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XP933: NTV physics at varied $\nu_i^*/q\omega_E$ and search for offset rotation in NSTX

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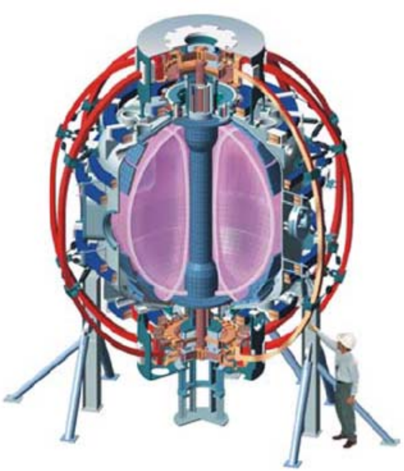

NSTX Research Team Review

May 11th, 2009

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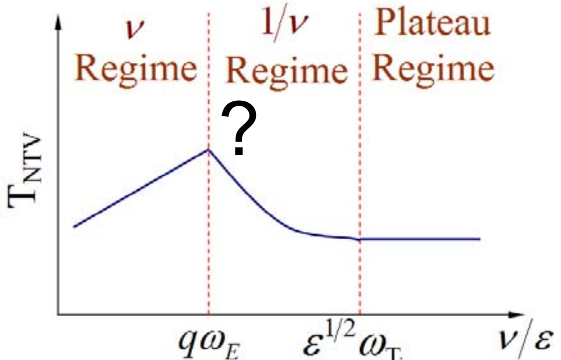
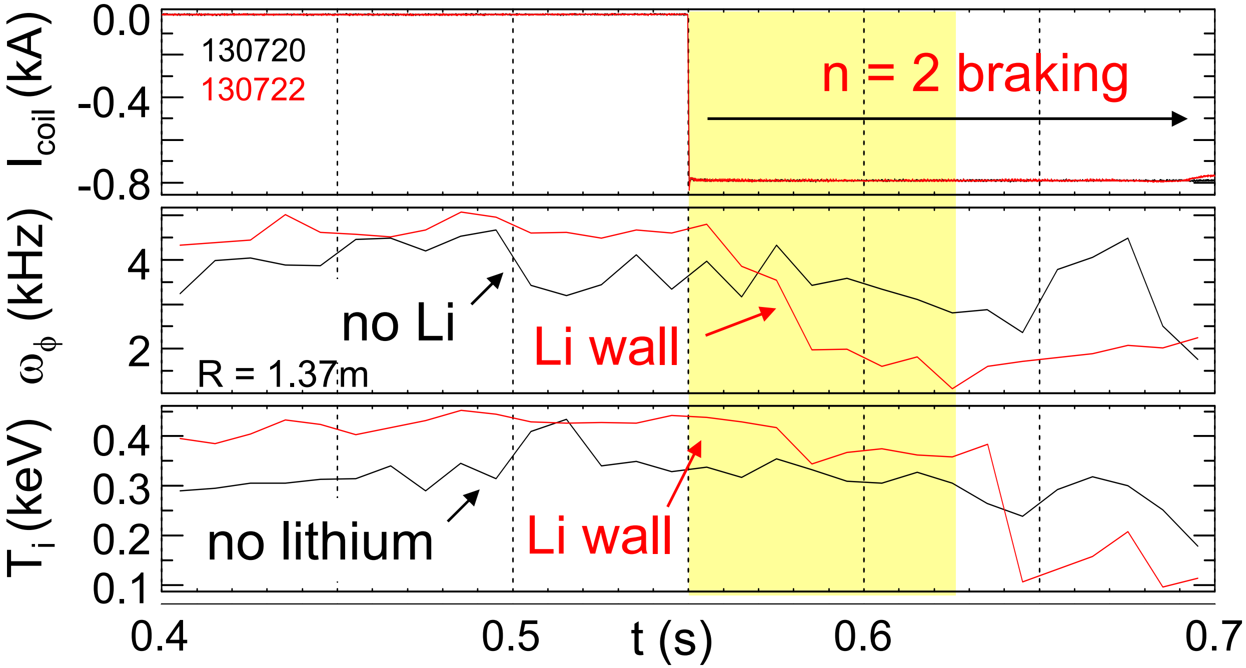
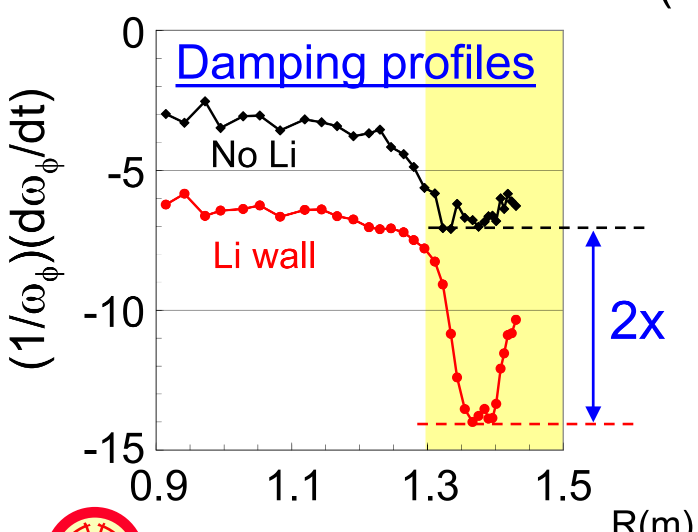
- **Motivation**
  - Determine key aspects of NTV physics to gain confidence in extrapolation to future devices
- **Goals**
  - Investigate damping over range of $\nu_i^*/q\omega_E$ to determine if the expected saturation of NTV at increased E_r actually occurs
    - Key for both low and high rotation devices (ITER, ST-CTF)
    - Does ST data reveal new physics, or revise applicability criteria?
  - Determine neoclassical offset rotation
    - NTV offset rotation found in tokamaks (Garofalo, 2008), but not yet determined in NSTX
    - Potentially important low ω_ϕ devices (ITER)
    - Reversed I_p operation will allow better determination of offset rotation
- **Addresses**
  - ITPA joint experiment MDC-12

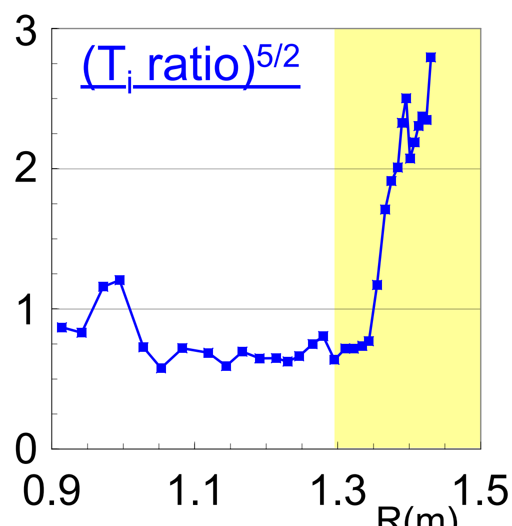


Does $1/\nu_i$ scaling $\rightarrow \nu_i/(\nu_i^2+\omega_E^2)$?

Stronger non-resonant braking at increased T_i

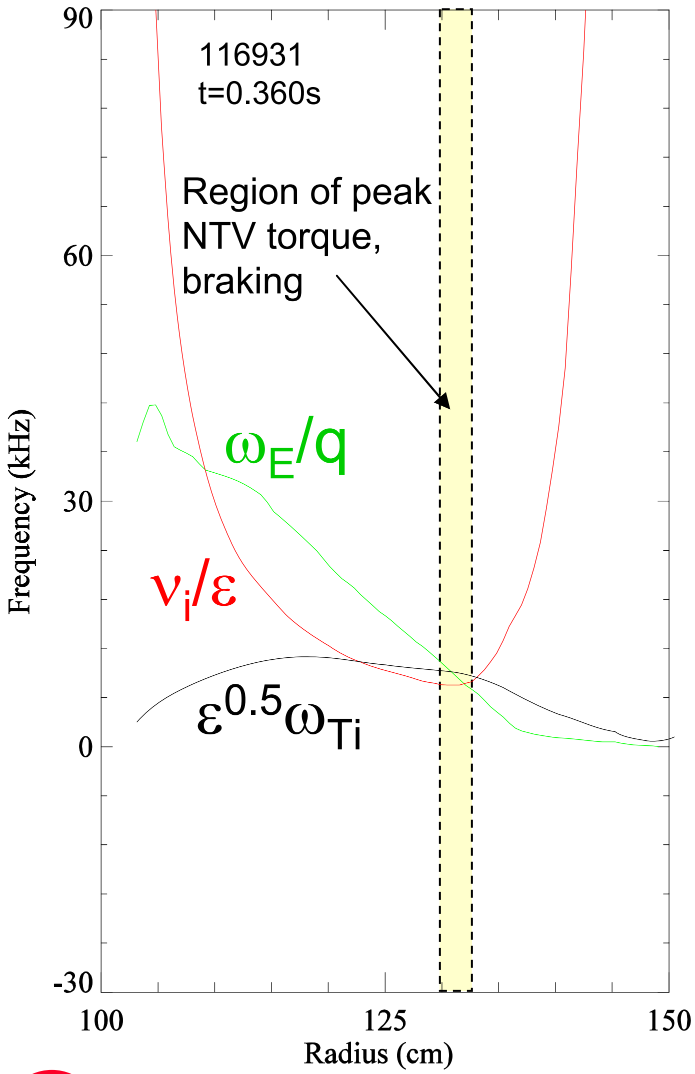






- XP804 (2008): Observed NTV braking using n = 2 field
- Expect stronger NTV torque at higher T_i ($-d\omega_\phi/dt \sim T_i^{5/2}\,\omega_\phi$)
  - At braking onset, T_i ratio$^{5/2}$ = $(0.45/0.34)^{5/2} \sim 2$
  - Consistent with measured $d\omega_\phi/dt$

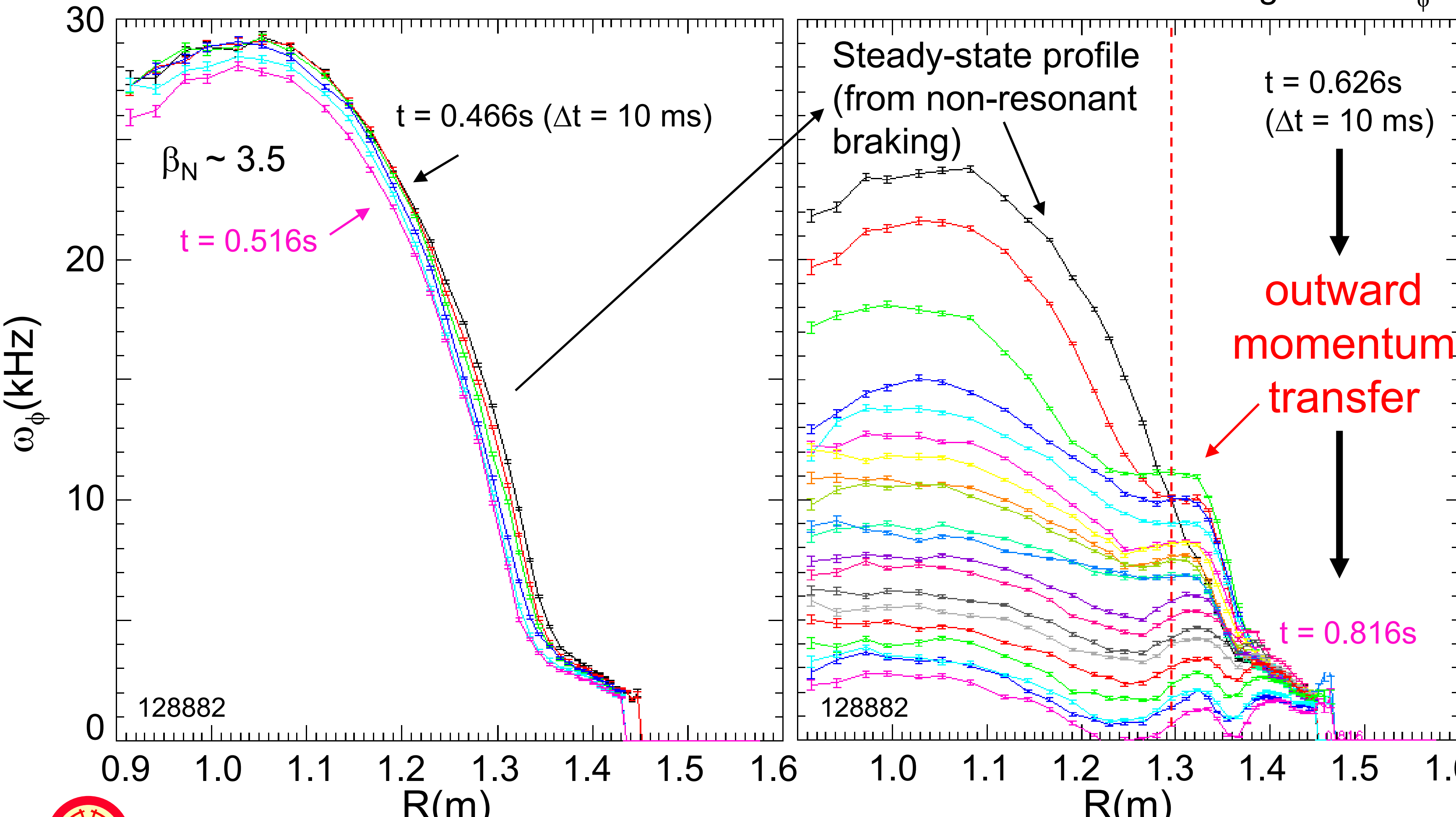
Past NSTX data shows a small region of applicability for NTV collisionless regime scaling



- n = 3 braking "configuration
- Frequency profiles
  - Collisionless NTV formulation valid in region of peak measured damping where $q\omega_E < \nu_i/\varepsilon < \varepsilon^{0.5}\omega_{Ti}$
  - Computed/observed damping near boundary (low T_i, collisional regime) typically far weaker
  - Uncertain if $\omega_E < \varepsilon^{0.5}\omega_{Ti}$ criterion is required for collisionless damping
    - Adequate criterion to describe NTV saturation due to E_r effects?
    - the ω_E calculation neglects poloidal flow and uses carbon ω^*, may be overestimated

Resonant braking eventually confuses non-resonant braking in past

- Non-resonant (n = 2 shown here):
  - broad, self-similar reduction of profile
  - Reaches steady-state (t = 0.626s)
  - NO n = 1 EFC (n = 2 SPA config.)
- Resonant:
  - Clear momentum transfer across rational surface
  - evolution toward rigid rotor core
  - Local surface locking at low ω_ϕ



Utilize lithium and n = 1 EFC to study non-resonant braking over long timescale > momentum diffusion time

- Past data
  - Non-resonant braking evolves into resonant braking, precludes accurate non-resonant NTV evaluation
- New approach
  - Utilize n = 1 EFC and lithium to delay or eliminate rotating n = 1 MHD
    - n = 1 MHD is the cause for strong resonant ω_ϕ damping
  - Examine braking from different initial ω_E ($\nu_i^* < 1$), at various R
    - Initial n = 3 braking field to vary initial ω_E, then increase braking
    - If $\nu_i^*/q\omega_E(R) > 1$, should observe $T_i^{5/2}$ scaling
    - If $\nu_i^*/ q\omega_E(R) < 1$, should observe saturation in braking, or other (?) scaling
  - Look for NTV offset rotation ($T_{NTV} \sim \delta B^2(\omega_\phi - \omega_{\phi-offset})$)
    - Allow second quasi-steady-state ω_ϕ to be reached after 2nd braking pulse; will data support existence of $\omega_{\phi-offset}$? (a counter-I_p offset)
    - Supplement co-injection data with *counter-injection* data - best conclusion

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Task	Number of Shots
1) Create targets and control shots near ideal no-wall beta limit (similar to 130722)	
(use 133078 fiducial as setup shot, 2 or 3 NBI sources, eventually use LITER)	
A) n = 1 fast feedback, no n = 3 field; 3, then 2 NBI sources, no Li, passivate with D glow if needed	2
B) If sufficiently long rotating MHD-free period, apply n = 3 field, 0.8 kA (control shot, no Li)	2
C) Apply lithium, apply n = 3 field at same time as 1(B) – for comparison to n = 2 data from 2008	2
D) Bring n = 3 field earlier (t ~ 0.2s), n = 1 EFC 50ms filter starting ~ 0.5s, to prepare for step (2)	2
2) ExB frequency variation	
A) Early n = 3 application (t ~ 0.2s), vary n = 3 current to produce three different quasi-steady ω_E levels	6
B) Step up n = 3 currents from three different quasi-steady levels produced in 2(A) at t ~ 0.5s (timing depends on rotating MHD); reach quasi-steady state with 3 different braking currents	6
3) Search for NTV offset rotation	
A) If data from step 2(B) insufficient to determine by $\omega_{\phi-\text{offset}} = \omega_\phi - K/\delta B^2$), run other n = 3 amplitudes	4
B) Reversed I_p scans	
Repeat scan 2 above in reversed I_p	12
Total (standard I_p; reversed I_p):	24 ; 12

XP933: NTV physics at varied $\nu_i^*/q\omega_E$ - Diagnostics

- Required diagnostics / capabilities
  - RWM coils in n = 1,3 configuration, n = 1 feedback and EFC
  - CHERS toroidal rotation measurement
  - Thomson scattering
  - MSE
  - Toroidal Mirnov array / between-shots spectrogram with toroidal mode number analysis
  - Diamagnetic loop
- Desired diagnostics
  - USXR and ME-SXR
  - FIReTip
  - Fast camera