M3D-C1 ZOOM Meeting

11/03/2020

Agenda

1. CS Issues
    1. GPU solve status and skeleton codes Jin Chen
    2. LBL Report (optional)
    3. Local systems
    4. Other systems
    5. NERSC Time
    6. Changes to github master since last meeting
    7. Comments on Explicit method for Alfven Wave Simulation –
    8. Status of bf=f with bfp=df/d(phi) and Bug report
2. Physics Studies
    1. Proposal to improve numvar=1 model with parallel velocity
    2. Status of first coupled M3D-C1/LP Simulation .. Lyons/Samulyak
    3. ITER External Field B_R vs R
    4. Update on sawtooth with runaways
    5. Status of other simulations
    6. Other?

GPU solve status – and Skeleton codes

Jin Chen to update

1. Debugging on Traverse

LBL Report

Local Systems

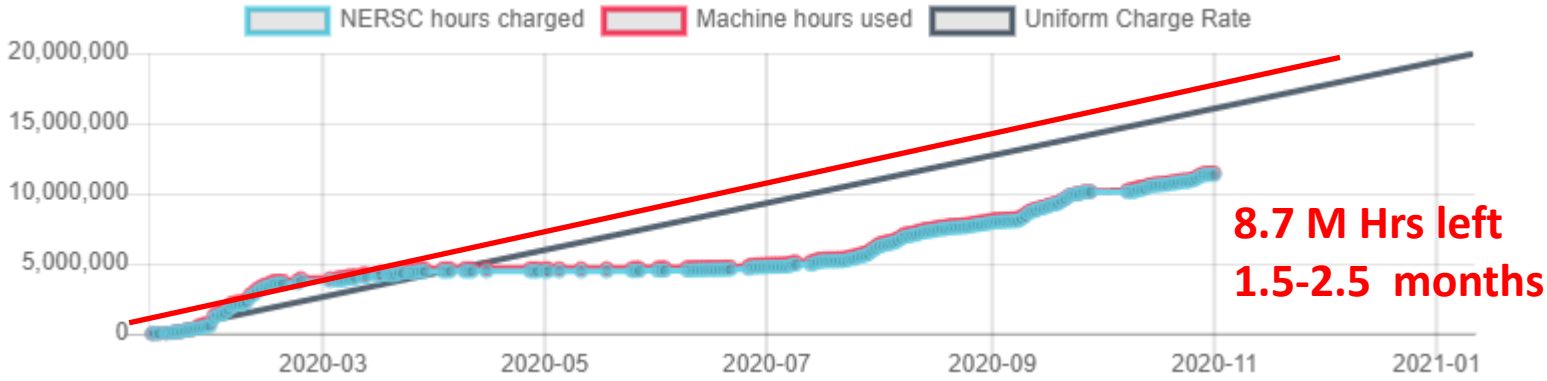
- PPPL centos7(11/2)
  - All 6 regression tests PASSED on centos7:
- PPPL greene (11/2)
  - 5 regression tests PASSED
  - No batch file found for pellet
- EDDY (11/2)
  - All 6 regression tests PASSED
- TRAVERSE(11/2)
  - Code compiles
  - Regression test failed: split_smb not found in PATH
  - Have not yet tried shipping .smb files from another machine

Other Systems

- Cori-KNL (11/2)
  - 6 regression tests passed on KNL
- Cori-Haswell (11/2)
  - 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
- 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)
  - ??

NERSC Time

mp288



m3163

Closed for general use

- Should be enough mp288 time to last until new PU/PPPL computer arrives in fall – red line is linear usage until Dec 15 (New estimated arrival date)
- New NERSC allocations start Jan 15 2021

Changes to github master since last meeting

- S. Jardin
  - 10/30/20: added test on input to flag if ipressplit=1 and numvar < 3 to prevent code crashing

Comments on Explicit Method for Alfven Wave Simulation

Chang Liu made the suggestion last week that we could greatly speed up the code if we didn't have to refactor the implicit matrix each timestep:

$$\mathbf{S}\bullet\mathbf{X}^{n+1} = \mathbf{D}\bullet\mathbf{X}^{n} + \mathbf{b} \quad \Rightarrow \quad \mathbf{S}_0\bullet\mathbf{X}^{n+1} = \mathbf{D}\bullet\mathbf{X}^{n} + \mathbf{b} - \left(\mathbf{S} - \mathbf{S}_0\right)\bullet\mathbf{X}^{n}$$

Something like this is possible for purely parabolic equations, called the semi-implicit method. Consider:

$$\frac{\partial u}{\partial t} = \sigma\nabla^2 u$$

Evaluate as:

$$\frac{\partial u}{\partial t} = \sigma_0\nabla^2 u^{n+1} + \left(\sigma - \sigma_0\right)\nabla^2 u^{n}$$

This can shown to be stable for $\sigma_0 > \sigma/2$. Not aware of any similar stability result for hyperbolic problems.

See Computational Methods in Plasma Physics, Sec. 7.3.3

Status of replacing bf = f with bfp = df/dφ

$$\mathbf{A} = R^2 \nabla \varphi \times \nabla f + \psi \nabla \varphi - F_0 \ln R \hat{Z}$$

$$\mathbf{B} = \nabla \psi \times \nabla \varphi - \nabla_\perp f' + F \nabla \varphi$$

$$F \equiv F_0 + R^2 \nabla \bullet \nabla_\perp f \qquad \text{(note: } f' \equiv \partial f / \partial \varphi\text{)}$$

Presently,

$$\dot{F} = \ldots$$

$$R^2 \nabla \bullet \nabla_\perp f = F - F_0$$

Proposed (by Yao) to eliminate one derivative on *f*

$$\dot{F} = \ldots$$

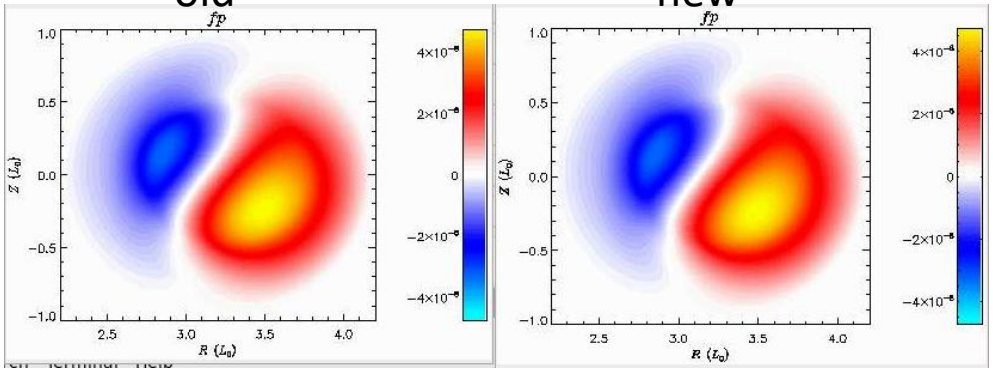
$$R^2 \nabla \bullet \nabla_\perp f' = F'$$

Status of replacing bf = f with bfp = df/dφ

- Changes were made (almost independently) by S. Jardin and Y. Zhou
- All regression tests passed
- Other, longer linear and nonlinear runs compared and passed
- Yao to verify restart backward compatibility and commit

old

new



Test Problem: Non-resonant (1,1) mode in a low magnetic shear tokamak with sheared rotation

Bug Report: 10/30/2020

When including 2-fluid corrections to the stabilization operator for the vorticity equation (only for itwofluid=2), the following term arises:

$$\mathrm{V1HCHIF} = +\frac{2}{R^2}\chi_Z\left[\nu_i, f''\right] + \frac{1}{R^2}\Delta^*\chi'\left(\nu_i, f'\right)$$

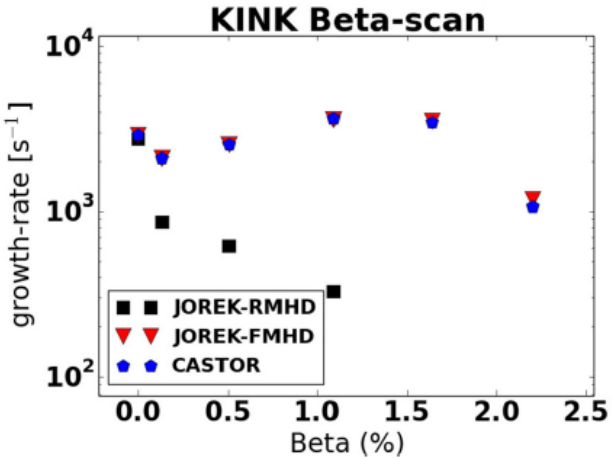
This was incorrectly coded as:

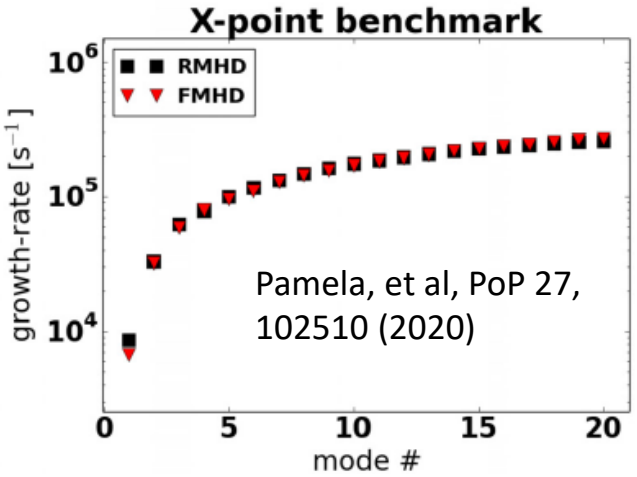
$$\mathrm{V1HCHIF} = +\frac{2}{R^2}\chi_Z\left[\nu_i, f''\right] + \frac{1}{R^2}\Delta^*\chi'\left(\nu_i, f'\right) - 2\frac{1}{R^3}\left[\nu_i, f\right]\chi'_R$$

And has been corrected as part of the bf → bfp change.

Proposal to improve numvar=1 model

- A recent PoP paper compares JOREK reduced MHD model with full MHD





- The reduced model shows very good agreement for ballooning modes, tearing modes, VDEs, but not so good agreement for the internal kink mode
- The reduce model is much faster than the full model and is widely used
- Question: Should we improve our numvar=1 model and user it more?

Proposal to improve numvar=1 model-2

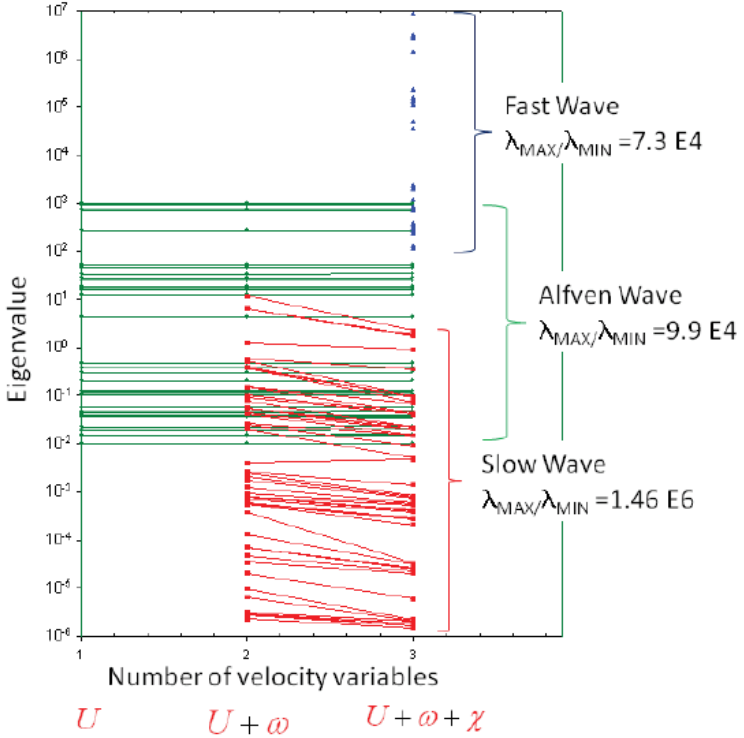
Presently, for numvar=1 we have 1 velocity variable, 1 magnetic field variable, but we can evolve the density and pressure(s) or temperature(s)

$$\mathbf{V} = R^2 \nabla U \times \nabla \phi \qquad \mathbf{B} = \nabla \psi \times \nabla \phi + I_0 \nabla \phi$$

This very effectively resolves the Alfven wave but not the slow wave.

I think it would be relatively easy to add a velocity parallel to B to bring in the slow wave by making some approximations

$$\mathbf{V} = R^2 \nabla U \times \nabla \phi + V_{\parallel} \mathbf{B} / B \quad \text{(proposed)}$$



Proposal to improve numvar=1 model-3

Just need to add 1 more equation for numvar=1:

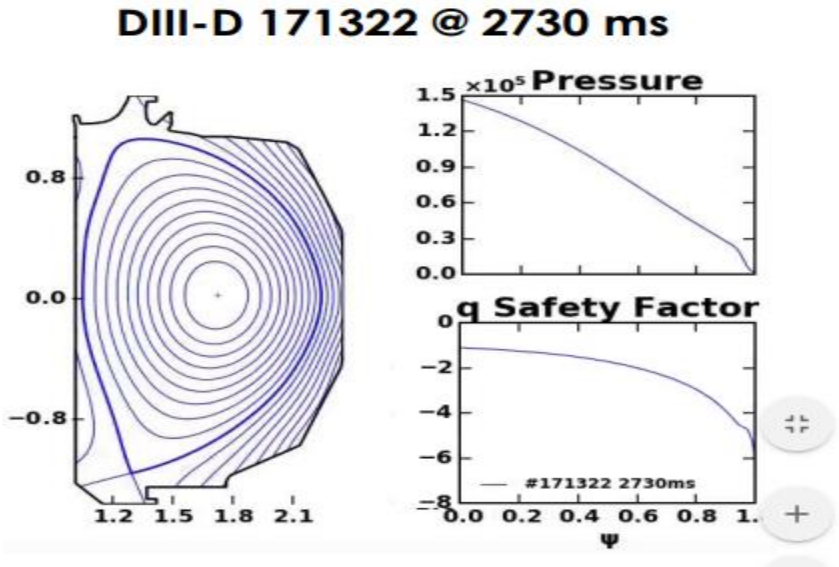
$$\rho \frac{dv_{||}}{dt} = -\mathbf{b}\bullet\nabla p + \mu\nabla^2 v_{||}$$

Using the differential approximation, we could stabilize this with the operator:

$$\left[\rho - (\theta\delta t)^2 \gamma p \left(\mathbf{b}\bullet\nabla\right)^2\right]\dot{v}_{||} = -\left(\mathbf{b}\bullet\nabla\right)p + \mu\nabla^2 v_{||}$$

Status of First Coupled M3D-C1 / LP Simulation

- **Iterate independent simulations of MHD and LP codes**
  - Run pellet injection in MHD code with analytic, Parks ablation formula
  - Send plasma states along pellet path to LP code to compute ablation rate at each point
  - Rerun MHD codes with LP ablation rates
  - Iterate between codes until convergence
- **Test case for DIII-D modeling**
  - 1 mm Ne pellet using extruder parameters
  - 160606, standard case for SPI modeling
  - 171322, super-H target for upcoming small-pellet ablation experiment
  - Latter will be used for predict-first of experiment



8/10/20 – proposed

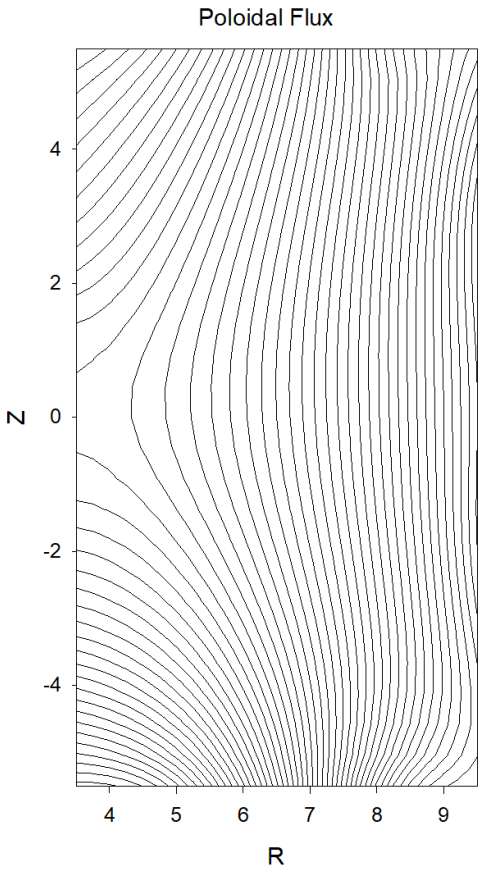
10/5/20 – Brendan sent data from a 2D run

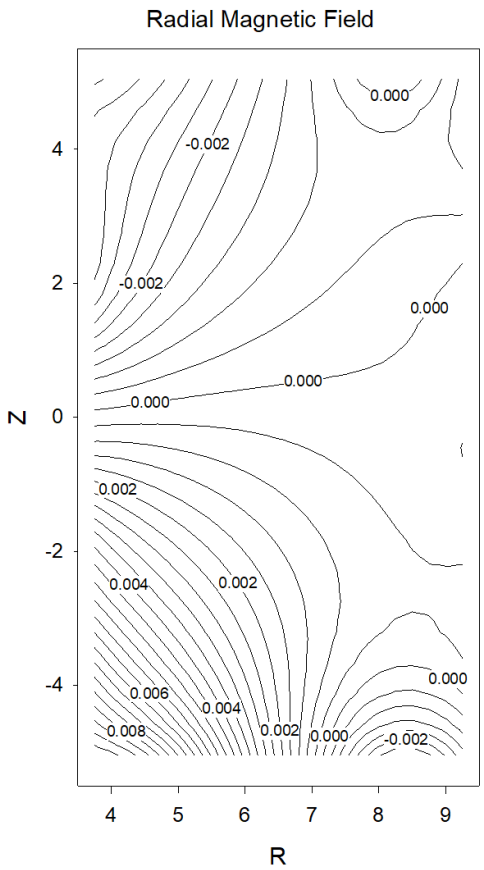
10/7/20 – Roman requested more concise data from around pellet vs time

10/20/20 – Brendan developed and documented postprocessor for LP ablation code.

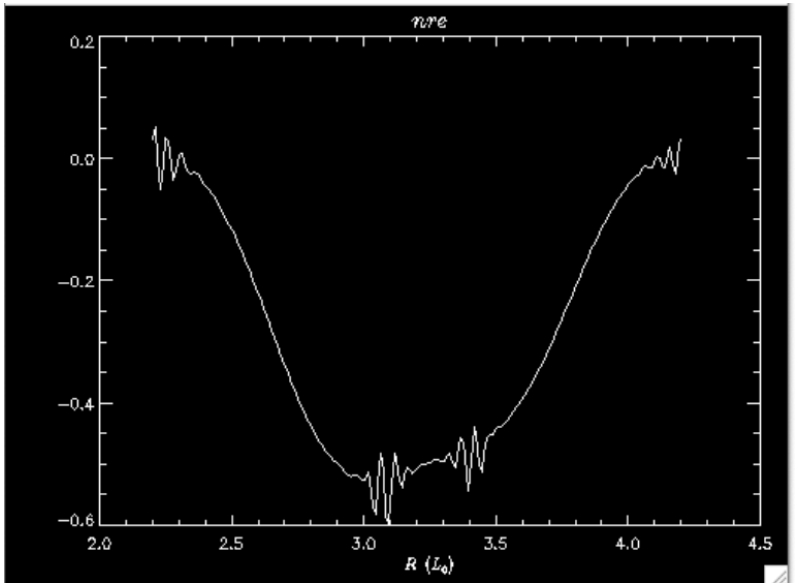
11/2/20 – Roman said they will use Brendan's data this week and then schedule a ZOOM

ITER External Field B_R vs R

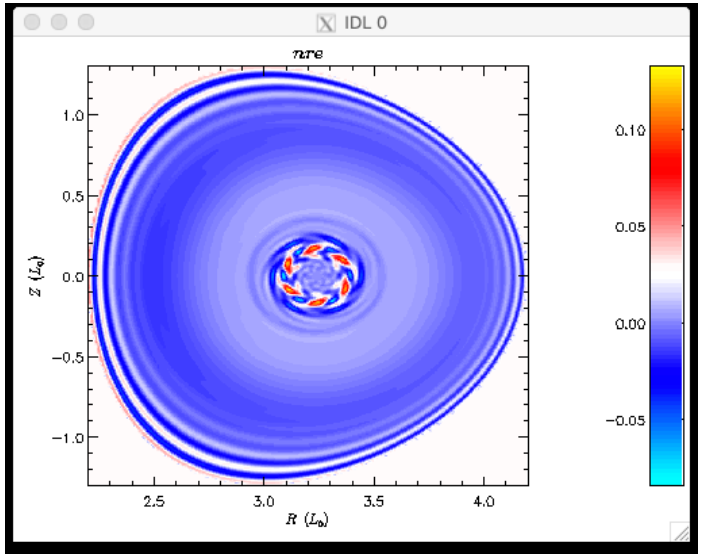




Update on Sawteeth with Runaways



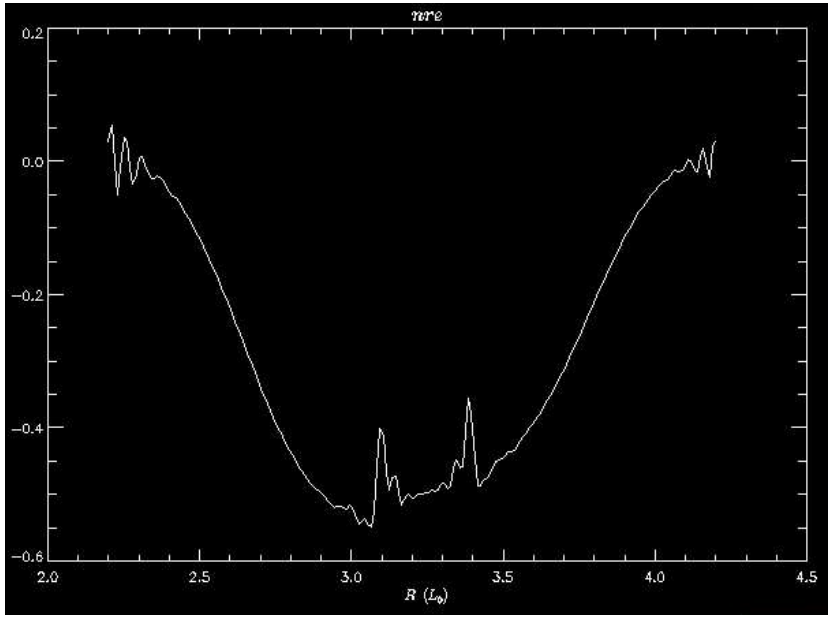
With diffusion term on (rdiff = 0.5) nre is now mostly smooth except in center and edge. Center may be due to n=6 mode. I would run first in 2D to work on eliminating edge oscillations.

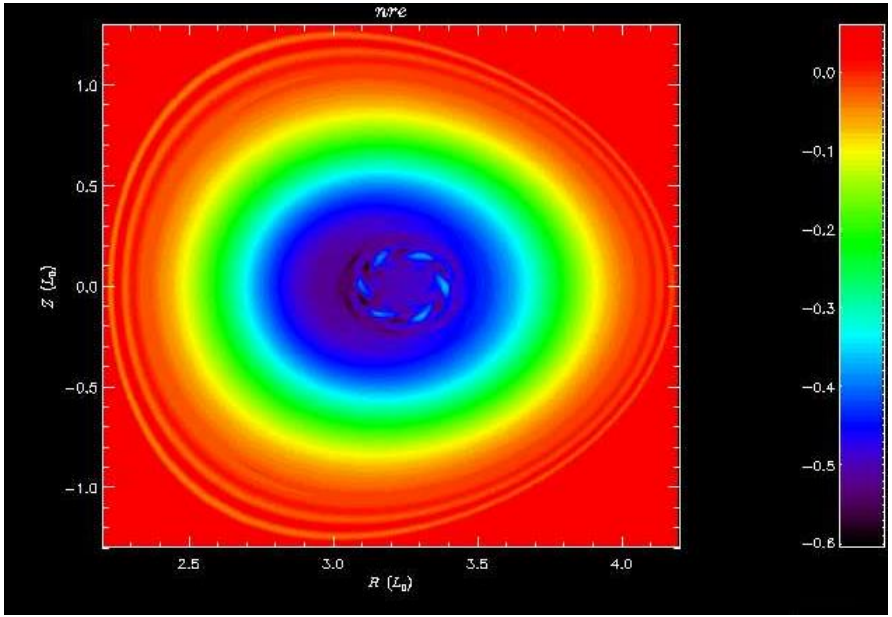


(6,6) mode with $q_0 \sim 1$?
Why does nre change signs?

I have replotted this and it is more consistent with fig. on left

Replot of sawtooth run slice 34





Progress on other shots?

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

- J. Yang, C. Liu. N. Ferraro … status of equilibrium reconstruction

DIII-D shot 177053 – Runaway generation with Ar injection

- Chen Zhao

DIII-D shot 177040 – saturated mode amplitude of (2,1) mode with runaways

- Chang Liu, Chen Zhao

DIII-D Neon pellet mitigation simulation for KORC

- Brendan Lyons

SPARK ?

That’s All I have

Anything Else ?

Grad-B drift in M3D-C1—HF side

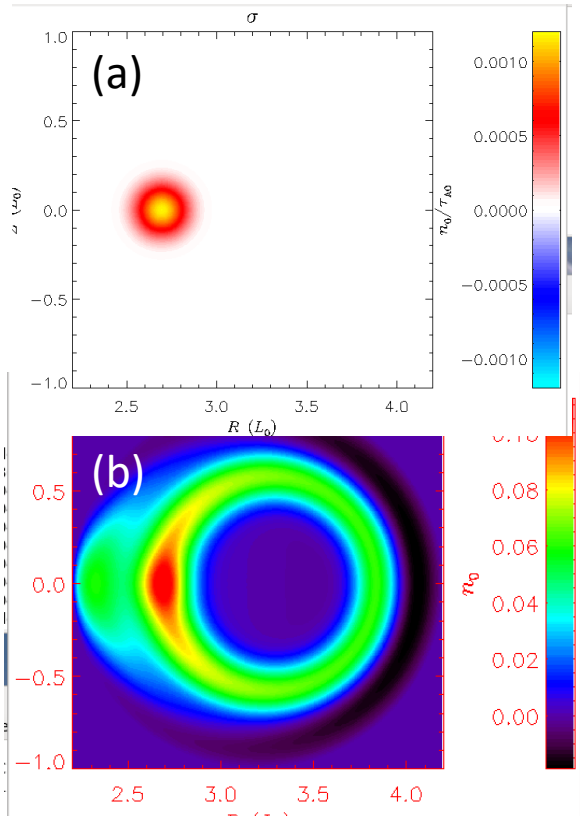
Request to calculate grad-B drift in M3D-C1 and to compare with that being put into the LP Code

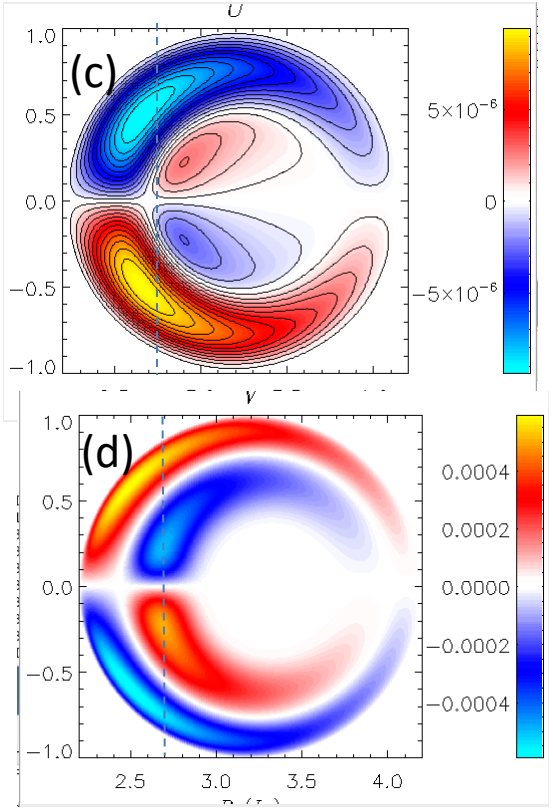
(a) Density source in 1F toroidal equilibrium

(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

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(c) Poloidal velocity stream function

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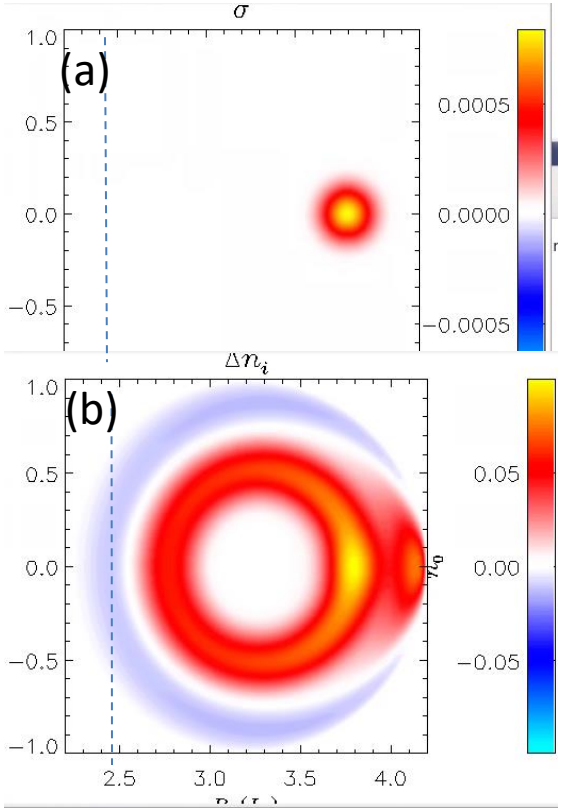
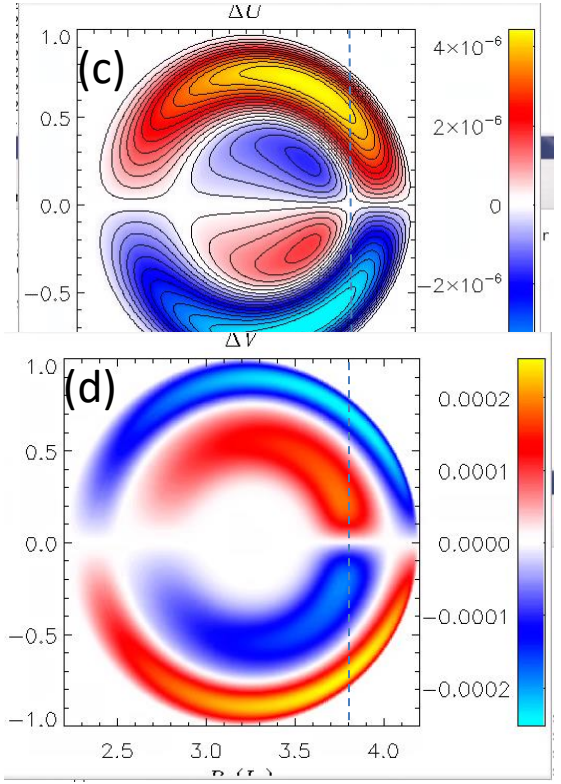




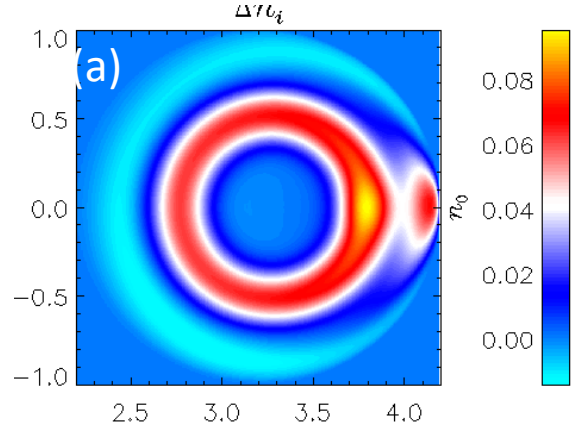
Grad-B drift in M3D-C1—2F effects

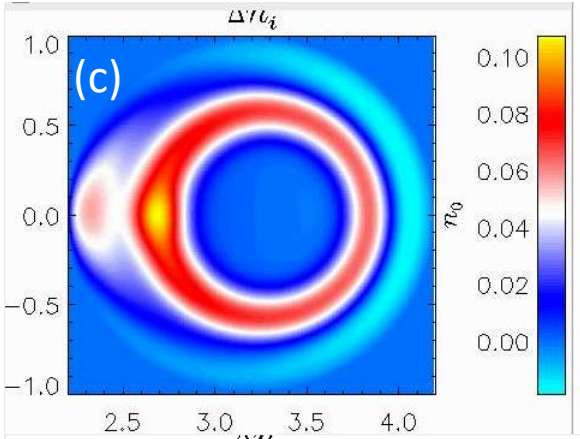
(a) 2F density change after 10^3 τ_A for LF side source

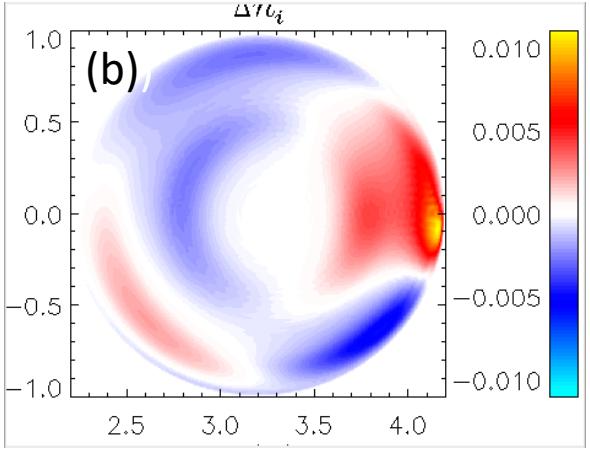
(b) Difference in 1F and 2F density (LF)

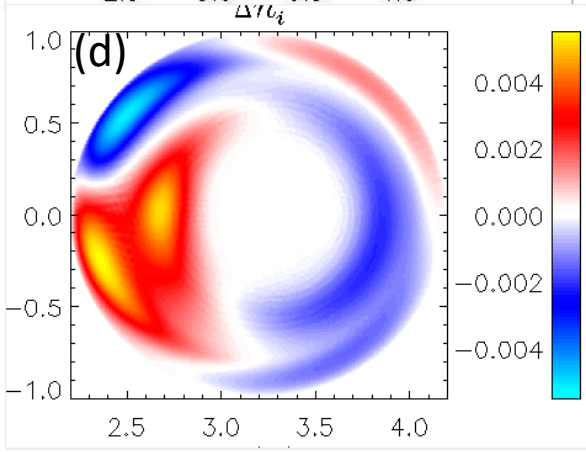
(c) 2Fdensity change after 10^3 τ_A for HF side source

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

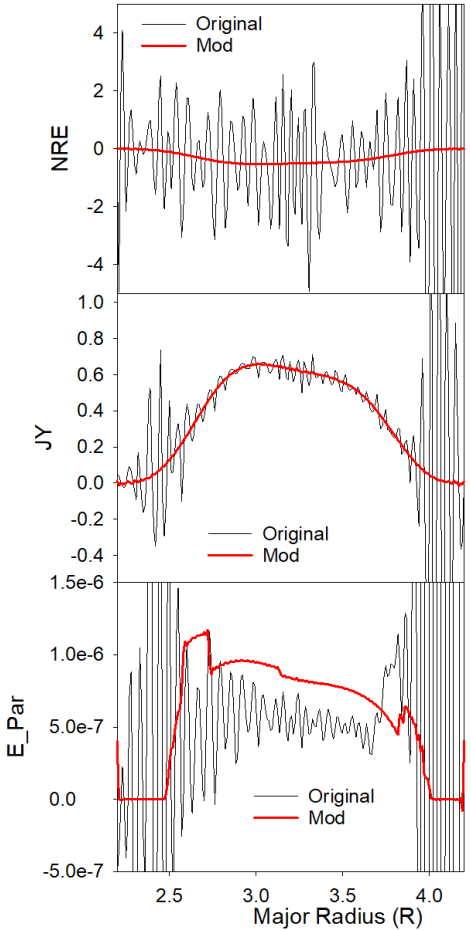








Sawtoothing discharge with runaway electrons

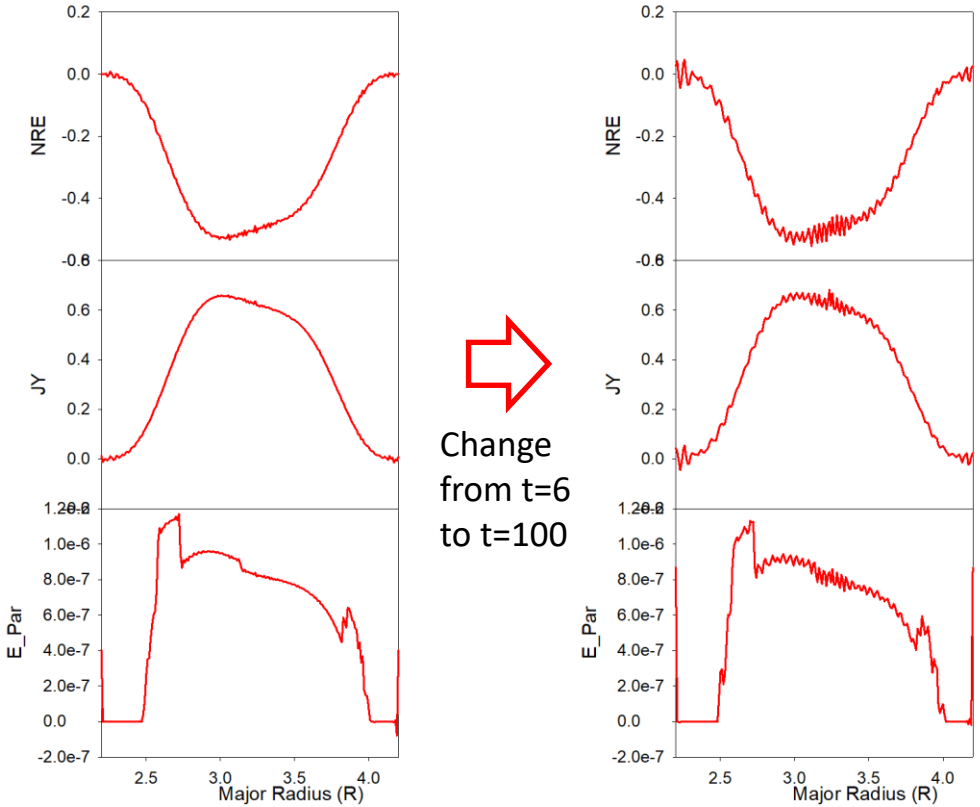


Profiles of nre, jy, and E_par after 30 timesteps

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?