The NSTX Research Program Plan: Non-inductive Startup and Sustainment Boundary Physics

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For the National NSTX Research Team

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Non-inductive Current Drive and Boundary Physics Central to Assessment of ST Attractiveness

<u>IPPA Goal 2.1</u>: Assess attractiveness of ST in terms of

- *high* β
- τ_E, τ_p
- ***bootstrap current and current drive***
- ***divertor heat loads***

- Current drive (CD) and divertor crucial to both long term ST needs <u>and</u> NSTX PoP mission
  - Small/no central solenoid (ARIES-ST <u>&</u> ARIES-AT)
  - High power density
- Elements of current drive program
  - High Harmonic Fast Wave (HHFW)
  - Coaxial Helicity Injection (CHI)
  - Exploratory EBW program (Ono)

NSTX research program poised to study detailed science; milestones measure progress

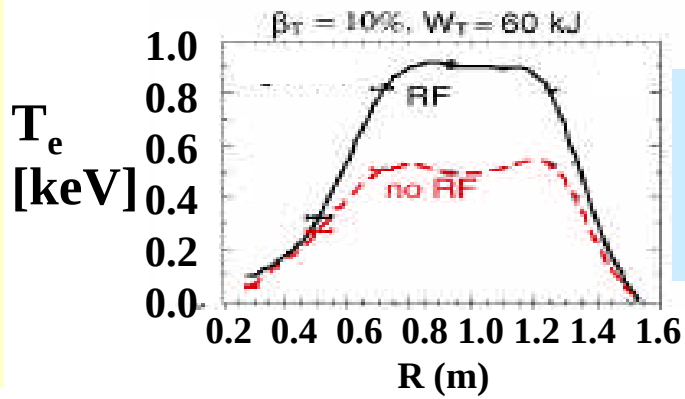
- HHFW program
  - –Electron heating and current drive in over dense plasmas
    - Effectiveness of HHFW CD (Milestone FY '02)
- CHI program
  - –Three-dimensional magnetic reconnection
    - 500 kA CHI discharge, feedback control, add ohmic to CHI (Milestone FY '02)

➔ Startup and Sustainment in 1-sec pulse with all CD (Mile. FY '03)

- Boundary physics program
  - –Edge/Scrape-off layer transport at high edge β, mirror ratio
    - Wall heat flux measurement (Milestone FY '03)

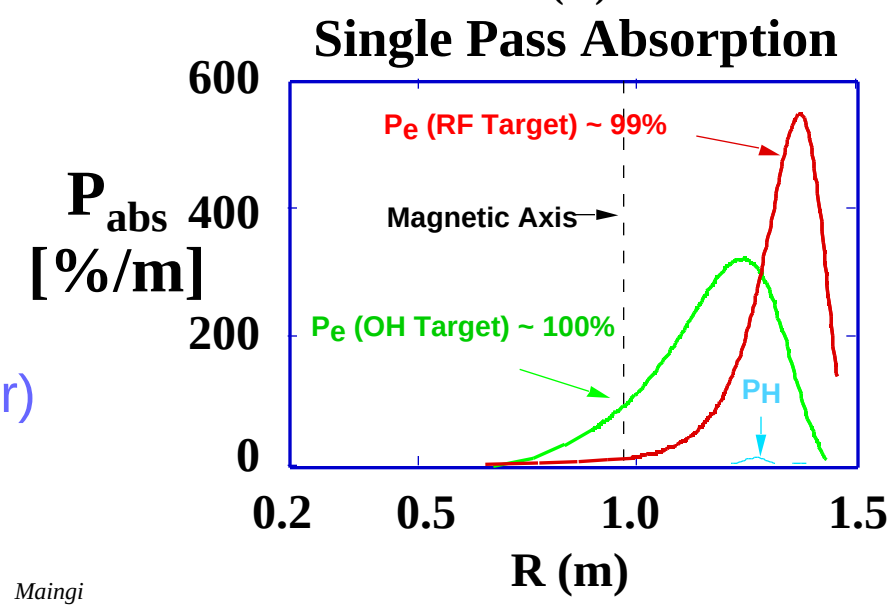
HHFW program to emphasize current drive in '02

<u>IPPA Goal 2.1.3</u>: Heat high β, over dense plasmas in ST
<u>IPPA Goal 1.3.1</u>: Understand wave-particle interactions in high dielectric constant plasma



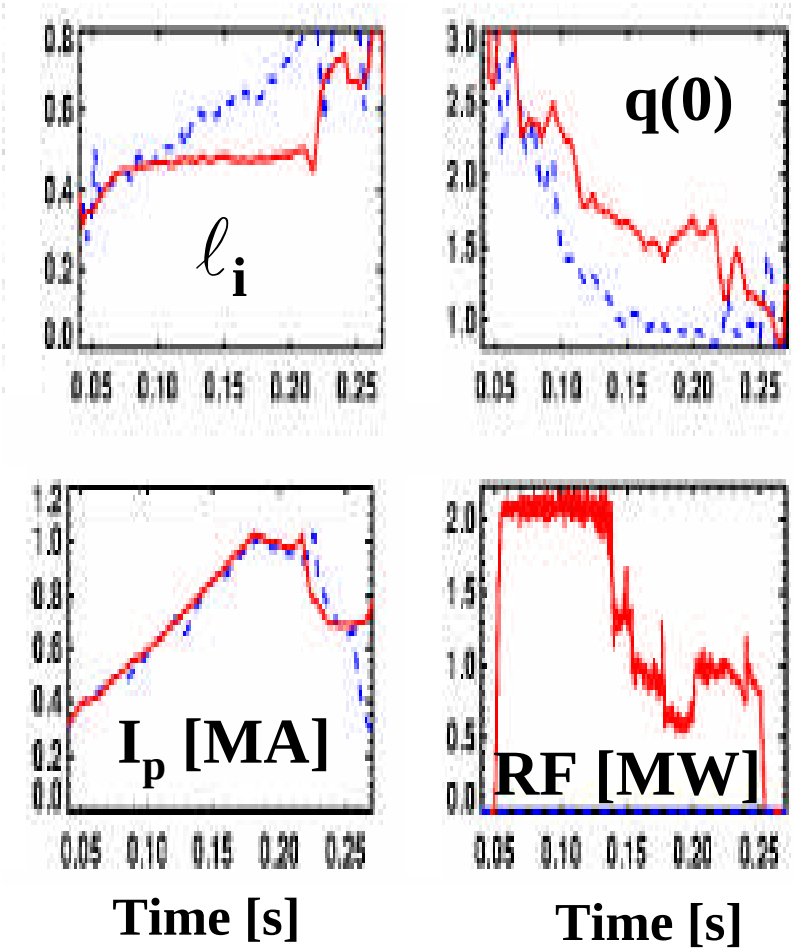
ORNL
MIT
UCSD

- Heating demonstrated - 9/00
  - broad T_e response
- <u>FY '02 Milestone</u>: <u>Measure effectiveness of HHFW CD</u>
  - Magnetics and EFIT for J(r)
  - Begin feedback control



HHFW tool development and ion interactions study continues in '02

- Current profile modification
  - ℓ_i reduced, q_0 -> 1 delayed
  - More early heating studies
- Ion interaction with HHFW (Ph. D. Thesis)
- Hardware upgrades through '02 will improve performance and reliability
  - New plasma control computer
  - Real time feedback signals
  - real-time EFIT GA
  - RF arc detection ORNL



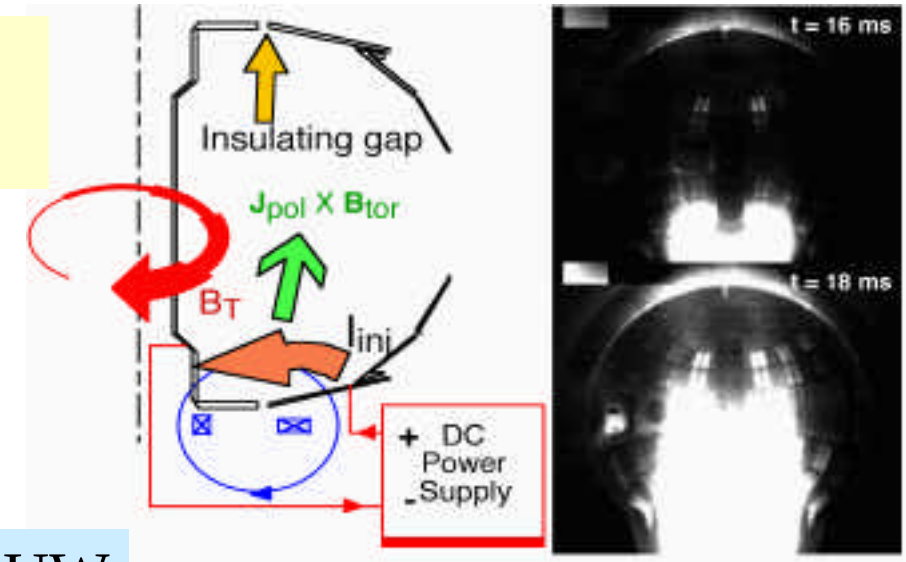
HHFW for FY '03 emphasizes current drive studies and tool usage

- Measurement of HHFW CD and theory comparison
  - Upgraded MSE for J(r) (Laser-Induced Fluorescence)
  - Investigate feed back control with MSE
- Couple HHFW to ohmic and CHI
  - Evaluate Ohmic ➔ HHFW for pulse sustainment
  - Evaluate CHI ➔ HHFW for transformer-less startup
- HHFW for discharge tailoring

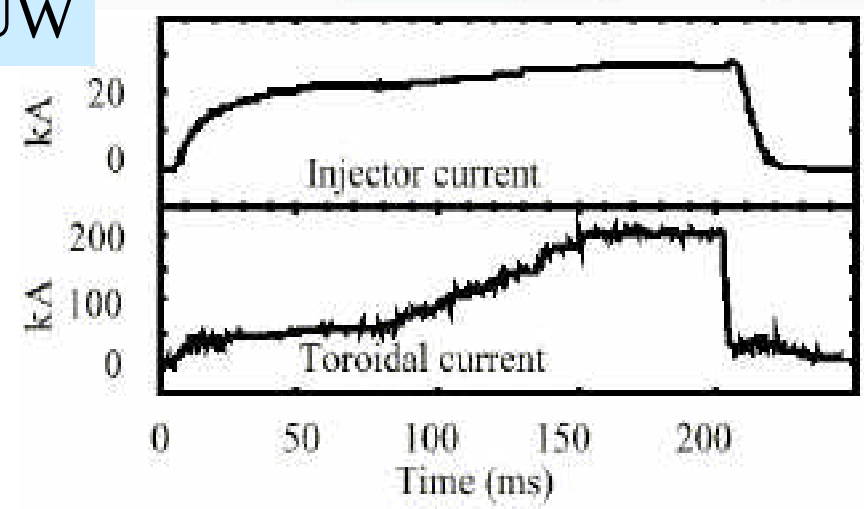
In FY '02, Coaxial Helicity Injection (CHI) will focus on flux closure studies

<u>IPPA Goal 2.1.4</u>: Non-inductive startup via magnetic reconnection

- Assess/drive closed flux
  - Suppress absorber arcs
  - Measure plasma properties for EFIT, MFIT, TSC constraints
  - add ohmic for flux closure
- <u>FY '02 milestone: CHI discharge with toroidal current ~ 500 kA, feedback</u>
- Add CHI to Ohmic discharge



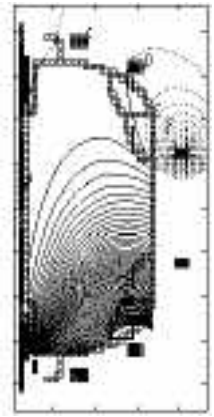
UW



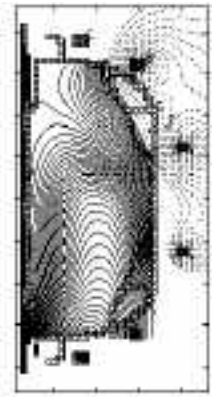
In FY '03, CHI focus on magnetic reconnection physics toward full transformer-less startup

- Physics of magnetic reconnection
  - $n_e/T_e/T_i$ measurements
  - Reciprocating fast (dynamo) probe at outer midplane UCSD
  - MSE for J(r) NOVA
- Optimize edge current drive on OH target
- Develop full feedback control for CHI startup and edge current drive
- Measure divertor tile response (impurity, fuel outgassing)

Poloidal Flux (TSC)

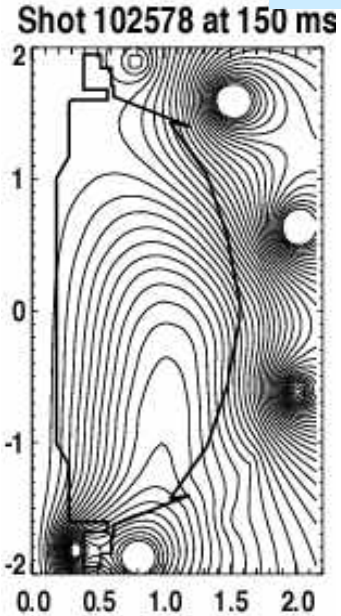


t = 15 ms



t = 150 ms

Poloidal Flux (MFIT) GA



Integration of CD techniques enables study of ST science with $\tau_{pulse} >> \tau_E$

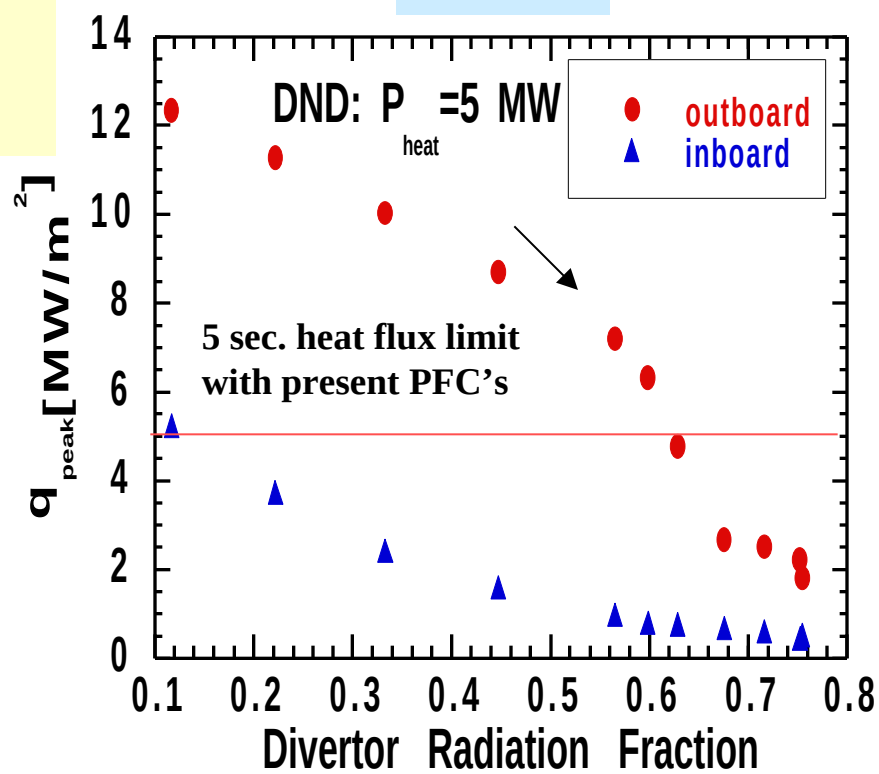
- FY '03 Milestone: Measure effectiveness of CD techniques for startup and sustainment of $\tau_{pulse} \leq 1$sec
  - CHI for startup
  - HHFW, bootstrap current, ohmic for sustainment
- Study CD dependence on plasma conditions
- Integration milestone equivalent for CD
- Checkpoint toward $\tau_{pulse} \geq \tau_{skin}$ (longer term)

In FY '02, boundary physics will advance both **edge physics** and enabling capability

IPPA Goal 2.1.5 & 1.4.3: Edge heat flux dispersion
IPPA Goal 1.4.1: SOL width and E_r
IPPA Goal 1.4.2: H-mode physics

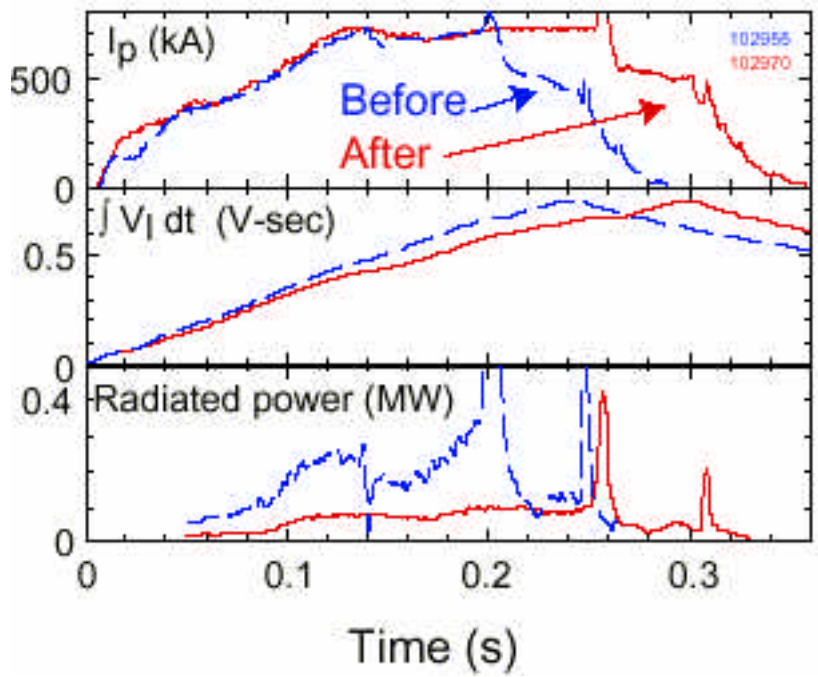
- Prepare for FY '03 milestone: edge heat flux, PFC assessment
- Compare edge data with 2-D transport and turbulence models
  LLNL, UCSD, ORNL
- Cross-machine: particle balance between NSTX/MAST

ORNL



In FY '02, boundary physics will advance both edge physics and **enabling capability**

- Boronization very successful MAST
  - HeGDC between shots now routine
  - center stack resistive bakeout
- Upcoming upgrades
  - High temperature bake
  - Plasma boronization UCSD, GA, Triniti
  - Li pellet injector

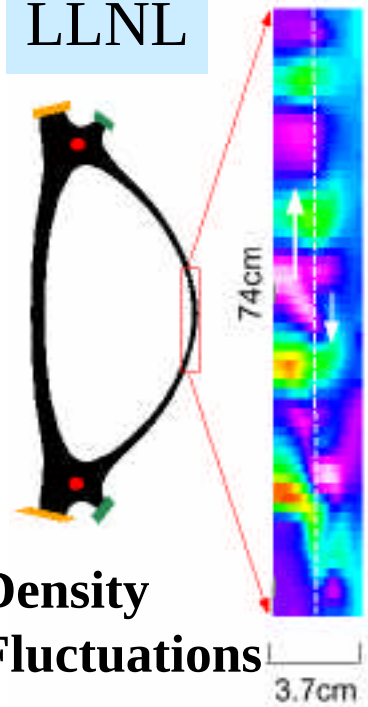


In FY '03, boundary physics research to focus on far edge/open field line transport

- How do the high mirror ratio and short outboard connection length affect NSTX scrape-off layer?
- Does high edge β decrease stability or drive edge transport?

  - Hardware plan
    - High resolution toroidal CHERS (end '01)
    - new IR camera ('02)
    - divertor D_α imaging ('02)
    - divertor bolometry ('02)
    - VB array ('02)
    - 30-channel Thomson ('02)
    - divertor Langmuir probes ('03)
    - incr. '03 – 40-channel Thomson (more edge chan.)

LLNL



Density Fluctuations

NSTX research program in position to address IPPA goals of high beta science and ST attractiveness

- HHFW program
  - Physics of electron heating, current drive and ion interactions in over-dense plasmas
  - Work with other CD mechanisms to extend pulse length
- CHI program
  - Mechanisms of flux closure and reconnection
  - Transformer-less startup and edge current profile modifications
- Boundary physics program
  - Edge power and particle fluxes and local transport
  - Continued enabling activity to improve discharges