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XP1062: NTV steady-state offset velocity at reduced torque

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NSTX Macrostability TSG Review

Friday May 13th, 2011

PPPL

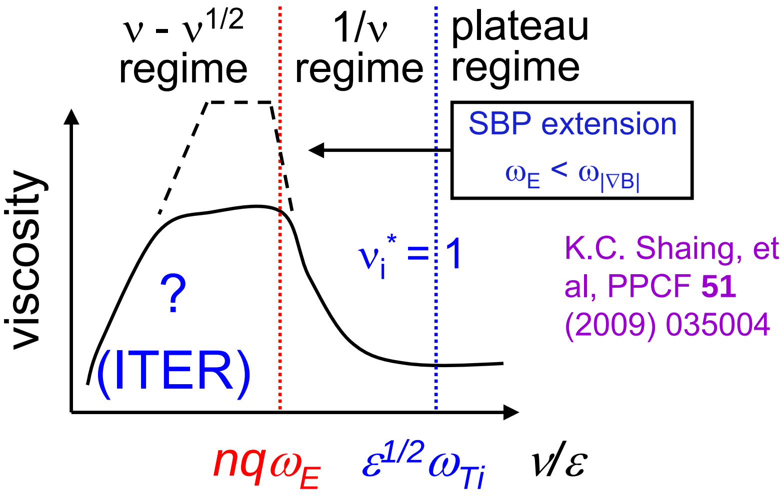
V1.0

XP1062: NTV steady-state offset velocity at reduced torque with HHFW

- Motivation
  - Measure and understand neoclassical toroidal viscosity (NTV) steady-state offset velocity physics to gain confidence in extrapolation of the effect to future devices
    - Background: NSTX low ω_ϕ NTV experiments with co-NBI + non-resonant magnetic braking do not show NTV steady-state offset velocity to be in the counter-I_p direction (e.g., shown in DIII-D (Garofalo, PRL 2008)
    - Steady-state offset velocity direction depends more generally on ion/elec. transport fluxes
- Goals
  - Complete XP1062, partially run in 2010 (excluded HHFW portion of shot list)
  - Determine NTV offset rotation in plasmas with no NBI torque (HHFW heated)
    - Use demonstrated technique to measure ω_ϕ in RF plasmas
    - Use n = 3 applied field, compare to results with n = 2 applied field
  - Determine if low ω_ϕ (low ω_E superbanana plateau (SBP) regime) can be reproduced during the NBI portion of these discharges with non-resonant braking
    - Determine changes in torque, and torque balance with HHFW + NBI
    - Can attempt to measure NTV steady state offset velocity this way as well when varying non-resonant applied field magnitude
- Addresses
  - NSTX Milestone IR(12-1), key data to complete XP1062
  - ITPA MDC-12

XP1062 will focus on measuring NTV offset velocity, leveraging "joint" experiment with KSTAR

- Understanding important for NSTX V_ϕ control, NSTX-U, and future devices
- Part of a "joint experiment"
  - Experiment MP2011-03-09-001 proposed and allocated run time on KSTAR
    - Will attempt n = 2 magnetic braking
    - Will focus on long-pulse torque balance (unique to KSTAR)
  - NSTX/KSTAR comparison will allow largest variation of aspect ratio
    - Larger than NSTX/DIII-D comparison
  - "Joint" experiment will give greater input to ITPA MDC-12



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

Simplified expression of NTV force ("1/ν regime")

$$\left\langle \hat{e}_t \bullet \vec{\nabla} \bullet \overleftrightarrow{\Pi} \right\rangle_{(1/\nu)} = B_t R \left\langle \frac{1}{B_t} \right\rangle \left\langle \frac{1}{R^2} \right\rangle \frac{\lambda_{1i} p_i}{\pi^{3/2} \nu_i} \varepsilon^{3/2} (\omega_\phi - \omega_{NC}) I_\lambda$$

$T_i^{5/2}$ (XP 1150)

Inverse aspect ratio (XP 1144)

Steady-state velocity (this XP)

(From original presentation) XP1062 aims at next-step goals from XP933, allowed by LLD, RF operation

Goals / Approach

Mostly completed

- Compare magnetic braking with largest variation of ν_i^* (using LLD if working)
  - 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

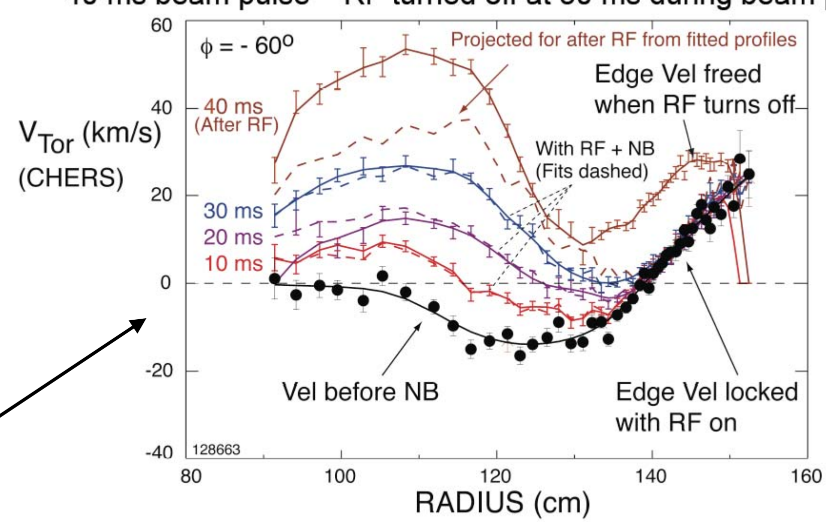
New

- Determine NTV offset rotation
  - Standard approach: attempt to observe offset by operating at near-zero ω_ϕ
  - 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 = 2, 3 braking field, determine if 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

- Determine NTV offset rotation – RF approach
  - 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 (or 2) field, determine if pre-NBI 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
- Attempt to maintain near-zero ω_ϕ during NBI phase
  - New way to enter/sustain low ω_E SBP regime

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



J. Hosea, APS DPP 2009

- 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

- Since SBP regime yields maximum NTV
  - Entering it by lowering ω_ϕ yielded an observed increase in NTV without mode locking (2009-10)
  - Conversely, attempt to measure decrease in NTV as SBP regime is exited
- Forum allocation: 0.5 run days

XP1062: NTV steady-state offset velocity at reduced torque – shot plan

Task	Number of Shots
1) Generate low and high collisionality comparison shots and apply braking	Mostly completed
(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
	New
3) Determine NTV offset rotation	
A) Comparison/supplement shots from step 2 to determine by $\omega_{\phi\text{–offset}} = \omega_\phi - K/\delta B^2$) or direct observation	3
B) Generate RF target (high temperature desired), adding NBI later in shot (ω_ϕ diagnosis, etc.)	5
C) Rerun 3B) with three different braking field magnitudes	5
D) Rerun 3B) with n = 2 applied field configuration	5
Total (new)	18

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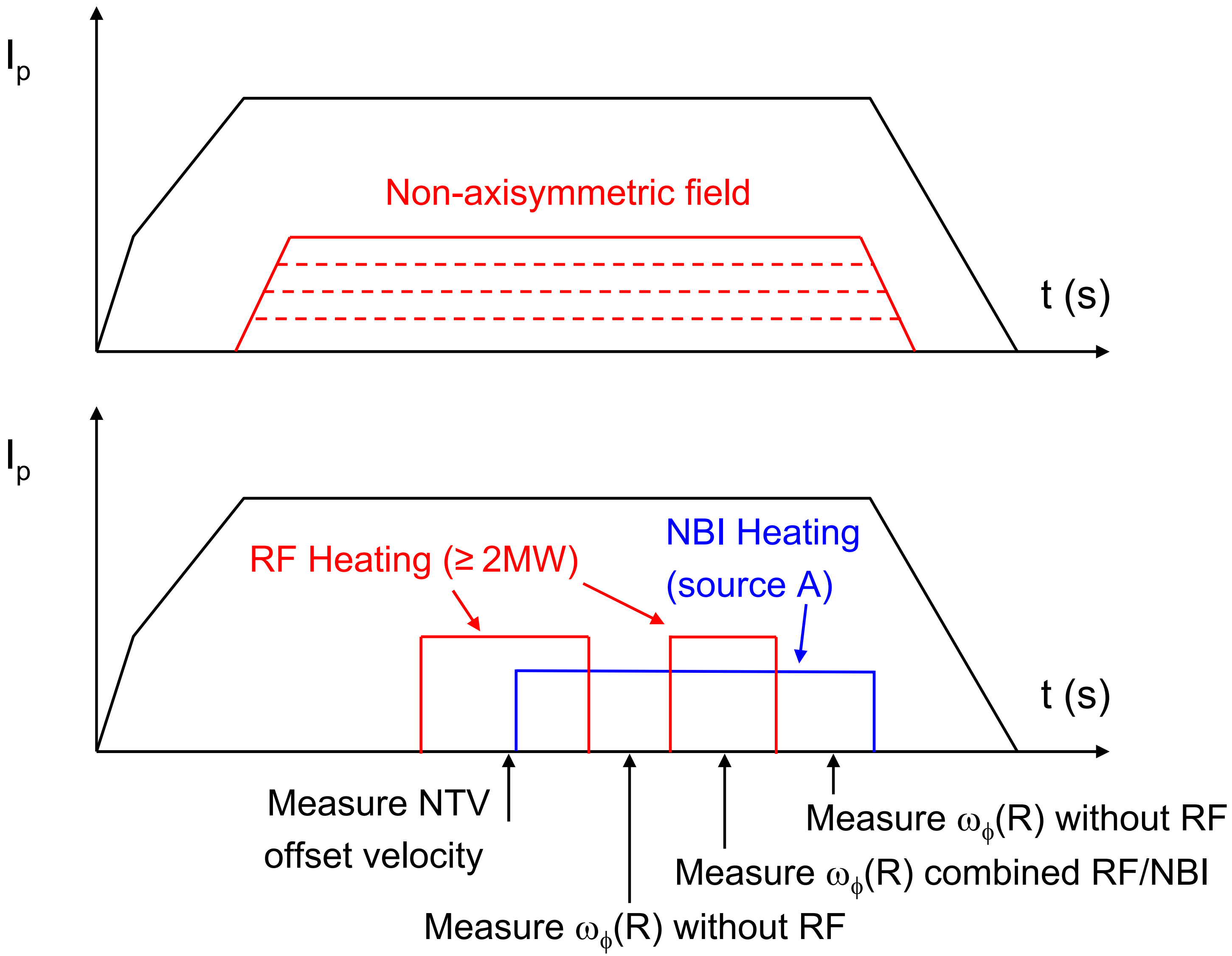
Suggested run period: aim for the 2nd (of 3) HHFW run period planned by Taylor / Hosea (~10/11)

XP1062: Schematic heating and applied field field waveforms



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XP1062: NTV steady-state offset velocity at reduced torque – Diagnostics, etc.

- Required diagnostics / capabilities
  - RWM coils in standard n = 1,3 configuration, n = 2 configuration
  - 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