# Impact of penalized SOL boundary conditions on plasma turbulence

E. Caschera, Guilhem Dif-Pradalier, P Ghendrih, V. Grandgirard, P. Donnel, X. Garbet, C. Gillot, G. Latu, C. Passeron, Y. Sarazin

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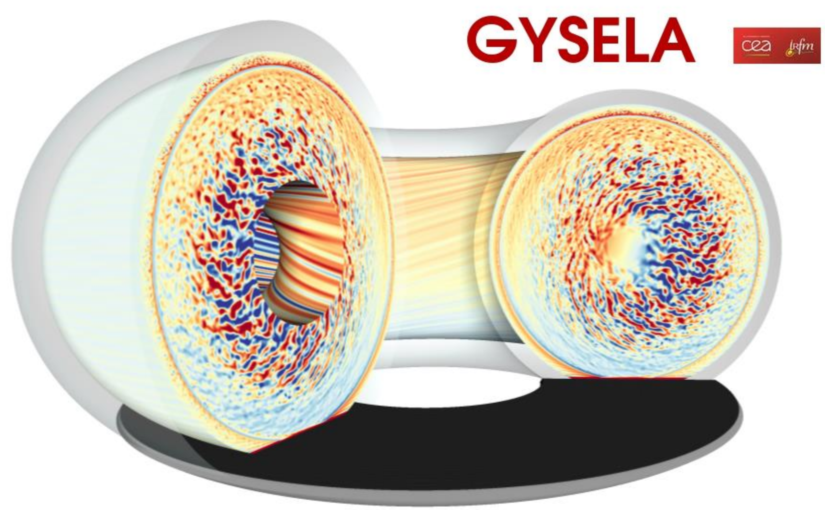
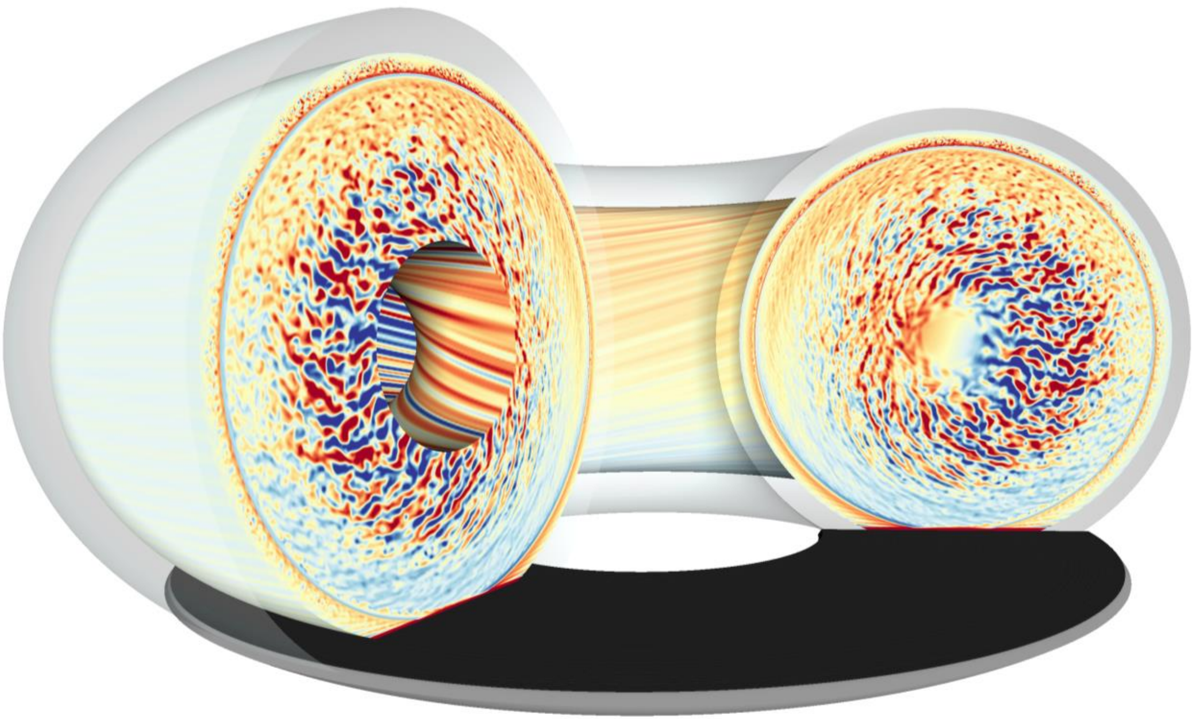


# HPC plasma modeling

## GYSELA GYrokinetic SEmi LAgrangian



- Electrostatic ITG
- Global
- 5D full-f

Huge computational effort

$10^4$ processors

10 millions h/monoproc

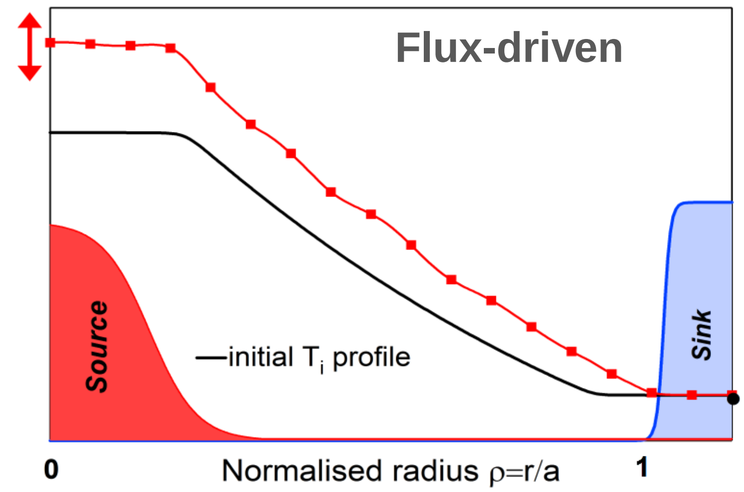
# Penalization for plasma-wall interaction

– Plasma open system→ boundary = Heat sink

– Affect edge-core turbulence [Dif-Pradalier PFR 2017]

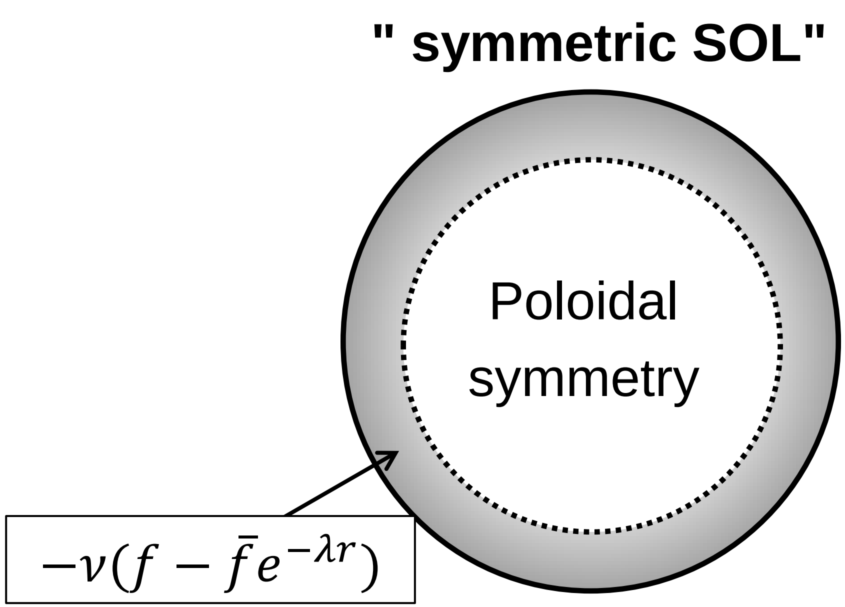
– Realistic boundary = 2 directions

– Penalized immersed boundary as edge fluid codes [Bufferand, JNM, 2013], [Isoardi, JPC,2010]



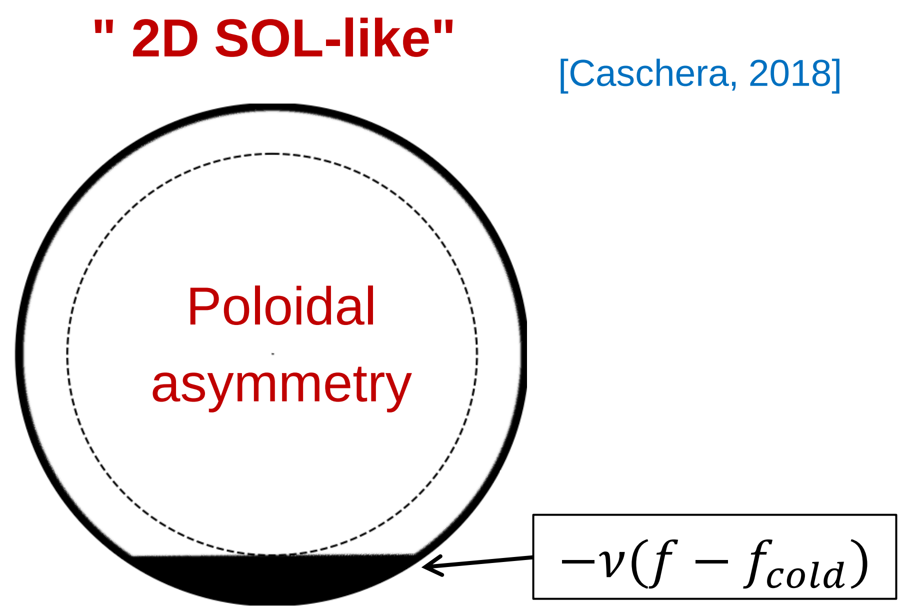
# Realistic heat sink = poloidal asymmetry

## Previous boundary




- Restoring towards exponential profiles

## Limiter immersed boundary




- Heat sink = Cold
- Resolution demanding $(v_{\parallel}, \mu)$ & $(r, \theta)$
- ∥ transport in SOL, interrupts current loop
- Adiabatic electrons = NO ⊥ $e^-$ transport

# The reversed Er builds a transport barrier

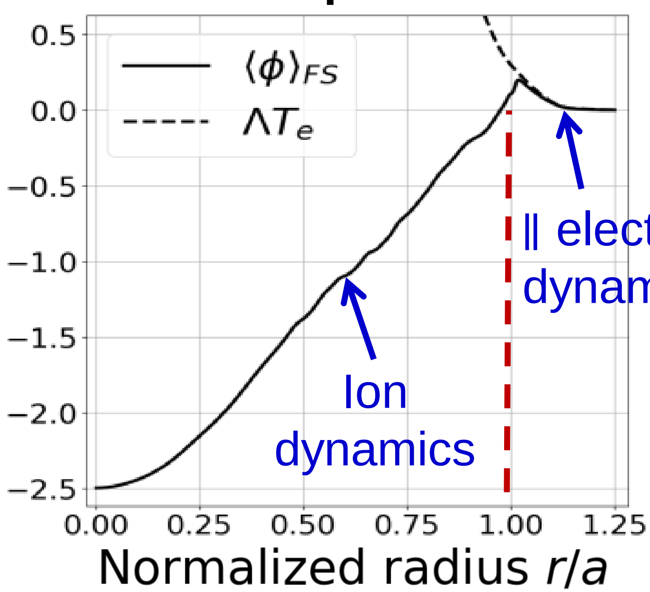
— ∥ electron dynamic in the SOL $\rightarrow \langle\phi\rangle_{FS} = \Lambda T_e$

— $core$ dominated by ion physics

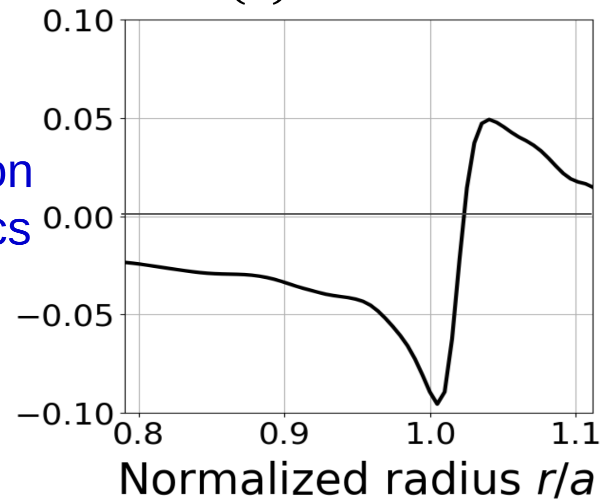
— Reversed Er self-consistently generated (as experimental measurements)

→ Edge transport barrier (not steady state simulation)

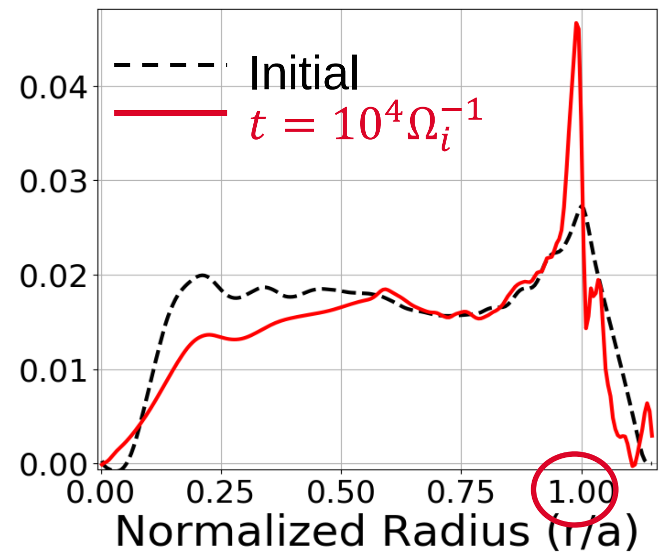
**Electric potential**



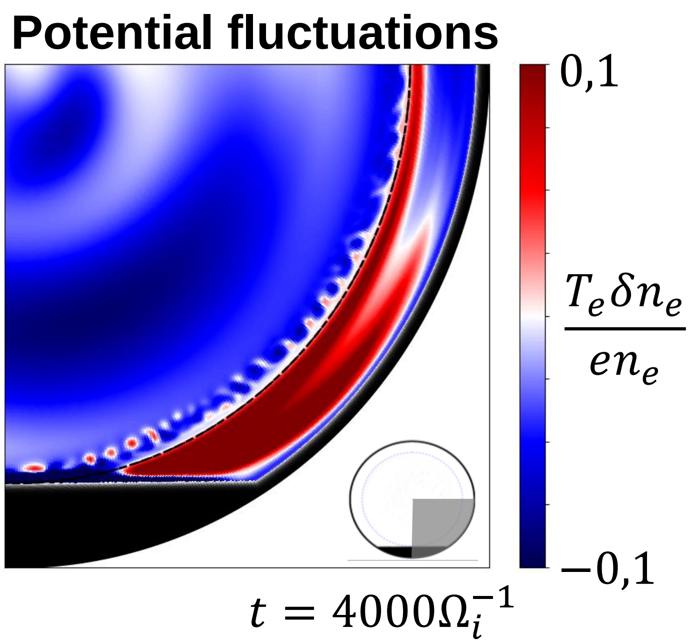

**$E(r)$ Reversal**

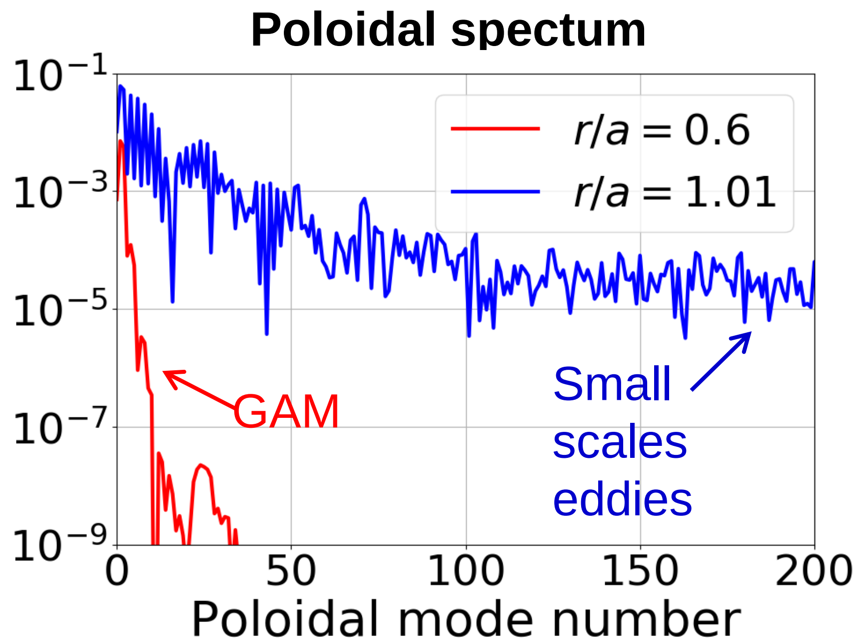



**Temperature gradient**



# A strong $E \times B$ shear drives axisymmetric instability



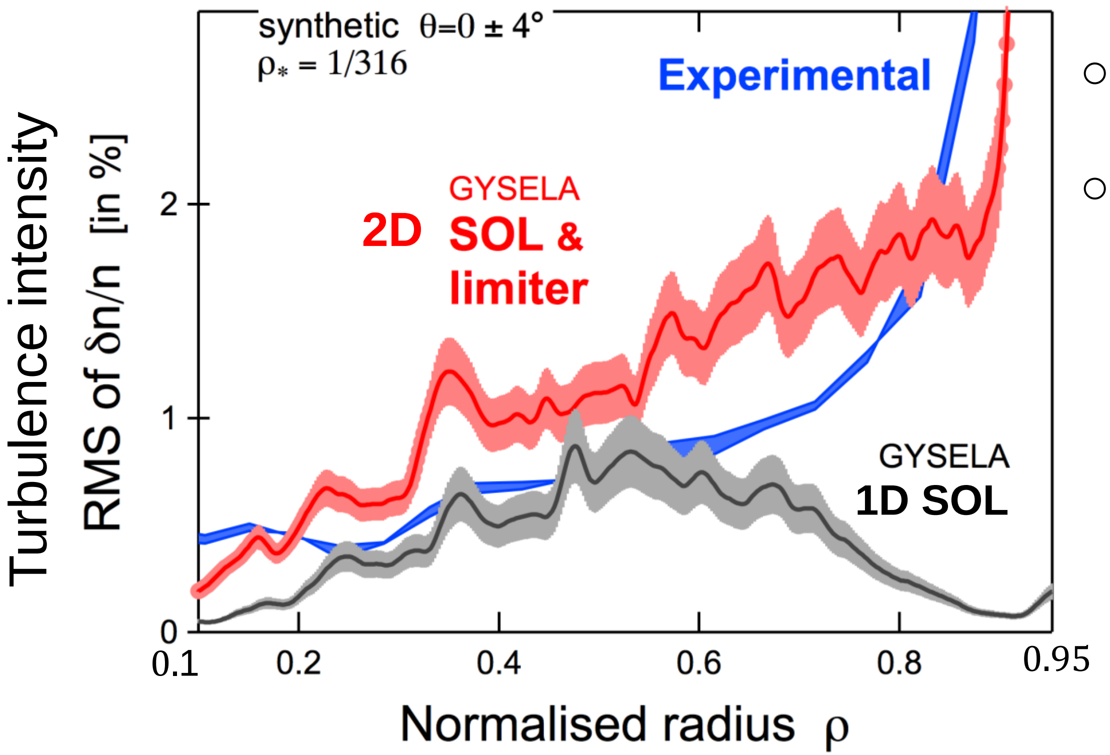

- **Axisymmetric** simulation, evolving <u>only n=0</u> → « Neoclassical »
    - Threshold on ExB shear
    - ExB shear = poloidal velocity → Kelvin-Helmholtz

→ *Plasma polarization is sufficient to drive turbulence*

# SOL is determinant for edge turbulence

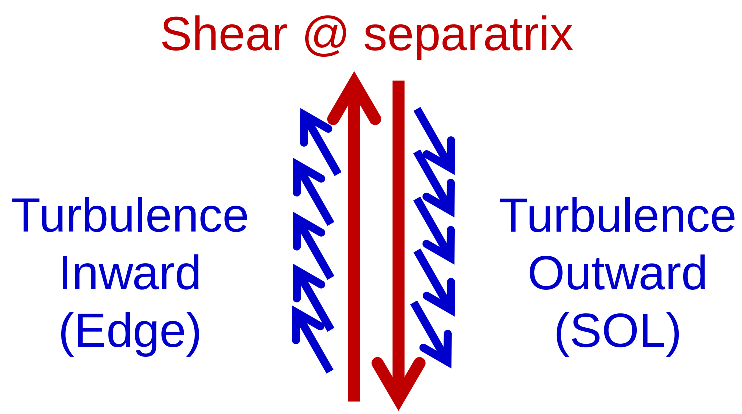


- **SOL impact on turbulent fluctuations**




- Tore Supra profiles, Edge linearly stable
- Edge turbulence only with SOL+Limiter

**Observed dynamics:**




- ITG modes
- Same core turbulence

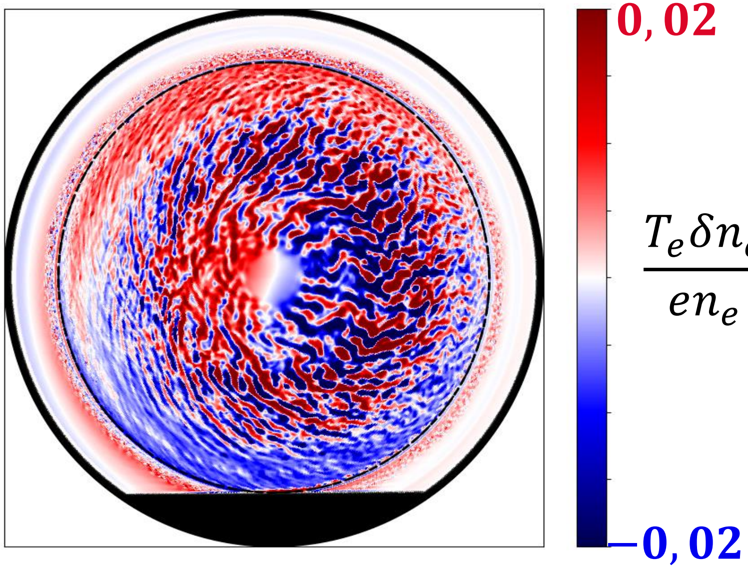
# Global = core + edge + SOL

1) Transient barrier by Er reversal

2) Instability even in axisymmetric framework

3) Qualitative $\delta n/n$ experimental trend

Potential fluctuations



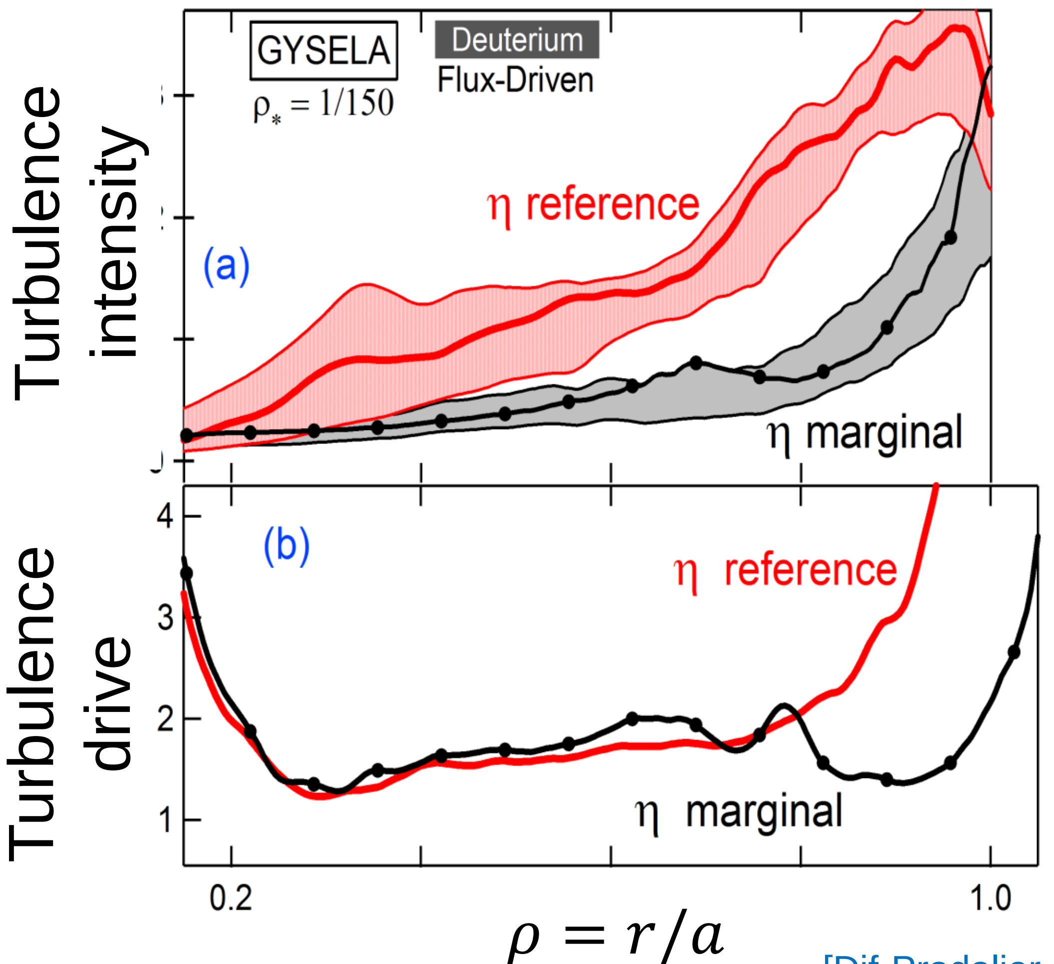

— Many different non-linear phenomena at a time:
Kelvin-Helmholtz, ITG, spreading, flows

— Push towards steady-state boundary layer

**Limiter boundary leads to new physics in GYSELA simulations**

# Back-up slides

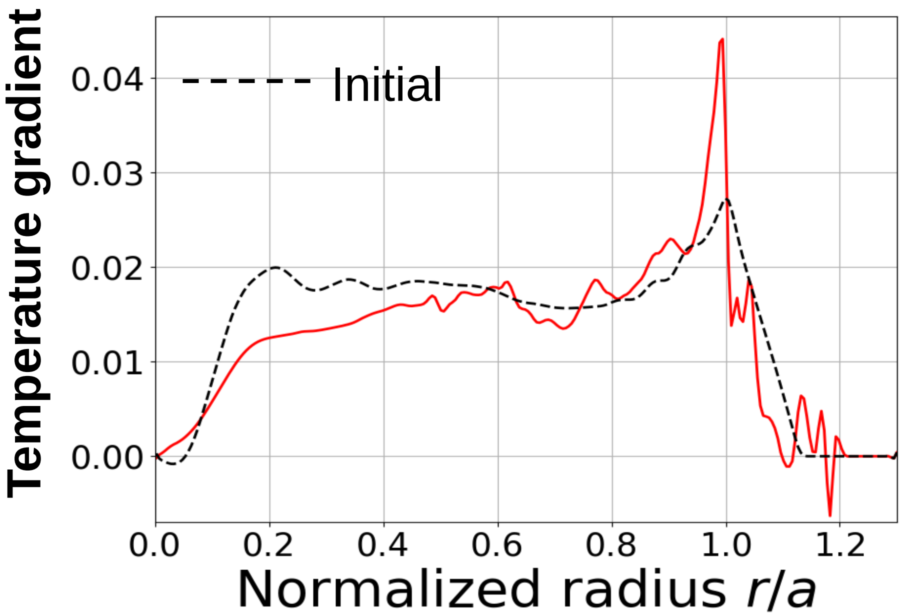
# Evidence of edge-core interplay



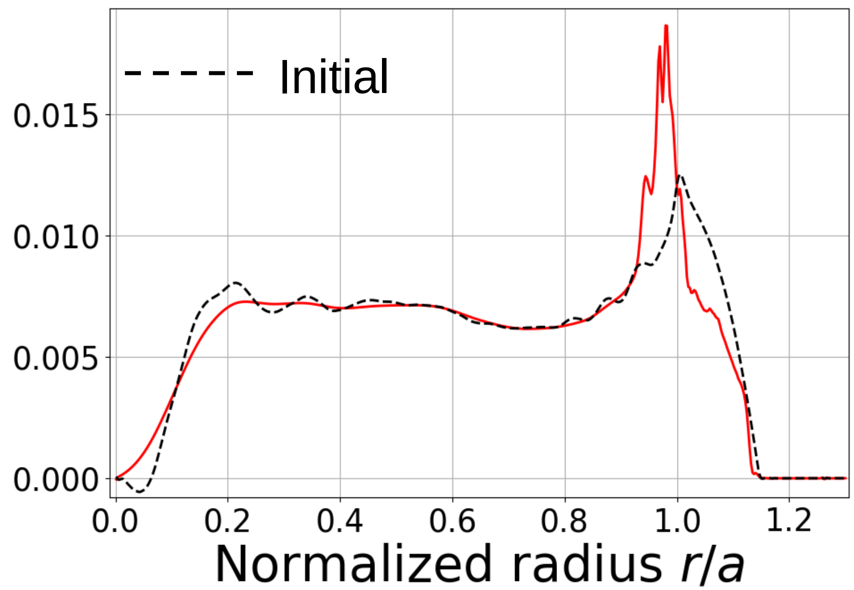

[Dif-Pradalier, 2017]

# The weak transport barrier depends on core dynamics

$E_r(r > a) = \Lambda T_e$




$E_r(r > a) = 0$



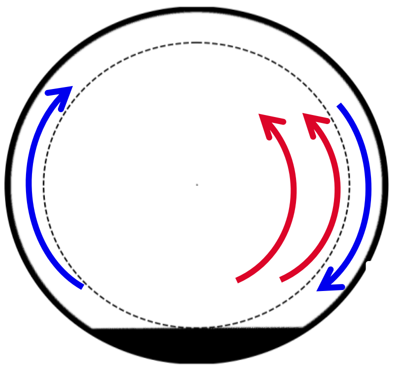
# $E_r$ Reversal at separatrix modifies SOL poloidal symmetries

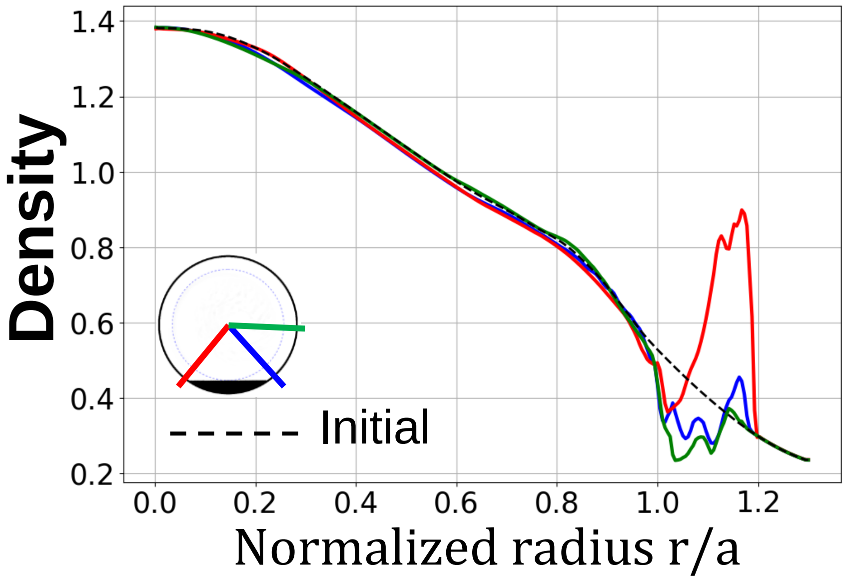
*LIMITER brakes the current loop → SOL poloidal asymmetries*

**SOL Polarization**

Reversed $E_r \leftrightarrow v_\theta$

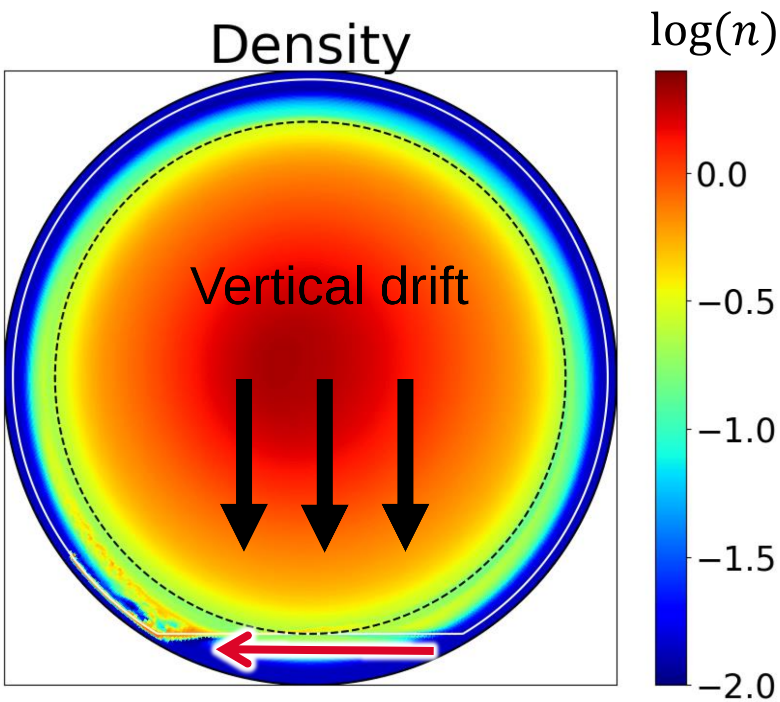
Inverse rotation btw core/SOL

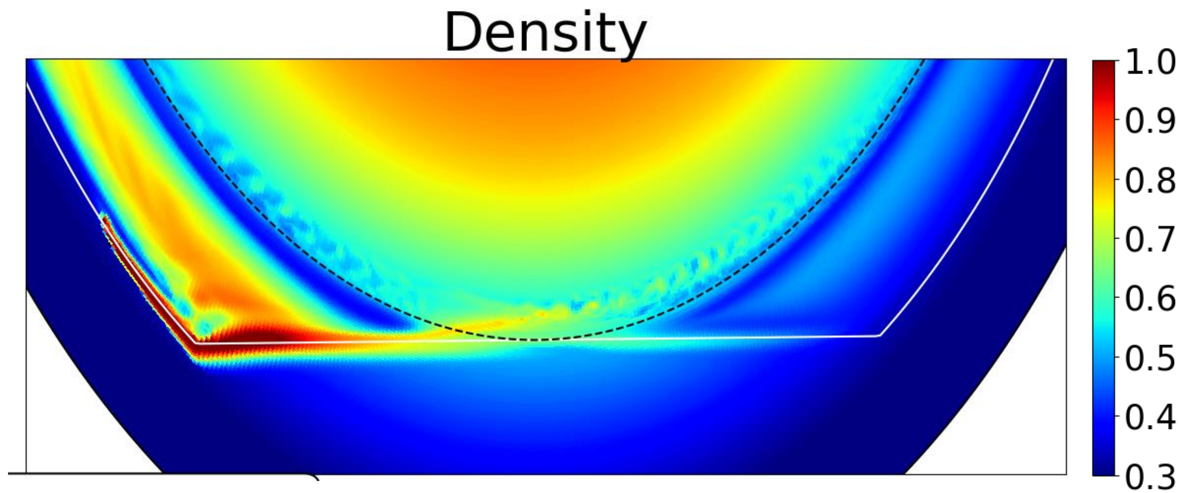




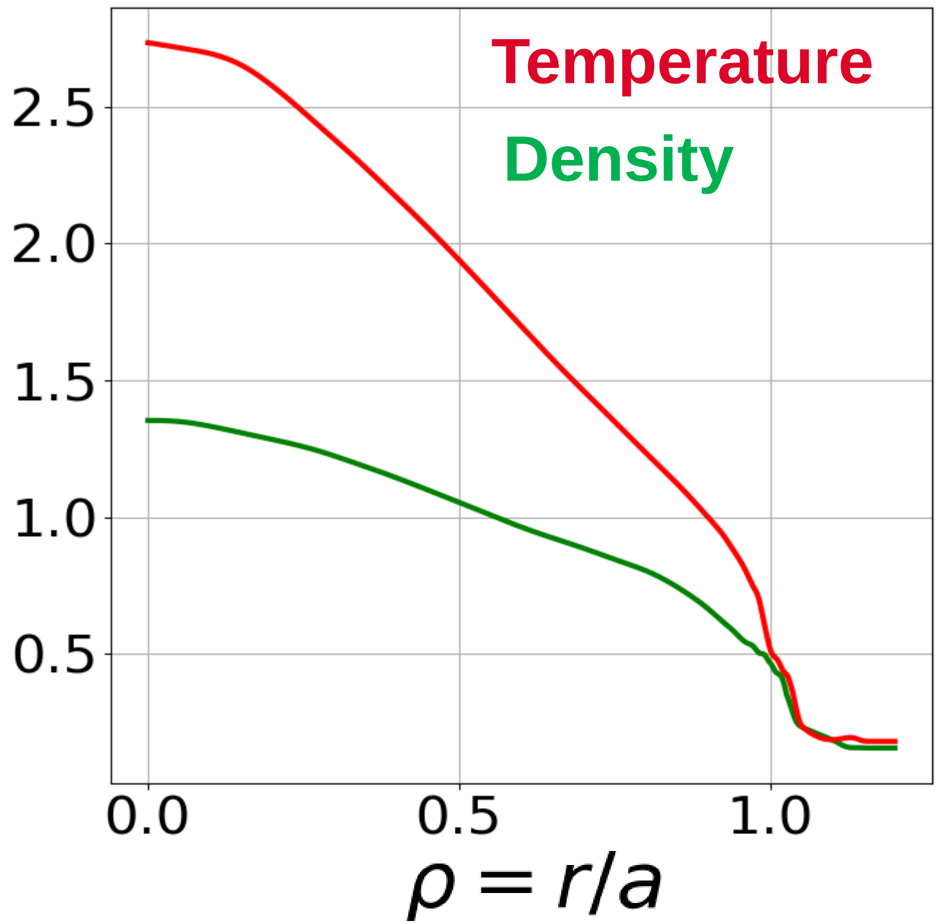

- Vertical drift + SOL flows
- HFS density accumulation
- Barrier at separatrix

# Initial transient in the SOL

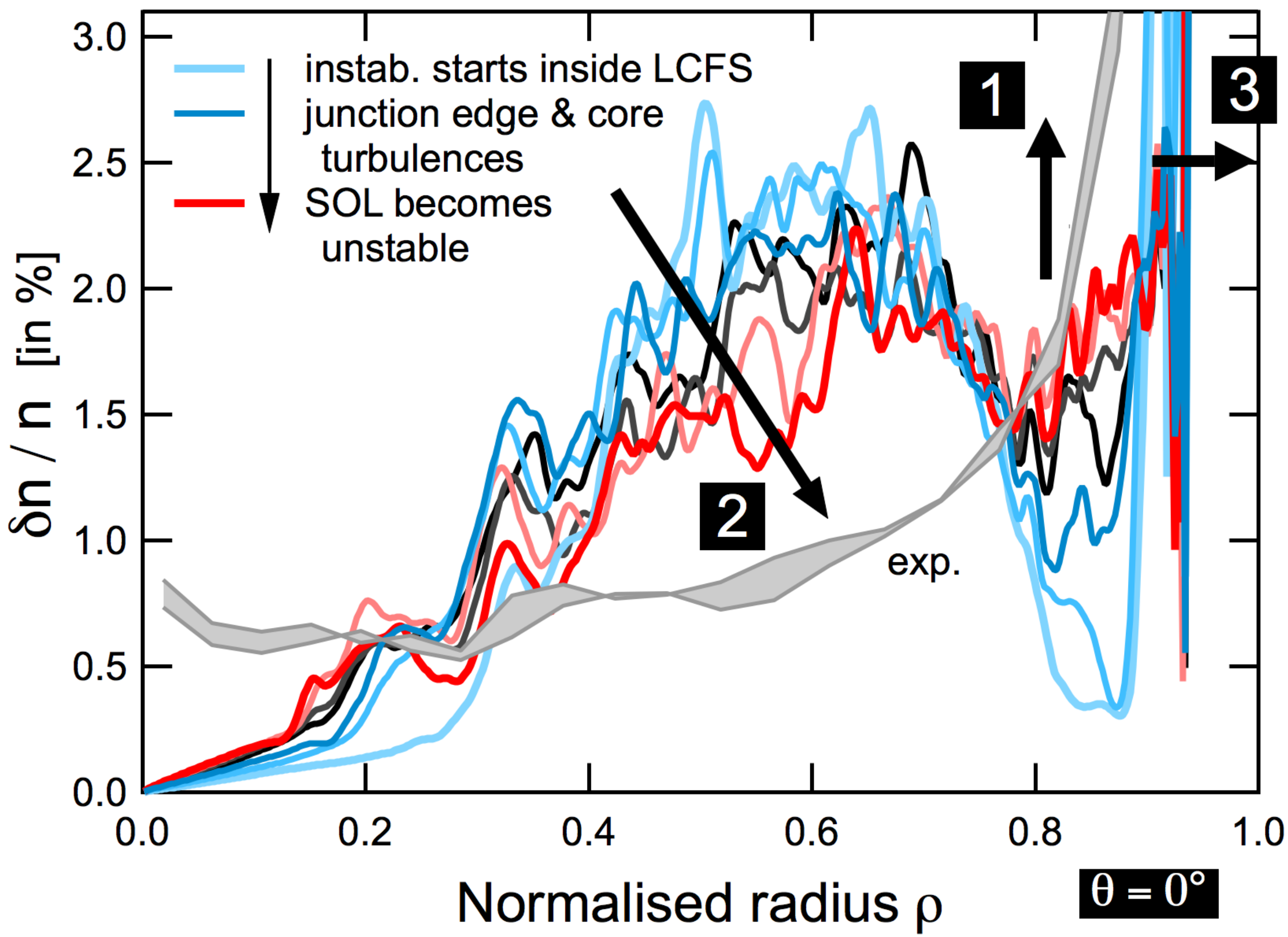


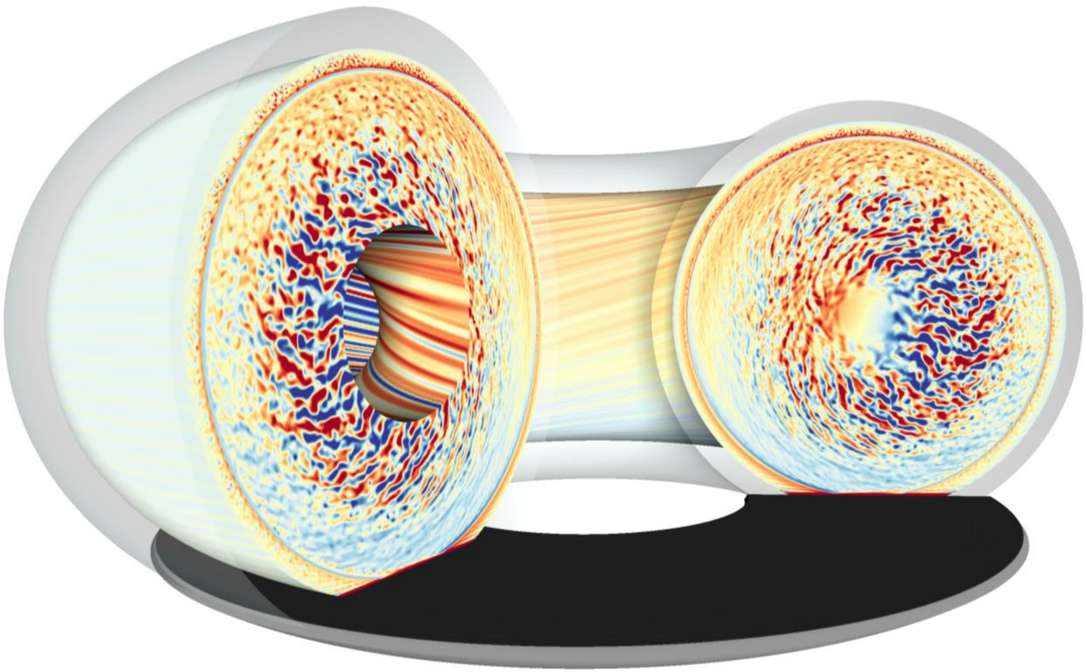
# Axisymmetric simulations: barrier on the profiles

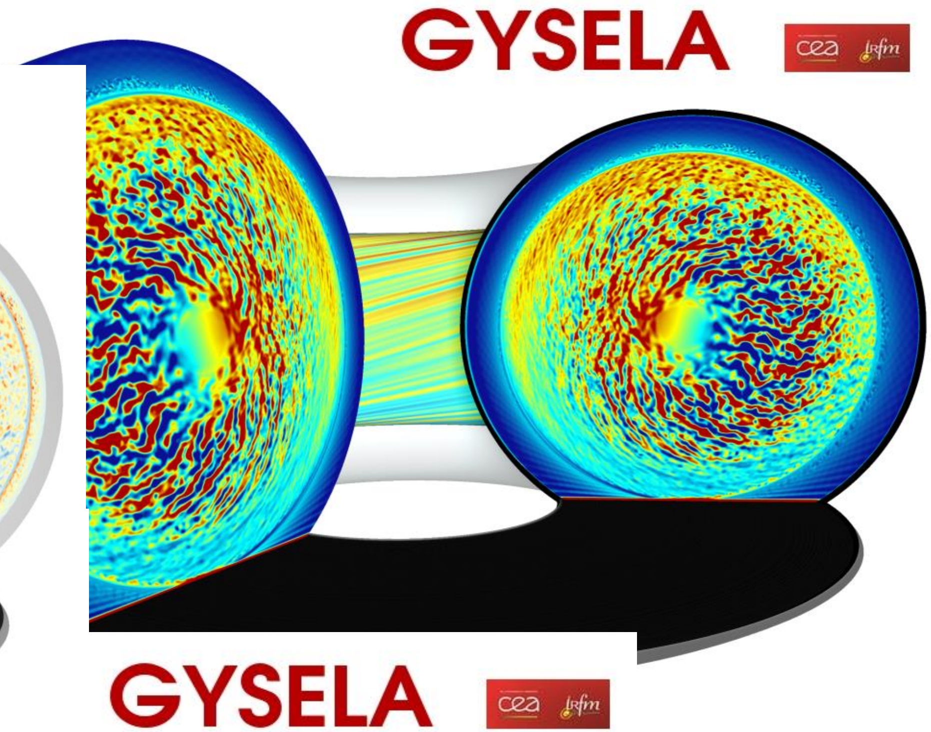


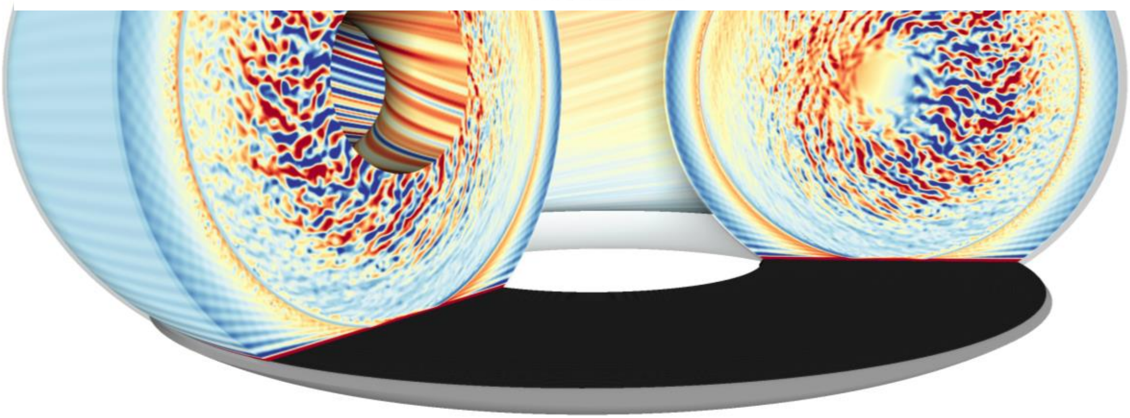
# Recovering $\delta n/n$ behavior



# 3D IMAGES



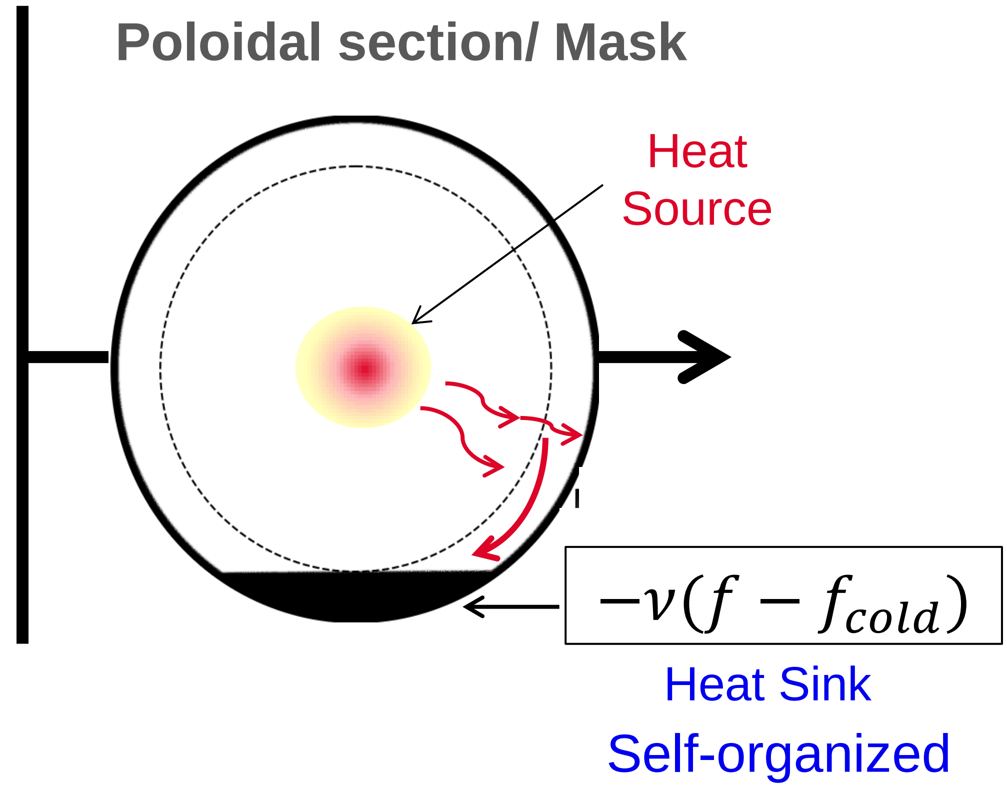


# Self-organized heat sink

## 1. Heat & momentum sink

- → Cold immersed boundary
- → Poloidally asymmetric
- → || transport in SOL




- ❑ *All heat reaching the limiter is removed*
- ❑ SOL = boundary for core
- ❑ Drift killed in the boundary

***Adiabatic electrons***

NO Particle sink,

Constrained ⊥ particle transport

NO recombination

# Different SOL equilibrium

Adiabatic electrons

Flux surface averaged profiles