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XP743: Island-induced neoclassical toroidal viscosity and dependence on ν_i

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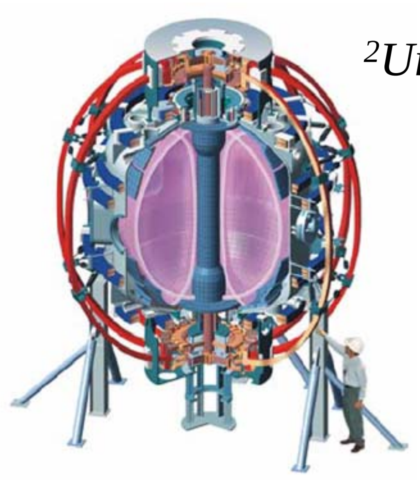


NSTX Team XP Review Meeting
May 8, 2007
Princeton Plasma Physics Laboratory

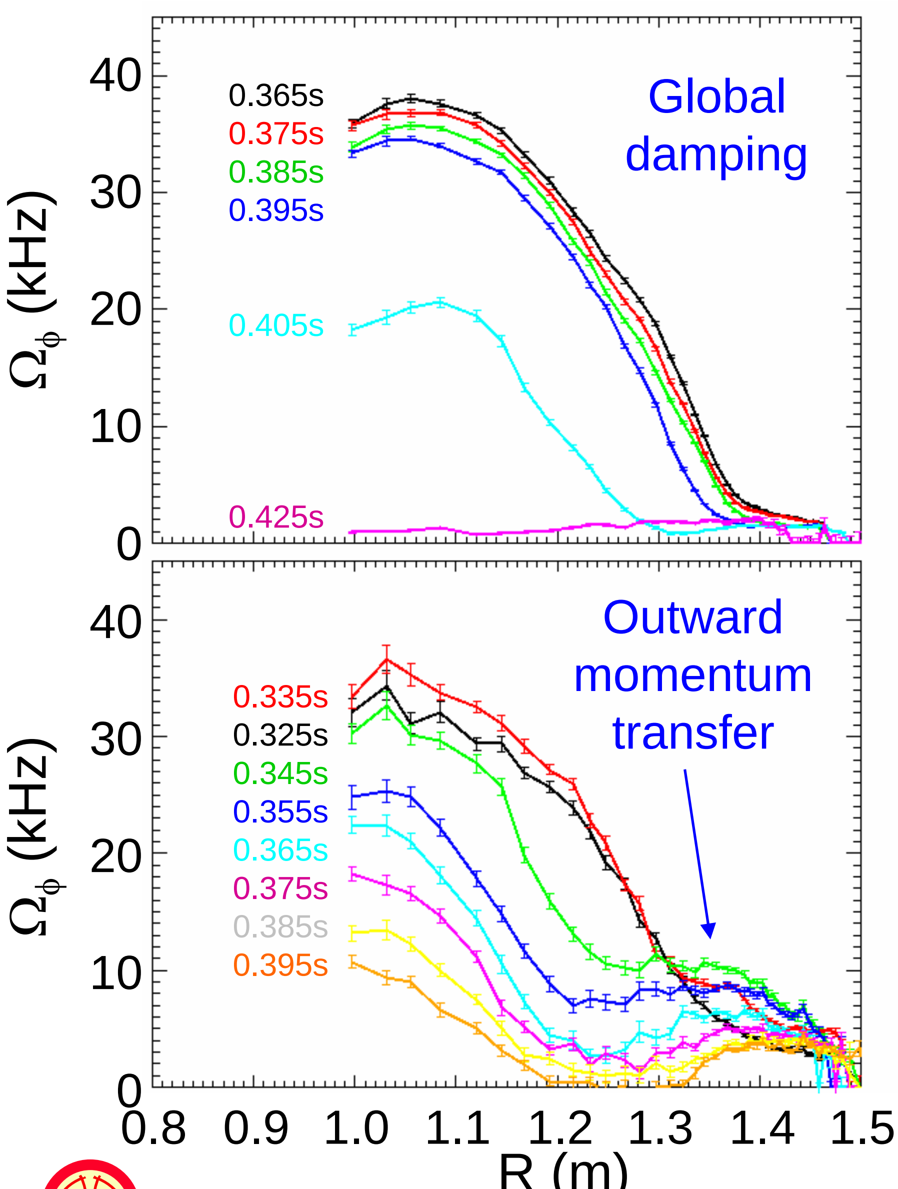
Investigate the role of islands and ν_i in neoclassical toroidal viscosity rotation damping physics

- Goals
  - Test theory of island-induced neoclassical toroidal viscosity (INTV)
  - Compare to theory of drag due to electromagnetic torque
  - Investigate damping over range of ion collisionality and island width to determine affect on rotation damping and to distinguish theories
  - Examine $1/\nu_i$ dependence of NTV without internal rotating modes
  - Determine percentage of torque from non-resonant NTV vs. INTV vs. electromagnetic

- Addresses
  - Rotation aspect of R(07-2) milestone, leverages ST geometry
  - ITPA experiments MDC-4, MDC-12
  - ITER issue card AUX-1

Note: this XP was combined from two XPs presented at last NSTX Forum

Rotating modes significantly alter rotation damping



- In absence of internal rotating modes
  - global rotation damping observed
  - non-resonant NTV theory describes toroidal rotation damping (W. Zhu, et al., PRL **96** (2006) 225002.)
- Appearance of internal rotating modes
  - local rotation damping near key rational surfaces; outward momentum transfer; evolution to rigid rotor core observed
  - qualitative evolution described by electromagnetic torque applied at rational surface (M. Yokoyama, *et al*., Nucl. Fusion **36** (1996) 1307.)

INTV theory to be compared to experiment

- Leading theories can be distinguished
  - Non-resonant NTV theory
    - Scales as $\delta B^2(p_i/\nu_i)(1/A)^{1.5}$, yields distinct rotation profile evolution
  - Electromagnetic torque at rational surface (R. Fitzpatrick, Nucl. Fusion **33** (1993) 1049.)
    - Scales as δB^2 (not ν_i), rotation profile evolution consistent with observation
  - Island-induced NTV (K.C. Shaing, PRL **87** (2001) 245003.)
    - Scales as δB *(island width Δw^2) due to toroidicity*, depends on ν_i
    - Theory can be evaluated quantitatively (as done for NTV)
- Experiment to vary key parameters to test theory
  - n = 1 mode most significant
    - Change ν_i at constant q (done successfully in XP619 - gas puffing / B_T and I_p variation); consider transitioning out of H-mode
    - Change δB by changing applied n = 1 field
    - Change rotating mode onset time by small change in elongation

XP743: INTV and dependence on ν_i - Run plan

Task	Number of Shots
1) Create target plasma near, but not well above the ideal no-wall beta limit (control shot)	
(use recent 123866 as setup shot, reduce I_p flat-top to 0.9 MA, 2 or 3 NBI sources and NO step-down of NBI power)	
A) Determine time of steady ω_ϕ and n = 1 tearing mode onset	1
B) Reduce elongation to 1.9 (increase PF1A current) if earlier n = 1 TM onset desired	1
2) Establish applied non-axisymmetric field scenarios (control shots)	
A) Apply n = 1 field at TM mode onset (t ~ 0.700s) (n = 1 setup from (2B))	2
B) Apply n = 1 field at steady ω_ϕ from (1A) (t ~ 0.490s) (n = 3 setup: 116939, 0.7 kA)	2
C) Apply n = 3 field at steady ω_ϕ from (1A) (t ~ 0.490s) (n = 1 setup: 123889, 0.8 kA)	2
3) Ion collisionality scan	
A) Vary ν_i for n = 1 applied field, with tearing mode (setup from (2A)	3
B) Vary ν_i for n = 1 applied field, no rotating modes (setup from (2B))	3
C) Vary ν_i for n = 3 applied field, no rotating modes (setup from (2C))	3
4) Applied field scan / vary island width (pick most favorable ν_i setup from part (1A)	
A) Vary n = 1 applied field (est. range 200A – 1200A)	5
Total:	22

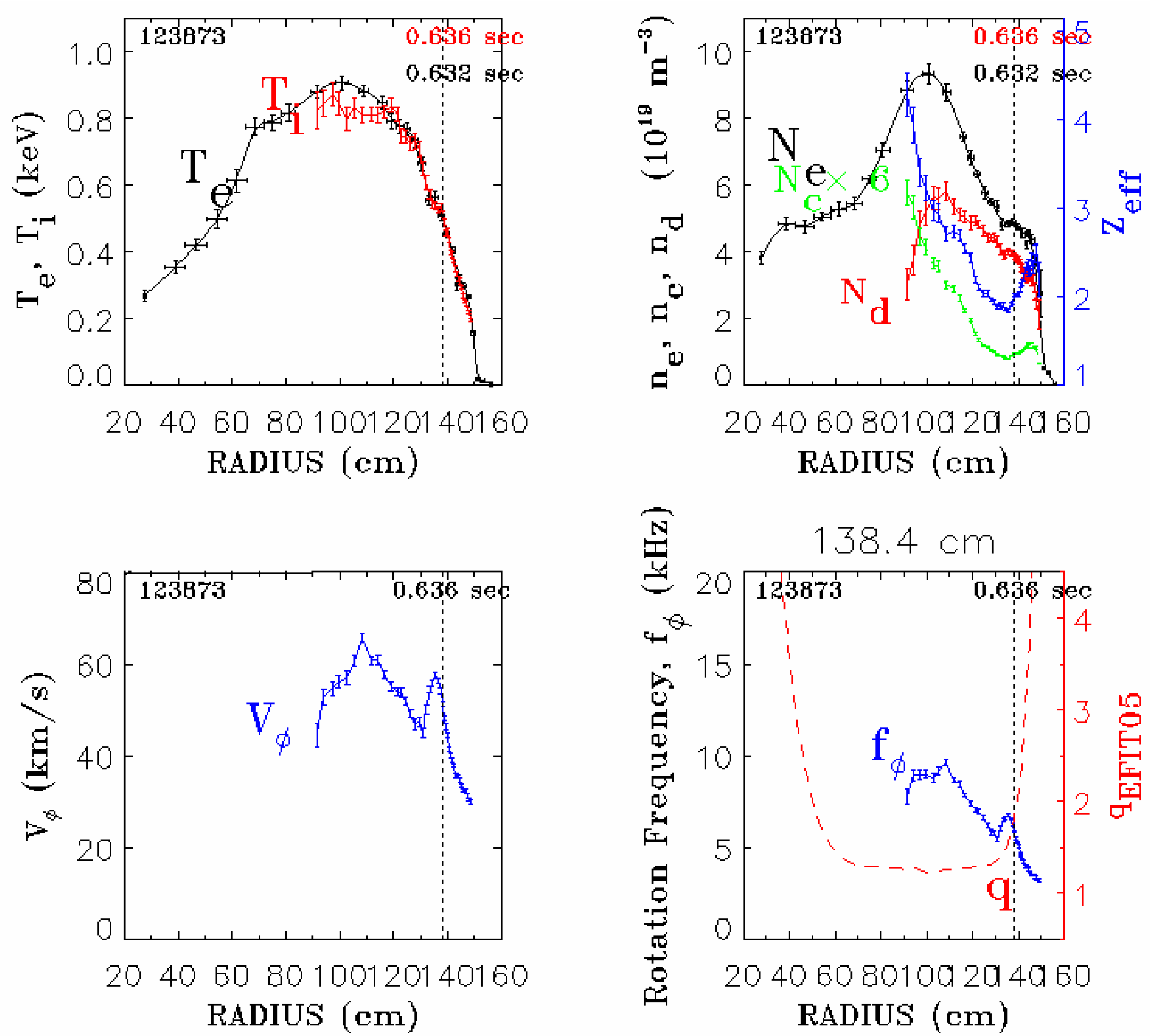
INTV XP743: Required / Desired Diagnostics

- Required diagnostics
  - Internal RWM sensors
  - CHERS toroidal rotation measurement
  - Thomson scattering (30 point)
  - USXR
  - MSE
  - Toroidal Mirnov array / between-shots spectrogram with toroidal mode number analysis
  - Diamagnetic loop
- Desired diagnostics
  - FIReTip
  - Fast camera

XP743: diagnosis of magnetic islands as in XP739/740

- USXR
  - appearance of phase inversions
  - matching to simple island models to estimate island width
- Thomson scattering: appearance / width of flat spot near rational surfaces
- CHERS
  - Radially-localized momentum transfer across key rational surfaces
  - Radially-localized rotating mode locking
  - NOTE: internal, localized electromagnetic torque cannot be responsible for rotation damping for an ideal plasma perturbation
- MSE: equilibrium reconstructions to accurately determine position of key rational surfaces
  - Coordinate with other diagnostics

Island appears in Te, Ti, and plasma rotation – XP739



- Island evident in kinetic profiles and plasma rotation
- Flat-spot in profiles appears just inside the q = 2 surface
- Rotation evolution shows outward momentum transfer across rational surface and core rotation decay
- Island disappears as mode restabilizes due to beta ramp-down