Non inductive plasma startup using CHI

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Status:

Test of CHI conducted on NSTX (260 kA toroidal current using 26kA injector current).

Next Steps:

Make CHI useful to NSTX and STs as follows.

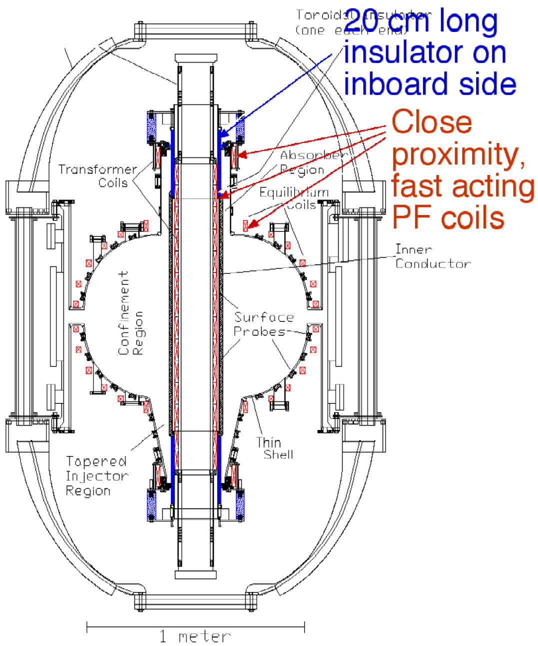
1. Identify issues
2. Study and develop necessary modifications
3. Implement needed hardware changes
4. New experiments

Issues:

HIT-II was designed with the specific purpose of developing CHI.
NSTX has multiple mission goals.

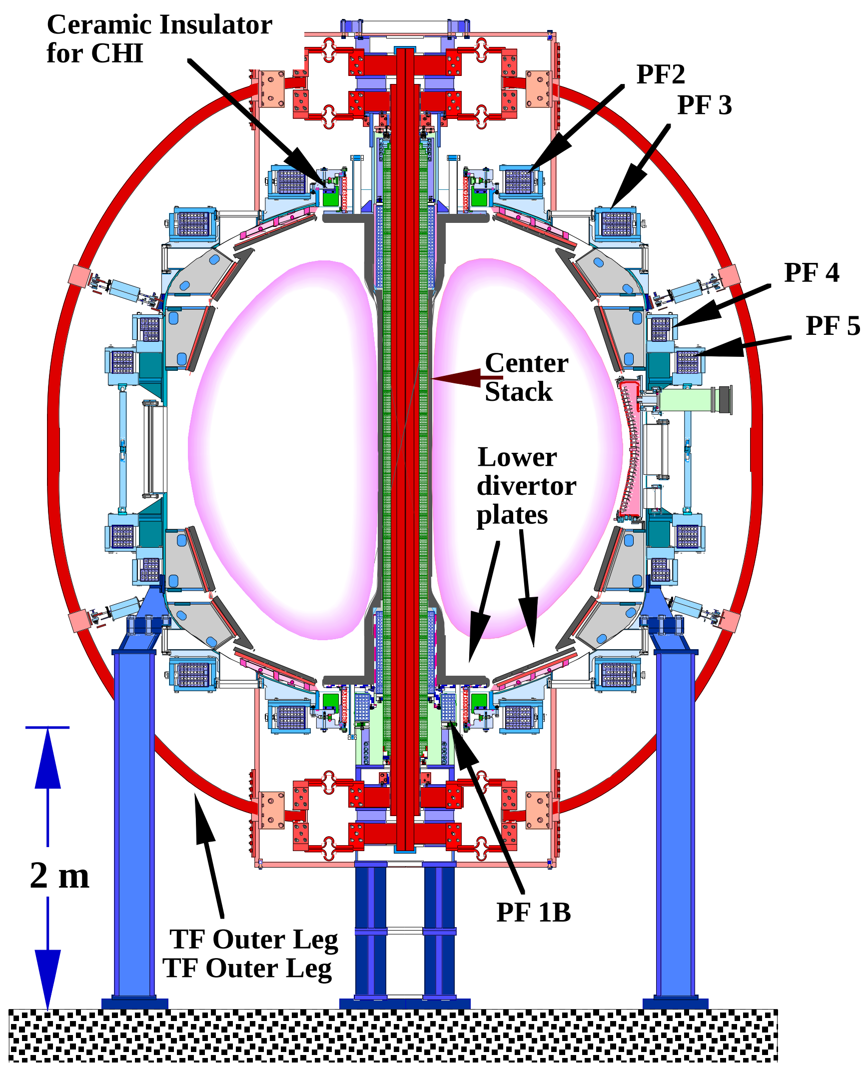
- HIT-II has 20 cm long toroidal insulators on inboard side (compared to 3.2 cm long insulators on NSTX on the outboard side).
- HIT-II has close fitting, fast acting PF coils for very good field null generation in absorber region.
- HIT-II has very good boundary control, as a result of a fast acting flux-feed-back control system that can maintain plasma equilibrium and produce the desired boundary shape.
- Configurations that lead to flux closure require good boundary shape control.

NSTX builds on progress made on HIT device



x 30 volume →

NSTX pulse length much longer (x 20)



NSTX needs:

(1) Long inboard side insulator
(2) A redesign of the absorber region to make it a simple cylindrical shape
(3) Additional PF coils for absorber field-null control

(4) Feedback control development in two steps.
(4.1) Start with simple methods such as toroidal current control via. injector current control, or a variation of this on CHI only discharges.
(4.2) In shots where CHI is added to an Ohmic discharge, modify the existing feedback control system, in steps, as the magnitude of the CHI added edge current increases.

Goals:

- Absorber arc suppression.
    PF1AU to create absorber null.
    Higher poloidal field in absorber
    New PF coils for absorber
    Redesign absorber

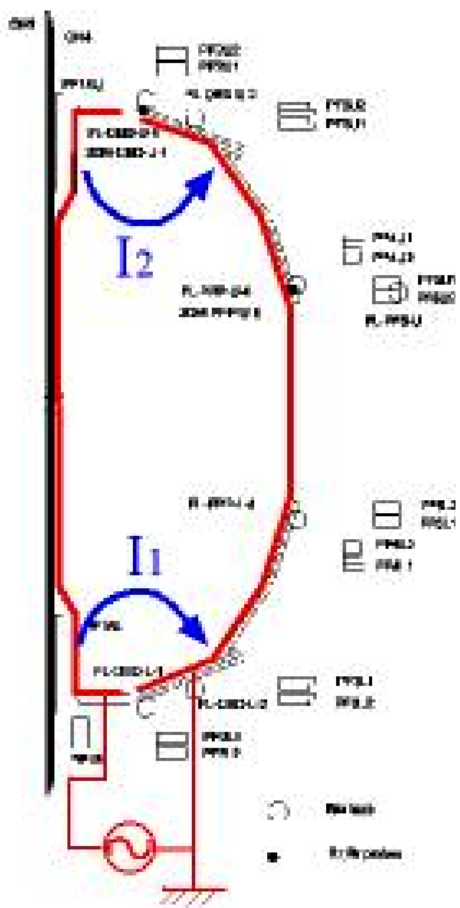
- Establish flux closure (use all available tools: absorber arc control, feedback control, OH induction).
    Additional PF coils and improvements to boundary shape control (via. feedback control) may be needed to establish flux closure.

- Feedback control development.
    Add CHI to Ohmic.

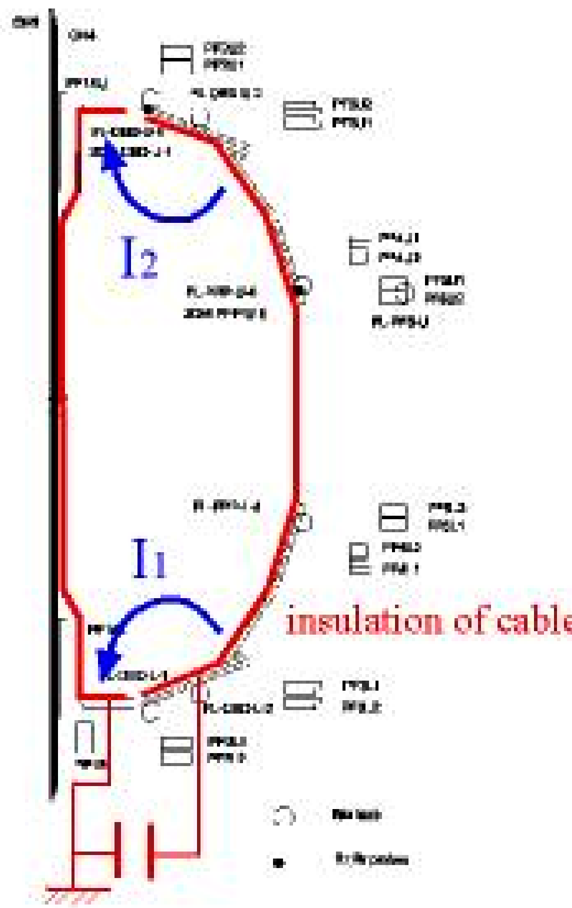
- Add Ohmic to CHI

- Study and consider implementation of FRC formation using both CHI electrodes (collaboration with Y. Ono of U-Tokyo and F. Perkins of PPPL). Study methods to float the outer divertor plates.

Experimental Setups in Stage 1



Stage1: FRC formation
by a DC power supply



Stage1: FRC formation
by a new capacitor bank

1) Slow field index control from negative to positive will be used to separate merging process from spheromak formation process (PF5 and PF3 coils).

1) An initial test could be conducted using the existing CHI power supply. Use of two faster capacitor banks (~200kJ, 20kV) may ease the formation process.

2) All components inside the inner electrode would be electrically connected. The TF coil will not be needed.

The plan is to have the first stage as an initial test of double CHI operation, since it lacks individual current control. The FRC formation may not be fully successful.

l First Stage Experiment

Objective:

- FRC merging formation without balanced control of discharge currents This may be difficult as the discharge currents in the top and bottom CHI electrode regions do not have individual current control.
- The first merging operation in NSTX using both CHI electrodes.

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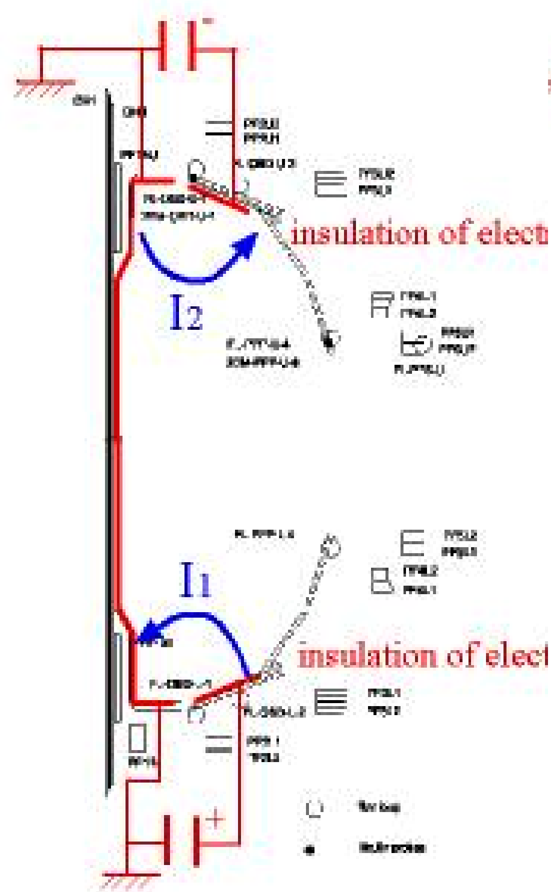
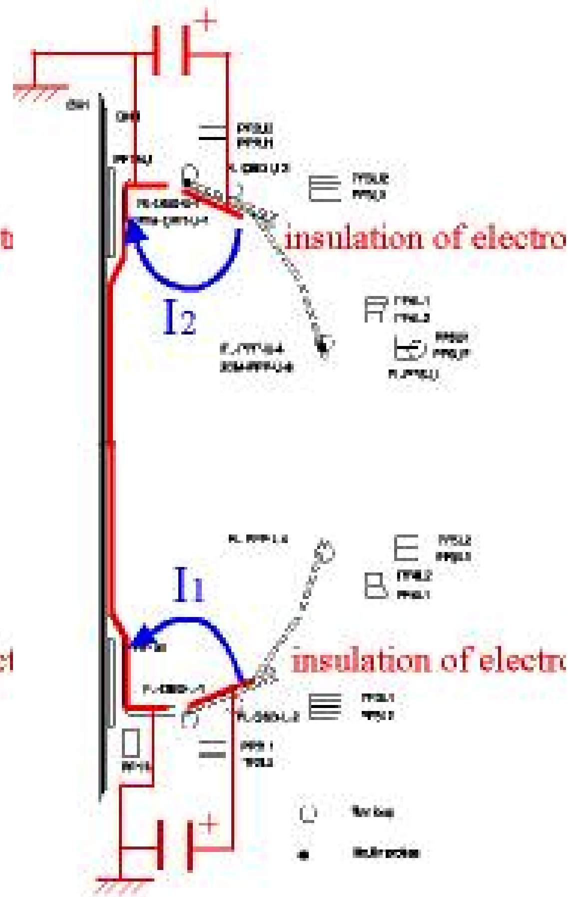
Advantages:

- No additional hardware modification.
- The existing two coaxial plasma guns would be used. The equivalent of the PF1B coil in the top electrode region may not be needed as the PF2 and PF1A coils may be adequate for the necessary injector flux.
- No insulating breaks are needed on the center stack or the outer vessel. The present CHI electrode polarity would be used.

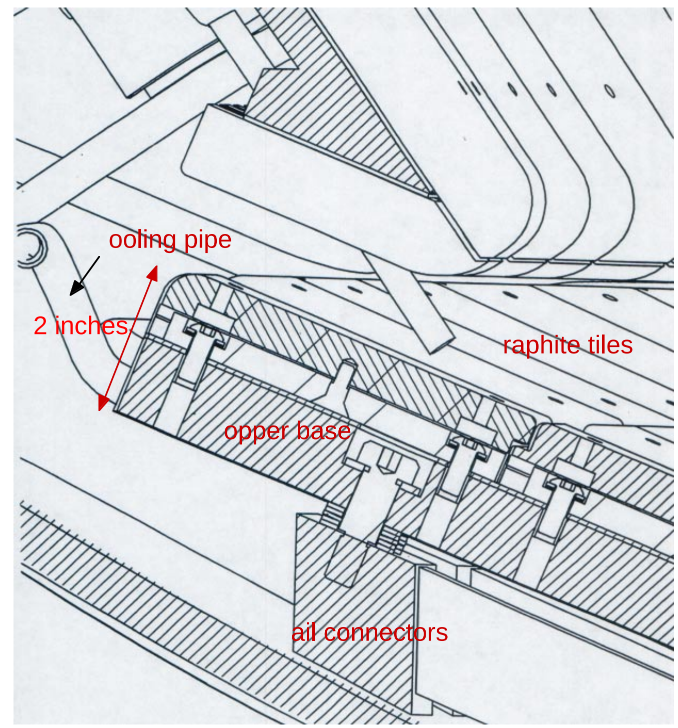
Modifications in Stage 2



Stage2: ST Merging for high-power heating



Stage2: FRC formation with current control



Lower divertor plate connection arrangement in NSTX

FY 01 to 02 (10/00 to 9/02) [Test plasma startup]

- Extend the CHI produced toroidal current up to the 500kA level.
- Investigate flux closure. Establish flux closure before (or after) hardware changes have been made.
- Initiate experiments on adding CHI to an Ohmic discharge (in collaboration with D. Mueller of PPPL) - The purpose here is to begin to develop understanding of feed back control of discharges that also contain a CHI component. Since these discharges will initially contain a much larger portion of transformer driven current and will be feedback controlled to start with, modifications to the feedback control system can be made in gradual steps as the portion of the CHI current is increased in gradual steps. Eventually, methods developed here will be used on CHI only discharges that are used for plasma startup.
- Drive a high current CHI produced target plasma using OH induction.
- Consider discharges with no TF for FRC formation (in collaboration with F. Perkins of PPPL and Y. Ono of U-Tokyo). This will be a transient experiment and not steady state in nature. This represents an alternate method for plasma startup. After FRC formation, currents in the CHI circuit will be turned off. Once the FRC plasmoid has formed, the TF can be ramped up in current while simultaneously others methods are used to sustain the discharge (HHFW, NBI, Ohmic).

- Improve EFIT to include open field line and private flux current (in collaboration with M. Schaffer, L. Lao of GA and S.M. Kaye of PPPL)
- Improve TSC to model CHI discharge evolution (in collaboration with S. Jardin, S. Kaye of PPPL).
- Design and install faster acting PF coils to reduce field in the absorber region (in collaboration with M. Ono, C. Neumeyer of PPPL and others). This means two new PF coils for the absorber region. The primary motivation for these coils is to reduce the stray poloidal fields in the absorber. Therefore these coils will have few turns (low inductance, faster acting) and low current capability (since the stray field magnitudes in the absorber are small).
- Initiate feedback control studies on discharges in which CHI is added to an Ohmic discharge and identify needed diagnostics (in collaboration with D. Gates of PPPL).
- Conduct discussion on the feasibility of advanced spheromak merging experiments and related hardware changes (in collaboration with the NSTX engineering team, Y. Ono, D. Mueller and others).

FY 03 (10/02 to 9/03) [Establish plasma startup , Non-inductive sustained operation]

- Implement fast PF coils for absorber field reduction.
- Establish plasma start-up without the OH coil.
- Produce reference operating conditions in which CHI provides edge current drive.
- Consider operation with no external TF for FRC formation test.

- Conduct fast camera measurements (in collaboration with R. Maqueda of LANL, S. Zweben of PPPL).
- Conduct edge probing studies (in collaboration with H. Ji and S. Zweben of PPPL).
- Initiate MSE measurements (in collaboration with F.M. Levinton).
- Conduct divertor heat load studies (in collaboration with R. Maingi of ORNL and H. Kugel of PPPL).
- Routine EFIT and TSC for CHI only discharges.

- Extend feedback control to CHI only discharges and implement needed diagnostics.
- Initiate work on 3D MHD modeling using existing codes (M3D, Nimrod) through graduate student involvement.

- Design improved insulator for CS upgrade (in collaboration with PPPL Engineers).
- Install improved design insulator.
- Consider and if necessary design and implement hardware modifications for advanced spheromak merging experiments.

≥ FY 04 (≥10/03) [Routine plasma startup, Routine operation with new CS, Current drive understanding]

- Initiate experiments with new CS.
- Implement full feedback control of CHI discharges using improved insulator, faster absorber PF coils and previously developed CHI discharges.

- Detailed measurements using edge probe, MSE, Fast Camera.
- Understand mechanisms that lead to closed flux generation based on edge probing studies, MSE measurements, EFIT, TSC simulations and other diagnostics.