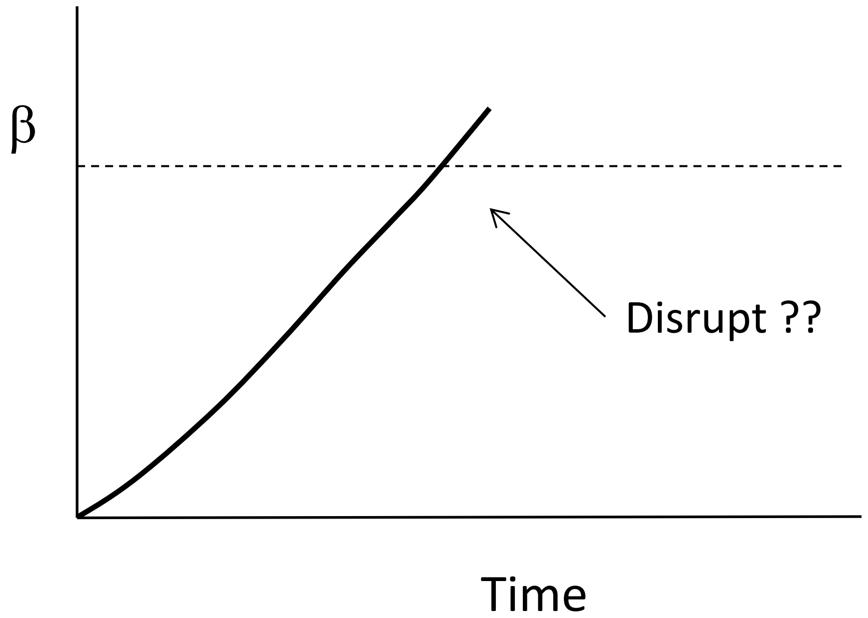
1.1 Prediction and Avoidance of Disruptions

- When does crossing a linear instability boundary lead to a disruption (hard limit)?

- When does it merely lead to increased transport which limits the β (soft limit)?



- To explore this, we have performed some long-time simulations of NSTX discharges that reach or exceed the linear ideal-MHD β-limit.

- To separate the physical mechanisms we perform identical calculations in 2D and in 3D to isolate the 3D effects

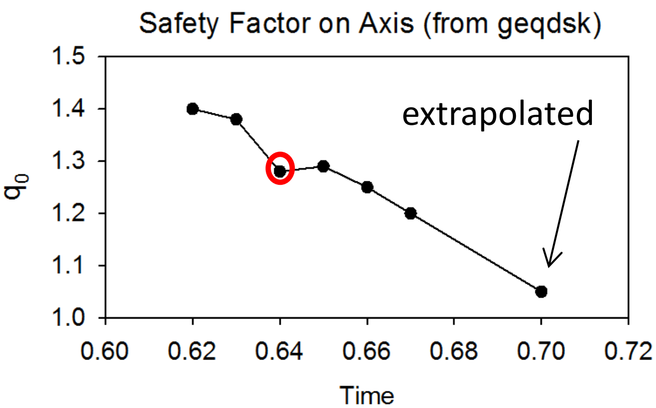
Possible mechanism for soft beta limit

Shot 124379

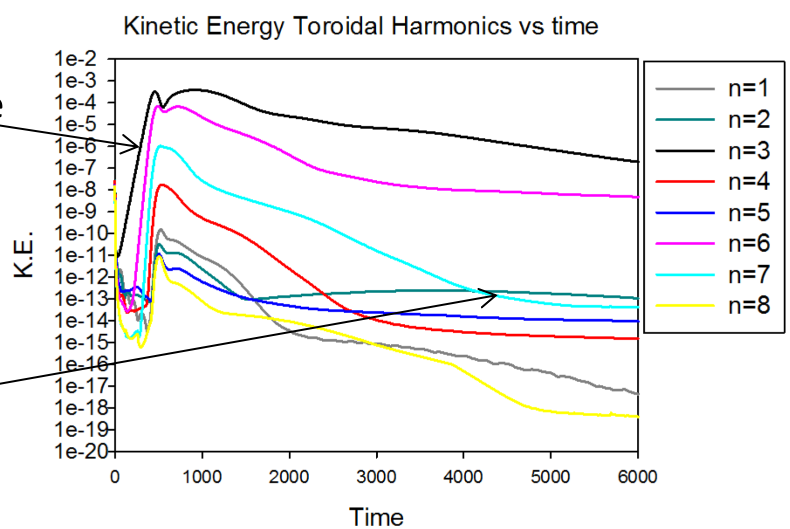
Time .640

q_0 = 1.28

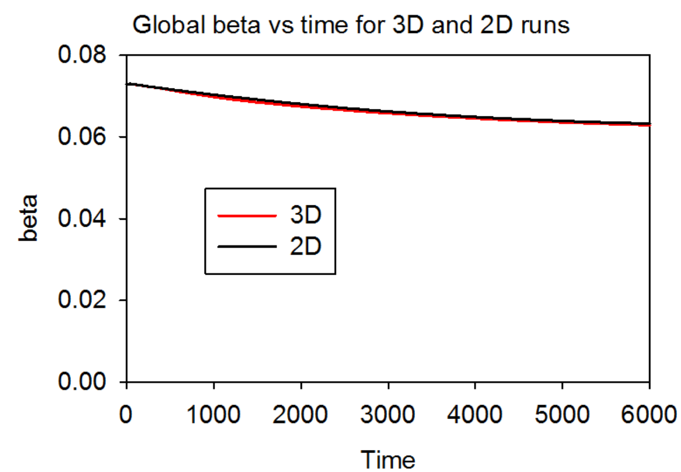
No toroidal rotation



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

$q_0 = 1.28$

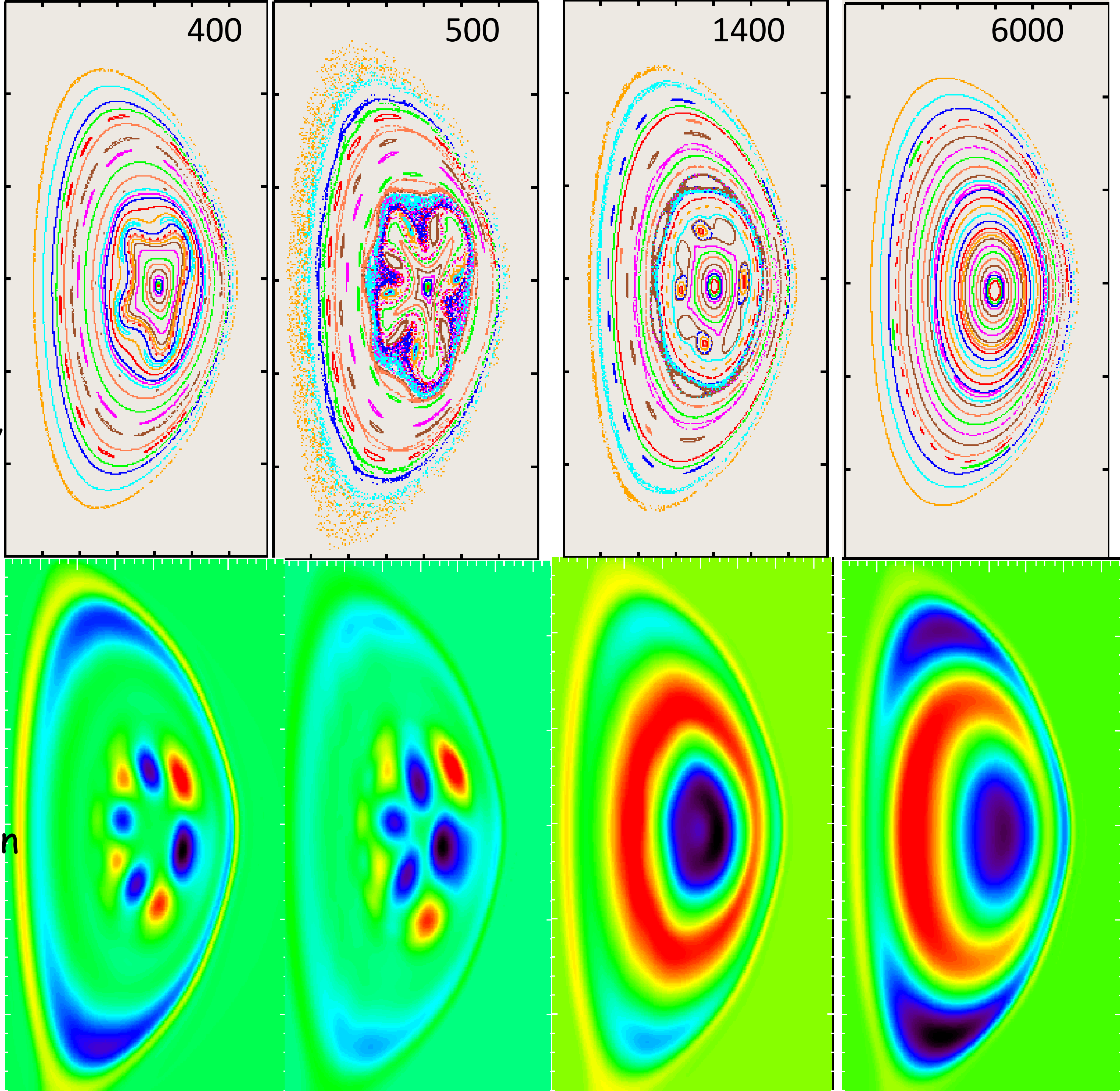
Poincare plots →

Surfaces deform, become stochastic, & completely heal.

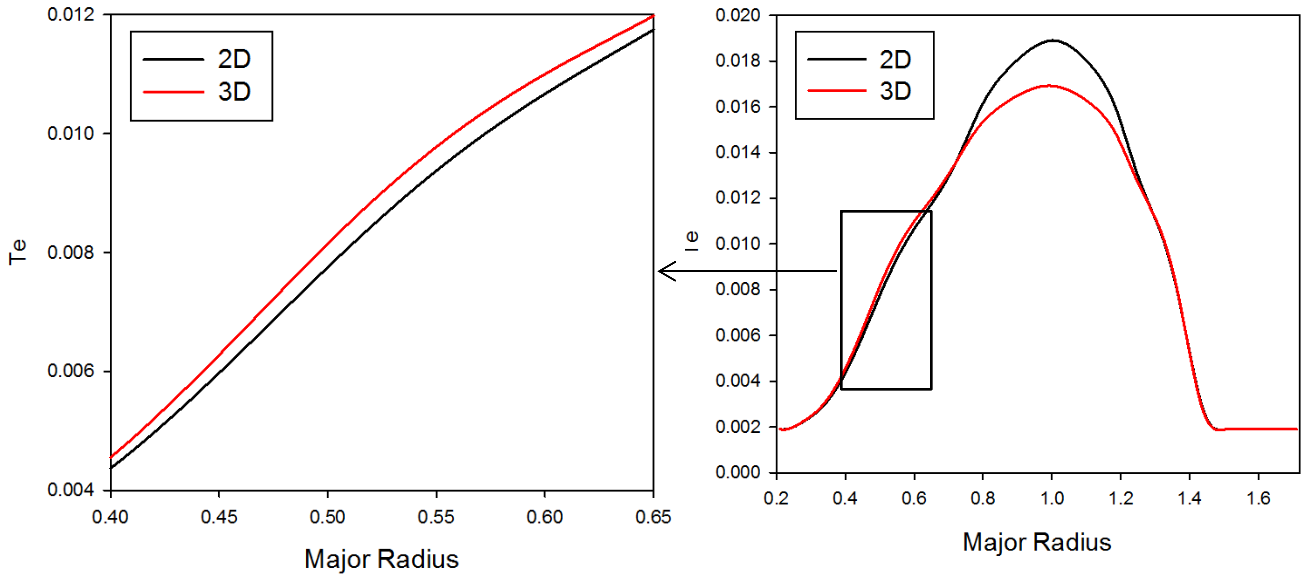
ΔTe →

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

Job33



soft beta limit -- continued



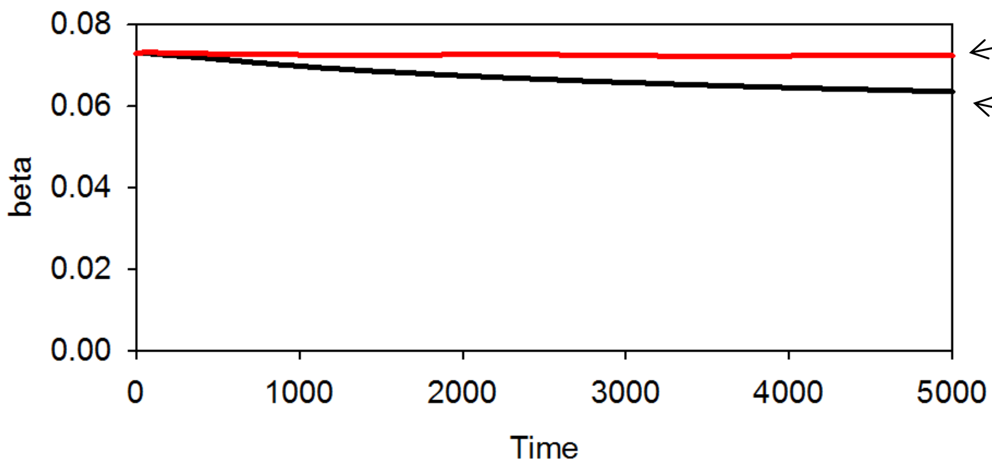
- Comparison of 3D run at t=6000 with 2D run with identical transport coeffs. shows thermal energy has been redistributed.

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

dependence on heating source

- Previous run had beta decreasing in time, even in 2D case, because there was no heating source (except Ohmic).

- Now add *neutral beam source* to keep beta constant and to drive sheared toroidal rotation

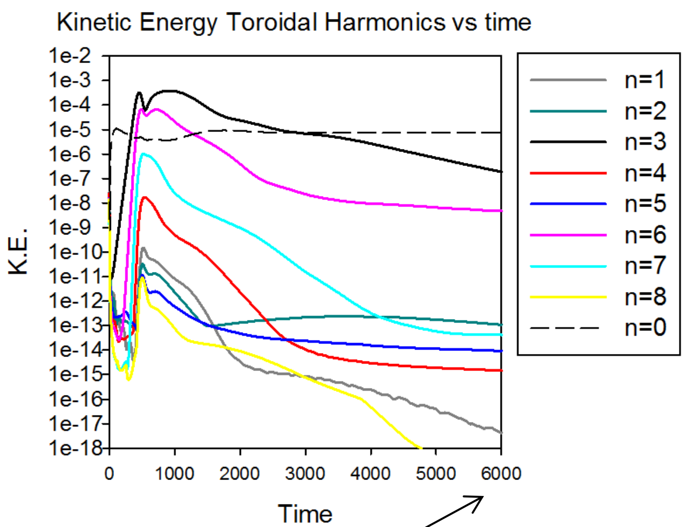


With neutral beam source

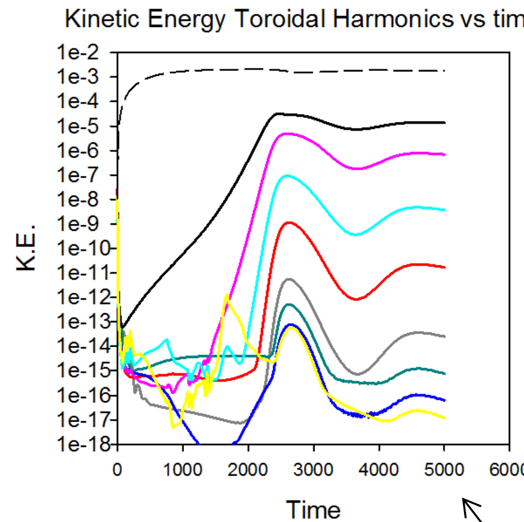
Previous run with Ohmic heating only

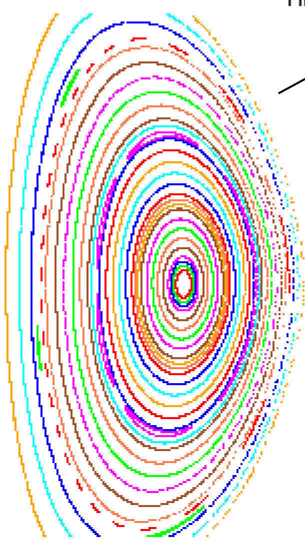
dependence on heating source-cont.

Ohmic heating only



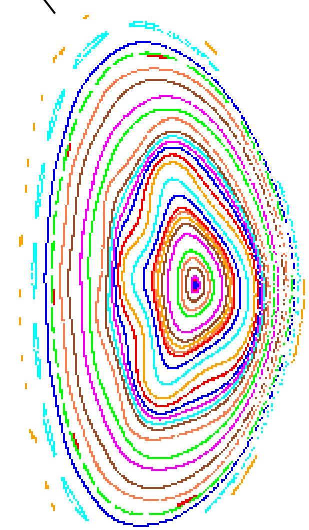
With neutral beam source



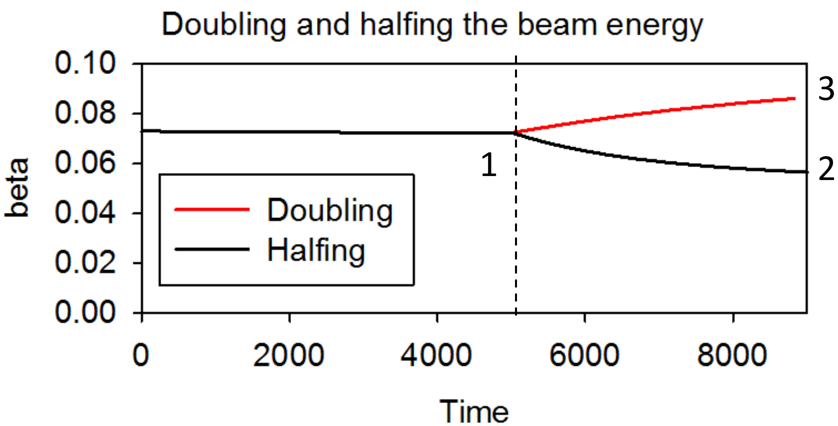


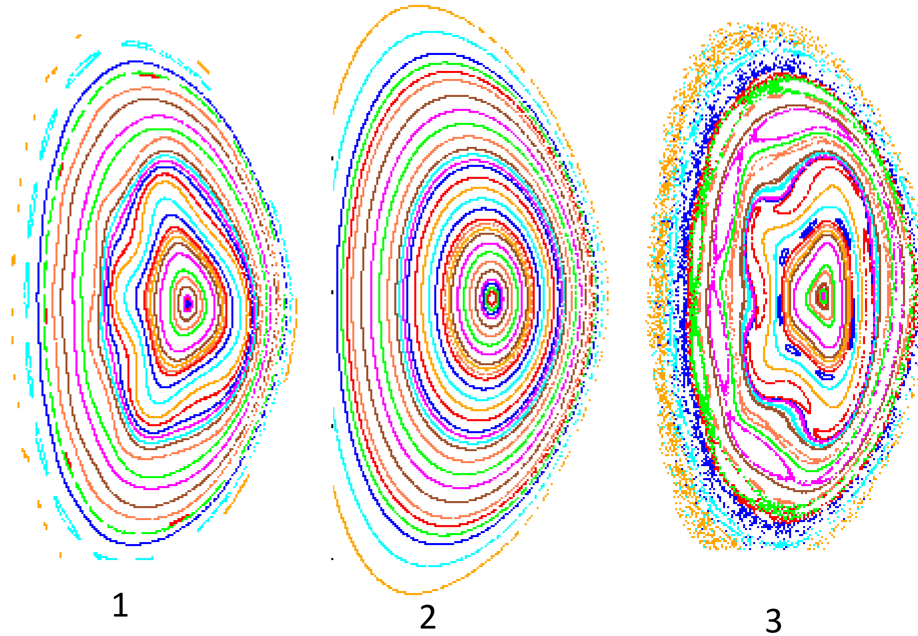
With heating and momentum source:
(constant beta and sheared rotation)

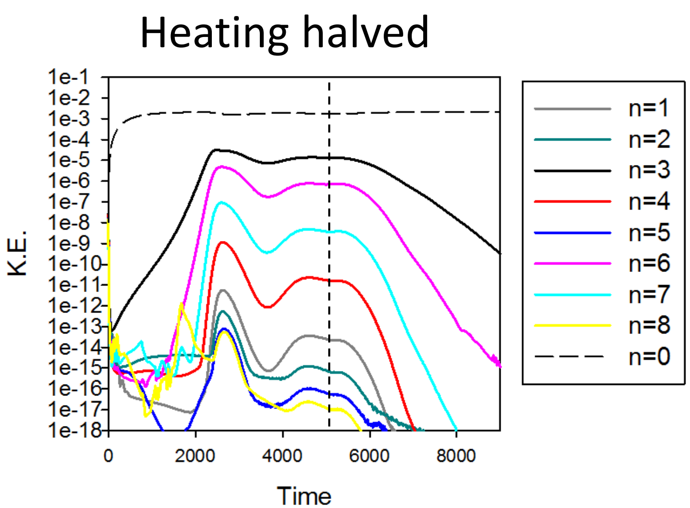
- Initial linear growth of n=3 mode much slower
- n=3 and higher harmonics do not decay away: surfaces distort

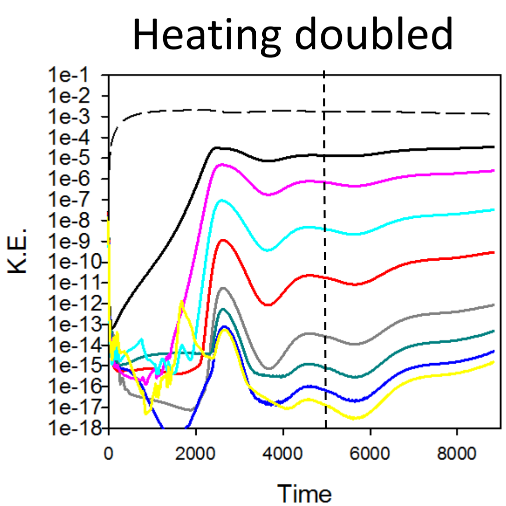


effect of increasing (decreasing) heating



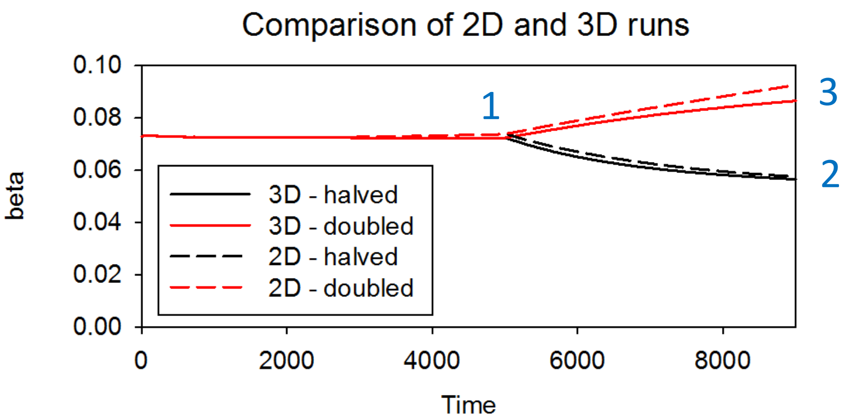




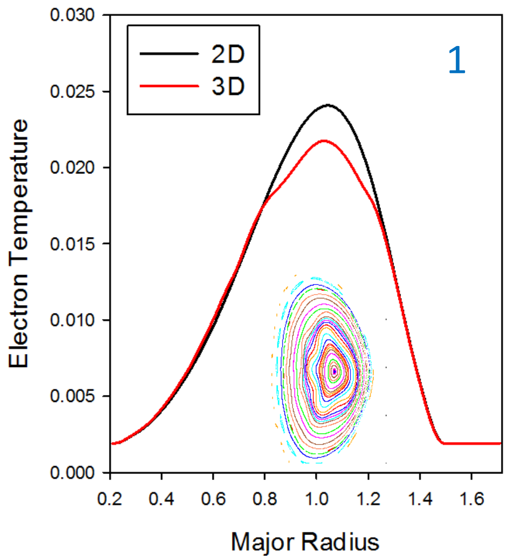


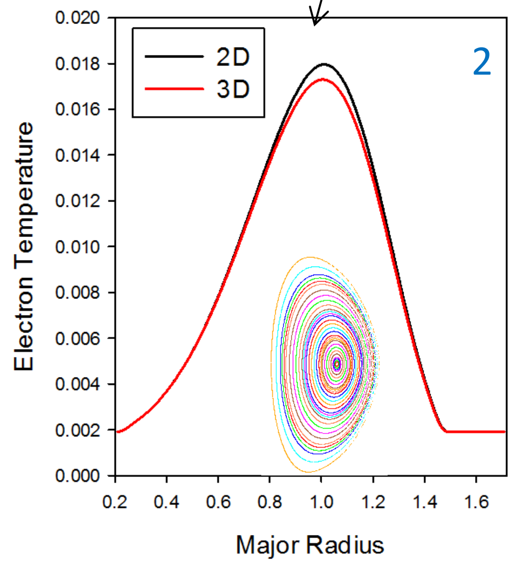
- With heating *reduced*, plasma returns to an axi-symmetric state (2)
- With heating *increased*, surfaces become more distorted, but still exhibits confinement (3)

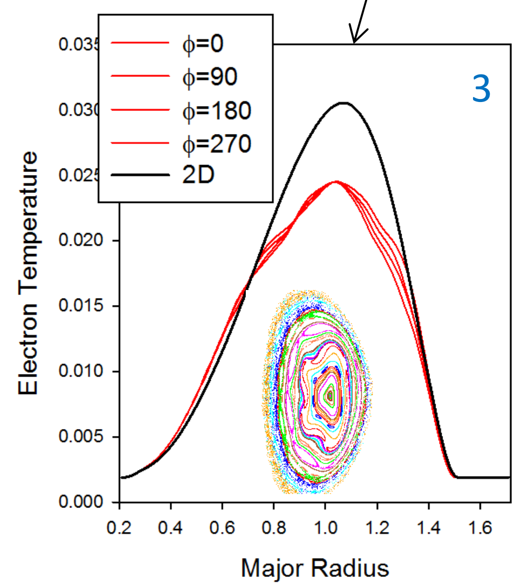
effect of increasing (decreasing) heating



- at low heating power, Te profiles from 2D and 3D agree
- at higher heating powers, they differ considerably



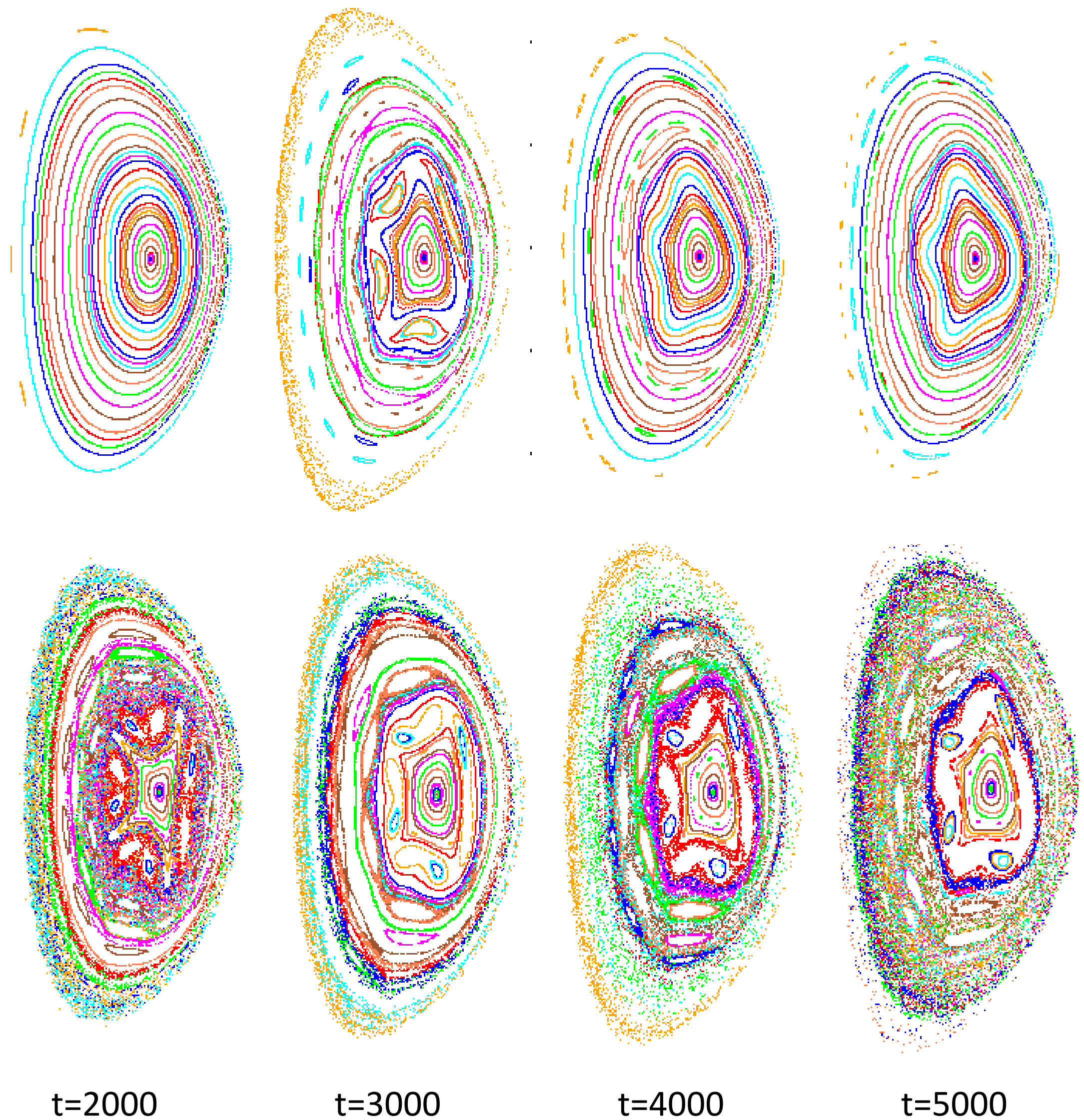




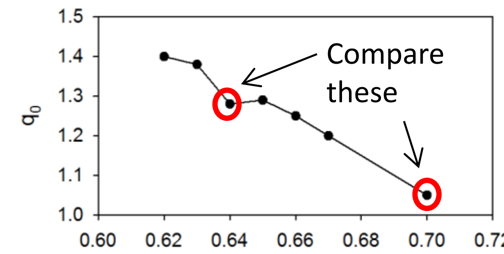
importance of sheared rotation

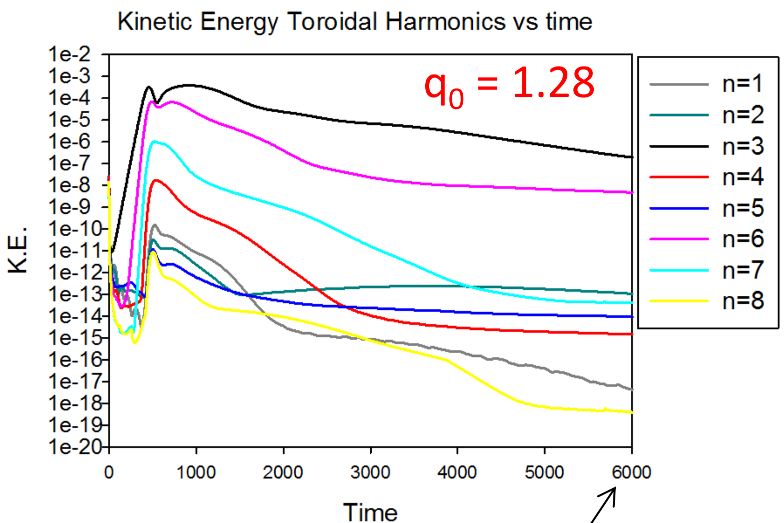
With heating and momentum input (sheared rotation)

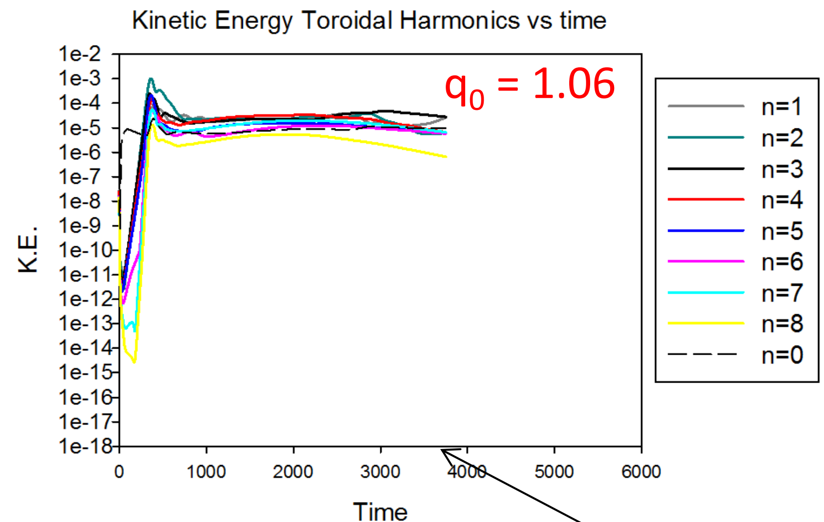
With heating only (no rotation)

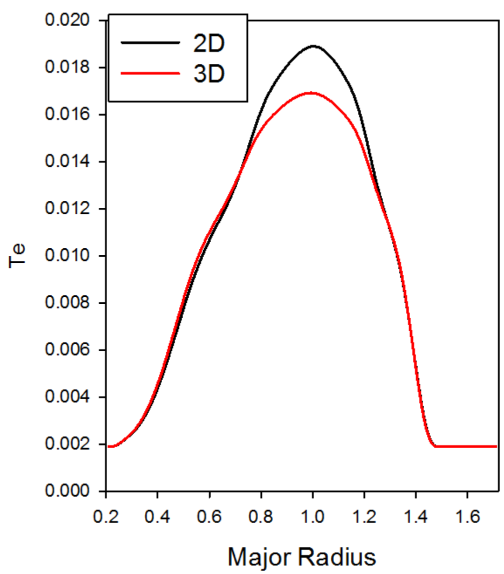


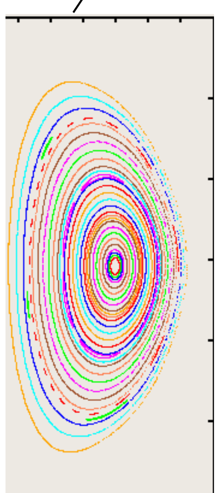
equilibrium with lower q_0 shows thermal collapse

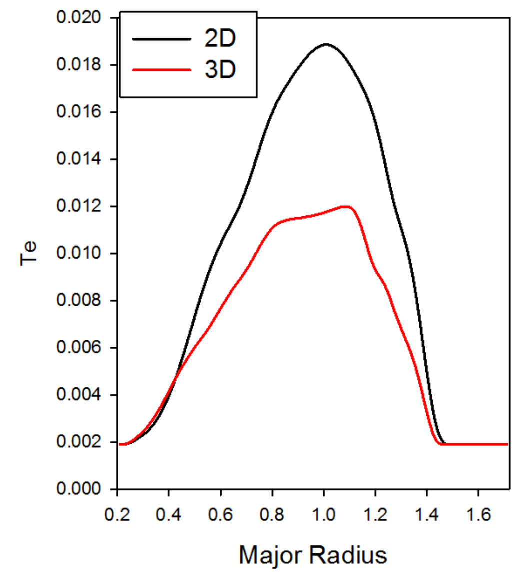


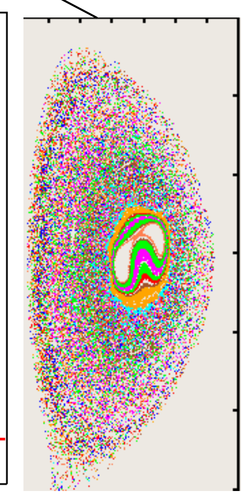






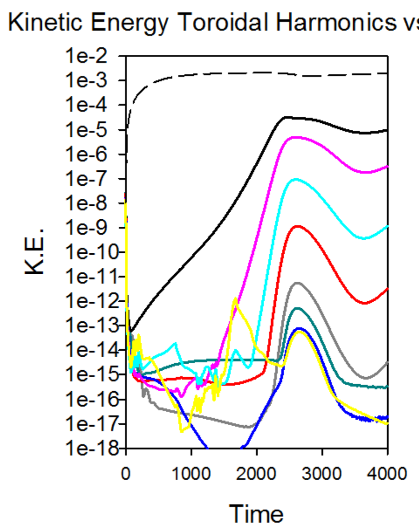


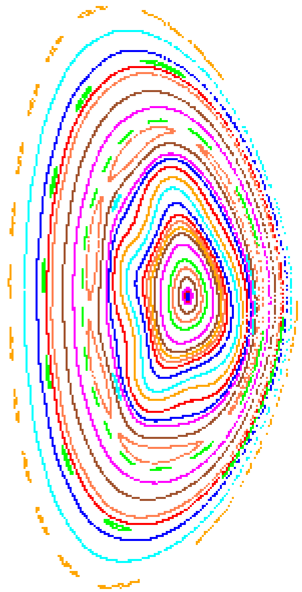




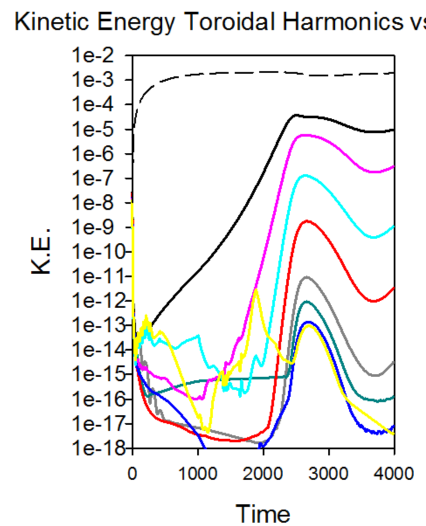
numerical convergence study

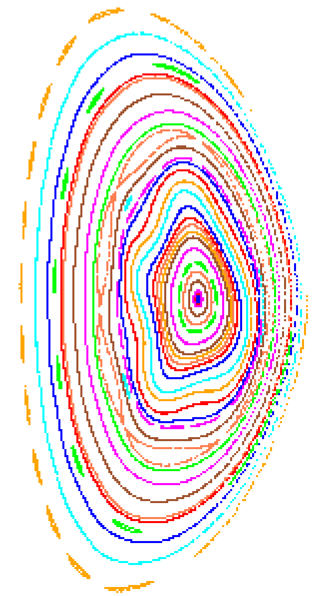
Original constant β run





With double the poloidal zones





Summary of NSTX β-limit studies

- We found some cases with q_0 ~ 1.28 where a soft limit exists
- Similar cases with q_0 ~ 1.08 seem to show a hard limit
- Important questions
  - What is the mechanism for reducing the pressure near marginal stability
  - Quantify the importance of sheared rotation
  - Is it useful to categorize things as the the # of unstable modes? (1 or more)
  - Can we see similar phenomena in NIMROD?