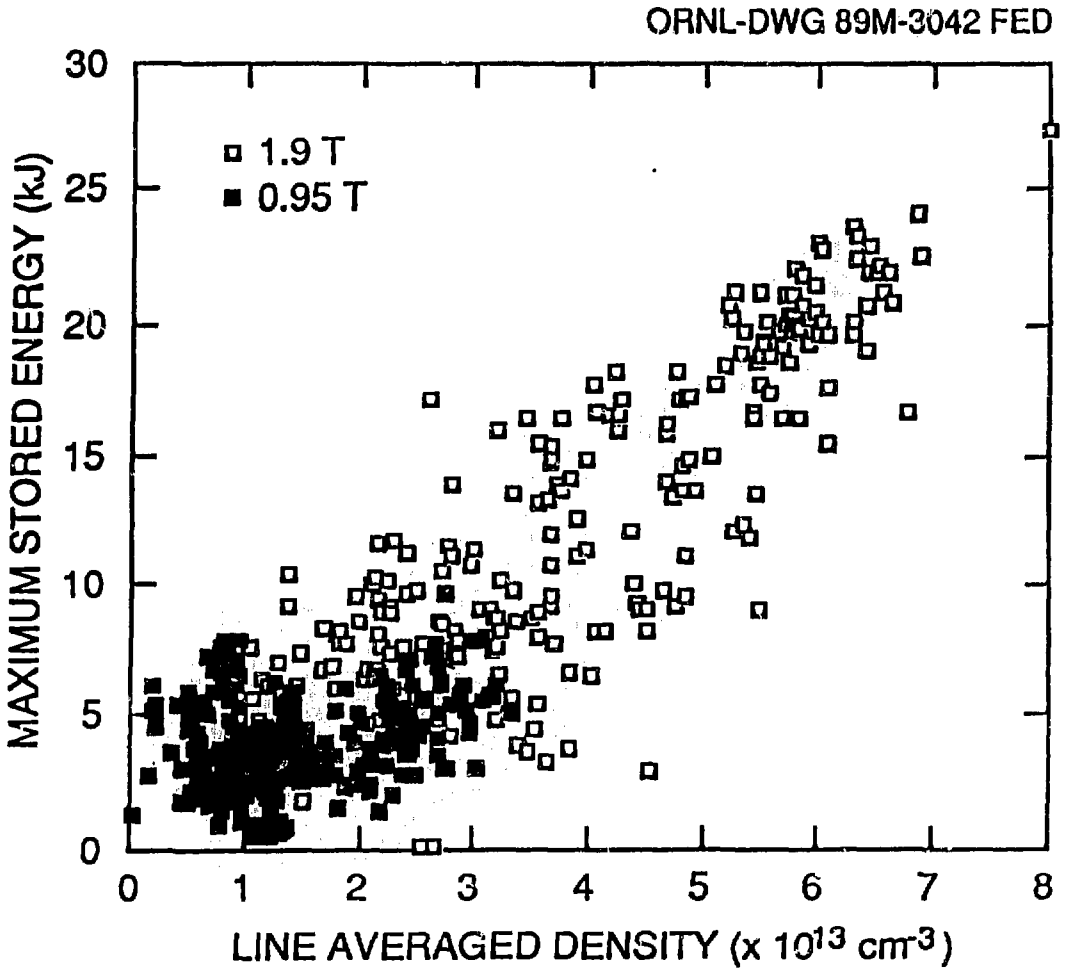
- Extensive Gettering (≈60% Wall Coverage) has Led to Extended Longevity (>250ms) for NBI Discharges.

- The Cause of the Thermal Collapse is Unknown. Low Radiation Levels Suggest that Impurities are not the Sole Culprit.

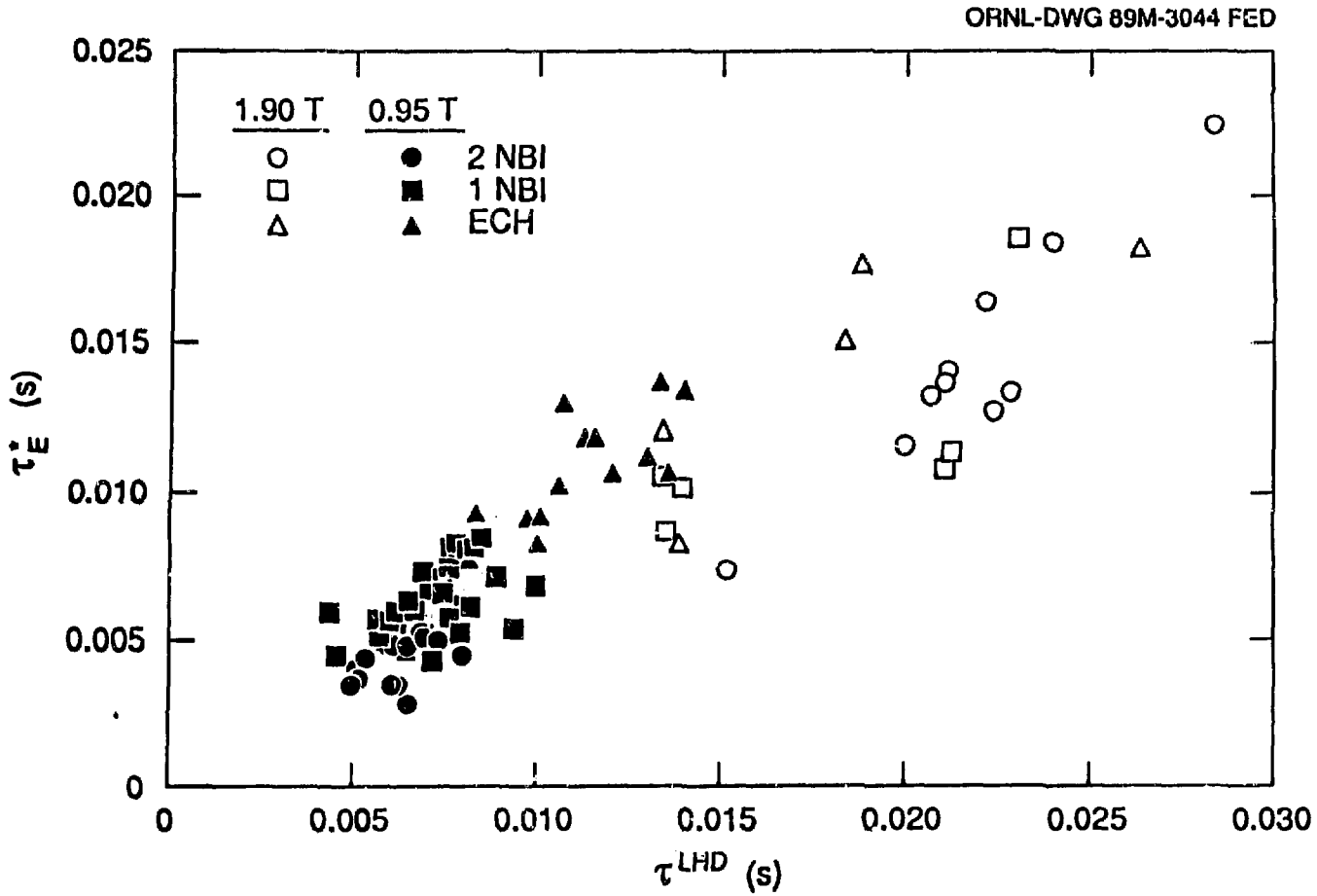
TYPICAL NBI DISCHARGE



STORED ENERGY INCREASES PROPORTIONAL TO THE DENSITY

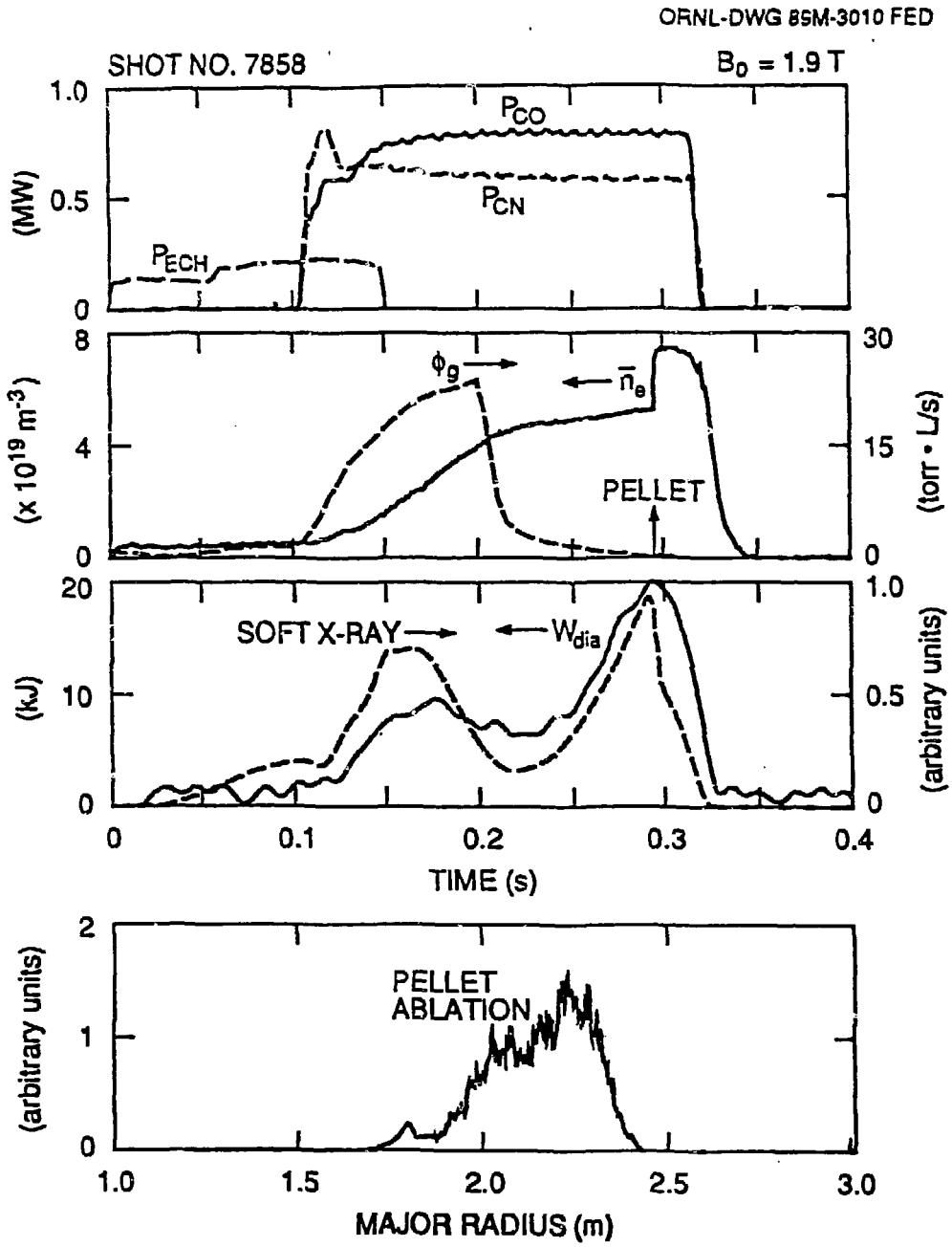


ATF CONFINMENT TIMES FOLLOW THE STELLARATOR/TORSATRON SCALING LAW

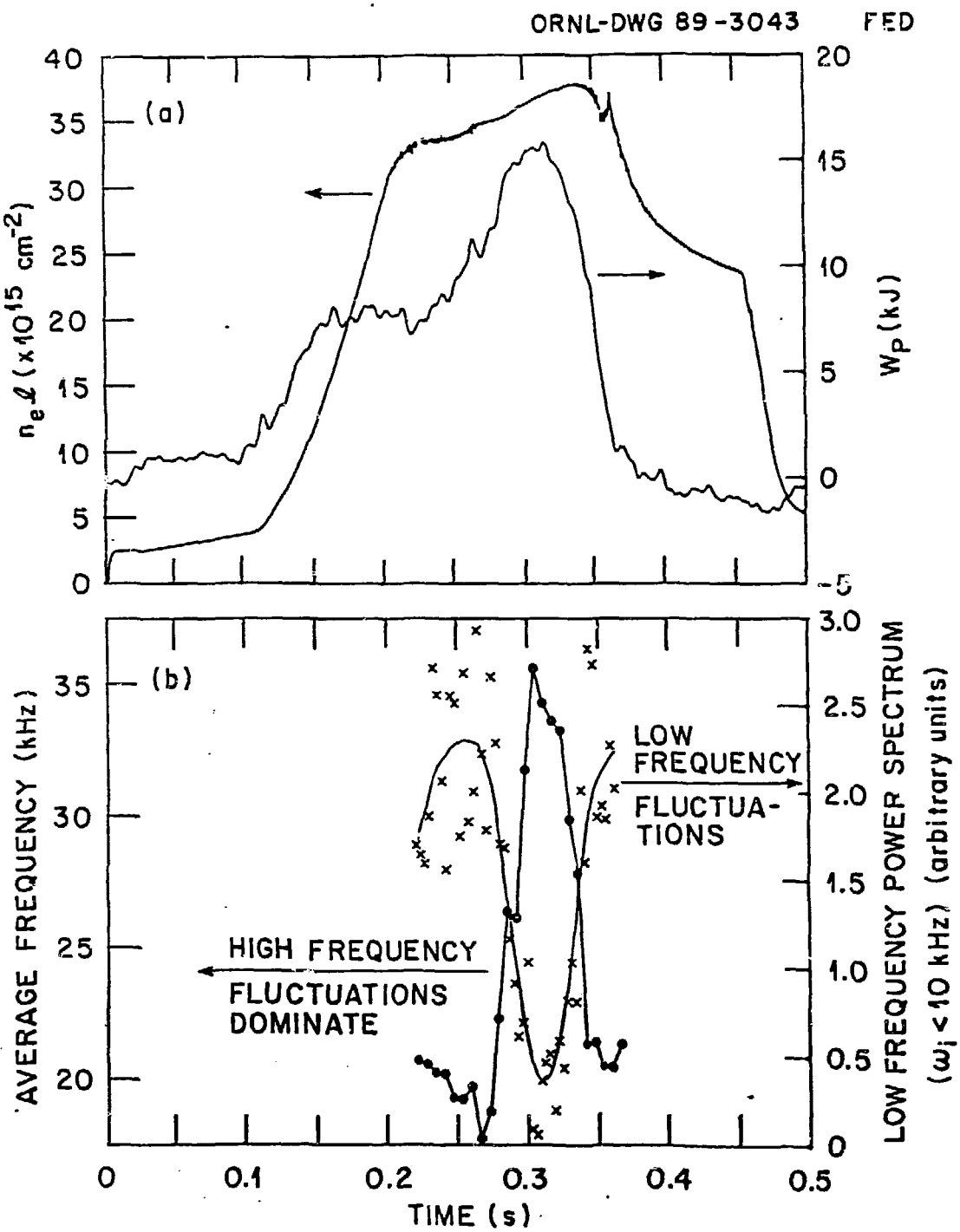


$$\tau^{LHD} = 0.17 P^{-0.58} n_e^{0.69} B^{0.84} a^2 R^{0.75} [s; MW, m^{-3} 10^{20}, T, m^2, m]$$

PELLET INJECTION LEADS TO FURTHER DENSITY INCREASES

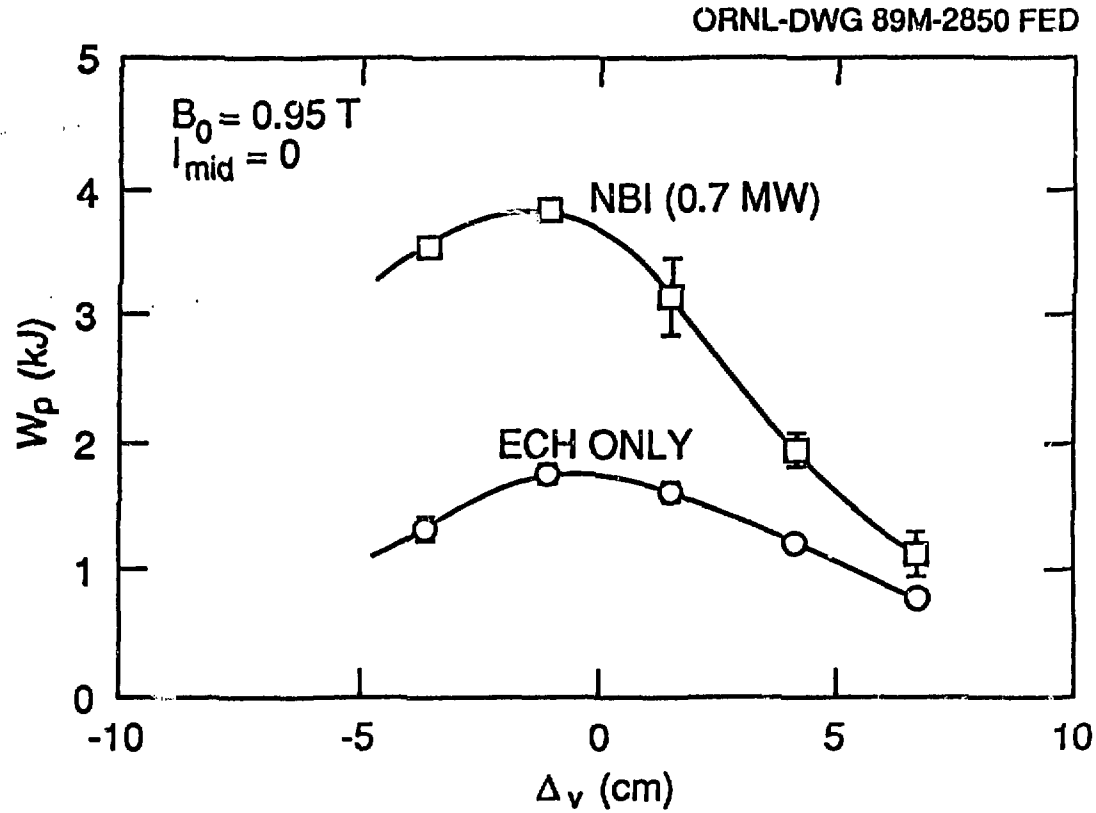


Instability Mode Changes Near the Peak of the Stored Energy

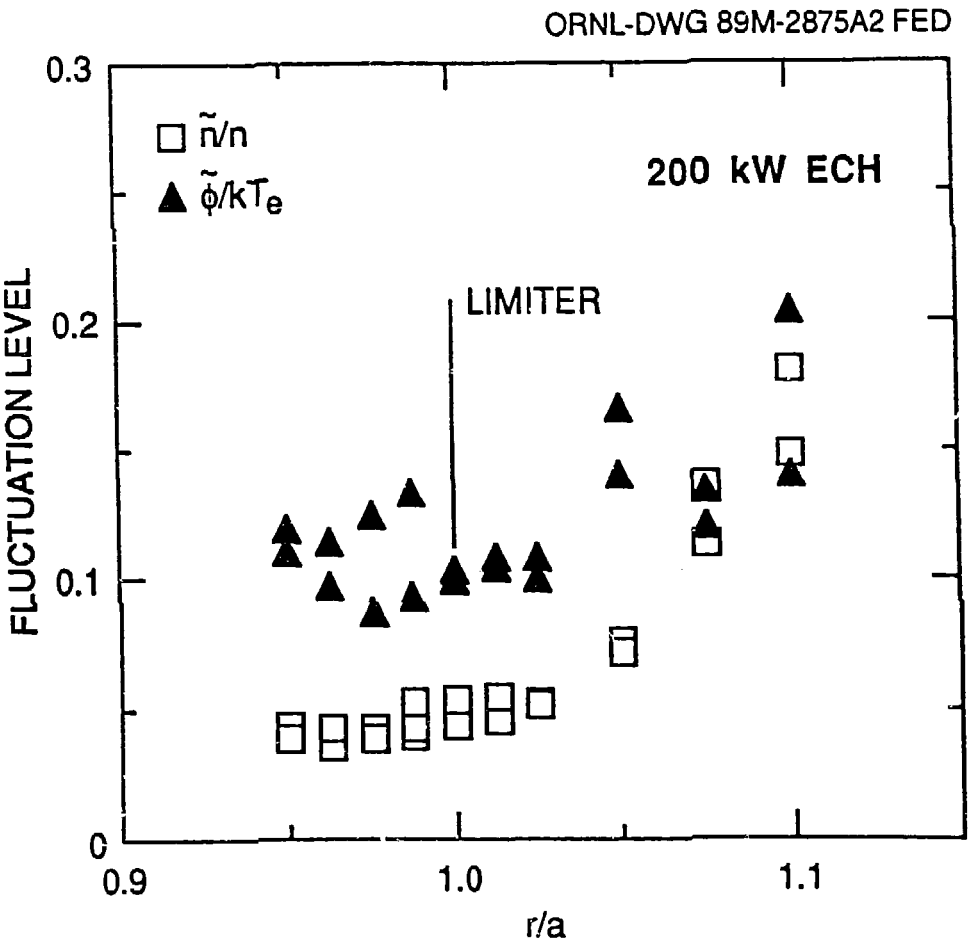


REFLECTOMETER EDGE FLUCTUATION MEASUREMENTS

MAXIMUM STORED ENERGY DEPENDS ON THE IN-OUT PLASMA POSITION SHIFT

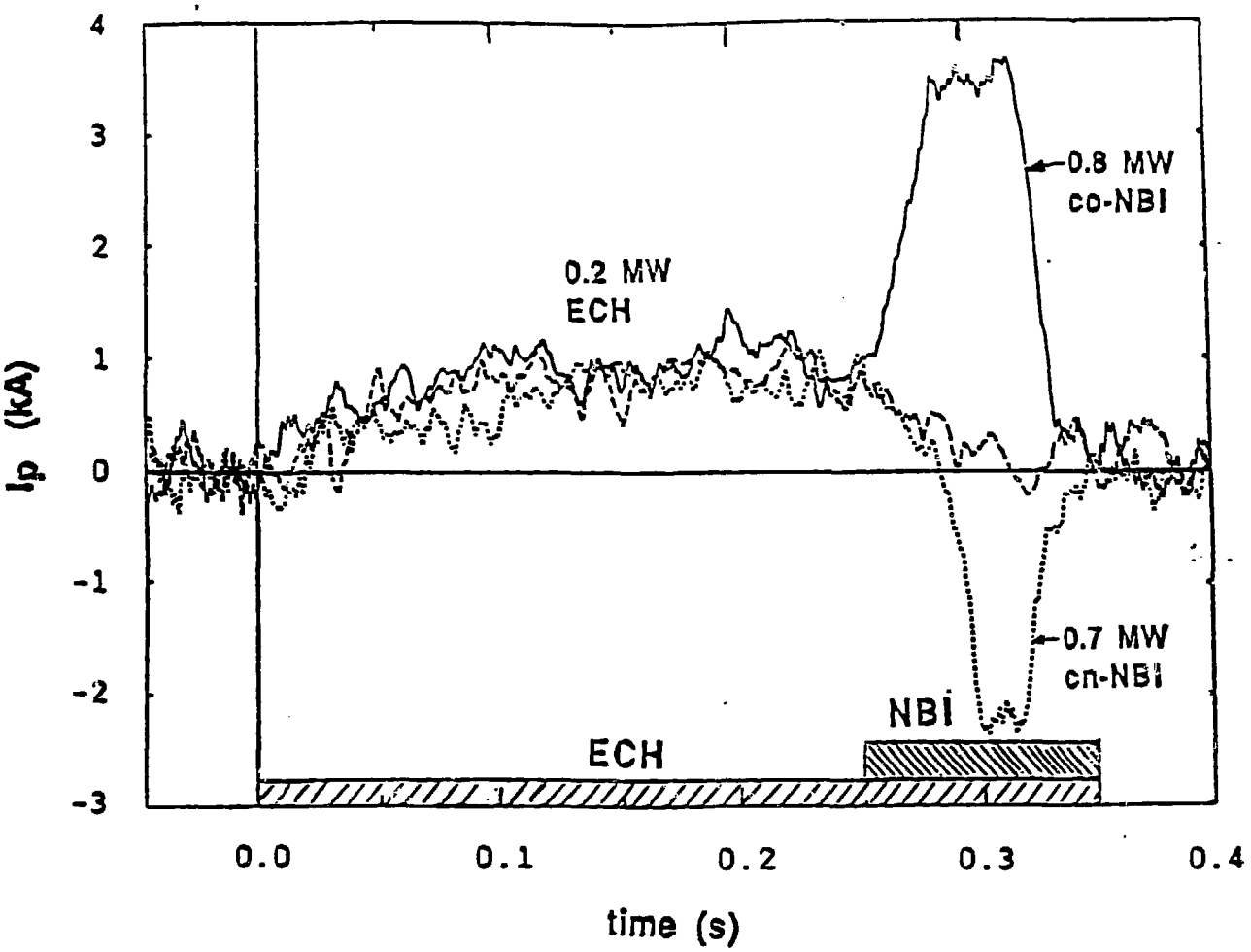


ATF EDGE FLUCTUATION STUDIES



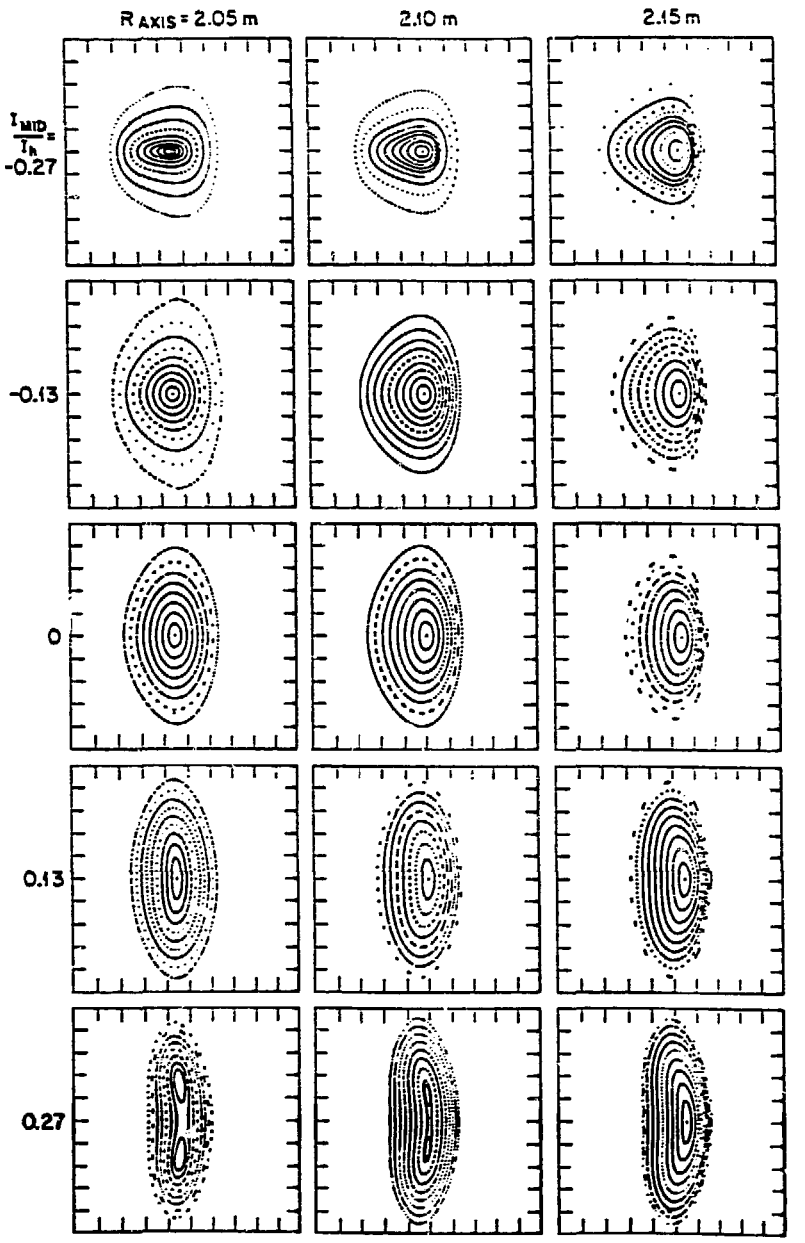
- The measured particle flux is consistent with global confinement.
- The radial density dependence and $\tilde{\phi}/kT_e > \tilde{n}/n$ (inside the limiter) are similar to observations on TEXT.
- There results are consistent with a resistive turbulence model coupled with a radiative instability drive.

Currents Observed in ATF



- The current observed during ECH is the bootstrap current.
  - The current reverses direction when the magnetic field is reversed.
- The current observed during NBI is dominated by beam-driven currents.

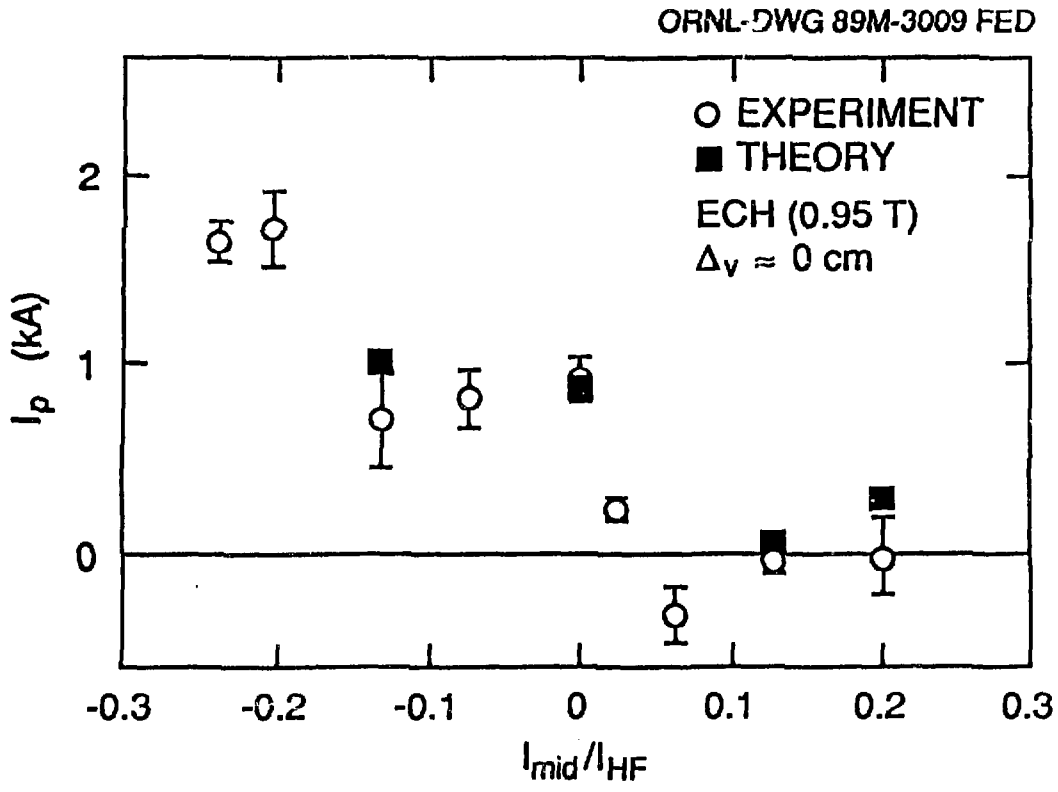
The Bootstrap Current May Be Varied by Changing the Flux Surface Configuration



Quadrupole Component of the Vertical Field
⇐Varied⇒

Dipole Component of the Vertical Field
⇐Varied⇒

Measured and Calculated Values of the Bootstrap Current Agree



Quadrupole Field Variation

SUMMARY

- ATF has achieved beam-injected plasmas with average densities of $\leq 10^{14}$ cm^{-3}, $\tau_E \lesssim$ 20 ms, and electron temperatures of several hundred eV.
  - Temperature limited by amount of NBI power ($\leq$1.7 MW).
  - Thermal collapse of the plasma controlled by wall conditioning and particle fueling.

- Confinement times scale directly with density and magnetic field, offsetting an inverse scaling with NBI power ($\tau_E \sim n_e^{0.69} B^{0.84} P^{-0.58}$).

- Edge fluctuation studies have established a direct correlation between an instability mode transition and an increase in the stored energy.

SUMMARY (CONT'D)

- Fast reciprocating Langmuir probe studies show that fluctuations in ATF and TEXT have many similarities.

- Bootstrap currents observed during ECH heating agree with neoclassical predictions both in magnitude and in their parametric dependencies.