CHI plans on NSTX for the Fy 04 to 08 period*

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Program Motivations

- The development of methods for non-inductive current initiation will improve the prospects of the ST as a fusion reactor.

- CHI is a promising candidate for this and has, in addition, the potential to drive edge current during the sustained phase of a discharge for the purpose of controlling the edge current profile. Other possible benefits include inducing edge plasma rotation for transport barrier sustainment and controlling edge SOL flows.

- The IPPA goal 3.2.1.4 for the ST is to: "*Characterize the integration of noninductive plasma startup via magnetic reconnection such as using Coaxial Helicity Injection (CHI) with other noninductive and inductive current drive techniques. Investigate a number of noninductive techniques to start and to increase the plasma current in ST plasmas while at the same time minimizing magnetic flux and helicity injection.*"

NSTX noninductive startup research is a dedicated program consistent with the IPPA goals

- With this program, we plan to accomplish:

  - Transfer a CHI produced plasma to the central solenoid

  - Transfer a CHI produced plasma to a non-inductive current drive system

- The program includes:

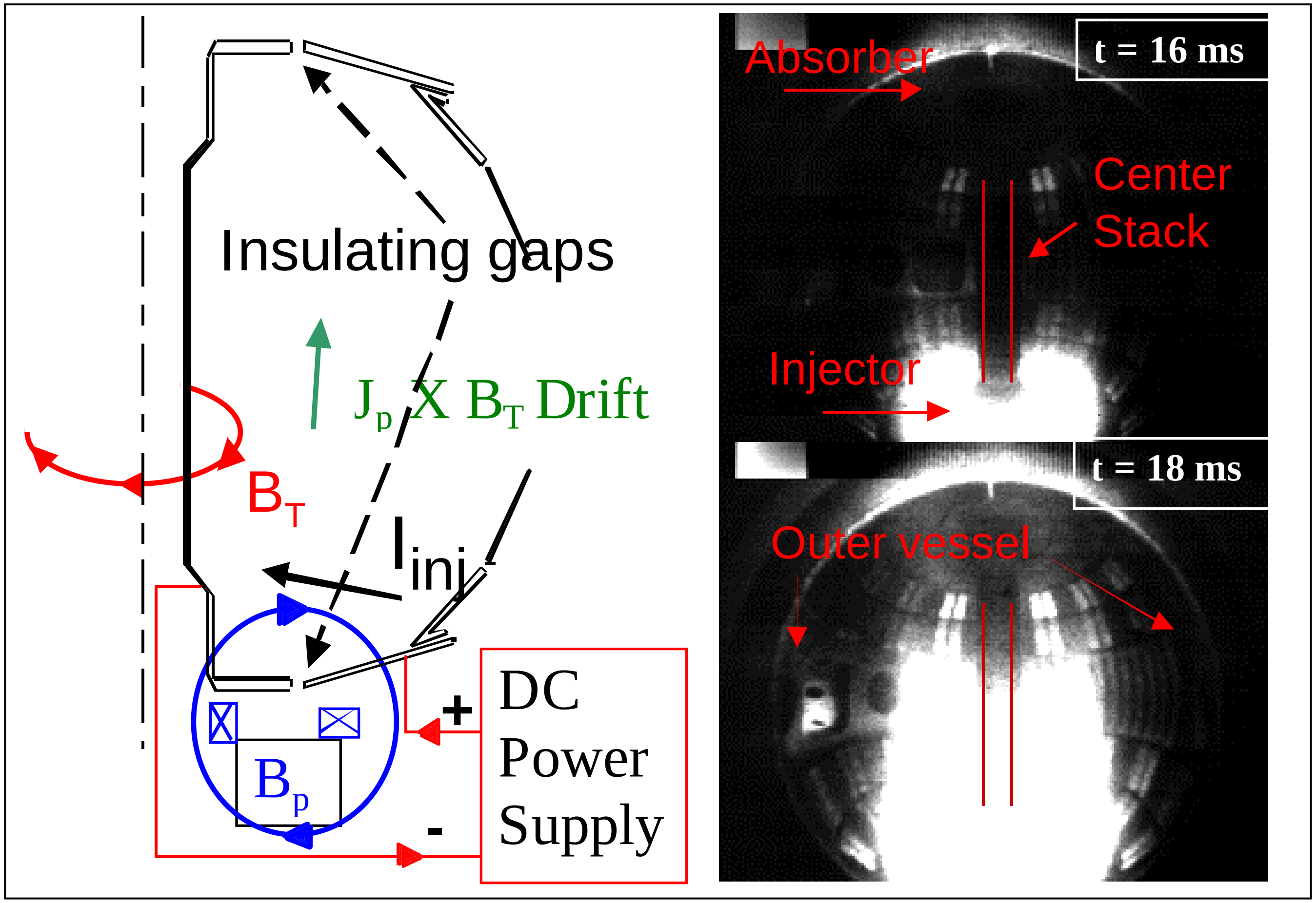
  - Dedicated experiments

  - Development of theory to analyze the results and extrapolate techniques to future devices

  - Upgrades to facility capabilities to explore new techniques and to optimize the most promising of them

Strong collaboration with HIT-II

Simple description of CHI start-up



Expect reconnection processes to redistribute edge current to the interior, forming closed surfaces

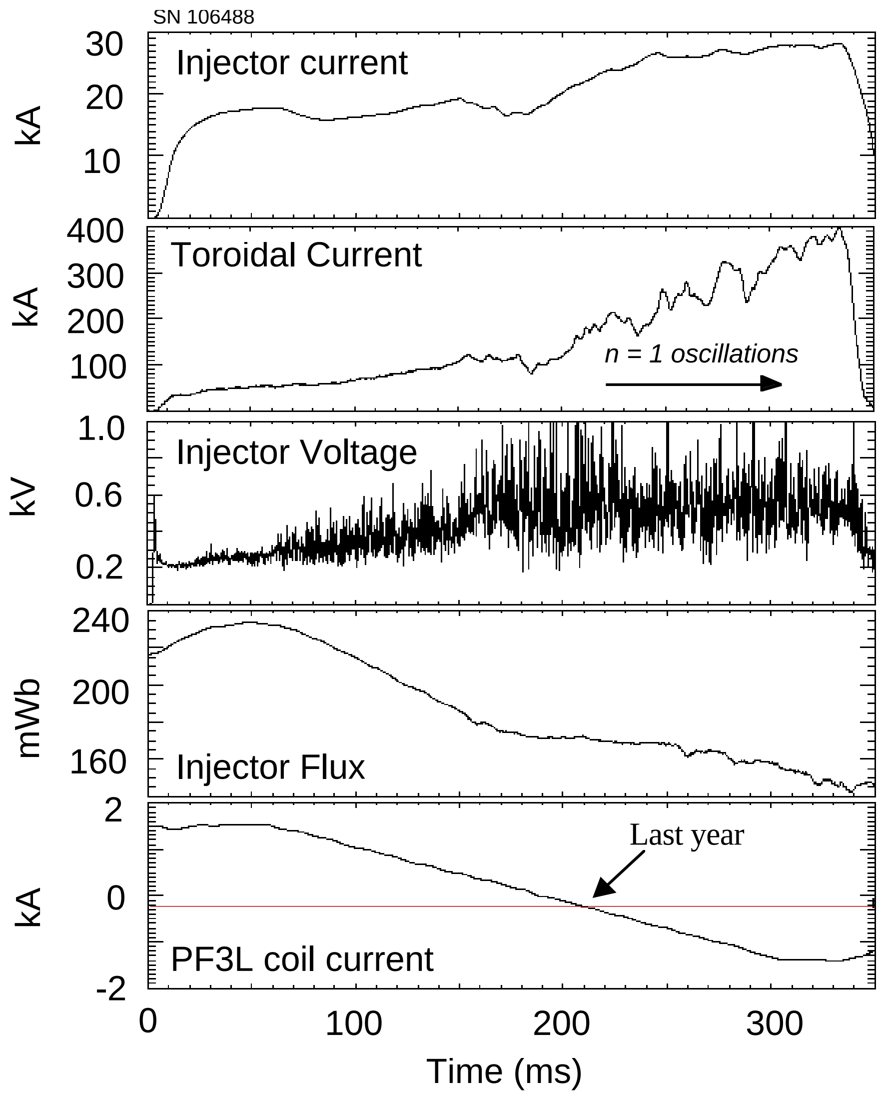
Experiment status

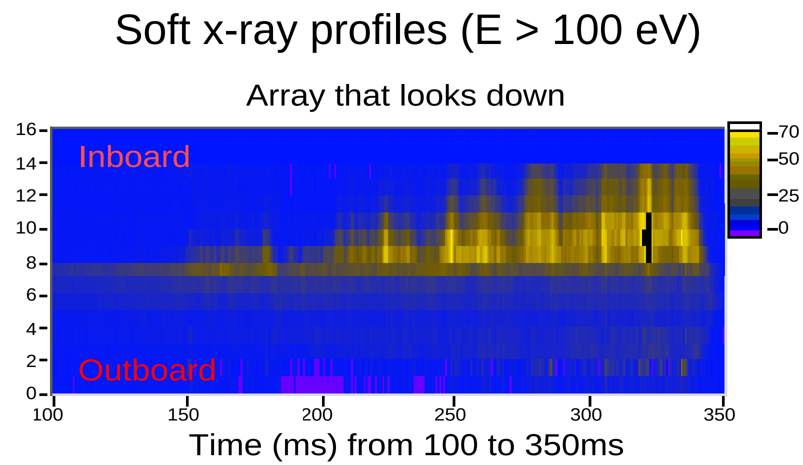
- Produced 400*kA* at 14 times current multiplication in 330*ms* long discharges

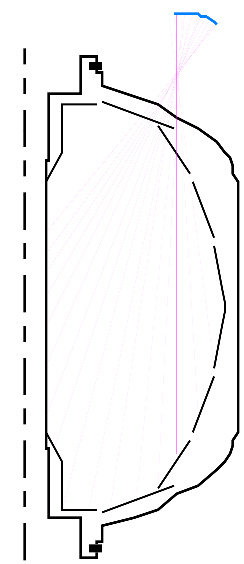
Accompanying observations

- Evidence for good *n=1* oscillations deemed necessary for flux closure on previous experiments
- Consistently encouraging MFIT reconstructions
- Evidence for higher temperature from SXR's (D. Stutman)
- Ion temperature and plasma rotation similar to that seen in HIT-II (V. Soukhanovskii, M. Nagata, R. Bell)

Long-pulse high current generation using CHI





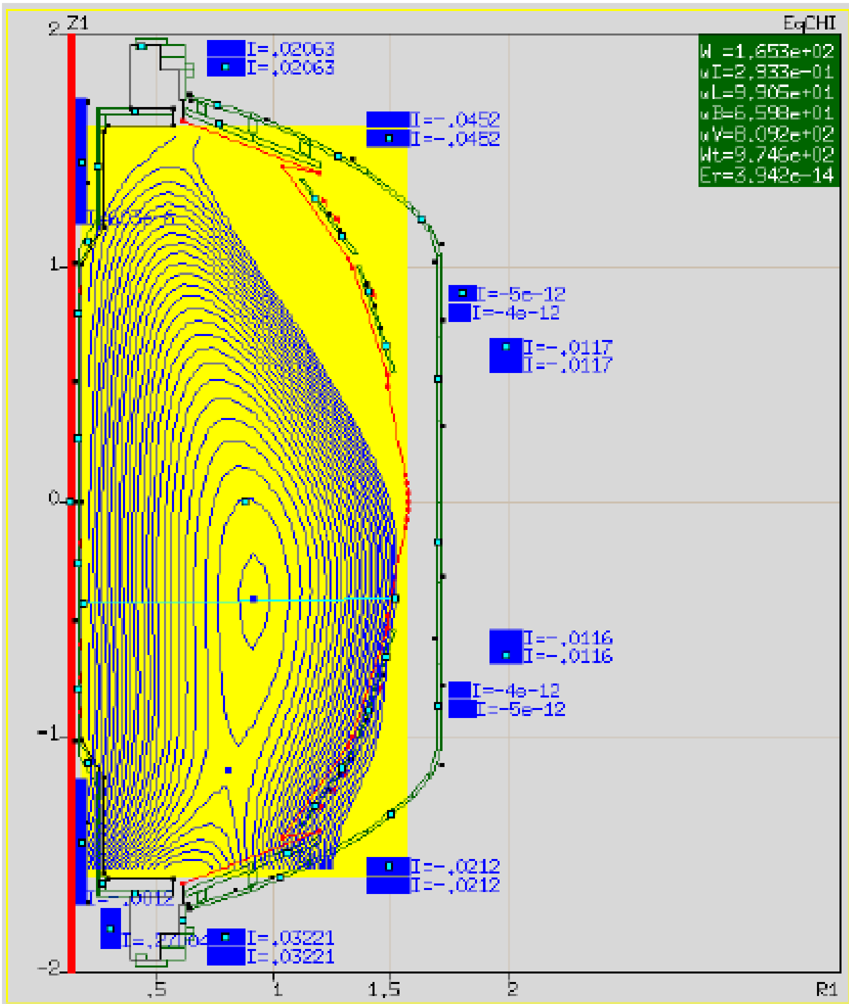


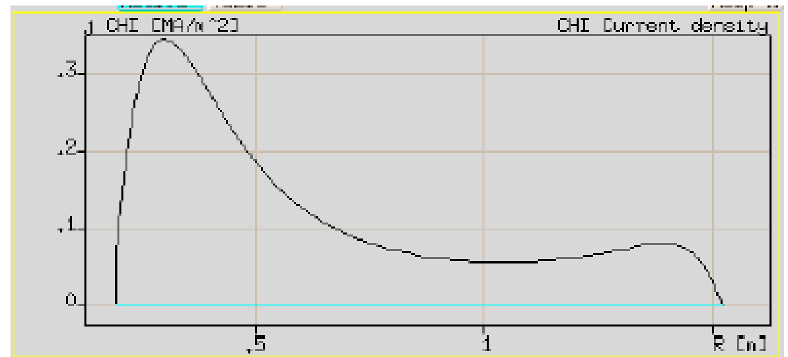
Soft X-ray:
D. Stutman (Johns Hopkins Univ.)

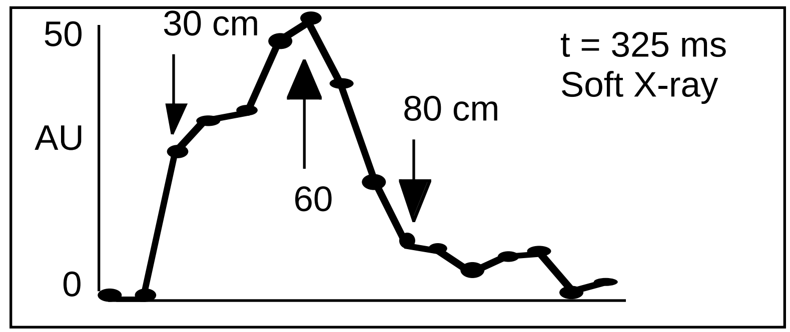
Theory status

- MFIT (M. Schaffer, GA) code used in control room
- ESC (L. Zakharov, PPPL) adapted for reconstructing CHI discharges
- EFIT (M. Schaffer, L. Lao, GA) also adapted for CHI
- Work in progress to use TSC (S.C. Jardin, PPPL) for new CHI discharge development
- Work initiated on using the CHIP, a 3DMHD code (X. Tang, LANL) to understand CHI current drive physics

Initial reconstructions of a CHI discharge by ESC







L. Zakharov, PPPL

CHIP, 3D MHD code contributes to CHI physics understanding

Simulations conducted in simple vessel geometry

- Implications of the presence of strong plasma flows in the CHI injector and absorber region to equilibrium reconstructions

- Implications of transient versus steady-state CHI discharges. 2D reconnection that produces high edge current profiles versus advantages of more favorable CHI discharges produced using relaxation activity

Implementing NSTX vessel geometry will allow closer comparison with experimental data

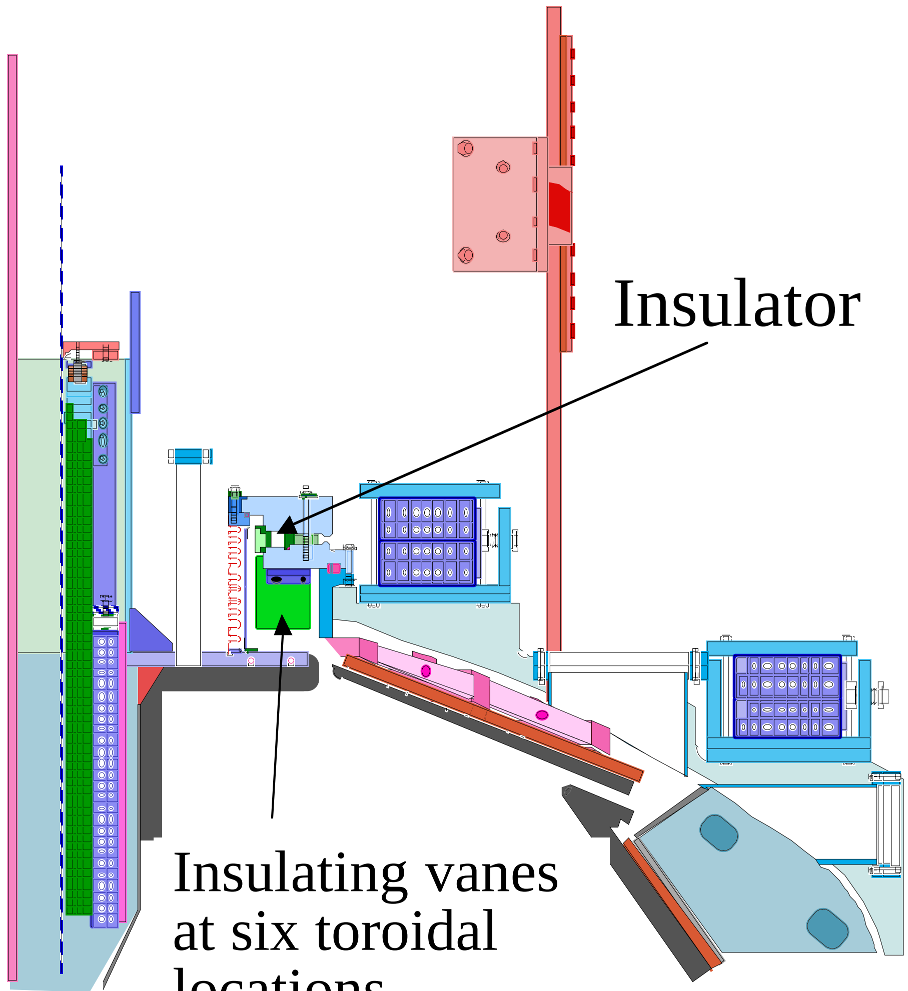
X. Tang (LANL)

Technical problems have limited the operational space

- Arcs across the gap at the top of the machine occur on nearly all CHI shots (Absorber arc)
- An operational regime that minimizes the occurrence of the Absorber arc has been developed (Re: the 400kA shot), but exploration of other scenarios is problematic
- In addition arcs external to the vessel have occurred

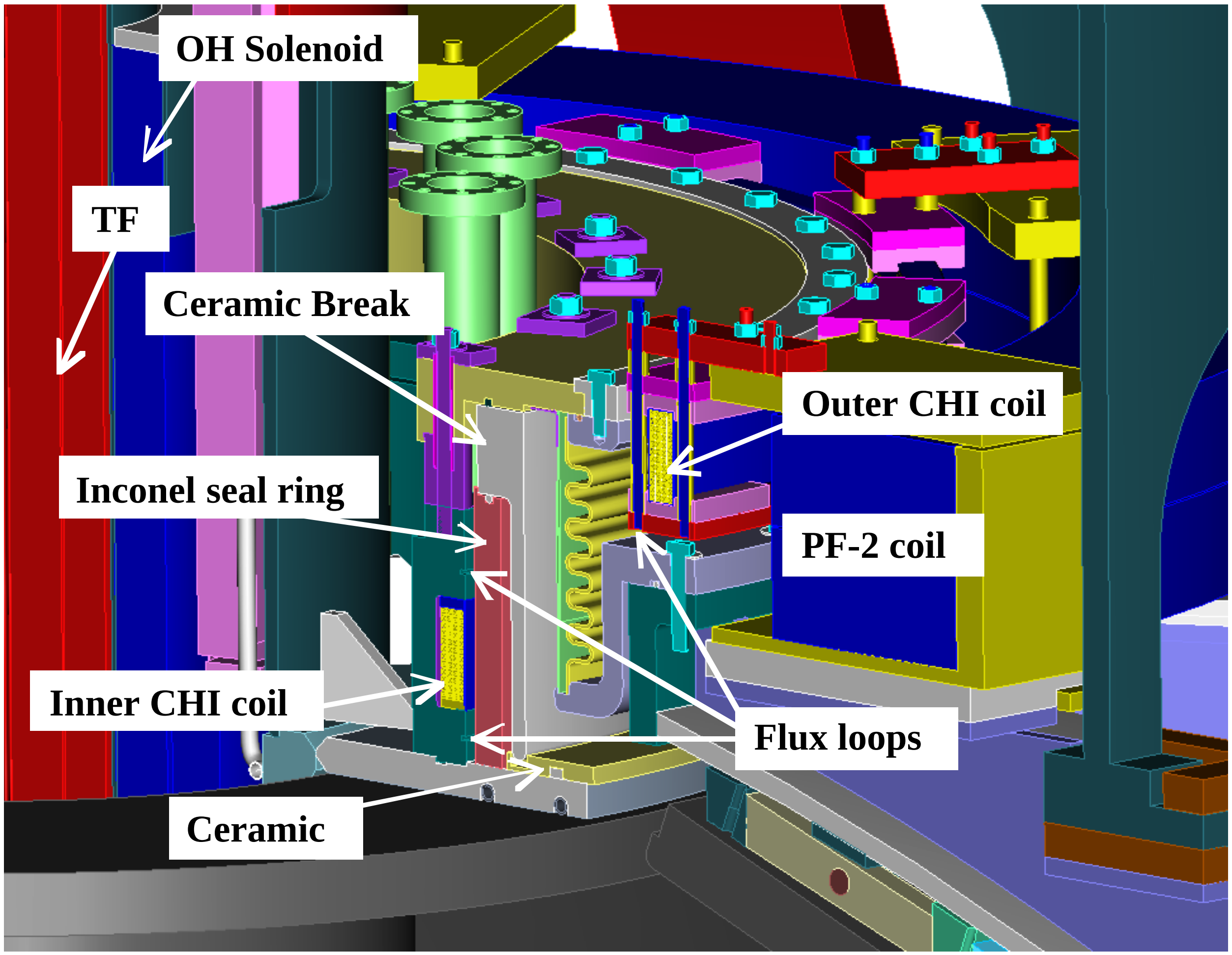
Hardware upgraded to address issues related to arcs

Old Absorber design uses short-length insulator and no PF coils



- Insulator on low-field side
- Inner and outer vessel can be connected by radial or vertical fields

New Absorber aims to reduce arcs



- Long, high-field side insulator
- No simple connection path in insulator region
- Stray field reducing coils
- Flux loops to measure field

New CHI plasma start-up method developed on the HIT-II experiment affects our planning

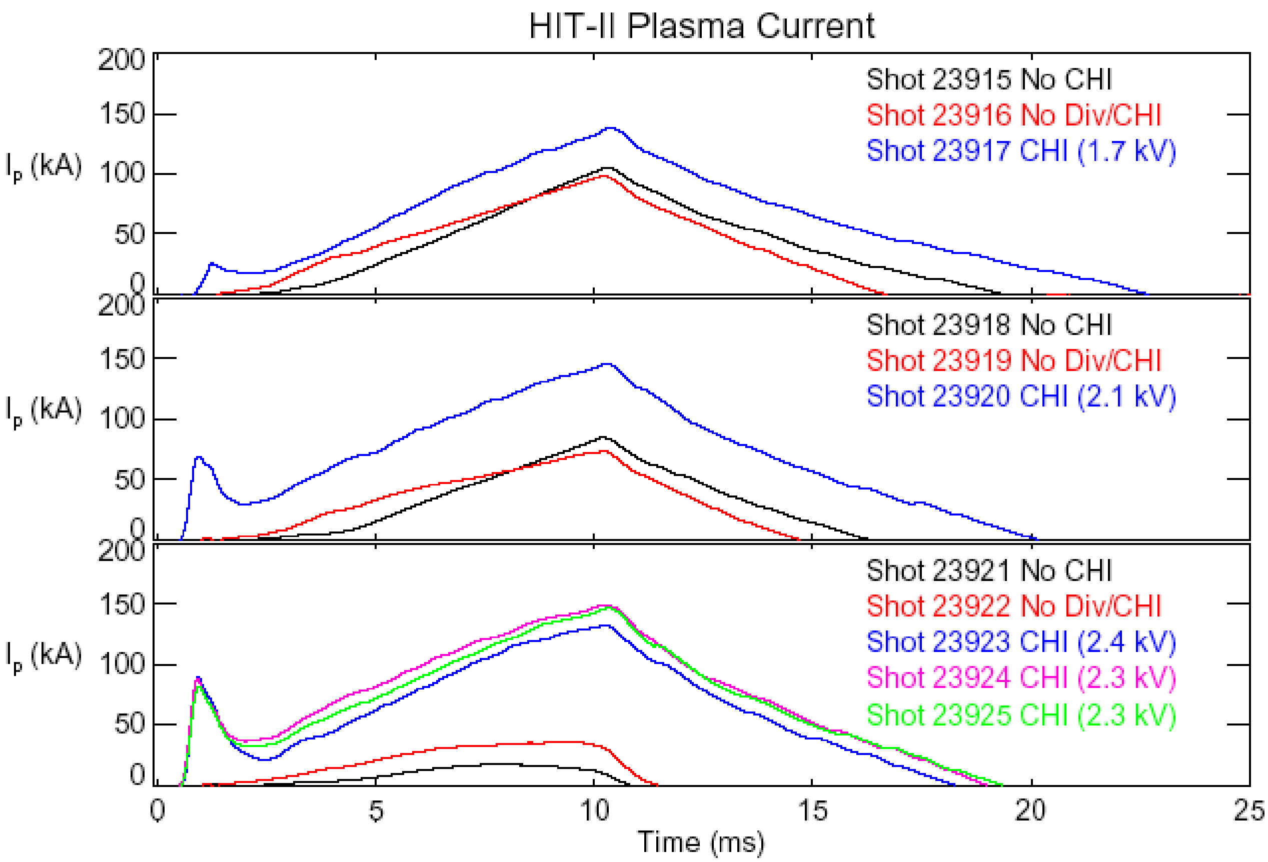
HIT-II

- Transient CHI Start-up
- Successfully handed-off a CHI produced plasma for inductive operation
- Saved volt-seconds
- Produced discharges that were more reproducible
- Produced new record performance plasmas (250kA, vs. 200kA record for past three years)

New start-up method will be tested on NSTX

Discharges with CHI start-up assist are robust, maintain shot-to-shot reproducibility and result in substantial volt-seconds savings

HIT-II



Transient approach may be preferable to the steady-state approach

Previous method (technically difficult)	New method (simpler)
Long CHI pulse (~300ms)	Short pulse (< 50ms), much simpler power system requirements for future NSST
Relies on good feedback controlled operation during a steady-state CHI pulse (Equilibrium feedback control for CHI not yet tested on NSTX)	Transient discharge considerably simplifies feedback control requirements 1. CHI pre-programmed phase 2. OH pre-programmed phase, CHI off 3. OH feedback control phase
Absorber and external hardware should be arc-free during 300 ms pulses	Probability of absorber and external arcs decreases as the CHI pulse length decreases
Relies on pressure profile characterization and possible auxiliary heating of CHI plasmas	Details of pressure profile not too important, auxiliary heating may not be needed

Other small NSTX hardware modifications (gas injection, speeding up CHI coils, absorber PF coil activation for absorber field control) will be implemented if needed.

Overall Activities for the CHI Fy 04-08 period

Primary Activity

- Transfer a CHI produced plasma to the central solenoid
- Transfer a CHI produced plasma to a non-inductive current drive system

Other Activity

- Potential of CHI to improve the edge current profile in an already established discharge
- Investigate CHI effects on SOL

⇒ Establish basis for building CHI systems for future STs

Fy 03 plans

Primary activity is to transfer a CHI produced plasma to the inductive system

- Short pulse startup scenario
  - Poloidal flux savings

Other activities: Develop tools for steady-state operation

- Reestablish CHI startup to ~0.3MA
  - Investigate new absorber performance

Fy 04 - 05 plans

- Coupling CHI initiation to heating and non-inductive current drive methods, including using assist from the outer PF coils

- Establish edge current drive in an already established discharge and investigate CHI effects on SOL (flow, edge rotation)

- Establish the preferred method for plasma startup (transient versus steady state CHI)

- Implement Absorber field nulling capability

- Resolve issue of ground fault during NBI/CHI operation

Fy 06 - 07 plans

The primary activity is to transfer a CHI plasma to a non-inductive current drive system

- Successfully demonstrate hand-off of a CHI plasma to a solenoid-free current drive system, ramping to a high poloidal beta plasma (Fy 06)
- Detailed MSE measurements of CHI discharges
- Understand mechanisms that lead to flux closure in a driven system and mechanisms that allow it to be sustained

Technology development?

- A tungsten divertor offers the possibility of producing a higher temperature CHI discharge. Tungsten is also considered for reactor divertors. Conducting a tungsten divertor campaign on NSTX also has potential benefits to the ST divertor technology program (to handle higher divertor heat flux). In conjunction with other task groups, we would be interested in a dedicated W divertor plate campaign on NSTX.

Fy 08 plans

Primary activity: Use CHI as a tool to enhance high performance NSTX plasmas

- Establish the extent of edge current drive to improve the edge current density profile in high beta, high bootstrap, steady-state discharge
- Use V-s savings to extend high perfomance flattop
- Design CHI engineering systems for future STs

21 weeks/year

IPPA: 5 year

IPPA: 10 yr

Fv 02 | 03 | 04 | 05 | 06 | 07 | 08

Transient start-up and hand-off to ohmic

Couple to non-inductive CD

Demonstrate coupling to non-inductive CD

Test steady-state CHI

Establish preferred Method for start-up

Investigate new absorber performance

Absorber field nulling

Optimize edge CD for high beta, long pulse expts.

Establish edge CD in a pre-established disch.

Resolve CHI/NBI ground fault issue

Current density profile measurements

Understand CD physics

W divertor ?

Summary

Plan offers a reasonable path forward to demonstrating CHI on NSTX

Two primary objectives:

- Transfer a CHI produced plasma to the central solenoid
- Transfer a CHI produced plasma to a non-inductive current drive system

NSTX ground fault monitoring circuit