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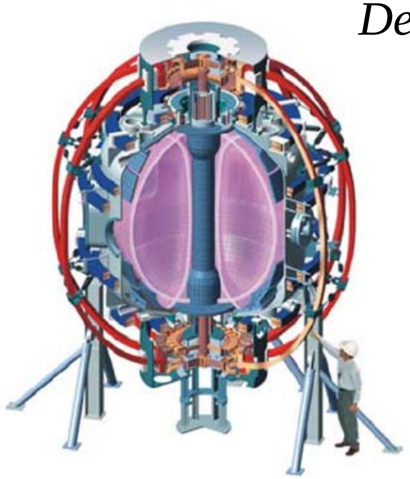
XP1062: NTV behavior at low ion collisionality and maximum variation of ω_E

S.A. Sabbagh, R.E. Bell, J.W. Berkery, S.P. Gerhardt, J-K Park, et al.

Department of Applied Physics and Applied Mathematics, Columbia University, New York, NY, USA

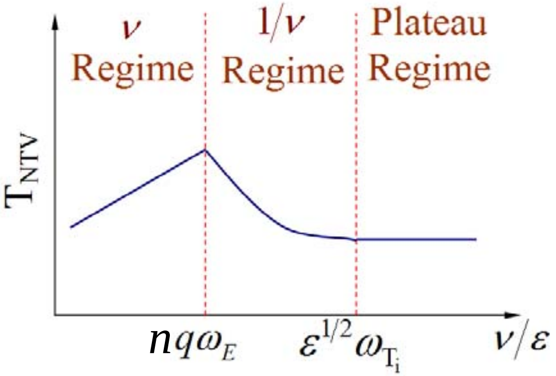
Princeton Plasma Physics Laboratory



NSTX Macrostability TSG Meeting
January 8, 2010
Princeton Plasma Physics Laboratory

XP1062: NTV behavior at low ion collisionality and maximum variation of ω_E

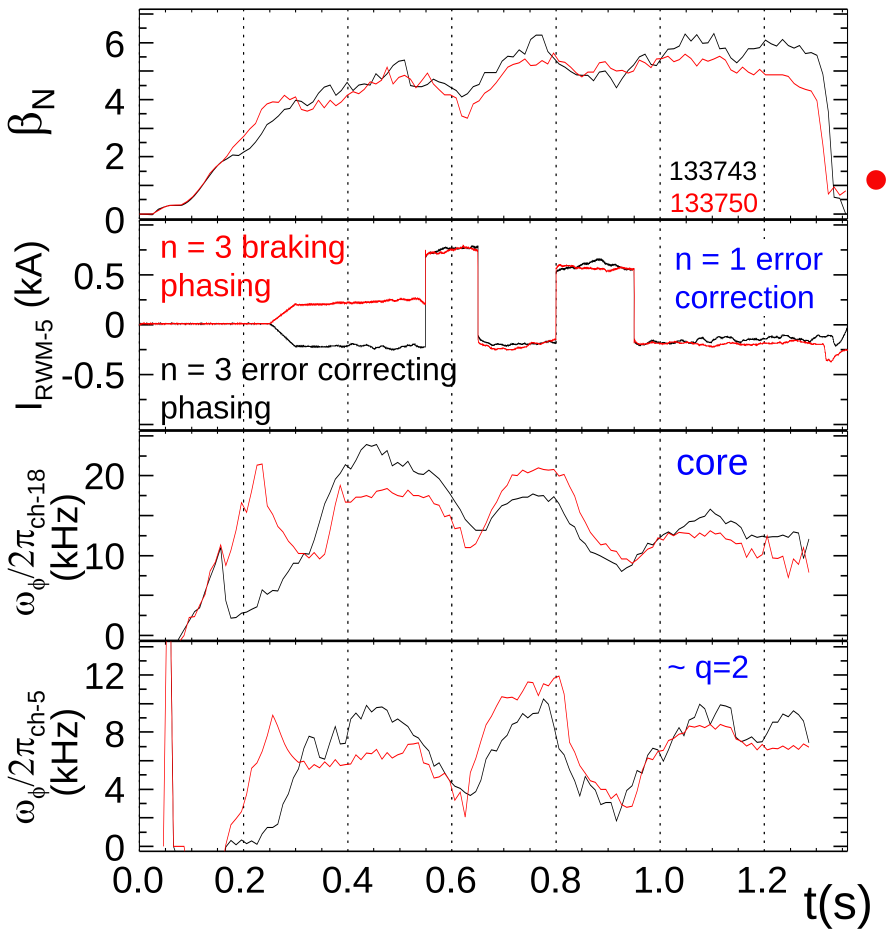
- Motivation
  - Determine key aspects of neoclassical toroidal viscosity (NTV) physics to gain confidence in extrapolation to future devices
- Goals / Approach
  - Examine dependence of NTV on ν_i, using new LLD capability, focus on the NTV scaling/comparison to theory at the lowest ν_i* possible
    - Key for both low and high rotation devices (ITER, ST-CTF)
  - Complete investigation of NTV increase at sufficiently low (nq)ω_E, (compare to superbanana plateau (SBP) theory); examine highest ω_E
    - Additional nqω_E variation by running n = 2 (vs. 3) if time allows
  - Determine NTV offset rotation (no strong effect seen yet)
    - Consider new approach using RF in addition to standard approach)
- Addresses
  - ITPA joint experiment MDC-12
  - ReNeW Thrust 16.4
  - NSTX Milestone IR(11-2)
  - NSTX planned rotation control system
- Request 1 run day (0.5 scheduled at Forum)



$|nq\omega_E| < \nu_i/\varepsilon < \varepsilon^{0.5}\omega_{Ti}$ for $1/\nu$ scaling

Significant variations made to $nq\omega_E(R)$ to examine effect on NTV braking in XP933

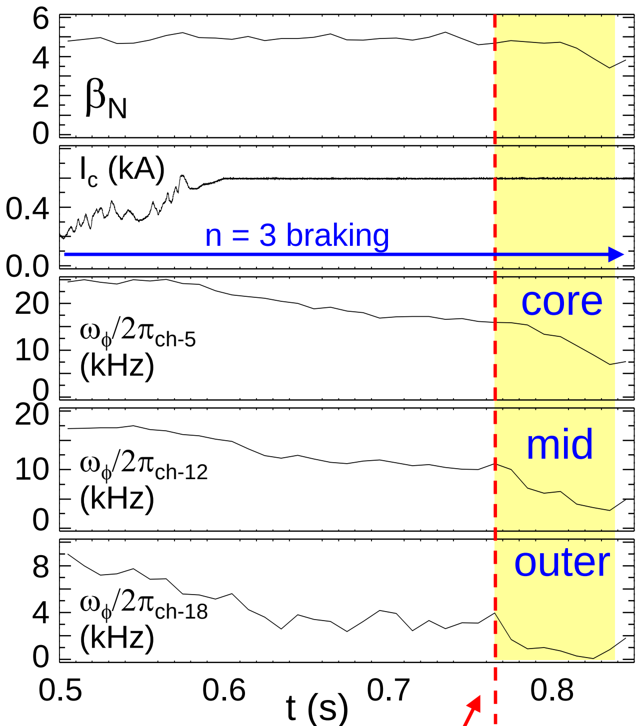
XP933 example: variation of initial ω_ϕ

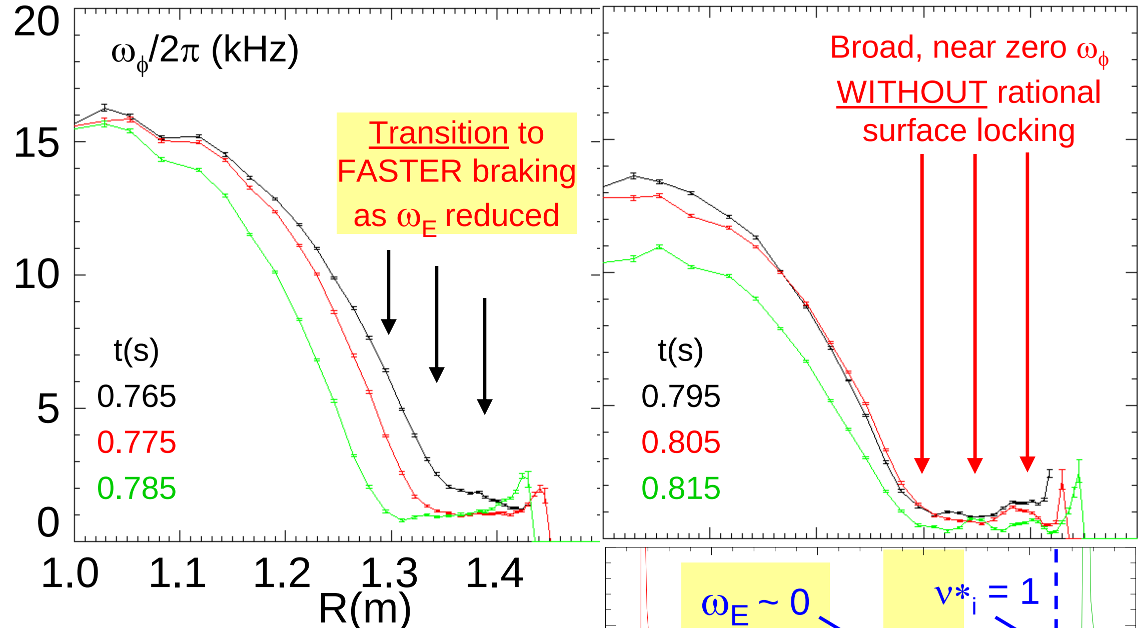


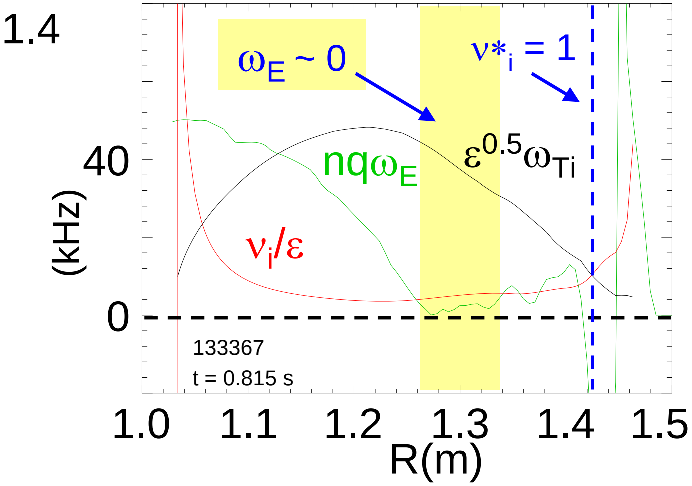
- **Earlier work**
  - V_ϕ damping consistent with "1/ν regime" magnitude & scaling ($T_i^{5/2}$)
    Zhu, et al., PRL 2006; Sabbagh, et al. (accepted NF 12/09)
- **XP933 status**
  - NTV braking observed over all $\nu_i/nq\omega_E(R)$ variations made in experiment
    - Strong braking at increased T_i with lithium, even if $(\nu_i/\varepsilon)/nq\omega_E < 1$
    - Want greater $(\nu_i/\varepsilon)/nq\omega_E$ variation; better quasi-steady-state w_ϕ condition
  - Apparent braking of resonant surfaces plasmas at low ω_ϕ, but without locking (e.g. ω_ϕ goes to ~ zero locally, then increases)
  - Apparent lack of $1/\omega_\phi$ scaling of drag torque on resonant surfaces at low ω_ϕ
    - Provocative result – is current layer / island width decreasing at low ω_ϕ
    - …or perhaps drag due to "island NTV" ~ ω_ϕ (K.C. Shaing et al., PRL **87** (2001))
    - …or perhaps due to superbanana plateau physics (K.C. Shaing et al., PPFC **51** (2009))

XP933: S.A. Sabbagh

Stronger braking with constant n = 3 applied field as ω_E reduced – accessing superbanana plateau NTV regime







- Faster braking with
  - Constant β_N, applied n = 3 field
  - No rotating mode activity
- Torque not $\propto 1/\omega_\phi$ (non-resonant)
  - NTV in "$1/\nu$ regime" ($|nq\omega_E| < \nu_i/\varepsilon$ and $\nu^*_i < 1$)
  - Stronger braking expected when $\omega_E \sim 0$ (superbanana plateau)

K.C. Shaing, et al. (PPCF **51** (2009) 035004; 035009)

NSTX

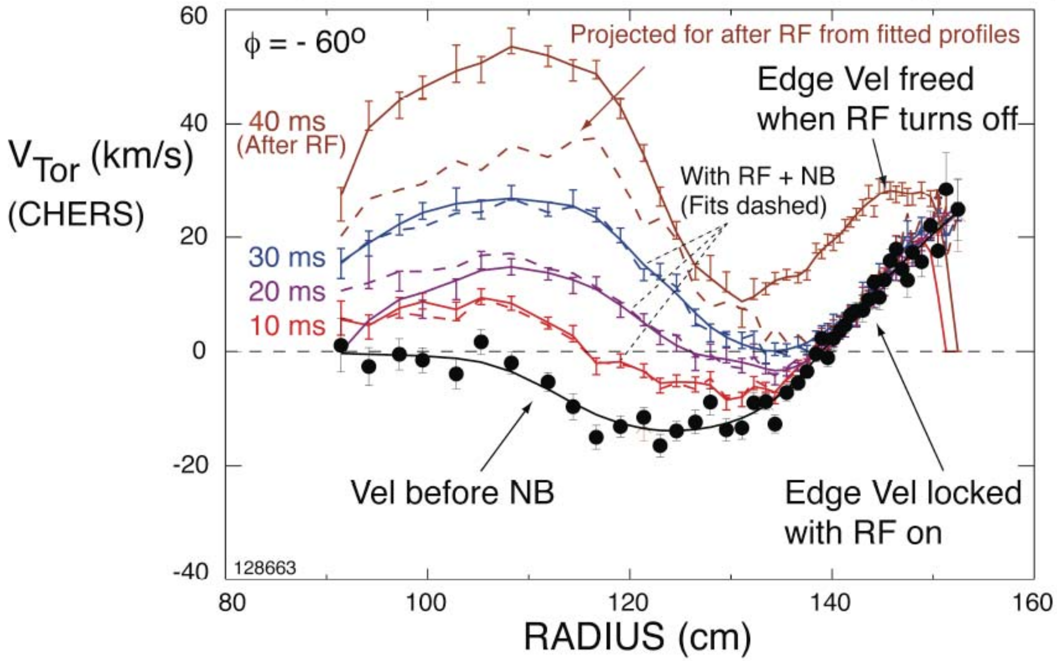
XP1062 aims at next-step goals from XP933, allowed by LLD, RF operation

- Goals / Approach
  - Compare magnetic braking with largest variation of ν_i* using LLD
    - Target a comparison of two conditions: low vs. high ν_i*
    - Concentrate on new low ν_i* condition
    - Compare to past braking XPs if high ν_i* condition is difficult to produce
  - Generate greater variation of key parameter $(\nu_i/\varepsilon)/|nq\omega_E|$
    - Operate some shots with 1 NBI source (higher ω_E)
    - Mostly run 2 - 3 NBI sources generate lowest ν_i, vary ω_E with braking as before
    - Concentrate on low ω_E to further examine superbanana plateau regime/theory
    - Additional $nq\omega_E$ variation possible by comparing n = 2 vs. 3 if time allows
  - Determine NTV offset rotation
    - Standard approach: attempt to observe offset by operating at near-zero ω_ϕ (might be easier with LLD)
    - Consider new approach using RF (based on RF XPs from 2009)
      - Generate ω_ϕ with RF at highest T_i, W_{tot} possible, diagnose similar to Hosea/Podesta 2009
      - Repeat for different *initial* values of n = 3 braking field, determine of initial ω_ϕ changes
      - Note that if NTV offset is indeed only in counter-I_p direction, the ω_ϕ profile will change (it's presently counter in core, co at the edge

Zero input torque ω_ϕ profile diagnosed in 2009 RF XPs

Edge toroidal velocity appears to be locked when the RF is on with the NB pulse

40 ms beam pulse – RF turned off at 30 ms during beam pulse



- Mechanism causing this edge effect not understood, but may point to edge ion loss
- RF apparently provides a drag on core plasma rotation as well

J. Hosea, APS DPP 2009

- May provide clearest measurement of NTV offset rotation in NSTX

XP1062: NTV behavior at low ion collisionality and maximum variation of ω_E – shot plan

Task	Number of Shots
1) Generate low and high collisionality comparison shots and apply braking	
(use ~fiducial targets established in 2010, 1-3 NBI sources)	
A) (if possible) Operate “high collisionality” comparison shot	2*
B) Operate low collisionality target shot (3 NBI sources, then 2)	2
C) Apply n = 3 braking in low and high collisionality targets	2*
D) (optionally) apply n = 1 EFC 75ms filter in low collisionality plasma (comparison)	1*
2) Generate greater variation of $(\nu_i/\varepsilon)/\lvert nq\omega_E\rvert$	
A) Early n = 3 application (t ~ 0.2s), vary n = 3 current to produce two different quasi-steady ω_E levels (high beta, high T_i condition); step n = 3 currents from two different quasi-steady levels, reach quasi-steady state with 2 different braking currents; more than one step/shot if long pulse	4
B) (if possible) Rerun most desirable case from 2A) in high collisionality target	2*
C) Concentrate on generating low ω_ϕ (low ω_E) in SBP regime by varying braking waveform	4
D) Operate with one NBI source for highest ω_ϕ (high ω_E)	2
3) Determine NTV offset rotation	
A) If desired, supplement shots step 2 to determine by $\omega_{\phi-offset} = \omega_\phi - K/\delta B^2$) or direct observation	2*
B) RF Approach: generate RF target (high temperature desired); add NBI late in shot for ω_ϕ diagnosis	4
C) Rerun 3B) with three different braking field magnitudes	4
D) Reversed I_p scans (for future)	
Repeat scans from 2 above in reversed I_p to diagnose NTV offset rotation	10

Total (leveraging survey XP, no optional shots*; no survey XP; I_p; reversed I_p): 20; 29 ; 10

XP1062: NTV behavior at low ion collisionality and maximum variation of ω_E – Diagnostics, etc.

- Required diagnostics / capabilities
  - RWM coils in standard n = 1,3 configuration (optionally, n = 2)
  - RF heating capability
  - 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