MHD Stability Analysis and studies of Alfvénic modes with Energetic Particles in DTT

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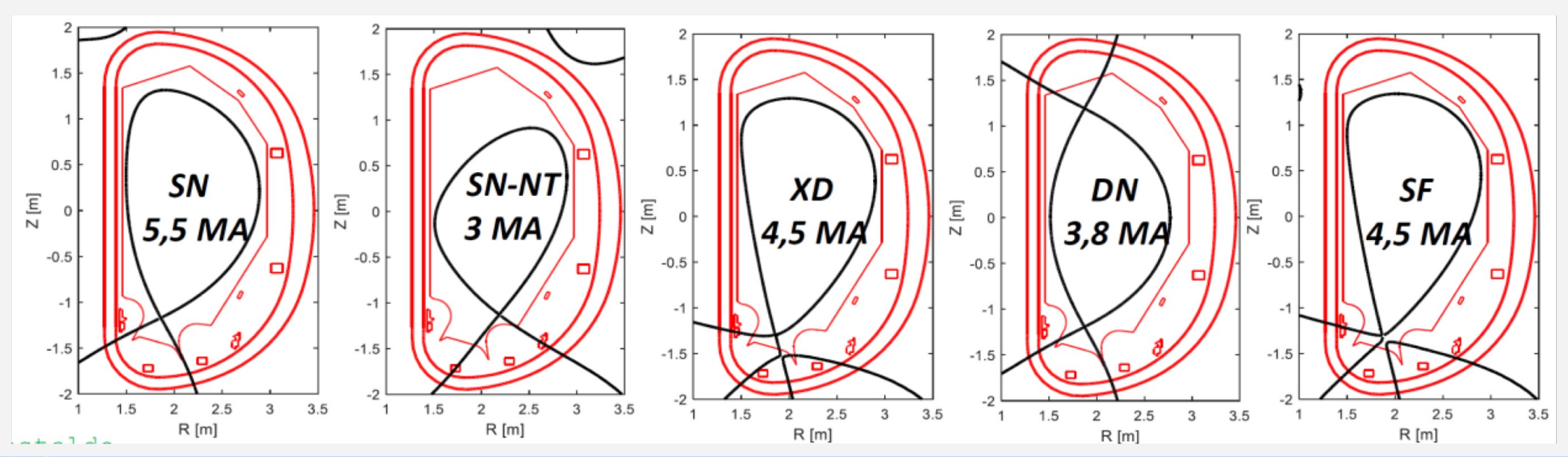
Purpose of the study

- ✓ **MHD stability**, **Alfvénic modes**, and **Energetic Particle dynamics** are both scientifically and operationally essential for **DTT.**

major radius R (m)	2.19
minor radius a (m)	0.70
Volume (m³)	35
Plasma current (MA)	5.5
Vacuum $B_{toroidal}$ at R=2.19 m	5.85
Electron density $\overline{n_e}$ (10^{20} m³)	1.5
Auxiliary power P_{tot} (MW)	45
P_{ECRH} (MW)	29
P_{ICRH} (MW)	6
P_{NBI} (MW)	10

- ✓ The **Divertor Tokamak Test** (DTT), a new machine under construction in Frascati, Italy, is aimed at designing and testing a divertor capable of handling high thermal loads and power exhaust.

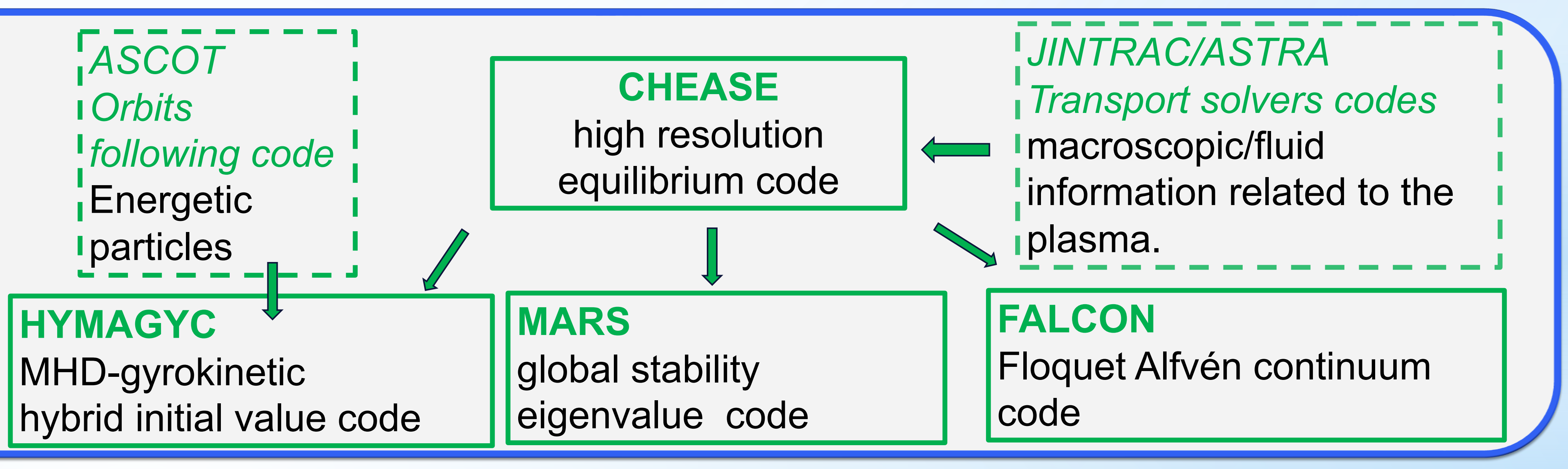


- ✓ **MHD Stability**: it is the prerequisite to allow operation of plasma fusion devices, preventing bad plasma performances and/or plasma wall damages.
- ✓ **Alfvénic modes (TAE, EAE):** they exist in Alfvén continuum frequency gaps
- ✓ **Energetic particles**: they can resonantly transfer power to Alfvén modes, driving them unstable. They interact with the modes affecting the confinement of energetic particles themselves, hindering their thermalization in the core plasma, preventing the achievement of burning plasma conditions, and potentially damaging the wall material surrounding the plasma.

We characterise internal kink, infernal, TAE and EPM stability and quantify growth rates and localization for a realistic slowing-down fast-ion distribution.

Numerical simulation approach

- ✓ global, kinetic, self-consistent approach
- ✓ realistic equilibrium geometry,
- ✓ plasma non-uniformities
- ✓ anisotropic slowing-down fast-ion distribution.
- ✓ Collisions neglected
- ✓ finite orbit width (drift-kinetic) rather than full FLR effects
- ✓ linear and non-linear kinetic approach but only linear evolution is considered here.



ASCOT
Orbits following code
Energetic particles

CHEASE
high resolution equilibrium code

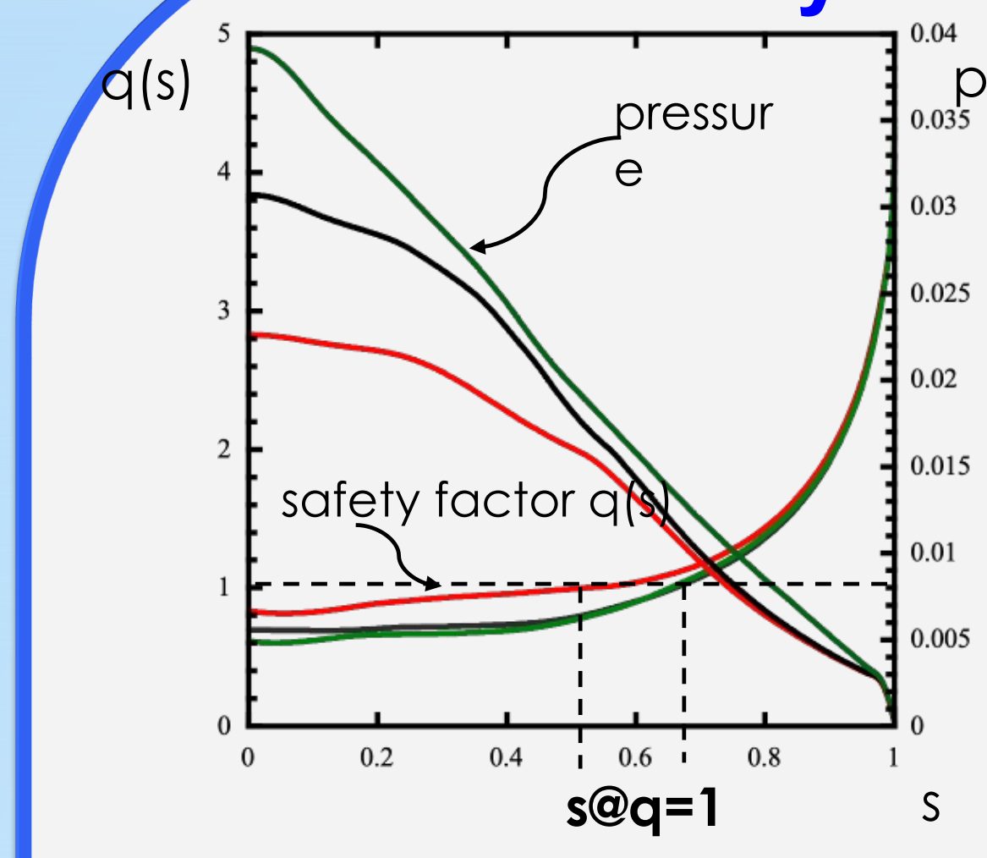
JINTRAC/ASTRA
Transport solvers codes
macroscopic/fluid information related to the plasma.

HYMAGYC
MHD-gyrokinetic hybrid initial value code

MARS
global stability eigenvalue code

FALCON
Floquet Alfvén continuum code

MHD Stability: MARS Analysis



Internal Kink & Sawtooth

- ✓ All equilibria show a q=1 surface inside the plasma thus being internal kink unstable.
- ✓ The large q < 1 region → sawtooth crashes → risk of NTM triggering
- ✓ Sawtooth empirical model (red curve) reduces the q = 1 radius and q_0 excursion, mitigating the drive.
- ✓ ECRH/ECCD tool for q-profile tailoring.

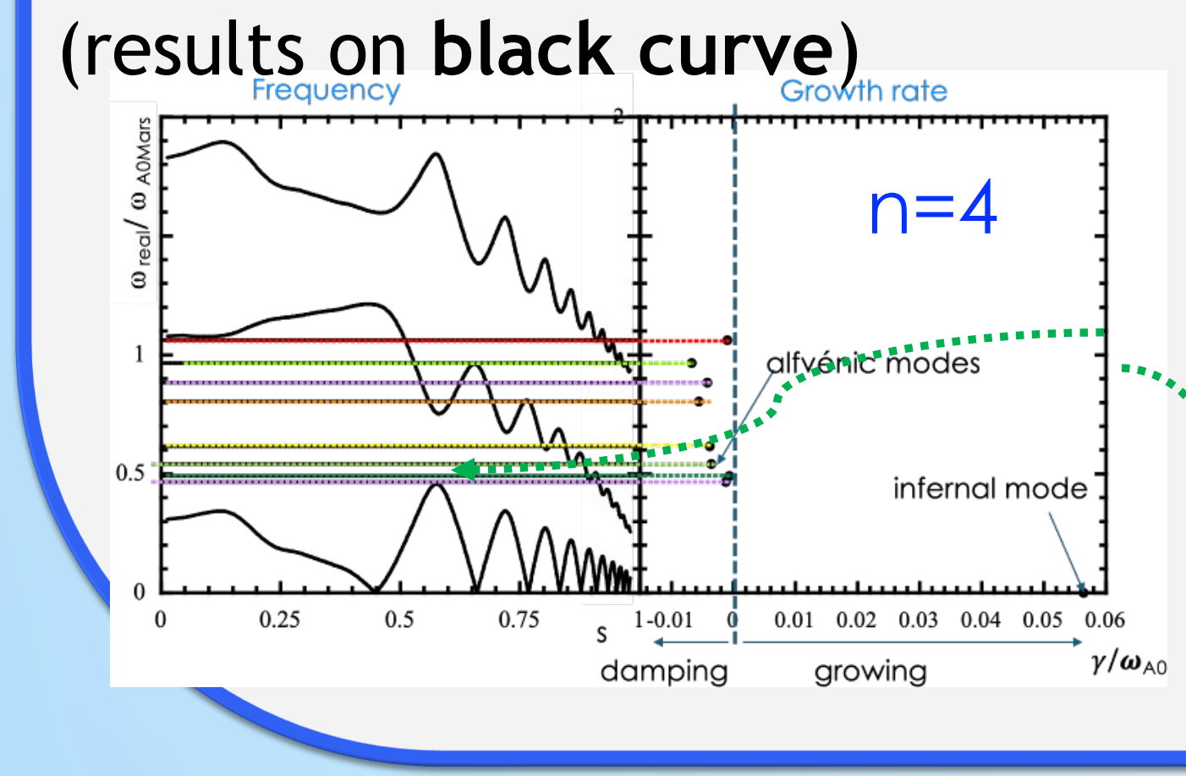
Infernal Modes

- ✓ Low shear + steep core pressure gradients → **infernal modes** → risk of NTM triggering
- ✓ Sawtooth empirical model (red curve): pressure flattening **removes infernal mode drive** suppression is transient, conditions may re-emerge as profiles rebuild between crashes → future investigation

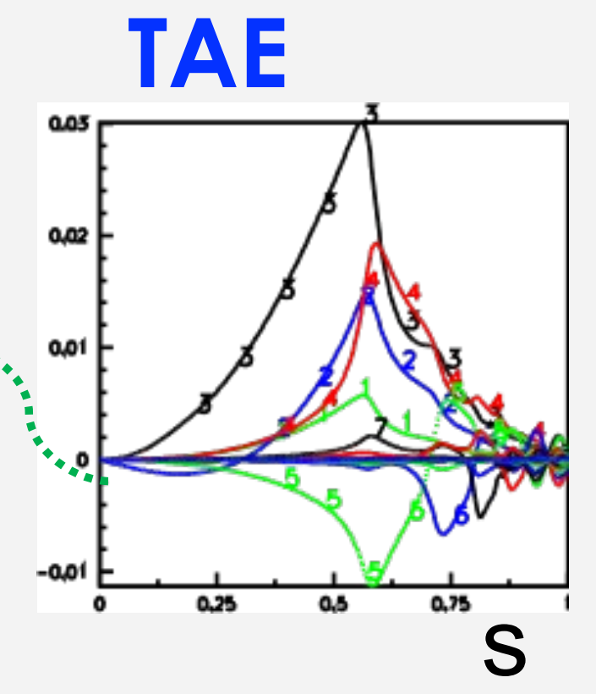
TAE Stability

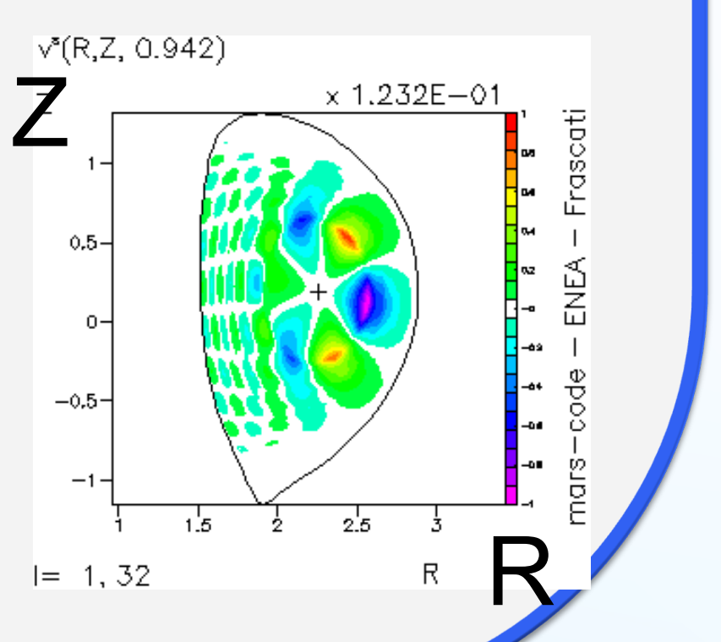
- ✓ TAE eigenmodes lie within the **continuum gap**; without fast ions all modes are damped (γ < 0) via continuum damping

(results on **black curve**)



TAE





Energetic Particles Driven Instabilities: HYMAGYC Analysis

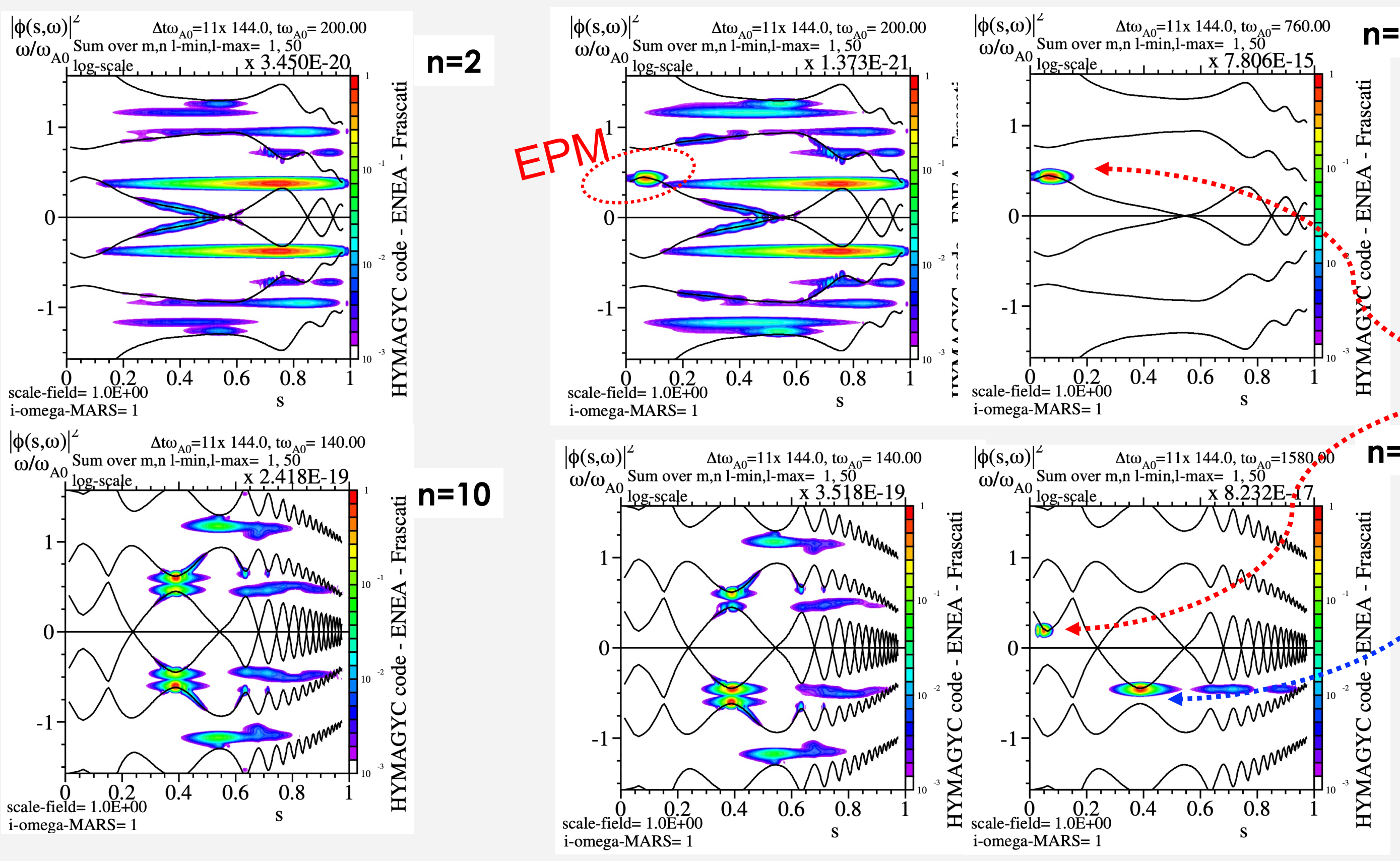
- ✓ The species considered are D, Ar, W: mass density $\rho = \sum m_i n_i$
- ✓ Model for anisotropic slowing down distribution function

T_{e0}=13[KeV]
E_0=510 KeV

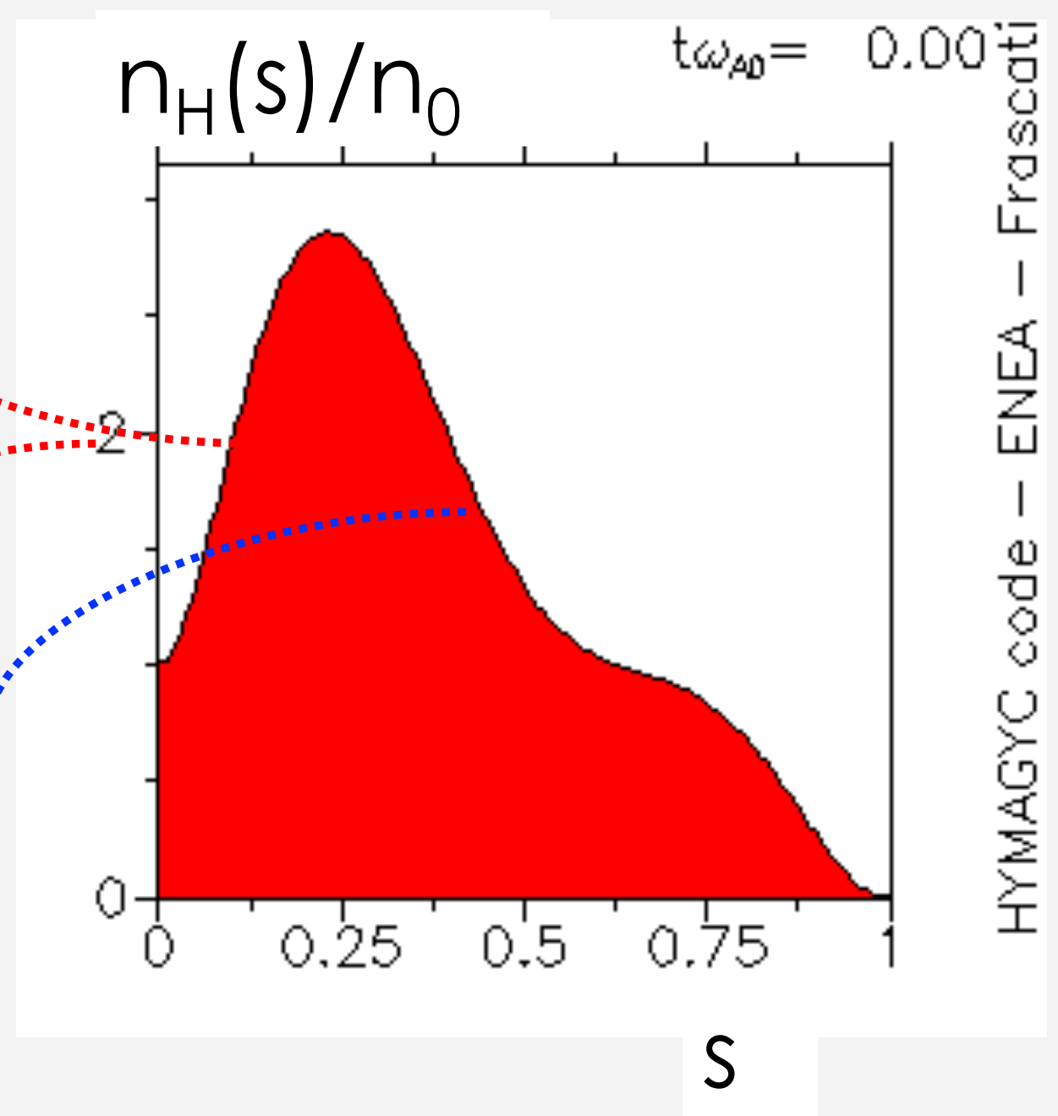
(results on **red curve**)

Without energetic particles

With energetic particles

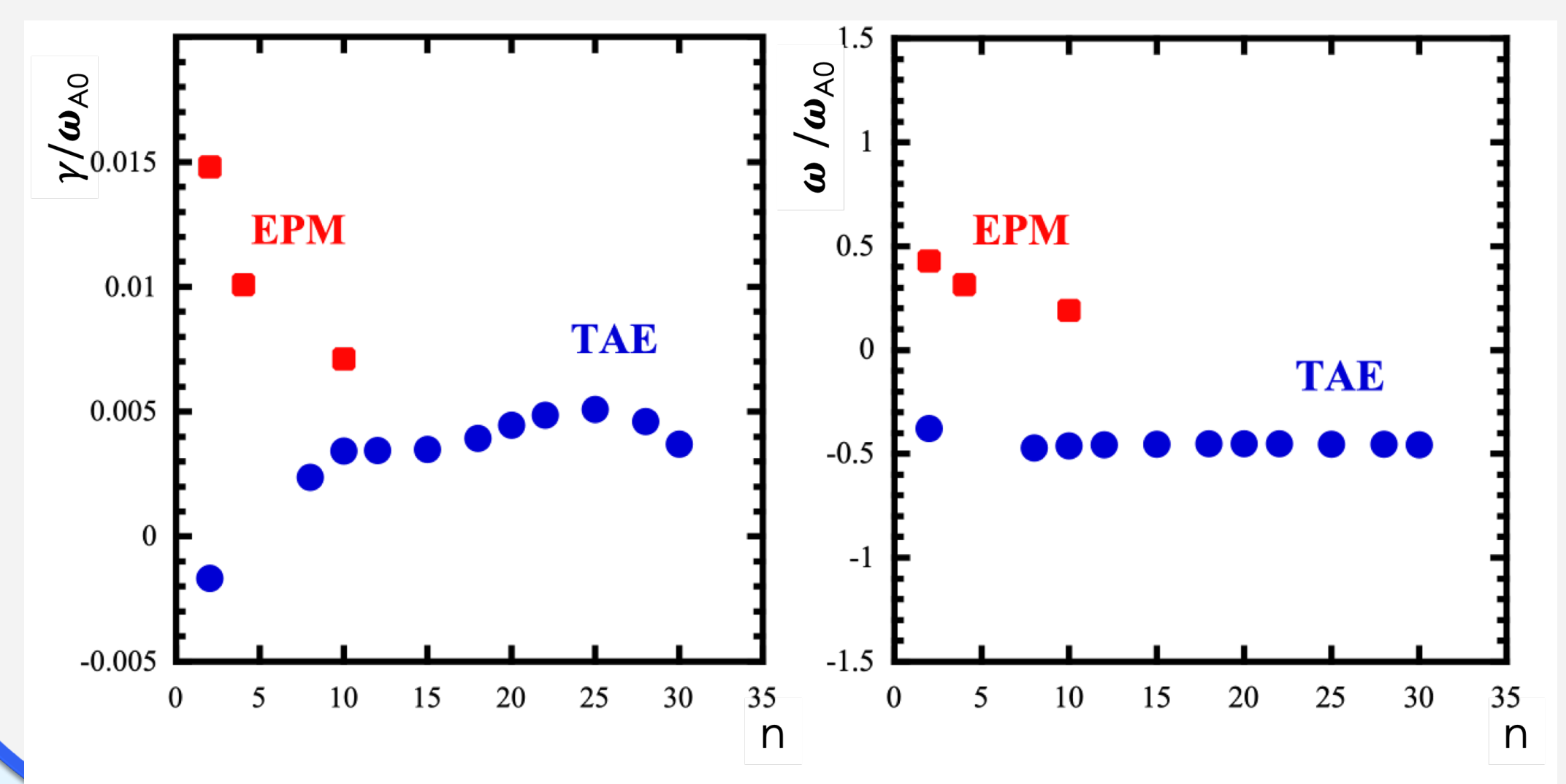


Density of energetic particles
n_{H0}=6.3 x10^{17}[m^{-3}]
n_{Hpeak}=1.18 x10^{18}[m^{-3}]



Growth rate

Frequency



- ✓ **Scan n=2-30**; convergence-validated poloidal harmonics, s-mesh and χ-mesh (high-n → finer grids)
- ✓ **EPMs** (s ≃ 0.1): driven by positive gradient (inward of peak)
- ✓ **TAEs** (s ≃ 0.4): driven by negative gradient (outer slope)
- ✓ Extends local analysis and Maxwellian study to a **global, slowing down** distribution

- ✓ **Energetic particles** have now been incorporated into the analysis, revealing a rich spectrum of modes well captured by the present suite of codes providing new physical insight into DTT scenarios

References

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