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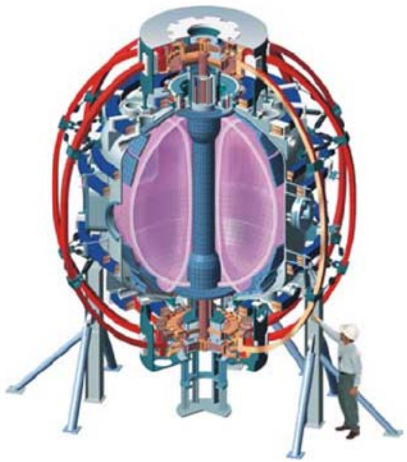
XP804: Comparison of NTV among tokamaks (n = 2 fields, ν_i scaling)

S.A. Sabbagh[1], R.E. Bell[2], J.W. Berkery[1], J.M. Bialek[1], S. Gerhardt[2], B. LeBlanc[2], J.E. Menard[2], K. Tritz[3]

[1]Department of Applied Physics, Columbia University, New York, NY
[2]Plasma Physics Laboratory, Princeton University, Princeton, NJ, USA
[3]Johns Hopkins University, Baltimore, MD, USA



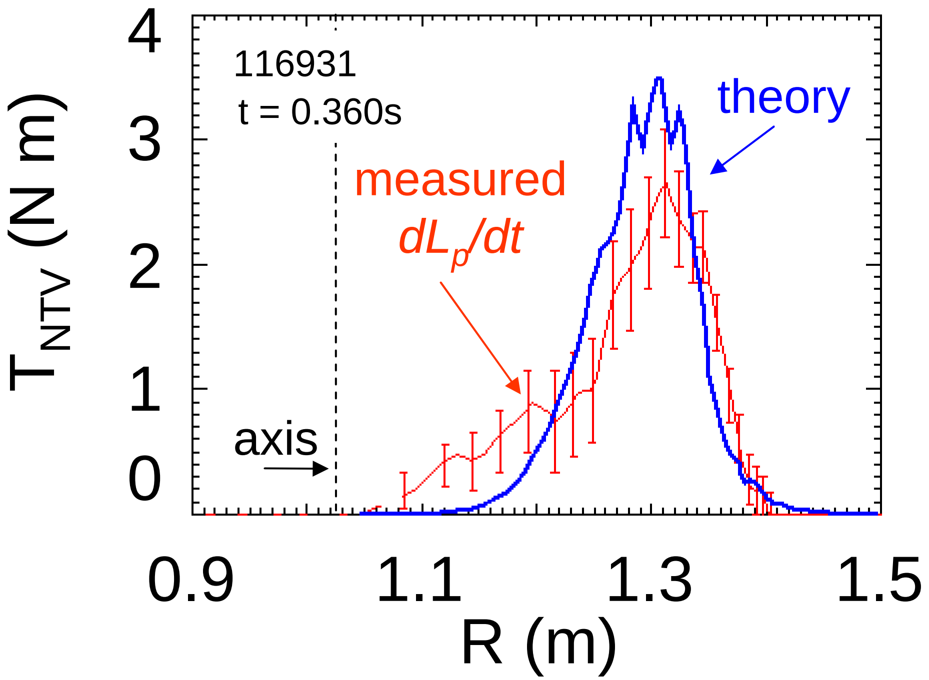
NSTX Team Review Meeting
March 5th, 2008
Princeton Plasma Physics Laboratory

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
    - n = 2 data available JET, C-MOD, initial results in MAST (writing MAST 08 XP)
  - 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 to determine affect on rotation damping and compare to theory
    - Key for ITER, comparison to other devices important
  - Supplement past published NSTX results (XP524) using n = 1, 3 fields
    - Modifications to theory to be examined (e.g. multiple trapping states)
    - Reversed I_p operation may allow ω_ϕ offset term measure (~ few kHz)
- Addresses
  - Joule milestone, leverages ST geometry
  - ITER support (RWM coil design), ITPA joint experiment MDC-12

Observed rotation decrease follows NTV theory

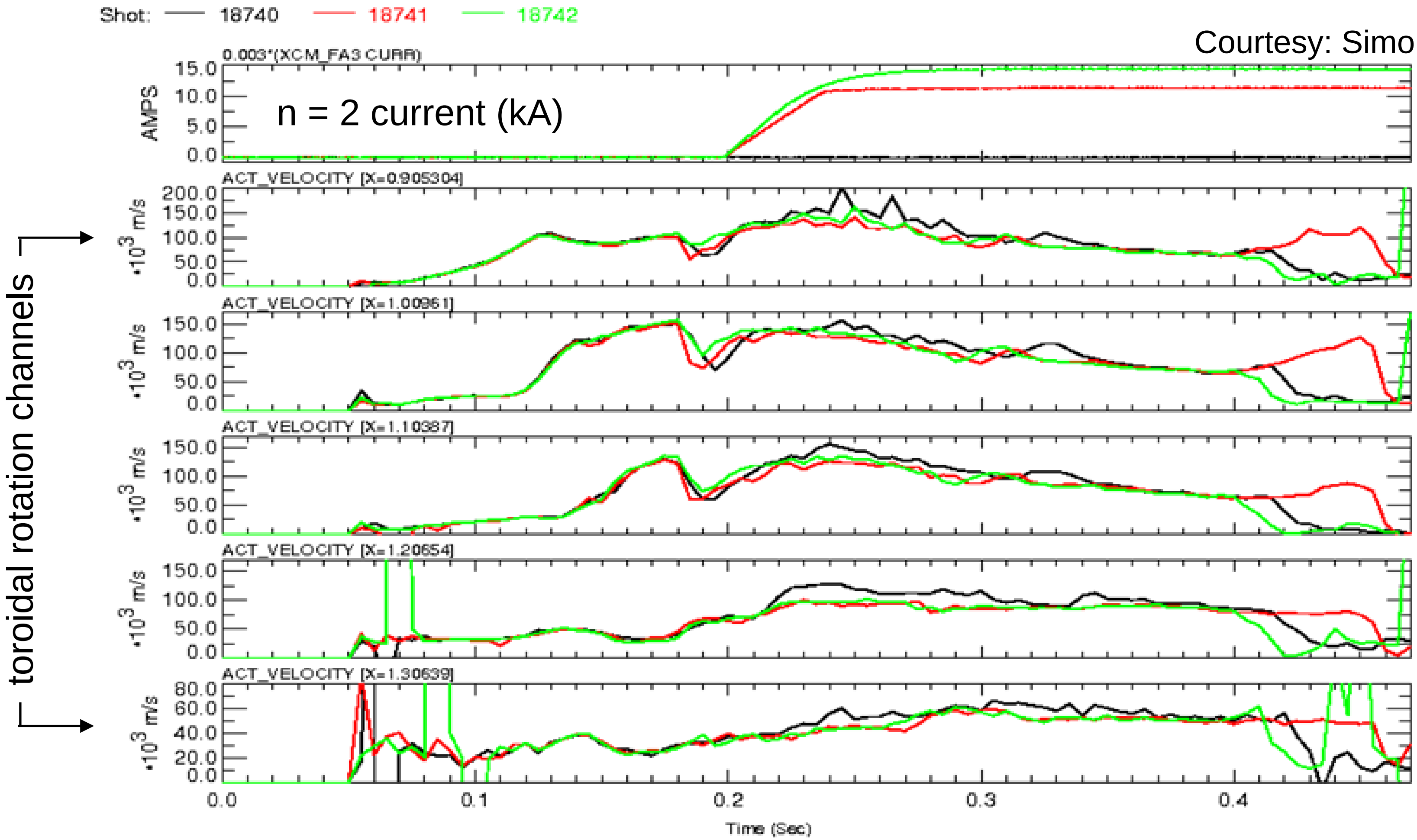
n = 3 applied field configuration



(Zhu, et al., PRL **96** (2006) 225002.)

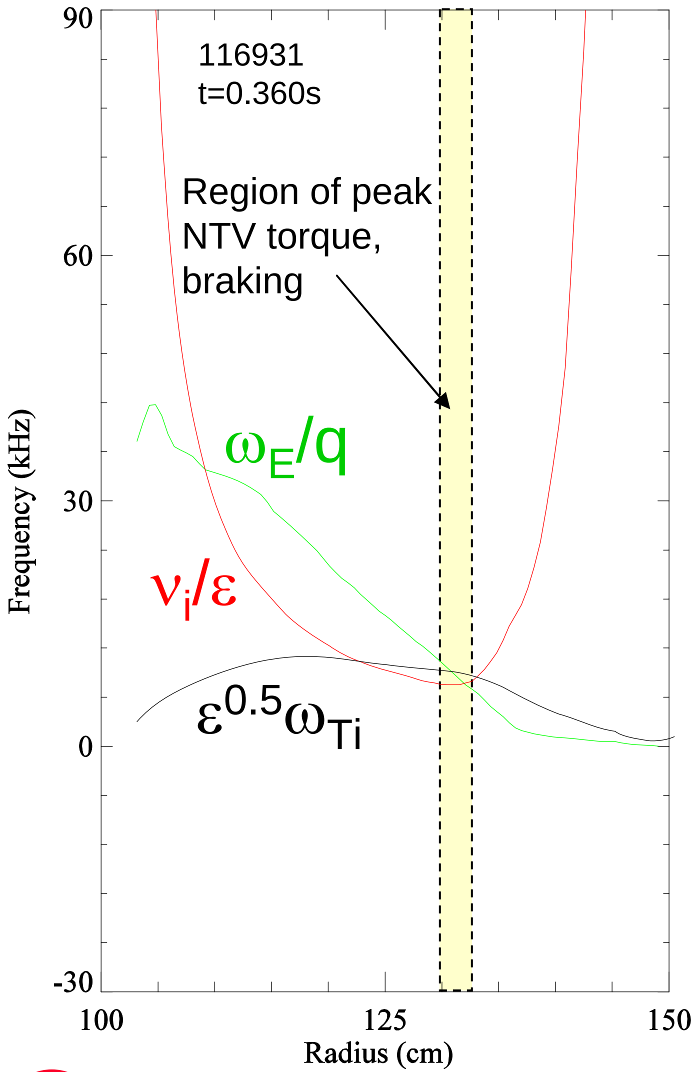
- Further test NTV theory; compare to other devices
  - Trapped particle effects, 3-D field spectrum important for quantitative agreement
  - Scales as $\delta B^2(p_i/\nu_i)(1/A)^{1.5}$
  - Low collisionality, ν_i, ITER plasmas expected to have higher rotation damping
  - Saturation of $1/\nu_i$ scaling expected by theory, can it be found?
- Approach
  - Use *n* = 2 field to slow ω_ϕ at low, high β_N (check RFA)
  - Vary collisionality (as in past XPs) to produce ~ at least a factor of 2 variation in NSTX

MAST first n=2 NTV experiment shows little effect



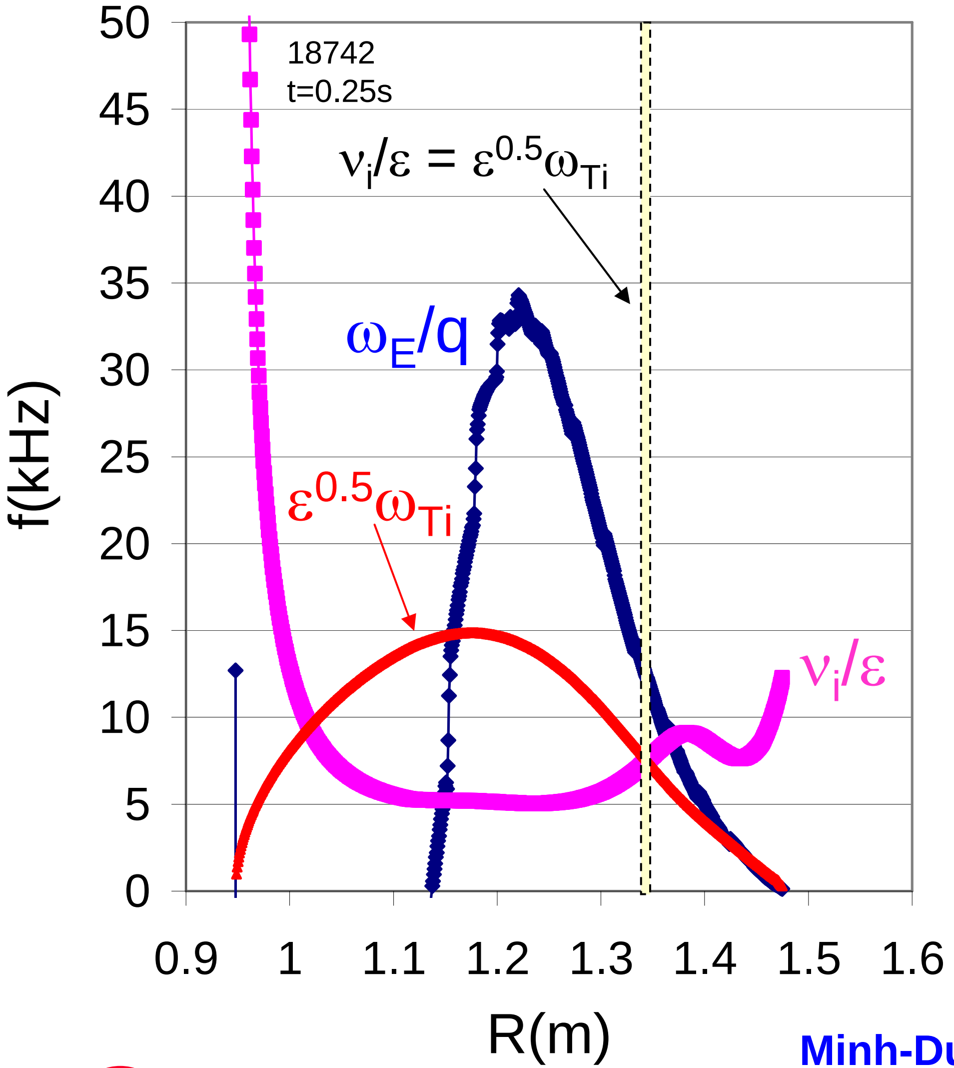
- MAST first results show an initial drop in rotation when the n = 2 field is switched on, but rotation the same in all three shots at a later time.
- BUT - JET n = 2 experiment showed clear braking effect!

ExB rotation, effective ion collision, and bounce frequencies – NSTX 116931



- n = 3 braking “configuration
- Frequency profiles
  - Collisionless NTV formulation valid in region of peak measured damping where $\omega_E/q \sim \nu_i/\varepsilon \sim \varepsilon^{0.5}\omega_{Ti}$
  - 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^* so is probably overestimated

MAST - ExB rotation, effective ion collision, and bounce frequencies – case with weak n = 2 braking



- n = 2 braking "configuration
- Frequency profiles
  - Collisionless NTV formulation valid in region of peak measured damping where $\omega_E < \nu_i/\varepsilon < \varepsilon^{0.5}\omega_{Ti}$
    - Does n = 2 field penetrate to this depth (1.34m)?
  - Also, $\omega_E > \nu_i/\varepsilon$, $\varepsilon^{0.5}\omega_{Ti}$ unlike NSTX
    - Could this be a key difference in braking result?
    - Need to compare ω_E calculations more closely

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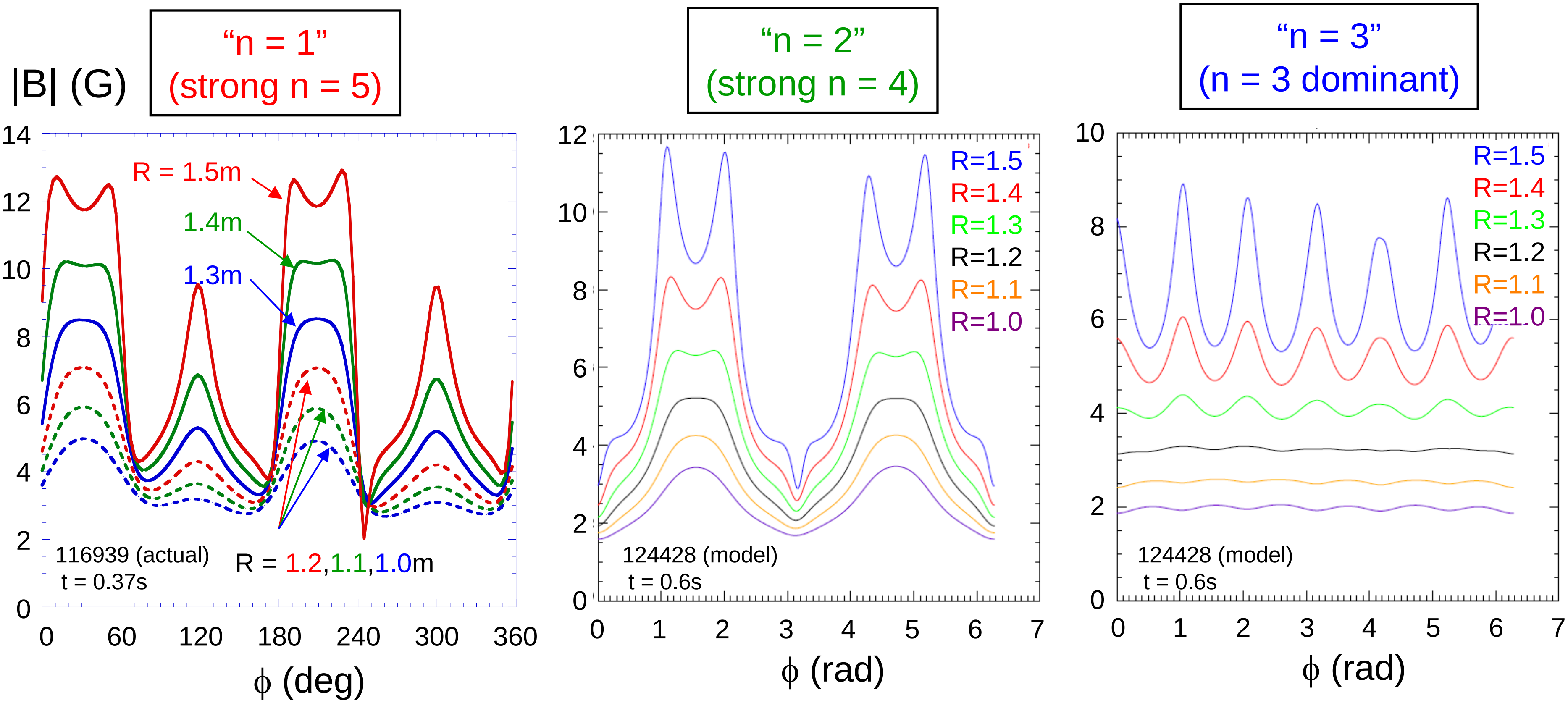
Significant differences in |B| between n = 1, 2, 3 applied field configurations

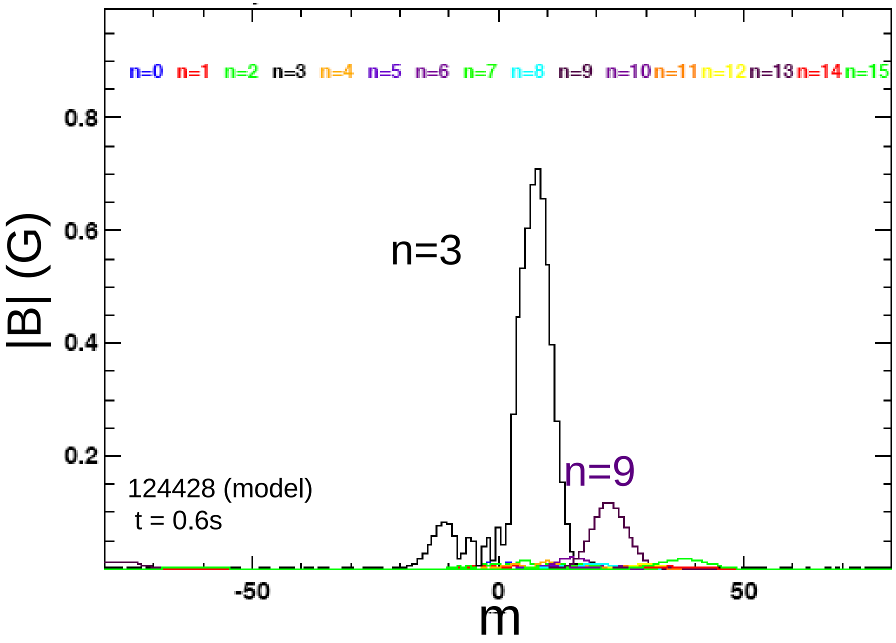


- Field more uniform vs. toroidal angle in higher n configuration
- Smaller n spectrum in higher n configuration

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

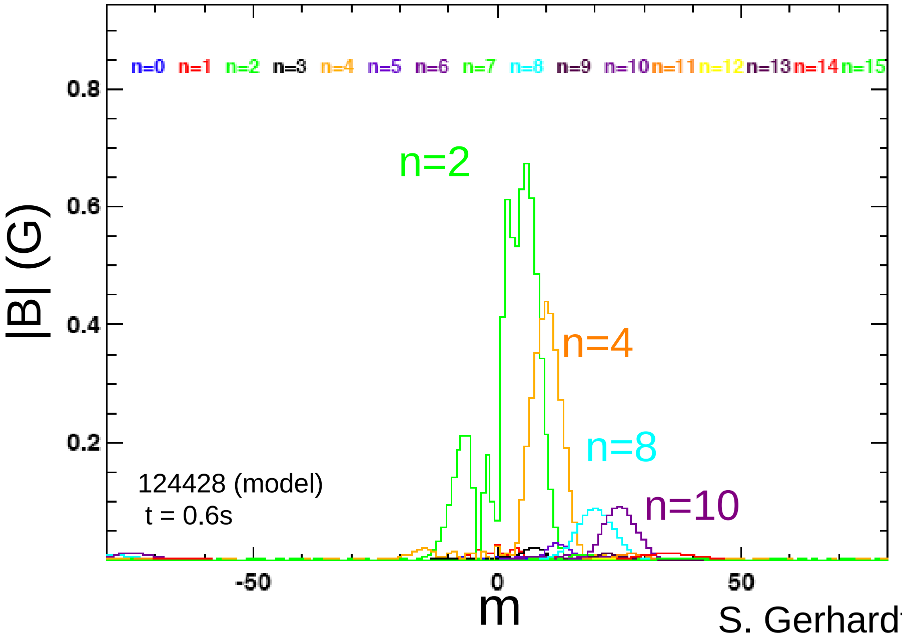
"n = 3 configuration"

Spectrum at r/a=0.8



"n = 2 configuration"

Spectrum at r/a=0.8



S. Gerhardt

- 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 RFA

XP804: NTV n = 2 and ν_i - Run plan

Task	Number of Shots
1) Create targets (i) below, but near and (ii) above ideal no-wall beta limit (control shots)	
(use 120038 as setup shot, 2 or 3 NBI sources, relatively high $\kappa \sim 2.4$ to avoid rotating modes)	
A) No n = 2 applied field; 3, then 2 NBI sources	2
2) Apply n = 2 field	
A) Step up n = 2 currents during discharge in 75ms steps, 3 NBI sources	2
B) Step up n = 2 currents during discharge in 75ms steps, 1 or 2 NBI sources	2
C) n = 2 DC pulse at steady ω_ϕ, measure spin down, pulse off to measure ω_ϕ spin-up, 3 NBI	3
D) n = 2 DC pulse at steady ω_ϕ, measure spin down, pulse off to measure ω_ϕ spin-up, 1 or 2 NBI	3
E) n = 6 DC pulse at steady ω_ϕ, measure spin down, pulse off to measure ω_ϕ spin-up, 3 NBI	3
3) Ion collisionality variation	
A) Vary ν_i at constant *q*, apply *n* = 2 field during period free of strong rotating modes	8
B) Increase n = 2 field at collisionality where damping is weakest	3
4) Reversed I_p scans	
A) Repeat scans 1 and 2 above in reversed I_p	13

Total (standard I_p; reversed I_p): 26 ; 13

XP804: NTV n = 2 and ν_i - Diagnostics

- Required diagnostics / capabilities
  - Ability to operate RWM coils in n = 2 configuration
  - CHERS toroidal rotation measurement
  - Thomson scattering
  - USXR
  - MSE
  - Toroidal Mirnov array / between-shots spectrogram with toroidal mode number analysis
  - Diamagnetic loop
- Desired diagnostics
  - Internal RWM sensors
  - FIReTip
  - Fast camera