EVOLUTION OF HELICITY INJECTED PLASMAS IN NSTX

NSTX

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Helicity Injection is Important for NSTX

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- STs have little or no room for an inductive drive coil.
  - Must be miserly with Volt-seconds.
  - It will be very helpful to:
    - Initiate plasma
    - Ramp I_p up to where conventional (e.g. RF) current drive can operate.
- Helicity injection is a good candidate to make the initial plasma.
- NSTX is designed and built with helicity injection in mind.
  - Vacuum vessel is split into inner and outer halves, mutually insulated.
  - The vessel halves serve as an electrode pair.
    - Electrodes are magnetized by external poloidal field coils
    - Driven by a controlled power supply.
    - 'Coaxial Helicity Injection' (CHI), as pioneered on HIT at U. Washington.
- NSTX will test, study, use and develop helicity injection.

Anticipated Sequence of CHI in a Fixed External Field

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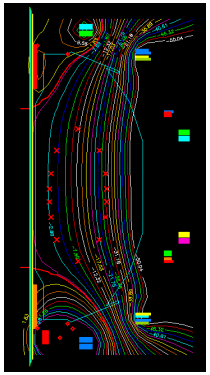
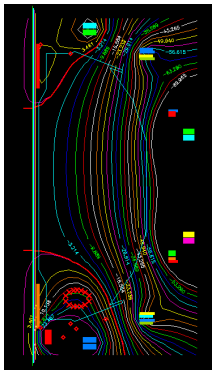
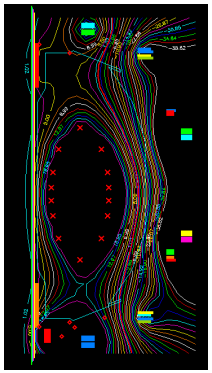


Vacuum flux consists of injector and vertical fluxes. Inner and outer vessel halves get polarized. Gas puffed. Ionization starts.



Current driven through plasma between the two vessel halves follows B. It has a toroidal component, represented by filaments 'x'.

Current continues to increase. Magnetic lines are strongly bent. Poloidal flux reconnects.



Full plasma with current driven in SOL and private divertor flux. Upper null 'diverts' vertical flux from inner wall.

Role of MFIT in NSTX Helicity Injection Experiments

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- Efficient experimental development of CHI requires knowledge of plasma flux geometry with respect to electrodes, vessel walls and external coils .
  - Need to provide information feedback to experimentalists between shots .
- The MFIT [1] magnetic fitting code uses toroidal ring current elements to represent plasma current.
  - Uses singular value decomposition of plasma ring currents, stabilizer and vessel currents, and external coil currents to fit magnetic data.
  - No Grad–Shafranov solution; can reconstruct open–field plasmas.
  - Replaced old MFIT filamentary elements by rectangular cross–section rings.
    - Yields smooth flux in plasma region.
- EFIT can be used once a large volume of plasma with closed magnetic surfaces is established.

[1]Lao et al Nucl. Fusion 25 (1985) 1421

Sets of MFIT Ring Elements with Rectangular Cross Sections are Constructed by Modified EFIT

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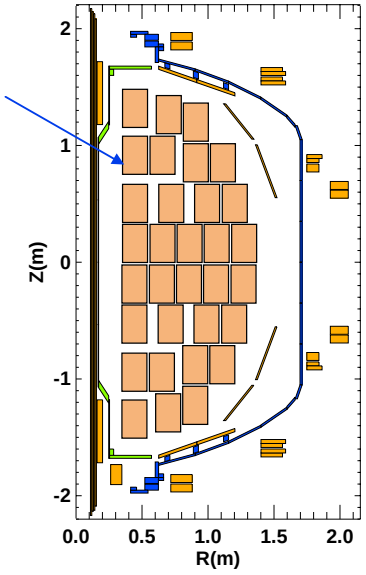
MFIT Ring Elements Represent Plasma Toroidal Current

This 32-Element Set Was Used for the Fits Shown in This Poster.



GENERAL ATOMICS

MFIT Reconstruction Agrees with EFIT

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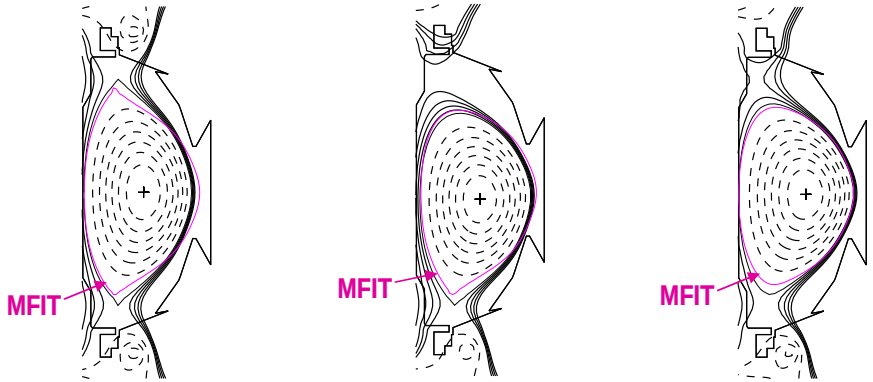
- MFIT uses toroidal ring currents without equilibrium constraint imposed.
  - MFIT test cases here used only 8 current rings inside plasma.
- Can be used early in the discharge when there are few or no closed surfaces.



Shot 100912 Shot 100921 Shot 100940

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MFIT Follows Evolution of Flux Surfaces During CHI

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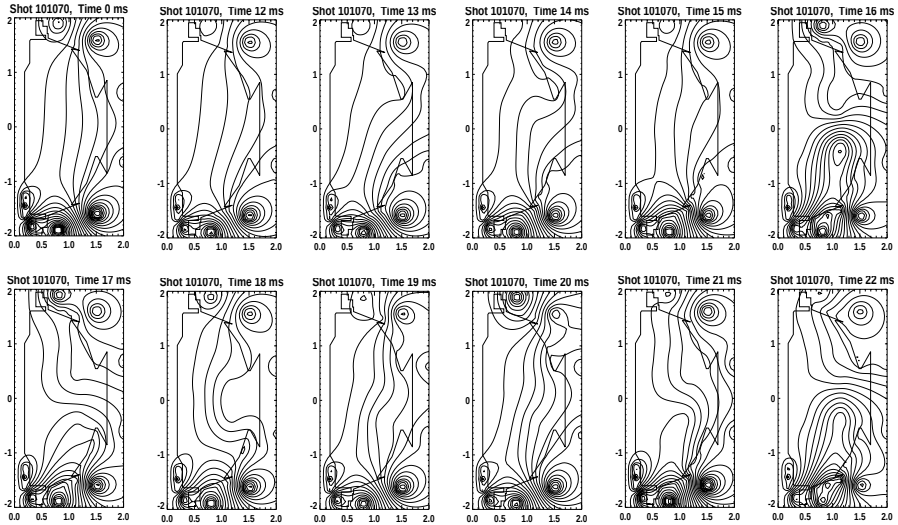

- Used 32 Rectangular Elements Filling Vessel

GENERAL ATOMICS

MFIT Follows Evolution of Flux Surfaces During CHI

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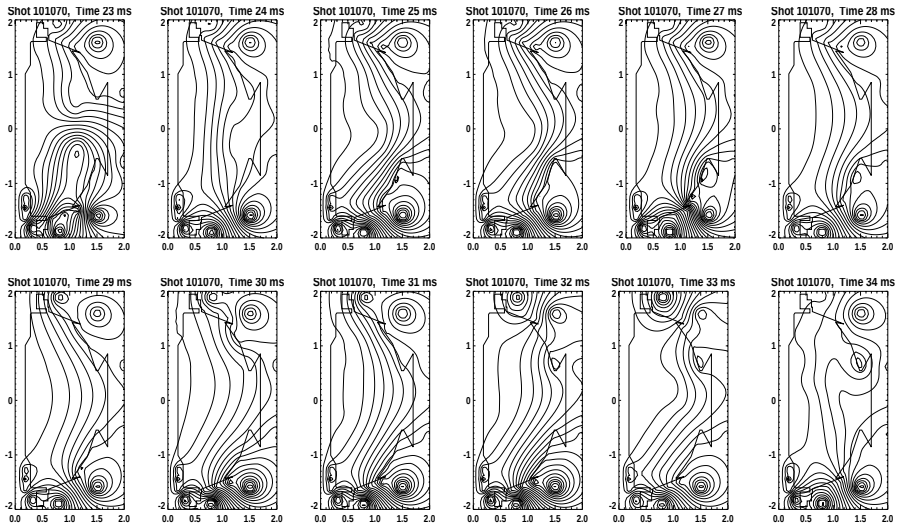

GENERAL ATOMICS

MFIT Follows Evolution of Flux Surfaces During CHI

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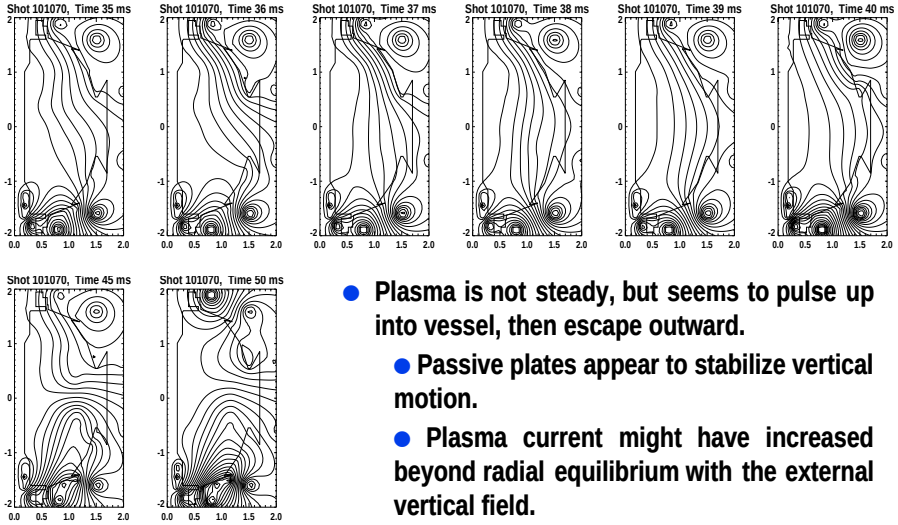

- Plasma is not steady, but seems to pulse up into vessel, then escape outward.
  - Passive plates appear to stabilize vertical motion.
  - Plasma current might have increased beyond radial equilibrium with the external vertical field.

Toroidal plasma Current and Helicity Injector Electrode Current

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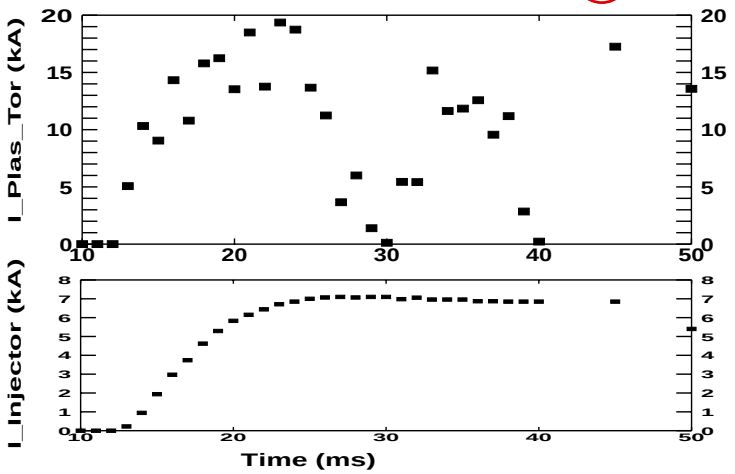

- Plasma current I_p fluctuates, despite steady injector current.

Passive Plates Contribute to Vertical Equilibrium

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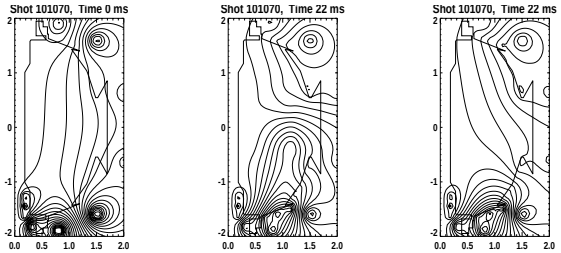

Vacuum flux, t=0

Flux with plasma, at t=22

Flux with plasma current removed, t=22

- Compare vacuum flux before plasma (left, t=0) and flux due to all currents except plasma (right–most box, t=22 ms).
  - Note flux–conserving action of upper plates (upper–outer wall).

CONCLUSI ONS

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- MFIT is a useful tool to visualize the evolution of magnetic flux during coaxial helicity injection (CHI)experiments.
  - Both in control room and for analysis after the experiment.
- In the first two days of NSTX CHI experiments, MFIT reveals:
  - Plasma pulses up repeatedly from the source into the main chamber space.
  - Plasma appears to escape vertically.
  - This process repeats.
  - Eddy currents in the passive stabilizing plates are seen to ‘push’ back on the plasma.

APS Abstract for M.J. Schaffer

Subject Classification Category: Pri. = 5.1.4, Sec. = 5.3
Experiment

Evolution of Helicity Injected Plasmas in NSTX,* M.J. Schaffer, L.L. Lao, *General Atomics*, R. Raman, *University of Washington*, S.M. Kaye, *Princeton Plasma Physics Laboratory* — Since very-low aspect-ratio spherical tori (ST) have a severely limited inductive current drive capability, they can benefit greatly from efficient non-inductive current drive techniques. Coaxial helicity injection (CHI) has been demonstrated in the small HIT ST, and CHI is now being implemented in the much larger NSTX ST at PPPL for plasma startup, current rampup and current sustainment. We modified the EFIT and MFIT magnetic equilibrium reconstruction codes to better fit CHI plasmas. In particular, the toroidal-current-ring code MFIT reconstructs and displays growth and reconnection of the initial open magnetic surfaces into the final closed surfaces. New experimental results will be presented.

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Group with NSTX papers.

I prefer poster, but will go wherever NSTX organizers think this paper fits best.