

EP-Stability-Workflow

a practical hands-on guide

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console commands (bold)

clicks 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)

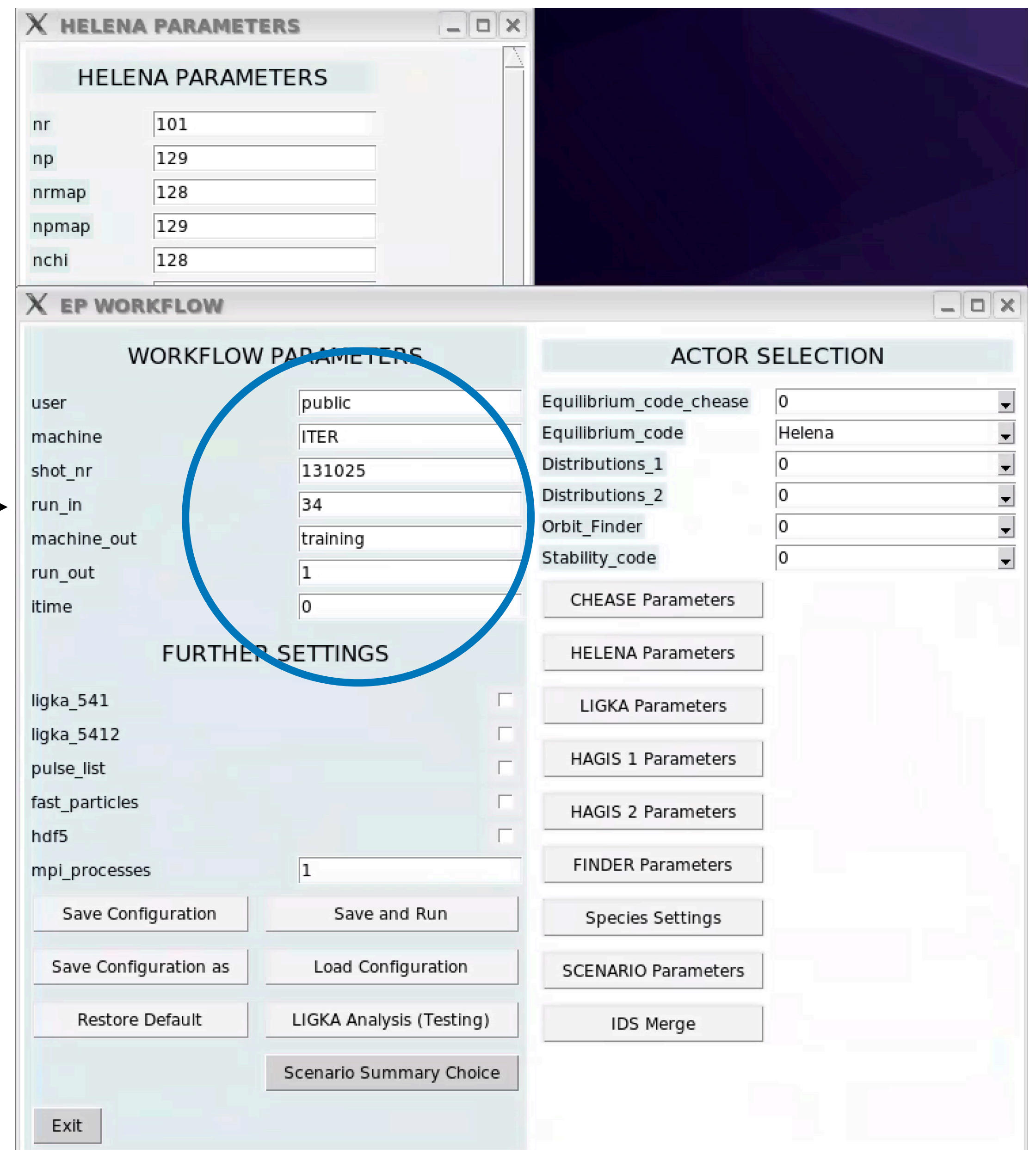
choose shot from public or private IMAS DB

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/ (mads+)

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

The screenshot shows the EP WORKFLOW GUI with the following sections:

- WORKFLOW PARAMETERS:** Includes fields for user (public), machine (ITER_SCENARIOS), shot_nr (131025), run_in (34), machine_out (training), run_out (1), and itime (0). A blue circle highlights the machine, shot_nr, run_in, and machine_out fields.
- FURTHER SETTINGS:** Includes checkboxes for ligka_541, ligka_5412, pulse_list, fast_particles, and hdf5, and a field for mpi_processes (1).
- ACTOR SELECTION:** Includes dropdown menus for Equilibrium_code_chease (Chease), Equilibrium_code (Helena), Distributions_1 (0), Distributions_2 (0), Orbit_Finder (0), and Stability_code (Ligka_m5).
- Buttons:** Save Configuration, Save and Run, Save Configuration as, Load Configuration, Restore Default, Scenario Summary Choice, Exit, CHEASE Parameters, HELENA Parameters, LIGKA Parameters, HAGIS 1 Parameters, HAGIS 2 Parameters, FINDER Parameters, Species Settings, SCENARIO Parameters, and IDS Merge.

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-

for older/newer versions, try: (not officially supported)
module use /home/ITER/hayward/.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:

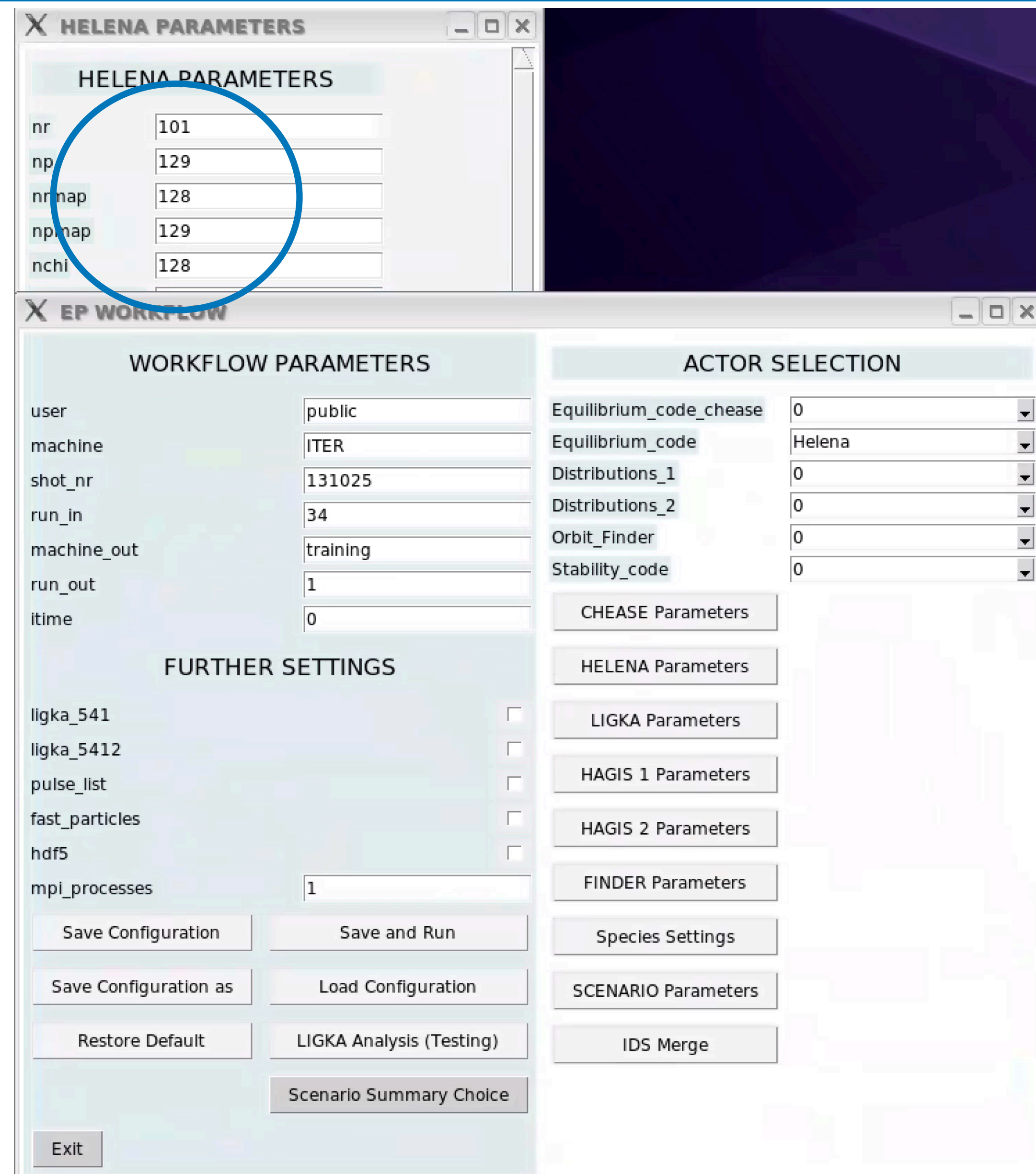
Save & Run

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

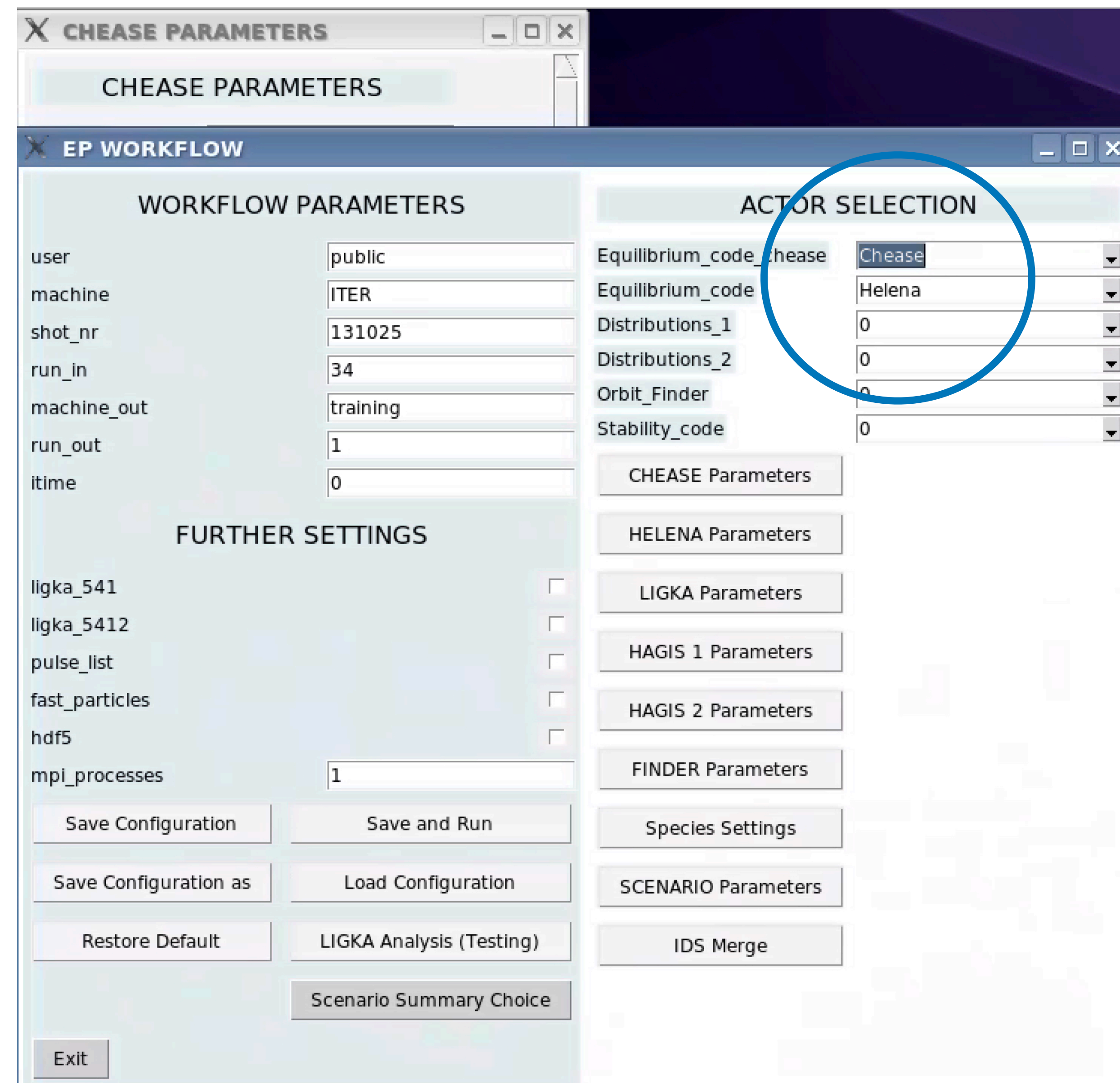


if **HELENA** does not converge or delivers problematic results,
CHEASE be run before HELENA:

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

The screenshot shows the IMAS database browser interface. On the left, the 'IMAS database browser' pane shows a tree view of the database structure, with 'training' > '131025' > 'HDF5' selected. The main pane displays a tree view of the selected data, with 'equilibrium' > 'occurrence 0 [displaying first time slice]' > 'Array of time_slice with 1 element(s)' > 'time_slice 1/1' > 'profiles_1d (structure)' > 'psi [Wb] (FLT_1D)' selected. The 'psi [Wb] (FLT_1D)' node is highlighted in blue. On the right, the 'Preview Plot' pane shows a plot of q vs. poloidal flux. The x-axis is labeled 'equilibrium.time_slice[0].profiles_1d.psi' and ranges from 30 to 0. The y-axis is labeled 'q [-]' and ranges from 1 to 4. The plot shows a blue curve that starts at $q \approx 3.8$ at $\psi = 30$ and decreases to $q \approx 1.1$ at $\psi = 0$. Below the plot, the 'Node documentation' pane shows the following information:

Node: equilibrium.time_slice[0].profiles_1d.q

Documentation: Safety factor (IMAS uses COCOS=11: only positive when toroidal current and magnetic field are in same direction)

Array size: 128

Min: 0.9985293010274181

Max: 3.8720840568674664

Number of zeros: 1

Invalid entries (nan):

The bottom pane shows a log of the application, with the following entries:

```
04/07/2023 15:15:32|INFO|Occurrence 0 of equilibrium IDS in memory, building view...|
04/07/2023 15:15:32|INFO|Building tree view took 0.07254147529602051 seconds.|
04/07/2023 15:15:32|INFO|View update ended.|
```


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 $\text{max}_m=\text{min}_m$

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 ~/ !

The image shows two overlapping software windows. The top window is titled 'LIGKA PARAMETERS' and contains a table of input fields: 'modus' (5), 'min_n_tor' (10), 'max_n_tor' (10), 'min_m' (10), and 'max_m' (11). A blue circle highlights these fields. The bottom window is titled 'EP WORKFLOW' and is divided into three sections: 'WORKFLOW PARAMETERS' (with fields for user, machine, shot_nr, run_in, machine_out, run_out, itime), 'FURTHER SETTINGS' (with checkboxes for ligka_541, ligka_5412, pulse_list, fast_particles, hdf5 and a field for mpi_processes), and 'ACTOR SELECTION' (with dropdown menus for Equilibrium_code_chease, Equilibrium_code, Distributions_1, Distributions_2, Orbit_Finder, and Stability_code). A blue circle highlights the 'Stability_code' dropdown, which is set to 'Ligka_m5'. At the bottom of the EP WORKFLOW window are several buttons: 'Save Configuration', 'Save and Run', 'Save Configuration as', 'Load Configuration', 'Restore Default', 'LIGKA Analysis (Testing)', 'Scenario Summary Choice', and 'Exit'.

check/visualise results: viz

The screenshot shows a software interface with a left sidebar and a main content area. The sidebar contains a 'Local data source' section with fields for 'User name' (lauberp), 'Database' (training), 'Shot number' (131025), and 'Run number' (1). Below this is an 'IMAS database browser' showing a tree view of folders like 'lauberp', 'MDS+', and 'training', with '131025' selected under 'training'. The main content area is titled 'Qt' and 'Database: training, user: lauberp, shot: 131025, run: 1'. It displays a hierarchical tree view of data nodes. The selected node is 'mhd_linear', which contains 'occurrence 0 [displaying first time slice]'. This node has several sub-nodes: 'ids_properties (structure)', 'model_type (structure)', 'equations (structure)', 'fluids_n=-999999999 (INT_OD)', 'ideal_flag=-999999999 (INT_OD)', and 'vacuum_toroidal_field (structure)'. The 'Array of time_slice with 1 element(s)' node is expanded to show 'time_slice 1/1', which contains 'documentation= Core plasma radial profiles for various time slices'. This documentation node is further expanded to show an 'Array of toroidal_mode with 136 element(s)', listing modes from 1/136 to 13/136. The 'toroidal_mode 13/136' node is expanded to show its 'documentation= Vector of toroidal modes. Each mode is described as $\exp(i(n_{\text{tor}}\phi - m_{\text{pol}}\theta - 2\pi \text{frequency} \dots))$ '. This node contains several sub-nodes: 'perturbation_type (structure)', 'n_tor=5 (INT_OD)', 'm_pol_dominant=5.0 [-] (FLT_OD)', 'm_pol_dominant_error_upper=-9e+40 [-] (FLT_OD)', 'm_pol_dominant_error_lower=-9e+40 [-] (FLT_OD)', 'ballooning_type (structure)', 'radial_mode_number=0.5842584258425843 [-] (FLT_OD)', 'radial_mode_number_error_upper=-9e+40 [-] (FLT_OD)', 'radial_mode_number_error_lower=-9e+40 [-] (FLT_OD)', 'growthrate=-36.55854713815936 [Hz] (FLT_OD)', 'growthrate_error_upper=-9e+40 [Hz] (FLT_OD)', 'growthrate_error_lower=-9e+40 [Hz] (FLT_OD)', 'frequency=81226.64386648593 [Hz] (FLT_OD)', 'frequency_error_upper=-9e+40 [Hz] (FLT_OD)', 'frequency_error_lower=-9e+40 [Hz] (FLT_OD)', 'phase=-9e+40 [rad] (FLT_OD)', 'phase_error_upper=-9e+40 [rad] (FLT_OD)', and 'phase_error_lower=-9e+40 [rad] (FLT_OD)'.

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 $s=\sqrt{\text{norm_pol_flux}}$
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 $\omega_{A0}=B_0/\sqrt{m_{\text{ion}} * n_0 \mu_0}$ on axis values
6 radiative damping, formula S.D. Pinches 2015 (to be checked) in γ/ω !
7 local beta at gap/mode rational surface: $2.0d0*\text{press}(s)*\mu_0/B_{\text{tor}}(s)**2!$
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 $\sqrt{\epsilon/\text{shear}}$ 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 ω_{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: ω/ω_{A0} of next gap
33: ω/ω_{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...

| LIGKA PARAMETERS | |
|------------------|----|
| modus | 5 |
| min_n_tor | 1 |
| max_n_tor | 40 |
| min_m | -5 |
| max_m | 40 |

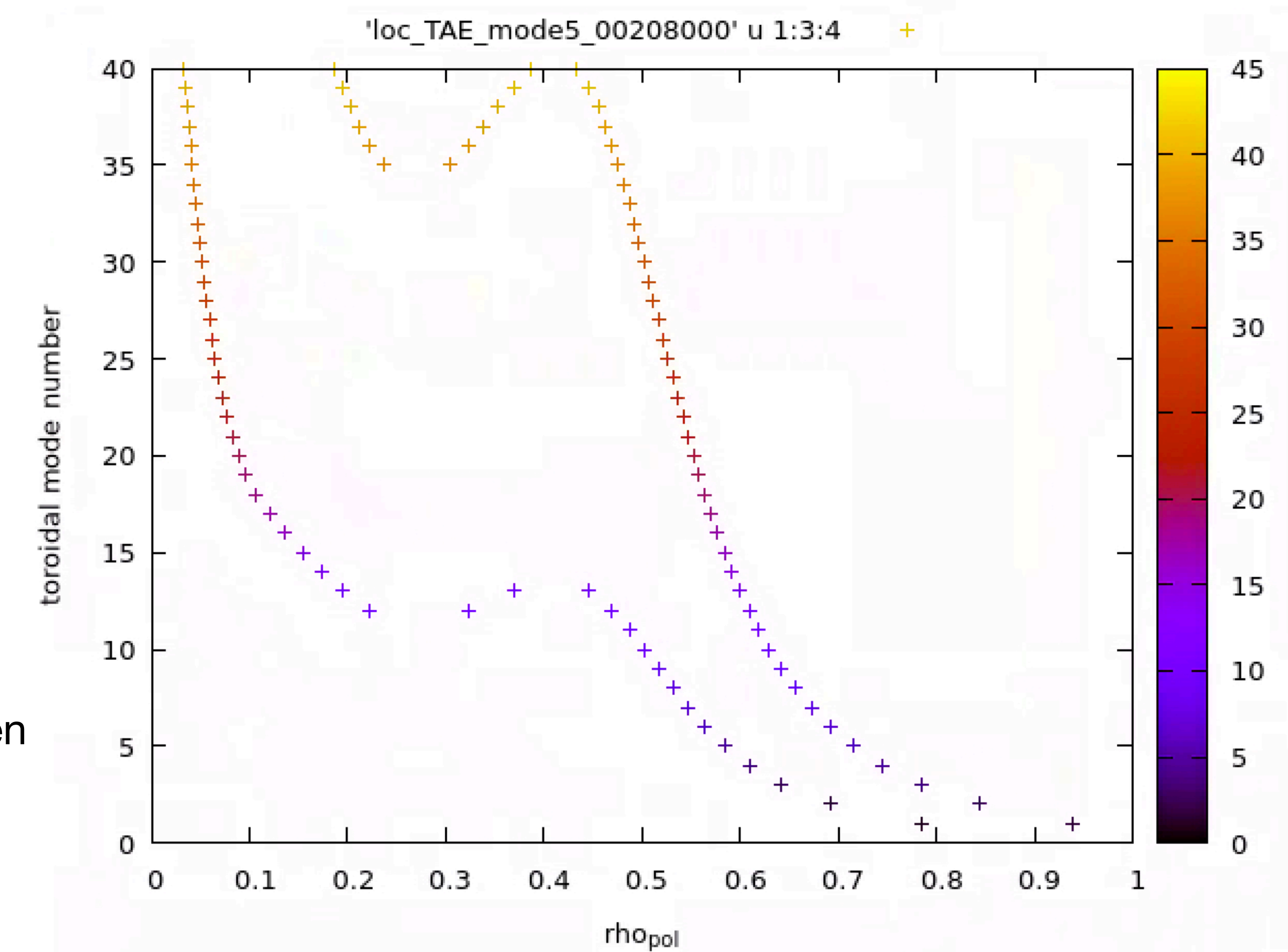
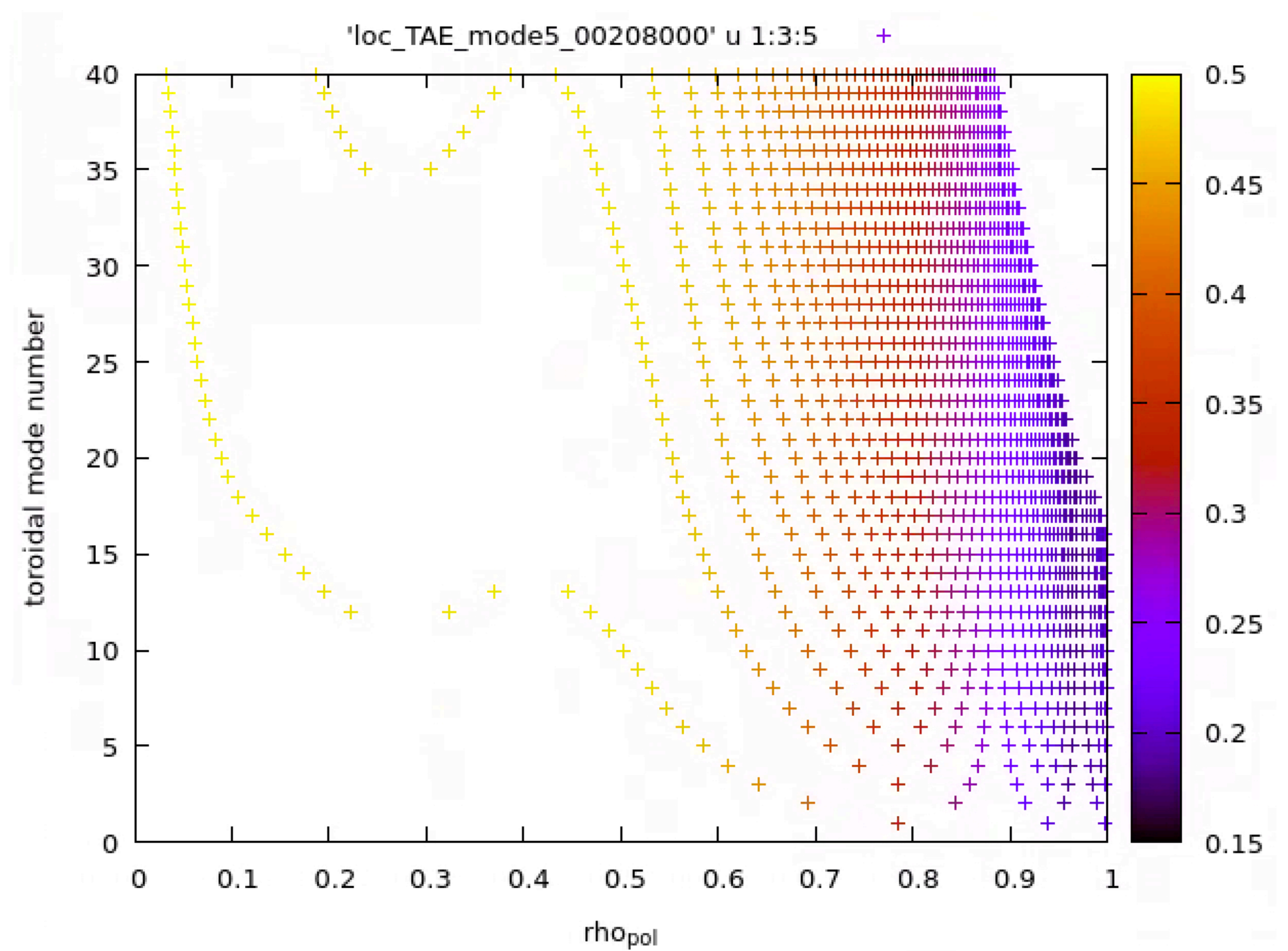
with gnuplot:

plot 'loc_TAE_mode5_00208000' u 1:3:5 palette

| LIGKA PARAMETERS | |
|------------------|----|
| modus | 5 |
| min_n_tor | 1 |
| max_n_tor | 40 |
| min_m | 1 |
| max_m | 2 |

with gnuplot:

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 $q \sim 1$

i.e. the pair (min_n, min_m) defines the relative difference between n and m that is kept the same when scanning n

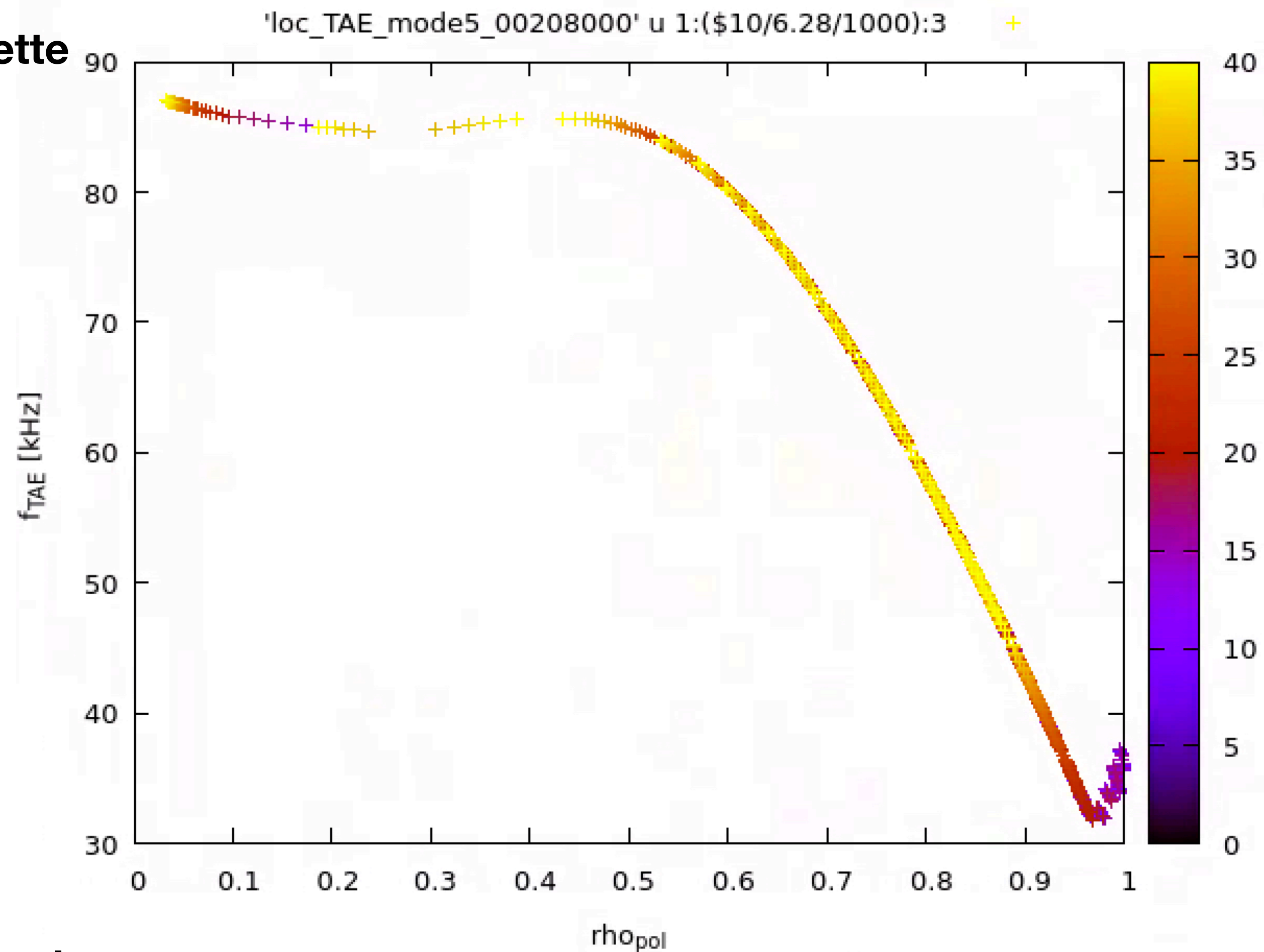
using like in this example min_m=1 and m_max=2 gives two TAE branches:

(n=1,m=1) ; (n=2,m=2) ; (n=3,m=3);...

(n=1,m=2) ; (n=2,m=3) ; (n=3,m=4);...

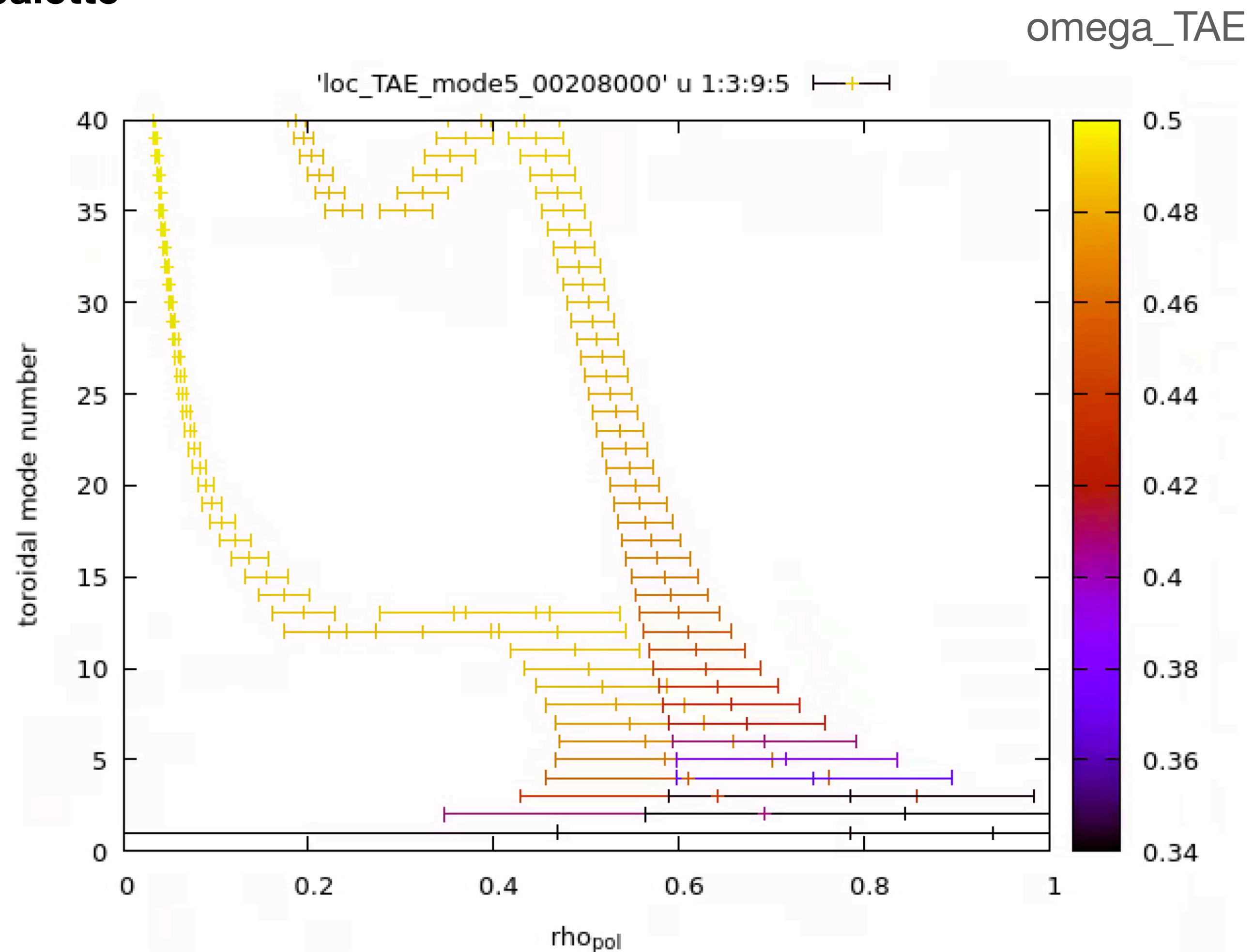
plot 'loc_TAE_mode5_00208000' u 1:(\$10/6.28/1000):3 palette

if you want to compare to experiment, add $n \cdot \text{tor_rot}$ 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



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.

The image shows two overlapping software windows. The top window is titled "LIGKA PARAMETERS <2>". It contains a table of parameters:

| LIGKA PARAMETERS | |
|------------------|----|
| modus | 5 |
| min_n_tor | 10 |
| max_n_tor | 10 |
| min_m | 10 |
| max_m | 11 |

The bottom window is titled "EP WORKFLOW". It is divided into several sections:

- WORKFLOW PARAMETERS:**

| | |
|-------------|----------|
| user | public |
| machine | ITER |
| shot_nr | 131025 |
| run_in | 34 |
| machine_out | training |
| run_out | 1 |
| itime | 0 |
- FURTHER SETTINGS:**

| | |
|----------------|--------------------------|
| ligka_541 | <input type="checkbox"/> |
| ligka_5412 | <input type="checkbox"/> |
| pulse_list | <input type="checkbox"/> |
| fast_particles | <input type="checkbox"/> |
| hdf5 | <input type="checkbox"/> |
| mpi_processes | 1 |
- ACTOR SELECTION:**

| | |
|-------------------------|----------|
| Equilibrium_code_chease | 0 |
| Equilibrium_code | 0 |
| Distributions_1 | 0 |
| Distributions_2 | 0 |
| Orbit_Finder | 0 |
| Stability_code | Ligka_m4 |

Buttons for "Save Configuration", "Save and Run", "Save Configuration as", "Load Configuration", "Restore Default", "LIGKA Analysis (Testing)", "Scenario Summary Choice", and "Exit" are visible at the bottom of the EP WORKFLOW window. On the right side of the EP WORKFLOW window, there are several buttons for actor parameters: "CHEASE Parameters", "HELENA Parameters", "LIGKA Parameters", "HAGIS 1 Parameters", "HAGIS 2 Parameters", "FINDER Parameters", "Species Settings", "SCENARIO Parameters", and "IDS Merge".

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 $s = \sqrt{\text{norm_pol_flux}}$
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 $\omega_{A0} = B_0 / \sqrt{m_{\text{ion}} * n_0 \mu_0}$ on axis values
6 radiative damping, formula S.D. Pinches 2015 (to be checked)
7 local beta at gap/mode rational surface: $2.0d0 * \text{press}(s) * \mu_0 / B_{\text{tor}}(s) ** 2!$
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 $\sqrt{\epsilon / \text{shear}}$ 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: ω / ω_{A0} of next gap
33: ω / ω_{A0} of previous gap

should be filled now in **loc_TAE_mode4_00208000**

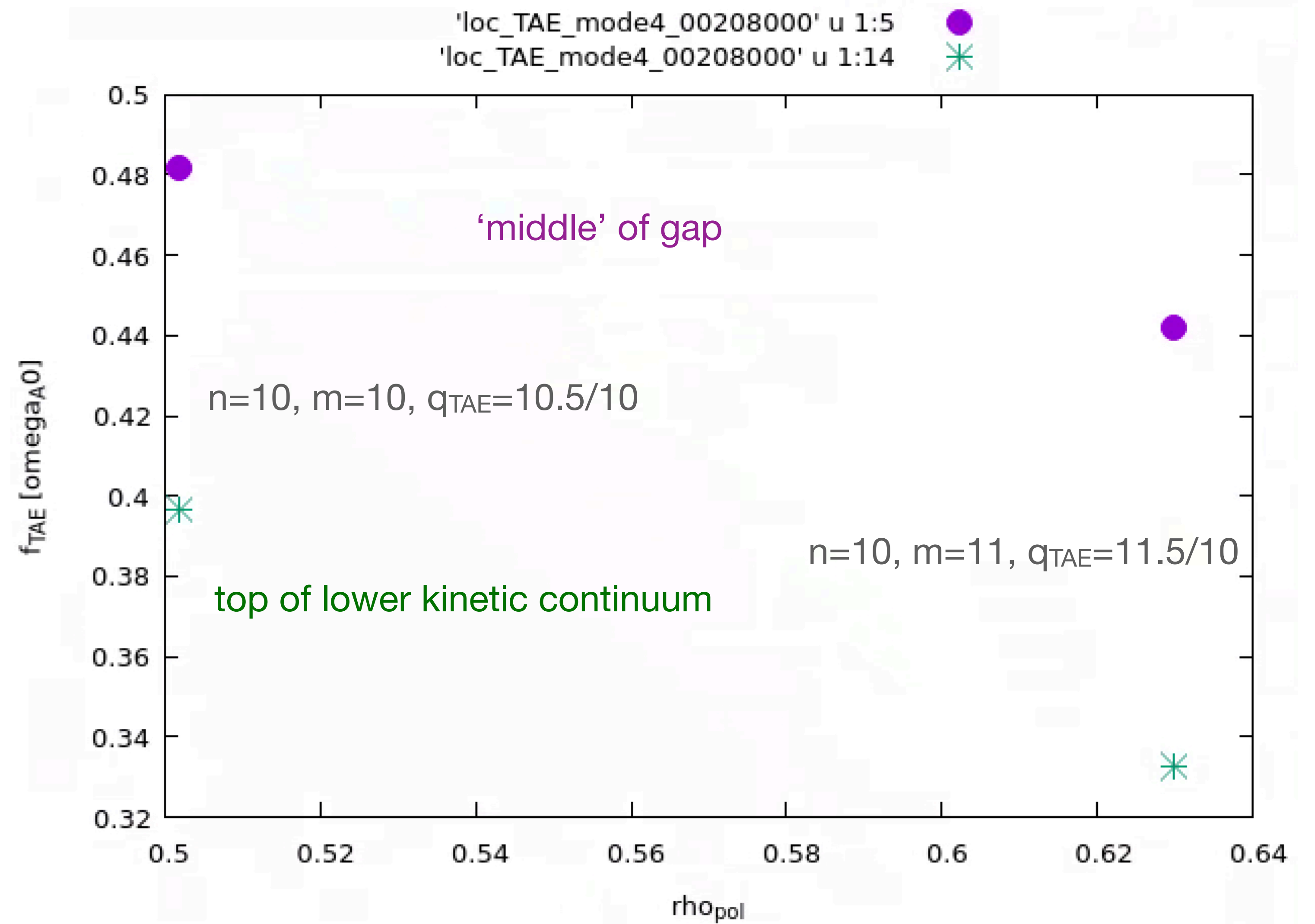
and so on in block of 4 for the next order gaps

use favourite plotting tool, or python script: (to be added)

e.g. gnuplot

plot 'loc_TAE_mode5_00208000' u 1:5

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.

LIGKA PARAMETERS

| | |
|---------------|----|
| modus | 2 |
| min_n_tor | 10 |
| max_n_tor | 10 |
| min_m | 10 |
| max_m | 11 |
| sidebands | 3 |
| sidebands_asy | 1 |
| mode_type | 1 |

EP WORKFLOW

WORKFLOW PARAMETERS

| | |
|-------------|----------|
| user | public |
| machine | ITER |
| shot_nr | 131025 |
| run_in | 34 |
| machine_out | training |
| run_out | 1 |
| itime | 0 |

ACTOR SELECTION

| | |
|-------------------------|----------|
| Equilibrium_code_chease | 0 |
| Equilibrium_code | 0 |
| Distributions_1 | 0 |
| Distributions_2 | 0 |
| Orbit_Finder | 0 |
| Stability_code | Ligka_m1 |

FURTHER SETTINGS

| | |
|----------------|--------------------------|
| ligka_541 | <input type="checkbox"/> |
| ligka_5412 | <input type="checkbox"/> |
| pulse_list | <input type="checkbox"/> |
| fast_particles | <input type="checkbox"/> |
| hdf5 | <input type="checkbox"/> |
| mpi_processes | 2 |

Buttons: Save Configuration, Save and Run, Save Configuration as, Load Configuration, Restore Default, LIGKA Analysis (Testing), Scenario Summary Choice, Exit

Buttons: CHEASE Parameters, HELENA Parameters, LIGKA Parameters, HAGIS 1 Parameters, HAGIS 2 Parameters, FINDER Parameters, Species Settings, SCENARIO Parameters, IDS Merge

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 $s = \sqrt{\text{norm_pol_flux}}$
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 $\omega_{A0} = B_0 / \sqrt{\mu_0 m_{ion} n_0}$ on axis values
6 radiative damping, formula S.D. Pinches 2015 (to be checked)
7 local beta at gap/mode rational surface: $2.0d0 * \text{press}(s) * \mu_0 / B_{tor}(s) ** 2!$
8 mode type: 0=GAM/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 $\sqrt{\epsilon / \text{shear}}$ 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: ω / ω_{A0} of next gap
33: ω / ω_{A0} of previous gap

should be filled now in glo_TAE_mode1_00208000

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

use favourite plotting tool, or python script: (to be added)

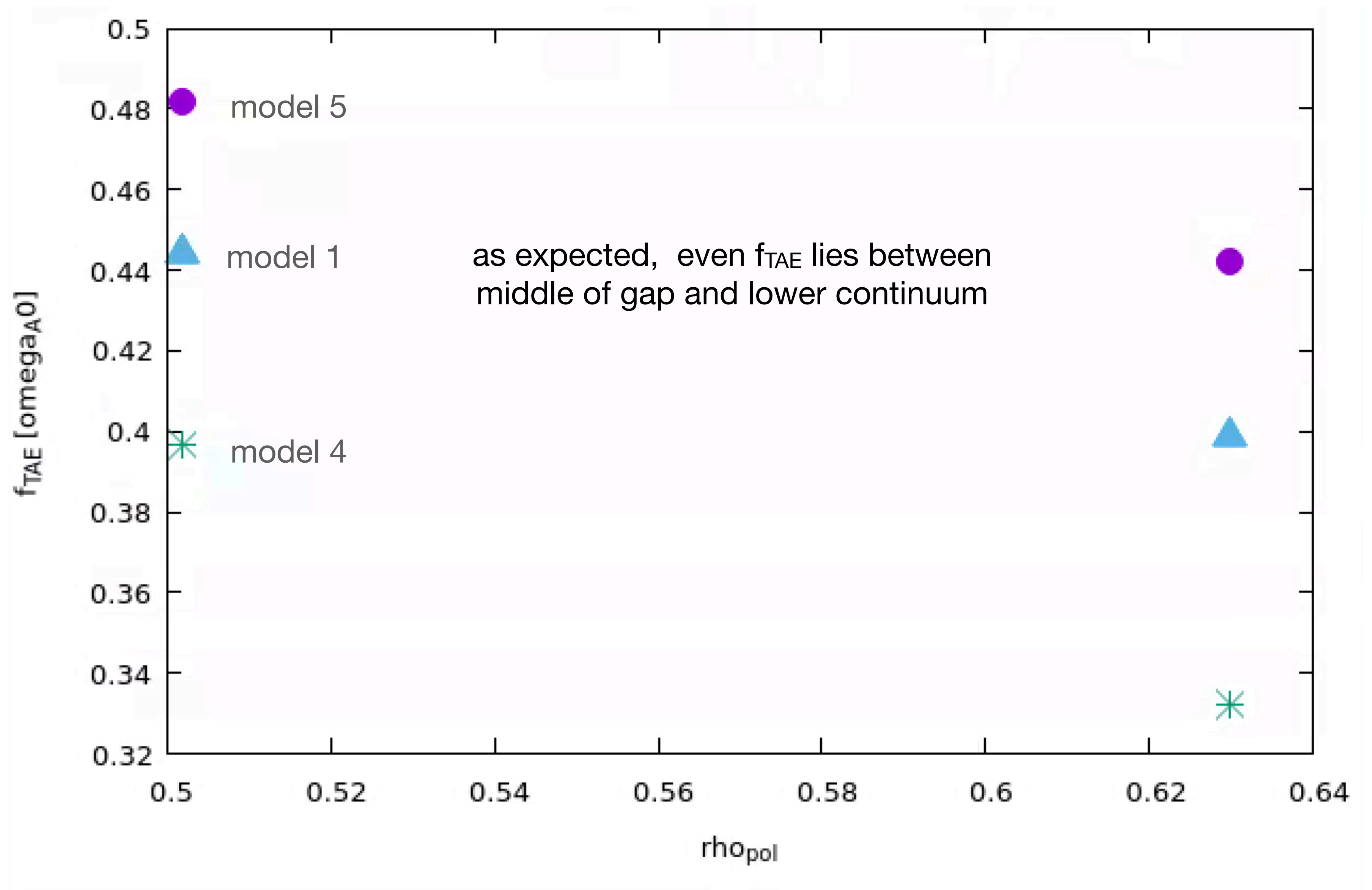
e.g. gnuplot

plot 'loc_TAE_mode5_00208000' u 1:5

try different n and m ranges...

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 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

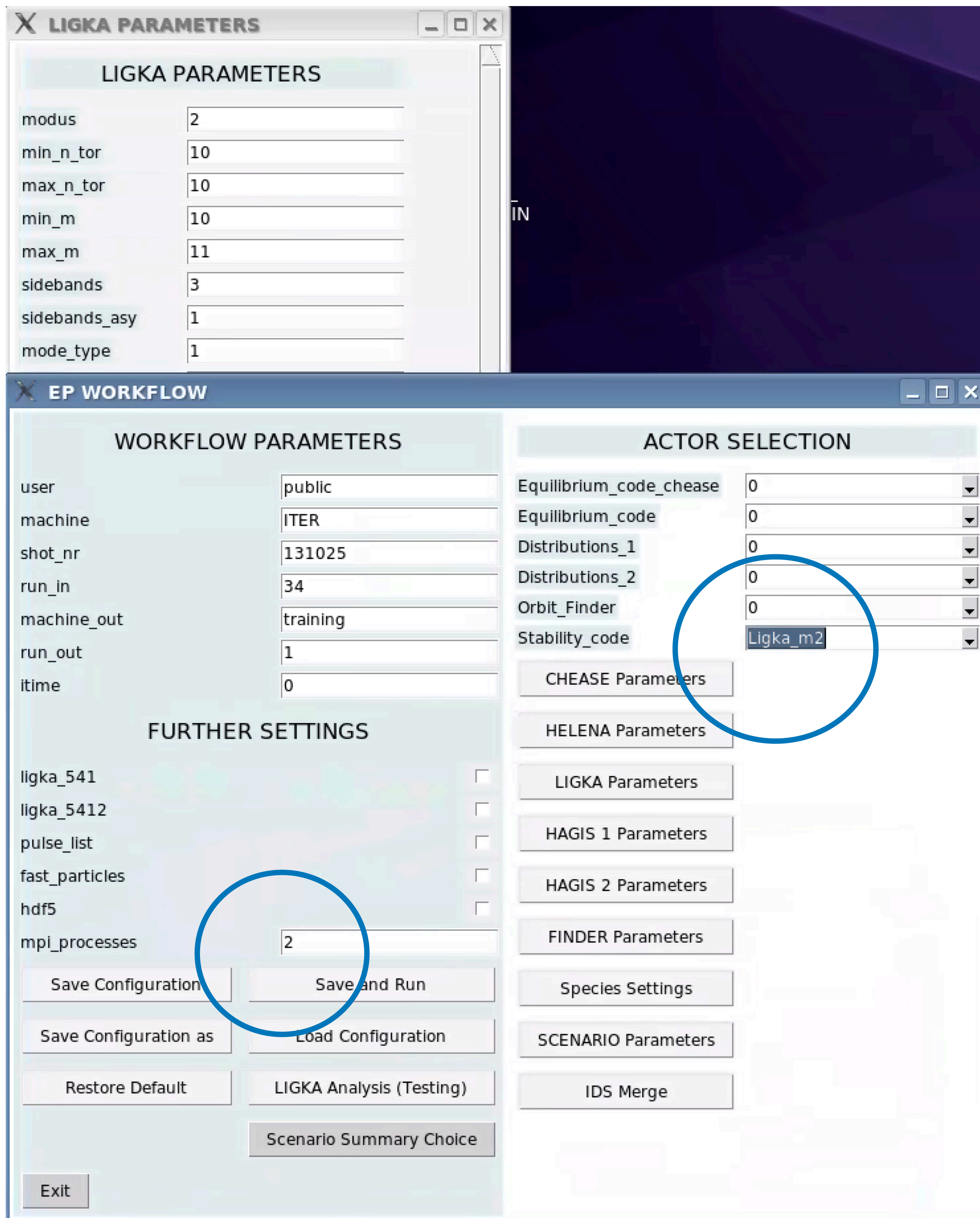
LIGKA Parameters

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 $s = \sqrt{\text{norm_pol_flux}}$
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 $\omega_{A0} = B_0 / \sqrt{\mu_0 m_{ion} n_0}$ on axis values
6 radiative damping, formula S.D. Pinches 2015 (to be checked)
7 local beta at gap/mode rational surface: $2.0d0 * \text{press}(s) * \mu_0 / B_{tor}(s) ** 2!$
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 $\sqrt{\epsilon_0 / \text{shear}}$ 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: ω / ω_{A0} of next gap
33: ω / ω_{A0} of previous gap

should be filled now in **glo_TAE_mode2_00208000**

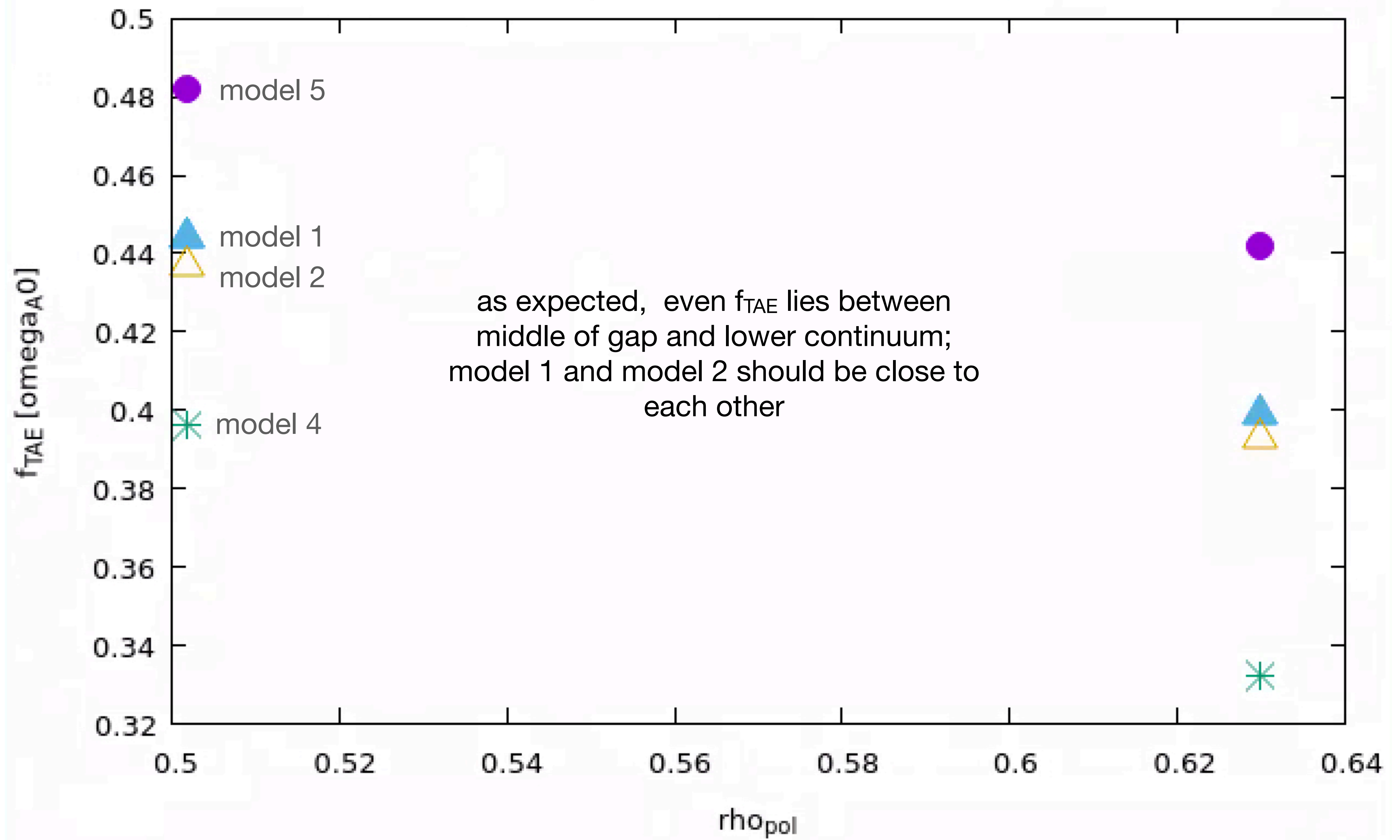
and so on in block of 4 for the next order gaps

use favourite plotting tool, or python script: (to be added)

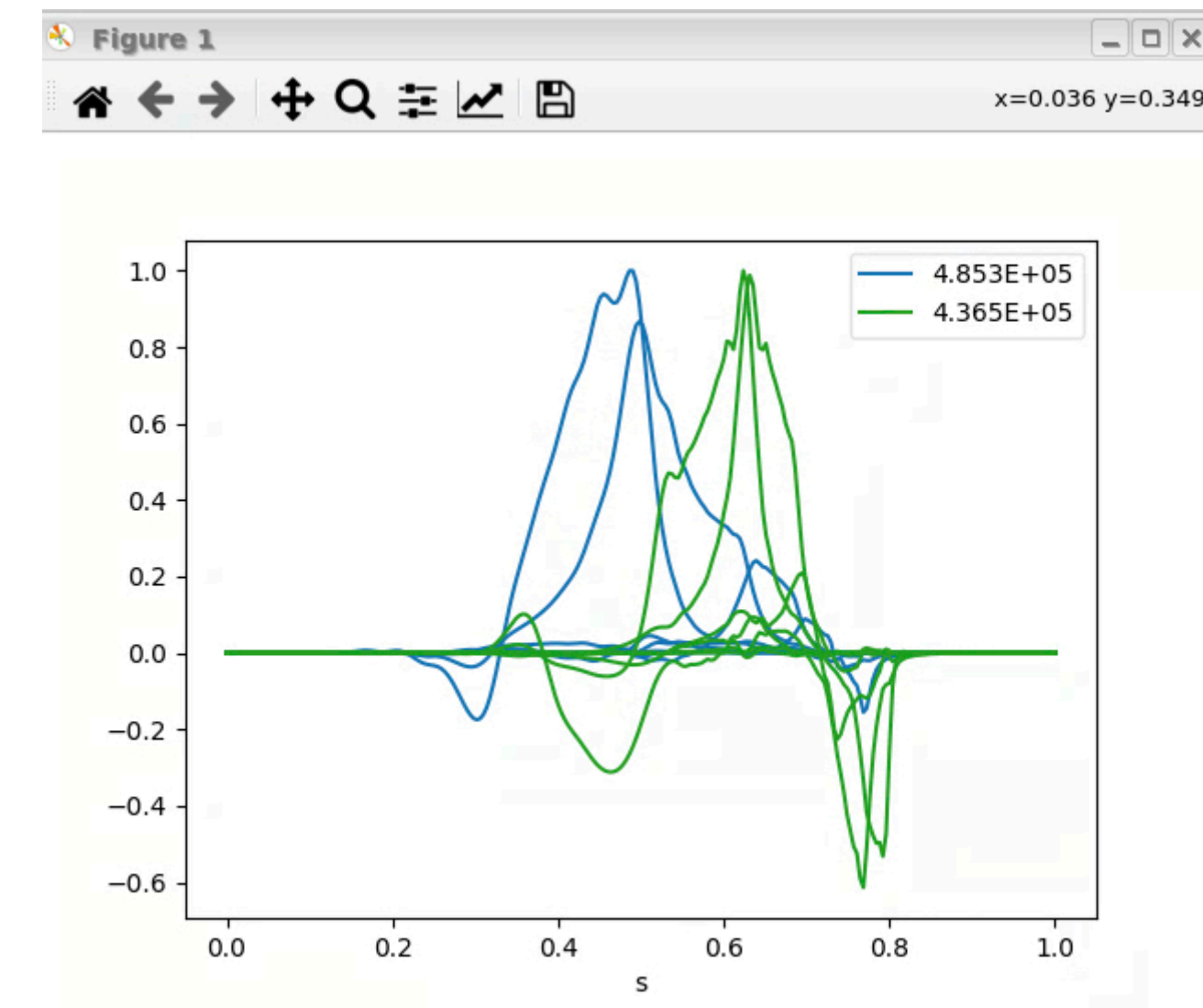
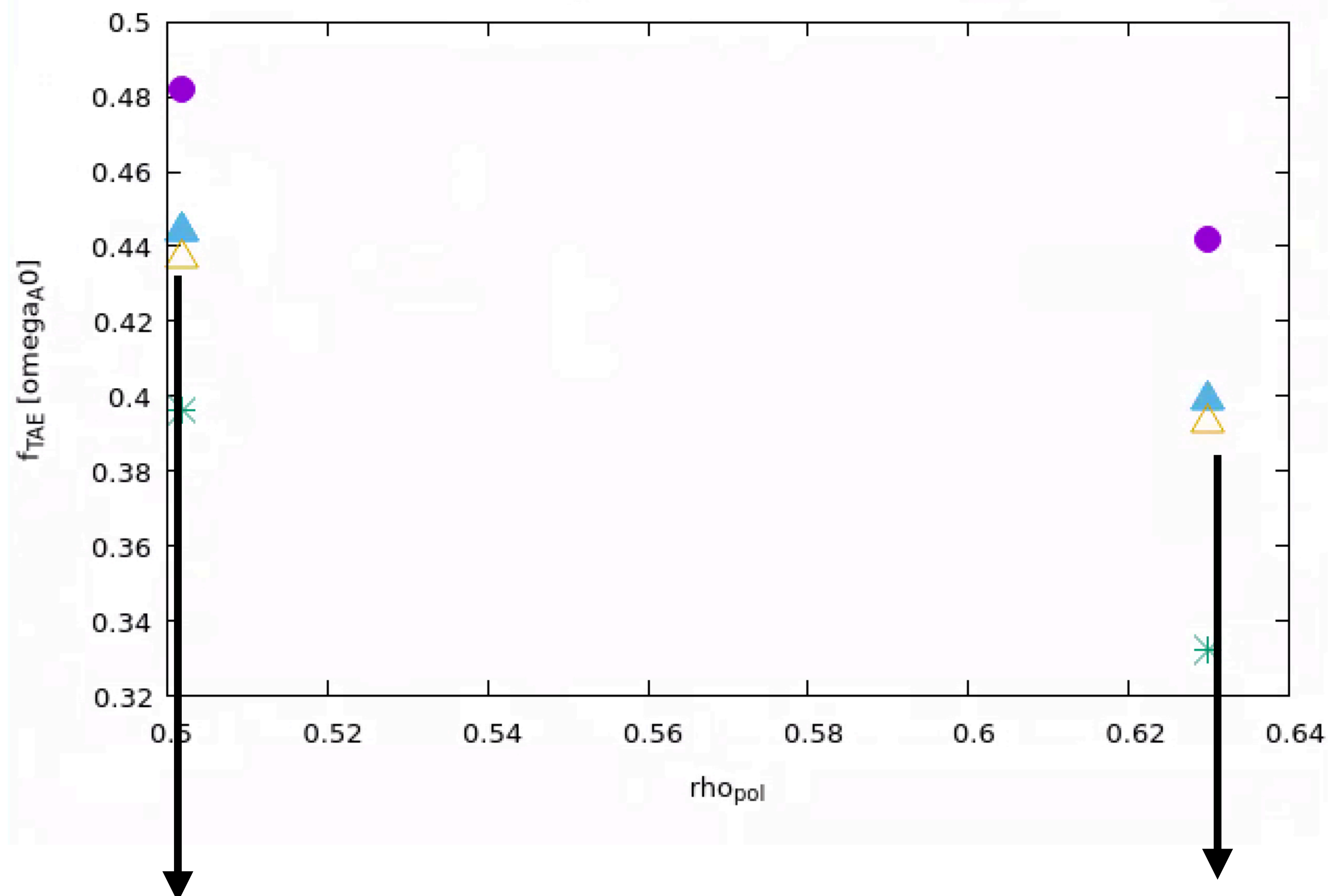
e.g. gnuplot

plot 'loc_TAE_mode5_00208000' u 1:5

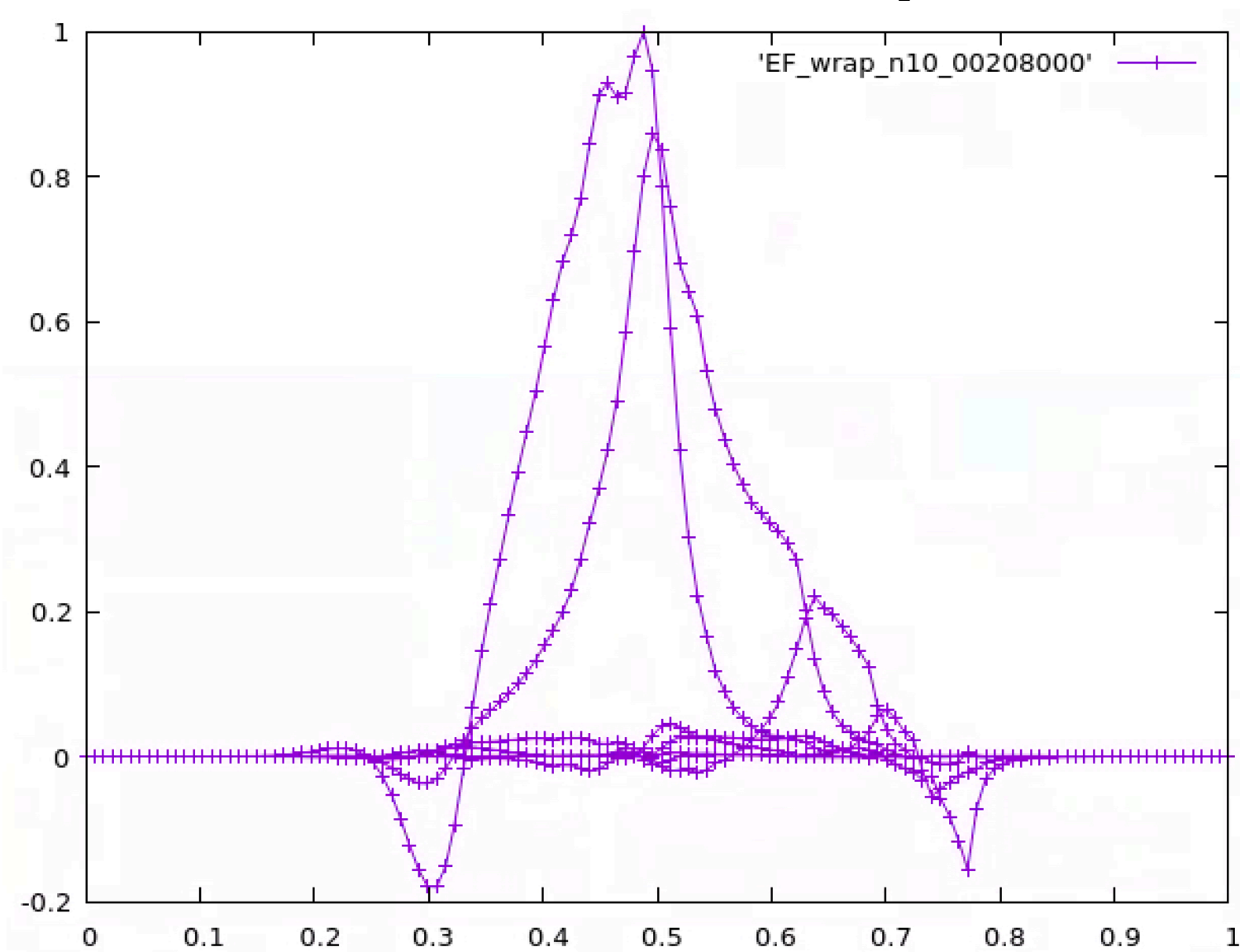
try different n and m ranges...



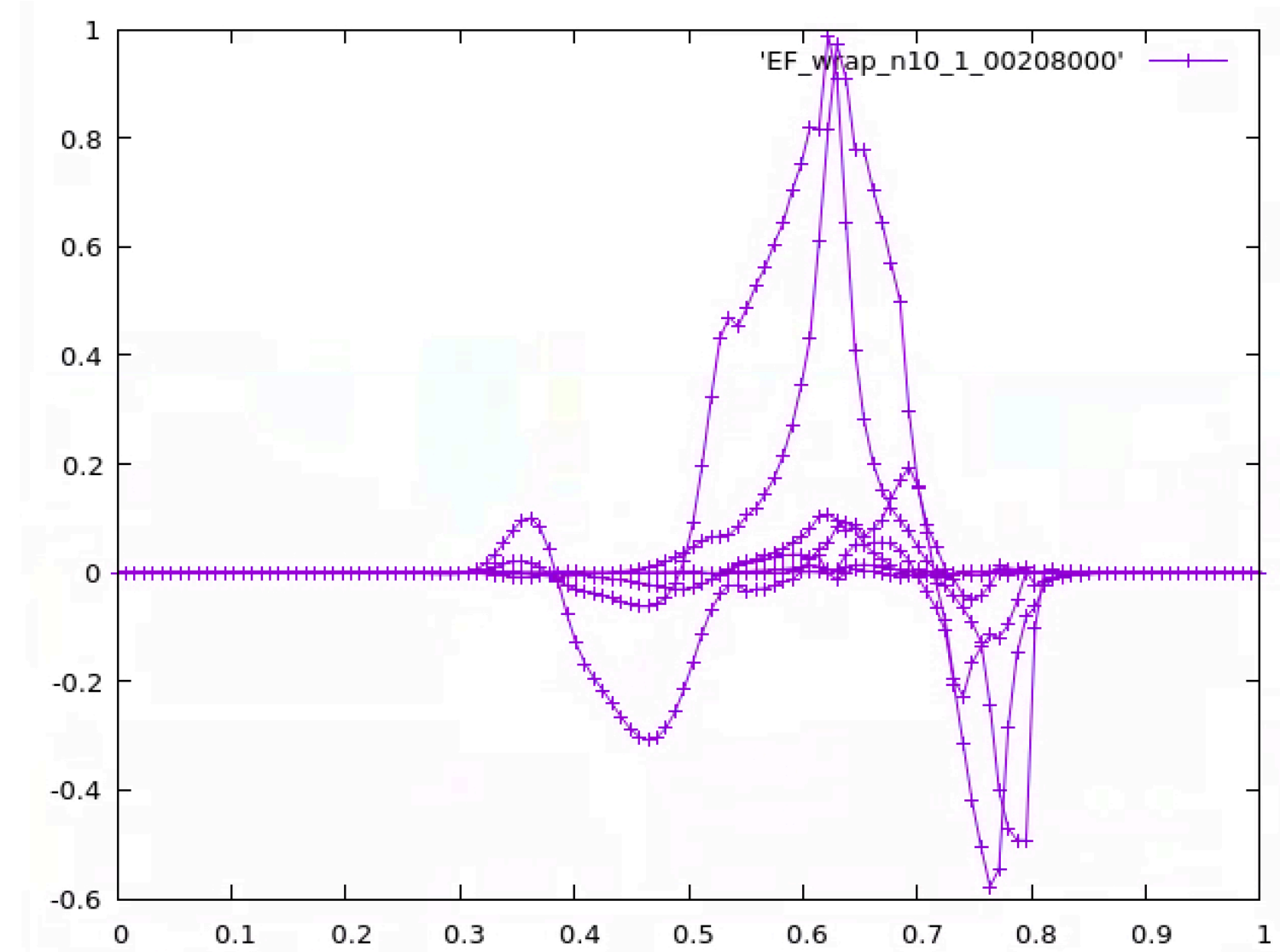
```
plot 'loc_TAE_mode4_00208000' u 1:5 ps 2 pt 7, 'loc_TAE_mode4_00208000' u 1:14 ps 2 pt 3,  
'glo_TAE_mode1_00208000' u 1:16 ps 3 pt 9, 'glo_TAE_mode2_00208000' u 1:20 ps 3 pt 8
```



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



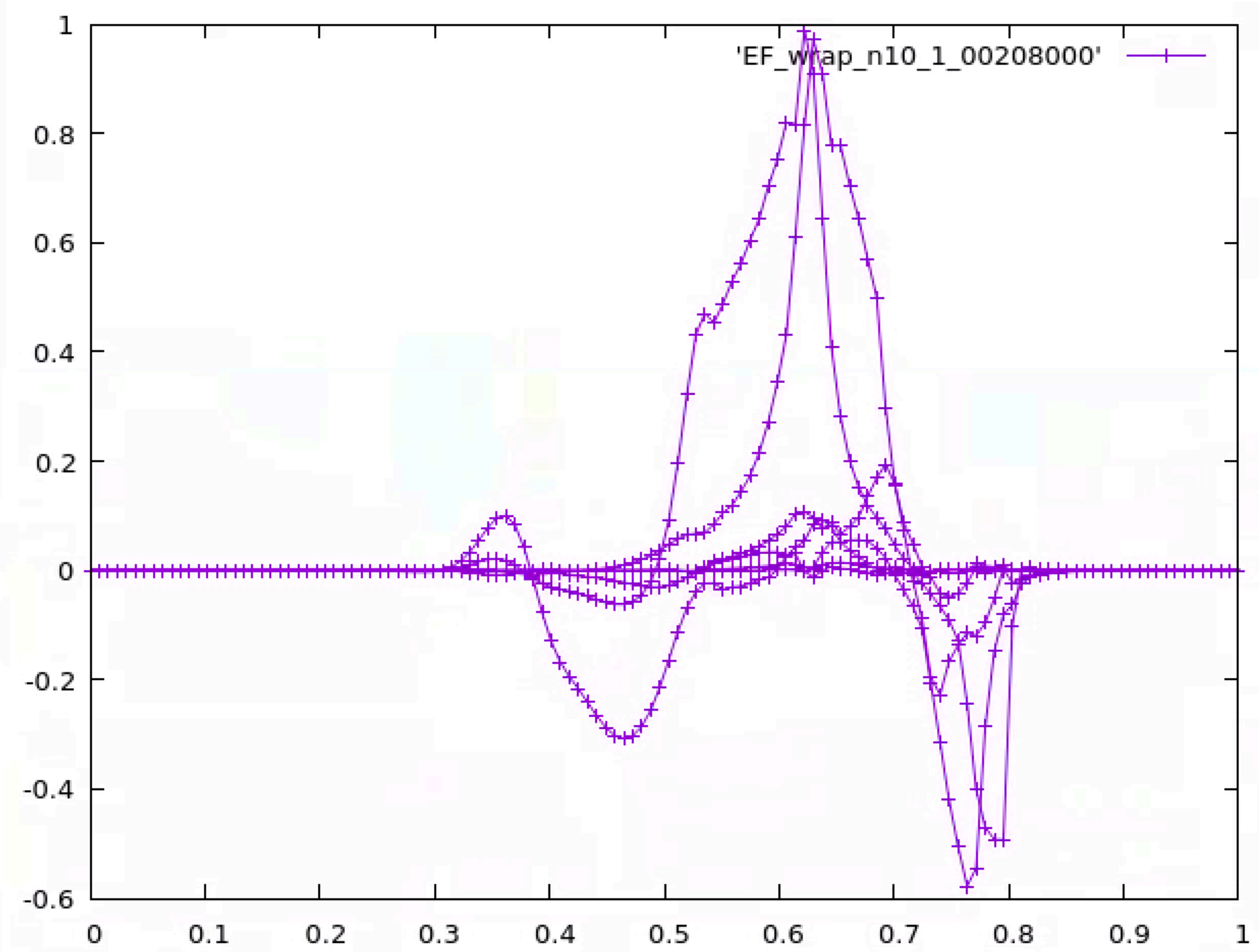
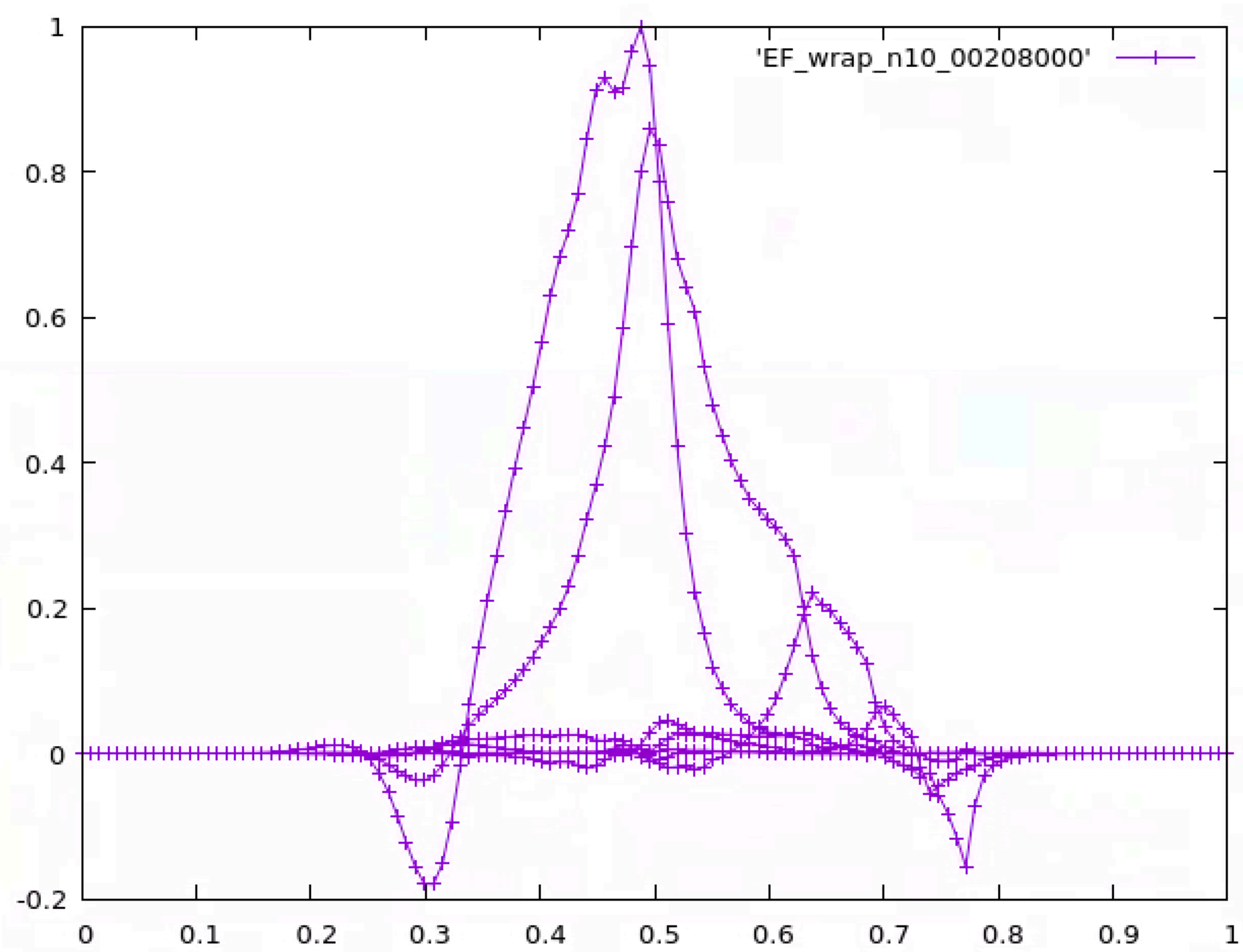
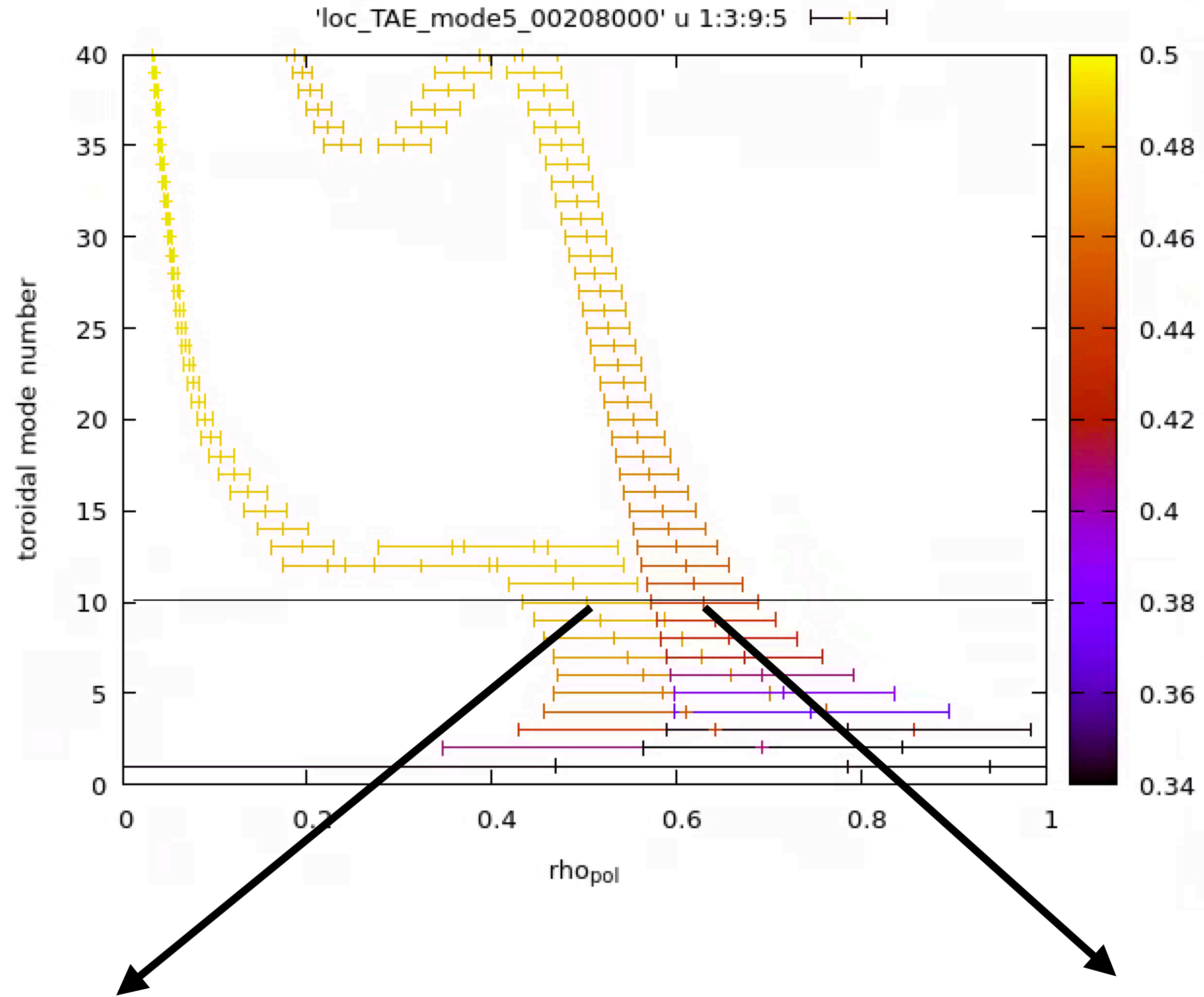
plot 'EF_wrap_n10_00208000' w lp



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



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: $s = \sqrt{\text{norm_pol_flux}}$

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 VWF;
- 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

The screenshot displays the EP WORKFLOW software interface, which is divided into several sections for configuring simulation parameters.

LIGKA PARAMETERS (top left):

| | |
|---------------|----|
| modus | 2 |
| min_n_tor | 10 |
| max_n_tor | 10 |
| min_m | 10 |
| max_m | 11 |
| sidebands | 3 |
| sidebands_asy | 1 |
| mode_type | 1 |

WORKFLOW PARAMETERS (middle left):

| | |
|-------------|----------|
| user | public |
| machine | ITER |
| shot_nr | 131025 |
| run_in | 34 |
| machine_out | training |
| run_out | 1 |
| itime | 0 |

FURTHER SETTINGS (bottom left):

| | |
|----------------|-------------------------------------|
| ligka_541 | <input type="checkbox"/> |
| ligka_5412 | <input checked="" type="checkbox"/> |
| pulse_list | <input type="checkbox"/> |
| fast_particles | <input type="checkbox"/> |
| hdf5 | <input type="checkbox"/> |
| mpi_processes | 2 |

ACTOR SELECTION (top right):

| | |
|-------------------------|---|
| Equilibrium_code_chease | 0 |
| Equilibrium_code | 0 |
| Distributions_1 | 0 |
| Distributions_2 | 0 |
| Orbit_Finder | 0 |
| Stability_code | 0 |

Buttons and Options:

- CHEASE Parameters
- HELENA Parameters
- LIGKA Parameters
- HAGIS 1 Parameters
- HAGIS 2 Parameters
- FINDER Parameters
- SCENARIO Parameters
- IDS Merge

Workflow Control Buttons:

- Save Configuration
- Save Configuration as
- Restore Default
- Load Configuration
- LIGKA Analysis (Testing)
- Scenario Summary Choice
- Exit

A blue circle highlights the 'ligka_5412' checkbox and the 'LIGKA Parameters' button. A tooltip for the 'mpi_processes' field reads: "How many MPI processes to use for the MPI actors."

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/relevant' 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>
```

1 mode:
(10,10)

```
<min_n_tor>10</min_n_tor>  
<max_n_tor>10</max_n_tor>  
  <min_m>10</min_m>  
  <max_m>11</max_m>
```

2 modes:
(10,10); (10,11)

```
<min_n_tor>10</min_n_tor>  
<max_n_tor>11</max_n_tor>  
  <min_m>10</min_m>  
  <max_m>10</max_m>
```

2 modes:
(10,10)
(11,11)

```
<min_n_tor>10</min_n_tor>  
<max_n_tor>11</max_n_tor>  
  <min_m>10</min_m>  
  <max_m>11</max_m>
```

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: $s = \sqrt{\text{norm_pol_flux}}$

col 2: ω/ω_{A0}

col 4: f[kHz]

col 8: $s = \sqrt{\text{norm_tor_flux}}$

EP WORKFLOW

WORKFLOW PARAMETERS

user: public
machine: ITER
shot_nr: 131025
run_in: 34
machine_out: training
run_out: 3
itime: 0

FURTHER SETTINGS

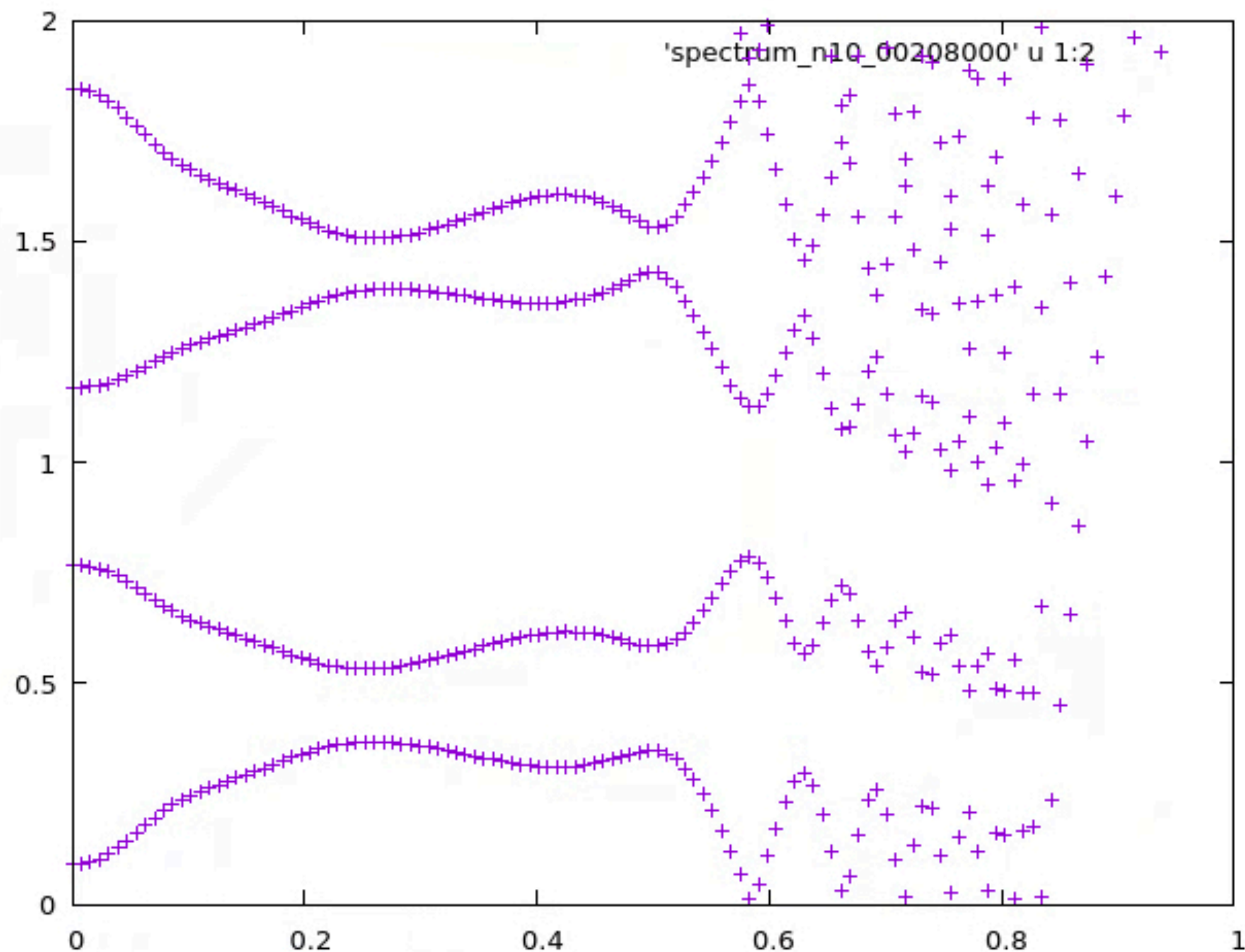
ligka_541:
ligka_5412:
pulse_list:
fast_particles:
hdf5:
mpi_processes: 1

ACTOR SELECTION

Equilibrium_code_chease: 0
Equilibrium_code: 0
Distributions_1: 0
Distributions_2: 0
Orbit_Finder: 0
Stability_code: Ligka_m6

CHEASE Parameters
HELENA Parameters
LIGKA Parameters
HAGIS 1 Parameters
HAGIS 2 Parameters
FINDER Parameters
Species Settings
SCENARIO Parameters
IDS Merge

Save Configuration Save and Run
Save Configuration as Load Configuration
Restore Default Scenario Summary Choice
Exit



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:

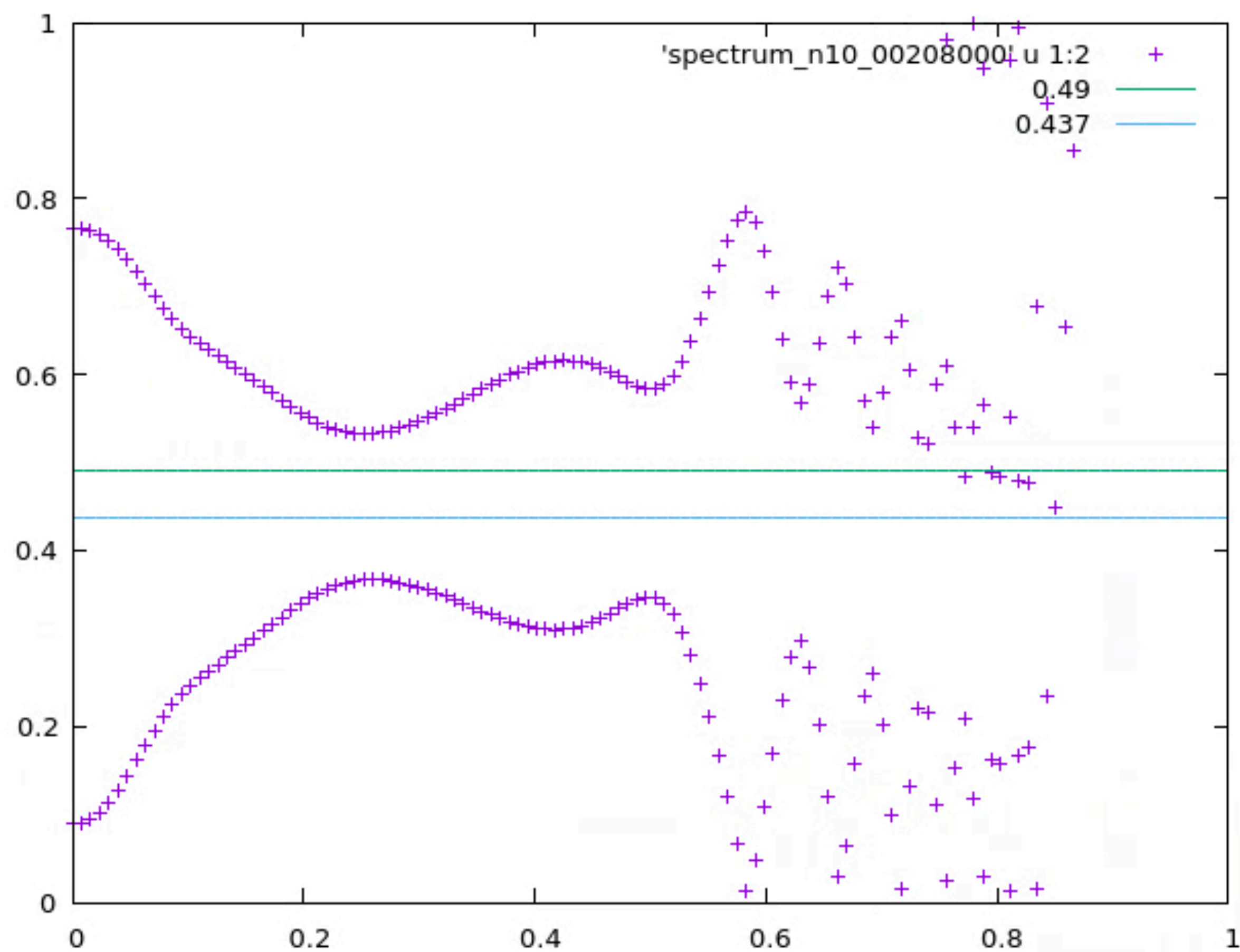
spectrum_n10_<time_str>

col 1: $s = \sqrt{\text{norm_pol_flux}}$

col 2: ω/ω_{A0}

col 4: f[kHz]

col 8: $s = \sqrt{\text{norm_tor_flux}}$



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 $(0.0,0.01)$ ω_{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 \pm 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:

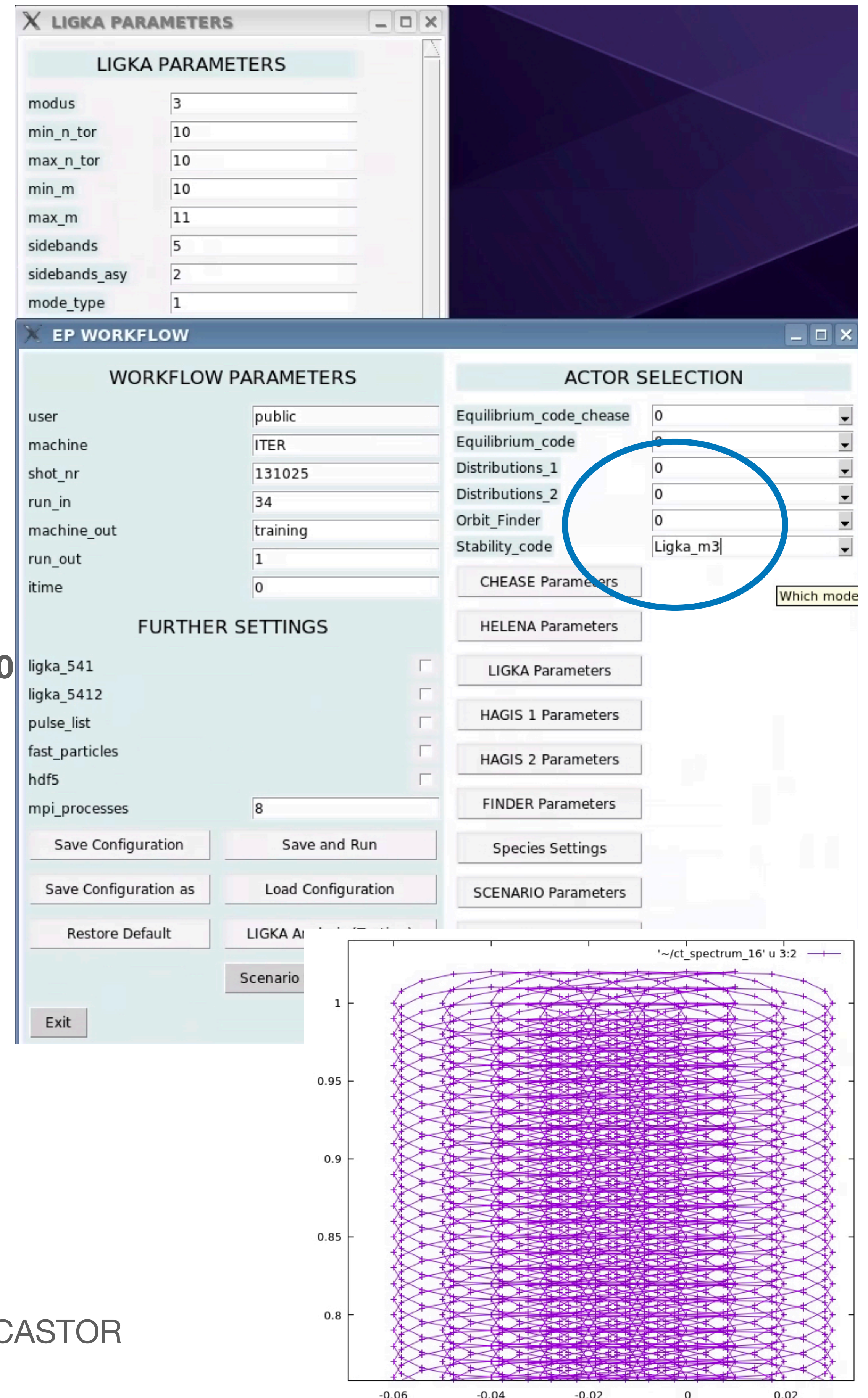
`kin_spectrum_n10_<time_str>`

col 1: $s=\sqrt{\text{norm_pol_flux}}$

col 2: $\text{Re}(\omega)/\omega_{A0}$

col 3: $\text{Im}(\omega)/\omega_{A0}$

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 are skipped

default values: start at $\omega=(1.0,-0.04)$ to $(0.0,0.01)$ ω_{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 \pm 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:

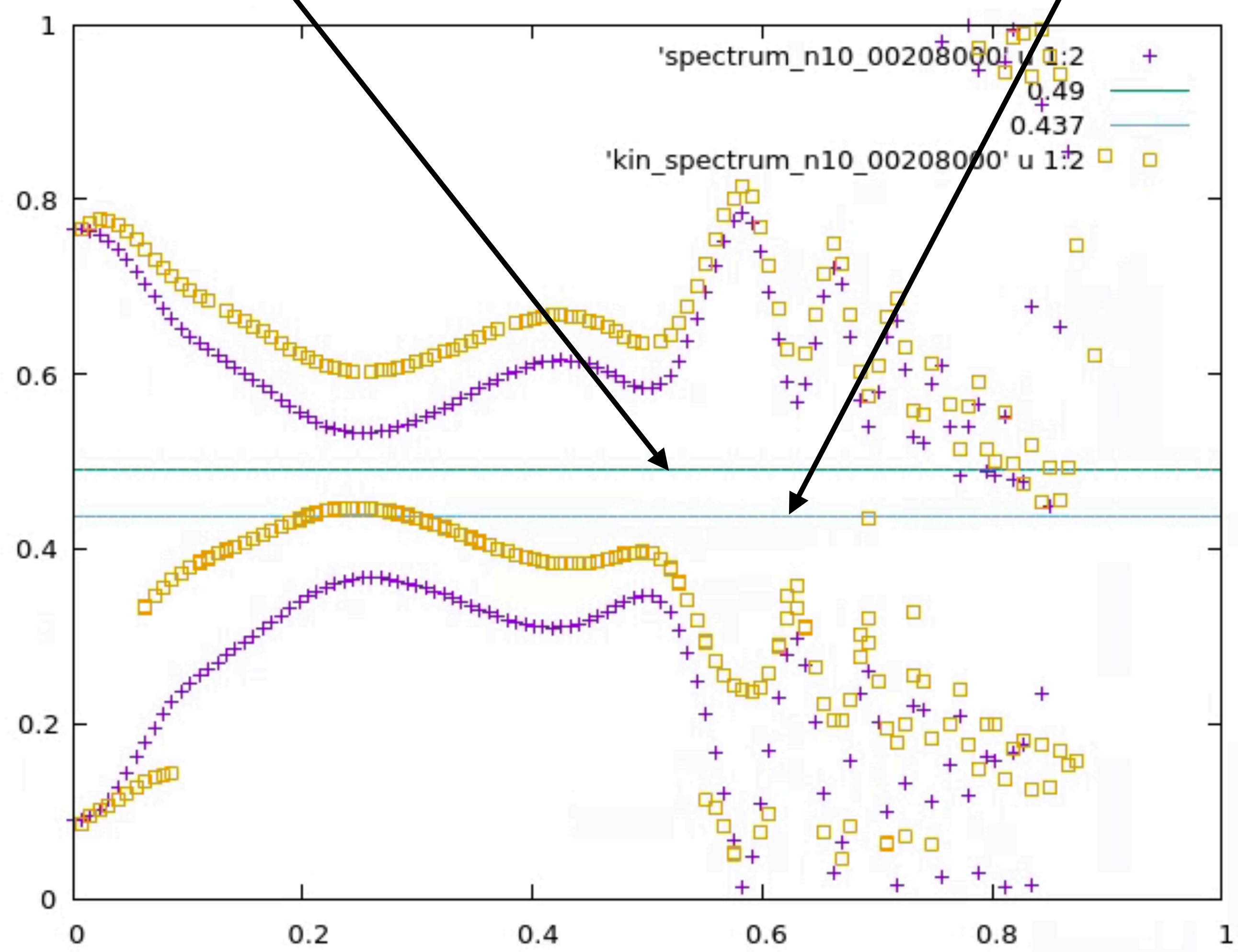
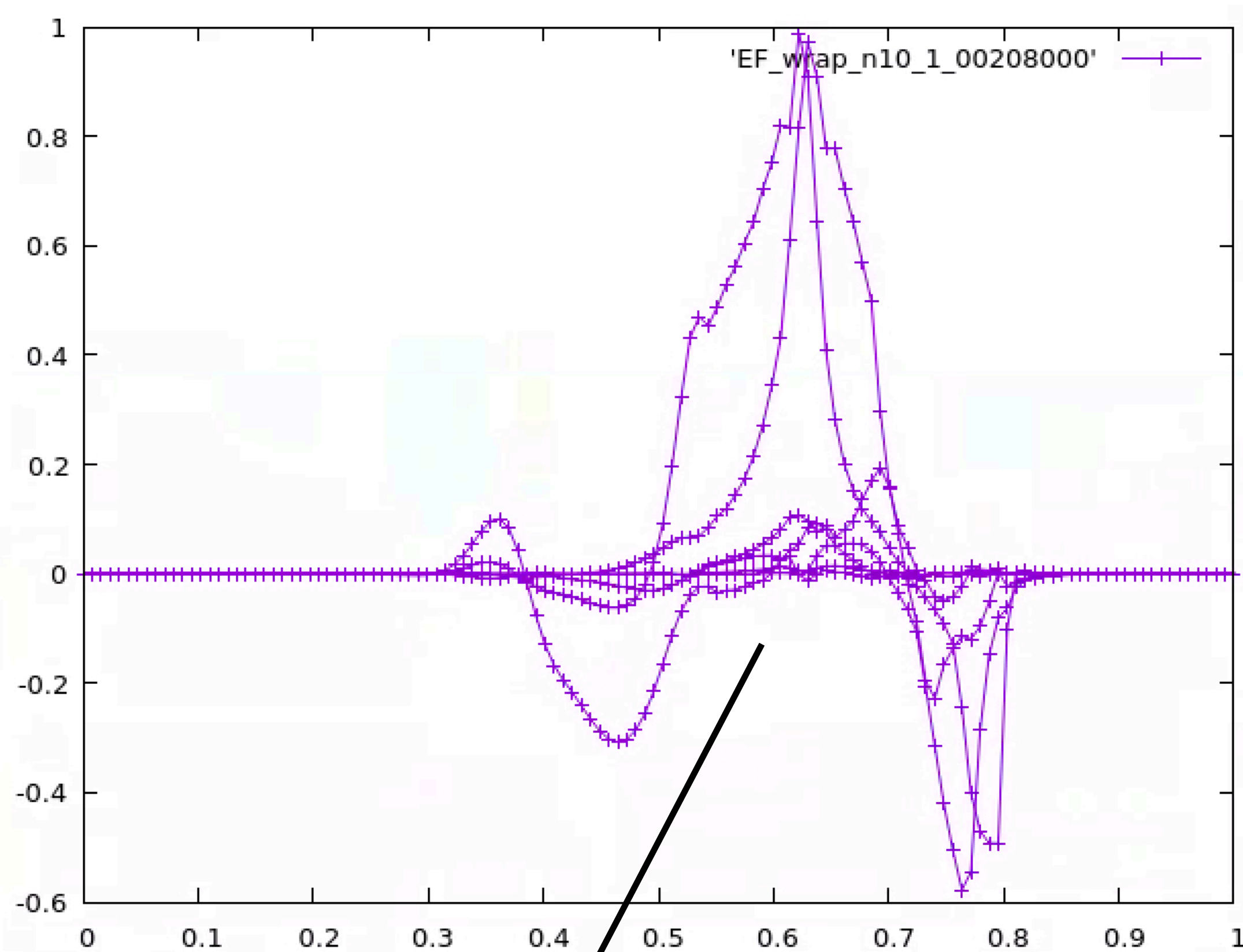
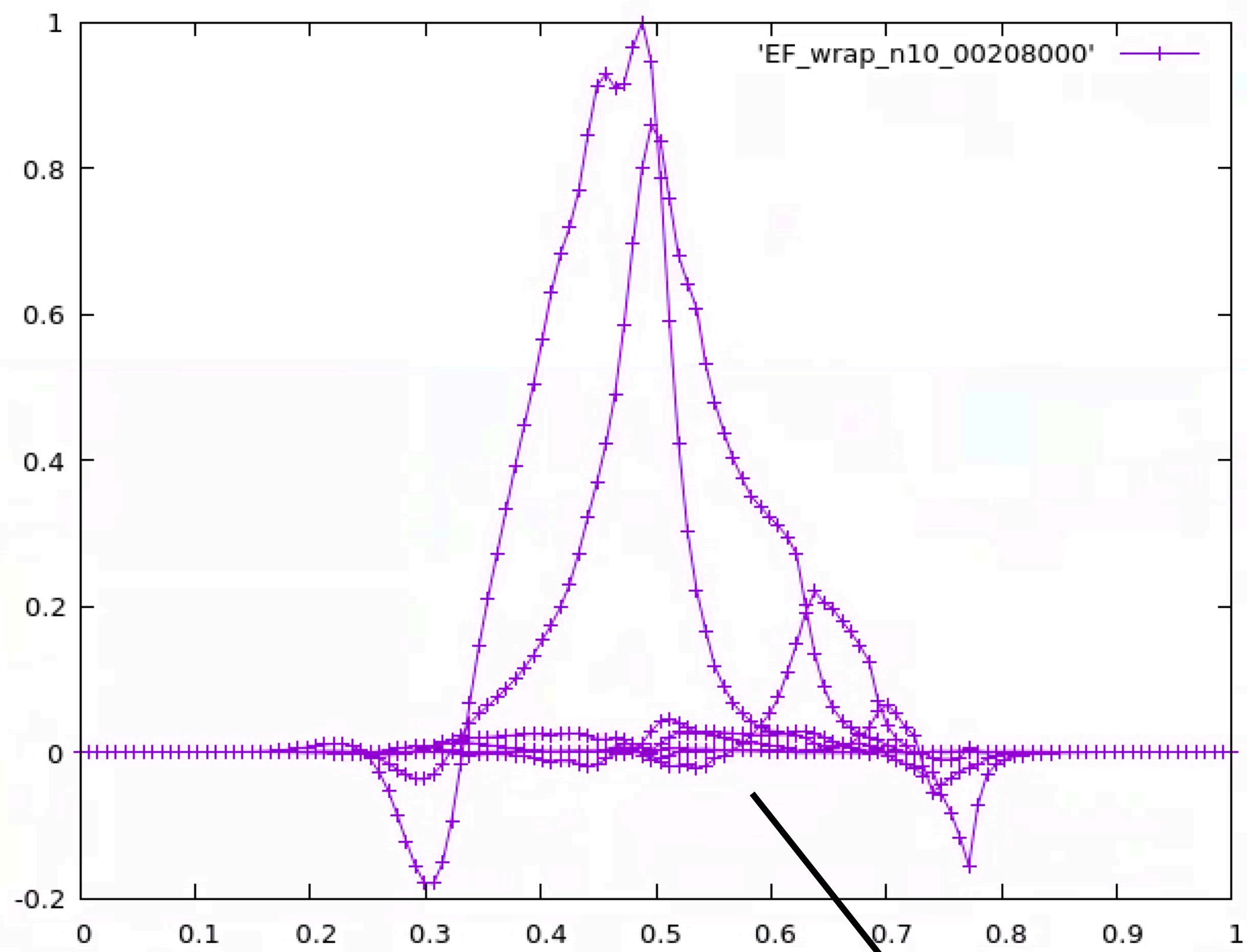
col 1: $s=\sqrt{\text{norm_pol_flux}}$

col 2: $\text{Re}(\omega)/\omega_{A0}$

col 3: $\text{Im}(\omega)/\omega_{A0}$

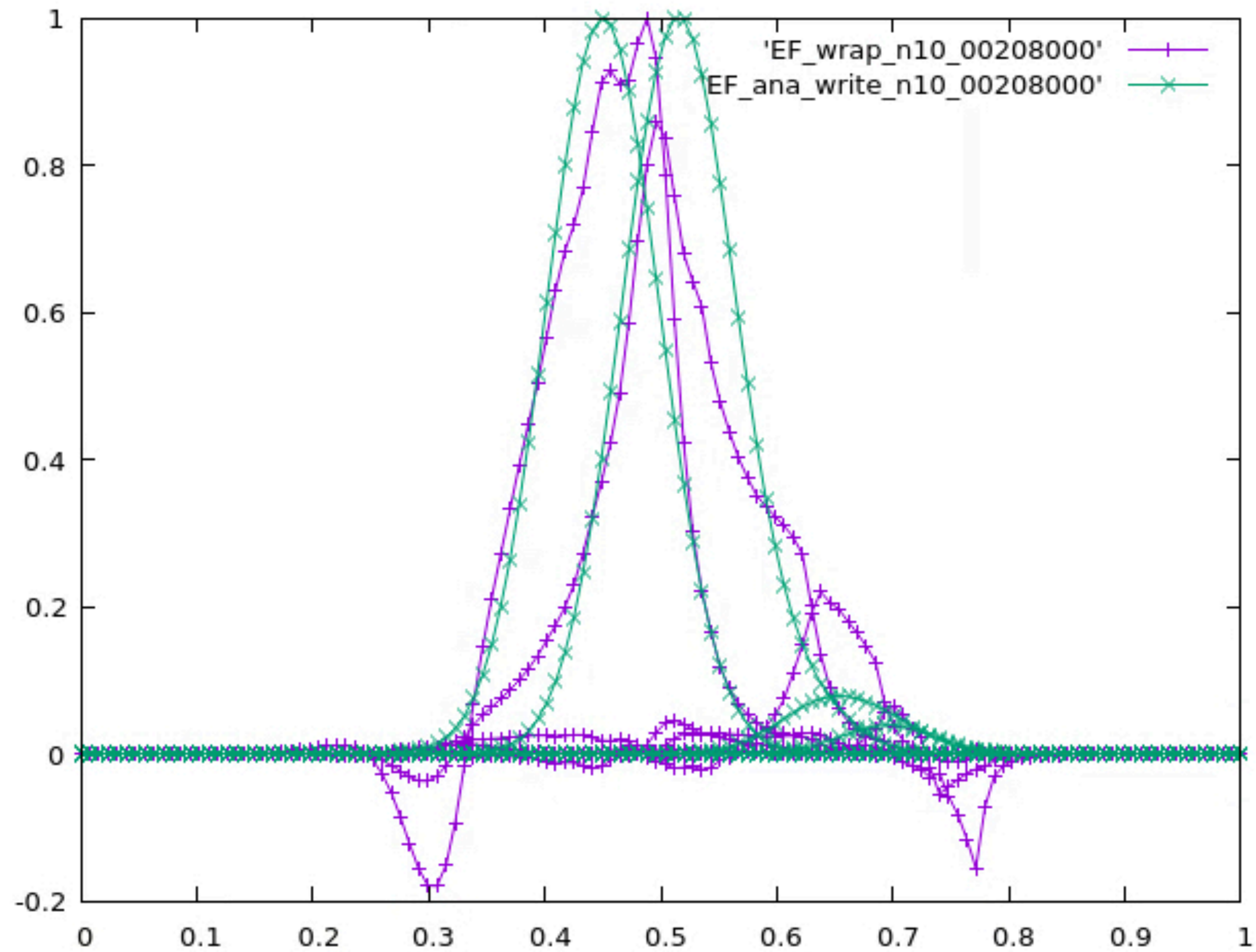
| | |
|-------------|-----------------------------------|
| mode_type | <input type="text" value="1"/> |
| even | <input type="text" value="0"/> |
| cocp | <input type="text" value="1"/> |
| start_pos | <input type="text" value="1"/> |
| guess_start | <input type="text" value="0.7"/> |
| guess_end | <input type="text" value="0.1"/> |
| offset_d | <input type="text" value="0.04"/> |
| d_guess | <input type="text" value="0.01"/> |

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



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]

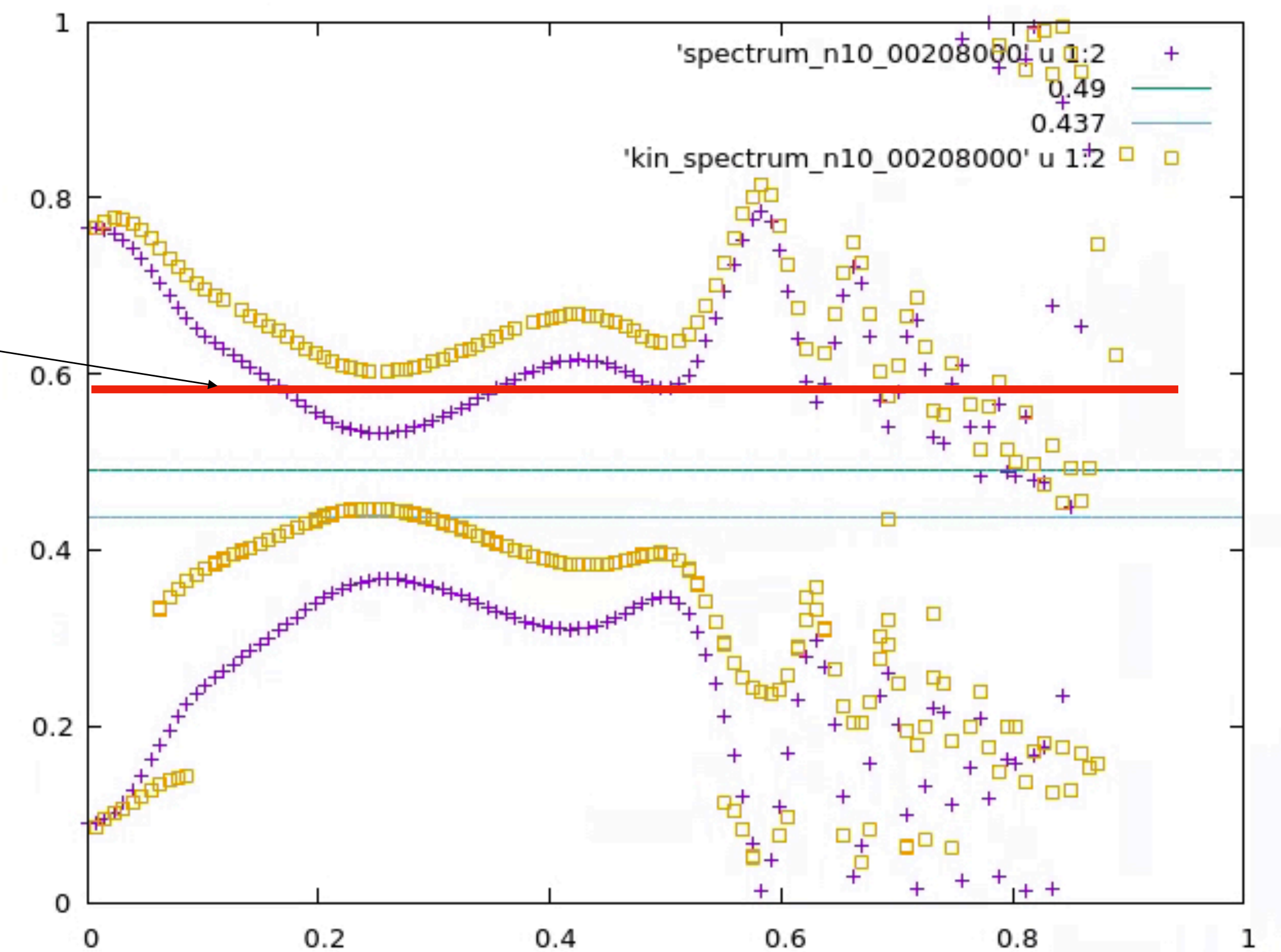
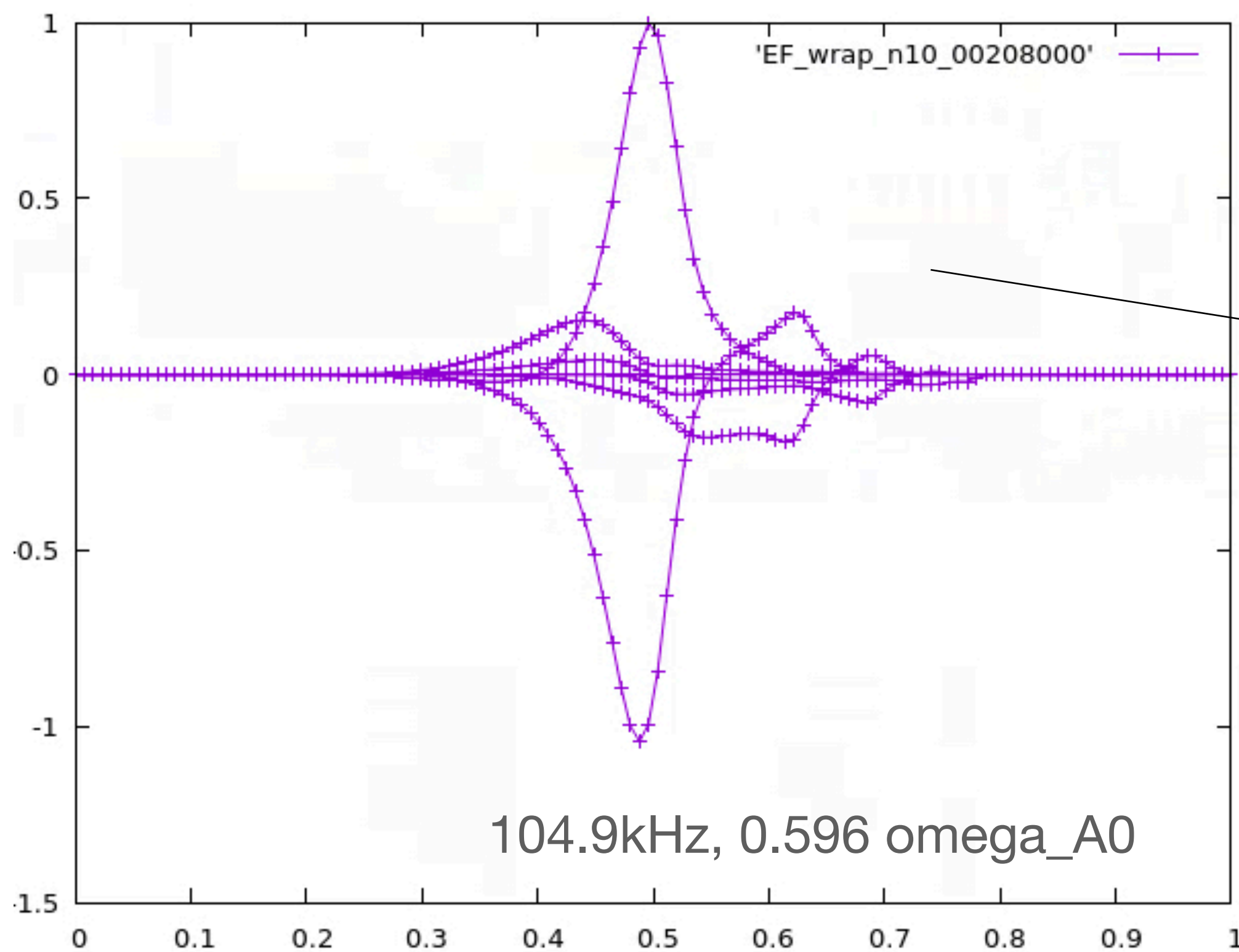
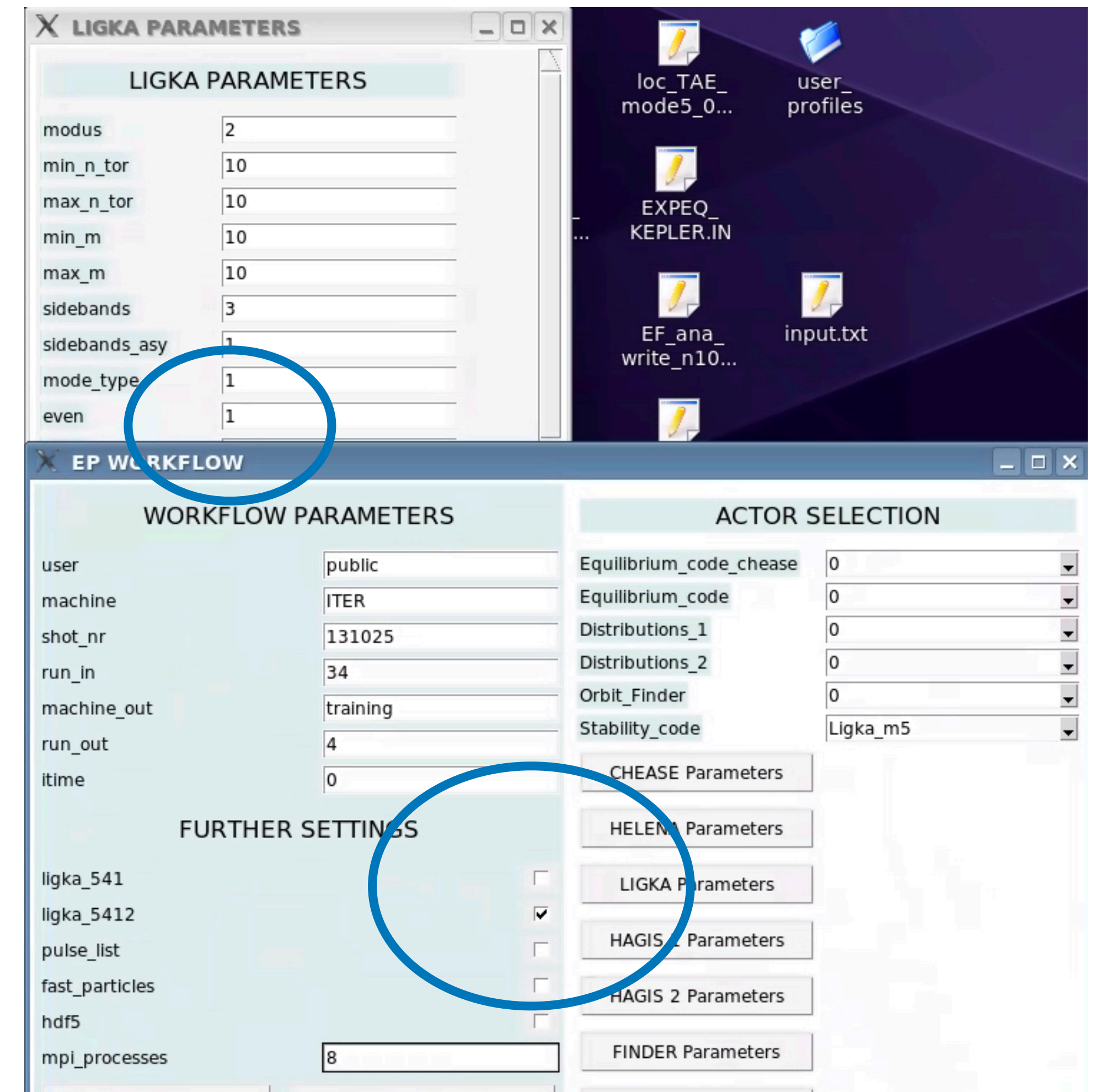
other types of modes: odd TAEs

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 one type of mode, as set in mode_type)

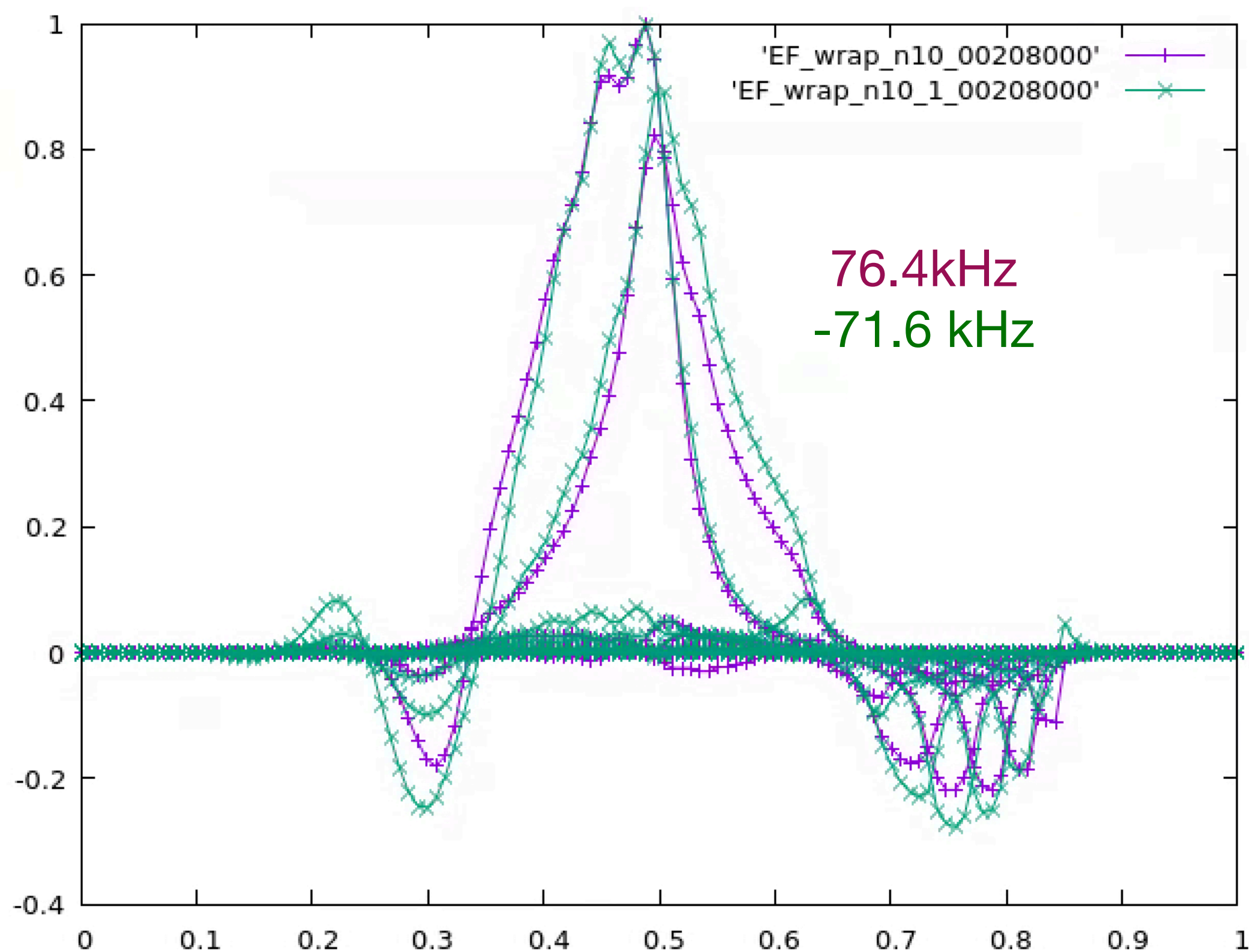
cocp: 2 (calculate both co/cp propagating modes)

default: 1

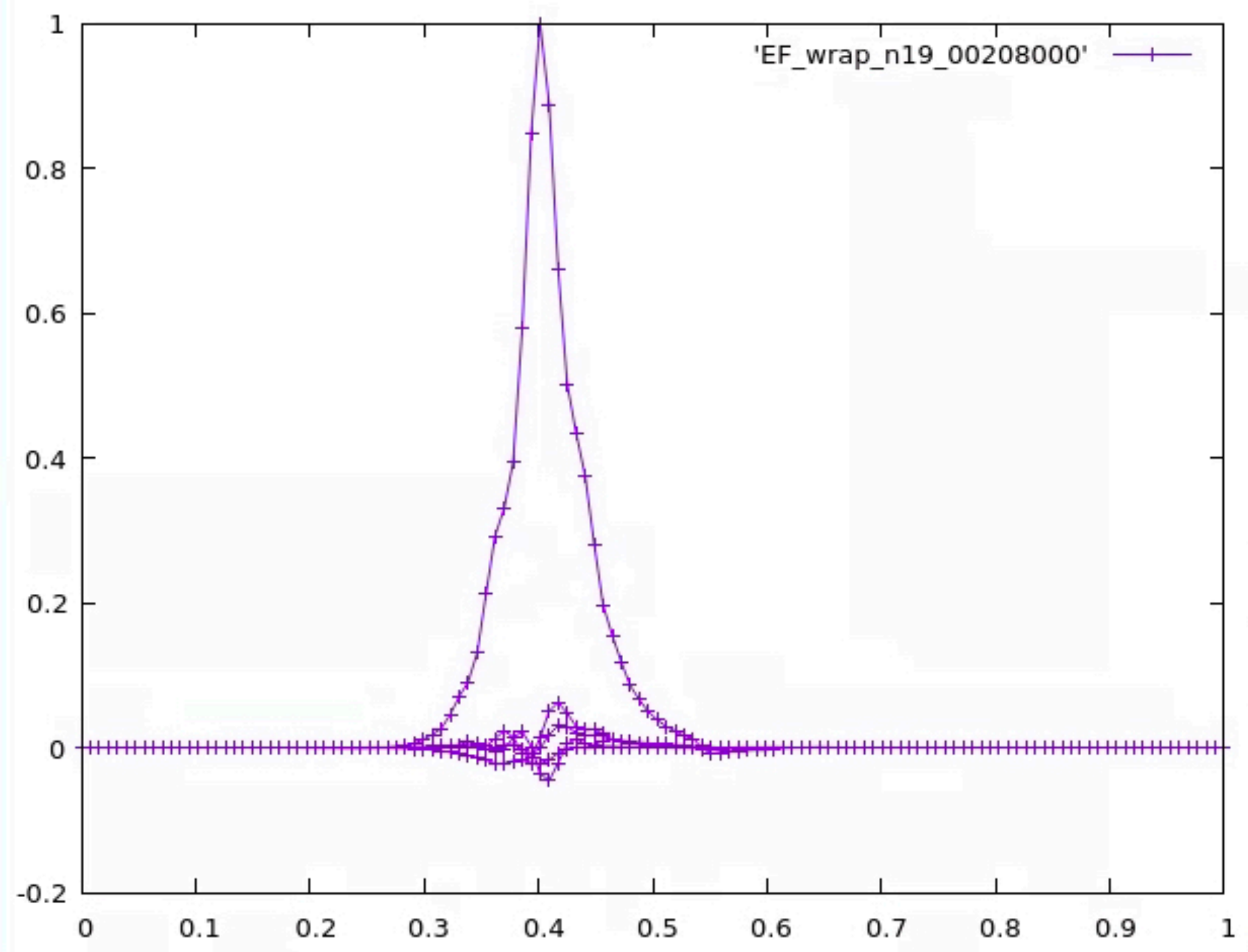
mode frequencies are positive for co-propagating modes

mode frequencies are negative for counter-propagating modes

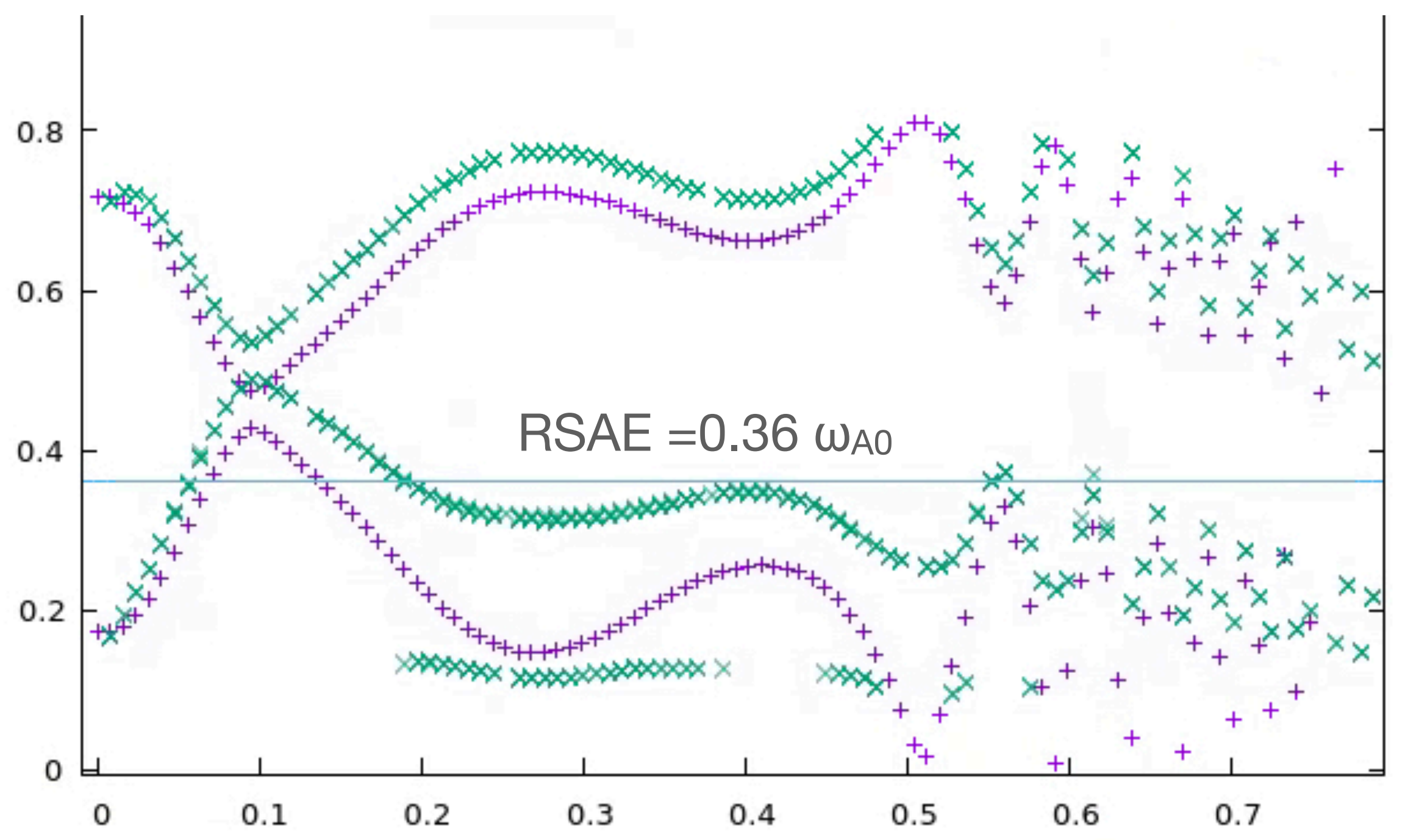
The image shows two software windows. The top window, titled 'LIGKA PARAMETERS', contains a list of parameters: modus (4), min_n_tor (10), max_n_tor (10), min_m (10), max_m (10), sidebands (5), sidebands_asym (2), mode_type (-1), even (0), and cocp (2). A blue circle highlights the 'mode_type' field. The bottom window, titled 'EP WORKFLOW', is divided into three sections: 'WORKFLOW PARAMETERS' (user: public, machine: ITER, shot_nr: 131025, run_in: 34, machine_out: training, run_out: 2, itime: 0), 'FURTHER SETTINGS' (checkboxes for ligka_541, ligka_5412, pulse_list, fast_particles, hdf5, and mpi_processes: 8), and 'ACTOR SELECTION' (dropdowns for Equilibrium_code_chease: Cheese, Equilibrium_code: Helena, Distributions_1: 0, Distributions_2: 0, Orbit_Finder: 0, Stability_code: 0, and buttons for various parameter sets like CHEASE, HELENA, LIGKA, HAGIS 1/2, FINDER, SPECIES, SCENARIO, and IDS Merge).



| | |
|---------------|----|
| 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....

| WORKFLOW PARAMETERS | | ACTOR SELECTION | |
|-------------------------|-------------------------------------|-------------------------|----------|
| user | public | Equilibrium_code_chease | Chease |
| machine | ITER | Equilibrium_code | Helena |
| shot_nr | 131025 | Distributions_1 | 0 |
| run_in | 34 | Distributions_2 | 0 |
| machine_out | training | Orbit_Finder | 0 |
| run_out | 5 | Stability_code | Ligka_m5 |
| itime | 0 | CHEASE Parameters | |
| FURTHER SETTINGS | | HELENA Parameters | |
| ligka_541 | <input type="checkbox"/> | LIGKA Parameters | |
| ligka_5412 | <input checked="" type="checkbox"/> | HAGIS 1 Parameters | |
| pulse_list | <input type="checkbox"/> | HAGIS 2 Parameters | |
| fast_particles | <input type="checkbox"/> | FINDER Parameters | |
| hdf5 | <input type="checkbox"/> | Species Settings | |
| mpi_processes | 8 | SCENARIO Parameters | |
| Save Configuration | Save and Run | IDS Merge | |
| Save Configuration as | Load Configuration | | |
| Restore Default | LIGKA Analysis (Testing) | | |
| Scenario Summary Choice | | | |

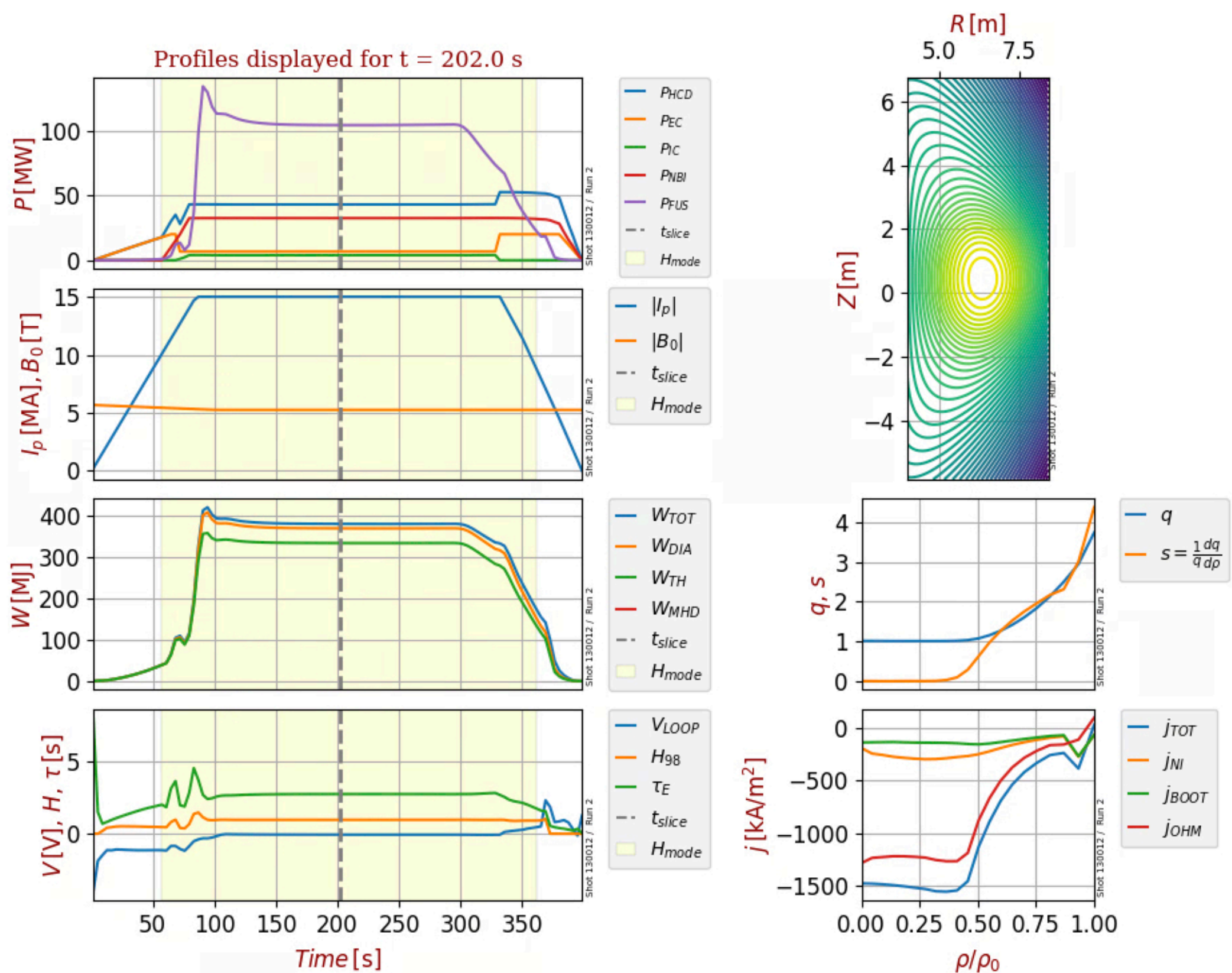
| | |
|--------------------------|-------|
| modus | 5 |
| min_n_tor | 19 |
| max_n_tor | 19 |
| min_m | 20 |
| max_m | 20 |
| sidebands | 2 |
| sidebands_asy | 0 |
| mode_type | 3 |
| even | 1 |
| cocp | 1 |
| start_pos | 1 |
| force_m | false |
| guess_start | 0.0 |
| guess_end | 0.0 |
| offset_d | 0.0 |
| d_guess | 0.0 |
| npsi_out | 128 |
| kr_read | 0.0 |
| q0 | 0.0d0 |
| rad_start | 0.0 |
| Save LIGKA Configuration | |

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

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

| ID | Run | Case | Description | Time | Power | Mode | Machine |
|--------|-----|------|------------------------------------|------|-------|------|---------|
| 130012 | 4 | ITER | ITER-baseline-DT_more_stable_q95>2 | -15 | -5.3 | D-T | H-L-H |
| 130012 | 2 | ITER | ITER-baseline-DT | 15.0 | 5.3 | D-T | H-L-H |

The screenshot shows the ITER database interface. On the left, there are fields for 'Local data source', 'User name' (public), 'Database' (ITER), 'Shot number' (130012), and 'Run number' (2). The main area displays a tree view of data nodes under 'IDSs(130012)'. The selected node is 'core_profiles.profiles_1d[0].t_i_average'. A 'Preview Plot' shows a graph of 't_i_average[eV]' vs 'core_profiles.profiles_1d[0].grid.rho_tor_norm'. On the right, a 'Figure:4' window shows a plot of 't_i_average[eV]' vs 'time[s]' with a blue line representing the data. Below the plot, there are controls for 'Mouse Enabled' and 'Coordinate1 slider'.



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

EP WORKFLOW

WORKFLOW PARAMETERS

| | |
|-------------|-------------|
| user | public |
| machine | ITER |
| shot_nr | 130012 |
| run_in | 2 |
| machine_out | training |
| run_out | 10 |
| itime | 23-25,30,35 |

FURTHER SETTINGS

| | |
|----------------|--------------------------|
| ligka_541 | <input type="checkbox"/> |
| ligka_5412 | <input type="checkbox"/> |
| pulse_list | <input type="checkbox"/> |
| fast_particles | <input type="checkbox"/> |
| hdf5 | <input type="checkbox"/> |
| mpi_processes | 1 |

Save Configuration
Save and Run

Save Configuration as
Load Configuration

Restore Default
LIGKA Analysis (Testing)

Scenario Summary Choice

LIGKA PARAMETERS

ACTOR SELECTION

| | |
|-------------------------|----------|
| Equilibrium_code_chease | 0 |
| Equilibrium_code | 0 |
| Distributions_1 | 0 |
| Distributions_2 | 0 |
| Orbit_Finder | 0 |
| Stability_code | Ligka_m5 |

CHEASE Parameters

HELENA Parameters

LIGKA Parameters

HAGIS 1 Parameters

HAGIS 2 Parameters

FINDER Parameters

Species Settings

SCENARIO Parameters

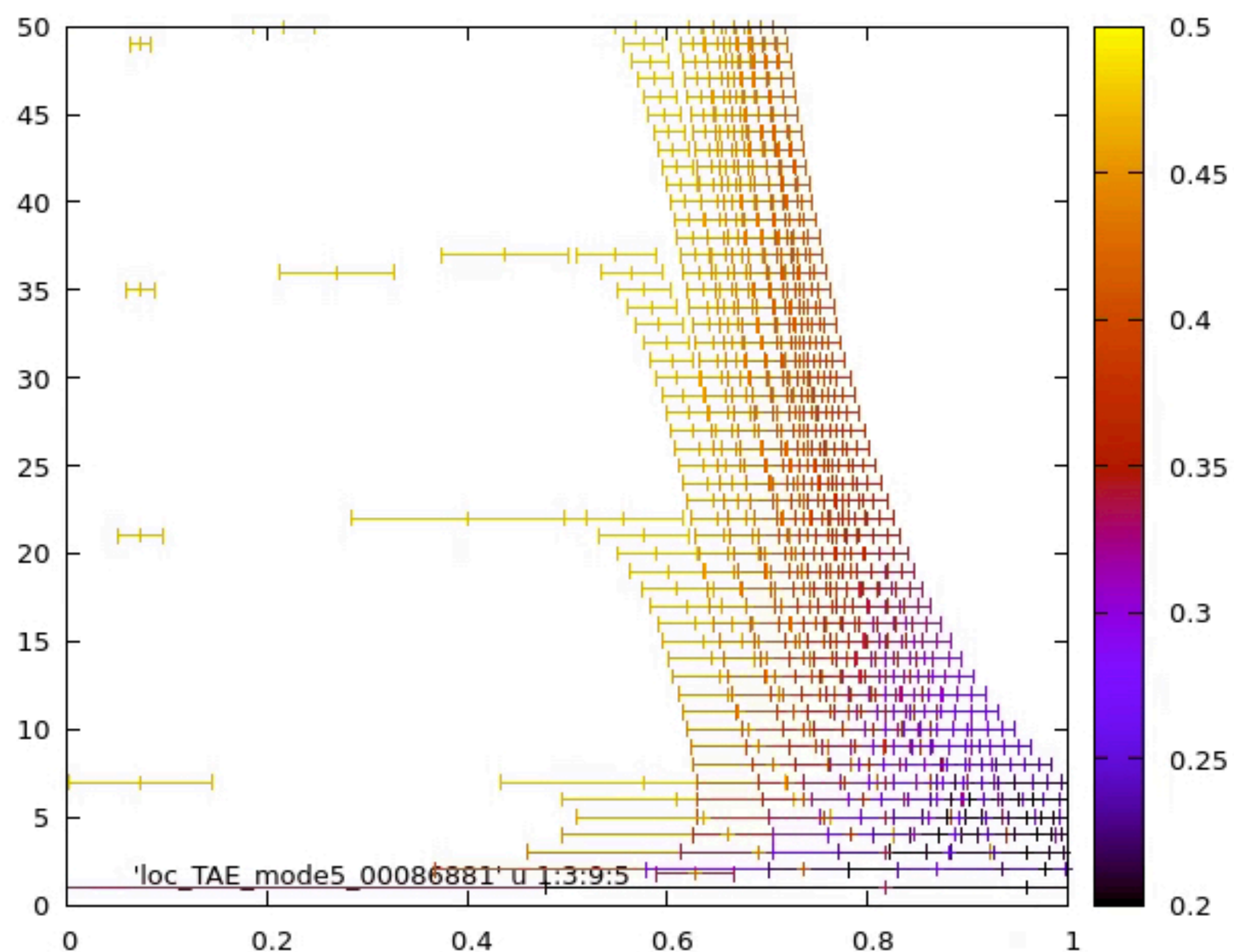
IDS Merge

LIGKA PARAMETERS

| | |
|---------------|-------|
| modus | 5 |
| min_n_tor | 1 |
| max_n_tor | 50 |
| min_m | -1 |
| max_m | 10 |
| sidebands | 2 |
| sidebands_asy | 0 |
| mode_type | 1 |
| even | 0 |
| cocp | 1 |
| start_pos | 1 |
| force_m | false |
| guess_start | 0.0 |
| guess_end | 0.0 |
| offset_d | 0.0 |
| d_guess | 0.00 |
| npsi_out | 128 |
| kr_read | 0.0 |

Save LIGKA Configuration

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

WORKFLOW PARAMETERS

| | |
|-------------|-------------|
| user | public |
| machine | ITER |
| shot_nr | 130012 |
| run_in | 2 |
| machine_out | training |
| run_out | 10 |
| itime | 23-25,30,35 |

FURTHER SETTINGS

| | |
|----------------|--------------------------|
| ligka_541 | <input type="checkbox"/> |
| ligka_5412 | <input type="checkbox"/> |
| pulse_list | <input type="checkbox"/> |
| fast_particles | <input type="checkbox"/> |
| hdf5 | <input type="checkbox"/> |
| mpi_processes | 1 |

Save Configuration

Save and Run

Save Configuration as

Load Configuration

Restore Default

LIGKA Analysis (Testing)

Scenario Summary Choice

Exit

ACTOR SELECTION

| | |
|-------------------------|----------|
| Equilibrium_code_chease | 0 |
| Equilibrium_code | 0 |
| Distributions_1 | 0 |
| Distributions_2 | 0 |
| Orbit_Finder | 0 |
| Stability_code | Ligka_m5 |

CHEASE Parameters

HELENA Parameters

LIGKA Parameters

HAGIS 1 Parameters

HAGIS 2 Parameters

FINDER Parameters

Species Settings

SCENARIO Parameters

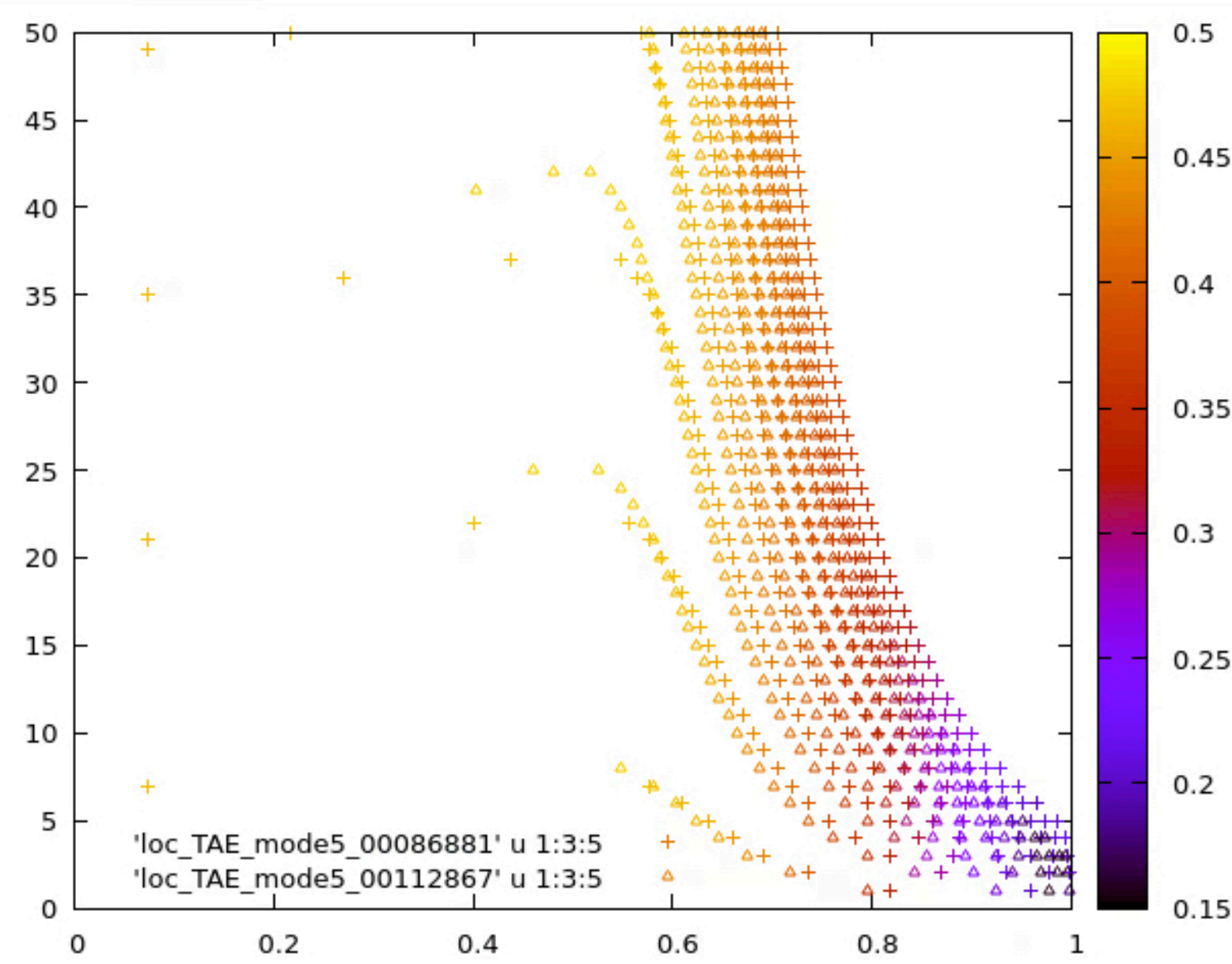
IDS Merge

LIGKA PARAMETERS

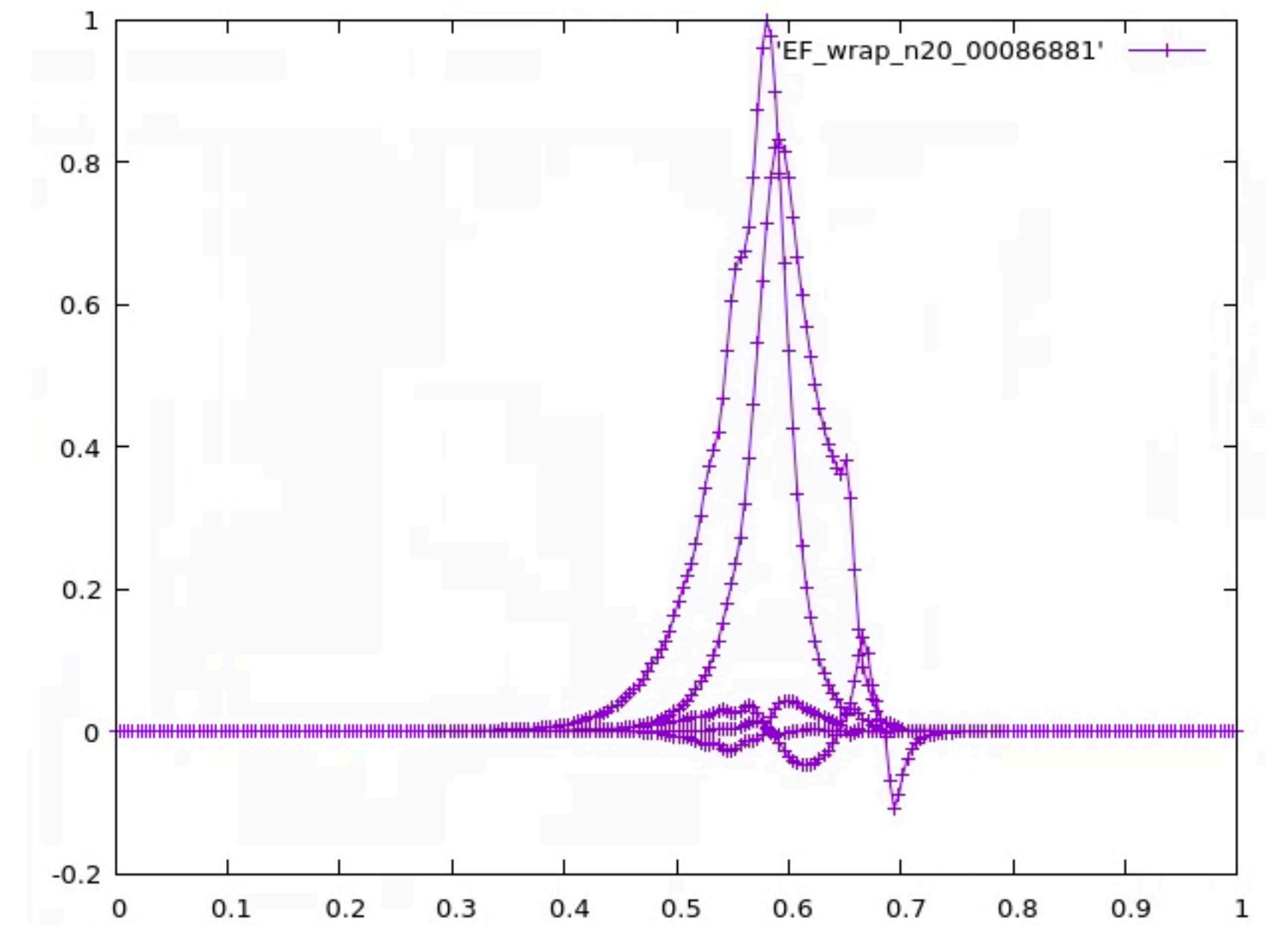
| | |
|---------------|-------|
| modus | 5 |
| min_n_tor | 1 |
| max_n_tor | 50 |
| min_m | -1 |
| max_m | 10 |
| sidebands | 2 |
| sidebands_asy | 0 |
| mode_type | 1 |
| even | 0 |
| cocp | 1 |
| start_pos | 1 |
| force_m | false |
| guess_start | 0.0 |
| guess_end | 0.0 |
| offset_d | 0.0 |
| d_guess | 0.00 |
| npsi_out | 128 |
| kr_read | 0.0 |

Save LIGKA Configuration

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



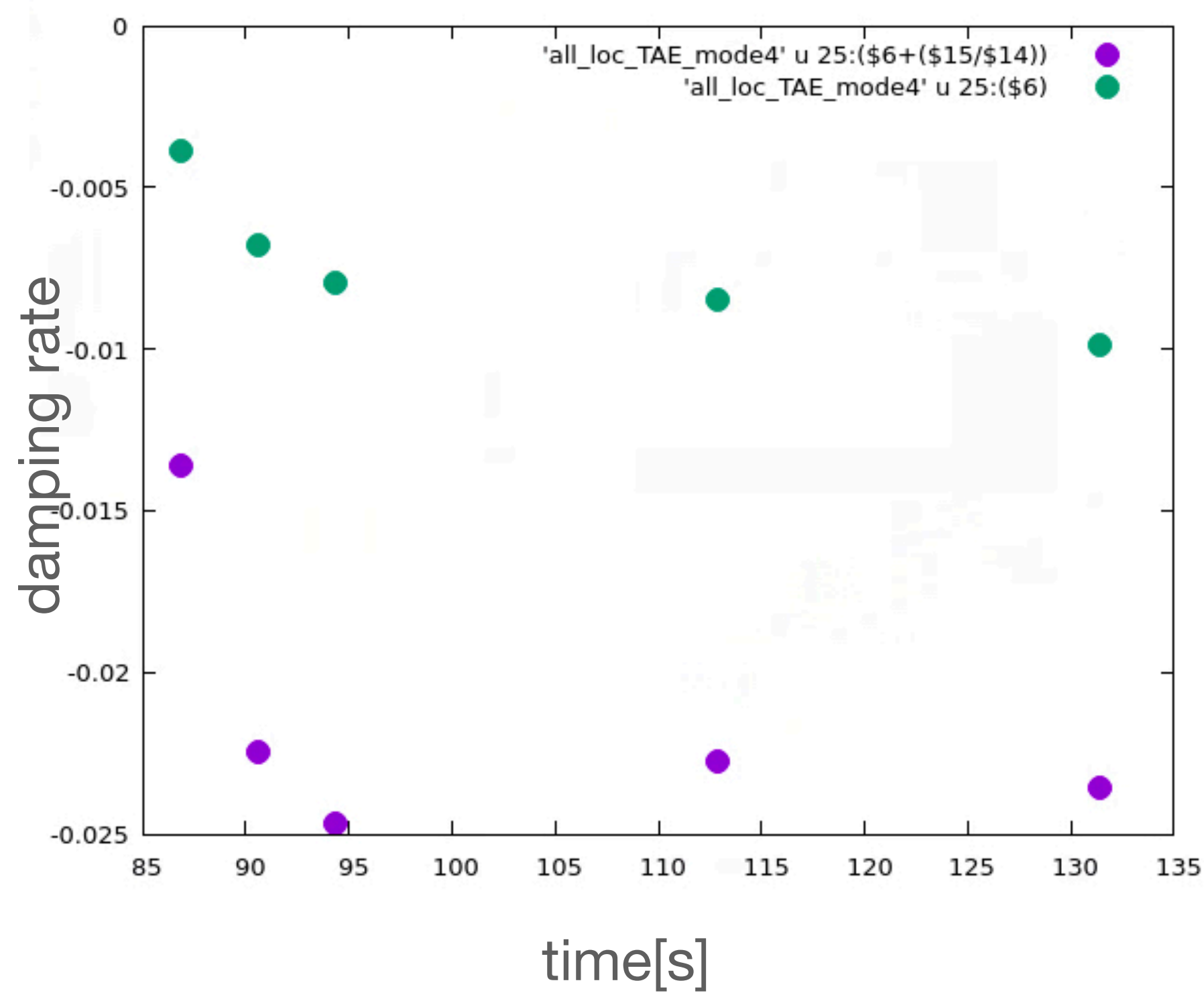
runs mode 5 for all time points
 runs mode 4 for all time points
 runs mode 1 for all time points
 runs mode 2 for all time points



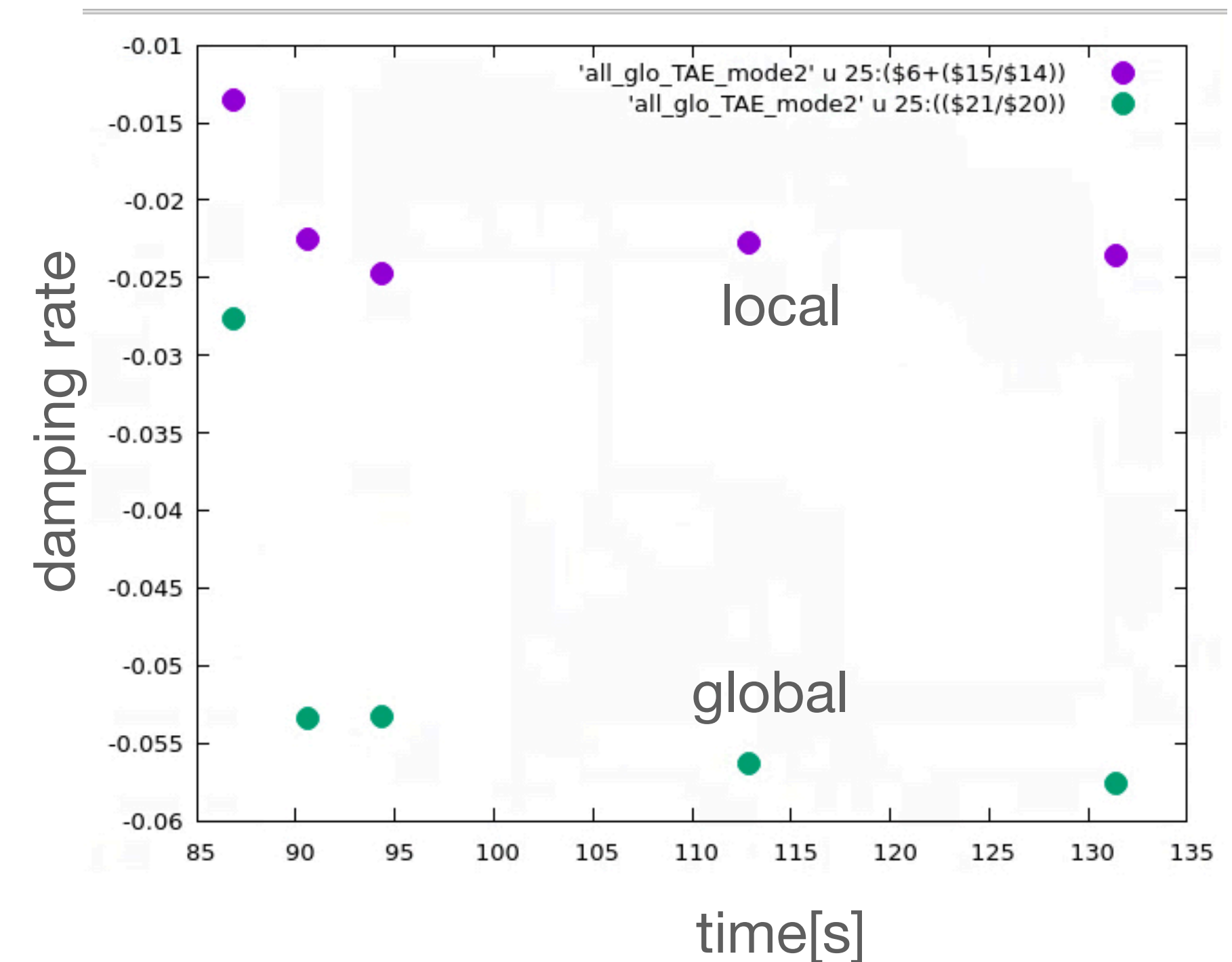
n=20.... use more harmonics, of course...

```
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)

WORKFLOW PARAMETERS

user: public
 machine: ITER
 shot_nr: 130012
 run_in: 2
 machine_out: training
 run_out: 11
 itime: 23-25,30,35

FURTHER SETTINGS

ligka_541:
 ligka_5412:
 pulse_list:
 fast_particles:
 hdf5:
 mpi_processes: 1

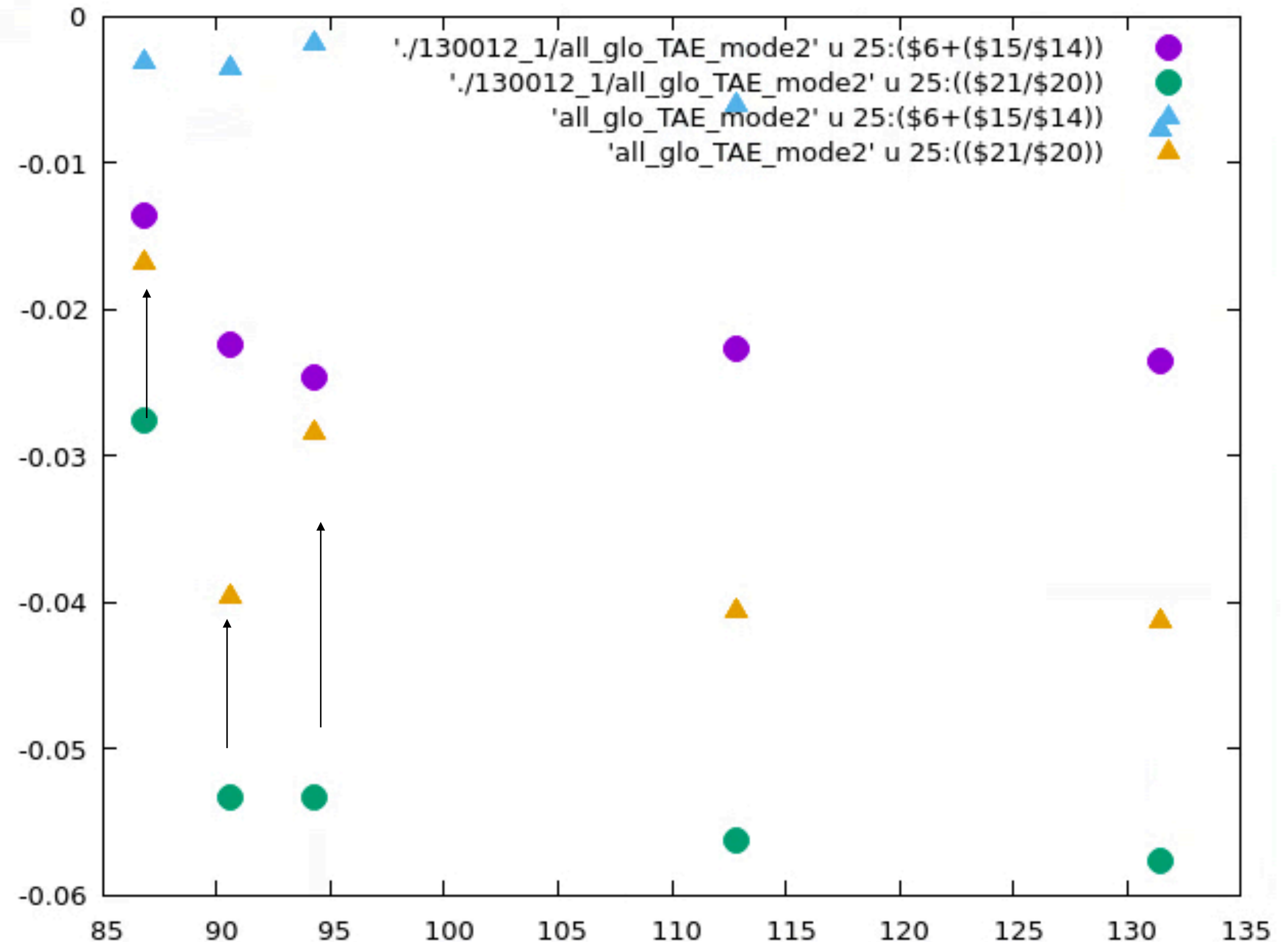
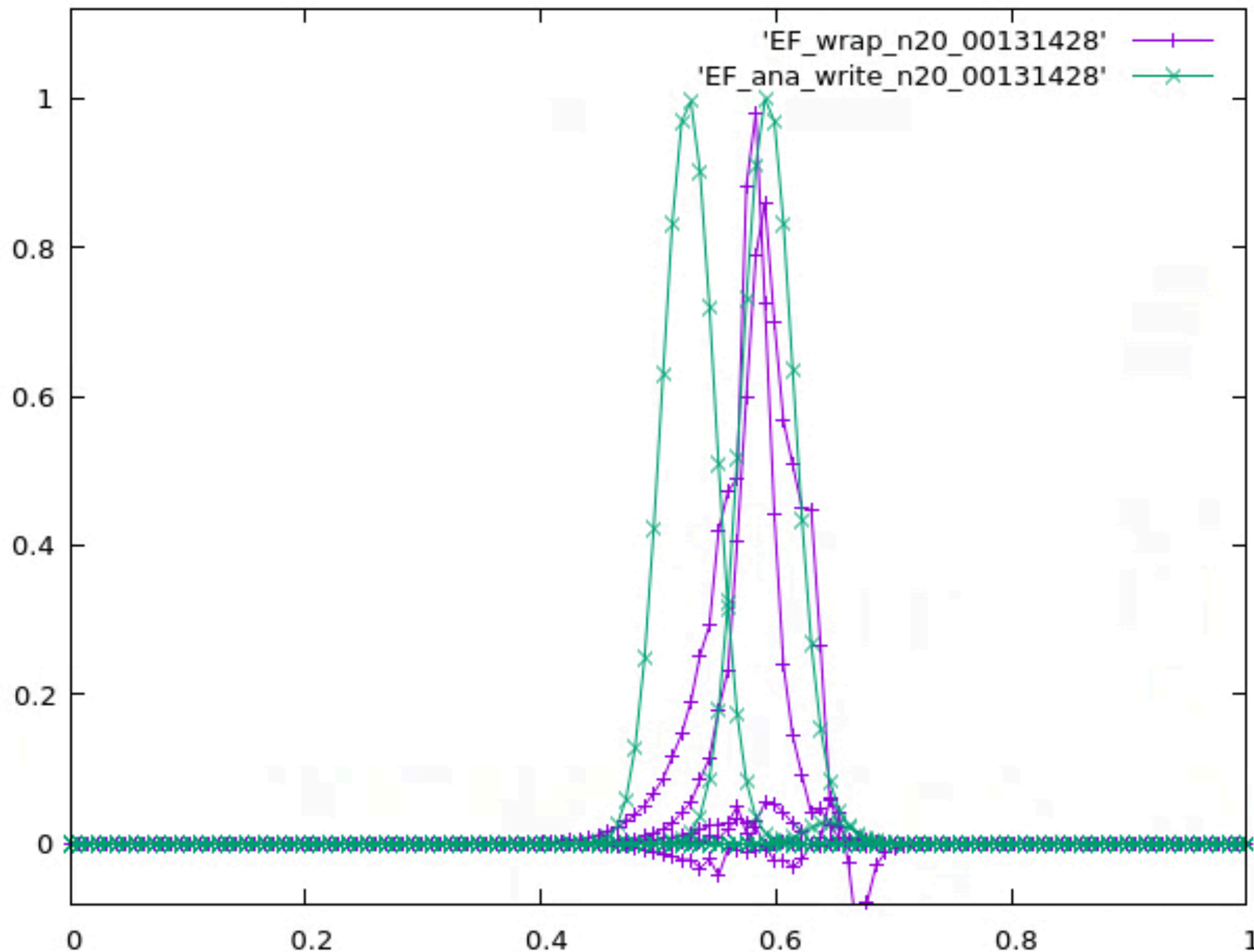
ACTOR SELECTION

Equilibrium_code_chease: Cheese
 Equilibrium_code: Helena
 Distributions_1: 0
 Distributions_2: 0
 Orbit_Finder: 0
 Stability_code: Ligka_m5

CHEASE Parameters
 HELENA Parameters
 LIGKA Parameters
 HAGIS 1 Parameters
 HAGIS 2 Parameters
 FINDER Parameters
 Species Settings
 SCENARIO Parameters
 IDS Merge

Buttons: Save Configuration, Save and Run, Save Configuration as, Load Configuration, Restore Default, LIGKA Analysis (Testing), Scenario Summary Choice, Exit

```
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 0.1000000000000000
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 latest 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 ~hayward/.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':

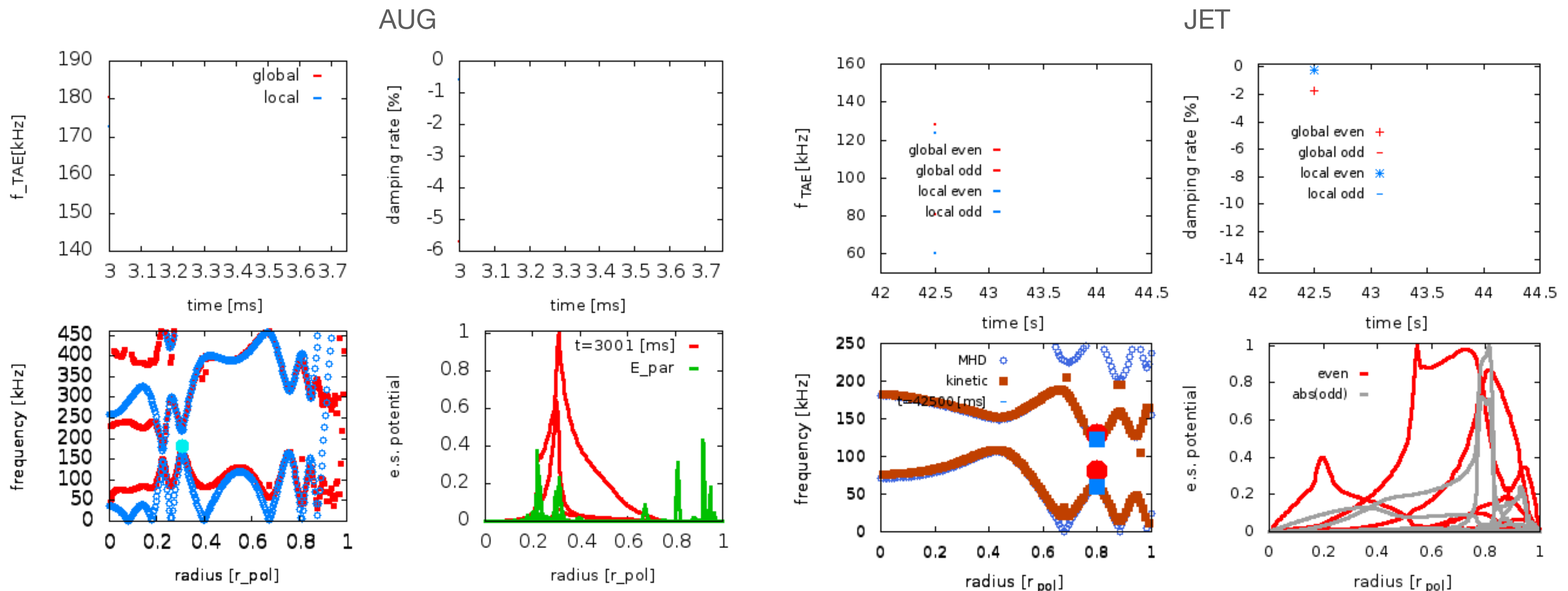
```
./general_plots_ids.py -user=popaa -database=test_DB -shot=130012 -run=10 -occurrence=0 -type=frequency  
-compare_modes=1 -interactivePlots=1
```

```
./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!



- **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:

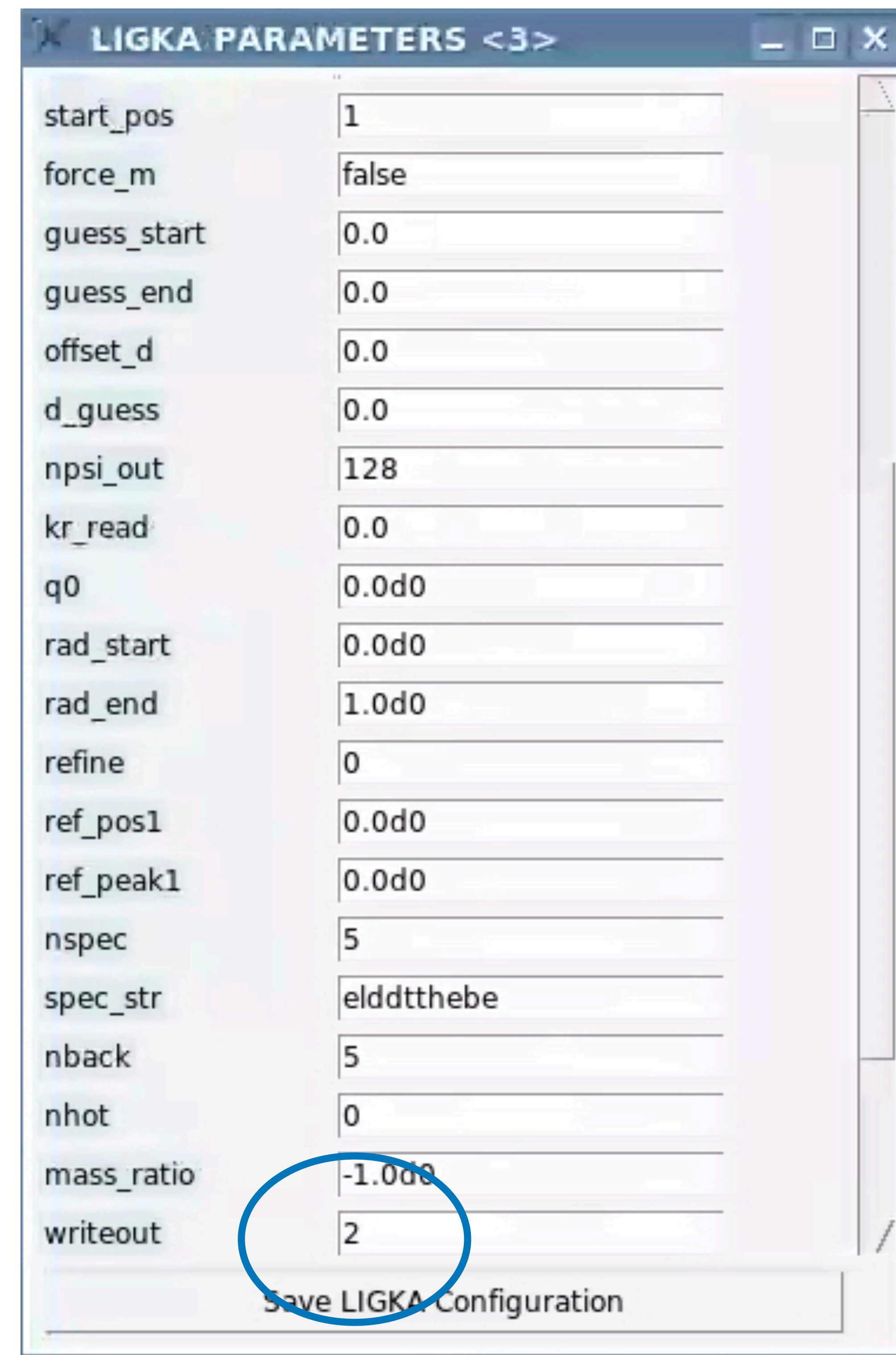
```
70528 Jul 14 11:48 eq_flux_00208000
 6528 Jul 14 11:48 elo_00208000
 6528 Jul 14 11:48 zeff_00208000
19328 Jul 14 11:48 dens_00208000
60928 Jul 14 11:48 temp1_00208000
60928 Jul 14 11:48 temp2_00208000
60928 Jul 14 11:48 temp3_00208000
60928 Jul 14 11:48 temp4_00208000
60928 Jul 14 11:48 temp5_00208000
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
($s = \sqrt{\text{pol_flux}}$)

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

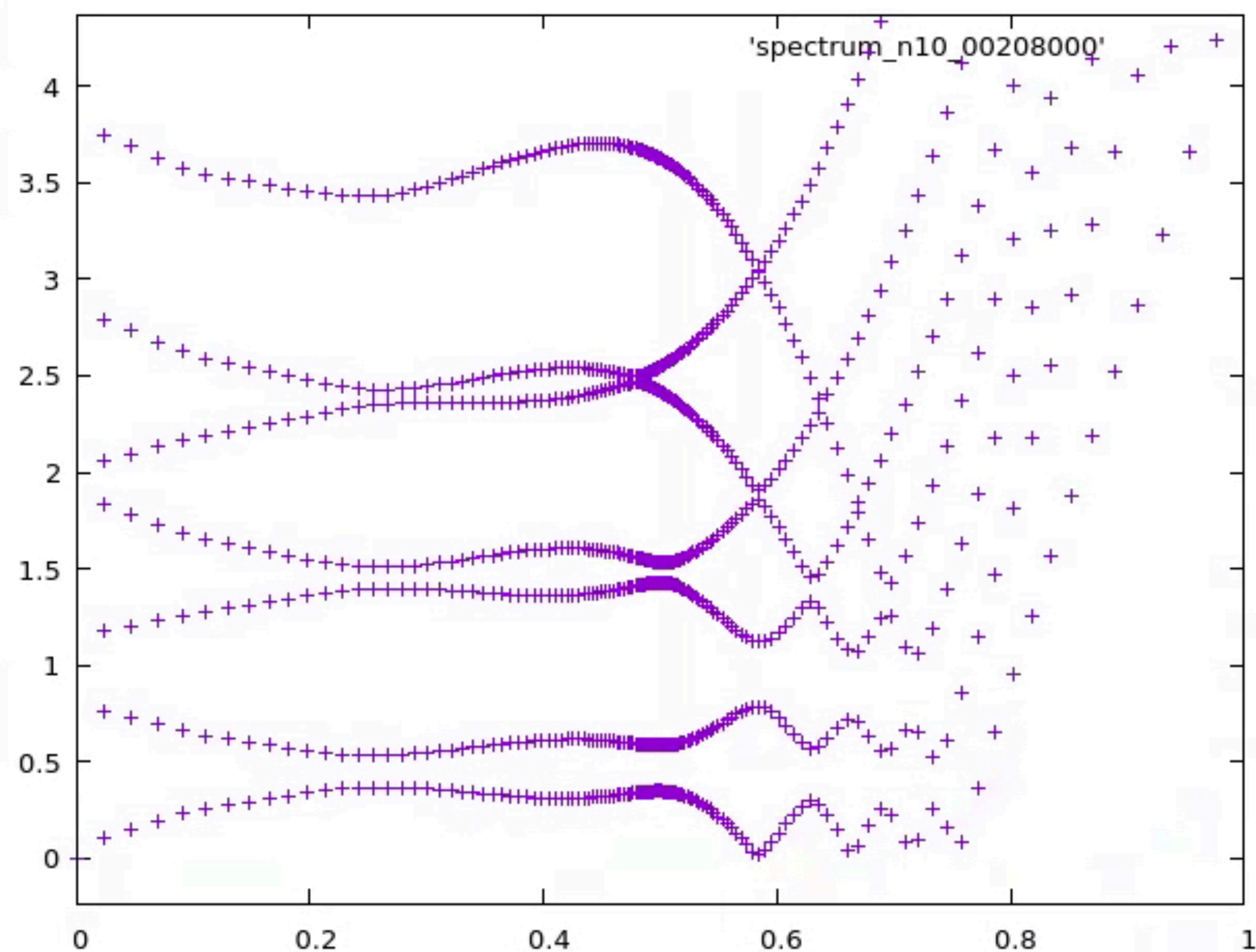
LIGKA can scale the equilibrium consistently, specifying q_0
if q_0 (in LIGKA always positive) is different from 0, it will be used to scale

- 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)

| | |
|-----------|-------|
| refine | 1 |
| ref_pos1 | 0.5d0 |
| ref_peak1 | 6.0d0 |

| | |
|-------------|-------|
| mode_type | 1 |
| even | 0 |
| cocp | 1 |
| start_pos | 1 |
| force_m | false |
| guess_start | 0.0 |
| guess_end | 0.0 |
| offset_d | 0.0 |
| d_guess | 0.0 |
| npsi_out | 128 |
| kr_read | 0.0 |
| q0 | 0.0d0 |
| rad_start | 0.0d0 |
| rad_end | 1.0d0 |



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

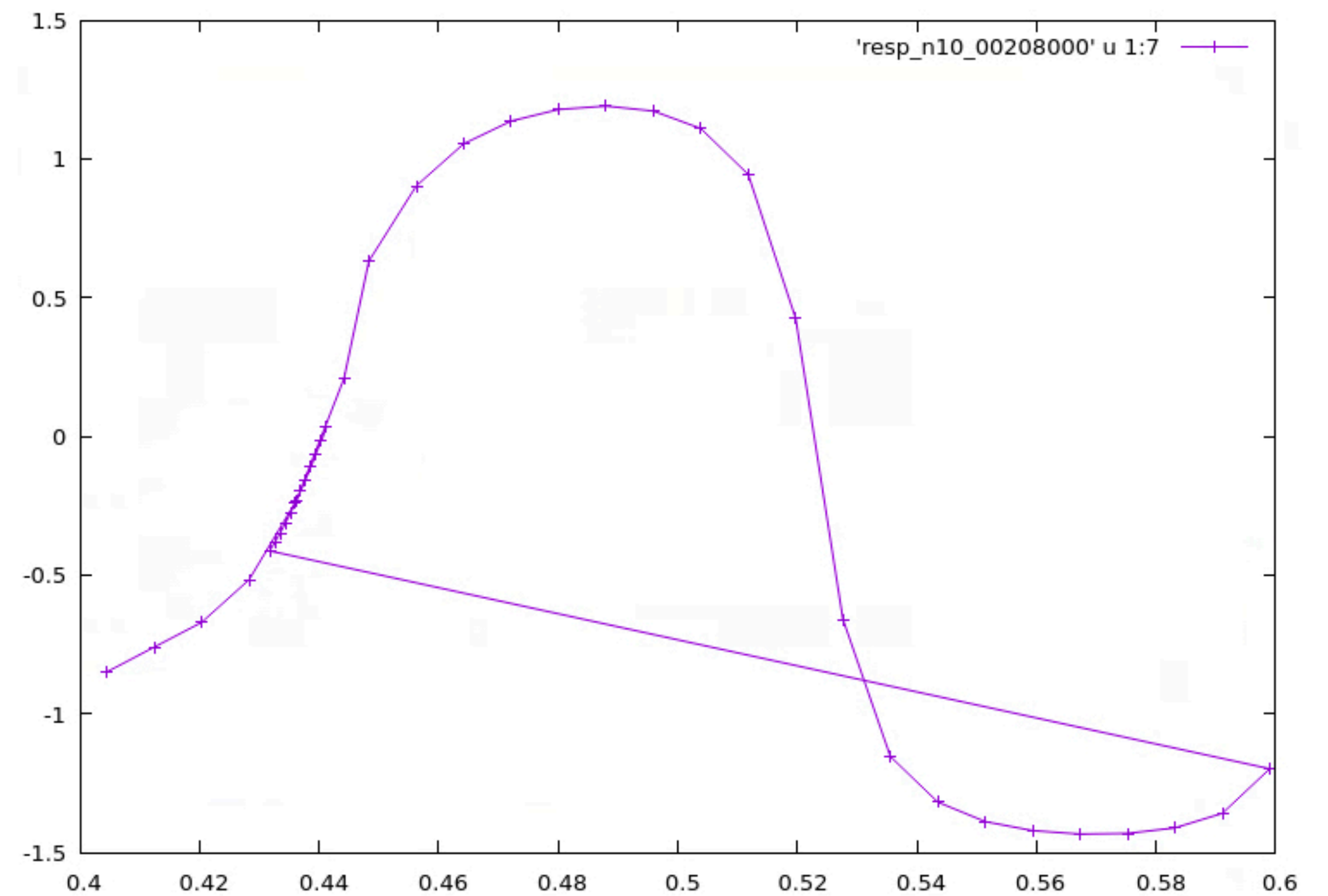
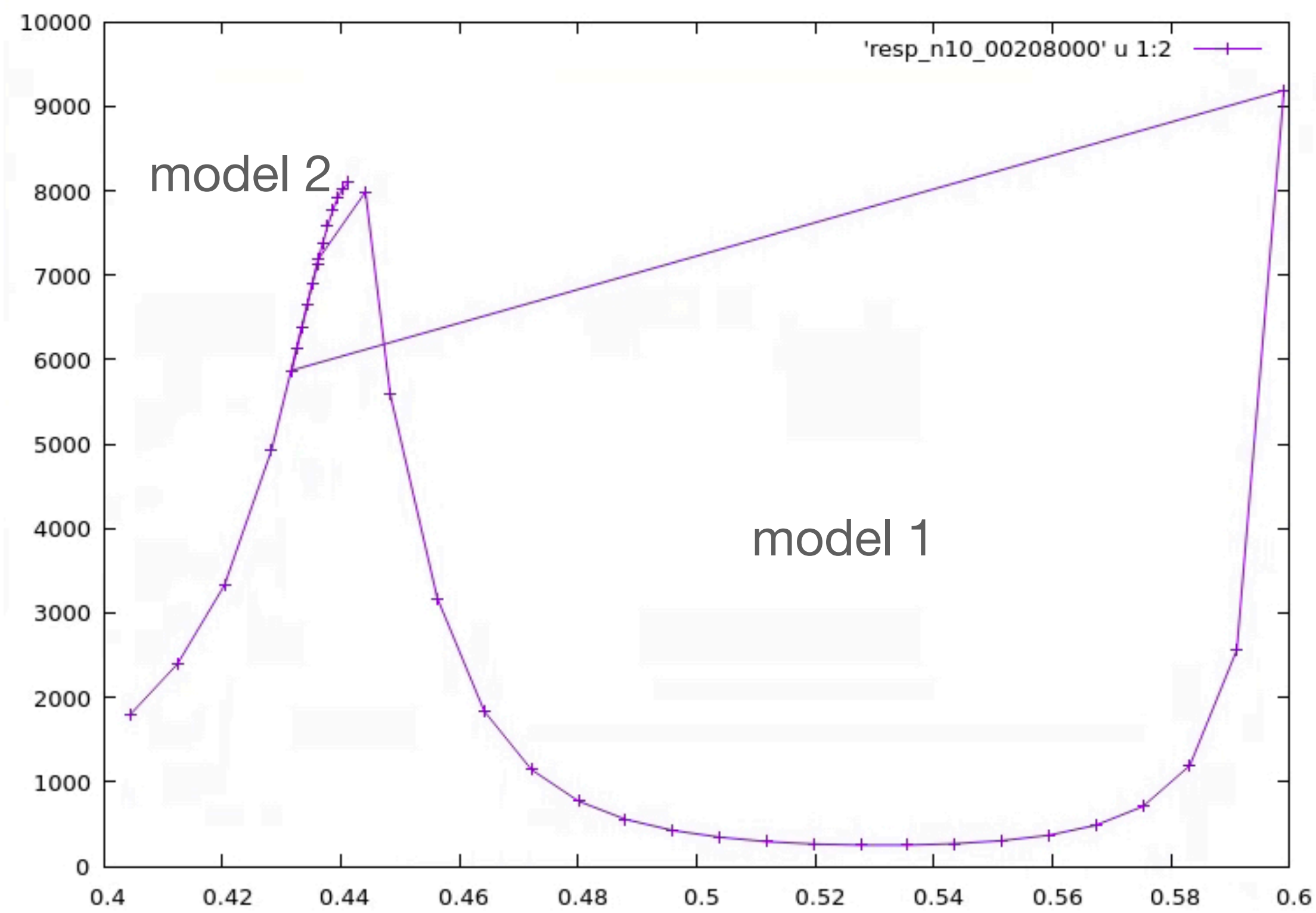
- model 3 needs a list of modes, as stored in mhd_linear/0; i.e. run model 5 first!
- it will skip all modes that have the same toroidal mode number
- some branches of the continua are missing: go deeper into complex plane with offset_d
- decrease integration radius: d_guess (code runs longer)

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 reduced 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 to 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...mapped in sub_imas_out.F; negative sign: counter propagating modes (co: ion diamagnetic 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 propagating 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 points

<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 $|\text{abs}(q_0)| > 0.0d0$

<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 integration range

<guess_start>0.0d0</guess_start> ! control mode 3 guess range (default) 1.0 [ω_A]

<guess_end>0.0d0</guess_end> ! control mode 3 guess range (default) 0.0 [ω_A]

<dguess>0.0d0</dguess> ! control radius of integration circle of mode 3, default =0.02 [ω_A]

<refine>0</refine> ! refine radial grid

<ref_pos1>0.0d0</ref_pos1> ! refine where radially?

<ref_peak1>0.0d0</ref_peak1> ! use $\exp\{\text{ref_peak1}\}$ 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 $\text{mass_dd}/\text{mass_ratio}$

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