Establishing the Science for Meeting 5 and 10 Year MHD Goals

S. A. Sabbagh

Columbia University

NSTX 5 Year Plan Ideas Forum – 6/24/2002

MHD Stability Group

Princeton Plasma Physics Laboratory

FESAC IPPA goals – define efficient methods to meet them

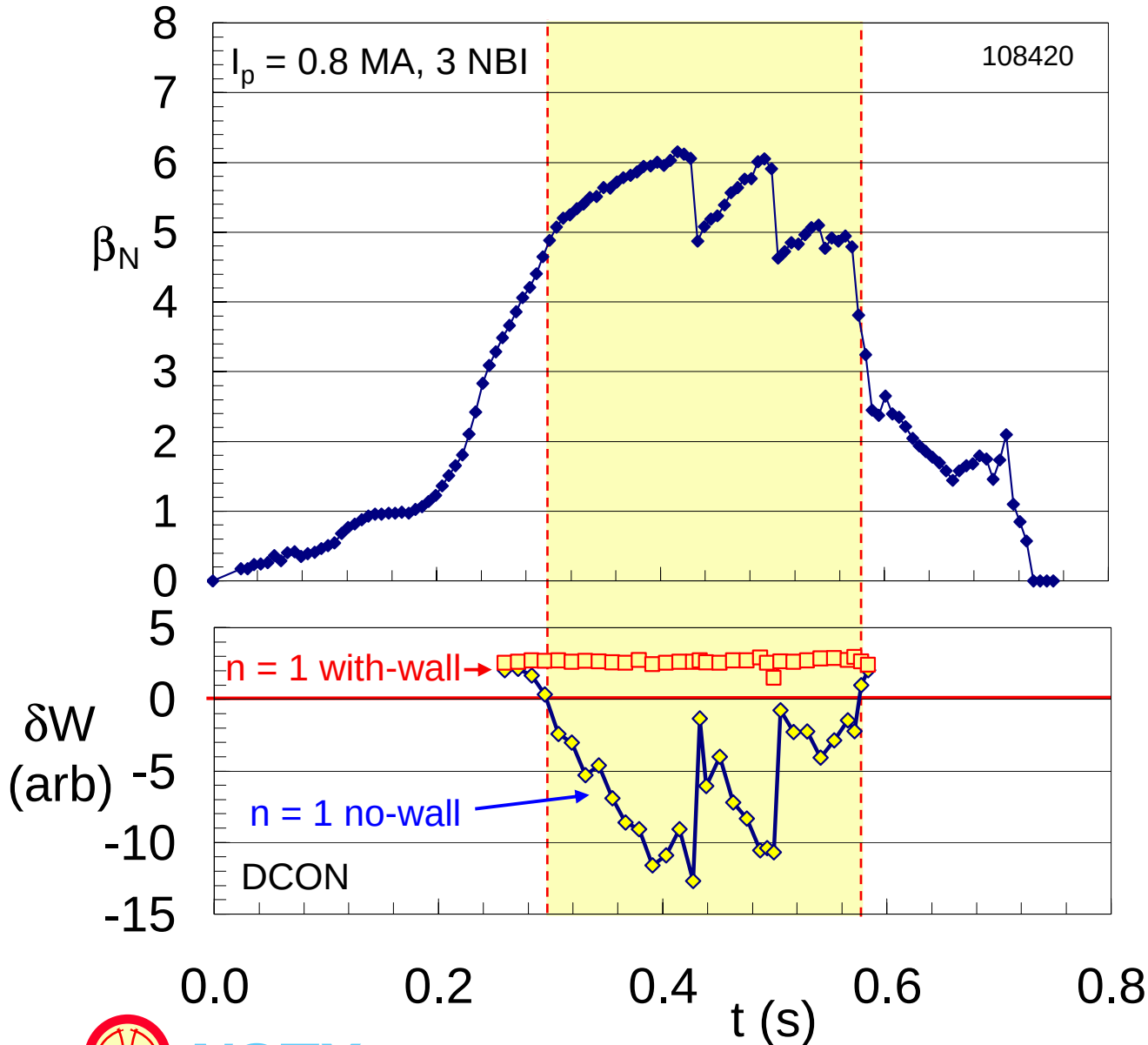
- Purpose of talk
  - Catalyst for discussion of group ideas in NSTX MHD science
- Guidance for Ideas Discussion
  - FESAC 5 and 10 year ST goals from IPPA report
    - *Make preliminary determination of the attractiveness of the ST by assessing high-beta stability, confinement, self-consistent high-bootstrap operation, and acceptable divertor heat flux, for pulse lengths much greater than energy confinement times (5 yr)*
    - *Assess the attractiveness of extrapolable, long-pulse operation of the ST for time scales much greater than current penetration time scales (10 yr)*
  - Start with broad, long term science goals
    - Articulate how these define, or blend in with major facility upgrades
  - Continue by defining practical short term methods to reach goals
    - Discuss and produce solutions that *exceed* expectations

Challenge: Continue to deliver key science ahead of schedule!

Demonstrate NSTX fast progress toward MHD science goals

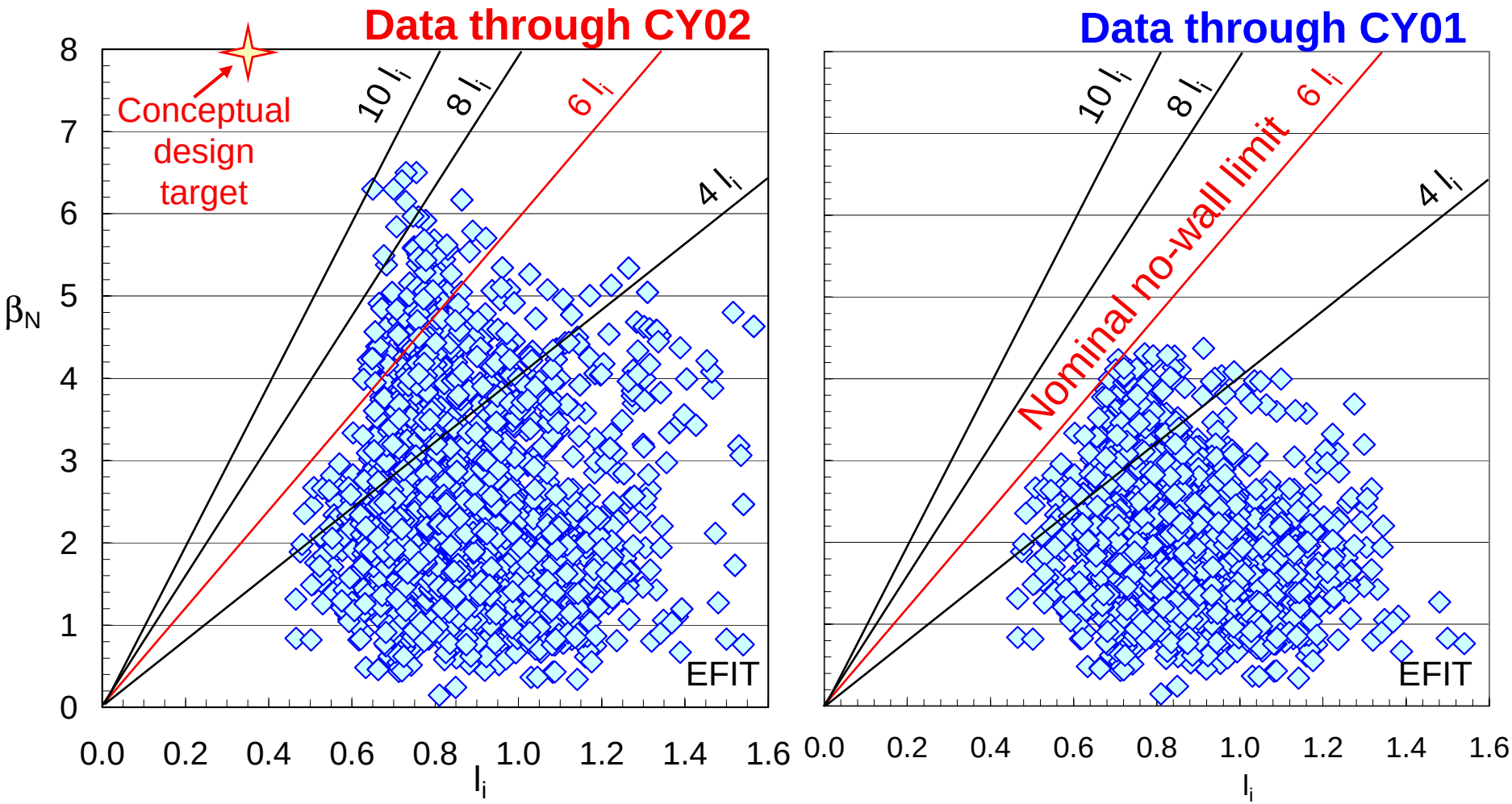
- 5 Year FESAC IPPA Goals
  - Develop detailed predictive capability for macroscopic stability, including resistive and kinetic effects
    - Progress measured by the level of agreement between predicted and observed stability regimes and by improvements in the stability of operating confinement devices
- 10 Year FESAC IPPA Goals
  - Develop fully integrated capability for predicting the performance of externally-controlled systems including…macroscopic stability…
  - Develop qualitative predictive capability for transport and stability in self-organized systems
  - Advance the forefront of non-fusion plasma science and technology…
- Implementation Approaches
  - Stability analysis of intermediate-*n* number mode
  - RWM theory development and experimental investigation
  - Improve usefulness of resistive stability predictions by extended theory / simulation
  - Physics of external control: boundary / profile shaping; instability feedback stabilization
  - Extend MHD: FLR physics, suprathermal particle effects, rotation effects
- NSTX progress toward 5 year goal (one example)
  - between-shots diagnostics available for quantitative, between-shots ideal stability analysis; Plans to include rotation, resistive effects; plan for kinetic effects

Between-shots stability extensively tested in CY02



- Diagnosis of wall-stabilized plasmas
  - A few thousand shot*times run
- Examined violation of ideal limits with onset of resistive wall modes and beta collapses
- Ideal no-wall limit violated for many τ_E and τ_{wall} in many plasmas

Significant progress in CY02 toward high beta goals



- CY02: β_N = 6.5, β_t = 32% reached; β_N / l_i ~ 10; above no-wall limit
- Significant progress also made in transport and non-inductive CD goals

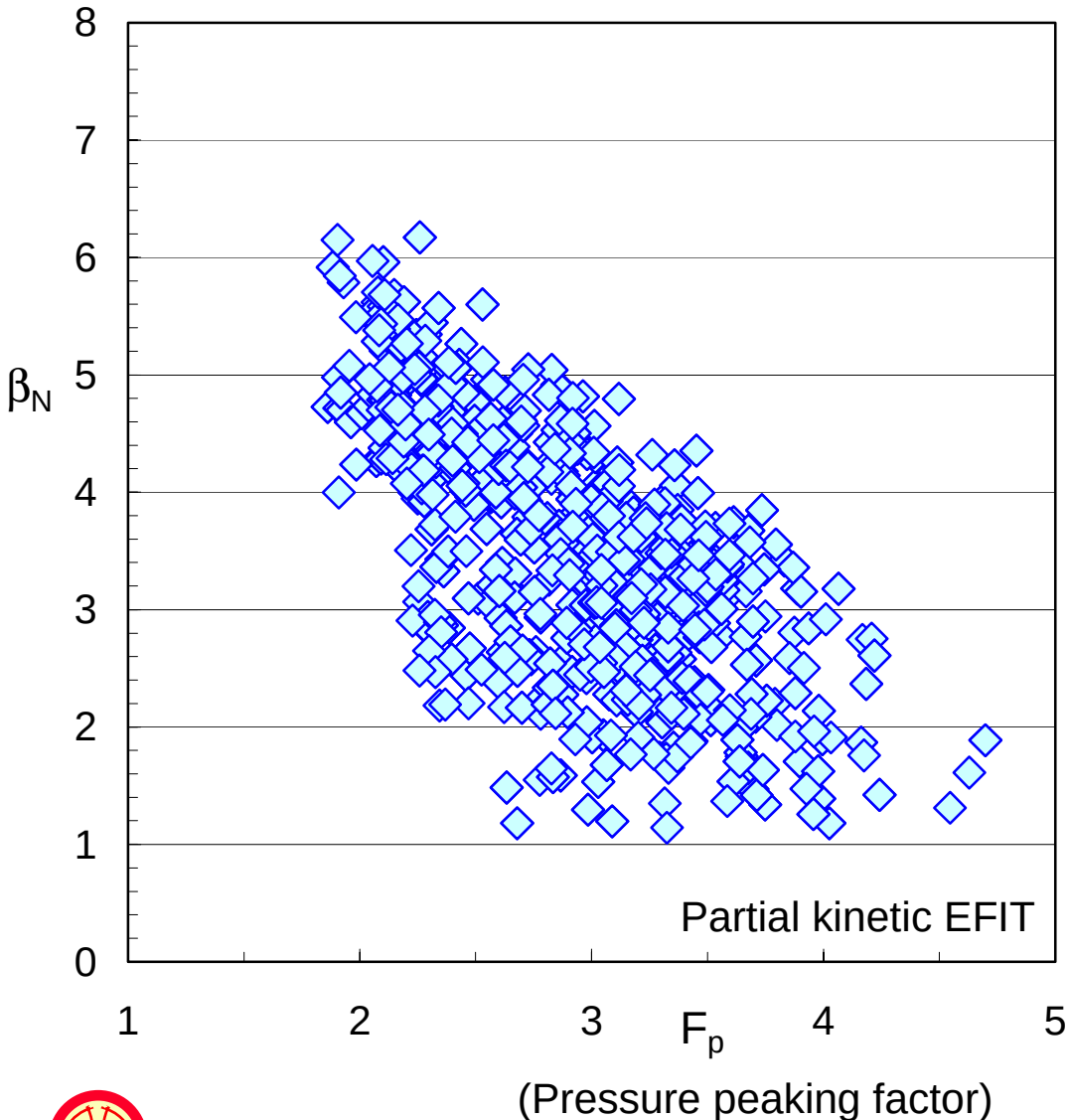
Can ST participate in science of high performance plasmas in an accelerated (5 year) timescale?

- FESAC Goal 3: Advance understanding in high performance plasmas, optimizing for power plant req's, burning plasma
  - Assess profile control methods for current sustainment (AT only?)
  - Develop / assess high-beta instability feedback control (AT only?)
  - Develop / assess burning plasma scenarios
- What approach to take?
  - Expand physics studies with minor facility upgrades?
  - Emphasize certain MHD science to satisfy goals?
  - Accelerate design and implementation of center stack upgrade?
- How does your research contribute to group ideas?

Key instabilities presently being researched

Instability	Beta limiting?
Ideal low-*n* kink/ballooning	yes
Resistive wall modes	yes
Neoclassical tearing modes	yes
Current-driven kinks	at reduced q
Locked modes	can be
Sawteeth	can trigger NTM
Alfven eigenmodes (CAE, TAE)	no

Strong correlation between max β_N and pressure peaking



- NSTX plasmas in CY02 have favorable profiles for stability in H-mode
- Increased β_N reached at reduced pressure peaking (H-mode)
- Further β_N increase through increased $\delta \sim 0.8$
- Long pulse, high β_N, β_p plasmas created
  - Partial kinetics reconstructions support $q_0 > 1$ hypothesis