Experimental Task Group 1: Macroscopic Stability

CY 2000 Results Assessment

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for the NSTX Research Team

NSTX Forum: ET1 MHD Stability Plenary Session II - 1/15/01

Princeton Plasma Physics Laboratory

Review CY 00 results and form group plan for 01

- Motivation
  - Familiarize group with present NSTX ET1 results
  - Motivate the afternoon group discussion

- Outline
  - General overview of present NSTX stability research
  - Summary of NSTX ET1 group XPs and current results
  - Primer for ET1 parallel session group discussion

General status of MHD research in NSTX

- NSTX CY 00 experiments bridged initial operating issues and the start of low A physics research with NBI and HHFW
- NSTX operational goals (first region plasma $\beta_T = 22\%$) have already been achieved
  - these plasmas provide an adequate testbed for stability research
- Present NSTX XPs cover a broad range of low A physics studies
  - Submission of new XPs to broaden the existing set is welcomed and encouraged
- Plasma performance is pushing the present limits of diagnostic capability

Several instabilities have been observed and are being studied

Instability	Beta limiting?
Current-driven kinks	can be avoided
Ideal low-*n* kink/ballooning (?)	yes
Tearing modes (neoclassical ?)	yes
Sawteeth	for large r(q = 1)
Reconnection events	can be delayed
High frequency modes (Alfven ?)	uncertain

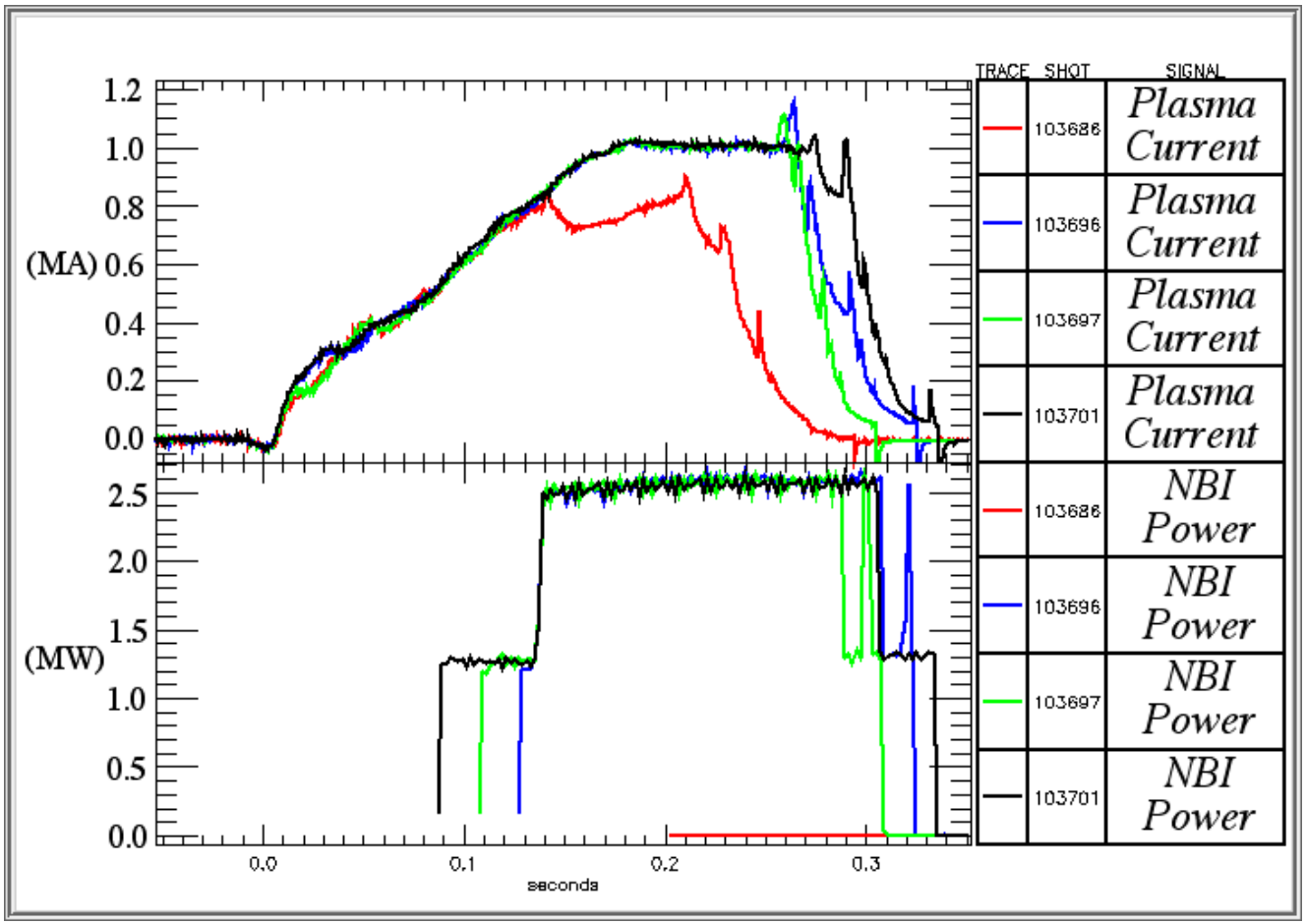
Status of NSTX MHD Task Force XPs: Jan 2001

Experimental Proposal	(run started)	Leader
XP14 Pulse length extension		D. Gates
XP22 Survey of modes in Alfven/ICE frequency range		E. Fredrickson
XP23 NBI Heating with small q=1 radius in NSTX		M. Bell
XP24 Observation of NTMs in NSTX		D. Gates
XP16 Investigation of Troyon Scaling in NSTX		J. Menard
XP17 Influence of J profile on MHD stability at low A		S. Sabbagh
XP28 Current driven kink modes in NSTX		(RC) J. Manickam
XP20 Characterization of resistive wall modes at low A		(FR) S. Sabbagh
XP## Physics of ballooning mode stabilization at low A		(GR) S. Sabbagh
XP## Ultra low-q operation in NSTX		(GR) H. Ji

(FR): Pending formal review (GR): Pending group review

(RC): Reviews completed

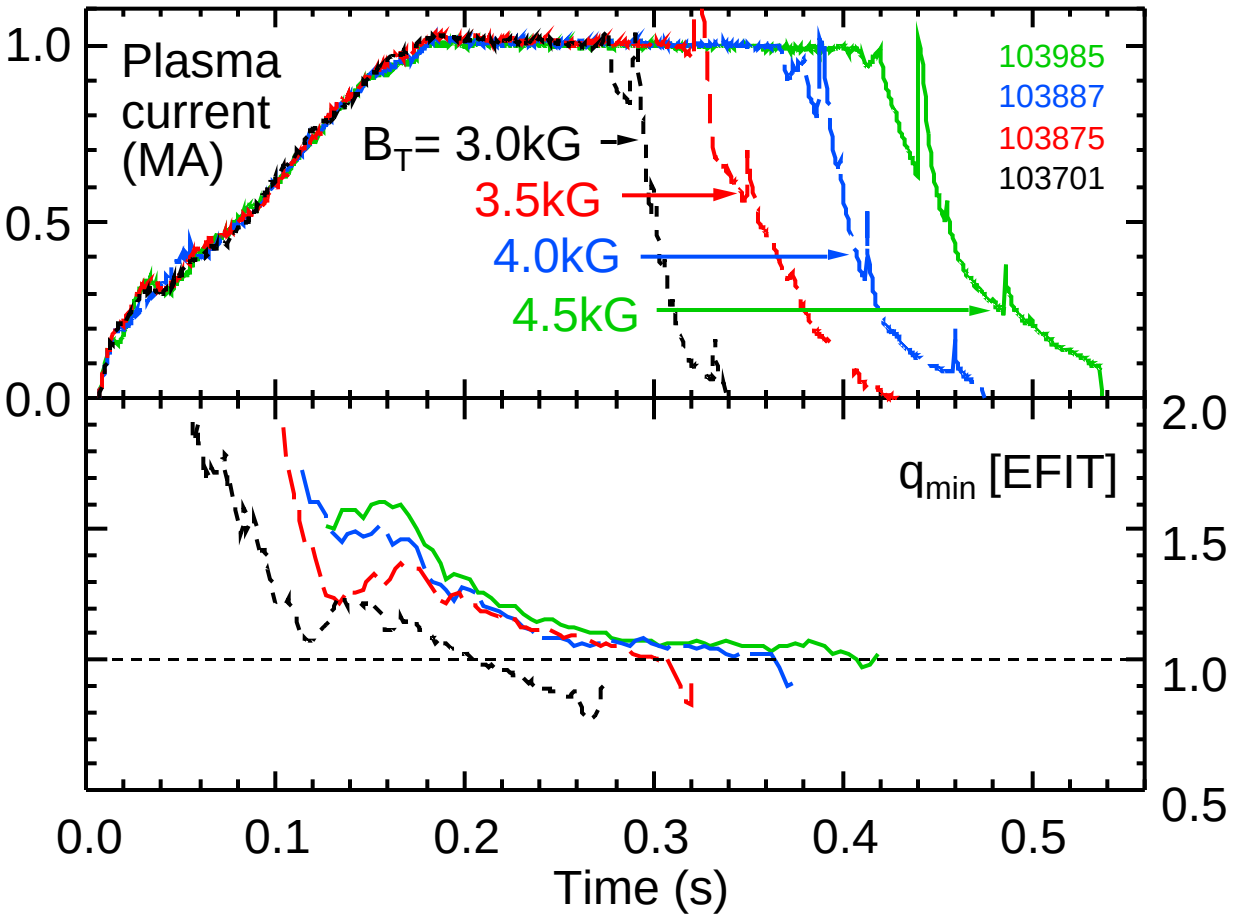
Neutral beam injection extends pulse length



- Neutral beam injection into current ramp extends plasma pulse length
- Precise timing of neutral beam injection does not radically lengthen pulse

D. Gates XP 14

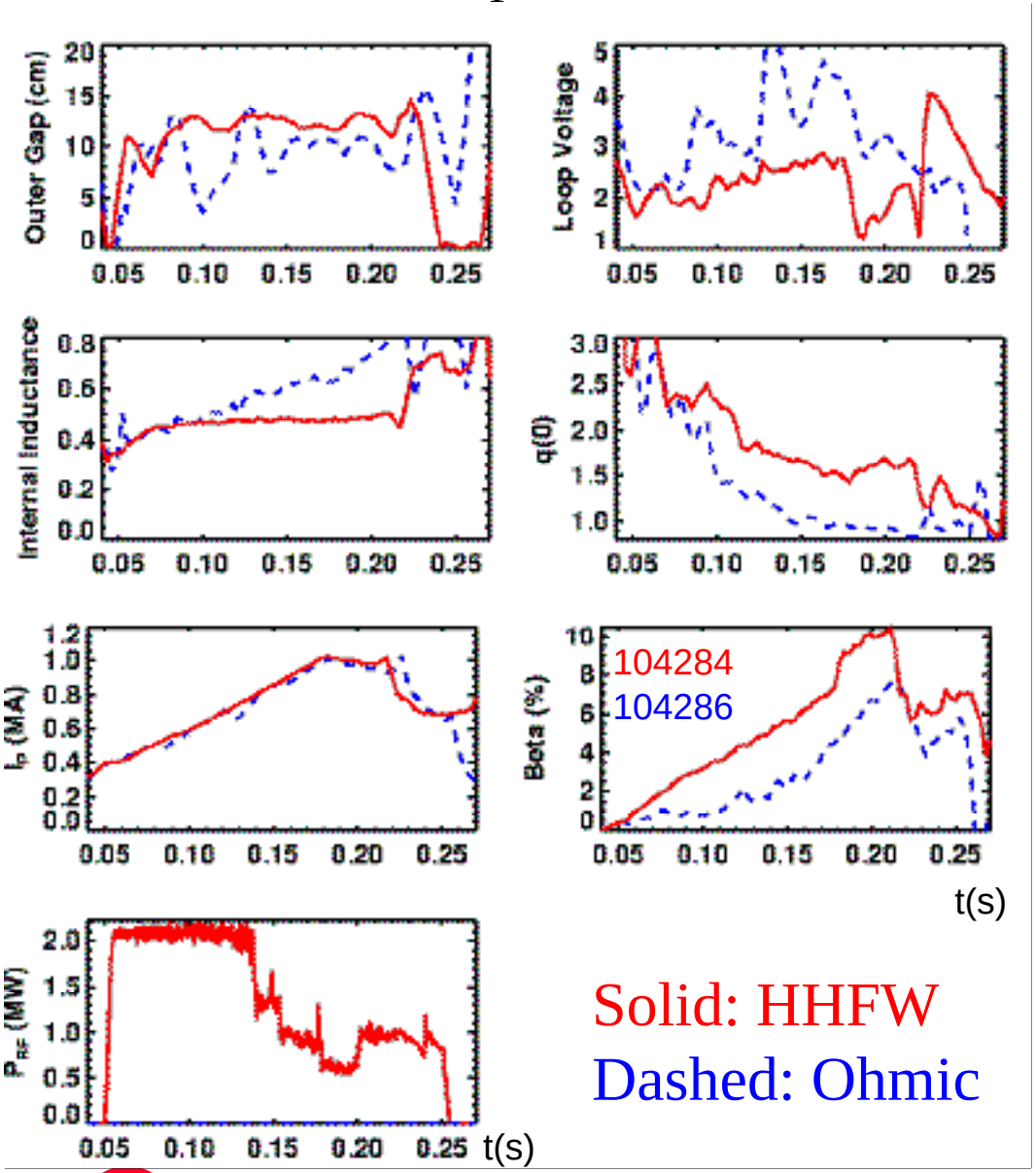
Raising B_T dramatically increases pulse length



- Final pulse length **determined by MHD** in all cases
  - correlates with delayed q_{min} = 1
  - Effect **not** due to increase of T_e with B_t
- Maximum I_p flat-top exceeds 0.2 s (several τ_E)
- Further increases to B_t may lead to longer pulses

D. Gates XP 14

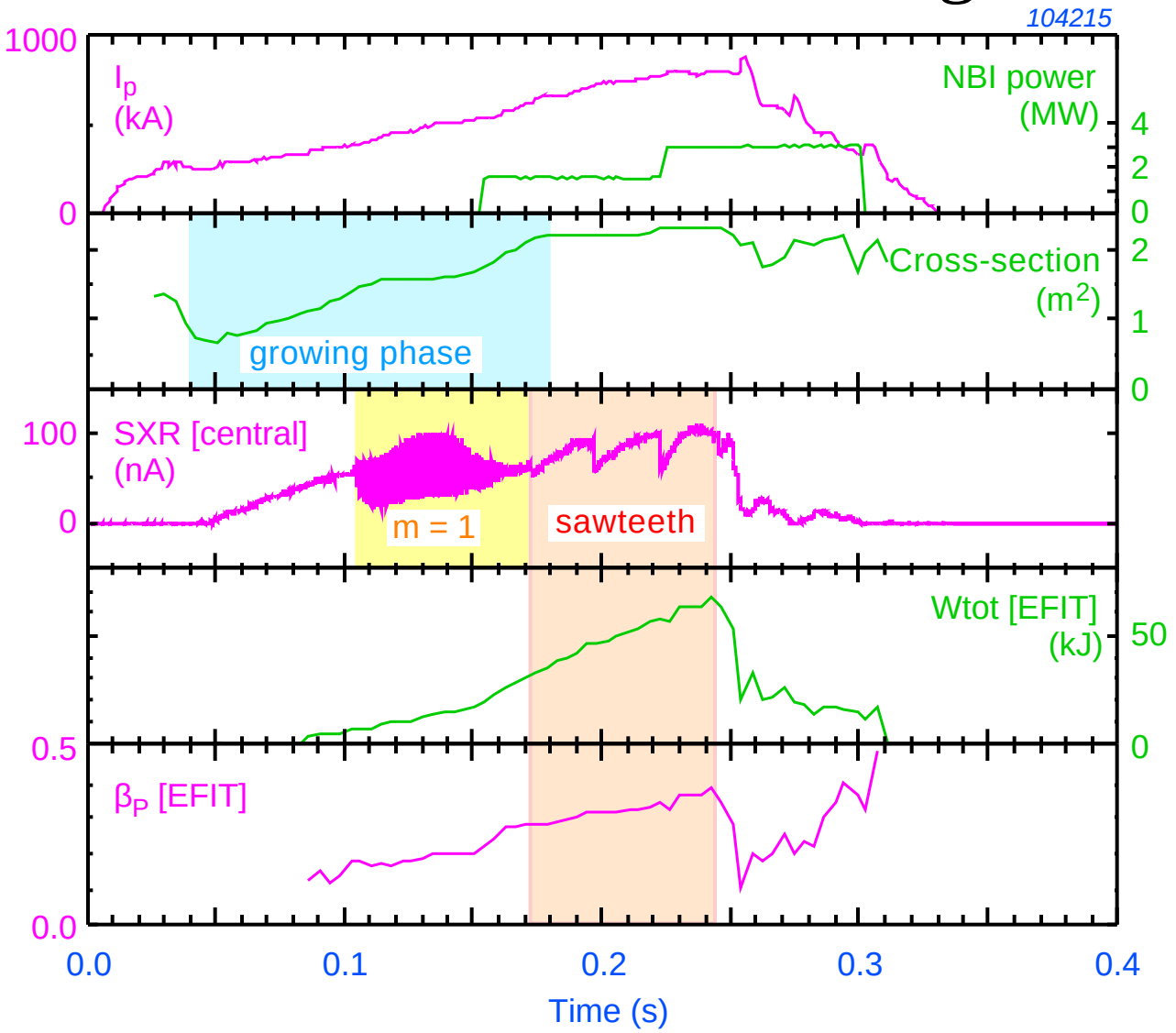
Decreased ℓ_i, increased q(0) attained with HHFW



- HHFW injection during early startup
- ℓ_i kept ≤ 0.5 up to 1MA and into flat-top
- q(0) elevated during and after ramp-up
- Flux consumption reduced

J. Menard XP 25

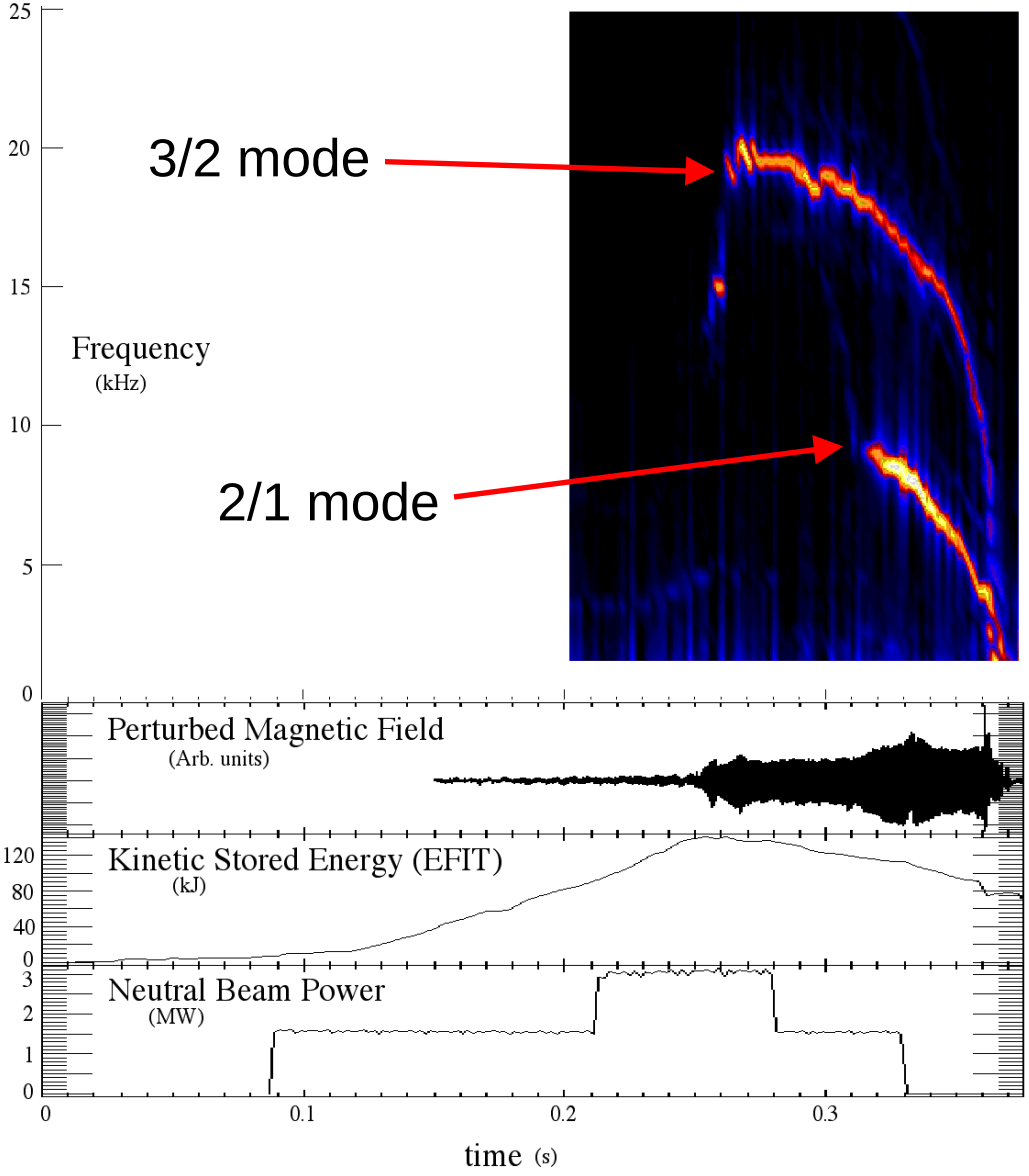
"Grown" Plasma Has Smaller, Benign Sawteeth



M. Bell
XP 23

- Small sawtooth relaxations do not affect NB heating at low β_p

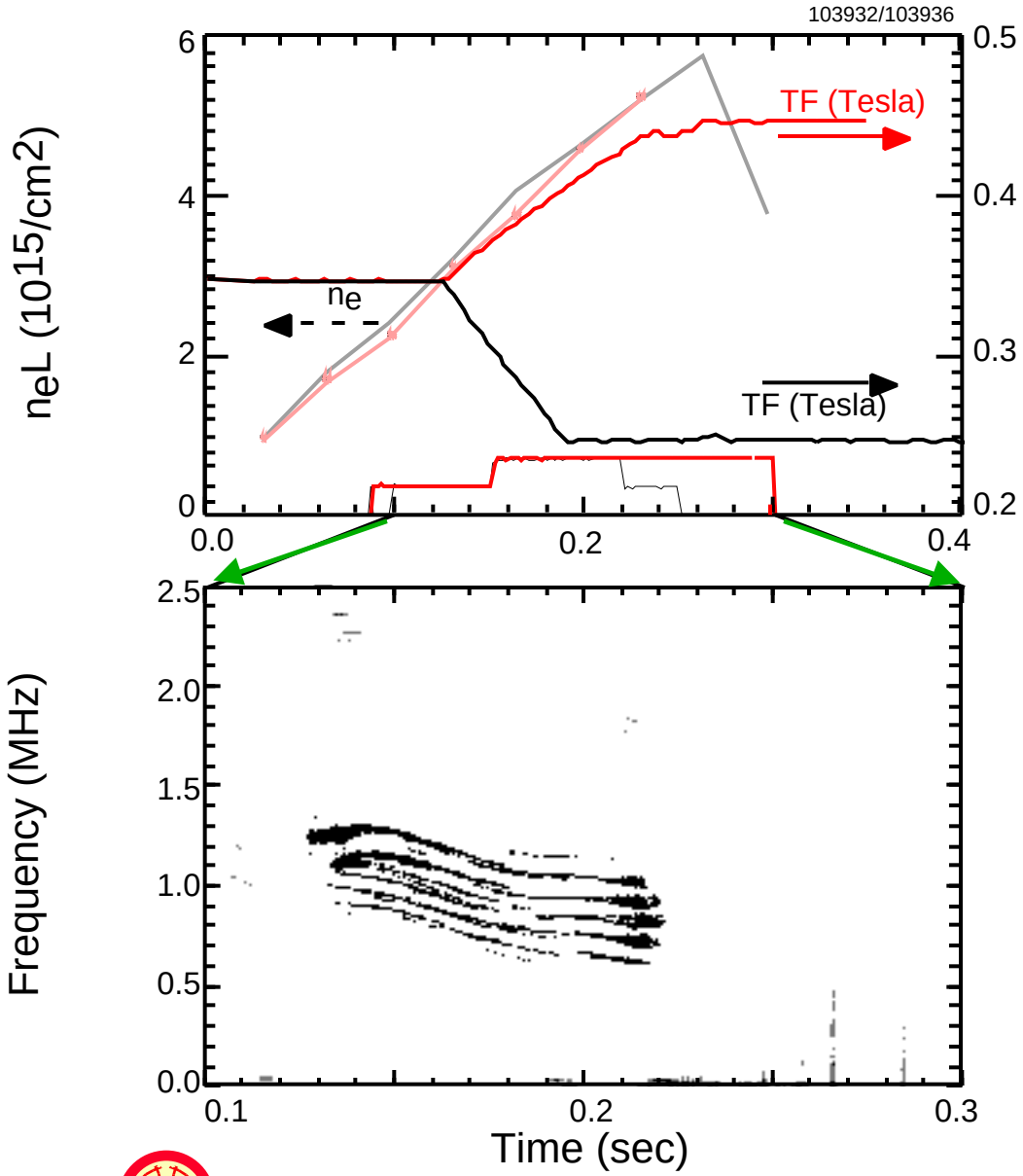
NTMs candidate for observed β-limiting mode



- Mode appears near poloidal beta β_p ~0.4
- Neoclassical tearing modes are candidate
  - mode amplitude dependence on β_p under investigation

D. Gates XP 24

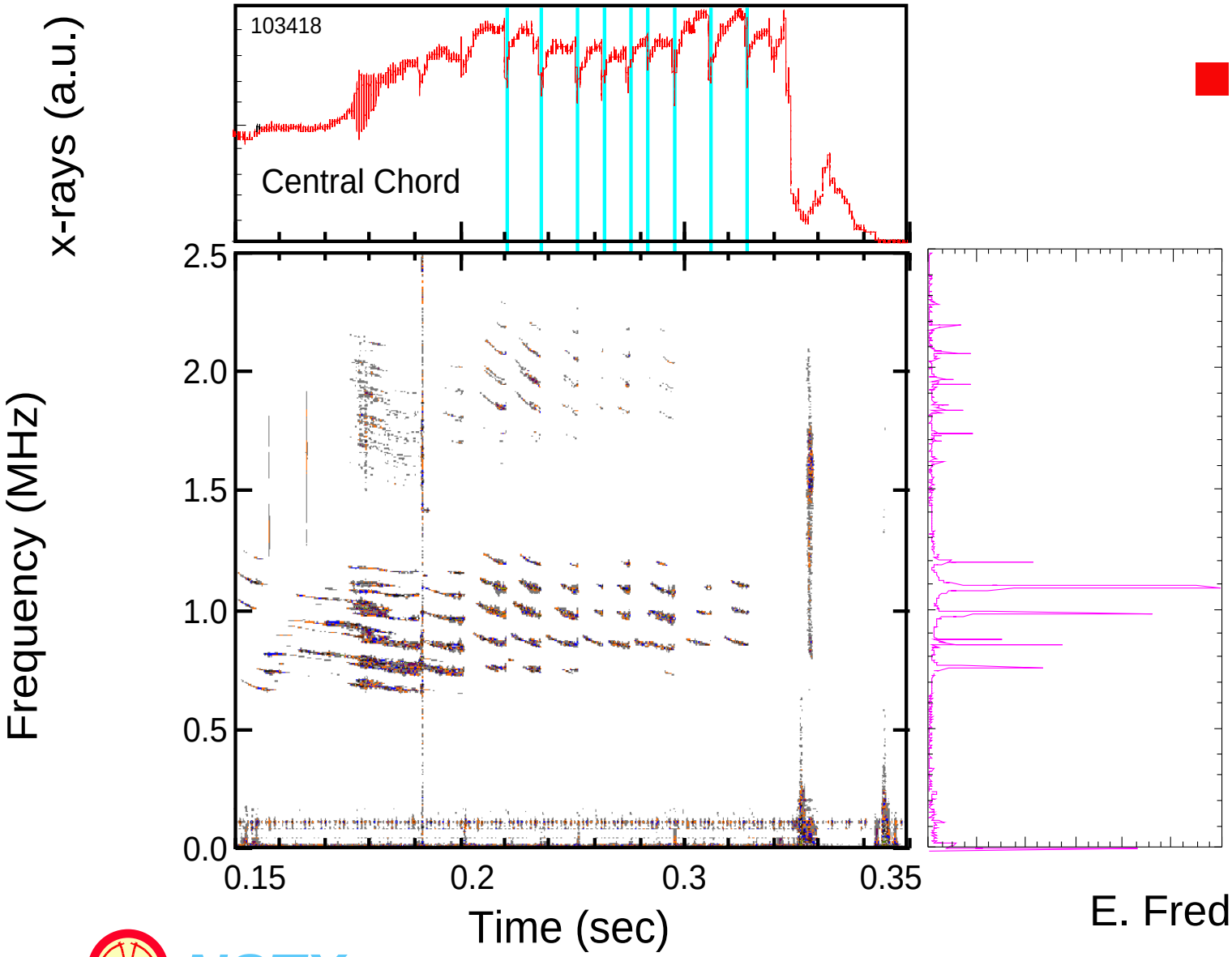
High frequency modes observed in NBI plasmas



- Frequency depends on magnetic field
- Plasma modes depend on fast ion distribution
- Mode frequency scales approximately inverse to (density)$^{0.5}$
- Modes are probably resonant compressional Alfvén waves

E. Fredrickson XP 22

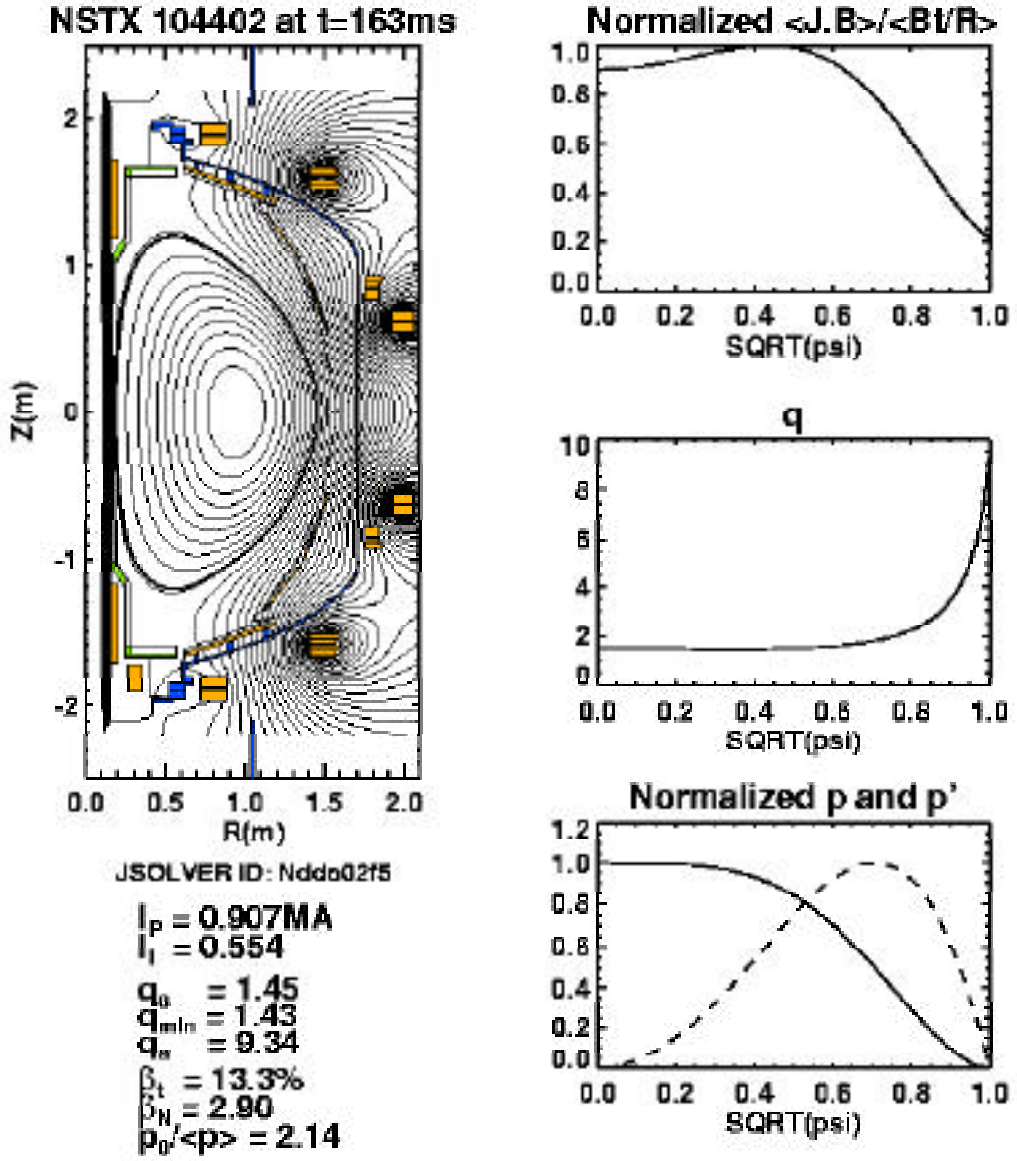
High frequency modes modulated by sawteeth



- Sawteeth might be affecting fast ions

E. Fredrickson XP 22

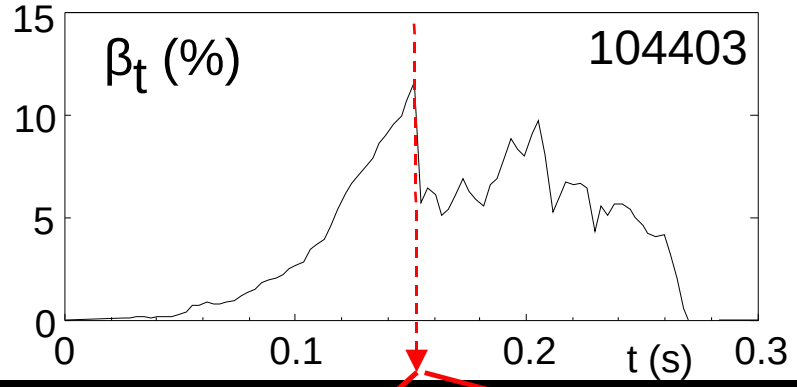
Testing Troyon Scaling in NSTX



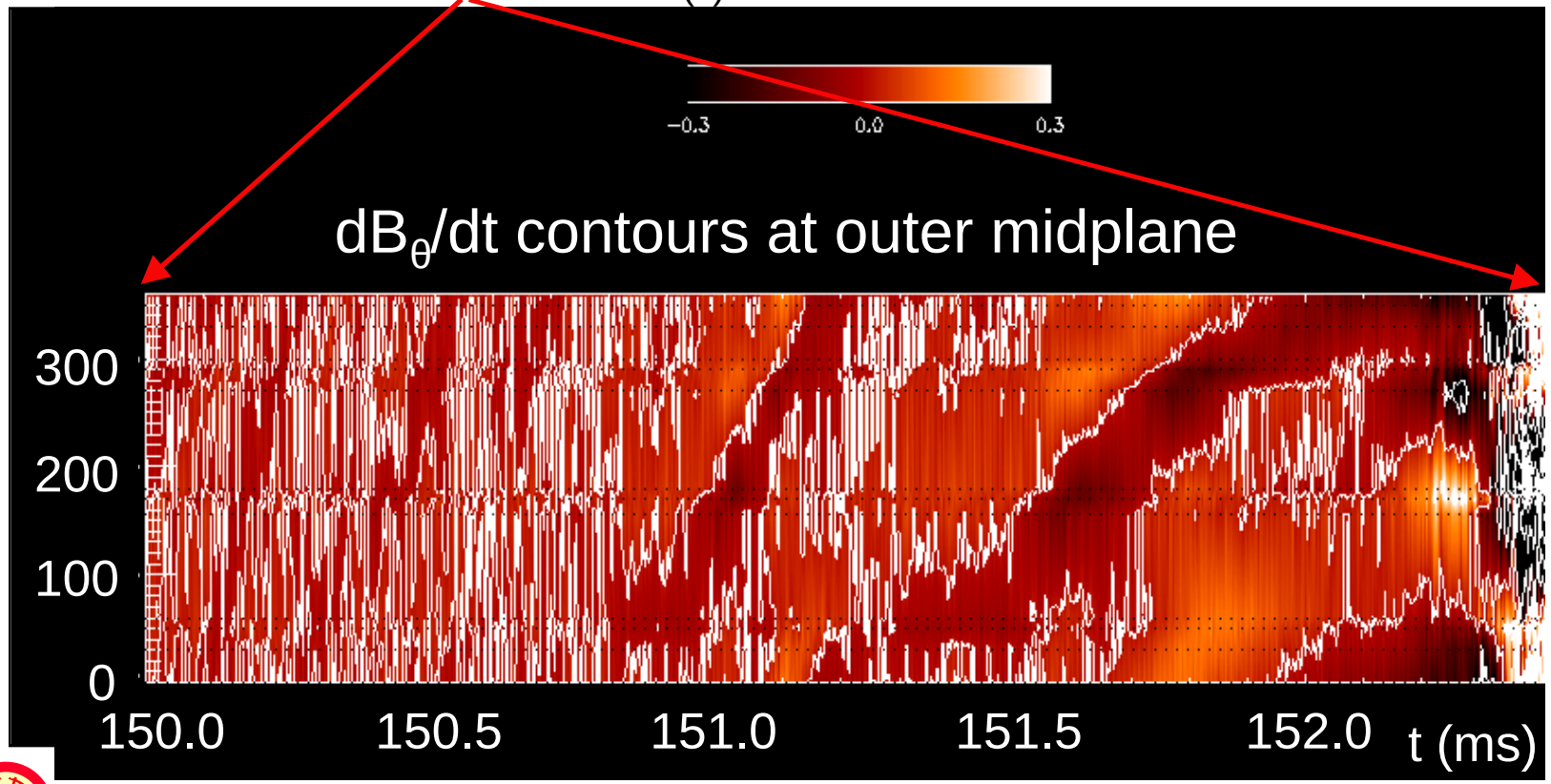
- GOAL: Determine κ, B_T (q*) scaling of ideal stability limit
- operate with q(0) > 1 (q(0) > 1.5 preferred)
- Hard β limit reached at reduced ℓ_i ~ 0.6
- Potential modes:
  - Locked tearing mode
  - Impurity driven "reconnection-event"
  - Edge current driven external kink

J. Menard XP 16

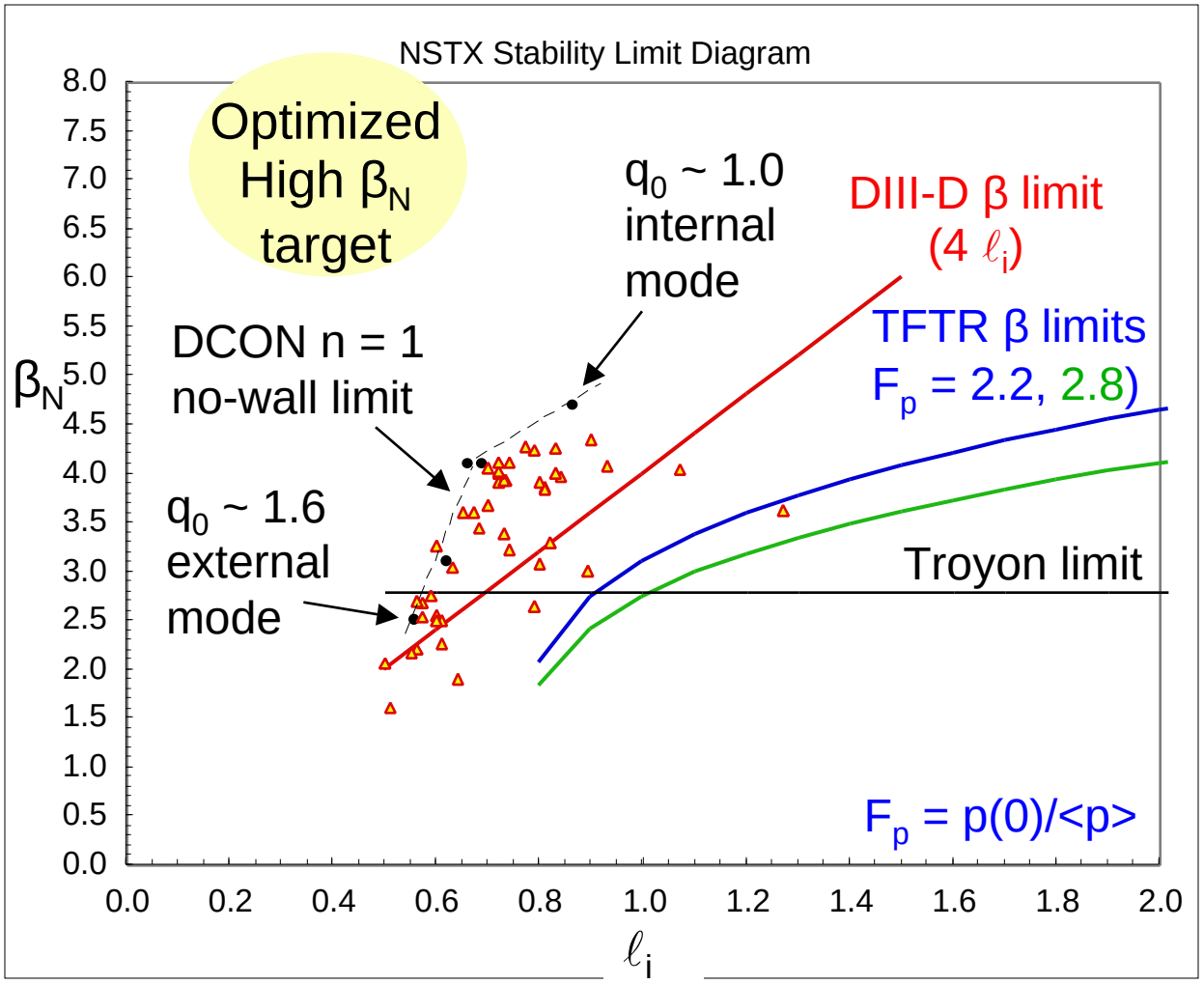
Mode locking observed during fast β collapse



- *n* = 1 observed on toroidal Mirnov array
- $\beta_{N\,max}$ = 2.5
- τ_{wall} > 5 ms; τ_A ~ 5 μs



Dependence of β limit on J profile studied at low A

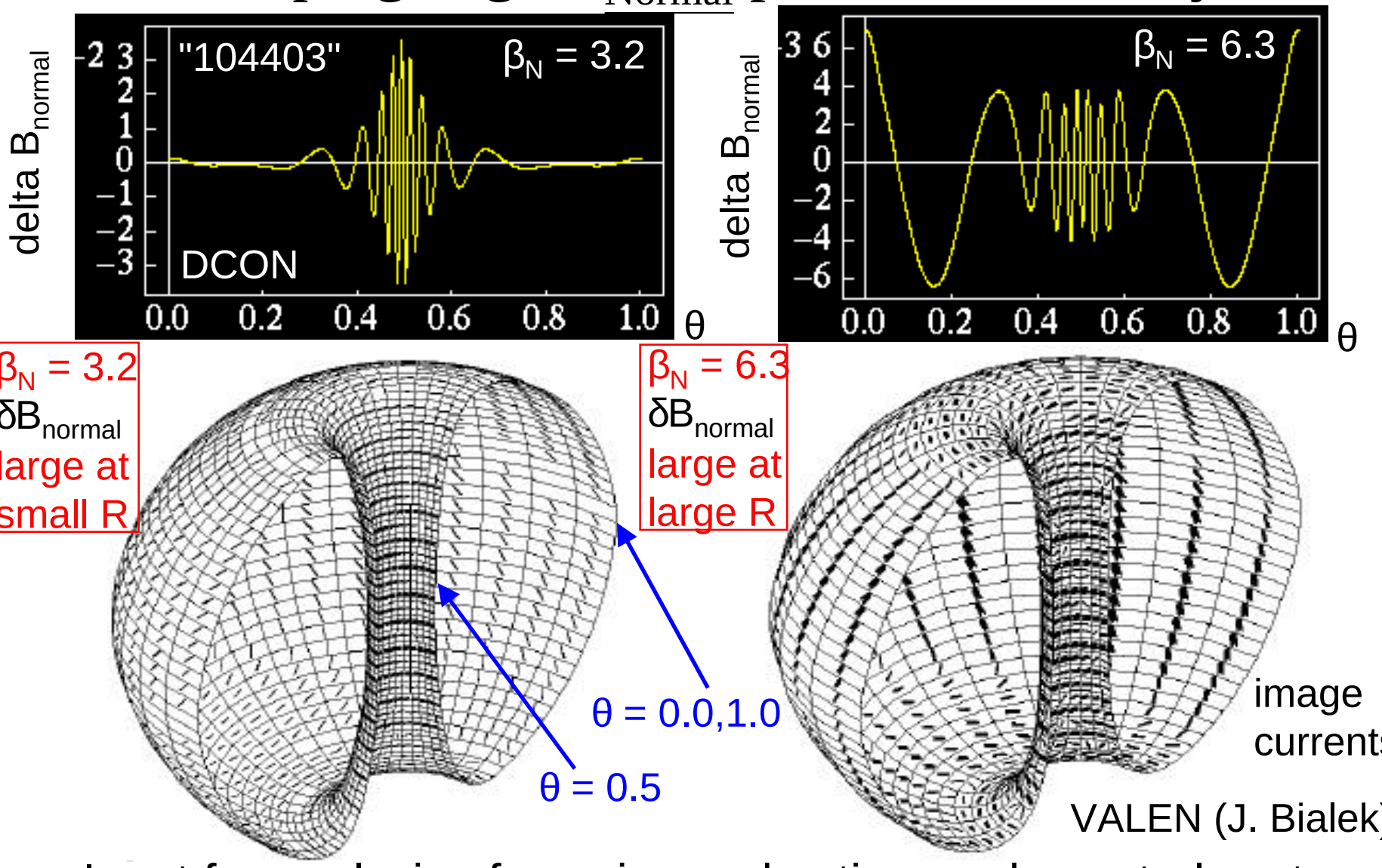


- Troyon limit, TFTR, and DIII-D β limits exceeded (β (EFIT))
- *n* = 1 ideal limit (DCON) in agreement with fast β collapses observed at $\ell_i \leq 0.8$
  - large outer gap => no-wall limit applies
- Ideal β_N limit is yet to be challenged at high ℓ_i
- Wall stabilization required to reach optimized target β_N
  - effective in low l_i plasmas with q(0) > 1

  (see talk by F. Paoletti, ET1 afternoon session)

DCON (A. Glasser)

Developing edge B_{Normal} perturbation analysis



- Input for analysis of passive and active mode control system

Review of CY 2000 prepares us to move forward...

- Present experiments have begun low A stability research, but...
  - Can your collaboration on present experiments aid the effort?
  - What further experiments would you propose?
  - What new low aspect ratio physics could be studied?
  - What diagnostics and/or analysis would you propose?
  - What comparison XPs to other devices could be conducted?

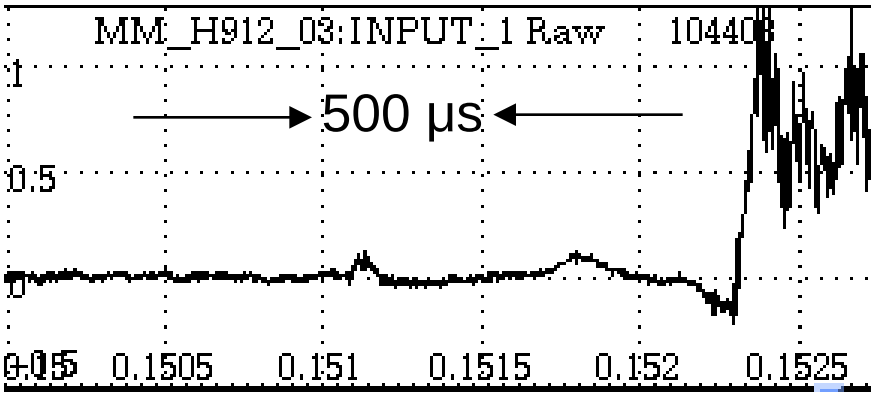
- Bring your ideas and comments to the

  ET1 CY 2001 Experimental Proposals Session

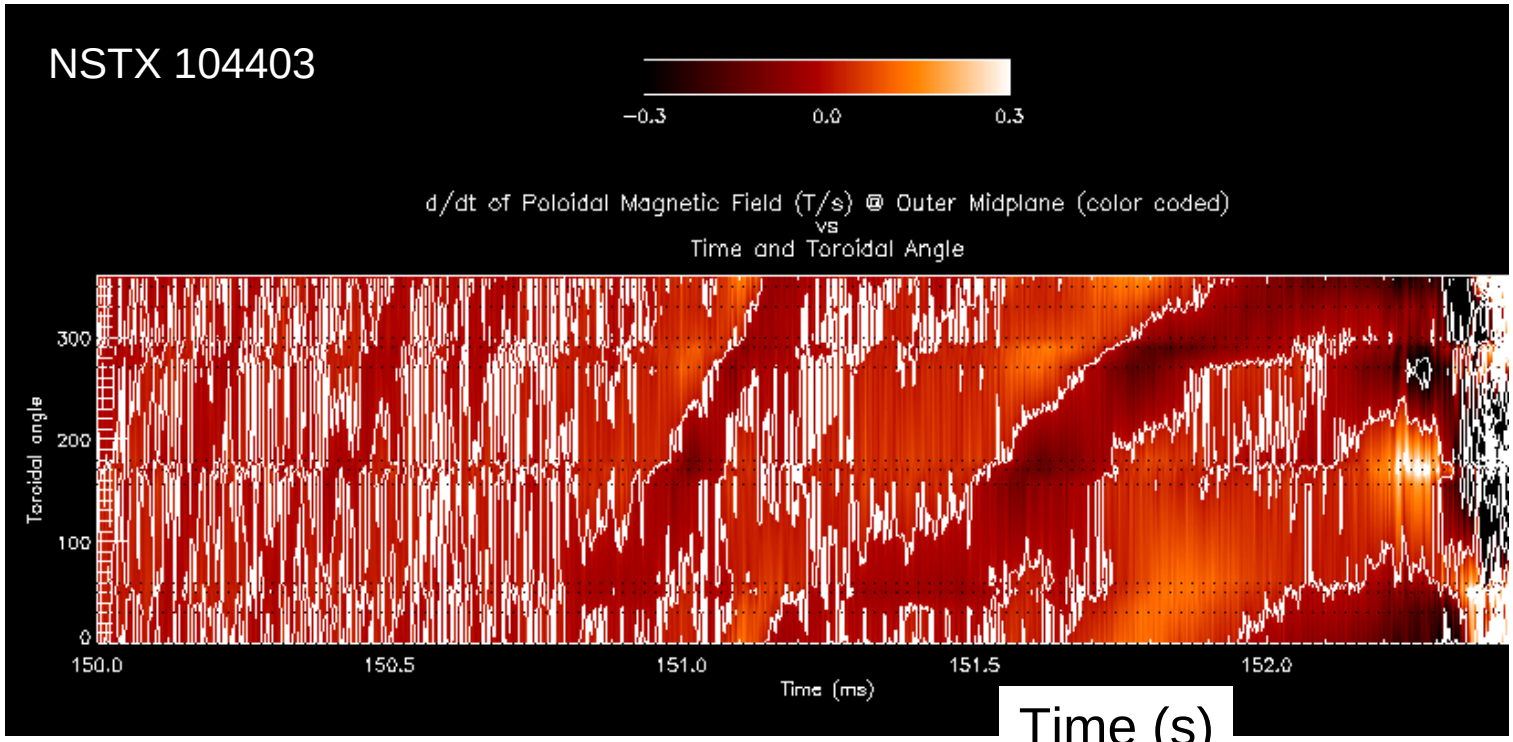
  2:40 pm *TODAY* LSB B318

Additional slides

Mode locking observed during fast β collapse



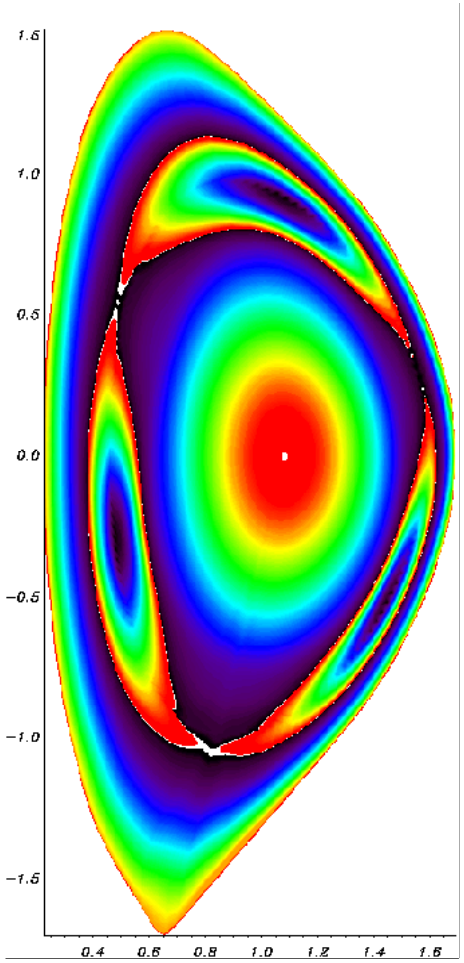
- *n* = 1 observed on toroidal Mirnov array
- τ_{wall} > 10 ms
- τ_A ~ 5 μs



Toroidal angle (deg)

Time (s)

Neoclassical Tearing Mode analysis is underway



Low-β NSTX equilibrium showing a 3/1 tearing mode

- Use PEST-III to calculate Δ', and eigen-function
- Use NIMROD subroutines to calculate neoclassical terms
- Combine and plot results in IDL
- Has led to numerous improvements in PEST-III (high-β, low-A resolution isssues) (See A. Pletzer's talk in ET 1 afternoon session)

A. Rosenberg

NBI with Small q = 1

- Technically successful run on Friday 11/17 (22 shots)
  - 700kA, 35kA TF, D2 targets grown in cross-section (from XMP-13)
    - early sawteeth after extended period of m=1 mode activity
  - Inject NB-B after or just before onset of sawteeth
    very little heating initially, but ..
    increasing gas produced some improvement
  - Extend Ip ramp to 800kA, add NB-C
    sawteeth during NBI without immediate degradation of confinement until ..
    onset of possible NTM at bP ≈ 0.4
- Tasks to complete experiment
  - Validate EFIT calculations of rq=1
  - Identify MHD activity
  - Compare grown cases with standard startup XP-23:

NBI Heated Plasma with High τ_E