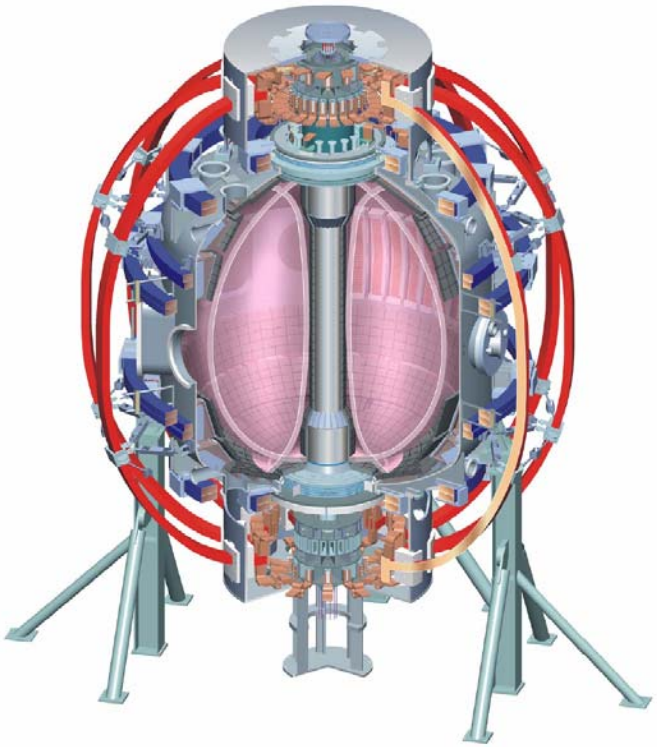
Supported by

NSTX Research Has Progressed as Planned: April – June 2004



- Physics Progress
- Research Milestone Status
- 4th Quarter Efforts & Future

Martin Peng & Ed Synakowski
For the NSTX Team

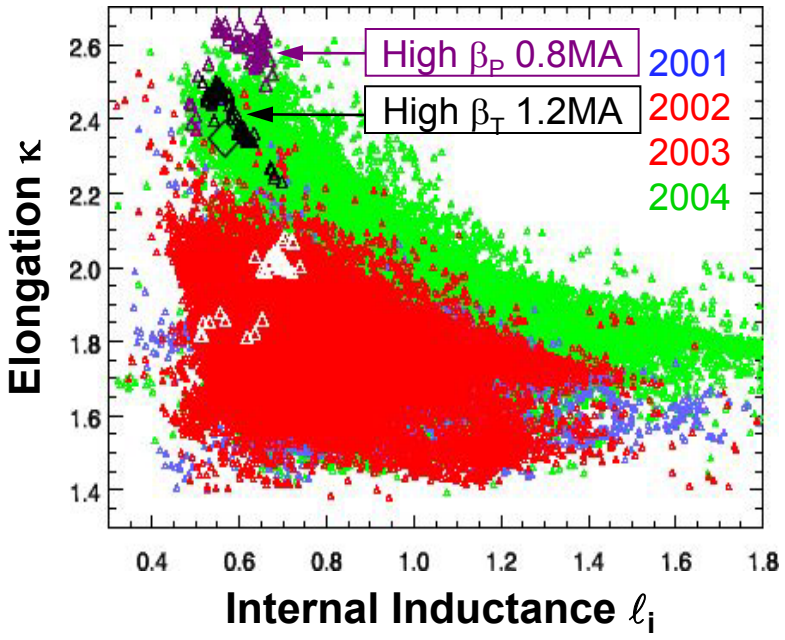
NSTX Quarterly Tele-Video Review

July 15, 2004
PPPL – Germantown

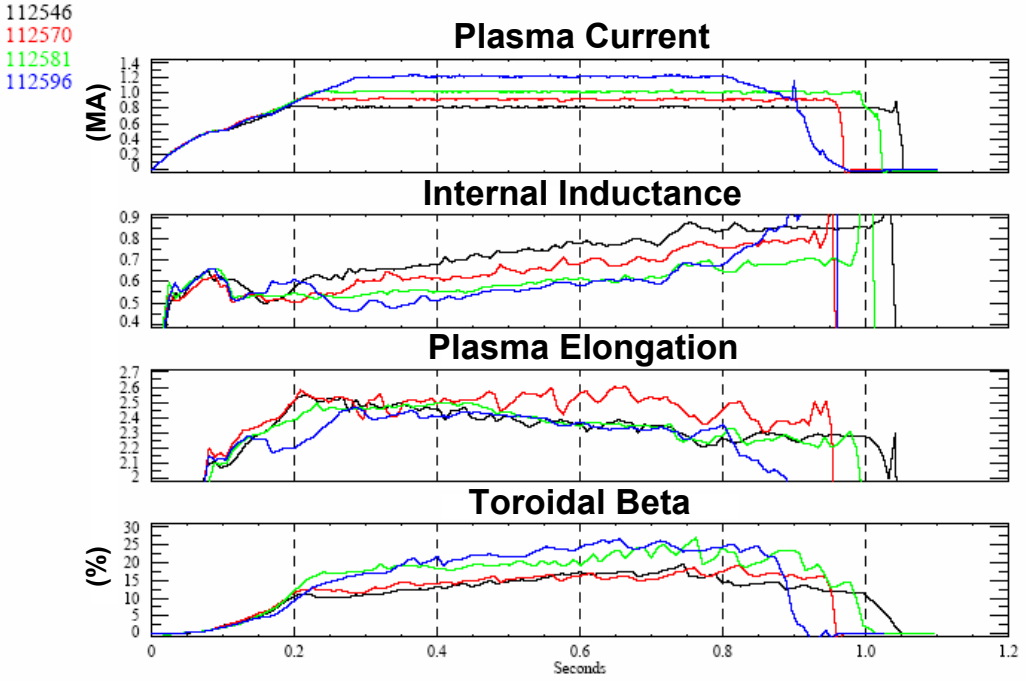
Columbia U
Comp-X
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
NYU
ORNL
PPPL
PSI
SNL
UC Davis
UC Irvine
UCLA
UCSD
U Maryland
U New Mexico
U Rochester
U Washington
U Wisconsin
Culham Sci Ctr
Hiroshima U
HIST
Kyushu Tokai U
Niigata U
Tsukuba U
U Tokyo
JAERI
Ioffe Inst
TRINITI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

Faster vertical position control & varied L-to-H times opened window for planned investigations

Broadened Operating Space



Improved Sustained Conditions



- Reduced **latency** of digital control system to **~700μs**
- **Achieved early H-mode** via pause shaping & lower gas puffing
  - Lower internal inductance allows higher elongation
  - Reduced flux consumption extends pulse

Gates, Menard (PPPL), Wade, Maingi (ORNL)

FY04 milestones explore high β and current drive physics – key to NSTX Proof-of-Principle mission

	FY04	FY05	FY06
Exp. Run-Weeks:	20	14	12

1) Transport & Turbulence: How does turbulence cause heat, particle & momentum losses?

- (04-2) Measure low-k turbulence
- (05-1) Measure high-k turbulence

2) Macroscopic MHD Stability: What limits maximum plasma pressure & bootstrap current?

- (05-2) Study plasmas near "with-wall" limit

3) Wave-Particle Interaction: How do electromagnetic waves interact with plasma?

- (04-3) Measure ΔJ from RF, NBI & ∇p
- (05-3) Assess EBW H&CD requirements
- (04-5) Characterize EBW emission, estimate H&CD

4) Start-up, Ramp-up and Sustainment: How is plasma magnetic flux generated?

- (04-4) Test current initiation
- (06-1) Test solenoid-free ramp-up to high current

5) Boundary Physics: How to interface fusion plasmas to surrounding materials?

- (06-2) Characterize edge of H-mode plasmas

6) Integration: How much external control vs. self-organization is needed?

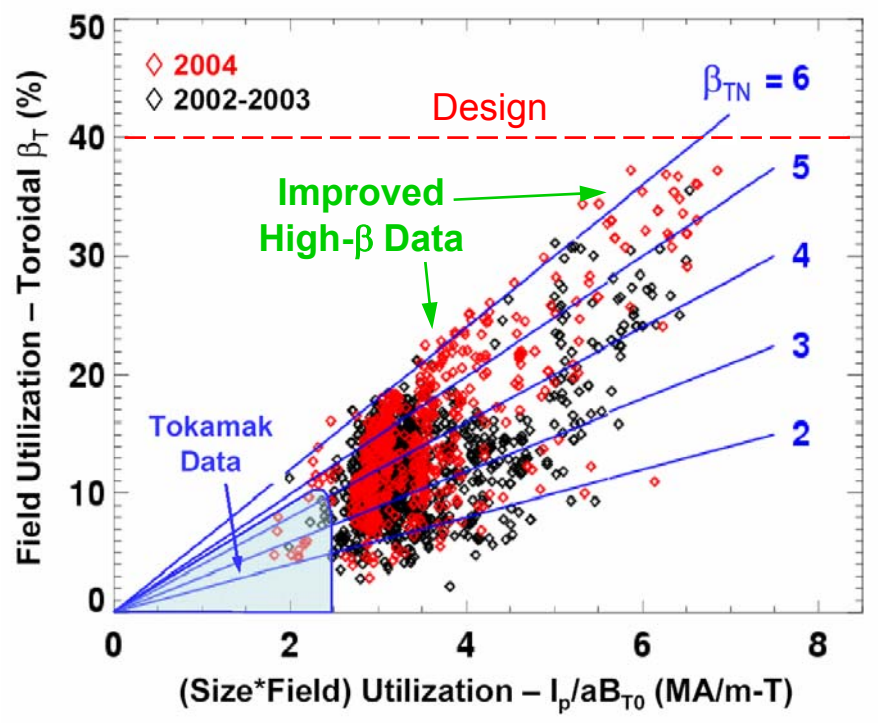
- (04-1) Assess high τ_E & high β_T H-mode for >> τ_E
- (05-4) Assess combined RF & NBI effectiveness
- (06-3) Evaluate J_{NI} ~ 100% for ≥ τ_{skin}

Research Milestone FY04-1: *Assess confinement and stability in NSTX by characterizing high confinement regimes with edge barriers and by obtaining initial results on the avoidance or suppression of plasma pressure limiting modes in high-pressure plasmas.* (DOE SC6-2a)

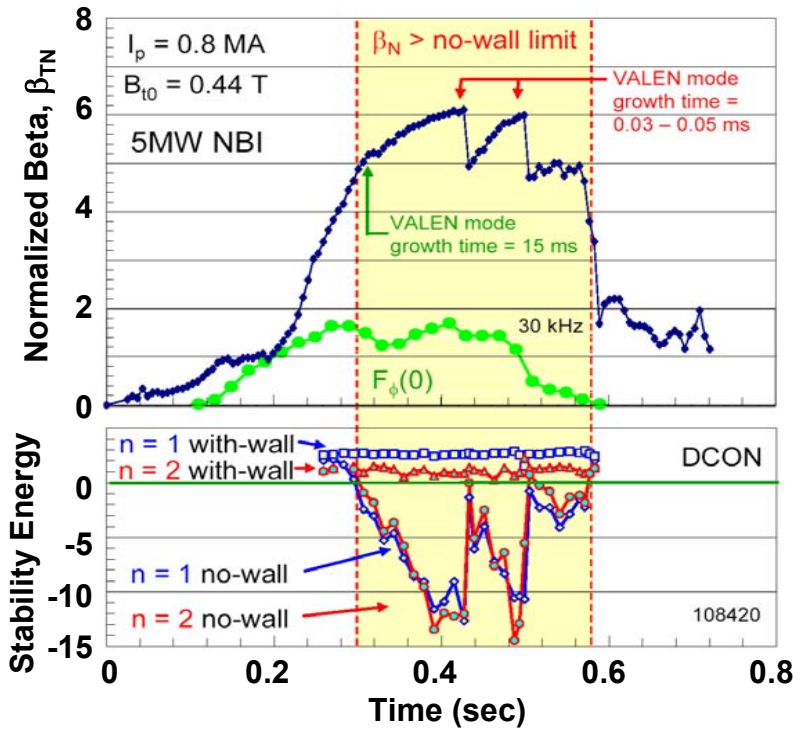
NSTX

3rd Quarter Target*: Characterize the benefits of the* ***spherical torus configuration*** *and* ***plasma rotation*** *on the avoidance or suppression of pressure limiting modes.*

- **Increased size*field utilization**
- **Verified ST benefit on β_T limits**



- **$\beta > \beta_{no\text{-}wall}$ for durations >> τ_{wall}**
- **Matches Chu-Bondeson theory**



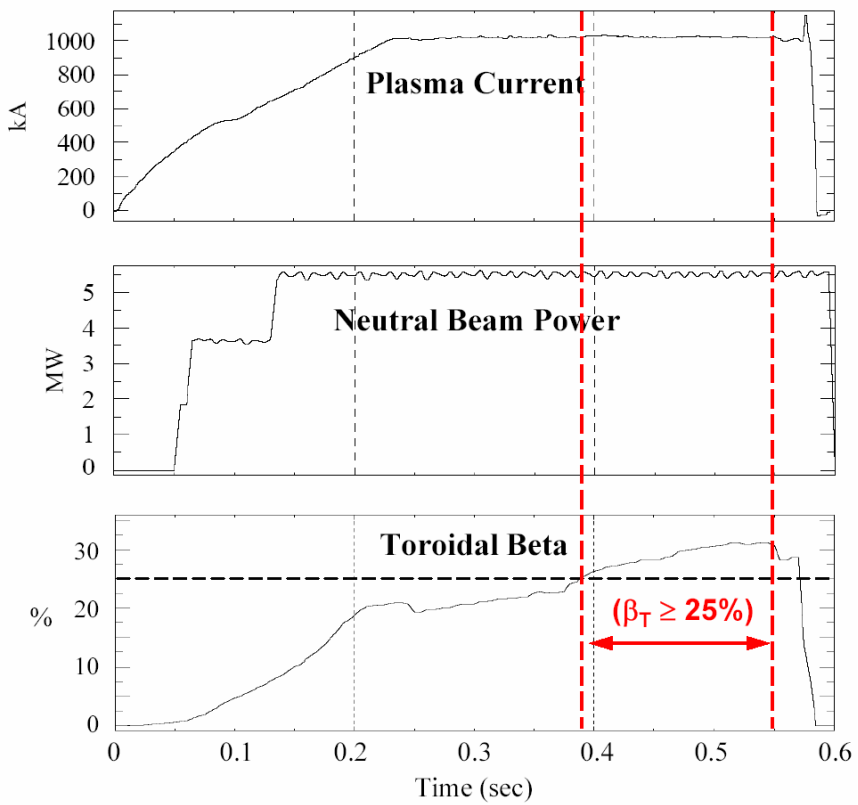
Menard, Gates (PPPL), Sabbagh, Sontag (Columbia)

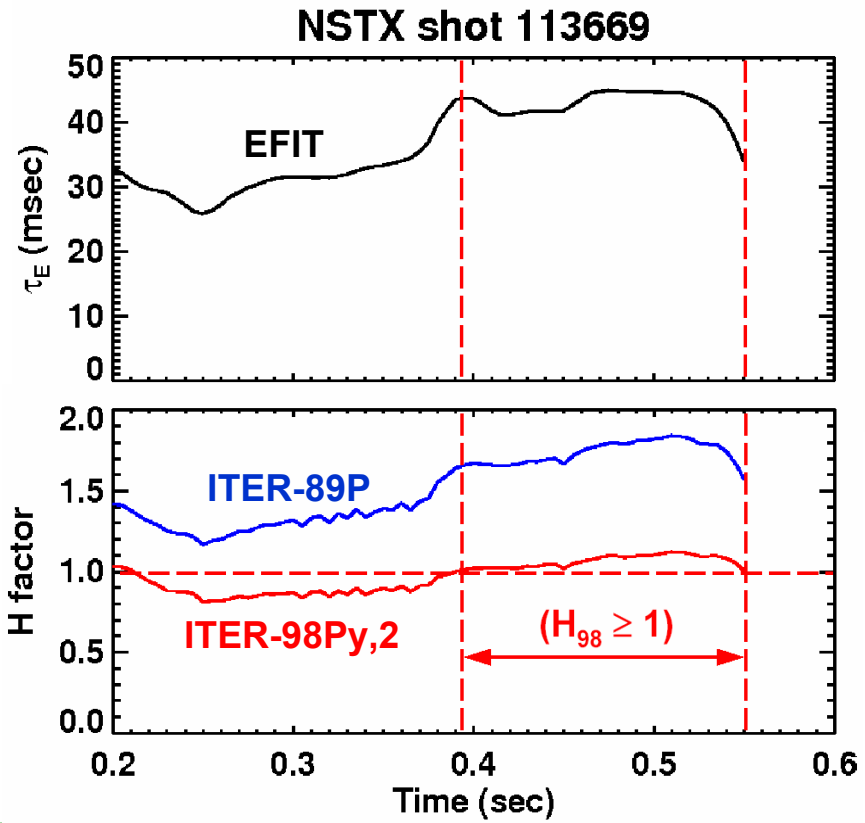
***4th Quarter Target**: Characterize the dependence of electron and ion thermal diffusivities on variations in plasma parameters at high pressure in high confinement regimes.* (SC6-2a; research milestone FY04-1)

NSTX

Appropriate Conditions Achieved!

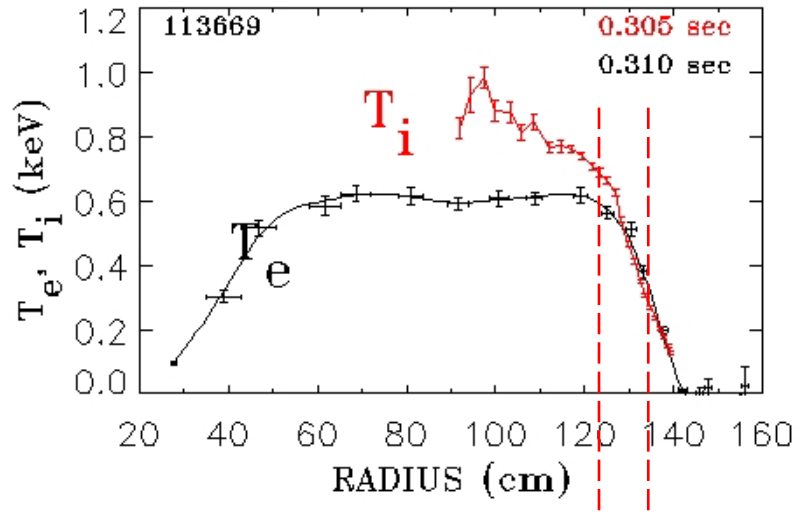
- High β_T and τ_E conditions sustained for times >> τ_E
- TRANSP and microstability analysis being carried out.

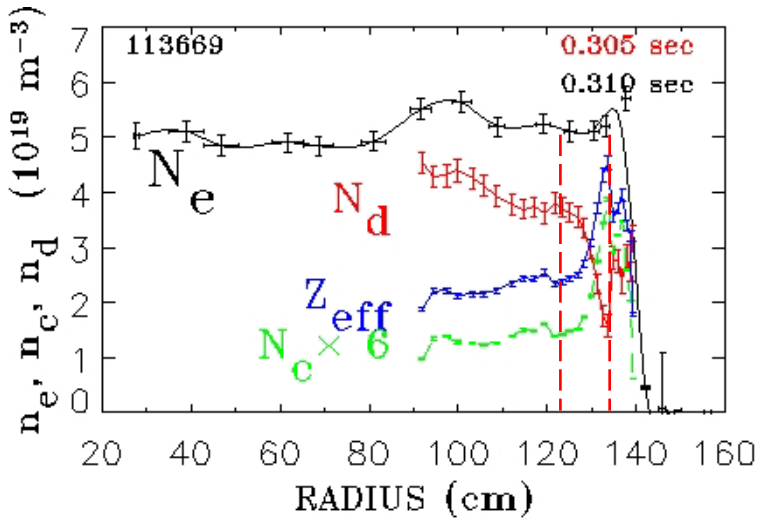


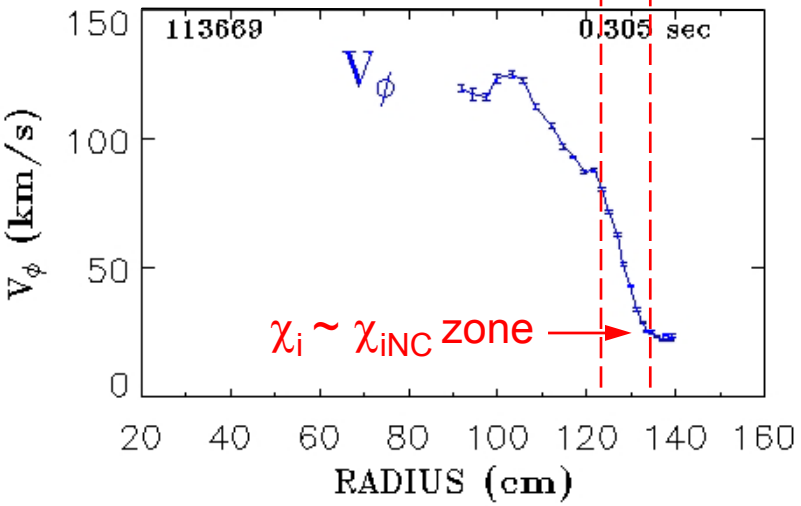


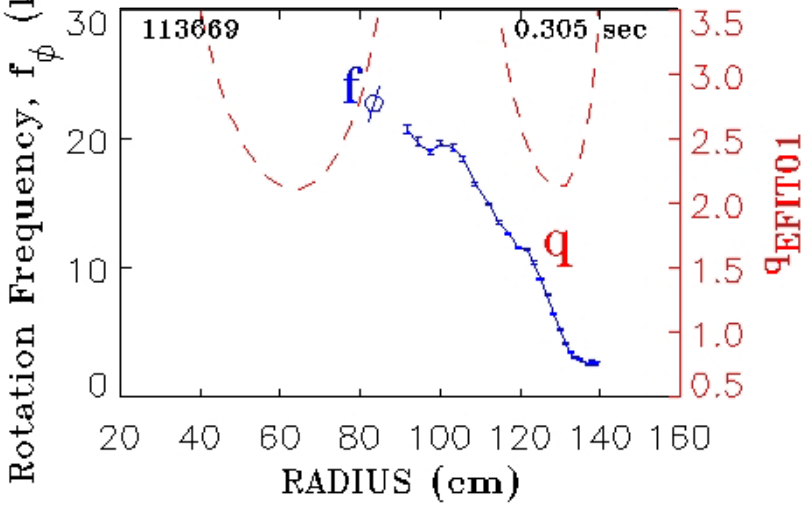
Menard, Gates, R. Bell (PPPL), Sabbagh (Columbia)

High resolution profile measurements provide data appropriate for analysis of thermal diffusivities







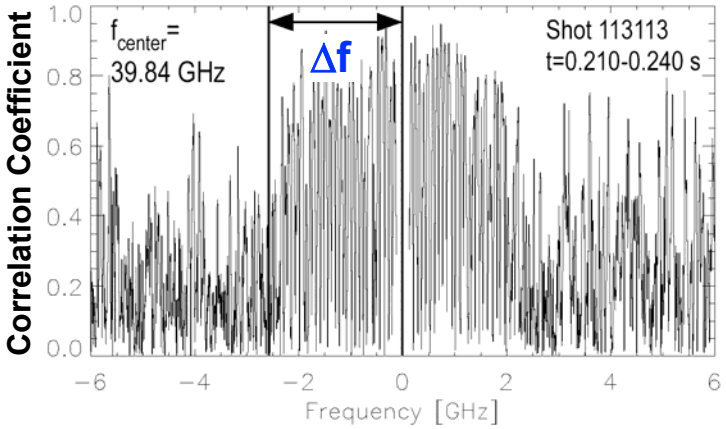


Measurements of long wavelength turbulence in the core & edge firm up basis for ST transport assessment

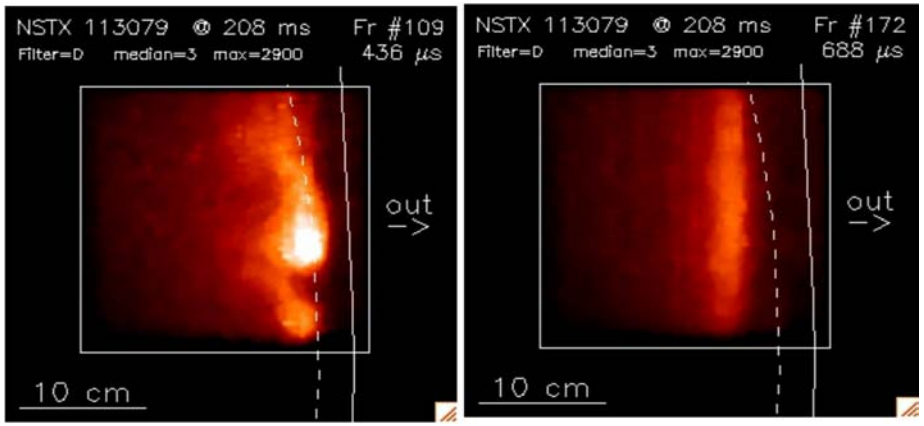
Milestone FY04-2 on Transport and Turbulence: *Measure long wavelength turbulence in spherical torus plasmas.*

- **Core: reflectometry** (UCLA)
  - Spatial correlation length ≤ 5 - 10 ρ_i in core of L mode plasmas (r/a ~ 0.35)
  - Data also in ITBs and edge
  - Complete analysis with GYRO (GA) and TRANSP
- **Edge: fast camera** (PSI)**, tokamak comparison** (C-Mod), **fast probe** (UCSD)
  - Turbulence structure evolution @ 4μs
  - H-transition, causality, ρ* scaling
  - Comparisons with BOUT (LLNL) underway: magneto-sounds?
- **Building a comprehensive picture**
  - Compare data from several diagnostics
  - Similar and different trends

Strong correlations measured for $\Delta f \leq 3$ GHz → spatial correlation length ≤ 6 cm ~ $6\rho_i$



L mode edge *H mode edge*



(http://www.pppl.gov/~szweben/NSTX04/NSTX_04.html)

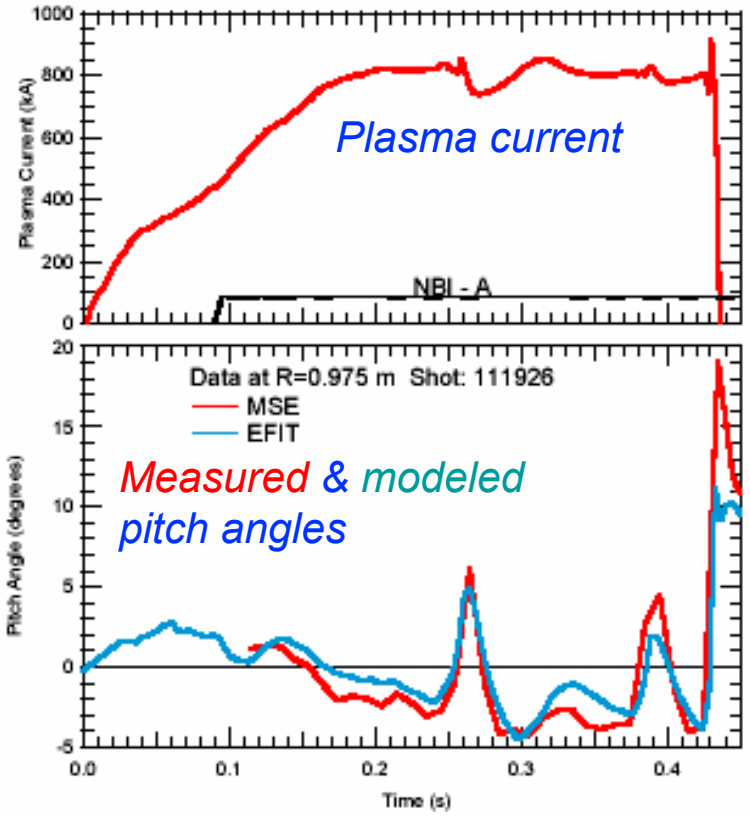
The MSE diagnostic is on-line, meets specs, and is taking data

Milestone FY04-3 on Wave-Particle Interactions: *Measure plasma current profile modifications produced by radiofrequency, neutral beam injection, and pressure-gradient techniques.*

MSE-measured core pitch angle (± 0.2 ° stat. error) compared with equilibrium by EFIT

- **Confirmed adequate resolution of new MSE system** (Nova)
  - Frontier advance in MSE for low field high beta configurations
- **Commissioned initial 4 channels**
  - Upgrade to 7 channels this run
- **Ready to document driven currents**
  - HHFW
  - Neutral beam
  - Bootstrap
- **19 channels to be readied for 2005 campaign**

Nova Photonics, Inc.



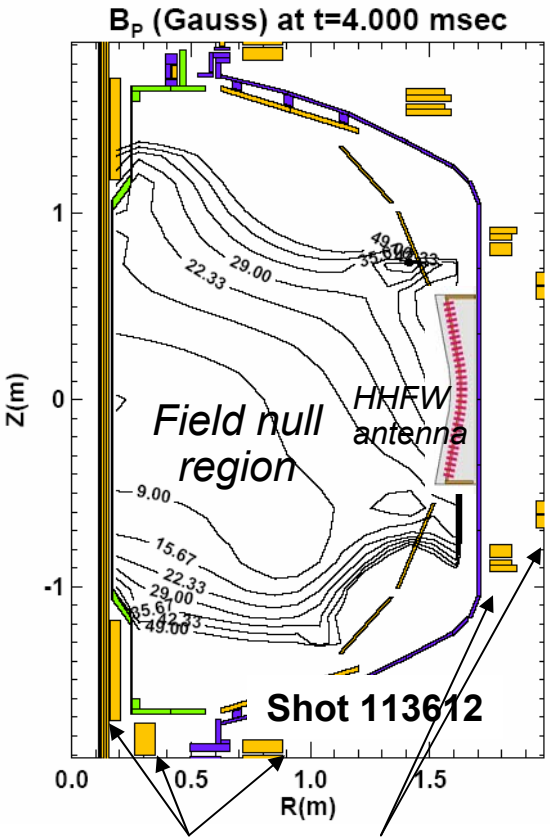
Solenoid-free PF-only startup experiments have begun, further CHI will be performed

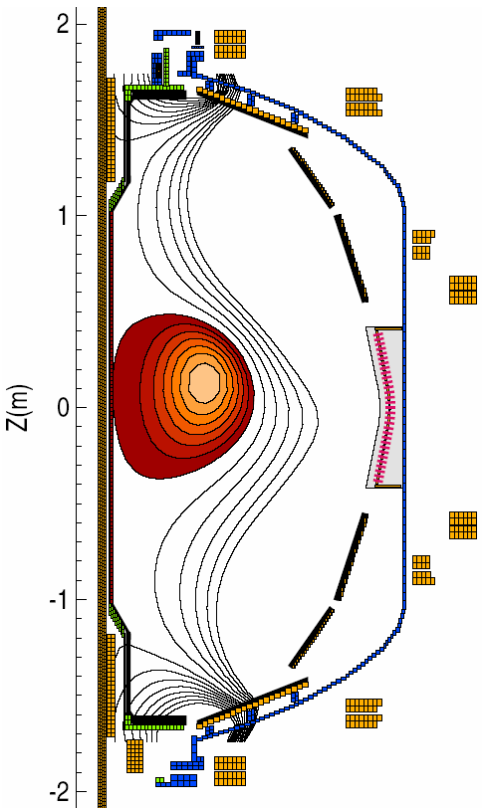
Milestone FY04-4 on Solenoid-free Startup, Ramp-up and Sustainment: *Conduct initial tests combining available techniques to achieve solenoid-free initiation to substantial plasma currents.*

- **Outer-PF only induction**
  - Three scenarios tested
  - HHFW pre-ionization
  - PPPL (KBSI), U. Tokyo collaboration
  - EBW would be beneficial
- **Transient coaxial helicity injection**
  - Success demonstrated on HIT-II (U. Washington)
  - Capacitor bank & control being commissioned

Tests continue
- *Inboard field-null (PPPL)*
- *Outboard field-null (PPPL)*
- *No field-null (U. Tokyo)*

Transient 15 kA produced
- *Inboard field-null*
- *Need to grow I_p and β and reduce vertical field*



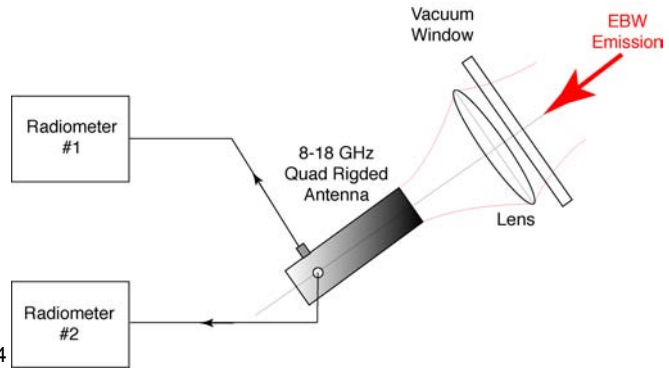


EBW milestone reached and theory confirmed – strong emission and conversion in over-dense plasmas

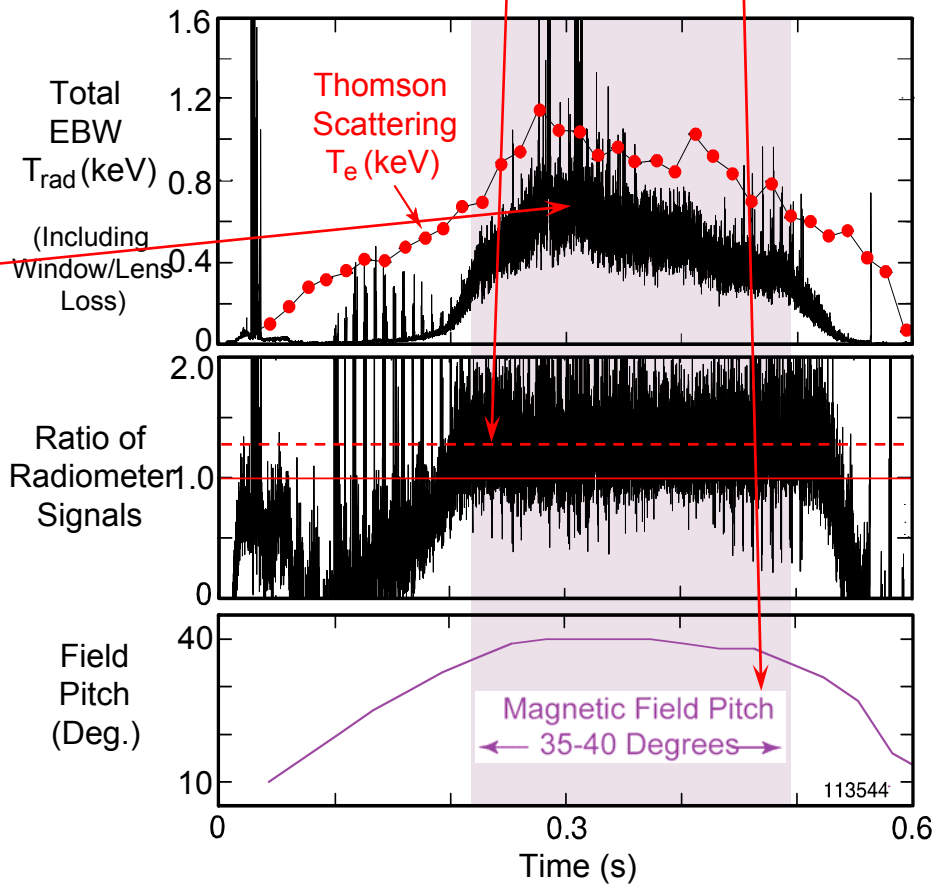
Milestone (FY04-5) on Wave-Particle Interactions: *Measure Electron Bernstein Wave (EBW) emissions to assess heating and current drive requirements.*

- Efficient and flexible conversion of elliptically polarized EBW between plasma core and antenna **predicted**
- Up to ~ 70% conversion measured over substantial range of pitch angles
- Basis for high-power EBW design

Tunable dual orthogonal radiometers



Confirmed field pitch and mode ellipticity



FY04-06 research milestones under incremental fund will enable timely support of FES strategic plan

	FY04	FY05		FY06		
Exp. Run-Weeks:	18	14	(7)	12	(6)	← Incr. Request

1) Transport & Turbulence: How does turbulence cause heat, particle & momentum losses?

- (04-2) Measure low-k turbulence
- (05-1) Measure hi-k turbulence

2) Macroscopic MHD Stability: What limits maximum plasma pressure & bootstrap current?

- (05-2) Study plasmas near "with-wall" limit
- (06-4-Incr) Identify tearing modes & onset conditions

3) Wave-Particle Interaction: How do electromagnetic waves interact with plasma?

- (04-3) Measure ΔJ from RF, NBI & ∇p
- (05-3) Assess EBW H&CD requirements
- (04-5) Characterize EBW emission, est. H&CD

4) Start-up, Ramp-up and Sustainment: How is plasma magnetic flux generated?

- (04-4) Test current initiation
- (06-1) Test solenoid-free ramp-up to high current

5) Boundary Physics: How to interface fusion plasmas to surrounding materials?

- (05-5-Incr) Characterize edge of H-mode plasmas
- (06-2-Incr)Assess long-pulse heat & particle control requirements

6) Integration: How much external control vs. self-organization is needed?

- (04-1) Assess hi τ_E & hi β_T H-mode for >> τ_E
- (05-4) Assess combined RF & NBI effectiveness
- (06-3) Evaluate J_{NI} ~ 100% for $\geq \tau_{skin}$

Complete FY04 experimental campaign and research and look to 2005

- NSTX research has progressed as planned
- July – approaching the finishing line
  - 12 more run-days to complete 20 run-weeks
  - Run coordination optimization successful
- Additional 2 run-weeks will enable important studies
  - Error field modification, expanded MSE measurements, CHI, driven current changes, additional solenoid-free studies, and additional very high β test
  - Lower field not a major handicap
- Fuller utilization in 2005 will be critically important and much appreciated