M3D-C1 ZOOM Meeting

01/04/2021

CS Issues

1. GPU solve status/ LBL Report ?/ RPI Update ?
2. Local and other systems
3. NERSC Time
4. Changes to github master since last meeting
5. Plotting terms in temperature equation now works

1. Physics Studies
   1. ITER cold VDE paper accepted by POP
   2. Progress in 3D M3D-C1/NIMROD benchmark
   3. Helical band to remove runaway electrons (Brendan)
   4. 2D (cylindrical) runaway electrons with sources (Chen)
   5. Other?

GPU Solve status, LBL Report?, RPI Update?

Local Systems

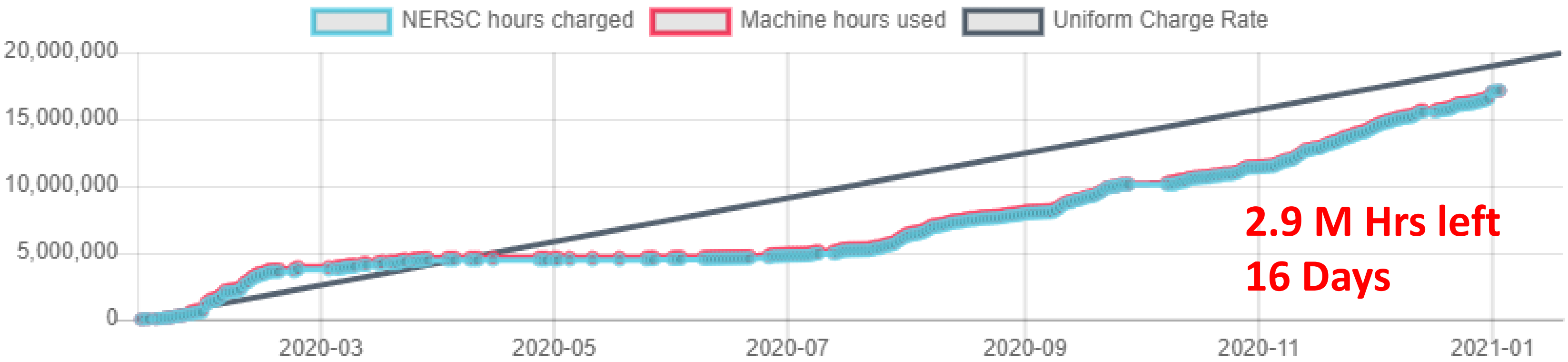
- PPPL centos7(1/4/21)
  - All 6 regression tests PASSED on centos7:
- PPPL greene (1/4/21)
  - 5 regression tests PASSED
  - No batch file found for pellet
- EDDY (1/4/21)
  - All 6 regression tests PASSED
- TRAVERSE(1/4/21)
  - Code compiles
  - Regression test failed: split_smb not found in PATH
  - Have not yet tried shipping .smb files from another machine

Other Systems

- Cori-KNL (1/4/2021)
  - 6 regression tests passed on KNL
- Cori-Haswell (1/4/2021)
  - 5 regression tests passed
  - KPRAD_RESTART did not pass, but differences are very small in velocity variables. All magnetic and thermal good. Similar difference as Cori-KNL
- PERSEUS
  - All 6 regression tests PASSED on perseus (J. Chen, 9/04/20)
- MARCONI
  - All regression tests PASSED on MARCONI (J. Chen, 9/04/20)
- CORI GPU (10/26)
  - ??

NERSC Time

mp288



m3163

Closed for general use

- New NERSC allocations start Jan 20, 2021: mp288 received only 10M Hrs

Changes to github master since last meeting

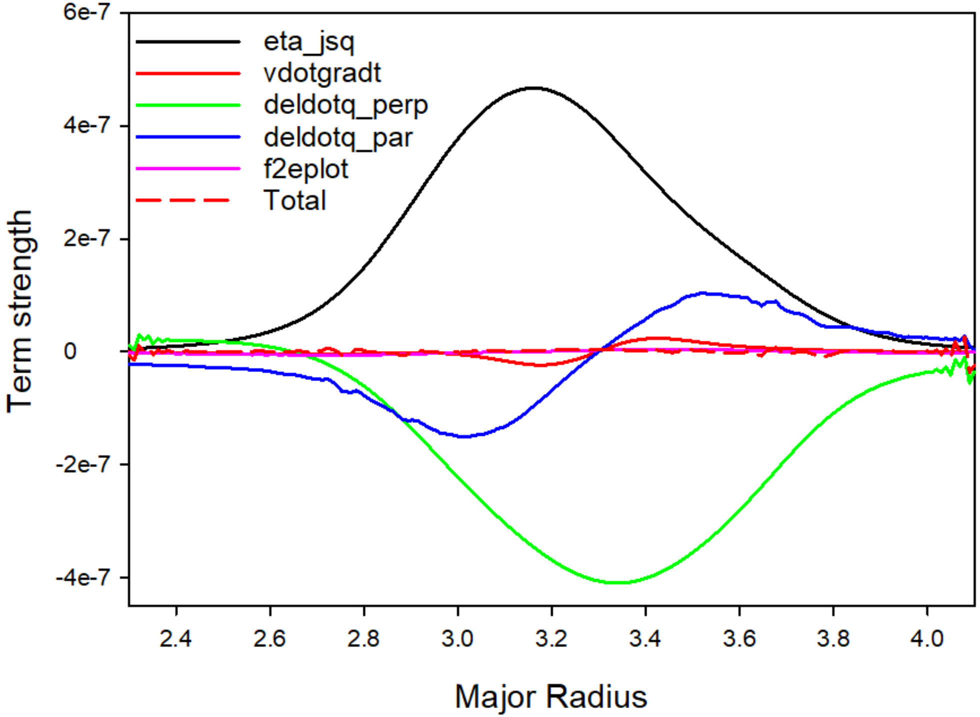
- S. Seol
  - 12/14/20: adding control parameters for m3dc1_mesh-adapt
  - 12/25/20: adding m3dc1_node_get | setfield

- S. Jardin
  - 12/18/20: Correction to plots for itemp_plot=1 (not plots all terms in temp equ)
  - 12/22/20: Fixed bug when itemp_plot=1 and no density source

- R. Usman
  - 12/22/20: Changes in the m3dc1_mesh_adapt and related routines

- B. Lyons
  - 12/22/20: Add capability for helical coil resistivity (#32). Intended to model runaway-electron killer coil.   So far, does not produce significant helical current.
    - WIP: add helical resistivity perturbation to resistive wall.
    - Helical resistivity is blended logarithmically
  - 12/23/20: Update plot_hmn outfile work for restarts with different number of planes

Plotting terms in temperature equation now works



ITER Cold VDE paper accepted by POP

ITER cold VDEs in the limit of a perfectly conducting first wall

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Princeton Plasma Physics Laboratory, Princeton, NJ 08543, United States of America

(Dated: 5 November 2020)

Recently, it has been shown that a vertical displacement event (VDE) can occur in ITER even when the walls are perfect conductors, as a consequence of the current quench [A. H. Boozer, Physics of Plasmas 26 114501 (2019)]. We used the extended-MHD code M3D-C^1 with an ITER-like equilibrium and induced a current quench to explore cold VDEs in the limit of perfectly conducting walls, using different wall geometries. In the particular case of a rectangular wall with the side walls far away from the plasma, we obtained very good agreement with the analytical model developed by Boozer that considers a top/bottom flat-plates wall. We show that the solution in which the plasma stays at the initial equilibrium position is improved when bringing the side walls closer to the plasma. When using the ITER first wall in the limit of a perfect conductor, the plasma stays stable at the initial equilibrium position far beyond the value predicted by the flat-plates wall limit. On the other hand, when considering the limit in which the inner shell of the ITER vacuum vessel is acting as a perfect conductor, the plasma is displaced during the current quench but the edge safety factor stays above 2 longer in the current decay compared to the flat-plates wall limit. In all the simulated cases, the vertical displacement is found to be strongly dependent on the plasma current, in agreement with a similar finding in the flat-plates wall limit, showing an important difference with usual VDEs in which the current quench is not a necessary condition.

I. INTRODUCTION

Vertical Displacement Events (VDEs) are major disruptions that occur in elongated tokamak plasmas. Reliable simulations to predict possible scenarios in ITER are essential. In a "cold VDE", the disruption thermal quench occurs when the plasma is still at the equilibrium position, and then the plasma displaces upward or downward (see for example, Ref. 1). This is in contrast to a "hot VDE" in which the hot plasma column displaces vertically due to loss of position control, and the thermal quench occurs later as a result of the plasma contacting the first wall.

In ITER, the first wall is expected to have poor toroidal conductivity since it is made of panels with gaps between them[2]. However, it has been pointed out[3] that if the plasma fills those gaps during a disruption event, it might short circuit the first wall making it toroidally conduct-

different geometries and show that in this limit, the ITER first wall keeps the plasma centered far beyond the value predicted by the flat-plates wall limit. However, when assuming that the perfectly conducting structure is the inner shell of the ITER vacuum vessel, the plasma is displaced during the current quench but the safety factor should not decrease as fast as in the flat-plates wall limit.

This paper is organized as follows: In Section II we present the plasma equilibrium and the different wall geometries employed. In Sec. III we show the limiting case in which the flat-plates wall limit is applicable. Finally, we show in Sec. V the results using the ITER first wall as a perfect conductor as well as the case in which the inner shell of ITER vacuum vessel acts as a perfect conductor.

II. NUMERICAL MODEL

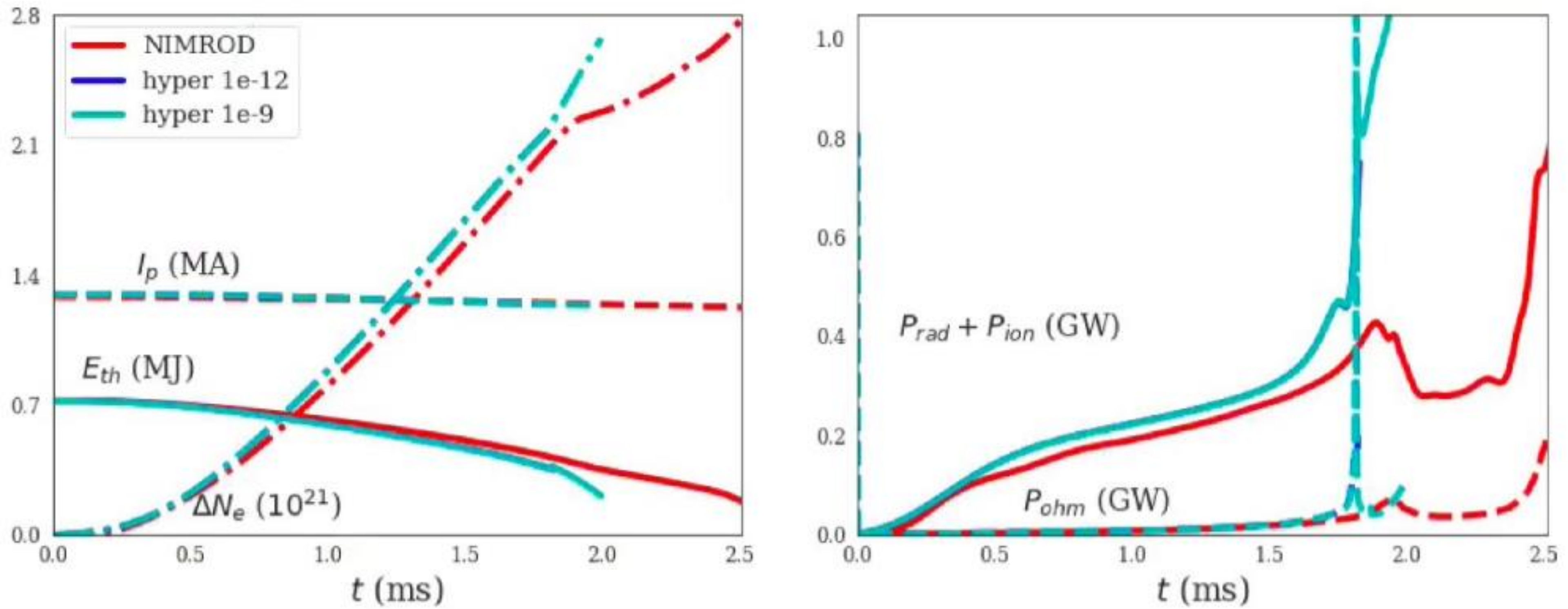
Congratulations to Cesar (who will be taking a new position at Lehigh)

B. Lyons 3D Benchmark case with NIMROD

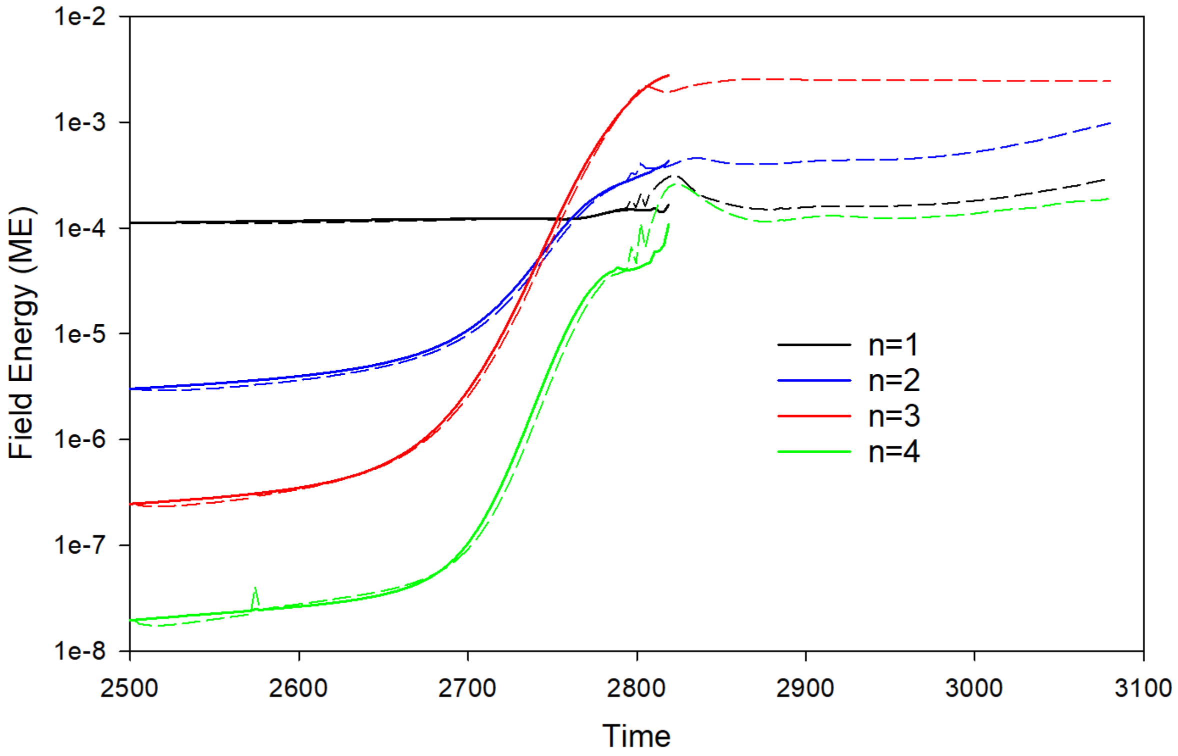
- Baseline case has denm = 6.5 e-8, hyper=1.e-12
  - Fails at t=2800 (1.8ms), P_ohm gets very large, ke_hmn blow up

- Tried some variations:
  - Decrease dt by 10 ….did not help
  - Increase planes from 8 to 16…did not help
  - Increase amupar by 100 ….did not help
  - Increase hyper to 1.e-9…ke_hmn does not blow up, but still has large P_ohm spike

Comparison of 0D quantities with NIMROD

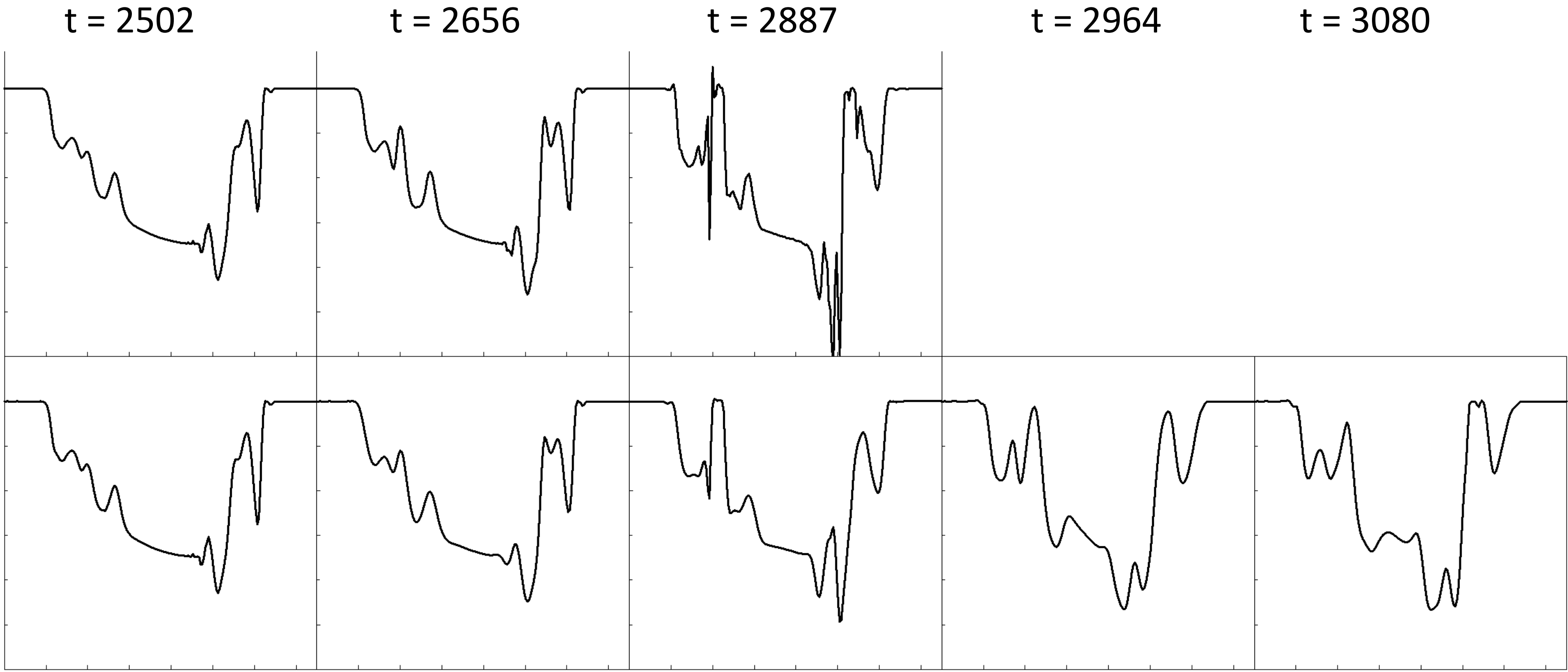


Energy in base case 36742317 (solid) and hyper=1.e-9 36779684 (dashed)



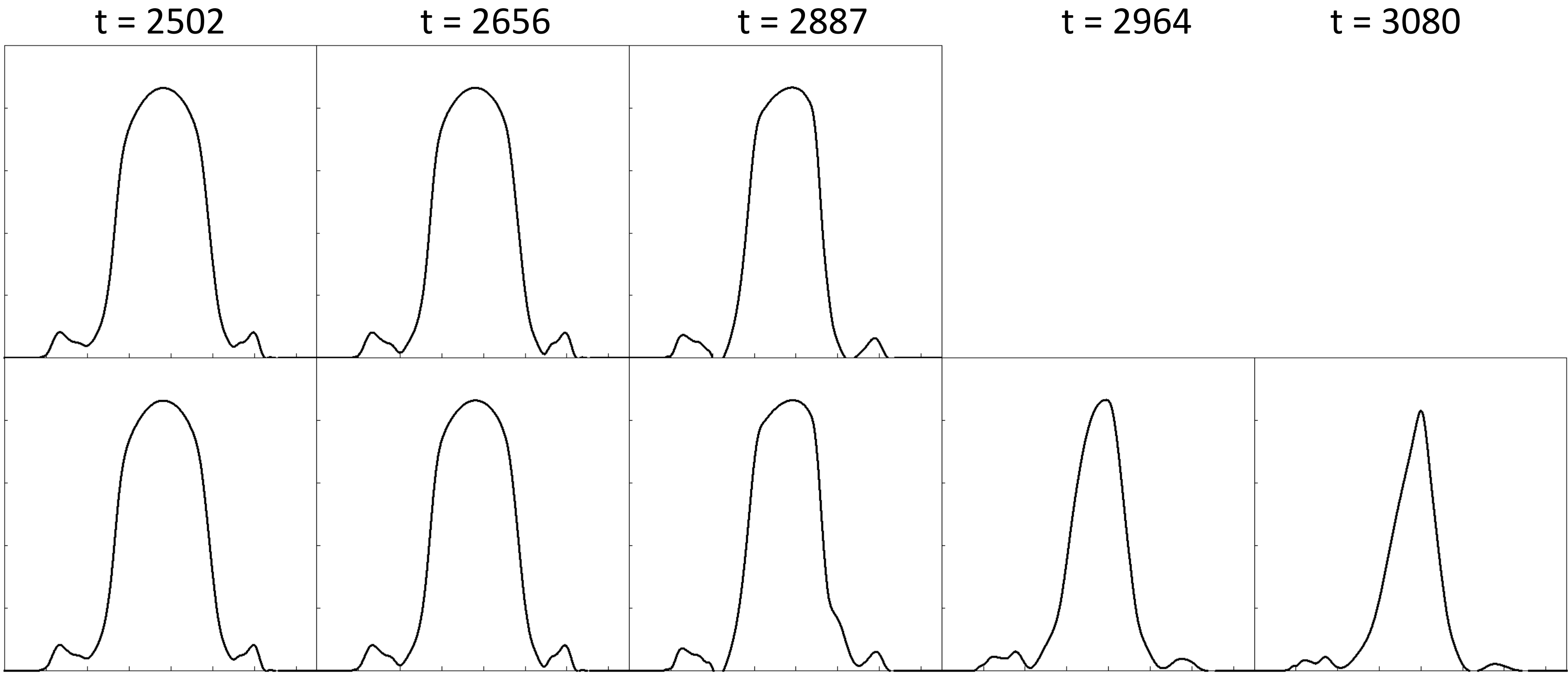
Hyper run seems to be smooth continuation of base case.

Midplane jphi for base case 36742317 (top) and hyper=1.e-9 36779684 (bottom)



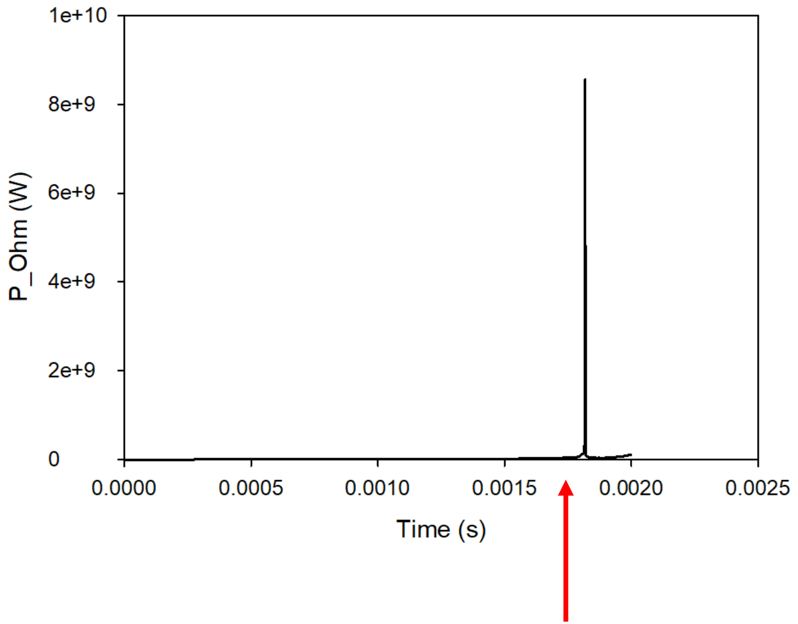
Again, hyper case appears to agree with base case, just smoother

Midplane Te for base case 36742317 (top) and hyper=1.e-9 36779684 (bottom)



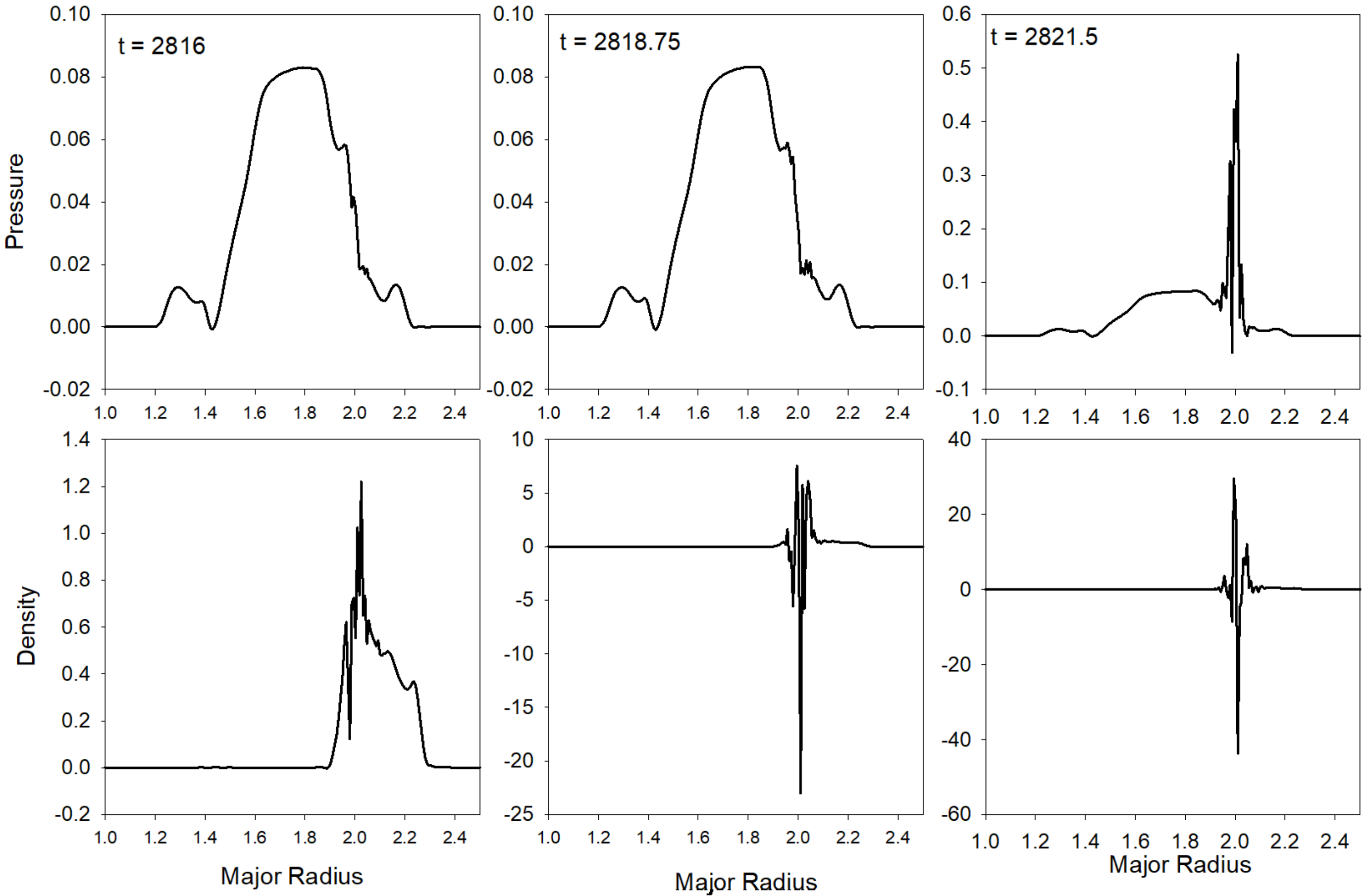
Again, temperatures in hyper case agree with those in base case

However, hyper case still has large p_ohm spike

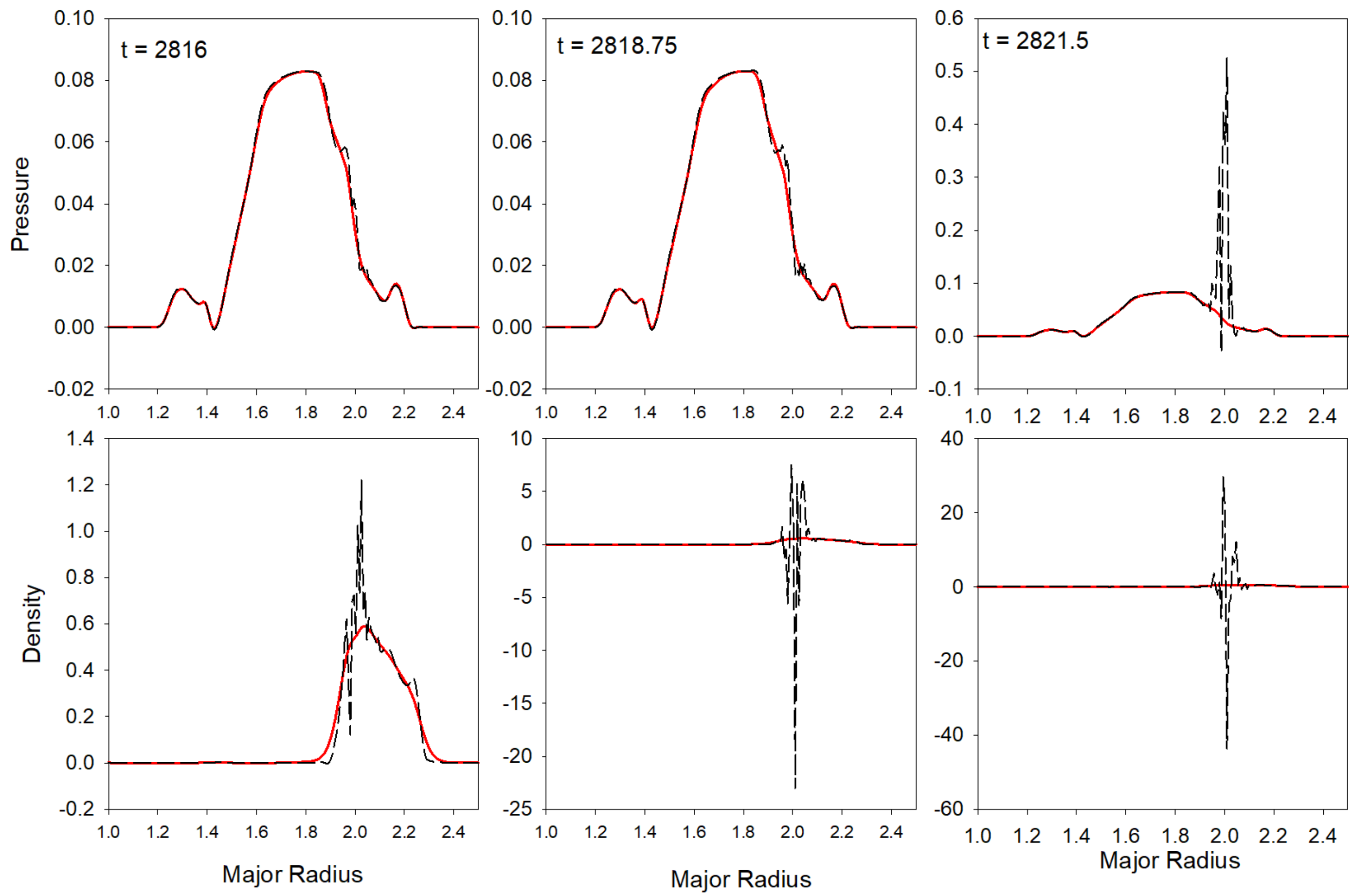


Examine configuration just before the spike

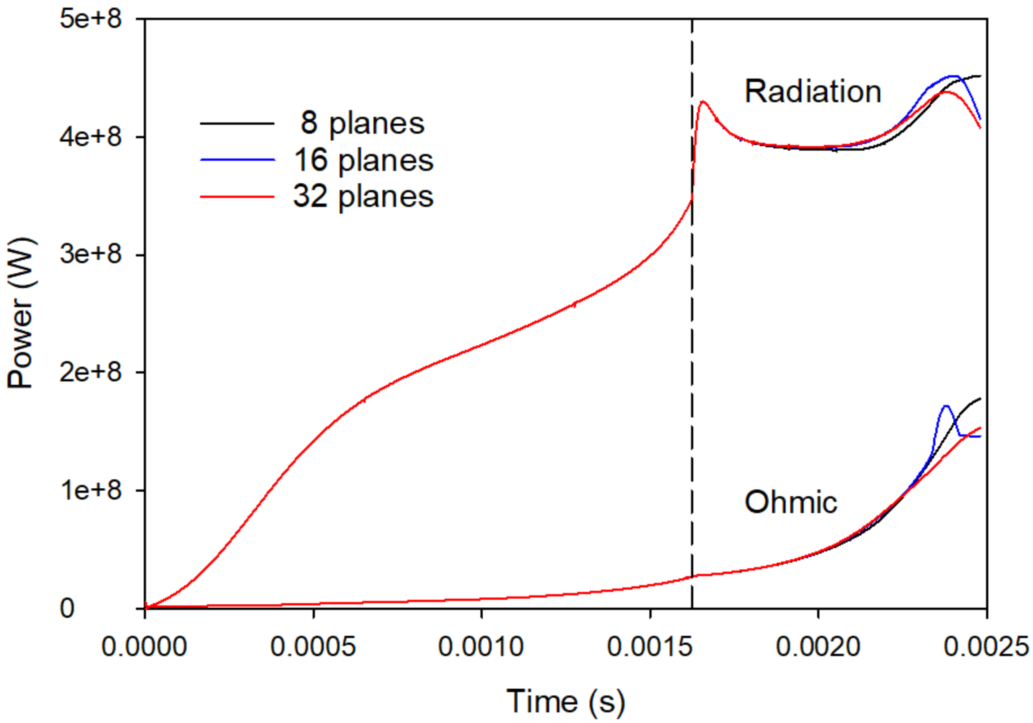
Pressure and density 3 time steps before the spike



Redo, increasing denm from 6.e-8 to 6.e-5



With denm increased, spike goes away



- Restarted hyper run at 1.6 ms (dashed line) with 3 different toroidal resolutions: 8,16,32
- Very similar 0D power results for all 3 cases
- Looks much more similar to NIMROD result

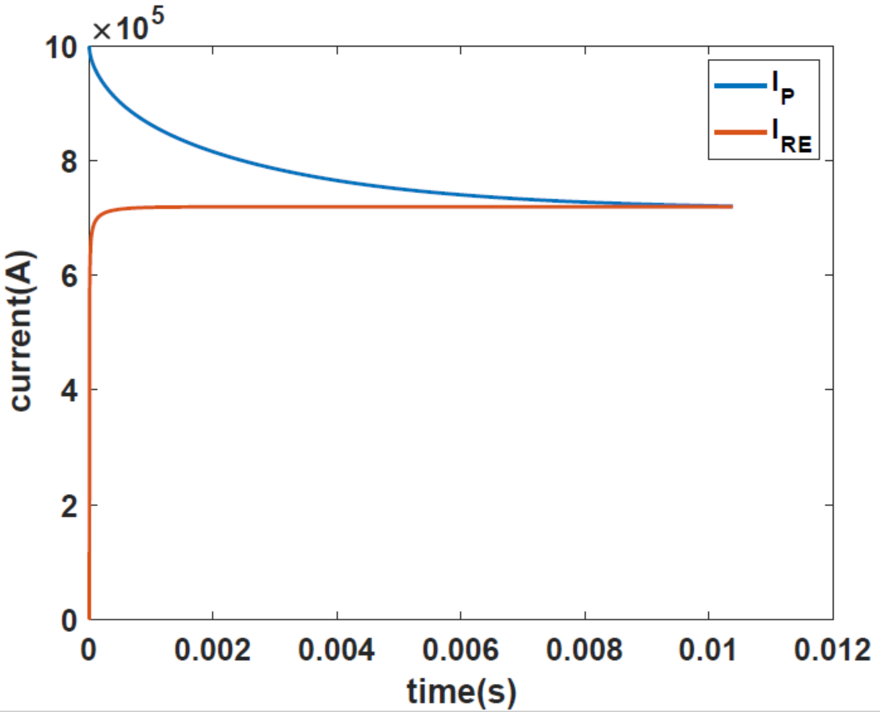
What to do next?

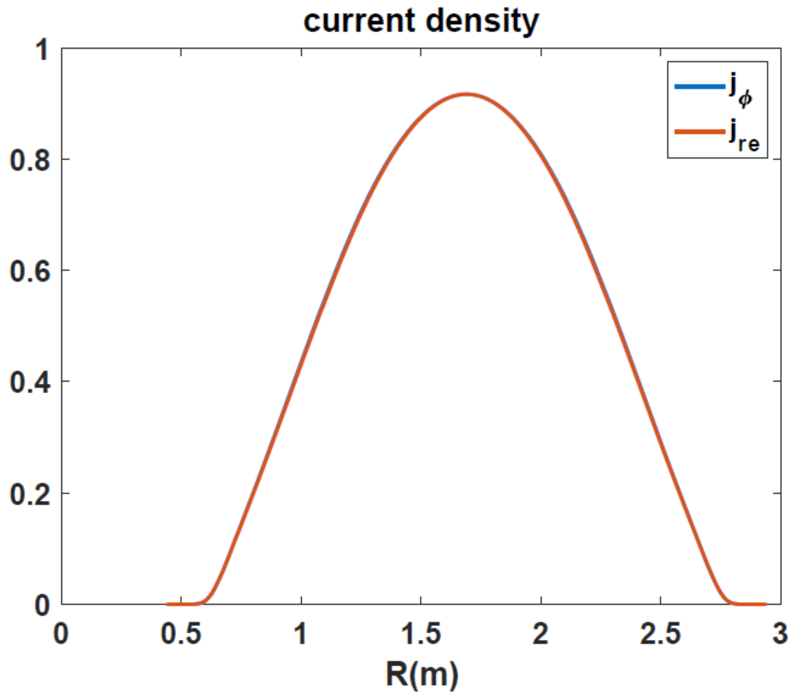
- Now running a case from the start with half the values of hyper and denm to test the sensitivity

Helical Band to remove runaway electrons

- Brendan Lyons performed a calculation last year with a conducting helical band that did not show large helical currents
- Can we try it again with the new coding that treats toroidal derivatives of resistivity correctly?
- GA is interested in getting a postdoc to work on this.   (Still need supporting letter?)

2D (cylindrical) RE with sources (12/19/2020)



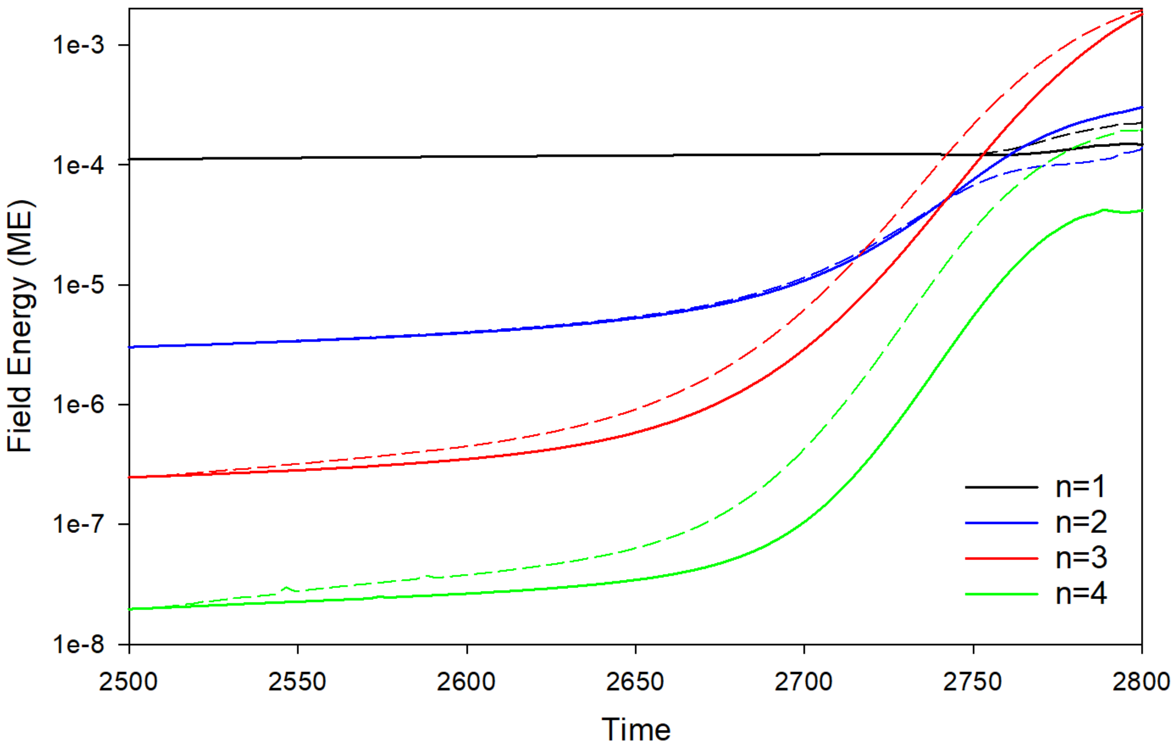


Chen Zhao

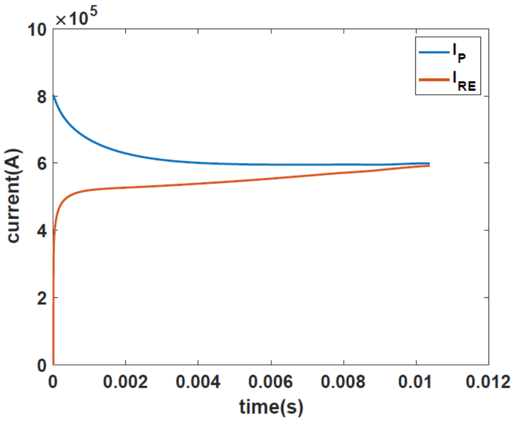
That's All I have

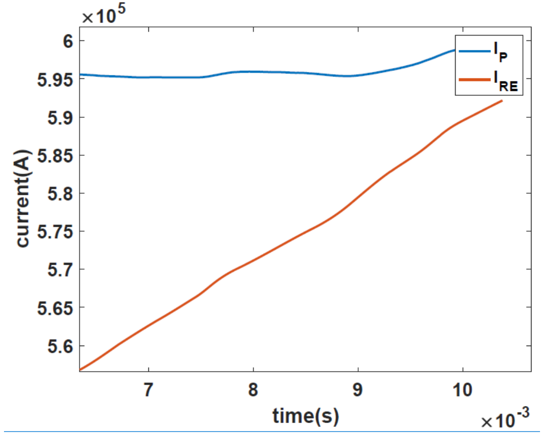
Anything Else ?

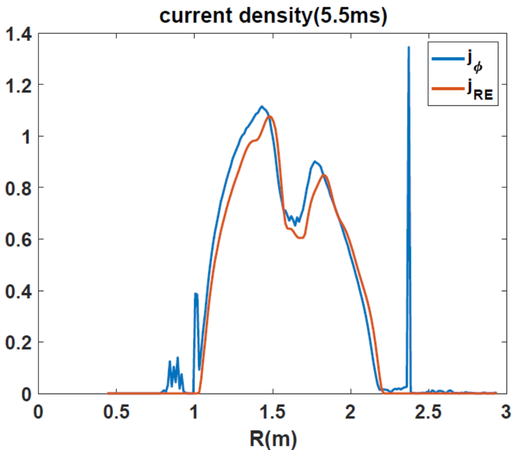
Energy in base case 36742317 (solid) and 16 plane case 37248033 (dashed)

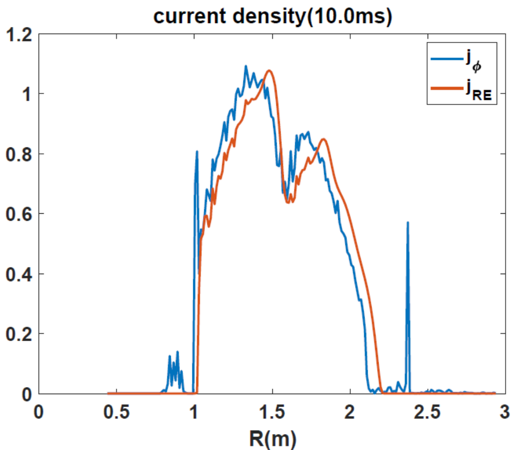


DIII-D 177053 with Argon





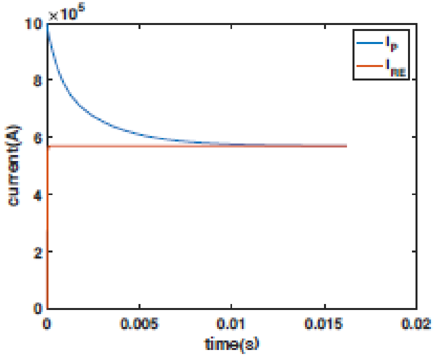


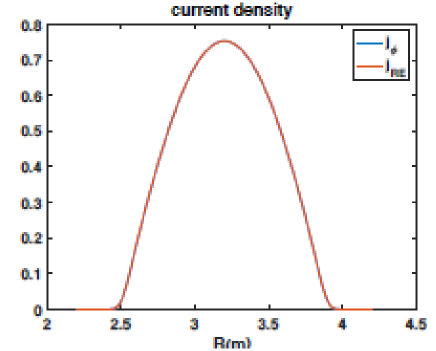


Chen Zhao

Same calculation in a Cylinder

M3D-C1 runaway generation with cylinder geometry





- Parameters:

$$\beta_0 = 0.15$$

$$a = 0.65m$$
$$\mathrm{R} = 1.7m$$
$$B_0 = 1.9T$$
$$\eta = 1.0\times10^{-4}$$
$$n_0 = 1.0\times10^{20}m^{-3}$$
$$c = 150v_A$$
$$N_{elements} = 12261$$
$$\Delta t = 1.0\tau_A$$

- The plasma current was equal with plasma current by the runaway current at about 12ms.
- The radial profile of runaway current profile are exactly same when the plasma current equal to runaway current.

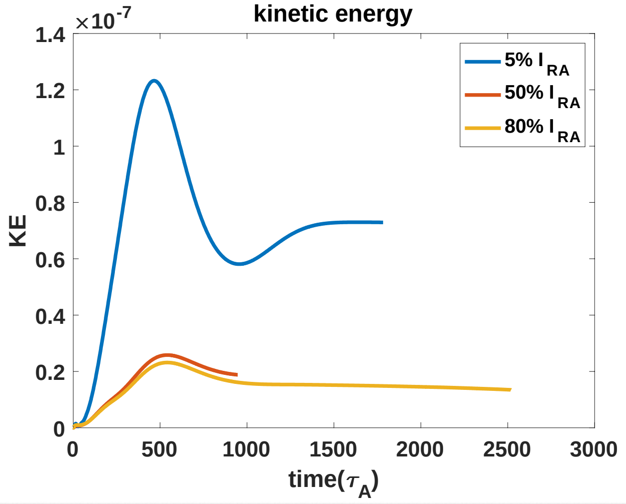
Progress on other shots?

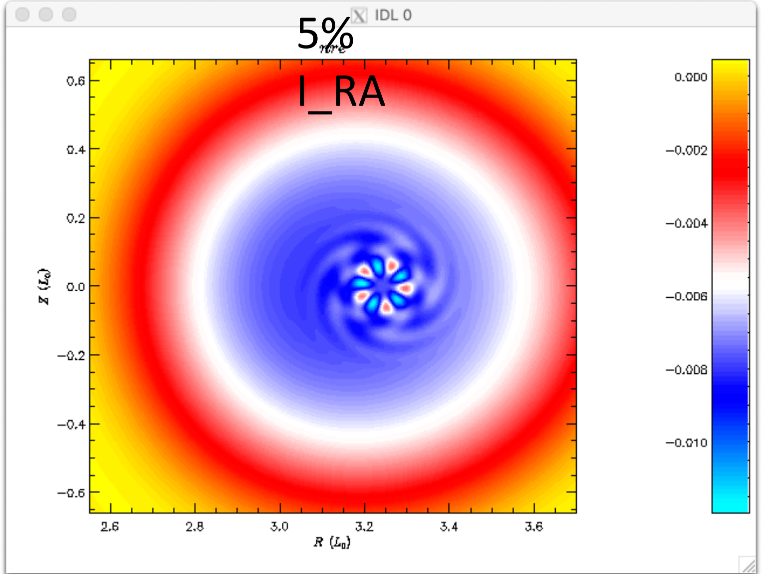
- M3D-C1/NIMROD 3D Benchmark

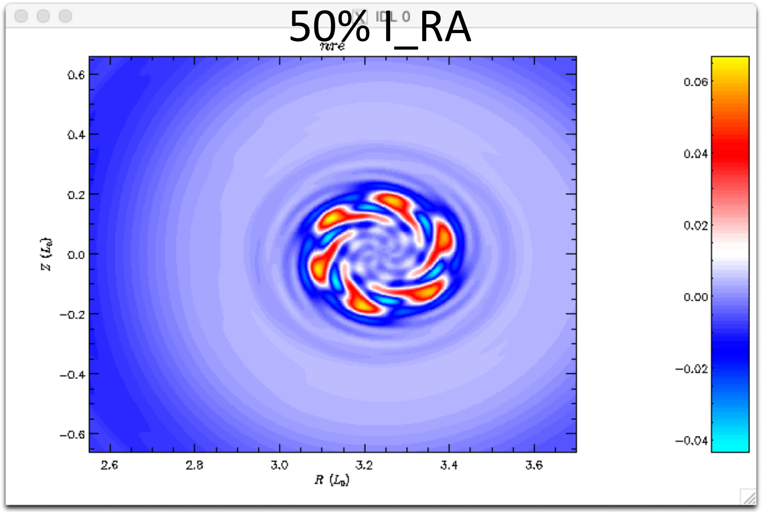
NSTX shot 1224020 – Fast ion transport with coupled kink and tearing modes
Chang Liu

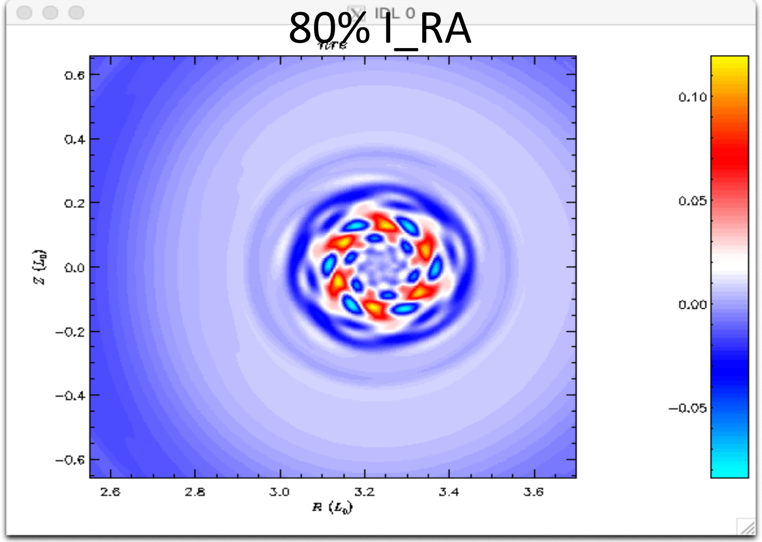
DIII-D Neon pellet mitigation simulation for KORC
- Brendan Lyons trying to extend 8 plane case to 32 planes

SPARK ? Do we need to do anything?

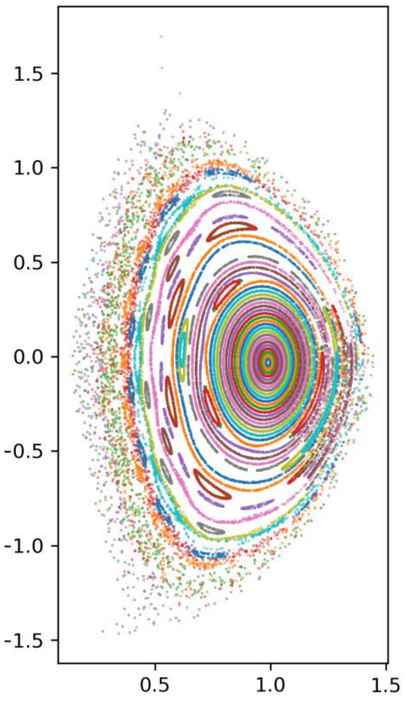

kinetic energy
×10^-7
KE
time(τ_A)
5% I_RA
50% I_RA
80% I_RA
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0
500
1000
1500
2000
2500
3000


5%
I_RA
IDL 0
R (L_0)
Z (L_0)


50% I_RA
R (L_0)
Z (L_0)


80% I_RA
R (L_0)
Z (L_0)

NSTX shot 1224020 – Fast ion transport with coupled kink and tearing modes
Chang Liu



- In the original geqdsk file, the equilibrium was poorly converged. New one is much better. Has q(0) = 1.3
- Chang has analyzed new equilibrium (left)
- No ideal (1,1) mode, several tearing modes

- If goal is to get unstable (1,1) mode, likely need to lower q(0)
- Adding sheared toroidal rotation should help stabilize resistive modes.

Grad-B drift in M3D-C1—HF side

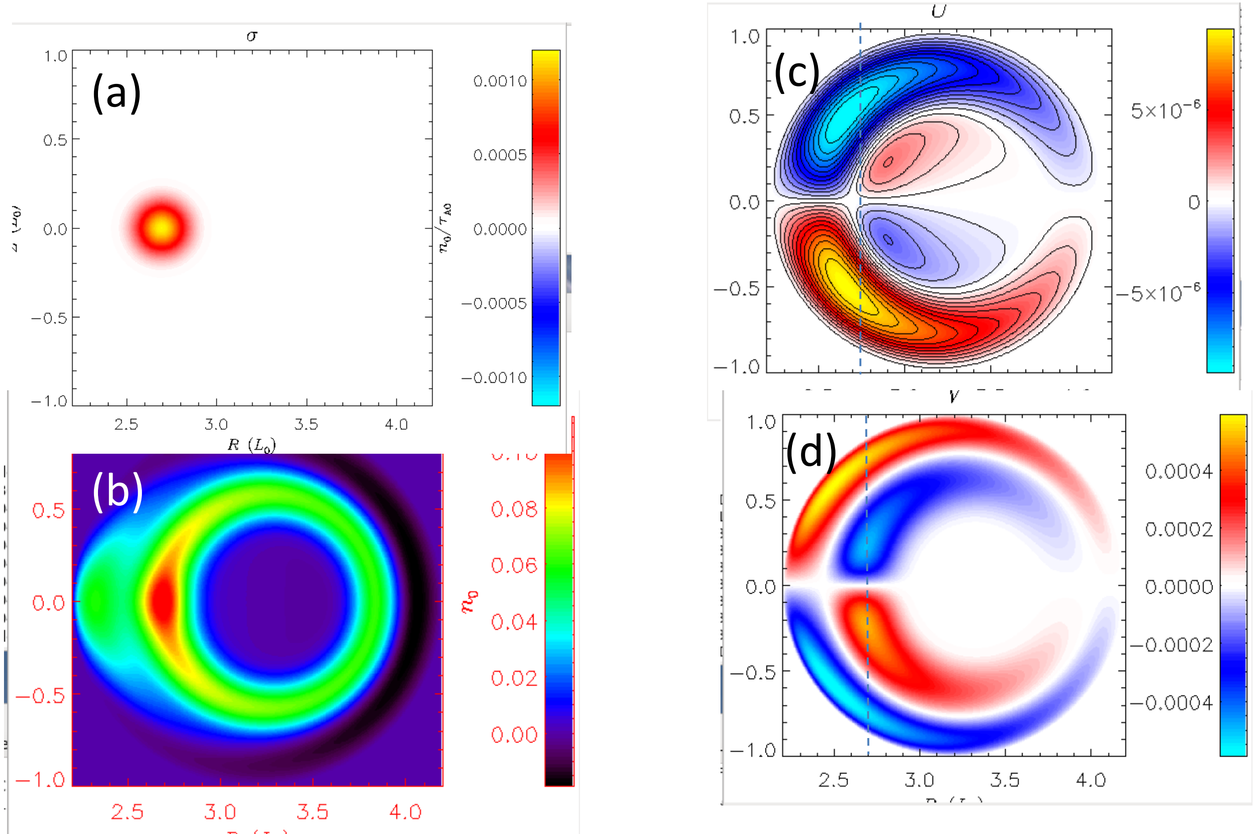
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

(a) Density source in 1F toroidal equilibrium

(b) Change in density after $10^3\ \tau_A$

(c) Poloidal velocity stream function

(d) Toroidal velocity contours



Grad-B drift in M3D-C1– LF source

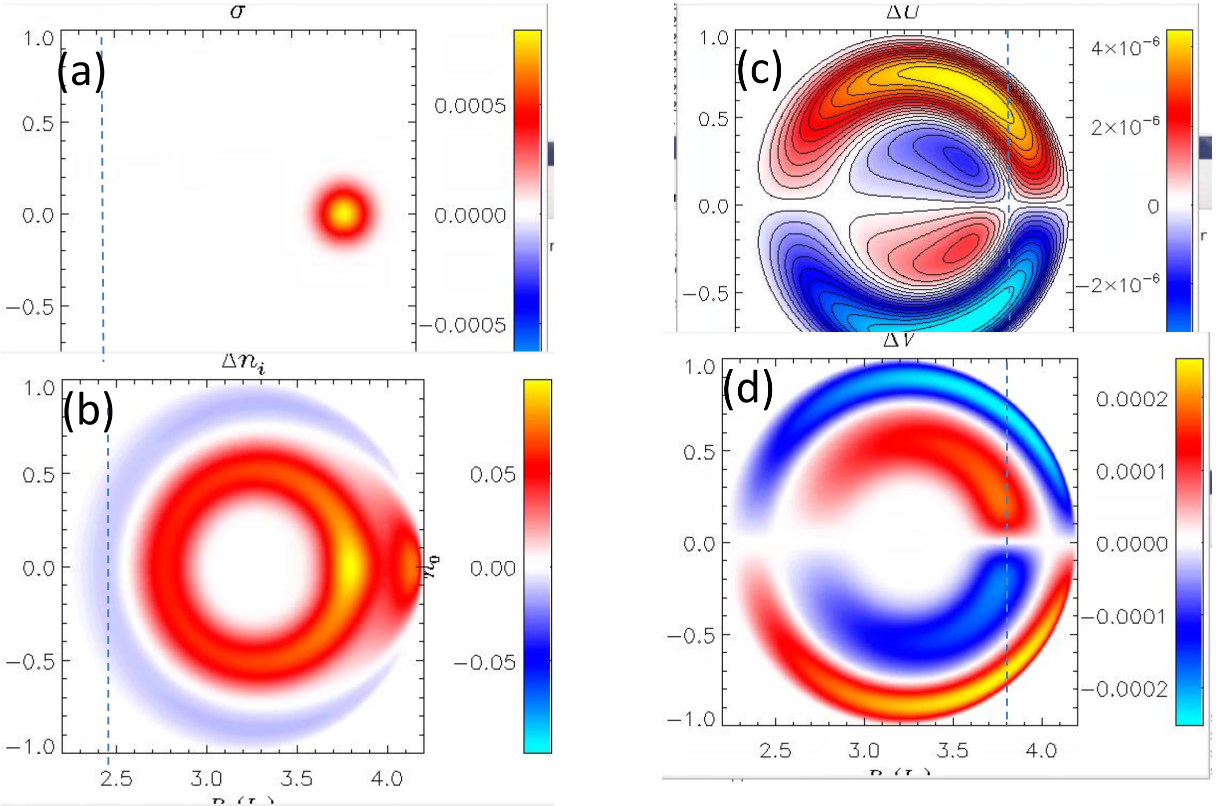
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

(a) Density source in 1F toroidal equilibrium

(b) Change in density after $10^3\ \tau_A$

(c) Poloidal velocity stream function

(d) Toroidal velocity contours



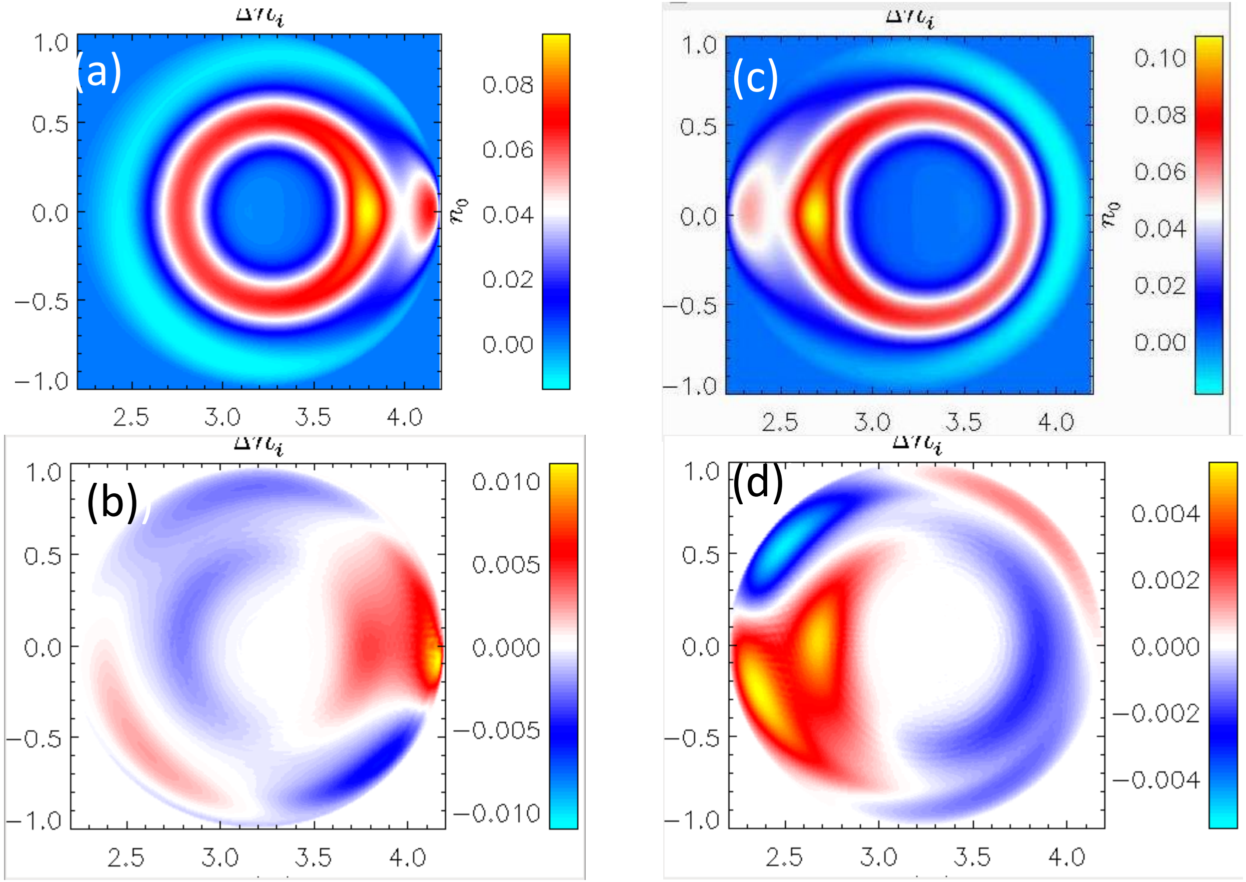
Grad-B drift in M3D-C1—2F effects

(a) 2F density change after 10^3 τ_A for LF side source

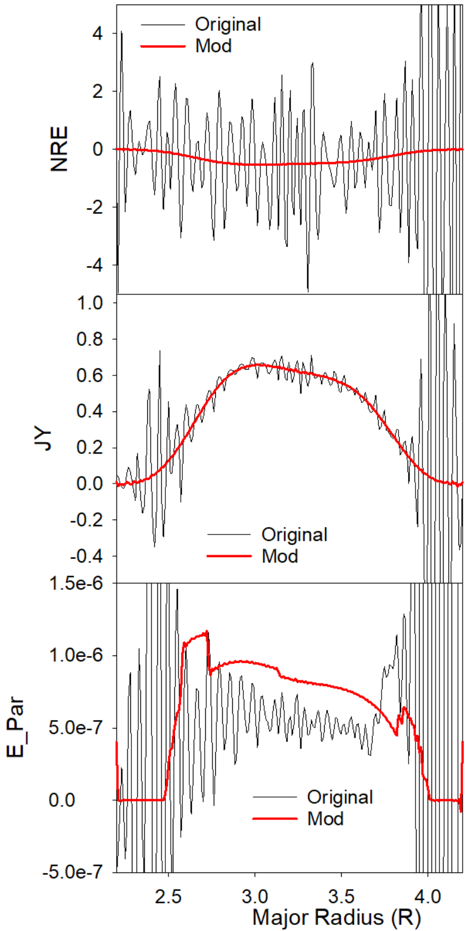
(b) Difference in 1F and 2F density (LF)

(c) 2Fdensity change after 10^3 τ_A for HF side source

(d) Differencein 1F and 2F density (HF)



Sawtoothing discharge with runaway electrons

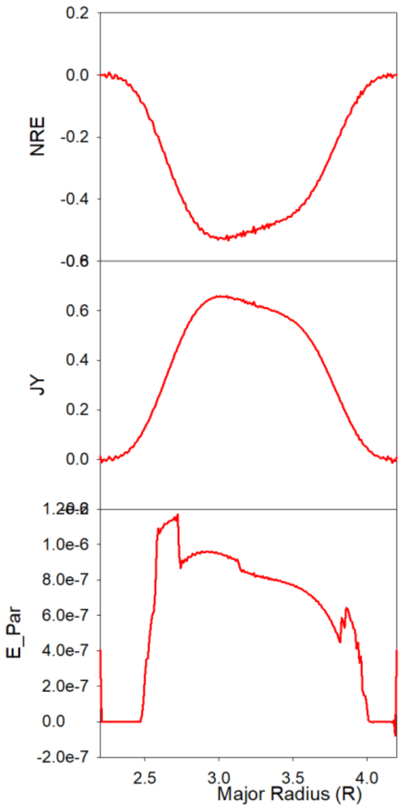


Profiles of nre, jy, and E_par after 30 timesteps

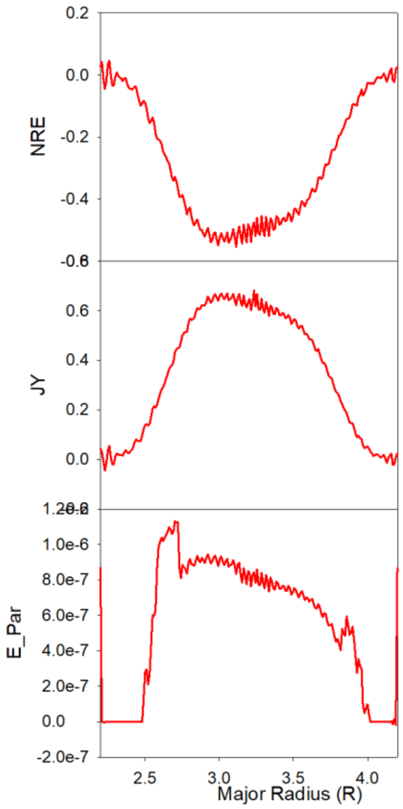
Original: /p/tsc/m3dnl/Isabel/Chen2D
Mod: /p/tsc/m3dnl/Isabel/Chen2D-mod1

Changed:
mesh size
"regular"
"integration points"
ipres=1
cre
pedge
viscosity
denm
equilibrium density

Longer times develops oscillations



Change from t=6 to t=100



- Short wavelength oscillations occur first in nre and then in other quantities (jy, e_par)
- Could we add some smoothing?