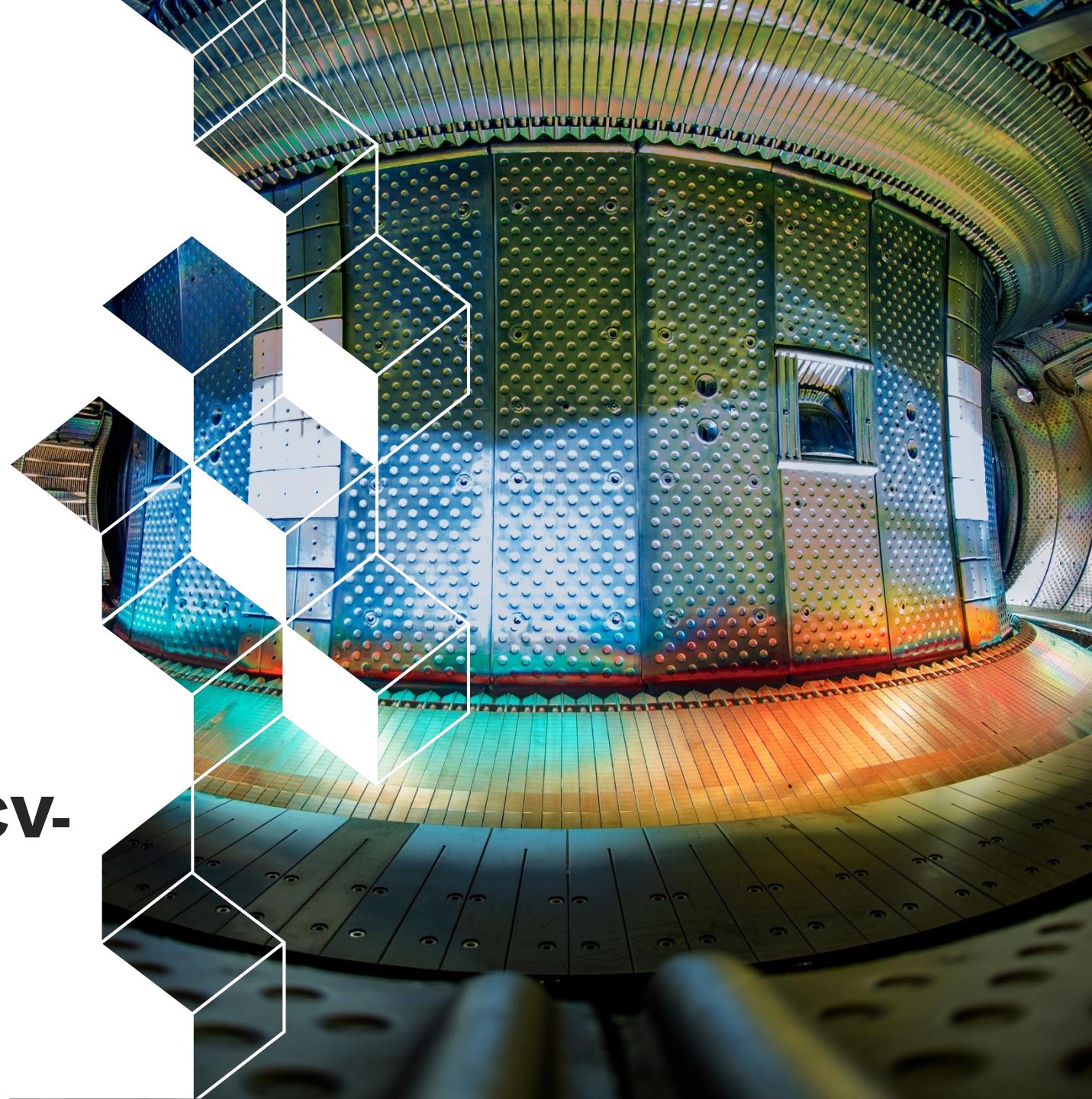
cea irfm

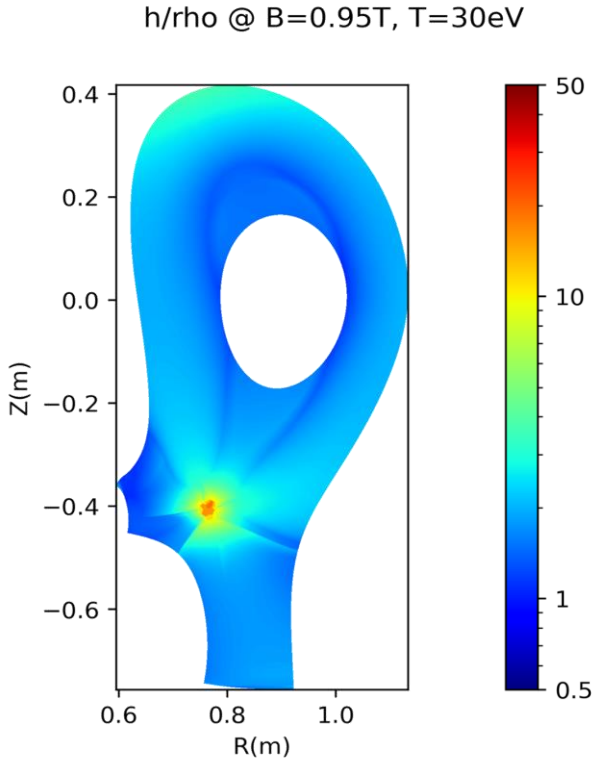
Power scan based on TCV-X21 case

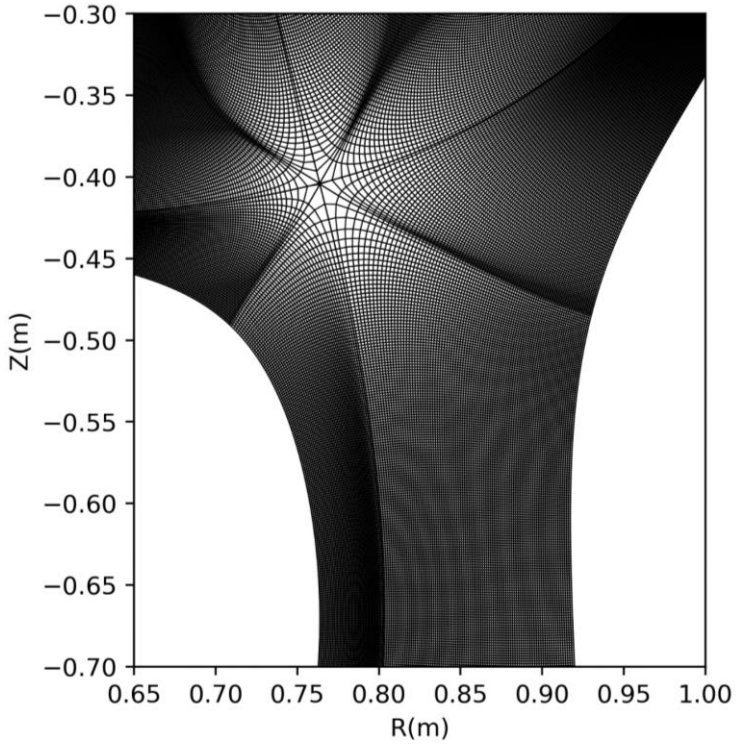


Simulations setup

- Equilibrium based on TCV#51333
  Full-field
- Wall geometry modified to fit a flux surface (to avoid potential artefacts due to a non-aligned wall – consequence: more closed divertor in the simulation)
- Simulation grids:

	Coarse	Fine
N_ψ	88	176
N_θ	710	1420
N_φ	32	64
$N\ points$	2 millions	16 millions

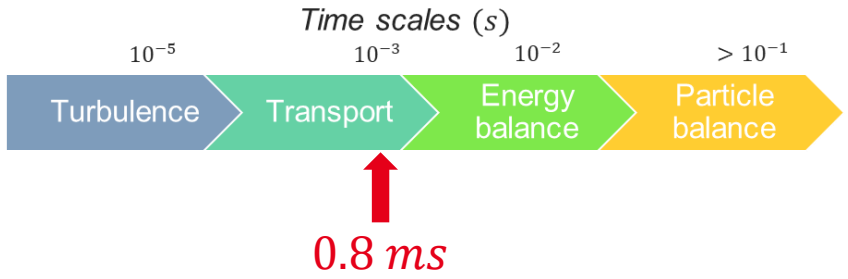


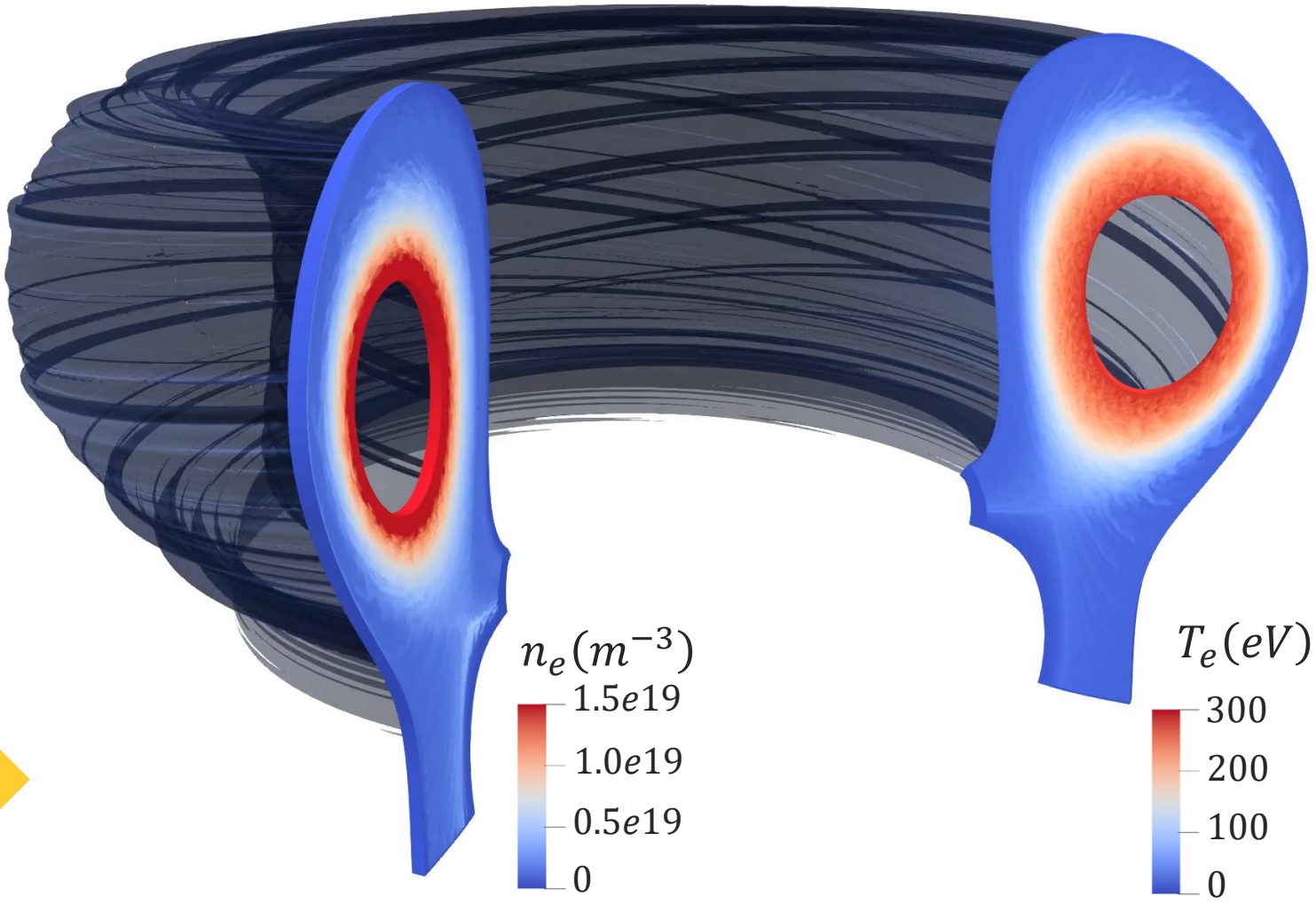


Simulation runtime and status: fine grid

- Simulation ran 12 days
  on 3072 CPUs $\sim 1\ MCPUh$

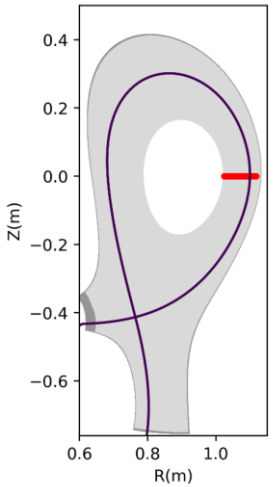
- Simulation time:
  - Time step $\sim 2ns$ (limited by CFL condition on poloidal advection at the innermost flux surface simulated)
  - Time to solve $\sim 2{,}5s$ per time step
  - Cost: $1.25MCPUh/ms$
  - 400 000 time steps simulated
    Total plasma time simulated $\approx 0.8\ ms$

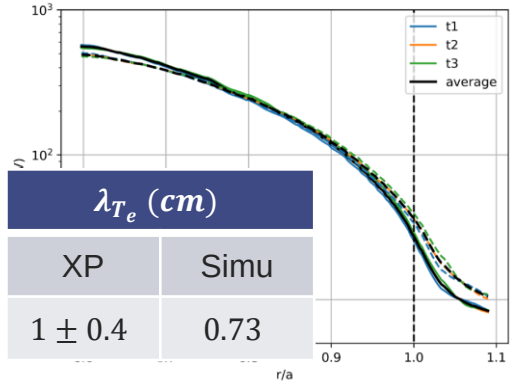




Focus on turbulence: midplane

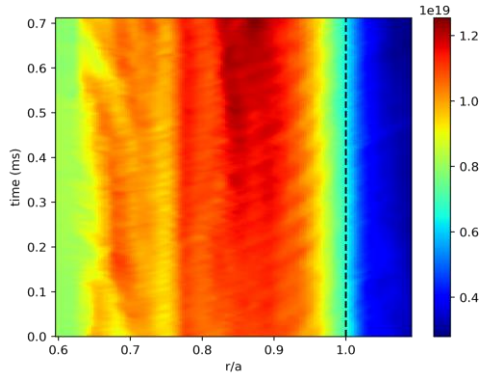
- Simulation far from quasi-steady state
  - Power balance not even reached ($P_{in} = 120kW$; $P_{out} \sim 30kW$)
  - Turbulence rather established though

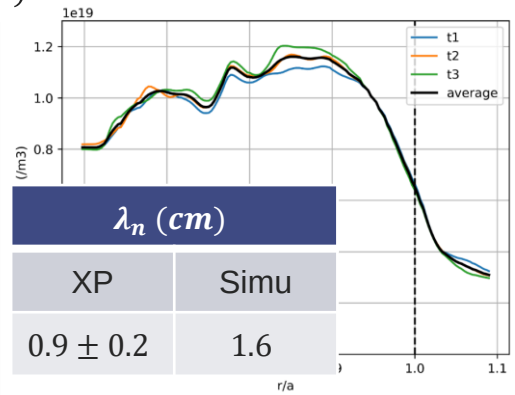




λ_{T_e} (cm)	
XP	Simu
1 ± 0.4	0.73

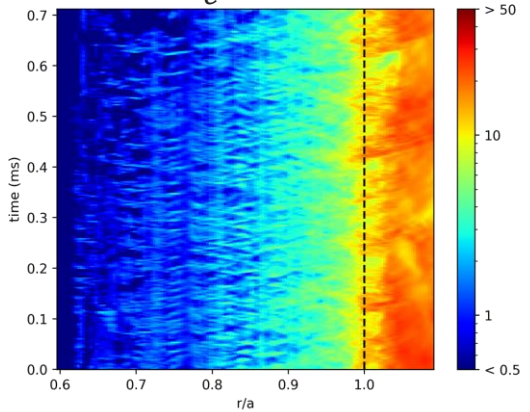
n_e (m^{-3})



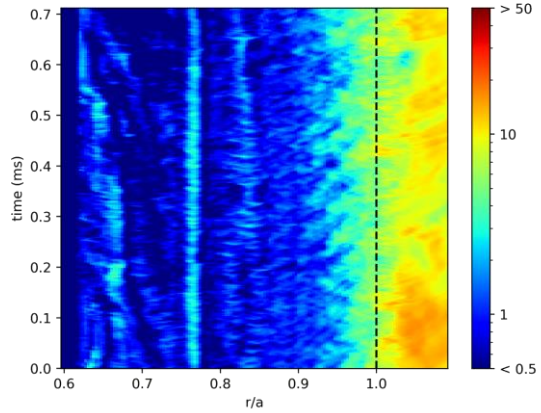


λ_n (cm)	
XP	Simu
0.9 ± 0.2	1.6

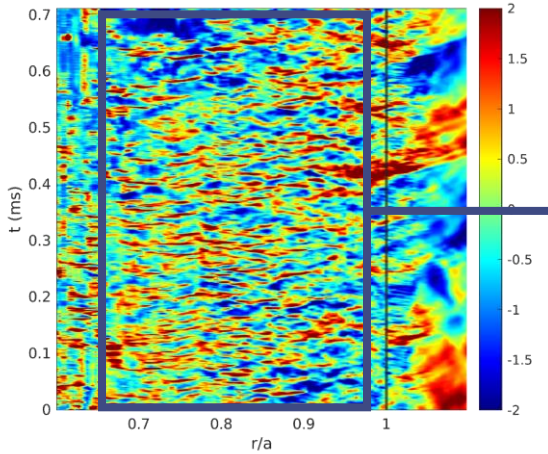
$\sigma_{T_e}/\langle T_e \rangle$



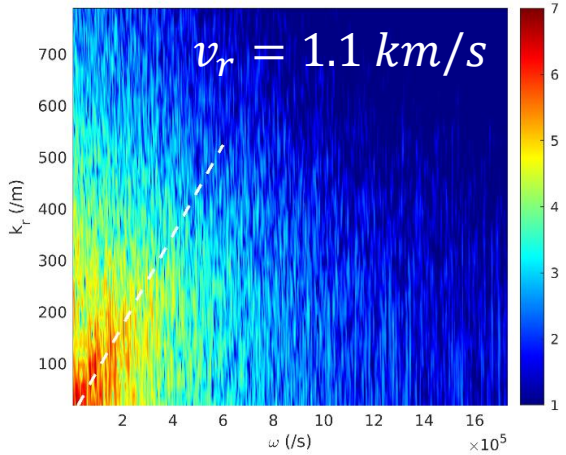
$\sigma_n/\langle n \rangle$



Normalizing

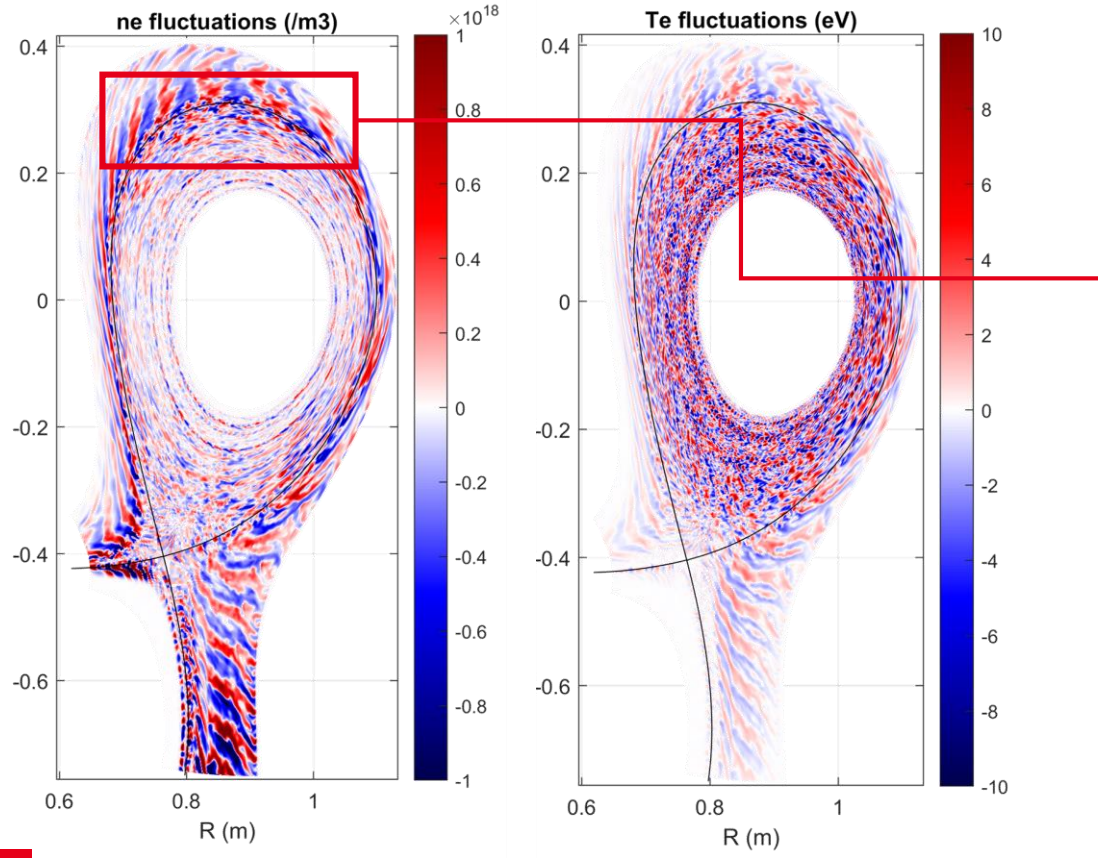


FFT



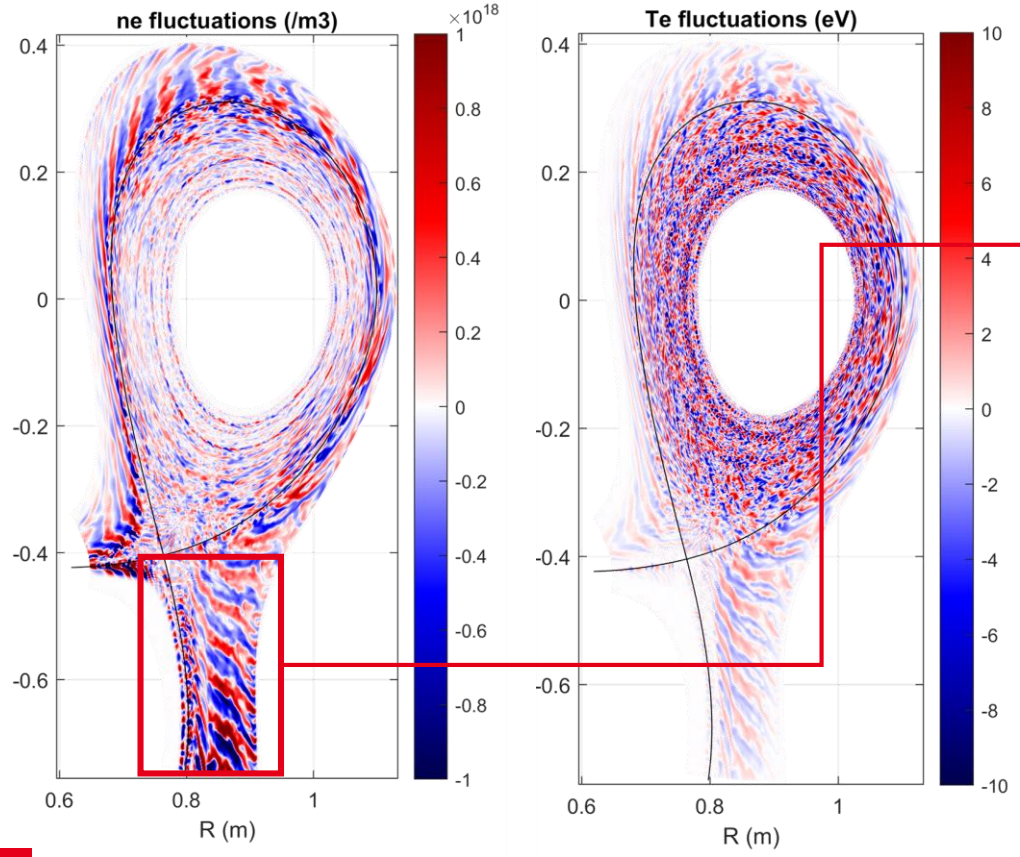
Focus on turbulence: structures

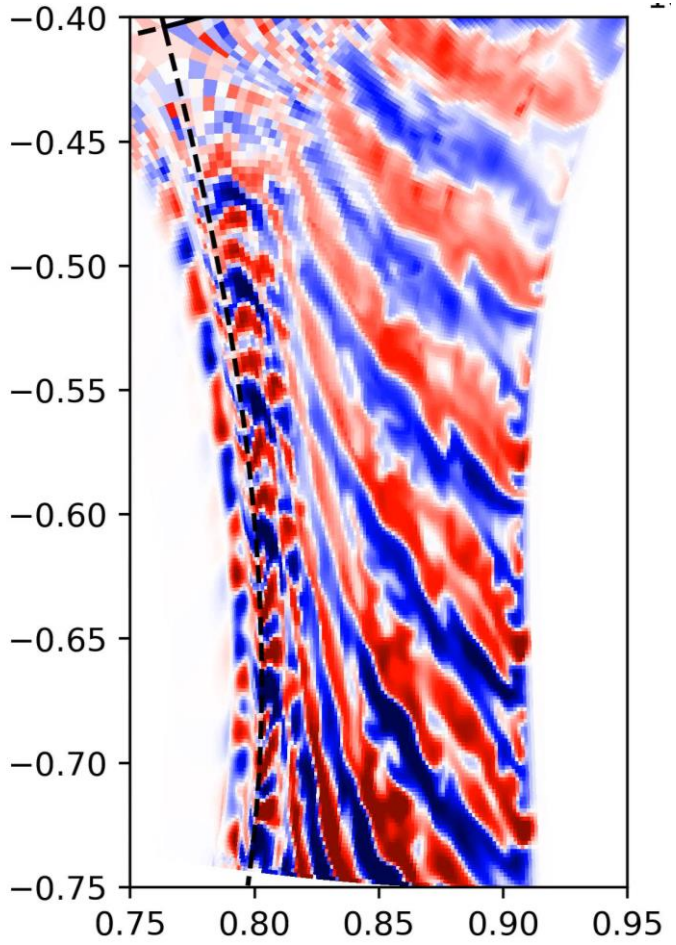
- Structures quite sheared
- Structures cross separatrix at the top



Focus on turbulence: structures

- Structures quite sheared
- Structures cross separatrix at the top
- Density structures along the divertor leg



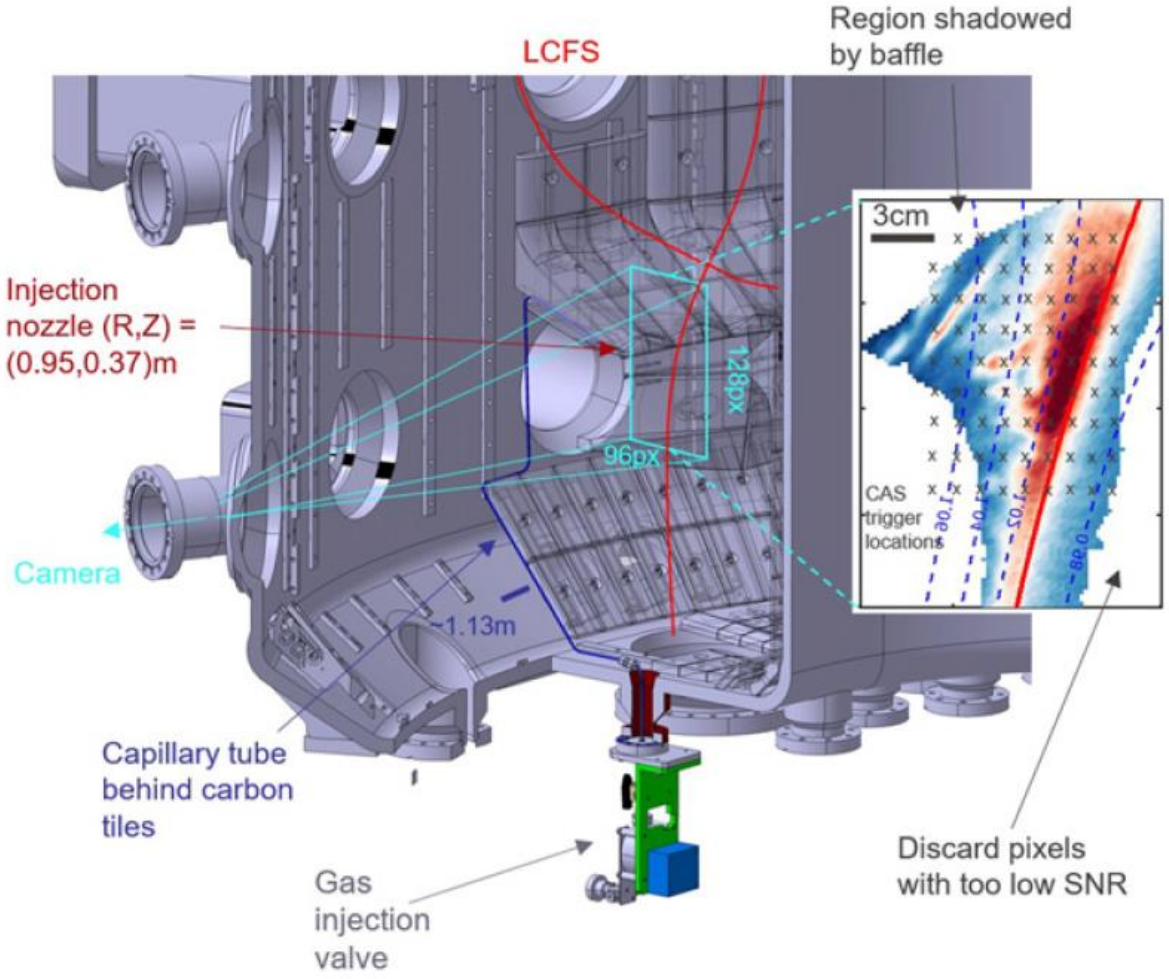


Focus on turbulence: Divertor Localized Filaments

- Divertor Localized Filaments
  - Observed experimentally with fast cameras C. Wüthrich et al., Nucl. Fusion 62 (2022) [3]
  - Distinction between:
    - Filaments generated in the main SOL (stretched in the divertor – downward)
    - Filaments generated in the divertor (‘blobby’ in the diveror – upward)

- Well recovered in the simulation
  → Ability to catch fine turbulence features and scales in realistic divertor conditions

- Instabilities behind to be investigated
  - Interchange? Kelvin-Helmholtz?



Sketch of the gas puff imaging diagnostic on TCV. Figure from [3]

Fine grid too slow → move to coarse grid

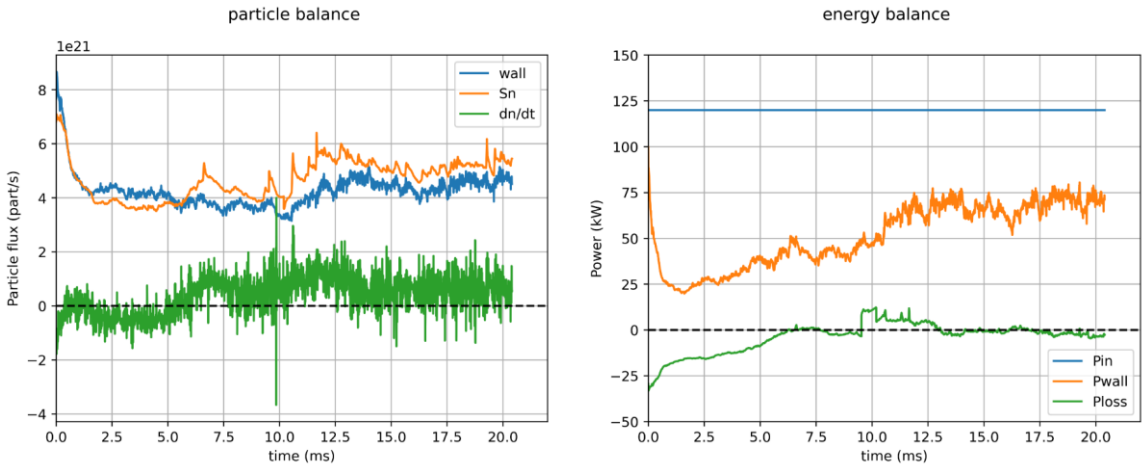
- Strategies to reach quasi-steady-state with neutrals:

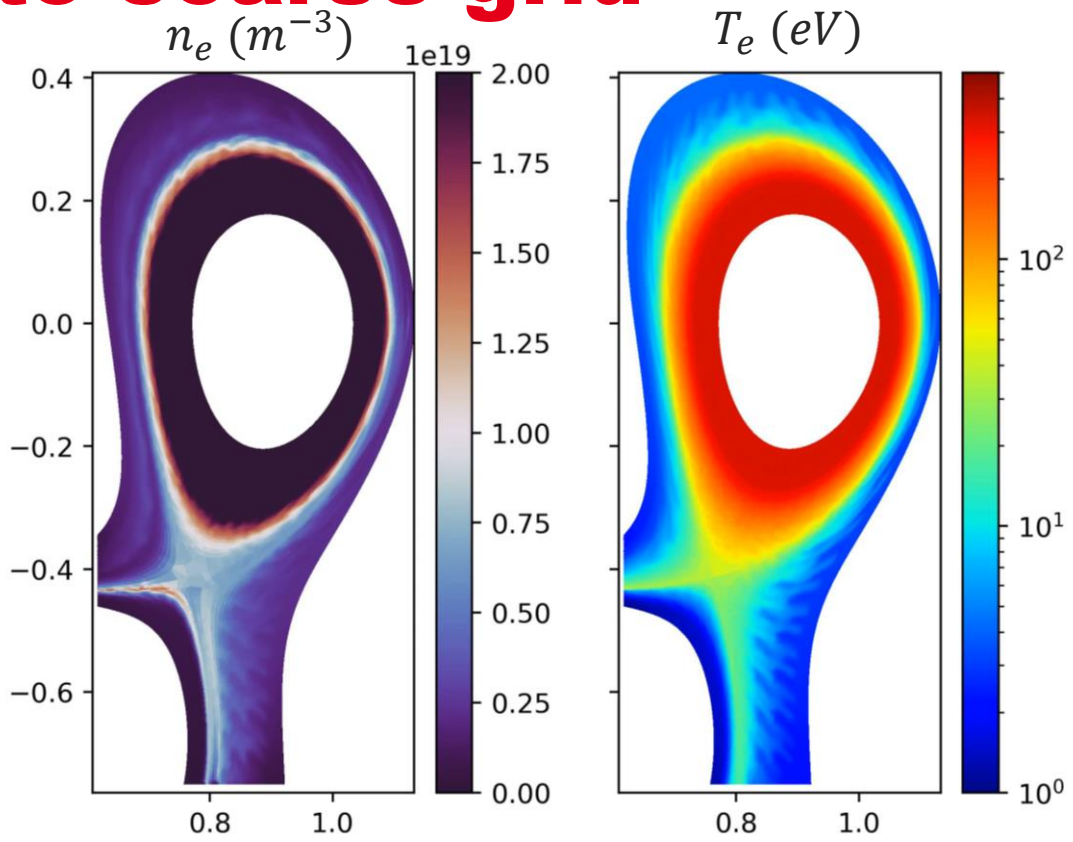
  2. Run turbulent case on coarse grid (aggressively)
  $N_\psi \sim 100$, $N_\theta \sim 700$, $N_\varphi = 32$ (1/4 torus)

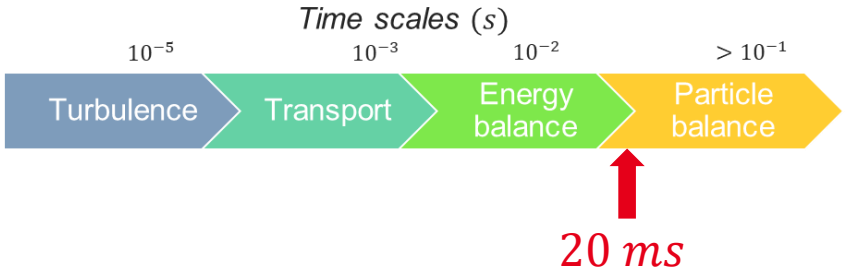
  → $N_{points} \sim 2$ millions

  → factor 2 in each direction, factor 8 on the number of DoF

  - Lower computation cost than fine grid case
    8 days on 2560 CPUs $\sim 0{,}5 MCPUh$ → $20ms$ of plasma
    Cost: $25 kCPUh/ms$ [vs $1.25 MCPUh/ms$]
  - Enables longer plasma time – though is turbulence representative?







Power scan

- Reference TCV-X21 power = 120kW (Psep)

→ Seem to converge with well developped turbulence (L-mode)

Power scan:

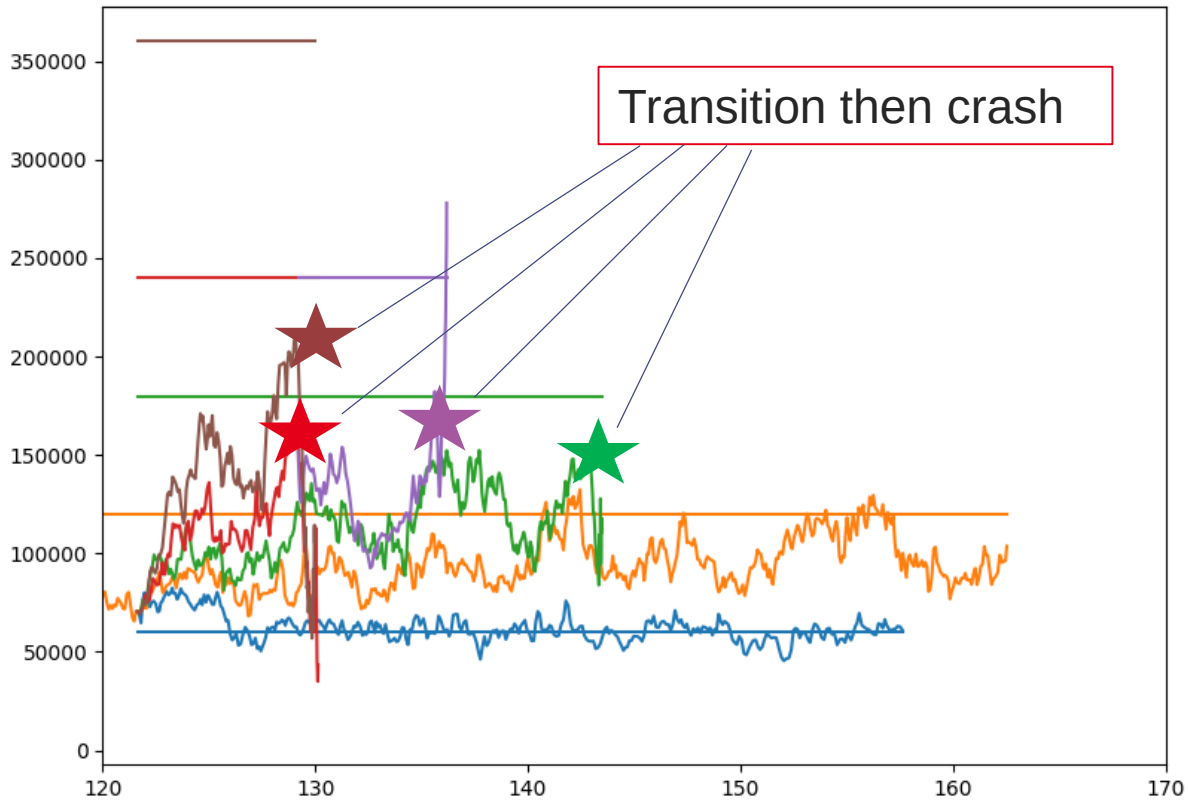
Factor	0.5	1	1.5	2	3
Power (kW)	60	120	180	240	360

Strong ExB shear at separatrix

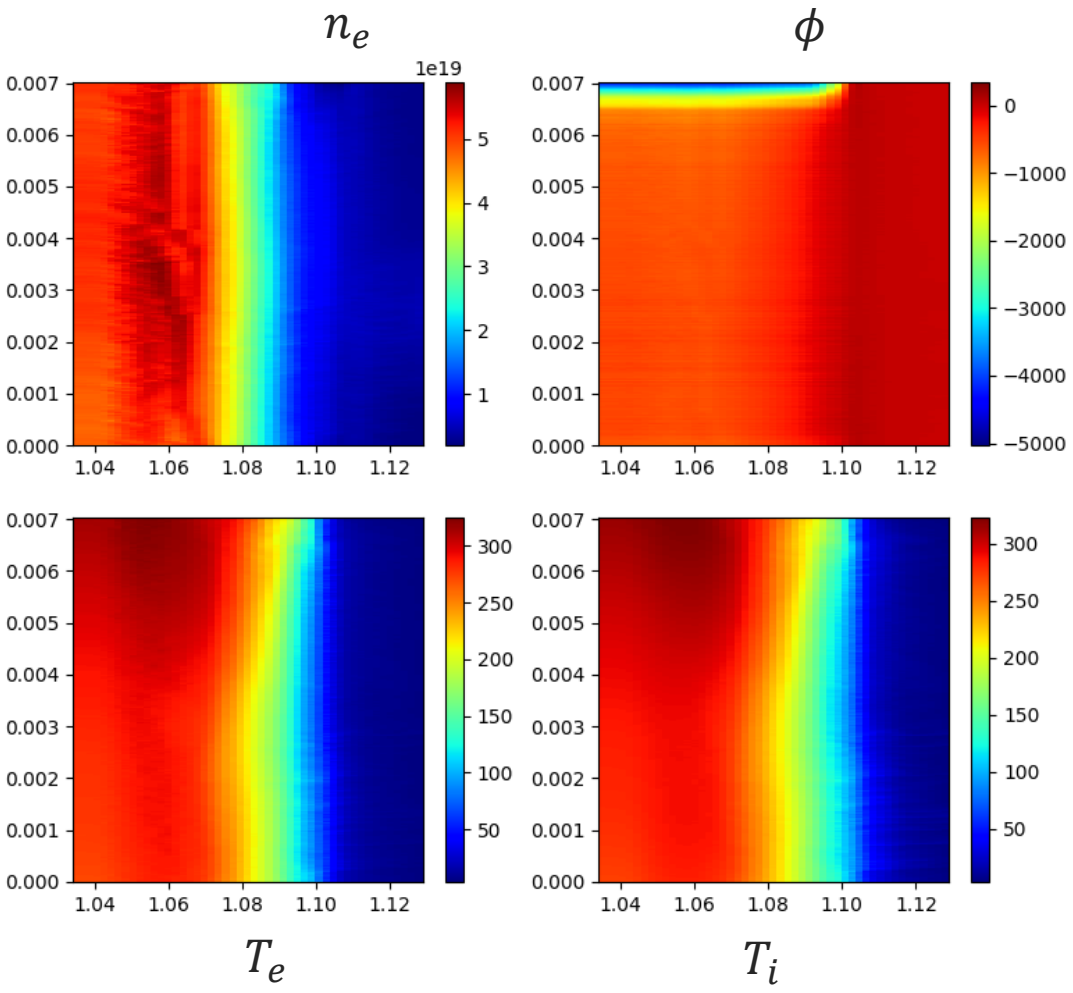
For powers greater than 120kW, strong ExB shear at separatrix leads to turbulence reduction, followed by irrealistic ExB poloidal rotation ➔ simulation crash

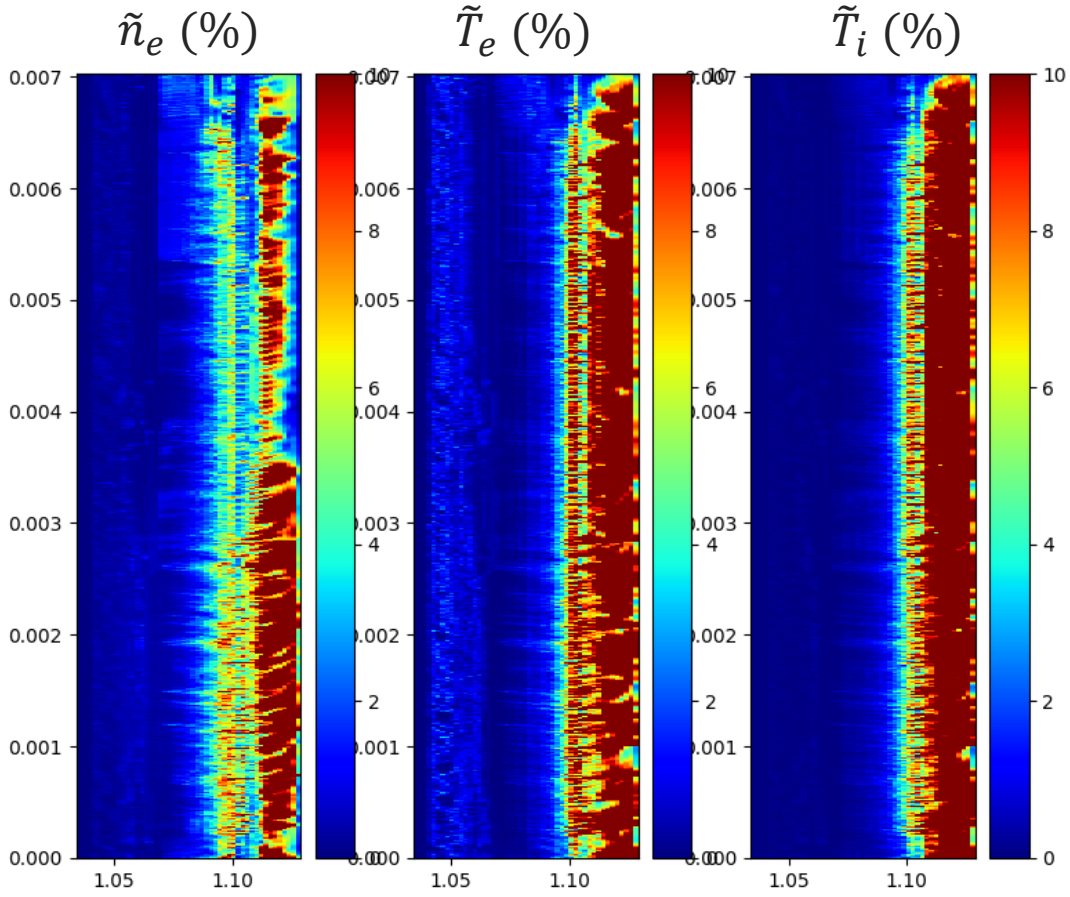
➔ May need to include drifts in energy balance

Power (Pheat and Pwall) [kW]



Example of transition (P = 240kW)

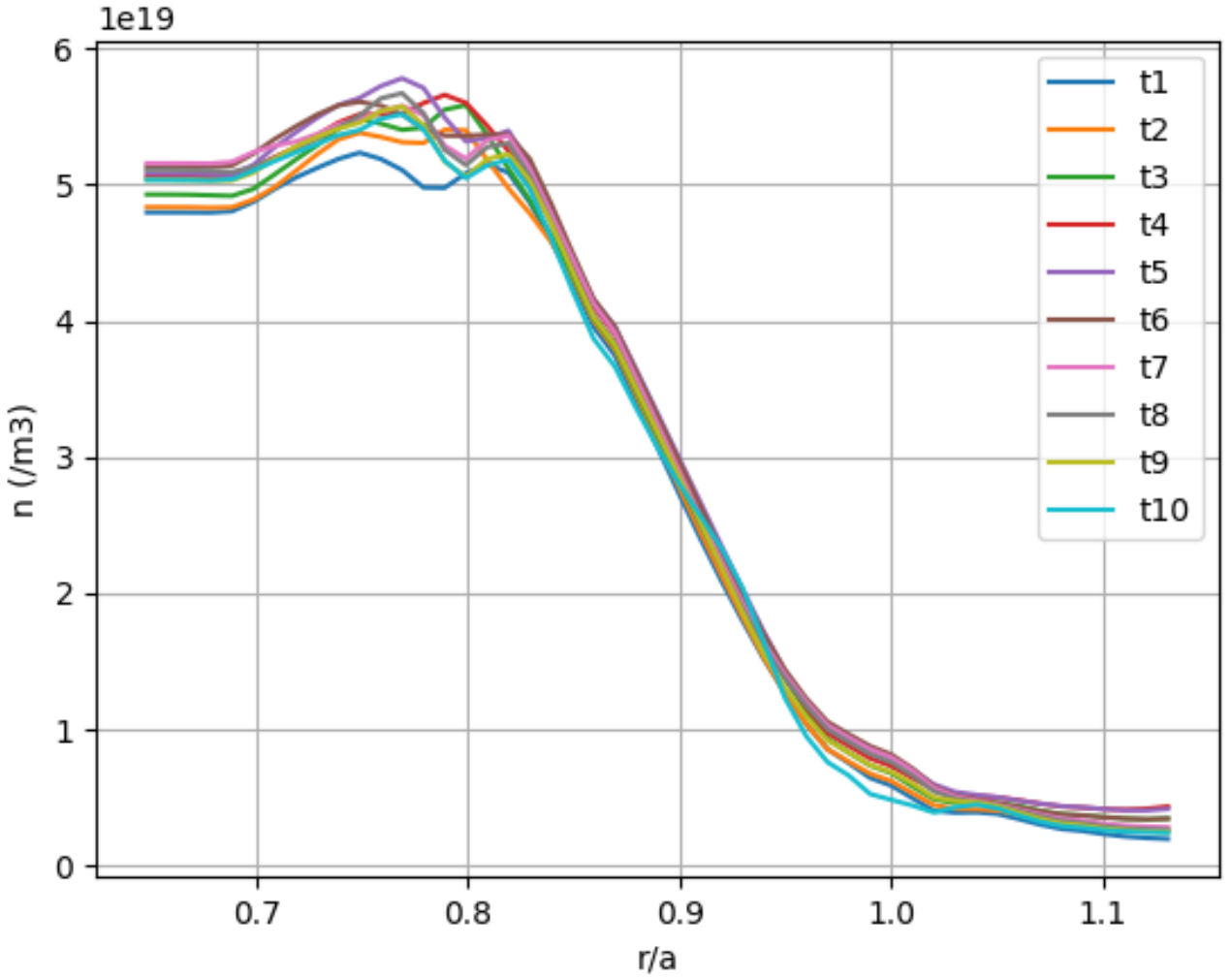




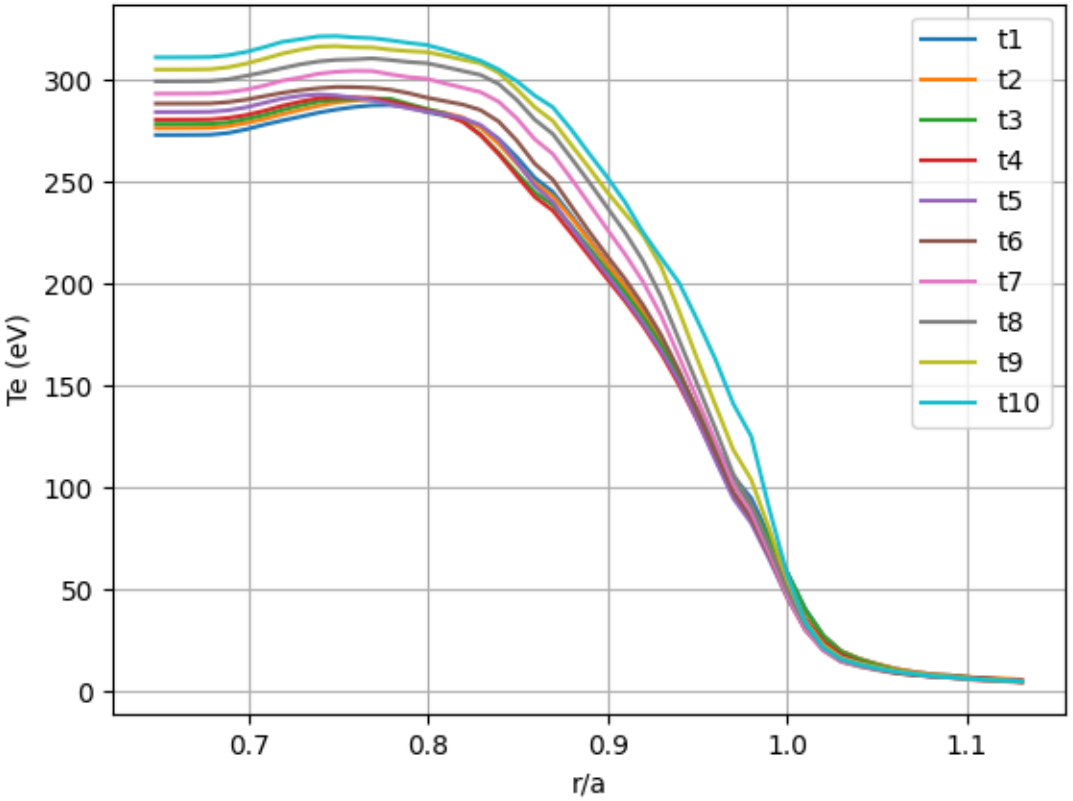
X-axis : R in m / Y-axis : time in s

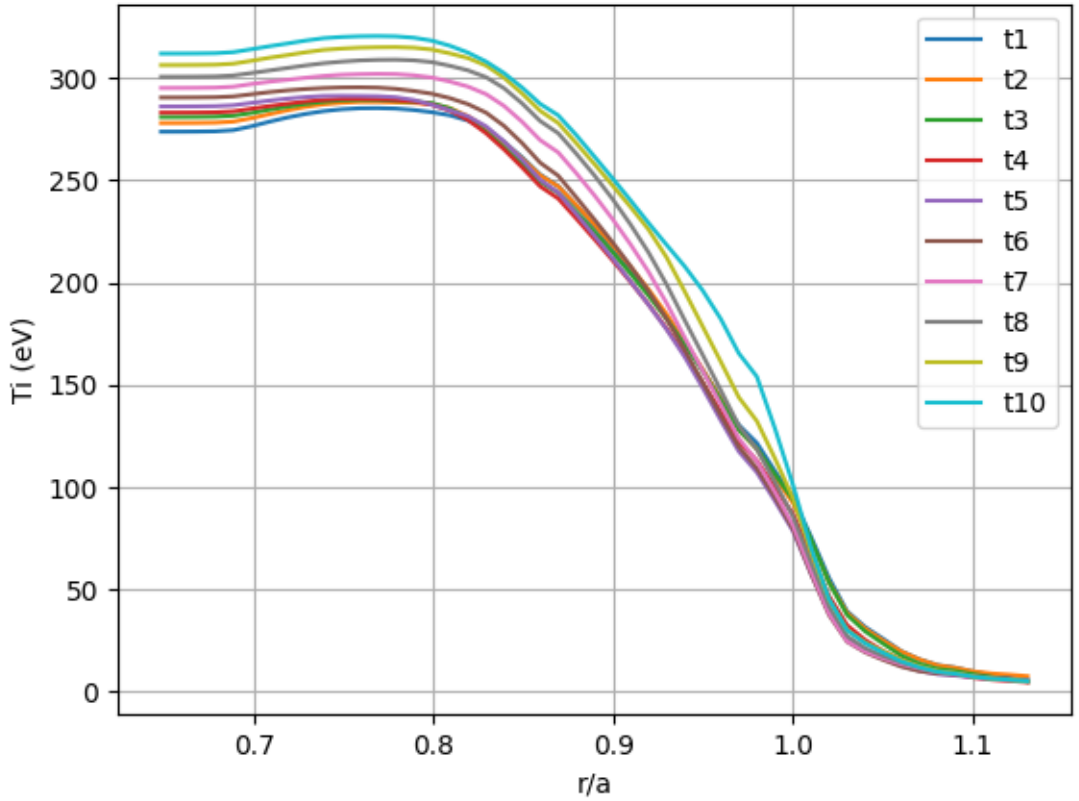
Midplane Profiles : density

- Transition between t9 and t10
- Nothing clear on n_e (decrease of n_e in the SOL)
- Density too high in the core (problem with too little turbulence due to coarse grid? / problem with the source [fluid neutral model])



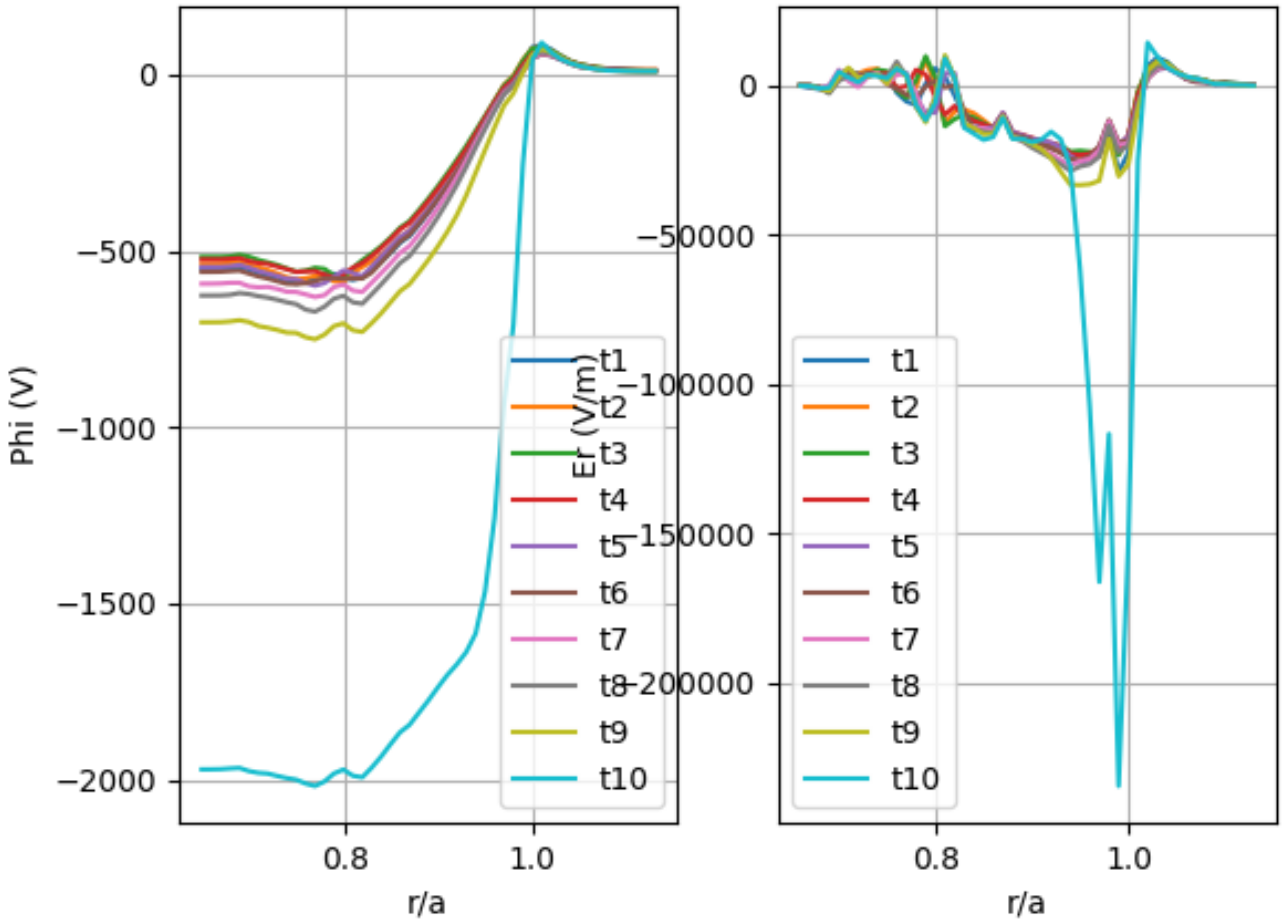
Midplane Profiles : Temperatures

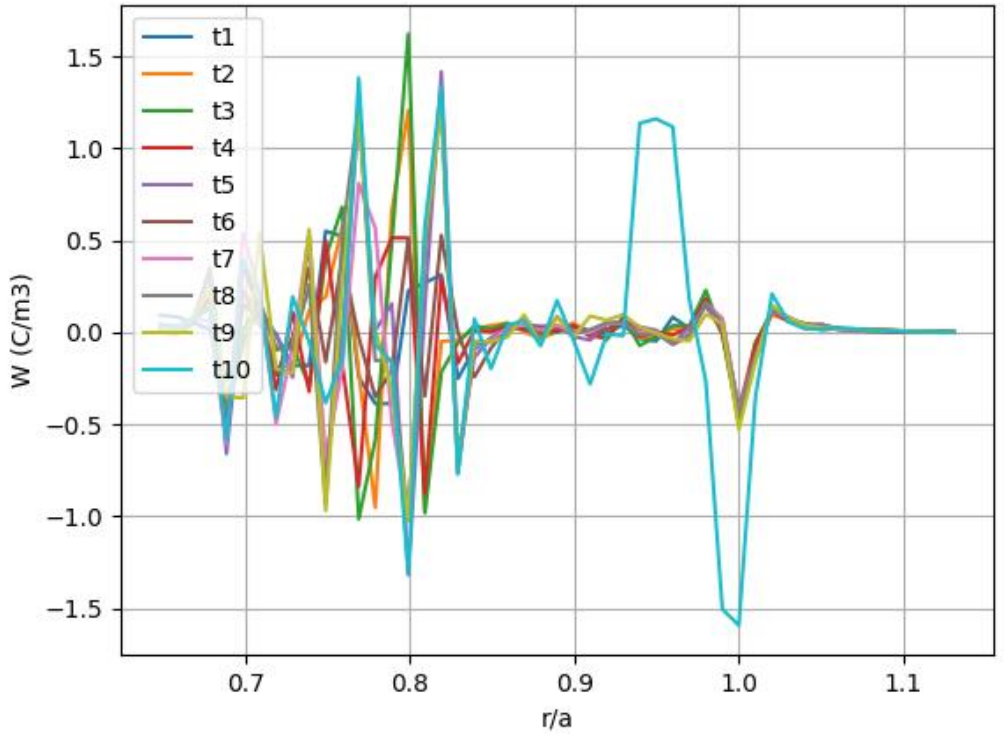




Evidence of steepening of profiles between t9 and t10

Midplane profiles : radial electric field

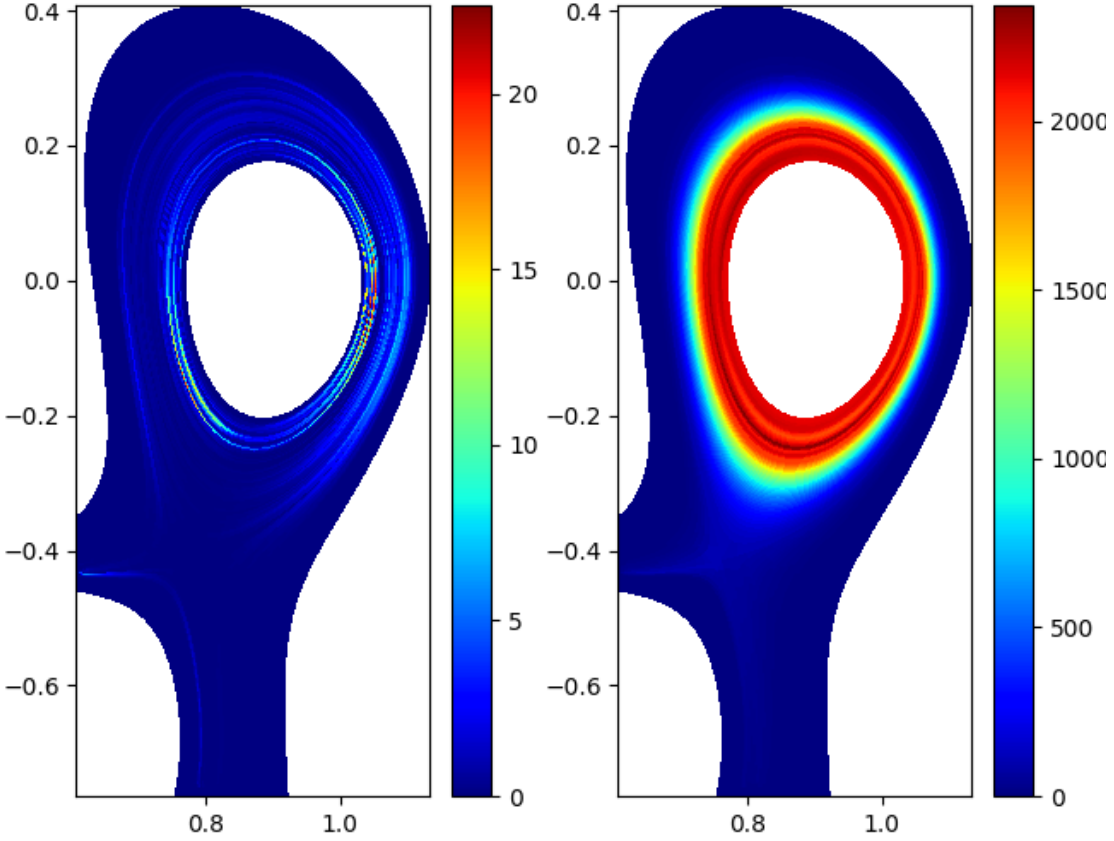




Strong Er well / strong vorticity dipole

Perp kinetic energy

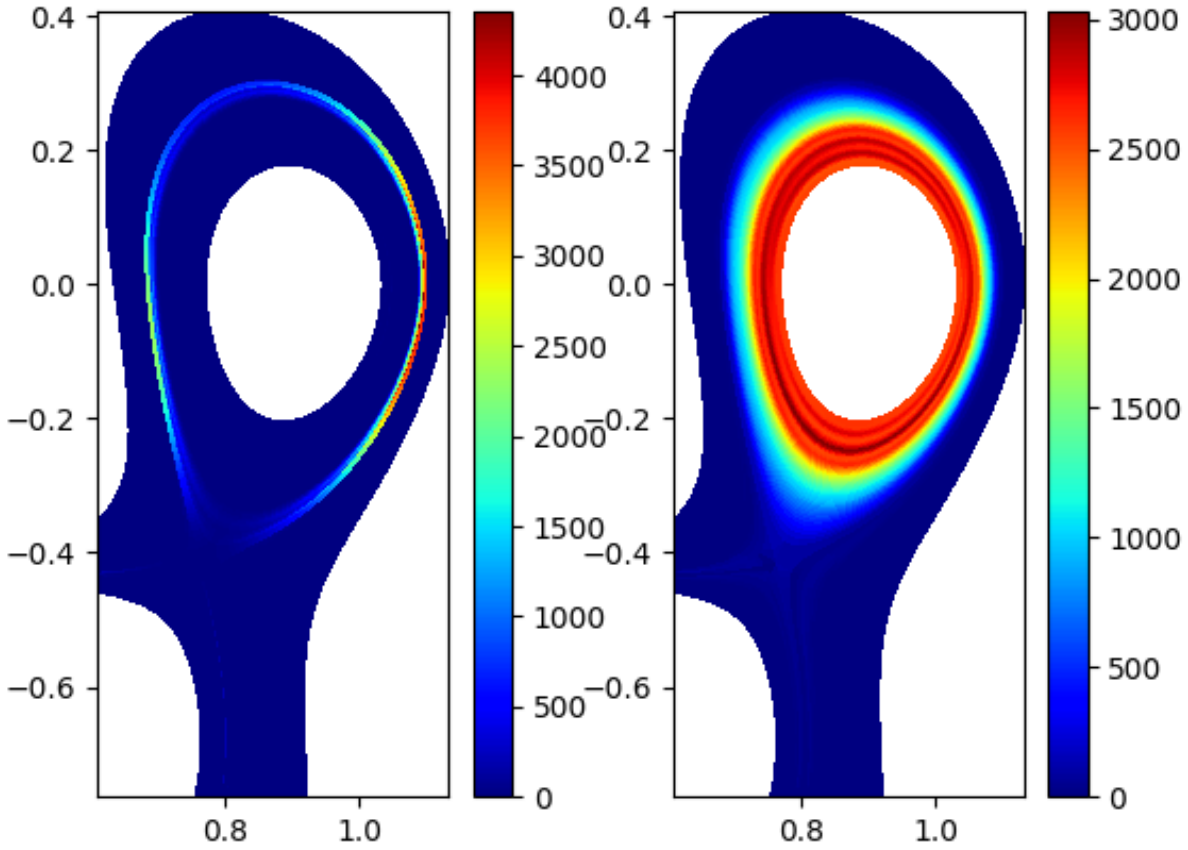
120 kW



ExB drift
kinetic energy

Thermal
energy

240 kW



ExB drift kinetic energy
No longer negligible

Thermal
energy

To go further

- Power scan reproduced with a doubled magnetic field. So far, no transition. But grid even more under-resolved.

- Power scan to be reproduced with halved magnetic field.