

M3D-C1 ZOOM Meeting

Announcements:

06/14/2021

CS Issues

1. GPU Hackathon and GPU solve status
2. Mesh adaptation update
3. NERSC Time
4. Changes to github master since last meeting
5. Regression tests

Physics Studies

1. Typical Tearing Mode – sj
2. RWTM – sj, Strauss
3. DIII-D 177028 – sj, Chang Liu
4. Update: 2D modeling of SPI in ITER H-mode –sj, Lyons
5. Other

Note: [meeting minutes posted on m3dc1.pppl.gov](https://m3dc1.pppl.gov)

In attendance

Steve Jardin

Hank Strauss

Mark Shephard

Addelle Wright

Jin Chen

Chang Liu

Seegyoung Seol

Andreas Klinger

Brendan Lyons

Usman

Priyankama Sinha

Announcements

- TSDW meeting July 19-23
 - Registration and abstracts due June 14 (Today!)
- Virtual Sherwood Meeting August 16-18
 - Abstracts due by July 9
 - Registration until August 9
- APS Nov 8-12
 - Abstracts due by July 15

GPU status

- Report on Hackathon: Chang Liu, Jin Chen, Chen Zhao

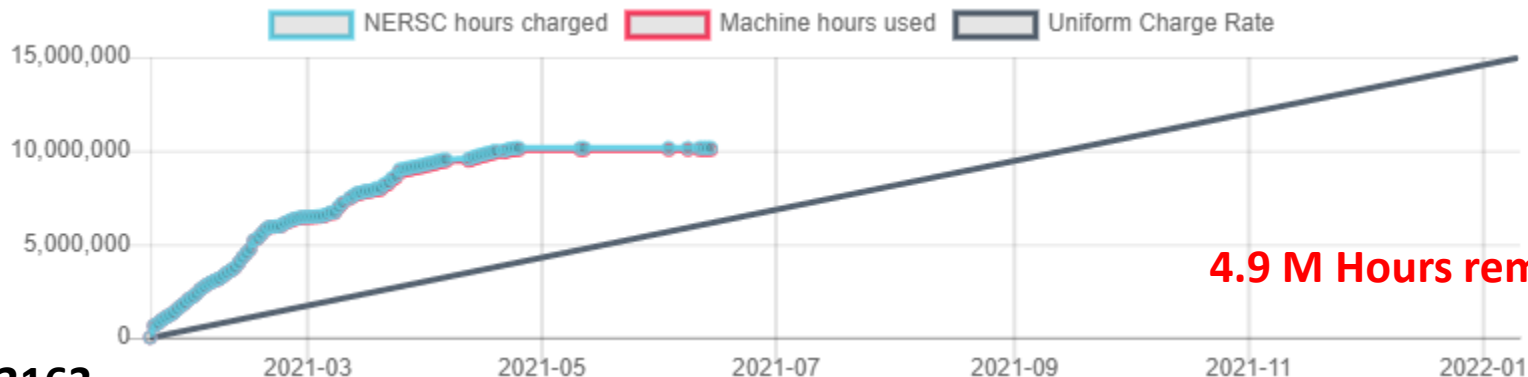
Mesh Adaptation Update

RPI has requested some good 2D cases for dynamic adaptation

- VDE ... (scj)
- Pellet ... (Lyons?)
- Linear tearing mode?
- Tilting Mode

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
- John Mandrekas (DOE) 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 05/16

- **Seegyung Seol**
 - **06/08/21:** commenting out field synch in after 3D adaptation (debugging on-going)
 - **06/08/21:** adapt_mesh modified to run adaptation in all planes in 3D
 - **06/11/21:** clean-up for deterministic adaptation in multiple 2D planes

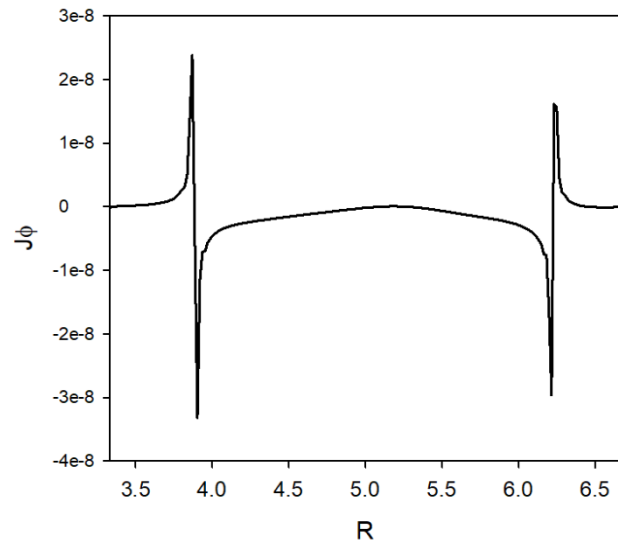
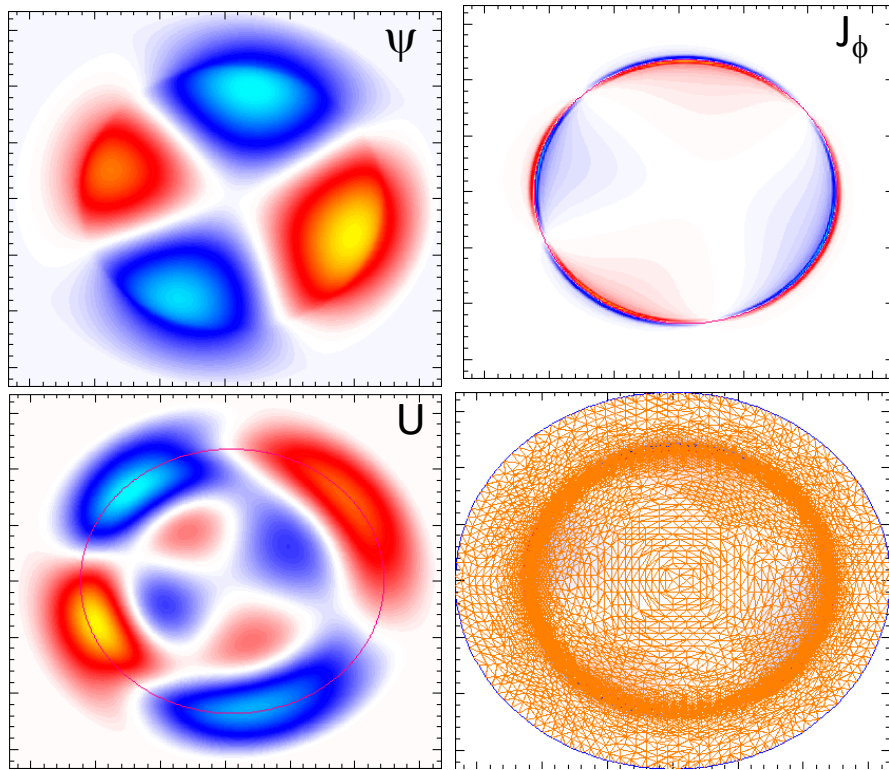
Local Systems

- PPPL centos7(06/14/21)
 - 6 regression tests **PASSED** on centos7:
- PPPL greene (06/14/21)
 - 5 regression tests **PASSED on greene (m3dc1)**
- STELLAR (06/14/21)
 - 6 regression tests **PASSED** on stellar
- TRAVERSE(03/29/21)
 - Code compiles
 - Regression test failed: split_smb not found in PATH

Other Systems

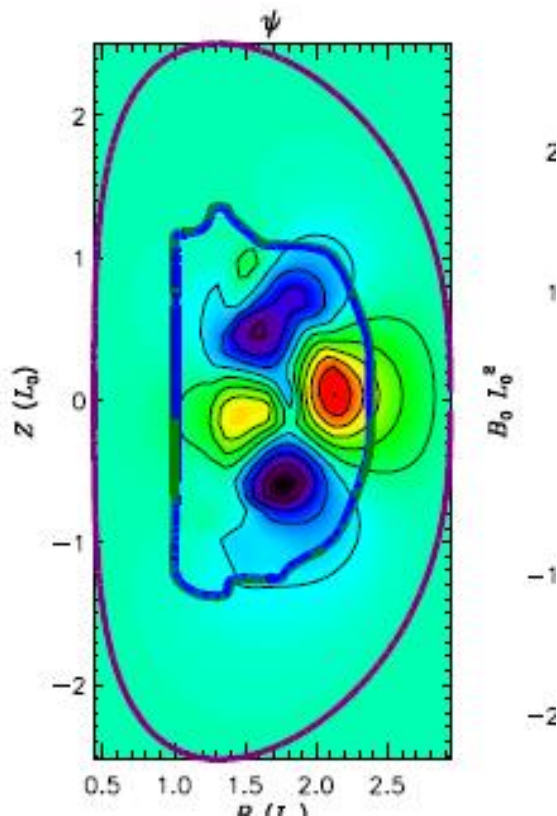
- Cori-KNL (2/08/2021)
 - 6 regression tests passed on KNL
- Cori-Haswell (2/08/2021)
 - 5 regression tests passed
 - KPRAD_RESTART did not pass, but differences are very small in velocity variables. All magnetic and thermal good. Similar difference as Cori-KNL
 - RMP_nonlin initially failed ...: There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

Typical Tearing Mode



$$\begin{aligned}\eta &= 2.e-6 \\ 1.1 &< q < 2.9 \\ \gamma\tau_A &= 10^{-4}\end{aligned}$$

DIII-D shot 154576 (Strauss)

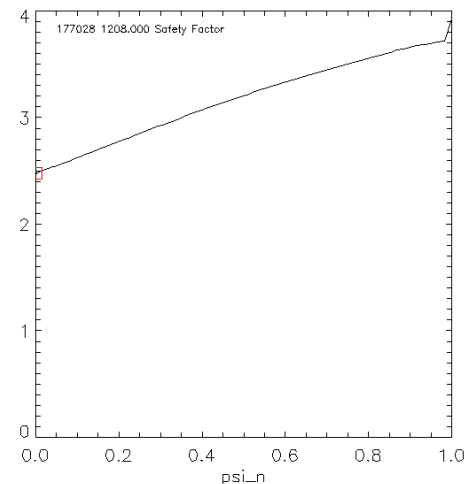
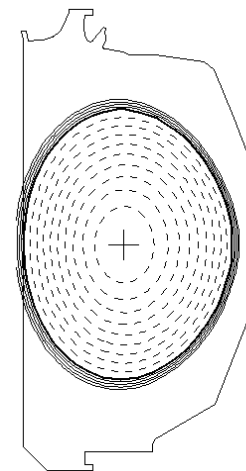


- “Mode” is stable !
- There is no tearing layer
- To identify a RWTM, must have the following
 - Mode is unstable when no wall is present
 - Mode is stable when ideal wall is present
- Need to show these 2 properties before starting RWTM study and finding dependence on wall resistivity

/scratch/gpfs/hs9956/d3d_eb1_1f_stab4b

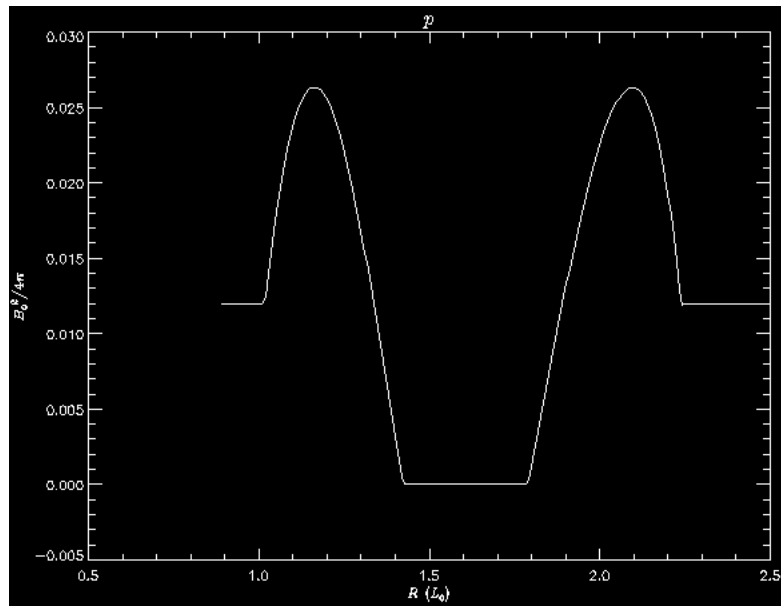
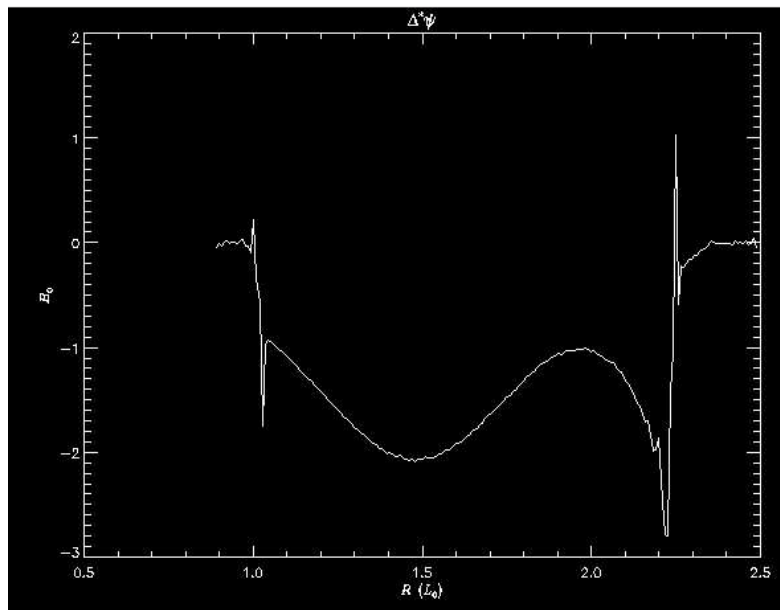
DIII-D 177028 (Chang Liu)

- When I load the file without calling the Grad-Shafranov solver in M3D-C1 (igs=0), the flux information can be read correctly, but the code will then get **some numerical error at boundary** as the simulation goes on. I guess it may be due to the insufficient accuracy of g file.
- Then I tried to call the **G-S solver** with igs=200, this time the solver gives an **equilibrium that is very different** from the original one. The q value can be larger than 100. I tried to use ifixedb=0 or 1 and the result is the same.
- Brendan, if you have time, I wonder if you can try to find a way to read this g file with ifixedb=0, like what you did in our previous work for shot 177040. I think for that case we got it successful using M3D-C1 G-S solver to obtain almost the same result as the EFIT one.



DIII-D 177028 - cont (Chang Liu)

- I tried reading the geqdsk and profile_p file without calling Grad-Shafranov solver:
- Midplane plots below ... need better quality data. GS solver will not cure this!

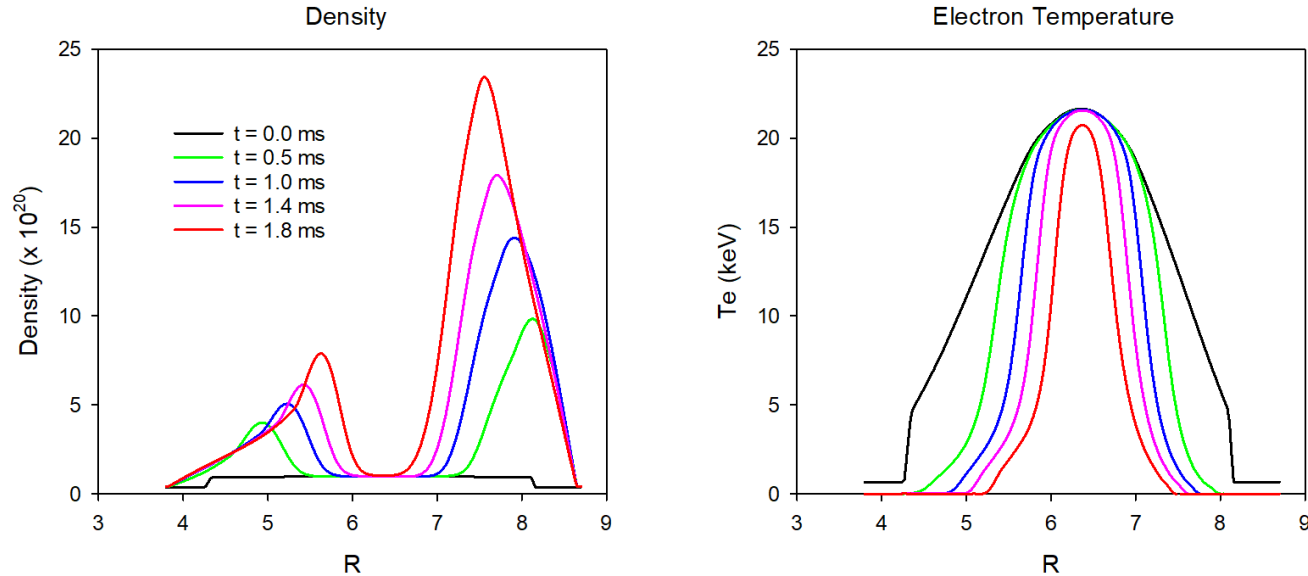


Same for iread_p = 0,1

2D ITER modeling of SPI -- Brendan Lyons 5/6/21

- Good NEWS
 - I got this to run to 2 ms by setting `pedge=.01`, `idenmfunc=1`
- Bad NEWS
 - After that time, code crashes with segmentation fault in velocity solve
 - I now think this crash is due to pressure becoming negative
 - However, increasing edge pressure (`pedge`) doesn't seem to help!

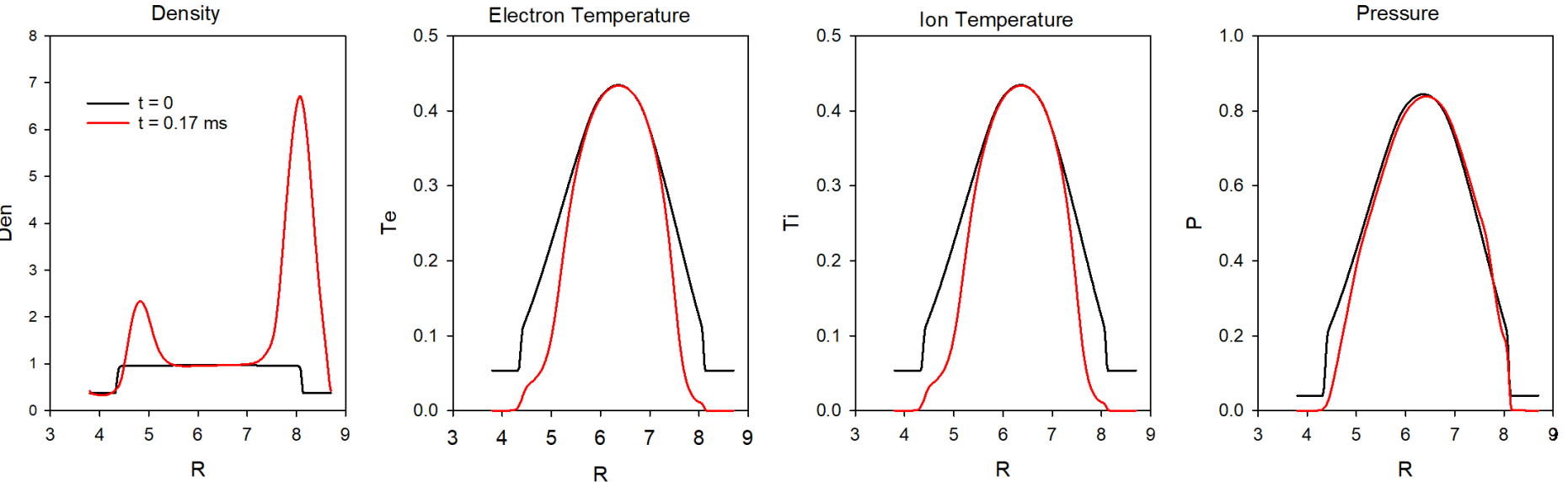
2D ITER SPI Modeling (cont)



- Density and temperature at $Z = 1\text{m}$ at different times
- However, calculation stops with “segmentation fault” at seemingly random time steps...also, differing results!

2D ITER SPI Modeling (cont.)

- Boundary value of T_e , T_i , and p gets reset to zero after initial equilibrium
- Happens on time step 1, even with $ikprad=0$
- Any ideas why the boundary temperature gets reset to 0 after equilibrium?



That's All I have

Anything Else ?

DIII-D Resistive Wall Mode

Email from Hank Strauss on 5/27/21

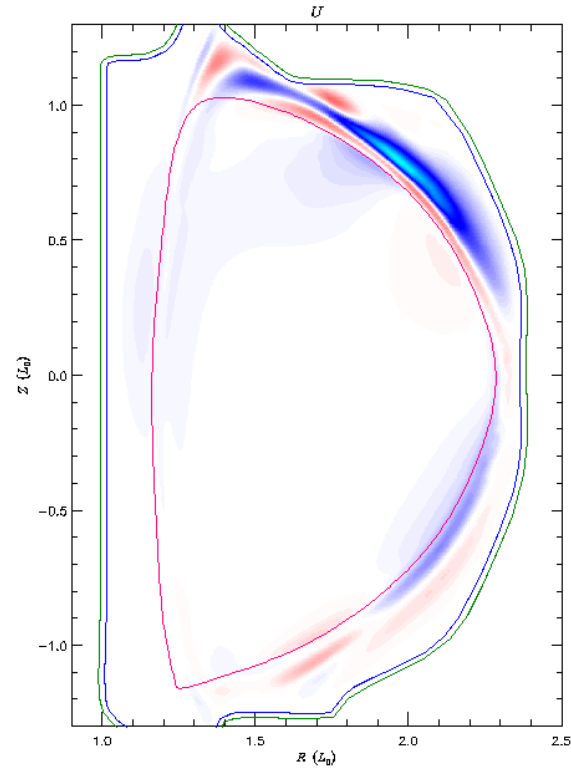
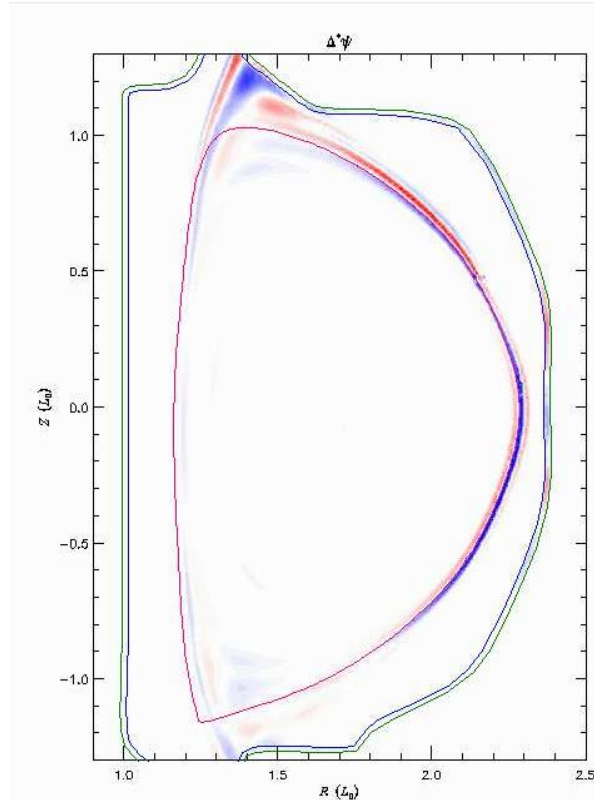
I tried to find D3D RWMs (RWTM)s with Brendan's mesh and C1input files, but it seems that the wall is behaving like an ideal wall. It needs much more adaptive refinement. I also tried a nonlinear run, but even though $\epsilon > 0$, it didn't have a 3D perturbation.

A linear run is in /scratch/gpfs/hs9956/d3d_eb1_1f_eq_l11 and nonlinear in rw1_nl_54576.03354_945b2.

I think lack of resolution at the wall is also causing AVDE simulations to fail at small η_{wall} . The mesh needs adaptive refinement at the wall.

An ADVE simulation is in JETm3dc1_0.12h9b4.

Linear Eigenfunction



Physical mode? Not tearing.

Chen Zhao paper on RE with sources

Simulation of the runaway electron plateau formation during current quench

C. Zhao¹, C. Liu¹, S. C. Jardin¹, N. M. Ferraro¹, B. C. Lyons²
V. Bandaru³, M. Hoelzl³

¹ Princeton Plasma Physics Laboratory, Princeton, NJ, United States of America

² General Atomics, San Diego, CA, United States of America
General Atomics, San Diego, CA, United States of America

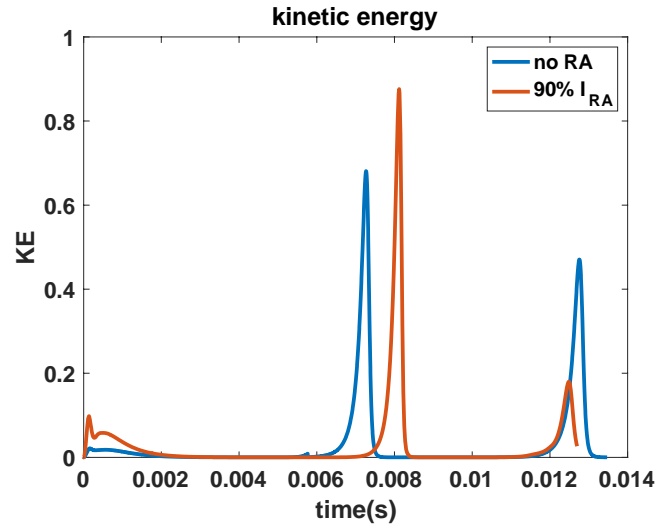
³ Max Planck Institute for Plasma Physics, Boltzmannstraße, Garching, Germany

- Source terms and coupling to MHD
- Runaway source test case and benchmark with JOEKE
- Current quench result with DIII-D parameters

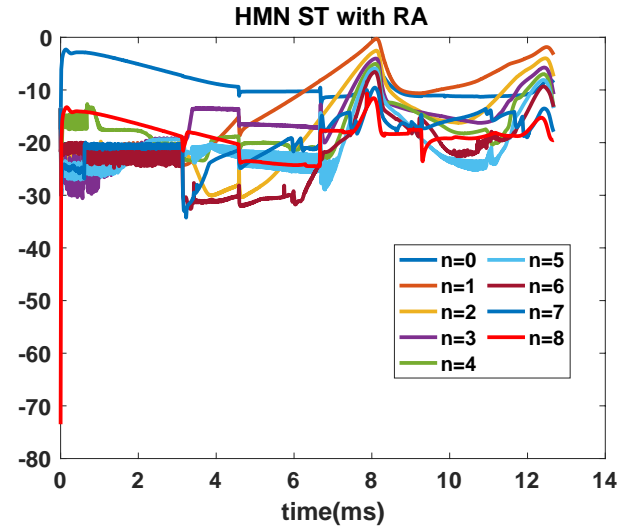
Isabel ST with RA

06/1/21

- Both cases are use Isabel eq with mesh 0.01m



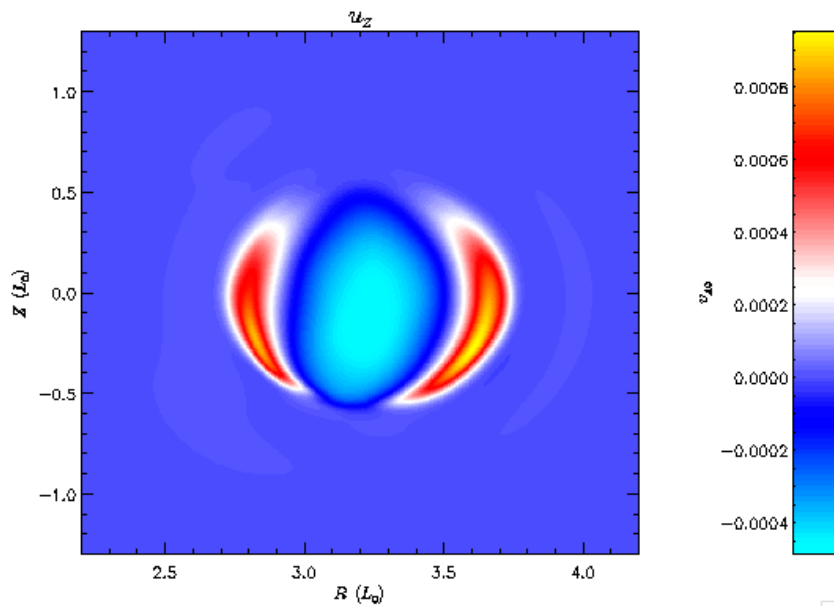
- It needs more time to see if there is only on ST phase with RA



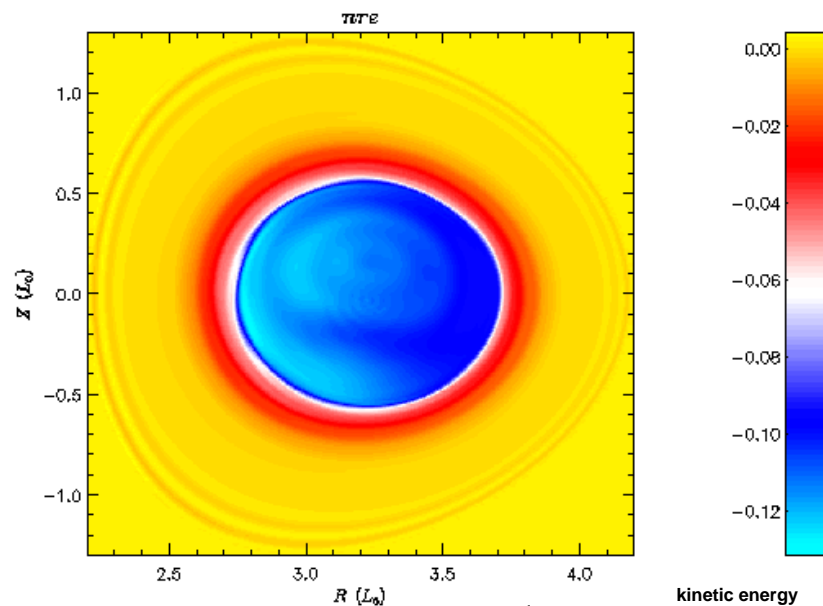
- Most unstable mode is n = 1 with RA

Profiles at 8ms with RA (1st ST phase)

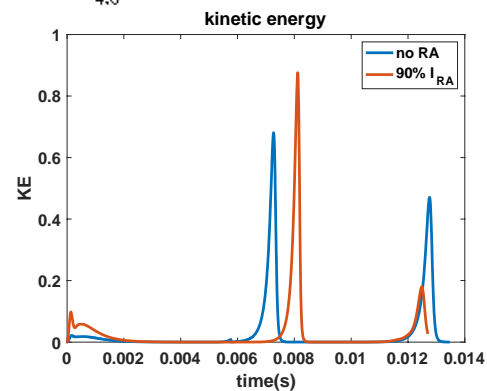
V_z



J_{RA}

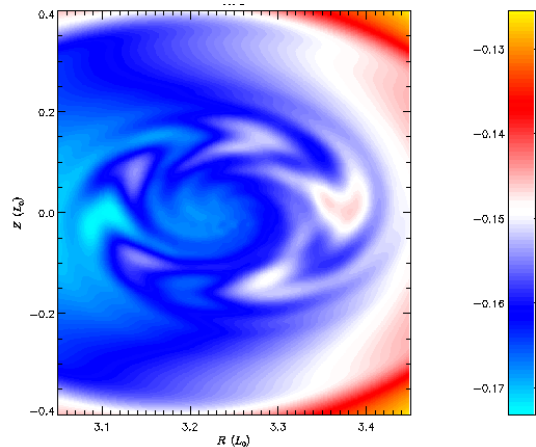


- No clear mode in runaway current

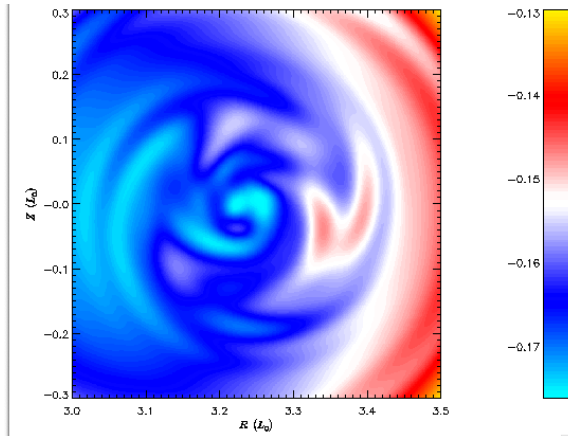


Runaway current during 2nd ST phase

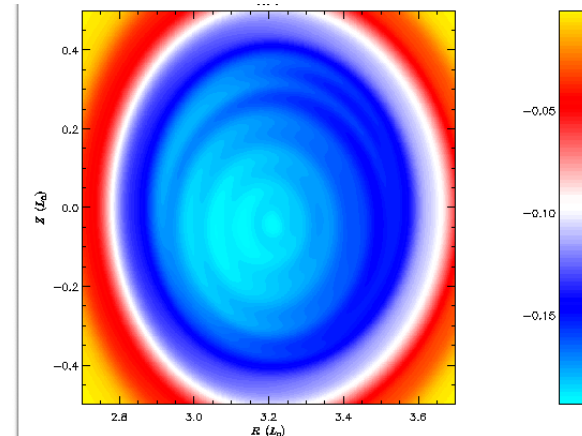
J_RA 10.6ms



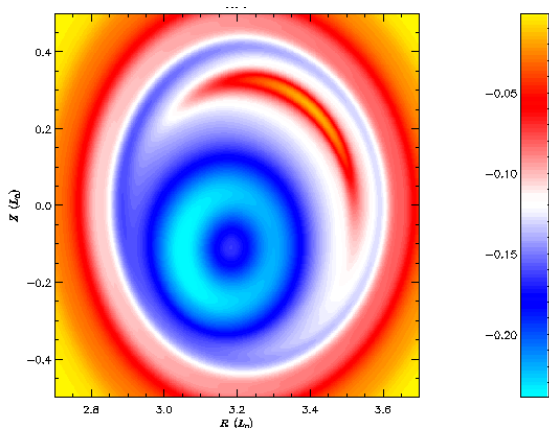
J_RA 10.8ms



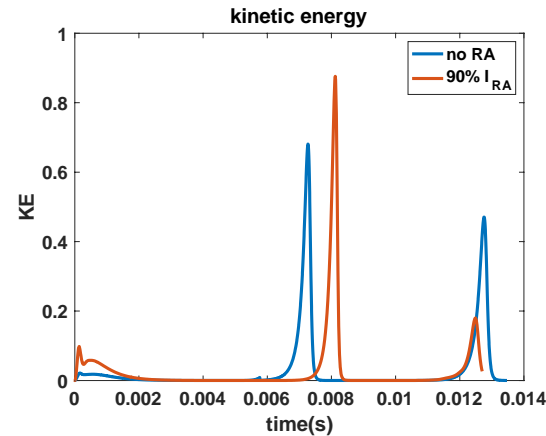
J_RA 11.4ms



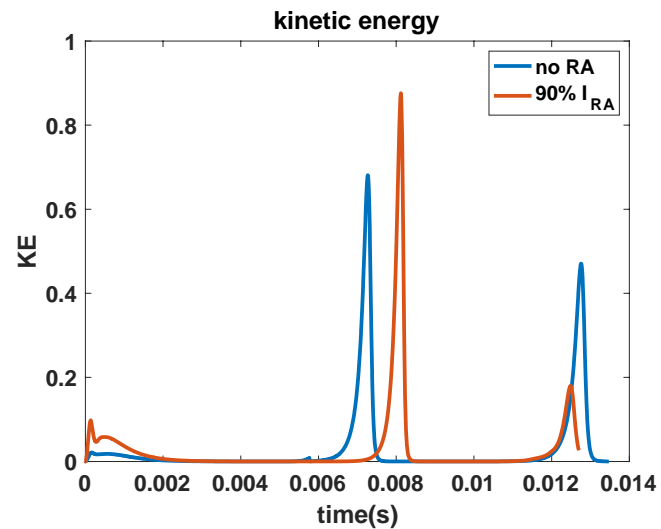
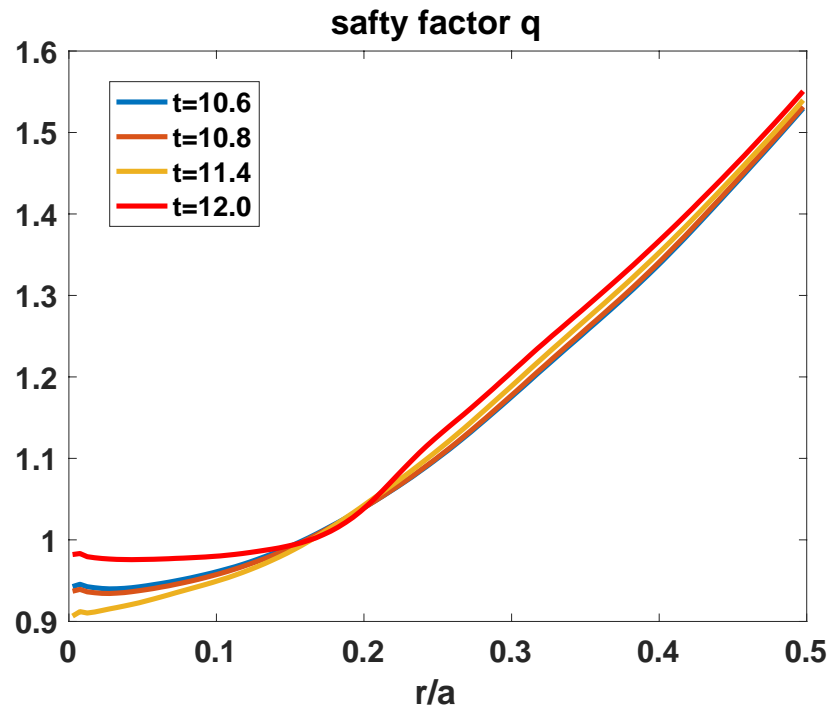
J_RA 12.0ms



- At 2nd ST phase there is a $n \sim 5$ mode reduced to $n \sim 1$ mode in runaway current
- The instabilities in runaway current may cause the much lower kinetic energy at 2nd ST phase.



q profile during 2nd phase



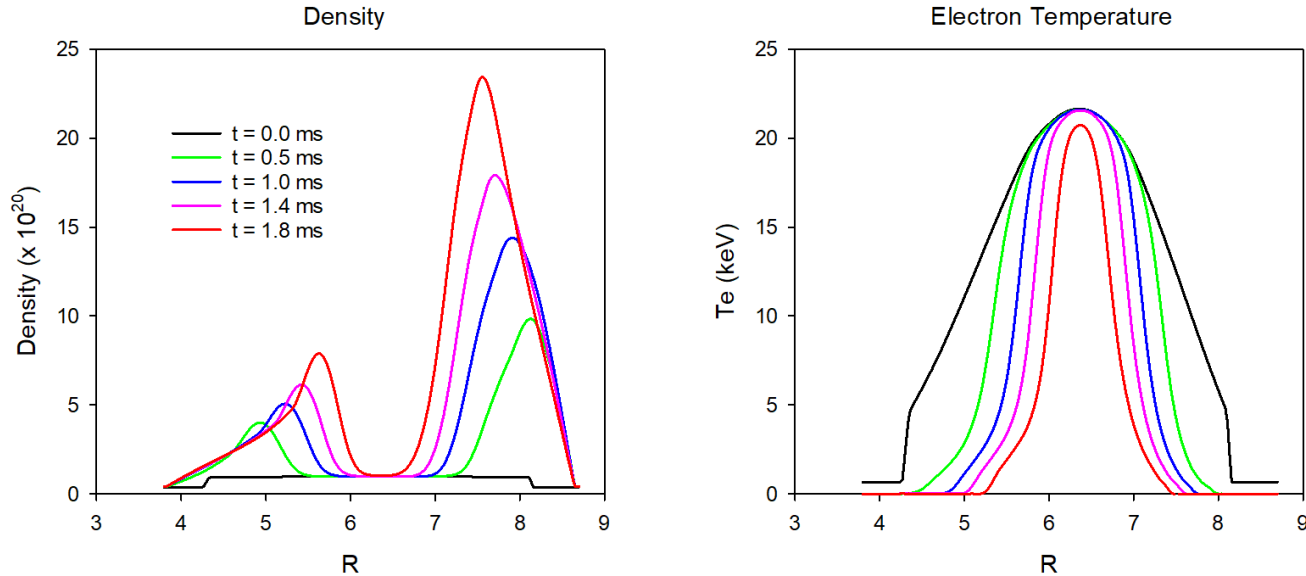
Directory : /projects/M3DC1/chenzhao/Chen2D-mod3/

2D ITER modeling of SPI -- Brendan Lyons 5/6/21

- 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.
- Good NEWS
 - I got this to run to 2 ms by setting `pedge=.01`, `idenmfunc=1`
- Bad NEWS
 - After that time, code crashes with segmentation fault in velocity solve
 - Doesn't always crash at same time step, and numbers can be different for different runs restarting from same time!!

`/scratch/gpfs/sjardin/Brendan`

2D ITER SPI Modeling (cont)



- Density and temperature at $Z = 1\text{m}$ at different times
- However, calculation stops with “segmentation fault” at seemingly random time steps...also, differing results!

Inconsistencies in 2D nonlinear restarting at N=1000

-1 slurm18347 died 1018 SEGV (SuperLU)

1000	2.7500E+03	3.0076E-01	3.6364E-01	2.8914E-02	2.7081E-01	1.0371E-03	6.3888E+02	2.1293E+04	3.2050E+02	2.22524E+04
1001	2.7528E+03	3.0125E-01	2.9180E-04	2.9007E-02	2.7121E-01	1.0298E-03	6.3882E+02	2.1293E+04	3.2028E+02	2.22521E+04
1002	2.7555E+03	3.0170E-01	2.7516E-04	2.9101E-02	2.7157E-01	1.0278E-03	6.3875E+02	2.1293E+04	3.2005E+02	2.22518E+04
1003	2.7582E+03	3.0214E-01	2.6496E-04	2.9189E-02	2.7193E-01	1.0246E-03	6.3869E+02	2.1293E+04	3.1982E+02	2.22515E+04

-2 slurm18516 died 1088 SEGV (SuperLU)

1000	2.7500E+03	3.0076E-01	3.6364E-01	2.8914E-02	2.7081E-01	1.0371E-03	6.3888E+02	2.1293E+04	3.2050E+02	2.22524E+04
1001	2.7528E+03	3.0124E-01	2.8901E-04	2.9007E-02	2.7120E-01	1.0298E-03	6.3882E+02	2.1293E+04	3.2028E+02	2.22521E+04
1002	2.7555E+03	3.0169E-01	2.7320E-04	2.9100E-02	2.7157E-01	1.0279E-03	6.3875E+02	2.1293E+04	3.2005E+02	2.22518E+04
1003	2.7582E+03	3.0214E-01	2.6685E-04	2.9188E-02	2.7192E-01	1.0250E-03	6.3869E+02	2.1293E+04	3.1982E+02	2.22515E+04

-3 slurm18607 died 1049 SEGV (SuperLU)

1000	2.7500E+03	3.0076E-01	3.6364E-01	2.8914E-02	2.7081E-01	1.0371E-03	6.3888E+02	2.1293E+04	3.2050E+02	2.22524E+04
1001	2.7528E+03	3.0124E-01	2.9042E-04	2.9007E-02	2.7121E-01	1.0298E-03	6.3882E+02	2.1293E+04	3.2028E+02	2.22521E+04
1002	2.7555E+03	3.0170E-01	2.7414E-04	2.9101E-02	2.7157E-01	1.0278E-03	6.3875E+02	2.1293E+04	3.2005E+02	2.22518E+04
1003	2.7582E+03	3.0214E-01	2.6593E-04	2.9189E-02	2.7193E-01	1.0248E-03	6.3869E+02	2.1293E+04	3.1982E+02	2.22515E+04

Each of these died in the velocity solve with a segmentation fault at different time steps!

5/31/21 meeting w JOREK regarding RE benchmark

* A recent paper has appeared using the 1 ½ D code ASTRA-STRAHL to examine in detail a ASDEX-U mitigation shot that produced Runaway Electrons. Linder, et al. “Self-consistent modeling of runaway electron generation in massive gas injection scenarios in AUG”, NF 60 (2020) 096031

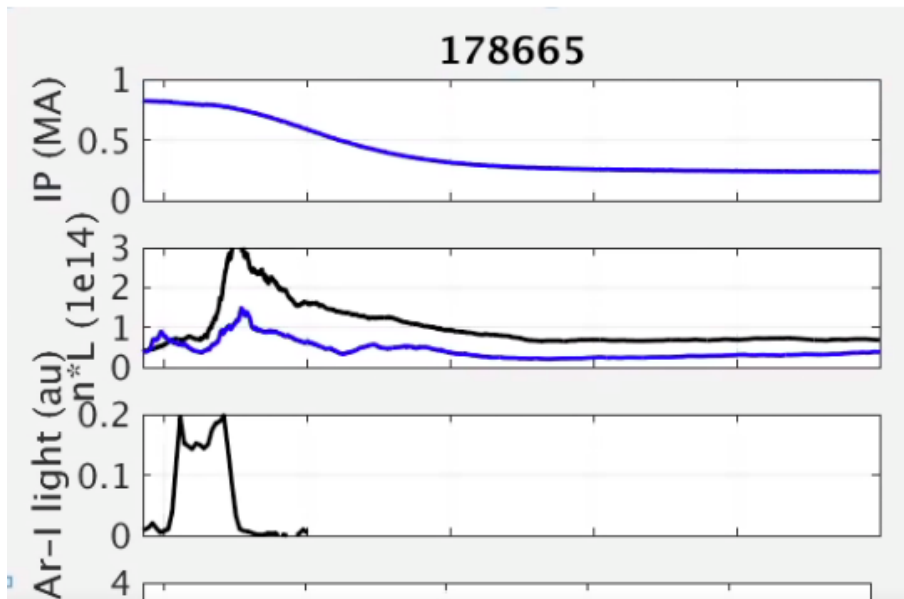
1) Vinodh and Matthias will look further into defining the setup for the AUG based benchmark case that was looked at with ASTRA-STRAHL and contact the M3D-C1 team as soon as they have something ready.

2) Chen will look into modeling the DIII-D discharge 178665 and will let JOREK team know when there are any interesting observations.

3) The two teams will meet again in a few weeks as soon as there is something new to look at for 1) or 2).

In attendance: Matthias Hoelzl, Vinodh Bandaru, Chen Zhao, Stephen Jardin

DIII-D RE generation with Ar shot 178665



Carlos suggested this shot:

$\langle n_e \rangle$, $Te(r,t)$, $IP(t)$, AR-1 (R,Z,t)

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

Use equilibria from 177053. You might want to look at matching the pre-TQ density integral to 665

That's All I have

Anything Else ?

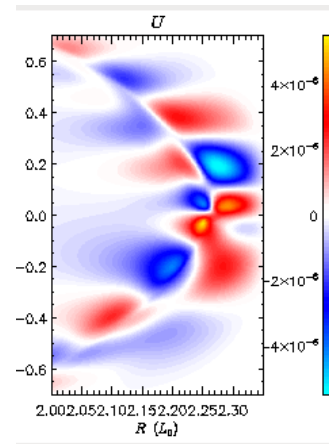
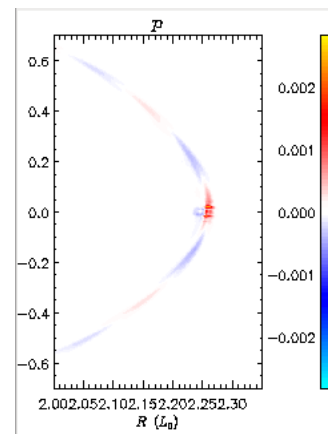
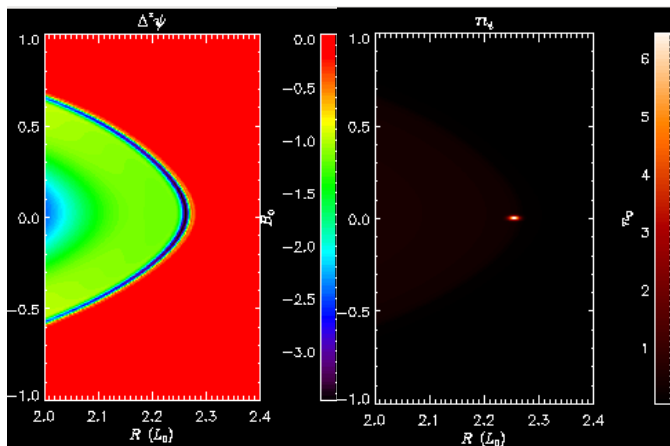
That's All I have

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 $i_{\text{pellet}}=1$ perturbs only the density profile. Large enough perturbation excites an unstable mode

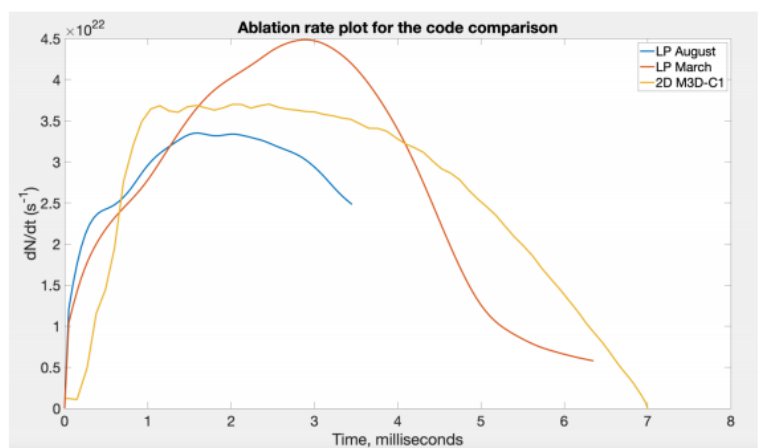
Q: How does a density perturbation excite a MHD mode?



Density perturbation causes decreased T_e at one location on flux surface. Thermal conduction during linear phase causes pressure to increase there. Gives an unstable mode for $n_{\text{tor}}=9$ only if $k_{\text{app}} \neq 0$

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)**



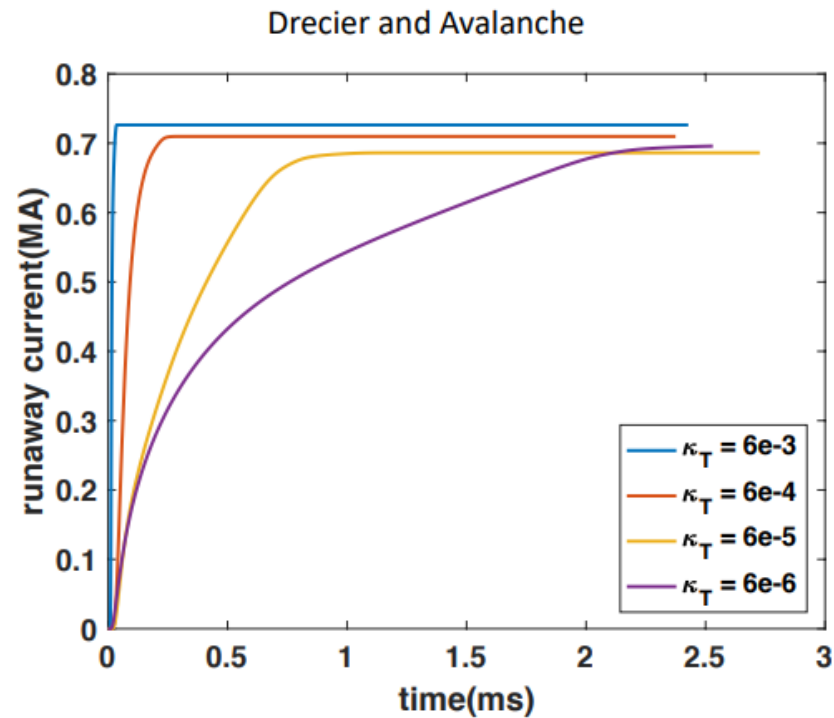
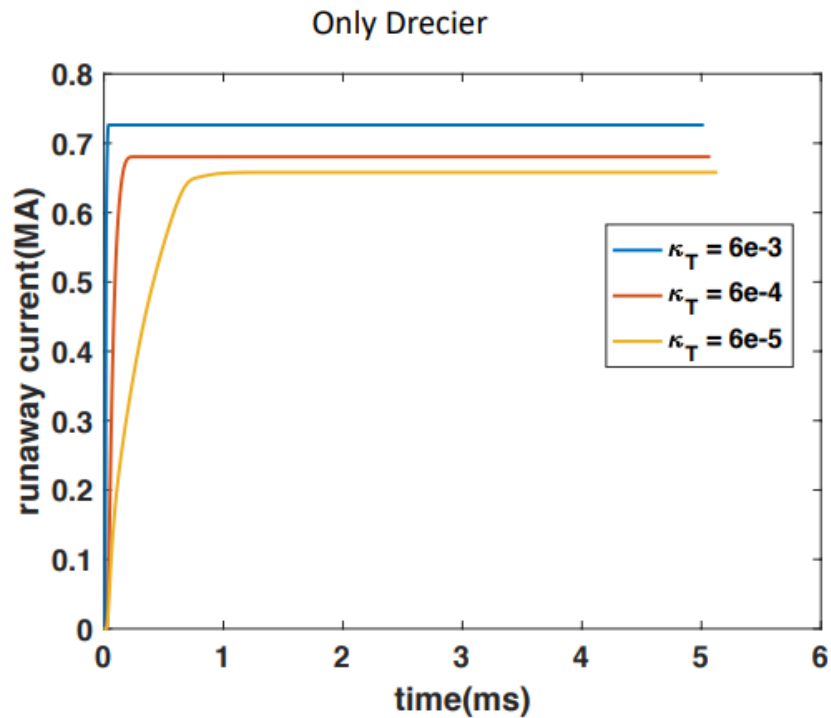
Approach to nonlinear MHD simulations in stellarator geometry

- 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



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 JOEREK group this morning. They will also check with ASDEX-U to see if there is a series of experiments that we could model

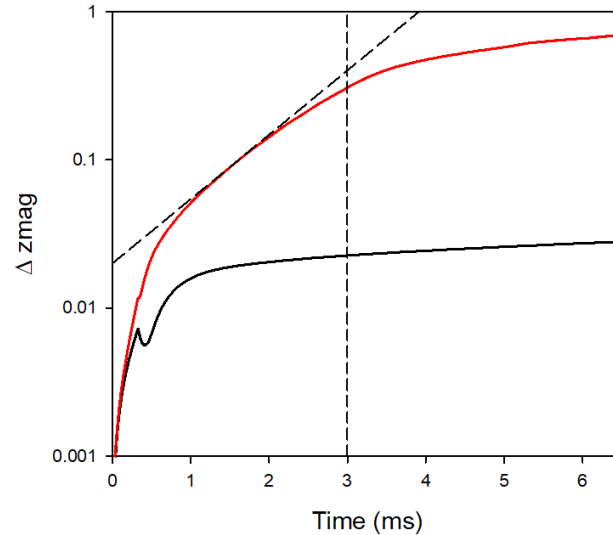
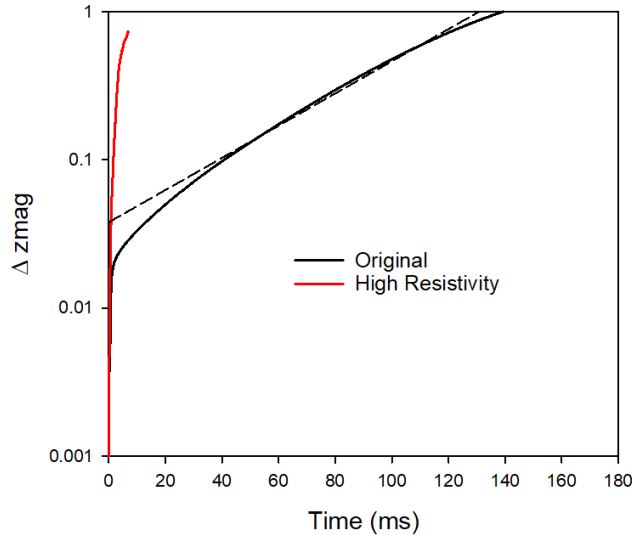
Effect of resistive wall on the thermal quench

- 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 T_e collapse. Can M3DC1 improve on this?

Current coupling scheme of fishbone simulation in M3D-C1

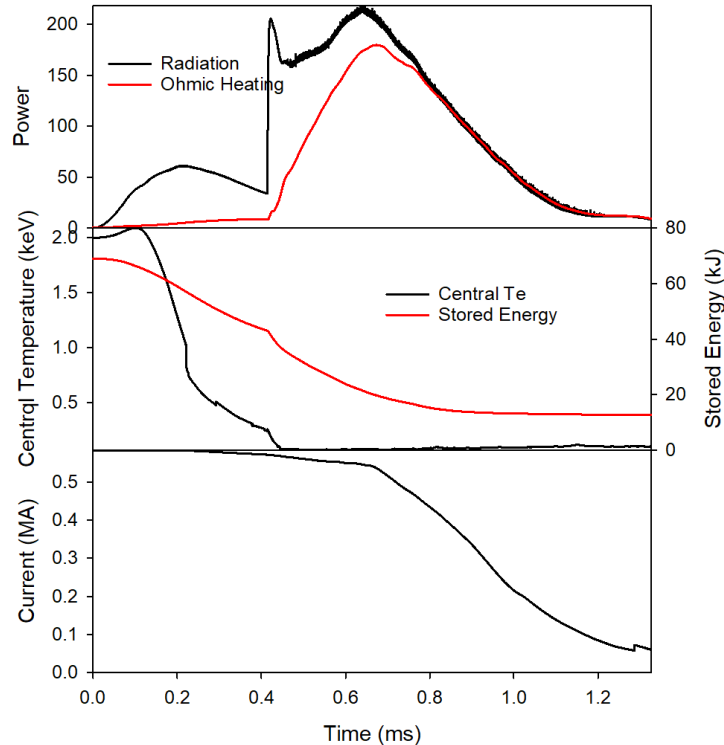
- Chang Liu to present

ITER disruption with more resistive vessel



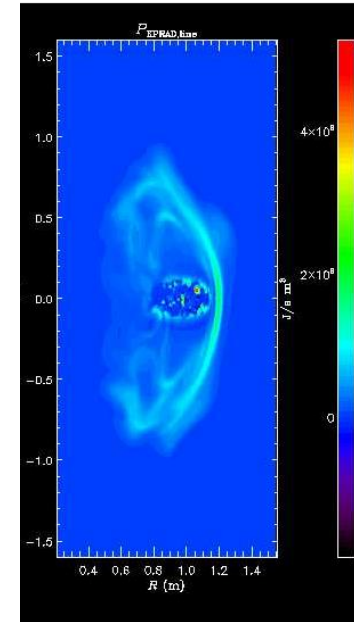
- Increased all vessel resistivities by 100
- Growth rate went from $.025 \text{ ms}^{-1}$ to 2.0 ms^{-1}
- New case greatly slows down after contact with wall is made

Carbon Mitigation in NSTX-U (shell pellet)



Shell carbon pellet in NSTX (now running)

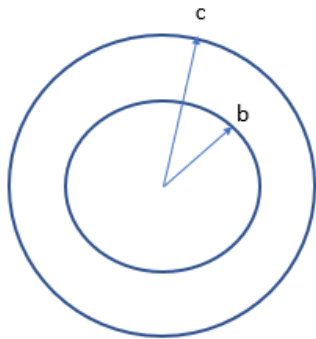
Radiation
 $t = 0.73$ ms



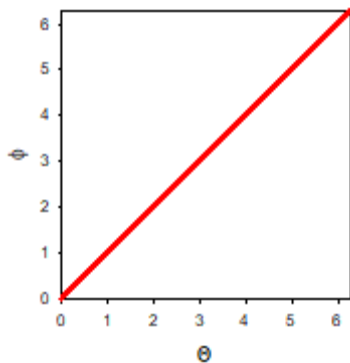
This run is essentially done and can be incorporated into Cesar's paper

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?

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

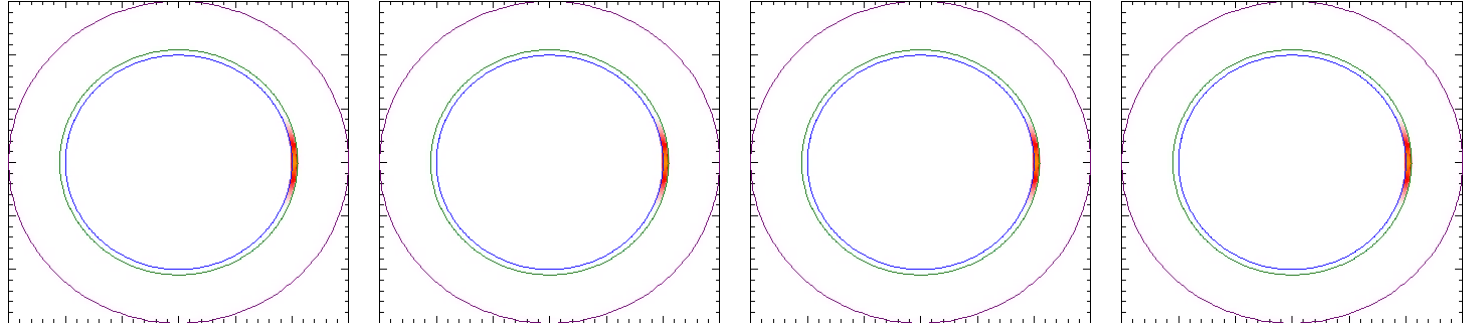
$$\mathbf{J} = \sigma \mathbf{E}$$

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

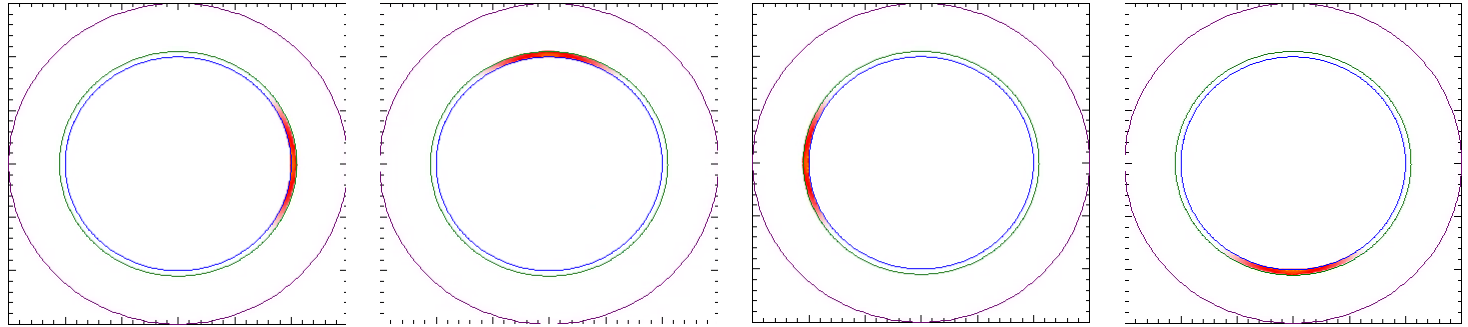
$$\int_0^{2\pi} \sigma^{-1} J_\theta d\theta = \int_0^{2\pi} \frac{d\Phi}{d\theta} d\theta = 0$$

Comparison between Straight and helical band

Straight →



Helical →

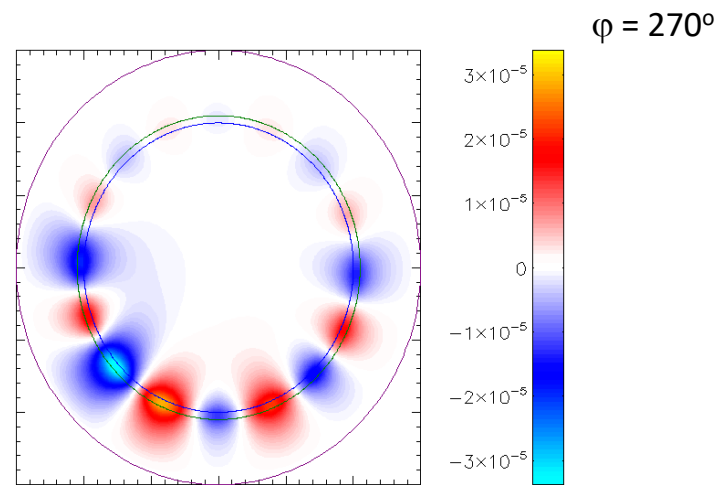
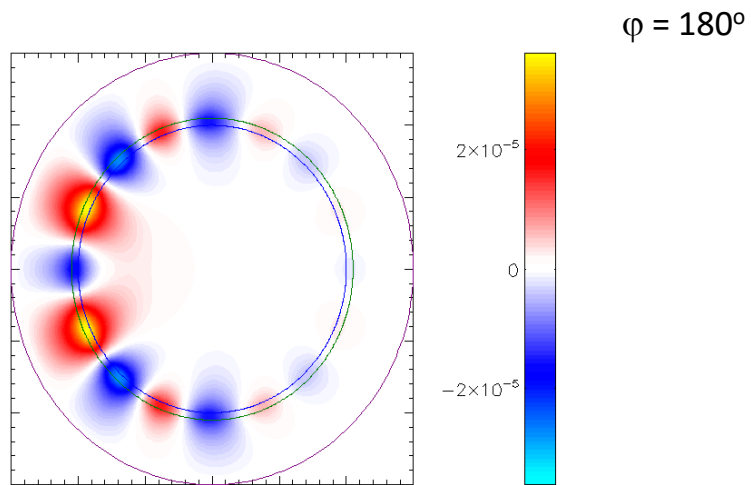
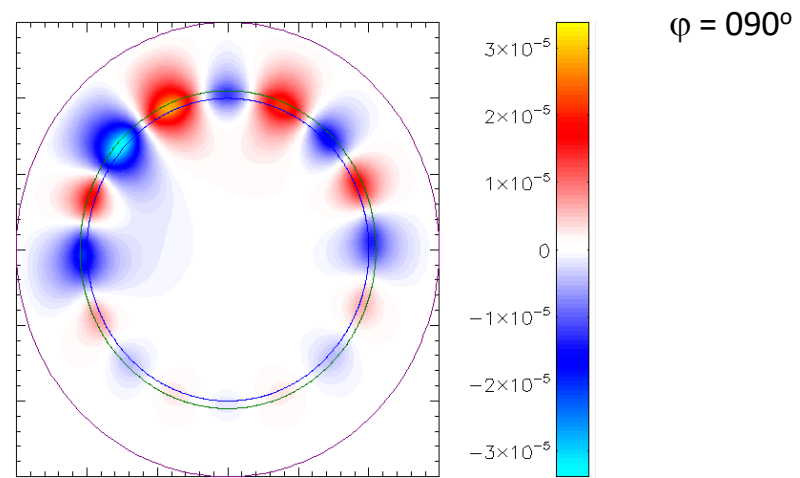
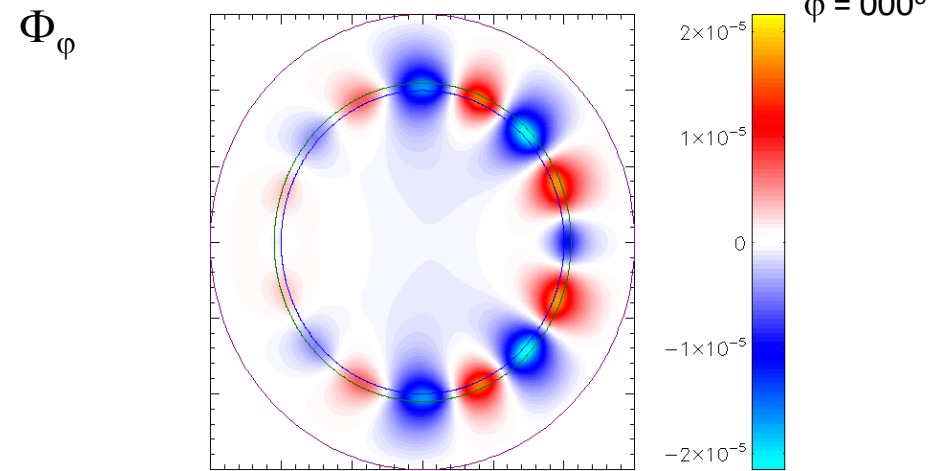


$$\varphi = 0$$

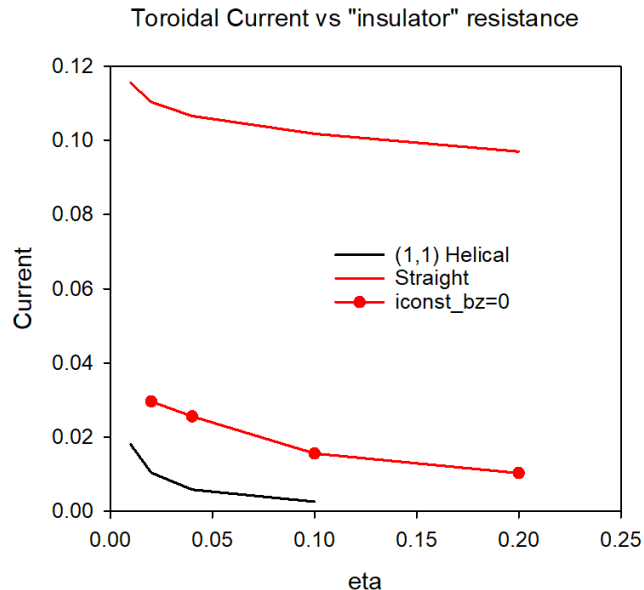
$$\varphi = \pi / 2$$

$$\varphi = \pi$$

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

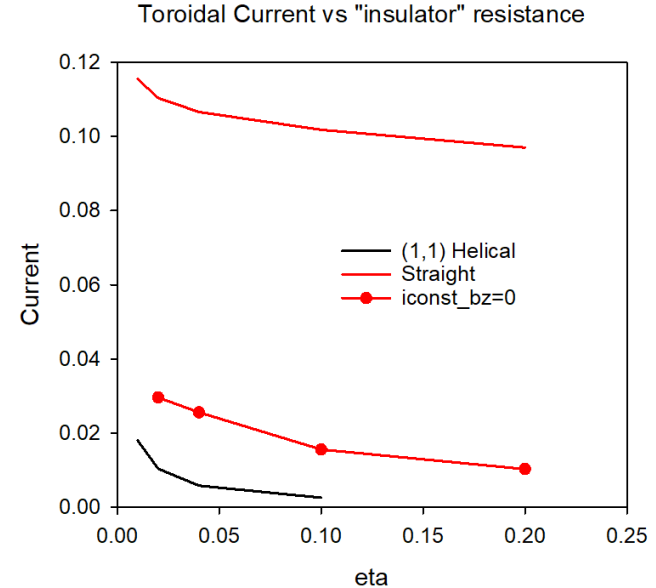
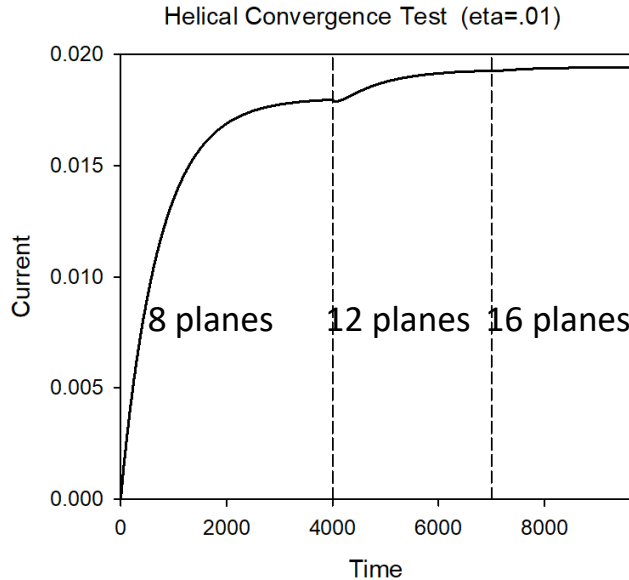


Helical resistive band to suppress runaways



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

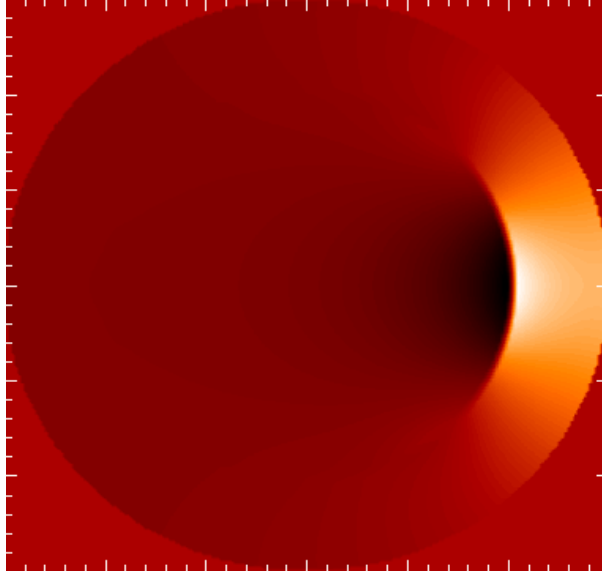
Some Convergence Tests



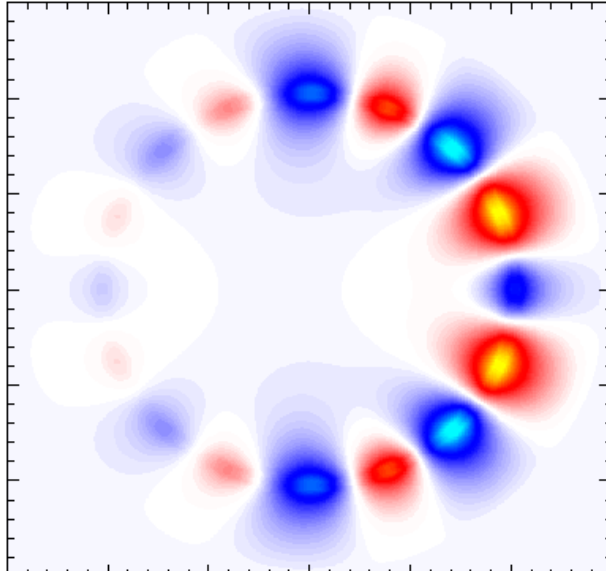
- Wall current appears to be converged in # of planes
- Helical wall current tending towards zero for large values of insulator resistance
- Now testing dependence on boundary conditions (location of ideal wall)
- Helical (1,2) case gives less than half the current of helical (1,1) case
- Iconst_bz=0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

Plots for iconst_bz=0

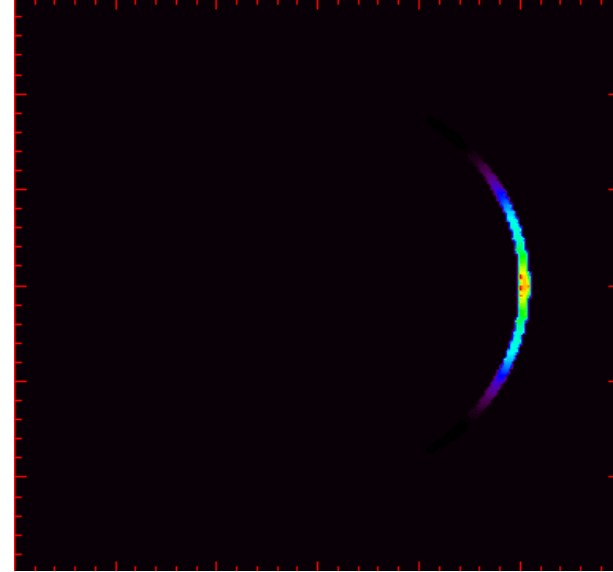
I



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



J_φ

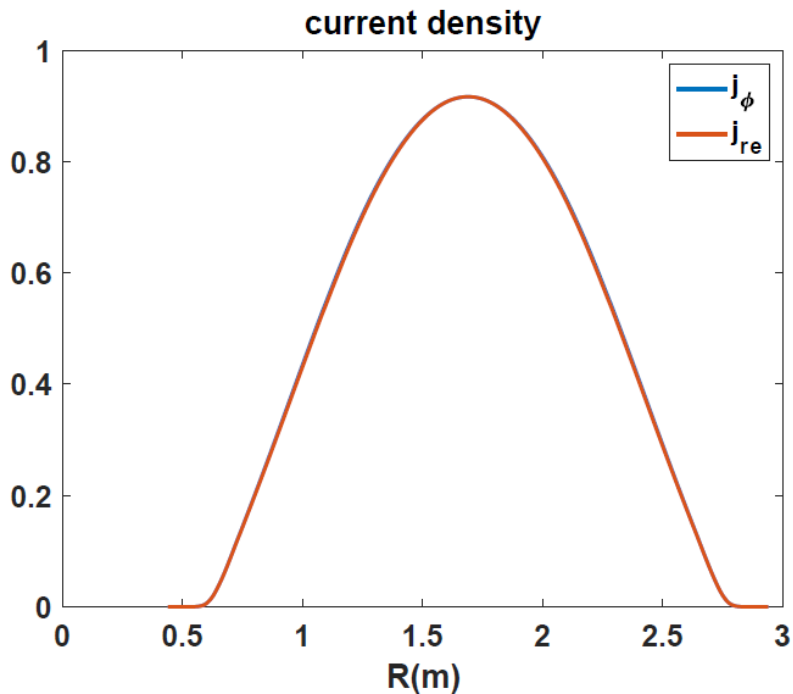
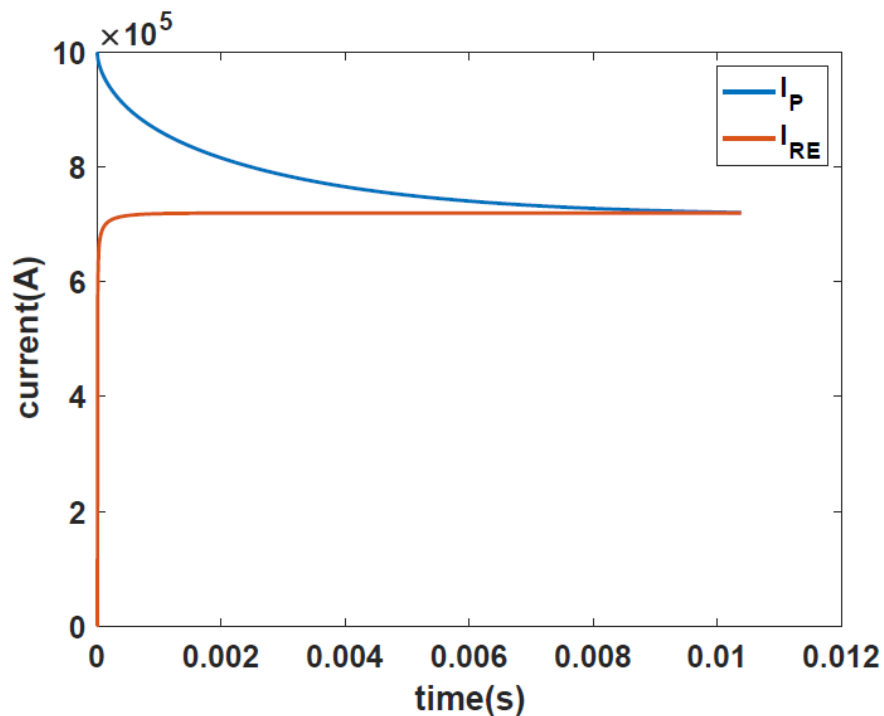


$$\nabla_\perp \cdot \frac{1}{R^2} \nabla \Phi = \nabla_\perp \cdot \eta \left[-\frac{1}{R^2} \nabla F \times \nabla \varphi - \frac{1}{R^2} \nabla f'' \times \nabla \varphi - \frac{1}{R^4} \nabla_\perp \psi' \right]$$

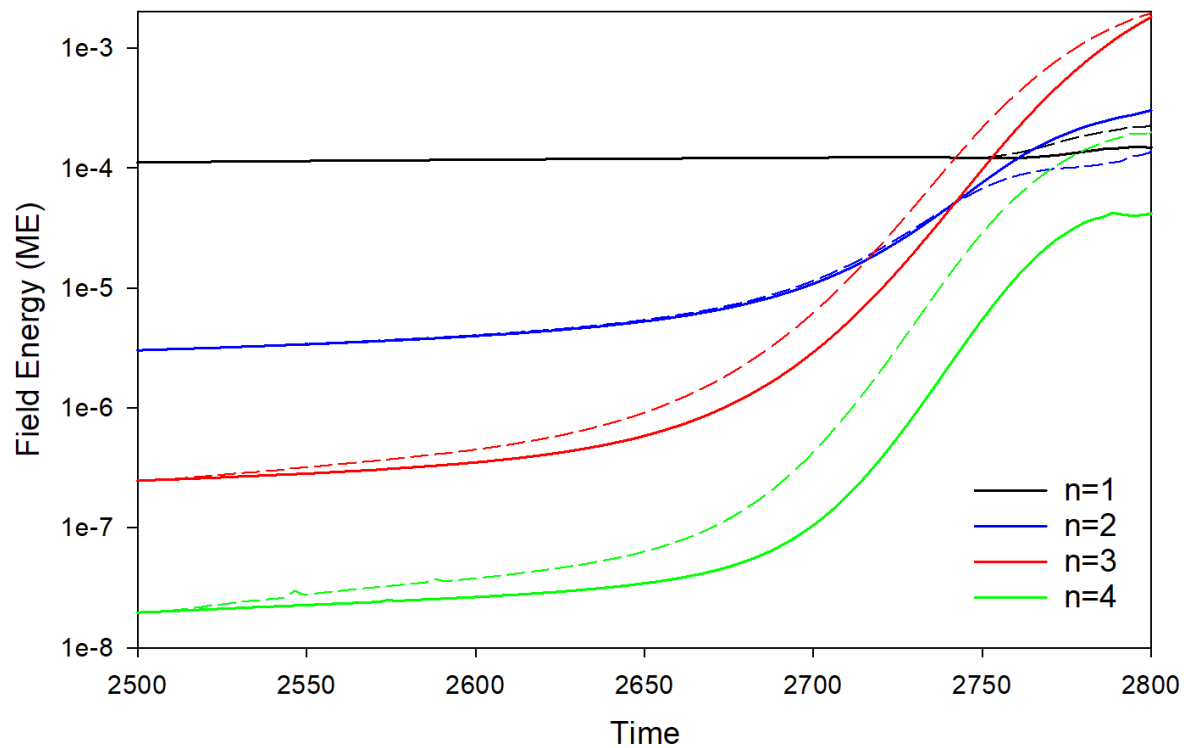
Local Systems

- 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

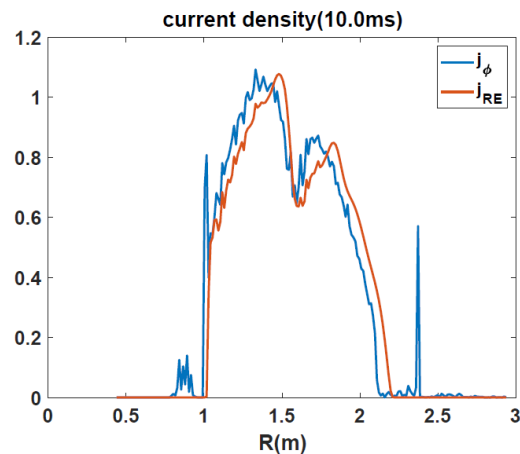
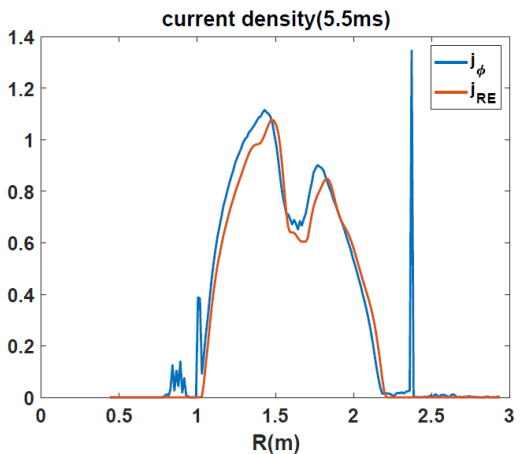
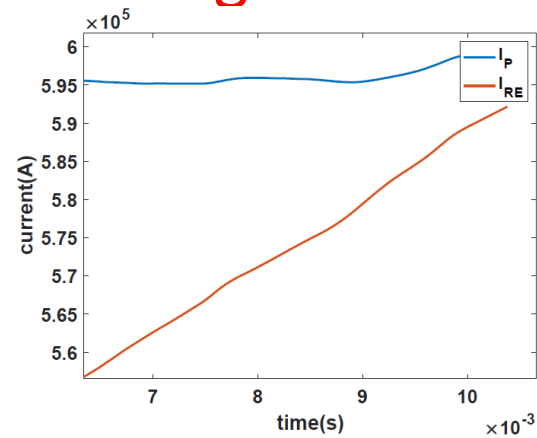
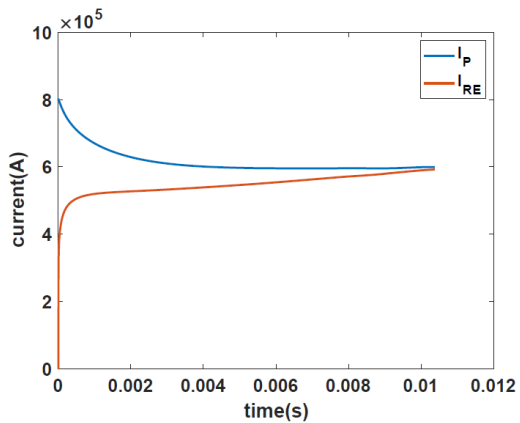
2D (cylindrical) RE with sources (12/19/2020)



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



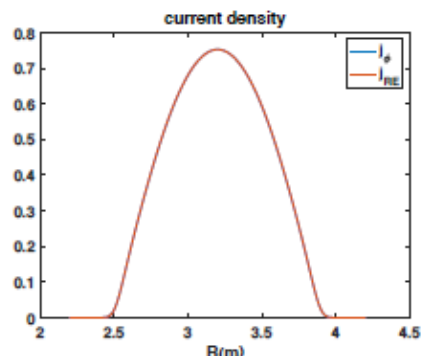
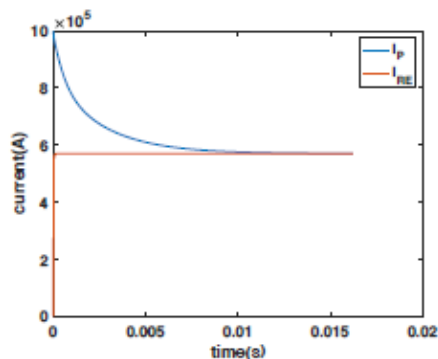
DIII-D 177053 with Argon



Chen Zhao

Same calculation in a Cylinder

M3D-C1 runaway generation with cylinder geometry



- Parameters:
$$\beta_0 = 0.15$$
$$a = 0.65m$$
$$R = 1.7m$$
$$B_0 = 1.9T$$
$$\eta = 1.0 \times 10^{-4}$$
$$n_0 = 1.0 \times 10^{20} m^{-3}$$
$$c = 150v_A$$
$$N_{elements} = 12261$$
$$\Delta t = 1.0\tau_A$$

- 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?

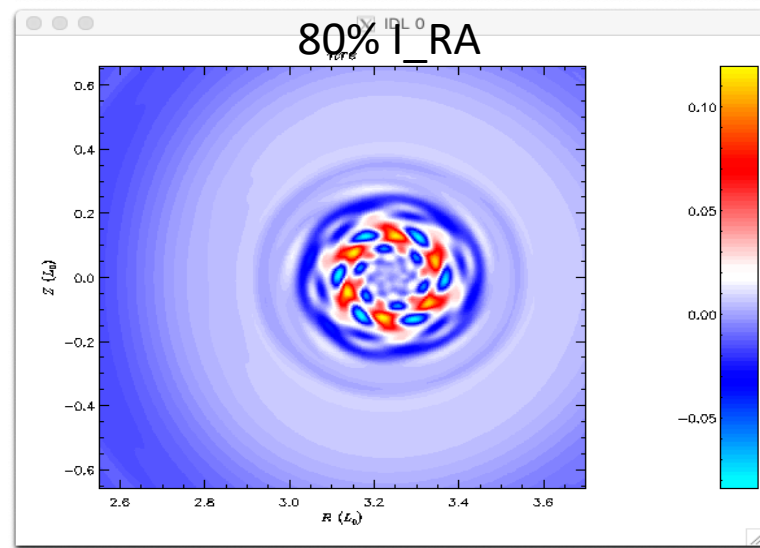
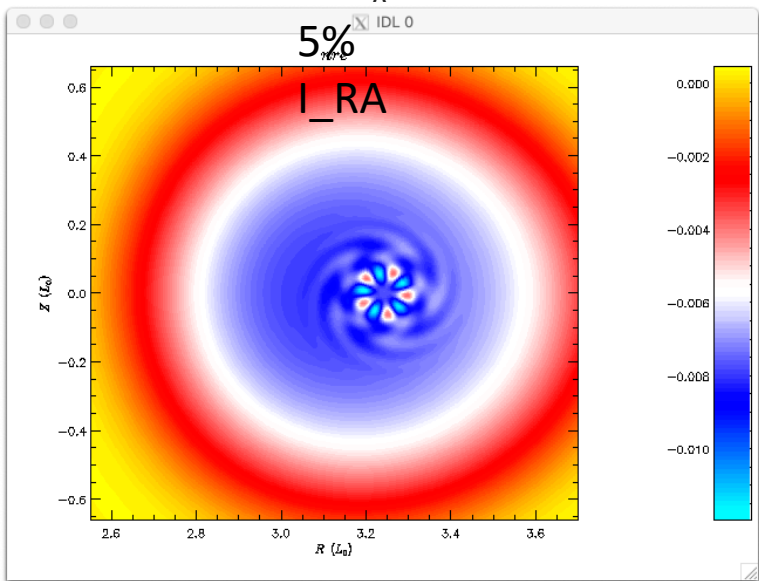
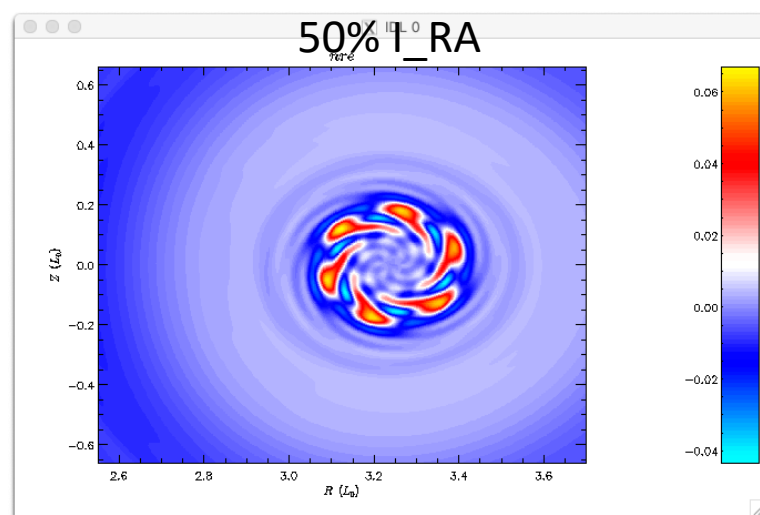
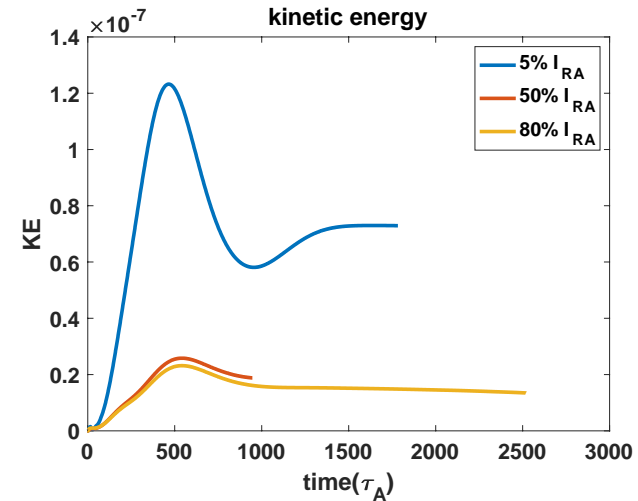
- M3D-C1/NIMROD 3D Benchmark

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

DIII-D Neon pellet mitigation simulation for KORC

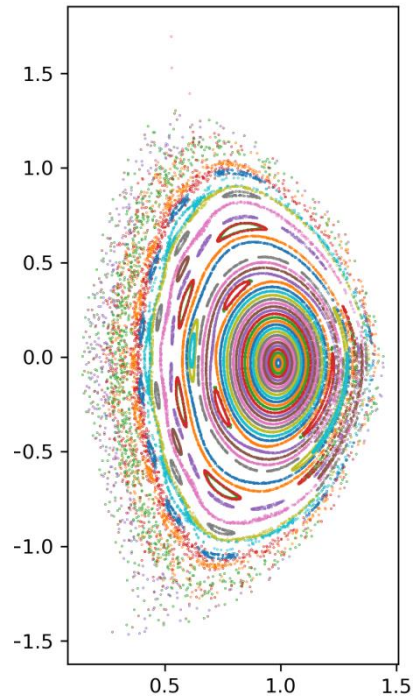
- Brendan Lyons trying to extend 8 plane case to 32 planes

SPARK ? Do we need to do anything?



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

Chang Liu

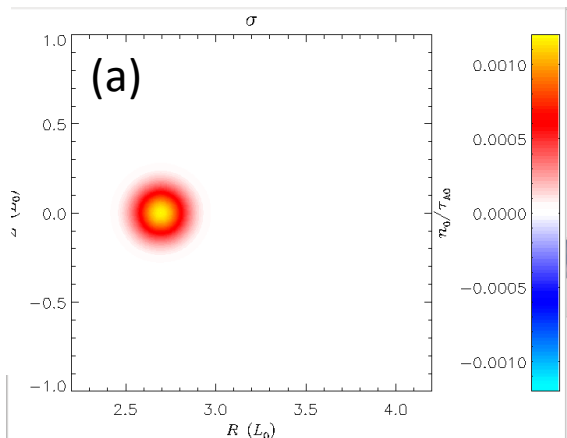


- In the original geqdsk file, the equilibrium was poorly converged. New one is much better. Has $q(0) = 1.3$
 - Chang has analyzed new equilibrium (left)
 - No ideal (1,1) mode, several tearing modes
-
- If goal is to get unstable (1,1) mode, likely need to lower $q(0)$
 - Adding sheared toroidal rotation should help stabilize resistive modes.

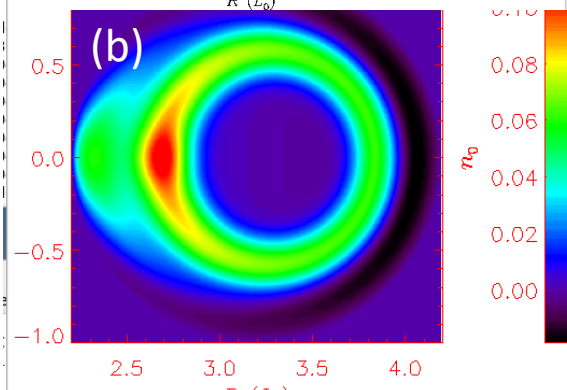
Grad-B drift in M3D-C1—HF side

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

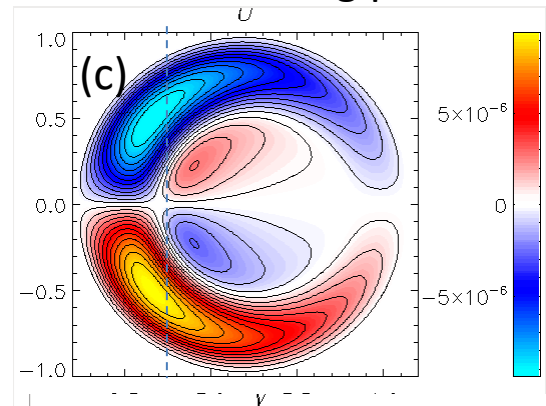
(a) Density source in 1F toroidal equilibrium



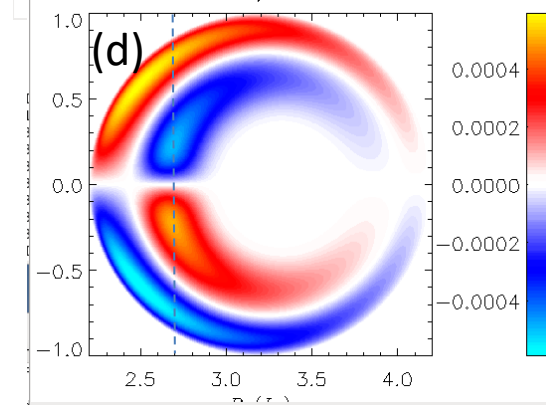
(b) Change in density after $10^3 \tau_A$



(c) Poloidal velocity stream function



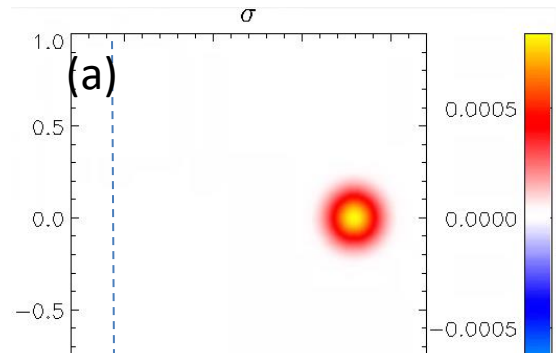
(d) Toroidal velocity contours



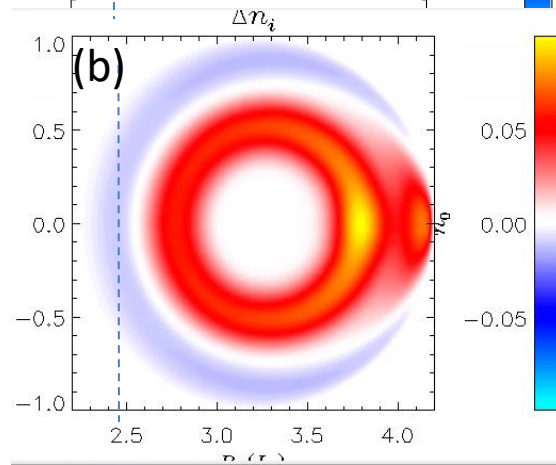
Grad-B drift in M3D-C1– LF source

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

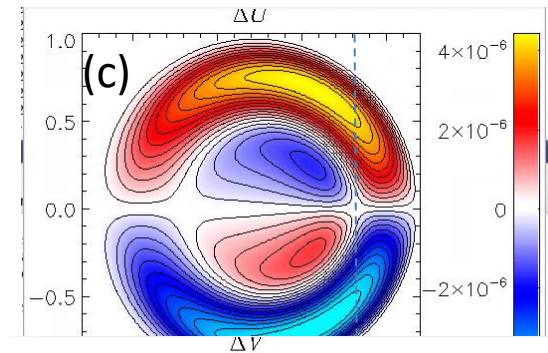
(a) Density source in 1F toroidal equilibrium



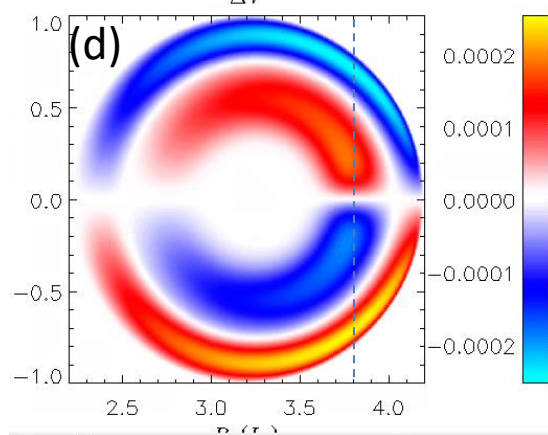
(b) Change in density after $10^3 \tau_A$



(c) Poloidal velocity stream function

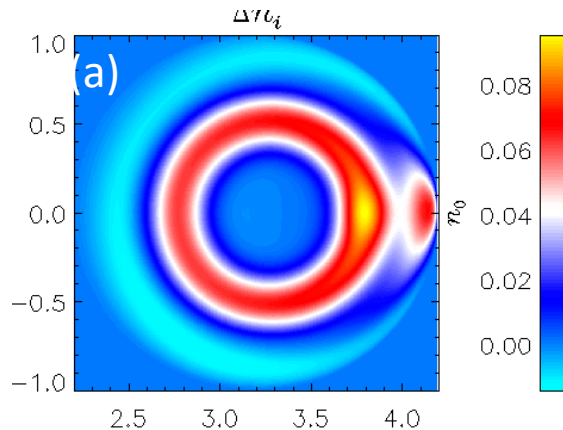


(d) Toroidal velocity contours

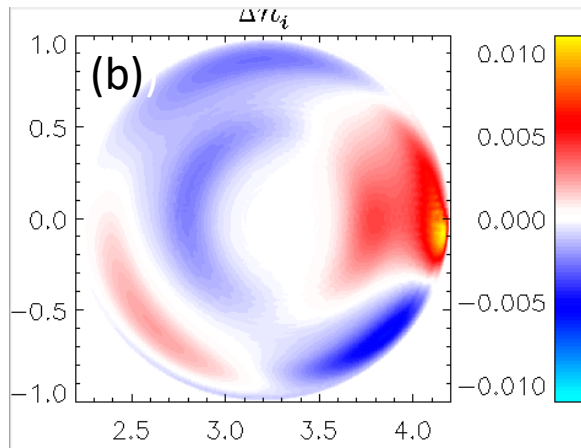


Grad-B drift in M3D-C1—2F effects

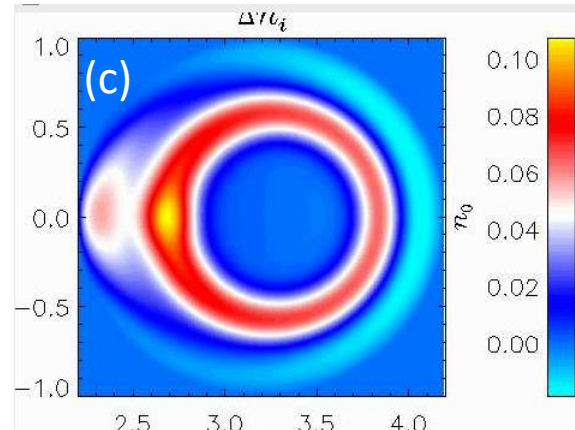
(a) 2F density change
after $10^3 \tau_A$ for LF
side source



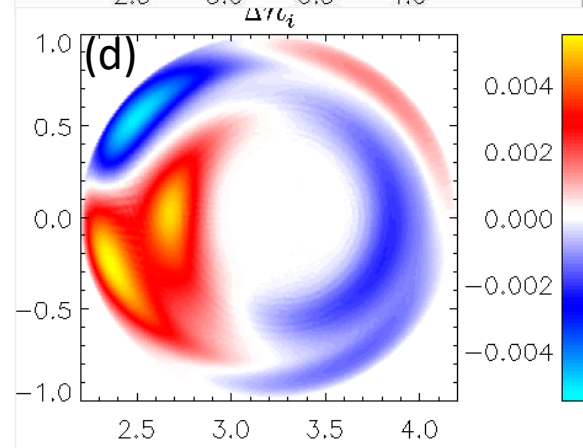
(b) Difference in 1F and
2F density (LF)



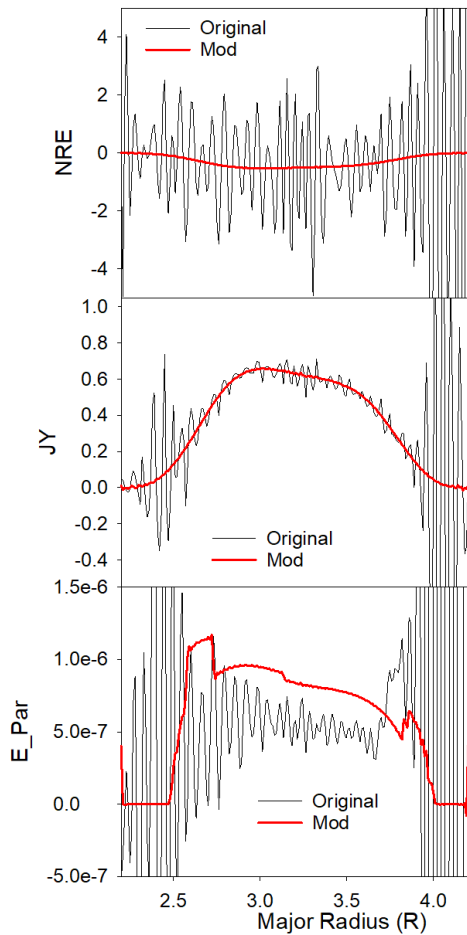
(c) 2F density change
after $10^3 \tau_A$ for HF
side source



(d) Difference in 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

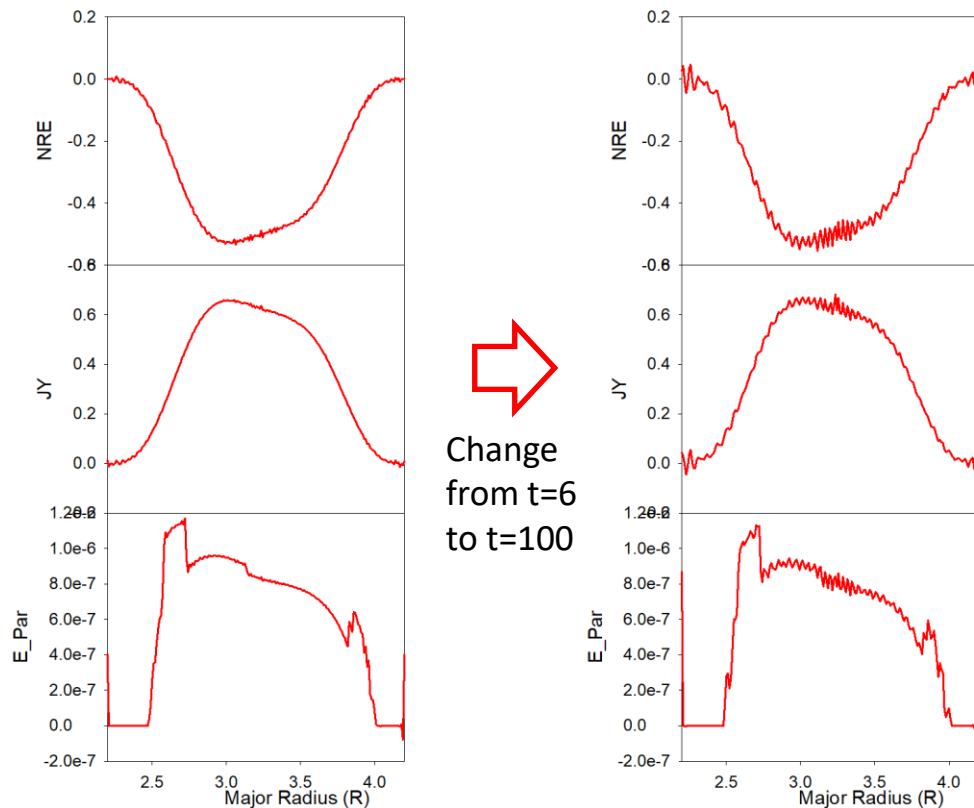
pedge

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?