Global Fluid Turbulence Simulations of Pedestal Relaxation Events in the I-mode regime with GRILLIX

C Pitzal *1, A Stegmeir1, T Happel1, K Zhang1, K Eder1, W Zholobenko1, P Ulbl1, M Herschel1 and F Jenko1
1Max Planck Institute for Plasma Physics, Garching, Germany
*Corresponding author: christoph.pitzal@ipp.mpg.de

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INTRODUCTION

- The Improved-confinement mode (**I-mode**) is a **reactor-relevant scenario** [1,2] featuring
  - Absence of type-I ELMs
  - Improved energy confinement time
  - Low impurity content
- Pedestal Relaxation Events (**PREs**) occur when close to the I-H transition
- PREs oberserved in ASDEX Upgrade and Alcator C-Mod [3]
- PREs eject energy periodically, similar to ELMs
- Underlying mechanism different to ELMs
- Turbulence simulations with **GRILLIX** [4] (including recently implemented Landau-fluid closure [5]) performed to investigate PREs

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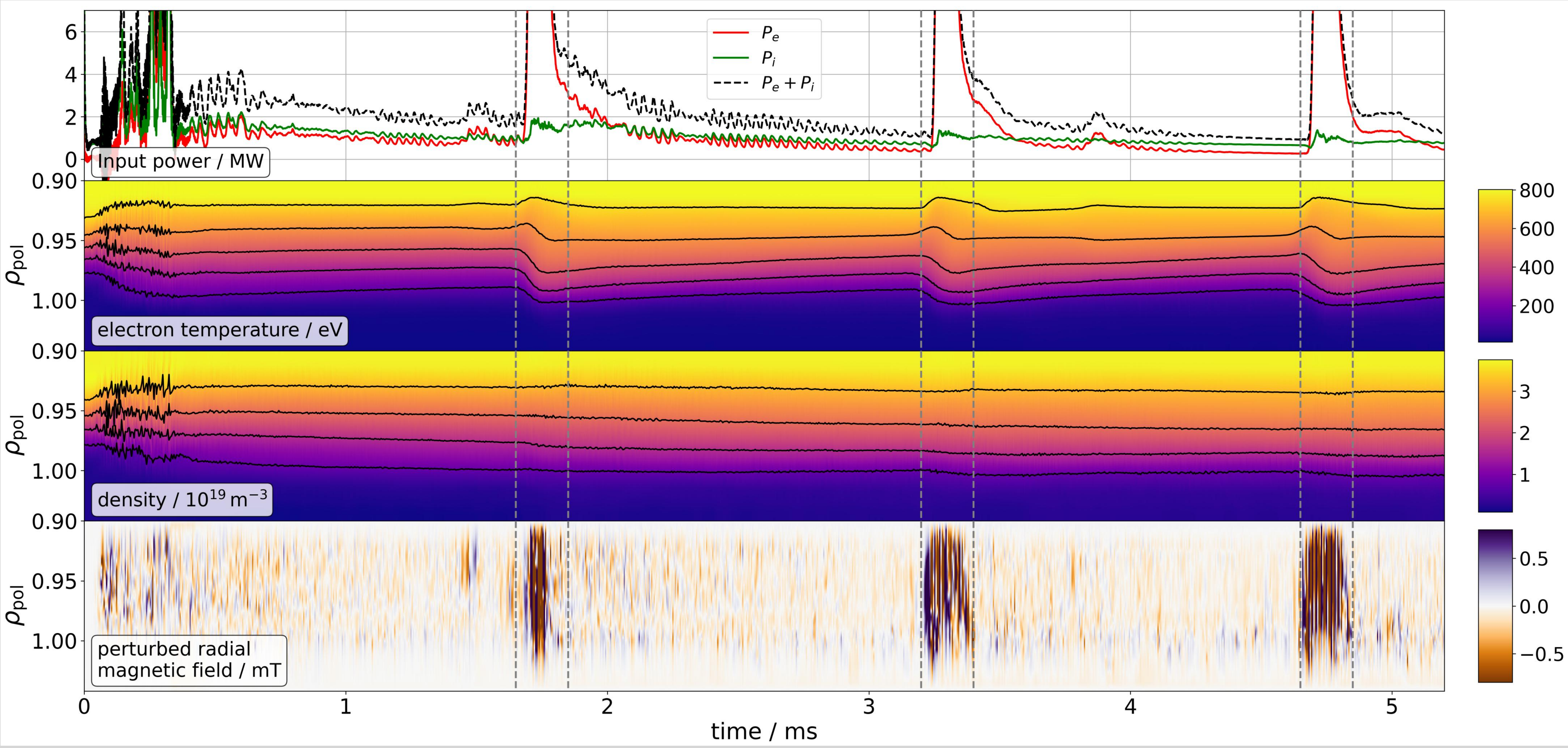
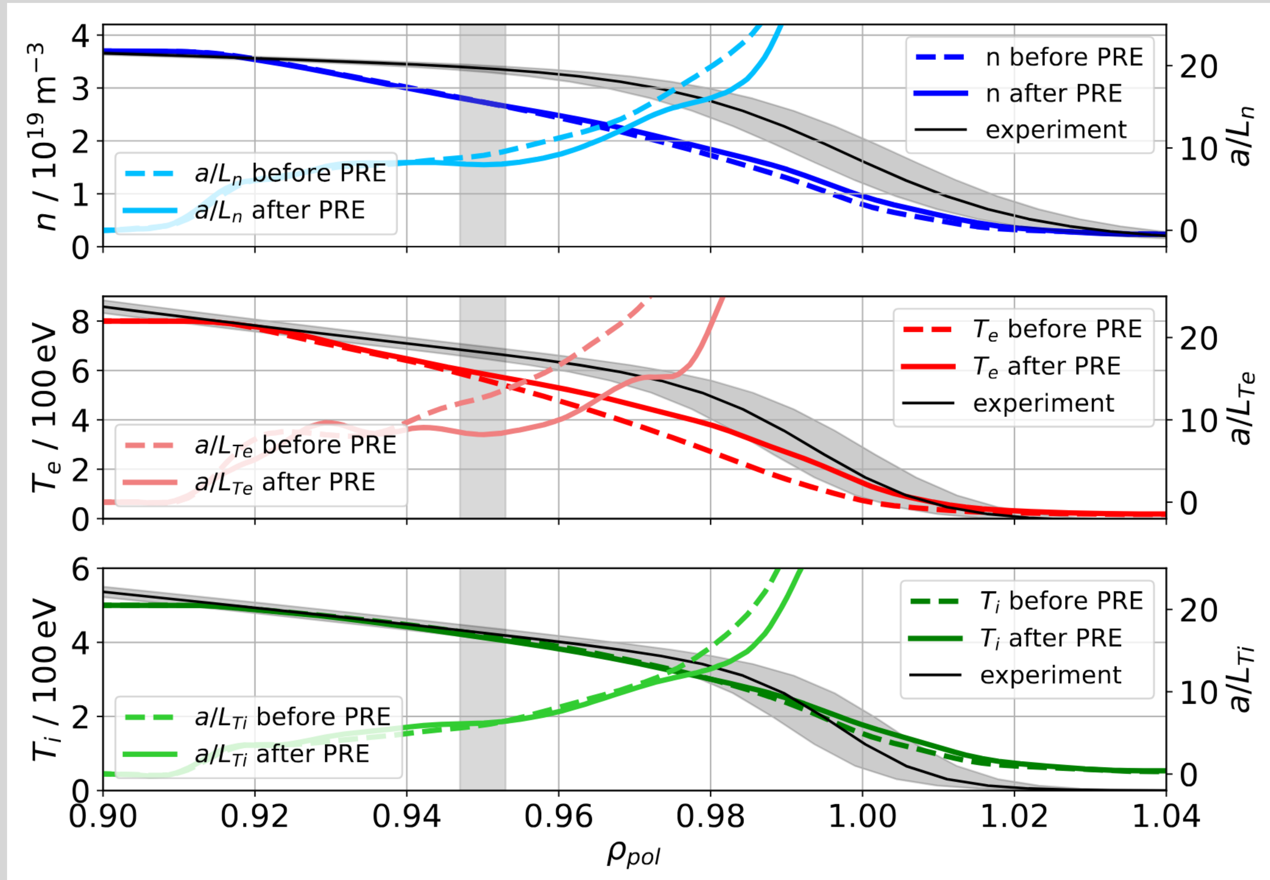
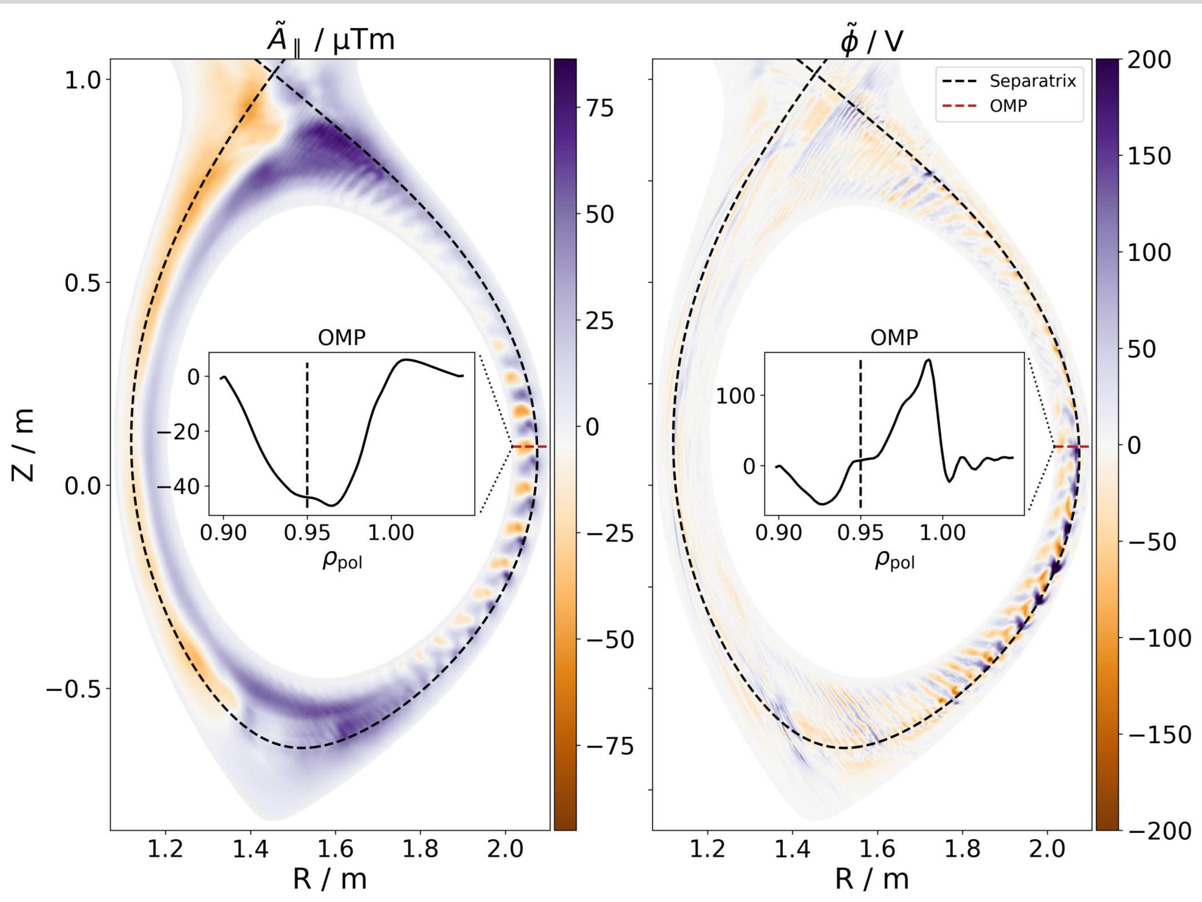
TURBULENCE SIMULATION



- ASDEX Upgrade discharge #37980
- Within 5 ms of simulated time three PREs occur
- Increase of stored energy after PRE due to adaptive core boundary conditions
- PREs in simulation reproduce experimental observations [3]:
  - Electron temperature profile changes, density nearly unaffected
  - Increased magnetic activity during PRE (perturbed magnetic field)
  - Duration of ca. 0.3 ms for simulation matches

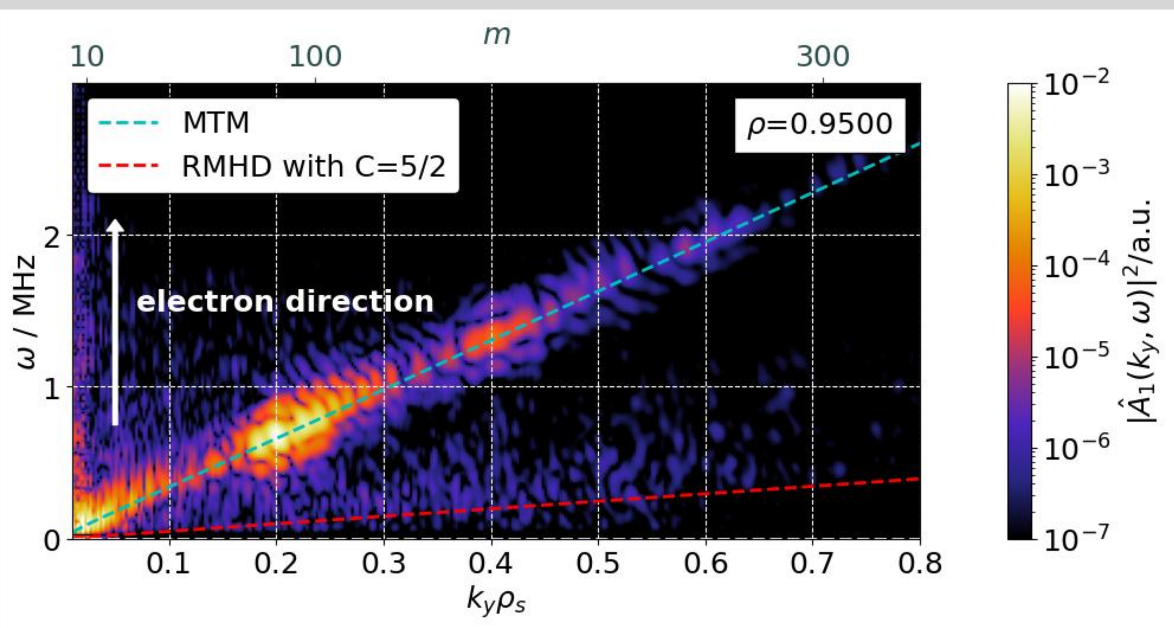


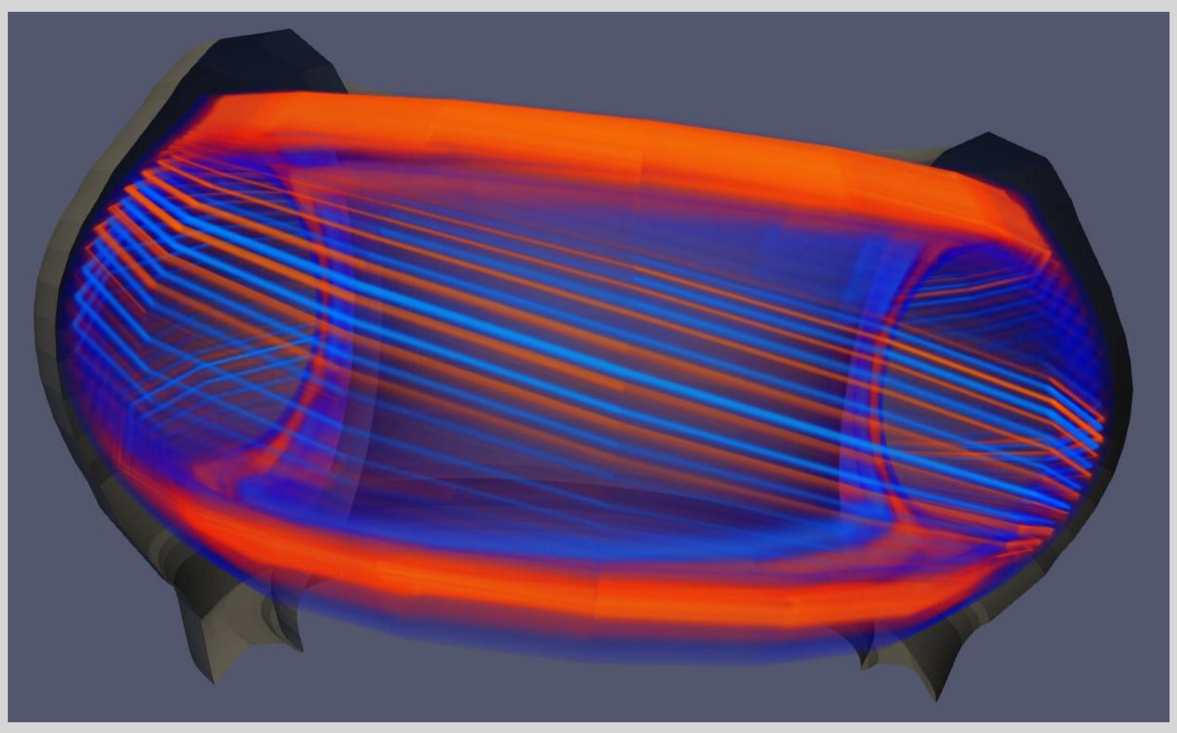
PRES CAUSED BY MTMS



Fingerprints of MTMs:
- Mainly electron radial heat flux is increased
- This heat flux is electromagnetic (magnetic flutter)
- Mode shows tearing parity
- Dispersion relation computed from simulation data matches linear kinetic estimate [6]:

$$(\nu - 0.51 i\omega)\left(\omega - \omega_p^\star\right) - 0.8\omega_T^\star \nu = 0$$





GLOBAL MECHANISM FOR PRE CYCLES

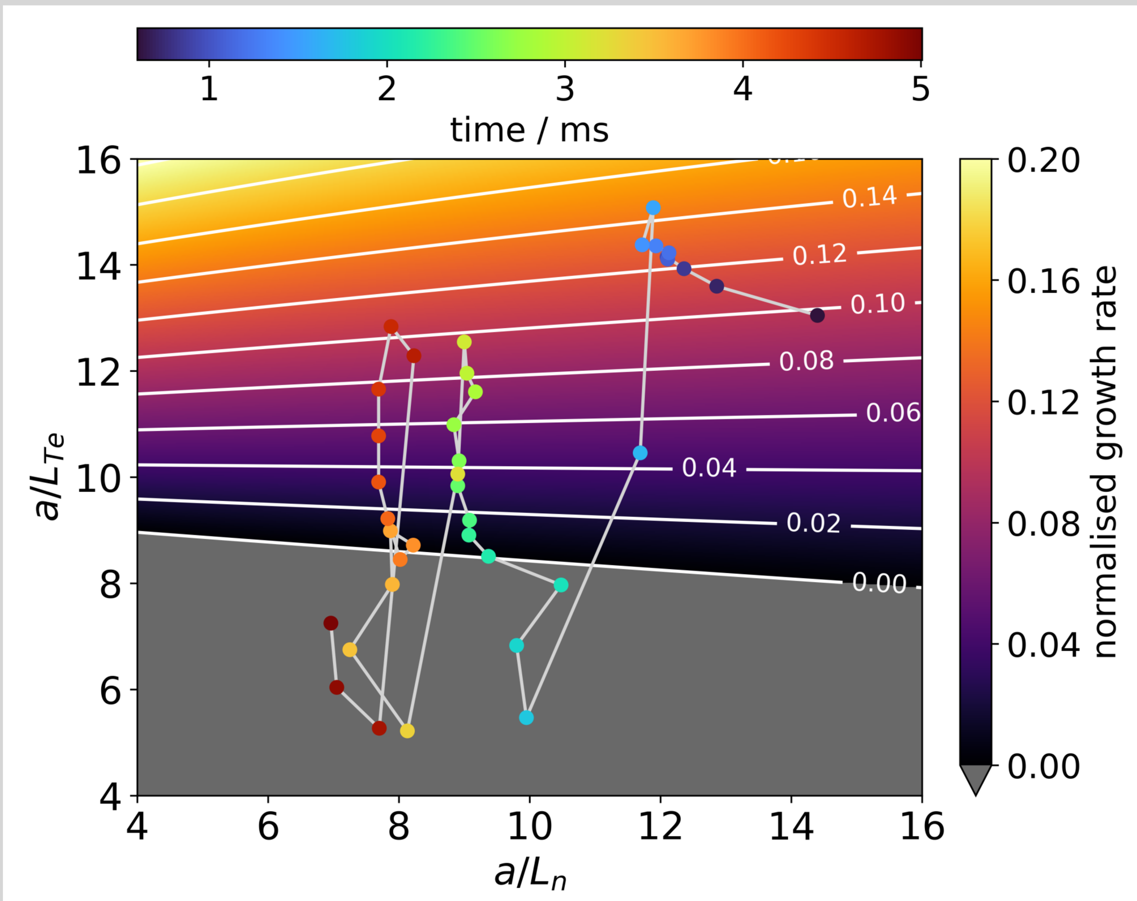
- Inverse gradient lengths a/L_{Te} and a/L_n at $\rho_{pol} = 0.95$ measured for simulation
- Compared to linear growth rate calculated for our fluid model:

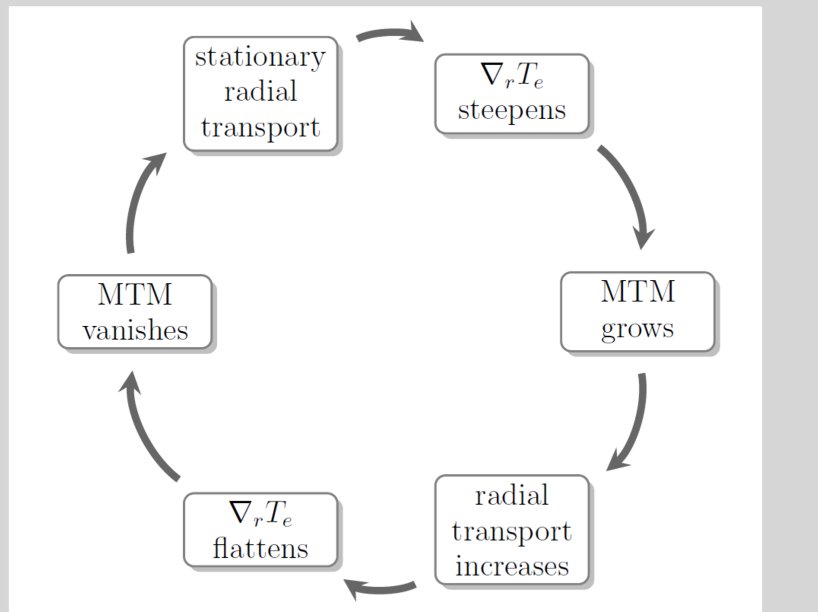
$$\gamma = 1.71 \frac{3n}{A k_z} \omega_T^\star \left(\omega_p^\star + 4.13\omega_T^\star\right) - \frac{\eta}{4\pi} k_y^2 + \ldots$$

$$\omega_p^\star = k_y \rho_s c_s \left(1/L_n + 1/L_{Te}\right)$$

$$\omega_T^\star = k_y \rho_s c_s \left(1/L_{Te}\right) \qquad A = n v_{e,th} \sqrt{8/\pi}$$

- PREs visible via strong flattening of a/L_{Te} over short time
- Before PRE system always in MTM unstable region ($\gamma > 0$), after the PRE system always in stable region ($\gamma < 0$)
- Mechanism for a global PRE cycle according to our simulations is proposed





CONCLUSION

- Simulation with GRILLIX shows **three** intermittent bursts, that are linked to **PREs**
- PREs in simulation match nicely experimental observations
- Detailed analysis reveals **PREs** in **simulation are caused by MTMs**
- Path of system in gradient length space is in excellent agreement with linear growth rate estimate for the fluid model
- With these insights a **global mechanism underlying PREs** is proposed

REFERENCES

[1] D Whyte et. al., Nuclear Fusion, vol. 50, no. 10, p. 105005, (2010)
[2] T Happel et al., Plasma Phys. Control. Fusion, vol. 59, no. 1, p. 014004, (2016)
[3] D Silvagni et al., Nuclear Fusion, vol. 60, no. 12, p. 126028, (2020)
[4] A Stegmeir et al., Physics of Plasmas, vol. 26, no. 5, p. 052517, (2019)
[5] C. Pitzal et al., Physics of Plasmas, vol. 30, no. 12, p. 122502, (2023)
[6] D Hatch et al., Nuclear Fusion, vol. 61, no. 3, p. 036015, (2021)

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