M3D-C1 ZOOM Meeting

04/17/2023

Upcoming Meetings

CS Issues

1. Adaptation update …. RPI
2. Perlmutter Scaling update and issue with large jobs
3. Request for 64 bit scorec libraries…. J. Chen
4. NERSC Time
5. Changes to github master since last meeting
6. Regression tests
7. Debug for Dingyun’s application

Physics Studies

1. Highlights from ITPA MHD meeting
2. Highlights from NSTX-U PAC meeting
3. New PoP publication involving M3D-C1
4. Anything else

In attendance

Steve Jardin
Hank Straus
Chang Liu
Jin Chen
Brendan Lyons
Cesar Clauser
Priyanjana Sinha

Mark Shephard
Seegyoung Seol
Usman Riaz

Upcoming Meetings

Sherwood Theory	May 8-10	Knoxville, TN
EPS	July 3-7	Bordeaux, France
TSDW	July 19-21	Princeton, NJ
IAEA	Oct 16-21	London, UK
APS	Oct 30 – Nov 1	Denver, CO
AAPPS-DPP	Nov 12-17	Nagoya, JP

Adaption Update

RPI?

perlmutter_cpu update

- Large jobs with 73 K vertices(N) and 98 K vertices (L) with 380 vertices/partition
  - Normally fail with 64 cpu/node and 64 planes (SUBPC error)
  - Sometimes fail with 64 cpu/node and 32 planes
  - Both 32 and 64 plane cases more likely to run with 48 cpus/node

- Smaller meshes with 9 K vertices (B) and 19 K vertices (H)
  - Normally run ok with 128 cpu/node and 150 vertices/partition
  - Also run ok with 64 cpu/node and 300 vertices/partition
  - Too many vertices/partition gives oom error (not SUBPC)

- perlmutter is down this week for extensive testing
  - I will resume these tests next week

NSTX-Grid B 9614 2D Vertices

par	V/par	cpu/n	npl	nodes	time
128	75	128	8	8	9:14
			16	16	10:45
			32	32	15:27
			64	64	23:02
64	150	128	8	4	14:34
			16	8	16:39
			32	16	22:04
			64	32	41:00
32	300	64	8	4	19:51
			16	8	21:58
			32	16	26:10
			64	32	35:04

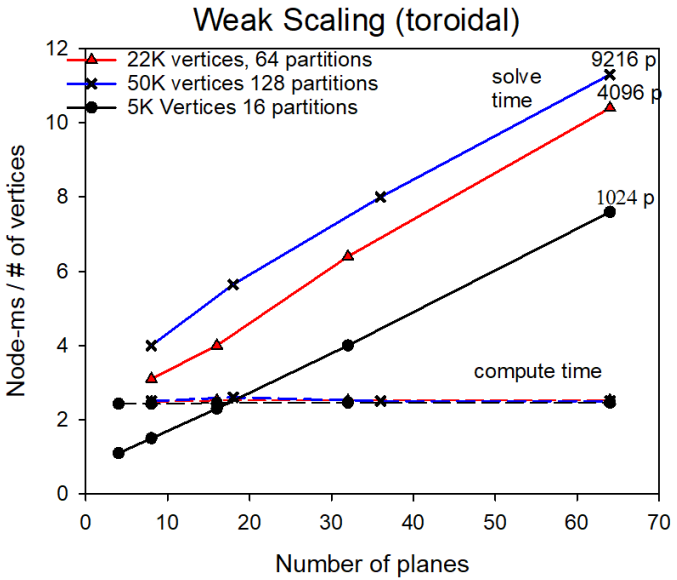
NSTX-Grid H 19218 2D Vertices

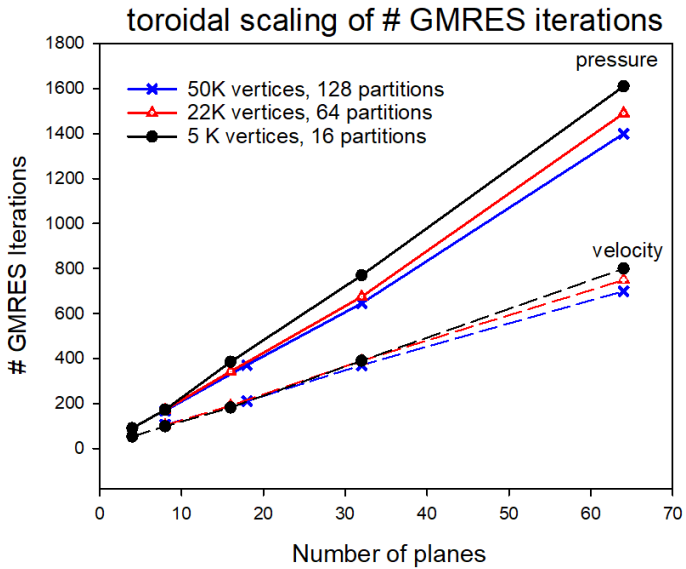
par	V/par	cpu/n	npl	nodes	time
256	75	128	8	16	13:33
			16	32	16.23
			32	64	23:07
			64	128	Hung
128	150	128	8	8	18:00
			16	16	23:08
			32	32	30:22
			64	64	45:35
64	300	64	8	8	23:47
			16	16	27:15
			32	32	34:53
			64	64	46:13

Perlmutter Scaling Update (1)

Toroidal Weak Scaling

- Compute time (defining matrix) scales perfectly
- Solve time (solving matrix) increases linearly with # planes
- # of GMRES iterations also increases linearly with # planes

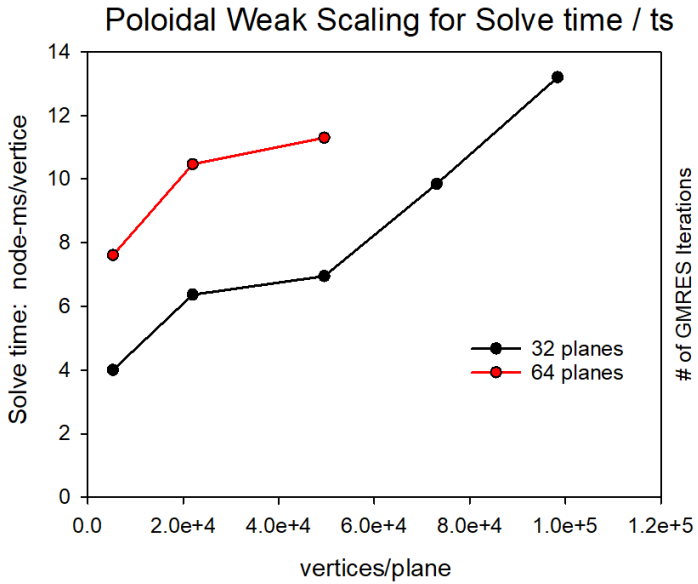


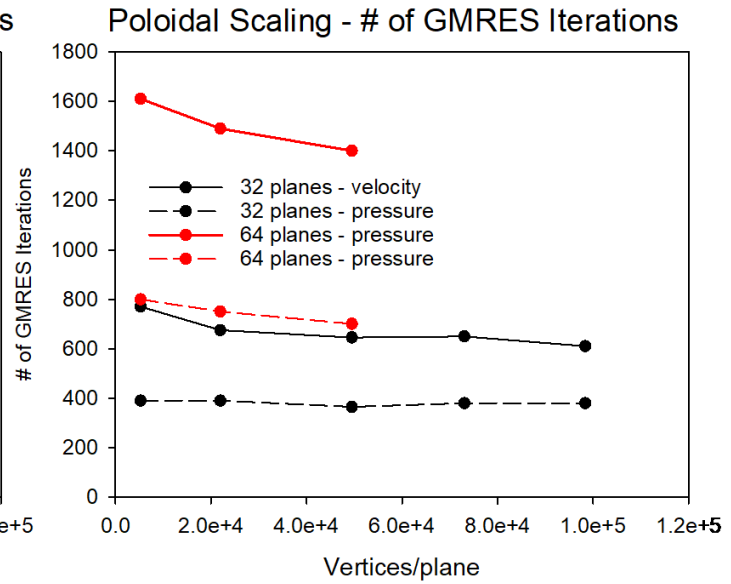


Perlmutter Scaling Update (2)

Poloidal Weak Scaling

- # of GMRES iterations does NOT increase linearly with #poloidal vertices
- Solve time does increase approximately linearly with #poloidal vertices

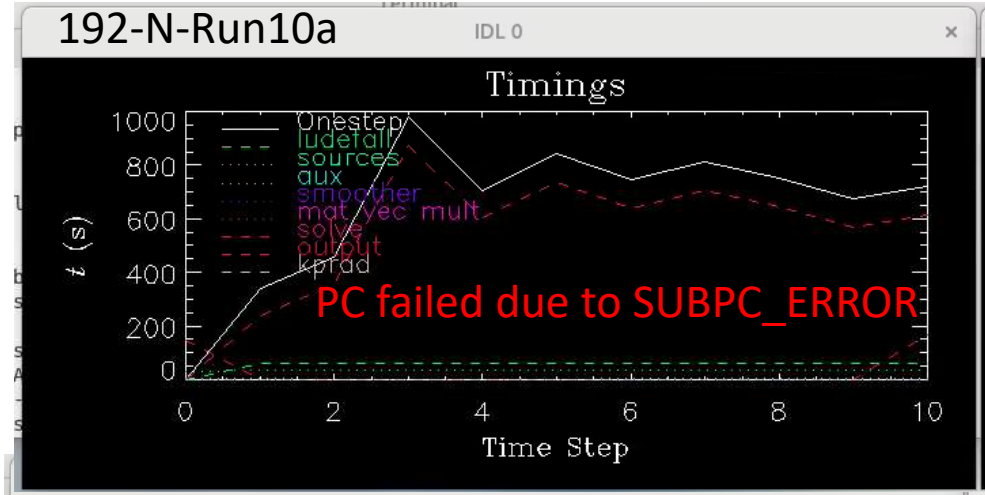




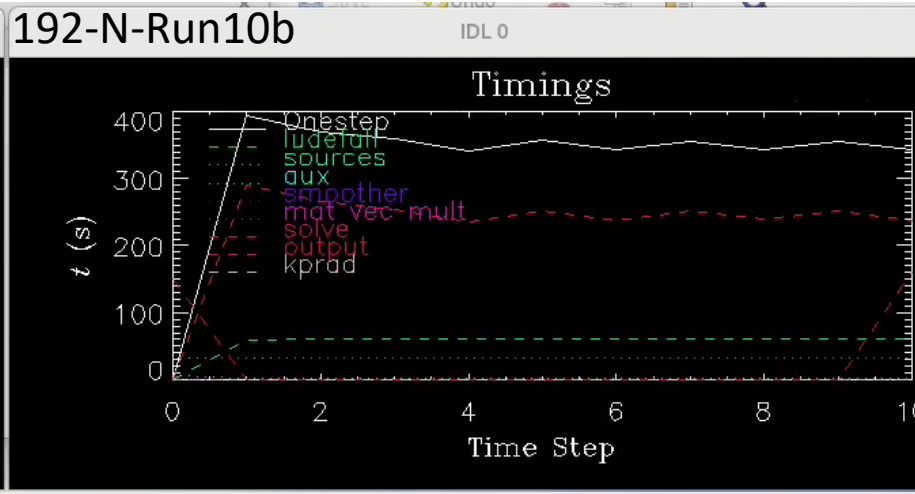
Problem with large jobs on Perlmutter_cpu:

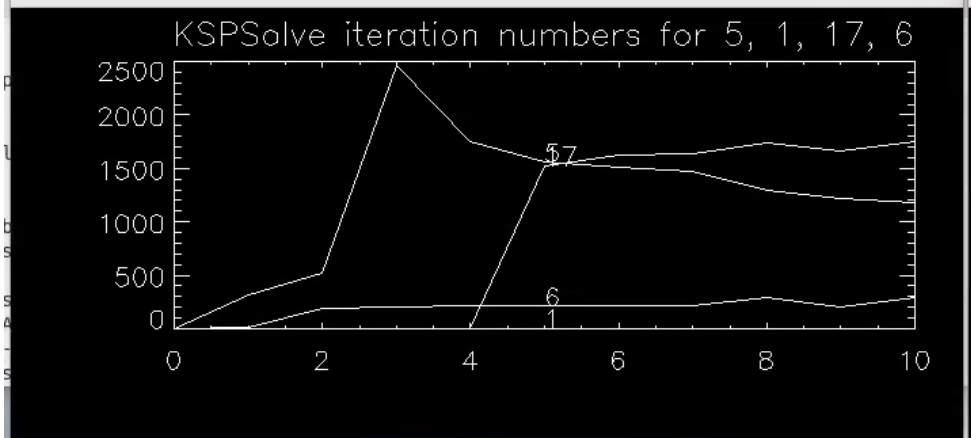
Same job, submitted twice, 192 partitions. 32 planes, 96 nodes, 6144 p, 73044 V/P, 64 cpu/nod

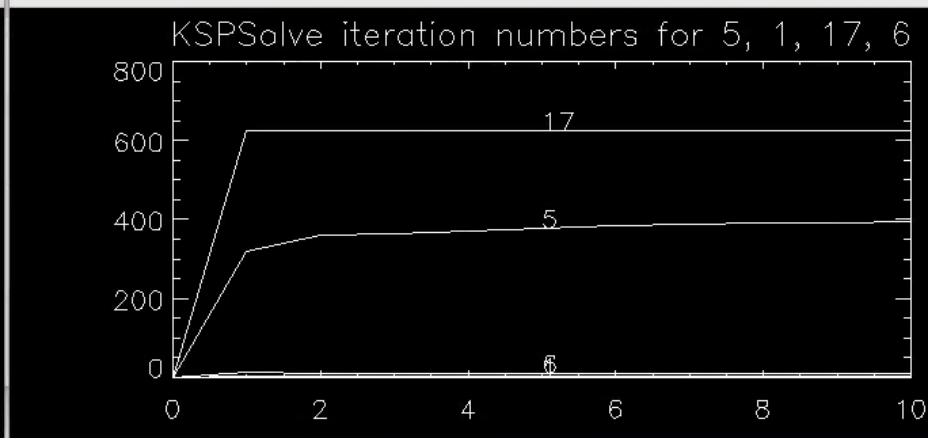
192-N-Run10a



192-N-Run10b







Request for 64 bit scorec libraries

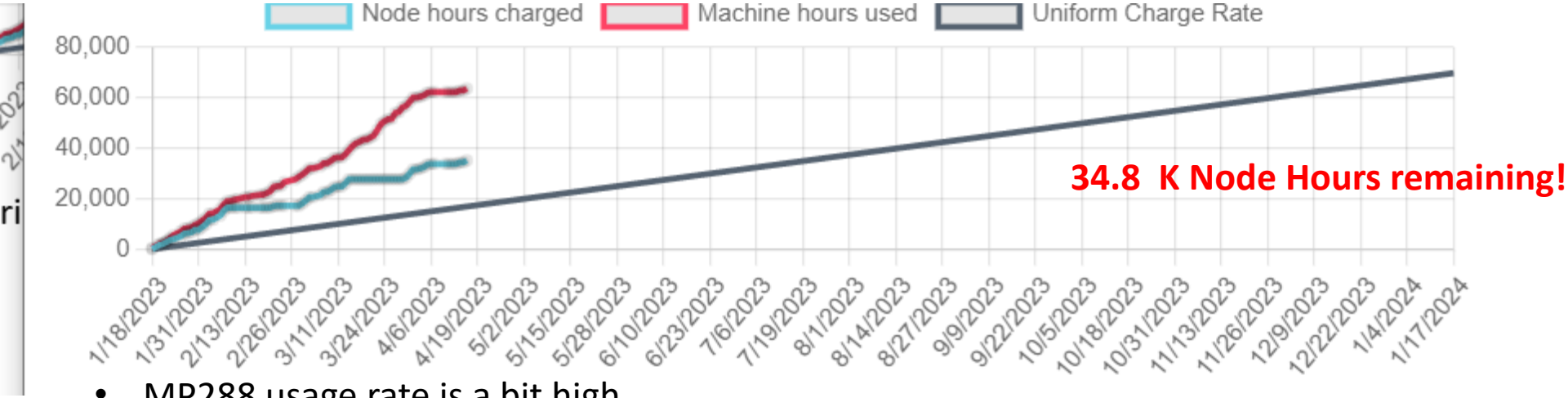
Jin Chen has compiled 64-bit petsc libraries:

/global/cfs/cdirs/mp288/jinchen/PETSC/petsc.20220915
drwxrws--- 9 jinchen mp288 4096 Mar 24 12:10 perlmuttercpu-nvidia-64bit
drwxrws--- 9 jinchen mp288 4096 Mar 25 15:33 perlmuttercpu-nvidia-st-64bit
drwxrws--- 9 jinchen mp288 4096 Mar 25 18:19 perlmuttercpu-nvidia-cplx-64bit

and now needs the RPI group to port their scorec library to be compatible with this build.

NERSC Time 2023

mp288



34.8 K Node Hours remaining!

- MP288 usage rate is a bit high
- Also, 10k GPU node hours
- Cori to go away end of April 2023

Changes to github master --after 2023-02-27

Nate Ferraro:

03/03/23: Added kprad_dt to scalar output.
Incremented output version to 44
Removed ihypamu input variable and newvar matrices associated with old h
hyperviscosity code

03/13/23: Extended hyperp terms to include toroidal derivatives

03/20/23: Allowing subtraction of vacuum fields in general case

Andreas Kleiner:

03/07/23: Added new functionalities to Python routines
Interactive adjustment of sizfieldParam parameterstoroi
Calculate toroidal peaking factor
Return time of time slice in code or MKS units
Plot M3D-C1 input namelist parameters as a function of time
Overplot toroidal planes in plot_field vs phi
Updates do docstrings
Updated documentation

03/17/23: A small typo in last commit

03/17/23: Python routines : Added missing script that returns shaping parameters

Changes to github master --after 2023-02-27

Seegyoung Seol:

02/28/23: Added Morteza 3D adaptation code
02/28/23: adding 3D adaptation with ADAPT=1 compilation flat
02/28/23: invalidating obsolete adaptation routine
03/13/23: model adjacency function added
03/14/23: cleaning up m3dc1_scorec
03/18/23: Fixing compilation error in unstructured
03/19/23: adding config files for stellar intelmpi
03/21/23: adding config files for centos7

Jin Chen:

03/23/23: Perlmutter_cpu nodes pumi and scorec libraries update
03/23/23: Perlmutter gpu nodes pumi and scorec libraries updated
04/04/23: superlu_dist print nnz of each jacobi block added

Yao Zhou:

03/02/23: Allow itaylo=41 in non-ST case
03/02/23: moved 3D vacuum field subtraction to rmp_per
03/02/23: Allow vacuum field subtraction in general case

Changes to github master --after 2023-02-27

Usman Riaz:

03/03/23: A test case to run mesh adapt on single model face with smooth transition on boundaries. A small bug in m3dc1+_scorec/scr/m3dc1 adapt.cc is fixed

03/13/23: The failing adapt regression test with compilation flag ADAPT=1 has been fixed

03/14/23: Adding mesh file for the adapt test

03/17/23: The functionality to adapt elements on selected mode faces has been added.
The parameter “iadaptFaceNumber” sets the desired model face for adaption.
“iadaptFaceNumber” defaluts value is -1. It should be set greater than 0 to work.
If the ID of the face specified by “iadaptFaceNumber” doesn’t exist, the code will
Throw an error with the warning message.
The functionality works with “adapt_by_field” (psiField”

03/23/23: Updating create_smb routine

Local Systems

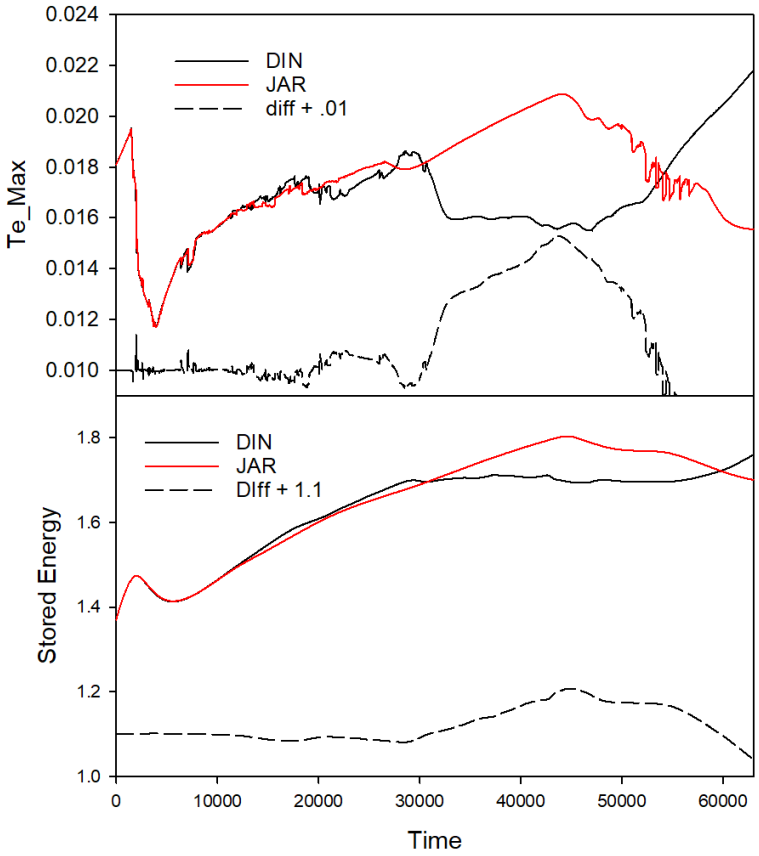
- PPPL centos7(04/14/23)
  - 7 jobs PASSED
- PPPL greene (04/14/23)
  - 5 jobs PASSED
- STELLAR (04/14/23)
  - 7 regression tests **PASSED** on stellar
- TRAVERSE_gpu(11/04/22)
  - Compilation error (being looked at by Seegyound , Jin, and Chang)

NERSC

- Perlmutter_cpu (04/14/23)
  6 jobs **PASSED**
  NCSX failed with very small difference in C1ke

- Perlmutter_gpu (02/19/2023) **04/02/23: will not compile**
  - pellet, RMP, & RMP_nonlin, adapt all **PASSED**
  - KPRAD_2D, KPRAD_restart, NCSX all failed with very small differences
  - adapt not submitted

Dingyun is trying to reproduce a case in my 2020 paper



Need to find when these differences first occur:

git log --after 2018-06-30 > logout

git clone https://github.com/PrincetonUniversity/M3DC1

git checkout 8a6a036

Had to:

- remove wrrestartglobal from output.f90 and restart.f90
- Comment out MPI_Comm_split in newpar.f90
- Copy stellar.mk from current version

Progress on debug

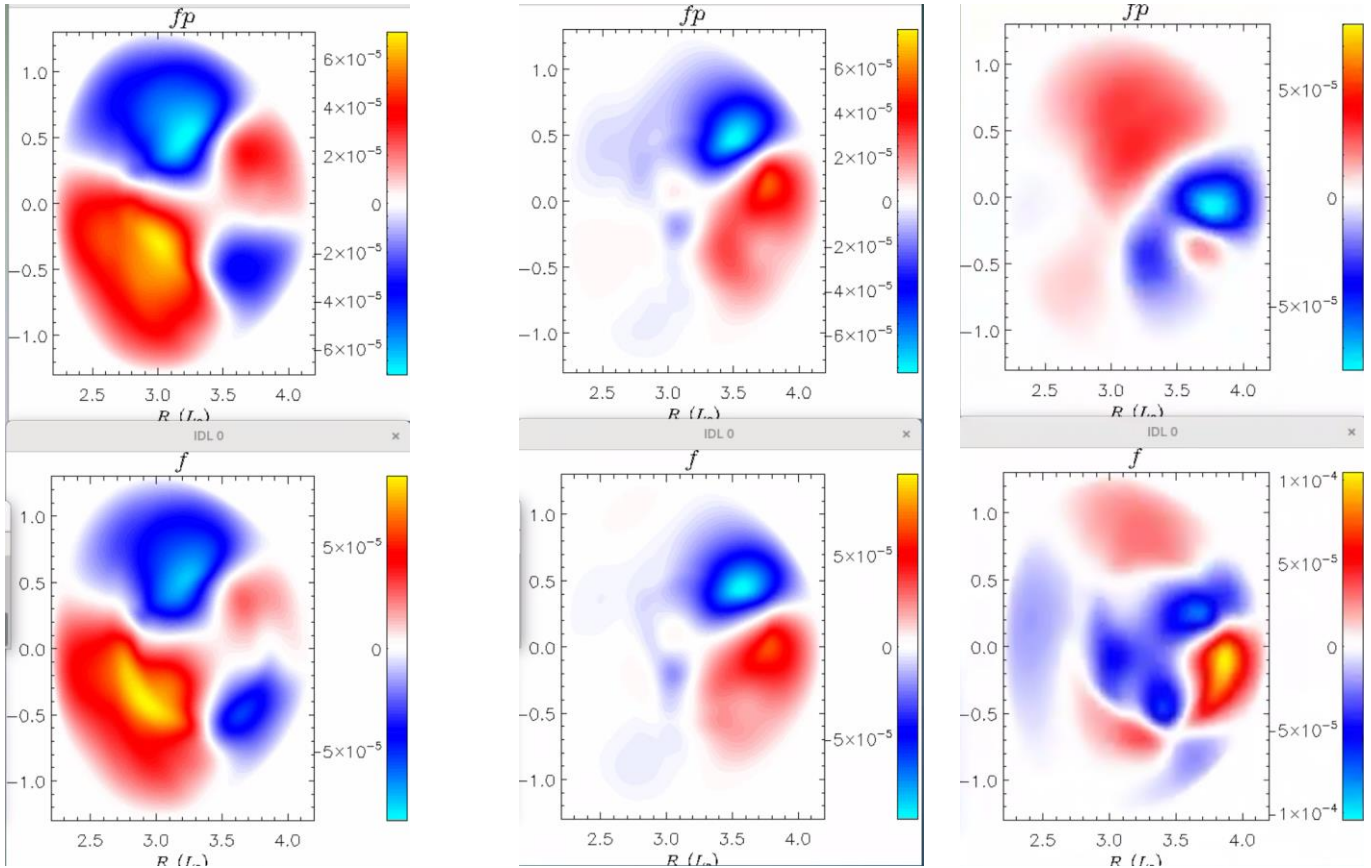
Differences first appear on 11/17/20

- 5 commits that day by Yao Zhao
- Mostly concerned with bf to bfp change
- Commit at 14:48 with hashtag 4306198 looks ok
- Commit at 17:00 with hashtag b572e1e shows difference…..merge

- The two versions agree exactly in 2D !

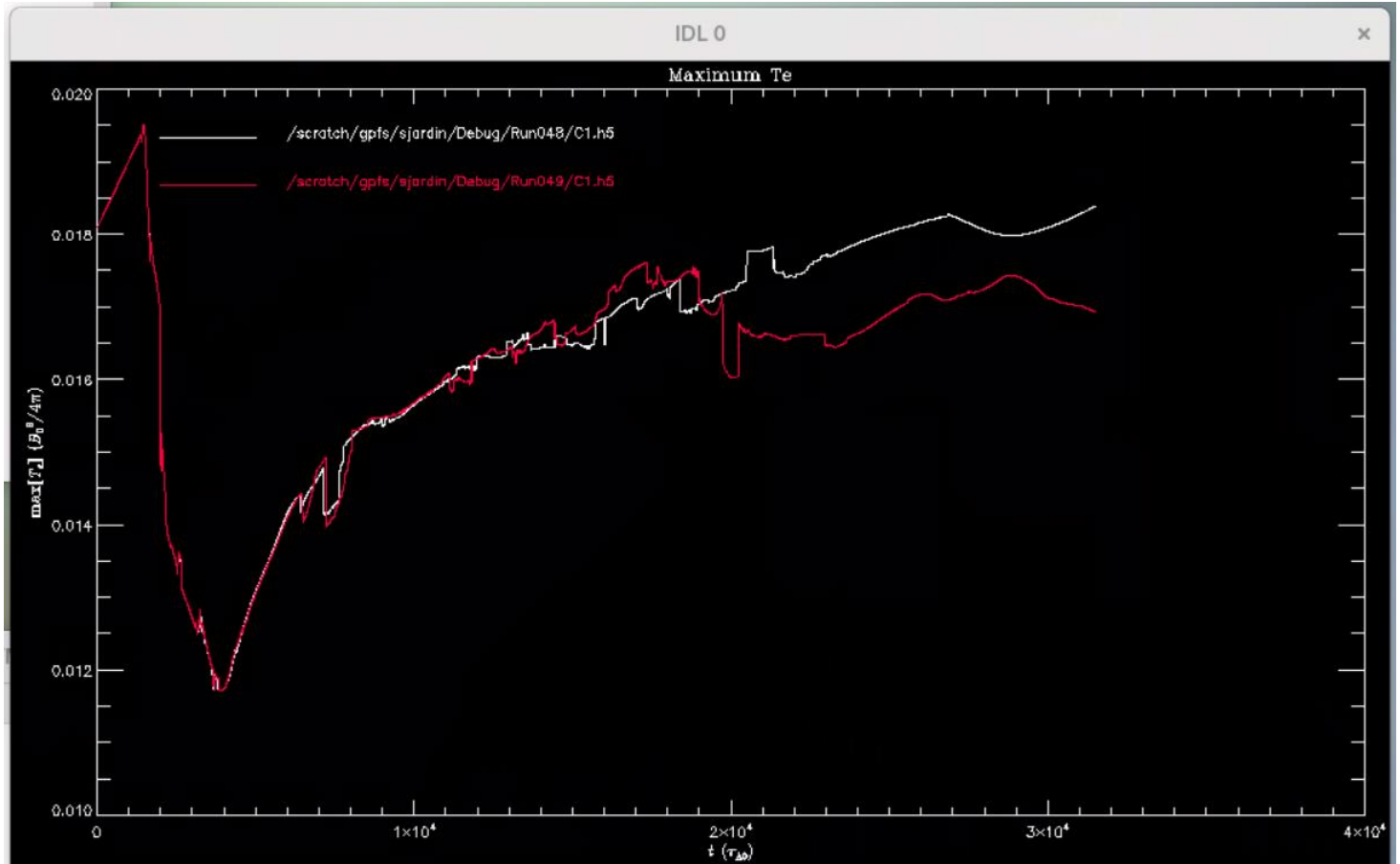
Run49, fp, op=1
11_17_20: 17:00
Commit: b572e1e7

Run48, f, op=11
11_17_20: 14:48
Commit: 43061986



t=4500 t=9000 t=13500

Comparison of TEMAX for versions in Run48 and Run49



41st Meeting of ITPA Disruption and Control Topical Group
28-31 March 2023

some highlights

From Michael Lehnen, “Update on the ITER project”

Conclusions

- ITER site construction and commissioning has made good progress
- Technical issues during tokamak assembly (VV sector non-conformities and cooling pipe cracking in TSs) → solutions identified and plan for implementation developed. Implications for schedule not yet quantifiable in detail
- Re-optimization of assembly and ITER Research Plan is being carried out in order to minimize impact on start of DD+DT operation
- Time from now to start of operation should be used to develop full capabilities for ITER scientific exploitation → Support from ITER Members R&D institutions is essential

From Pustovitov “Disruption forces – theory and modeling”

Summary

- The resistive wall effects are the parts of the processes leading to large integral forces
- The kink-like perturbations give much smaller sideways force than that prescribed by the Noll’s scaling (by factor of 10, at least)
- To move further, we need

  - precise information on the wall-forced in JET

  - real physics of RWMs, not “understanding”

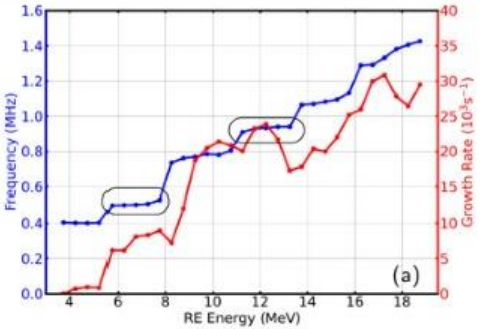
Eric Nardon: “Characterization of power deposition to PFCs by RE”

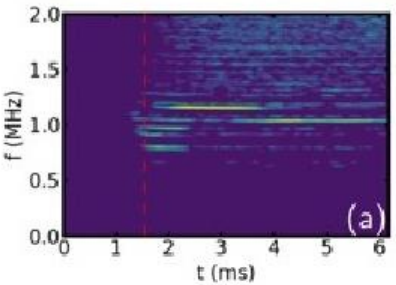
Outline

- News from ITER
- JOREK modelling of RE beam impact in ITER (V. Bandaru, H. Bergström)
- Investigations with JOREK on the role of resistivity (E. Nardon)
- Modelling of RE beam impact on DiMES in DIII-D (M. Beidler)

C. Paz-Soldan “RE Wave/MHD Interactions”

Kinetic-MHD simulation of CAE driven by REs in DIII-D 178631



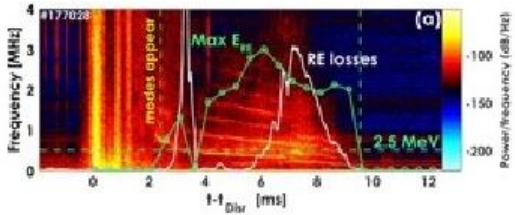


Simulation

Experiment

Through kinetic-MHD simulation, the excitation of CAEs driven by high-energy REs are reproduced using experimental parameters

- Positive correlation between the excited mode frequency and the RE energy consistent with observation
- In nonlinear simulation, multiple discrete n=1 modes can be excited simultaneously.
- Analysis of RE distribution in phase space reveals the mode are excited by trapped REs generated by high-Z impurity scattering, which can satisfy the Cherenkov resonance condition.

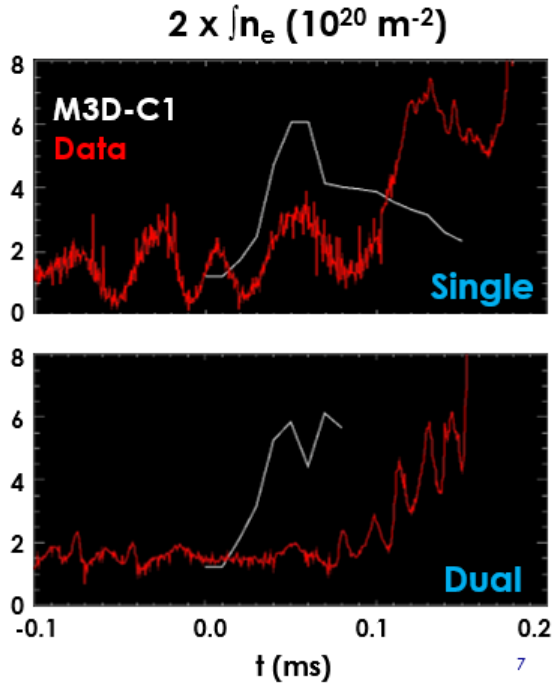


C. Liu, et al. http://arxiv.org/abs/2303.03622

N. Eidietis "SPI Physics Validation"

SPI Simulation Validation with KSTAR Data underway

- **M3D-C1 & NIMROD modeling single, dual-symmetric, and time-staggered injection in KSTAR**
- **M3D-C1 comparison to line-averaged density shows notable discrepancies**
  - Time scales differ
    - Simulations consistent with pellet propagation
    - Onset time of density rise delayed in experiment
    - Could just be offset issue
  - Experimental density rises after thermal quench – cause unknown
- **Validation to-do**
  - Poloidally localized radiation
  - Time histories: plasma current & stored energy
- **Higher toroidal resolution runs underway**

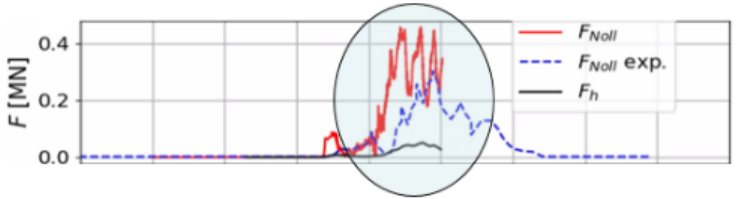


Courtesy B. Lyons (GA)

An issue with Noll's formula?

JOREK reproduces the experimental F_{Noll}…

but $F_h \sim F_{Noll}/10$!!



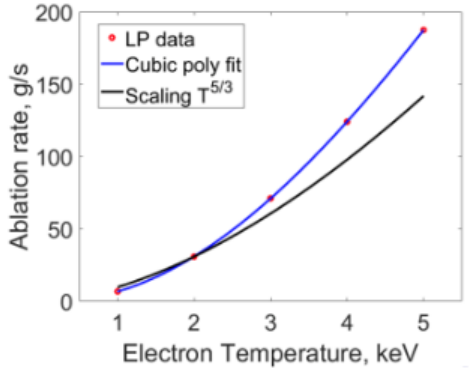
However, a mechanical analysis in JET indicates that $F_h \sim F_{Noll}$

[Riccardo, V., *Fusion engineering and design* 47.4 (2000): 389-402]

Why is the force in JOREK so small then?

Update on Lagrangian Particle Simulations

- **Massively-parallel LP Code.** Published a paper describing the massively parallel Lagrangian particle algorithms, V&V and scalability tests and a summary of fusion applications [S. Yuan, M. Zepeda, N. Naitlho, R. Samulyak, Massively-parallel Lagrangian particle code and applications, Mech. Research Communications, 129 (2023) 104075]
- **Simulations of SPI into runaway beam in ITER.** Published a paper describing structure and global properties / penetration dynamics of SPI clouds into RE beams. Simulations resolved thousands of SPI fragments [S. Yuan, N. Naitlho, R. Samulyak, E. Nardon, B. Pegoruie, P. Parks, M. Lehnen, Phys. Plasmas 29, 103903]
- **Composite neon-deuterium pellets.** Completed numerical algorithms for ablation of composite neon-deuterium pellets in the Lagrangian Particle code. Built tabulated data bases for thermodynamic and electrodynamic propertied of neon-deuterium mixtures of partially-ionized plasmas in temperature-density ranges relevant to pellet ablation. Simulations will support future experiments on composite pellets at DIII-D.
- **Striation instabilities of pellet ablation clouds.** Performed initial simulations studies aimed to clarify the causes and the role of various factors on striation instabilities of pellet ablation clouds.
- **Scaling laws for pellet ablation in hot magnetized plasmas.** Conducted a series of simulations of deuterium pellets ablating in hot plasmas in magnetic fields ranging from 0 to 6 T. We showed that the pellet ablation in strong magnetic fields with grad-B drift deviates from the spherically-symmetric theoretical scaling law. Corresponding data fits will be used by tokamak MHD codes.



Courtesy Roman Samulyak (Stony Brook U)

NSTX Program Advisory Presentation

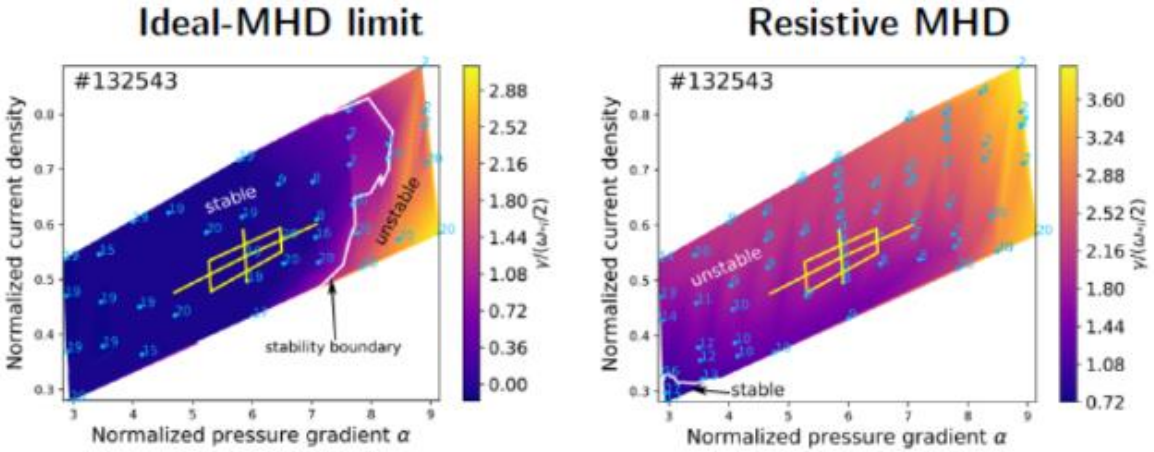
Walter Guttenfelder

March 22, 2023

ELMy discharges most consistent with resistive, not ideal, peeling-ballooning (P-B) stability

- Resistivity matters for NSTX ELMy discharges near kink-peeling boundary (using linear M3D-C1)
- Impact of resistivity varies across experiments (tested for NSTX, MAST, DIII-D)
  - Most correlated with magnetic shear → possible role of tearing mode physics
- **Ongoing work to project whether or when non-ideal P-B important for NSTX-U**
- **Ongoing work to explore nonlinearly saturated pedestal modes in ELM-free scenarios [backup slide]**

Peeling-ballooning growth rates (M3D-C1)

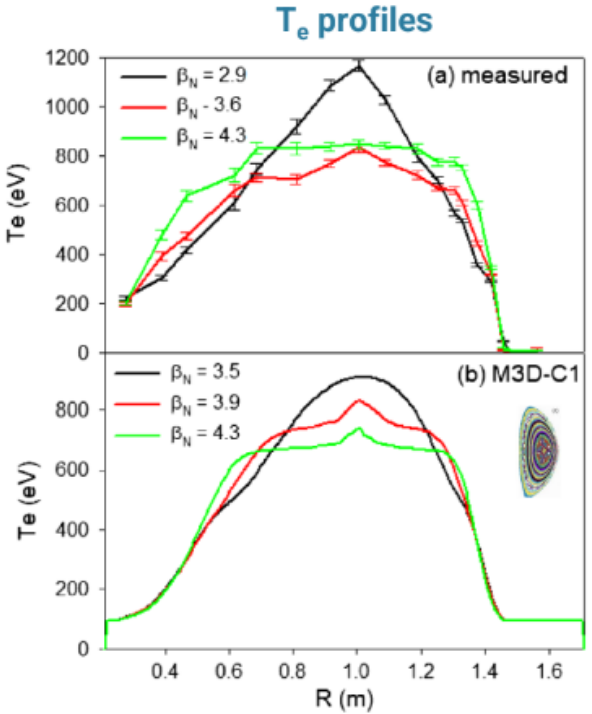


Kleiner, NF (2021, 2022)

Nonlinear 3D MHD simulations (M3D-C1) predict ideal MHD infernal modes can flatten core T_e due to stochastic surfaces

- Low-n, pressure-driven infernal modes saturate via relaxed core pressure ("soft" beta limit)
  - Small but finite resistivity required for surface breakup from otherwise ideal modes
- **Ongoing work to understand stability & nonlinear impact, predict how to avoid for NSTX-U operations**

- Alternative hypotheses for flattened core T_e: GAE/CAE modes can:
  - Enhance electron thermal transport [Gorelenkov, 2010]
  - Modify NBI deposition via CAE-KAW coupling [Belova, 2015]
- Significant progress in understanding linear stability & nonlinear saturation [Belova, backup slide]
- **Future work: develop GAE-based prediction of T_e profile flattening**



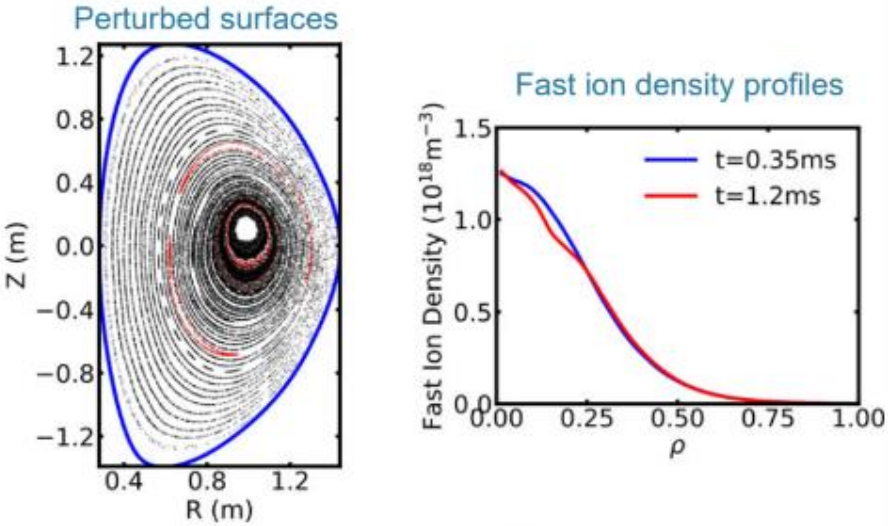
Jardin et al., PRL (2022), PoP (2023)

Progress in Objective 1 research

Kinetic fast ion & thermal ion effects implemented & validated in kinetic-MHD code (M3D-C1-K)

- Thermal effects can be important for high-T_i
  - Decreases n=1 fishbone growth rate (Landau damping)
- Nonlinear simulations of fishbone mode predicts stochasticized surfaces + EP transport
  - Saturation sensitive to q_{min} and pressure
- **Future work will extend to validate TAE avalanches, other low-frequency modes**

Nonlinear kinetic-MHD simulation of n=1 fishbone in NSTX



Liu (2022a, b)

New Physics of Plasmas Publication

Nonlinear magnetohydrodynamic modeling of current-drive-induced sawtooth-like crashes in the W7-X stellarator

Cite as: Phys. Plasmas **30**, 032503 (2023); doi: 10.1063/5.0136654
Submitted: 28 November 2022 · Accepted: 17 February 2023 ·
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ABSTRACT

Sawtooth-like core electron temperature crashes have been observed in W7-X experiments with electron cyclotron current drive. We present nonlinear single-fluid magnetohydrodynamic simulations of this phenomenon using the newly developed stellarator modeling capability of the M3D-C^1 code. The near-axis current drive gives rise to two $\iota = 1$ resonances in the equilibrium rotational transform profile so that two consecutive (1, 1) internal kink modes are seen in the simulations. A small-amplitude crash at the inner resonance occurs first, which may correspond to the sawtooth precursors observed in the experiments. A bigger crash at the outer resonance then flattens the core temperature profile, which shows semi-quantitative agreements with experimental measurements on certain metrics such as the crash amplitude and the inversion radius of the temperature change. These results illustrate a likely mechanism of the current-drive-induced sawtooth-like crashes in W7-X and, to some extent, validate the stellarator modeling capability of M3D-C^1.

That’s All I have

Anything Else ?