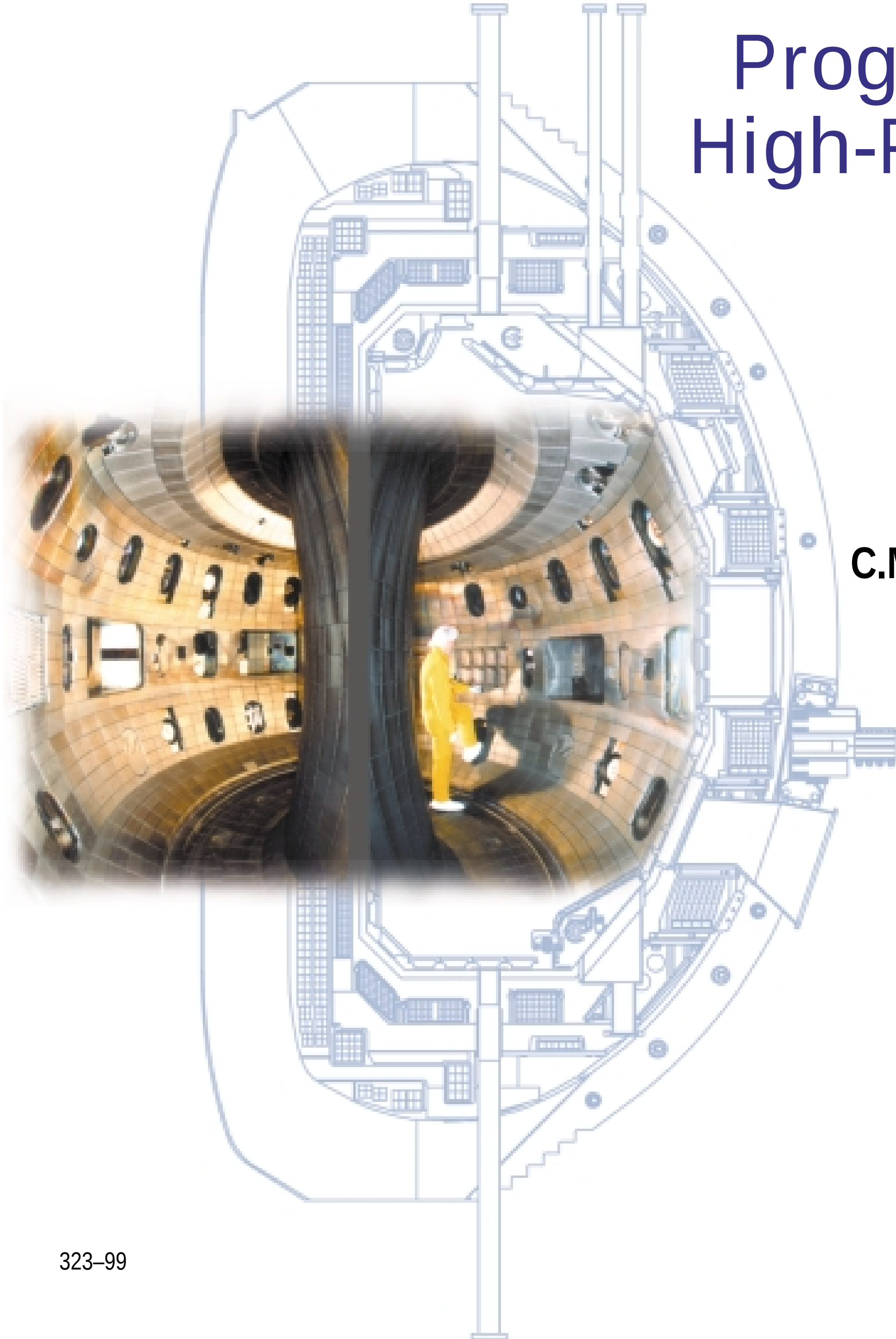

Progress Toward Long-Pulse High-Performance Discharges in the DIII–D Tokamak

by
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presented by P.A. Politzer
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Presented at
the American Physical Society
Division of Plasma Physics Meeting
Seattle, Washington

November 15–19, 1999

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Abstract Submitted
for the DPP99 Meeting of
The American Physical Society

Sorting Category: 5.1.1.2 (Experimental)

Progress Toward Long-Pulse High Performance Discharges in the DIII-D Tokamak[1] T.C. LUCE, P.A. POLITZER, J.R. FERRON, C.M. GREENFIELD, E.J. STRAIT, R.I. PINSKER, L.L. LAO, General Atomics, M.R. WADE, M. MURAKAMI, ORNL, B.W. RICE, LLNL, A.M. GAROFALO, Columbia U., M.E. AUSTIN, U.Texas — Discharges with high normalized performance ($\beta_{\rm N} \lesssim 4$, $H_{89}\beta_{\rm N} \lesssim 10$) have been sustained for up to 2 s with an ELMing H–mode edge. The performance was limited by resistive wall modes, not neoclassical tearing modes. The pressure is well above the calculated no-wall limit and $\beta_{\rm N} > 4\ell_{\rm i}$ for the entire high performance phase. Measurements of the internal loop voltage show that about 75% of the current is supplied non-inductively and greater than 50% of the total current is calculated to be bootstrap current. The q profile is flat, as is the calculated bootstrap current profile, due to the absence of any sharp internal transport barrier. The remaining inductive current is localized around the minor radius $\rho = 0.5$ which agrees with the design modeling. Density control is necessary to apply the ECCD in these discharges, and preliminary experiments with the cryopump have reduced the density by $\sim 20\%$.

[1]Supported by U.S. DOE Contracts DE-AC03-99ER54463, DE-AC05-96OR22464, and W-7405-ENG-48, and Grants DE-FG02-89ER53297 and DE-FG03-97ER54415.

[X] Prefer Oral Session
[ ] Prefer Poster Session

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Special instructions: DIII-D Contributed Oral Session, immediately following SL Allen

Date printed: July 20, 1999

Electronic form version 1.4

GOALS

- A steady-state high-gain fusion system requires
  - Maximized bootstrap current $\Rightarrow$ higher q_{min}, q_{95}
  - Maximized wall loading $\Rightarrow$ operation above conventional ELMing H–mode limits ($\beta_N \sim 2.5$, $H_{89} \sim 2.0$)

- In the near-term the goal is to demonstrate simultaneously in DIII–D
  - Normalized performance twice that of conventional ELMing H–mode ($\beta_N H_{89} \gtrsim 10$)
  - Fully non-inductive current sustainment with >50% bootstrap current

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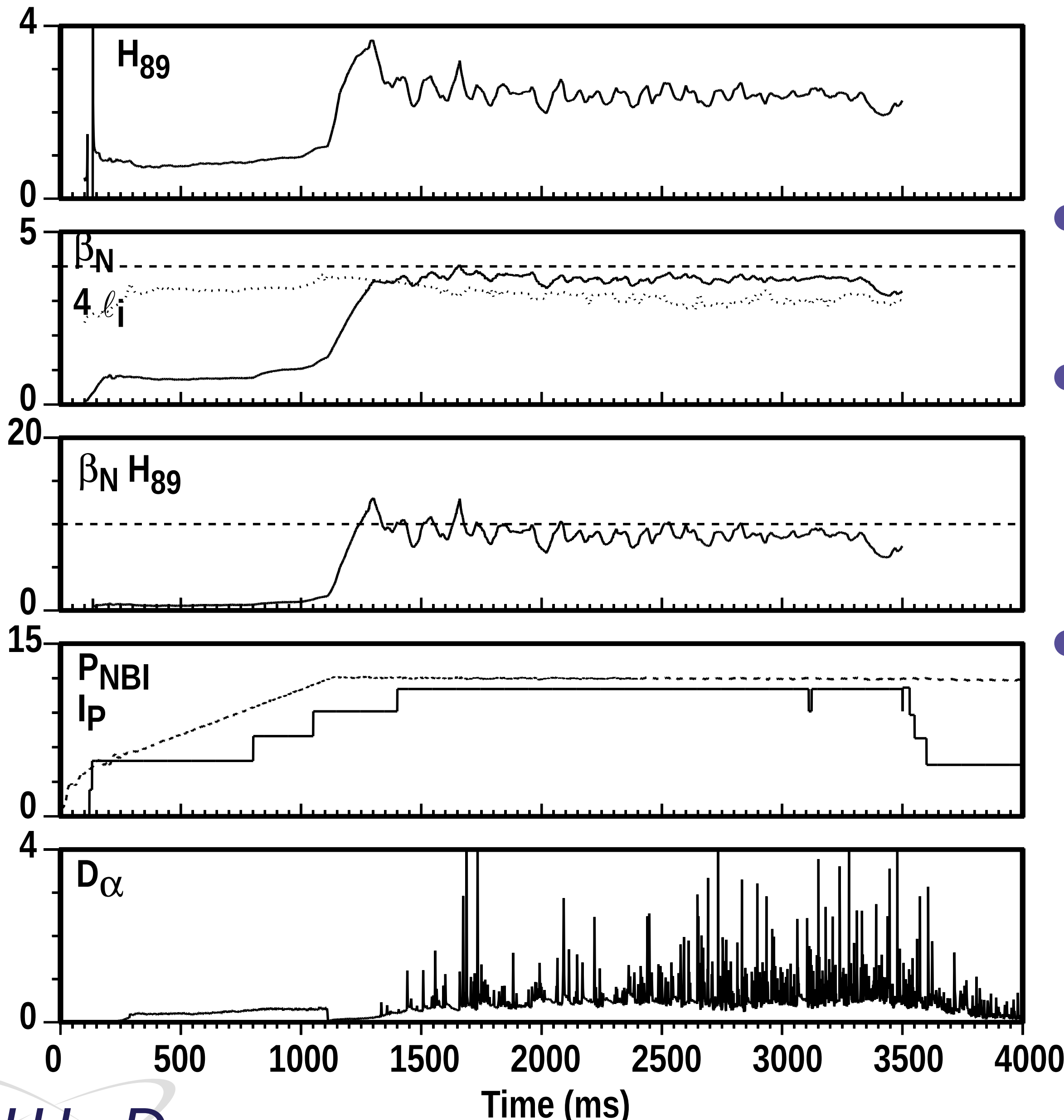
$\beta_N H_{89}$ ~9 SUSTAINED FOR ~$16\tau_E$, $1\tau_R$



Talk Outline

- Successful transition to ELMing phase
- Limits to steady performance magnitude and duration
- Necessary additions for fully non-inductive operation

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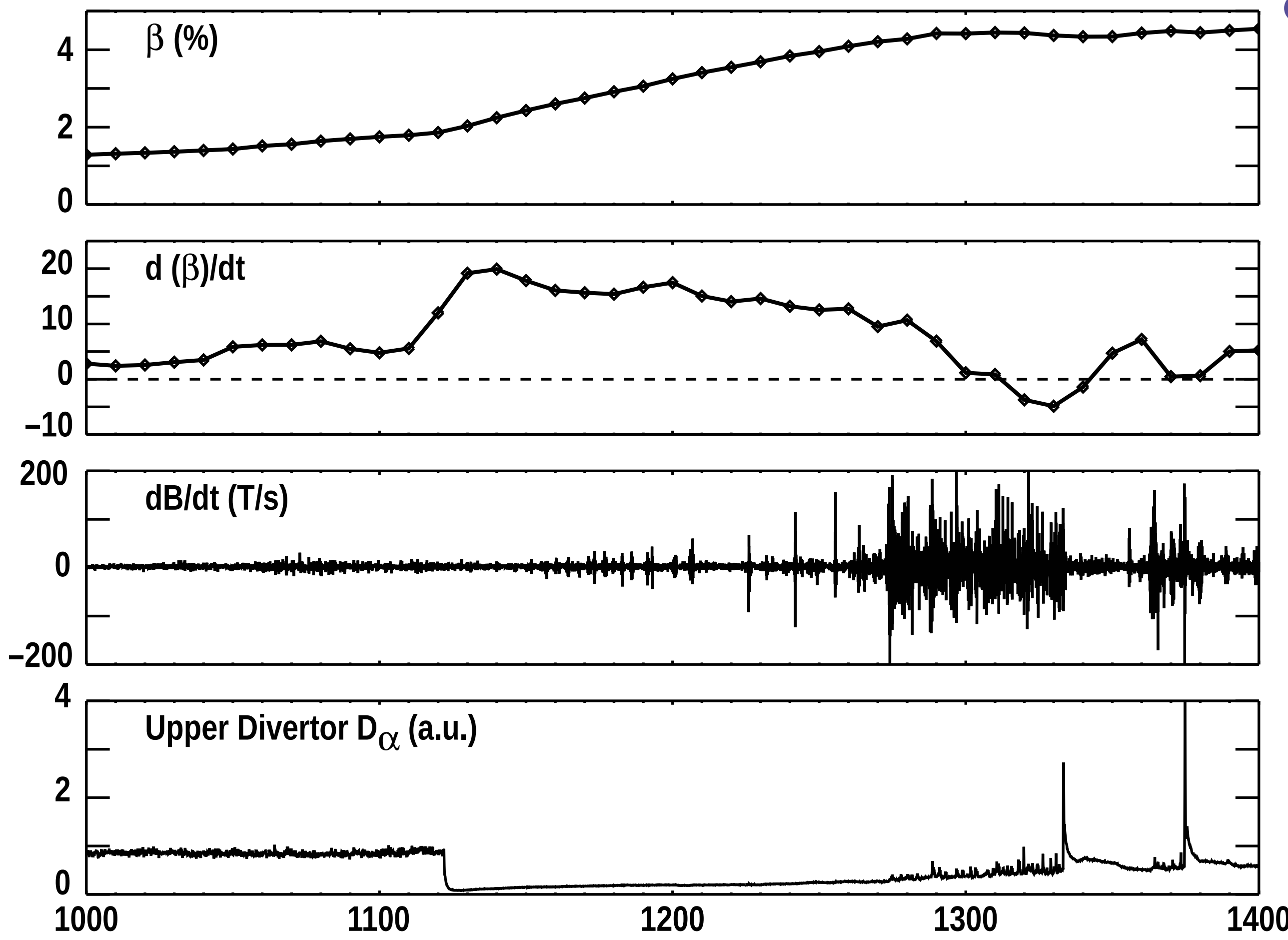
BETA SATURATION IN THE INITIAL PHASE IS DUE TO BURSTING HIGH-FREQUENCY MHD



- Bursts are consistent with Alfvénic modes driven by the fast ions:
  - f = 100 – 200 kHz
  - n = 5 – 9
  - Onset is roughly independent of total β, q profile

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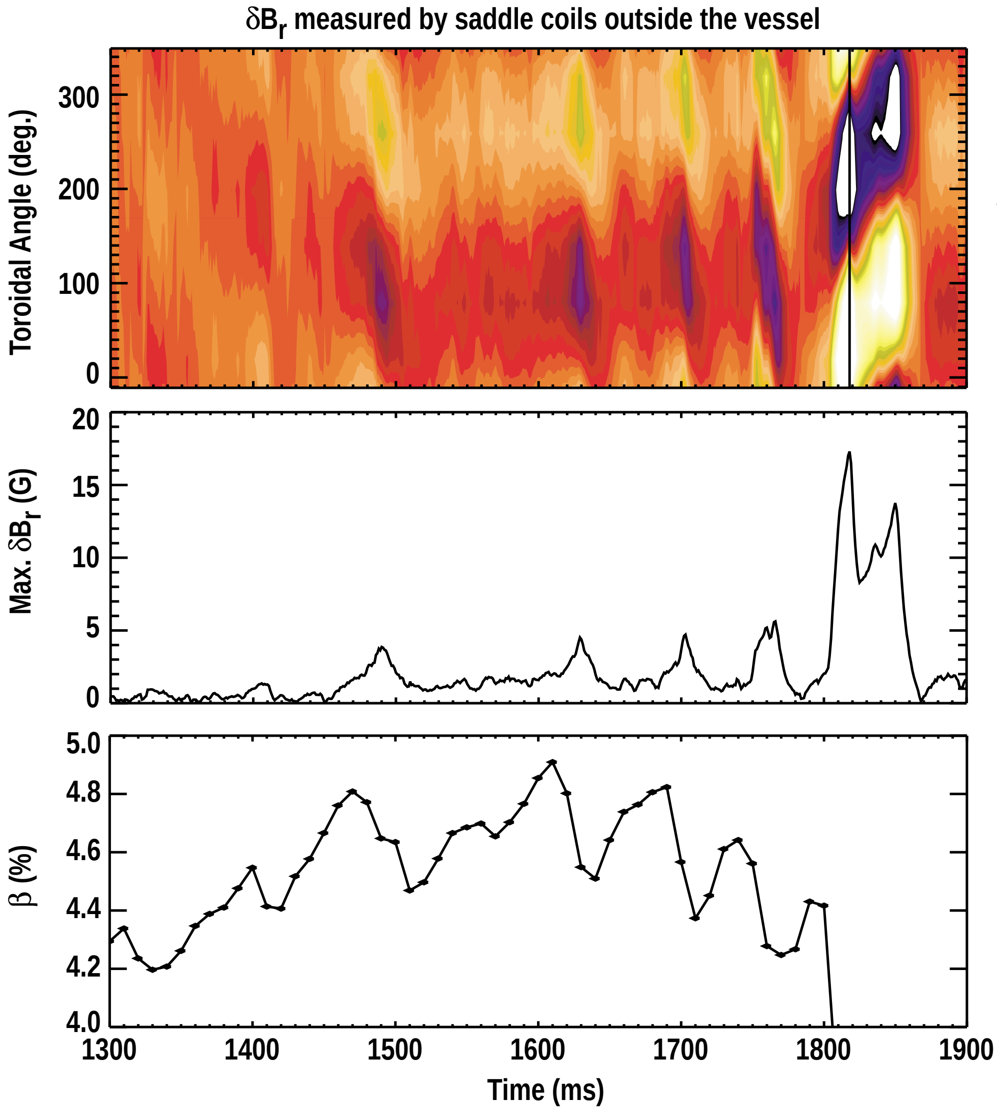
BETA IS LIMITED IN MAGNITUDE AND DURATION BY RESISTIVE WALL MODES



Limiting modes have the characteristics of resistive wall modes:

- Onset is at or above the no-wall ideal limit ($\beta_N \gtrsim 4\ell_i$)
- Growth rate consistent with characteristic wall time
- Real frequency (<100 Hz) consistent with wall time, not fluid rotation
- Stabilization of the mode at early times is not yet explained

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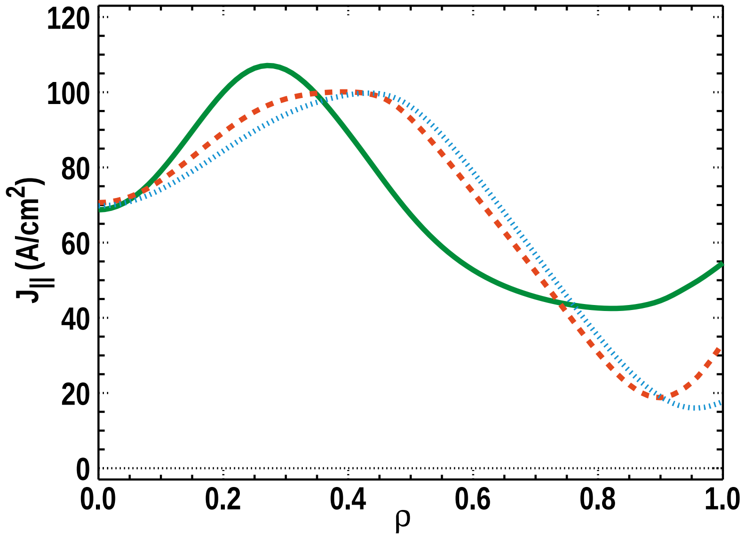
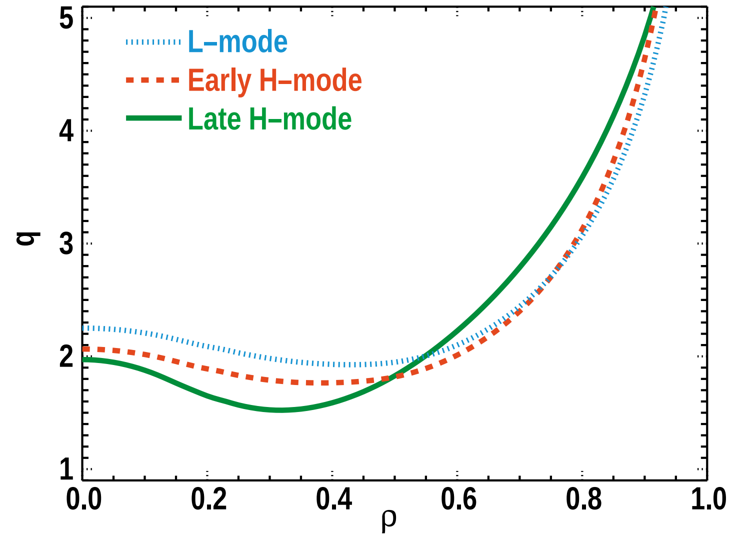
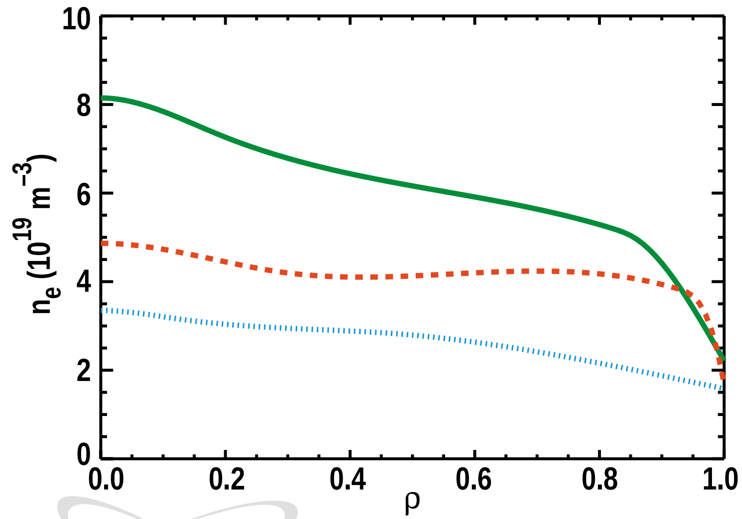
DENSITY CONTROL AND NON-INDUCTIVE CURRENT SUSTAINMENT ARE REQUIRED TO ACHIEVE STATIONARY HIGH PERFORMANCE

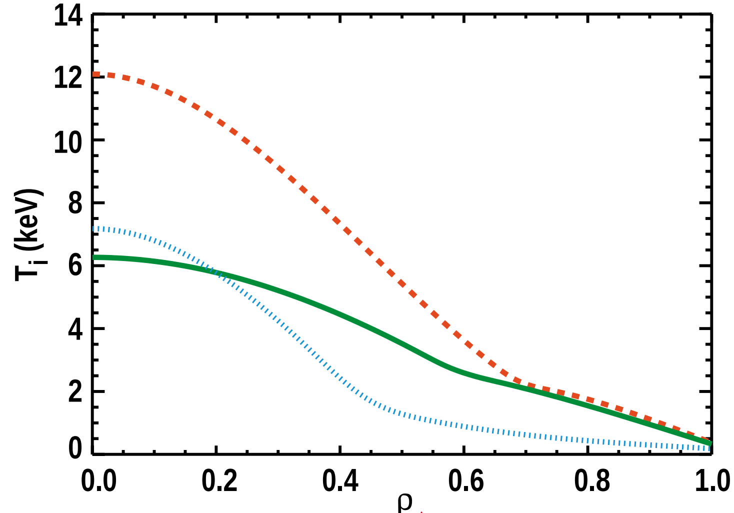
- Current profile diffuses to unstable profile





- Density continuously grows at constant β





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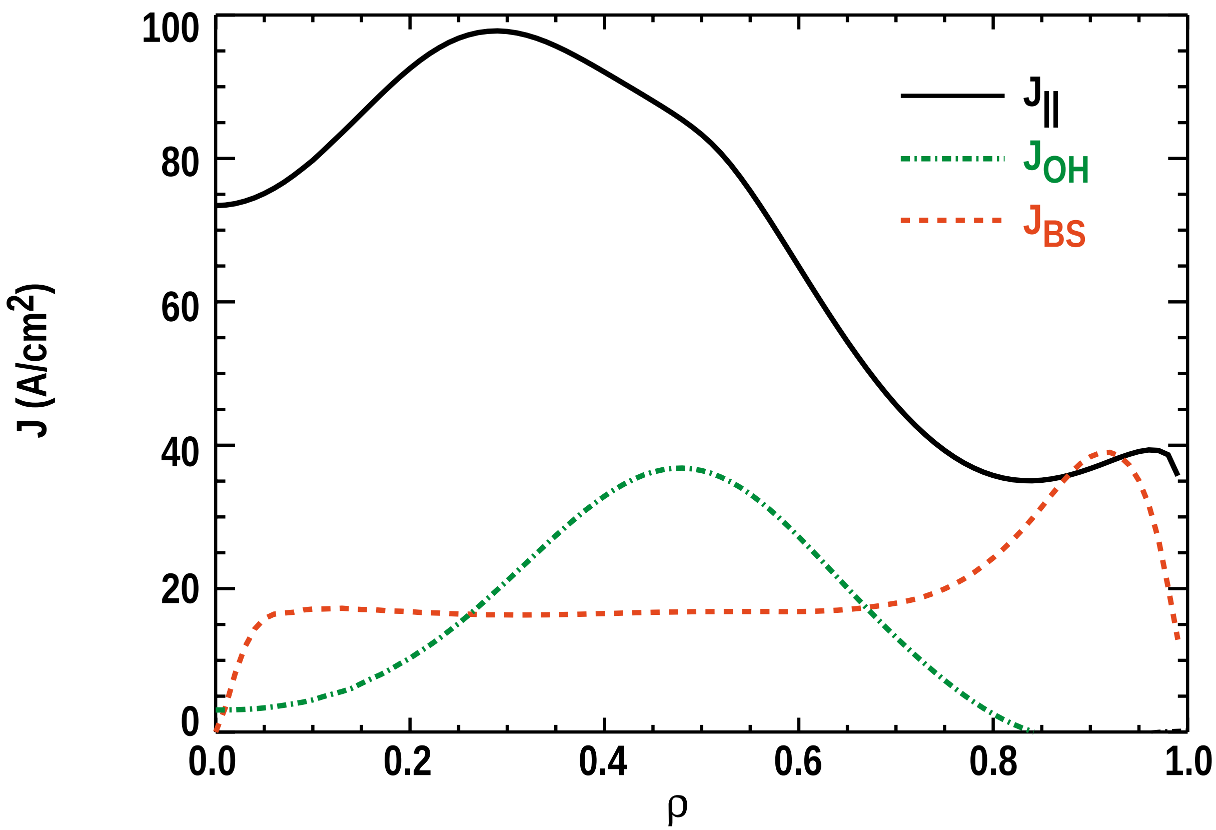
NON-INDUCTIVE CURRENT NEEDS TO BE SUPPLIED AT THE HALF RADIUS FOR STEADY STATE



- $J_{||}$, $E_{||}$ determined from the time history of magnetic reconstructions
- f_{BS} ~50%, f_{NI} ~ 75%
- ECCD at the half radius will be required for steady-state

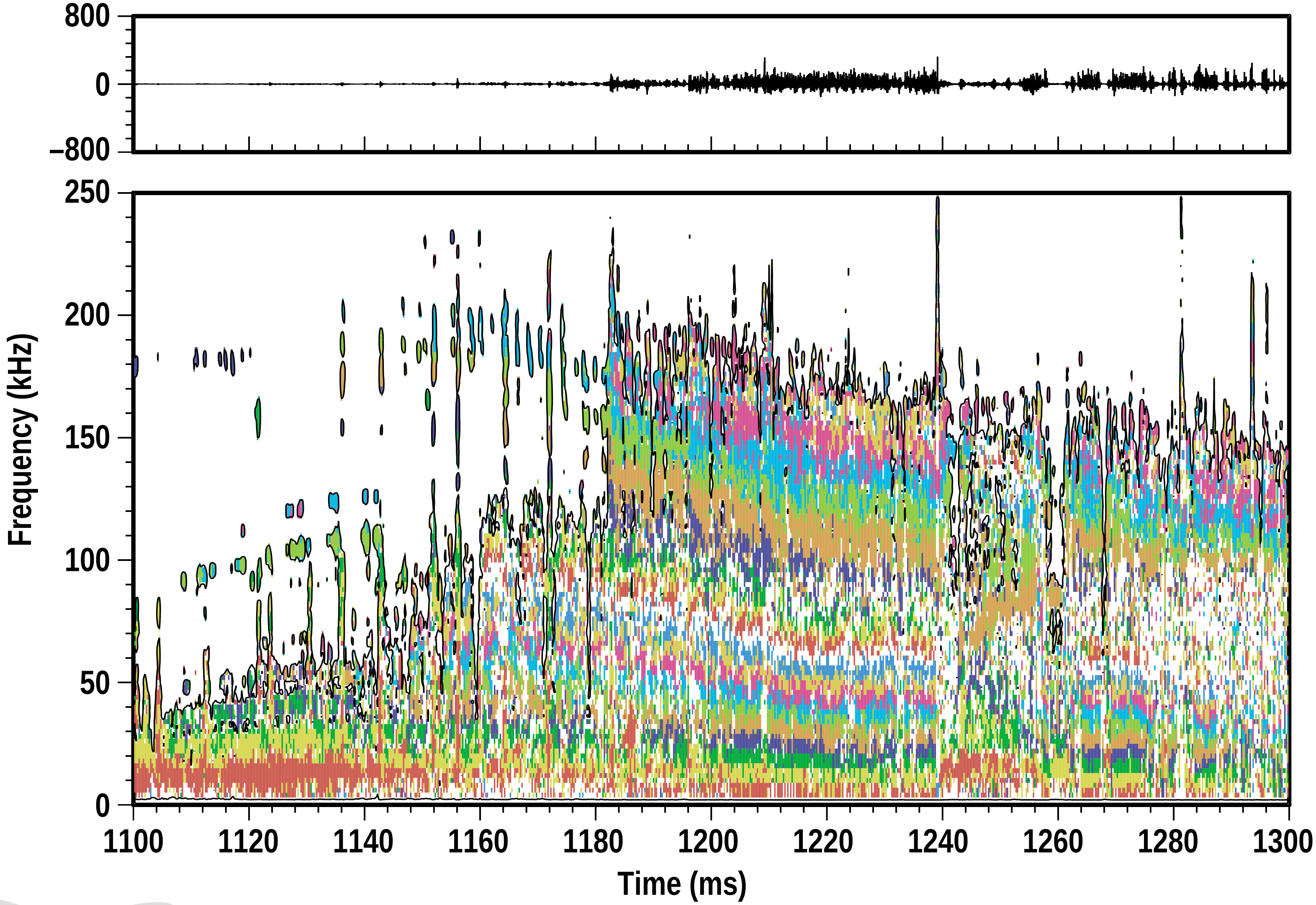
OUTLOOK

- **Density control is required to realize the goal of full non-inductive current sustainment. Preliminary experiments this year demonstrated reduction of the line-averaged density ~20%. The new pump in the upper divertor is expected to enhance the density control.**

- **The instabilities driven by fast ions and the overdrive of the central current by NBCD motivate reduction of the neutral beam power and voltage as much as possible.**

- **Upgrade of the ECH/ECCD system combined with density control should allow stationary, fully non-inductive, high performance operation.**

BETA SATURATION IN THE INITIAL PHASE IS COINCIDENT WITH THE ONSET OF HIGH–n, HIGH-FREQUENCY MAGNETIC FLUCTUATIONS



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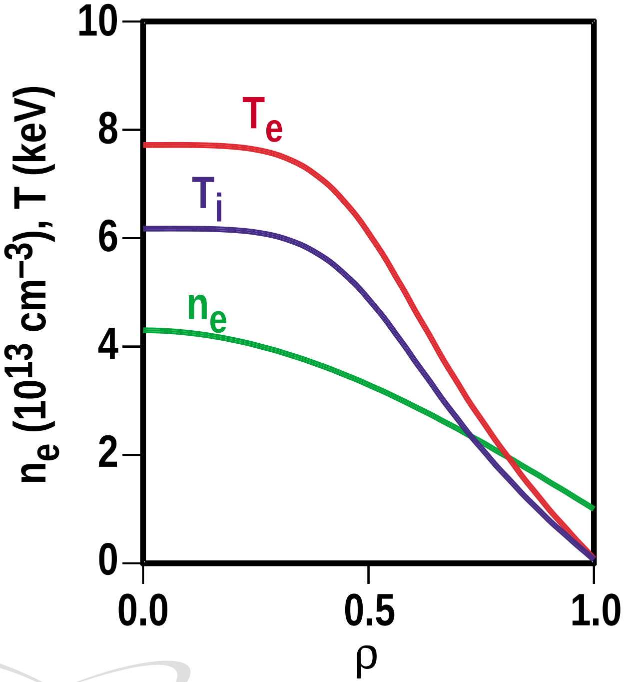
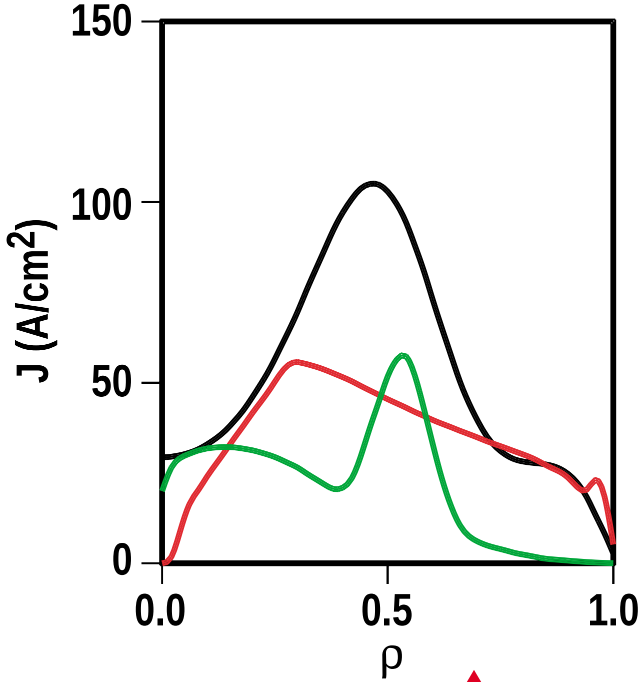
STEADY-STATE WITH $\beta_N H > 10$ CAN BE SUSTAINED BY < 2.5 MW EC POWER

$B = 1.6$ T	$I = 1.0$ MA
$n = 3.2\ 10^{13}\ cm^{-3}$	
$q_{95} = 5.7$	$q_0 = 4.6$
$\beta_N = 4.0$	$H = 2.8$
$P_{FW} = 3.6$ MW	
$P_{EC} = 2.3$ MW	$I_{EC} = 0.15$ MA
$P_{NBI} = 4.1$ MW	$I_{NBI} = 0.24$ MA
$\beta_P = 2.1$	$I_{BS} = 0.65$ MA





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