DIII–D STATUS AND PLANS

by
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Presented at
Princeton Plasma Physics Laboratory

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DIII–D
NATIONAL FUSION FACILITY
SAN DIEGO

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OUTLINE

- DIII–D program
- Planned and recent upgrades
- Recent results
- Experiments for FY 2005
  — Possible NSTX/DIII–D collaborations

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DIII–D PROGRAM ELEMENTS SUPPORT ITER

— In cooperation with our ITER partners and the International Tokamak Physics Activity —

Advanced Tokamak

- Develop long pulse, high performance discharges for ITER
  - — Hybrid scenarios
  - — Full noninductive steady-state Advanced Tokamak scenario
- MHD stabilization
  - — Neoclassical tearing mode stabilization
  - — Resistive wall mode stabilization
- Disruption mitigation
- Validate models of ECCD and FWCD

Transport

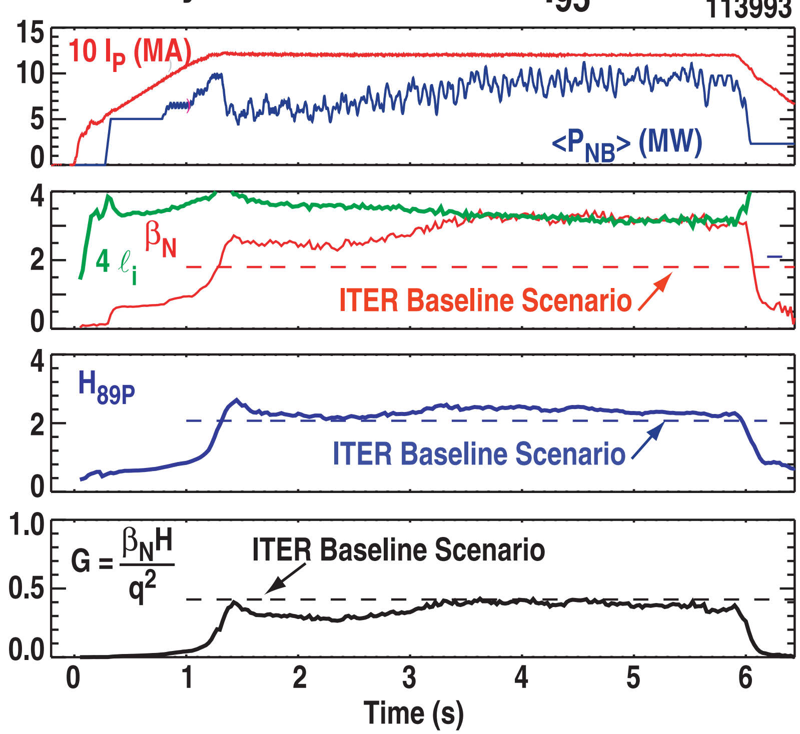
- Develop core transport models
  - — To validate performance projections
  - — To guide ITER operation
- H–mode pedestal understanding and control
  - — Predictive capability of the pedestal height
  - — ELM mitigation

Mass Transport

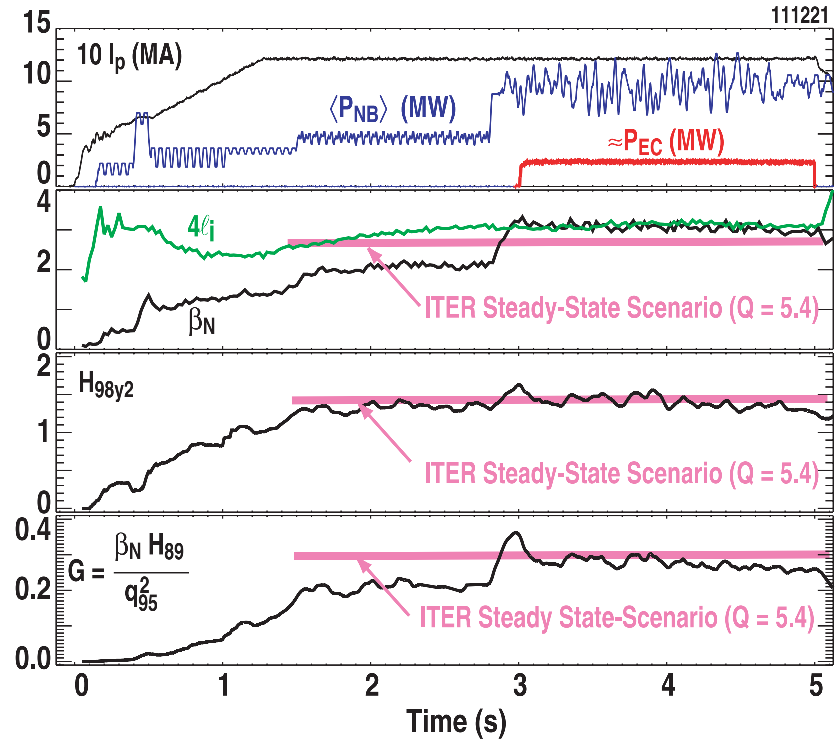
- In-depth understanding of the process contributing to impurity and tritium mass transport
  - — Erosion, redeposition, ELMs; measure flows
- Reduction of heat flux to the divertor, radiative divertor

STEADY-STATE *AT* AND STATIONARY "hybrid" SCENARIOS ARE DEVELOPING THE BASIS FOR ITER LONG PULSE DISCHARGES

Hybrid no Sawteeth q_{95} = 4.4



Full non-inductive AT



ITER projection		
	β_N = 3.2	β_N = 3.2
	H_{98y2} = 1.6	H_{98y2} = 1.6
	$Q_{Fus} \approx 5$	$Q_{Fus} \sim 5$
	τ_{DUR} = 5500 s	$\tau_{DUR} = \infty$ (physics)

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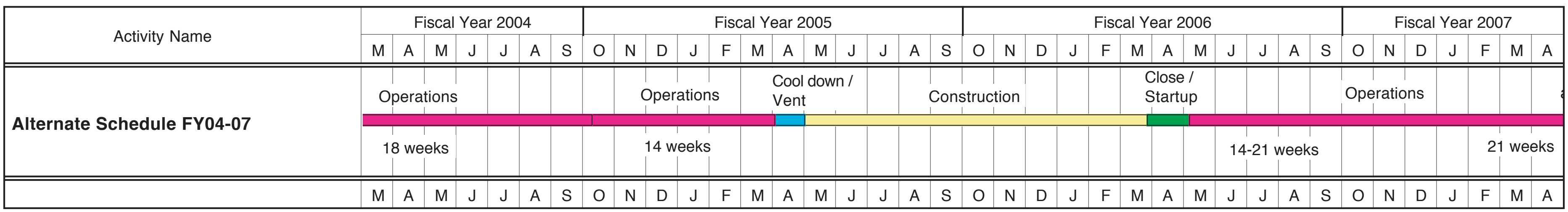
OPERATING SCHEDULE FOR DIII–D IN FY05–07

- Collects three vent periods (4 months each) into one 12 month torus opening
- Enables effective use of existing staff to take on some major projects
- Preserves run time
  - FY05 (14 weeks)
  - FY06 (14 weeks extendable to 21 at 1.5 shifts/day
  - FY07 (21 + run weeks – new capabilities

DIII–D Facility Schedule (04–07)



- Enables us to take on
  - ECH 6 MW upgrade
  - Lower divertor modification
  - 210 degree counter beamline and diagnostics
  - Cooling water tower
  - MG refurbishment
  - TF belt bus and diodes for 10 second ops

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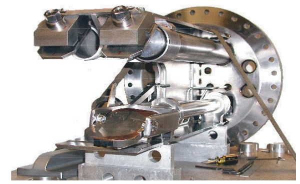
KEY PLASMA CONTROL TOOLS ARE PLANNED

Key Hardware Element — **Physics/Control**

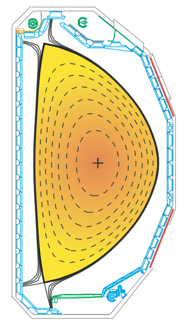
- Long-pulse EC systems

	Present		Plan
LP	3	⇒	6 ⇒ 8
SP	2	⇒	0



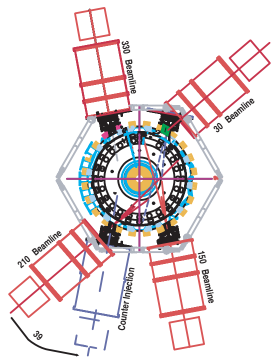
— J(ρ) control
— P(ρ), transport studies
— NTM stabilization

- High δ divertor



— n_e control in DND

- Counter NBI

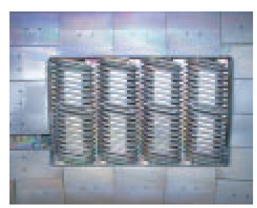


— Transport
— RWM (low rotation)

- Internal coil
  - — High bandwidth actuators

— RWM feedback
— Stochastic edge

- FW system operation
  - — ABB ⇒ EIMAC tubes



— J (ρ~0) and P(ρ) control
— β_e↑ for improved current drive efficiency

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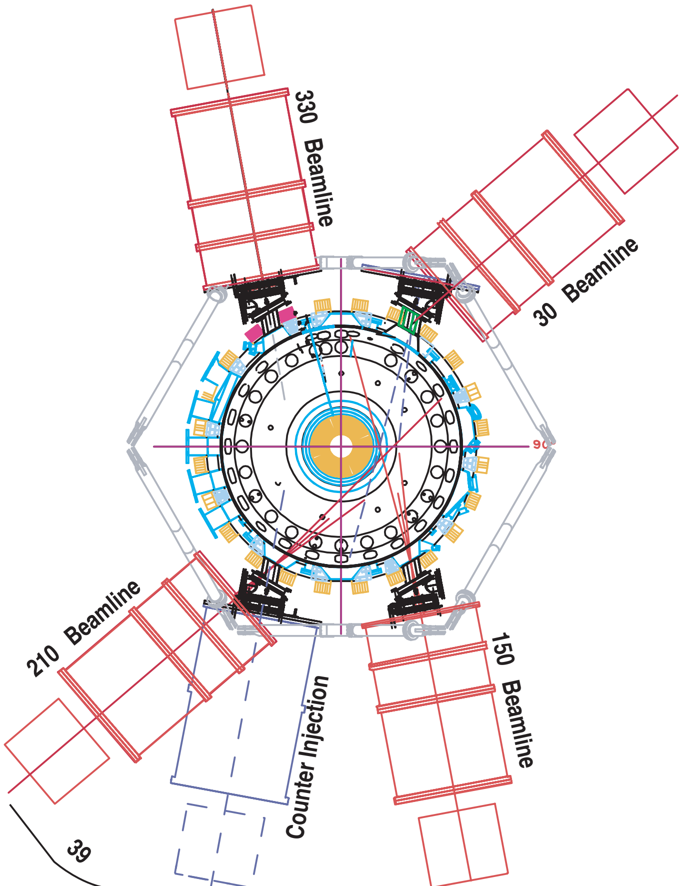
A BEAMLINE REVERSAL IS NECESSARY FOR NEW PHYSICS STUDIES AND IMPROVED PLASMA MEASUREMENTS



- QDB regime with central co-rotation
- Understanding physics of rotation
- RWM stability with low rotation
- NTM stabilization with modulated rf
- Transport barrier control (separate E×B and Shafranov shift effects)
- Separate E_r and J(r) in MSE measurement
- Co and counter CER
- Evaluate very high bootstrap fraction *AT* plasmas

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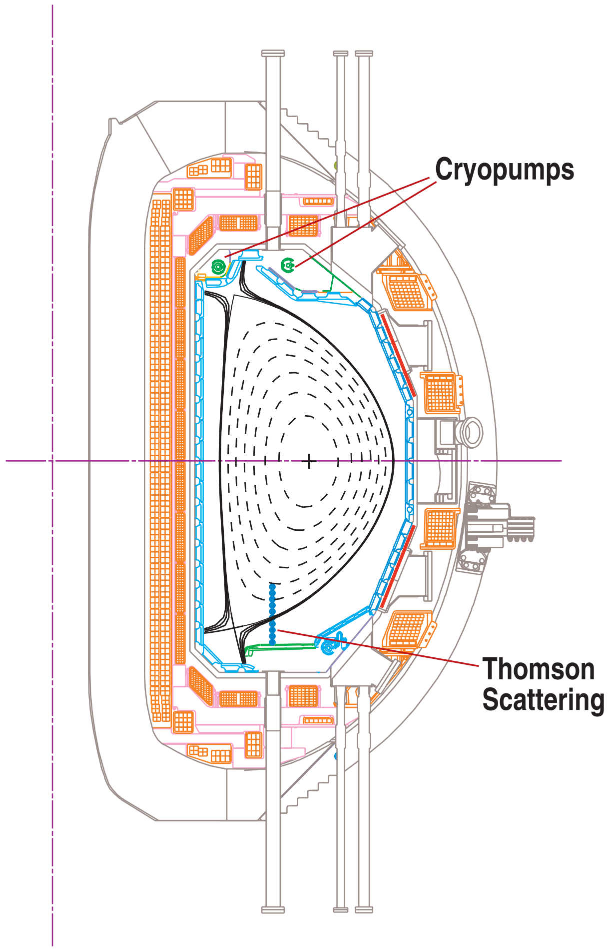
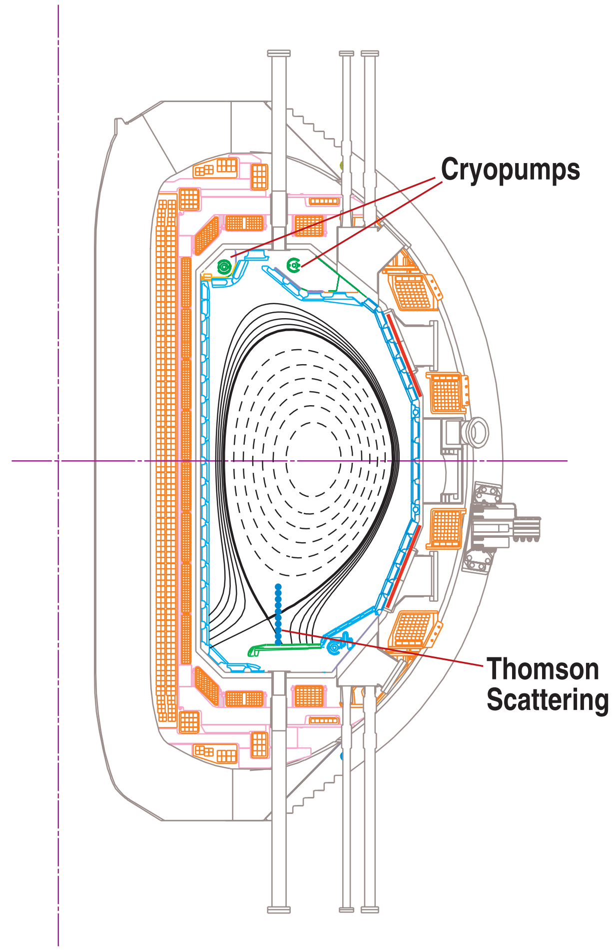
A SIMPLE LOWER DIVERTOR MODIFICATION WILL ENABLE DENSITY CONTROL IN OUR MOST PROMISING HIGH PERFORMANCE PLASMAS AND IMPROVE DIVERTOR RESEARCH





- 15-20% gain in β_N for double null
  (> 30% possible with optimized profiles)

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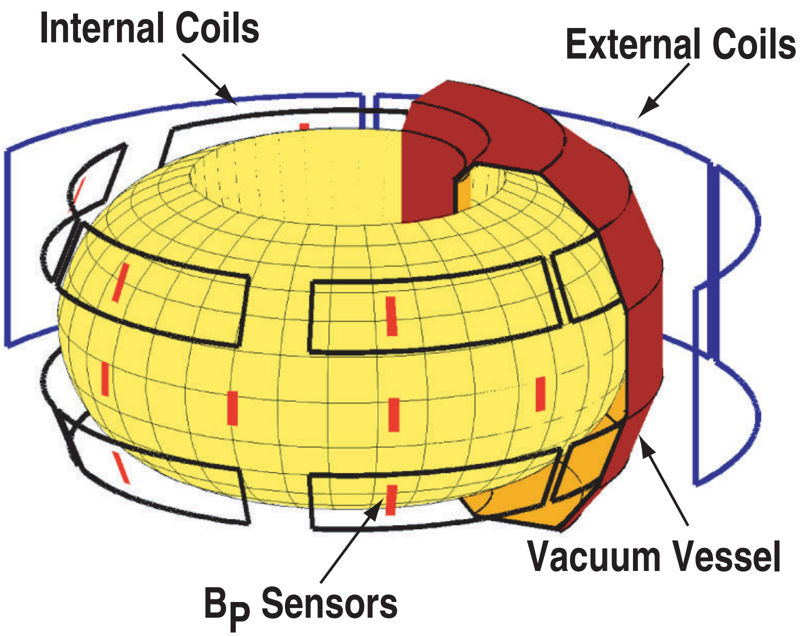
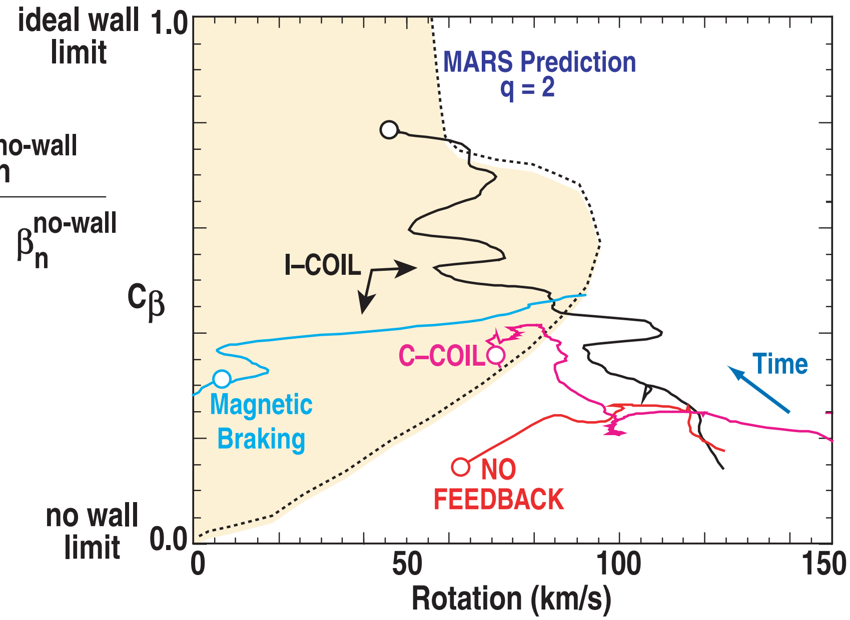
NEWLY INSTALLED INTERNAL CONTROL COILS: ACTIVE AND PASSIVE STABILIZATION OF THE RWM–PPPL COLLABORATION

- Key relevance to ITER, FIRE, CTF, and other magnetic configuration (ST, RFP...)
- Active feedback: $\beta_N > \beta_N^{no\ wall}$ without rotation (high bandwidth actuators)



$$C_\beta = \frac{\beta_n - \beta_n^{no\text{-}wall}}{\beta_n^{ideal\text{-}wall} - \beta_n^{no\text{-}wall}}$$



- RWM control expands operating space for ITER steady-state AT scenarios
  – Optimal use of external coils or simple design for internal coils

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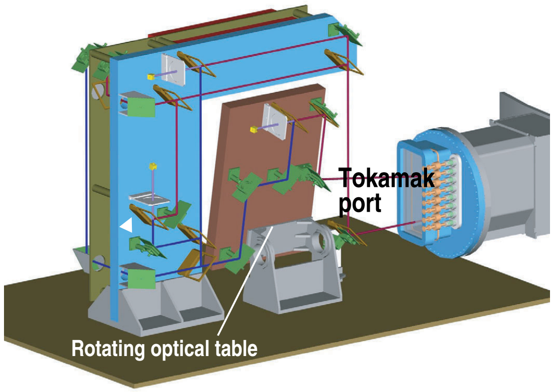
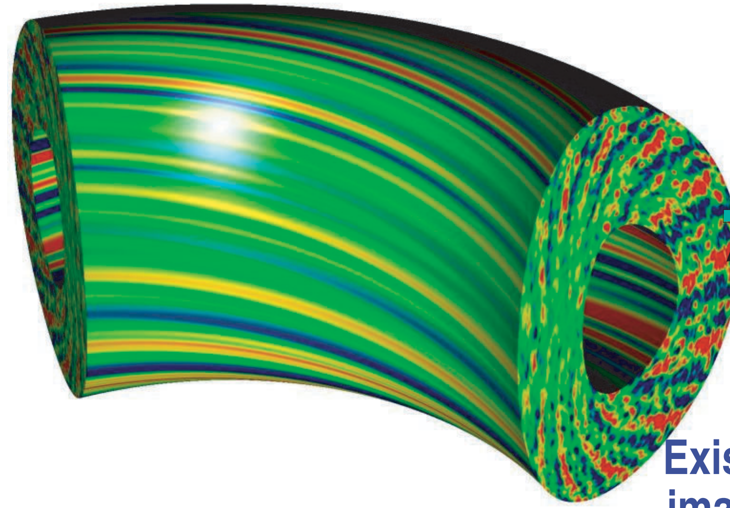
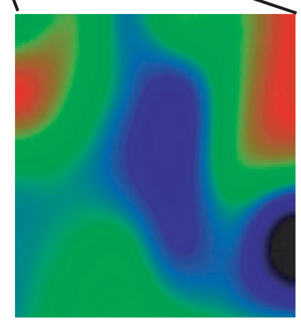
NEW TURBULENCE MEASUREMENTS NEEDED FOR SMALL SPATIAL SCALES AND 2-D IMAGING

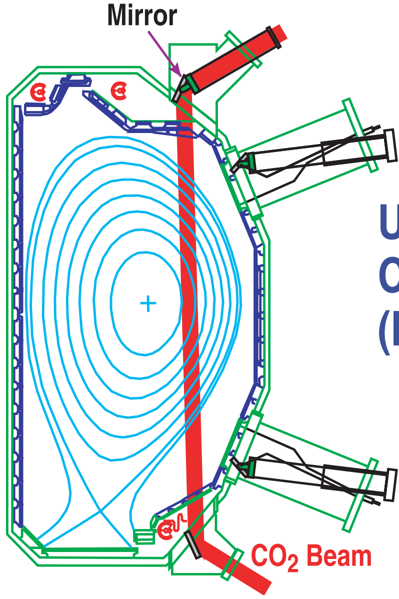


Enhanced spatial resolution high-k scattering (UCLA)

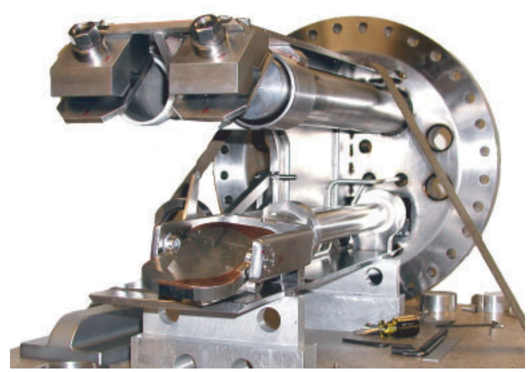


Existing BES (UW) imaging area





Upgraded Phase Contrast Imaging (MIT)



Microwave backscattering (UNM, UCLA, PPPL)

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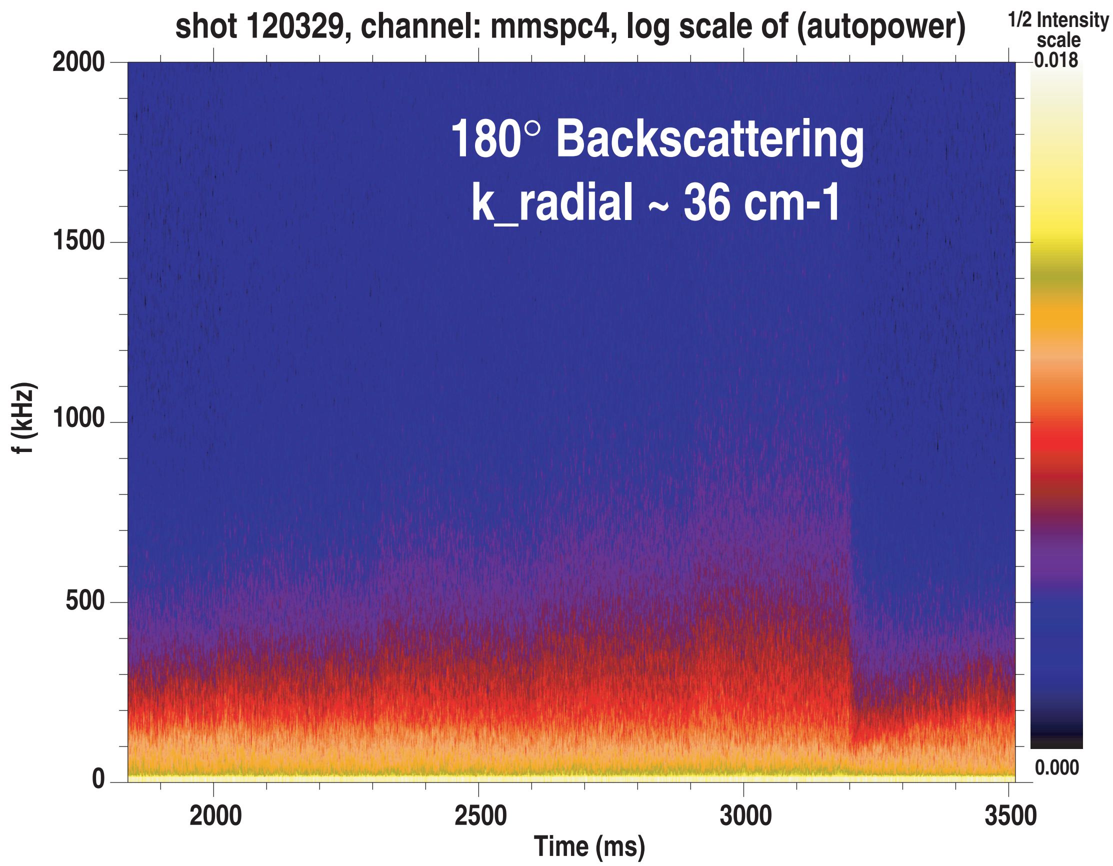
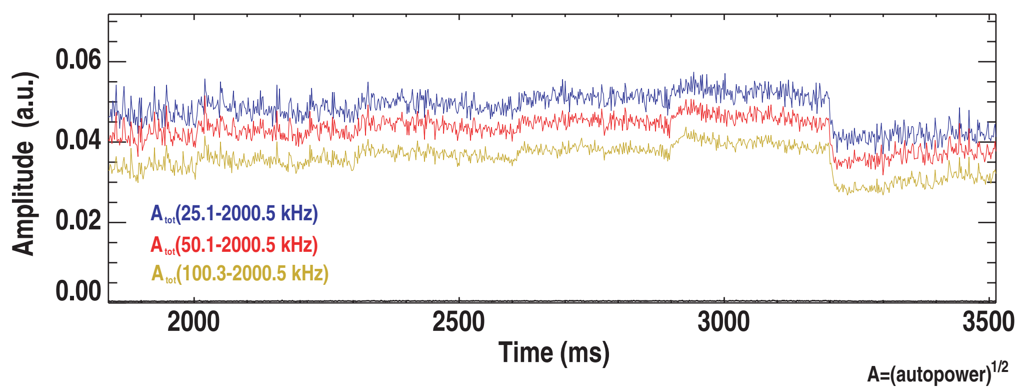
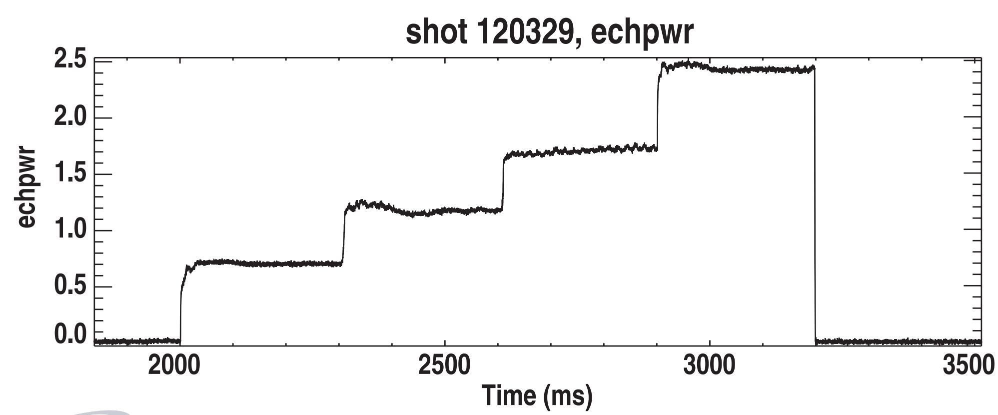
HIGH k BACKSCATTER DIAGNOSTIC RESULTS







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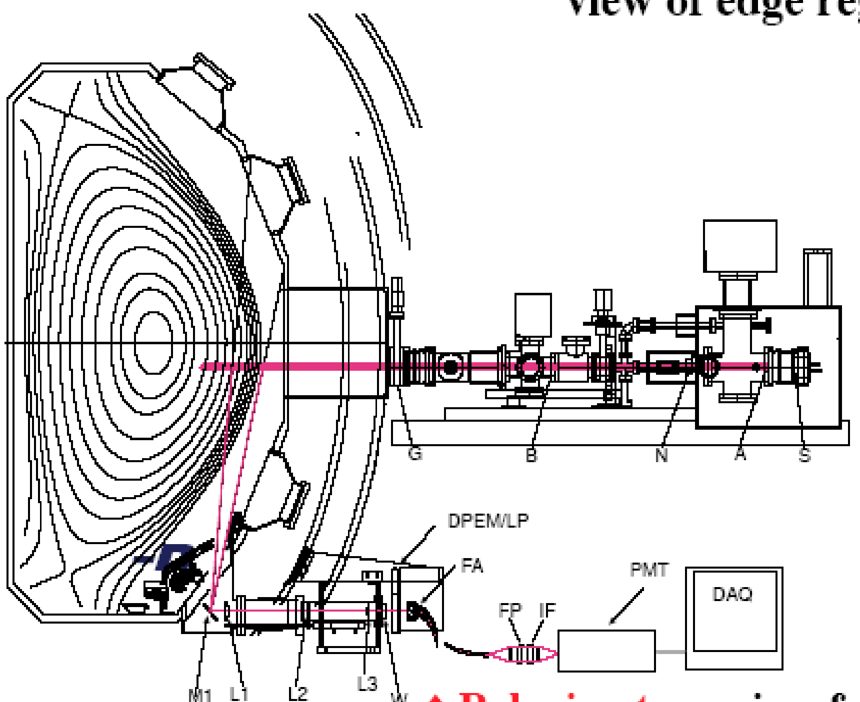
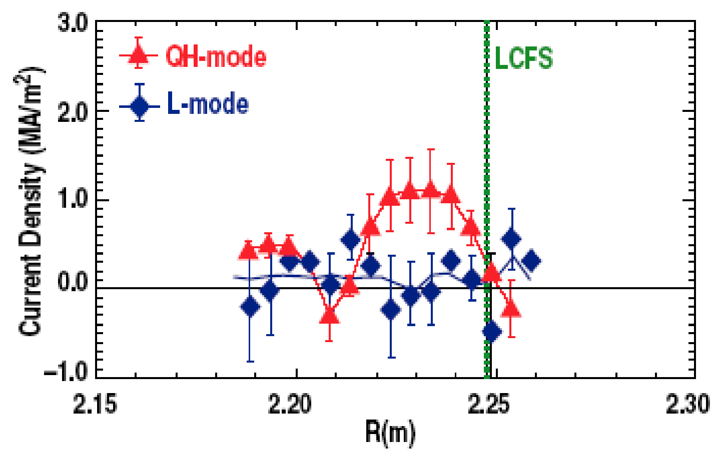
THE LITHIUM BEAM DIAGNOSTIC USES ZEEMAN POLARIZATION SPECTROSCOPY TO MEASURE THE EDGE CURRENT DENSITY

- **LIBEAM**: Neutral Lithium beam is injected just below the midplane at 75R0. This geometry along with vertical viewing from below gives best flux resolution for most DIII-D shapes. Good view of edge region (215-230cm)





- **Polarimeter**: view from below, near vertical viewchord fan

RECENT DIII–D RESEARCH RESULTS

- ECCD prevents 3/2 tearing mode, allowing β > non-stabilized value
  - — q-profile determination using realtime EFITs with MSE
  - — Precise localization of ECCD
- 3/2 NTM is shown to scale with ρ^*
  - — Instability is predicted for ITER baseline case
  - — AUG/JET/DIII–D ITPA
- Changes in core transport are observed to correlate with stability properties at q~1 (flux surface shape, magnetic shear)
- Data from new fluctuation diagnostics available
  - — Wide range of wavenumbers
  - — PCI (1–7), BES (0– 2), FIR (0–2 , 8–15), Backscattering (~40)
- Modulated ECH transport experiments
  - — No clear evidence of critical T_e gradient
- ECCD in high T_e plasmas show evidence of non-linear effects

RECENT DIII–D RESEARCH RESULTS (CONTINUED)

- Range of high q_{95} hybrid discharges extended
  - High density and T_i/T_e ~1.2
  - No observed decrease in overall fusion performance (ITPA)
- Sustain strong shear reversal with qmin > = 2 and ρ_{qmin} = 0.5–0.6 for >2.5 s
- All three FW systems resumed operation
  - Initial coupling and current drive data obtained
- Carbon 13 migration experiments
  - Measure poloidal flow of hydrocarbons
  - Deposition predominantly near the inner strike point (ITPA)
- Edge pedestal density width is consistent with neutral penetration,
  - Mahdavi-Englehardt-UEDGE models
- ELM suppression with stochastic layer

RECENT DIII–D RESEARCH RESULTS (CONTINUED)

- Comparison of RWM with co and counter NBI
  - Qualitatively consistent with collisionless damping
- Resonant field amplification observations
  - Range of size and plasma conditions (JET/DIII–D ITPA)
- Direct feedback of RWM is in good agreement with models
- Edge current density impacts stability (ELM occurrence) in QH–mode
- Increased density and beta achieved in DND QH–mode
  - Improved shape and profile control
- Alfvén modes in DIII–D/NSTX

DIII–D EXPERIMENTAL PLAN FOR FY2005

- FY2005 campaign starts on October 8^{th}
- Experiments remaining from original 21 week plan will start FY2005
  - FY2004 ended up with only 18 weeks
- Thrust and area leaders will organize plan for rest of 14 weeks
  - Based on previous research opportunities forum
  - Bottom up planning
  - Encourage collaborations

PROPOSED DIII–D FY2005 OPERATIONS SCHEDULE

Oct 04

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Nov 04

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Plasma physics Startup Vent Commissioning Contingency

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Plasma physics | Startup | Vent | Commissioning | Contingency

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Plasma physics | Startup | Vent | Commissioning | Contingency

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GOALS FOR THRUSTS IN FY2005

Thrust 1 – Pedestal

- Efforts on understanding and exploitation of the stochastic edge
- ITPA joint experiments on the pedestal height and width
- Evaluation and extension of VH-mode with new diagnostics to study the pedestal
- Continued development of testable models (for pedestal stability)

Possible NSTX collaboration areas

- Pedestal similarity – planned experiment for FY2005 – Maingi
- Edge and Pedestal turbulence measurements
- Imaging of ELM formation (Fast Camera) – Maingi
- Stochastic layers

GOALS FOR THRUSTS IN FY2005 (CONTINUED)

Thrust 4 – RWM

- RWM stability with high rotation
- Test high bandwidth actuators

Possible NSTX collaboration

- Existing PPPL/GA/Columbia RWM collaboration
- Scheduled for FY2005 – aspect ratio scaling of RWM and rotational stabilization
- Key NSTX collaborators
  - ★ M. Okabayashi, S Sabbagh, J. Menard

GOALS FOR THRUSTS IN FY2005 (CONTINUED)

Thrust 6 – High ℓ_i

- Study of stability and transport in plasmas with peaked current density profiles

Thrust 9 – QH and QDB

- Physics of ELM stability
- Identification of EHO
- Joint IEA/ITPA experiments

Possible NSTX collaboration areas

— We encourage ideas for NSTX/DIII–D collaboration in this area

GOALS FOR THRUSTS IN FY2005 (CONTINUED)

Thrust 8 – AT Scenario Development

- 100% non-inductive current drive
  - High normalized beta operation
    - ★ RWM stabilization
    - ★ Shape control
    - ★ Profile control

Possible NSTX collaboration areas

- H–mode Startup
- Ip ramp heating and control

GOALS FOR THRUSTS IN FY2005 (CONTINUED)

Thrust 10 – Hybrid Scenarios

- Demonstration of sustained high performance discharges (> ~10 s)
- Understanding the improvement in thermal transport
- Understanding of the physics mechanism for the poloidal flux transport

Possible NSTX collaboration areas

- We encourage ideas for NSTX/DIII–D collaboration in this area

POSSIBLE NSTX/DIII–D COLLABORATION IN TOPICAL SCIENCE AREAS

- **Stability**
  - Alfvén Modes – Fredrickson/Heidbrink, Nazikian
  - Error fields
- **Transport**
  - Comparison of Confinement of DIII–D and NSTX Plasmas
    - ★ Synakowski planned experiment for FY2005
  - TRANSP comparisons
- **Boundary**
  - Comparison of Divertor detachment – Soukvanofsky (LLNL)
- **H&CD**
  - EBW – Discussions and modeling needed
  - High Harmonic Fast Wave – part of existing collaboration?

CONTACTS FOR DIII–D NSTX COLLABORATION

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