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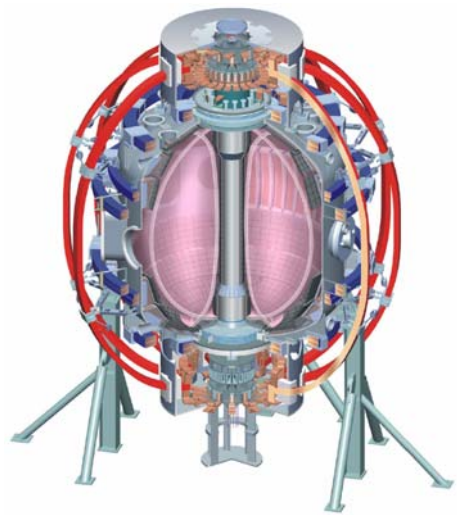
Status of XP-614

Comparison of error field correction techniques at high beta-N

Jonathan Menard

PPPL PRINCETON PLASMA PHYSICS LABORATORY

NSTX Mid-Run Assessment
May 10, 2006
PPPL



College W&M
Colorado Sch Mines
Columbia U
Comp-X
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
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Hebrew U
Ioffe Inst
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KBSI
KAIST
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

Run plan status

Day 1 – 30 shots → largely done – need to finish IP scan

1. Reproduce 800kA target plasma with edge locking → done
2. Add n=1 corrective field – try to reduce flow damping and mode locking → done
3. If EFC algorithm improves discharge, test at other plasma current and BT
   a. Compare plasma performance with and w/o EFC for 3 scenarios:
   (1) 1.0MA, 4.5kG (started) (2) 0.7MA, 3.5kG (TBD) (3) 1.0MA, 3.5kG (TBD)

Day 2 – 30 shots

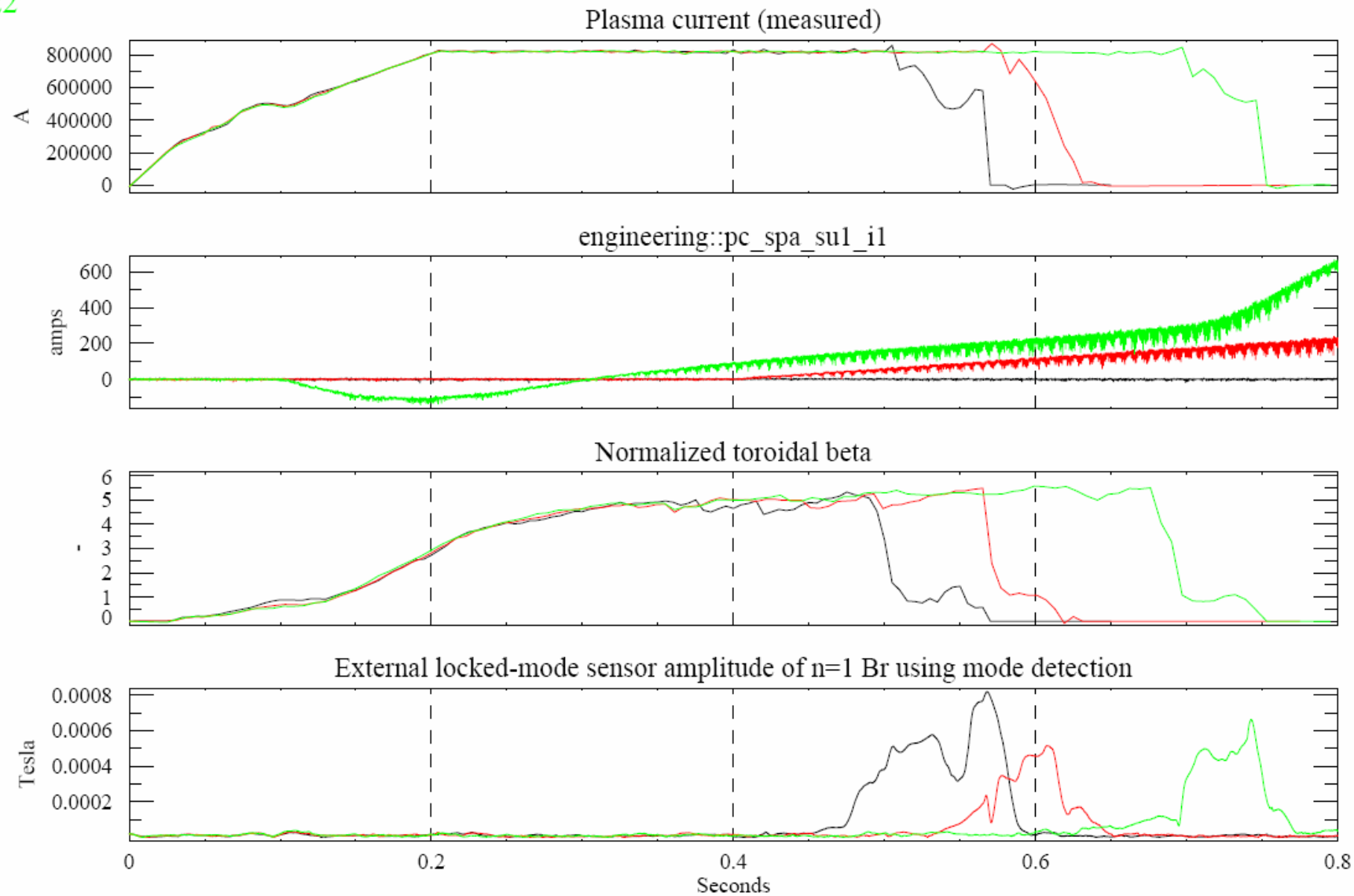
4. Use RWM/EF feedback control system for "dynamic" EFC – tried on 2 shots
. Test DEFC – use optimal RWM gain and phase if data is available (
   XP615 uses a target w/o *intrinsic* locking problems, lowers(?) rotation
   i. Scan and optimize gain and phase settings – 20 shots
   ii. Use different sensors now that this is available? BR, or mix upper/lower Bp? - 10 shots

5. Compare performance (shot duration, ELMs, beta-N, etc.) to EFC results
6. Determine if average time evolution of optimal DEFC SPA currents is similar to evolution of pre-programmed EFC SPA currents.

XP614: Comparison of EFC techniques at high β_N – Menard

119609
119615
119622

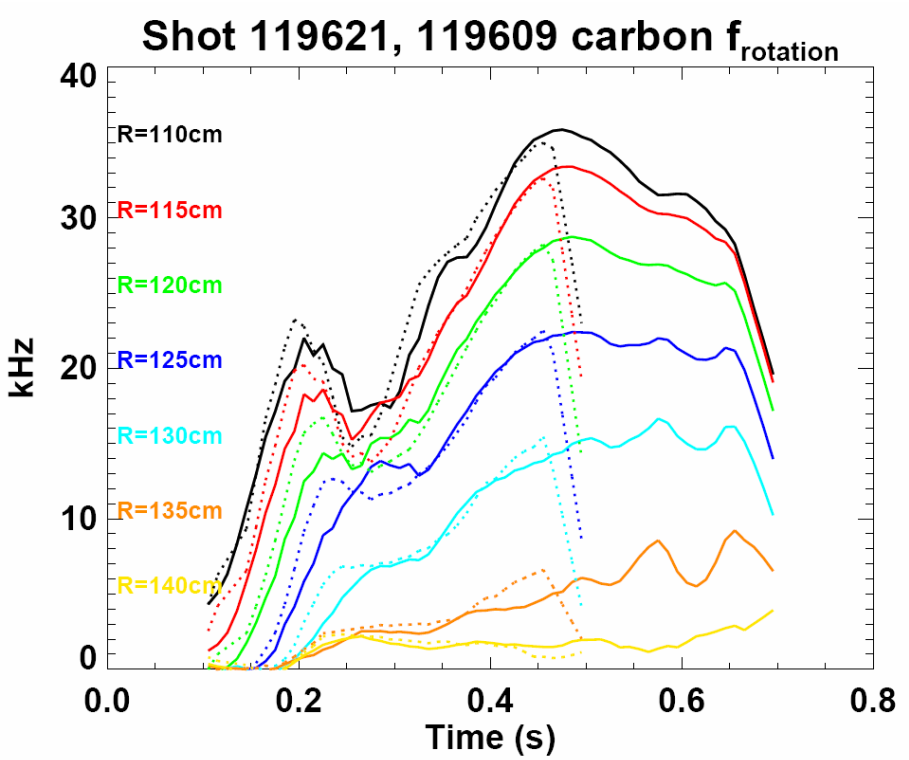
- Longest duration, highest β_N achieved with OHxTF predictive EFC (119622)
- Pre-programmed ramp (119615) guesses at OH evolution ⇒ not as good

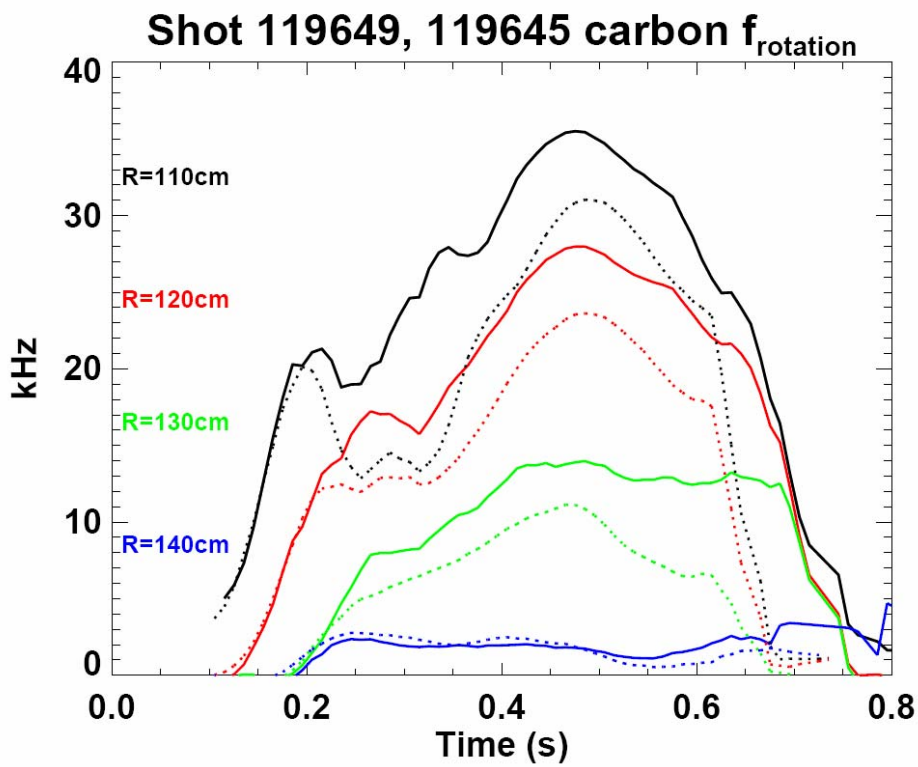


XP614: Comparison of EFC techniques at high β_N – Menard

- Applying EFC sustains plasma rotation and can increase β (119621,609)

- Scan of EFC amplitude finds that optimal proportionality value (119649) results in higher rotation and beta than shot with non-optimal value (119645)



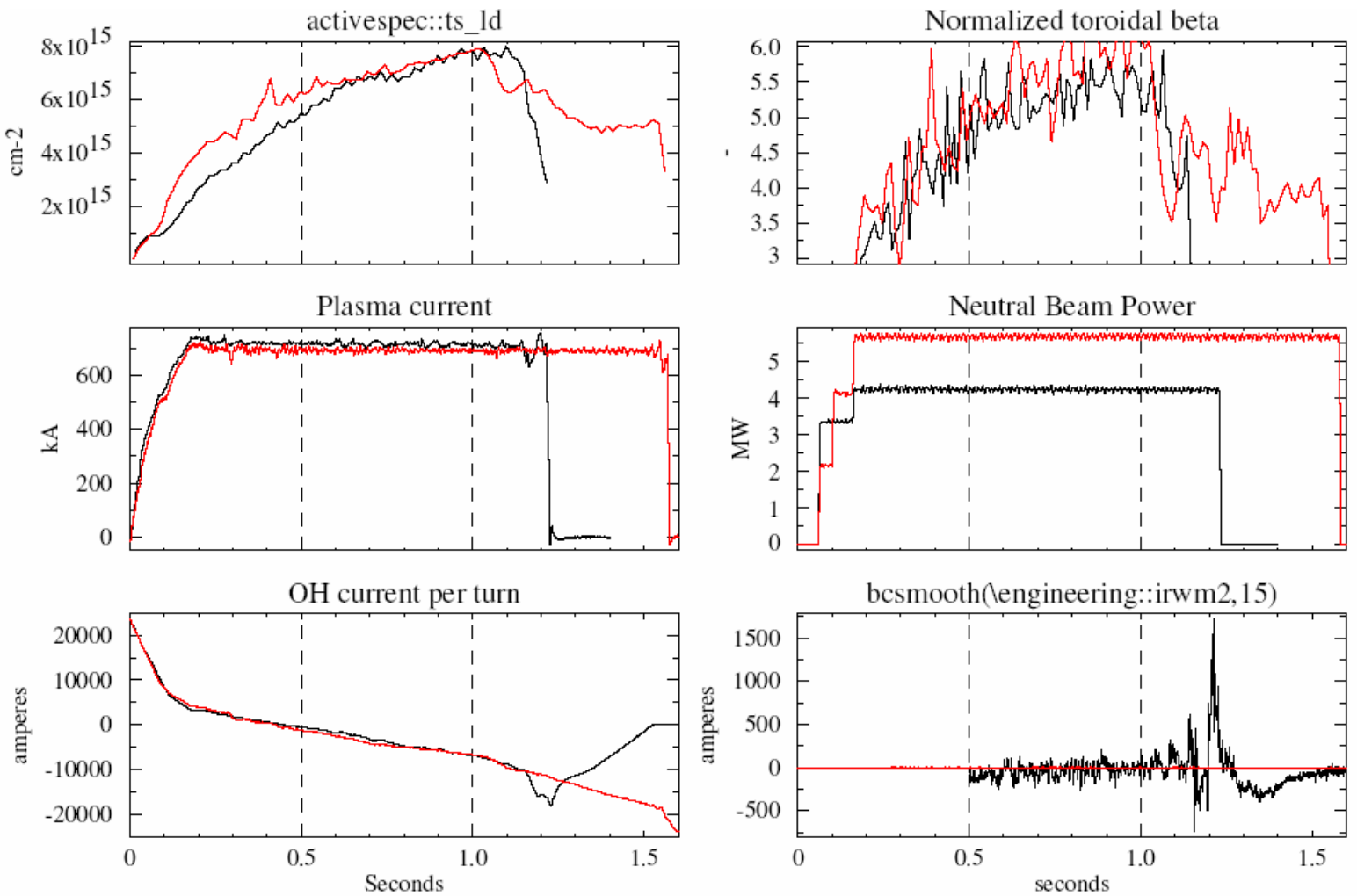


XP614: Comparison of EFC techniques at high β_N

Tested feedback during 700kA long-pulse for first time

- Same flux consumption as 116318 but w/ much lower NBI power
- Improved confinement this year… (and/or cleaner early phase…)

Shots:
120339
116318

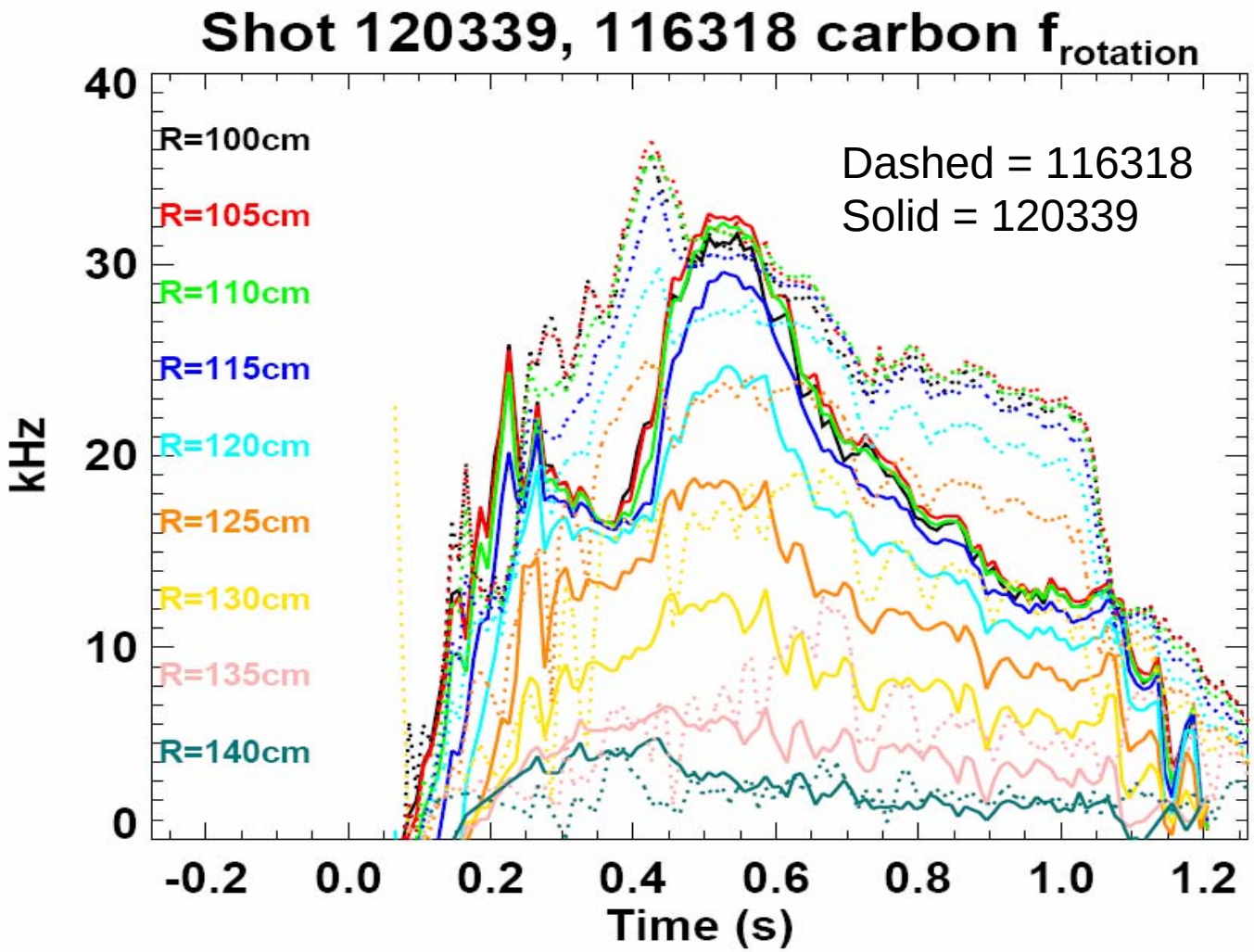


XP614: Comparison of EFC techniques at high β_N

Rotation systematically higher in reference shot w/o feedback (116318)

- But NBI power is much lower in this year's shot with feedback…
- **Need comparison shots w/o feedback, and with EFC from OHxTF**

Shots:
120339
116318



Run plan wish-list

- Compare feedback (DEFC) to OHxTF EFC
  - Use target with intrinsic locking behavior
  - Test combined DEFC + TF-EFC – new capability
    - Test mix of U/L BP, and/or BR sensors, if time permits
  - 30 shots
- Finish plasma current and field scan
  - 8 shots

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Status of XP-618 → COMPLETE

Optimize error field correction vs. rotation

R. La Haye, T. Strait (GA)

College W&M
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Columbia U
Comp-X
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
ORNL
PPPL
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Think Tank, Inc.
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UC Irvine
UCLA
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U Washington
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Culham Sci Ctr
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York U
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Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAERI
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
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ASCR, Czech Rep
U Quebec

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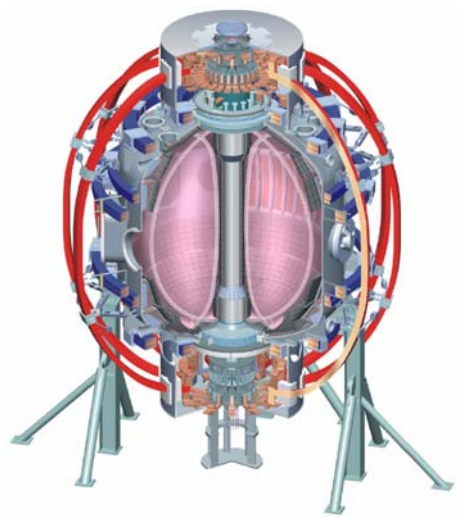
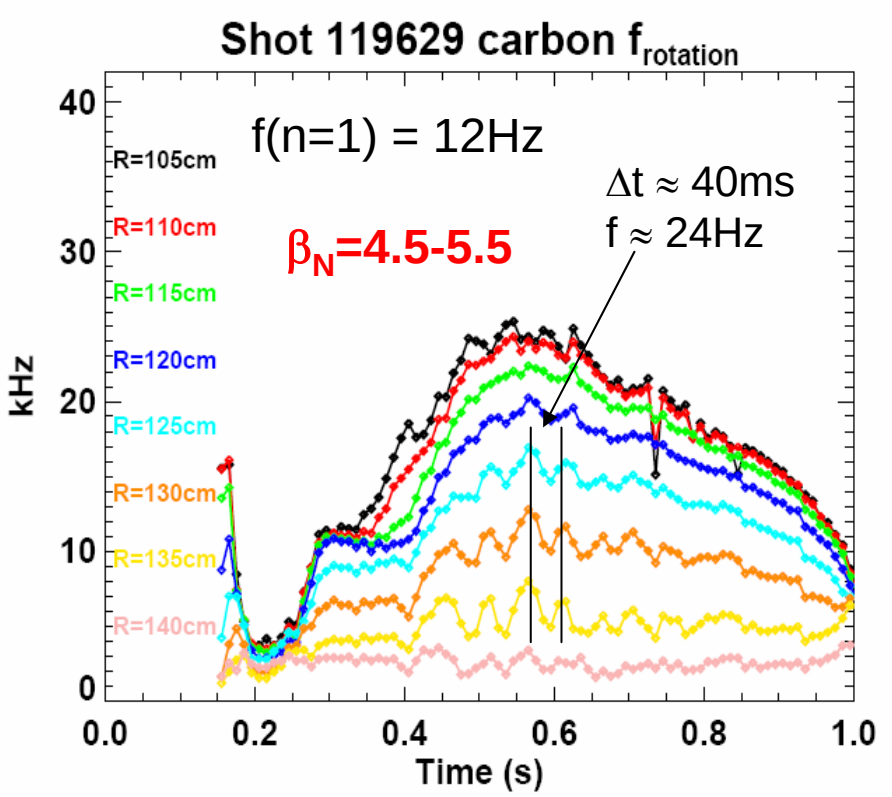
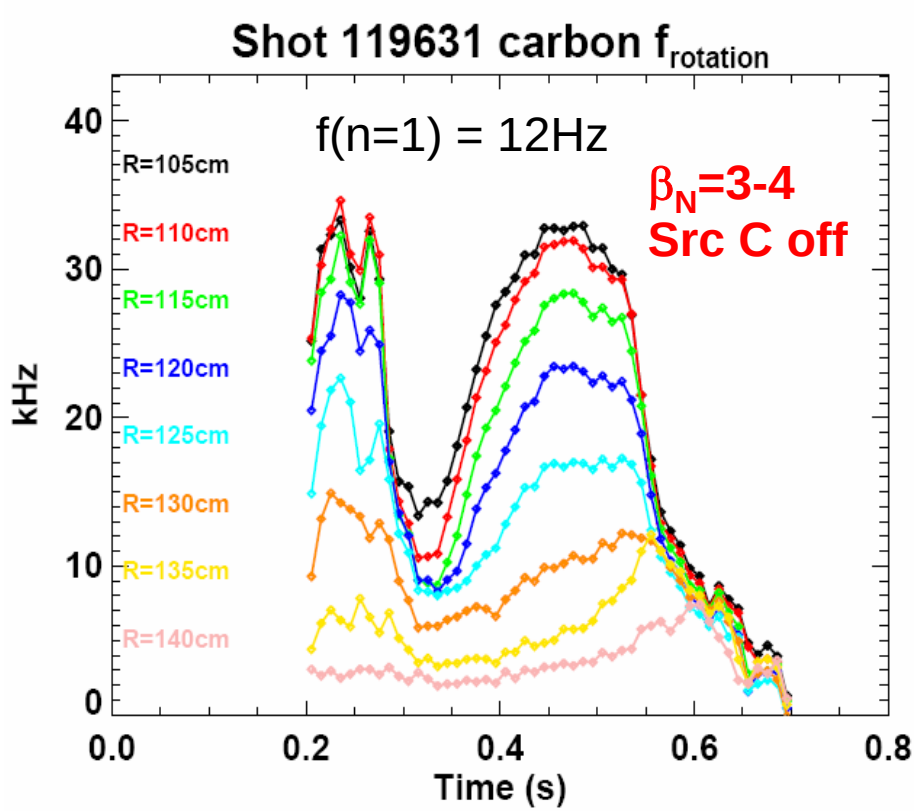
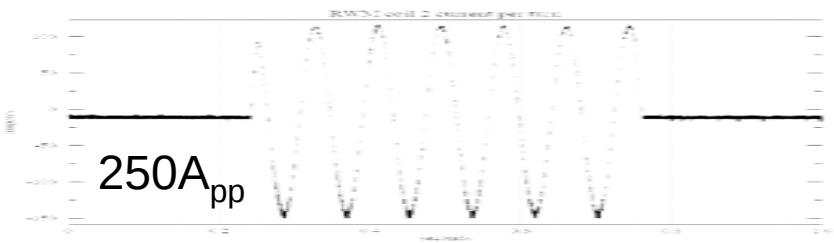


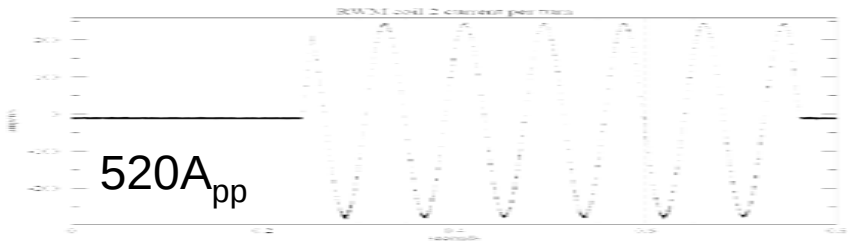
XP618: Optimize error field correction vs. rotation – LaHaye, Strait

- Observe rotation modulation at 2nd harmonic of applied field
- Little to no rotation modulation observed below no-wall limit



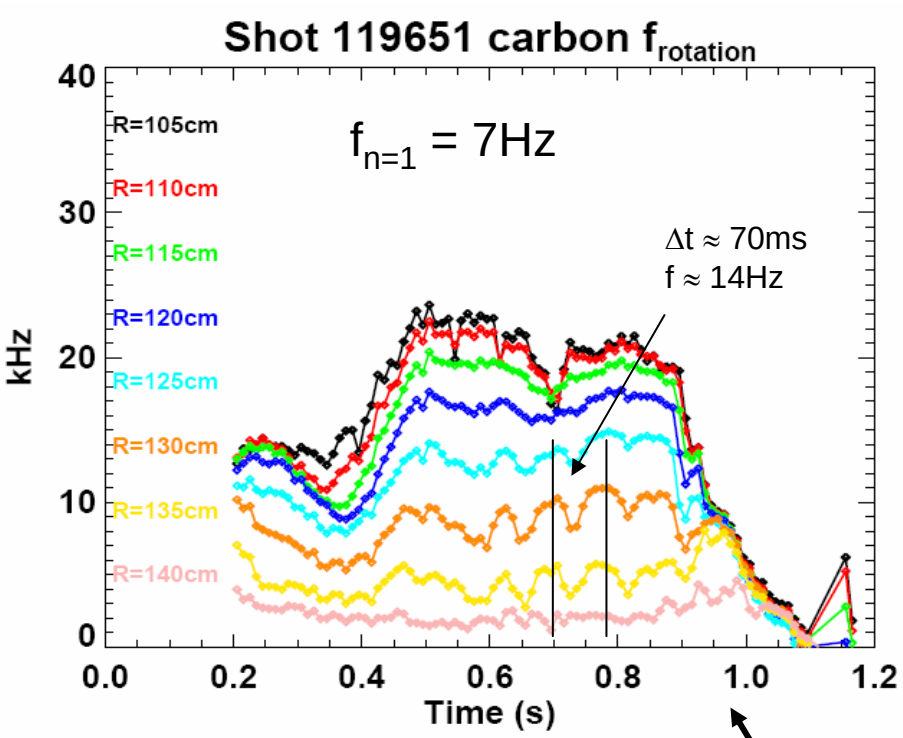


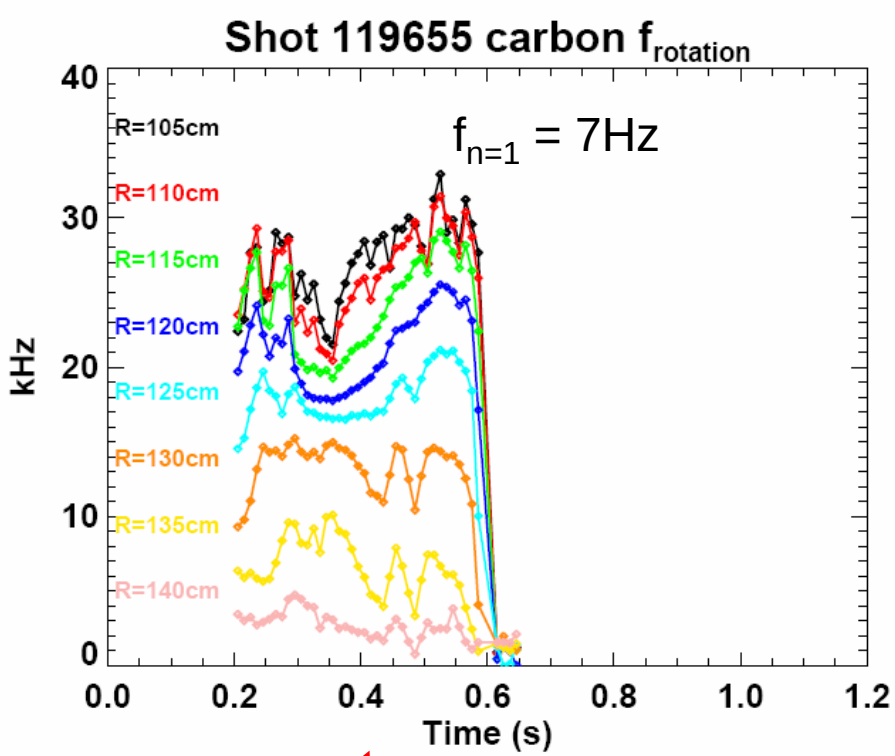


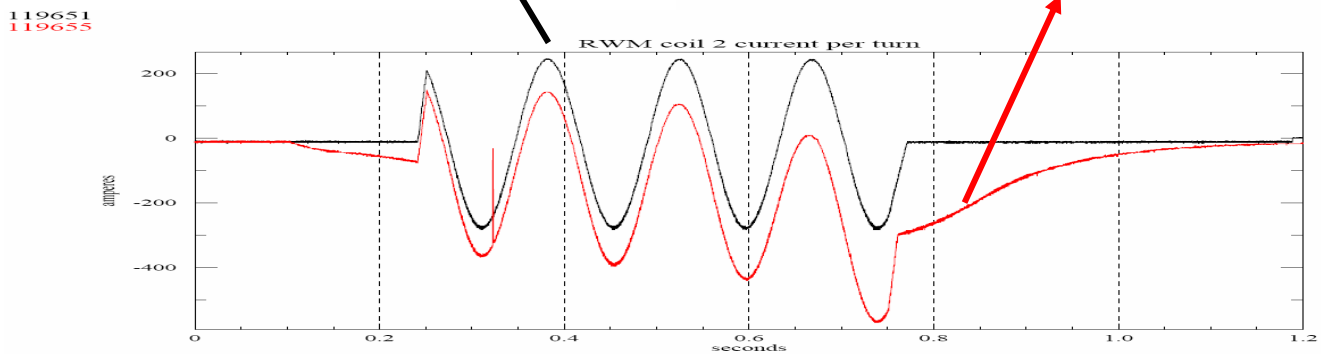


XP618: Optimize error field correction vs. rotation – LaHaye, Strait

- Also observe rotation modulation at 2nd harmonic of applied field at lower f=7Hz
- Shot with OHxTF EFC + n=1 achieves higher rotation, β_N (& RFA?), but is shorter



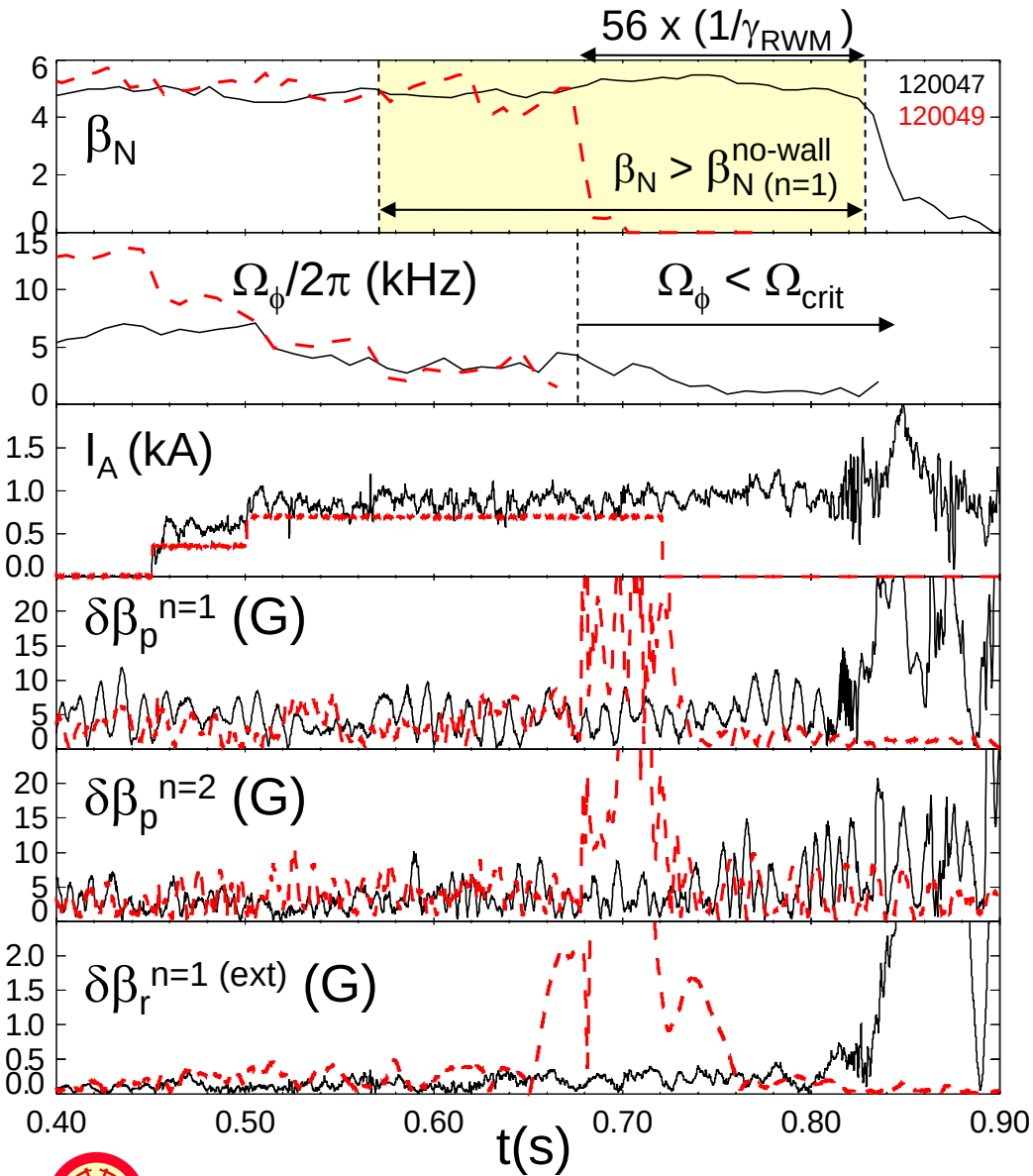




XP615 Demonstrated Active RWM Stabilization in High Beta, Low Rotation Plasmas

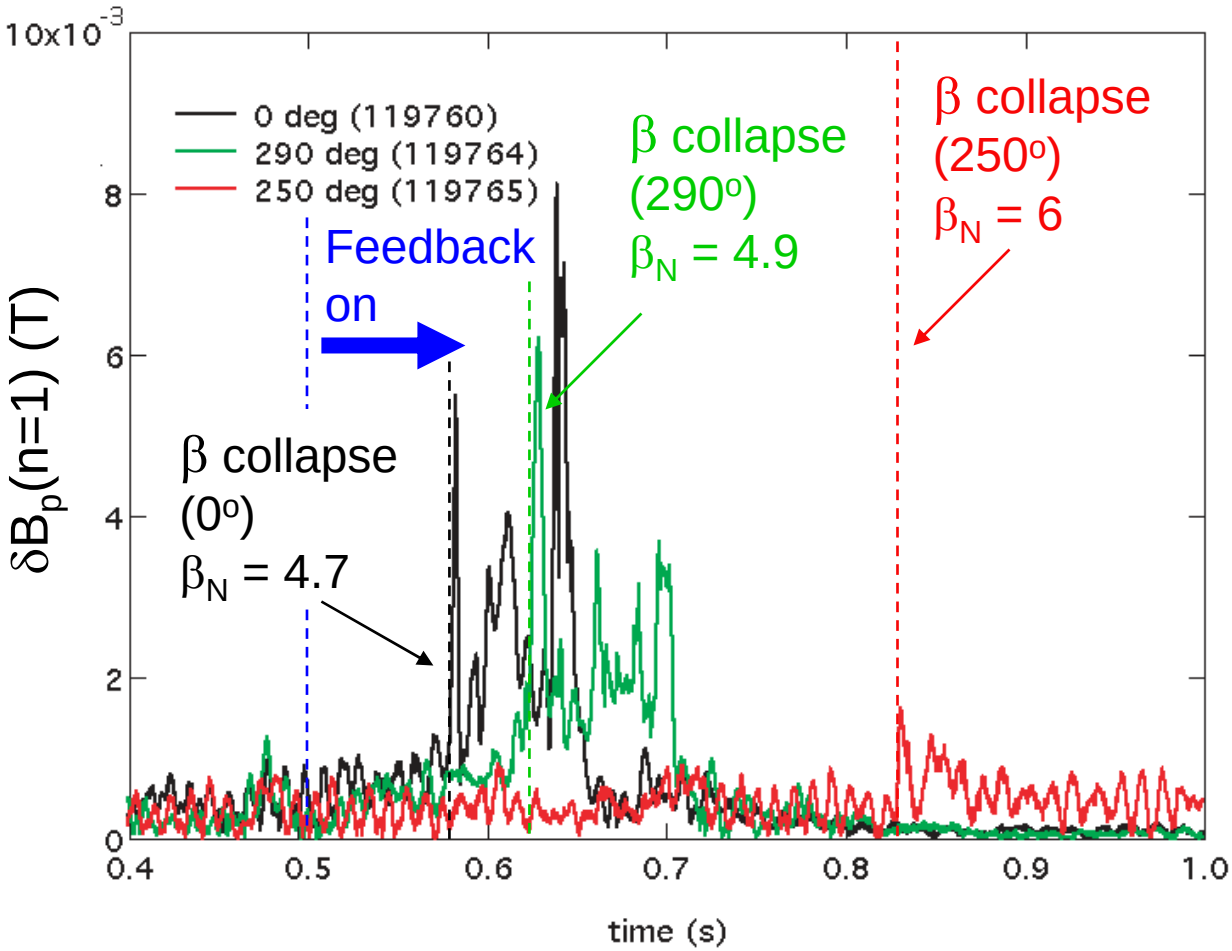
- First active stabilization of the pressure-driven RWM in a low aspect ratio tokamak
  - Demonstration of positive/negative feedback vs. phase and gain
- Stabilization of a low rotation plasma – ITER relevance
  - $\Omega_\phi/\Omega_{crit} \sim ¼$; in range of predicted ITER rotation
  - System geometry similar to ITER
  - Rotation profile reduction/variation gives insight into RWM stabilization mechanism
- Significant n = 2 observed in n=1 active stabilized cases
- Mode rigidity violated in certain cases
  - Mode rigidity observed in DIII-D; assumed in RWM calculations made in the community
  - New observation demonstrates need for “multi-mode” calculation in future theoretical investigations

RWM stabilized at low rotation for longer than $50/\gamma_{RWM}$



- Reduction of Ω_ϕ by non-resonant n = 3 magnetic braking
  - Due to neoclassical toroidal viscosity
  - In ITER Ω_ϕ range
- Significant n = 2 amplitude during active stabilization
- Mode rigidity violated in certain cases
- Stabilized for longer than published DIII-D result

Varying RWM feedback relative phase demonstrates positive/negative feedback



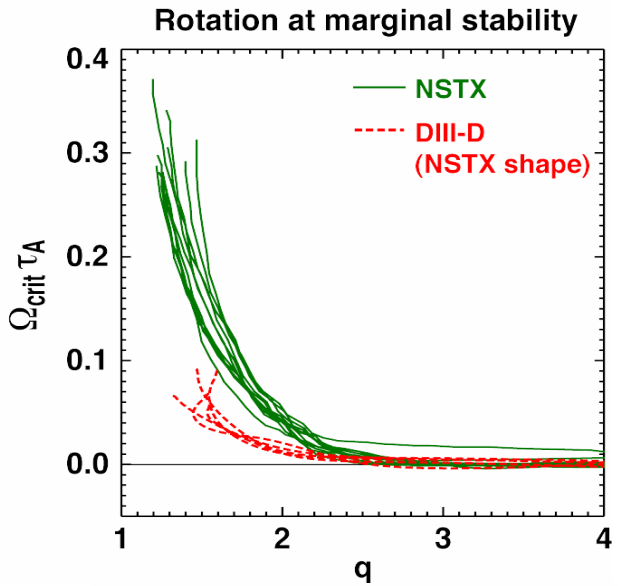
- Phase scan
  - Varied through 360°, finer scan in 270° range; 225° appears to be "best"
  - Positive feedback (destabilizing) in range ~ 90° - 290°
  - n = 3 braking required to generate RWM when phase set to most favorable settings

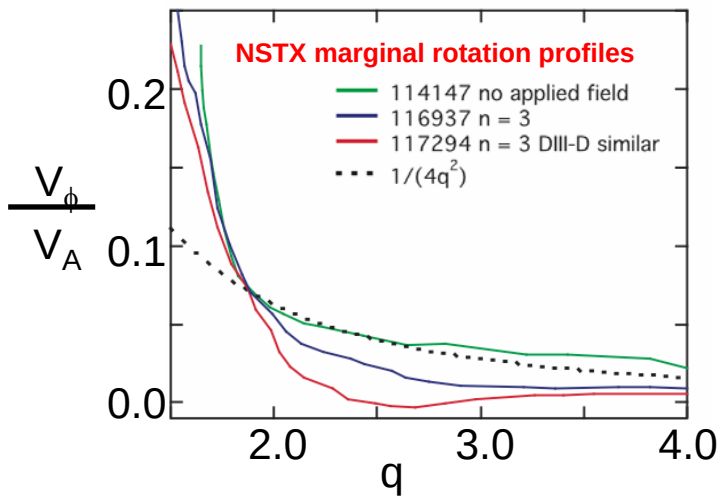
XP615: requests for second-half of run; planned publications

- Goals (run time request = 1 day)
  - Extend actively stabilized duration by reducing n = 3 braking
    - Could be very valuable data to have in the near-term
  - Use different sensors / demonstrate related physics regarding mode rigidity, etc.
    - Use combination of upper and lower B_p sensors, rather than one group
    - Use B_r sensors
  - Fill in feedback gain / relative phase scans from first run
- Planned publications
  - Paper in preparation for PRL – submission ASAP
  - Request nomination for 2006 APS DPP invited talk (+ PoP paper)
- Extra run time requested above should greatly help APS Invited talk, also could help satisfy PRL referee concerns

XP 619: Scaling of RWM Stability Leads to Understanding of Physical Model

- Alfven speed important in stabilization models
  - coupling to Alfven continuum
  - degree of inertial enhancement
  - has become standard normalization for inter-machine comparison
- NSTX requires higher rotation than DIII-D using v_A normalization
  - aspect ratio dependence or other physics?
  - rotation similar using v_s normalization
- All NSTX Ω_{crit} data obtained at single B_t
  - no large variation in v_A
- XP 619 will vary v_A at constant q
  - wide variation in marginal rotation at q > 2 surfaces observed during braking
  - try to isolate v_A dependence
- Density scan to alter collisionality
  - variation in neoclassical & NTV damping/dissipation
- Will also account for variation in marginal rotation due to MHD





MHD ET XP Usage to Date

- XP614: Used 13 hours out of allocated 20 hours
- XP615: Used 12-15 hours out of allocated 16 hours
- XP618: Used 5+ hours out of allocated 4 hours
- XMP45: Used about 8 hours out of allocated 8 hours
- Total MHD Usage: 40-ish hours out of 64 allocated

- Would be interesting to compile shot count, and compare to requests in experimental proposal.

MHD run-time request

Priority order (more or less…)

- XP615 – 1 day – active feedback at low Ω_ϕ
  - APS Invited, likely PRL if successful, ITPA, 07 Milestone complete?
- XP614 – 1 day – use feedback to reduce EF drag on Ω_ϕ?
  - 06 Milestone, ITPA, PRL on multiple RFA sources? (m=0 and higher?)

Not in priority order:

- Sontag – 1 day - RWM passive stability boundary
  - Understand RWM critical rotation – publish paper
- Menard – ½ day - Low density locked mode – finish BT scan
  - Finish locked-mode threshold scaling study – publish paper
- Gates – 1 day - High Beta-t using EFC
  - Take advantage of EFC – record beta? - publish