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Macroscopic Stability TSG XP status mid-run 2008

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for the

NSTX Macroscopic Stability Topical Science Group

NSTX mid-run assessment

Princeton Plasma Physics Laboratory

April 16th, 2008

College W&M
Colorado Sch Mines
Columbia U
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General Atomics
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Hebrew U
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RRC Kurchatov Inst
TRINITI
KBSI
KAIST
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

MHD XPs for 2008 guided by Milestones, ITPA needs

- General mission statement (2008 Forum)
  - *Develop physics understanding applicable to the ST development path and to tokamaks in general, leveraged by the unique low-A and high-β operational regime of NSTX*
- Priorities (summarized in two lines – 2008 Forum)
  - Assess active and passive RWM stabilization physics for improved mode control (NSTX Milestone R09-1)
  - Evaluate MHD sources of plasma viscosity and assess the impact of plasma rotation on plasma stability, including NTM (Joule milestone)
- XPs serve NSTX and DOE (Joule) Milestones, ITPA joint XPs, ITER support, several joint experiments / comparisons
  - 80% support Joule milestone
  - 80% support ITPA / ITER

Macroscopic MHD TSG XPs – Forum 2008 Priority

- XP Idea presentations requesting run time

6.5 - 7 days

- Beta ramp down 2/1 tearing mode: study of self-stabilization (LaHaye) 1.0 days
  - Rotation dependence of 2/1 NTM thresholds (Buttery)
- Active RWM stabilization optimization and ITER support (Sabbagh) 1.0 days
  - SXR tomography of neon-seeded RWM stabilized plasmas (Tritz) 0.5 days
- Comparison of NTV among tokamaks (n = 2 fields, ν_i scaling) (Sabbagh) 1.0 days
  - Testing NTV theory of error field penetration (Buttery)
- Studies of the 3/2 NTM: Rotation and Beta Rampdown (Gerhardt/Gates) 1.0 – 1.5 days
- RWM stabilization physics – comparison to theory (Berkery) 1.5 days
  - DIII-D/NSTX RWM joint XP – stability vs. A, rotation profile, ν_i (Berkery)
  - Parametric dependence RWM damping in rotating plasmas (Reimerdes)
- n=2 intrinsic error fields and RWM critical rotation (Gerhardt/Menard) 1.0 days

9 days

- Island-induced neoclassical toroidal viscosity (NTV) (Sabbagh/Shaing) 1.0 days
- Deformation of RWM and multi-mode characteristics (Sabbagh) 1.0 days
  - Assessment of non-rigidity in RWM feedback (Okabayashi)
- Measurement of Halo Currents in the Lower Divertor (Gerhardt) piggyback

Run time guidance: 6.5 – 8.0 run days

Run days: 15.5 - 16.5

Macroscopic MHD TSG 2008 XPs – Status 4/14/08

Group review | Team review | Scheduled | Has run time

- XP Idea presentations requesting run time

base

- 801: Beta ramp down 2/1 tearing mode: self-stabilization study (LaHaye) 1.0 days
- 810: n = 1 error field, V_ϕ influence on 2/1 NTM thresholds (Buttery) 0.5 days
- 802: Active RWM stabilization optimization and ITER support (Sabbagh) 1.0 days
- 803: SXR tomography of neon-seeded RWM stabilized plasmas (Tritz) piggyback
- 804: Comparison of NTV among tokamaks (n = 2 fields, ν_i) (Sabbagh) 1.0 days
  - Testing NTV theory of error field penetration (Buttery)
- ###: Studies of the 3/2 NTM: Rotation and Beta Rampdown (Gerhardt) 1.0 – 1.5 days
- 830: RWM stabilization physics – comparison to theory (Berkery) 1.5 days
  - DIII-D/NSTX RWM joint XP – stability vs. A, rotation profile, ν_i (Berkery)
  - Parametric dependence RWM damping in rotating plasmas (Reimerdes)
- 805: n=2 intrinsic error fields and RWM critical rotation (Gerhardt/JEM) 1.0 days

extended

- 743: Island-induced neoclassical toroidal viscosity (NTV) (SAS/Shaing) 1.0 days
- ###: Deformation of RWM and multi-mode characteristics (Sabbagh) 1.0 days
  - Assessment of non-rigidity in RWM feedback (Okabayashi)
- Measurement of Halo Currents in the Lower Divertor (Gerhardt) piggyback
- 818: ELM mitigation with midplane control coils (SAS/JKP/RM/SG) 3.0 days

XP801 examines the small island physics of 2/1 NTM

- Goal / Approach
  - Trigger the 2/1 mode, then step down NB power to restabilize mode.
    - This was accomplished in 1 post-lithium shot in CY2007 run
  - Data to be compared with DIII-D 2/1 rampdown data.
  - Key to i) Stay in H-mode and & ii) Avoid mode locking before restabilizing.
  - Vary the rotation with n = 3 braking, and vary "drive" with an I_P scan.
- Status
  - This was essentially the first XP of the year, and was plagued with technical problems (NBI, ground loops,…).
  - A number of β ramp-down attempts were completed, all of which ended with a mode-lock before island was restabilized.
- Plan
  - Return to XP - use EF correction in order to allow a lower locking threshold
    - These techniques are now being optimized in the MHD (XP 802) and ASC groups (XP 823) with improved feedback control.
  - Share 1 run day with continuation of XP810 – run post-lithium to reduce MHD

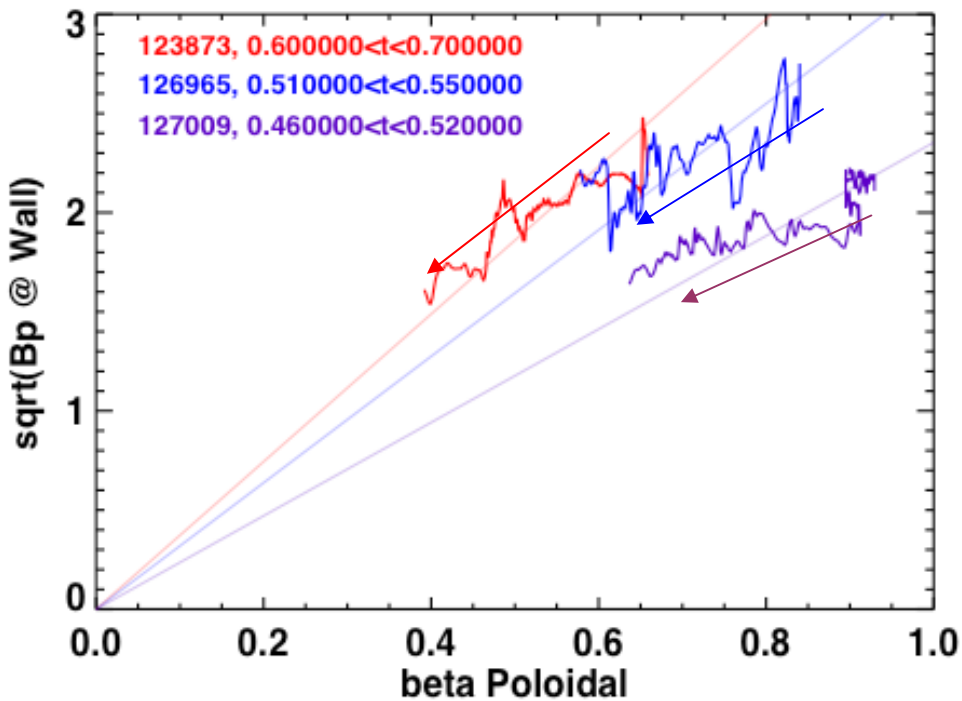
Data collected was useful for demonstrating the neoclassical nature of the mode

- NTM should have island width proportional to β_P

$$w \propto \sqrt{\tilde{B}_P}$$

$$w \propto \beta_P$$

Arrows Indicate Direction of Time



123873: Survived into β ramp-down phase, re-stabilized in CY2007

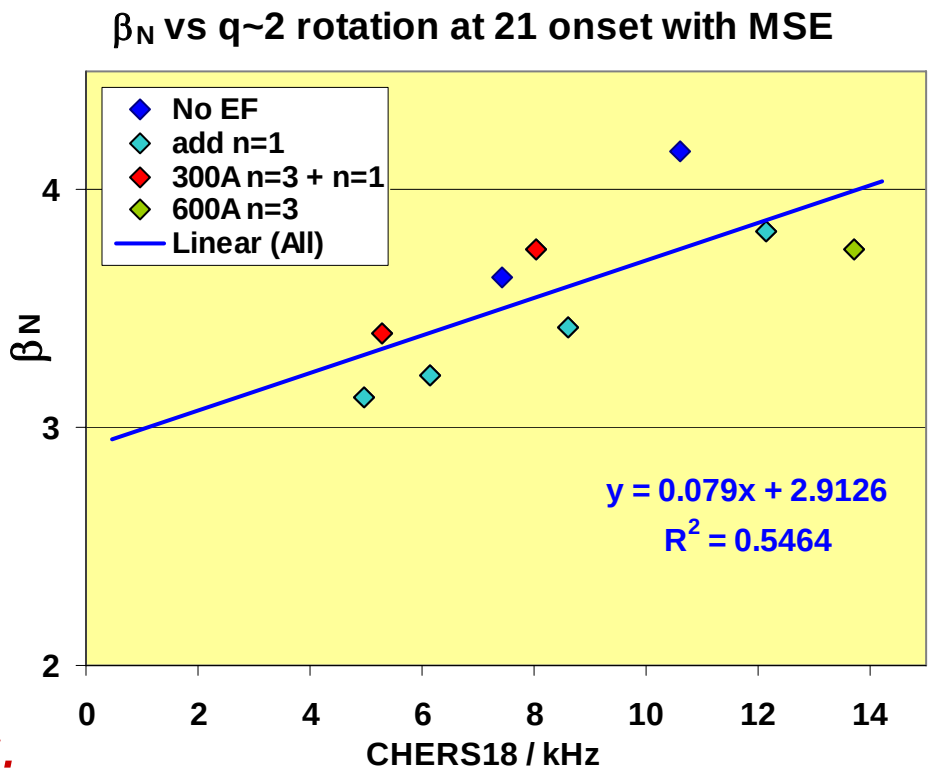
126965, 127009: Locked in CY2008

XP810 Examining role of n=1 error fields at high and low rotation

- Goal / Approach
  - Trigger the 2/1 mode at high and low rotation, with and without n =1 error field
  - Maintain H-mode and avoid mode-locking
  - Determine if the threshold in β_N changes…important for assesing role of EF in plasmas without momentum input (read: ITER)
- Status
  - Limited data collected, lack of error field correction made interpretation difficult
    - This was essentially the second run day of the year, plagued with technical problems
  - Beta ramp-down techniques to stabilize mode implemented, mode locking problems
    - Possibly related to machine conditions and intrinsic error fields
  - 4 point 2/1 NTM onset scan obtained vs. n=1 field
    - Error fields act to lower rotation and decrease NTM β threshold
  - 2 point scan of n=1 field obtained with modest n=3 braking
  - ***Scope very limited by available time - higher n=3 & n=1 levels desired to explore key question – is error field sensitivity worse at low rotation?***
- Plan
  - Return and complete XP, with well-conditioned machine and n = 1 feedback capability to allow error field correction if desired

XP810 Initial results – lower β_N threshold for 2/1 mode with n = 1 field applied

- Preliminary onset scan obtained with n=1 fields & 2 beam recipe…
- …but very limited data with n=1 applied when lowering rotation from n=3 braking…
  - ***(this was main objective)***
- *Nevertheless, useful extension of present NSTX database to get at rotation vs. rotation shear issue…*

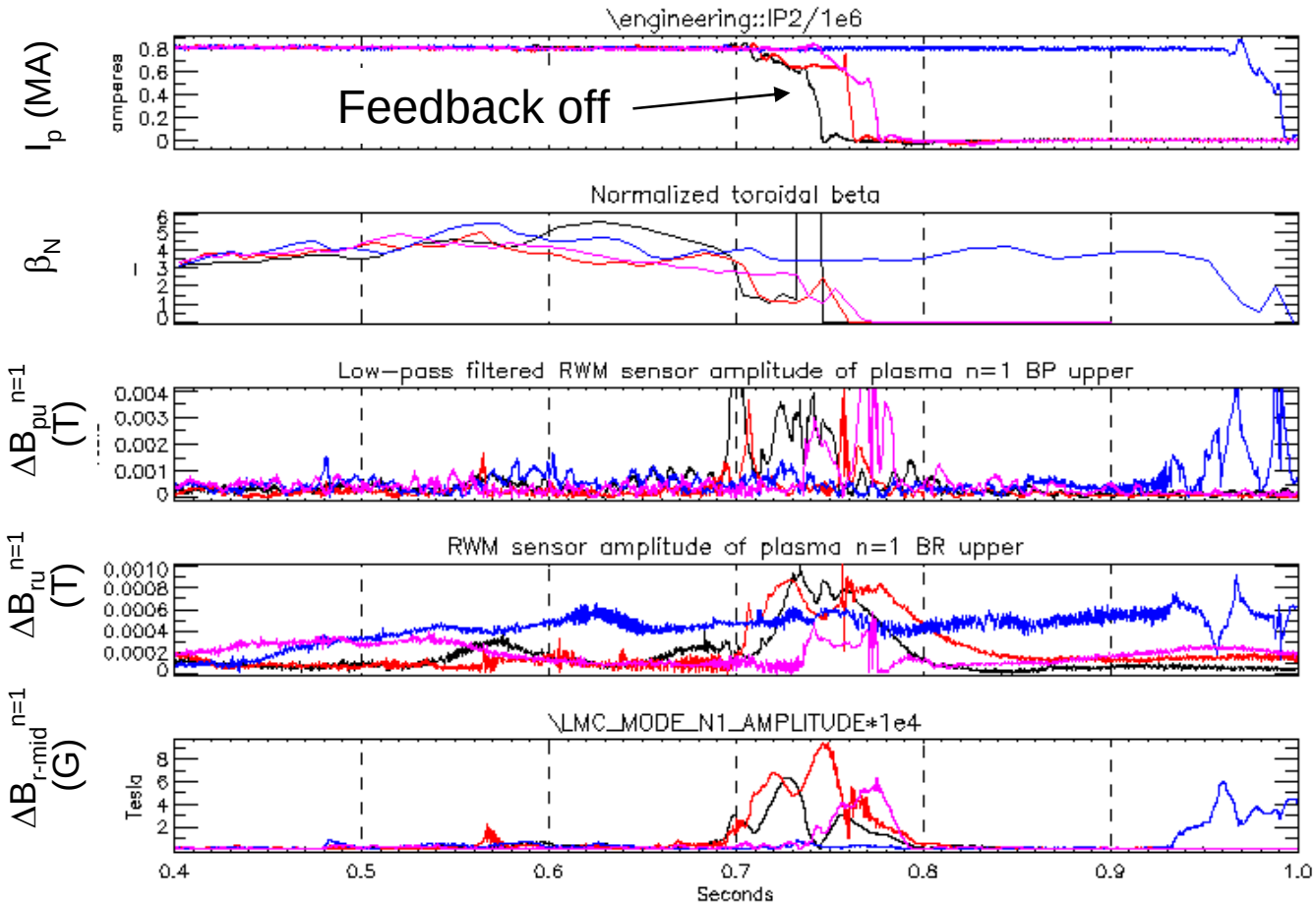


R. Buttery

XP802 RWM feedback Optimization - good initial run

- Goal / Approach
  - Alter active control configuration to achieve highly reliable RWM stabilization at various plasma rotation, ω_ϕ
    - Upper/lower RWM B_r, B_p sensors, follow from best CY2007 feedback settings
    - Determine if stable, low $\omega_\phi < \omega_{*i}$ operation exists with feedback gated off
    - If achieved, control system open as a tool for all NSTX XPs as desired
  - Specific ITER support requests (not yet run)
    - Determine impact of a large toroidal gap on active RWM stabilization to simulate ITER port plug coil geometry (take out one of six control coils)
    - Study effect of applied time delay on feedback
- Status
  - Rotating (~ V_ϕ) n = 1 mode activity stronger than post-lithium run last year
  - $B_{pu,l}$ sensor feedback successful, good statistics, relatively broad V_ϕ created
    - Neon puff taken on one shot to better diagnose RWM (K. Tritz XP803 piggyback)
  - $B_{ru,l}$ sensor feedback showed n = 1 amplitude successfully reduced
    - Necessary but not sufficient for mode stabilization - need more understanding here
- Plan
  - Complete shot list in plasma target with reduced n = 1 rotating mode activity

$B_{ru,l}$ sensor feedback- n = 1 amplitude successfully reduced



n = 1 B_r feedback (Gain = 1.5)

128479 - no feedback

128484 - 270° phase

128487 – 270° phase
0.2s baseline re-zero

128486 – 45° phase

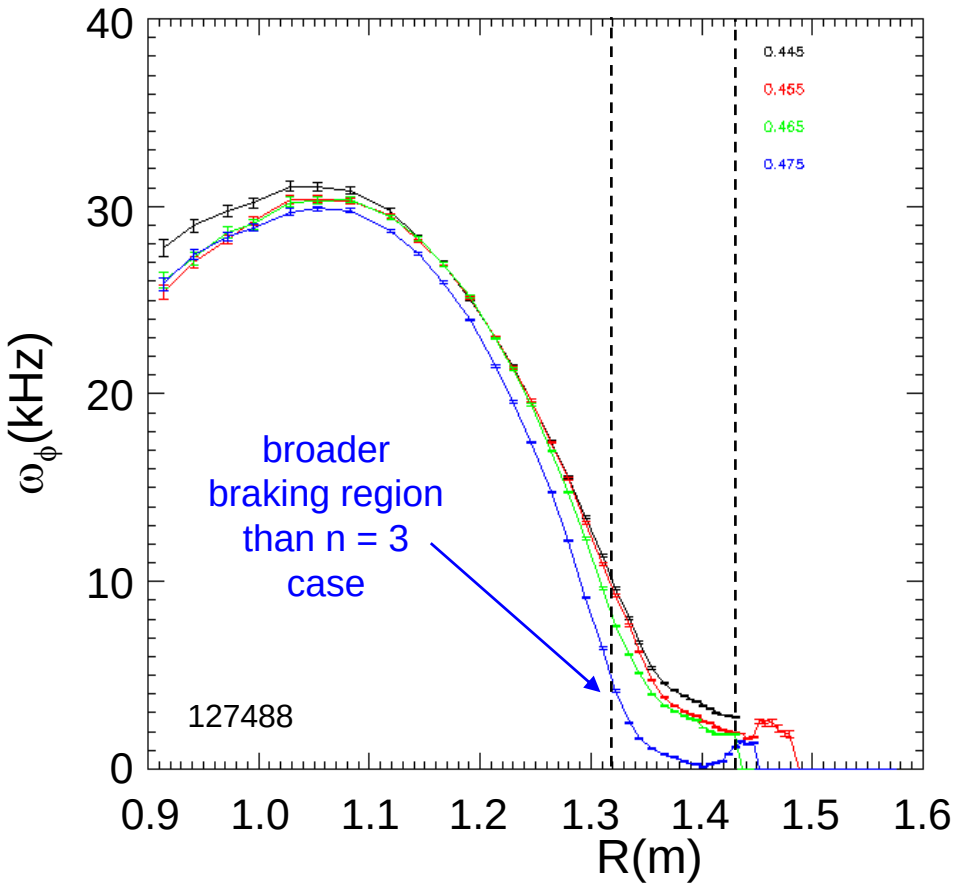
- Analyze role of n = 1 B_r amplitude in stabilization
  - Necessary to keep < 10G, not sufficient for RWM stability
  - Influence on n = 1 rotating mode unclear
    - Changing B_r re-zero time didn't make large difference in pulse length

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

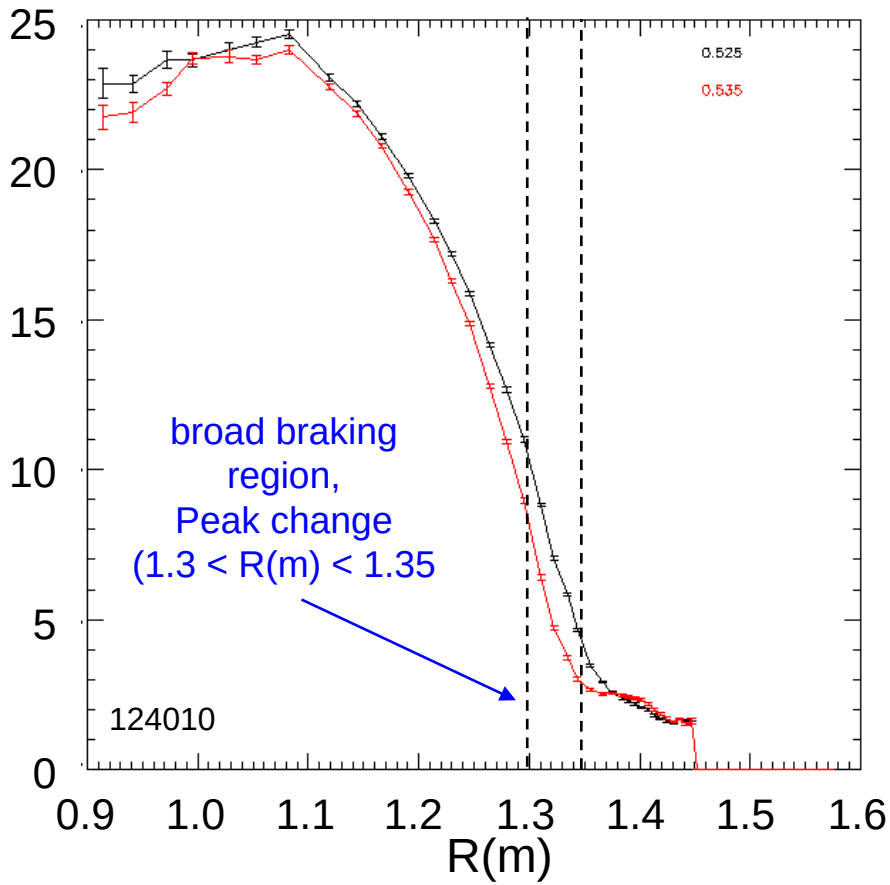
- Goals
  - Compare NTV results/analysis on NSTX to other devices (MAST, JET, etc.)
  - Test NTV theory for n = 2 applied field configuration
    - n = 2 may be best for comparison to other devices (n = 1 strongest resonant rotation damping, n = 3 weak in some devices, many machines run n = 2)
    - 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
- Status
  - Inferior plasma conditions led to many lost shots during startup
  - Regardless, good data taken for ~ 7 shots!
    - n = 2 braking clearly demonstrated, braking profile established
- Plans
  - Complete shot list by varying collisionality – operation after lithium deposition

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)

XP805: Designed to Isolate the Presence of an n=2 Error Field

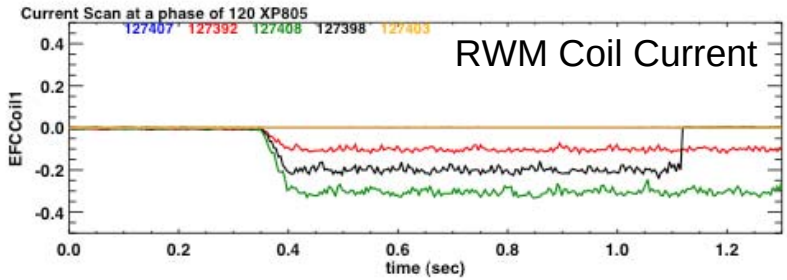
- Goal / Approach
  - Apply n=2 error field of varying phases and magntitude
  - Look for asymmetric response in (and increase of) pulse length and plasma rotation.
  - Mimics procedure that has found the n=3 EF in XP701, XP823
- Status
  - Day was plagued by irreproducible startup and early MHD.
  - Two phase scans were completed:
    - 150A: No strong effect on performance
    - 300 A: Some indication of a favorable applied field phase
- Plan
  - Run remainder of XP in tandem with the other EF proposal (XP823) to benefit from similar discharges and methods.
  - 1/2 day on schedule in last week of April

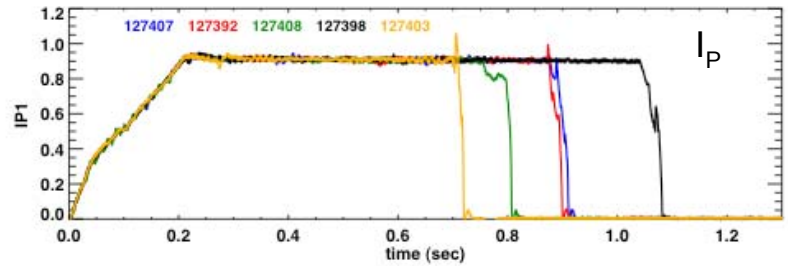
Evidence of n = 2 correcting phase found, needs confirmation

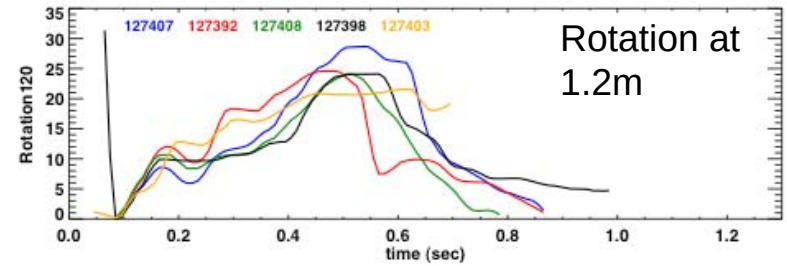
Consider Shot 127398

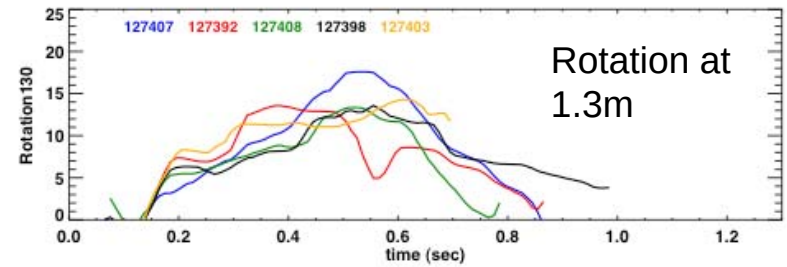
- Longest fiducial up to that date
- Rotation increases across the profile when field is applied
- Tolerates the rotating mode for longer

Need to confirm this trend!









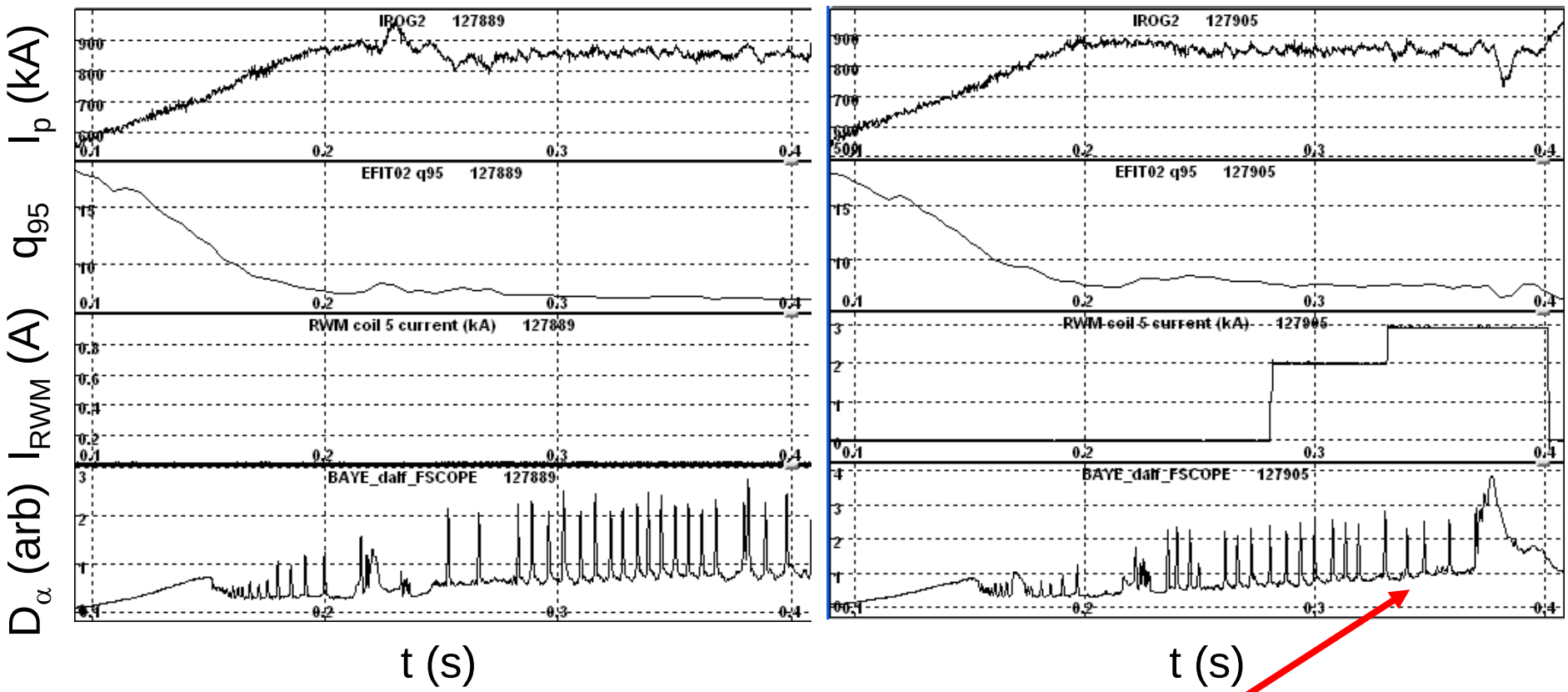
XP818: Exploratory approach to finding ELM mitigation solution with midplane non-axisymmetric coils

- Goal / Approach
  - Demonstration of ELM mitigation with NSTX midplane RWM coil set
  - Target development: (i) low $q_{95} < 6$; (ii) swept q_{95}
  - Application of DC fields (broader *n* spectrum, new 2008 capabilities)
    - New combined odd/even parity field (theoretical favorite $n = 2 + 3$ field)
    - New even parity field (dominant $n = 2$) created with new RWM coil patch panel
  - Application of AC fields
- Status
  - ELMs not fully mitigated; PHAT ELMs created in some cases
  - n = 2 + 3 configuration was not particularly favorable
    - PHAT ELMs produced in other field configurations
  - (aside) Good non-resonant and resonant magnetic braking detail shown
- Plans
  - Re-run most favorable cases in lower recycling conditions – post-lithium run

ELMs not fully mitigated by n = 2 + 3 field; frequency decreased

ELM target control shot (no n > 1 field,)

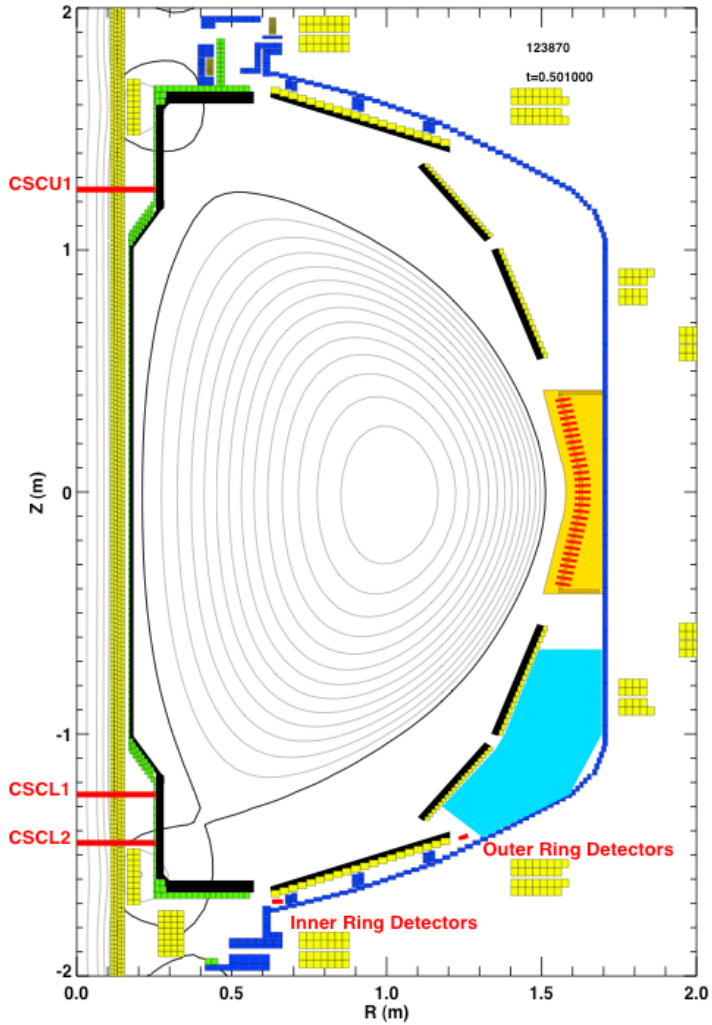
n = 2+3 field, 2.0 – 3.0kA peak RWM current



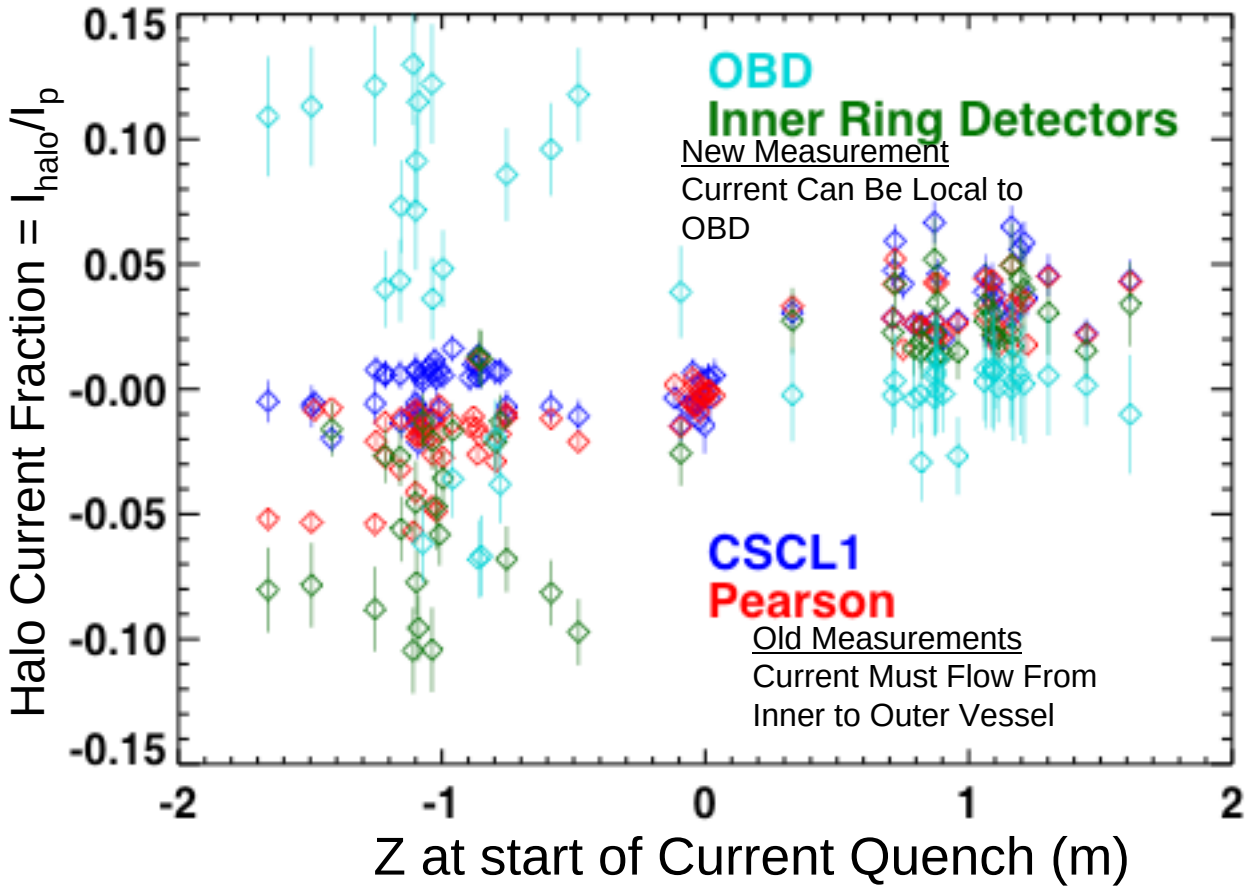
- Decrease in ELM frequency at maximum applied field
- Continue to investigate physical cause for changes in ELM behavior
  - Results consistent with Chirikov parameter > 1 being necessary, not sufficient condition for ELM mitigation; but could be due to different physics

Upgraded Halo Current Diagnostics Significantly Improve Measurements

- Method
  - Array of 12 B_T sensors
    - "Inner Ring" Inside of OBD
    - "Outer Ring" Outside of OBD
  - Treat as sections of a partial rogowski coil
  - Use in combination with existing measurements
- Status
  - Collecting data on every shot
  - New Sensors Increase the HCD estimate by factor of two
    - HCF much larger when current path doesn't include the CHI buswork
- Plan: group suggests dedicated XP - examine
  - halo current vs. plasma current
  - halo current fraction vs. diamag. flux (β)



New Sensors Increase the Halo Current Fraction by a Factor of Two



Interpretation: HCF much larger when current path doesn't include the CHI buswork

Suggestions for remainder of run – Macro Stability XPs

- Run XPs presently on schedule
  - XP830 RWM stabilization physics: April 24th
    - Key input for R09-1 milestone
    - kinetic δW analysis (J. Berkery) starting to show trends in data
  - XP805 n = 2 Error field reduction: April 29th (0.5 day)
- Continue XPs / re-run shots from XPs under lithium
  - Supports call by Jon for extrapolation of ST to low collisionality – a significant goal of future NSTX research
- New XPs suggested by present results
  - Dedicated halo current XP (Gerhardt)
  - RWM feedback examining poloidal deformation of mode
  - Role of islands in resonant / non-resonant rotation braking (XP743)
- Estimated run time to complete XPs
  - Active XPs: 4.5 run days (+ cross-cutting XP818 ELM Mitigation run)
  - Scheduled XPs: 1.5 run days
  - Run planned / new XPs: 4 run days