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(vugraphs)

OVERVIEW OF RESULTS FROM THE ATF TORSATRON

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RF MASTER

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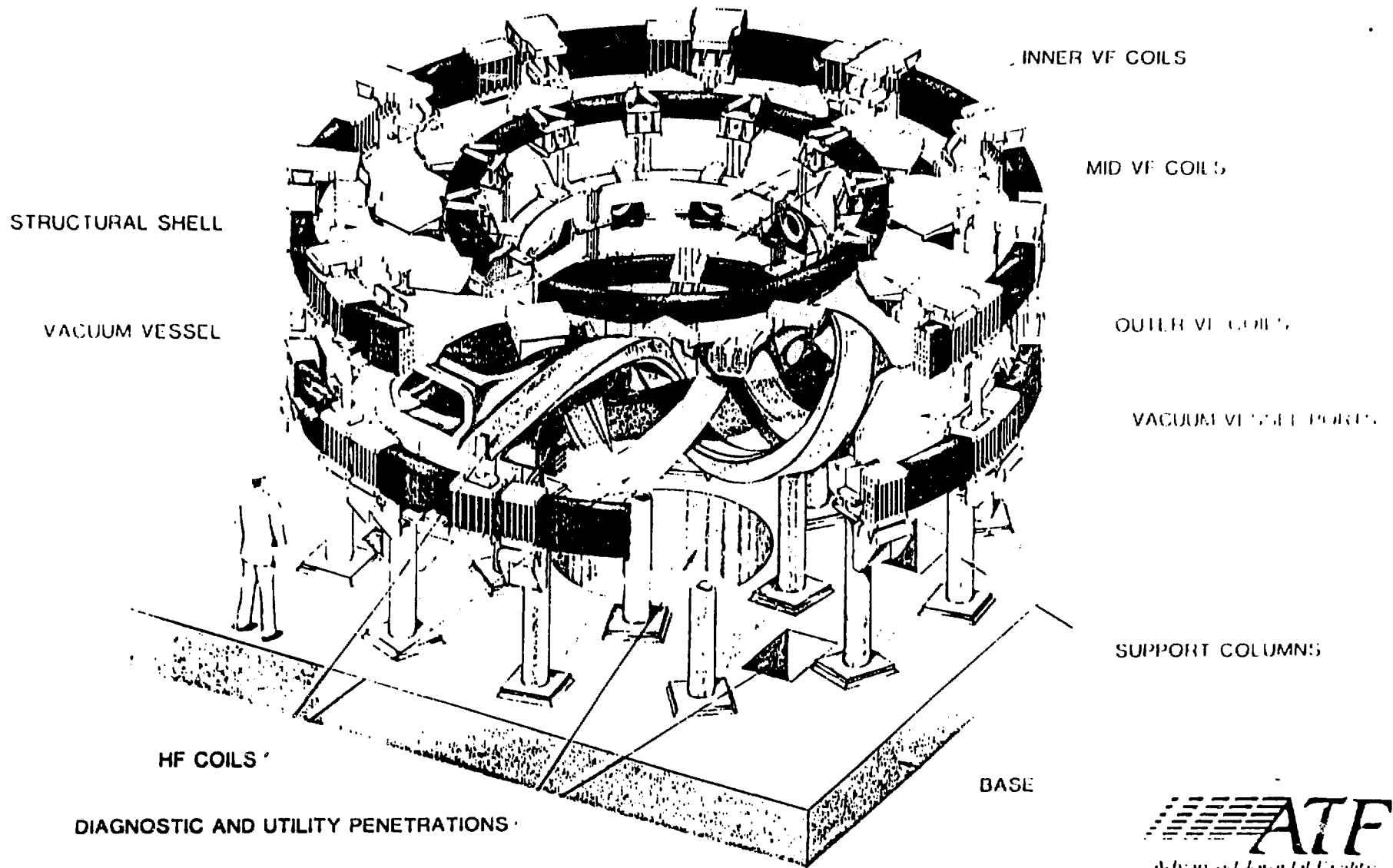
Physics Goals of the ATF Experiment

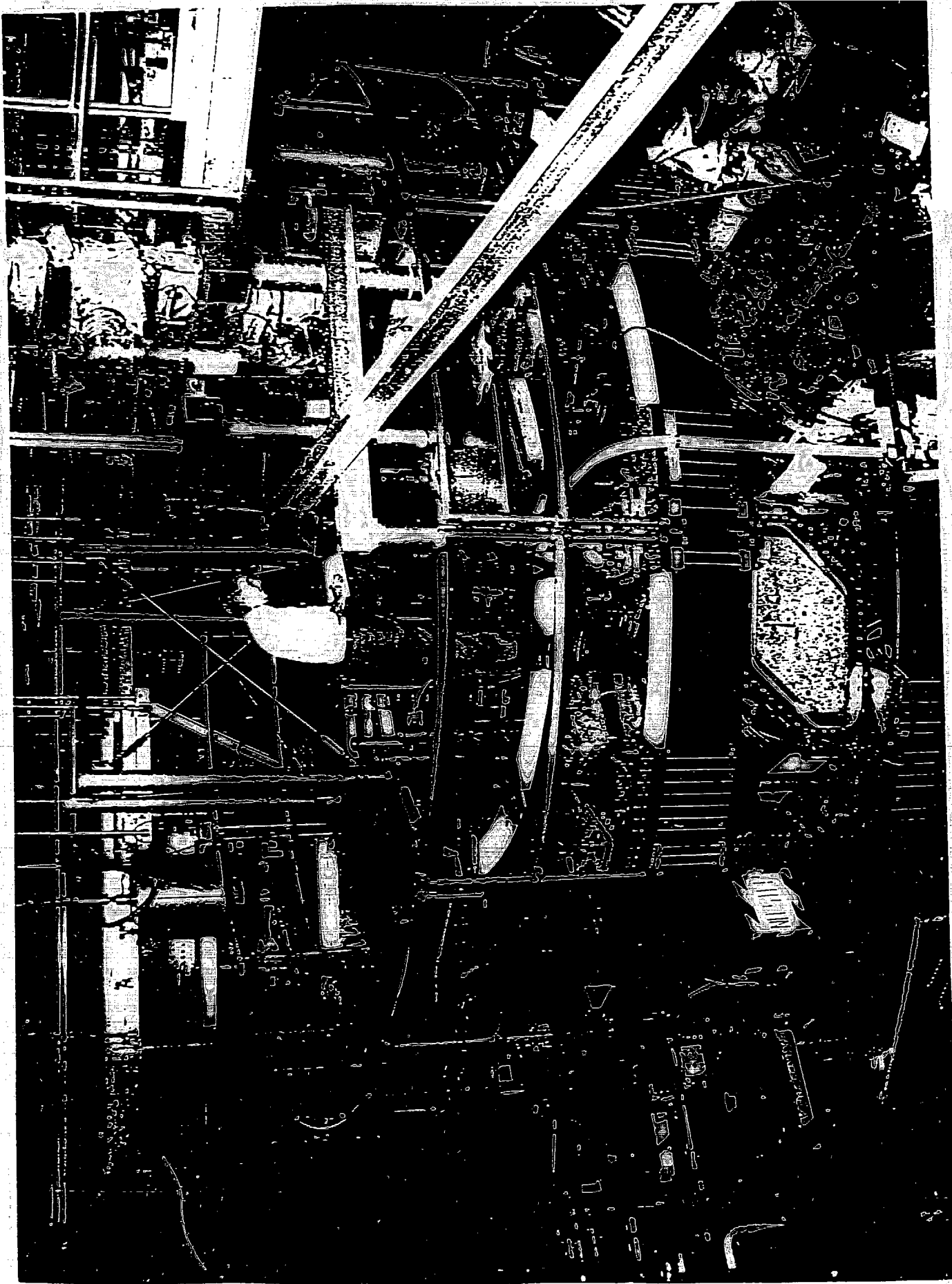
To gain a better understanding of toroidal confinement, and in particular of:

- **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

DEVICE PARAMETERS

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

$$R_0 = 2.1 \text{ m}$$

$$\langle a \rangle = 0.27 \text{ m}$$

$$V_p = 3 \text{ m}^3$$

$$B_0 = 0.95 \text{ T (2nd harmonic ECH)}$$

$$B_0 = 1.9 \text{ T (1st harmonic ECH)}$$

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

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

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)

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

$$\tau_E \leq 20 \text{ ms}$$

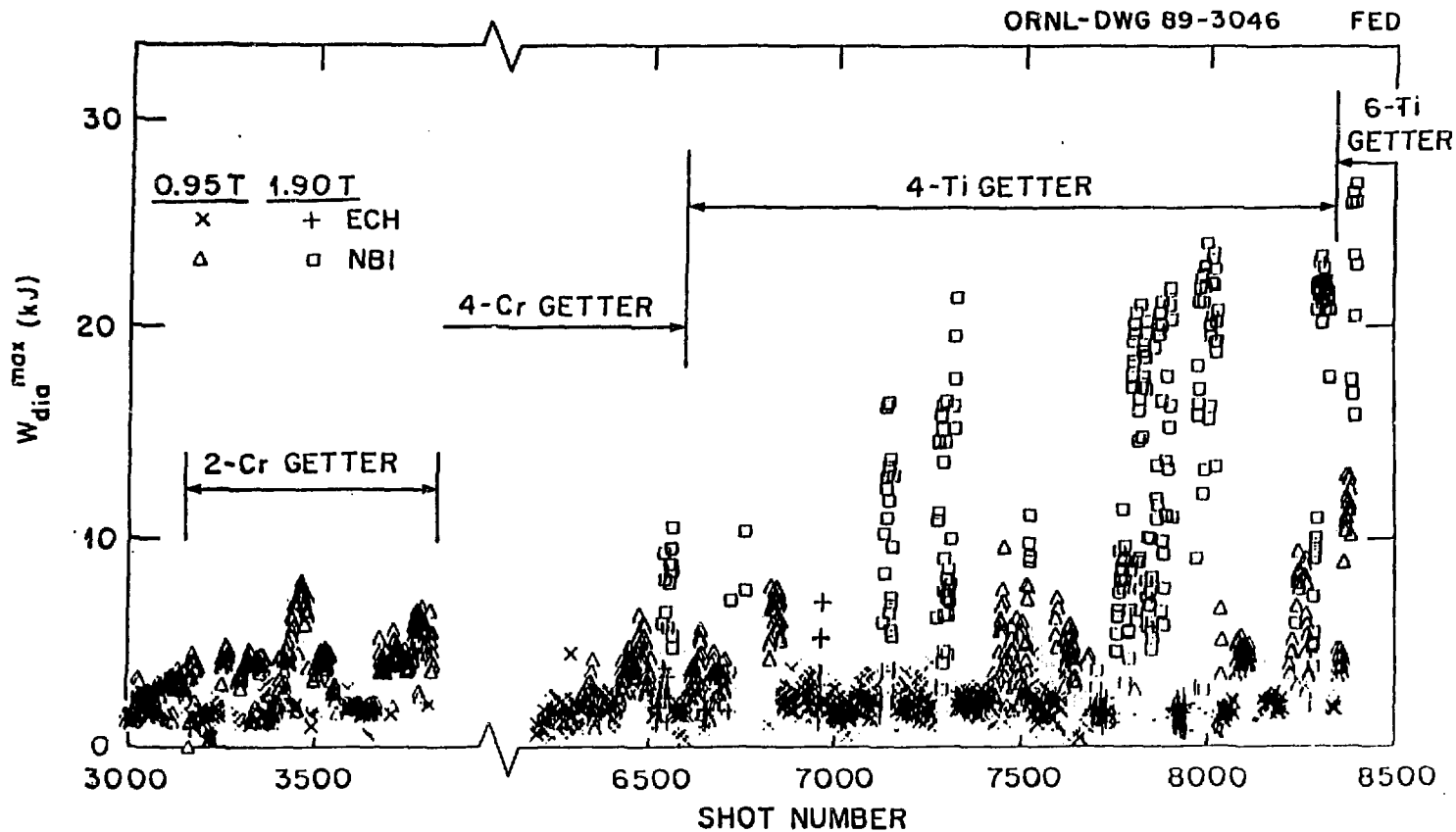
$$W_p \leq 28 \text{ kJ}$$

$$T_e \leq 1 \text{ keV}$$

$$\beta_0 \leq 3\%$$

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

STORED ENERGY INCREASES WITH IMPROVED GETTERING

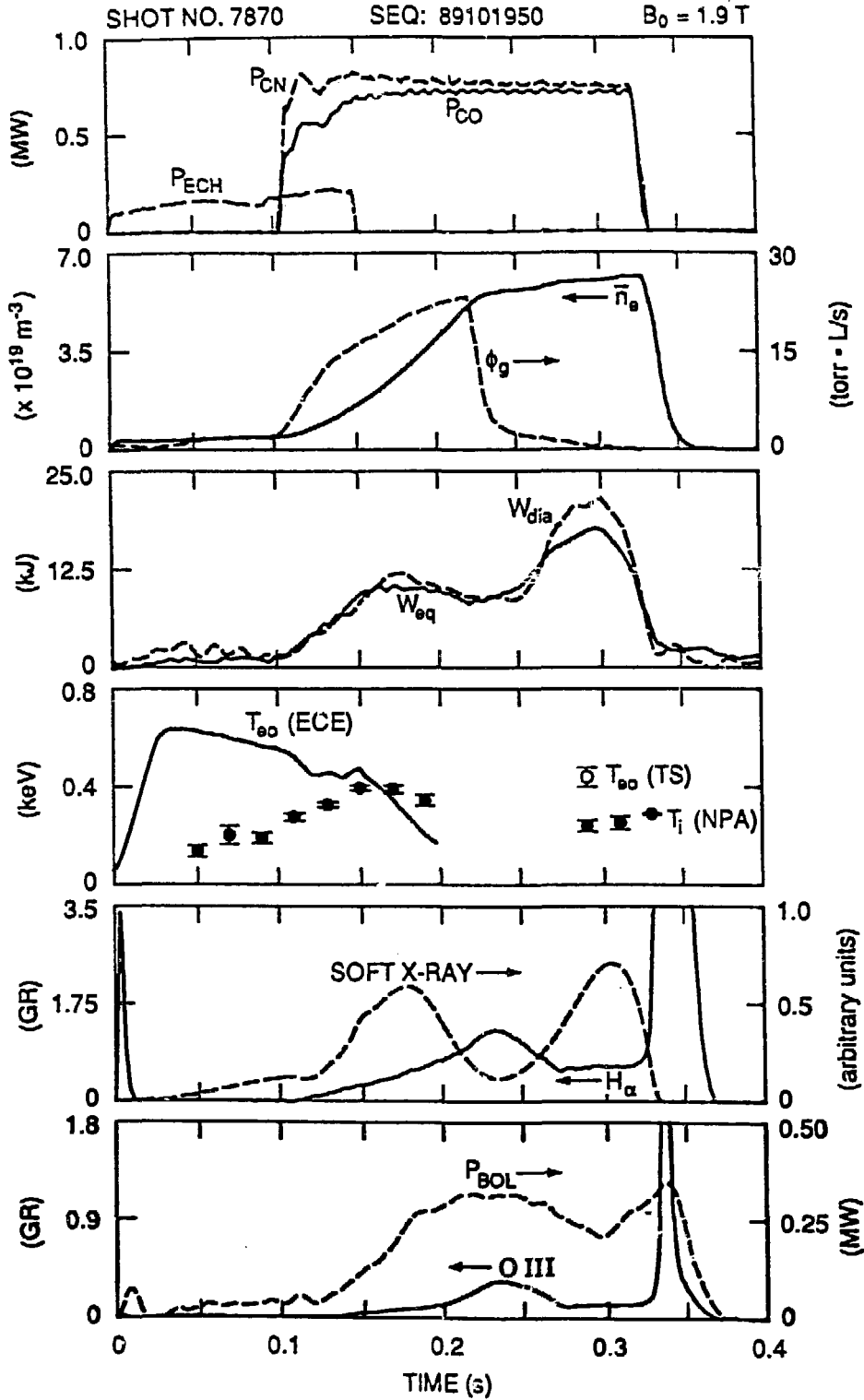


Recent Plasma Improvements Due to Improved Impurity Control

- **Vacuum Vessel Baking + Glow Discharge Cleaning:**
 - **1 sec. ECH Discharges @ 1 T.**
 - **NBI Discharges Suffered Thermal Collapse in Spite of Low $Z_{\text{eff}} \leq 2$, and Low Radiated Power Fraction ($P_{\text{rad}}/P_{\text{input}} \leq 40\%$) up to the Time of the Collapse.**
- **Extensive Gettering ($\approx 60\%$ Wall Coverage) has Led to Extended Longevity ($>250\text{ms}$) for NBI Discharges.**
- **The Cause of the Thermal Collapse is Unknown. Low Radiation Levels Suggest that Impurities are not the Sole Culprit.**

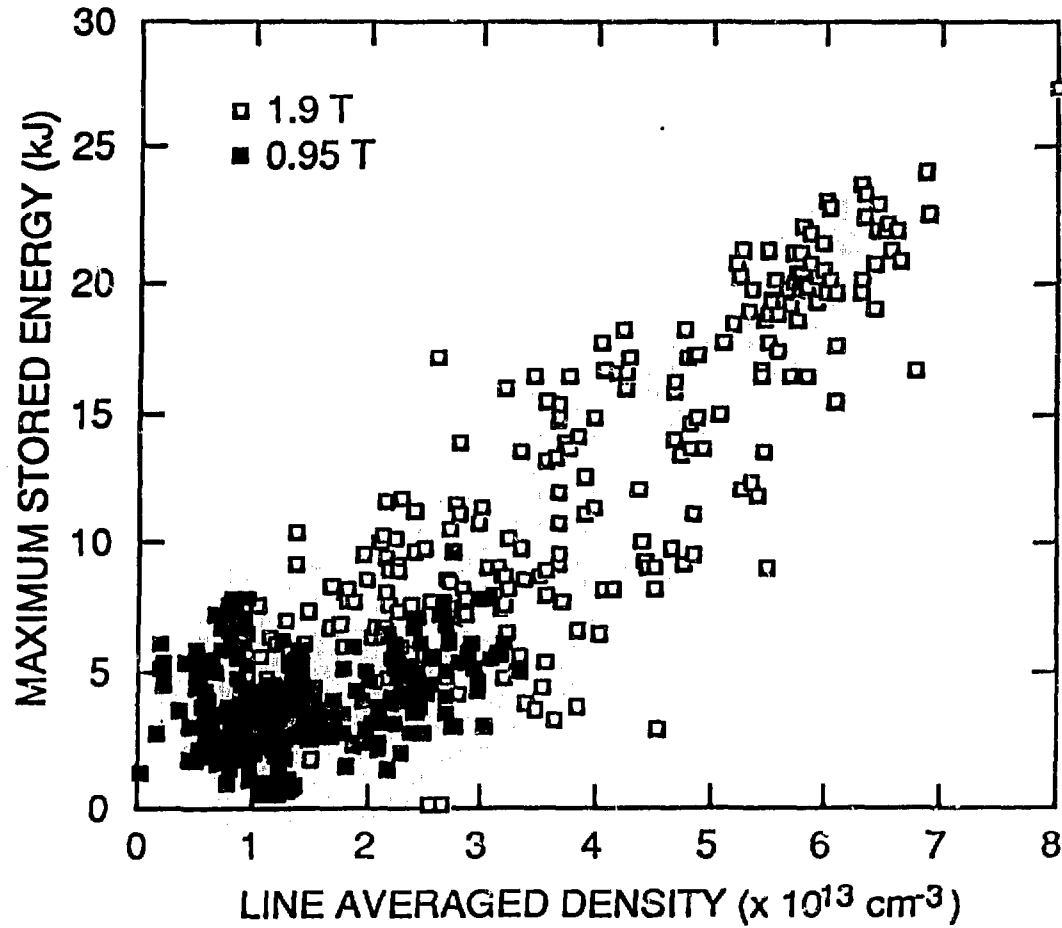
TYPICAL NBI DISCHARGE

ORNL-DWG 99M-3006 FED



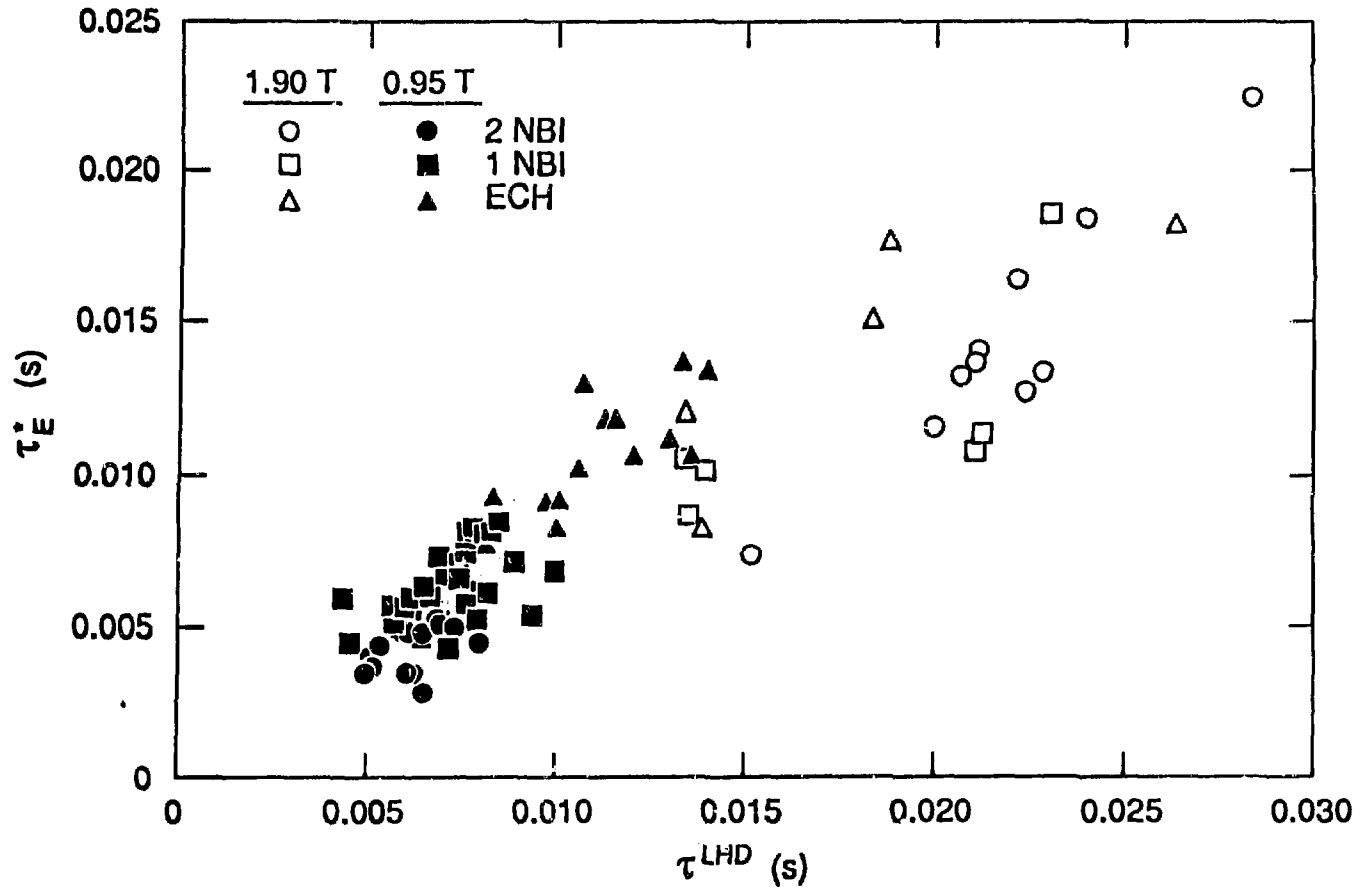
STORED ENERGY INCREASES PROPORTIONAL TO THE DENSITY

ORNL-DWG 89M-3042 FED



ATF CONFINEMENT TIMES FOLLOW THE STELLARATOR/TORSATRON SCALING LAW

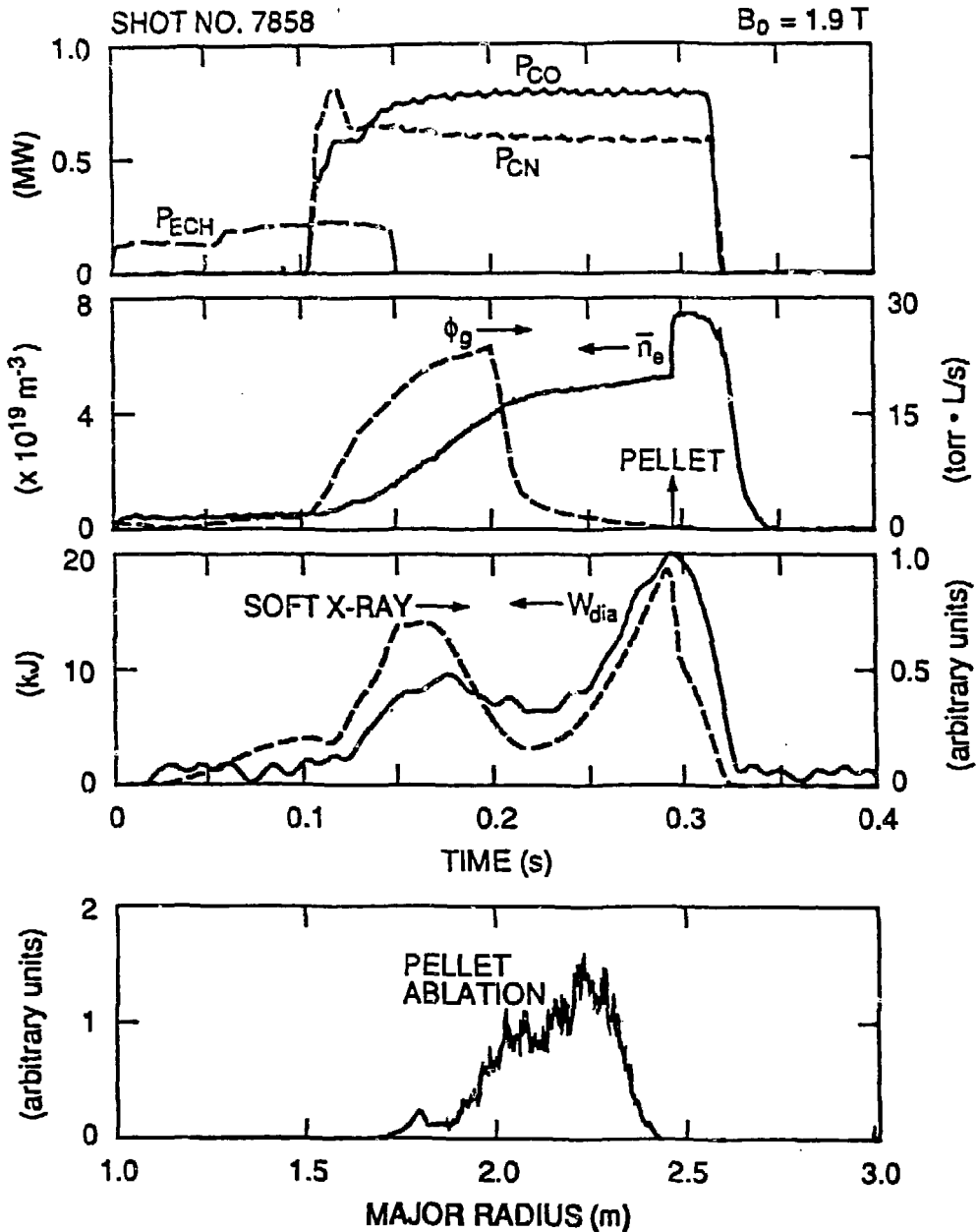
ORNL-DWG 89M-3044 FED



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

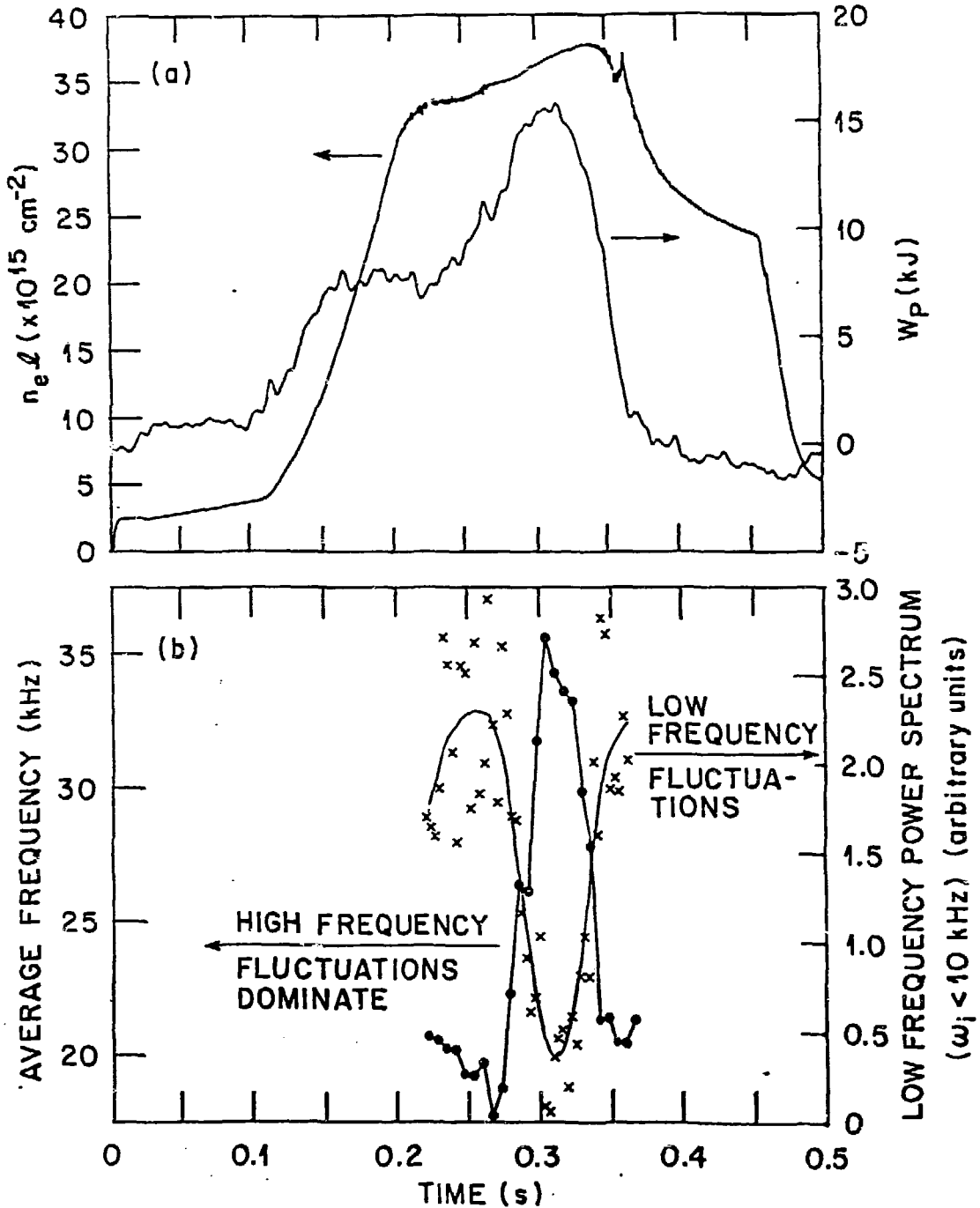
PELLET INJECTION LEADS TO FURTHER DENSITY INCREASES

ORNL-DWG 85M-3010 FED



Instability Mode Changes Near the Peak of the Stored Energy

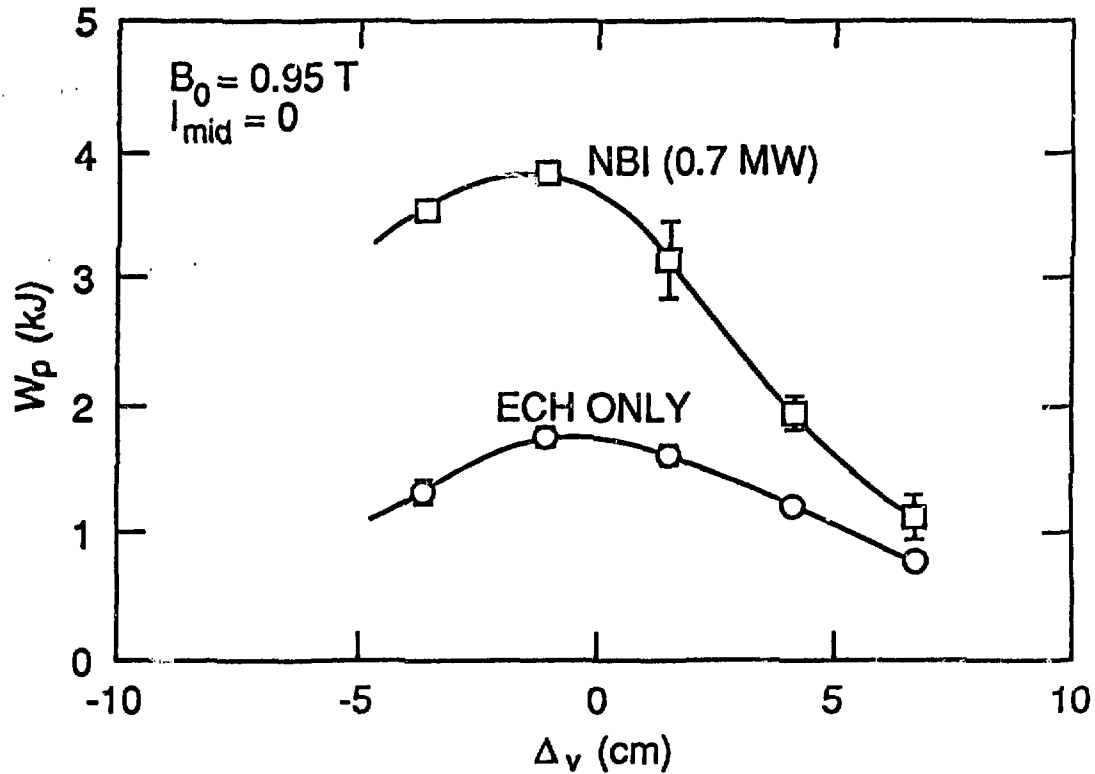
ORNL-DWG 89-3043 FED



REFLECTOMETER EDGE FLUCTUATION MEASUREMENTS

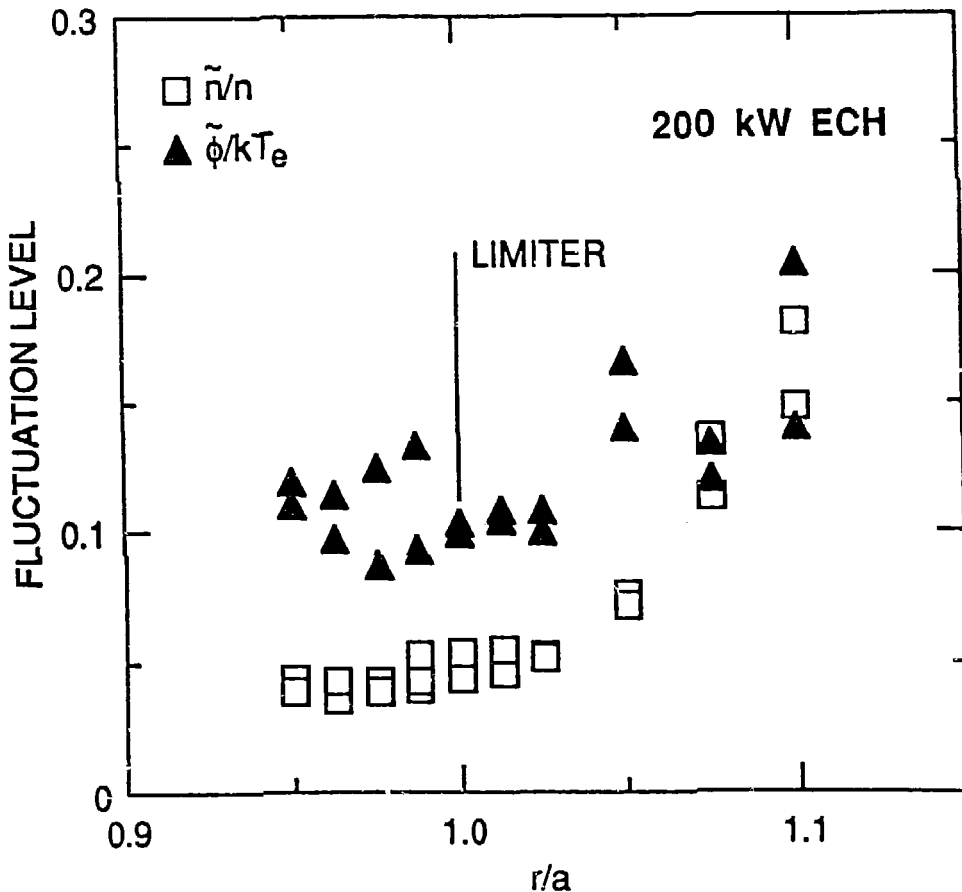
MAXIMUM STORED ENERGY DEPENDS ON THE IN-OUT PLASMA POSITION SHIFT

ORNL-DWG 89M-2850 FED



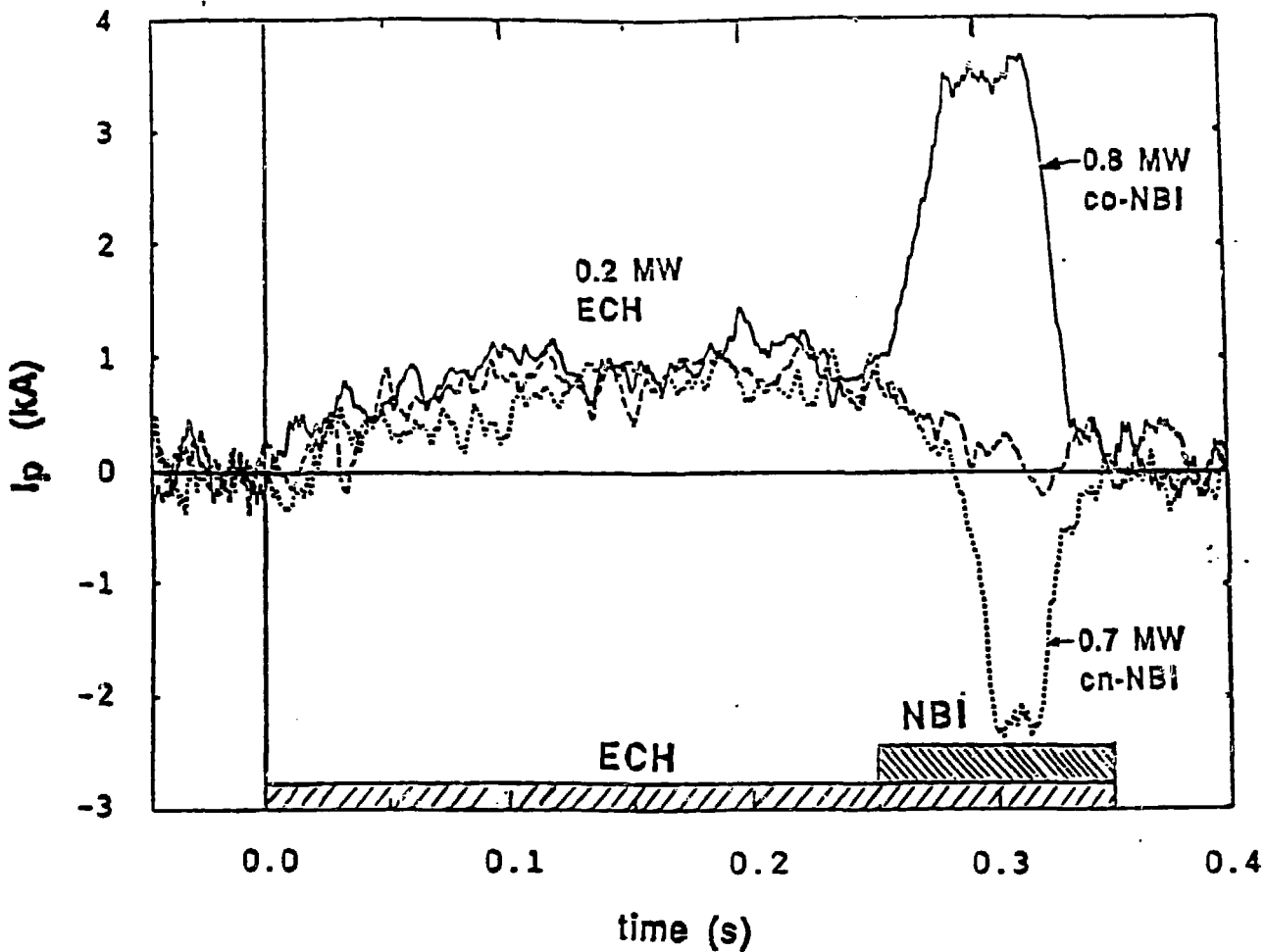
ATF EDGE FLUCTUATION STUDIES

ORNL-DWG 89M-2875A2 FED



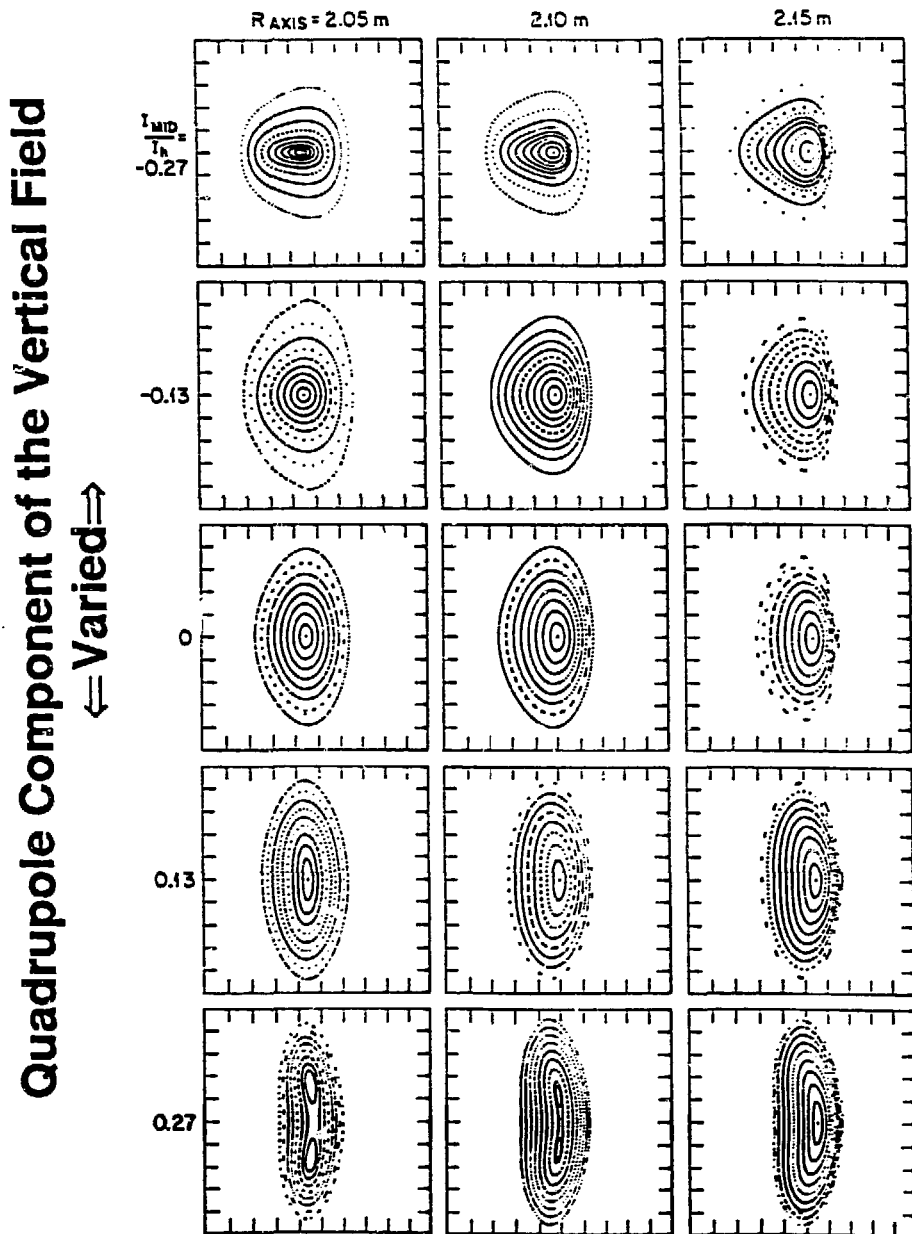
- The measured particle flux is consistent with global confinement.
- The radial density dependence and $\tilde{\phi}/kT_e > \tilde{n}/n$ (inside the limiter) are similar to observations on TEXT.
- These results are consistent with a resistive turbulence model coupled with a radiative instability drive.

Currents Observed in ATF



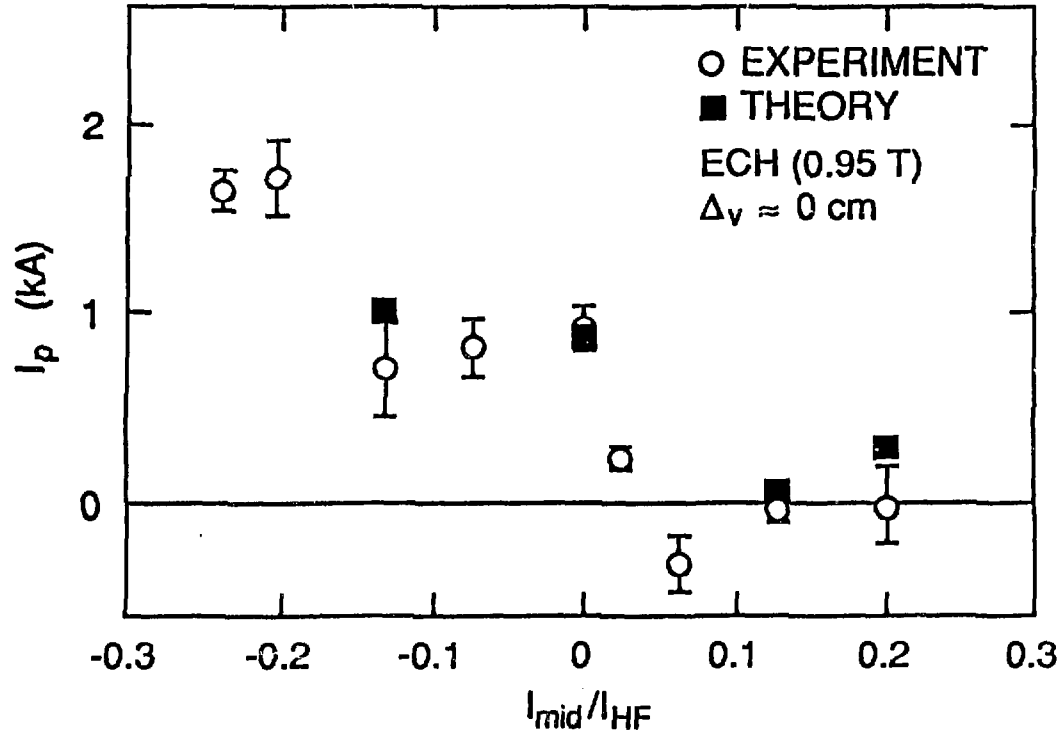
- The current observed during ECH is the bootstrap current.
 - The current reverses direction when the magnetic field is reversed.
- The current observed during NBI is dominated by beam-driven currents.

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



Measured and Calculated Values of the Bootstrap Current Agree

ORNL-DWG 89M-3009 FED



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 (≤ 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.**