M3D-C1 ZOOM Meeting

05/17/2021

Announcements:

CS Issues

1. GPU solve status
2. Mesh adaptation update
3. DREAM code installed on stellar.pppl.gov
4. stellar .Princeton.edu -- range of solve times
5. NERSC Time
6. Changes to github master since last meeting DIII
7. Regression tests

Physics Studies

1. SPI simulations of Ohmic JET plasma, for EPS poster – Oliver Bardsley
2. DIII-D shot 177053 with Argon – Chen Zhao
3. DIII-D shot 178665 (proposed by Carlos Paz-Soldan)
4. Effect of resistive wall on the thermal quench in DIII-D 154576 – Strauss
5. 2D ITER modeling of SPI – Brendan Lyons
6. 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
Oliver Bardsley
Mark Shephard
Andreas Kleiner

Announcements

- Cori down May 19-20
- PPPL Theory Meeting Monday May 24 3:00 on data management
- TSDW meeting July 19-23
  - Abstracts due June 14
- SciDAC PI meeting July 27-29
- APS Nov 8-12
  - APS Invited Talk nominations due 5/26
  - Abstracts submitted 5/26 – 7/15
- Dara Lewis sent request for grad-students projects/thesis

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

This was held 4/27/21 at 4:30 PM ET

Much of the discussion had to do with saving some of the symbolic data structure information and reusing it. Jin Chen to do some tests.

Jin Chen

From Jin 5/12/21

total run: 3 time steps
case 1, 2, 3, 4: create mat and destroy it at each time step
case 1.1, 2.1, 3.1, 4.1: create mat at the 1st time step and zero it thereafter so that its structure is reused.
a

1 MatSolve 308 1.0 7.8213e+00 1.0 0.00e+00 0.0 0.0e+00 0.0e+00 0.0e+00 1 0 0 0 0 31
1.1 MatSolve 352 1.0 8.9194e+00 1.0 0.00e+00 0.0 0.0e+00 0.0e+00 0.0e+00 1 0 0 0 0 52

-mat_superlu_dist_rowperm norowperm
2 MatSolve 308 1.0 8.7347e+00 1.1 0.00e+00 0.0 0.0e+00 0.0e+00 0.0e+00 1 0 0 0 0 32
2.1 MatSolve 352 1.0 9.1180e+00 1.0 0.00e+00 0.0 0.0e+00 0.0e+00 0.0e+00 1 0 0 0 0 55

-mat_superlu_dist_fact SamePattern_SameRowPerm
3. MatSolve 308 1.0 8.9063e+00 1.1 0.00e+00 0.0 0.0e+00 0.0e+00 0.0e+00 1 0 0 0 0 28
3.1 MatSolve 352 1.0 8.9836e+00 1.0 0.00e+00 0.0 0.0e+00 0.0e+00 0.0e+00 1 0 0 0 0 51

-mat_superlu_dist_fact SamePattern
4. MatSolve 308 1.0 7.8210e+00 1.0 0.00e+00 0.0 0.0e+00 0.0e+00 0.0e+00 1 0 0 0 0 31
4.1 MatSolve 352 1.0 8.9000e+00 1.0 0.00e+00 0.0 0.0e+00 0.0e+00 0.0e+00 1 0 0 0 0 51

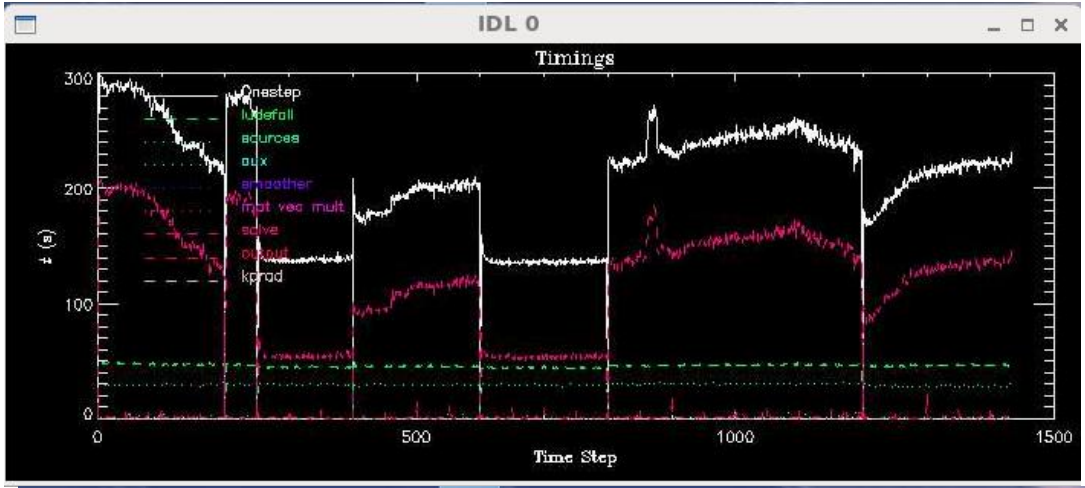
It's more time consuming because more iterations are needed
when the preconditioner becomes less efficient at the reuse time steps.

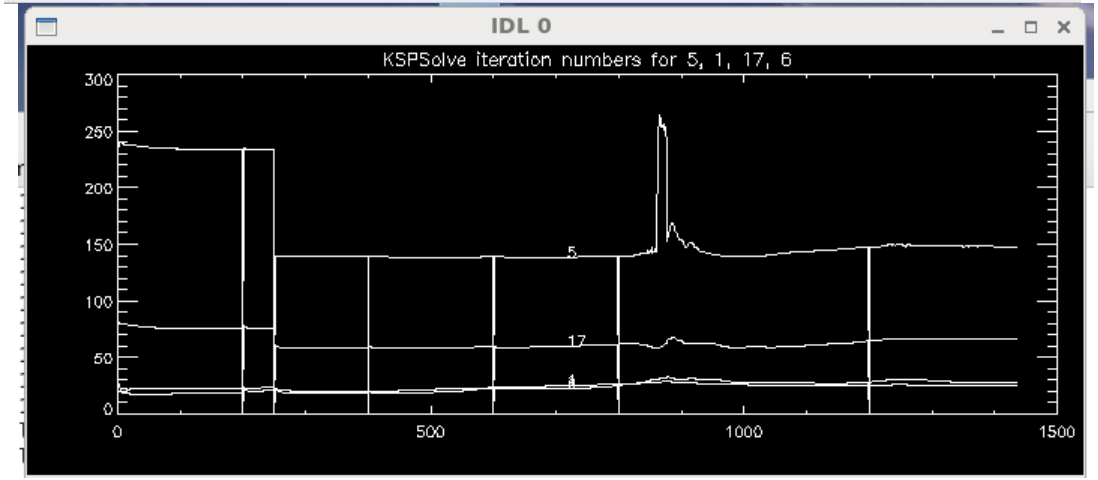
Mesh Adaptation Update

RPI?
Brendan Lyons ?

DREAM code installed on stellar

- Installed by Jin Chen on 4/30/21
- Sample cases ?



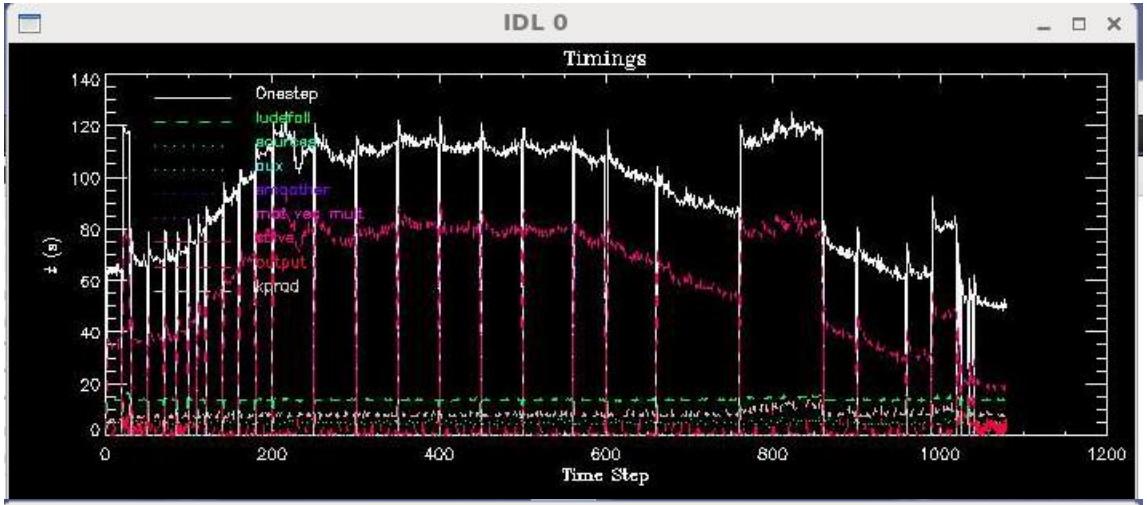


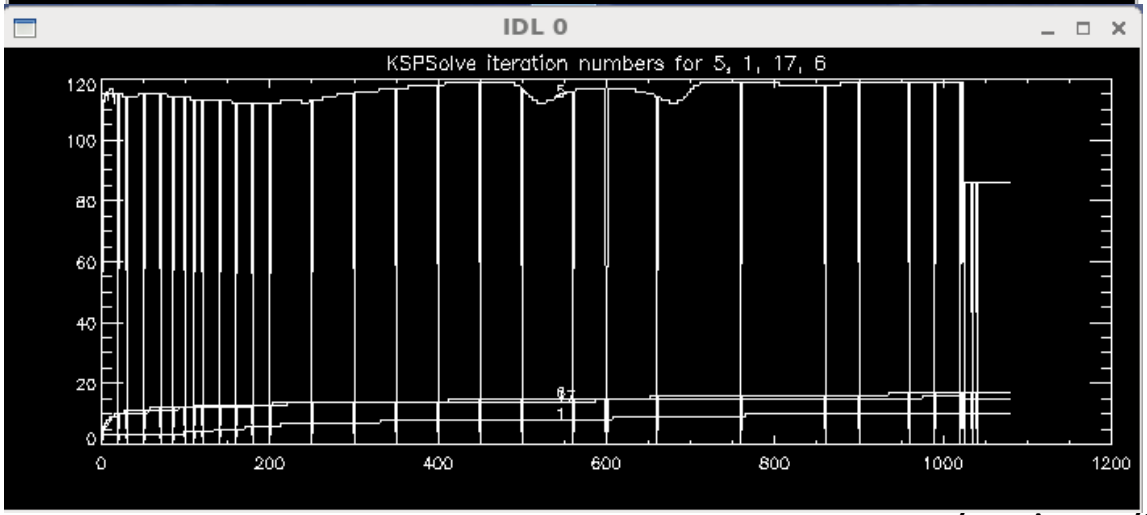
stellar.pppl.gov

Solve time varies by over a factor of 2 when # of iterations doesn't change.

This is using mumps for the preconditioner

/scratch/gpfs/sjardin/3D-2F2





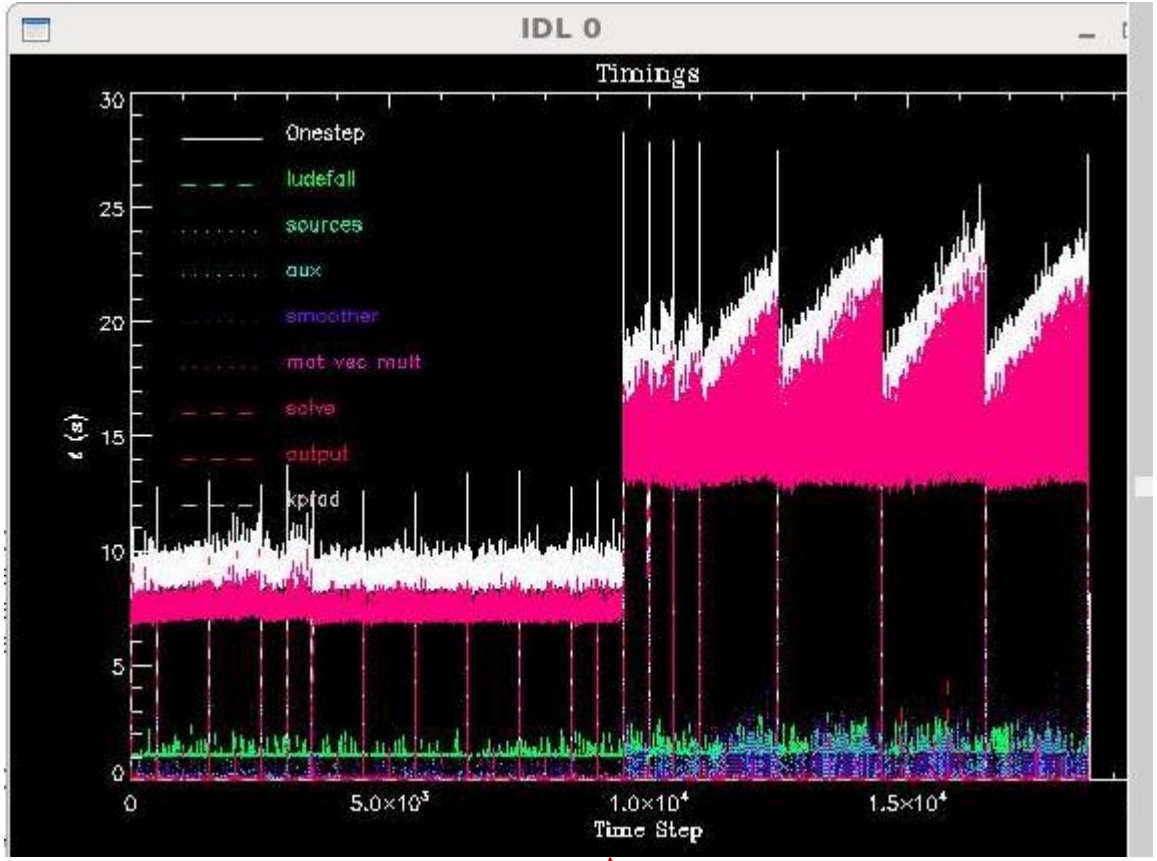
stellar.pppl.gov

Solve time varies by over a factor of 2 when # of iterations doesn't change.

This is using mumps for the preconditioner

/projects/M3DC1/chenzhao/177053_test

stellar.princeton.edu



Switch from mumps to SuperLU_dist

2D (real) runs with 96p

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

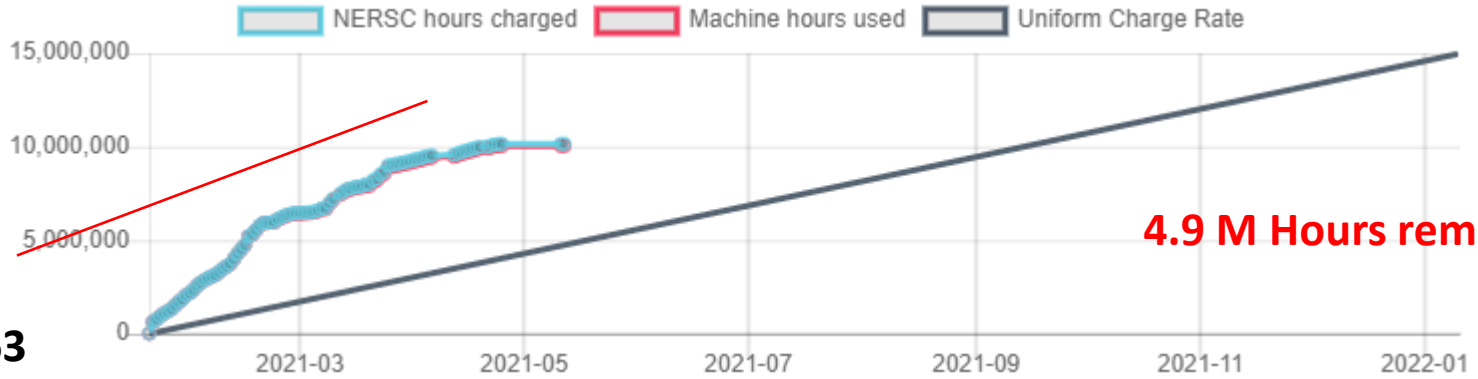
End of plot range
Solve time varies between 13-21s

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



4.9 M Hours remaining!

m3163

Closed for general use

- mp288 received 10M Hrs for CY 2021
- Initial allocation exhausted by May 1
- Jardin contacted John Mandrekas (DOE) who added 5M Hrs additional
- More time may be possible if this is exhausted
- Pearlmutter time will not be charged for this FY

Changes to github master since 04/26

- **Brendan Lyons:**
  - **04/26/21:** New KPRAD cutoff options (#35)
    - New option for turning off KPRAD radiation & ionization, but not recombination, below minimum ne & Te
    - Change where kprad_nemin and kprad_temin get unnormalized for ikprad_min_option=2
    - Add ikprad_min_option=3 which also turns off radiation
    - Prevent frequent allocation within KPRAD subroutine
  - **05/04/21:** Get plane locations in IDL directly from mesh if available

- **Jin Chen**
  - **04/28/21:** add Stage Profiling for velocity equation s1_mat

- **Andreas Kleiner**
  - **05/04/21:** Enabled a2cc to write coil currents from MAST a-files

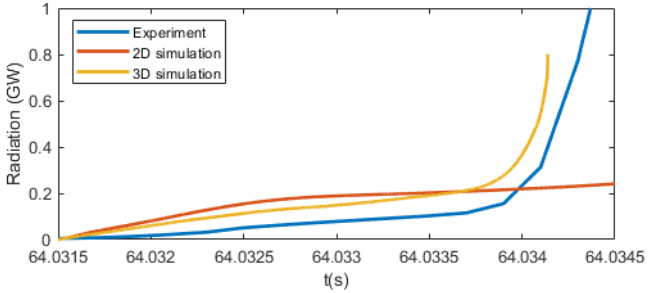
Local Systems

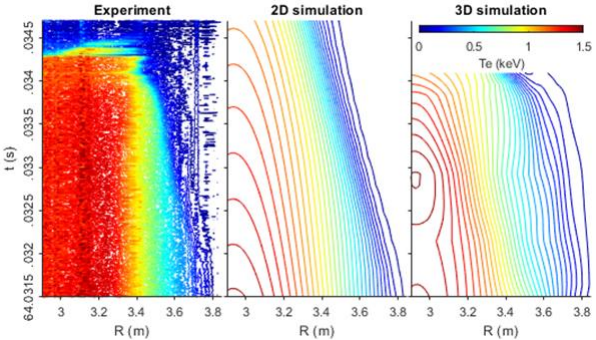
- PPPL centos7(05/16/21)
  - 6 regression tests **PASSED** on centos7:
- PPPL greene (05/16/21)
  - 5 regression tests **PASSED**
- STELLAR (05/16/21)
  - 6 regression tests **PASSED** on stellar
- TRAVERSE(03/29/21)
  - Code compiles
  - Regression test failed: split_smb not found in PATH

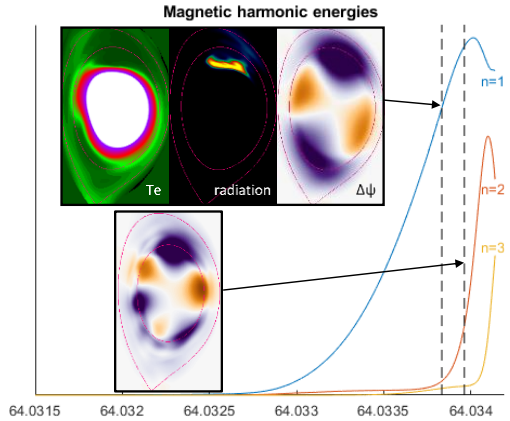
Other Systems

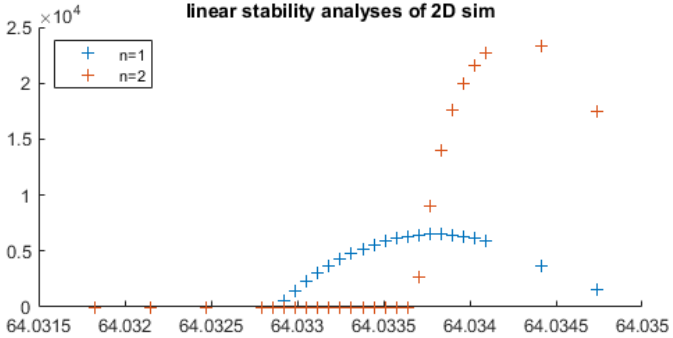
- Cori-KNL (2/08/2021)
  - 6 regression tests passed on KNL
- Cori-Haswell (2/08/2021)
  - 5 regression tests passed
  - KPRAD_RESTART did not pass, but differences are very small in velocity variables. All magnetic and thermal good. Similar difference as Cori-KNL
  - RMP_nonlin initially failed …: There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

SPI simulations of Ohmic JET plasma, for EPS poster – Oliver Bardsley 17.5.21

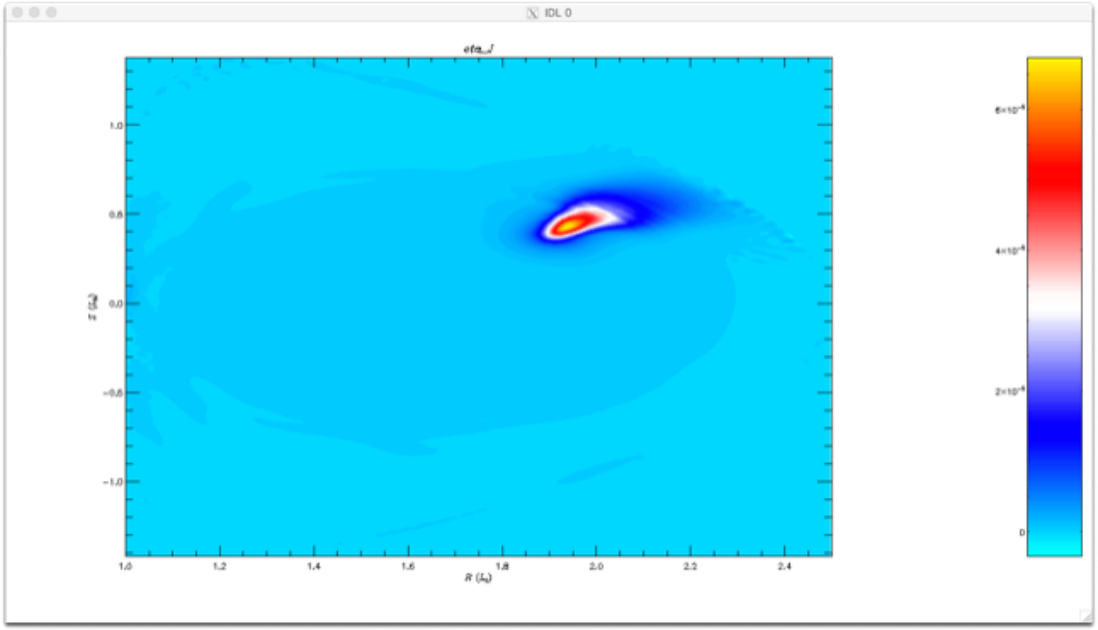








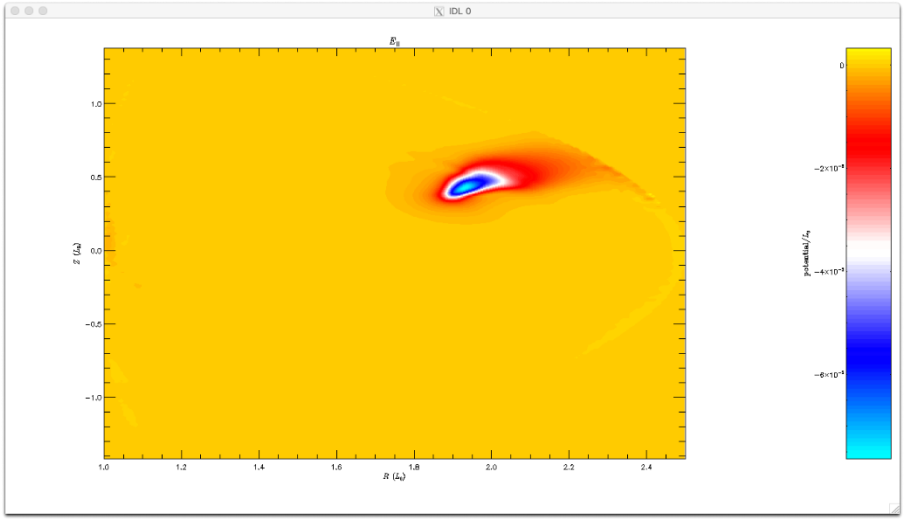
DIII-D shot 177053 with Argon



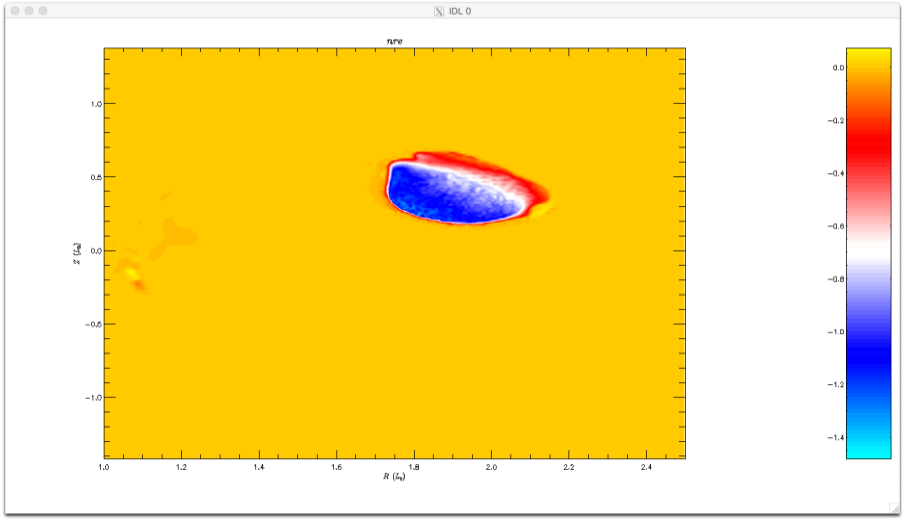
- eta * J larger near pellet as eta increases rapidly and J changes only slowly
- Chen was getting negative temperatures, but lowered timestep and now seems ok
- Might check kprad parameters with Brendan

Chen Zhao

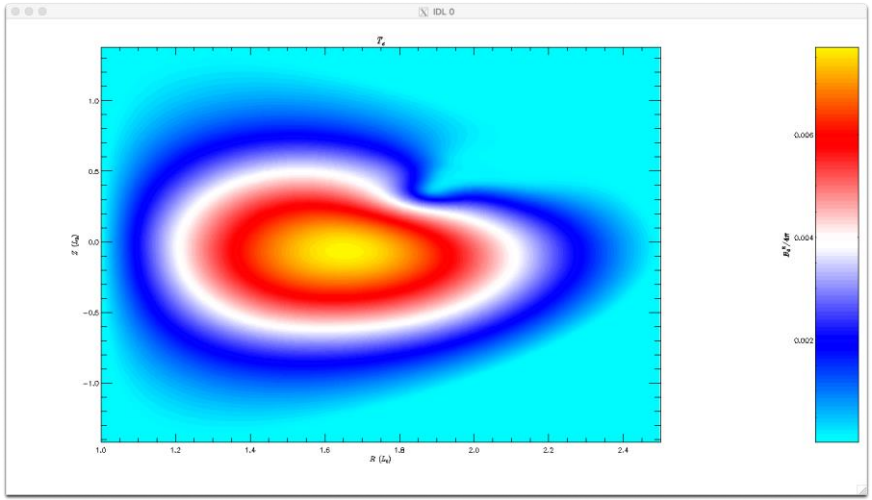
Eta * J



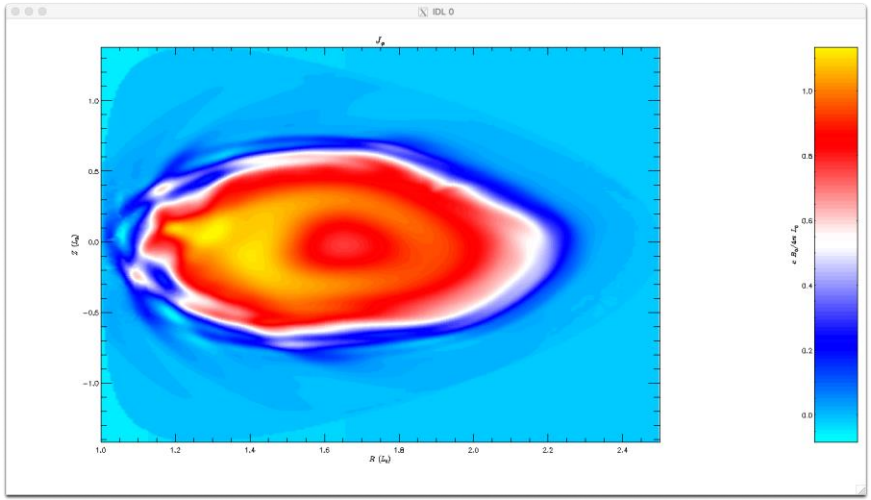
J_RA



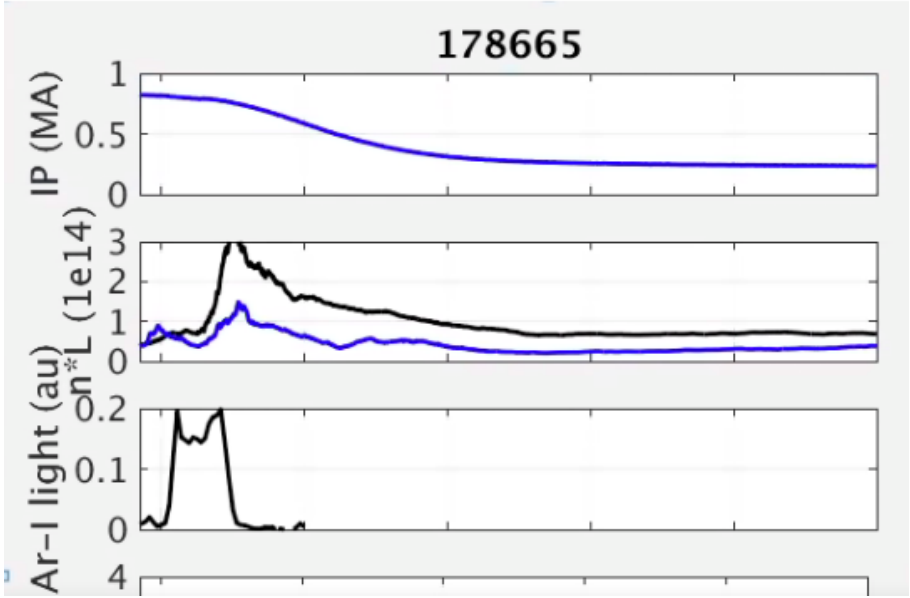
T_e


IDL 0
T_e
1.0
0.5
0.0
−0.5
−1.0
z (L_g)
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
R (L_g)
0.006
0.004
0.002
$K_b^2 / 4\pi r$

J_phi


IDL 0
J_ϕ
1.0
0.5
0.0
−0.5
−1.0
z (L_g)
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
R (L_g)
1.0
0.8
0.6
0.4
0.2
0.0
$z \cdot B_\phi / 4\pi r \cdot L_g$

DIII-D RE generation with Ar shot 178665



Carlos suggested this shot:

<ne>, Te(r,t), IP(t), AR-1 (R,Z,t)

Eric Hollman studied this shot in detail in an upcoming paper so we may want to write to him

/p/tsc/blyons/M3D-C1/data/OMFIT/DIII-D/154576/03354_945/hs2/rw1_equil

DIII-D Thermal Quench Shot 154576

- Brendan has set up mesh, obtained equilibrium at time 3.354 and given to Hank
- /p/tsc/blyons/M3D-C1/data/OMFIT/DIIID/154576/03354_945/hs2/rw1_equil

2D ITER modeling of SPI

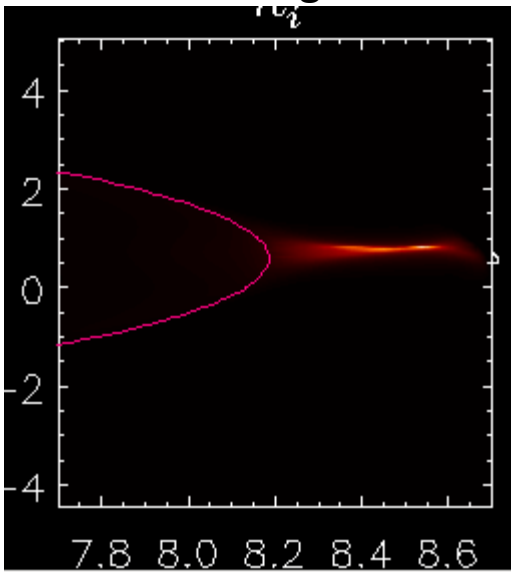
- I've recently started some 2D ITER modeling of SPI and I'm getting a weird result.
- The attached video show the density, every time step, from /scratch/gpfs/bclyons/C1_11735 on stellar.
- Overlaid is the poloidal velocity.
- There is a line of pellets that start near the separatrix and then go outward toward the wall.
- You can see that a divergent flow develops inside the separatrix, which makes sense.
- Outside the separatrix though, the flow converges to the pellet location. This causes a build up of density and eventually a numerical instability.
- The temperature is low in the SOL, so there's not a lot of pressure to repel the flow. I don't know why the flow is forming in the first place though. Any thoughts?

Brendan Lyons 5/6/21

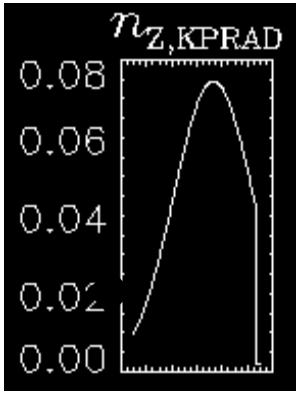
2D ITER SPI Modeling (cont)

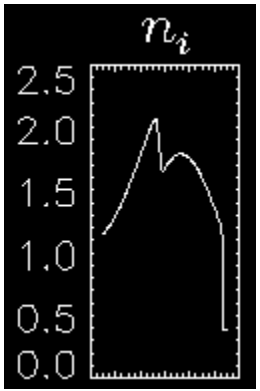
den ~ 120 kprad_totden !!
Can we plot individual kprad_n(i)?

Area plotted: 7.7 < R < 8.7
Z = 0.8 on right

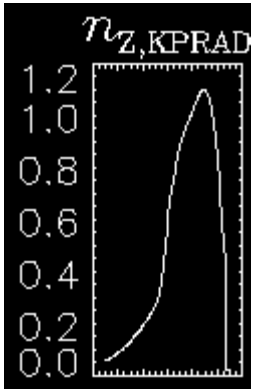


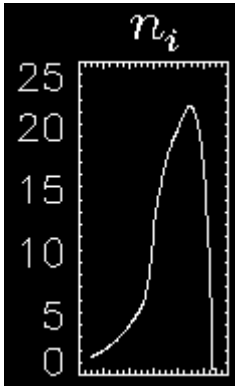
N = 1



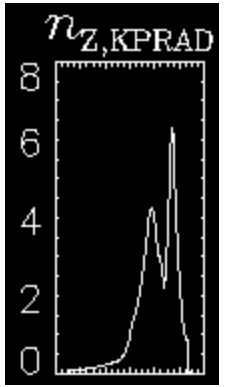


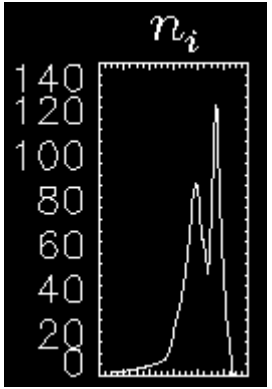
N = 10





N = 20





That’s All I have

Anything Else ?

That’s All I have

Anything Else ?

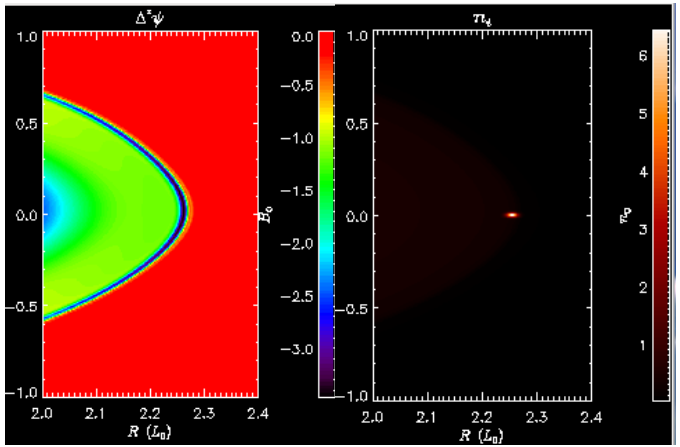
That’s All I have

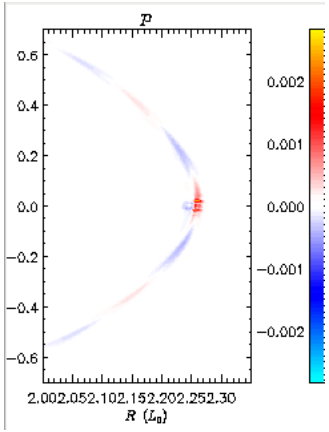
Anything Else ?

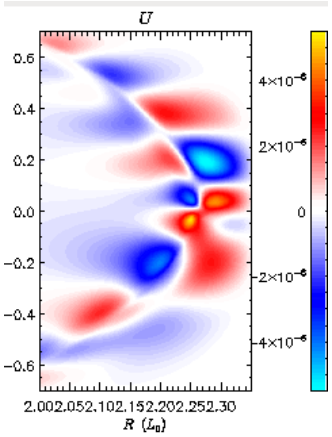
M3D-C1 modeling of pellet ELM triggering in low-collisionality discharges

- 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?



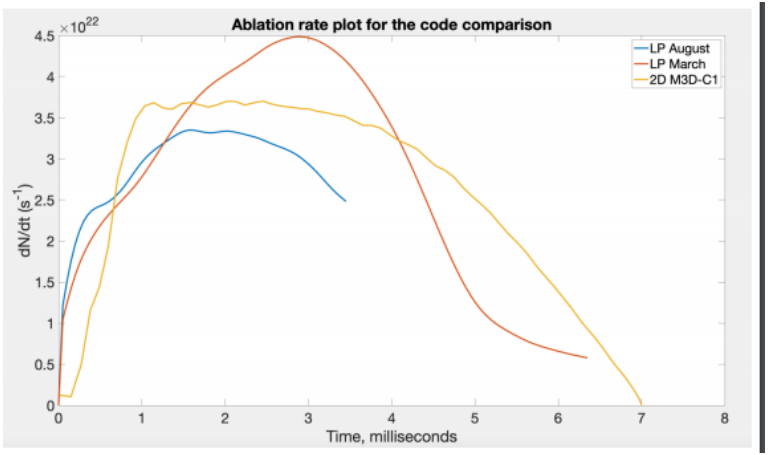




Density perturbation causes decreased Te at one location on flux surface. Thermal conduction during linear phase causes pressure to increase there. Gives an unstable mode for ntor=9 only if kappar .ne. 0

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)**



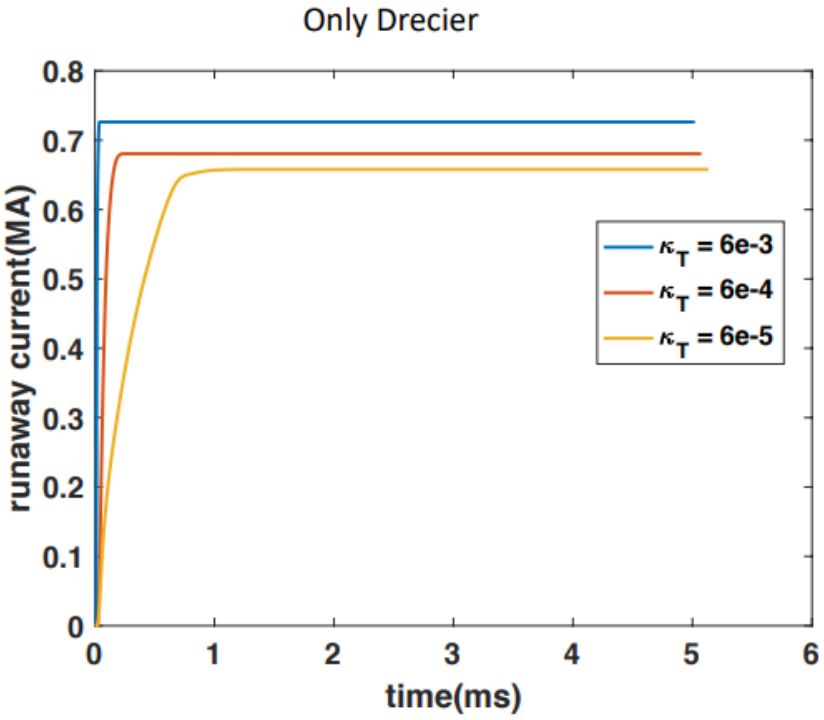
Approach to nonlinear MHD simulations in stellarator geometry

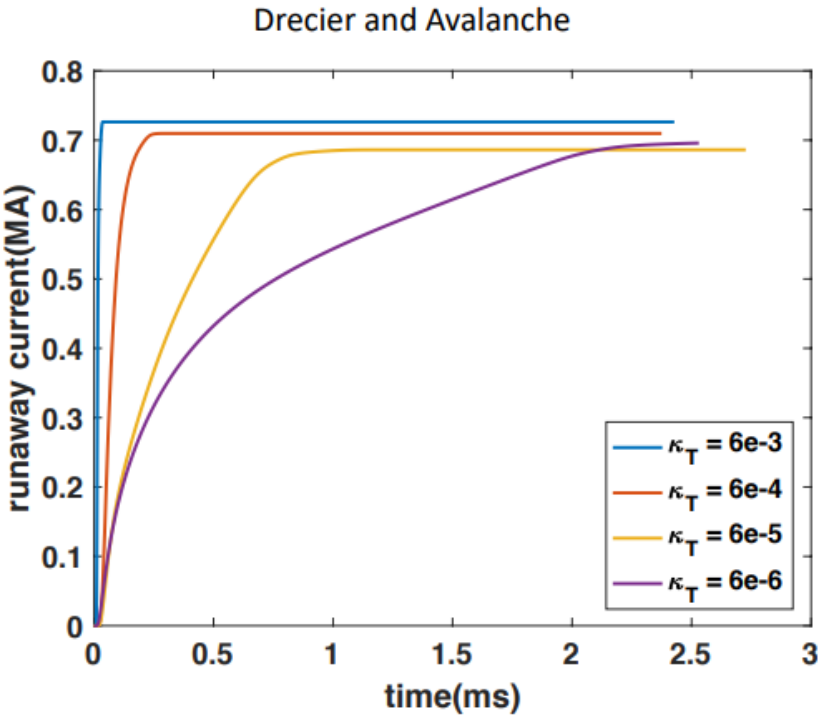
- Yao Zhou has an excellent preprint he plans to submit to Nuclear Fusion

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

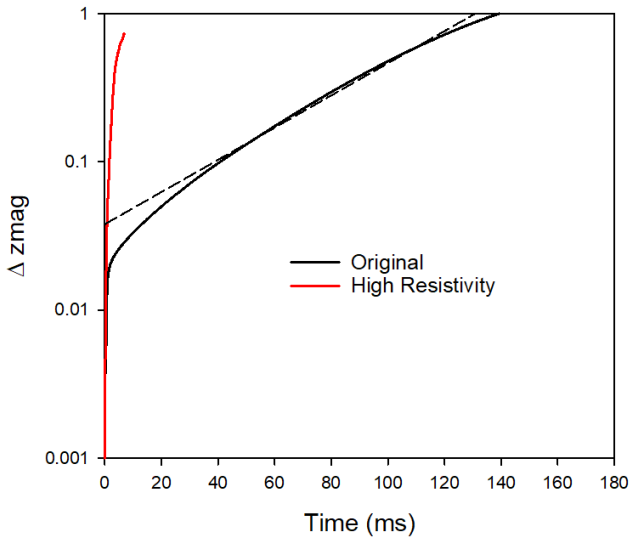
Effect of resistive wall on the thermal quench

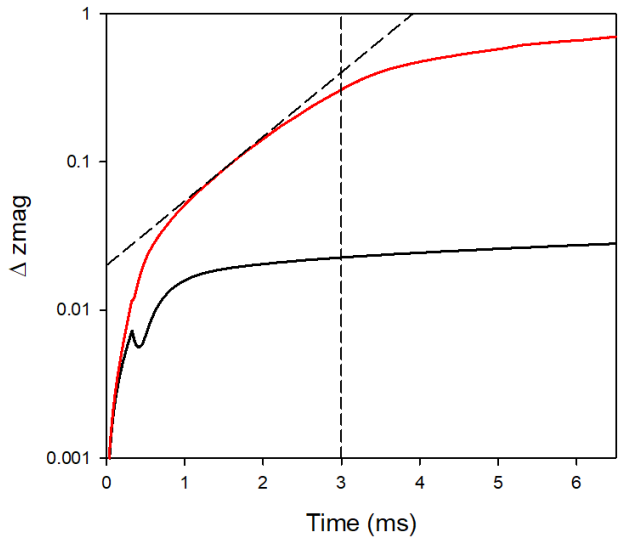
- Hank Strauss requested an EFIT equilibrium for shot 154576 at 3312ms, just before it disrupts
- This was studied in the paper: R. Sweeney, et al, “Relationship between locked modes and thermal quenches in DIII-D”
- Focus of paper is that sometimes overlapping locked modes just flatten the temperature 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

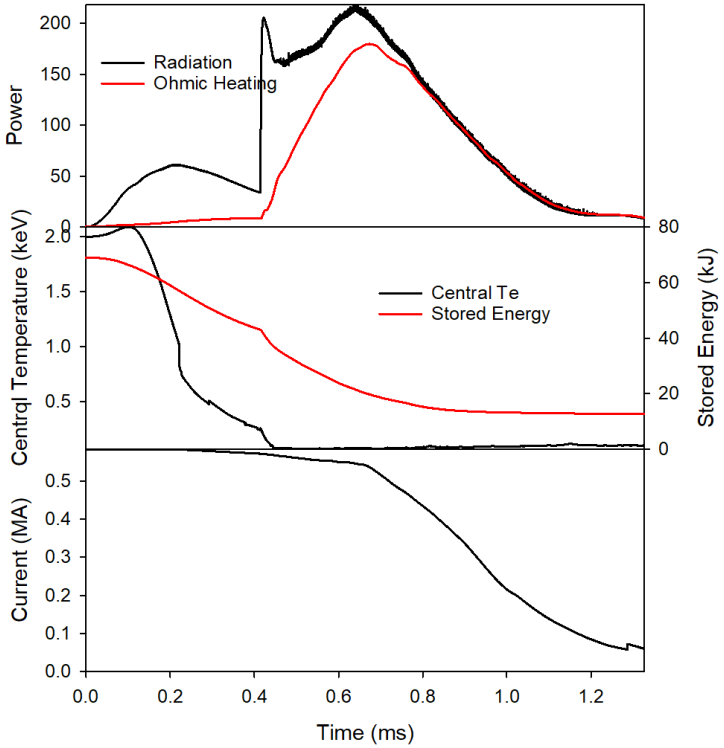
ITER disruption with more resistive vessel





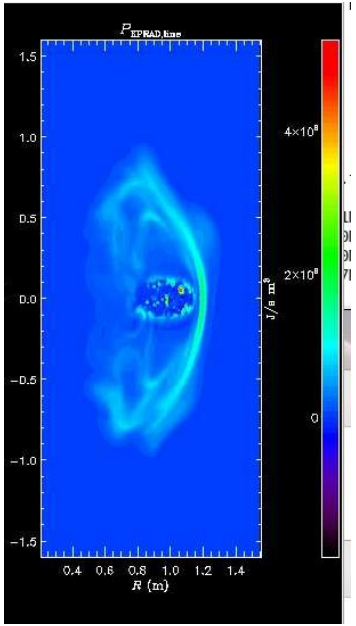
- Increased all vessel resistivities by 100
- Growth rate went from .025 ms^{-1} to 2.0 ms^{-1}
- New case greatly slows down after contact with wall is made

Carbon Mitigation in NSTX-U (shell pellet)



Shell carbon pellet in NSTX (now running)

Radiation
t = 0.73 ms

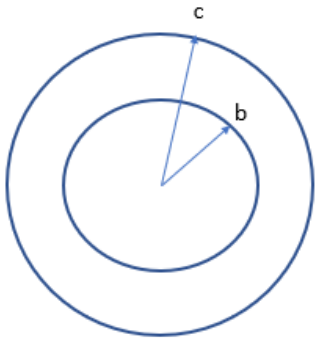


This run is essentially done and can be incorporated into Cesar's paper

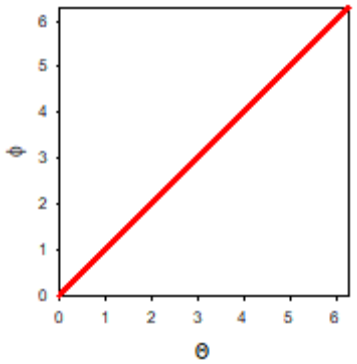
Cesar Clauser

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

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

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

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

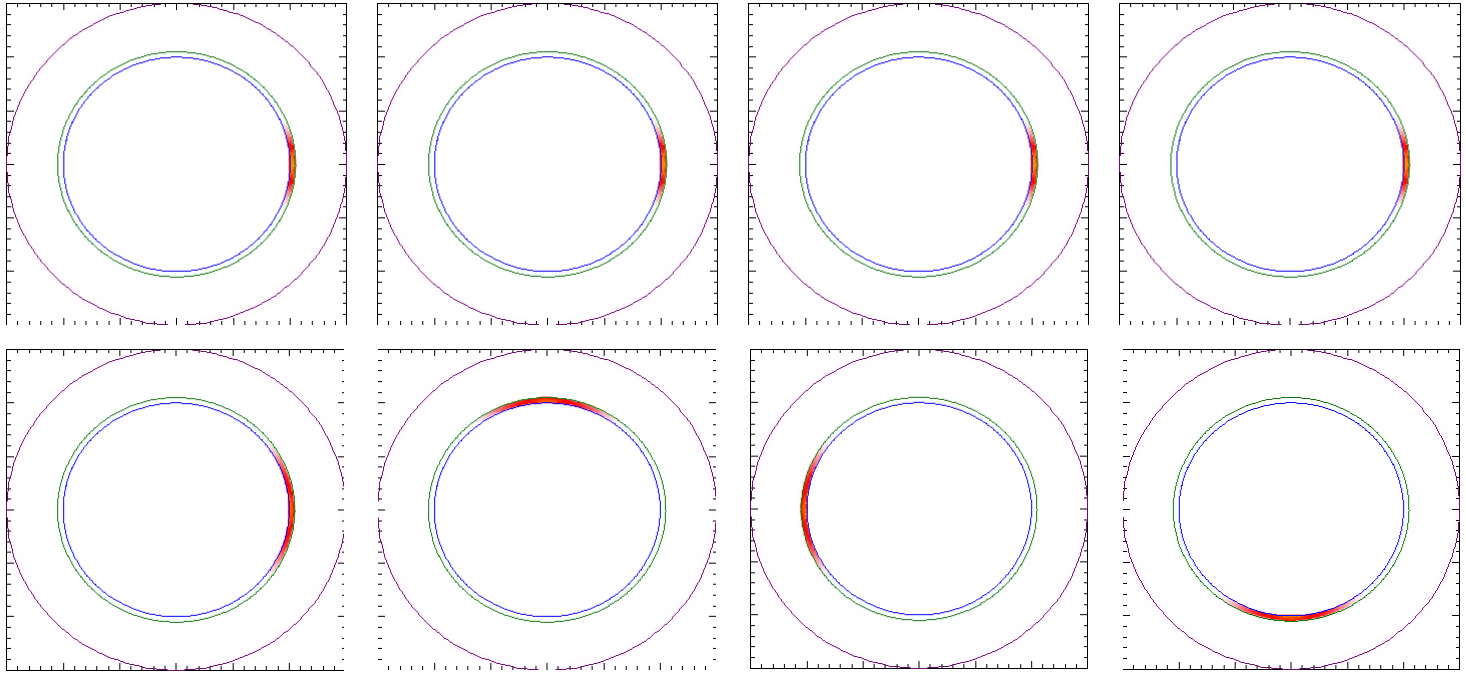
What is driving the current in the θ direction? It can't be Φ unless

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

Comparison between Straight and helical band

Straight ➔

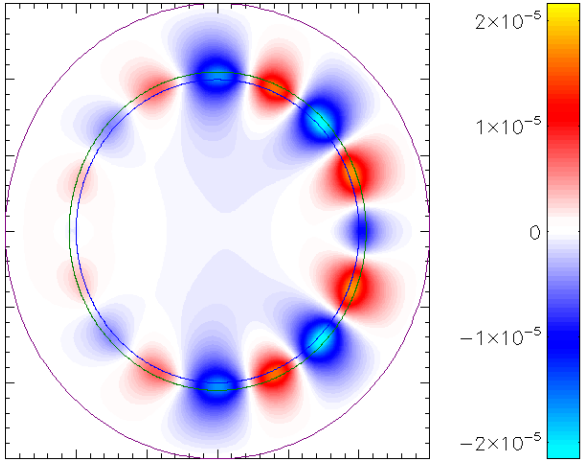
Helical ➔



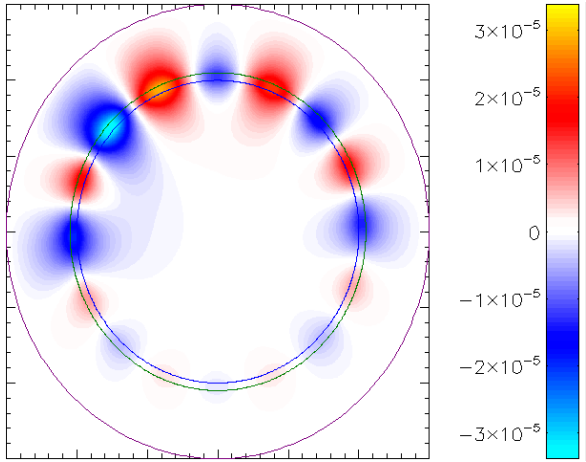
$\varphi = 0$ $\varphi = \pi / 2$ $\varphi = \pi$ $\varphi = 3\pi / 2$

Φ_φ

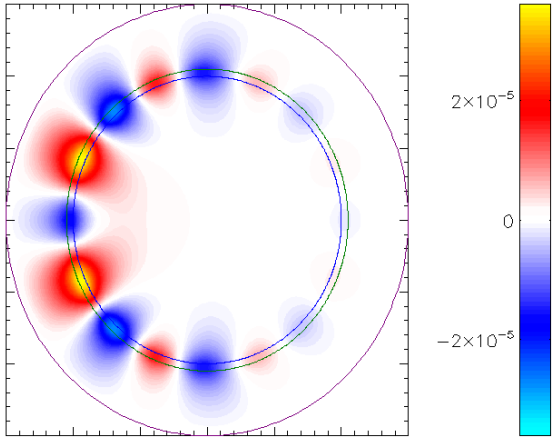
φ = 000°



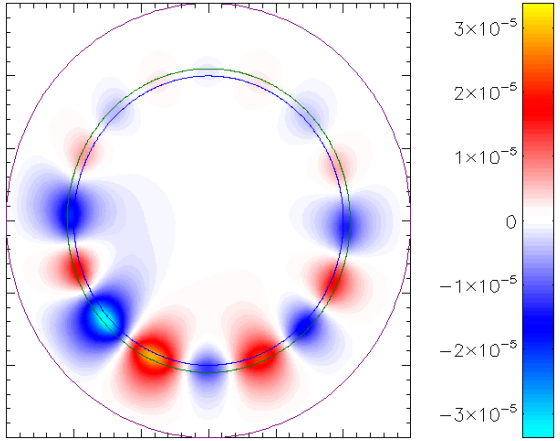
φ = 090°



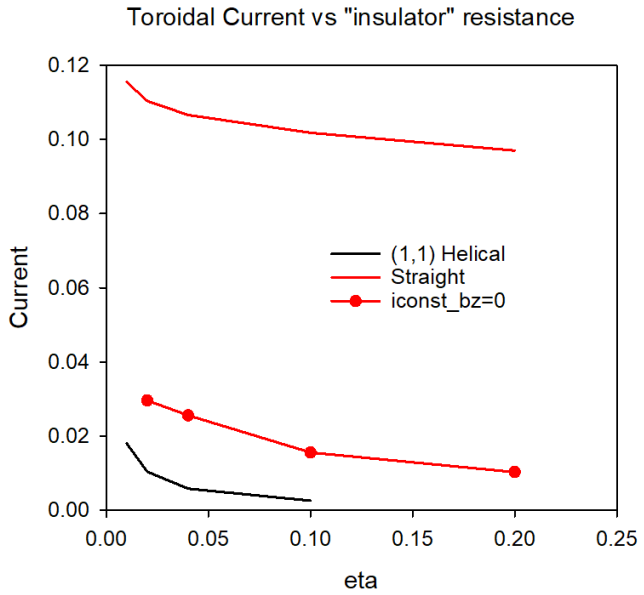
φ = 180°



φ = 270°

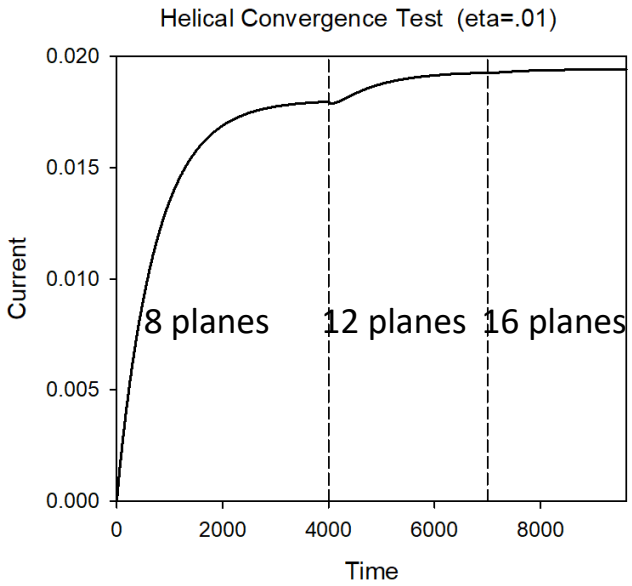


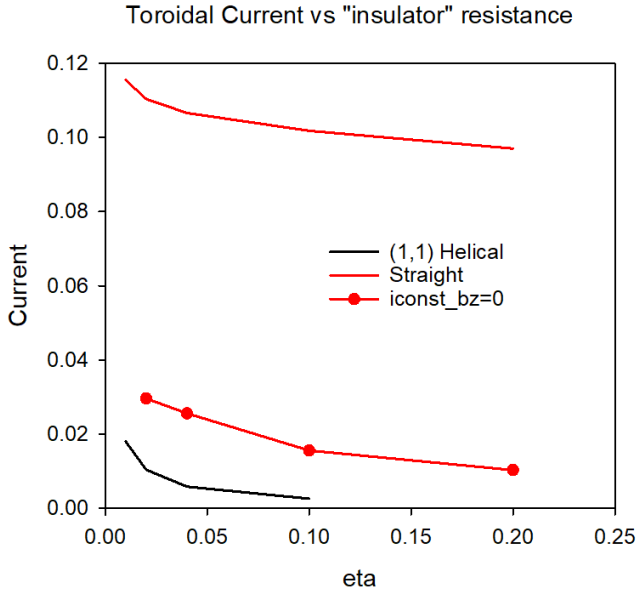
Helical resistive band to suppress runaways



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

Some Convergence Tests

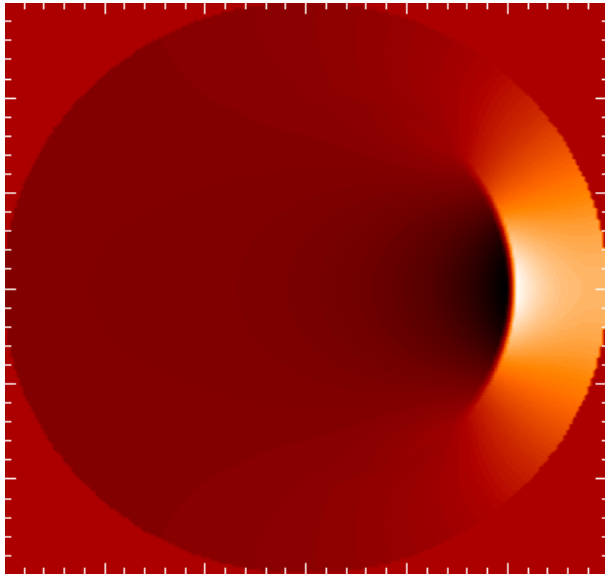




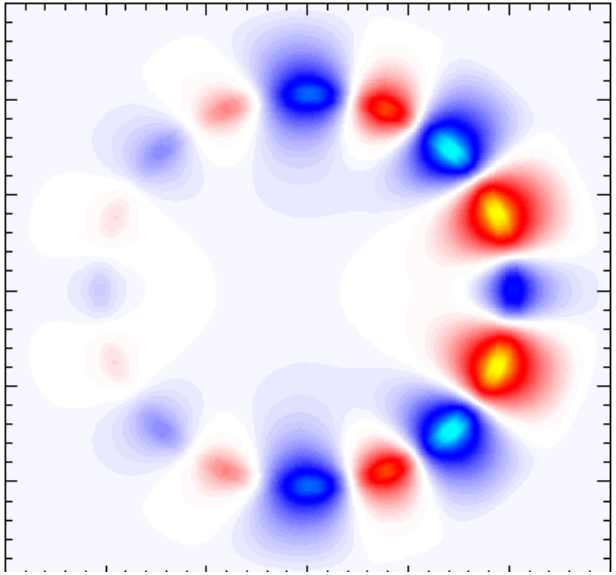
- Wall current appears to be converged in # of planes
- Helical wall current tending towards zero for large values of insulator resistance
- Now testing dependence on boundary conditions (location of ideal wall)
- Helical (1,2) case gives less than half the current of helical (1,1) case
- Iconst_bz=0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

Plots for iconst_bz=0

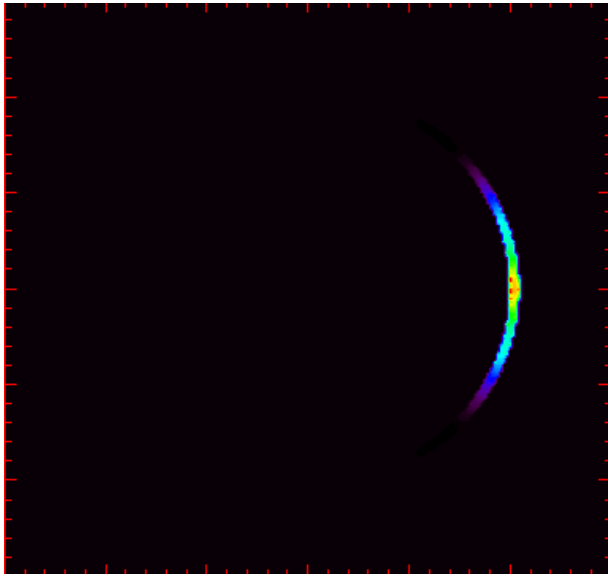
I



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



J_{φ}



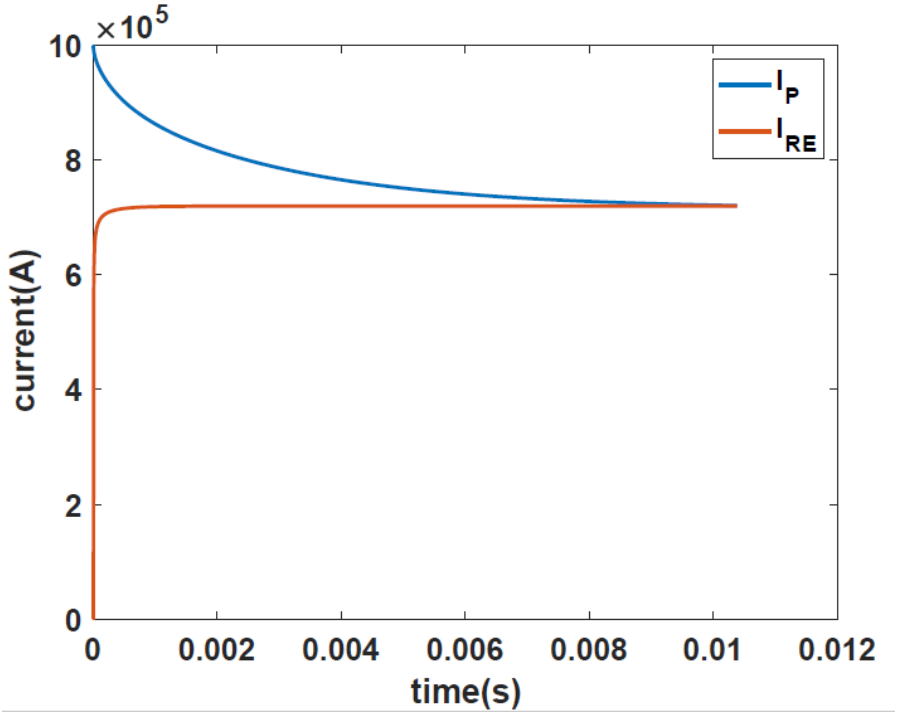
$$\nabla_{\perp} \bullet \frac{1}{R^2} \nabla \Phi = \nabla_{\perp} \cdot \eta \left[-\frac{1}{R^2} \nabla F \times \nabla \varphi - \frac{1}{R^2} \nabla f'' \times \nabla \varphi - \frac{1}{R^4} \nabla_{\perp} \psi' \right]$$

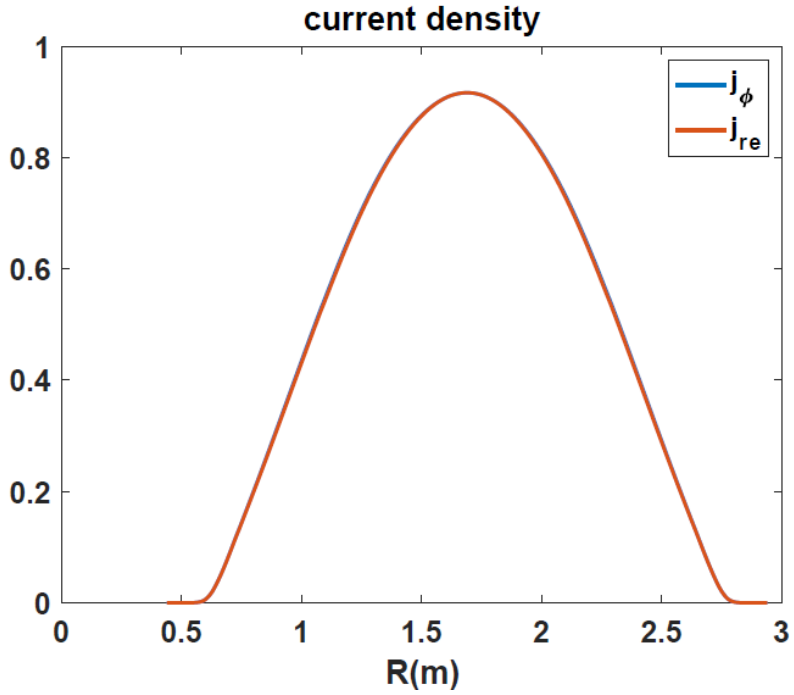
Local Systems

- 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

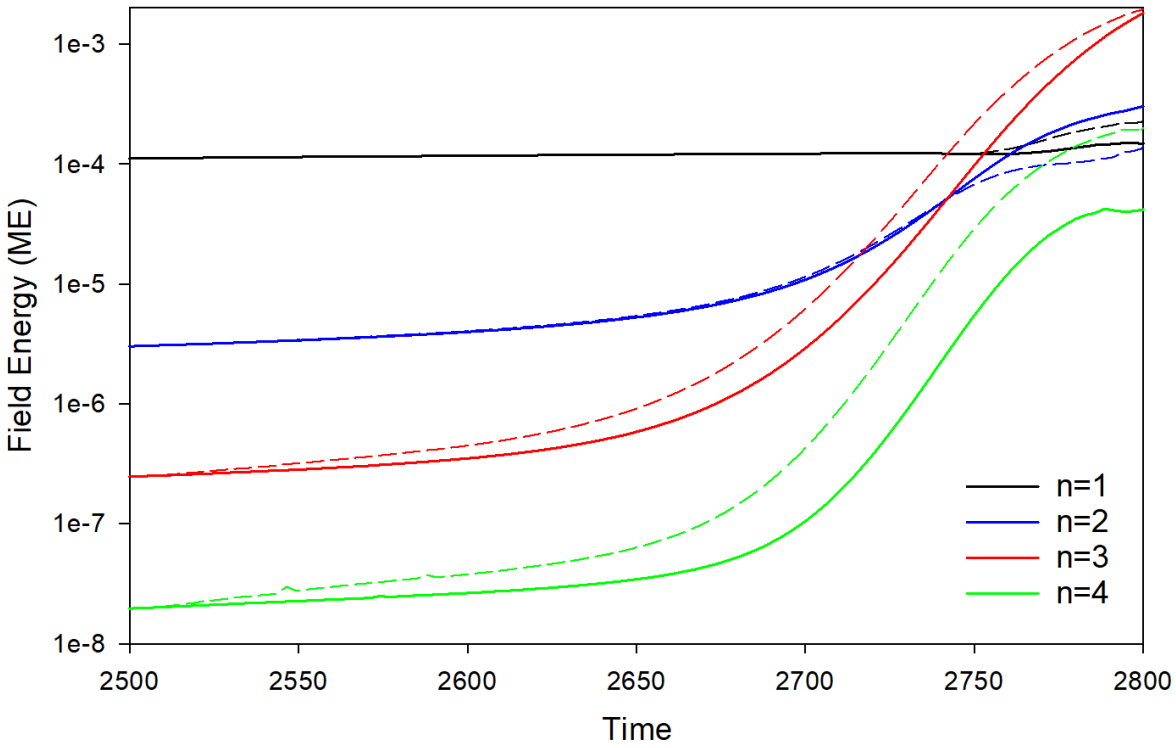
2D (cylindrical) RE with sources (12/19/2020)



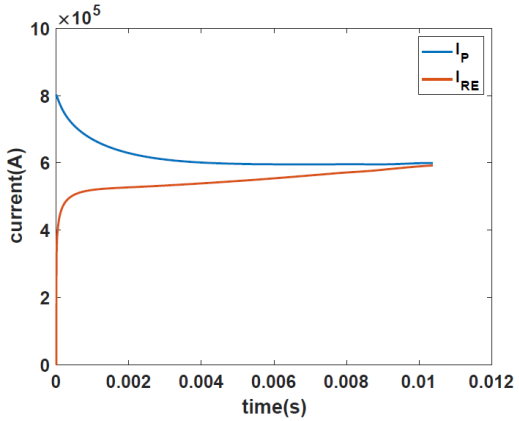


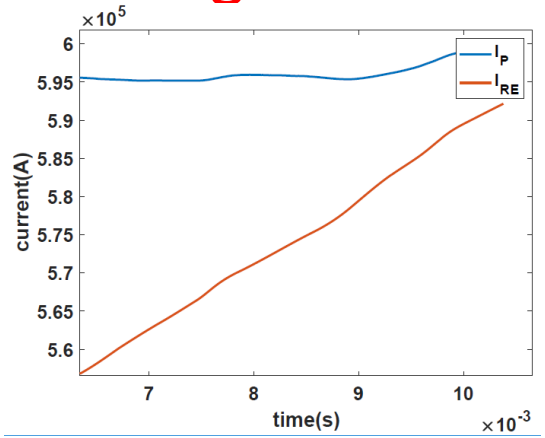
Chen Zhao

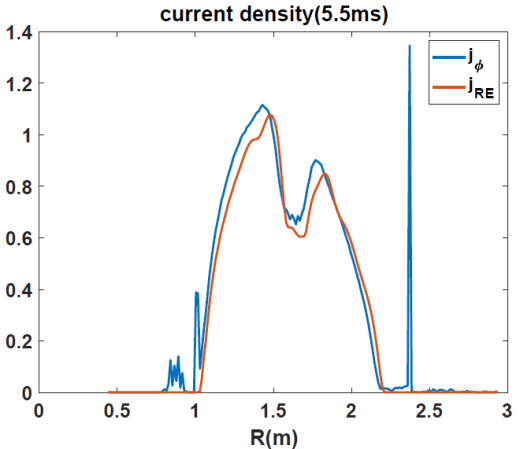
Energy in base case 36742317 (solid) and 16 plane case 37248033 (dashed)

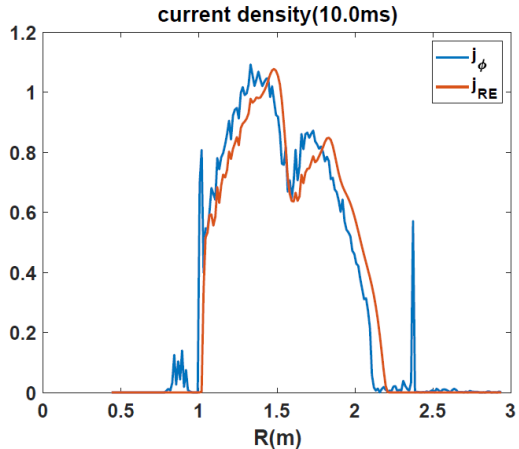


DIII-D 177053 with Argon





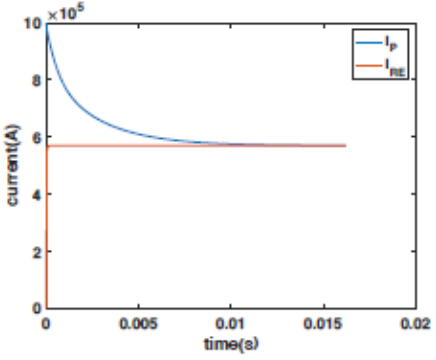


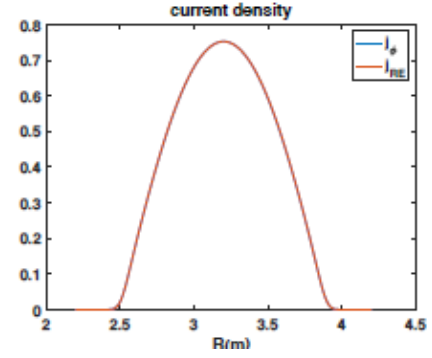


Chen Zhao

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?

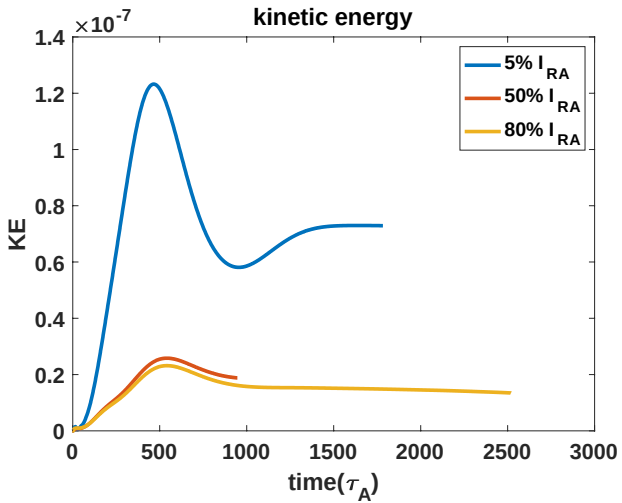
- M3D-C1/NIMROD 3D Benchmark

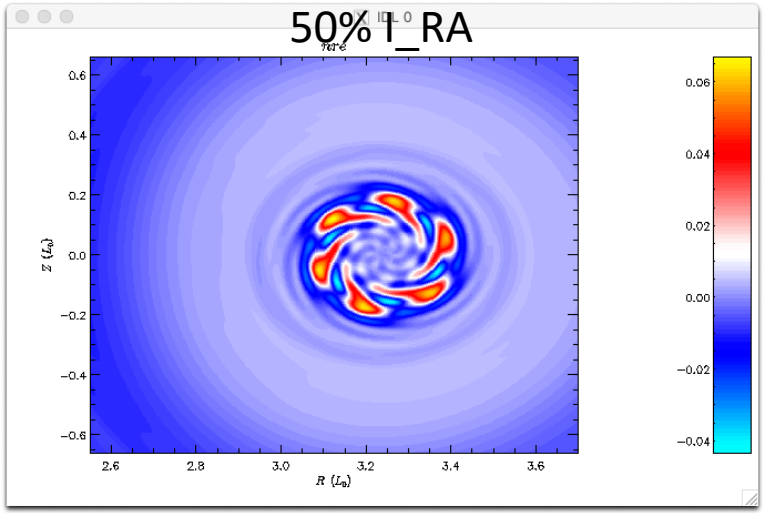
NSTX shot 1224020 – Fast ion transport with coupled kink and tearing modes
Chang Liu

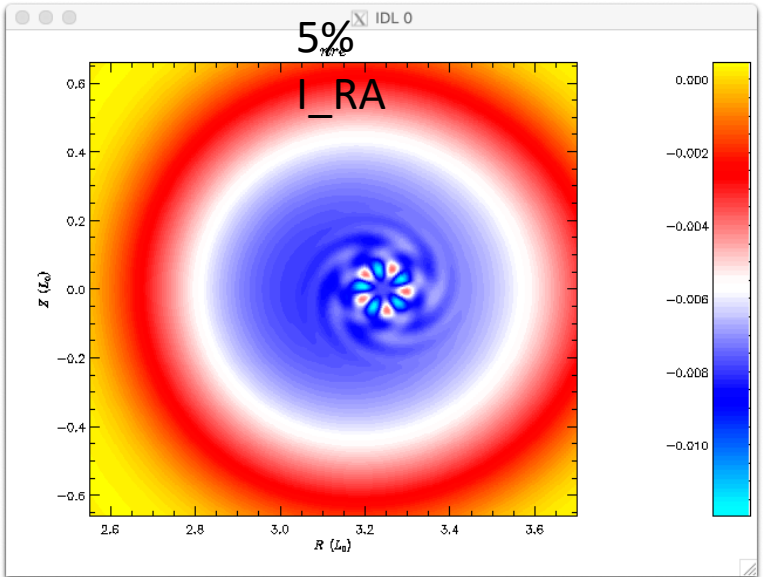
DIII-D Neon pellet mitigation simulation for KORC

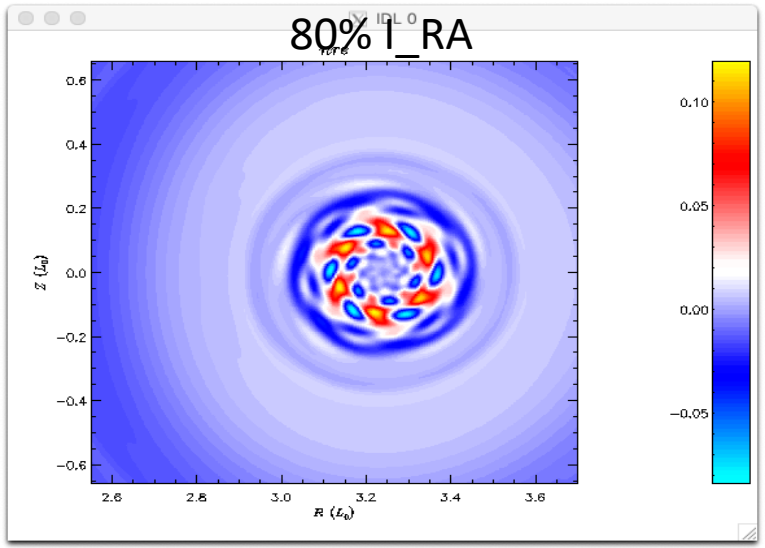
- Brendan Lyons trying to extend 8 plane case to 32 planes

SPARK ? Do we need to do anything?


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

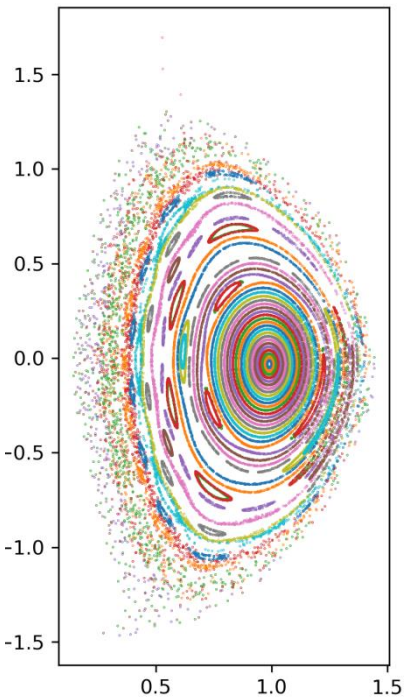

50% I_RA
IDL 0
Z (L_0)
R (L_0)


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

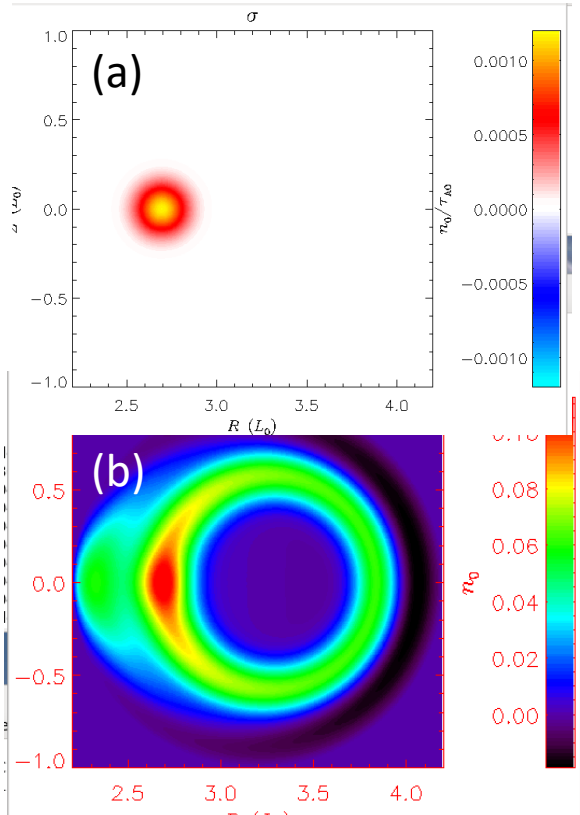
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

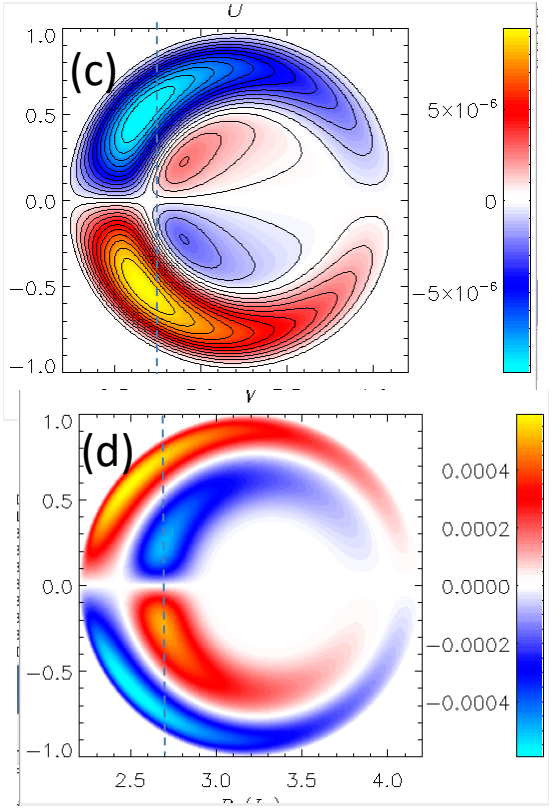
(a) Density source in 1F toroidal equilibrium

(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

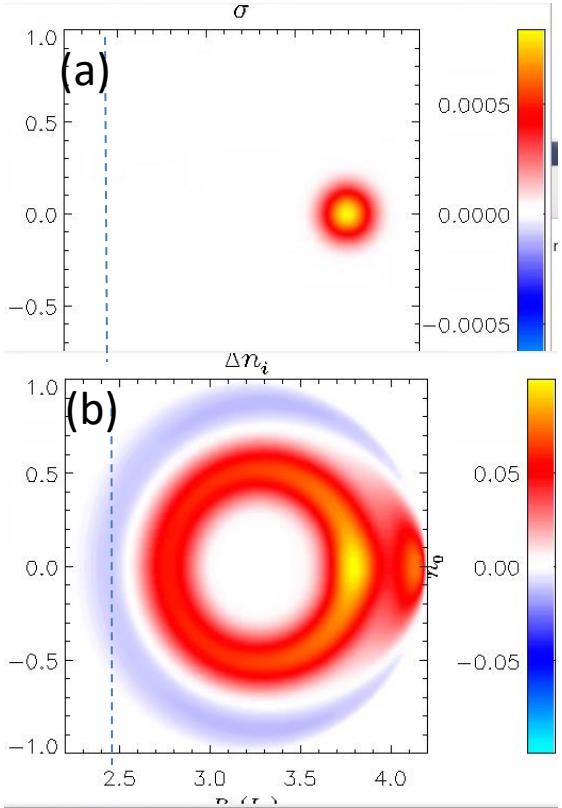
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

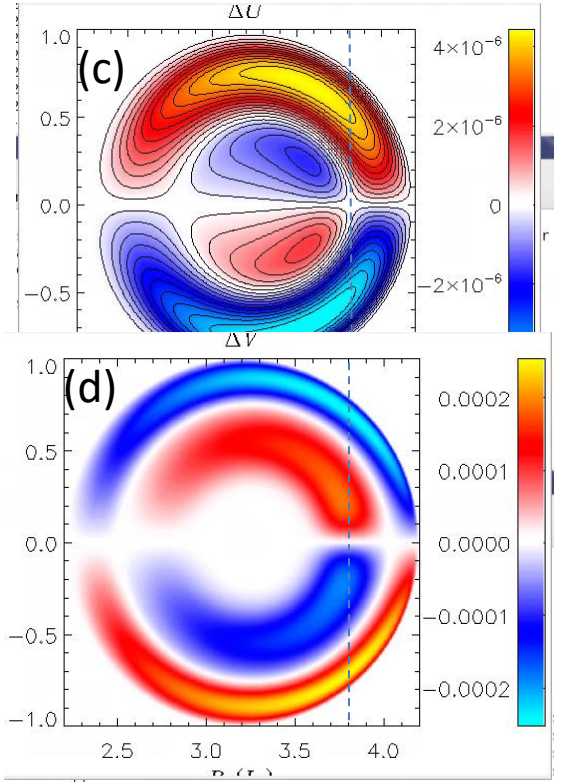
(a) Density source in 1F toroidal equilibrium

(b) Change in density after 10^3 τ_A

(c) Poloidal velocity stream function

(d) Toroidal velocity contours





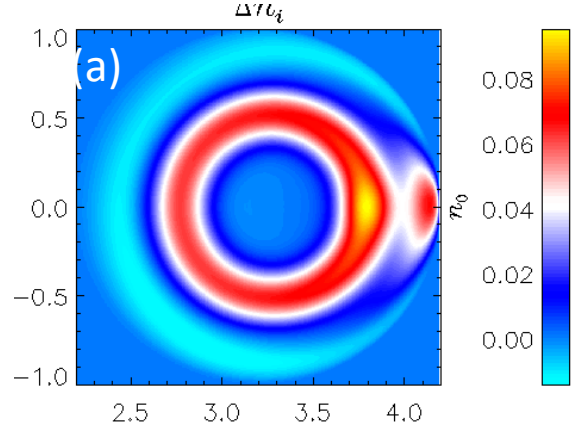
Grad-B drift in M3D-C1—2F effects

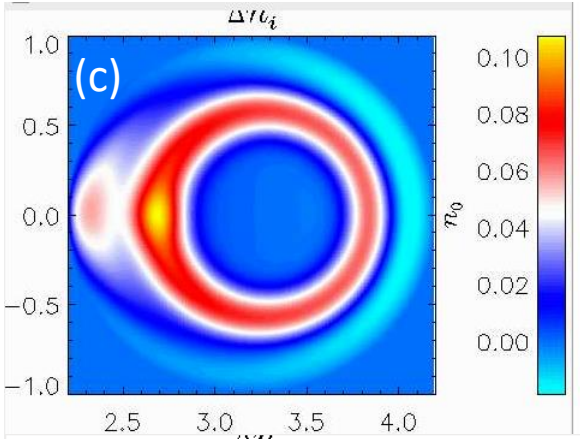
(a) 2F density change after 10^3 τ_A for LF side source

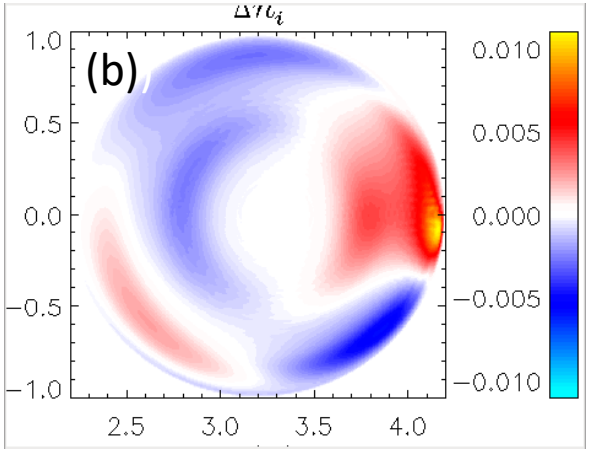
(b) Difference in 1F and 2F density (LF)

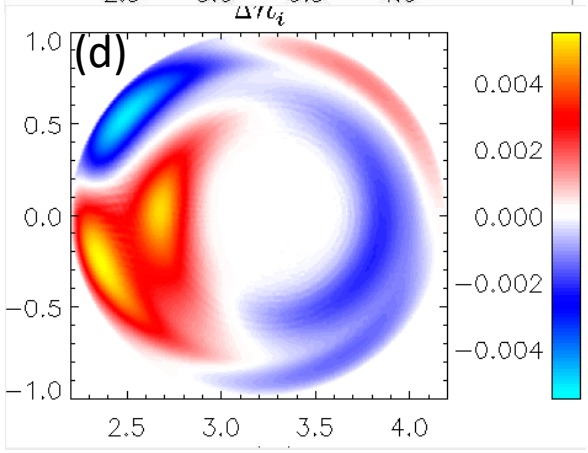
(c) 2Fdensity change after 10^3 τ_A for HF side source

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

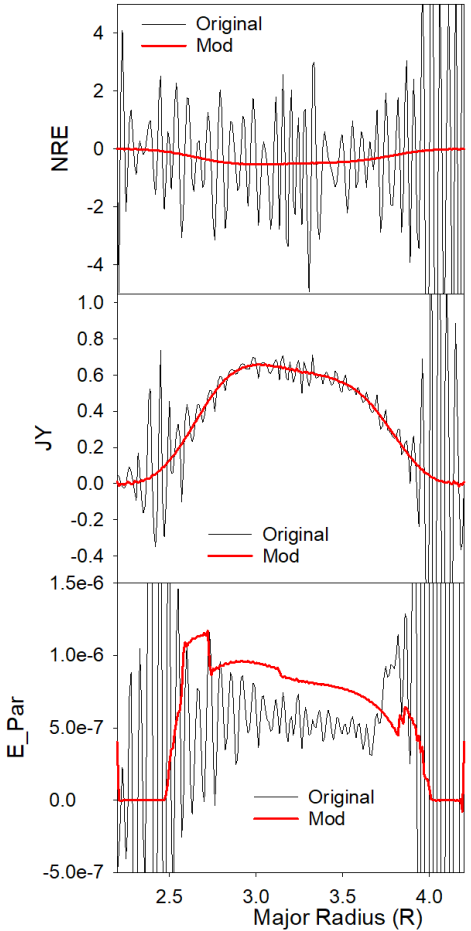








Sawtoothing discharge with runaway electrons

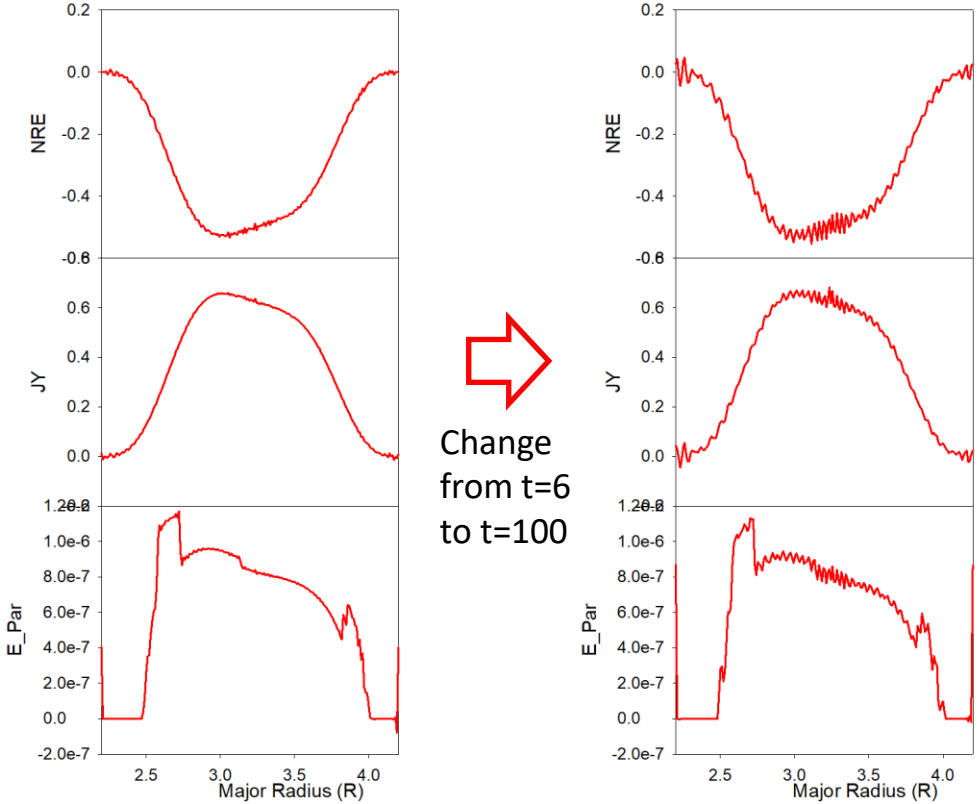


Profiles of nre, jy, and E_par after 30 timesteps

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?