Supported by

Coaxial Helicity Injection Research in NSTX

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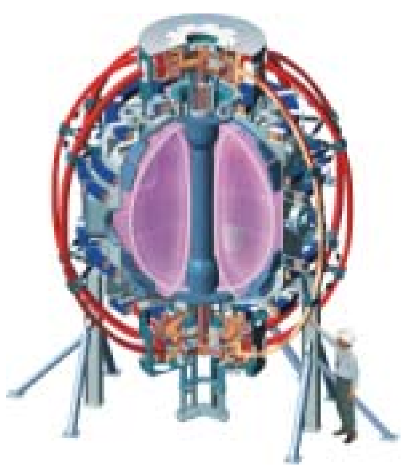

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Abstract

CHI is a promising candidate for solenoid-free plasma startup in an ST. CHI on NSTX has thus far shown the capability for producing long pulse high current discharges (390*kA* of CHI generated toroidal current in 330*ms* long pulse discharges). This is referred to as ***steady-state*** CHI, during which the CHI power supply actively drives the plasma load. These discharges, in addition to their use for plasma startup, have the potential for optimizing the edge SOL region by controlling SOL flows, inducing edge rotation and modifying the edge current profile. NSTX will test a new short pulse CHI startup method for the purpose of initiating the solenoid-free startup current. This is referred to as ***transient*** CHI, which has been demonstrated on the HIT-II experiment. Both these methods and their contribution to NSTX research will be described.

Non inductive current initiation needed for STs

- The favorable properties of the ST arise from its very small aspect ratio, which leaves very restricted space for a central solenoid and related neutron shielding
- NSTX is focused on solenoid-free plasma startup research
- Plasma startup research on HIT-II has demonstrated CHI startup and coupling to induction
- Results on HIT-II also show that CHI is capable of driving edge current in a pre-establish diverted discharge

CHI research on NSTX has two objectives

1 Solenoid-free plasma startup

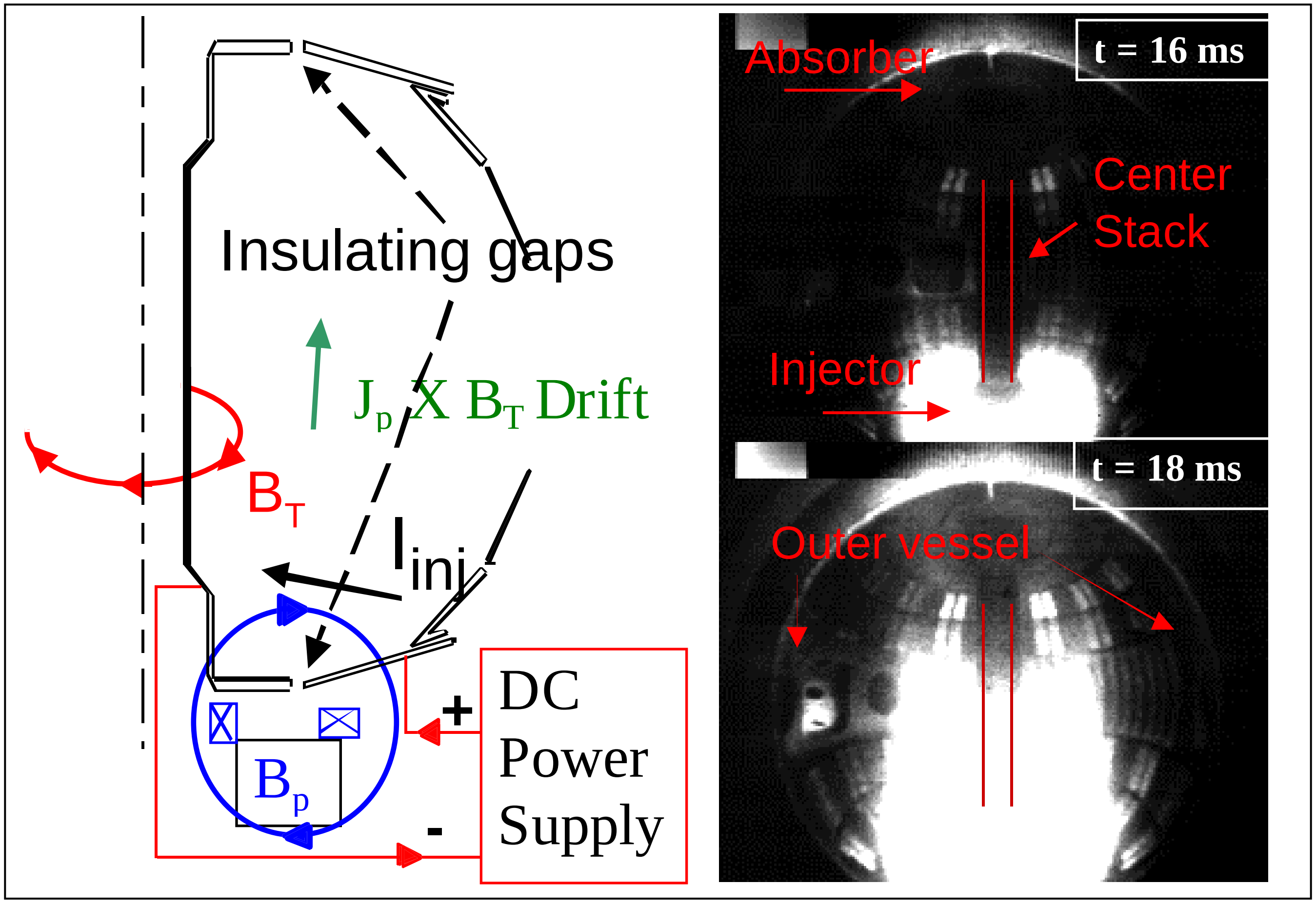
A new method developed on HIT-II (referred to as ***transient CHI*** startup) will be tested on NSTX during Fy 04

2 Edge current sustainment

Subsequent experiments on NSTX will use the ***steady-state capability of CHI*** to test edge current drive for the purpose of:

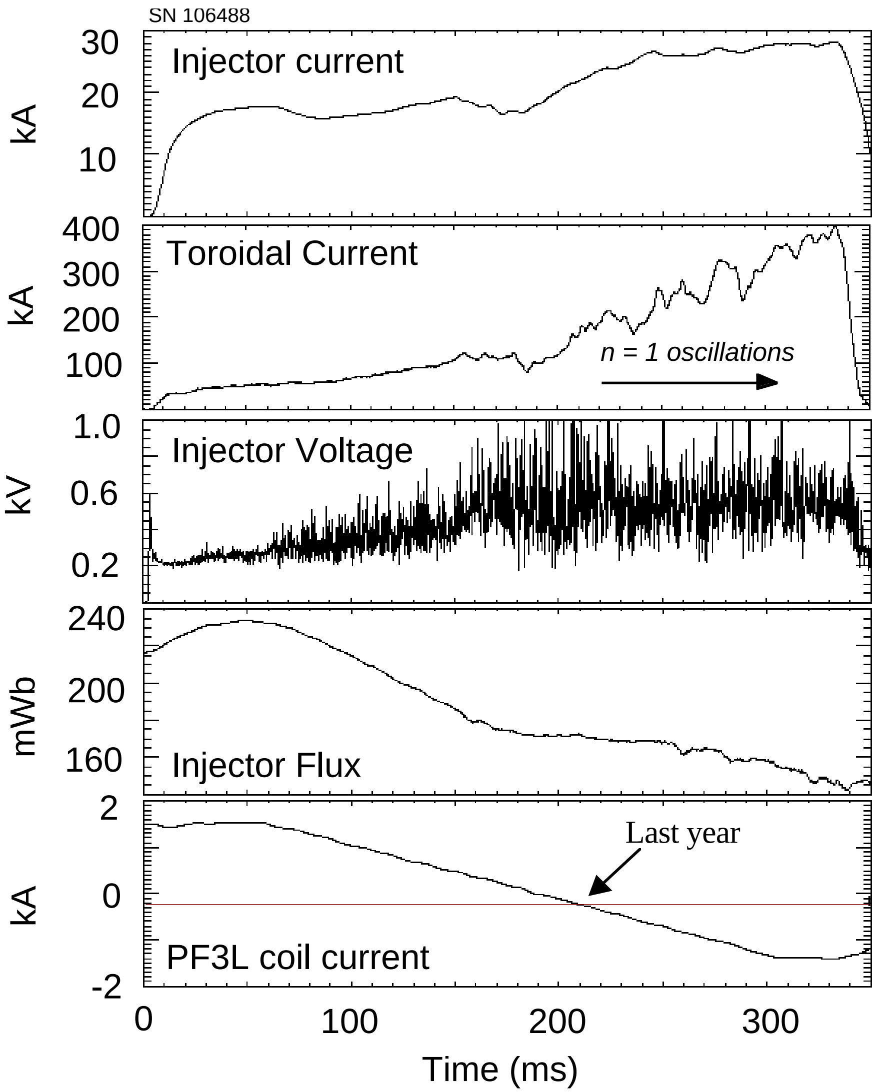
- controlling edge SOL flows
- improving stability limits
- inducing edge rotation

Co-axial electrodes inject helicity

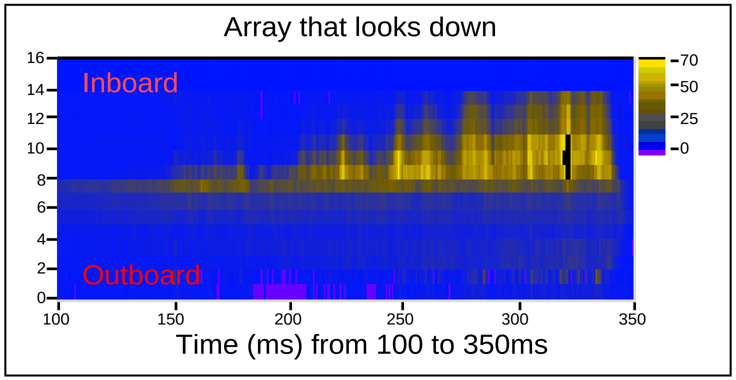


Expect reconnection processes to redistribute edge current to the interior, forming closed surfaces

Obtained 390kA with current multiplication of 14 in 330ms long discharges (steady-state CHI)



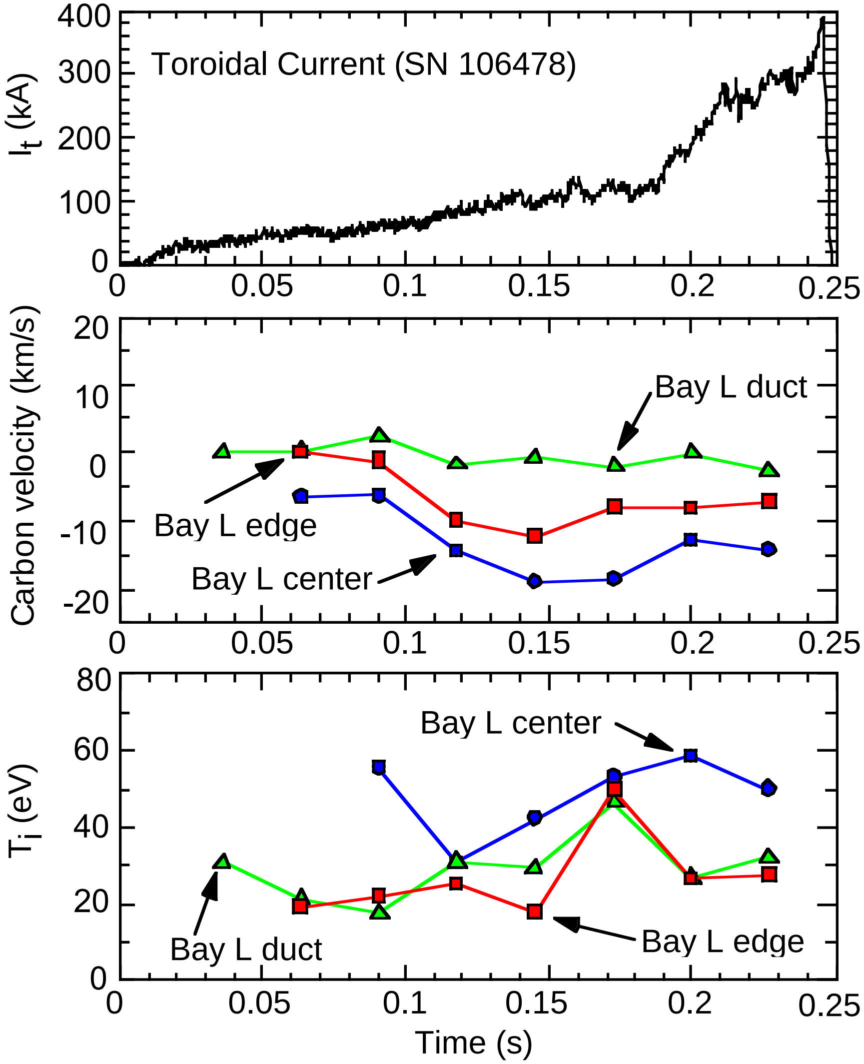
- Evidence for good *n=1* oscillations deemed necessary for flux closure
- ESC and EFIT reconstructions consistent with but not conclusive of flux closure
- Evidence for higher temperature from SXR's (D. Stutman)

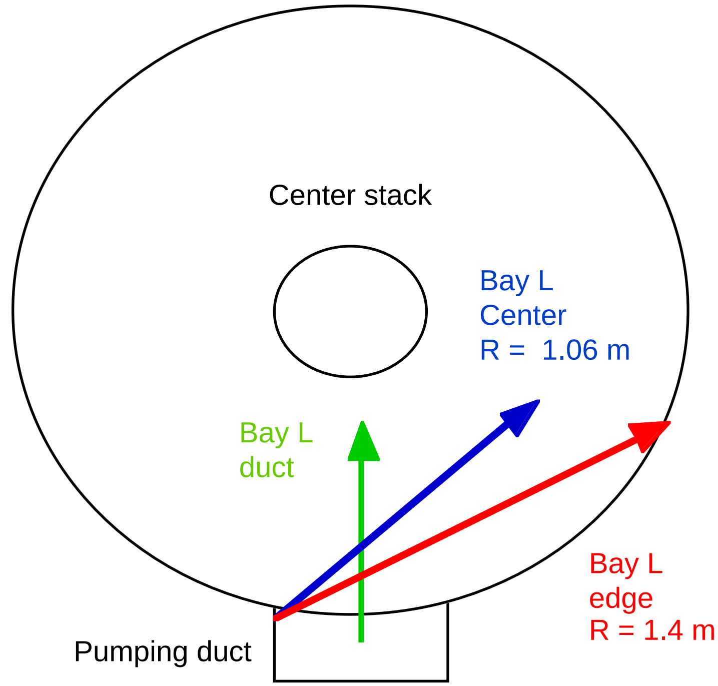


Soft x-ray profiles (E > 100 eV)

SS CHI: Voltage is applied for as long as the current needs to be sustained

CIII Ion Doppler measured rotation consistent with HIT-II





Time resolution : 26 ms

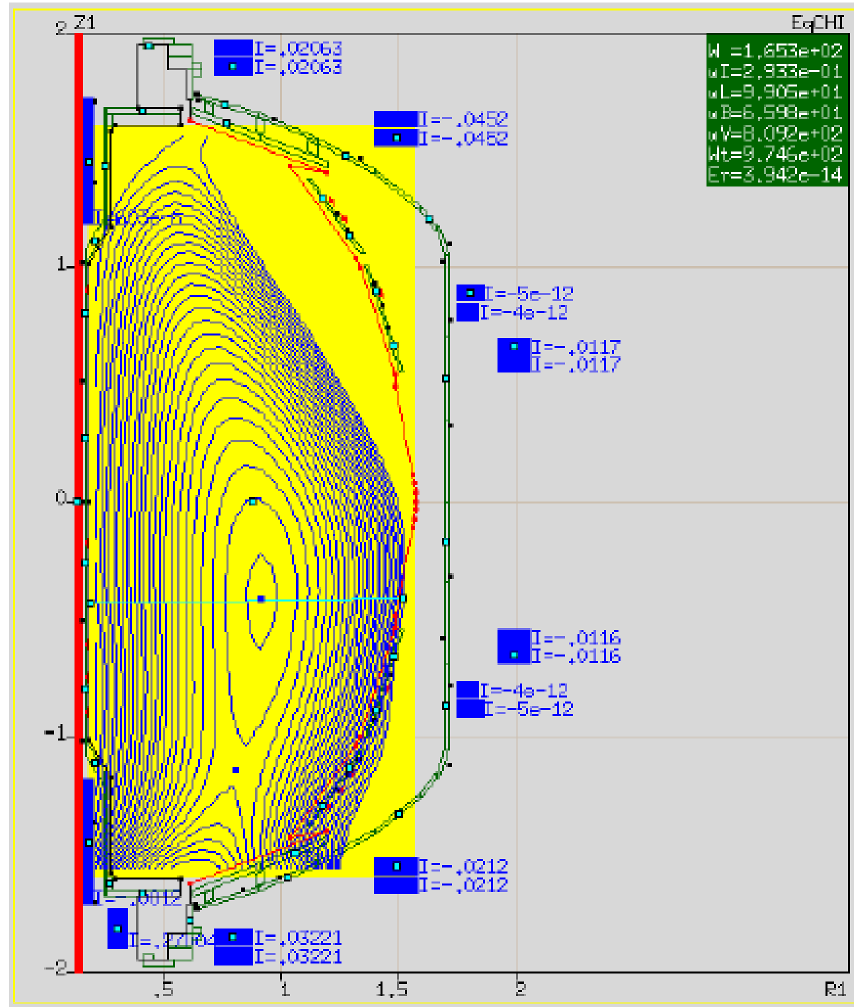
Direction of rotation: clockwise
(same as on HIT-II)
Rotation speed ~ -10 to -20 km/s

Ion Temperature ~ 30 - 50 eV

M. Nagata (HIT, Japan), R. Bell, V. Soukhanovskii (PPPL)

Reconstruction of a CHI discharge obtained by ESC

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



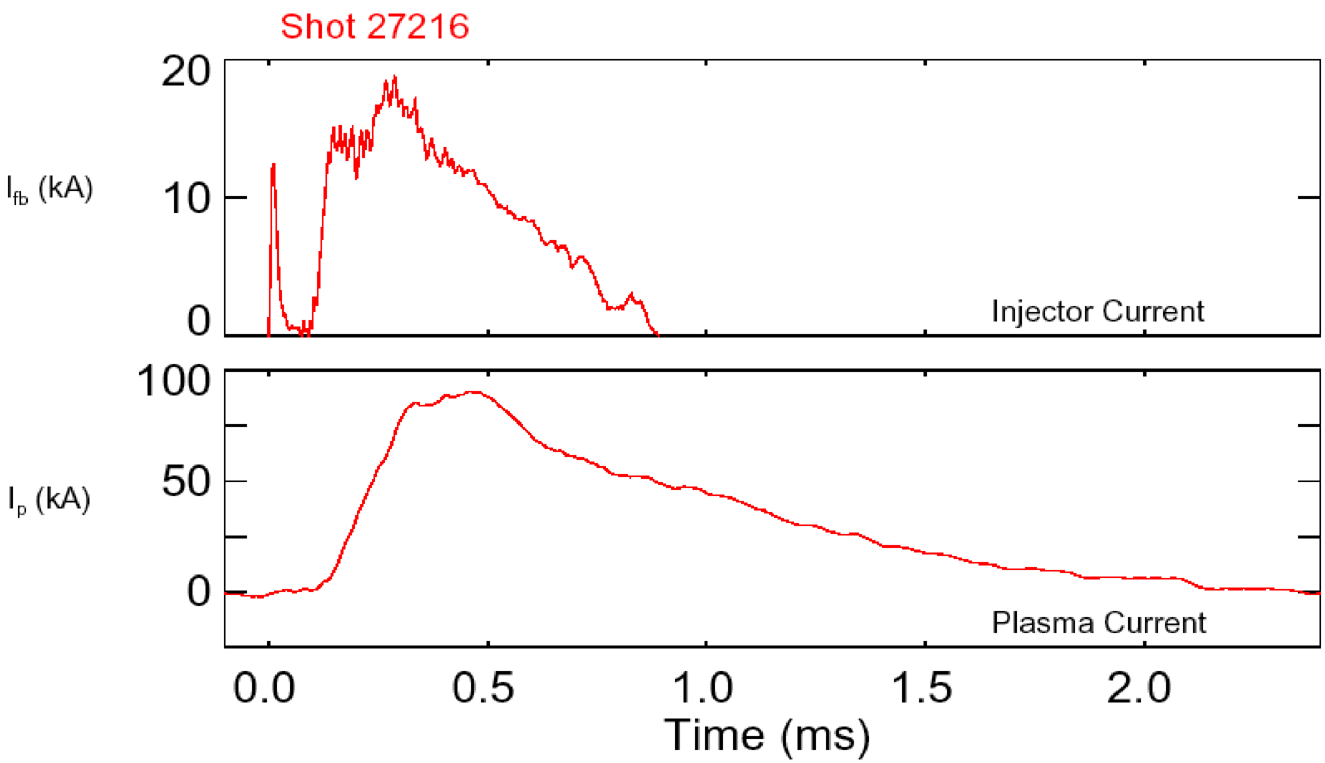
ESC: L. Zakharov, PPPL

Summary of long pulse CHI discharges

NSTX

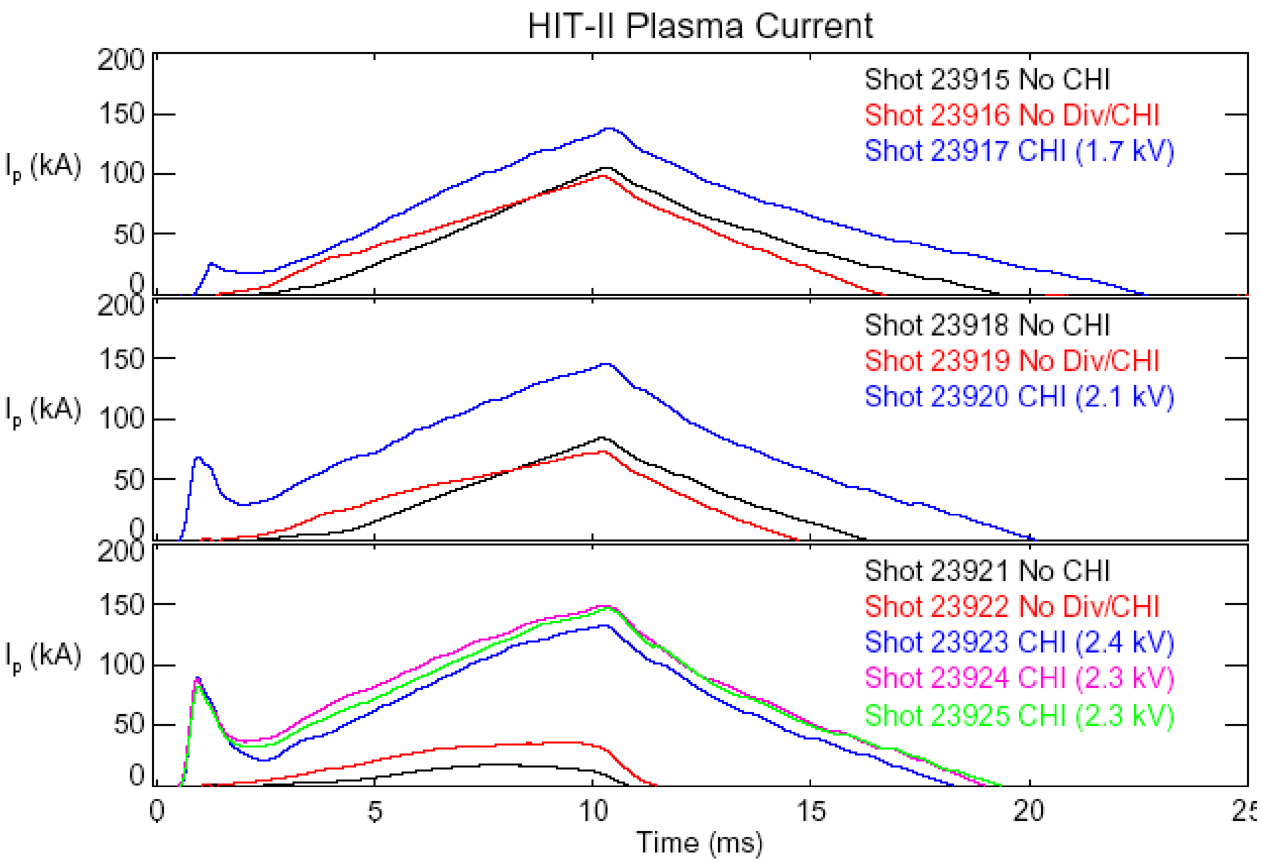
- Absorber arcs considerably limited operating space
  - Longer pulse duration increases probability of absorber and external arcs
  - Not adequately tested with new absorber
- Relies on good feedback control to maintain discharge position
  - Equilibrium feedback control not yet tested on NSTX
- Flux closure assessment is difficult
  - Requires internal current density profile measurements
  - Requires pressure profile measurements

New Transient CHI developed on HIT-II: Short voltage pulse (for approximately the time needed for the plasma column to grow) is applied, then quickly reduced to below the level needed for helicity injection



Note the persistence of toroidal current after the injector current has been reduced to zero

Transient CHI startup on HIT-II improved performance of inductive discharges



Saved Volt-seconds

More reproducible

Produced record currents on HIT-II (290kA using 52mV.s of Ohmic flux)

Advantages of Transient CHI startup

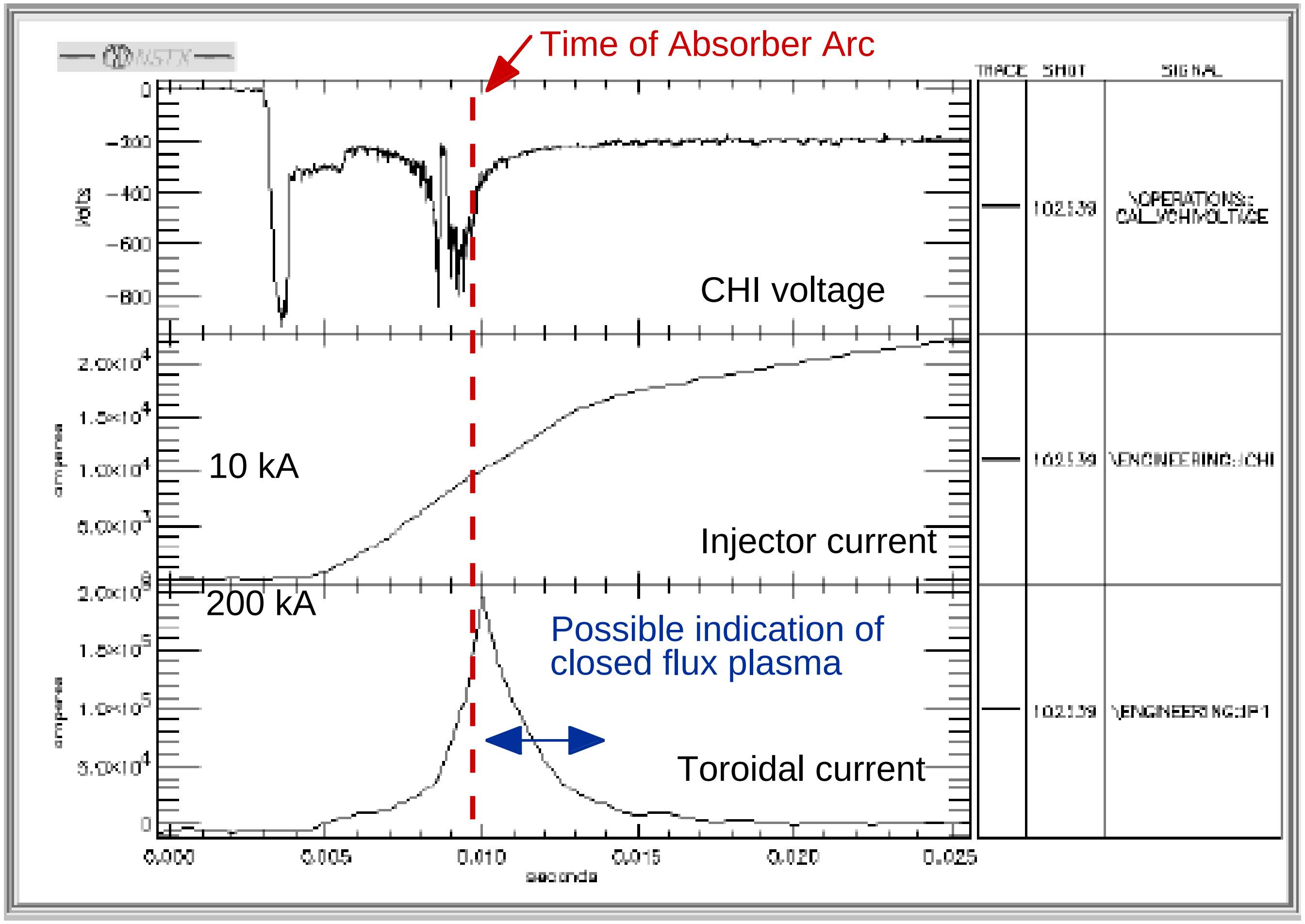
- Short pulse length (< 20ms) reduces incidence of absorber and external arcs

- Considerably simplifies feedback control requirements
  - CHI pre-programmed phase
  - OH pre-programmed phase, CHI off
  - Existing OH feedback control phase

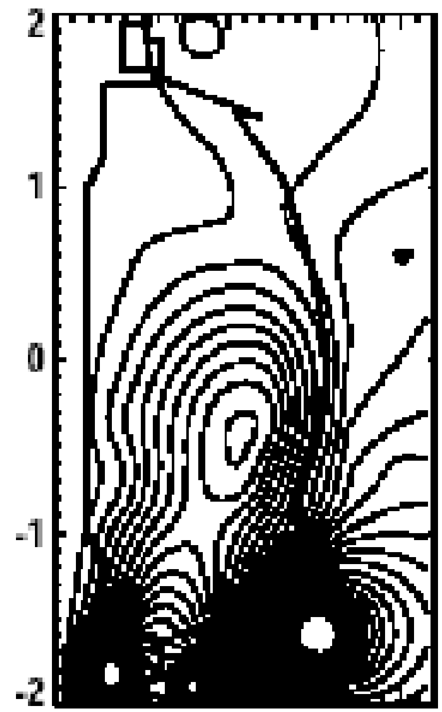
- Power supply requirements for future machines is simpler

- Flux closure can be easily assessed by the persistence of toroidal current after the injector current has been reduced to zero

Possible indication of toroidal current persistence in NSTX
(Old absorber configuration)



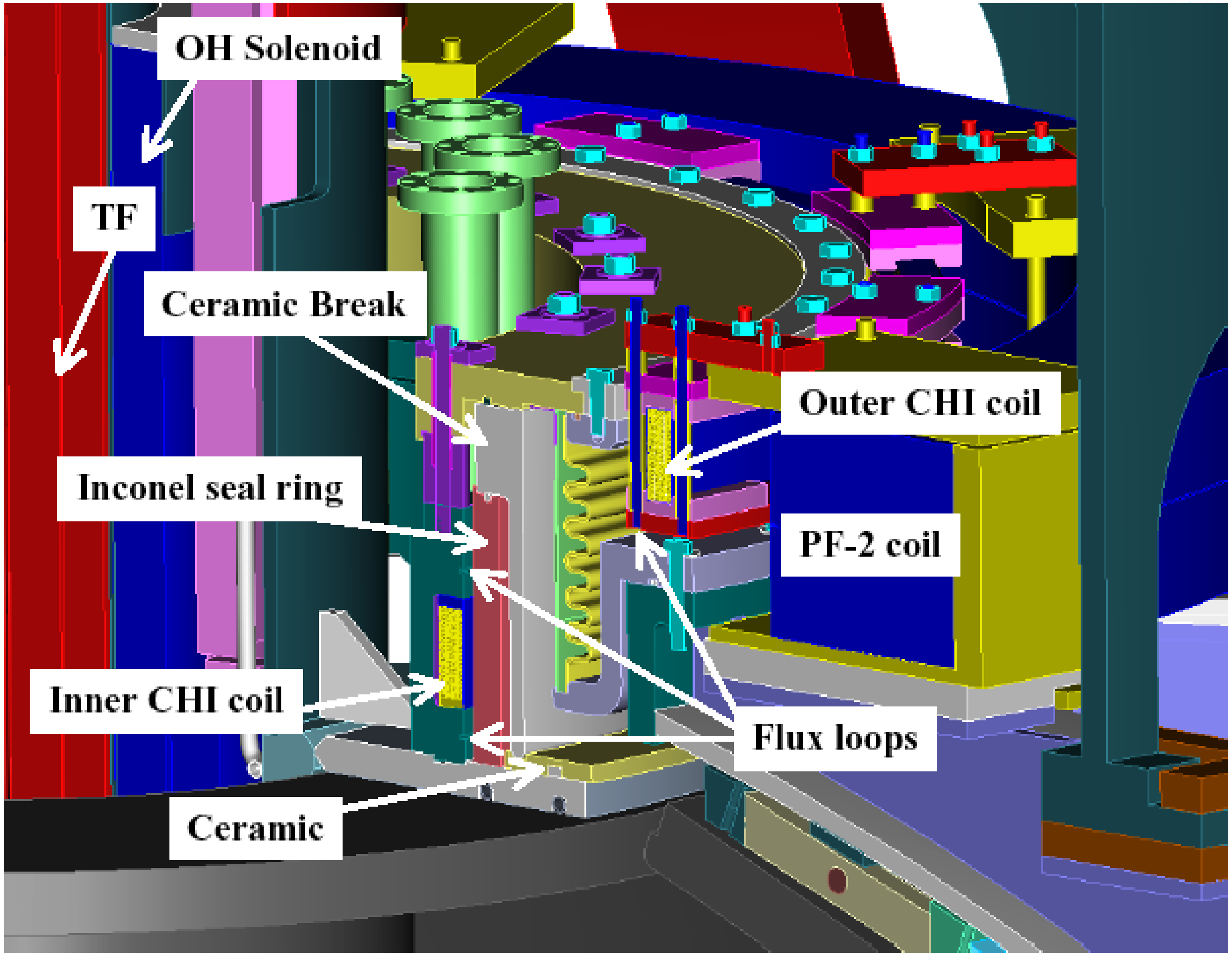
Shot 102539 at 10 ms



MFIT:
M.J. Schaffer

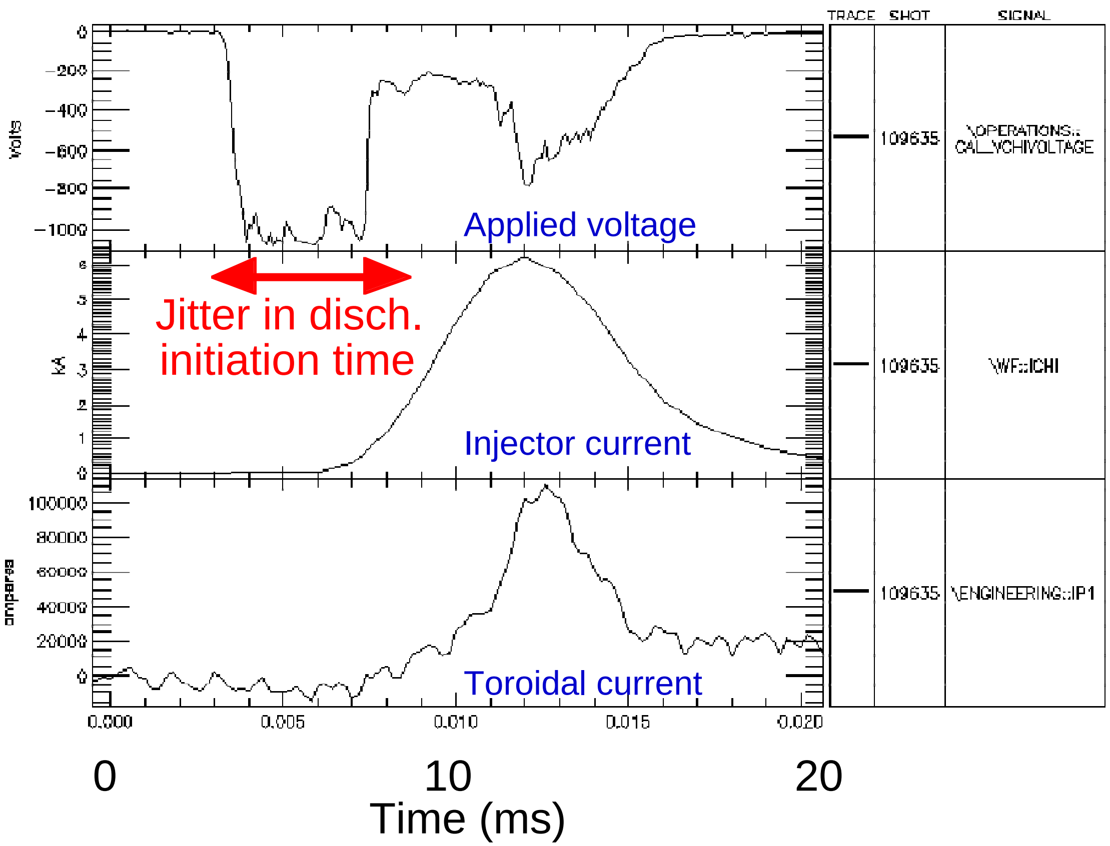
If one makes the reasonable assumption that the injector current through the plasma load in the vessel is zero after the initiation of an absorber arc, then the toroidal current left over would be indicative of the presence of closed flux plasma. This is to be unambiguously verified under conditions where the injector current is ramped down quickly in a controlled manner.

Redesigned NSTX Absorber has undergone a full day of short pulse CHI discharges without incidence of absorber arcs



- Insulator on high field side
- No simple connection path in insulator region
- Coils to produce local poloidal field to reduce stray field from plasma and PF coils, 1kA peak current
- Flux loops to measure field in absorber region will permit feedback

Controlled transient CHI tests initiated during Fy 03



1. Large jitter in discharge initiation time, with long current rampdown time

2. Total amount of injected gas to be reduced

3. Pre-ionization to be improved

- Several short pulse discharges in the 100kA level produced.
- Injector current needs to be increased to about the 10-15kA level and the current needs to ramped down in about 2ms.

Hardware upgrades in progress for transient CHI tests

- New “HIT-II like” capacitor bank under construction to rapidly increase and then ramp down the injector current as on HIT-II, at a precise discharge initiation time.

- CHI gas injection plenum volumes reduced to decrease the amount of injected gas

- High power HHFW will be used as a new pre-ionization tool to initiate CHI discharges at lower gas pressures

- New result from HIT-II (which shows that the divertor coils current need not be reduced) further simplifies the application of transient CHI on NSTX

Fy04 to Fy06 Research Plan

FY04: Transfer transient CHI plasma to the PF system

- Fully commission new absorber (assess field nulling requirements)
- Initiate edge current drive studies

FY05: Transfer transient CHI plasma to non-inductive CD system

- Increase current levels produced by transient CHI

Reestablish 300kA steady-state discharge

FY06: Establish transfer of CHI to non-inductive CD system and establish edge current drive

- Investigate SOL effects
- Establish preferred method for startup

Summary

- NSTX discharges have shown capability of CHI to produce high current (390kA), long pulse (330ms) discharges with 14 times current multiplication
  - Desirable features observed (n=1, MFIT recons. and SXR emission)
- CHI Research on NSTX will decouple the current startup and sustainment objectives
  - Transient CHI will be used for startup
  - Steady-state CHI will be used for edge current drive
- The NSTX absorber region has been considerably improved
  - Absorber field nulling requirements will be assessed during Fy04-05
- Hardware upgrades are in progress for implementing transient CHI
  - New capacitor based power supply

[Please see poster LP1.023 by D. Mueller for work on edge current drive]