M3D-C1 ZOOM Meeting

Announcements:

04/26/2021

CS Issues

1. GPU solve status
2. Mesh adaptation update
3. stellar .Princeton.edu
4. NERSC Time
5. Changes to github master since last meeting & Lyons email 04/21/21
6. Regression tests

Physics Studies

1. M3D-C1 modeling of pellet ELM triggering in low collisionality discharges
2. Interfacing M3D-C1 and LPC
3. Update on M3D-C1-S
4. Self-consistent simulation of resistive kink with runaway electrons
5. RE source terms in DIII-D 177053 and next steps..
6. Effect of resistive wall on the thermal quench in DIII-D 154576
7. Current coupling scheme of fishbone simulation in M3D-C1 – Chang Liu
8. Other

In attendance

Steve Jardin
Jin Chen
Nate Ferraro
Hank Strauss
Usman Riaz
Adelle Wright
Chang Liu
Brendan Lyons
Cesar Clauser
Yao Zhou
Chen Zhao
Priyanjana Sinha
Mark Shephard
Andreas Kleiner

Announcements

- I will be on vacation 4/29 – 5/10
- Next Monday LBL will make a presentation at the 3:00 PM meeting, and I will try and attend
- The week of 5/10 – 5/14 will be the IAEA Meeting.   Since I will be traveling on 5/10, I will not schedule a meeting
- APS Invited Talk nominations due 5/26
- Today, I need to leave promptly at 4:00 PM

GPU Solve status

Sherry Li set up a zoom meeting with Barry Smith (head of PETSc) to discuss detailed timing log from traverse M3DC1 3D run using PETSC GPU solves

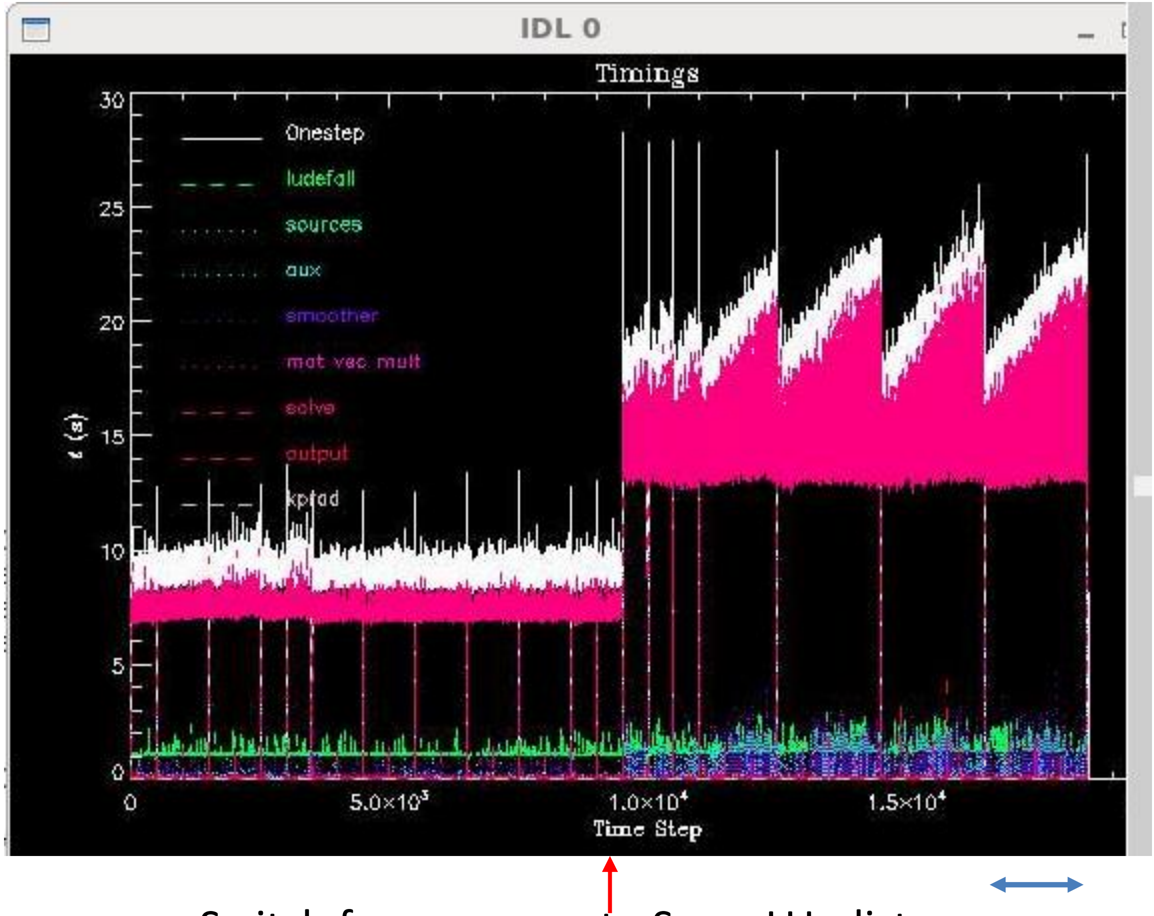
Tomorrow (Tues) at 4:30 PM ET

Jin Chen

Mesh Adaptation Update

RPI?
Brendan Lyons ?

stellar.princeton.edu



Switch from mumps to SuperLU_dist

2D (real) runs with 96p

Beginning of restart.
Solve time varies between 12-16 s

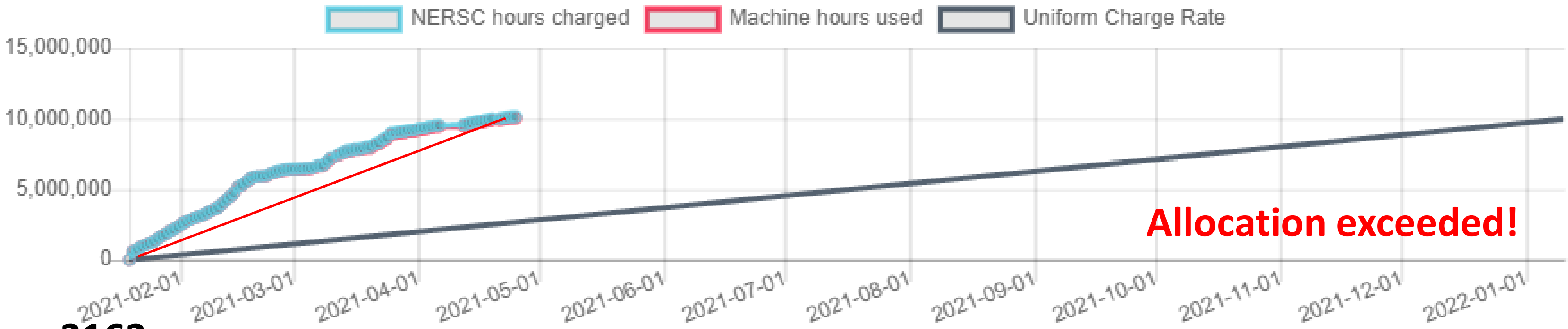
End of plot range
Solve time varies between 13-21s

NOT SHOWN:
Just before mpi crash, solve time increases to 86 s

mumps runs often end in NaN, although it may be possible to eliminate these with more frequent output cycles (every 100 instead of every 500)

NERSC Time

mp288



m3163

Closed for general use

- mp288 received 10M Hrs for CY 2021
- Now completely exhausted!   (May get more time)
- Jardin contacted John Mandrekas. Waiting for reply.
- Transition to stellar (PU/PPPL)

Changes to github master since 03/28 !

- **Brendan Lyons:**
  - **04/20/21:** Add output script for KPRAD benchmarking

- **Seegyoung Seol**
  - **04/25/21:** adding m3dc1_mesh_load_3d which reads 3D mesh exported from M3DC1

Lyons email 4/21/2021

- I did some testing and it looks like the new method works properly and I understand why it's more stable. For the runs I'm doing, I'm using **ikprad_evolve_internal = 1**, so that the density & temperature value at each point is updated during each KPRAD sub-cycle.
- This should prevent overshoots on the radiation.
- For example, with constant Te, it's possible the radiation at that temperature integrated over an MHD step will exceed the thermal energy, driving the temperature negative.
- The old method of turning off KPRAD below a threshold value (now called **ikprad_min_option=1**) is based on the initial ne & Te given to KPRAD.
- With **ikprad_evolve_internal = 1**, however, the ne and Te given to KPRAD in each sub-cycle could fall below the threshold, perhaps giving spurious ionization or radiation rates.
- **ikprad_min_option=1** would not ignore those values.
- Now, with either **ikprad_min_option=2 or 3**, the radiation is set to zero whenever the internal ne or Te given to KPRAD falls below the cutoff.
- My testing shows that this is more stable.

Documentation ?

Local Systems

- PPPL centos7(04/26/21)
  - 6 regression tests **PASSED** on centos7:
- PPPL greene (04/26/21)
  - 3 regression tests **PASSED**
  - Adapt **FAILED**
  - RMP_nonlin **FAILED**
- STELLAR (04/26/21)
  - 6 regression tests **PASSED** on stellar
- TRAVERSE(03/29/21)
  - Code compiles
  - Regression test failed: split_smb not found in PATH

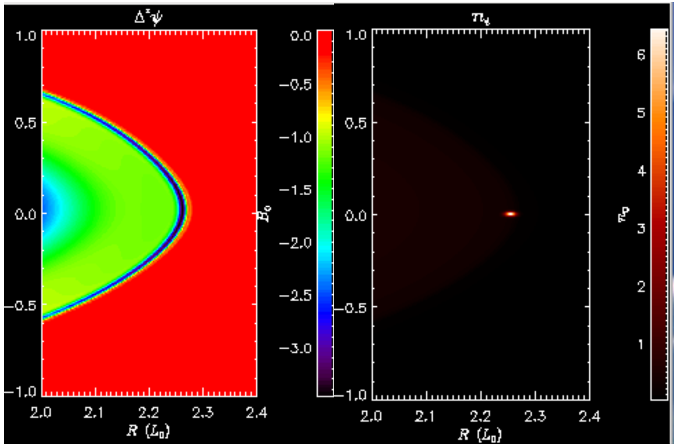
Other Systems

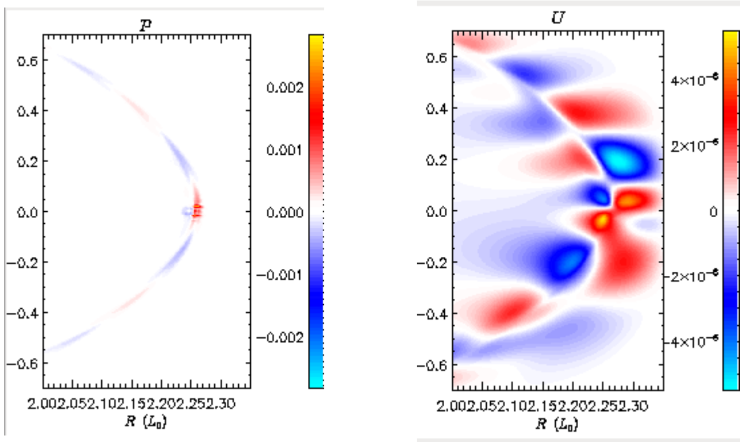
- Cori-KNL (2/08/2021)
  - 6 regression tests passed on KNL
- Cori-Haswell (2/08/2021)
  - 5 regression tests passed
  - KPRAD_RESTART did not pass, but differences are very small in velocity variables. All magnetic and thermal good. Similar difference as Cori-KNL
  - RMP_nonlin initially failed …: There 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)
  - ??

M3D-C1 modeling of pellet ELM triggering in low-collisionality discharges

- Preprint by A. Wingen (ORNL), Linear and non-linear simulations
- Linear simulation with ipellet=1 perturbs only the density profile. Large enough perturbation excites an unstable mode

Q: How does a density perturbation excite a MHD mode?

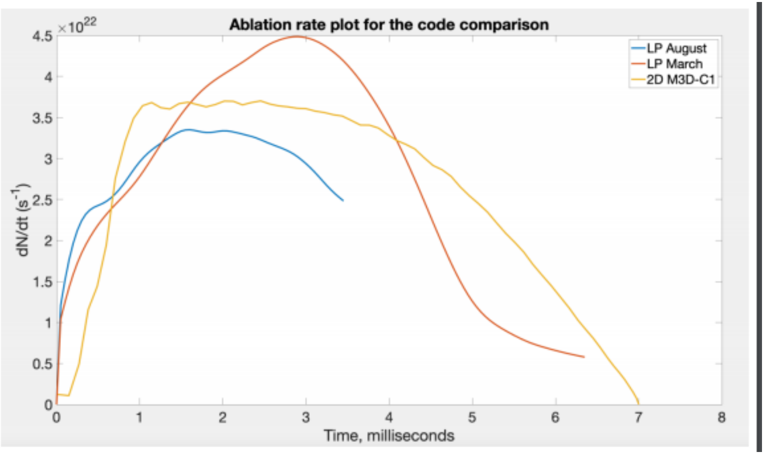




Density perturbation causes decreased Te at one location on flux surface. Thermal conduction during linear phase causes pressure to increase there. Gives an unstable mode for ntor=9 only if kappar .ne. 0

Interfacing M3D-C1 and LPC

- Zoom meeting was held 04/08/21 with Roman Samulyak and students
- Presentation posted on m3dc1.pppl.gov
- Small differences between m3dc1 pellet model and LPC local model
- Brendan to see what data is available for single neon pellet ablation test
- **Daisuke Shiraki will address this in a special call set for Tuesday at 2:00 ET. Lyons, Samulyak, Jardin, ….. (assuming Samulyak availability)**



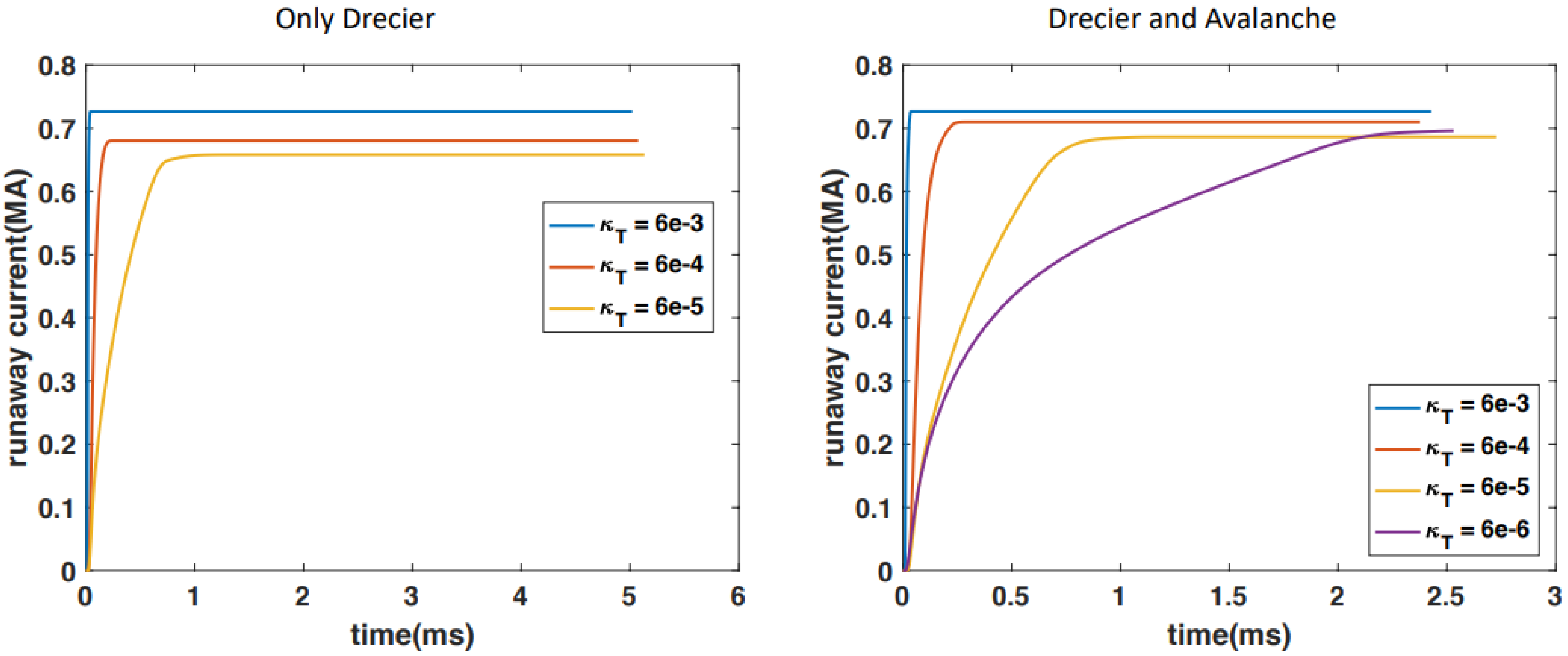
Approach to nonlinear MHD simulations in stellarator geometry

- Yao Zhou has an excellent preprint he plans to submit to Nuclear Fusion

Self-consistent simulation of resistive kink instabilities with runaway electrons

- Chang Liu, et al manuscript submitted to Plasma Physics and Controlled Fusion 04/21/2021

Effect of Avalanche term on DIII-D 177053



Chen Zhao

Next Steps

- Chen Zhao should consider writing a paper on the incorporation of the runaway source term in M3D-C1 and include the DIII-D result

- NIMROD is interested in doing a benchmark of the runaway source calculations. I gave them Chen's equilibrium and results. This could be included in paper if done sufficiently fast.

- I asked Carlos Paz-Soldan to help us identify a series of DIII-D shots where runaways are generated and there are good diagnostics. Still waiting to hear. (he did indicate that he's working on it)

- We had a zoom call with the JOREK group this morning. They will also check with ASDEX-U to see if there is a series of experiments that we could model

Effect of resistive wall on the thermal quench

- Hank Strauss requested an EFIT equilibrium for shot 154576 at 3312ms, just before it disrupts
- This was studied in the paper: R. Sweeney, et al, "Relationship between locked modes and thermal quenches in DIII-D"
- Focus of paper is that sometimes overlapping locked modes just flatten the temperature around the q=2 surface (q=3/2 to edge) whereas sometimes they also cause a collapse of the core temperature
- NIMROD simulations were initialized with islands of the size and phase of the experiment: 3/2, 2/1, 3/1, and 4/1
- In the simulation, the 2/1 island decays in time, unlike in the experiment. Also, the experiment shows a wider region of Te collapse. Can M3DC1 improve on this?

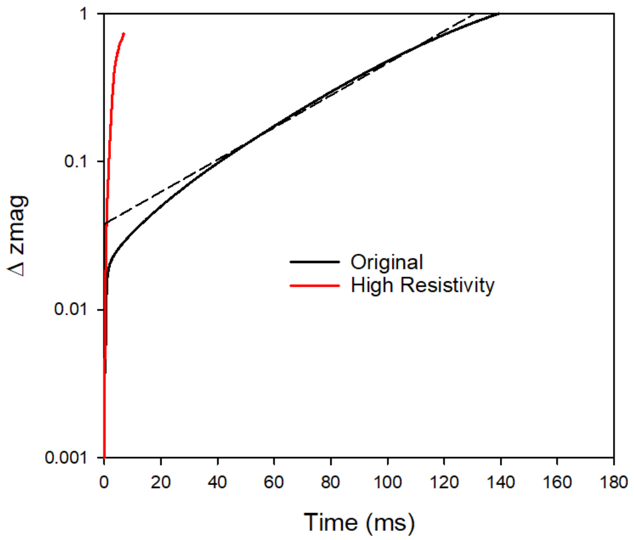
Current coupling scheme of fishbone simulation in M3D-C1

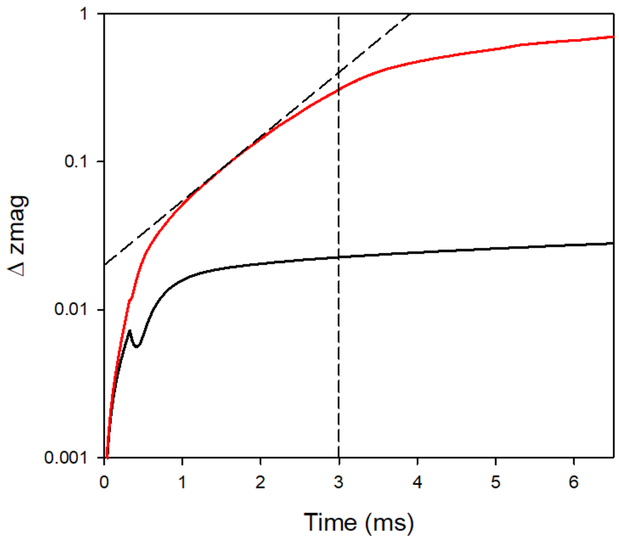
- Chang Liu to present

That’s All I have

Anything Else ?

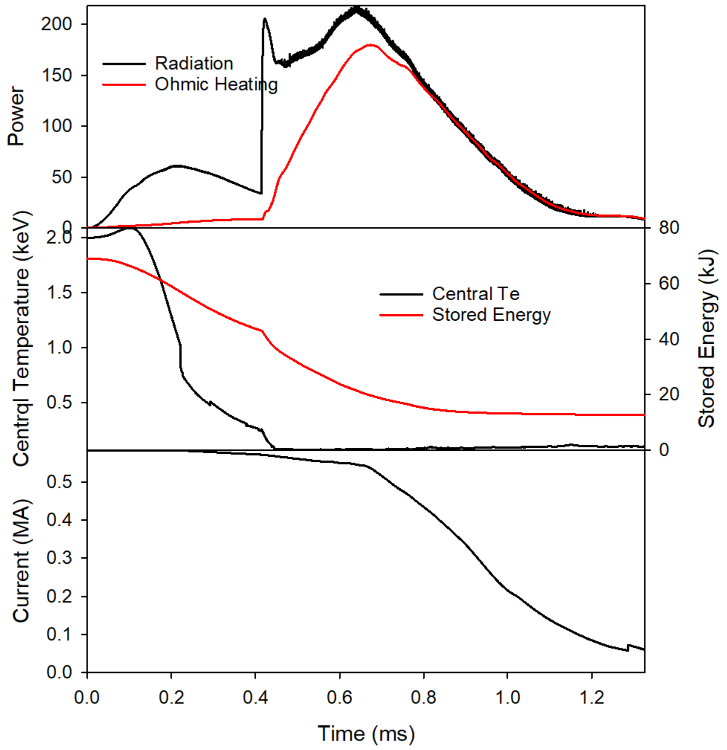
ITER disruption with more resistive vessel





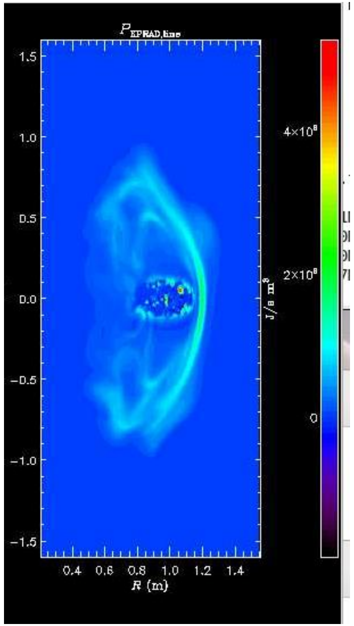
- Increased all vessel resistivities by 100
- Growth rate went from .025 ms^{-1} to 2.0 ms^{-1}
- New case greatly slows down after contact with wall is made

Carbon Mitigation in NSTX-U (shell pellet)



Shell carbon pellet in NSTX (now running)

Radiation
t = 0.73 ms

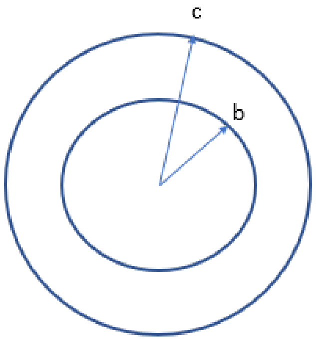


This run is essentially done and can be incorporated into Cesar's paper

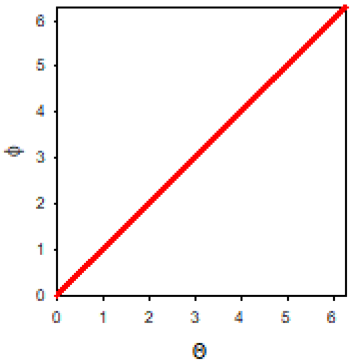
Cesar Clauser

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?

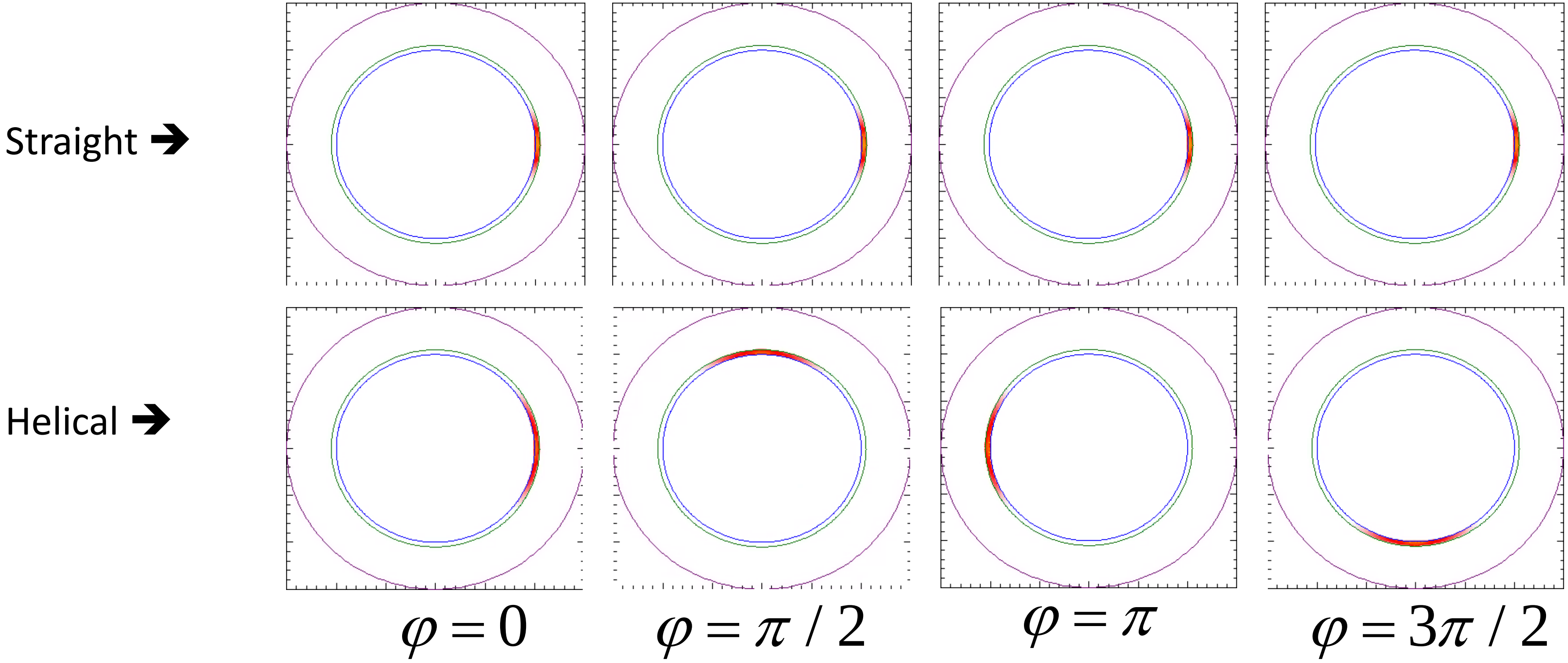
$$\nabla \times \mathbf{E} = 0 \quad \Rightarrow \quad \mathbf{E} = -\nabla\Phi + \frac{V_L}{2\pi}\nabla\phi$$

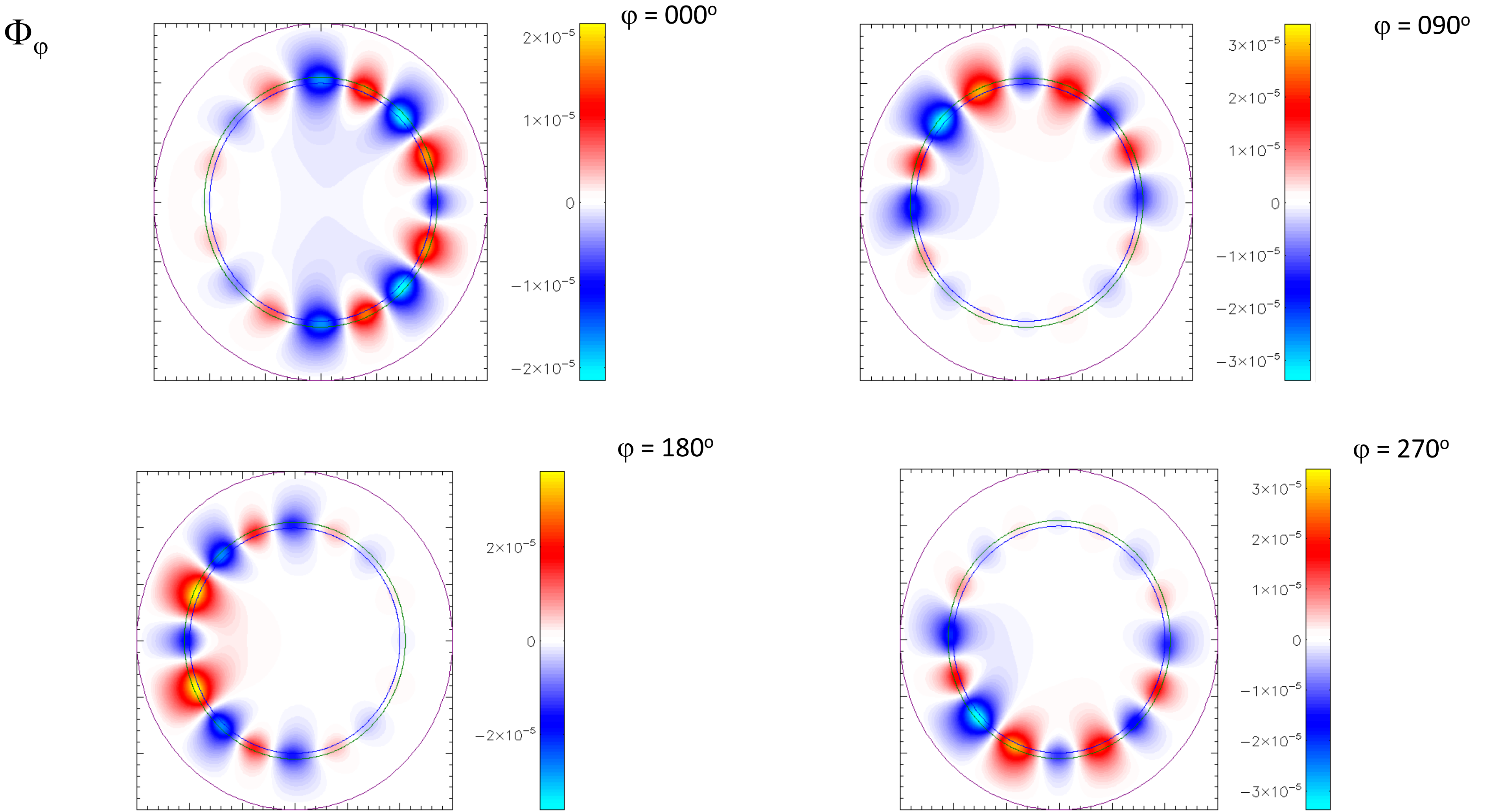
$$\mathbf{J} = \sigma\mathbf{E}$$

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

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

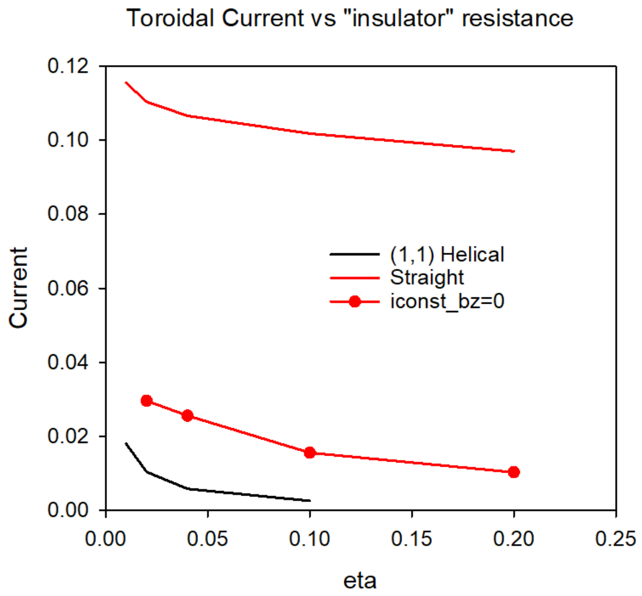
Comparison between Straight and helical band





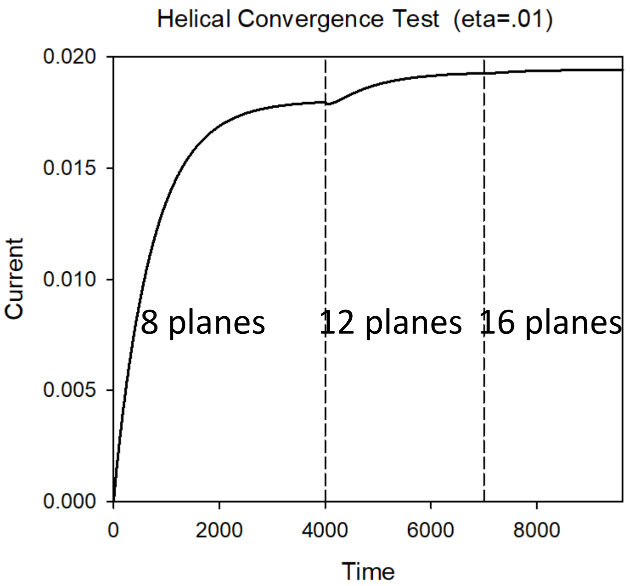
Φφ
φ = 000º
2×10⁻⁵
1×10⁻⁵
0
−1×10⁻⁵
−2×10⁻⁵
φ = 090º
3×10⁻⁵
2×10⁻⁵
1×10⁻⁵
0
−1×10⁻⁵
−2×10⁻⁵
−3×10⁻⁵
φ = 180º
2×10⁻⁵
0
−2×10⁻⁵
φ = 270º
3×10⁻⁵
2×10⁻⁵
1×10⁻⁵
0
−1×10⁻⁵
−2×10⁻⁵
−3×10⁻⁵

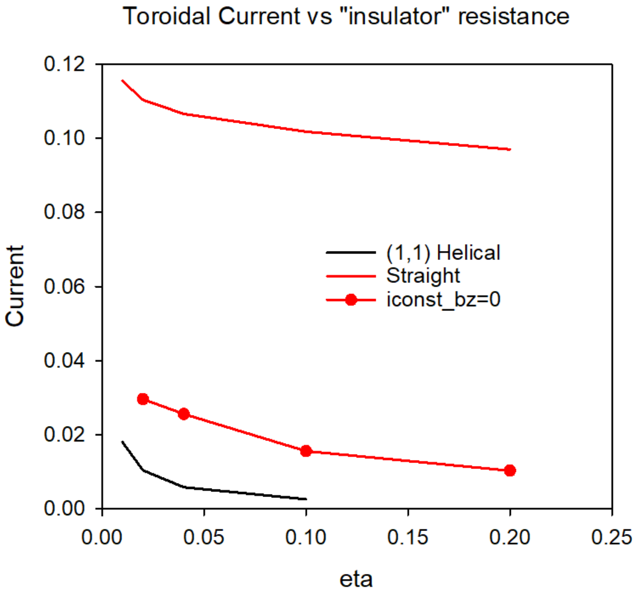
Helical resistive band to suppress runaways



- I have asked Matthias Hoelzl if he could try and reproduce this with the STARWALL code. He seems interested

Some Convergence Tests

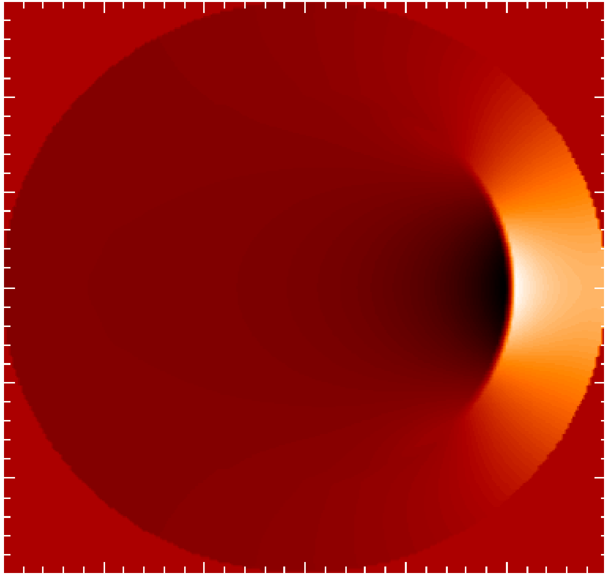




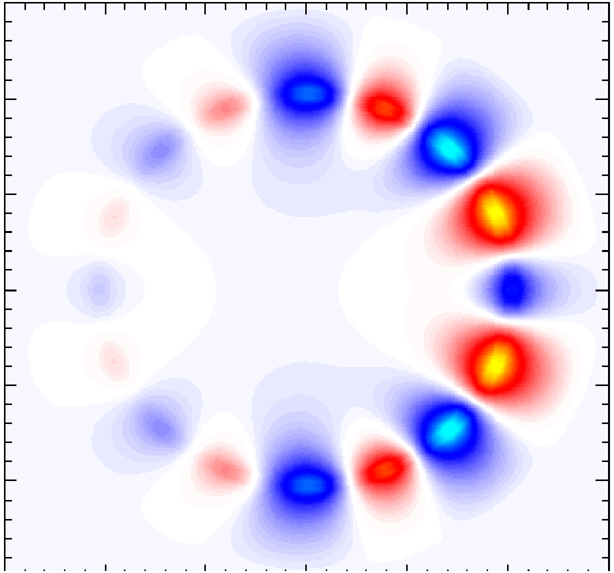
- Wall current appears to be converged in # of planes
- Helical wall current tending towards zero for large values of insulator resistance
- Now testing dependence on boundary conditions (location of ideal wall)
- Helical (1,2) case gives less than half the current of helical (1,1) case
- Iconst_bz=0 increases current, but still far below straight case

Plots for iconst_bz=0

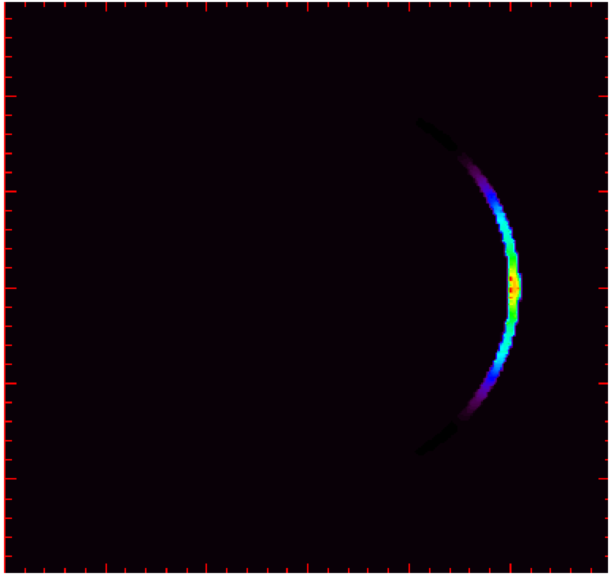
I



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



J_φ



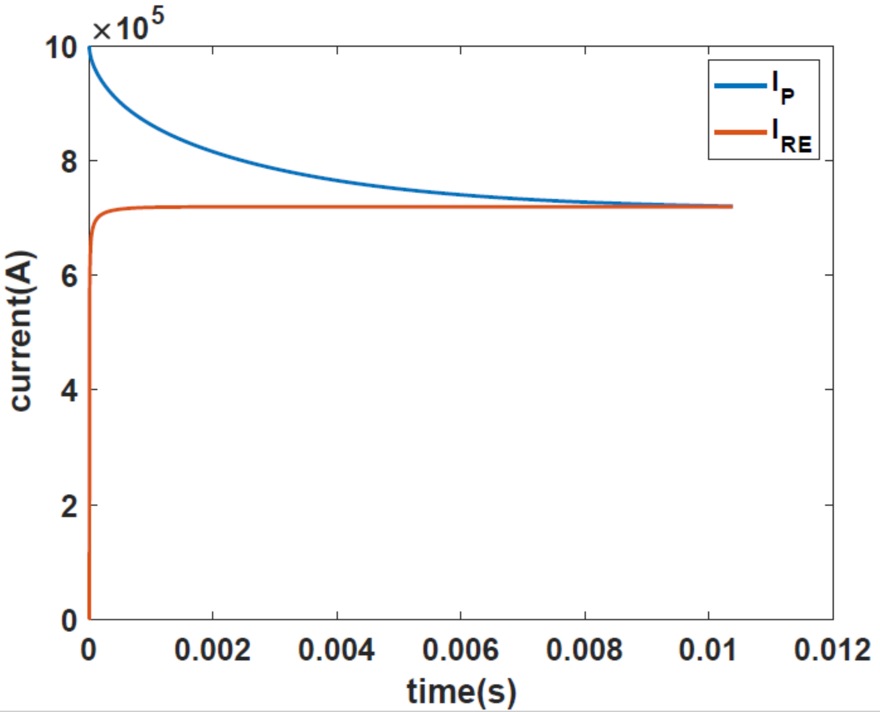
$$\nabla_\perp \bullet \frac{1}{R^2} \nabla \Phi = \nabla_\perp \cdot \eta \left[-\frac{1}{R^2} \nabla F \times \nabla \varphi - \frac{1}{R^2} \nabla f'' \times \nabla \varphi - \frac{1}{R^4} \nabla_\perp \psi' \right]$$

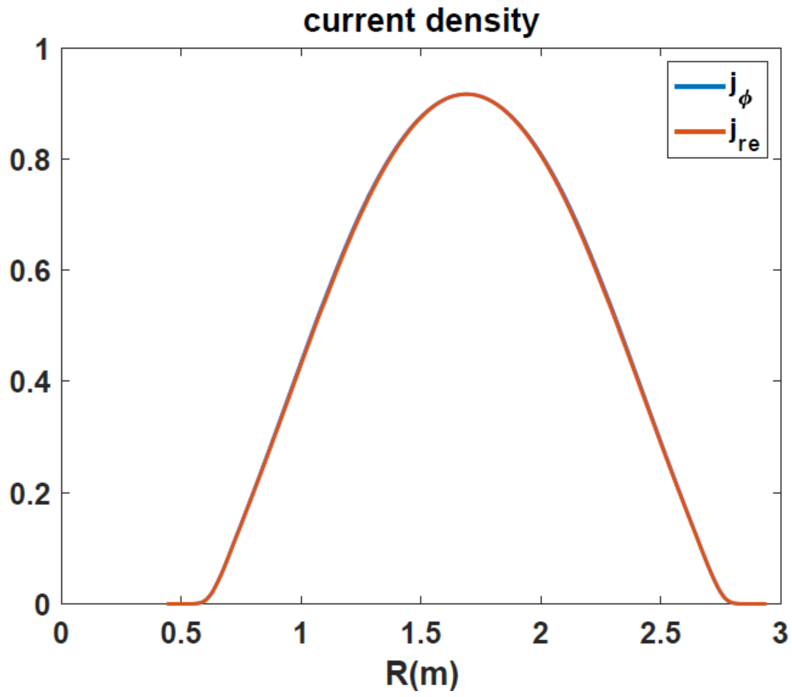
Local Systems

- PPPL centos7(02/22/21)
  - 6 regression tests PASSED on centos7:

- PPPL greene (02/15/21)
  - 4 regression tests PASSED
  - RMP_nonlin timed out (but gave correct results)
  - No batch file found for pellet
- EDDY (2/15/21)
  - 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

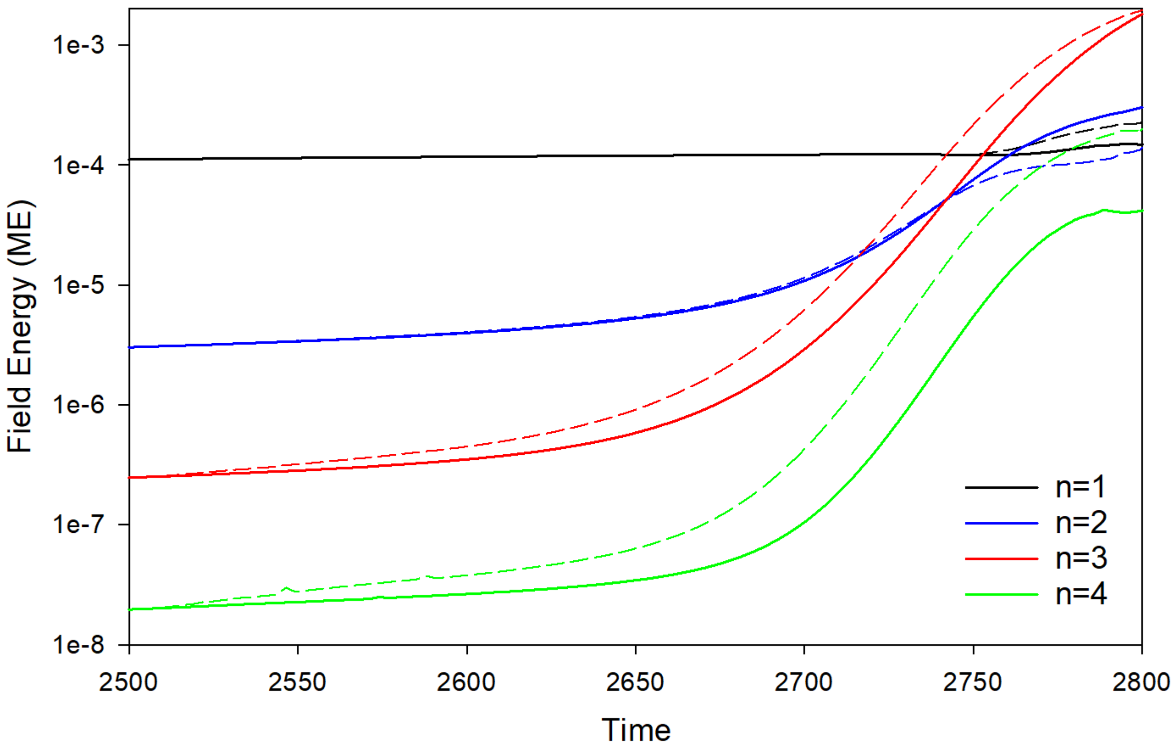
2D (cylindrical) RE with sources (12/19/2020)



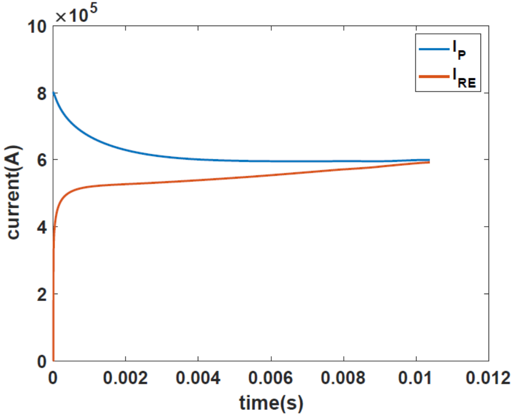


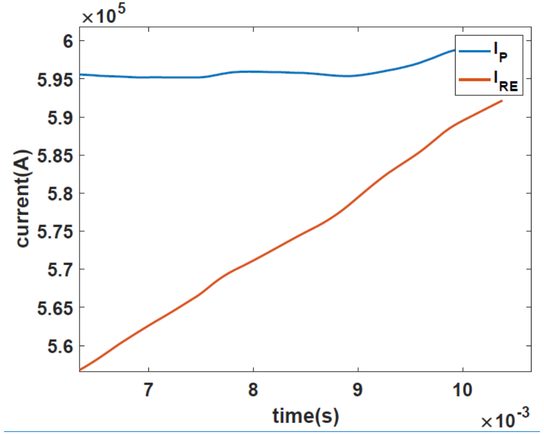
Chen Zhao

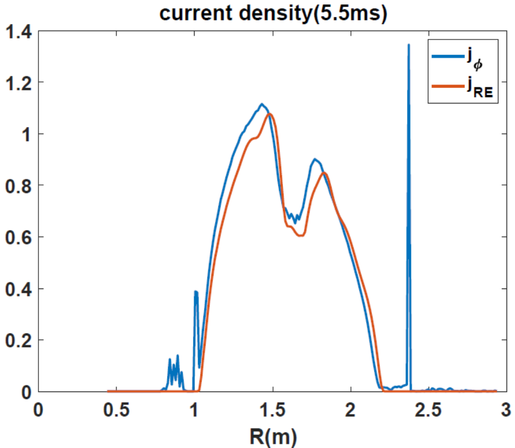
Energy in base case 36742317 (solid) and 16 plane case 37248033 (dashed)

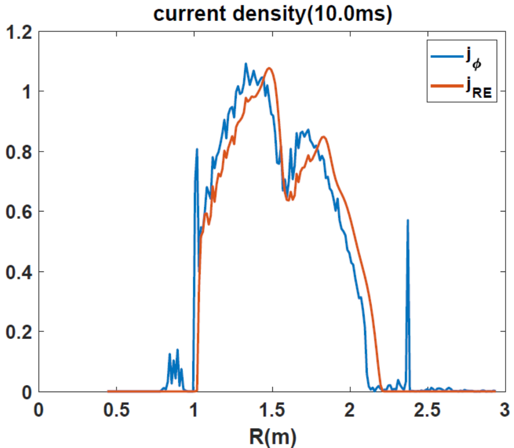


DIII-D 177053 with Argon





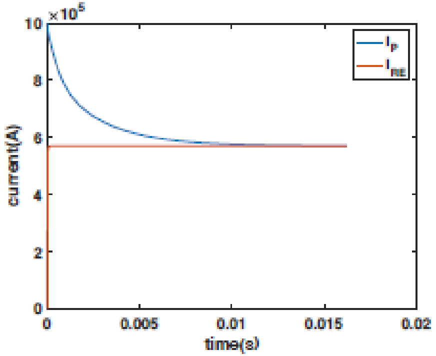


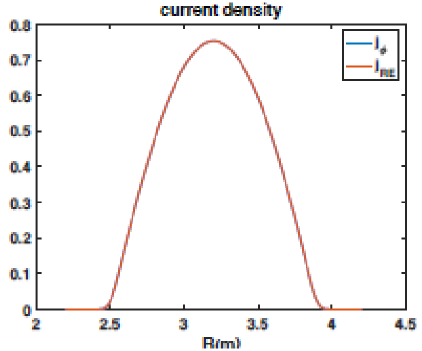


Chen Zhao

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.

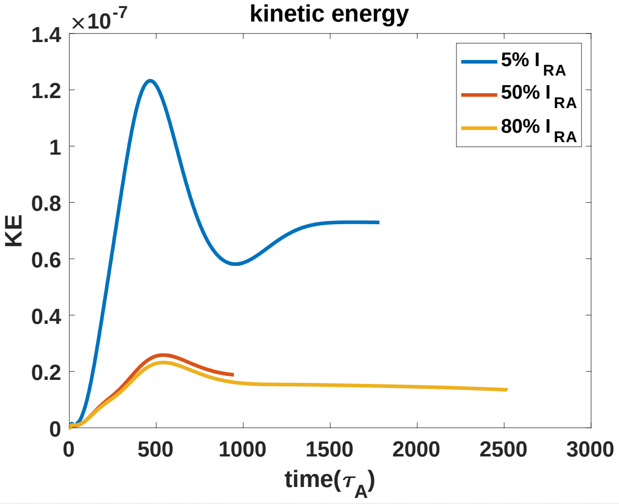
Progress on other shots?

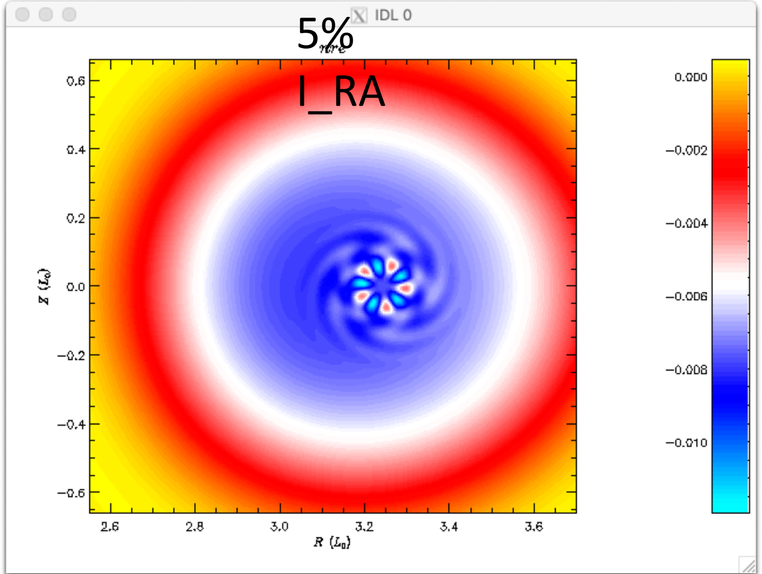
- M3D-C1/NIMROD 3D Benchmark

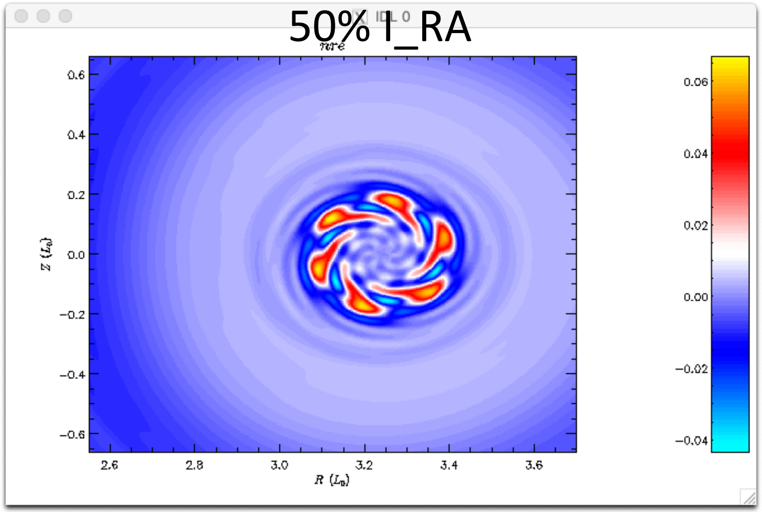
NSTX shot 1224020 – Fast ion transport with coupled kink and tearing modes
Chang Liu

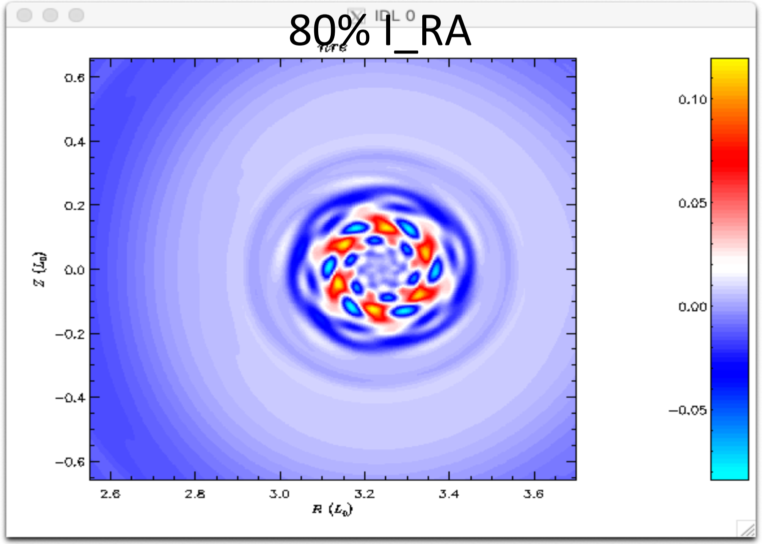
DIII-D Neon pellet mitigation simulation for KORC
- Brendan Lyons trying to extend 8 plane case to 32 planes

SPARK ?   Do we need to do anything?

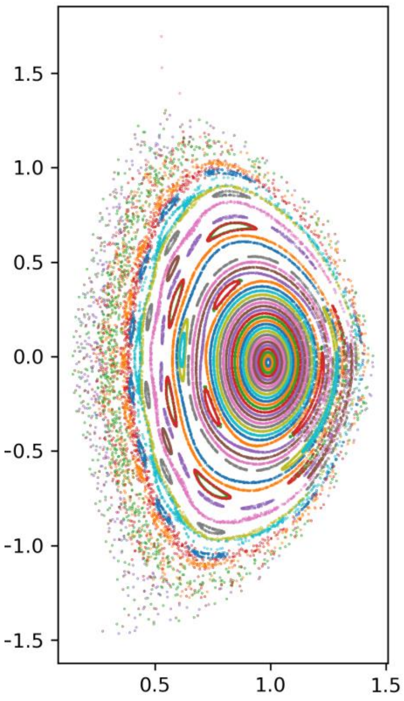

kinetic energy
×10^-7
KE
time(τ_A)
5% I_RA
50% I_RA
80% I_RA
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0
500
1000
1500
2000
2500
3000


IDL 0
5% I_RA
Z (L0)
R (L0)
2.6
2.8
3.0
3.2
3.4
3.6
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
0.000
−0.002
−0.004
−0.006
−0.008
−0.010


IDL 0
50% I_RA
Z (L0)
R (L0)
2.6
2.8
3.0
3.2
3.4
3.6
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
0.06
0.04
0.02
0.00
−0.02
−0.04


IDL 0
80% I_RA
Z (L0)
R (L0)
2.6
2.8
3.0
3.2
3.4
3.6
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
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

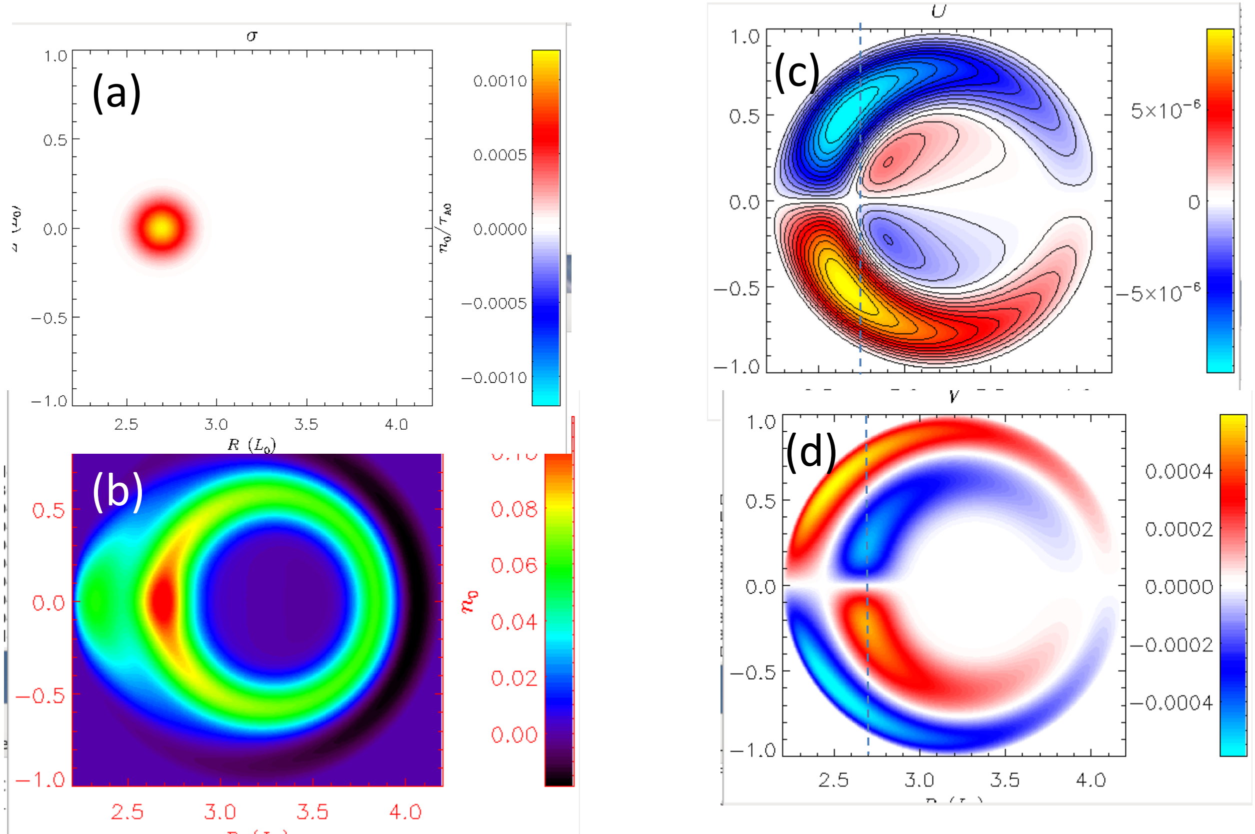
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

(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

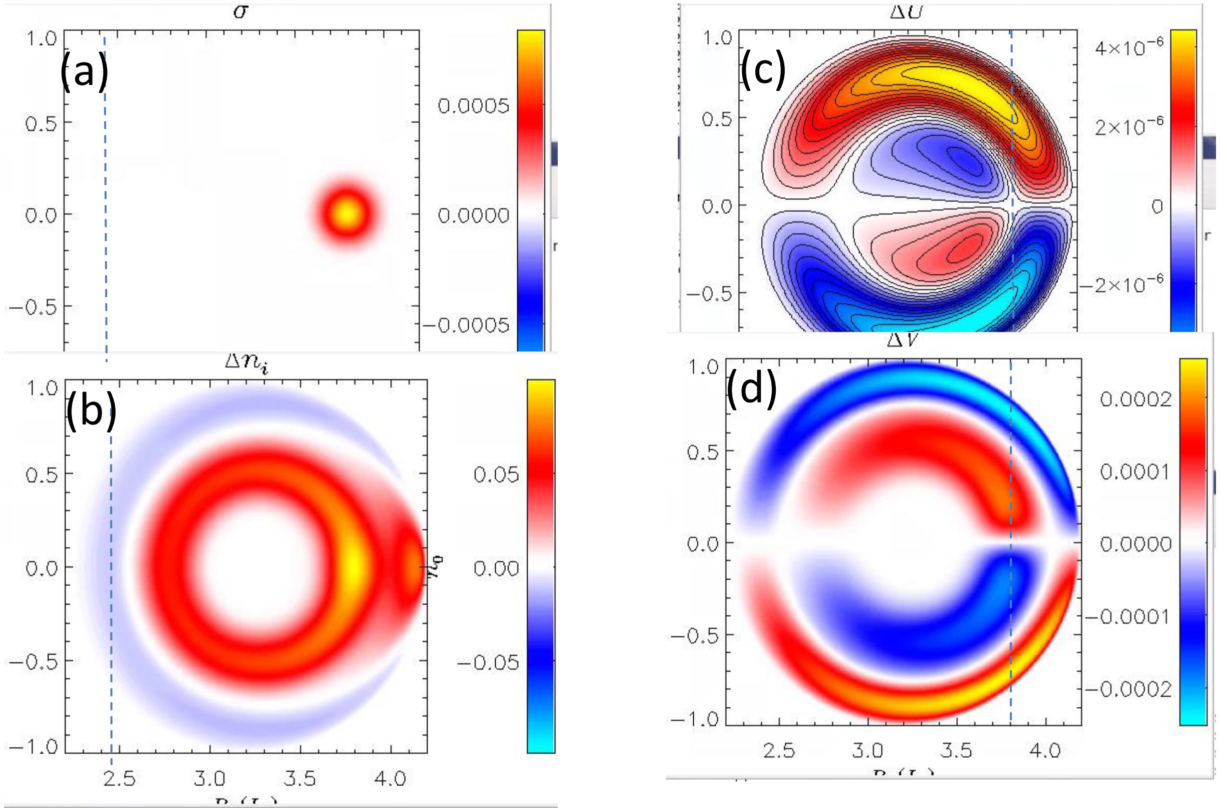
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

(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



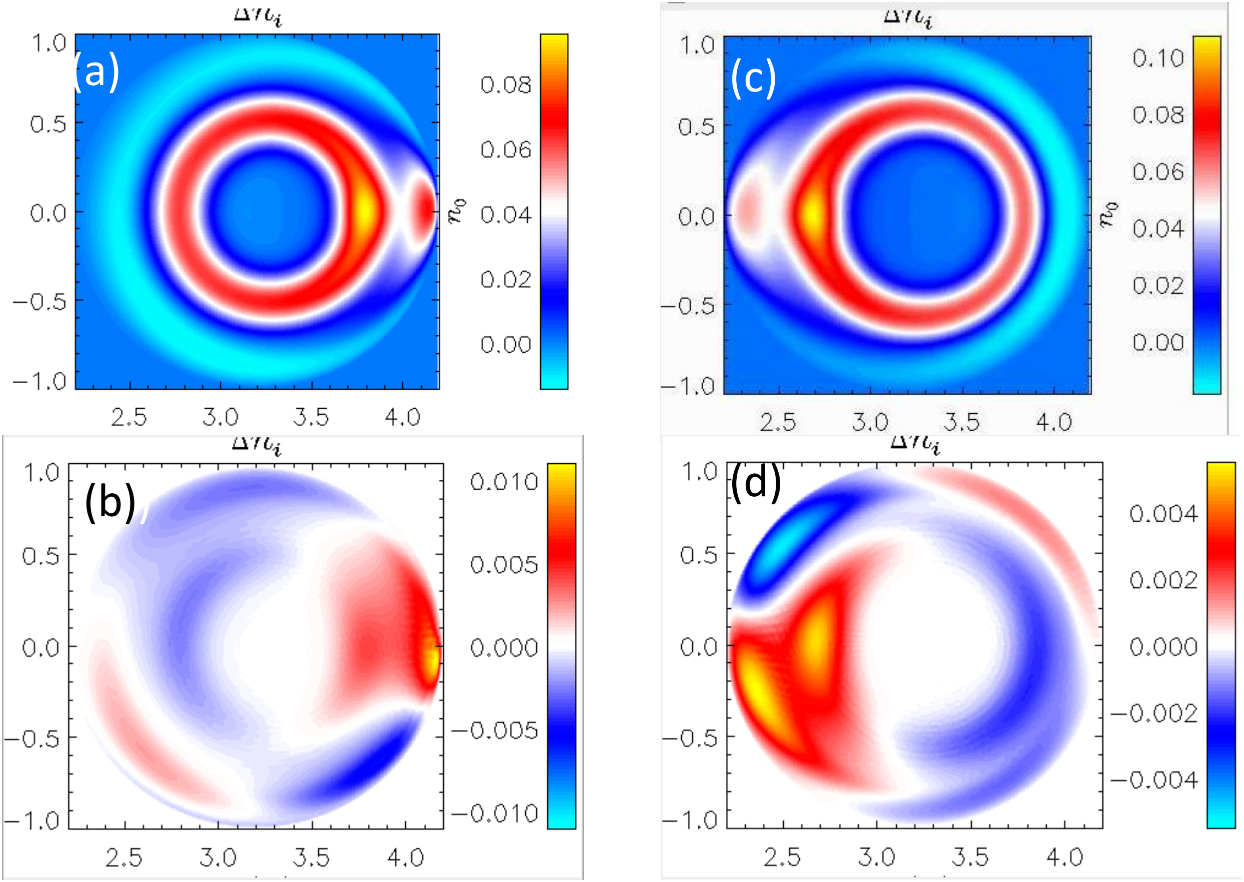
Grad-B drift in M3D-C1—2F effects

(a) 2F density change after $10^3\ \tau_A$ for LF side source

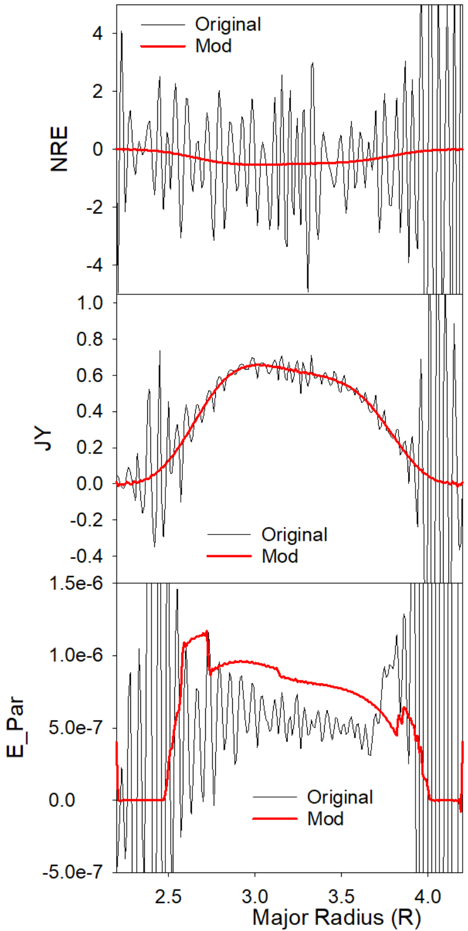
(b) Difference in 1F and 2F density (LF)

(c) 2Fdensity change after $10^3\ \tau_A$ 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

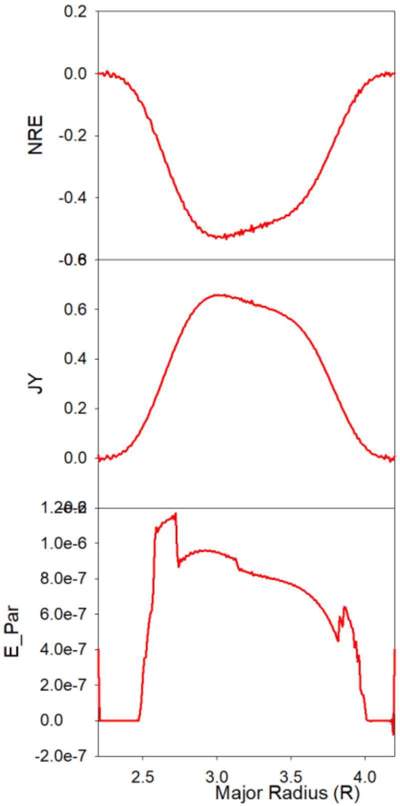
pedge

viscosity

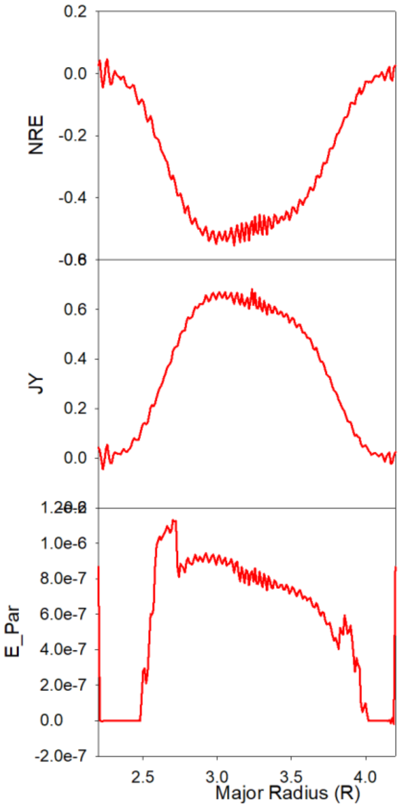
denm

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?