M3D-C1 ZOOM Meeting

02/01/2021

General

1. Status of new Princeton/PPPL computer "stellar"

CS Issues

1. GPU solve status (J. Chen, LBL)
2. Mesh Adaptation status RPI/Brendan
3. Local and other systems
4. NERSC Time
5. Changes to github master since last meeting

Physics Studies

1. Cylinder case with Avalanche source term
2. Sawteeth with runaways
3. Progress in 3D MHD-C1/NIMROD mitigation benchmark
4. Helical band to remove runaway electrons (Brendan)
5. Carbon Mitigation in NSTX-U (shell pellet)
6. Other?

Status of new Princeton/PPPL Computer "stellar"

Bill Wichser (2/1/21)

- We have two nodes up, the scheduler has been configured, and space for /home is available. We await IBM to install the hardware required for /scratch/gpfs so there is no big filesystem available as of yet.We were hoping to have IBM come today to start the install but that isn't happening!

- The operating system is installed but all tools may not yet be available. Josko continues to build the MPI and related tools.

- By the end of this month we should have a rack or three of equipment available along with filesystems but again this would be in a friendly user mode as we work out any bugs and issues as we continue to rack and wire up the nodes.

- The core Infiniband has yet to be installed so we are working with a single IB switch at this time. On the node front, due to covid, we are only able to rack about 15 nodes per day so it has been a very slow go.

GPU Solve status

- GPUs give little or no speedup on solves for small problem size
- Larger problem sizes run out of memory

M3DC1/unstructured/regtest/RMP_nonlin

PERSEUS 6.5GB/core
TRAVERSE CPU 8. GB/core
TRAVERSE GPU 8. GB/gpu

Matrix	282	221	17,768,178,788	0.
Vector	3448	2759	329,011,624	0.
Krylov Solver	54	40	15,992,160	0.

PERSEUS 4 nodes and 16 cores per node, totally 64 cores, runs
TRAVERSE CPU 4 nodes and 16 cores per node, totally 64 cores, failed
TRAVERSE GPU 8 nodes and 8 cores per node, totally 64 cores, runs

Jin Chen

Mesh Adaptation Status

01/17/21: RPI Email to Brendan

“The capability to adapt 2D meshes is ready and everything is updated in the git. Please find attached the document describing the procedure to use the capability along with a few examples of meshes.”

Brendan now testing.

Local Systems

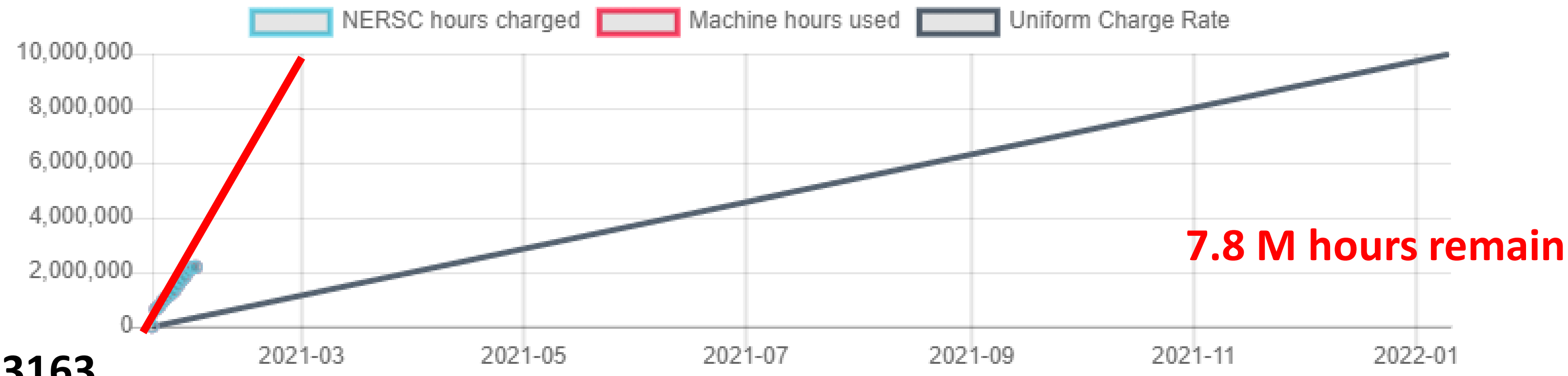
- PPPL centos7(02/01/21)
  - 5 regression tests PASSED on centos7:
  - RMP_nonlin failed
- PPPL greene (02/01/21)
  - 4 regression tests PASSED
  - RMP_nonlin failed
  - No batch file found for pellet
- EDDY (2/01/21)
  - 6 regression tests PASSED
- TRAVERSE(1/4/21)
  - Code compiles
  - Regression test failed: split_smb not found in PATH
  - Have not yet tried shipping .smb files from another machine

Other Systems

- Cori-KNL (1/25/2021)
  - 6 regression tests passed on KNL
  - RMP_nonlin **failed …** differences growth in time, agrees with eddy
- Cori-Haswell (1/25/2021)
  - 4 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
  - RMP_nonlin **failed** …however, agrees with Cori-KNL and eddy
- 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 started 10:00 AM ET Jan 20, 2021:
- mp288 received 10M Hrs for CY 2021
- We will certainly exhaust this in 2-3 months. Transition to stellar (PU/PPPL)

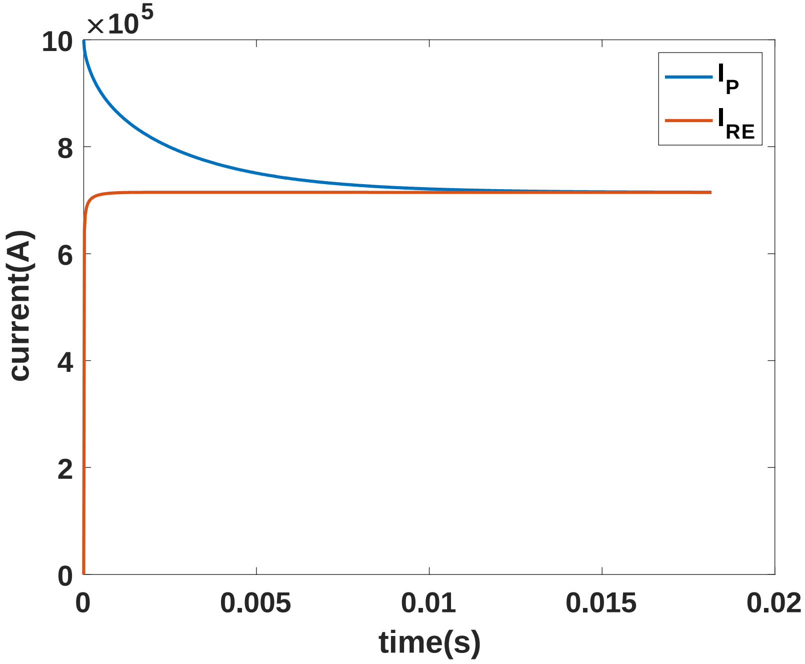
Changes to github master since last meeting

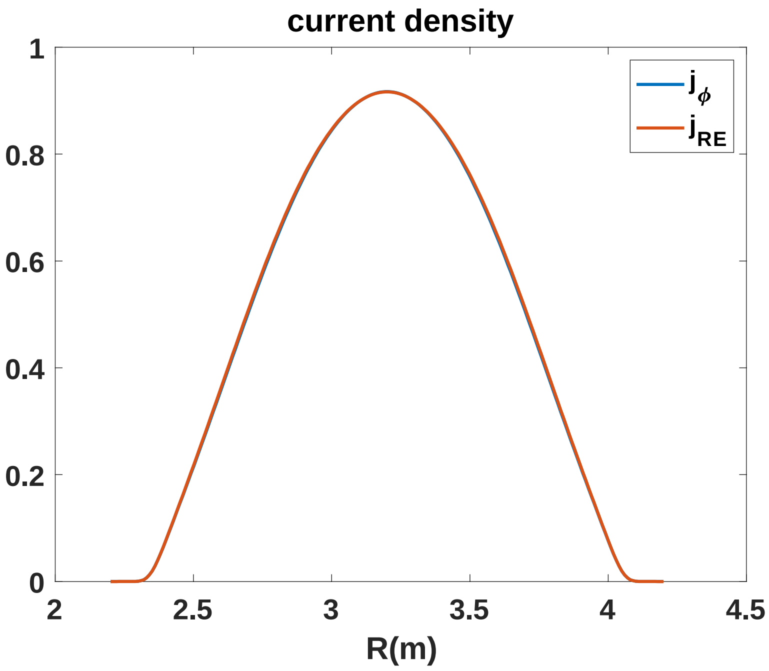
- S. Seol
  - 01/26/21: m3dc1_mesh_adapt modified to run on 3D mesh
  - 01/30/21: adding Brendan's adaptation routine
  - 01/30/21: debugging in m3dc1_mesh_adapt

- N. Ferraro
  - 01/26/21: Updated RMP_nonlin which was broken by the fix for the toroidal current
  - 01/26/21: "version number" corrections to plasma, wall, and toroidal current
  - 01/28/21: Updates to how code finds and treats private flux regions. This should help with near-double-null cases where two private flux regions are in the domain

- S. Jardin
  - 02/01/21: added diagnostic field "potential2"

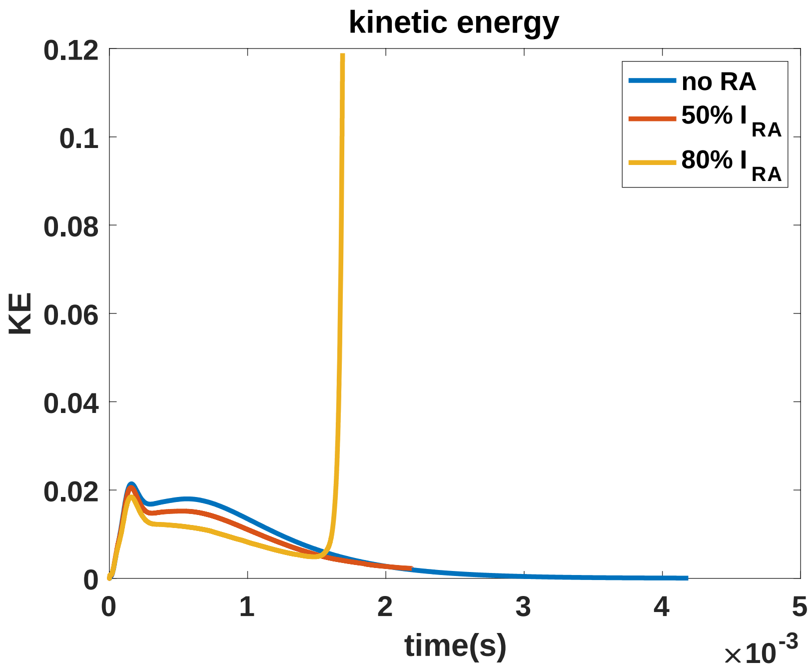
Cylinder case with avalanche runaway source term



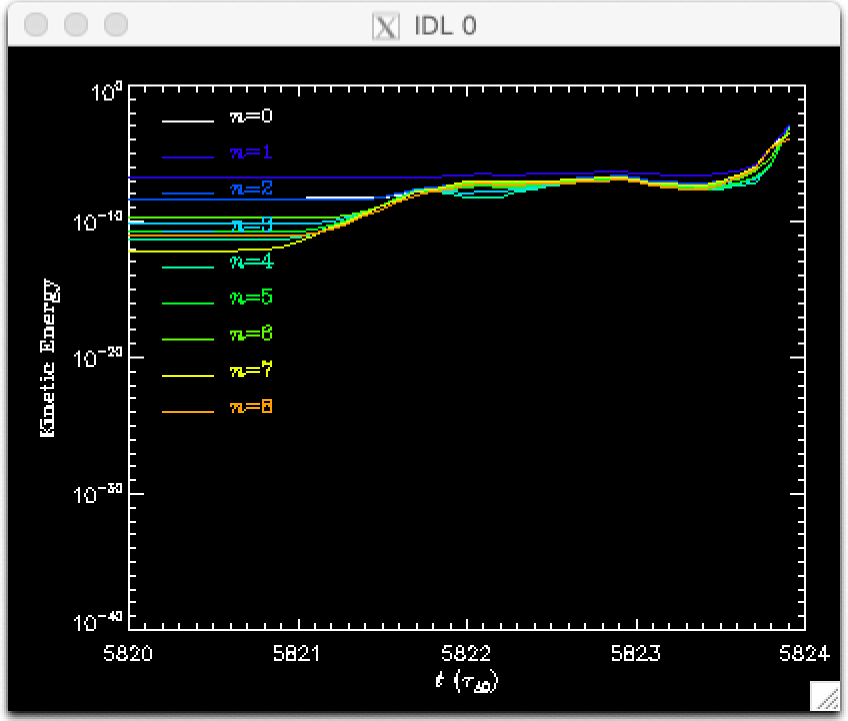


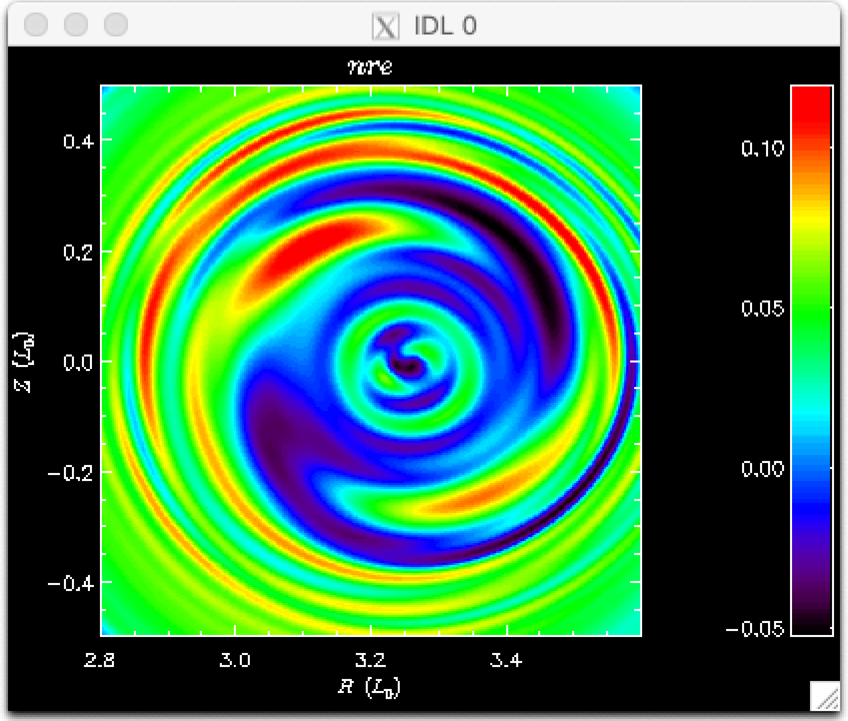
The avalanche term works well on 2d cylinder case

Sawteeth case with runaways



The case with 80% runaway current has instability at about t=1.5ms.
No runaway current and 50% runaway current cases do not have instabilities.

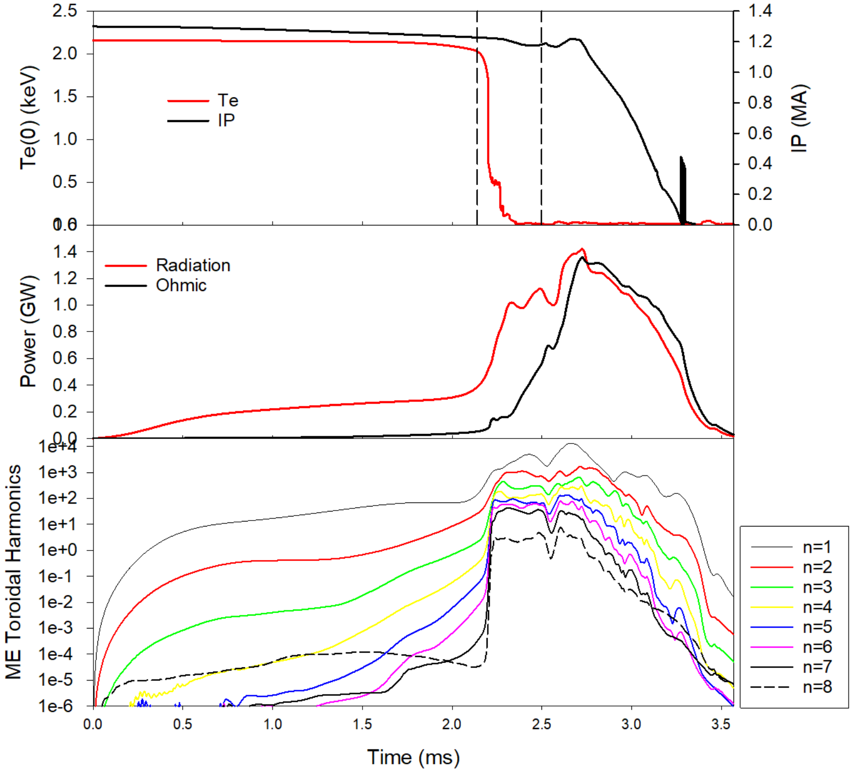


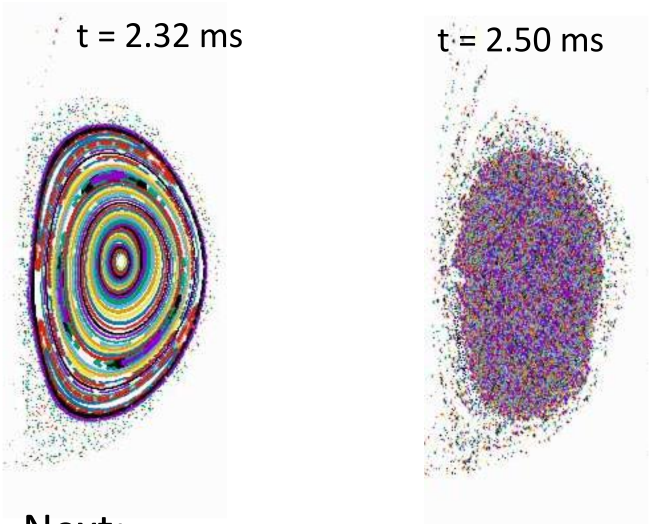


I think all harmonics (n=0~8) coupled together at about t = 5823.8 tau_A and maybe this caused the the numerical instability later. And then the energy evolution became strange.

B. Lyons 3D Benchmark case with NIMROD

case “f” with denm= 4.05 e-6





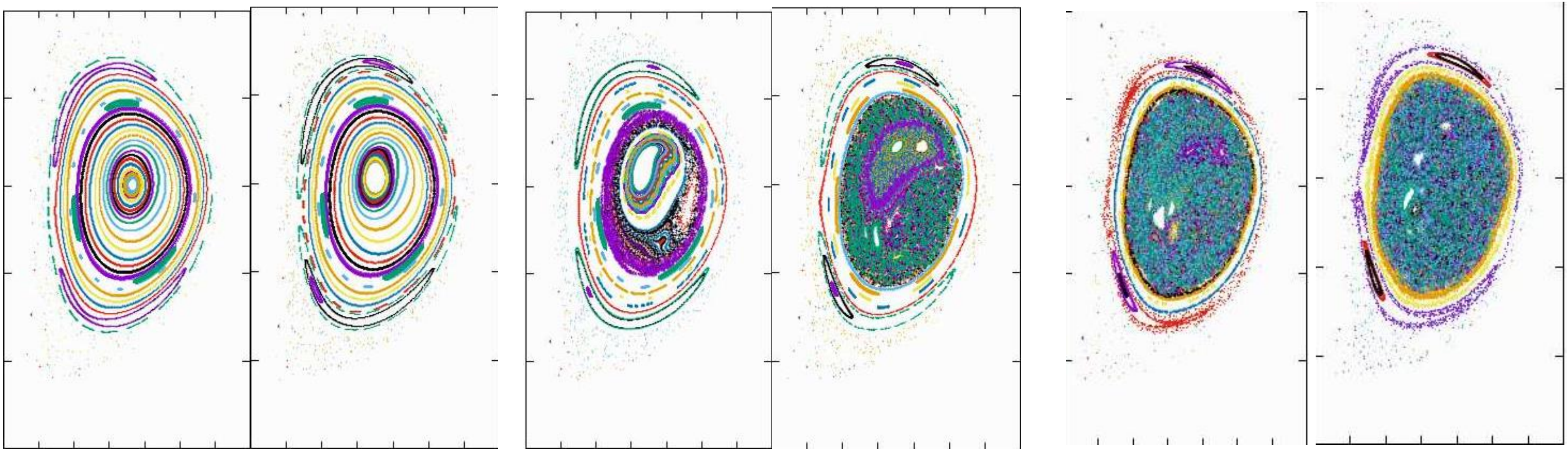
Next:

- More Poincare plots between 2.32 & 2.50
- convergence test in # of planes: NPLANES

/global/cscratch1/sd/u431/BLH8f

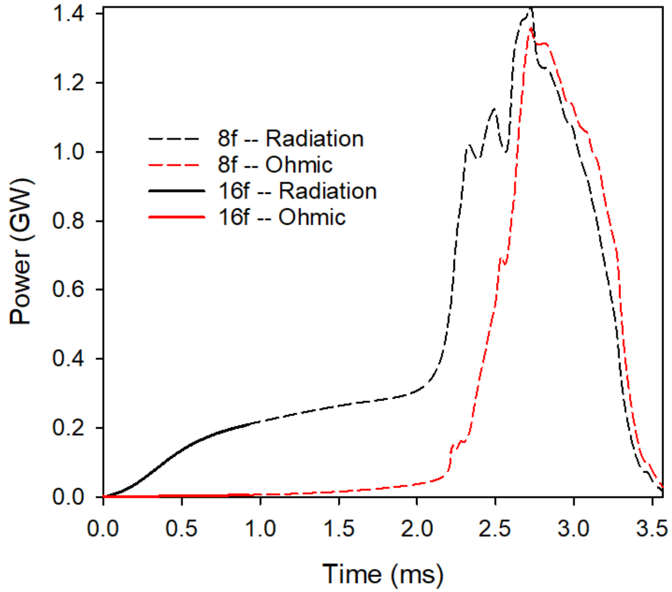
Additional Poincare Plots

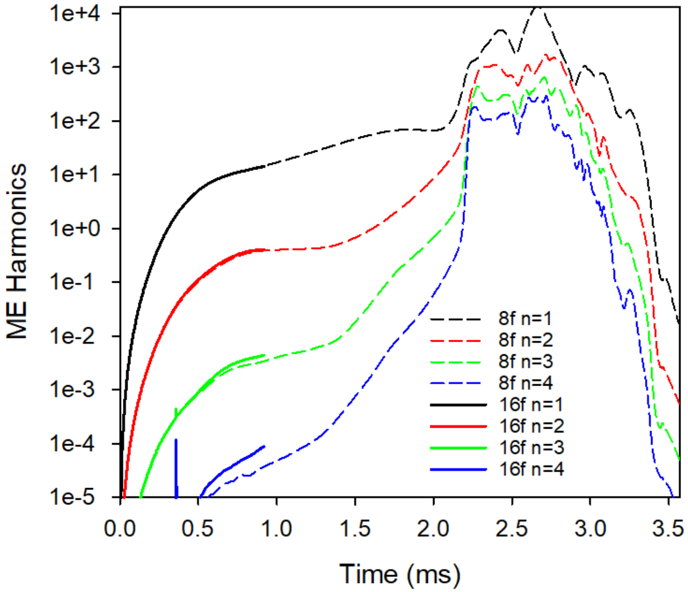
12—t=2.14 ms 14—t=2.18 ms 16—t=2.21 ms 18—2.25 ms 20—t= 2.28 ms 22—t=2.32 ms



/global/cscratch1/sd/u431/BLH8f-CU/Plots

16 vs 8 planes convergence test (now running)

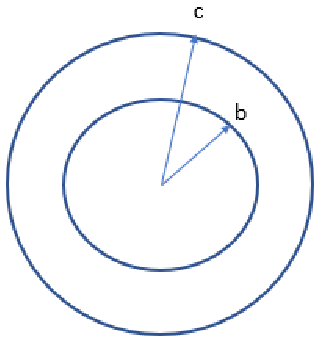




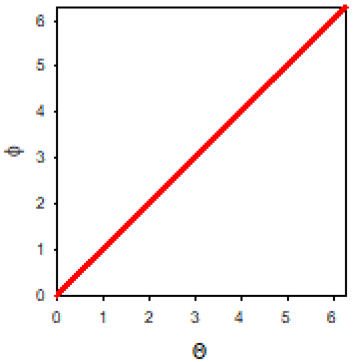
/global/cscratch1/sd/u431/BLH16f

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
- Want to try and reproduce, first in circular cylindrical geometry.



Circular cylindrical geometry.
Conductor in region b < r < c



3D helical band of good conductivity at |Θ-ϕ| < δ

#1. Will a purely toroidal voltage from the plasma current decaying drive a helical current in this geometry?

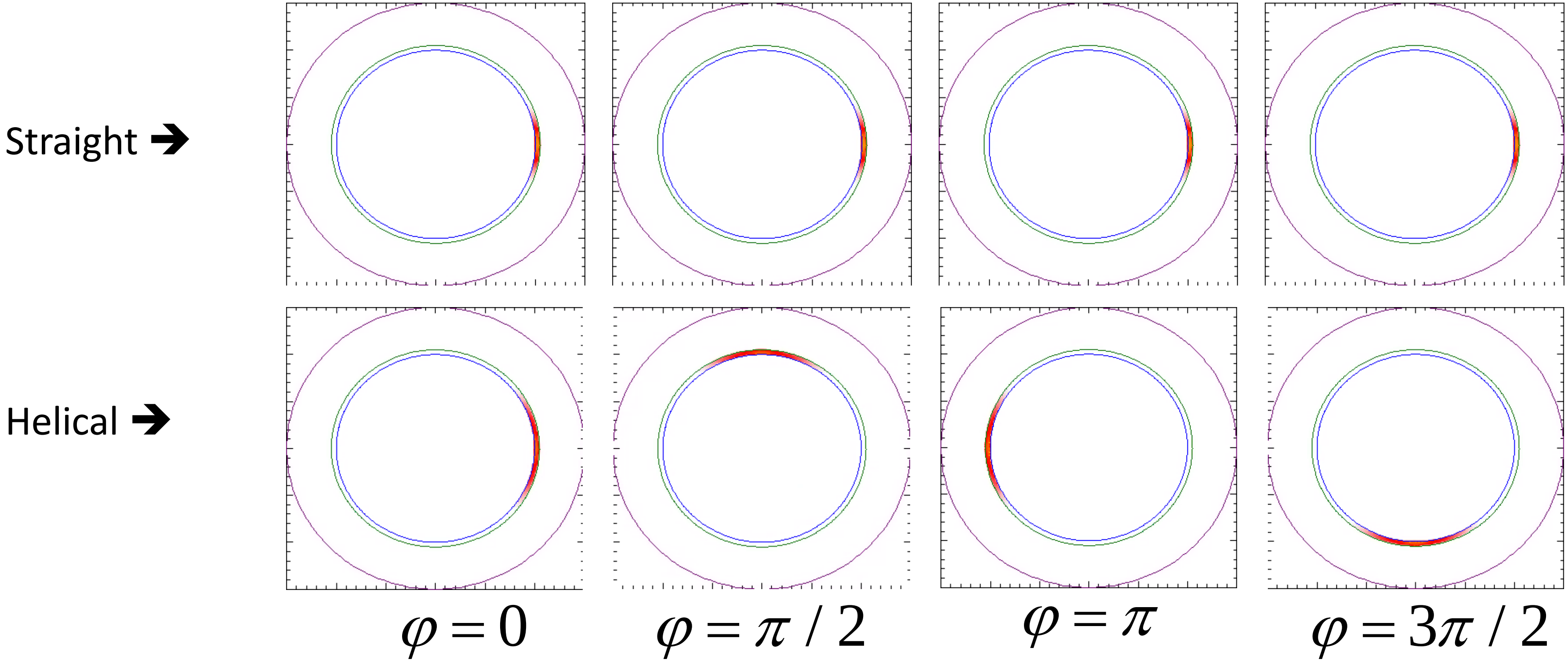
$$\nabla \times \mathbf{E} = 0 \quad \Rightarrow \quad \mathbf{E} = -\nabla\Phi + \frac{V_L}{2\pi}\nabla\phi$$

$$\mathbf{J} = \sigma\mathbf{E}$$

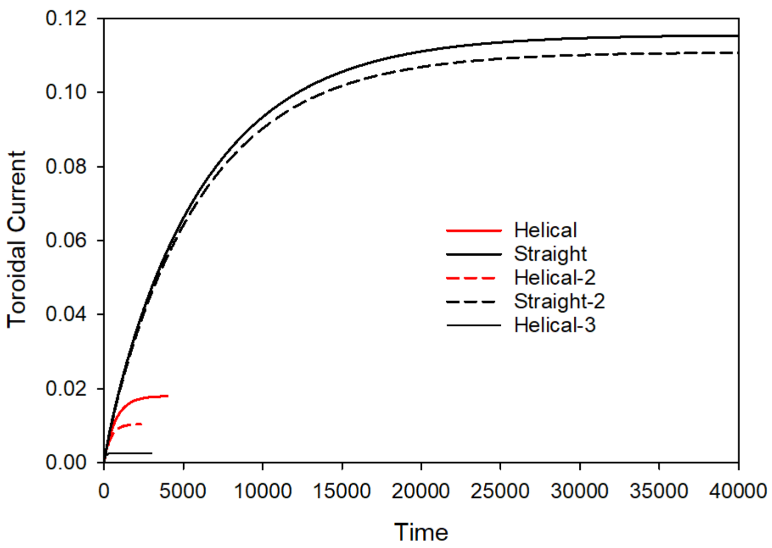
What is driving the current in the θ direction? It can't be Φ unless

$$\int_0^{2\pi} \sigma^{-1} J_\theta d\theta = \int_0^{2\pi} \frac{d\Phi}{d\theta} d\theta = 0$$

Comparison between Straight and helical band



Toroidal current vs time for same applied voltage V_L



Helical and Straight

1.e-2 > η > 1.e-6

Helical-2 and Straight-2

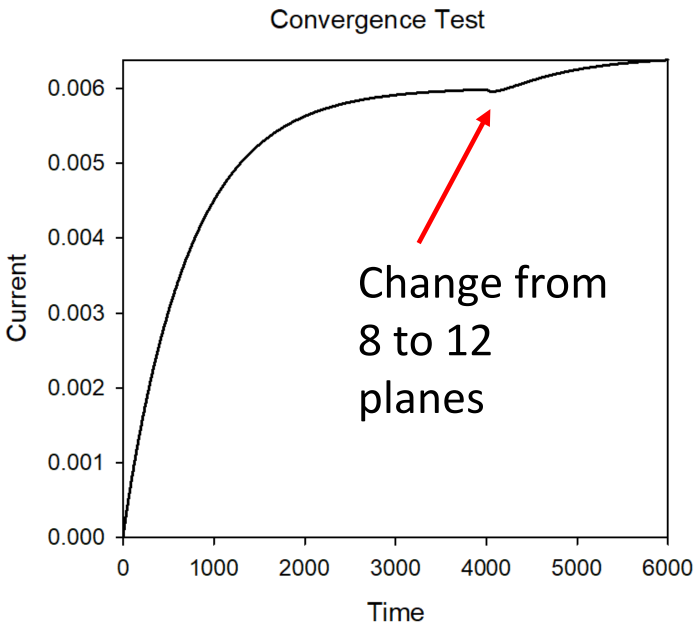
2.e-2 > η > 1.e-6

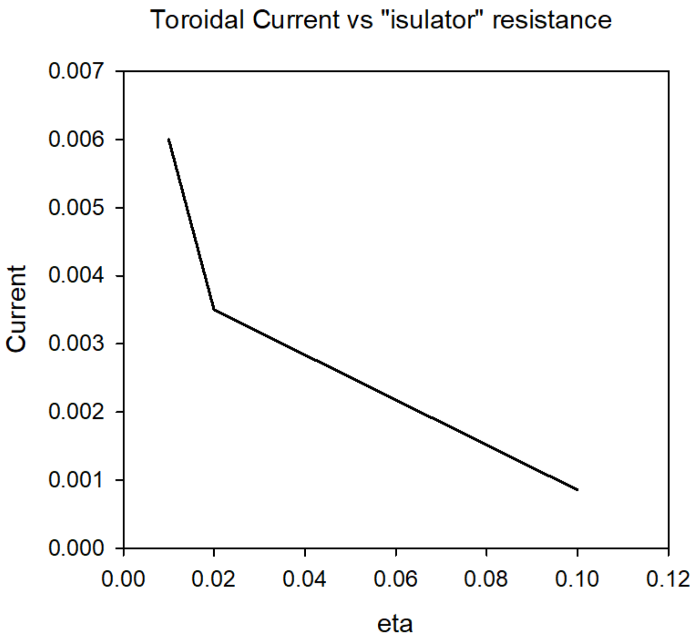
Helical-3

1.e-1 > η > 1.e-6

Same applied voltage V_L drives about 6 times less current in helical band than in straight band. Even less when “insulator” conductivity is increased.

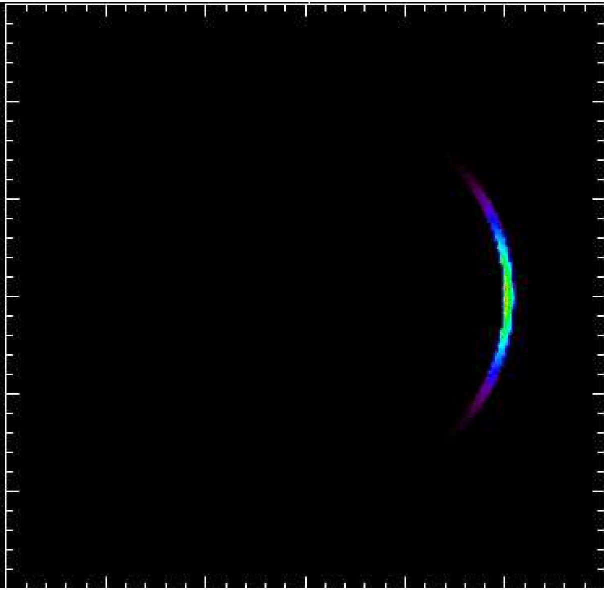
Some Convergence tests



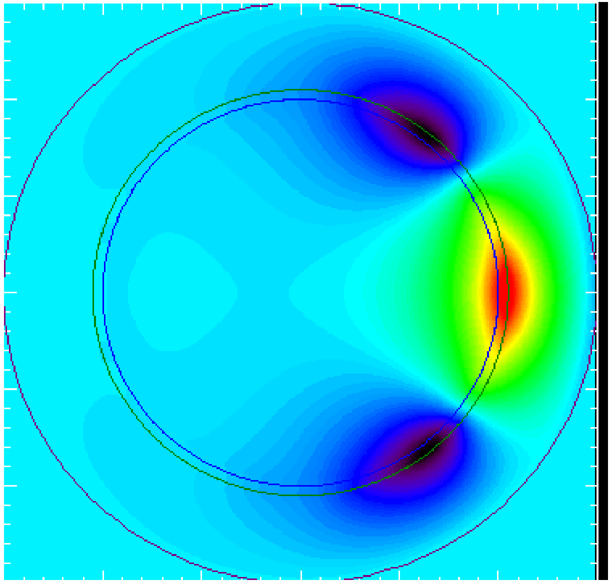


Scalar Electrical Potential Plots

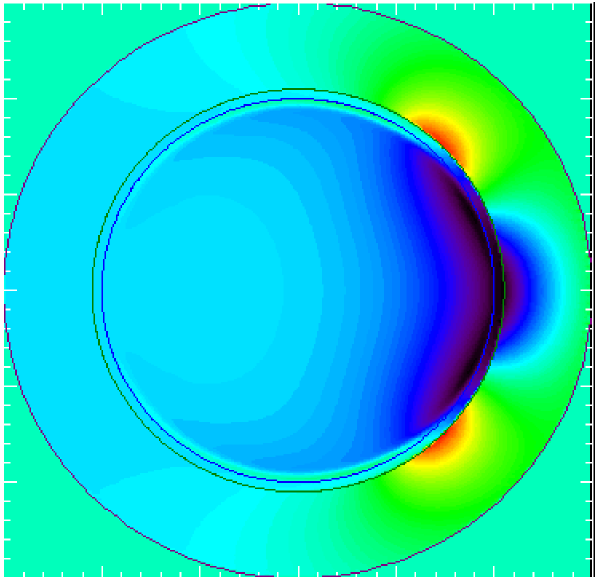
J_φ



$\frac{\partial \Phi}{\partial \varphi}$

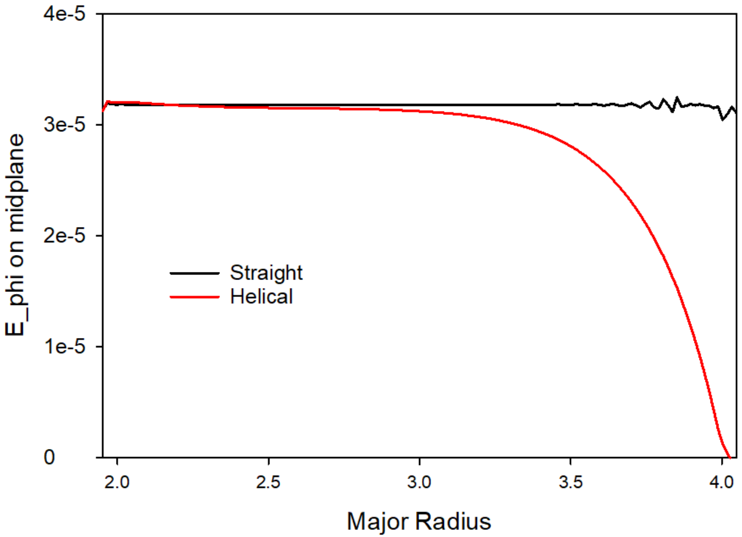


$\frac{\partial \Phi}{\partial z}$



$$\nabla_\perp \bullet \frac{1}{R^2} \nabla \Phi = \nabla_\perp \cdot \eta \left[-\frac{1}{R^2} \nabla F \times \nabla \varphi - \frac{1}{R^2} \nabla f'' \times \nabla \varphi - \frac{1}{R^4} \nabla_\perp \psi' \right]$$

Compare E_phi on midplane at ϕ=0



For straight case: $E_\varphi = V_l / 2\pi R_0$

For helical case: $E_\varphi = V_l / 2\pi R_0 - R_0^{-1} \partial\Phi / \partial\varphi$

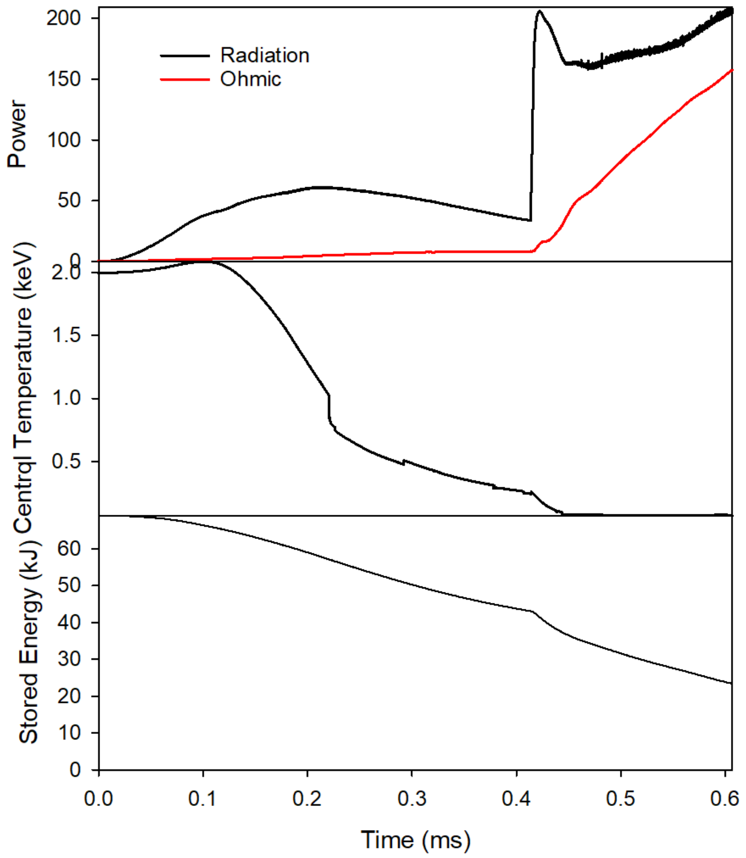
The electrical potential arises, opposing the loop voltage, as it is needed to drive the poloidal current

$$\Phi \cong \left(V_L / 2\pi\right)\left(\frac{r}{a}\right)^2 \sin(\theta - \varphi)$$

This electrical potential drives the current in the theta direction:

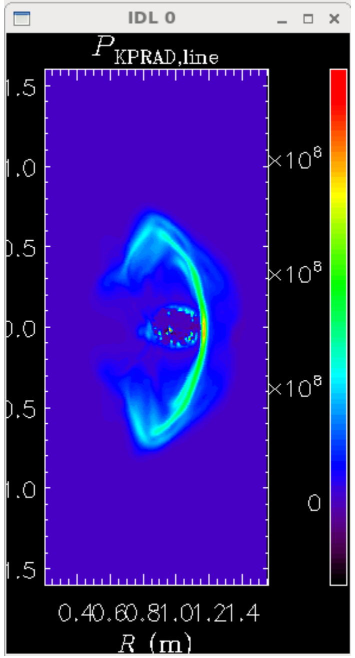
$$J_\theta = \sigma \frac{1}{r}\frac{\partial\Phi}{\partial\theta} = \frac{\sigma V_L}{2\pi a}\left(\frac{r}{a}\right)\cos(\theta - \varphi) \qquad J_\varphi = \frac{\sigma V_L}{2\pi R_0}\left(1 - \left(\frac{r}{a}\right)^2 \cos(\theta - \varphi)\right)$$

Carbon Mitigation in NSTX-U (shell pellet)



Shell carbon pellet in NSTX (now running)

Radiation
t = 0.598 ms

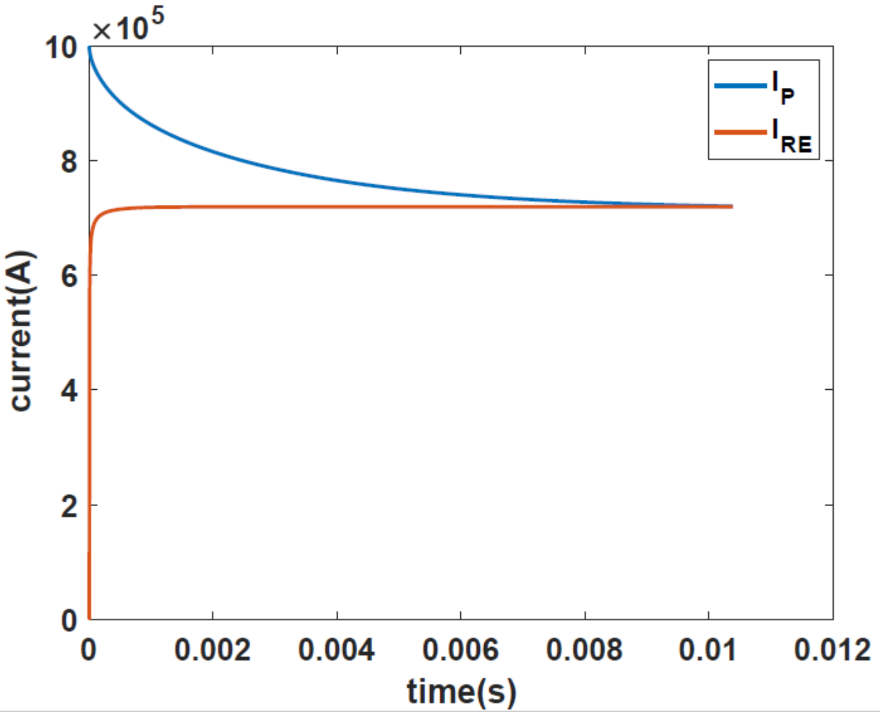


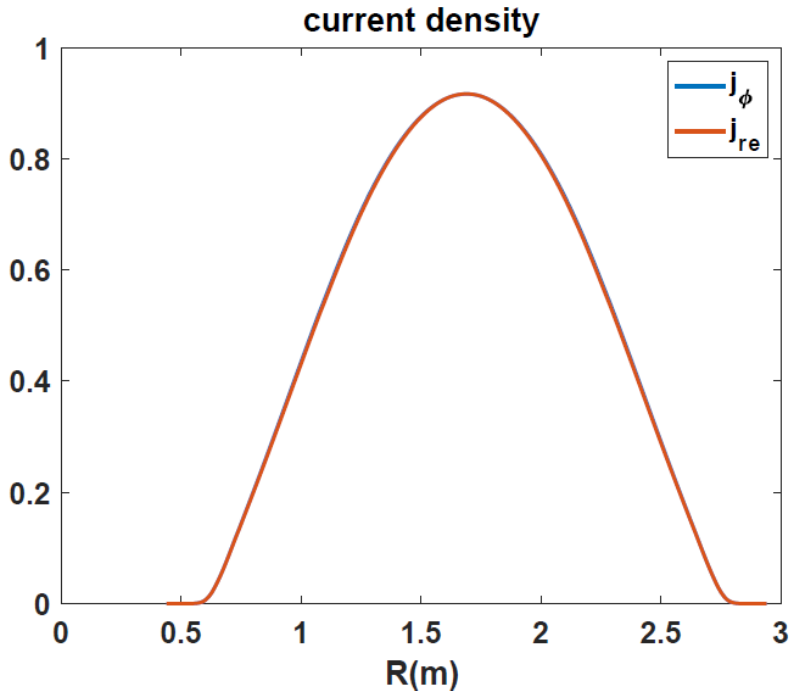
Trying to keep radiation "hot spots" from forming and causing crash. To date, by decreasing dt.

That’s All I have

Anything Else ?

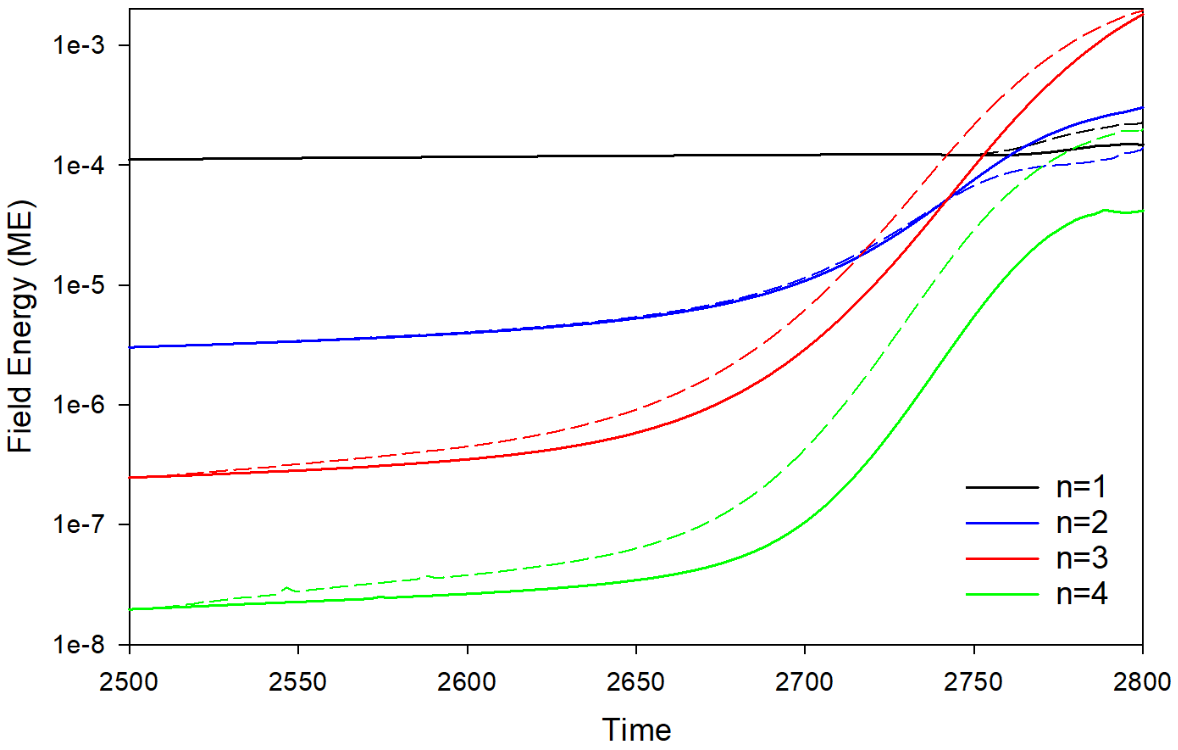
2D (cylindrical) RE with sources (12/19/2020)



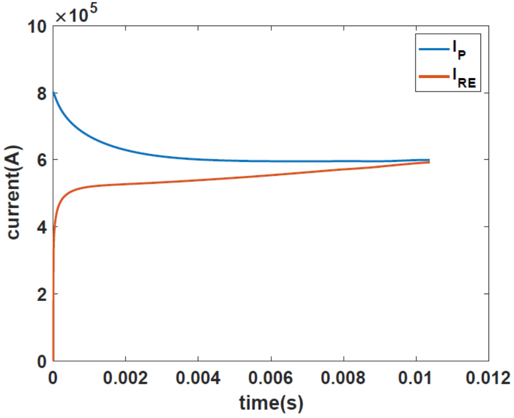


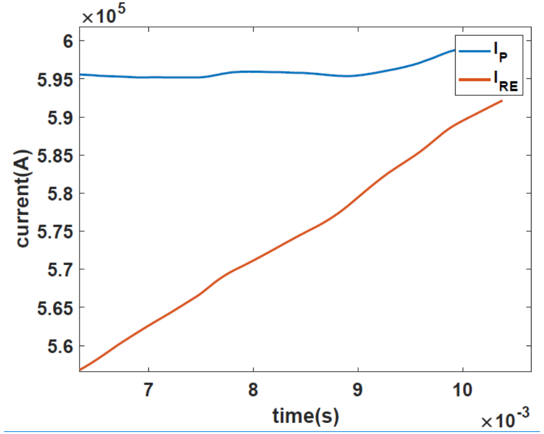
Chen Zhao

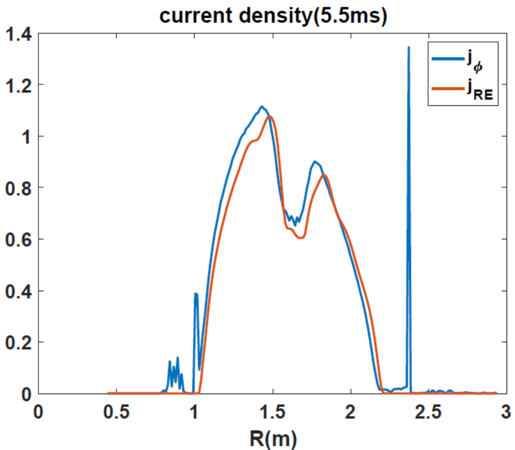
Energy in base case 36742317 (solid) and 16 plane case 37248033 (dashed)

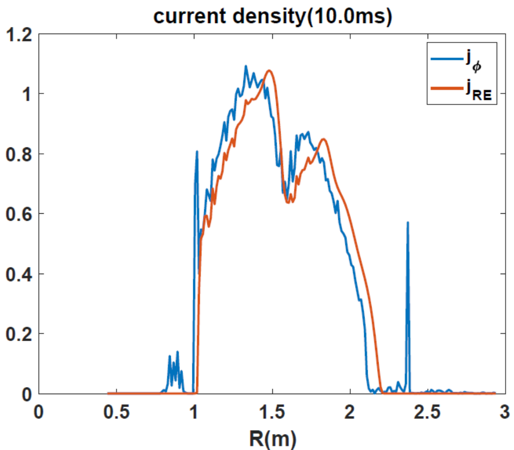


DIII-D 177053 with Argon





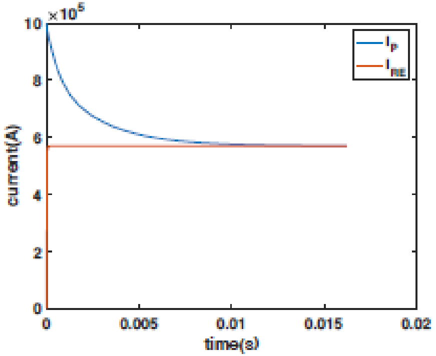


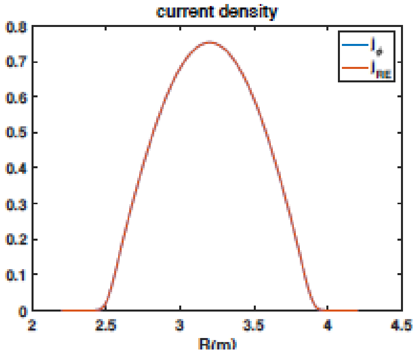


Chen Zhao

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.

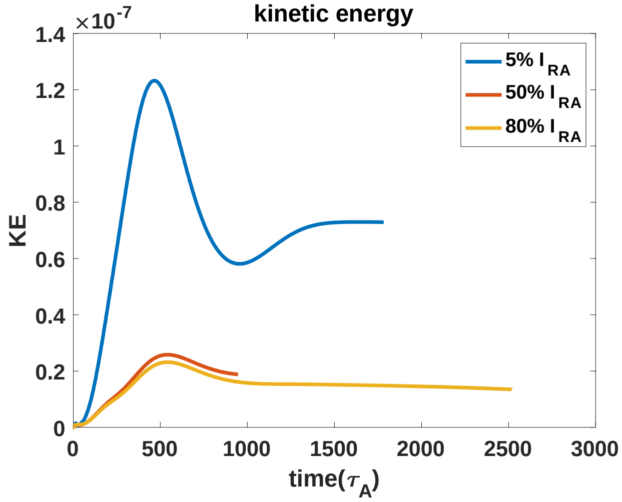
Progress on other shots?

- M3D-C1/NIMROD 3D Benchmark

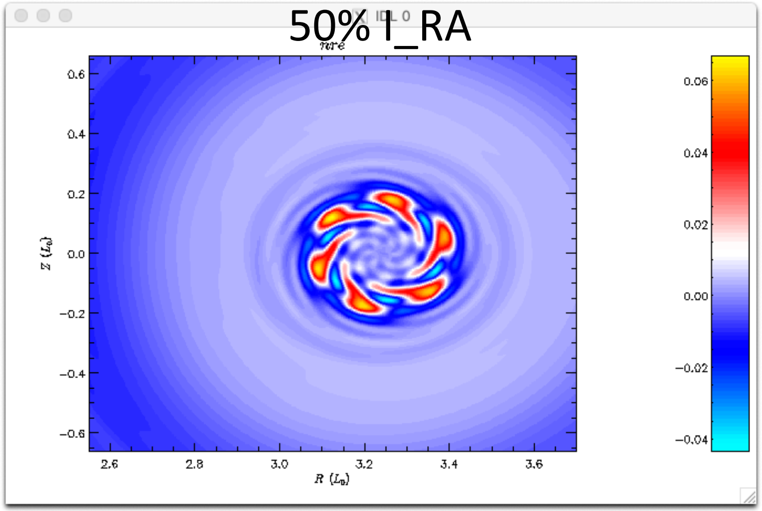
NSTX shot 1224020 – Fast ion transport with coupled kink and tearing modes
Chang Liu

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

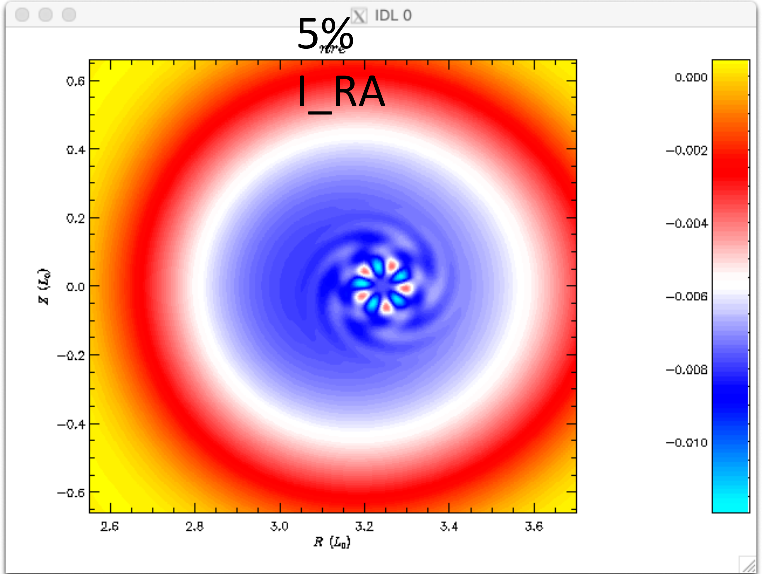
SPARK ? Do we need to do anything?



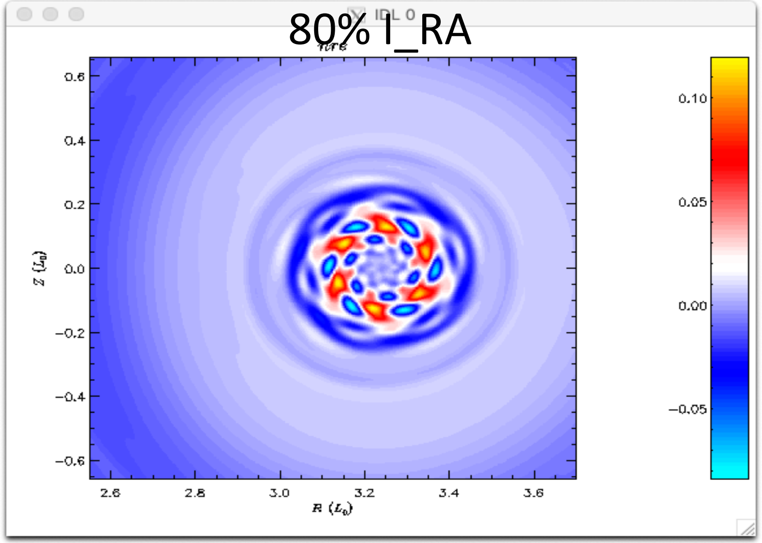
kinetic energy
×10^-7
KE
time(τ_A)
5% I_RA
50% I_RA
80% I_RA
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0
500
1000
1500
2000
2500
3000



50% I_RA
IDL 0
Z (L_0)
R (L_0)
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
2.6
2.8
3.0
3.2
3.4
3.6
0.06
0.04
0.02
0.00
−0.02
−0.04

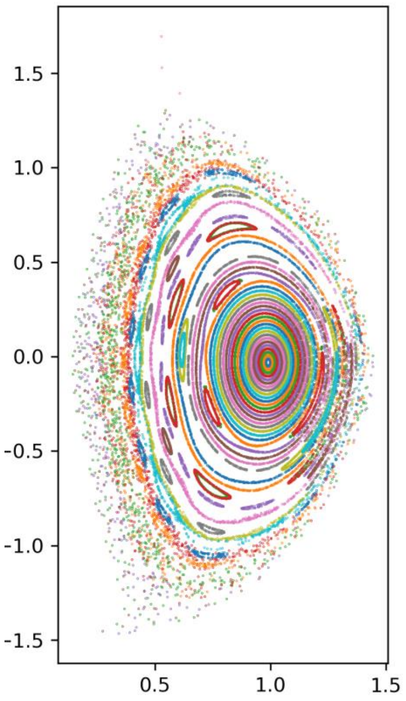


IDL 0
5%
I_RA
Z (L_0)
R (L_0)
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
2.6
2.8
3.0
3.2
3.4
3.6
0.000
−0.002
−0.004
−0.006
−0.008
−0.010



80% I_RA
IDL 0
Z (L_0)
R (L_0)
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
2.6
2.8
3.0
3.2
3.4
3.6
0.10
0.05
0.00
−0.05

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

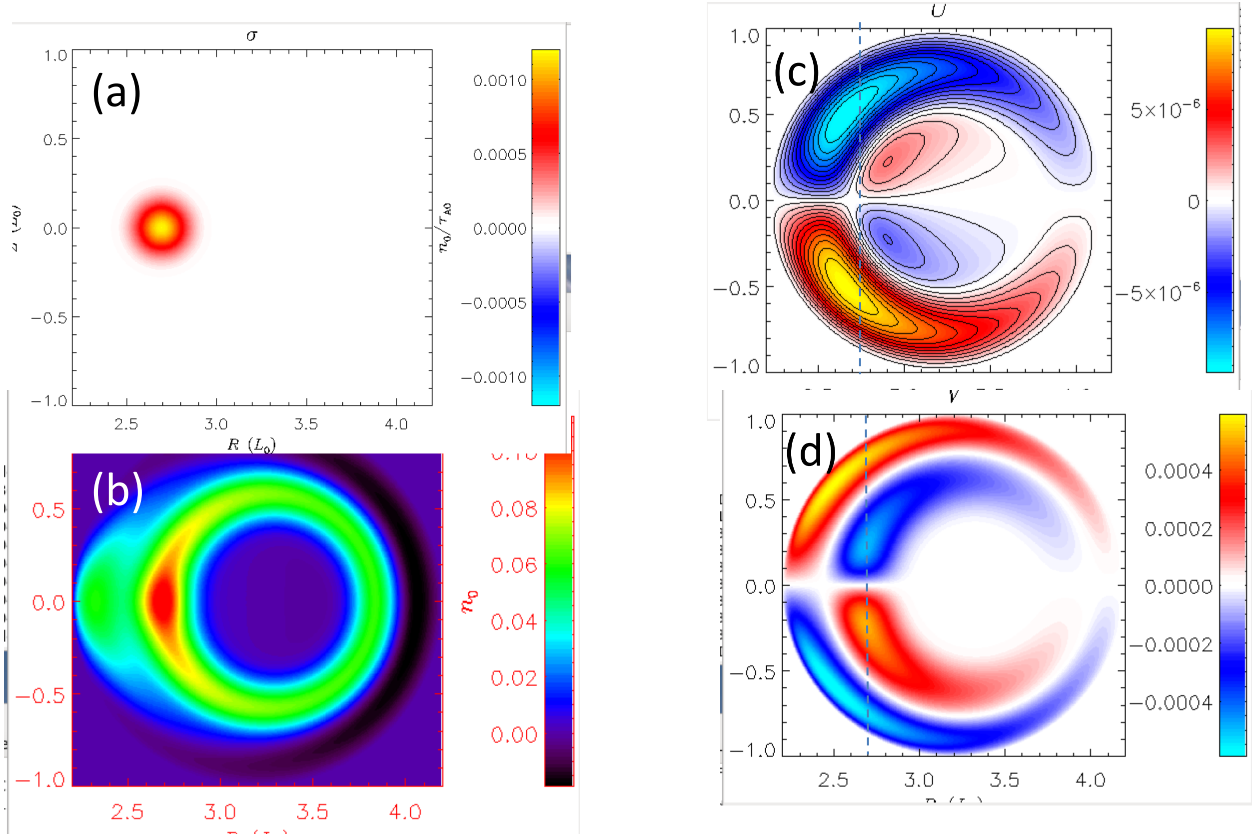
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

(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

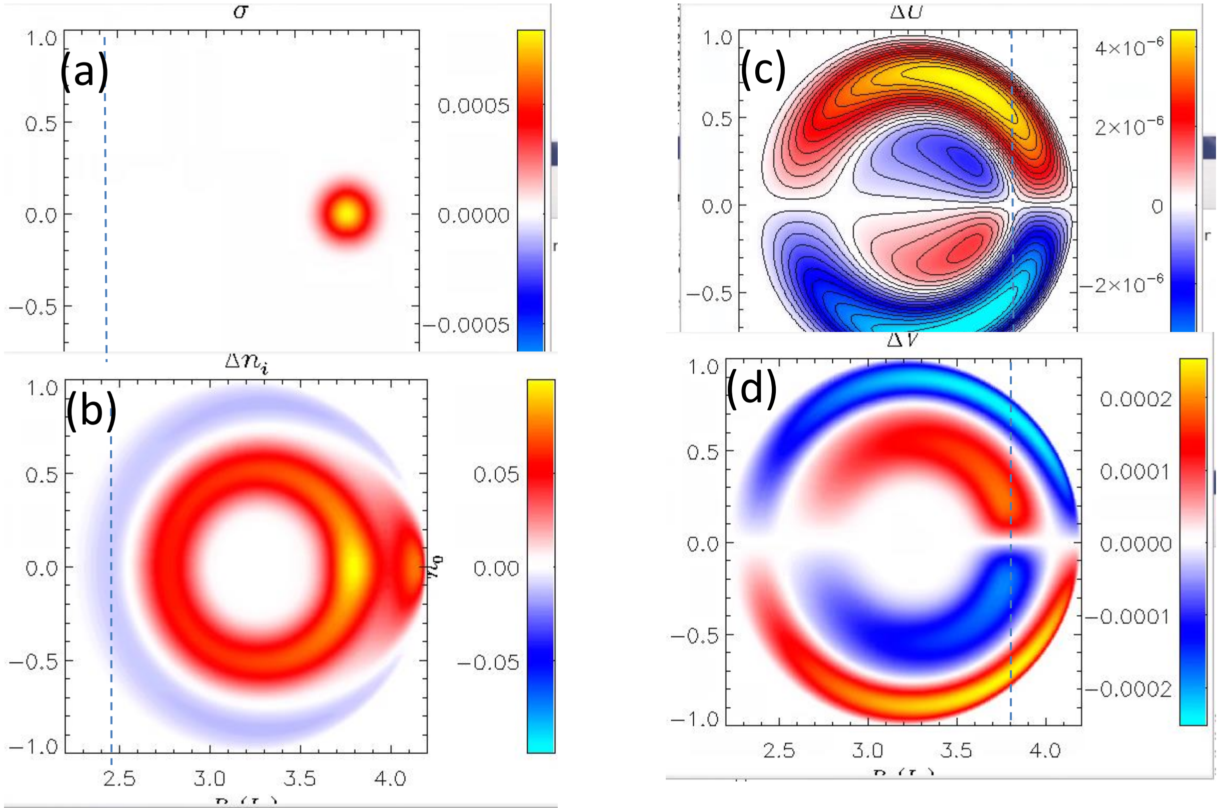
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

(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



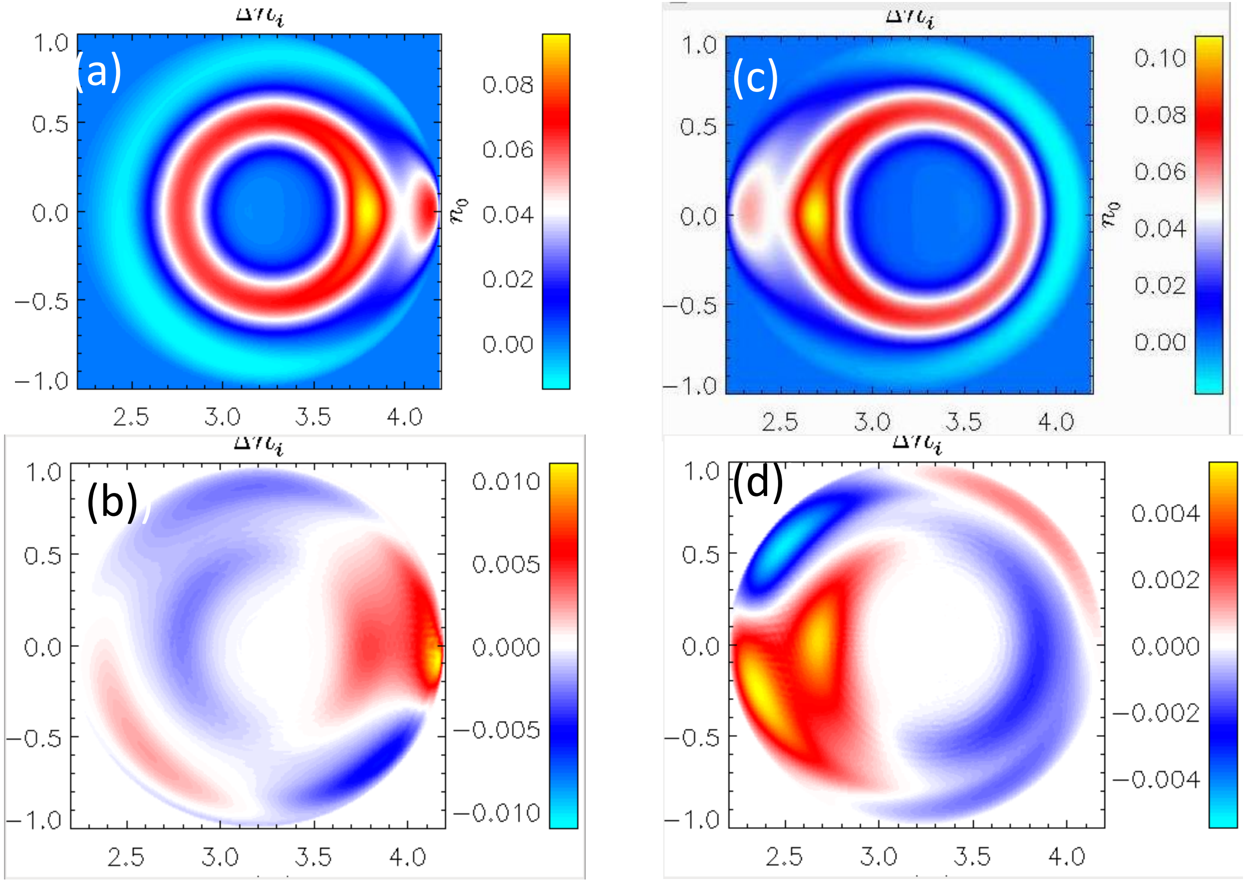
Grad-B drift in M3D-C1—2F effects

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

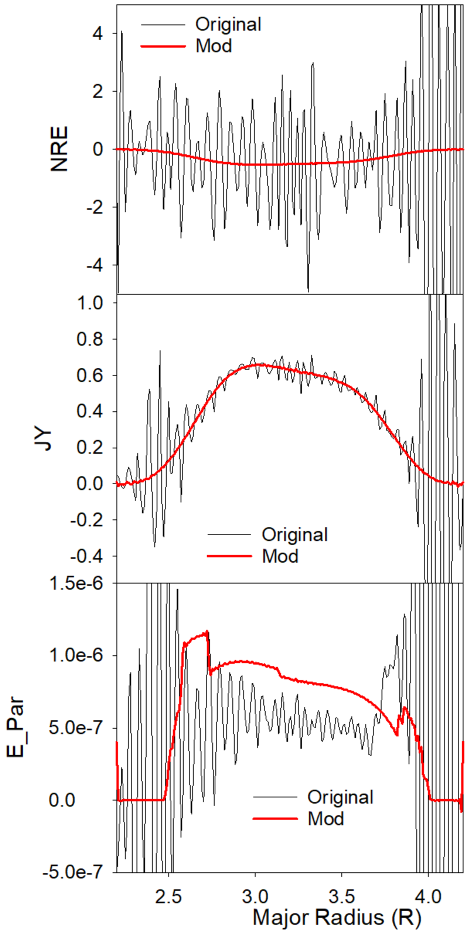
(b) Difference in 1F and 2F density (LF)

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

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



Sawtoothing discharge with runaway electrons

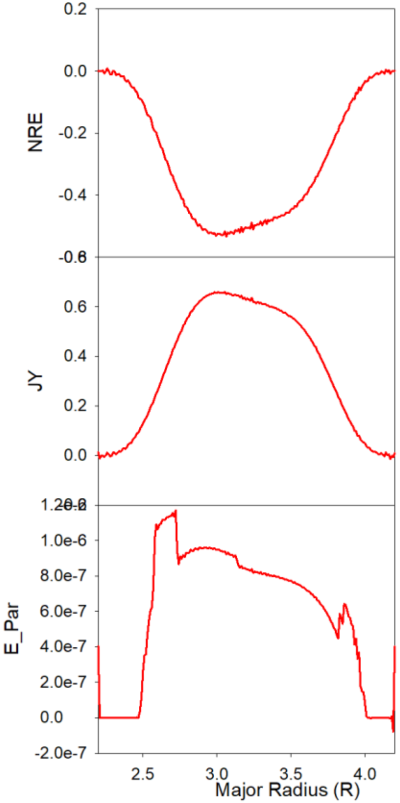


Profiles of nre, jy, and E_par after 30 timesteps

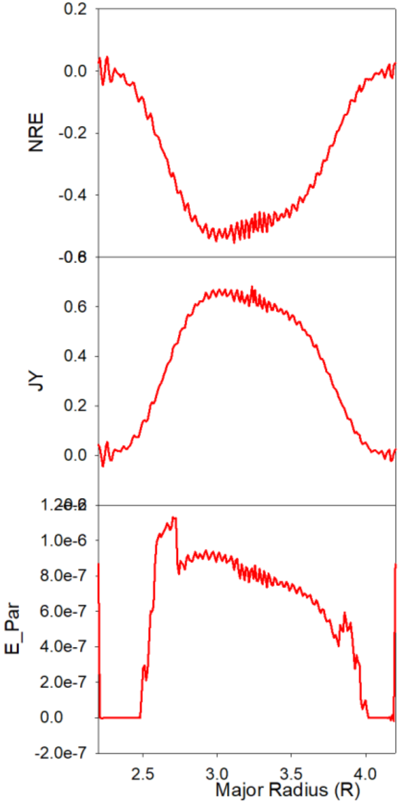
Original: /p/tsc/m3dnl/Isabel/Chen2D
Mod: /p/tsc/m3dnl/Isabel/Chen2D-mod1

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?