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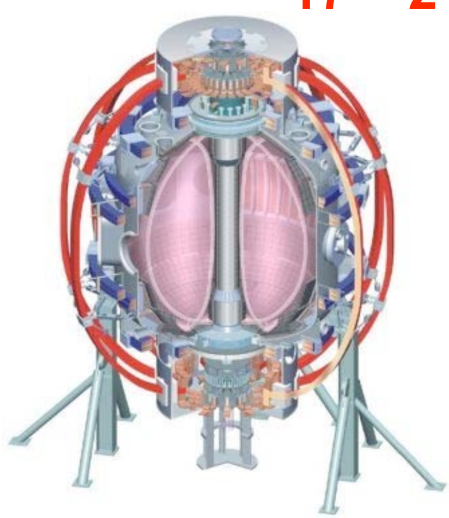
An Overview of NSTX 2008 Results

M.G. Bell
Princeton Plasma Physics Laboratory
for the ***NSTX Research Team***

50th Annual Meeting of the Division of Plasma Physics, APS
Dallas, Texas
17 – 21 November 2008



College W&M
Colorado Sch Mines
Columbia U
Comp-X
General Atomics
Idaho NEL
Johns Hopkins U
Los Alamos NL
Lawrence Livermore NL
Lodestar
MIT
Nova Photonics, Inc.
New York U
Old Dominion U
Oak Ridge NL
PPPL
PSI
Princeton U
Purdue U
Sandia NL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Maryland
U Rochester
U Washington
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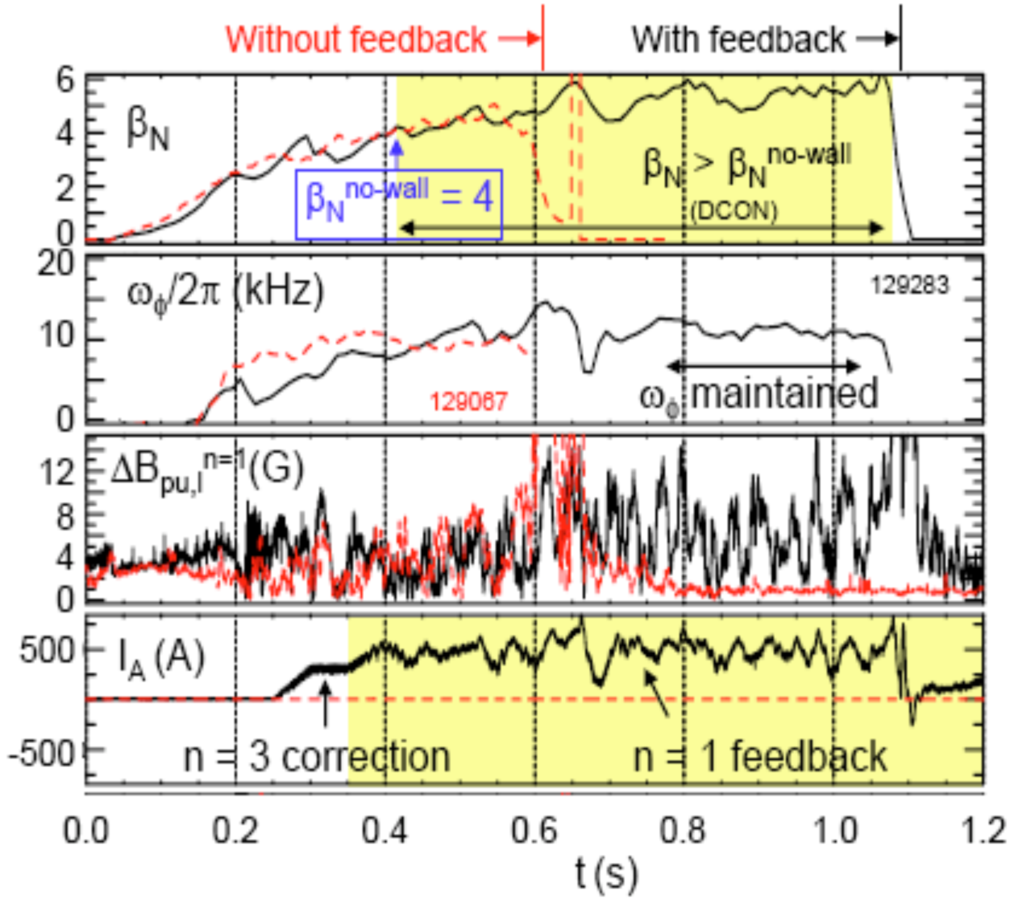
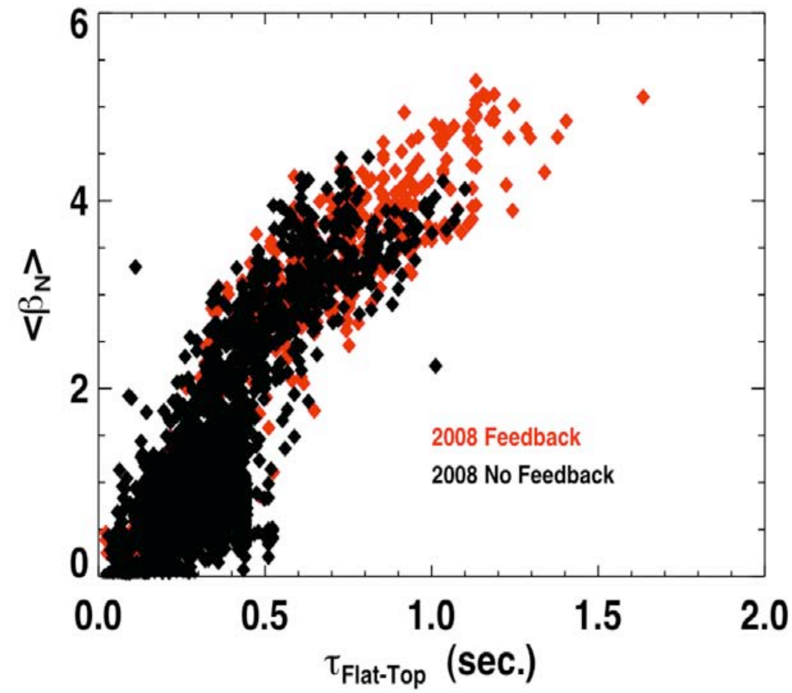
Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
KBSI
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

MHD Mode Control with Midplane External Correction Coils Maintains High Normalized-β



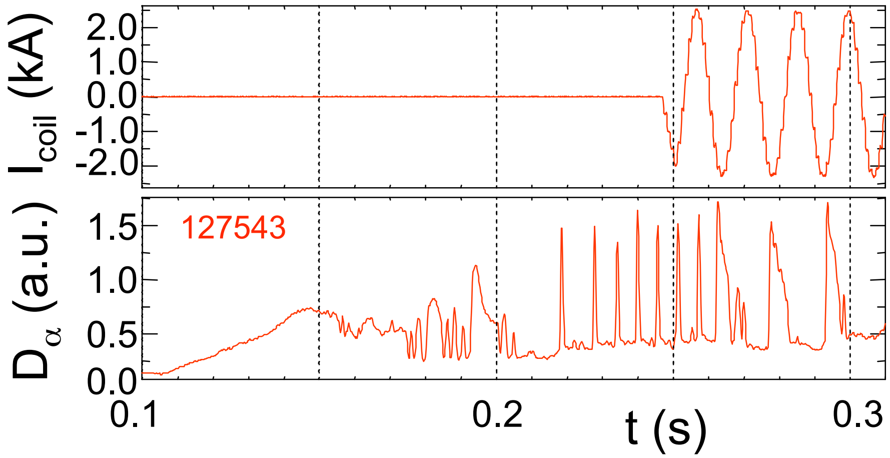
Optimized feedback scheme
applied routinely in 2008



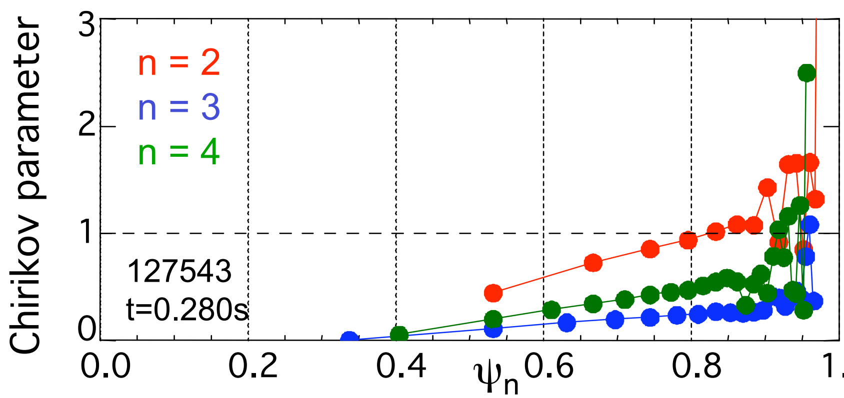
- Preprogrammed correction of n = 3 error field maintains toroidal rotation
- Resistive Wall Mode can develop at high normalized-β: terminates discharge
- Feedback on measured n = 1 mode reliably suppresses RWM growth

Investigated Use of Midplane External Correction Coils to Control ELMs

n = 2 field, 70 Hz, 5.5 kA p-p; q_{95} = 7.4

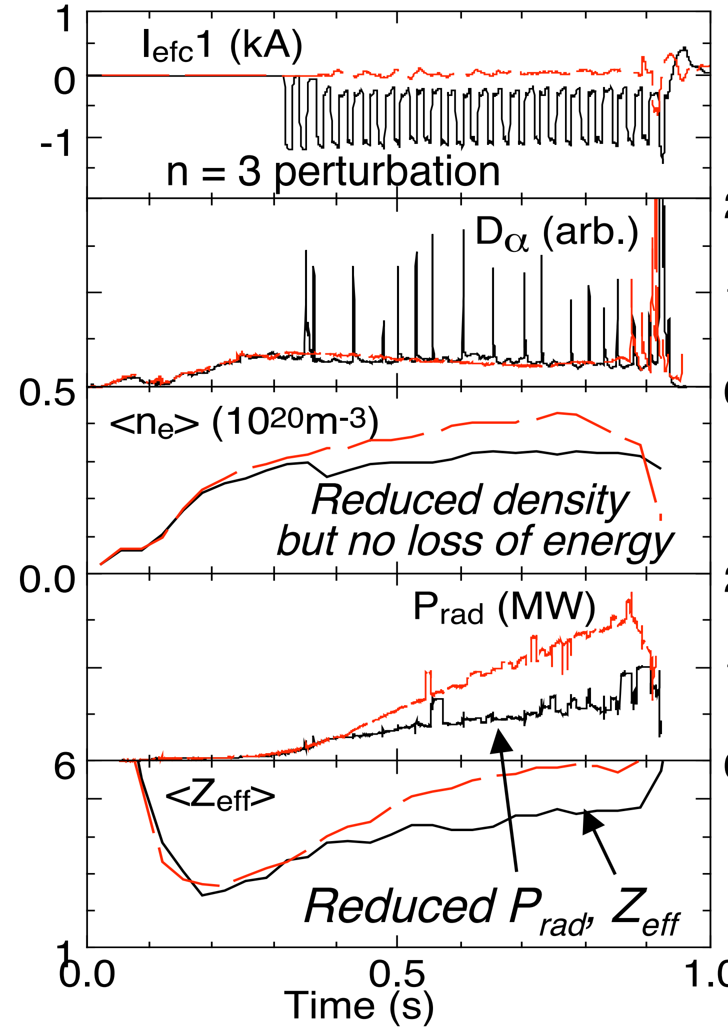


- ELMs broaden and lock to perturbation
- Calculations with IPEC show significant island overlap near edge



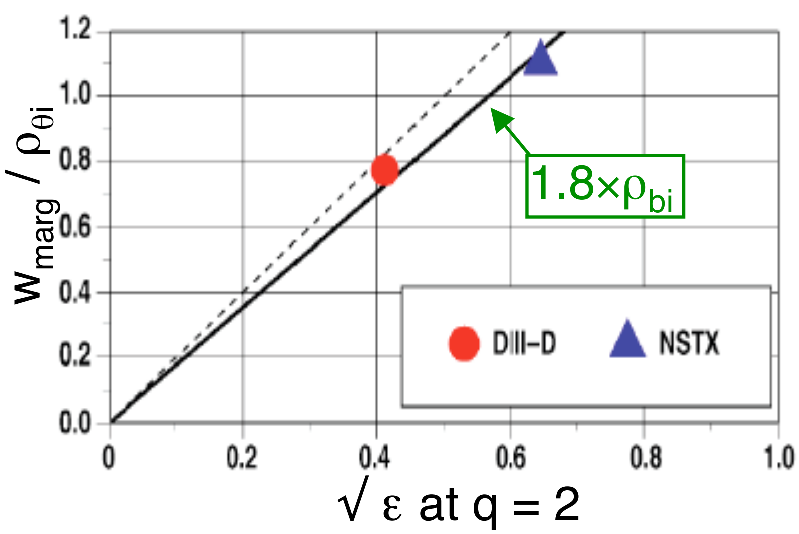
- Similar results for n = 3 & mixed n = 2 + 3

Coils can *induce* ELMs after ELM suppression by lithium

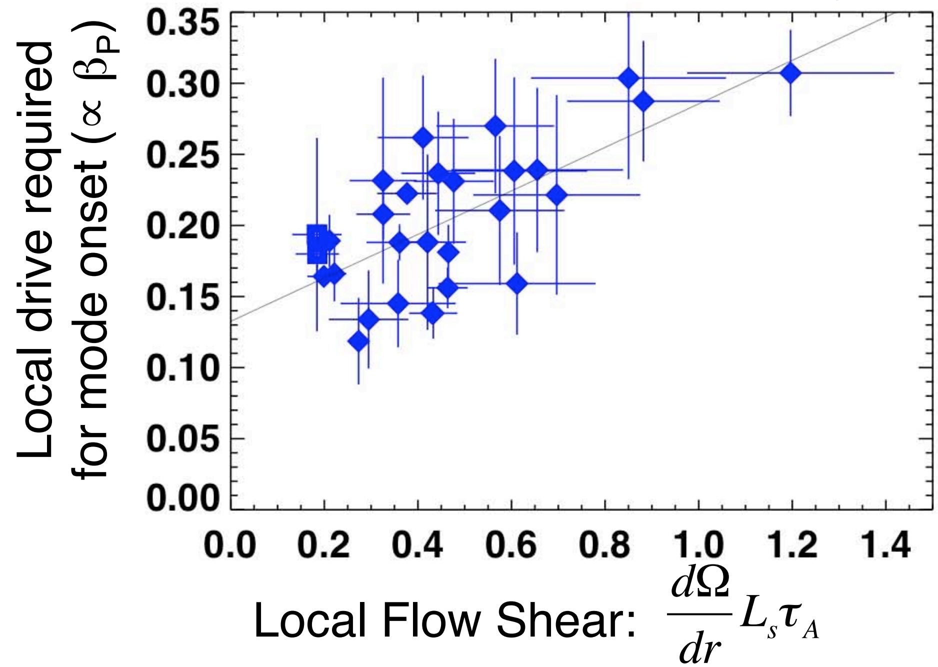


Studies of 2/1 NTM Reveal Physics Important for ITER

2/1 Marginal Island Width Scales with Ion Banana Width at q = 2



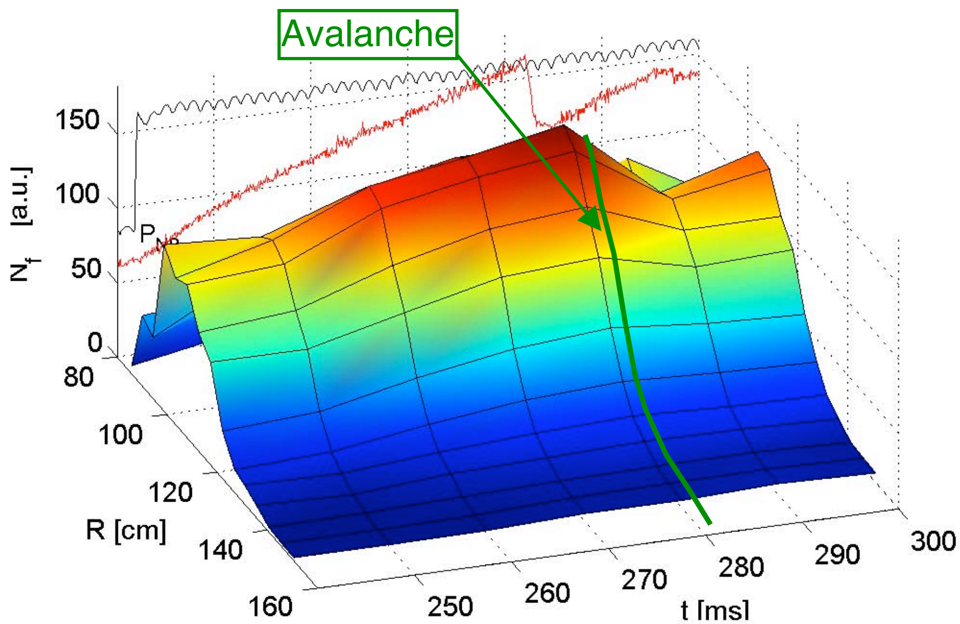
2/1 NTM threshold increases with V_{ϕ} shear



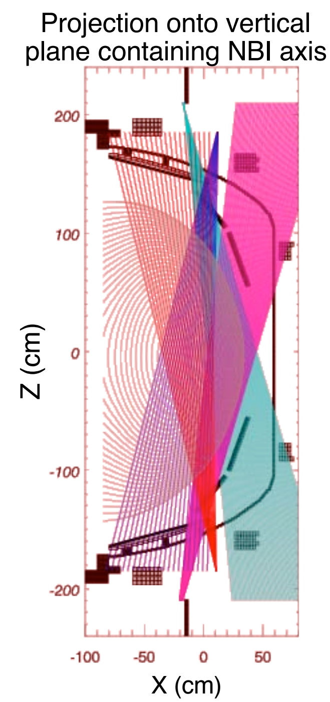
- Comparison of DIII-D, NSTX distinguishes ρ_{bi} from $\rho_{\theta i}$ dependence
- Flow varied using different NBI and *n* = 3 non-resonant braking
  - Trend with local flow shear likely due to dependence of Δ'
  - Correlation with flow velocity itself is weaker
  - Similar trend observed in co-/counter mix experiments in DIII-D

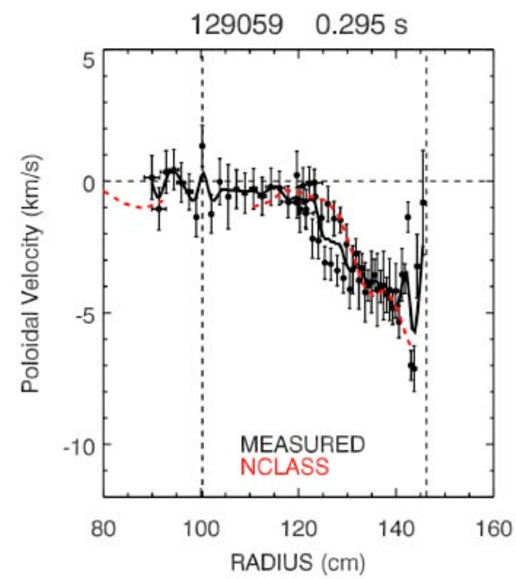
New Diagnostics Are Contributing to Confinement and Transport Studies

- **FIDA:** measures density of fast ions from Doppler-shifted D_α emission created by charge-exchange with NBI neutrals
- Measured fast-ion losses up to 30% during TAE avalanches
  - Consistent with neutron rate drop



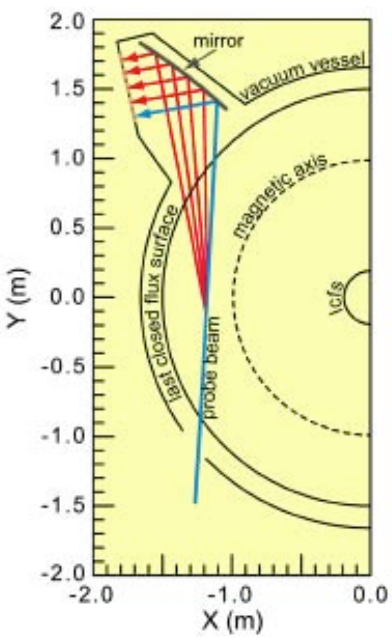
- **Poloidal-CHERS** system (75 active, 63 background, top & bottom symmetric sightlines) operated through 2008 run
- Comparing measurements to theory (NCLASS, GTC-Neo) in range of conditions

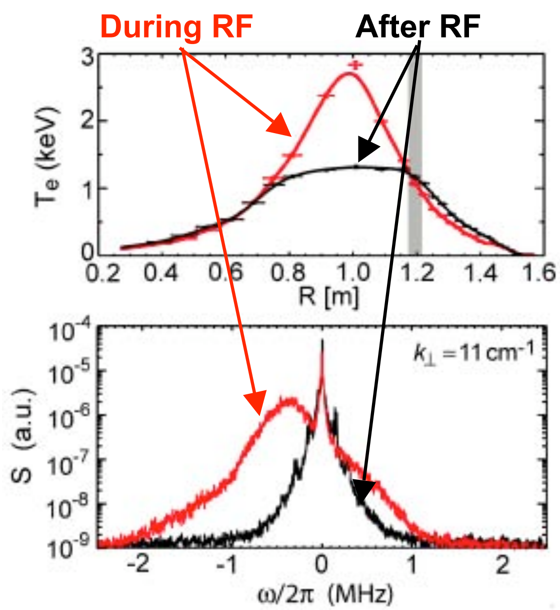


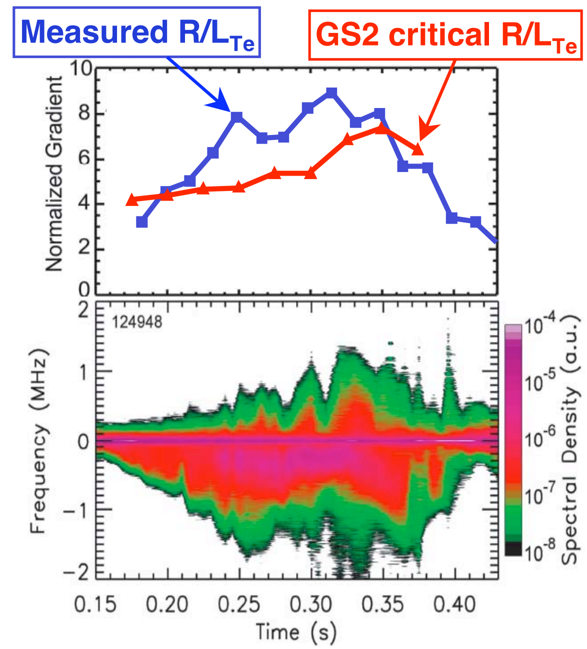


Heating Electrons with RF Waves Drives Short-Wavelength Turbulence in Plasma Core

- Fast waves at high harmonics of ion-cyclotron frequency heat electrons







- Detected fluctuations in range $k_\perp\rho_e = 0.1 – 0.4$ ($k_\perp\rho_s = 8 – 16$) propagate in electron diamagnetic drift direction in plasma frame
  - Rules out ITG mode ($k_\perp\rho_s \sim 1$) as source of turbulence
  - Reasonable agreement with linear gyrokinetic code (GS2) for **ETG mode** onset
- Also observed suppression of apparent ETG mode by central shear-reversal [Jenko & Dorland, PRL **89** (2002)] and high T_e/T_i

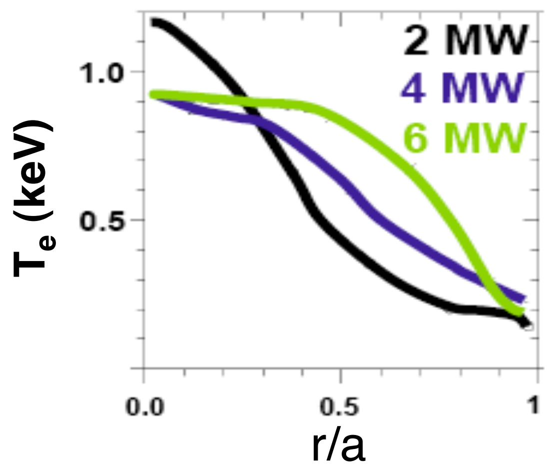
Investigating Role of High-Frequency MHD Modes in Core Electron Transport

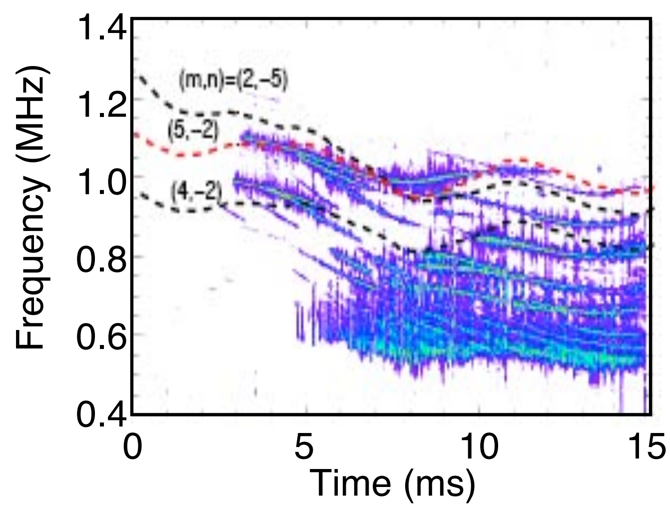
- Observe "flat T_e" region in core of plasmas with high NBI power

⇒Implies mechanism for electron transport *not* driven by T_e gradient

- Global Alfvén Eigenmodes (GAEs) driven by fast-ion pressure gradient a possible source

$$\omega_{GAE} \simeq v_{A0}(m - nq_0)/q_0R.$$

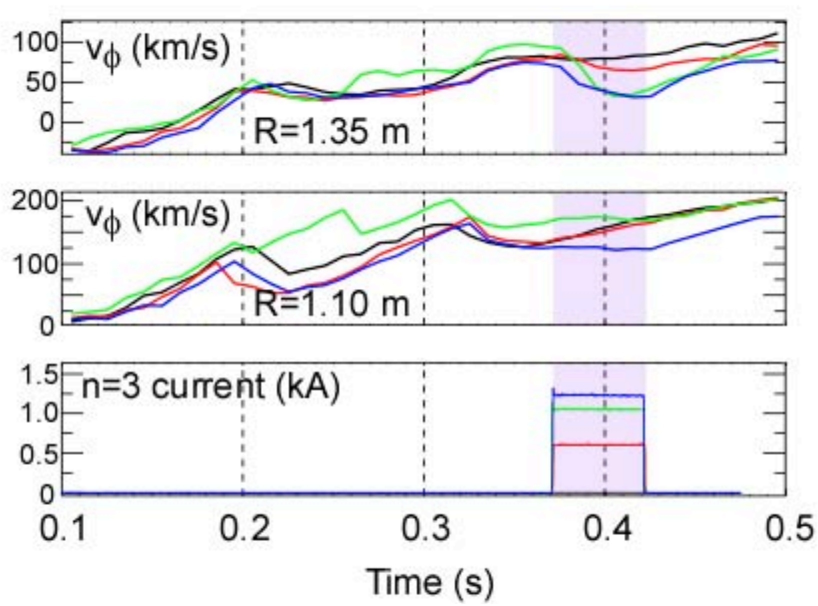




- GAEs localized near center
- $f_{GAE} \sim f_{be}$ (trapped electron bounce frequency)
- Model effects with ORBIT code with typical GAE frequency and amplitude
  - See rapid radial diffusion of electrons

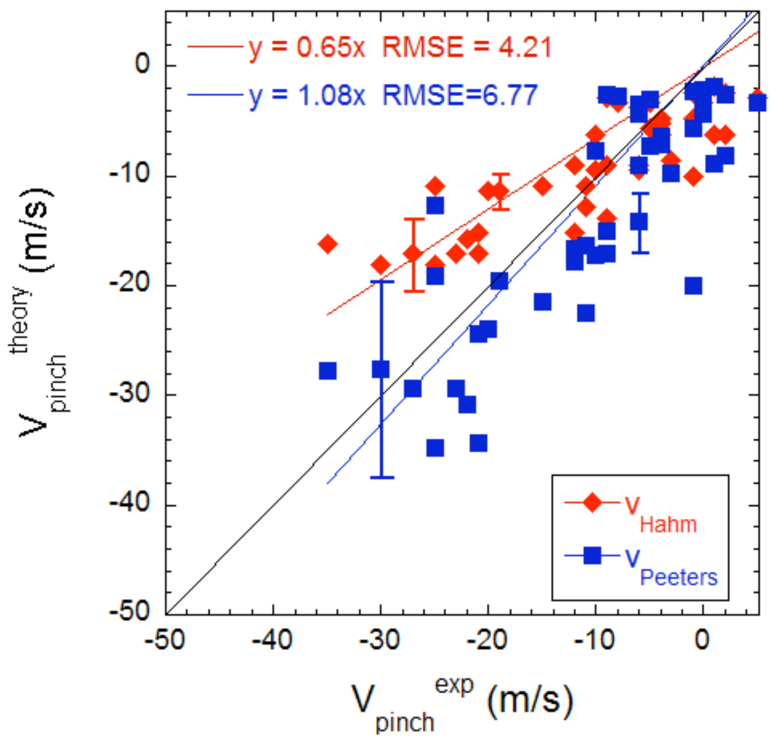
Investigated Momentum Transport Using Transient Perturbations to Separate Diffusivity and Pinch Terms

- n = 3 braking pulses perturb rotation in outer region



- Determine χ_ϕ, v_{pinch} after turn-off of n=3 pulse
  - NBI provides only known torque (calculated by TRANSP)

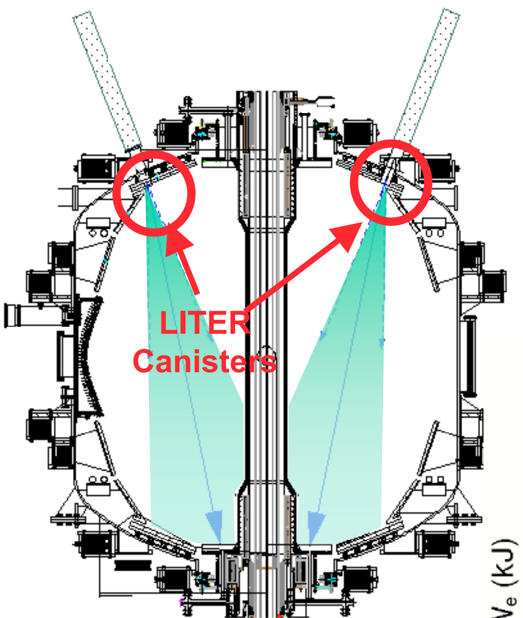
- Inferred pinch velocities in outer region agree reasonably well with theories based on low-k turbulence



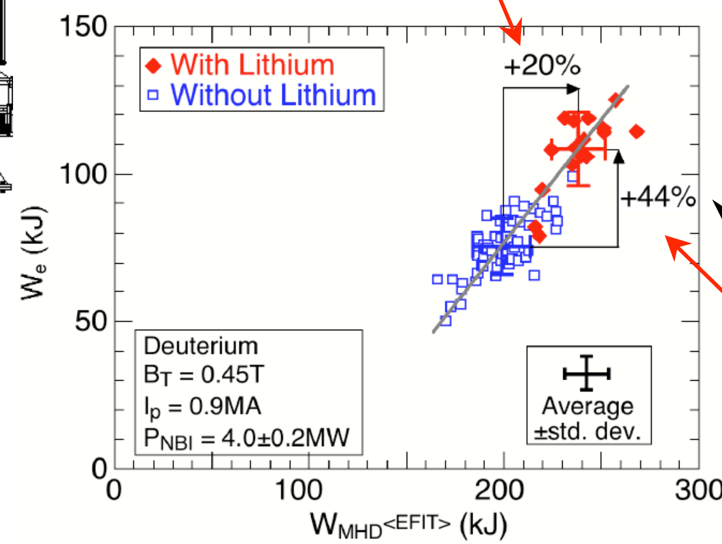
Peeters *et al.* (PRL, 2007)
Hahm *et al.* (PoP, 2007)

Solid Lithium Coating Reduces Deuterium Recycling, Suppresses ELMs, Improves Confinement

- Second lithium evaporator added in 2008
  - Lithium on entire lower divertor surfaces
  - Shutters interrupt vapor during discharges

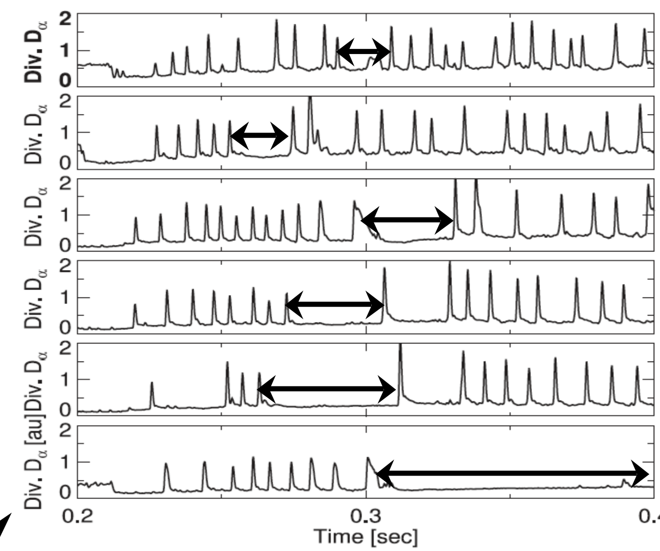


- ***With lithium stored energy increases 20%***



Increasing lithium coating thickness

- ***Lithium extends ELM free periods***

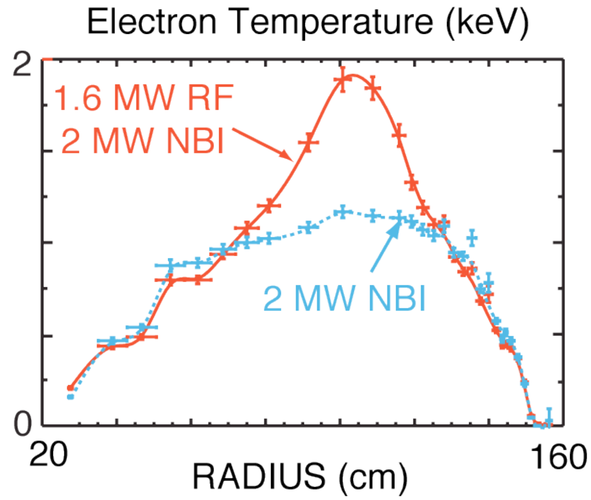


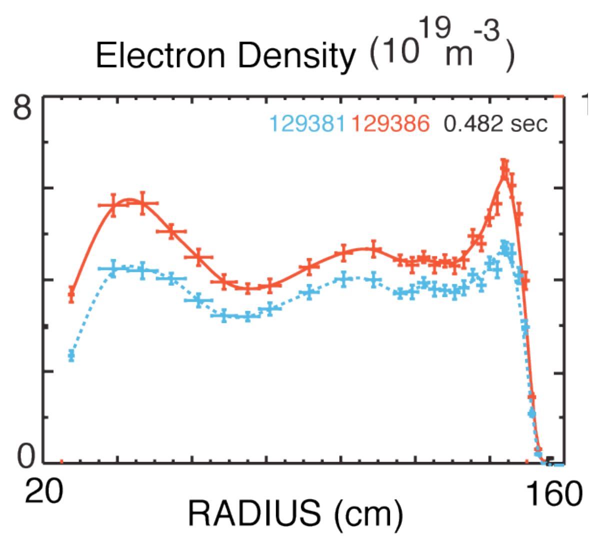
- ***Most of the improvement in confinement is in the electron channel***

- *Similar effects produced by injecting stream of lithium powder into scrape-off*

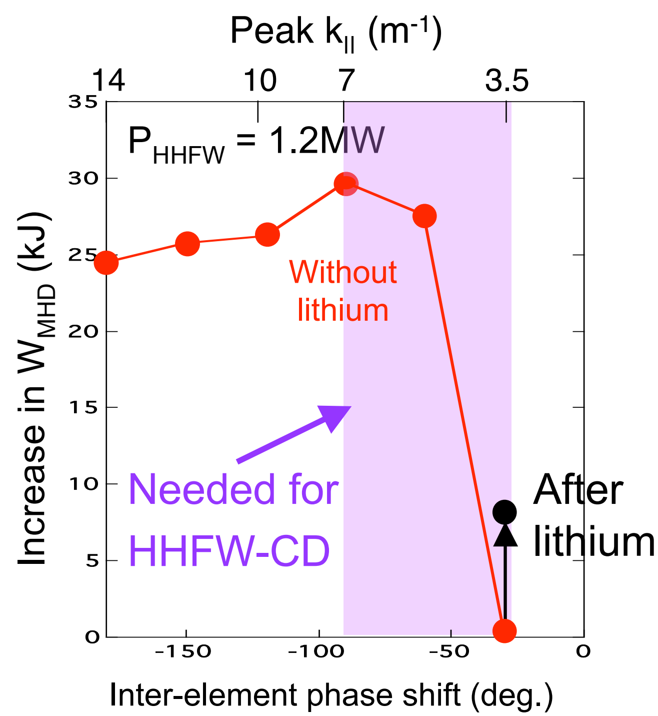
Lithium Coating Improves HHFW Heating Efficiency in NBI H-Modes and at Low $k_{||}$ for Current Drive

Core Electron Heating in Deuterium NBI H-Mode





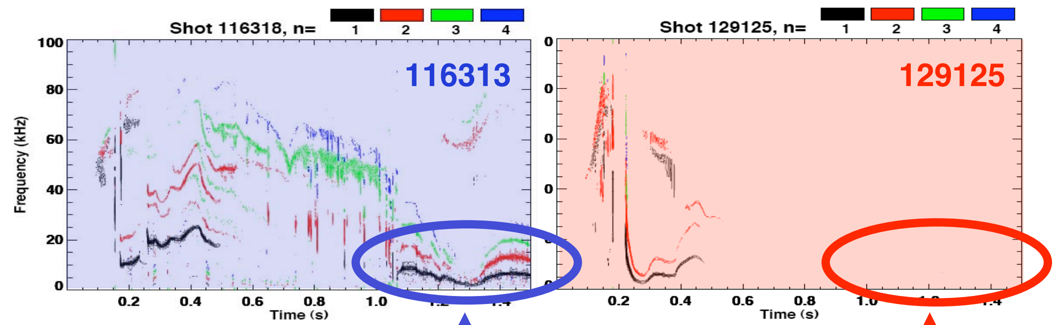
Electron Heating by HHFW in Deuterium L-Mode



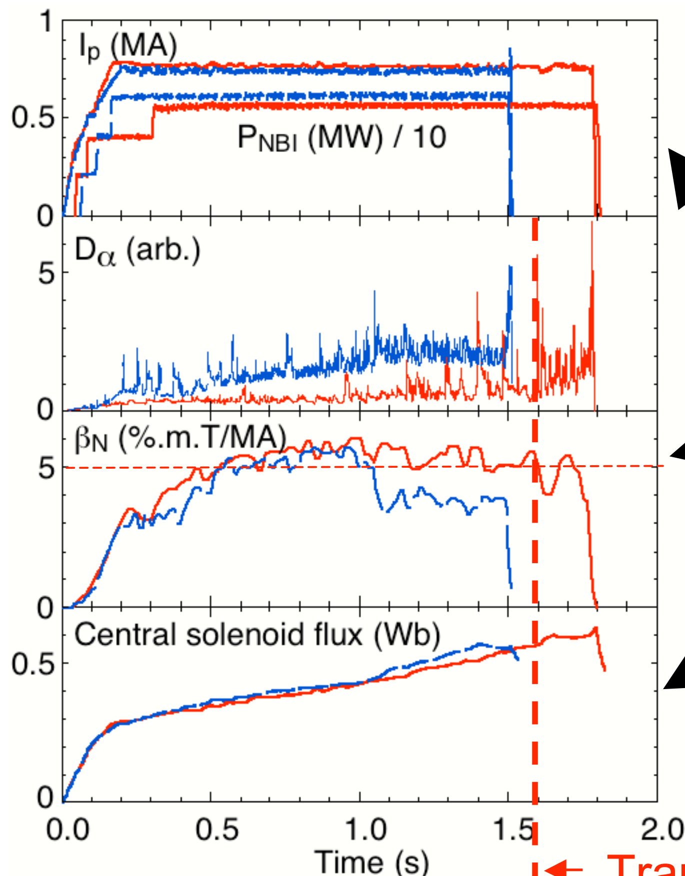
- Without lithium, increase in W_{MHD} during HHFW vanishes for $\Delta\phi < 60^{\circ}$
- Reduction in edge density with lithium suppresses excitation of surface waves

n=3 Error Field Correction With n=1 RWM Feedback and Lithium Coating Extends High-β_N Discharges

116313 – no mode control or Li
129125 – with mode control + Li



Onset of n=1 rotating modes avoided



NSTX record pulse-length = 1.8s

$\beta_N \geq 5$ sustained for 3-4 τ_{CR}

- EF/RWM control sustains rotation, high β

Flux consumption reduced by sustained high β + Li conditioning

- High elongation κ = 2.4 increases bootstrap current fraction

← Transition to phase with larger, more frequent ELMs

NSTX is Revealing New Physics in Toroidal Magnetic Confinement and Developing the Potential of the ST

- Extending understanding of MHD stability at high β
  - Extending pulse length through active control of low-n modes
  - Investigating possibilities for ELM suppression and mitigation
  - Developing NTM physics
- Investigating the physics of electron, fast-ion and momentum transport
- Assessing the potential of lithium as a plasma facing material
  - Solid lithium coatings of PFCs reduce recycling, improve confinement
  - ELMs can be suppressed by lithium *but triggered on demand by RMPs*
- Making good progress towards goal of non-inductive sustainment
  - Maximizing bootstrap current contribution
  - Developing CHI startup *(Raman, CO3.13)*
  - Developing RF current drive by HHFW

Many more details will be provided in this session and in the NSTX posters
NP6.81–125 *- Wednesday morning, and invited talks:*

GI1.1 *M. Podestà*	***GI1.2*** *N. Gorelenkov*	***GI1.5*** *J-K. Park*
TI2.3 *R. Maqueda*	***TI2.5*** *H. Yuh*	***YI2.5*** *D. Smith*