Plasmoid instability and flux closure during CHI Theory and Experiment

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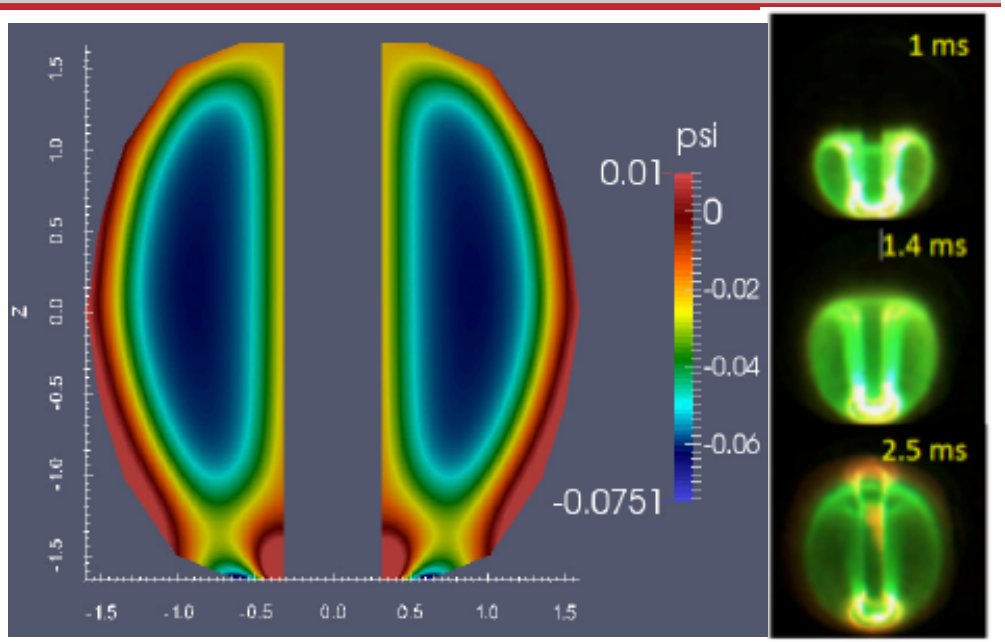
Physics of Flux Closure during Plasmoid-mediated Reconnection in Coaxial Helicity Injection

Transient CHI is used as a *solenoid-free* plasma start-up method in NSTX and NSTX-U & can be used to simplify the Tokamak

- Two mechanism for flux closure seen in Resistive MHD simulations
- Sweet-Parker type reconnection (electromagnetic forces cause oppositely directed field lines to come closer in injector region and reconnect)
- New Plasmoid mediated reconnection also observed (the S-P current channel becomes unstable at high Lundquist number and breaks up into plasmoids that merge)
- High flux closure observed during the presence of both mechanisms



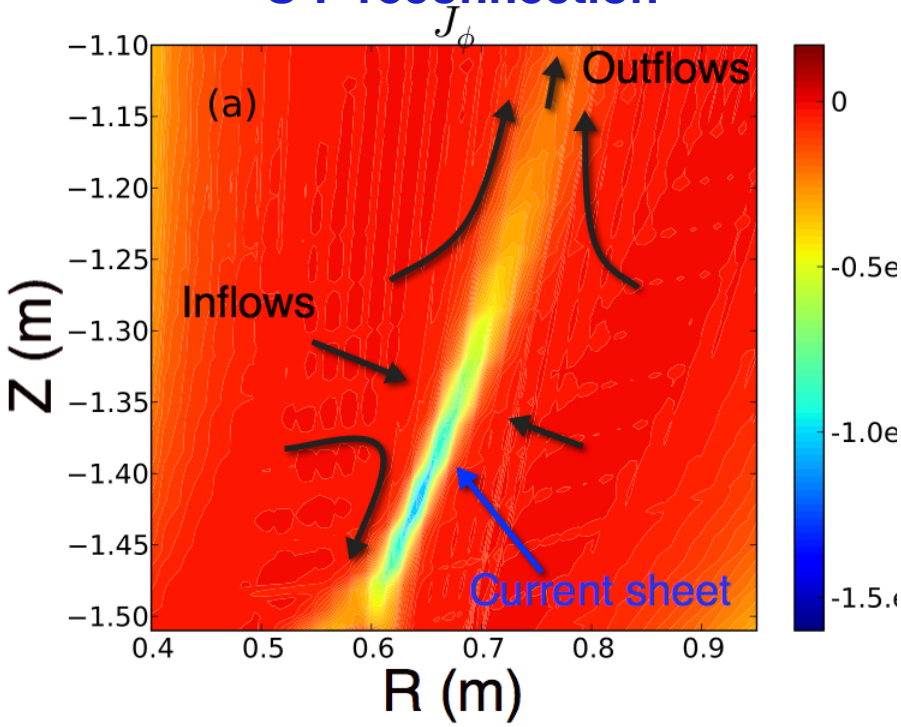
Poloidal flux in simulations and fast camera images during NSTX experiments

Transient CHI is applicable to STs and Tokamaks that use superconducting poloidal field coils

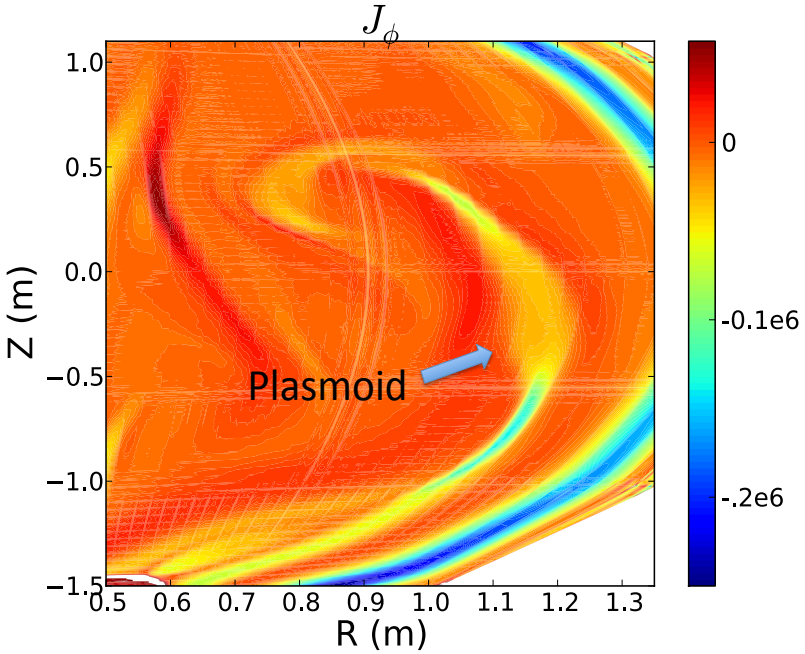
- High flux closure (>70%) observed in simulations in which the coil currents are held constant in time

How are the closed flux surfaces formed?

S-P reconnection



Plasmoid instability

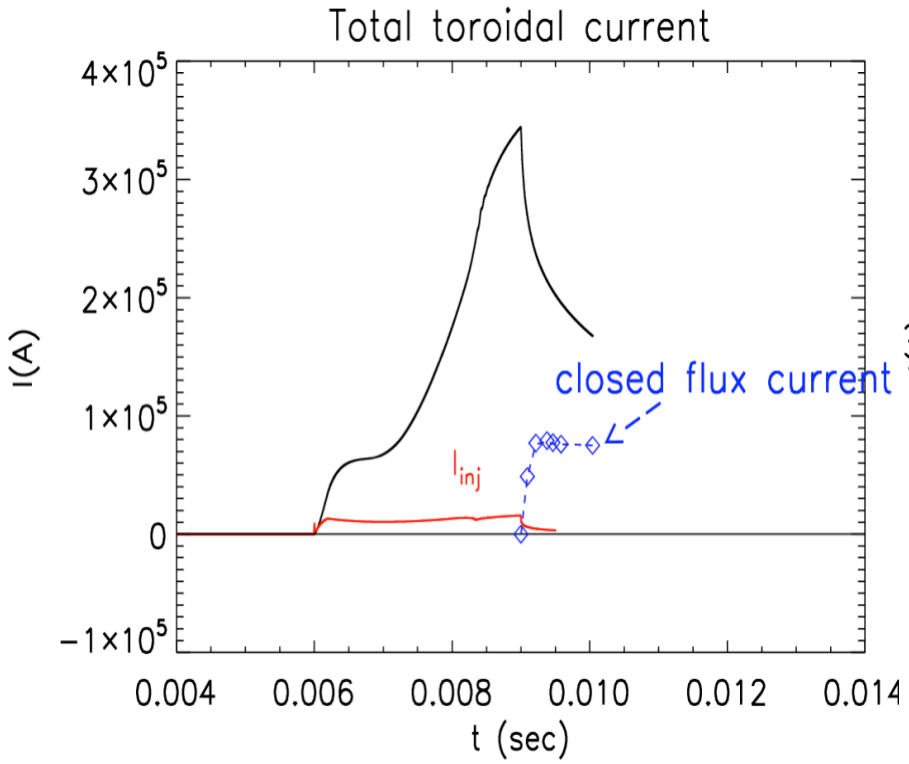


Forced reconnection: A local 2-D Sweet-Parker type reconnection is triggered in the injection region.
[F. Ebrahimi et al. PoP 2013, 2014]

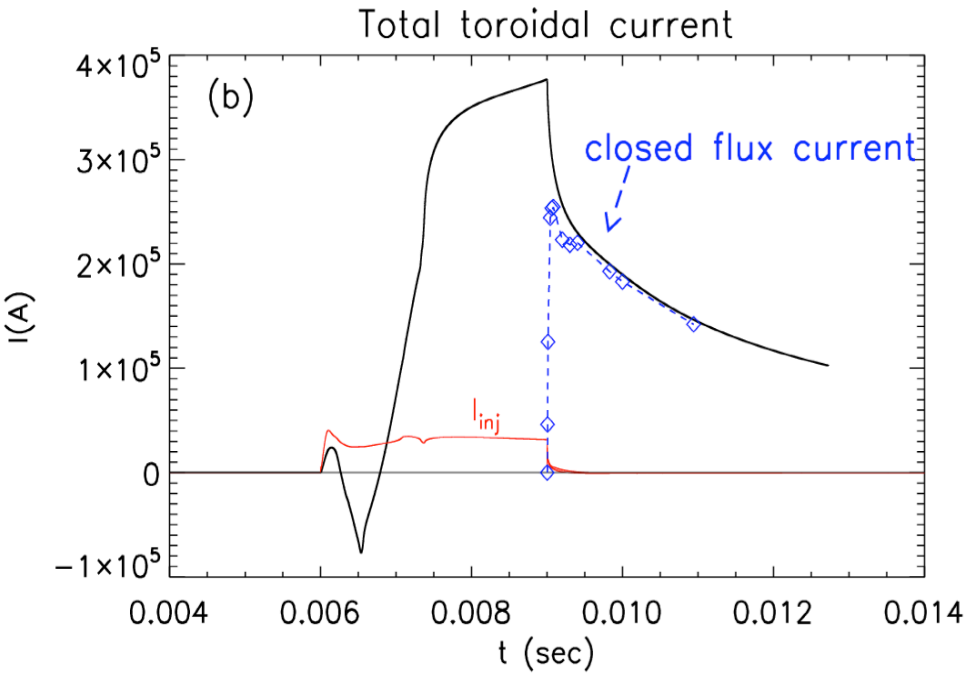
Spontaneous reconnection: At high S, a transition to a plasmoid instability is demonstrated in the simulations.
[Ebrahimi&Raman PRL 2015]

With shaping flux coils, nearly all of the CHI-generated current is closed-flux current (MHD simulations of NSTX-U)

Wide flux footprint



Narrow flux footprint



With narrow flux footprint almost all of the total current is in the closed flux region (with a large closed-flux current of about 240kA).
[Ebrahimi&Raman NF Letter 2016]

Ongoing research

- The parameter range that supports our new findings, is now being studied (the results in Ebrahimi's invited APS talk/paper), the influence of
- toroidal magnetic field
- plasma temperature
- 3D effects (is shown to have no effect on the final flux closure in transient CHI) after the voltage is off.

In a different set of NIMROD simulation (Hooper)

- the electron temperature was increased from the nominal 25eV (corresponding to present experimental condition) to 100eV. In these over-*driven* simulations a high poloidal mode number, n=1 instability is observed during the driven phase.
- Magnetic flux closure regions seen in the injection phase of purely axisymmetric simulations do not occur.

CHI Hardware Status for the FY16 NSTX-U Run

Systems Available at end of FY16 Run

- Capacitor Bank capable of supporting operations with all three ignitrons
- Fast and Slow vessel voltage monitors – (Diagnostics)
- Vessel MOV's and Snubber – (Safety systems)
- Fast gas valves and gas plenums
- Eight individuals certified as cap bank accessors

Essential systems that were not ready

- Installation of gas line components between gas bottle and gas plenums and PLC based control system to fill the plenums to the required pressure

Other Improvements in Progress (non essential)

- Fiber optic based CHI permissive board to replace old wired permissive board
- Doug Westover is training one or more accessors as Cap Bank Operators