M3D-C1 ZOOM Meeting

03/15/2021

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

Physics Studies

1. Runaway electron loss by MHD events– Chang Liu
2. Carbon Mitigation in NSTX-U (shell pellet)
3. RE Benchmark with JOREK .. Chen Zhao
4. Helical band to remove runaway electrons
5. Other?

Announcements

- ITPA on MHD, Disruptions, Control March 22-25
- IAEA Papers Due 9 April
- Jon Menard request for Research Highlights by March 16
  - ITER Cold VDE (Cesar)?
  - DIII-D Runaway Electron MHD event (Chang)?
  - Other?

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???

Jin Chen email 2/2/21:

Memory Utilized: 16.27 GB (estimated maximum)
While matrices only took less than 4GB:

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

Nate Ferraro: modules m3dc1/1.12 and m3dc1/devel are available

Seegyoung Seol: (3/13/21) I wasn't able to configure PETSc with the existing MKL module (it has scalapack, blacs, blas, lapack, etc.). I am trying the many different configuration options to make use of the most of the existing modules in Stellar but didn't have a luck yet.

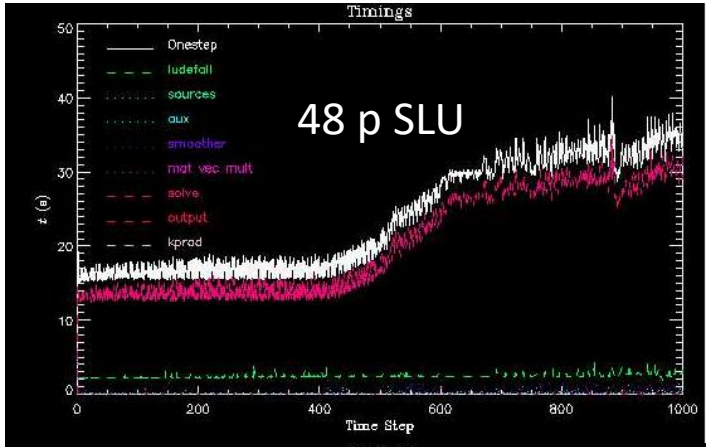
Timing Tests

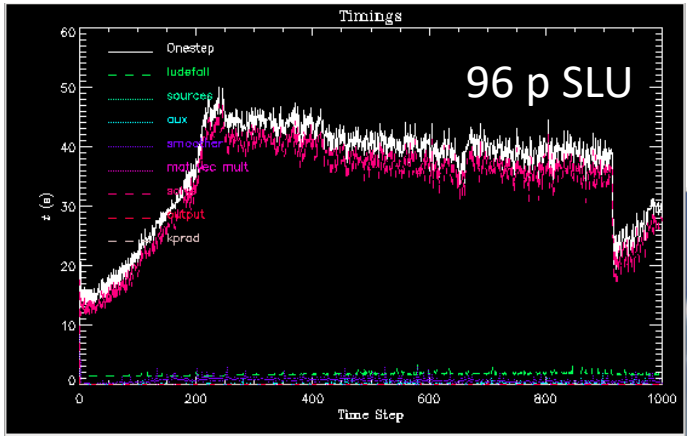
S. Jardin: Case study: 2D ITER VDE case 1000 TS (/home/sjardin/data/ITER)

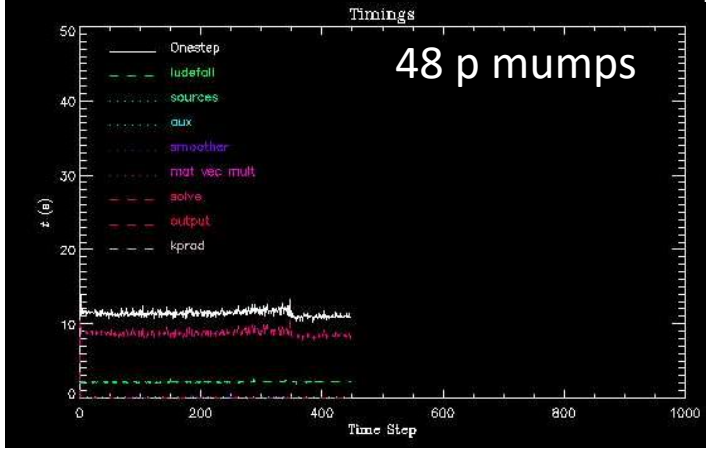
Nodes	cpu/node	partitions	compute time	solve time (SLU or MUMPS)	
1	64	64	1.8 s	13-16 s	
1	96	96	1.1-1.2 s	18-30 s	**SUPER_LU**
1	96	96	1.25	13-16 s	
2	48	96	1.1-1.2 s	12-13 s	
1	80	80	1.4 s	13-60 s	hangs at end, CDLL
1	72	72	1.5 s	13-16 s	hangs at N=5, no message
1	48	48	2.2 – 2.3 s	13-31 s	hangs at end, no message
1	48	48	2.1	8 - 10 s	NaN at N=447 **MUMPS**
1	96	96	1.1 s	7 – 8 s	NaN at N=430
1	64	64	1.6 s	8 s	NaN at N=40
1	72	72			hangs in GS, no message

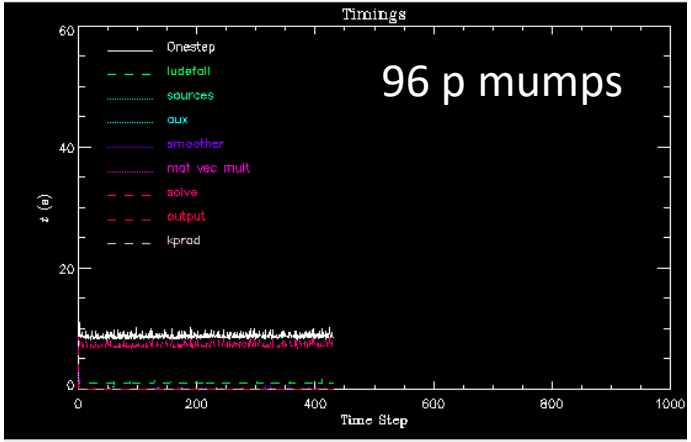
CDLL: corrupted double-linked list

More on Timing Tests









Even more on Timing Tests

1 node 96 p jobs with the same parameters (N=1000) often behave/fail differently

	SuperLU		MUMPS	
Submission	solver_timings	result	solver_timings	result
1	13-16	CDLL at end (hangs)	7-8 s	NaN @ 602
2	“	“	7-8 s	good!
3	13-**30** s	“	7-8 s	NaN @ 193

CDLL = corrupted double linked list

Mesh adaptation update

Seegyoung Seol (03/13/2021): In terms of 3D mesh adaptation, we fixed all the known errors so now we can re-construct the 3D mesh out of 2D adapted mesh in the master node. Now I am looking at the field transfer in 3D and Usman is working on the error estimator. As soon as my part (field transfer) is done, we can release the software so Brendan should be able to run mesh adaptation in 3D.

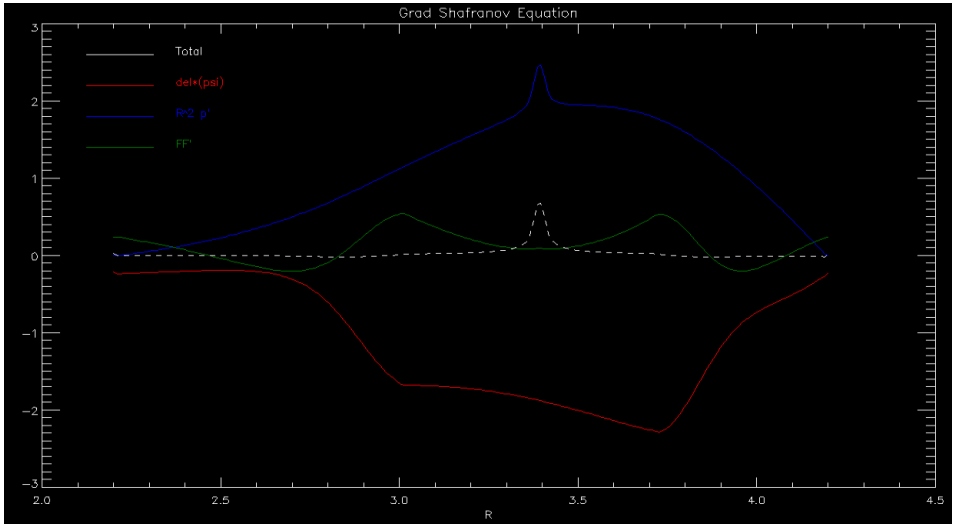
I

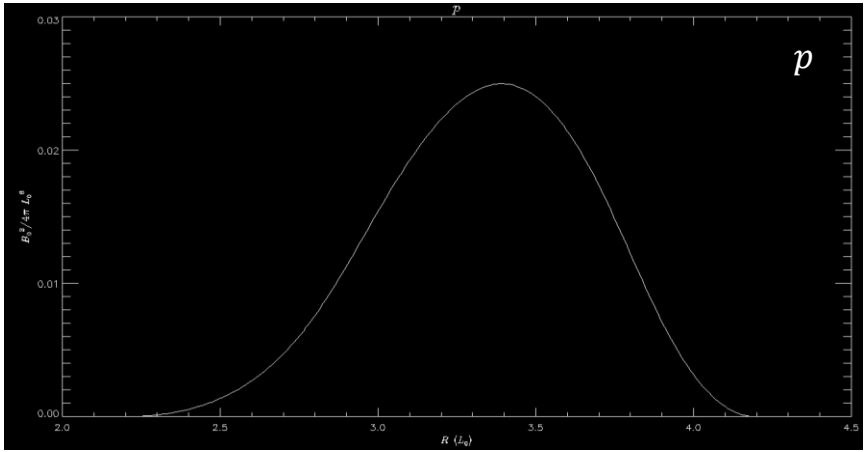
From Adelle Wright:

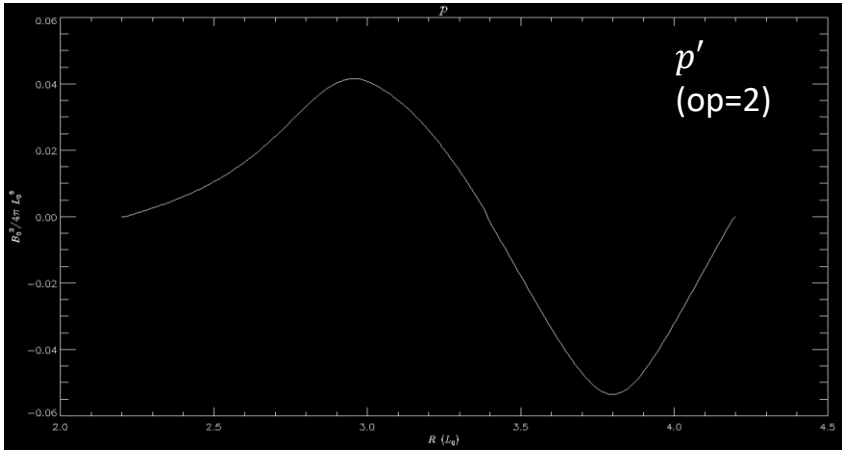
>**plot_equation, 'gradshafranov'** has large non-zero component at $p' = 0$. Diagnostic issue?

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.

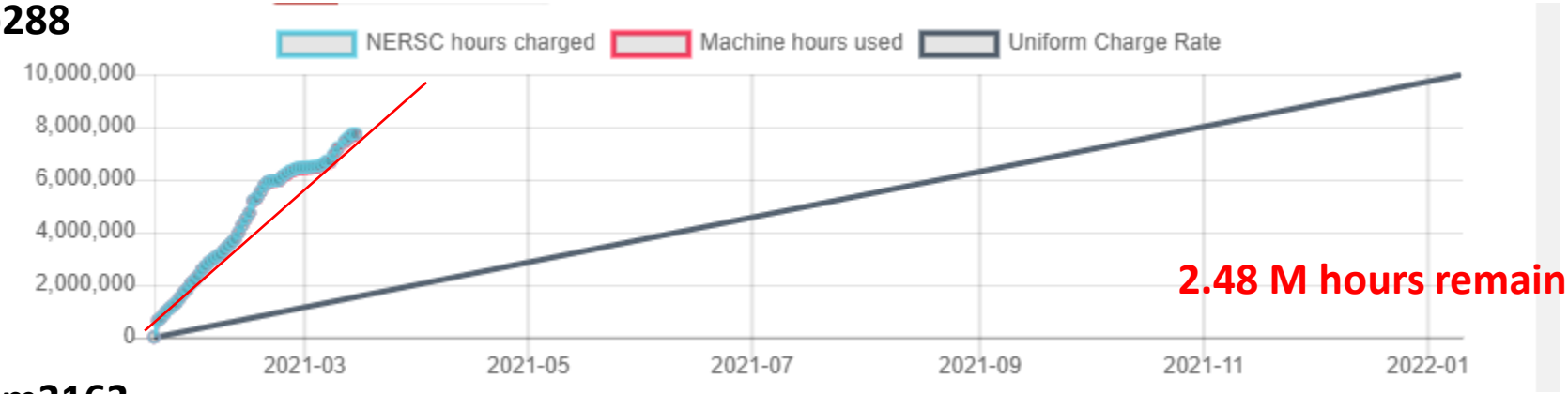






NERSC Time

mp288



m3163

Closed for general use

- mp288 received 10M Hrs for CY 2021
- We will exhaust this by the end of March at this rate. (May get more time)
- Transition to stellar (PU/PPPL)
- I plan to not start any new jobs on Cori

Changes to github master since last meeting !

Seegyoung Seol

- 03/03/21: errors with 3D mesh reconstruction fixed
- 03/10/21: debugging of 3D mesh reconstruction after adaption

Steve Jardin

- 03/04/21: Added new input variable “ifixed_temax” . If nonzero, temax IDL diagnostic will be temperature at fixed location xmag0,zmag0

Brendan Lyons

- 03/08/21: Output pellet ablation temperature and density

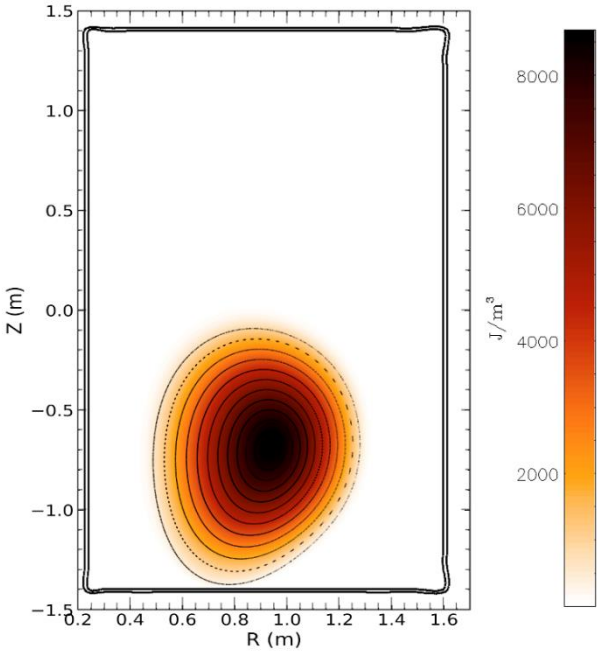
Local Systems

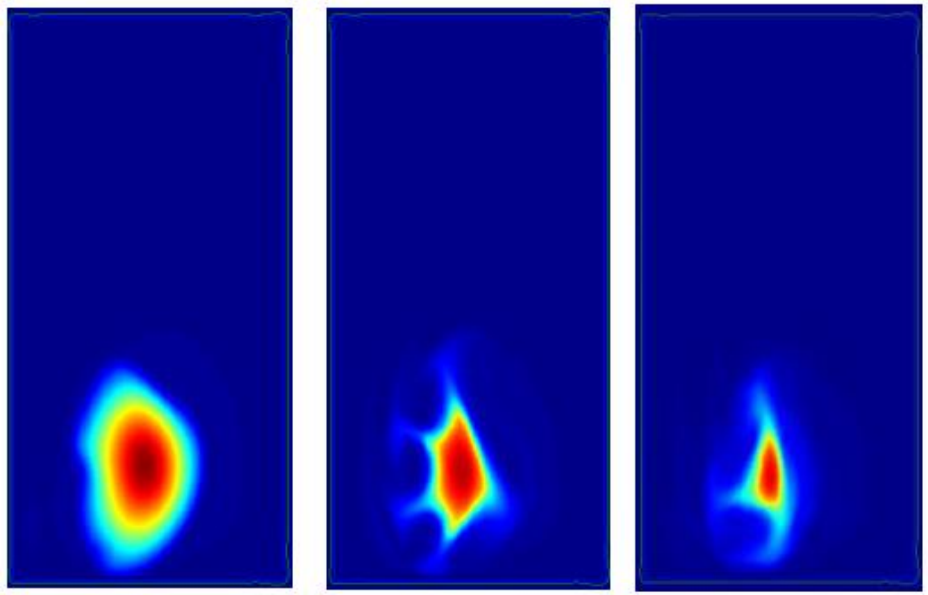
- PPPL centos7(03/15/21)
  - 6 regression tests **PASSED** on centos7:
- PPPL greene (02/15/21)
  - 4 regression tests PASSED
  - RMP_nonlin timed out (but gave correct results)
  - No batch file found for pellet
- EDDY (2/15/21)
  - 6 regression tests PASSED
- TRAVERSE(1/4/21)
  - Code compiles
  - Regression test failed: split_smb not found in PATH
- STELLAR (03/15/21)
  - 5 regression tests PASSED
  - Adapt **FAILED:** unsorted double linked list corrupted

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

Can this be applied to this sequence to for 3DVDE M3D-C1/JOREK/NIMROD paper?

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

- Includes 3 co-authors & 1 figure from M3D-C1 team
- Also, JOREK modeling of JET

Chang Liu

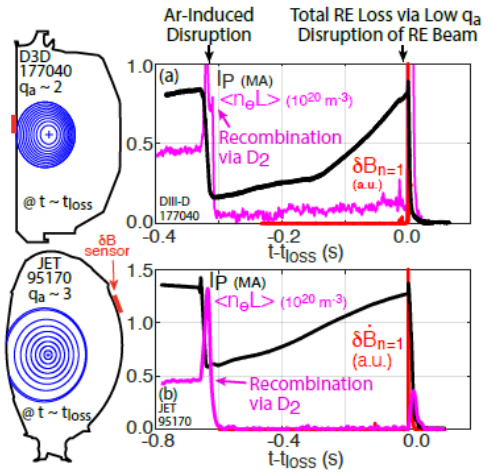
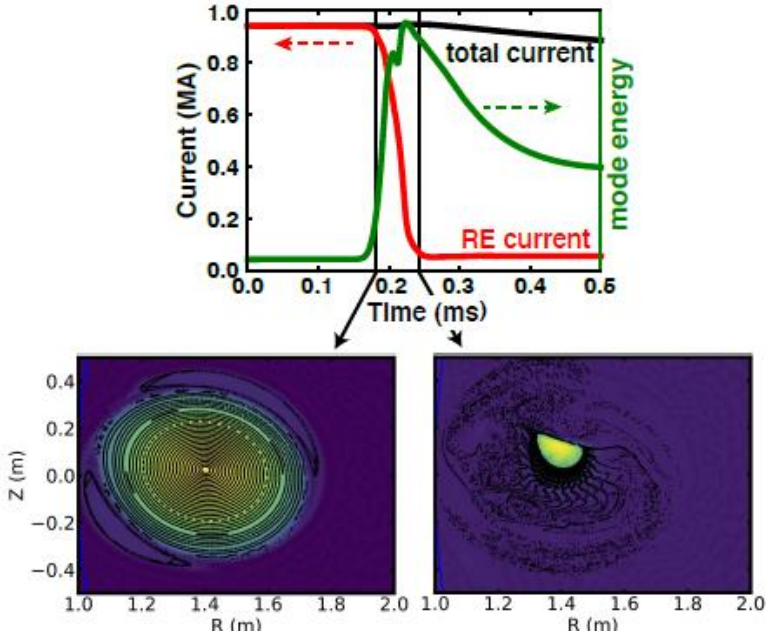
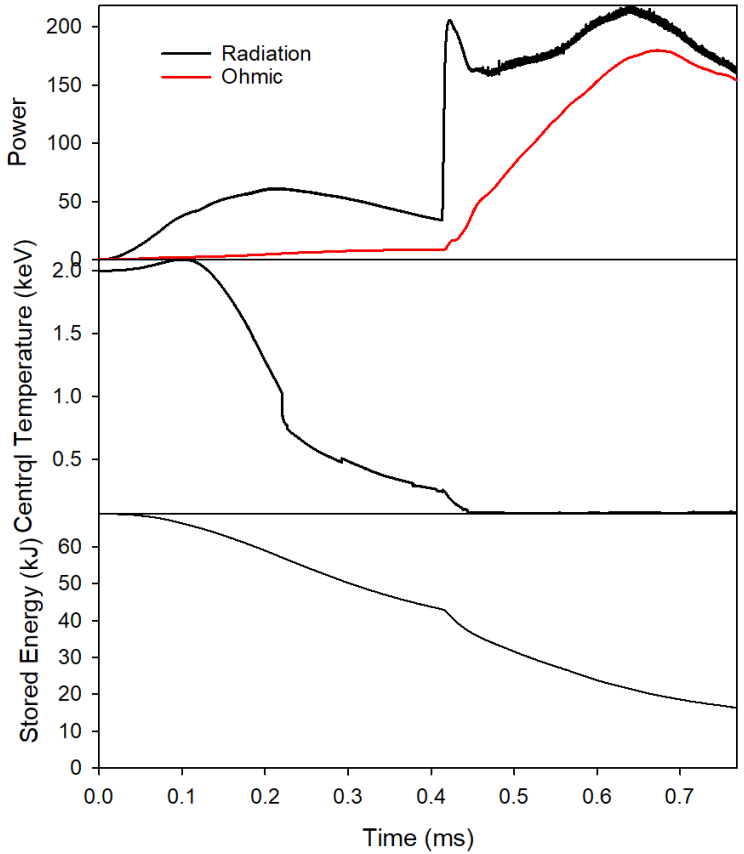


Figure 1: Observation of "D_2+kink" loss events in DIII-D and JET. Access to relatively low q_a in the presence of a re-combined plasma state resulting from D_2 injection promotes large-scale MHD instabilities that benignly terminate the RE beam. Examples with flat I_P also exist.

- D_2 injection into RE beam to purge high Z atoms from RE beam
- Lower q_a by I_P increase or a decrease
- RE beam becomes de-confined and current transferred to background plasma

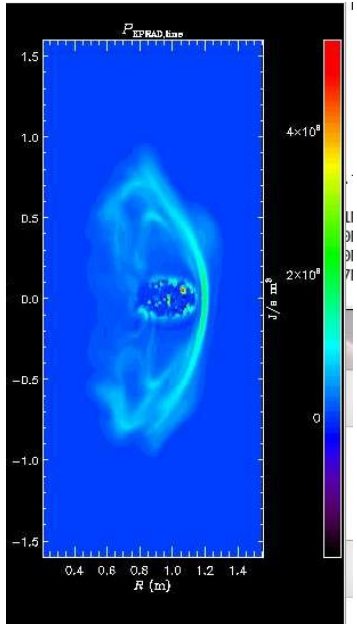


Carbon Mitigation in NSTX-U (shell pellet)



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 → 0.45 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

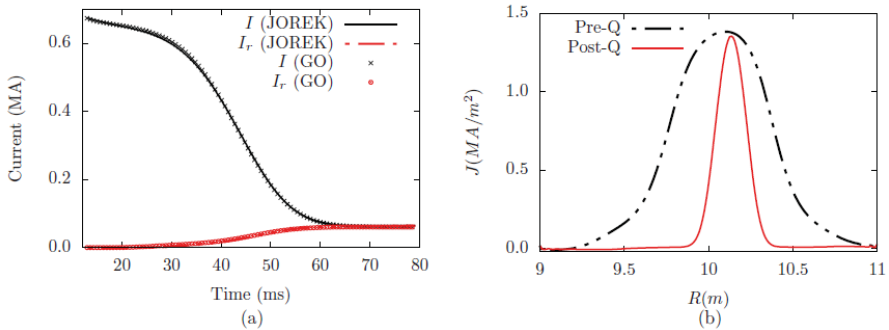
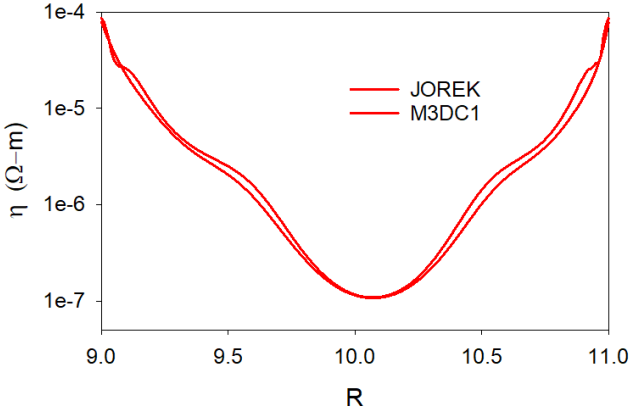
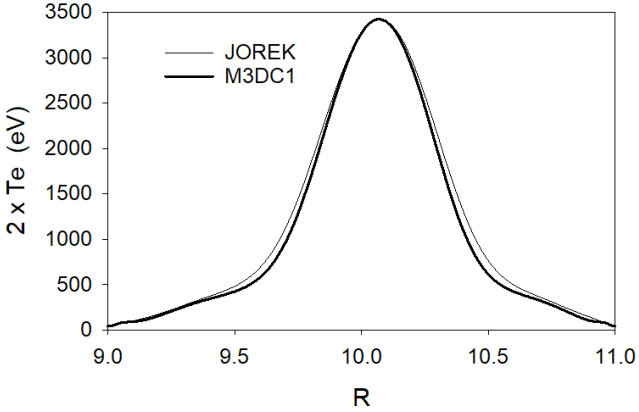


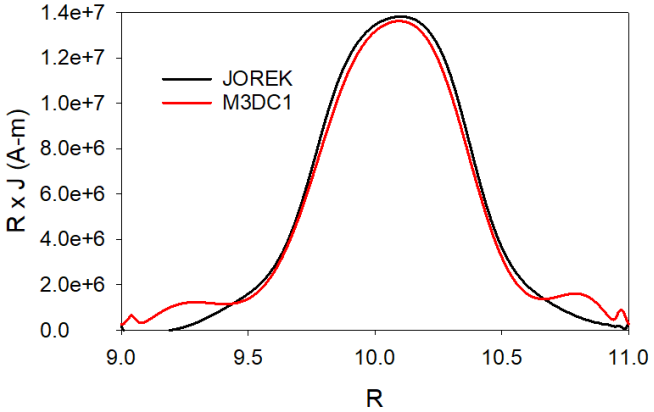
FIG. 3. (a) Time evolution of the total plasma current I and the RE current I_r during the current quench phase. (b) Midplane current density profiles before and after the current quench obtained from JOREK, showing a relatively peaked RE current profile.

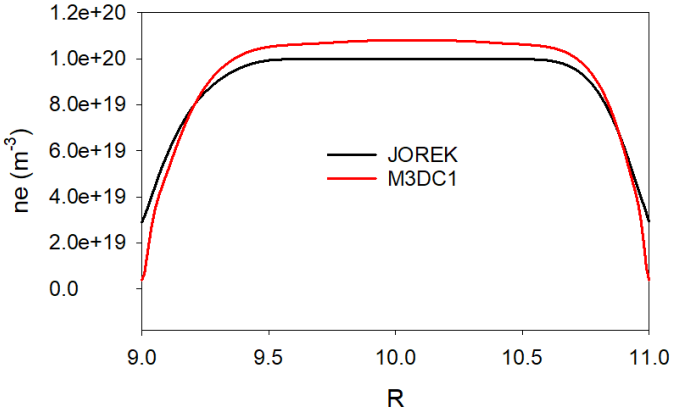
Chen Zhao

Comparison of initial profiles

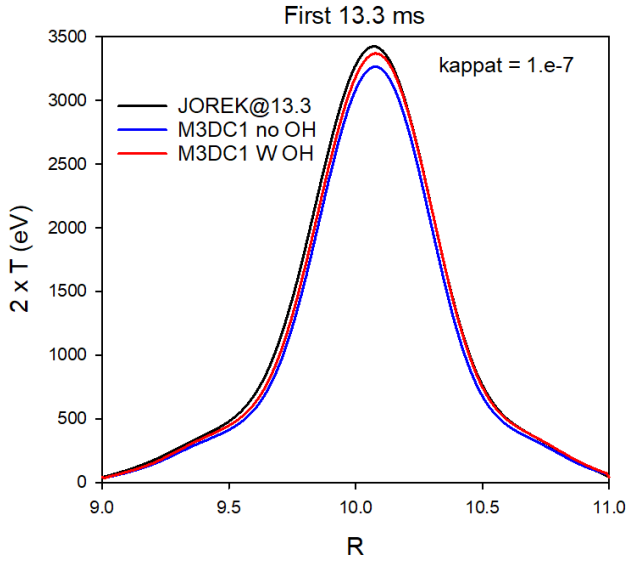


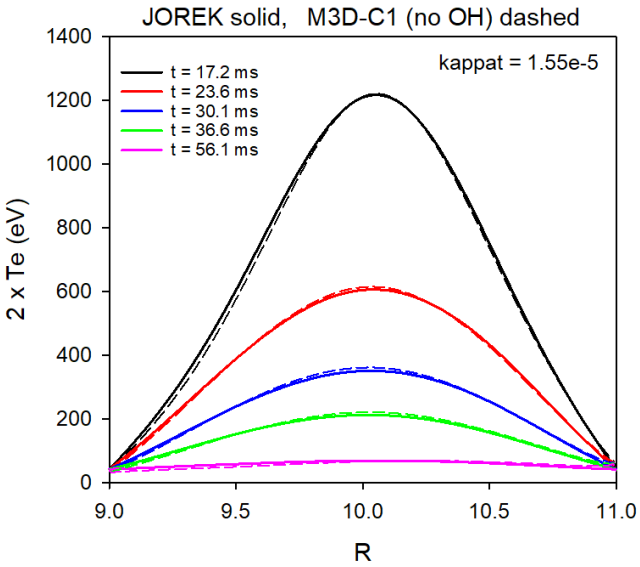






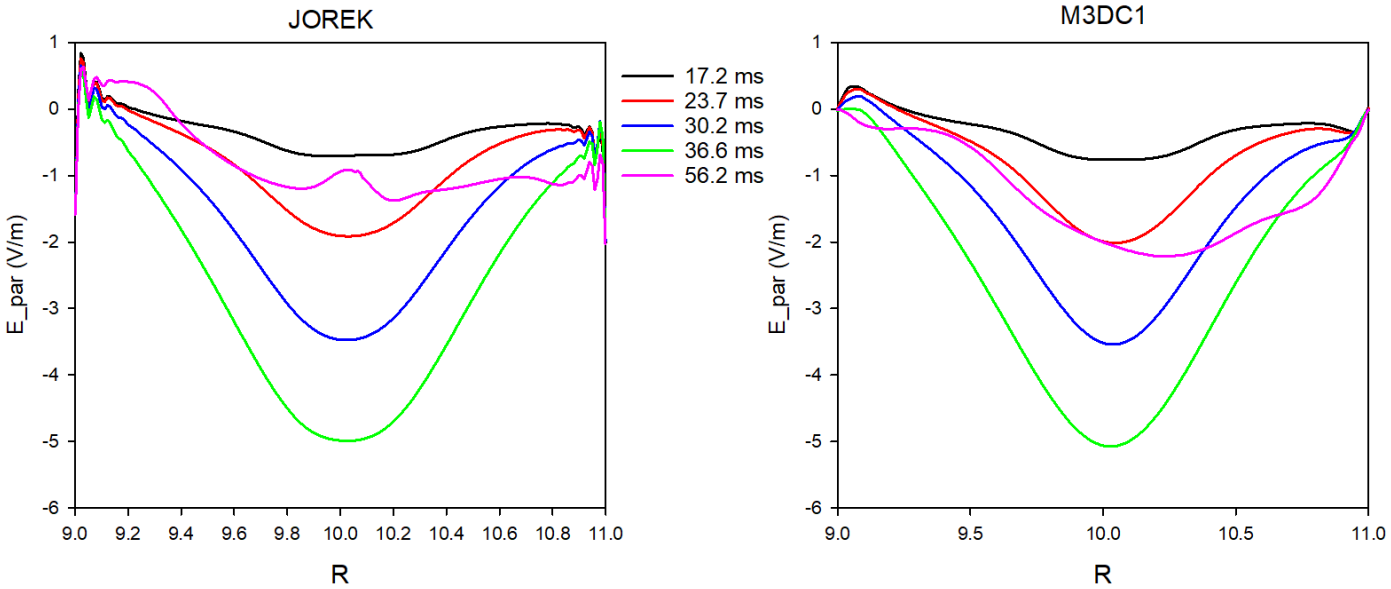
Comparison of T(R) at several times with no runaways



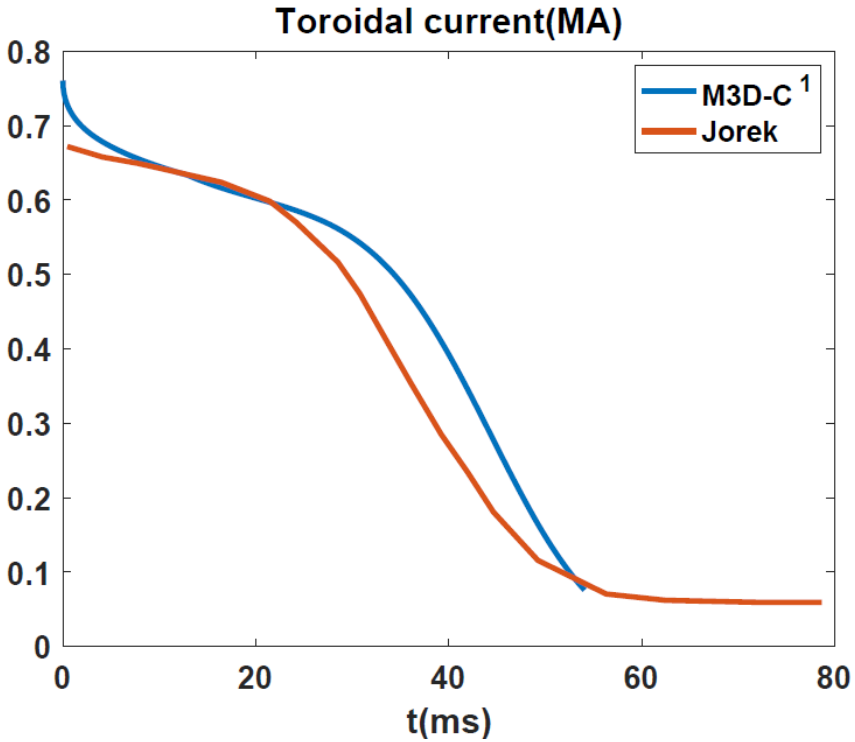


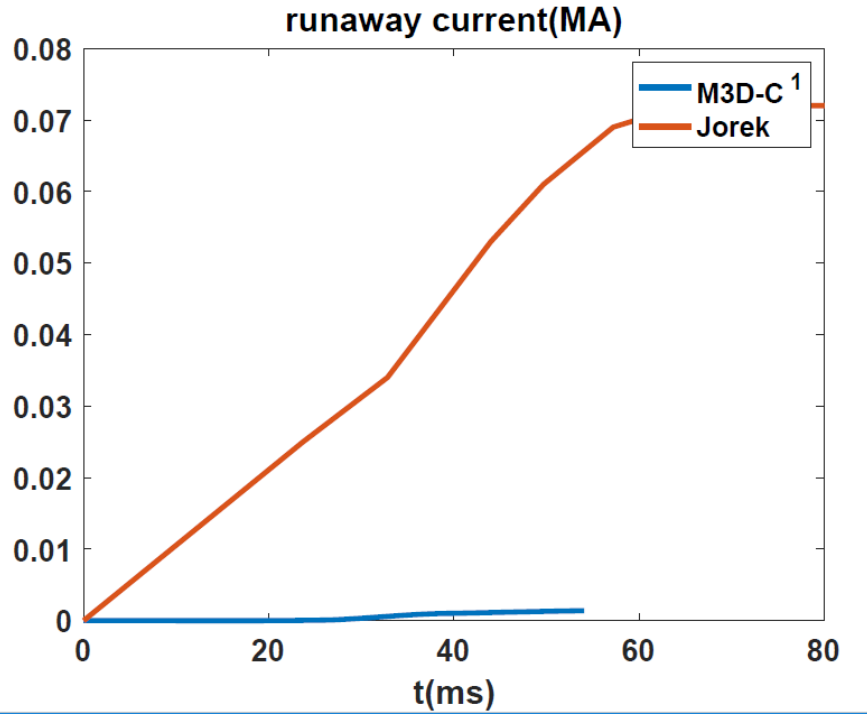
/p/tsc/m3dnl/Bandaru3

Comparison of E_par

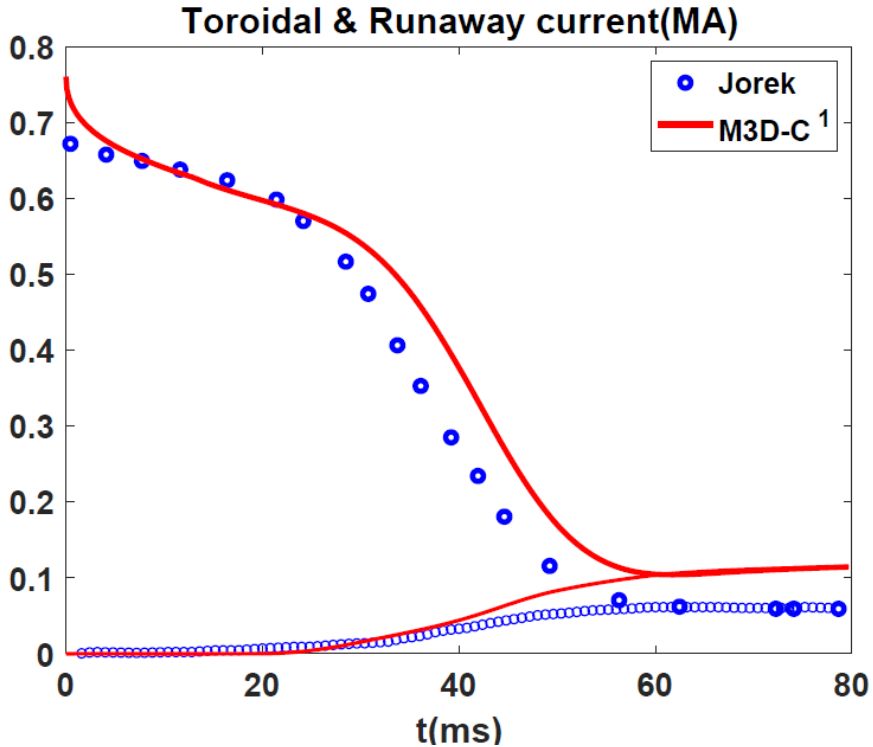


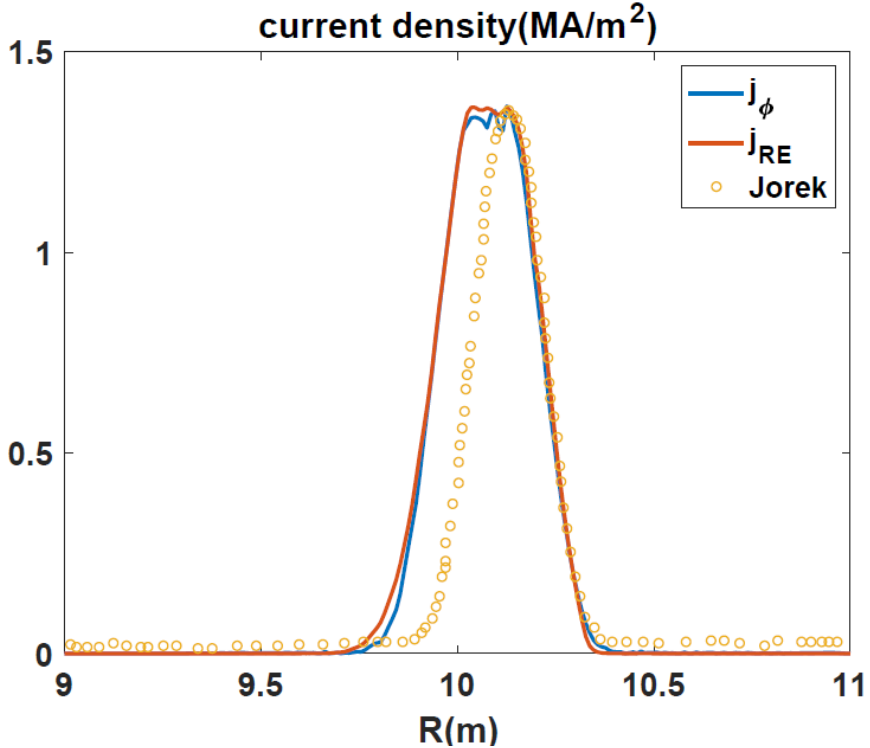
Initial results with Runaways (2/15/21) (Chen)





More recent results (2/26/21) (Chen)





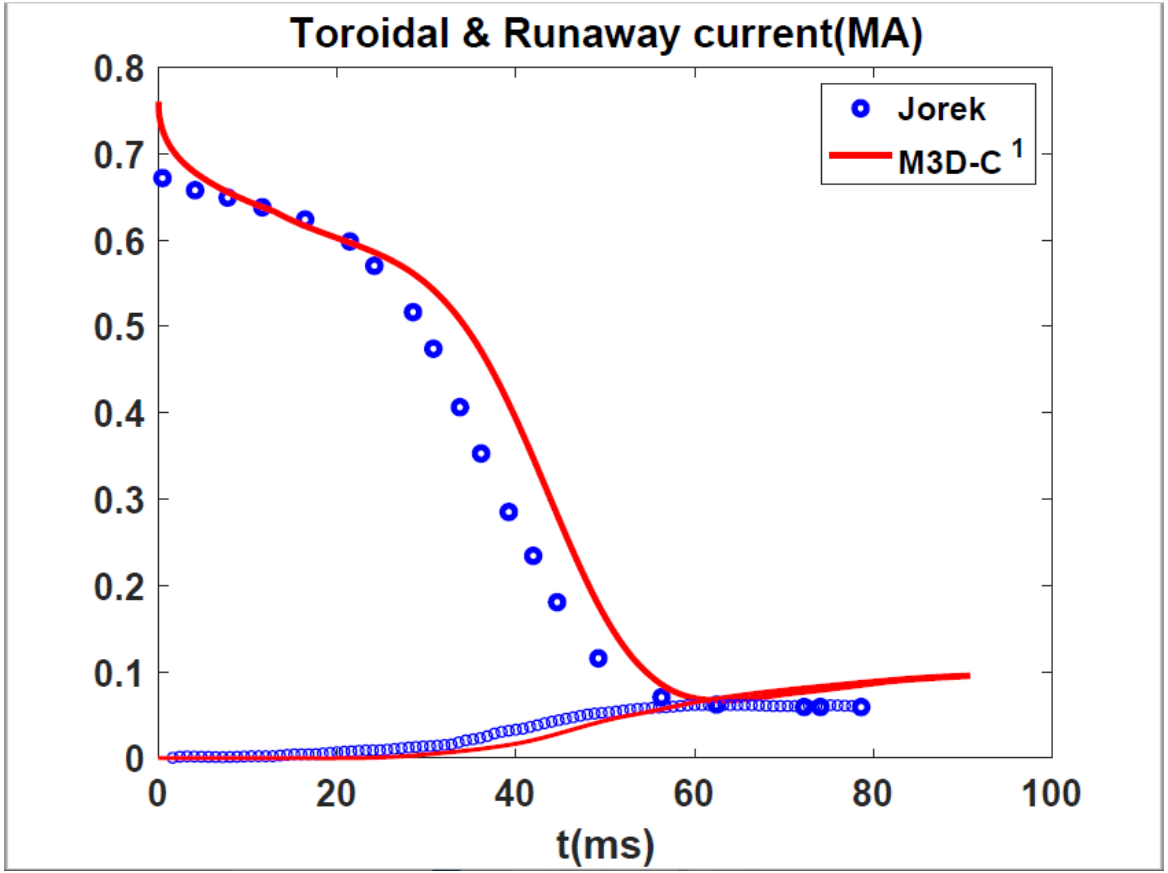
What is difference in old vs new?

$$\frac{dn_r}{dt} = n_e \nu_{ee} E^{-3(1+Z)/16} \exp\left[-1/(4E) - \sqrt{(1+Z)/E}\right] \qquad \nu_{ee} = n_e e^4 \ln\Lambda / 4\pi\varepsilon_0^2 m_e^2 v_{th}^3 \qquad v_{th} = \sqrt{2T_e / m_e}$$

$$E = (T_e / m_e c^2)(E_{EF} / E_c) \qquad E_c = n_e e^3 \ln\Lambda / 4\pi\varepsilon_0^2 m_e c^2 \qquad E_{EF} = \frac{\eta}{\mu_0}\left[\frac{4}{R}\frac{\partial}{\partial y} y \frac{\partial \psi}{\partial y} - \mu_0 J_{RE}\right]$$

(2x) Inserting this factor of 2 (as was done for the newer results) gives much better agreement. This could be due to the difference in ln Λ . JOREK used ln Λ = 10

Update 03/08/21

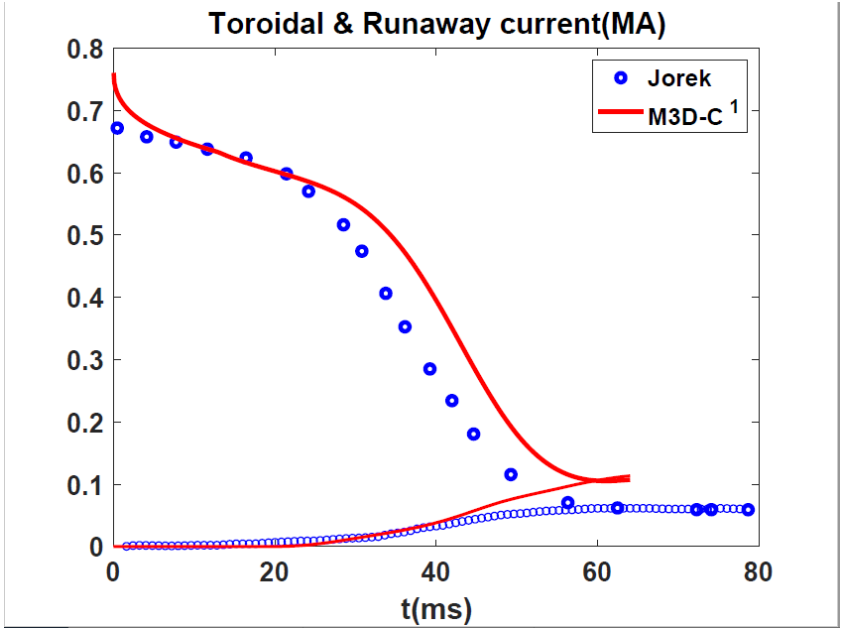


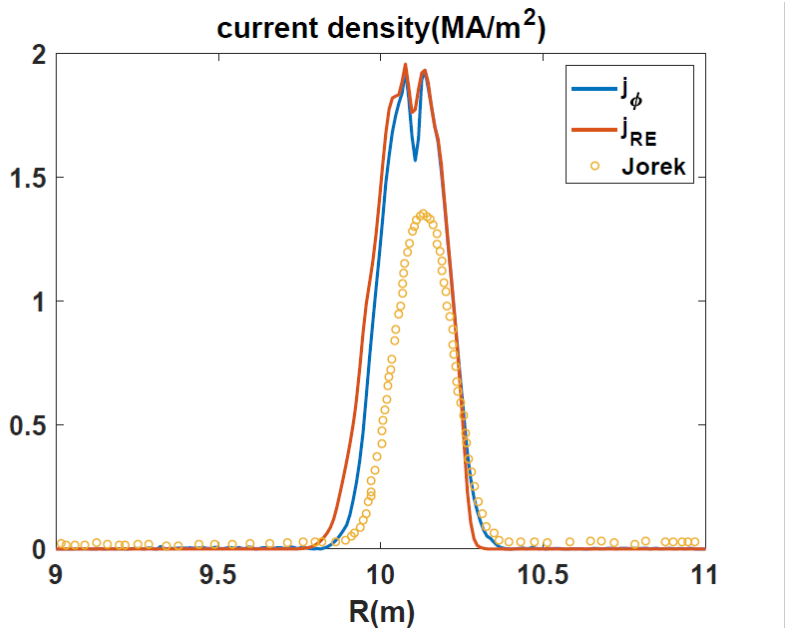
Chen email 03/08:

I have read the reference mentioned in the Jorek paper about the Go code **Nucl. Fusion 53 (2013) 123017**. The Go code assume the runaway velocity as speed of light. I have tried the using v_ra ~ c and log(lambda) = 10, the results is much closer to the paper as attached.

- Is the GO code open source? Can we get a copy and compare directly with it?

Update 3/13/21

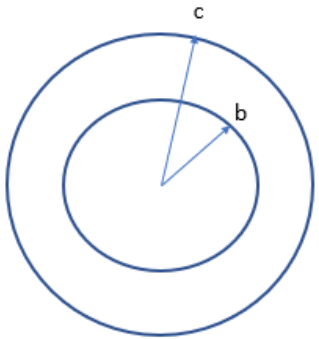




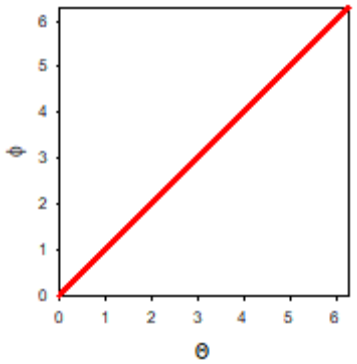
$\ln\Lambda = 13$ and $V_{RA} = c$

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?

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

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

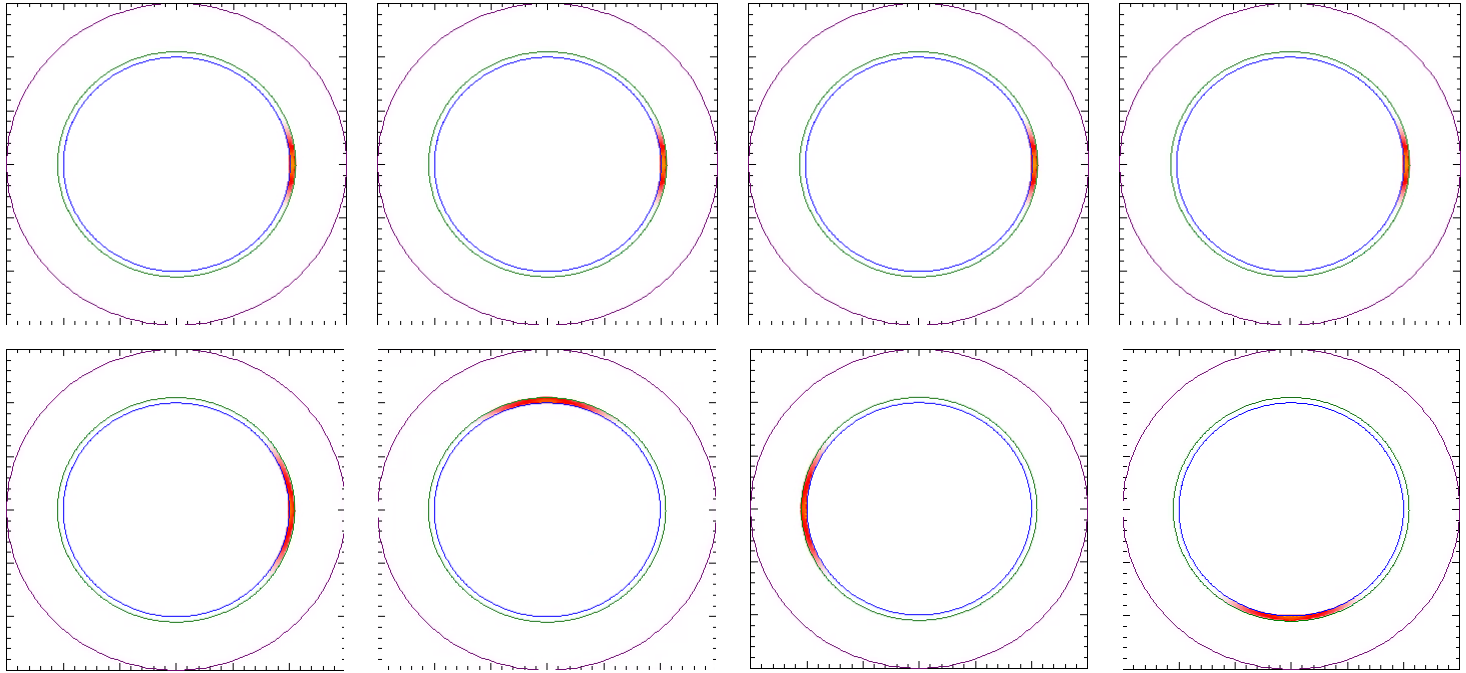
What is driving the current in the θ direction? It can't be Φ unless

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

Comparison between Straight and helical band

Straight ➔

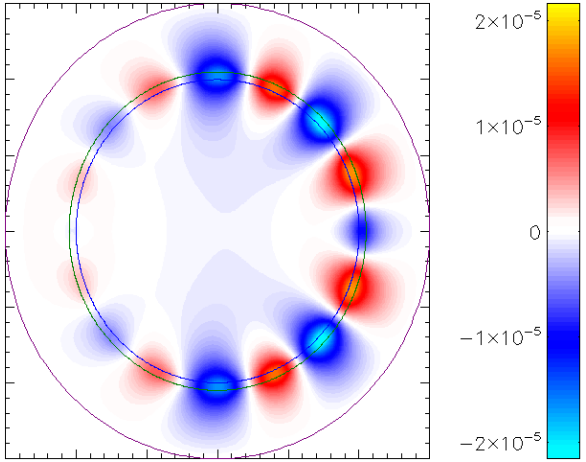
Helical ➔



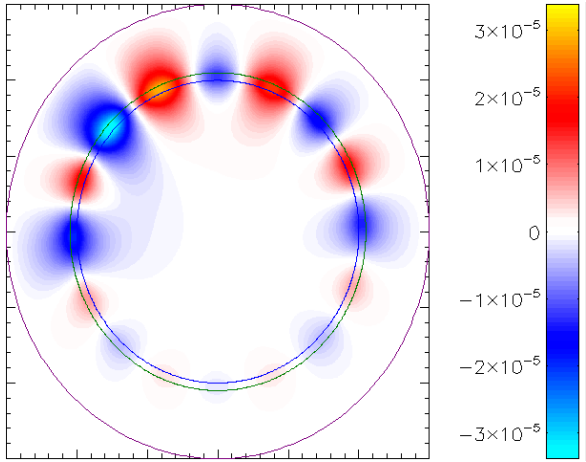
$\varphi = 0$ $\varphi = \pi / 2$ $\varphi = \pi$ $\varphi = 3\pi / 2$

Φ_φ

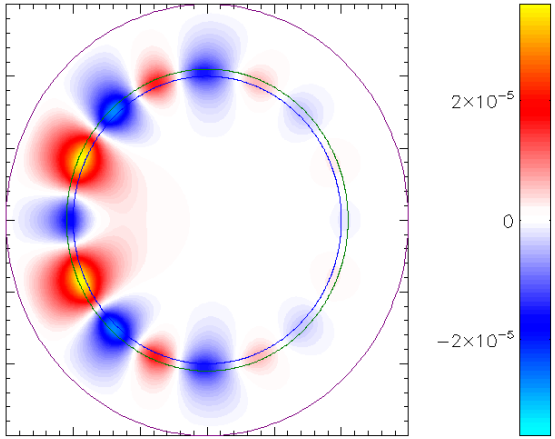
φ = 000°



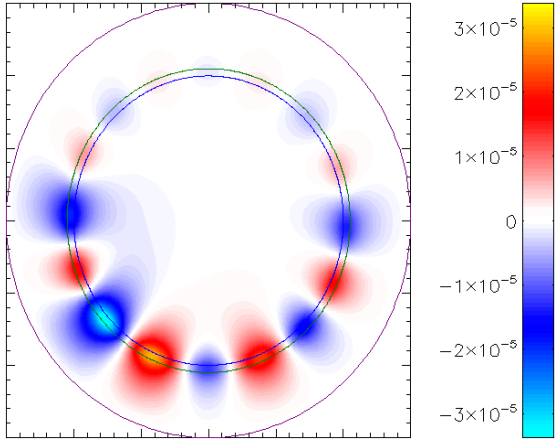
φ = 090°



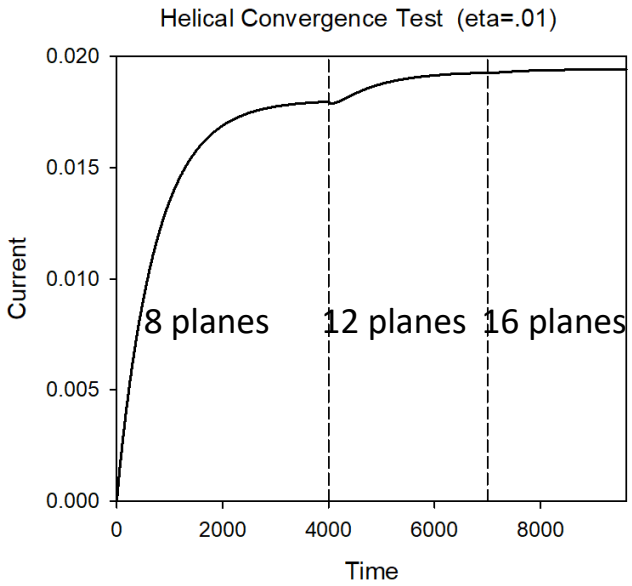
φ = 180°

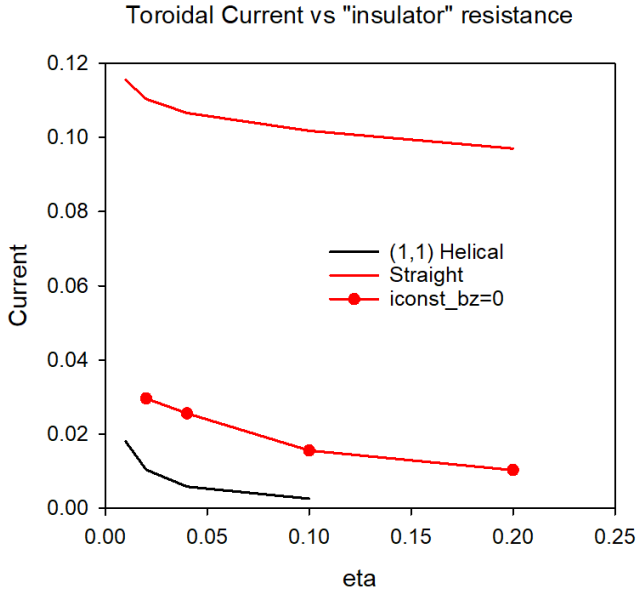


φ = 270°



Some Convergence Tests

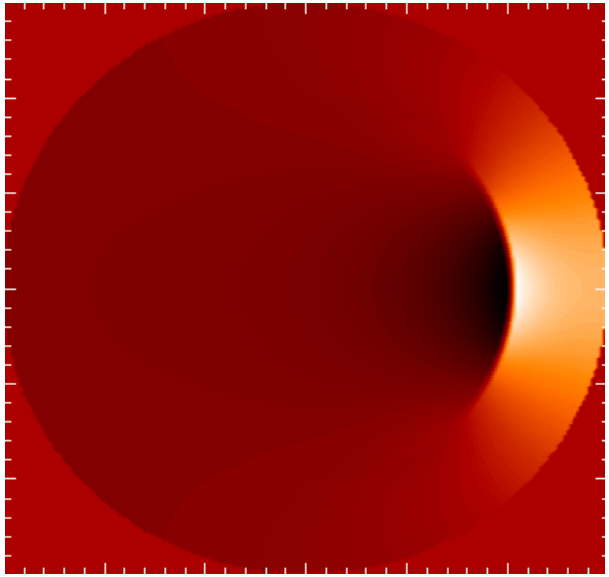




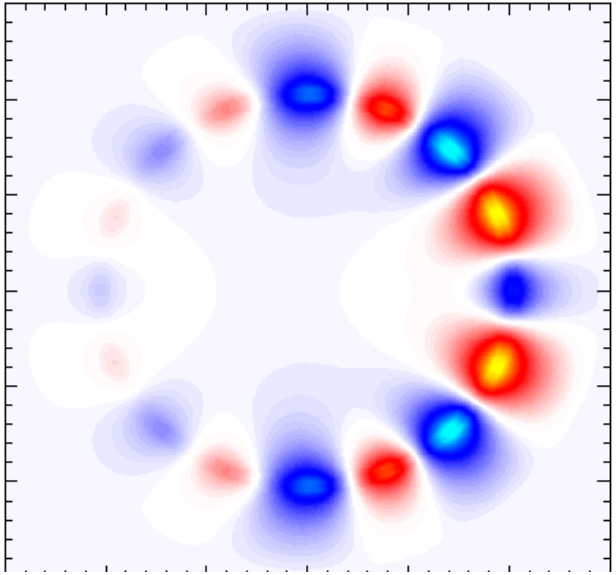
- Wall current appears to be converged in # of planes
- Helical wall current tending towards zero for large values of insulator resistance
- Now testing dependence on boundary conditions (location of ideal wall)
- Helical (1,2) case gives less than half the current of helical (1,1) case
- Iconst_bz=0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

Plots for iconst_bz=0

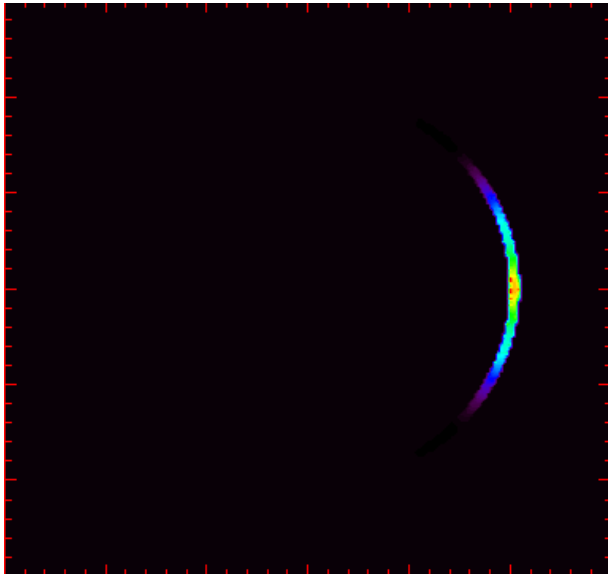
I



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



J_{φ}



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

That’s All I have

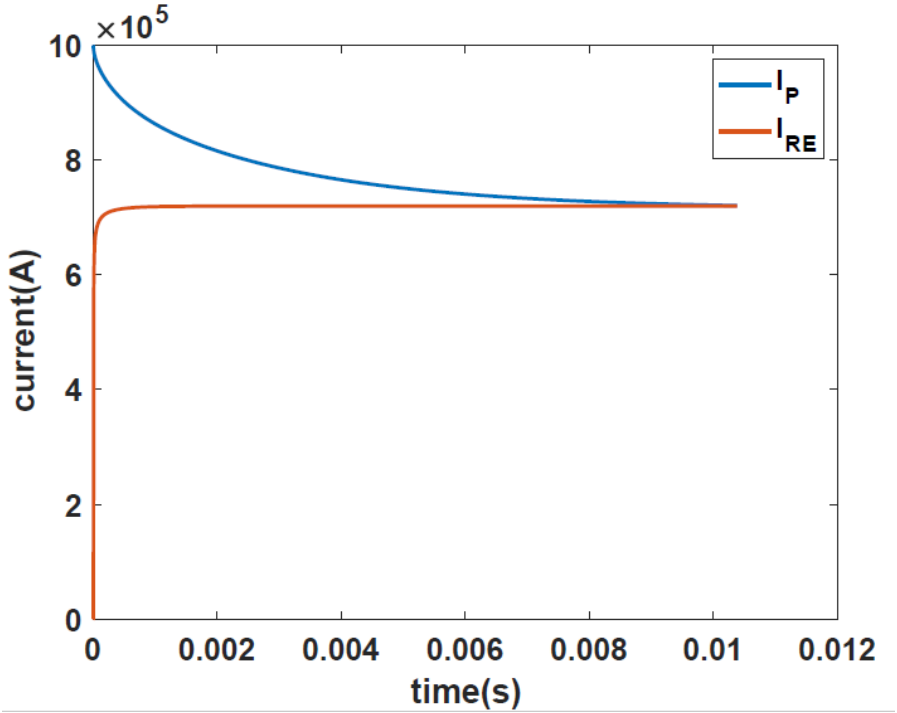
Anything Else ?

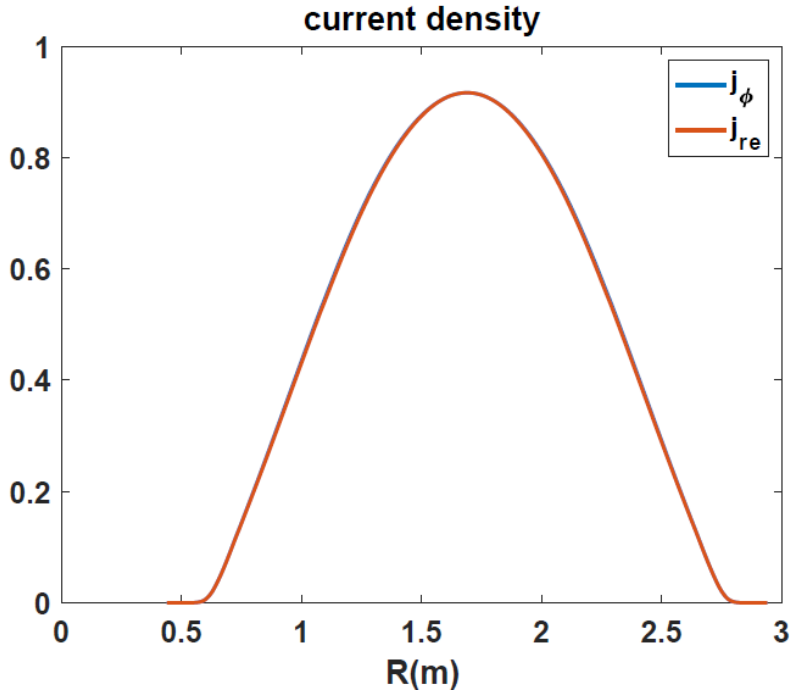
Local Systems

- 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

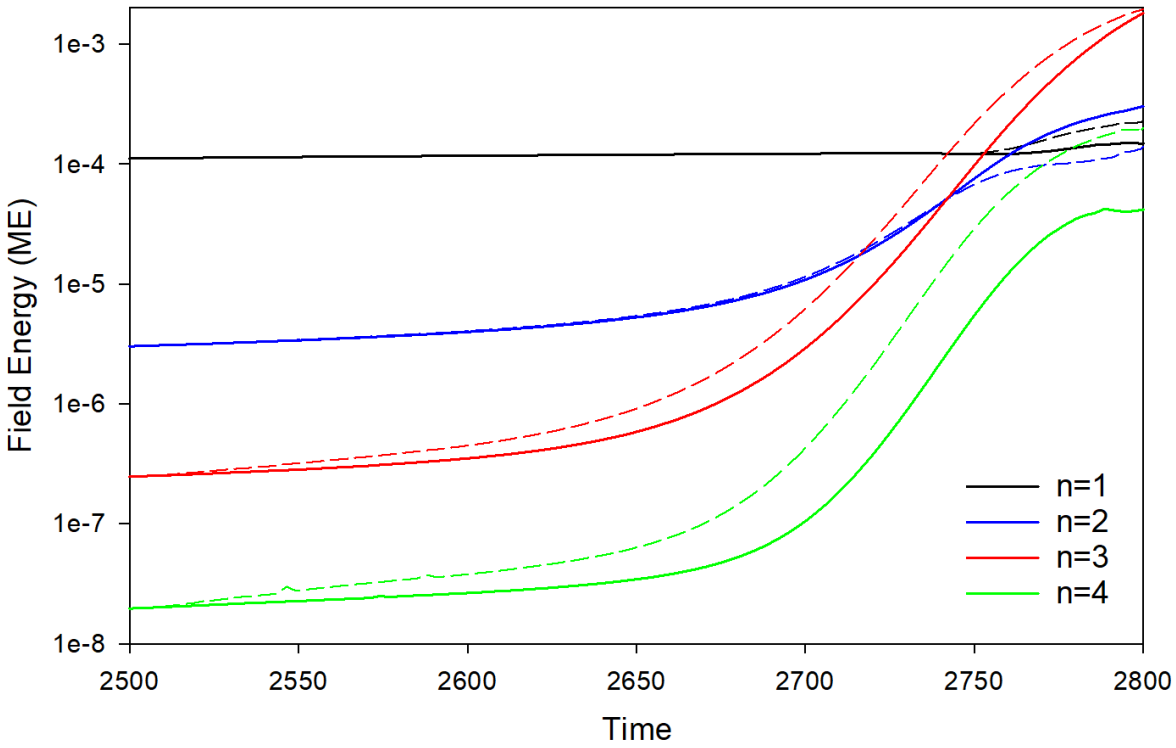
2D (cylindrical) RE with sources (12/19/2020)



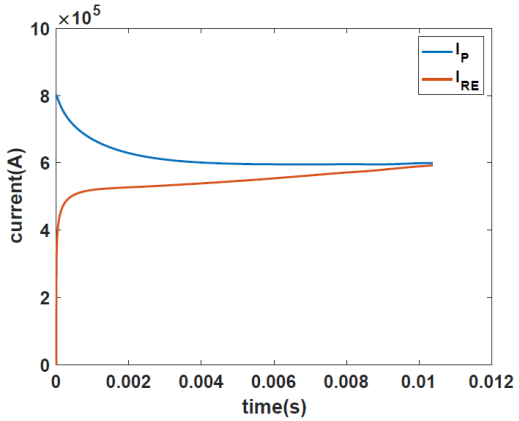


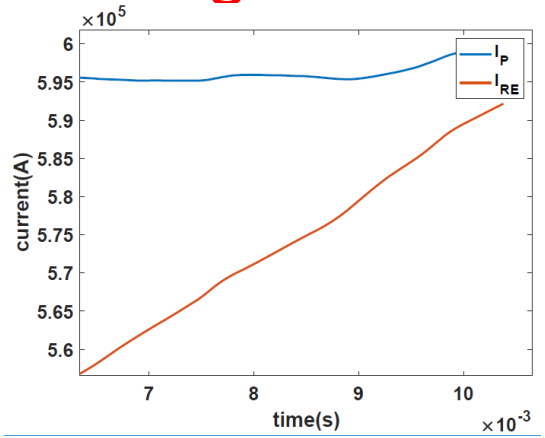
Chen Zhao

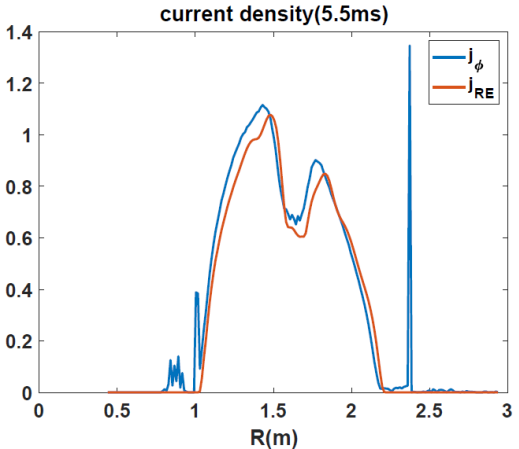
Energy in base case 36742317 (solid) and 16 plane case 37248033 (dashed)

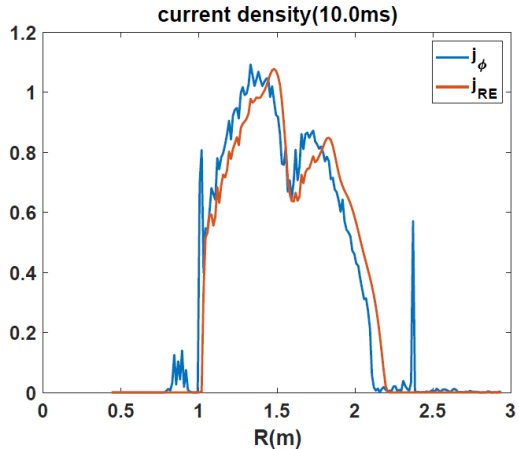


DIII-D 177053 with Argon





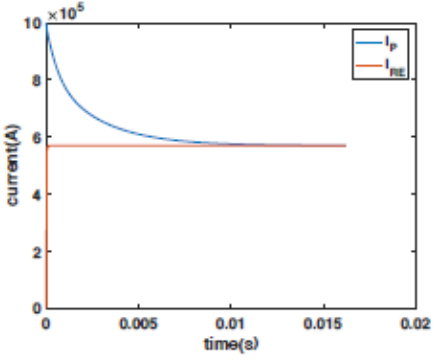


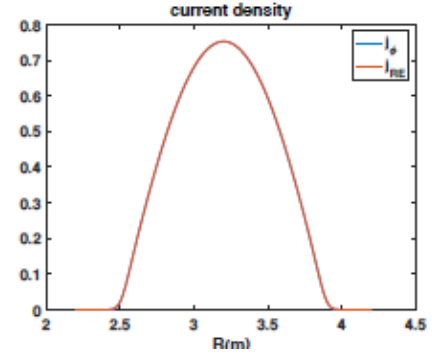


Chen Zhao

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?

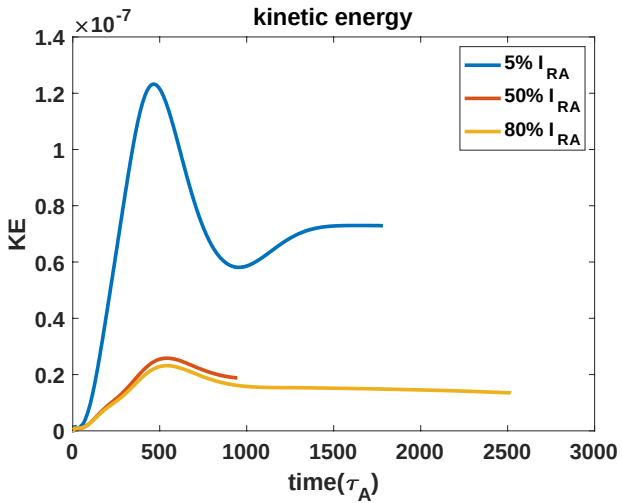
- M3D-C1/NIMROD 3D Benchmark

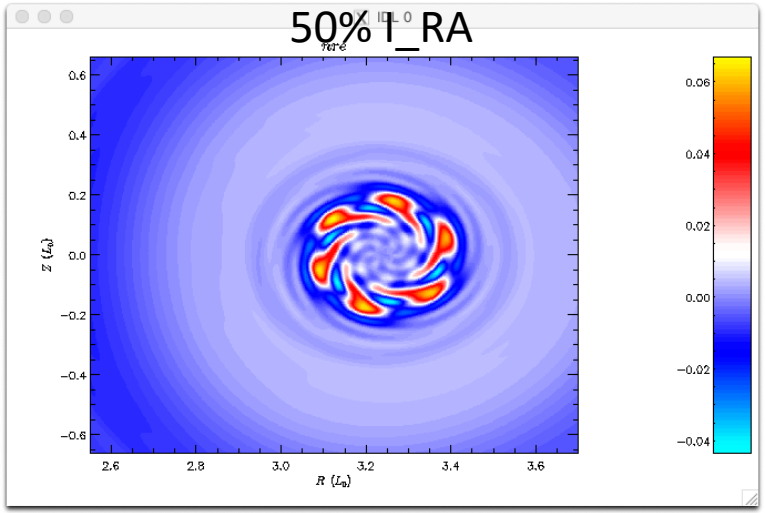
NSTX shot 1224020 – Fast ion transport with coupled kink and tearing modes
Chang Liu

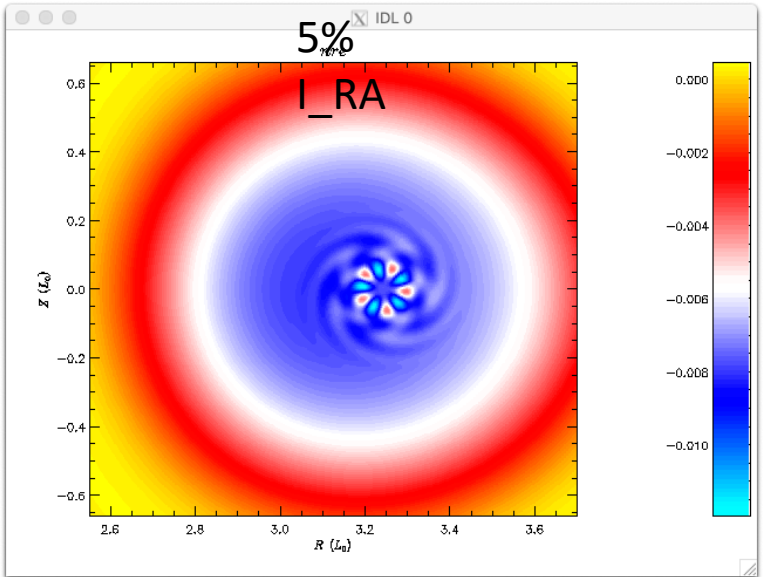
DIII-D Neon pellet mitigation simulation for KORC

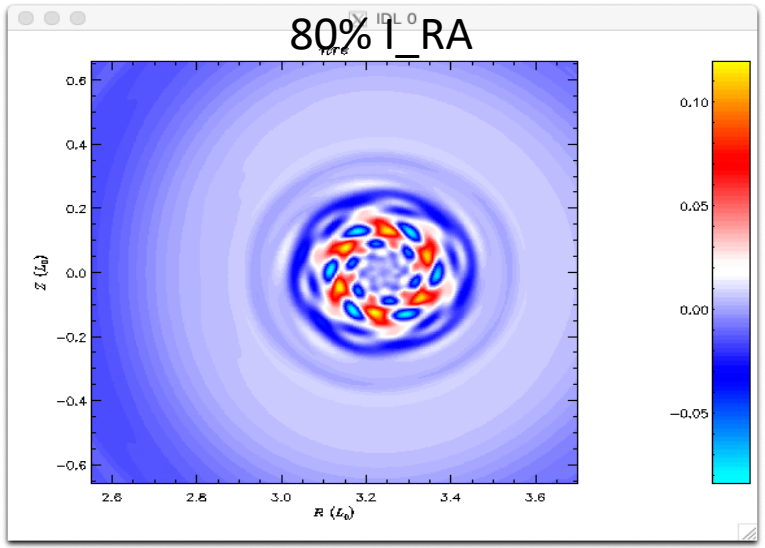
- Brendan Lyons trying to extend 8 plane case to 32 planes

SPARK ? Do we need to do anything?


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

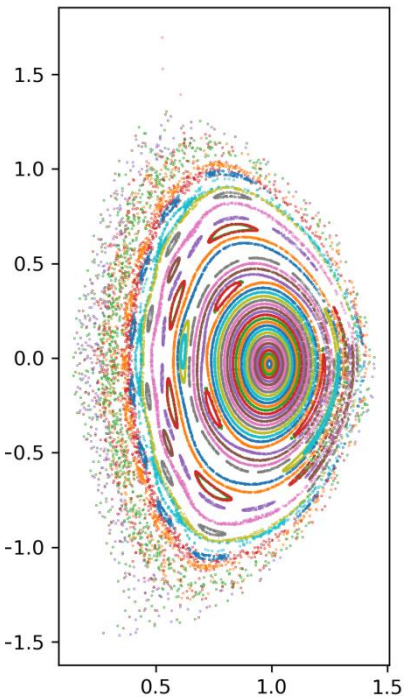

50% I_RA
IDL 0
Z (L_0)
R (L_0)


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

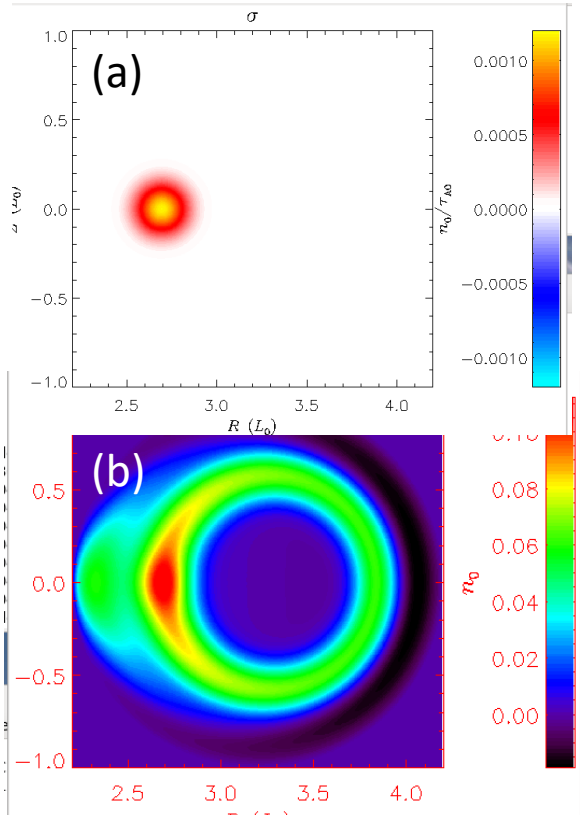
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

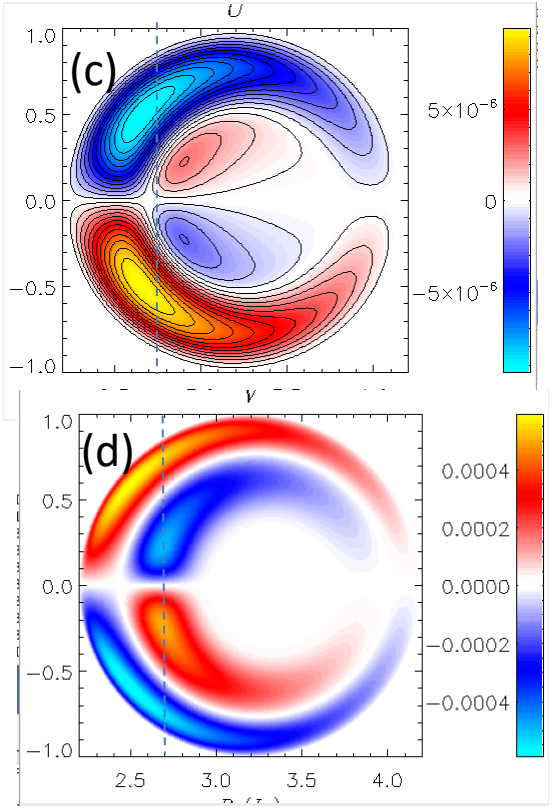
(a) Density source in 1F toroidal equilibrium

(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

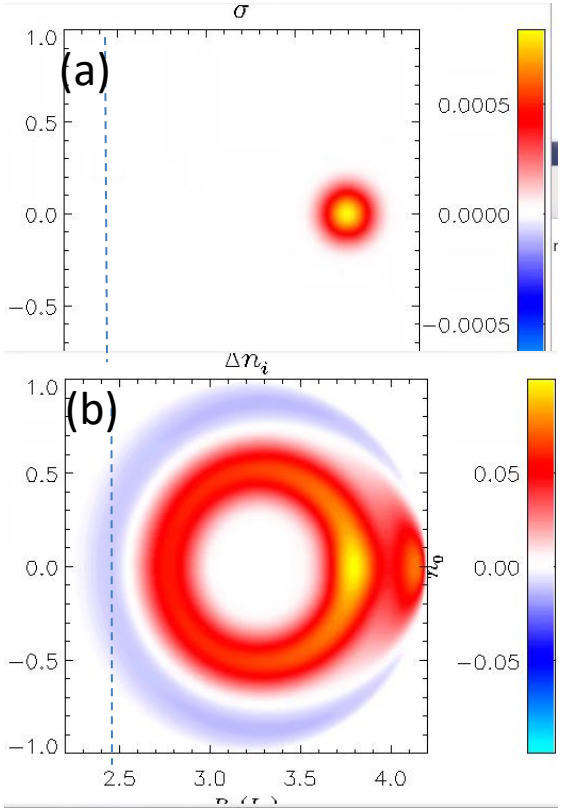
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

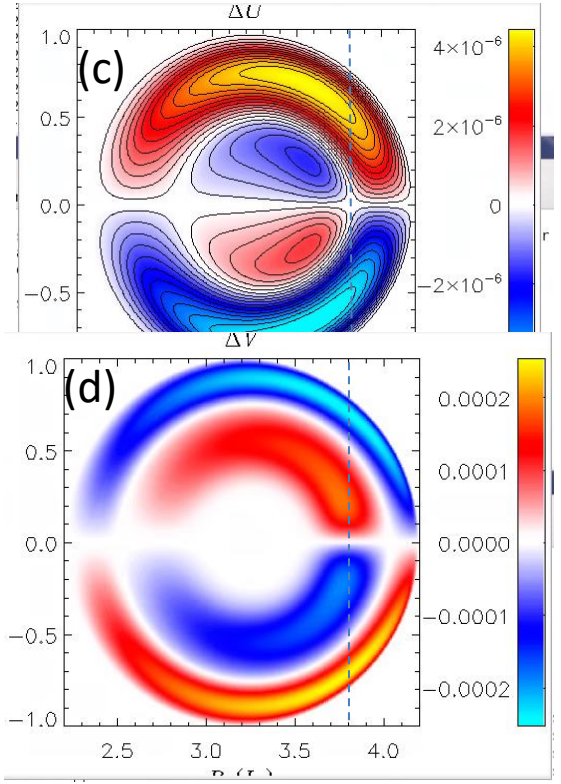
(a) Density source in 1F toroidal equilibrium

(b) Change in density after 10^3 τ_A

(c) Poloidal velocity stream function

(d) Toroidal velocity contours





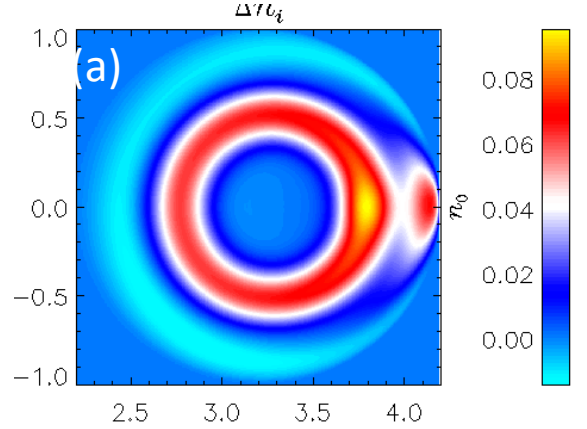
Grad-B drift in M3D-C1—2F effects

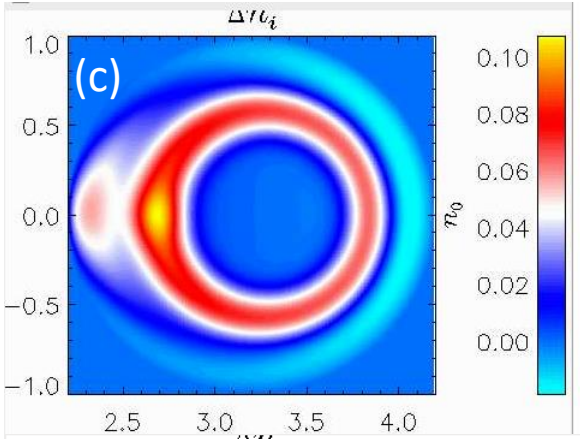
(a) 2F density change after 10^3 τ_A for LF side source

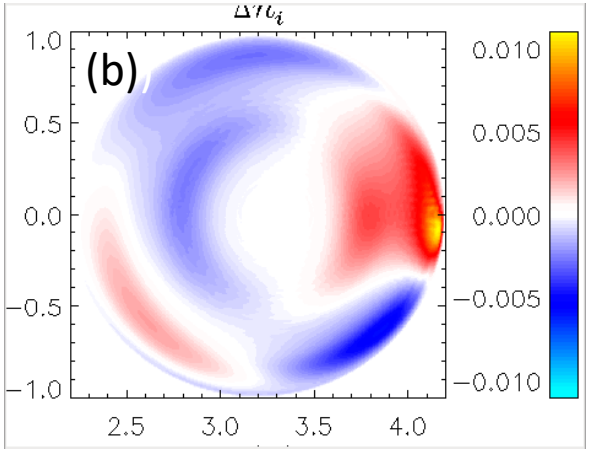
(b) Difference in 1F and 2F density (LF)

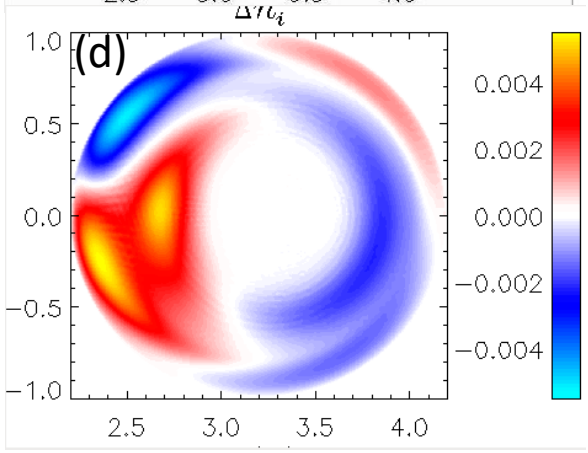
(c) 2Fdensity change after 10^3 τ_A for HF side source

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

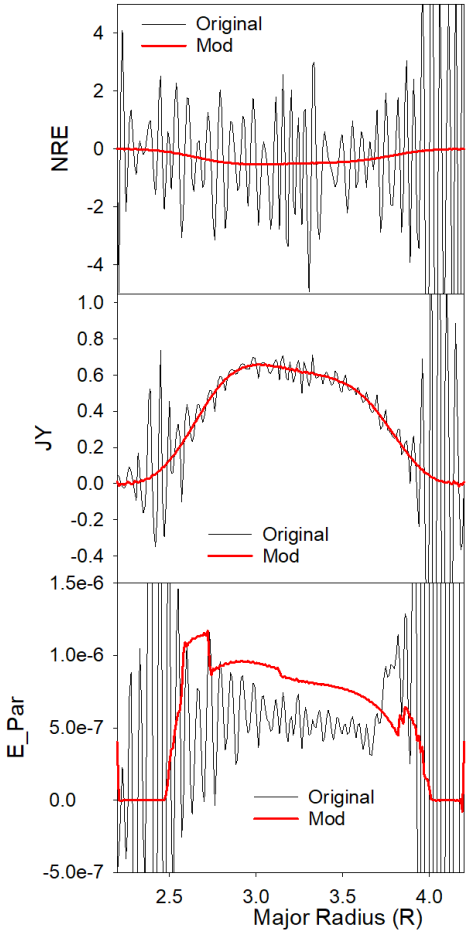








Sawtoothing discharge with runaway electrons

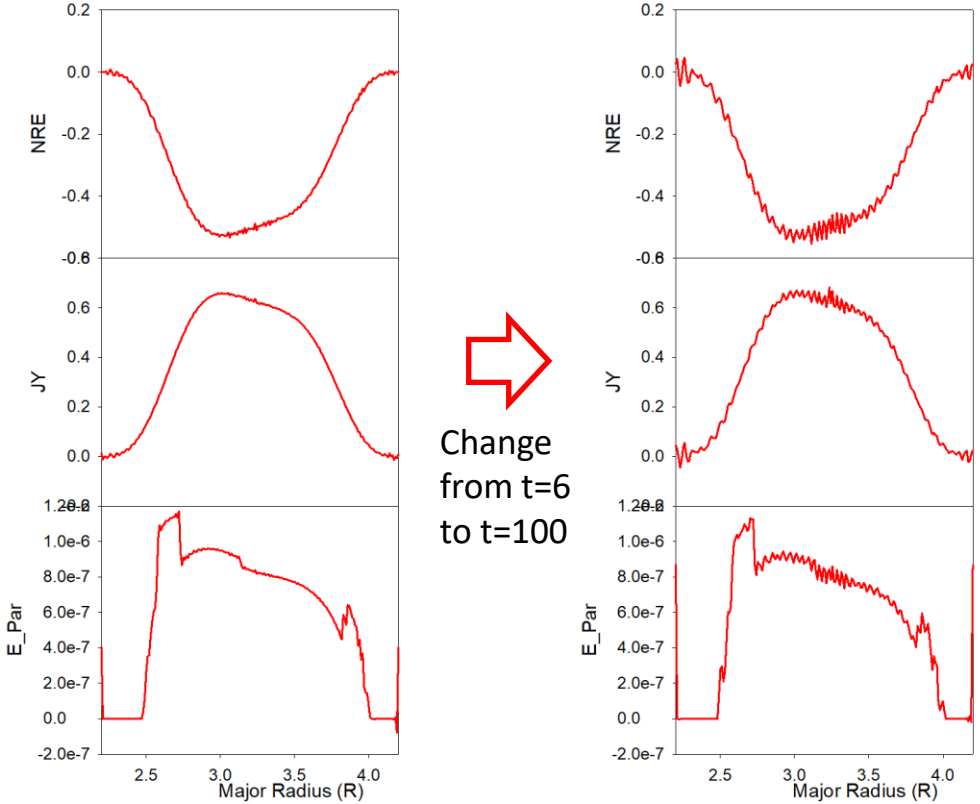


Profiles of nre, jy, and E_par after 30 timesteps

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?