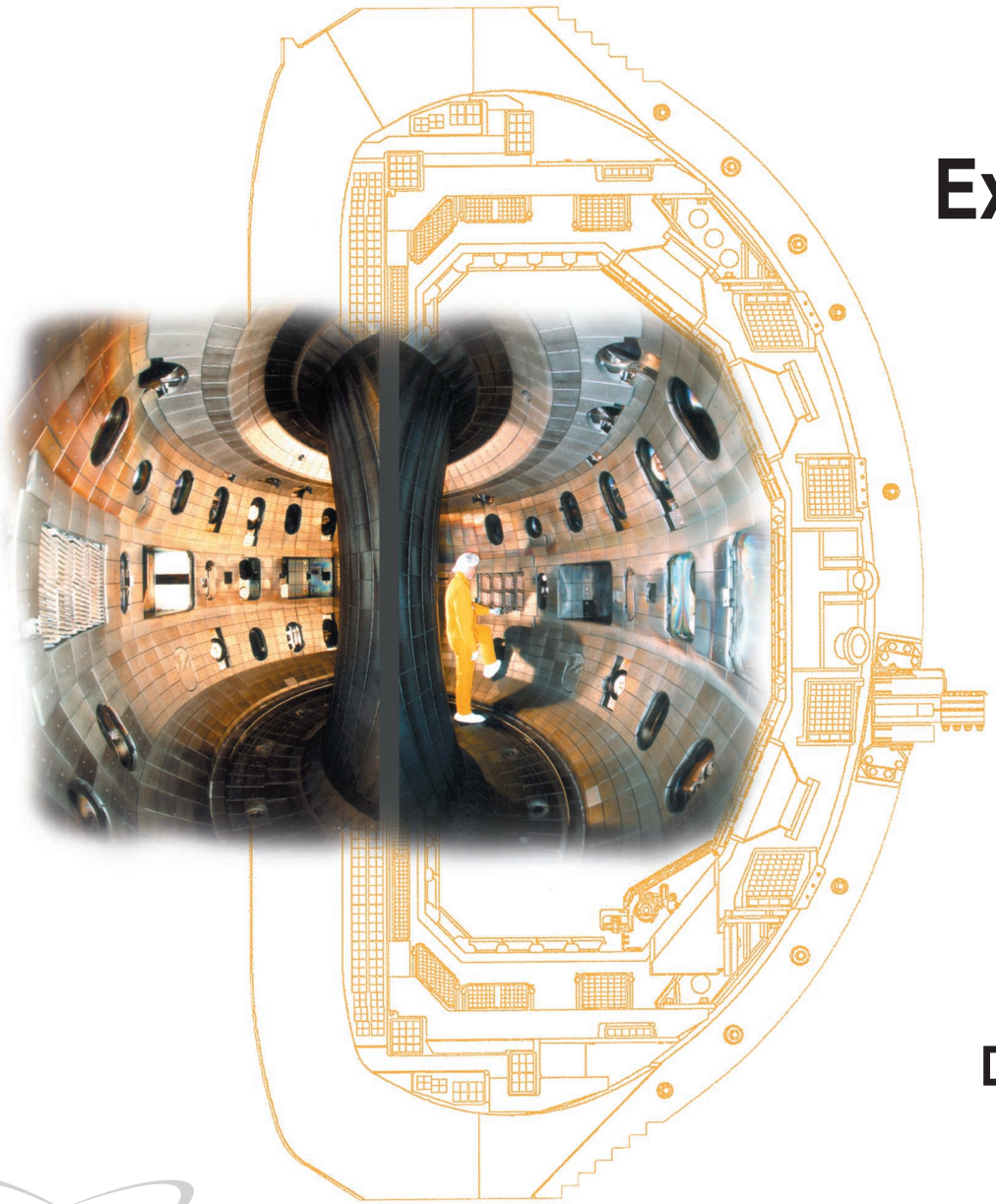
# Overview of the 2001 DIII–D Experimental Campaign



S. L. Allen
and the
DIII-D Team

Presented at
the American Physical Society
Division of Plasma Physics Meeting
Long Beach, CA

October 30, 2001

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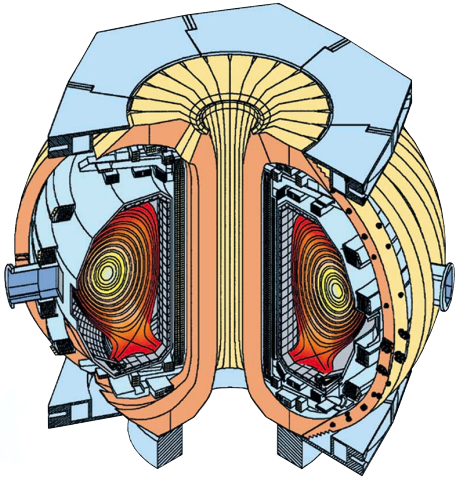
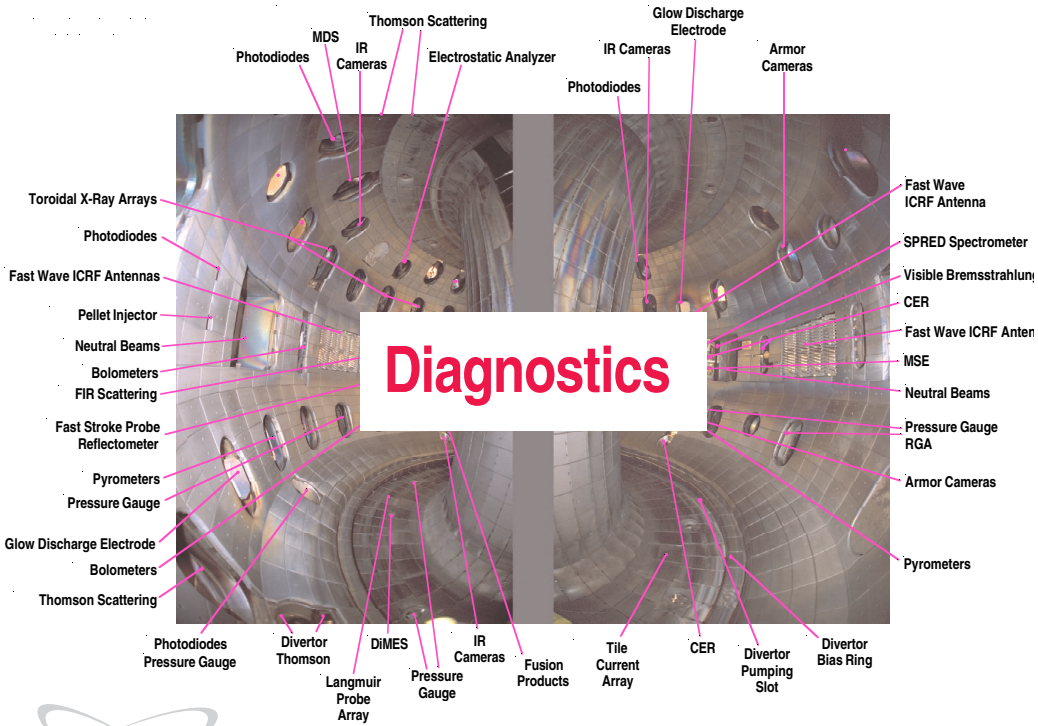
# DIII–D National Program is a Multi-Institution Collaborative Effort

## Plasma Shape Flexibility



## Control

## Diagnostics

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## International Research Team
## Collaborations with 60 institutions – 300 users

| NATIONAL LABS | UNIVERSITIES | INTERNATIONAL LABS |
|---|---|---|
| ANL | Alaska | ASIPP (China) |
| INEL | Alberta (Canada) | Cadarache (France) |
| LANL | Cal Tech | CCFM (Canada) |
| LLNL | Chalmers U. (Sweden) | Culham (England) |
| ORNL | Columbia U. | FOM (Netherlands) |
| PNL | Georgia Tech | Frascati (Italy) |
| PPPL | Hampton U. | Ioffe (Russia) |
| SNLL | Helsinki U. (Finland) | IPP (Germany) |
| | Johns Hopkins U. | JAERI (Japan) |
| | Lehigh | JET (EC) |
| **INDUSTRY COLLABS** | MIT | KAIST (Korea) |
| CompX | Moscow State U. (Russia) | KBSI (Korea) |
| CPI (Varian) | RPI | Keldysh Inst. (Russia) |
| GA | U. Maryland | KFA (Germany) |
| Gycom | U. Texas | Kurchatov (Russia) |
| Orincon | U. Toronto (Canada) | Lausanne (Switzerland) |
| Creare | U. Wales (Wales) | NIFS (Japan) |
| FAR Tech | U. Washington | Troitsk (Russia) |
| Gycom | U. Wisconsin | SWIP (China) |
| HiTech Metallurgical | UC Berkeley | Southwestern Inst. (China) |
| IR&T | UC Irvine | Tsukuba U. (Japan) |
| Surmet | UCLA | |
| Thermacore | UCSD | |
| TSI Research | | |

# DIII-D Progress in 2001 in *A*dvanced *T*okamak *–AT–* Physics

## Focus Areas in 2001 (Thrusts):

- *Resistive Wall Mode (n=1 kink):* Sustaining Rotation and Controlling Error Fields enables higher $\beta$ operation
- *Neoclassical Tearing Mode (3/2):* Local ECCD controls 3/2 mode (even with sawteeth) and allows higher $\beta$ operation
- *Pedestal Studies:* Model predicts $n_e$ pedestal width ( at low $T_e$), Non-dimensional scaling studies with C-MOD are promising
- *Internal Transport Barriers*: Quiescent Core and Edge Barriers in $T_e$ and $T_i$, H-mode edge, no ELMS, (high-Z impurities!)
- *–AT–* Scenario Development: Use RWM stabilization for higher $\beta$ target, target plasma optimized (shape, q-profile)

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# DIII-D Progress in 2001 in *A*dvanced *T*okamak *–AT–* Physics

## Topical Science Areas:

- *Heating and Current Drive:* ECCD efficiency increases with $\beta_e$ -- agrees with models
- *Transport and Confinement:* Comparison of measured correlation lengths with analytical and numerical models
- *Divertor and SOL:* Main chamber may play an important role in impurity levels; efficient H-mode density control
- *Stability:* Roles of interchange and internal kink stability in the sawtooth were studied in "bean" and "oval" shaped plasmas

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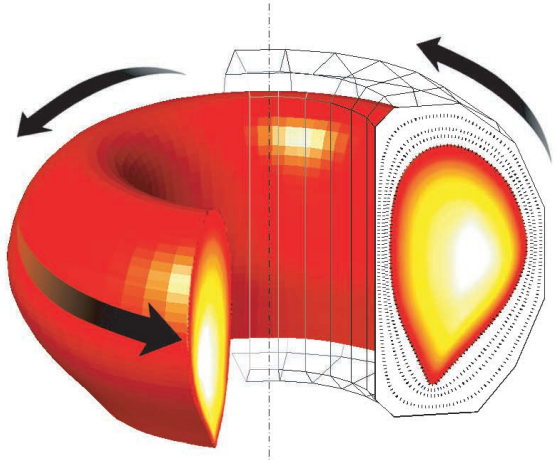
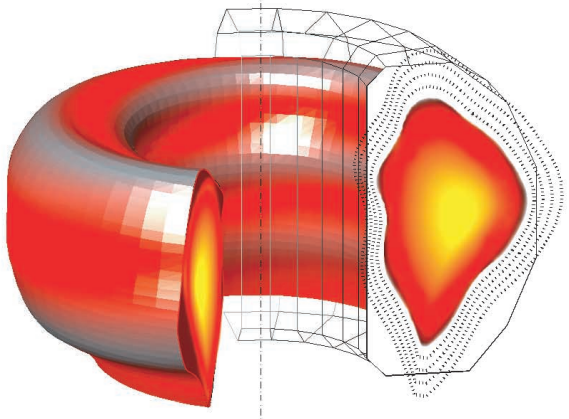
# Error Field Control and Stabilization Of RWM Results in HIGHER β



Stable



Unstable (x10 -Exaggerated)

- Stable high pressure operation important for *-AT-* Tokamak
  - Fusion power ~ (Pressure)$^2$
  - n=1 Kink mode can limit performance
- "Resistive wall mode" is stabilized by:
  - Minimizing error fields
  - Maintaining plasma rotation
- External Active control coils are used in feedback loop with magnetic sensors

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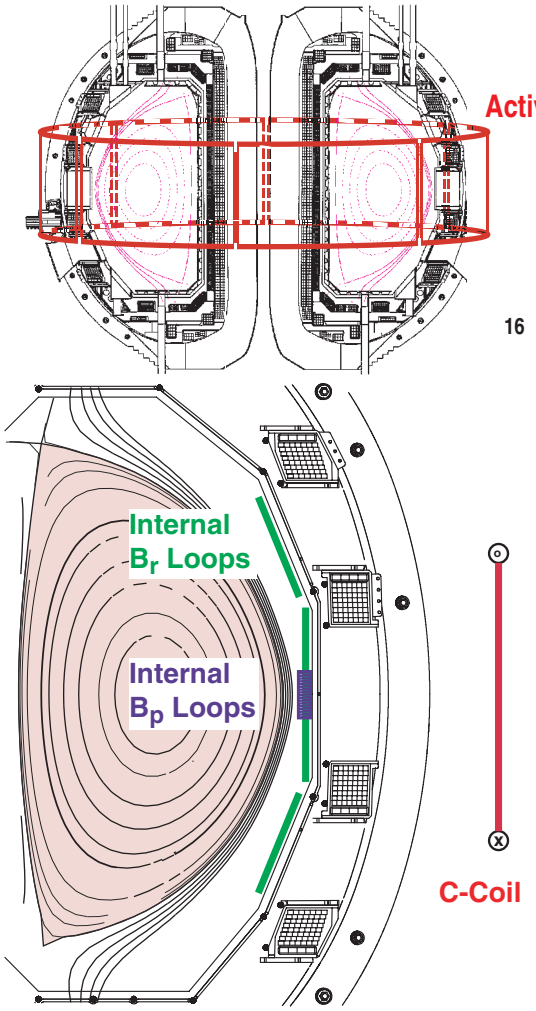
# $\beta_N$ is Maintained Well Above the No-Wall Limit for 1.5 Seconds

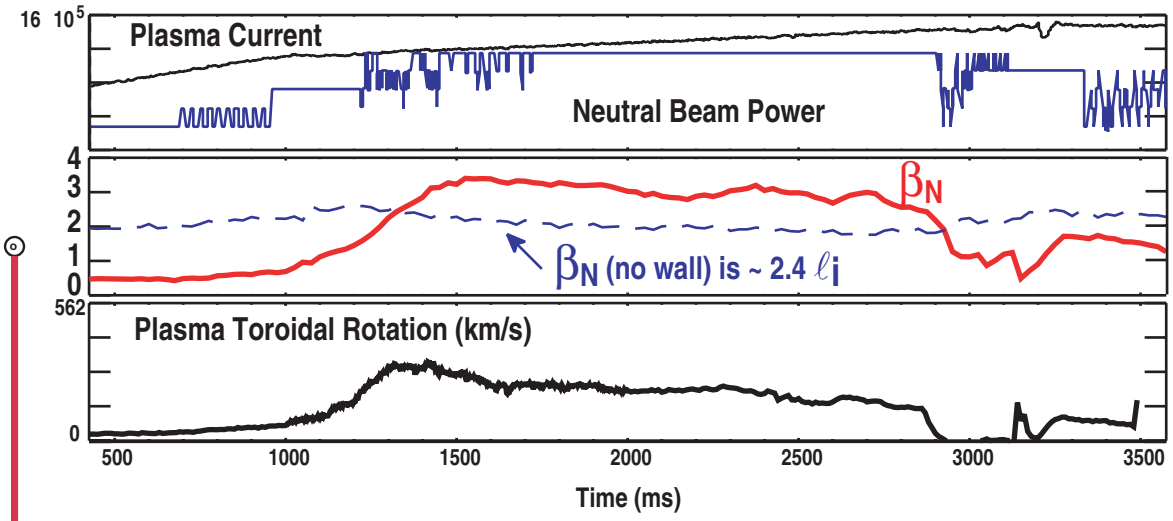



**Error Field Reduction:**

→ **Sustained plasma rotation**

→ **Stabilization of RWM**

**Results in High - β Operation**

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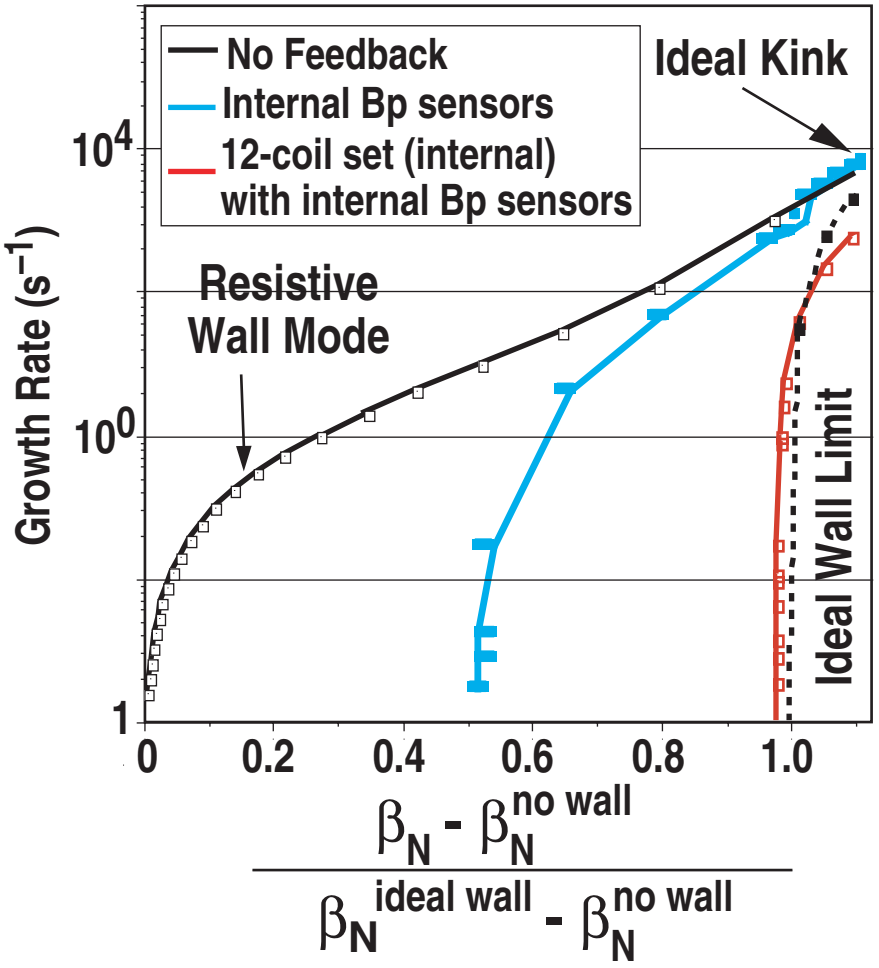
# RWM Stabilization (low rotation) and Error Field Optimization will be Studied with New Internal Coils

## VALEN Calculations




## 2 Prototype Coils In 2001

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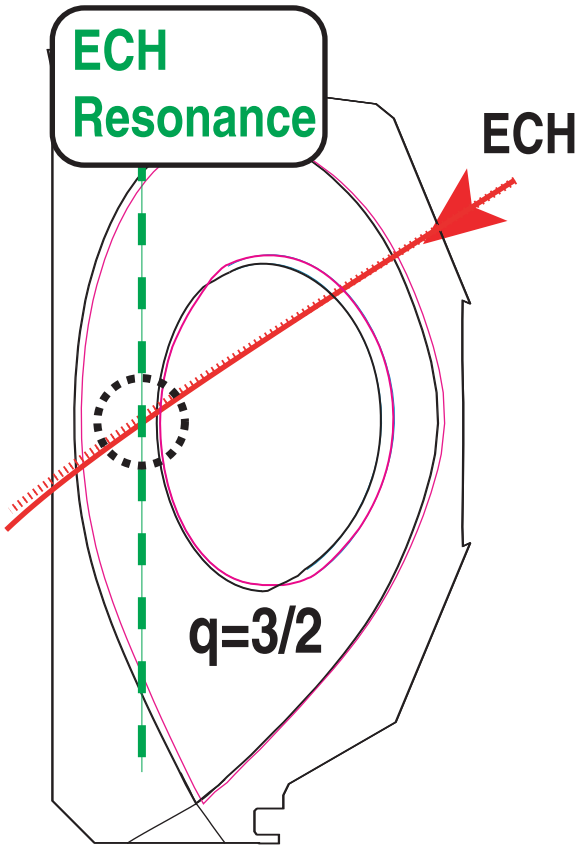
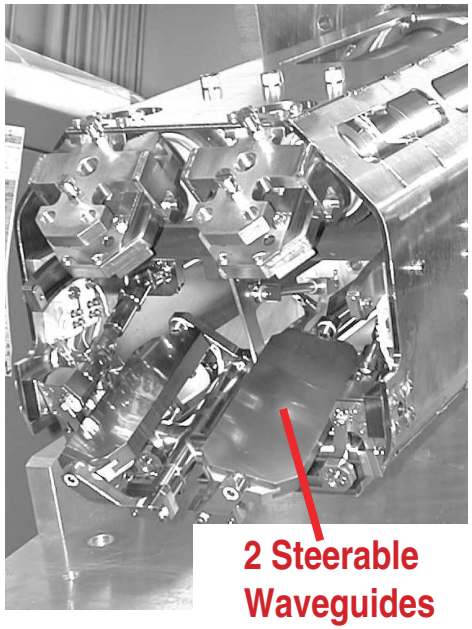
# Steerable ECCD is a Important Control Tool on DIII-D



2 Steerable Waveguides

PPPL Steerable
(Between Shots)
ECH Launcher
1 in 2001
2 in 2002

2001
Experiments with 4 gyrotrons

2002
Experiments with up to 6 gyrotrons

1 MW Class GYROTRON

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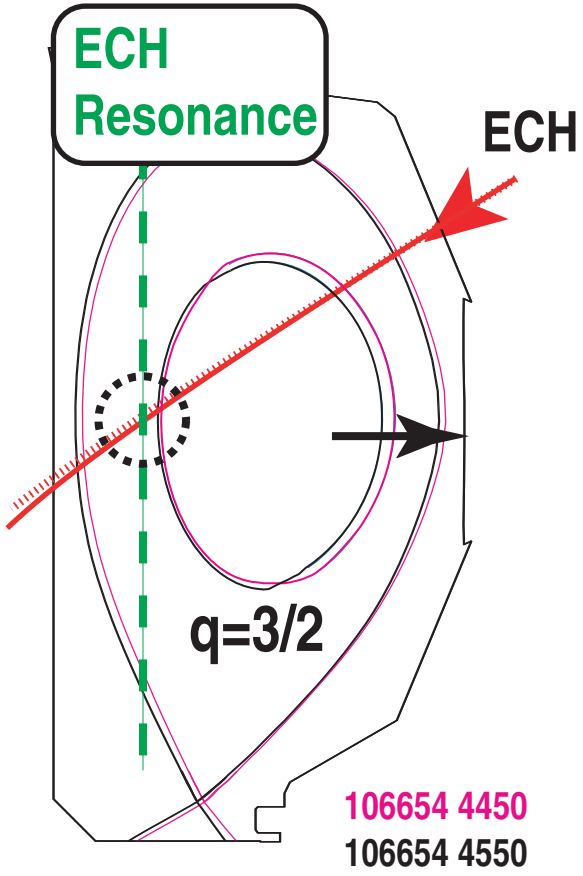
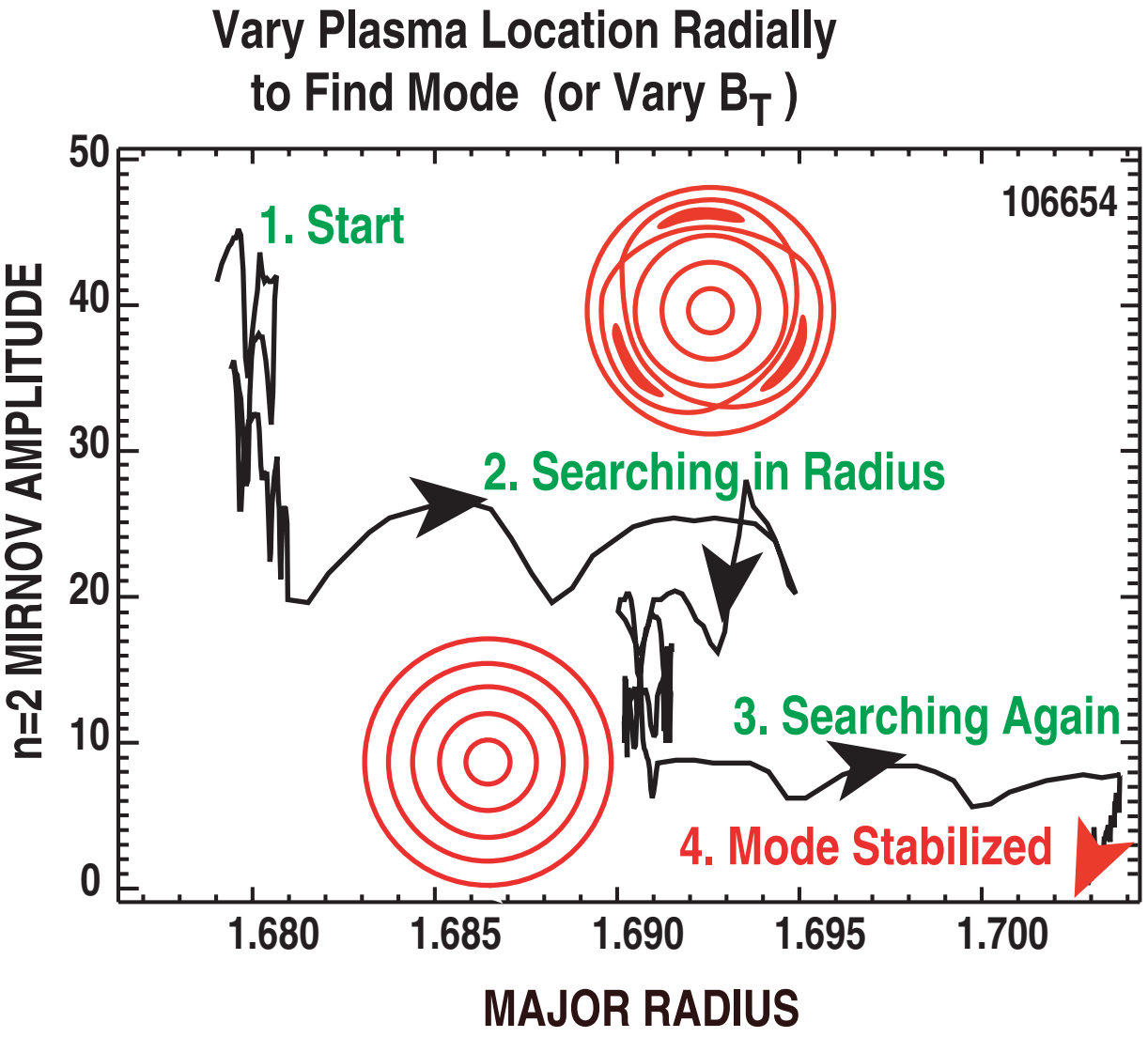
# 3/2 NTM Suppression with "Feedback" to Find Mode Location

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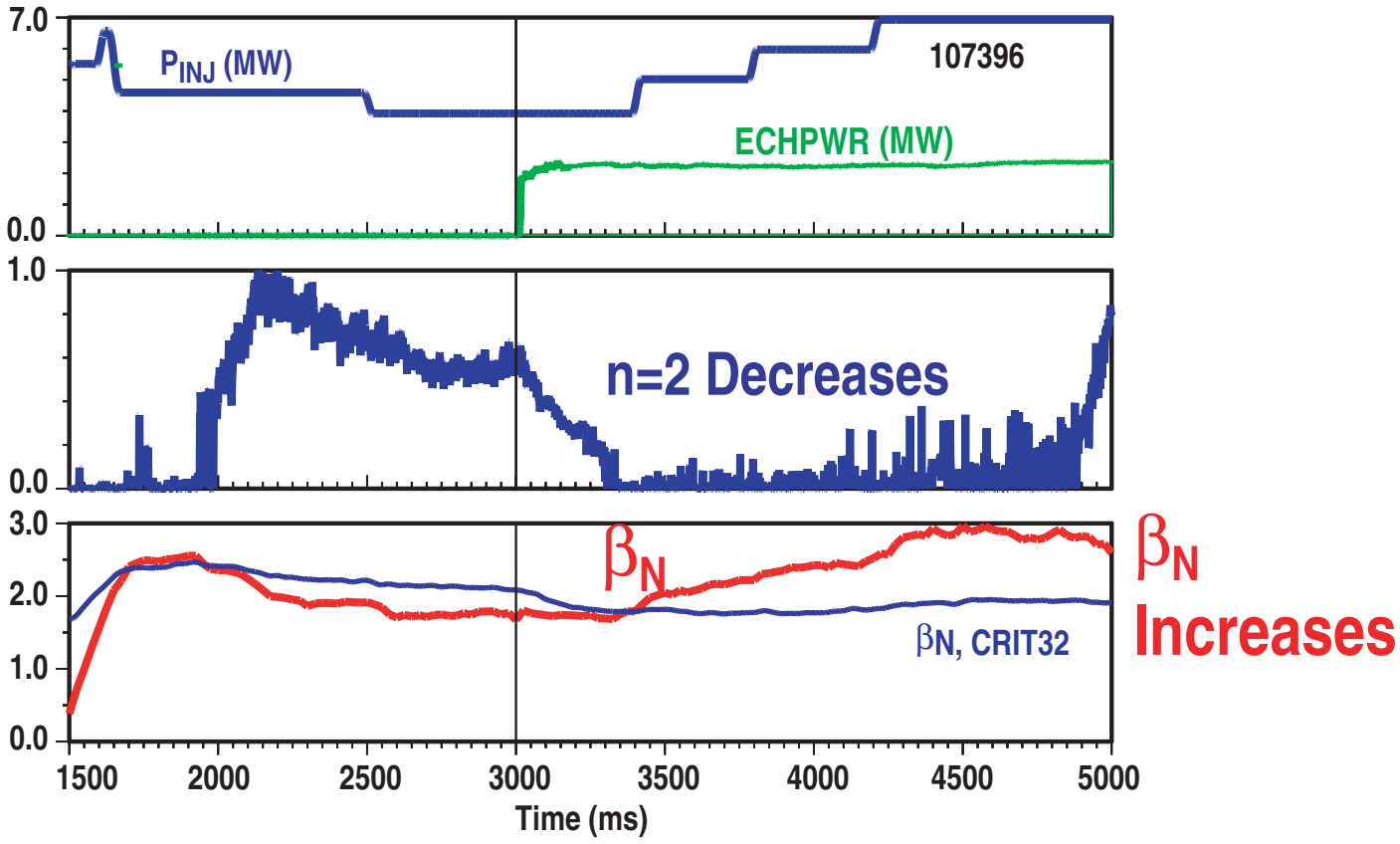
241-01/rs

# Localized ECCD Stabilizes NTM and Results in Higher $\beta_N$ Operation - Even with Sawteeth Present

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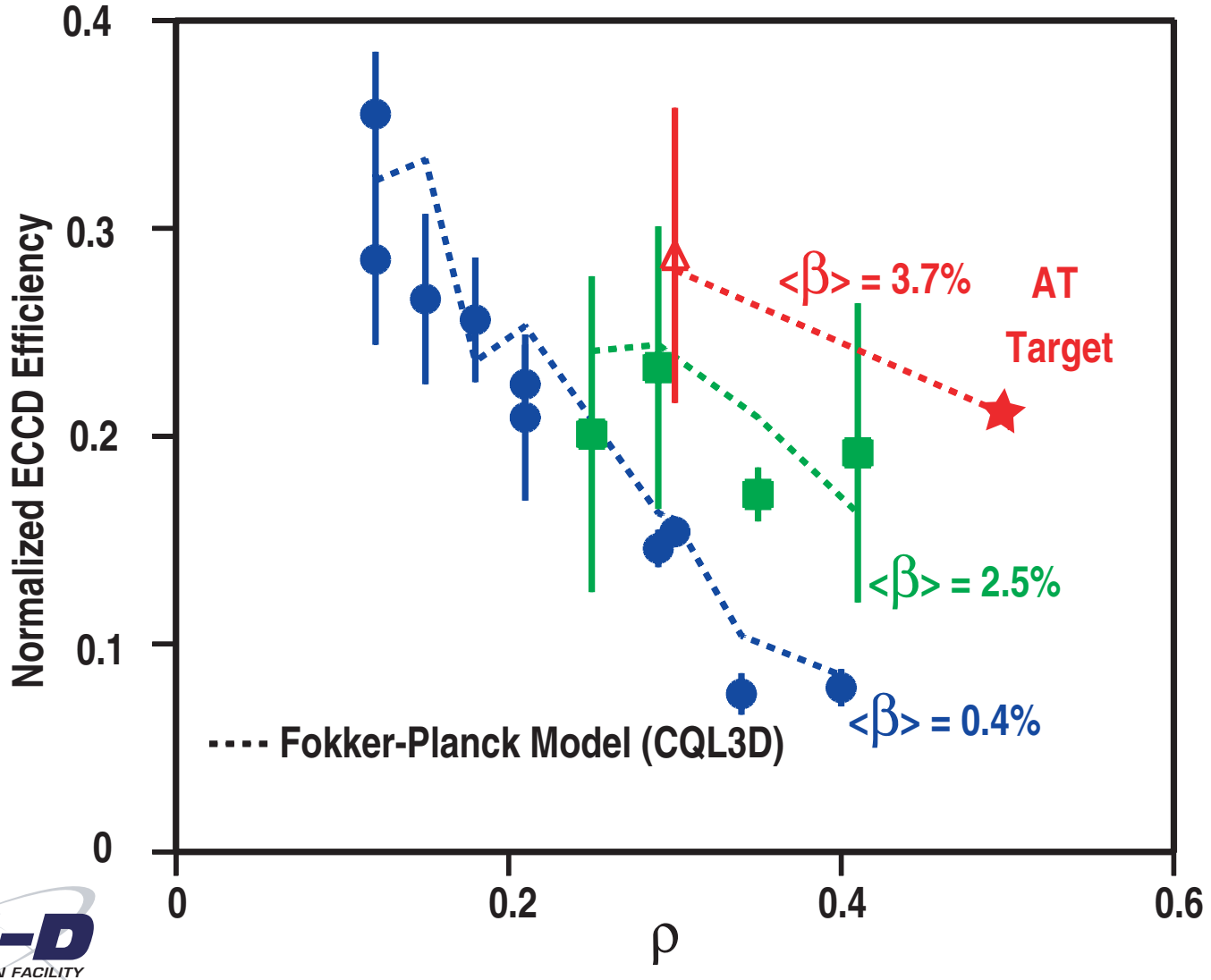
# OFF-AXIS ECCD EFFICIENCY AT HIGH ELECTRON BETA IS CONSISTENT WITH *-AT-* TARGET

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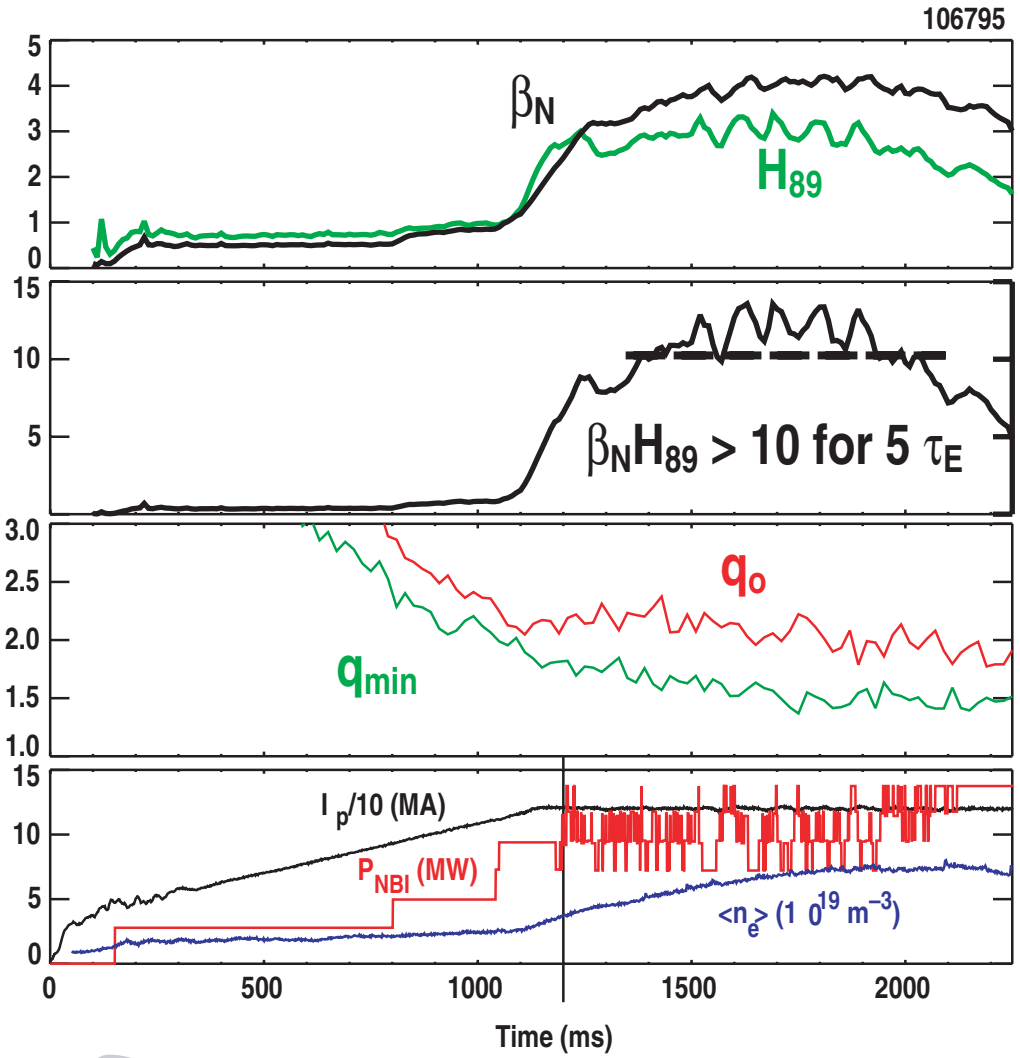
# 2001 Progress In –*AT*– Scenario Development

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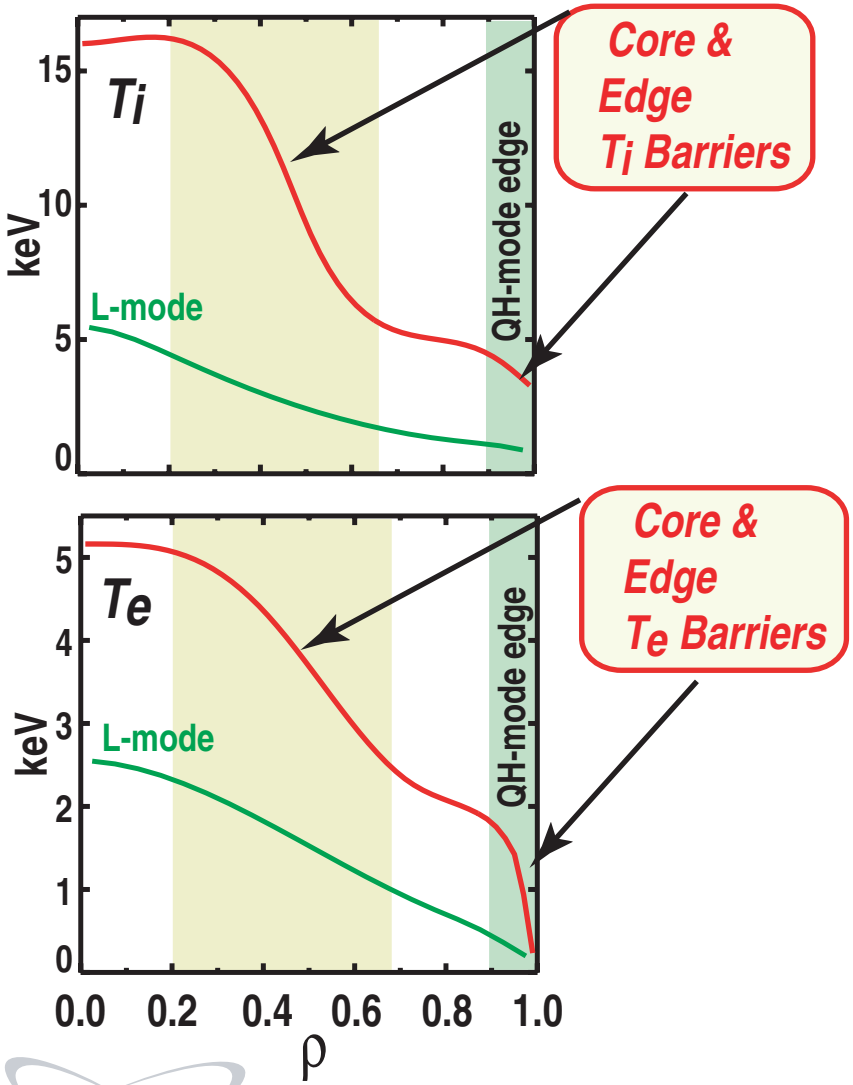
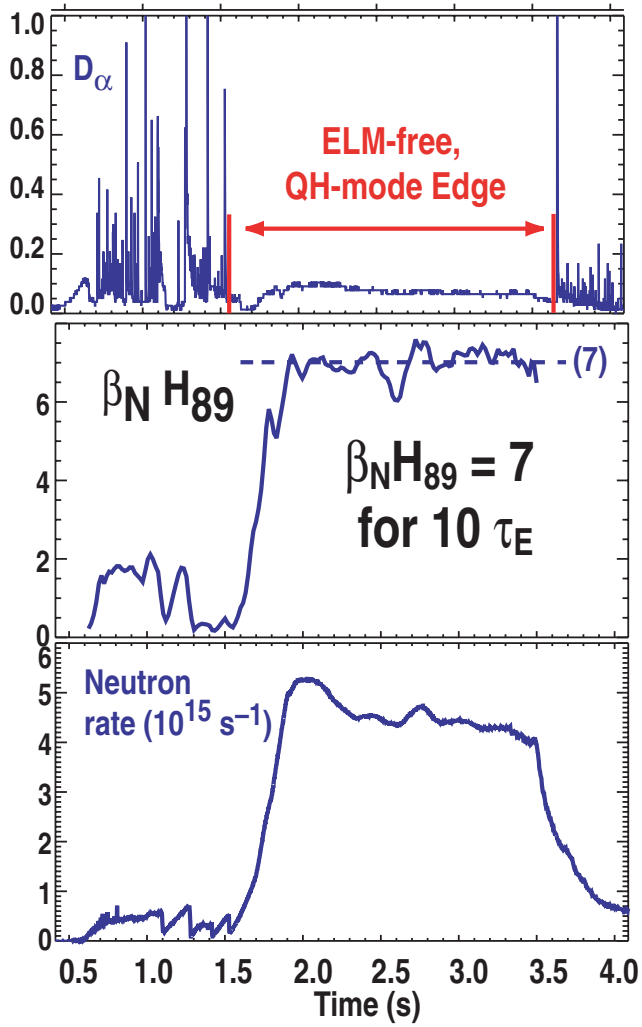
## Improvements:

- Error Field and RWM control
- Density control in AT shape
- Current drive efficiency consistent with predictions
- Bootstrap fraction 65%
- q-profile control:
  3/2 NTM controlled, working on 2/1 NTM control

# PROGRESS IN OPTIMIZING TRANSPORT BARRIERS -- Quiescent Double Barrier (QDB) Mode

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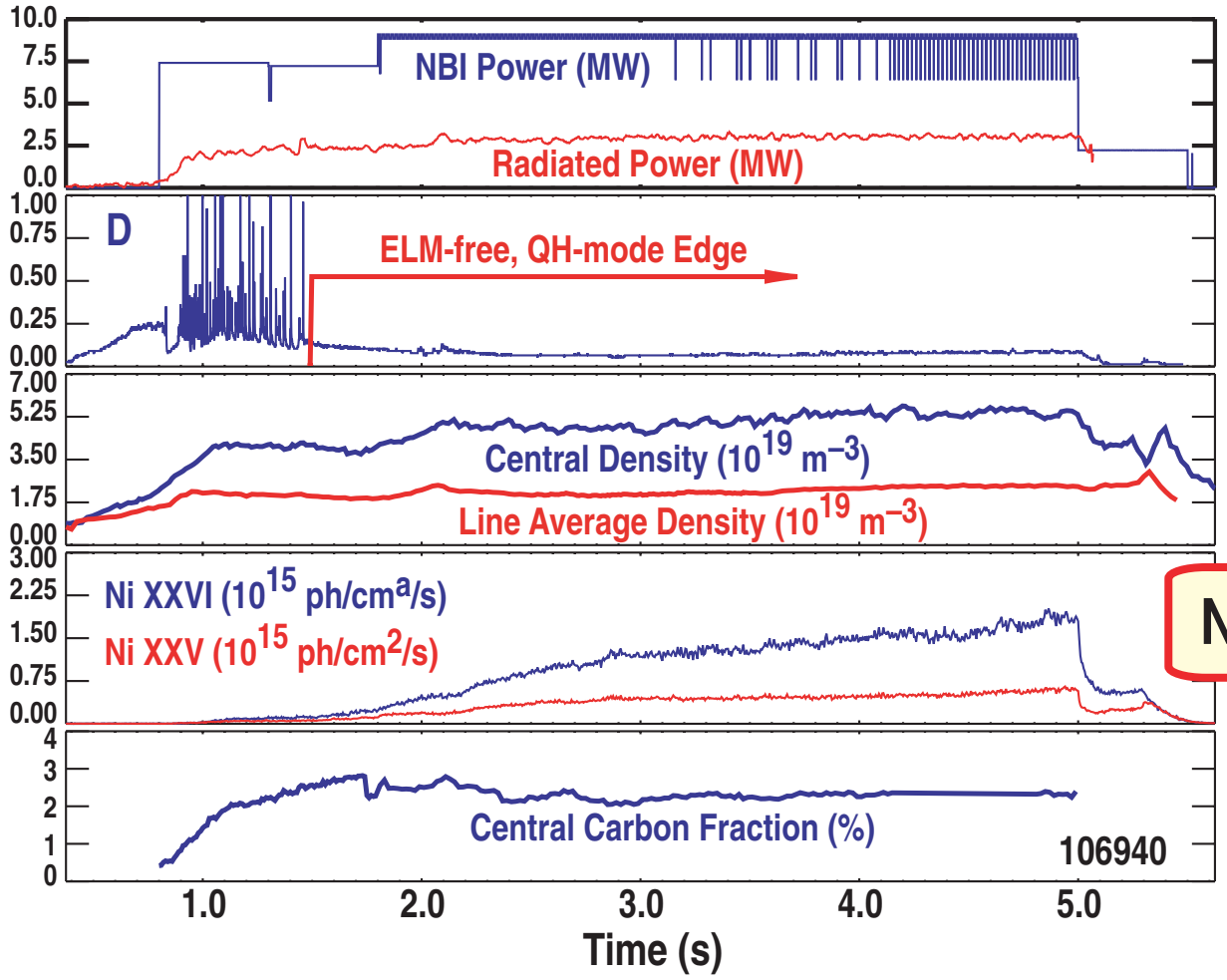
# High-Z Impurity Accumulation Is An Important Issue for Long Pulse QDB Discharges




Ni Increases

C Constant

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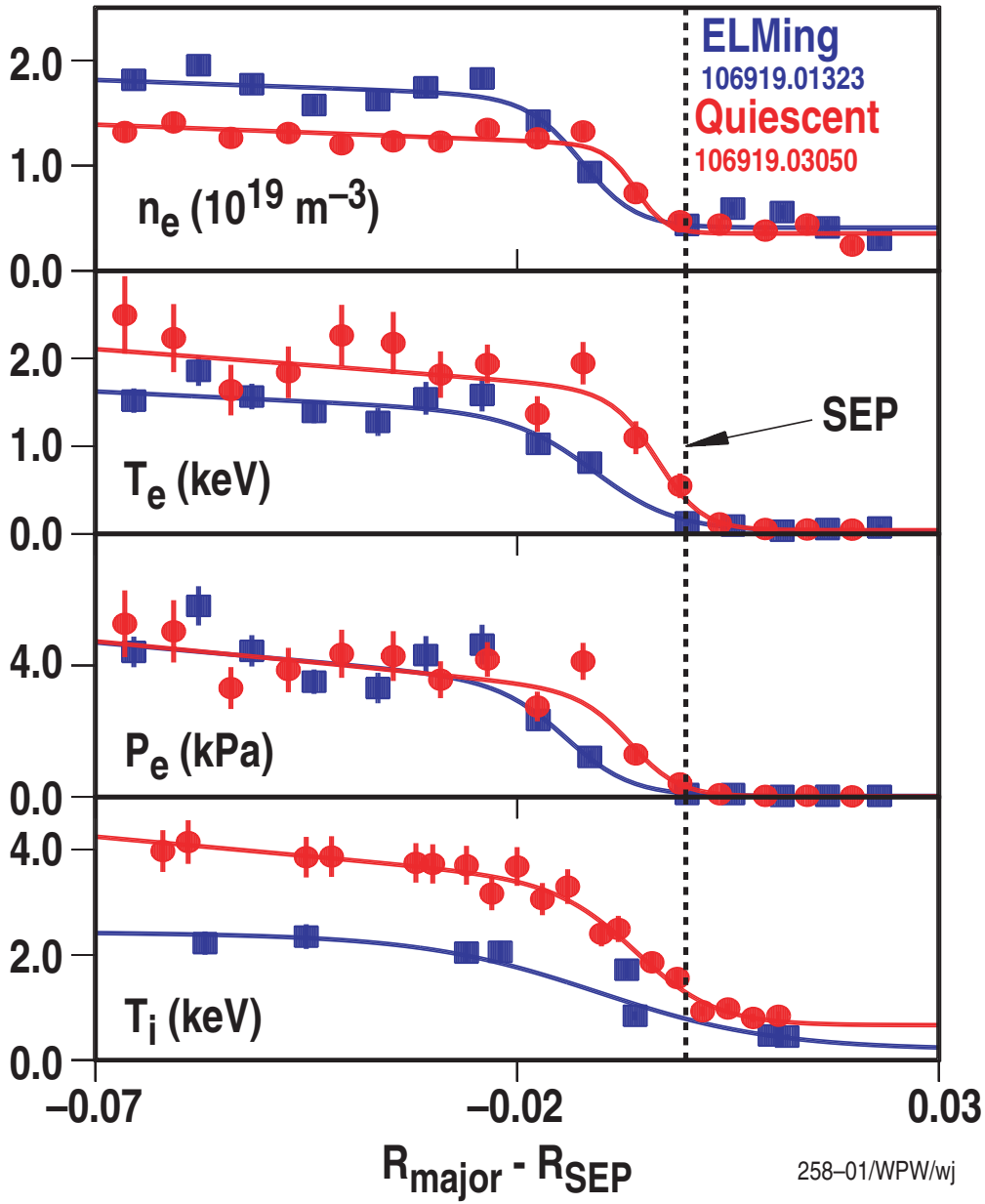
# The Plasma Edge of the QDB plasma is an H – Mode Edge

- Edge gradients in quiescent phase are comparable to those in ELMing phase
  - Note high $T_i$ pedestal
- QH–mode edge also has other standard H–mode signatures
  - Edge $E_r$ well
  - Reduced turbulence
- ELMs are replaced by a coherent MHD mode, the edge harmonic oscillation (EHO)

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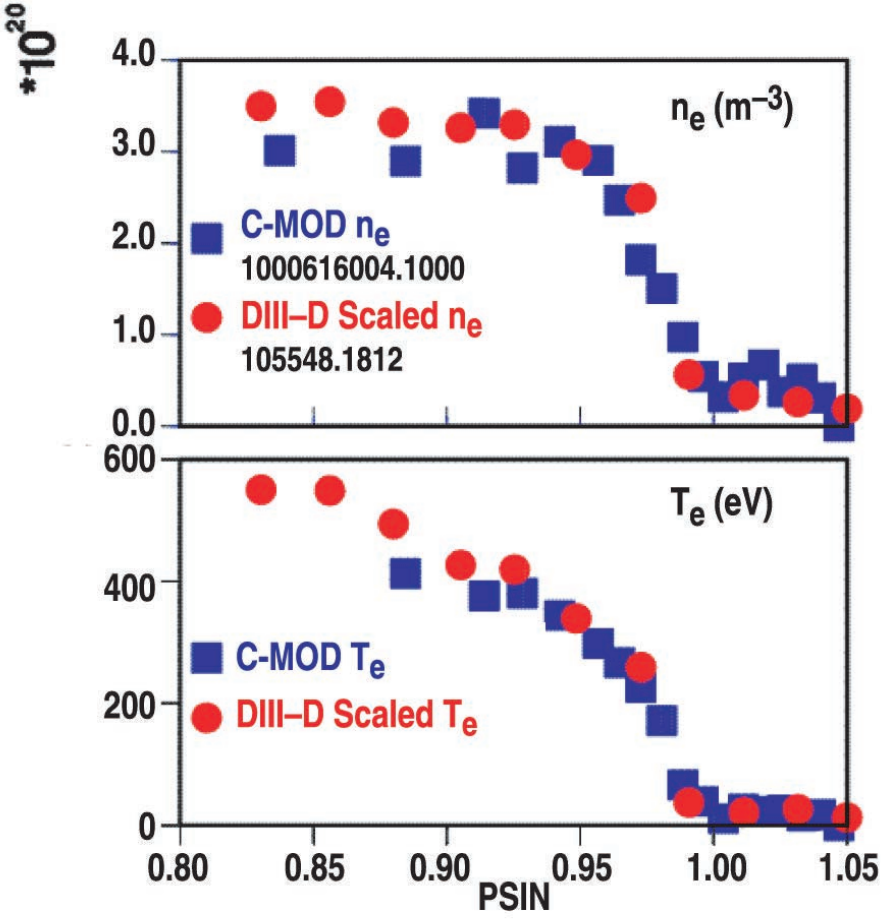
# C-MOD and DIII-D PEDESTALS SHOW "Nondimensional " Scaling

- Plasma shapes and q matched
- Maintain constant $\nu^*$, $\rho^*$, $\beta$ and Scale $T_e$ and $n_e$ in the Pedestal
- Reasonable agreement

$$\text{DIII-D:}\quad \frac{P_{sep}^{\text{scaled}}}{P_{sep}^{\text{measured}}} \sim \frac{7}{6}$$

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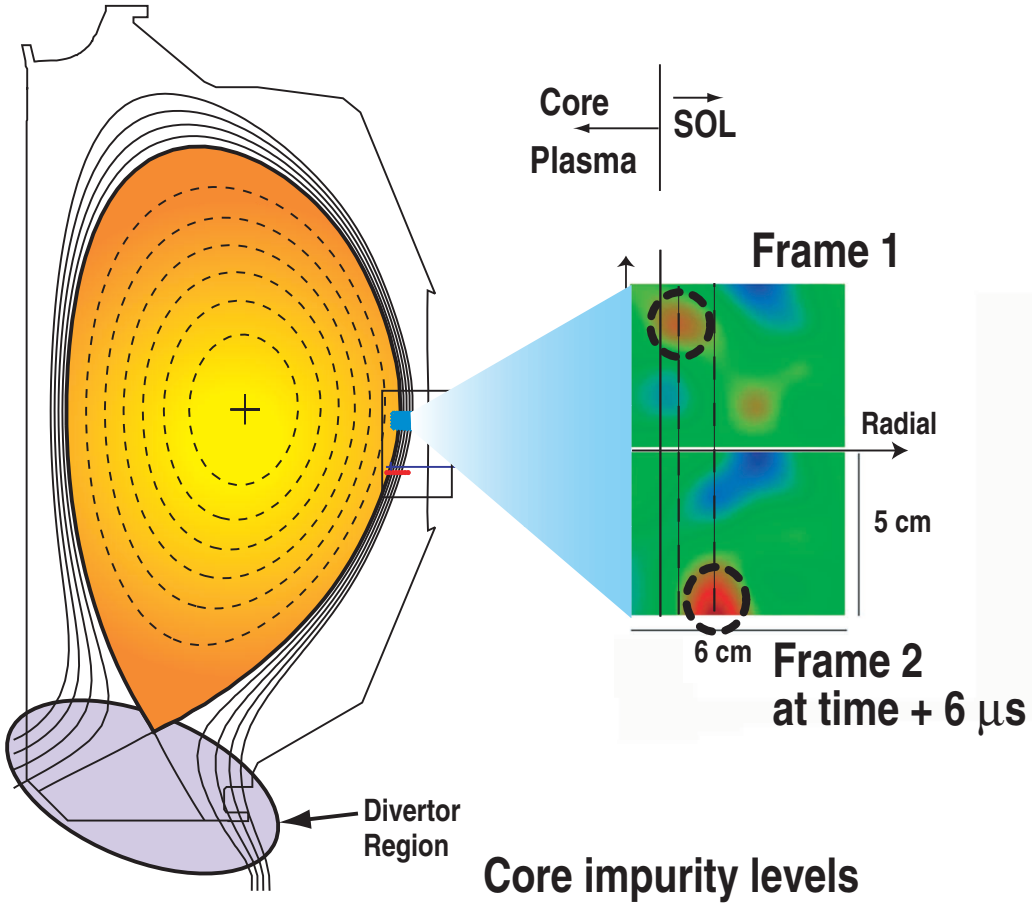
MIT PSFC

# INTERMITTANT CONVECTIVE TRANSPORT IMPORTANT, ESPECIALLY FOR IMPURITY GENERATION




Core impurity levels seem to correlate better with "main chamber" edge properties

- BES shows largest effect in L-mode, decreases in H-mode
- Probes show similar "blobs" of plasma
- Play a role in main chamber recycling and impurity sources

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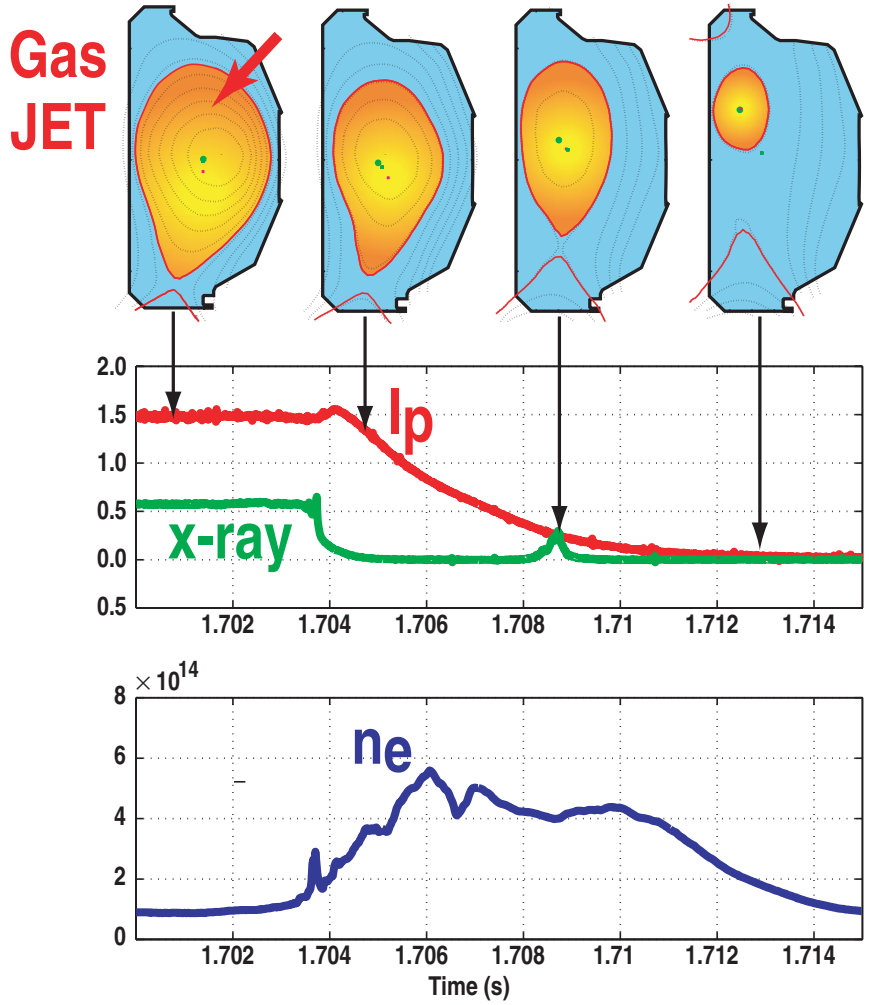
# Controlled Plasma Termination with High Pressure Noble Gas Injection Inhibits Fast Electrons




- Simple high pressure gas Jet preemptively terminates plasma
- Reduces disruption effects
  - Low thermal loads
    - 99% radiation
  - Low mechanical stress
    - reduces "halo" currents
  - No fast electrons
- Next shot returns to high performance

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# DIII-D Progress in 2001 in *A*dvanced *T*okamak –*AT*– Physics

## DIII-D Presentations:

- Monday morning -
  - morning --Resistive Wall Mode: *Garafalo*
  - --Neoclassical Tearing Mode: *La Haye*
- Wednesday*:*
  - morning --QDB and Impurities: *West*
  - afternoon --Pedestal studies: *Groebner*
  - --Poster Session
- Thursday:
  - morning --more oral talks
  - afternoon --Avalanches: *Politzer*
  - --Poster Session
- Friday:
  - morning --Turbulence scale lengths: *Rhodes*
  - --Gyrokinetic modeling: *Waltz*

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