Study of Disruptions in NSTX with M3D-C1

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B. Lyons and J. Ramos are incorporating neoclassical effects into M3D-*C*[1]

motivation

- What causes a plasma to disrupt?
- Linear stability to all global modes for all time will ensure disruption-free operation.
- However, the converse is not true.
  - Linear instability does not necessarily imply a disruption.
- Can we use a non-linear MHD code to identify nonlinear events that lead to a disruption (or not)?

M3D-C^1 code

- High accuracy
  - High order finite elements in 3D with C^1 continuity
  - Optimal decomposition of vector fields into scalars
  - Full 2F MHD equations without common approximations
  - Accuracy of linear flux-coordinate (FC) codes without using FC
- Long-time simulations (large time steps)
  - Requires fully implicit algorithm
  - Unique preconditioning techniques
- Geometrical flexibility
  - Unstructured mesh allows variable mesh size (mesh packing)
  - Does not use flux coordinates ➔ Plasma region with seperatrix
  - Arbitrary shaped vacuum vessel and conductors

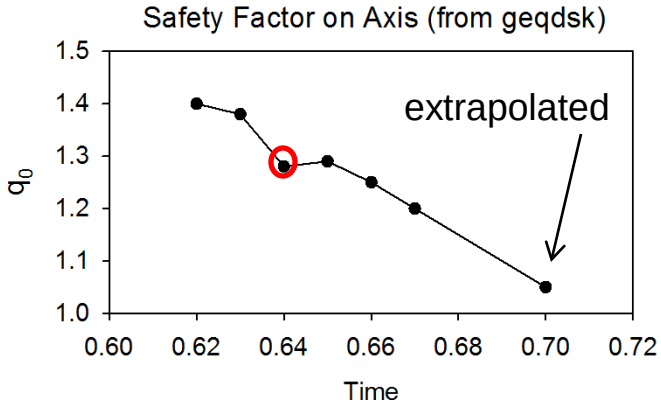
Possible mechanism for soft beta limit

Shot 124379

Time .640

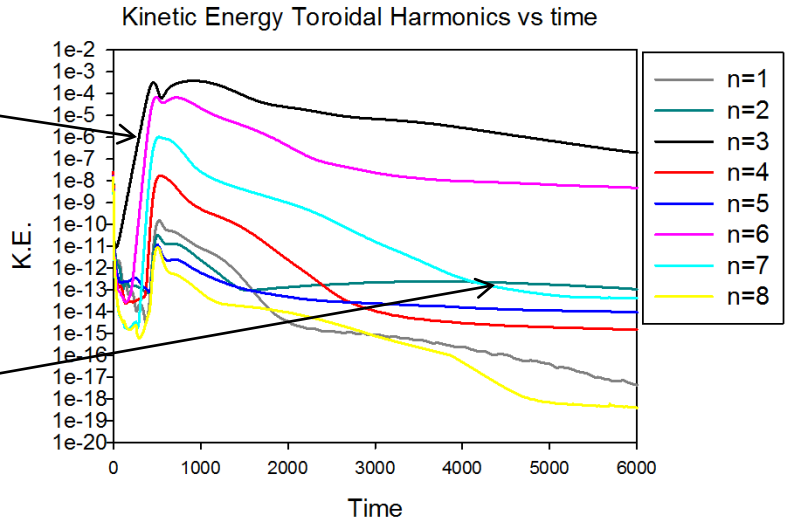
$q_0 = 1.28$

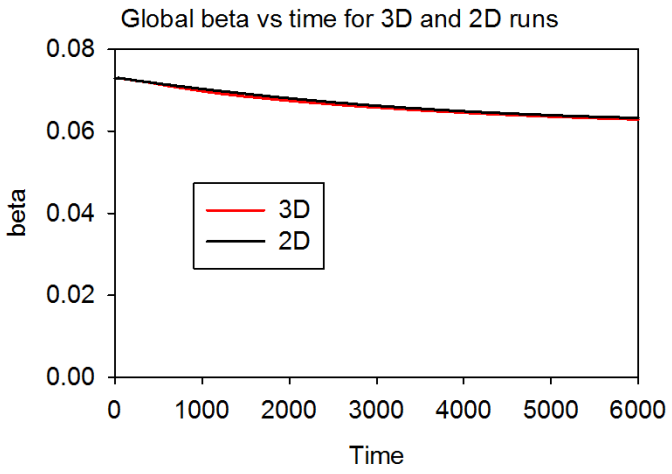
No toroidal rotation



Initially, only n=3 is unstable

All modes saturate with K.E. decreasing with time



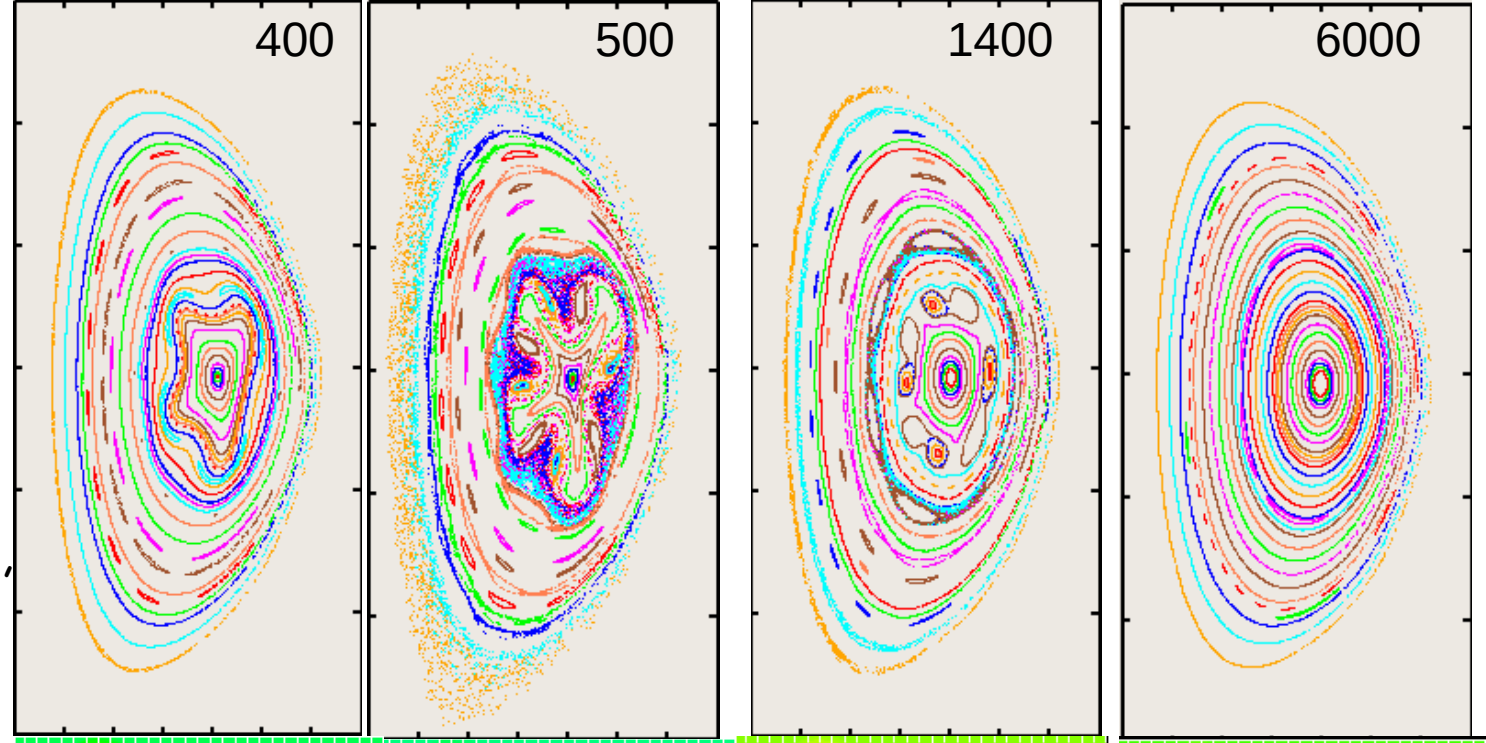


β decreases slightly in time, but no more than in an 2D run with same transport model

Soft beta limit
$q_0 = 1.28$

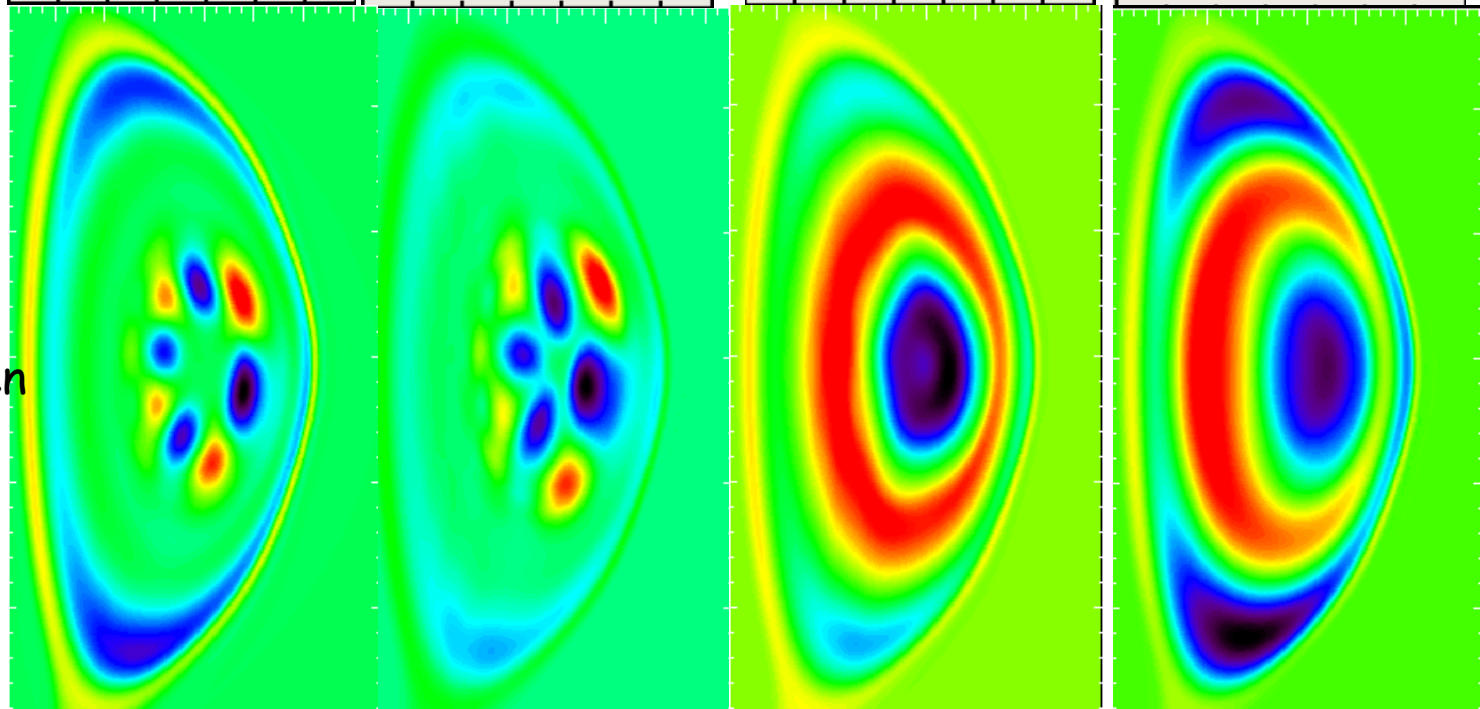
Poincare plots →

Surfaces deform, become stochastic, & completely heal.



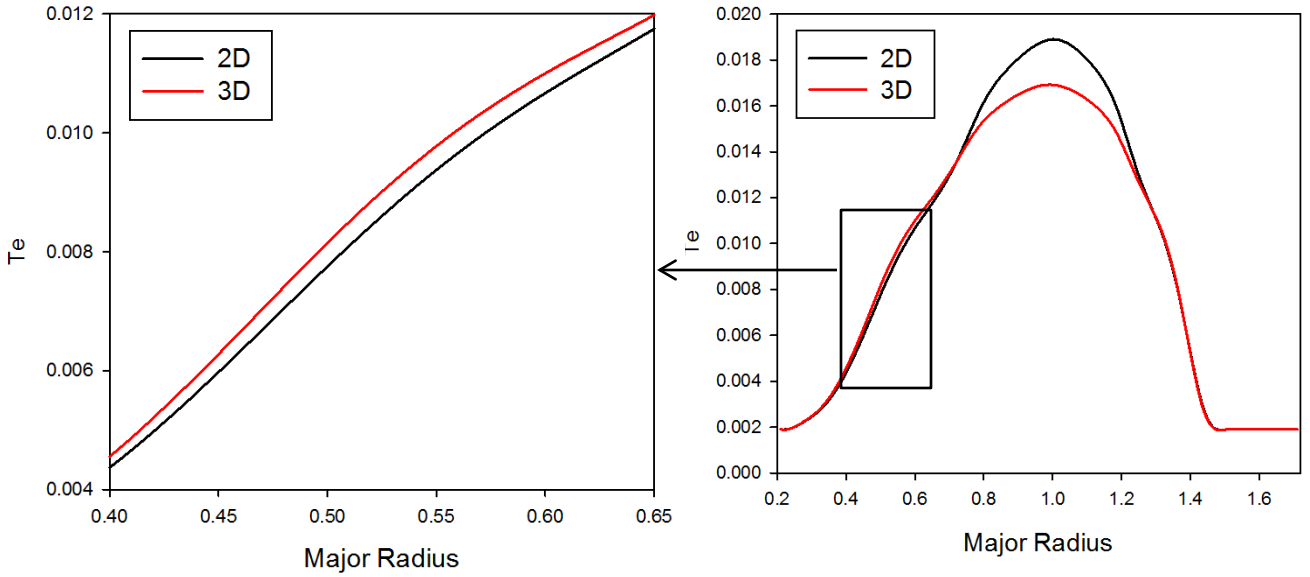
ΔTe →

First pure n=3, then nonlinear, finally axisymmetric annulus



Job33

soft beta limit -- continued



- Comparison of 3D run at t=6000 with 2D run with identical transport coeffs. shows thermal energy has been redistributed.

- Central Te differs by 10%, beta differs by only 0.6 %

summary

- M3D-C^1 working nonlinearly in production mode
- Studying nonlinear consequences of exceeding beta limits in NSTX for $q_0 > 1$.
- Mechanism for soft beta limit identified.
- Sheared rotation is stabilizing
- More violent behavior expected as $q_0 \rightarrow 1$
- Convergence studies underway

Work Plan

- We would like to work with a few experimentalists to apply the nonlinear M3D-C1 to better understand the conditions that lead to a disruption in NSTX
  - I_P and q_0 limits
  - role of plasma rotation and error fields
  - Role of impurities in the duration and final temperature of thermal quench
  - Are there existing data sets of interest that we can start from?

- Disruptions are the Achilles heel of the tokamak
  - Any insight we gain as to their cause and prevention is valuable