ATEP progress meeting

March 9th, 2022

agenda:

A. Bottino: PSZS diagnostics in ORB5
Y.Y Li: Numerical Results of DAEPS Code with General Axisymmetric Toroidal Geometry
Ph. Lauber: WP4 and WP2 updates

administrative news:

- ATEP 2021 report accepted
- ACH support for advanced transport models and STRUPHY development submitted, 2023/2024
- 5 EPS abstracts with ATEP contributions
- ITPA spring meeting, May 2nd -6th, ITER (abstracts till 1st April)

WP4:

Preparation of time-dependent reference cases

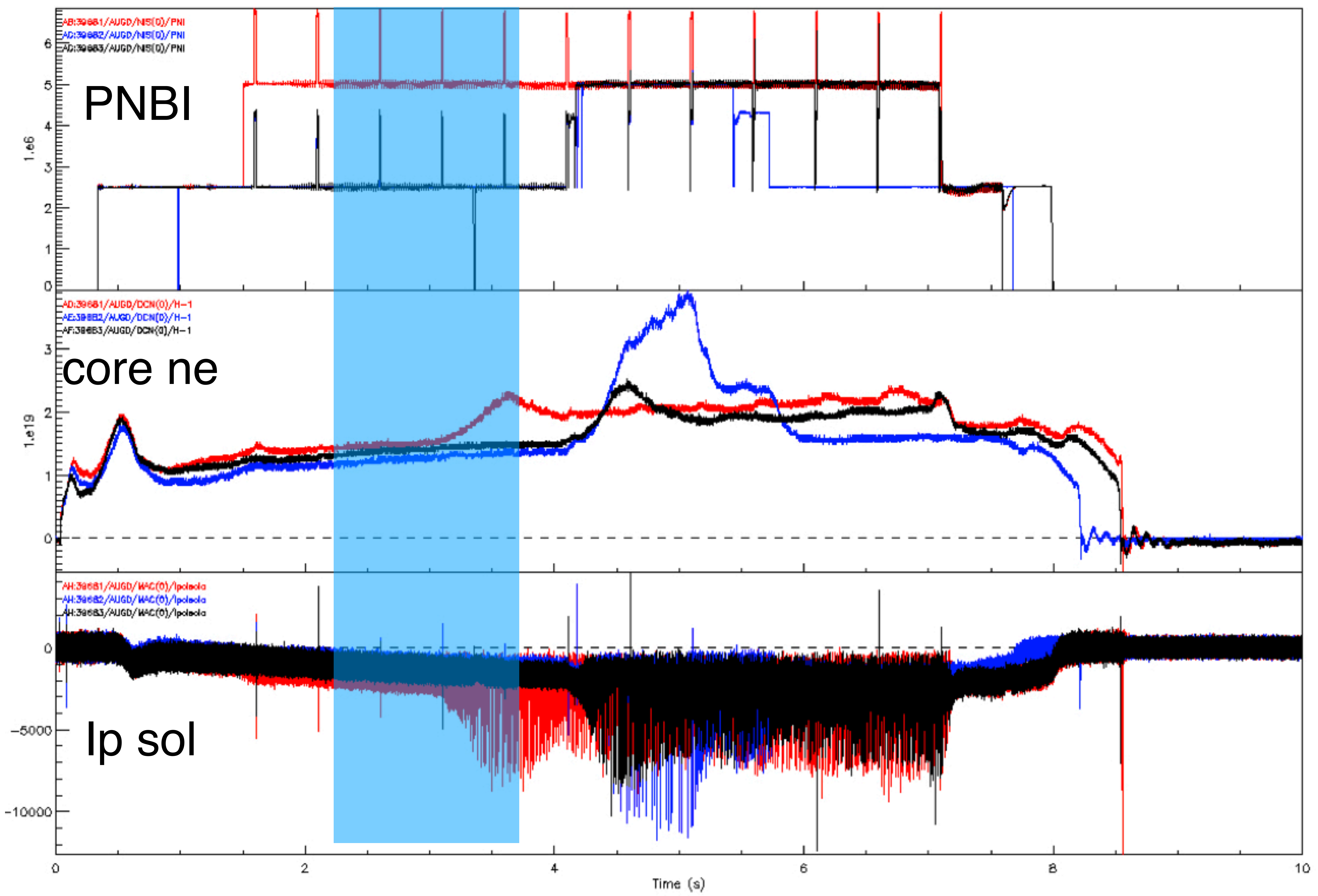
AUG: EP driven modes change bursting characteristics during slow L-H transition in hydrogen: discharge stays in L mode despite 5MW heating

- beam box 1: H - measurements, control core Ti
- beam box 2: D - drive instabilities

in all discharges: 55-60% H/(H+D)

despite low H/(H+D) we have L mode phase with 5MW NBI - most interesting phase (& diagnostics availability)

MHI, SXR,RFL,ECEI,FILD,CXS



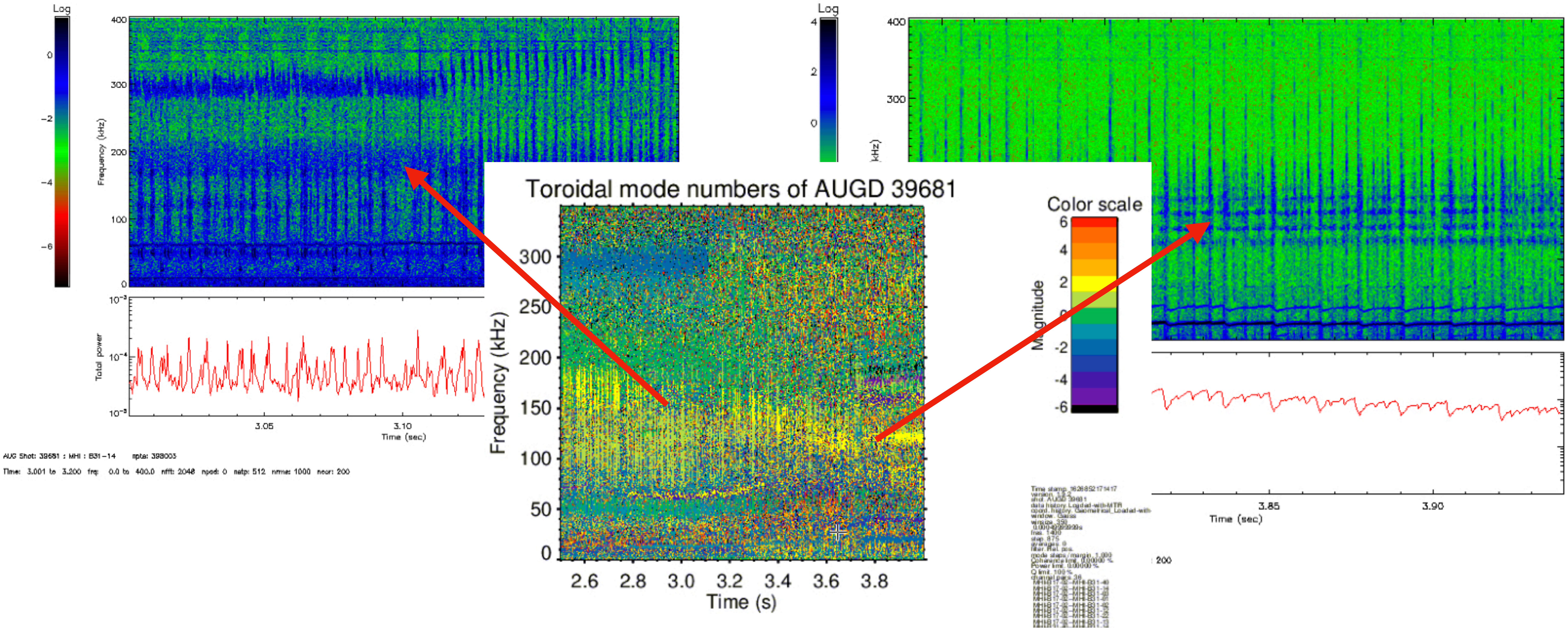
off-axis NBI heating: positive and negative spatial EP gradient
study inwards transport of EPs and its effect on core background plasmas

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

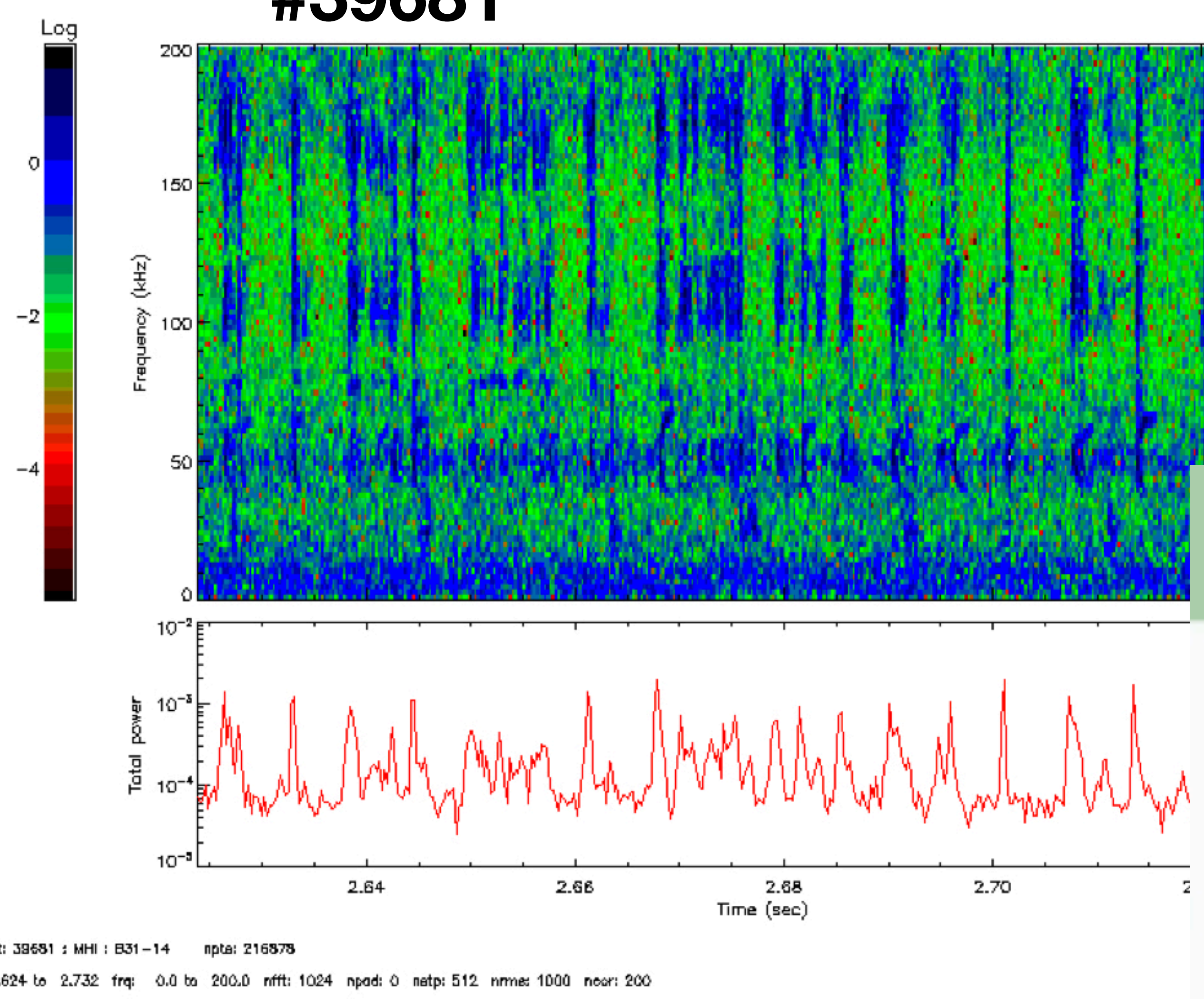
L mode [2.9-3.2s]

#39681 H-mode [3.7-3.9s]

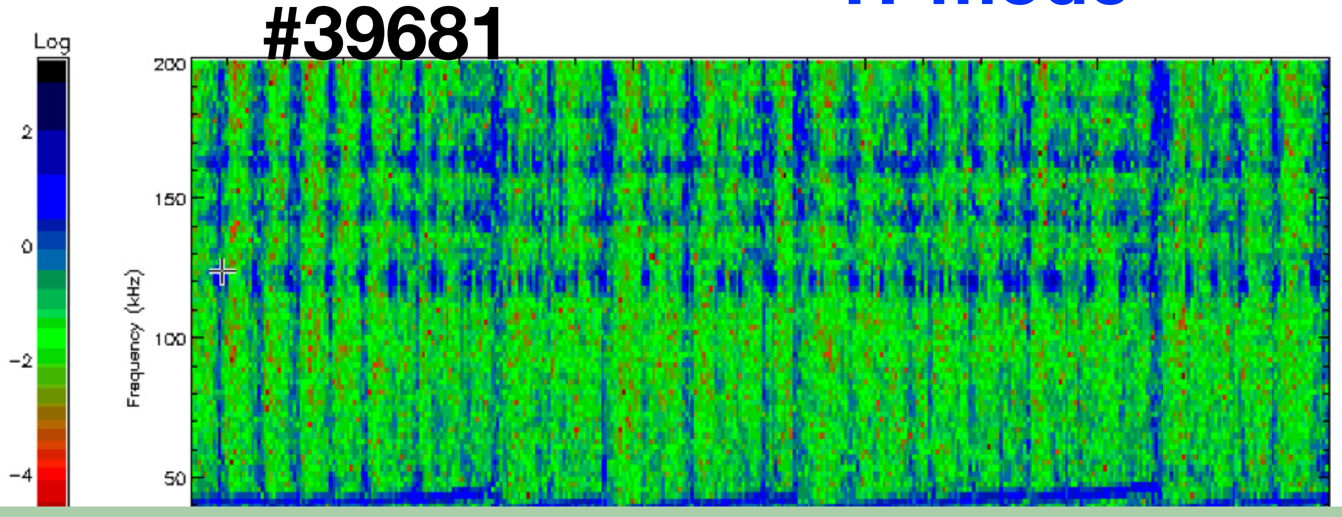


July 2021

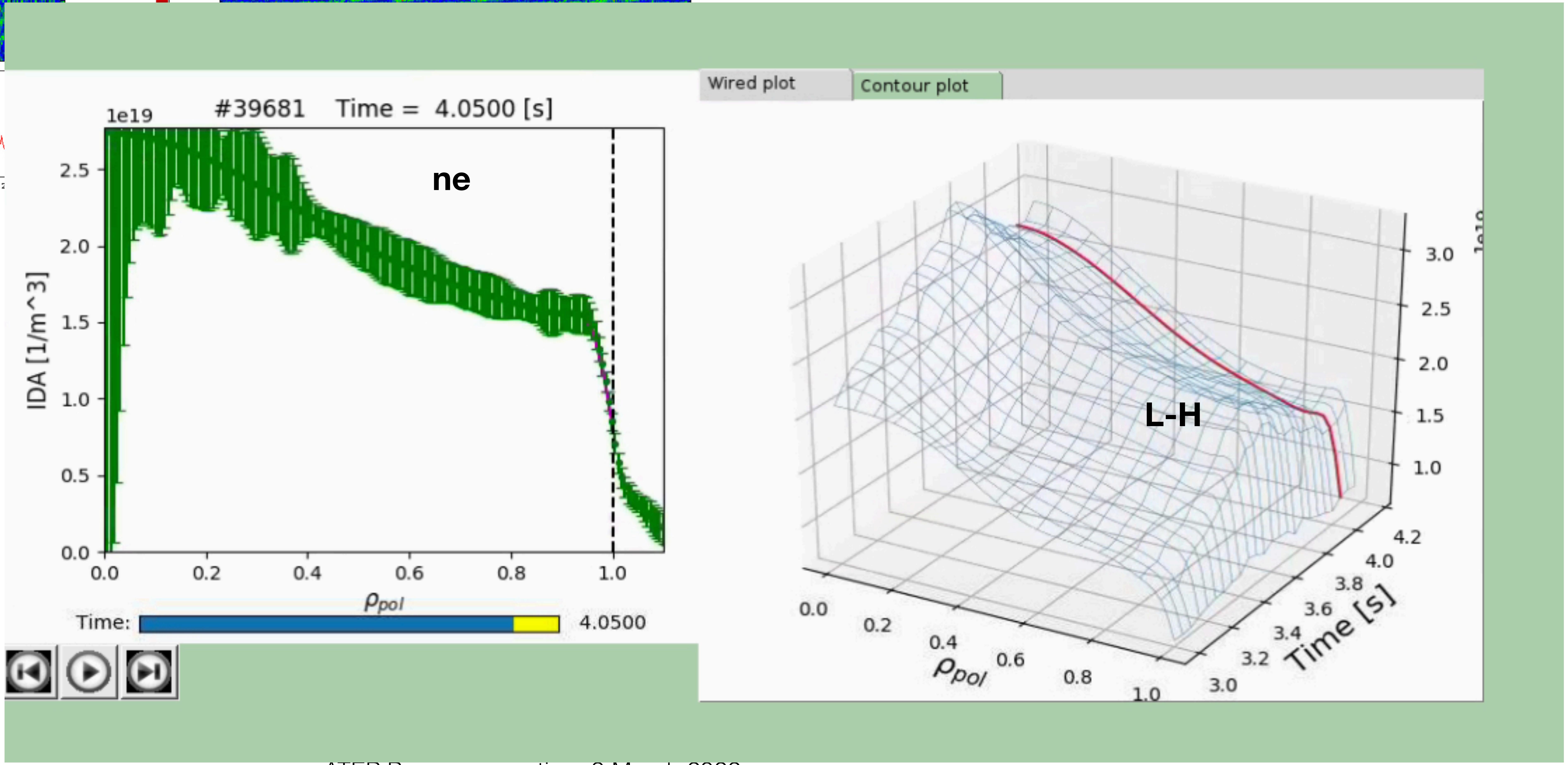
#39681 **L mode**



#39681 **H-mode**

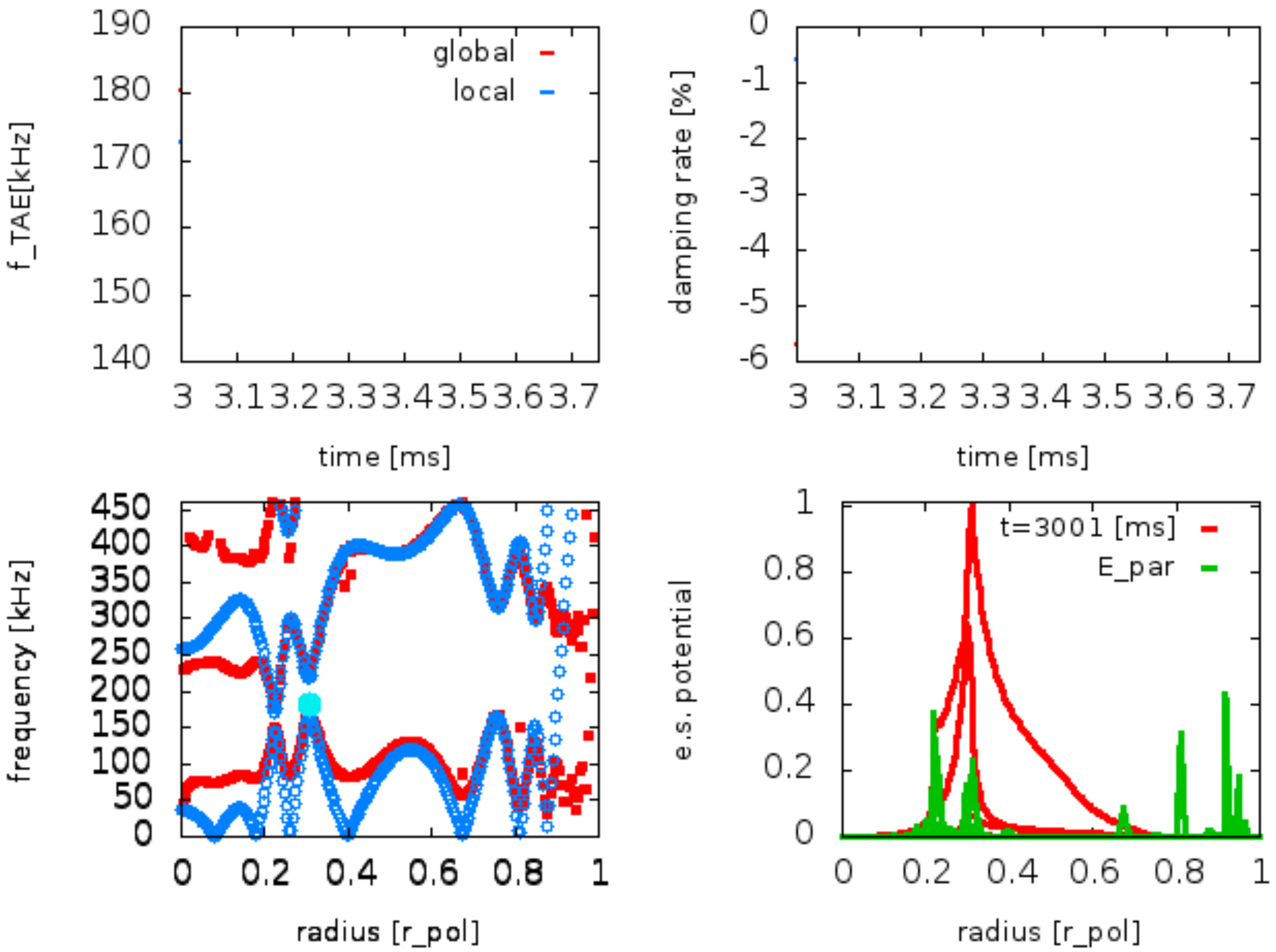


AUG experimental data base -> trview [gateway]
credits: G Tardini



EP WORKFLOW SCHEMATICS

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



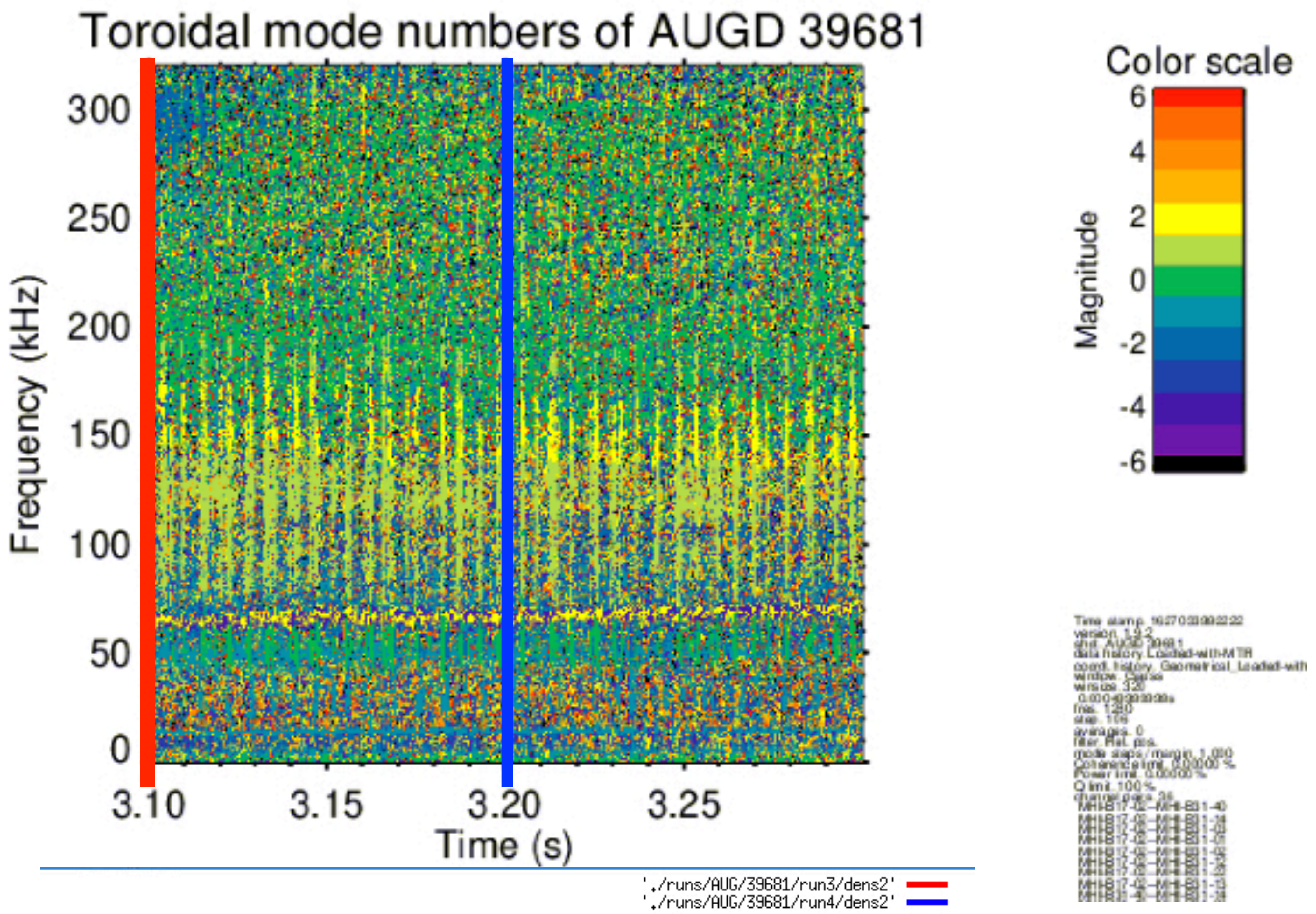
160 time slices based on IDA
largely automated analysis
(except visualisation)

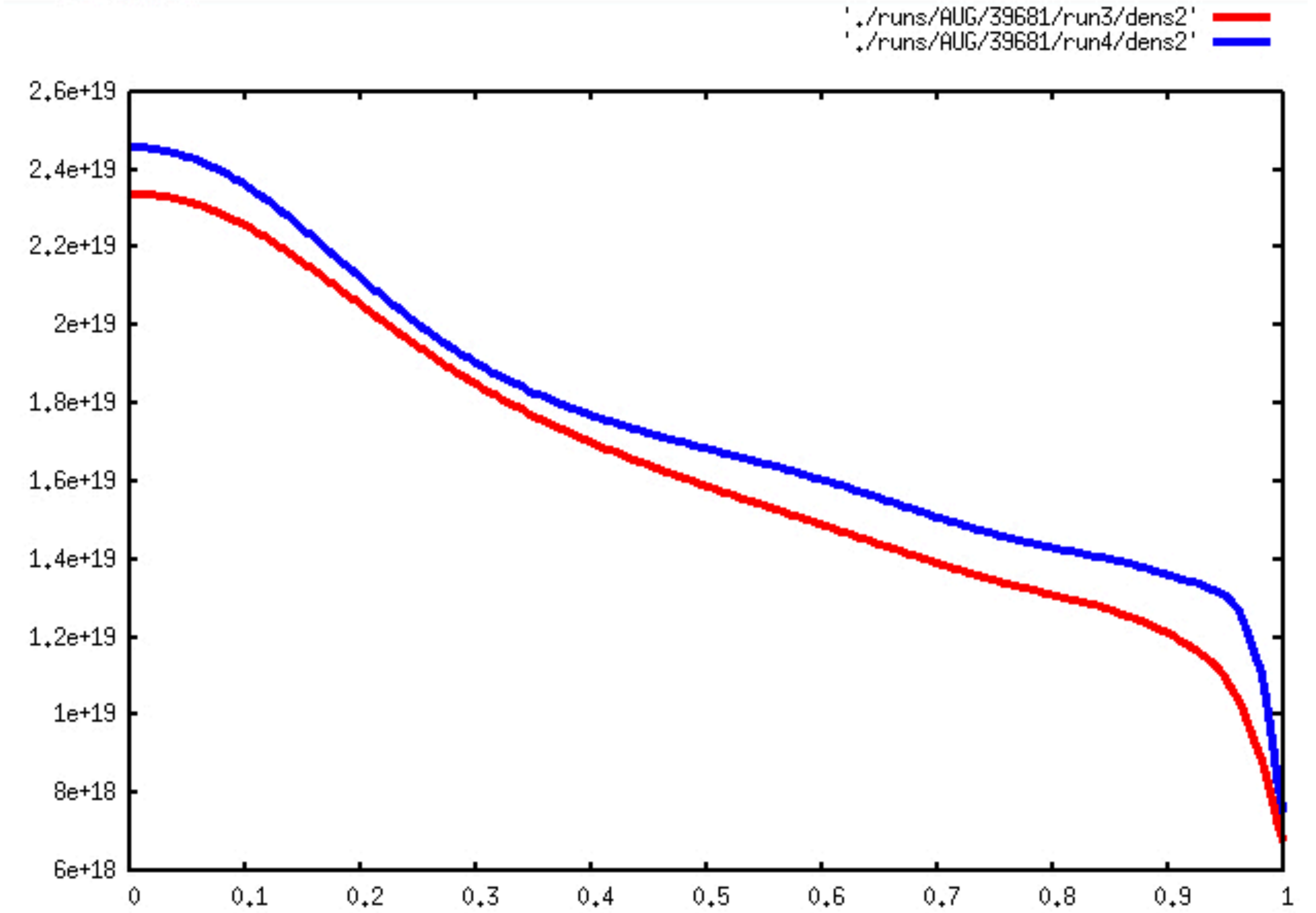
ready for:

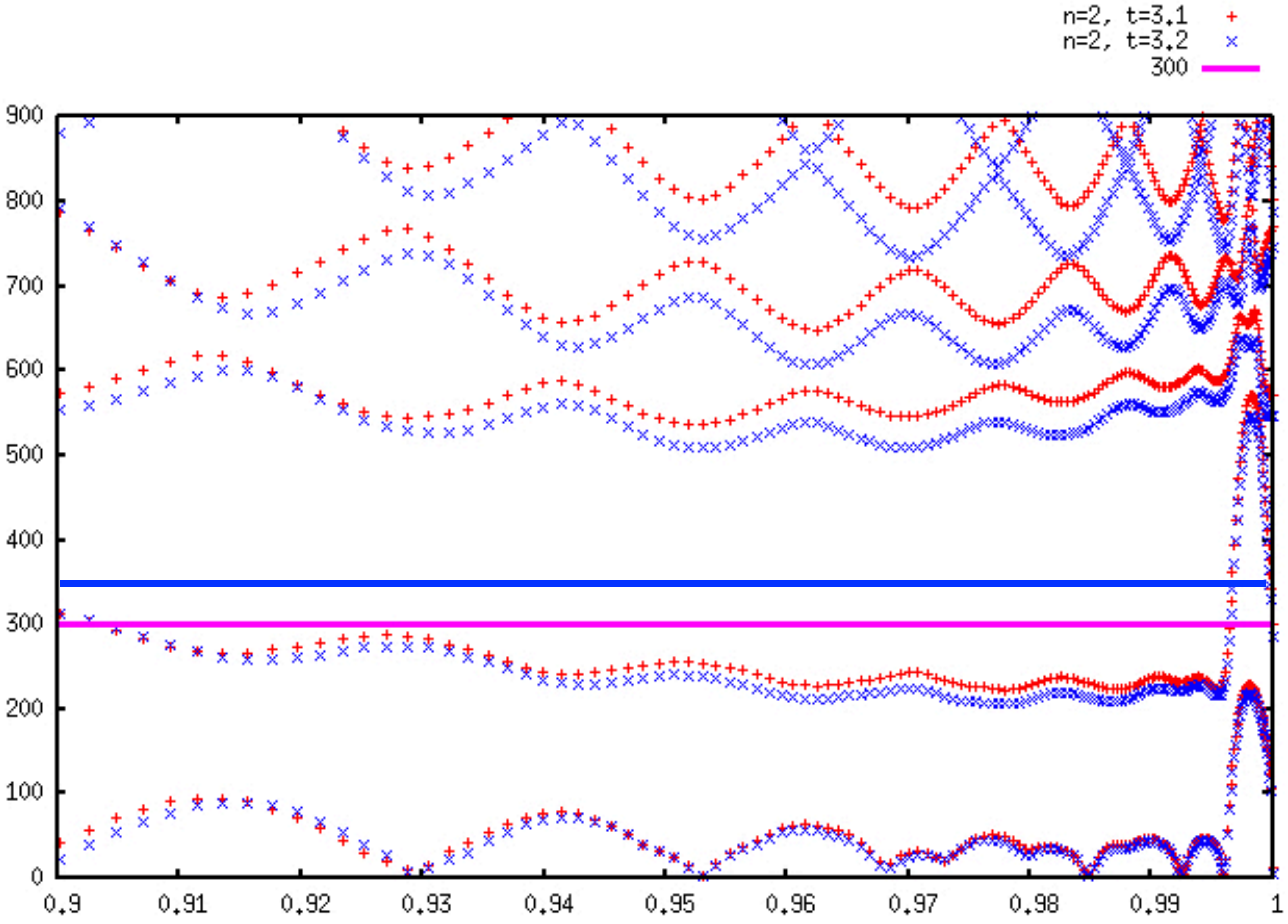
coupling to transport codes
systematic UQ, ‘error bars'
scenario optimisation

after finishing NBI module, ready for CG calculations
(TSVV10, started testing with eq. Maxwellian)

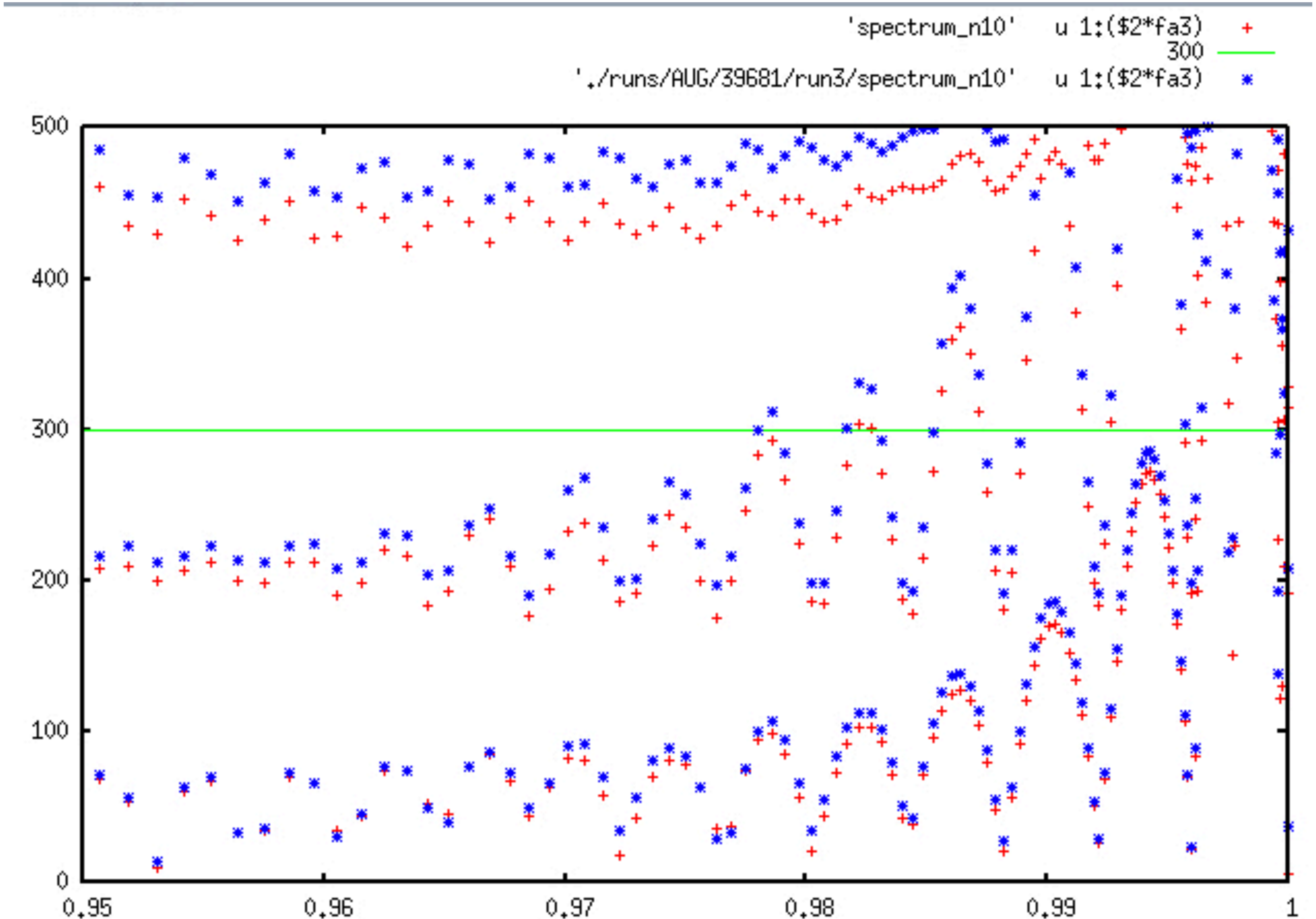
damping for n=2 is not changing in 100ms time window - drive must vanish!







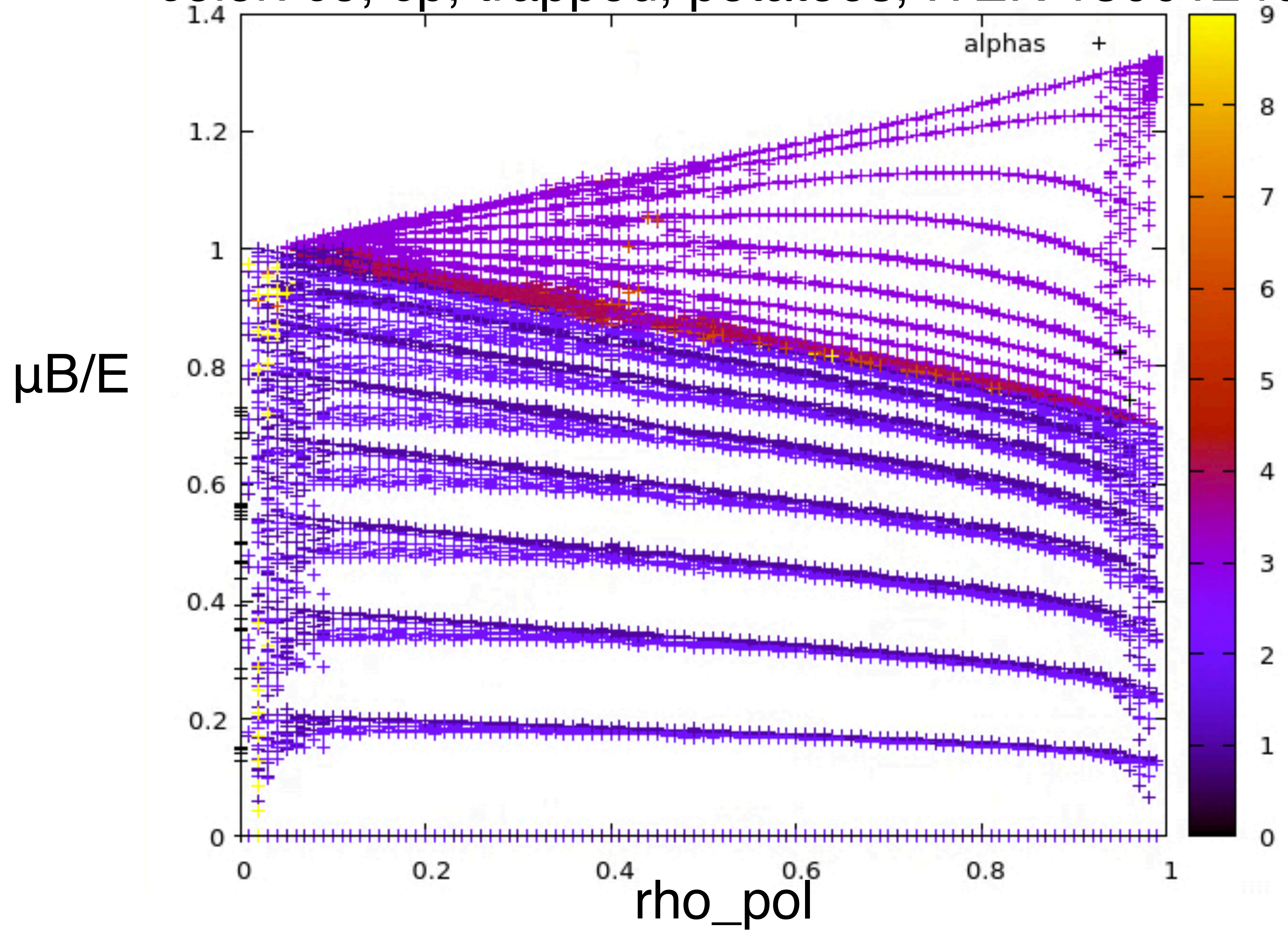
n=10

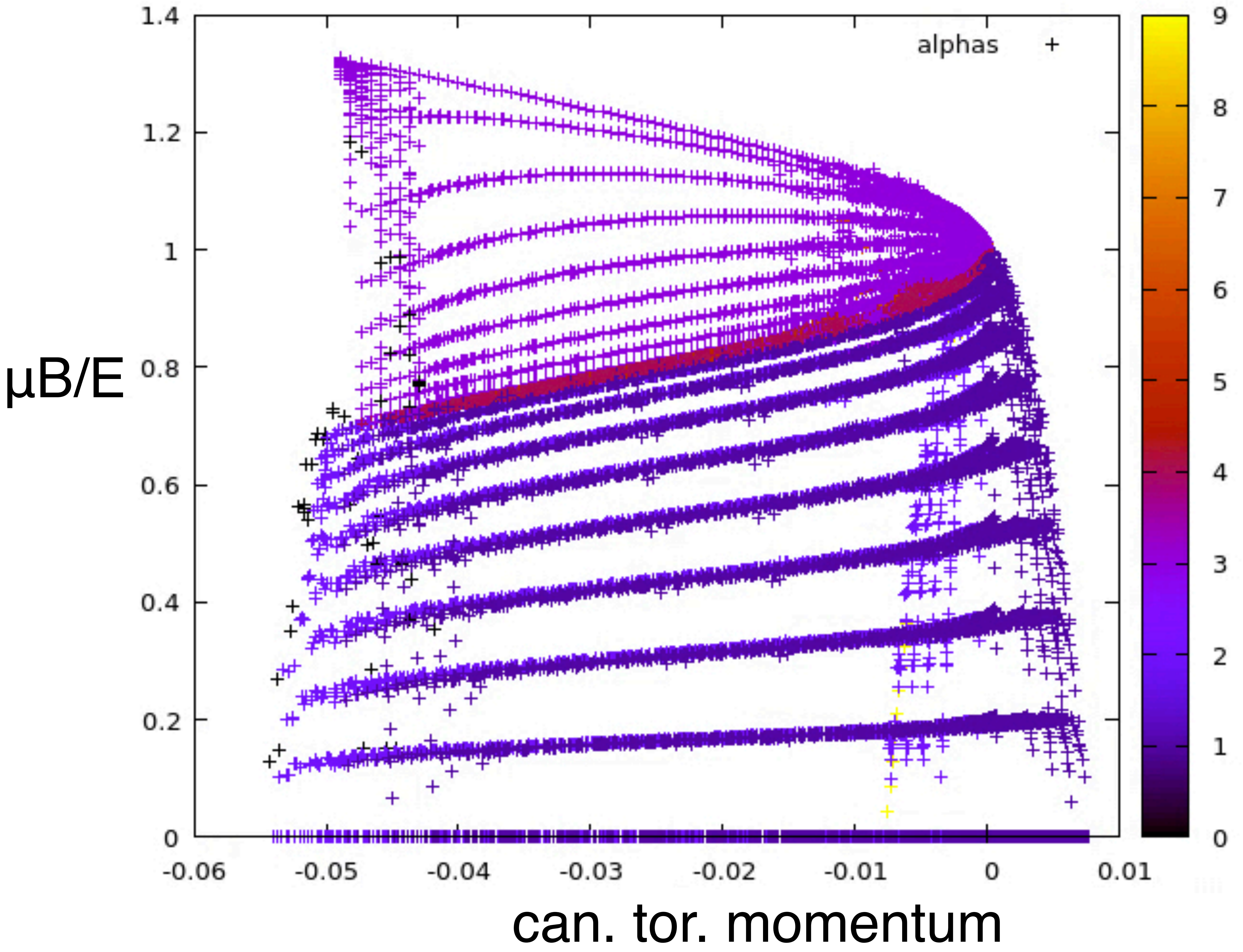


'spectrum_n10' u 1:($2*fa3)
300
'./runs/AUG/39681/run3/spectrum_n10' u 1:($2*fa3)
500
400
300
200
100
0
0.95
0.96
0.97
0.98
0.99
1

next step: how to calculate bounce-averaged quasi-linear fluxes i.e. PSZS of EPs?

color: co, cp, trapped, potatoes, ITER 130012 run 2

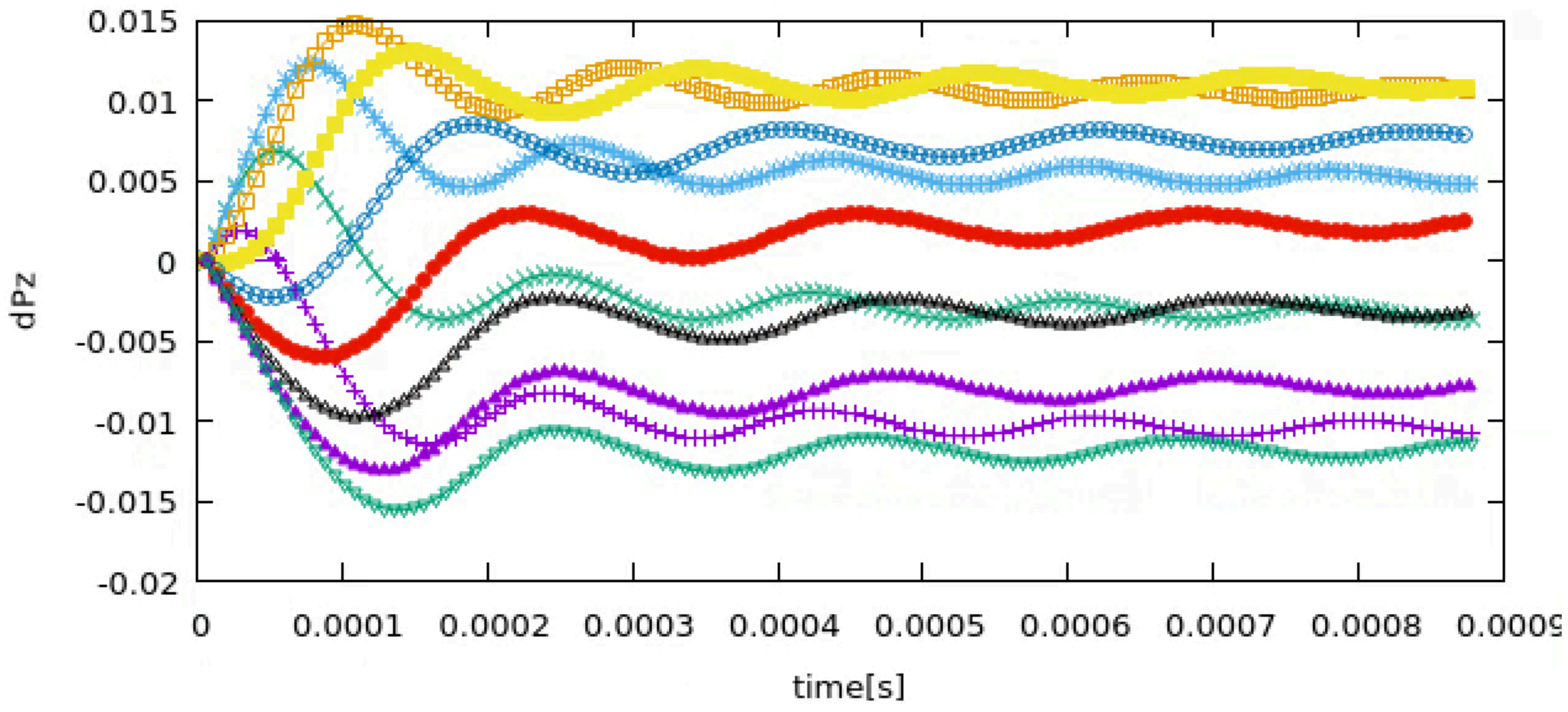


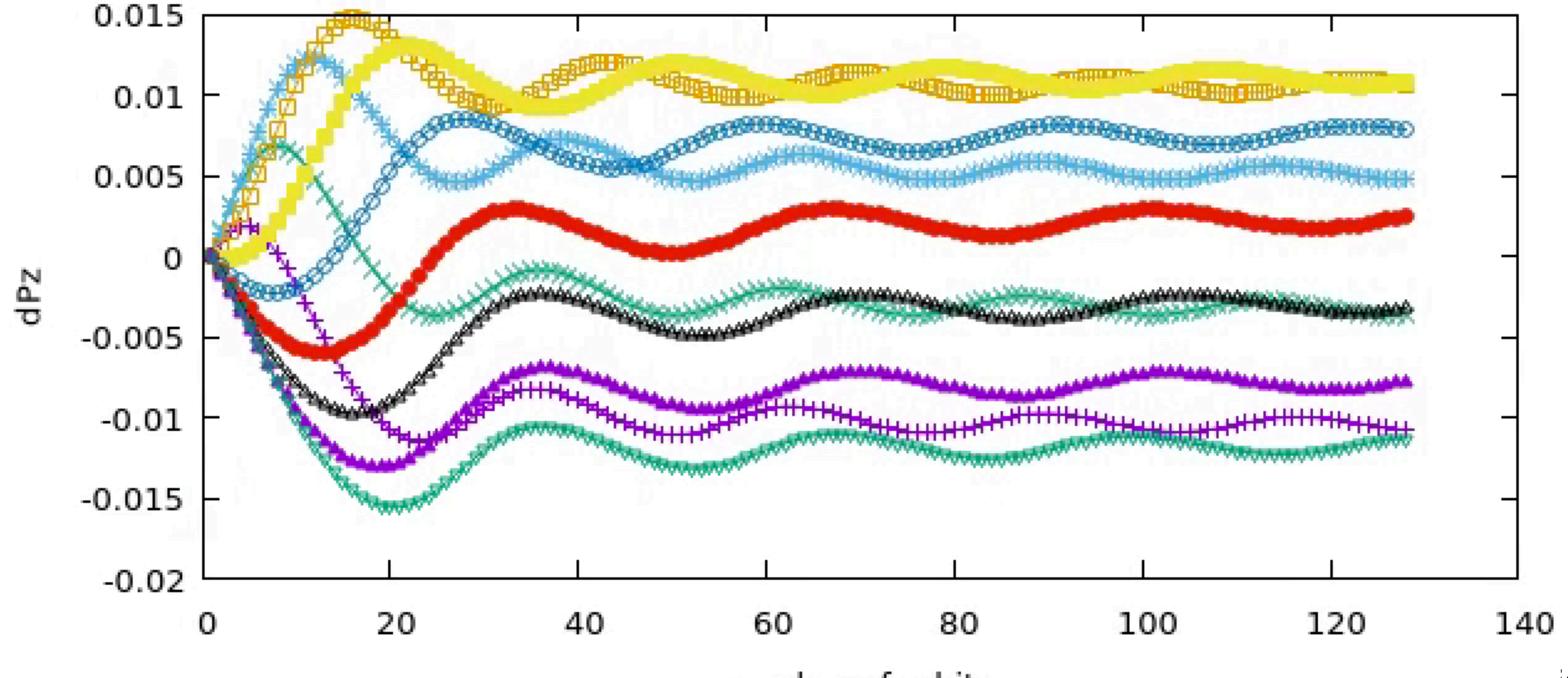


- IMAS adopted 'finder' routine (fortran) to set up marker space, determine trapped-passing bnd, sort and select particles, calculate LIGKA propagators etc by calling IMAS-adopted HAGIS2 library (to be ported to PYTHON?)
- fast, and repetitive calls are possible (avoid reading equilibria, profiles, markers etc), perfect parallel scaling (128 procs)
- distributions IDS holds all orbit-averaged information about marker space - following markers one closed orbit gives full properties and all coordinate transform information [ideas similar to Bierwage CPC 2022: 'orbit database']

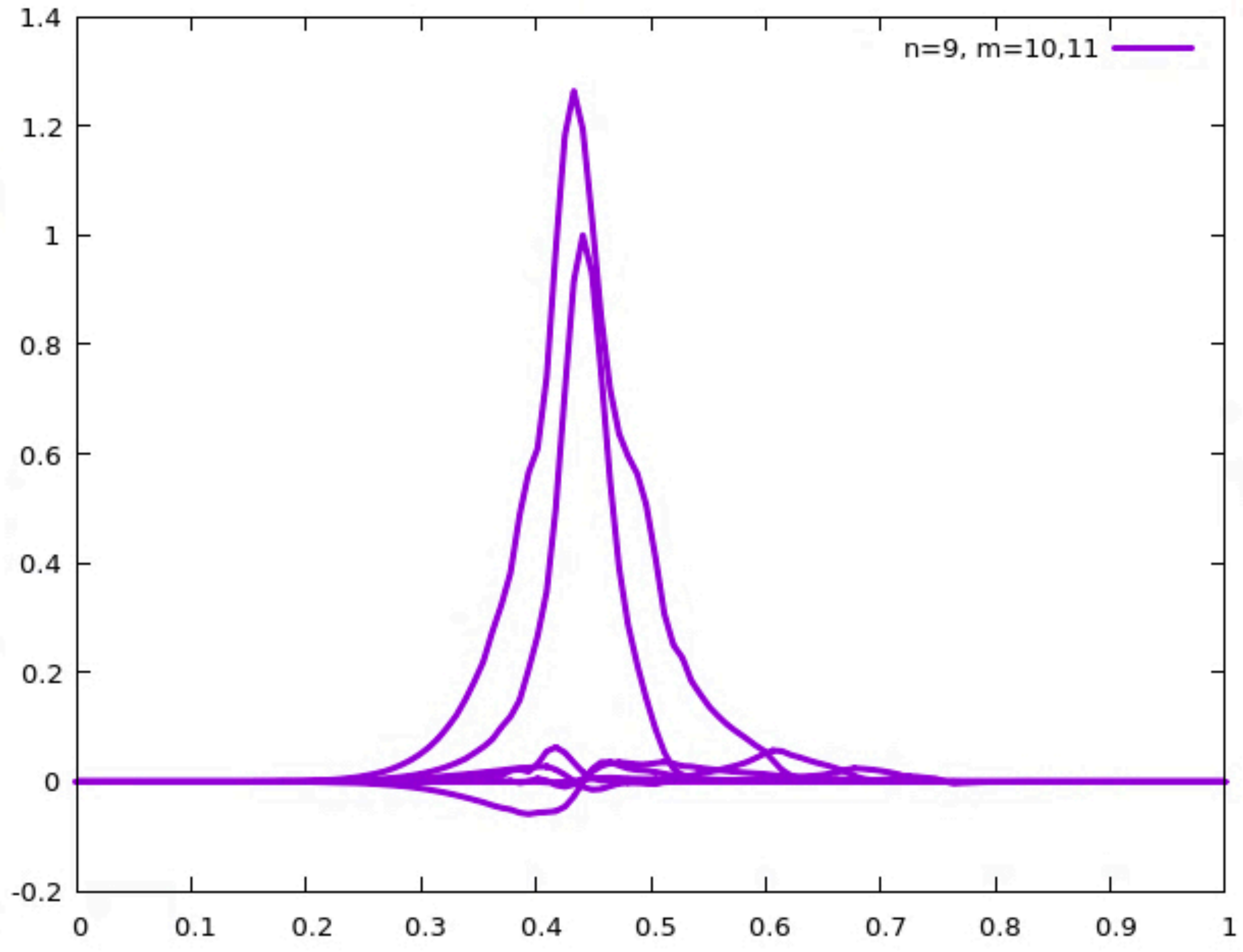
adding LIGKA calculated perturbation: follow set of market for wave-periods, time or no. orbits

mid-radius, 1 MeV, He, co-passing, Λ=0, n=9 TAE with $dB/B=10^{-3}$





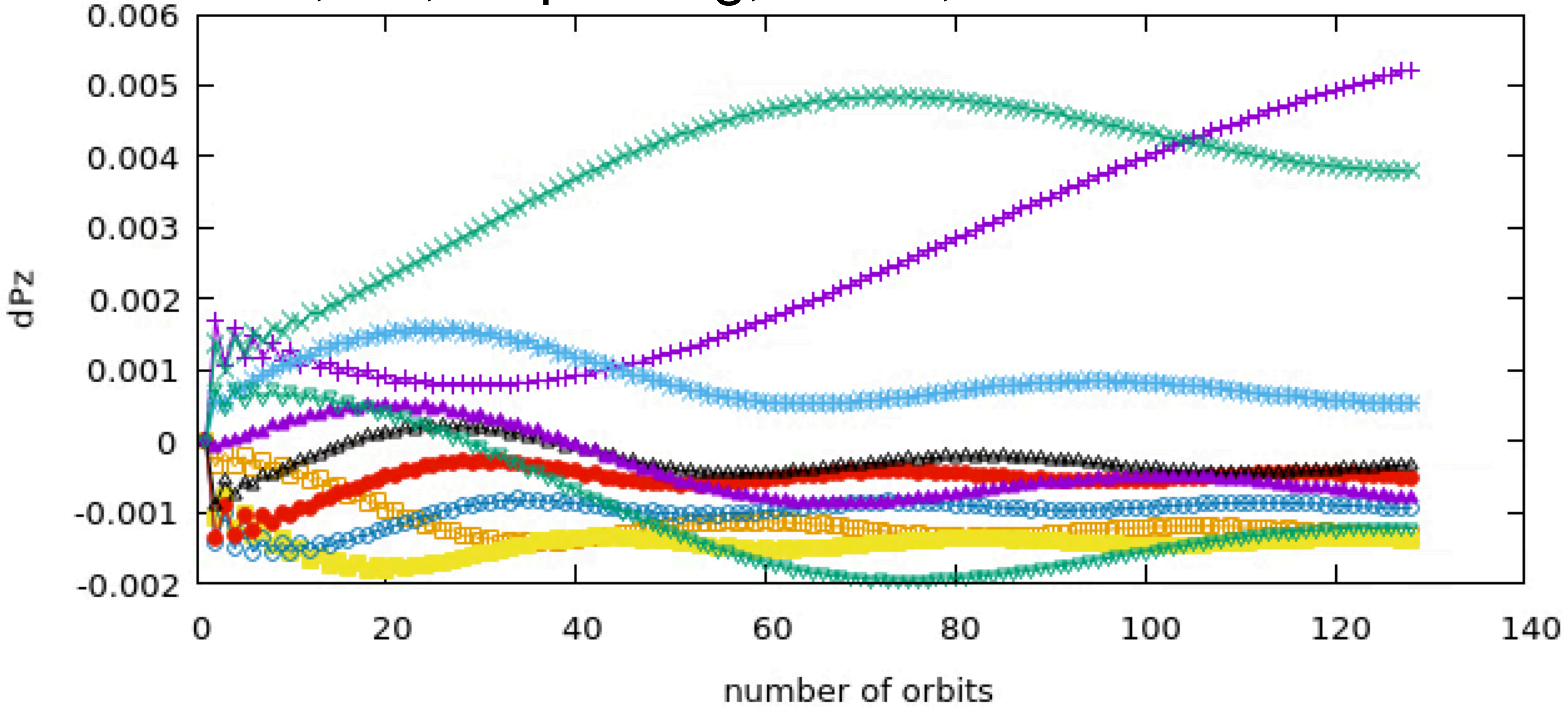
colours: different starting phase, 10 markers with starting tor. angle [0: 2π/n]



important: averaging over phase is crucial to obtain correct fluxes

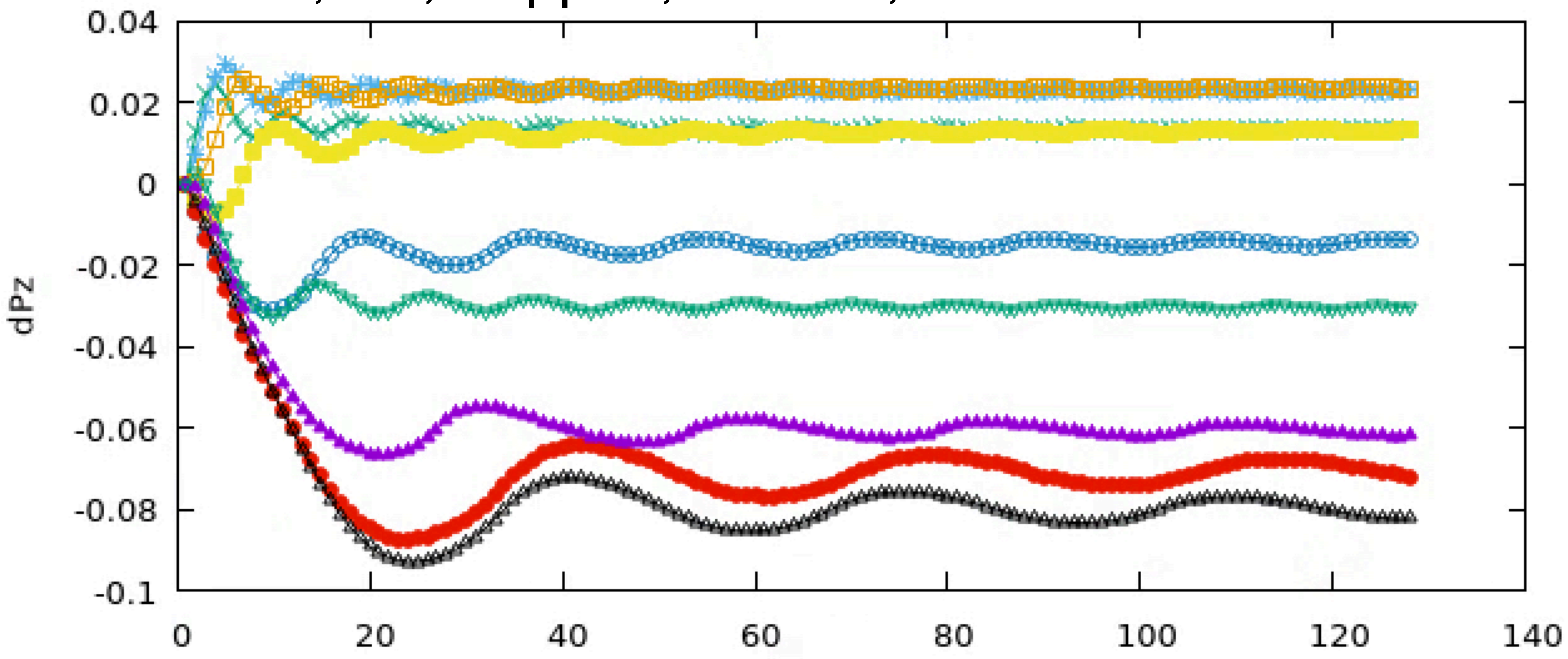
adding LIGKA calculated perturbation: follow set of market for wave-periods, time or no. orbits

1 MeV, He, co-passing, Λ=0.7, n=9 TAE with $dB/B=10^{-3}$



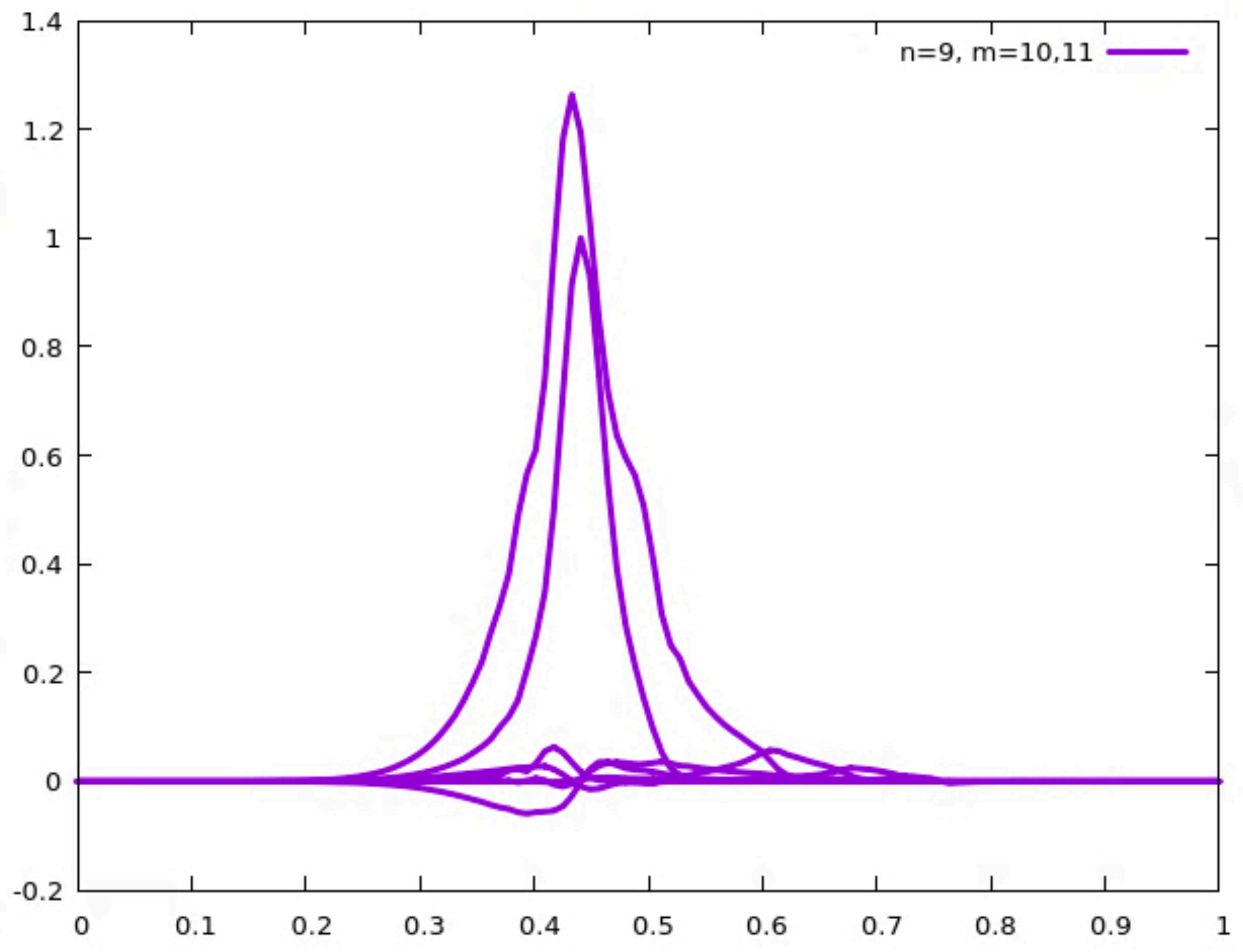
secular transport for resonance co-passing

1 MeV, He, trapped, Λ=1.03, n=9 TAE with $dB/B=10^{-3}$

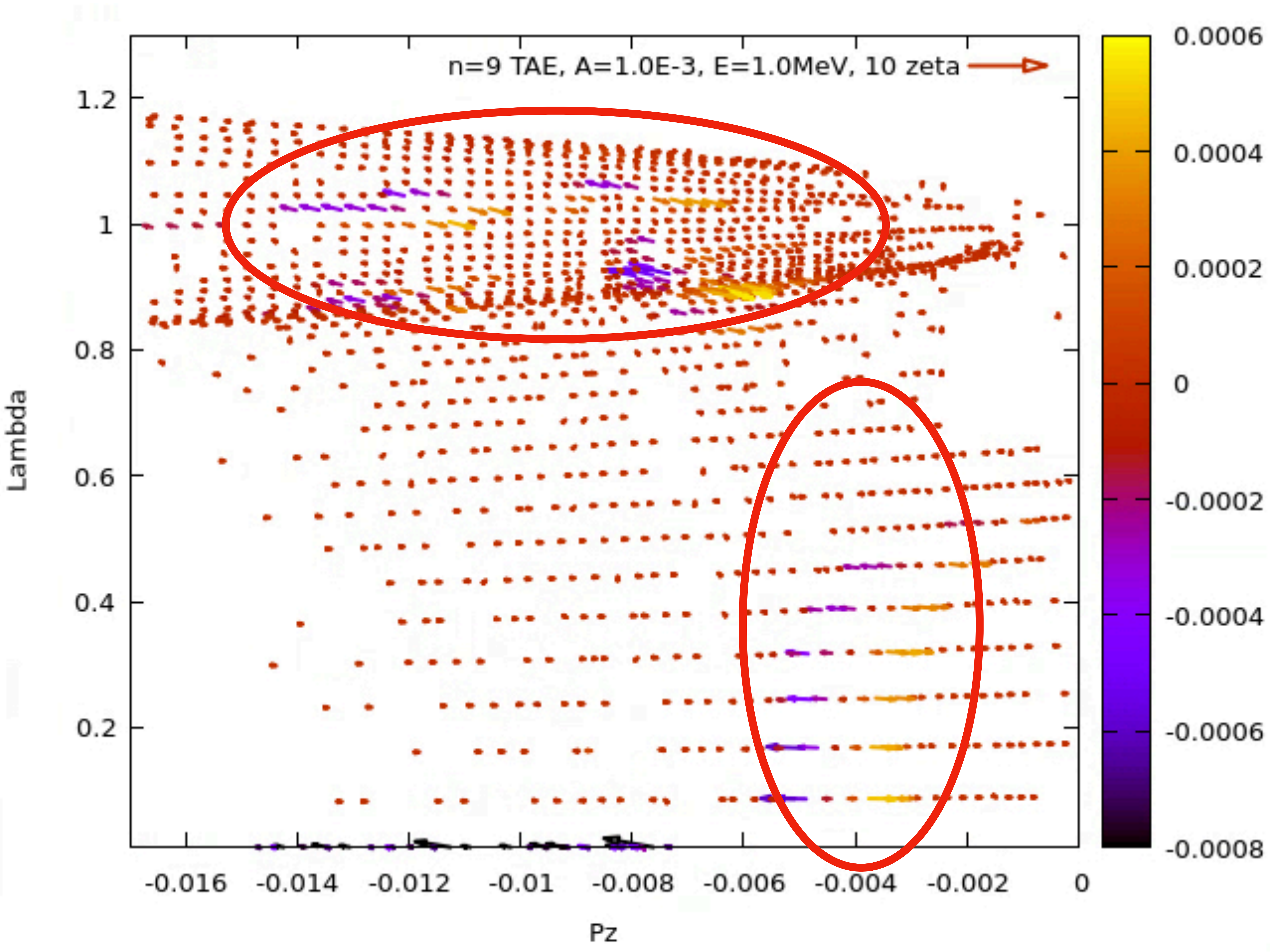


or trapped particles

HAGIS2 as library is crucial element for PSZS transport model
What is dPz,dE,dLambda for given perturbation after x completed orbits?



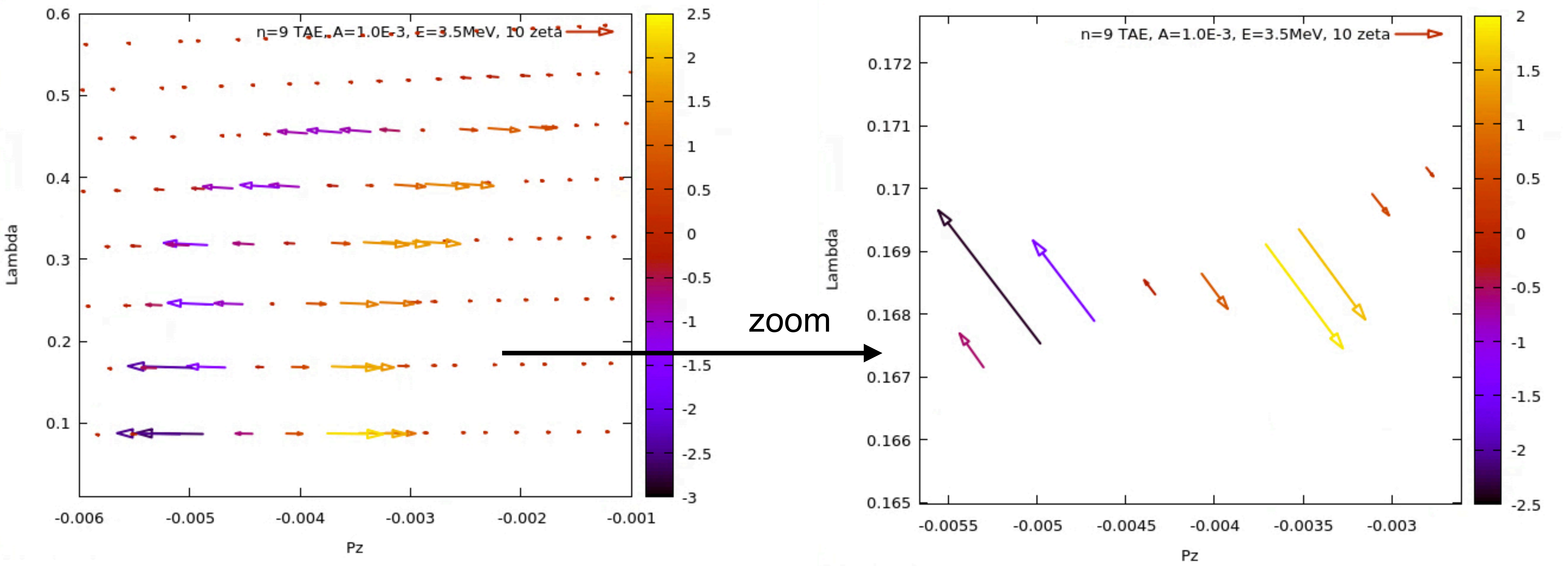
- arrows: initial (Pz,Λ) → (Pz+δPz,Λ+δΛ)
- color: δPz
- averages over 10 phases, 64 orbits
- 2-5 minutes to calculate
- trivial to overlay resonances…in progress
- now needs to be weighted with f to calculate QL fluxes and convective transport in phase space
- replace probability matrices of kick-model



calculate fluxes: dPz/dt [(eV/s)/s]

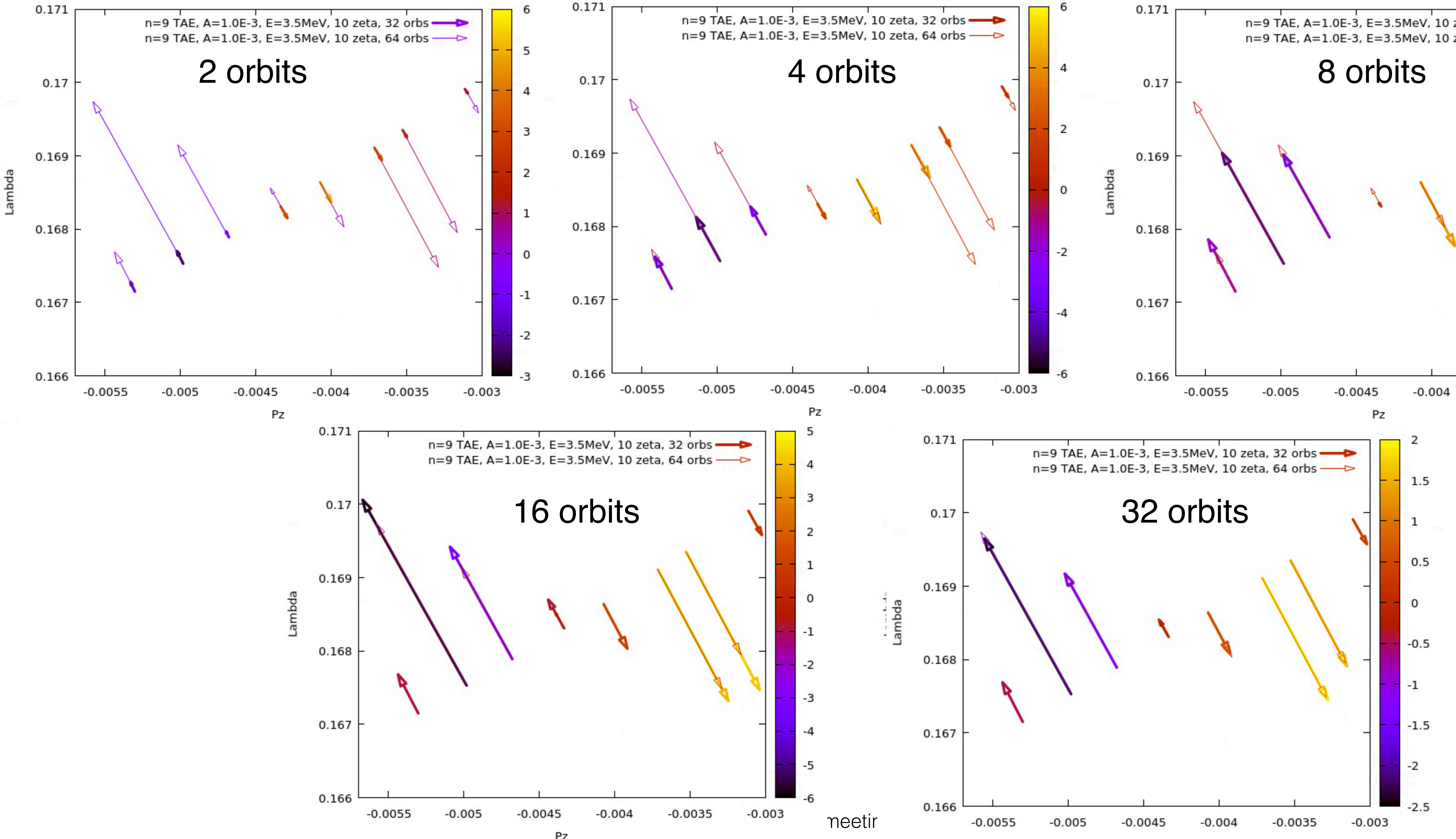
color: dPz/dt

color: dPz/dt



- divide δPz by orbit transit time and number of orbits (here 32)
- the same information is available for Λ and E
- transport coefficients $D_{Pz}=(dPz)^2/dt$ and $K_{Pz}=(dPz)/dt$ can be evaluated

calculate δPz as function of number of orbits; compare to converged δPz (64 orbits, thin arrows)

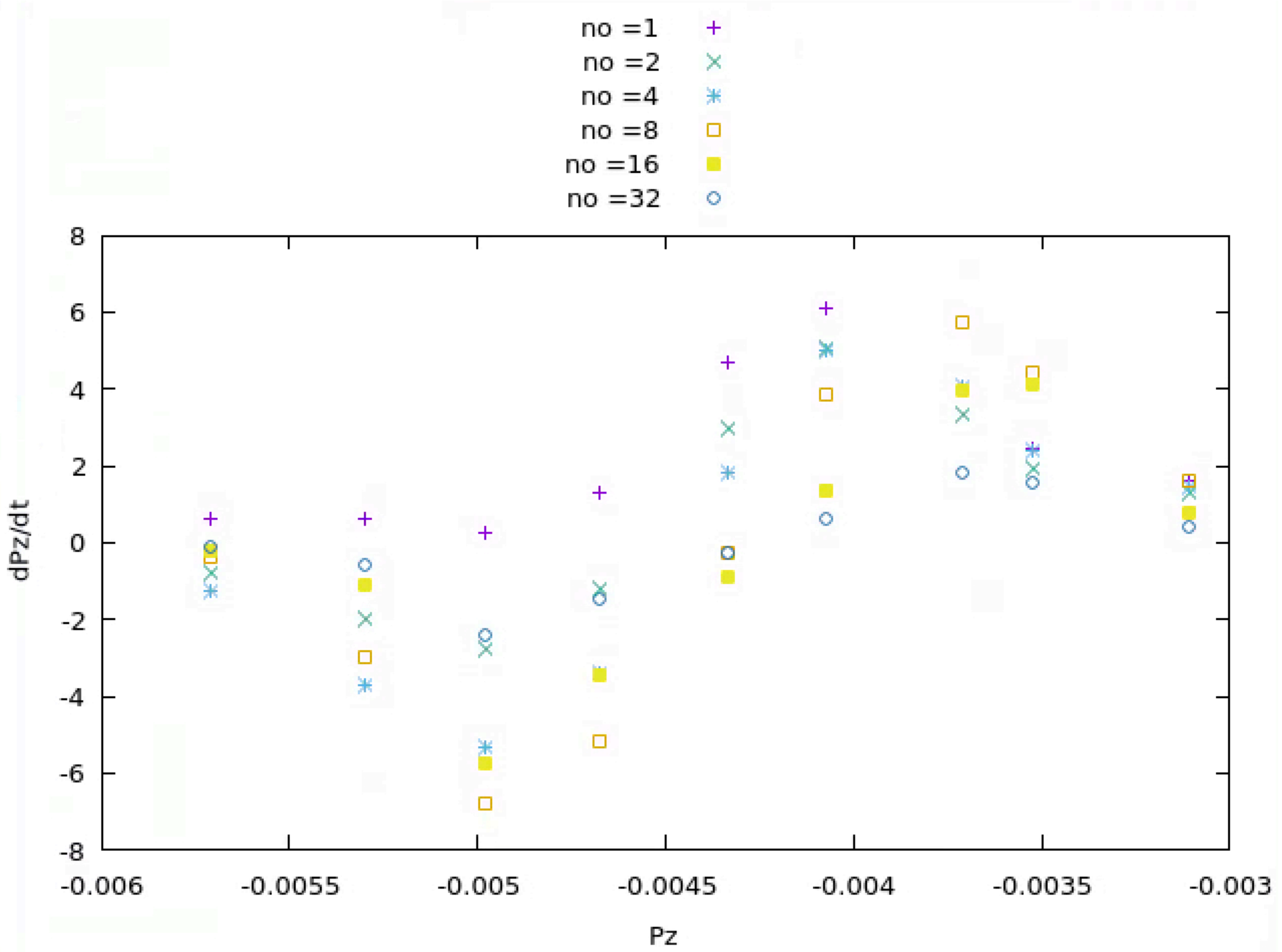


color:

$\delta Pz/t_{orbit}$

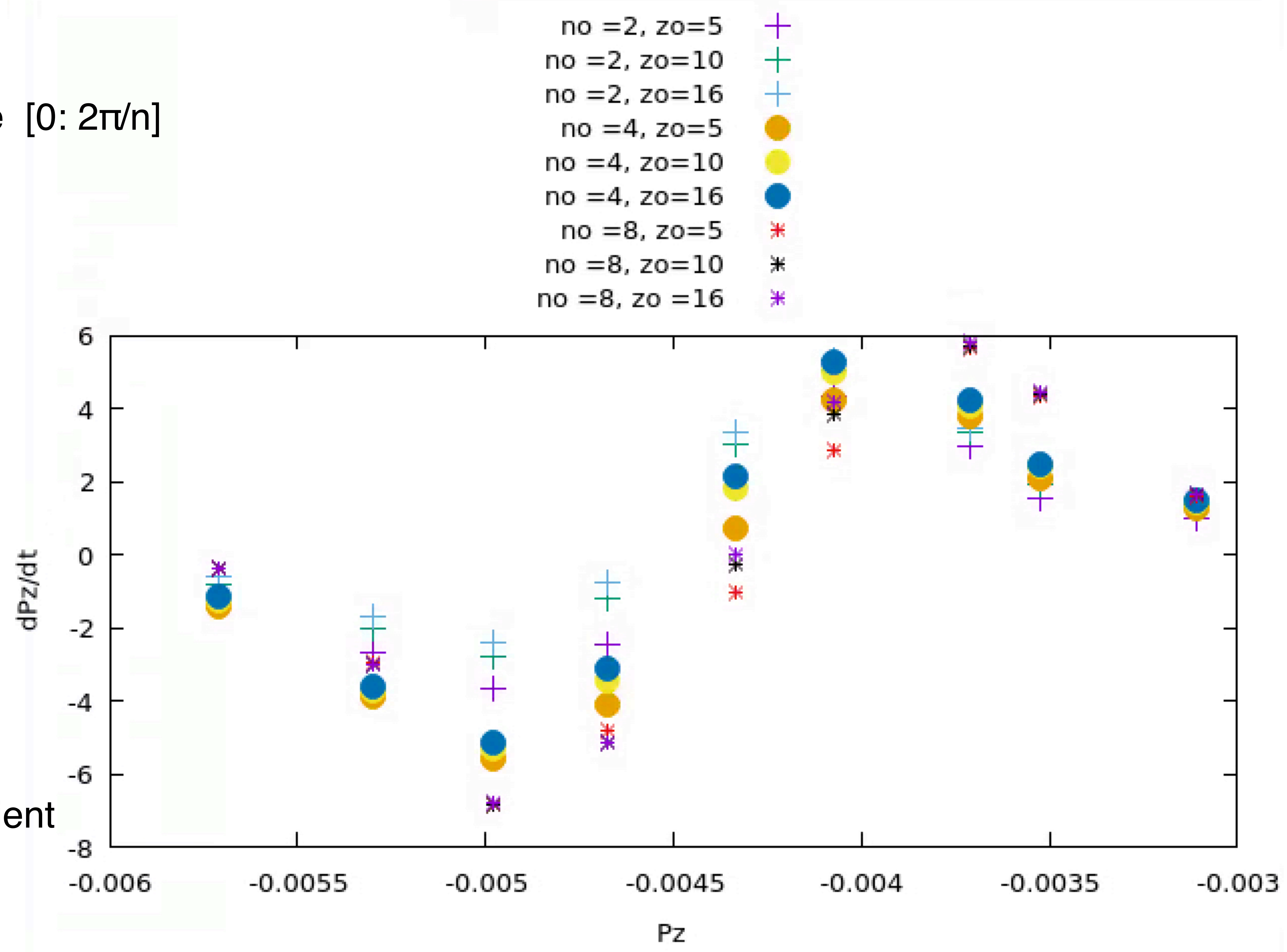
δPz/dt is not uniform during redistribution process: when particles move, they feel different wave potential during the redistribution process, depending on the mode structure

depending on what type of problem is to be solved (shortest time scale to be resolved), very few orbit transits (4-8) are sufficient.



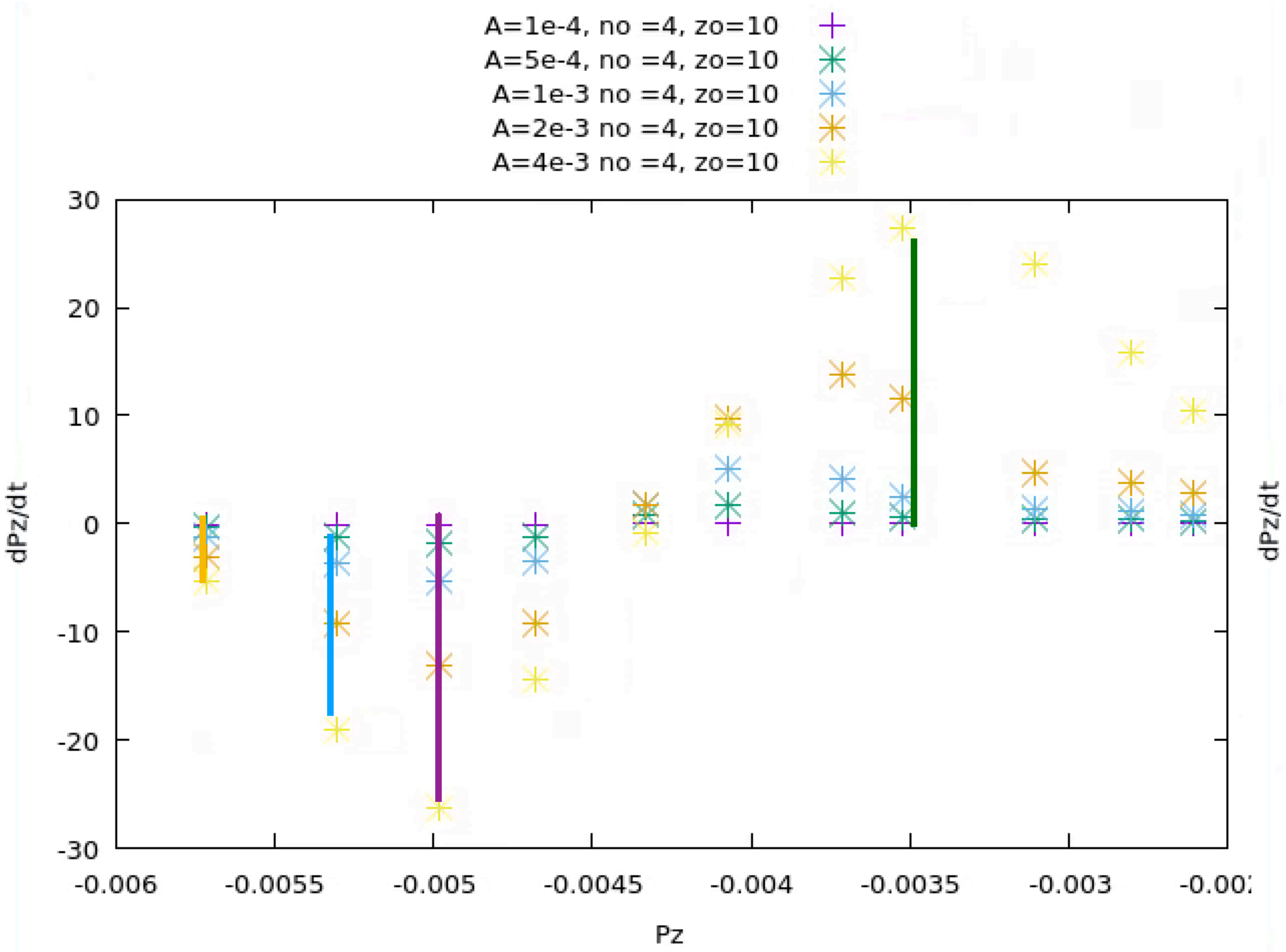
convergence with respect to number of particles with different phase (starting tor. angle)

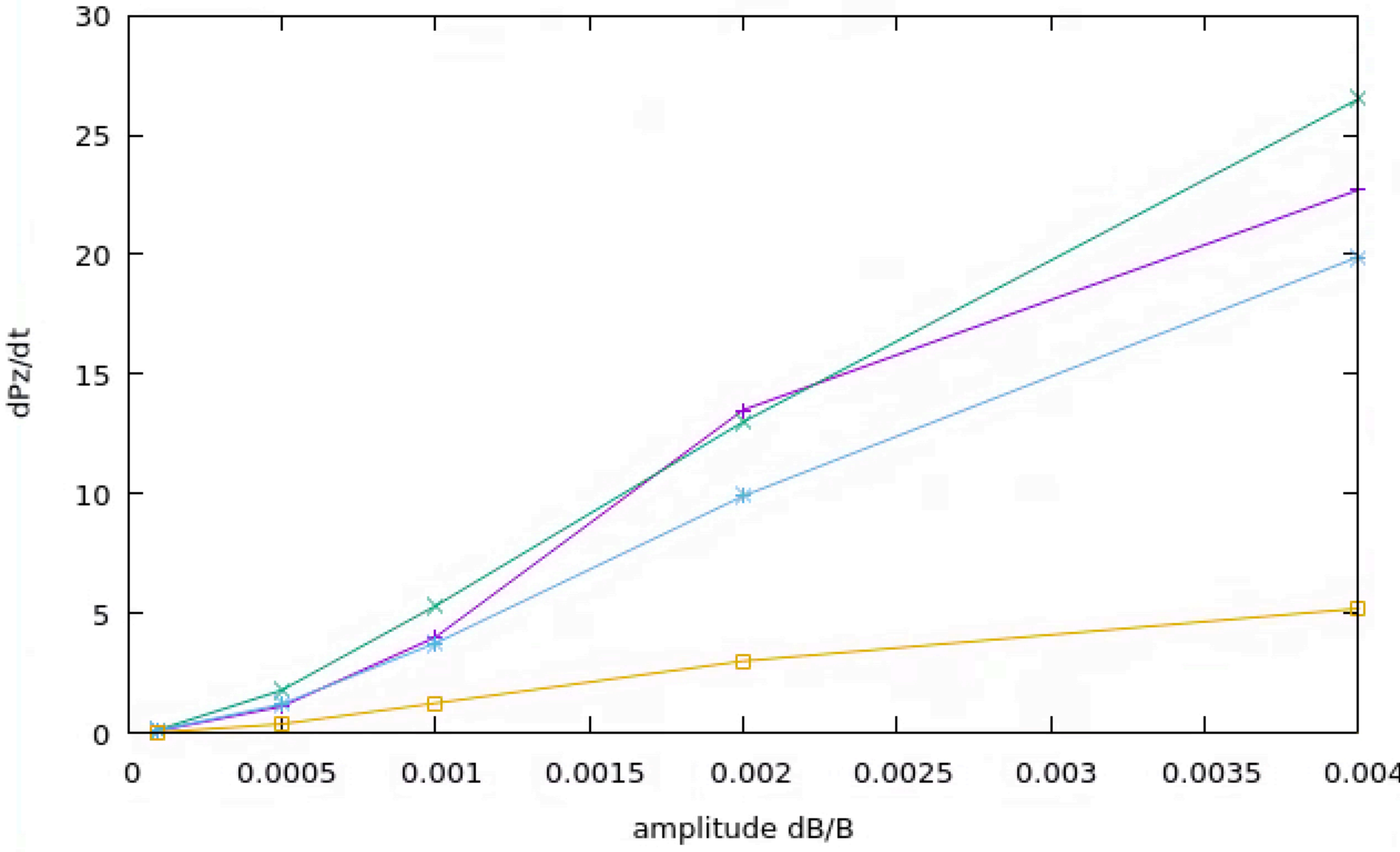
different starting phase:
zo markers with starting tor. angle [0: 2π/n]



~5-10 markers per mode is sufficient

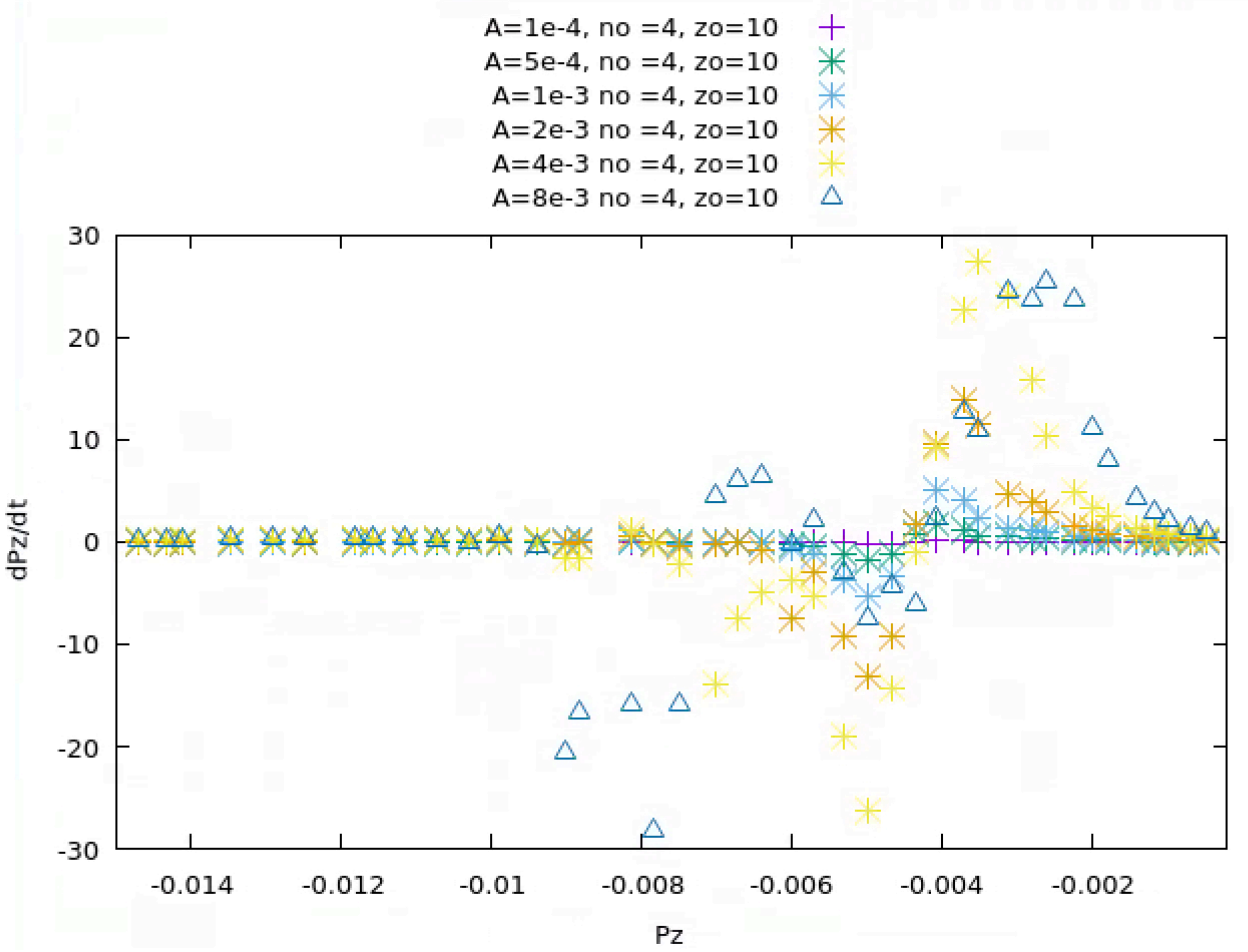
amplitude dependence: dB/B =[10^{-4} - $4 \cdot 10^{-3}$]

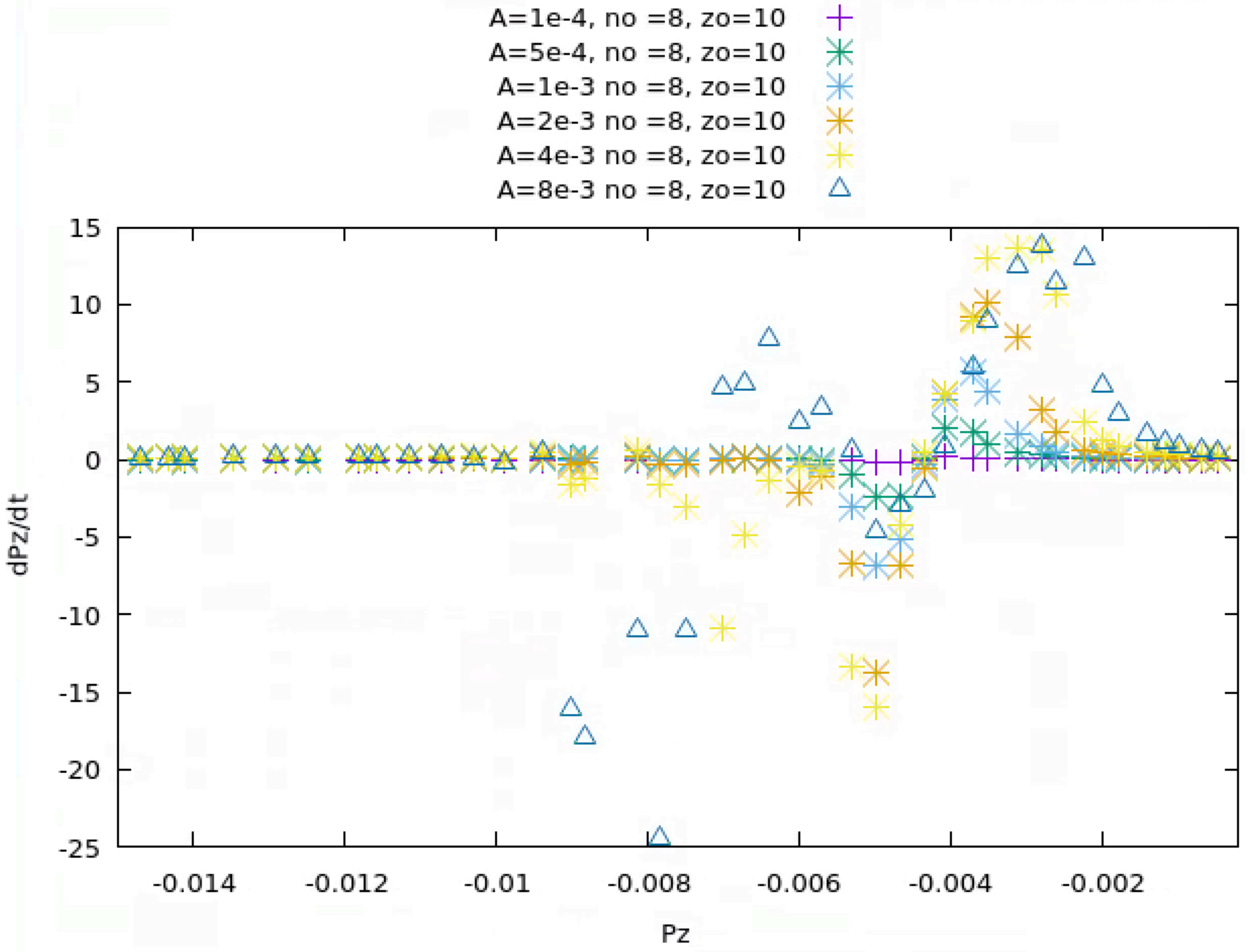




dPz/dt ~ quadratic for small amplitudes, linear for larger amplitudes

limit: simple scaling breaks down for dB/B > 4 · 10^{-3}





for larger perturbations, case-by-case calculation is necessary

$$\frac{\partial}{\partial t}\overline{\delta F}_z + \frac{1}{\tau_b}\left[\frac{\partial}{\partial P_\phi}\overline{\left(\tau_b \delta \dot{P}_\phi \overline{F_{z0}}\right)}_z + \frac{\partial}{\partial \mathcal{E}}\overline{\left(\tau_b \delta \dot{\mathcal{E}} \overline{F_{z0}}\right)}_z\right] +$$
$$+\frac{1}{\tau_b}\left\langle \frac{\partial}{\partial P_\phi}\overline{\left(\tau_b \delta \dot{P}_\phi \delta F\right)}_z + \frac{\partial}{\partial \mathcal{E}}\overline{\left(\tau_b \delta \dot{\mathcal{E}} \delta F\right)}_z \right\rangle_F = \overline{C^g}_z - \overline{C^g}_{z0} + \langle \bar{S} \rangle_F$$

- IMAS-based orbits data-base and QL orbit averaged particle response implemented
- next: import distribution with weights and bin to get QL fluxes, or project markers on 3D function
- speed up, neglect markers with small transport, parallelisation issues (no MPI version of IDS)
- validation: 'replay' transport of set of markers with time dependent amplitudes as given by full HAGIS2 simulation
- can be used to check diffusive vs convective model, different mode spectra
- work on various intensity closures, PSZS model implementation with M. Falessi
- orbit database in appropriate shape to use bounce-averaged collision operators [Brizard, Slaby/Kleiber, Hoppe etc] i.e. pitch angle on outboard mid plane and average radial positions are available - use RABBIT formulation?