NSTX

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XP1144: RWM stabilization, control, and NTV rotation alteration of higher A ST targets

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NSTX Macrostability TSG Review

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PPPL

V1.2

XP1144: Aims to characterize RWM stabilization, control, and NTV rotation alteration of higher A ST targets

- Motivation
  - Next-step ST devices (and the planned upgrade of NSTX) aim to operate at higher aspect ratio (A) than usual NSTX values
  - Evaluate changes in RWM stabilization physics, RWM control, and NTV V_ϕ alteration to directly address R(11-2), IR(12-1) milestone tasks
- Goals / Approach
  - Utilize higher A plasmas developed by ASC TSG to study key n > 0 stability physics, control, and non-resonant NTV alteration
    - RWM stabilization physics: effect of A changes, plasma/plate gap, EP profile on marginally stable β_N, ω_ϕ profile
    - RWM control physics: Influence of proximity to plates, influence of snowflake divertor
    - Neoclassical toroidal viscosity: dedicated A scan to address explicit R(11-2) milestone task, IR(12-1) milestone
- Addresses
  - NSTX Research Milestones R(11-2), IR(12-1)
  - ITPA joint experiment MDC-2, MDC-17, MHD Working Group 7

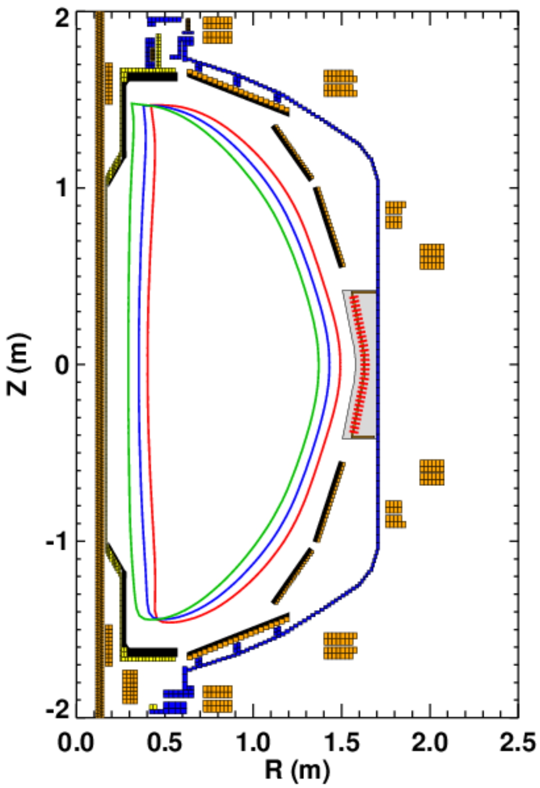
Investigate RWM stability physics, control, NTV at higher A most efficiently by starting from ASC target development

- Further target development
  - Where possible, run target attributes closest to next step STs and determine affect on stability (e.g. high κ, low l_i, snowflake divertor)
  - Generate "future ST" target comparison plasma
    - with most consistent parameters for "next-step" STs (stability challenge)
- RWM stabilization physics
  - Scan of A at fixed κ yields
    - Variation of plasma/plate distance
    - Variation of EP profile, ω_ϕ profile
  - Determine influence on RWM marginal boundary vs. ω_ϕ
  - Compare to A scan with fixed outer gap
  - Compare to "future ST" target plasma
- RWM control
  - Determine control alteration for A scan at fixed κ by examining change in RWM controllability, RWM marginal boundary vs. ω_ϕ
  - Compare control of "future ST" target with/without snowflake div.
- NTV plasma rotation alteration
  - Use both n = 2, n = 3 applied field if possible (broader NTV profile)
  - Run A scan with <u>fixed outer gap</u>, compare to A scan fixed κ
    - Make maximum A variation possible! (largest gaps possible)
- XP needs
  - Forum allocation: 1.0 run day

<u>ASC TSG XP1103 to develop higher A targets (S.P. Gerhardt)</u>

<u>Aspect ratio scan</u>

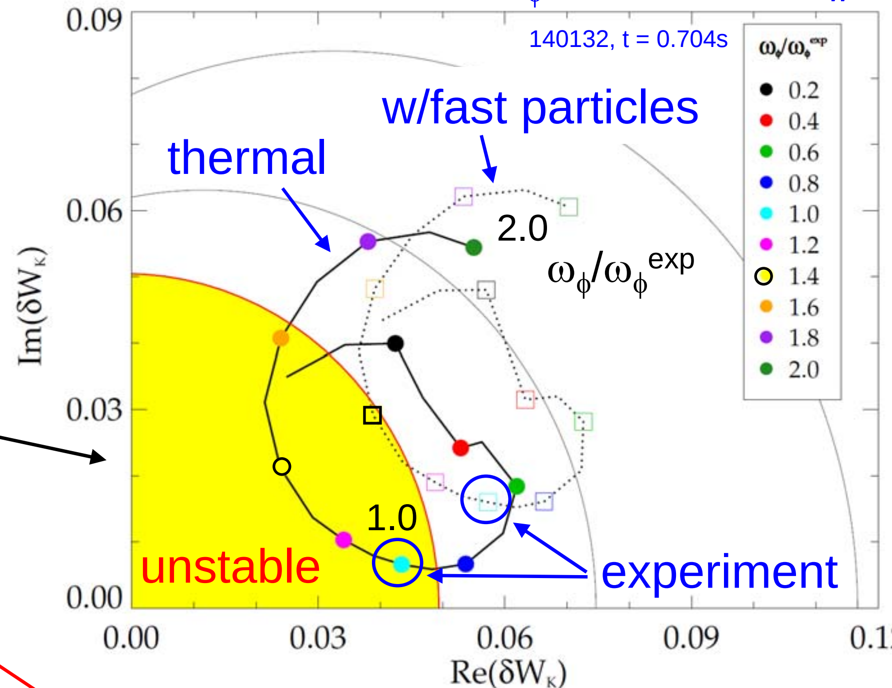
($1.53 < A < 1.74$, $\kappa \sim 2.7$)

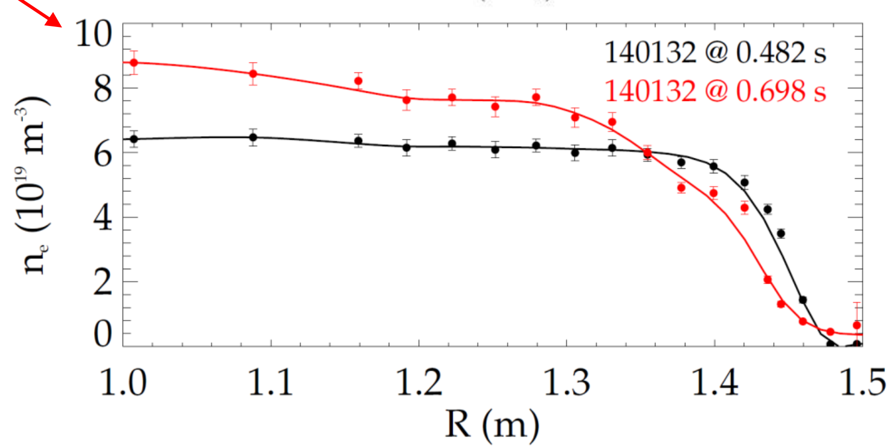


MISK calculations show reduced stability in low l_i target plasma as ω_ϕ is reduced, RWM instability is approached

- **Stability evolves**
  - MISK computation shows plasma to be stable at time of minimum l_i
  - Region of reduced stability vs. ω_ϕ found before RWM becomes unstable (l_i = 0.49)
    - Co-incident with a drop in edge density gradient – reduces kinetic stabilization
- **Investigate / compare to high β_N/l_i plasma evolution at increased A**
  - Ideal δW indicates less stability at higher A – do EPs compensate?

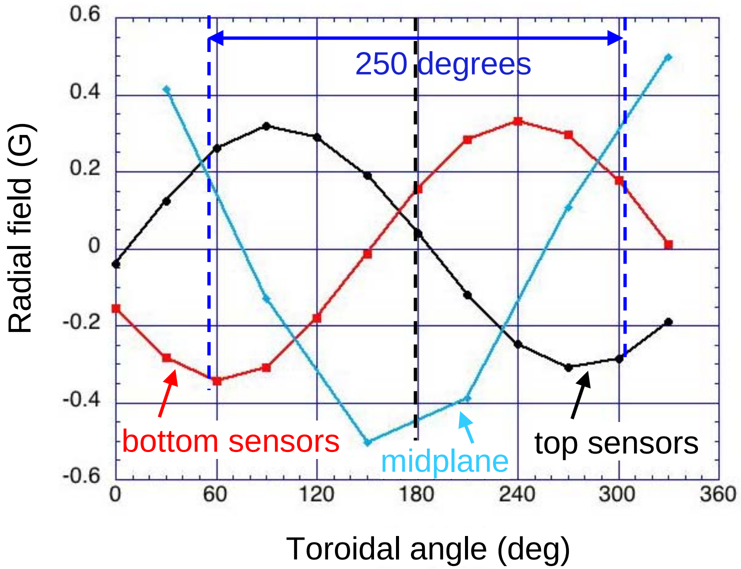
RWM stability vs. ω_ϕ (contours of $\gamma\tau_w$)

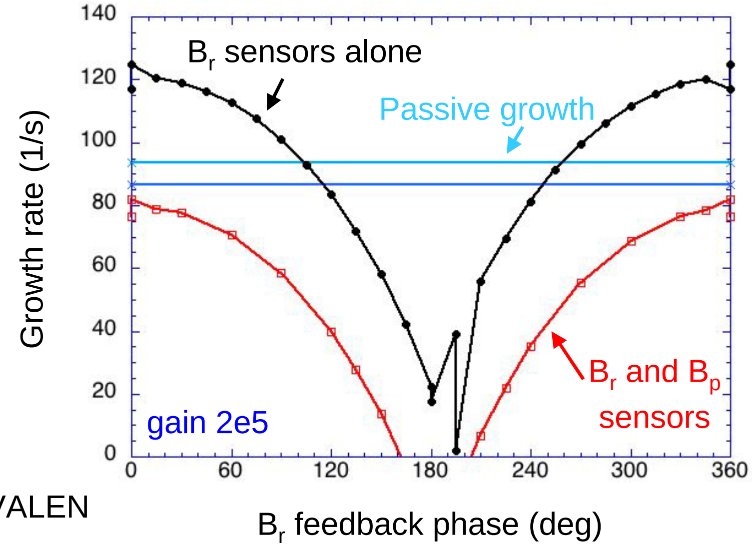




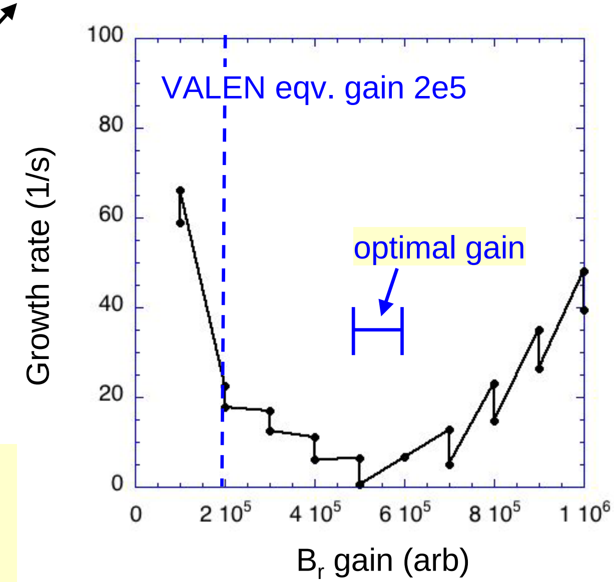
RWM feedback using upper/lower B_p and B_R sensors modeled and compared to experiment

Modeled B_r field at sensors and midplane





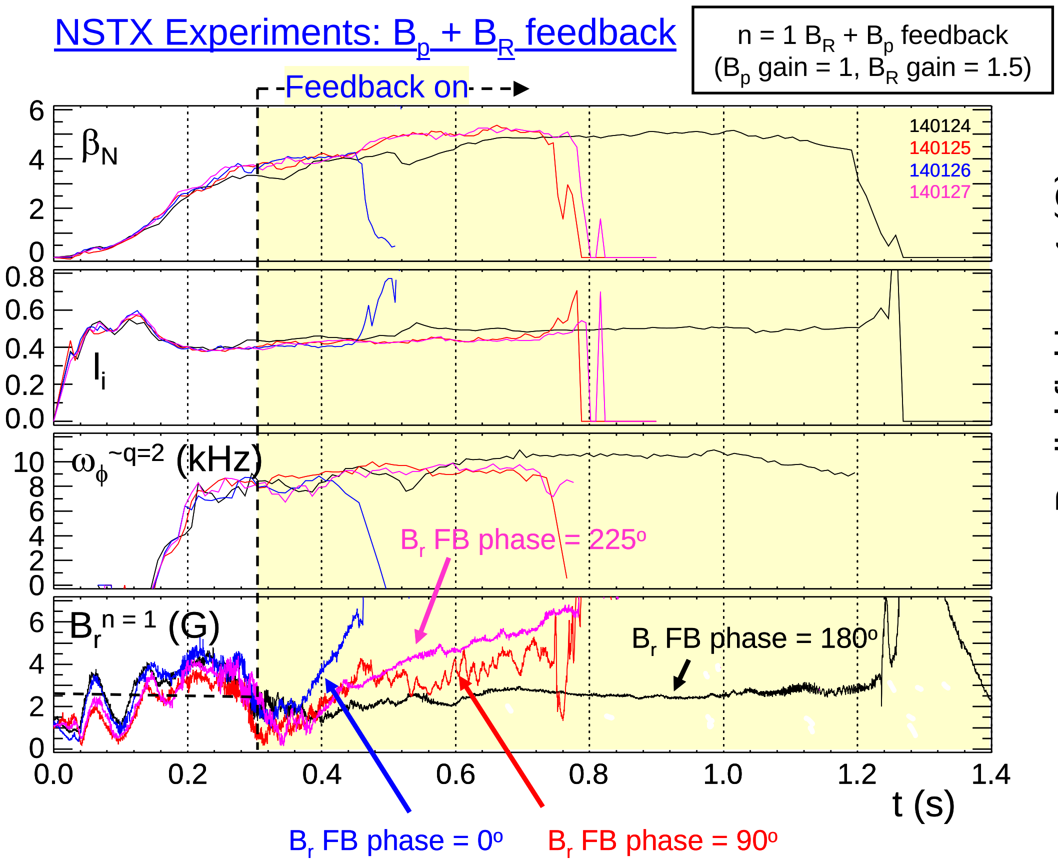
DCON, VALEN codes

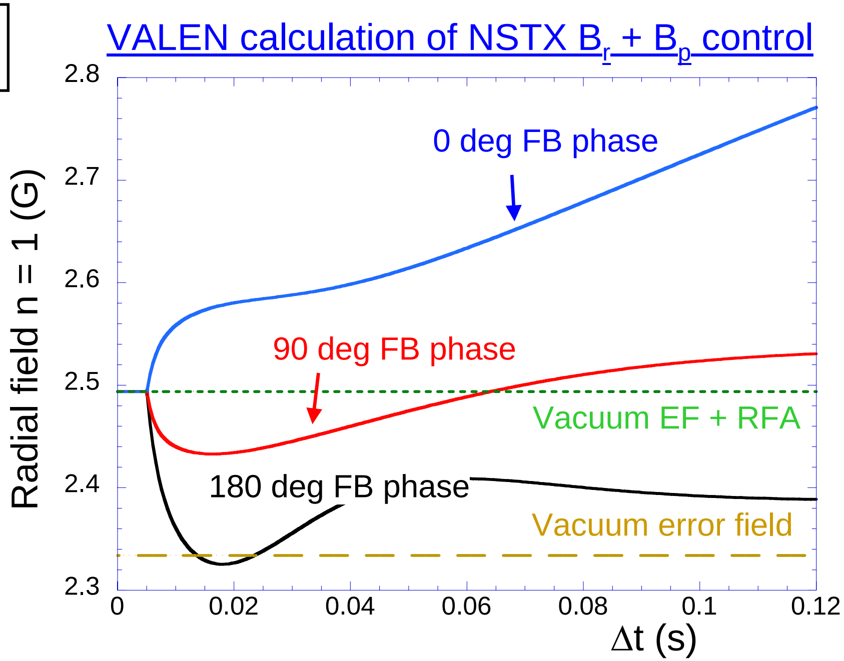


- Both B_r, B_p feedback contribute to active control
  - B_r mode structure and optimal feedback phase agrees with parameters used in experiment
  - B_r feedback alone provides stabilization for growth times down to ~ 10 ms with optimal gain
  - Physics of best feedback phase for B_p sensors in low l_i plasmas under investigation

Will results change significantly due to stability changes caused by A variation, plate proximity, edge eigenfunction changes due to snowflake divertor?

RWM B_r sensor n = 1 feedback phase variation shows superior settings when combined w/B_p sensors; good agreement w/theory so far



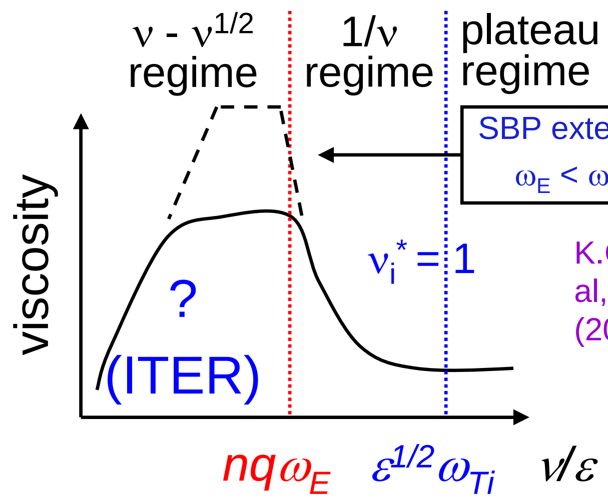


- Favorable B_p feedback settings, varied B_R settings
  - Positive/negative feedback produced at theoretically expected phase values

- VALEN calculation of B_r+B_p feedback follows XP
  - stable plasma (negative "s")
  - Now examining plasma response model variation
    - impact of "s", and diff. rotation ("α") on results
  - Will A variation, snowflake change results significantly?

NTV component of XP1144 will focus on measuring braking torque differences at higher A

- Understanding important for NSTX V_ϕ control, NSTX-U, and future devices
  - Primary scan: run A scan with fixed outer gap
  - Secondary scan: run A scan with fixed elongation
- Leverage with KSTAR experiment
  - Experiment MP2011-03-09-001 proposed and allocated run time on 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 (This XP)

Steady-state velocity (XP1062)

XP1144: RWM stabilization, control, and NTV rotation alteration of higher A ST targets – shot plan

Task	Number of Shots	optional
0) Plasma target development (6 shots)		
A) From XP1103 A scan at fixed κ, choose case with lowest l_i, highest κ, further decrease l_i, increase κ, adjust I_p for maximum β_N ("future ST" target configuration)	3	
B) Generate snowflake divertor in this case	3	
1) RWM stabilization physics (10 shots)		
(find marginal stability point; include low current AC field as desired for active MHD spectroscopy)		
A) Vary plasma rotation by n = 3 NTV, search for RWM marginal stability point at highest A	2	
B) Repeat scan (A) at lowest, and middle A values	4	
C) Vary plasma rotation in "future ST" target plasma configuration	2	
D) Vary plasma rotation in higher A target with snowflake divertor	2	
2) RWM n = 1 feedback control (higher A target) (9 shots)		
A) (if unstable RWM found in 1)): feedback using B_p + B_r sensors, best settings from XP1111	2	
B) (if unstable RWM found in 1)): feedback using B_p sensors alone, best settings from XP1111		2
C) (if unstable RWM not found in 1)): brief B_p sensor phase scan at "best gain" (from XP1111)	3	
D) Snowflake configuration: n = 1 FB or FB phase variation (depending on 1D)	4	
E) Lower A target comparison: n = 1 FB or FB phase variation (depending on 1B)		2
3) NTV scans (9 shots)		
A) n = 2, 3 applied field configurations, aimed for long pulse, 3 point A scan, outer gap fixed	6	
B) n = 2 or 3 applied field configuration, aimed for long pulse, 3 point A scan, kappa fixed	3	
	Total: 34	4

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XP1144: RWM stabilization, control, and NTV rotation alteration of higher A ST targets – Diagnostics, etc.

- Required diagnostics / capabilities
  - Independent RWM coil control allowing n = 1 feedback and n = 2, 3 pre-programmed field configurations
  - RWM PID feedback using B_p and B_r sensors
  - CHERS toroidal rotation measurement
  - Thomson scattering
  - MSE
  - Toroidal Mirnov array / between-shots spectrogram with toroidal mode number analysis
  - Diamagnetic loop

- Desired diagnostics
  - USXR, ME-SXR, BES
  - FIDA variants
  - FIReTip
  - Fast camera