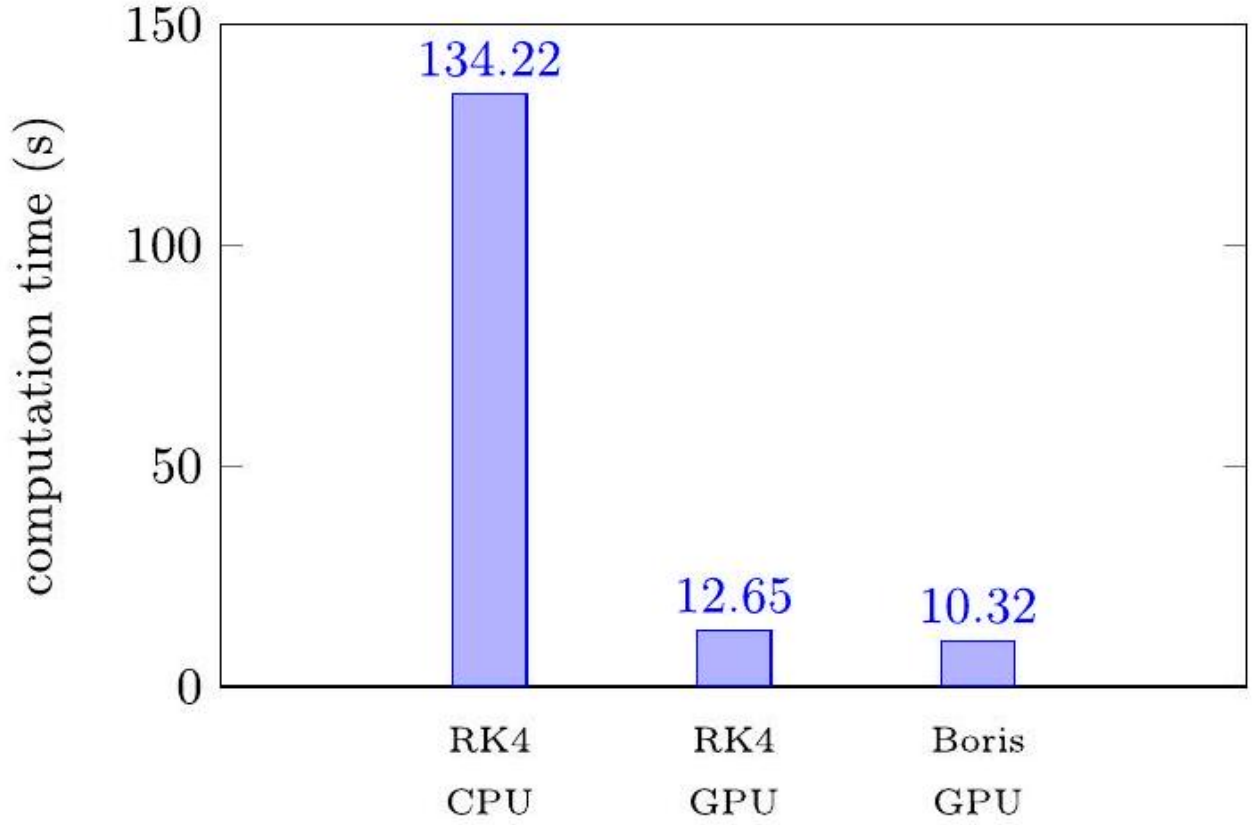
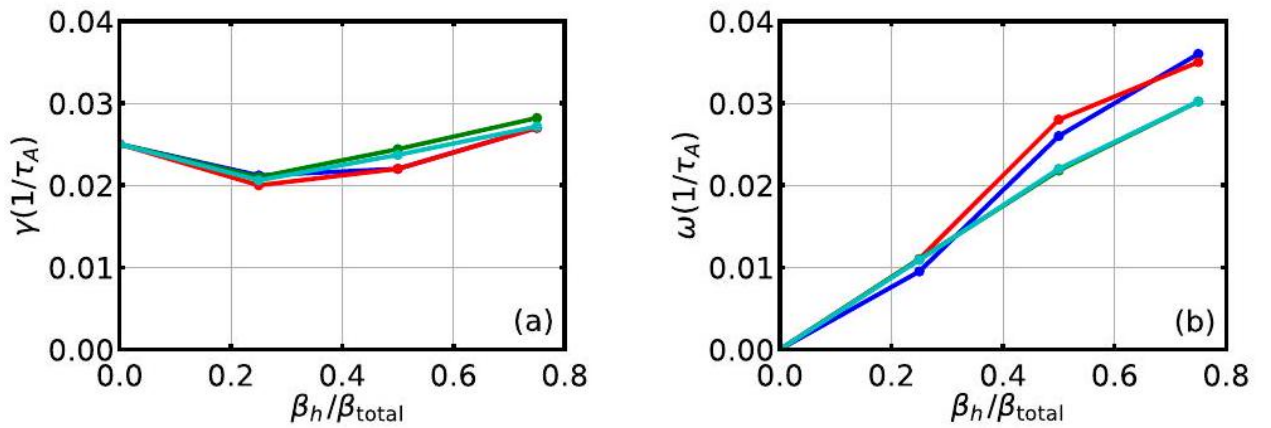


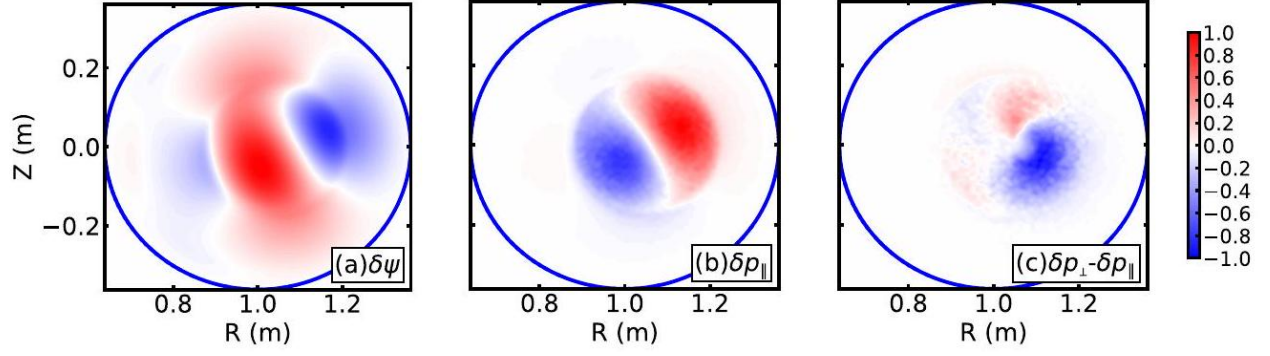
**Figure 1:** The above plots show the simulation results of a passing particle with  $v_{\parallel} = 2.4 \times 10^6$  m/s,  $v_{\perp} = 7 \times 10^5$  m/s, including the particle orbit (red line in (a)), relative error of toroidal angular momentum  $P_\phi$  (b) and energy  $E$  (c) using Boris and RK4 methods. The below plots show the simulation results of a trapped particle with  $v_{\parallel} = 7 \times 10^5$  m/s,  $v_{\perp} = 2.4 \times 10^6$  m/s, including the particle orbit (red line in (d)), relative error of  $P_\phi$  (e) and  $E$  (f). The data points are plotted for every 100 timesteps.



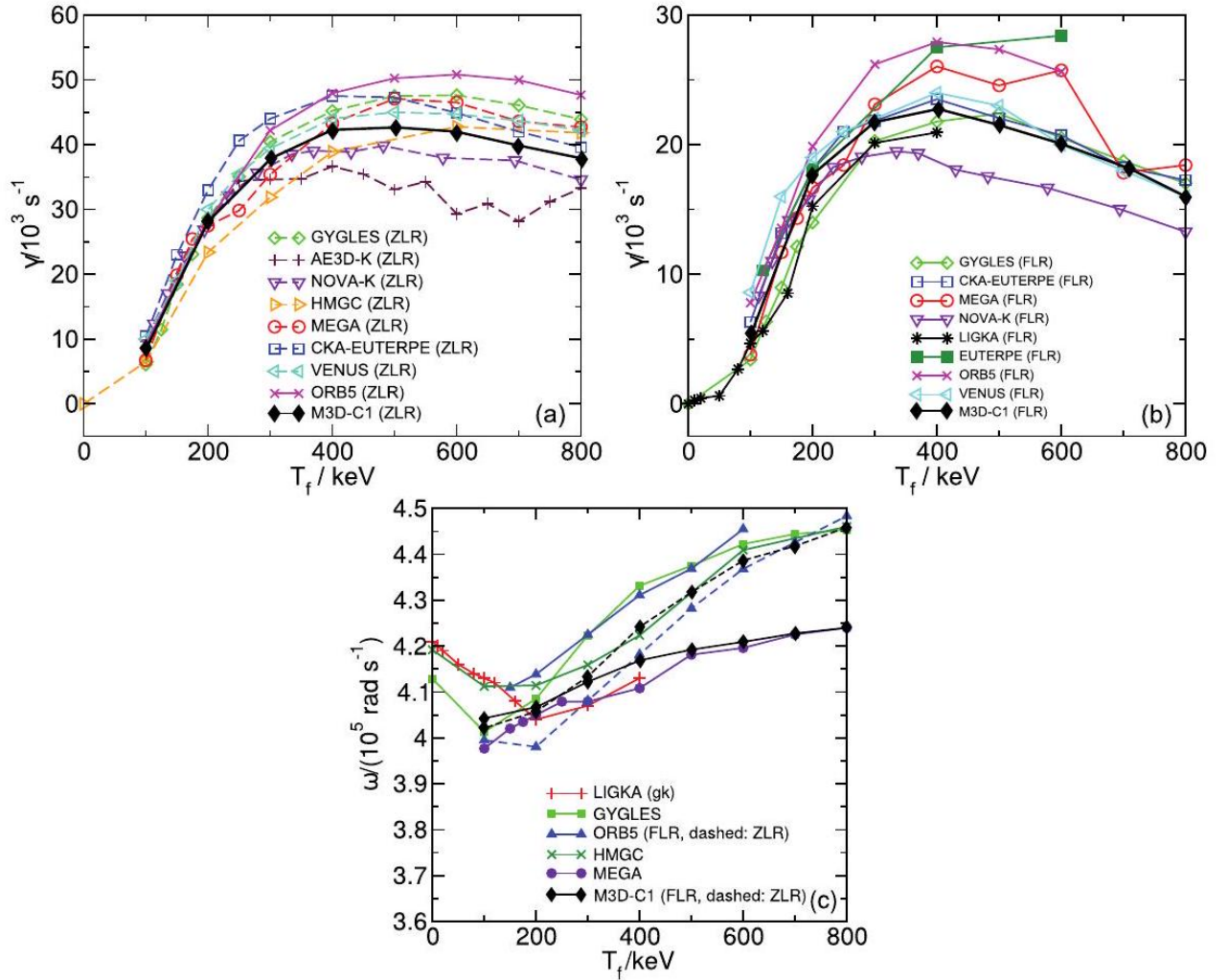
**Figure 2:** Computation time for pushing 16 million particles in a 3D mesh with 4 toroidal planes (5679 elements per plane) using different methods and processors. For RK4 the particle-pushing was done for 50 steps and for the Boris algorithm the pushing was done for 200 steps with the timestep 1/4 of that used in RK4 simulation. Note that this is a comparison for the computation time for particle pushing only and not including MHD calculation.



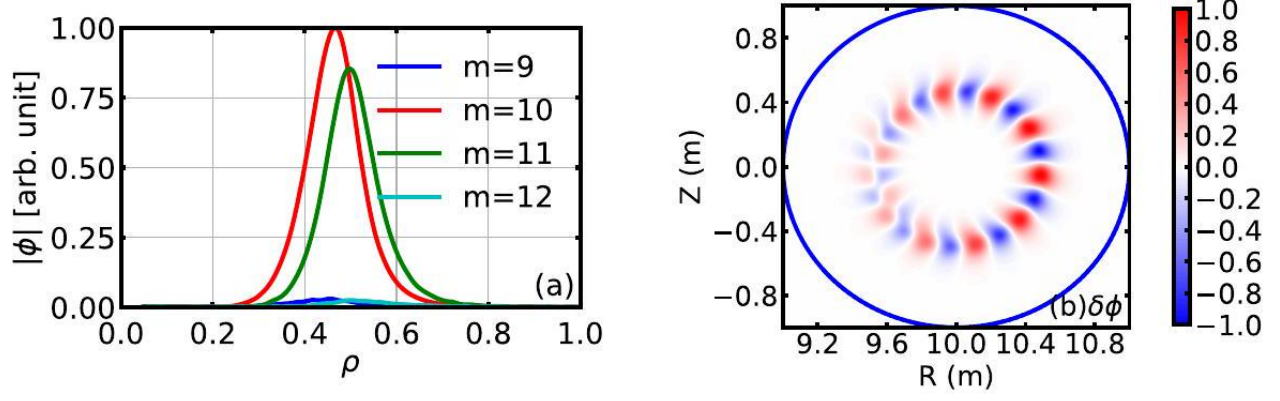
**Figure 3:** Simulation results of mode growth rate (a) and real frequency (b) as functions of EP beta fraction of the  $n = 1$  fishbone. Blue line is the result of NIMROD [3]. Red line is the result of M3D-K [2]. Green line is the result of M3D-C1-K using pressure coupling, and the cyan line is the result using current coupling.



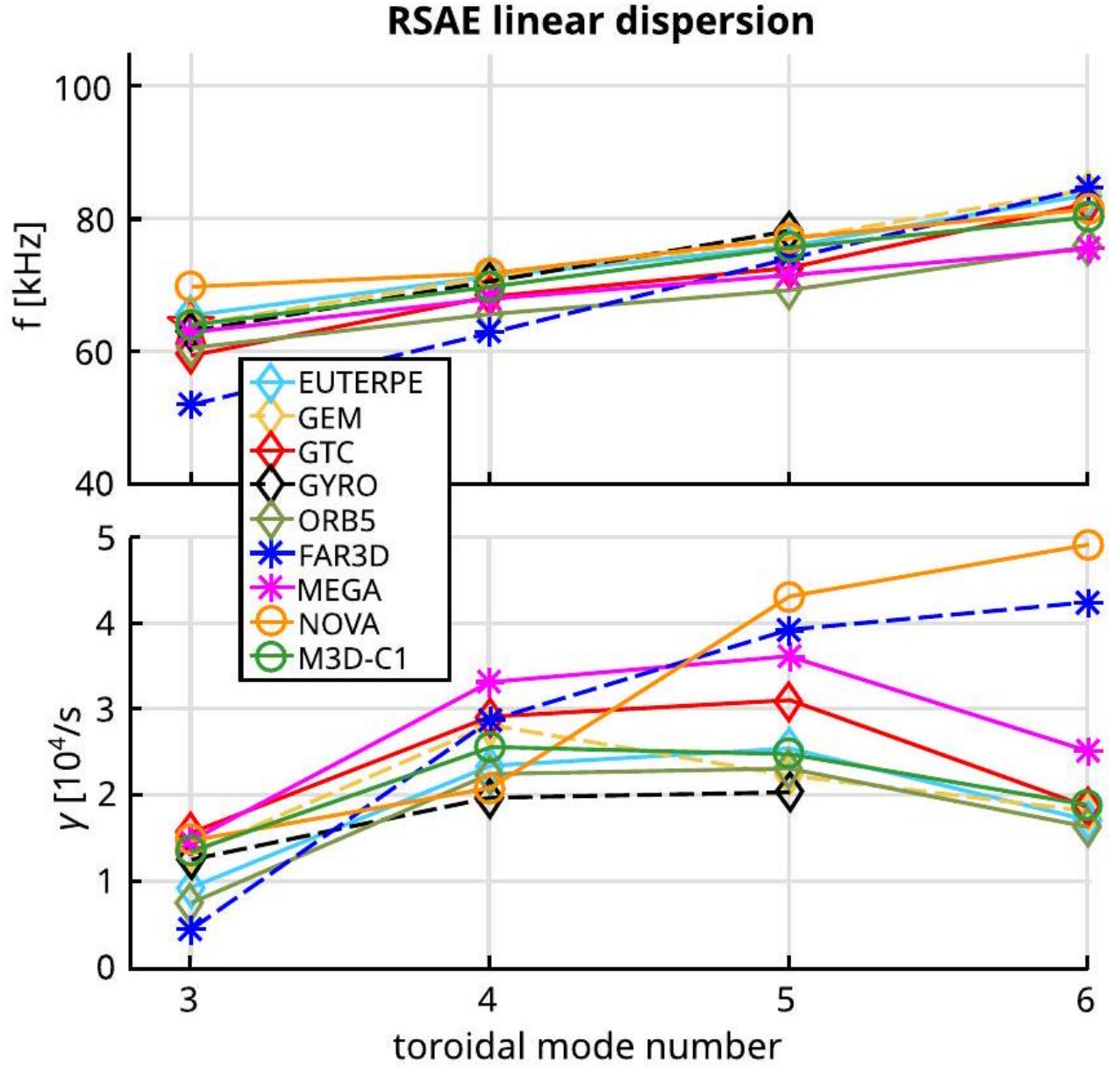
**Figure 4:** Structure of the perturbed poloidal flux  $\delta\psi$  (a), the perturbed EP parallel pressure  $\delta p_{||}$  (b) and the difference between the perturbed parallel and perpendicular EP pressure  $\delta p_{\perp} - \delta p_{||}$  (c) from the  $n = 1$  linear fishbone simulation with  $\beta_h/\beta_{total} = 0.5$  using M3D-C1-K. The values are normalized according to the maximum absolute value.



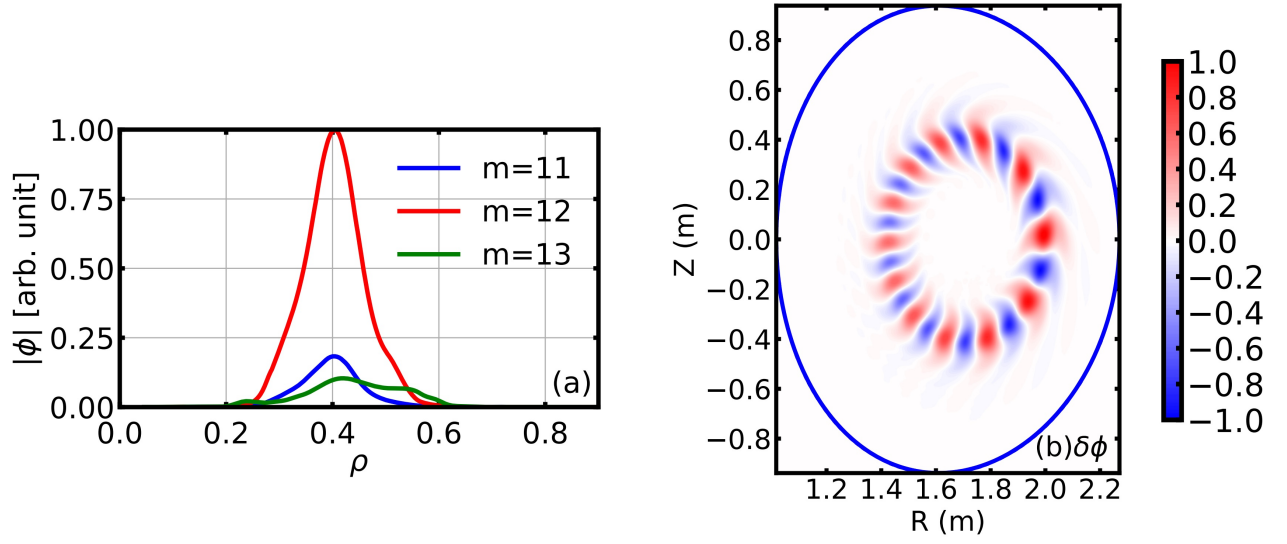
**Figure 5:** Mode growth rates from calculations without FLR effects (a), with FLR effects (b) and the mode frequencies (c) as functions of  $T_f$  for the linear  $n = 6$  TAE simulation. The black diamonds show the results from M3D-C1-K, on top of results from other codes presented in [30].



**Figure 6:** (a) Poloidally averaged radial structure of perturbed poloidal vorticity  $\delta_\phi$  of different poloidal harmonics from the  $n = 6$  TAE simulation using M3D-C1-K. (b) Poloidal structure of  $\delta_\phi$ . The values are normalized according to the maximum absolute value.



**Figure 7:** Mode frequencies ( $f$ ) and growth rates ( $\gamma$ ) from calculations with FLR effects for different  $n$  numbers for the linear RSAE simulation. The green circles show the results from M3D-C1-K, on top of results from other codes presented in [34].



**Figure 8:** (a) Poloidally averaged radial structure of perturbed poloidal vorticity  $\delta_\phi$  of different poloidal harmonics of the  $n = 4$  RSAE simulation using M3D-C1-K. (b) Poloidal structure of  $\delta_\phi$ . The values are normalized according to the maximum absolute value.