M3D-C1 ZOOM Meeting

06/26/2023

Upcoming Meetings

CS Issues

1. New M3D-C1 developer at PPPL
2. Adaptation update --RPI
3. Reduced precision SuperLU …Jin Chen
4. Perlmutter_cpu update
5. NERSC Time
6. Changes to github master since last meeting
7. Regression tests
8. Debug for Dingyun's application

Physics Studies

1. Double Tearing Mode in NSTX
2. Study of DTM with analytic profiles…β stabilization, importance of RI
3. Possible bug in init_basicq.f90
4. APS Invited Talk
5. DIII-Theory highlight
6. Anything else

In attendance

Steve Jardin
Hank Straus
Chang Liu
Jin Chen
Brendan Lyons
Cesar Clauser
Priyanjana Sinha
Chen Zhao
Andreas Kleiner
Nate Ferraro
Min Gu Yoo
Adelle Wright
Saurabn Saxena
Usman Riaz
Seegyoung Seol

Upcoming Meetings

EPS	July 3-7	Bordeaux, France
TSDW	July 19-21	Princeton, NJ
NSTX results rev.	July 24-25	Princeton
ITPA(MHD)	Sept 19-22	General Atomics
IAEA	Oct 16-21	London, UK
APS	Oct 30 – Nov 1	Denver, CO
AAPPS-DPP	Nov 12-17	Nagoya, JP

New p M3D-C1 Developer at PPPL

Saurabh Saxena….introduction by Adelle Wright

Adaption Update

RPI?

Reduced Precision SuperLU

Any new results –Jin Chen

perlmutter_cpu update

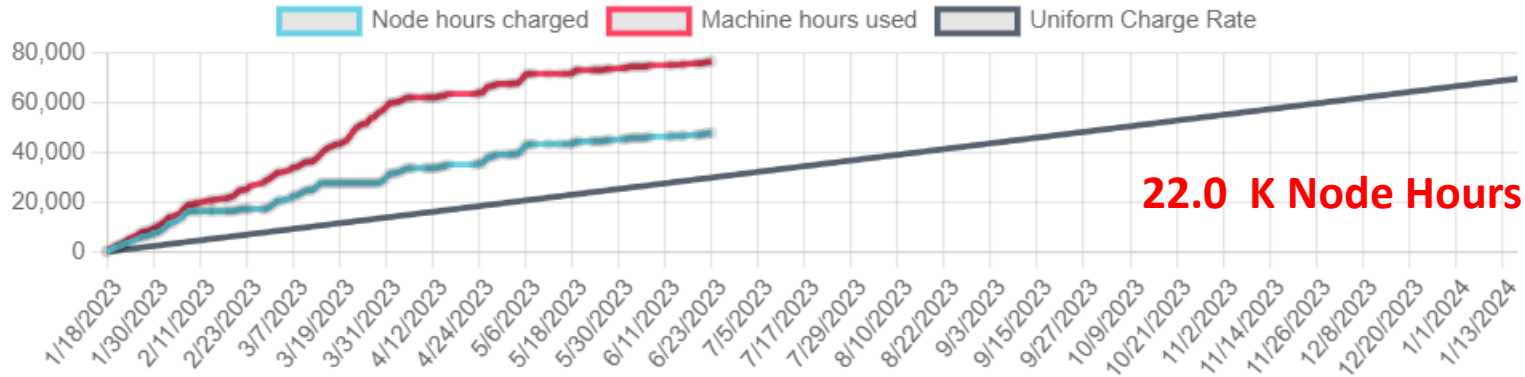
- Large jobs with 73 K vertices(N) and 98 K vertices (L) with 380 vertices/partition
  - 192-N-09 with 192 partitions, 380 v/p, 64 planes, 64 cpu/node: runs ok!
  - 192-N-10 with 192 partitions, 380 v/p, 32 planes, 64 cpu/node: runs ok!
  - 128-K-09 with 128 partitions, 386 v/p, 64 planes, 64 cpu/node: runs ok!
  - 128-K-10 with 128 partitions, 386 v/p, 32 planes, 64 cpu/node: runs ok!
  - 256-L-09 with 256 partitions, 384 v/p, 64 planes, 64 cpu/node: segmentation v
  - 256-L-10 with 256 partitions, 384 v/p, 32 planes, 64 cpu/node: runs ok!

- Smaller meshes with 9 K vertices (B) and 19 K vertices (H)
  - Normally run ok with 128 cpu/node and 150-200 vertices/partition
  - Also run ok with 64 cpu/node and 300-400 vertices/partition

Thanks to Jin for correcting my options_bjacobi file with -sub_mat_mumps_icntl_14 100

NERSC Time 2023

mp288



22.0 K Node Hours remaining!

- MP288 usage rate is a bit high but leveling off
- Also, 6.1K k GPU node hours remaining
- Cori is gone!
- I have contacted DOE to see the likelihood of getting more time – no time available now but more may become available at next clawback

Changes to github master --after 2023-05-21 (page 1)

Yao Zhou:

06/02/23: Fixed bug in tepsifkappar

Nate Ferraro:

05/23/23: Some changes to the random perturbation initialization routine to use the correct values ofor psi when external coils are present

06/14/23: Fixed bug where transport coefficients were defined before x-points were calculated, affecting some linear calculations with psi-dependent transport coefficients

06/19/23: Added a routine to output boundary node positions and normal vectors to an ascii file

06/19/23: Implemented viscosity that is a function of wall distance

06/21/23: Added an idl routine plot_norm to plot the normal vector data in the normcuv file

S.Jardin

06/24/2023: Added option for itor=0, itaylor=35

Changes to github master --after 2023-05-21 (page 2)

Jin Chen

06/25/23: updates for perlmutter cpu and gpu nodes

Seegyoung Seol

06/05/23: 2.5D adaptation support added, compilation error corrected, code cleaned up

06/07/23: m3dc1_scorec compilation error with –Werror flag fixed

06/08/23: model face adaptation revive

06/14/23: fixing compilation error with m3dc1_scorec

06/21/23: 2.5D adaptation support added to centos7 (compile with ADAPT=1)

Usman Riaz

06/09/23: Fixed few small bugs from recent Adapt update

Local Systems

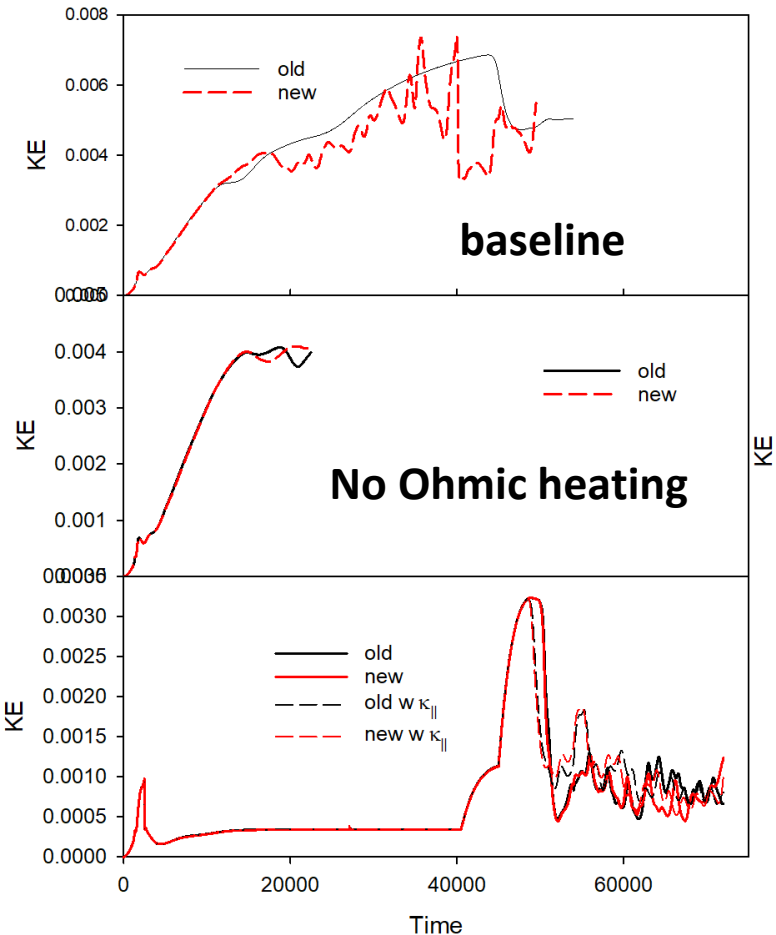
- PPPL centos7(06/24/23)
  - 7 jobs PASSED
- PPPL greene (06/24/23)
  - 5 jobs PASSED
- STELLAR (06/25/23)
  - 7 regression tests **PASSED** on stellar
- TRAVERSE-nvhpc-cuda
  - **Missing .mk file**

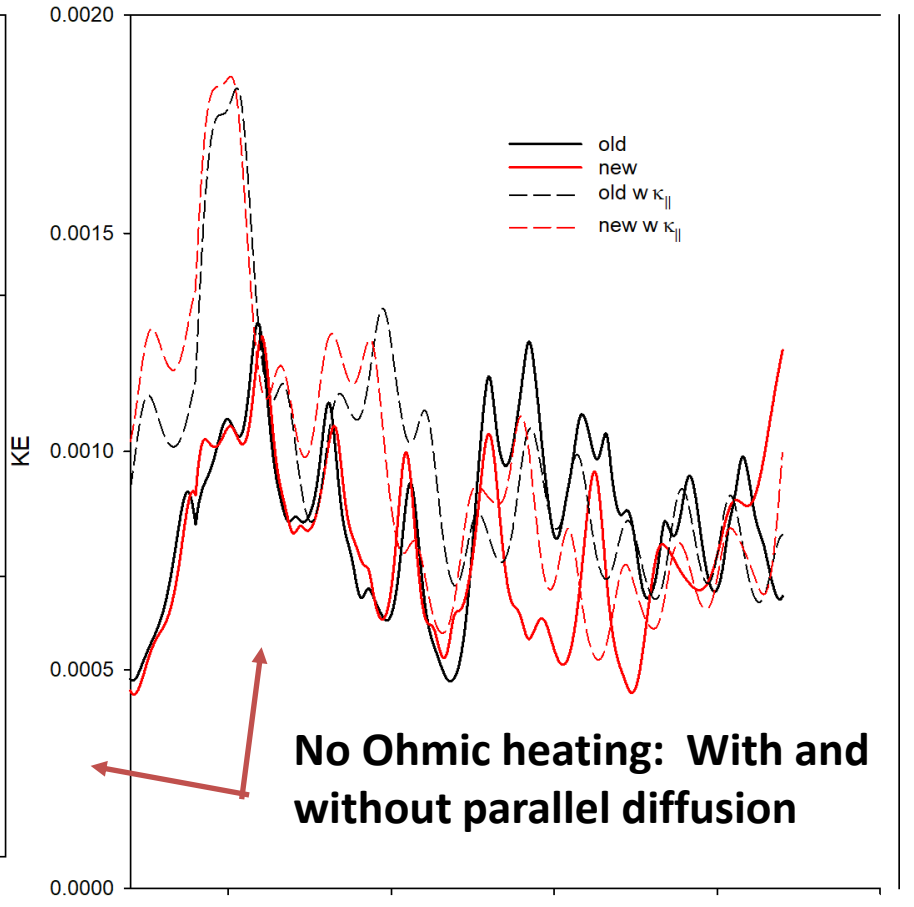
NERSC

- Perlmutter_cpu (06/26/23)
  6 jobs **PASSED**
  NCSX failed with very small difference in C1ke

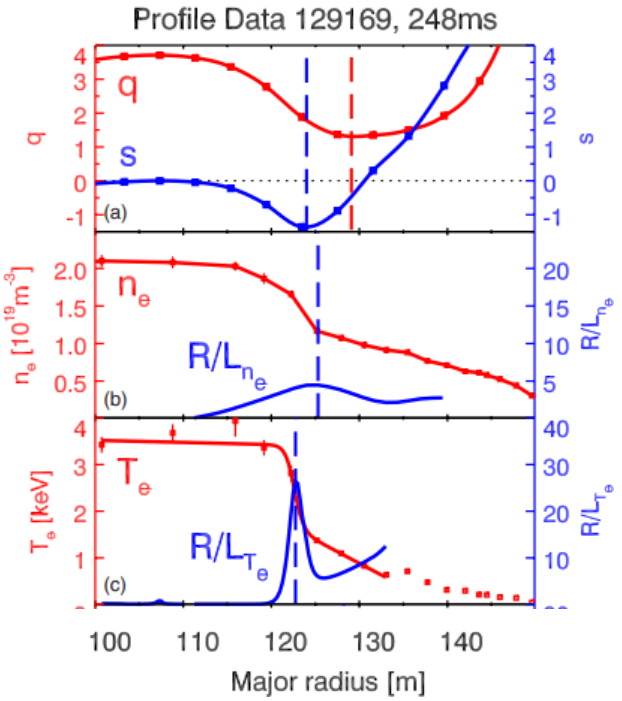
- Perlmutter_gpu (06/26/2023)
  - pellet, RMP, & RMP_nonlin, adapt all **PASSED**
  - KPRAD_2D, KPRAD_restart, NCSX all failed with very small differences

Try turning off certain terms -- no success

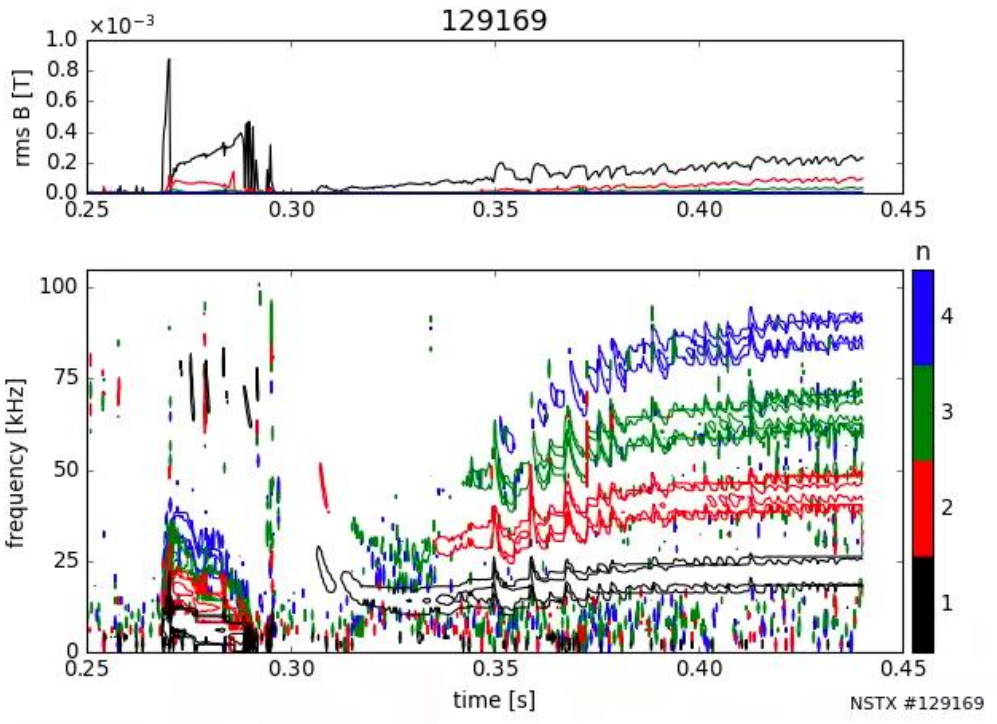




Double Tearing Mode in NSTX

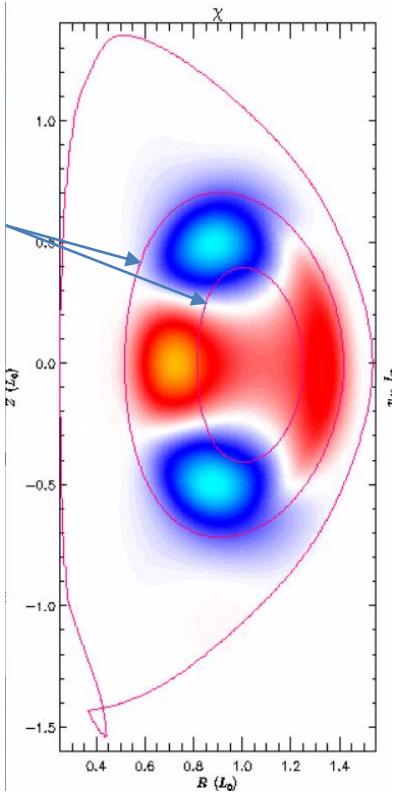


From: Yuh, et al, Phys. Plasma (2009)

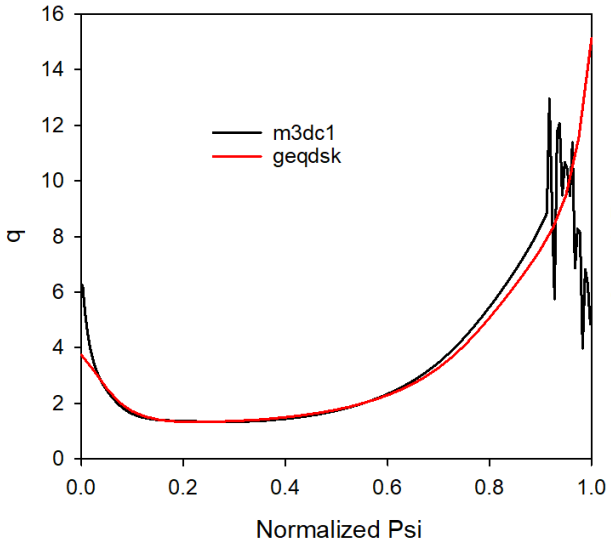


Some MHD activity starting at about 270 ms

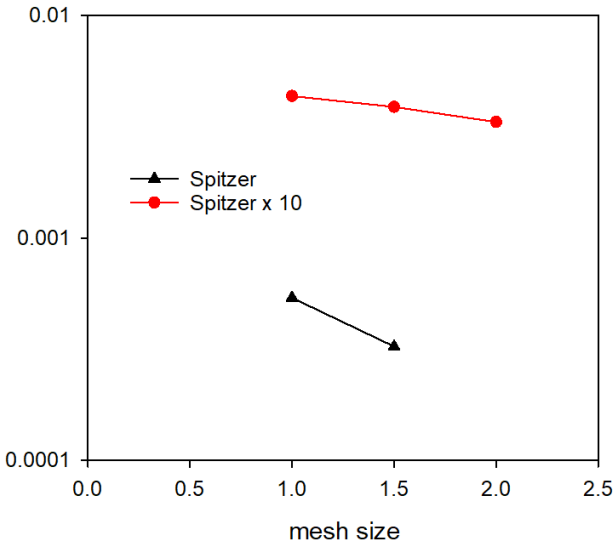
DTM n=1 Eigenfunction and growth rate



Linear χ at 247 ms

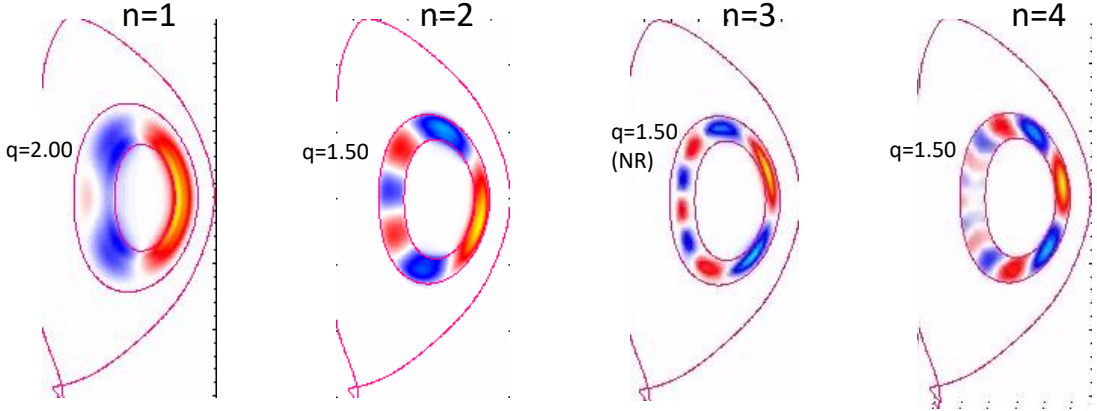


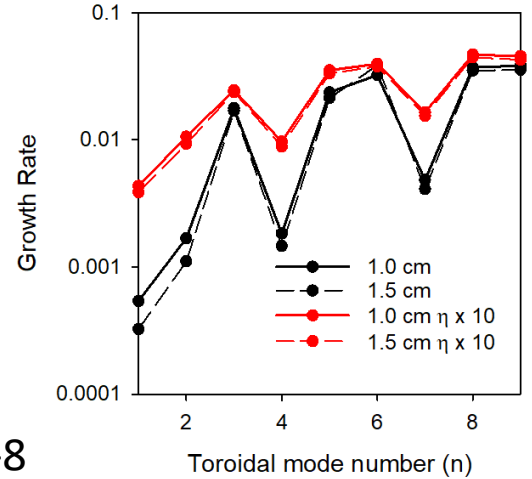
q-profile in geqdsk file is smooth. However, when we recompute the equilibrium in M3D-C1, oscillations appear



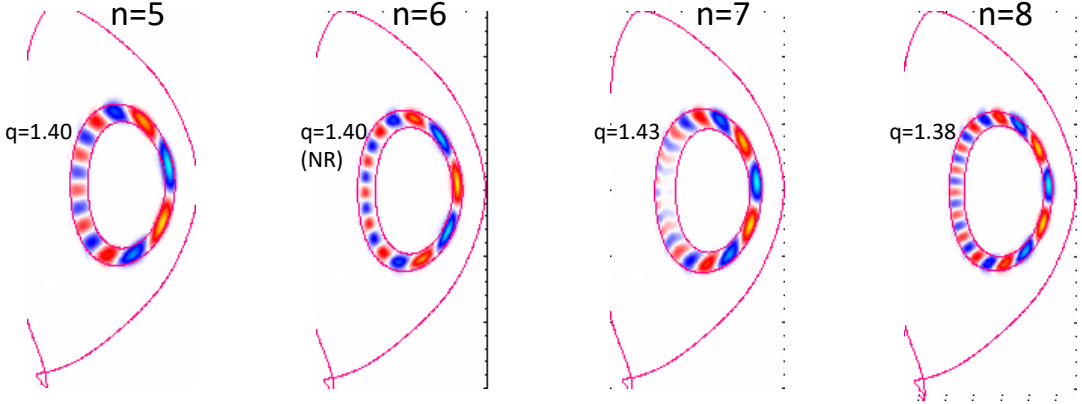
Linear growth rate as a function of linear mesh size for spitzer η and spitzer x 10

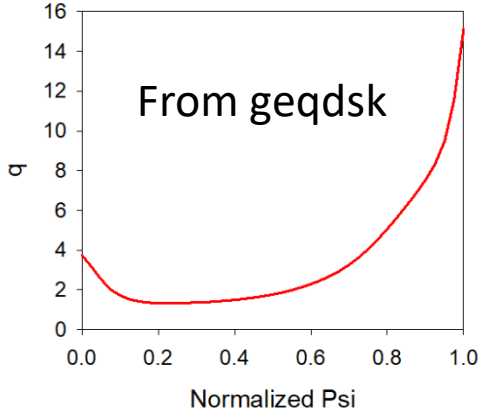
NSTX Reversed Shear shot 129169 @ t=247 ms



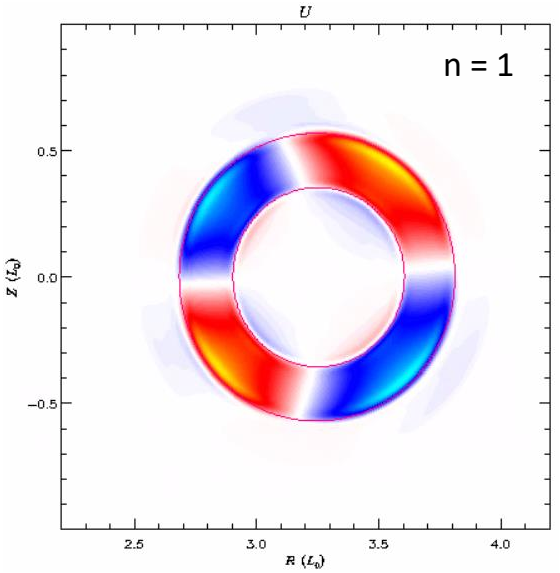


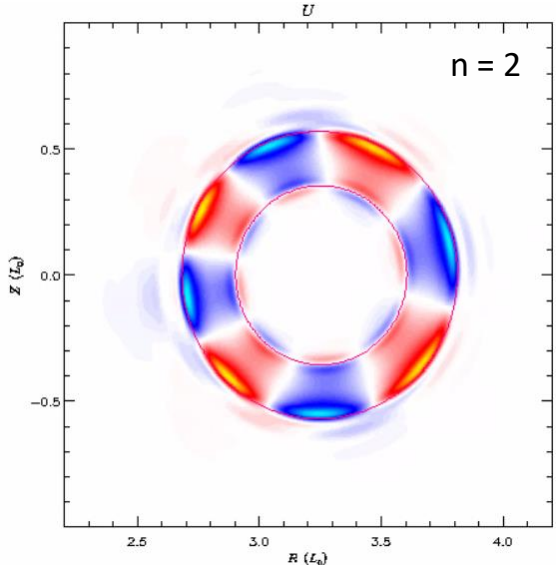
Plotted are perturbed pressure and some q-contours for n=1-8

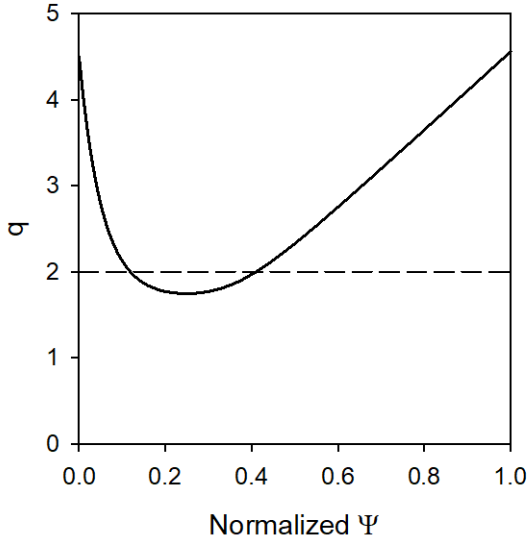


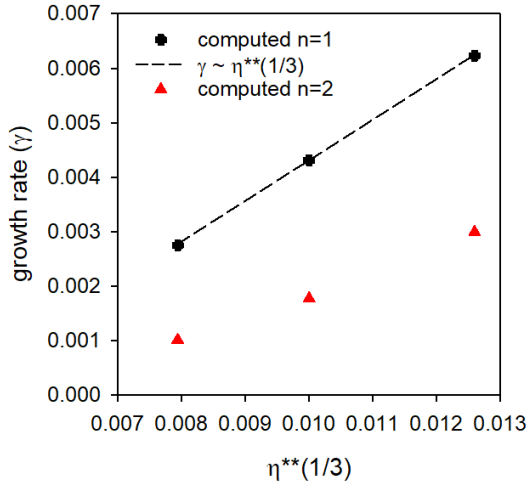


Analytic profiles in circular x-section plasma







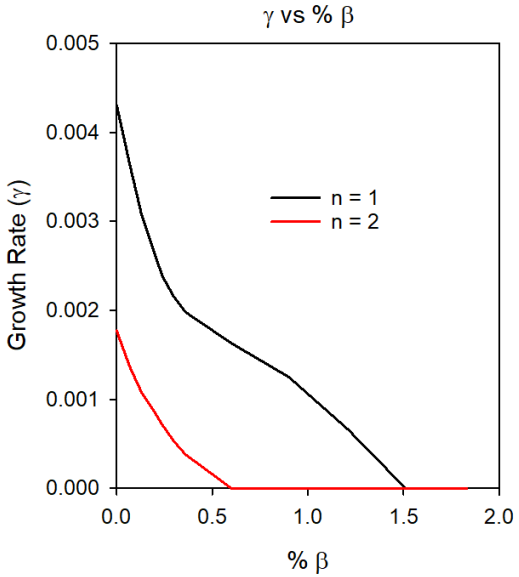


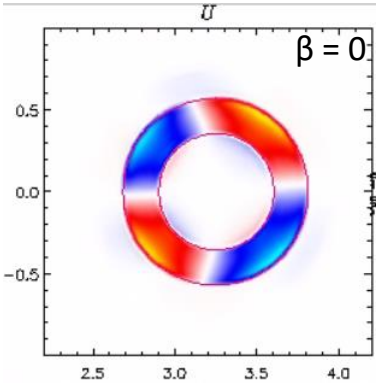
- Both n=1 and n=2 are unstable at zero pressure
- Instability is localized between the two q=2 surfaces
- n=1 growth rate scales like $\eta^{1/3}$, as predicted by theory in a cylinder

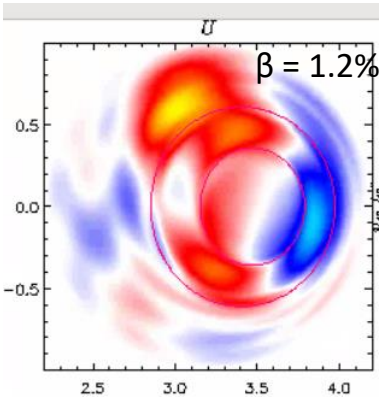
$$q(\psi) = q_0\left[1+\left(\psi/r_0^2\right)^{\lambda}\right]^{1/\lambda}\left[1+A\exp\left(-\psi/\delta^2\right)\right]/(1+A)$$

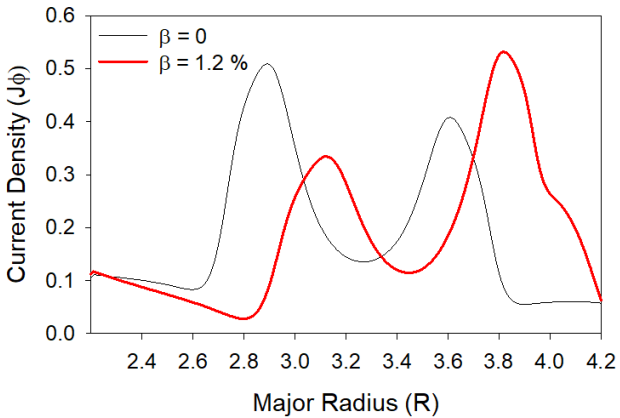
$$q_0 = 4.5, \quad r_0 = 0.612, \quad \lambda = 6.48, \quad A = 1.64, \quad \delta = 0.23$$

This double tearing mode is stabilized by β in a torus





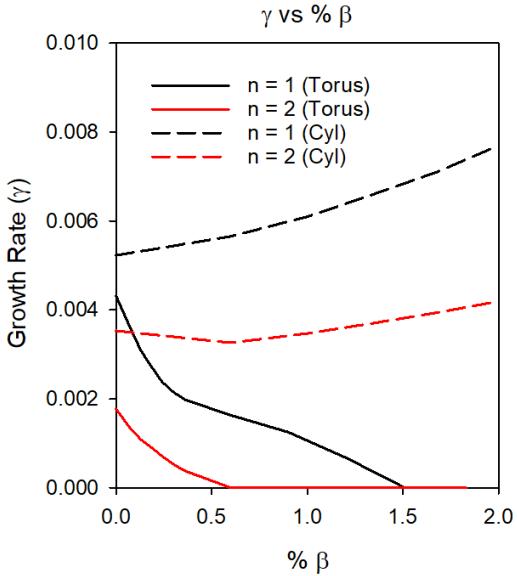


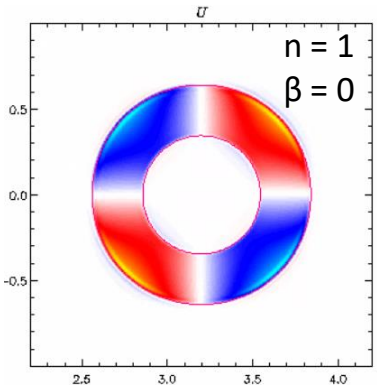


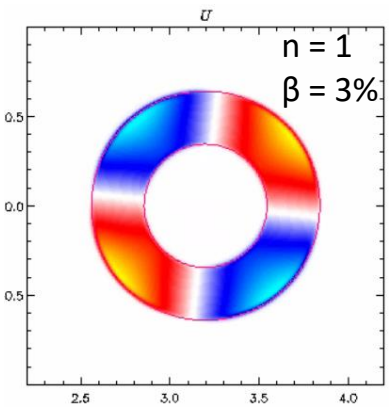
$$q(\psi) = q_0\left[1+\left(\psi/r_0^2\right)^{\lambda}\right]^{1/\lambda}\left[1+A\exp\left(-\psi/\delta^2\right)\right]/(1+A)$$

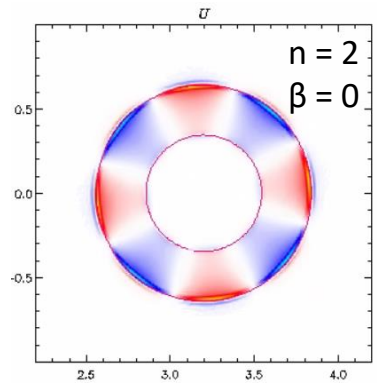
$$q_0 = 4.5, \quad r_0 = 0.612, \quad \lambda = 6.48, \quad A = 1.64, \quad \delta = 0.23$$

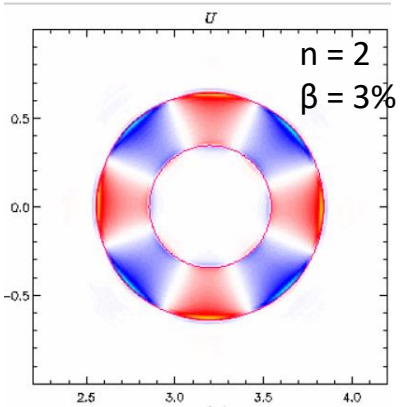
In cylinder geometry, double tearing mode is NOT stabilized by β











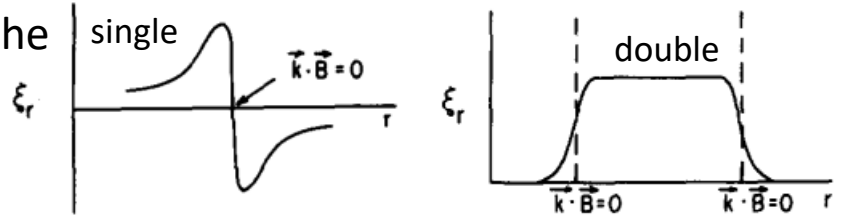
$$q(\psi) = q_0 \left[1 + \left(\psi / r_0^2\right)^{\lambda}\right]^{1/\lambda} \left[1 + A\exp\left(-\psi/\delta^2\right)\right] / (1 + A)$$

$$q_0 = 4.5, \quad r_0 = 0.612, \quad \lambda = 6.48, \quad A = 1.64, \quad \delta = 0.23$$

Comment on double tearing mode literature

P. Pritchett, Y. Lee, J. Drake, "Linear analysis of the double tearing mode", Phys. Fluids **23** (1980)

- Slab geometry, reduced MHD
- 156 citations !



J. Leboeuff, V. Lynch, B. Carreras, "Linear and nonlinear resistive MHD stability of tokamak discharges with negative central shear", PoP **8** (2001)

- Full MHD, toroidal geometry
- 7 citations

There are many papers emphasizing the importance of the resistive interchange mode in a tokamak with reversed shear. It would be useful if we could evaluate the surface averaged D_R criteria.

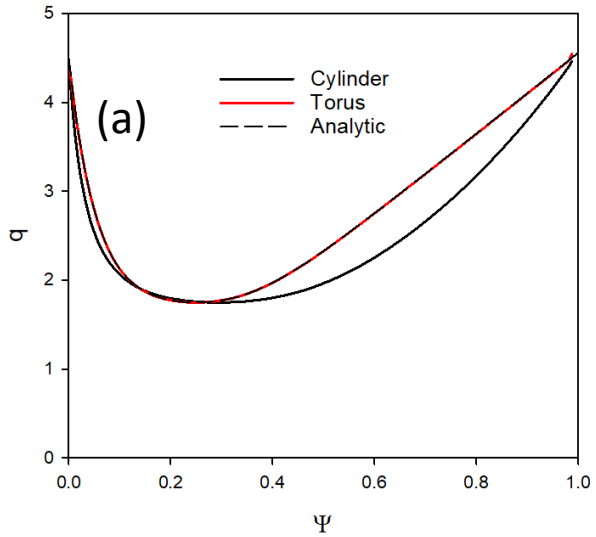
…However, for $\beta_0 > 1\%$, the double tearing mode disappears and only a resistive interchange mode remains at the inner rational surface…..

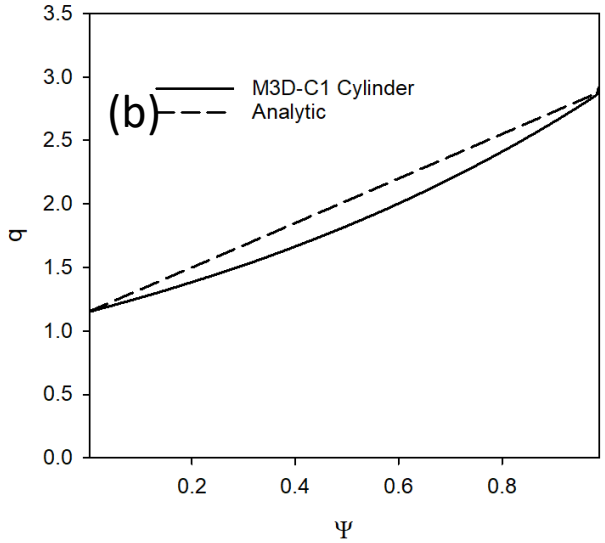
$$D_R = D_I + \left(H - \tfrac{1}{2}\right)^2$$

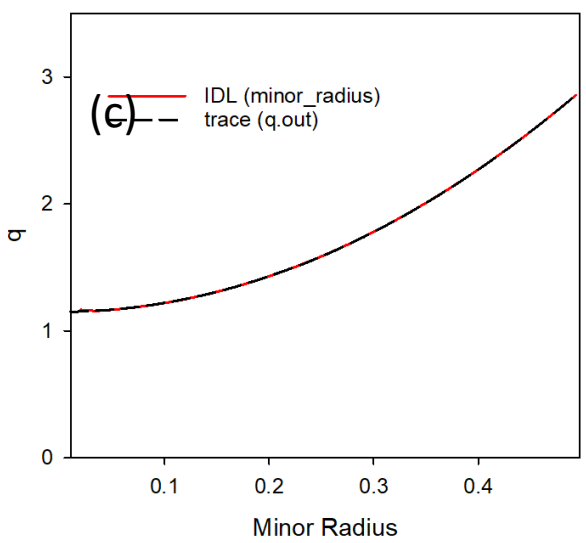
$$H = \frac{2\pi R B_0 g p' V'}{q'}\left(\left\langle \frac{1}{|\nabla\Psi|^2}\right\rangle - \frac{\left\langle B^2/|\nabla\Psi|^2\right\rangle}{\langle B^2\rangle}\right)$$

Glasser, Greene, Johnson, PF (1976)

Possible problem in init_basicq.j90







- (a) low β fixed-q equilibrium defined in torus (QSOLVER) and cylinder (ITOR=0, ITAYLOR=35)
  - IDL plot of q(Ψ) in torus agreed with analytic formula, but not for the Cylinder
- (b) Another cylindrical case with itor=0, itaylor=26 also showed disagreement
  - Both cases use the routine "fixed_qprofiles()" to define equilibrium
    - as do itaylor=21,22,25,27,28,30,32,34
- (c) as a check on the IDL plot_surface_average,"q", we compared with "trace" q

➔ IDL q-calculation looks correct, must be problem in fixed-qprofiles equilibrium

➔ Changing nint from 1000 to 4000 had no effect!

APS Invited Talk

Chen Zhao has an APS invited talk on “Simulation of DIII-D disruption with pellet injection and runaway electron beam.

Priya Sinha is giving an APS invited talk “Neoclassical transport due to resonant magnetic perturbations in DIII-D and NSTX”

DIII-D Theory Weekly Highlight

The M3D-C1 code is being actively extended to simulate and study the feasibility of shattered pellet injection (SPI) in the ITER device. However, the simulations require very expensive computing power to calculate the 3-dimensional MHD dynamics triggered by shattered pellets with sufficient resolution in the ITER-scale tokamak. One of the most expensive parts of the M3D-C1 simulation is solving various systems of field equations to evolve the MHD quantities, such as velocity and temperature, over time. To improve the performance of the field solvers, the interval between costly preconditioner updates was increased and better initial guesses were provided to the iterative solvers to converge to a solution faster. As a result, field solver performance increased significantly, from **between 3 to 10 times**, while still finding accurate solutions. With the improved field solver, the total performance of the M3D-C1 simulation also **increased by about 70 % or more**, helping to accelerate the ITER SPI simulations. In addition, a new interactive GUI application, visM3D, was developed to allow users to quickly and easily visualize and analyze large data sets from M3D-C1 SPI simulations using a license-free Matlab runtime library.

That’s All I have

Anything Else ?