M3D-C1 ZOOM Meeting

8/31/2020

Agenda

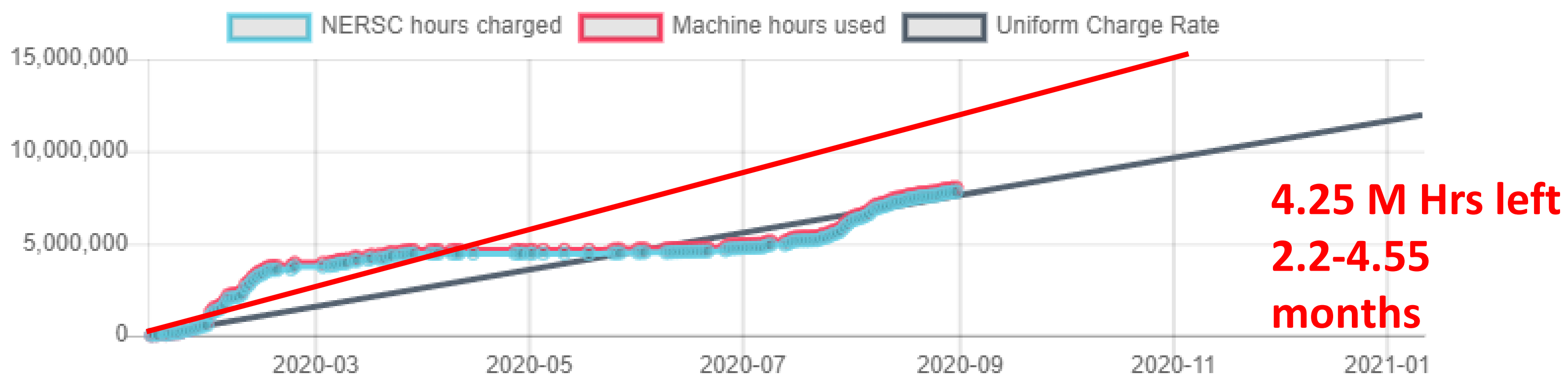
1. CS Issues
    1. Local systems
    2. NERSC Time
    3. Changes to github master since last meeting
    4. PETSC/SuperLU bug for complex solves
    5. Status of GPU solves on cori-GPU
2. Physics Studies
    1. Conservation laws and energy conservation
    2. Use of GS equation when runaways are present
    3. M3D-C1 coupling to RE code KORC -- Lyons
    4. RE Fluid Modeling of DIII-D Experiments -- Chang Liu
    5. Runaways with sources Chen Zhao/ S. Jardin
    6. Test of Boozer Theory for Cold VDE … Clauser
    7. Nonlinear frequency chirping using M3D-C1 .. Chang Liu
    8. Status of first coupled M3D-C1/LP Simulation .. Lyons
    9. Other

Local Systems

- PPPL
  - As of 08/31/20 8:00 AM: To compile on centos7, need to copy u/jchen/p_swim/m3dc1/gitrepo/M3DC1/unstructured/centos7.mk
  - 5 regression tests PASSED on centos7: adapt failed (08/31/20)
  - 4 PASSED on greene
    - pellet batch file not found for greene
    - Adapt failed 08/31/20
- EDDY
  - All 6 regression tests PASSED on eddy as of 08/31/20 9:00 AM
- TRAVERSE
  - Updated to RHEL8
  - Do regression tests run on Traverse?

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 Nov 1

Changes to github master since last meeting

- B. Lyons
  - 08-25 Add impurity source terms to momentum equation
  - 08-25 Angular momentum diagnostics use total ion mass density
  - 08-26 Further additions of impurity source terms in momentum and p/T equations
  - 08-26 Fix source term in p/T equation when iadiabat=1
    Update KPRAD regression tests given these bug fixes
- N. Ferraro
  - 08-26 Improved momentum and energy conservation with impurities
- S. Seol
  - 08-27 3D mesh adaptation and unit test added on behalf of Usman
  - 08-28 Fixing minor bugs with 3D adaptation unit test
  - 08-28 Fixing crash on adapt_3d unit test
- J. Chen
  - 08-29 petsc update on cori_knl, eddy, perseus

Complex SuperLU_dist bug fixed (~ 8/17)

- Jin is rebuilding PETSc on all platforms with the new SuperLU

08/26/20 Jin Chen
I was able to update petsc with the complex code bug fixing and installed the libraries on cori haswell and marconi.

On all the other machines: cori knl, centos7, eddy, and perseus, I got configuration error to compile superlu. **Still the case?**

Status of GPU solves on cori-gpu

8/25/20 Jin Chen

1. 2D real solvers worked on GPU with matrices residing on CPU
2. 2D real solvers worked on GPU when matrices were loaded onto GPU using options:
   -mat_type aijcusparse -vec_type cuda
3. 3D real solvers worked on GPU when matrices were kept on CPU.
4. 3D real solvers failed with thrust errors when matrices were loaded onto GPU using
   -mat_type aijcusparse -vec_type cuda

08/26/20 Sherry LI:

At least from superlu side, the matrix cannot start from GPU, must start from CPU. So GPU is used as an off-load device.

Yang Liu (8/26/20):

maybe you can try further mimic the m3dc1 run pattern using a standalone test, which is to create a matrix, call petsc factorization on the jacobi blocks, call pestc solve, then refill the matrix, call petsc factorization on the jacobi blocks and call petsc solve. Hopefully the error can be reproduced that way.

Energy Conservation

$$\mathbf{B}\bullet\left[\frac{\partial \mathbf{B}}{\partial t} = -\nabla\times\mathbf{E}\right] \Rightarrow \frac{\partial}{\partial t}\tfrac{1}{2}B^2 = -\mathbf{E}\bullet\mathbf{J} - \nabla\bullet\left(\mathbf{E}\times\mathbf{B}\right)$$

$$\left.\begin{array}{c}\dfrac{\partial p}{\partial t} = -\nabla\bullet\left(p\mathbf{V}\right) - \left(\gamma-1\right)p\nabla\bullet\mathbf{V} + \left(\gamma-1\right)\left[\eta J^2 - \nabla\bullet\mathbf{q} - \mathbf{V}\bullet\nabla\bullet\mathbf{\Pi} + S_E\right] \\ \mathbf{E}+\mathbf{V}\times\mathbf{B} = \eta\mathbf{J} \Rightarrow \eta J^2 = \mathbf{J}\bullet\mathbf{E} - \mathbf{V}\bullet\mathbf{J}\times\mathbf{B}\end{array}\right\} \Rightarrow$$

$$\tfrac{1}{(\gamma-1)}\frac{\partial p}{\partial t} = -\tfrac{\gamma}{(\gamma-1)}\nabla\bullet\left(p\mathbf{V}\right) + \mathbf{V}\bullet\nabla p + \mathbf{J}\bullet\mathbf{E} - \mathbf{V}\bullet\mathbf{J}\times\mathbf{B} - \nabla\bullet\mathbf{q} - \mathbf{V}\bullet\nabla\bullet\mathbf{\Pi} + S_E$$

$$\mathbf{V}\bullet\left[nM_i\left(\frac{\partial \mathbf{V}}{\partial t} + \mathbf{V}\bullet\nabla\mathbf{V}\right) + \nabla p = \mathbf{J}\times\mathbf{B} - \nabla\bullet\mathbf{\Pi} - \tfrac{1}{2}M_i\mathbf{V}\left(\bullet D_\rho\nabla n + S_n\right)\right] \Rightarrow$$

$$\tfrac{1}{2}nM_i\frac{\partial}{\partial t}V^2 = -\tfrac{1}{2}nM_i\nabla\bullet\left(\mathbf{V}V^2\right) + \tfrac{1}{2}nM_iV^2\nabla\bullet\mathbf{V} - \mathbf{V}\bullet\nabla p + \mathbf{V}\bullet\mathbf{J}\times\mathbf{B} - \nabla\bullet\left[\mathbf{\Pi}\bullet\mathbf{V}\right] + \nabla\mathbf{V}:\mathbf{\Pi} - \tfrac{1}{2}M_iV^2\left(\bullet D_\rho\nabla n + S_n\right)$$

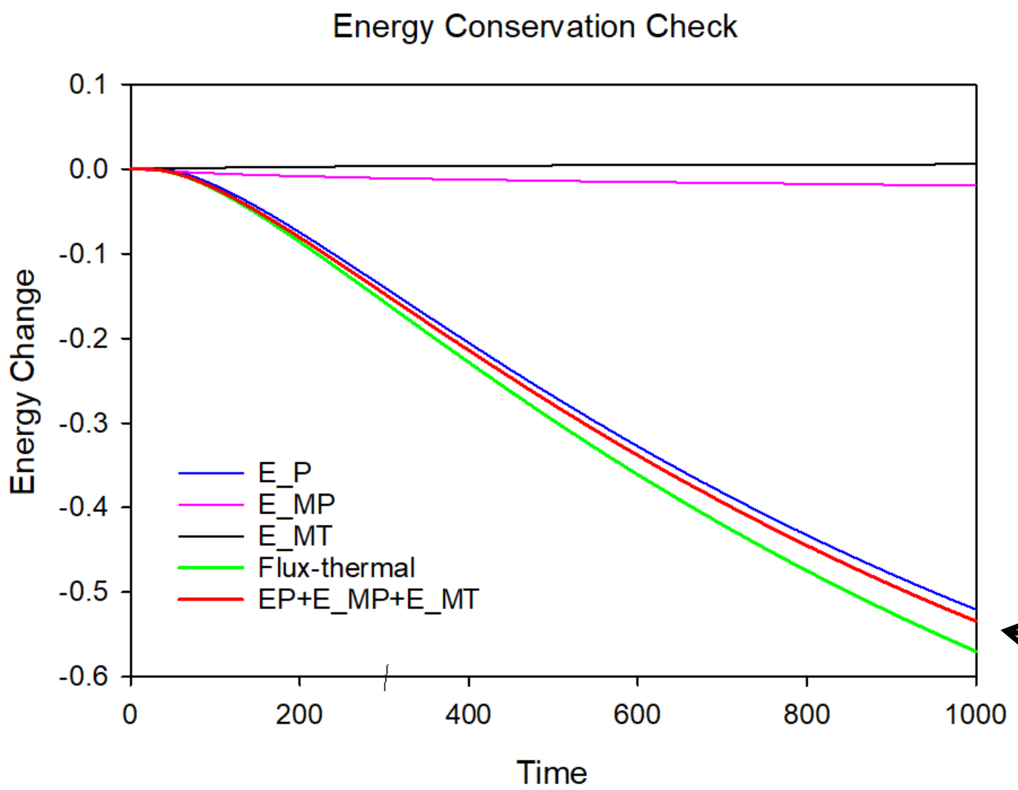
$$\tfrac{1}{2}M_iV^2\left[\frac{\partial n}{\partial t} + \nabla\cdot\left(n\mathbf{V}\right) = \nabla\bullet D_\rho\nabla n + S_n.\right] \Rightarrow$$

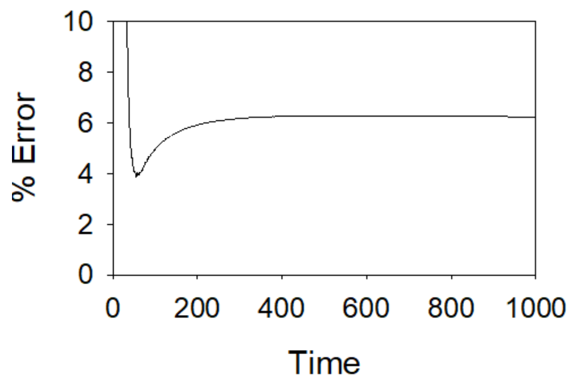
$$\tfrac{1}{2}M_iV^2\frac{\partial n}{\partial t} = -\tfrac{1}{2}M_inV^2\nabla\cdot\mathbf{V} - \tfrac{1}{2}M_iV^2\mathbf{V}\bullet\nabla n + \tfrac{1}{2}M_iV^2\nabla\bullet D_\rho\nabla n + \tfrac{1}{2}M_iV^2S_n$$

$$\frac{\partial}{\partial t}\left[\tfrac{1}{2}B^2 + \frac{p}{(\gamma-1)} + \tfrac{1}{2}nM_iV^2\right] + \nabla\bullet\left[\left(\tfrac{\gamma}{(\gamma-1)}p + \tfrac{1}{2}M_inV^2\right)\mathbf{V} + \mathbf{E}\times\mathbf{B} + \mathbf{q}_e + \mathbf{\Pi}\bullet\mathbf{V}\right] = S_E$$

E_P + E_MT + E_MP Flux_thermal

Energy conservation(2)





GREEN and RED curves should overlay ~ 6% error

bclyons file ……/kngt_ohmic/kr_0 with:
iconst_bz = 0

Energy conservation(3)

6% error does not depend on:

- dt=0.5, 1.0, 2.0
- inocurrent_pol=0,1
- inocurrent_tor=0,1

itemp = 0 leads to instability….now checking

Use of Grad Shafranov equation when runaways are present

$$\nabla\bullet\left(\mathbf{v}_r n_r\right)=0 \quad\Rightarrow\quad \mathbf{v}_r=\frac{1}{n_r}\left[\nabla u\times\nabla\varphi-\frac{RJ_\varphi}{e}\nabla\varphi\right]$$

$$\nabla\bullet\left(\gamma m_{e,0} n_r \mathbf{v}_r \mathbf{v}_r\right)=-e\mathbf{v}_r\times\mathbf{B} \quad\Rightarrow\quad \tfrac{1}{2}\nabla v_r^2-\mathbf{v}_r\times(\nabla\times\mathbf{v}_r)=-\tfrac{e}{\gamma m_{e,0}}\mathbf{v}_r\times\mathbf{B} \qquad (*)$$

(1)

$$\nabla\varphi\bullet(*) \quad\Rightarrow\quad -\gamma m_{e,0}\frac{RJ_\varphi}{n_r e}+e\psi=A(u)$$

$$\left(\mathbf{J}-\mathbf{J}_r\right)\times\mathbf{B}=\nabla p_{th} \qquad (**)$$

$$\nabla\varphi\bullet\left[\left(\mathbf{J}-\mathbf{J}_r\right)\times\mathbf{B}\right]=0$$

$$\nabla\varphi\bullet\left[\left[\nabla(RB_\varphi+eu)\times\nabla\varphi\right]\times\left[\nabla\psi\times\nabla\varphi\right]\right]=0$$

(2)

$$\Rightarrow\quad RB_\varphi+eu=F(\psi)$$

$$\nabla\psi\bullet(**)\Rightarrow$$

$$\Delta^*\psi=-R^2 p'_{th}-RJ_\varphi-RB_\varphi F'$$

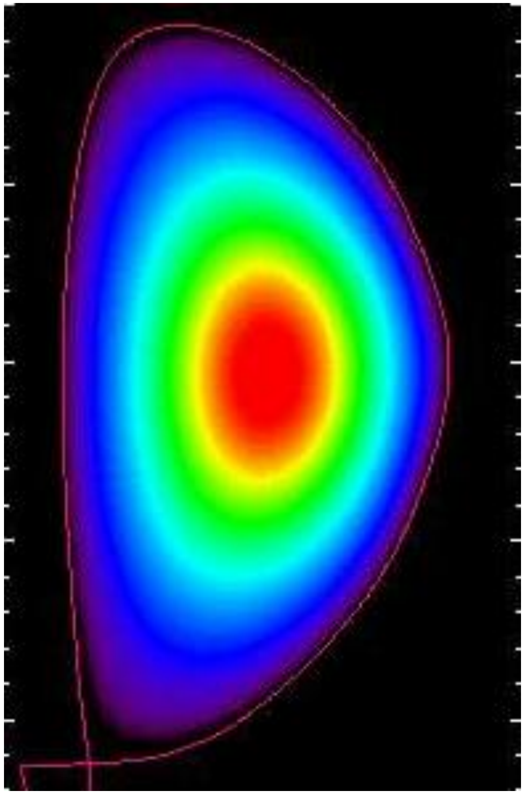
Use (1)&(2)

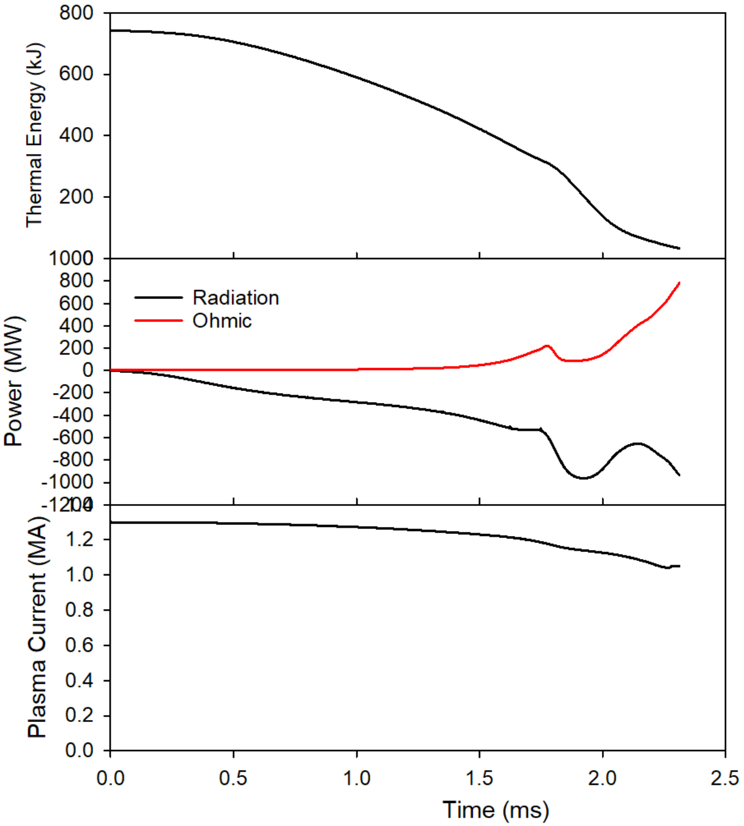
$$=-R^2 p'_{th}-FF'$$

$$+e\left[uF'+\tfrac{n_r}{\gamma m_{e,0}}\left(A+e\psi\right)\right]$$

Bandaru, Hoelzl, Lackner, Huijsmans, presentation at 2019 MHD ITPA meeting, IPP, Garching

M3D-C1 coupling to RE code KORC





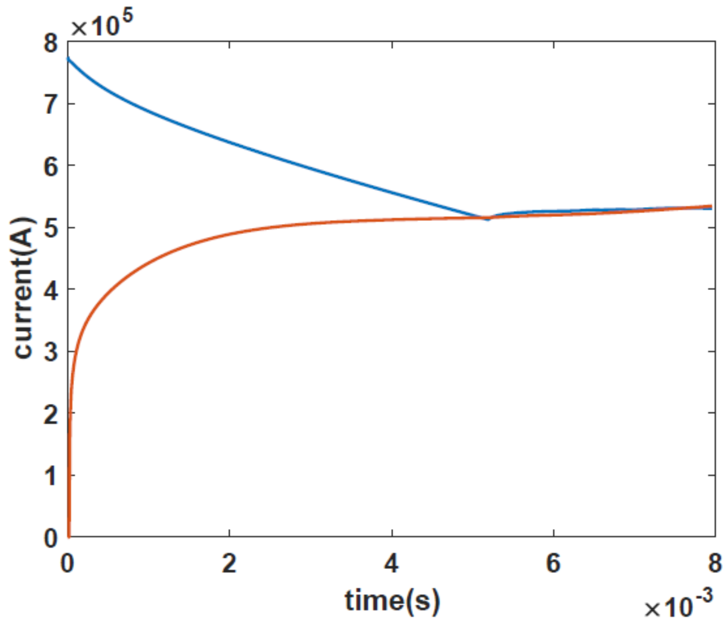
Brendan has agreed to run this case out longer, thru most of the current quench. ORNL is interested in using this case for M3D-C1/KORC coupling demo. **Status?**

RE Fluid Modeling of DIII-D Experiments

- shot 177040 has been looked at by Liu with the (linear) MARS code
- Brendan has created a new geqdsk with same q-profile but lower pressure
- ZOOM to be held Tuesday Sept 1 @ 2:00 PM ET
  - Chang Liu, Chen Zhao, Steve Jardin, Yueqiang Liu, Carlos Paz-Soldan
  - Has this been scheduled?
- Chang Liu to compare with MARS results, extend to non-linear

Runaways with Sources(1)

Chen is concerned that since runaway current is parallel to B, it will never balance $J_\perp$ and current will continue to decay.



$$\frac{\partial \mathbf{B}}{\partial t} = 0 \quad \Rightarrow \quad \nabla \times \mathbf{E} = 0 \quad \mathbf{E} = -\nabla \Phi + \frac{V_L}{2\pi} \nabla \varphi \quad (1)$$

$$\mathbf{E} + \mathbf{V} \times \mathbf{B} = \eta(\mathbf{J} - \mathbf{J}_{RE}) \qquad (2)$$

$$\mathbf{B} \bullet [(1) + (2)] \quad \Rightarrow \quad \eta(\mathbf{B} \bullet \mathbf{J} - \mathbf{B} \bullet \mathbf{J}_{RE}) = -\nabla \bullet (\mathbf{B}\Phi) + \frac{V_L}{2\pi} \mathbf{B} \bullet \nabla \varphi$$

now surface average and set $V_L = 0$

$$\langle \mathbf{B} \bullet \mathbf{J} \rangle = \langle \mathbf{B} \bullet \mathbf{J}_{RE} \rangle \qquad (3)$$

$\mathbf{J}_\perp$ will be determined by the equilibrium condition

$$\nabla p = \mathbf{J} \times \mathbf{B} \quad \Rightarrow \quad \mathbf{J}_\perp = \mathbf{B} \times \nabla p / B^2 \qquad (4)$$

Update 08/31/20. restarted with fixes. Will start again from beginning.

Runaways with Sources(2)

New terms to be added to field-advance $\mathbf{E}+\mathbf{V}\times\mathbf{B}=\eta(\mathbf{J}+n_{re}ce\mathbf{B}/B)$

Toroidal Field Advance: $\frac{1}{R^2}\dot{F}=\cdots+\nabla_\perp\bullet\eta\left[\frac{n_{re}ce}{R^2 B}\nabla_\perp\psi\right]$

Poloidal Field Advance: Either:

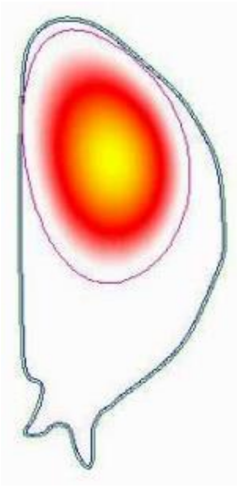
jadv=0
$$\begin{cases} \dot{\psi}= \quad \ldots \quad -\Phi'+\eta\left[-ecn_{re}F/B\right] \\ \nabla_\perp\bullet\frac{1}{R^2}\nabla\Phi= \quad \ldots \quad +\nabla_\perp\cdot\eta\left[-\left(\frac{n_{re}ec}{R^2 B}\right)\left(\nabla\psi\times\nabla\varphi-\nabla_\perp f'+F\nabla\varphi\right)\right] \end{cases}$$

Or

jadv = 1 $\nabla_\perp\bullet\frac{1}{R^2}\nabla_\perp\dot{\psi}=\cdots\nabla_\perp\cdot\left[\eta\left(\frac{n_{re}ec}{R^2 B}\right)\left(\nabla\psi\times\nabla\varphi-\nabla_\perp f'+F\nabla\varphi\right)\right]'+\nabla_\perp\bullet\frac{1}{R^2}\nabla_\perp\left[-\eta ecn_{re}F/B\right]$

Test of Boozer Theory for Cold VDE

- Boozer's analytic theory that if ITER suffers a disruption on the mid-plane, such that the current decreases to $I = 0.83\ I_0$, vertical stability will be lost, even for an ideally conducting wall.
- Cesar has tried to verify this, and finds the plasma is still VDE stable with $I = 0.3\ I_0$
- Difference is likely the wall model, Cesar to confirm.

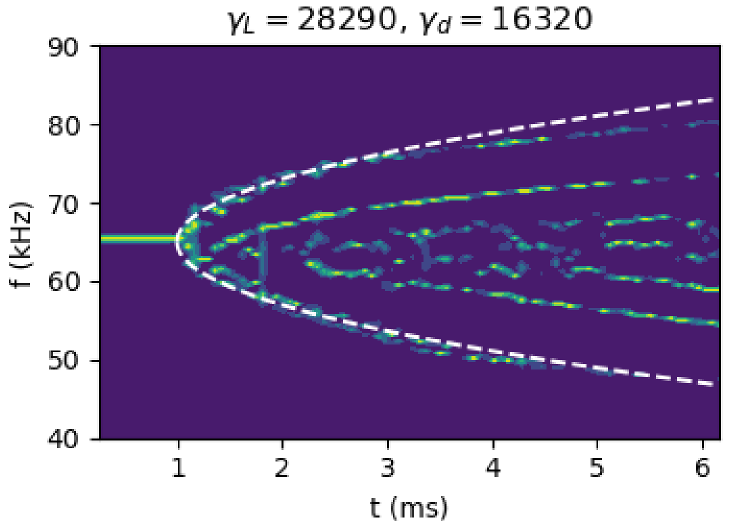


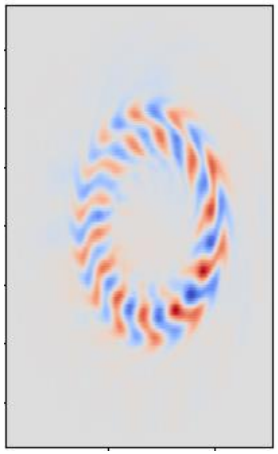
Vs.

Boozer, "Halo currents and vertical displacements after ITER disruptions", Phys. Plasmas 26, 114501 (2019)

Nonlinear frequency chirping using M3D-C1

Chang Liu to present

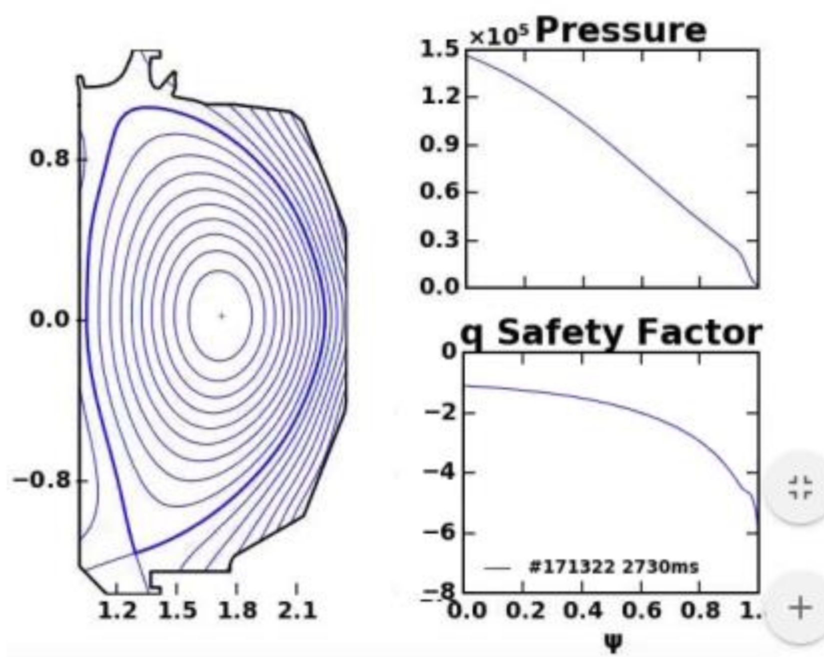




Status of First Coupled M3D-C1 / LP Simulation

- **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

DIII-D 171322 @ 2730 ms



Proposed 8/10/20 ..... **Status?**

That’s All I have

Anything Else ?