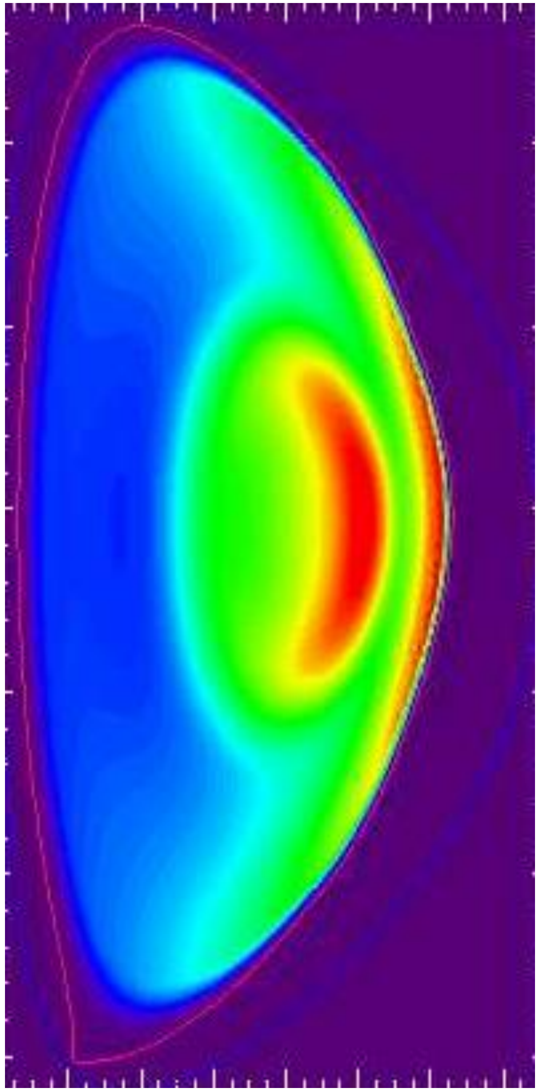
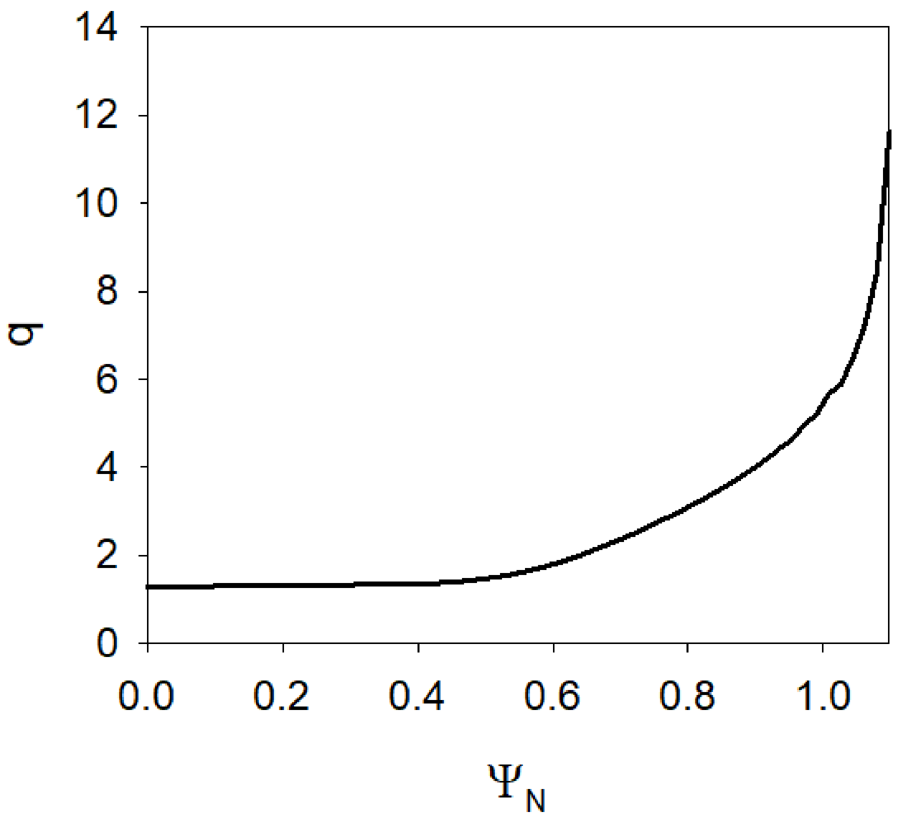
Soft Beta Limit Studies (SBL)



NSTX Shot 124379 @640 ms

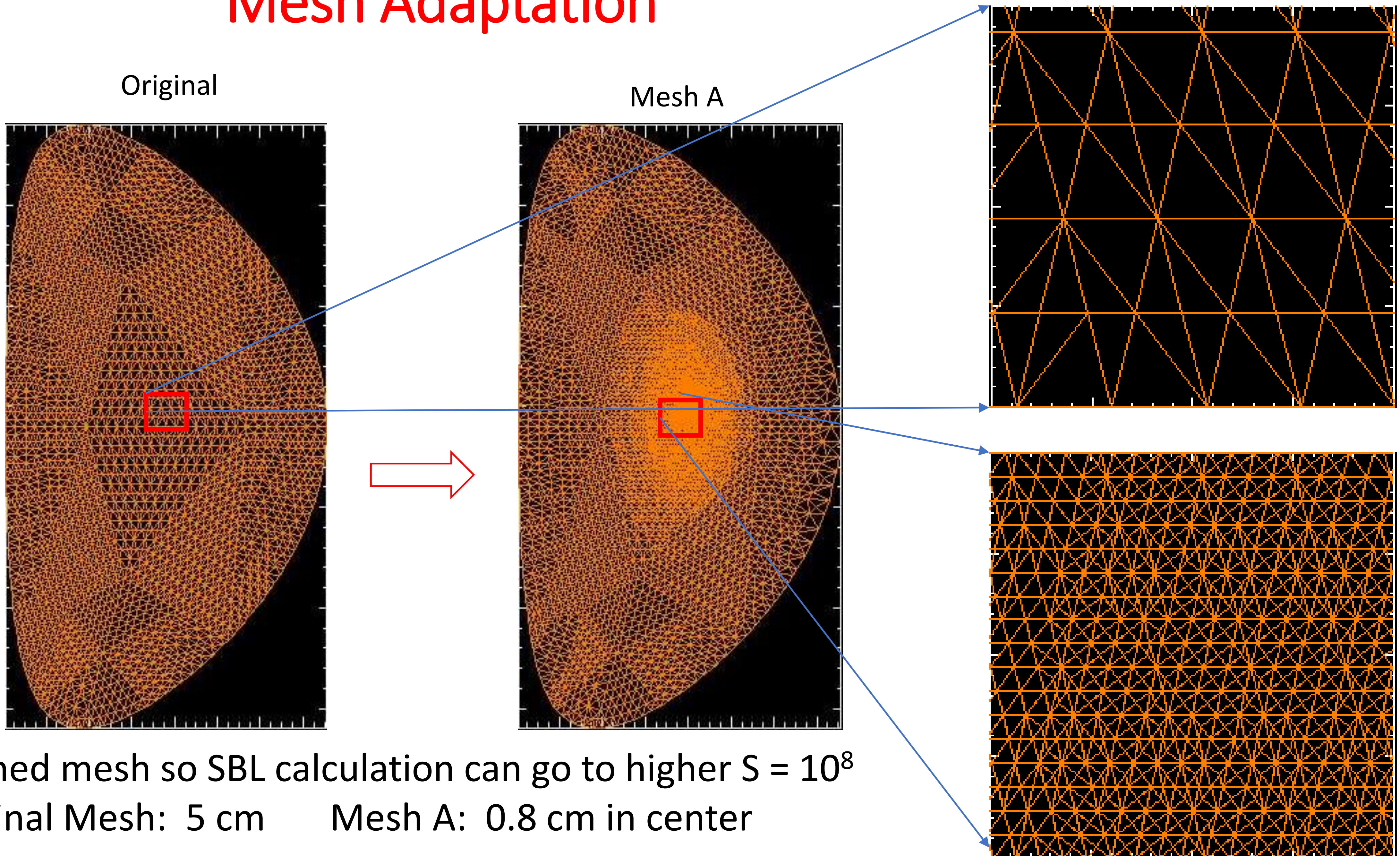
β = 7% I_P = 990 kA q(0) = 1.29



Meshes

#	max_size	min_size l
A	5.0 cm	0.8 cm
B	5.0 cm	0.4 cm
C	5.0 cm	0.2 cm
D	4.0 cm	4.0 cm
E	2.0 cm	2.0 cm
F	4.0 cm	1.0 cm
G	2.0 cm	1.0 cm

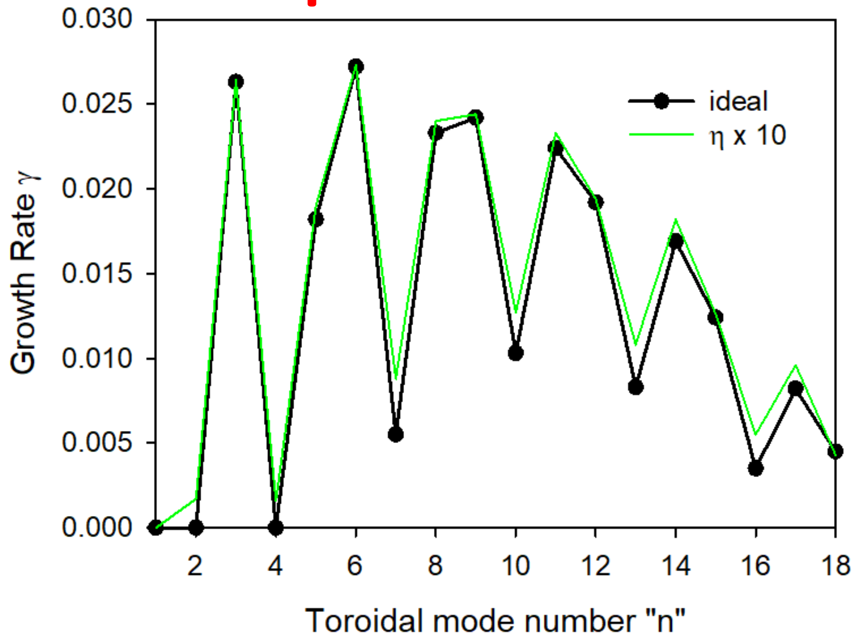
Mesh Adaptation

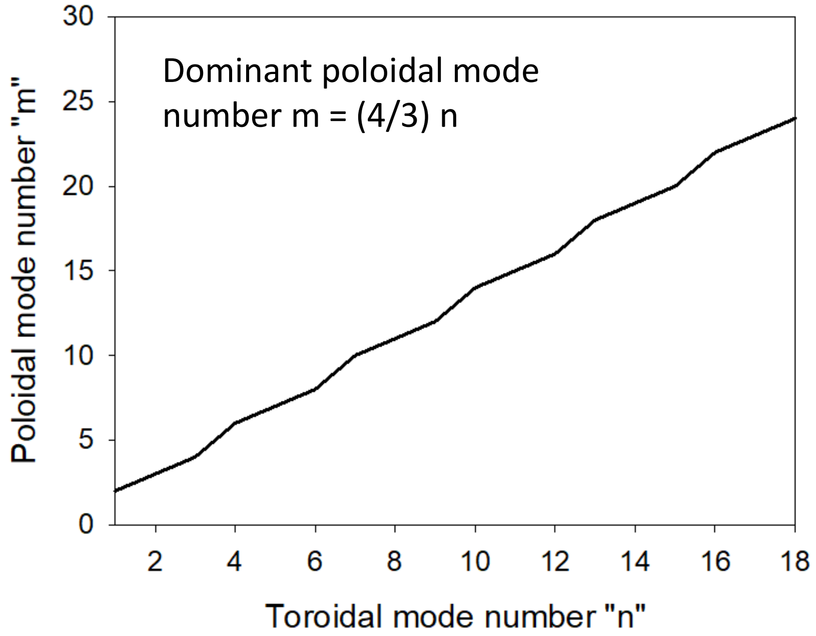


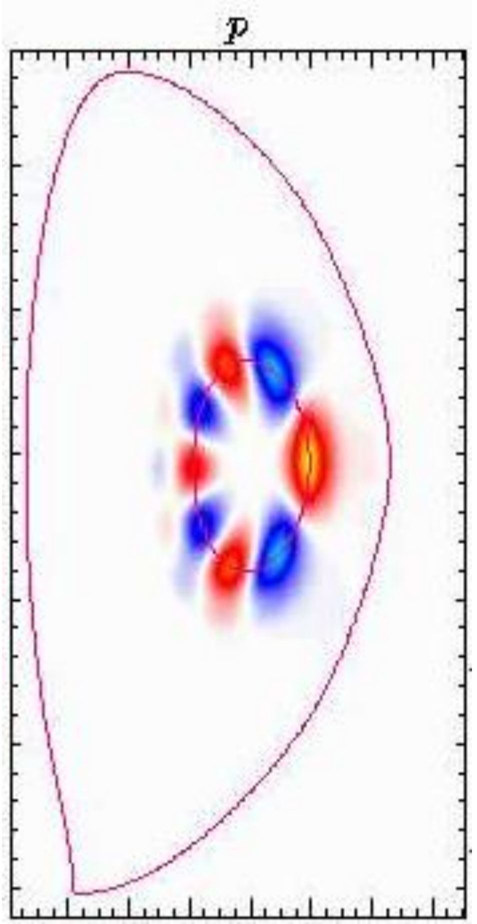
Refined mesh so SBL calculation can go to higher S = 10^8

Original Mesh: 5 cm   Mesh A: 0.8 cm in center

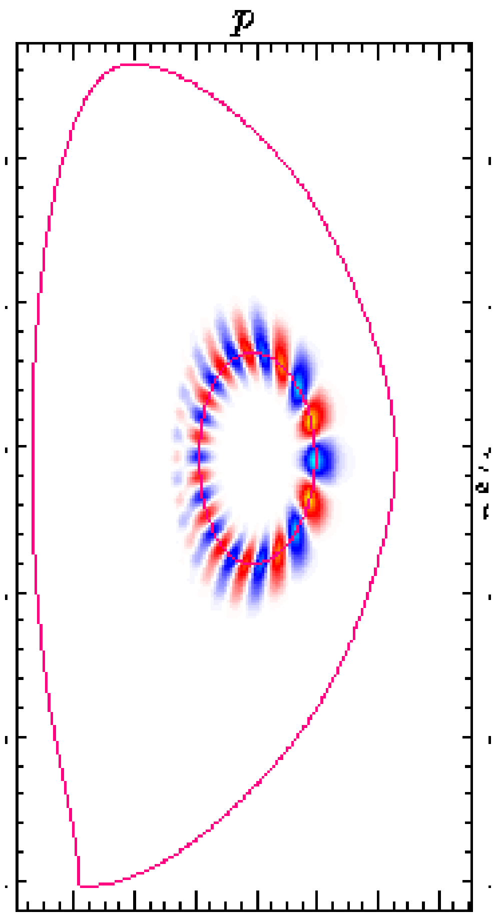
Equilibrium linearly unstable to many ideal modes



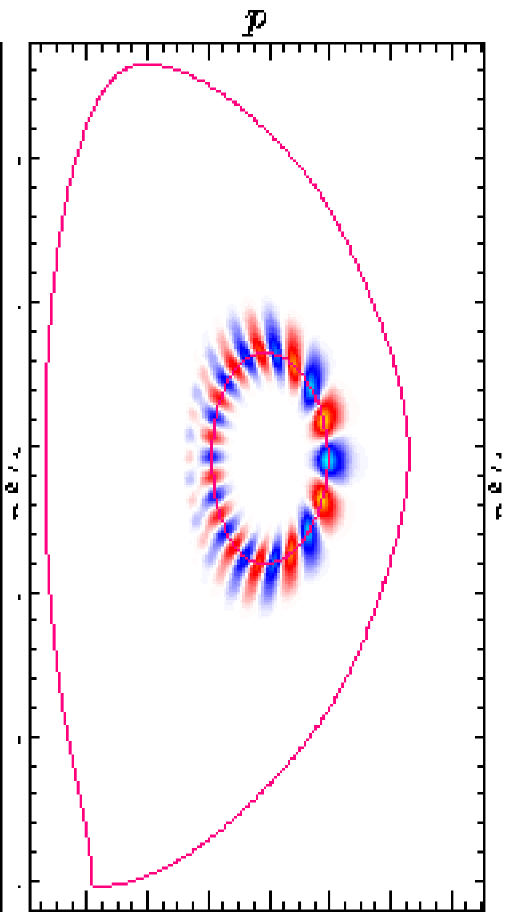




n = 3



n = 9

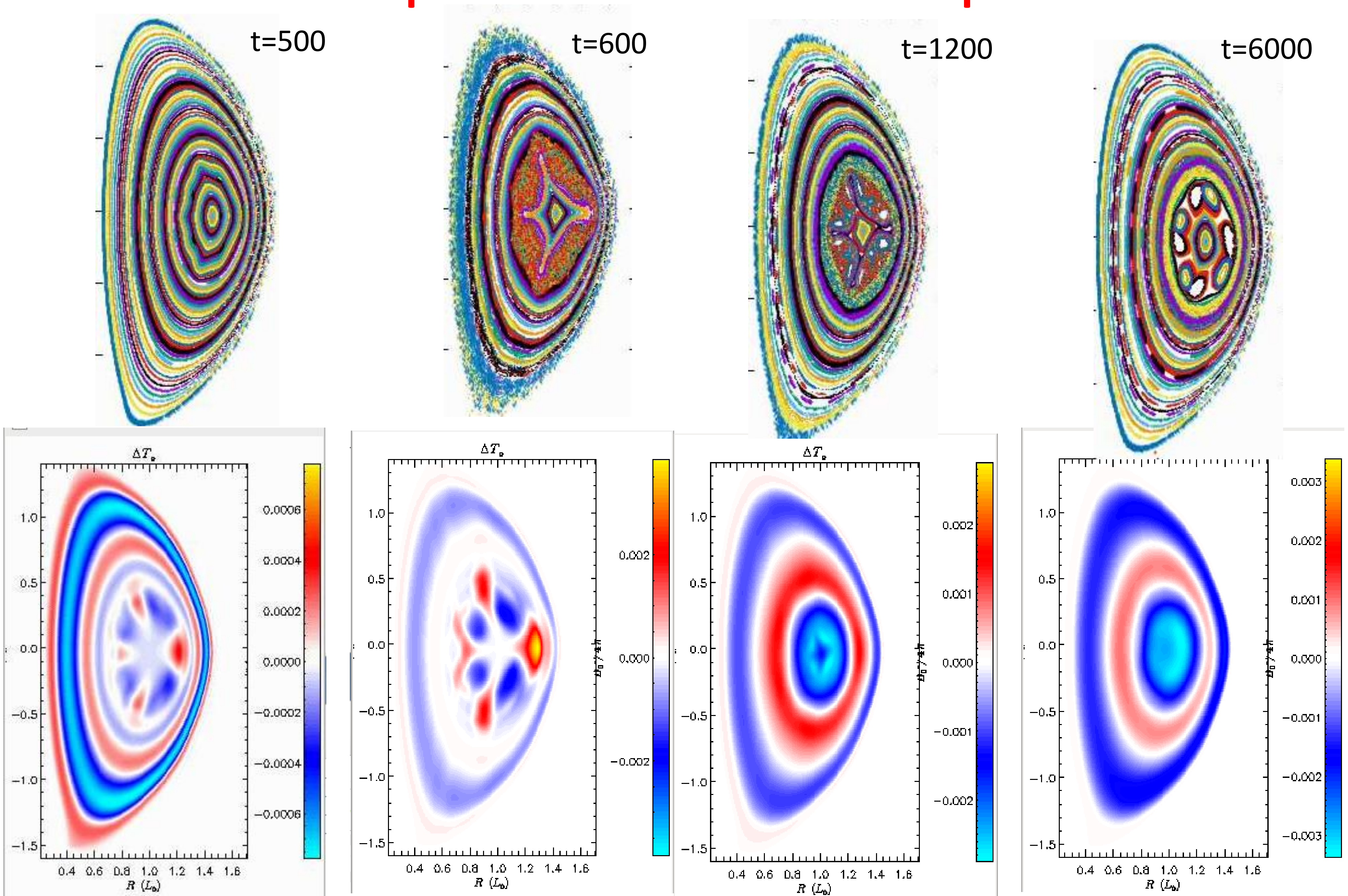


n = 15

Nonlinear Development of surfaces and temperature

Poincare Plots →

Change in Temperature from time t=0 →



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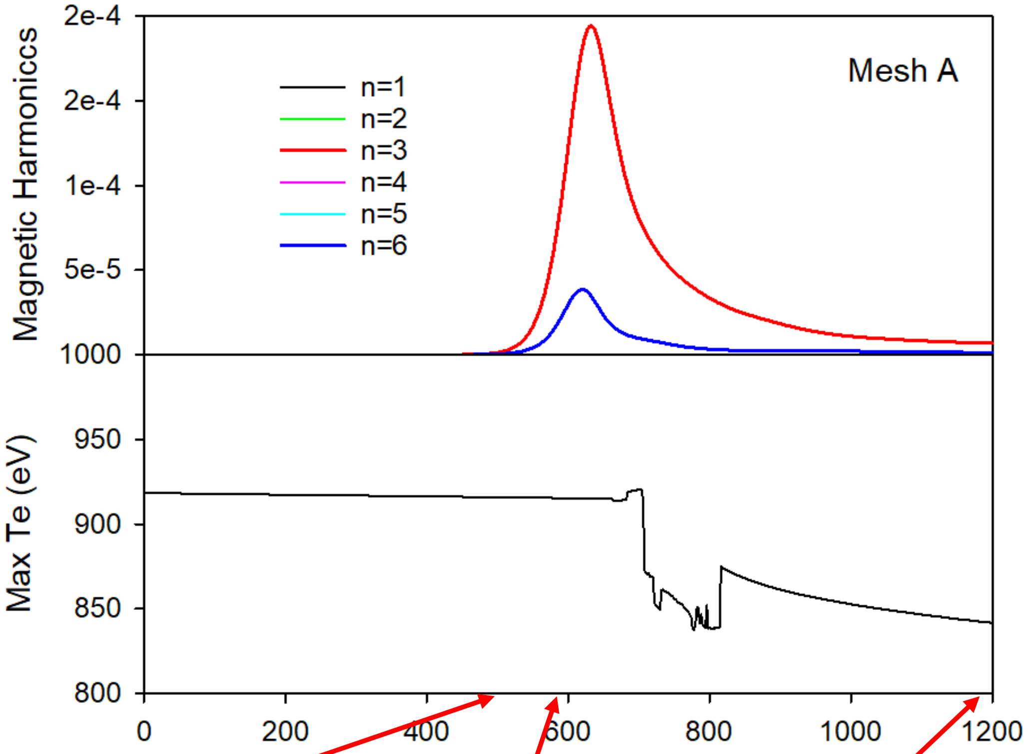
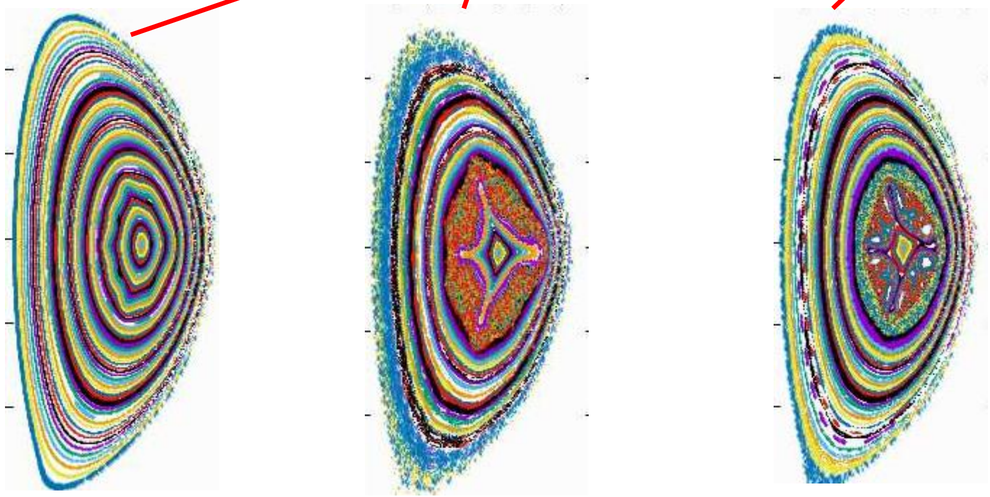
Summary of $0 < t < 1200\ \tau_A$





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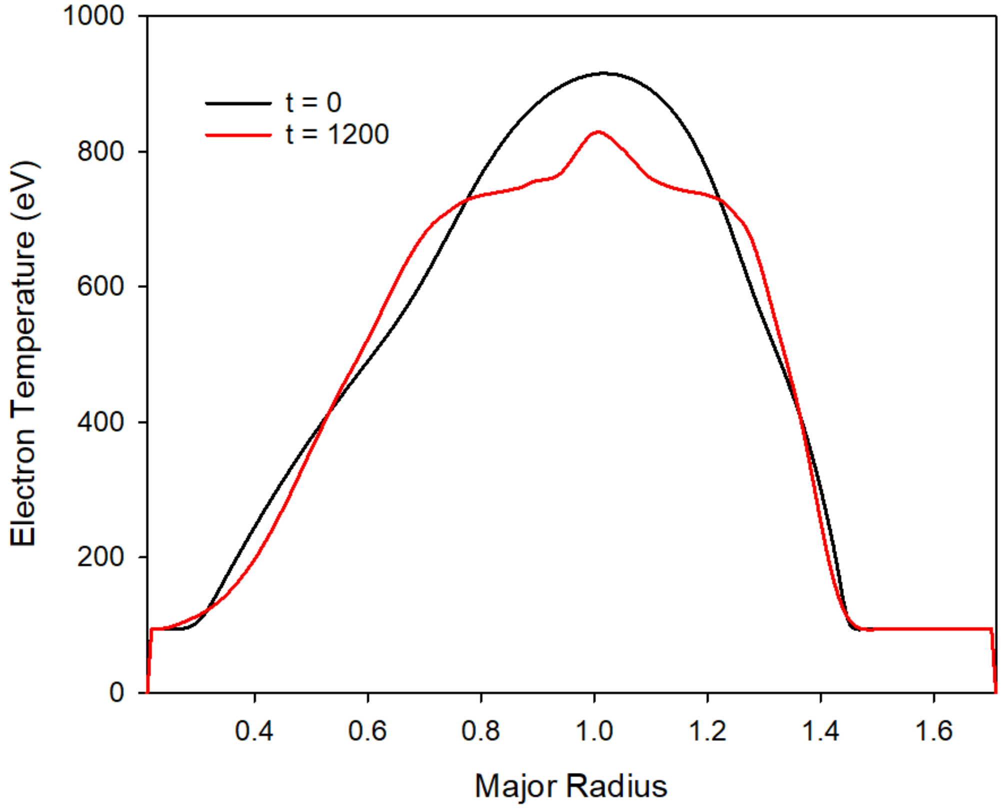
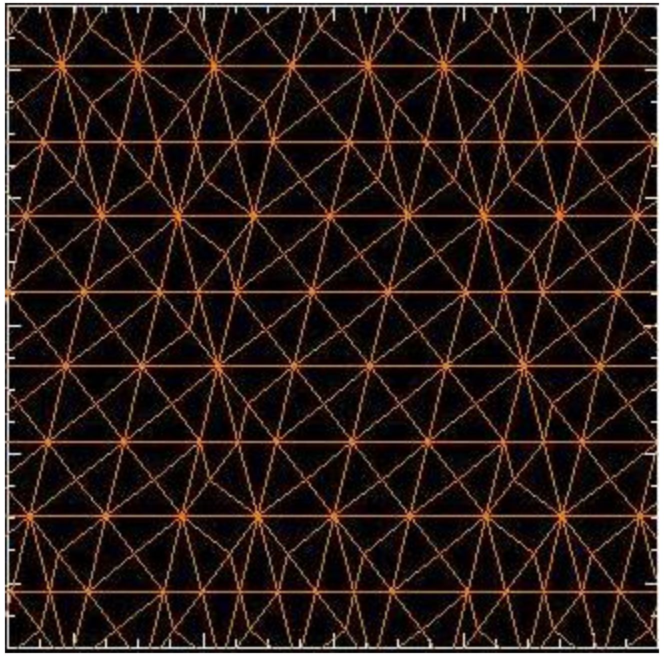


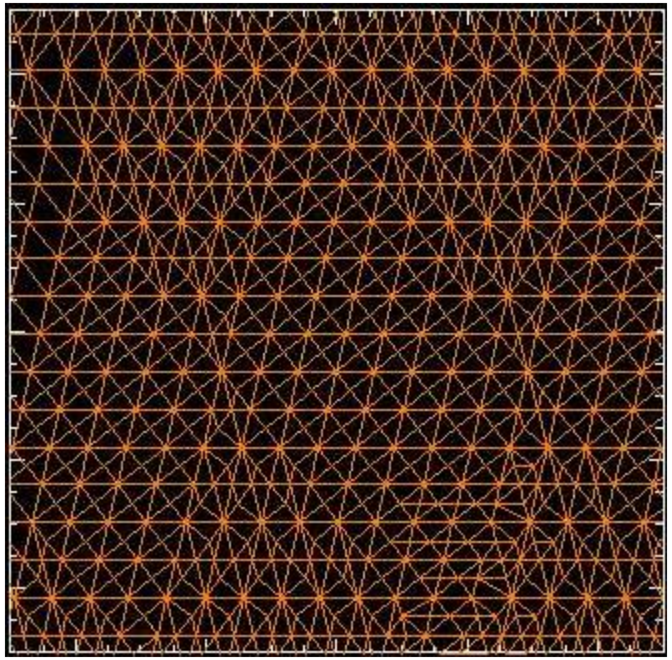
Unstable (4,3) mode grows up, breaks magnetic surfaces near and interior to rational surface, causing central temperature and pressure to decrease, stabilizing plasma

Central mesh density doubled again for convergence check

Mesh A: 0.8 cm

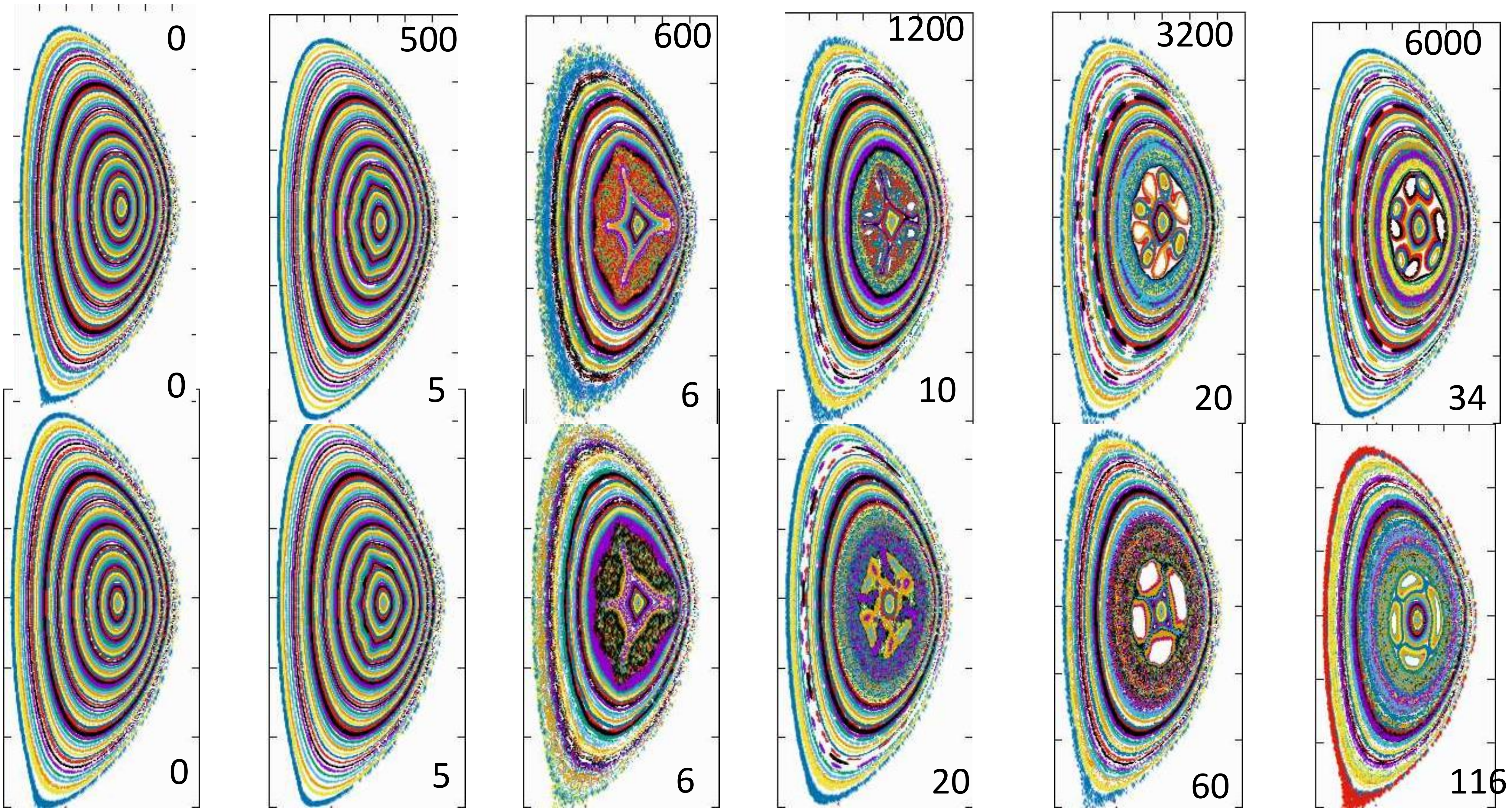


Mesh B: 0.4 cm

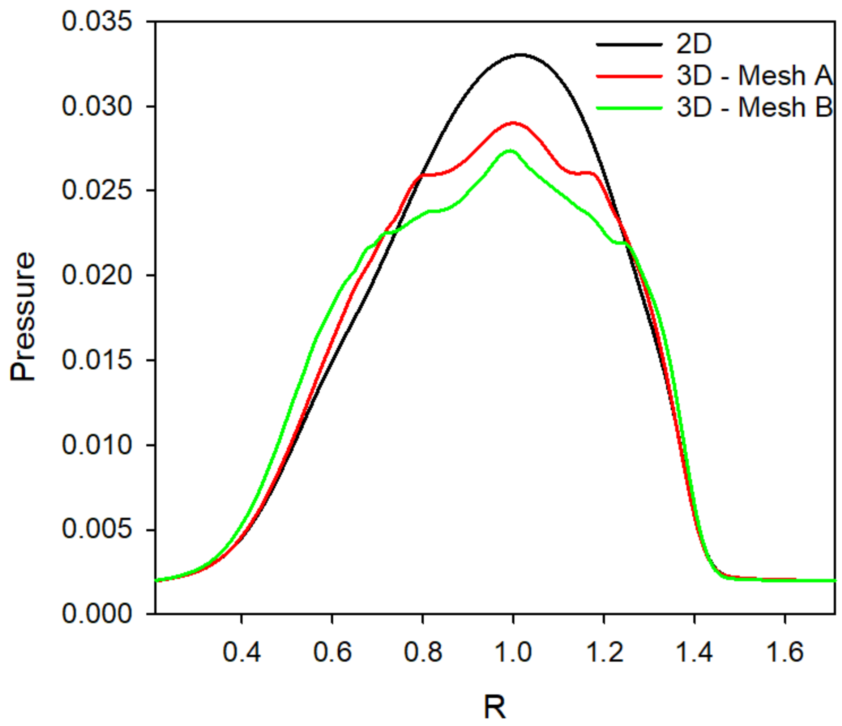


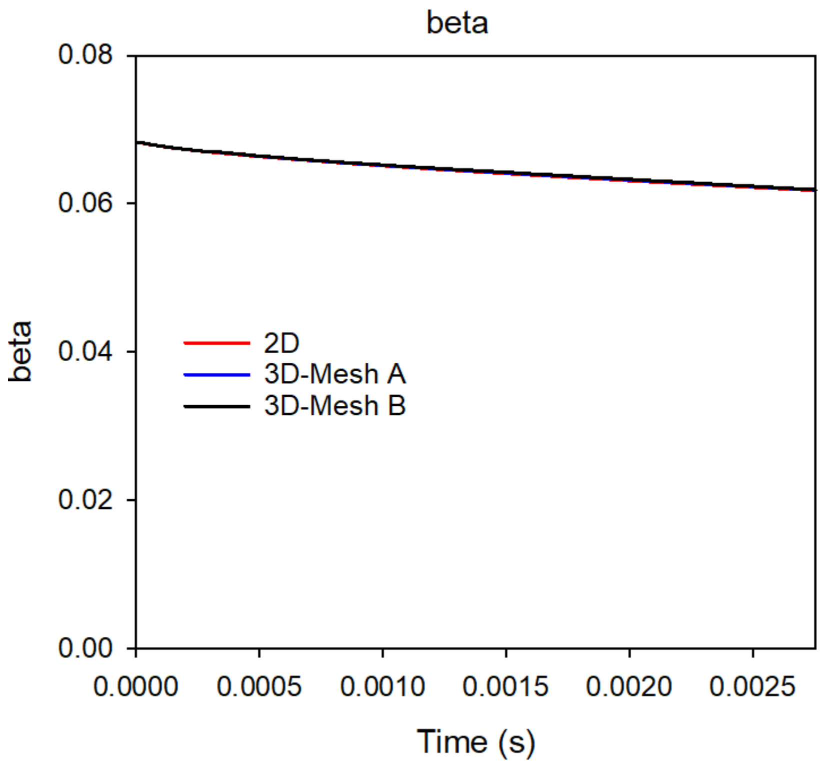
10 cm x 10 cm square in center

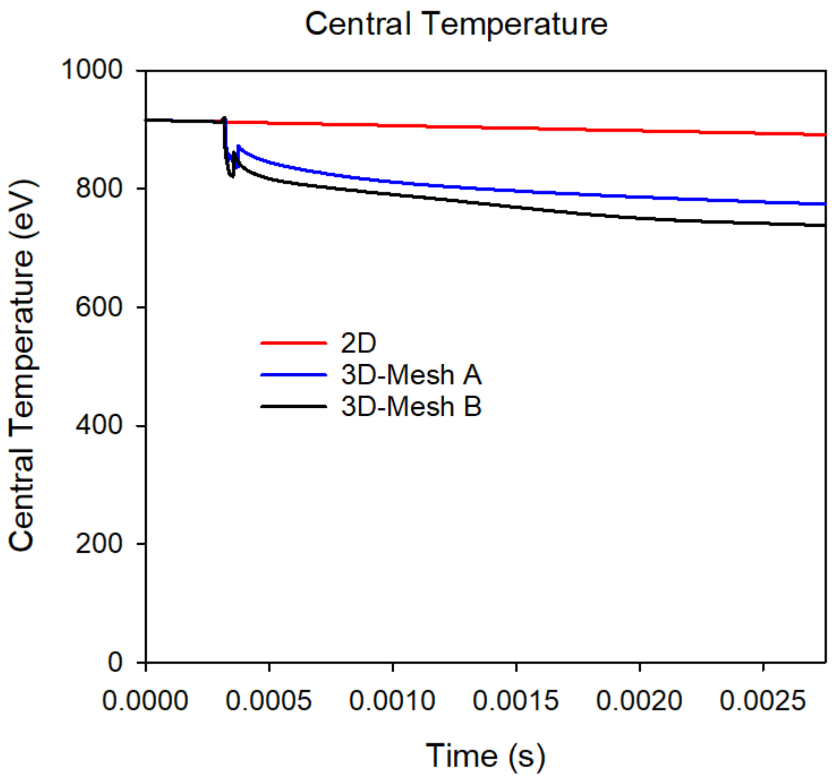
Comparison of Poincare Plots (grid A on top, fine grid B on bottom)



Result of Convergence Study



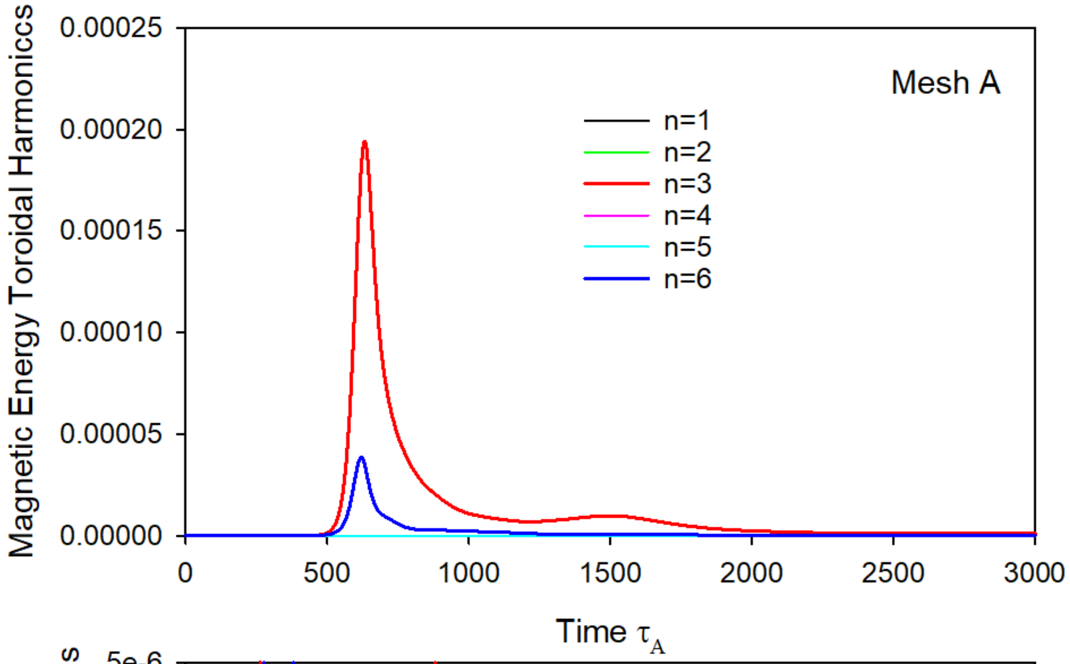


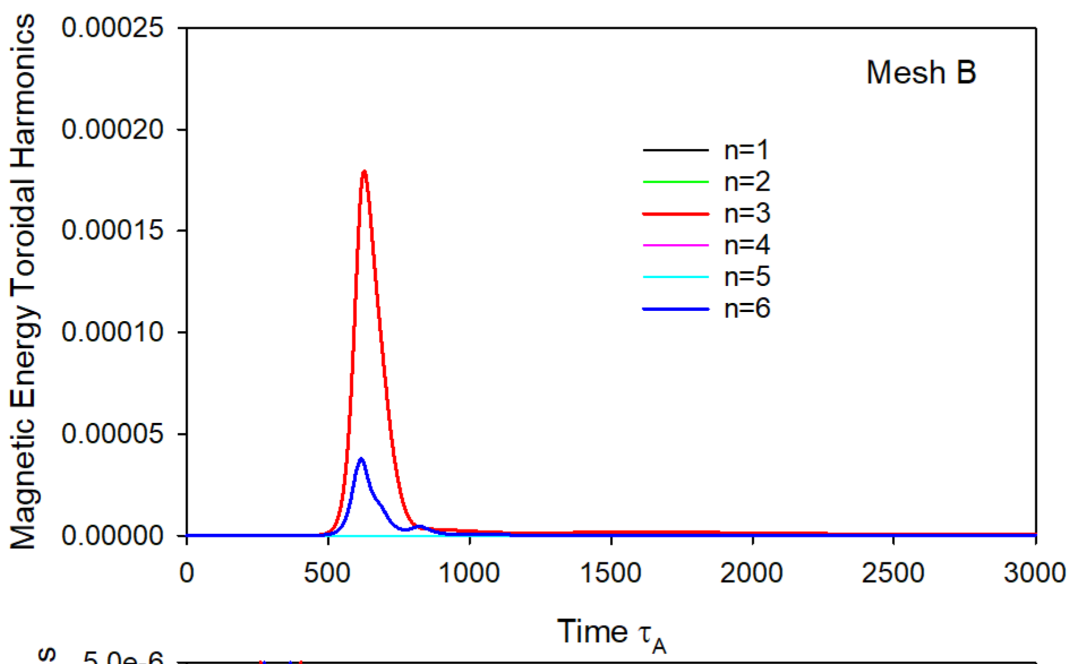


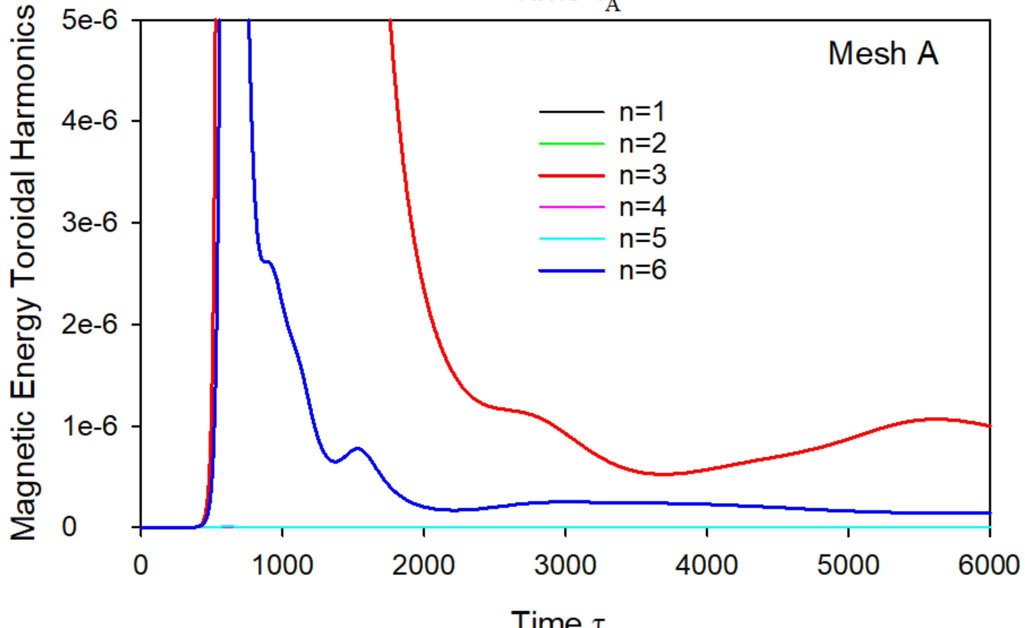
Not clear this has converged on Fine Grid. Will try one more round of refinement

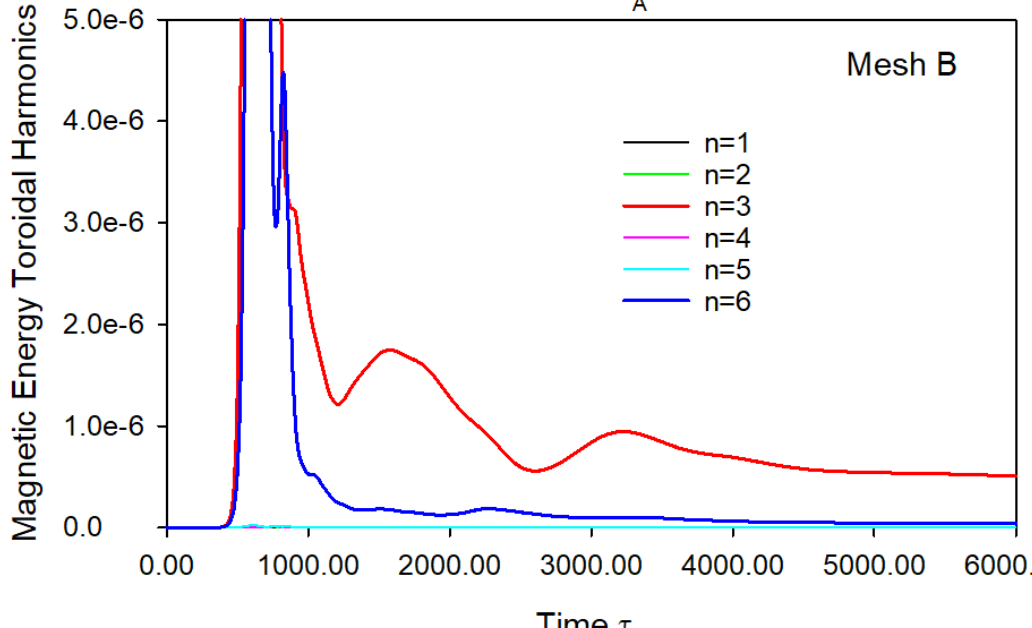
However, it is clear original 2D case was unstable, saturated 3D case is stable.

Comparison of magnetic energy toroidal harmonics using Meshes A and B





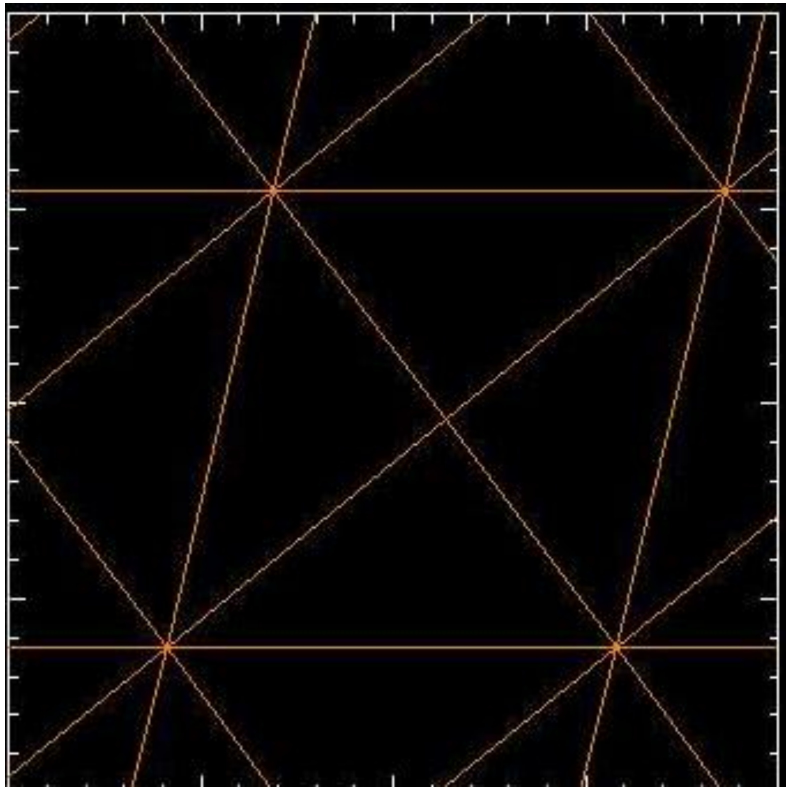




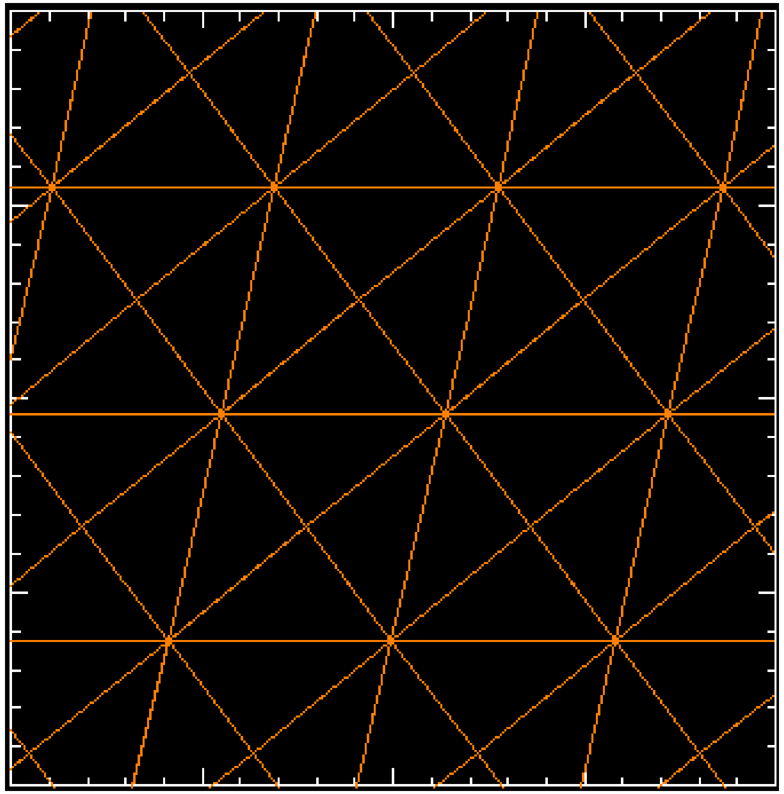
Note: primarily n=3 (and n=6) at final time

Introduce Grid C with additional refinement in center

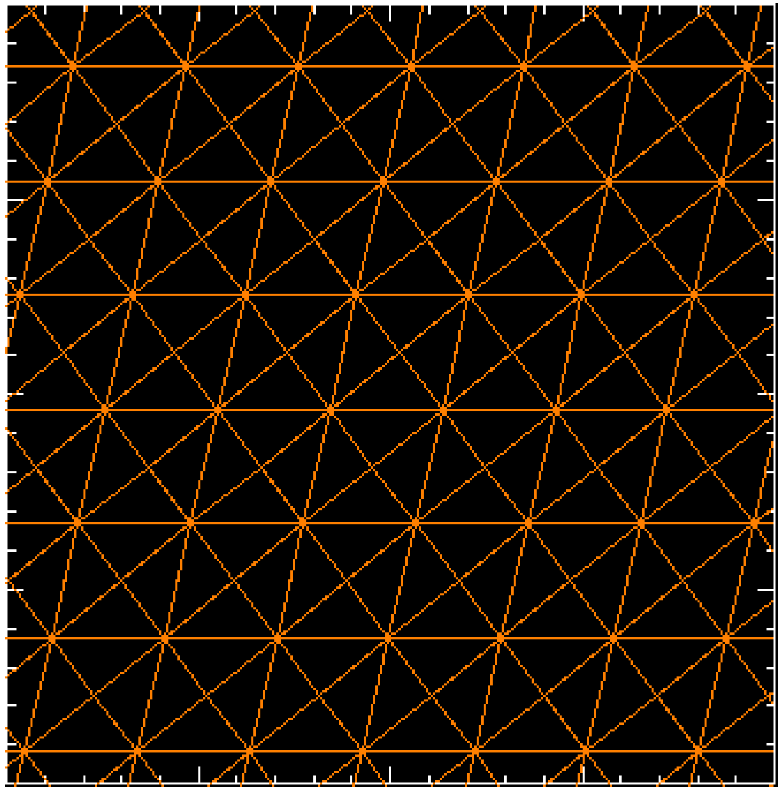
Grid A: 0.8 cm



Grid B: 0.4 cm

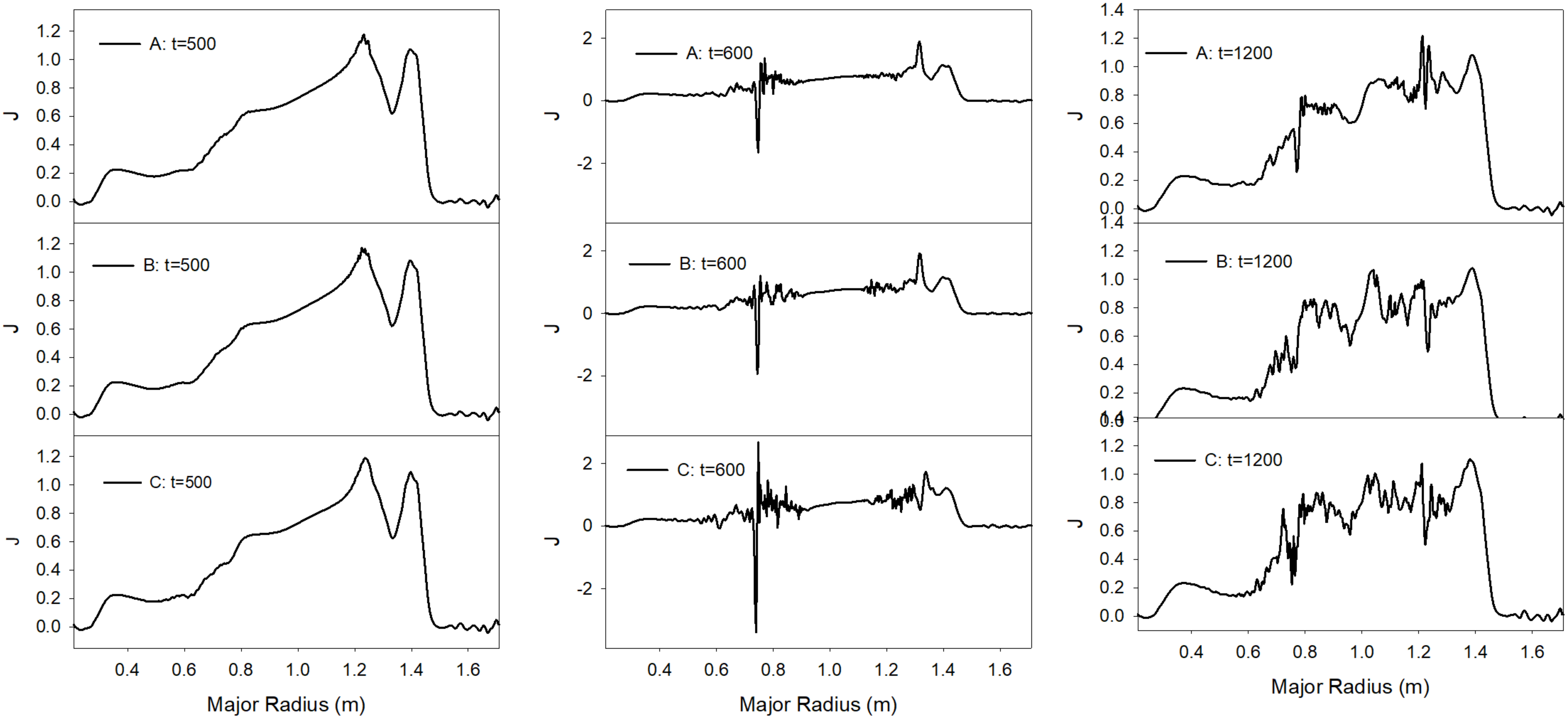


Grid C: 0.2 cm

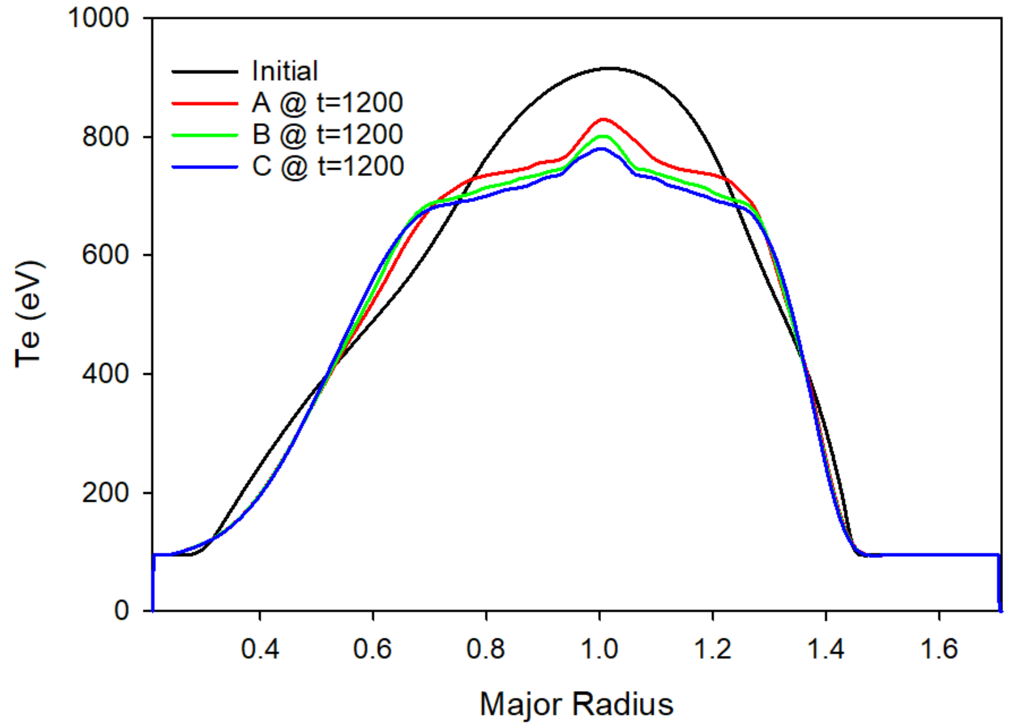


These are close-ups of 2cm x 2cm square in center of grid (near magnetic axis)

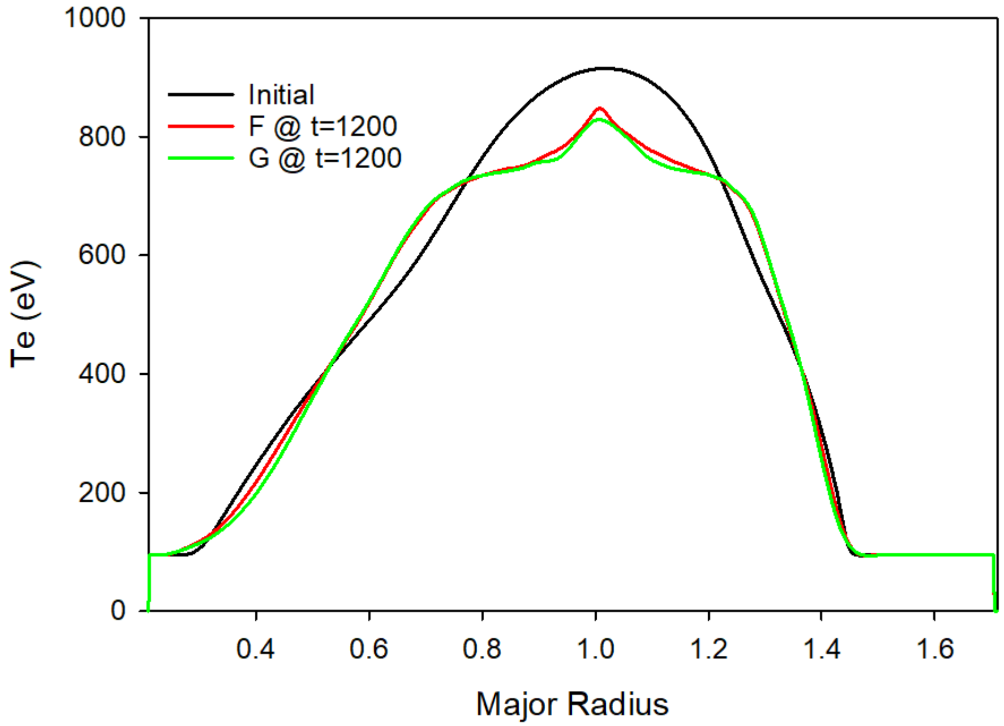
Comparison of midplane current profiles at 3 times for Grids A,B,C



Convergence study #1: Midplane temperatures for 5 meshes at 2 times

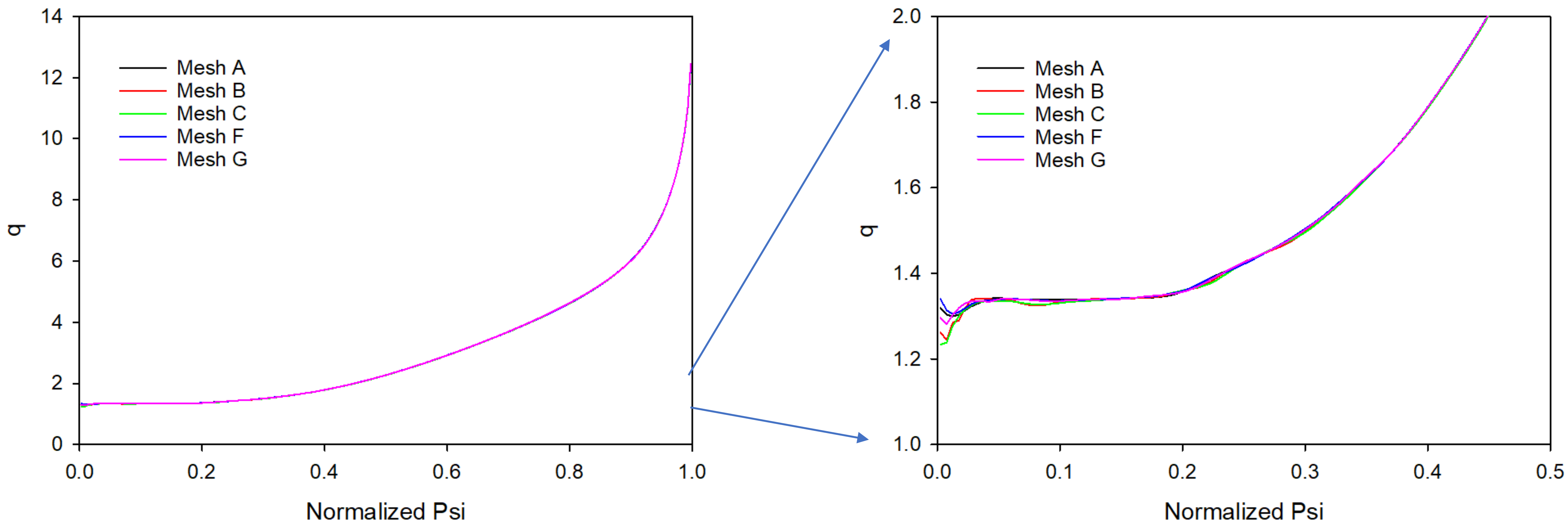


Meshes A, B, C have 5 cm zones in outer region and 0.8, 0.4, 0.2 cm in inner region



Meshes F, G have 4 cm and 2 cm zones in outer region and 1 cm in inner region

Convergence study #2: q-profiles at t=1200 from the 5 meshes

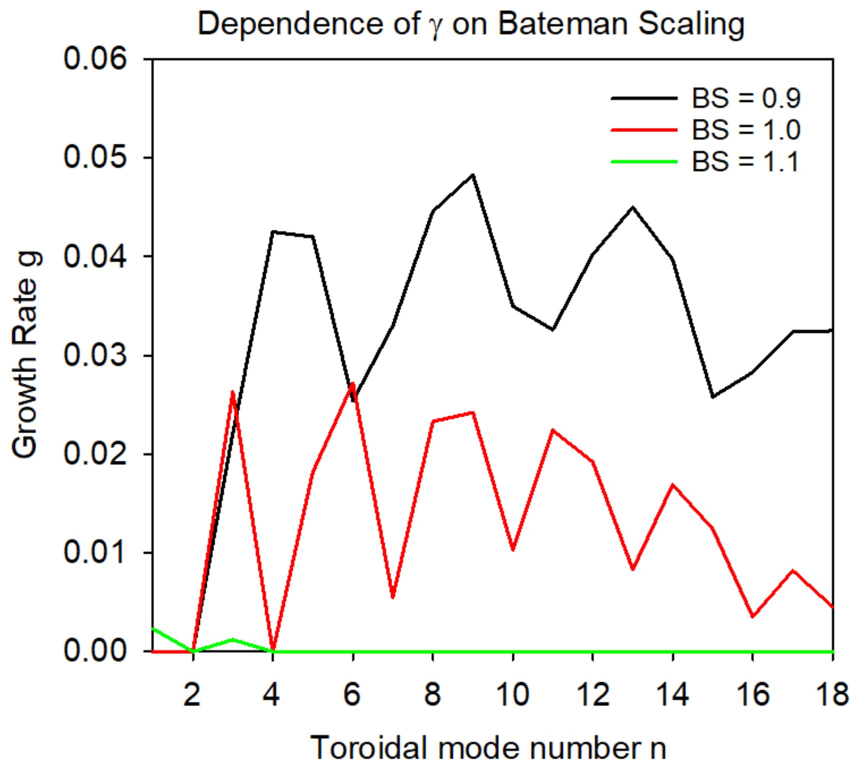


- q-profiles from solutions on the 5 meshes agree except for the very center (diagnostic problem?)

Generate a family of equilibrium by Bateman scaling

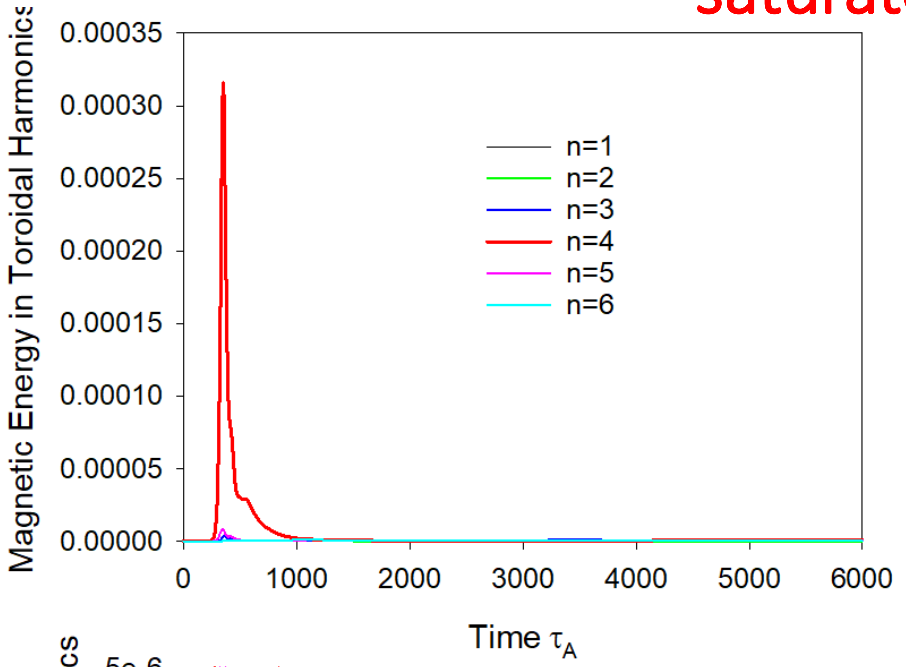
A Bateman scaling factor of 0.9 produces a more unstable equilibrium with q(0) = 1.2 and β = 8.2 %

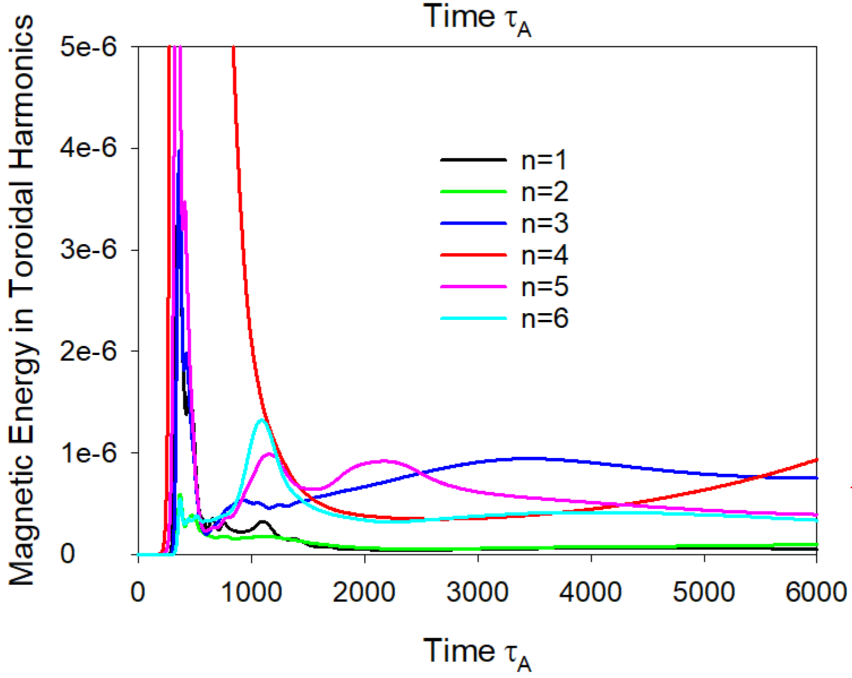
We find that it also saturates nonlinearly and leads to a new stable but slightly non-axisymmetric equilibrium

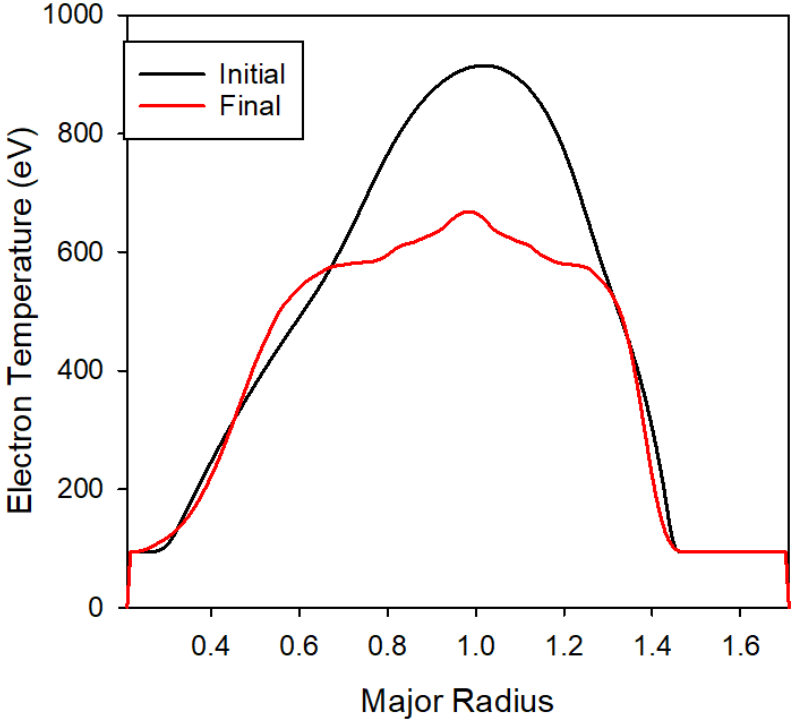


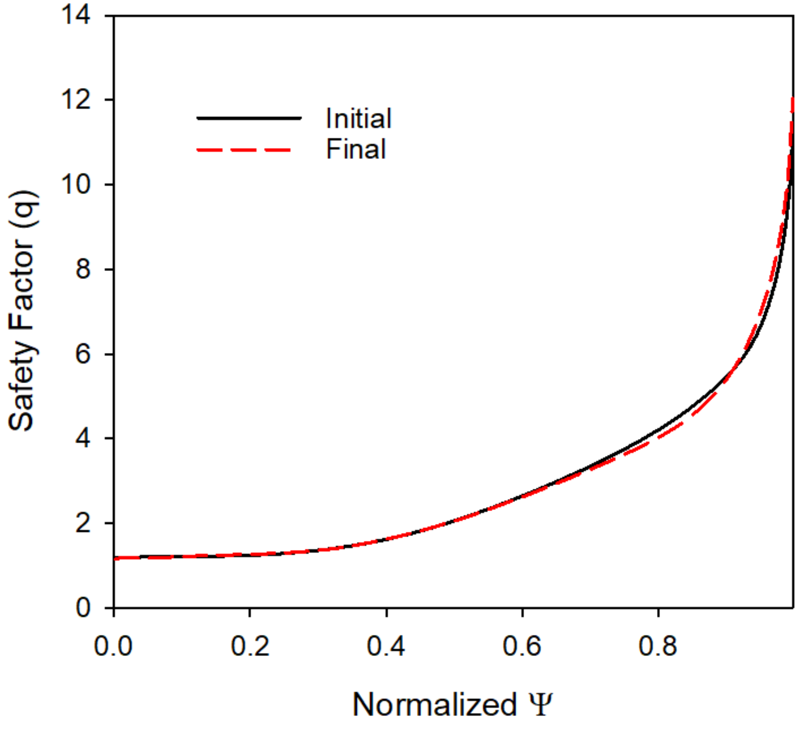
Bateman scaling keeps the current density fixed (P' and FF') but varies the toroidal field to generate a family of equilibrium from a given geqdsk file

Bateman scaled equilibrium with BS=0.9, q(0) = 1.2, β=8.2% also saturates but final state has multiple n modes









Note:

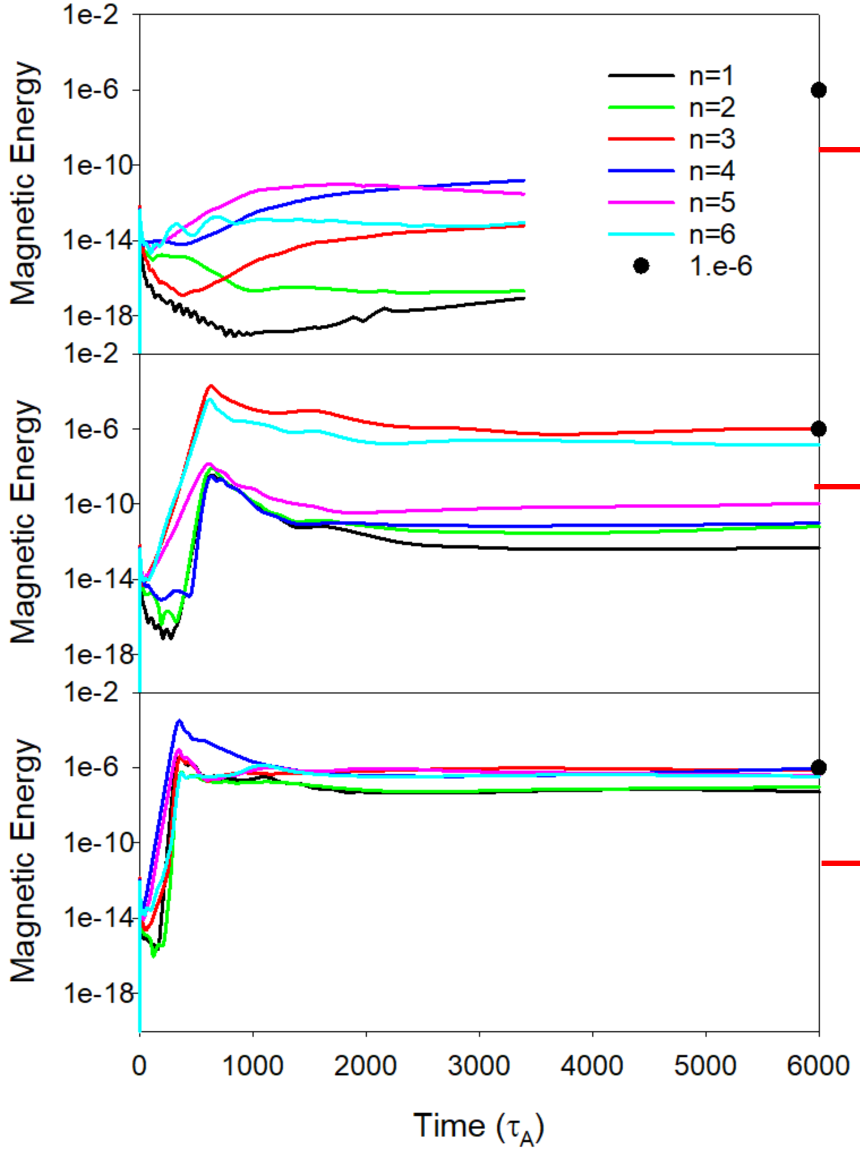
- n =3,4,5,6 toroidal harmonics all comparable at end
- q-profiles does not change during evolution
- Axis temperature greatly reduced during evolution

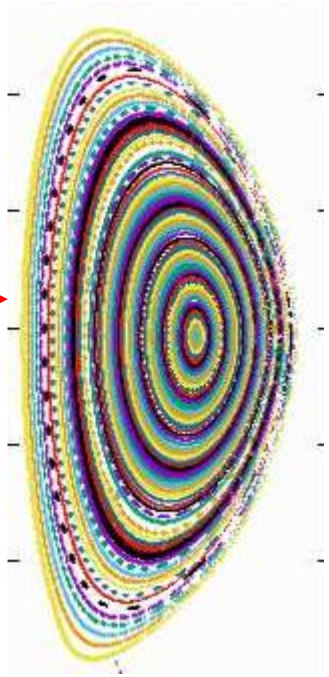
Comparison of the 3 scaled equilibria

BS=1.1
β=5.8%

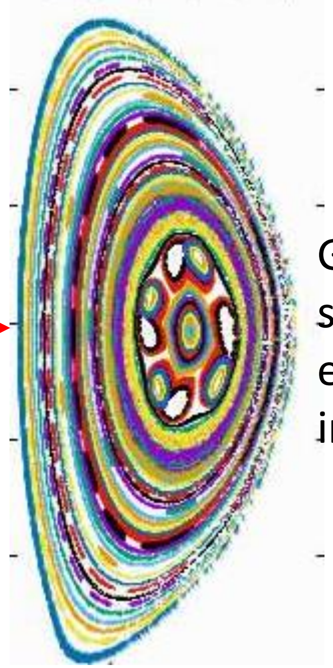
BS=1.0
β=6.8%

BS=0.9
β=8.2%

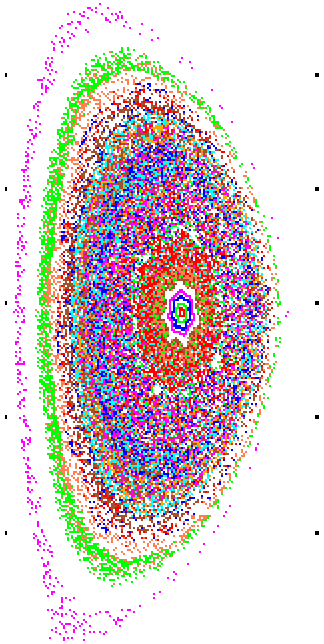




Good surfaces everywhere

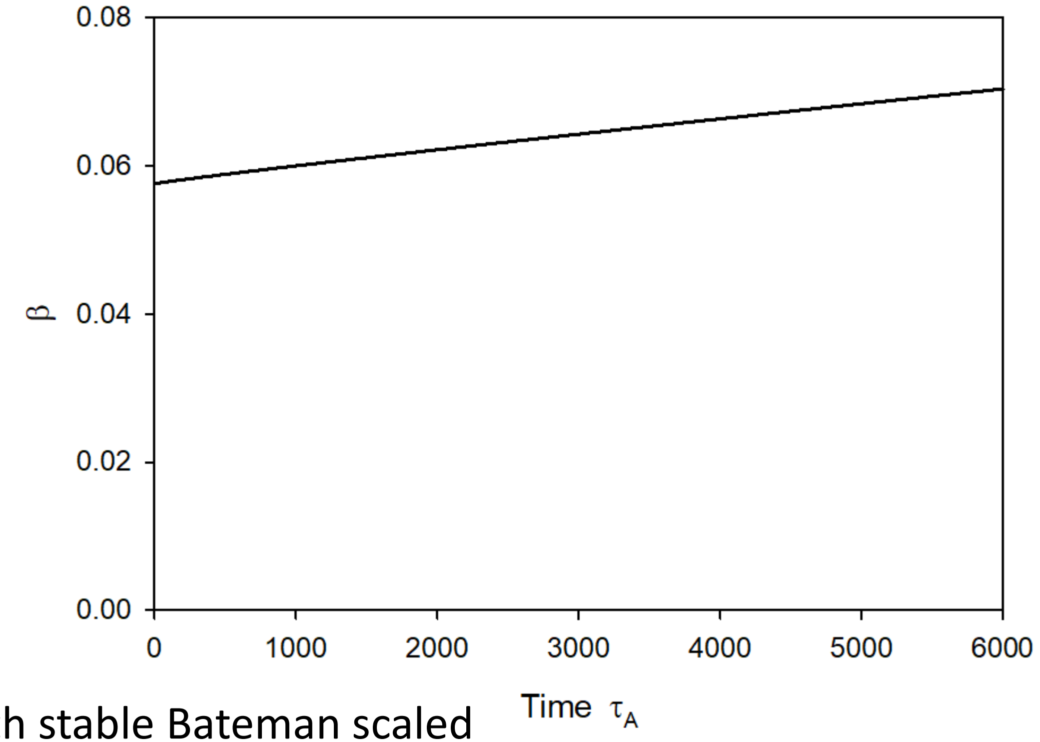


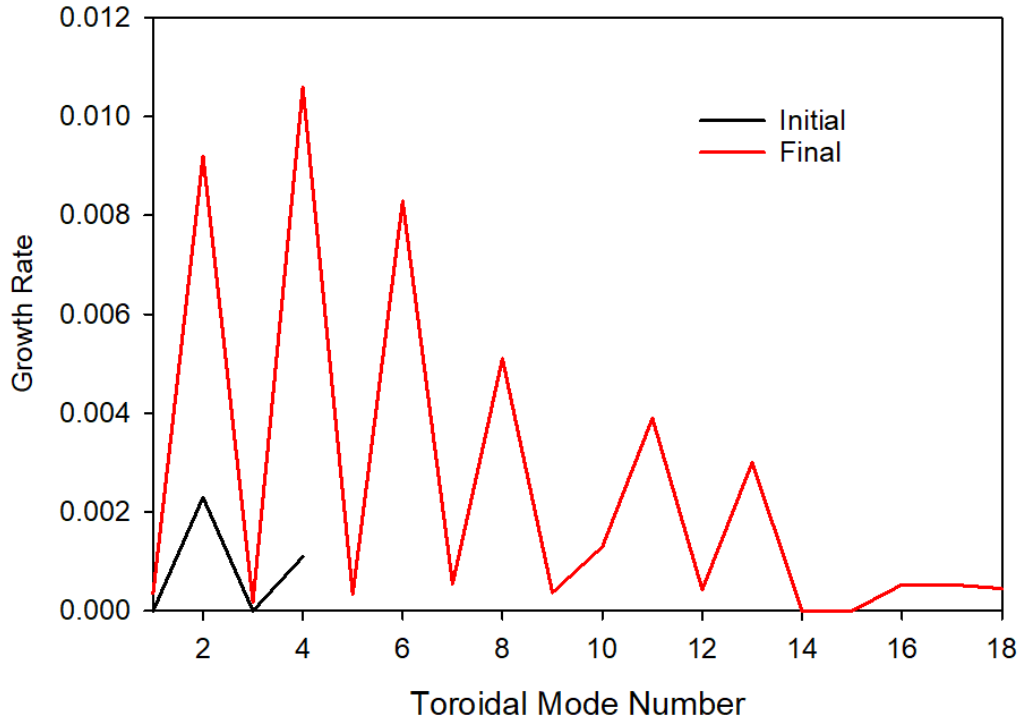
Good surfaces except n=3 in center



Poor surfaces with multiple n-modes

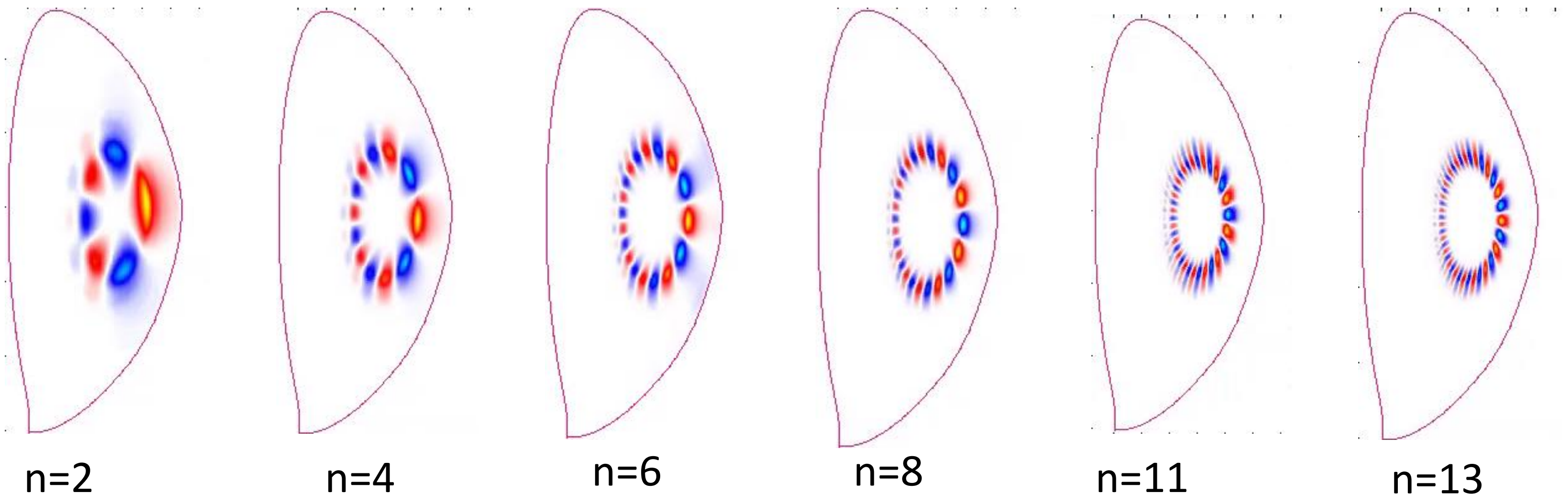
More realistic: Start with stable equilibrium and apply heating power: First in 2D





- Start with stable Bateman scaled equilibrium with β = 5.8%
- Run in 2D with heating source, increasing β to 7%
- Linear analysis shows final equilibrium unstable to many modes (shown on right)

- Now repeat with 3D run. Do these saturate nonlinearly?



Summary

- NSTX equilibrium 124379 @640 ms found to be linearly unstable to ideal MHD modes that saturate at modest amplitude with small non-axisymmetric n=3 toroidal harmonic
- Higher beta equilibrium obtained by Bateman scaling are much more unstable linearly, and saturate with n=3,4,5,6 toroidal harmonics which lead to stochastic surfaces
- Calculations performed with actual Spitzer resistivity, $S = 10^8$ and with variable fine meshes
- Now attempting to start with lower-beta equilibria, apply heating source to drive it through the beta limit. Should stay at marginal stability.
- Future: Can we examine other high-β NSTX equilibria that are linearly unstable to see if they also saturate nonlinearly?