**Transient CHI initiation and hand-off to induction**

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Fy03 experimental results from HIT-II on the transfer of a Coaxial-Helicity-Injection- (CHI) produced discharge to inductive operation show that the method works very well on HIT-II. On HIT-II, CHI assisted plasma startup is more robust than inductive only operation and reduces volt-seconds consumption. After handoff to inductive operation, the initial 100 kA of CHI produced current drops to 50 kA, then ramps up to 180 kA, using only 30 mVs, about 40% higher than that produced by induction alone. Results show that initiation of CHI discharges at lower densities produce higher levels of coupling current. Coupling a CHI produced discharge to induction from a pre-charged central solenoid has produced record currents of 290 kA using only 52 mWb of central solenoid flux. CHI discharges can also be generated while the central transformer is in the process of being pre-charged, during which period it induces a negative loop voltage on the CHI discharge.

Transient CHI startup was developed on HIT-II primarily for the purpose of developing a solution for CHI startup in NSTX. During Fy03, as part of XP-301, one day was devoted to Transient CHI startup in NSTX. Two issues were quickly apparent. These were (a) large jitter in the discharge initiation time, (2) inability to quickly ramp-down the injector current. Further supporting experiments on HIT-II indicated that proper injector voltage programming was important and that there was no need to ramp-off the injector flux. Capacitor scaling studies on HIT-II pointed to the requirement of a small capacitor bank for NSTX that would easily resolve both issues encountered in the Fy03 NSTX CHI experiments, and it would be better suited for the required voltage programming capability needed for transient CHI discharges in NSTX. This capacitor bank is at present in the detailed design phase, with planned power testing during mid-February. Improvements to pre-ionization in NSTX could be achieved by application of high power HHFW to allow one to initiate discharges at lower gas pressures, which should result in higher handoff current when coupled to induction. Applying a short pulse of NBI offers a means to increase the initial temperature of the CHI initiated discharges, which should result in an extension of the current decay time of CHI produced discharges. This should allow easier coupling to induction and in future to other current drive methods.

There are indications from an old NSTX discharge (No. 102539), in the old absorber configuration, that seems to show persistence of toroidal current after the initiation of an absorber arc. The new capacitor based power supply, in combination with the new NSTX absorber should allow for a controlled ramp-down of the injector current under conditions where an absorber arc is not initiated. After successful demonstration of the persistence of toroidal current, after the injector current has been reduced to zero, further optimization can be carried out through small variations to the injector flux, current in the PF3L coil and currents in the other PF coils used for initial static boundary shape specification.

# Transient CHI startup and handoff to induction

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# Procedure for successful plasma start-up

1. Produce a short pulse discharge in the narrow foot-print condition
   - PF3a is used to adjust injector gap
   - Other PF coils used to produce a magnetic well

2. Simultaneously reduce the CHI injector voltage
   - Appropriately sized capacitor does this naturally

3. Apply OH induction during the CHI current ramp-down phase
   - Pre-programmed inductive voltage

4. After the OH drive couples to the CHI produced discharge, hand-off for OH feedback control operation at a new current level for feedback control operation.
   - Already developed feedback control for OH operation will be used

# Other tools

## Pre-ionization

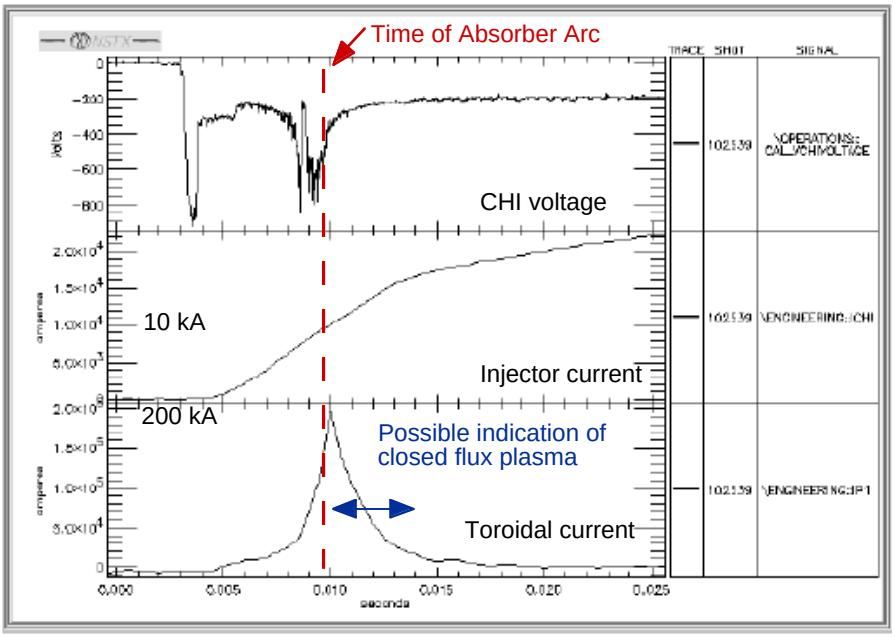
- Use 5 to 10ms HHFW pulse for pre-ionization
  - Existing 20kW ECH will be initiated before HHFW to produce a plasma load for HHFW

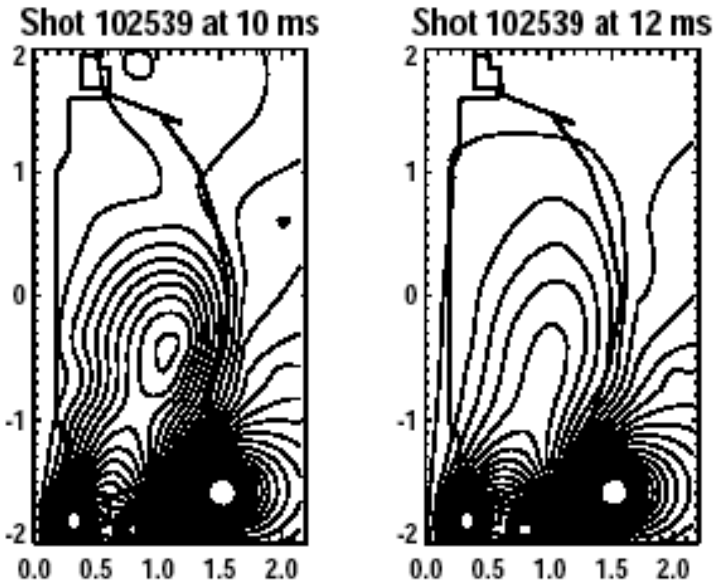
## Heating

- Use 5 to 20ms NBI pulse (50keV) to heat the CHI discharge
  - Inject NBI few ms after a CHI discharge has initiated

# Possible indication of toroidal current persistence in NSTX

(Old absorber configuration)

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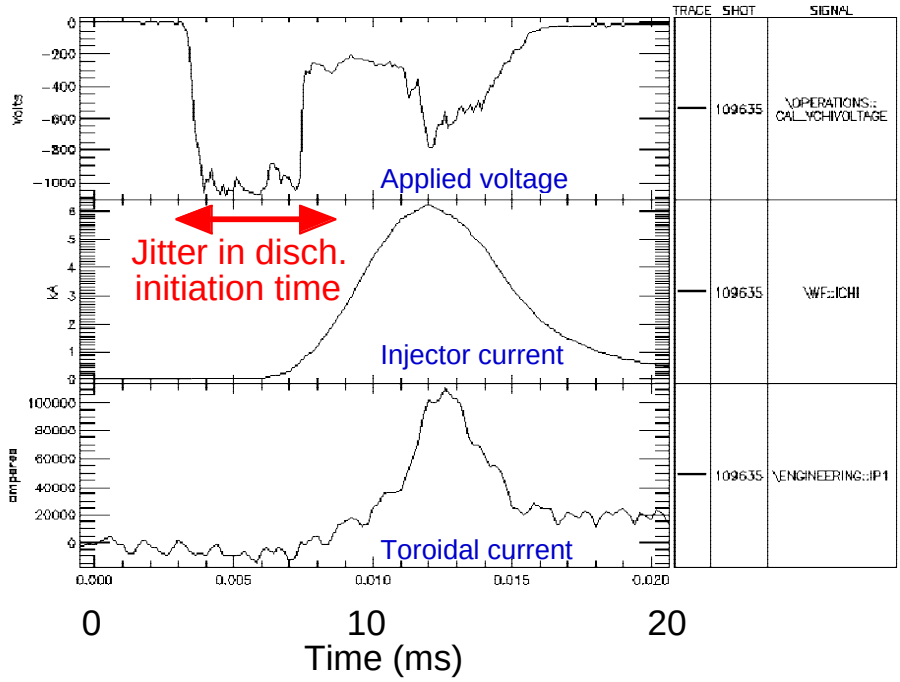
# Controlled transient CHI tests initiated during Fy 03




- 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.
- Jitter to be reduced, gas injection to be reduced, and possibly the pre-ionization needs to be improved

# Optimization

After successful discharges are obtained, vary injector flux and PF3L current to maximize CHI produced current

Reduce gas pressure as much as possible in combination with HHFW pre-ionization

Immediately after CHI discharge initiation, use a 10-20ms pulse of auxiliary heating to increase Te

# Present status

Cap bank for Transient CHI in detailed design phase, construction to begin soon

Cap bank testing scheduled for mid-February

Gas injection plenum volumes reduced