NSTX Supported by U.S. DEPARTMENT OF ENERGY Office of Science

Overview of Results from the FY10 National Spherical Torus Experiment Run

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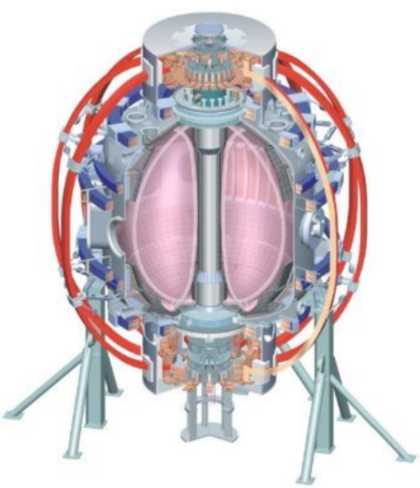
Eric Fredrickson

For the NSTX Team

52nd APS-DPP Meeting
Chicago, Illinois, Nov. 8-12, 2010



Culham Sci Ctr
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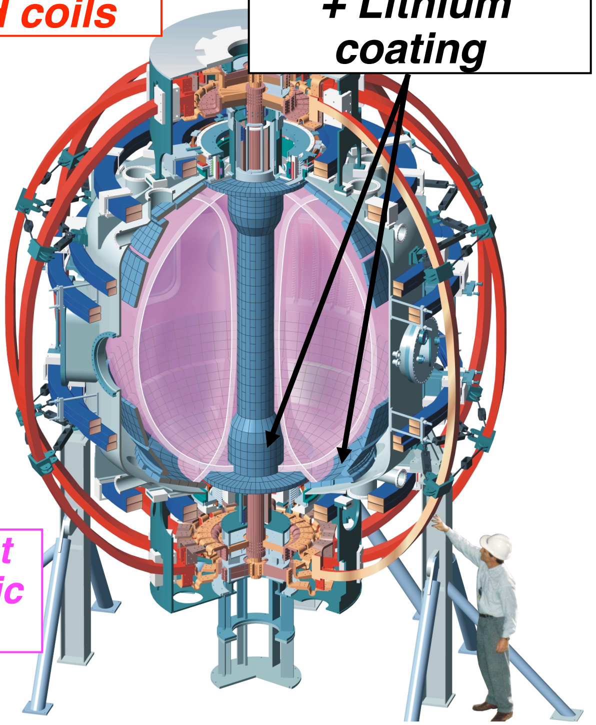
NSTX is a midsize Magnetic Confinement Fusion Device, a Spherical Tokamak (ST)



$R_0 = 0.86$ m

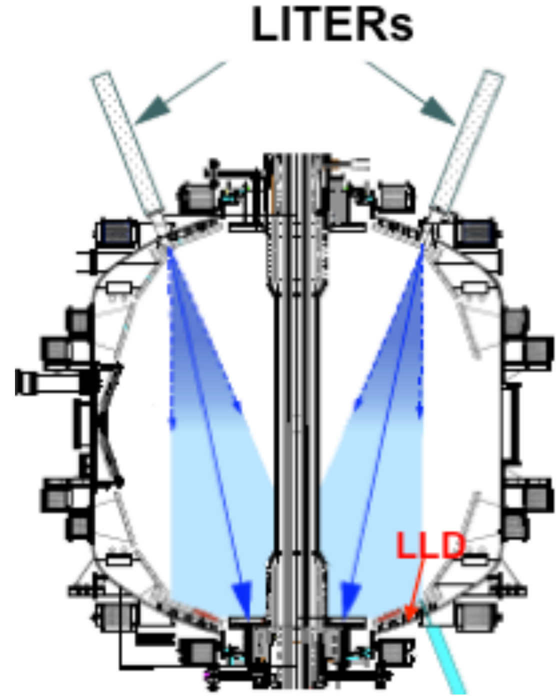
$a \approx 0.62$ m

$B_0 = 0.3\text{-}0.55$ T

$I_p \leq 1.4$ MA

$\beta_{tor} \geq 35\%$

$n_e \leq 1.2 \times 10^{20}/m^3$



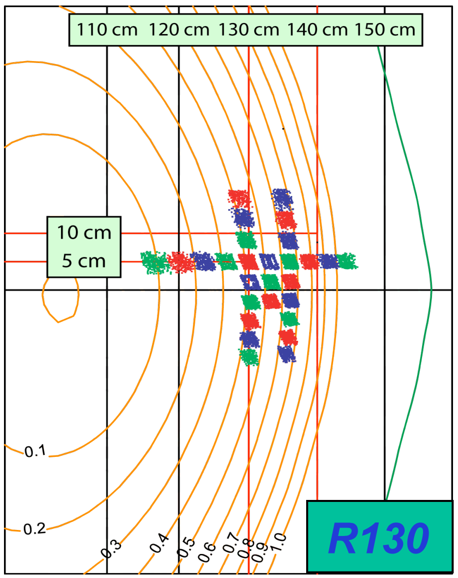
- New Capabilities for 2010 Campaign:
  - Liquid Lithium Divertor plates; D pumping and ELM suppression.
  - Beam Emission Spectroscopy diagnostic; measure low-k turbulence up to 1 MHz.
  - Fast, two-color IR camera for time-resolved divertor heat flux measurements
- Experiments performed to support NSTX upgrade

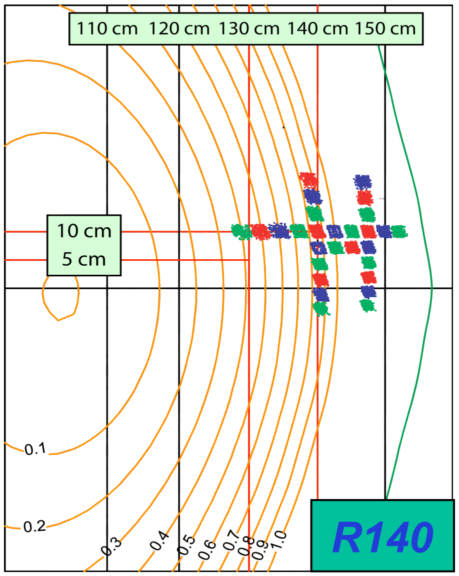
D.P. Boyle BP9.00048

BES complements high-k scattering to cover broad range of turbulence wavelengths

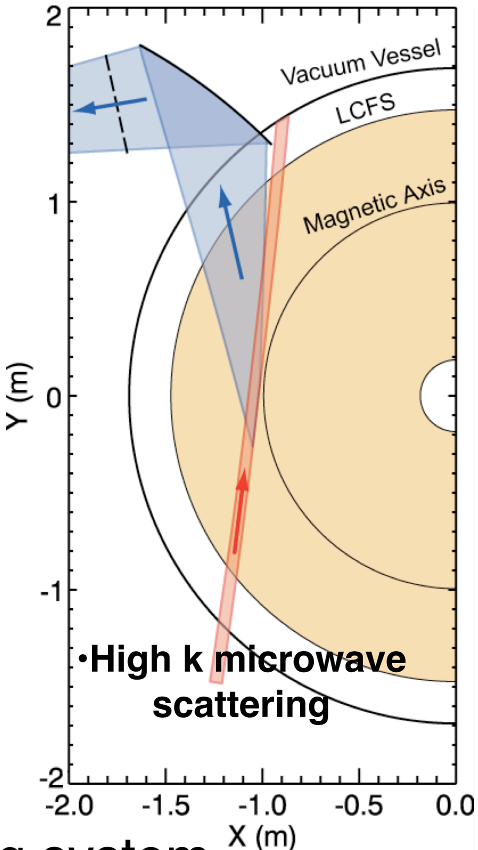
- Multiple BES sightlines in two views are available.
- This year, 16 channels of BES were instrumented in various configurations.
- BES also complements 16-channel reflectometer array for studies of high frequency, coherent Alfvénic activity (TAE, GAE and CAE).

BES (UofW): D.R. Smith, NO4.00009
N.L. Schoenbeck, BP9.00070





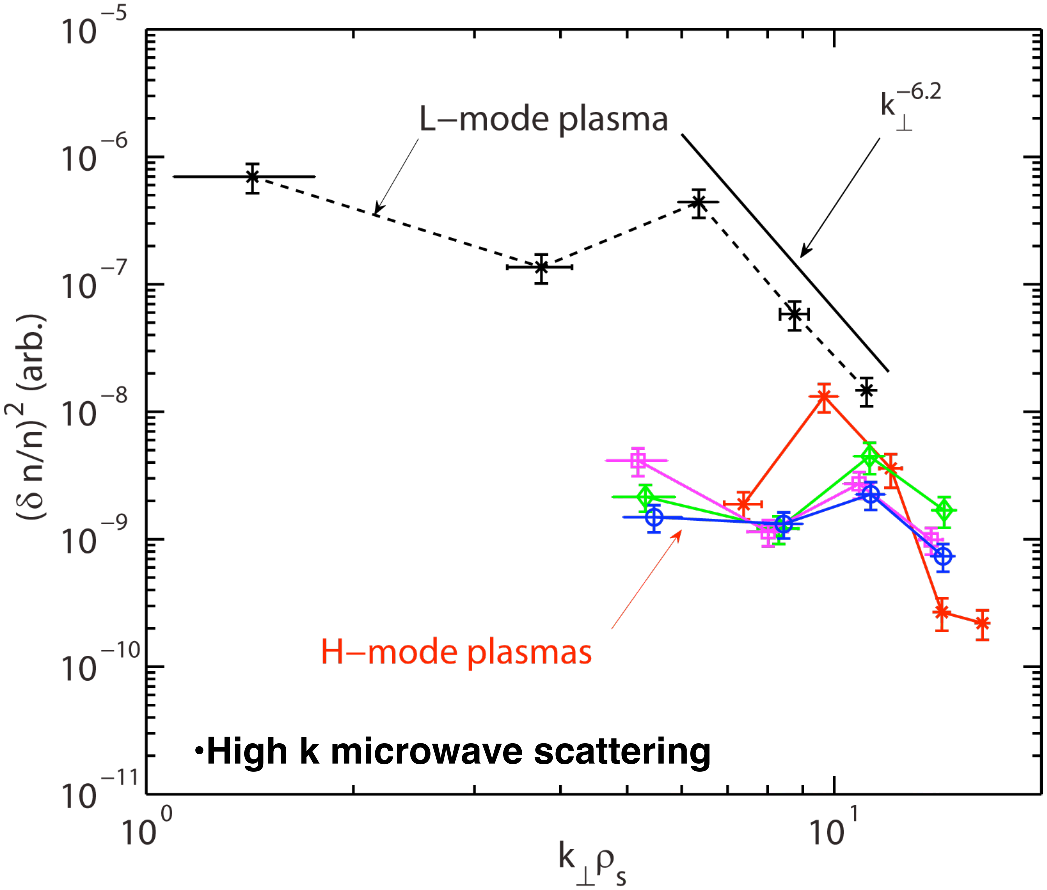
Y. Ren, BP9.00067
F.M. Poli, BP9.00068



- High-k scattering system measures short wavelength turbulence ($1 < k_\perp \rho_s < 20$).
- Measurement localized radially to ±2 cm.

Measured k-spectra Imply $k_{\perp}\rho_s$ < 10 Turbulence Responsible for Anomalous L-mode Transport

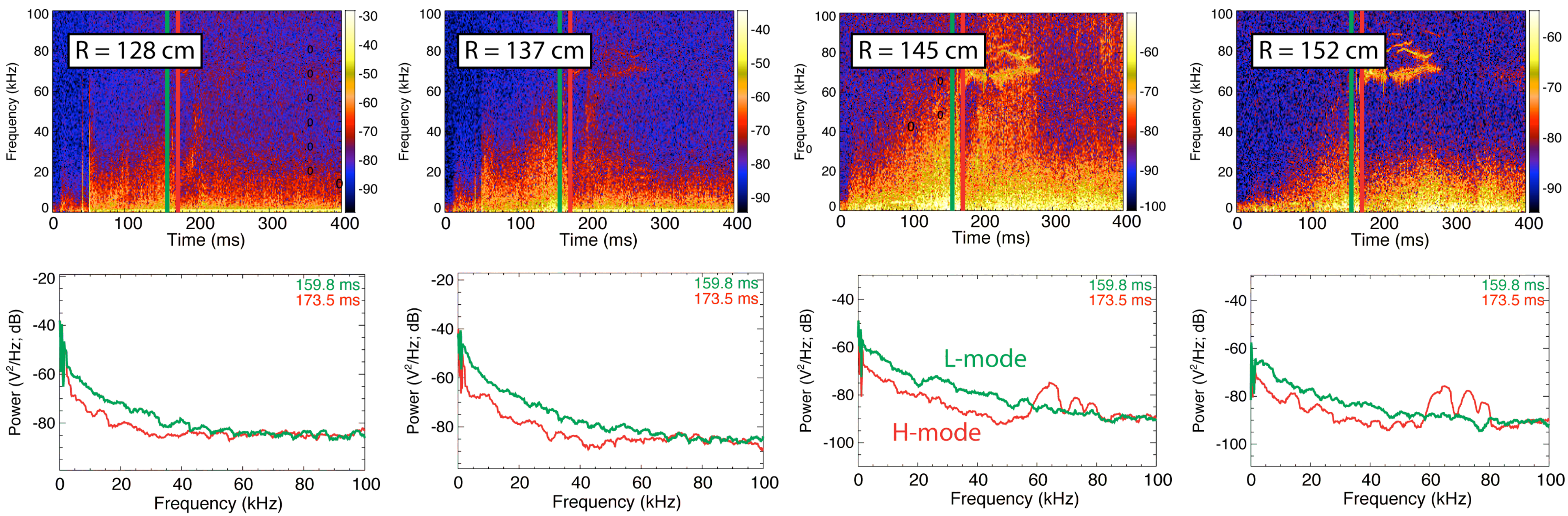
k spectra of normalized density fluctuations in beam-heated L and H-mode plasmas



- Spectral power for $k_{\perp}\rho_s$ >10 similar for L and H-mode.
- Large differences, more than 2 orders of magnitude, in spectral power found at $k_{\perp}\rho_s$ <10 between L and H-mode.
- Consistent with long wavelength turbulence being more important for driving anomalous transport.
- BES will give information for $k_{\perp}\rho_s$ <1.

Y. Ren, BP9.00067

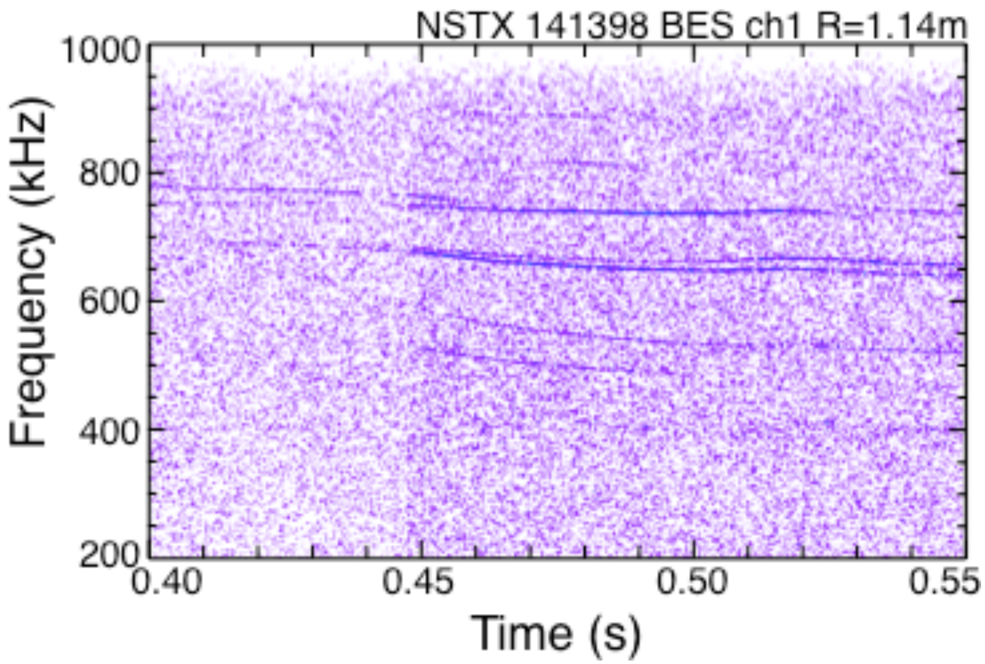
BES measurements show drop in turbulence across plasma cross-section at L-H transition



- Drop in fluctuation power is ≈ 10db at lower frequencies.
- *Fluctuations are not just at plasma edge.*
- TAE activity is apparent in spectrograms of channels towards plasma edge.

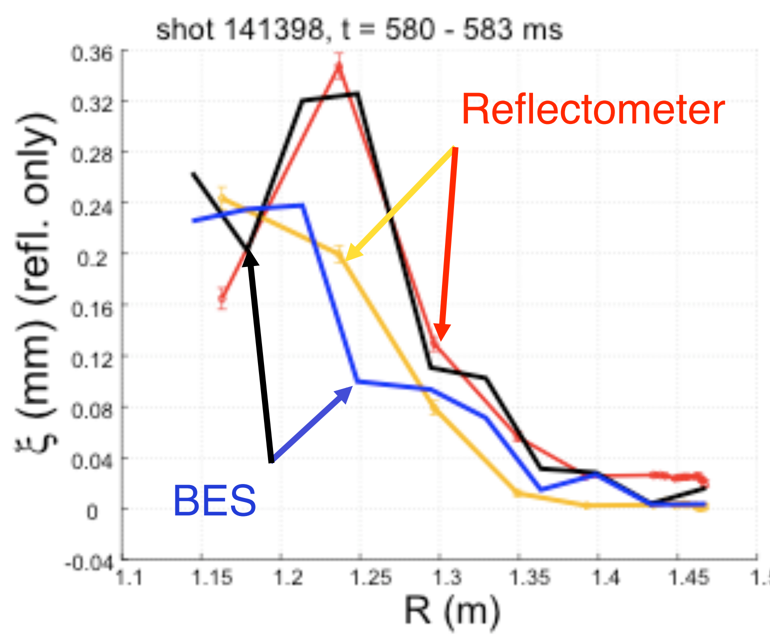
D.R. Smith,NO4.00009
N.L. Schoenbeck, BP9.00070

BES also important for study of high frequency coherent Alfvénic modes



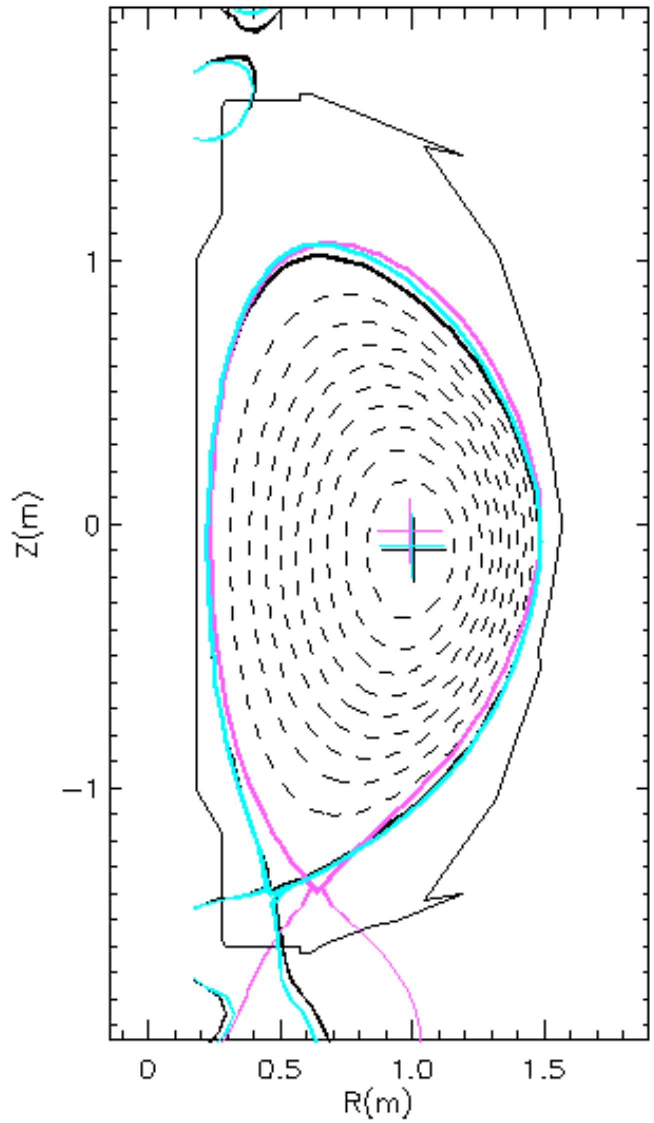
- GAE activity has been correlated with increased core electron transport.
- Transport scales strongly with GAE amplitude (~α^6).

- BES and 16 channel reflectometer array provide mode amplitude and radial structure.



K. Tritz, PI2.00002
N.A. Crocker, BP9.00058
E. Belova, TI2.00003

Observation that P_{LH} scales with toroidal field at X-point unifies triangularity and field scaling



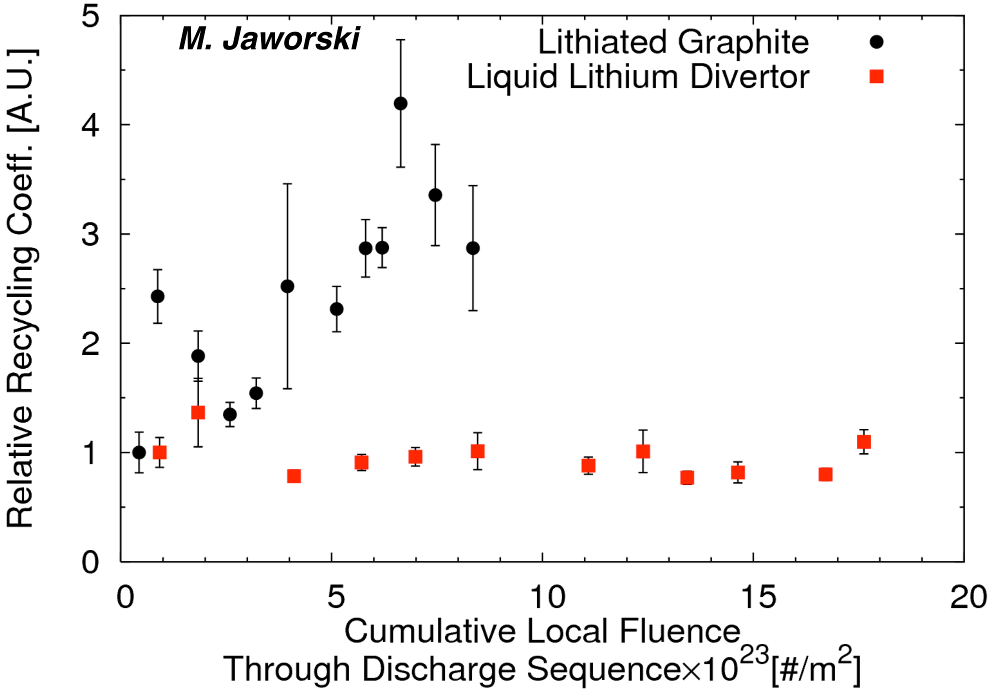
- ST geometry enhances B_{tX} variation with R_X
- Three comparable discharges:
  - Matched I_p, n_e, Z_X, wall-conditioning

B_{t0} (T)	R_X (m)	B_{tX} (T)	P_{NBI} (MW)	P_{Loss} (MW)
0.55	0.47	0.86	1.9	1.1
0.55	0.64	0.63	1.0	0.7
0.40	0.47	0.63	1.0	0.6

- Result consistent with XGC-0 calculations E_r well is deeper with larger R_X
  – Smaller B_{tX} → larger gyro-orbit → enhanced ion loss at x-point

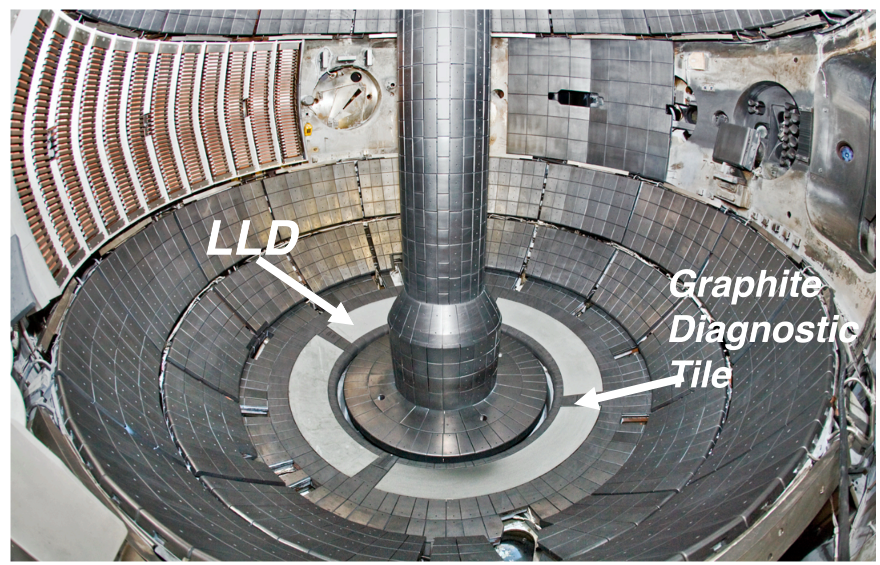
D. J. Battaglia, BP9.00050, S.M. Kaye, UO4.00010

With outer strike point on LLD, evidence of persistent low recycling; no saturation of lithium



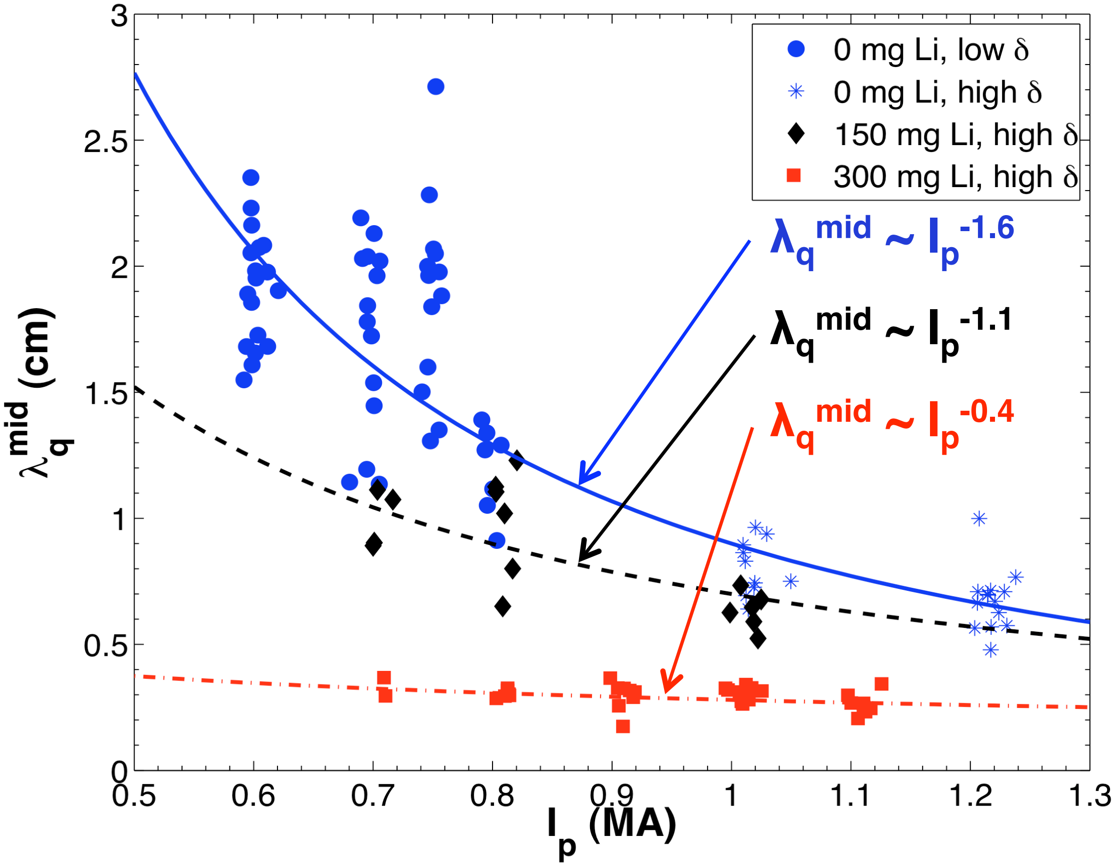
- On area of lithiated graphite, relative recycling coefficient increases with total fluence

- On pre-loaded LLD heated above lithium melting point (180°C), relative recycling remains low even at higher total fluence



R Kaita, NO4.00003,
H. W. Kugel, BP9.00041,
M.A. Jaworski, BP9.00052

Heat flux profile width decreases with increasing plasma current and lithium coating

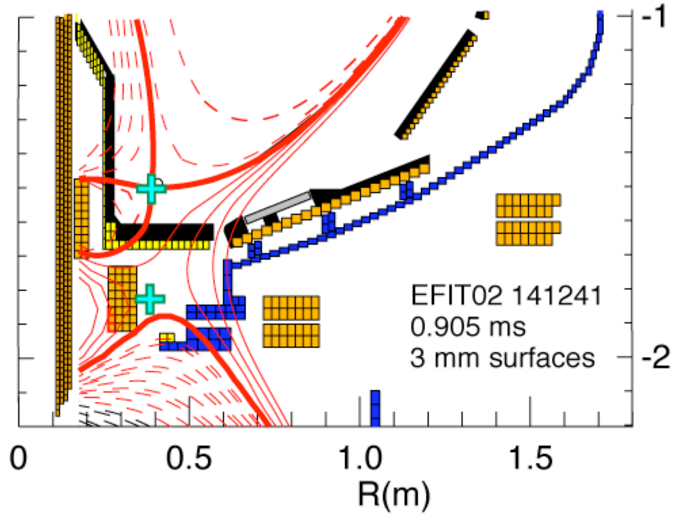


- Heat flux profile width, $\lambda_q^{mid} \sim I_p^{-\alpha}$
- Lithium causes contraction of SOL heat flux profile
- Divertor heat flux width increases with flux expansion, *e.g.*, in the 'snowflake' shape

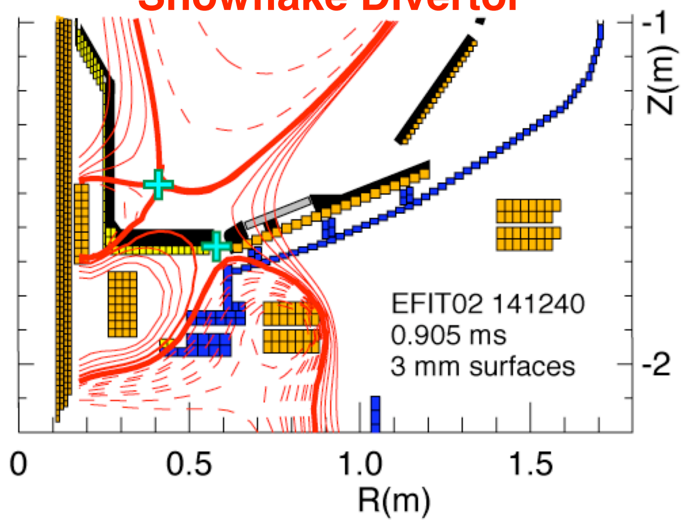
Travis Gray, NO4.00006
J. Canik, JI2.00001
A. McLean, BP9.00083

“Snowflake” divertor configurations obtained in NSTX have significantly reduced peak heat flux

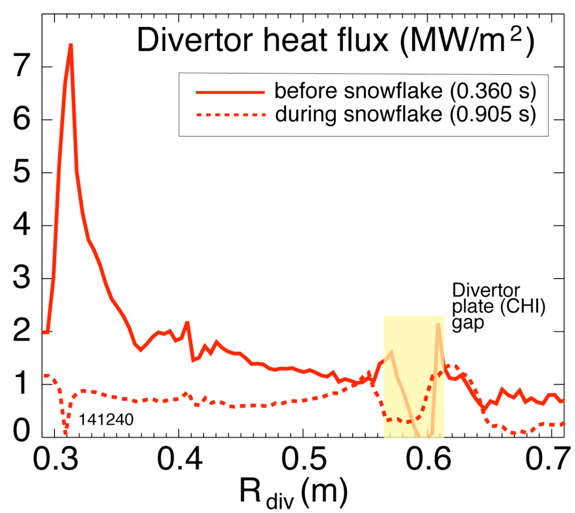
Standard Divertor

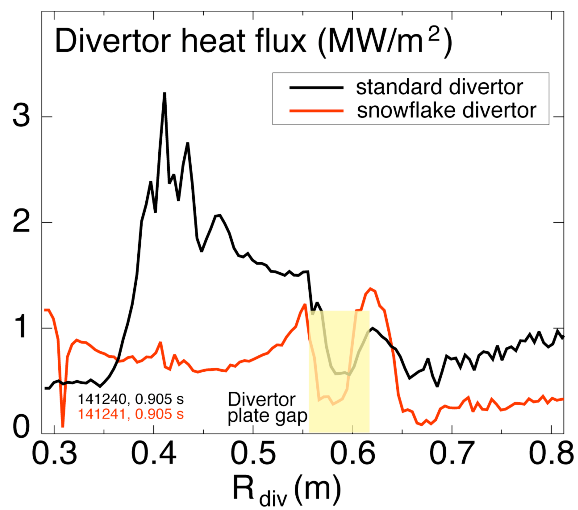


Snowflake Divertor



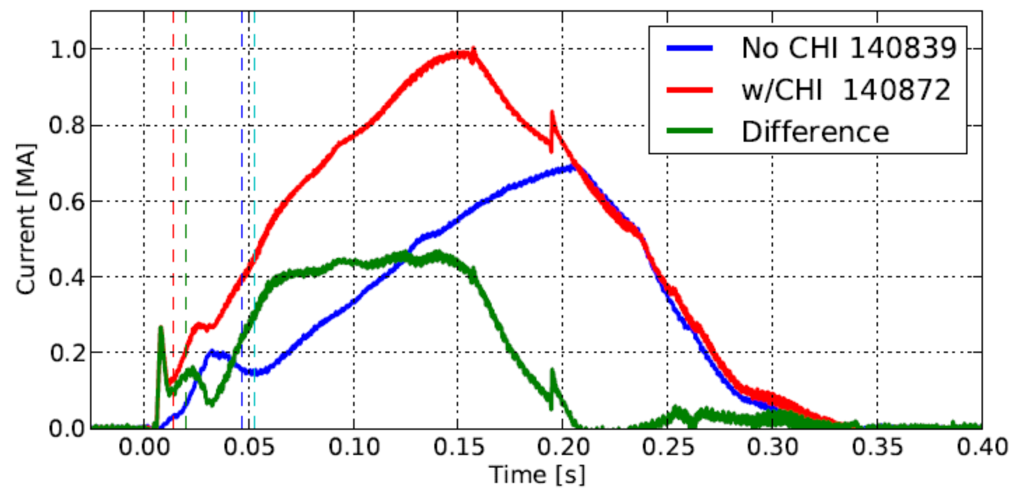
- High-δ divertor configuration is transformed into “Snowflake” divertor.
- Significant reduction of peak heat flux observed in “snowflake” divertor.
  - Potential divertor solution for NSTX-U with 2-3x higher input power:
    - Projected peak divertor heat fluxes ≤ 24 MW/m^2 3-5 x longer pulse duration

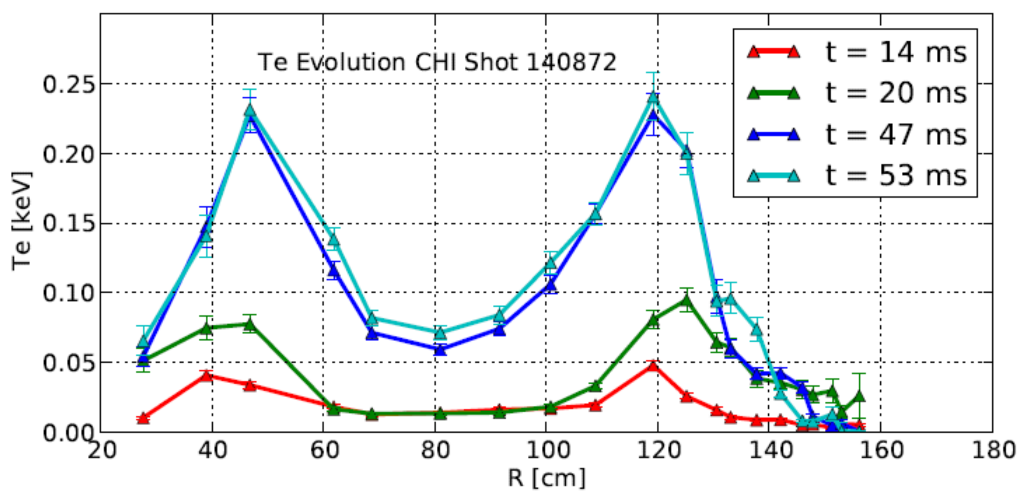




V. Soukhanovskii, LLNL JI2.00002

CHI startup reduces OH flux consumption during current ramp





- Ramped up to 1 MA after startup, using 0.3 Wb change in OH coil current
- Hollow electron temperature profile maintained during current ramp

Discharges with early high T_e ramp-up to higher current

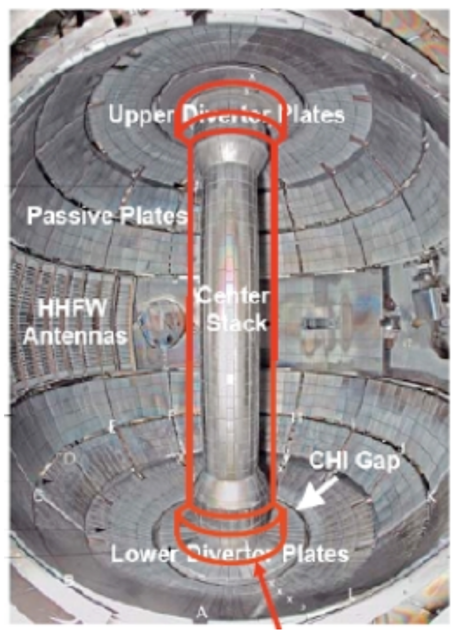
R. Raman, DI3.00004
D.Mueller, BP9.00071

NSTX Upgrade provides substantial increase in device performance

	NSTX	NSTX Upgrade
Aspect Ratio = R_0 / a	≥ 1.3	≥ 1.5
Plasma Current (MA)	1	2
Toroidal Field (T)	0.5	1
P/R, P/S (MW/m,m^2)	10, 0.2*	20, 0.4*

Includes 4MW of high-harmonic fast-wave (HHFW) heating power

- NSTX Upgrade will extend normalized divertor and first-wall heat-loads much closer to FNS and Demo regimes.

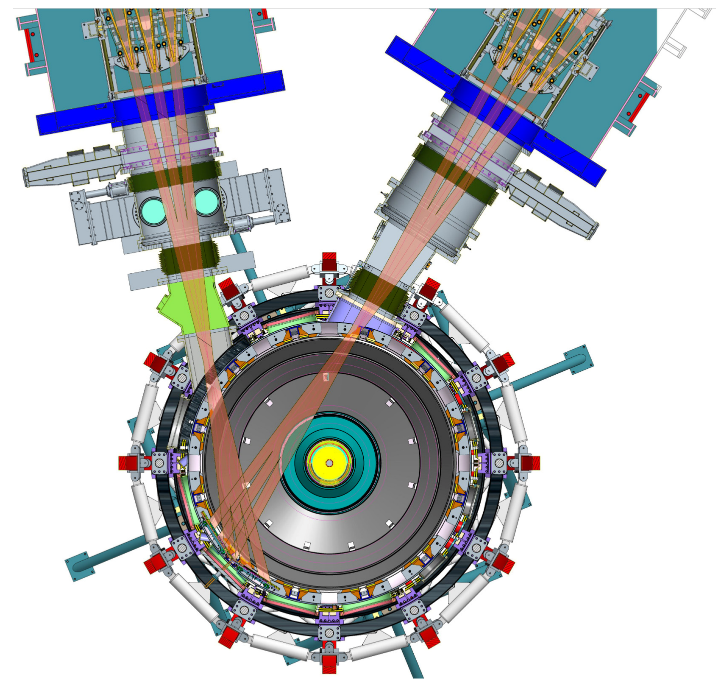


Outline of new center-stack (CS)

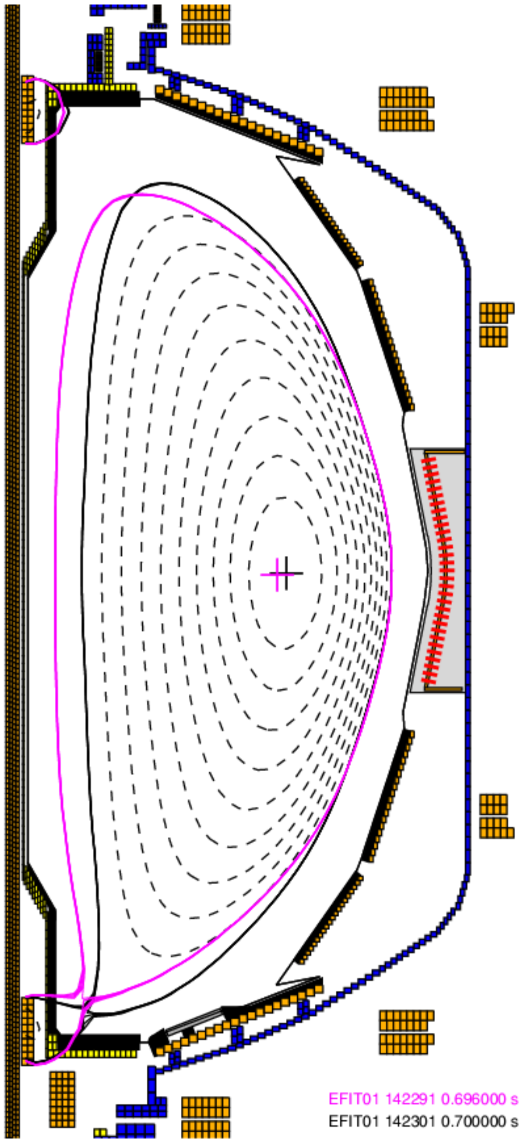
- Higher plasma current and toroidal field reduce collisionality, increase confinement towards reactor-relevant regimes.
- 2nd Neutral Beam Injector with larger tangency radius for current profile control.

New 2nd NBI
(R_{TAN}=110, 120, 130cm)

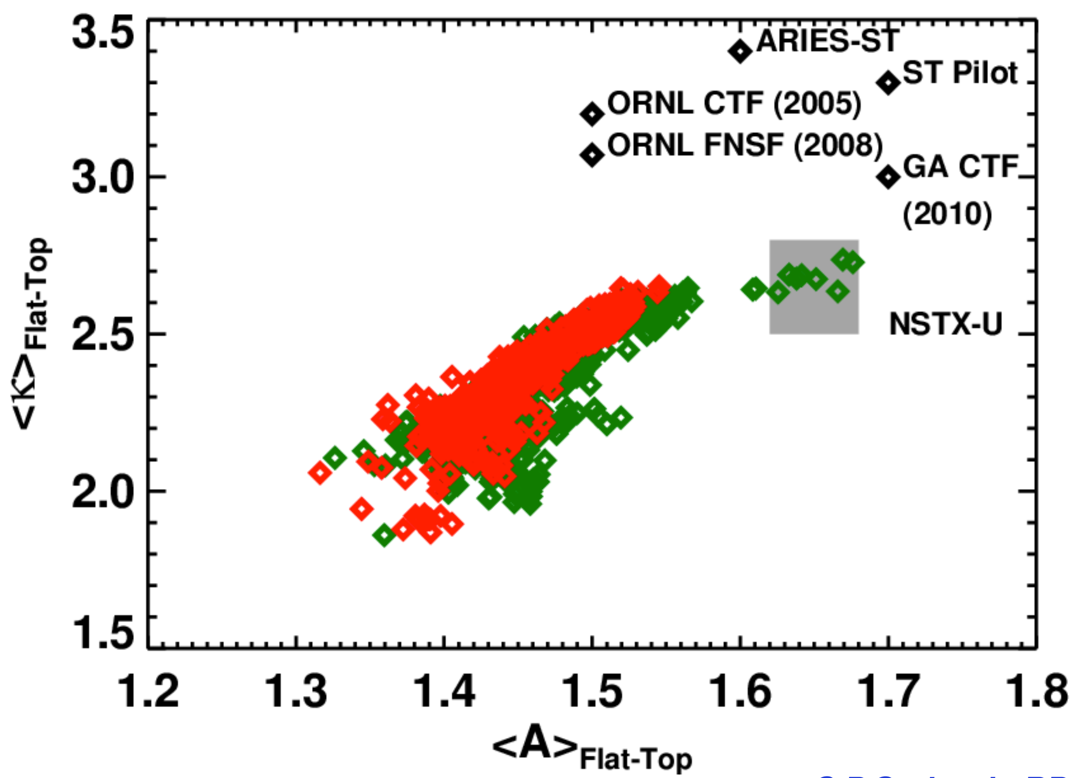
Present NBI
(R_{TAN}= 50, 60, 70cm)



Higher aspect ratio (NSTX-U) discharges demonstrated to reach high β_n (≥ 5), κ (≥ 2.6)

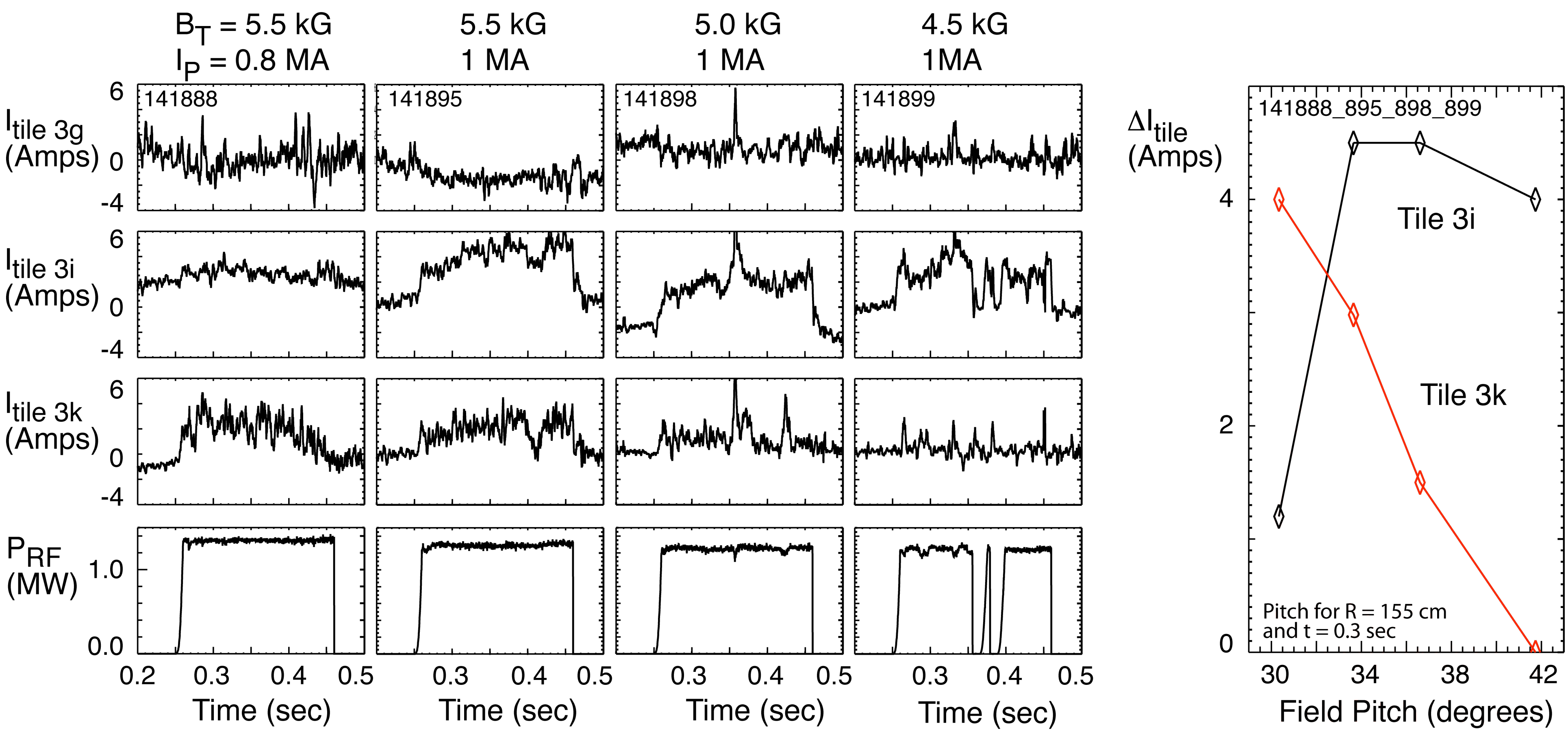


- Compare new, higher aspect-ratio boundary, consistent with NSTX-U centerstack, with current high performance plasma shape.



S.P.Gerhardt, BP9.00051

Studies of RF power flow to lower divertor finds RF "hot zone" follows field as pitch is changed

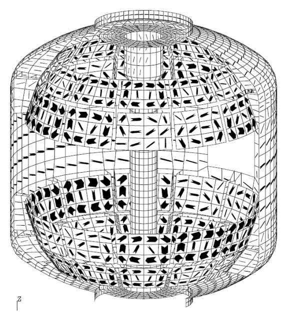


- $\Delta I_{tile\ 3k}$ decreases and $\Delta I_{tile\ 3i}$ increases as field pitch increases and RF spiral hot zone moves toward the center stack

J. Hosea, et al., Poster BP9.00074, Mon AM

New RWM state space controller sustains high β_N plasma

Full 3-D model ~3000+ states

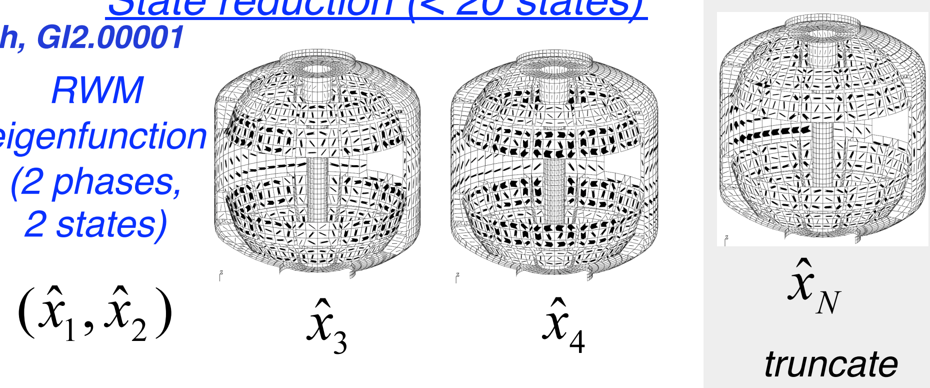


- device R, L, mutual inductances
- instability B field / plasma response
- modeled sensor response

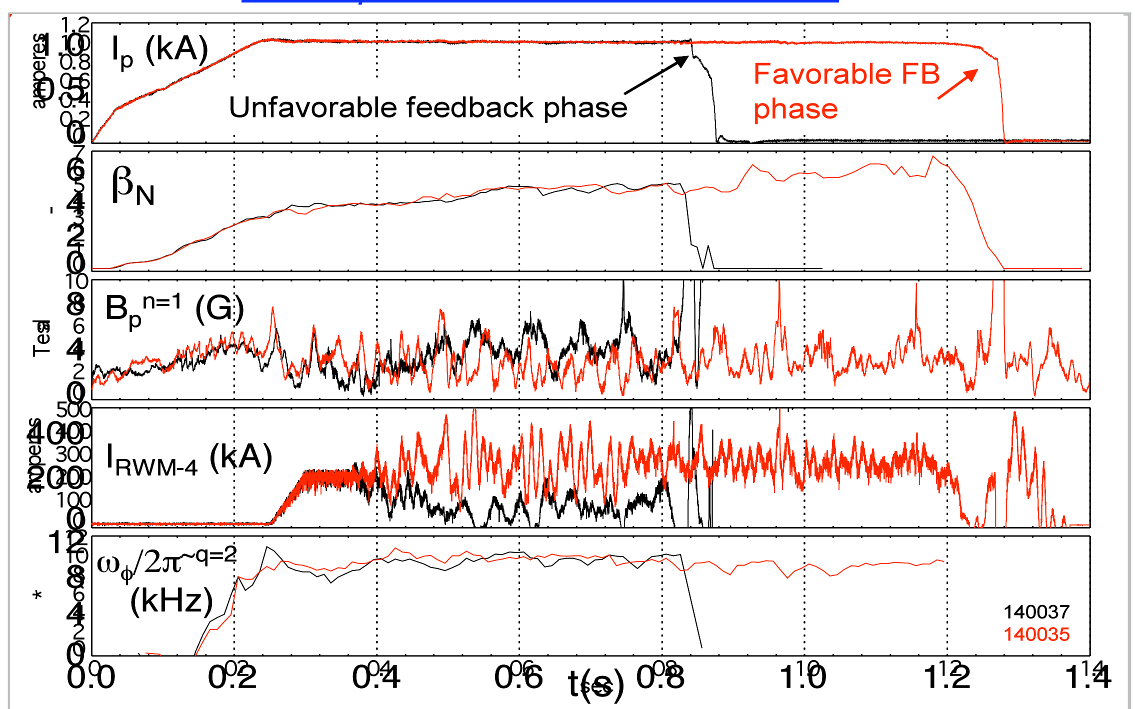
State reduction (< 20 states)

S.A. Sabbagh, GI2.00001

RWM eigenfunction (2 phases, 2 states)



State space feedback with 12 states



- Controller can compensate for wall currents
  - Including mode-induced current
  - Examined for ITER
- Successful initial experiments
  - Suppressed disruption due to n = 1 applied error field
  - Best feedback phase produced long pulse, $\beta_N = 6.4$, $\beta_N/l_i = 13$