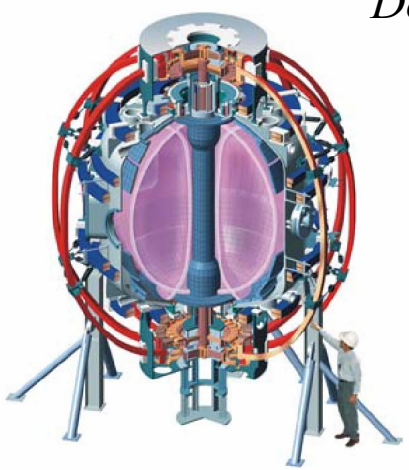
Supported by

NSTX 2005 Experimental Proposals: RWM XPs+

S. A. Sabbagh

*Department of Applied Physics and Applied Mathematics, Columbia University, New York, NY, USA



NSTX Research Forum
September 22 - 24, 2004
Princeton Plasma Physics Laboratory

Columbia U
Comp-X
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
NYU
ORNL
PPPL
PSI
SNL
UC Davis
UC Irvine
UCLA
UCSD
U Maryland
U New Mexico
U Rochester
U Washington
U Wisconsin
Culham Sci Ctr
Hiroshima U
HIST
Kyushu Tokai U
Niigata U
Tsukuba U
U Tokyo
JAERI
Ioffe Inst
TRINITI
KBSI
KAIST
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
U Quebec

Advanced RWM research can be supported in 2005

- Motivation
  - Active RWM control a major research objective since Day 0
  - New diagnostic and control capabilities put NSTX at the forefront of RWM physics research
- RWM physics goals
  - Perform low frequency MHD spectroscopy to probe RWM stability
  - Use RWM coil to dynamically suppress resonant field amplification (RFA)
  - Actively stabilize RWM in a low rotation plasma $\omega_\phi < \Omega_c$
- Other goals
  - Effects of rotation on low A, high β_p equilibria

XP: MHD spectroscopy of wall stabilized high β plasmas

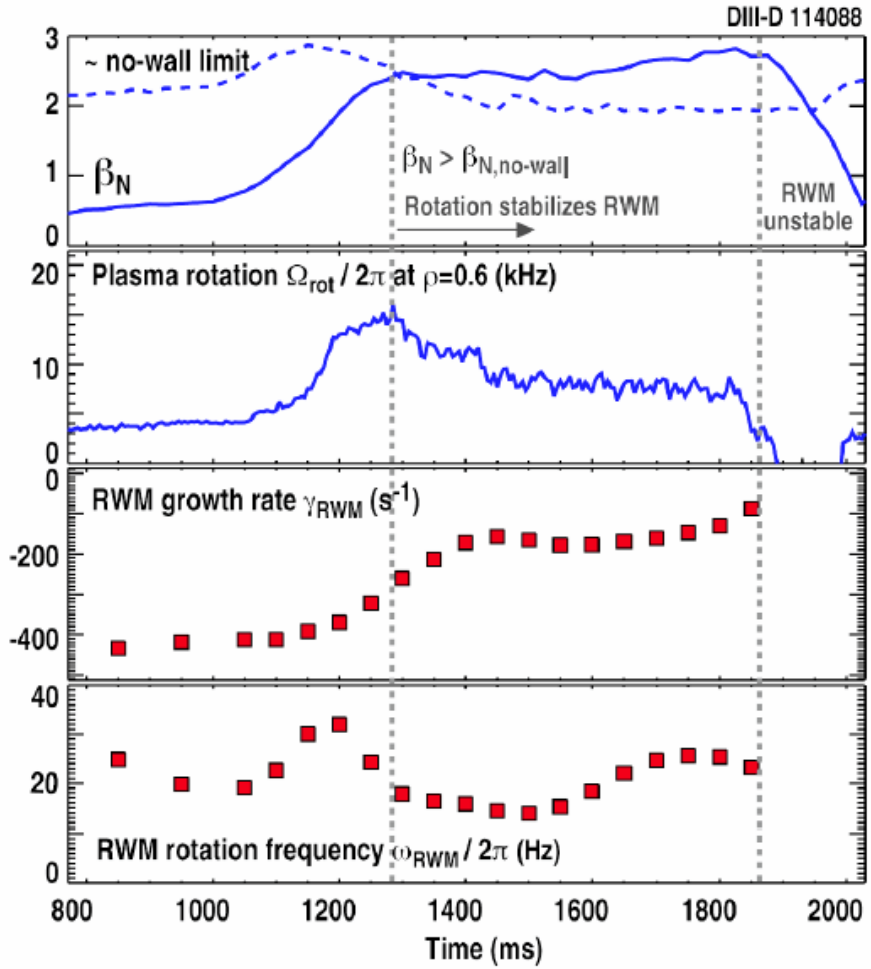
- Motivation
  - Examine RWM physics: measure damping rate / natural frequency
  - Determine time-dependent RWM stability

- Goals
  - Use full RWM coil/SPA capability in pre-programmed mode to perform MHD spectroscopy on passively stabilized plasmas
  - Examine low frequency mode resonances
    - by varying frequency of applied RWM coil perturbation
    - by varying frequency of power systems to shaping coils

Spectroscopy XP similar to experiments in other devices

- Generate relatively long pulse target with $\beta_N > \beta_{Nno\text{-}wall}$
  - follows 2004 NSTX XP452
- Scan applied n=1 field frequency
  - utilize CY2005 RWM coil capabilities
    - Only requires pre-programmed modulated n=1 field
- Compare RFA to theory / other devices
  - dependence on frequency
  - dependence on β_N
- Scans to examine resonances
- Request 1 run day
  - CHERS, RWM sensors needed

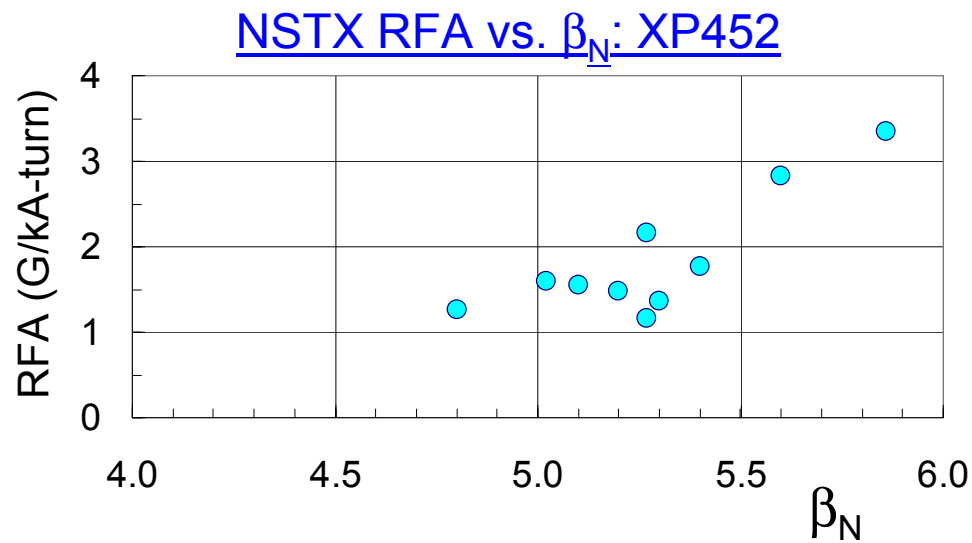
MHD spectroscopy in DIII-D (H. Reimerdes et al.)



XP: Suppression of resonant field amplification at high β_N

- Motivation
  - Marginally stable RWM causes resonant field amplification (RFA) causing rotation damping, leading to mode growth, β collapse
- Goals
  - Using pre-programmed or active control (attempt both if possible) eliminate the time dependent RFA measured by the RWM sensors
    - dynamic error field suppression, not active feedback

RFA generated in 2004 – study suppression



XP plan

- Stable plasma with $\beta_N > \beta_{Nno\text{-}wall}$
- Dynamic suppression
  - measure / cancel RFA
    - slow feedback sufficient
  - pick best scans of stability space (β_N, l_i, F_p, etc.)
- Pre-programmed suppression
  - programmed waveform follows from dynamic suppression (DIII-D method)
  - if slow dynamic suppression not available, perform pre-programmed RWM coil scans
- Request 1 run day
  - Slow feedback capability desired but not required
  - CHERS, RWM sensors required

XP: Active stabilization of the resistive wall mode

- Motivation
  - Slowly rotating plasmas ($\omega_\phi < \Omega_c$) not passively stabilized to RWM
  - Reactor plasmas (ITER) may have insufficient rotation, so may require active stabilization
- Goals
  - Initial experiment to stabilize RWM when rotation is below Ω_c
  - Investigate physics of the stabilization of low rotation plasma

Initial XP to demonstrate active stabilization at high β

- Generate plasma with unstable RWM
- Stabilize RWM in low rotation target
  - Choose targets with $\omega_\phi < \Omega_c$ (e.g. high I_p, high β_t shots of CY2004)
  - Pick best scans of stability space with low rotation (β_N, l_i, F_p, etc.)
- Stabilize RWM in rotation damped target
  - demonstrate pulse length extension in targets with high V_ϕ damping
  - scan stability space
- Study RWM physics / feedback physics
  - mode rigidity, *n* spectrum, feedback control parameters
- XP may require 2 run days
  - First day may be needed for RWM control system shakedown
  - Fast feedback control required
  - CHERS, RWM sensors required

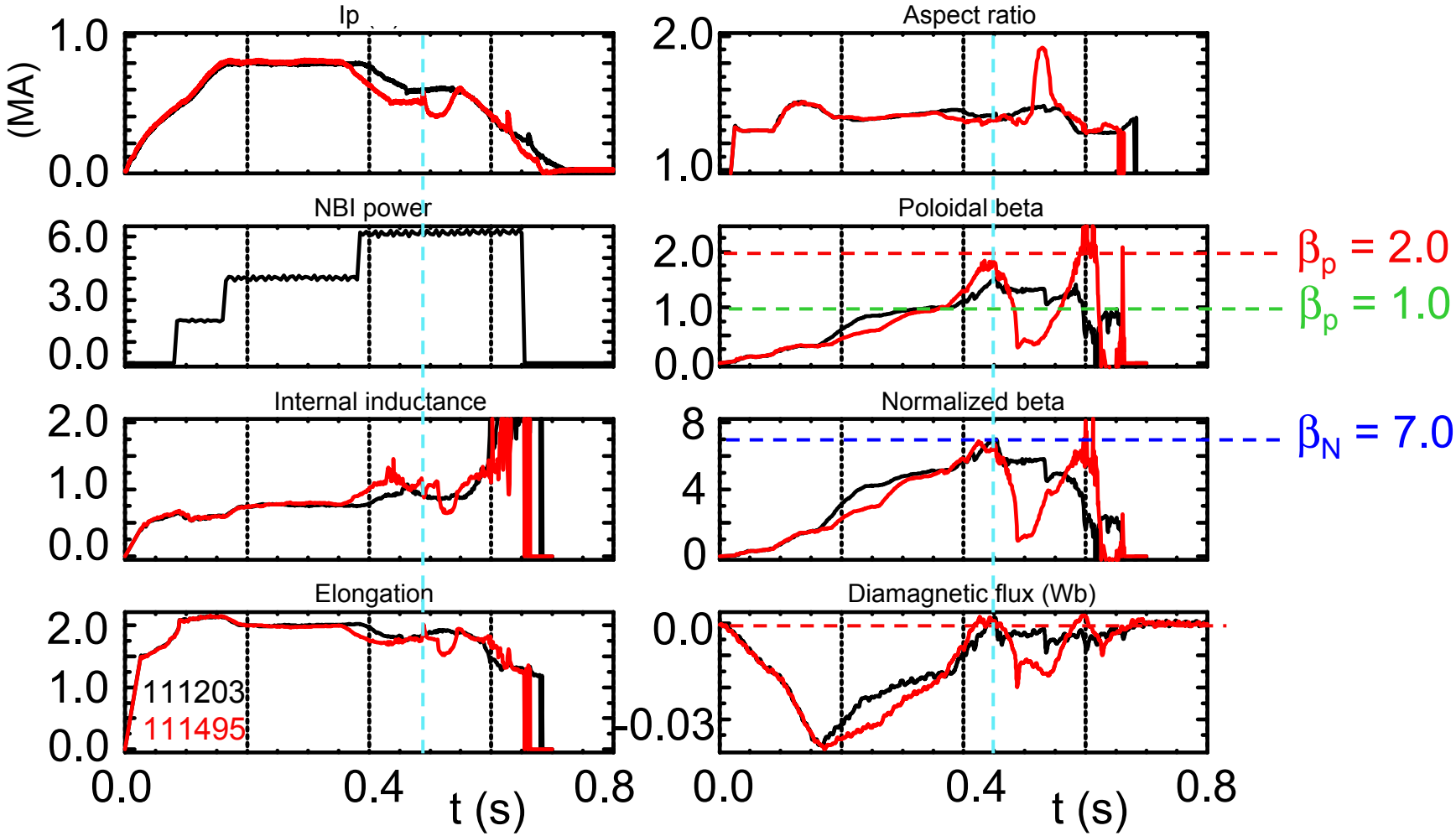
XP414: Aspect ratio effects near the high β_p equilibrium limit

- Goals
  - Complete the experiment started in 2004
  - Examine aspect ratio dependence of rotation effects at high β_p
    - Maximize $\Delta_{Shafranov}/a = 1/(2A)*(\beta_p(1 + 5/6\ M^2) + 1/4)$; (High A limit)
    - Test strong theoretical dependence of $(R_{Pmax} - R_{axis})/a$ on aspect ratio
  - Produce maximum β_p and β_N in NSTX
    - Approach (reach?) the equilibrium limit ($\varepsilon\beta_p > 1.8$)
    - Examine bootstrap current at maximum β_p
    - Achieve $\beta_N > 10$ (possible based on best CY2004 shots at $B_t = 4.5$kG)
    - Test equilibrium reconstruction with rotation at maximum β_p
  - Determine global stability / confinement in new equilibrium regime
    - Increased diamagnetism and omnigeniety; drift reversal
    - test theoretical expectation of improved confinement

XP414: Progress toward the ST equilibrium limit

- XP to examine rotation effects at low aspect ratio, high β_p
  - Early run (before vent for CHERS): calibrated CHERS not available
  - Late run: restricted to B_t = 3kG, limiting peak plasma performance
- High β_p target conditions established
  - Plasma β_p up to 2, world record β_N = 7, W_{tot} = 200 kJ
- Target development: significantly improved mode behavior
  - Neutron collapse at β_N = 7 plasma indicates internal/global mode
  - Subsequently, beta collapses not correlated with neutron collapses
  - Last run (B_t = 3kG) showed that modes could be *eliminated* by maintaining $\kappa > 2$ during I_p ramp-down
- Request 1 – 1.5 run days
  - Scan I_p and aspect ratio
  - XP requires B_t > 4 kG capability, 4.5kG desired, calibrated CHERS

High β_N plasma reaches β_p= 1.8; β_p = 2 late



- Highest β_p plasma is slightly diamagnetic (2 mWb)
- Plasmas approaching equilibrium limit ~ 2.5