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Study on Continuum Effects in GYSELA: ITPA-KTAE benchmark

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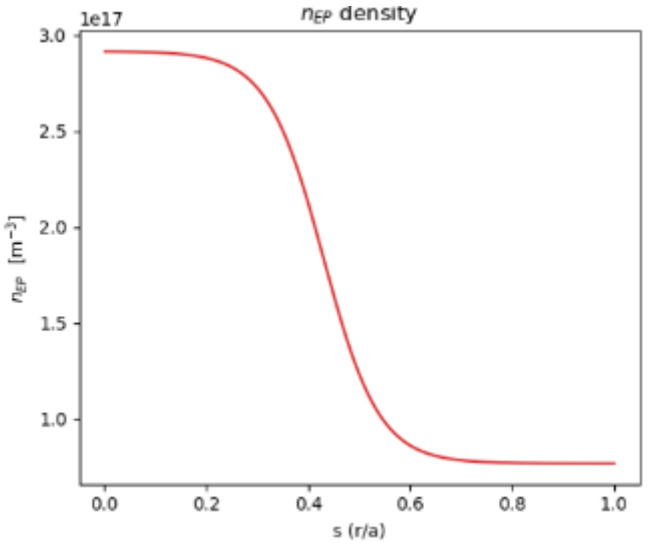
TSVV-G Meeting

Date: 09/07/2026

Benchmark setup & safety factor

Toroidal mode	n = 6
Geometry	concentric circular, $R_o/a = 10$
Species	deuterium bulk + energetic particles
EP temperature	T_{EP} = 400 keV (fixed)
Bulk-ion scan	Ti = 1, 3, 5, 7, 9 keV
Safety factor	$q(r) = 1.5 + (r/a)^2$
Poloidal harmonics	m = 9, 10, 11, 12



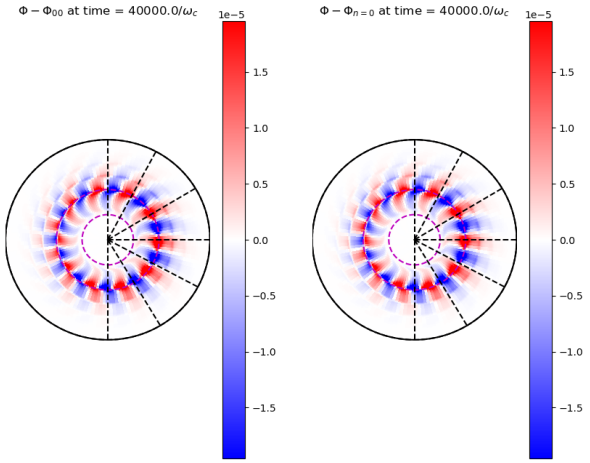
Alexey et al. Physics of Plasmas **21**, 052114 (2014); doi: 10.1063/1.4881417

V. Grandgirard, et al., *Computer Physics Communications* **207**, 35–68 (2016)

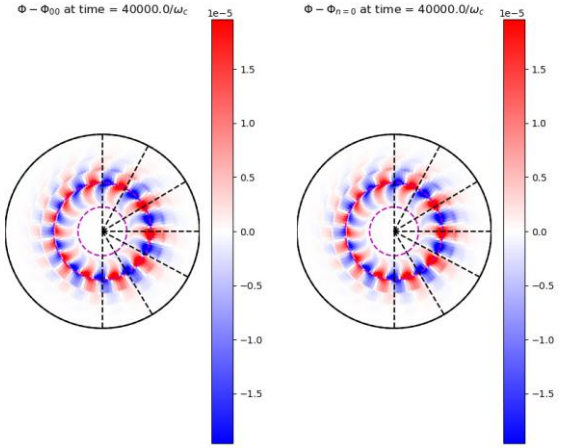
Z. S. Qu, et al., *Journal of Computational Physics* **563**, 115070 (2026). DOI: 10.1016/j.jcp.2026.115070

Convergence Test (T_i = 1 keV)

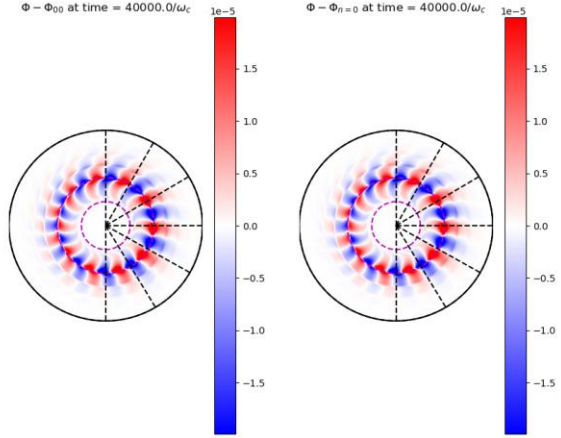
Case	Δt	Nθ	γ (norm. units)	ω (norm. units)
Nr, Nθ, NØ, Nμ, $Nv_{||}$ (512, 128, 8, 32, 128)	20	128	7.8315×10^{-5}	2.9718×10^{-3}
Δt halved	10	128	7.8290×10^{-5}	2.9718×10^{-3}
Nθ doubled	20	256	7.8520×10^{-5}	2.9718×10^{-3}



(Δt=20, Nθ=128)

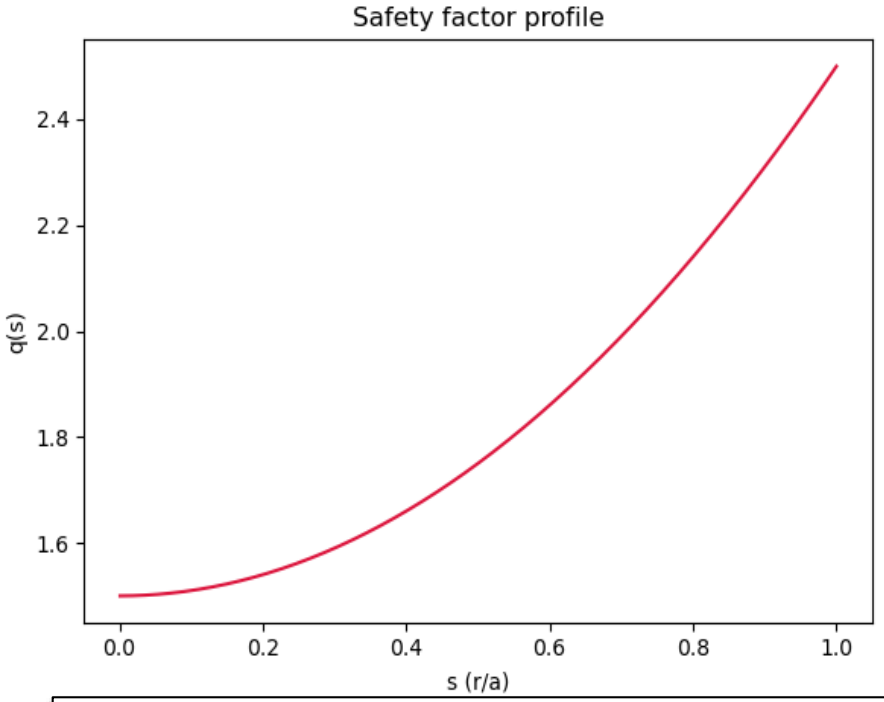


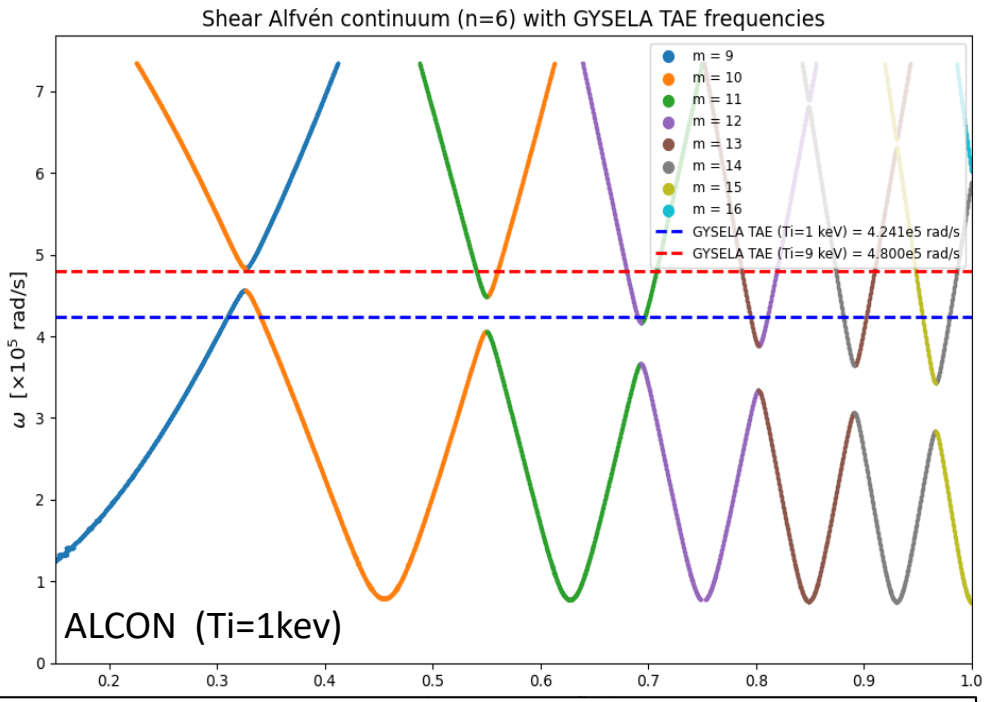
Δt halved



Nθ doubled

Converged: both γ and ω change by <0.3% under Δt-halving and Nθ-doubling, and the poloidal Φ structure is visually identical in all three cases — the baseline resolution is adequate.





- q(s) = 1.5 + s^2

  Steeper than the ITPA low-shear profile (1.71+0.16s^2): leads to wider gaps and enhanced continuum interaction.

- GYSELA ω sits inside the gap

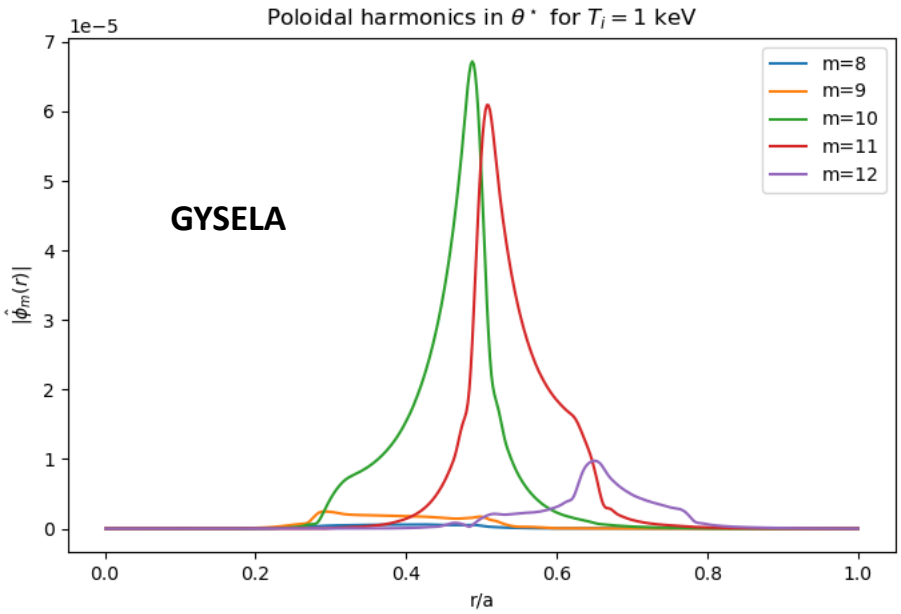
  Both T_i=1 keV and 9 keV frequencies fall inside the m=9/m=10 toroidicity gap (near $s \approx 0.55$ and $s \approx 0.33$ respectively), indicating a weakly-damped TAE.

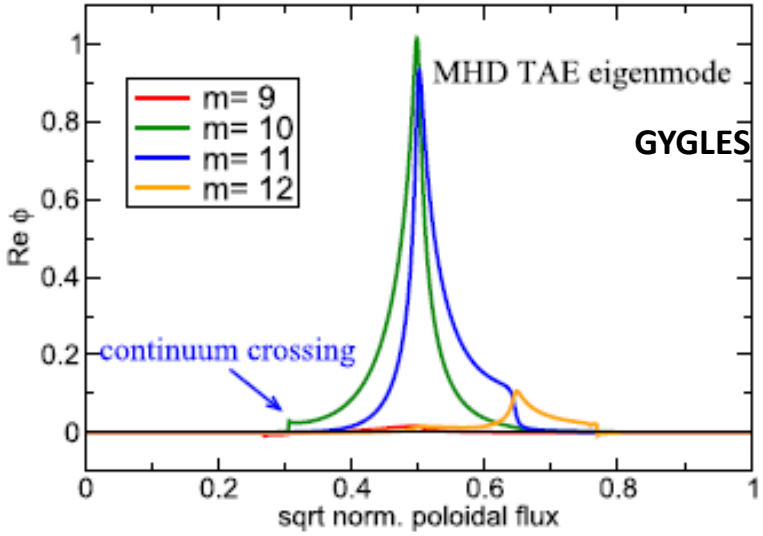
- The mode frequency ω increases with T_i .

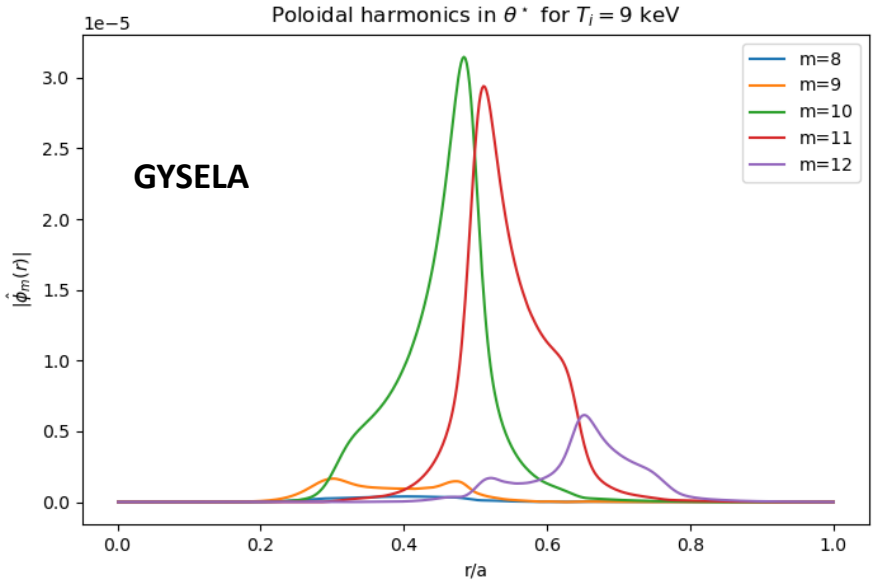
- m=10 / m=11 dominate
  Peak amplitude sits near the accumulation point s ≈ 0.5, for both temperatures.

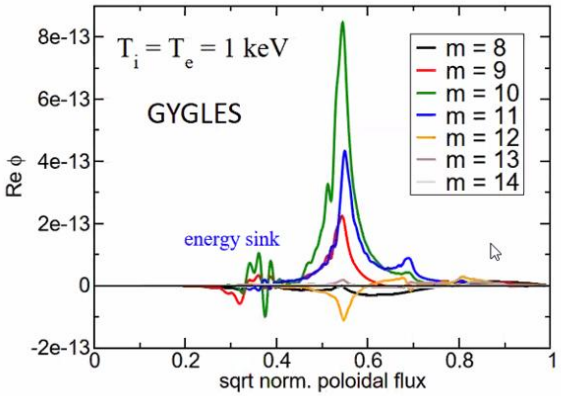
- T_i : 1 → 9 keV
  Structure appears near the continuum-resonance region, enhanced KAW coupling.

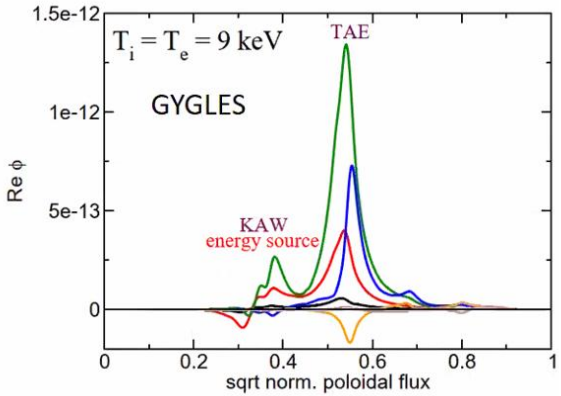
- The global (K)TAE–KAW picture: at high T_i the mode amplitude is reduced.

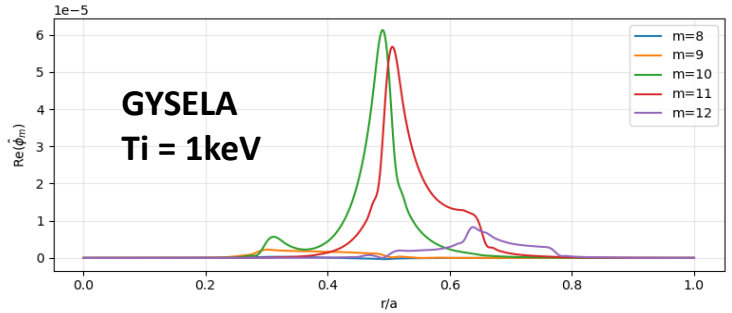


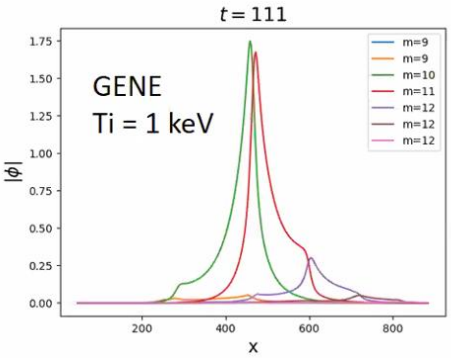


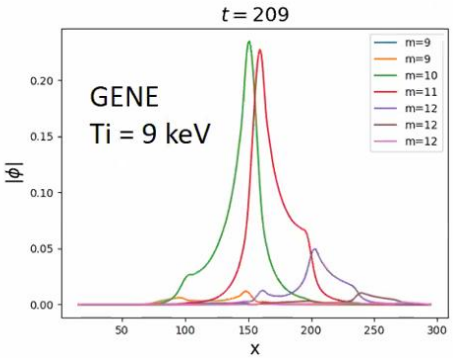


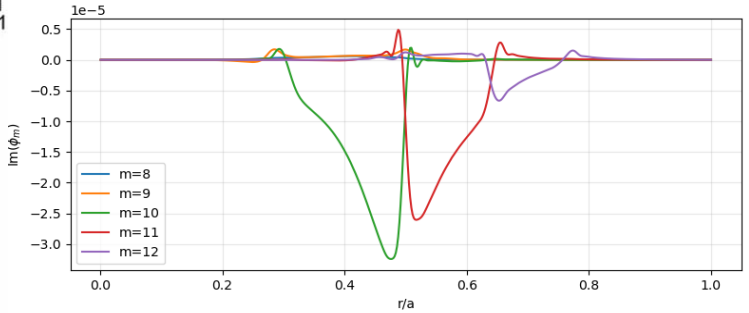


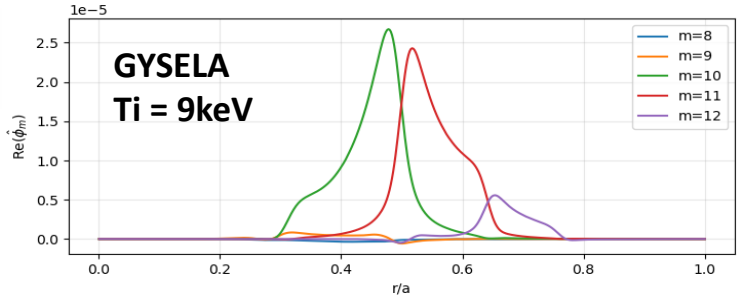


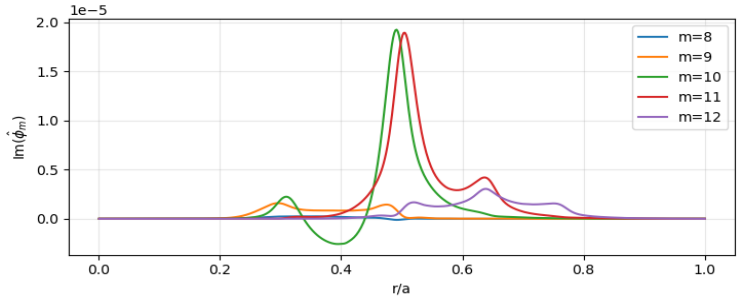




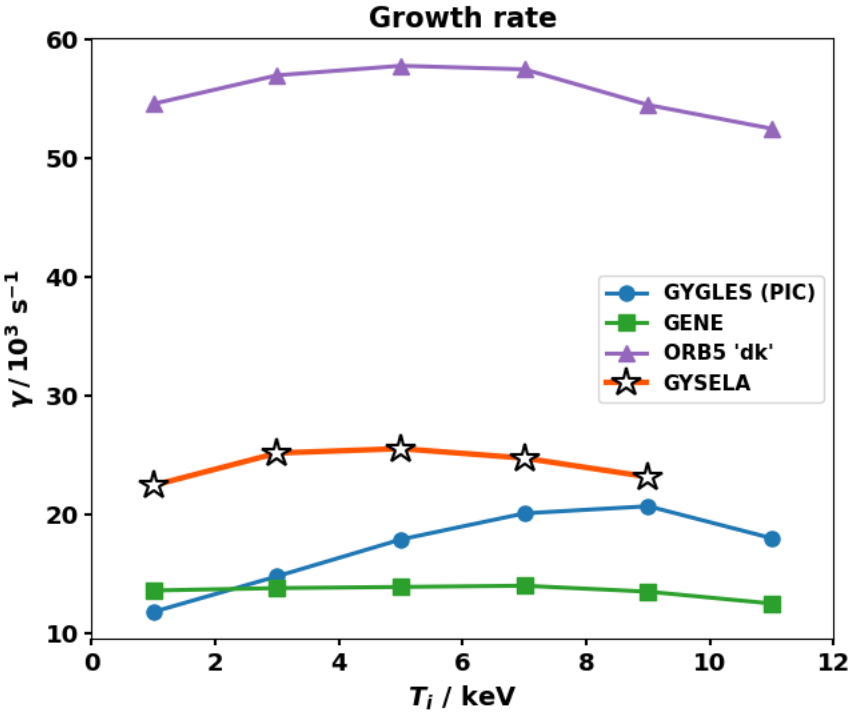


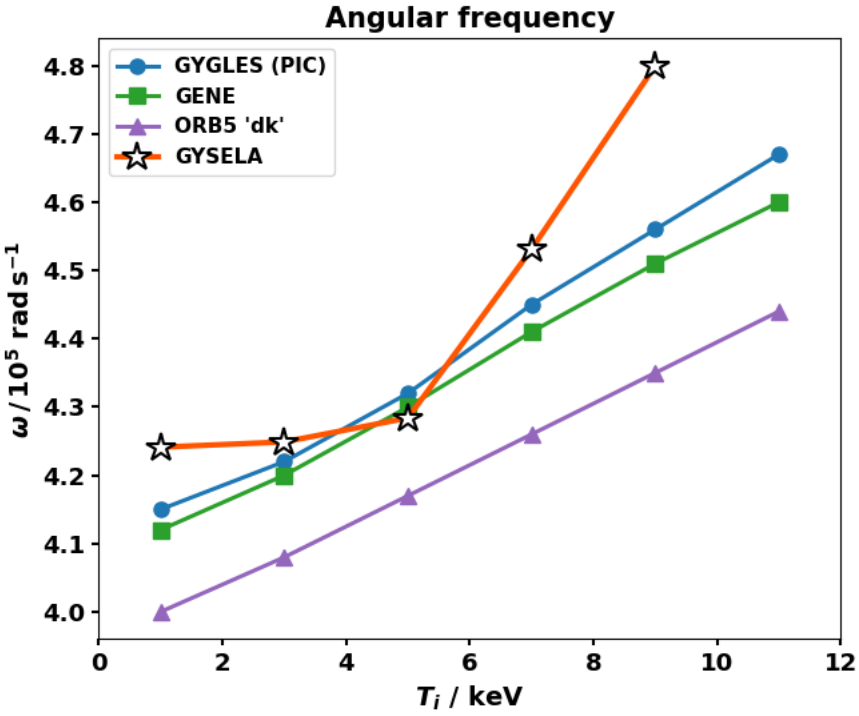






- In GYSELA, Re(ϕ_m) peaks at mid-radius and is dominated by m=10/11, consistent with GYGLES and GENE.
- At 1 keV, the deep negative dip in ϕ_m confirms a localized fluid continuum damping (energy sink), matching GYGLES.
- At 9 keV, the reduction of the dip and appearance of a positive peak indicate phase realignment and radial energy leakage via KAWs.





- GYSELA data points lies between GENE (lowest) and ORB5 (highest), above GYGLES.

- GYSELA follows GYGLES and GENE closely up to $T_i \approx 5$ keV; but exhibits a diverge at higher T_i.

The rising $\omega(T_i)$ trend is consistent with the finite-pressure / continuum-coupling physics expected from the published literature.

Conclusions

- Clear TAE peak attenuates from T_i=1 to 9 keV — reduction in Re(ϕ) response.

- The higher growth rate (vs. GYGLES) and broadened mode structure suggest that GYSELA captures stronger continuum interaction.