M3D-C1 ZOOM Meeting

02/08/2021

CS Issues

1. stellar.princeton.edu allowing early users
2. GPU solve and memory utilization status (J.Chen)
3. Local and other systems
4. NERSC Time
5. Changes to github master since last meeting
6. Documentation error involving “vz”

Physics Studies

1. Next Eric Nardon 3D MHD progress meeting
2. Progress in Lyons 3D MHD-C1/NIMROD mitigation benchmark
3. Carbon Mitigation in NSTX-U (shell pellet)
4. SPI run by Oliver Bardsley
5. Helical Band to remove runaway electrons
6. RE Benchmark with JOREK
7. Sawteeth case with runaways
8. SCREAM cc 2/10/21
9. Other?

stellar.Princeton.edu allowing early users

Jin Chen ?
Seegyoung Seol ?

02/08/21
Prentice announced eddy will shut down during the time that stellar being installed, but before stellar is fully functional. I am looking into the best way to transfer data.

GPU Solve status

- GPUs give little or no speedup on solves for small problem size
- Larger problem sizes run out of memory
- What is using all the memory???

Jin Chen email 2/2/21:

Memory Utilized: 16.27 GB (estimated maximum)

While matrices only took less than 4GB:

Matrix	118	57	3704181940	0.
Vector	820	151	5383208	0.
Krylov Solver	22	8	3198432	0.

Jin Chen

Local Systems

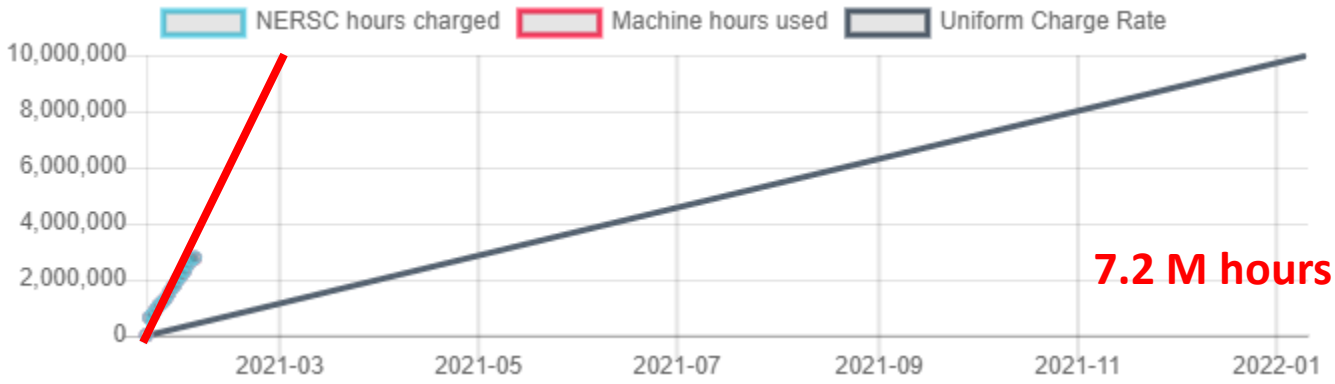
- PPPL centos7(02/08/21)
  - 5 regression tests PASSED on centos7:
  - RMP_nonlin failed
- PPPL greene (02/01/21)
  - 4 regression tests PASSED
  - RMP_nonlin failed
  - No batch file found for pellet
- EDDY (2/08/21)
  - 6 regression tests PASSED
- TRAVERSE(1/4/21)
  - Code compiles
  - Regression test failed: split_smb not found in PATH
  - Have not yet tried shipping .smb files from another machine

Other Systems

- Cori-KNL (2/08/2021)
  - 6 regression tests passed on KNL
- Cori-Haswell (2/08/2021)
  - 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
  - RMP_nonlin initially failed …: There was an error in partitioning the mesh, but passed on resubmission
- 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



7.2 M hours remain

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 1-2 months. Transition to stellar (PU/PPPL)

Changes to github master since last meeting

- S. Seol
  - 02/01/21: bin directory name for adaptation changed
- B. Lyons
  - 02/05/21: Prevent reading of mesh when reading equilibrium component of field (e.g., linear, ieqsubtract)
- S. Jardin
  - 01/08/21: corrected e_phi diagnostic field for itor=0 (divide by rzero)

Documentation error involving plot_field,'vz'

"vz" is the $\hat{z}$ component of the velocity -- $\mathrm{vz} = \hat{z}\bullet\left[R^2\nabla U \times \nabla\varphi + \omega R^2 \nabla\varphi + R^{-2}\nabla_\perp \chi \right]$

$$= R\frac{\partial U}{\partial R} + R^{-2}\frac{\partial \chi}{\partial Z}$$

Not ωR

Newdoc has been corrected and posted to m3dc1.pppl.gov

Next Eric Nardon 3D MHD progress Meeting

- Week of March 8, 10-12 AM ET, day to be determined

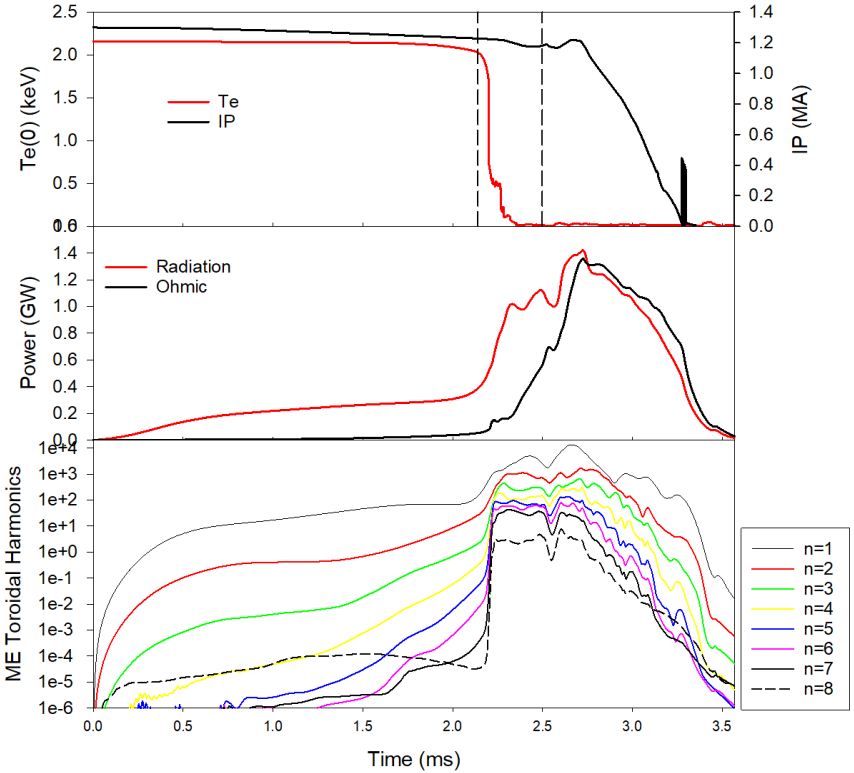
- Brendan Lyons to discuss M3D-C1 progress.

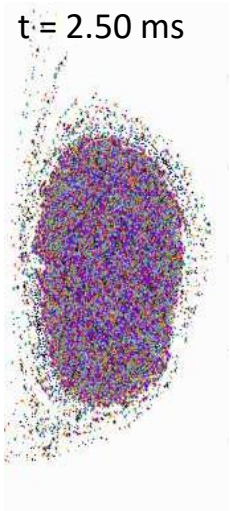
Brendan:

- What cases to present ?
- Progress on coupling to LP code?
- Runaway Electron?

B. Lyons 3D Benchmark case with NIMROD

case “f” with denm= 4.05 e-6





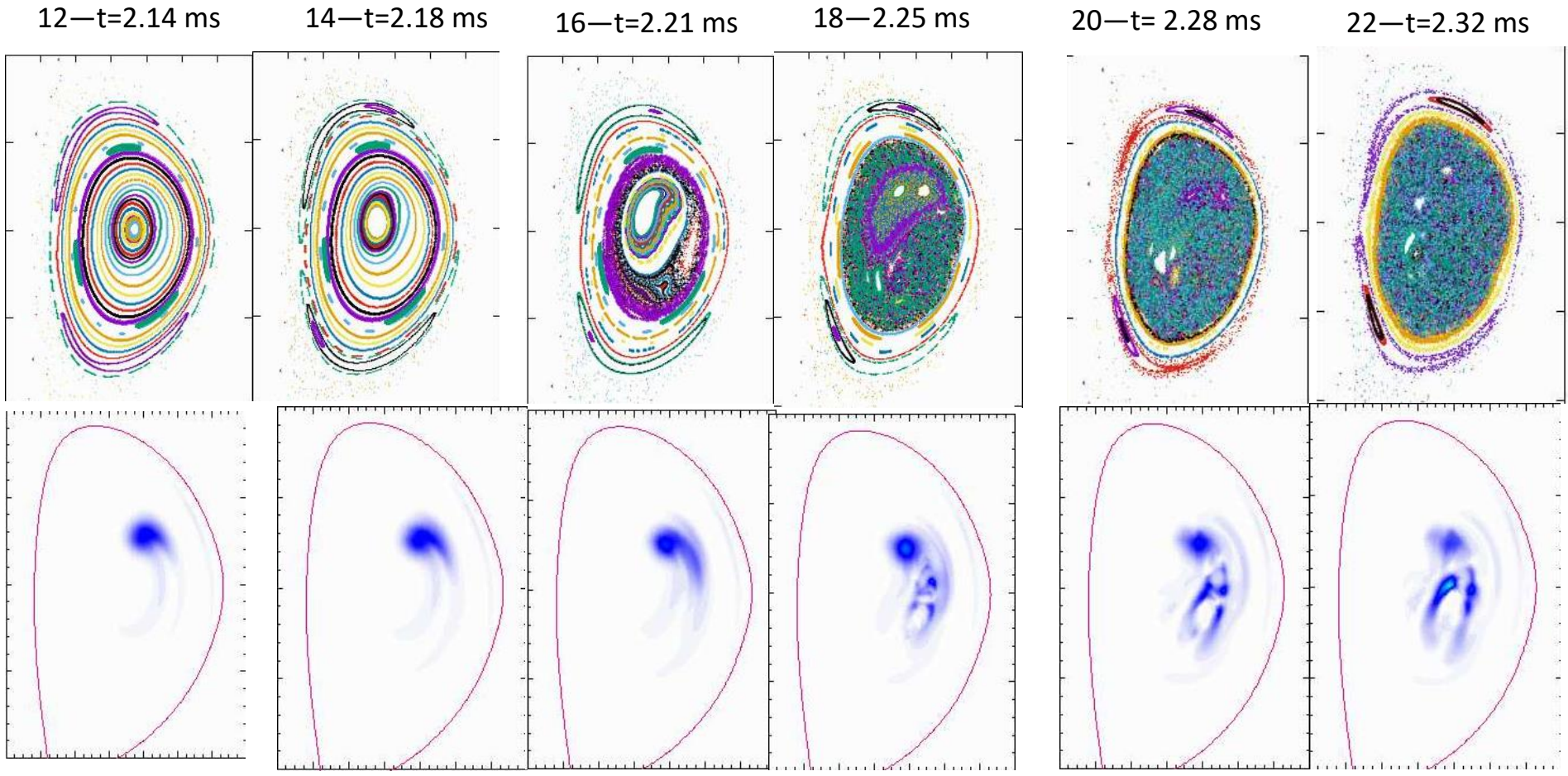
Next:

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

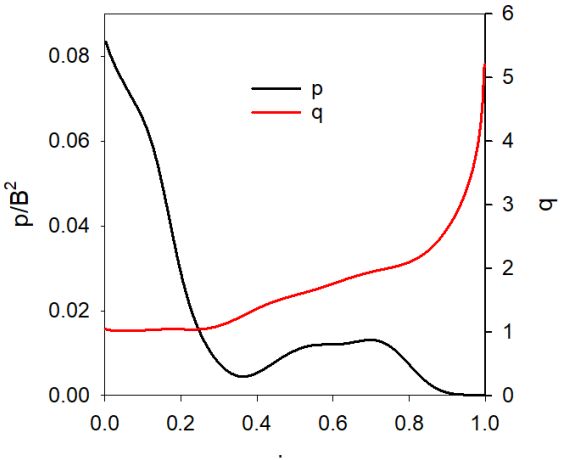
/global/cscratch1/sd/u431/BLH8f

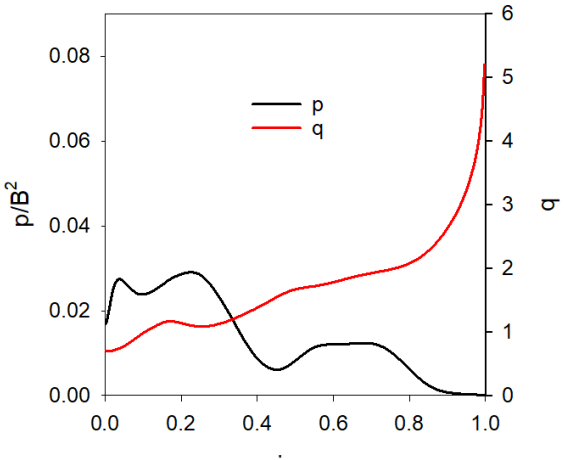
Additional Poincare Plots

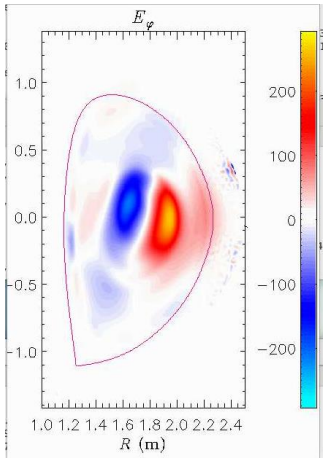
/global/cscratch1/sd/u431/BLH8f-CU/Plots

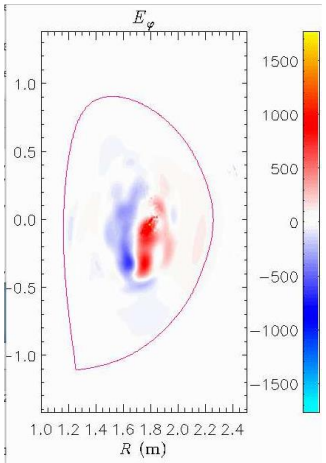


p and q profile and Eφ plot just before and after TQ

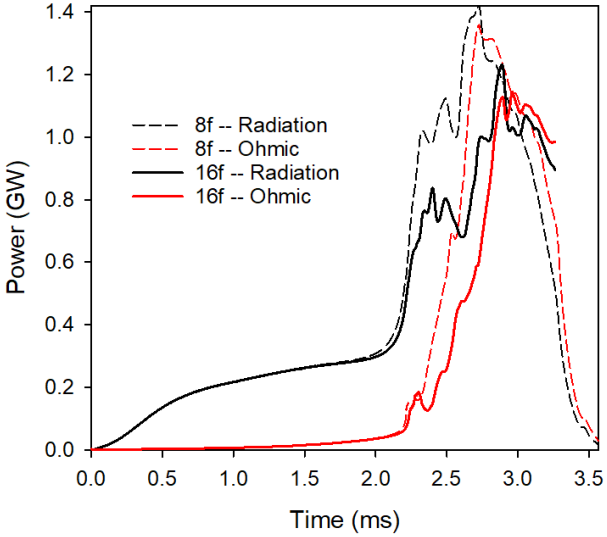


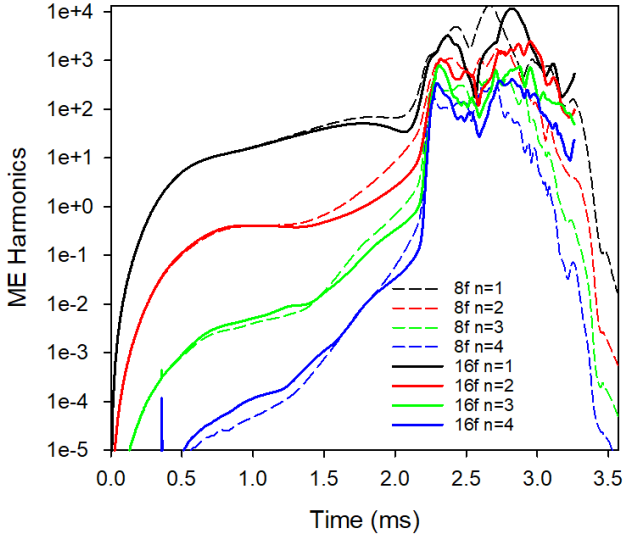






16 vs 8 planes convergence test (now running)





- 16 plane case goes stochastic at t ~ 2.2ms, very close to that of the 8 plane case
- These differ enough that I have started a 32 plane case

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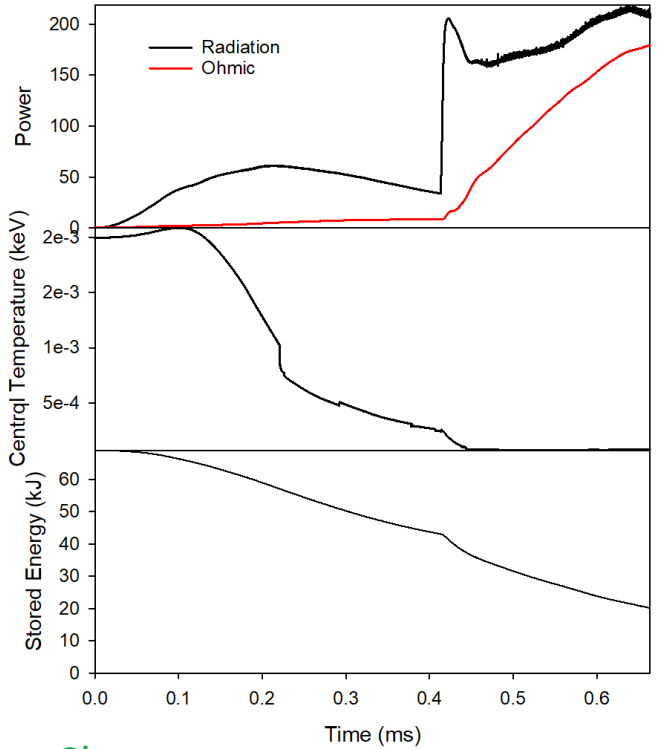
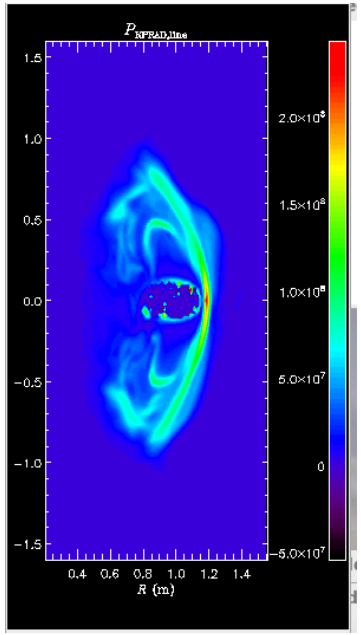
Carbon Mitigation in NSTX-U (shell pellet)



Shell carbon pellet in NSTX (now running)

Radiation
t = 0.663 ms

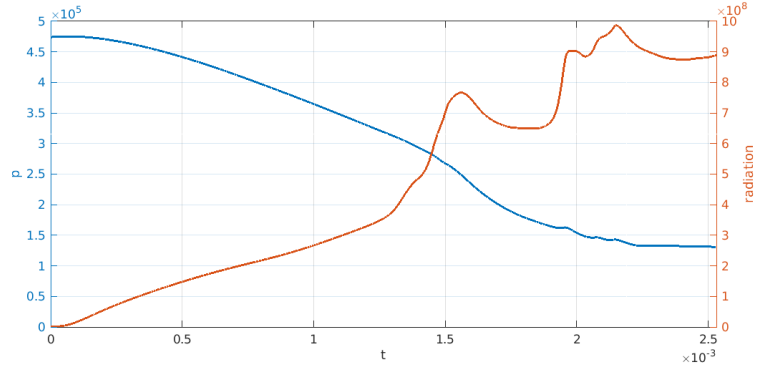


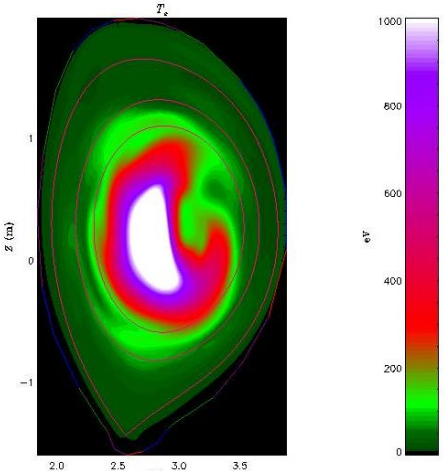
Trying to keep radiation “hot spots” from forming and causing crash by decreasing dt as necessary. Now starting to increase dt at restart.

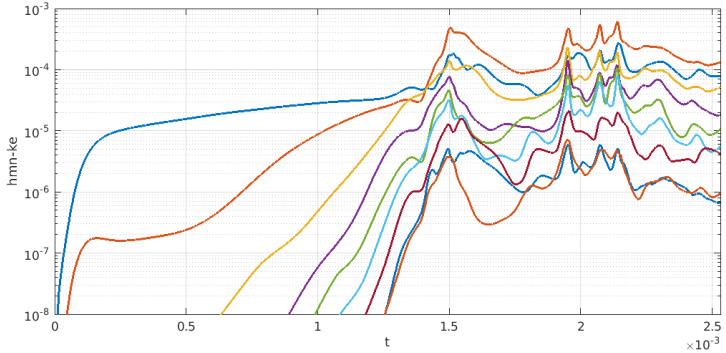
Cesar Clauser

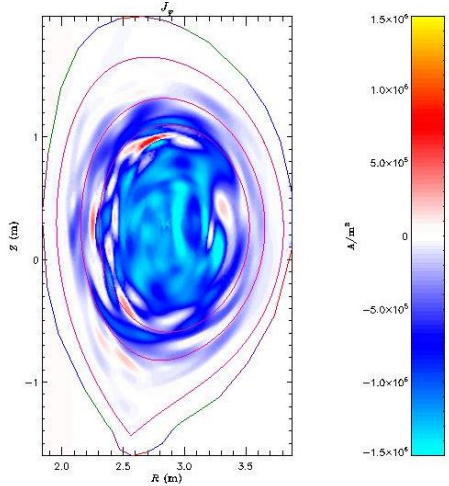
SPI run by Oliver Bardsley

Next 2 vgs are from Oliver Bardsley (UK) who also asks “How can we work with the JOREK team to start a comparative study in this area?”


×10^5
×10^8
p
radiation
t
×10^-3


T_e
Z (m)
eV


hmn-ke
t
×10^-3


J_φ
Z (m)
R (m)
A/m²

Inputs:

- Ohmic L-mode JET plasma, pure Ne SPI (241 fragments) at double speed
- Mesh 4K elements (1-region) with packing around LCFS & q=2, 8 planes
- Transport parameters
  - Resistivity: Spitzer x5 with eta_max=5e-3
  - Viscosity: 1e-4
  - Density: 1e-5
  - Isotropic thermal: 5e-6
  - Parallel thermal: 1
  - hyper=hyperi=1e-9
- dt=t_A

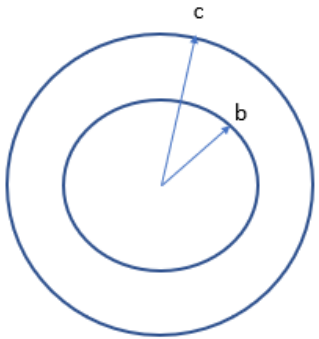
(case is on Portal at /u/obardsle/M3DC1/jet-spi/analysis/Ne3D_SP_95149_1)

Next steps…

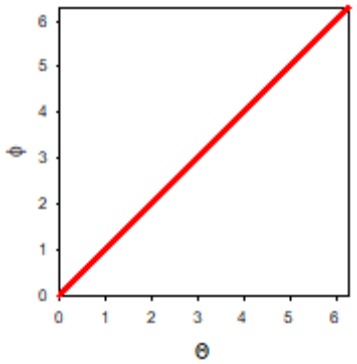
- More detailed analysis
- Most worthwhile modifications/improvements to this case?
- JOREK meeting this Weds – opportunities for comparisons…

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 $|\Theta-\phi| < \delta$

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

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

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

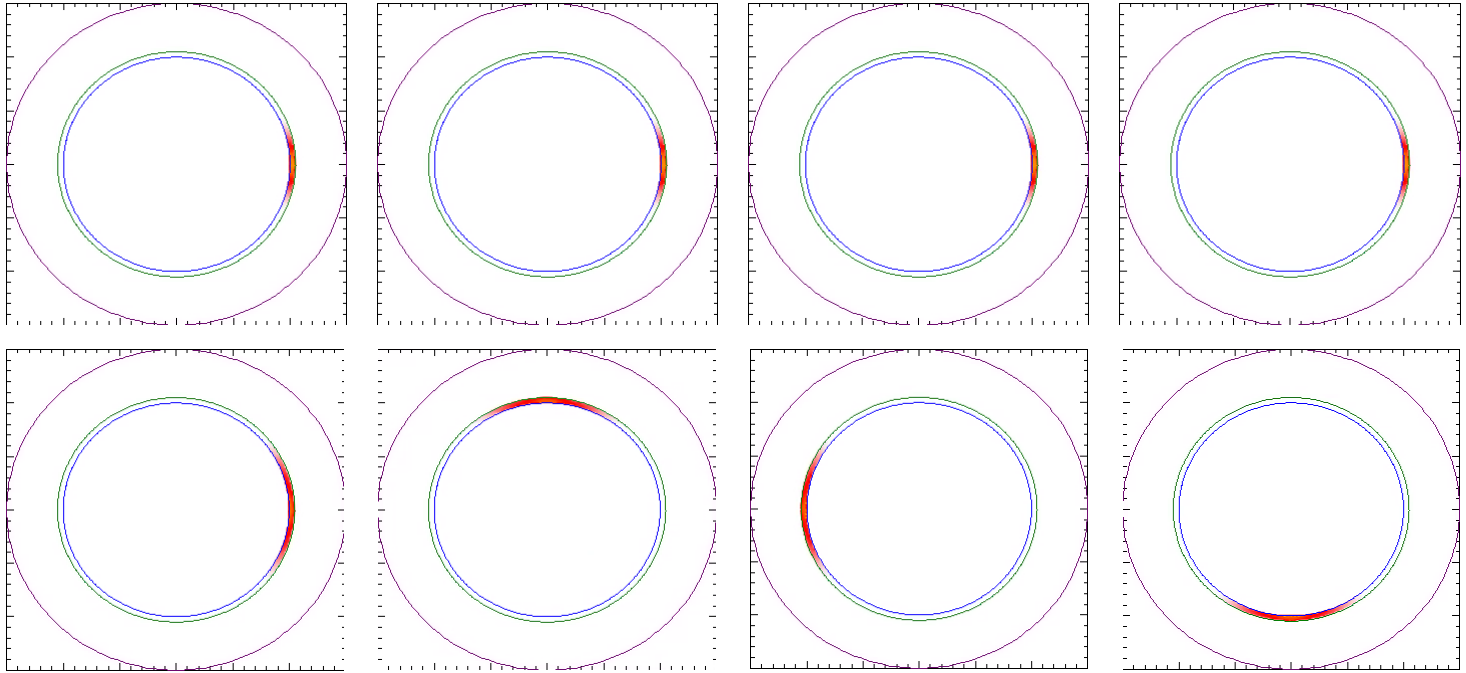
What is driving the current in the θ direction? It can't be Φ unless

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

Comparison between Straight and helical band

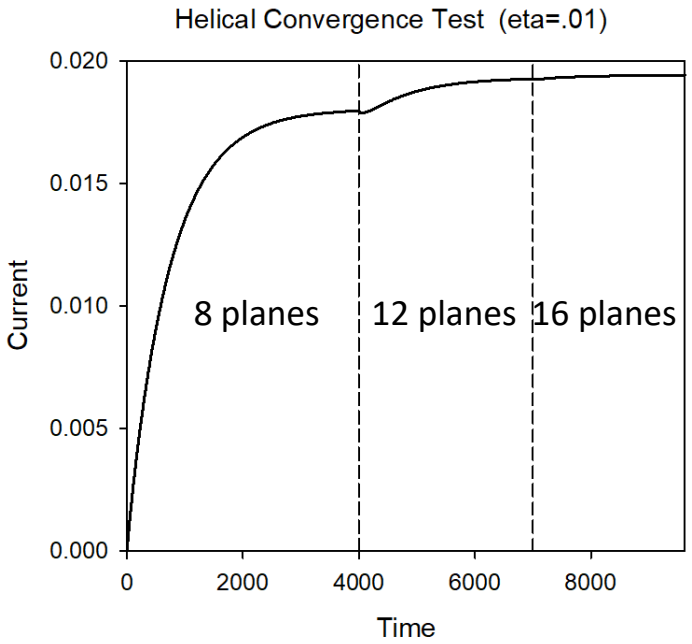
Straight ➔

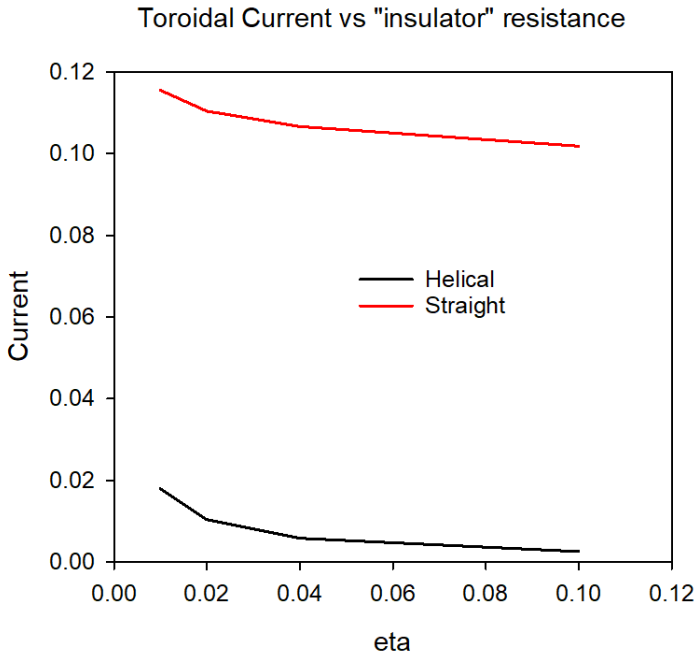
Helical ➔



$\varphi = 0$ $\varphi = \pi / 2$ $\varphi = \pi$ $\varphi = 3\pi / 2$

Some Convergence Tests

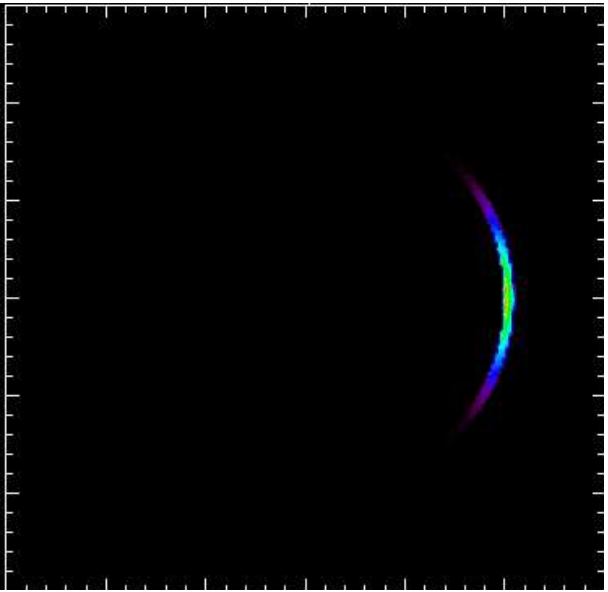


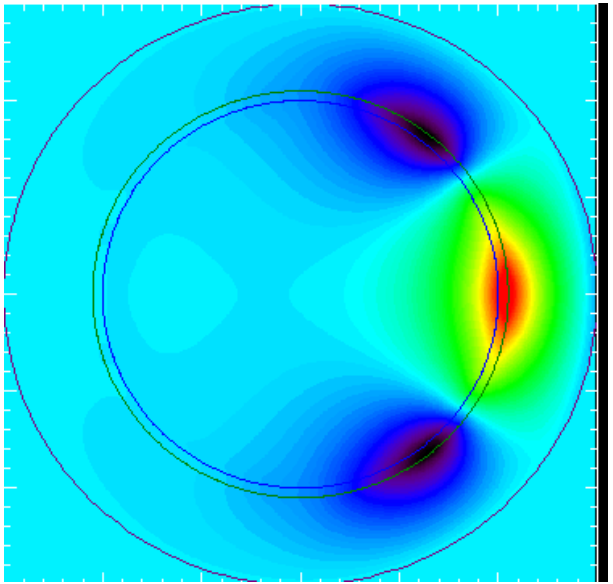


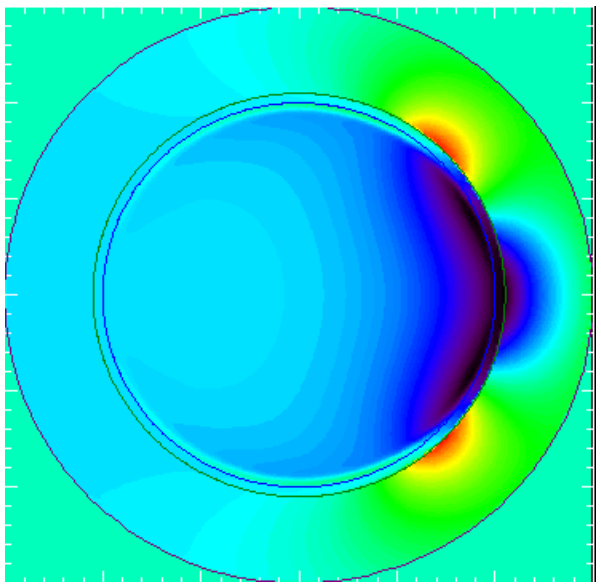
- Wall current appears to be converged in # of planes
- Helical wall current tending towards zero for large values of insulator resistance
- Now testing dependence on boundary conditions (location of ideal wall)
- Also running a (2,1) case

Scalar Electrical Potential Plots

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

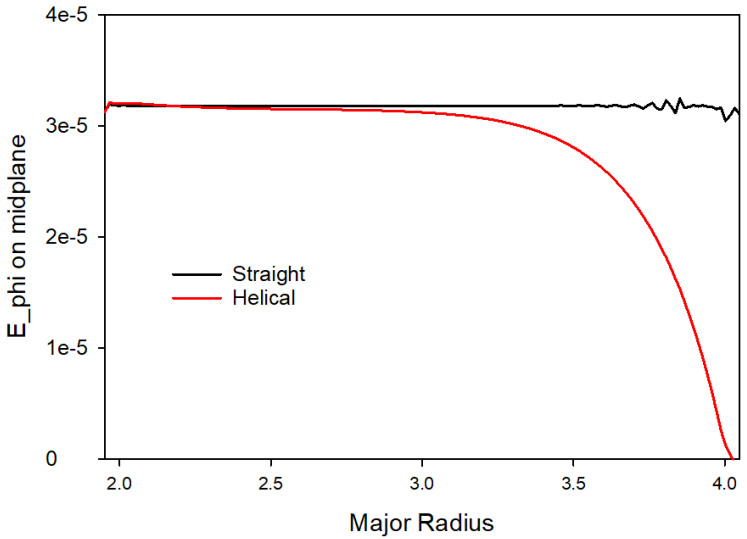






$$\nabla_\perp \bullet \frac{1}{R^2}\nabla\Phi = \nabla_\perp \cdot \eta\left[-\frac{1}{R^2}\nabla F \times \nabla\varphi - \frac{1}{R^2}\nabla f'' \times \nabla\varphi - \frac{1}{R^4}\nabla_\perp \psi'\right]$$

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

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

This electrical potential drives the current in the theta direction:

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

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

RE Benchmark with JOREK

Chang Liu proposed to V. Bandaru and M. Hoelzl on 2/1/21:
V. Bandaru responded on 2/2/21 with 4 profile files and additional data. Has Chen been able to set up equilibrium?

Artificial Thermal Quench with Dreicer and avalanche sources

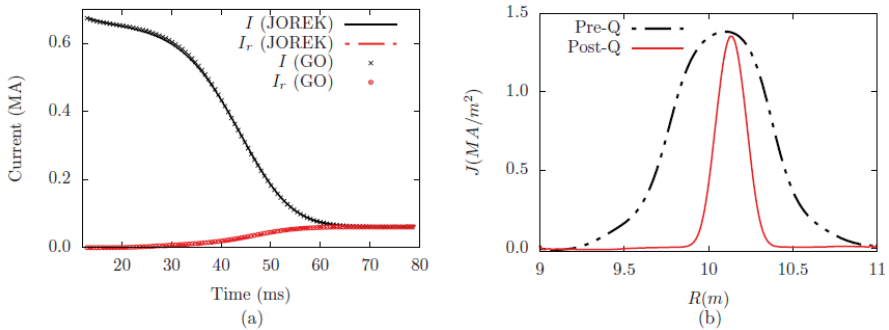
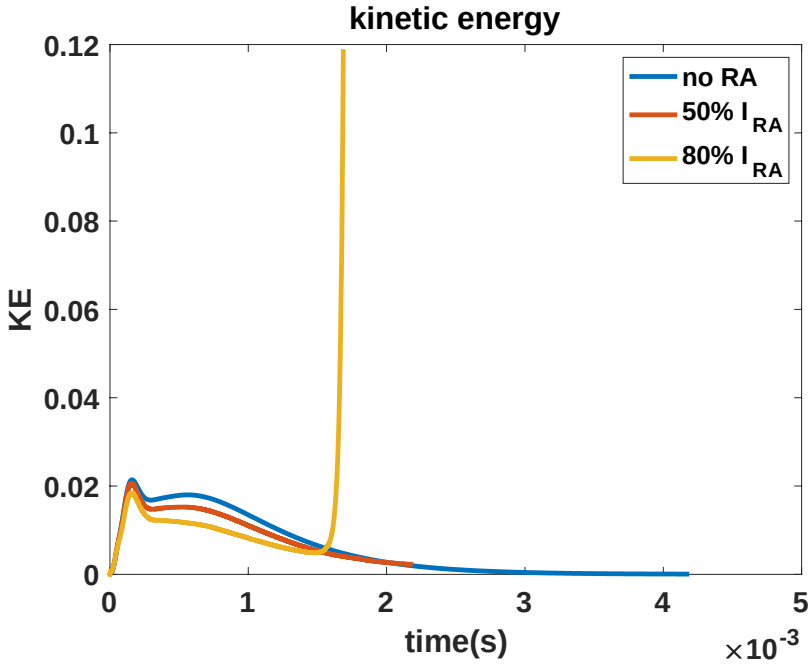


FIG. 3. (a) Time evolution of the total plasma current I and the RE current I_r during the current quench phase. (b) Midplane current density profiles before and after the current quench obtained from JOREK, showing a relatively peaked RE current profile.

Chen Zhao

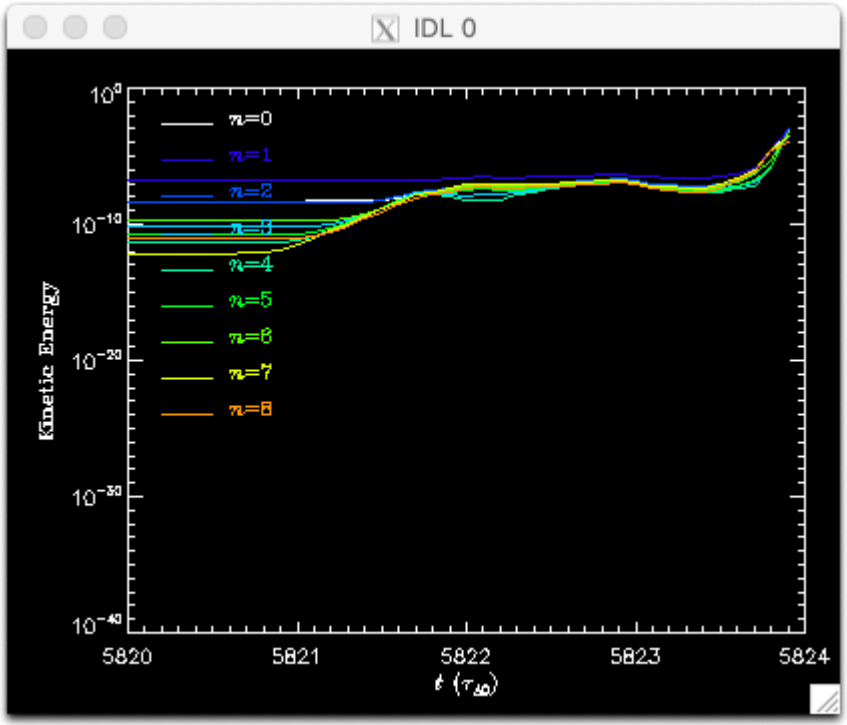
Sawteeth case with runaways

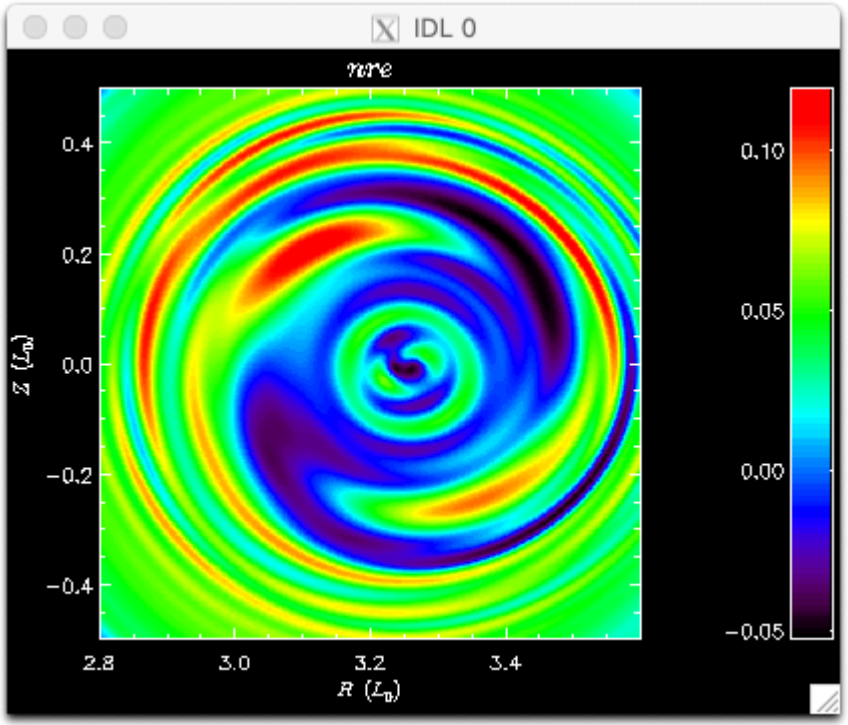


The case with 80% runaway current has instability at about t=1.5ms.

No runaway current and 50% runaway current cases do not have instabilities.

Chen Zhao



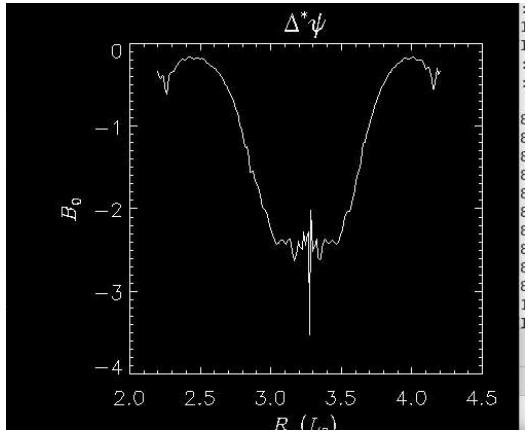


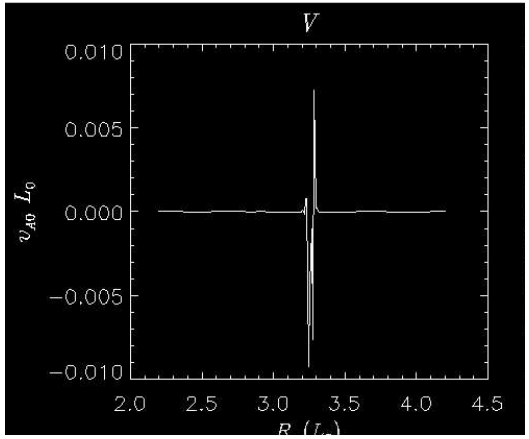
I think all harmonics (n=0~8) coupled together at about t = 5823.8 tau_A and maybe this caused the the numerical instability later. And then the energy evolution became strange.

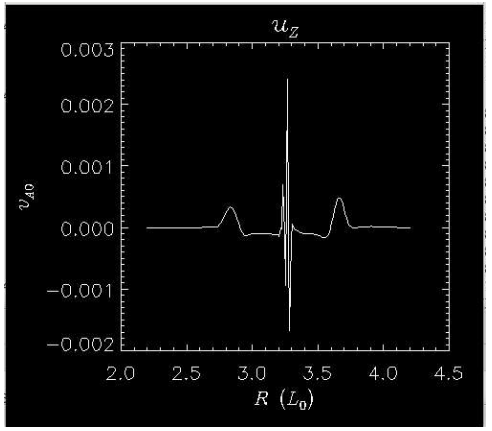
Chen Zhao

Result of increasing viscosity (amu) from 6.e-5 to 3.e-4 (x 5)

original

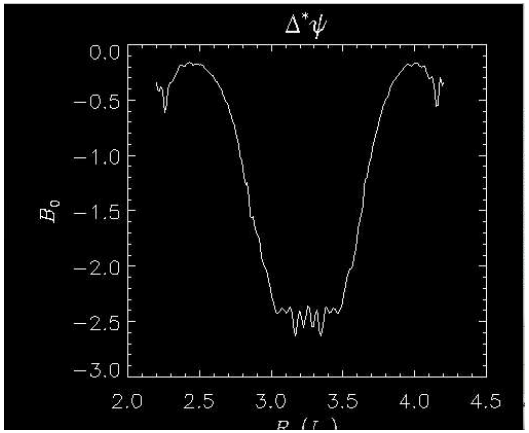


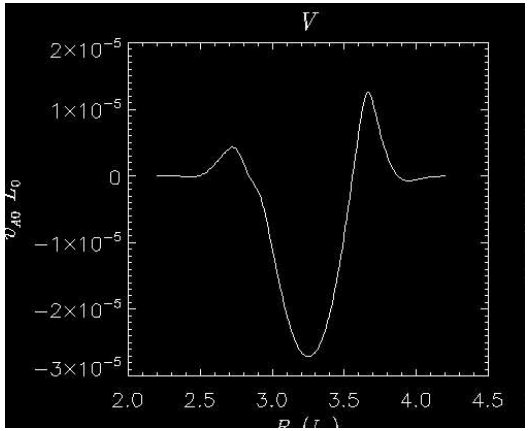


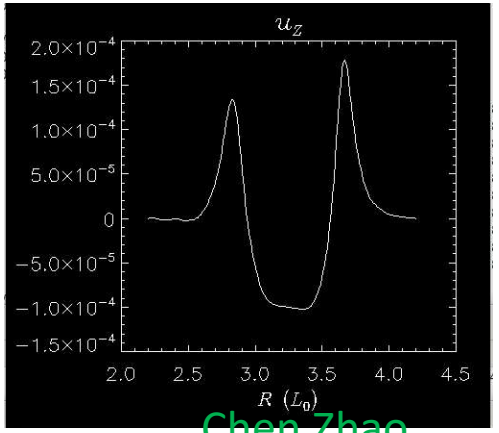


With increased viscosity

amu







Chen Zhao

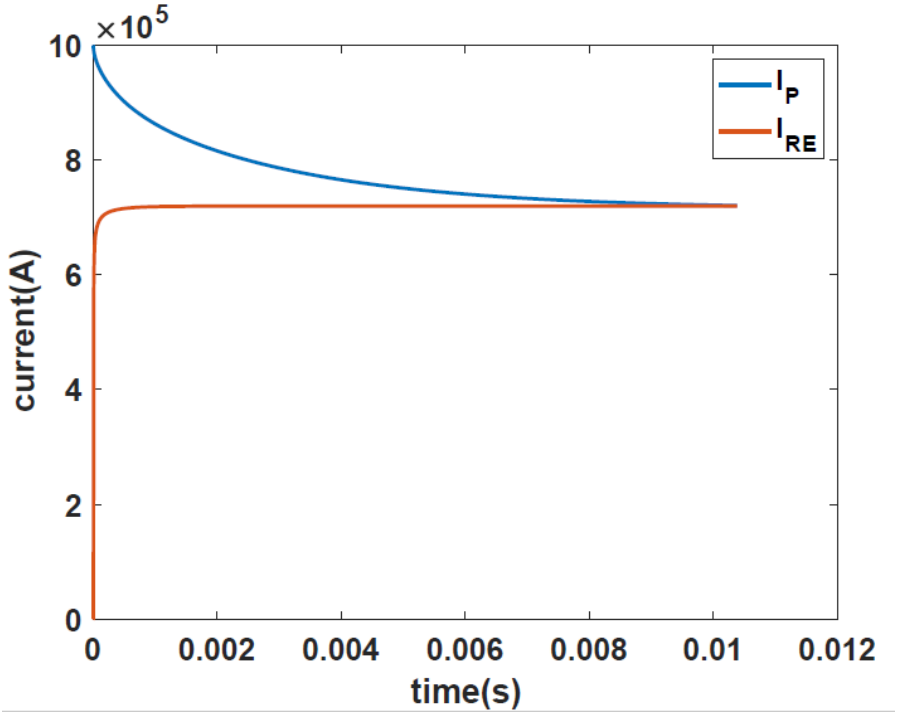
SCREAM ZOOM Call 2/10/21

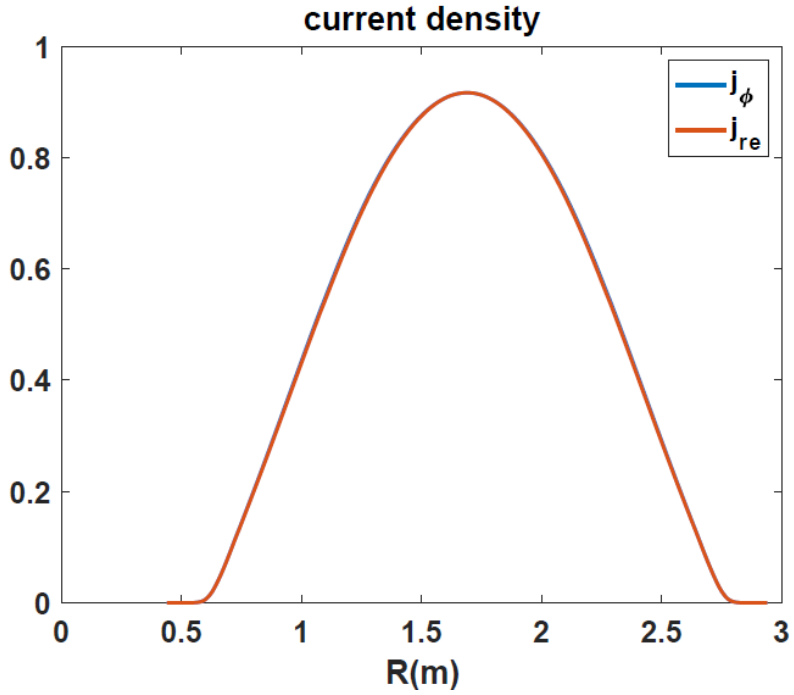
1Q2: January 1st – March 31st 2) Varying rates of thermal collapse will continue to be investigated in a series of phase space simulations, to inform the 3D simulations on what seeds are predicted. The iRFP code will be used for studying the Dreicer seed formation mechanism. MHD simulations using M3D-C1 and NIMROD will be analyzed to investigate the time dynamics of the thermal collapse rate and effect of MHD instabilities and stochastic fields on seed formation. The dependence of the RE seed production rate on the radial and temporal evolution of the electric field, the temperature, and density will be studied using the Backward Monte Carlo (BMC) method. KORC will simulate RE transport in stochastic magnetic fields obtained from 3D MHD simulations. RAMc simulations will be performed to assess RE dissipation by secondary material injection in ITER relevant scenarios.

That’s All I have

Anything Else ?

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





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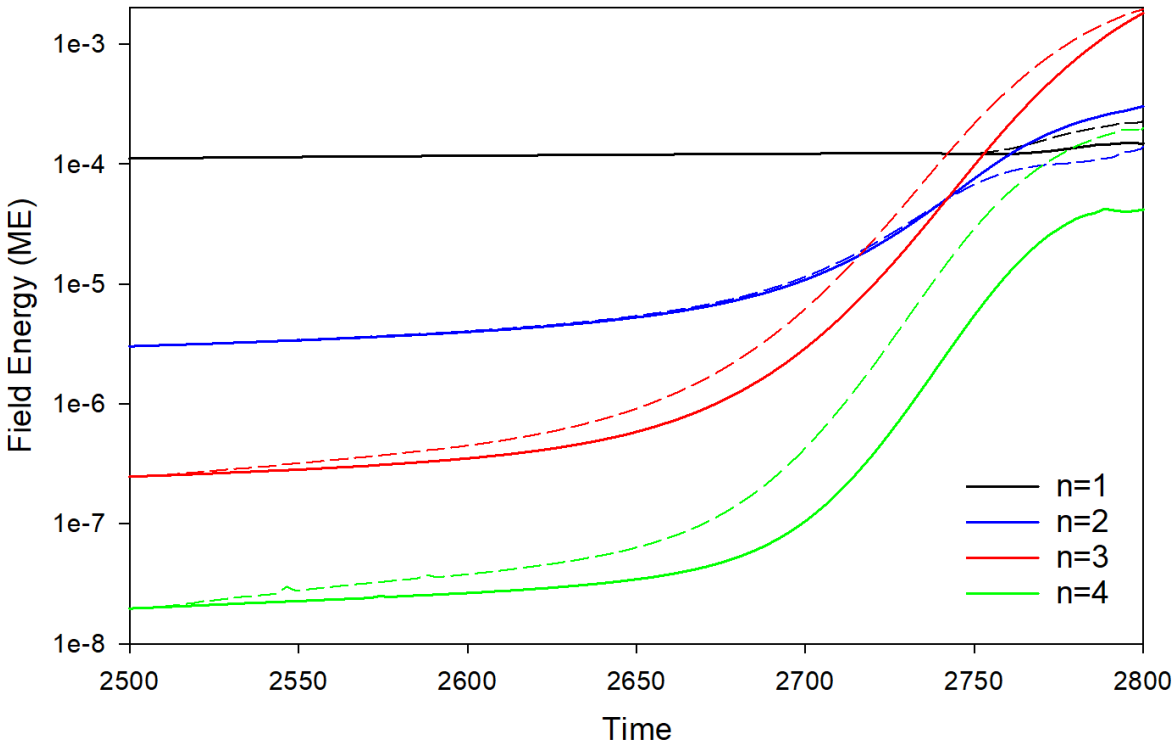
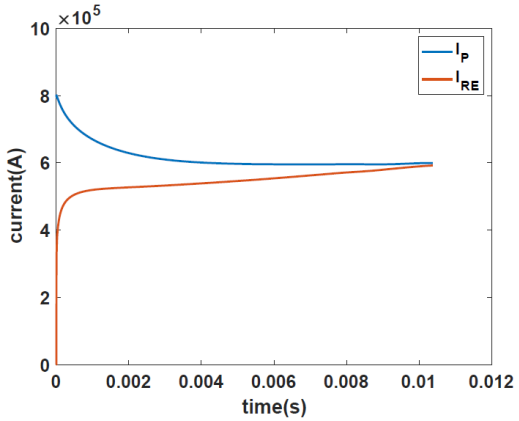
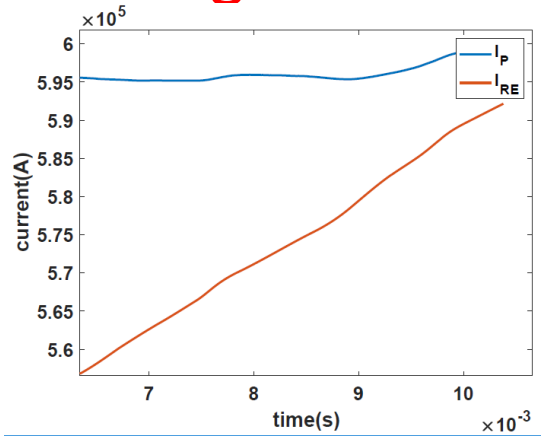
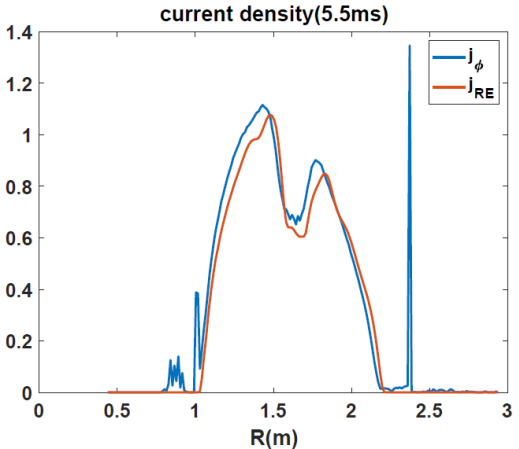
Energy in base case 36742317 (solid) and 16 plane case 37248033 (dashed)

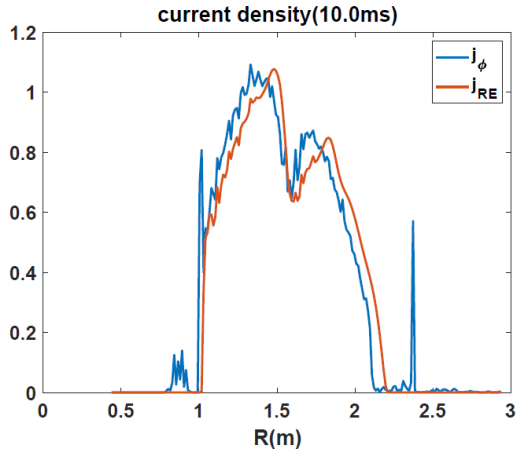


DIII-D 177053 with Argon





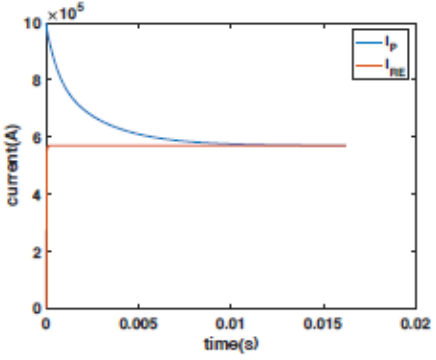


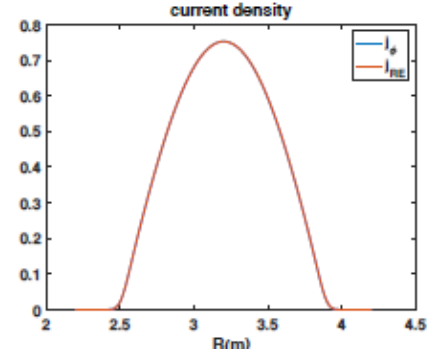


Chen Zhao

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?

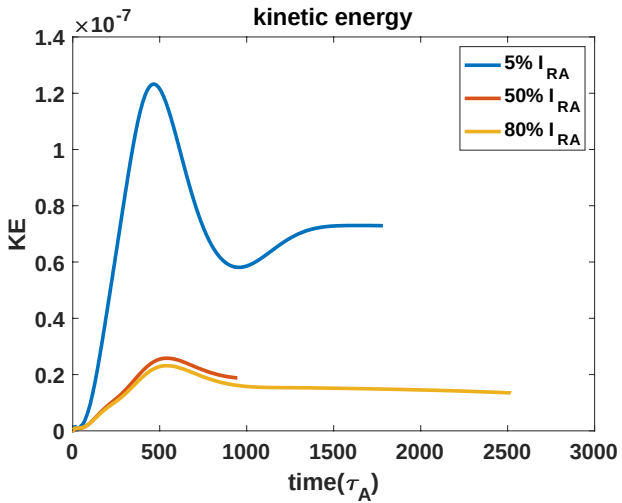
- M3D-C1/NIMROD 3D Benchmark

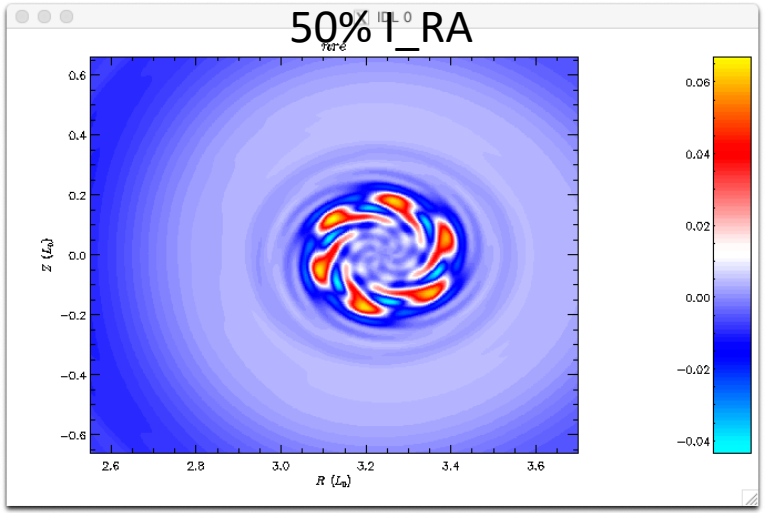
NSTX shot 1224020 – Fast ion transport with coupled kink and tearing modes
Chang Liu

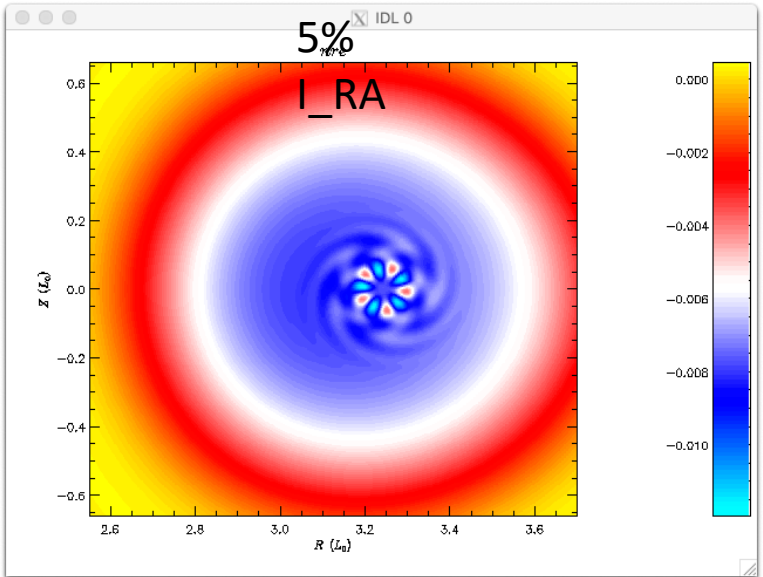
DIII-D Neon pellet mitigation simulation for KORC

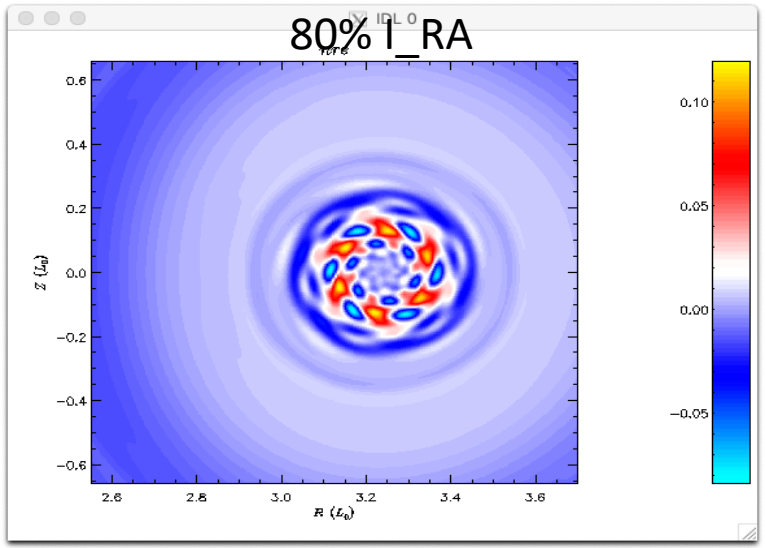
- Brendan Lyons trying to extend 8 plane case to 32 planes

SPARK ? Do we need to do anything?


kinetic energy
×10^-7
KE
time(τ_A)
5% I_RA
50% I_RA
80% I_RA

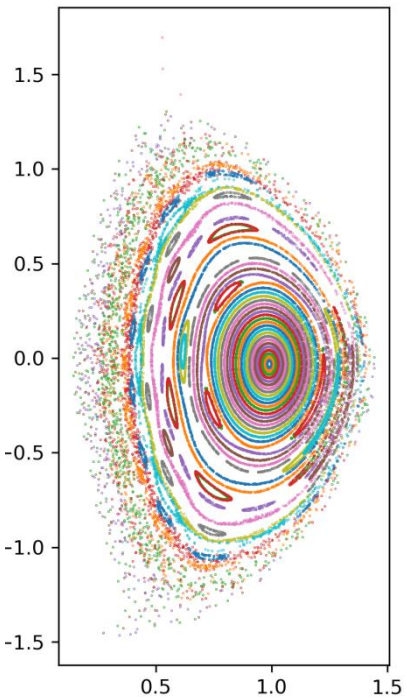

50% I_RA
IDL 0
Z (L_0)
R (L_0)


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


80% I_RA
IDL 0
Z (L_0)
R (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

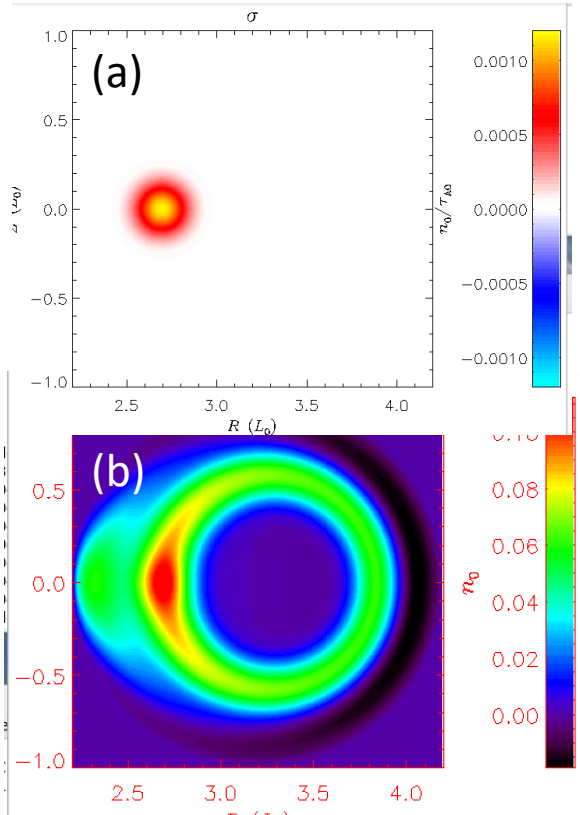
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

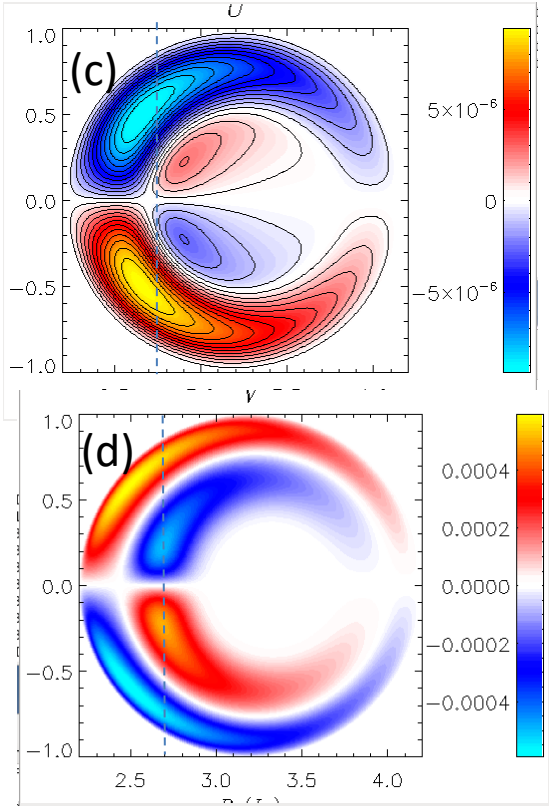
(a) Density source in 1F toroidal equilibrium

(b) Change in density after 10^3 τ_A

(c) Poloidal velocity stream function

(d) Toroidal velocity contours





Grad-B drift in M3D-C1– LF source

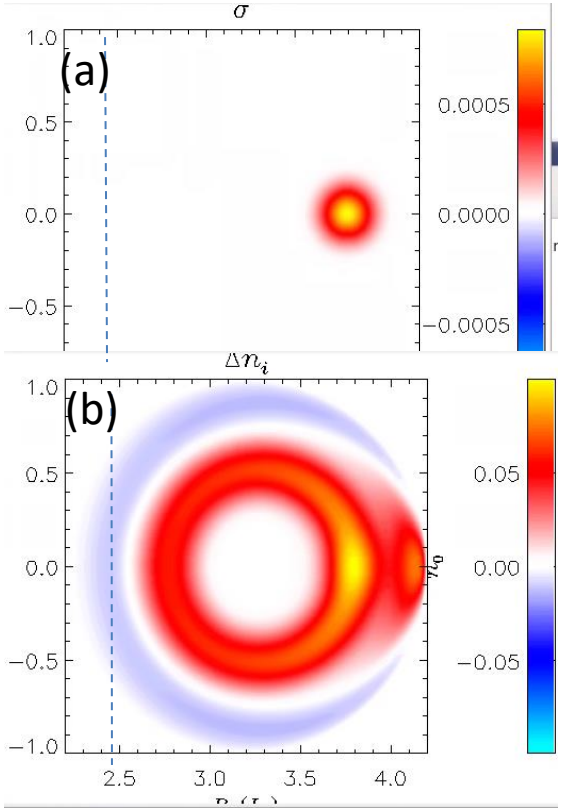
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

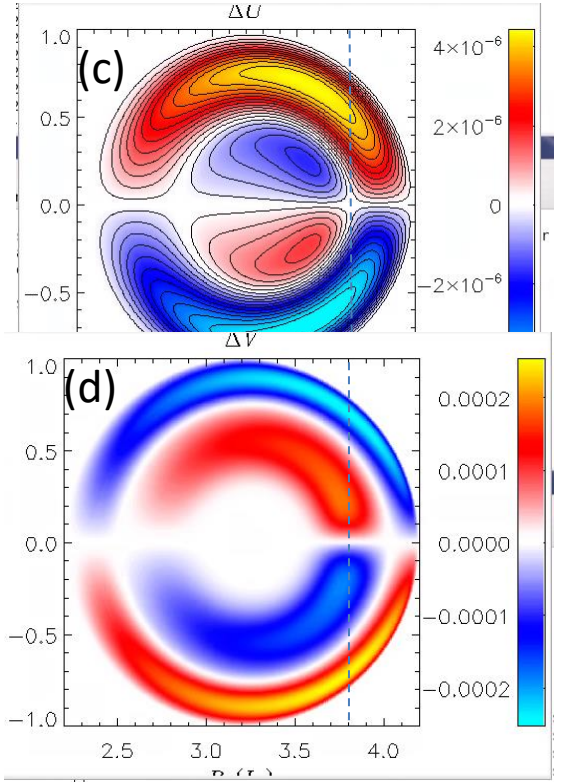
(a) Density source in 1F toroidal equilibrium

(b) Change in density after 10^3 τ_A

(c) Poloidal velocity stream function

(d) Toroidal velocity contours





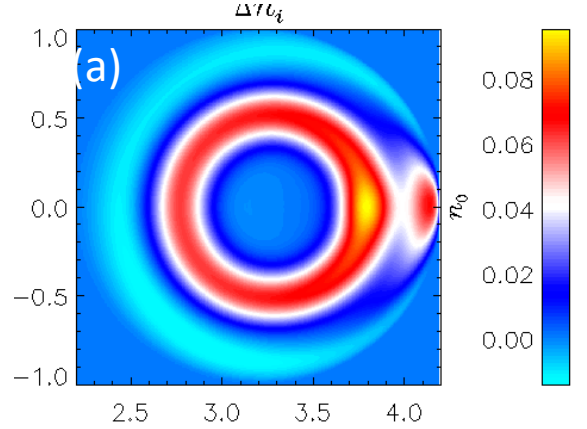
Grad-B drift in M3D-C1—2F effects

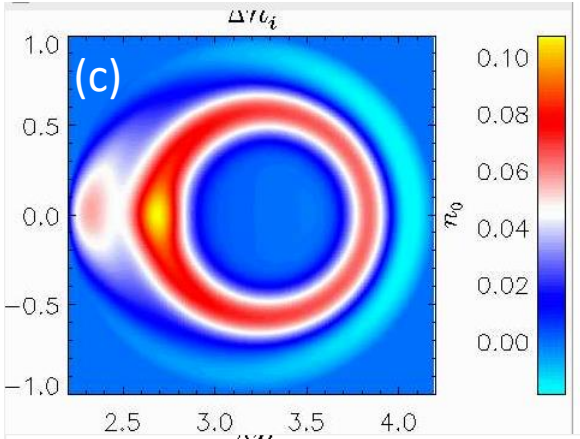
(a) 2F density change after 10^3 τ_A for LF side source

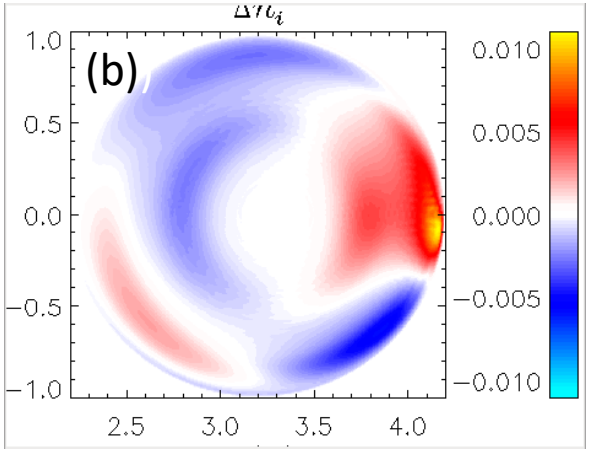
(b) Difference in 1F and 2F density (LF)

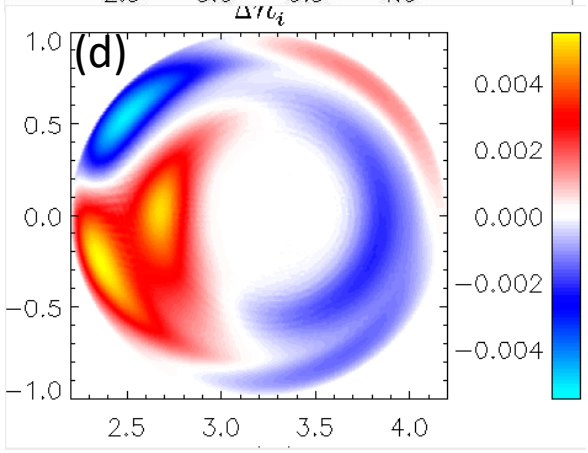
(c) 2Fdensity change after 10^3 τ_A for HF side source

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

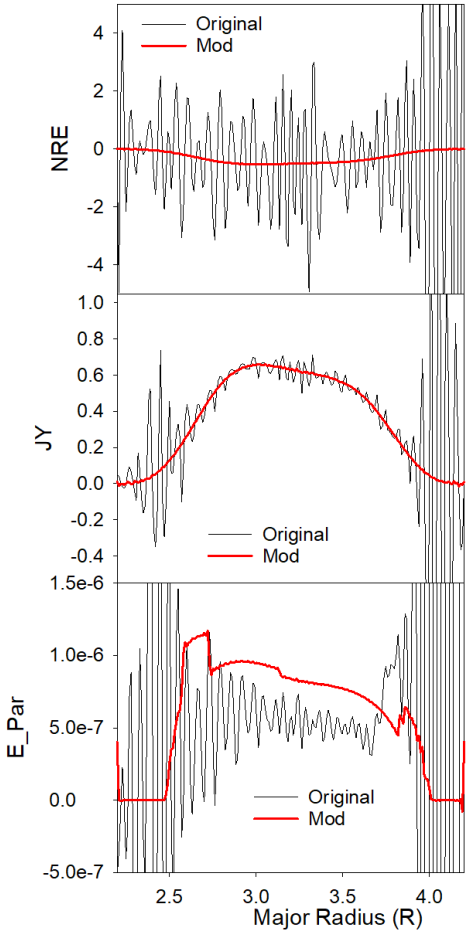








Sawtoothing discharge with runaway electrons

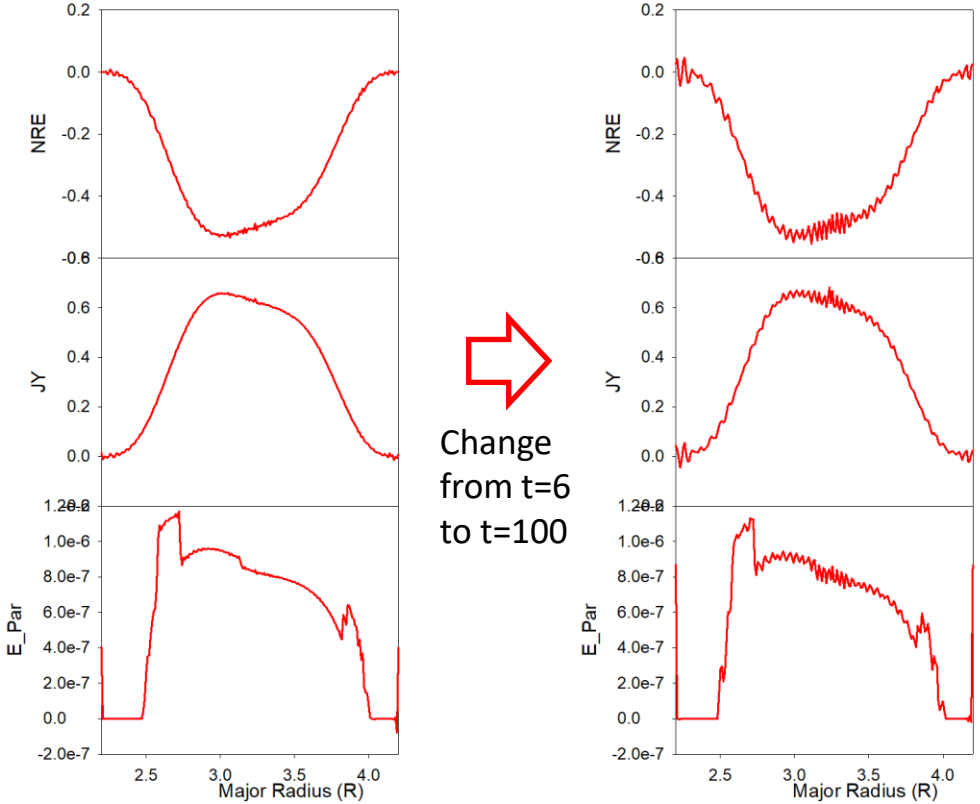


Profiles of nre, jy, and E_par after 30 timesteps

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



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