NSTX

Supported by

U.S. DEPARTMENT OF ENERGY | Office of Science

Search for Multiple Resistive Wall Modes at High Normalized Beta in NSTX*

S.A. Sabbagh[1], J.W. Berkery[1], J.M. Bialek[1], L. Delgado-Aparicio[2], K. Tritz[2], R.E. Bell[2], S.P. Gerhardt[3], B. LeBlanc[3], J.E. Menard[3], F. Levinton[4], H. Yu[4]

[1]Department of Applied Physics, Columbia University, New York, NY
[2]Johns Hopkins University, Baltimore, MD
[3] Princeton Plasma Physics Laboratory, Princeton, NJ
[4]Nova Photonics, Inc., Princeton, NJ

51st Annual Meeting of the Division of Plasma Physics American Physical Society

November 3, 2009

Atlanta, GA

v1.4

*Work supported by U.S. DOE Contracts DE-FG02-99ER54524 and DE-AC02-09CH11466.

College W&M
Colorado Sch Mines
Columbia U
Comp-X
General Atomics
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
ORNL
PPPL
PSI
Princeton U
Purdue U
Sandia NL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Maryland
U Rochester
U Washington
U Wisconsin

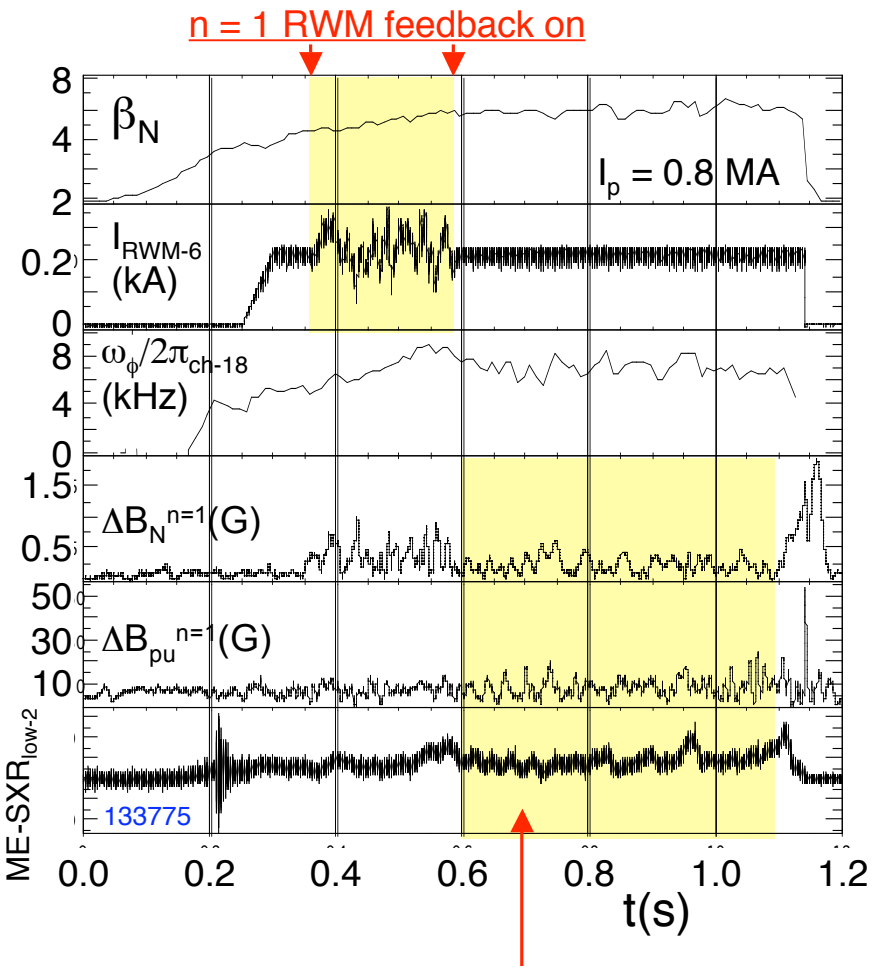
Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
KBSI
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

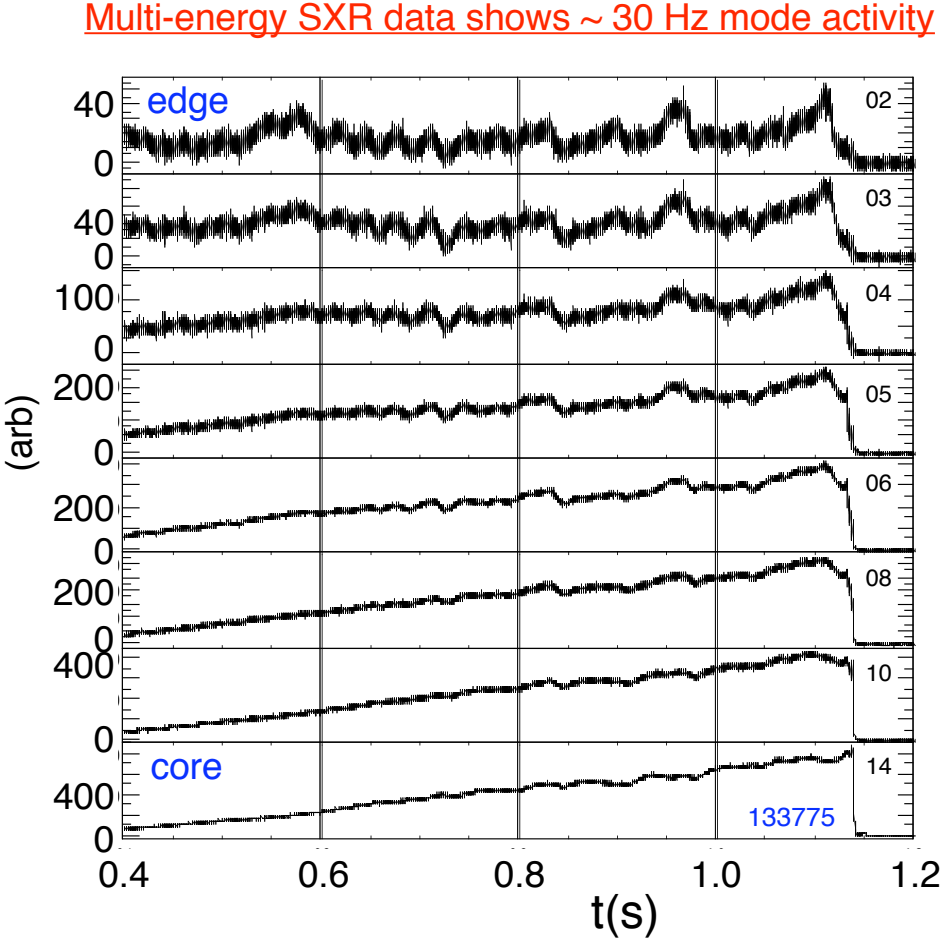
Appearance of low frequency oscillations in magnetic and kinetic diagnostics at high β_N investigated as multiple RWMs

- Motivation
  - Maintenance of plasma at high β_N with minimal time variation is needed for future fusion devices
  - Physics understanding of significant measured resistive wall mode (RWM) sensor activity is important to sustain steady high β_N
    - avoid feedback on mode activity not leading to unstable RWMs
- Observations / Goals
  - Mode activity observed in RWM frequency range in magnetic and kinetic diagnostics at high β_N (β_N up to 7.4 reached in 2009)
  - Is the observed mode activity related to, or independent of unstable RWM activity?
    - If same mode, supports single mode physics model
    - If another mode, supports multi-mode theory

Either conclusion is important to optimize β_N and RWM feedback control

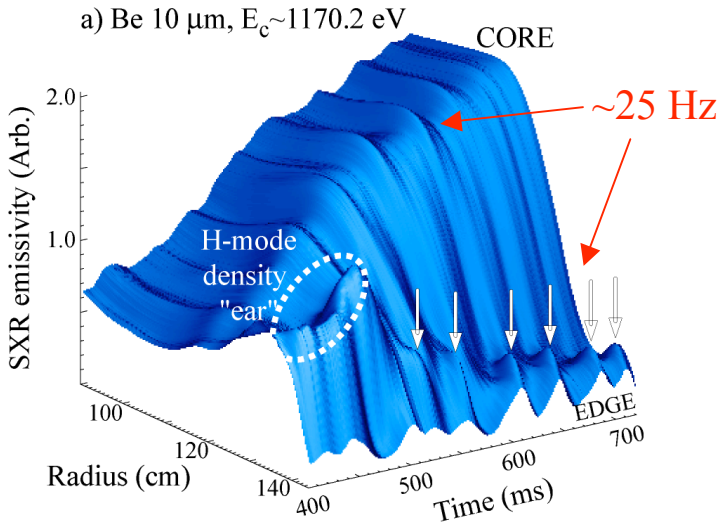
High β_N shots exhibit low frequency mode activity in magnetic and kinetic diagnostics

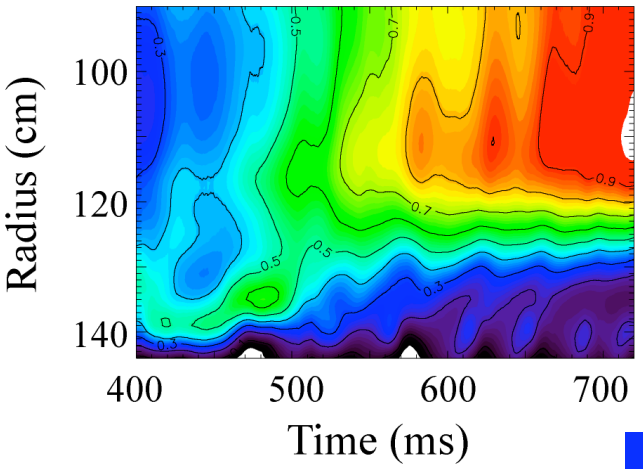




- Mode activity in RWM frequency range coincident in magnetics, SXR
- Soft X-ray measurements show low frequency mode activity is global

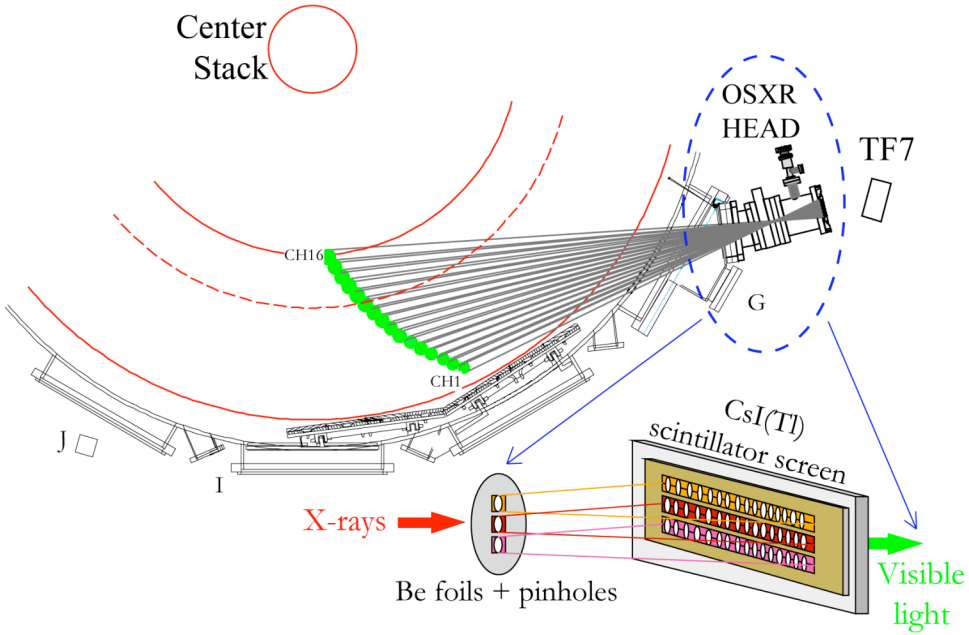
Multi-energy soft X-ray measurements consistent with mode being a driven RWM





L. Delgado-Aparicio - PP8.053

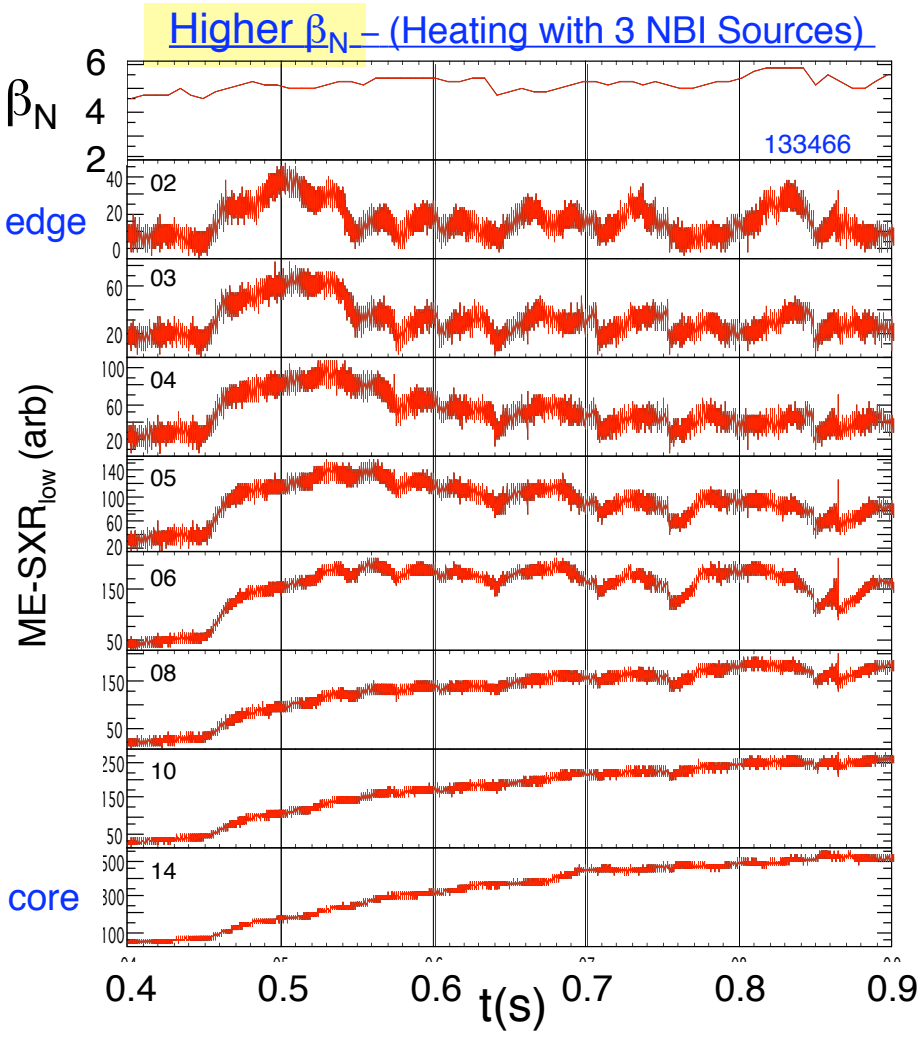
Multi-energy soft X-ray (ME-SXR) viewing geometry

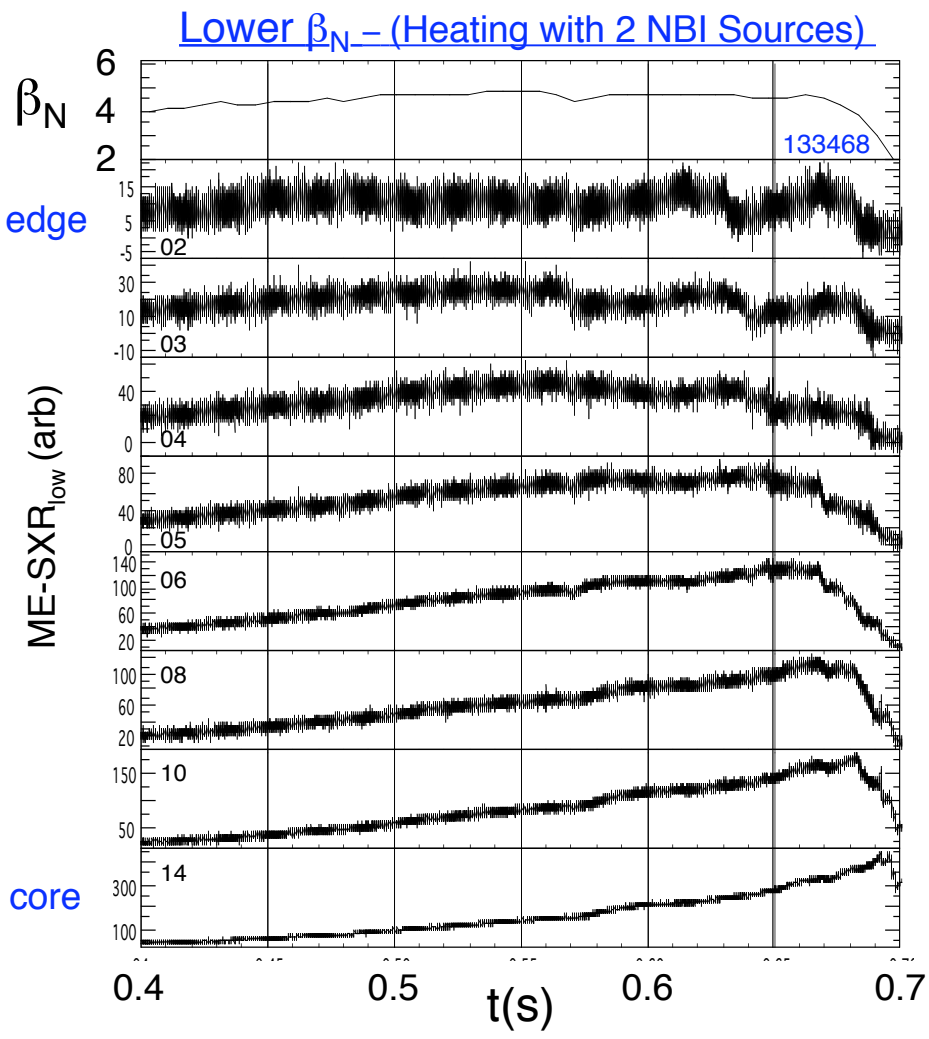


- RWM characteristics
  - Propagation in the co-NBI direction
  - Observed frequency near measured RWM resonance
    (Sontag, et al., NF **47** (2007) 1005.)

JOHNS HOPKINS UNIVERSITY

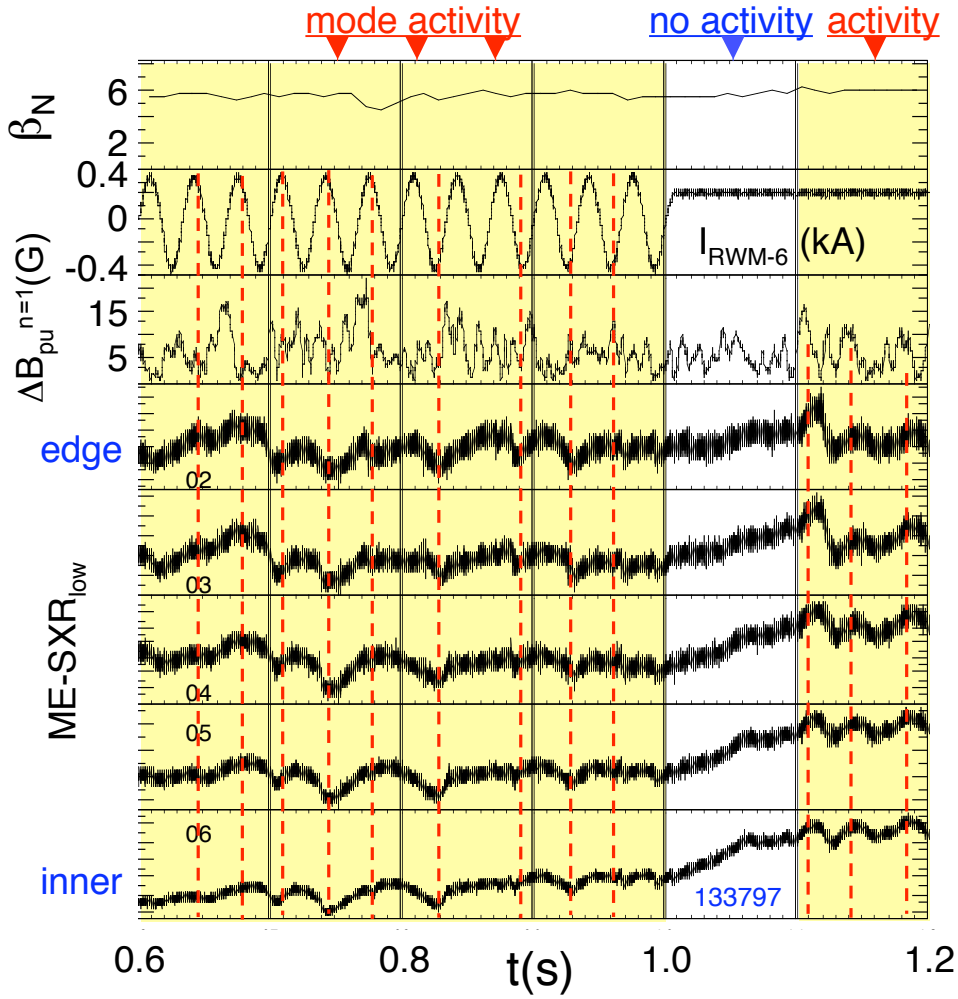
Low frequency mode observed in ME-SXR covers greater radial extent as β_N increased

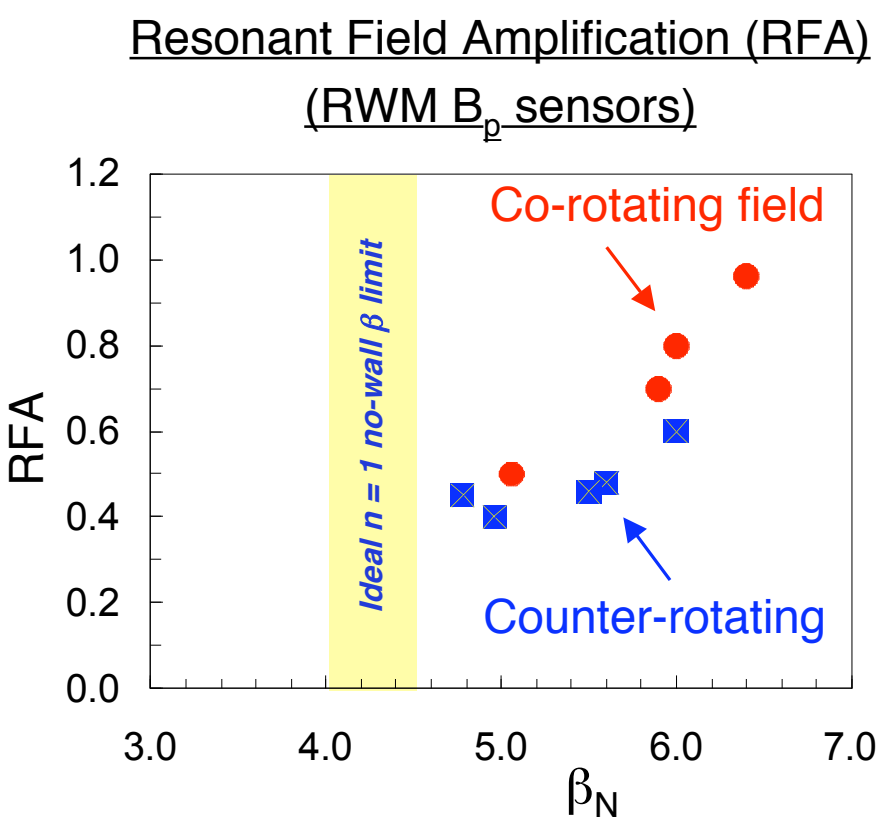




- Proximity to marginal stability (e.g β_N plus ω_ϕ level) may be key
  - The ideal $\beta_N^{no\text{-}wall}$ ~ 4 - 4.4 for n = 1 modes in these plasmas

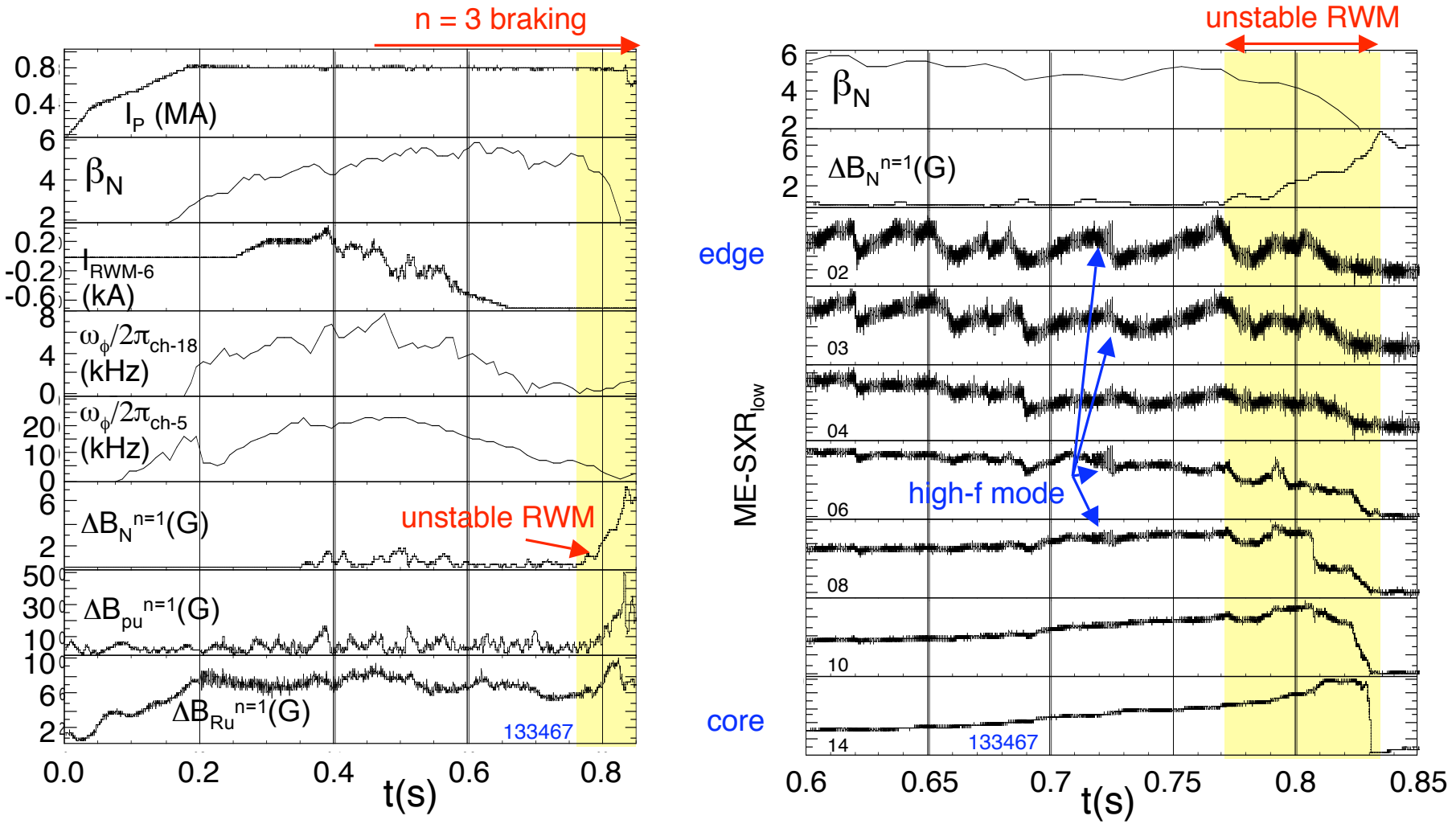
Resonant field amplification of rotating applied field observed in magnetics, along with oscillations in ME-SXR signals





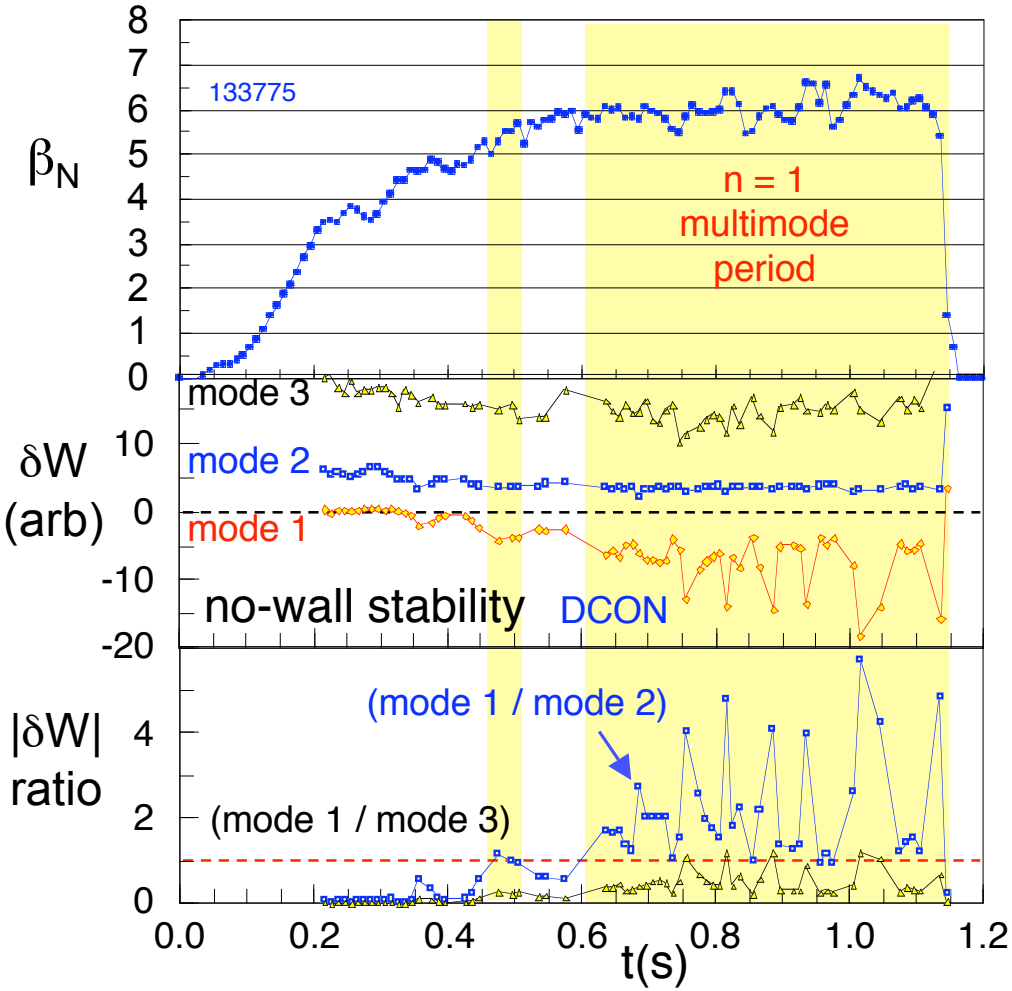
- Mode activity in ME-SXR observed during applied co-rotating AC field
- Activity stops when applied AC field stops; returns when magnetic activity returns

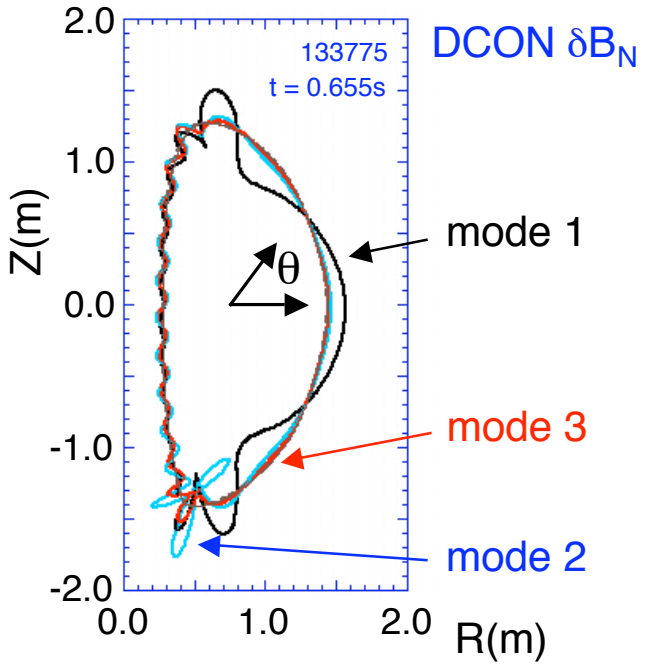
When unstable, observed growing n = 1 RWM appears to be independent of the driven, ~30 Hz activity

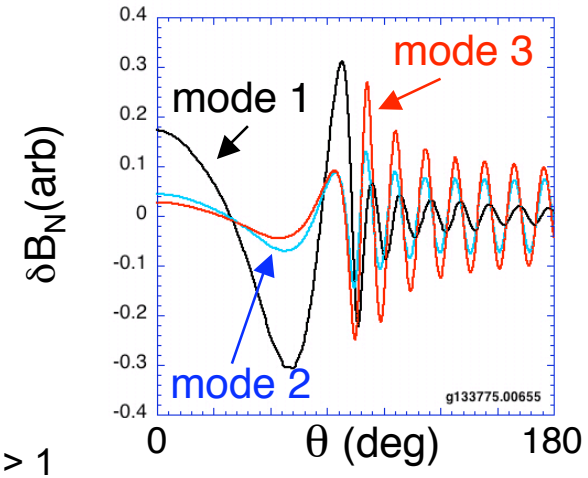


- Unstable RWM is locked; driven mode co-rotating at low frequency
- Unstable RWM grows (magnetics); low frequency mode appears steady in SXR

Multimode response theoretically is expected to be significant at high β_N

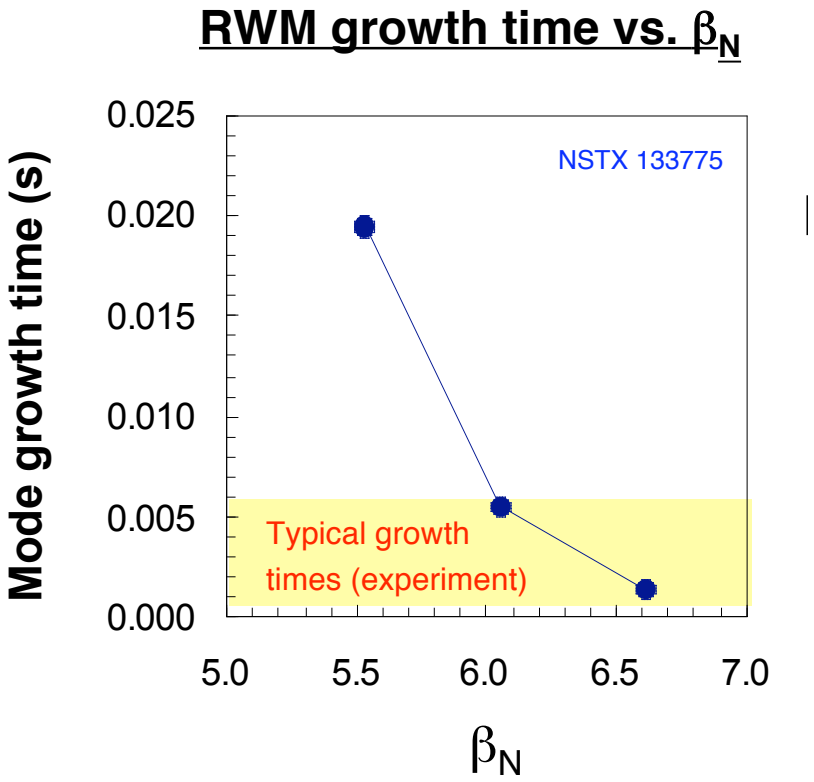


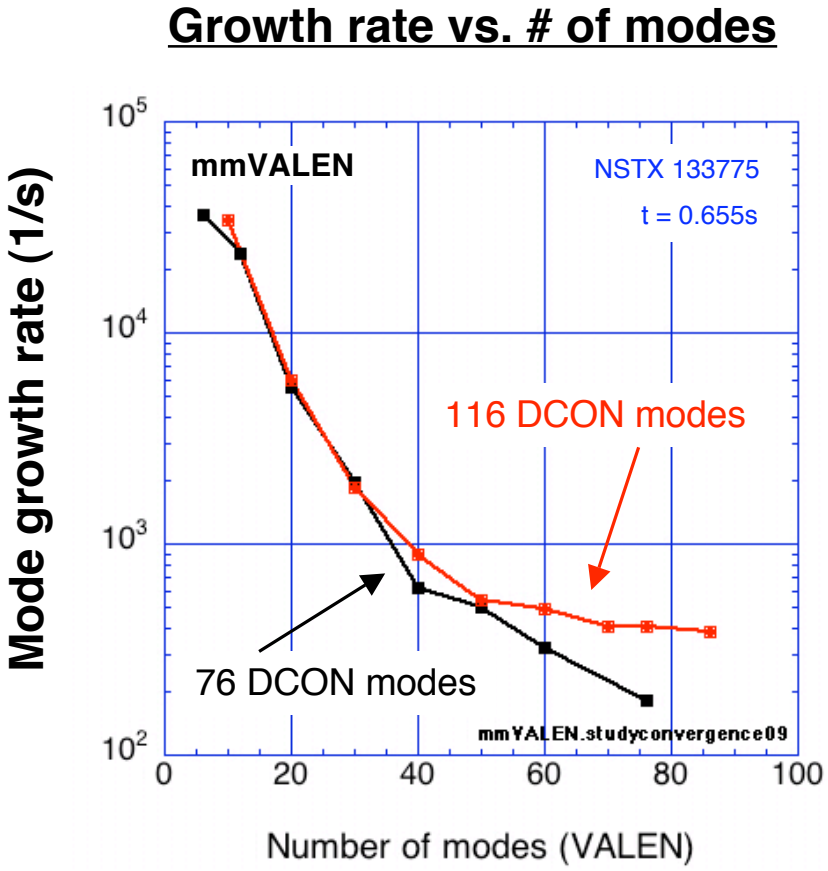




- Boozer multimode criterion for n = 1 met at high β_N (PoP **10** (2003) 1458.)
  - |δW| smallest for 2nd n = 1 eigenfunction
  - Ratio of |δW| for 3rd vs. 1st least stable mode sometimes also > 1

New multi-mode VALEN code reproduces typical observed RWM growth times in high β_N NSTX plasmas

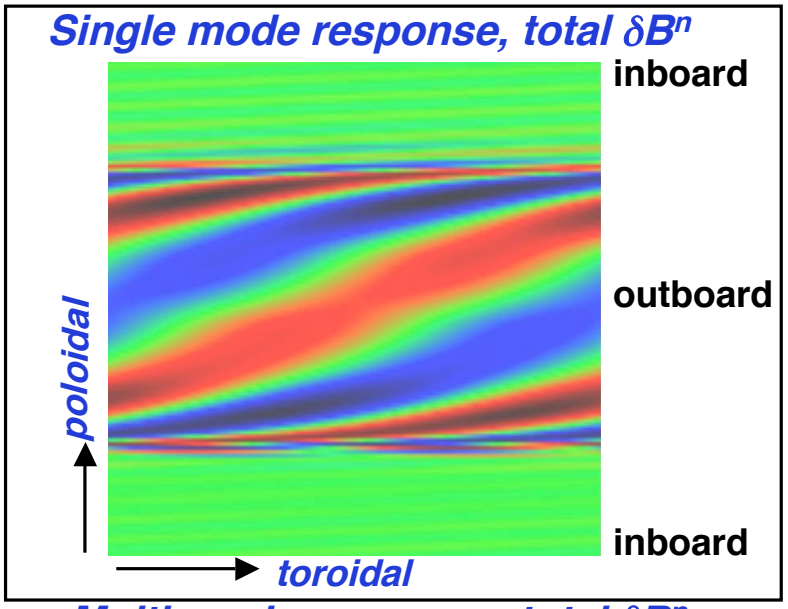


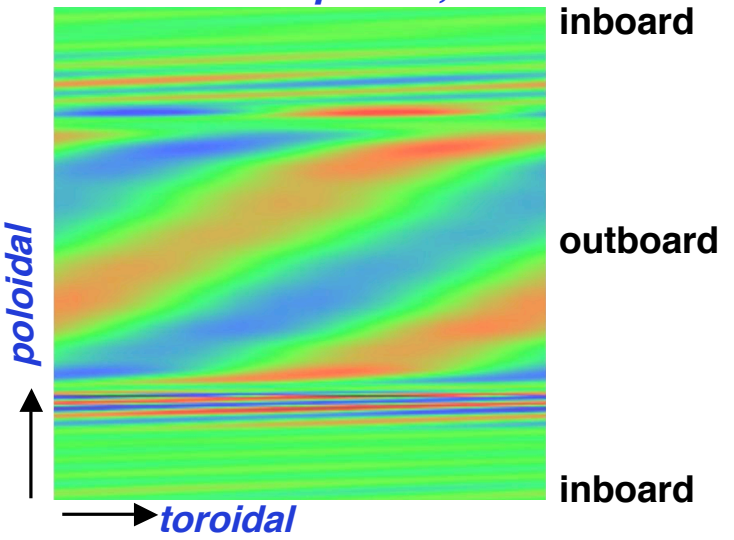


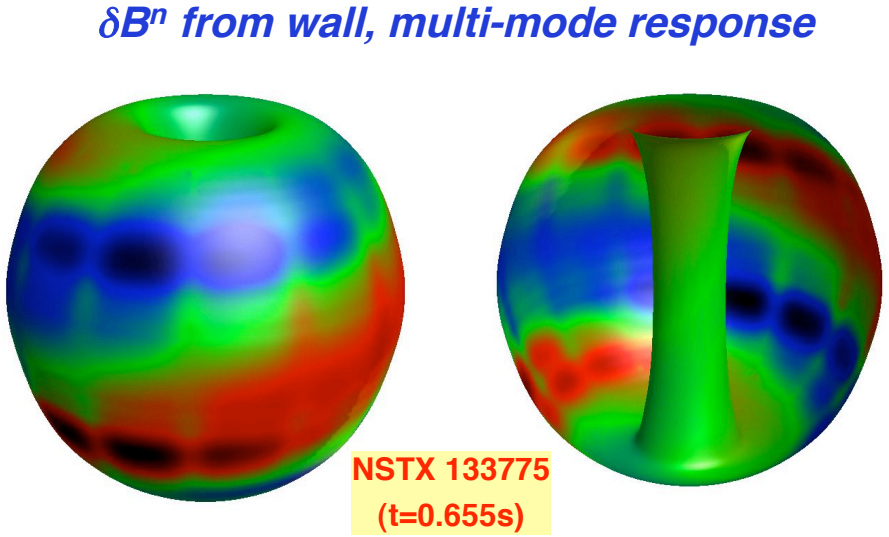
- Typical experimental growth times are reproduced with no free parameters
- Significant number of modes needed for convergence

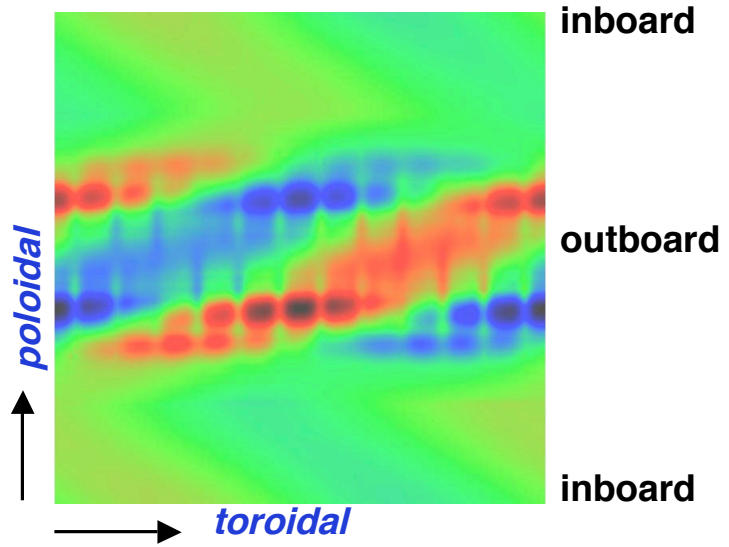
J. Bialek

Multi-mode perturbed field response in mmVALEN shows influence of 3-D structures









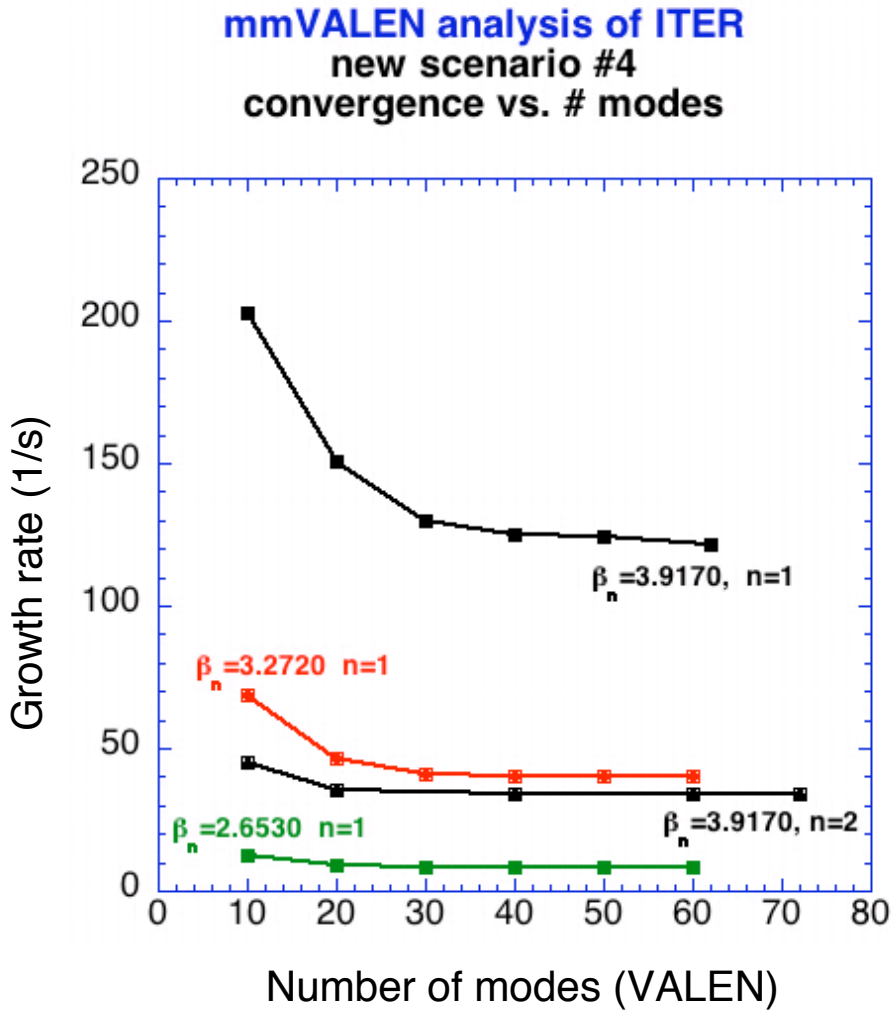
J. Bialek

Low frequency oscillations in magnetic/kinetic diagnostics at high β_N apparently a separate mode from unstable RWM

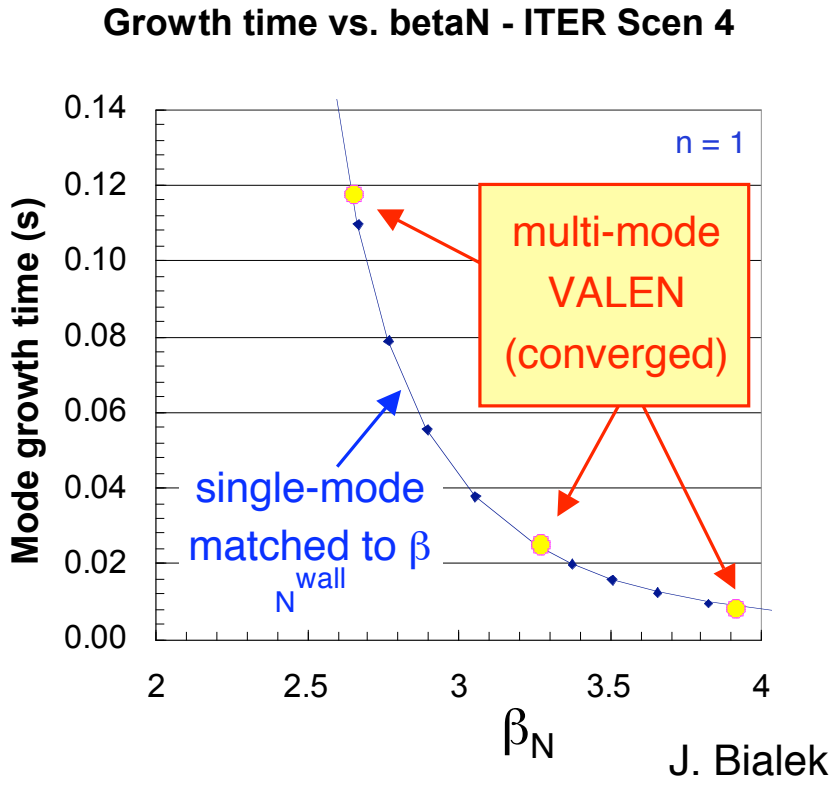
- Low frequency ~ $O(1/\tau_{wall})$ mode activity at high β_N has characteristics of a driven RWM
  - Mode is co-rotating at frequency near natural n = 1 RWM resonance
  - Mode observed in ME-SXR at ~30Hz is global and covers greater radial extent as β_N increased
  - Resonant field amplification of co-rotating applied field observed in magnetics, along with oscillations in ME-SXR
- Theory: multi-mode RWM response important at high β_N
  - 2nd mode is stable, so experimental mode must be driven (not saturated)
  - multi-mode VALEN code reproducing typically observed growth rates
- Observed growing n = 1 RWM appears to be independent of the driven, ~ 30 Hz mode activity
  - Supports multi-mode RWM theory

Additional slides

Multi-mode VALEN code testing successfully on ITER Scenario 4 cases (reversed shear)



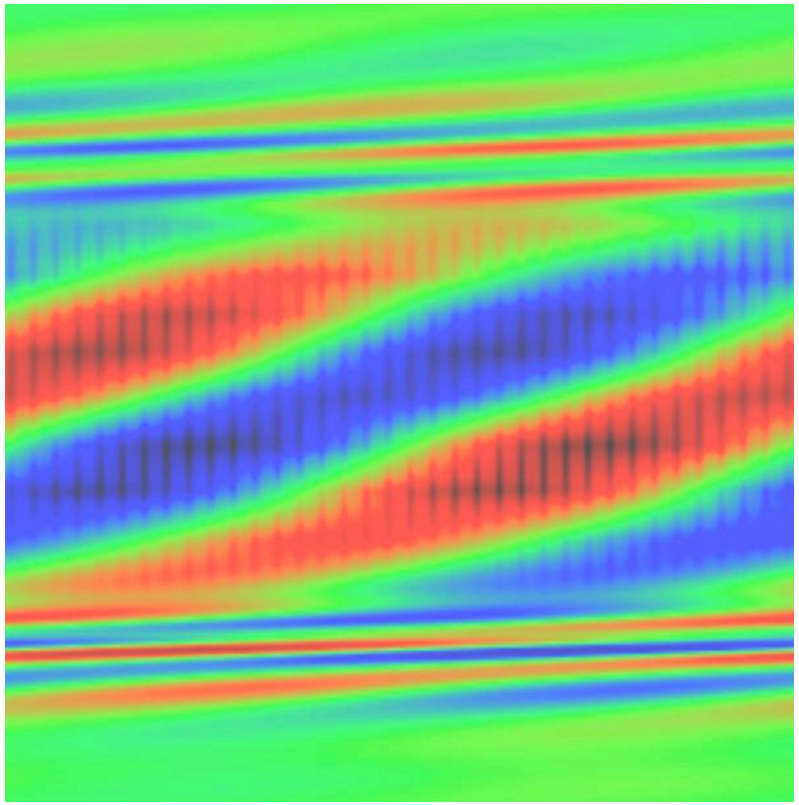
- At highest β_N, n =1 and 2 are unstable



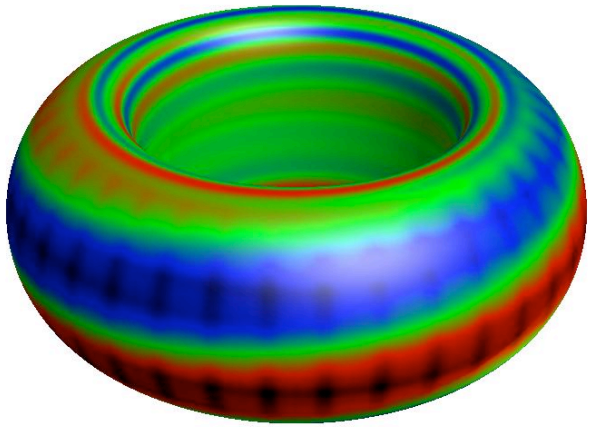
- DCON δW shows several modes with high response
  - Three n = 1 modes at high β_N
  - Two n = 2 modes at high β_N

Illustration of $B^n(\theta,\phi)$ on plasma surface from mmVALEN for ITER Scenario 4, $\beta_N = 3.92$

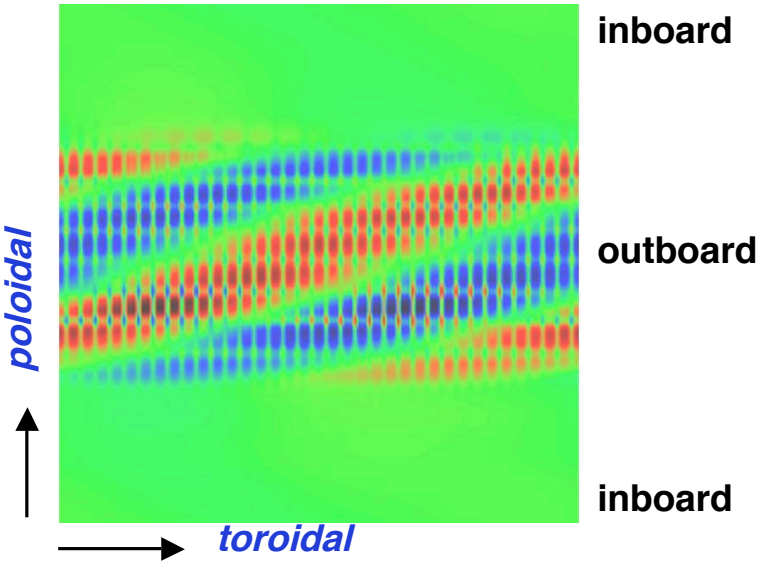
multi mode response (incl. wall), total B^n



B^n from wall, plasma



B^n from wall alone



- n = 1 eigenfunctions shown

J. Bialek