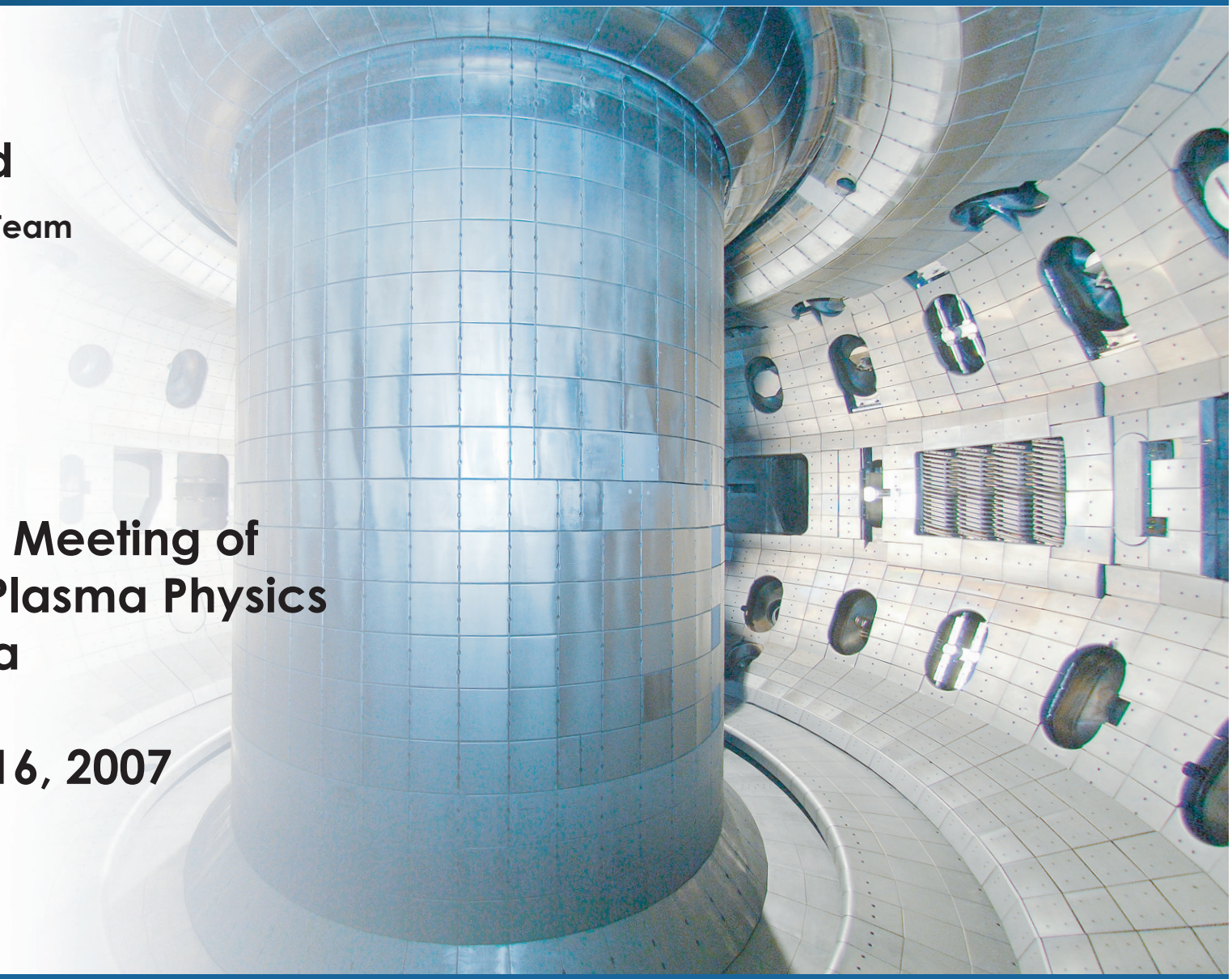
Overview of Recent DIII-D Experimental Results



by
C.M. Greenfield

for the DIII-D National Team

Presented at
Forty-Ninth APS Meeting of
the Division of Plasma Physics
Orlando, Florida

November 12–16, 2007

DIII-D NATIONAL FUSION FACILITY

GENERAL ATOMICS

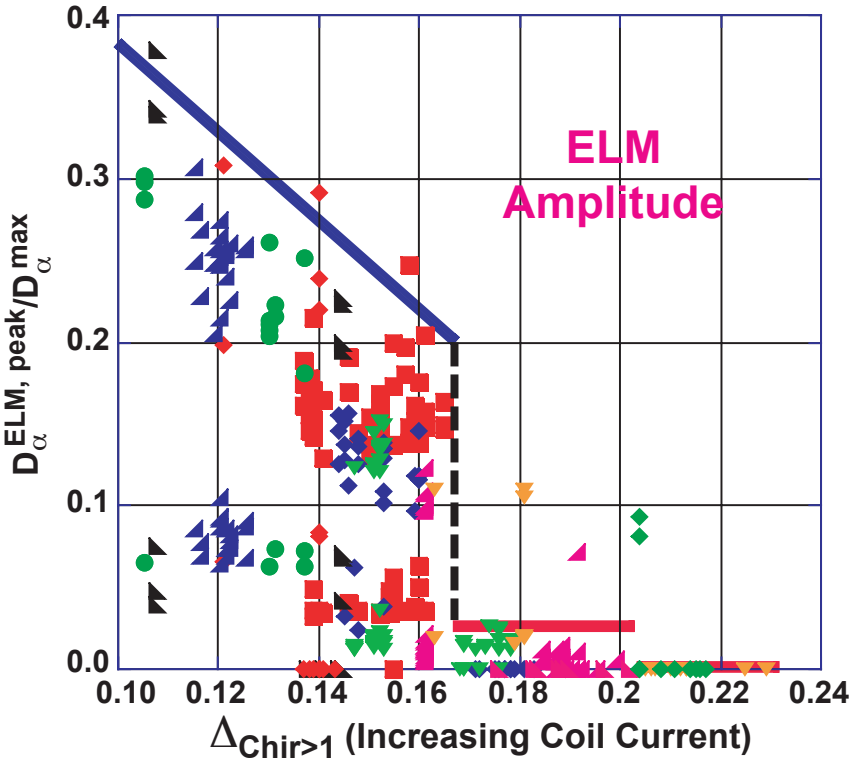
229-07/CMG/rs

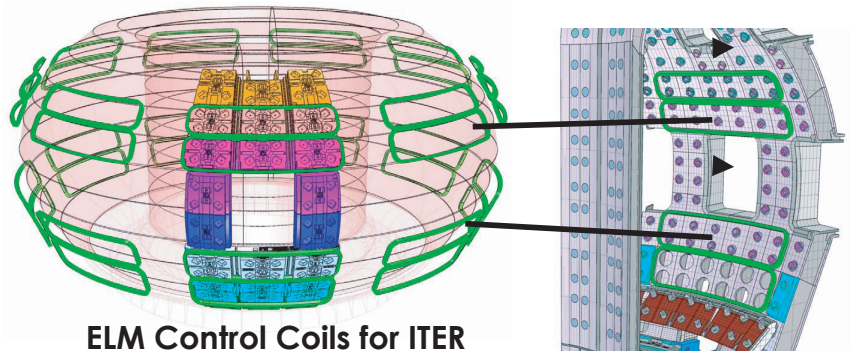
Research in 2007 Was Broad Based, But With Special Emphasis on the ITER Design Review

- **Enable the success of ITER by providing physics solutions to key physics issues**
  - ELM-control coils
  - RWM control requirements
  - ITER startup scenarios
  - Disruption mitigation
  - Dust in a tokamak plasma
- **Develop the physics basis for steady-state operation in ITER and beyond**
  - AT plasmas reproducibly maintained for $>1\tau_R$ with stationary condition
- **Advance the fundamental understanding of fusion plasmas along a broad front**
  - Simultaneous measurements of density and temperature fluctuations
  - Studies of rotation, facilitated by re-oriented neutral beamline
    - L-H threshold reduced at low rotation
  - ECH may provide a control tool for Alfvénic activity

DIII-D Research Strongly Supported the Evaluation of ELM Control Coils for ITER

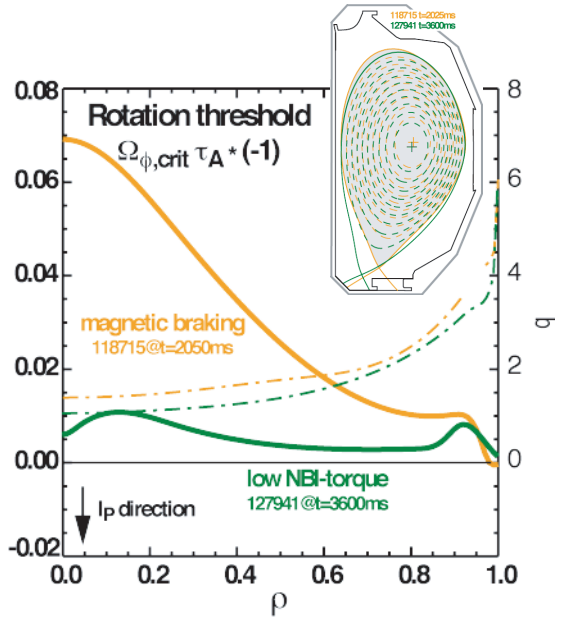
- **2007 experiments focused on providing quantifiable physics criterion for ELM suppression**
  - Chirikov parameter $\equiv \frac{\text{average island size}}{\text{island separation}}$
  - $\Delta_{chir>1} \equiv$ width (ψ_N) of region in plasma edge with Chirikov > 1.0
  - Determined by coil current, safety factor and geometry
  - ELMs below detection limit limit for $\Delta_{chir>1} > 0.2$
- **Codes developed to treat 3-D fields in actual DIII-D and ITER geometry**
  - TRIP3D, SURFMN
  - Applied to ITER to provide information tradeoffs in coil locations

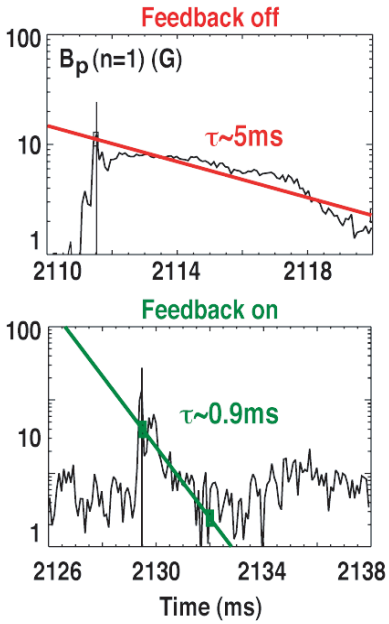


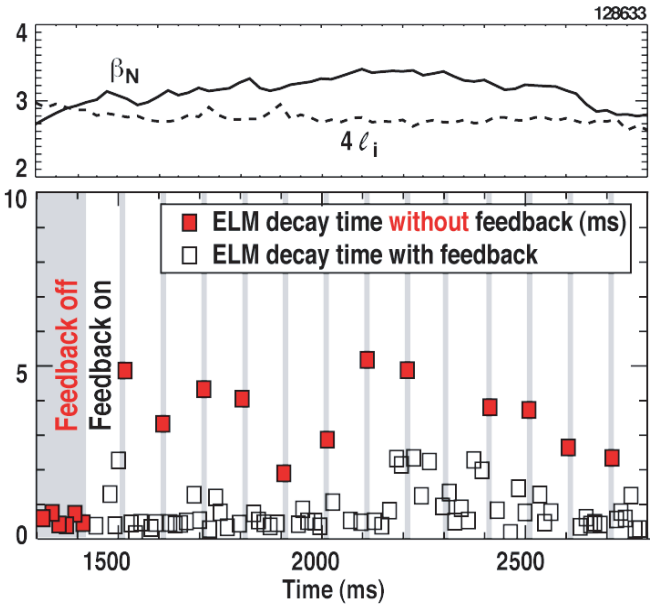


ELM Control Coils for ITER

Resistive Wall Mode Rotation Threshold is Small, but Control Still Needed for Transient Events



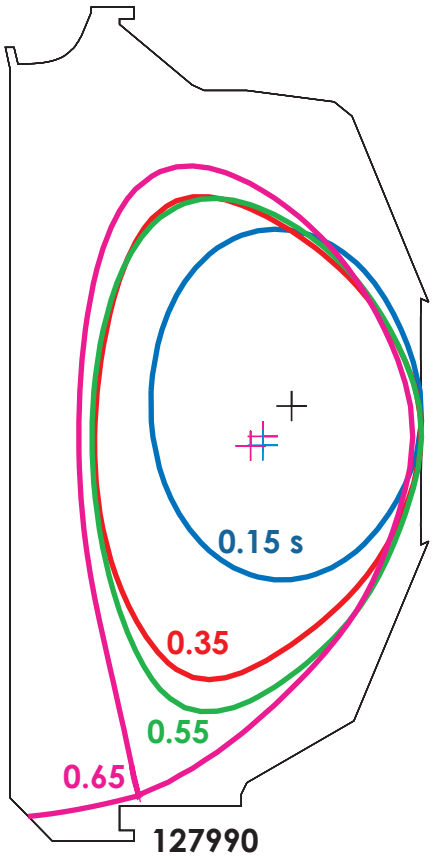


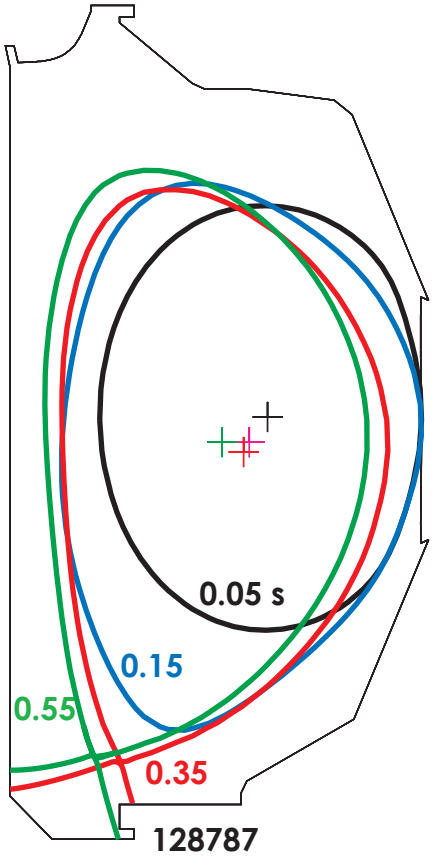


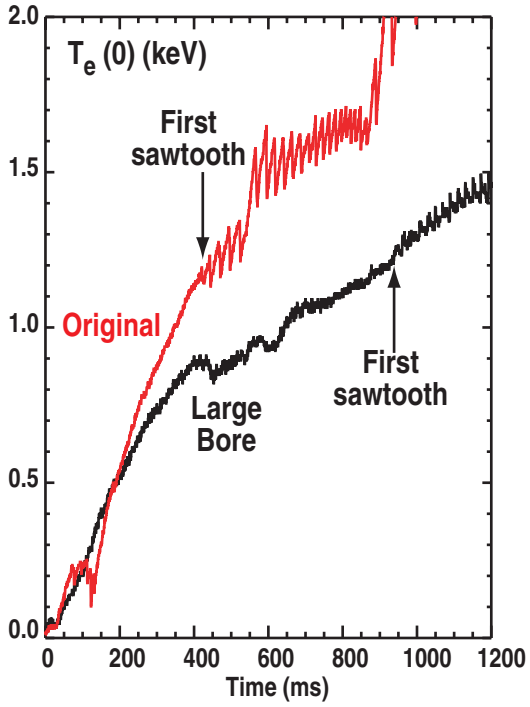
- **Low rotation threshold for RWM stabilization**
  - Low NBI torque yields considerably lower Ω_{crit} than previous results with n=1 magnetic braking
  - Applies to all operating scenarios tested
- **RWM feedback may still be necessary to mitigate the effects of transient events at high β**
  - Accelerates damping of n=1 perturbation following ELMs

DIII–D Has Responded to Requests for Experimental Input on ITER Startup Scenario

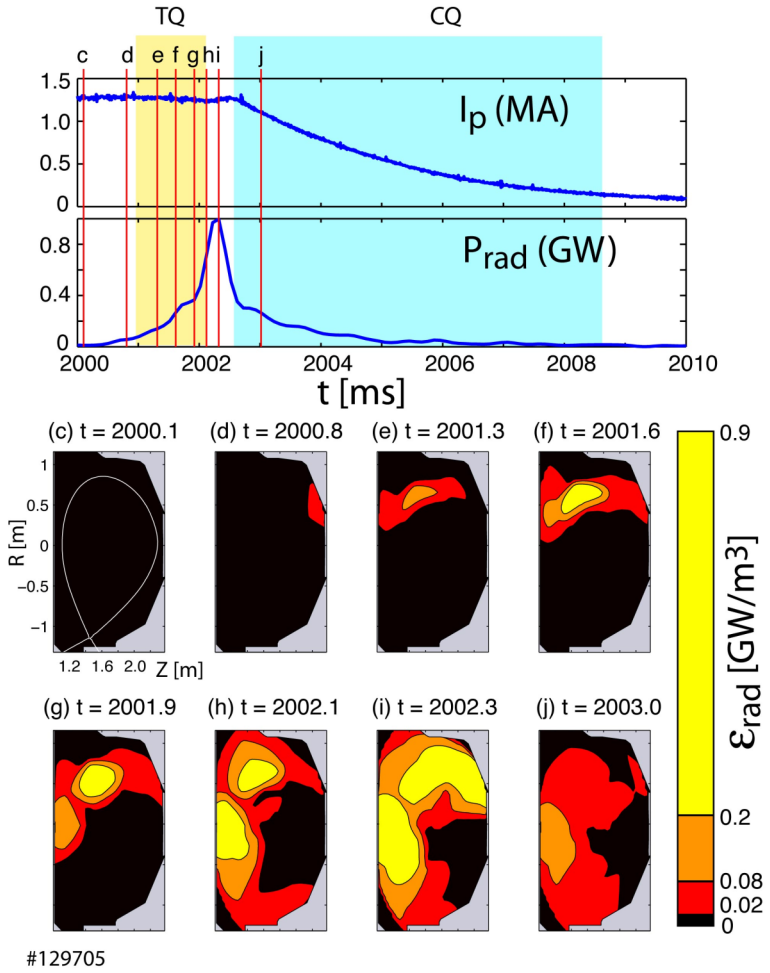
- **Original scenario**
  - Small bore at breakdown
  - Late X-point
- **New scenario**
  - Large bore at breakdown
  - Early X-point
- **New startup results in lower ℓ_i and later sawtooth appearance**





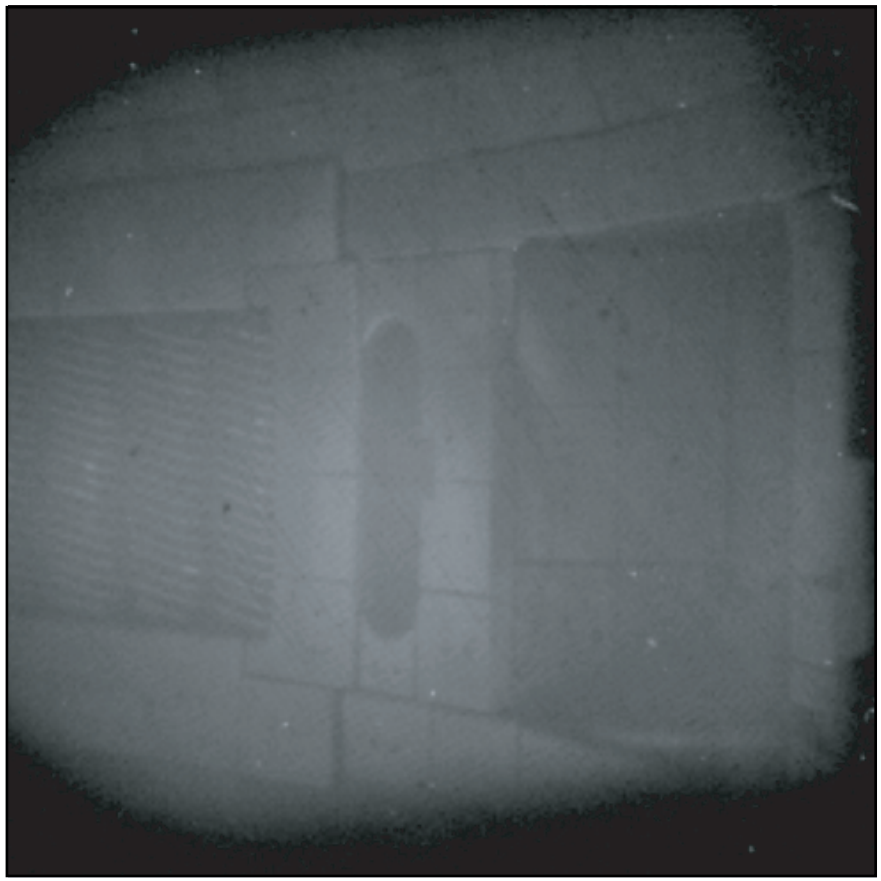


Fast Radiated Power Tomography Shows Transport of Injected Neon



- Disruption mitigation requires efficient mixing of injected impurities to suppress runaway electron avalanche
- Fast bolometry allows study of poloidal and radial transport during the thermal quench
- Experiment uses new "Medusa" valve with high throughput and fast risetime

Behavior of Dust Studied with Optical Imaging



- **Micron size dust commonly found in tokamaks**
  - Many concerns for ITER, including tritium retention, accumulation of radioactive material, explosion hazard, core contamination
- **Observed in DIII–D with**
  - Thomson scattering: particle sizes
  - Optical imaging: velocities and trajectories
- **Following vent, elevated dust levels return to normal in 2–3 days**
- **Micron sized dust in lower divertor becomes highly mobile when exposed at strike point and migrates around torus**
  - Penetration into plasma ~1–3%

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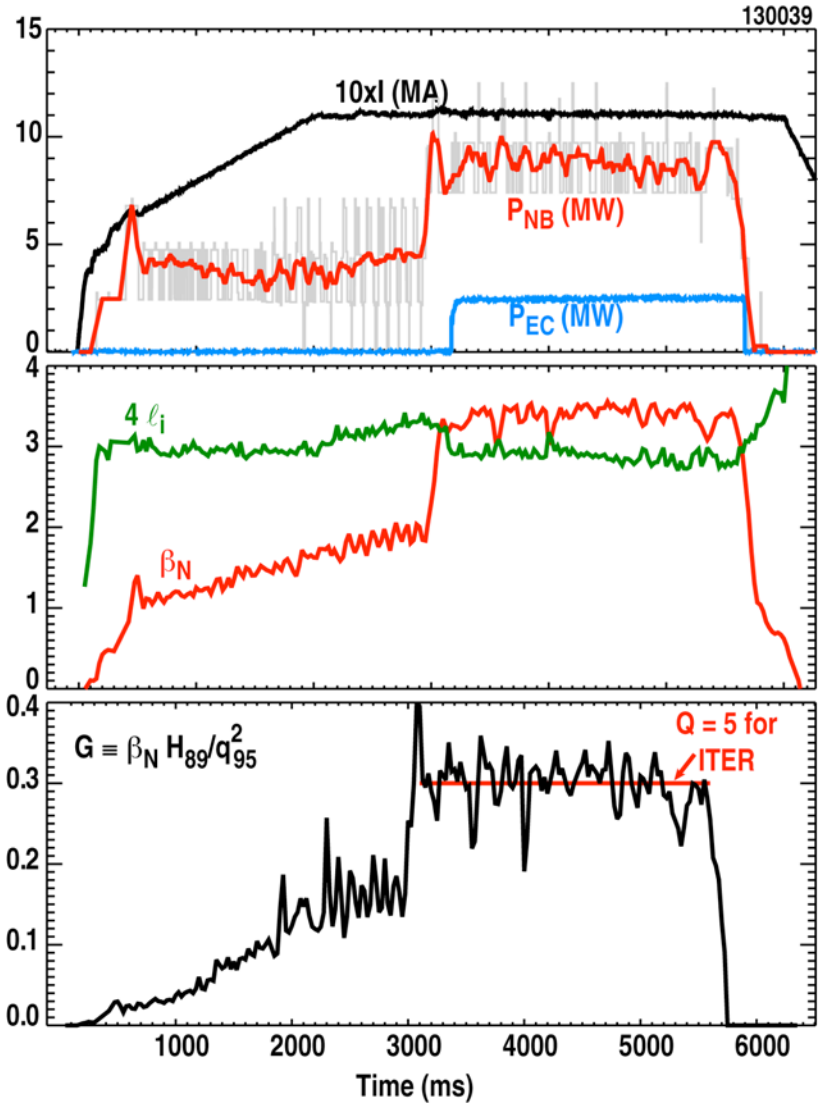
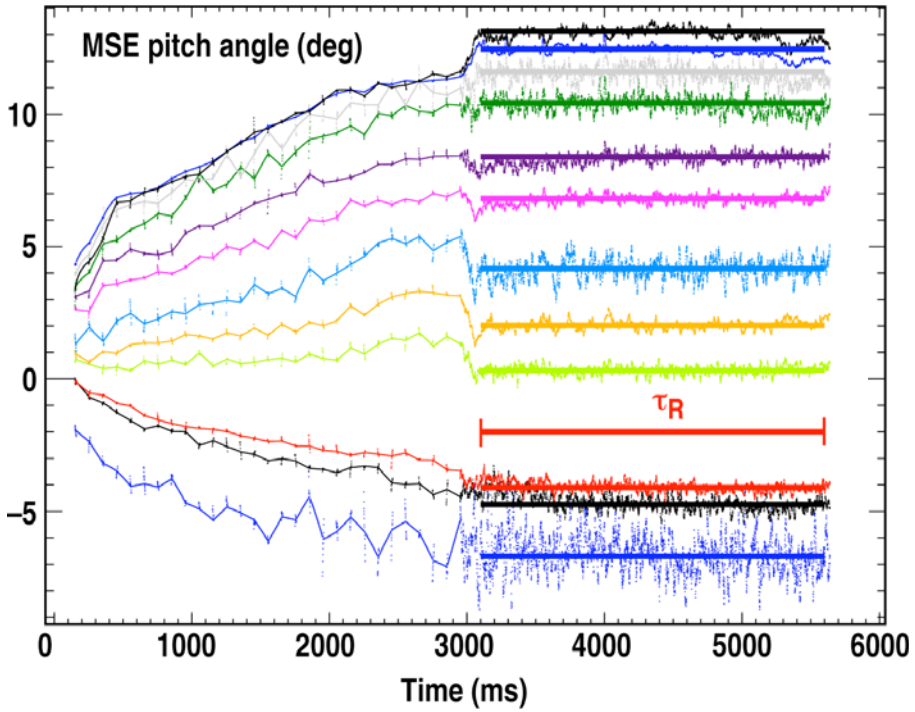
Steady-State Scenario Reproducibly Maintained for $1\tau_R$ at High β





- **Pulse length now limited by co-NB deliverable energy, not EC energy**
- **Current profile is very stationary, but not fully non-inductive**
  - $f_{ni} \approx 90\%$

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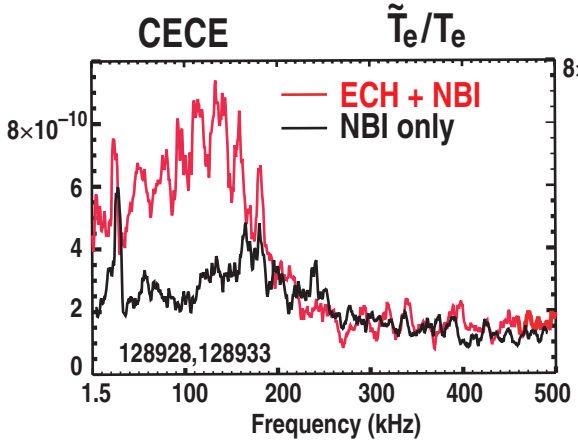
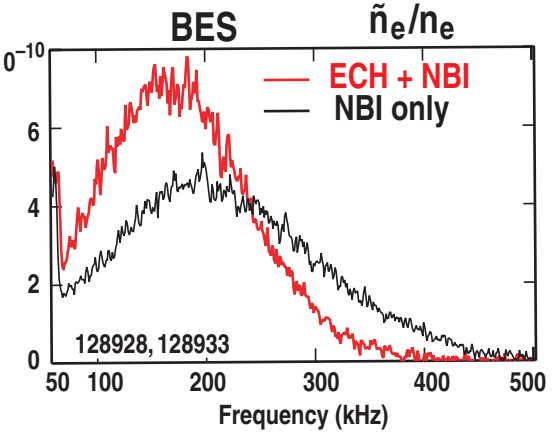
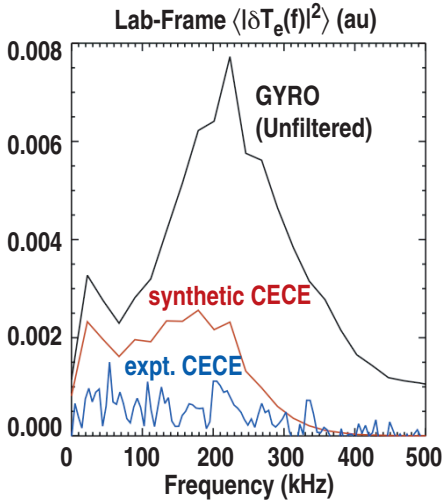
New Simultaneous Turbulence Measurements of a Variety of Fluctuating Fields are Providing a Unique Test Bed for Gyrokinetic Simulations

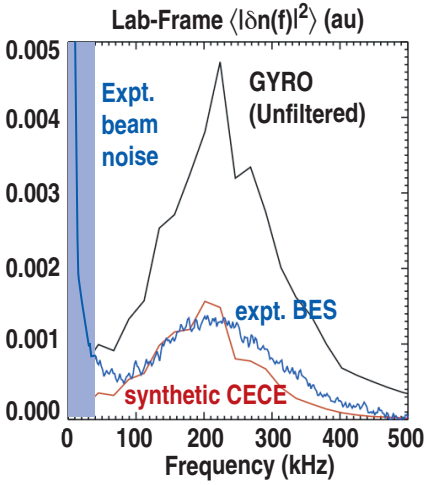
- **Multiple fluctuating fields now available**
  - $\tilde{T}_e$, $\tilde{n}_e$, $\tilde{v}$
- **Fields show varying response to applied heating**
- **GYRO simulations in progress**
  - CECE: amplitude over predicted
  - BES: excellent agreement





L-Mode
$P_{NBI} \approx 2.5$ MW
$P_{EC} \approx 2.5$ MW
inner-wall limited

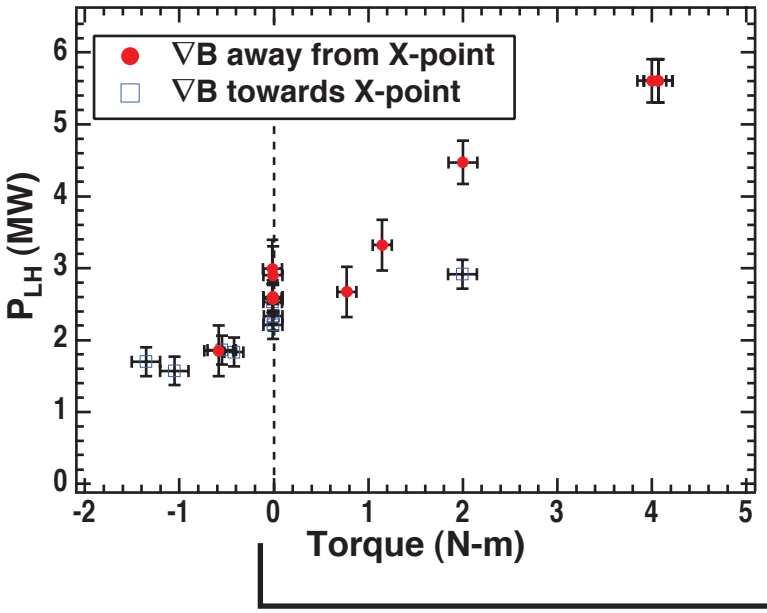


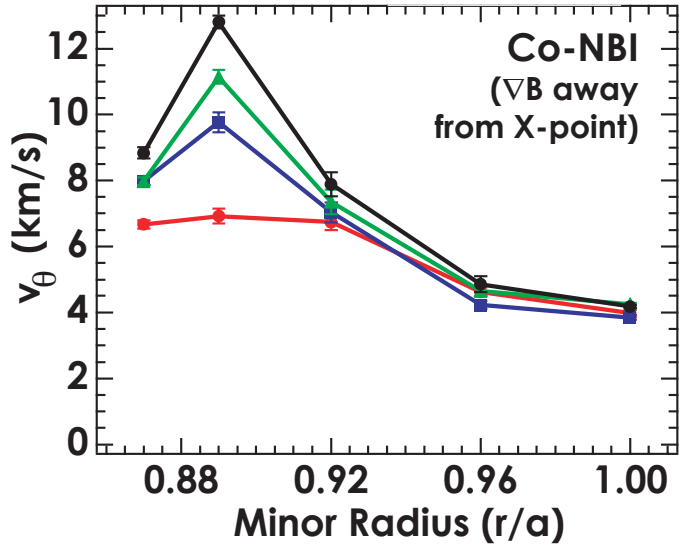


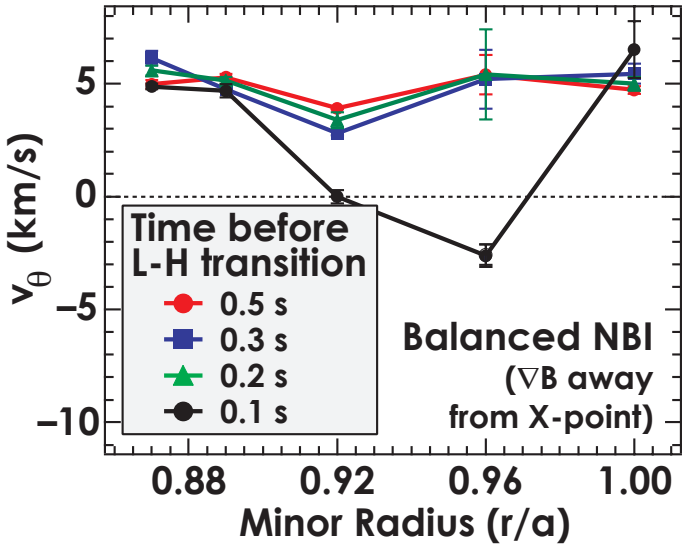
L-Mode
$P_{NBI} \approx 2.5$ MW
upper-single null

L-H Threshold Strongly Depends on Rotation

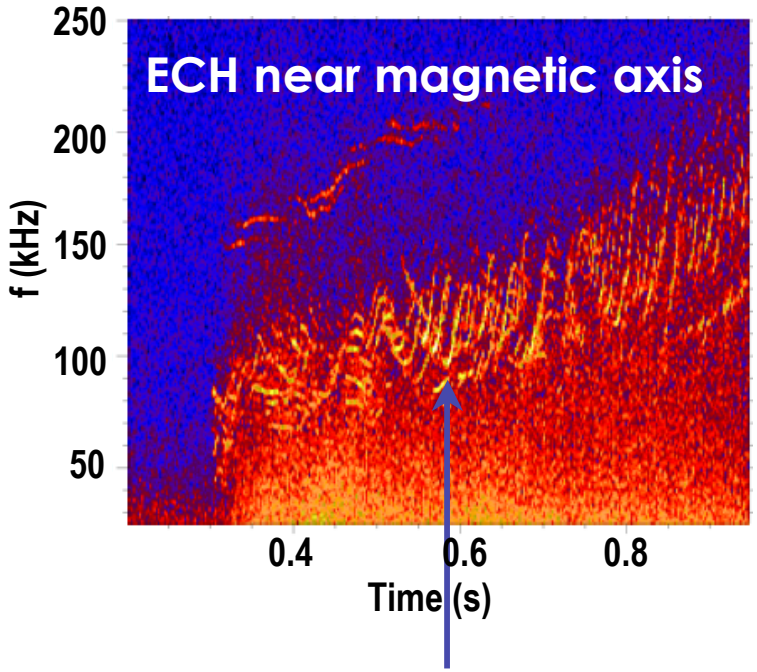
- **Threshold decreases at low torque**
- **Sudden reversal of poloidal flow with balanced NBI prior to transition**
  - Turbulence poloidal velocity obtained via cross-correlation analysis of BES data



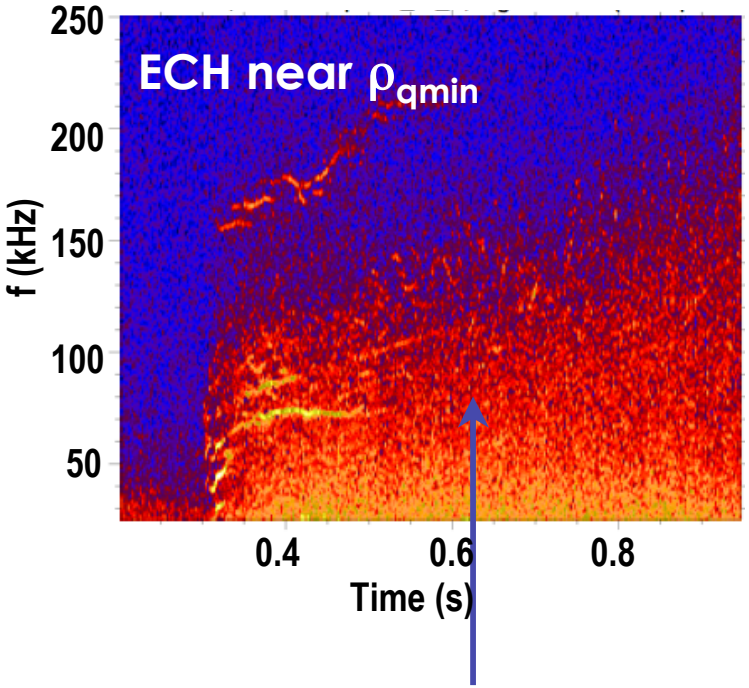




ECH a Possible Control Tool for Alfvénic Modes



RSAE activity similar to NB only case - slightly stronger



RSAE activity almost completely gone!

What You'll Hear About in this Session

- **Enable the success of ITER by providing physics solutions to key physics issues**
  - J.A. Boedo; ELM control
  - A.M. Garofalo: Resistive Wall Mode and Plasma Stability at High Beta and Slow Rotation
  - G.L. Jackson: ITER start-up
  - W.P. West: High Performance and Wall Conditioning
  - D.L. Rudakov: Carbon Dust
- **Develop the physics basis for steady-state operation in ITER and beyond**
  - E.J. Doyle: Operation with $T_e \sim T_i$ and Low Rotation
  - T.C. Luce: Steady-State High-Performance Scenarios
  - J.M. Park: Integrated Scenario Modeling
- **Advance the fundamental understanding of fusion plasmas along a broad front**
  - F. Volpe: Locked Neoclassical Tearing Mode Control on DIII-D by Electron Cyclotron Current Drive and Magnetic Perturbations
  - M.W. Shafer: q_{min}-Triggered Internal Transport Barriers
  - R.J. Groebner: Role of Pedestal in Hybrid Discharges in DIII-D
  - W.M. Solomon: Effect of Reverse Shear Alfvén Eigenmodes on Torque
  - K.H. Burrell: Quiescent H-mode Experiments
  - A.D. Turnbull: Prediction of Sawtooth Periods in Fast-Wave Heated Plasma

Other DIII–D and Related Talks and Posters at this Meeting

Review Talk		
Friday, 8:00AM (XR1.00001)	W.W. Heidbrink	Instabilities Driven by Energetic Particles in Magnetized Plasmas
Invited Talks		
Monday, 10:00AM (BI1.00002)	M.E. Fenstermacher	Effect of Island Overlap on ELM Suppression by Resonant Magnetic Perturbations in DIII-D
Monday, 10:30AM (BI1.00003)	A.W. Leonard	Influence of Beta, Shape, and Rotation on the H-mode Pedestal Height in DIII-D
Tuesday, 2:00PM (JI1.00001)	R. Nazikian	Excitation of Alfvén Eigenmodes by Low Velocity Beam Ions in the JET and DIII-D Tokamaks
Wednesday, 10:00AM (NI1.00002)	A.E. White	Turbulent electron temperature fluctuation measurements in the core of high-performance DIII-D plasmas
Thursday, 3:00PM (UI1.00003)	R. Buttery	Extrapolating Neoclassical Tearing Mode Physics to ITER -- Physics Basis and Experimental Comparison
Thursday, 3:30PM (UI1.00004)	P.A. Politzer	Advancing Tokamak Physics with the ITER Hybrid Scenario onDIII-D
Thursday, 4:00PM (UI1.00005)	V.A. Izzo	MHD Simulations of Disruption Mitigation on DIII-D and Alcator C-Mod
Friday, 11:00AM (YI1.00004)	G.R. McKee	Dependence of Edge Turbulence Dynamics and the L-H Power Threshold on Toroidal Rotation
DIII-D Poster Sessions: JP8 (Tuesday afternoon), UP8 (Thursday afternoon)		