# Space structure of the EGAM modes in TCV, experimental observations and modeling

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WPTE RT09 and TSVV-G: Physics of Burning Plasmas

TCV

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* *See See Duval et al 2024*

TSVV-G seminar, Feb. 23 2026

# Introduction and Motivation

- Synergy :
  to RT09 – advanced modeling from TSVV
  to TSVV – codes validation

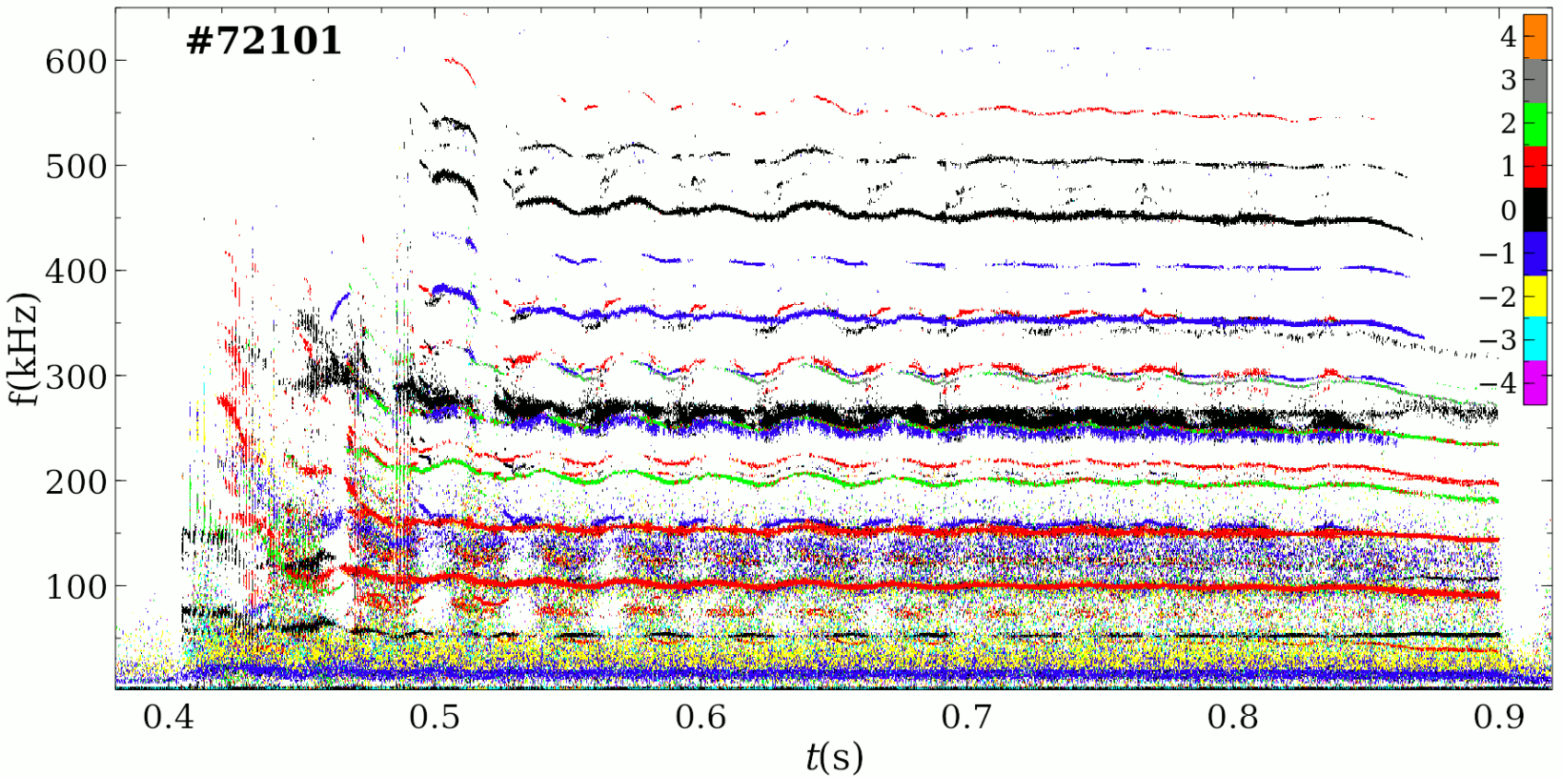
- Contents

  Information of my activity in RT09 framework

  Techniques of modes description by SXR , Magnetics

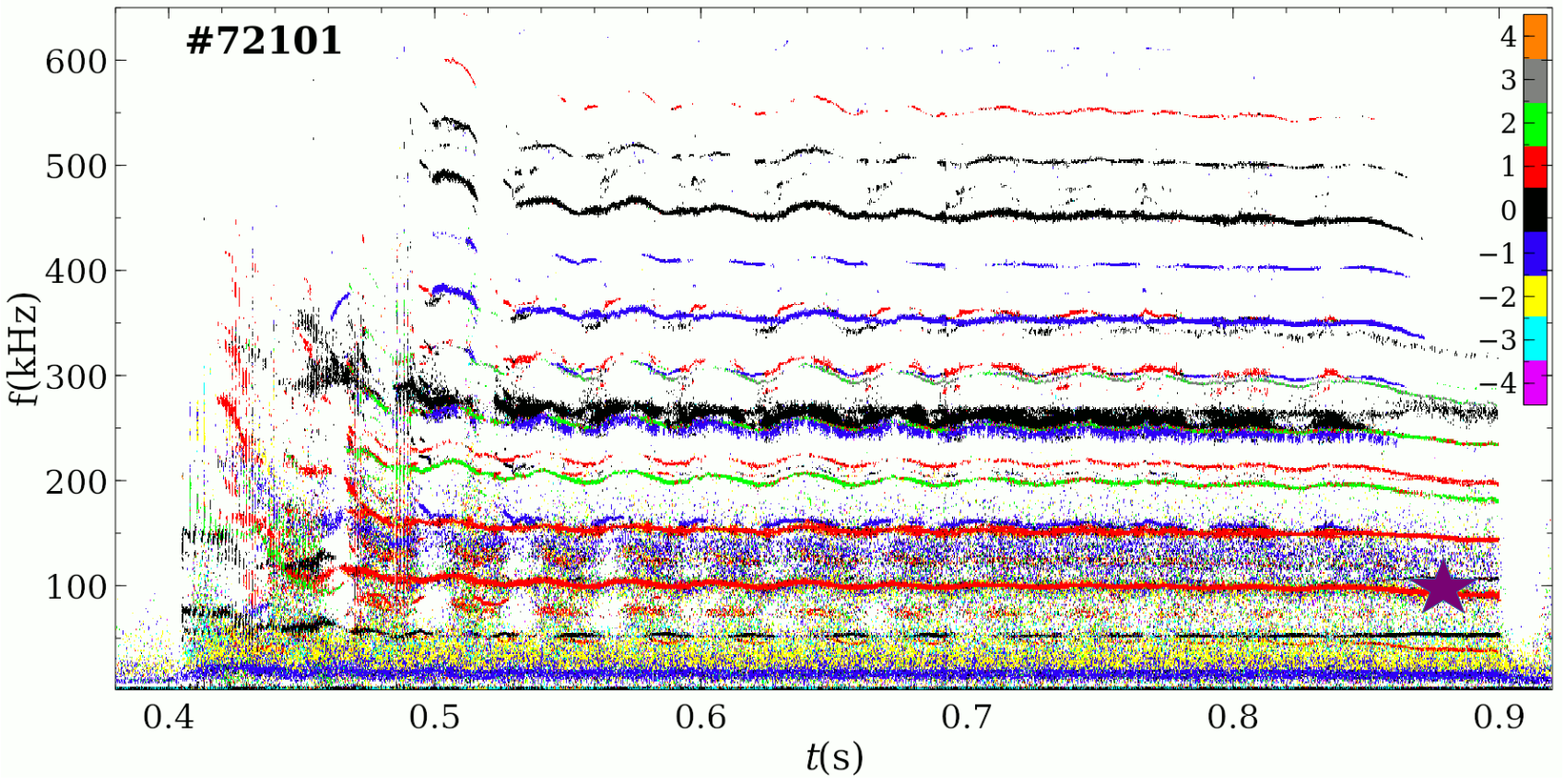
  “SXR” diagnostics for ORB5, “Magnetic” diagnostics for ORB5

# Info:Various AE modes in elivated $q$, counter $I_p$ NBI direction, TCV




M.B. Dreval et al., 2023 Plasma Phys.Control. Fusion **65** 035001

# Info:TAE by MISHKA + SXR forward modeling[1]




[1]M.B. Dreval et al., 2023 Plasma Phys.Control. Fusion **65** 035001

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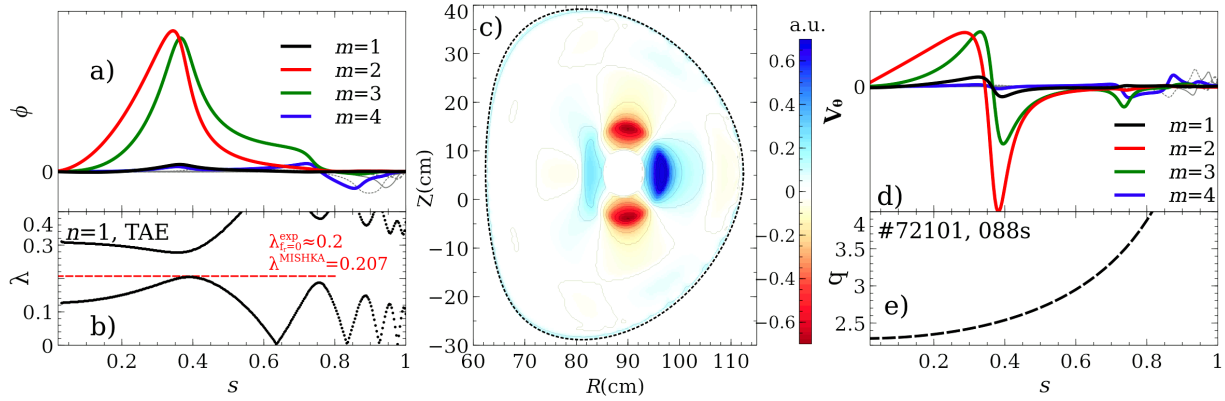
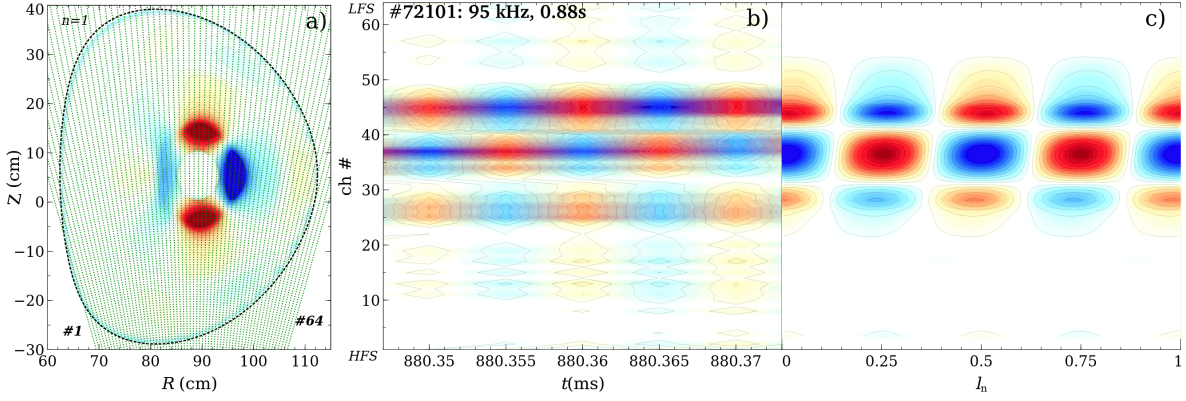
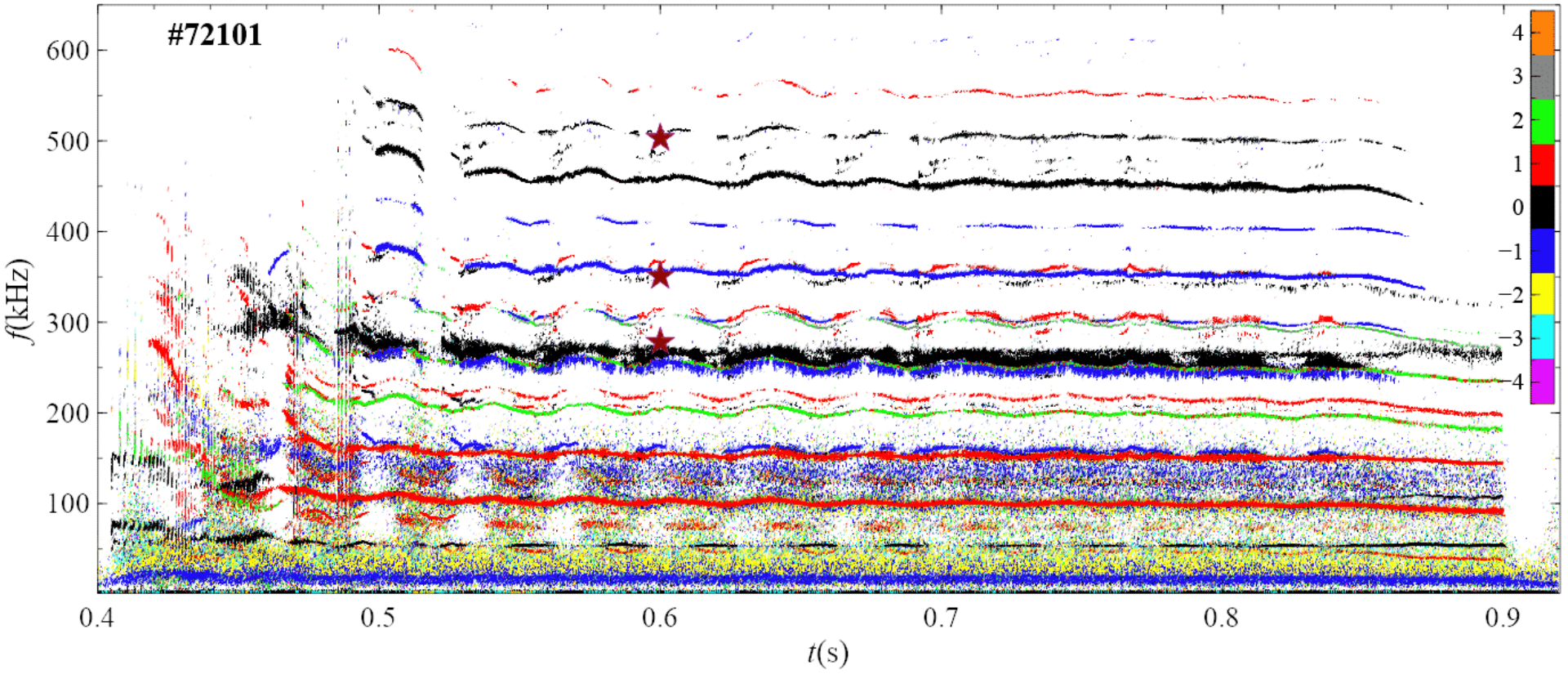


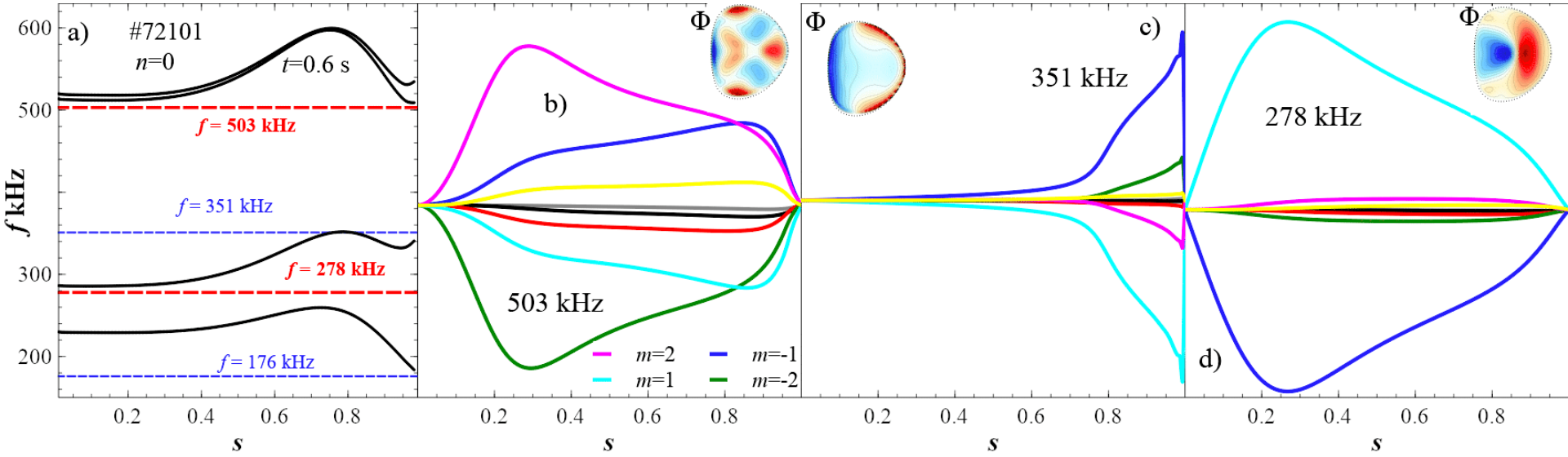

[1]M.B. Dreval et al., 2023 Plasma Phys.Control. Fusion **65** 035001

# Info: $n$=0 GAE by MISHKA modeling[2]



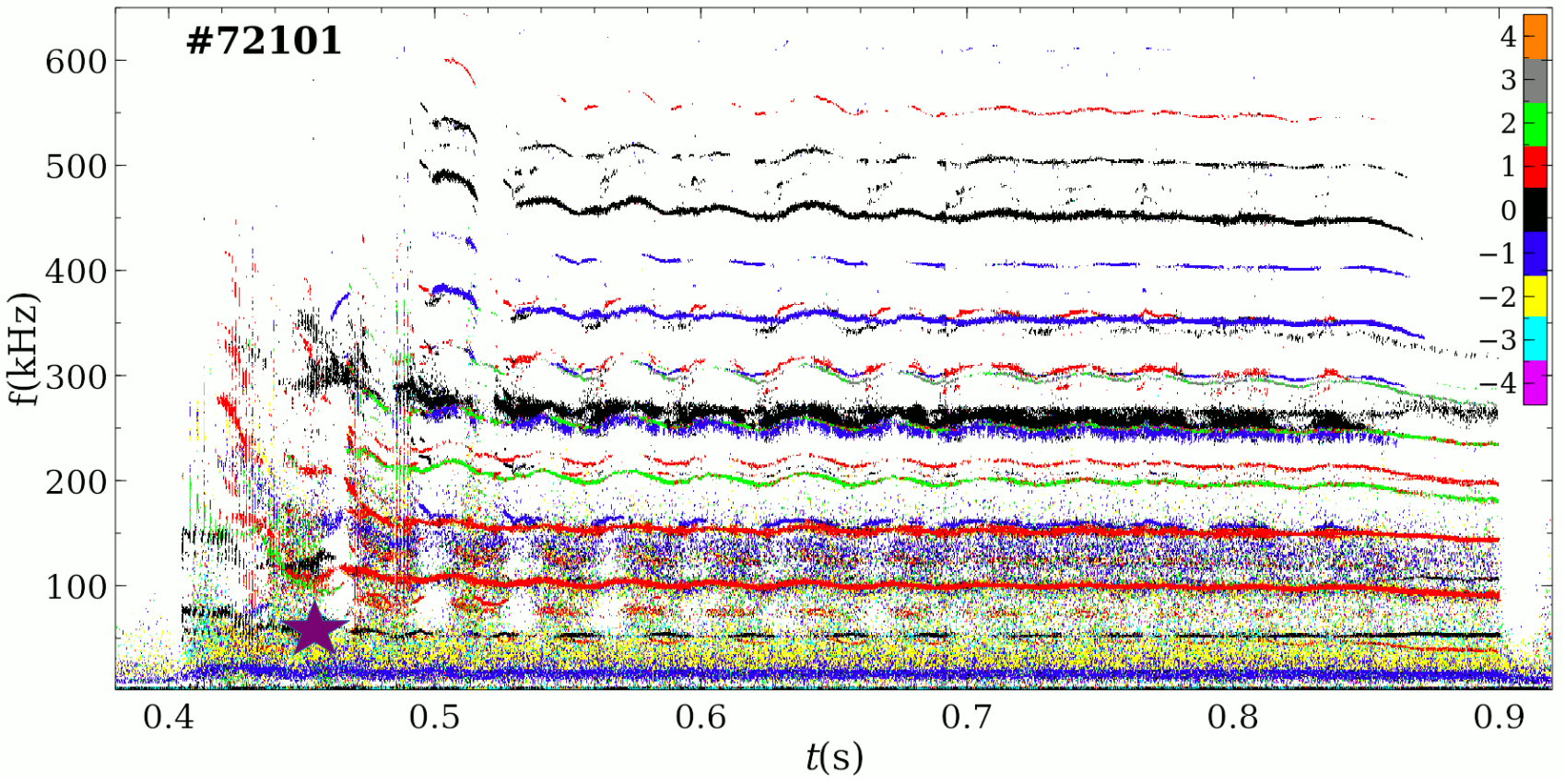

[2]M.B. Dreval et al., EUROfusion pinboard #112

# Info: *n*=0 GAE by MISHKA modeling[2]



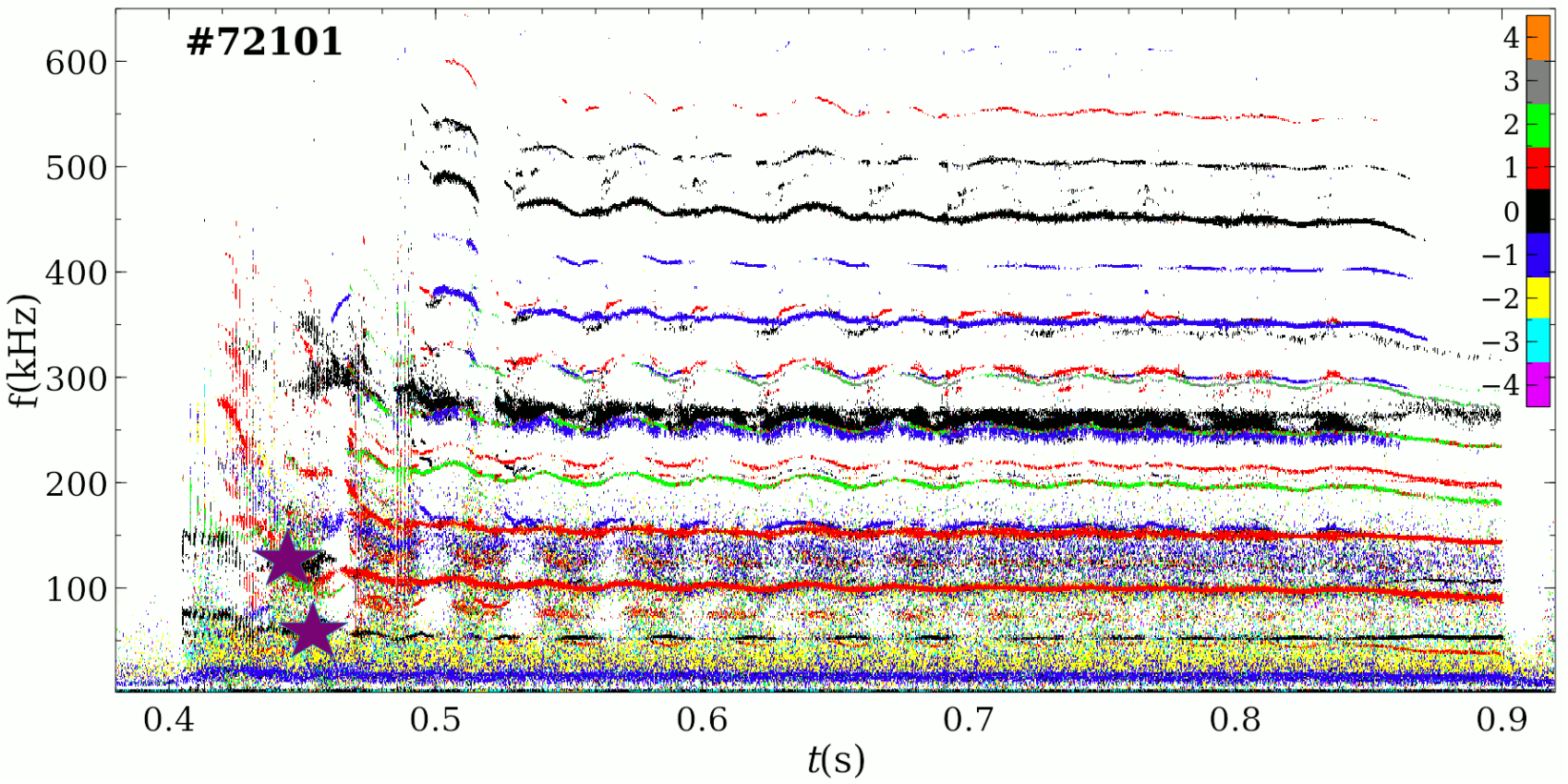

[2]M.B. Dreval et al., EUROfusion pinboard #112

# Info: EGAM by ORB5 + SXR forward modeling[3]




[3]M.B. Dreval et al., 2025 Nucl. Fusion **65** 016037
[4]M.B. Dreval et al., EUROfusion pinboard 2025 #589

# Info: EGAM by ORB5 2nd harmonics



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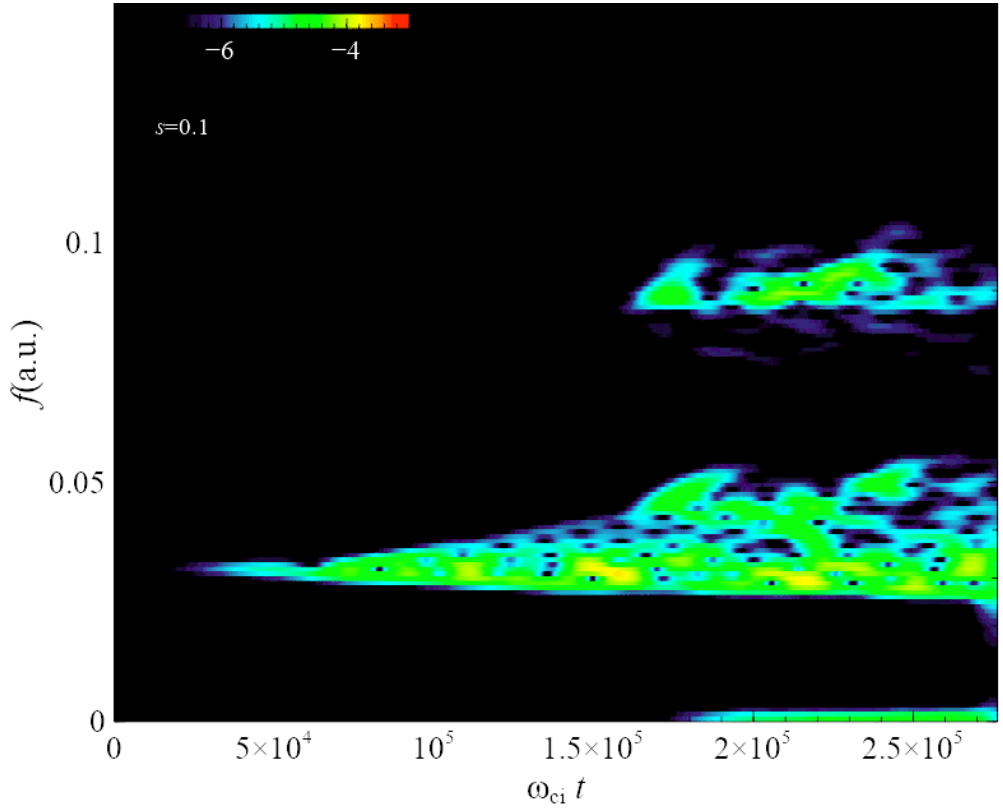
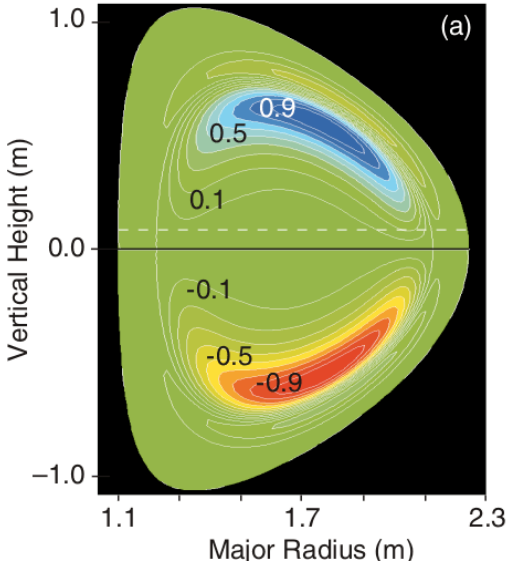
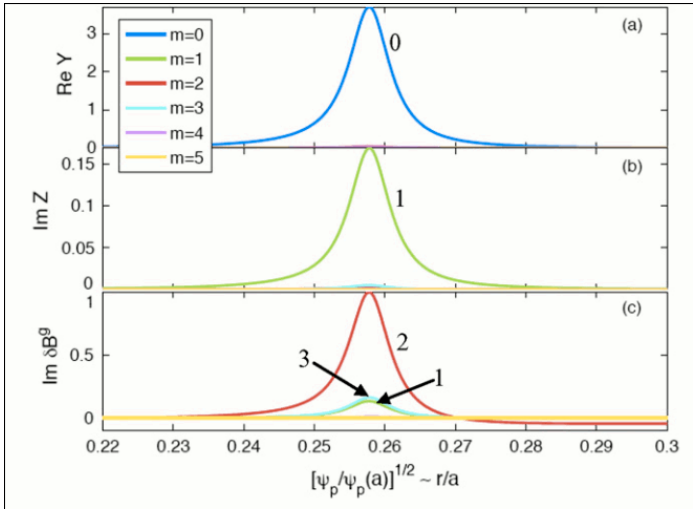


# EGAM:Introduction: **EGAM** vs fast particles driven GAM vs **GAM**




EGAM[1] as well as GAM

***-n*=0**

*-m*=1 **standing wave** localized vertically for $n_e$

- ***m*=2** of Magnetic field oscillations at plasma edge (c)[2]

- fast particles pressure gradient impact overcome main plasma pressure impact => EGAM (EMPs)[2,3]

-EGAM frequency can be different to GAM (0.5 of GAM frequency in[1])

[1]Nazikian R. et al 2008 Phys. Rev. Lett. **101** 185001
[2]Berk H.L. el al 2006 Nucl. Fusion **46** S888
[3]L. Horváth et al 2016 Nucl. Fusion **56** 112003

# EGAM:Introduction and Motivation

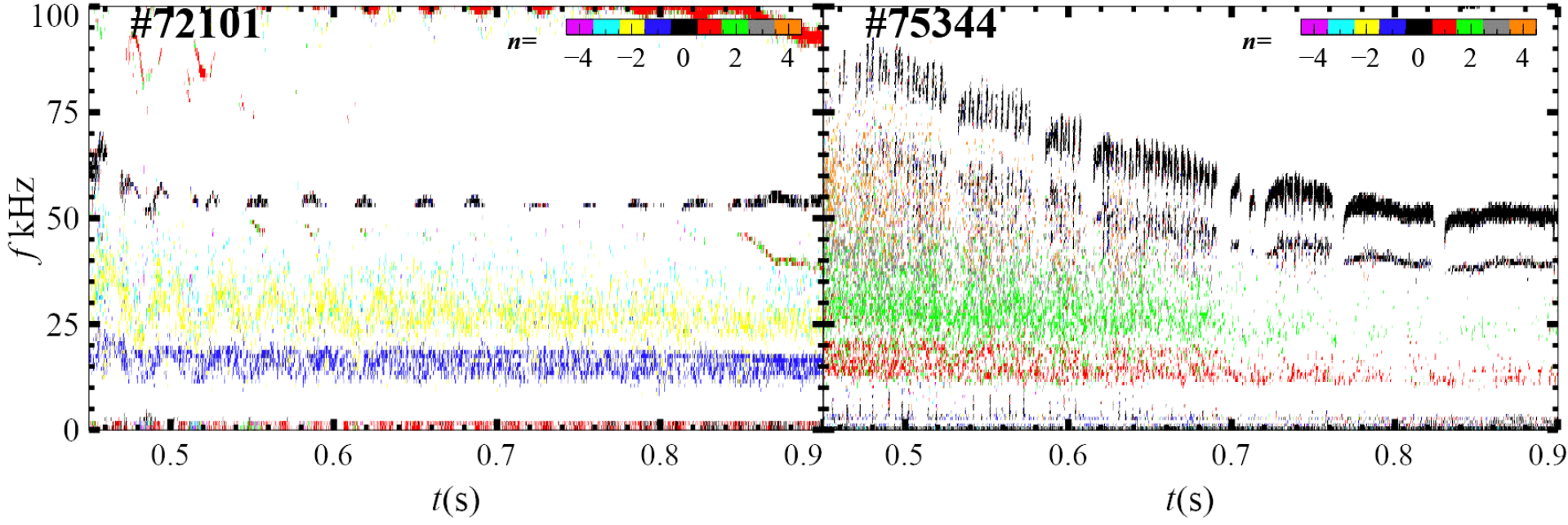



Fig.1 Toroidal mode numbers n in TCV pulses #72101 ($B_0 = +1.3$ T, $I_p = +120$ kA) and #75344 ($B_0 = -1.45$ T, $I_p = -150$ kA). Two different frequencies of the EGAMs is observed in #75344 shot.

1M.B. Dreval et al., 2025 Nucl. Fusion **65** 016037

[2]M.B. Dreval et al., 2023 Plasma Phys.Control. Fusion **65** 035001

# EGAM:*q* dependence

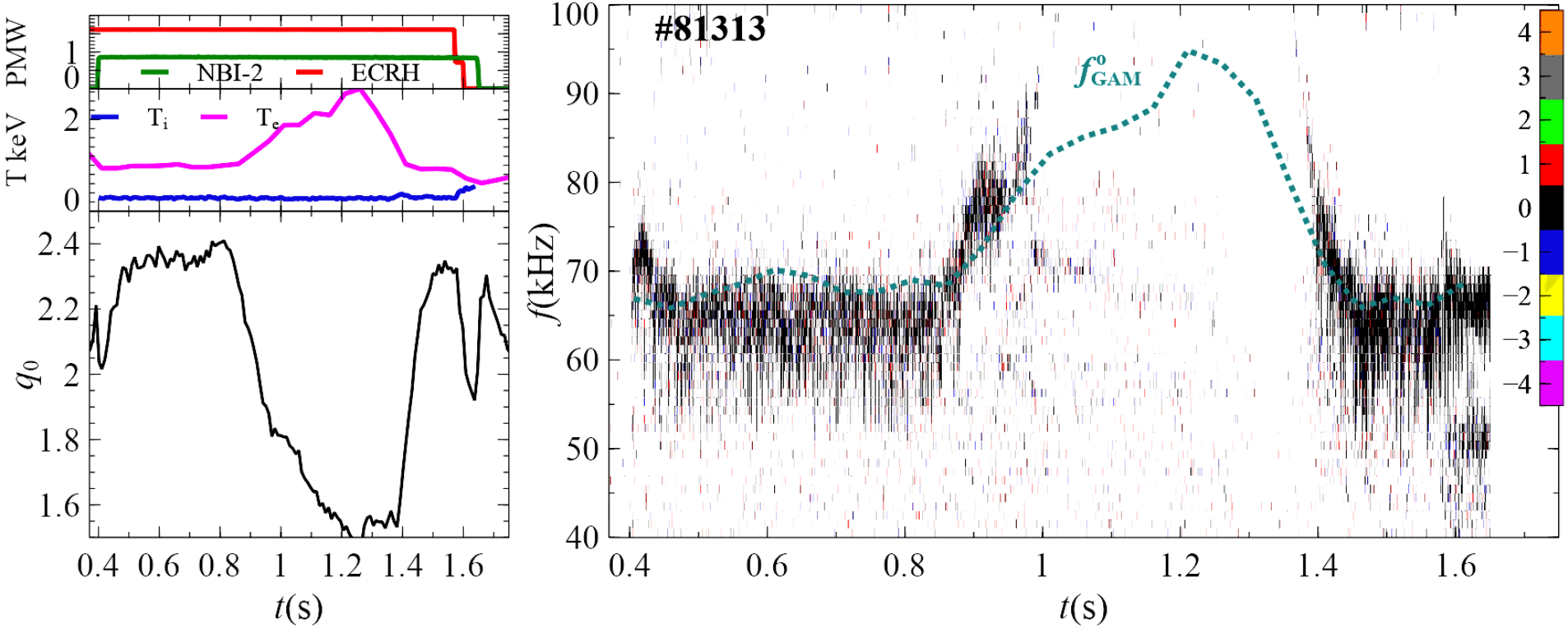



Fig.2 #81313 ($B_0 = -1.45$ T, $I_p = -120$ kA), NBI-2 and ECRH power, central ion and electron temperatures, central safety factor from magnetic LIUQE equilibrium. Toroidal mode numbers (n) are evaluated by radial-component magnetic LTCC coils with central GAM frequency calculated by Eq.1 form Ref. [1].

# EGAM:*q* dependence

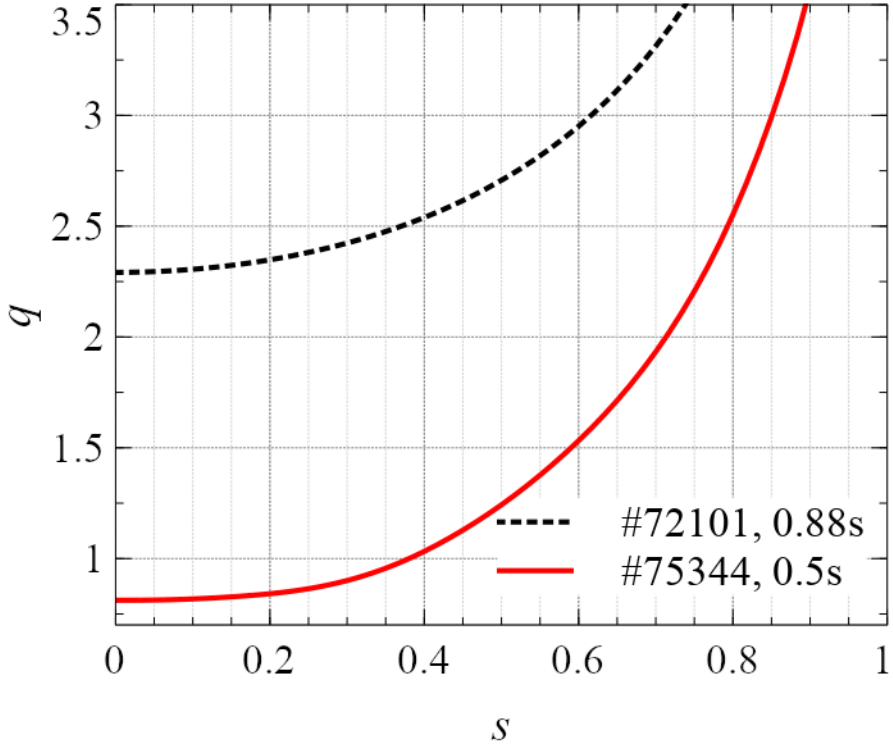



Fig.5 Radial profiles of safety factor in TCV discharge #75344 at 0.5s. (in red) and TCV discharge #72101 at 0.88s. (in black, dashed line) .

# EGAM:Input profiles

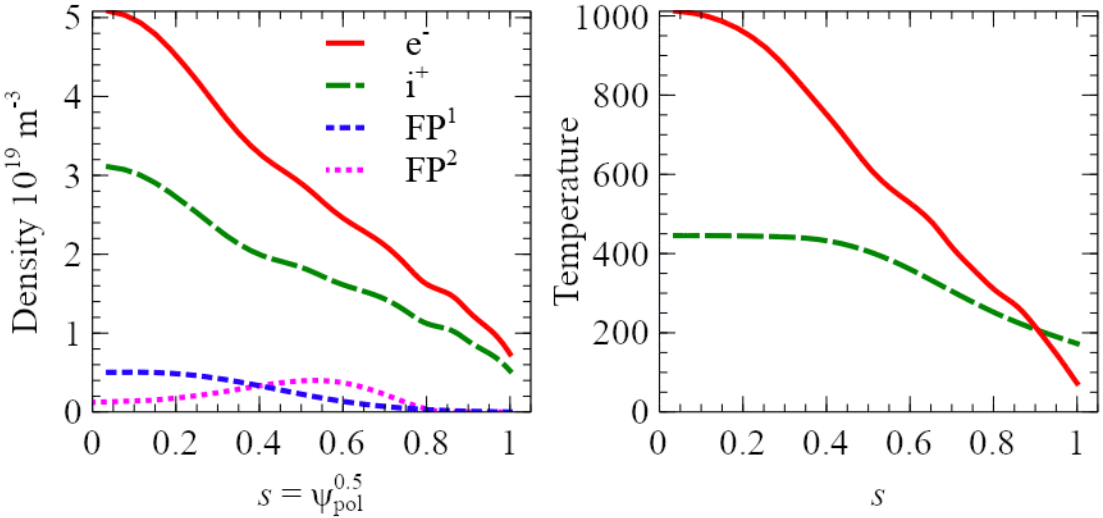



Fig.4 Radial profiles of ion and electron temperature and density. In addition, two modeling profiles of fast particles density are shown corresponding to different NBI scenarios (on-axis vs. off-axis).

[1]M.B. Dreval et al., 2025 Nucl. Fusion **65** 016037

# EGAM:Model of ORB5 FI distribution Orb restriction - $F_0(\psi)$

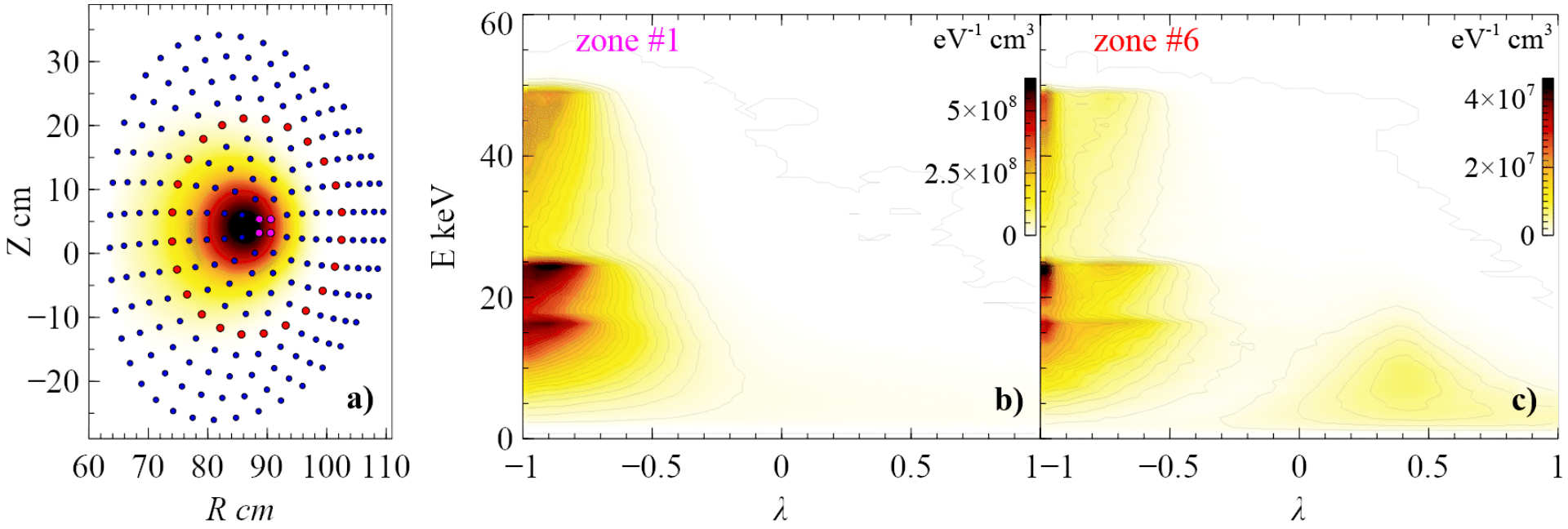



Fig.3 a) TRANSP cells ( in blue) and distribution of 45-49 keV averaged fast ions in poloidal cross-section, zone-averaged FP distributions for zones #1 (b) and #6 (c). TCV discharge #75344 at 0.5s.

[1]M.B. Dreval et al., 2025 Nucl. Fusion **65** 016037

# EGAM:EGAM space structure by ORB5

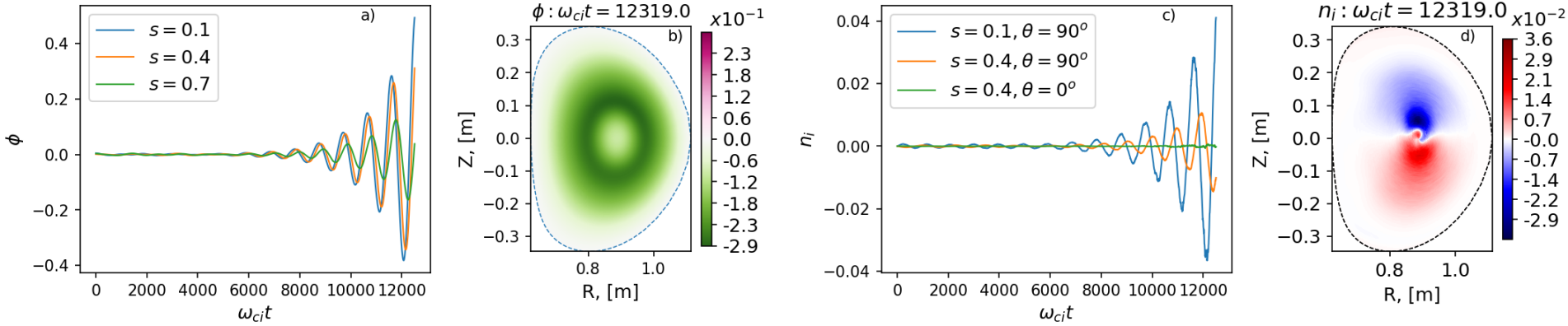



Fig.6 a) evolution of the plasma potential fluctuations at 3 radial positions, b) space distribution of plasma potential fluctuations at $\omega_{ci}t$ =12319, c) evolution of the ion density fluctuations at 2 radial and 2 poloidal positions marked in the legend, d) space distribution of ion density fluctuations at $\omega_{ci}t$ =12319.

# EGAM space structure by ORB5

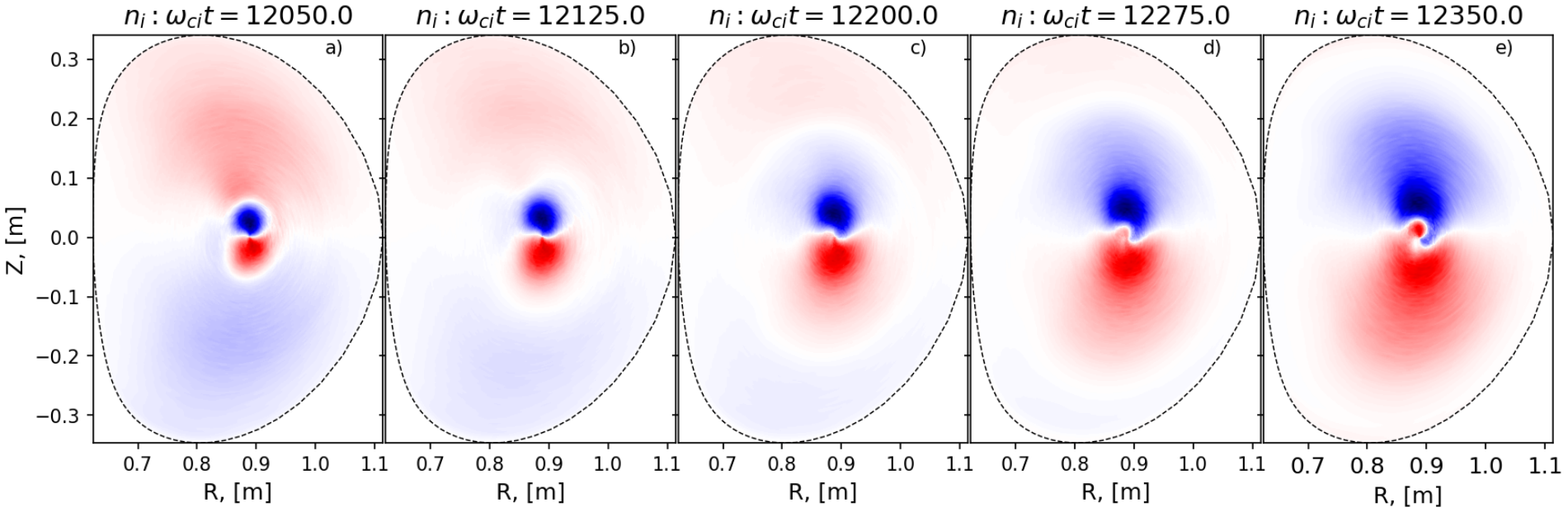
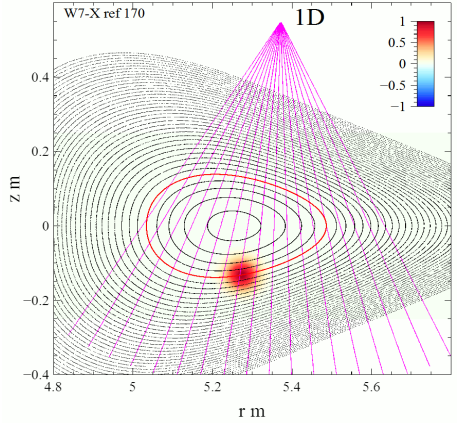


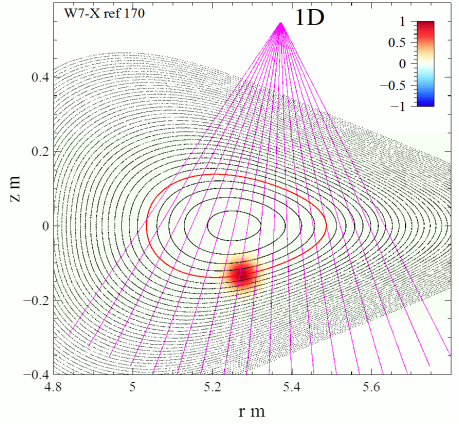

Fig.7 Space distribution of plasma density fluctuations at different moments $\omega_{ci}t$.

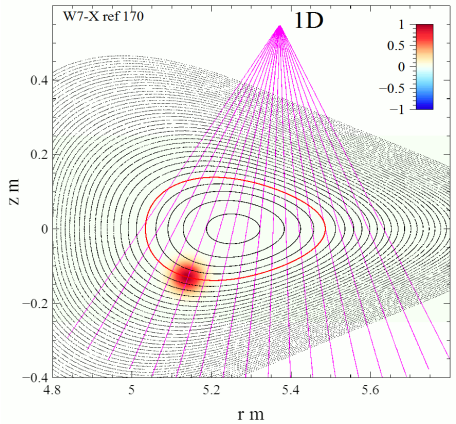
# Introduction: SXR spatiotemporal plot




[1]Dreval M B et al 2021 Plasma Phys. Control. Fusion **63** 065006

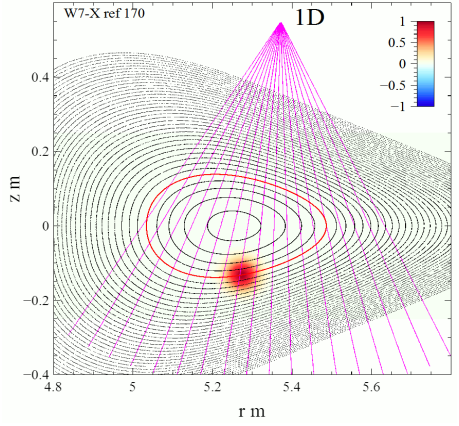
# Introduction: SXR spatiotemporal plot

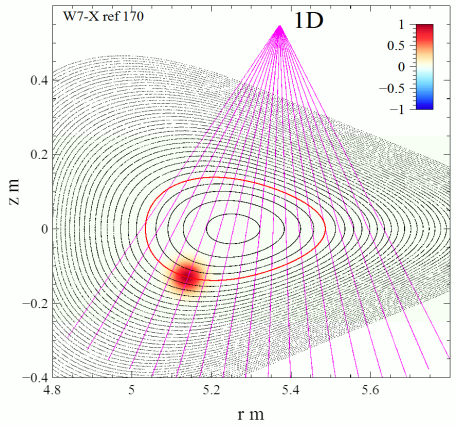


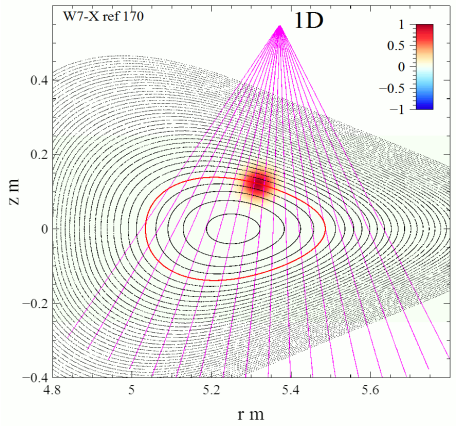




[1]Dreval M B et al 2021 Plasma Phys. Control. Fusion **63** 065006

# Introduction: SXR spatiotemporal plot




[1]Dreval M B et al 2021 Plasma Phys. Control. Fusion **63** 065006

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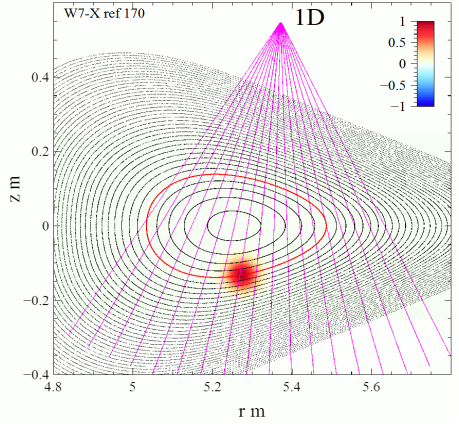
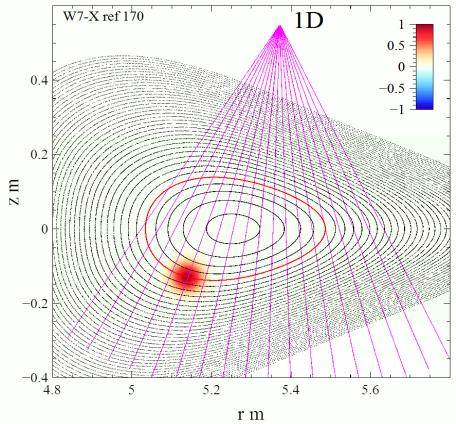
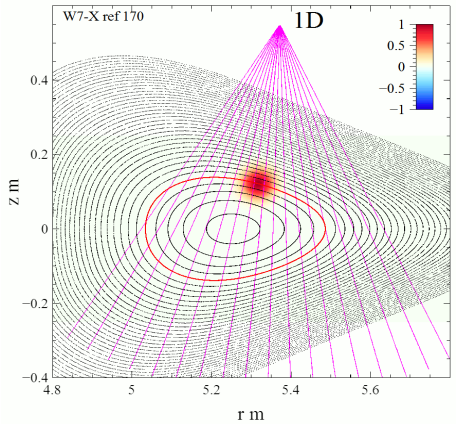
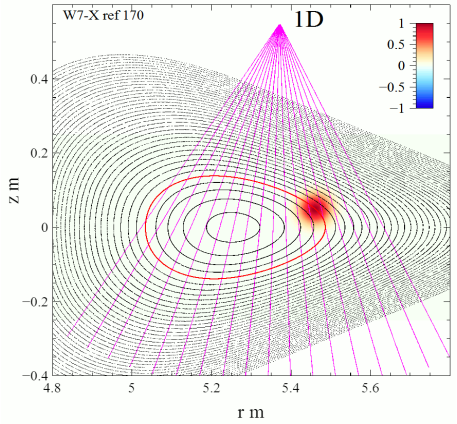


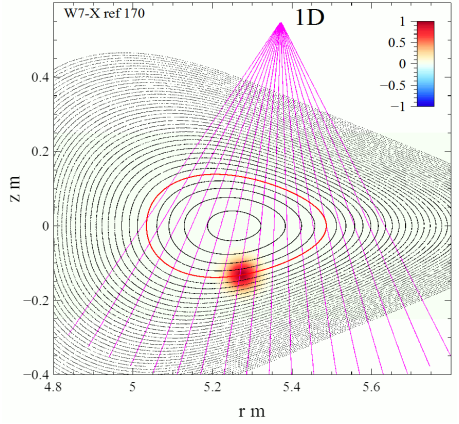



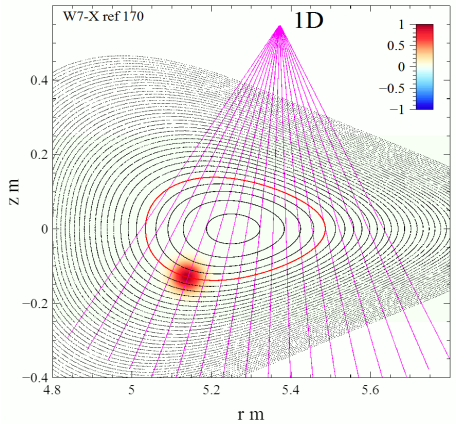



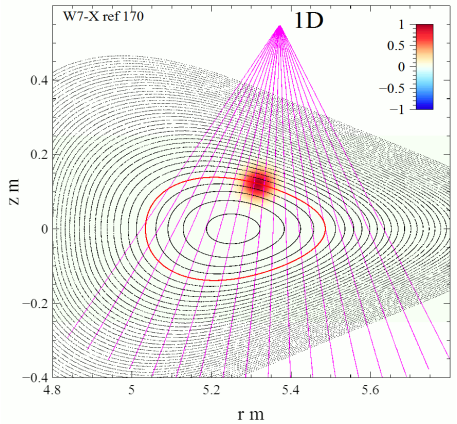



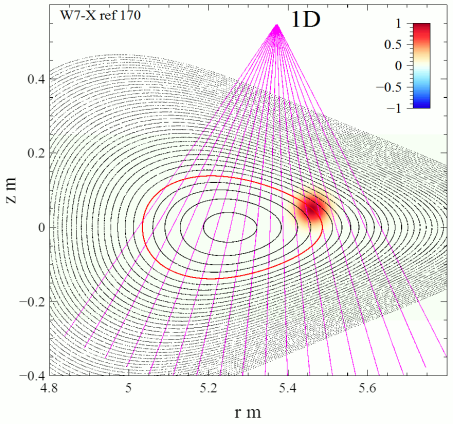

[1]Dreval M B et al 2021 Plasma Phys. Control. Fusion **63** 065006

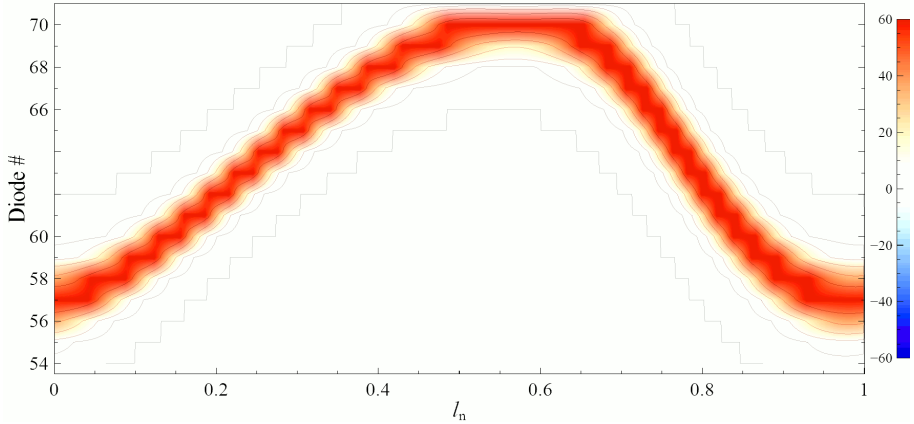
# Introduction: SXR spatiotemporal plot and forward modeling



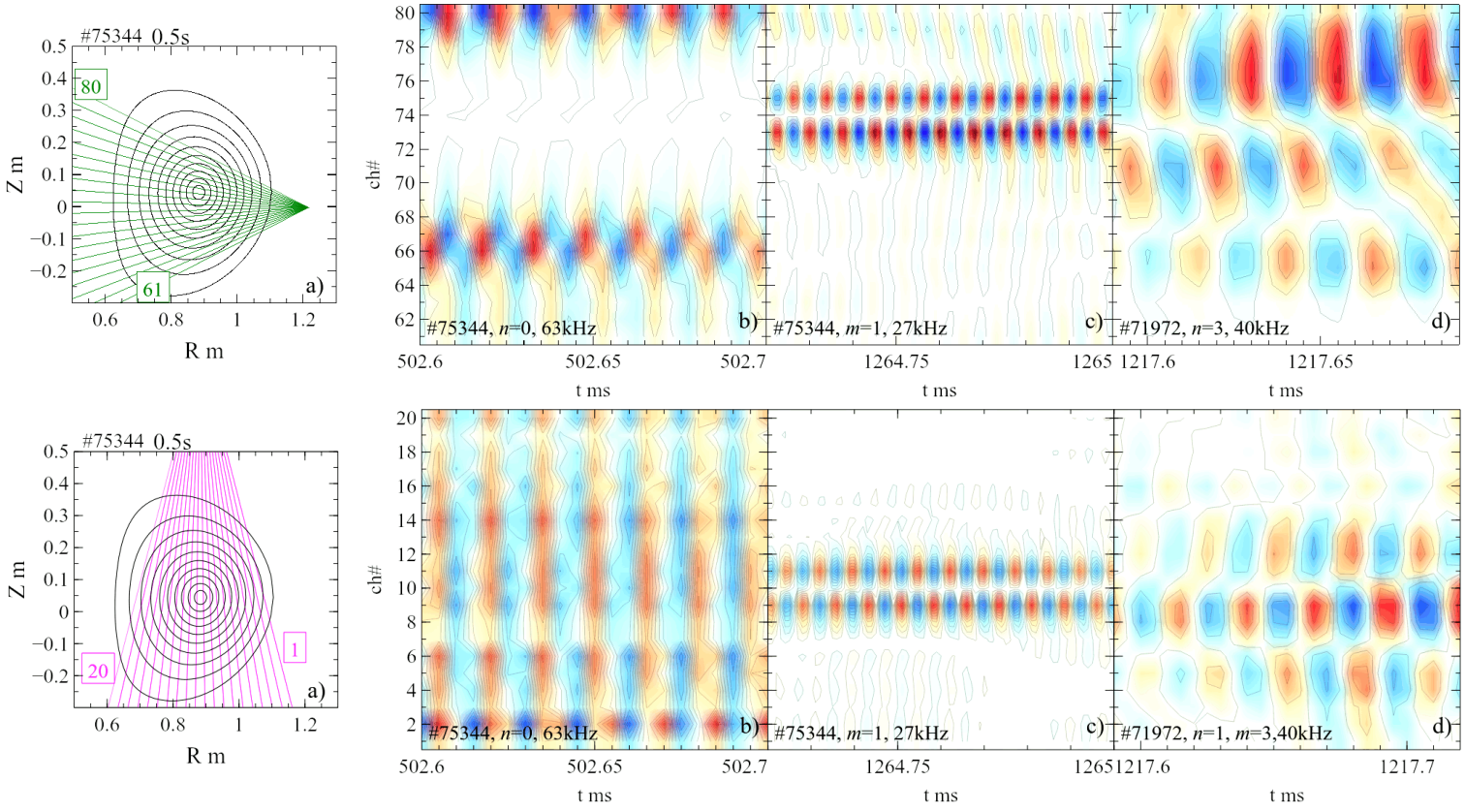




[1]Dreval M B et al 2021 Plasma Phys. Control. Fusion **63** 065006
[2]M B Dreval et al 2023 Plasma Phys. Control. Fusion **65** 035001

# EGAM versus rotating mode: SXR

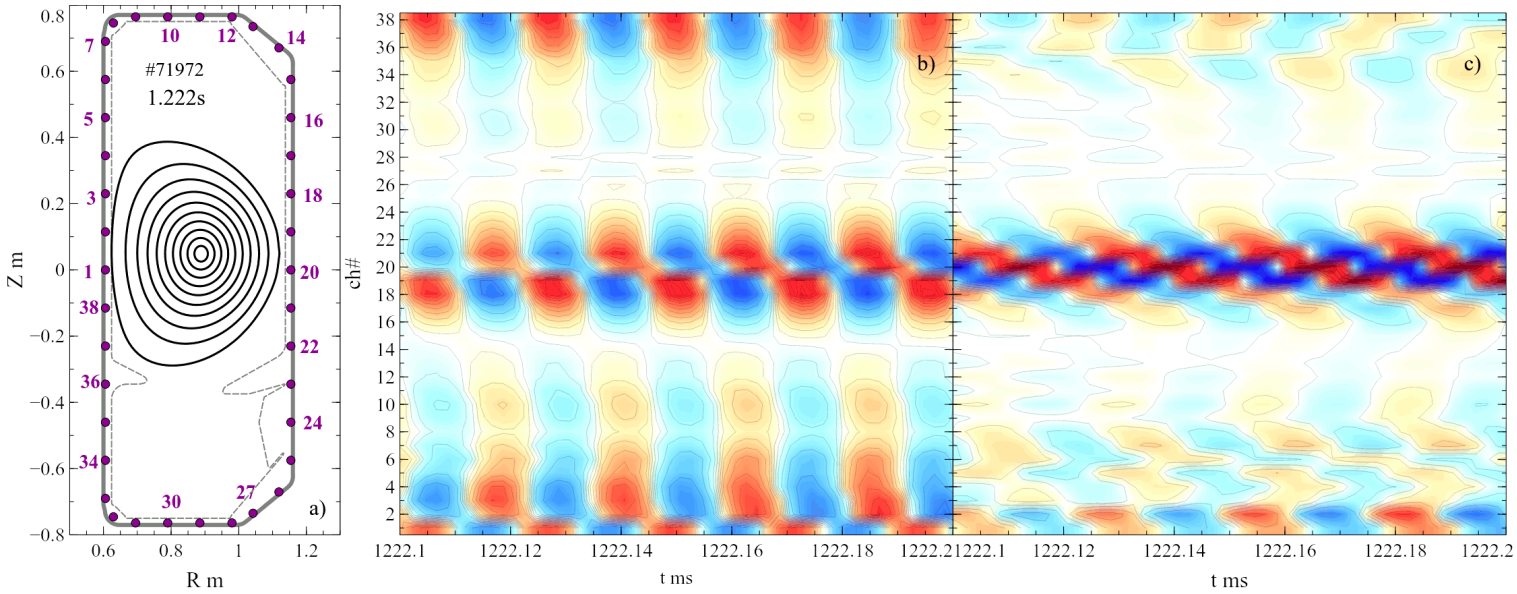




3M.B. Dreval et al., 2025 Nucl. Fusion **65** 016037

[4]M.B. Dreval et al., EUROfusion pinboard 2025 #589

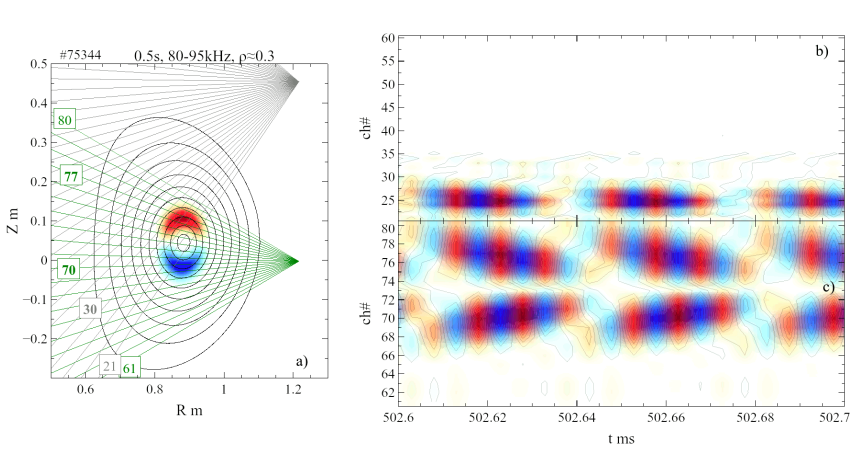
# EGAM versus rotating mode: Magnetics



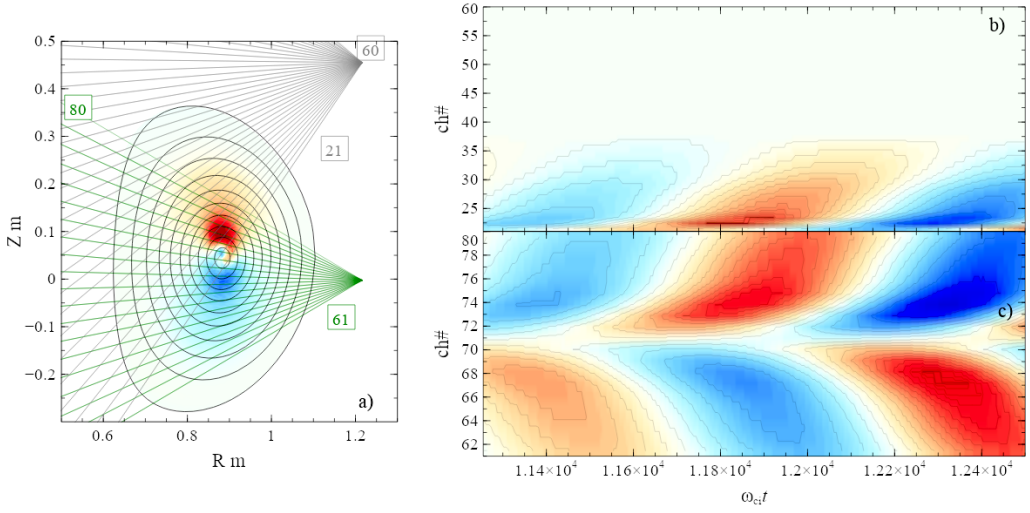

a) Distribution of poloidal coils 1-38 across TCV poloidal cross-section. Evolution of magnetic perturbations data measured by the poloidal array in #71972 at 1.222s. Amplitudes of perturbations in sqrt scale. b) n=0, a 40–50 kHz band-pass filter is applied to the data, c) n=1,m=3 a 30–40 kHz band-pass filter is applied to the data.


3M.B. Dreval et al., 2025 Nucl. Fusion **65** 016037
[4]M.B. Dreval et al., EUROfusion pinboard 2025 #589

# EGAM space structure by ORB5: “SXR” Diagnostics



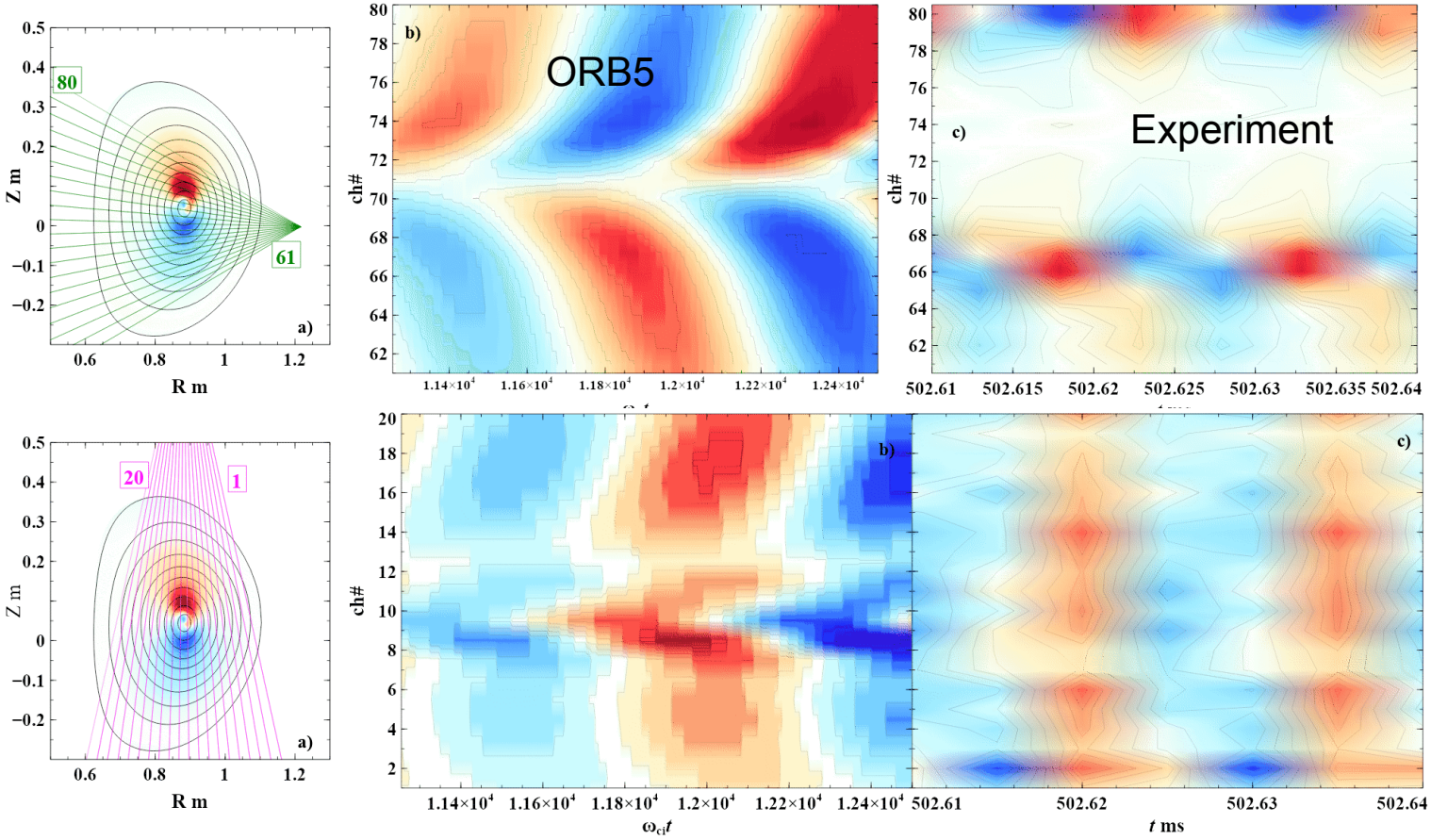

Experiment[1]



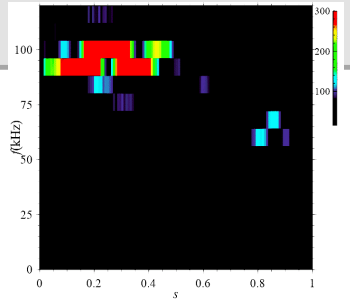

ORB5

Fig.8 (a) Lines-of-sight of the AXUV side camera in green, top-side camera in gray across the magnetic flux surfaces in TCV discharge #75344 at 0.5 s and EGAM ion density perturbations distribution calculated by ORB5; (b),(c) Spatiotemporal evolution of emission data obtained by integration of ORB5 EGAM ion density perturbation along lines of sights of top-side and side AXUV cameras.

# EGAM space structure by ORB5: “SXR” Diagnostics



# Two simulteneous EGAMs



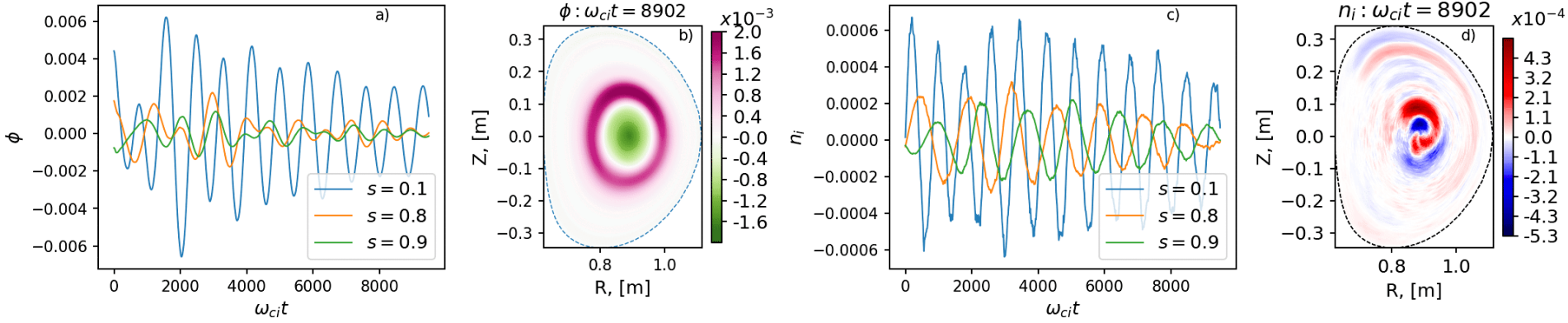




Fig.10 a) evolution of the plasma potential fluctuations at 3 radial positions, b) space distribution of plasma potential fluctuations at $\omega_{ci}t$ =8902, c) evolution of the ion density fluctuations at 3 radial positions marked in the legend, d) space distribution of ion density fluctuations at $\omega_{ci}t$ =8902.

# Summary and conclusions of Ref.4

In the present work, we model the spatial structure of the EGAM modes in the TCV equilibrium using a **realistic fast ion distribution function**, implemented in the gyrokinetic particle-in-cell code ORB5. For a peaked radial profile of fast ions, the EGAM spatial structure coincides with that of the conventional GAM, characterized by an **n/m=0/0 plasma potential** perturbation and an **m=1 standing perturbation**, where the amplitude of the **density** oscillations is proportional to the sine of the poloidal angle. In contrast, for a hollow radial profile of fast ions, our simulations reproduce a **complex EGAM spatial structure**—similar to that observed experimentally in TCV—with two coexisting frequencies.

[3]M.B. Dreval et al., 2025 Nucl. Fusion **65** 016037
[4]M.B. Dreval et al., EUROfusion pinboard 2025 #589