M3D-C1 ZOOM Meeting

10/05/2020

Agenda

1. ITPA Meeting Announcement
2. CS Issues
    1. GPU solve status… Chen
    2. Local systems
    3. Other systems
    4. NERSC Time
    5. Changes to github master since last meeting
    6. Matrix terms involving resistivity
    7. Error in derived quantities
    8. Request to replace bf = f with bfp = df/dφ
    9. Order of the do-loops
    10. Restarting with a different number of planes…Lyons
    11. Proposed API for mesh adaptation…M. Shephard
3. Physics Studies
    1. Status of first coupled M3D-C1/LP Simulation .. Lyons
    2. Peeling-ballooning modes at low aspect ratio: Andreas Kleiner
    3. New Results from Chen on DIII-D RE shots (if time)

ITPA Meeting

The 36th Meeting of the ITPA MHD Disruption and Control Topical Group will be held remotely, from 19 to 21 October 2020, hosted by IO.

The main headline of the meeting will be the reports on the MDC activities:

- MDC-8 Current drive prevention/stabilization of NTMs
- MDC-17 Active disruption avoidance
- MDC-18 Evaluation of axisymmetric control aspects
- MDC-19 Error field control at low plasma rotation
- MDC-20 Requirements for real-time sawtooth control
- MDC-22 Disruption prediction for ITER
- MDC-23 Formation, avoidance, and suppression of RE by massive material injection
- MDC-24 Shattered Pellet Injection (SPI Physics Validation)
- MDC-25 Sources and Scalings of Nonaxisymmetric “Sideways” Disruption Forces for ITER
- MDC-26 RE Wave / MHD Interactions
- MDC-JA-3 Disruption forces - theory and modelling
- MDC-IOS-1 Control for disruption-free operation

The leaders of the above groups have already expressed their readiness to make presentations. In addition to the summary reports, we expect several additional talks on the most interesting achievements in those directions.

GPU solve status

Any update on traverse and/or cori-GPU ?

Did Chang get an account on Tulip ?

Anything for next week's call with LBL?

Local Systems

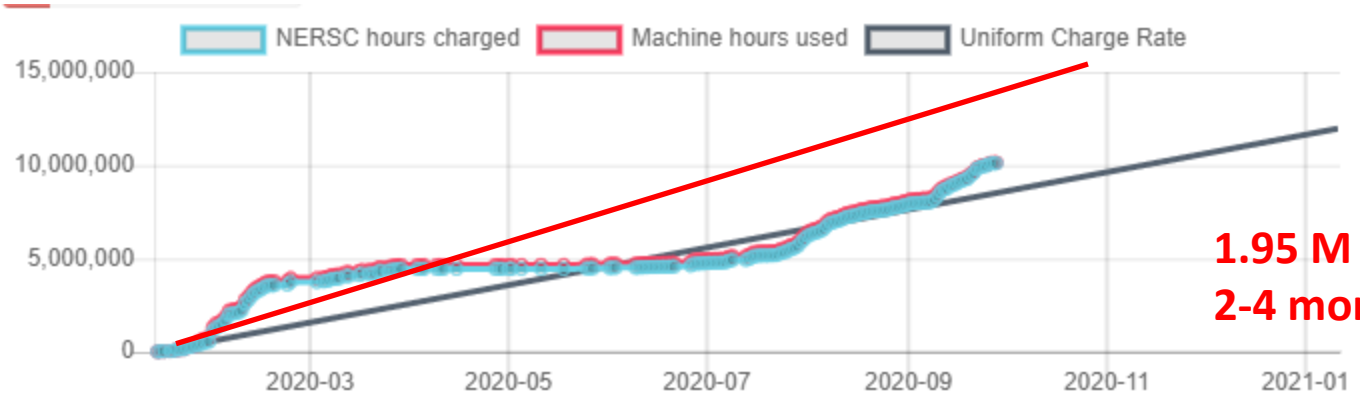
- PPPL centos7(9/22)
  - 5 regression tests PASSED on centos7:
  - “adapt” failed due to “corrupted double-linked list”
- PPPL greene (9/22)
  - 4 regression tests PASSED
  - “adapt” failed due to “corrupted double linked list”
  - No batch file found for pellet
  - Longer run hung on /p/tsc/… but ran ok on /pfs/nobackup/…
- EDDY (9/22)
  - All 6 regression tests PASSED on eddy
  - /scratch disk quota increased from 2 to 10 TB !!
- TRAVERSE(9/20)
  - Code compiles
  - Regression test failed: split_smb not found in PATH
  - Jin working with LBL to resolve SuperLU_dist failure

Other Systems

- Cori-KNL (09/23)
  - 6 regression tests passed on KNL
  - Presently has disk problems
- Cori-Haswell j(09/23)
  - 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
  - Presently has disk problems
- 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
  - ???

NERSC Time

mp288



1.95 M Hrs left
2-4 months

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
- John Mandrakes (DOE) has 45M hours to distribute, but got requests for 3x that. Has not yet decided. We can expect ~ 5 M hours.

Changes to github master since last meeting

- N. Ferraro
  - 09/24/20: Updated partition on batch scripts from centos7 to general
- J. Chen
  - 09/22/20: centos7.mk changes for superlu_dist on greene
- B. Lyons
  - 09/22/20: Define toroidal period before it's use
  - 09/22/20: Minor corrections for HDF5 scalar update to avoid compiler error
- S. Jardin
  - 9/22/20: re-baselined the C1KE file in adapt regression test
  - 9/22/20: added "read ne_field" to rdrestart to fix bug in eta plot after restarting

Matrix terms involving resistivity

Chen Zhao wrote that he had coded up a runaway electron term involving resistivity 2 ways that should give identical results but they gave very different results.

$$-\nu_i \nabla_\perp \bullet \frac{1}{R^2} \nabla_\perp \left[\eta e c n_{re} F / B \right]$$

$$= \nabla_\perp \nu_i \bullet \frac{1}{R^2} \nabla_\perp \left[\eta e c n_{re} F / B \right] + \mathrm{BT}$$ ← Poor Results

$$= -\frac{1}{R^2} \Delta^* \nu_i \left[\eta e c n_{re} F / B \right] + \mathrm{BT}'$$ ← Good Results

The reason is that he was using IRESFUNC=3 in which the resistivity is discontinuous at the plasma boundary. The first form involved derivatives of the resistivity, which don't exist there. The second form does not involve derivatives of the resistivity and should always be used. If η was analytic everywhere, the two forms would give the same result.

Error in derived_quantities

```
793  if(imp_bf.eq.0 .or. ilin.eq.0 .or. ntime.eq.0) then
794    if((i3d.eq.1 .or. ifout.eq.1) .and. numvar.ge.2) then
795      if(myrank.eq.0 .and. iprint.ge.2) print *, "  f", ilin
796      if((ilin.eq.0 .and. eqsubtract.eq.1) .or. eqsubtract.eq.0)then
797        if(itor.eq.0) then
798          temp = bzero
799        else
800          temp = bzero*rzero
801        end if
802        call add(bz_field(ilin),-temp)
803      endif
804      call solve_newvar1(bf_mat_lhs,bf_field(ilin),mass_mat_rhs_bf, &
805          bz_field(ilin), bf_field(ilin))
806     if((ilin.eq.0 .and. eqsubtract.eq.1).or.eqsubtract.eq.0  &
807          call add(bz_field(ilin), temp)
807     endif
808  end if
```

Yao Zhou observed that the terms in red should be removed. (Note that this will not affect tokamak calculations, since they only involve df/dφ, which is not affected)

Request to replace 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*

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

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

Order of the do-loops

(1) Loop over all elements (MPI and OPENMP)
- Loop over basis function (nu)
  - Calculate integral of (mu,F[nu]) with INTX
    -loop over tst function mu

(2) Loop over all elements (MPI and OPENMP)
- Loop over basis function (nu)
  - Loop over test function (mu)
  - Calculate integral of (mu,F[nu]) with INT

(3) Loop over all elements (MPI and OPENMP)
  - Calculate integral of (mu,F[nu]) with INTXX
    -loop over test function mu and basis function nu

Original code was method (2). Nate changed it to (1) during KNL Dungeon Session and got substantial speedup. Chang proposed going back to (1) as better for GPUs, but has sense performed timing tests and withdrew suggestion. Is it worthwhile exploring (3) ?

Proposed API

For 2D Mesh Adaptation, SCOREC requires two sizes (h_1, h_2) and one unit vector (v_1 or v_2) for the direction at each node as shown in the API below.

m3dc1_set_adapt_size (*r, z,* h_1, v_{1r}, v_{1z}, h_2)

Inputs:

r, z: R and Z coordinates of a point for which the output parameters are to be provided.

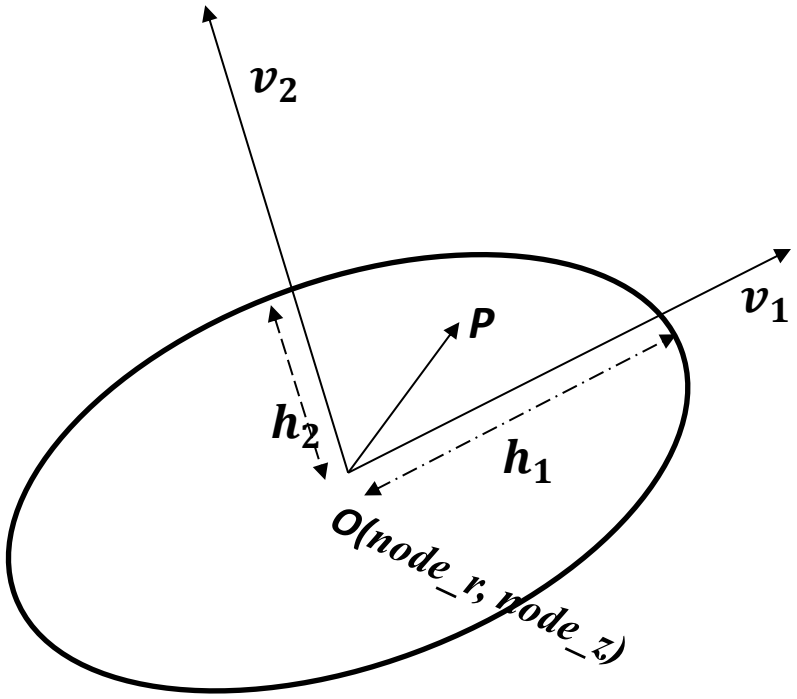
Outputs:

h_1 : Desired edge length along the direction v_1

v_{1r} , v_{1z} : Two components of the unit vector for direction corresponding to size h_1

h_2 : Desired edge length along the direction v_2 (perpendicular to v_1)

Note: h_1 and $v_1(v_{1r}, v_{1z})$ are the size and direction for one of the axis (It could be any of the major or minor axis). Followed by h_2 the desired size in the direction perpendicular to v_1.



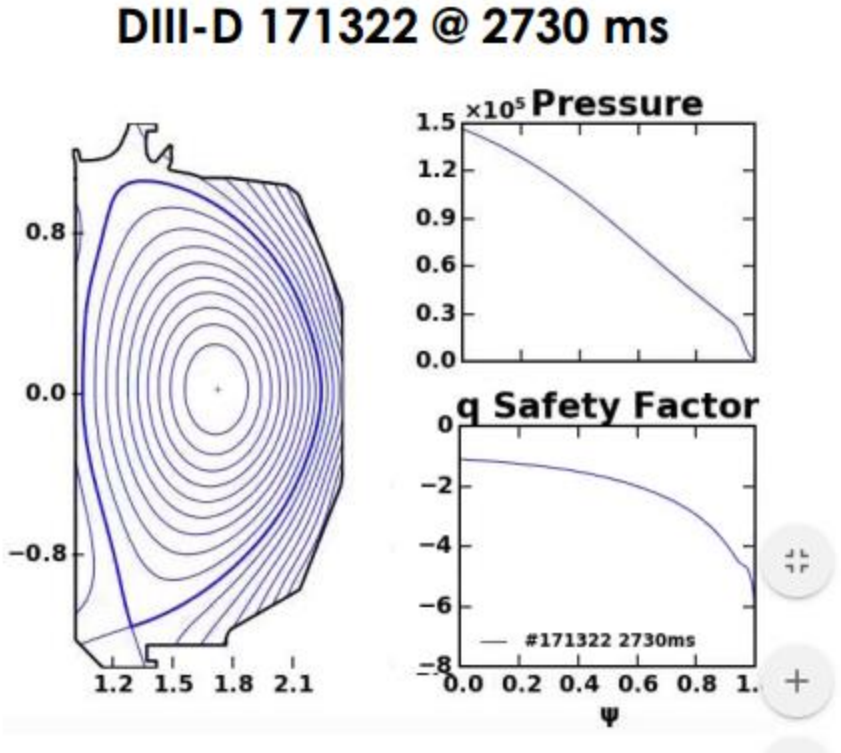
OP is an edge in current configuration that needs be adapted according to the size of ellipse

Jump in KE when restarting with increased planes

Brendan to show some slides how there is a glitch in the kinetic energy when he restarts with additonal planes.

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
9/16/20 – Roman requested status

Peeling-ballooning modes at low A

Andreas Kleiner to present

New results from Chen on DIII-D RE shots

Switch to Chen’s vgs

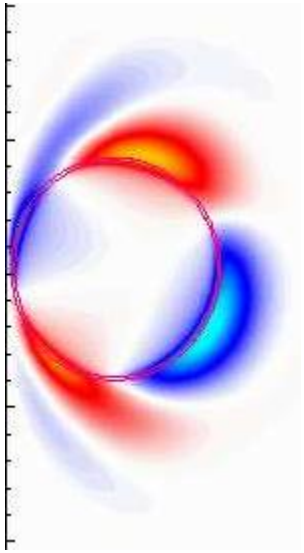
That’s All I have

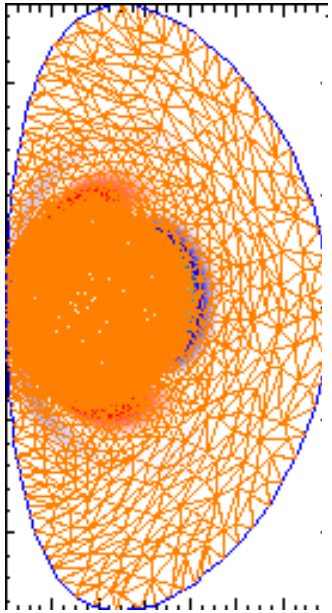
Anything Else ?

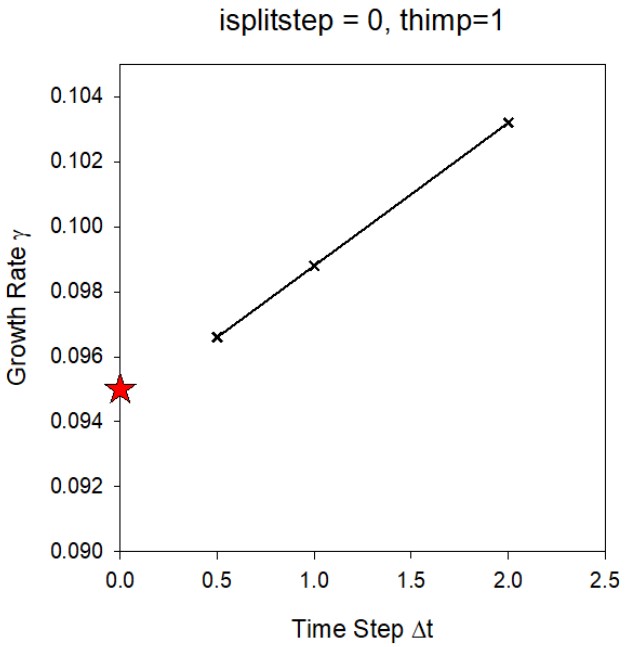
RE Fluid Modeling of DIII-D shot 177040

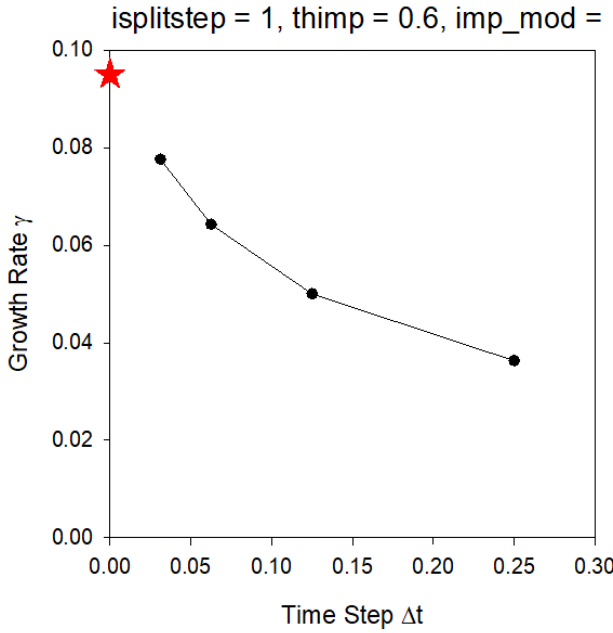
Carlos Paz-Soldan email 9/14/20

- 1) Dependence of RE current carriers (or not) on saturated mode amplitude (dB/B)?
- 2) Dependence of saturated dB/B on absolute B&I (fixed a, all q=2). —> ITER extrapolation
- 3) Dependence of saturated dB/B on absolute I (fixed B, smaller a, all q=2). —> DIII-D comparison

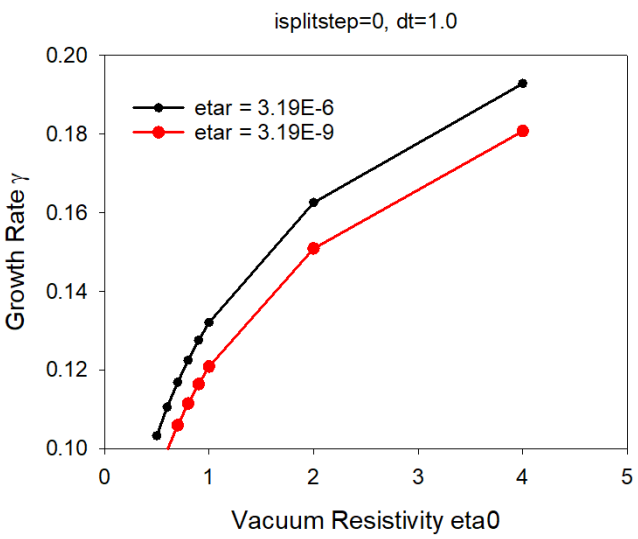


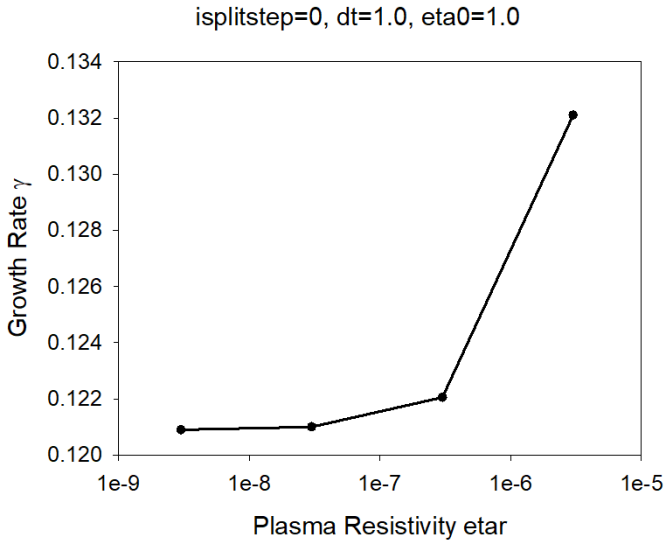


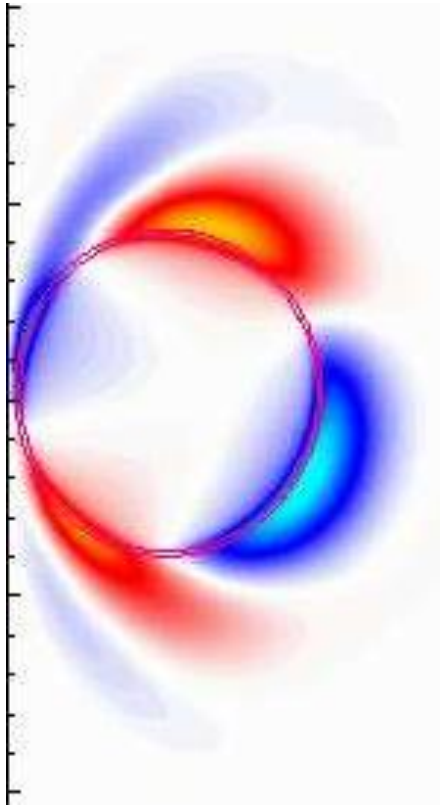




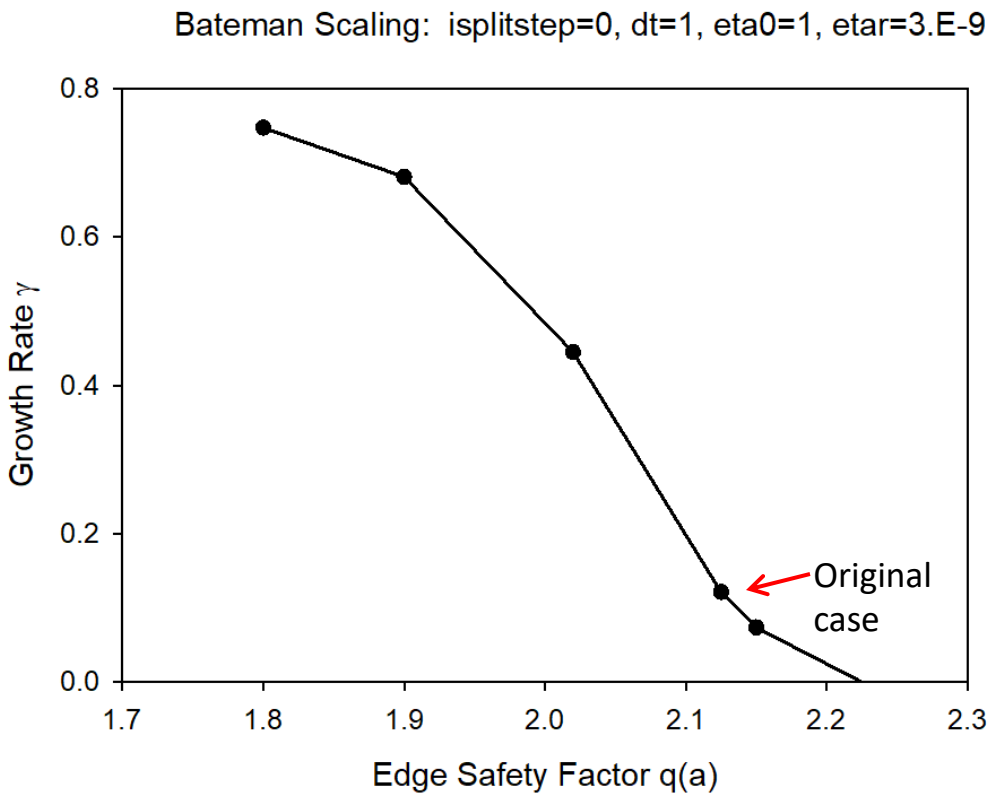
Dependence of Growth Rate on Plasma and Vacuum resistivity







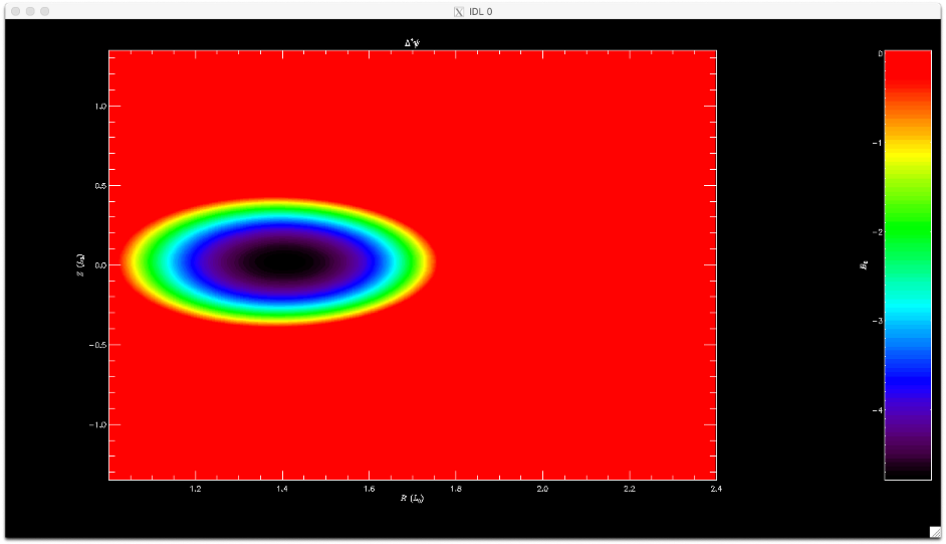
Growth Rate vs q(a)

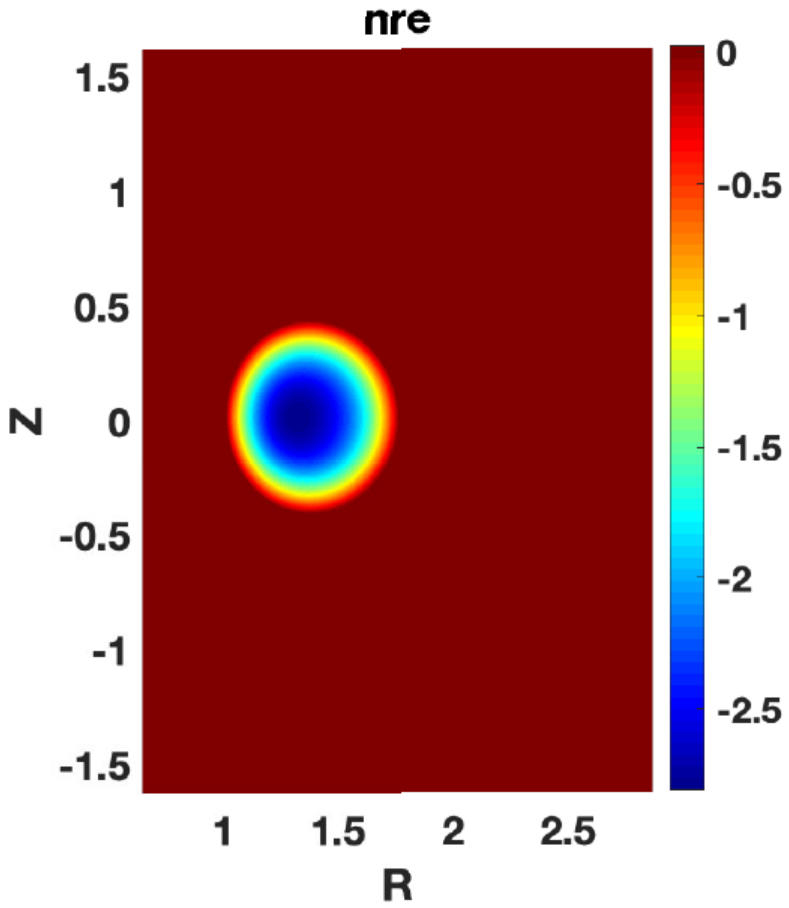


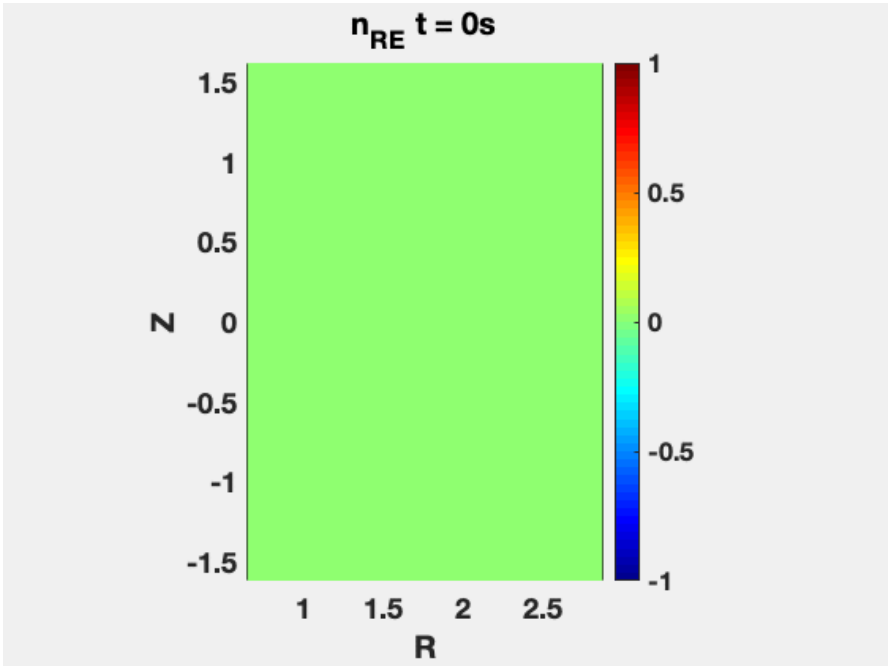
Batemanscale modifies F(1) but keeps p' and FF' fixed.

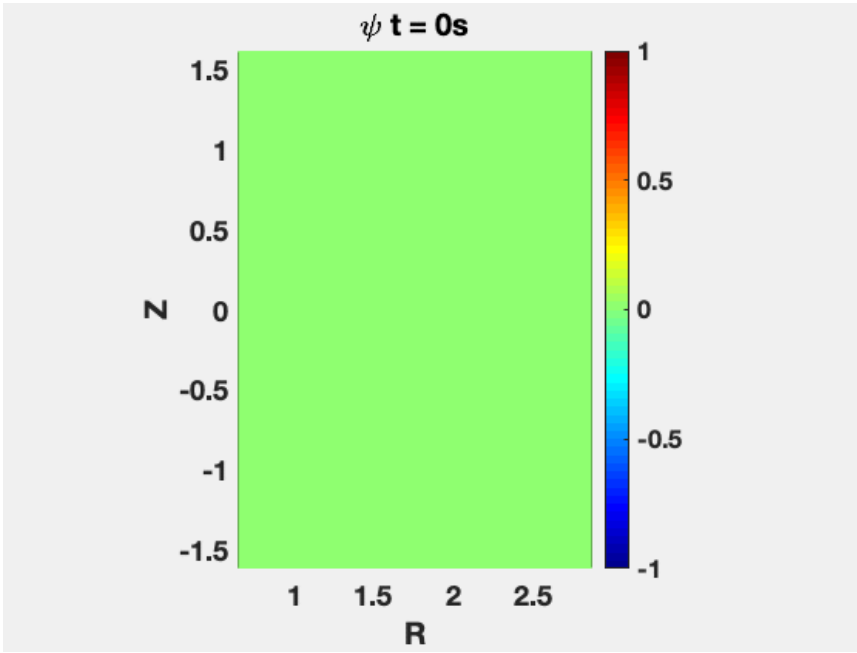
We should ask MARS to make a similar plot.

9/18/20 Chen Zhao: Shot 177040 with RE

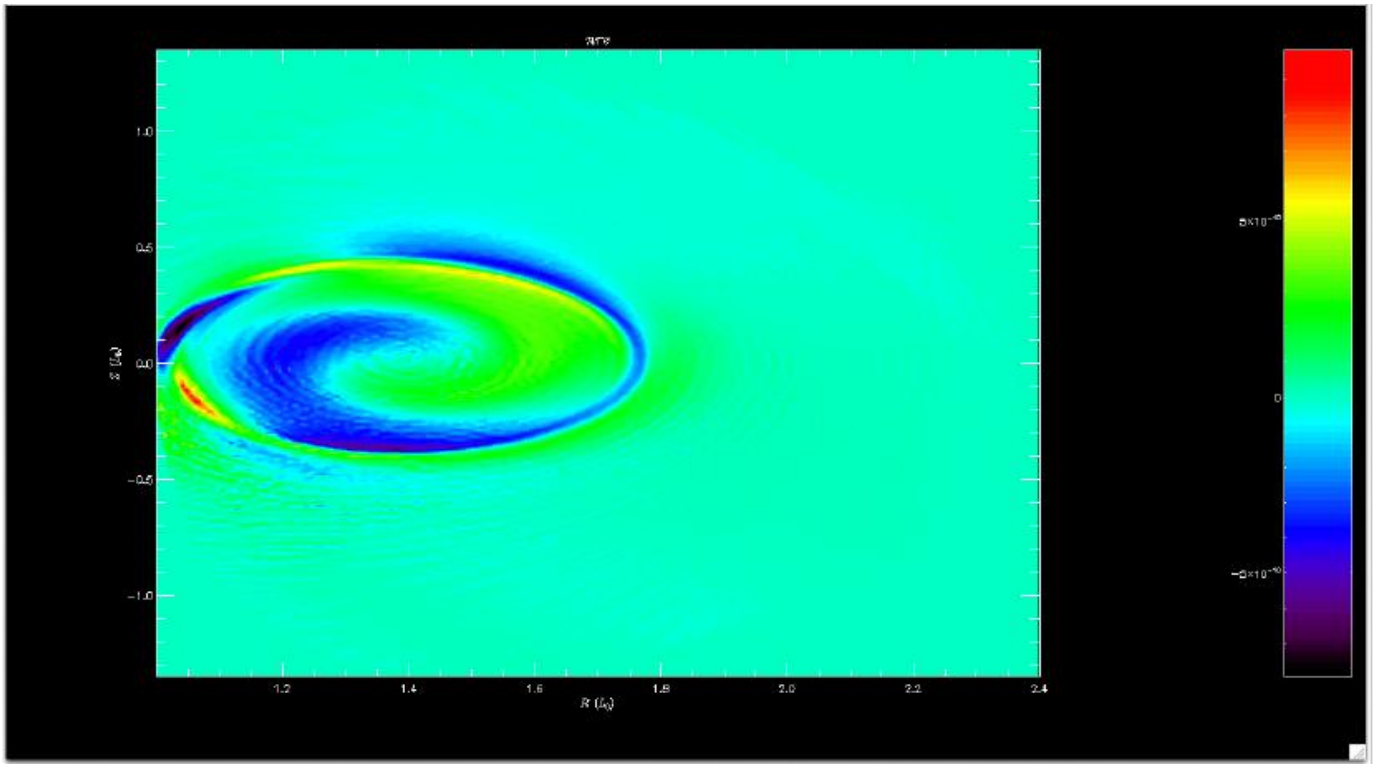




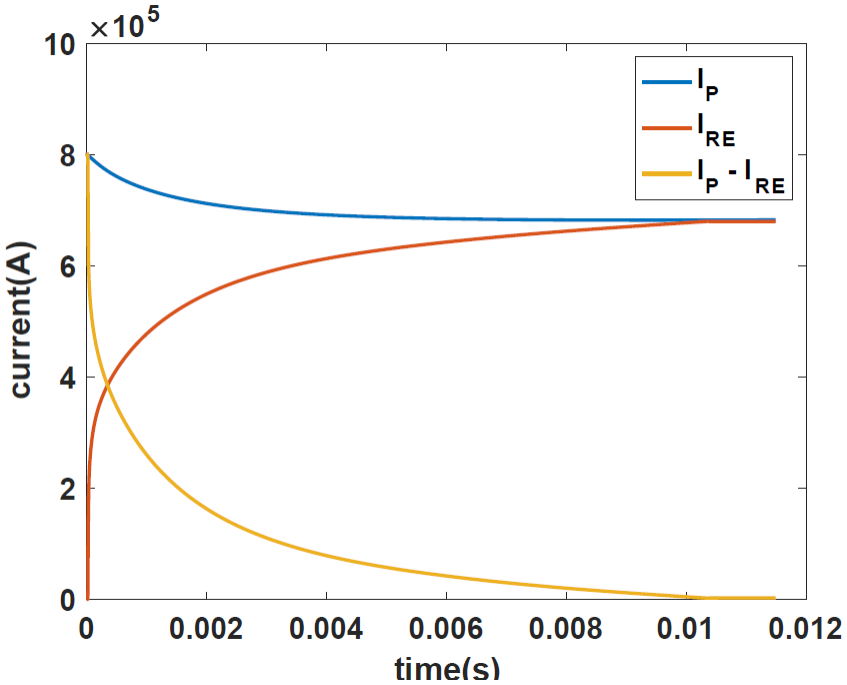

n_{RE} t = 0s
1.5
1
0.5
0
-0.5
-1
-1.5
Z
1
1.5
2
2.5
R
1
0.5
0
-0.5
-1


ψ t = 0s
1.5
1
0.5
0
-0.5
-1
-1.5
Z
1
1.5
2
2.5
R
1
0.5
0
-0.5
-1

With ExB drift terms removed



DIII-D Shot 177053 (with RE sources) – Chen Zhao

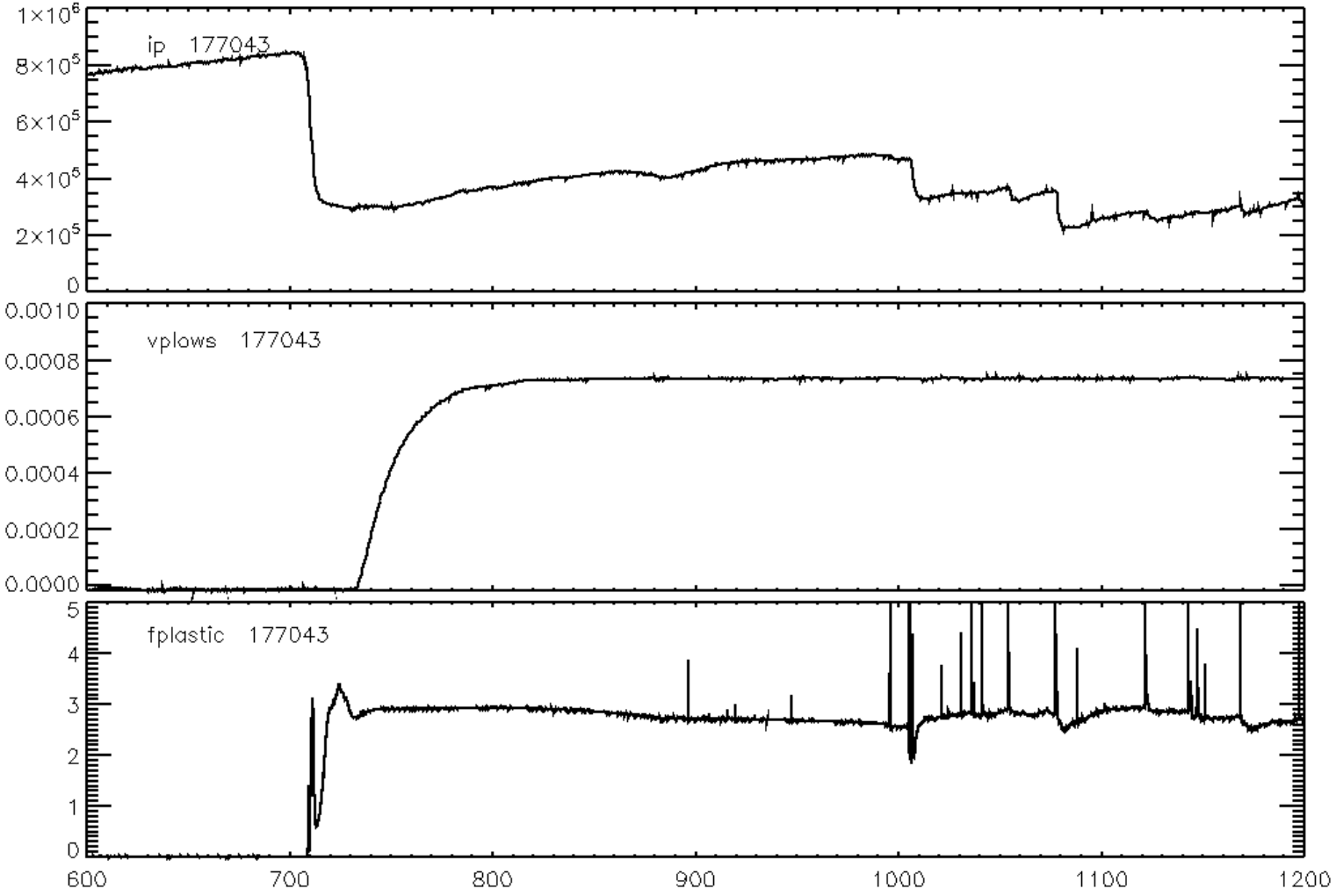


Code changes now committed to GIT

NEXT Steps:

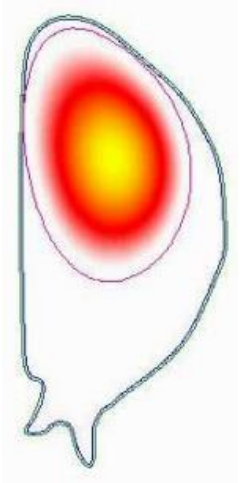
1. Study of sensitivity to $\kappa_{\perp}$?
2. Comparison with shot results
3. Presentation at DIII-D disruption meeting

177053 Exp. Traces (Lyons 06/08/20)



Test of Boozer Theory for Cold VDE (Clauser)

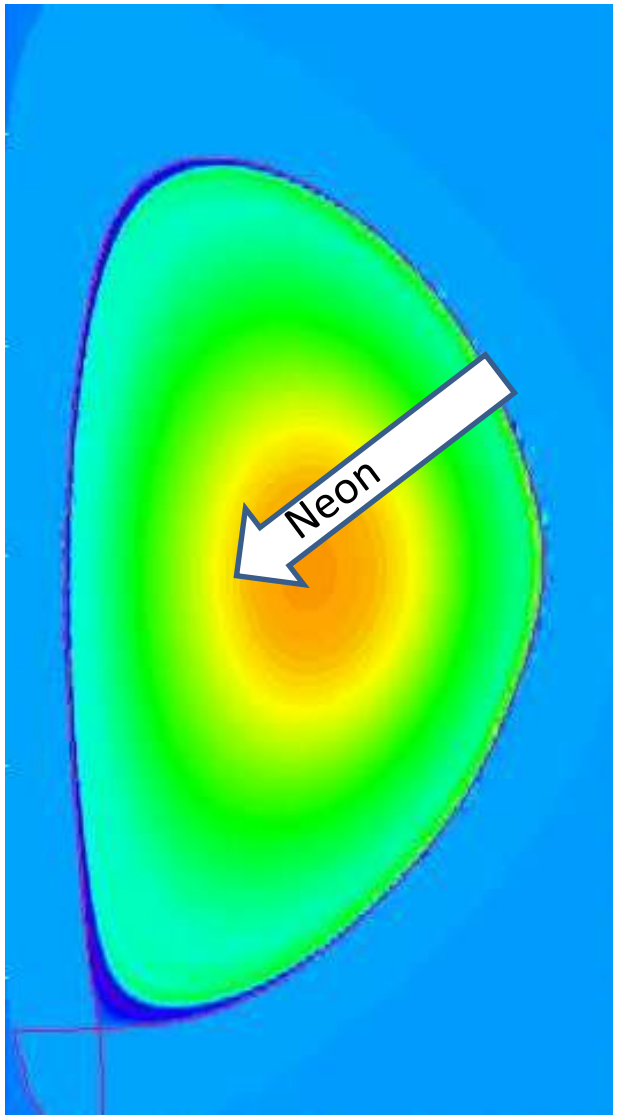
- Boozer's analytic theory that if ITER suffers a disruption on the mid-plane, such that the current decreases to I = 0.83 I_0, vertical stability will be lost, even for an ideally conducting wall.
- Cesar has tried to verify this, and finds the plasma is still VDE stable with I = 0.3 I_0
- Difference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

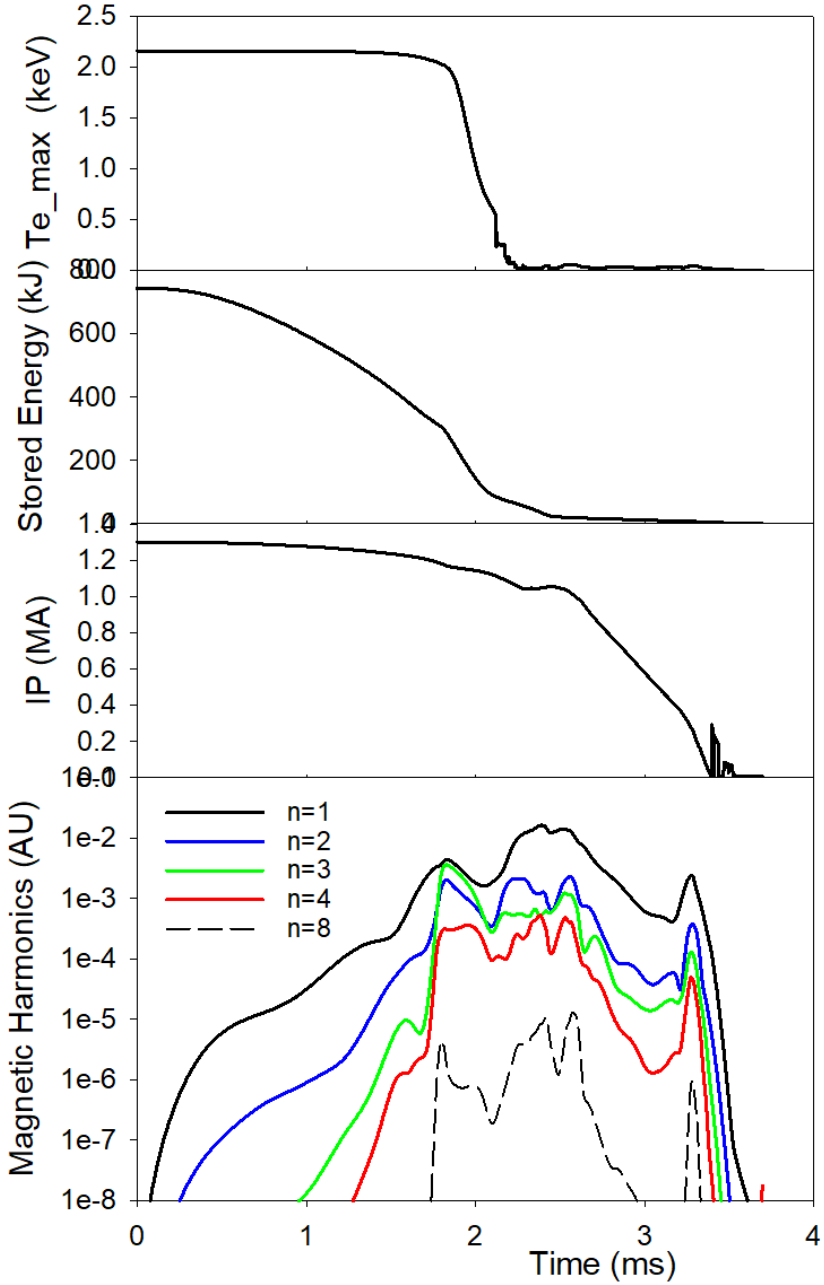


Vs.

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

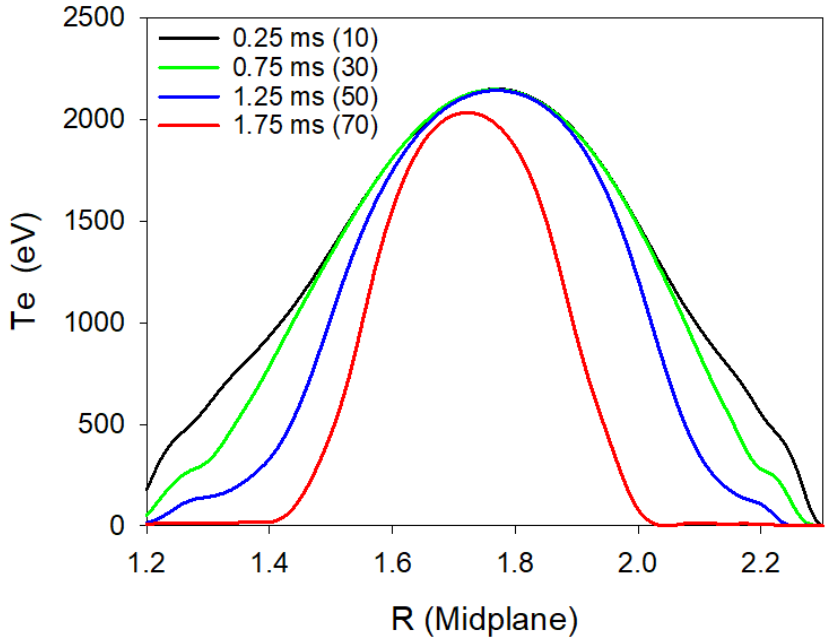
DIII-D Neon pellet mitigation simulation (for KORC)

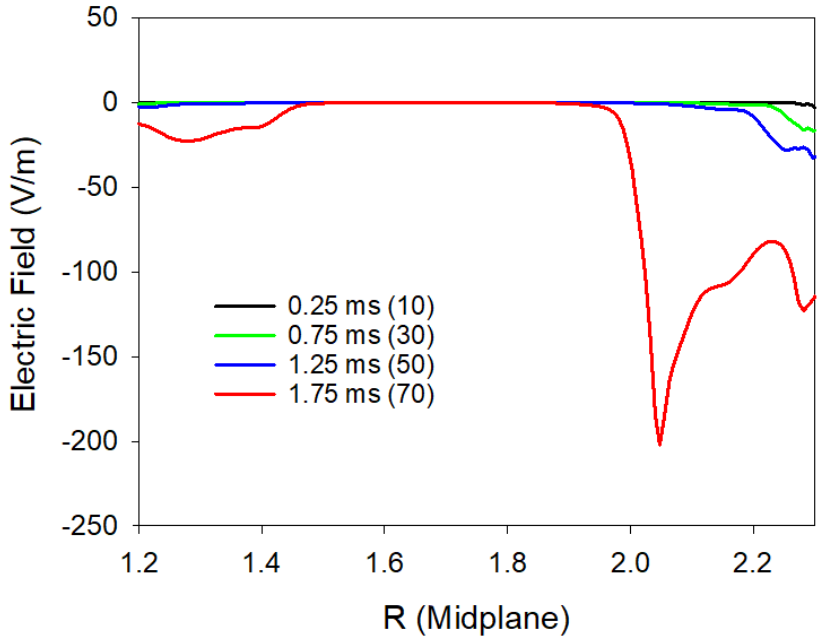


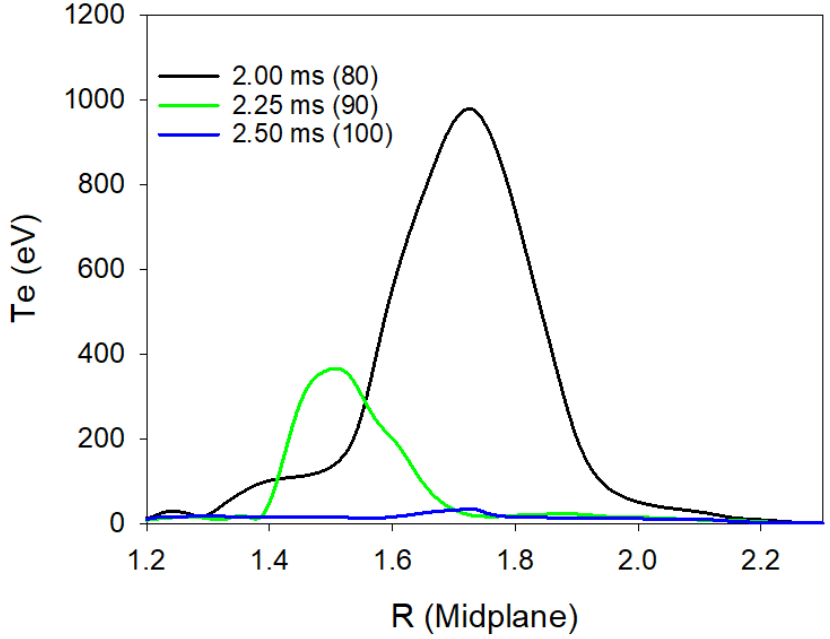


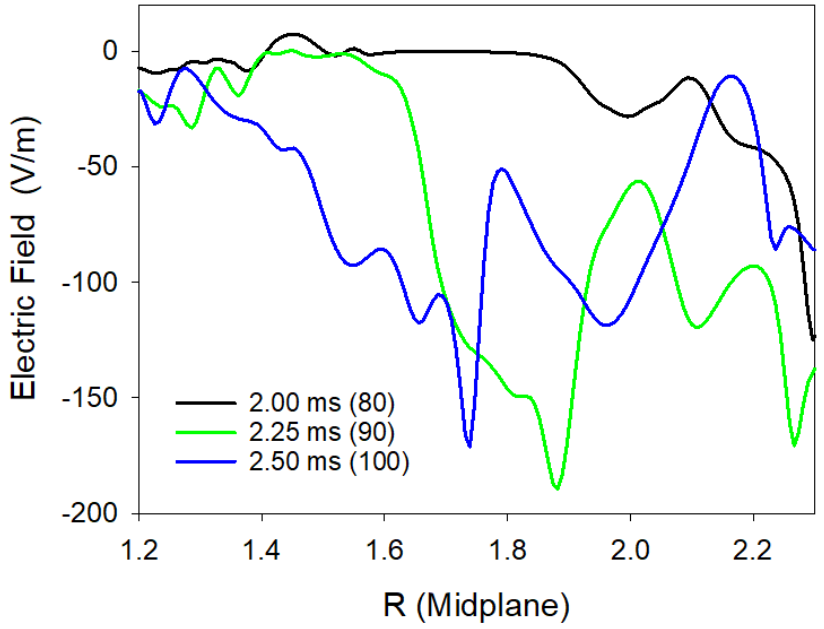
/global/cscratch1/sd/blyons/C1_33984065

Mid-plane Electron Temperature and Electric Field

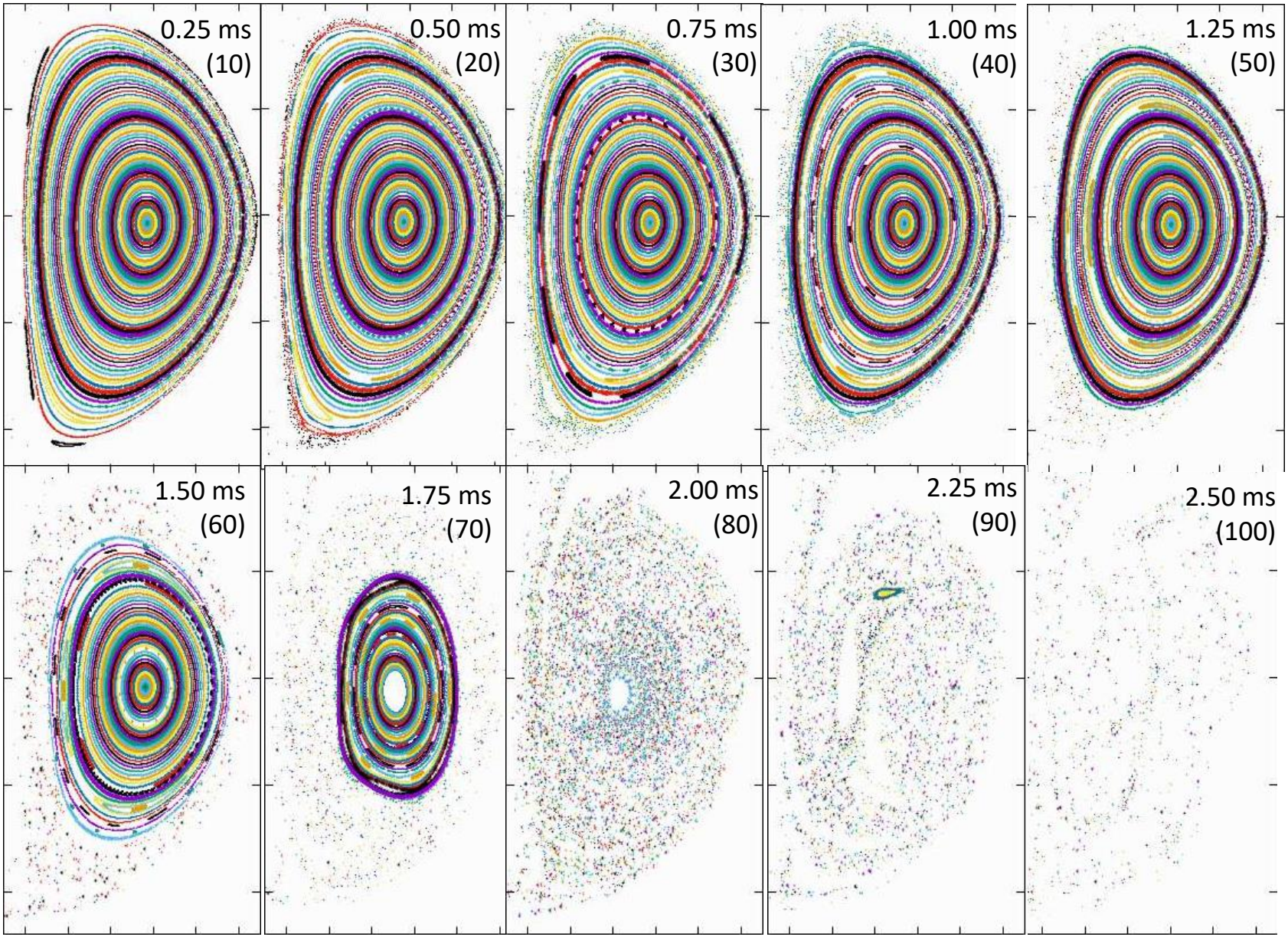




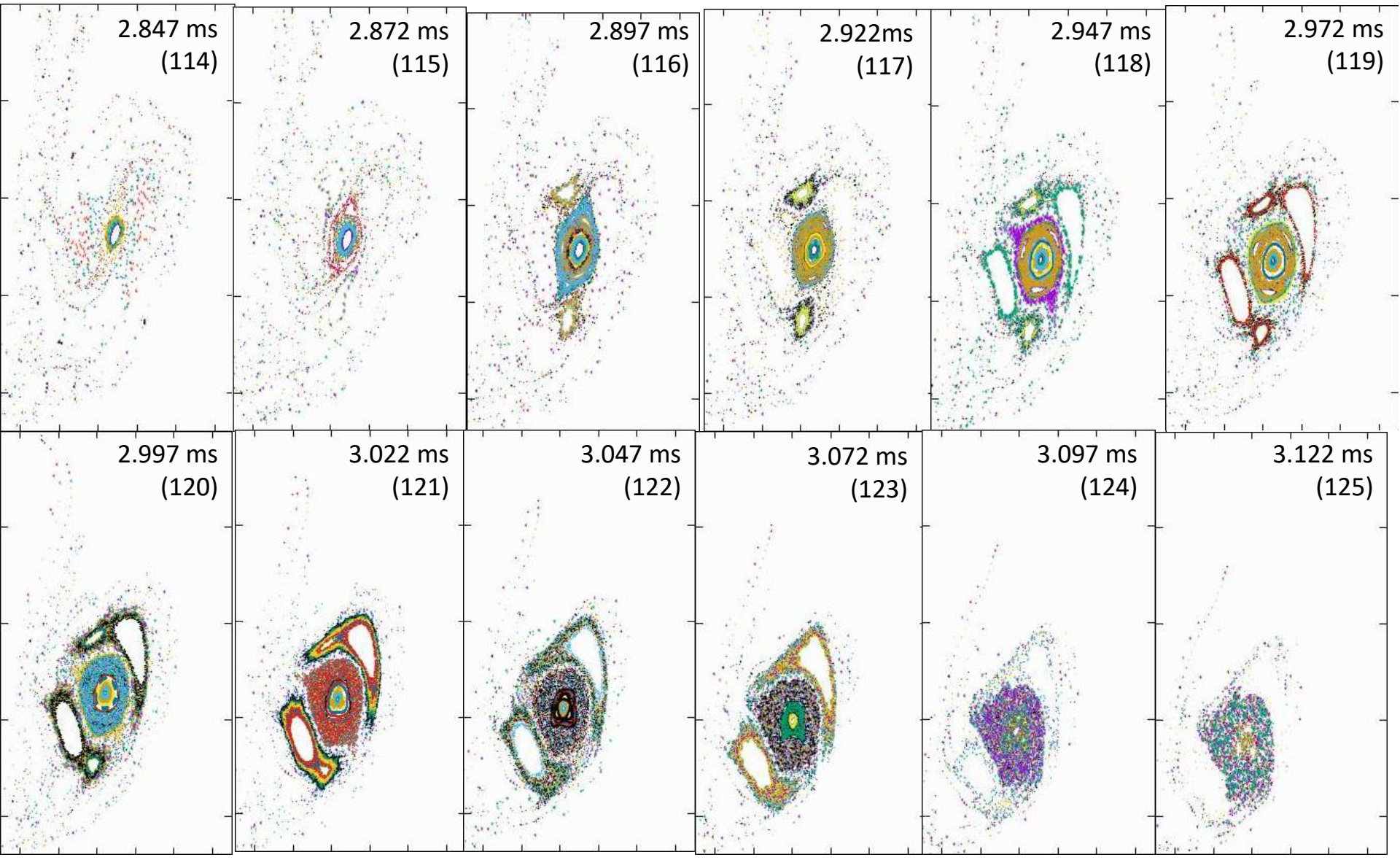




Magnetic Surface Breakup

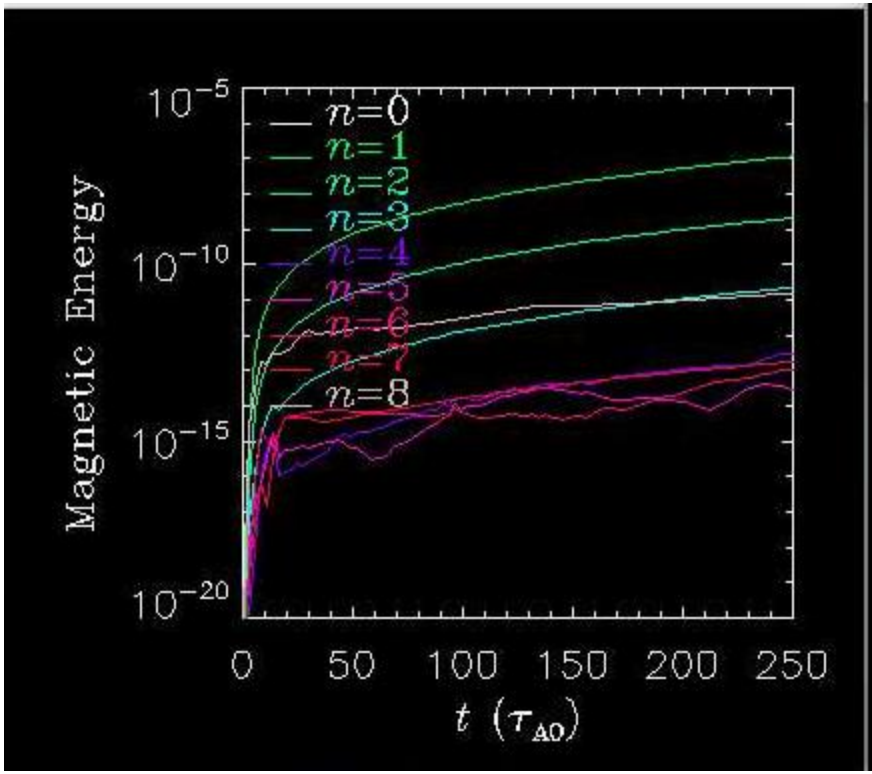


Partial Surfaces Reforming

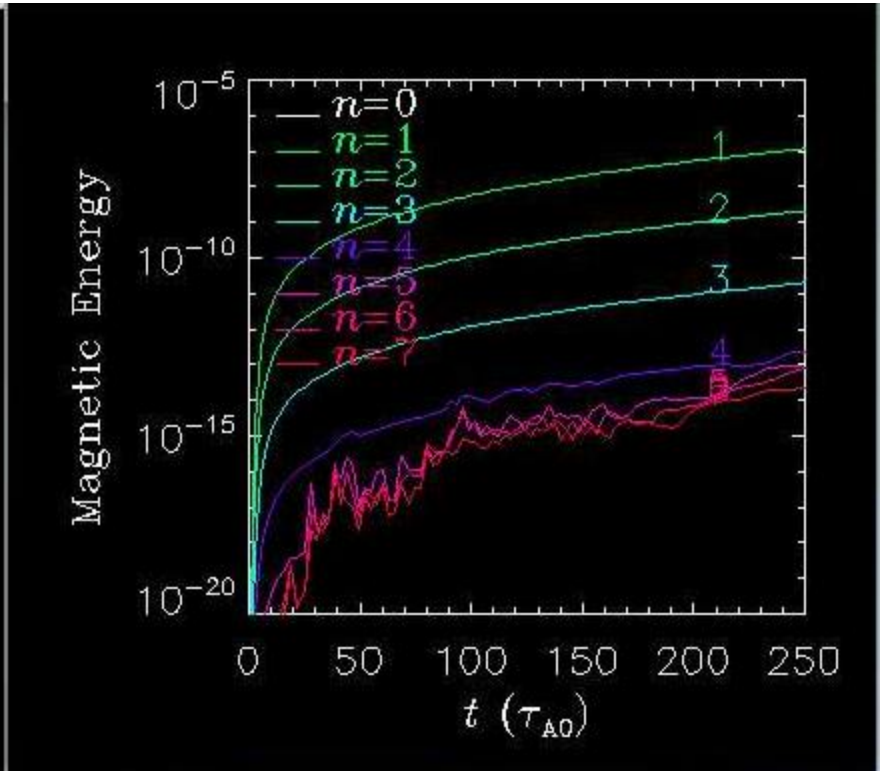


32 plane rerun now in progress

8 planes

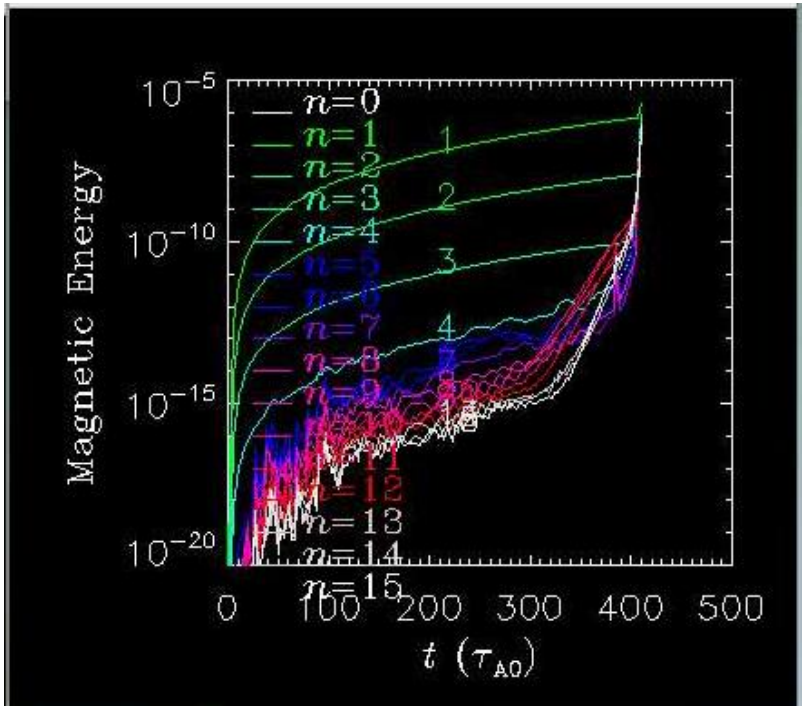


32 planes

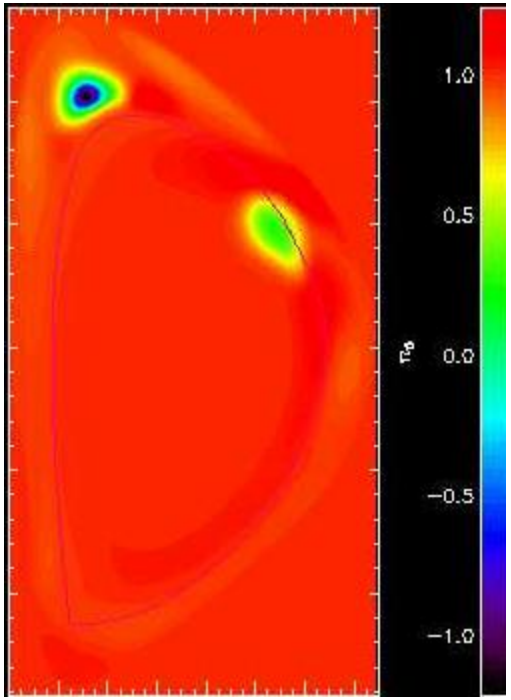


32 plane case crashed with negative density

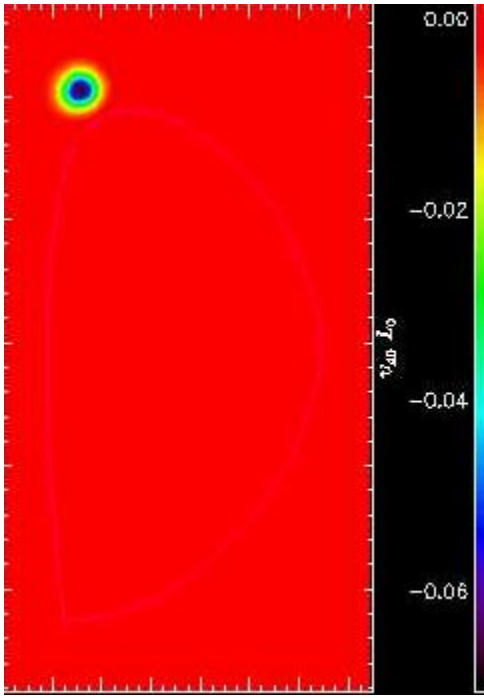
N=32 blows up at later time



density



Toroidal velocity @ 18



Near the end, dt > dx / V in the toroidal direction, which can lead to oscillations. Recommendations:

(1) iupstream=1, (2) smaller dt, (3) increase hyperv, (4) increase denm

Energy conservation

6% error does not depend on:

- dt=0.5, 1.0, 2.0
- inocurrent_pol=0,1
- inocurrent_tor=0,1
- Itemp = 0.1
- jadv = 0,1
- etar = 1.e-7, 1.e-9
- idens = 0,1

- Now checking dependence on magnetic boundary conditions and form of Poyting Flux divergence: $\nabla \cdot (\mathbf{E} \times \mathbf{B})$