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XP728: RWM active stabilization and optimization – ITER scenario

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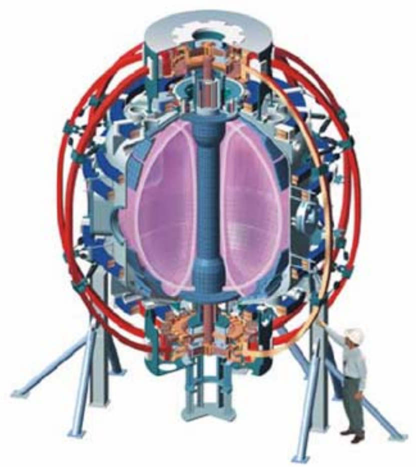


NSTX Results Review

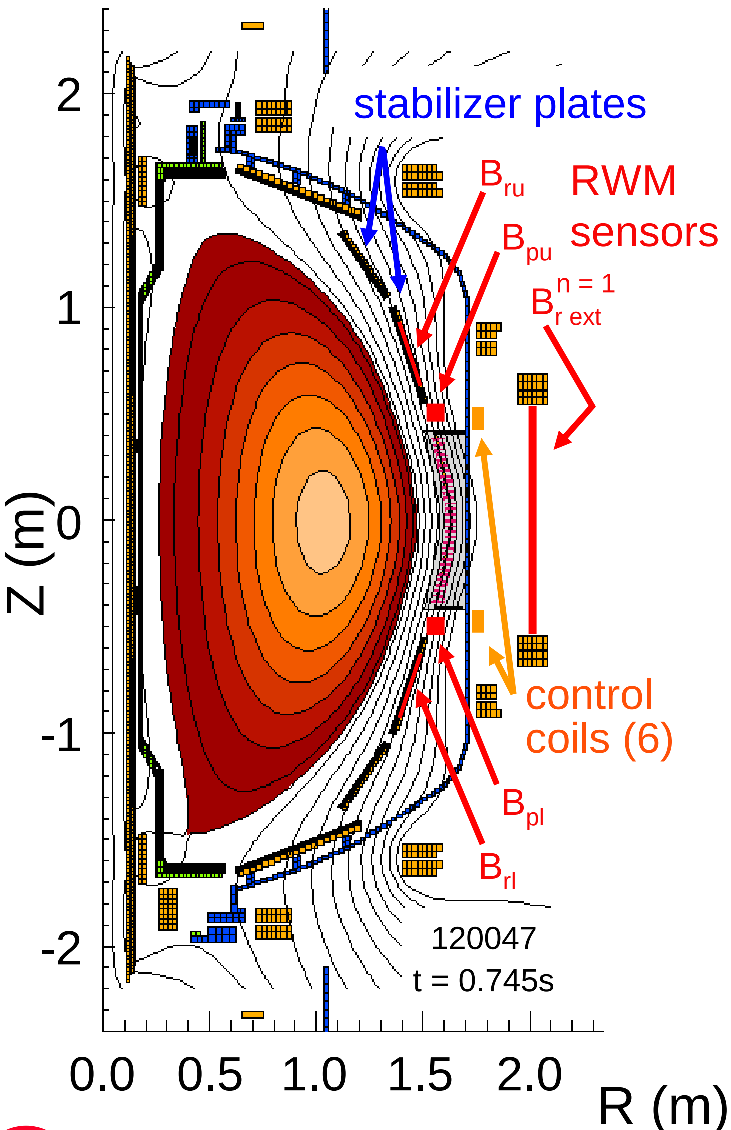
July 24th, 2007

Princeton Plasma Physics Laboratory

RWM feedback studied with expanded sensor set, reduced V_ϕ

- Goals
  - Investigate variations of control sensor combinations to optimize RWM stabilization at low plasma rotation, ω_ϕ (more robust, reach higher β_N)
    - Use upper/lower RWM B_r, B_p sensors for feedback (ran out of time in 2006)
    - Examine possible poloidal deformation of RWM during feedback
  - Investigate active stabilization of recent plasmas that exhibit unstable RWM activity leading to discharge termination at *high* ω_ϕ.
  - Explore possible stable region at $\omega_\phi < \omega_{*i}$ with feedback is turned off
  - Investigate RWM active stabilization of low ω_ϕ plasma with superposed time-averaged n = 1 error field correction + n = 3 magnetic braking
    - (Fredrickson, Garofalo suggestion from 2006, but no run time)
  - Measure n =2-3 RFA, attempt to destabilize n = 2 RWM with n = 1 stable
  - Introduce and study effect of applied time delay on feedback (ITER support)
    - Depends on control system time delay capability in 2007
- Addresses
  - **NSTX milestone R(07-2),** NSTX PAC request
  - ITPA experiment MDC-2, ITER issue card RWM-1, USBPO MHD task

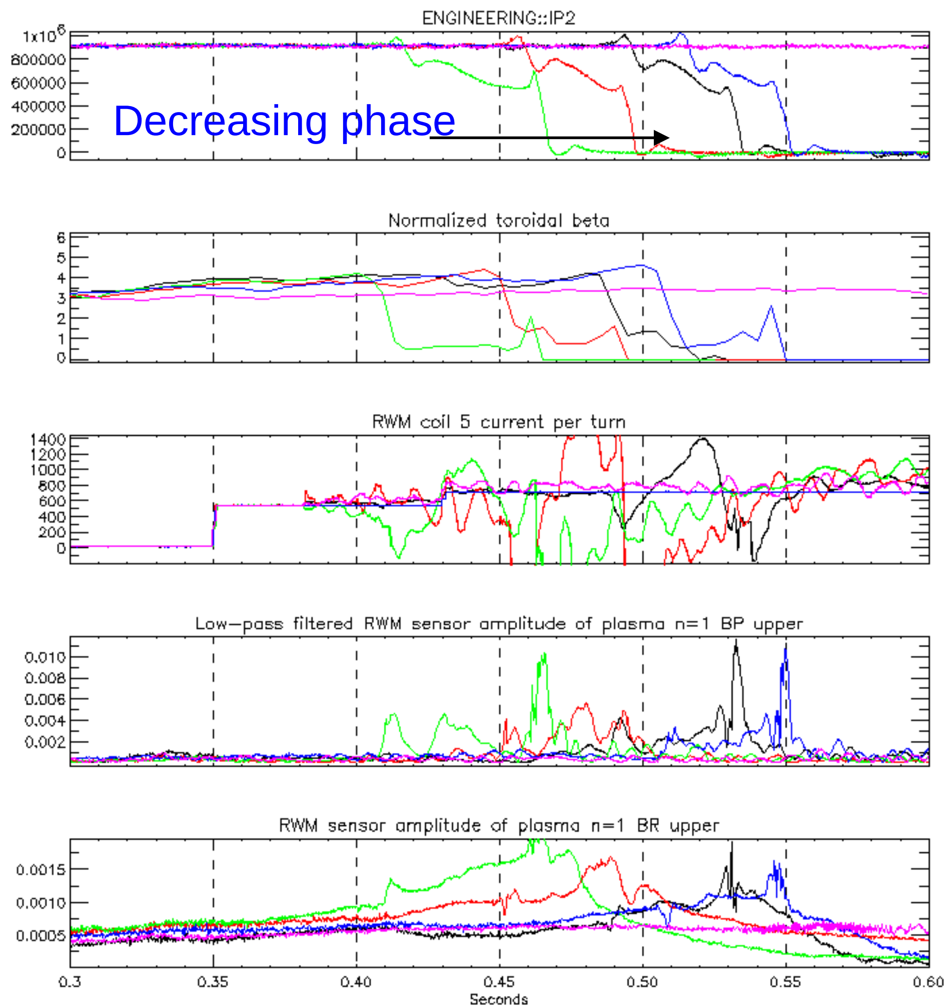
RWM active feedback system now uses more sensors



- Stabilizer plates for kink mode stabilization
- External midplane control coil closely coupled to vacuum vessel
  - Similar to ITER port coil designs
- New sensor combinations
  - B_{pu} + B_{pl} (used B_{pu} in past)
  - B_{ru}; B_{ru} + B_{rl}
  - B_{pu} + B_{pl} with spatial offset
  - All sensors in combination

Feedback phase continues to be a key feedback variable

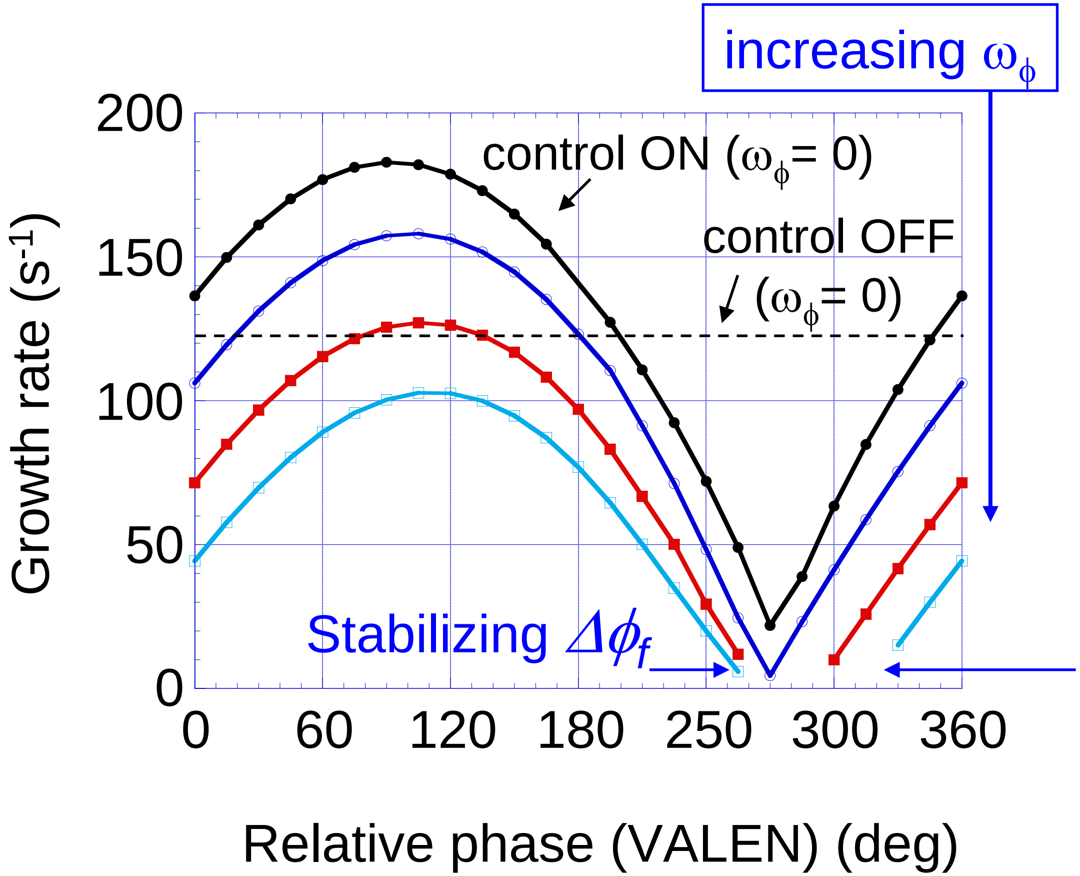
Feedback phase scan with $B_p^{upper} + B_p^{lower}$



- Recreated past active feedback with B_p^{upper} sensors
  - Plasma rotation slowed using n = 3 non-resonant magnetic braking
- Completed feedback phase scan using with $B_p^{lower} + B_p^{upper}$ sensors
- Key detail in mode dynamics during feedback – further analysis needed
  - Poloidal deformation of mode reported in 2006 PRL seen again with upper sensors; changed by upper/lower sensor feedback

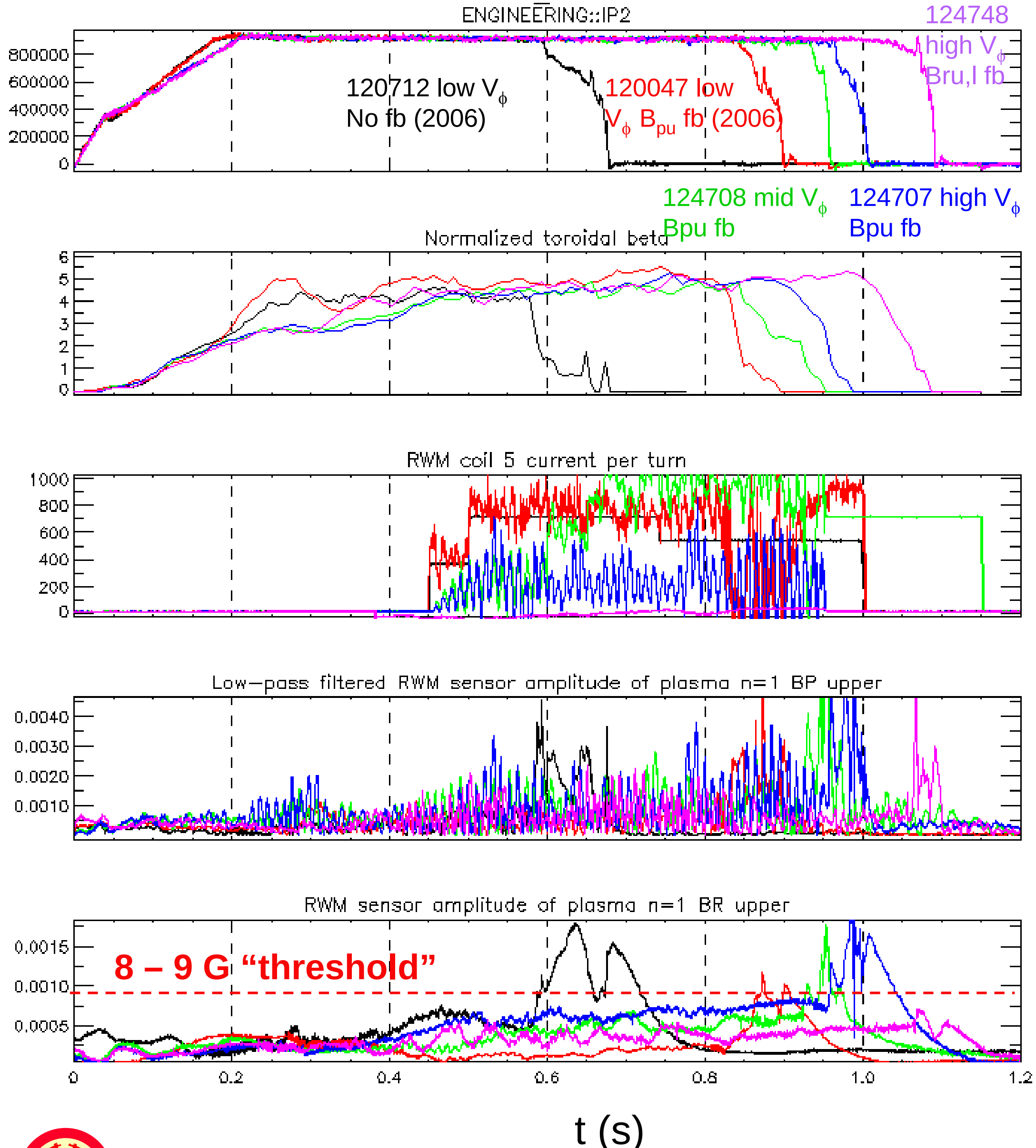
NSTX

Past VALEN-3D analysis of optimal relative phase $\Delta\phi_f$ for active control being expanded for XP728



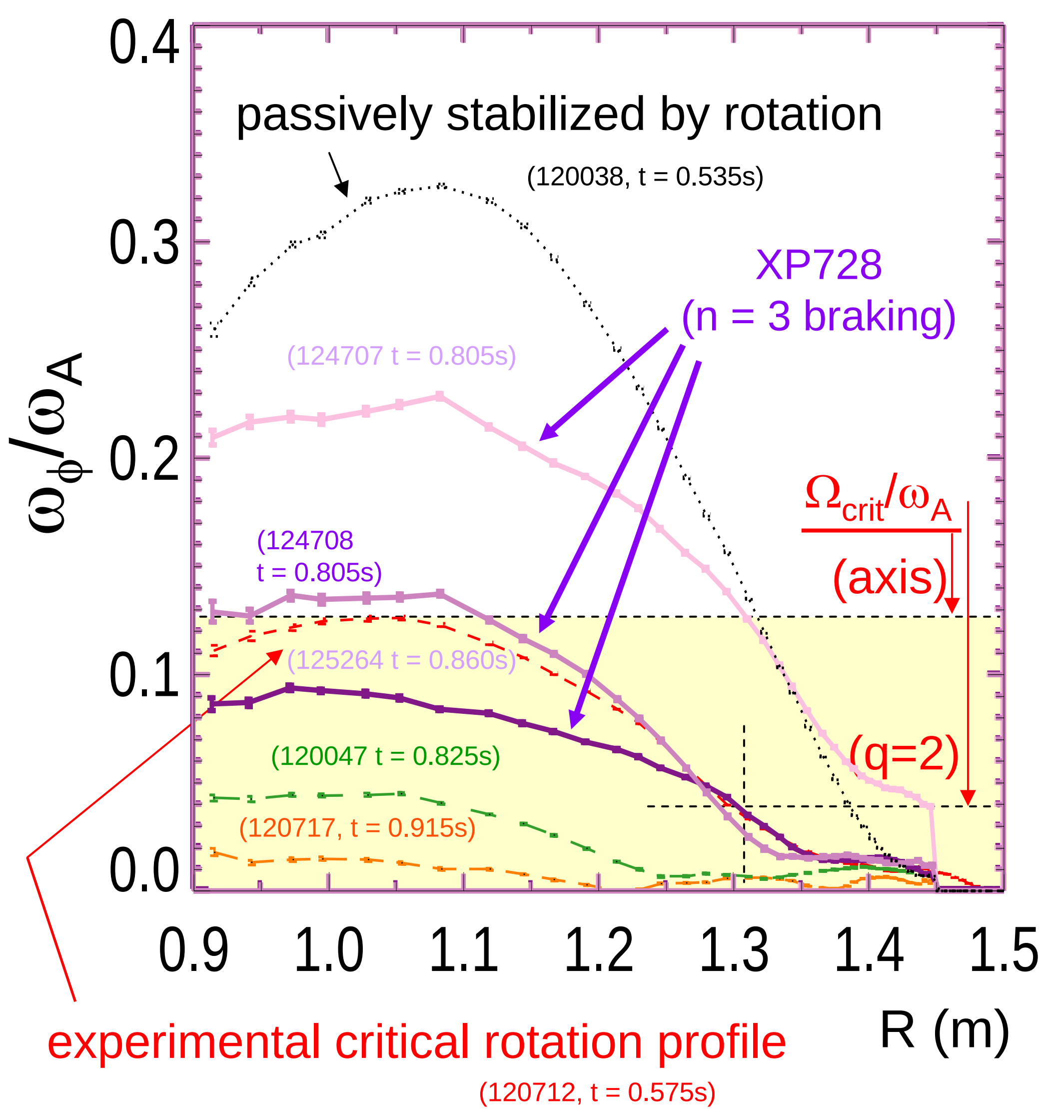
- Past results ("midplane sensors")
  - Unfavorable $\Delta\phi_f$ drives mode growth
  - Stable range of $\Delta\phi_f$ increases with increasing ω_ϕ
- NEW analysis uses actual experimental sensor positions
  - Stabilization found without the need for plasma rotation (B_p sensors)
  - Further calculations will model all sensor combinations used

Upper / lower B_r sensors for feedback for first time



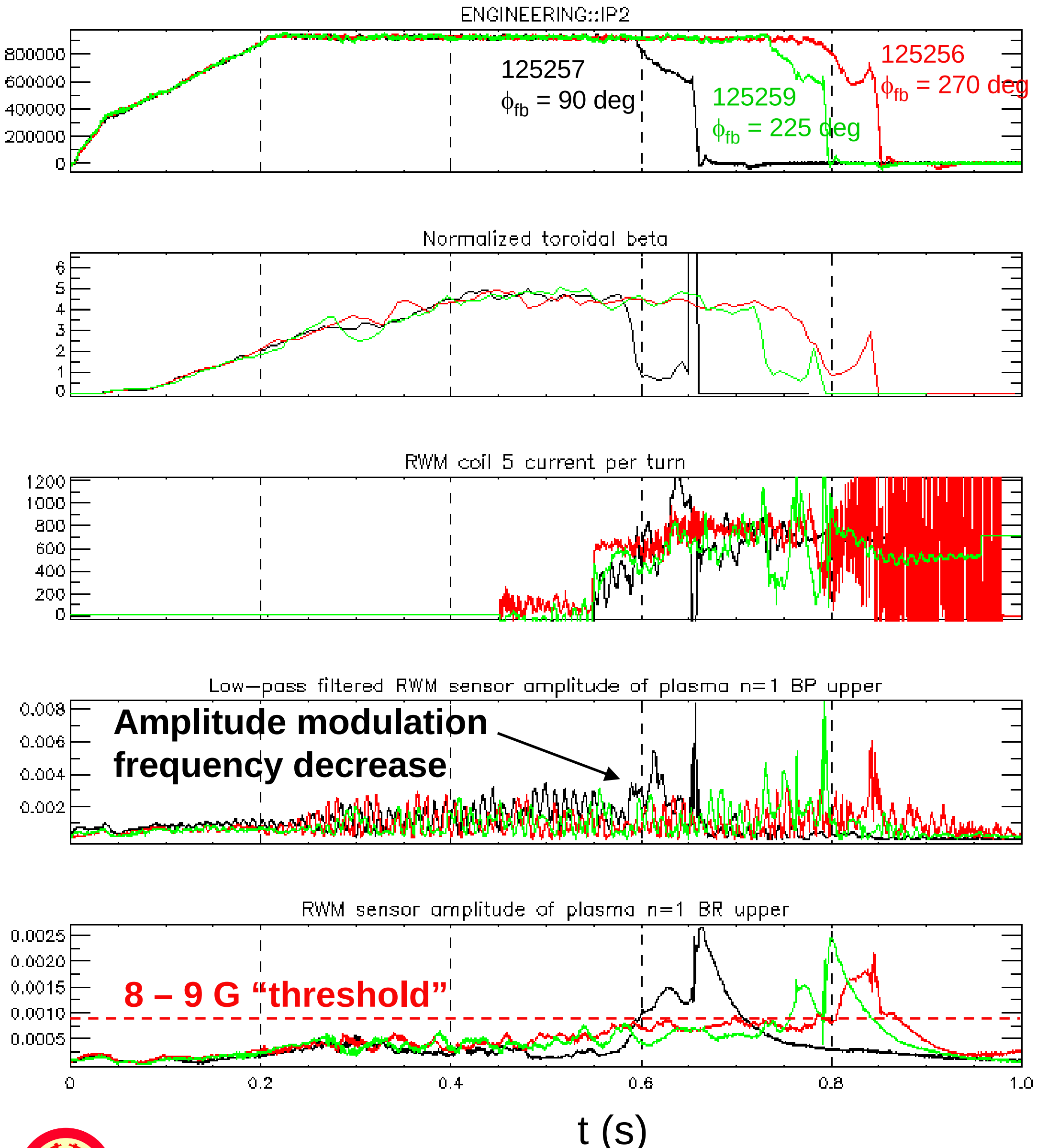
- Determined feedback phase for best response with Br^{upper} + Br^{lower} sensors
  - Detailed feedback dynamics, apparent poloidal deformation of mode
- Maximum n = 1 B_r amplitude plasma can tolerate ~ 8 – 9 G
  - Analogous n = 1 B_p sensor value of about 15–20 G
- Feedback using Br^{upper} + Br^{lower} sensors at high rotation available as tool for other XPs

XP728 filled in rotation profiles produced during RWM feedback



- 2007 data - range of rotation profiles for RWM analysis
  - Broader ω_ϕ in some cases
  - Created RWM *passively* stable plasma with zero rotation at q = 2 surface
    - Supports past NSTX data showing rotation profile important to stability, not just at single q surface
  - Unstable RWM observed at high rotation (~ 40 kHz core)
    - Is the mode observed an RWM?
- No indication, so far, of stable low rotation state, feedback off
  - Rotation may not have been slowed enough; analysis of trapped particle precession stabilization may tell

Further sensor combinations used for feedback



- Feedback phase scan for $B_p^{lower} + B_p^{upper}$ sensor average, 180 degree spatial offset
  - favorable 270 degree feedback phase expected by simple RWM theory
  - B_p sensor amplitude modulation decreases in frequency during mode onset
- Feedback with full B_r, B_p sensor set
  - XP702 – plasma stable at high V_ϕ to 1.3s with feedback
  - Similar plasma showed instability – again showing mode amplitude modulation decrease in frequency