M3D-C1 ZOOM Meeting

03/29/2021

Announcements

CS Issues

1. GPU solve and memory utilization status (Jin Chen)
2. stellar.princeton.edu status
3. Mesh adaptation update (RPI, Brendan Lyons)
4. plot_equation,'gradshafranov' bug?
5. NERSC Time
6. Changes to github master since last meeting
7. Regression tests
8. New plotting option
9. Variable density diffusion

Physics Studies

1. Runaway electron loss by MHD events– Chang Liu
2. Carbon Mitigation in NSTX-U (shell pellet)
3. RE Benchmark with JOREK and comparison with DIII.. Chen Zhao
4. Jet SPI simulatons and possible fix …Lyons
5. Other?

In attendance

S. Jardin
C. Clauser
Y. Zhou
H. Strauss
A. Wright
A. Kleiner
R. Usman
B. Lyons
S. Seol
N. Ferraro
J. Chen
O. Bardsley
P. Sinha

Announcements

- ITPA on MHD, Disruptions, Control Held March 22-25
  - 3 M3D-C1 talks

- IAEA Papers Due 9 April
  - Hank wrote on 3/29: It should have JET in the title
  - “Vessel forces from a vertical displacement event in JET and ITER”?

- Sherwood Meeting ?

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???

Any updates?

Jin Chen

stellar.Princeton.edu allowing early users

All M3DC1 users with eddy accounts should now be able to log into stellar

- /scratch/gpfs/yourname now available, 1 TB limit
- /home directory , 100 GB limit
- /projects/M3DC1/yourname 10 TB total for all users

- Visualization node for PPPL: ssh stellar-vis2

96 cpu-per-node runs now seem to be running ok!

Final Configuration: 296 Intel nodes, 100-140 dedicated to PPPL

~100 M cpu-hours/year

Equivalent to over 400 M NERSC hours on cori-Haswell

Mesh adaptation update

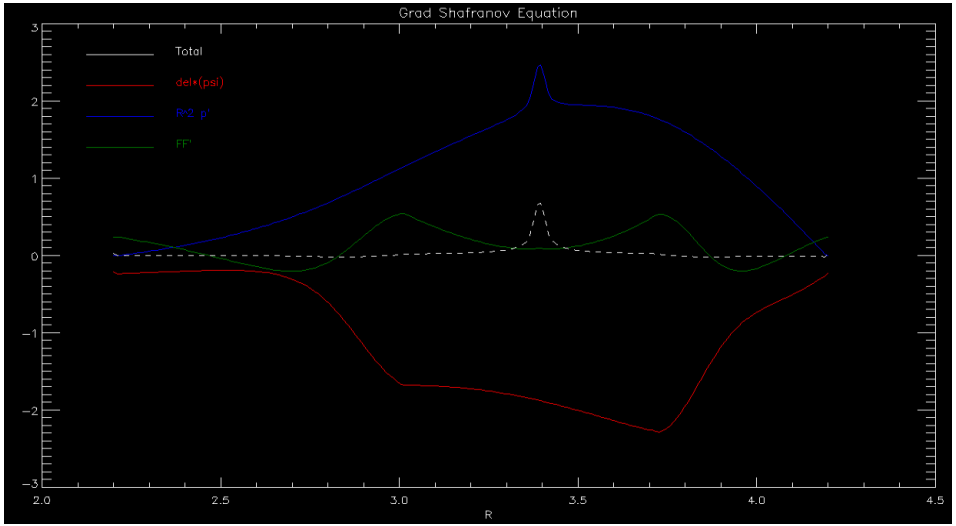
Any updates ?

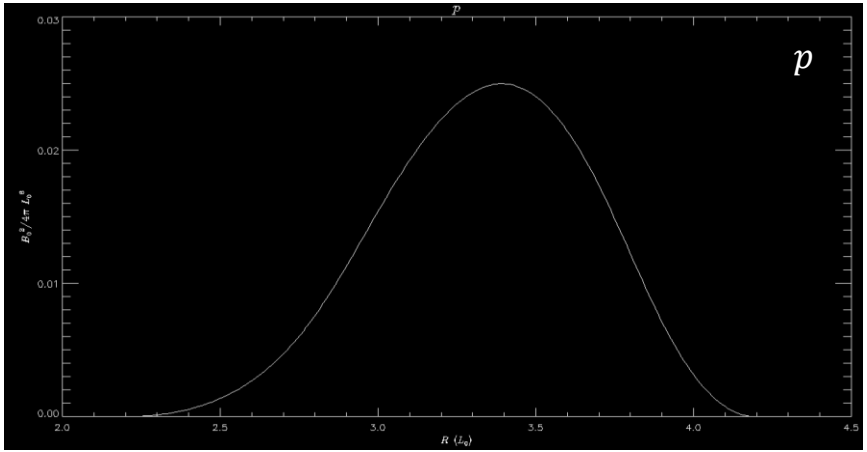
From Adelle Wright:

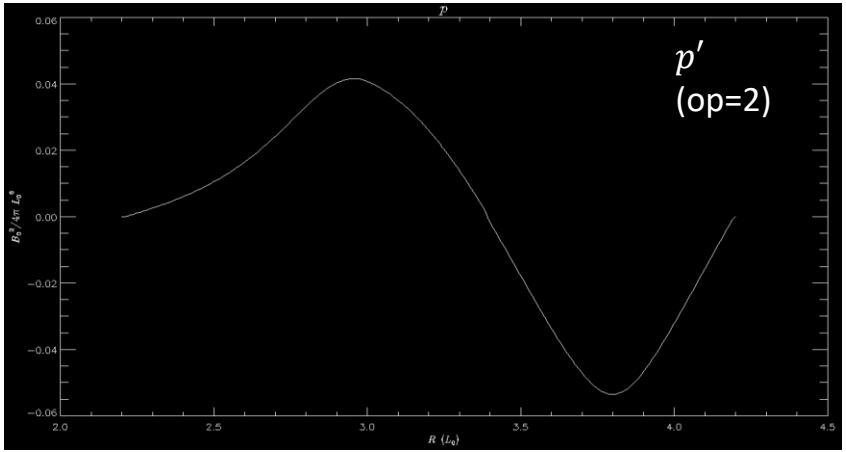
>**plot_equation, 'gradshafranov'** has large non-zero component at $p' = 0$. Diagnostic issue?

GS solver converged
(Error in last GS iteration: 1.15E-007)
(Final error in GS solution: 1.27E-002)

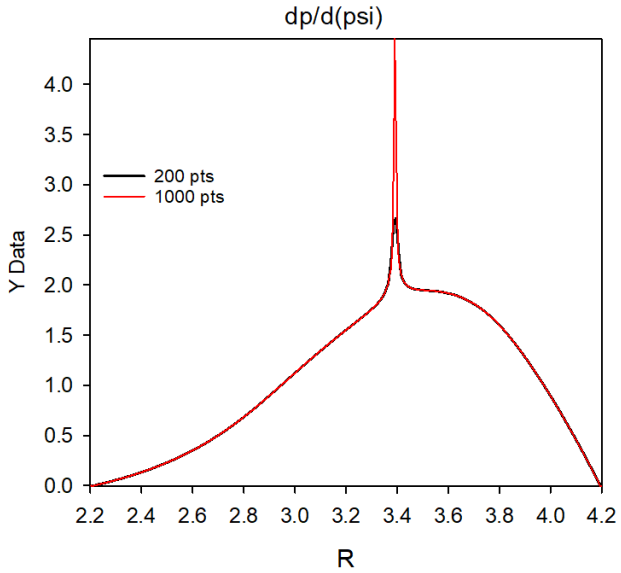
p and p' look well-behaved.

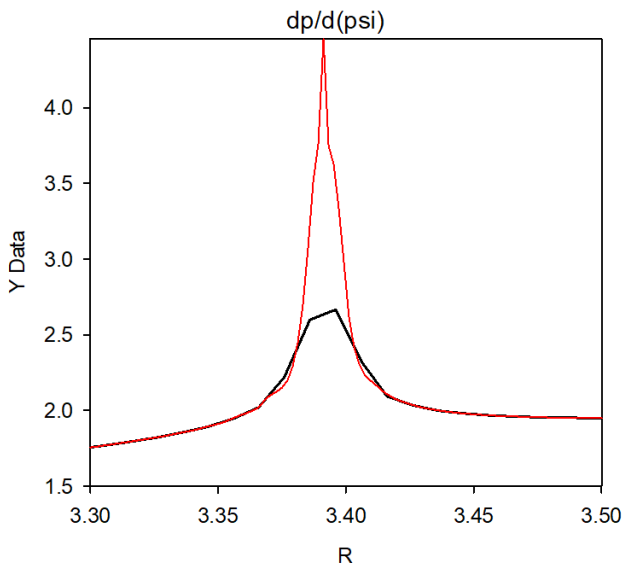






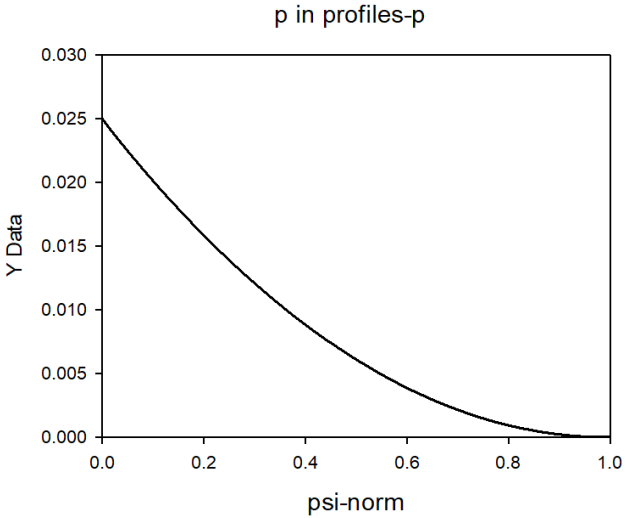
More on plot_equation, ‘gradshafranov’

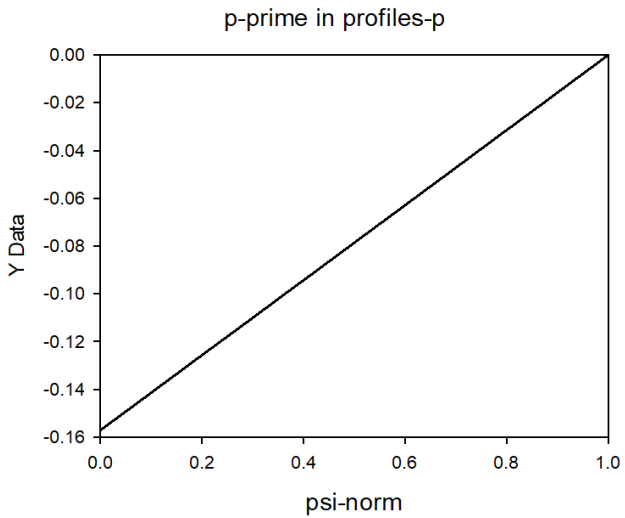




- 1000 pts more singular that 200 points
- Other equilibrium from analytic p(ψ) and F(ψ) look fine
- Increasing # of mesh points in m3dc1 doesn’t help
- Resulting equilibrium looks good…doesn’t generate large velocities for nonlinear n=0 eqsubtract=0 run
- Could be a boundary condition on spline at origin when reading files from qsolver?

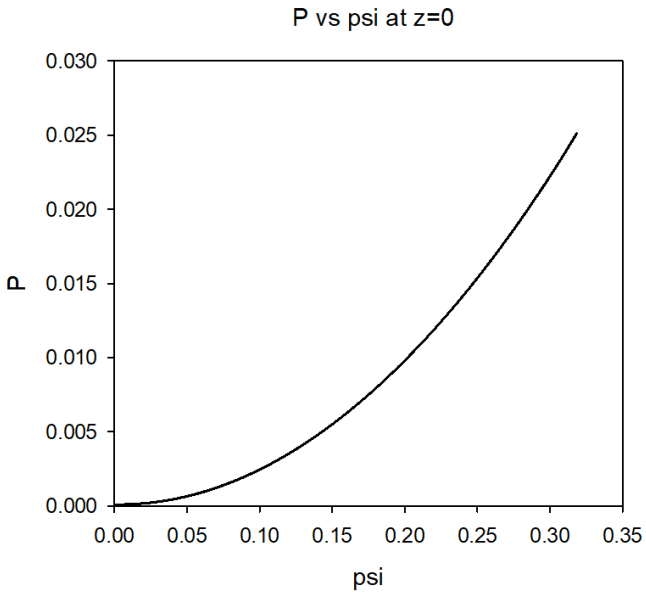
Profiles-p file from qsolver looks fine

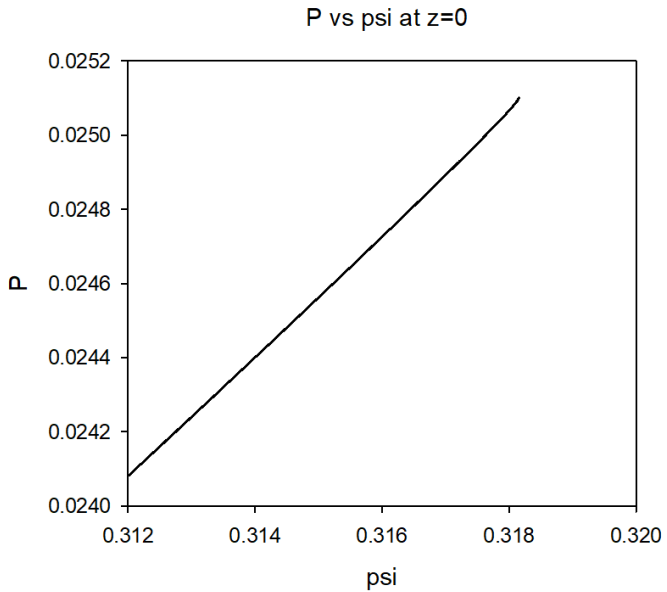




- Look to be smooth at origin (on left)

P from IDL cutz=0 vs psi from IDL cutz=0 look fine

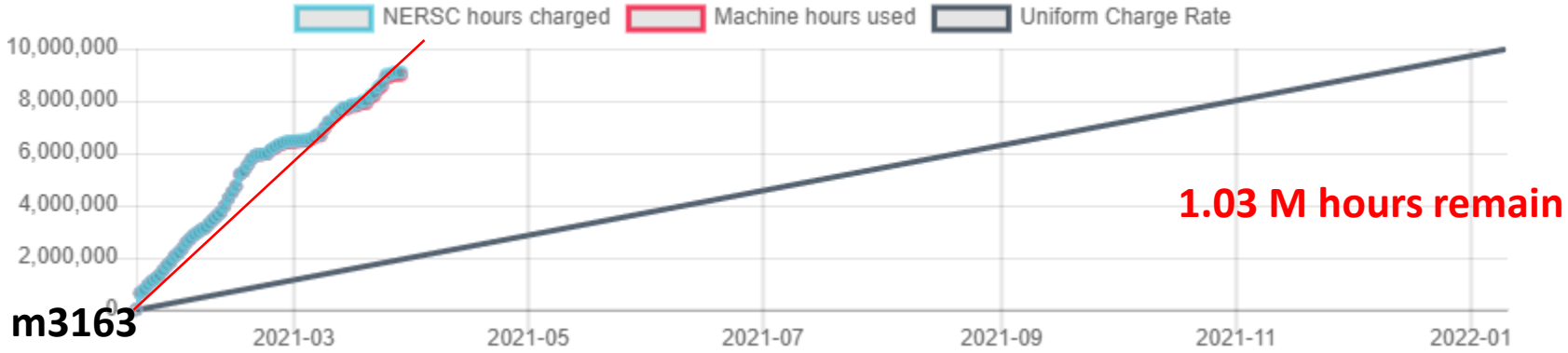




- Looks to be smooth at origin (on right). Graph on right is closeup of area near magnetic axis.
- Other ideas?

NERSC Time

mp288



m3163

Closed for general use

- mp288 received 10M Hrs for CY 2021
- We will exhaust this by the mid April at this rate. (May get more time)
- Transition to stellar (PU/PPPL)

Changes to github master since last meeting !

Jin Chen

- 03/17/21: stellar.mk update

Seegyoung Seol

- 03/19/21: Adding config file for stellar
- 03/22/21: updating stellar.mk to use new SCOREC build

Yao Zhou

- 03/24/21: minor change to bfp output condition
- 03/24/21: Output version 38 resolving fprime inconsistencies

Steve Jardin

- 03/28/21: Added idenmfunc=1 option (for density diffusion)

Brendan Lyons

- 03/19/21: Add python color tables to IDL

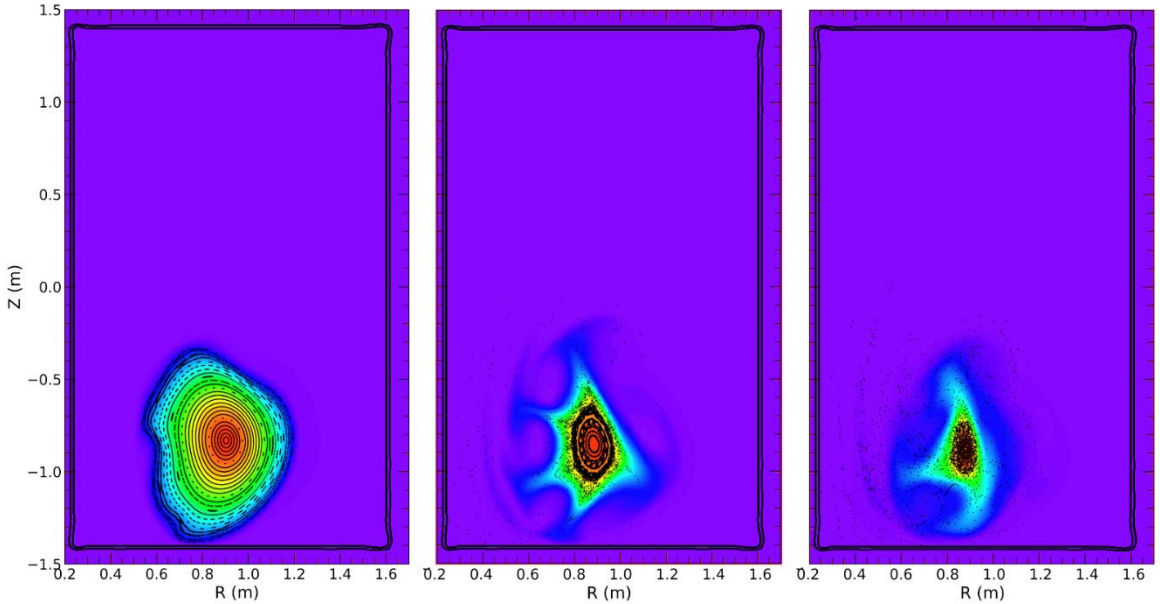
Local Systems

- PPPL centos7(03/29/21)
  - 6 regression tests **PASSED** on centos7:
- PPPL greene (03/29/21)
  - 5 regression tests **PASSED**
  - No batch file found for pellet
- STELLAR (03/29/21)
  - 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)
  - ??

New Plotting Option



Superimpose IDL field with trace Poincare plot

This was included in the 3DVDE M3D-C1/JOREK/NIMROD benchmark paper.

Cesar Clauser

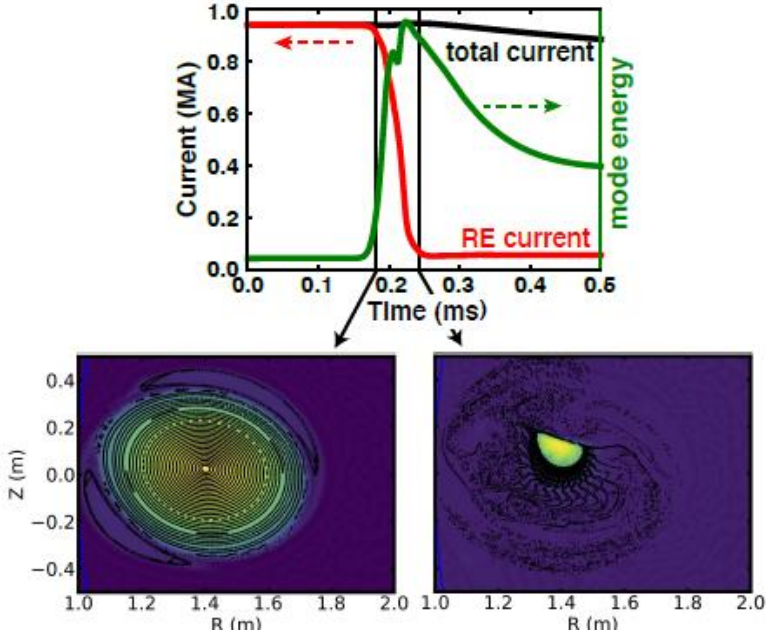
Variable density diffusion now available

idenmfunc		0	Selects form of particle diffusion
	0	denm79 = denm	
	1	denm79 = denm + denmt/Te	
	10	read from file profile_denm in m^2/sec	
	11	read from file profile_denm in normalized units	
denmt		0	multiplier of 1/Te for idenmfunc = 1
denmmin		1.e-12	minimum value of denm
denmmax		1.e6	maximum value of denm

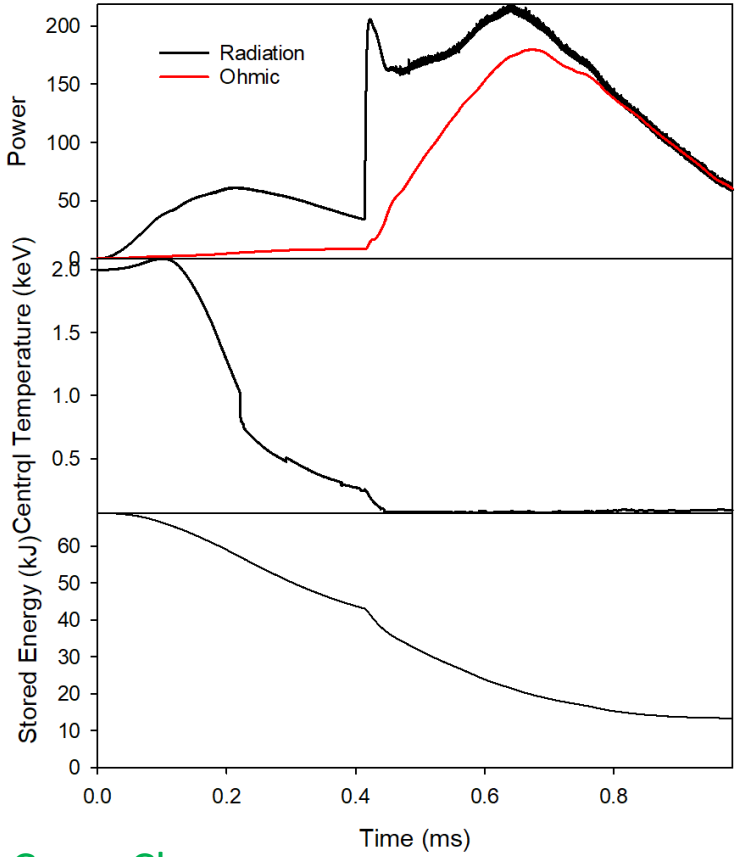
Paz-Soldan IAEA paper on runaway electron loss by MHD events

- D_2 injection into RE beam to purge high Z atoms from RE beam and drive recombination of the background plasma
- Lower q_a by I_P increase or a decrease
- RE beam becomes de-confined and current transferred to background plasma
- Q: Do we see recombination of the background plasma when injecting D2 ?
- Can we apply this to ITER?

Chang Liu



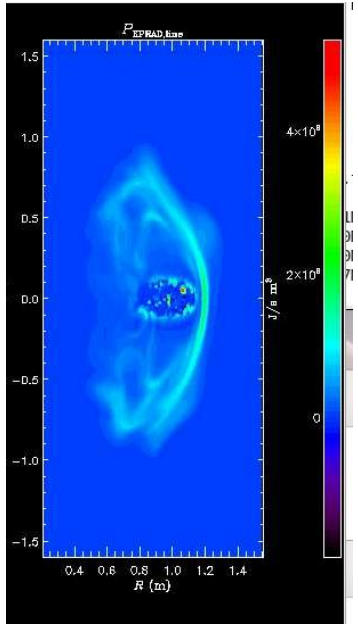
Carbon Mitigation in NSTX-U (shell pellet)



Cesar Clauser

Shell carbon pellet in NSTX (now running)

Radiation
t = 0.73 ms



Had to back this up to t=0.69ms to turn off the constant ablations rate (Thanks Cesar)

Current quench has begun: 0.7 → 0.23 MA

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

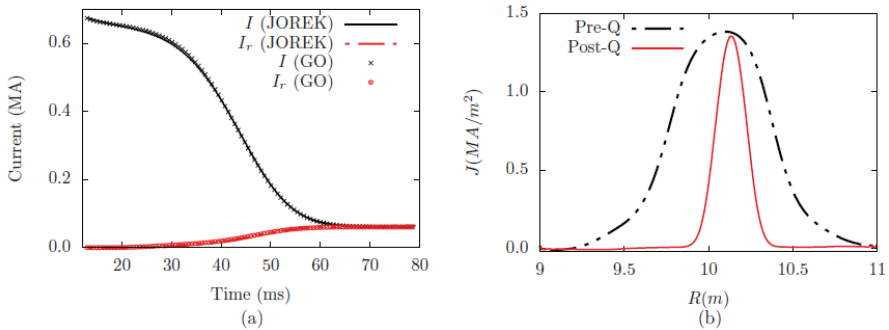
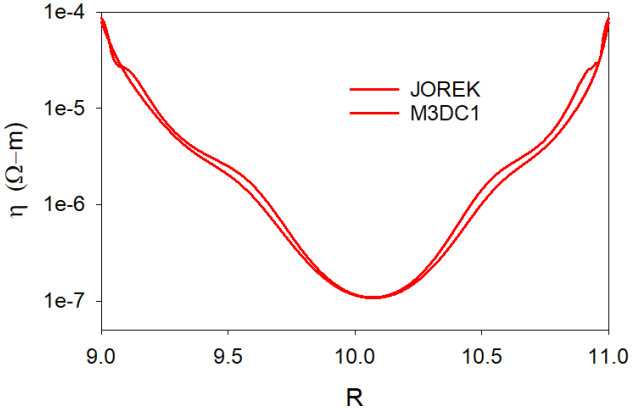
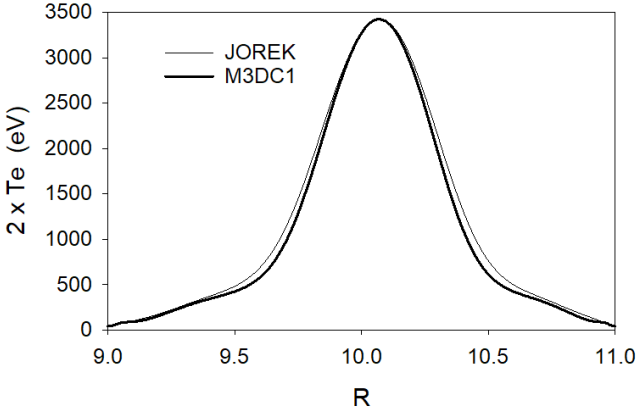


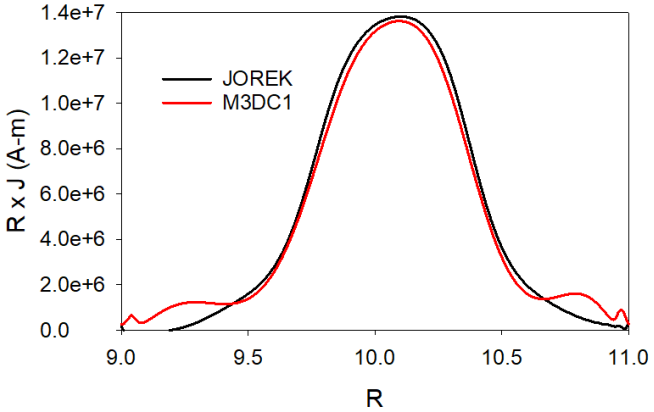
FIG. 3. (a) Time evolution of the total plasma current I and the RE current I_r during the current quench phase. (b) Midplane current density profiles before and after the current quench obtained from JOREK, showing a relatively peaked RE current profile.

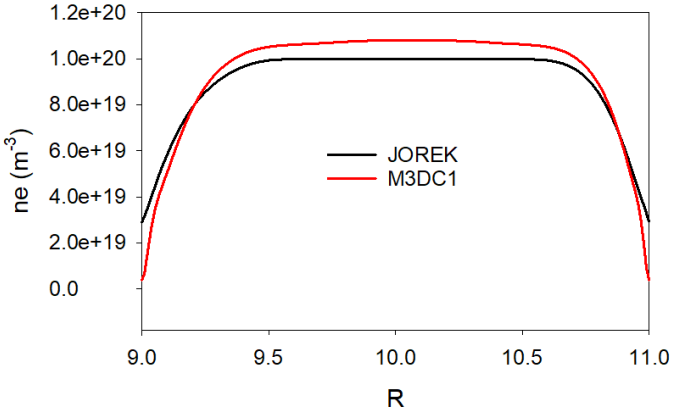
Chen Zhao

Comparison of initial profiles

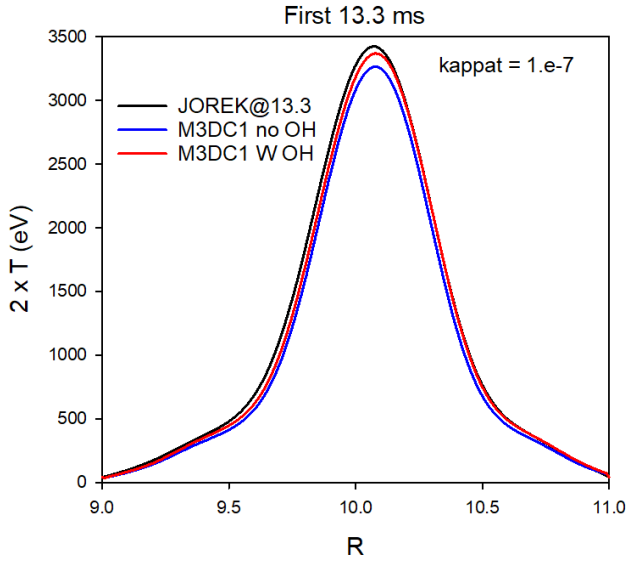


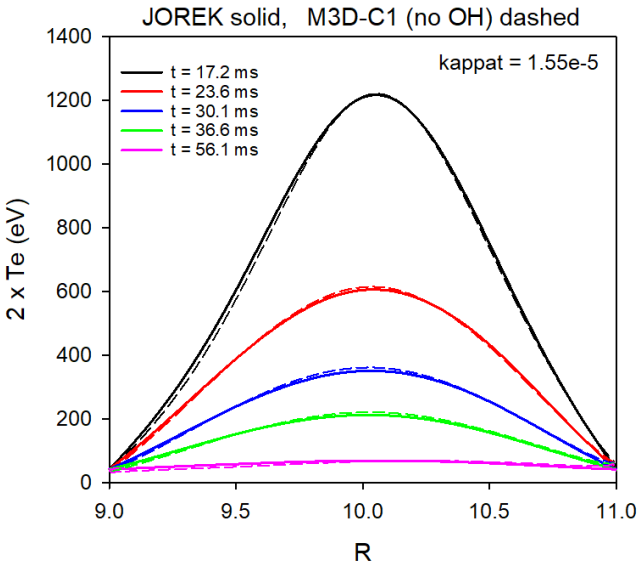






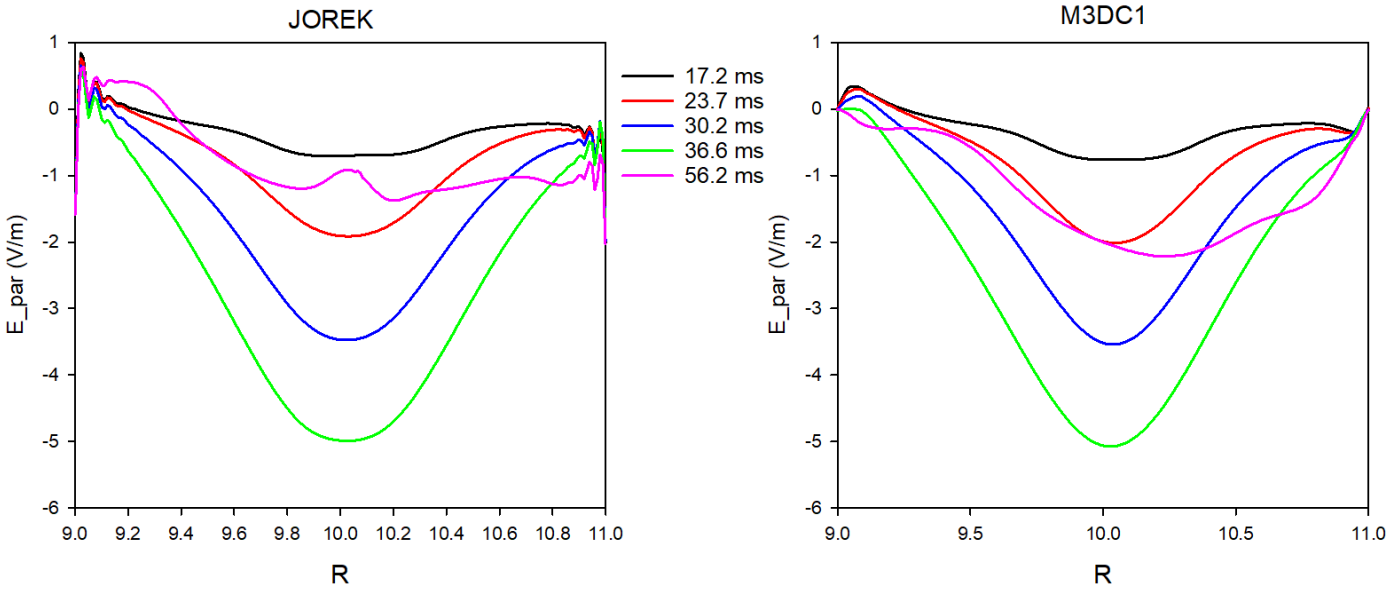
Comparison of T(R) at several times with no runaways



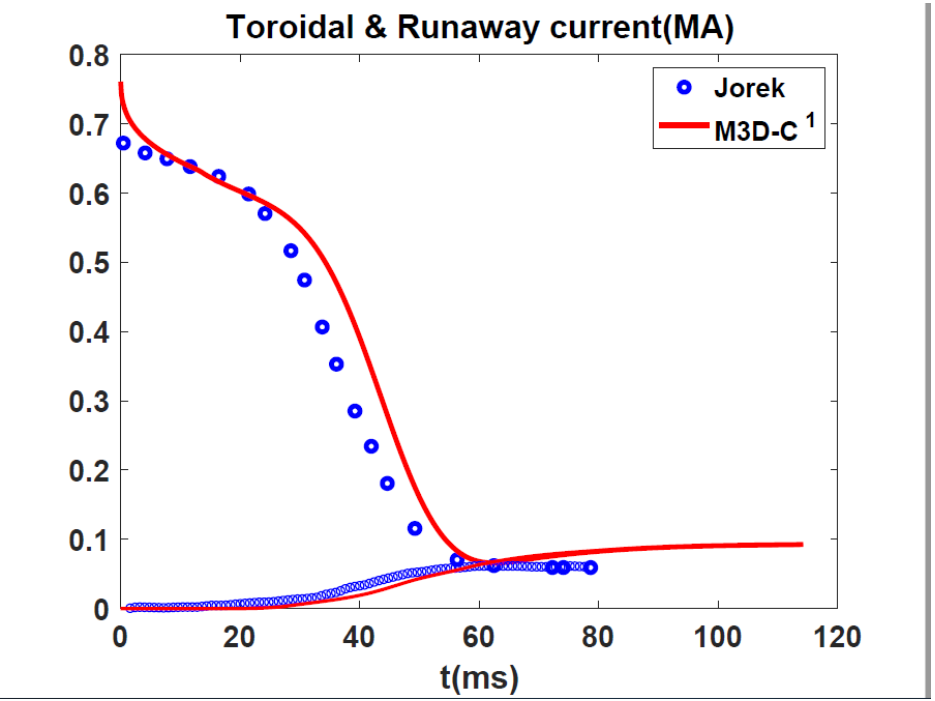


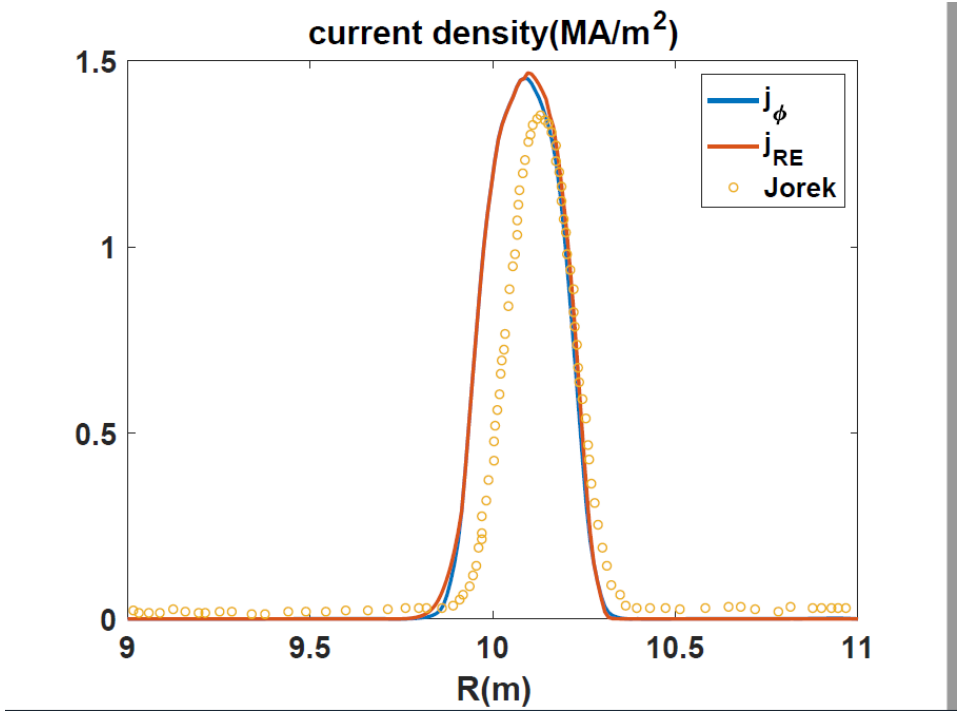
/p/tsc/m3dnl/Bandaru3

Comparison of E_par

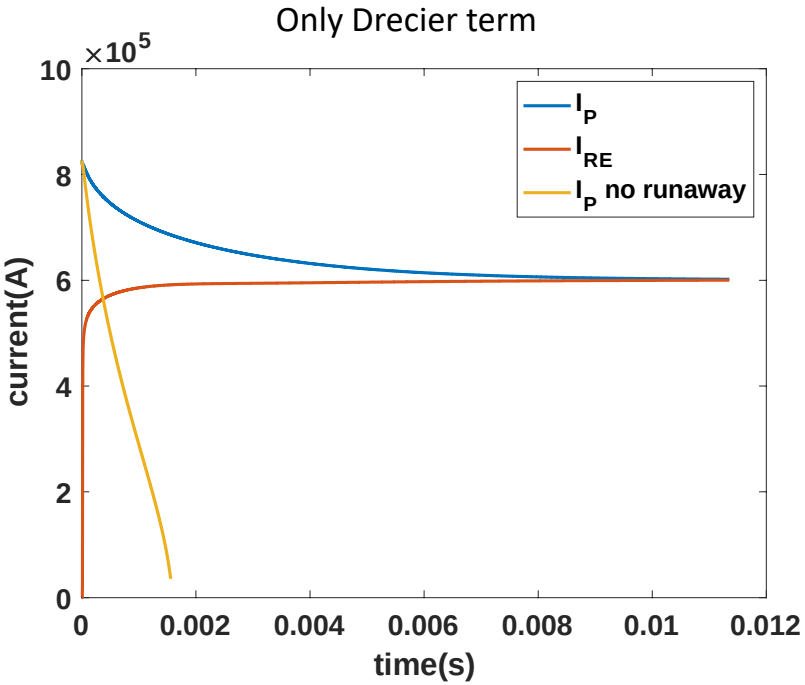


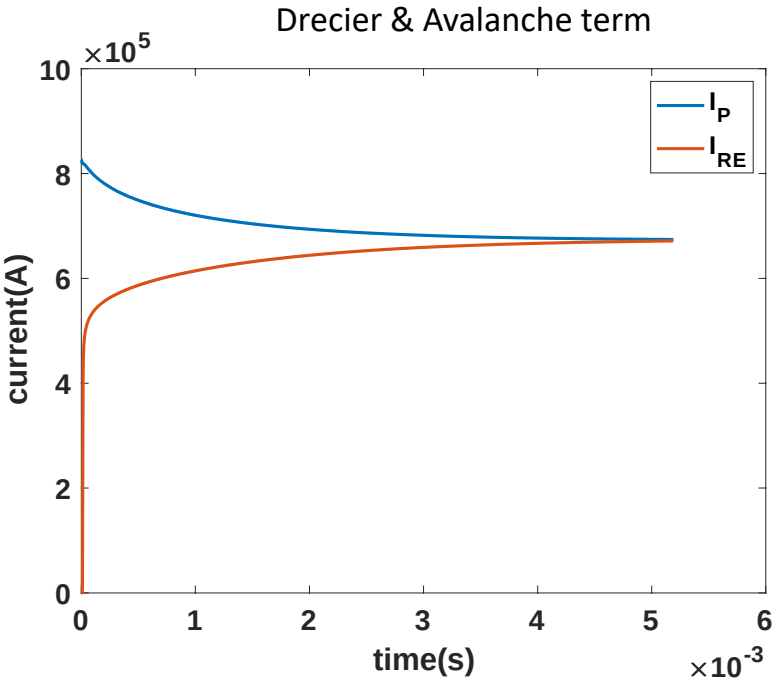
Latest results with Runaways (03/24/21) (Chen)





Effect of Avalanche term on DIII-D run



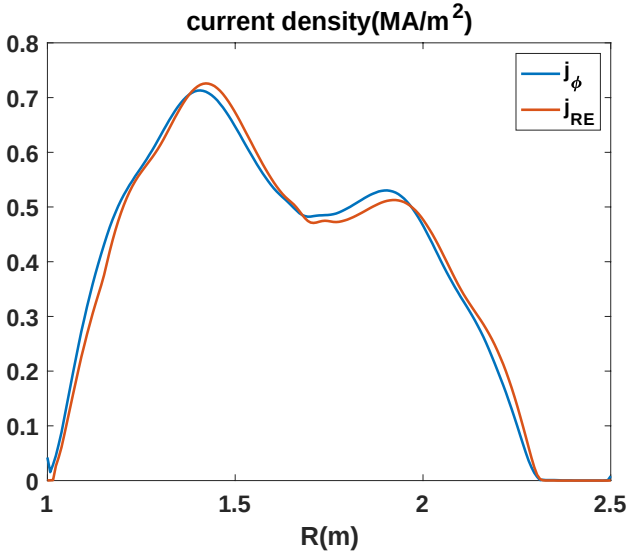


- The Avalanche term become significant after about 1ms.
- The Avalanche term made the runaway current and the plasma current saturate much faster (at 5ms).
- The plasma current became constant a little higher with Avalanche than without.

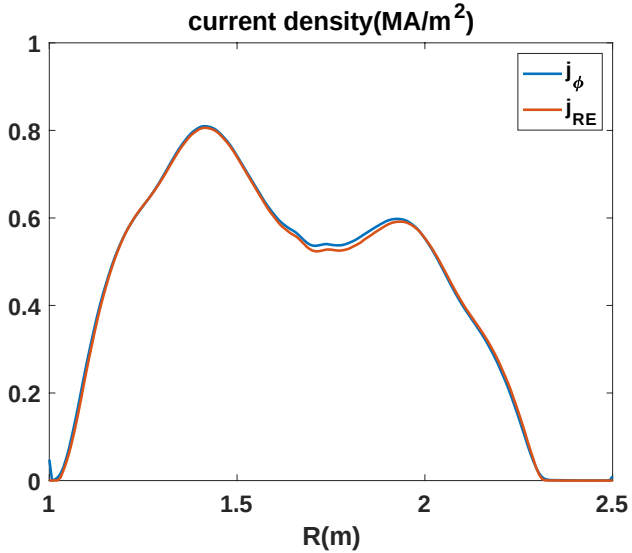
Chen Zhao

Final radial profile of current density

Only Drecier term



Drecier & Avalanche term



- The plasma current was closer to runaway current density profile with Avalanche than without

Chen Zhao

Next Steps

- Can we compare in more detail with DIII-D shot
- What thermal quench time is necessary to produce runaways?
- Can we combine with Ar injection modeling?
- NIMROD is interested in doing a RE benchmark with sources

Update on JET SPI Numerical Instabilities

by

Brendan C. Lyons

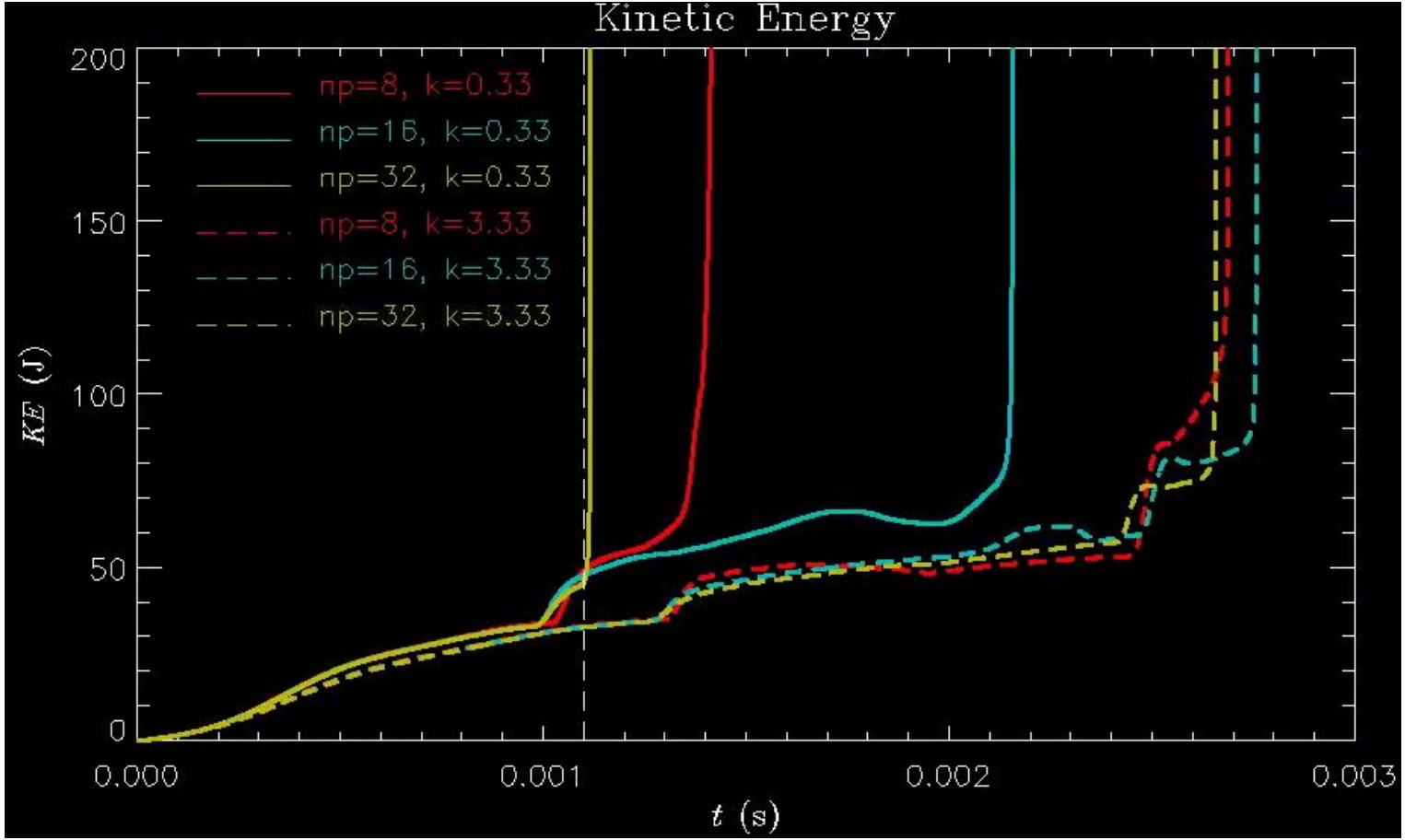
Email

March 15th, 2021

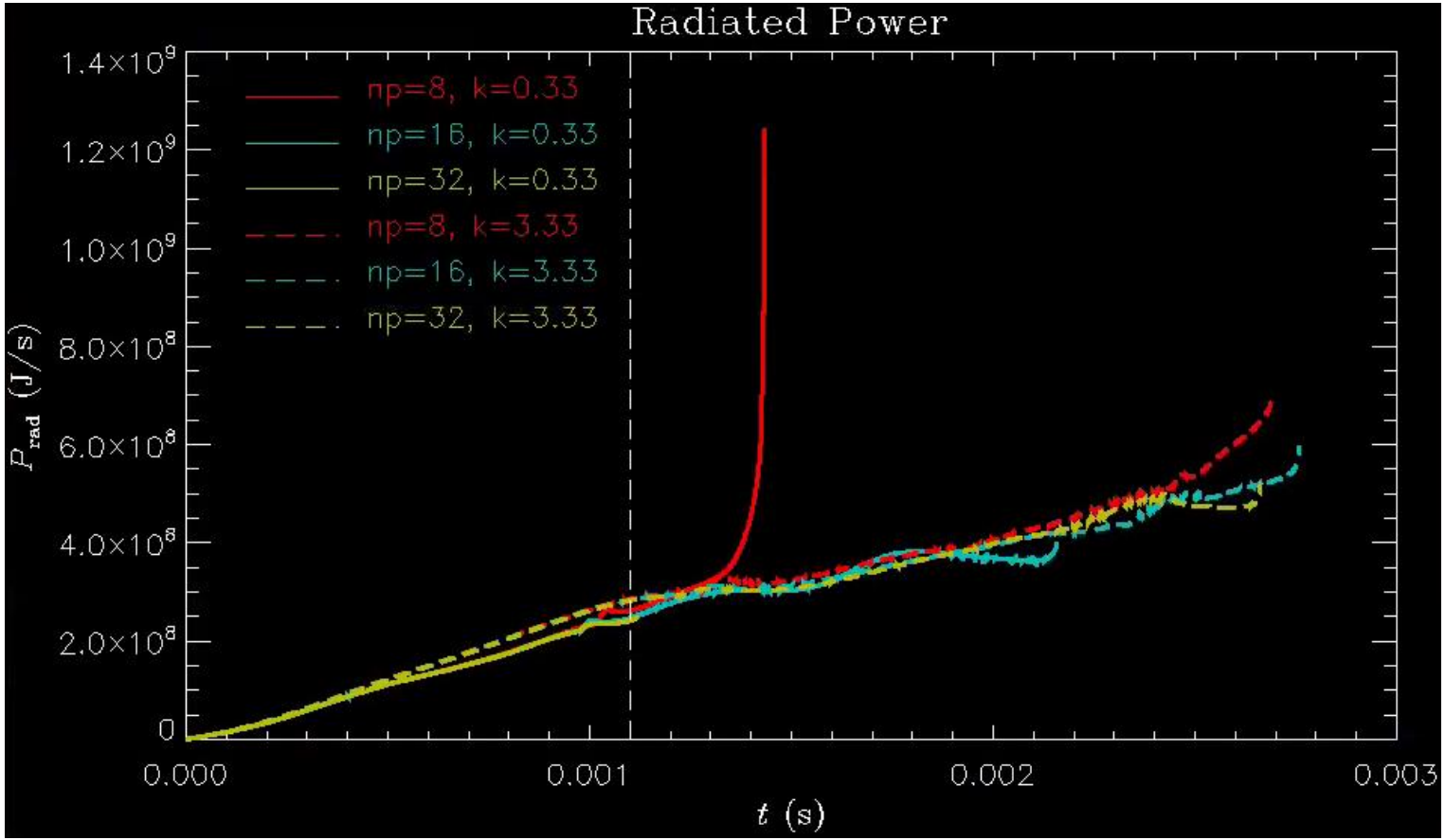
JET SPI explored along two axes: toroidal planes and kappat

- All results on cori
- 8 planes
  - $\kappa_{\perp}$=0.33 m^2/s: `/global/cscratch1/sd/blyons/C1_39717` (Originally on eddy)
  - $K_{\parallel}$=3.33 m^2/s: `/global/cscratch1/sd/blyons/C1_38642664`
- 16 planes
  - $\kappa_{\perp}$=0.33 m^2/s: `/global/cscratch1/sd/blyons/C1_39188541`
  - $K_{\parallel}$=3.33 m^2/s: `/global/cscratch1/sd/blyons/C1_39304141`
- 32 planes
  - $\kappa_{\perp}$=0.33 m^2/s: `/global/cscratch1/sd/blyons/C1_39879975`
  - $K_{\parallel}$=3.33 m^2/s: `/global/cscratch1/sd/blyons/C1_40554797`

Kinetic Energy For All Runs



Radiated Power For All Runs

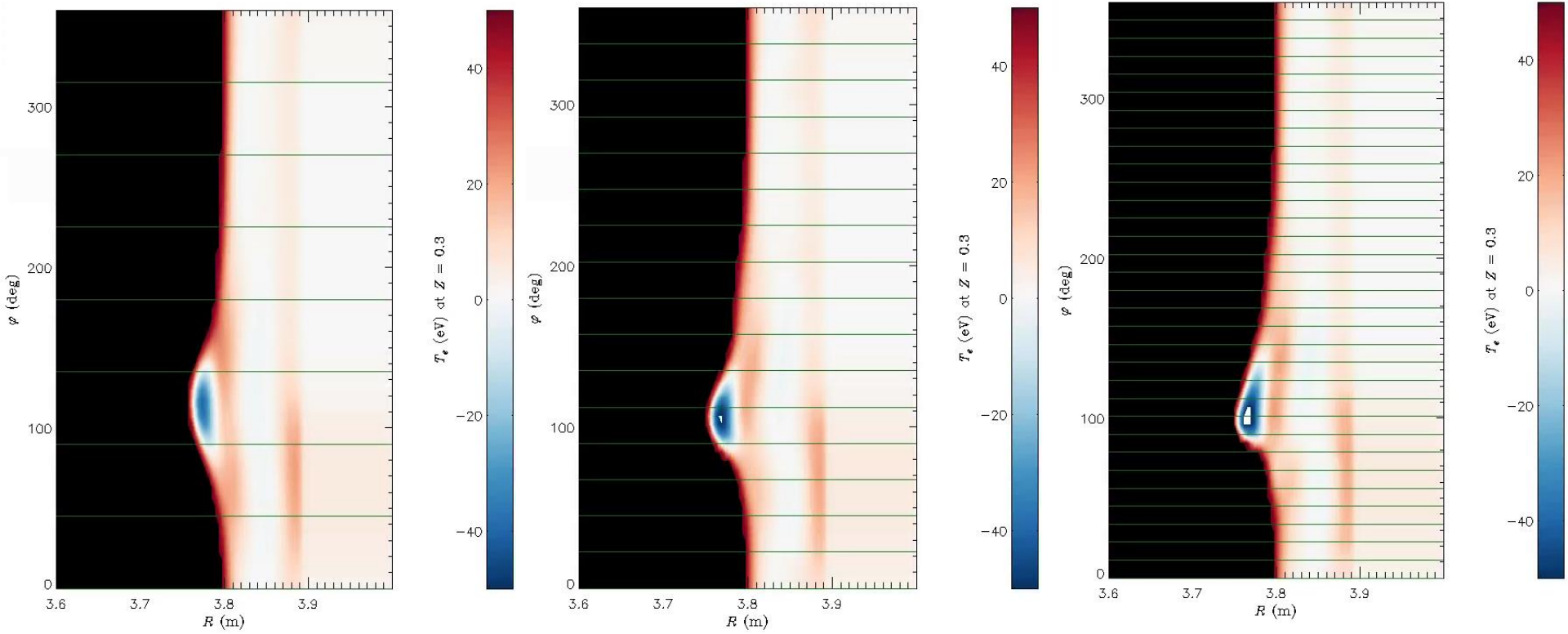


Electron Temperature at Outboard Midplane at 1.1 ms

8 planes

16 planes

32 planes



Conclusions

- Increasing $\kappa_{||}$ moves the problem from q=3 to the q=2 surface
- Toroidal resolution does not seem to help
  - 16 “better” than 8 “better” than 32
  - Probably just got luck that 16 planes survives longer
  - Negative region does not look like FE overshoot to me
- Possible but costly solution: crank down time step near instability
- Question: Why do these negative regions develop?

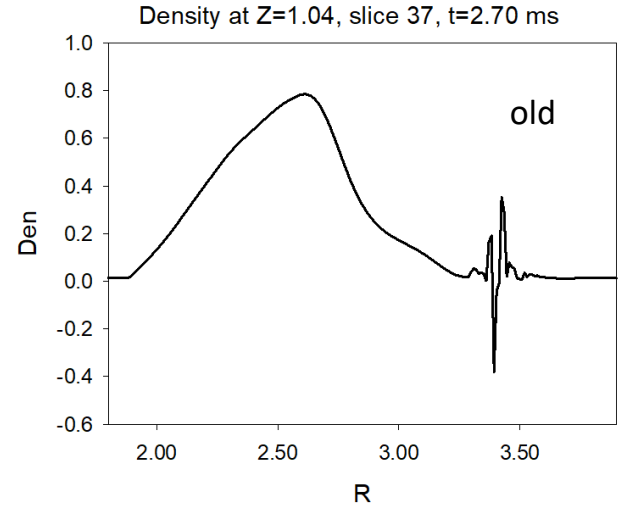
Summary … 3/23/21 (SCJ)

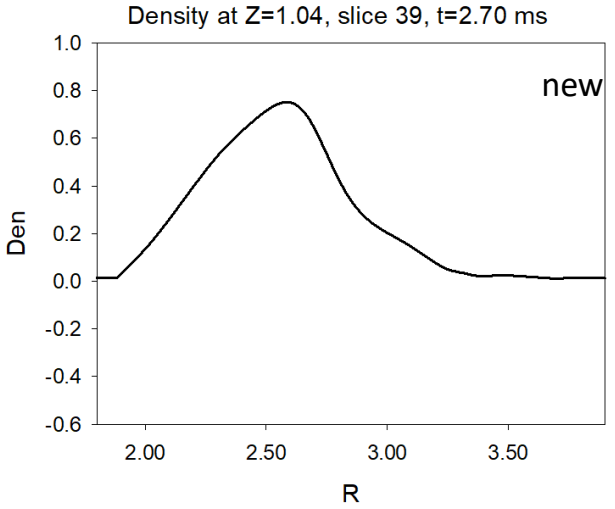
I restarted the 8 plane run C1_38642662 at slice 26 with the following changes.

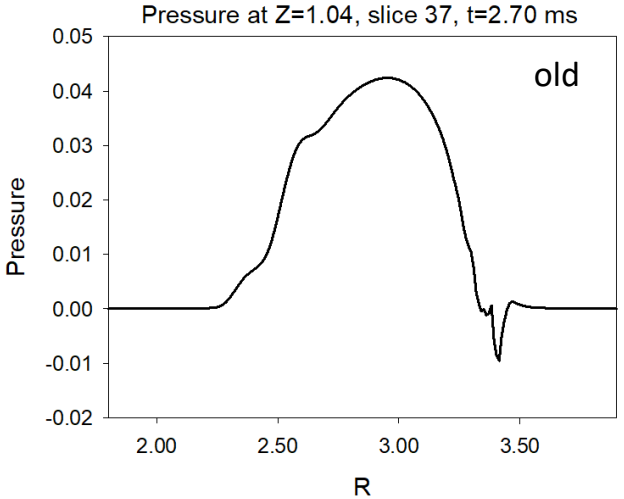
iupstream = 1
magus - .05
amuc = .01
denm = 6.48361e-05 (increased by 10)
dt varied between 0.5 and 2.0

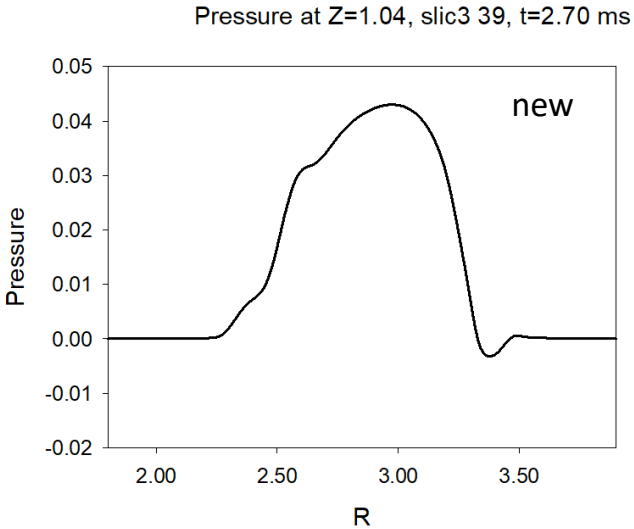
Next two pages compare old and new run

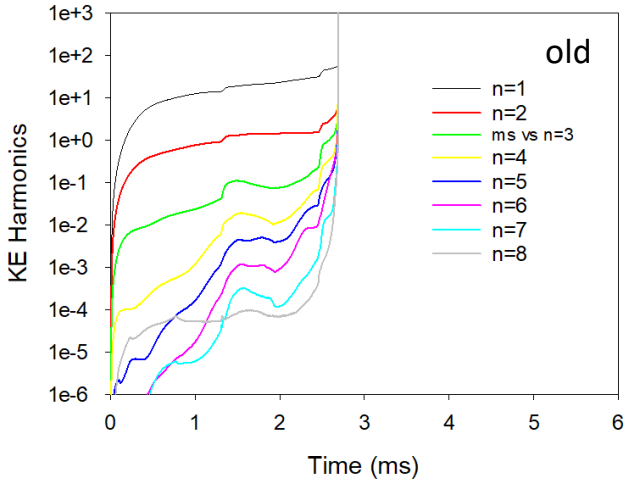
The new run is still running on stellar in /scratch/gpfs/sjardin/Brendan

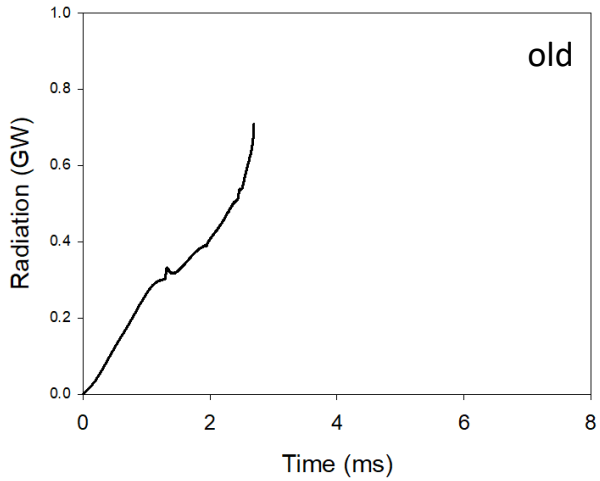

Density at Z=1.04, slice 37, t=2.70 ms
old
Den
R
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
2.00
2.50
3.00
3.50

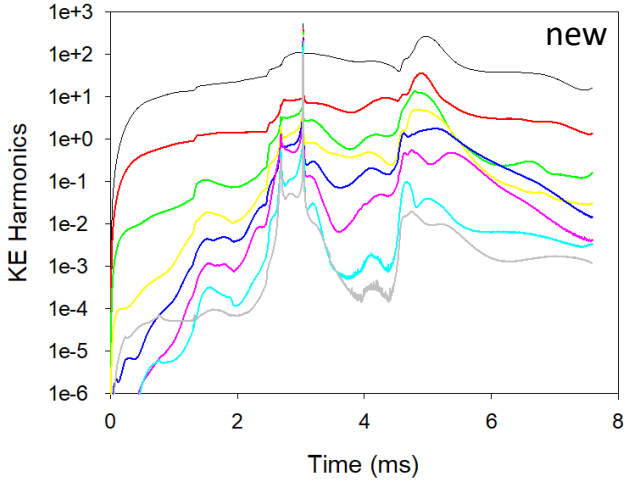

Density at Z=1.04, slice 39, t=2.70 ms
new
Den
R
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
2.00
2.50
3.00
3.50

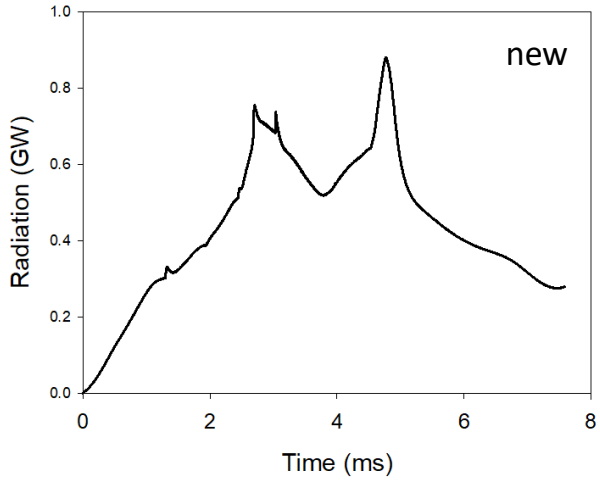

Pressure at Z=1.04, slice 37, t=2.70 ms
old
Pressure
R
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
2.00
2.50
3.00
3.50


Pressure at Z=1.04, slic3 39, t=2.70 ms
new
Pressure
R
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
2.00
2.50
3.00
3.50


old
KE Harmonics
Time (ms)
n=1
n=2
ms vs n=3
n=4
n=5
n=6
n=7
n=8
1e+3
1e+2
1e+1
1e+0
1e-1
1e-2
1e-3
1e-4
1e-5
1e-6
0
1
2
3
4
5
6


old
Radiation (GW)
Time (ms)
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8


new
KE Harmonics
Time (ms)
1e+3
1e+2
1e+1
1e+0
1e-1
1e-2
1e-3
1e-4
1e-5
1e-6
0
2
4
6
8

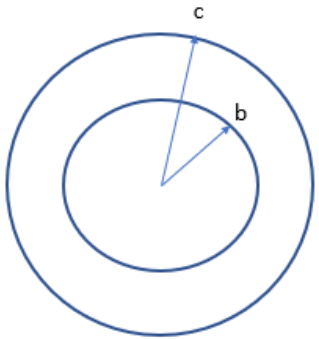

new
Radiation (GW)
Time (ms)
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8

That’s All I have

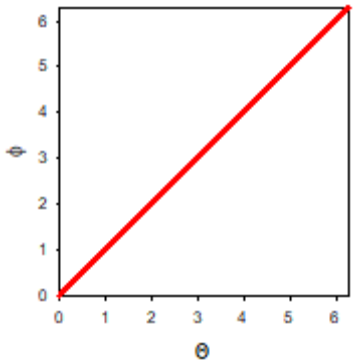
Anything Else ?

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?

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

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

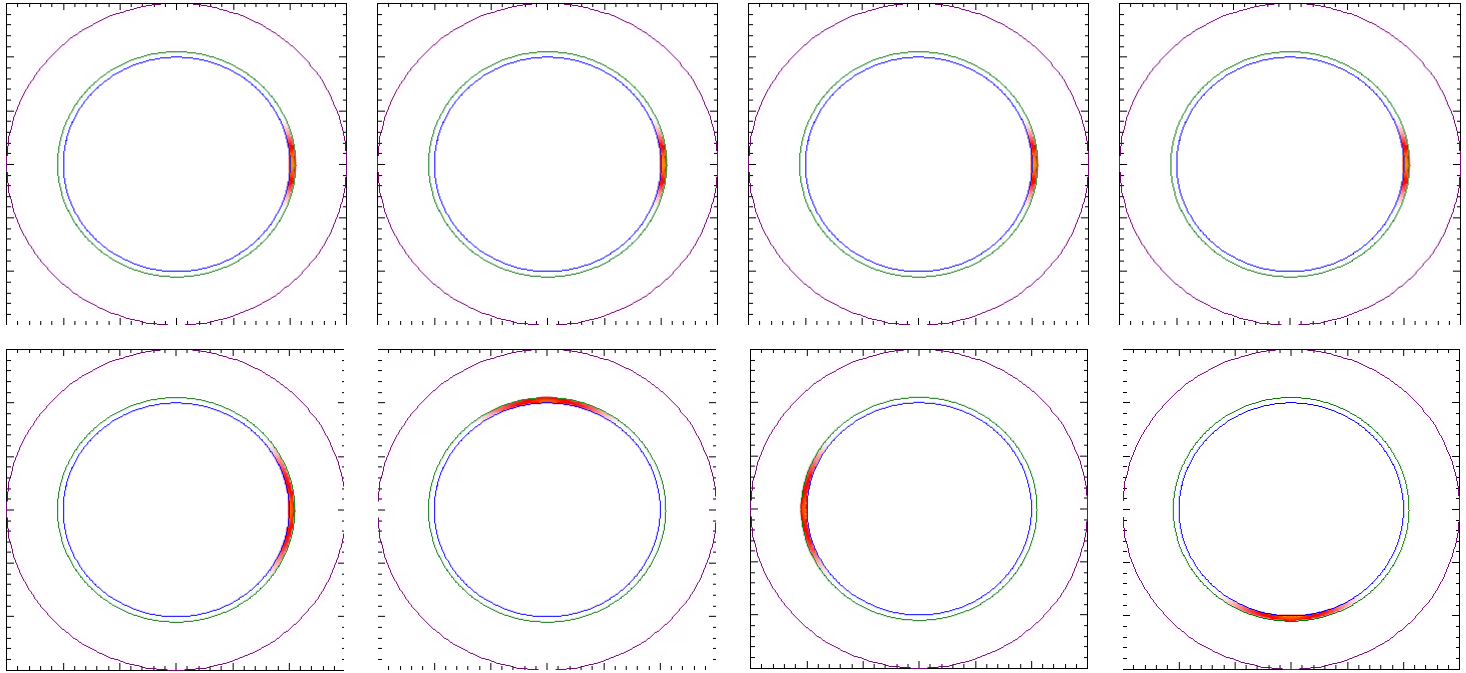
What is driving the current in the θ direction? It can't be Φ unless

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

Comparison between Straight and helical band

Straight ➔

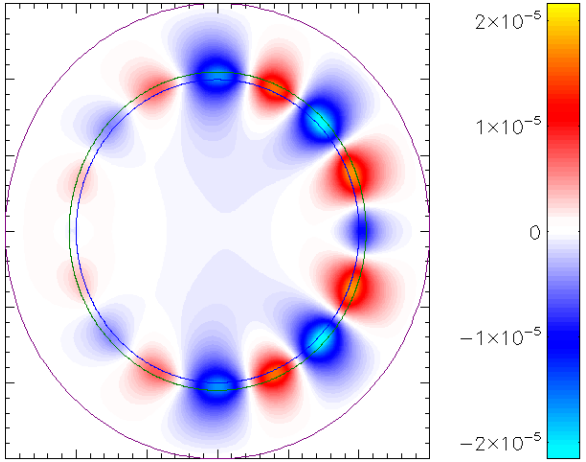
Helical ➔



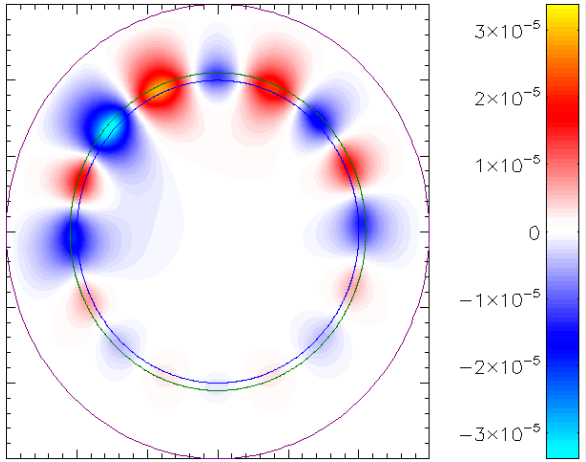
$\varphi = 0$ $\varphi = \pi / 2$ $\varphi = \pi$ $\varphi = 3\pi / 2$

Φ_φ

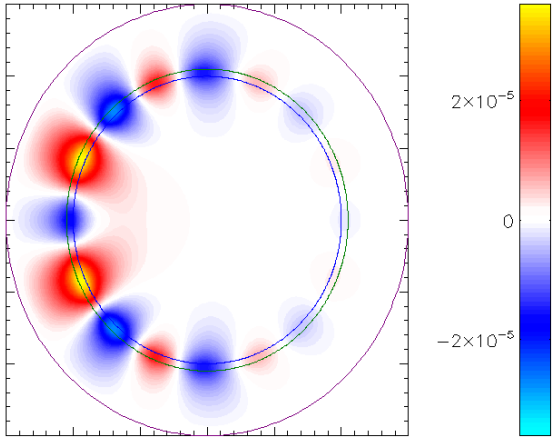
φ = 000°



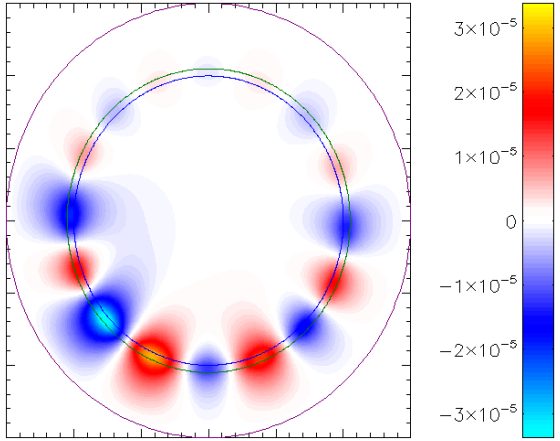
φ = 090°



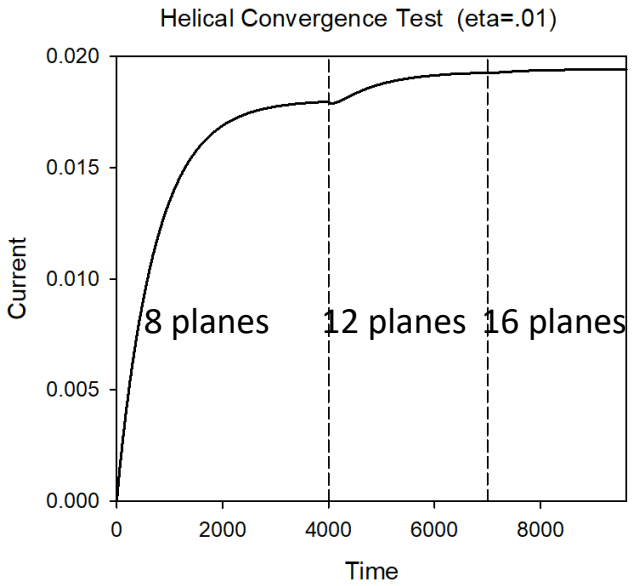
φ = 180°

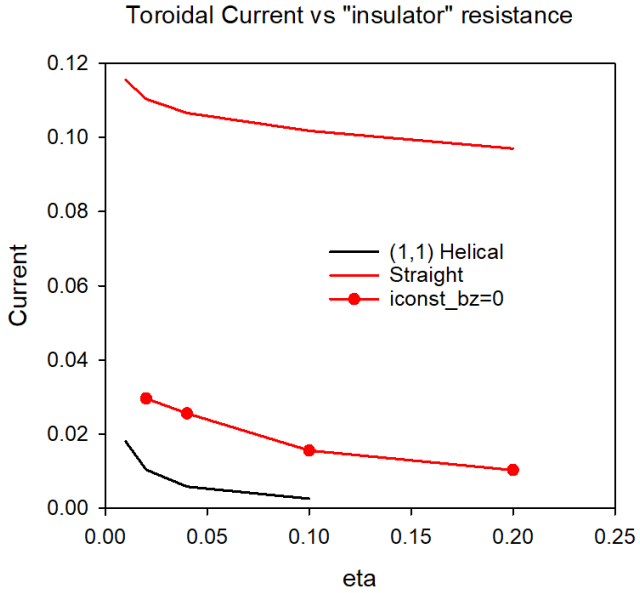


φ = 270°



Some Convergence Tests

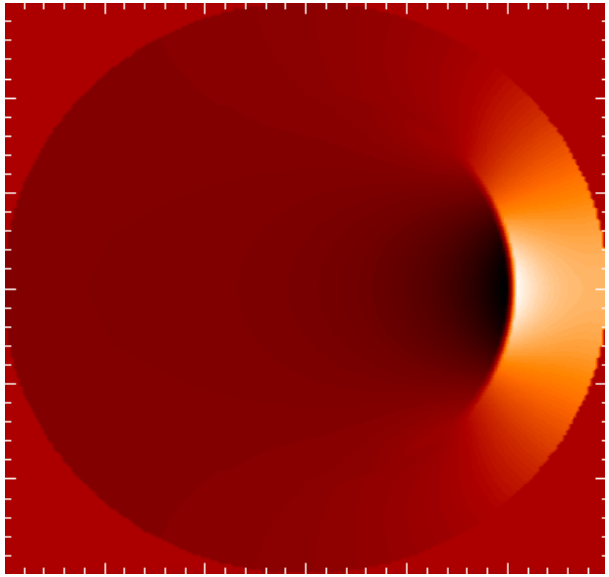




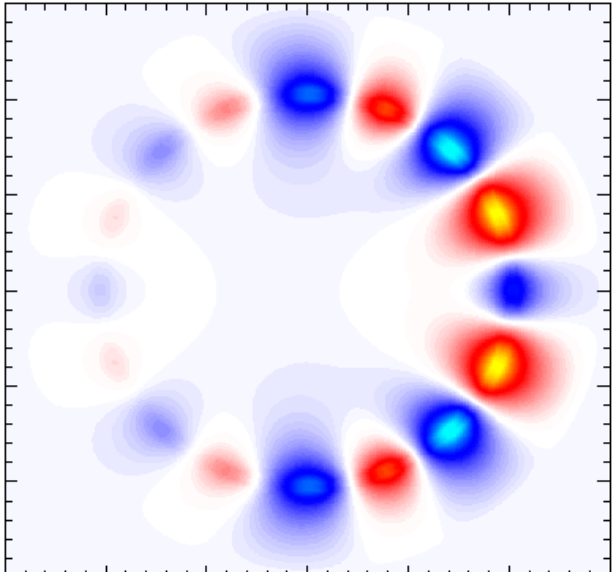
- Wall current appears to be converged in # of planes
- Helical wall current tending towards zero for large values of insulator resistance
- Now testing dependence on boundary conditions (location of ideal wall)
- Helical (1,2) case gives less than half the current of helical (1,1) case
- Iconst_bz=0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

Plots for iconst_bz=0

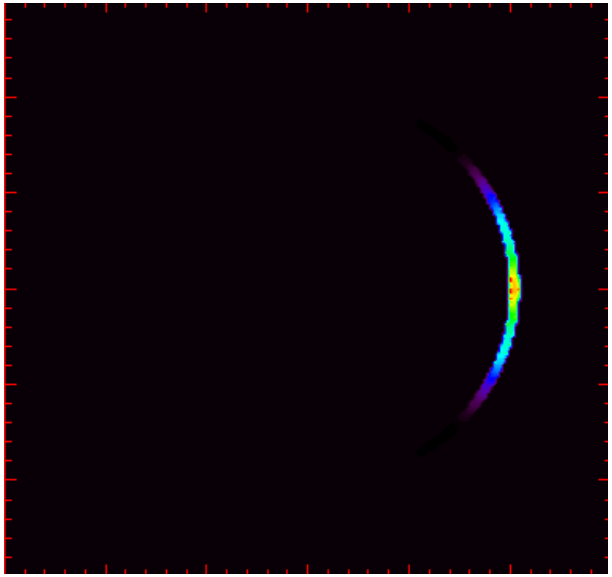
I



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



J_{φ}



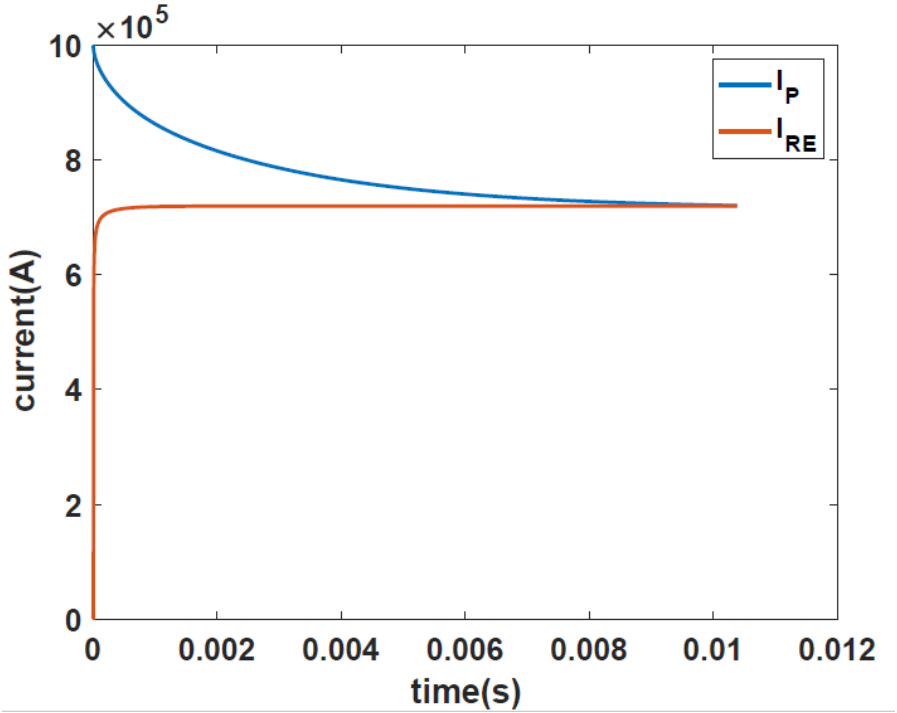
$$\nabla_{\perp} \bullet \frac{1}{R^2} \nabla \Phi = \nabla_{\perp} \cdot \eta \left[-\frac{1}{R^2} \nabla F \times \nabla \varphi - \frac{1}{R^2} \nabla f'' \times \nabla \varphi - \frac{1}{R^4} \nabla_{\perp} \psi' \right]$$

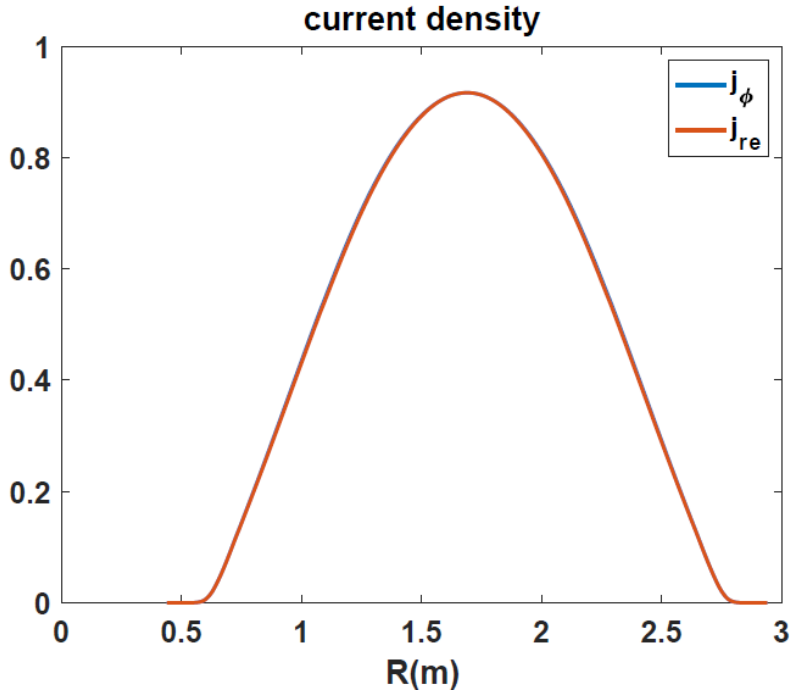
Local Systems

- 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

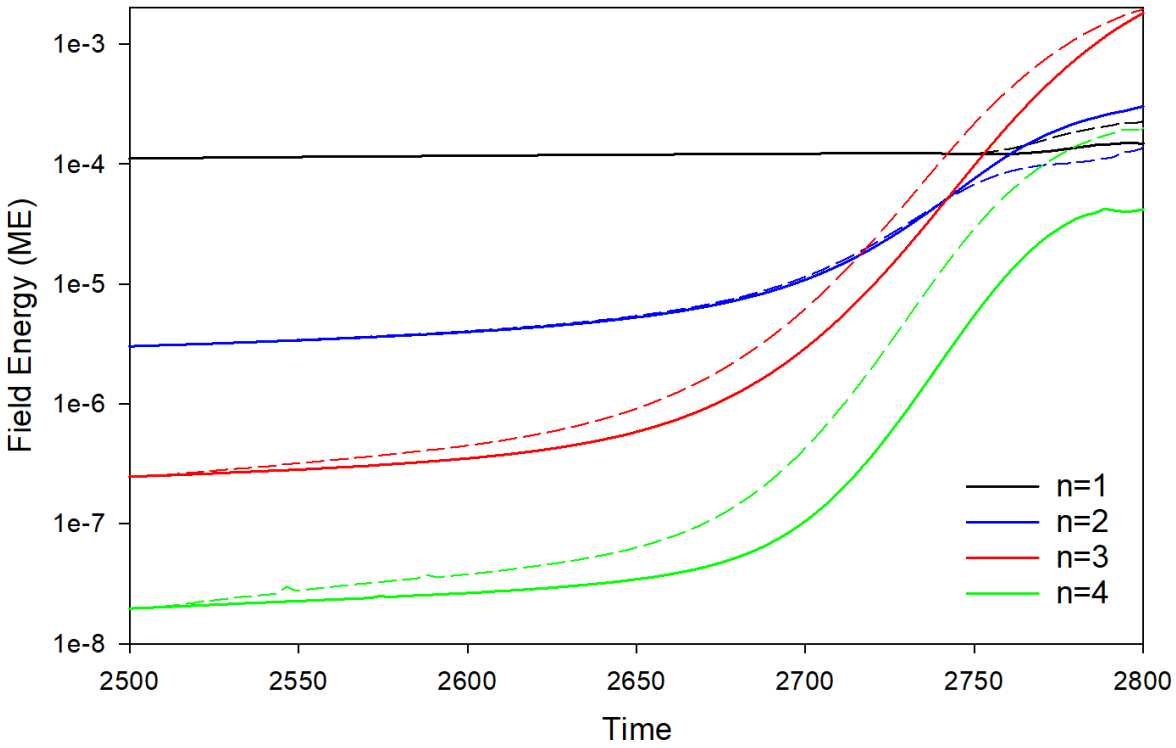
2D (cylindrical) RE with sources (12/19/2020)



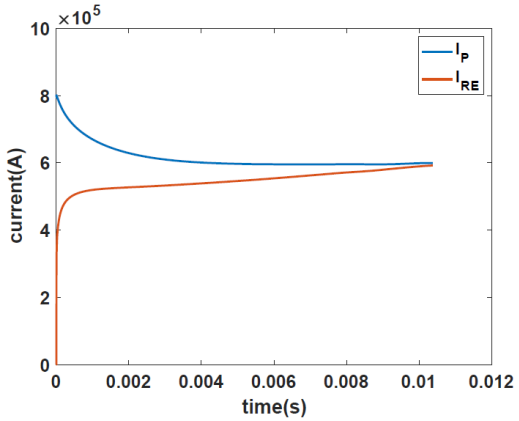


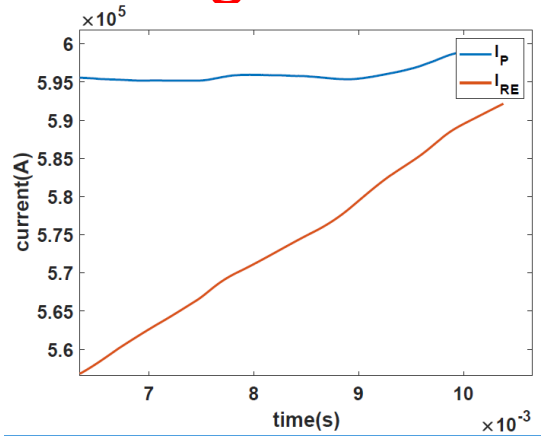
Chen Zhao

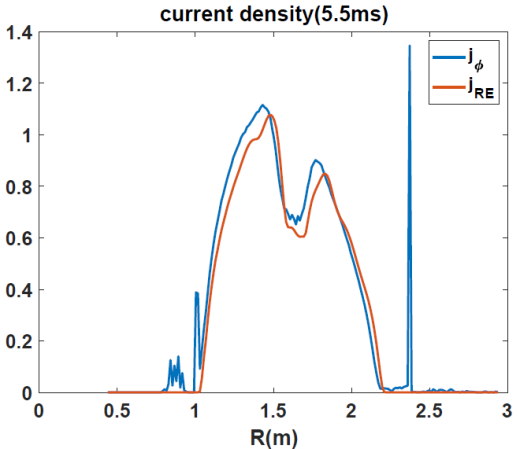
Energy in base case 36742317 (solid) and 16 plane case 37248033 (dashed)

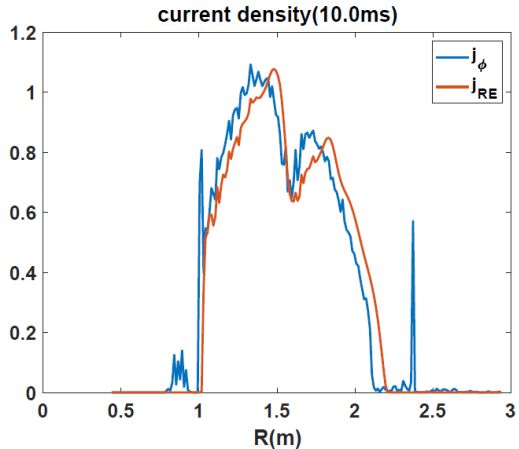


DIII-D 177053 with Argon





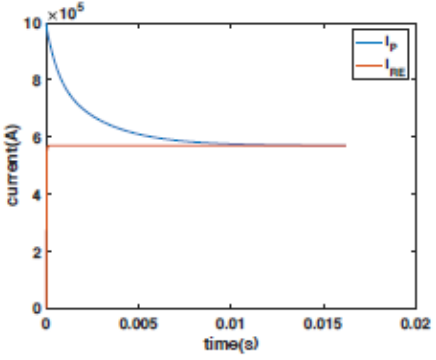


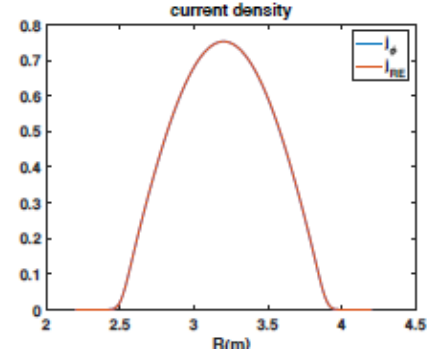


Chen Zhao

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?

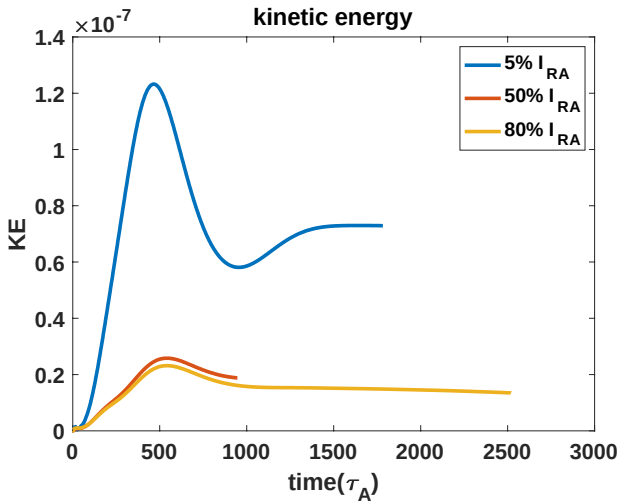
- M3D-C1/NIMROD 3D Benchmark

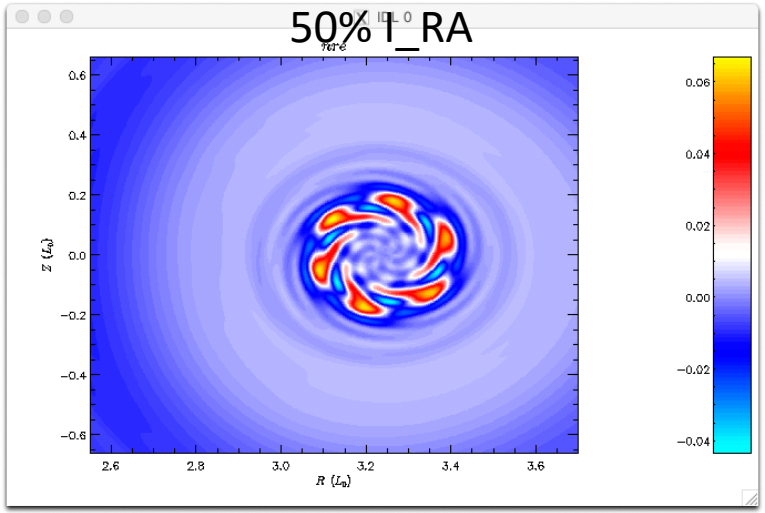
NSTX shot 1224020 – Fast ion transport with coupled kink and tearing modes
Chang Liu

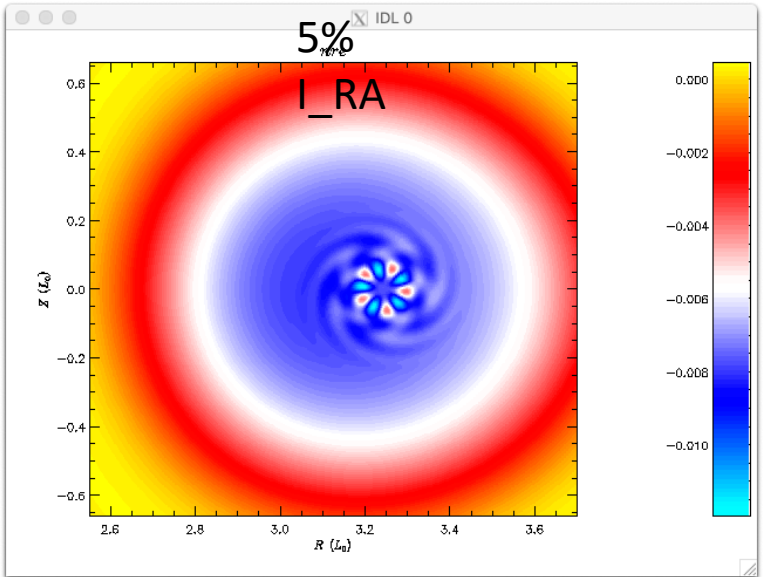
DIII-D Neon pellet mitigation simulation for KORC

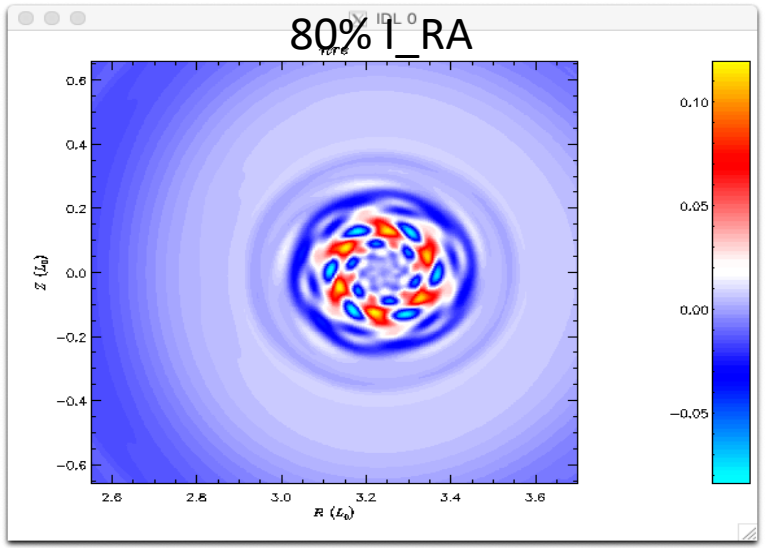
- Brendan Lyons trying to extend 8 plane case to 32 planes

SPARK ? Do we need to do anything?


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

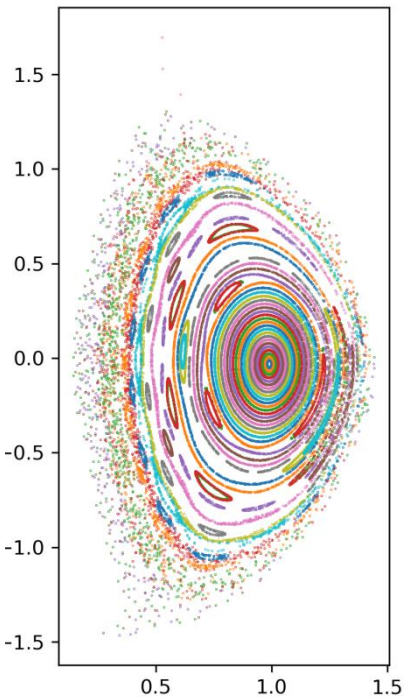

50% I_RA
IDL 0
Z (L_0)
R (L_0)


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

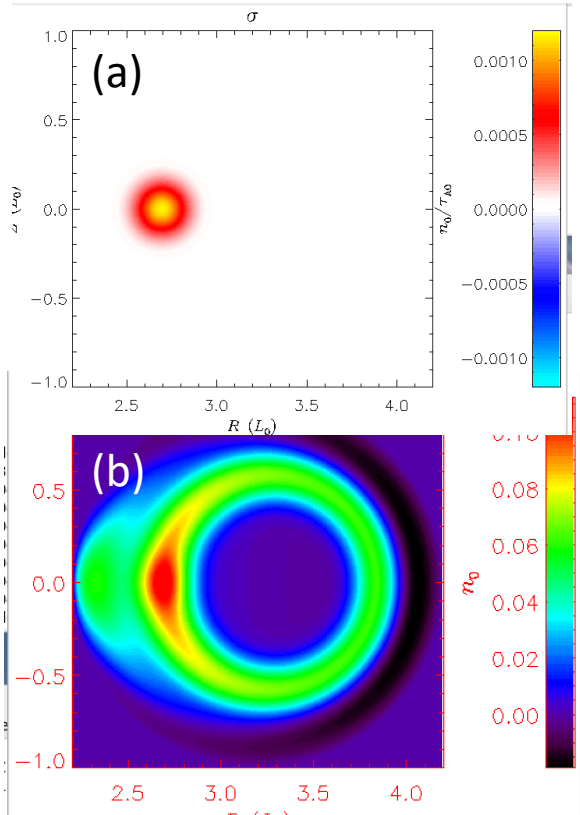
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

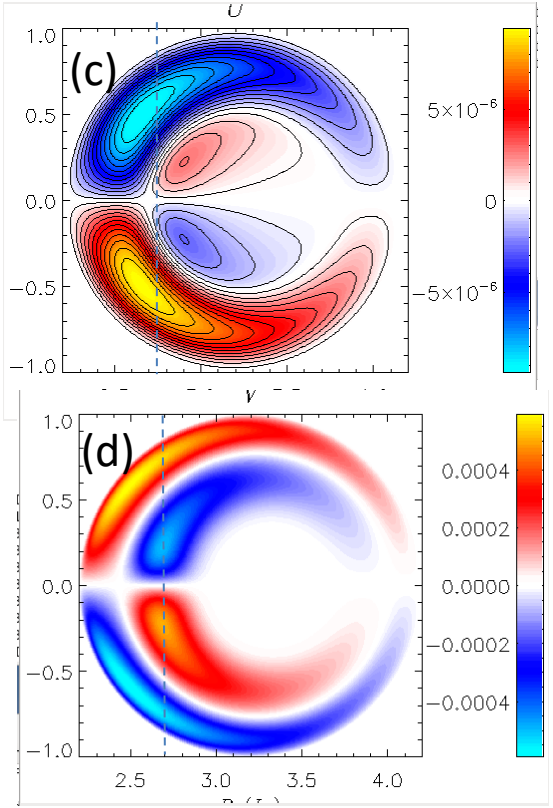
(a) Density source in 1F toroidal equilibrium

(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

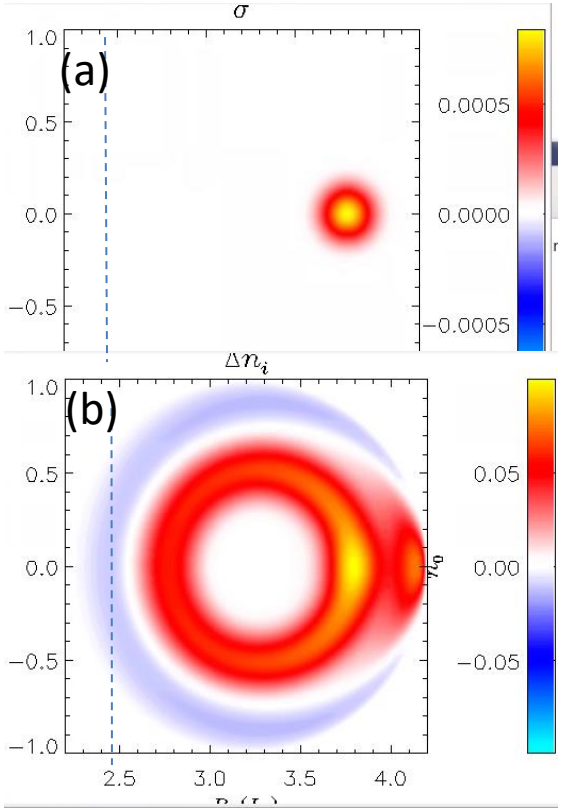
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

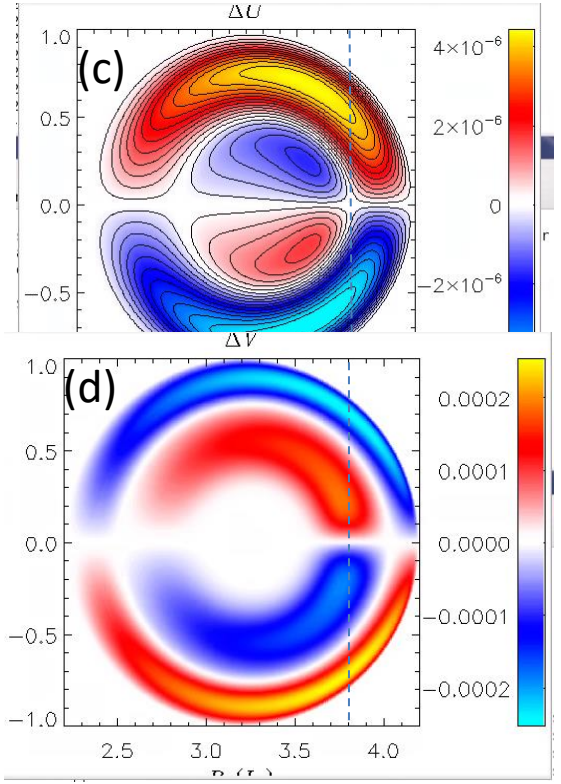
(a) Density source in 1F toroidal equilibrium

(b) Change in density after 10^3 τ_A

(c) Poloidal velocity stream function

(d) Toroidal velocity contours





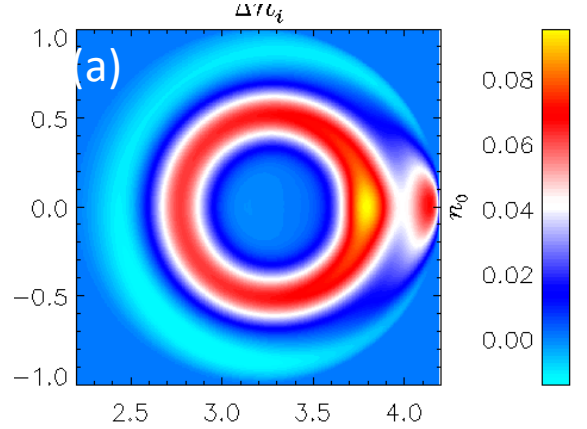
Grad-B drift in M3D-C1—2F effects

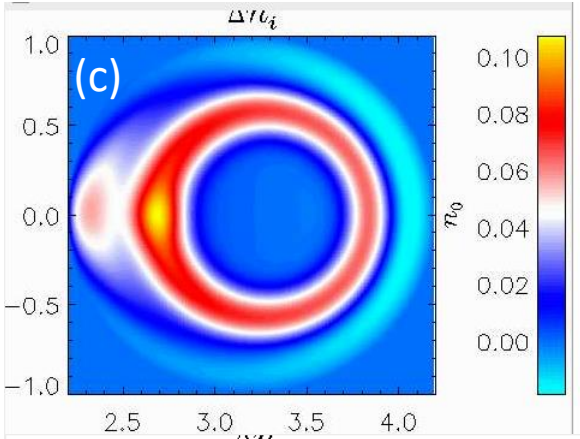
(a) 2F density change after 10^3 τ_A for LF side source

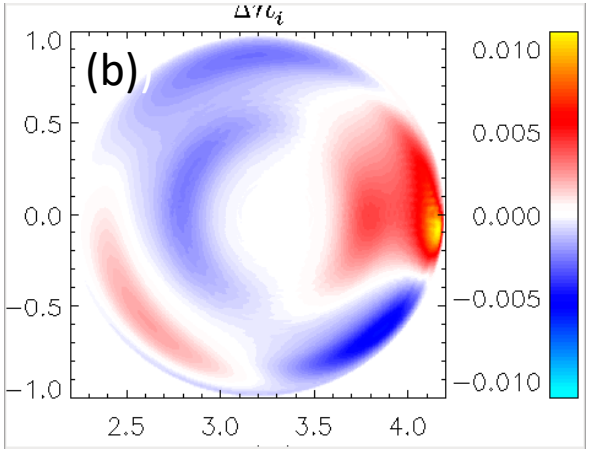
(b) Difference in 1F and 2F density (LF)

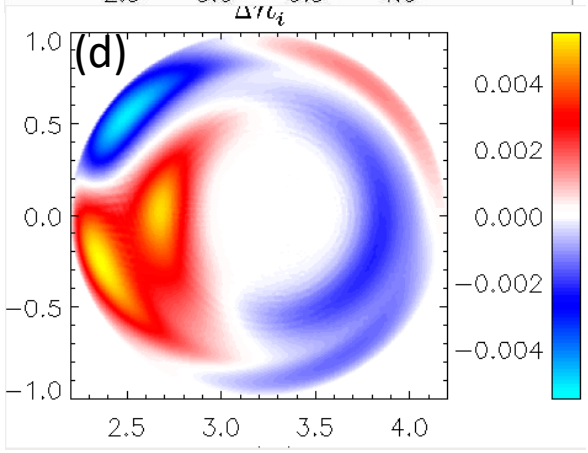
(c) 2Fdensity change after 10^3 τ_A for HF side source

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

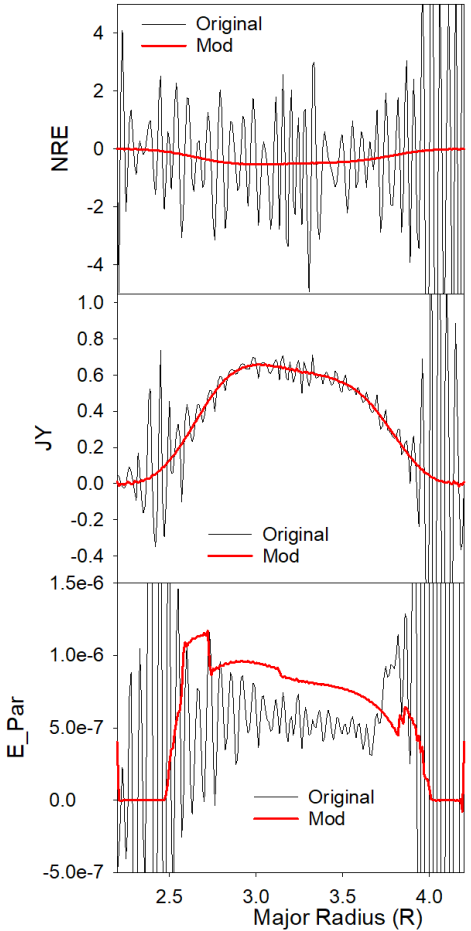








Sawtoothing discharge with runaway electrons

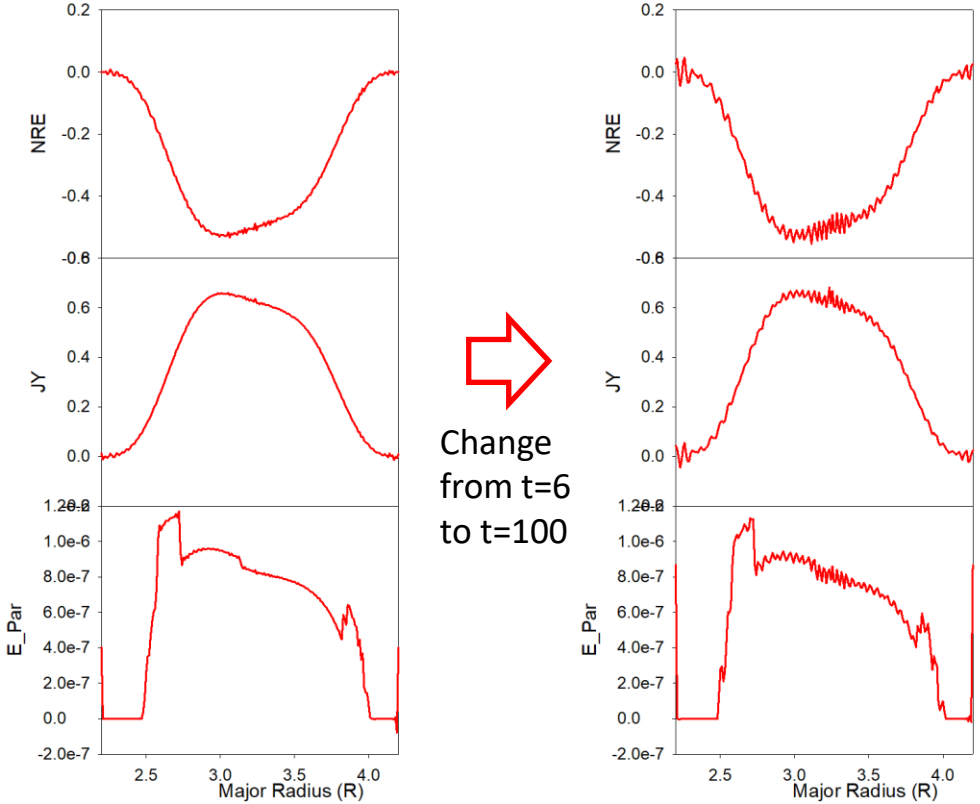


Profiles of nre, jy, and E_par after 30 timesteps

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?