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XP804: Comparison of NTV among tokamaks

(n = 2 fields, ν_i scaling)

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NSTX Results Review
Princeton Plasma Physics Laboratory
August 7th, 2008

XP804: Comparison of neoclassical toroidal viscosity (NTV) among tokamaks (n = 2 fields, ν_i scaling)

- **Goals**
  - Compare NTV results/analysis on NSTX to other devices (MAST, JET, etc.)
  - Test NTV theory for n = 2 applied field configuration
    - n = 2 may be best for comparison to other devices (n = 1 strongest resonant rotation damping, n = 3 weak in some devices, many machines run n = 2)
    - Examine possible RFA effects by varying proximity to no-wall limit
  - Investigate damping over widest possible range of ion collisionality
    - Key for ITER, determine affect on rotation damping and compare to theory
  - Compare to braking due to using n = 1, 3 fields

- **Progress**
  - Observed non-resonant braking with n = 2 field configuration
  - Increased rotation damping observed with lithium evaporation

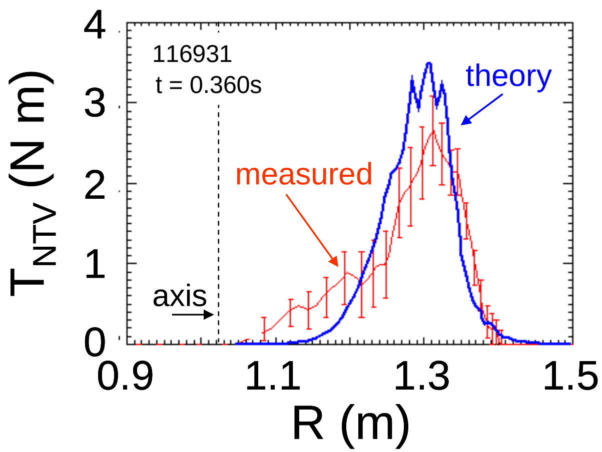
Even parity non-axisymmetric fields recently used on NSTX to determine impact on V_ϕ

- Past quantitative agreement in NSTX between neoclassical toroidal viscosity (NTV) theory and non-resonant damping due to odd parity fields
  - Expected saturation of $1/\nu_i$ dependence important for ITER

- n = 2 applied field configuration shows expected global, non-resonant character of damping
  - Damping not due to resonant n = 1 component as suggested for n = 3 configuration (n = 1 component is very small)

Measured $d(I\Omega_p)/dt$ profile and theoretical NTV torque (n = 3 field) in NSTX)

W. Zhu, et al., *Phys. Rev. Lett.* **96,** 225002 (2006).



Dominant NTV Force for NSTX collisionality…

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

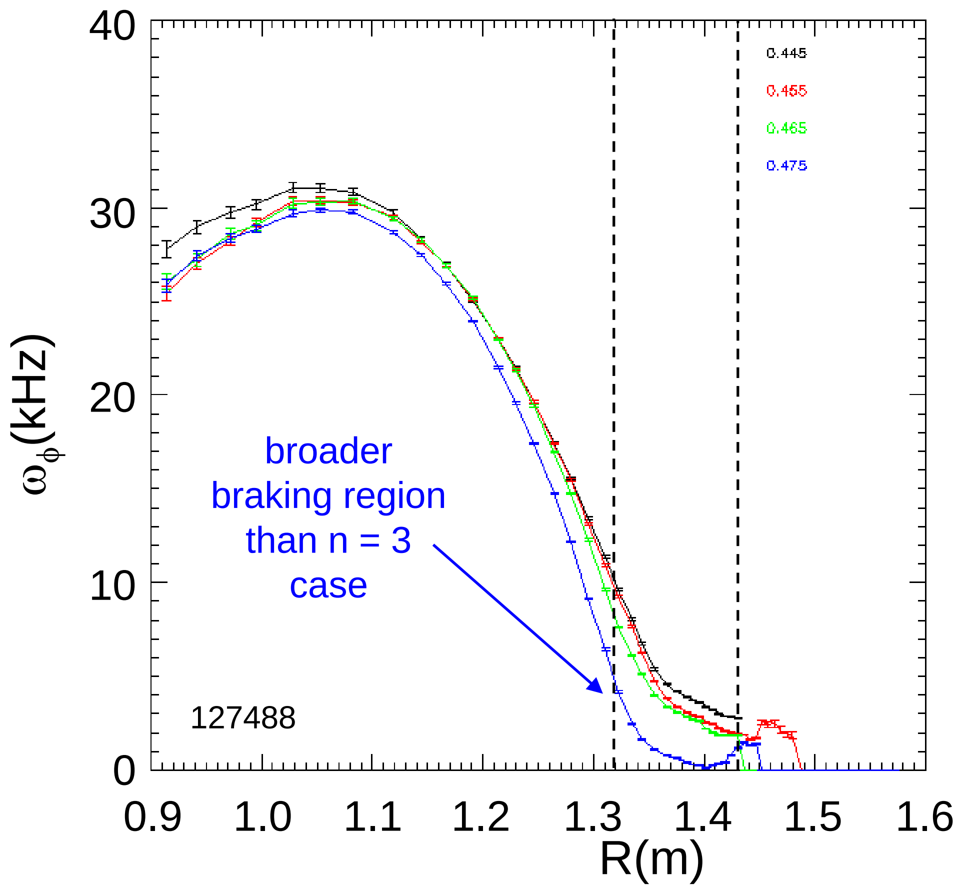
…expected to saturate at lower ν_i

$$\frac{1}{\nu_i} \Rightarrow \frac{\nu_i}{\left(\nu_i^2 + \omega_E^2\right)}$$

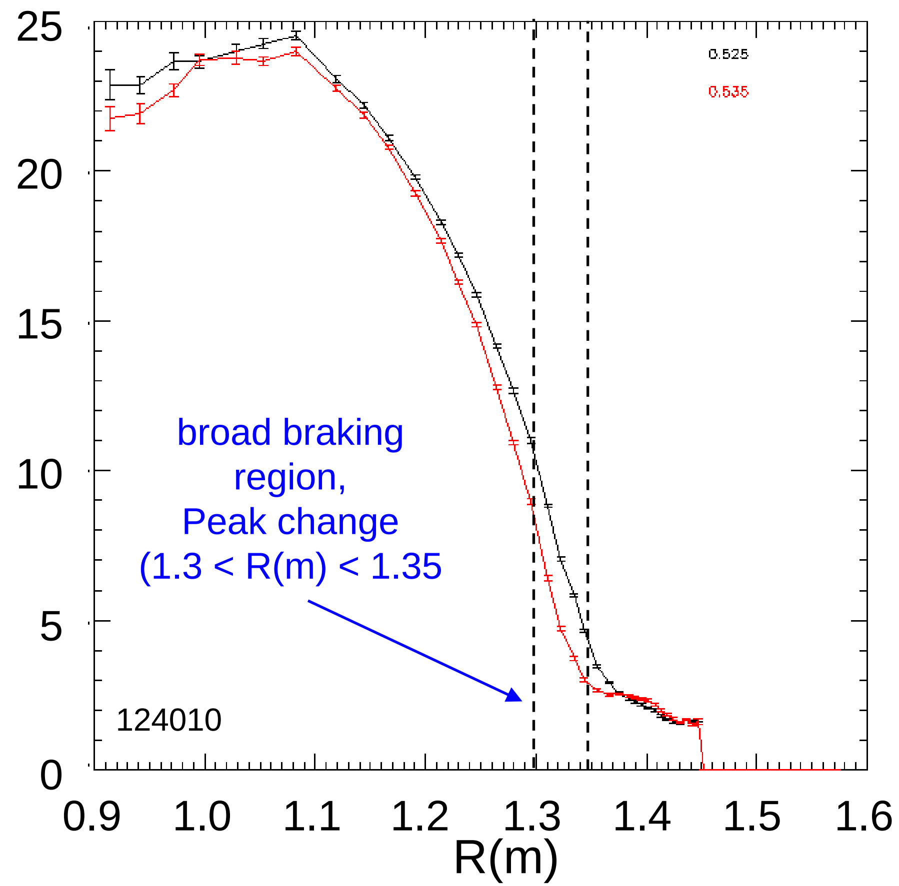
Can verify at order of magnitude lower ν_i with center stack upgrade

XP804: Clear braking observed due to n = 2 field

Rotation evolution during n = 2 braking



Rotation evolution during n = 3 braking

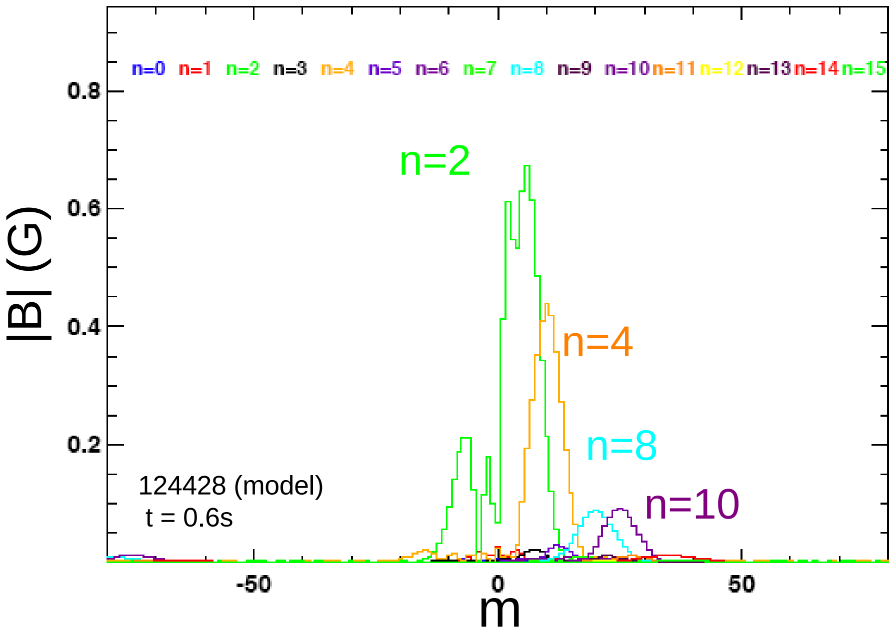


- n = 2 has broader braking profile than n = 3 field (field spectrum?)
- Next step: analyze non-resonant NTV profile, examine resonant effects
  - Joint XP proposed to MAST (didn't see strong n = 2 braking, while JET has)

Broader field spectrum in n = 2 vs. n = 3 configuration

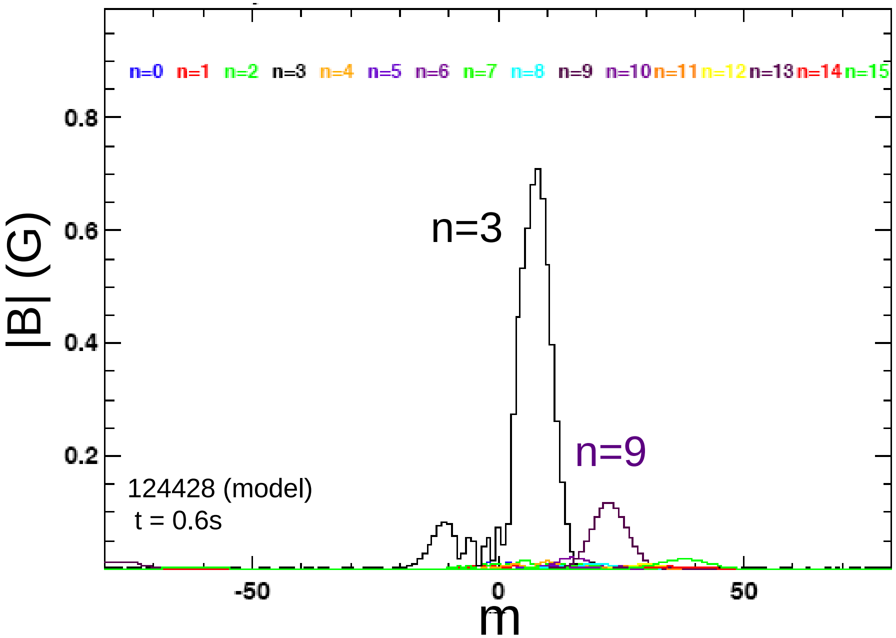
"n = 2 configuration"

Spectrum at r/a=0.8



"n = 3 configuration"

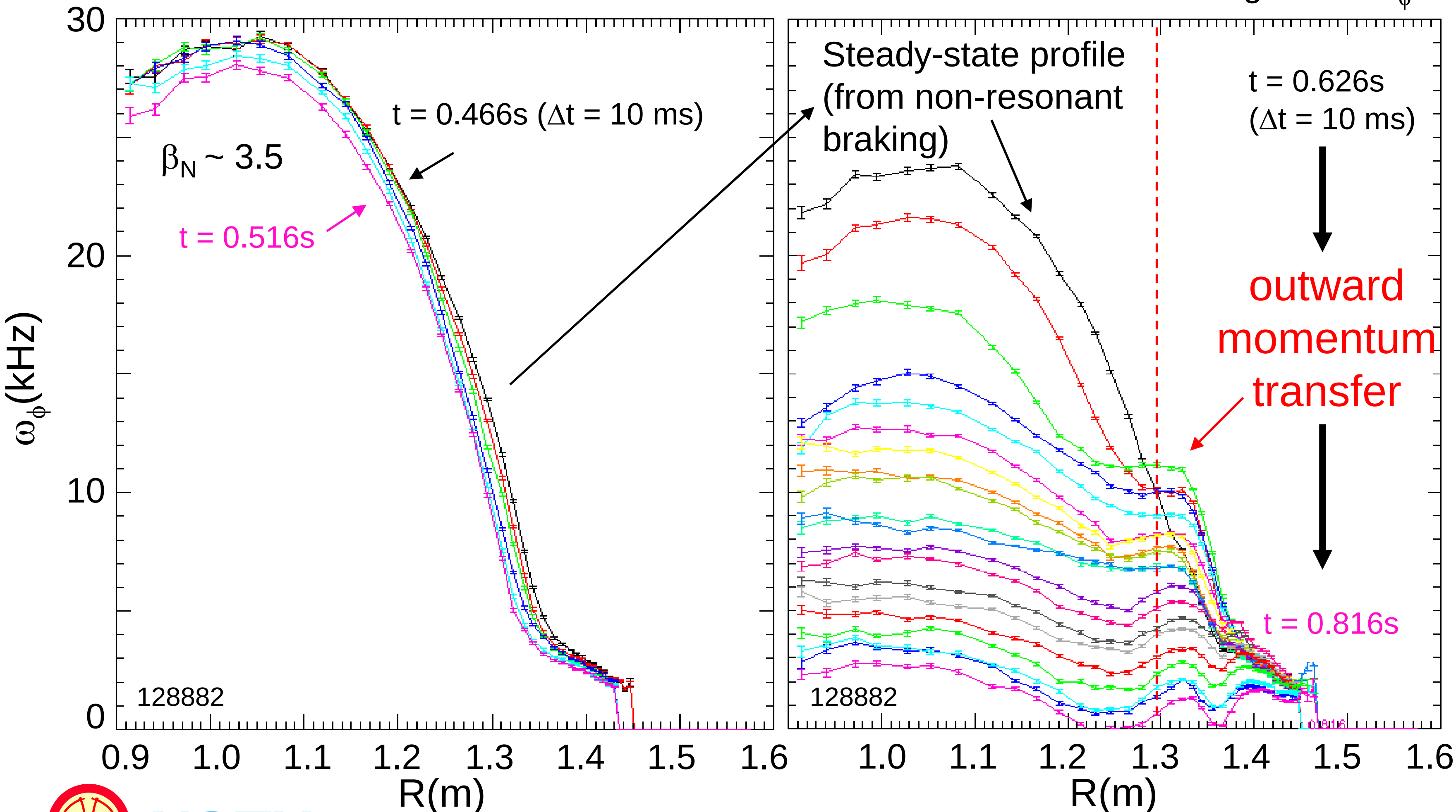
Spectrum at r/a=0.8



- Broader spectrum and greater radial penetration should lead to larger NTV damping and extended radial profile
- n = 2 configuration has very small n = 1 component – reduces resonant braking and n = 1 NTV due to resonant field amplification

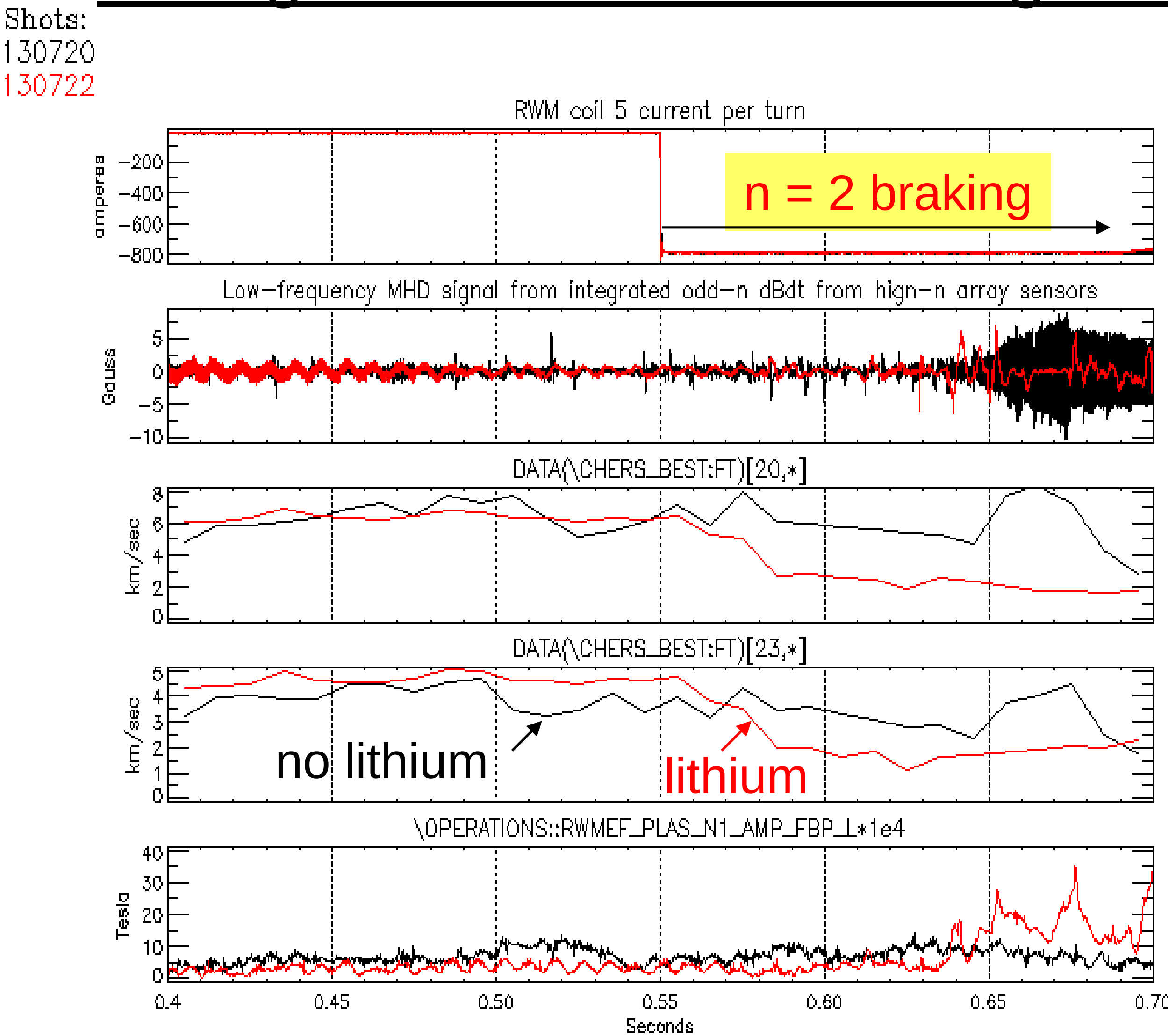
n = 2 non-resonant braking evolution distinct from resonant

- Non-resonant:
  - broad, self-similar reduction of profile
  - Reaches steady-state (t = 0.626s)
- Resonant:
  - Clear momentum transfer across rational surface
  - evolution toward rigid rotor core
  - Local surface locking at low ω_ϕ



NSTX

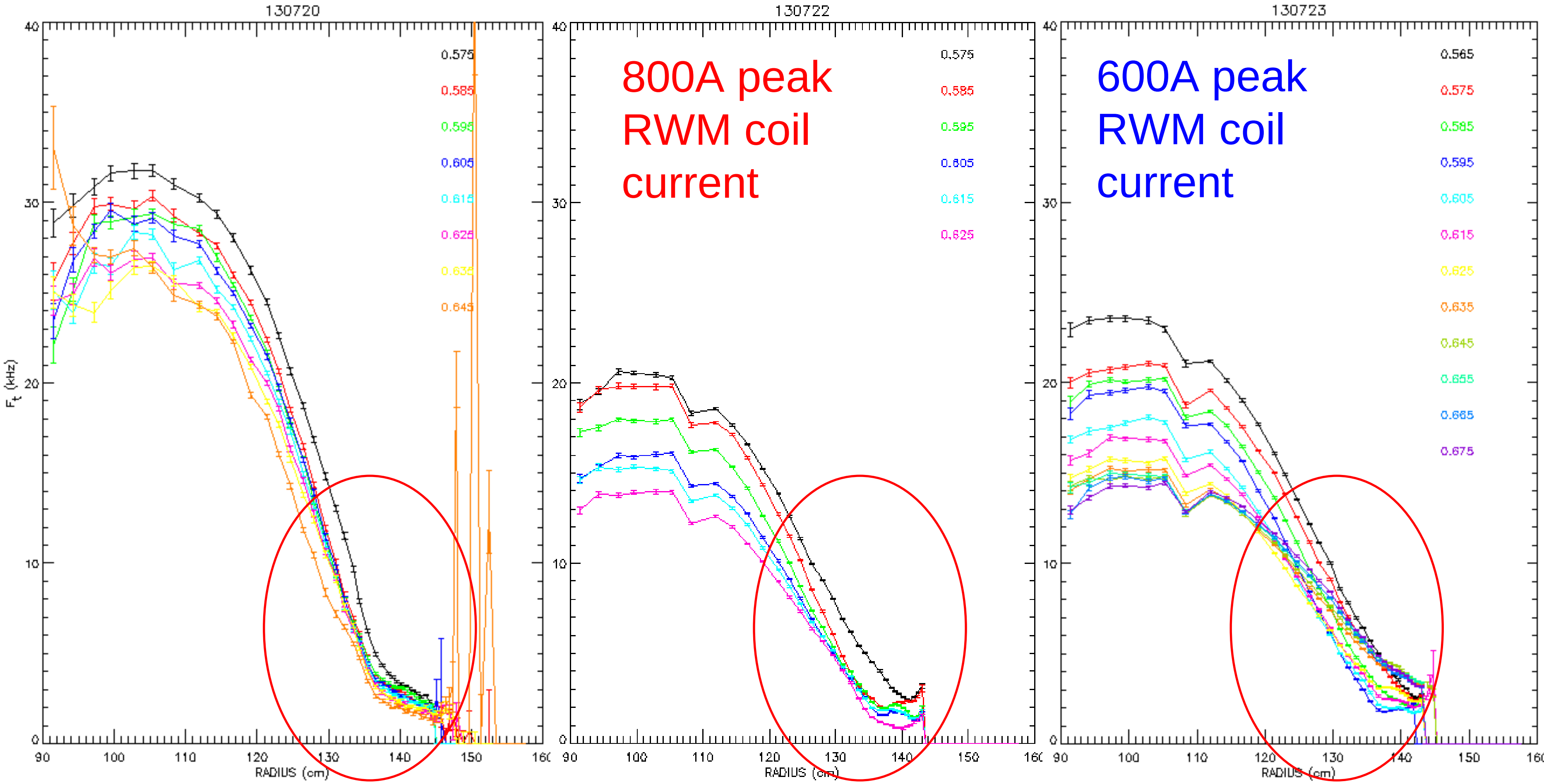
Stronger non-resonant braking with Li evaporation



- Examine ν_i dependence of NTV by injecting lithium
- Li produces higher T_i in region of high rotation damping
- Expect stronger V_ϕ damping by NTV at higher T_i ($\sim T_i^{5/2}$)
- Rotating MHD eliminated with Li evaporation
  - Eliminates resonant braking due to mode

Non-resonant braking evolution altered by Li evaporation

Before Li evaporation | After Li evaporation | After Li, reduced δB

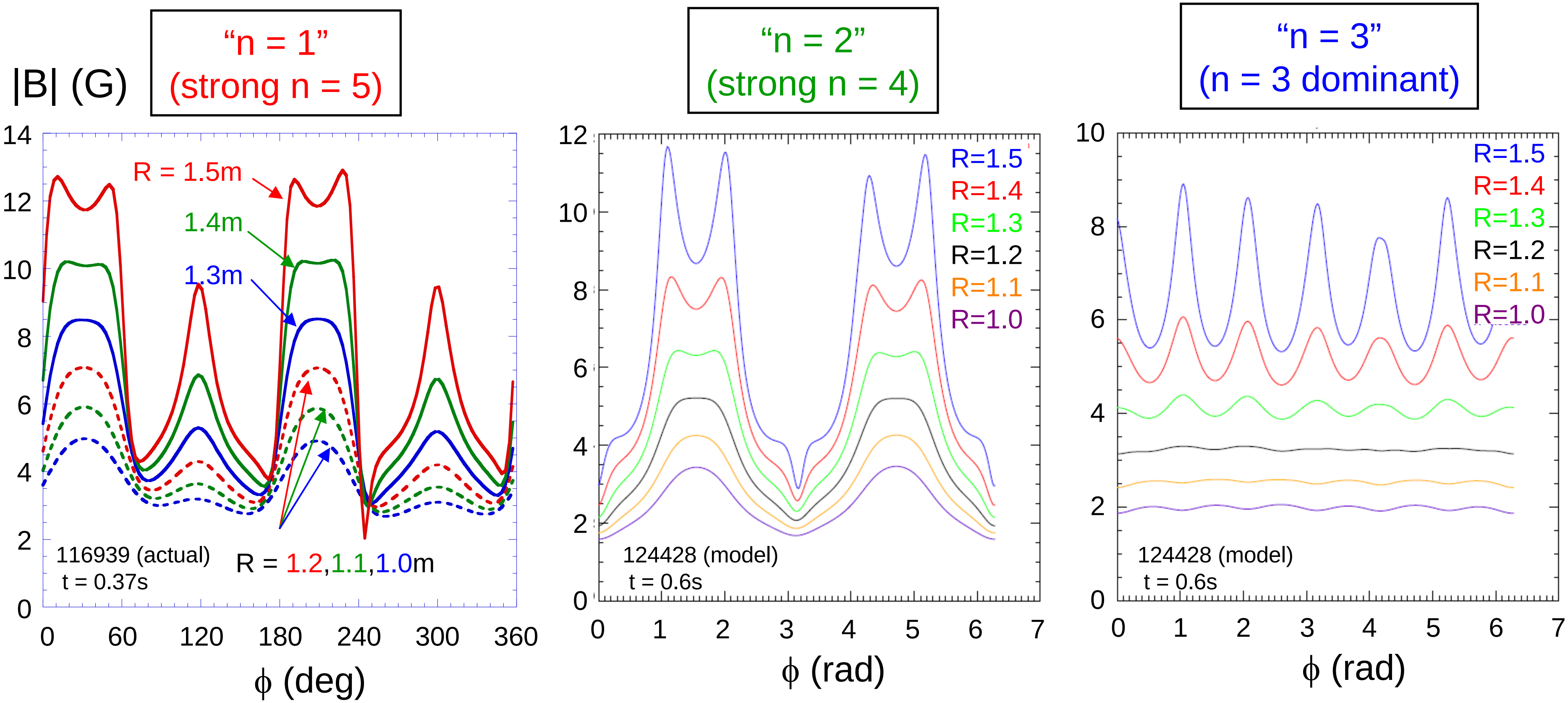


- Expect stronger V_ϕ damping by NTV at higher T_i ($\sim T_i^{5/2}$)
- Li eliminates rotating mode – allows V_ϕ to saturate at reduced applied δB

Analysis of new n = 2 NTV braking observation just starting

- Further comparison of pre/post-lithium shots
- Full evaluation of NTV braking torque profile
  - Detailed comparison of n = 2 and n = 3 configurations
  - Comparison to measured change in angular momentum and rotation damping timescale
- Determine if braking evolution can be explained by NTV braking torque with $1/\nu_i$ dependence in present collisionality regime
  - Expect that scaling will hold, as variation in deuterium collisionality profile has not changed drastically

Significant differences in |B| between n = 1, 2, 3 applied field configurations



- Field more uniform vs. toroidal angle in higher n configuration
- Smaller n spectrum in higher n configuration