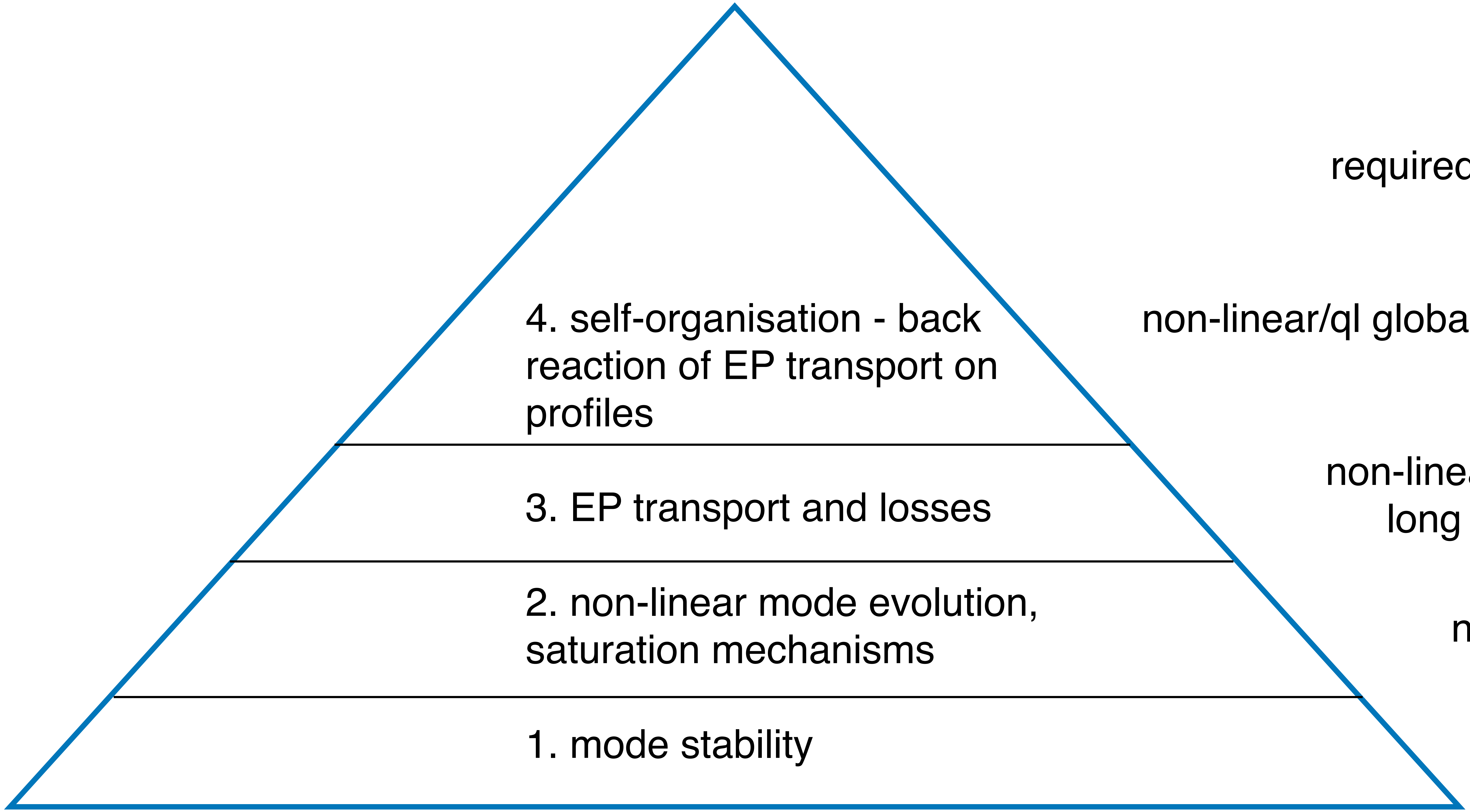
Status of the EP-WF, development towards CG and kick models with applications to AUG, SA and JET

Ph. Lauber, V.-A. Popa, T. Hayward-Schneider

needed for scaling from TCV-AUG-JET,… to JT-60SA-ITER-DEMO:



required model:

non-linear/ql global kinetic + background transport

non-linear/quasi-linear global kinetic + long time scales (source +sink)

non-linear global kinetic

linear global kinetic


EP WORKFLOW SCHEMATICS
input
equilibrium (transport code)
core_prof (tansport code)
distributions (H&CD)
time
time_slice(itime)
get_slice(itime)
get_slice(itime)
interpol.
time_slice(itime+1)
get_slice(itime+1)
ported to gateway
read ETS and JINTRAC generated data
read trview generated AUG data
automated tests & installation
H
HELENA
orbit finder/ propagator integrals
Ha1
HAGIS1 - equilibrium
H2
distributions/1
RABBIT
L5
LIGKA mode 5/6 (analytical)
L4
LIGKA mode 4 (local)
L1/2
LIGKA mode 1/2 (global)
transport models: CG,RBQ,Kick ,PSZS
transport models: CG,RBQ,Kick, PSZS
HAGIS1 - transform AEs
HAGIS2: add sat. amplitudes, FEP
Ha2
equilibrium
mhd_linear
distributions
output
time

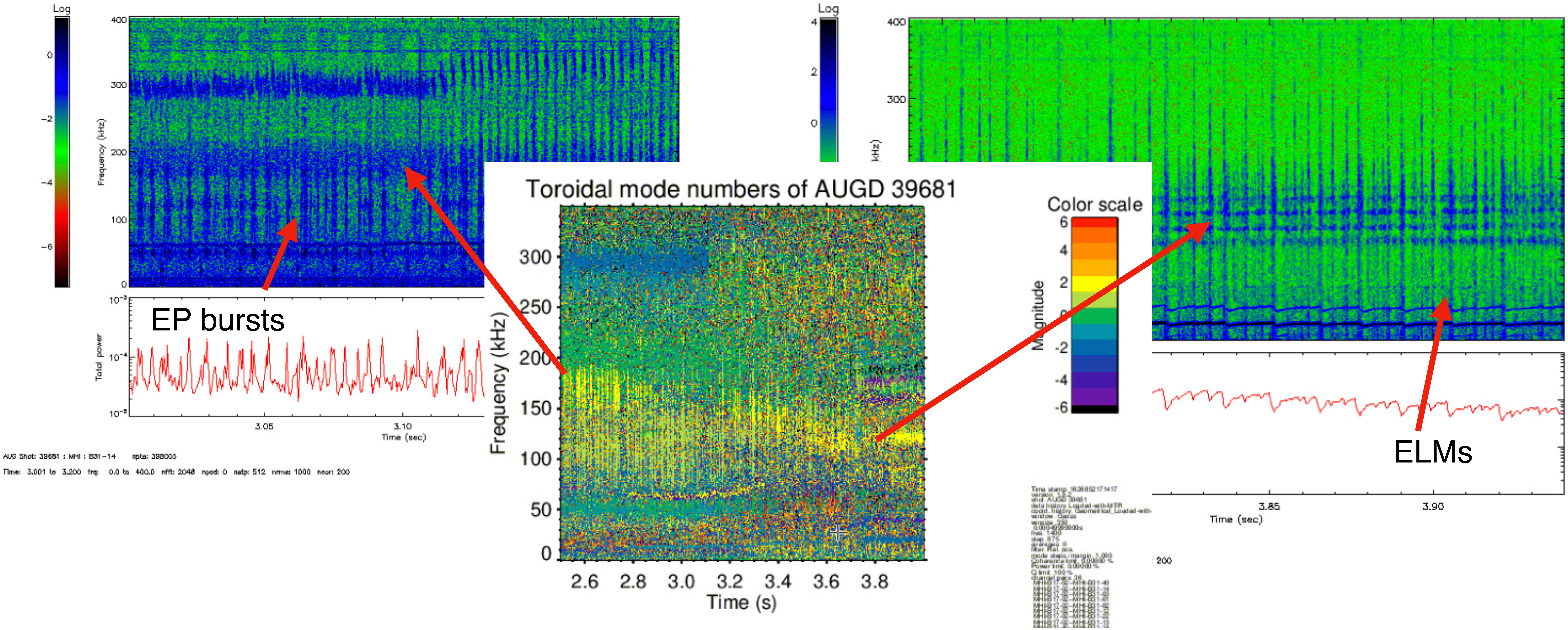
1. ASDEX Upgrade

AUG-IMAS modelling: EP driven modes change bursting characteristics during slow L-H transition in hydrogen: discharge stays in L mode despite 5MW heating

July 2021

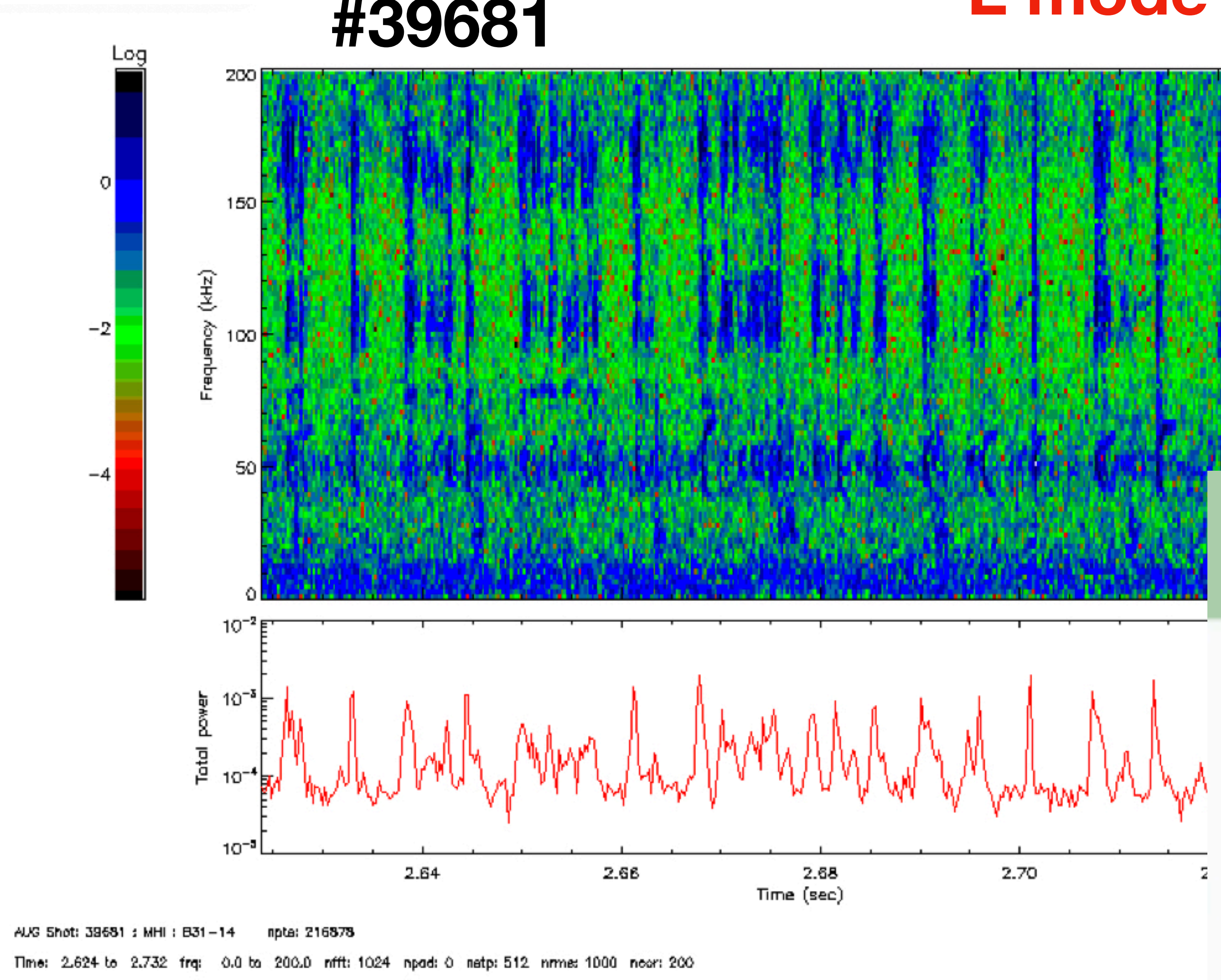
L mode [2.5-2.7s]

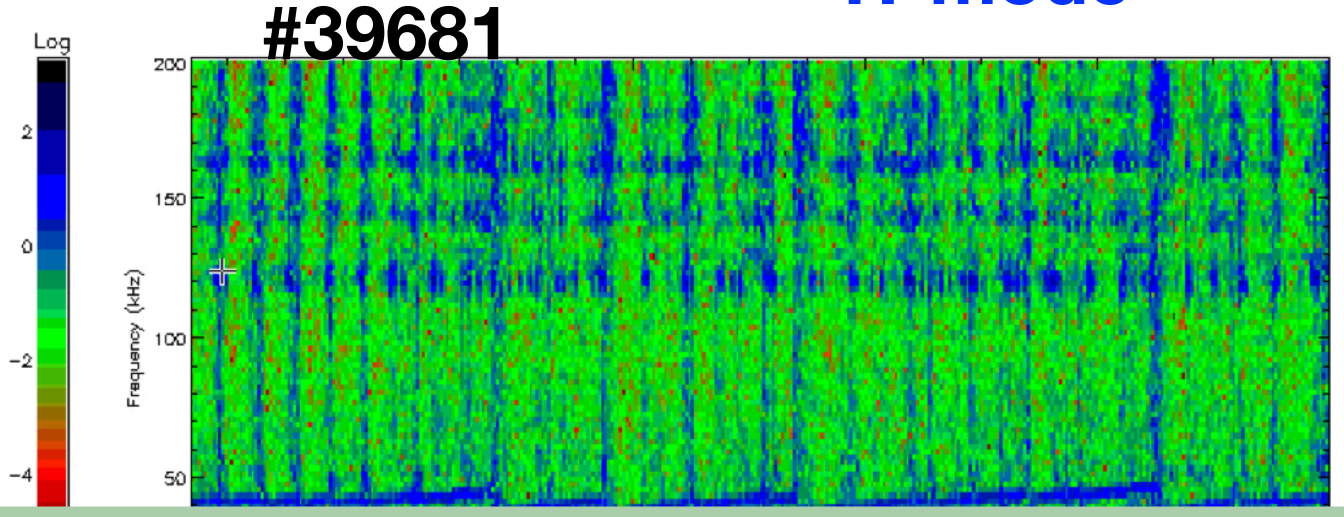
#39681 H-mode [4.3-4.4s]



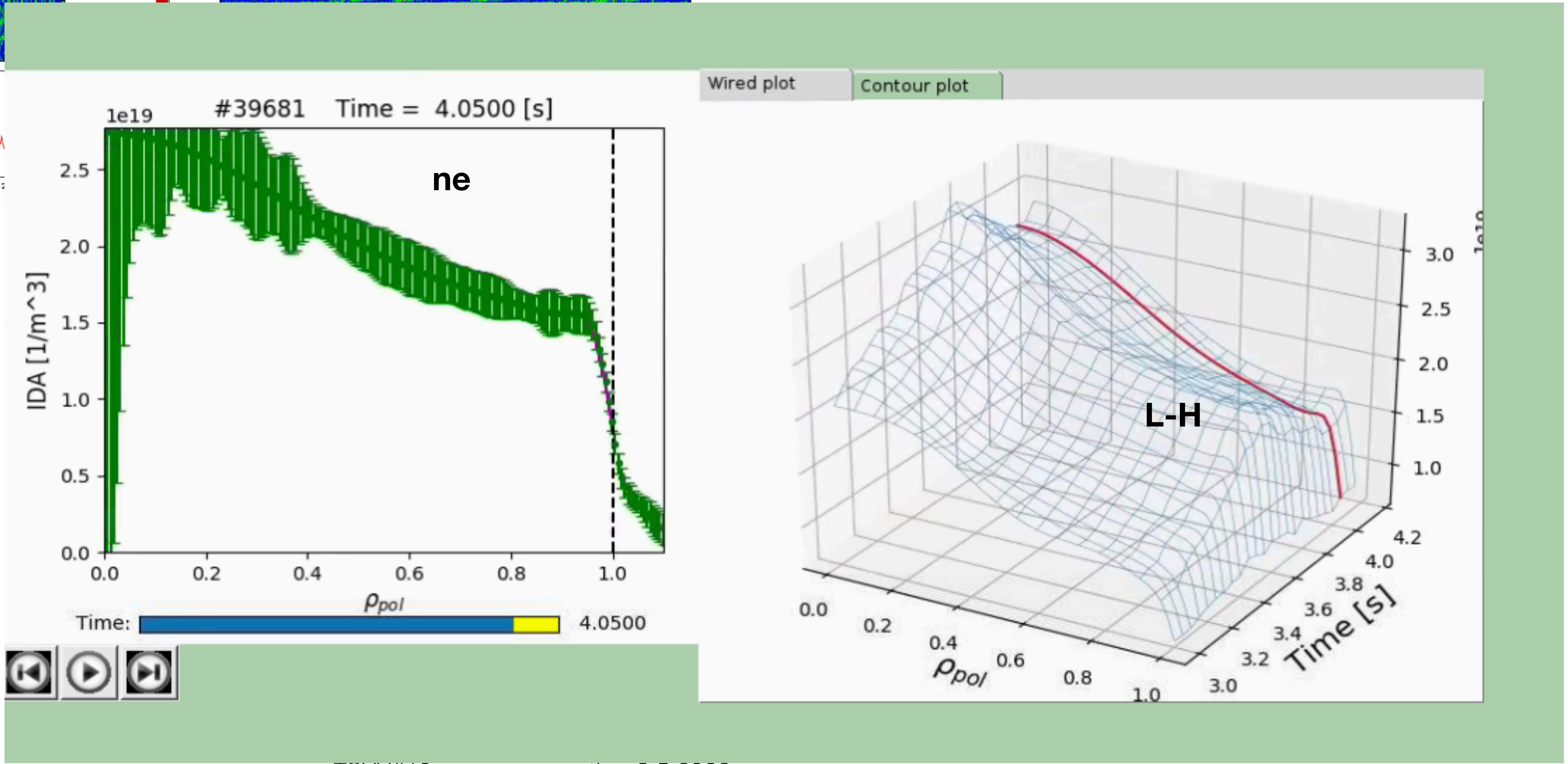
model transition using time-dependent EP workflow using trview-IMAS interface

July 2021

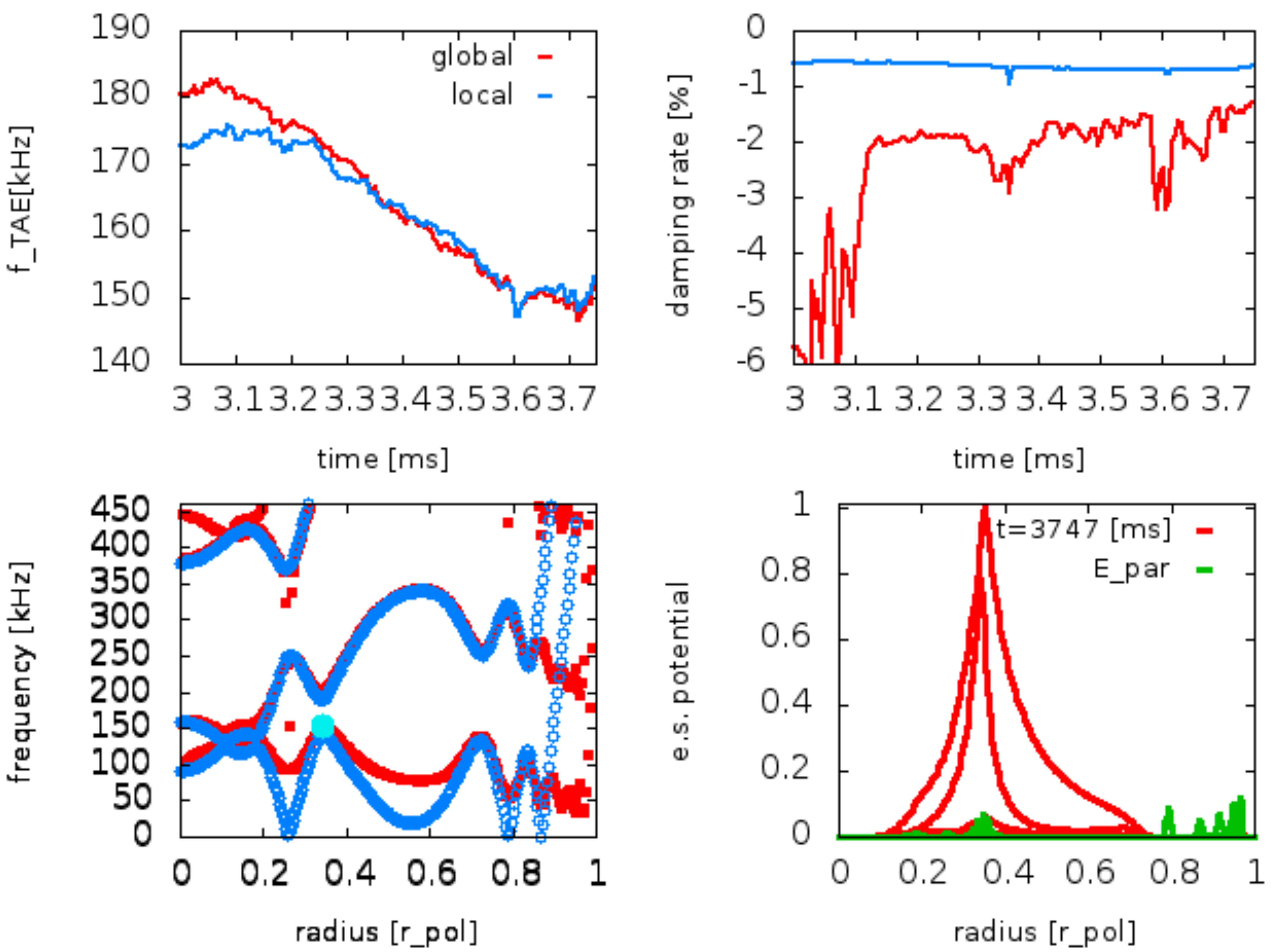




AUG experimental data base -> trview [gateway]
credits: G Tardini



EP WF- LIGKA: combined data of 3 different models: red. MHD, GK local, GK global



160 time slices based on IDA
largely automated analysis
(except visualisation)

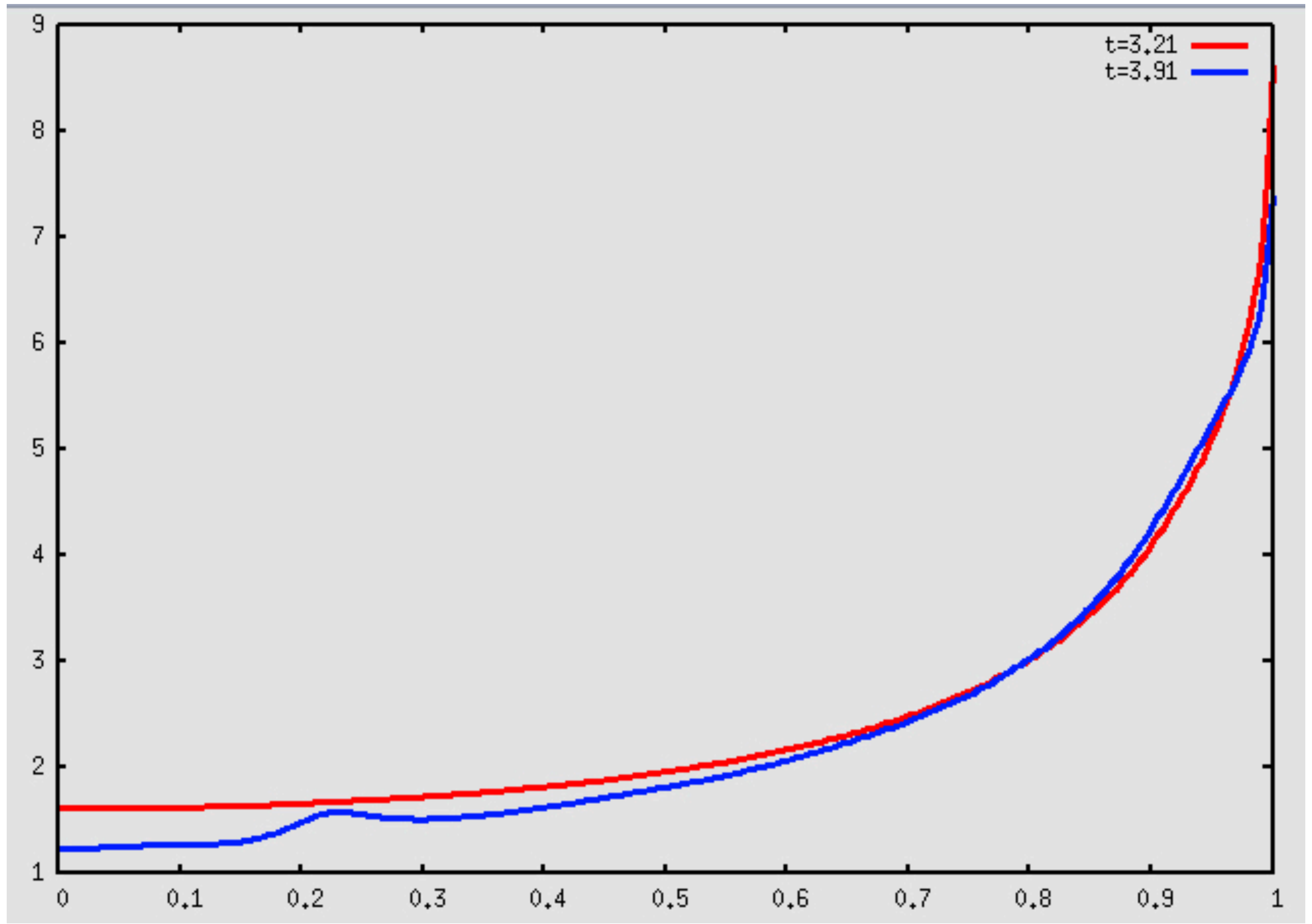
presently working on NBI EP

ready for:

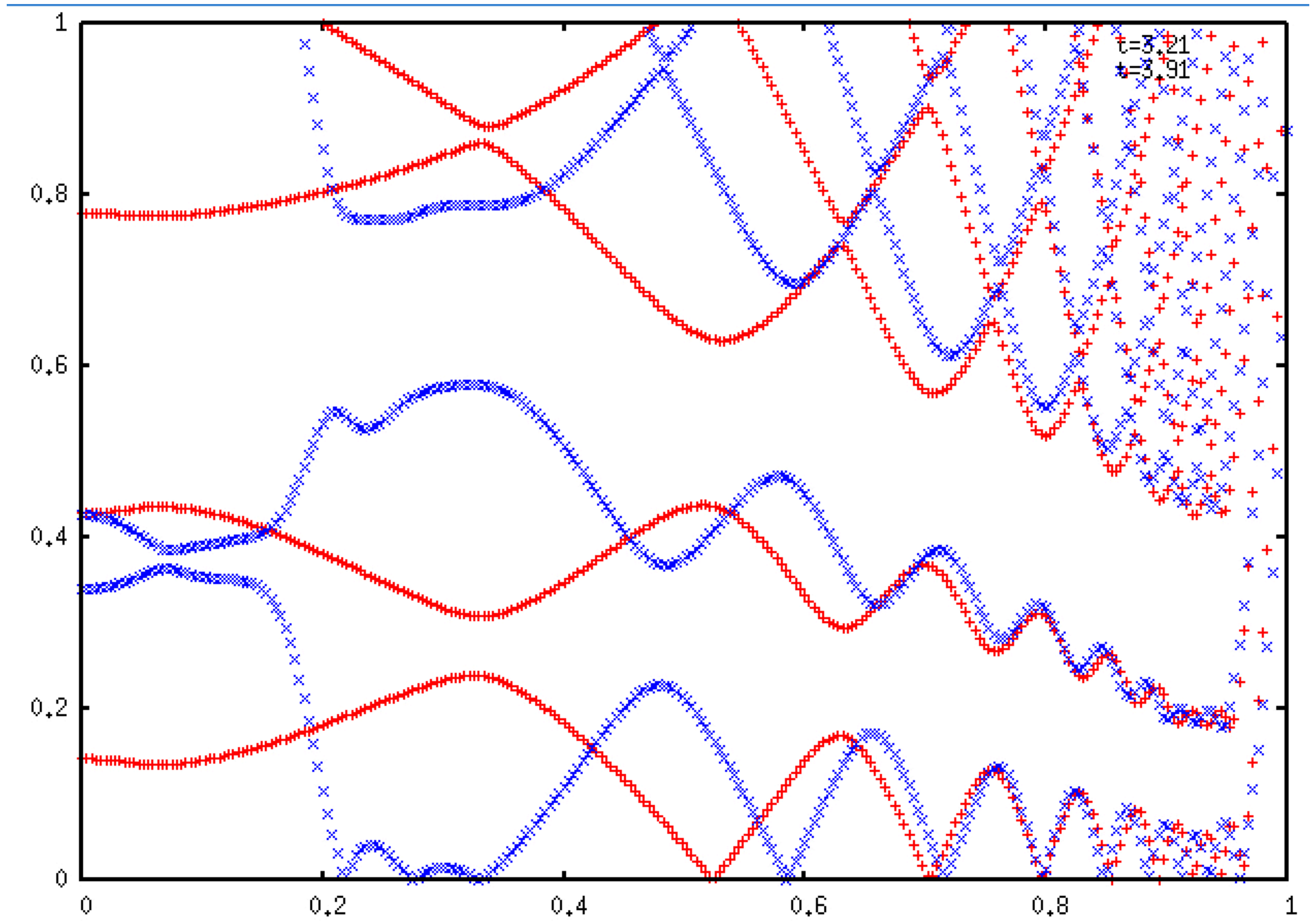
coupling to transport codes
systematic UQ, ‘error bars'
scenario optimisation

problem: deal with incomplete data
(e.g. beam blips missing for Ti)
IDS merger tool (V.-A. Popa)

AUG observation: switching on core ECCD at 3.5s, n=2 TAE disappears

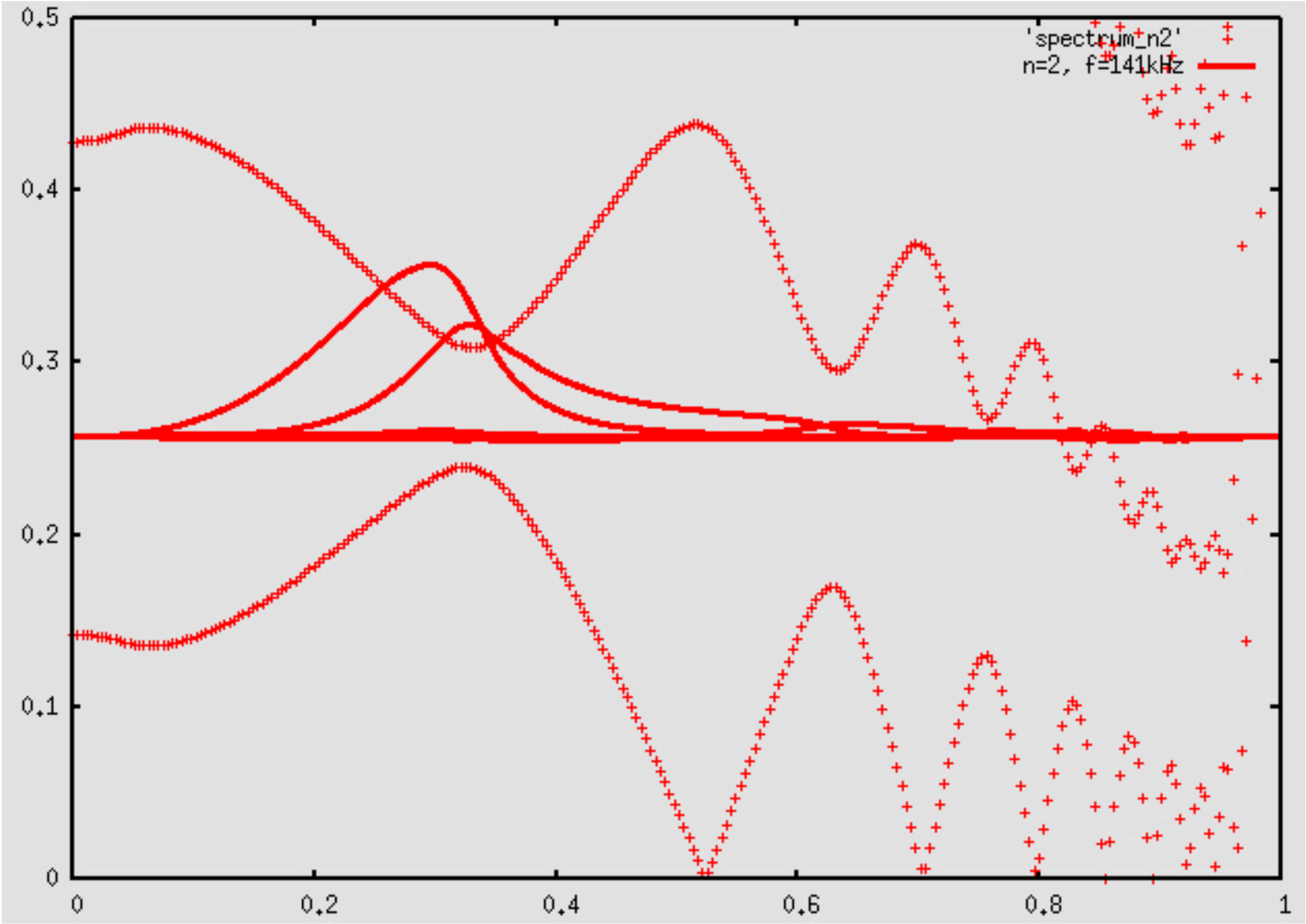


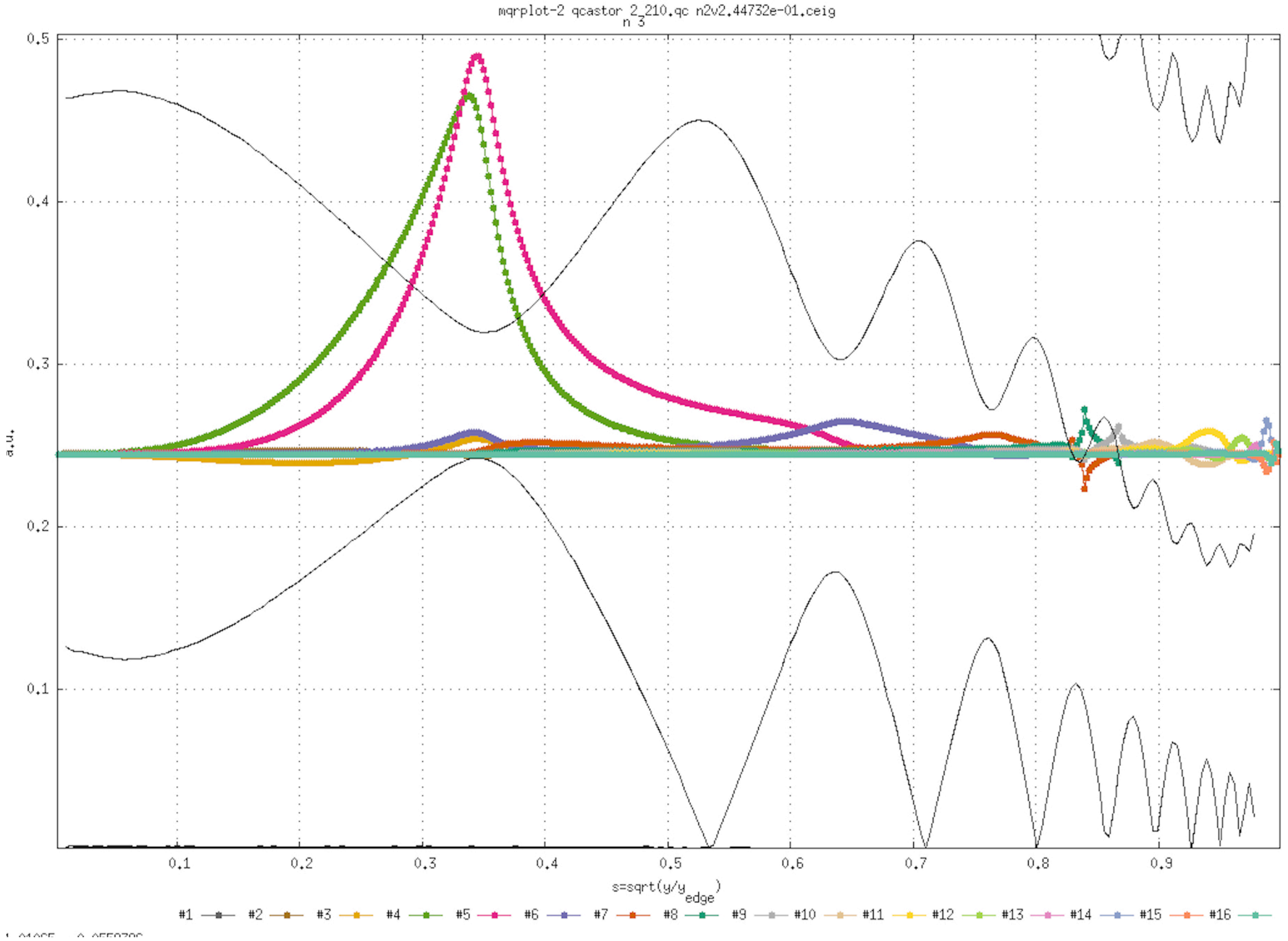
ITER helena IMAS version



LIGKA mode 6

LIGKA-CASTOR comparison: differences of WFs due to different q's in reconstructed eq - to be resolved





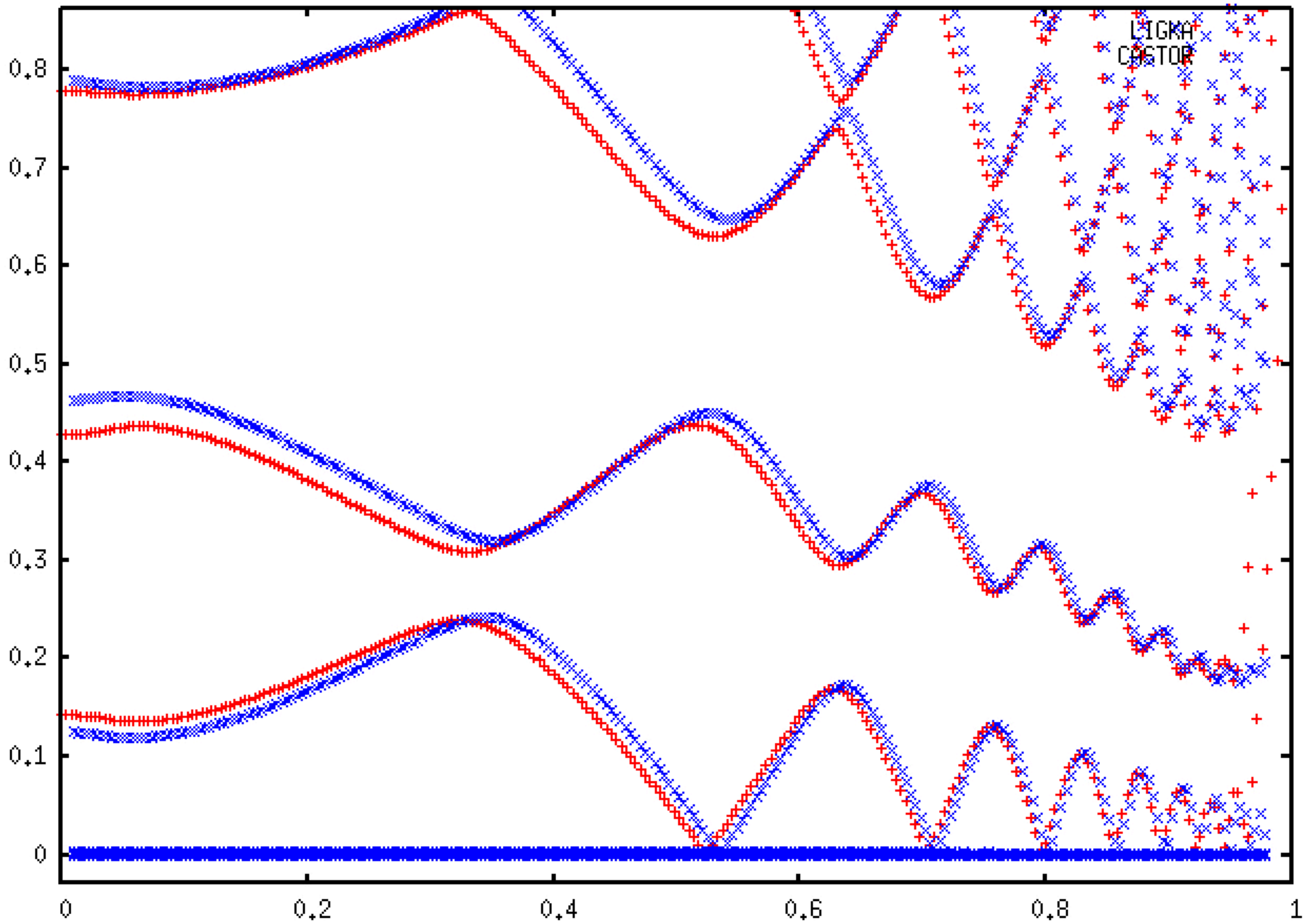
LIGKA

CASTOR

n=2 TAE eigenfunctions - similar, but different equilibria lead to observed differences

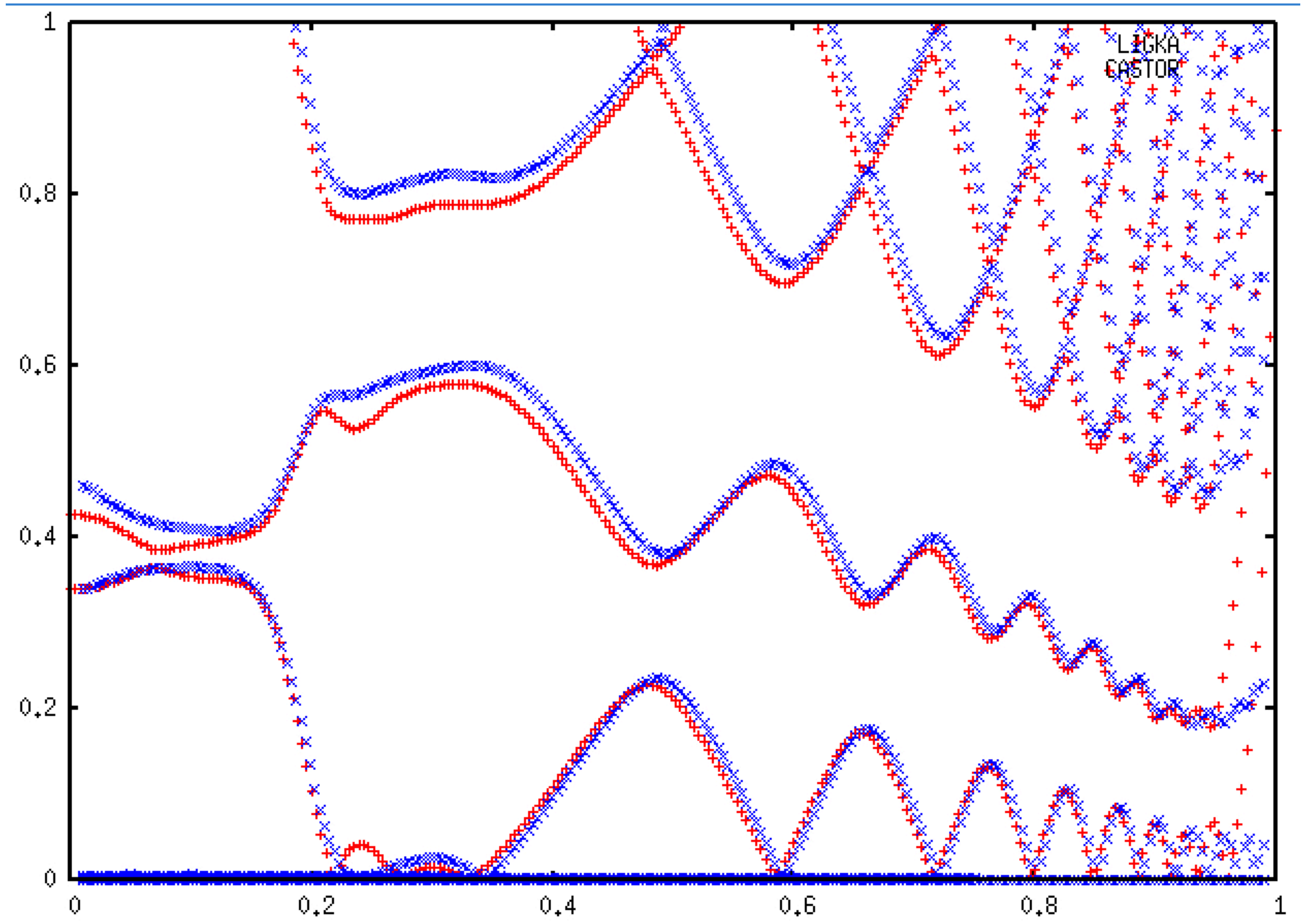
LIGKA-CASTOR comparison: differences of WFs due to different q's in reconstructed eq - to be resolved

t=3.21



LIGKA CASTOR

t=3.91

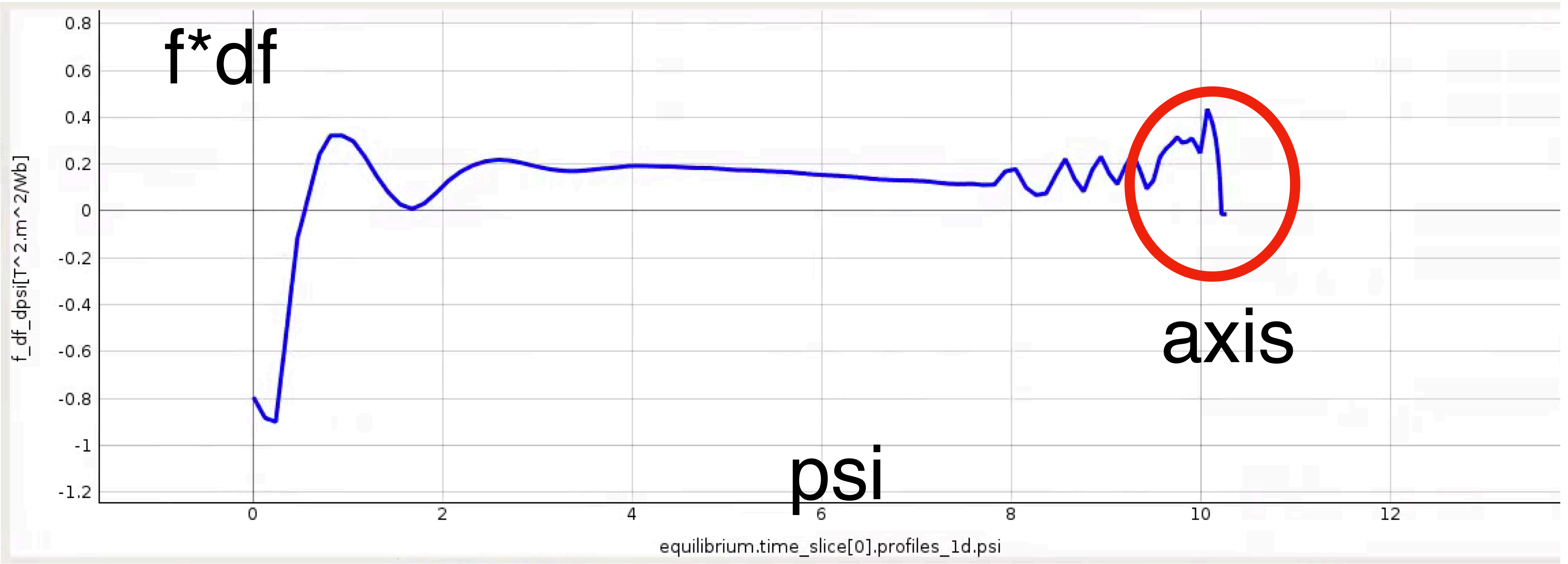


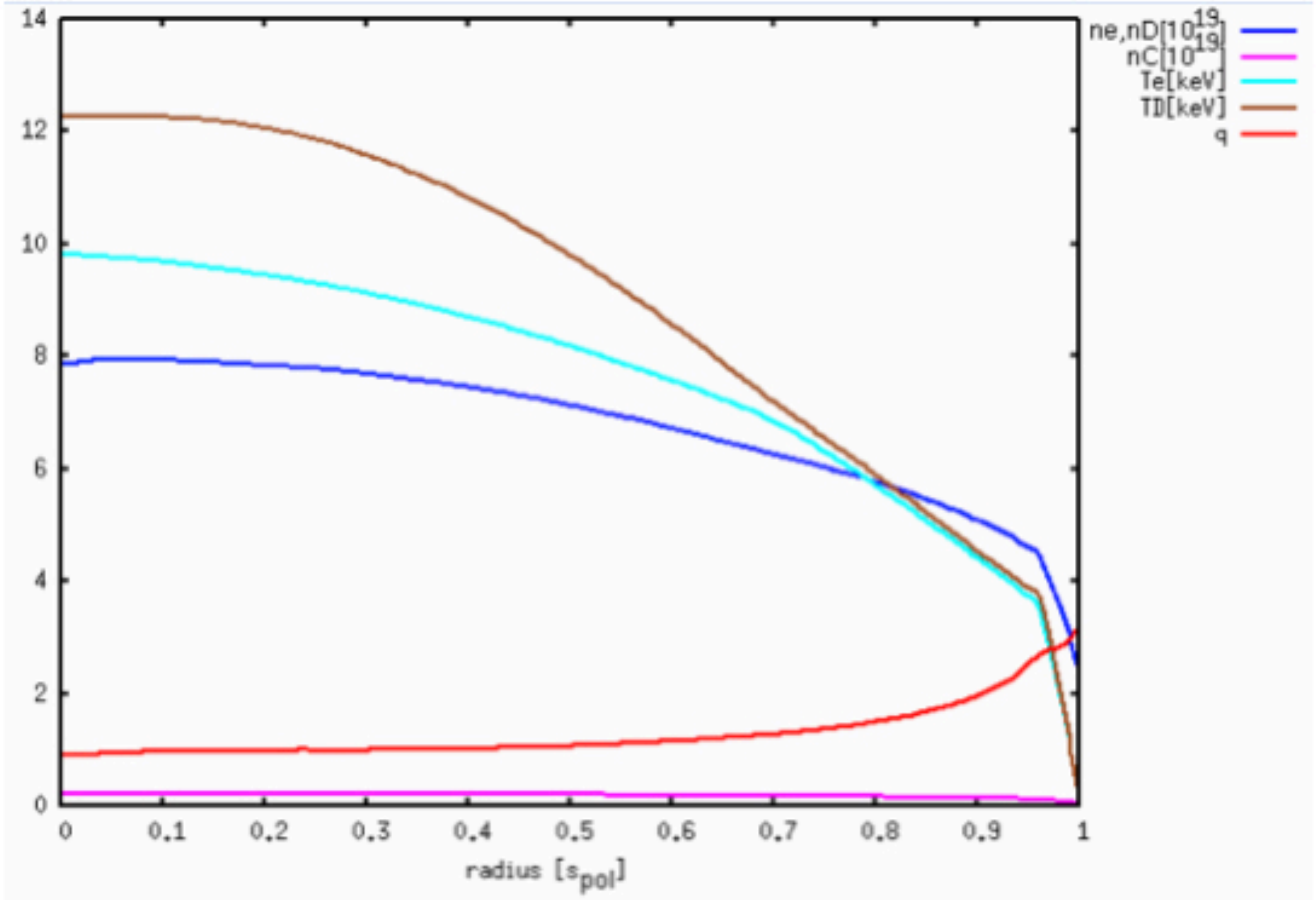
LIGKA CASTOR

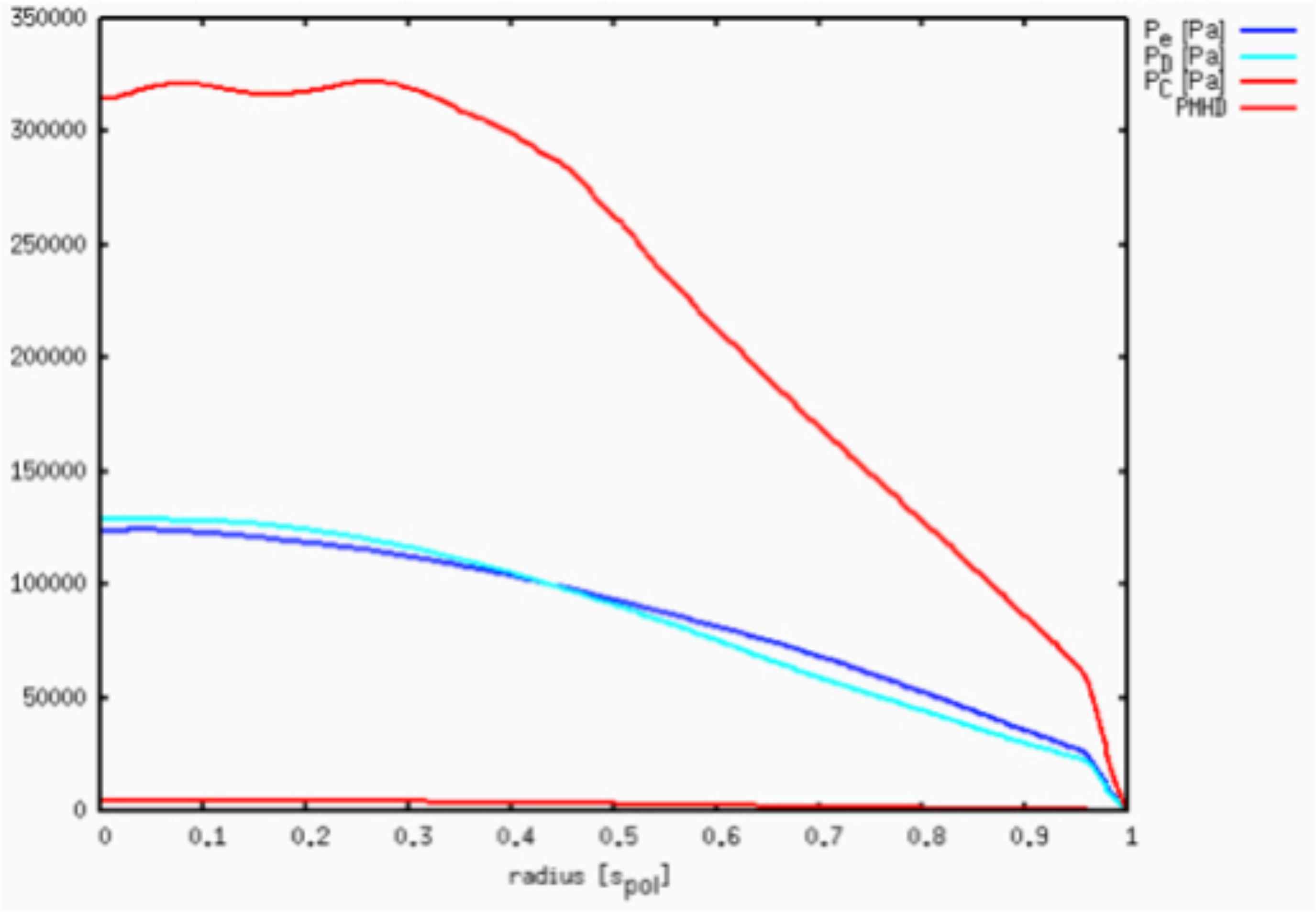
can be resolved by re-reading helena-written IDS by different eq-codes (now experience with chease->helena)

2. JT-60SA

JT-60SA: successful coupling of EP WF to JINTRAC output (scenario 2, 70000,419) [L Garzotti]

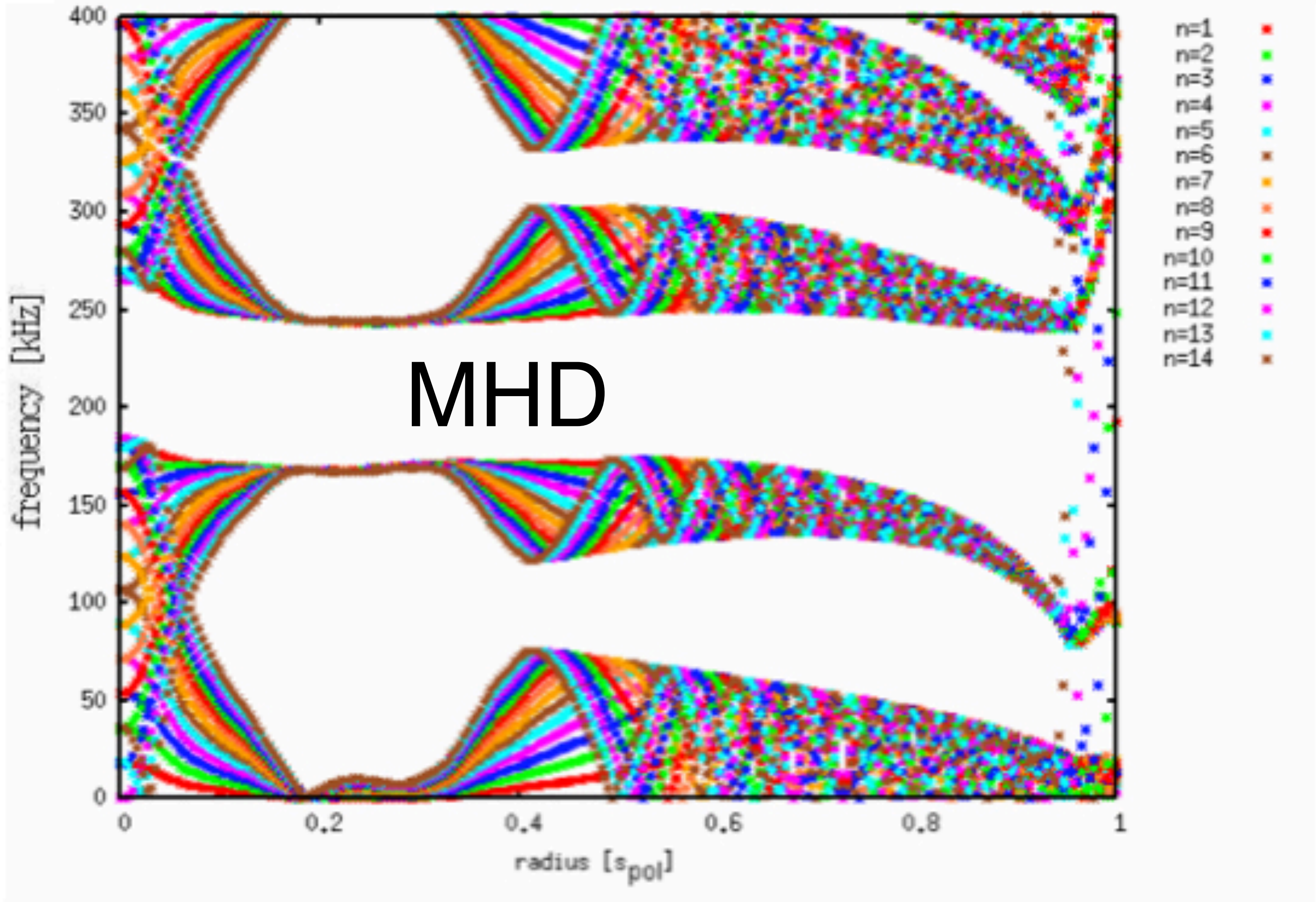


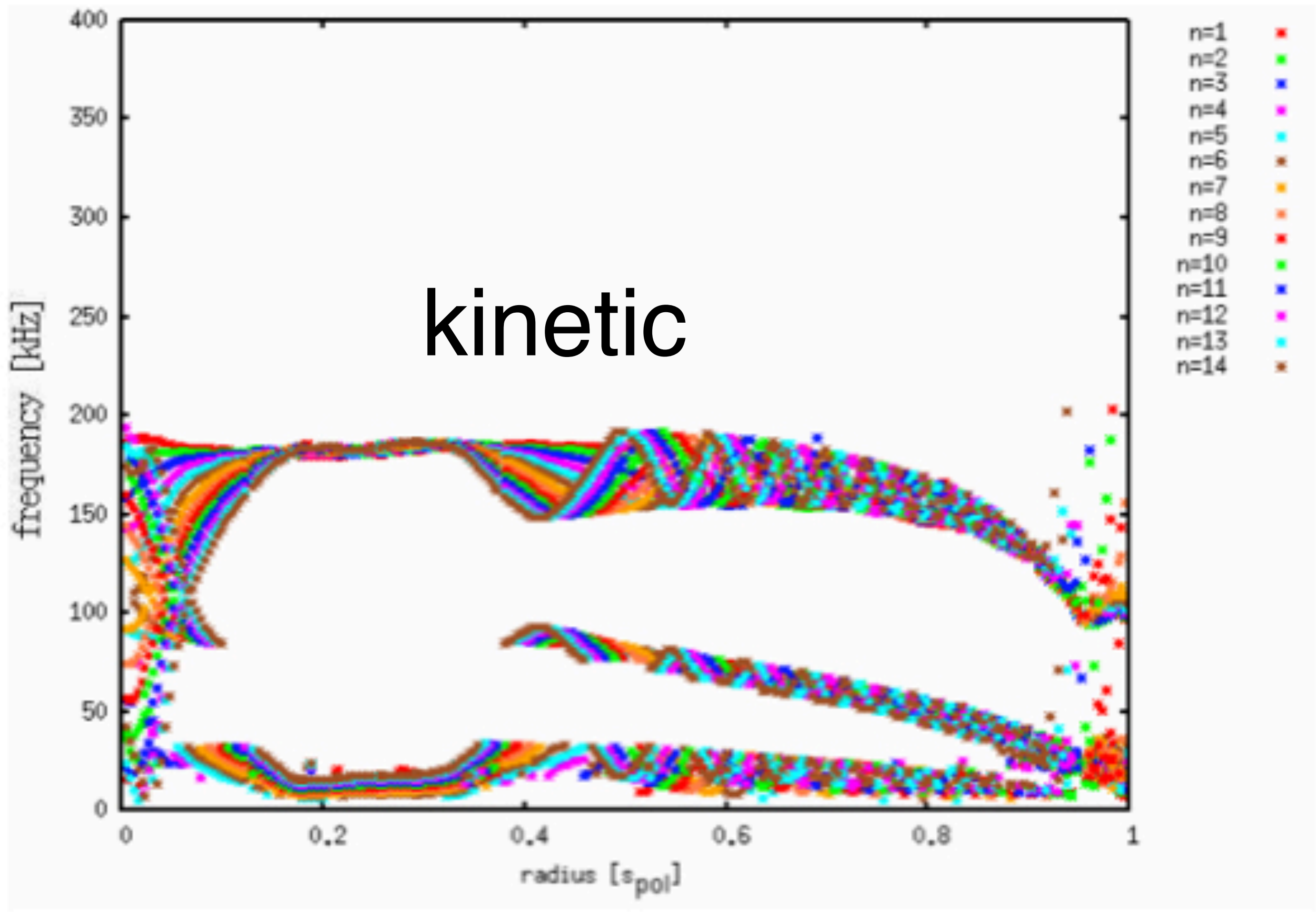




difficulty: profile input from transport codes to equilibrium code

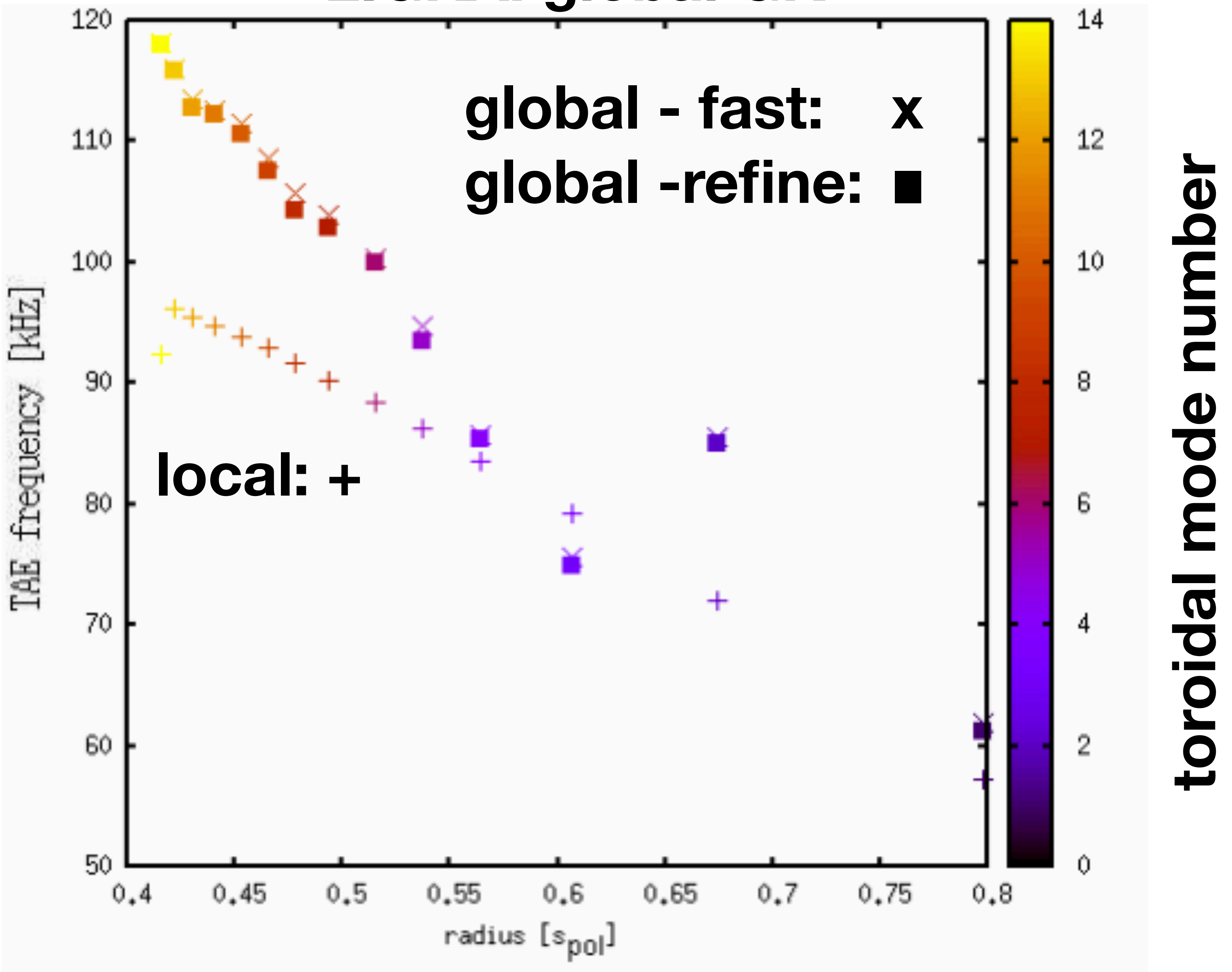
was resolved by re-reading CHEASE-written IDS by HELENA



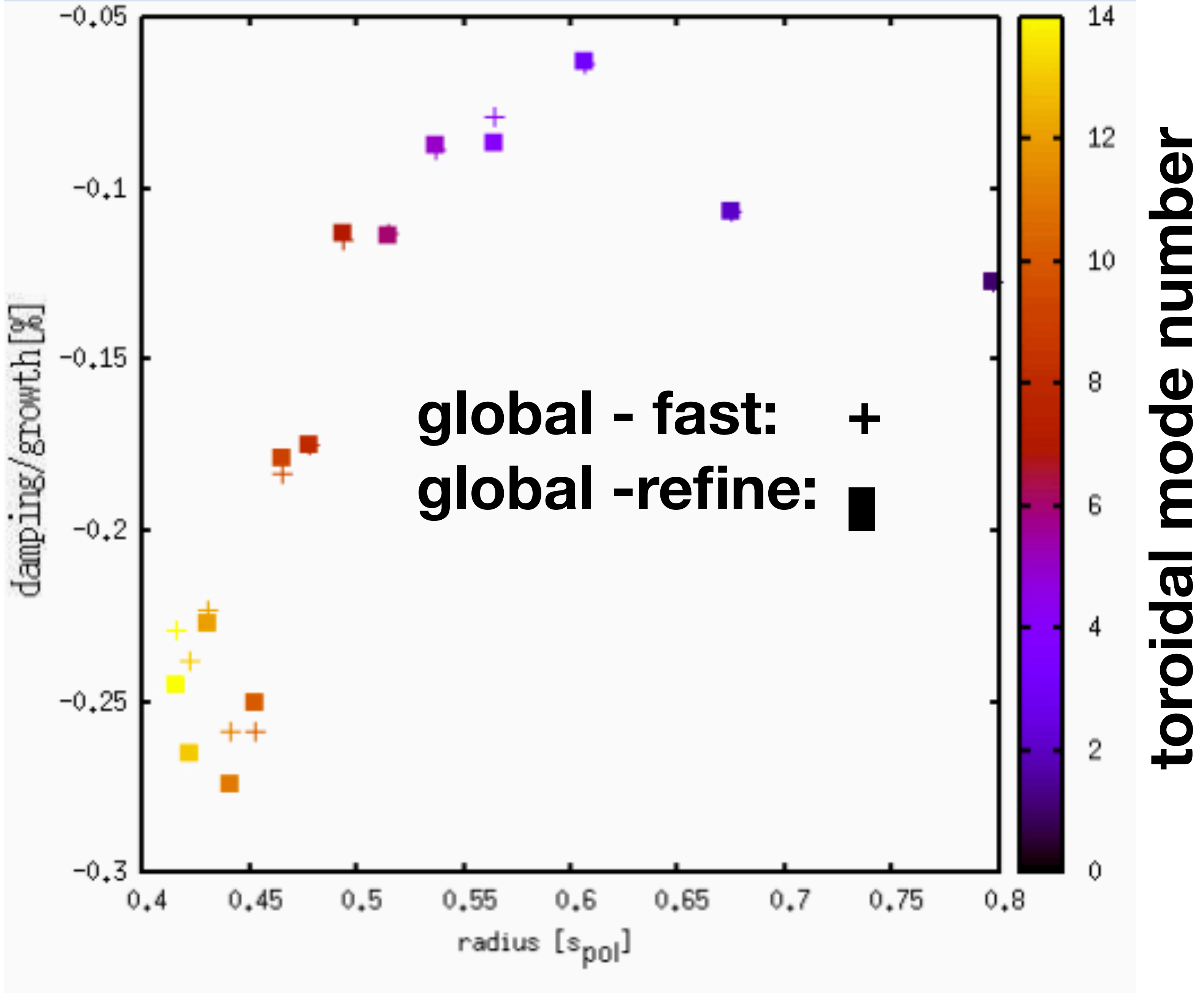


JT-60ASA: successful coupling to JINTRAC output (scenario 2, 70000,419) [L Garzotti]

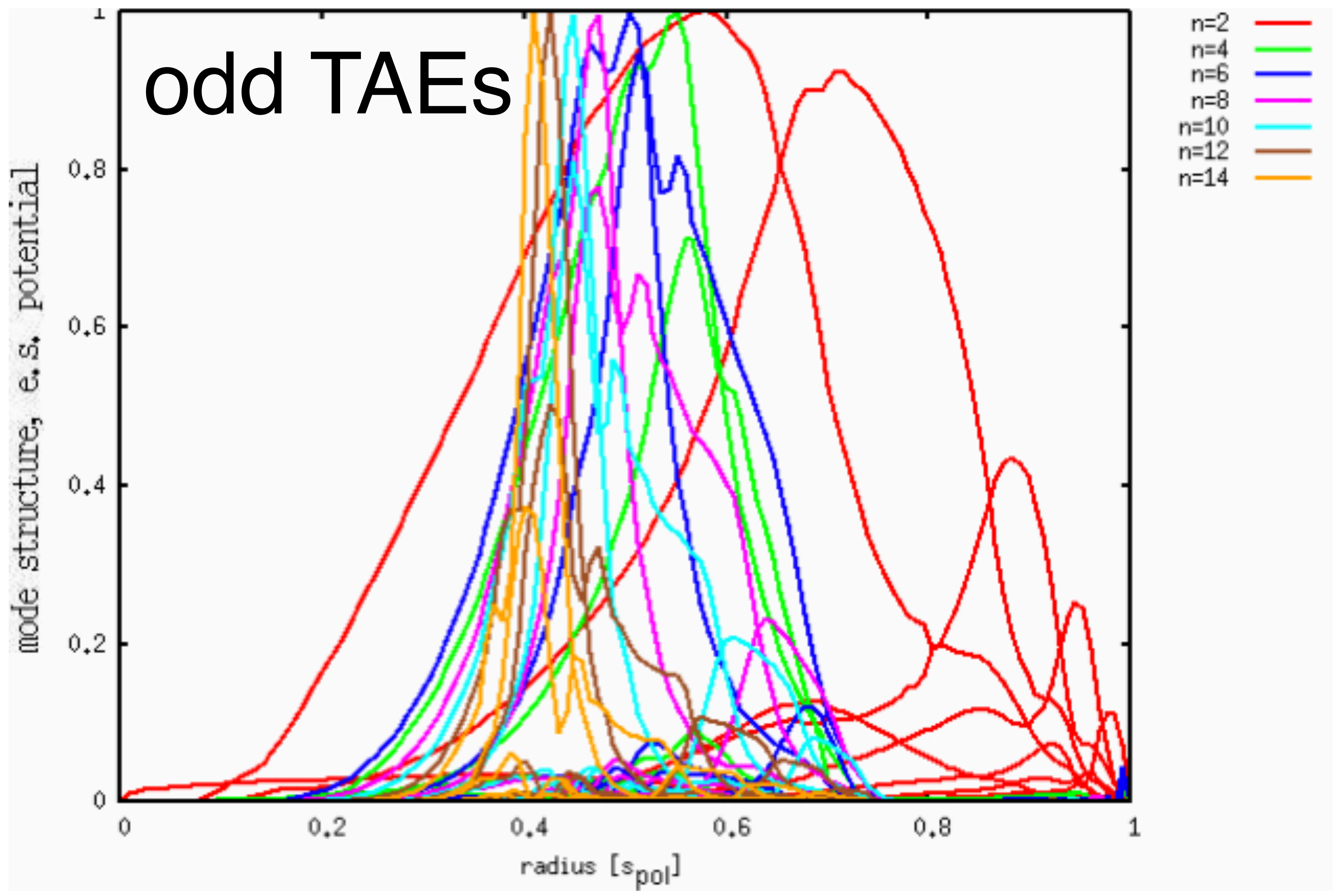
LIGKA: global GK

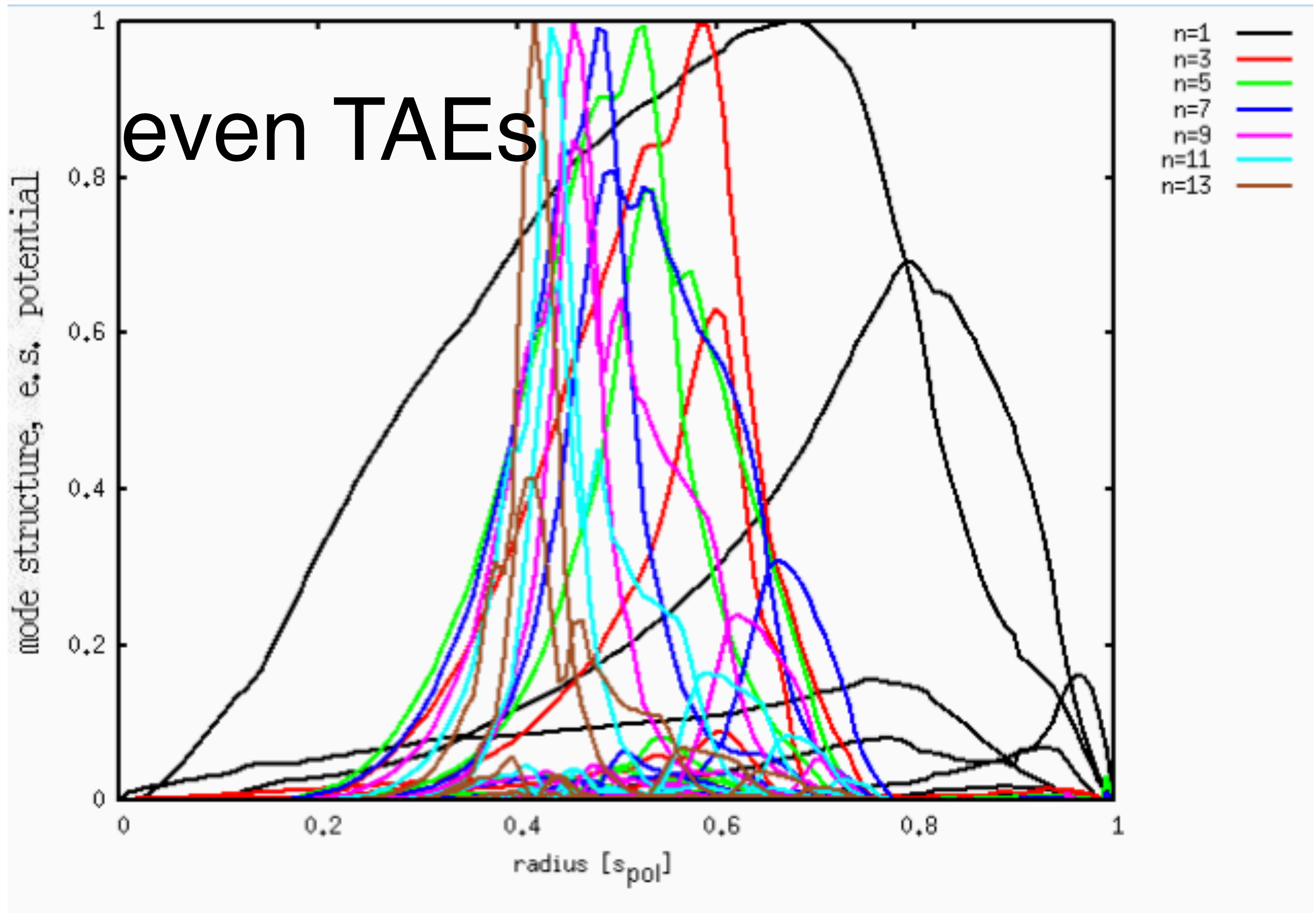


LIGKA: global GK

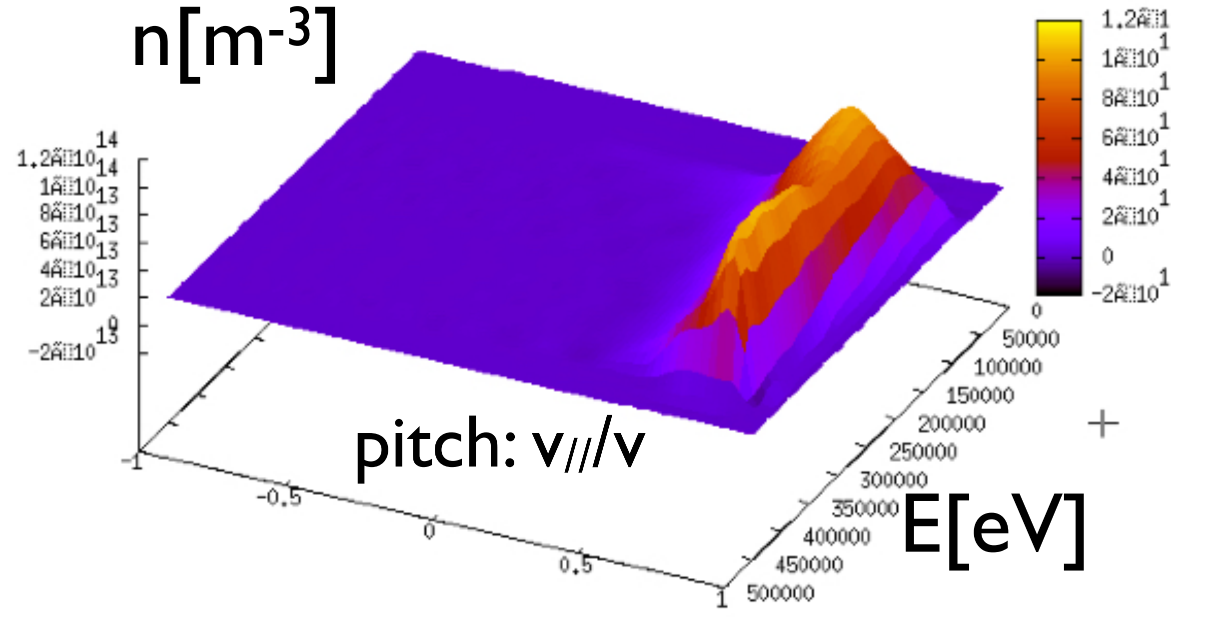


waiting for time-dependent runs to be available in IMAS on gateway…



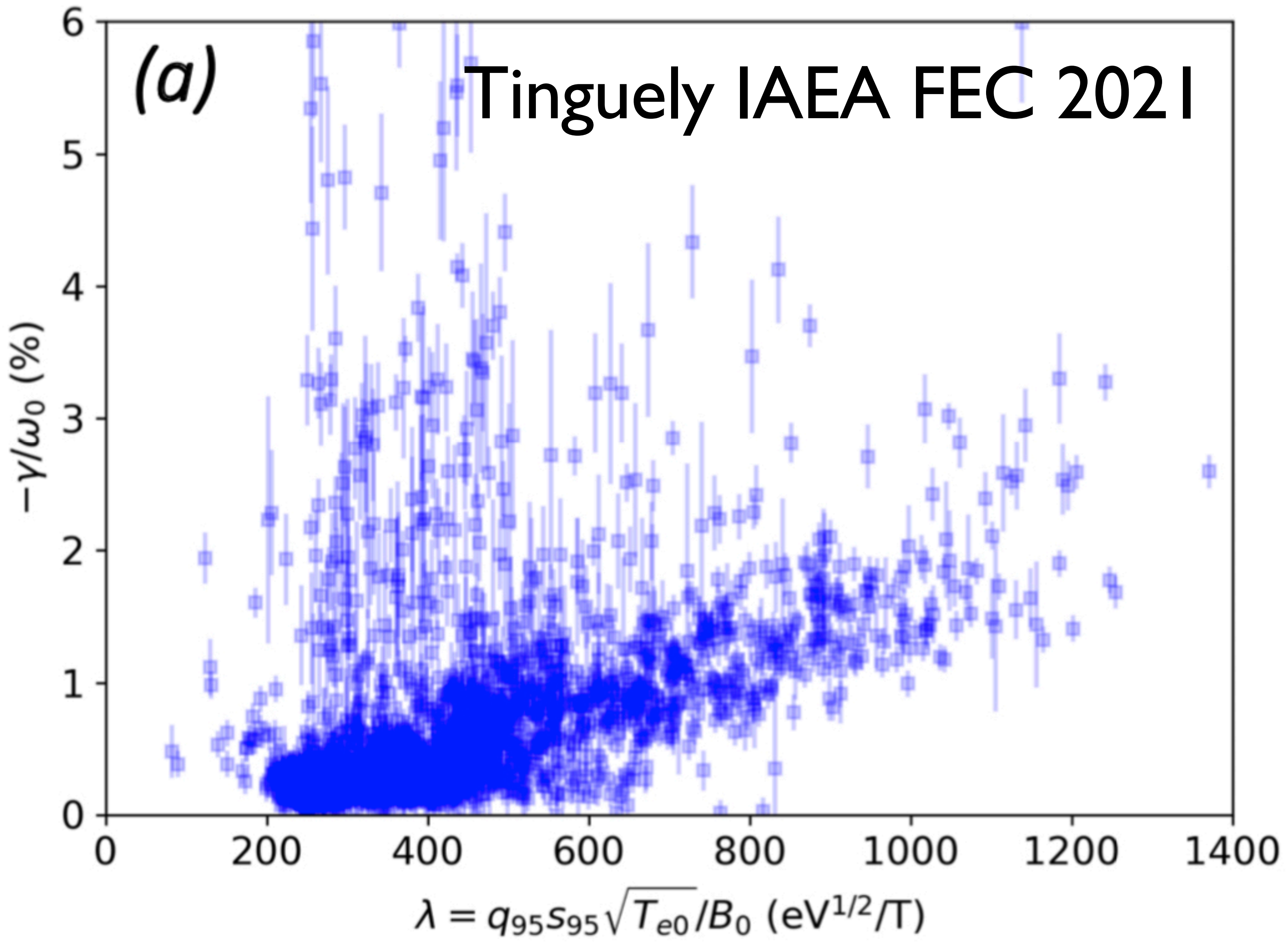


and combine with NNBI F_{EP}:



3. JET

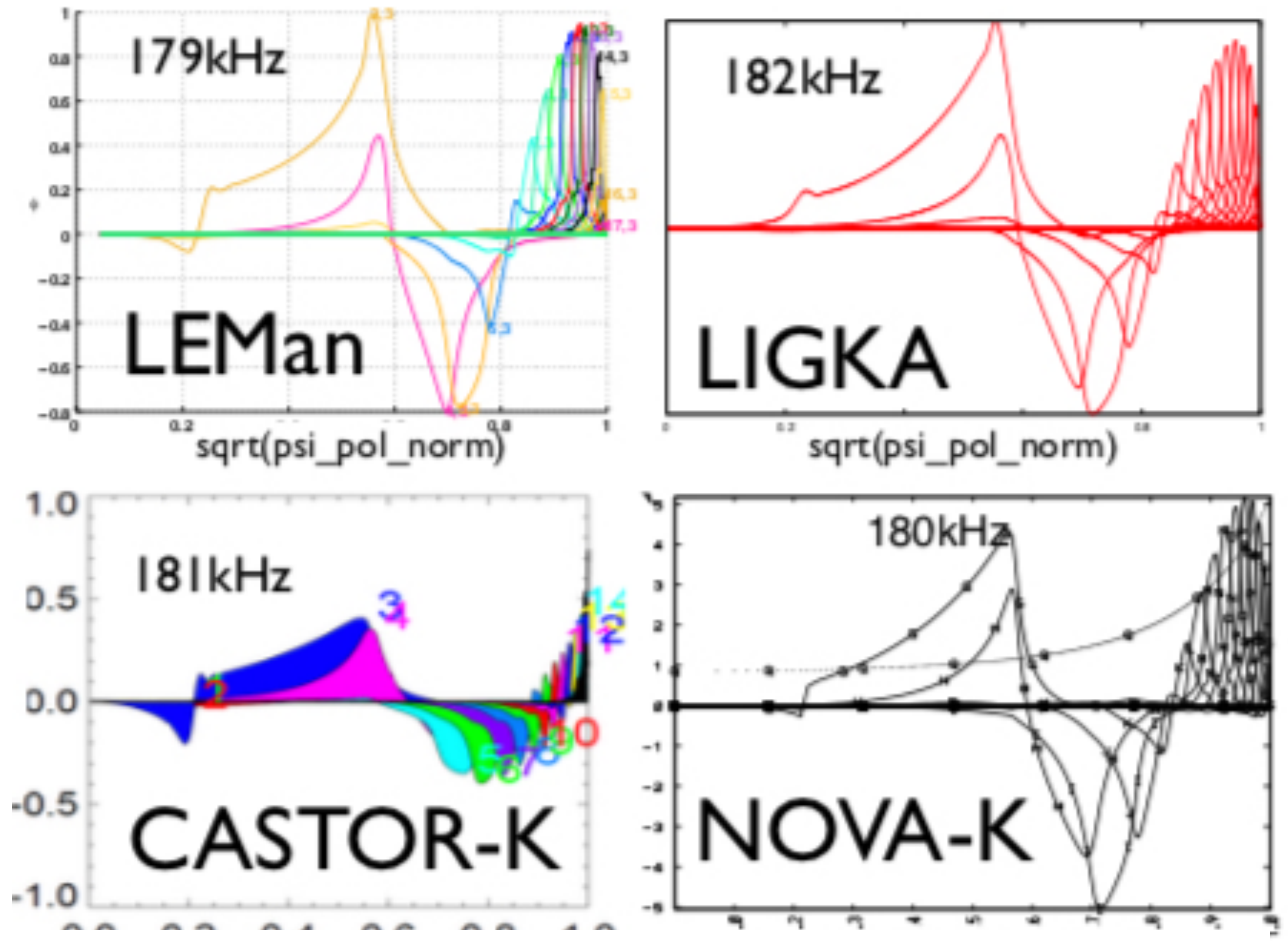
JET: repeated damping study of AEs for predicted DT scenario after 2010 ITPA effort - similar results...



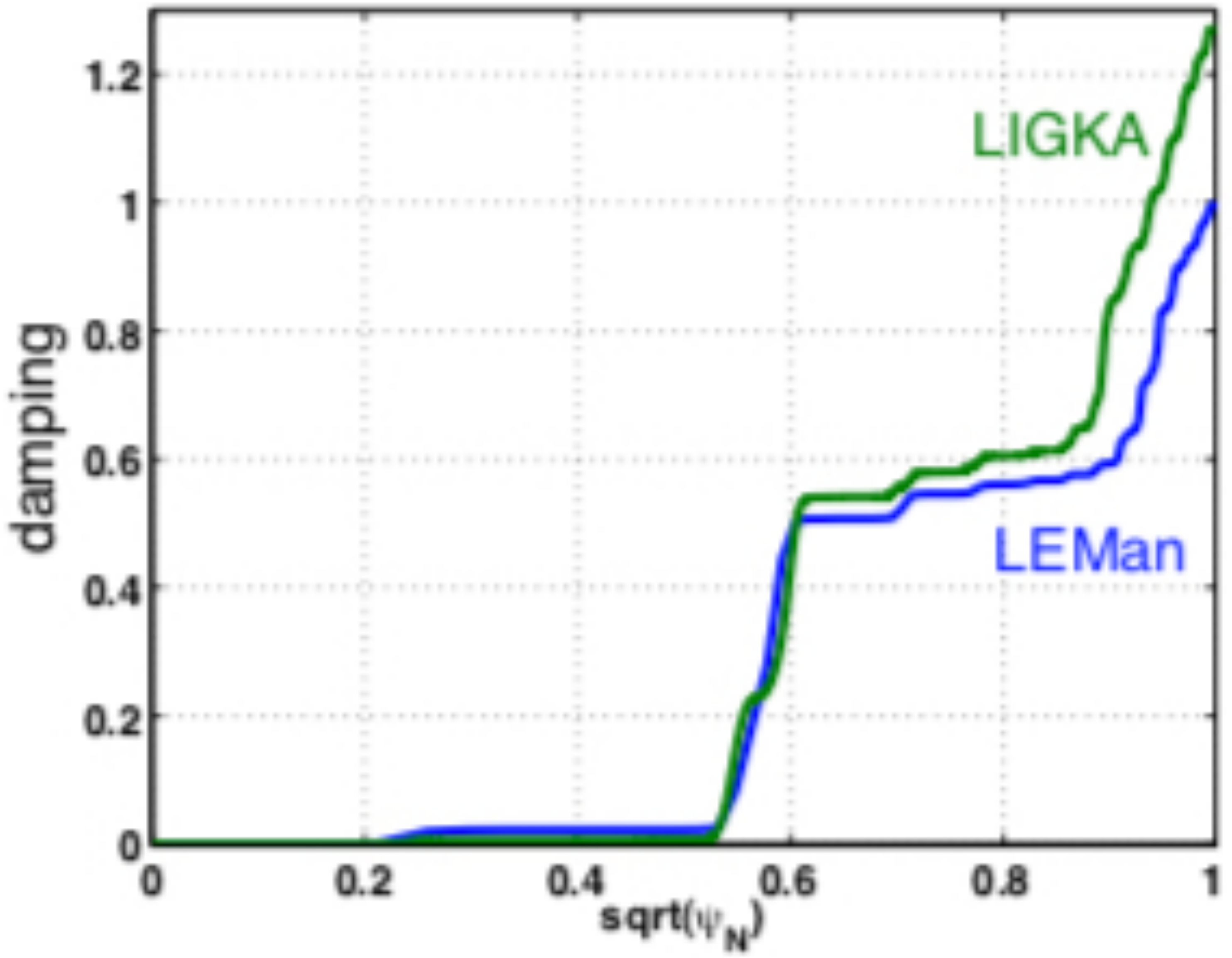
global modes not accurately described by one local parameter: large scatter!

radiative damping dominates, often non-locally

ITPA IAEA FEC 2010

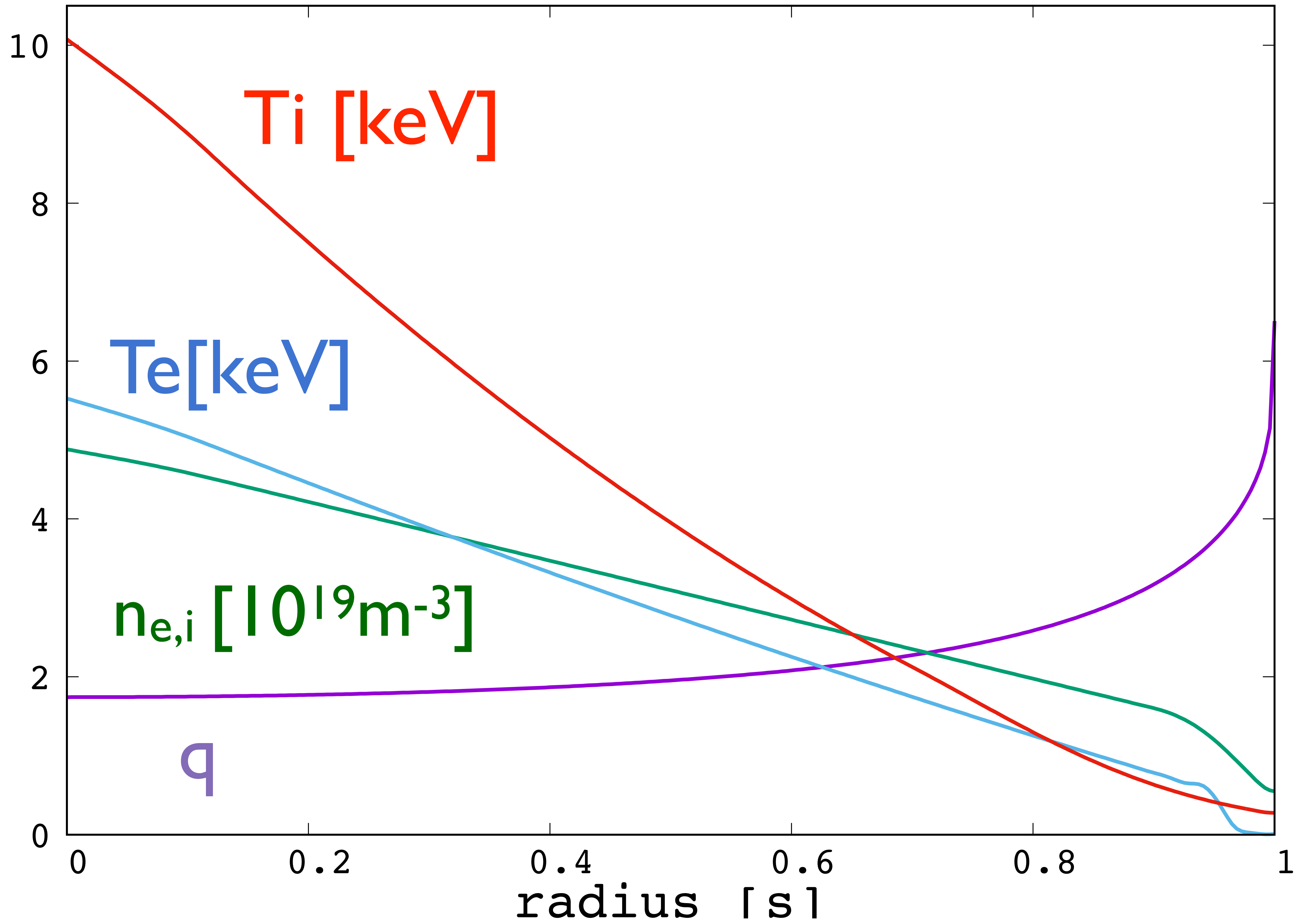


new case: [M. Fitzgerald]
(scenario modeling
studies for DT)
n=5 TAE
radiative damping dominated

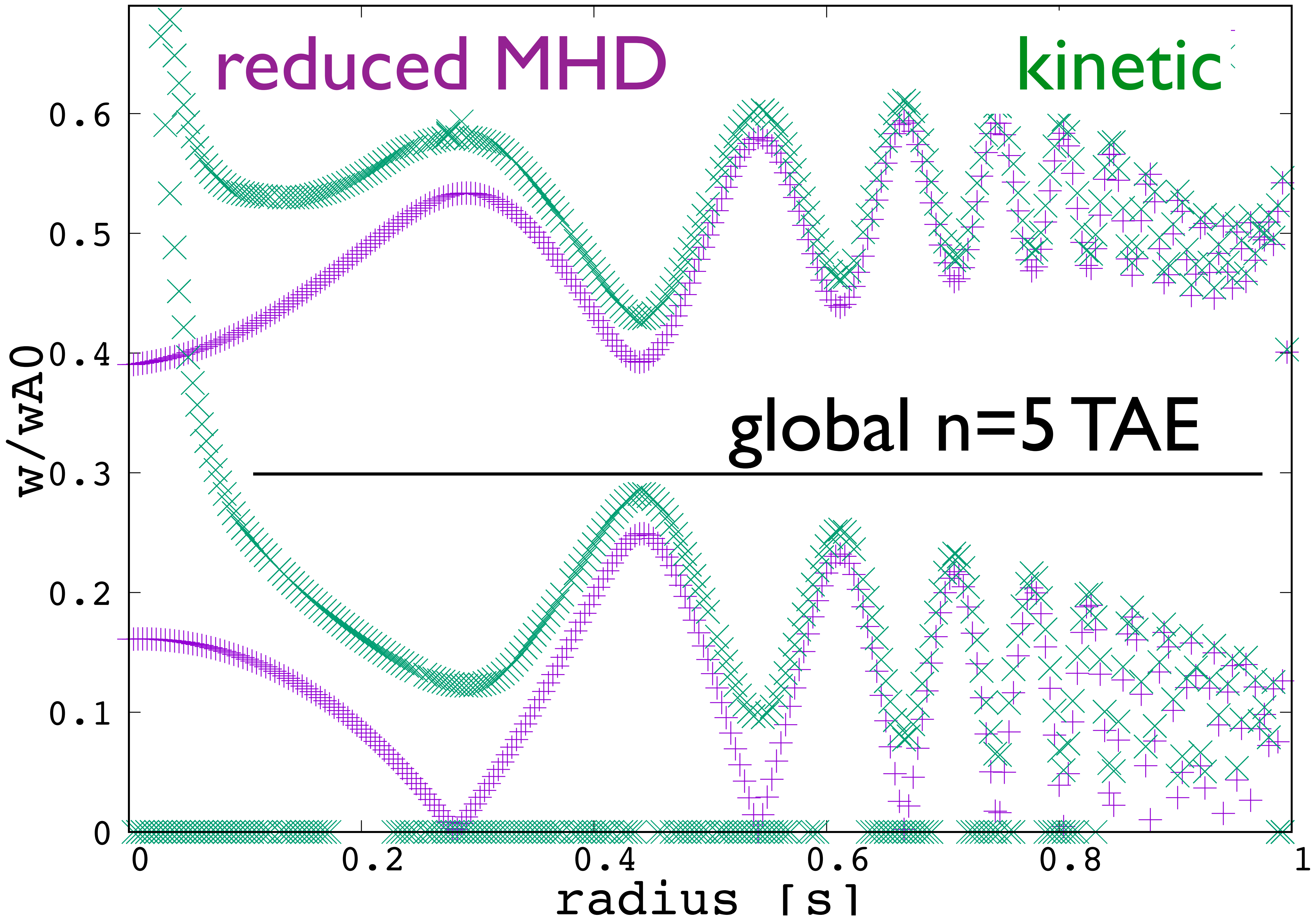


JET (no data, scenario projection on request by M. Fitzgerald)

similar to [M Fitzgerald et al in prep 2021]



B0=3.4, R0=2.97m



What is the role of KAWs for the damping of low-n TAEs?

analyse ion and electron contributions, structure of mode structures and $E_{//}$:

JET: analysis of damping mechanisms [Lauber, AAPPS-DPP 2021]

adding step by step electron resonances:
no electron LD damping:

γ/ω = -0.16% (ion LD)

adding circulating k=0 resonance:

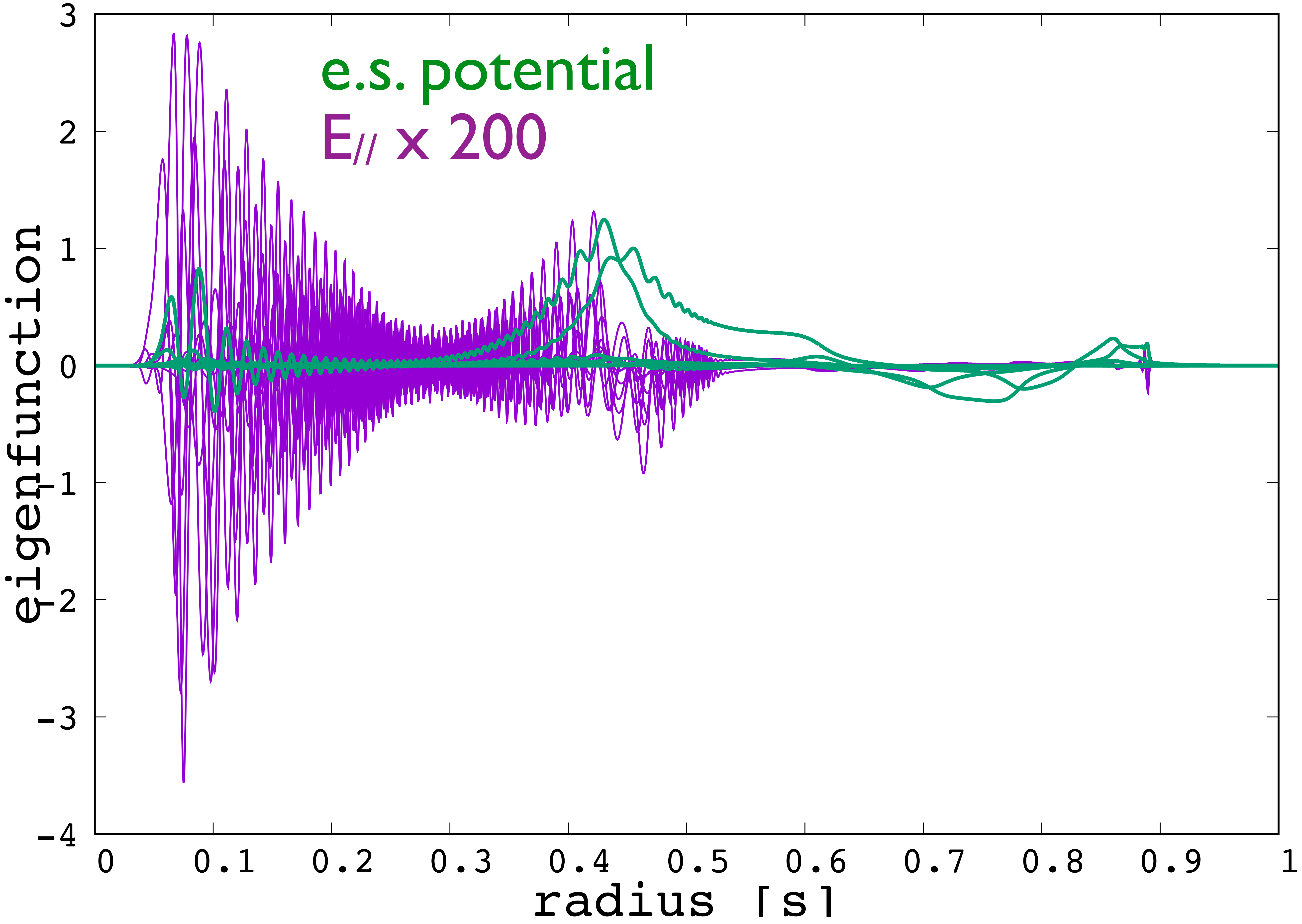
γ/ω = -0.67% (ion LD+circ el)

adding circulating k=±1 sidebands:

γ/ω = -0.77% (ion LD+circ el+sb)

adding trapped electrons:

γ/ω = -0.87% (ion LD+all el)



almost undamped KAW - in agreement with theory

JET: analysis of damping mechanisms

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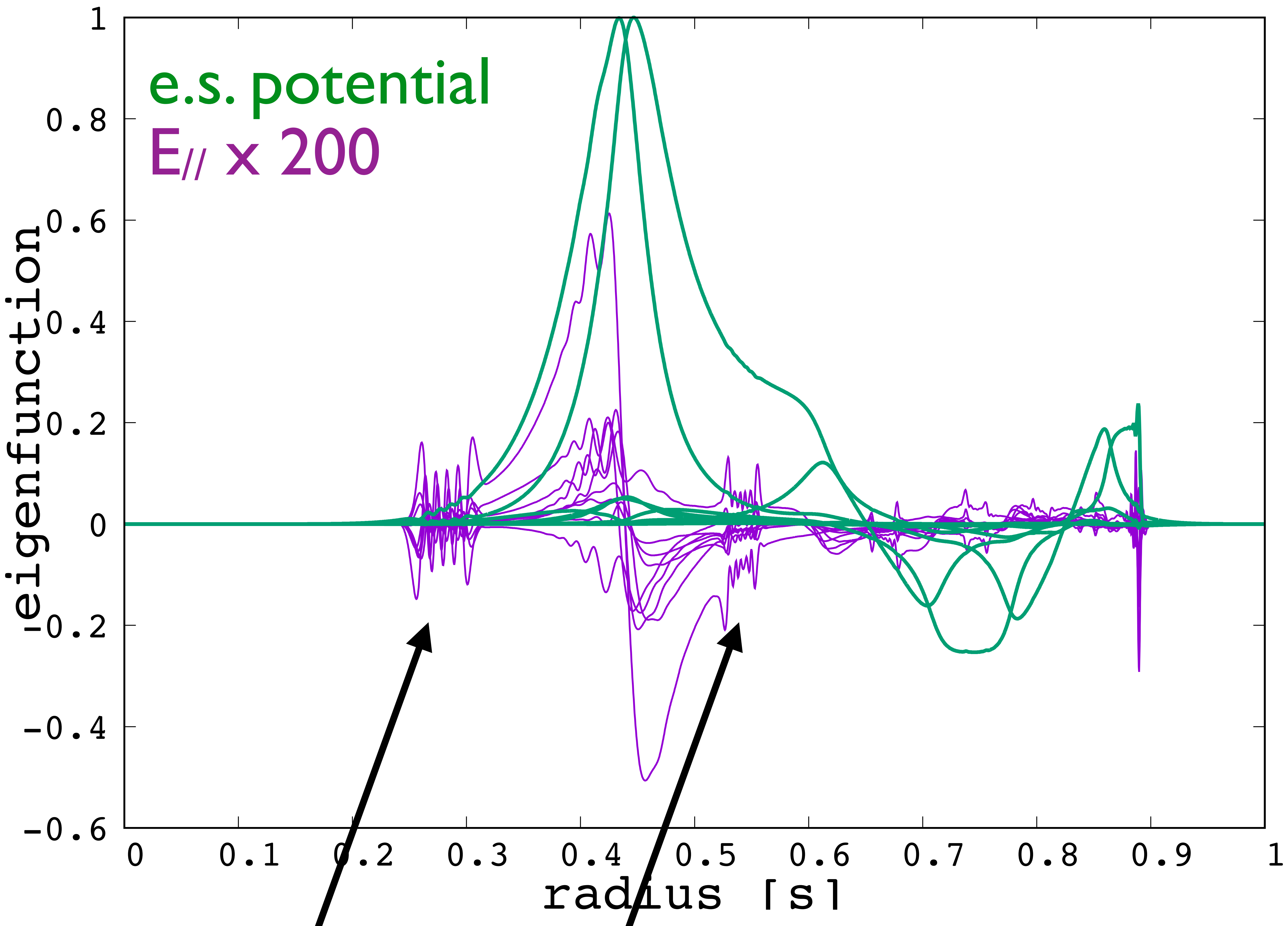

missing trapped electrons lead to weakly damped region close to k//=0

adding step by step electron resonances:
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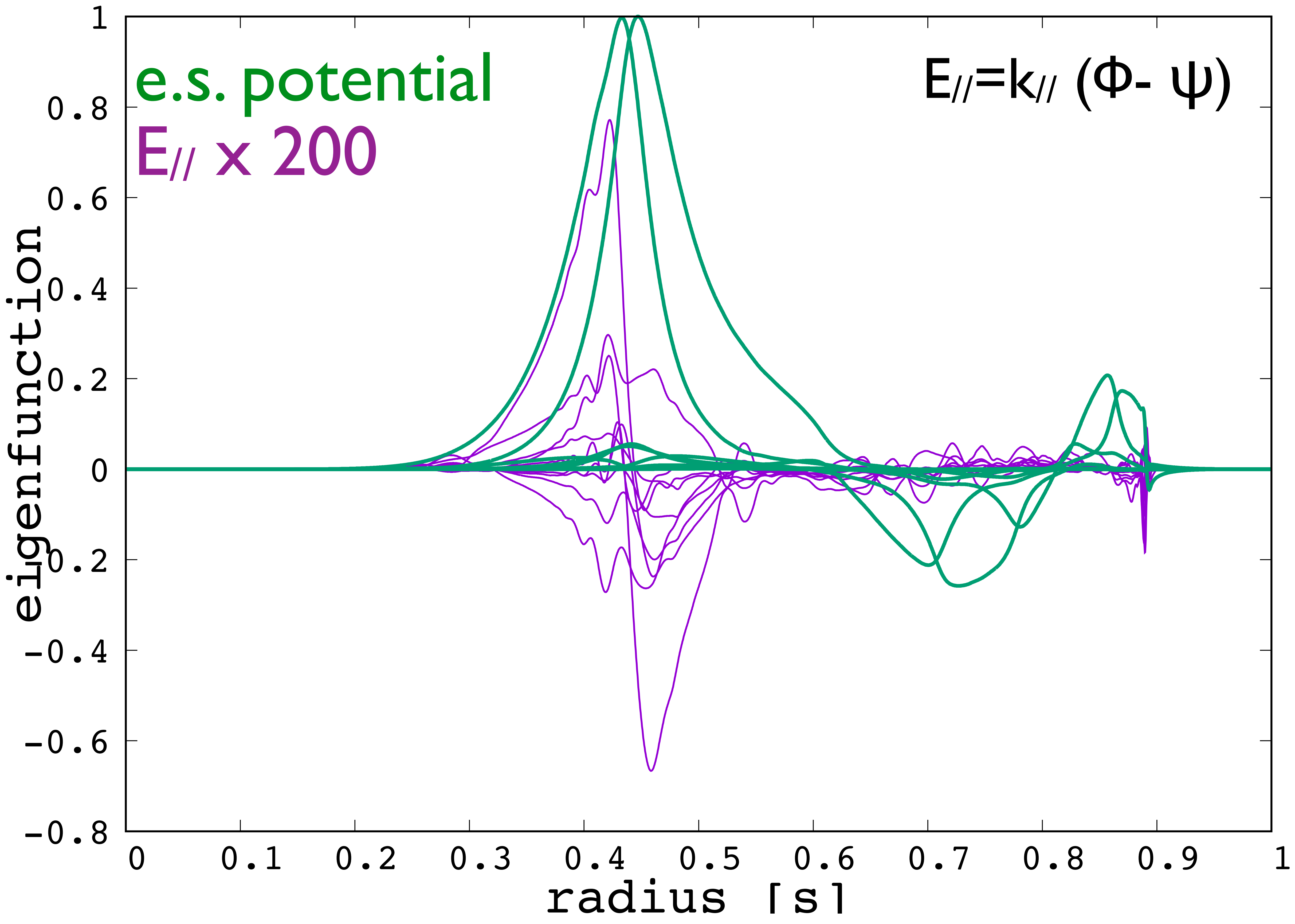
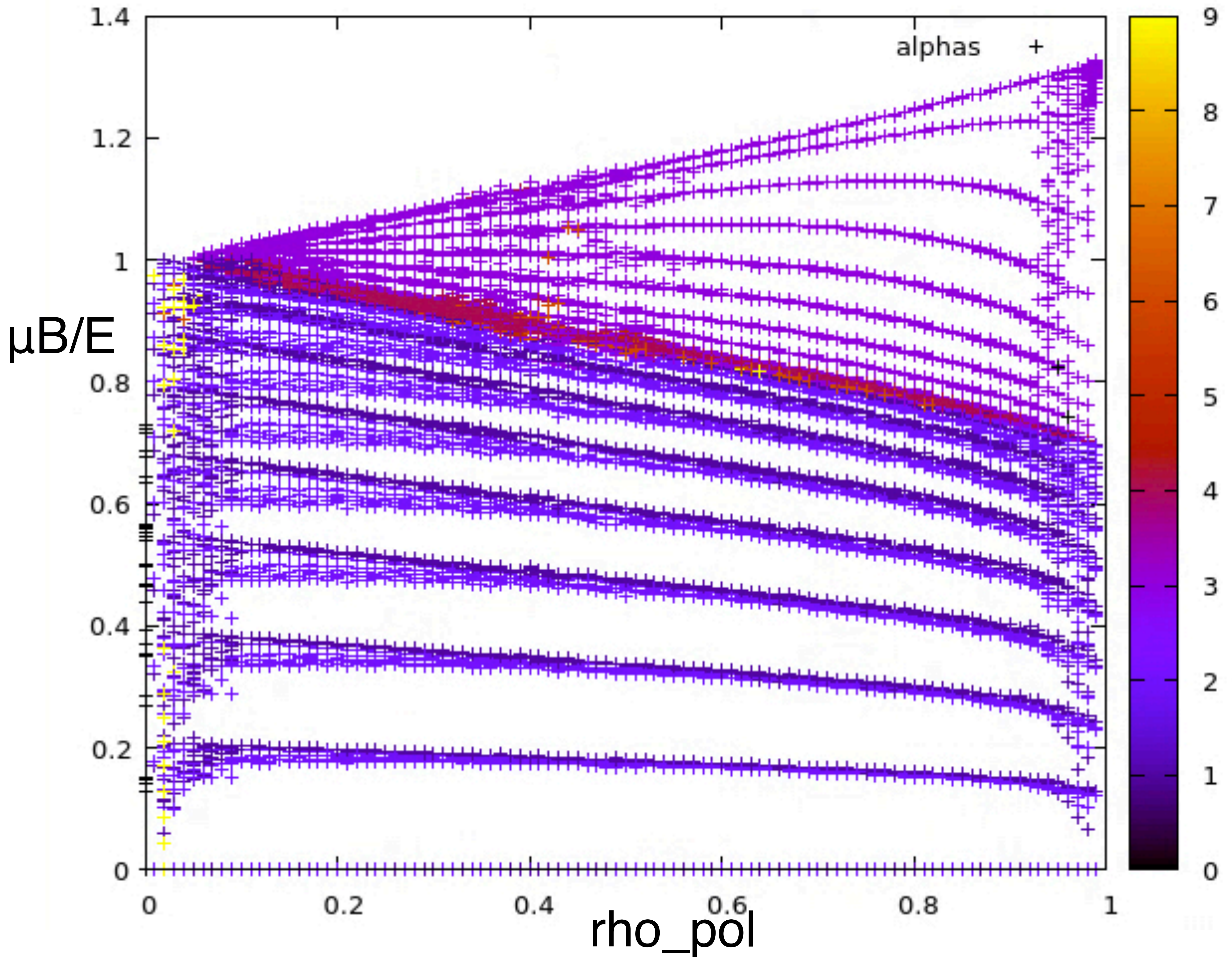


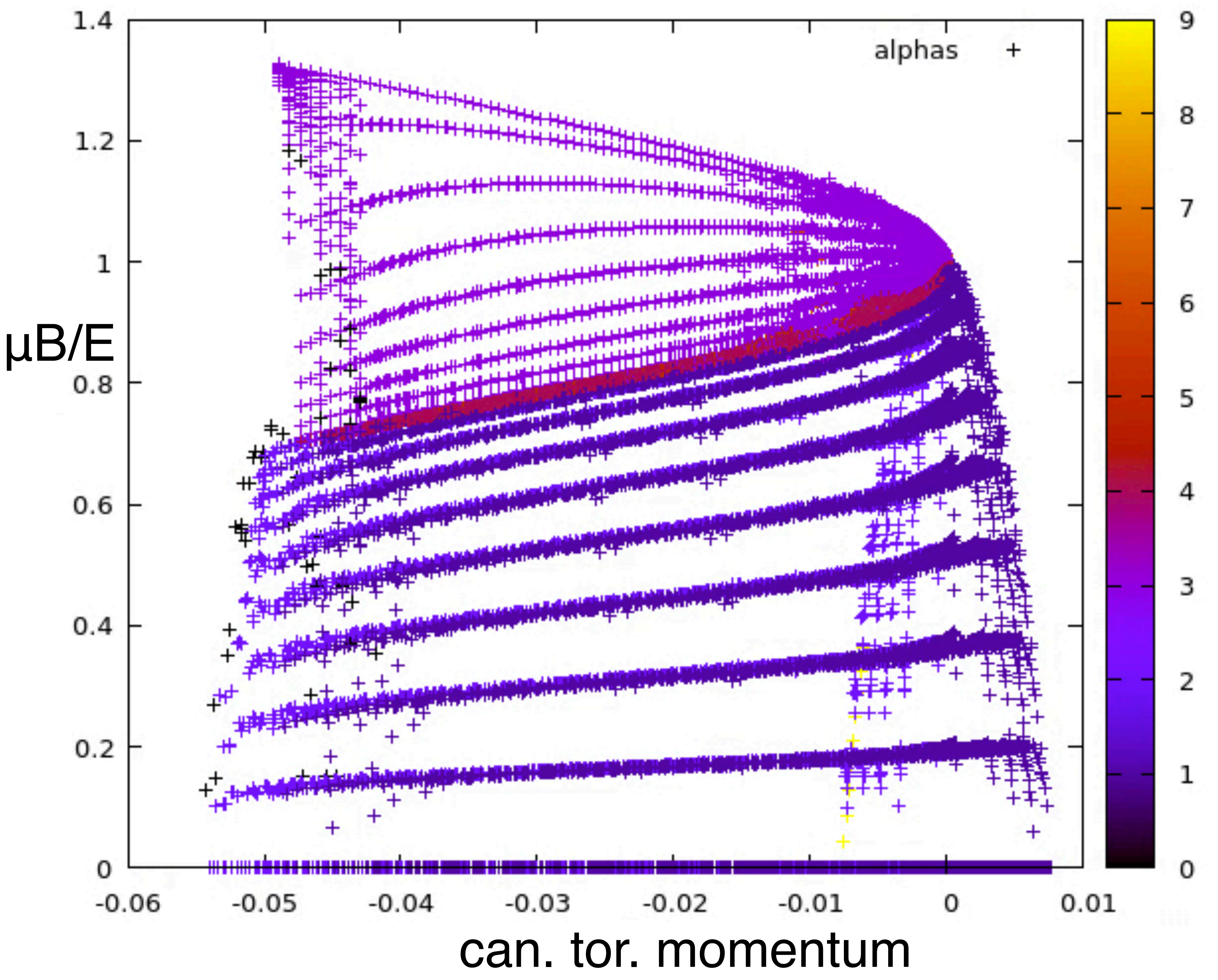
smooth structure - KAW coupling visible in E//
mode structure differs from MHD result - **non-perturbative**

towards EP transport models

towards EP transport: HAGIS2 as library is crucial element for various transport models

color: co, cp, trapped, potatoes



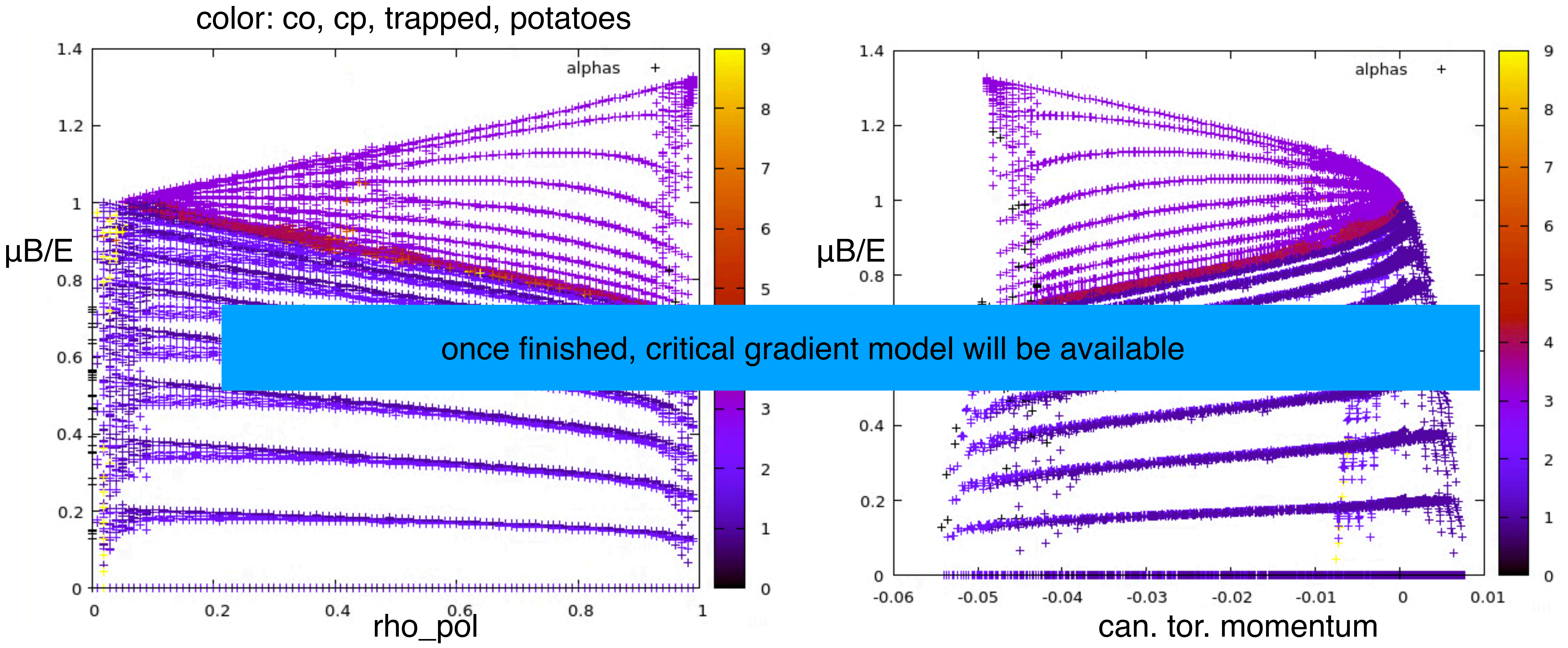


distributions IDS holds all orbit-averaged information about marker space - fast, repetitive calls are possible

[A. Bierwage, CPC 2022, LIGKA orbit integrals, CPC 2007]

'finder' routine to set up marker space, determine trapped-passing bnd, sort, classify and select particles,…

now full implemented in IMAS, also with extended IDS structures etc, MDS+ limitations (2GB) identified towards EP transport: HAGIS2 as library is crucial element for various transport models



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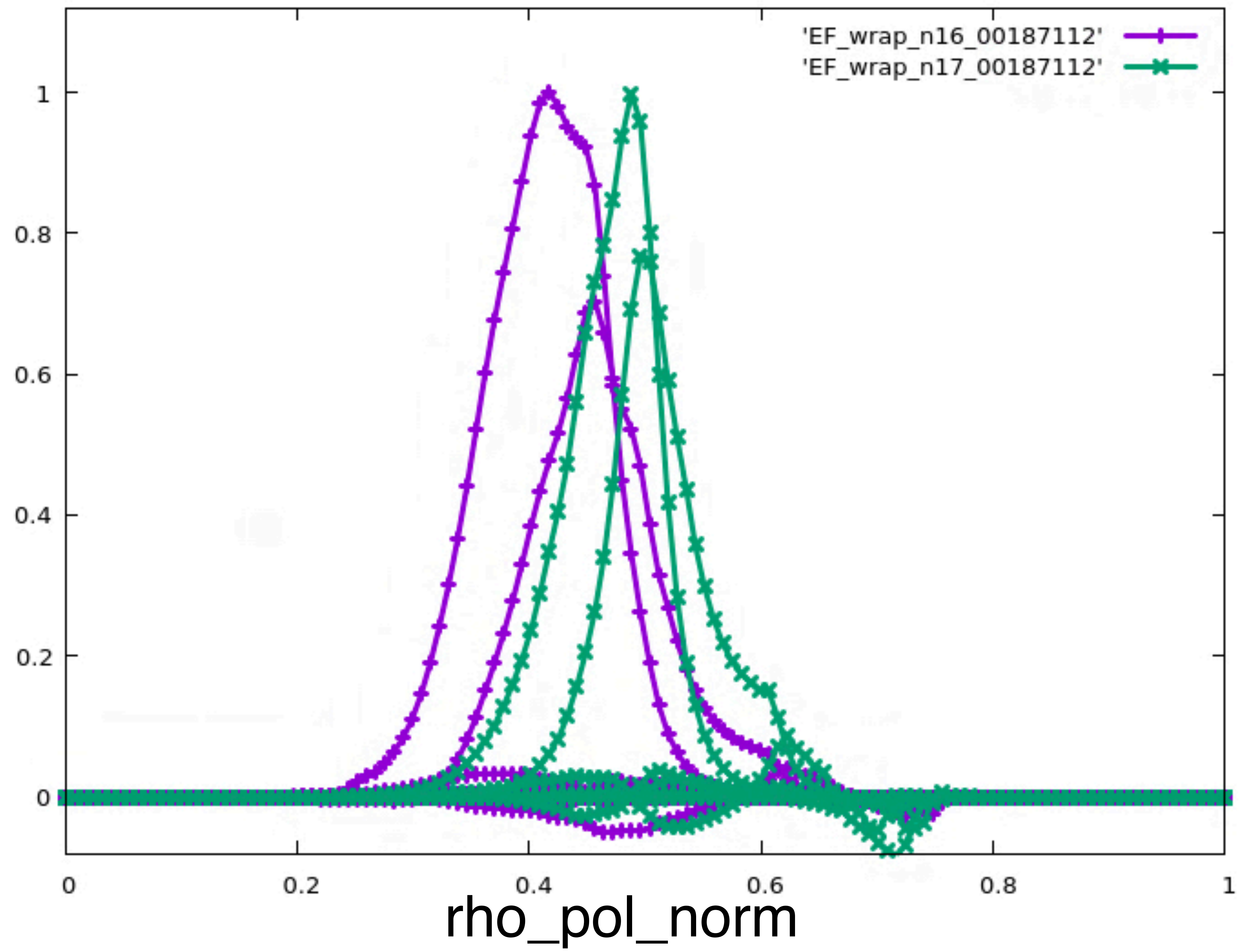
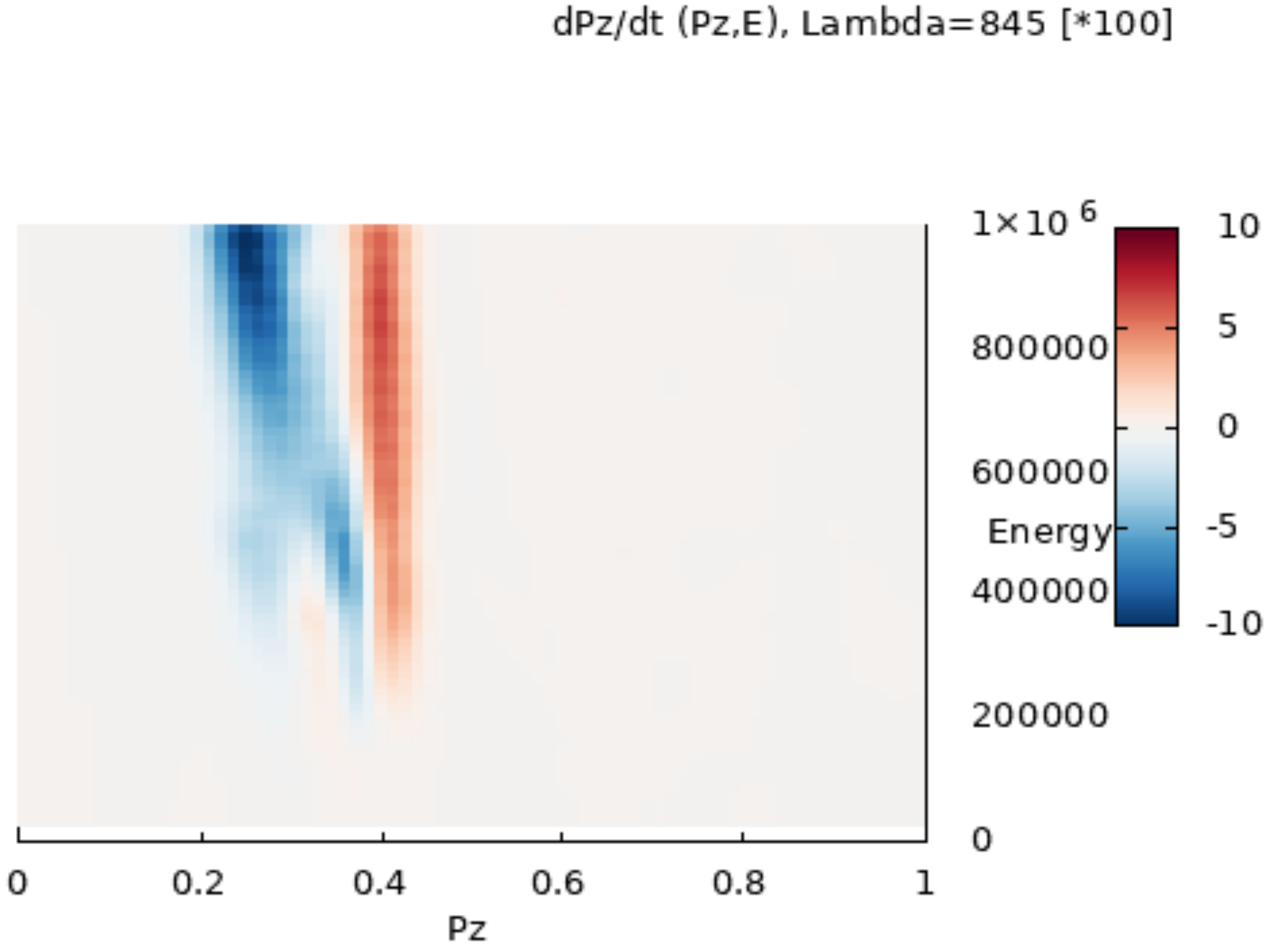
implementation of PSZS transport models - here: kick-model limit (ITER case)

[M.V. Falessi, 2017-2022, ENR ATEP project]

calculate <dPz/dt> , <dE/dt> for given fixed mode structures at fixed amplitude:





- apply to F_{EP}(Pz,E,mu) using various (diffusive, convective,…) ‘Ansätze’
- extend to 4D i.e. including amplitude - opens path to intensity closure models
- pass either F_{EP} or moments back to transport codes

outlook

- **EP -WF also successfully applied to TCV [M. Vallar] - some EAE problems of WF to be resolved**
- **first application to JT-60SA, scenarios will be available soon**
- **ITER scenario studies ongoing [V.A. Popa, IAEA TCM Data Analysis, Dec 2021]**
- **JET-TAE studied in [Ph. Lauber AAPPS-DPP, 2021], no WF application so far**
- **DEMO: start to test EP-WF on a few generic scenarios to be determined soon**

- **further needs:**

- **interfaces between experiments and IMAS databases (JET, JT-60SA)**

- **consistently filled IDSs (core_profiles, equilibrium, distributions)**

- **depending on smoothness, interpretative transport runs necessary - IDA analysis is sufficient**
- **error analysis and UQ is now possible**

- **set of standardised smoothing/fitting tools for exp. data, in particular EP distribution functions - reproducibility; IMAS based orbit data-base routines available [Bierwage et al 2021]**