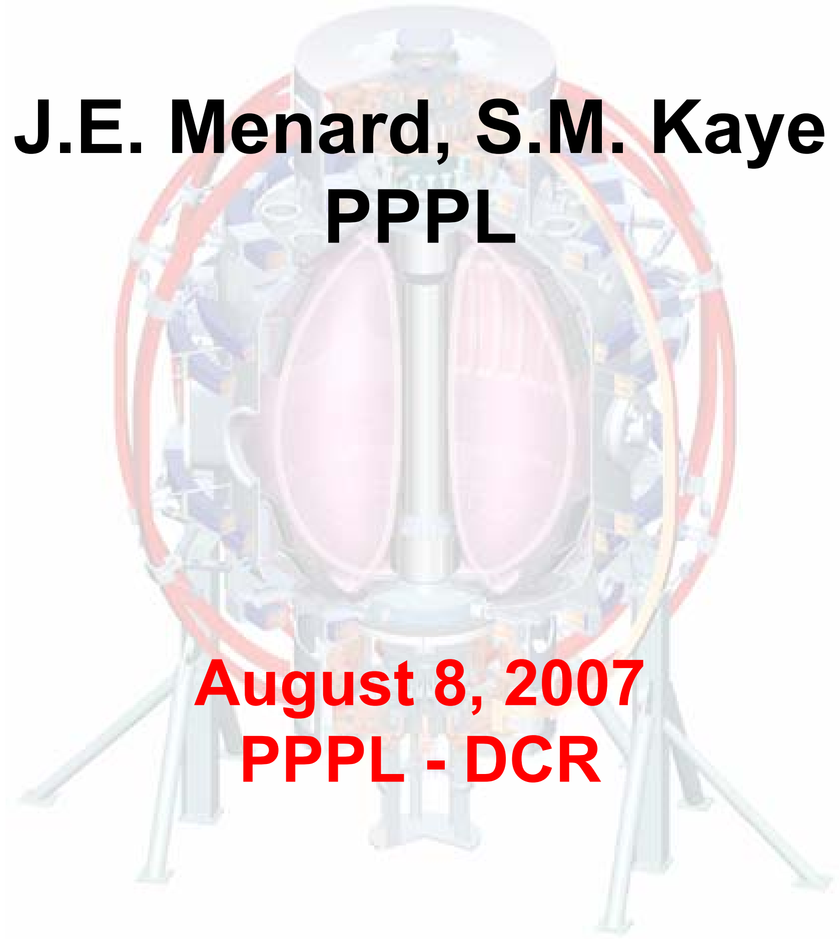
Supported by Office of Science

NSTX

Overview of NSTX Research Results from the FY2007 Run



J.E. Menard, S.M. Kaye
PPPL

August 8, 2007
PPPL - DCR

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NSTX contributes broadly to fundamental toroidal confinement science in support of ITER and future ST’s

- Macroscopic Stability
- Transport and Turbulence
- Wave-Particle Interactions
- Boundary Physics
- Integrated Scenarios + Solenoid-free Start-up

NSTX contributes broadly to fundamental toroidal confinement science in support of ITER and future ST’s

- Macroscopic stability: NSTX is developing predictive understanding and control of performance-limiting MHD
  - Improved low-f mode detection improves RWM and EF control
  - n > 1 error fields discovered & corrected, improving plasma sustainment
  - Low-A, low B_T locked mode threshold scaling favorable for ITER, ST’s
  - NTM onset β increases with increased rotation – important for next-steps

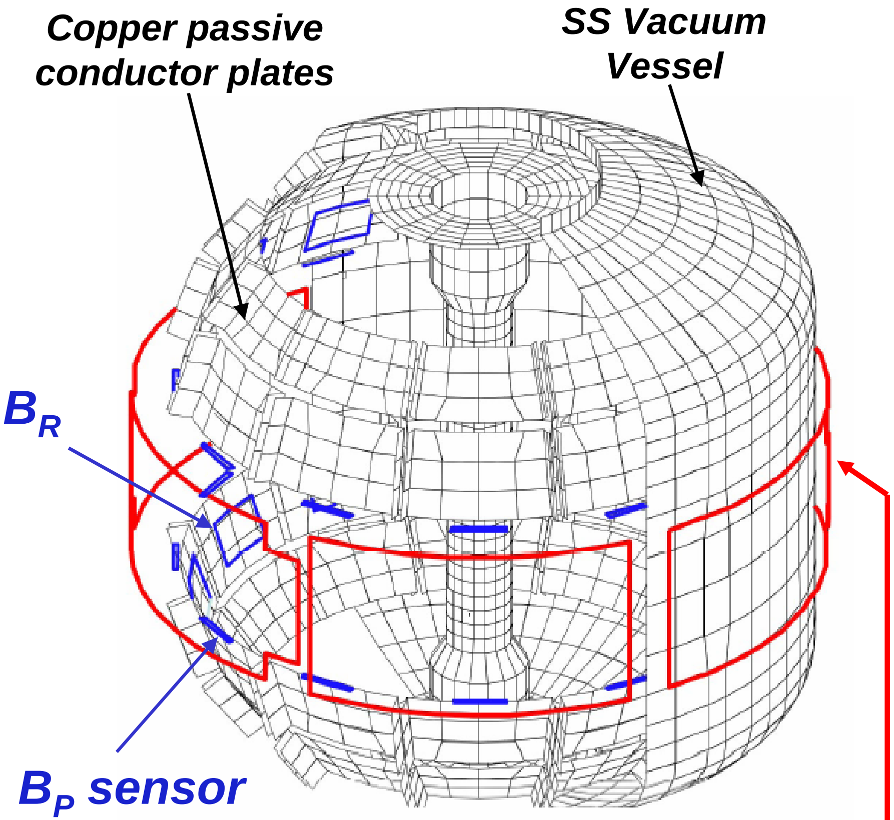
Improved mode detection improved the performance of resistive wall mode/error field (RWM/EF) control in NSTX in 2007

- Effective RWM and EF control relies heavily on robust detection of small (~1G) non-axisymmetric B-fields

- NSTX has unique and powerful low-f real-time mode detection capabilities:
  - 48 sensors, 2 components of B:
    - 24 radial (B_R) and 24 poloidal (B_P)
  - Toroidal mode-numbers n=1,2,3

- Only $B_{P\text{-}U}$ used for control in FY06
  - Limited by available run time

- Several new RWM/EF sensor combinations tested in FY07:
  - $B_{P\text{-}U} + B_{P\text{-}L}$
  - $B_{R\text{-}U} + B_{R\text{-}L}$
  - $B_{P\text{-}U} + B_{P\text{-}L}$ with spatial offset
  - All sensors in combination



Copper passive conductor plates

SS Vacuum Vessel

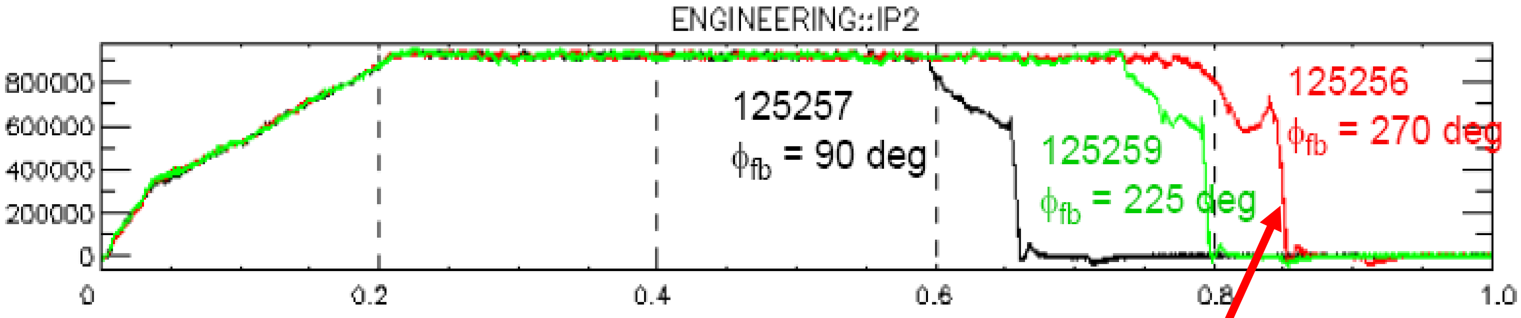
B_R

B_P sensor

VALEN Model of NSTX (Columbia Univ.)

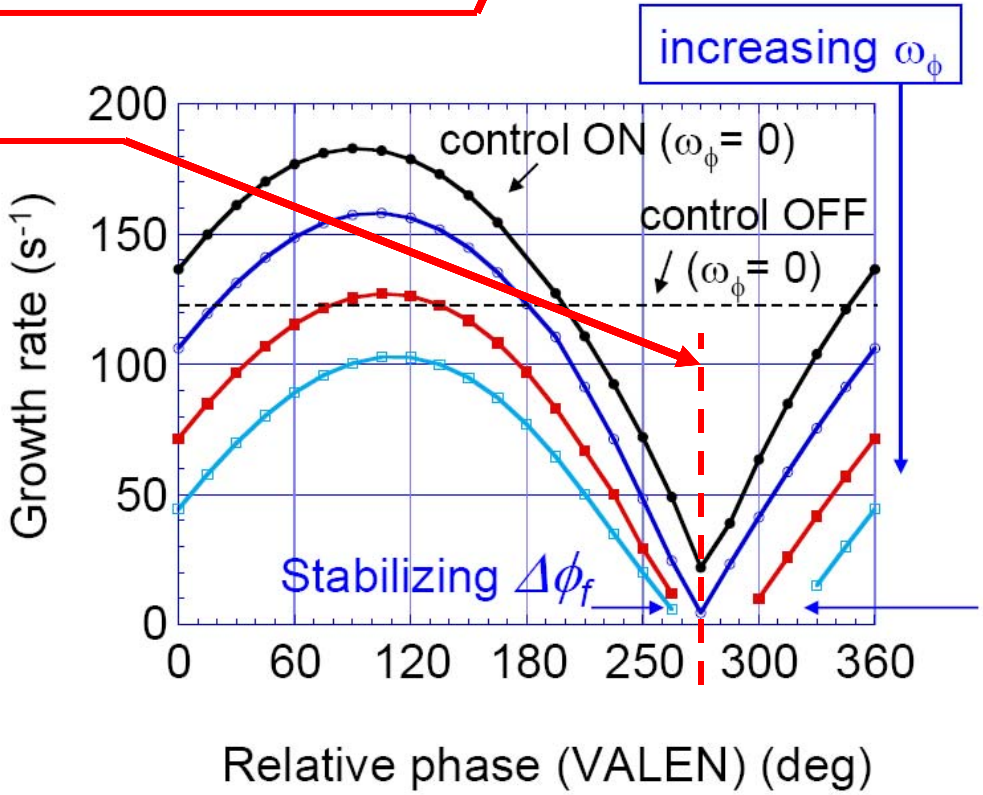
6 ex-vessel midplane control coils

RWM feedback stabilization experiments at low toroidal rotation now utilizing $B_{P\text{-}U}$ + $B_{P\text{-}L}$ sensors are validating VALEN code



- Optimal 270° phase difference between mode B_P and applied B_R consistent with **VALEN**
  - Also investigating role of plasma rotation in RWM feedback control

- "Mode deformation" reduced (not shown here) using combined U/L sensors in mode-ID for feedback
  - → More robust feedback with additional sensors



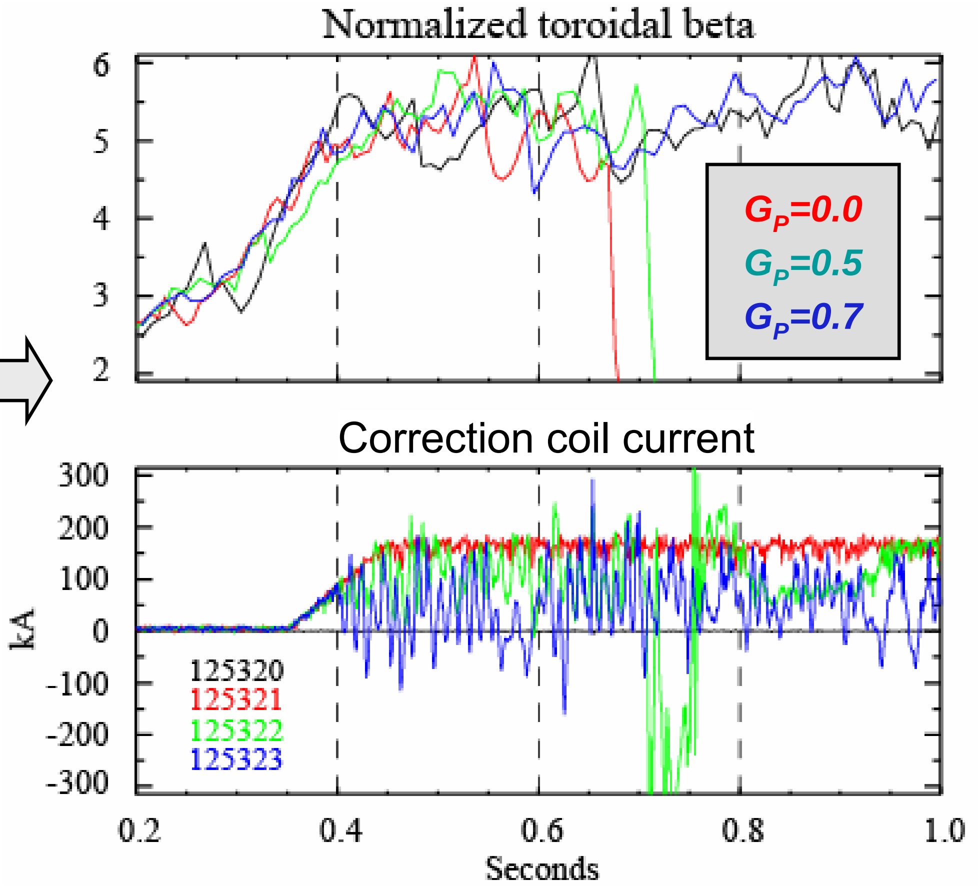
Using additional B_P sensors in n=1 control system allows feedback to provide most/all n=1 error field correction at high β

- **Previous n=1 EF correction required a priori estimate of intrinsic EF**
- Additional sensors → detect modes with RWM helicity → increased signal to noise
- Improved detection → higher gain → **feedback does most/all EF correction**

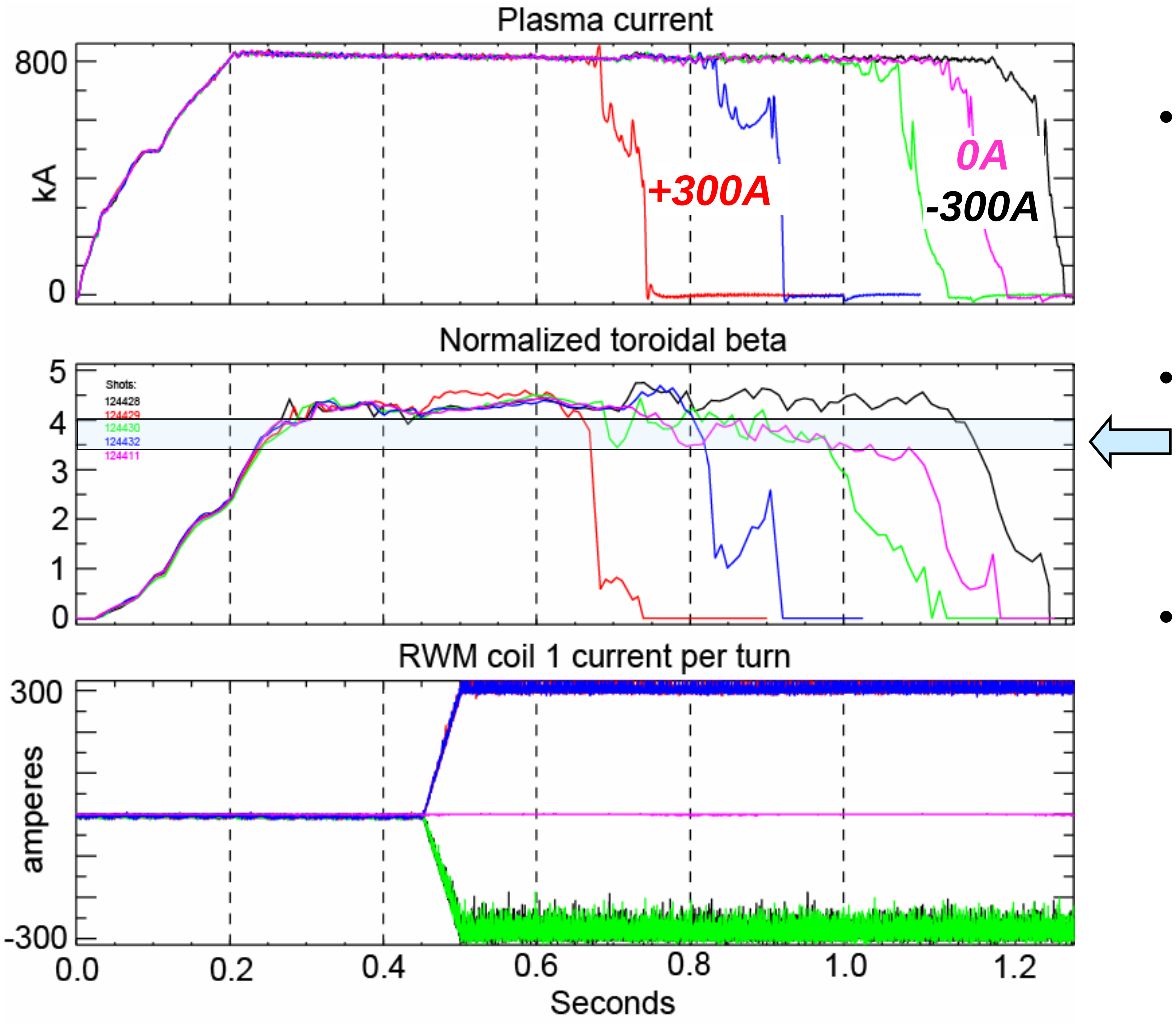
Optimized EFC developed in FY07:

- Start with plasma with RWM stabilized by rotation
- Add n=1 EF to reduce rotation, destabilize RWM → β collapse
- Find corrective feedback phase that reduces applied EF currents
- Increase gain until applied EF currents are cancelled and plasma stability is restored

Use same gain/phase settings to suppress intrinsic EF RFA and any unstable RWMs



NEW: Discovered high-*n* error fields (*n*=3) important at high β_N



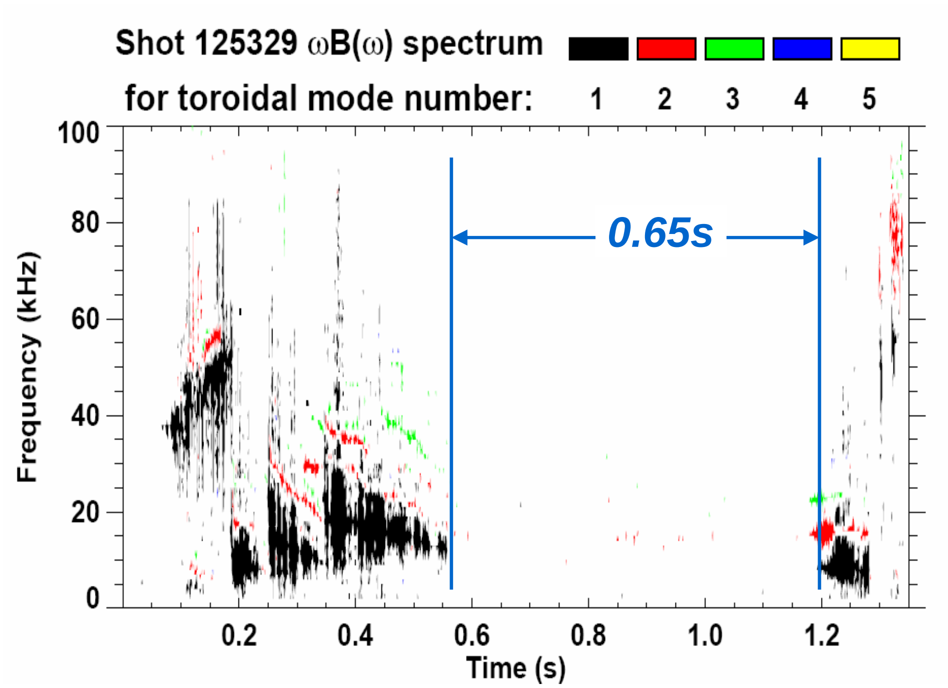
- Pulse-length depends on polarity of applied n=3
  - Anti-corrective polarity disrupts I_P and β
- Plasmas operate above n=1 no-wall limit → RFA
  - slows rotation →
  - destabilizes n=1 RWM
- Correction current magnitude for n=3 similar to that for n=1 correction
  - Applied n=3 $|B_R|$ is ≈ 6G at outboard midplane
  - Fortuitous phase match between intrinsic n=3 EF and field coils can apply

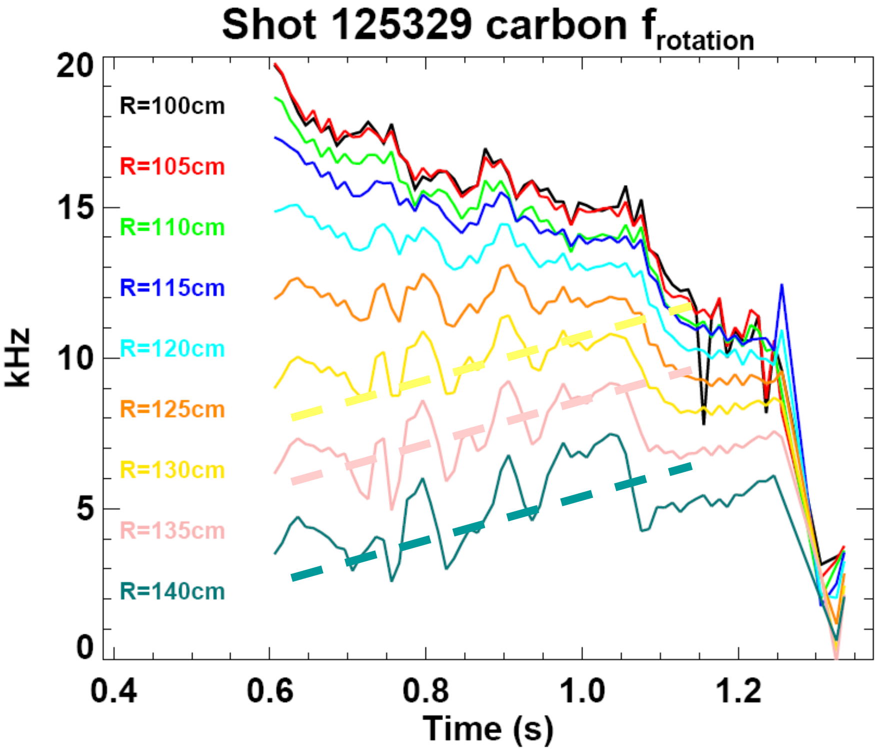
- ***n* > 1 error fields not commonly addressed in present devices, or in ITER**

Simultaneous multiple-n correction improves performance
(Active feedback control of n=1 RFA + pre-programmed n=3 correction)

- Long period free of core low-f MHD activity
- Plasma rotation sustained over same period
  - Core rotation decreases with increasing density (f_{GW} → 0.75), but…
  - R > 1.2m rotation slowly ***<u>increases</u>*** until large ELM at t=1.1s

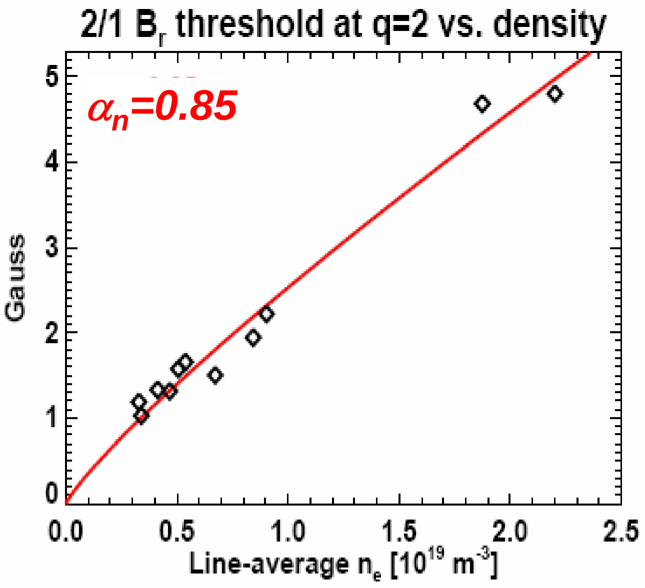
→ Record pulse-length at I_P=900kA

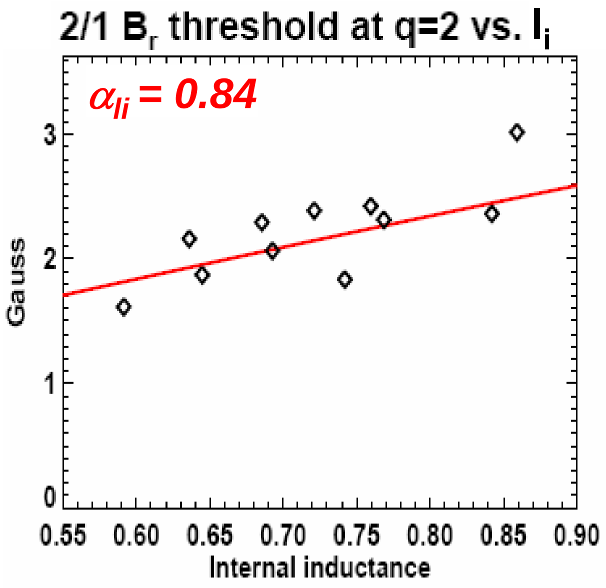


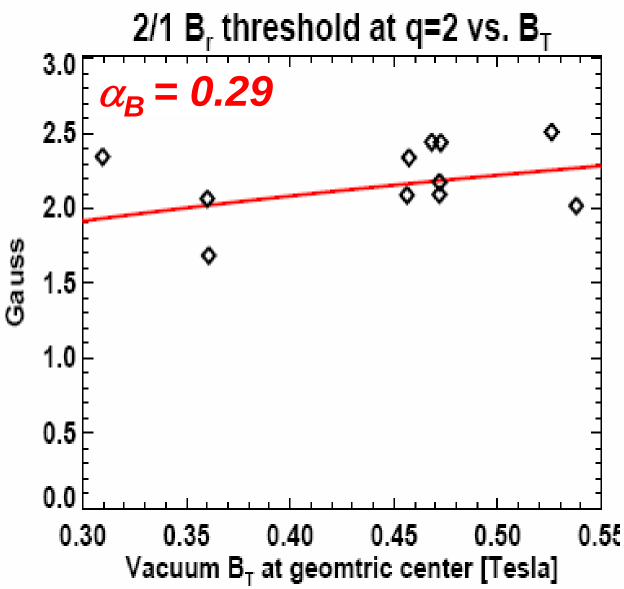


Low-A, low-B_T locked-mode threshold study extends high-A database, now comparing to 3D MHD codes IPEC and M3D *(Ph.D. thesis)*

Threshold scales nearly linearly on n_e, l_i, weakly on B_T – similar to DIII-D, JET, most C-MOD data


2/1 B_r threshold at q=2 vs. density


2/1 B_r threshold at q=2 vs. l_i


2/1 B_r threshold at q=2 vs. B_T

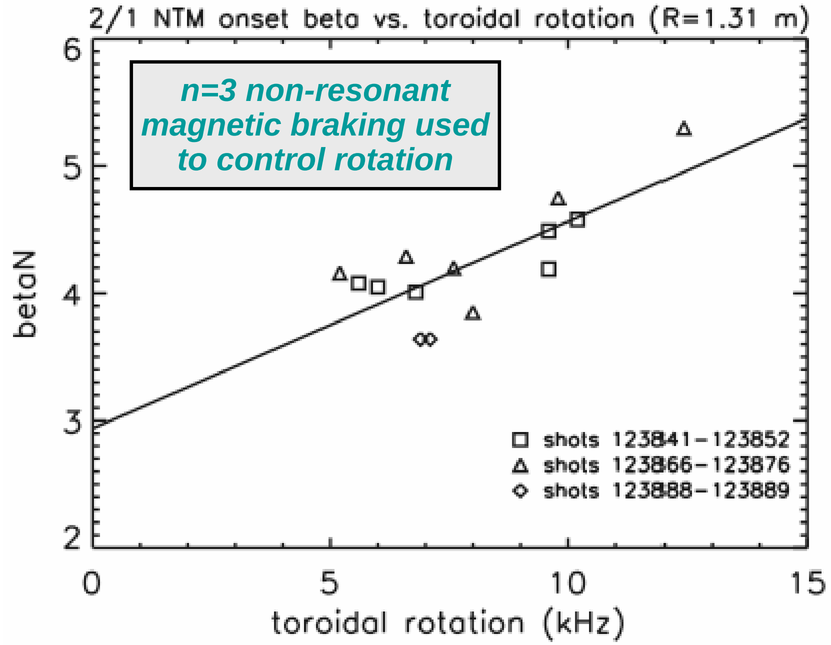
Assuming size scaling coefficient $\alpha_R = 2\alpha_n + 1.25(\alpha_B - 1) \rightarrow$ NSTX $\alpha_R = 0.8 \rightarrow$

ITER threshold $B_{21}/B_T = 2\text{-}5 \times 10^{-4} \rightarrow$ favorable for ITER

Caveat: no q=1 surface in NSTX plasmas – presence of q=1 could lower thresholds in ITER & NSTX

- Find that commonly used q* and q_{95} are not good variables for J(r) dependence of scaling
- Ideal Perturbed Equilibrium Code (IPEC) now being used to understand scaling
  - **Error field correction results already submitted to PRL**

Tearing mode experiments find β_N threshold for onset of 2/1 NTM decreases as rotation decreases



n=3 non-resonant magnetic braking used to control rotation

- 30% reduction in β is qualitatively consistent with DIII-D results (& JET)

→ Impact of rotation on NTM stability is broad result vs. aspect ratio and β

  - **Important implications for ITER which is expected to have low rotation**
  - **Highlights advantage of q_{min} > 2**

- ST-CTF with unidirectional tangential NBI may be relatively immune to NTM

Possible influences of rotation on NTM stability:

- NTM seeding
  - Decreased rotational shear between resonant surfaces enhances ELM/sawtooth seeding
- NTM threshold terms
  - Ion polarization introduces rotation dependence: $a_{pol}\,\mu\,\rho_{i\theta}^2\,g(\nu,\varepsilon)\,\omega\,(\omega_{i*}-\omega)/\omega_{e*}^2$
  - Depends on rotation in ExB frame of reference, sets seed size and/or Δ' to trigger NTM
- “Classical” tearing mode stability
  - Wall stabilization of rotating islands, or enables error field to help drive the island

NSTX contributes broadly to fundamental toroidal confinement science in support of ITER and future ST's

- Transport and Turbulence: NSTX is developing a first-principles understanding of the transport of electron energy, particles, and angular momentum
  - β dependence of H-mode confinement is shape/ELM dependent
  - High-k fluctuation data correlates with χ_e variation
  - Microtearing modes can contribute to electron thermal transport
  - Impurity particle transport is neoclassical
  - Coriolis effects on ITG/TEM may induce angular momentum pinch

Dimensionless parameter scans show degradation of confinement with β depends on boundary shape, possibly through ELM stability

β-dependence important to ITER advanced scenarios ($B\tau_{98y2} \sim \beta^{-0.9}$) and ST's

κ=2.1, δ=0.6

Weak degradation at high κ, δ

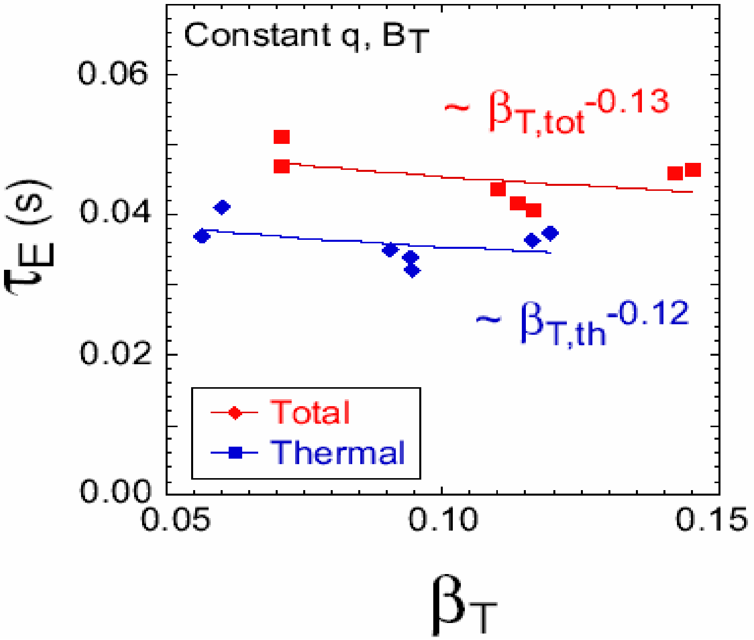
Small (Type V) ELMS for all β

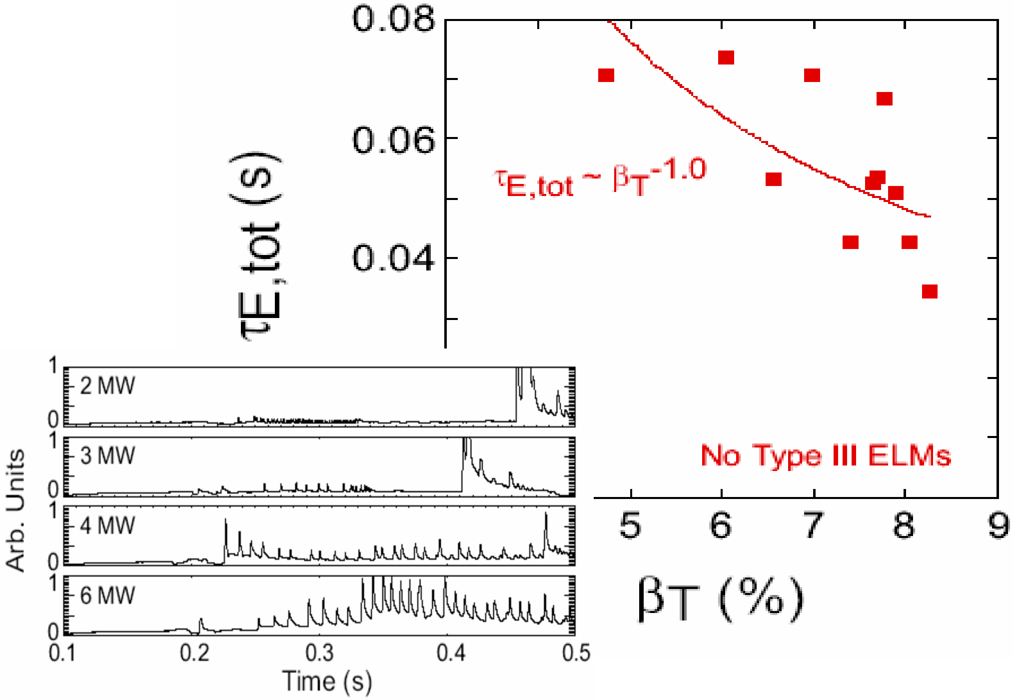
β-scans at fixed q, B_T

κ=1.85, δ=0.4

Strong degradation at lower κ

ELM severity varies w/ β, power





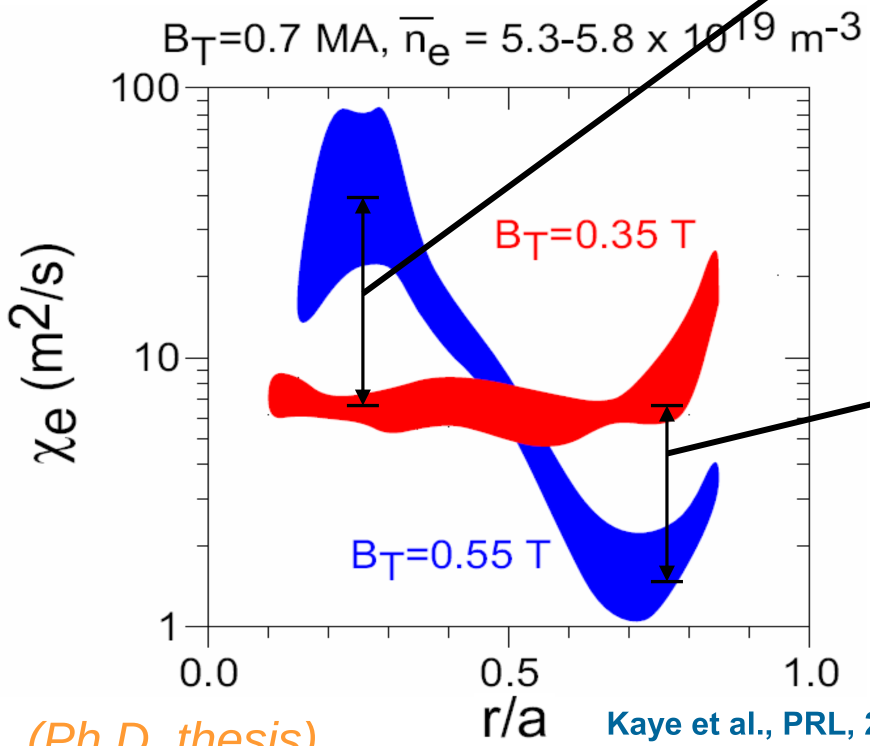
Type III ELMs severely degrade confinement

Consistent with recent results from AUG

High-k measurements beginning to elucidate spatial dependence of strong toroidal field scaling of electron transport in NSTX

Decrease of high-k at higher B_T inboard
Increase of high-k at higher B_T outboard

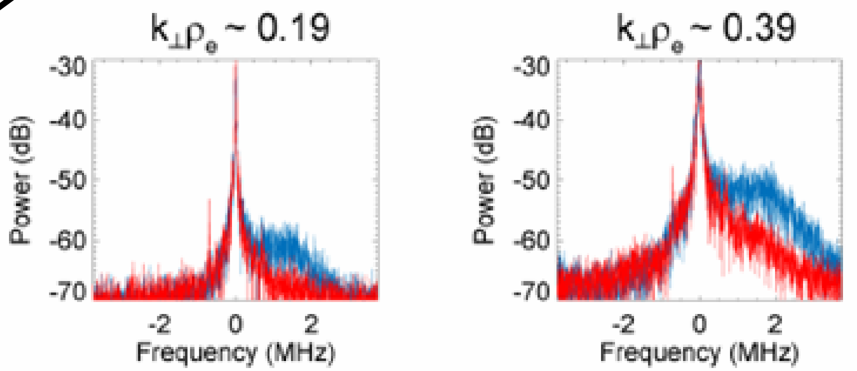
Consistent with change in power-balance χ_e and gyrokinetic calculations (ETG unstable outboard at low B_T)



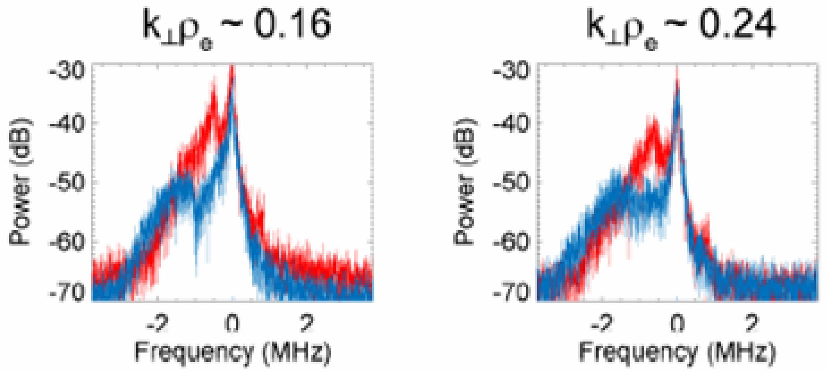
Kaye et al., PRL, 2007

(Ph.D. thesis)

r/a = 0.26 & R = 113 cm
124882 - 3.5 kG - 365 ms
124885 - 5.5 kG - 432 ms

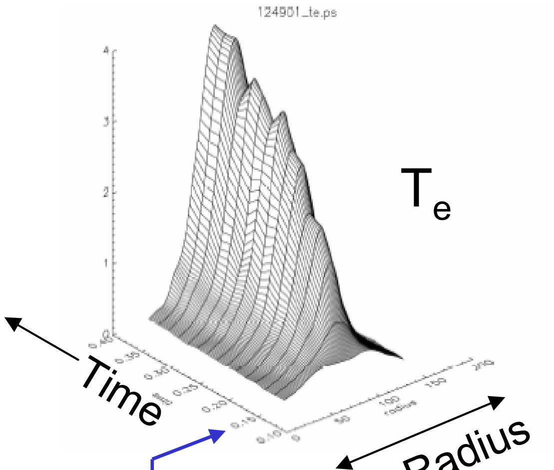


r/a = 0.76 & R = 135 cm
124892 - 3.5 kG - 348 ms
124891 - 5.5 kG - 415 ms



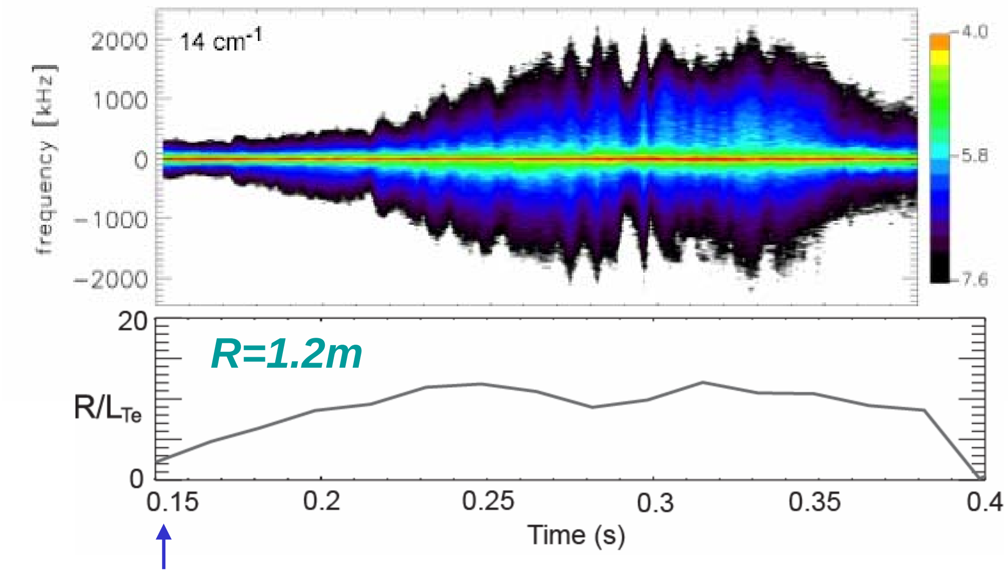
Temporal evolution of high-k scattering measurements exhibits broadening of fluctuation spectrum as R/L_{Te} increases

Electron transport barrier develops with HHFW heating



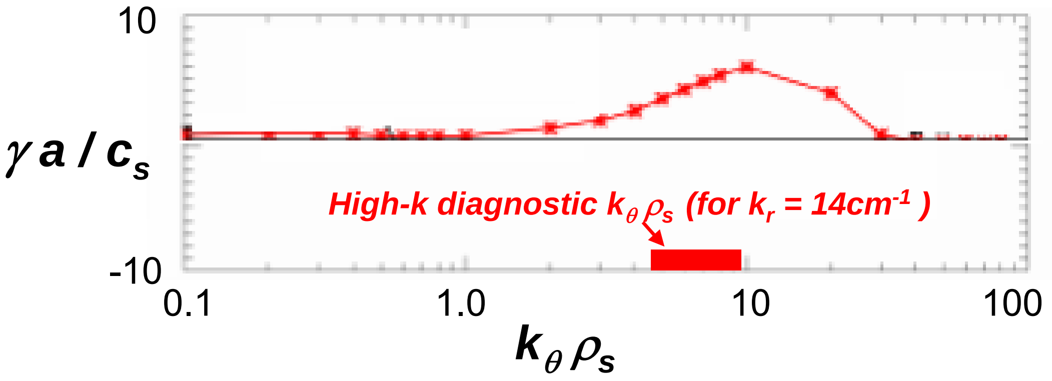
RF turn-on

High-k scattering diagnostic fluctuation amplitude



RF turn-on

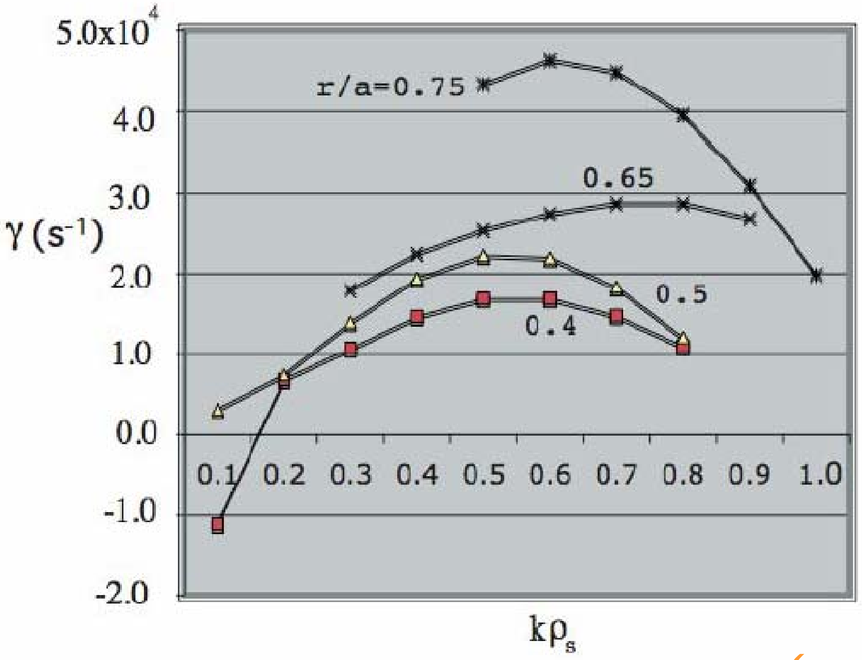
- Linear GS2 calculations indicate high-k mode (ETG) unstable at peak R/L_{Te}

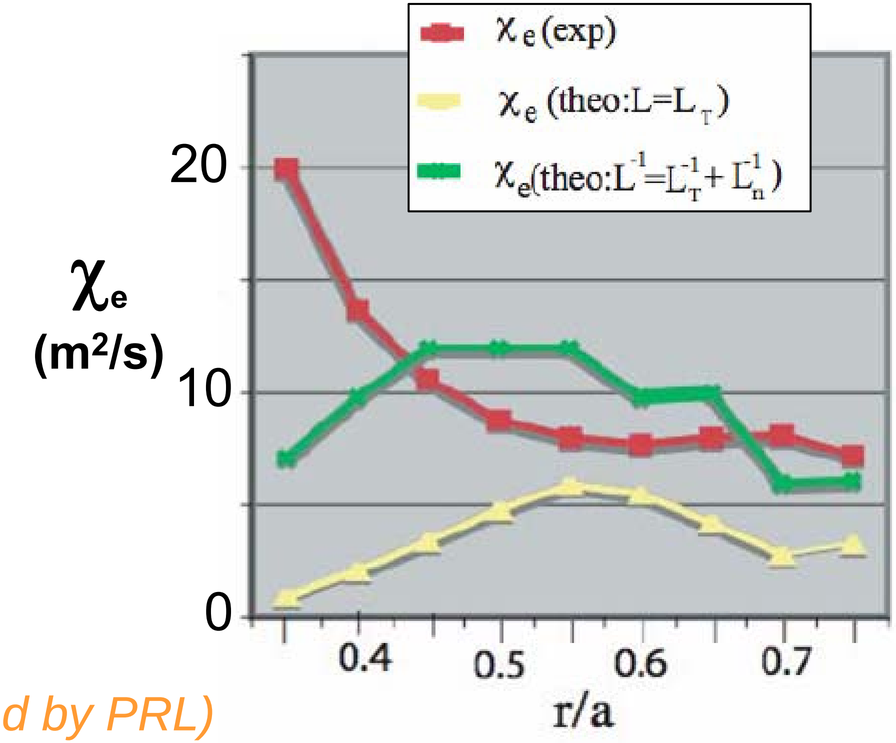


Low-k microtearing modes may be important in driving electron transport in some NSTX plasmas

- Linear GS2 calculations indicate microtearing modes unstable in NSTX “hybrid” discharge (monotonic q, q_0 = 1.2)

- χ_e predicted by microtearing mode theory within a factor of 2 of inferred experimental values





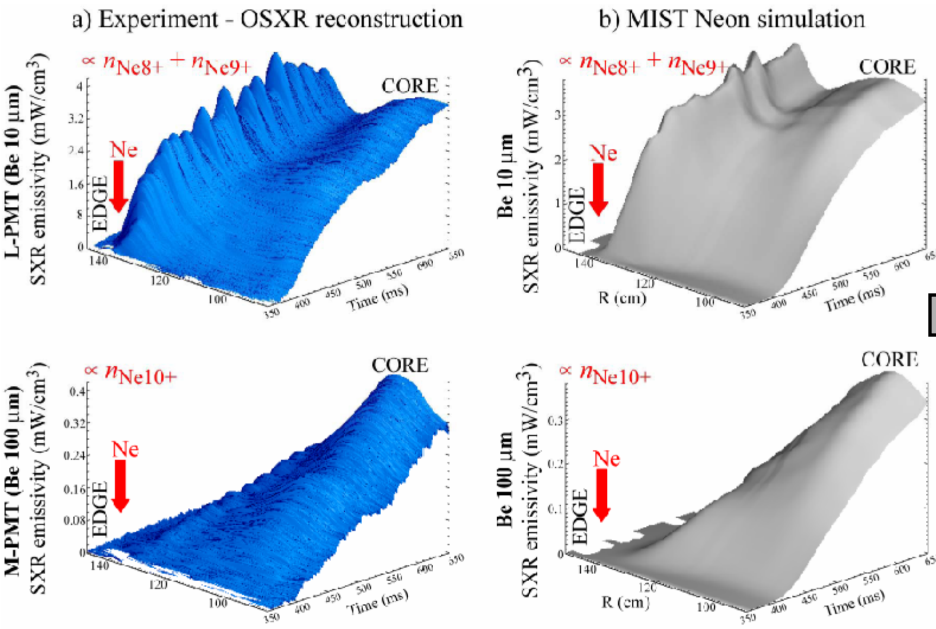
(accepted by PRL)

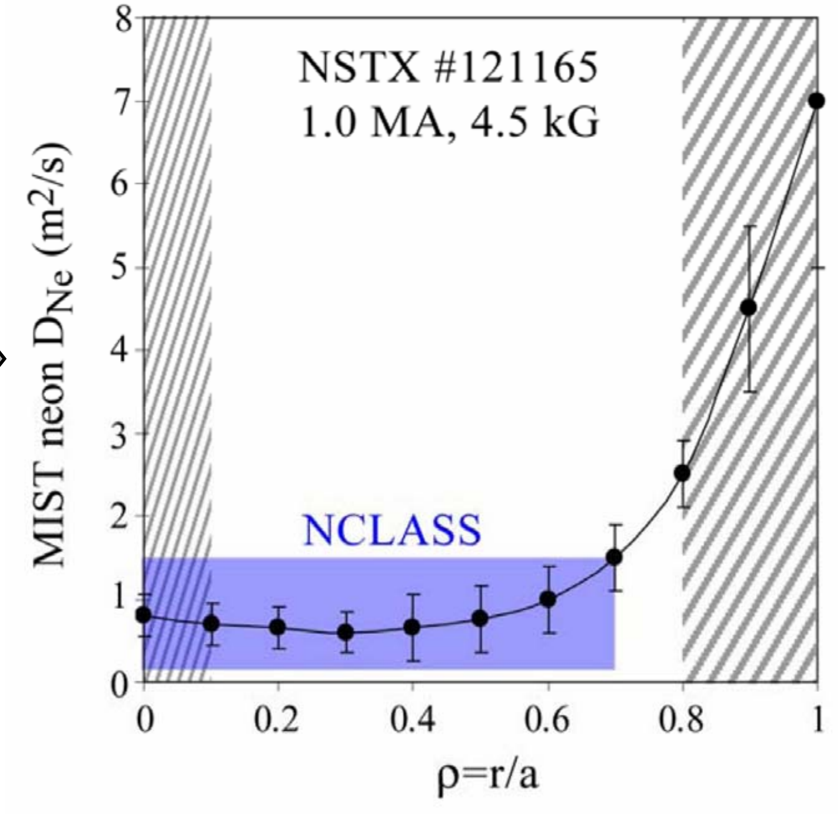
- *Both ETG and microtearing may contribute to anomalous electron transport*

Impurity transport studies confirm ion particle transport near neoclassical over most of profile (extends previous L-mode results)

- New multi-color “optical” SXR tracks inward transport of Ne impurities
- MIST transport simulations yield particle diffusivity and v_{pinch}

(Ph.D. thesis – JHU)

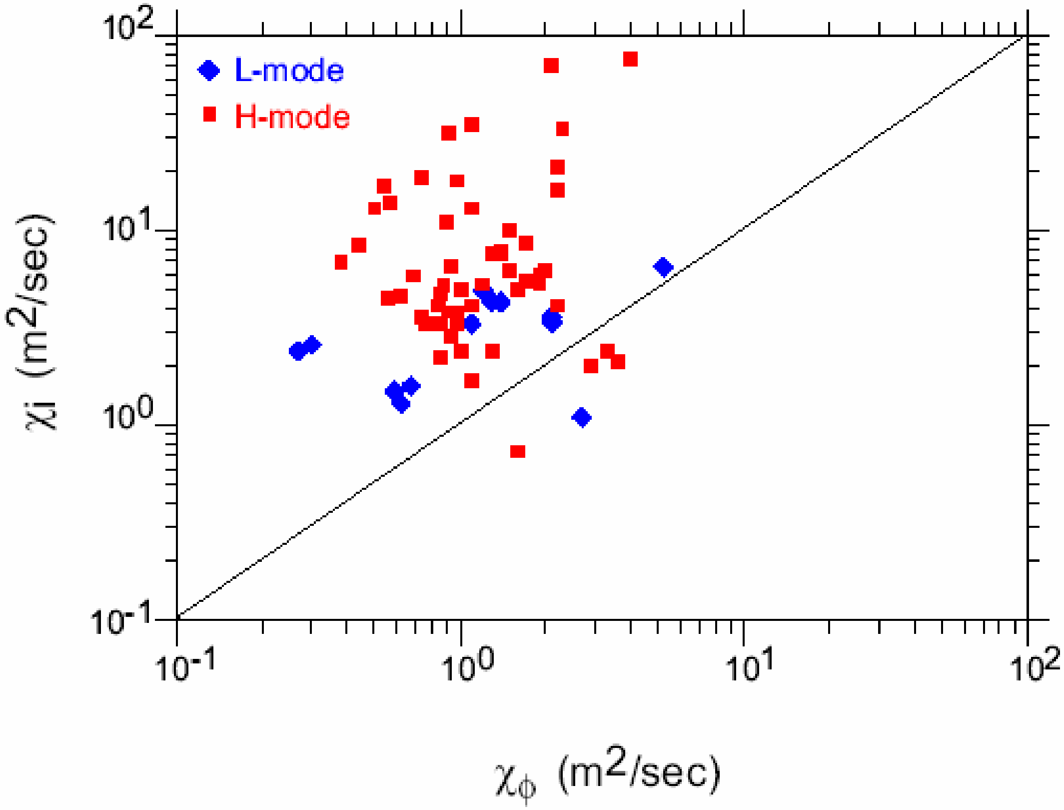




Small inward particle pinch (~few m/s) required for agreement

Statistical studies find effective χ_ϕ is much lower than χ_i in NSTX

- Different than higher-A tokamak where $\chi_\phi \approx \chi_i$
- Low B_T (0.35-0.55 T) → values of ω_{ExB} up to the MHz range
  - – Shearing rates can exceed ITG/TEM growth rates by 5 to 10×



- Due to suppression of ITG modes?
- What is level of $\chi_{\phi,neo}$?
- Does χ_ϕ scale with χ_e?
  - - One dedicated scan indicates so

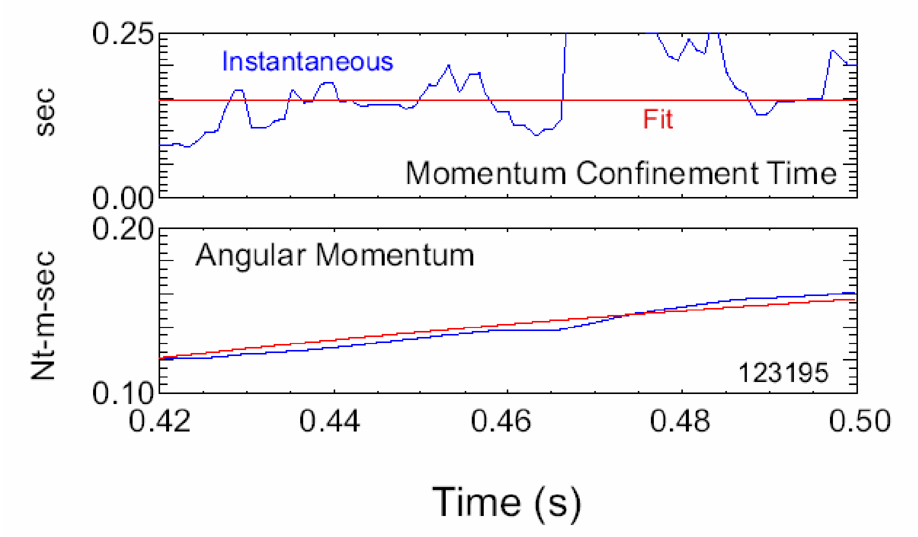
Dedicated *perturbative* momentum confinement studies confirm high τ_ϕ and indicate inward angular momentum pinch

- Use non-resonant n=3 magnetic perturbations to damp rotation
  - turn off n=3 for plasma spin-up
  - Use plasma spin-up dynamics to determine τ_ϕ, χ_ϕ, v_{pinch}

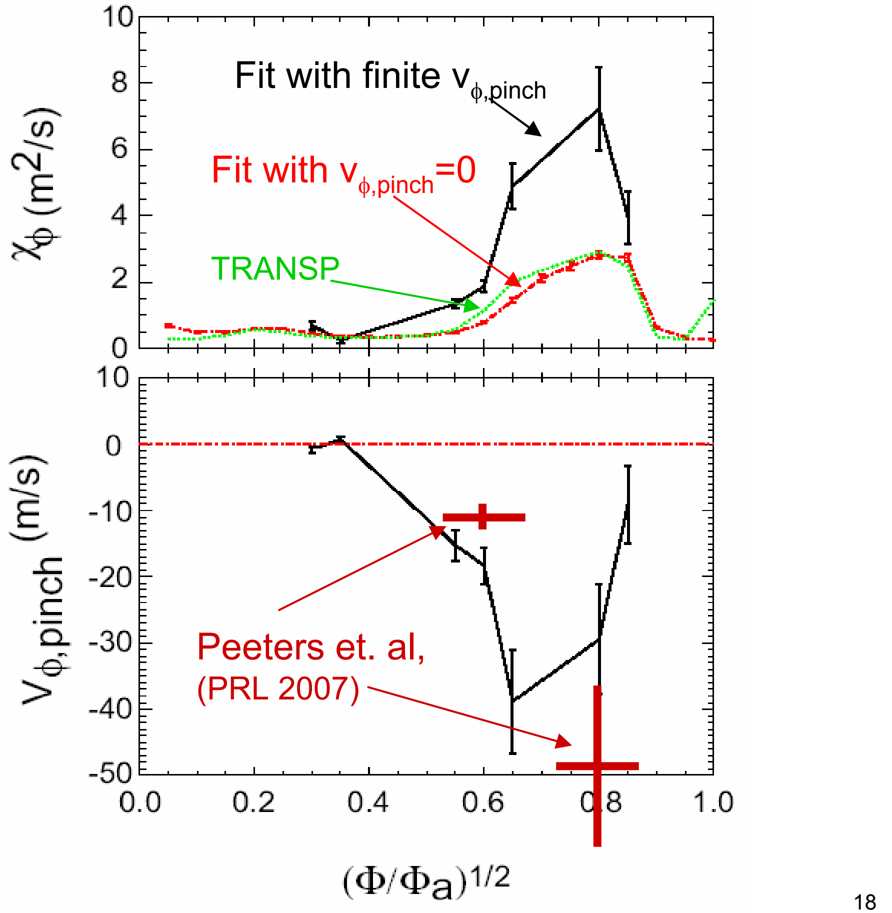
- Model spin-up to determine perturbative τ_ϕ using:

  $L(t) = \tau_\phi * [T - (T-L_0/\tau_\phi) * \exp(-t/\tau_\phi)] \rightarrow$

  τ_ϕ = 150-200ms = 4-5 x τ_E



- Experimental inward pinch not inconsistent with Peeters et al, based on Coriolis effect on ITG/TEM:
  - $v_{\phi,pinch} = \chi_\phi/R\,[-4-R/L_n]$

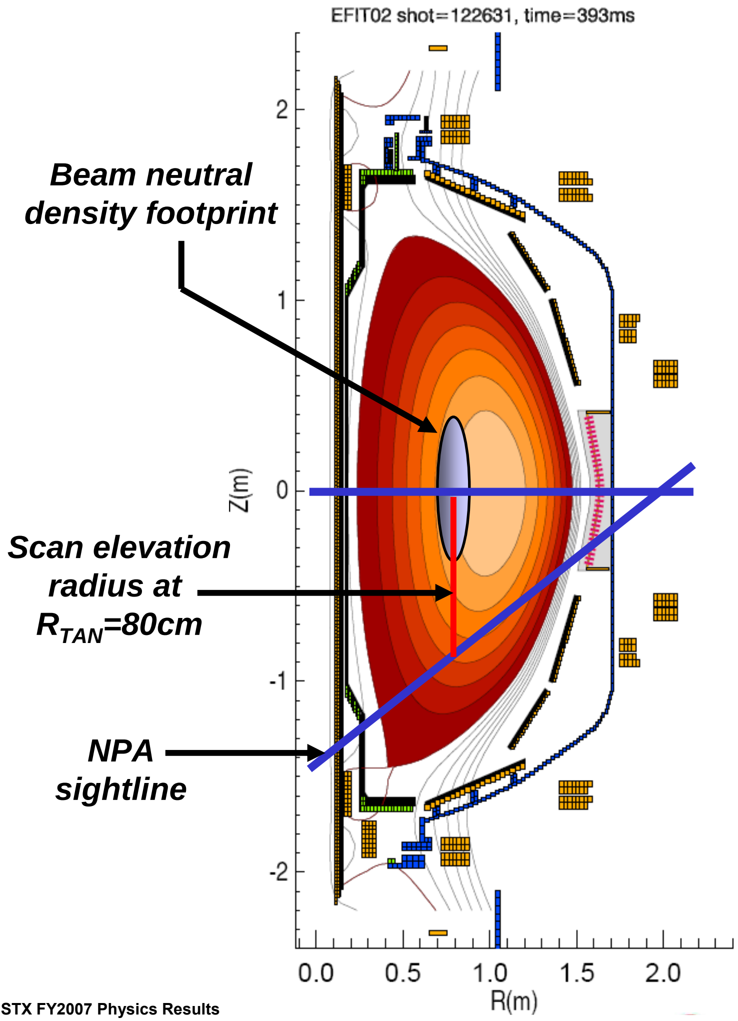


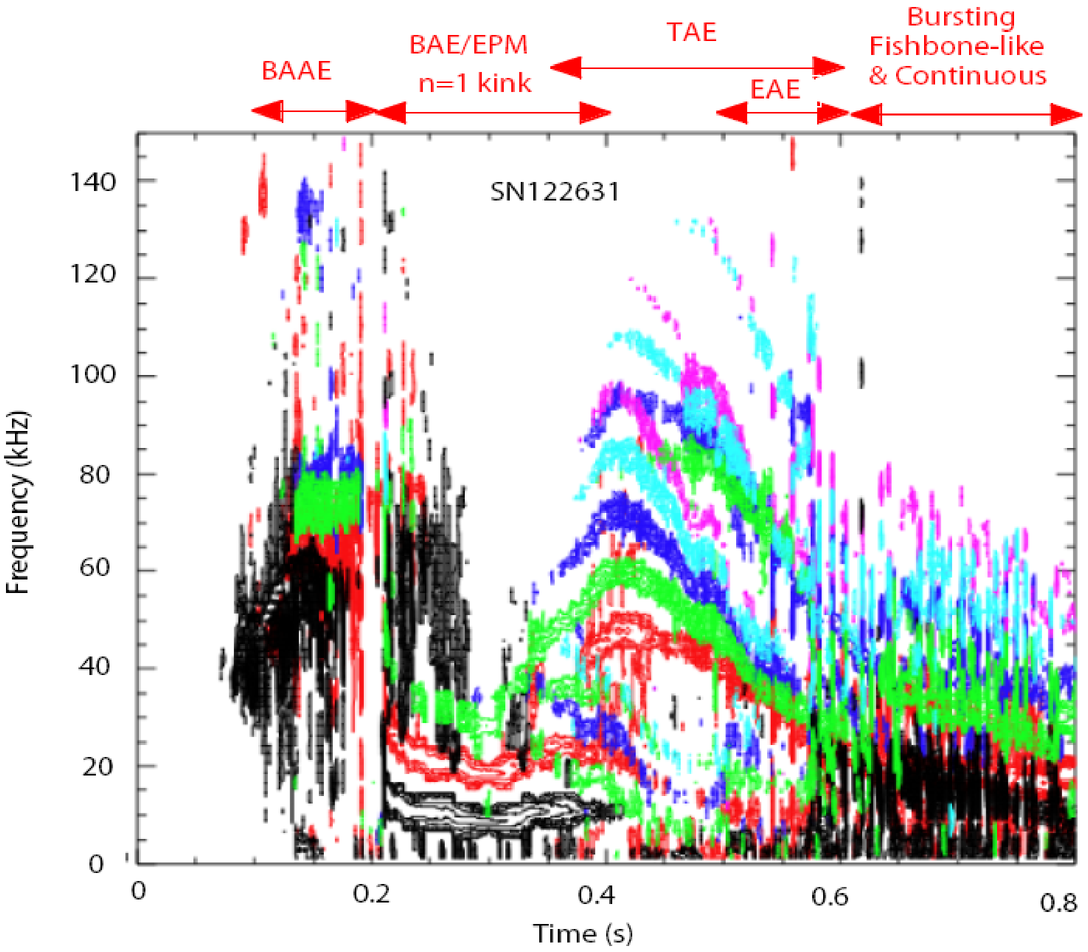
NSTX contributes broadly to fundamental toroidal confinement science in support of ITER and future ST's

- Fast-ion-driven MHD: Unique combination of fast-ion instability drive flexibility and complete diagnostic coverage continues to lead to new discoveries in NSTX
  - Fast ion density profile is significantly broadened by strong MHD
  - The TAE stability space has been fully mapped for first time
  - 3D non-linear simulations are elucidating multi-mode TAE properties
  - Beta dependence of Cascade/GAM coupling demonstrated for first time
  - New Beta-induced Alfvén Acoustic Eigenmodes identified, characterized

Vertical scanning capability of Neutral Particle Analyzer (NPA) used to diagnose fast-ion transport in an “MHD-active” discharge

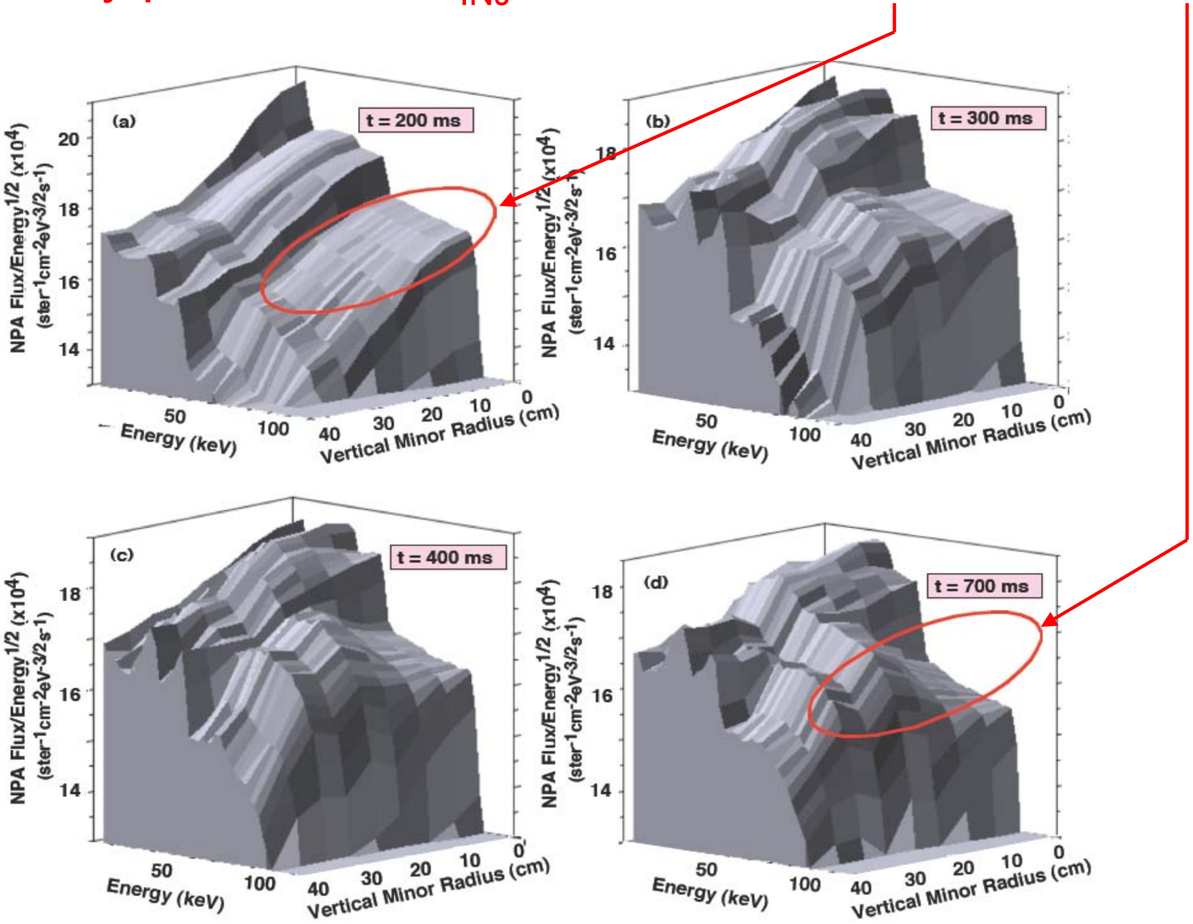
- Discharge with low-f kink-type + bursting fishbone-like MHD activity + “sea of Alfvénic modes” → very strong effect on fast ions expected





TRANSP reproduction of NPA vertical scan requires anomalous fast ion diffusion and shows outward redistribution of core fast ions

- Fast ion density profile near E_{INJ} evolves from monotonic to hollow

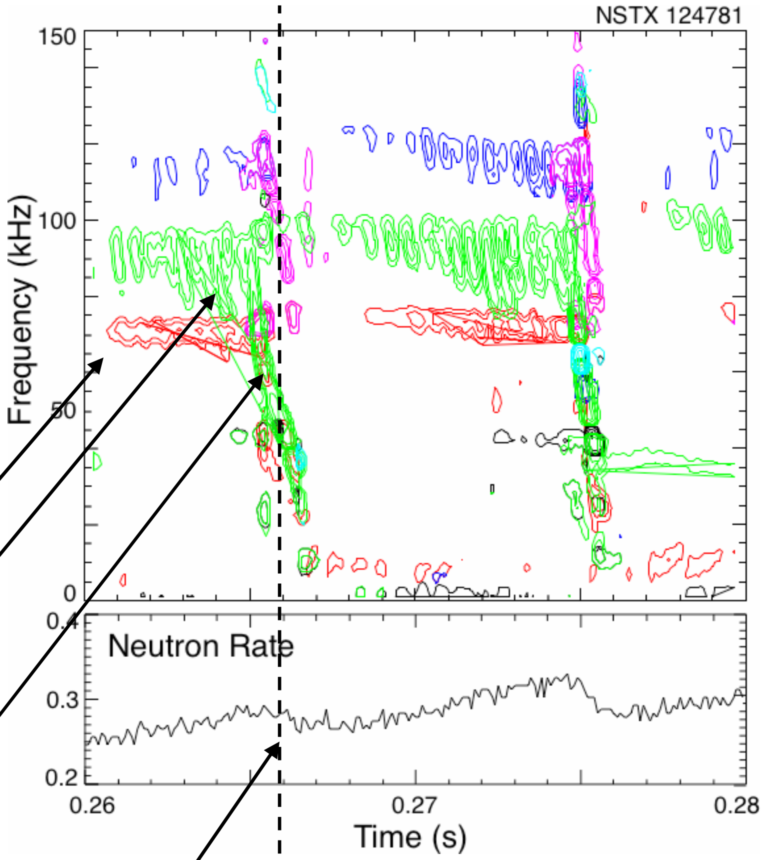


Consistent with NBI current redistribution measured in 2006 (PRL)

Anomalous diffusion much weaker/absent for majority of NSTX discharges

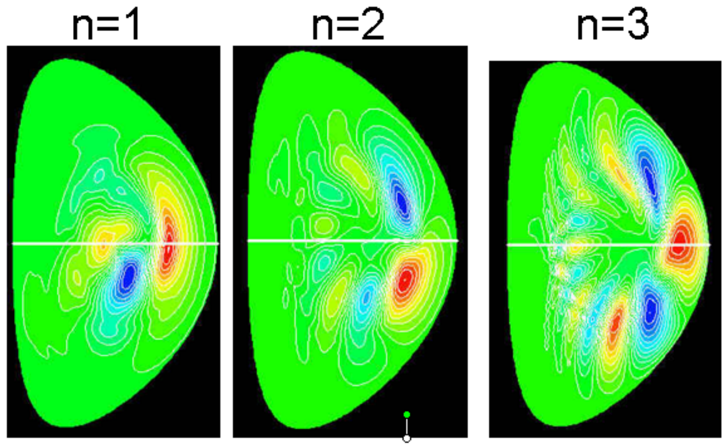
TAE stability space - from no modes to avalanche threshold - mapped and comprehensively diagnosed for first time in NSTX

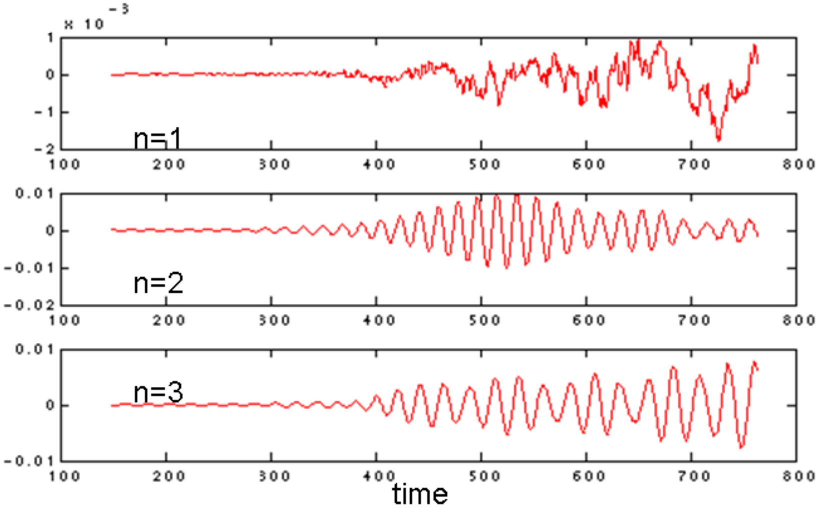
- One source ≈ 62 kV is just below threshold for TAE.
- q-profile measured both before and after quiescent period - **current profile evolution will be modeled between these times.**
  - + NPA, reflectometers, lost ions, fast D_α
- As power is raised, first see TAE
  - then chirping TAE
  - then avalanches, multi-mode transport
- Avalanches are strong bursts of multiple TAE modes ($2 \leq n \leq 6$), with weak or no n=1 fishbone modes, and correlated with neutron drops



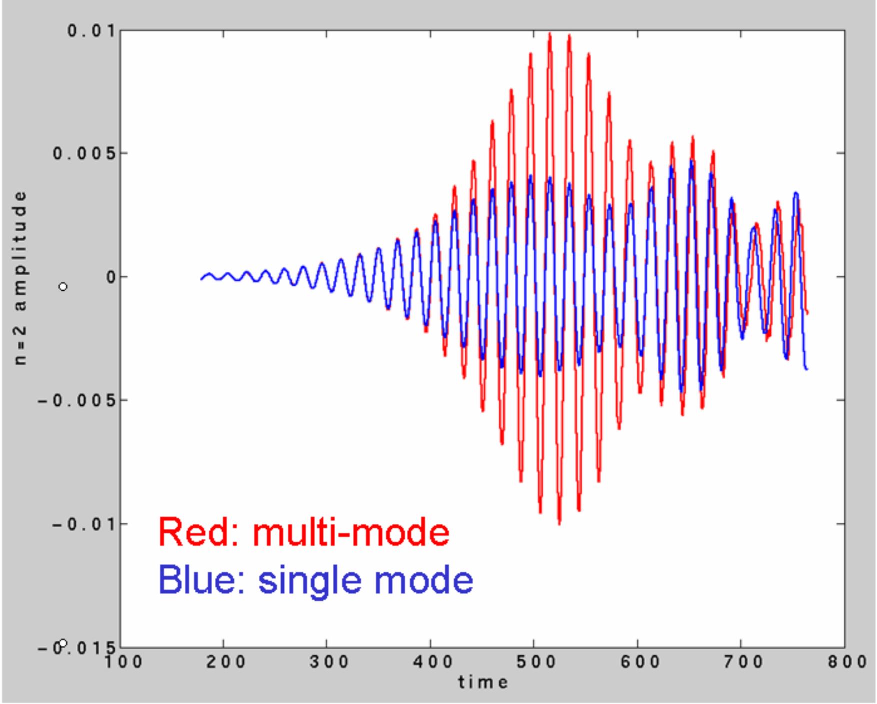
M3D simulations of multi-mode TAE find significant nonlinear interaction via mode-mode coupling and resonance overlap

- Nonlinear evolution with multiple modes (n=1,2 & 3)



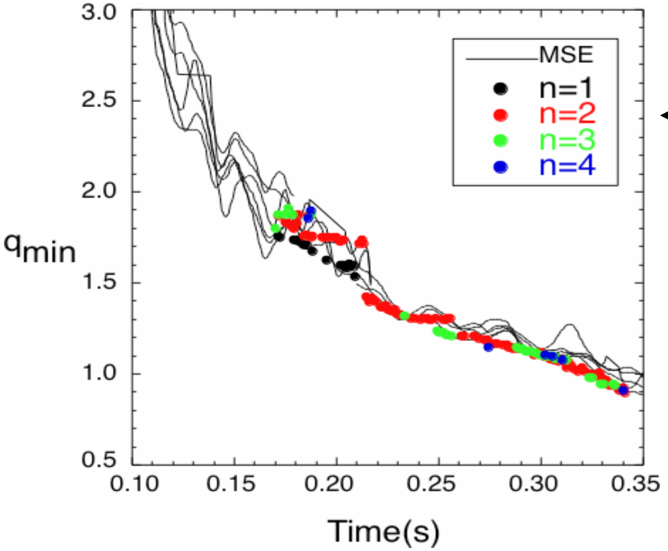


n=2 amplitude: *multi-mode amplitude higher than for single mode treatment → increased fast-ion transport from mode*

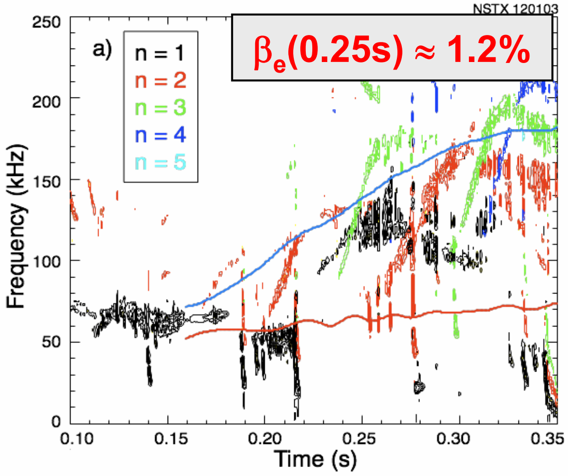


Red: multi-mode
Blue: single mode

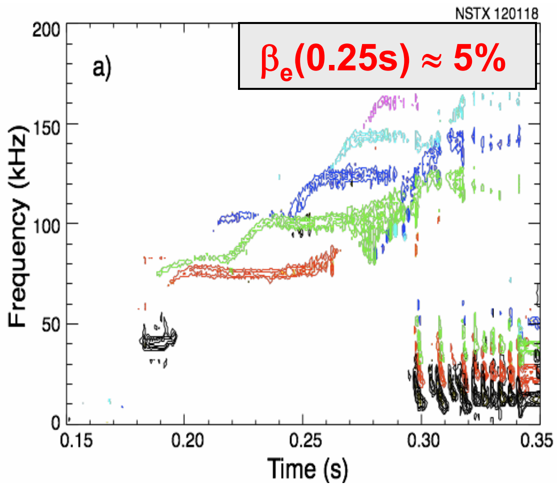
NSTX observations support recent theoretical models of Alfvén Cascade modes coupling to Geodesic Acoustic Modes



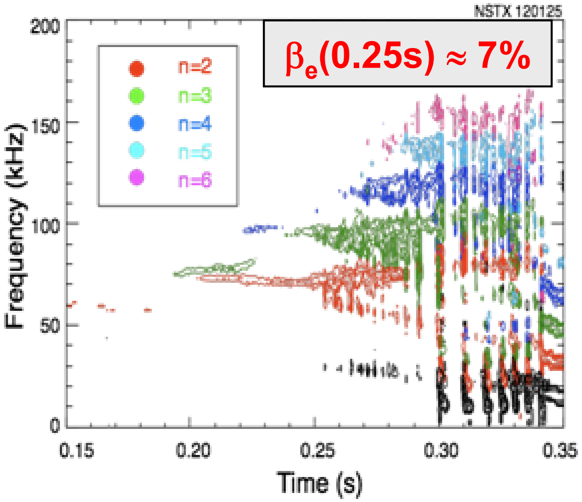
- MSE data agrees with q_{min} deduced from mode frequency sweeps
- Range of frequency sweep is reduced as β is raised, in agreement with theory
- Mode frequency evolution:
  - Onset near GAM frequency (lower red curve)
  - Frequency sweeps upwards
  - Saturates near TAE frequency (blue curve)



Largest frequency sweep



Frequency sweeps reduced



Frequency sweeps absent

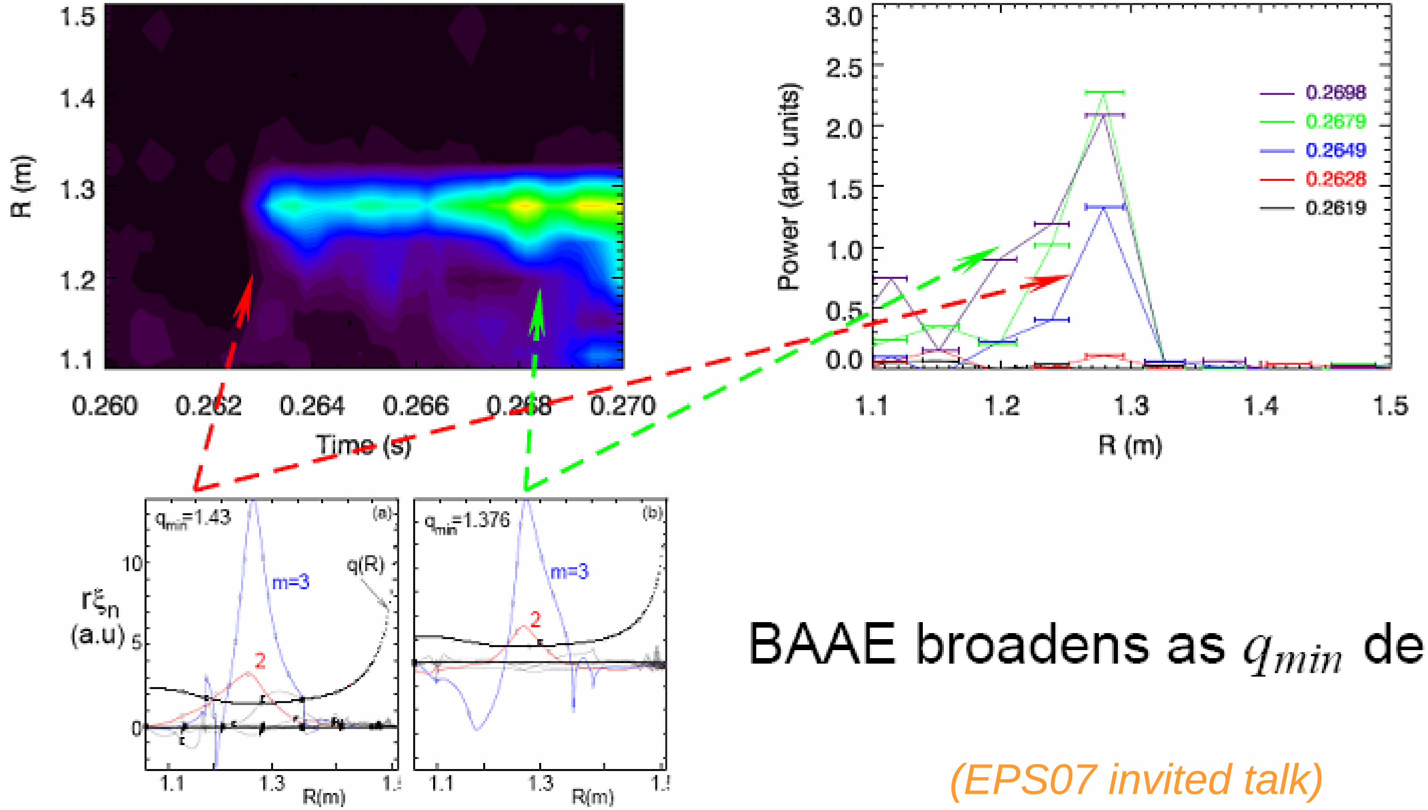
β scan demonstrating AC/GAM coupling is first of its kind

At high β ($\geq$ 15% in NSTX), TAE/RSAEs are suppressed, and NBI can excite Beta-induced Alfvén Acoustic Eigenmode (BAAE)

- Coupling is due to geodesic curvature: between *m* Alfvénic and *m*±1 acoustic harmonics
- NOVA-K ω and eigenfunction evolution consistent with observation

Raw USXR signal (∼BAAE structure)

Radial profile evolution



BAAE broadens as q_{min} decreases

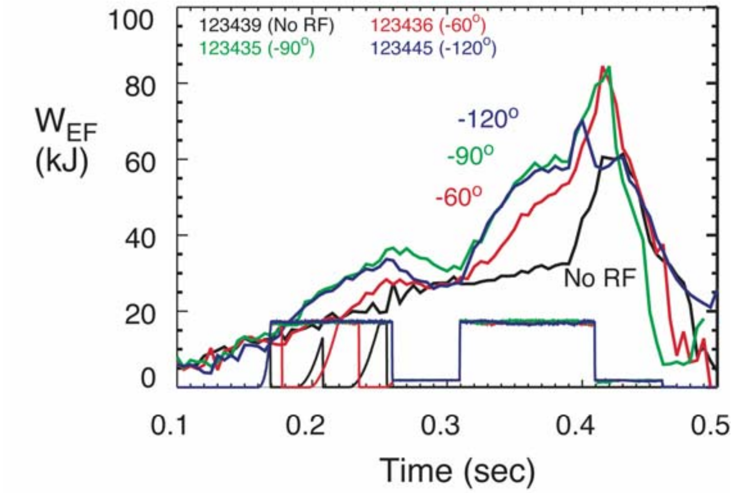
(EPS07 invited talk)

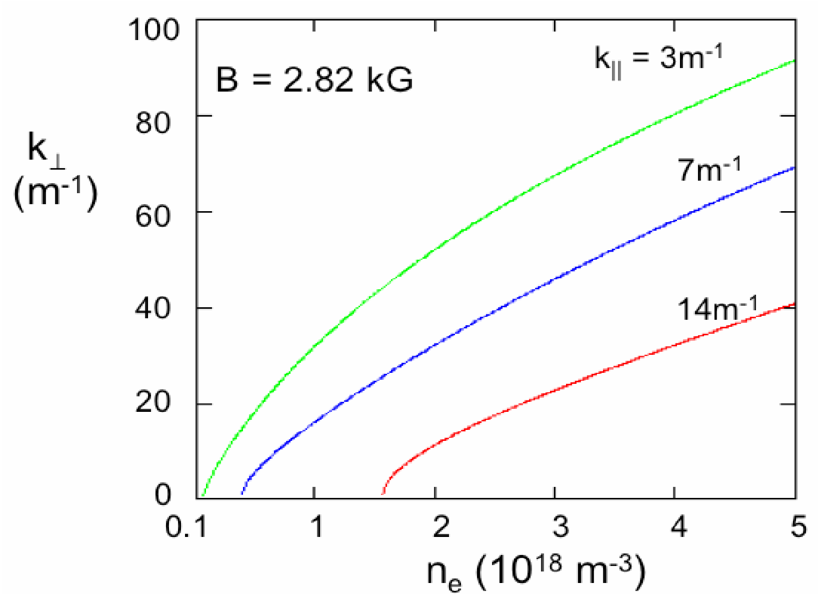
NSTX contributes broadly to fundamental toroidal confinement science in support of ITER and future ST’s

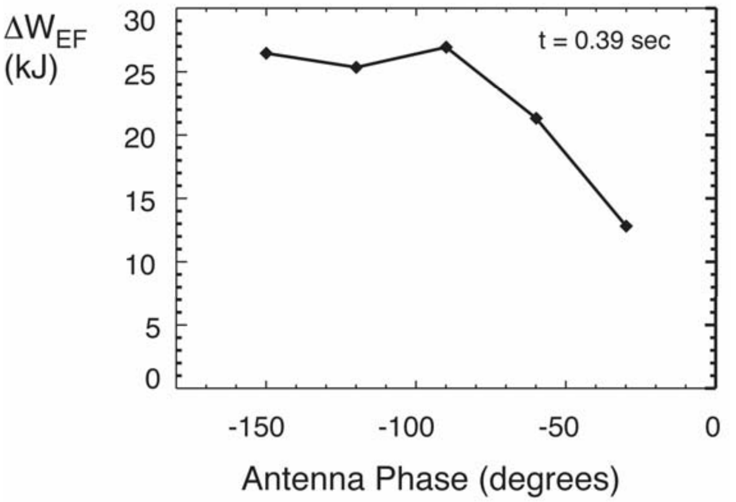
- Externally excited waves: NSTX is contributing uniquely to wave heating and current drive techniques applicable to high-β, over-dense plasma conditions
  - HHFW coupling improved by reduced surface wave excitation
  - EBW coupling improved by boundary changes and Lithiumization

HHFW heating efficiency studies confirm important role of surface loss dependence on launched toroidal wavenumber

- Efficient core coupling requires:
  - Sufficiently high n_e at plasma edge
    - Shorten evanescent decay length →
    - Loading high, V_{ANT} low → high P_{RF}
  - Sufficiently low n_e at antenna
    - No propagation close to antenna/wall



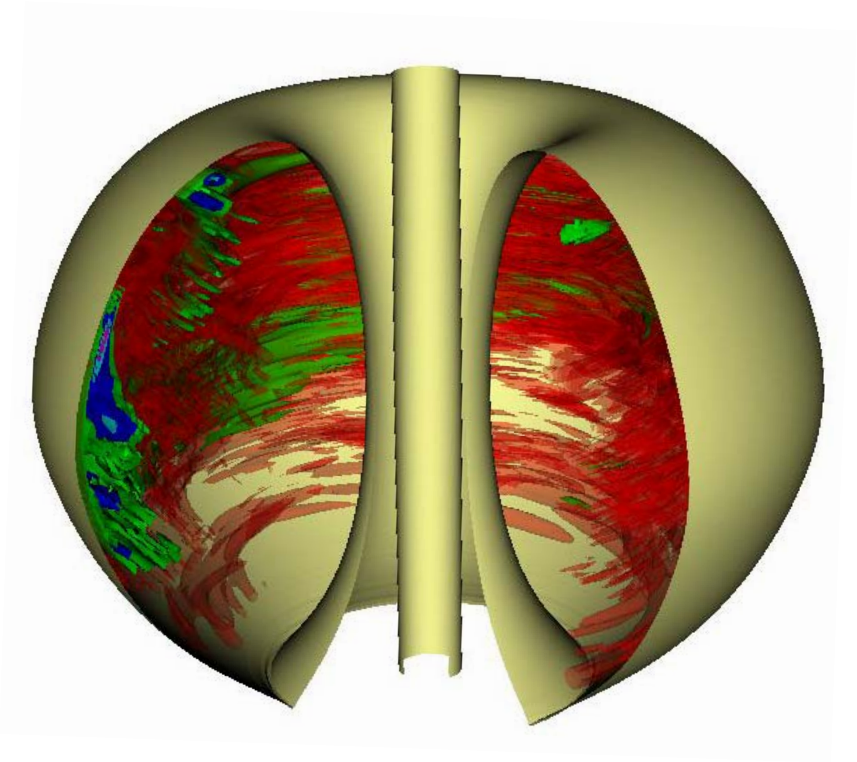




Heating at -30° is ~ 1/2 that at -90°

Surface wave physics being simulated with AORSA for NSTX HHFW has potential application to ITER ICRF coupling physics

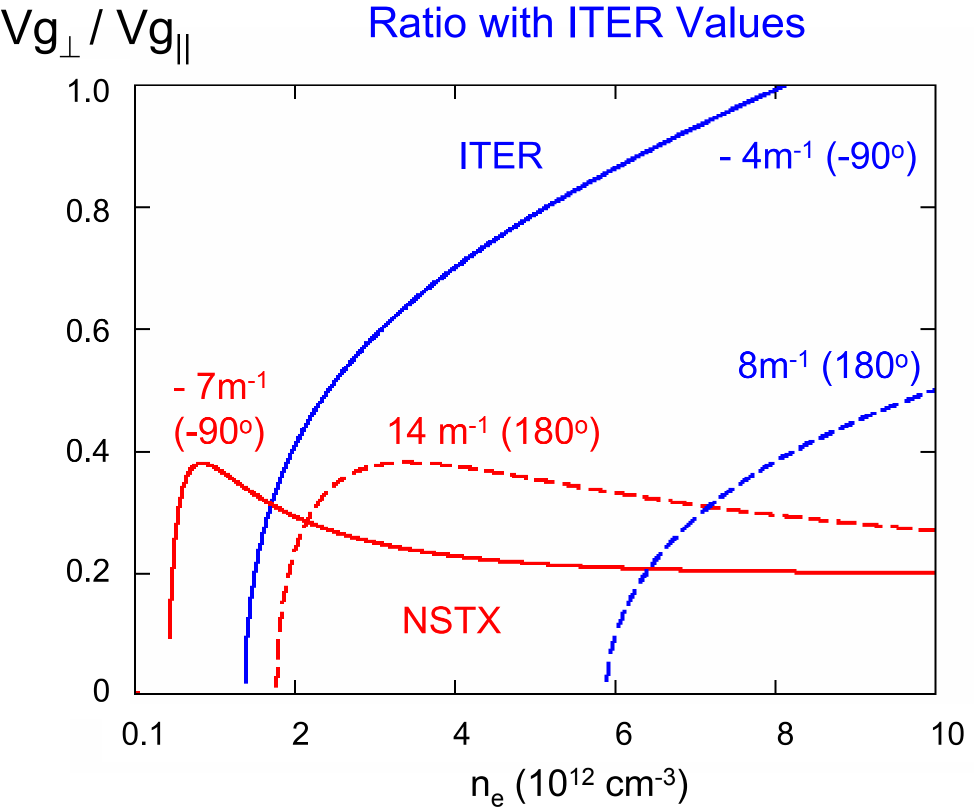
AORSA simulation for NSTX -90^o case



NSTX simulation summed over 81 toroidal modes.
[AORSA run on JAGUAR using 2048 processors for 8 hrs]

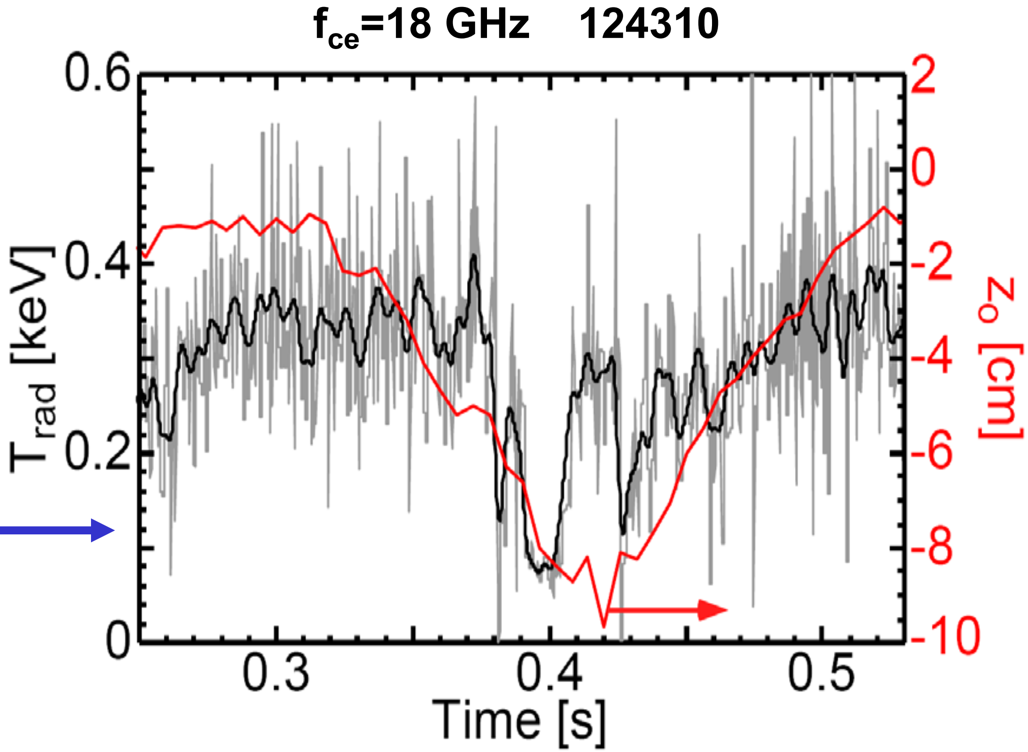
- With edge density enhancement for improved coupling on ITER, onset n_e could be exceeded at antenna/wall

Comparison of NSTX Group Velocity Ratio with ITER Values



FY07 EBW experiments in H-mode provide insight into plasma parameters that may control B-X-O mode conversion efficiency

- Example: emission may depend on outboard boundary curvature
  - Observe good f_{ce} and $2f_{ce}$ coupling at high $\kappa \geq 2.4$
  - Controlled z_0 scan w/ rtEFIT → emission varies with z_0
- T_{rad} decreased from ~350 eV to ~100 eV with 8 cm decrease in z_0

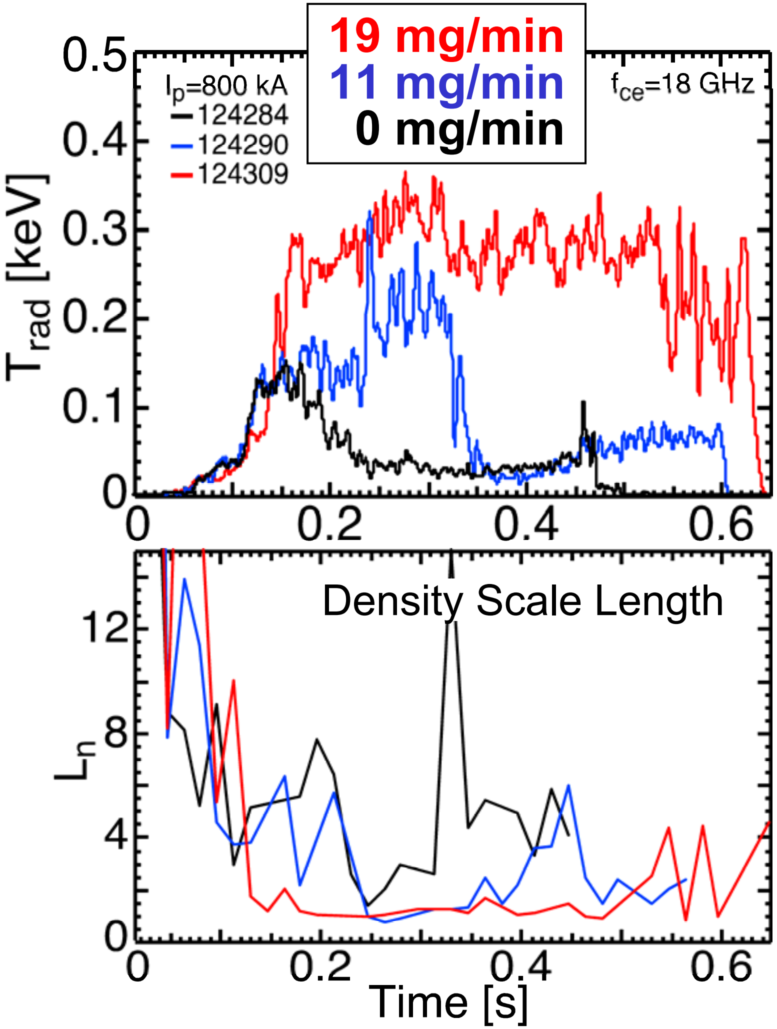


(Ph.D. thesis)

Increase in EBW transmission efficiency observed with Lithium PFC conditioning (LITER)

- T_{rad} increased from 40 eV (no Li) to ~300 eV for f_{ce}= 18 GHz emission
  - Similar trend observed for $2f_{ce}$ frequencies
- $T_e(0)$~0.8-0.9 keV

  → 30-40% transmission, subject to change with ongoing calibration, etc.
- Possible explanations of enhanced transmission efficiency:
  1. Li may decrease L_n at EBW mode conversion layer, widening EBW transmission window
  2. Li may increase T_e at mode conversion layer, decreasing collisional damping of EBW

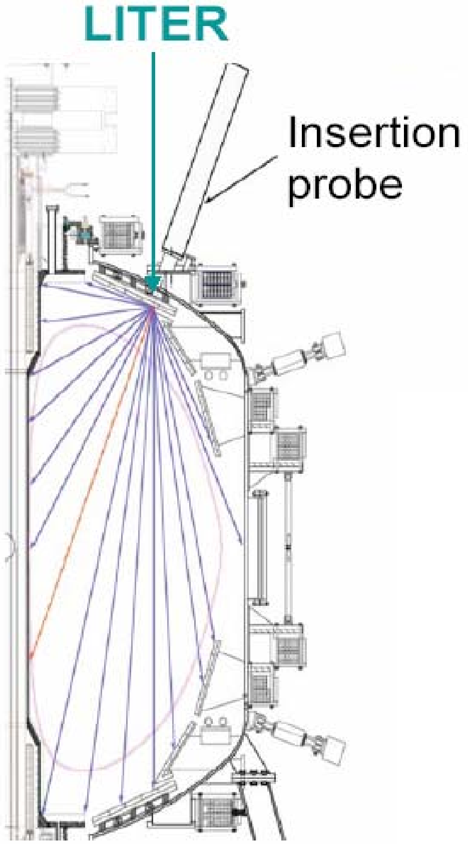


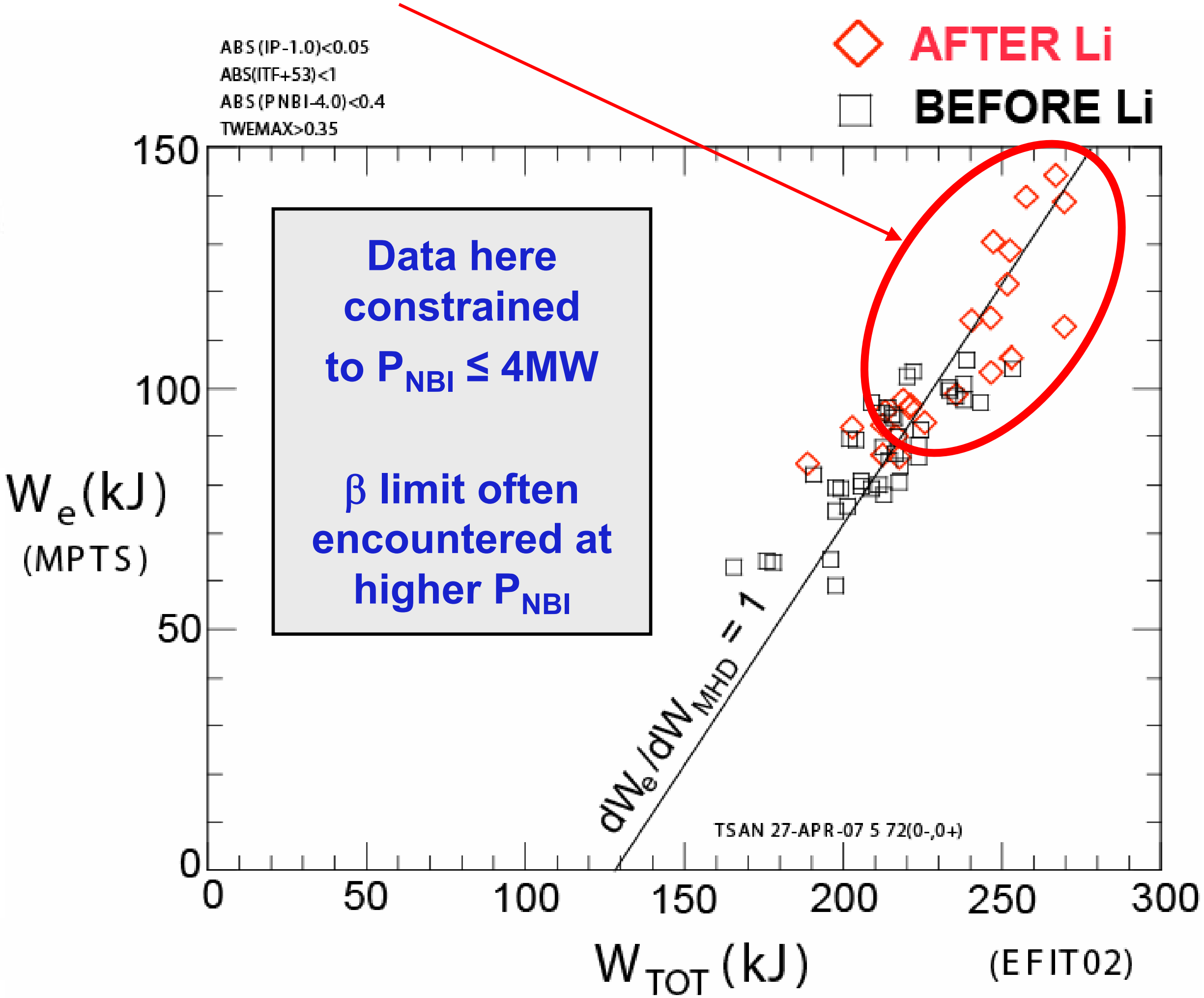
NSTX contributes broadly to fundamental toroidal confinement science in support of ITER and future ST's

- Boundary Physics: NSTX is unique in the world as the only diverted tokamak studying Li for particle pumping and power handling, while retaining a broad boundary program studying divertor heat flux, edge turbulence, pedestal physics, ELMs, and fueling
  - Li improves energy confinement and increases particle pumping
  - Partial divertor detachment reduces peak divertor heat flux while remaining compatible with high performance plasmas
  - SOL width scalings being developed to extrapolate to next-steps
  - Significant progress in predictive capability for SOL turbulence

Lithium Evaporator (LITER) was upgraded in FY07 to allow for continuous operation → frequent use of LITER in many expts.

- Improved energy confinement in H-mode plasmas (30-40%)
- Much of increase in stored energy comes from electrons (broader T_e)



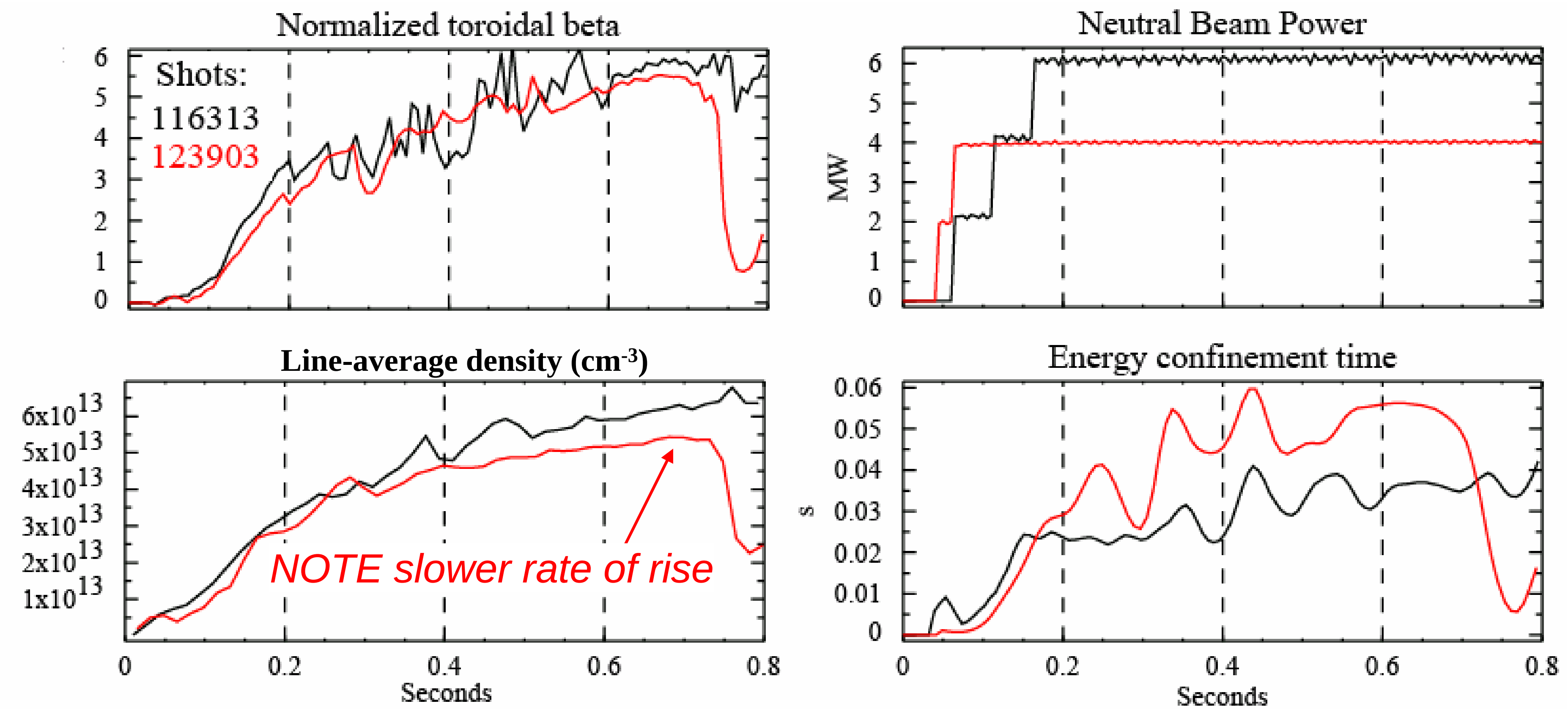


Data here constrained to $P_{NBI} \leq$ 4MW

β limit often encountered at higher P_{NBI}

LITER-conditioned discharges can achieve same β_N as previous best discharges with 1/3 less NBI power

- Black → w/o LITER - 2005 long-pulse discharge at 750kA and 4.5kG
- Red → with LITER, same β_N → 5-5.5 with 2 sources → τ_E = 35ms → 55ms

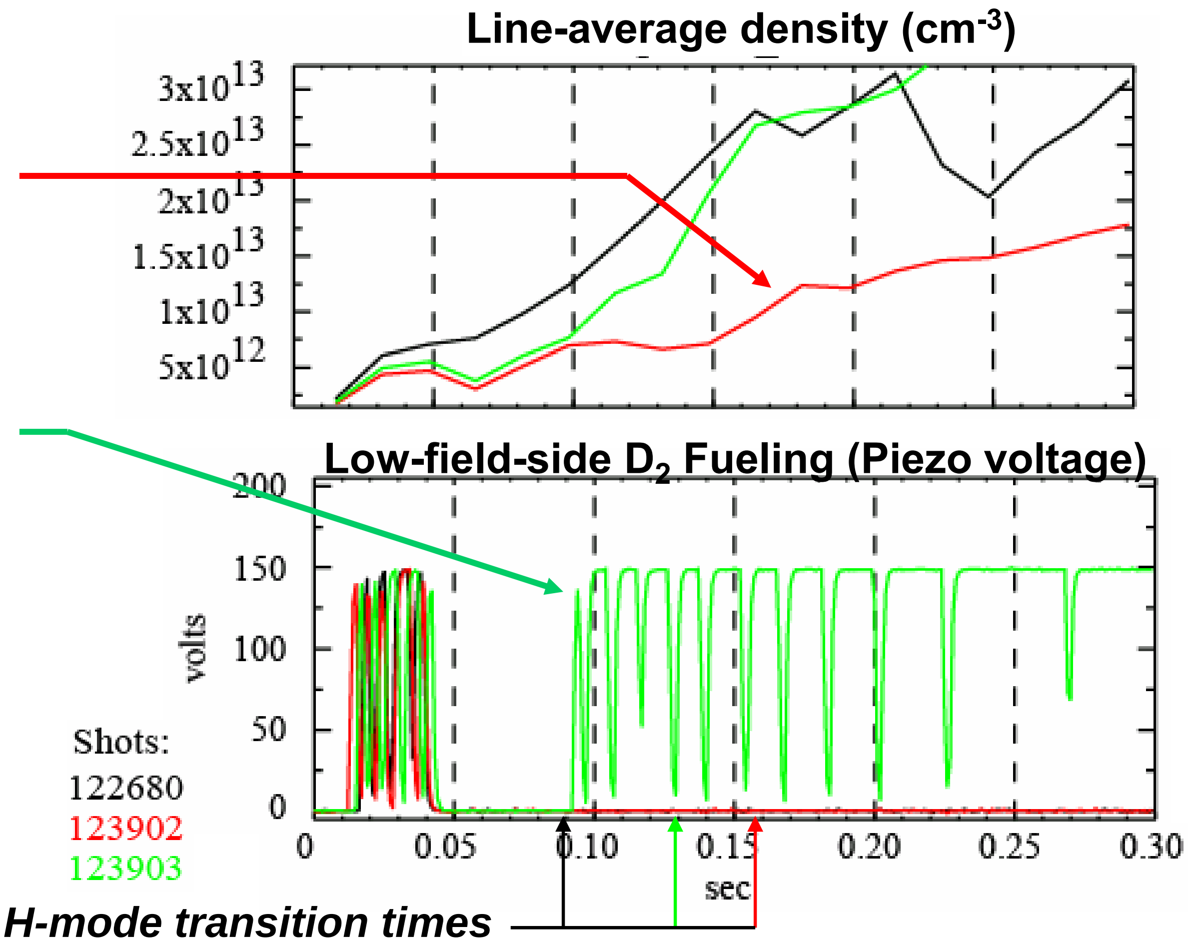


NOTE slower rate of rise

At high evaporation rates, significant additional fueling is required to maintain reference n_e

At high LITER evaporation rates, significant D pumping is observed, indicating Li can be an efficient particle pump in NSTX

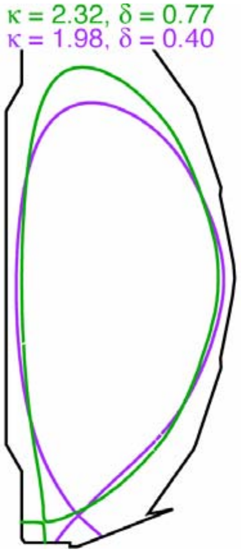
- Black → reference discharge w/o LITER from 2007
- Red → reference + 35mg/min LITER (Commonly used rate = 15-20mg/min)
- Green → 35mg/min LITER + strong low-field-side fueling

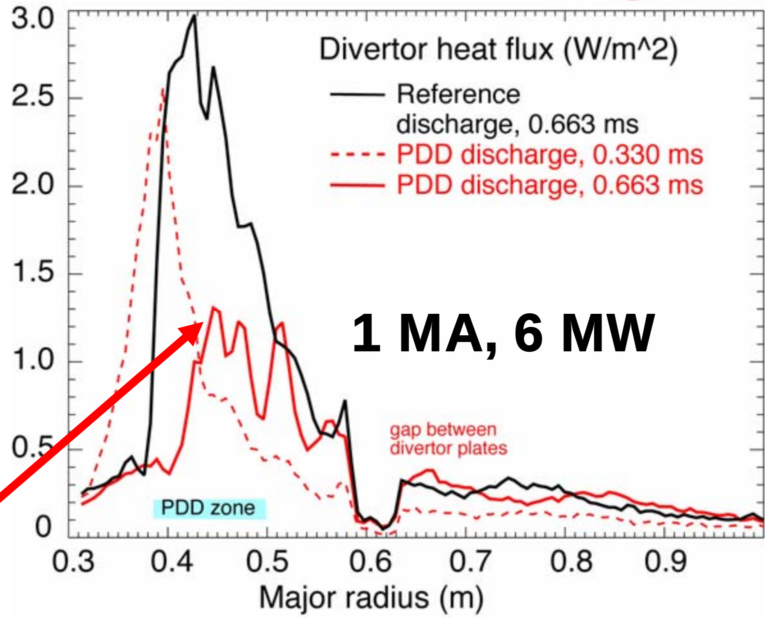


- Density reduced by factor of 2-3 using high evaporation rate and reference fueling rate
- Green → Strong LFS fueling required in I_P ramp to recover reference density
- Improved fueling (Supersonic Gas Injector) being pursued to achieve n_e pump-out

Partially Detached Divertor (PDD) achieves significant heat flux reduction at high κ, δ with no decrease in H-mode confinement

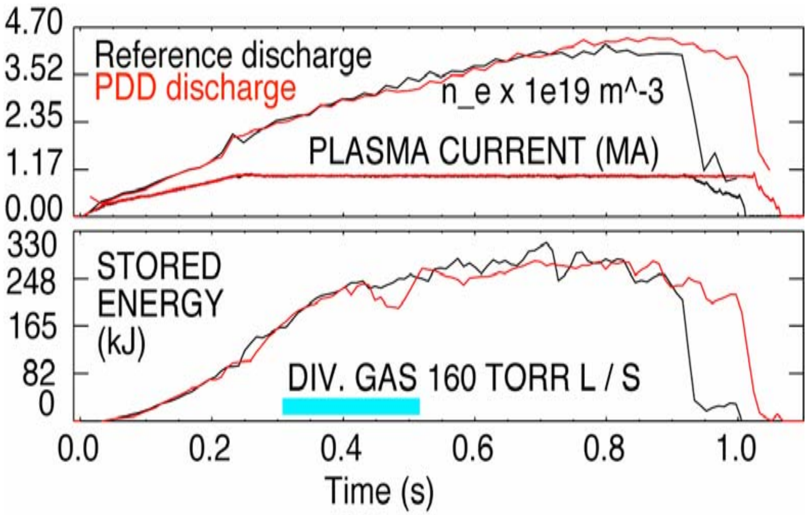
Extended results from low κ, δ (2006) to high κ, δ, high flux expansion shape for high performance scenarios





1 MA, 6 MW

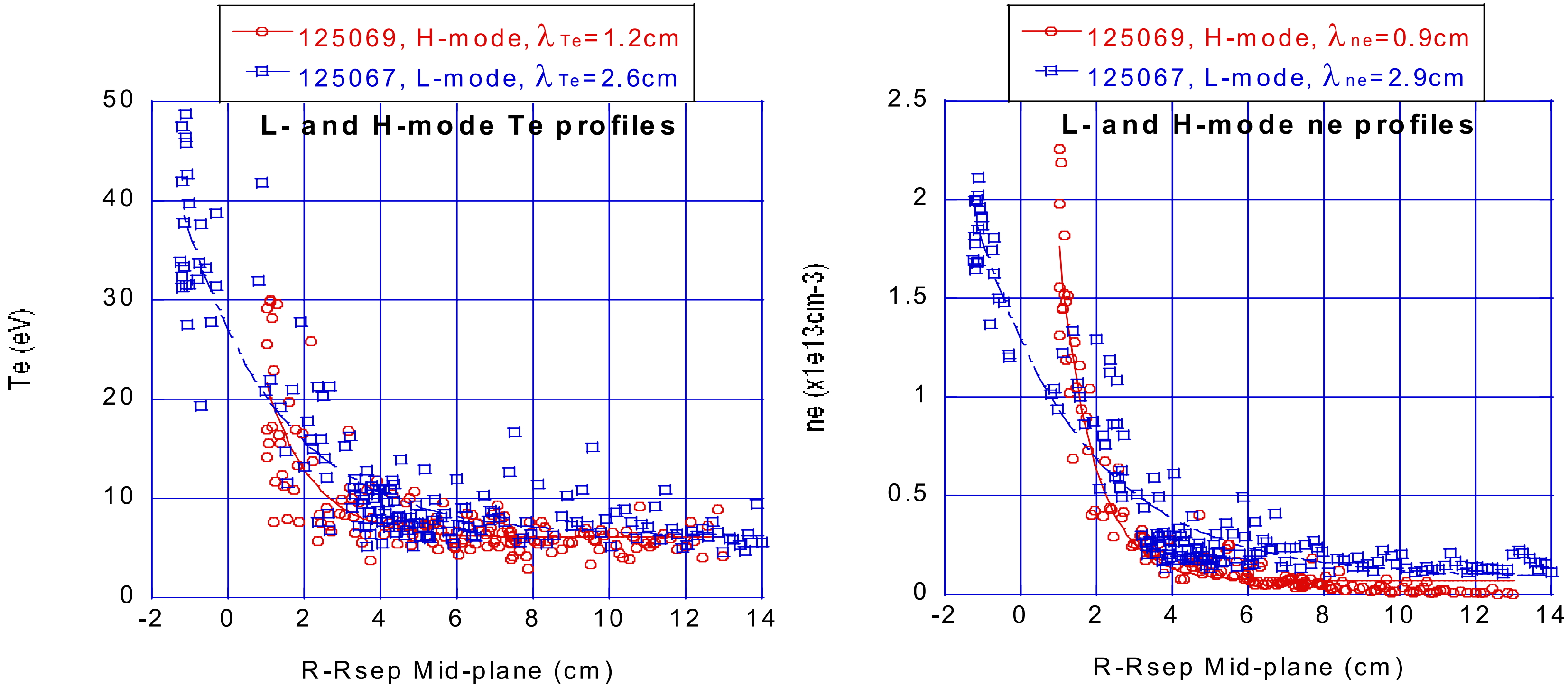
- Peak divertor heat flux **reduced by factor 2-3× during PDD phase** by injecting D_2 in divertor
- No increase in main plasma density
- No degradation of confinement
  - Same W_{TOT} for same P_{NBI} = 6MW



Heat flux mitigation techniques compatible with high performance crucial for next-steps

Scrape-off Layer (SOL) T_e, n_e width scaling studies crucial for estimating expected peak heat fluxes in next-step devices

- Prior studies showed discrepancy between NSTX SOL widths and those from conventional aspect ratio scalings
- Experiments performed in both L- and H-mode
- H-mode SOL widths 2-3 × narrower than those in L-mode

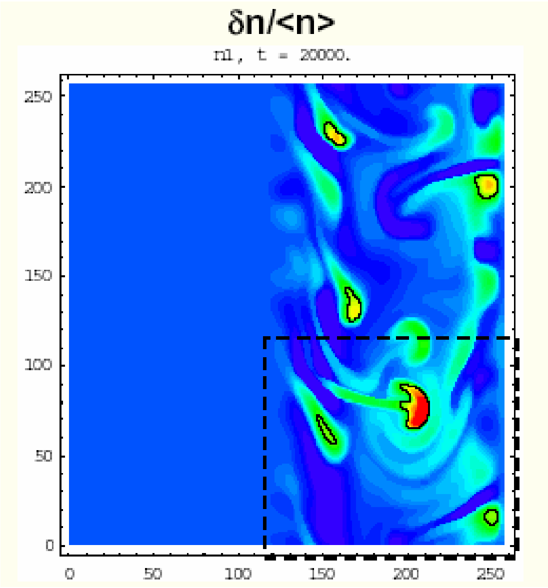


H-mode scaling results indicated decrease of SOL width with increasing I_p

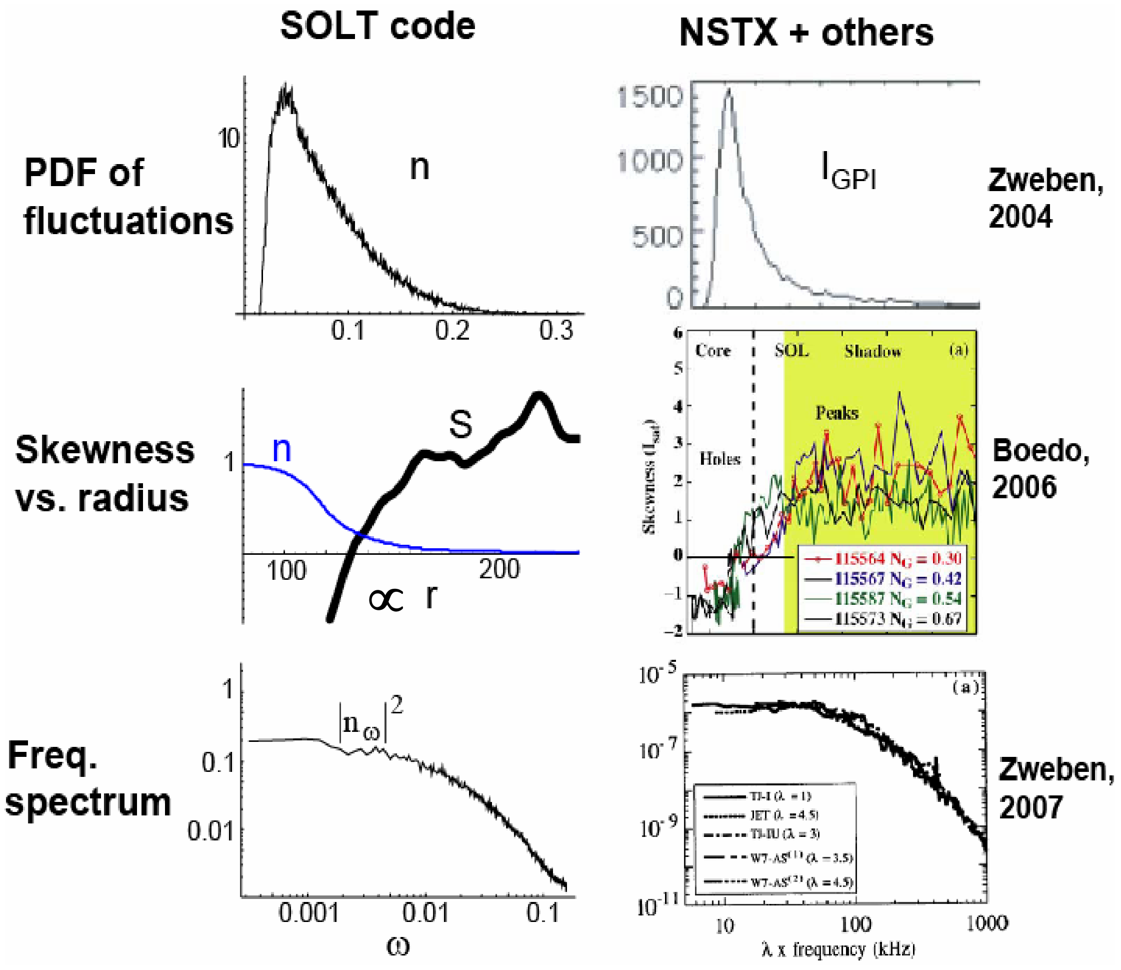
SOLT turbulence code shows blob formation and ejection

and reproduces many features of boundary turbulence observed experimentally

Validation and verification of code on several hierarchical levels



Working to resolve discrepancy between theory and exp't on blob acceleration when disconnected



Analytic work on effect of parallel electron physics, e-s vs electromagnetic Effects in creating non-adiabatic fluctuations for driving blob formation

NSTX contributes broadly to fundamental toroidal confinement science in support of ITER and future ST’s

- Integrated Scenarios: NSTX is ST world leader in integrating and sustaining high confinement, high-non-inductive current fraction, and high β
  - Breakdown, ramp-up, and plasma shape successfully modified to access high-q_{min} q profile aimed at increasing non-inductive fraction

- Plasma formation: NSTX is unique in world investigating coaxial helicity injection (CHI) plasma startup
  - Successfully coupled CHI to inductive current drive, demonstrating ohmic flux savings is possible

Stable & fully non-inductive target scenario utilizing only NBI and BS current drive has been identified

Present high-f_{NI} long-pulse H-modes:

I_P = 750kA, f_{NI} < 65%, f_{BS} < 55%

β_N < 5.6, β_P < 1.5, β_T < 17%

l_i = 0.6, q_{min}=1.3, B_T=4.5kG

κ = 2.3, δ_{X-L} = 0.75, q*=3.9

Target scenario:

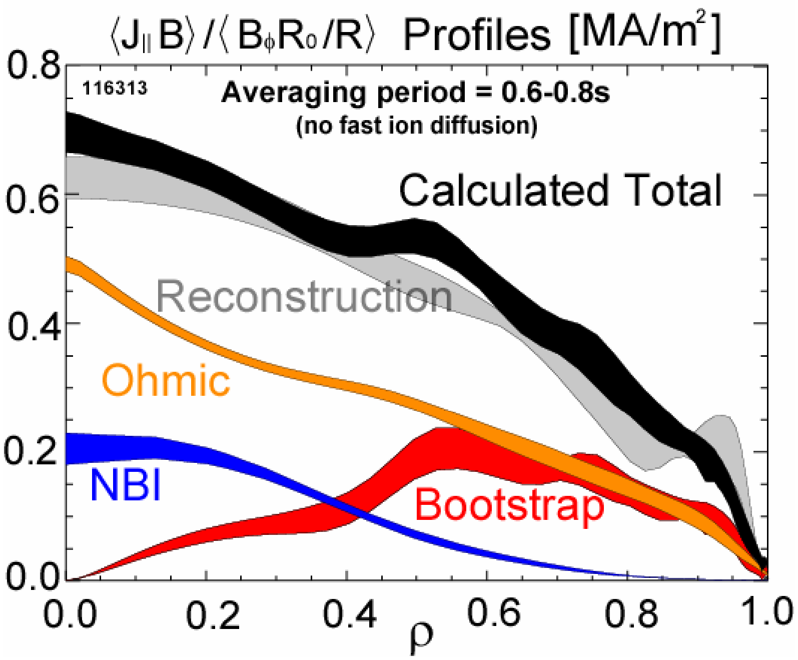
I_P = 700kA, f_{NI} =100%, f_{BS}= 80%

β_N = 6.7, β_P = 2.7, β_T =15%

l_i = 0.5, q_{min} = 2.4, B_T=5.2kG

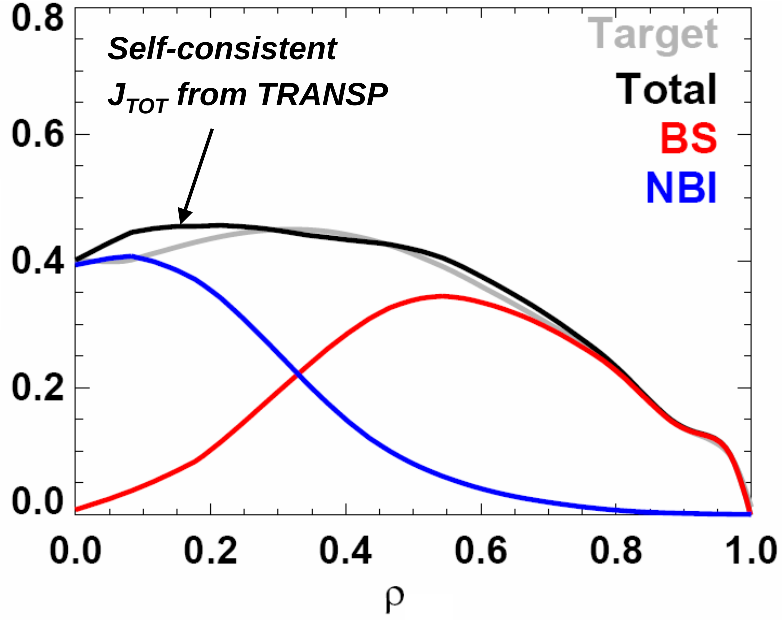
κ = 2.6, δ_{X-L} = 0.85, q*=5.6

Inductive current drive is replaced by:



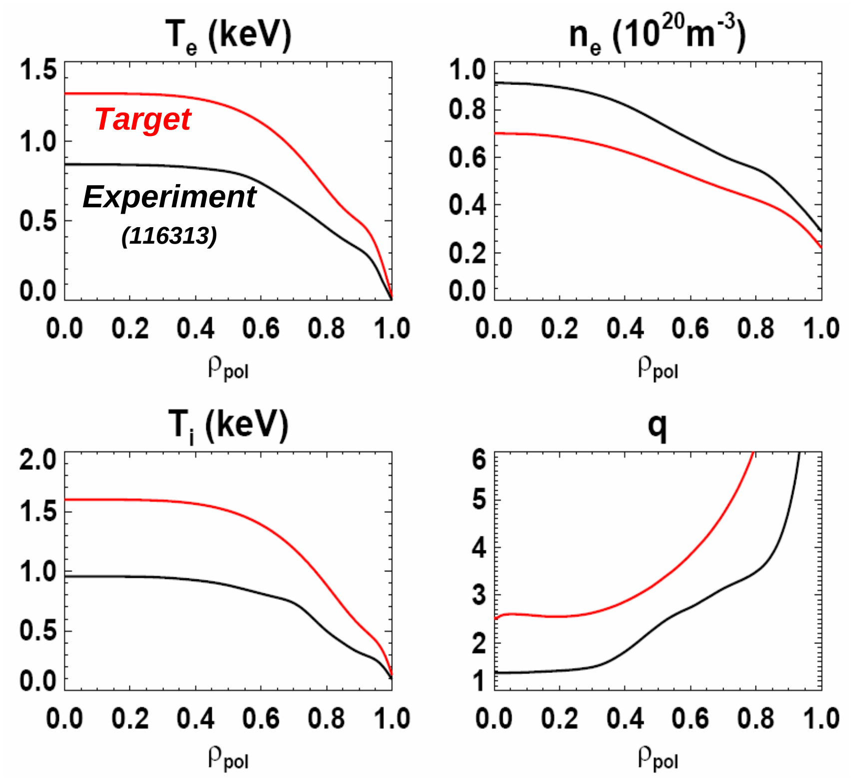
Higher J_{NBI} from higher T_e & lower n_e

Higher J_{BS} from higher $\beta_{P\text{-thermal}}$



Fully non-inductive scenario using only BS and NBI requires higher *q*, higher confinement, strong plasma shaping

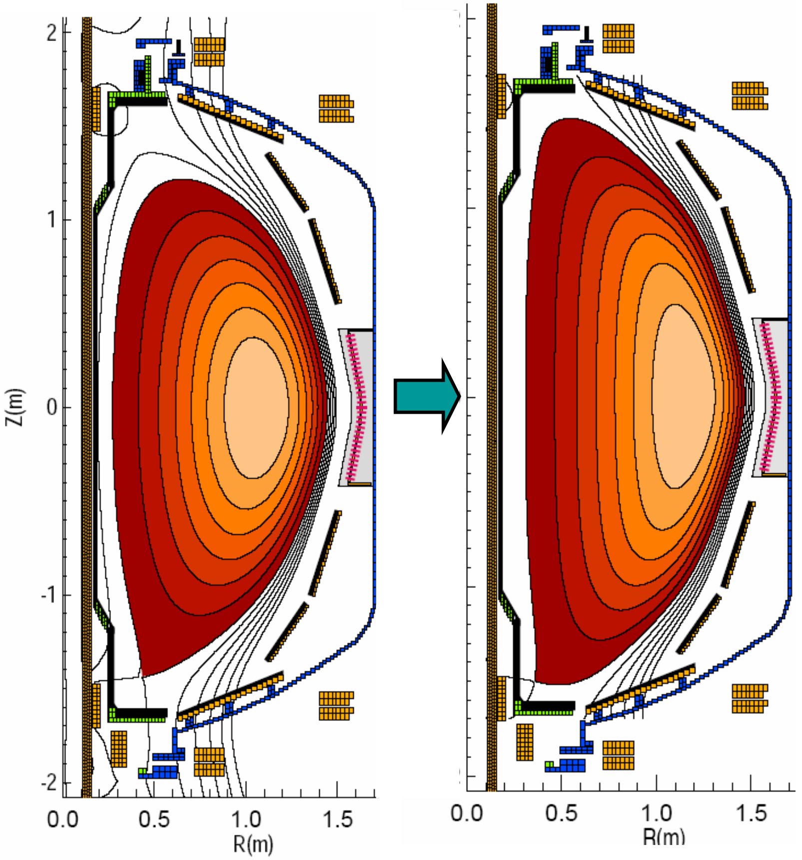
- Need 60% increase in T, 25% decrease in n_e
  - **Lithium for higher τ_E & density control**
    - **20% increase in thermal confinement**
    - **30% increase in HH_{98}**
  - **Core HHFW heating**
- Want $q_0 \approx q_{min} \approx 2.4 \Rightarrow$ higher with-wall limit



- Higher κ for higher q, β_P, f_{BS}
- High δ for improved kink stability

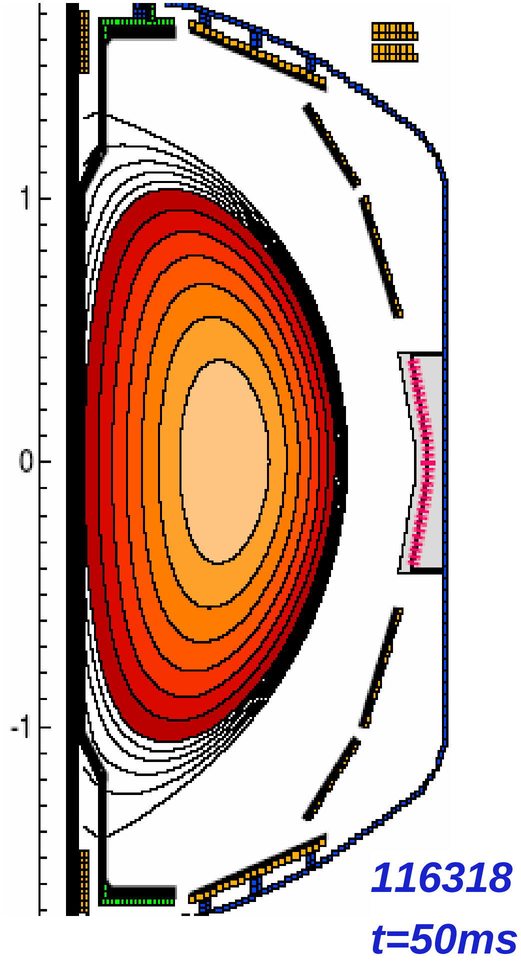
κ= 2.3, $\delta_{X\text{-}L}$ = 0.75
δR_{SEP} = -1cm

κ= 2.6, $\delta_{X\text{-}L}$ = 0.85
δR_{SEP} = -2mm

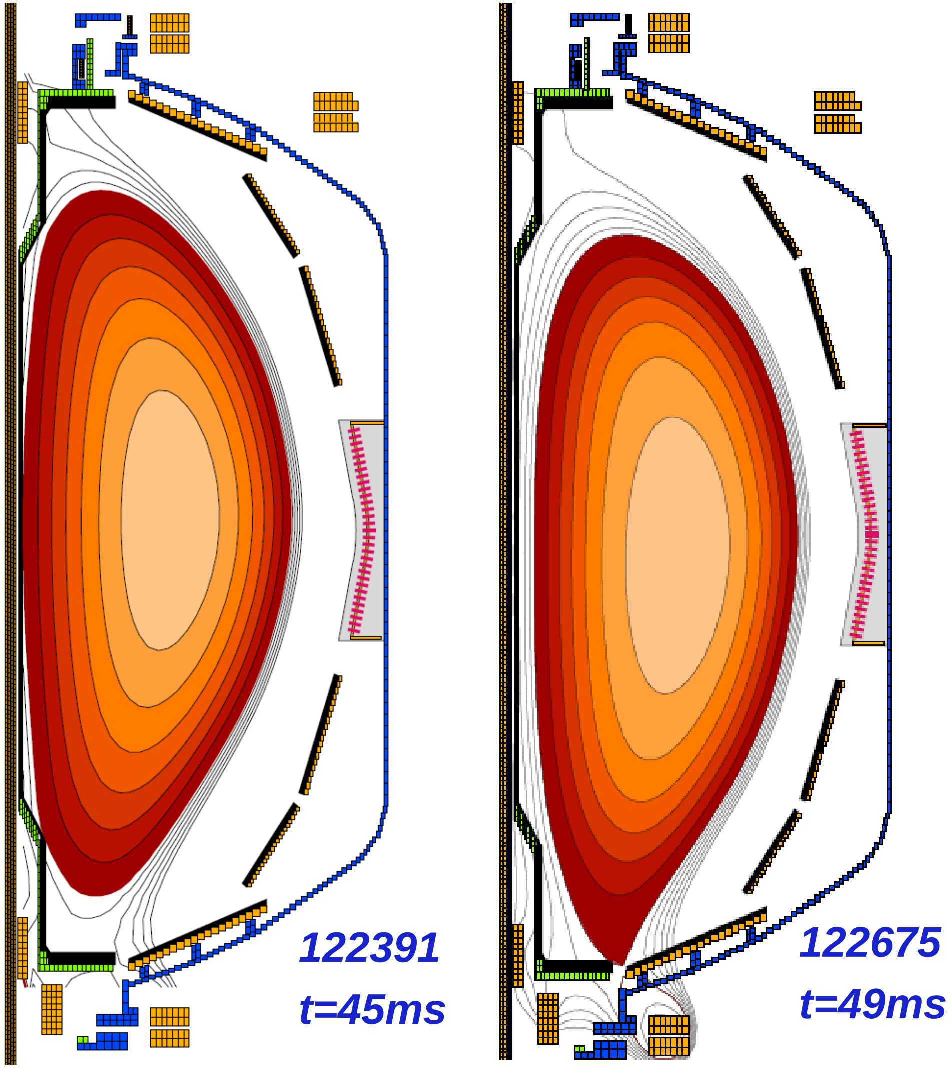


Divertor coil current during break-down phase enables increased ramp-up elongation, very early diverting+H-mode → **elevated *q***

- Plasma shape during I_P ramp with old breakdown

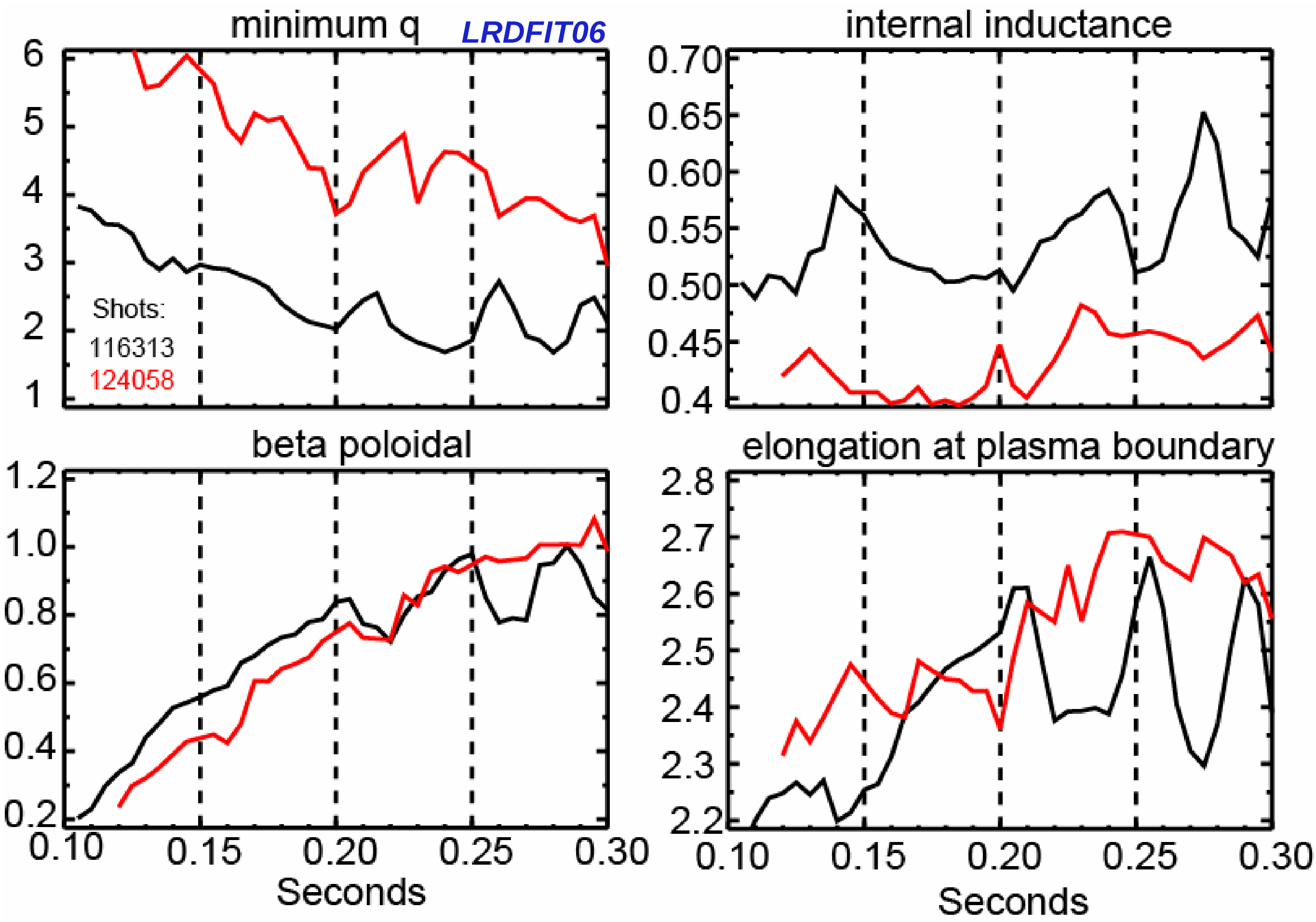


- Plasma shape w/ new breakdown



High-κ breakdown scenario + LITER (15-20mg/min) successfully elevated safety factor *q* early in discharge

- In first 300ms, high $q_{min} > 3$, $l_i = 0.45$, $\kappa = 2.6\text{-}2.7$
  - Previous long-pulse shots (116313) had $q_{min} \rightarrow 2$ by t=0.2s

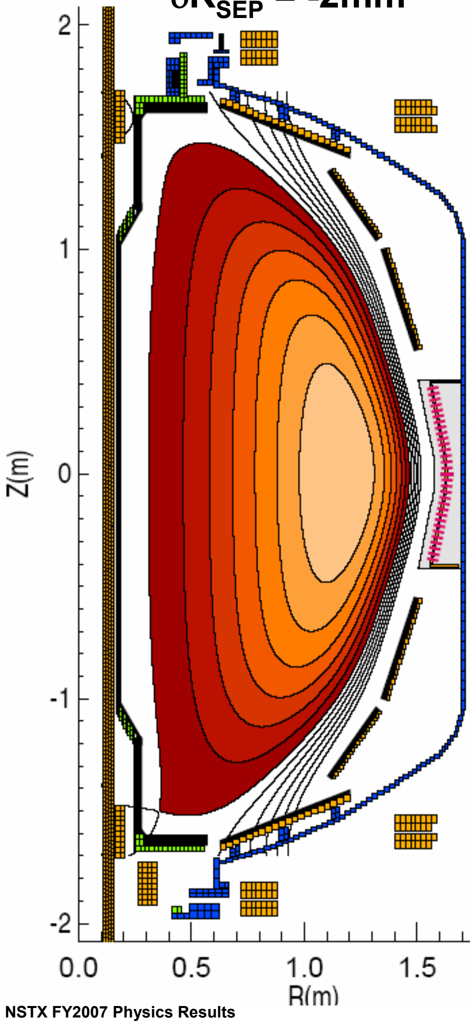


rt-EFIT isoflux control algorithm achieves and maintains shape very close to desired target shape

High q_{min} TARGET

κ= 2.6, δ_{X-L} = 0.85

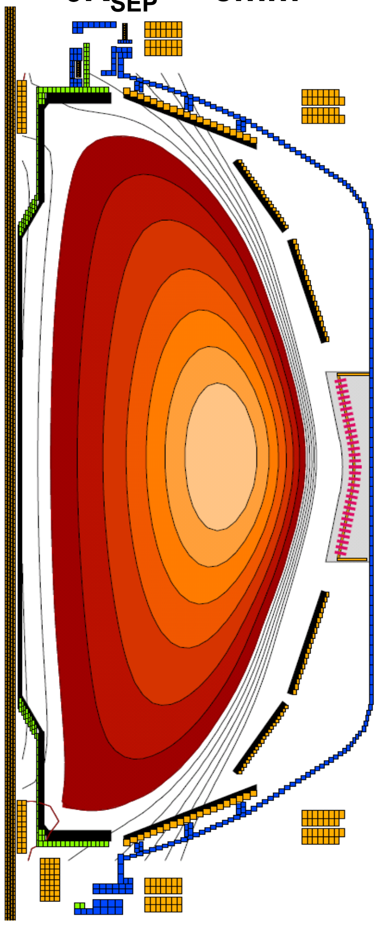
δR_{SEP} = -2mm



125006, 550ms (LRDFIT06)

κ= 2.75, δ_{X-L} = 0.85

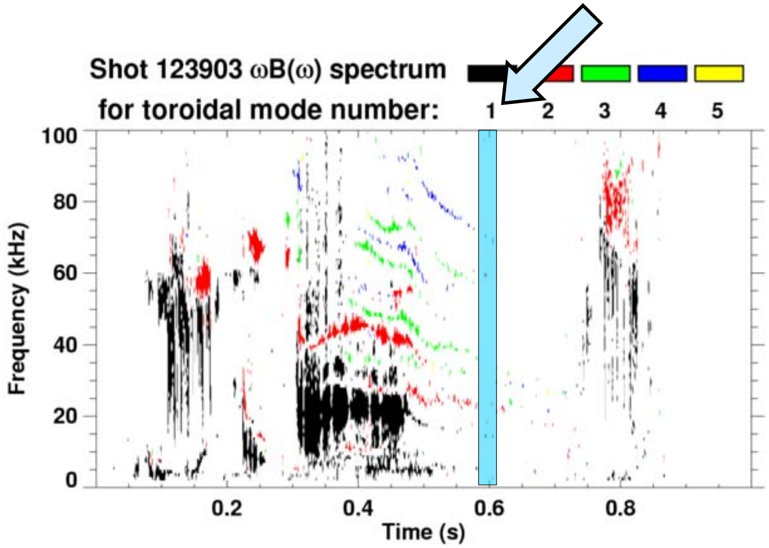
δR_{SEP} = -8mm

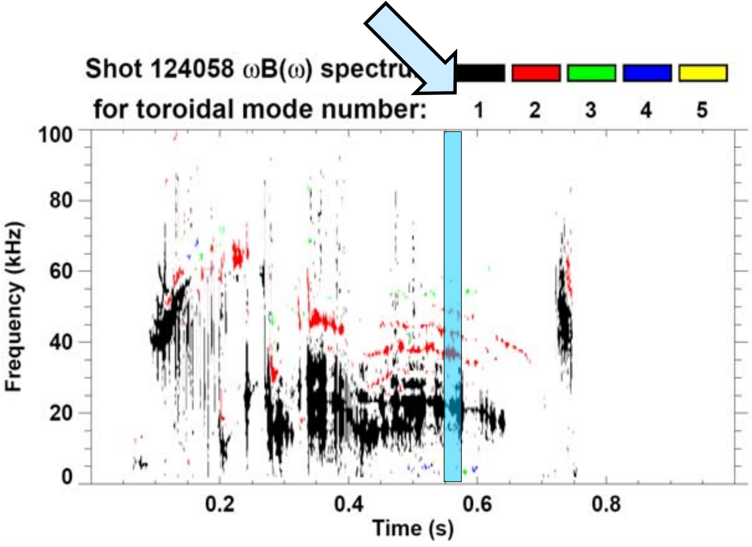


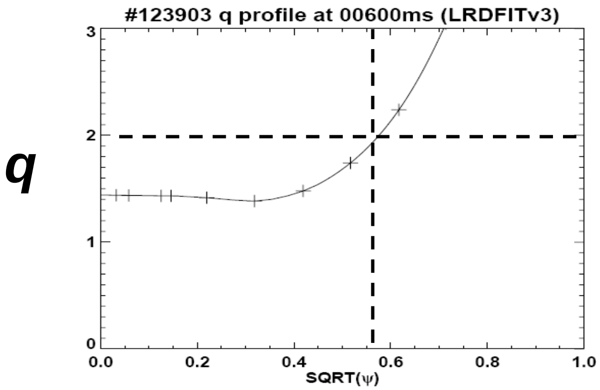
- Future: additional shape modifications will be performed to optimize edge and global stability:
  - Magnetic balance (δR_{SEP})
    - ELM type/severity
  - Outer gap
    - Wall coupling for n=0,1
  - Upper triangularity
    - ELM and n=1 stability
  - Squareness
    - ELM and n=1 stability

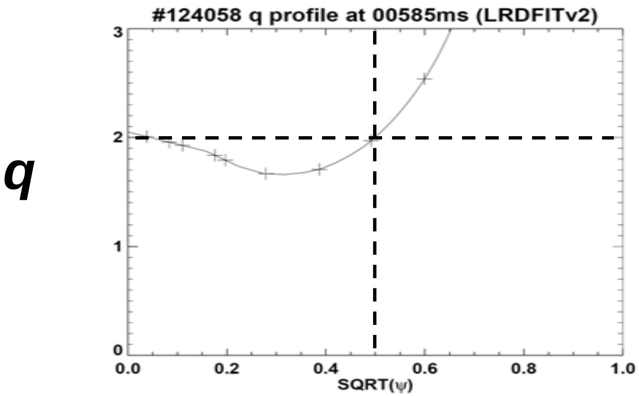
Elevated q_{min} shots are limited to $\beta_P < 1.5$ by core n=1 activity associated with q=2 → highlights need for maintaining $q_{min} > 2$

- Mode f matches rotation frequency at q=2 surface → 2/1 NTM or DTM
  - Mode absent for monotonic shear → RS q-profile may destabilize mode









- **HHFW heating/CD in ramp-up and flat-top will be used to further elevate q_{min}**

Coaxial Helicity Injection (CHI) plasmas successfully coupled to transformer induction in NSTX for first time

CHI can reduce OH flux consumption

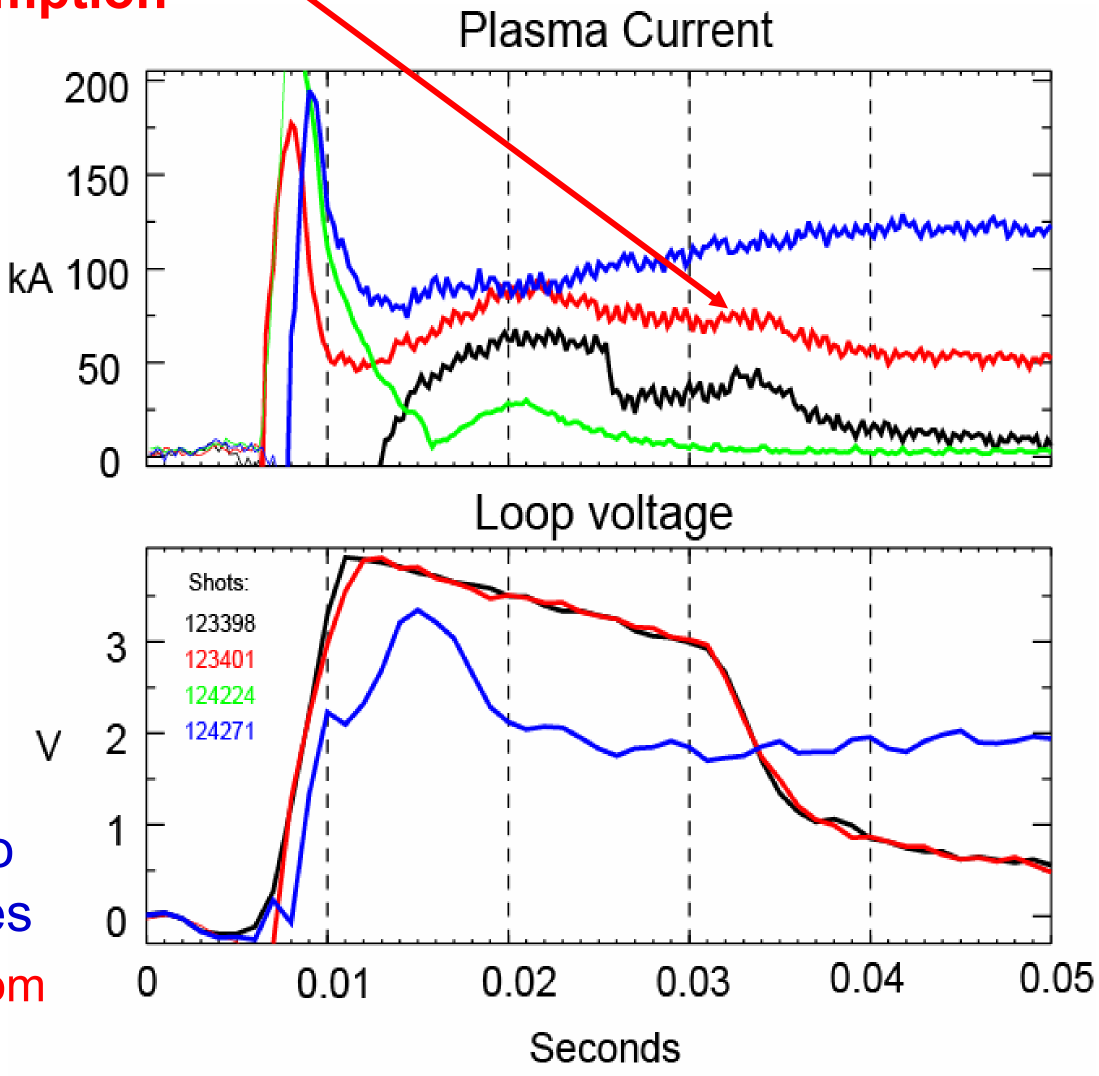
CHI only

Induction only

CHI + induction

CHI + induction: I_P = 120kA

(Boronization + improved PF programming)



- FUTURE optimization:
  - LITER during CHI
    - stronger pumping
    - reduced impurities
  - Use flux savings from CHI to extend long-pulse discharges
    - Use pre-charged solenoid from standard OH I_P ramp

NSTX in 2007 contributed strongly to fundamental toroidal confinement science in support of ITER and future ST's

Key Results for 2007:

- Improved RWM and EF feedback, discovered n > 1 EF, characterized tearing modes
- Measured & modeled electron, particle, and angular momentum transport
- Measured & modeled fast ion redistribution, TAE stability, AC/GAM coupling, BAAE
- Improved understanding of HHFW and EBW coupling efficiency vs. edge params.
- Enhanced confinement and pumping with Li, reduced and elucidated divertor heat flux
- Developed plasma shape and elevated q profile toward fully non-inductive scenarios
- Demonstrated CHI coupling to transformer action in NSTX for first time

NSTX contributes strongly to fundamental toroidal confinement science in support of ITER and future ST's

Unique NSTX Capabilities:

- Only ST in world with advanced mode stabilization tools and diagnostics
- High-k + MSE + $\chi_i = \chi_{i\text{-neo}}$ = unique opportunity for understanding transport & turbulence
- Developing unique heating and current drive tools essential for ST, useful for AT
- Uniquely able to mimic ITER fast-ion instability drive with full diagnostics
- Unique Li research + broad ITER and NCT-relevant boundary physics research
- Most capable ST in world for developing high-non-inductive fraction, high β plasmas
- Developing unique plasma start-up and ramp-up research crucial to ST concept
- ST offers compact geometry + high β for attractive fusion applications:
  - Nuclear Component Testing (NCT)
  - More attractive fusion reactor - simpler/cheaper magnets, simplified maintenance