Resistive MHD (Nimrod) simulations
CHI status and plans

(Working document – not reviewed)

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PPPL discussion
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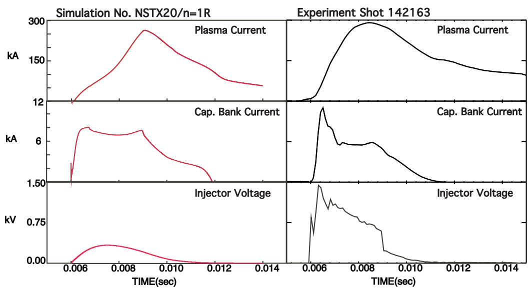
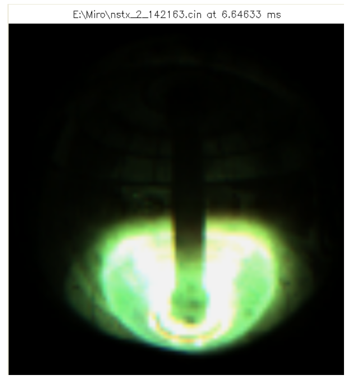
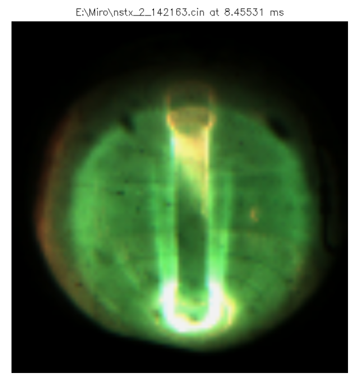
Results as of APS — Shot 142163

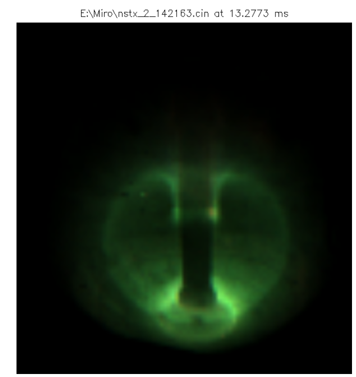




6.65 ms

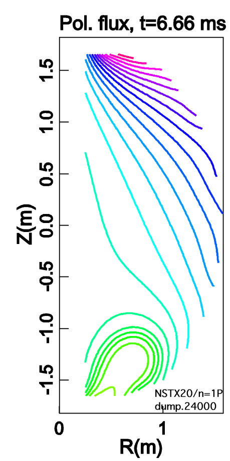


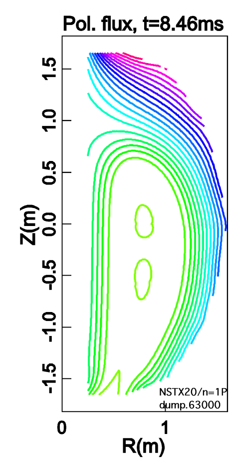
8.46 ms

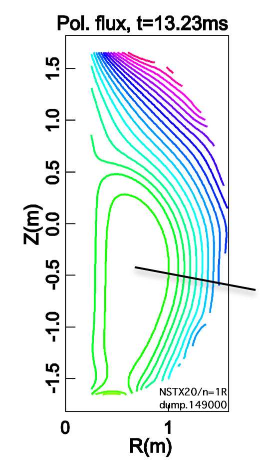


13.28 ms

- **The HIT-II model been generalized**
  - **Voltage across the injection gap — From a model of the NSTX PS**
  - **Current — measured from R*B_φ at the gap and coupled to PS**
  - **Injected plasma and toroidal flux — extracted at absorber by ExB flow**
- **Evolves using NSTX time-dependent boundary conditions (including wall eddy currents) — demonstrated**
- **Discharge currents and current amplification (toroidal current/ discharge current) — approximate agreement with experiment**
- **Ohmic heating and thermal conductivity (along open field lines) — temperatures in approximate agreement with experiment**
- **Simulations show an n=1 mode — an instability in the current channel with poloidal wavelength 0.1-0.3 m, an helical structure at the surface of the expanding flux bubble**







Flat poloidal flux; surface not closed

Notes:
- Power supply capacitor charging voltage: simulation = 0.75 kV; experiment=1.5 kV.
- The voltage rise time in the simulation differs from the experiment in part as there is no pre-electrical breakdown period; thus the power supply inductance limits the rate of rise.

Also, there is added power-supply damping for stability reasons.

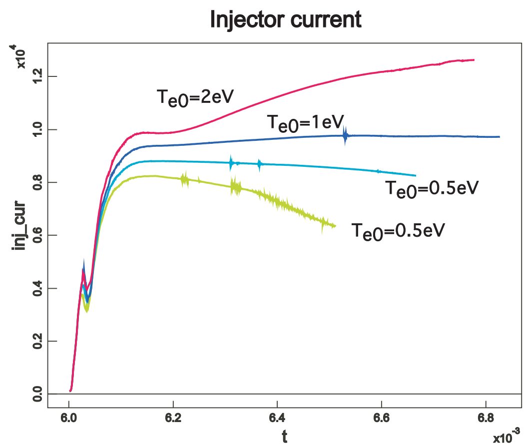
Ongoing work – progress since APS

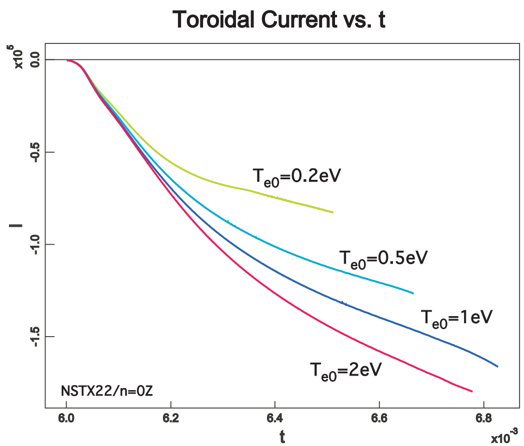
Demonstrated resistive flux closure (reconnection near injector) during decay

- However, the enclosed volume was small. Further research is needed

Devised and tested means of improving the response in the plasma outside the expanding flux bubble

- The problem: Compression and bending of poloidal field lines generates current. This heats the downstream plasma locally; Te increases and the current persists (locally) and grows
- The solution: The temperature outside the flux bubble is reset each time step
  - There is a range of “optimum” temperatures that allow compressing and bending field lines without generating excessive currents





There is an apparent optimum at T_{e0} =0.5-1 eV

This is consistent with estimates of magnetic (resistive) diffusion

Underway: determining the voltage requirements to approx. match experiment — finding that V_{inj} is closer to exp. than in earlier simulations

Physics plans

- Near term: Complete simulation-based physics study of CHI in NSTX
  - Understand the implications of the sensitivity to the downstream plasma temperature for experimental optimization, e.g. by impurity control, auxiliary heating, etc.
  - Quantify the influence of the time-changing surface flux on the dynamics of CHI.
  - Determine the conditions for generating flux-surface closure at the end of the injection time, as in the experiment. (e.g. resistive effects, localized magnetic fluctuations).
  - Complete quantitative comparison with experiment.
  - Determine scaling of electron heating and temperature, etc. during CHI, with injection parameters and the resulting effect on plasma current, size, flux-surface closure, etc.
  - Demonstrate ohmic (loop-voltage) drive of plasma current in the closed flux region; compare with experiment. (collaboration with Ibrahimi)

- Longer term: Extend the CHI modeling to NSTX-U
  - Build model of NSTX-U in NIMROD; demonstrate CHI.
  - Determine characteristics of helicity injection in the new geometry, scaling of plasma current with bias magnetic flux, injected current, etc. Compare results to those from NSTX.
  - Examine current drive in the injected flux region, initially using a loop voltage. (collab. With Ebrahimi)
  - Model current drive by neutral beams; determine conditions to successfully drive the current (e.g. is additional heating needed?), maximize plasma current, etc. (Ebrahimi to lead)

Note: This work is in collaboration with Carl Sovinec; Fatima Ebrahimi will also be participating — our work will be coordinated to ensure maximum progress