Choice of NSTX-U/Theory Disruption Projects

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Ideally NSTX-U/Theory projects should:

1. Develop world-leading research programs on NSTX-U that would otherwise either not be possible or could not be expected to be optimally planned or interpreted.

2. Require few resources but have many implications.

3. Use sufficiently constrained physics for reliable results.

   High sensitivity to plasma transport makes evolution towards disruptions difficult—many runs required to study possibilities.

Two disruption projects satisfy these criteria.

I. Path of halo currents; II. Preconditions for runaway avalanche

I. Path of Halo Currents

Importance:

Although typical force of halo current on wall structures is easily estimated from $F=I_hBL$. Actual path of halo currents through wall structures is critical for determining damage to structures and potential for arcing in ITER and for future ST missions

NSTX-U potential for contribution:

Disruptions can be allowed on NSTX-U without machine damage.

Tiles can be instrumented to determine halo currents (path in wall and plasma) and magnetic diagnostics can determine currents induced in walls (path only in wall).

Impedance of current paths through walls can be measured.

Provides tests of theoretical understanding and a world-leading program for PPPL.

Theory of Halo Current Path is Highly Constrained

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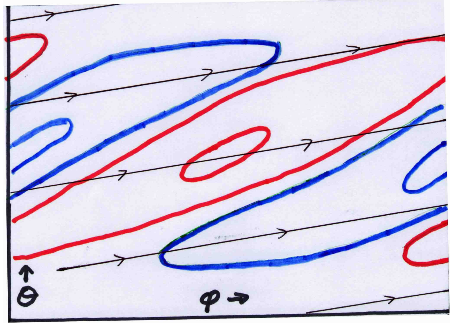
1. **Halo currents must produce a particular external field.**

As in a resistive wall mode (RWM), a magnetic perturbation would grow at an Alfvénic rate unless the induced current produces the external field distribution $\vec{B}_x \cdot \hat{n}$ *required for force balance.*

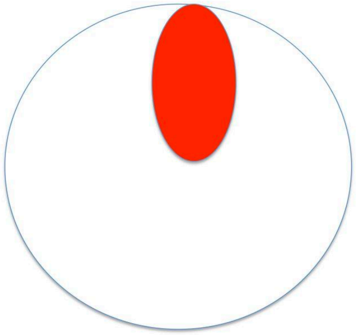
IPEC or M3D-C1 could calculate the required $\vec{B}_x \cdot \hat{n}$*.*



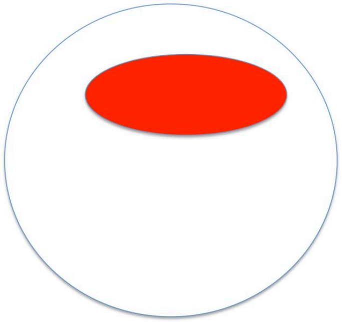
2. **Halo currents must flow along $\vec{B}$ in plasma.**

Edge-plasma pressure is too low to support

3. Simple geometry limits halo current entry and exit points



A helical distortion pushes the plasma towards the wall at some φ *and pulls the plasma from the wall at other* φ.



Increasing toroidal angle φ →

For a simple wall, the halo current enters and leaves the wall in an elongated elliptical region

$$\delta_\theta \sim \sqrt{2\Delta_k / a} << 1 \text{ and } \delta_\varphi \sim \sqrt{2\Delta_h / \Delta_k}$$

Δ_h is halo width; Δ_k is the kink amplitude;

a is the plasma radius;

$\vec{B}$ lines exit in top half of ellipse and enter in bottom.

II. Possible Plasma Conditions for Runaway Avalanche

Number of e-folds of a runaway current is $\sim 2\ \Delta I/10^6\text{A}$;
ΔI change in plasma current until $I_{runaway} = I_{plasma}$.

One runaway electron gives full ITER current with 19 e-folds.

Importance:

Avalanche a problem for ST missions using large currents.

Potentially a fatal issue for ITER.

NSTX-U potential for contribution:

NSTX-U could be world-leader on avalanche preconditions.

No pre-ITER tokamak has a current large enough to study the avalanche significantly beyond the precondition phase.

Theory for Post-Precondition Phase of Avalanche Highly Constrained

Runaway mechanism is simple involving well-studied cross sections. Only significant theoretical uncertainty is potential for whistler-mode type instabilities.

Dylan Brennan's code determines avalanche consequences—including MHD stability—for given plasma preconditions.

Information from NSTX-U on potential range of preconditions would be invaluable and could give PPPL world leadership in the most critical physics issue for ITER.