Ideal MHD Driven Disruptions

Year	Milestone
1	Develop criteria for when locally exceeding β-limit leads to a disruption
2	Develop validated model that reproduces thermal quench in an ideal MHD disruption
3	Develop validated model for current quench that reproduces current spike and decay times
4-5	Interface M3D-C1 and NIMROD with runaway electron model as developed by SCREAM

Develop criteria for when locally exceeding β-limit leads to a disruption

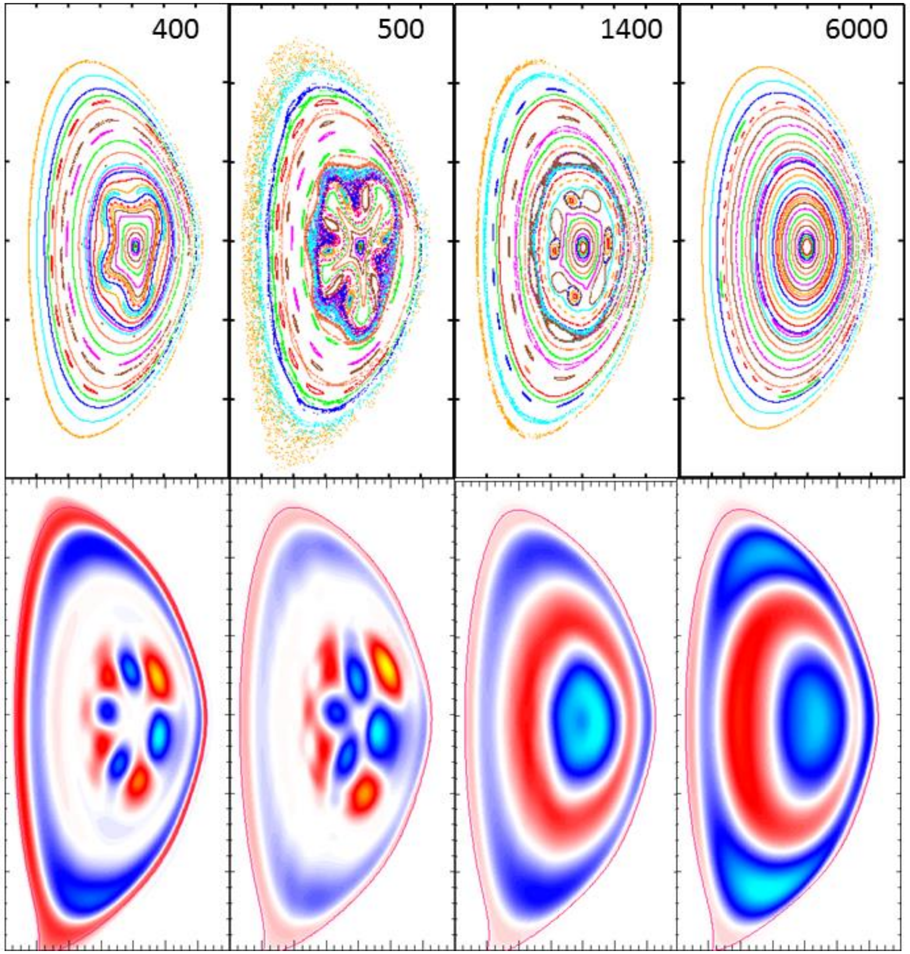
- Perform numerical experiments:
  - start with equilibrium that is marginally unstable to pressure-driven (ballooning) modes on some surfaces
  - When does this just lead to a nonlinear flattening of the pressure gradient….similar to increased transport?
  - Can we start with a stable equilibrium, increase heating locally, and see β saturate?

- Possible guidance from experimental discharges that see β saturate even as additional heating is applied?

- Can we make contact with Cowley et al. theory?

- Suggest: Exploratory teams then joint benchmark. Key may be in semi-analytic family of equilibrium (p,q)

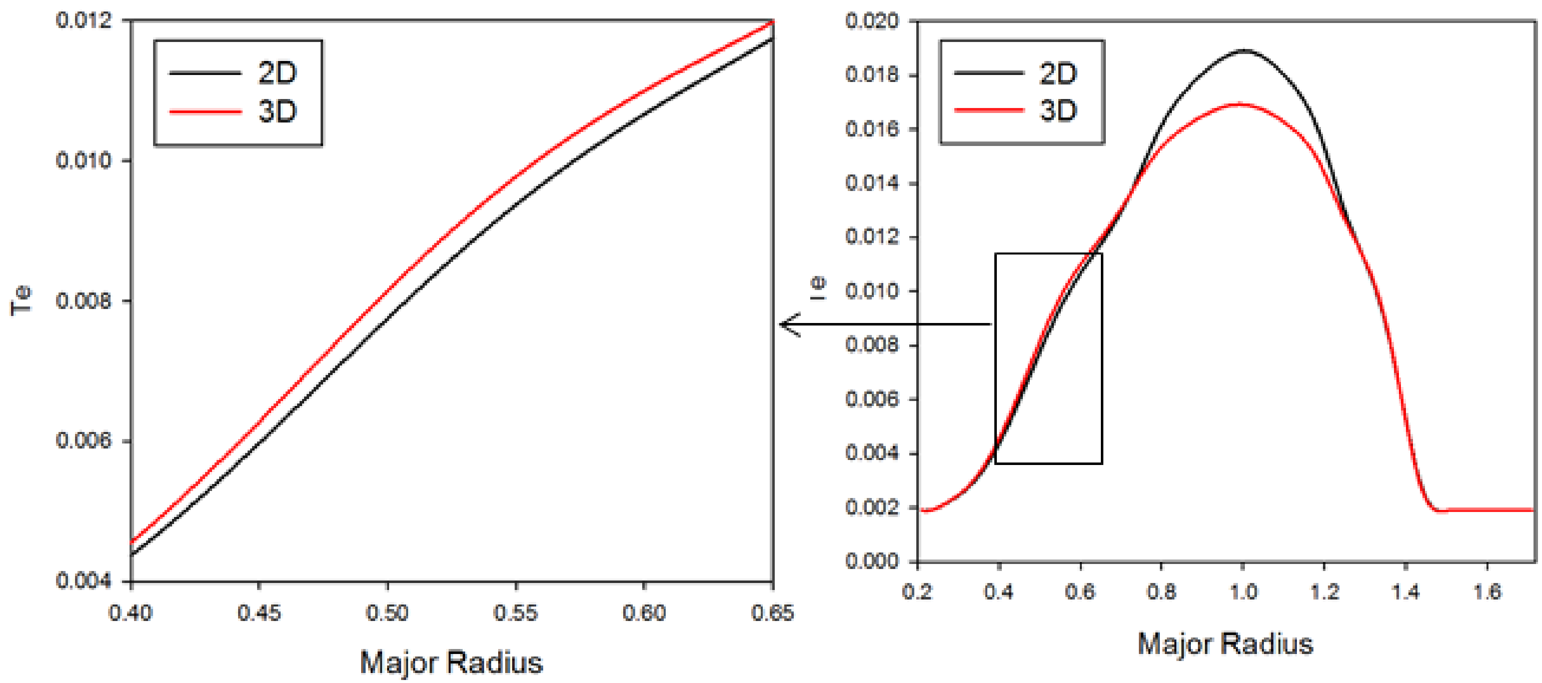
Example: Heating Past the Beta Limit



Poincaré plots (top) and change in temperature (bottom) at 4 times (units of τ_A)

- NSTX plasma discharge 124379 at t=0.64 sec.
- Initial pressure in EFIT file is slightly above β limit, causing instability
- An internal (4,3) mode goes unstable near the q=1.33 surface
- Instability distorts the magnetic surfaces in such a way that $\chi_{||}$ acts to reduce the pressure in the center.
- Discharge becomes stable and re-symmetrizes

Heating Past the Beta Limit (continued)



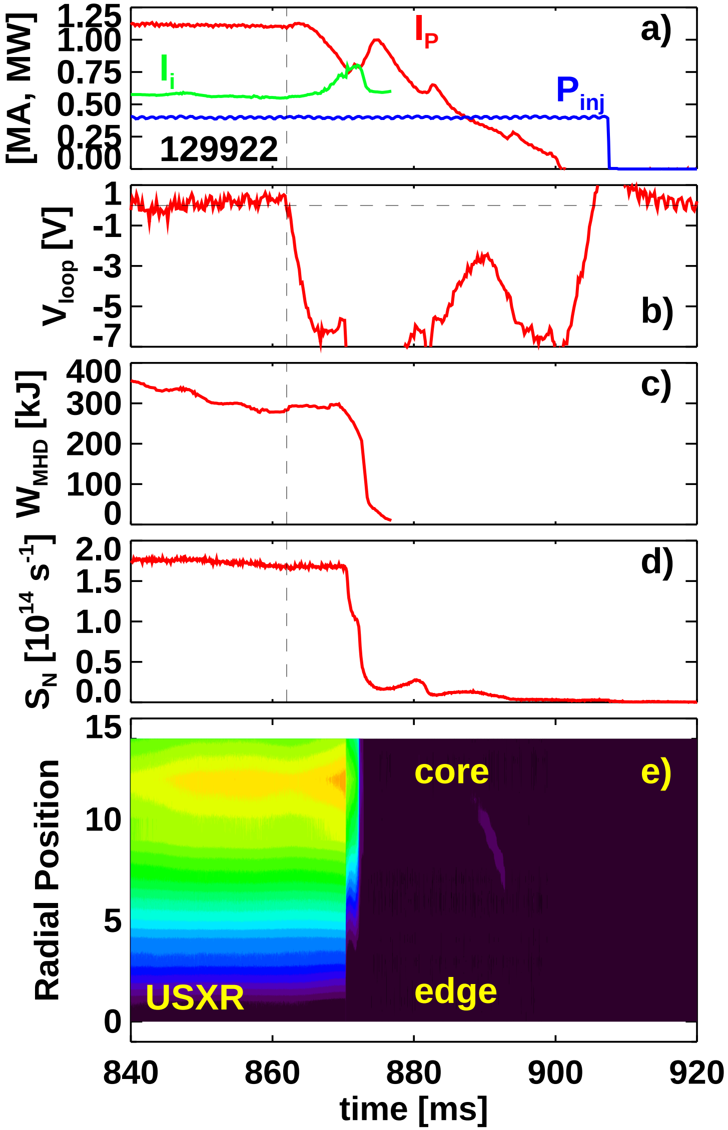
- Final mid-plane temperature profiles for the 3D calculation and for an equivalent 2D calculation with the same transport coefficients.
- It is seen that the net effect of the 3D instability is to reduce the temperature in the center slightly and increase it at mid-radius.
- Thus, the nonlinear effect is simply to increase the central transport.

Develop validated model that reproduces thermal quench in an ideal MHD disruption

- Can we reproduce thermal quench times with just unstable modes and large $\kappa_{||}$??
  - Do we need hyper $\kappa_{||}$ (or PIC closure?)
- What role does impurity radiation play?? How are the impurities transported ?

Unique Class of Major Disruptions Identified in NSTX

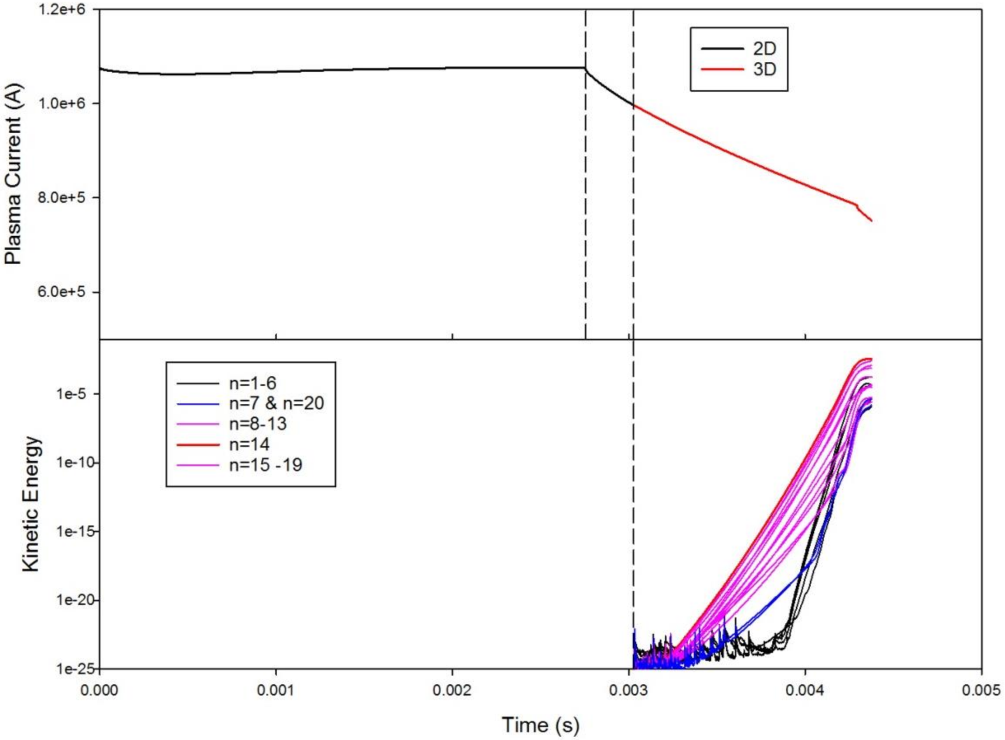
- Recipe:
  - Generate a stable low(er) q95 discharge.
  - Run it to the current limit of the OH coil.
  - Ramp the OH coil back to zero, applying a negative loop voltage, while leaving the heating on.
  - Watch l_i increase, then disruption occurs.
- Mechanism responsible for 21 for the 22 highest W_{MHD} disruptions in NSTX.
- Specific example in the general area of how unstable current profiles lead to catastrophic instability

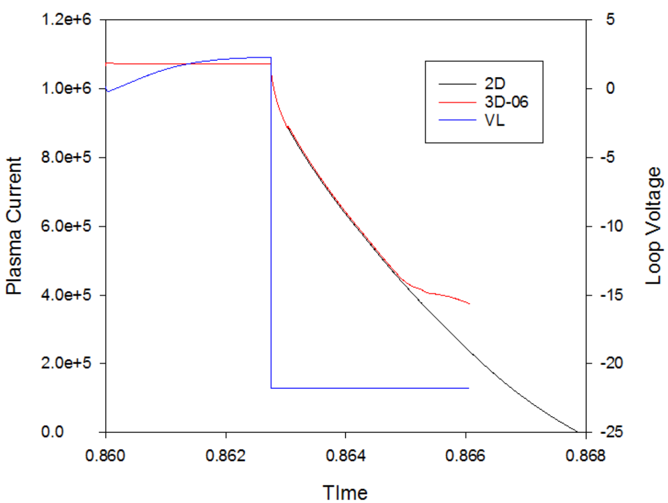


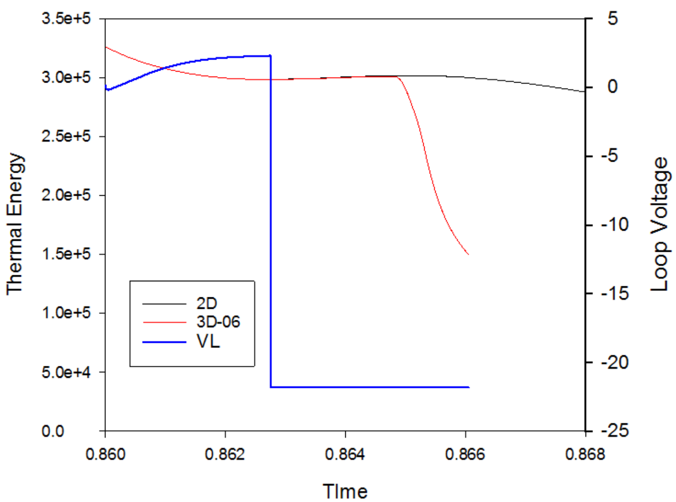
[S. Gerhardt, Nov. 2013]

Initial attempts to model this with M3D-C1 show some promise.

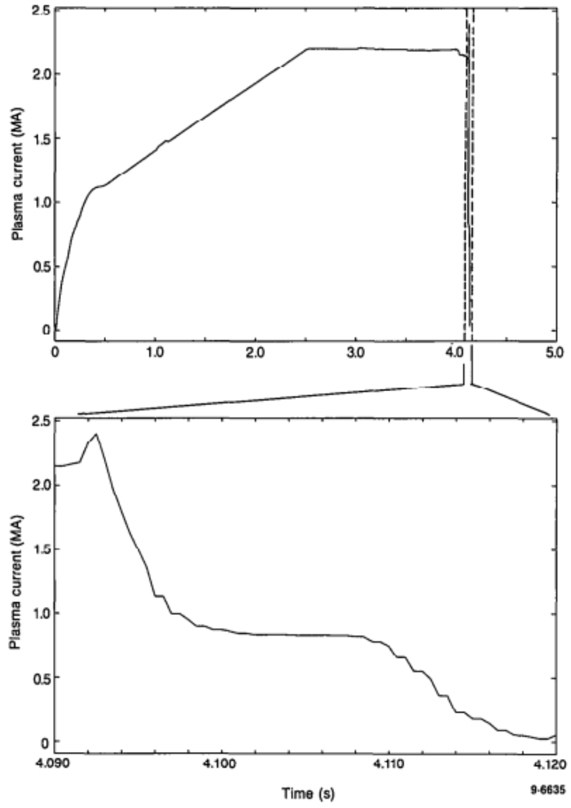
Convergence and control runs now underway.





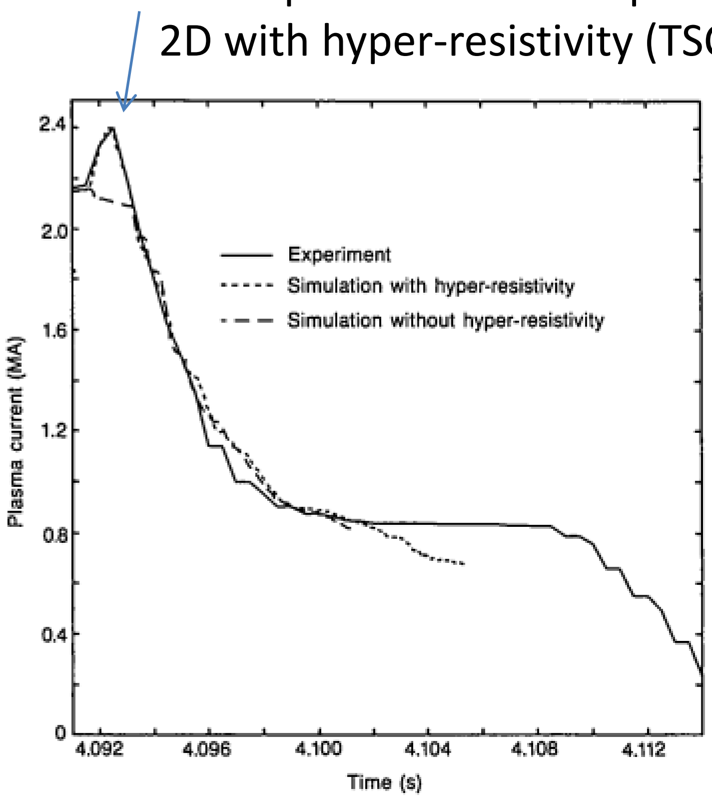


Develop validated model for current quench that reproduces current spike and decay times



Plasma current in TFTR shot 19960

Can reproduce current spike in 2D with hyper-resistivity (TSC)



Can this be done in 3D in a consistent and defensible way?

To Do:

- Teams proposing illustrative cases that can be reproduced by other codes.
  - Initial equilibrium
  - Boundary conditions
  - Sources

- Initially emphasize generic physics of the disruption
  - Self-Healing of ***some*** marginally unstable states
  - Not so for others….what is the difference
  - Physics of the Thermal Quench
  - Physics of the Current Quench (and spike)