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NSTX

Research on Transport and Turbulence in NSTX for 2006 – 08

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NSTX PAC-19

22–24 February 2006

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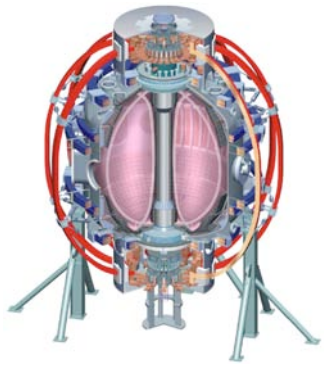
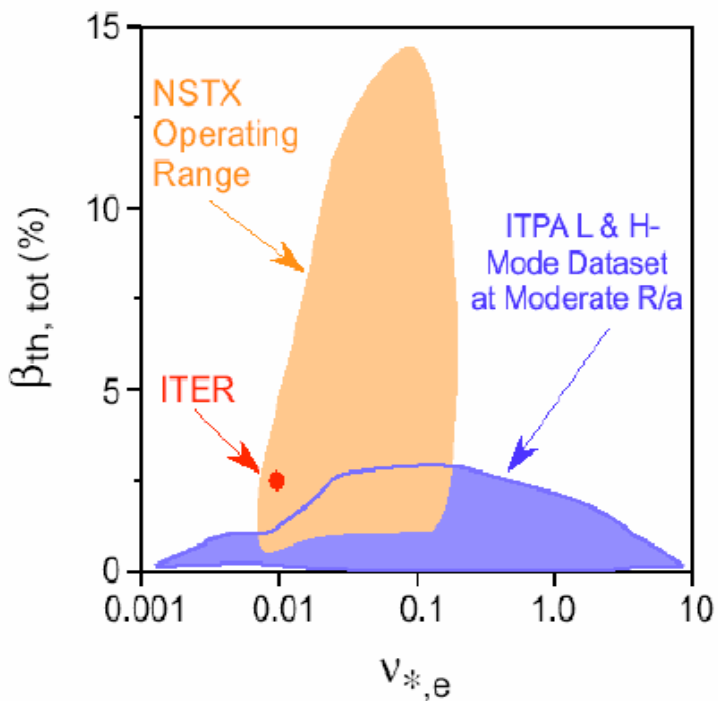


NSTX Operates in Regimes that can Resolve Fundamental Issues in Plasma Transport

- Dominant electron heating by supra-Alfvénic ions
  - Analogous to α-heating
- Electrostatic $\rightarrow$ electromagnetic turbulence as β increases
- Low aspect-ratio and plasma parameters facilitate measurements of both ion- and electron- scale turbulence
- Apparent suppression of anomalous ion transport
  - Turbulence suppression by high flow shear predicted by theory: *ab initio* and in recent calculations
- Electron transport dominant in most regimes
  - Discovered methods to control and reduce electron transport
- Milestone R(06-1): *Measure short wavelength turbulence in the plasma core in a range of plasma conditions. (Sep. 2006)*

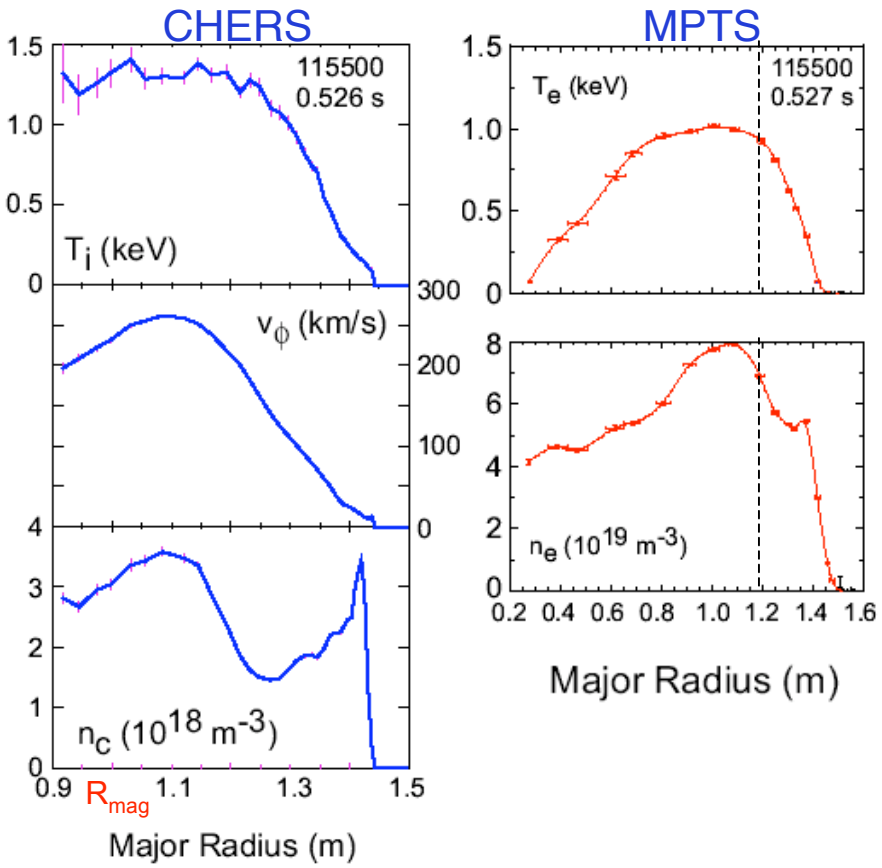
NSTX Research on Transport and Turbulence Contributes to High-Priority Issues for ITPA

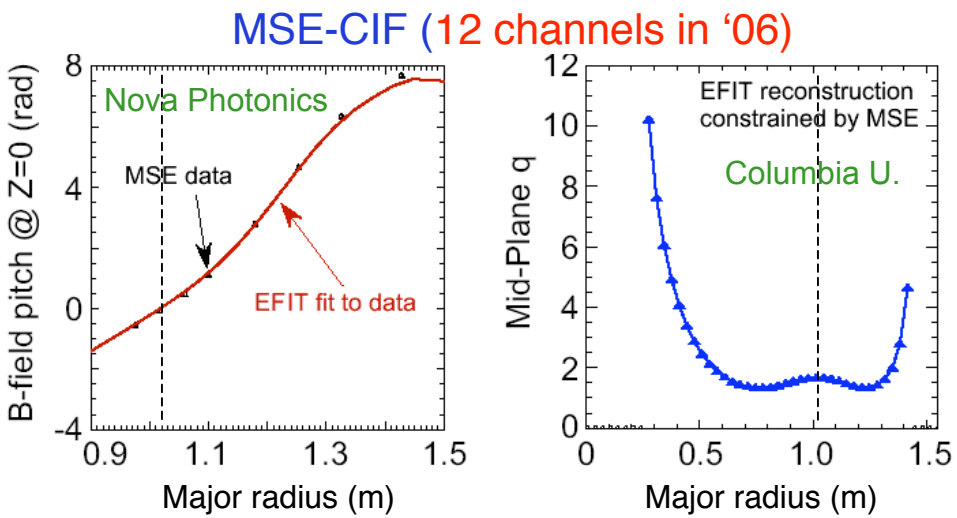
- Resolve β scaling in dimensionless formulation of scaling
  - Reduce uncertainties in ITER performance predictions
- NSTX data can help overcome limitation of (ρ*, ν*) colinearity in conventional R/a dataset
  - *see talk by S. Kaye*



- Low A can act as "tie-breaker" between competing theories and formulations for turbulence-driven transport
  - Trapped particles, mode coupling, magnetic shear
- Similarity experiments with DIII-D, identity experiments with MAST

Developing a Comprehensive Suite of Diagnostics to Research Transport and Turbulence





Profile data rapidly available for:

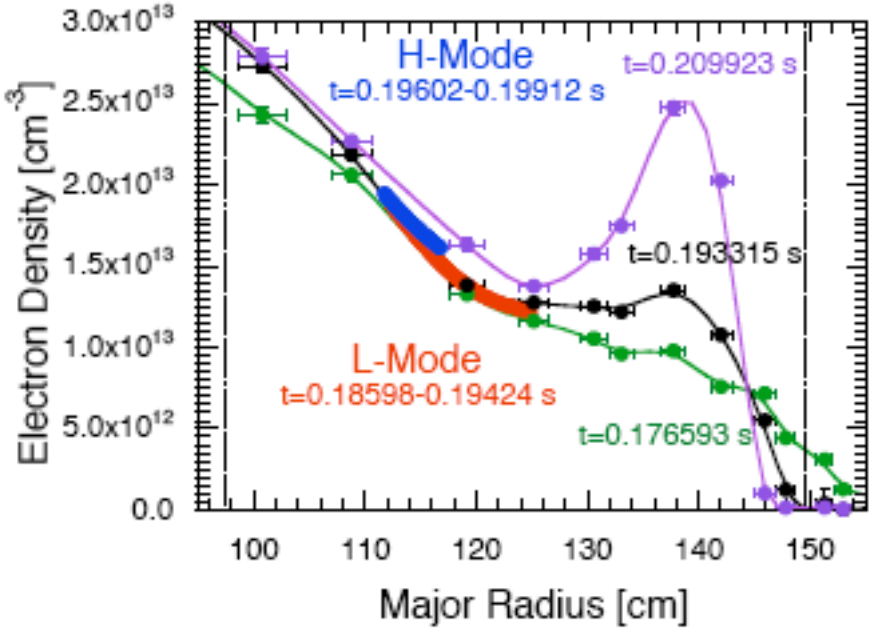
- Equilibrium analysis (EFIT, LRDFIT);
- Stability analysis (DCON, PEST, ...);
- Transport analysis (TRANSP)

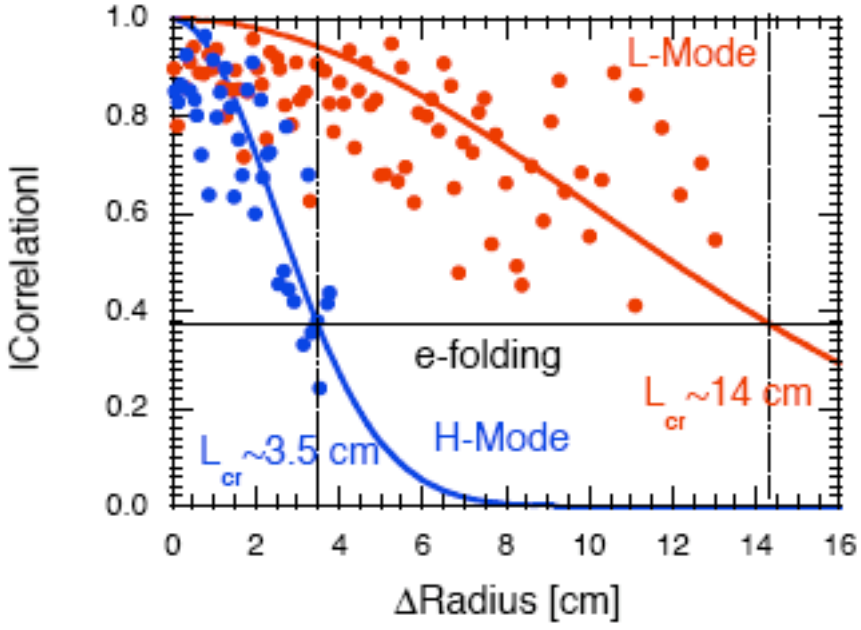
Fluctuation Diagnostics (upgrade)

USXR	4 arrays, 300kHz, multi-color for fast T_e
Correlation Reflect'r	Swept 26 – 40 GHz, $k_r < 5$ cm^{-1} $k_\theta < 0.5$ cm^{-1} (MHD to ion scale)
Quadrature Reflect'rs	30, 42, 50 GHz, $k_\theta < 0.5$ cm^{-1} (2006)
FIReTIP	4 (7) channels, $\delta n_e l$ at 0.5 (2.5) MHz
Tangential Scattering	$k_r \sim 4 – 22$ cm^{-1} (ion to electron-scale), $\delta k \sim 0.7 cm^{-1}$, $\rho < 0.7$, $\delta r \sim 3$cm; k_θ

Reflectometers Show Decrease in Radial Correlation Length of Signal Fluctuations at H-mode Transition

- Correlation reflectometers (20 – 40 GHz) work across H-mode transition in ohmically heated plasmas with initially peaked density profiles

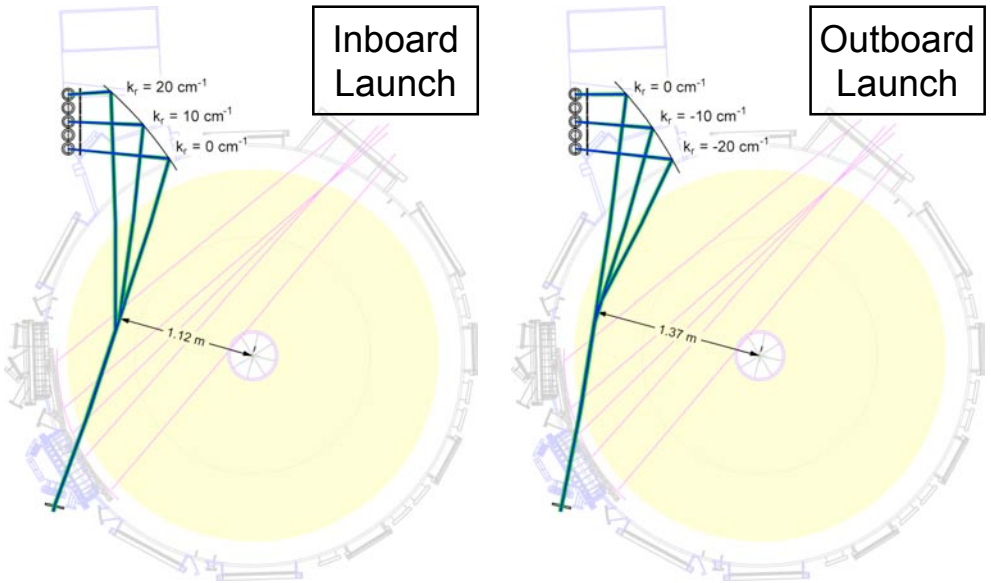


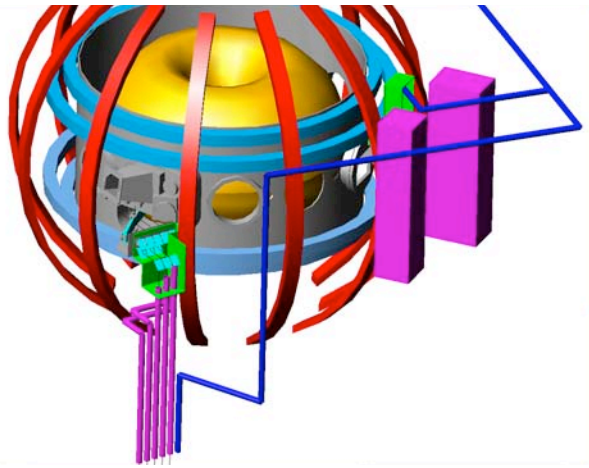


- Signal fluctuation spectra and amplitudes show little change
- Is reduction in radial correlation length evidence for flow-shear suppression?
- Measure *poloidal* correlation lengths with quadrature reflectometers this year

Tangential Microwave Scattering Can Probe Fluctuations of Interest for Electron Transport

- λ = 1.07 mm probe beam launched tangentially near midplane
- Inboard (ρ **< 0.1**) / outboard ($\rho \approx$ **0.7**) launch sightlines
- Five receiver sightlines scan $k_\perp$
  - **$k_\perp$ = 4 – +22 cm^{-1} (in), 4 – -22 cm^{-1} (out)**
  - Beam waist radius **~ 3 cm, $\delta k_\perp$ ~ 0.7 cm^{-1}**
- Detectable **$\delta n_e/n_e \sim 3 \times 10^{-5}$**

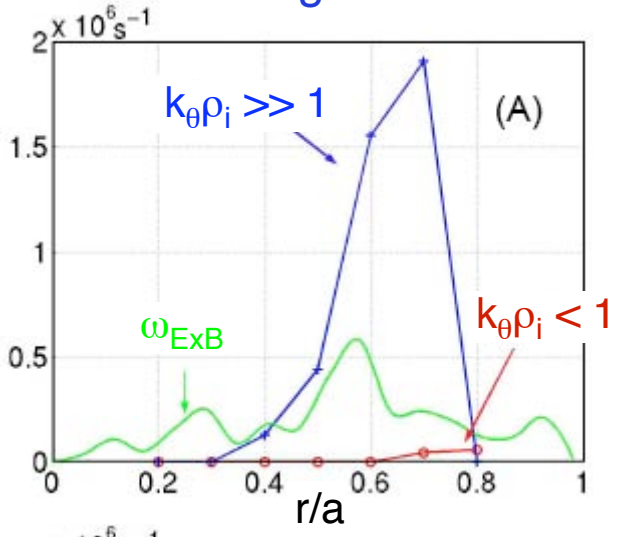


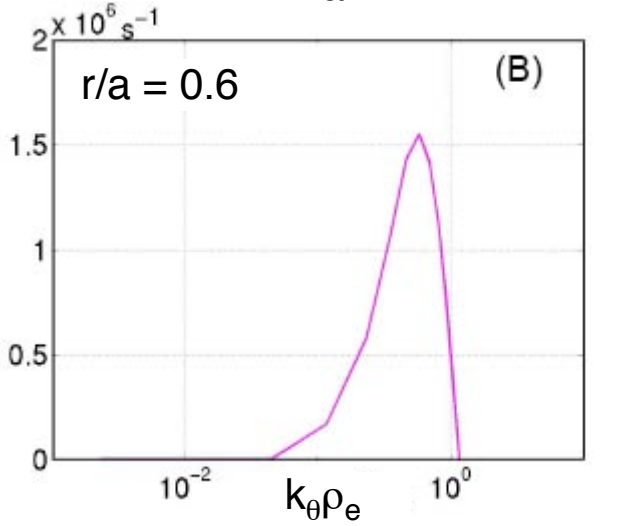


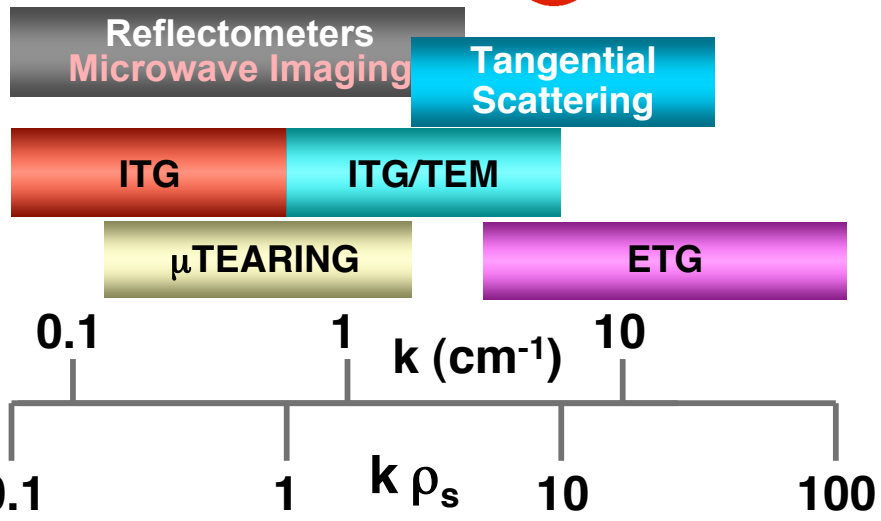
- Made possible by exceptional port access
- Measurement localized by toroidicity: good spatial resol'n
- Well matched to investigating ITBs in NSTX

NSTX Provides an Ideal Laboratory to Study Fluctuations Underlying Electron Transport

GS2 linear growth rates



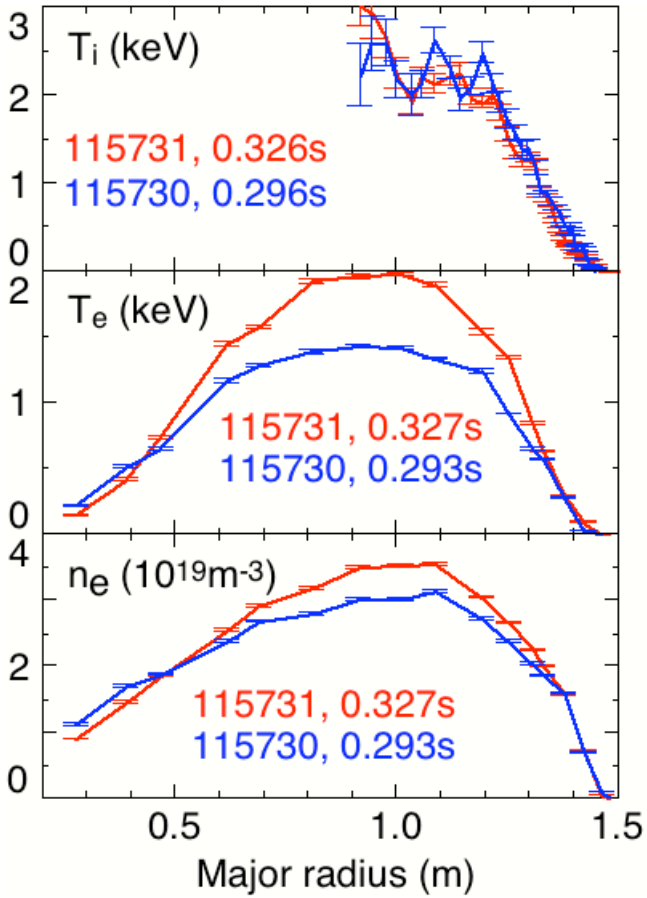


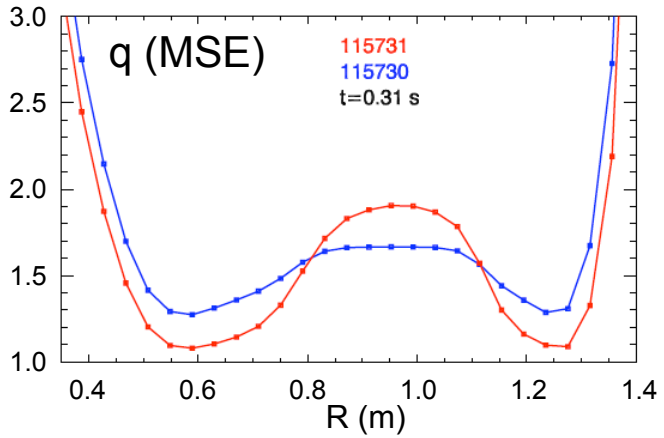


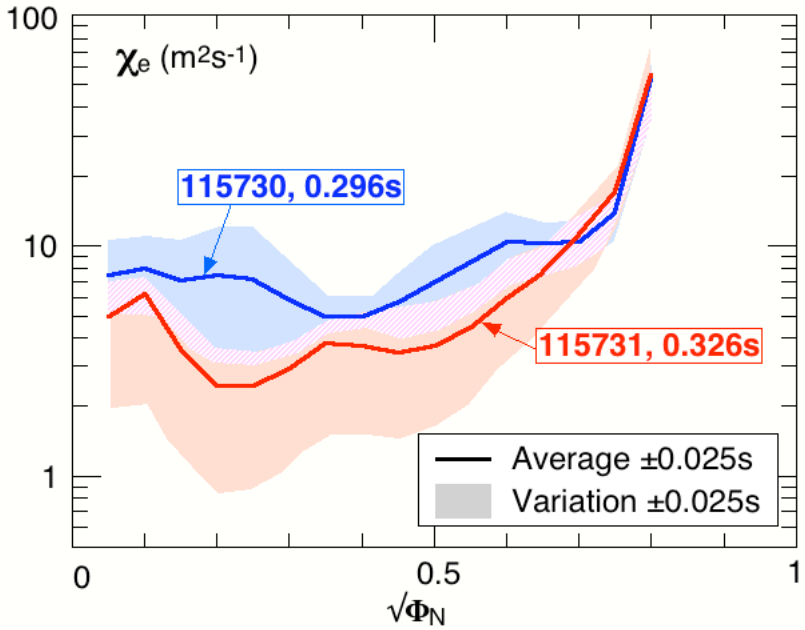
- New results from non-linear GYRO calculations of ITG/TEM applied to NSTX
  - Non-adiabatic electrons destabilizing
    - TEM effects magnified
  - E×B flows strongly stabilizing
  - Results sensitive to size of radial domain
    - Possibility of "turbulence draining"

Deeply Reversed-Shear Appears to Produce an Electron Internal Transport Barrier

- Compare shots with deeply and slightly reversed shear



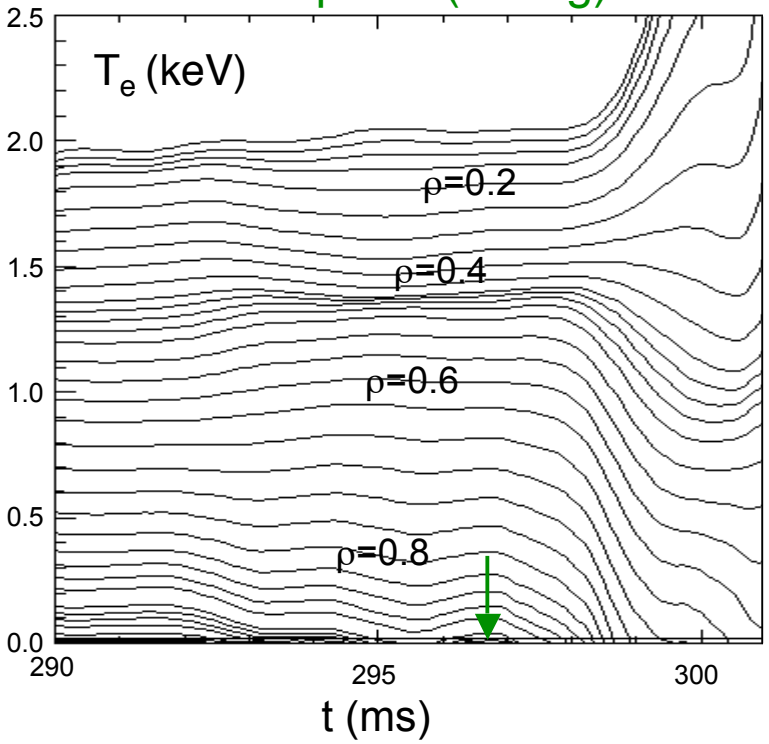


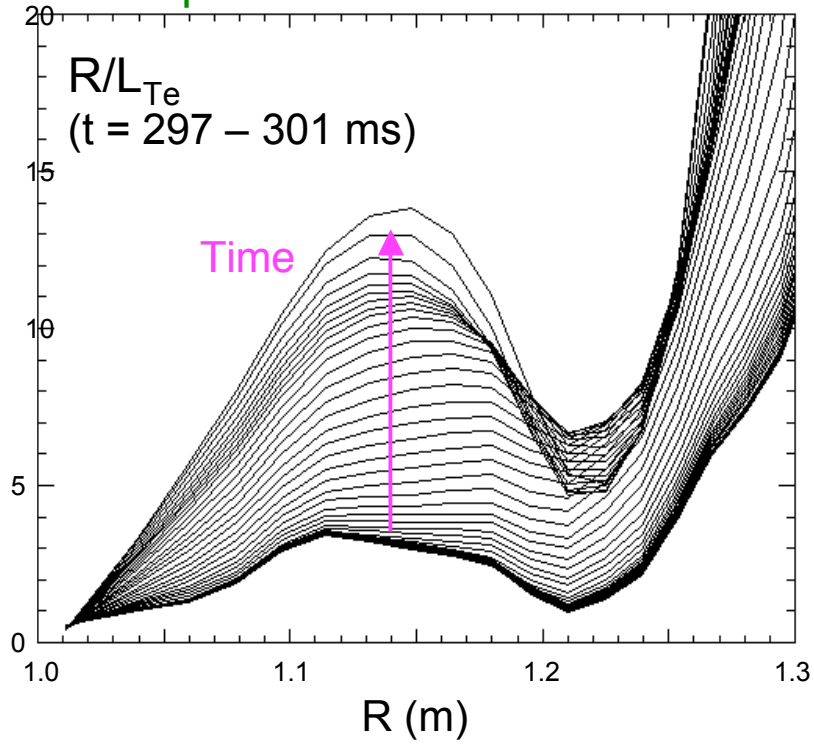


Perturbative Measurements with eITB Suggests Suppression of Turbulence Affecting Electrons

- Inject low-velocity lithium pellet to perturb T_e at edge
  - Density perturbation inside $\rho = 0.8$ is small
  - Follow T_e evolution with two-color SXR technique

Lithium pellet (0.5mg) into L-mode eITB plasma with 2 MW NBI

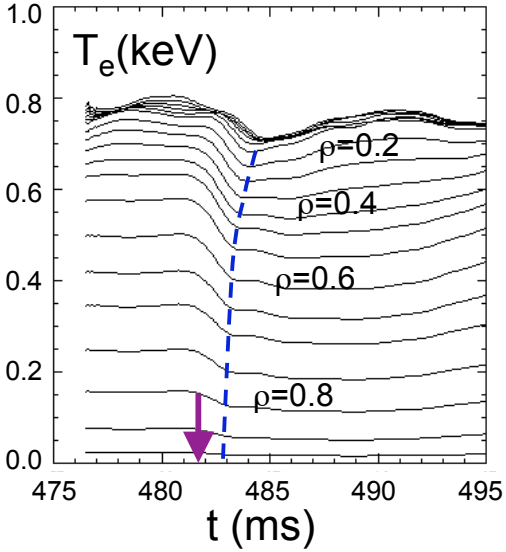




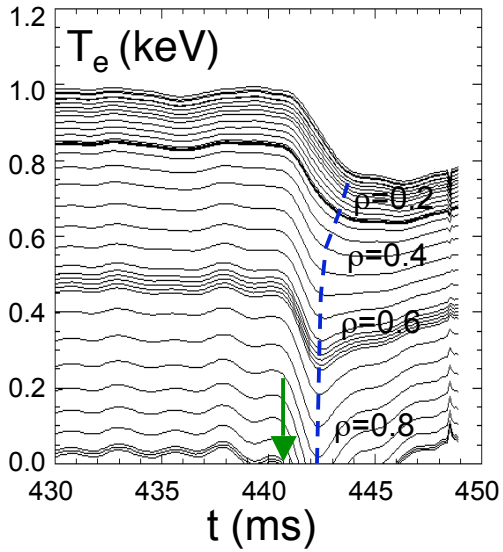
- Slow propagation, increase in $R/L_{Te} \Rightarrow$ marginal stability unlikely

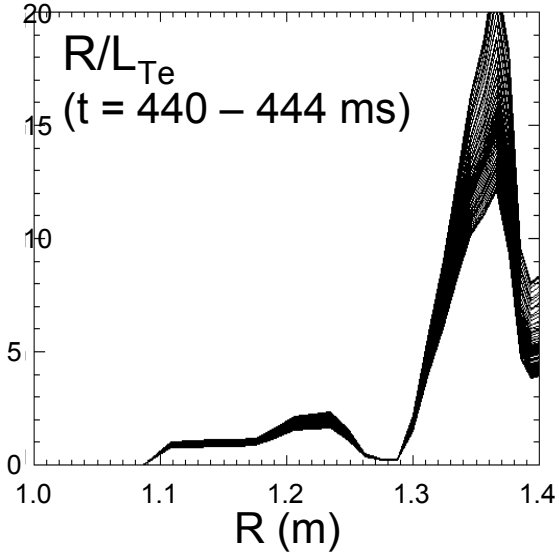
Perturbative e-Transport Large in NBI H-modes

Type-I ELM



Lithium pellet (0.5mg) into H-mode with 6 MW NBI





- T_e profile evolves with little change in $\nabla T_e/T_e$
  - Suggests critical gradient applies: marginal stability
  - c.f. earlier work on heat-pulse propagation
- Two time scales apparent
  - Perturbative χ_e *higher* in H-mode edge barrier

Research Interests for 2006 Experiments in Transport & Turbulence

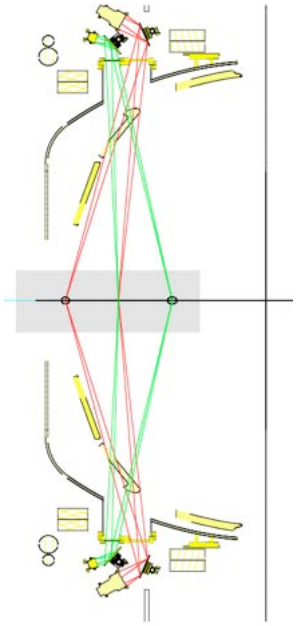
- Measurements of high-k fluctuations to meet milestone R(06-1)
  - Final alignment of high-k μ-wave scattering in first week (OH L-mode)
  - Observe during initial experiments on eITBs & perturbative transport
  - Develop dedicated experiment to measure in optimum conditions
- Study of low-density, RS discharges with & without eITBs
  - Continue '05 work with upgraded 12-channel MSE
  - Exploit possible benefits of lithium coating to control $n_e(R)$
- Perturbative studies of electron transport
  - Continue '05 work with upgraded 3-color "optical" SXR array (JHU)
  - Examine roles of collisionality, critical gradient and current
  - TESPEL (doped pellets) injection (NIFS collaboration)
- Momentum transport study with NBI heating
  - ITPA task TP-6.3

Research Interests for 2006 Experiments in Transport & Turbulence *(2)*

- Effects on transport of reducing recycling by lithium coating
  - Dramatic benefit in TFTR & favorable indications from CDX-U
- Transport in discharges with counter-NBI
  - MAST observed very different profiles and transport: eITB
- High-performance double-barrier regime – eITB + H-mode
  - Possibility for global suppression of turbulent transport
  - ITPA task TP-8.1: ITB Similarity Experiments with MAST, DIII-D
- Scaling of confinement, particularly β & A, B dependence
  - Contributions to both ITPA *(S. Kaye talk)* and CTF path
- Investigation of ion transport and heating
  - Neoclassical theory as $B_T \rightarrow B_P$ (GTC-Neo), FLR effects
  - Non-classical heating mechanisms, *e.g.* stochastic ion heating

Research Interests for FY 2007 – 8

- Continue work initiated in FY'06 and curtailed by limited run time
- Milestone for FY'07: *Study variation of local high-k turbulence with plasma conditions*
  - Develop from preliminary studies with tangential scattering in FY'06
  - Scans dominant scaling variables (I_p, B_T, P_{aux}, n_e) in all accessible modes of operation and heating to compare with theory
- Milestone for FY'08: *Measure poloidal rotation at low A to constrain theory*
  - Install interim poloidal CHERS this year for FY'07
  - Full system commissioned for FY'08 experiments
  - Compare with neoclassical poloidal flow
  - Full shearing rate data for simulating turbulence
  - Role of poloidal flow in internal transport bifurcations *c.f.* v_θ shear layer measured at TFTR ERS transition



NSTX Will Continue to Play a Vital Role in Transport & Turbulence Research

- Low aspect ratio creates unique plasma regimes
  - Reveals underlying physics
  - Stresses theory and pushes its development
  - High β: electrostatic $\rightarrow$ electromagnetic phenomena
  - Breaks colinearity in scaling data at standard A
- Overlaps with and extends standard tokamak operational regimes
  - L-mode, H-mode, ITBs, modified shear
- State-of-the-art diagnostics available and under development
  - Excellent access
  - Low B makes electron-scale turbulence measurable
- Planned experimental program contributes both to ITPA and to CTF development