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Flux Savings and Improved Coupling of a Transient CHI Started Discharge to Induction

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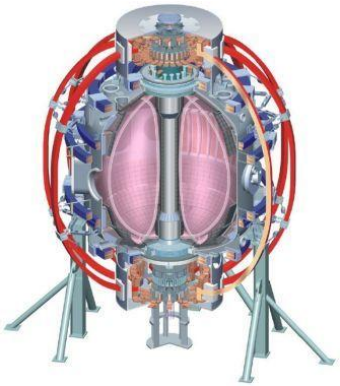
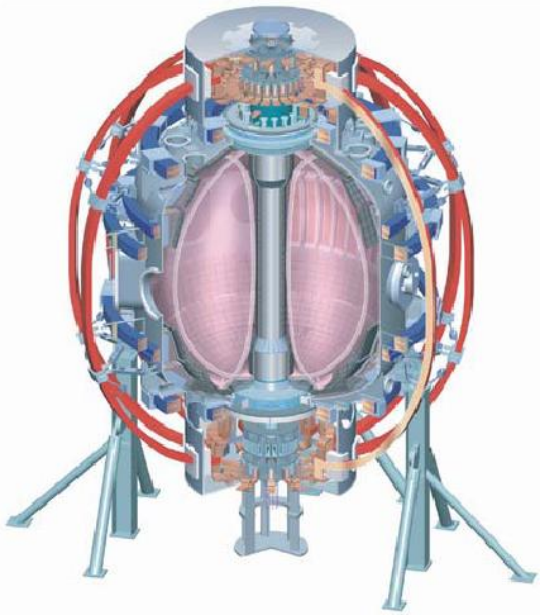
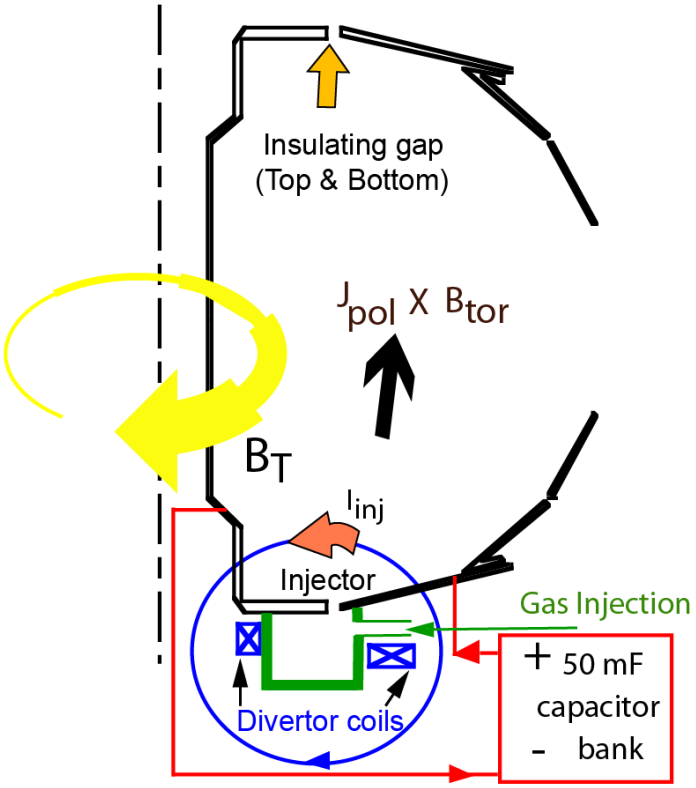
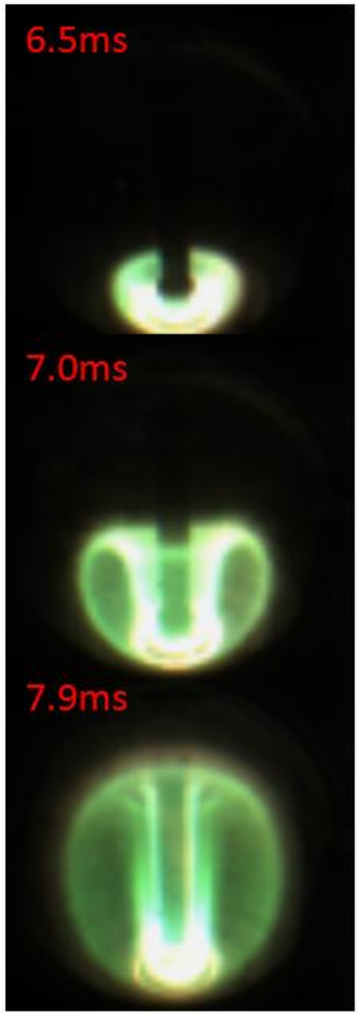


NSTX Research Forum for
FY2010 Research
1-3 December 2009

Transient CHI: Axisymmetric Reconnection Leads to Formation of Closed Flux Surfaces



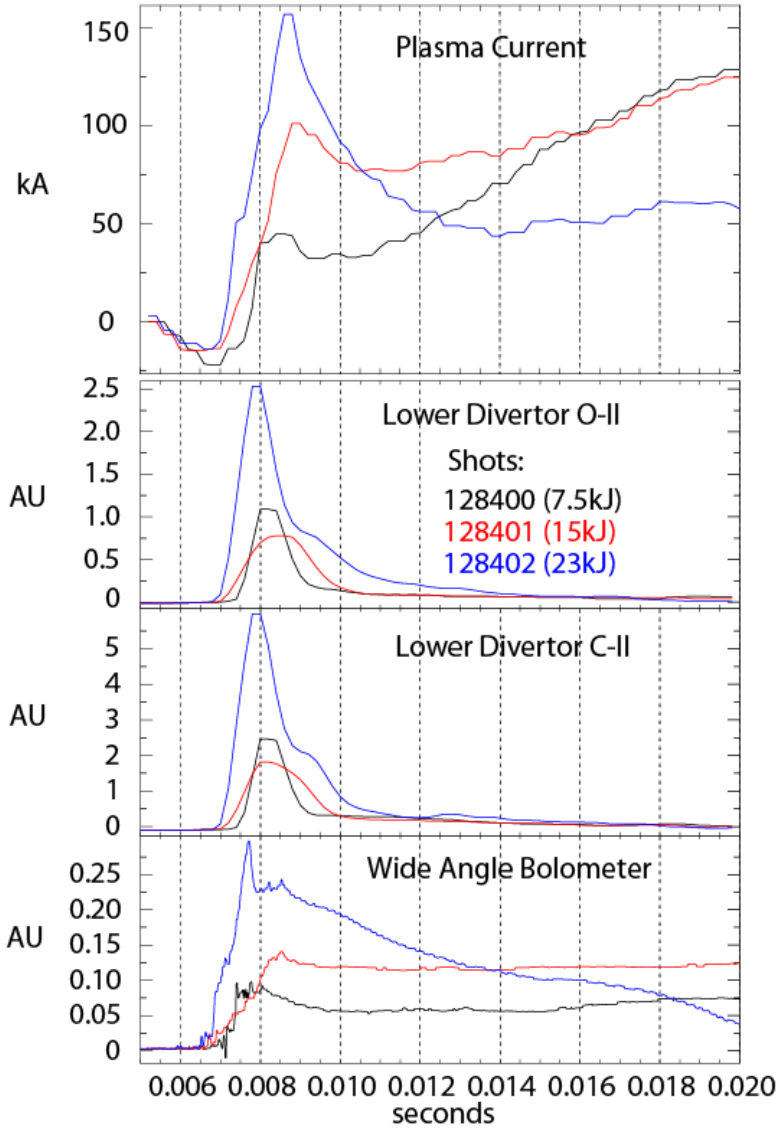




- Demonstration of closed flux current generation
  - Aided by gas injection from below divertor plate region
- Demonstration of coupling to induction (2008)
  - Aided by staged capacitor bank capability

CHI for an ST: T.R. Jarboe, Fusion Technology, 15 (1989) 7
Transient CHI: R. Raman, T.R. Jarboe, B.A. Nelson, et al., PRL 90, (2003) 075005-1

Low-z Impurity Radiation Should be Reduced for Inductive Coupling (FY2008 Conclusion)



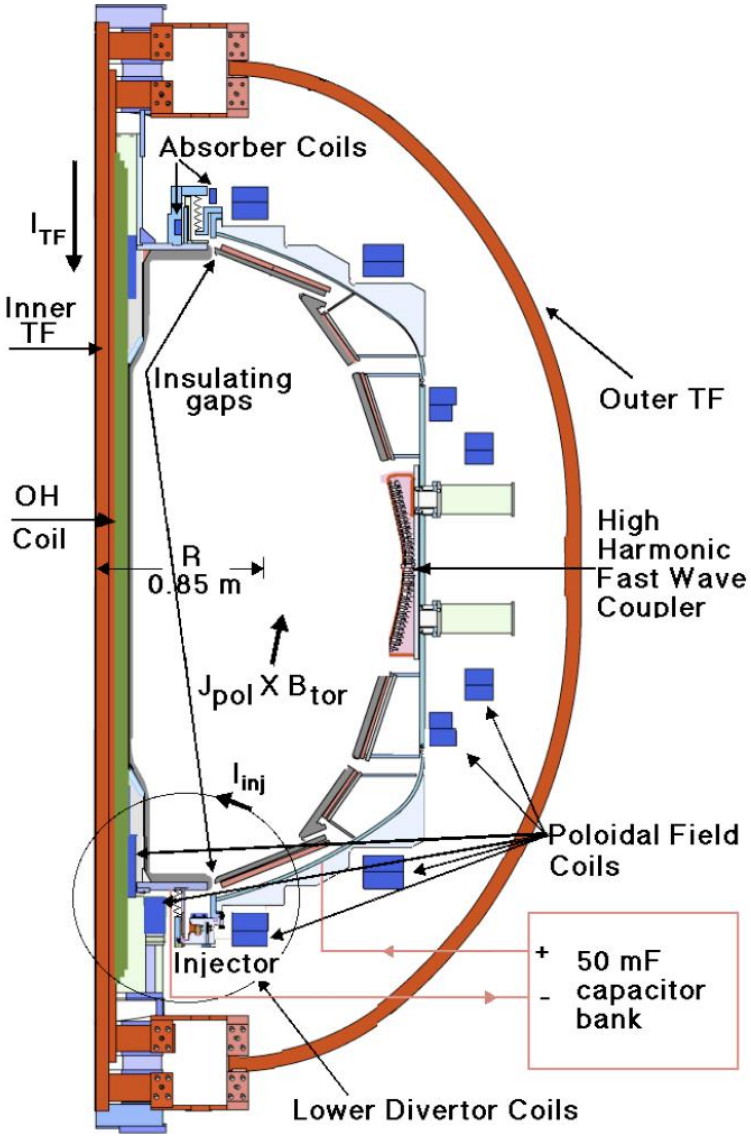
- Low-z impurity radiation increases with more capacitors
- Possible improvements
  - Test CHI in NSTX with partial metal outer divertor plates as part of liquid Li divertor upgrades
    - High Te in spheromaks (500eV) obtained with metal electrodes

    [Not yet studied – FY10 goal]
  - Discharge clean divertor with high current DC power supply

    [Helped FY09 CHI Run]

"If the coupling current could be doubled, pronounced flux savings should happen naturally" – FY2009 SFPS Research Forum Conclusion

Flux Savings on NSTX Now Realized (FY09 Results)



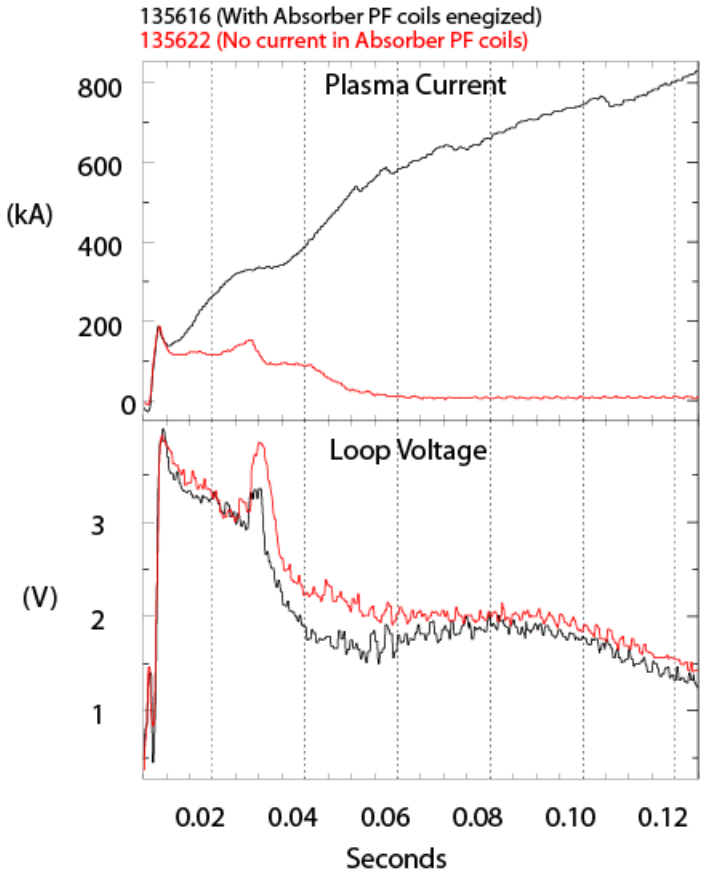
Long-pulse (400ms) CHI discharges in a 'stuffed- injector' current mode used to ablate Low-Z impurities from lower divertor [Helped FY09 CHI]

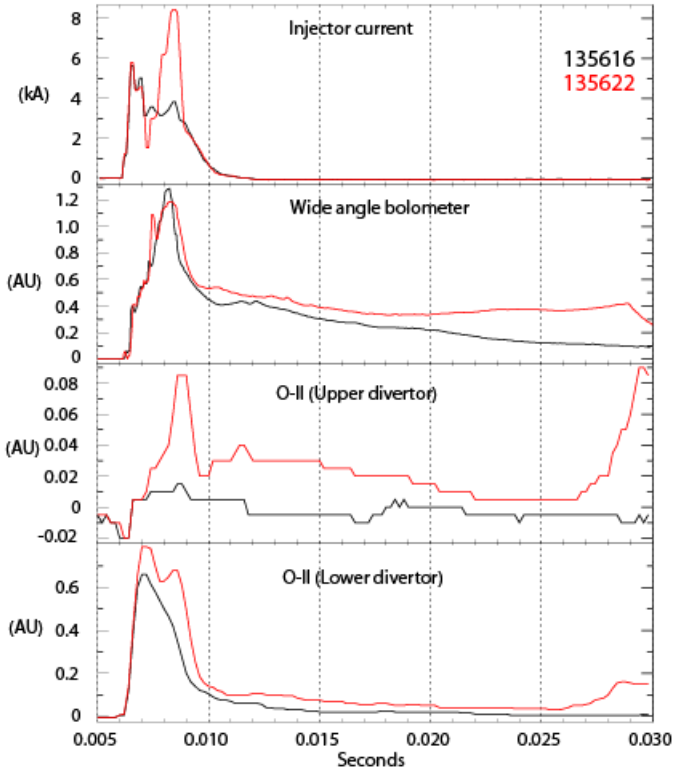
Deuterium Glow Discharge cleaning employed to chemically sputter and reduce oxygen levels [Helped FY09 CHI]

A buffer field was provided using new PF coils located in the upper divertor region (Absorber region) to reduce interaction of CHI discharge with un-conditioned upper divertor plates [Helped FY09 CHI]

Lithium evaporation on lower divertor plates improved discharge performance [Helped FY08 and 09 CHI]

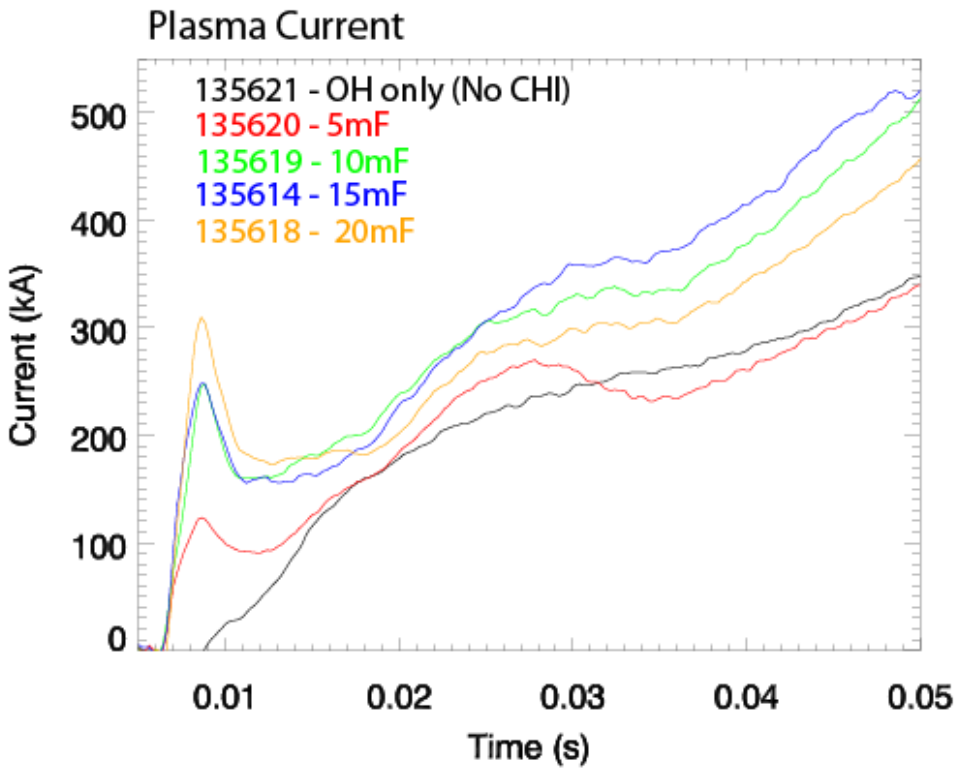
Absorber PF Coils Have Reduced Influx of Oxygen Impurities From Upper Divertor

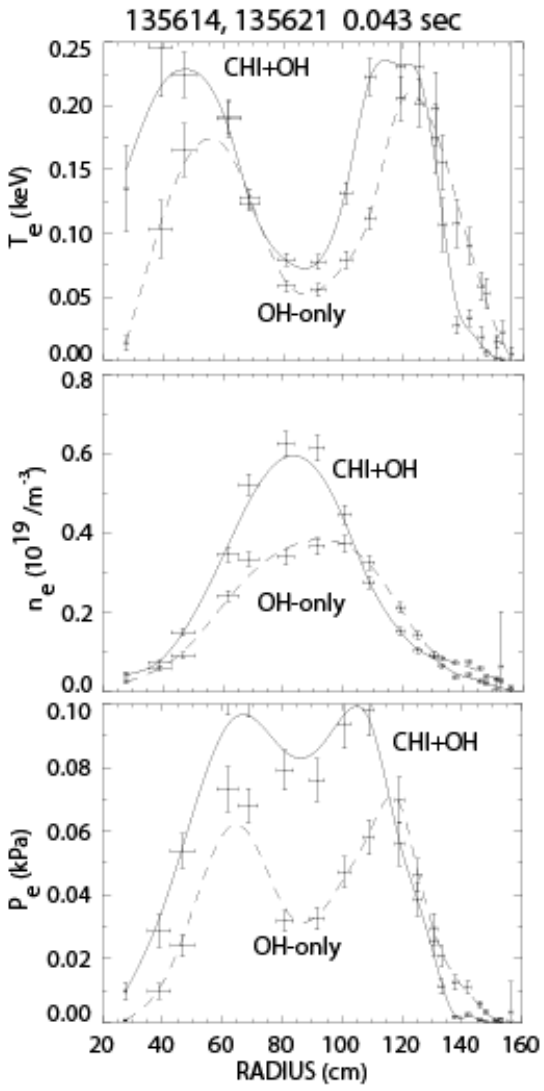




Need more buffer flux to allow operation at >250kA

Using Only 25kJ of Capacitor Bank Energy 300kA of CHI Started Discharge Generated and Coupled to Induction





Need to improve equilibrium during current ramp-up phase

Additional effort to reduce absorber arcs to allow operation above 300kA

New Hardware Improvements for 2010 to Allow Higher Current CHI Operation (Divertor surfaces)

- Reduction of Impurities from Lower Divertor
  - As in 2009, the DC power supplies would be used to clean the lower divertor tiles
    - Use LDGIS in flow-mode to compensate for Li-pumping
  - As in 2009, use the Li evaporator to initially deposit 100mg/shot.
    - Time permitting, increase the amount of evaporated Li to see a benefit during the CHI startup phase
- Reduction of Impurities from the Upper Divertor
  - Increase the magnitude of the buffer flux
    - Increase current limits in PFAB1 and 2 (working with Ron Hatcher)
    - Increase the voltage on PF2U to 2kV (should be easy to do)
    - Generate a USN or a DN and use the Li dropper to coat the upper divertor, may need a few shots or do it between shots
      - With CHI plasma contact Li (in preference to oxygen) would be released
      - Li will act as a pump (similar to the effects seen on the lower divertor)
      - Deposit as high a level of Li the plasma will tolerate

New Hardware Improvements for 2010 to Allow Higher Current CHI Operation (metal electrodes)

- Use metal outer divertor plate in the preferred cathode configuration
  - Switch the direction of TF to make the outer electrode the cathode and investigate the effect of reduced low-Z impurity influx from the largely metal outer electrode.
  - Compare with shots with the metal plate as the anode

Run Plan

- Prior to the start of CHI experiment, run high injector current discharges using the DC rectifier power supplies (400ms, 5-8kA), in a stuffed injector current mode to further clean the lower divertor electrodes
  - Use LDGIS in Flow Mode & reduce series resistance
  - Reduce the gain on the filterscopes to be able to track the reduction in C and O line emission
  - Use the divertor infrared camera to monitor the divertor tile temperature
  - Run 5-10 LSN or DN discharges and use the Li-dropper to coat the upper divertor with Li - then this may be needed between CHI discharges as the deposited Li wears out.
- Then reconnect the CHI capacitor bank power supply and initially repeat the 2009 reference discharges.
  - Improve the discharge and by adjusting the injector flux and toroidal field, determine the highest level of closed flux current that can be obtained.
  - Initially repeat with 4 capacitors and increase the capacitor bank size, which would be limited by the current limits on the buffer field coils
  - Readjust the start of hand-off phase (move it closer to 20ms) and readjust the initial PF5 coil current and the ramp rates to avoid plasma contact with the walls.

Run Plan

- After reliable ramp-up discharges are obtained
  - Use NBI during the current ramp-up phase, all three sources, but starting at lower power and then increasing the NBI power to reduce the loop voltage consumption
  - To avoid locked modes, the SGI (or one of the outer gas injectors at 5000Torr) would be needed for additional gas injection
  - The pre-programmed loop voltage will need to be reduced or more likely the discharge may need to be handed off to pre-programmed plasma current control, and the current maintained at some reference level (~800kA).
  - Avoid using the CS gas injector (but this may be needed)
  - Avoid using the outer gas injector at less than 5000Torr (during current ramp-up)
  - Repeat with the Li deposition amount increased from 100mg/shot (for all above cases) to 200mg, then 300mg. Note that the gas injection from Branch-5 may be inadequate for the higher levels of Li.
  - Initially operate with the LLD in the cold state for the above steps. After reference discharges have been produced, over several shots, gradually increase the LLD temperature to asses the benefits of the liquid Li.

Run Plan

- Operate with Reversed TF
  - After the TF has been reversed, conduct the DC PS conditioning shots
  - Repeat a lower power reference shot from the anode outer electrode case
  - Start at an intermediate value (4 capacitors) and gradually move up to the limits established for the anode outer electrode case
  - If the best cases generated in the anode outer electrode configuration cannot be reproduced, then operate at a nearly identical condition at a lower current level, to establish the magnitude of low-Z impurities in the anode and cathode configurations (injector flux, TF and injector current should be similar).

Run Time

1-day (DC PS operation – anode outer electrode)

3-days (CHI cap- bank)

- Because this is a new configuration, the 3 days may be insufficient. We will not know until we start running CHI.

1-day (DC PS operation – cathode outer electrode)

2- days (CHI cap bank)

Need about 7 days. With less than 5 days (may not be able to operate in the cathode configuration).