M3D-C1 ZOOM Meeting

08/09/2021

Announcements

CS Issues

1. Intel-MPI on stellar
2. Mesh adaptation update
3. NERSC Time
4. Changes to githuon b master since last meeting
5. Regression tests
6. Progress on optimizing the matrix assembling on GPUs – Chang Liu

Physics Studies

1. Energy conservation with itemp=0,1, ipres=0,1 -- Lyons
2. Resistive wall mode in a periodic Cylinder – Strauss
3. Sawteeth with 50% runaways – Chen Zhao

Note: meeting minutes posted on m3dc1.pppl.gov

In attendance

Steve Jardin
Hank Strauss
Patrick Kim
Mark Shephard
Jin Chen
Adelle Wright
Nate Ferraro
Andreas Kleiner
Chen Zhao
Brendan Lyons
Chang Liu
Seegyoung Seol
Priyanjana Sinha

Announcements

- Virtual Sherwood Meeting August 16-18
  - Registration until August 9 (Today)
  - No m3dc1 meeting August 16

- APS Nov 8-12
  - Meeting will be IN PERSON with virtual option
  - M3D-C1 Invited talks by C. Liu, A. Wingen
  - CTTS meeting? Will DOE allow travel?

- EPS 6/27 – 7/1 2022 in Maastricht, Netherlands
  - Nominate invited speakers by 29 October 2021

stellar.princeton.edu

From Adelle Wright 8/5/2021:

I tested intelmpi on the stellarator version for a 3D fixed boundary case (24 planes, 6 nodes). There was no noticeable speedup but the memory usage was roughly halved.

While it's probably just that I did not configure everything correctly, I did have issues with post-processing (trace and IDL) when the modules needed for intelmpi were loaded.

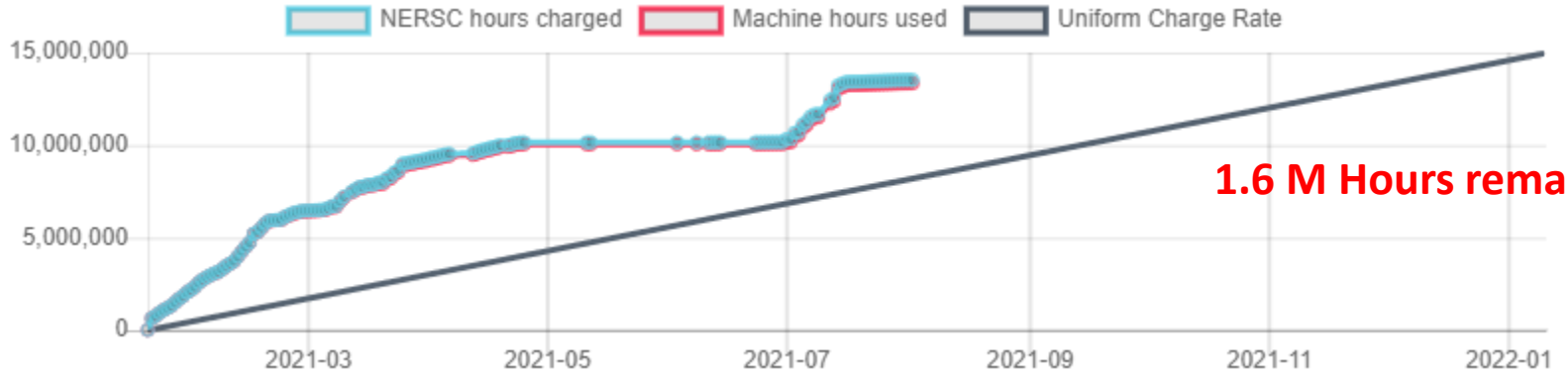
Update?

Mesh Adaptation Update

RPI?

NERSC Time

mp288



1.6 M Hours remaining!

- mp288 received 10M Hrs for CY 2021
- Initial allocation exhausted by May 1
- John Mandrekas (DOE) added 5M Hrs additional
- More time may be possible if this is exhausted
- Pearlmutter time will not be charged for this FY
- We are NESAP Tier 2. Machine not yet ready. Phase-I w GPUs

Changes to github master since 08/02/21

No Changes!

Local Systems

- PPPL centos7(08/02/21)
  - 6 regression tests **PASSED** on centos7:
- PPPL greene (08/02/21)
  - 5 regression tests **PASSED on greene (m3dc1)**
- STELLAR (08/02/21)
  - 6 regression tests **PASSED** on stellar
- TRAVERSE(03/29/21)
  - Code compiles
  - Regression test failed: split_smb not found in PATH

Other Systems

- Cori-KNL (2/08/2021)
  - 6 regression tests passed on KNL
- Cori-Haswell (6/29/2021)
  - 6 regression tests passed
- 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)
  - ??

Progress on optimizing the matrix assembling on GPUs

Chang Liu

Discrepancies in Heat Flux Diagnostic

by

Brendan C. Lyons

August 2nd, 2021

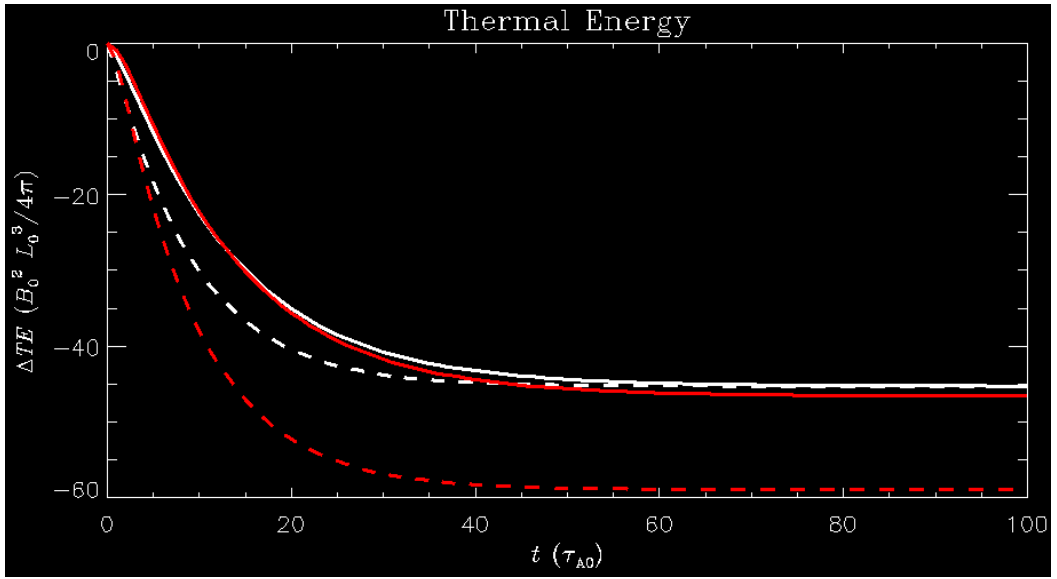
GENERAL ATOMICS

General Comments

- **Based on a 2D ITER L-mode simulation**
- **Heat conduction should be the dominant source/sink**
  - No ohmic heating: `iohmic_heating=0`
  - No impurities
  - Kinetic energy << Thermal energy
- **In figures, white is the change thermal energy, red is the integrated `flux_thermal`**
- **All folders in `/pfs/nobackup/blyons/kappa_test/` on portal**
- **"Perpendicular" dominant case: `kappat=1e-1, kappar=1e-8`**
- **"Parallel" dominant case: `kappat=1e-1, kappar=1e+4`**
- **Boundary conditions**
  - `itemp=1` cases use `iconst_t=1` with `tebound=tibound=2e-5`
  - `itemp=0` cases use `iconst_p=1`, since `iconst_t=1` doesn't work for pressure equations
- **Lowering time step doesn't seem to make a qualitative difference in my tests**

Two Temperature Equations: `ipres=1`, `itemp=1`

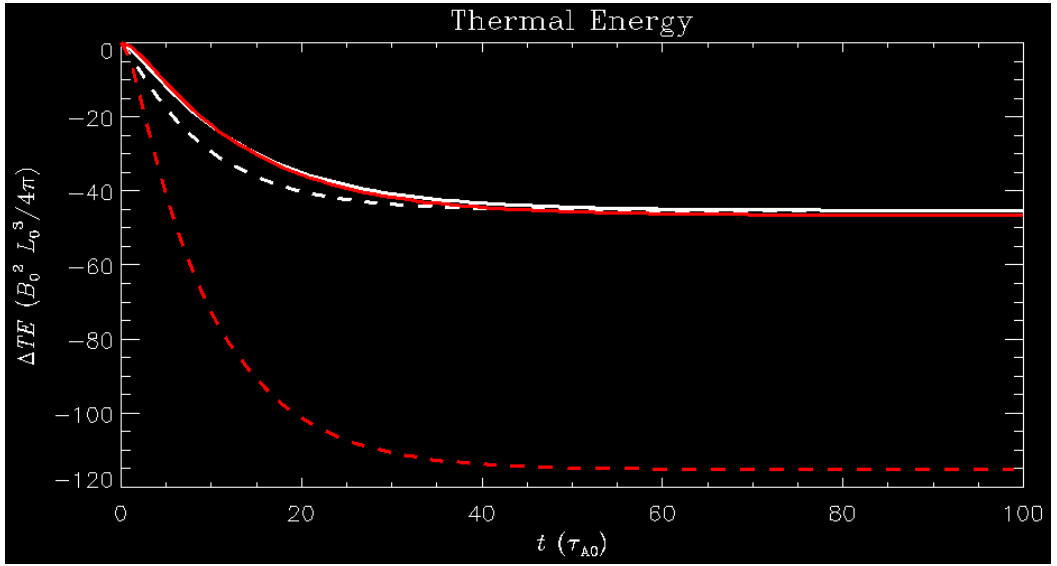
- **Perpendicular (solid)**
  - `kth_krl_ip1_it1/`
  - Not terrible, but not good
- **Parallel (dashed)**
  - `kth_krh_ip1_it1/`
  - Significant excess in the calculated heat flux
- **These discrepancies are what has made me look into this problem in the first place, since they mess up energy accounting**



For itemp=1, ipres=1, larger error for $\kappa_{||}$ large

Single Temperature Equation: `ipres=0`, `itemp=1`

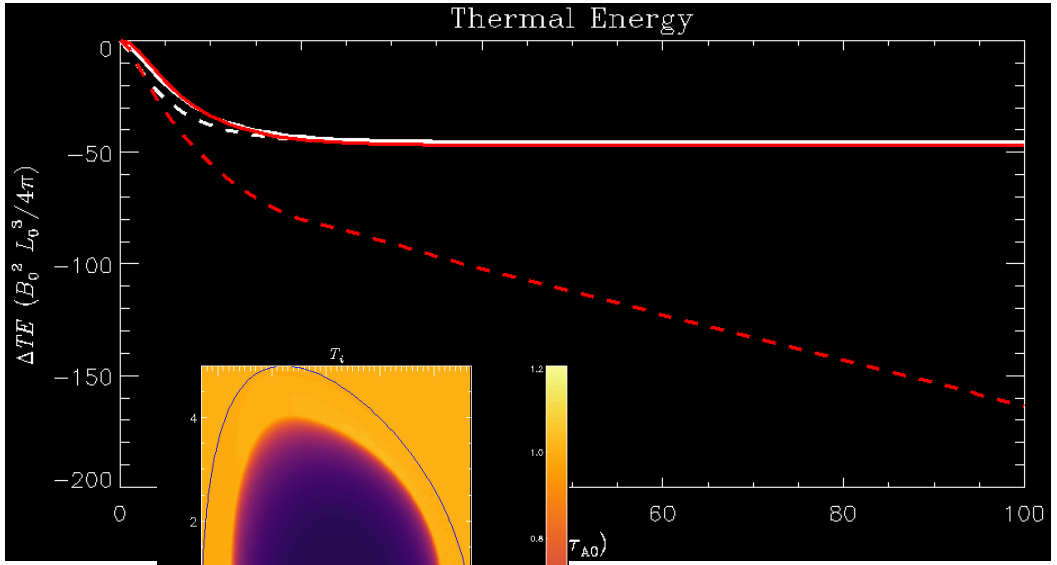
- **Perpendicular (solid)**
  - `kth_krl_ip0_it1/`
  - Same as `ipres=1`
- **Parallel (dashed)**
  - `kth_krh_ip0_it1/`
  - Roughly double the heat flux even though thermal decay is only very slightly different
  - Parallel heat flux appears to be double counted in `flux_heat()`
  - Maybe because it accounts for the ion and electron temperature gradients?

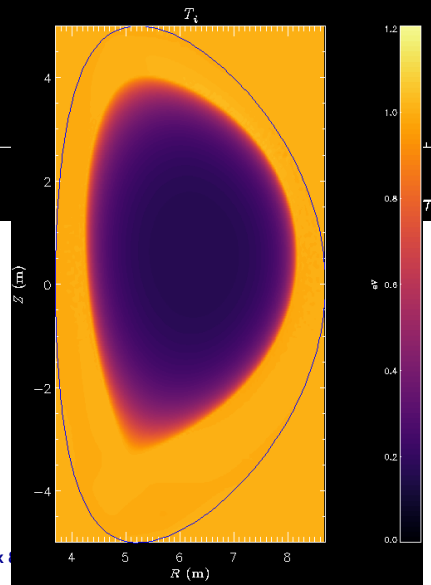


For itemp=1 ipres=0 gives larger error than ipres=1

Single Pressure Equation: `ipres=0`, `itemp=0`

- **Very strange behavior**
  - Temperature becomes lower in core than edge
  - Something wrong with heat flux implementation for open field lines?
- **Perpendicular (solid)**
  - `kth_krl_ip0_it0/`
  - No qualitative impact from temperature hole
- **Parallel (dashed)**
  - `kth_krh_ip0_it0/`
  - Shows persistent heat flux even after thermal energy is dissipated





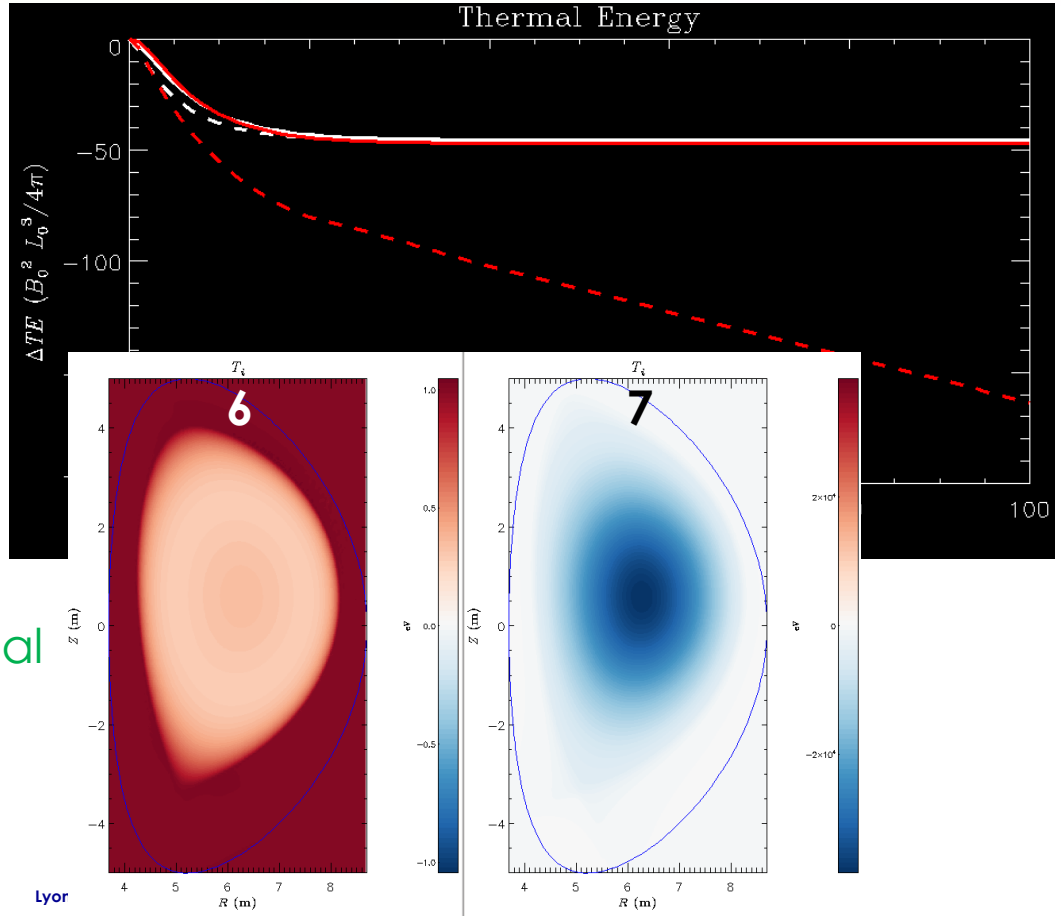
Poor unphysical behavior for itemp=0 and large $\kappa_{||}$

GENERAL ATOMICS

Lyons Heat Flux

Two Pressure Equations: `ipres=1, itemp=0`

- **Even stranger behavior**
  - Ion temperature because huge and negative between outputs 6 and 7
  - No idea what to make of this
- **Traces are basically identical to `ipres=0`**
- **Perpendicular (solid): `kth_krl_ip1_it0/`**
- **Parallel (dashed): `kth_krh_ip1_it0/`**



Poor unphysical behavior for itemp=0 and large $\kappa_{||}$

GENERAL ATOMICS

Conclusions

- Something is off with the `flux_heat()` diagnostic
- Nature of discrepancy is dependent on the `ipres` and `itemp`
- There may be something wrong about how the heat flux itself, not just the diagnostic, is implemented in the code for `itemp=0`

Do not use itemp=0 when kappar.ne.0

Itemp = 0

$$\frac{\partial p}{\partial t} = \ldots + \nabla \bullet \kappa_{\parallel} \frac{\mathbf{BB}}{B^2} \bullet \nabla \left(\frac{p}{n} \right)$$

$$= \ldots + \nabla \bullet \kappa_{\parallel} \frac{\mathbf{BB}}{B^2} \bullet \left(\frac{1}{n} \nabla p - \frac{p}{n^2} \nabla n \right)$$

This term is a problem since p and n are solved separately. Will cause very large errors and possibly numerical instability

Itemp = 1

$$n \frac{\partial T}{\partial t} = \ldots + \nabla \bullet \kappa_{\parallel} \frac{\mathbf{BB}}{B^2} \bullet \nabla \left(T \right)$$

Well behaved, diagonally dominant

function flux_heat

$$-\left[\kappa_e \hat{n}\bullet\nabla T_e + \kappa_i \hat{n}\bullet\nabla T_i\right] \qquad \text{HF\_perp}$$

$$-\frac{1}{B^2}\left[\hat{n}\bullet\nabla\psi\times\nabla\varphi\right]\left[\nabla\psi\times\nabla\varphi\bullet\left(\kappa_{\|}\nabla T_e + \kappa_{\|}\nabla T_i\right)\right] \qquad \text{HF\_par}$$

	itemp=1	ipres=1	temp=1	ipres=0
	A		B	
kappar	HF_perp	HF_par	HF_perp	HF_par
1.	46.1	0.46	46.3	0.46
10	42.5	4.2	44.5	4.42
100	26	23	33.0	30.2
1000	06	48.5	10.6	84.2
10000	00.25	58	00.77	114.

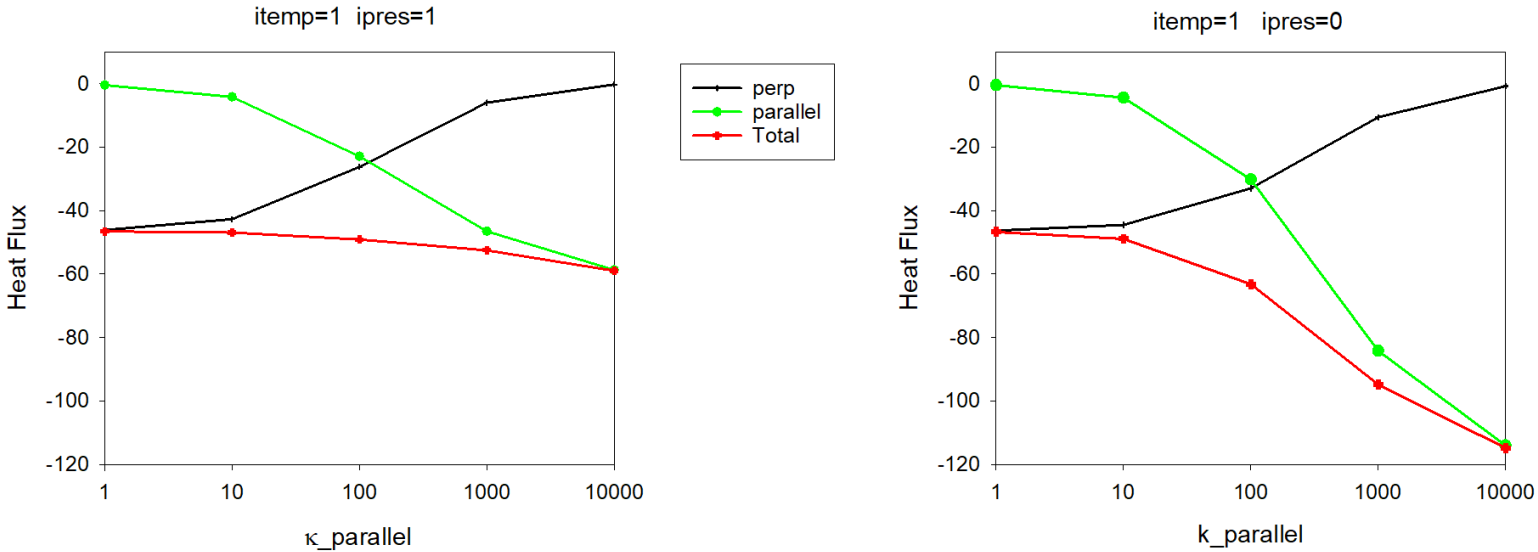
For both A @ B: ion par HF = electron par HF
For both ions and elecs : B_par_HF = 2 x A_par_HF

Te = Ti and are almost the same for both cases A and B

Graphs look much better if we multiply the HF_par in case B by ½

Problem seems to be with the parallel heat flux with ipres=0

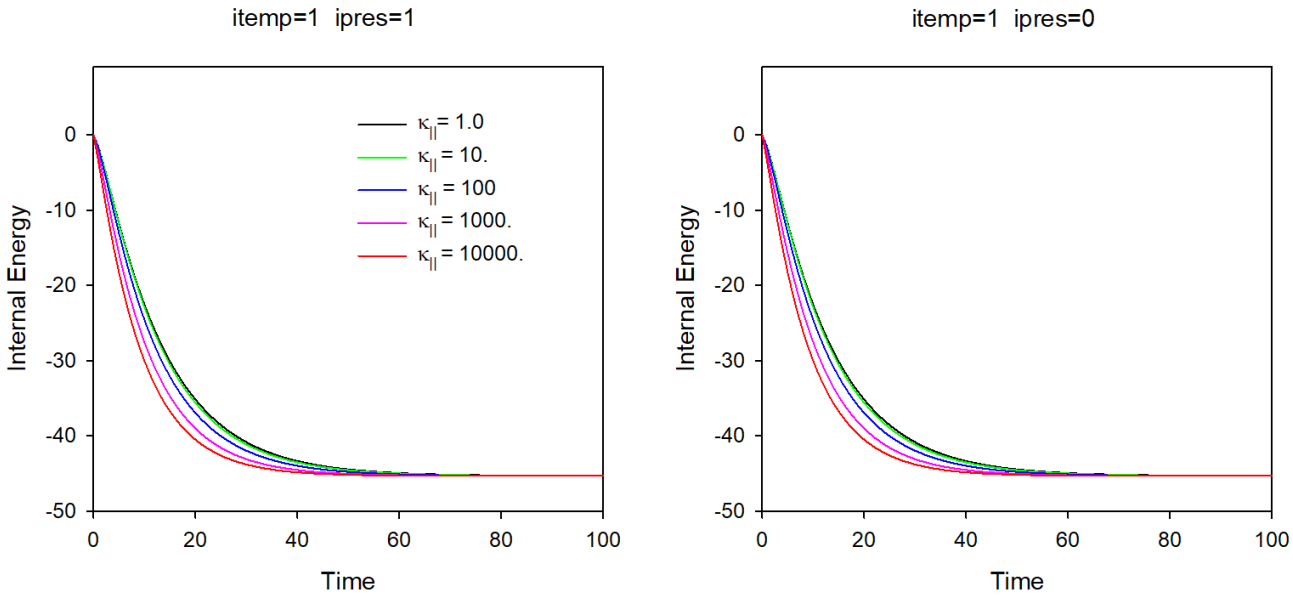
Parallel heat flux is much larger for ipres=0



Note:

- Red line (total heat lost) should be horizontal if energy conserved for all $\kappa_{||}$
- Perpendicular heat loss almost the same for ipres=1 and ipres=0
- Parallel heat loss at large $\kappa_{||}$ slightly too large for ipres=1, much too large for ipres=0

Decay of internal energy similar for ipres=1,0

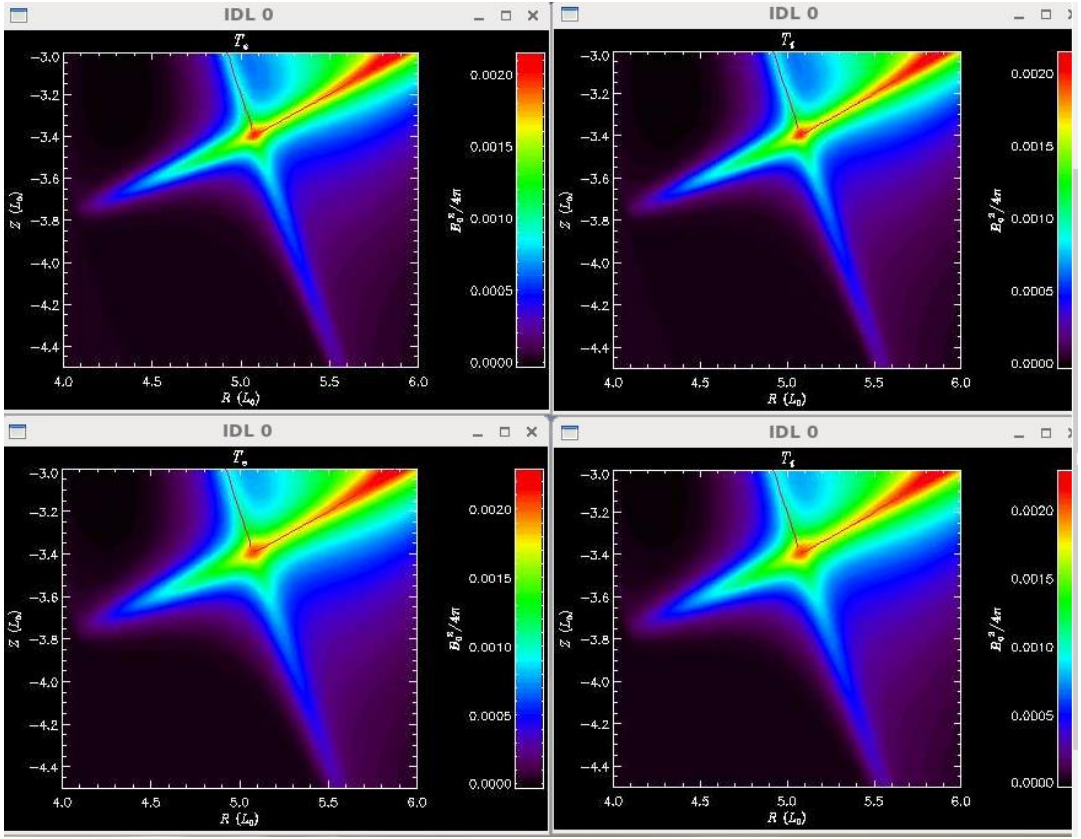


Only weakly dependent on $\kappa_{||}$ for both cases, and very similar

dTe,i/dy profiles look nearly the same in SOL for itemp=1, ipres=0,1

ipres=1

ipres=0



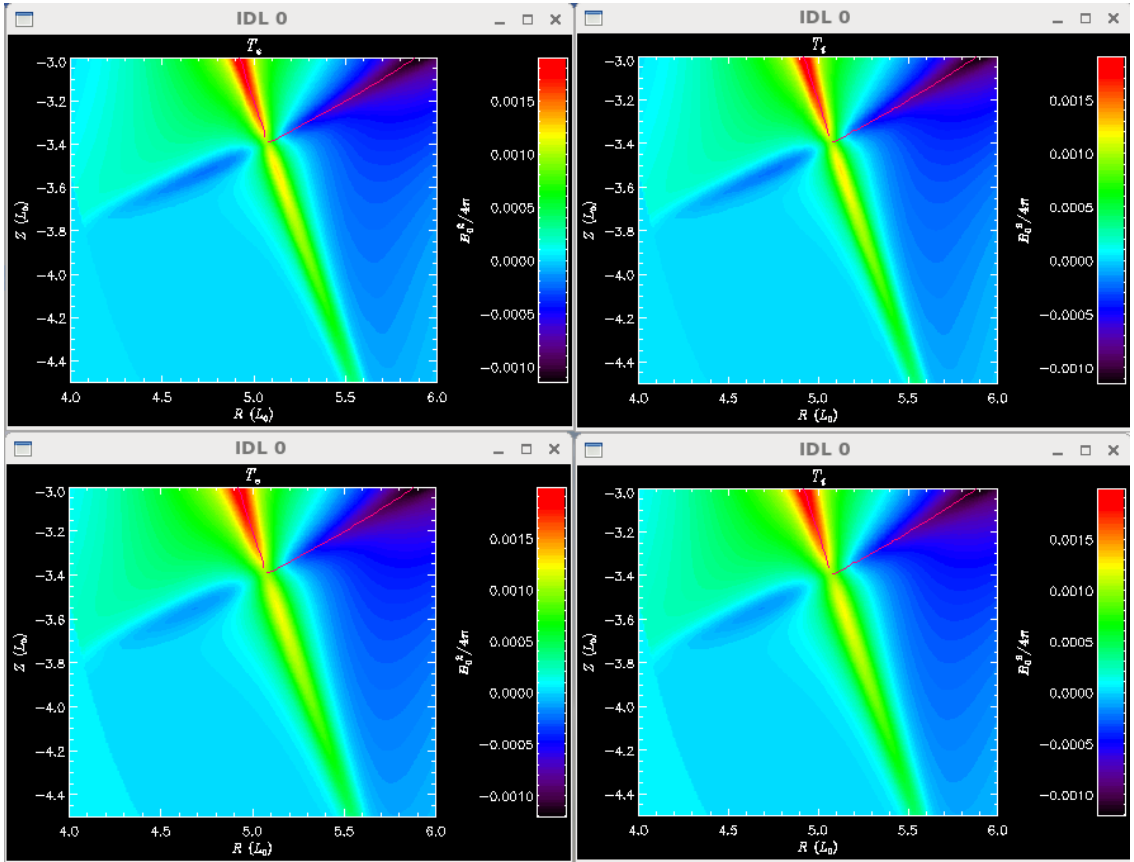
Time slice 2

$\kappa_{||} = 10^4$

dTe,i/dx profiles look nearly the same in SOL for itemp=1, ipres=0,1

ipres=1

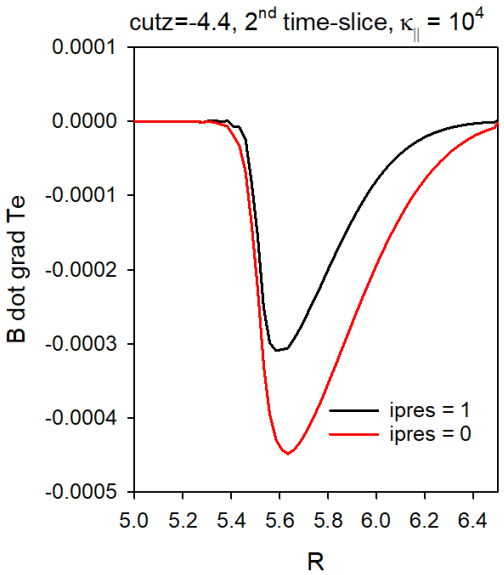
ipres=0

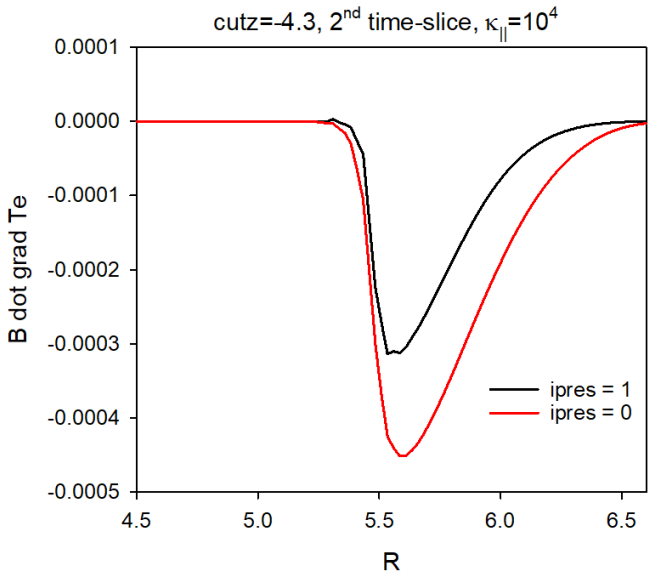


Time slice 2

$\kappa_{||} = 10^4$

B ·∇Te along z=-4.4, 4.3 much larger for ipres=0





Perpendicular temperature equation for ipres=0

$$n_e \dot{T}_e = \nabla \cdot \kappa \nabla T_e \qquad (1)$$

$$n_i \dot{T}_i = \nabla \cdot \kappa (\text{kappai\_fac}) \nabla T_i$$

$$T_i = \frac{(1\text{-pefac})}{\text{pefac}} T_e$$

$$n_i \frac{(1\text{-pefac})}{\text{pefac}} \dot{T}_e = \nabla \cdot \kappa (\text{kappai\_fac}) \frac{(1\text{-pefac})}{\text{pefac}} \nabla T_e \qquad (2)$$

Equation for T_e that conserves energy is obtained by adding (1)+(2)

$$\left[n_e + n_i \frac{(1\text{-pefac})}{\text{pefac}} \right] \dot{T}_e = \nabla \cdot \left[1 + (\text{kappai\_fac}) \frac{(1\text{-pefac})}{\text{pefac}} \right] \kappa \nabla T_e$$

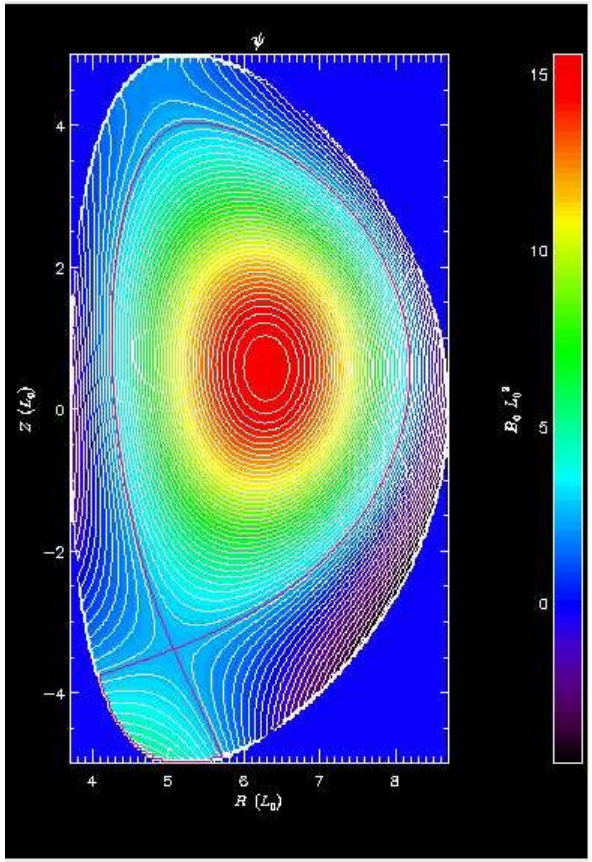
Same needs to be done for parallel heat conduction for ipres=0!

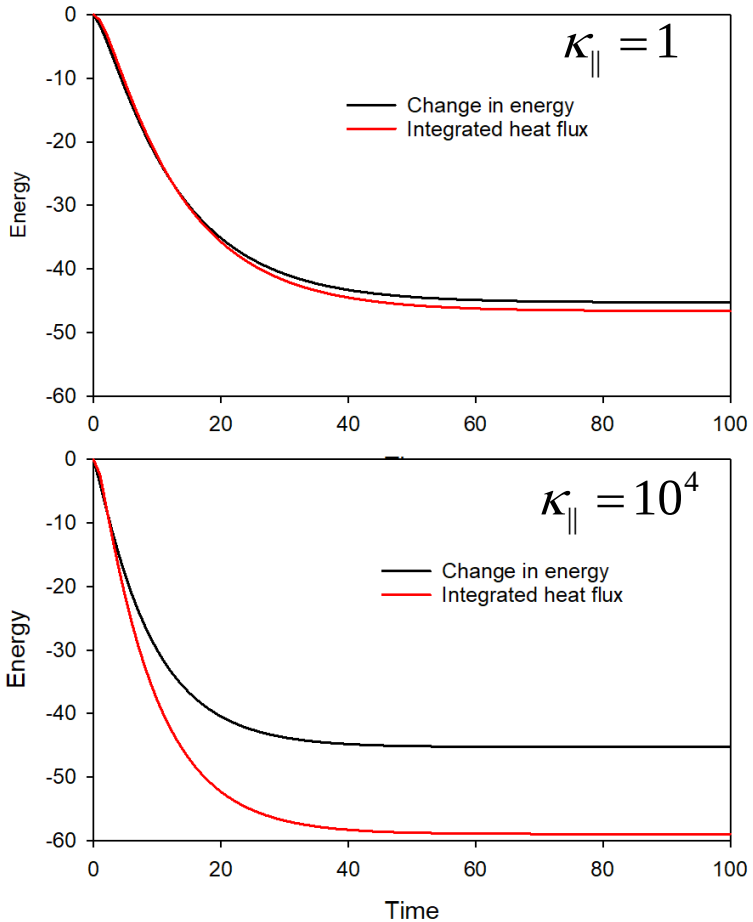
for ipres=0, replace (in temperature_lin)

$$\text{kappar} \dashrightarrow \left[1 + \text{kappai\_fac} \frac{(1 - \text{pefac})}{\text{pefac}} \right] \text{kappar}$$

← This needs to be changed

Parallel heat flux term requires high resolution





Now, exactly the same results for ipres=1 and ipres=0 for itemp=1.

Much better energy conservation at small values of $\kappa_{||}$

Large $\kappa||$ energy conservation may improve if mesh is refined

Problem Solved !

1. Do not use itemp=0 if kappar .ne. 0

2. To make itemp=1, ipres=1 and itemp=1, ipres=0 identical

   for ipres=0, replace (in temperature_lin)

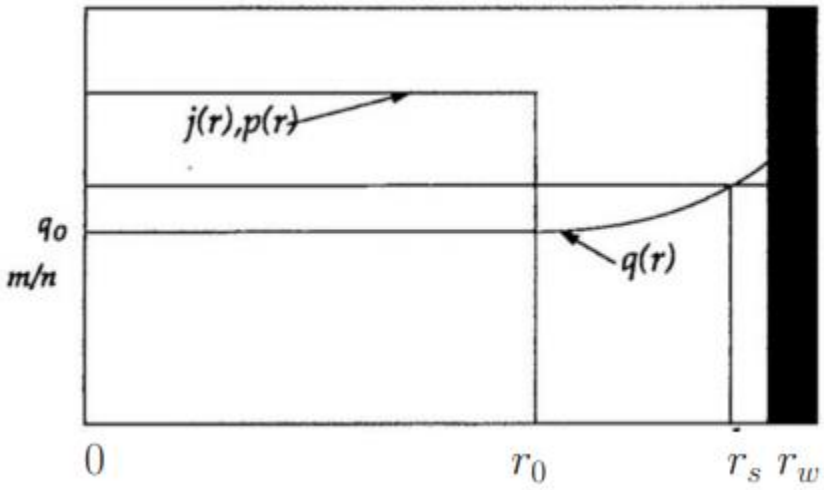
   $$\text{kappar} \rightarrow \left[1 + \text{kappai\_fac}\frac{(1-\text{pefac})}{\text{pefac}}\right]\text{kappar}$$

3. To get more precise energy balance for large kappar, may need to increase spacial resolution in SOL:

4. I have not yet committed the change as it makes one of the regression tests fail (RMP_nonlin)

Resistive Wall Mode in Periodic Cylinder

H. Strauss, 8/9/21



RWM

$$\gamma\tau_{wall} = -m\frac{1-(m-nq)}{1-(m-nq)-(r_0/r_w)^{2m}}$$

RWTM

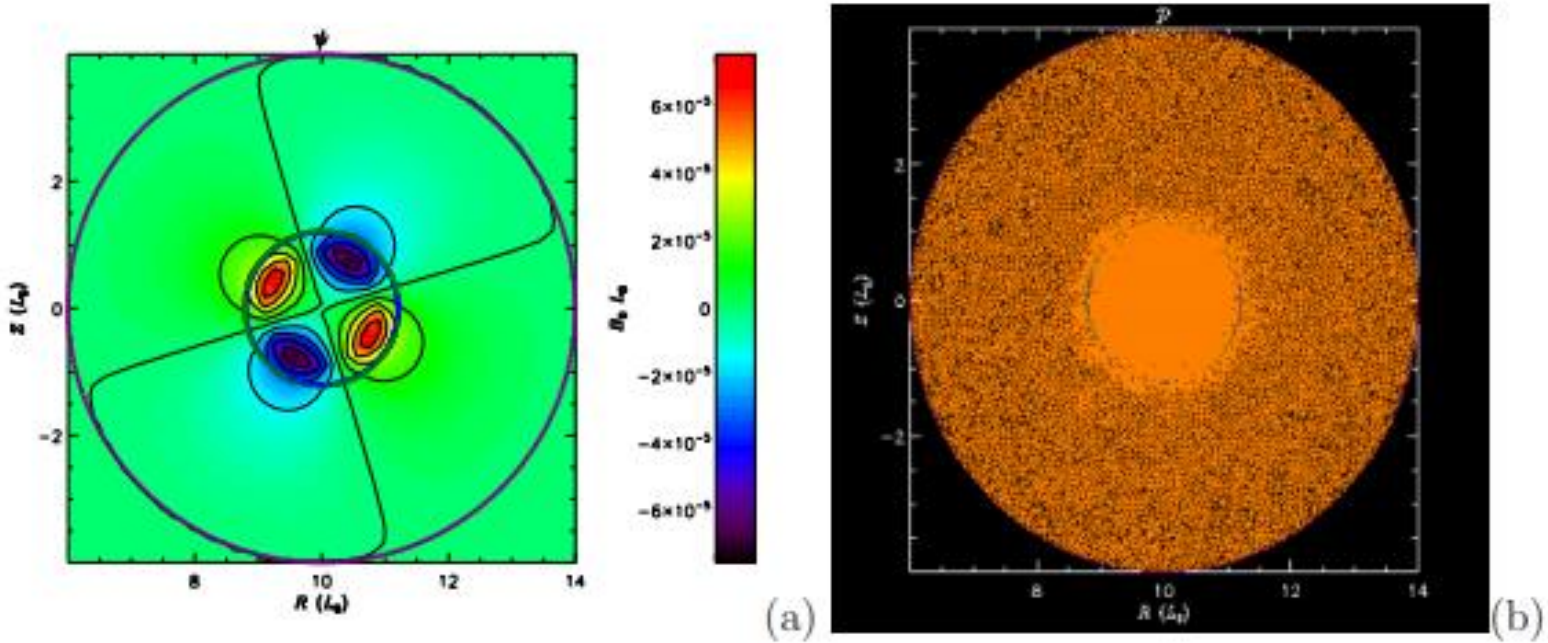
$$\gamma\tau_A = \frac{c_0}{S^{1/3}S_{wall}^{4/9}}$$

$$c_0 = 2.46\left(\frac{q'r_s}{q}\right)^{2/9} f^{4/9} = 2.46 f^{4/9}$$

$$f = \frac{(r_s/r_w)^{2m}}{[1-(r_s/r_w)^{2m}]^2}$$

Plasma resistivity?

What is f ?


ψ
z (L0)
R (L0)
8
10
12
14
2
0
−2
6×10⁻⁵
4×10⁻⁵
2×10⁻⁵
0
−2×10⁻⁵
−4×10⁻⁵
−6×10⁻⁵
B0 L0
P
(a)
(b)

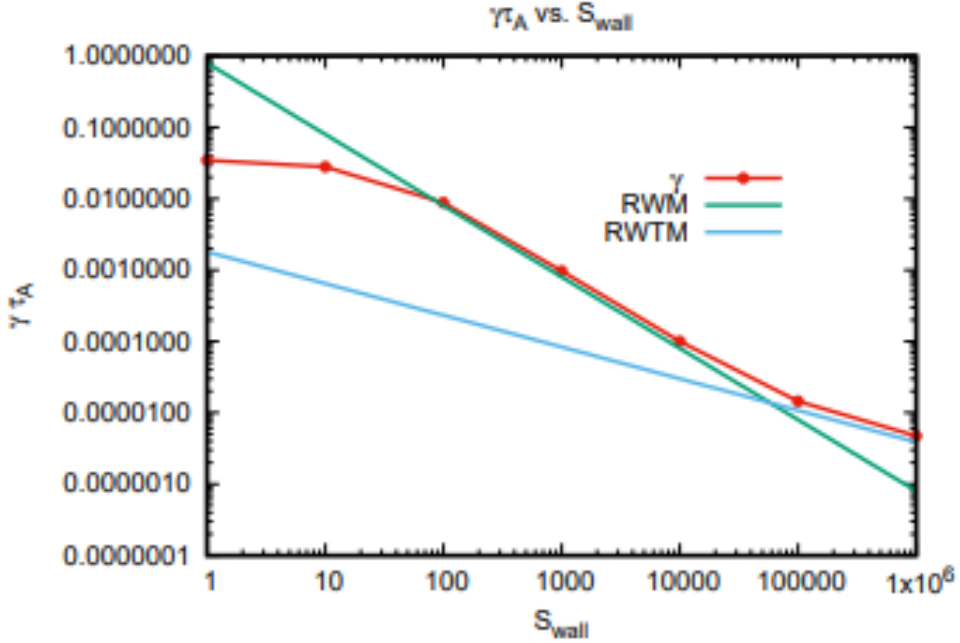
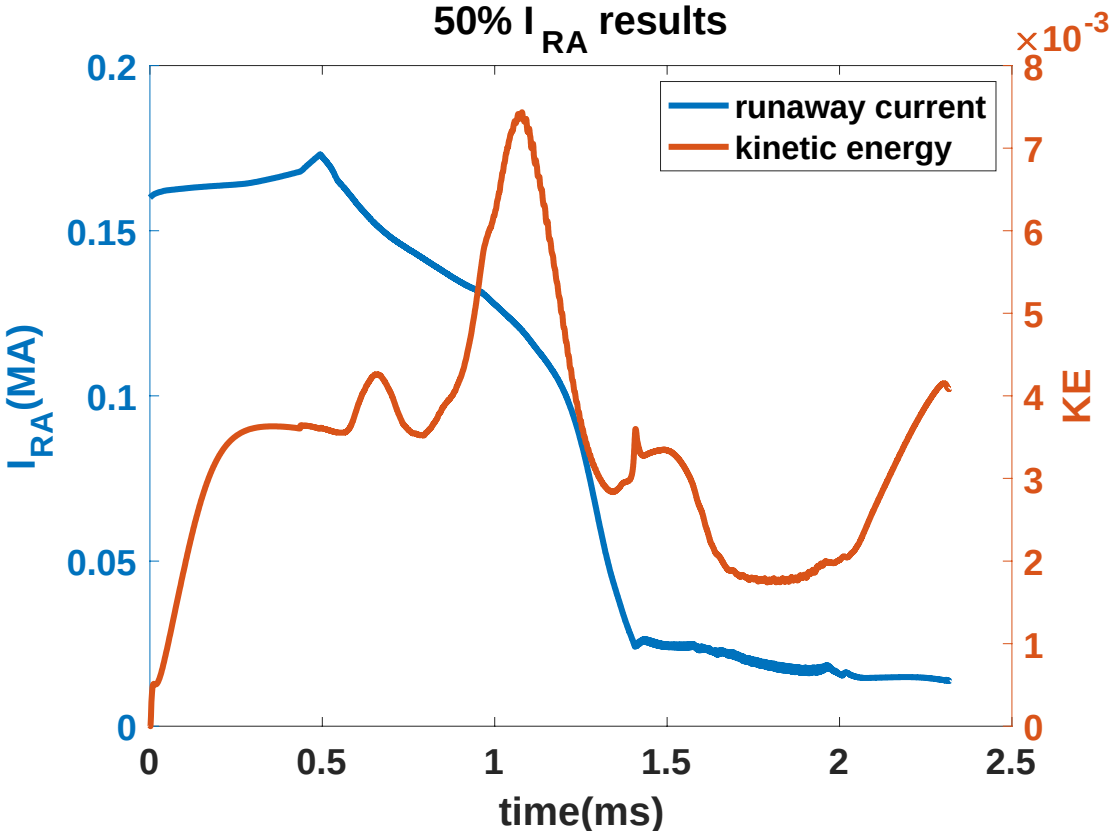


Fig.2(a) shows linear ψ for the case $S_{wall} = 10^4$. Fig.2(b) shows the adapted mesh used in all the cases. The mesh has a thin wall, $\delta = 0.02$. Fig.3 shows growth rate γ as a function of S_wall. For $S_{wall} \geq 10^5$, the most ustable mode appears to be a RWTM. The straight line fits are to S_{wall}^{-1} for a RWM and $S_{wall}^{-4/9}$ for a RWTM.

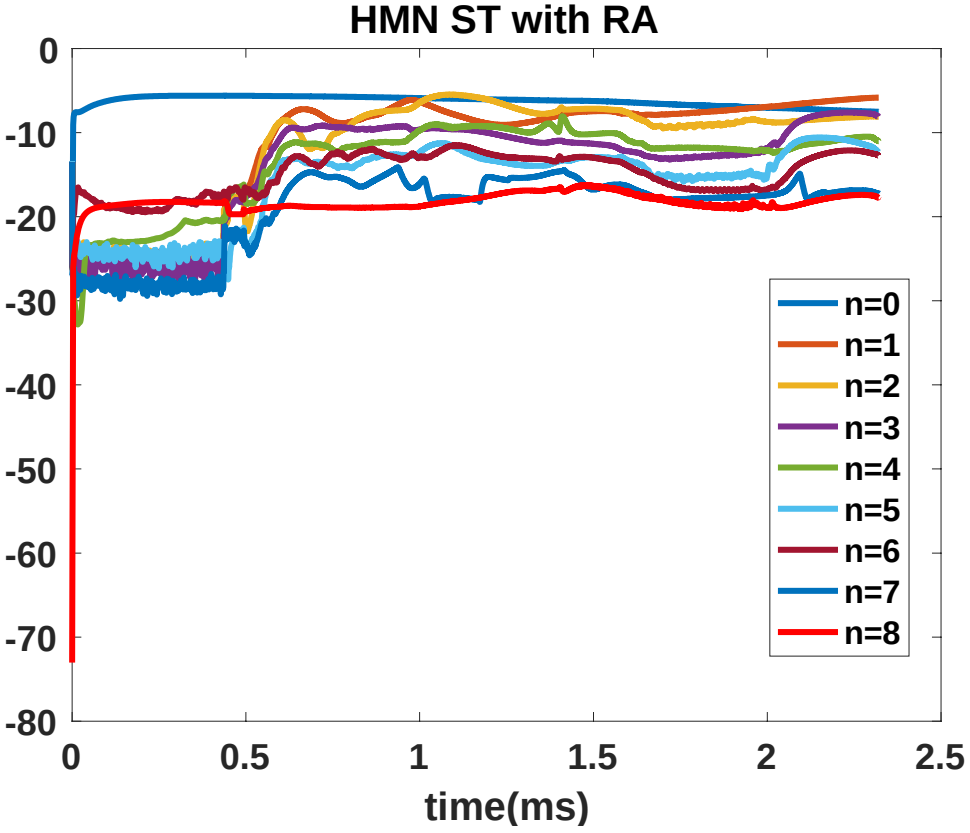
Dependence on η ?
Does mode structure change?

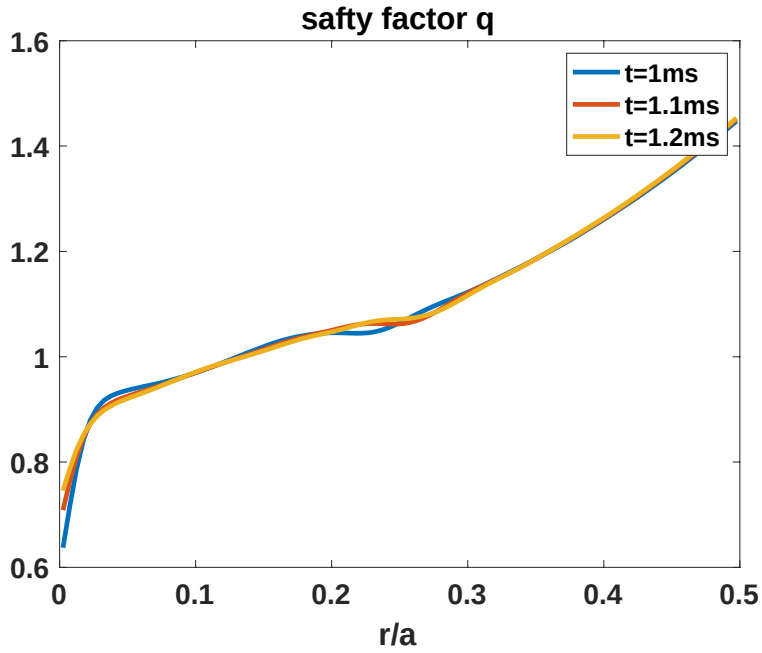
Sawteeth with 50% runaway current

08092021



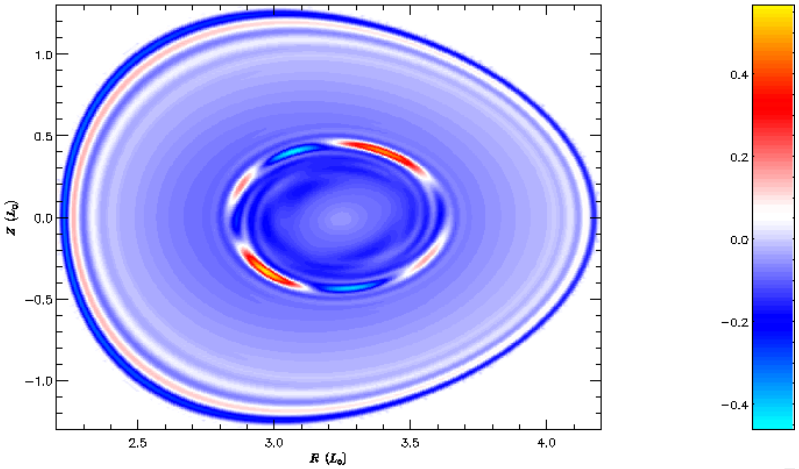
- The runaway electron current dropped dropped to nearly 0 at about t=1.1ms by the MHD instability during ST.





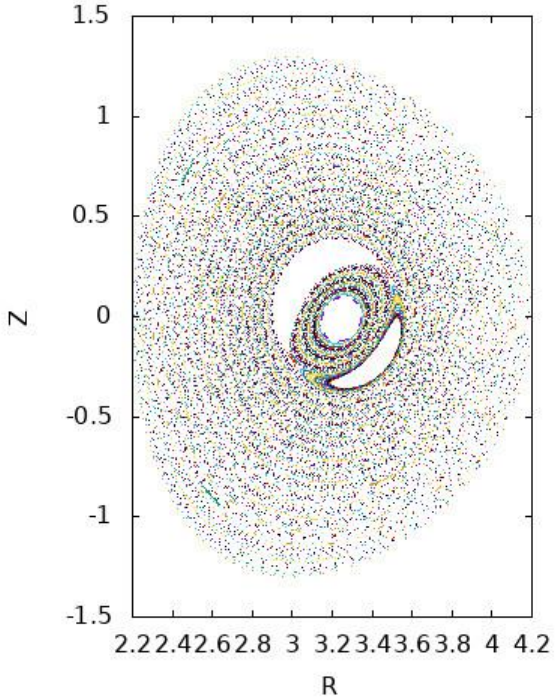
The highest is n=2 at t=1.1ms

Runaway current density profile at t=1.1ms



Maybe n=2 m=3 mode

Poincare plot at t=1.1ms

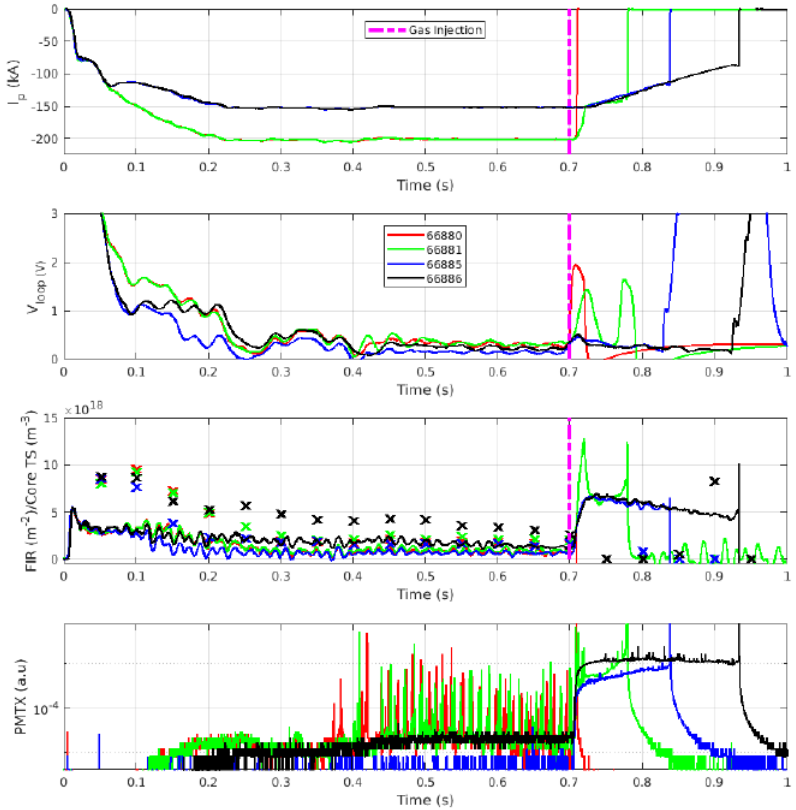


Expulsion of RE Seed - Sawteeth

From Umar Sheikh (7/22/21)

- Sawteeth expel Res
  - Seed population lost - HXR spikes
  - No RE beam after MGI
- Lower I_p removed Sawteeth
  - HXR spikes gone
- Stable RE beams produced

- Sharp drop in I_p indicates larger Ohmic current contribution
  - Sharp drop in I_p if fewer REs (green)
  - Significant RE current before MGI



That’s All I have

Anything Else ?