Progress on Demonstration of ITER Operational Scenarios on DIII-D

E.J. Doyle[1],
for R.V. Budny[2], J.C. DeBoo[3], J.R. Ferron[3], T.C. Luce[3], T.H. Osborne[3], P.A. Politzer[3], A.W. Hyatt[3], R.J. La Haye[3], J. Kinsey[3], G.M. Staebler[3], E.J. Strait[3], A. Weilander[3], and the ITER Demo. Working Group

[1] University of California, Los Angeles
[2] PPPL
[3] General Atomics

Presented at the
51st APS DPP Meeting
Atlanta, Georgia
November 2-6, 2009

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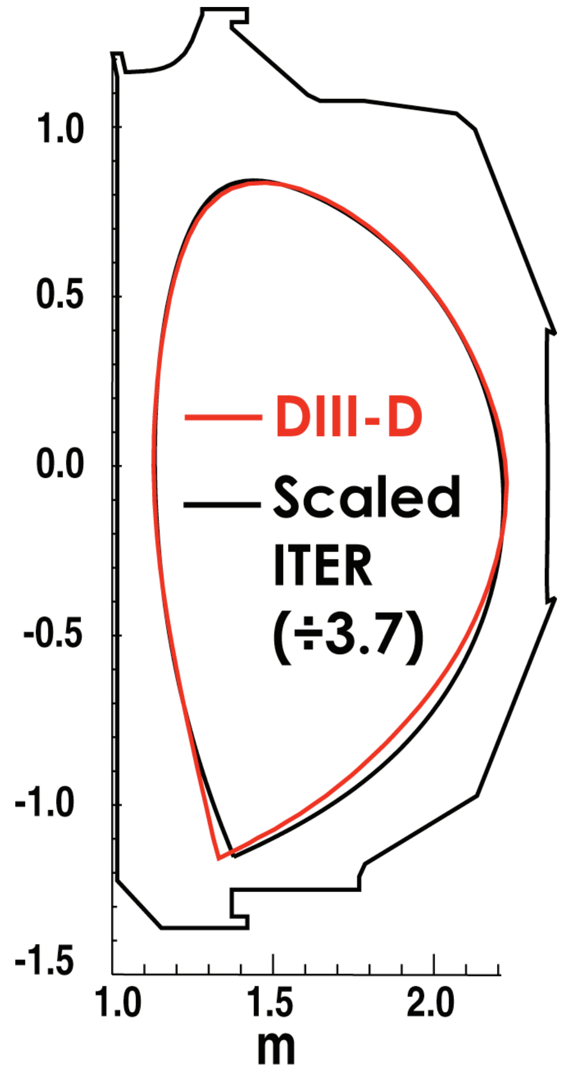
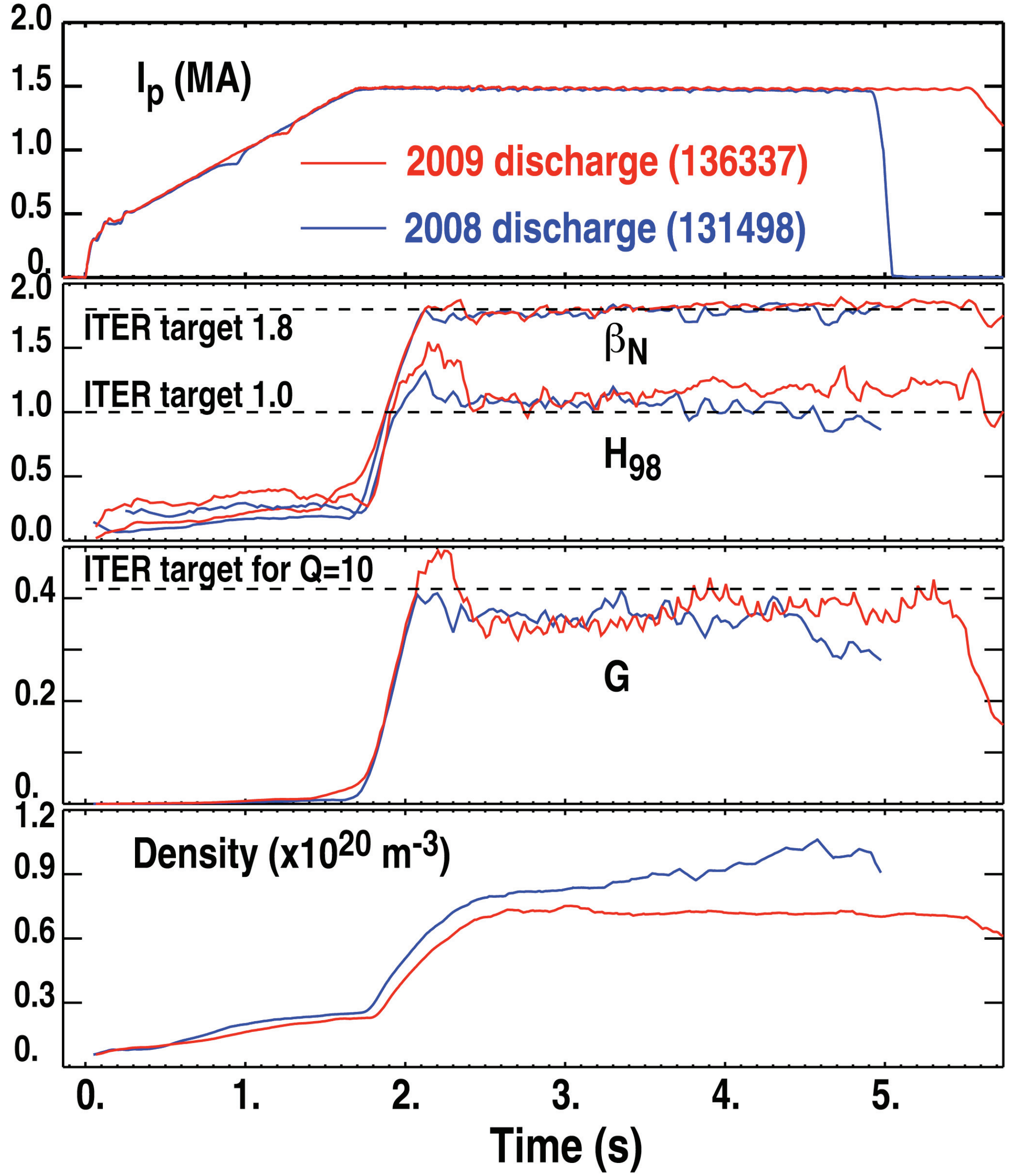
DIII-D has Unique Capability to Evaluate ITER Scenarios While Matching Leading Normalized Design Parameters

- **In 2008, four main ITER scenarios were demonstrated: baseline, steady-state, hybrid, and advanced inductive**
  - Matched ITER shape, aspect ratio, I/aB, β_N, H_{98}, f_{NI}
- **In 2009, match to ITER baseline scenario was improved:**
  - Improved density control and stationarity
  - Added match of ITER target collisionality
  - First demonstration of preemptive stabilization of 2/1 NTM in ITER baseline plasma with ECCD
  - Initiated study of effect of reduced plasma rotation on confinement
  - Successful TGLF modeling of scenarios



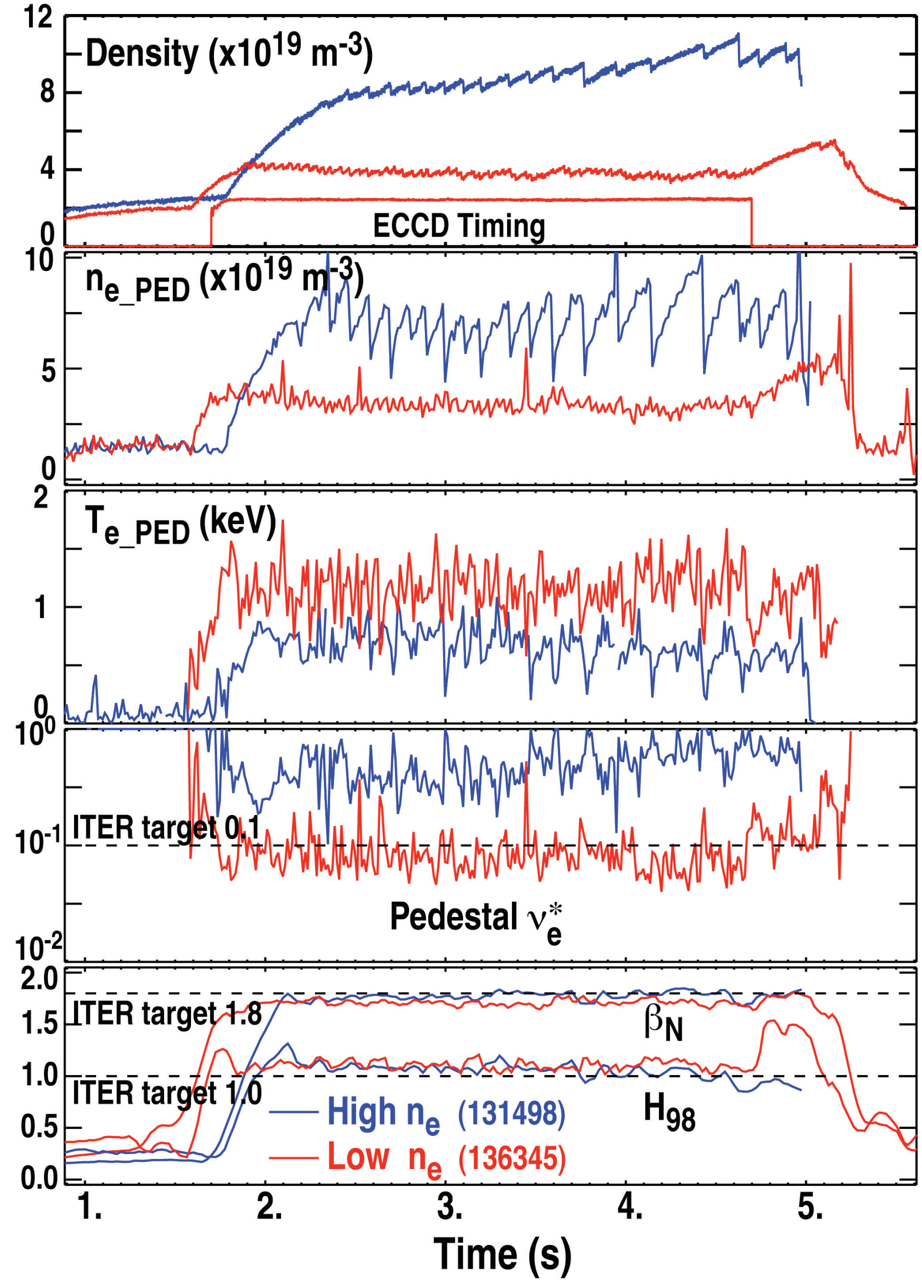
DIII-D Baseline Scenario Plasmas Match ITER Performance Targets; Density Control and Stationarity Improved in 2009

- **I/aB equivalent to 15 MA operation on ITER, q_{95} of 3.1**
- **Match ITER targets for β_N, H_{98}**
  - **$G \equiv \beta_N H_{89}/q_{95}^2$ is a measure of fusion performance**
- **Performance projects to meet ITER Q=10 target**
- **Absolute density up to ITER target of 1×10^{20} m^{-3}, n/n_{GW}~0.65 (ITER 0.85)**
- **H-mode duration is ~$3\tau_R$, same normalized duration as ITER**



Lower Density Baseline Discharge Developed to Match ITER Edge Pedestal Collisionality Target

- **Density reduced by factor of ≥2 and temperatures raised by:**
  - Lowering I_p
  - Application of ECH
- **ECH is dual purpose, also ECCD for NTM suppression**
- **Target values for β_N and H_{98} are maintained with lower collisionality/density operation**
  - No loss in fusion performance



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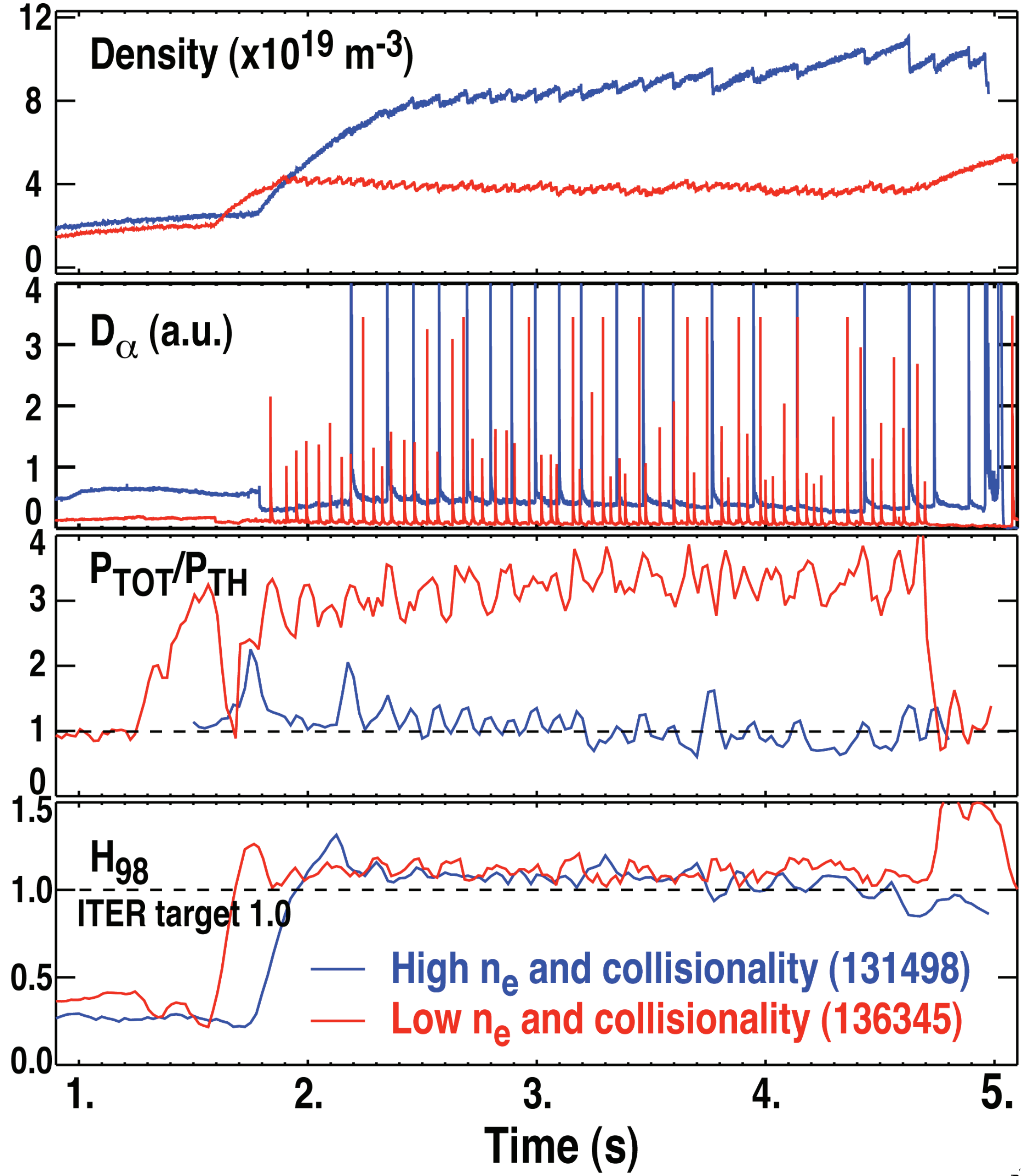
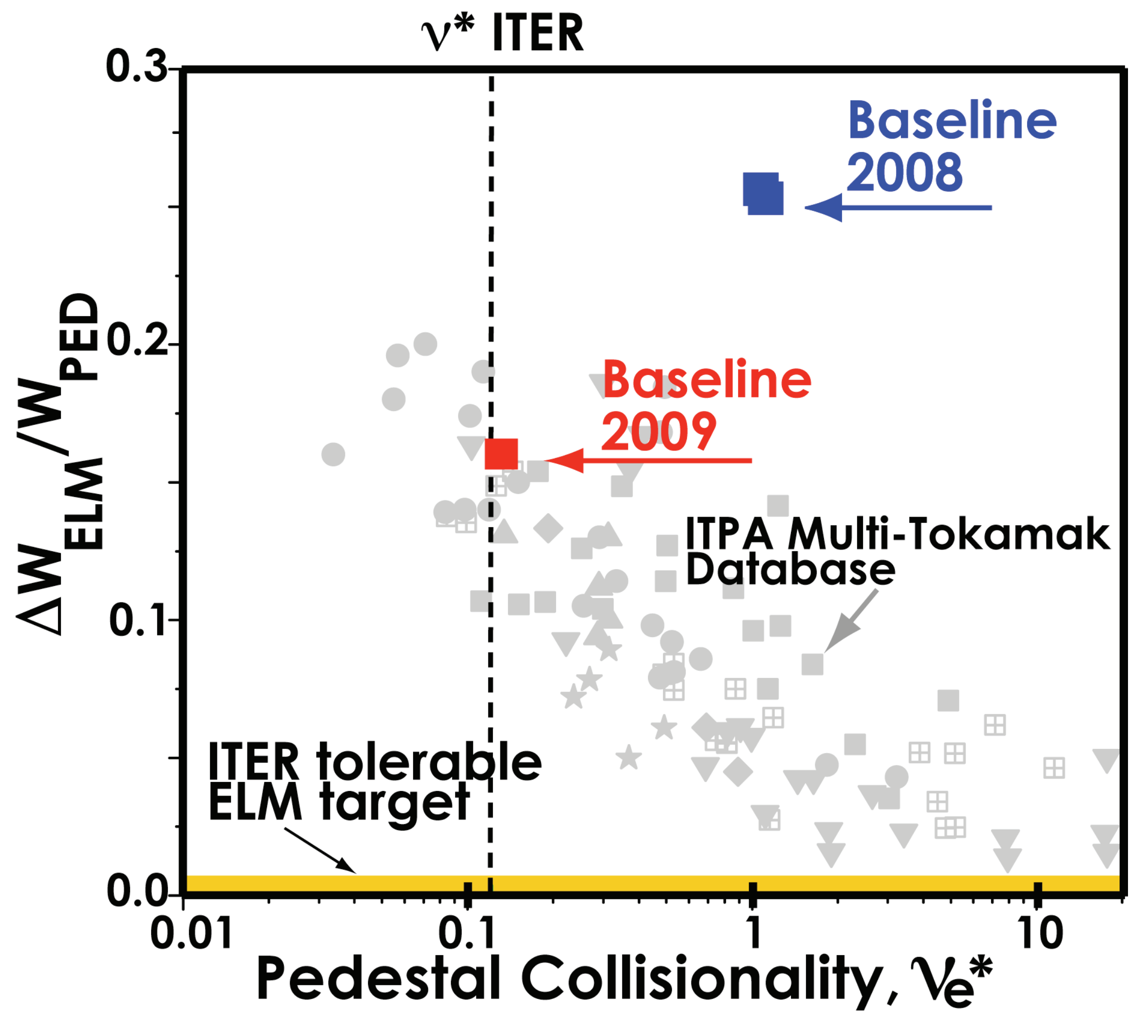
Change in ELM Characteristics with Change in Collisionality Probably Due to Change in P_{TOT}/P_{TH}

- **Empirical scaling used for L-H power threshold, P_{TH} (Y. Martin, et al., 2008)**
  - $P_{TH}=0.049*n^{0.72}B^{0.8}S^{0.9}$
- **High density discharges operate with P_{TOT}/P_{TH}~1 throughout H-mode phase**
  - Large, infrequent ELMs
- **Low density discharges have P_{TOT}/P_{TH}~3**
  - Smaller, more frequent ELMs
- **Initial ITER operation may correspond to P_{TOT}/P_{TH}~1 case**
  - Confinement is at target level, despite operation close to predicted L-H power threshold



Fractional Energy Loss at ELMs in High Collisionality Baseline Scenario Plasmas Exceeds ITPA Scaling

- **In high density baseline discharges, energy loss/ ELM is up to 25% of pedestal energy**
- **Reduction of energy loss at lower collisionality in 2009 discharges is counter to scaling observed in ITPA database**
  - Most discharges in database operate above P_{TH}



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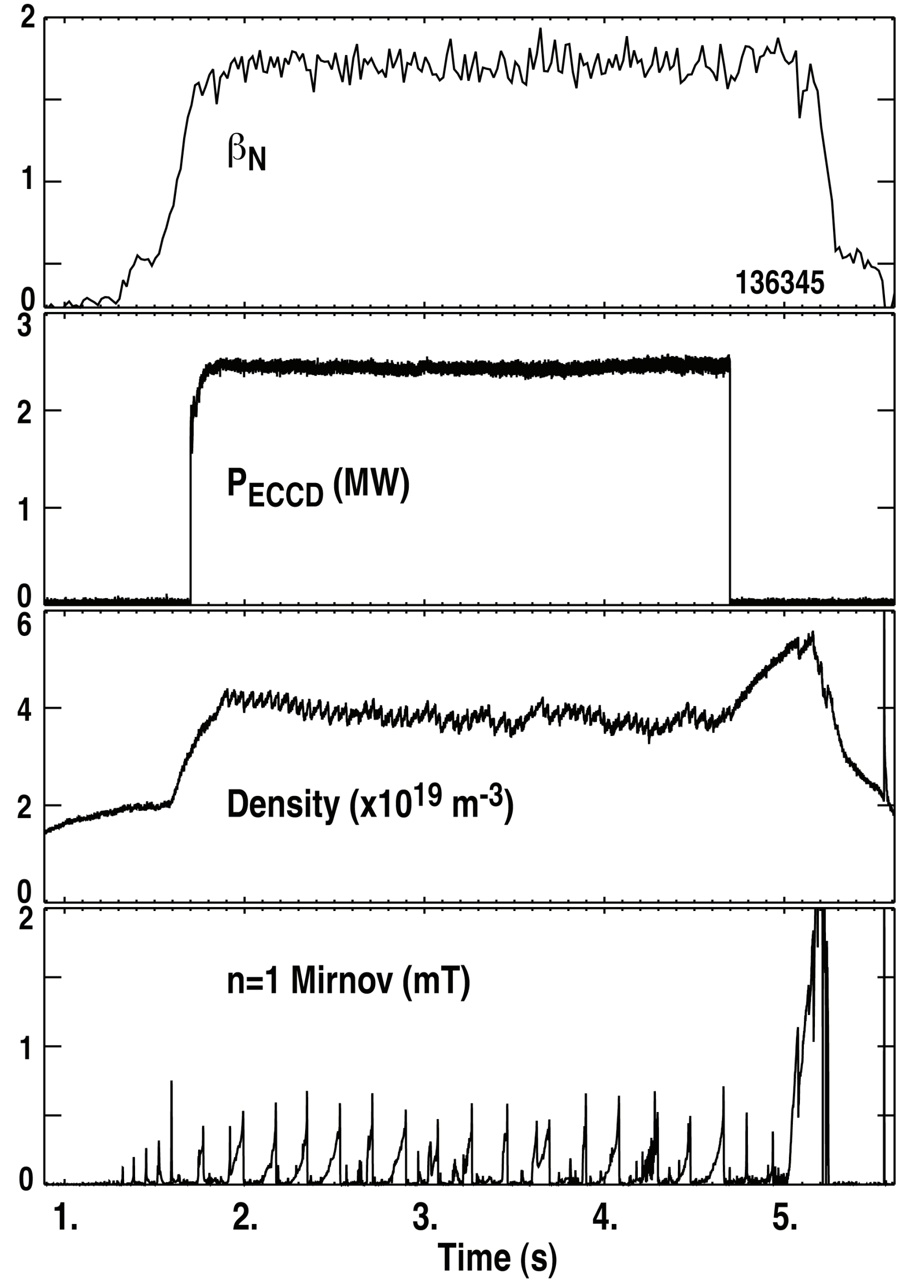
ECCD Provides First Demonstration of Preemptive Stabilization of 2/1 NTM in ITER Baseline Scenario Plasmas

- **ECCD directed at q=2 surface successfully preempts destabilization of 2/1 NTM:**
  - Stationary ELMing H-mode with q_{95}~3, β_N~1.8
- **Four gyrotrons, delivering ~2.5 MW to the plasma**
  - More than 1.25 MW required
- **2/1 mode turns on when gyrotrons commanded off**



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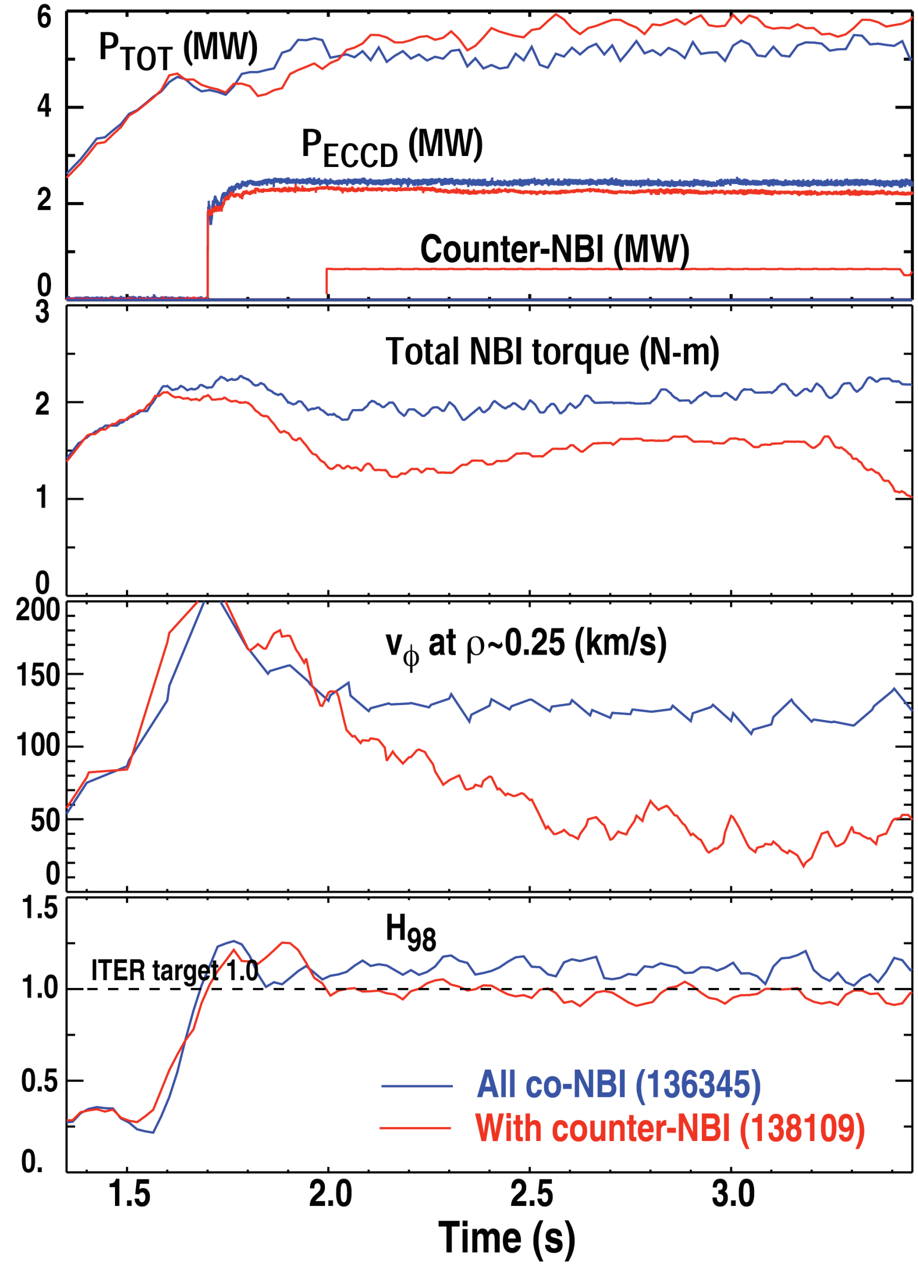
Initial Data Indicate that Reduced Plasma Rotation Reduces Confinement in Baseline Scenario

- **Plasma rotation reduced by adding counter-NBI in low collisionality case:**
  - Modest 1/4 counter-beam substantially changes rotation
  - ECH in these discharges also modifies rotation
- **Confinement factor H_{98} reduced by ~15%**
- **Indicates need for performance margin to account for effect of lower rotation, etc. in projecting to ITER**



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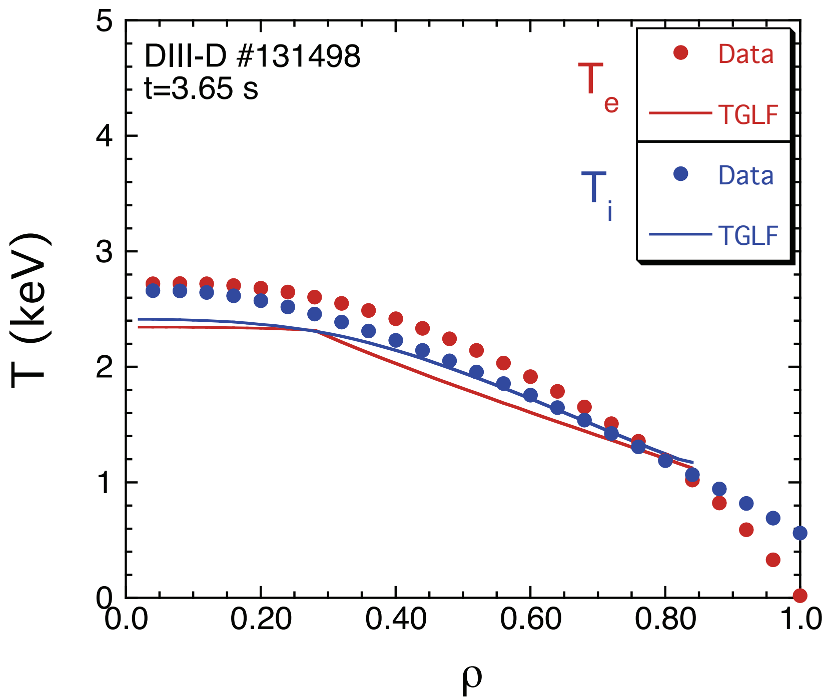
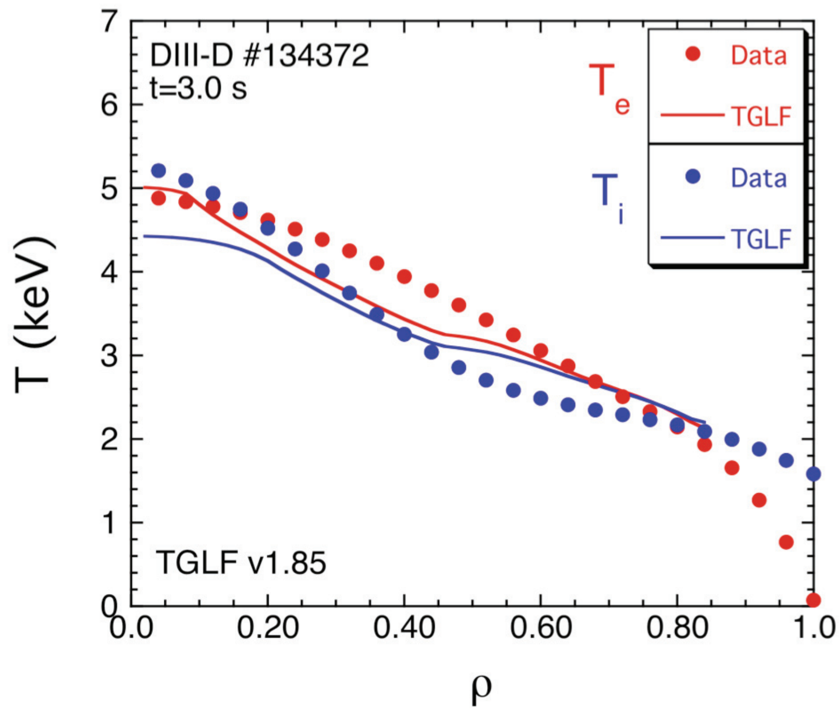
Data from ITER Demonstration Discharges Used to Test and Develop TGLF Transport Model

- **TGLF modeling of T_i and T_e profiles performed for baseline, steady-state, hybrid and advanced inductive scenarios**
  - Examined 2 discharges per scenario, examples shown from two scenarios
  - Agreement within typical range

Baseline scenario case



Steady-state scenario case



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Summary: Match to Expected Conditions for ITER Baseline Scenario has been Significantly Improved

- **Improvements in 2009 include:**
  - Matched ITER collisionality target with no loss in performance
  - First demonstration of 2/1 NTM avoidance using ECCD under ITER-similar conditions
  - Improved stationarity and density control
  - Initial data on impact of reduced rotation on confinement

- **The demonstration discharges address many key ITER physics issues, e.g. ELMs, L-H transition, pedestal scaling, beta limits, etc.**

- **DIII-D evaluations of ITER scenarios can be further extended and improved:**
  - Complete investigation of impact of lower plasma rotation on confinement
  - Extend T_e=T_i operation to more scenarios