EP-Stability-Workflow

a practical hands-on guide

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console commands (bold)

klicks in gui (bold italic)

on SDCC, login01-03:

module avail EP-S

---------- /work/imas/etc/modules/all ----------
EP-Stability-WF/1.0.0-intel-2020b-DD-3.35.0 EP-Stability-WF/1.0.4-intel-2020b-DD-3.37.0
EP-Stability-WF/1.0.3-intel-2020b-DD-3.37.0 EP-Stability-WF/1.0.4-intel-2020b-DD-3.39.0

module show EP-Stability-WF/1.0.4-intel-2020b-DD-3.37.0

for older/newer versions, try: (not officially supported)
module use /home/ITER/haywart/.local/easybuild/modules/all

module load EP-Stability-WF/1.0.4-intel-2020b-DD-3.37.0

mkdir training

cd training

most non-IMAS output files will be written in this directory
IMAS files in ~/public/imasdb/training/3/0/ (mds+ or hfd5)

ep_gui

(see below: ep_nogui, editing directly .xml files)

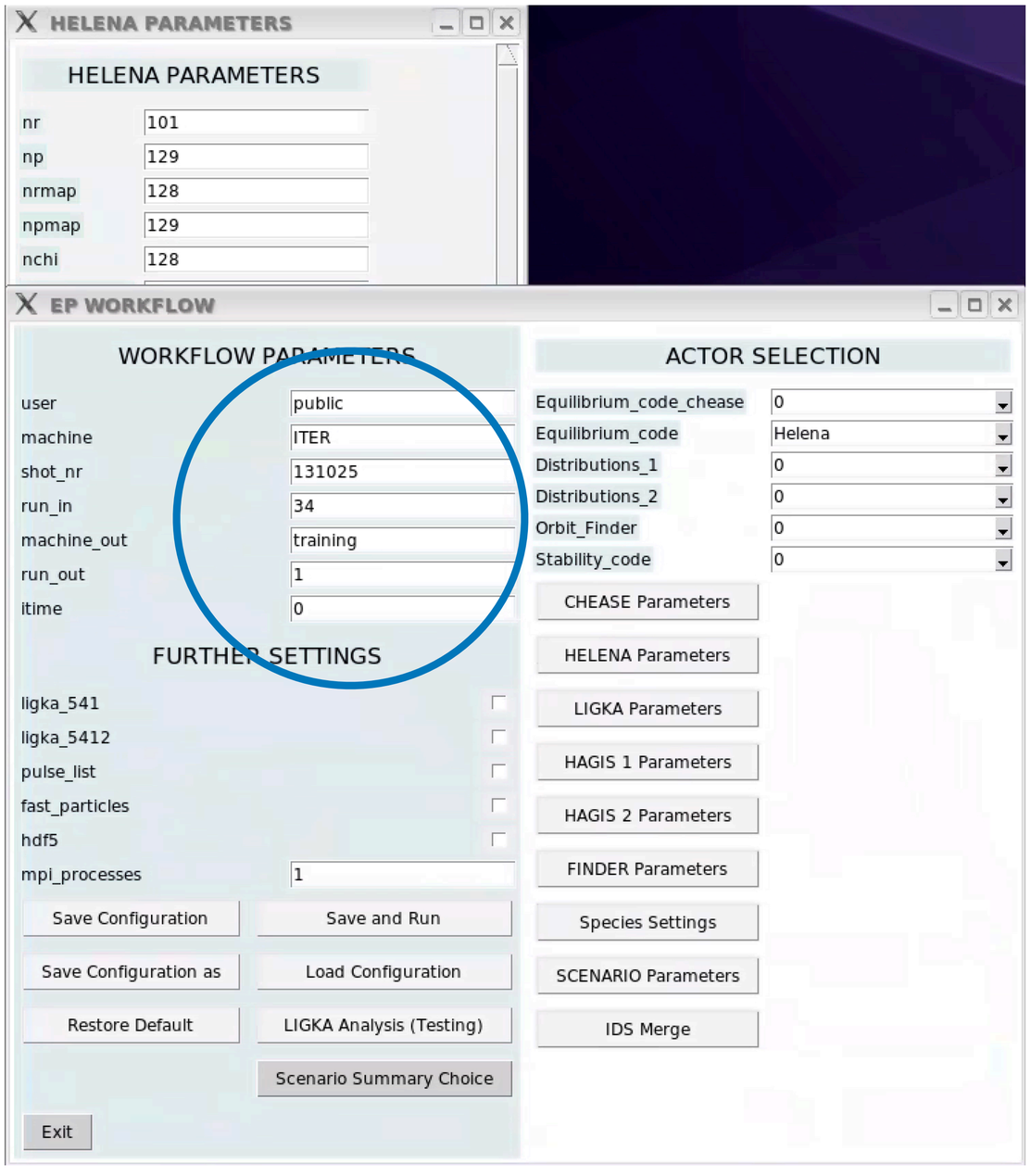
choose shot from public or private IMAS DB

Save configuration as (give useful name)

otherwise a standard name based on time stamp is used

then:

Save & Run



on gateway:

(module load cineca)
module use ~g2thayw/public/easybuild/modules/all
module avail EP-S

---------- /afs/eufus.eu/user/g/g2thayw/public/easybuild/modules/all ----------
EP-Stability-WF/1.0.0-DD-3.35.0 EP-Stability-WF/1.0.2-DD-3.35.0 EP-Stability-WF/1.0.4-DD-3.35.0
EP-Stability-WF/1.0.1-DD-3.35.0 EP-Stability-WF/1.0.3-DD-3.35.0

module load EP-Stability-WF/1.0.4-DD-3.35.0

mkdir training

cd training

most non-IMAS output files will be written in this directory
IMAS files in ~/public/imasdb/training/3/0/ (mds+)

ep_gui

(see below: ep_nogui, editing directly .xml files)

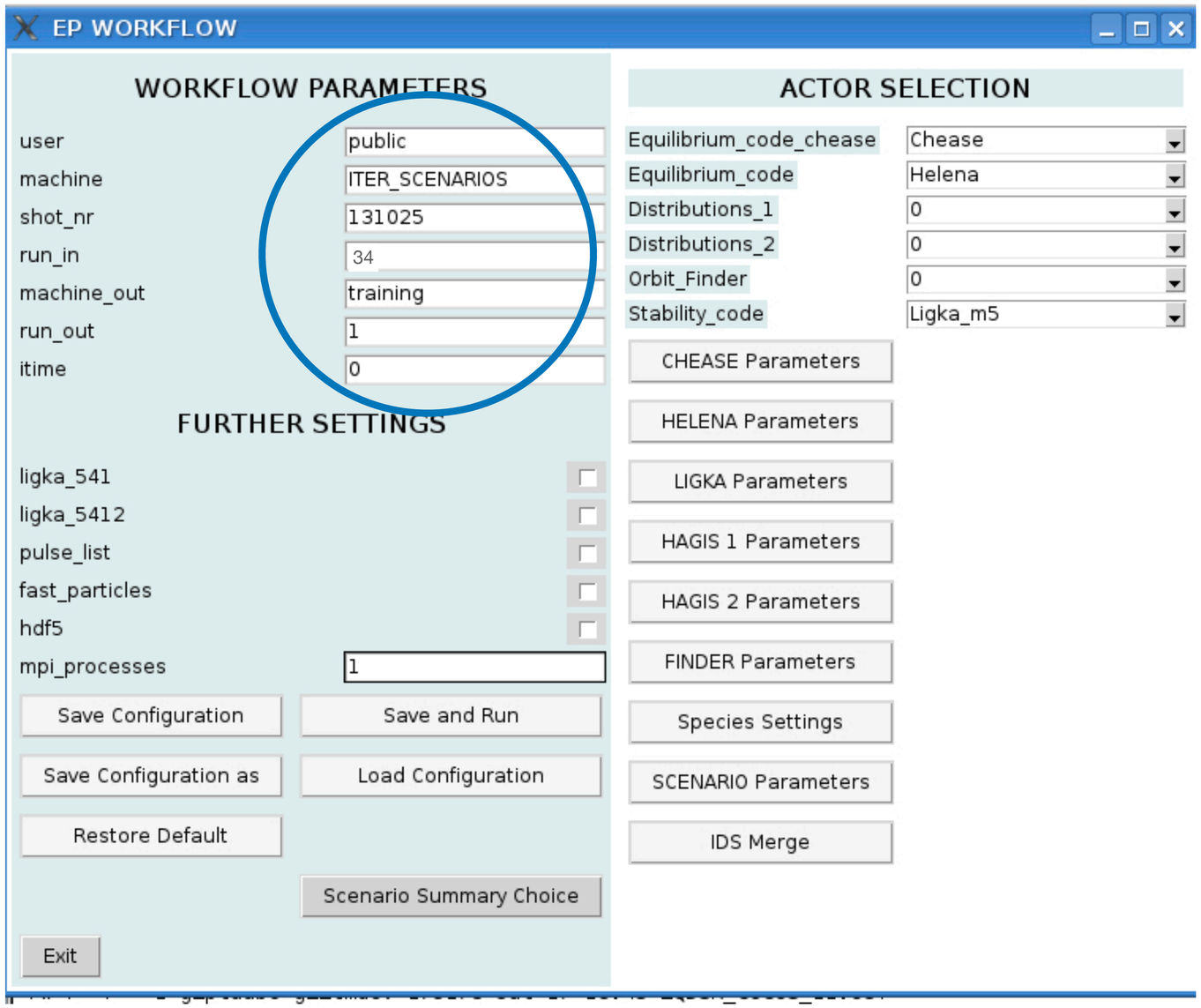
choose shot from public or private IMAS DB

Save configuration as (give useful name)

otherwise a standard name based on time stamp is used

then:

Save & Run



On SDCC, login01-03:

module avail EP-S

EP-Stability-WF/1.0.0-intel-2020b-DD-3.35.0

module show EP-Stability-WF/1.0.3-intel-2

for older/newer versions, try: (not officially su
module use /home/ITER/haywart/.local/easy

module load EP-Stability-WF/1.0.3-intel-2

mkdir training

cd training

most non-IMAS output files will be written in this directory
IMAS files in ~/public/imasdb/training/3/0/ (mds+)

ep_gui

choose shot from public or private IMAS DB

Save configuration as (give useful name)

otherwise a standard name based on time stamp is used

then:

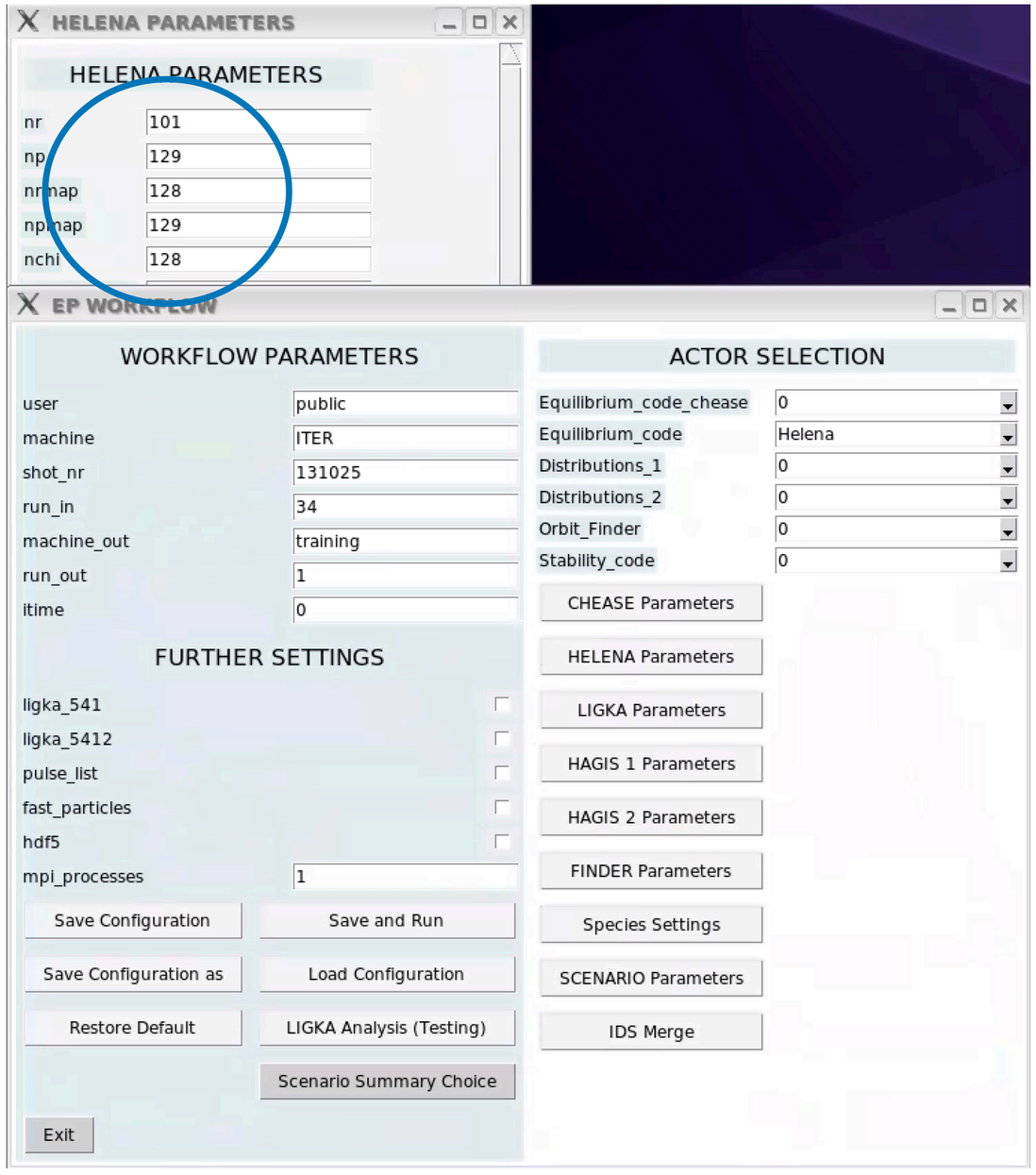
Save & Run

HELENA:

https://git.iter.org/projects/EQ/repos/helena/browse

number of radial points used internally
number of poloidal points used internally
number of radial points used for mapping final result (<500)
number of poloidal points used for mapping final result (<500)
number of angular points used for mapping final result (<500), typically same as np

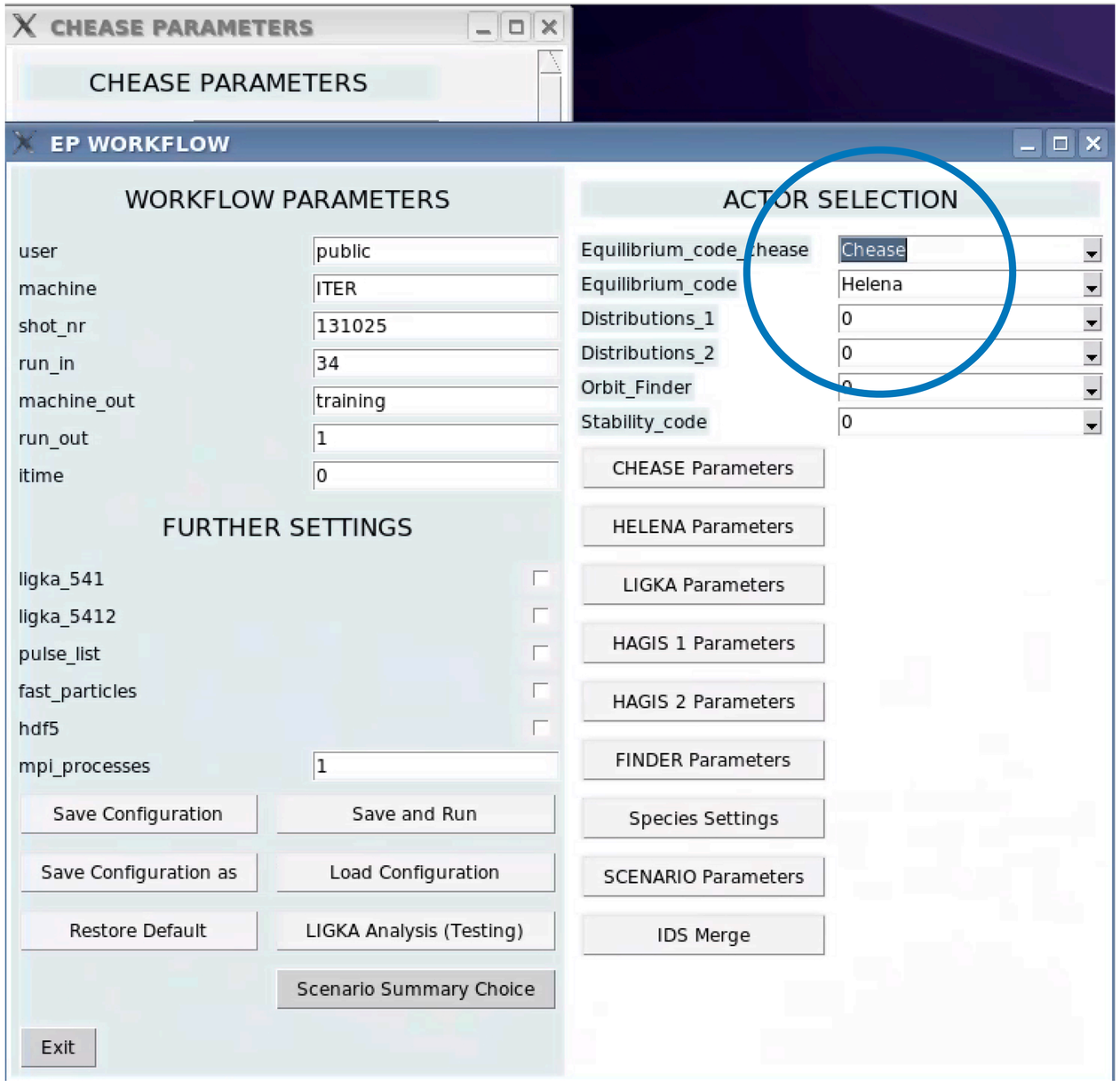
best for LIGKA 128/256/384/ (512 and more points available in private HELENA version) - LIGKA uses HELENA-given resolution!
number of radial points to be divisible by number of parallel procs to be used in LIGKA later



if **HELENA does not converg**e or delivers problematic results, **CHEASE** be run before HELENA:

Equilibrium_code_chease (drop down)

typically, no changes in the defaults are needed (refer to CHEASE documentation)
https://git.iter.org/projects/EQ/repos/chease/browse



Checking entries in IDS:

module load Viz

viz

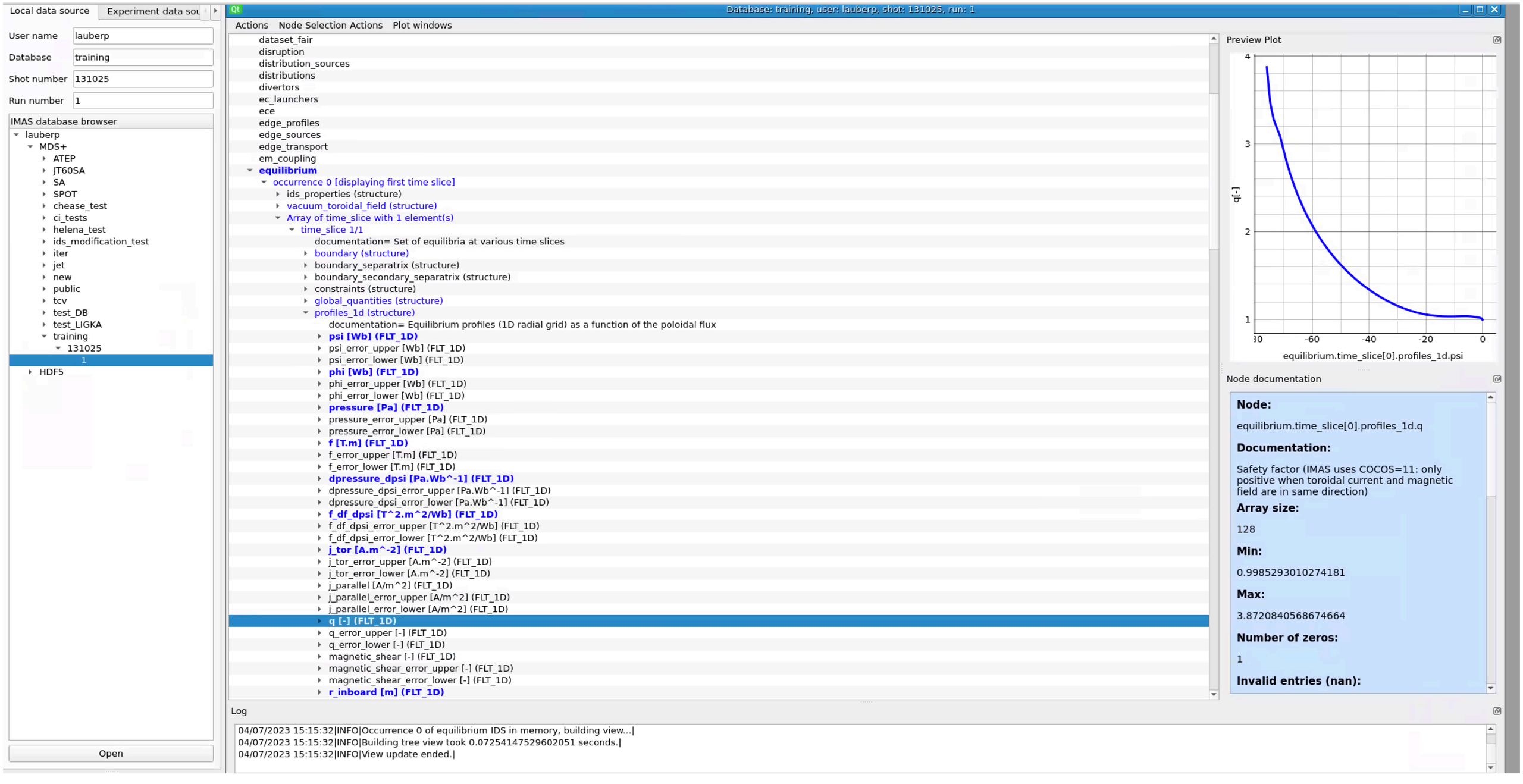
gateway:
module load imas-viz
viz

or:
first check if data exists:

ls -ltr ~/public/imasdb/training/3/0/

then:
idsdump lauberp training 3 131025 1 equilibrium/0 > eq_occ_0
idsdump lauberp training 3 131025 1 equilibrium/1 > eq_occ_1

use editor to look at the files



Run analytical, local LIGKA: model 5

<min_n_tor>10</min_n_tor> ! start search from this minimal tor. mode number

<max_n_tor>10</max_n_tor> ! end search from this max tor. mode number

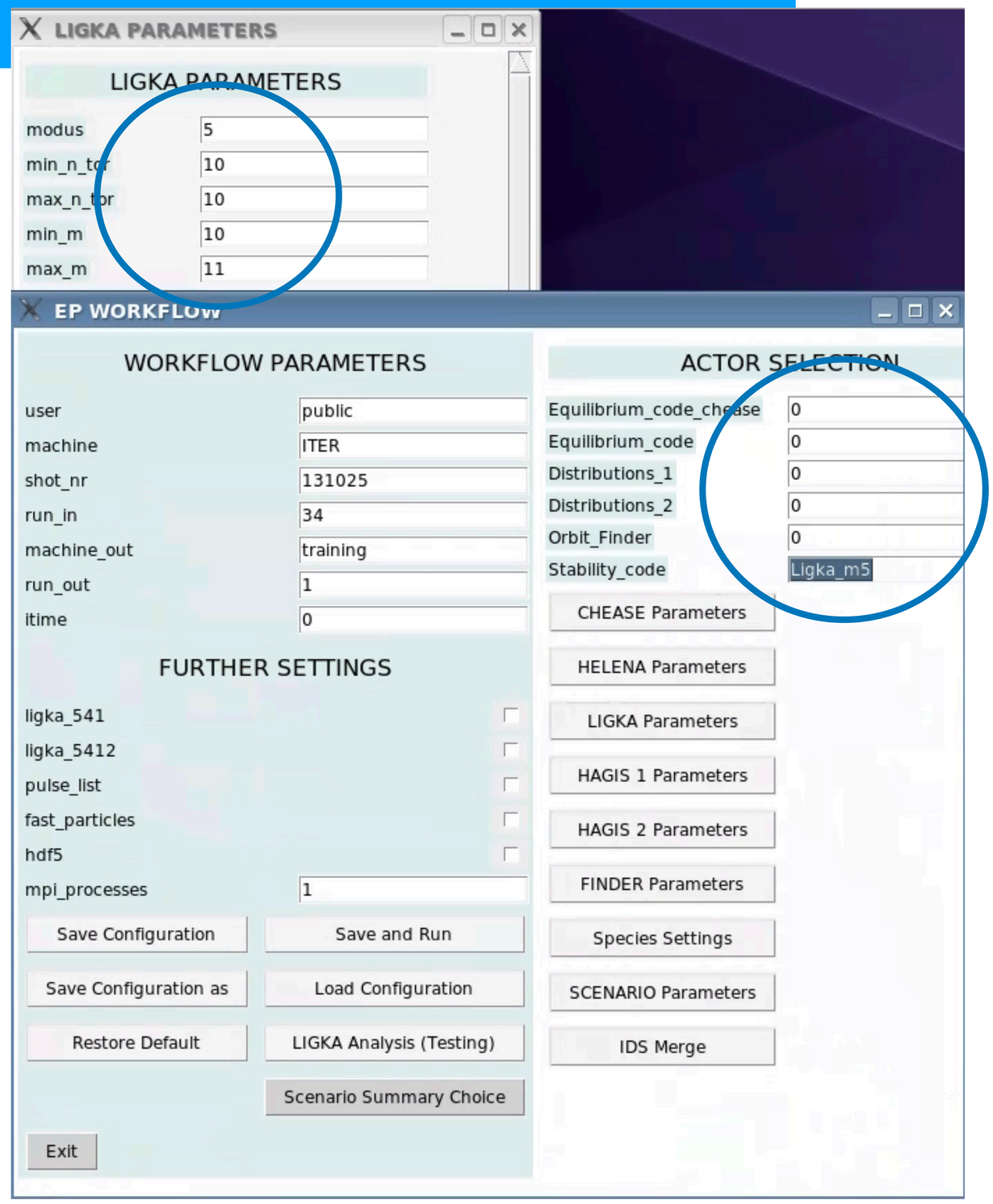
<min_m>10</min_m> ! start poloidal mode number (nq-m=0, BAEs; q_{TAE}=(m+0.5)/n) ; for next n, look for (m+1+0.5)/n!

<max_m>11</max_m> ! number of gaps to be searched: for one (main) TAE gap use max_m=min_m

Stability code (drop down): Ligka_m5

LIGKA Parameters

Save & Run



****

Initial Output
Saved Ligka_m5 mhd_linear under occurrence 0
****

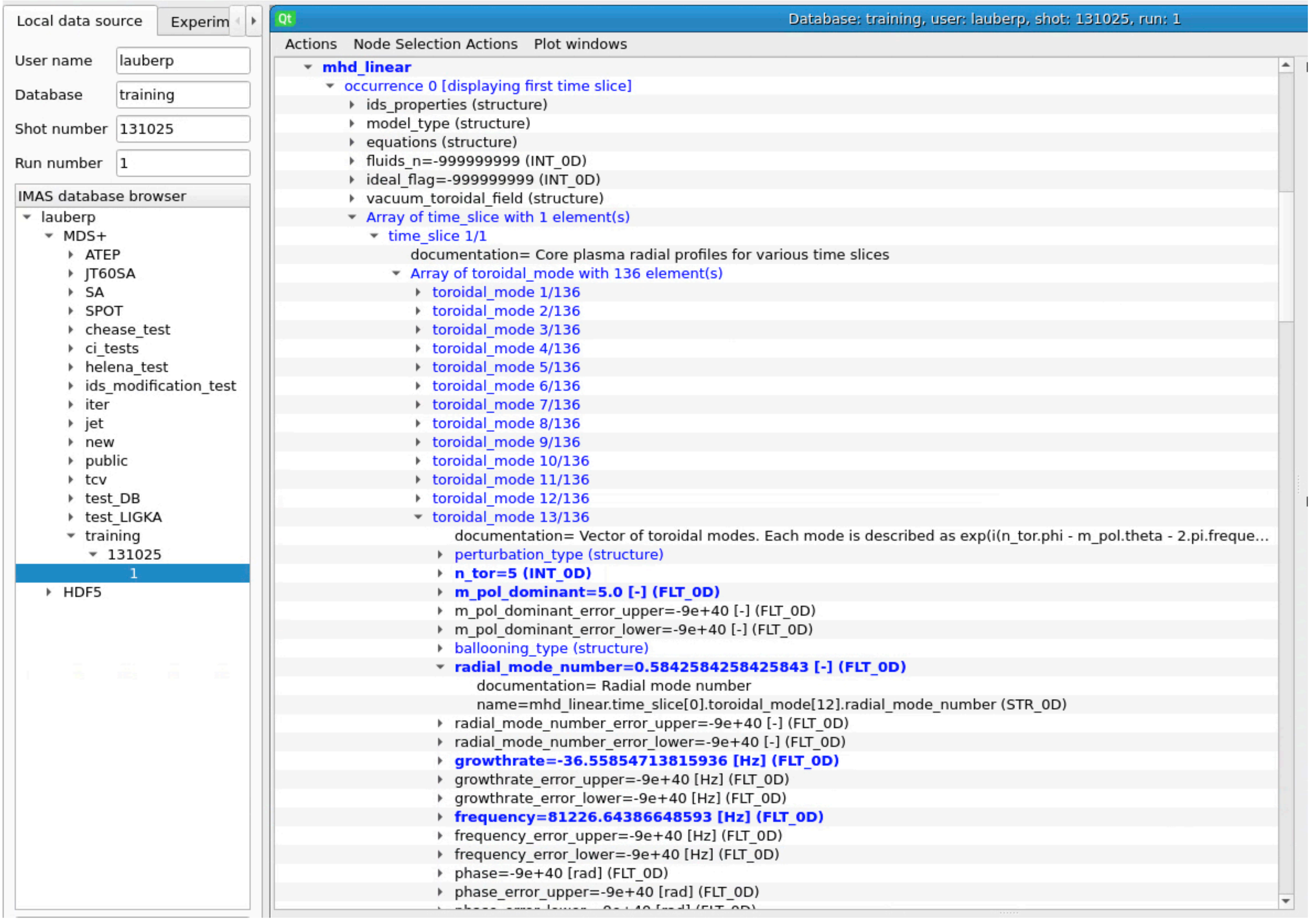
Workflow Finished.

check/visualise results:

idsdump lauberp training 3 131025 1 mhd_linear/0 > mhd_occ_0

or look at additionally written ASCII files in local dir or ~/ !

check/visualise results: viz



try different n and m ranges…

ASCII files in local directory: loc_<AE-type>_mode<LIGKA model>_<time_stamp>
e.g.: loc_TAE_mode5_00208000

Note: the output for the global models 1 and 2 are similar: e.g. glo_TAE_mode1_00208000, glo_TAE_mode2_00208000

description of columns in ASCII files:
note that model 5 does not fill cols 14-23; model 4 adds 14,15; model 1: 16-19; model 2: 20-23

```
1 radial position of mode in s=sqrt(norm_pol_flux)
2 corresponding q value
3 toroidal mode number
4 dominant poloidal mode number (for TAEs: m, and not m+1)
5 frequency, analytical estimate in units of omega_A0=B_0/sqrt(m_ion * n_0 mu_0) on axis values
6 radiative damping, formula S.D. Pinches 2015 (to be checked) in gamma/omega!
7 local beta at gap/mode rational surface: 2.0d0*press(s)*mu0/Btor(s)**2!
8 mode type: 0=GAM-EGAM/1=TAE/2=RSAE/3=BAE/4=EAE/5=NAE/6=EPM/7=BAAE/8=KBM/9=ITG,10 even TAE, 10 odd TAE: 11
9 estimated radial width: s/m (large shear), s/m sqrt(eps/shear) small shear (Candy Phys Lett A 215, 299-304, 1996)
10 mode frequency in rad/s (divide by 2 pi for Hertz) hint: dividing this value by value of col 5 gives omega_A0
11 TAE frequency using Fesenyuk's analytical expression (Fesenyuk PoP 20, 2013)
12 not used
13 not used
14 real frequency of continuum extremum belonging to mode - model 4
15 imaginary frequency of continuum extremum belonging to mode - model 4
16 real frequency model 1
17 imaginary frequency model 1
18 m_min used in model 1 run
19 m_max used in model 1 run
20 real frequency model 2
21 imaginary frequency model 2
22 m_min used in model 2 run
23 m_max used in model 2 run
24: IMAS only: time index itime
25: IMAS only: equilibrium_in%time(itime): absolute time
26: not used
27: not used
28  unstable mode? negative: mode damped, positive: mode unstable
29: direction of phase jump: positive correct, negative - possible problem with mode - check response file
30: distance to next gap
31: distance to previous gap
32: omega/omega_A0 of next gap
33: omega/omega_A0 of previous gap

and so on in block of 4 for the next order gaps
```

use favourite plotting tool, or python script: (to be added)
e.g. gnuplot

plot 'loc_TAE_mode5_00208000' u 1:5

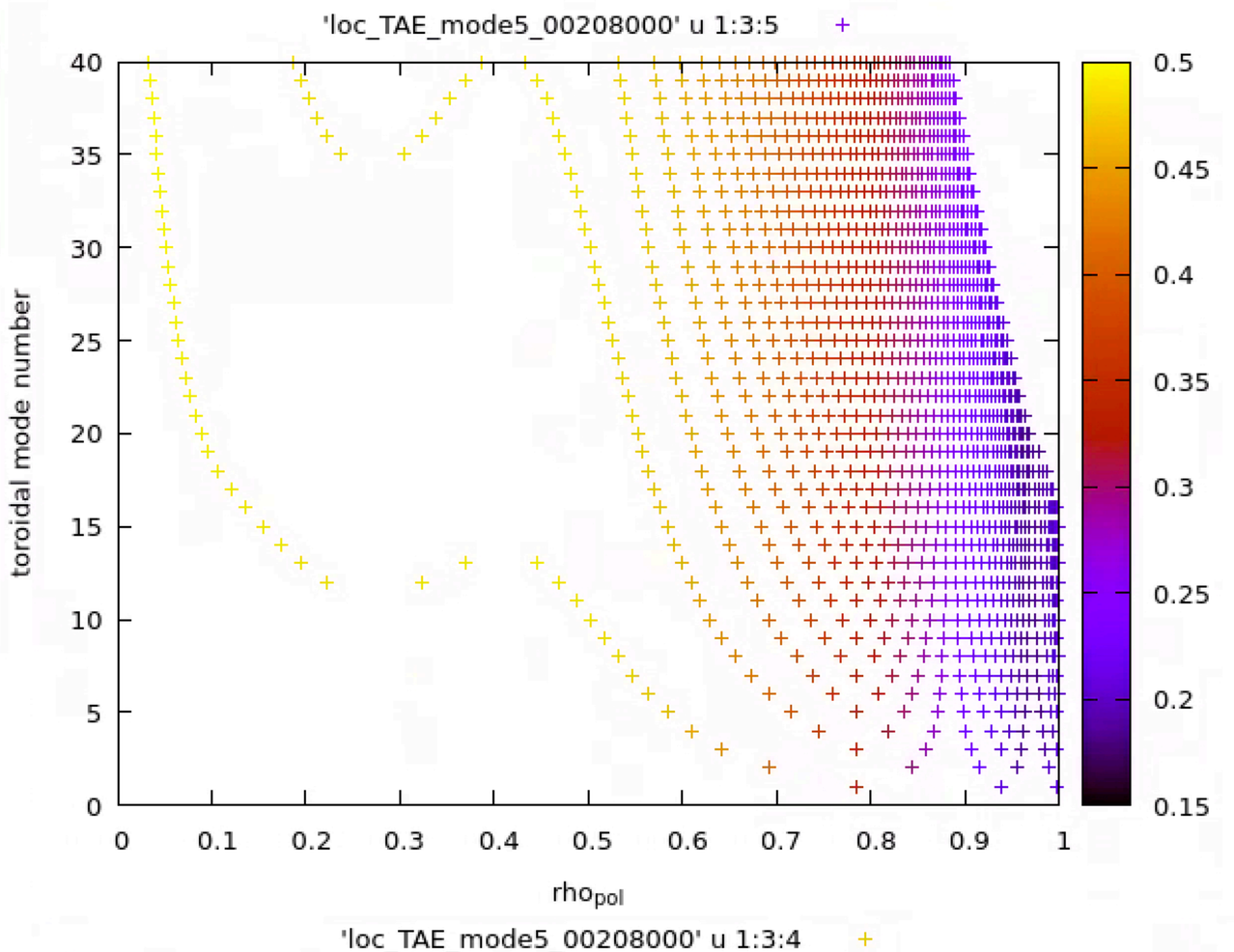
try different n and m ranges…

with gnuplot:

LIGKA PARAMETERS

modus	5
min_n_tor	1
max_n_tor	40
min_m	-5
max_m	40

plot 'loc_TAE_mode5_00208000' u 1:3:5 palette



with gnuplot:

LIGKA PARAMETERS

modus	5
min_n_tor	1
max_n_tor	40
min_m	1
max_m	2

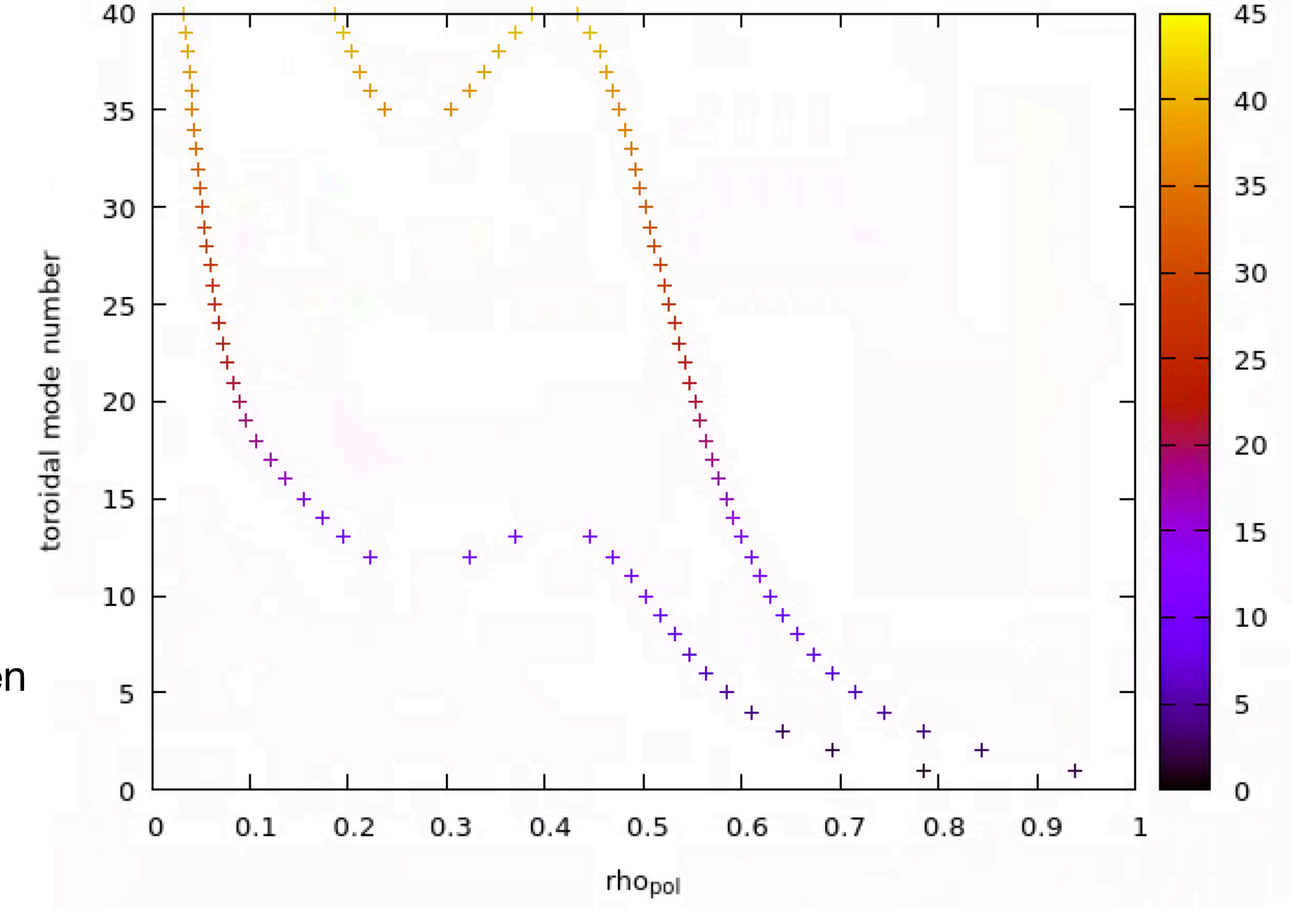
plot 'loc_TAE_mode5_00208000' u 1:3:5 palette

algorithm is designed find: q_TAE=(m+0.5)/n

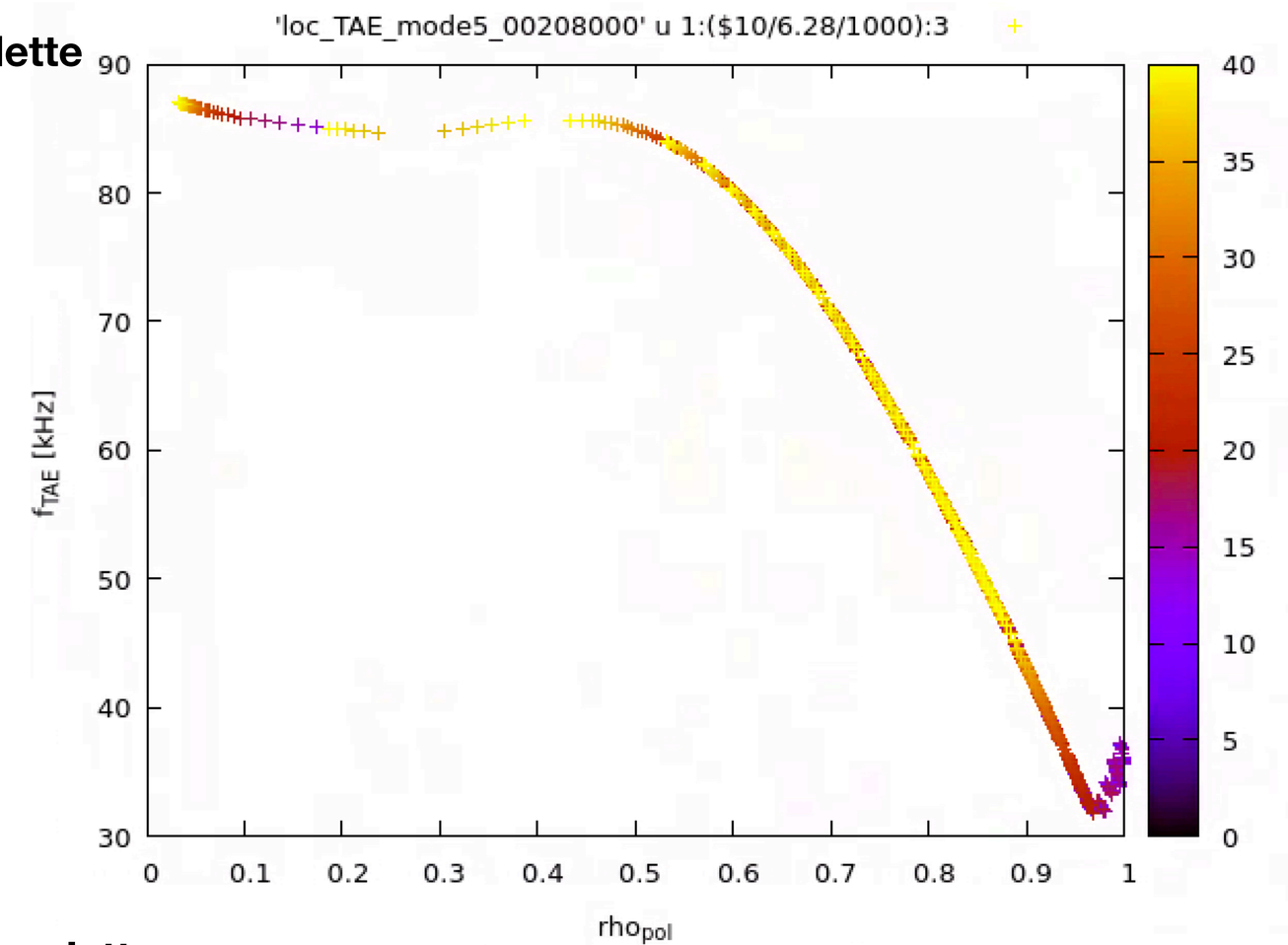
for increasing n also m is increased:
 (n=1,m=1) ; (n=2,m=2) ; (n=3,m=3);…

logical choice to follow TAE branches for q~1

i.e. the pair (min_n, min_m) defines the relative difference between n and m that is kept the same when scanning n
using like in this example min_m=1 and m_max=2 gives two TAE branches:
(n=1,m=1) ; (n=2,m=2) ; (n=3,m=3);…
(n=1,m=2) ; (n=2,m=3) ; (n=3,m=4);…

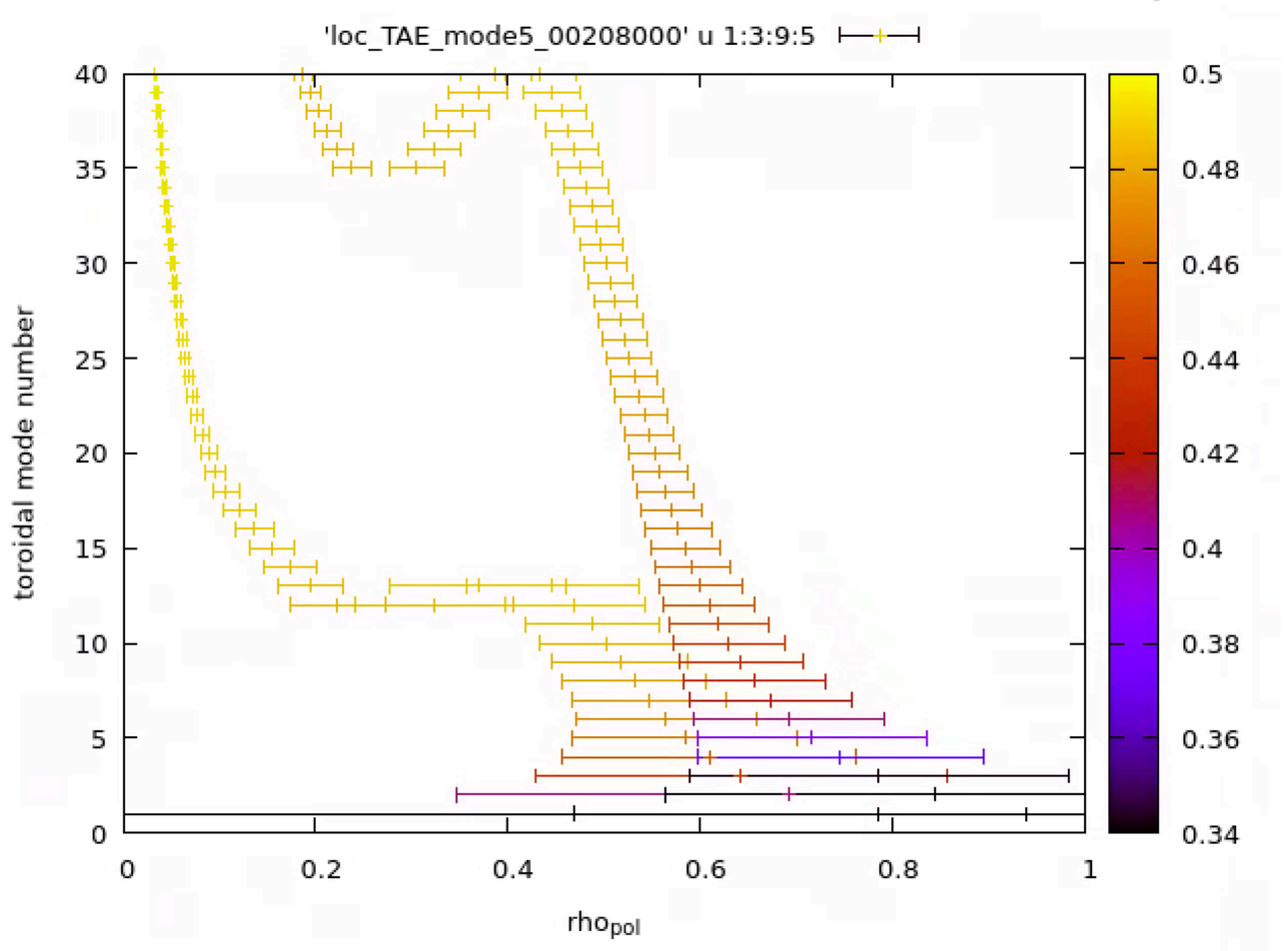


plot 'loc_TAE_mode5_00208000' u 1:($10/6.28/1000):3 palette



if you want to compare to experiment, add n*tor_rot to each mode!

plot 'loc_TAE_mode5_00208000' u 1:3:9:5 with xerrorbars palette



add estimate of radial mode width

gives hints about resonance overlap regions

omega_TAE

Run analytical, local LIGKA: model 4

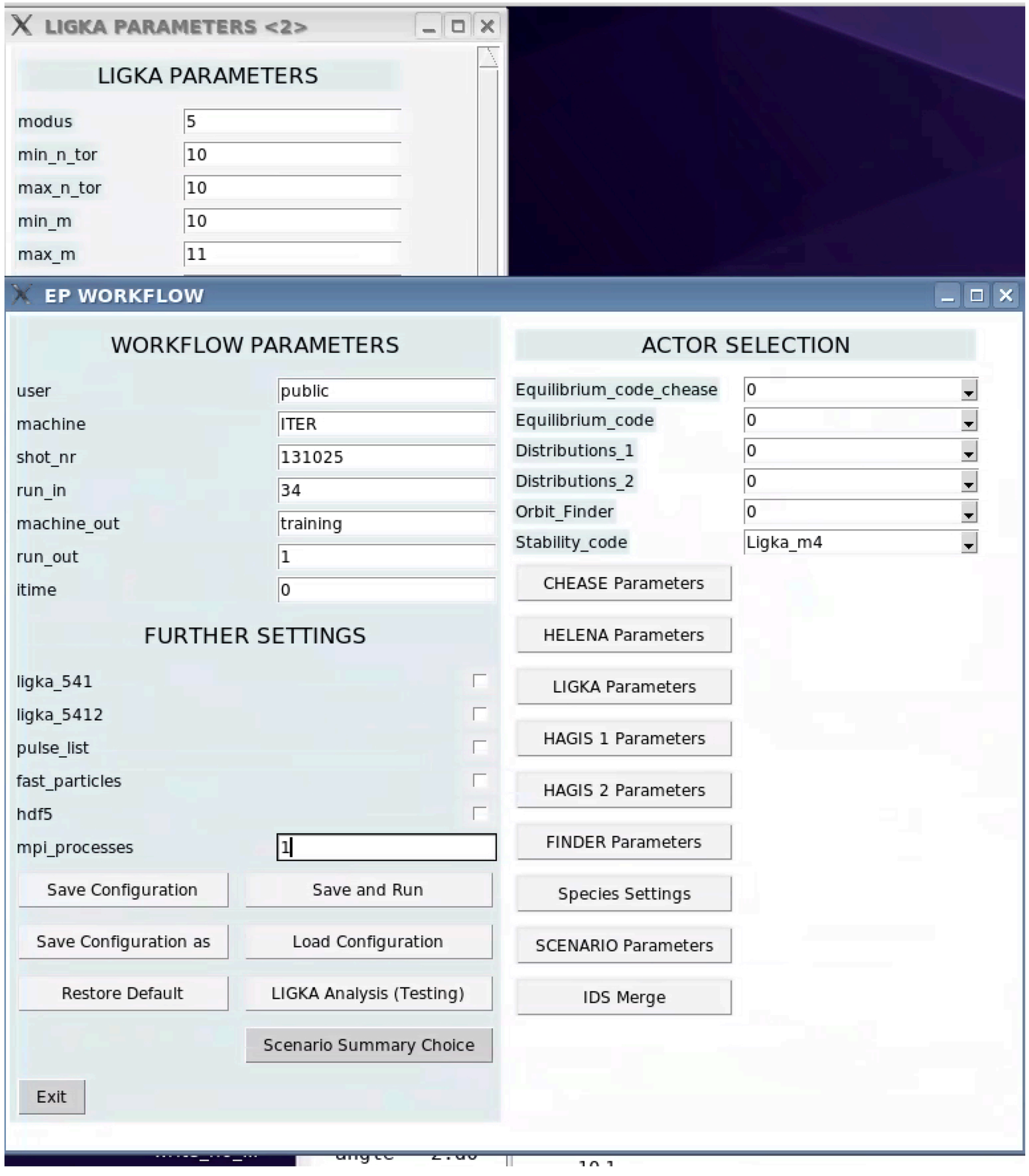
model 4 takes all modes found in previous model 5 run! run mode 5 with restricted set of modes, since model 4 is slightly more expensive (5s per mode) - local integration in complex plane, one pol. sideband, hardcoded (physics model see lecture!)

Stability code (drop down): Ligka_m4

LIGKA Parameters

Save & Run

Initial Output
Saved Ligka_m4 mhd_linear under
occurrence 1
****
Workflow Finished.



ASCII files in local directory: loc_<AE-type>_mode<LIGKA model>_<time_stamp>
e.g.: **loc_TAE_mode4_00208000**

Note: the output for the global models 1 and 2 are similar: e.g. glo_TAE_mode1_00208000, glo_TAE_mode2_00208000

description of columns in ASCII files:
note that model 5 does not fill cols 14-23; model 4 adds 14,15; model 1: 16-19; model 2: 20-23

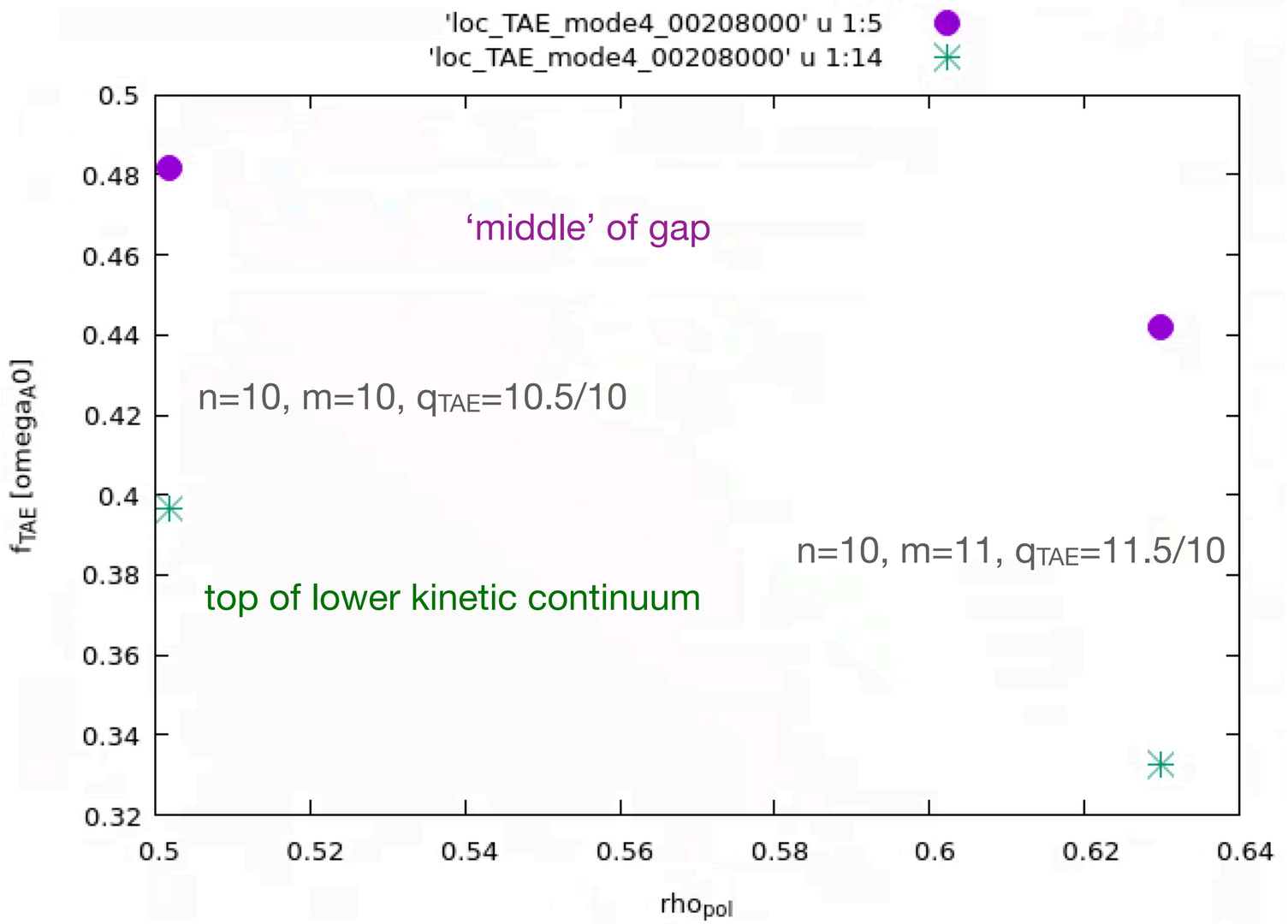
```
1 radial position of mode in s=sqrt(norm_pol_flux)
2 corresponding q value
3 toroidal mode number
4 dominant poloidal mode number (for TAEs: m, and not m+1)
5 frequency, analytical estimate in units of omega_A0=B_0/sqrt(m_ion * n_0 mu_0) on axis values
6 radiative damping, formula S.D. Pinches 2015 (to be checked)
7 local beta at gap/mode rational surface: 2.0d0*press(s)*mu0/Btor(s)**2!
8 mode type: 0=GAM-EGAM/1=TAE/2=RSAE/3=BAE/4=EAE/5=NAE/6=EPM/7=BAAE/8=KBM/9=ITG,10 even TAE, 10 odd TAE: 11
9 estimated radial width: s/m (large shear), s/m sqrt(eps/shear) small shear (Candy Phys Lett A 215, 299-304, 1996)
10 mode frequency in rad/s (divide by 2 pi for Hertz)
11 TAE frequency using Fesenyuk's analytical expression (Fesenyuk PoP 20, 2013)
12 not used
13 not used
14 real frequency of continuum extremum belonging to mode - model 4
15 imaginary frequency of continuum extremum belonging to mode - model 4
16 real frequency model 1
17 imaginary frequency model 1
18 m_min used in model 1 run
19 m_max used in model 1 run
20 real frequency model 2
21 imaginary frequency model 2
22 m_min used in model 2 run
23 m_max used in model 2 run
24: IMAS only: time index itime
25: IMAS only: equilibrium_in%time(itime): absolute time
26: not used
27: not used
28  unstable mode? negative: mode damped, positive: mode unstable
29: direction of phase jump: positive correct, negative - possible problem with mode - check response file
30: distance to next gap
31: distance to previous gap
32: omega/omega_A0 of next gap
33: omega/omega_A0 of previous gap

and so on in block of 4 for the next order gaps
```

should be filled now in **loc_TAE_mode4_00208000**

use favourite plotting tool, or python script: (to be added)
e.g. gnuplot

plot 'loc_TAE_mode5_00208000' u 1:5

plot 'loc_TAE_mode4_00208000' u 1:5 ps 2 pt 7, 'loc_TAE_mode4_00208000' u 1:14 ps 2 pt 3



or:

idsdump lauberp training 3 131025 1 mhd_linear/1 > mhd_occ_1

check/visualise results: viz - problems with occurrences!

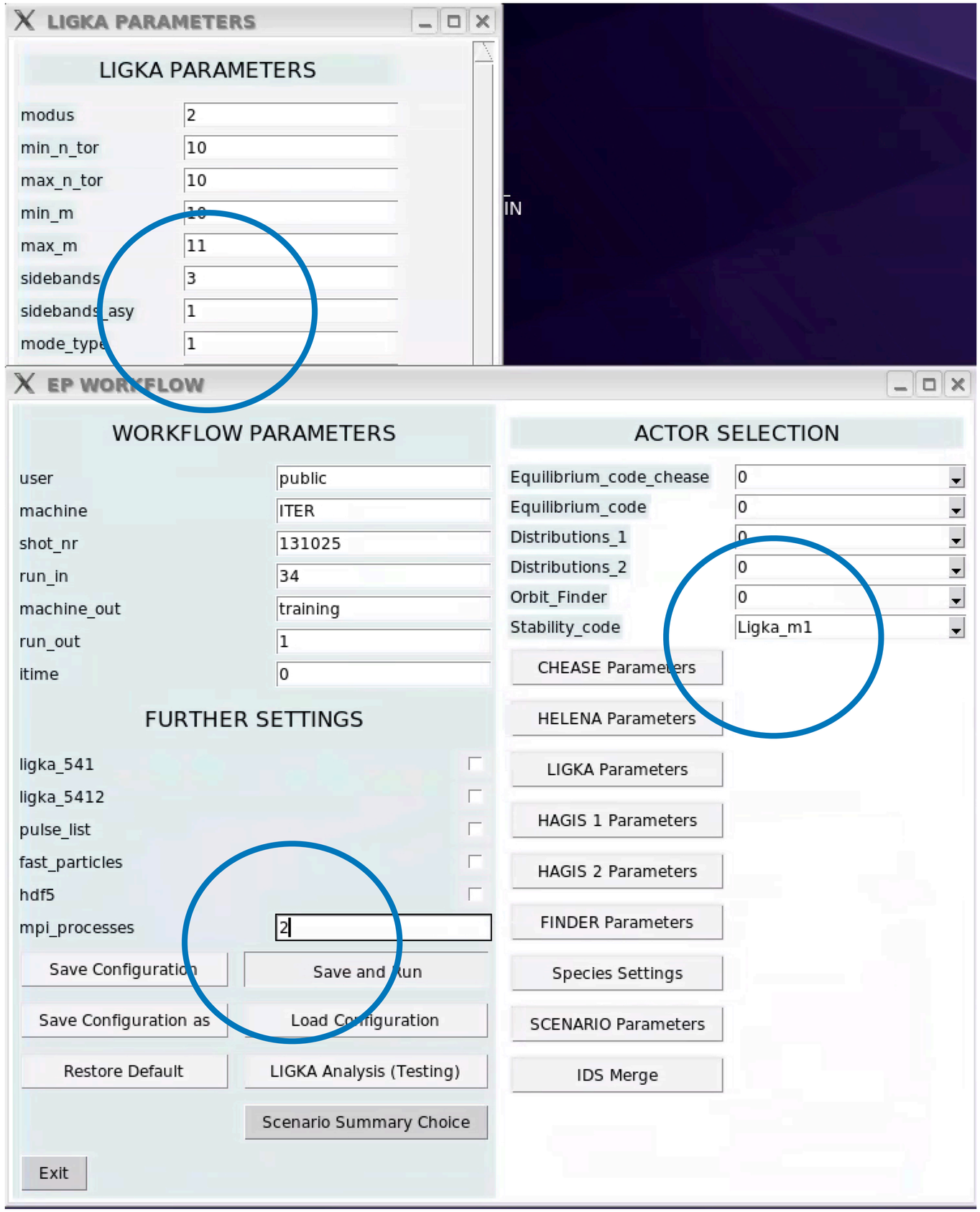
Run analytical, global LIGKA: model 1

Stability code (drop down): Ligka_m1

LIGKA Parameters

Save & Run

Initial Output
Saved Ligka_m1 mhd_linear under
occurrence 2
****
Workflow Finished.



Run analytical, global LIGKA: model 1

- model 1 takes all modes found in previous model 4 run!
- run mode 5,4 with **restricted** set of modes, since model 1 is more expensive (minutes-hours **per** mode)
- use **more than one proc** (2,4,8,16,32) are typically good choices - use batch script to submit! (see below)
- model 1 scans the TAE gap region using LIGKA's antenna model (approx 40 iterations): scan whole gap region with coarse resolution; possible issues with dense multiple modes
- use number of poloidal sidebands as given in LIGKA configuration menu/xml file
- typically, more pol. sidebands are needed low and intermediate n's. For high-n's two sidebands are often enough: sidebands=2….16 (2*sb+1 total pol. harmonics)
- typically, mode pol. sidebands are needed on the high-m side: e.g. if central m's are 10 and 11, it is better to choose m=8…16 than m=6…14 or m=4…12 reason: q increases and becomes steeper towards the edge, coupling to outer pol. harmonics with larger m is typically found : the parameter sideband_asy controls this:
    - 0: symmetrically around main m
    - positive (smaller than 2*sidebands+1): move pol. harmonics window to larger m
    - negative (abs smaller than 2*sidebands+1): move pol. harmonics window to smaller m
- this is not the case for strongly reversed shear profiles
- if LIGKA stores the **first** mode it finds with a damping rate smaller than ~15%.
- other even TAEs that can reside in the same gap, are found by scanning other pairs of main (n,m) - as in the example above

ASCII files in local directory: loc_<AE-type>_mode<LIGKA model>_<time_stamp>
e.g.: loc_TAE_mode5_00208000

Note: the output for the global models 1 and 2 are similar: e.g. glo_TAE_mode1_00208000, glo_TAE_mode2_00208000

description of columns in ASCII files:
note that model 5 does not fill cols 14-23; model 4 adds 14,15; model 1: 16-19; model 2: 20-23

```
1 radial position of mode in s=sqrt(norm_pol_flux)
2 corresponding q value
3 toroidal mode number
4 dominant poloidal mode number (for TAEs: m, and not m+1)
5 frequency, analytical estimate in units of omega_A0=B_0/sqrt(m_ion * n_0 mu_0) on axis values
6 radiative damping, formula S.D. Pinches 2015 (to be checked)
7 local beta at gap/mode rational surface: 2.0d0*press(s)*mu0/Btor(s)**2!
8 mode type: 0=GAM-EGAM/1=TAE/2=RSAE/3=BAE/4=EAE/5=NAE/6=EPM/7=BAAE/8=KBM/9=ITG,10 even TAE, 10 odd TAE: 11
9 estimated radial width: s/m (large shear), s/m sqrt(eps/shear) small shear (Candy Phys Lett A 215, 299-304, 1996)
10 mode frequency in rad/s (divide by 2 pi for Hertz)
11 TAE frequency using Fesenyuk's analytical expression (Fesenyuk PoP 20, 2013)
12 not used
13 not used
14 real frequency of continuum extremum belonging to mode - model 4
15 imaginary frequency of continuum extremum belonging to mode - model 4
16 real frequency model 1
17 imaginary frequency model 1
18 m_min used in model 1 run
19 m_max used in model 1 run
20 real frequency model 2
21 imaginary frequency model 2
22 m_min used in model 2 run
23 m_max used in model 2 run
24: IMAS only: time index itime
25: IMAS only: equilibrium_in%time(itime): absolute time
26: not used
27: not used
28  unstable mode? negative: mode damped, positive: mode unstable
29: direction of phase jump: positive correct, negative - possible problem with mode - check response file
30: distance to next gap
31: distance to previous gap
32: omega/omega_A0 of next gap
33: omega/omega_A0 of previous gap

and so on in block of 4 for the next order gaps
```

should be filled now in **glo_TAE_mode1_00208000**

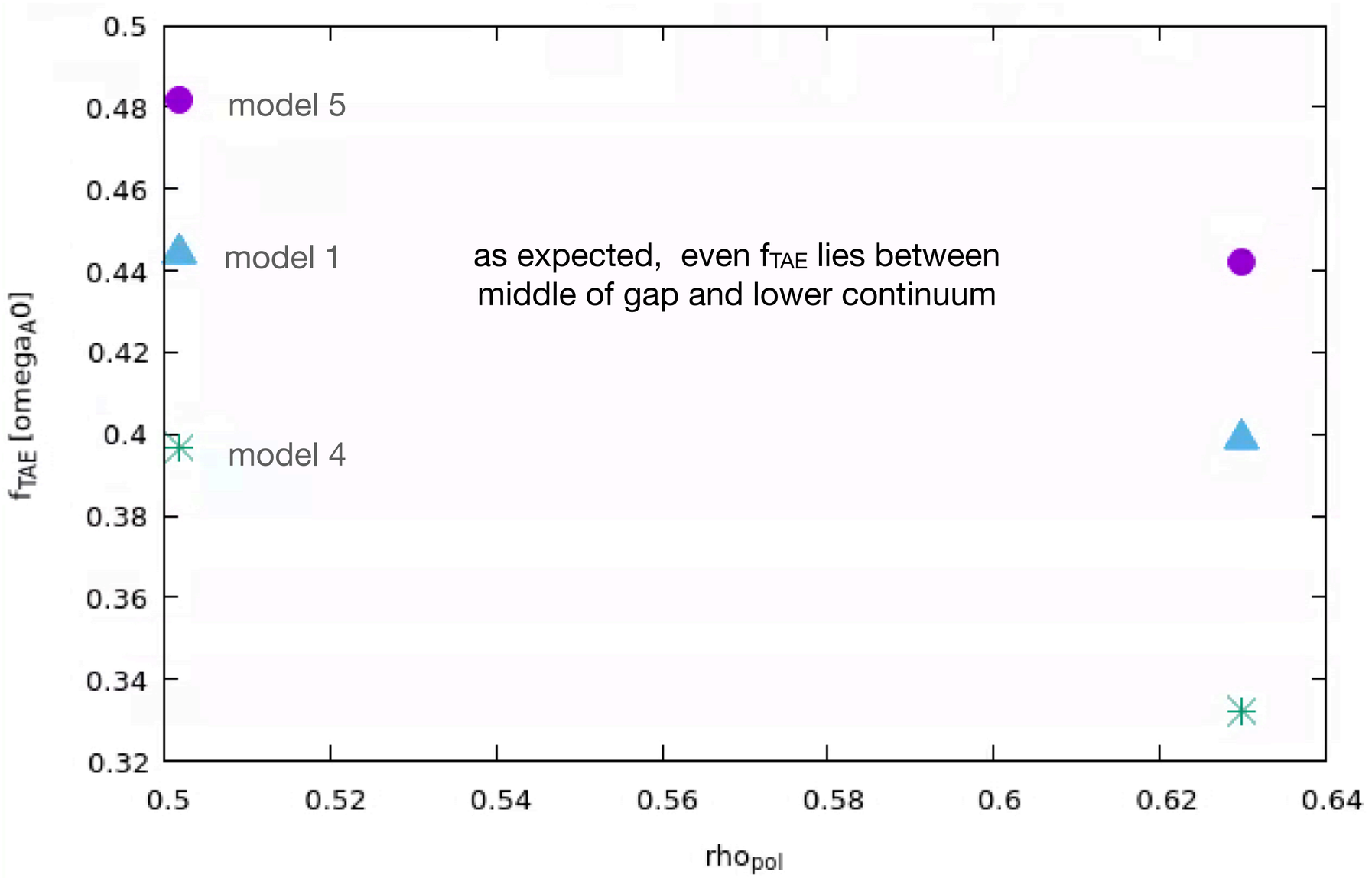
use favourite plotting tool, or python script: (to be added)
e.g. gnuplot

plot 'loc_TAE_mode5_00208000' u 1:5

try different n and m ranges…

gnuplot

plot 'loc_TAE_mode4_00208000' u 1:5 ps 2 pt 7, 'loc_TAE_mode4_00208000' u 1:14 ps 2 pt 3, ‘glo_TAE_mode1_00208000’ u 1:16 ps 3 pt 9



Run analytical, global LIGKA: model 2

model 2 uses the model 1 result to
to iterate and to determine accurately
f, gamma and mode structure

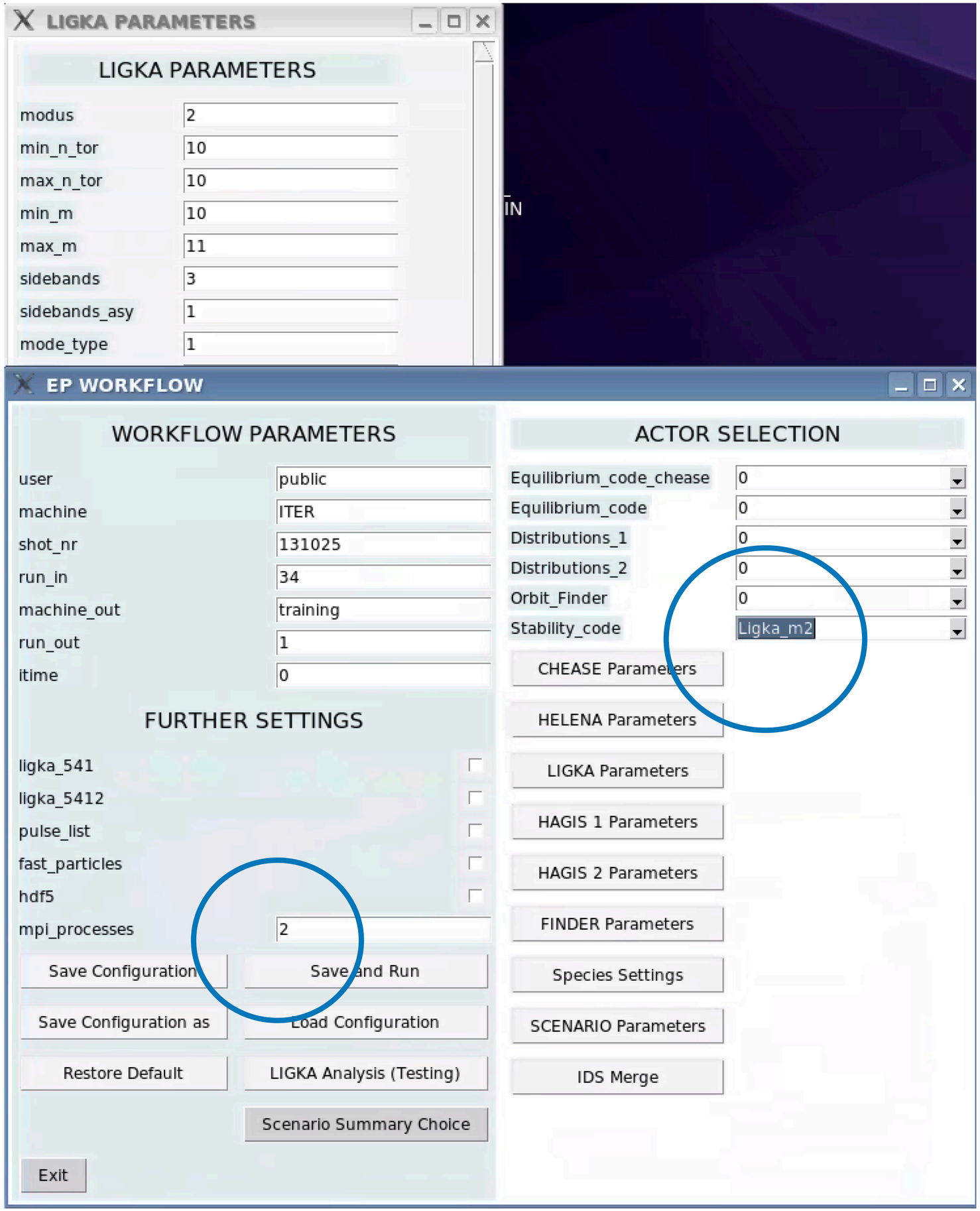
needs less iterations, stops calculation after
mode has been found

Stability code (drop down): Ligka_m2

LIGKA Parameters

Save & Run

Initial Output
Saved Ligka_m2 mhd_linear under occurrence 6
****
Workflow Finished.



ASCII files in local directory: loc_<AE-type>_mode<LIGKA model>_<time_stamp>
e.g.: loc_TAE_mode5_00208000

Note: the output for the global models 1 and 2 are similar: e.g. glo_TAE_mode1_00208000, glo_TAE_mode2_00208000

description of columns in ASCII files:
note that model 5 does not fill cols 14-23; model 4 adds 14,15; model 1: 16-19; model 2: 20-23

```
1 radial position of mode in s=sqrt(norm_pol_flux)
2 corresponding q value
3 toroidal mode number
4 dominant poloidal mode number (for TAEs: m, and not m+1)
5 frequency, analytical estimate in units of omega_A0=B_0/sqrt(m_ion * n_0 mu_0) on axis values
6 radiative damping, formula S.D. Pinches 2015 (to be checked)
7 local beta at gap/mode rational surface: 2.0d0*press(s)*mu0/Btor(s)**2!
8 mode type: 0=GAM-EGAM/1=TAE/2=RSAE/3=BAE/4=EAE/5=NAE/6=EPM/7=BAAE/8=KBM/9=ITG,10 even TAE, 10 odd TAE: 11
9 estimated radial width: s/m (large shear), s/m sqrt(eps/shear) small shear (Candy Phys Lett A 215, 299-304, 1996)
10 mode frequency in rad/s (divide by 2 pi for Hertz)
11 TAE frequency using Fesenyuk's analytical expression (Fesenyuk PoP 20, 2013)
12 not used
13 not used
14 real frequency of continuum extremum belonging to mode - model 4
15 imaginary frequency of continuum extremum belonging to mode - model 4
16 real frequency model 1
17 imaginary frequency model 1
18 m_min used in model 1 run
19 m_max used in model 1 run
20 real frequency model 2
21 imaginary frequency model 2
22 m_min used in model 2 run
23 m_max used in model 2 run
24: IMAS only: time index itime
25: IMAS only: equilibrium_in%time(itime): absolute time
26: not used
27: not used
28  unstable mode? negative: mode damped, positive: mode unstable
29: direction of phase jump: positive correct, negative - possible problem with mode - check response file
30: distance to next gap
31: distance to previous gap
32: omega/omega_A0 of next gap
33: omega/omega_A0 of previous gap

and so on in block of 4 for the next order gaps
```

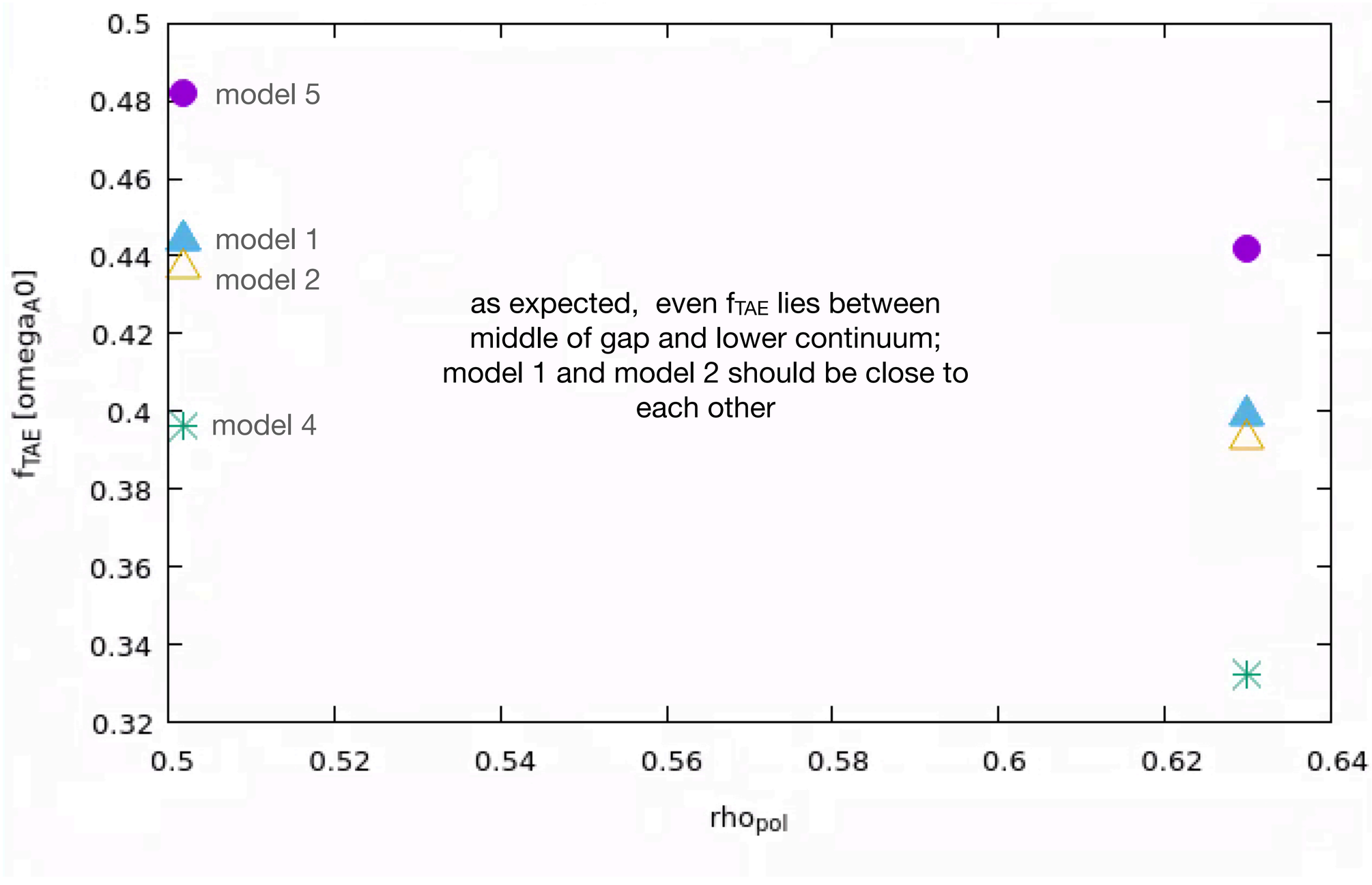
should be filled now in **glo_TAE_mode2_00208000**

use favourite plotting tool, or python script: (to be added)
e.g. gnuplot

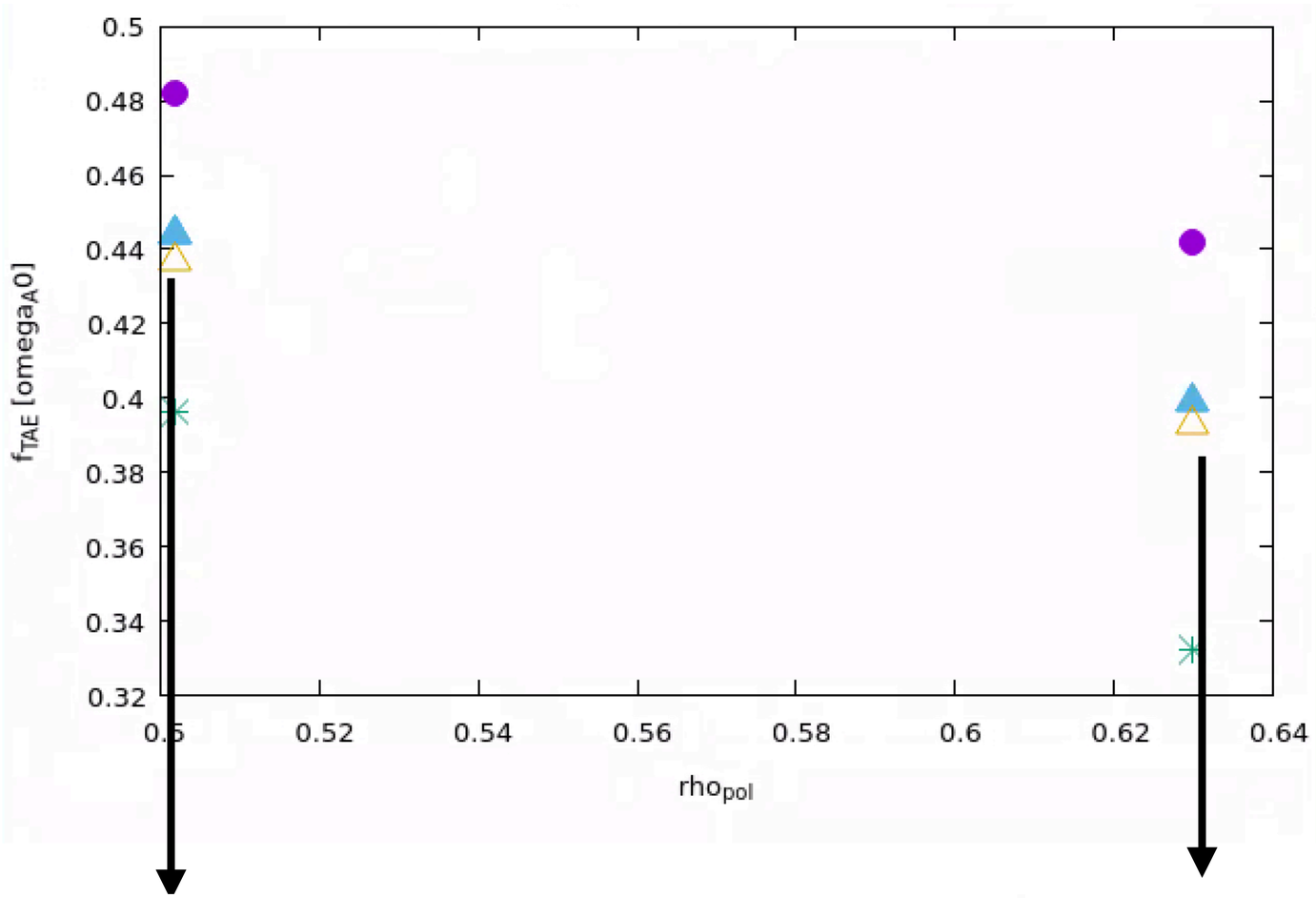
plot 'loc_TAE_mode5_00208000' u 1:5

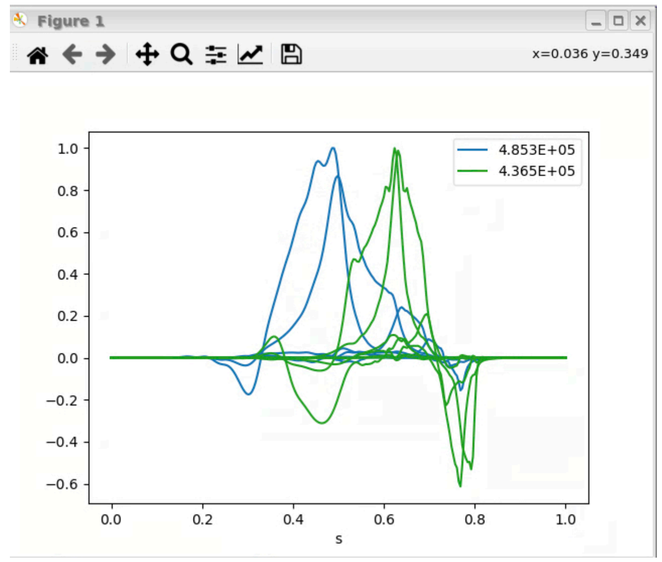
try different n and m ranges…

gnuplot

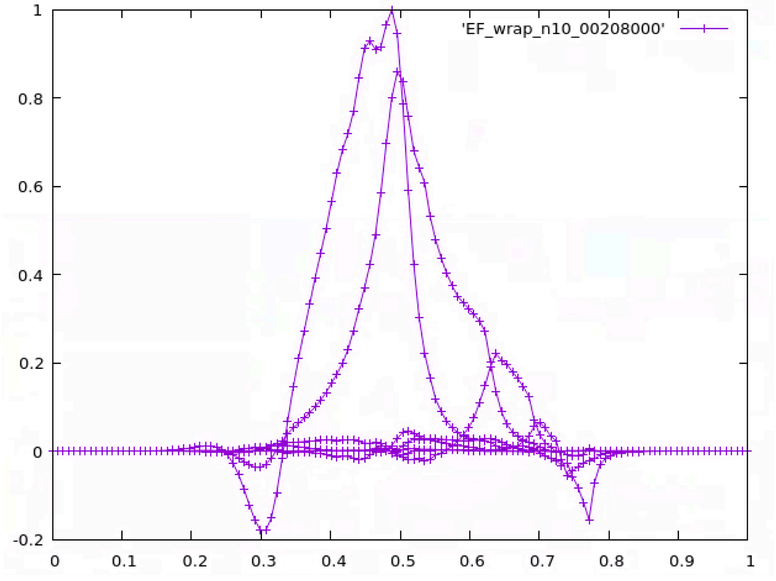


plot 'loc_TAE_mode4_00208000' u 1:5 ps 2 pt 7, 'loc_TAE_mode4_00208000' u 1:14 ps 2 pt 3, ‘glo_TAE_mode1_00208000’ u 1:16 ps 3 pt 9, ‘glo_TAE_mode2_00208000’ u 1:20 ps 3 pt 8

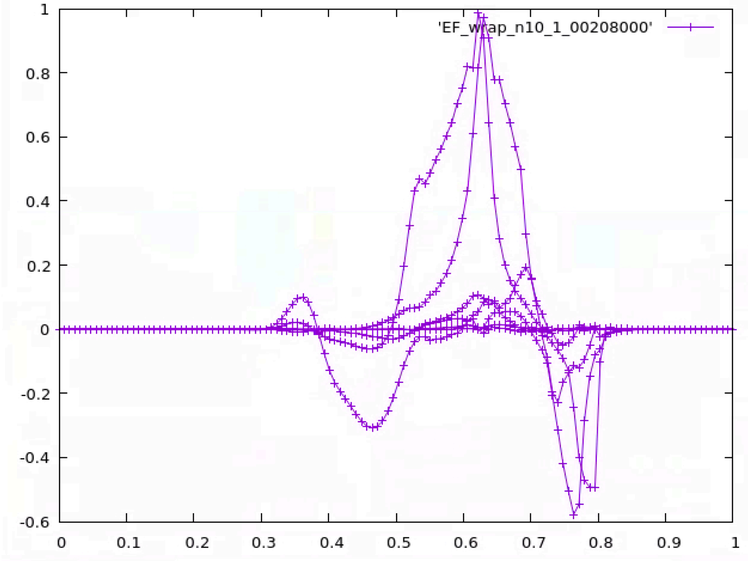




or use python script:
plot_EF.py ./EF_wrap_n10*



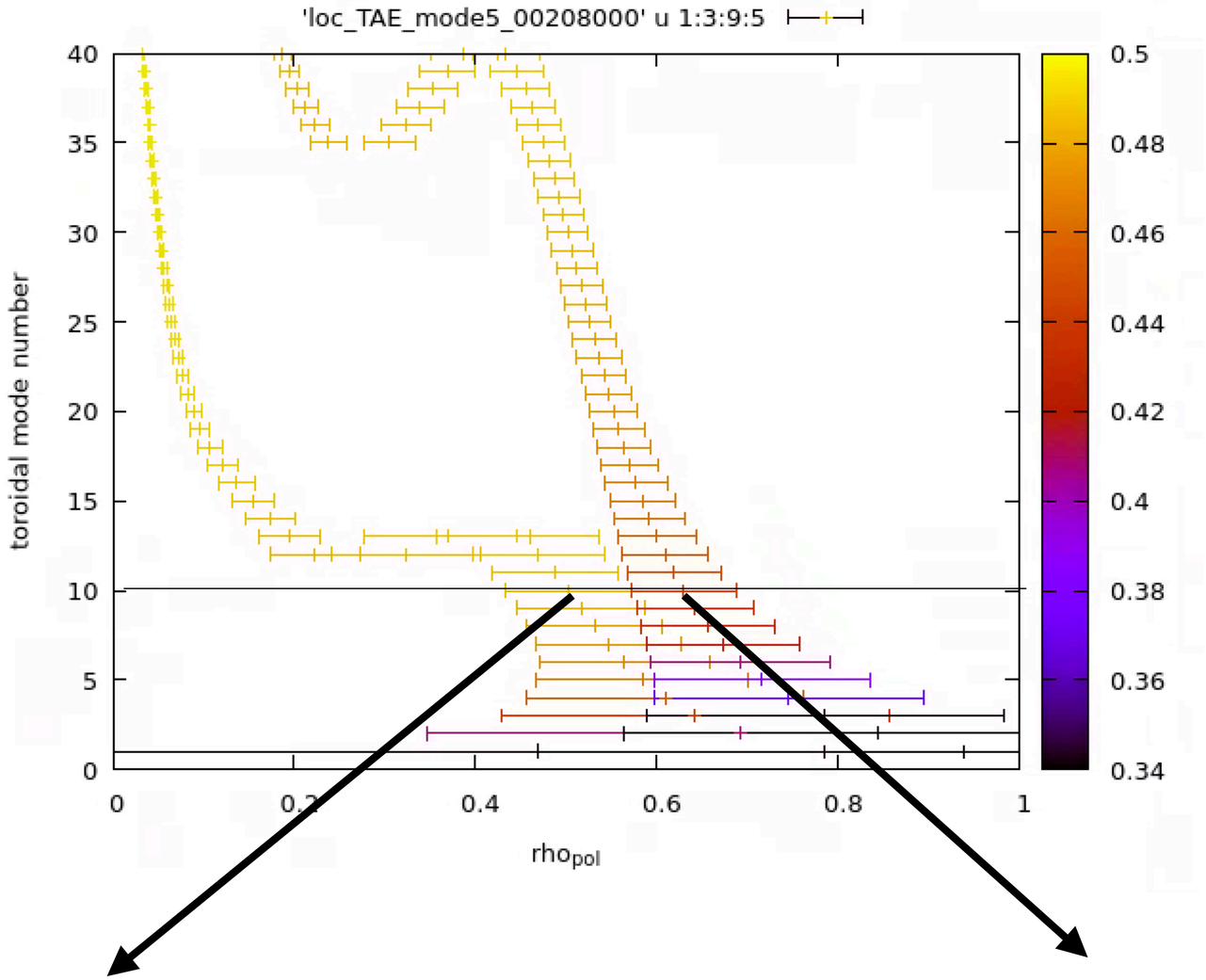
plot 'EF_wrap_n10_00208000' w lp

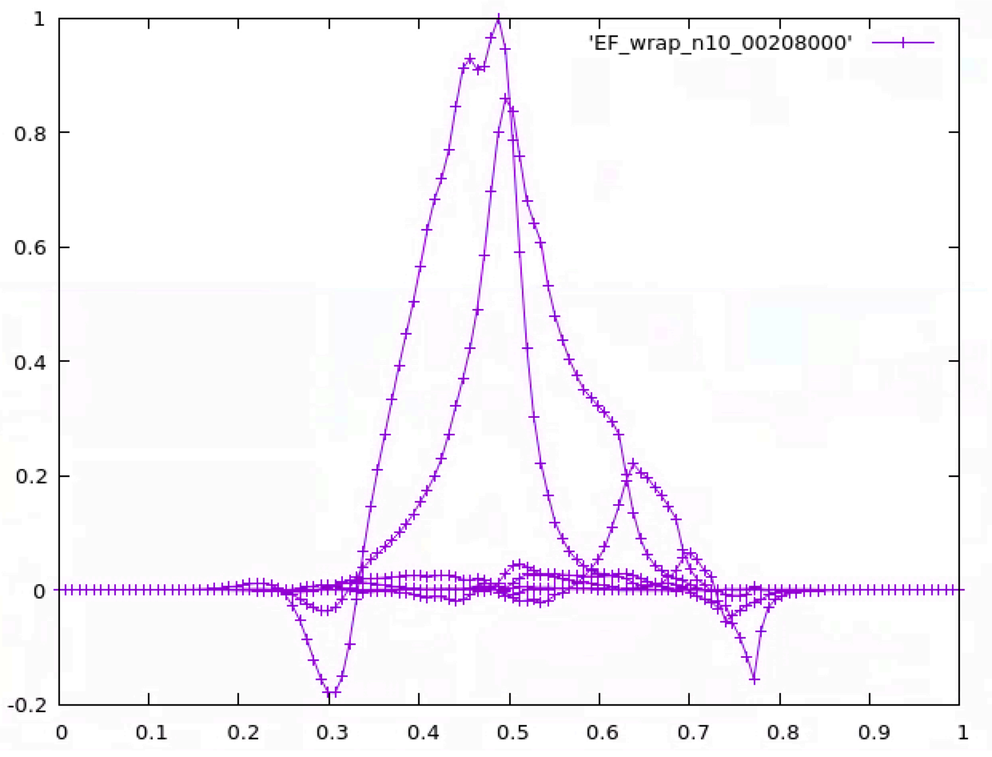


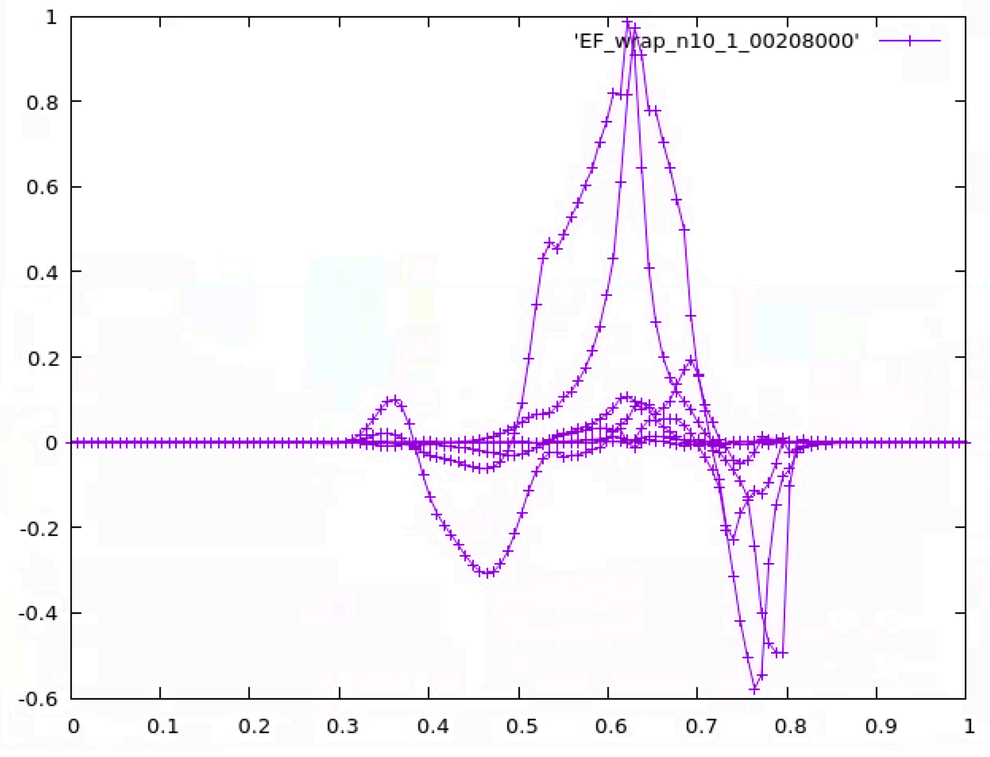
plot 'EF_wrap_n10_1_00208000' w lp

usage: plot_EF_ids.py [-h] [-user USER] [-database DATABASE] [-backend BACKEND] [-version VERSION] [-shot SHOT] [-run RUN]
[-itimes [ITIMES [ITIMES ...]]] [-times [TIMES [TIMES ...]]] [-ntor [NTOR [NTOR ...]]]
[-mpol [MPOL [MPOL ...]]] [-imode [IMODE [IMODE ...]]] [-occurrence OCCURRENCE]
[-plot_per_mode PLOT_PER_MODE] [-plot_per_time PLOT_PER_TIME] [-interactivePlots INTERACTIVEPLOTS]

plot_EF_ids.py -database training -shot 131025 -run 1 -user lauberp


'loc_TAE_mode5_00208000' u 1:3:9:5
toroidal mode number
rho_pol
0
5
10
15
20
25
30
35
40
0
0.2
0.4
0.6
0.8
1
0.5
0.48
0.46
0.44
0.42
0.4
0.38
0.36
0.34


'EF_wrap_n10_00208000'
1
0.8
0.6
0.4
0.2
0
-0.2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


'EF_wrap_n10_1_00208000'
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Saved Ligka_m2 mhd_linear under occurrence 6

idsdump lauberp training 3 131025 1 mhd_linear/6 > mhd_occ_6

plot_EF_ids.py -user=lauberp -database=training -shot=131025 -run=1 -times 1 -occurrence=6 -interactivePlots=1

usage: plot_EF_ids.py [-h] [-user USER] [-database DATABASE] [-backend BACKEND] [-version VERSION] [-shot SHOT] [-run RUN]
[-itimes [ITIMES [ITIMES ...]]] [-times [TIMES [TIMES ...]]] [-ntor [NTOR [NTOR ...]]]
[-mpol [MPOL [MPOL ...]]] [-imode [IMODE [IMODE ...]]] [-occurrence OCCURRENCE]
[-plot_per_mode PLOT_PER_MODE] [-plot_per_time PLOT_PER_TIME] [-interactivePlots INTERACTIVEPLOTS]

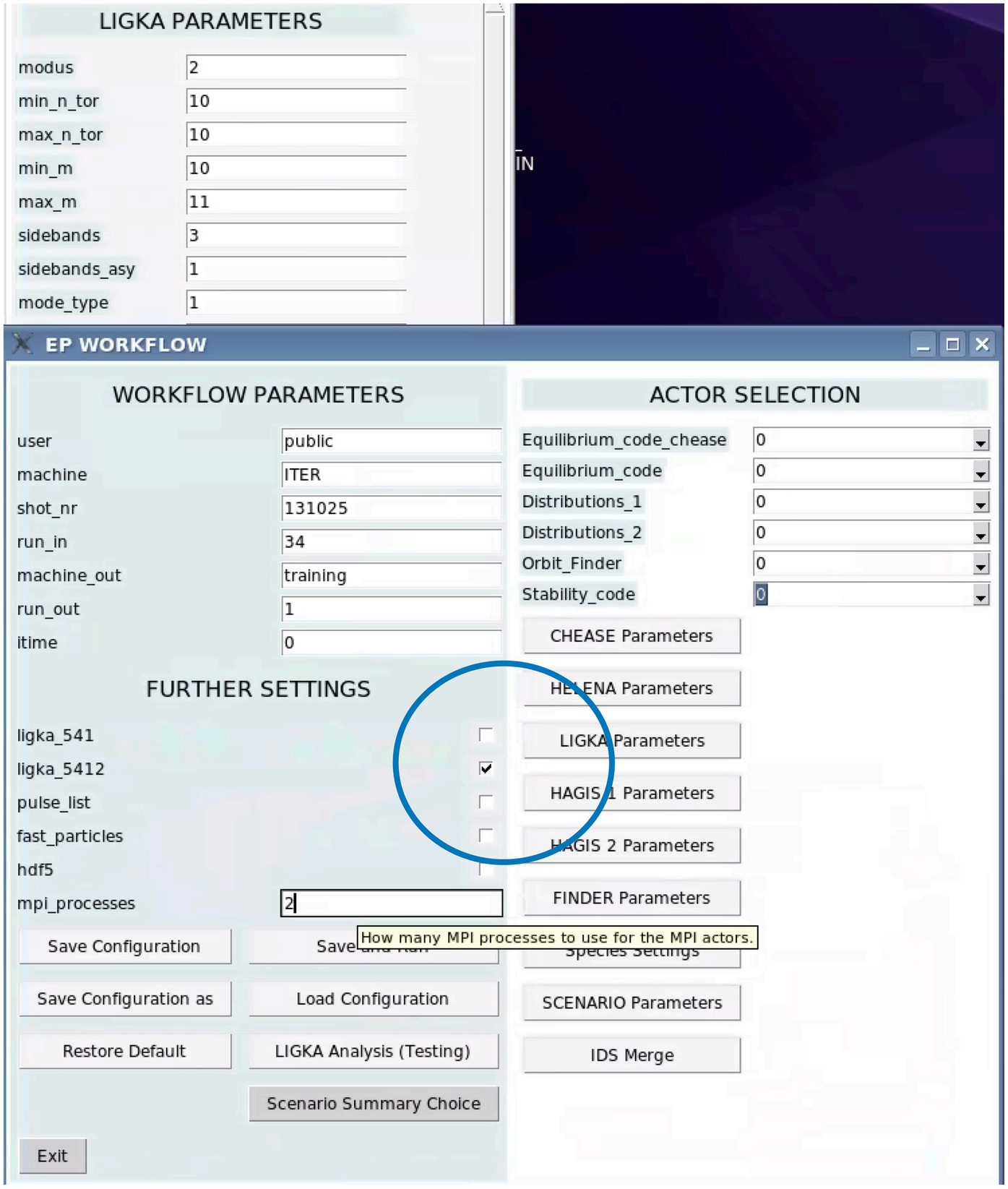
or: ASCII files in run-directory:

structure EF_wrap files:
number of radial points, number of pol. harmonics
Imag (omega [1/s]), Re (omega [rad/s]), Imag (omega/omega_A0), Re (omega/omega_A0)
range of pol. harmonics

col 1: s=sqrt(norm_pol_flux)
col 2: Re[e.s. potential]
col 3: Im[e.s. potential]
col 4: Re[e.s. potential]/ds
col 5: Im[e.s. potential]/ds
col 6: Re[e.s. potential]dds
col 7: Im[e.s. potential]/dds

col 8: Re[e.m. potential]
col 9: Im[e.m. potential]
col 10: Re[e.m. potential]/ds
col 11: Im[e.m. potential]/ds
col 12: Re[e.m. potential]/dds
col 13: Im[e.m. potential]/dds

- model sequence 5-4-1-2 is the standard WF;
- tick to run all steps in sequence
- runtime with 2 procs, two modes: 4.5 mins;
- i.e.: 7 pol harmonics on 2 proc -> 2.2 mins per mode
- model 5,4: only 10s
- for higher equilibrium resolution: run helena with larger nrmap, npmap: 128/256/384 (512 presently not allowed)
- note that 'ligka_5412' button overrules 'modus' and 'Stability_code' selection
- note that Stability_code' selection button 'overrules' 'modus' in LIGKA menu



run without gui:

ep_nogui -c ./<name of configuration directory>

edit xml files by hand -> same structures, since gui is generated from xml files

please use batch nodes for submitting larger jobs!

export SBATCH_TIMELIMIT=00:30:00 **(in case you want to use the 30 mins debug queue)**

ep_batch -n 8 -t 1 -e my@email.org -q gen10_debug -c <dir with xml files>/

use *gen10_ib* for production jobs!

gateway: **ep_batch -n 4 -t 1 -e email@aa.bb -q gw -c /<profile>**

wrap up:

1. use CHEASE + HELENA +model5 : narrow down to the set of ‘interesting/revelant’ modes

2. press 5/4/1/2 on reduced set of modes; set a sensible range of sidebands

remember:

if you reprocess the equilibrium (HELENA,CHEASE selected), all LIGKA results in mhd_linear will be deleted
(not to create inconsistencies between equilibrium and linear analysis). Please re-run, starting from model 5!
or tick 5/4/1/2

Two different kinds of setting-up runs:

- gui
- edit xml files

Two different kinds of looking at results:

- plot data mhd_linear IDS
- use ASCII output in local folder or ~/
- idsdump as last resort to check output

definition of TAE range: suggested exercise: look at the model 5 results of:

<min_n_tor>10</min_n_tor> <max_n_tor>10</max_n_tor> <min_m>10</min_m> <max_m>10</max_m>	<min_n_tor>10</min_n_tor> <max_n_tor>10</max_n_tor> <min_m>10</min_m> <max_m>11</max_m>	<min_n_tor>10</min_n_tor> <max_n_tor>11</max_n_tor> <min_m>10</min_m> <max_m>10</max_m>	<min_n_tor>10</min_n_tor> <max_n_tor>11</max_n_tor> <min_m>10</min_m> <max_m>11</max_m>
1 mode: (10,10)	2 modes: (10,10); (10,11)	2 modes: (10,10) (11,11)	4 modes: (10,10); (10,11) (11,11); (11,12)

issues to be fixed:

- itime to start at 1 (not 0)
- fix printout of (wrong) shot number in LIGKA output

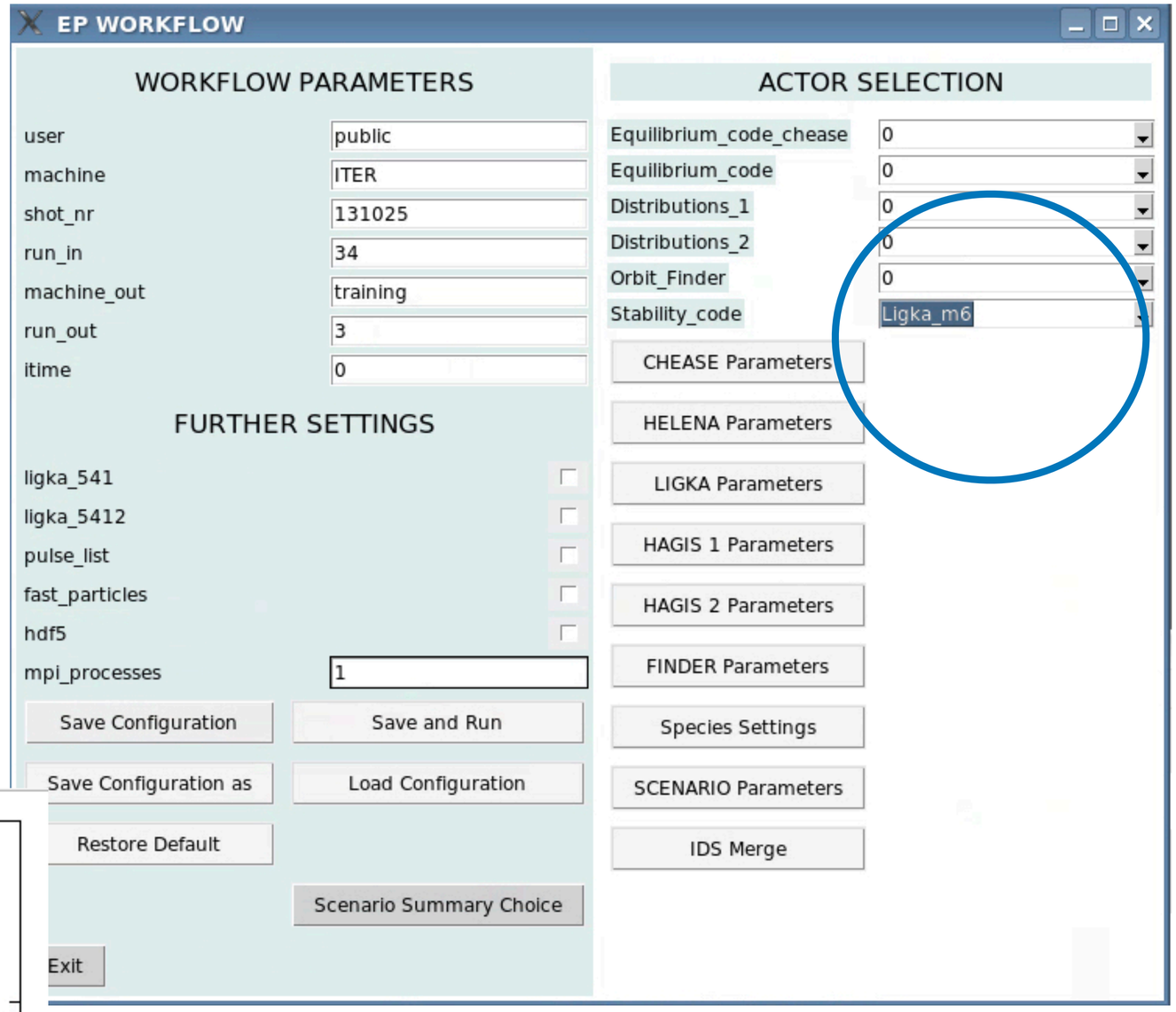
reduced mhd/ kinetic spectra:

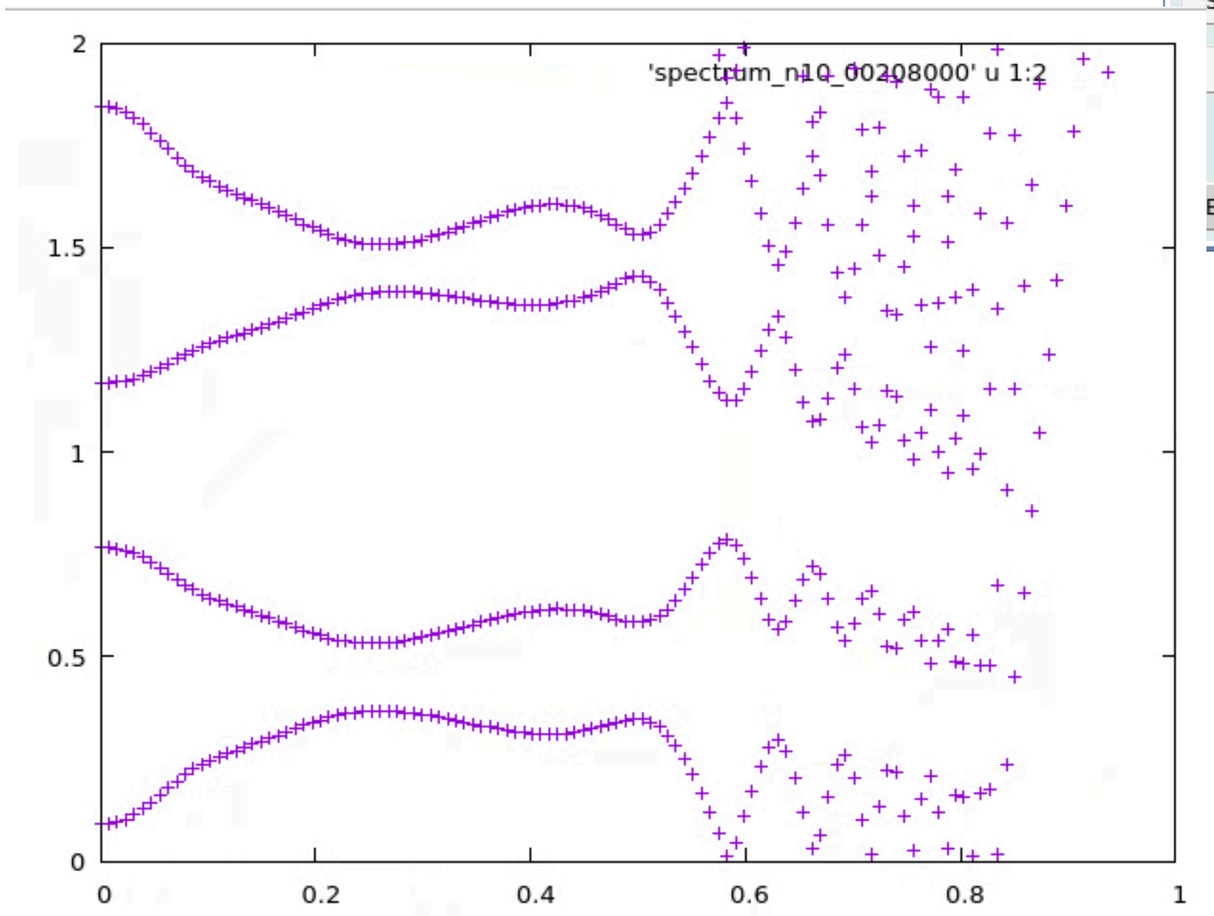
model 6 performs a local matrix inversion in the MHD limit
for each mode found with model 5;
modes with the same toroidal mode number a skipped

Saved Ligka_m6 mhd_linear under occurrence 5

ASCII:
spectrum_n10_<time_str>

col 1: s=sqrt(norm_pol_flux)
col 2: omega/omega_A0
col 4: f[kHz]
col 8: s=sqrt(norm_tor_flux)





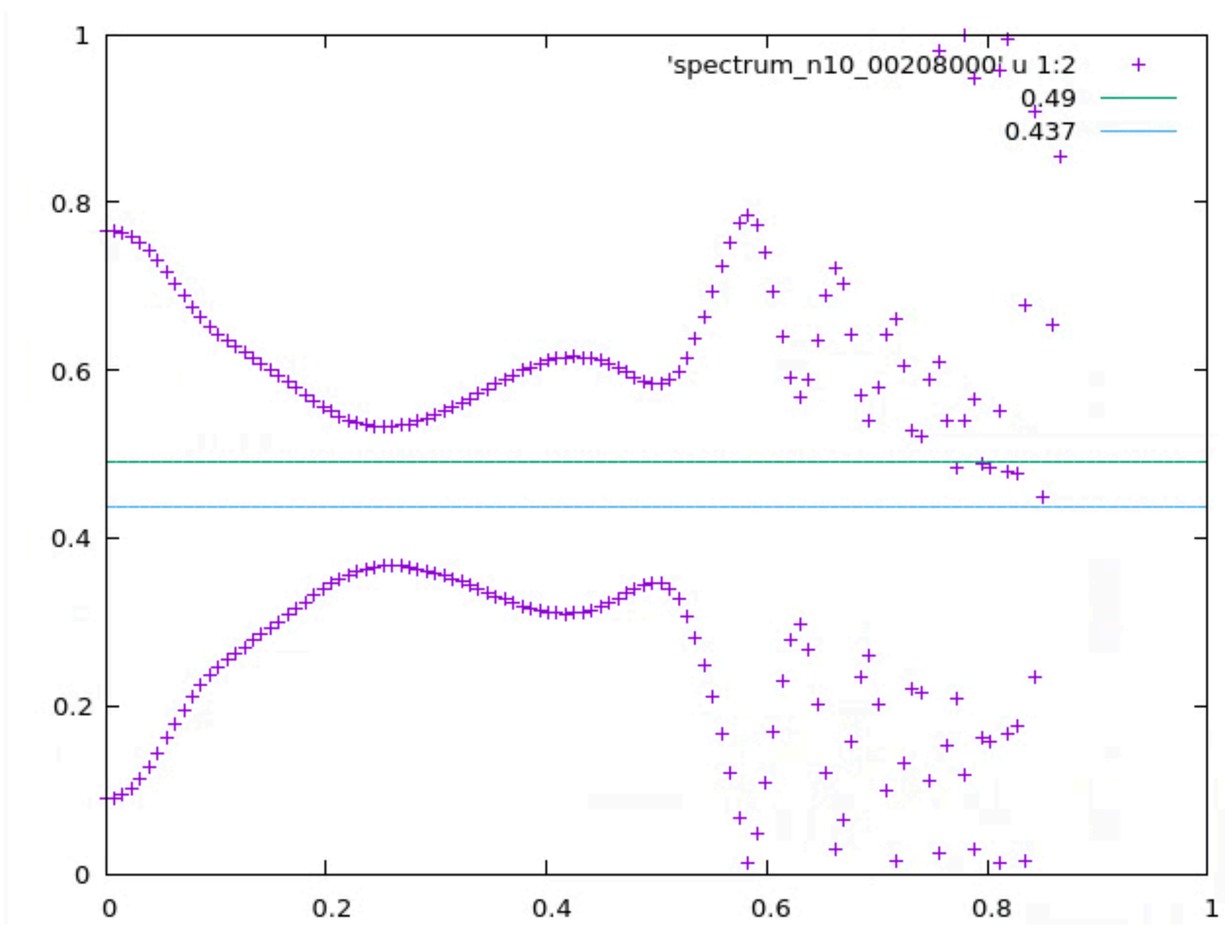
reduced mhd/ kinetic spectra:

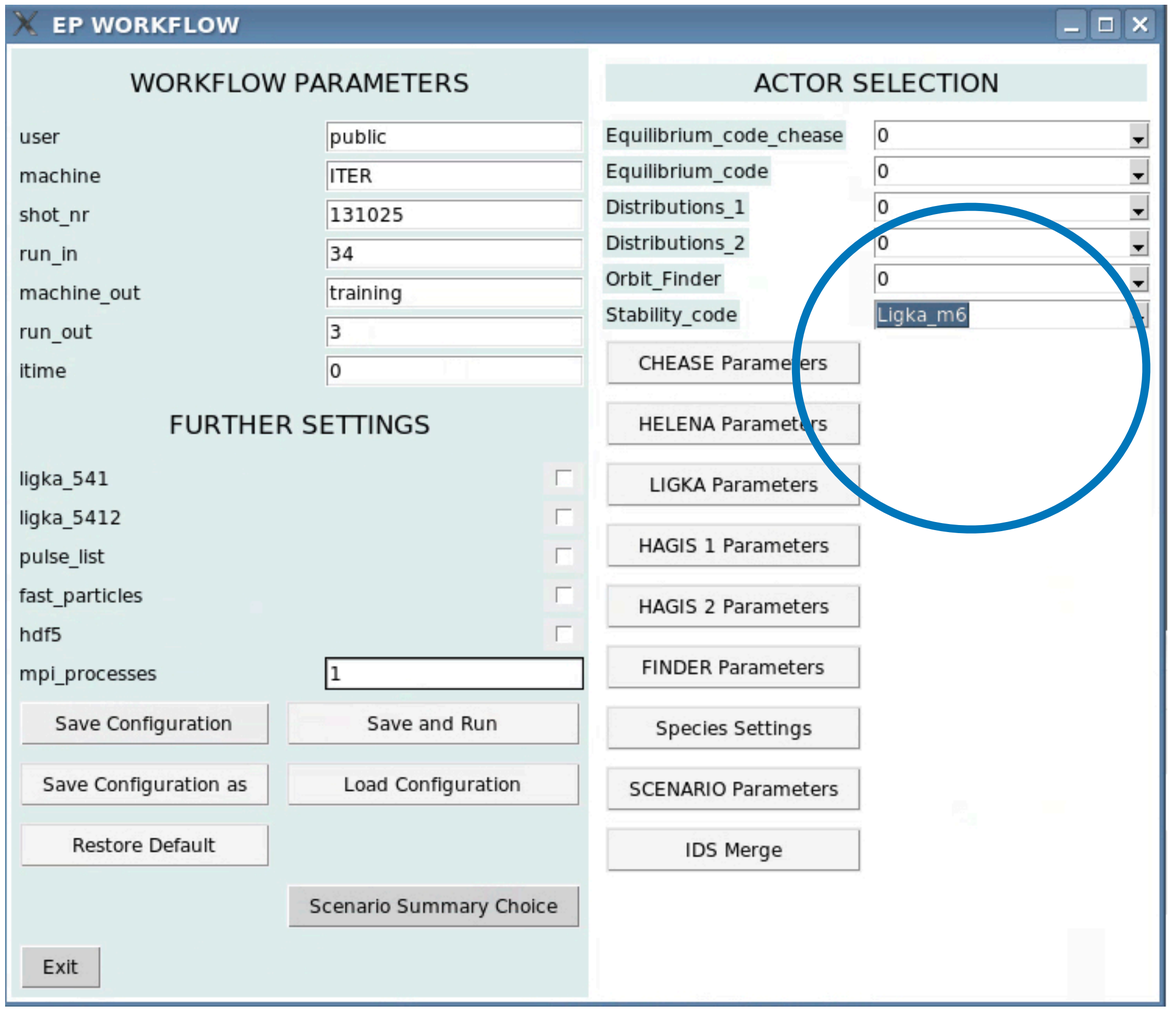
model 6 performs a local metric inversion in the MHD limit for each mode found with model 5;
modes with the same toroidal mode number a skipped

Saved Ligka_m6 mhd_linear under occurrence 5

ASCII:
spectrum_n10_<time_str>

col 1: s=sqrt(norm_pol_flux)
col 2: omega/omega_A0
col 4: f[kHz]
col 8: s=sqrt(norm_tor_flux)





Why are these even TAEs not in the lower part of the gap?

pressure upshift & diamagnetic effects missing in reduced MHD model!

kinetic spectrum: model 3

model 3 performs a local kinetic solve for each mode found with model 5;
modes with the same toroidal mode number a skipped
default values: start at omega=(1.0,-0.04) to (0.0,0.01) omega_A0
radius of integration circle: 0.02

manual settings:
<guess_start>0.7</guess_start> start of Re (guess)
<guess_end>0.1</guess_end> end of Re(guess)
<offset_d>0.02</offset_d> offset ± Im(guess)
<d_guess>0.001</d_guess> radius of integration circle

Saved Ligka_m3 mhd_linear under occurrence 7

if run in parallel mode:

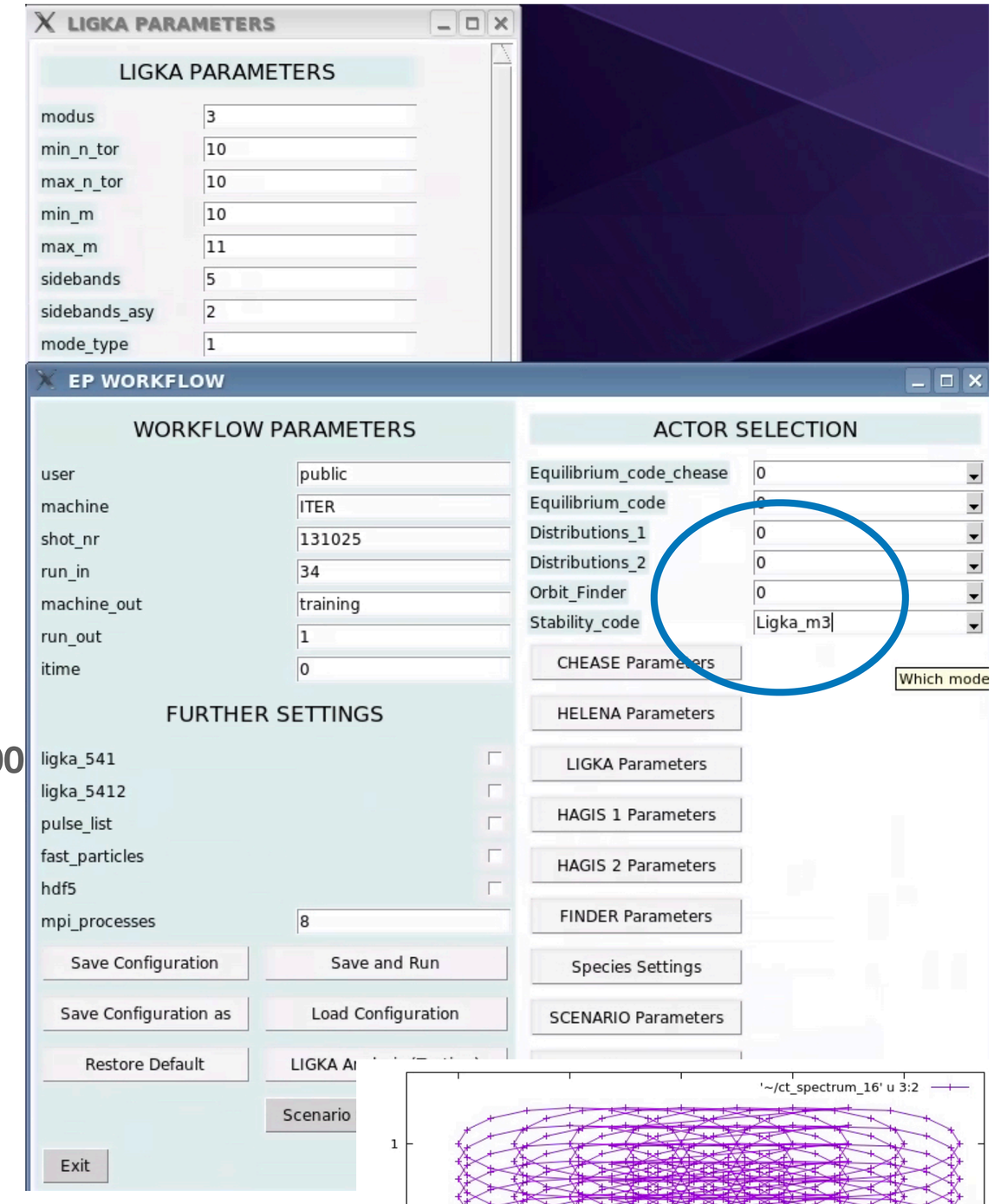
cat spectrum_kin_n10_00208000_1* > kin_spectrum_n10_00208000

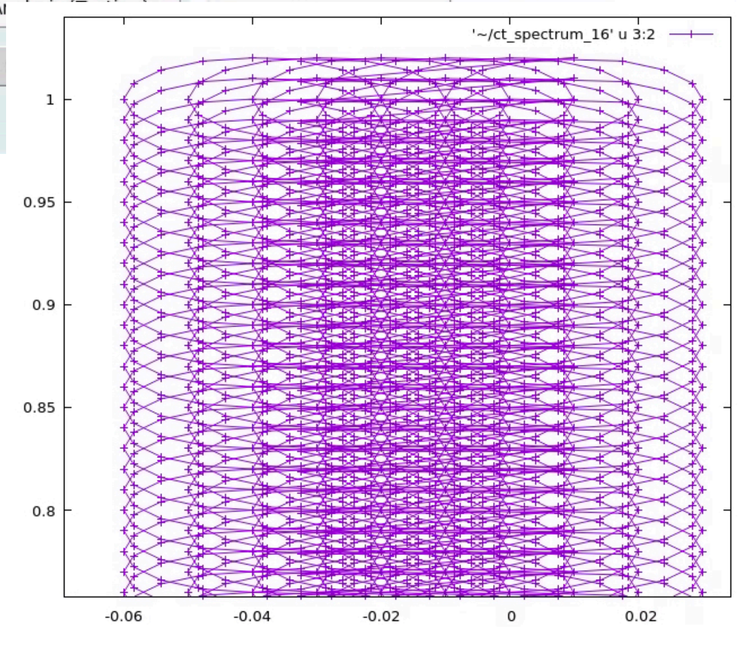
Note: due to asynchronous nature of result on different processors, the IDS is not yet filled - will soon provide script to do this after the run

ASCII:
kin_spectrum_n10_<time_str>

col 1: s=sqrt(norm_pol_flux)
col 2: Re(omega)/omega_A0
col 3: Im(omega)/omega_A0

note: for MHD-type pressure coupling model, e.g. use FALCON, or CASTOR



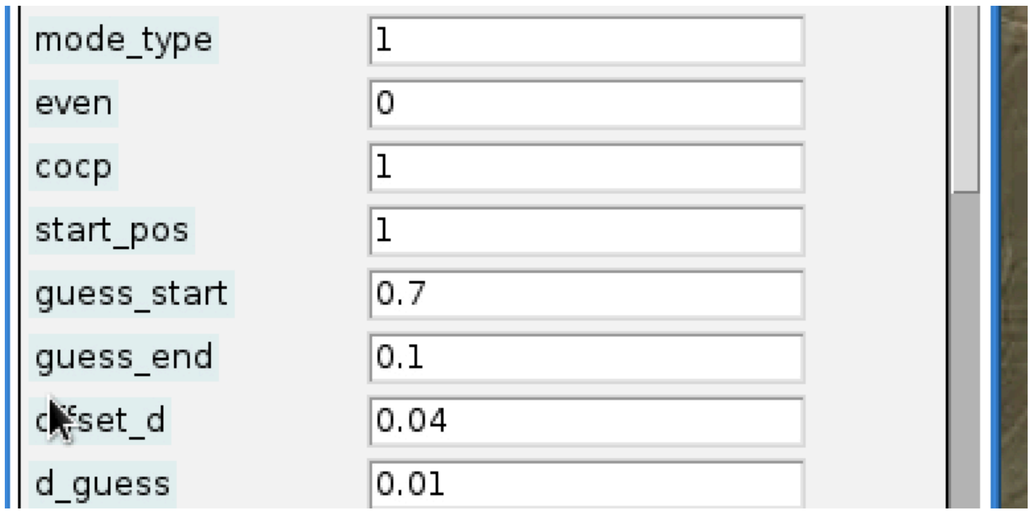


kinetic spectrum: model 3

model 3 performs a local kinetic solve for each mode found with model 5;
modes with the same toroidal mode number a skipped
default values: start at omega=(1.0,-0.04) to (0.0,0.01) omega_A0
radius of integration circle: 0.02

manual settings:
<guess_start>0.7</guess_start> start of Re (guess)
<guess_end>0.1</guess_end> end of Re(guess)
<offset_d>0.02</offset_d> offset ± Im(guess)
<d_guess>0.001</d_guess> radius of integration circle

Saved Ligka_m3 mhd_linear under occurrence 7



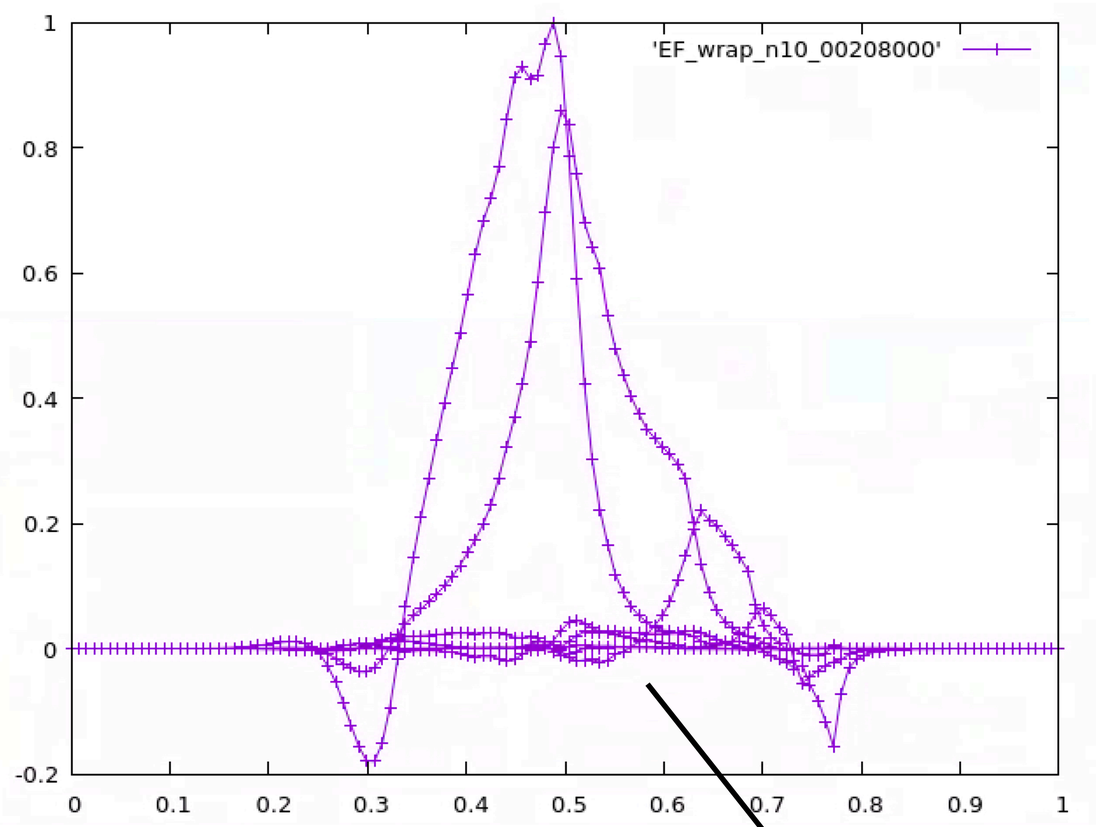
if run in parallel mode:

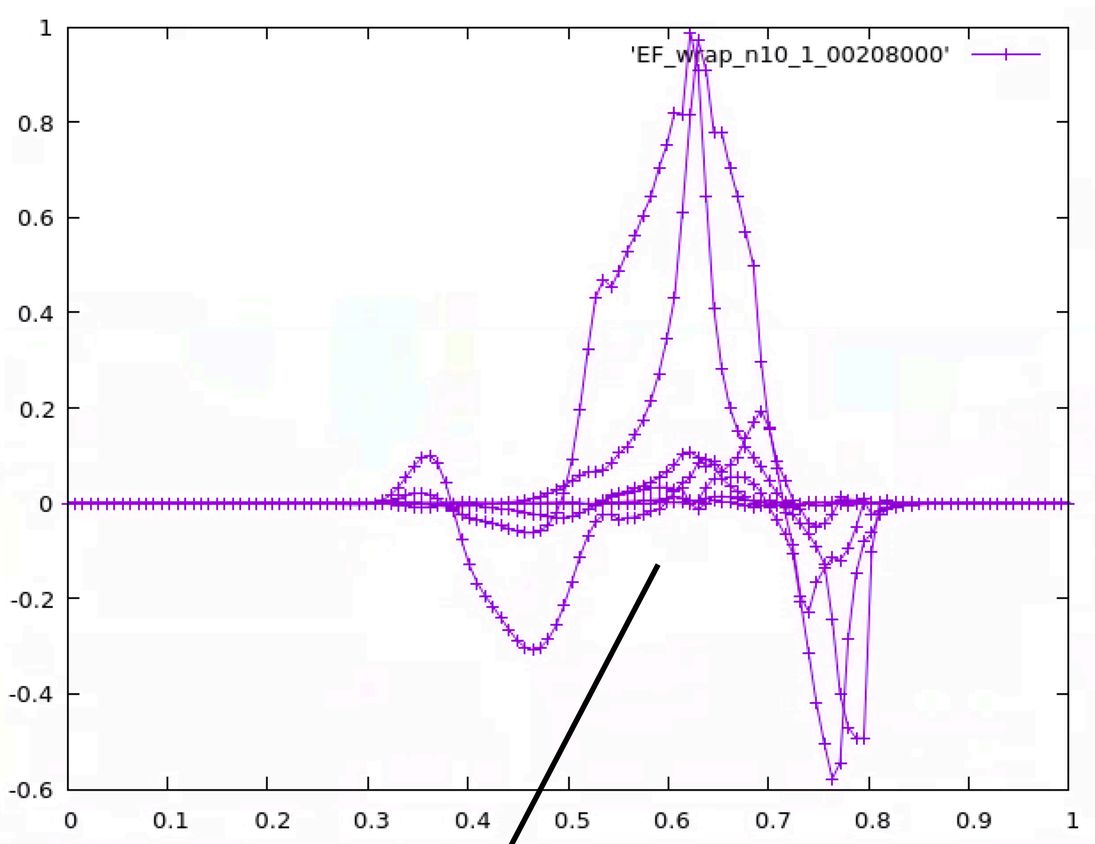
cat spectrum_kin_n10_00208000_1* > kin_spectrum_n10_00208000

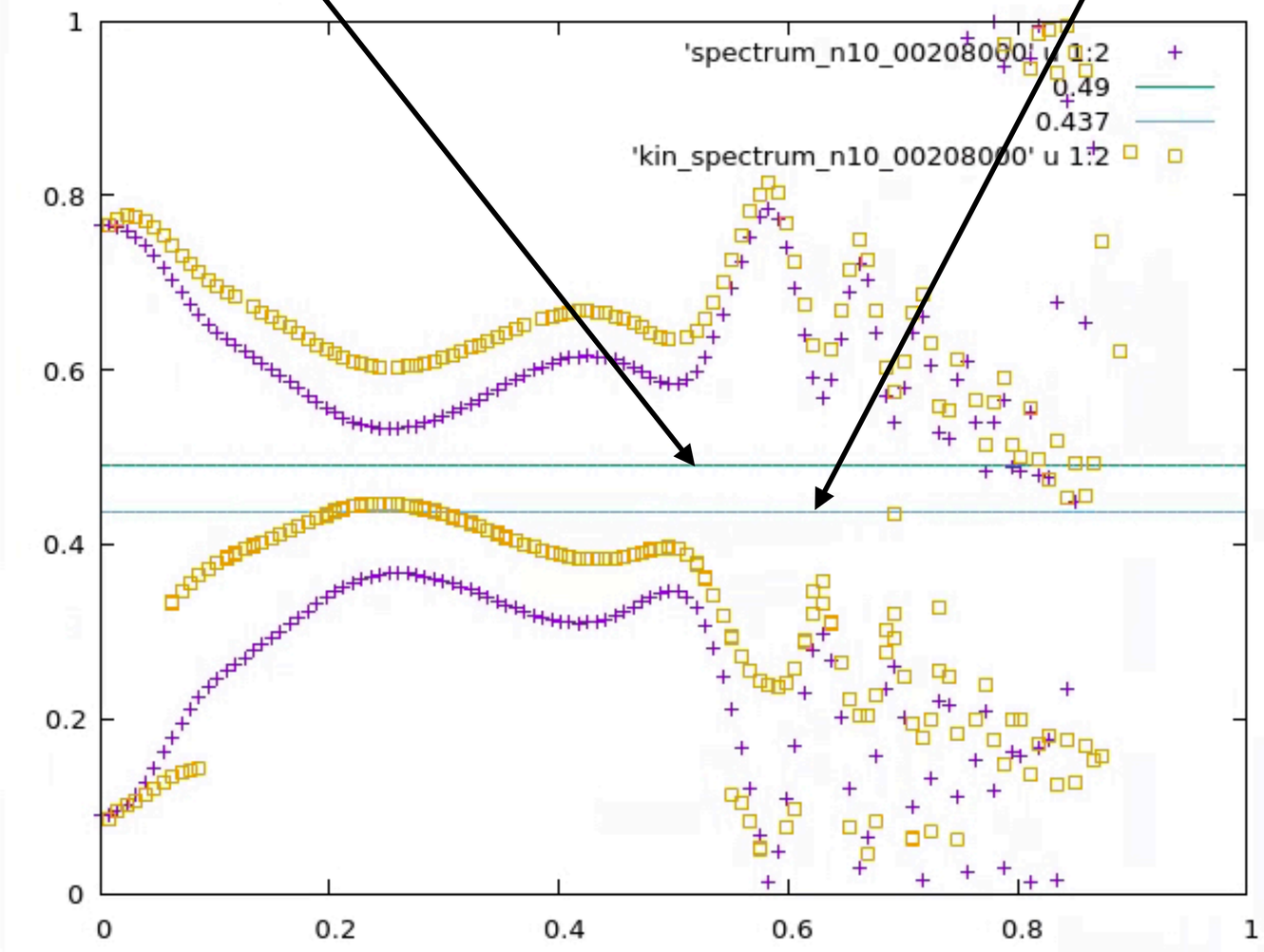
ASCII:

col 1: s=sqrt(norm_pol_flux)
col 2: Re(omega)/omega_A0
col 3: Im(omega)/omega_A0

note: for MHD-type pressure coupling model, e.g. use FALCON, or CASTOR

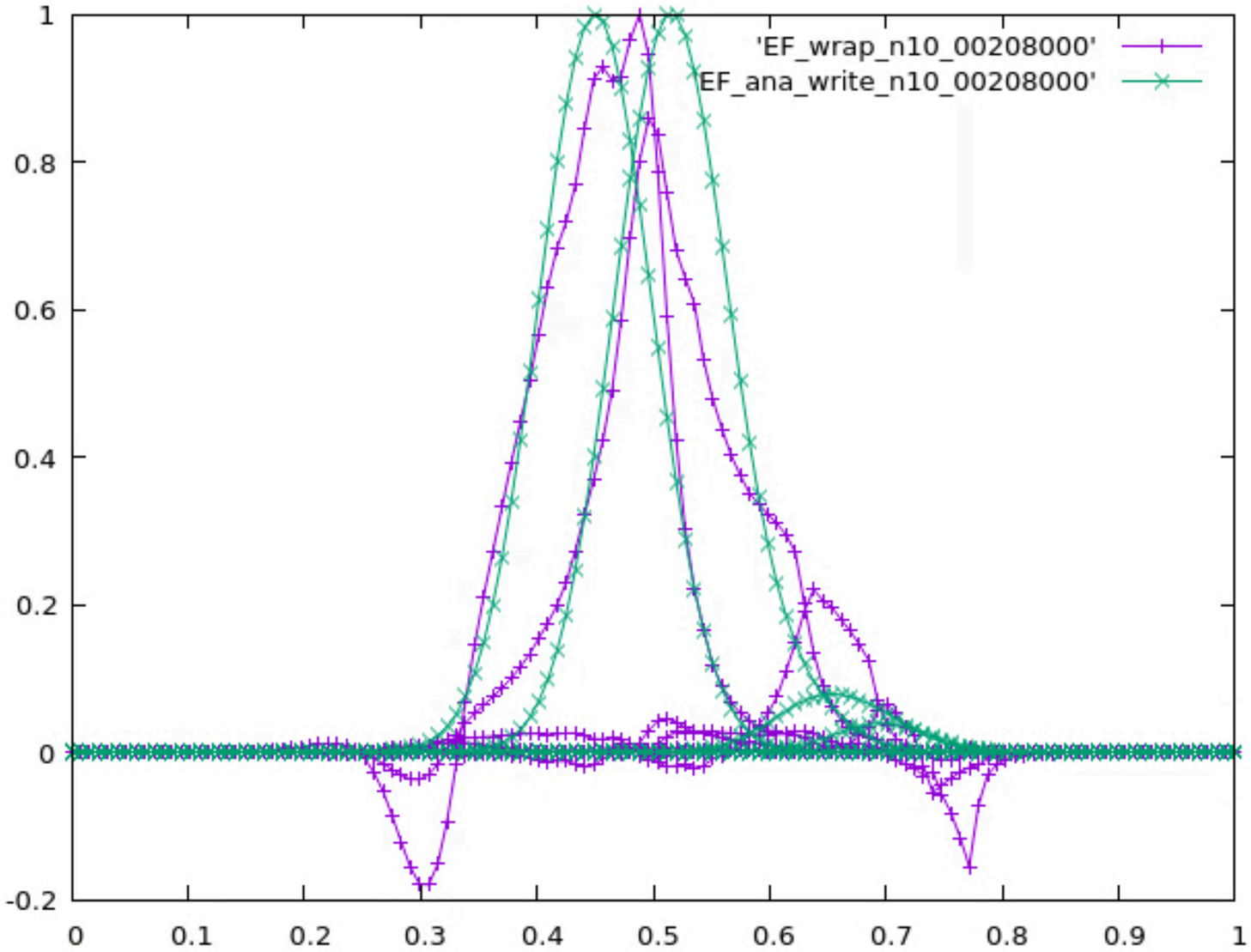

'EF_wrap_n10_00208000'


'EF_wrap_n10_1_00208000'


'spectrum_n10_00208000' u 1:2
0.49
0.437
'kin_spectrum_n10_00208000' u 1:2

Note: there is a fast, crude guess for mode structures available in mode 5 - also in IDS

plot 'EF_wrap_n10_00208000' w lp , 'EF_ana_write_n10_00208000' w lp



not too bad!

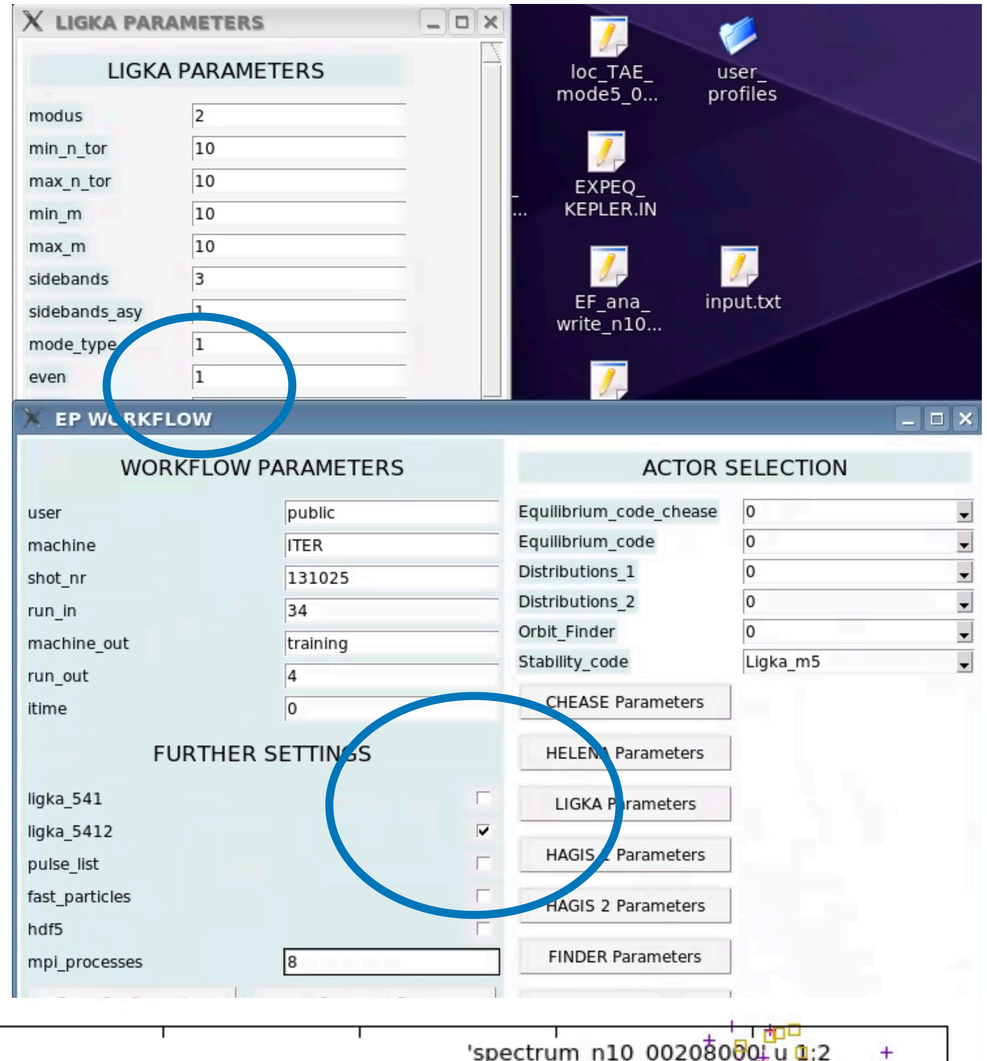
presently improved using various methods [V.-A. Popa]

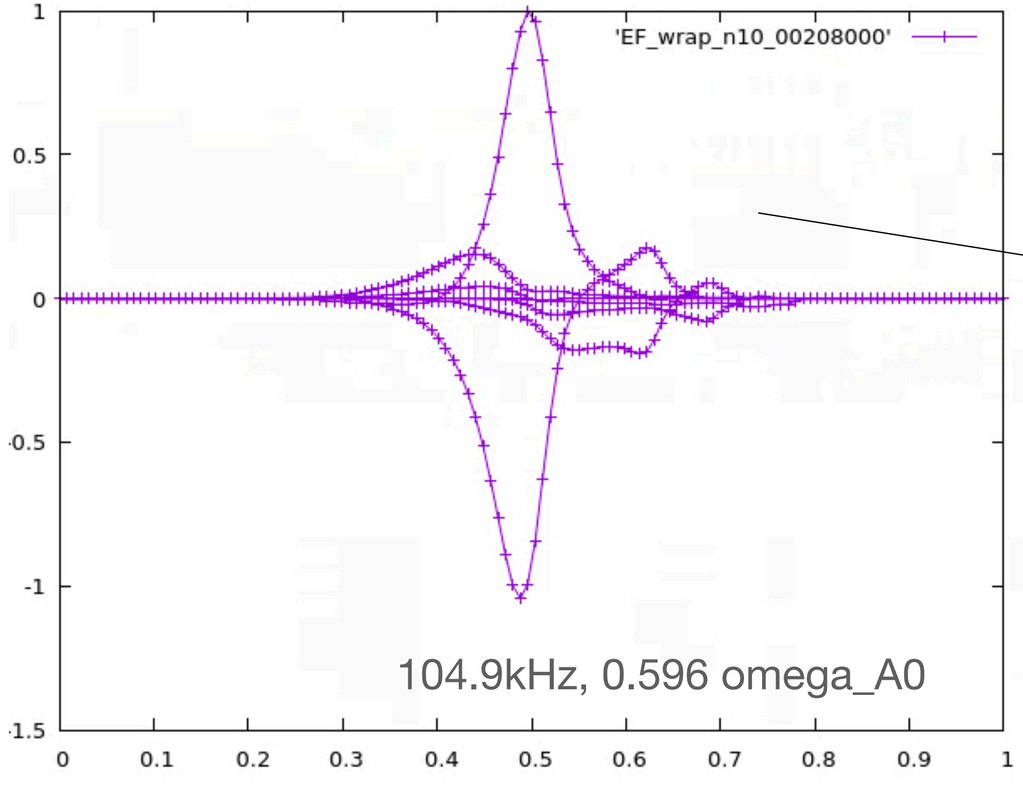
other types of modes: odd TAEs

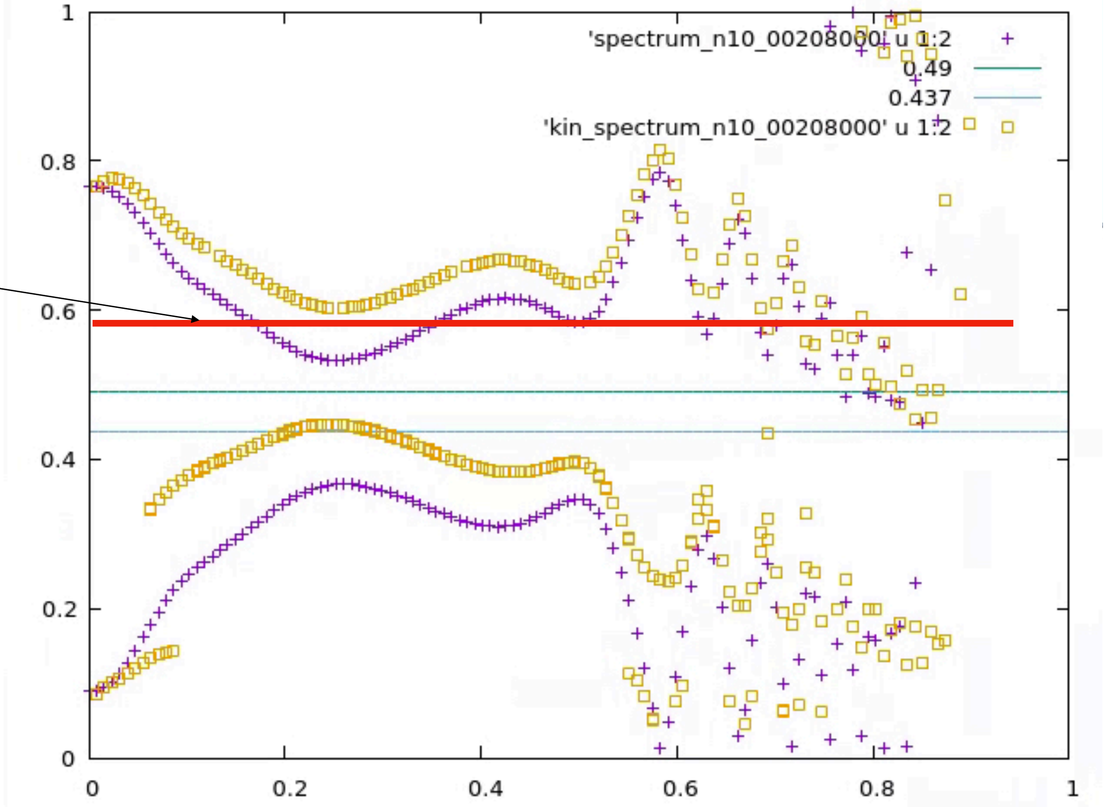
please change directory and output IDS!
files will be overwritten!
also clear/move files in home-directory!

even: 0 (even TAE, EAE)
even: 1 (odd TAE, EAE)
even: 2 (both odd and even)

- note that ‘ligka_5412’ button overrules ‘modus’ and ‘Stability_code’ selection
- note that Stability_code’ selection button ‘overrules’ ‘modus’ in LIGKA menu







co and counter propagating modes:

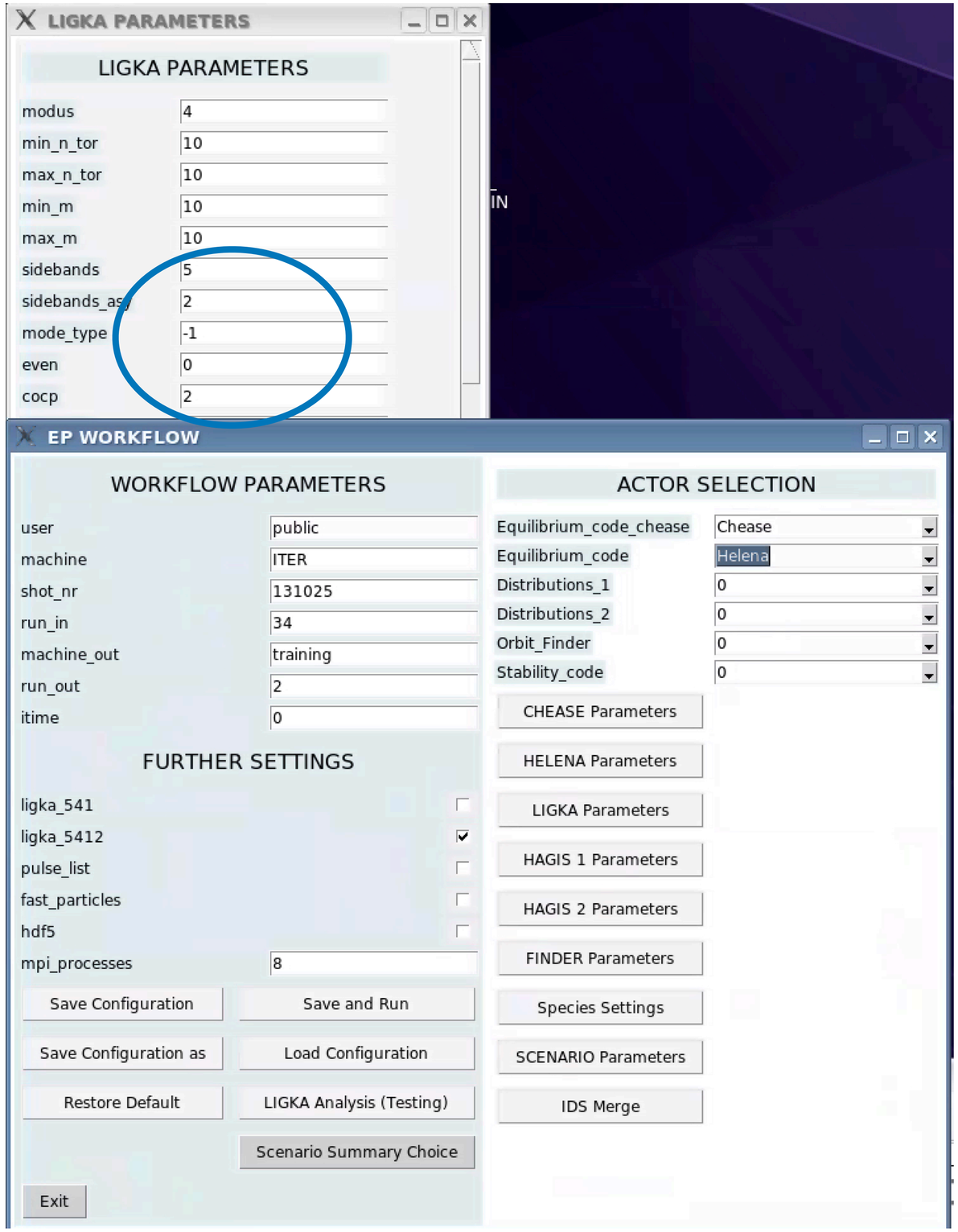
in LIGKA, co-propagation is defined as ion diamagnetic direction
(=driven/damped by typical negative gradient of ions)
counter-propagation as electrons as diamagnetic direction
(=driven by off-axis heating schemes)

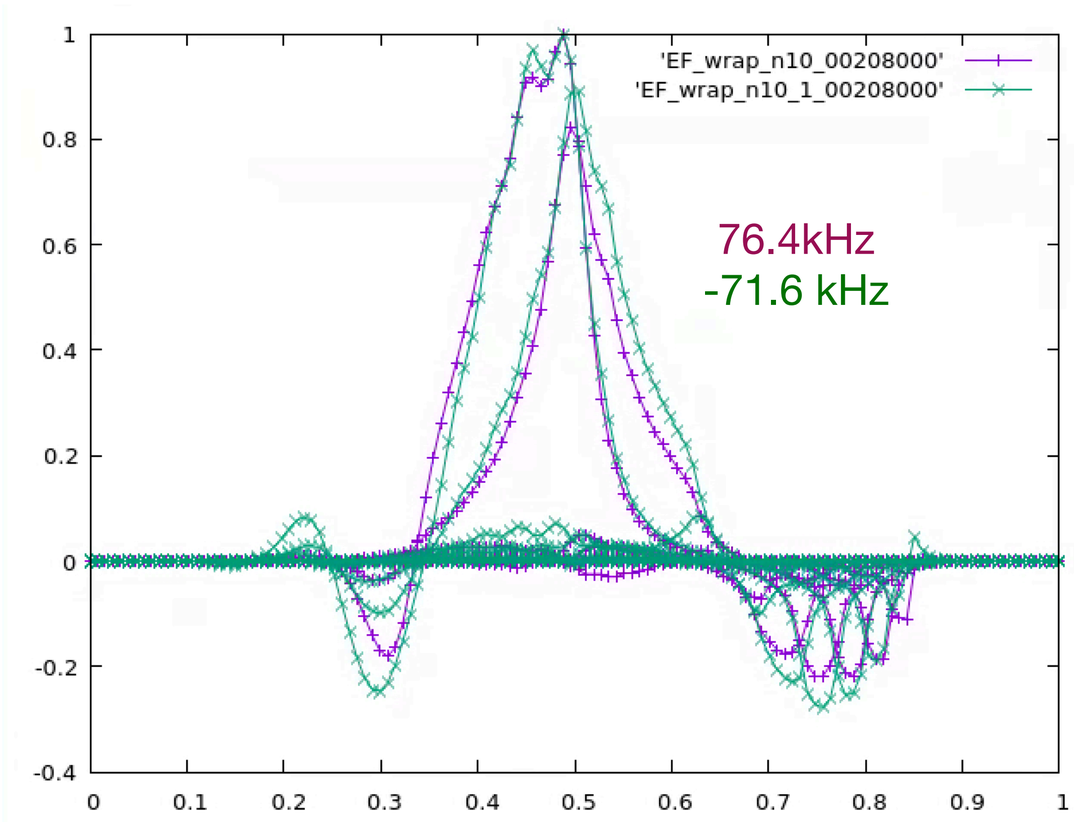
settings in LIGKA:

mode_type: 1 (co-propagating TAE)
mode_type: -1 (counter-propagating TAE)

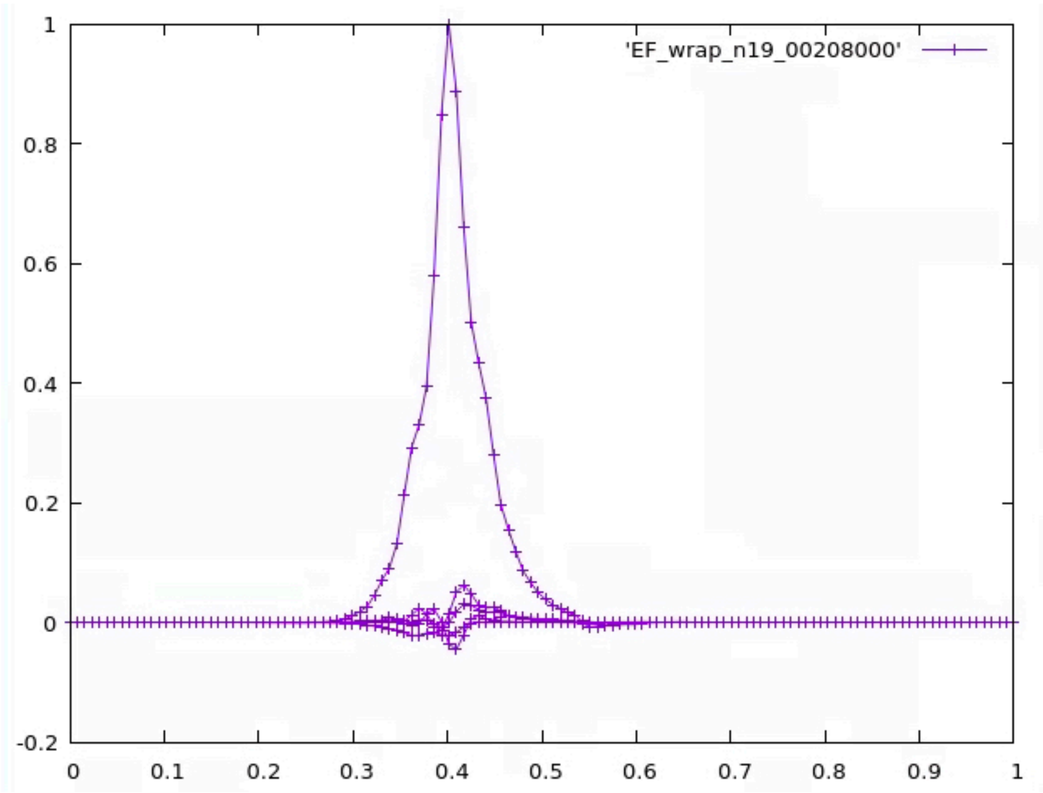
cocp: 1 (calculate only only one type of mode, as set in mode_type)
cocp: 2 (calculate both co/cp propagating modes)
default: 1

mode frequencies are positive for co-propagating modes
mode frequencies are negative for counter-propagating modes

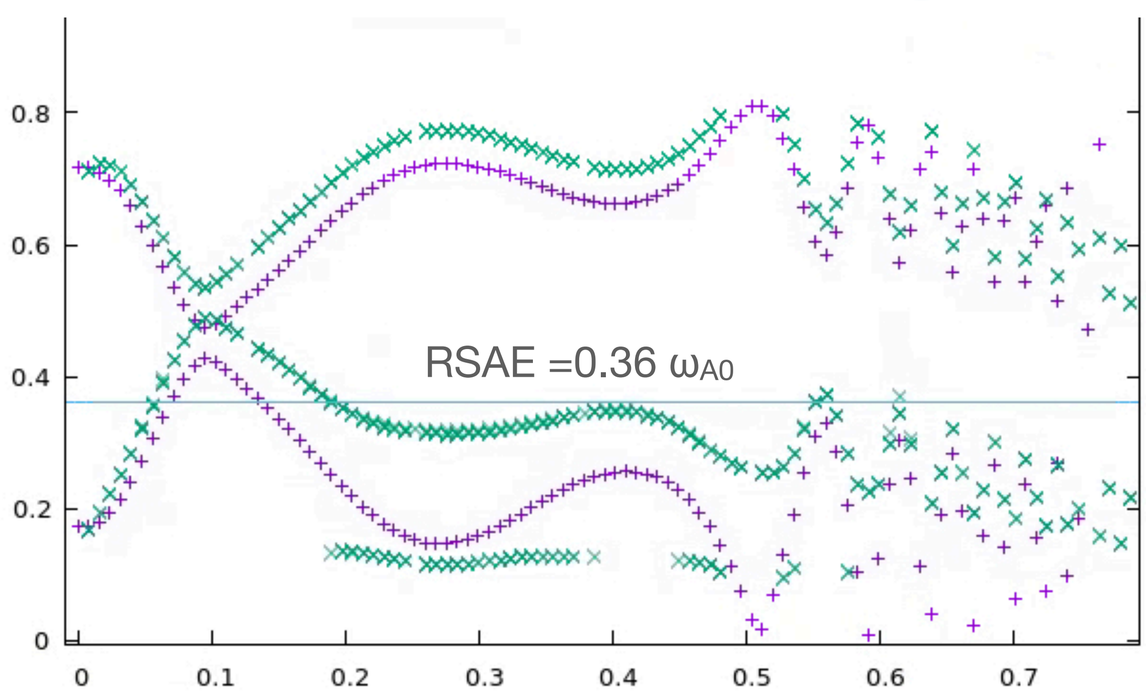




min_n_tor	19
max_n_tor	19
min_m	20
max_m	20
sidebands	5
sidebands_asy	1
mode_type	2

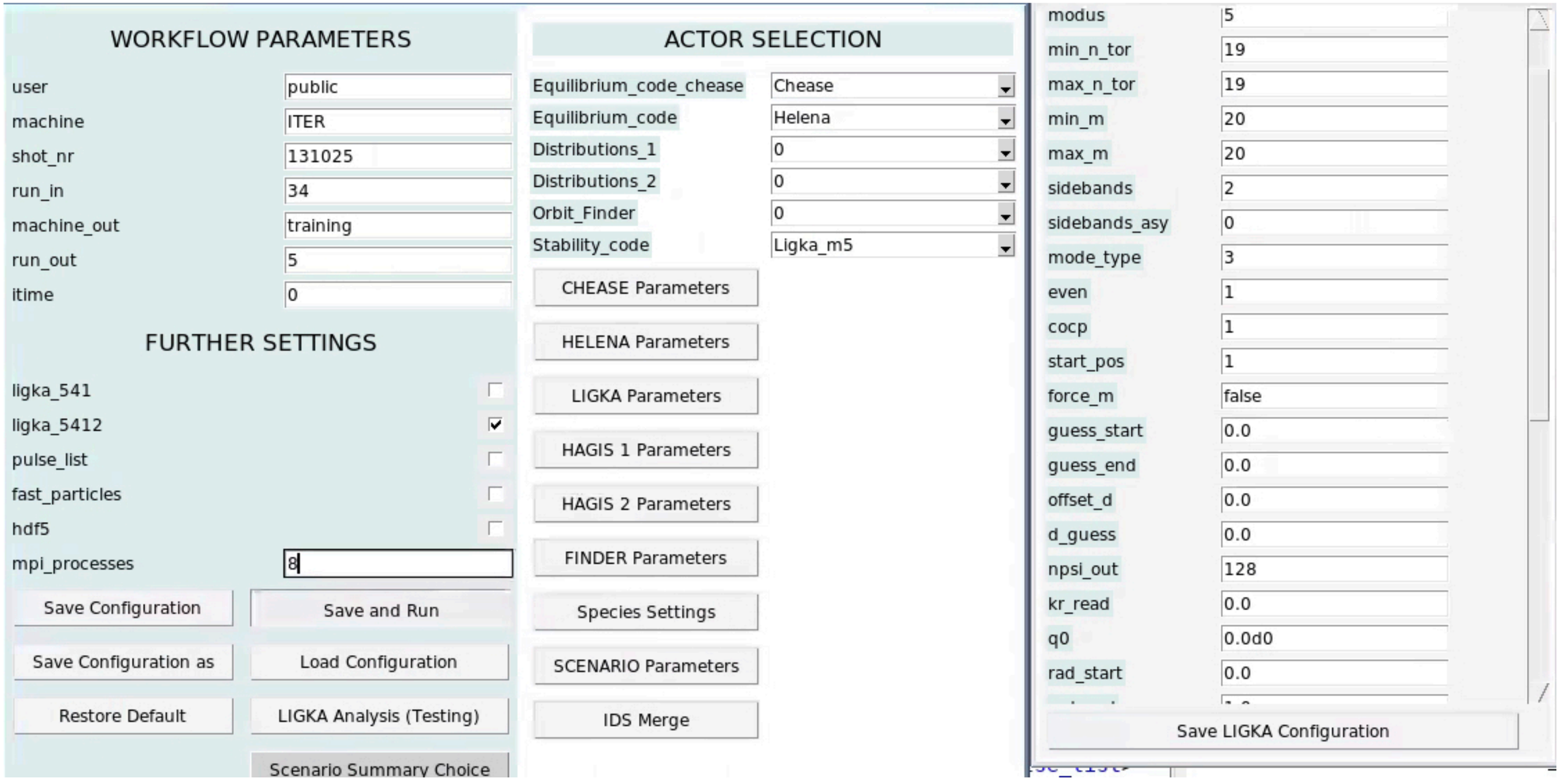


min_n_tor	19
max_n_tor	19
min_m	20
max_m	20
sidebands	8
sidebands_asy	1
mode_type	2
even	1
cocp	1
start_pos	1
force_m	false
guess_start	0.8
guess_end	0.1
offset_d	0.05
d_guess	0.0



run also model 3 to check that mode is close to kinetic continuum…
note! damping is large, need to go deeper in negative complex plane

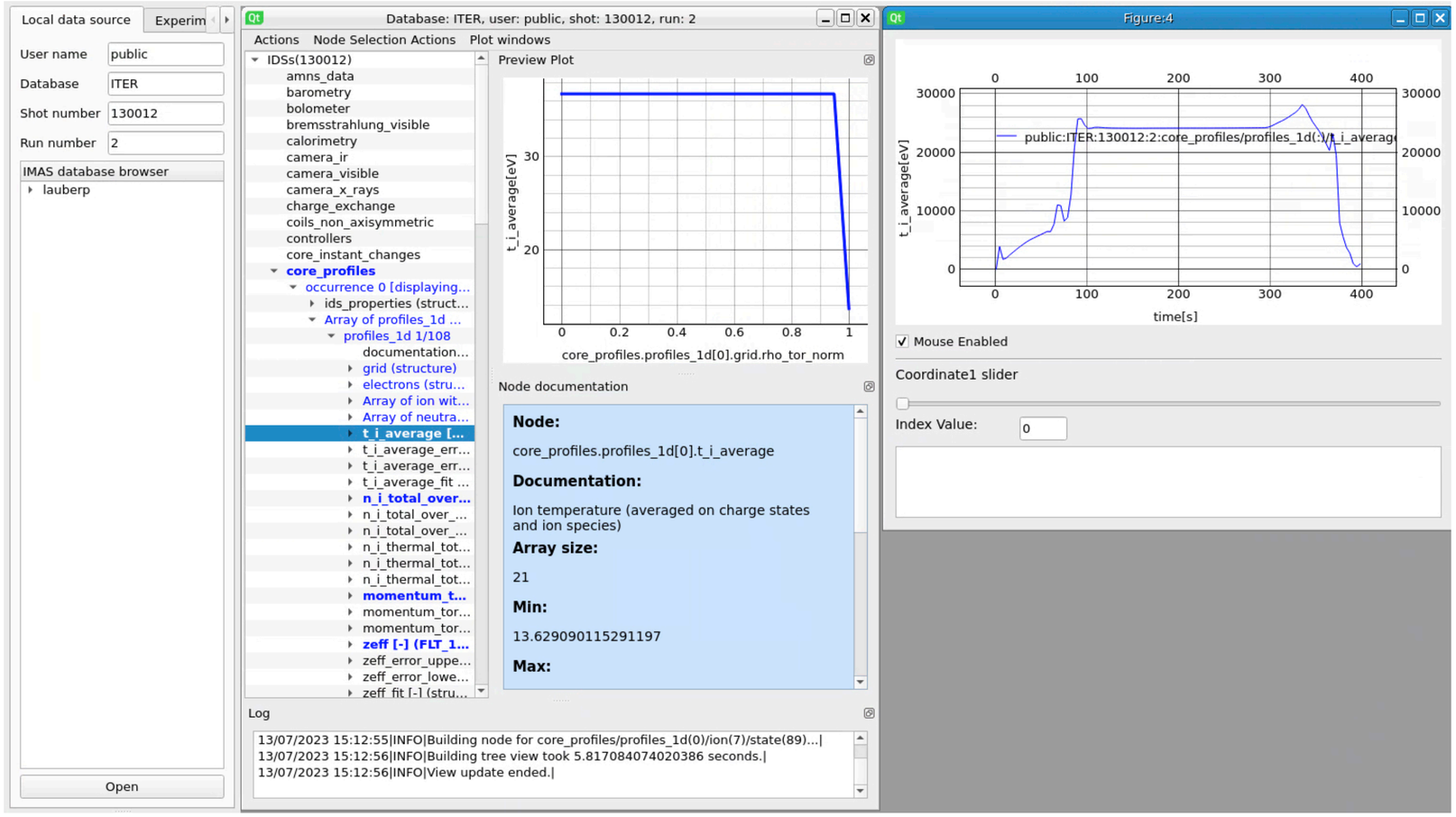
BAEs: no weekly damped BAEs found - see other cases….

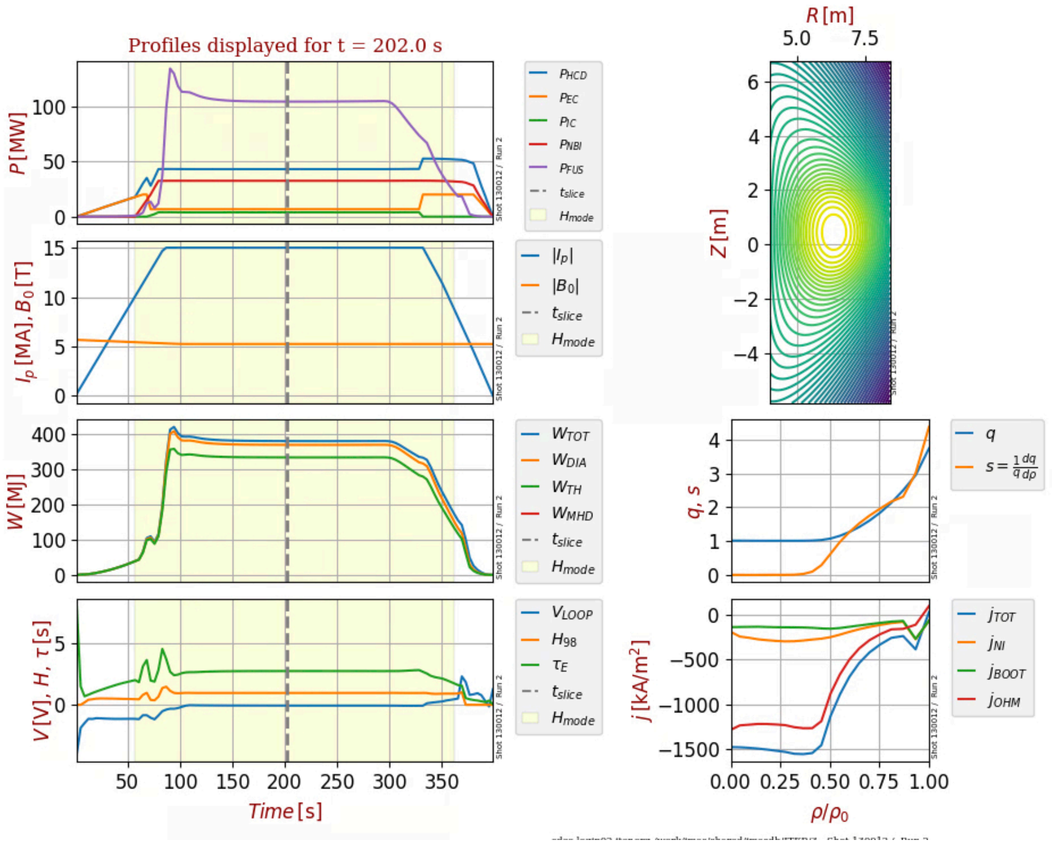


strongly damped! no global BAE can be found with these parameters, no mode calculated.

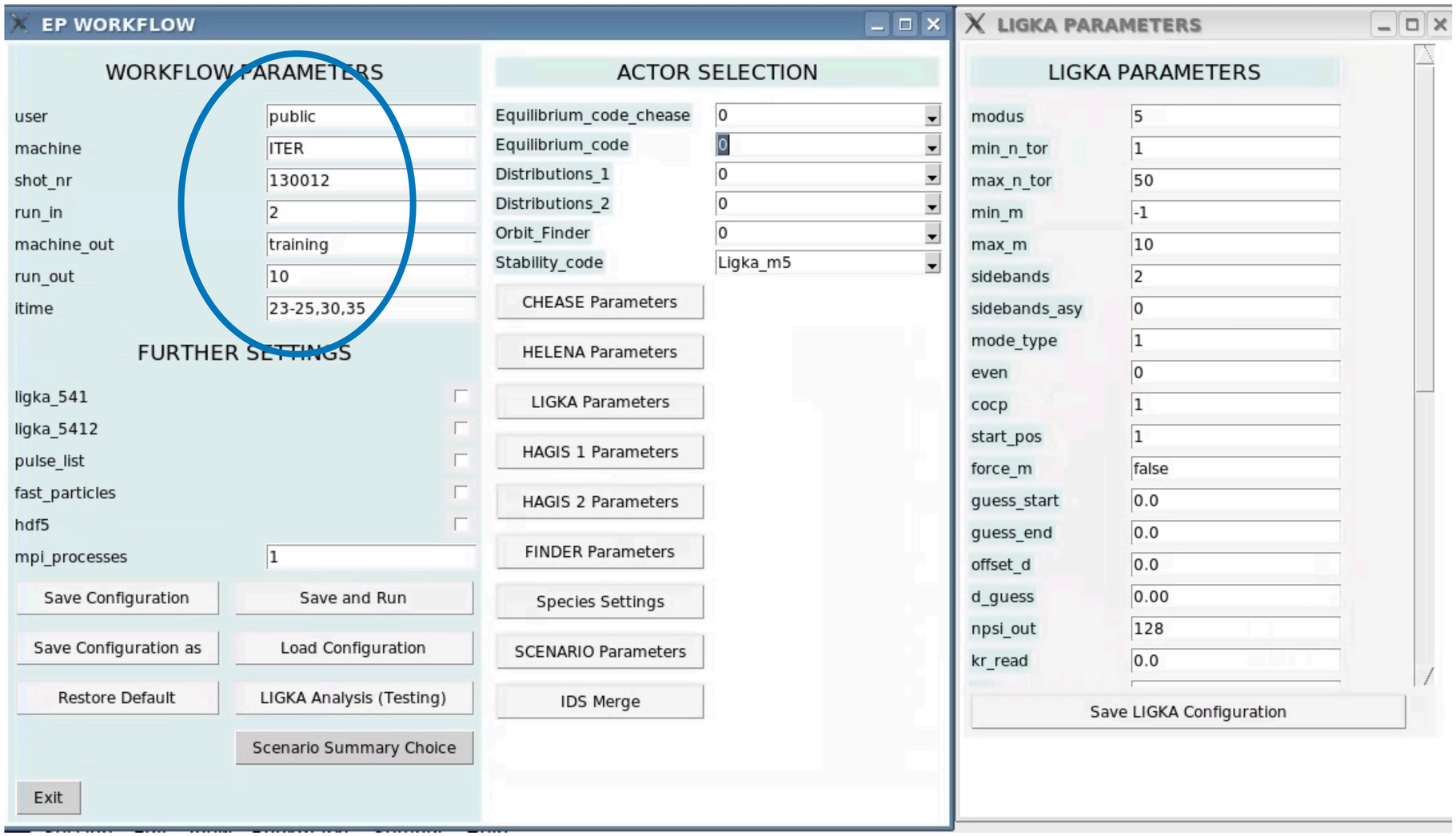
time dependent cases: (METIS 130012,2), credits M. Schneider

130012	4	ITER	ITER-baseline-DT_more_stable_q95>2	-15	-5.3	D-T	H-L-H	METIS

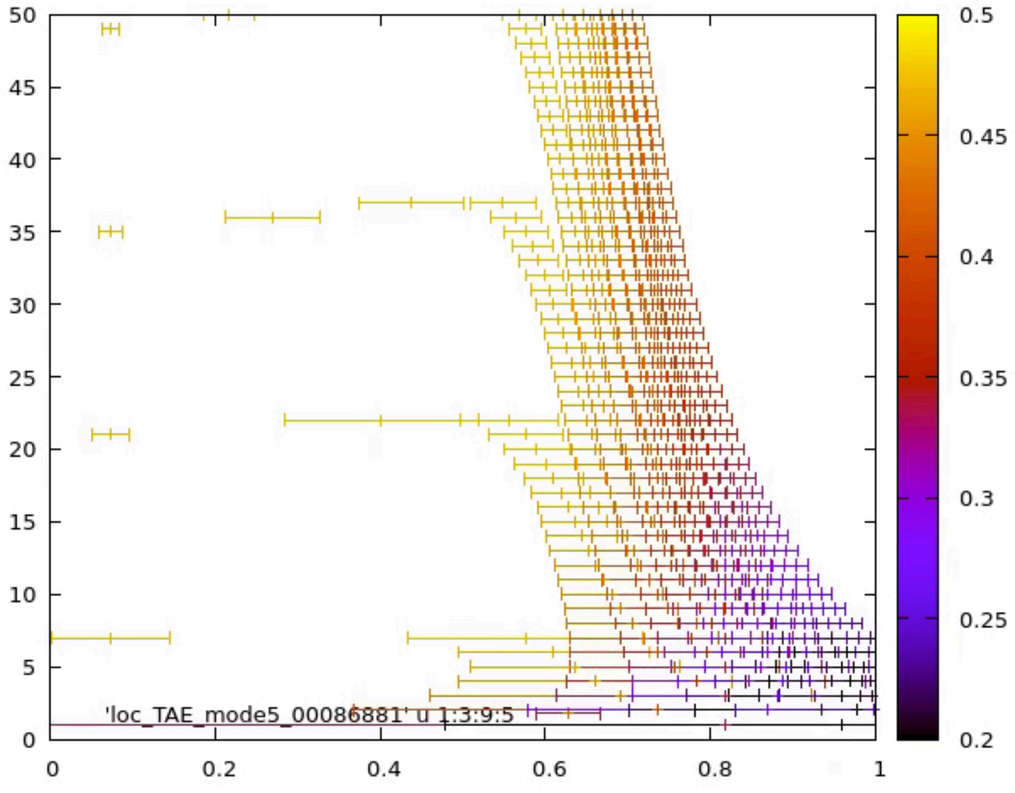




scenplot -u public --database ITER -s 130012 -r 2



plot [0:1]'loc_TAE_mode5_00101730' u 1:3:5 palette, 'loc_TAE_mode5_00112867' u 1:3:5 palette pt 8

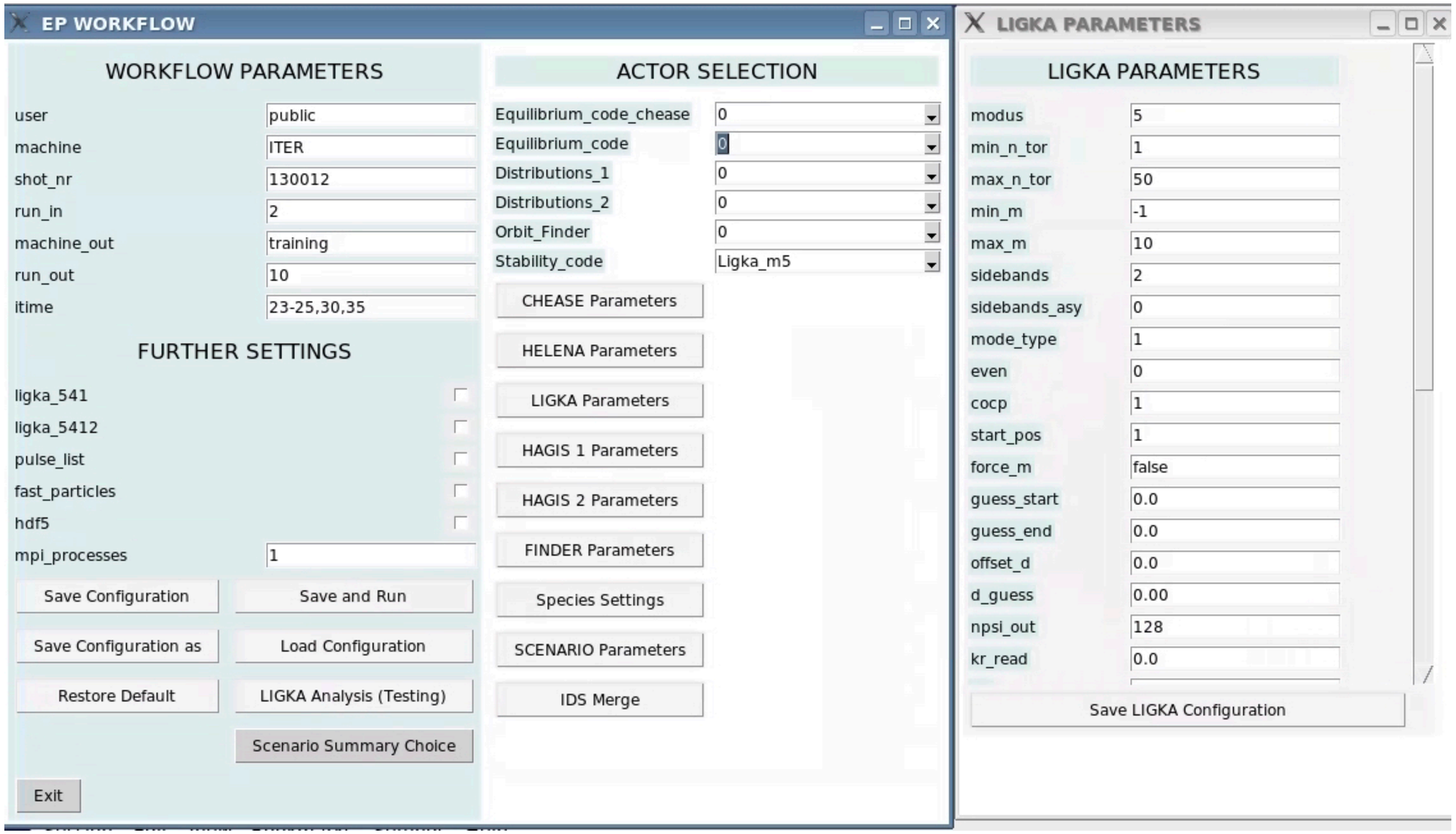


to run in with no-gui:
ep_nogui -c ./<name_of _configuration_files_folder>

to run with batch:
ep_batch -n 8 -t 1 e email@your.domain—q gen10_debug -c ./<name_of _configuration_files_folder>

check status: **squeue -u $USER**

note: in earlier ramp-up phase of some shots e.g. 100015,
helena does not converge for some time points
can be fixed with changing internal resolution for solver

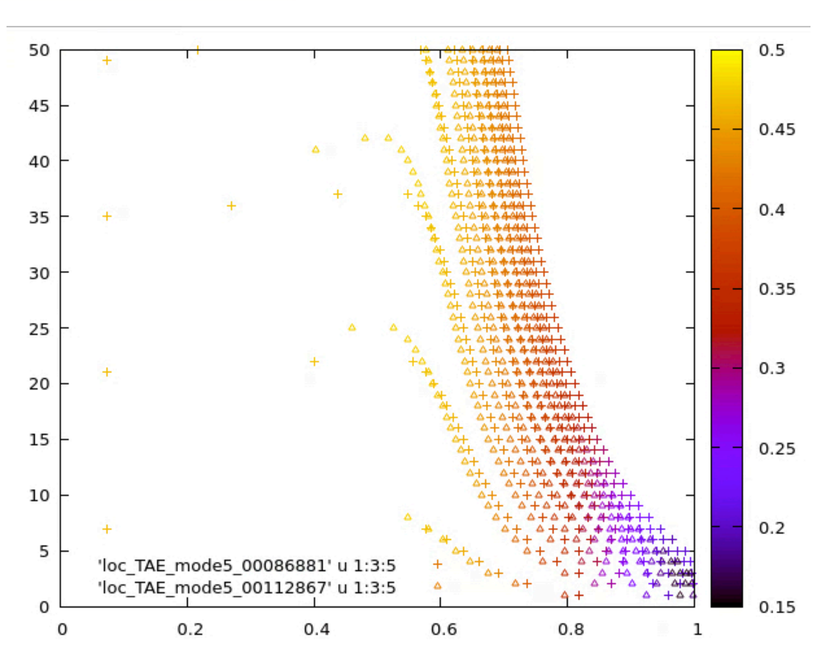


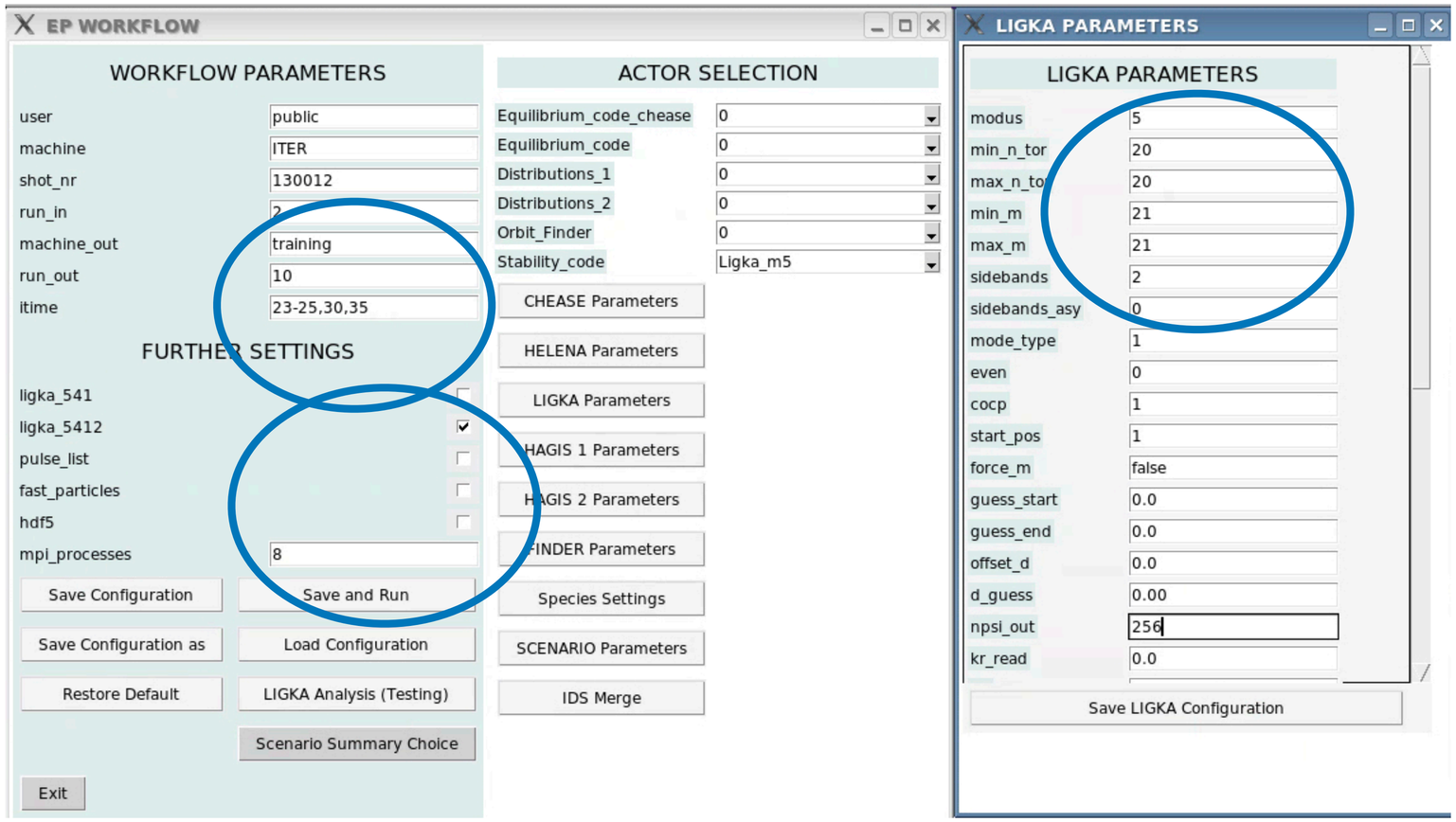
runs mode 5 for all time points

runs mode 4 for all time points

runs mode 1 for all time points

runs mode 2 for all time points



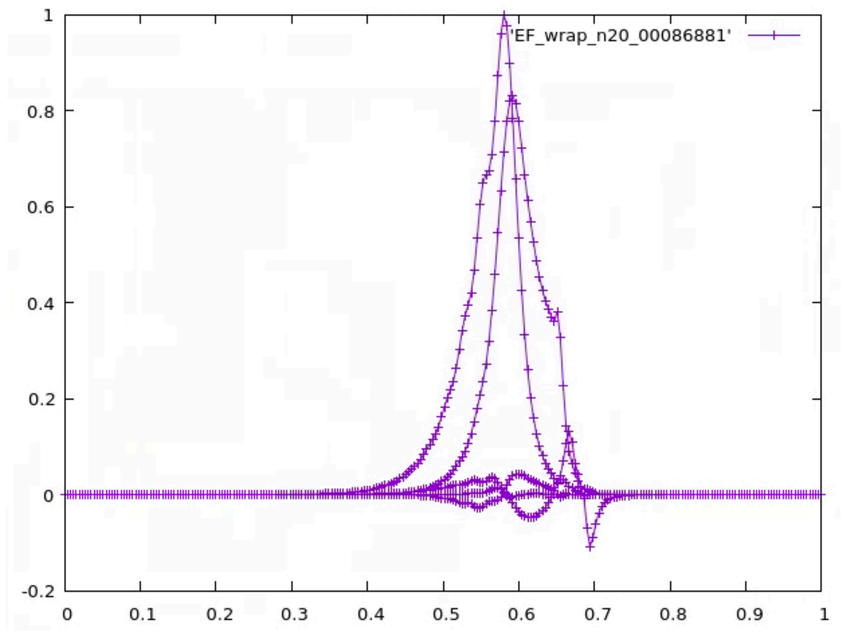


runs mode 5 for all time points

runs mode 4 for all time points

runs mode 1 for all time points

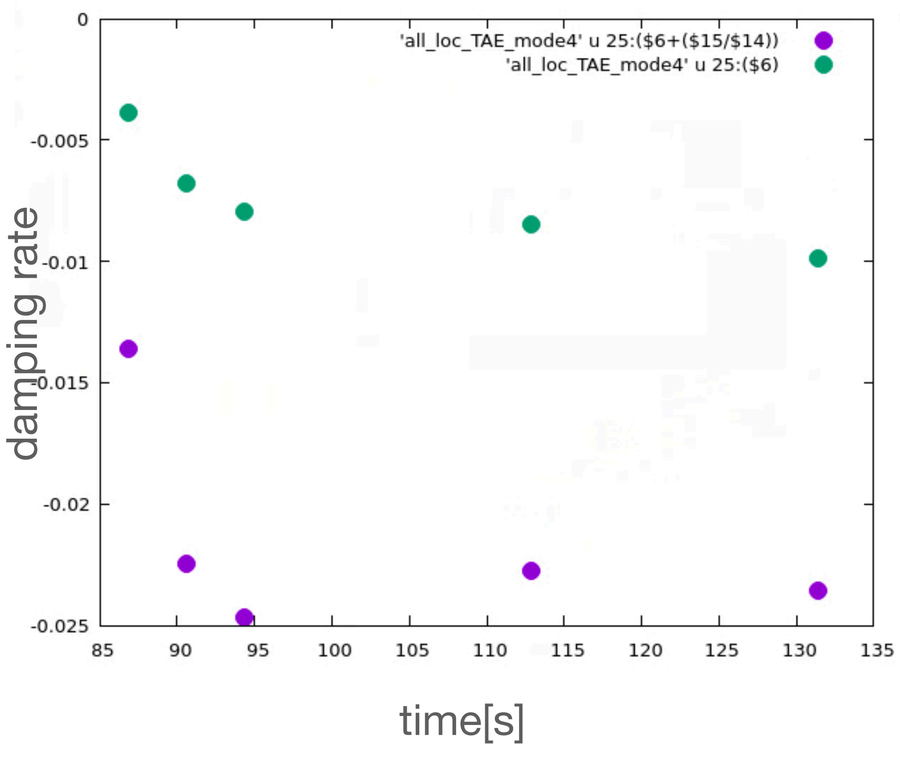
runs mode 2 for all time points



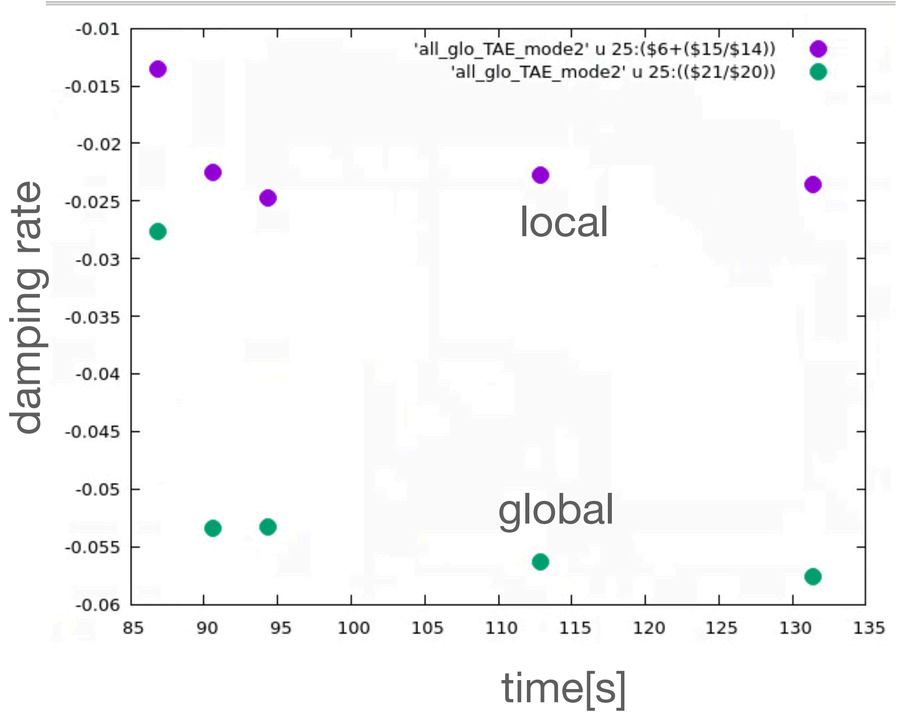
n=20…. use more harmonics, of course…

cat loc_TAE_mode4_00* > all_loc_TAE_mode4
cat glo_TAE_mode2_00* > all_glo_TAE_mode2

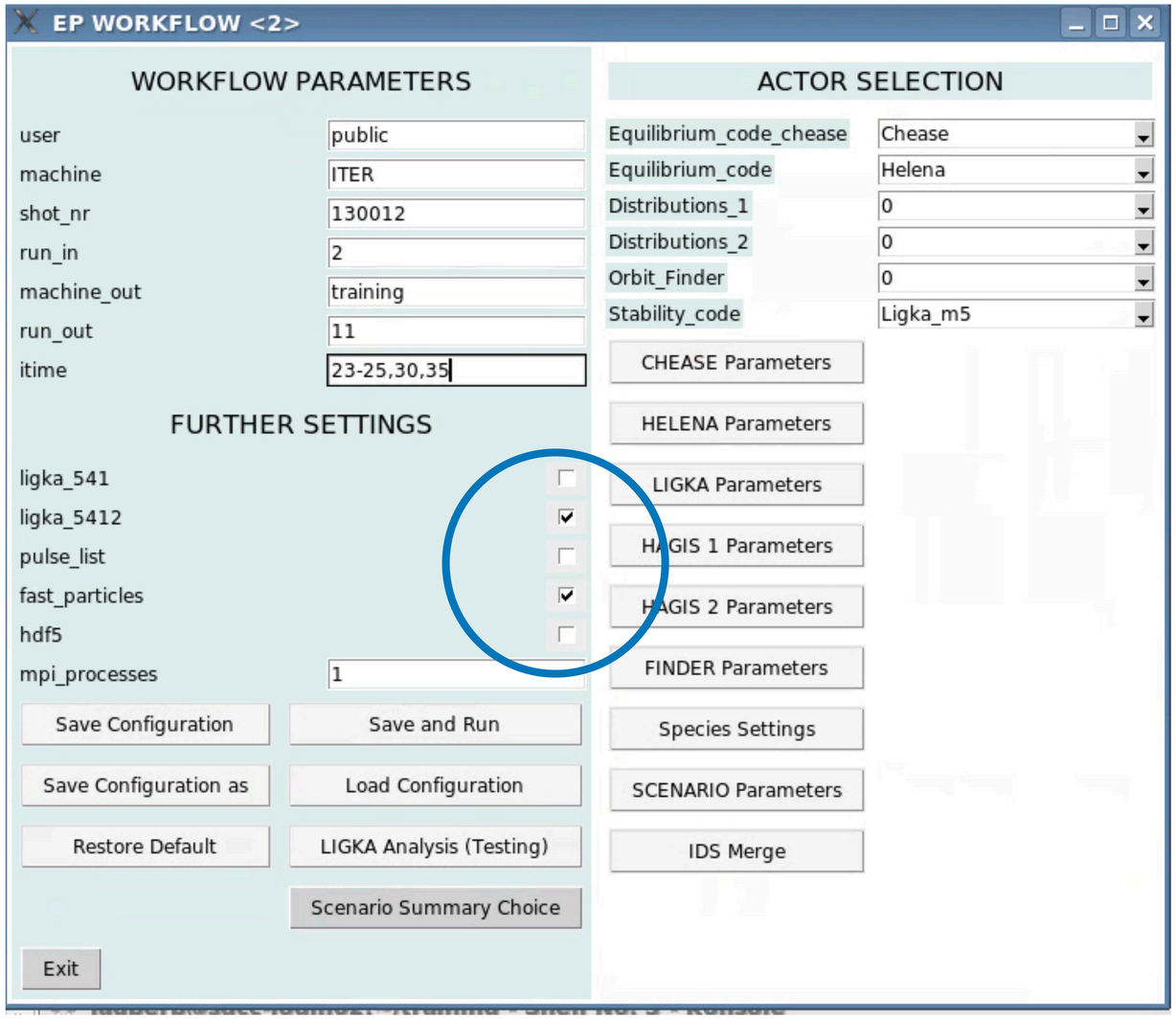
plot 'all_loc_TAE_mode4' u 25:($6+($15/$14)), 'all_loc_TAE_mode4' u 25:($6)



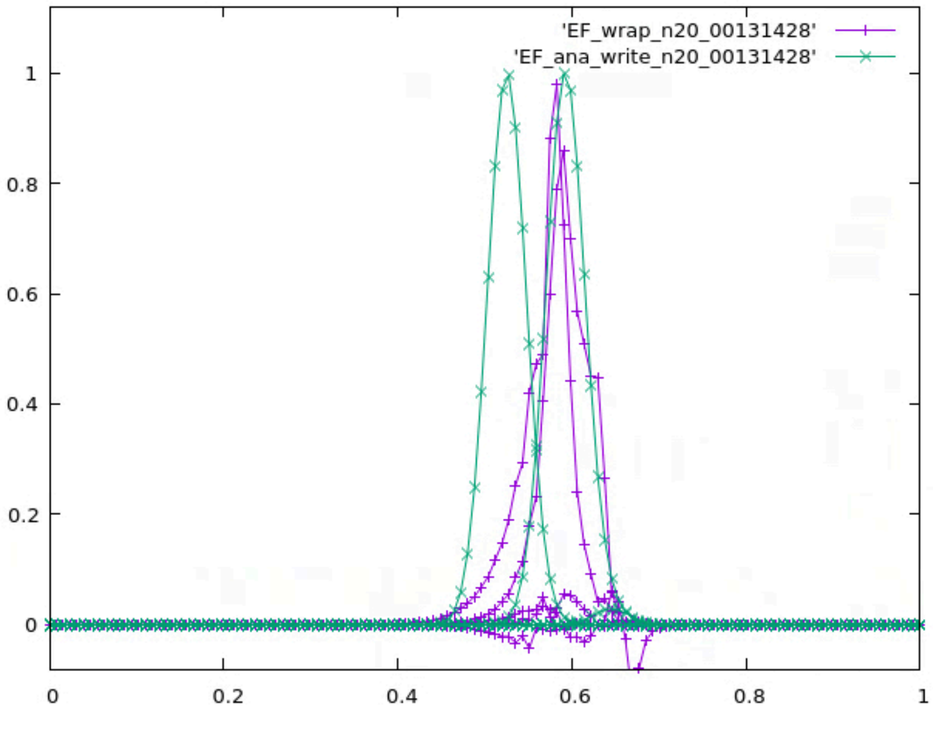
plot 'all_glo_TAE_mode2' u 25:($6+($15/$14)) , 'all_glo_TAE_mode2' u 25:(($21/$20))

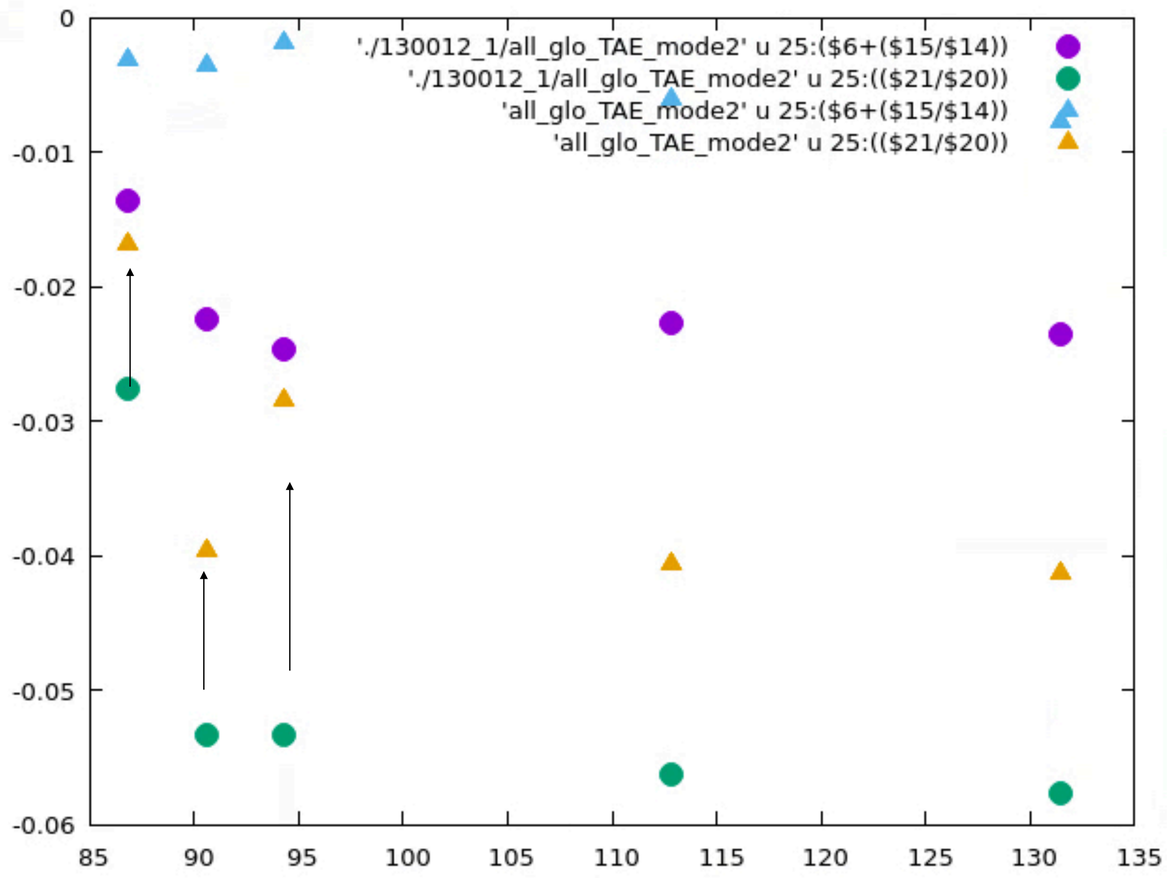


switch on EPs (use equivalent Maxwellian)




```
spec el: vth/va0   12.0004421963921
spec dd: vth/va0  0.191839372477651
spec tt: vth/va0  0.156636191715323
spec al: vth/va0   1.14083538370134
     T [kev] el    =    25.7043368943448       8.217748166356718E-002
     P [Pa] el     =    417690.723618820       585.617821383136
     n [m^-3] el    =   1.014233456772389E+020  4.447858509848111E+019
n_dpsi [m^-3] el    =    31163219437.6700      -2.304975191055403E+021
     T [kev] dd    =    24.1221553701961       7.762676065491934E-002
     P [Pa] dd     =    194794.456456403       276.583677453482
     n [m^-3] dd    =   5.040225764363166E+019  2.223845390113919E+019
n_dpsi [m^-3] dd    =   2.923650015250022E+016 -1.152485181787519E+021
     T [kev] tt    =    24.1221553701961       7.762676065491934E-002
     P [Pa] tt     =    194794.456456403       276.583677453482
     n [m^-3] tt    =   5.040225764363166E+019  2.223845390113919E+019
n_dpsi [m^-3] tt    =   2.923650015250022E+016 -1.152485181787519E+021
     T [kev] al    =    1706.14752719279       0.100000000000000
     P [Pa] al     =    84580.2007337157      1.343662699096967E-002
     n [m^-3] al    =   3.094151949877985E+017   838648101362688.
n_dpsi [m^-3] al    =  -2.923649776376930E+016 -2.068599540021377E+016
```





Tips and tricks, troubleshooting

how to load custom modules , e.g. LIGKA actor has been updated:

load lastest version of EP-Stability WF:

module load EP-Stability-WF/1.0.3-intel-2020b-DD-3.37.0
module unload -f LIGKA
module load LIGKA/1.0.5-intel-2020b-DD-3.37.0

new (and old) modules usually available here:
(module use ~haywart/.local/easybuild/modules/all)

similar with other WF components such as CHEASE and HELENA
to see which models are used:
module show EP-Stability-WF/1.0.3-intel-2020b-DD-3.37.0

plotting with python:

if one wants frequency: -type=frequency, damping -type=damping, radial_location -type=radial_location
to compare models (occurrence is overwritten in this case); if one wants plots without comparison, don't include ‘compare_modes’:

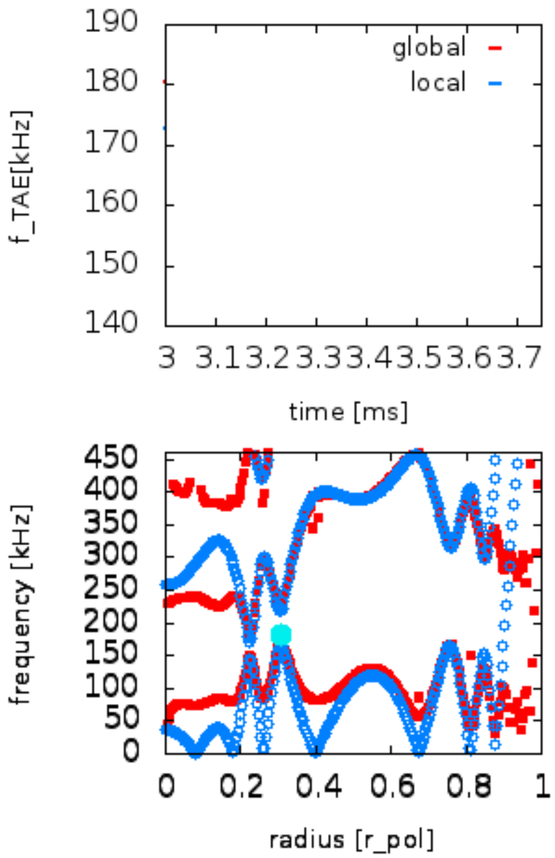
./general_plots_ids.py -user=popaa -database=test_DB -shot=130012 -run=10 -occurrence=0 -type=frequency -compare_modes=1 -interactivePlots=1
./general_plots_ids.py -user=popaa -database=test_DB -shot=130012 -run=10 -occurrence=0 -type=damping -compare_modes=1 -interactivePlots=1
./general_plots_ids.py -user=popaa -database=test_DB -shot=130012 -run=10 -occurrence=0 -type=radial_location -compare_modes=1 -interactivePlots=1

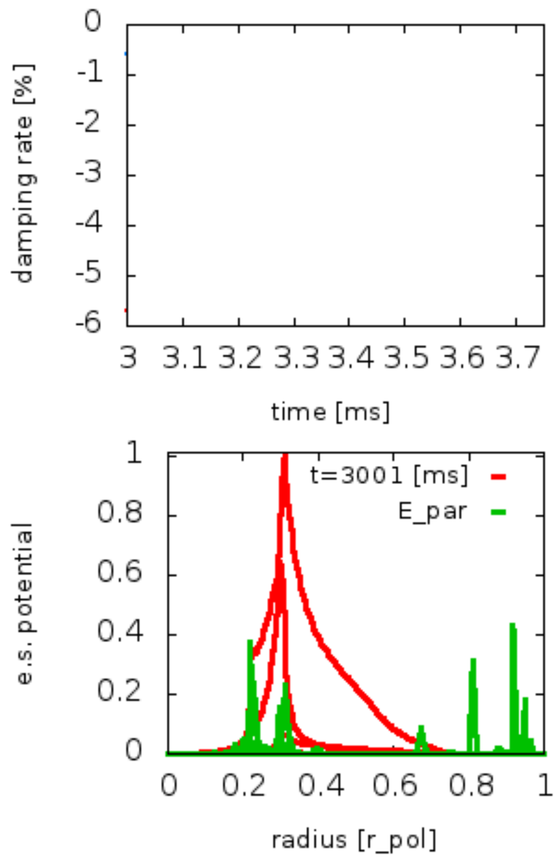
Prepare equilibrium:

- **use scenario as given by transport code - METIS, ASTRA, JINTRAC have been tested**
  - known issues: HFPS
    - IDSs not filled correctly: problematic: ff' and p' on magnetic axis
    - resolve: run CHEASE before running HELENA - still somewhat arbitrary q in core; problem reported to HPFS developers
    - no EP profile data available, distribution IDS not filled (dedicated ASCOT/SPOT runs needed)
  - ASTRA: step-type profile data - writing out too few digits - causes problems in splines, fuzzy spectra, om_start effects unreliable
    - resolve: reported to ASTRA team, should be resolved in recent simulations. LIGKA internal hack available (on request)

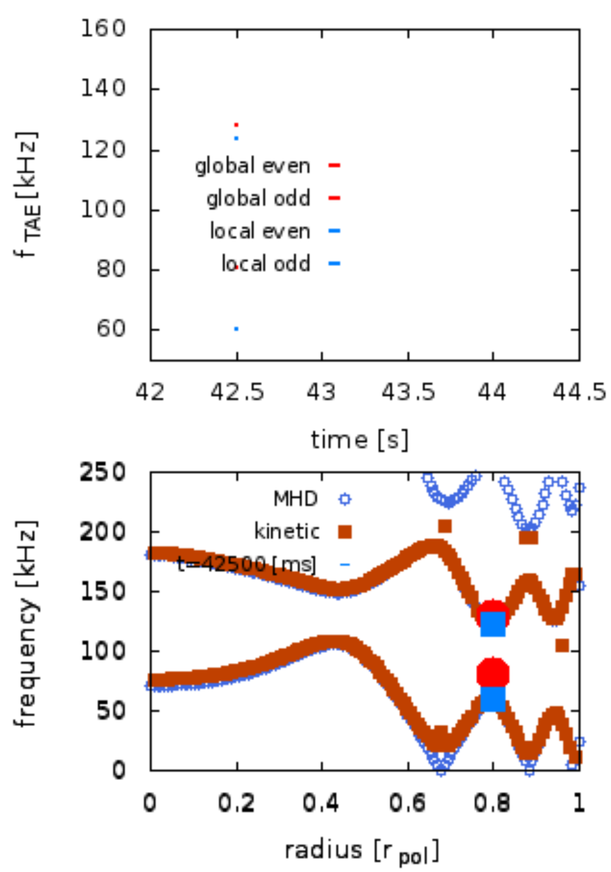
- **use experimental data:** use trview: https://www.aug.ipp.mpg.de/aug/manuals/transp/trview/index.html
  attention: results depends on quality of equilibrium reconstruction!

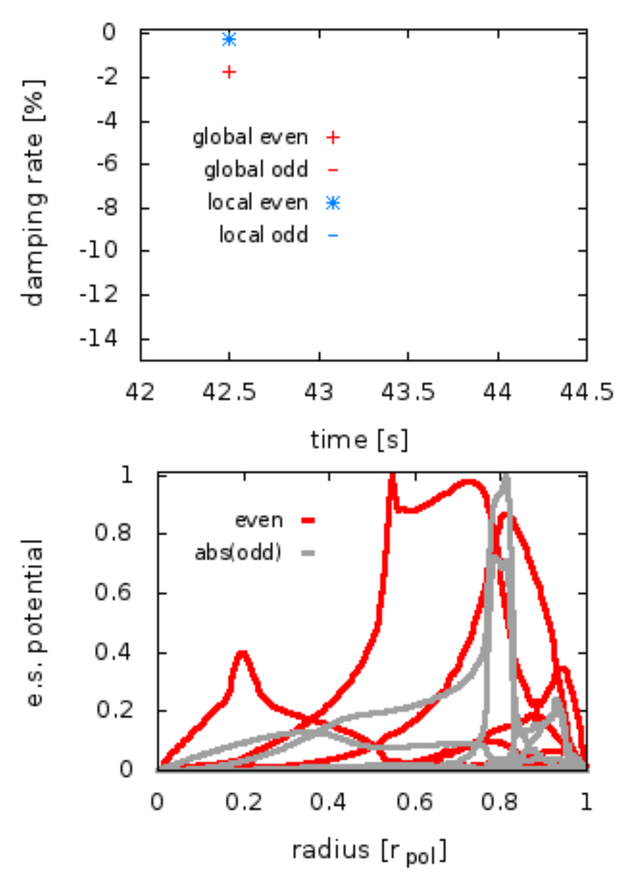
AUG





JET





- **custom equilibrium:** use CHEASE to write IDS based on EQDSK file (or use eqdsk2ids is available on SDCC)
need to add profiles in core_profiles IDS - one may use IDS_merge tool as inspiration/ scripts on request

Troubleshooting

model 5 fails

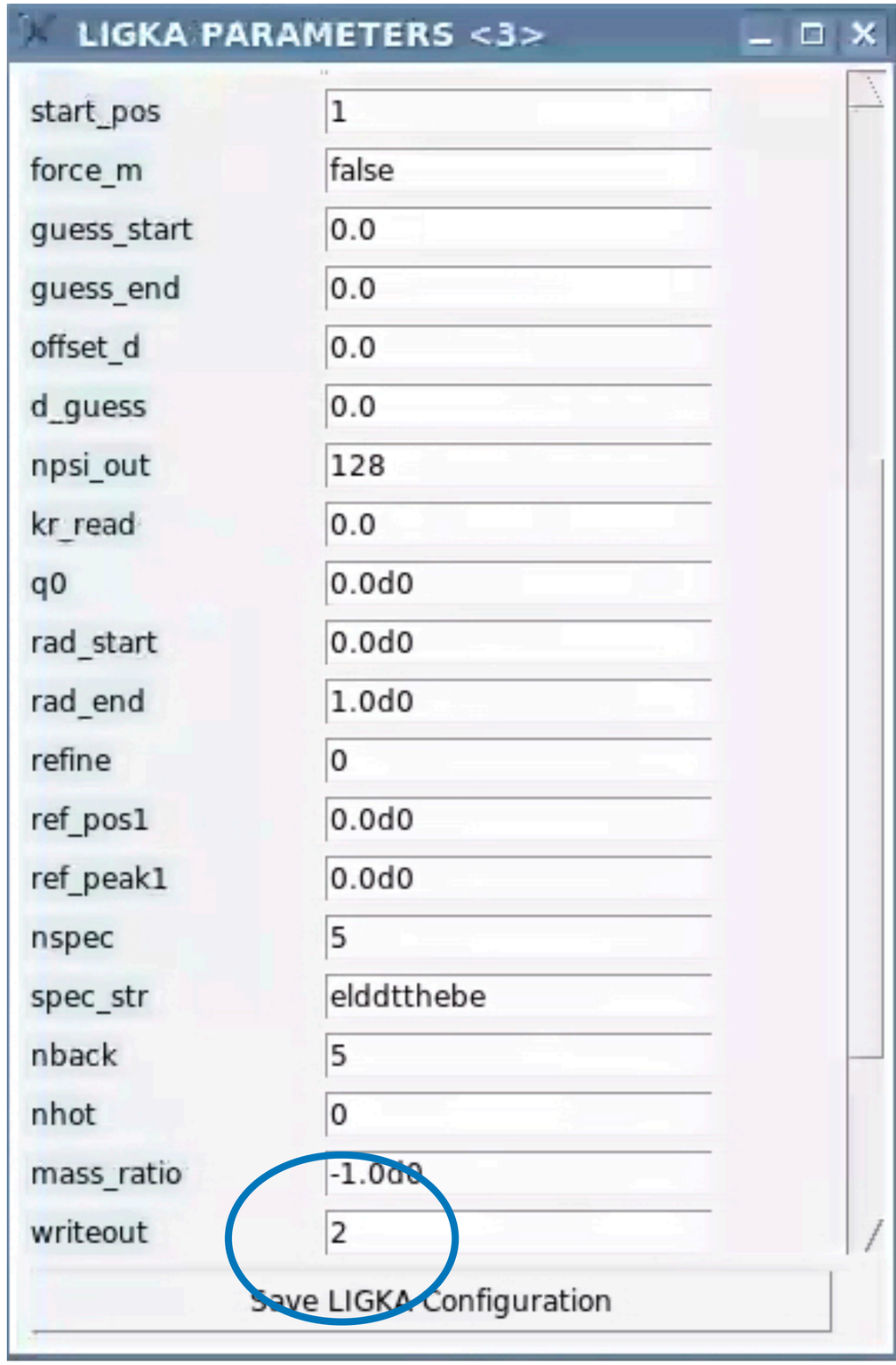
- widen n/m range
- equilibrium is not ok - check IDS

in addition:
switch on writeout =2

and check profiles that are actually used in LIGKA:

```
 70528 Jul 14 11:48 eq_flux_00208000
  6528 Jul 14 11:48 elo_00208000
  6528 Jul 14 11:48 zeff_00208000
 19328 Jul 14 11:48 dens_00208000
 60928 Jul 14 11:48 temp1_00208000
 60928 Jul 14 11:48 temp2_00208000
 60928 Jul 14 11:48 temp3_00208000
 60928 Jul 14 11:48 temp4_00208000
 60928 Jul 14 11:48 temp5_00208000
 28928 Jul 14 11:48 press1_00208000
 28928 Jul 14 11:48 press2_00208000
 28928 Jul 14 11:48 press3_00208000
 28928 Jul 14 11:48 press4_00208000
 28928 Jul 14 11:48 press5_00208000
 16128 Jul 14 11:48 dens1_00208000
 16128 Jul 14 11:48 dens2_00208000
 16128 Jul 14 11:48 dens3_00208000
 16128 Jul 14 11:48 dens4_00208000
 16128 Jul 14 11:48 dens5_00208000
```

q-profile: plot 'eq_flux_00208000' u 1:2 w lp lw 3
density spec 1(=electrons): plot 'dens1_00208000' u 1:2 w lp lw 3
temperature spec 1(=electrons): plot 'temp1_00208000' u 1:2 w lp lw 3
....



also, for troubleshooting switch on this flag and send the output to us….

- **model 5 gives me modes I do not want to carry all along the modelling chain**

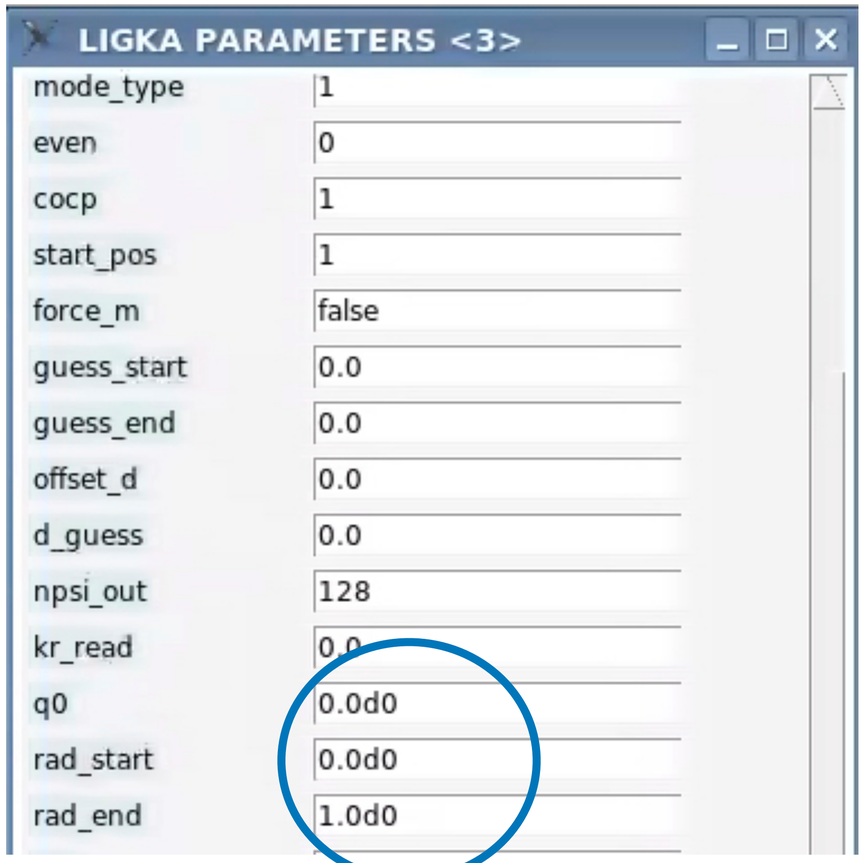
  solution restrict radial range: choose around mode's rational surface (s=sqrt(pol_flux))

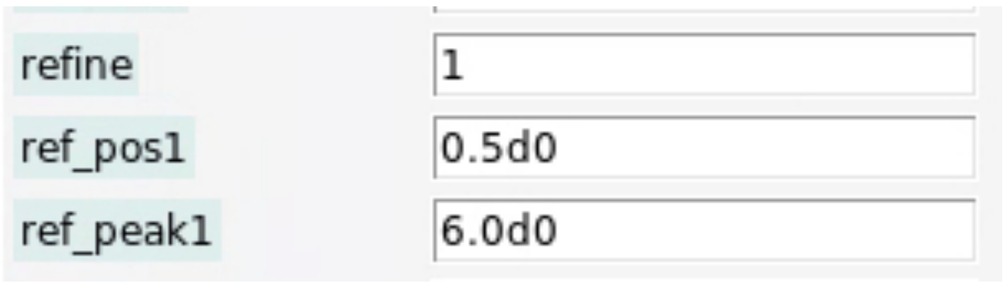
- **I want to scan the on-axis q-value**

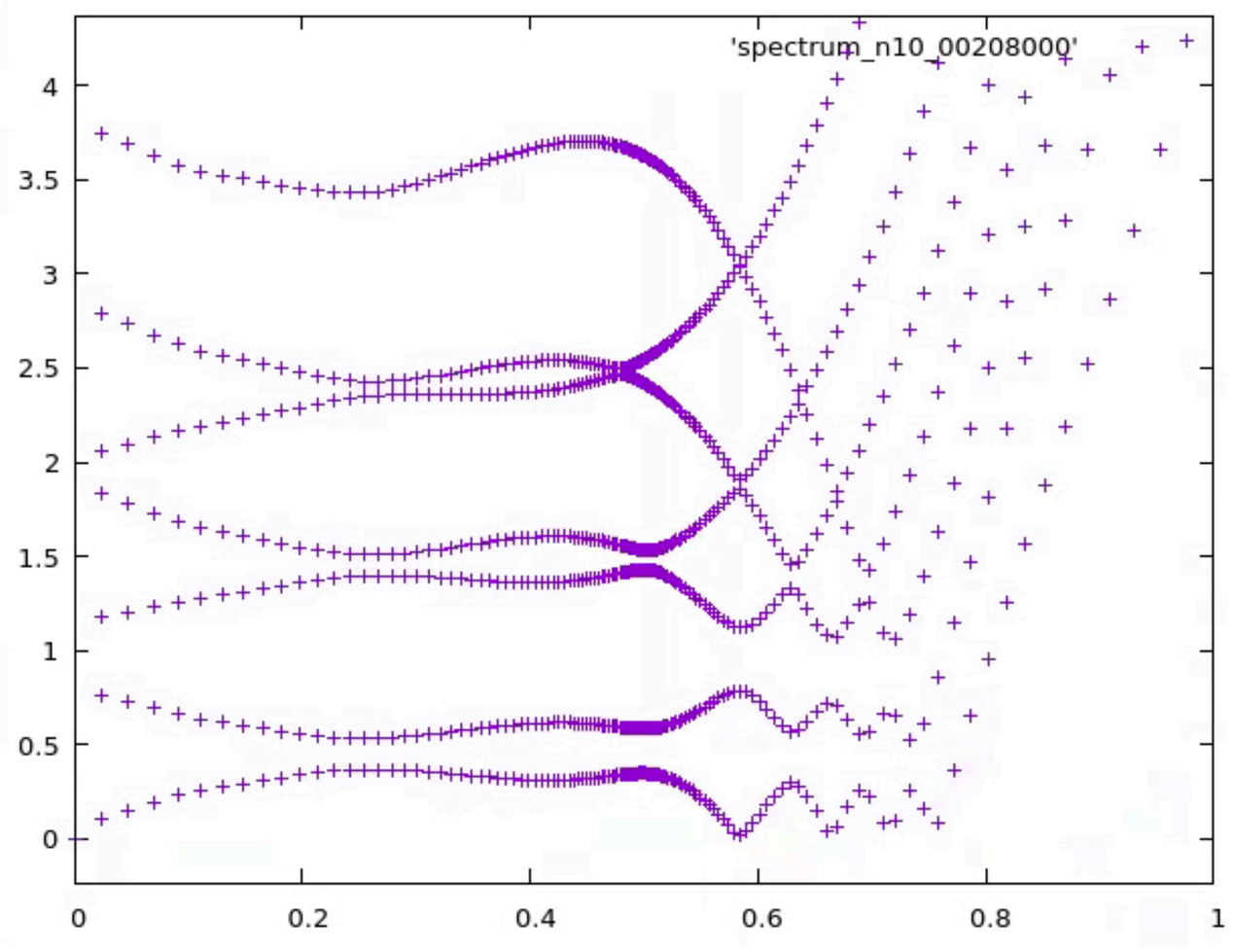
  LIGKA can scale the equilibrium consistently, specifying q0
  if q0 (in LIGKA always positive) is different from 0, it will be used to scale

- **I want a fine resolution (e.g. of my continuum model 3,6) around a certain radial point**

set <refine> to 1
choose radial position to refine around: <ref_pos1>
choose <ref_peak1>: the larger, the more refined (exp)







model 4 fails

- model 4 needs a list of modes, as stored in mhd_linear/0; i.e. run model 5 first!
- algorithm does not find an extremum in the continuum
- wrong initial guess: typically extreme is strongly damped, and integration contour does not reach it
- do I really need this mode? If local damping is large, global damping is typically even larger - will not be unstable
- if yes: change <offset_d> (negative increases circle, positive decrease, move in stable complex plane)
- (check ct_spectrum_<mpi_proc+10> file)
- if mode numbers are high, a higher radial grid will be needed: use more radial points in HELENA (but <500)

model 6 fails

- model 6 needs a list of modes, as stored in mhd_linear/0; i.e. run model 5 first!
- it will skip all modes that have the same toroidal mode number
- use more harmonics
- model 6 is not parallelised - do not use more than ~35-40 harmonics, or machine with lots of memory
- one can also combine separate runs with different pol. harmonics to cover the full radial range

model 3 fails

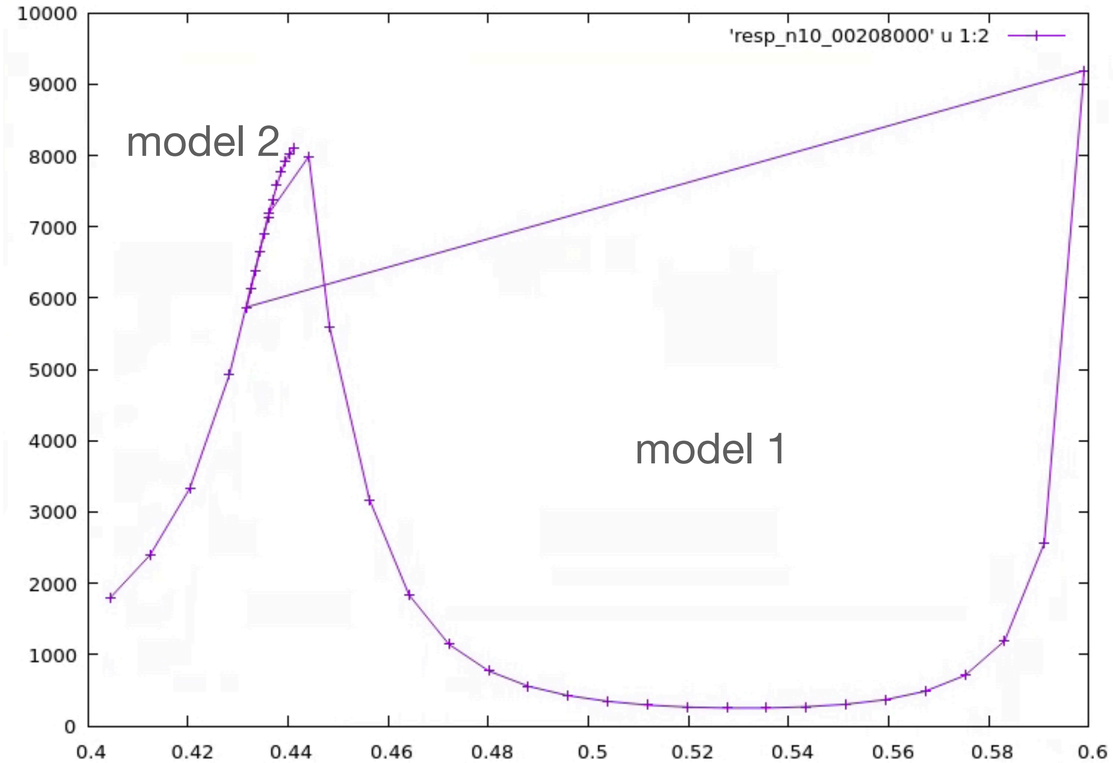
- model 3 needs a list of modes, as stored in mhd_linear/0; i.e. run model 5 first!
- it will skip all modes that have the same toroidal mode number
- some branches of the continua are missing: go deeper into complex plane with offset_d
- decrease integration radius: d_guess (code runs longer)

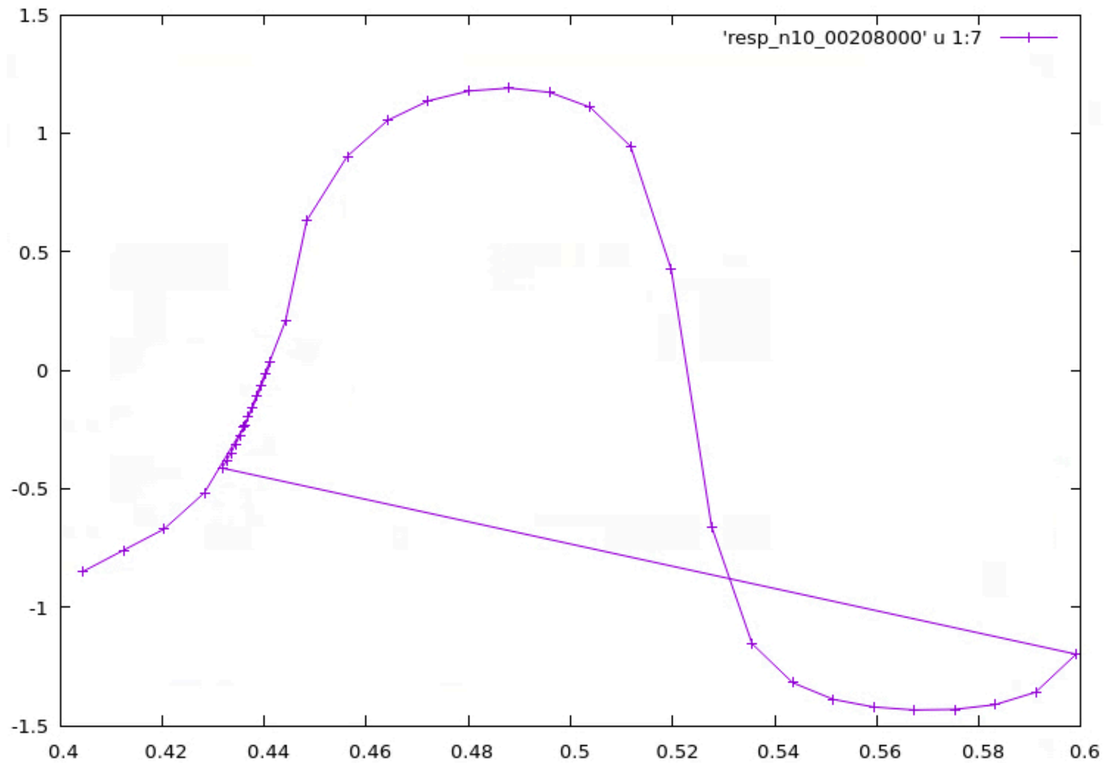
model 1 fails

- algorithm does not find a maximum in response **and** phase crossing 0 (oscillator theory)
- check response_n10_<time_stamp> file

- wrong initial guess: guess can be set manually at guess_start [omega_A0] - to omega_end [omega_A0]

- do I really need this mode? If local damping is large, global damping is typically even larger - will not be unstable





WF/code still fails

- set in LIGKA options writeout=2 ; maybe the output gives a hint?
- if not, please send me (philipp.lauber@ipp.mpg.de) the output + case (xml files)
- don’t expect always an immediate answer….

on request, also standalone (non-IMAS) LIGKA version and sample input files: z_ligka.xml; Y_LIGKA_namelist for more advanced settings can be supplied; not generally supported

all LIGKA parameters (z_ligka.xml):

```
<parameter>

  <modus>5</modus> ! 1: global antenna, full gap; 2: global antenna track mode; 3: scan complex plane as given by guess_start_1, guess_start_2 with dguess; 4: find local guesses for kinetic continuum close to specified gap; 5: local analytical estimates for various AEs; 6: local and global redcued MHD solve
   This parameter is automatically set in the main WF window.

    <min_n_tor>1</min_n_tor> !  start search from this minimal tor. mode number
    <max_n_tor>10</max_n_tor> !  end search from this max tor. mode number
    <min_m>1</min_m> ! start poloidal mode number: typically nq_0=m (e.g. BAEs) or nq_TAE=m (TAEs)
    <max_m>2</max_m> ! number of gaps to be searched: for one (main) TAE gap use max_m=min_m
    <sidebands>5</sidebands> !side band poloidal harmonics to be used around peak_m; in analytical estimates for damping only up to 2 is implemented, for ideal MHD can be up tp 20-30 (memory limit depending on npsi....)
    <sidebands_asy>2</sidebands_asy> ! shift symmetrically defined pol sidebands array by <sidebands_asy> to higher m (if positive) or lower m (if negative)

    <mode_type>1</mode_type>,!0=GAM-EGAM/1=TAE/2=RSAE/3=BAE/4=EAE/5=NAE/6=EPM/7=BAAE/8=KBM/9=ITG ! note slight difference to IMAS standard...mapp ed in sub_imas_out.F;   negative sign: counter propagating modes (co: ion diagmanetic direction, co: el-diamagnetic direction)

 <even>0</even>  even (ballooning) or odd (anti-ballooning) branch for TAEs to be considered
   <cocp>      1   </cocp> !1 include only co  (ion diamagn. direction)  or counter propagating modes, depending on sign of mode_type; 2: include both co and counter progating modes

   <start_pos>1</start_pos> ! use only mode with index larger than startpos - sometimes convenient when more modes are found in one mode 1 run
   <force_m>false</force_m> ! use automatic pol mode number range as defined above, can be forced to min_m, max_m for  mode 1/2 runs
  <npsi_out>128</npsi_out> ! number of output points for all radial quantities, default=number of eq pointa
   <kr_read>0.0d0</kr_read> ! for mode 4 and 3 a kr can be specified - will be mode 9, not yet active

    <q0>0.0d0</q0>           ! scale equilibrium, if abs(q0) > 0.0d0
    <rad_start>0.0d0</rad_start>  ! restrict radial range  for modes of interest
    <rad_end>1.0d0</rad_end>     ! restrict radial range  for modes of interest

    <offset_d>0.0d0</offset_d>   ! add offset imaginary part for unstable modes manually (mode 1/2): positive to find strongly growing modes, negative to find strongly damped modes; or control complex plane (imag part) of mode 3 intergration range

    <guess_start>0.0d0</guess_start> ! control mode 3 guess range (default) 1.0 [omega_A]
    <guess_end>0.0d0</guess_end>     ! control mode 3 guess range (default) 0.0 [omega_A]
    <dguess>0.0d0</dguess>           ! control radius of integration circle of mode 3, default =0.02 [omega_A]

    <refine>0</refine>               ! refine radial grid
    <ref_pos1>0.0d0</ref_pos1>       ! refine where radially?
    <ref_peak1>0.0d0</ref_peak1>     ! use exp {ref_peak1} to control spacing - 3 is moderate accumulation, >6 strong accumulation see sub_setgrid.F90

    <nspec>2</nspec>    ! this is typically set and controlled by the WF and overwritten
    <spec_str>eldd</spec_str>  !  this is typically set and controlled by the WF and overwritten: species string: el,eh (heavy electrons for reduced mass ratio benchmarks), hh ,dd, tt, dt, he(ash), be, ca [carbon!],ne,tu,al, fh (fast hydrogen), fd (fast deuterium),
    <nback>2</nback> ! number of background species
    <nhot>0</nhot> ! number of hot species

    <mass_ratio>-1.0d0</mass_ratio>! electron mass= first ion mass/mass_ratio, e.g. for elddttal it would be mass_dd/mass_ratio

    <writeout>0</writeout> ! write out level: 1,2 for eq and profile output typically needed for debugging and checking, 3 for kinetic ouput, 5 full output

    ! only needed when run outside WF:
    <shot_number_wrap>130015</shot_number_wrap>
    <run_wrap>1</run_wrap>
    <itime_wrap>40</itime_wrap>
    <user_wrap>lauberp</user_wrap>
    <machine_wrap>ITER</machine_wrap>
</parameter>
```