Helicity Injection in NSTX

Status of Simulations

E. B. Hooper
in collaboration with Carl Sovinec

Nimrod Team meeting
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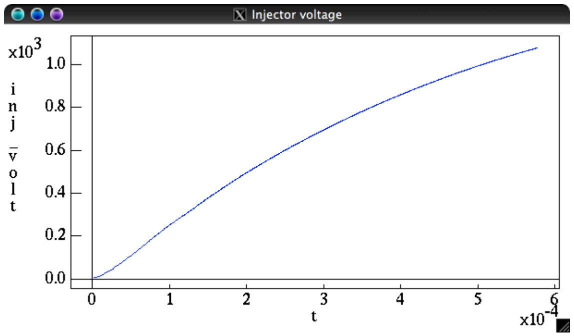
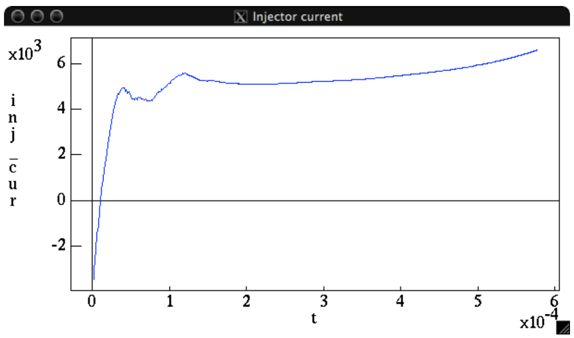
Accomplishments and Status

- The model used in simulations of HIT-II has been generalized
  - Voltage across the injection gap is determined by a model of the NSTX power supply (capacitor bank)
  - Current is measured from R^*B_φ at the gap and determines the evolution of the capacitor charges and voltages
  - Plasma and toroidal flux are extracted at the absorber gap by ExB flow
- Grids for the NSTX geometry and a simplified geometry with a straight central column — developed
- Time evolution 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) have been implemented — temperatures in approximate agreement with experiment
- Initial simulations with an n=1 mode — an instability in the current channel with poloidal wavelength 0.1-0.3 m (Preliminary result — requires further work to validate.)

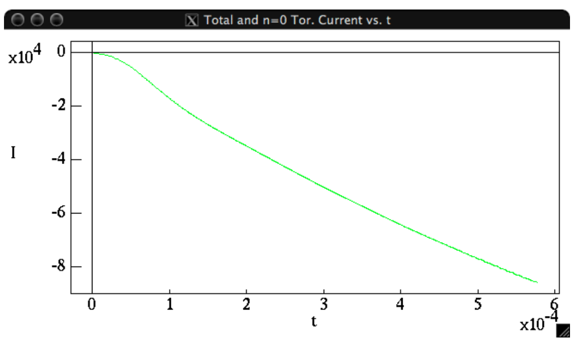
Discharge current, voltage, plasma evolution



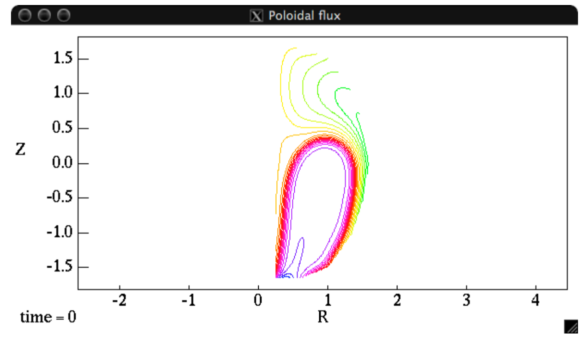
Discharge Voltage



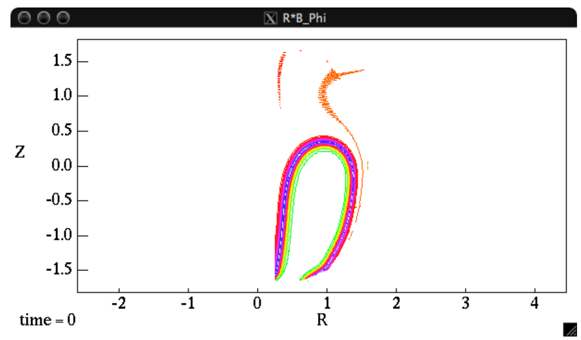
Discharge Current



Toroidal Current



Poloidal flux at 0.57 ms



RB_{φ} at 0.57 ms

NSTX16/n=0R

Plasma heating

Plasma temperature — determined primarily by:

- **ohmic heating**
- **thermal losses along open field lines to the wall**

$$3n\frac{dT}{dt} \approx \nabla_{\parallel}\left(\kappa_{\parallel}\cdot\nabla_{\parallel}T\right)+\eta_{\parallel}j_{\parallel}^{2}$$

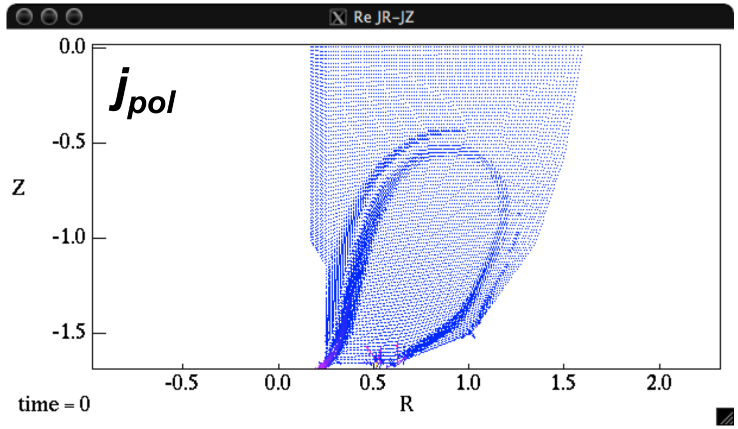
$$\kappa_{\parallel} \sim T^{5/2}/Z_{eff}$$

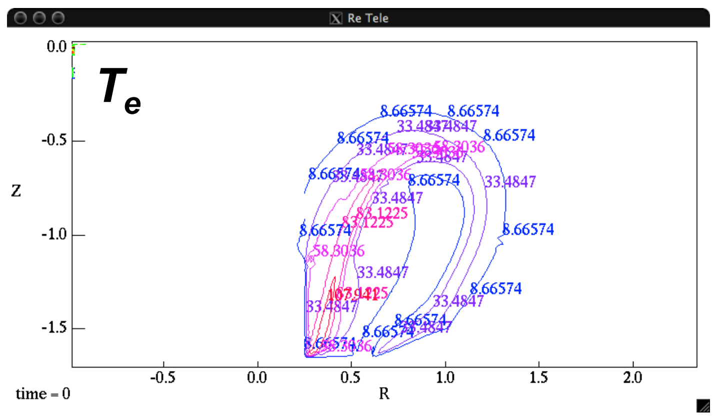
$$\eta_{\parallel} \sim Z_{eff}/T^{3/2}$$

so

$$T \sim \left(Z_{eff}\,j_{\parallel}\ell\right)^{2/5}$$

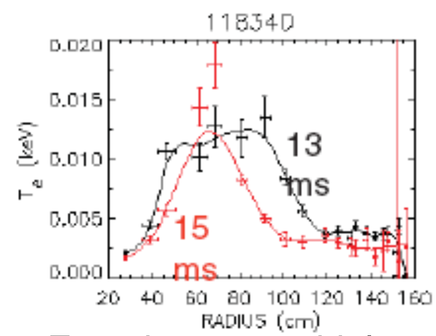
with ℓ an effective scale length





Simulation at 0.52 ms: Z_{eff}=1.

T_e is highest (126 eV) near the lower left corner (small R) where poloidal flux tube areas ($2\pi Rw$) are small and $j_{||}$ is large



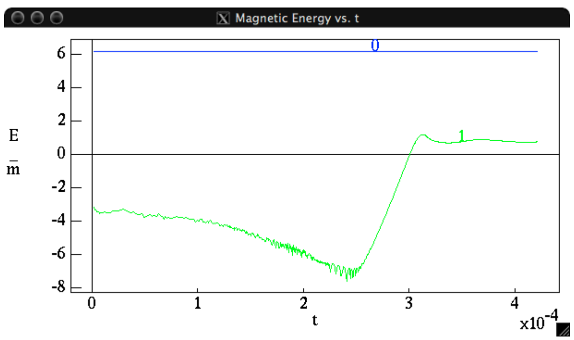
Experiment at midplane

Simulation temperatures

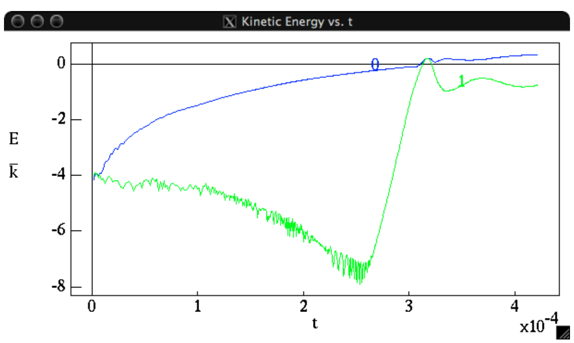
T_e is consistent with experiment

n=1 mode — PRELIMINARY RESULT

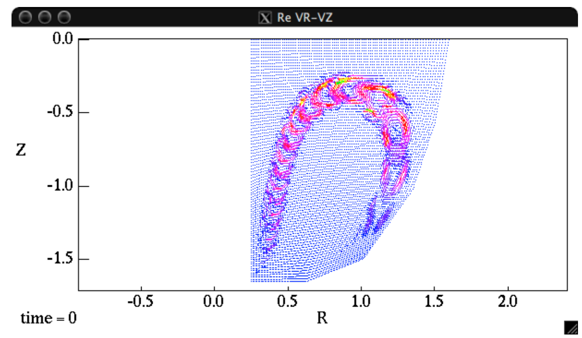
- **Initial n=1 calculations show a mode in the discharge-current channel**
- **Fluid vortices and local current flow are generated in a region with large n=0 velocity and current shear**



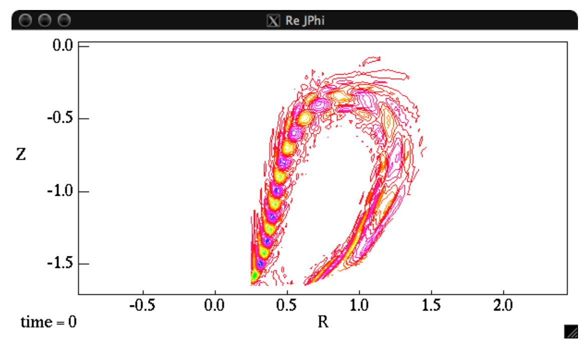
Magnetic energy



Kinetic energy



Poloidal velocity (vectors)



Azimuthal current (contours)

NSTX17/n=1A
t=0.41 ms

Fusion Energy Program

What next?

Ongoing improvements

- **Develop a new grid that improves accuracy near the injector and emitter slots**
- **Improve the handling of the upstream plasma — minimize the differences between its characteristics and the experiment's vacuum**
  - **Example: minimize the structure in upstream plasma flow responding to the ExB outflow at the absorber, e.g. by broadening the absorber slot**

Physics

- **Develop a better understanding of the distributions of current density and flow associated with the expanding flux bubble**

- **Validate initial simulations showing the n=1 instability and develop an understanding of its physics. Add more modes to the simulation**

Longer term

- **Continue improving simulations so they can be compared quantitatively with experiment**