Electron temperature fluctuations of the quasi-coherent mode across the plasma radius

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ASDEX Upgrade

Overview of the talk

- EDA H-mode at AUG
- Observations in the core (ECE) and the edge of C(ECE)
- Modeling
- Conclusions

Key features of EDA H-mode

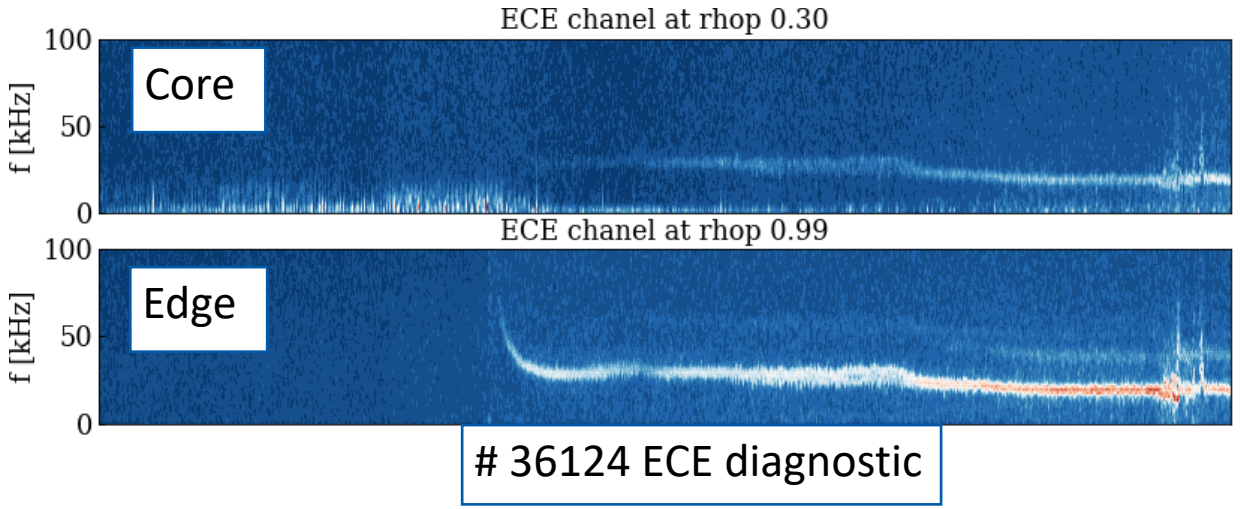
- EDA - Enhanced Dα regime
- Has been studied on C-Mod [1] and recently at ASDEX Upgrade [2]
- Stationary, no ELM regime, with high core density
- Good energy confinement
- No impurity accumulation
- Dominant ECRH heating at ASDEX Upgrade

[1] M Greenwald et al 2000 Plasma Phys. Control. Fusion **42** A263

[2] L. Gil, et al., Nuclear Fusion 60, 054003 (2020)

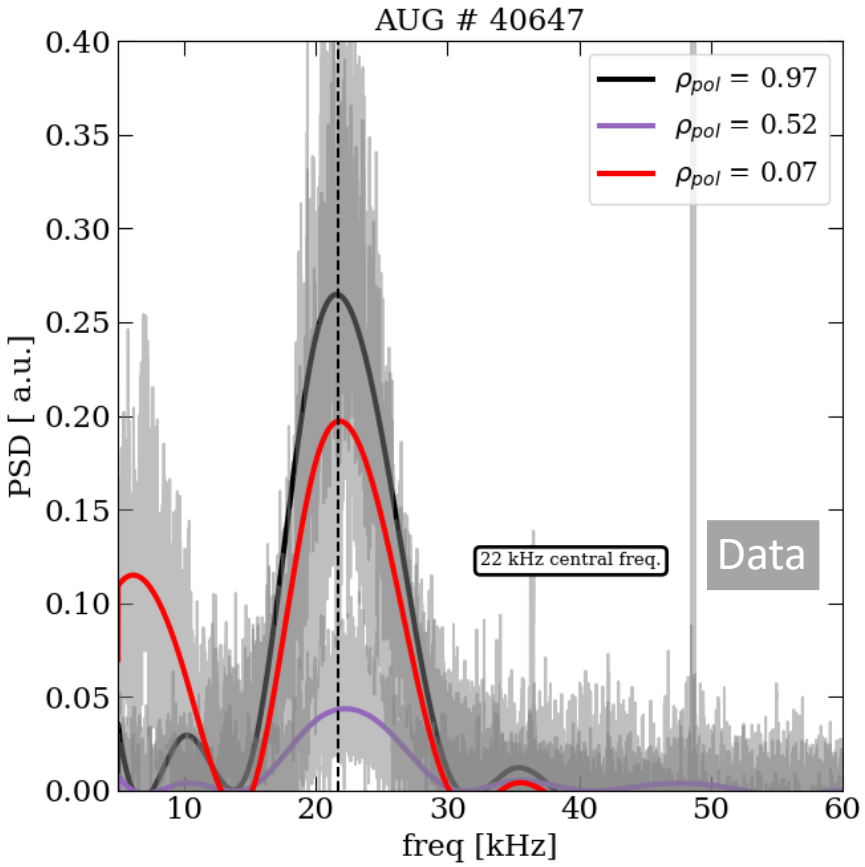
EDA H-mode & the quasi-coherent mode (QCM)

- Quasi-coherent mode (QCM): high amplitude edge density and temperature fluctuations
- Some core ECE channels show QCM but QCM absent in SXR
- Is core mode diagnostic effect or real mode - an open question



ECE measures the same features in the core and at the edge

- ECE data at different radial locations measure QCM frequency across plasma radius
- Usually, the peak frequency is between 15 - 60 kHz
  - 22 kHz in this discharge
- QCM broadening comes from frequency modulation of coherent mode



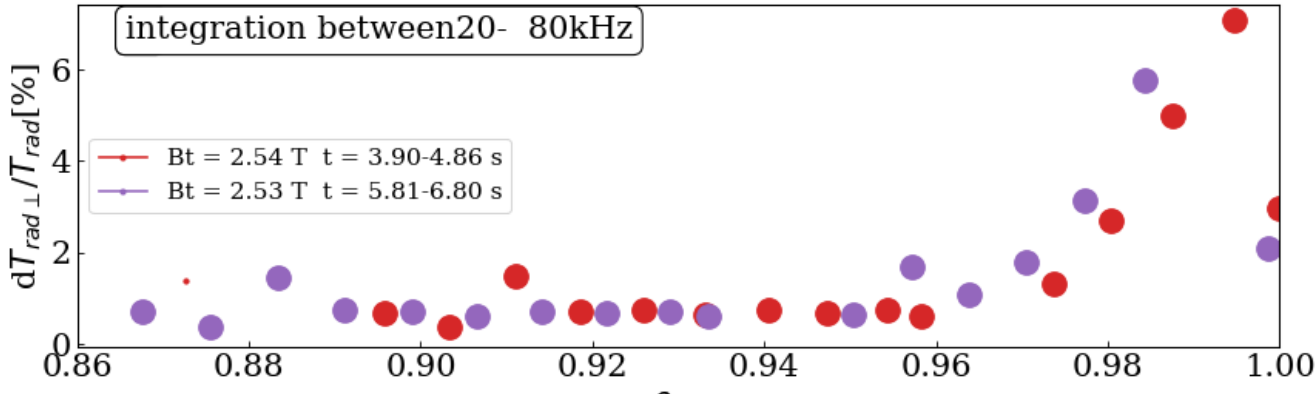
QCM affects the whole pedestal

- Changing the magnetic field strength within one discharge and tracking the location of the strongest amplitude

- Coherency spectra from CECE show strong turbulence/mode in edge channels

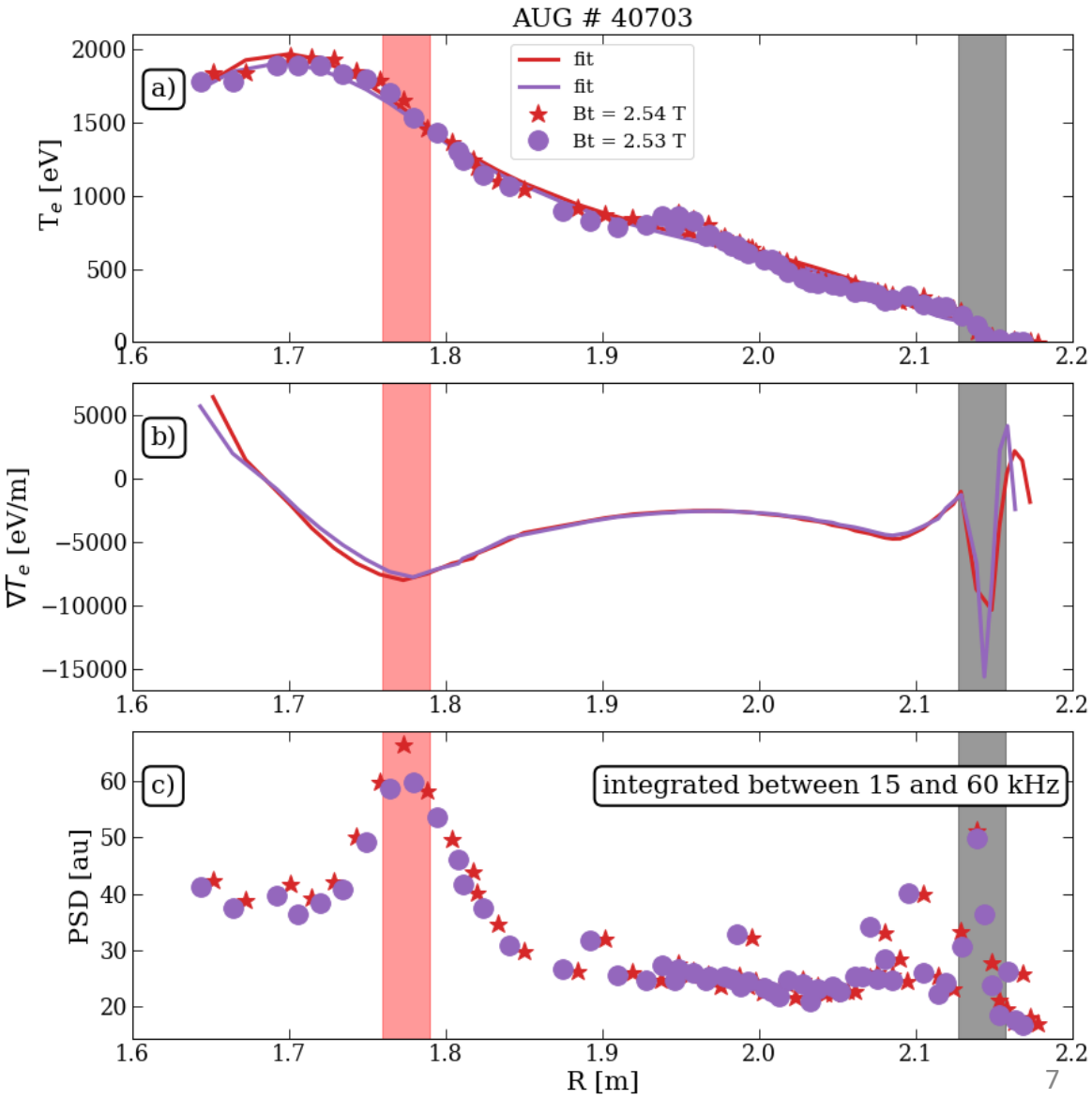
- δT/T peak close to the separatrix

AUG # 40703



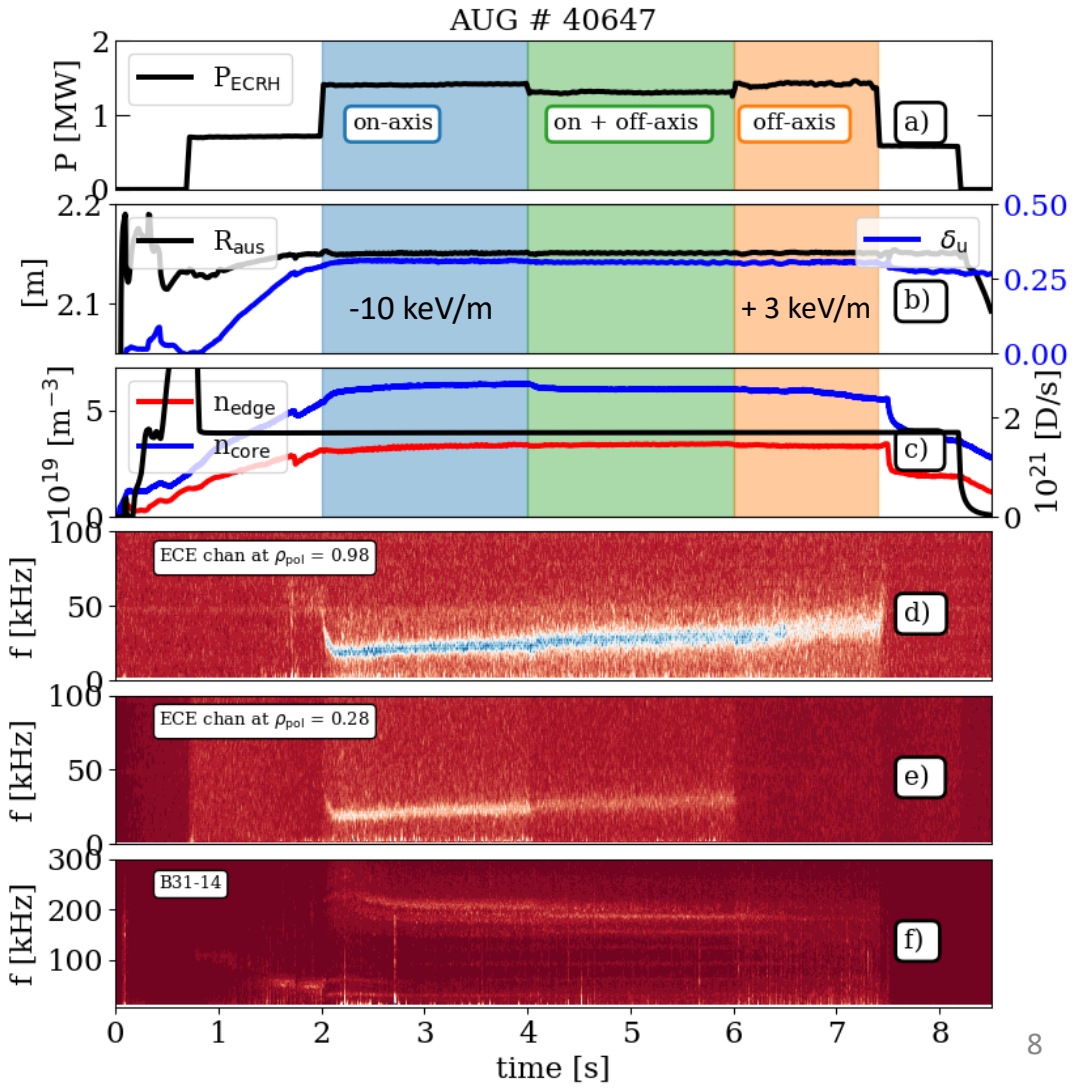
ECE amplitude matches the strongest gradients

- Bt change from profile ECE perspective
- Strong gradients of T_e in the core
- ECE maximum amplitude matches the maximum T_e gradient



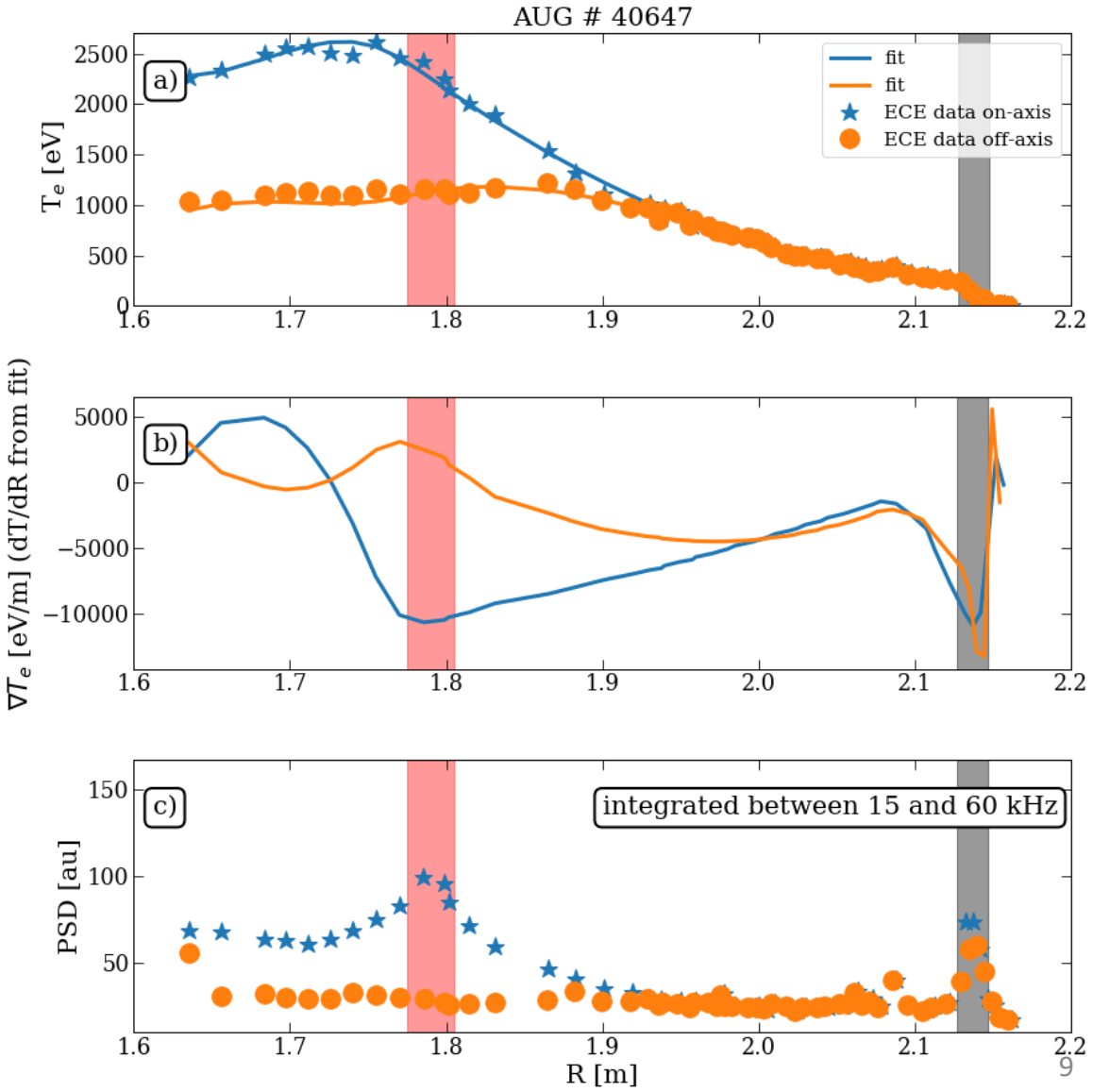
Experiment with changing ∇T_e

- 3 phases with varying ECRH deposition
- Constant density
- QCM at the edge measured in all three phases
- QCM in the ECE core channels disappears with flat T_e gradient



Core ECE mode disappears with flat ∇T_e

- Comparison between on-axis (strong ∇T_e) and off-axis (flat ∇T_e) heating
- Mode amplitude from the core ECE disappears in the off-axis case
- Edge measurements are not affected
- Other diagnostics do not measure core mode with steep ∇T_e



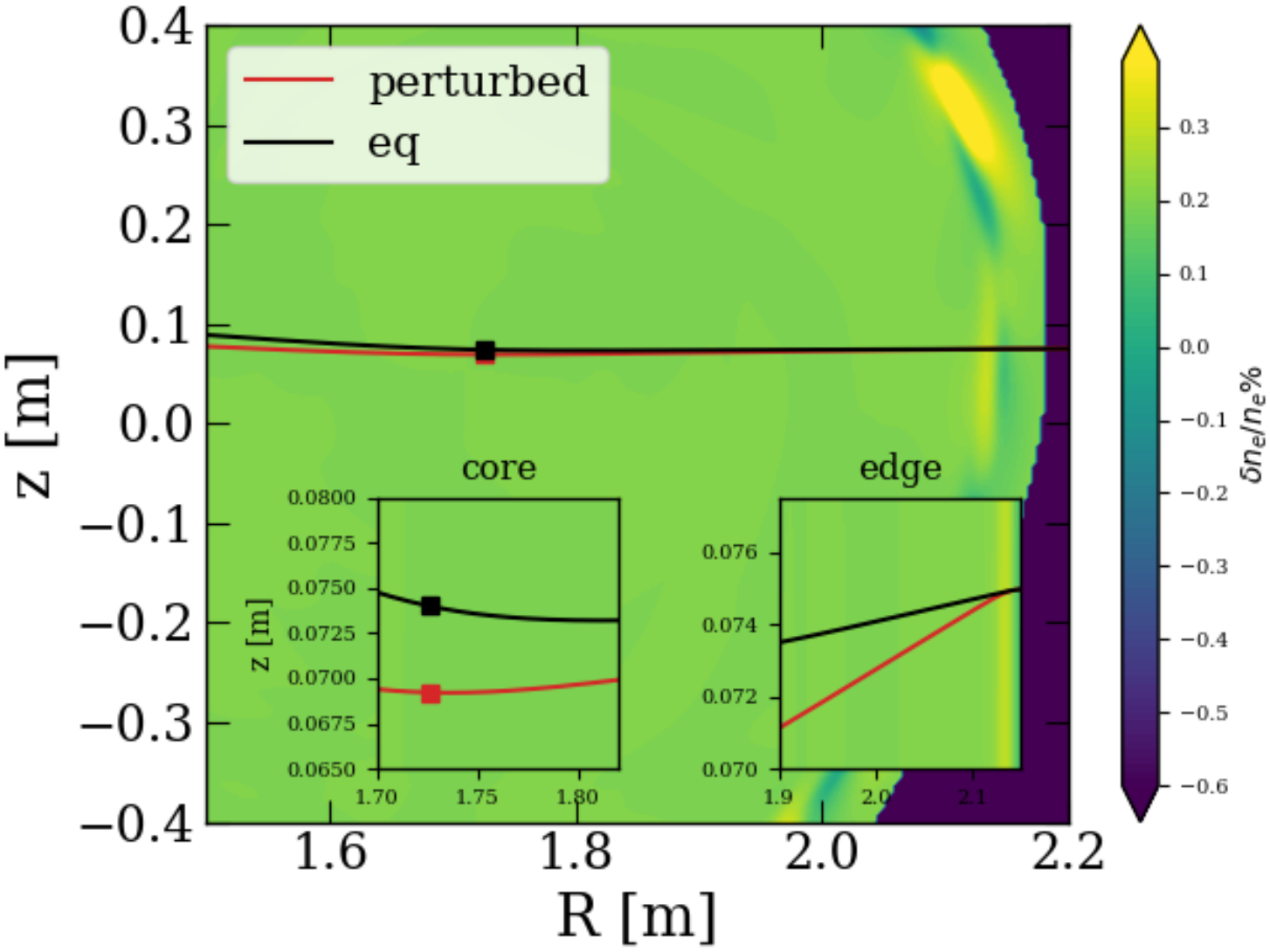
Modeling of EC radiation for steep and flat ∇T_e

- We use ECRad [3] to compute time-resolved T_{rad}
  - Refraction included; realistic geometry of ECE
- 2D n_e and T_e data from a recent JOREK high-density simulation [4] with strong edge modes were used as input
  => up to 40% density perturbation
  => n = 10
  => perturbed vs equilibrium
- Density and temperature fluctuations are in phase in JOREK
- JOREK data are modified to match the background Te and ne profile

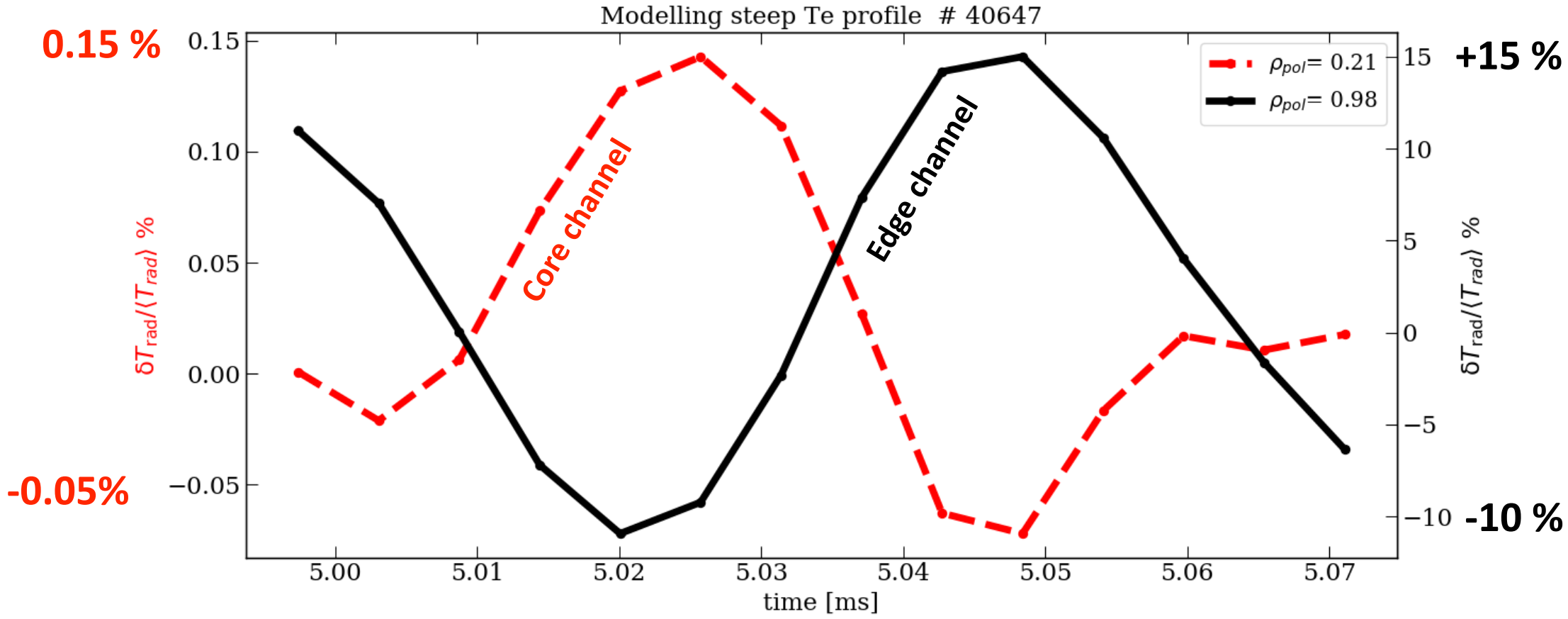
[3] S. Denk, et al Com- puter Physics Communications 253, 107175 (2020)

[4] A. Cathey et al. ,Plasma Physics and Controlled Fusion 64, 054011 (2022)

The effect of refraction in modeling

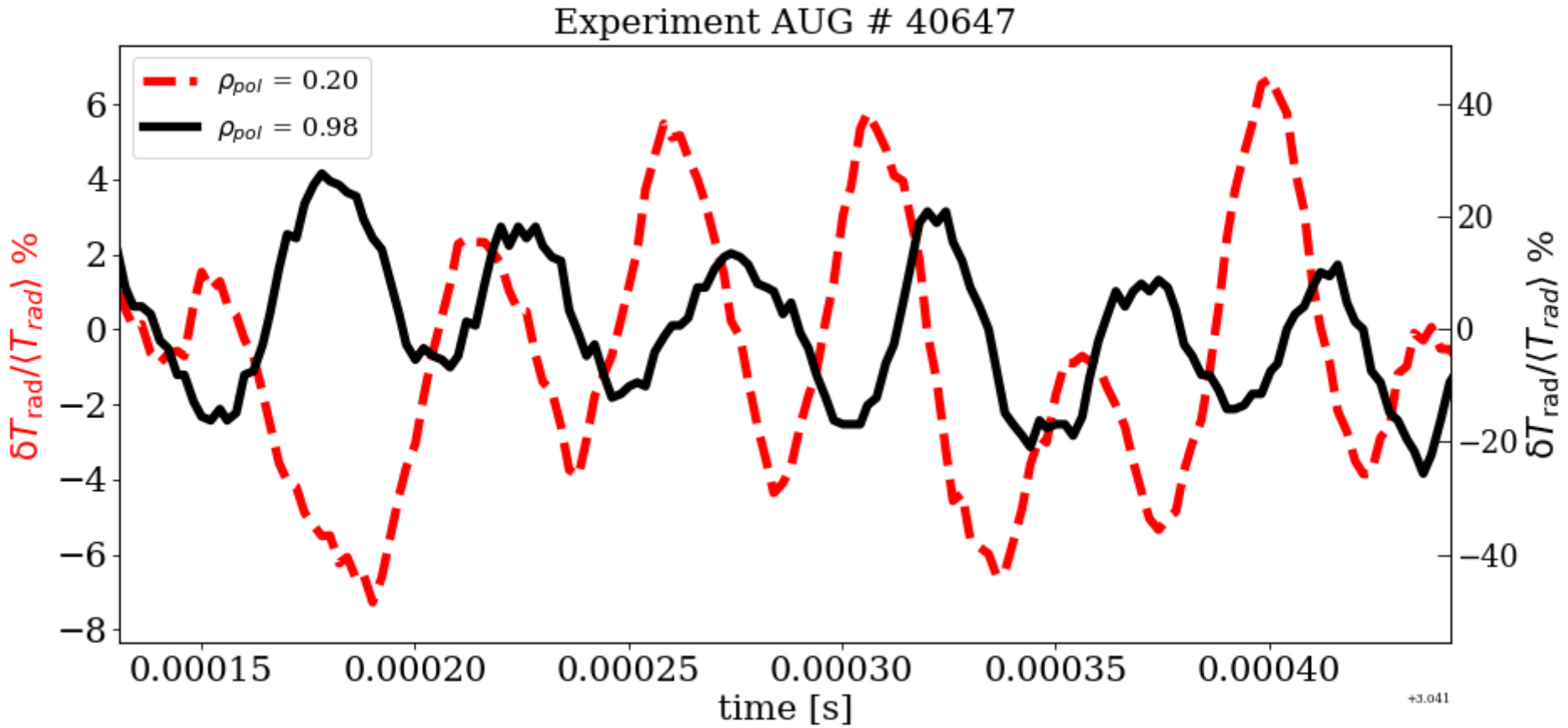


Steep gradients case - modeling



- Core-edge in anti-phase

Steep gradients case - experiment



- Experiment shows similar phase relation as in the modeling but large amplitude

Flat gradients case - modeling

Strong ∇Te

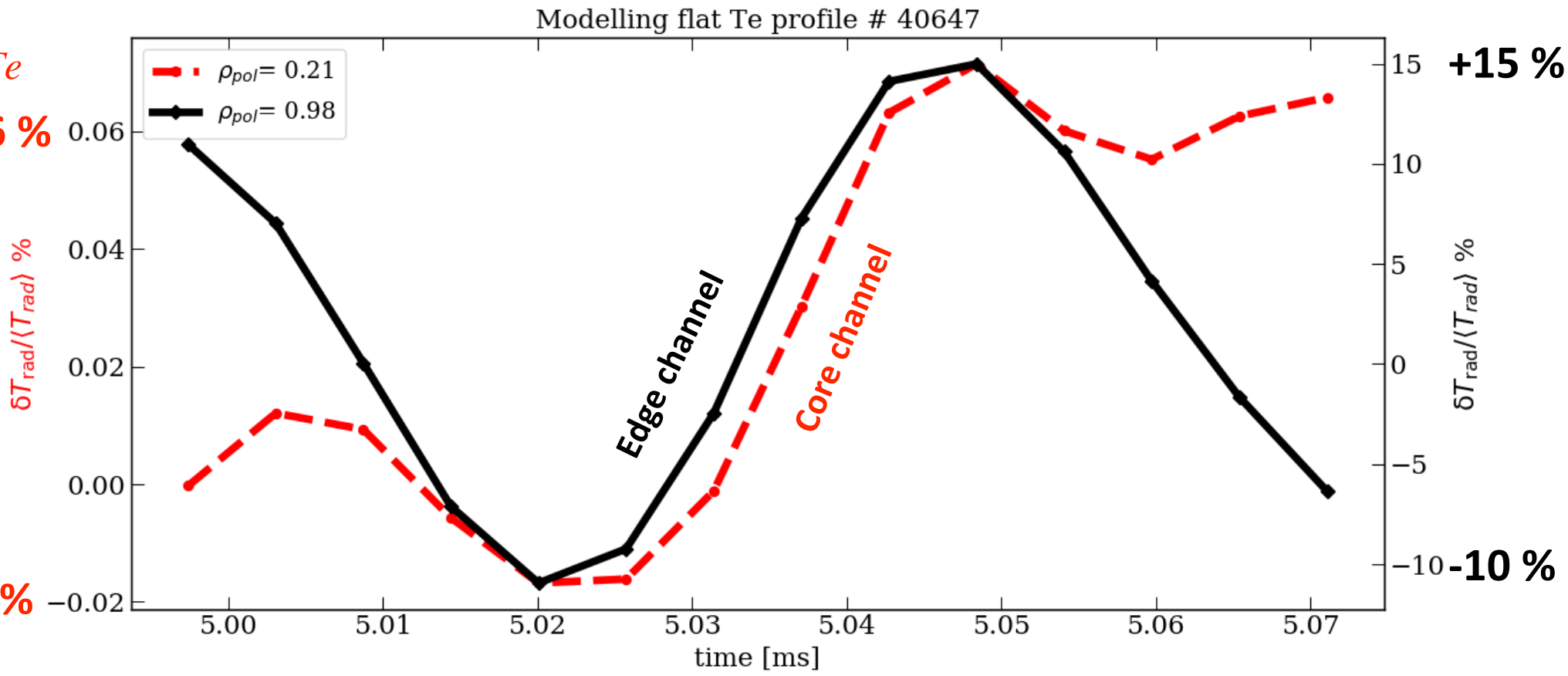
0.15 %

-0.05%

Flat ∇Te

0.06 %

-0.02%



- Core and edge in phase => core amplitude smaller compared to strong ∇Te

Conclusions

- QCM at the edge of the plasma causes temperature and density fluctuations
- Modeling with refraction included can explain the behavior of core ECE measurements => phase matches

- In the present modeling the amplitudes do not reach the measurement BUT:
  => The quasi-coherent mode is potentially stronger and broader

  => The ECE LOS for the modeled case was vertically closer to the axis, (perpendicular incidence)

- The core ECE measurements give us information on the edge density fluctuation levels and n_e T_e phase relation