M3D-C1 ZOOM Meeting

04/05/2021

Announcements

CS Issues

1. stellar.princeton.edu status
2. TOMMS and SIMMODELER Usman Riaz
3. More on plot_equation,'gradshafranov' bug
4. NERSC Time
5. Changes to github master since last meeting
6. Regression tests

Physics Studies

1. Update on M3D-C1-S   Yao Zhou
2. Quasilinear simulation of Alfven mode excitation by energetic particles: Chang Liu
3. Carbon Mitigation in NSTX-U w shell pellet Clauser/Jardin
4. RE Benchmark plans.. Chen Zhao
5. Update on Jet SPI simulations …Lyons/Jardin
6. Other?

In Attendance

Nate Ferraro
Brendan Lyons
Adelle Wright
Yao Zhou
Chen Zhao
Chang Liu
Usman Riaz
Mark Shephard
Hank Strauss
Seegyoung Seol
Cesar Clauser
Priyanjana Sinha

Announcements

- Chang Liu will give a talk on 14 April to JET T17-13 task force on JET RE beams after D2 injection
    - Simulation of interaction between runaway electrons and MHD instabilities using M3D-C1
- IAEA Papers Due 9 April
    - "Vessel forces from a vertical displacement event in JET and ITER" (S. Jardin) Strauss, Clauser, Ferraro
    - "Theory and Modelling Activities in Support of the ITER Disrupton Mitigation System" (E. Nardon)   Ferraro, Jardin, Liu, Lyons, Strauss, Samulyak
    - Prototype Tests of the Electromagnetic Particle Injector Concept Demonstrate its Primary Advantages for Fast Time Response Disruption Mitigation in Tokamaks (Raman) Clauser, Jardin
    - A Novel Path to Runaway Electron Mitigation via Deuterium Injection and Current-Driven Kink Instability (Pas-Soldan) Liu, Zhao, Jardin
- Sherwood Meeting ?

GPU Solve status

- Jin Chen on vacation this week.   Meeting with LBL cancelled

Jin Chen

stellar.Princeton.edu

- /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

Lyons: Sherpa_princeton.edu Globus endpoint works for the shared Traverse/Stellar/scratch/gpfs system

Wright: quota increases for both /scratch/gpfs and /projects/M3DC1 can be requested from https://forms_rc.Princeton.edu/quota quick and painless

Jardin: Some of my 2D (real) jobs fail at random cycles. 3D jobs run fine. Anyone else having problems?

Final Configuration: 296 Intel nodes,   100-140 dedicated to PPPL Should be ready by end of April

TOMMS and SimModeler

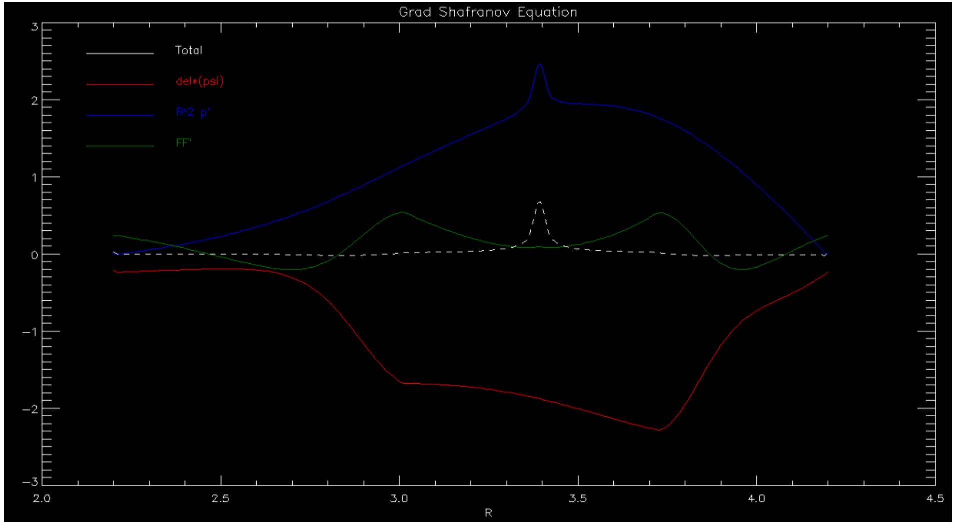
- Usman Riaz

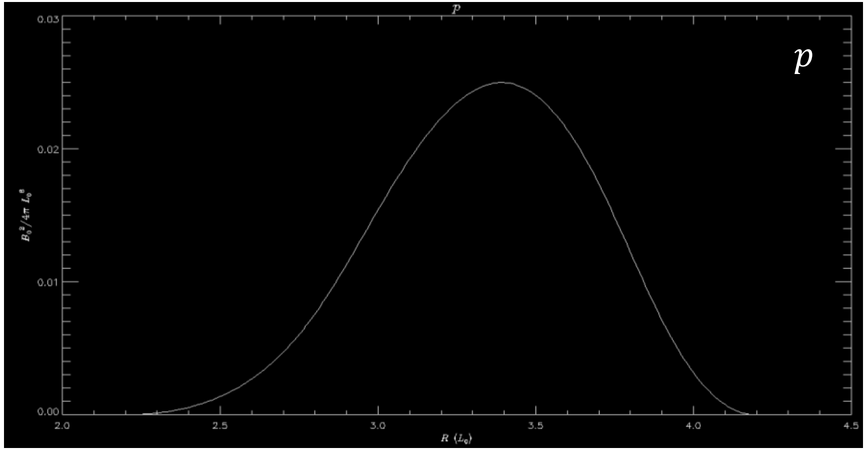
From Adelle Wright:

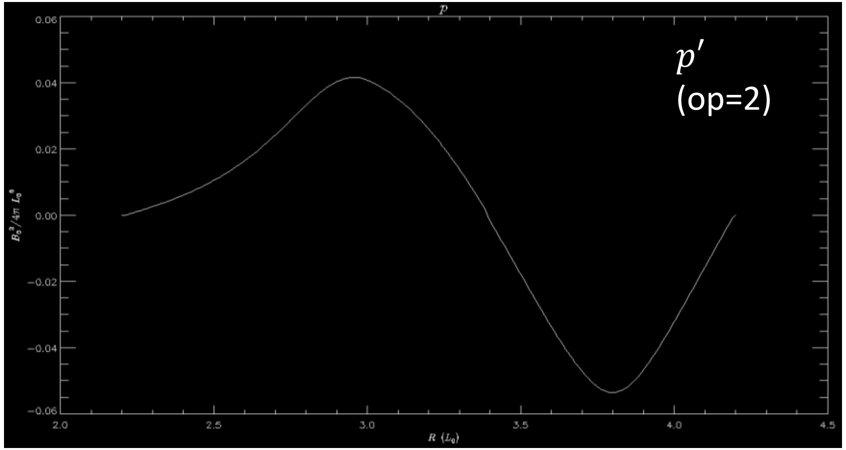
>**plot_equation, ‘gradshafranov’** has large non-zero component at $p' = 0$. Diagnostic issue?

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

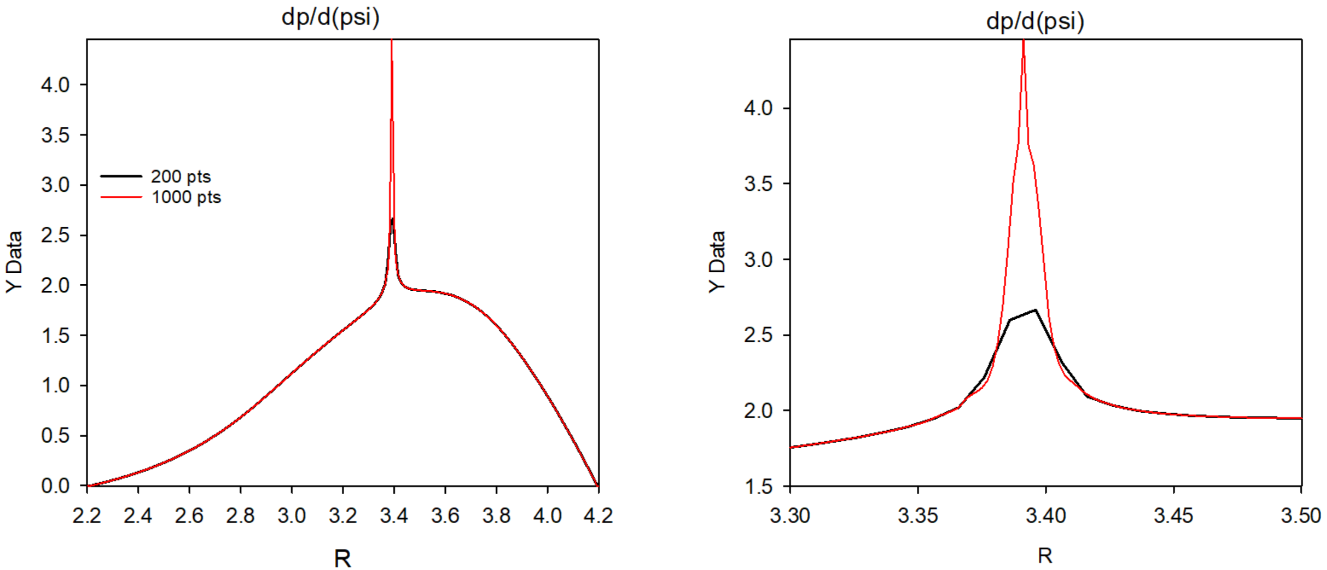
p and p' look well-behaved.





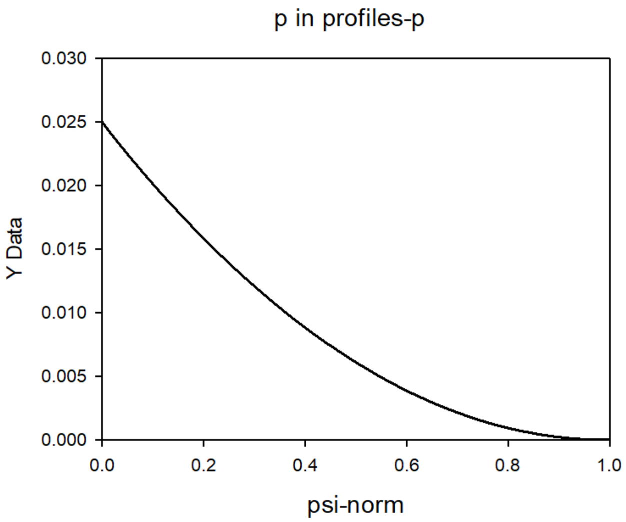


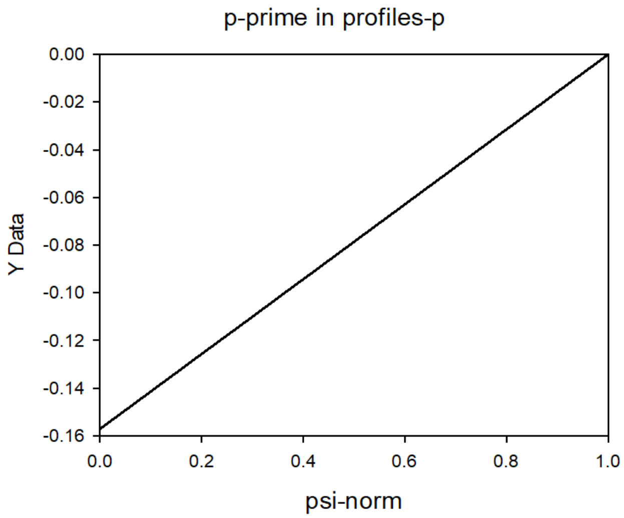
More on plot_equation, 'gradshafranov'



- 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?

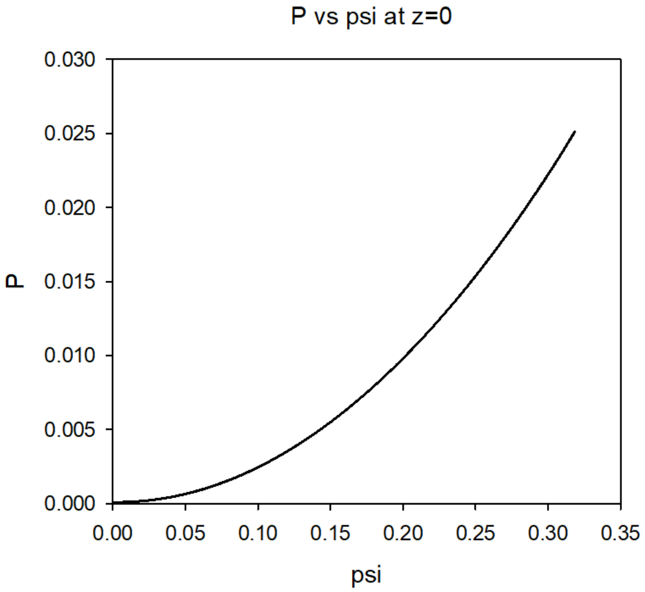
Profiles-p file from qsolver looks fine

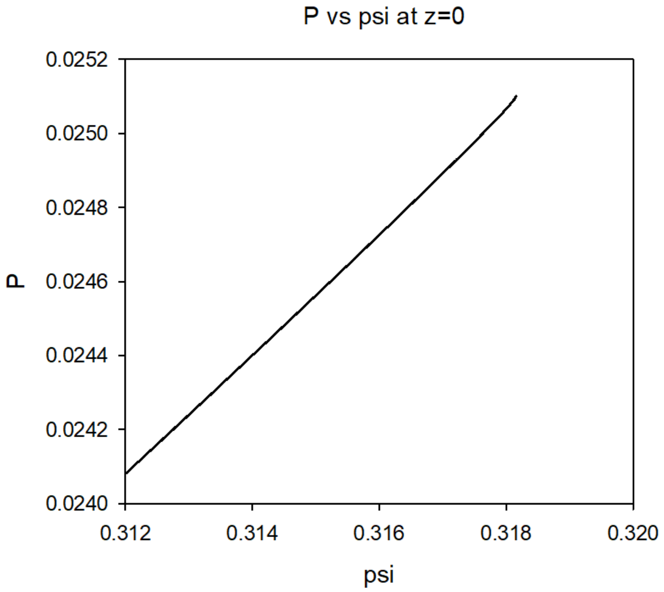




- Look to be smooth at origin (on left)

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?

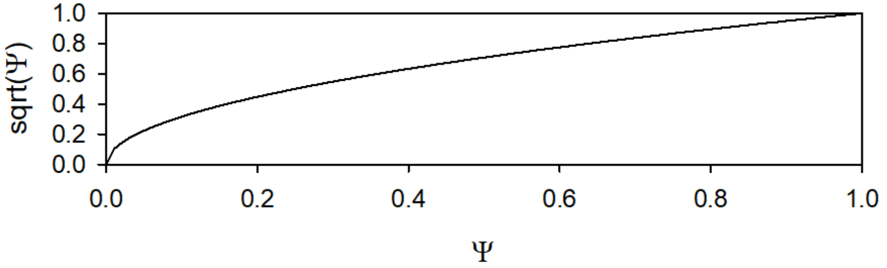
Update 4/5/21

- Problem arises because QSOLVER equilibrium code uses sqrt(Ψ) as a radial coordinate rather than Ψ. It writes a file for p equally spaced in sqrt(Ψ)
- Since Ψ ~ r^2 near the origin, p cannot vary as sqrt(Ψ)

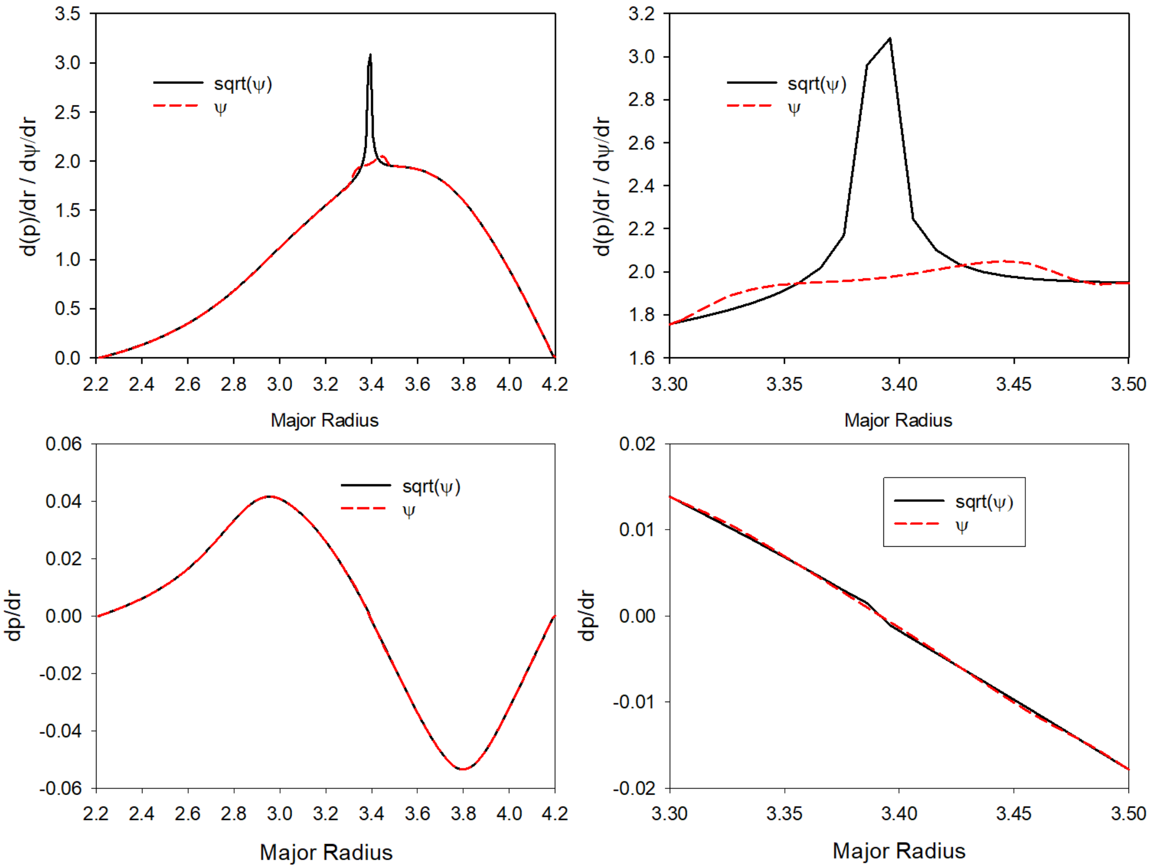
$$p(x,z) = p_0 + p_x x + p_z z + \tfrac{1}{2} p_{xx} x^2 + \tfrac{1}{2} p_{zz} z^2 + \ldots$$

- However, m3dc1 reads in p with sqrtΨ) spacing, and constructs a spline based on sqrt(Ψ) rather than Ψ. This introduces a small error near origin

- To test this, I constructed a p(Ψ) file equally spaced in Ψ by interpolation



Comparison of GS solution for p: equally spaced in Ψ vs sqrt(Ψ)



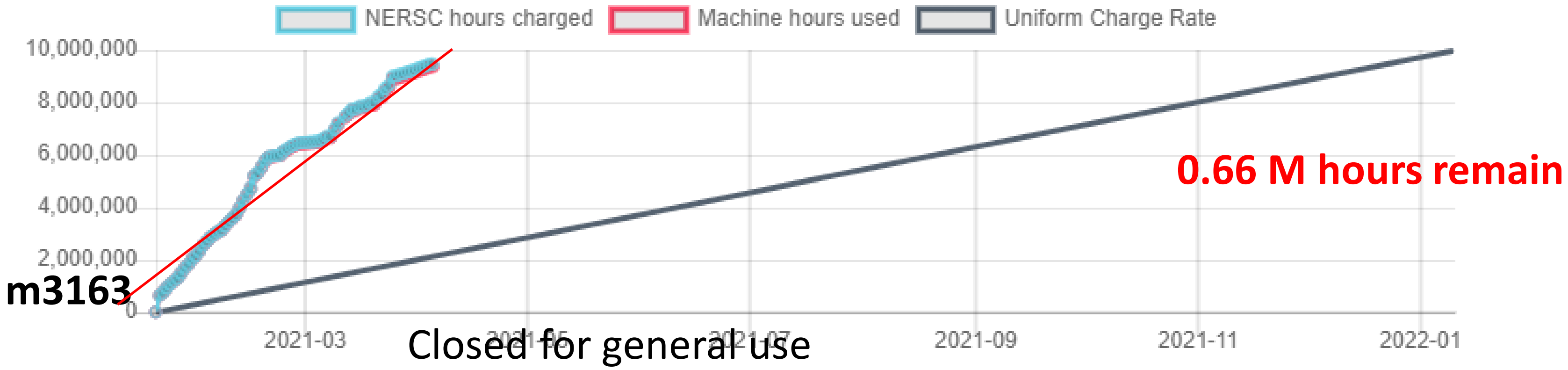
IDL: $$\frac{dp}{d\Psi} = \frac{dp}{dr} / \frac{d\Psi}{dr}$$

But, near the origin, neither p nor Ψ should have a linear dependence on r

dp/dr looks fine

NERSC Time

mp288



- 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 !

No changes since 3/28

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)
  - ??

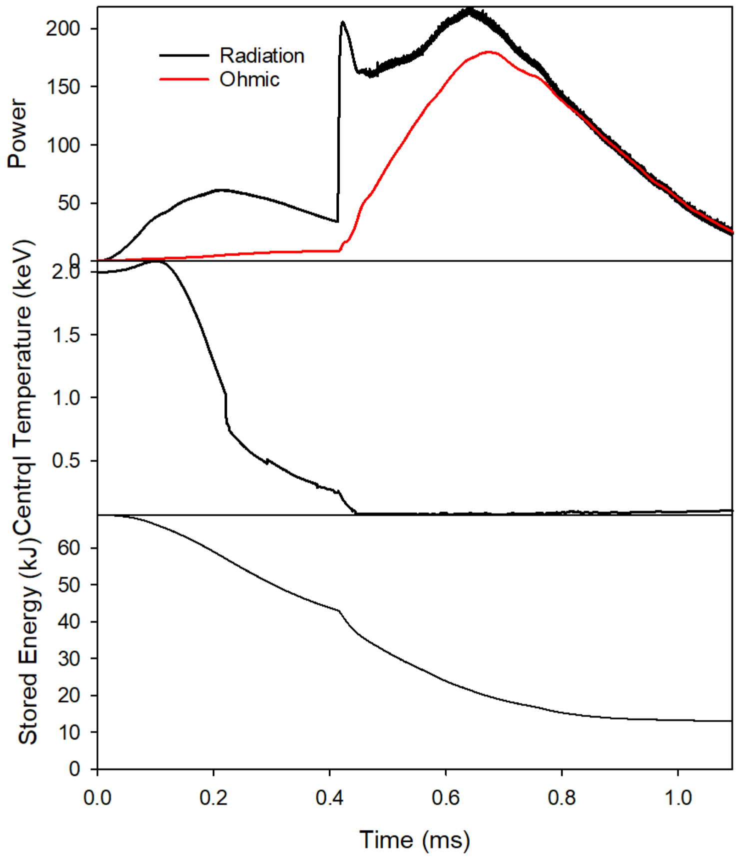
Update on M3D-C1-S

- Yao

Quasilinear simulation of Alfven mode excitation by energetic particles:

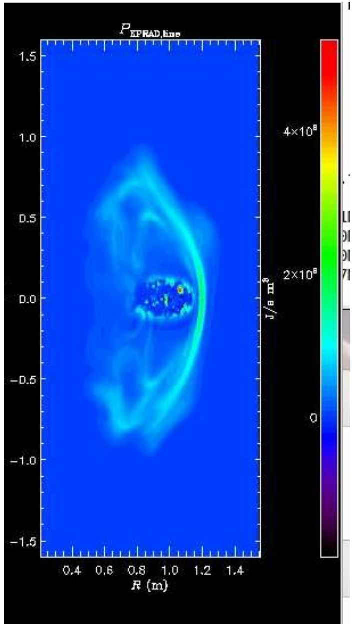
- Chang Liu

Carbon Mitigation in NSTX-U (shell pellet)



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 → 0.14 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

V. BANDARU *et al.* PHYSICAL REVIEW E **99**, 063317 (2019)

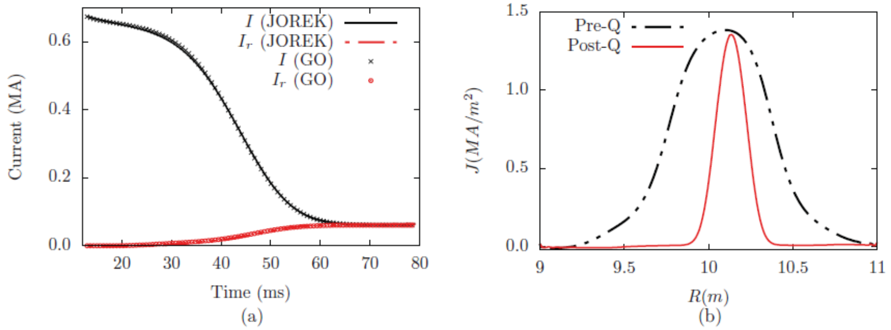
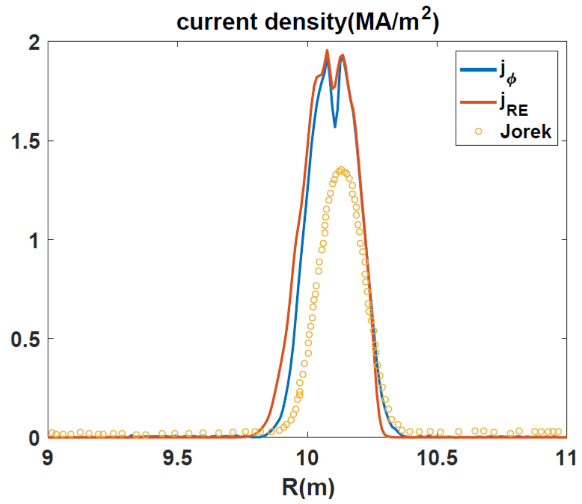


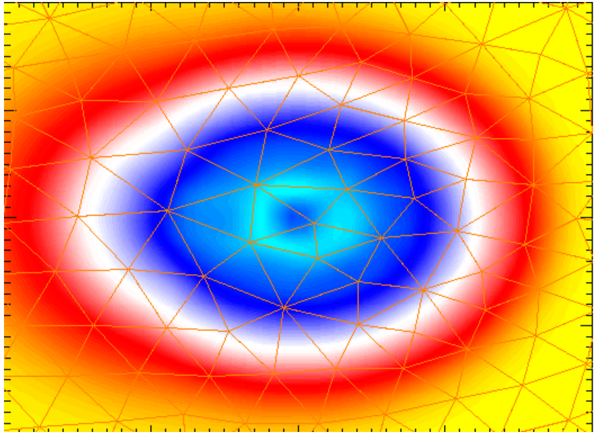
FIG. 3. (a) Time evolution of the total plasma current I and the RE current I_r during the current quench phase. (b) Midplane current density profiles before and after the current quench obtained from JOREK, showing a relatively peaked RE current profile.

Chen Zhao

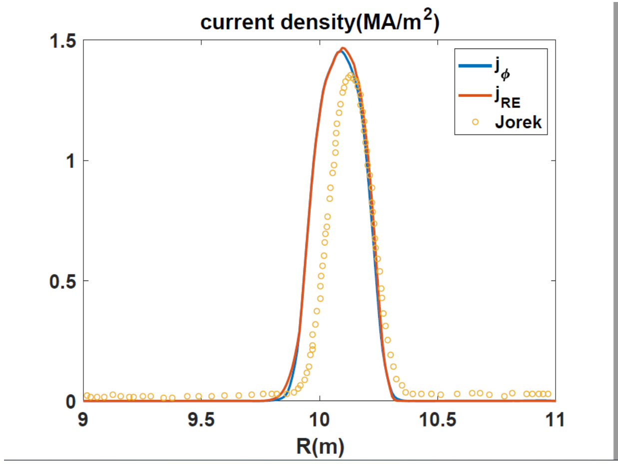
JOREK benchmark improved with finer grid

March 15

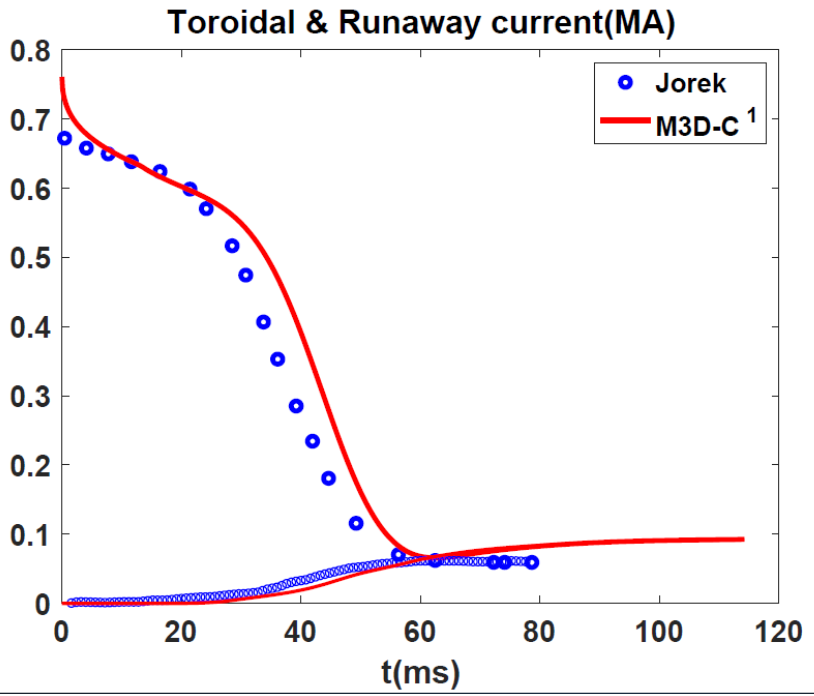


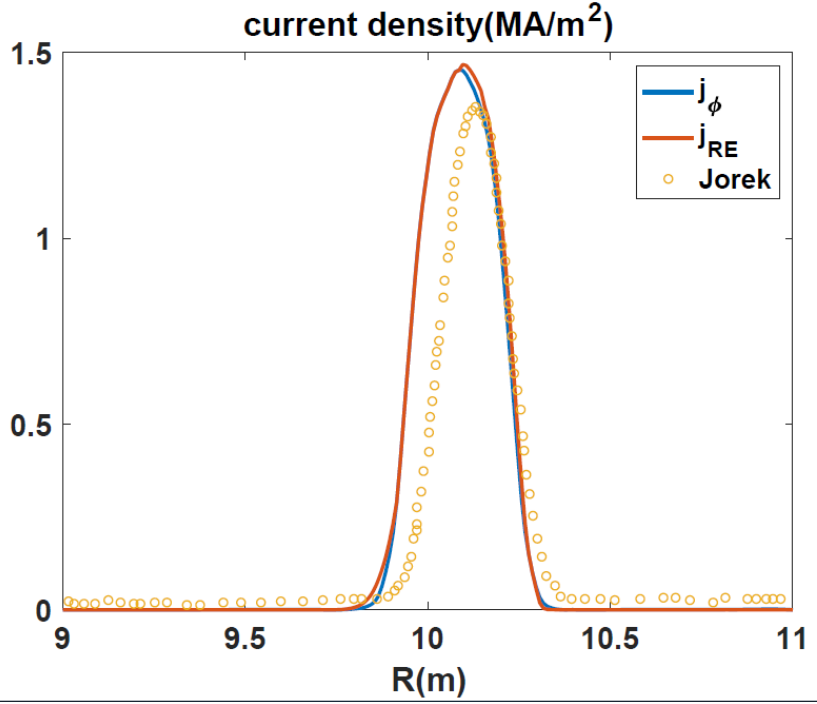


March 24

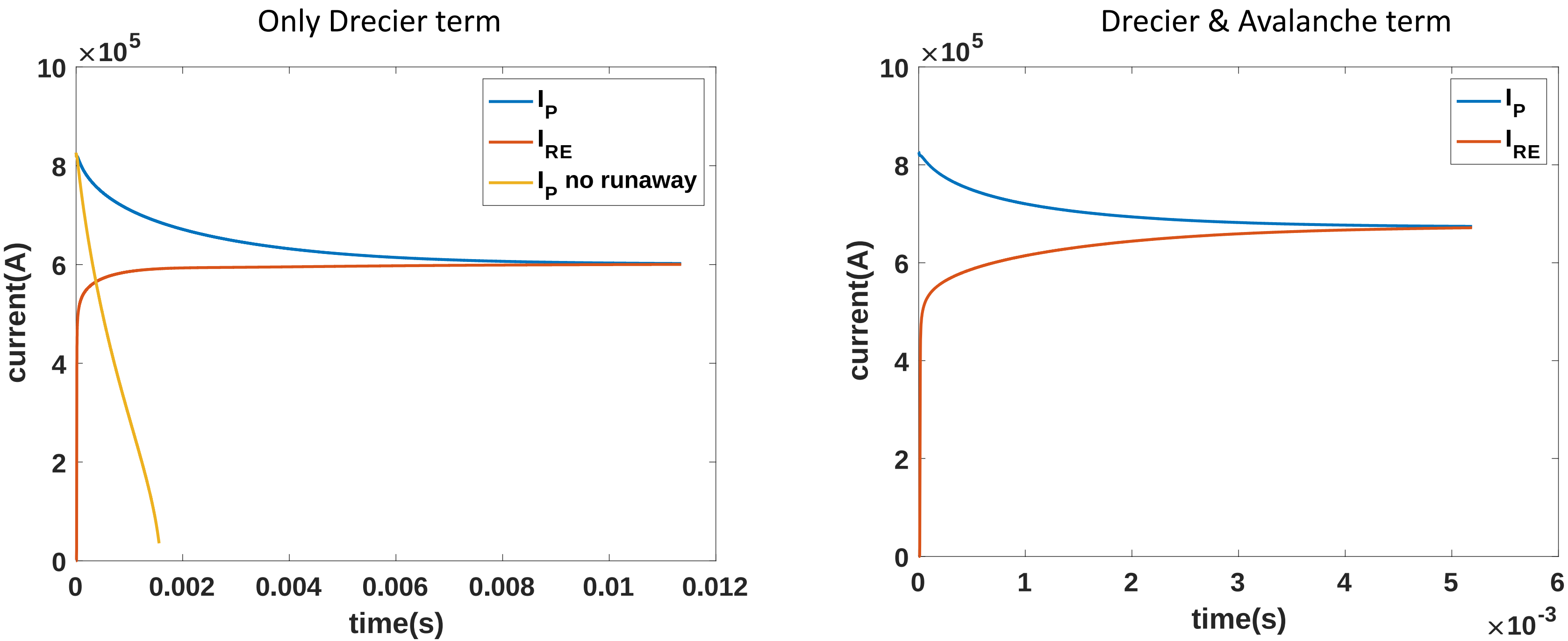


Latest results with Runaways (03/24/21) (Chen)





Effect of Avalanche term on DIII-D run

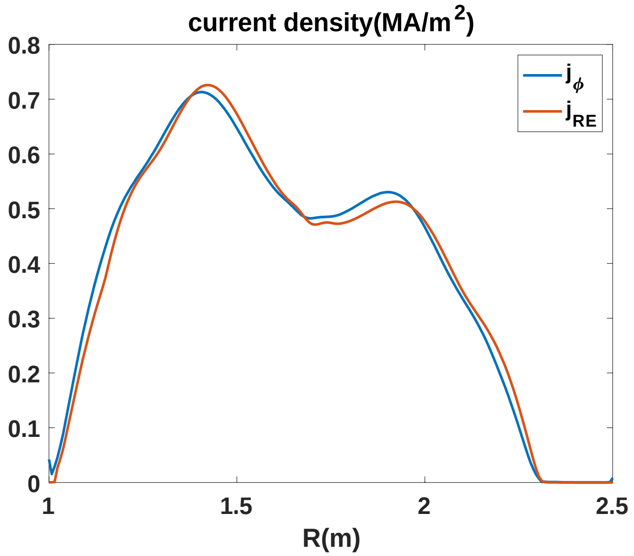


- The Avalanche term become significant after about 1ms.
- The Avalanche term made the runaway current and the plasma current saturate much faster (at 5ms).
- The plasma current became constant a little higher with Avalanche than without.

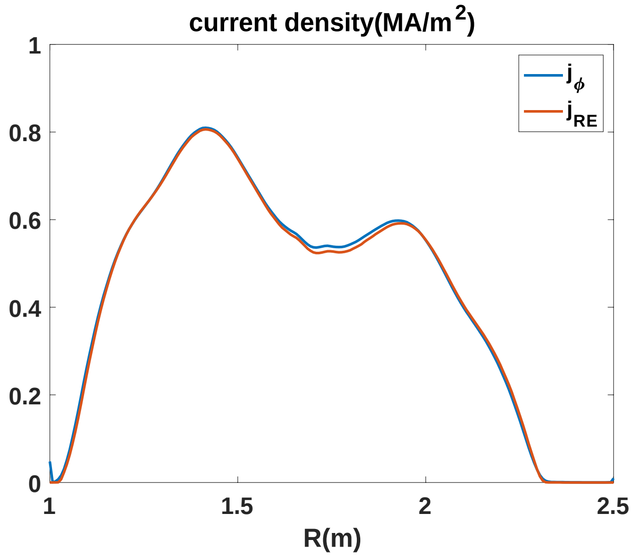
Chen Zhao

Final radial profile of current density

Only Drecier term



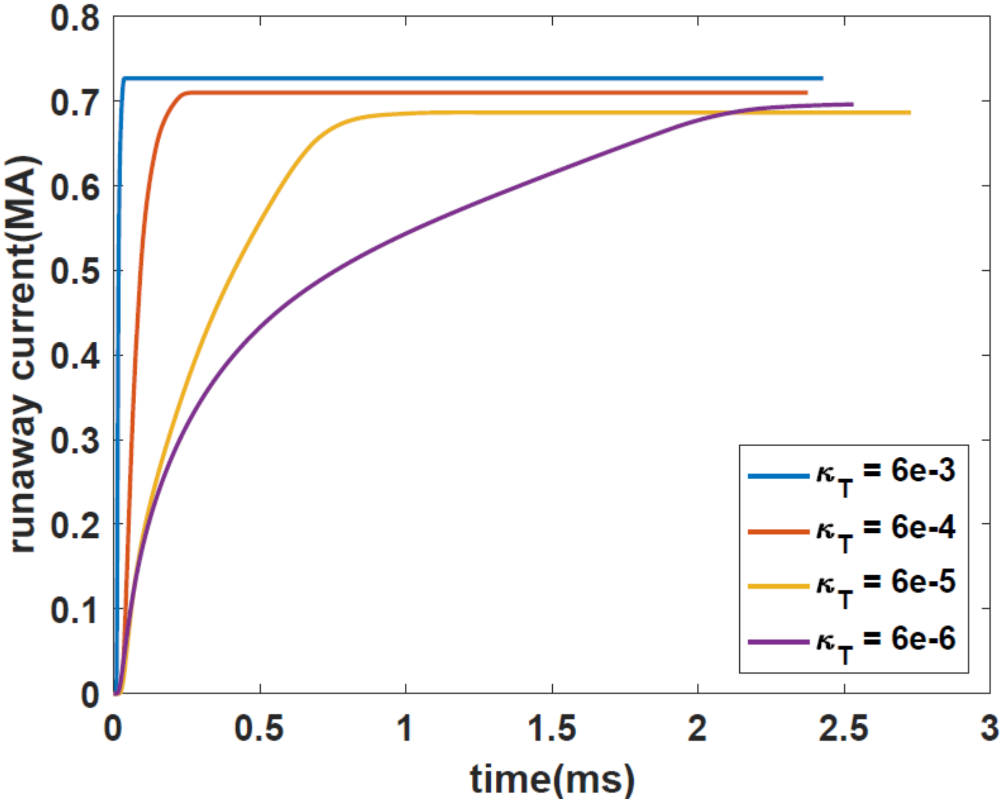
Drecier & Avalanche term



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

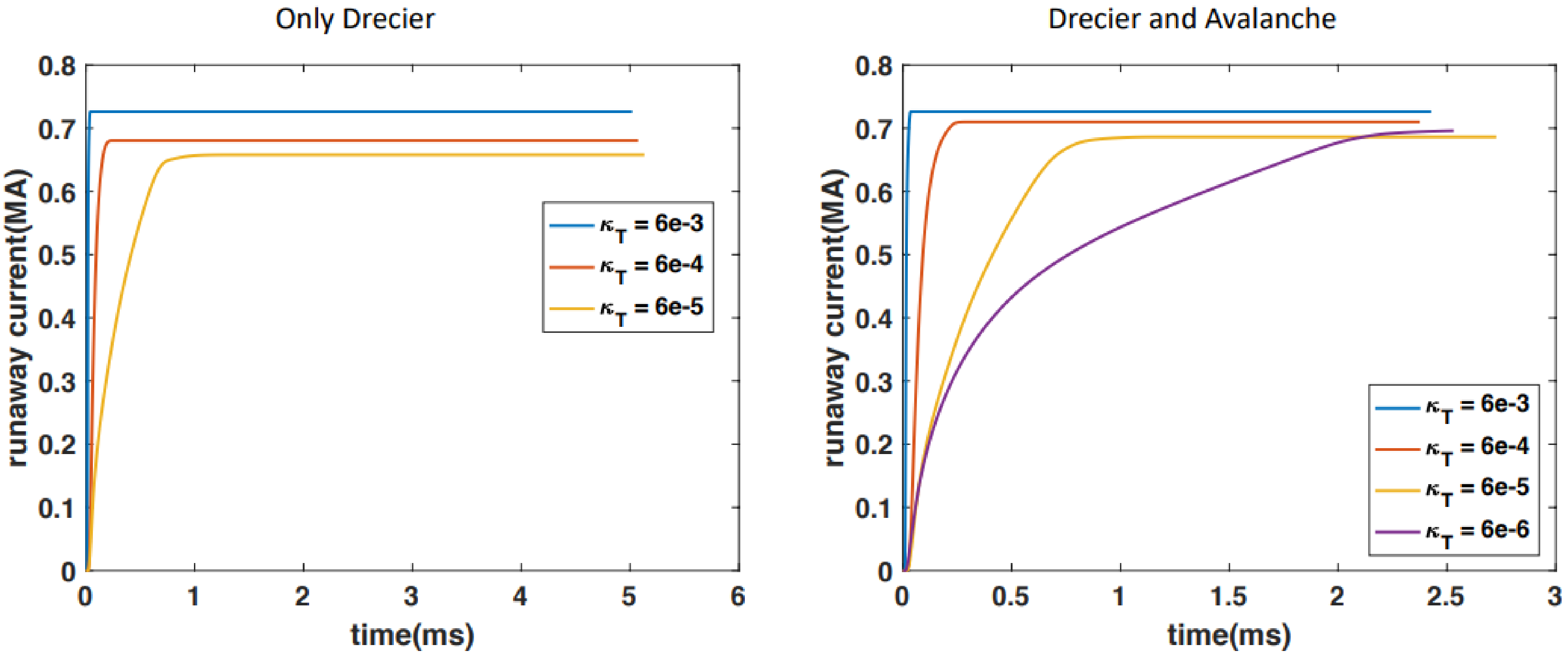
Chen Zhao

Effect of $\kappa_{\perp}$ on Runaway Current



- Total Runaway current almost independent on cooling rate !!
- Is this due to avalanche term? Shown on next slide.

Effect of Avalanche term



Next Steps

- Both JOREK and NIMROD are interested in doing a benchmark of the runaway source calculations
- Is there a series of experiments on DIII-D that produce runaways that we could all try and model?
- Who to contact? Daisuke Shiraki ?

Update on JET SPI Numerical Instabilities

by

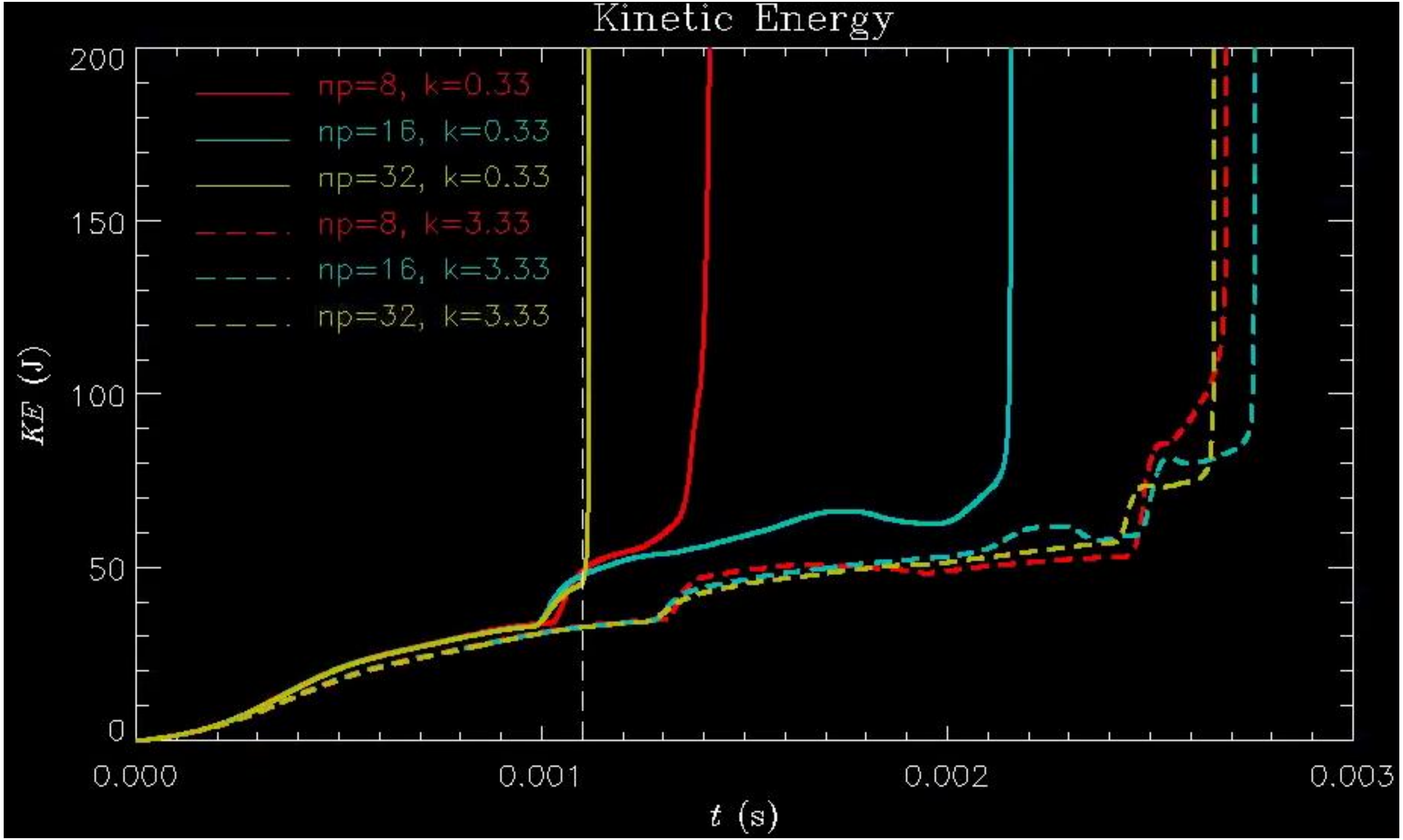
Brendan C. Lyons

Email
March 15th, 2021

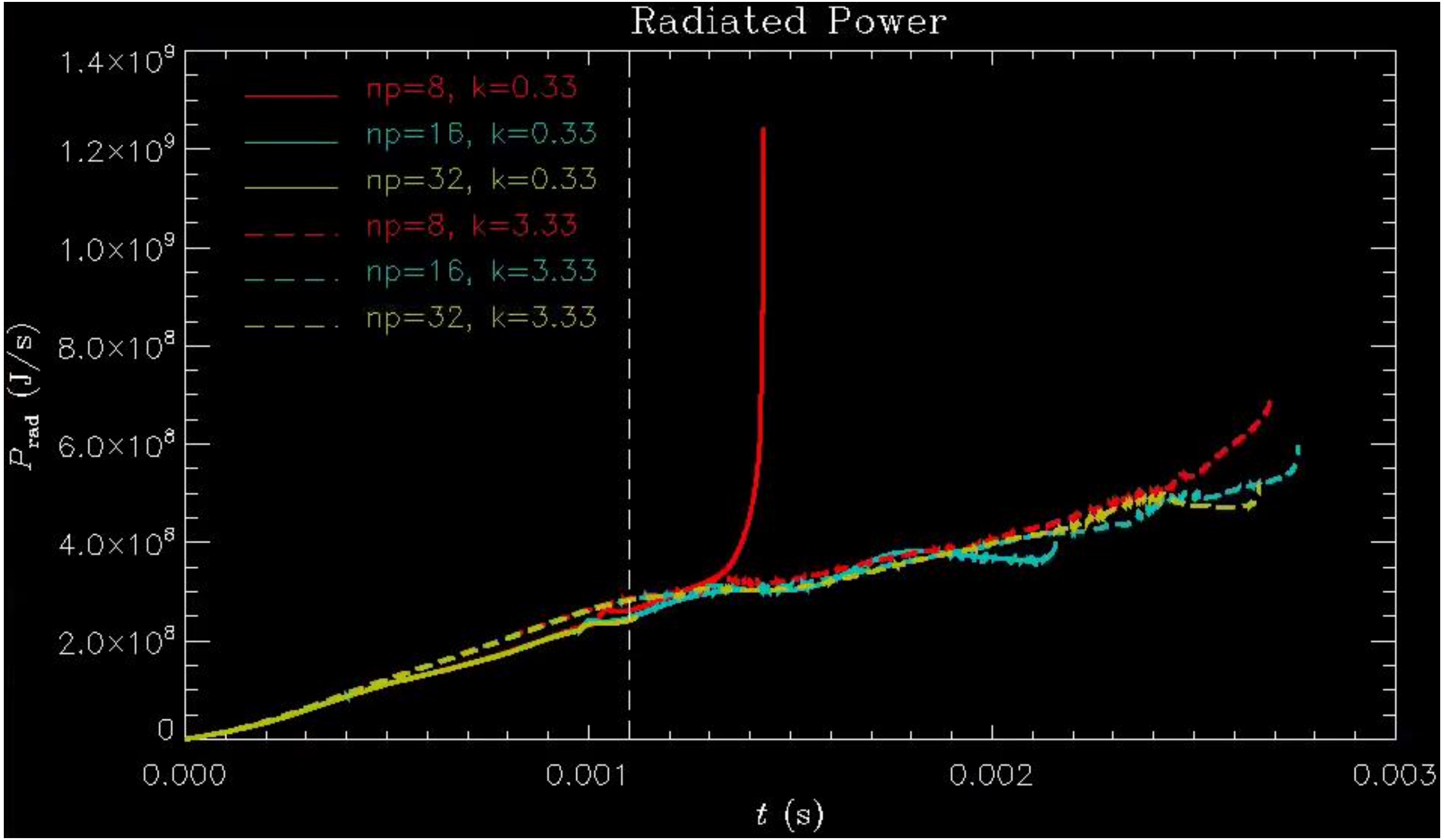
JET SPI explored along two axes: toroidal planes and kappat

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

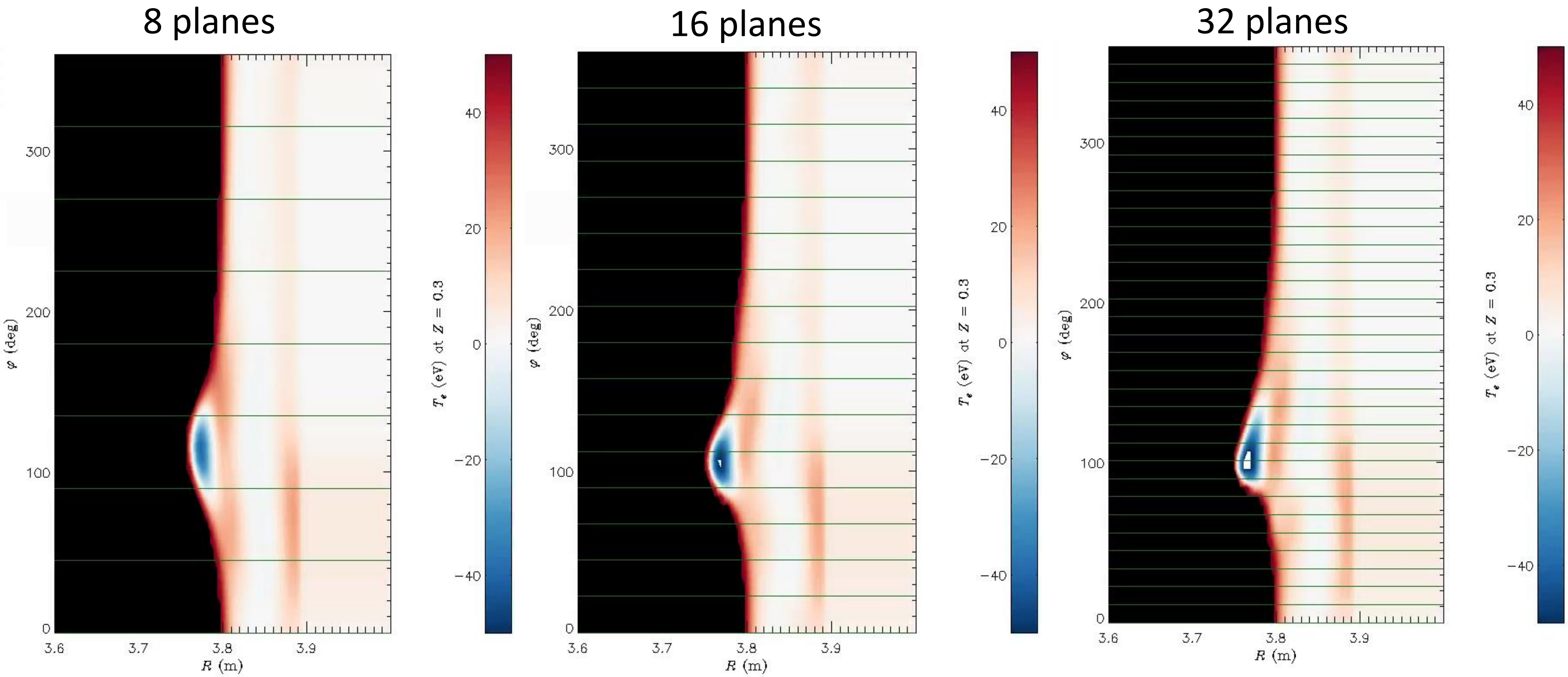
Kinetic Energy For All Runs



Radiated Power For All Runs



Electron Temperature at Outboard Midplane at 1.1 ms



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 … 4/05/21 (SCJ)

I reran the 8 plane run C1_38642662 with the following changes.

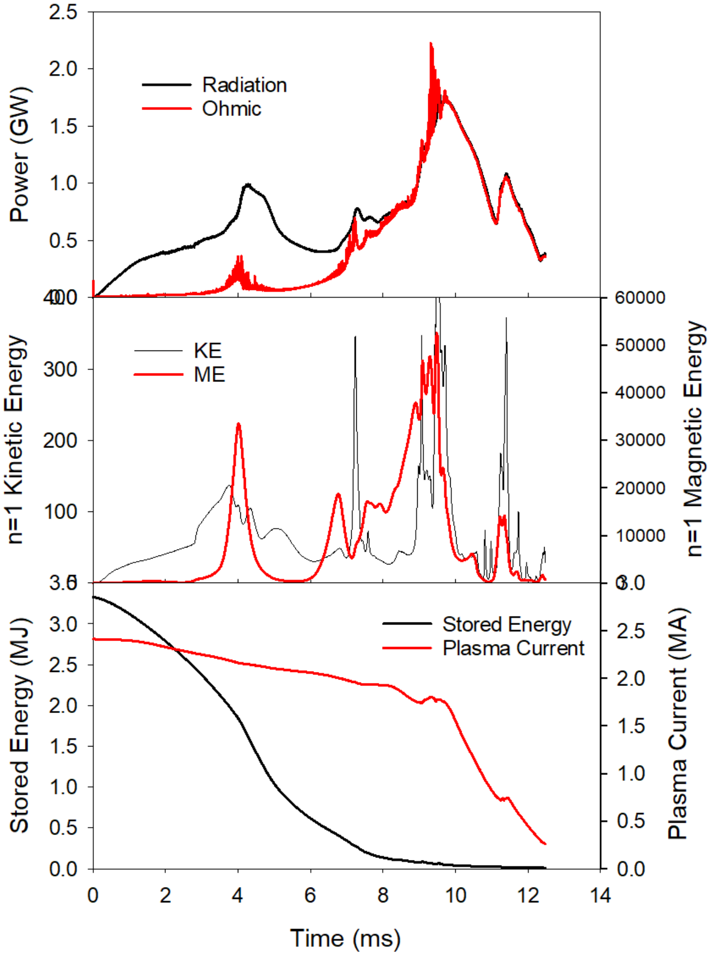
iupstream = 1
magus - .005
amuc = 6.48361e-03
Denm = 6.48361e-06 (same as original)

Idenmfunc = 1
denmt = 6.48361e-8
denmmin = 1.e-6
denmmax = 1.e-4

denm79 = denm + denmt/Te

The new run is in /scratch/gpfs/sjardin/Brendan96-2

JET SPI Variable denm run



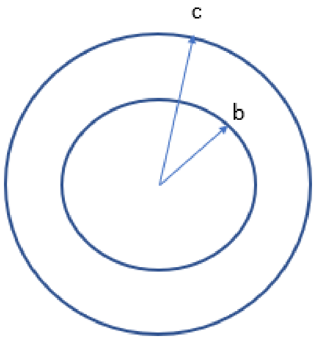
- Thermal + current quench
- Note each MHD event associated with a spike in radiation
- Brendan has had similar results using ikappafunc=5 (now documented)
  Kap79 = kappat + kappa0/Te
- Opens up transport coefficient space
  2 density + 2 kappa

That’s All I have

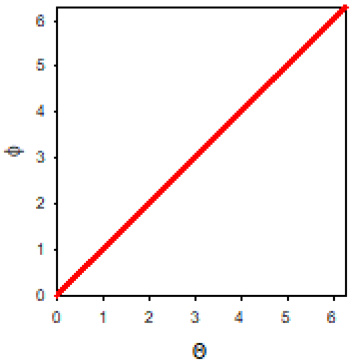
Anything Else ?

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 |θ-φ| < δ

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

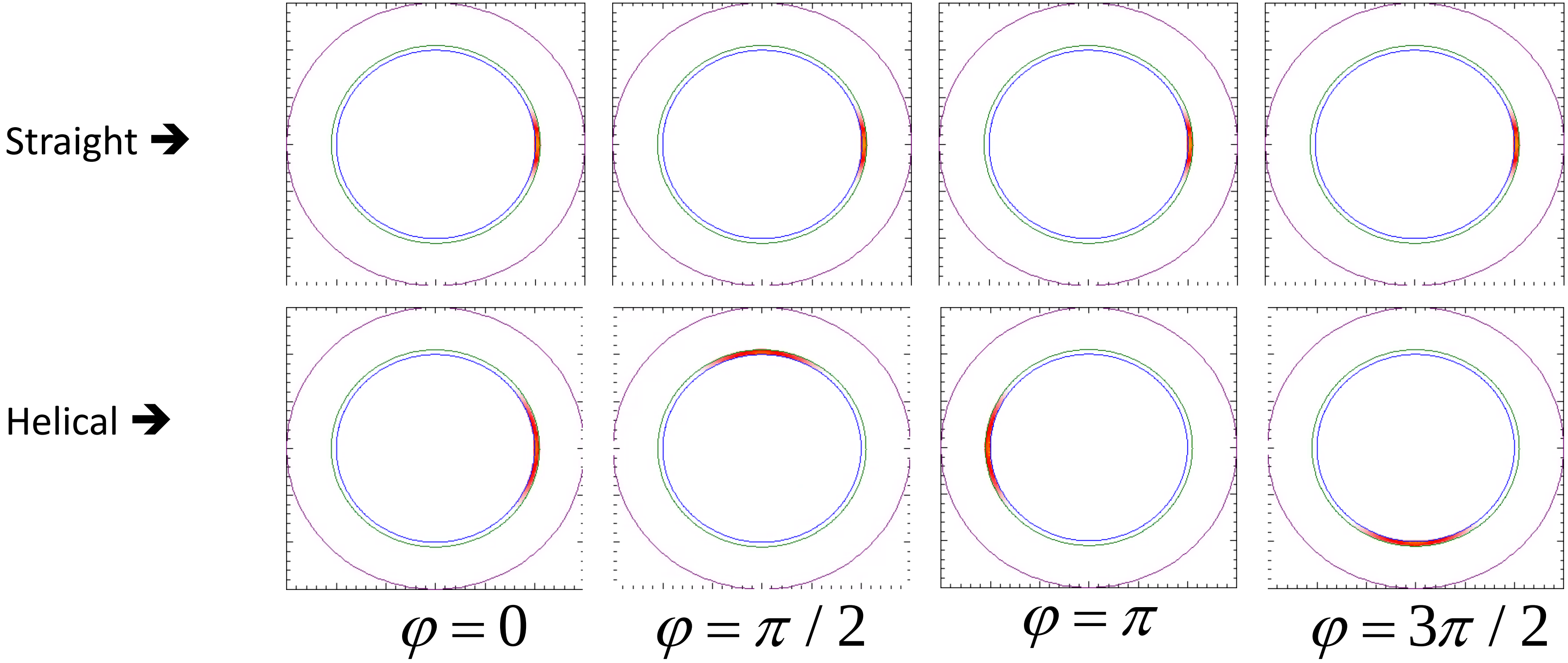
$$\nabla \times \mathbf{E} = 0 \quad \Rightarrow \quad \mathbf{E} = -\nabla\Phi + \frac{V_L}{2\pi}\nabla\phi$$

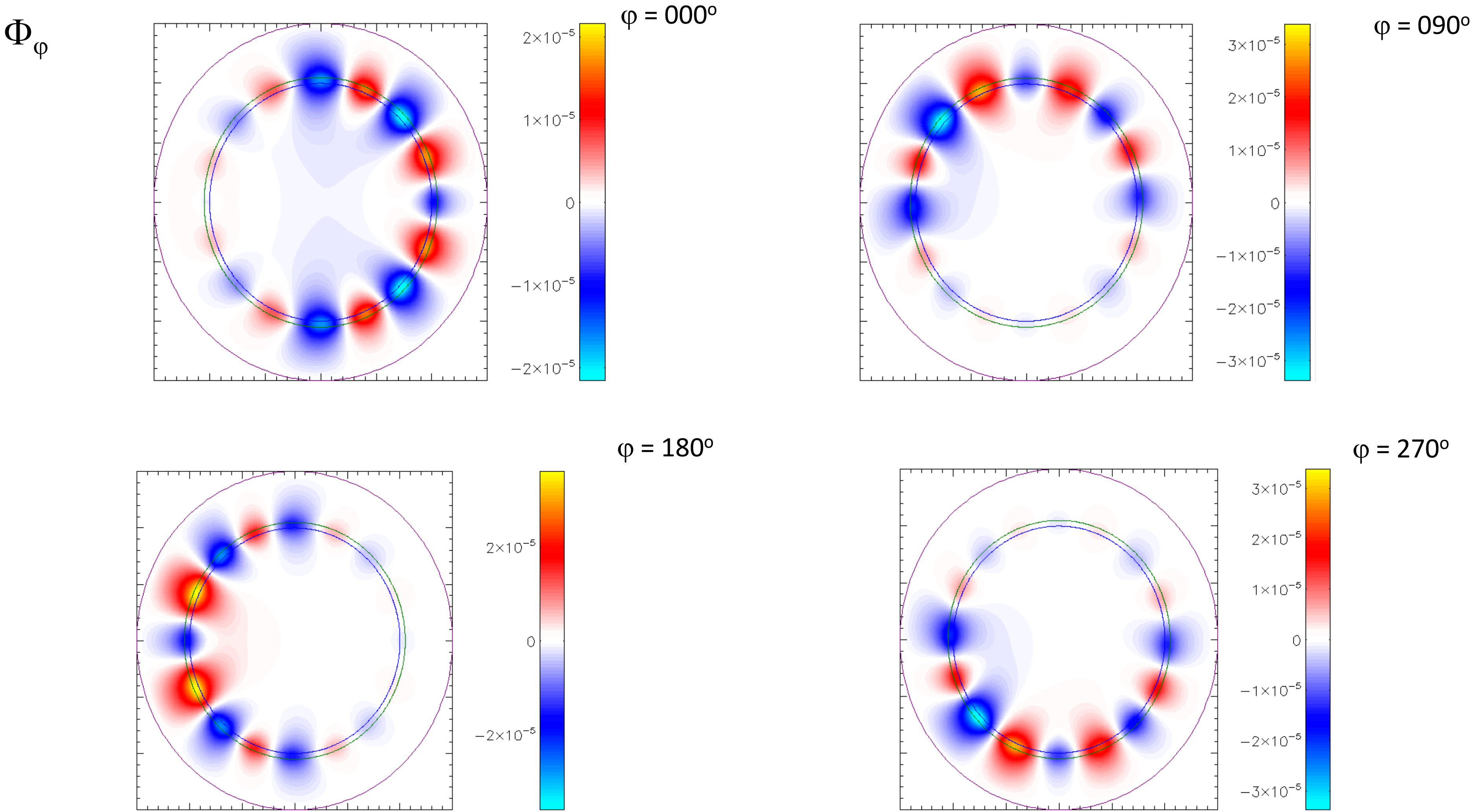
$$\mathbf{J} = \sigma\mathbf{E}$$

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

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

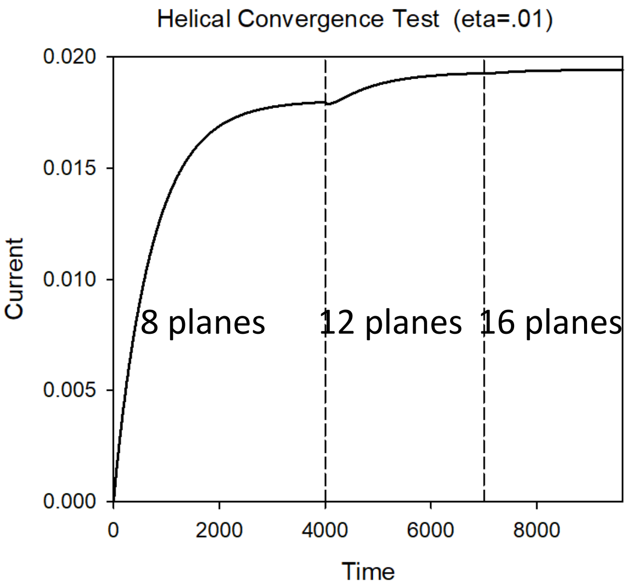
Comparison between Straight and helical band

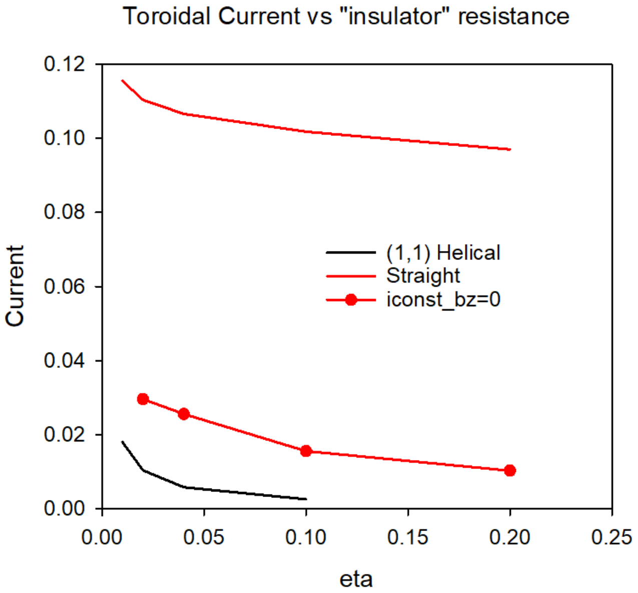




Φ_φ
φ = 000º
2×10⁻⁵
1×10⁻⁵
0
−1×10⁻⁵
−2×10⁻⁵
φ = 090º
3×10⁻⁵
2×10⁻⁵
1×10⁻⁵
0
−1×10⁻⁵
−2×10⁻⁵
−3×10⁻⁵
φ = 180º
2×10⁻⁵
0
−2×10⁻⁵
φ = 270º
3×10⁻⁵
2×10⁻⁵
1×10⁻⁵
0
−1×10⁻⁵
−2×10⁻⁵
−3×10⁻⁵

Some Convergence Tests

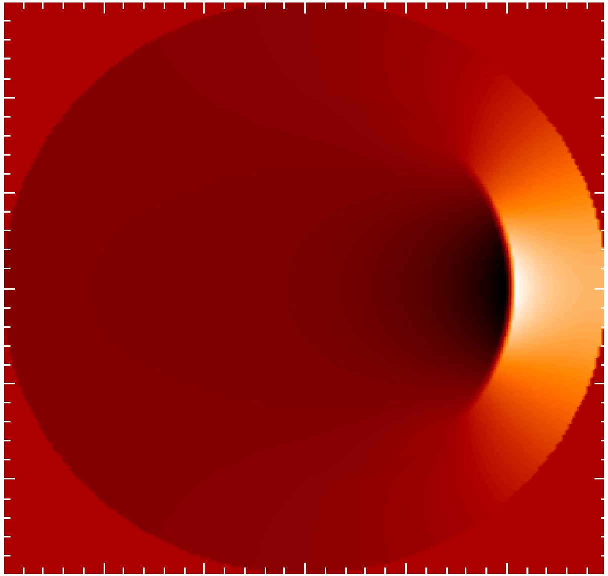




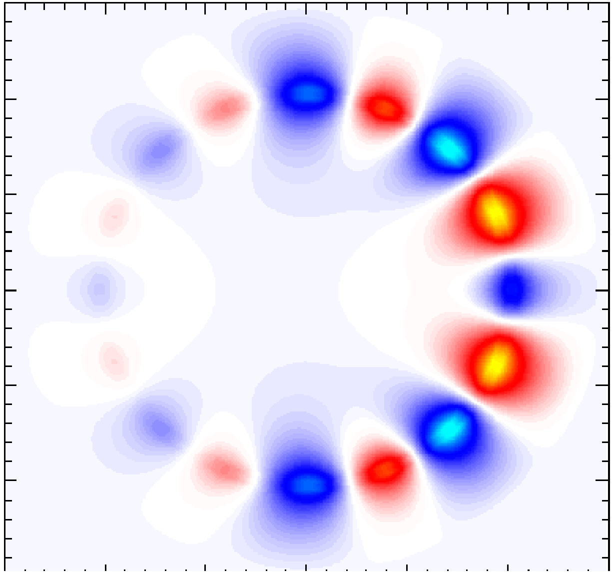
- Wall current appears to be converged in # of planes
- Helical wall current tending towards zero for large values of insulator resistance
- Now testing dependence on boundary conditions (location of ideal wall)
- Helical (1,2) case gives less than half the current of helical (1,1) case
- Iconst_bz=0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

Plots for iconst_bz=0

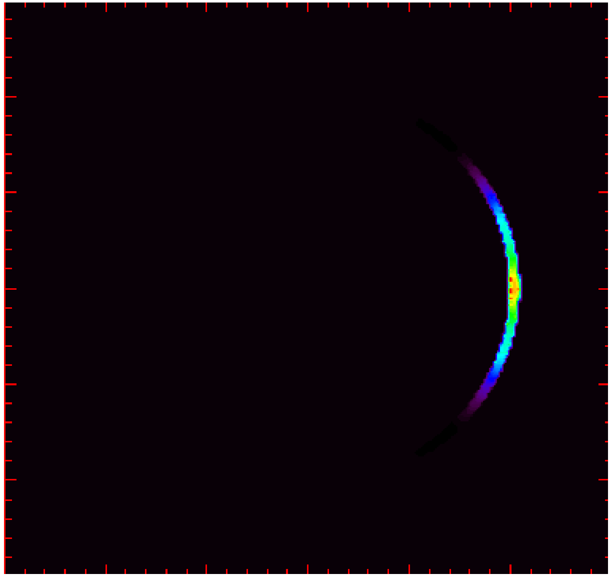
I



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



J_φ



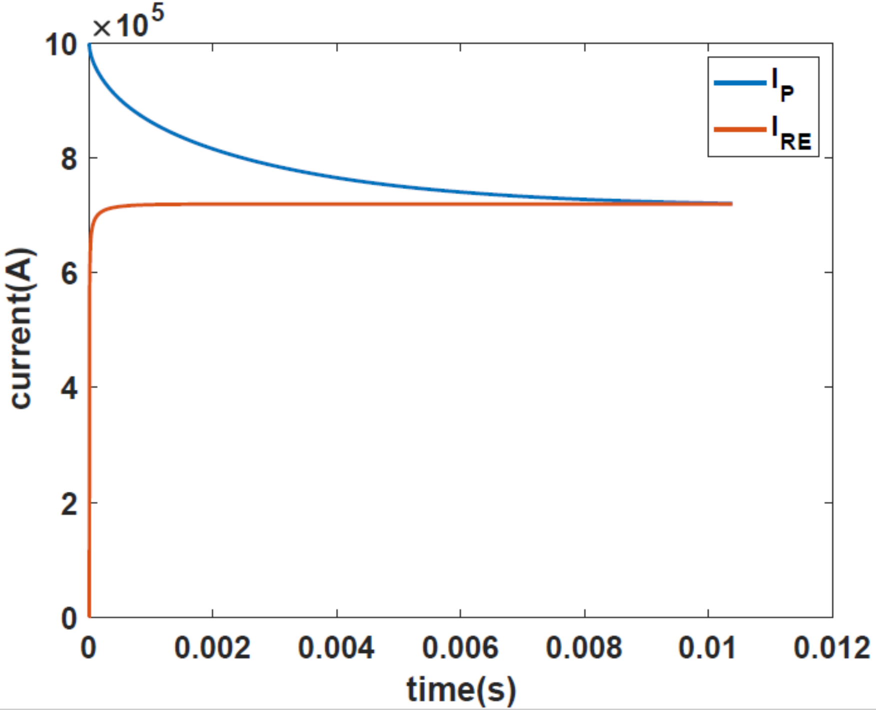
$$\nabla_\perp \bullet \frac{1}{R^2} \nabla \Phi = \nabla_\perp \cdot \eta \left[-\frac{1}{R^2} \nabla F \times \nabla \varphi - \frac{1}{R^2} \nabla f'' \times \nabla \varphi - \frac{1}{R^4} \nabla_\perp \psi' \right]$$

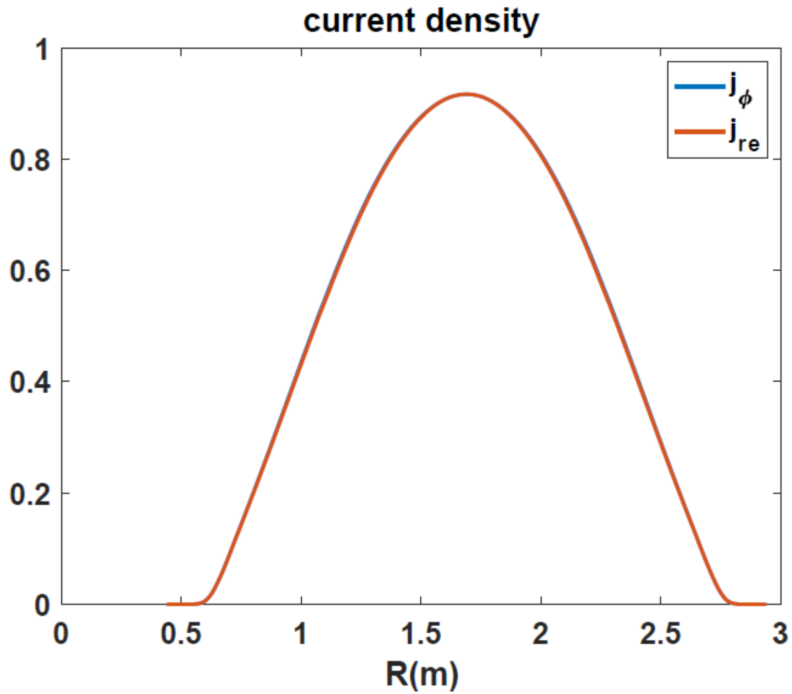
Local Systems

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

- PPPL greene (02/15/21)
  - 4 regression tests PASSED
  - RMP_nonlin timed out (but gave correct results)
  - No batch file found for pellet
- EDDY (2/15/21)
  - 6 regression tests PASSED
- TRAVERSE(1/4/21)
  - Code compiles
  - Regression test failed: split_smb not found in PATH
  - Have not yet tried shipping .smb files from another machine

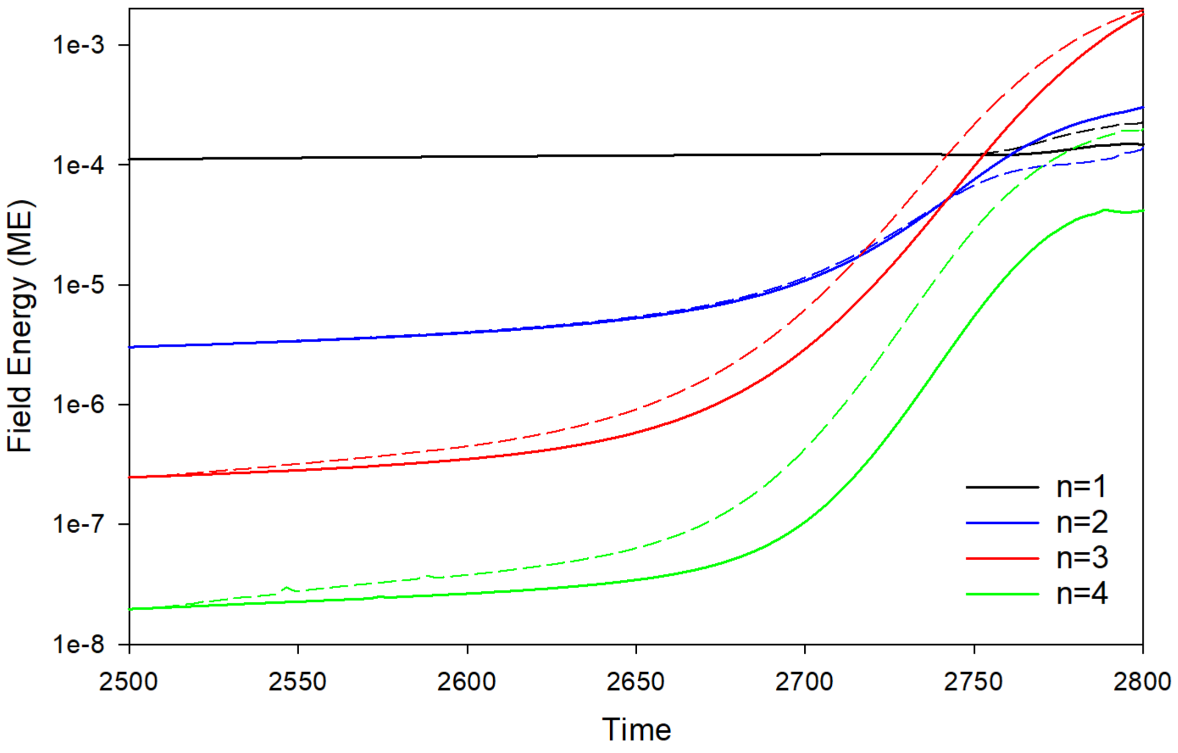
2D (cylindrical) RE with sources (12/19/2020)



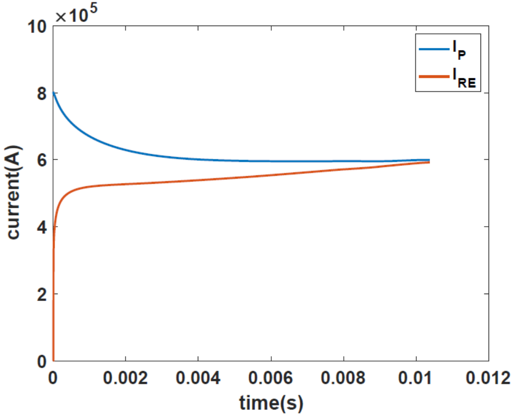


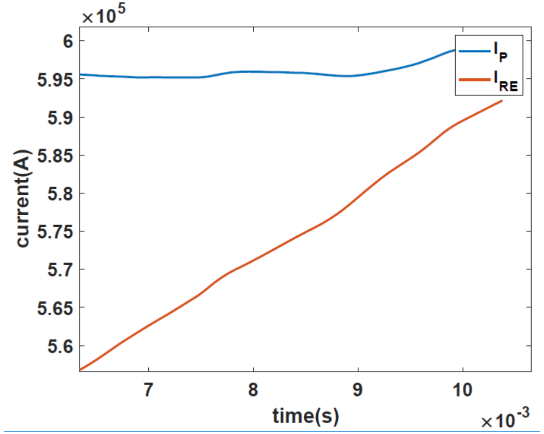
Chen Zhao

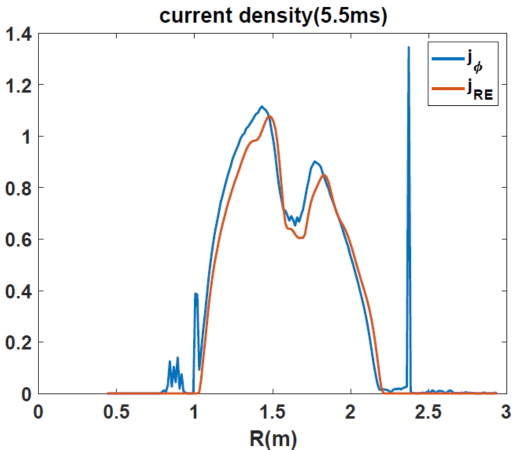
Energy in base case 36742317 (solid) and 16 plane case 37248033 (dashed)

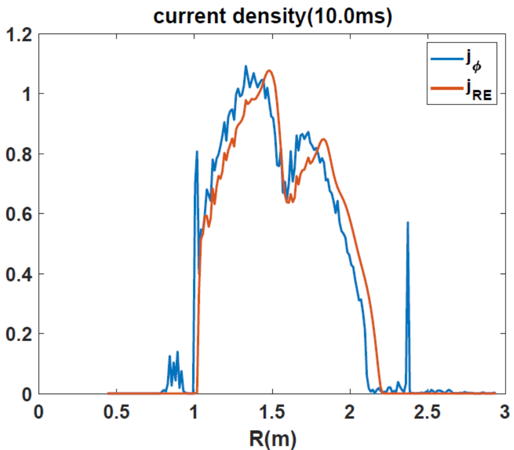


DIII-D 177053 with Argon





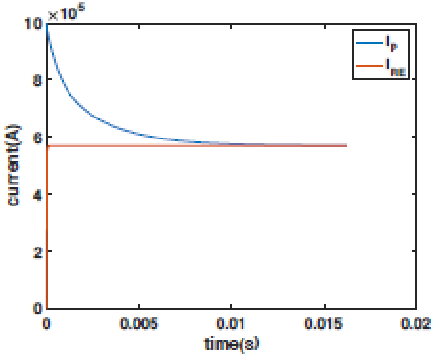


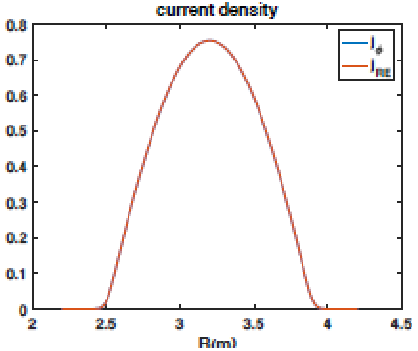


Chen Zhao

Same calculation in a Cylinder

M3D-C1 runaway generation with cylinder geometry





- Parameters:

$$\beta_0 = 0.15$$

$$a = 0.65m$$
$$\mathrm{R} = 1.7m$$
$$B_0 = 1.9T$$
$$\eta = 1.0\times10^{-4}$$
$$n_0 = 1.0\times10^{20}m^{-3}$$
$$c = 150v_A$$
$$N_{elements} = 12261$$
$$\Delta t = 1.0\tau_A$$

- The plasma current was equal with plasma current by the runaway current at about 12ms.
- The radial profile of runaway current profile are exactly same when the plasma current equal to runaway current.

Progress on other shots?

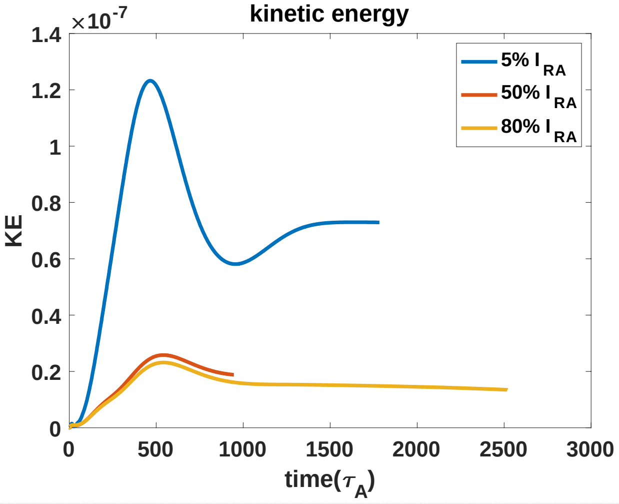
- M3D-C1/NIMROD 3D Benchmark

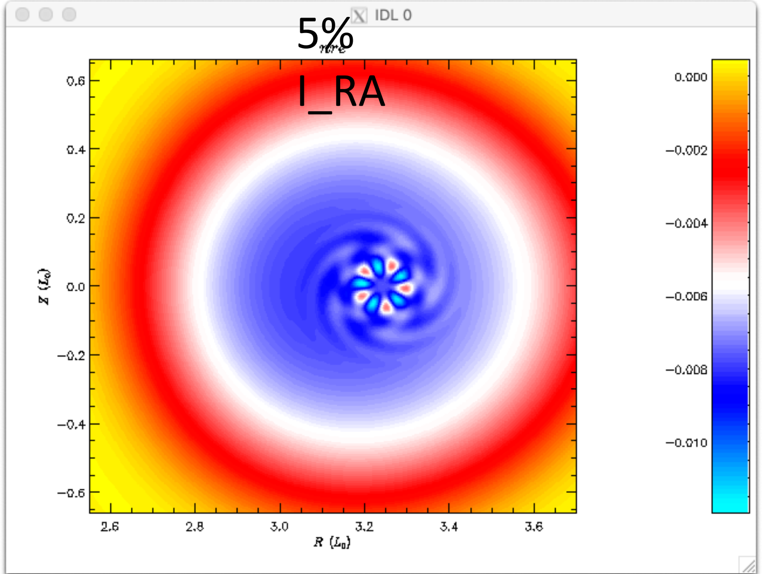
NSTX shot 1224020 – Fast ion transport with coupled kink and tearing modes
Chang Liu

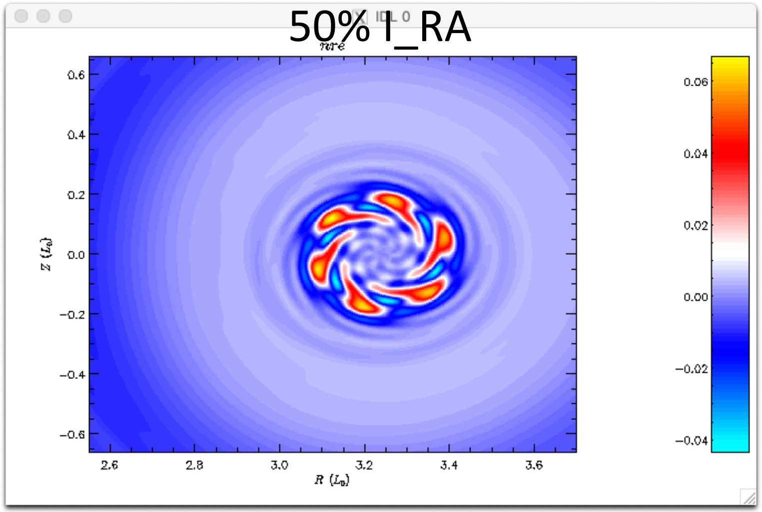
DIII-D Neon pellet mitigation simulation for KORC

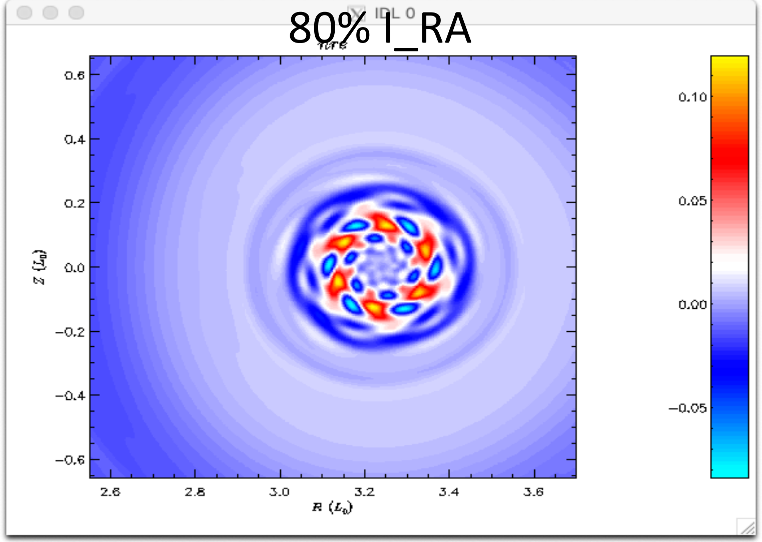
- Brendan Lyons trying to extend 8 plane case to 32 planes

SPARK ?   Do we need to do anything?

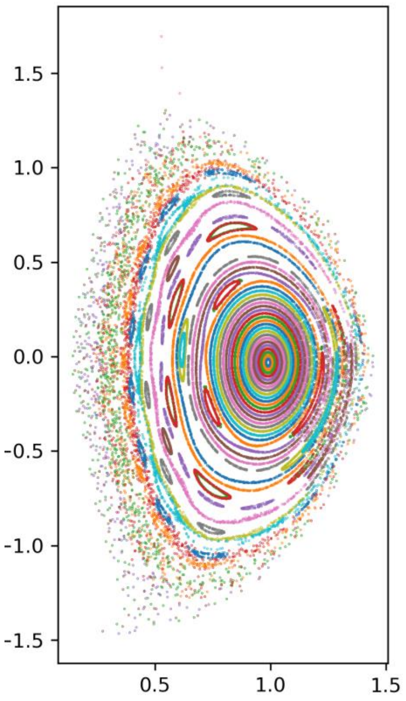

kinetic energy
×10^-7
KE
time(τ_A)
5% I_RA
50% I_RA
80% I_RA
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0
500
1000
1500
2000
2500
3000


IDL 0
5% I_RA
Z (L_0)
R (L_0)
0.000
−0.002
−0.004
−0.006
−0.008
−0.010


IDL 0
50% I_RA
Z (L_0)
R (L_0)
0.06
0.04
0.02
0.00
−0.02
−0.04


IDL 0
80% I_RA
Z (L_0)
R (L_0)
0.10
0.05
0.00
−0.05

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



- In the original geqdsk file, the equilibrium was poorly converged. New one is much better. Has q(0) = 1.3
- Chang has analyzed new equilibrium (left)
- No ideal (1,1) mode, several tearing modes

- If goal is to get unstable (1,1) mode, likely need to lower q(0)
- Adding sheared toroidal rotation should help stabilize resistive modes.

Grad-B drift in M3D-C1—HF side

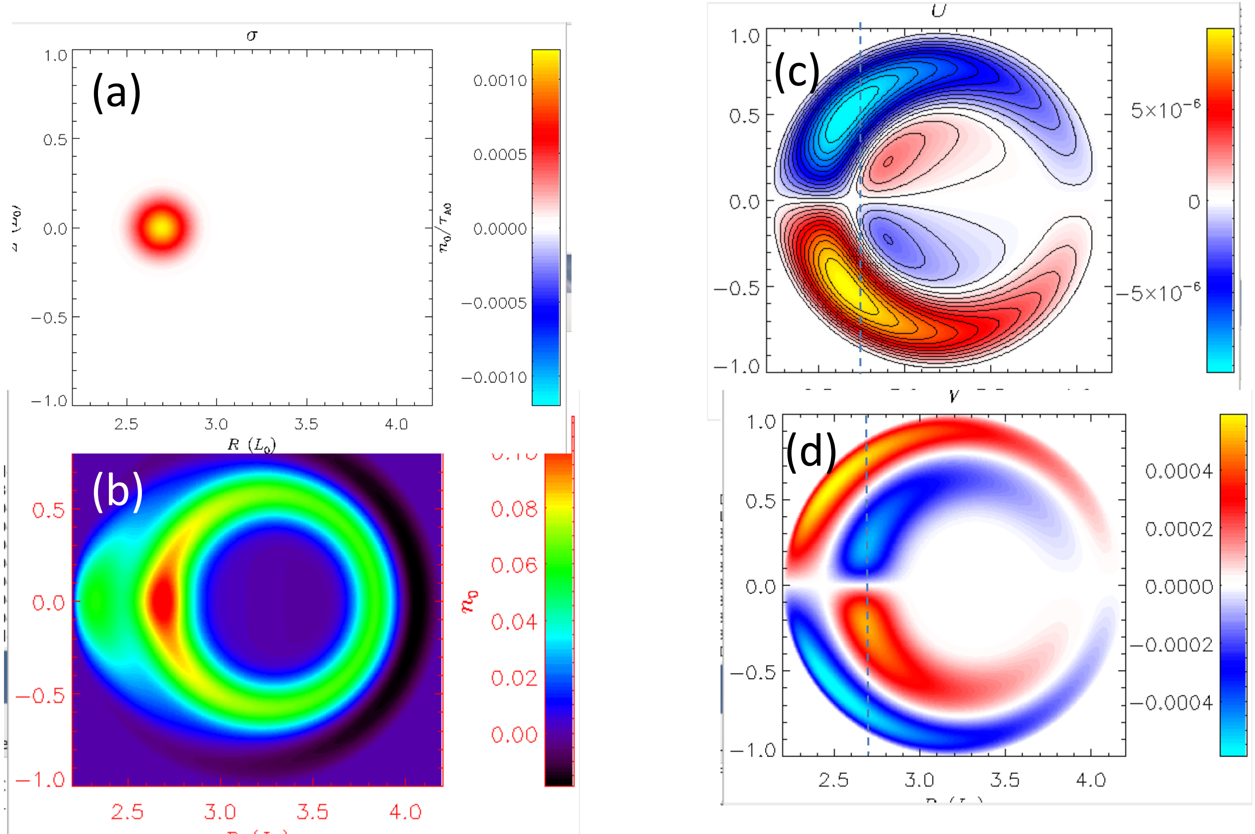
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

(a) Density source in 1F toroidal equilibrium

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

(c) Poloidal velocity stream function

(d) Toroidal velocity contours



Grad-B drift in M3D-C1– LF source

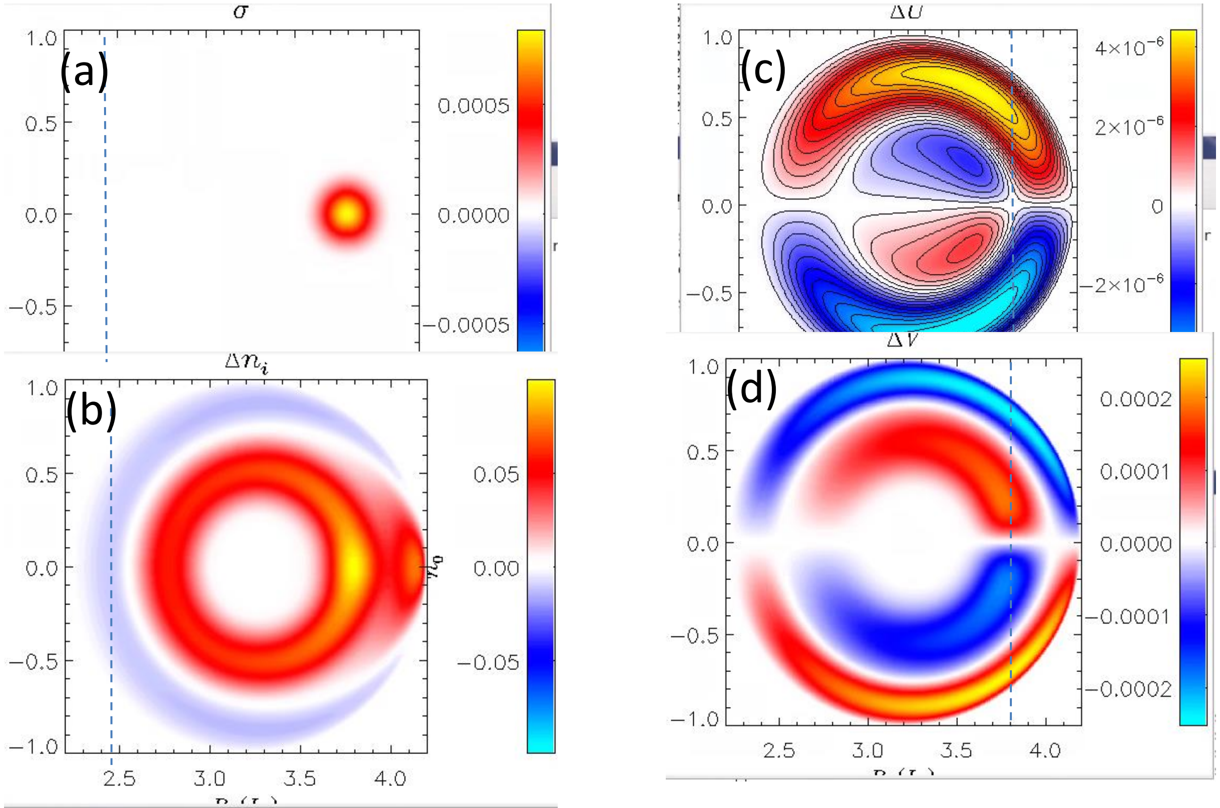
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

(a) Density source in 1F toroidal equilibrium

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

(c) Poloidal velocity stream function

(d) Toroidal velocity contours



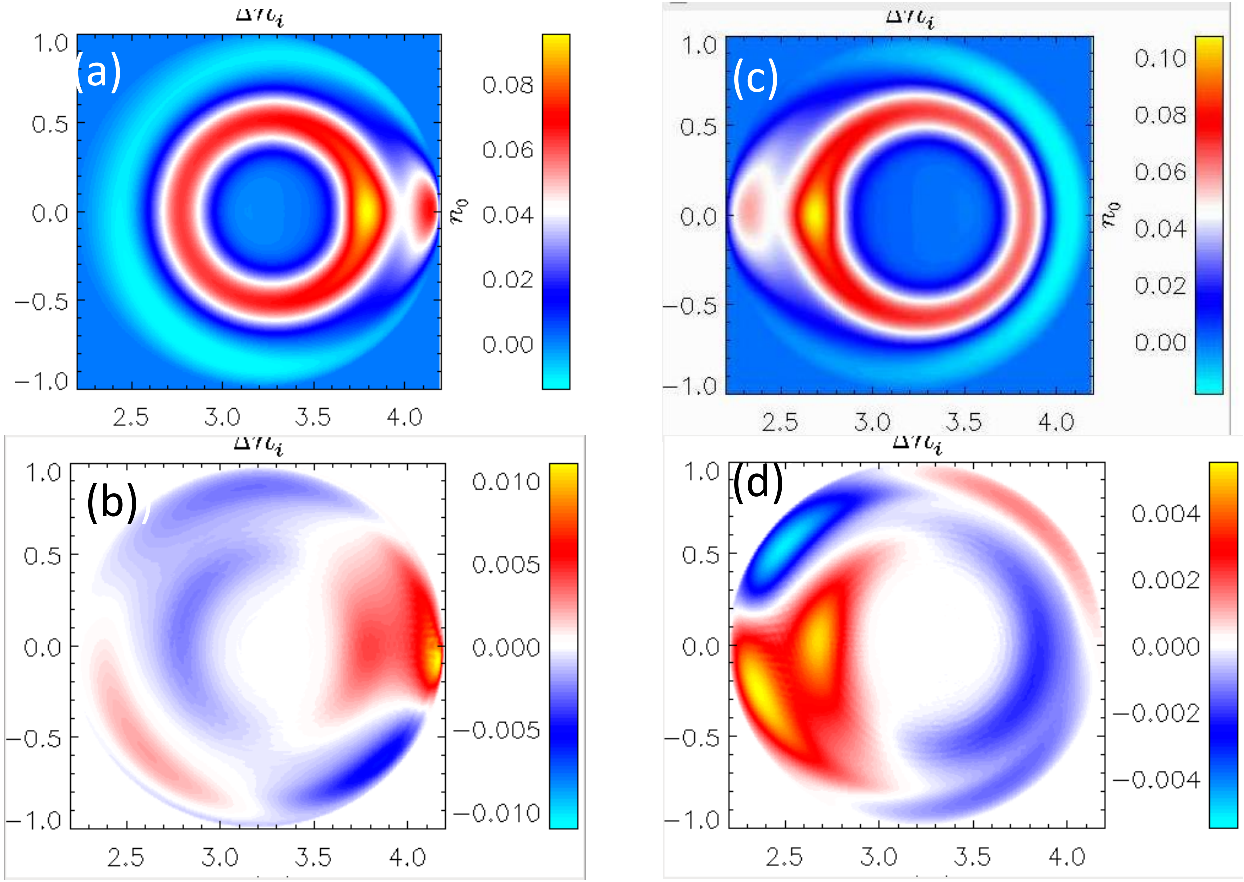
Grad-B drift in M3D-C1—2F effects

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

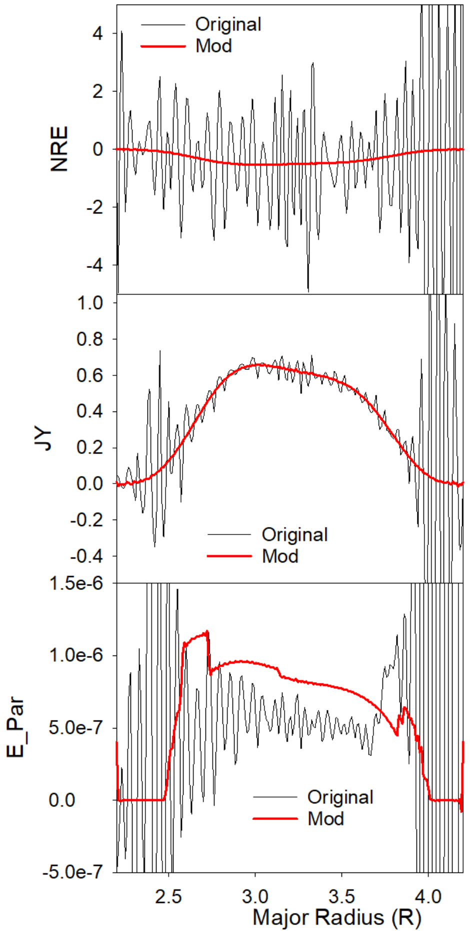
(b) Difference in 1F and 2F density (LF)

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

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



Sawtoothing discharge with runaway electrons

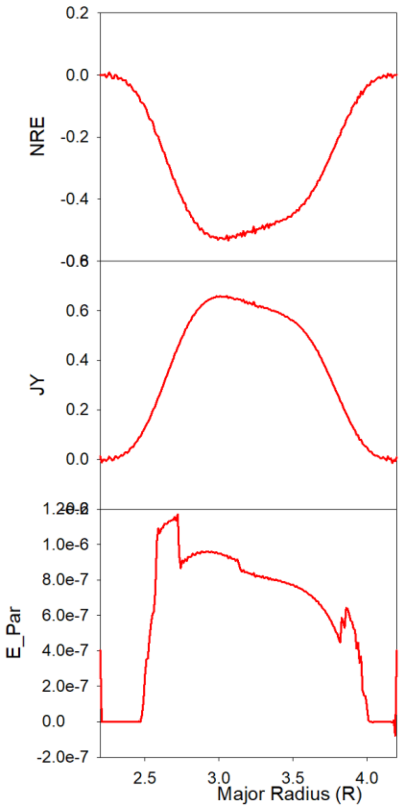


Profiles of nre, jy, and E_par after 30 timesteps

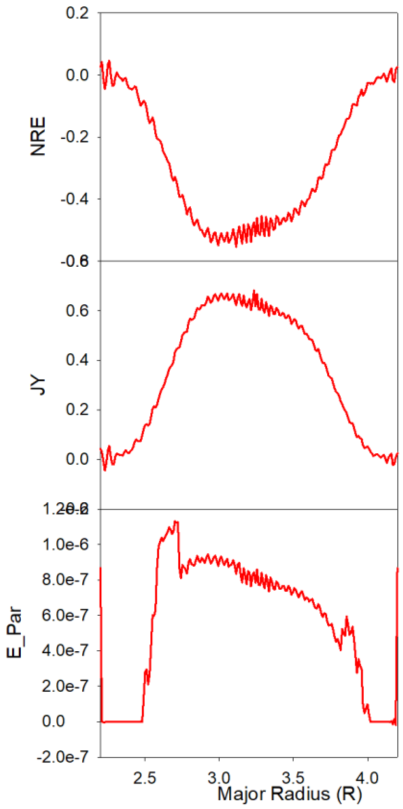
Original: /p/tsc/m3dnl/Isabel/Chen2D
Mod: /p/tsc/m3dnl/Isabel/Chen2D-mod1

Changed:
mesh size
"regular"
"integration points"
ipres=1
cre
pedge
viscosity
denm
equilibrium density

Longer times develops oscillations



Change from t=6 to t=100



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