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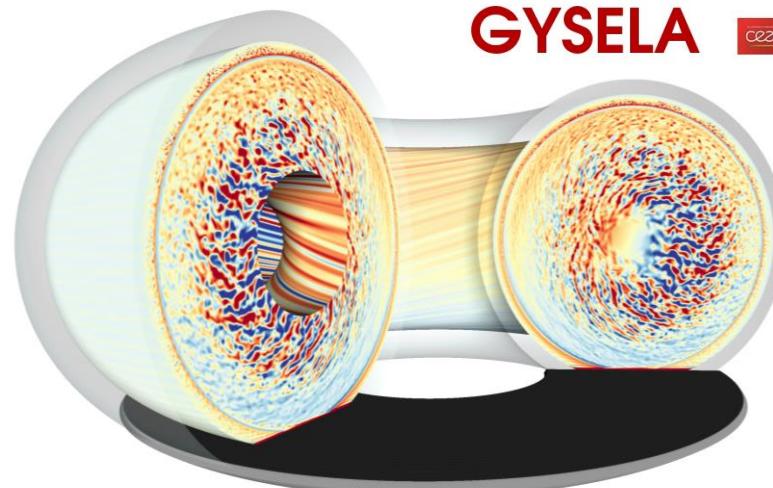
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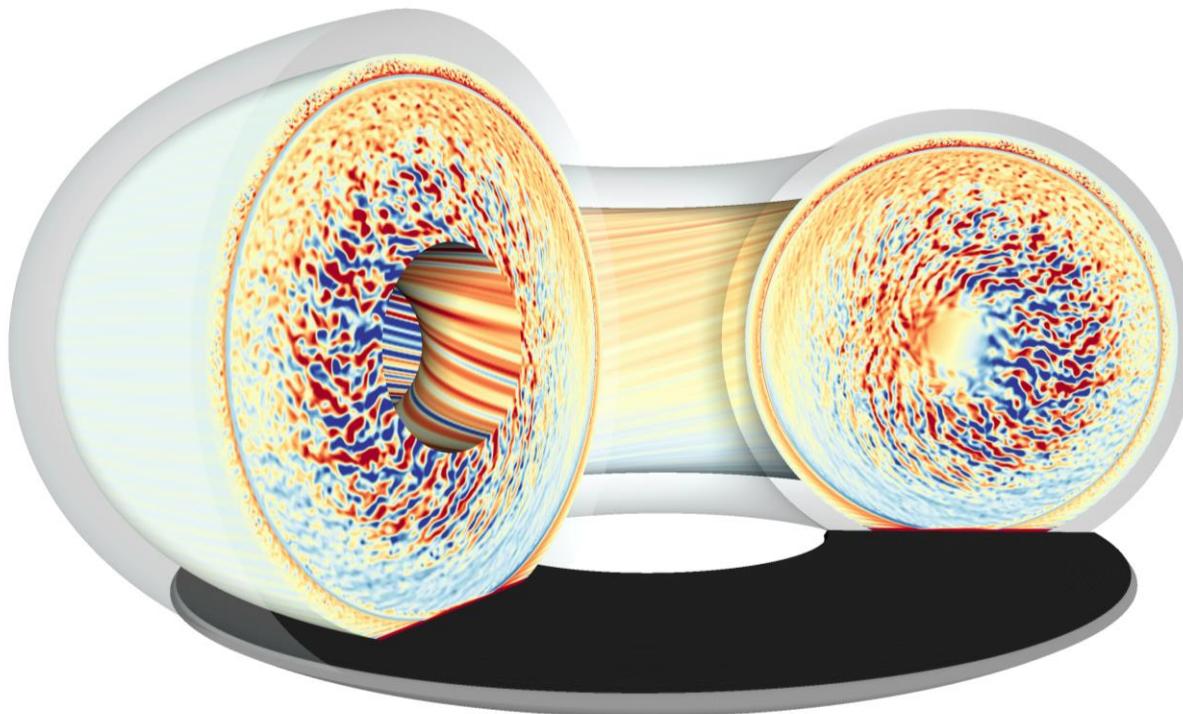
CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France

GYSELA



HPC plasma modeling

GYSELA GYrokinetic SEmi LAgrangian



- Electrostatic ITG
- Global
- 5D full-f

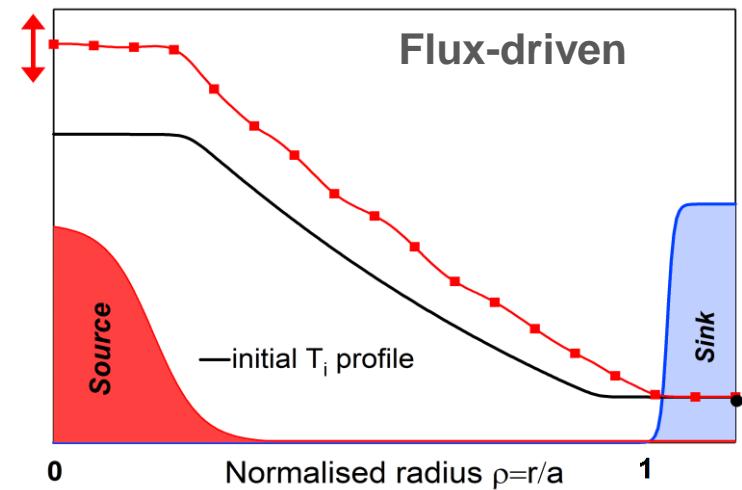
Huge computational effort

10^4 processors

10 millions h/monoproc

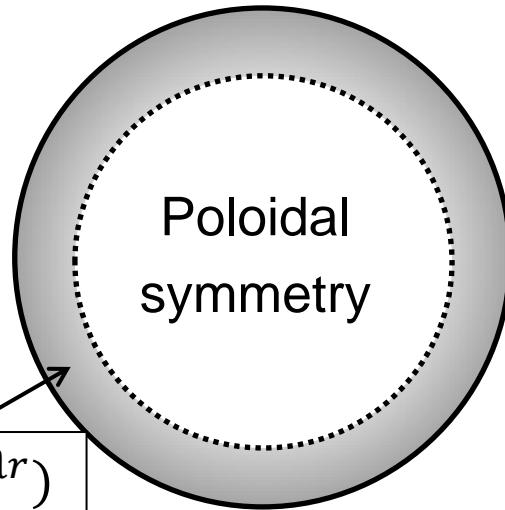
Penalization for plasma-wall interaction

- 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]



Previous boundary

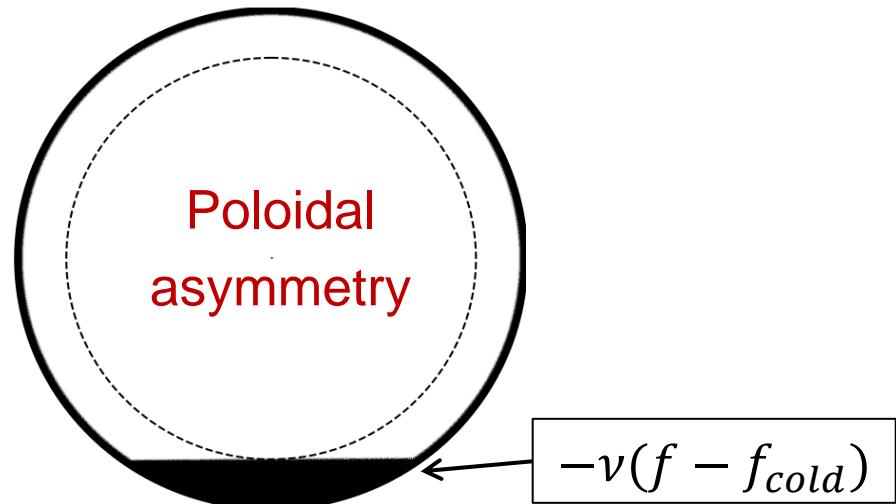
" symmetric SOL"



Limiter immersed boundary

" 2D SOL-like"

[Caschera, 2018]



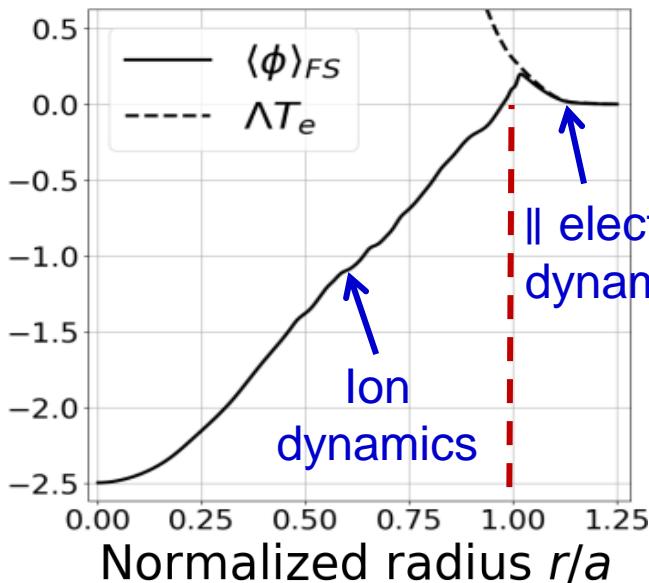
- Restoring towards exponential profiles

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

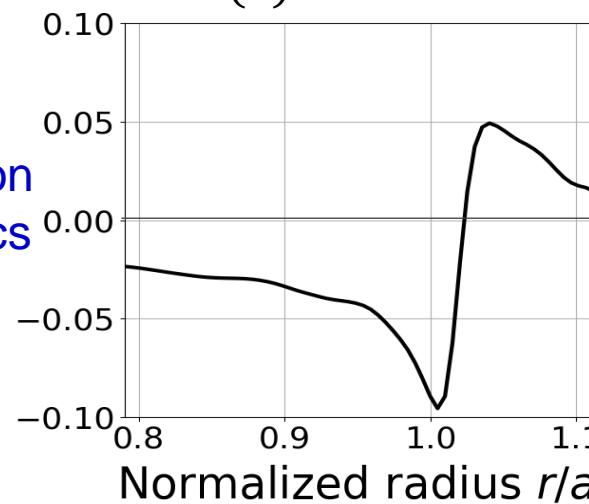
The reversed Er builds a transport barrier

- \parallel 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)

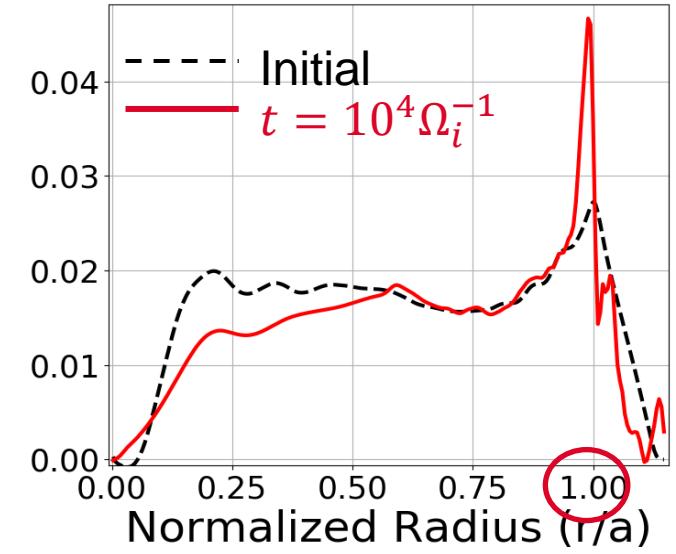
Electric potential



$E(r)$ Reversal

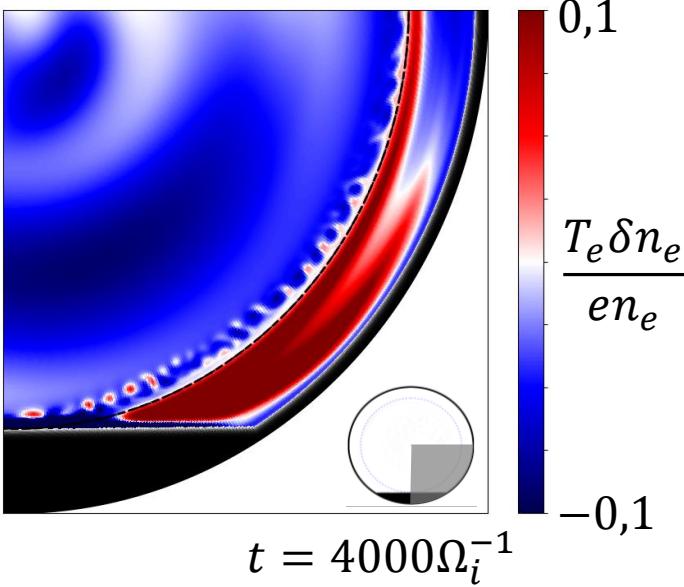


Temperature gradient

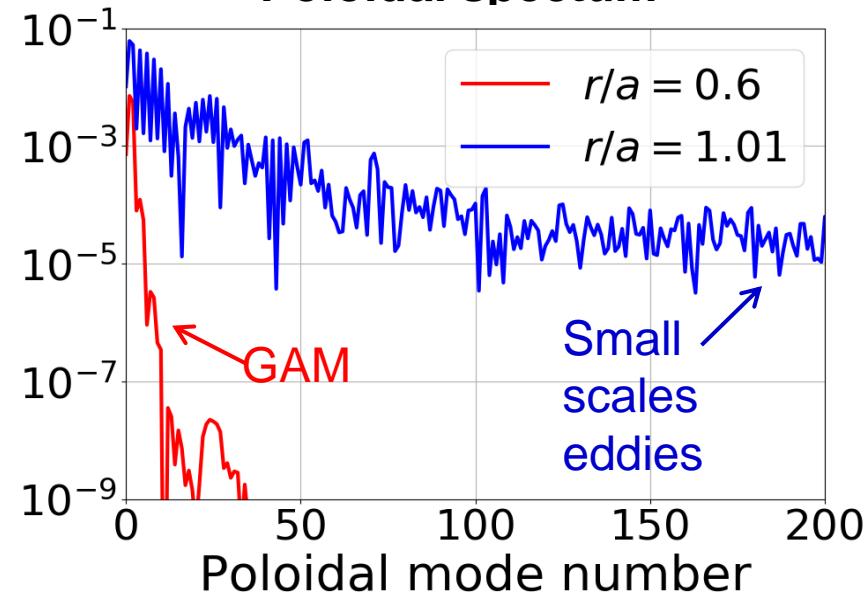


drives axisymmetric instability

Potential fluctuations



Poloidal spectrum



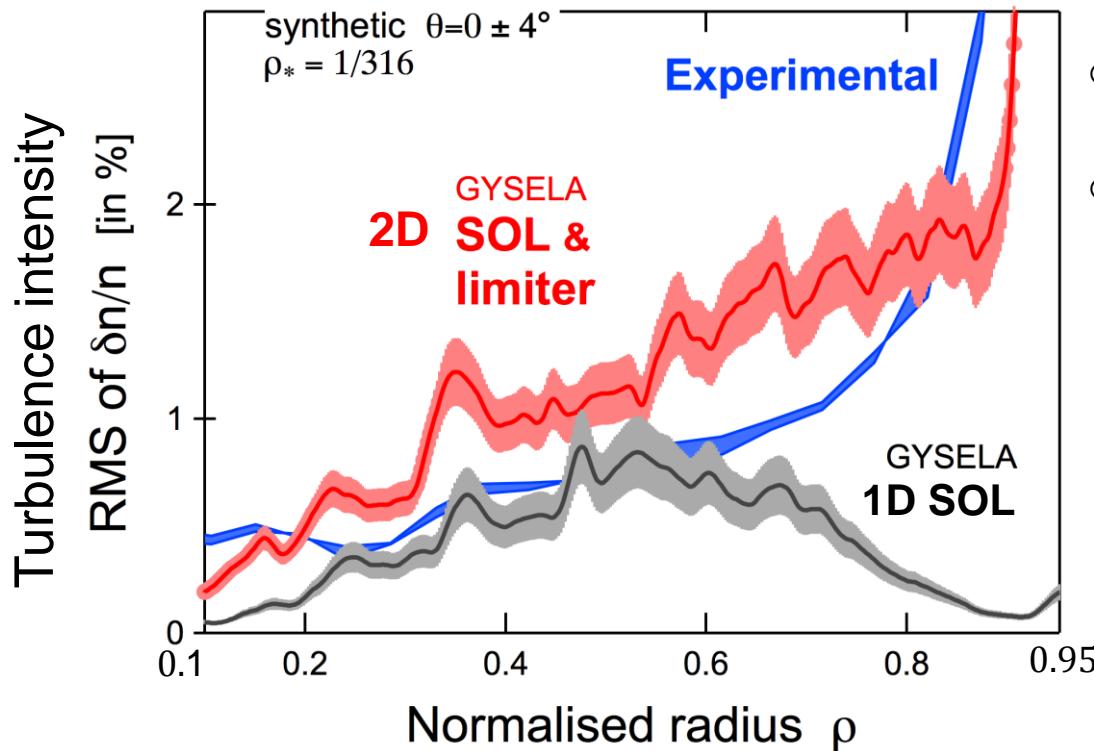
➤ Axisymmetric simulation, evolving only $n=0$ → « Neoclassical »

- 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

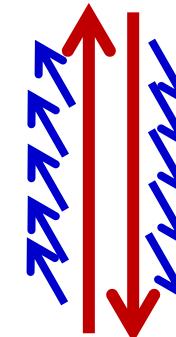


- Tore Supra profiles, Edge linearly stable
- Edge turbulence only with SOL+Limiter

Observed dynamics:

Shear @ separatrix

Turbulence
Inward
(Edge)



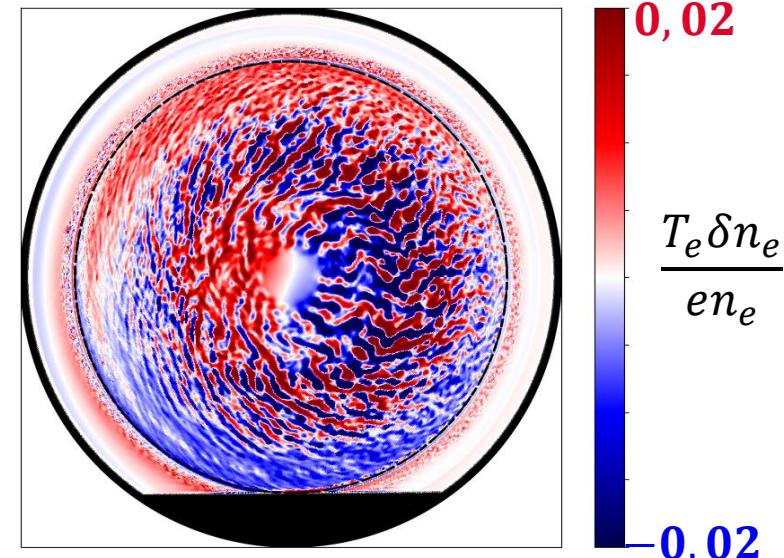
Turbulence
Outward
(SOL)

- 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



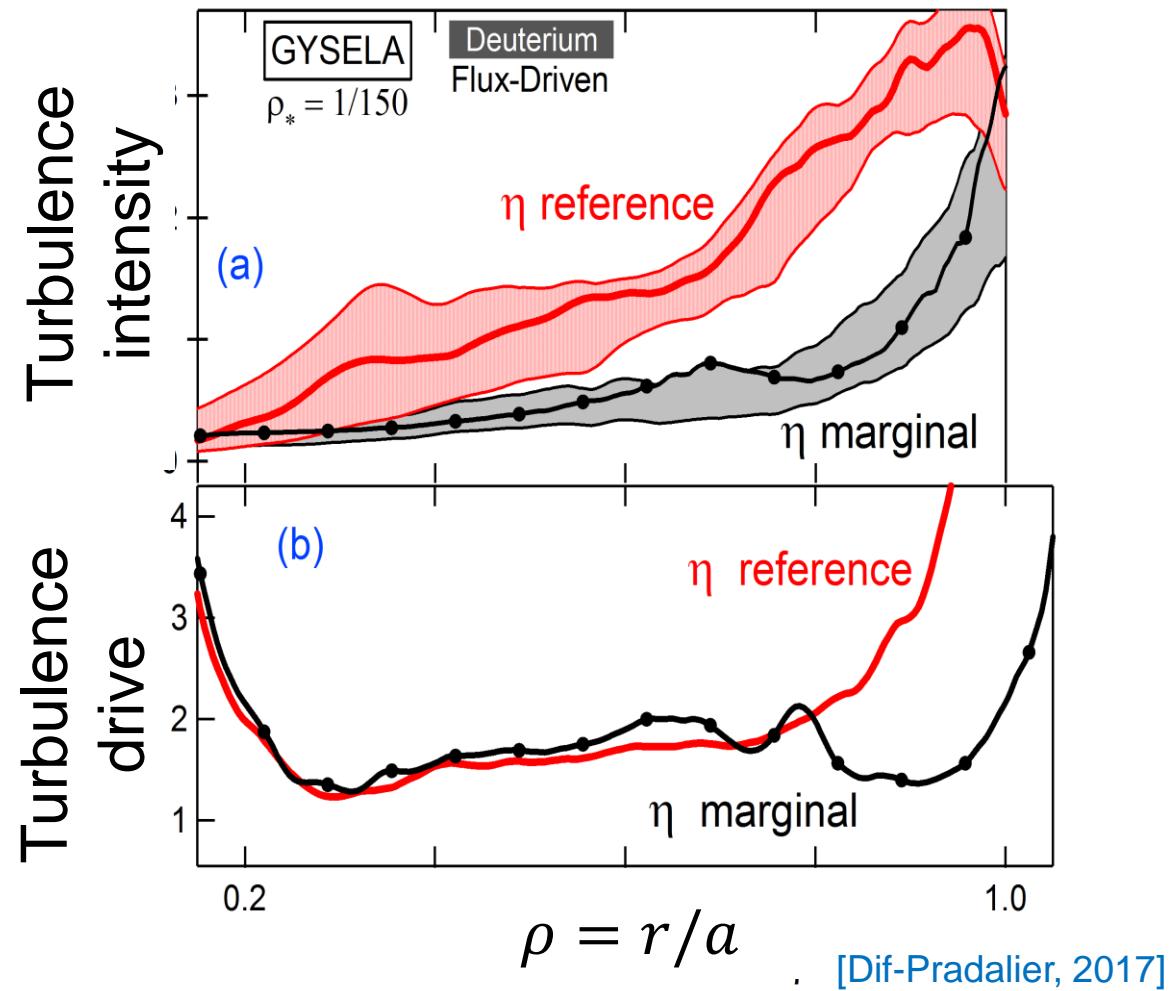
- Many different non-linear phenomena at a time:
Kelvin-Helmholtz, ITG, spreading, flows
- Push towards steady-state boundary layer

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



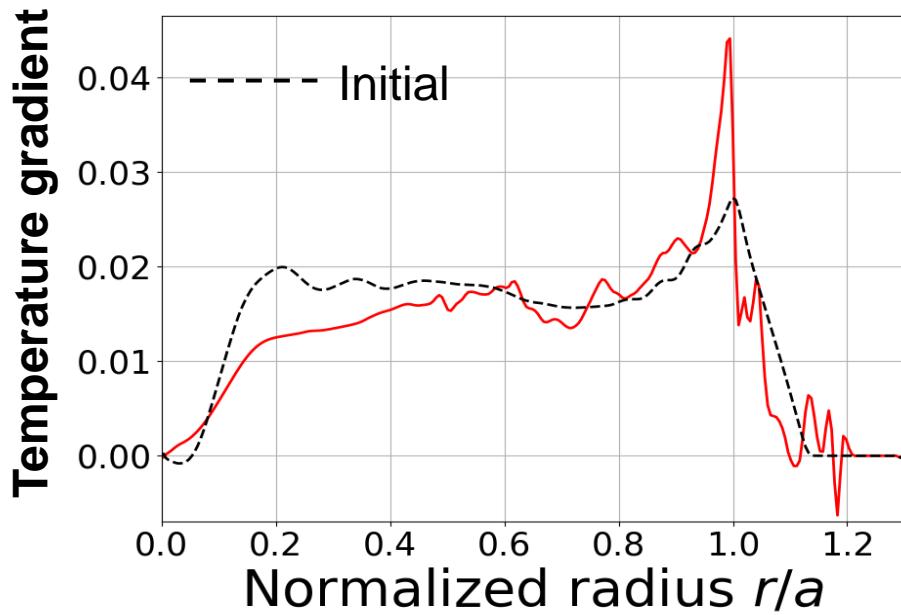
Back-up slides

Evidence of edge-core interplay

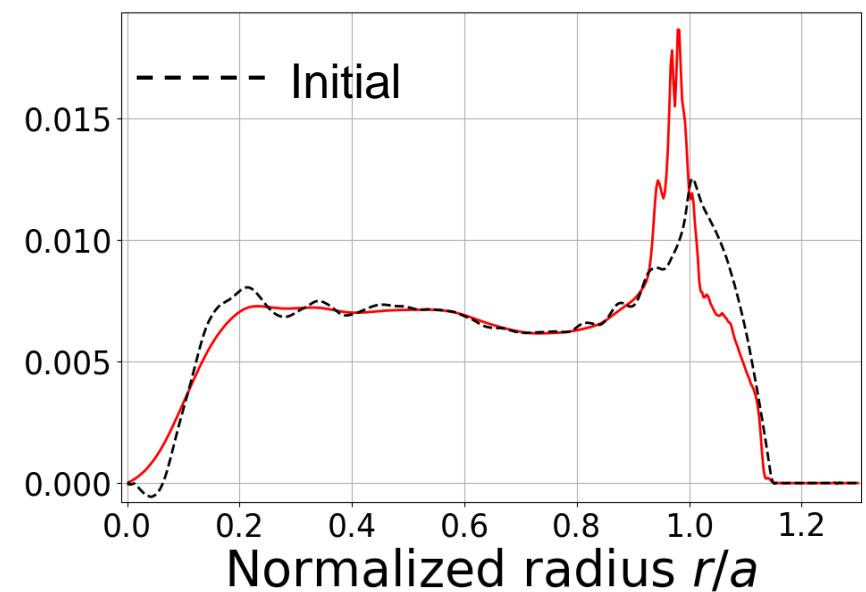


The weak transport barrier depends on core dynamics

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



$$E_r(r > a) = 0$$



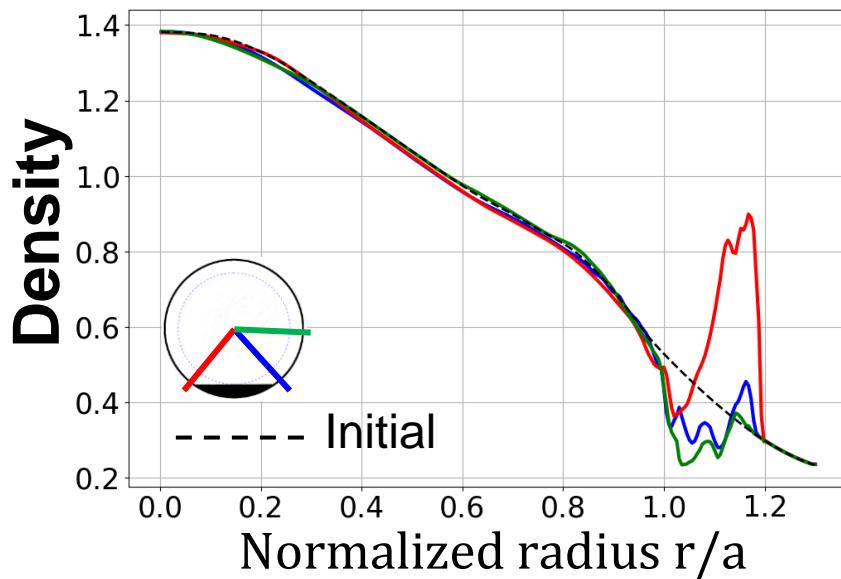
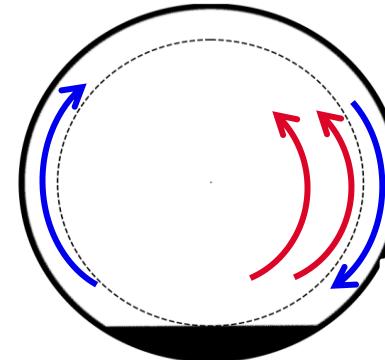
E_r Reversal at separatrix modifies SOL poloidal symmetries

LIMITER brakes the current loop → SOL poloidal asymmetries

SOL Polarization

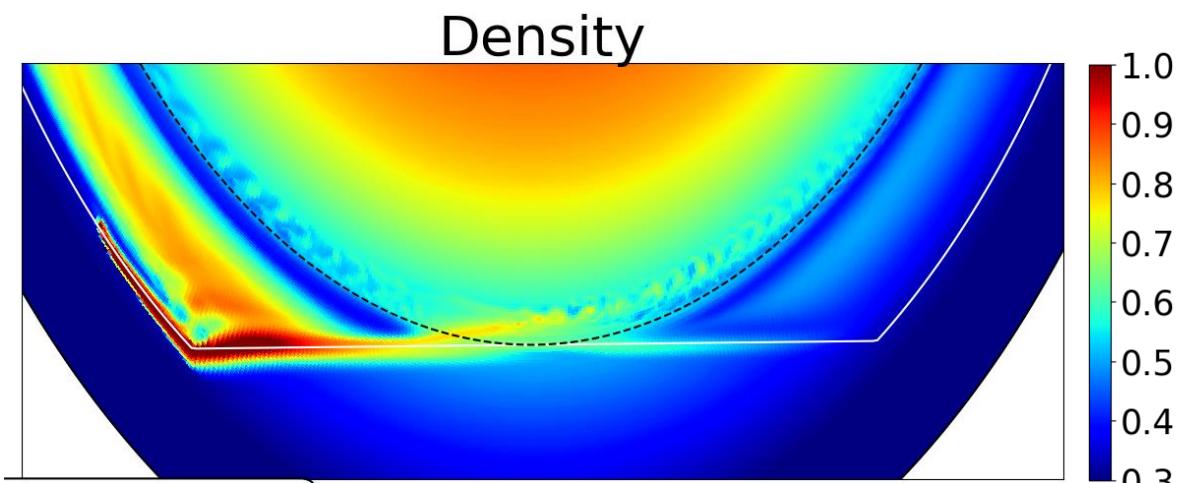
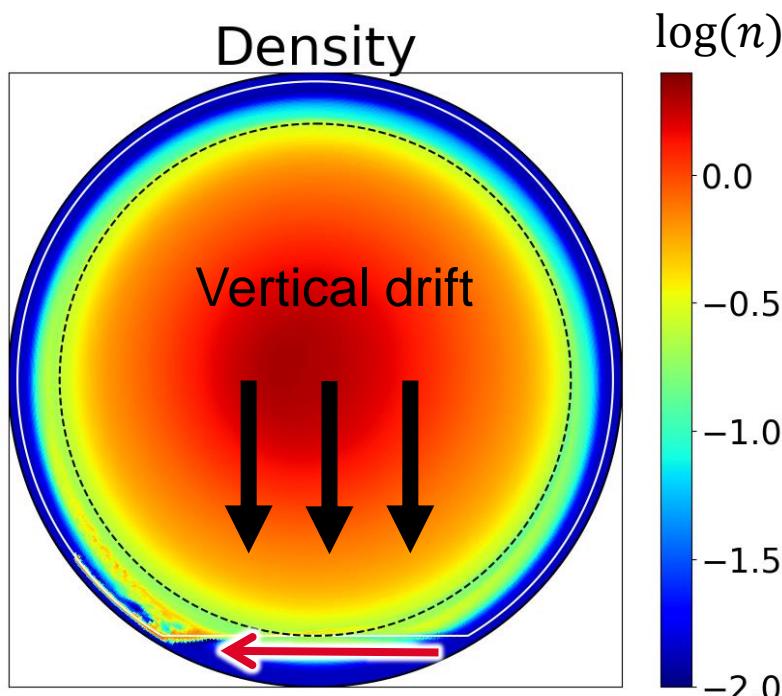
Reversed $E_r \leftrightarrow v_\theta$

Inverse rotation btw core/SOL

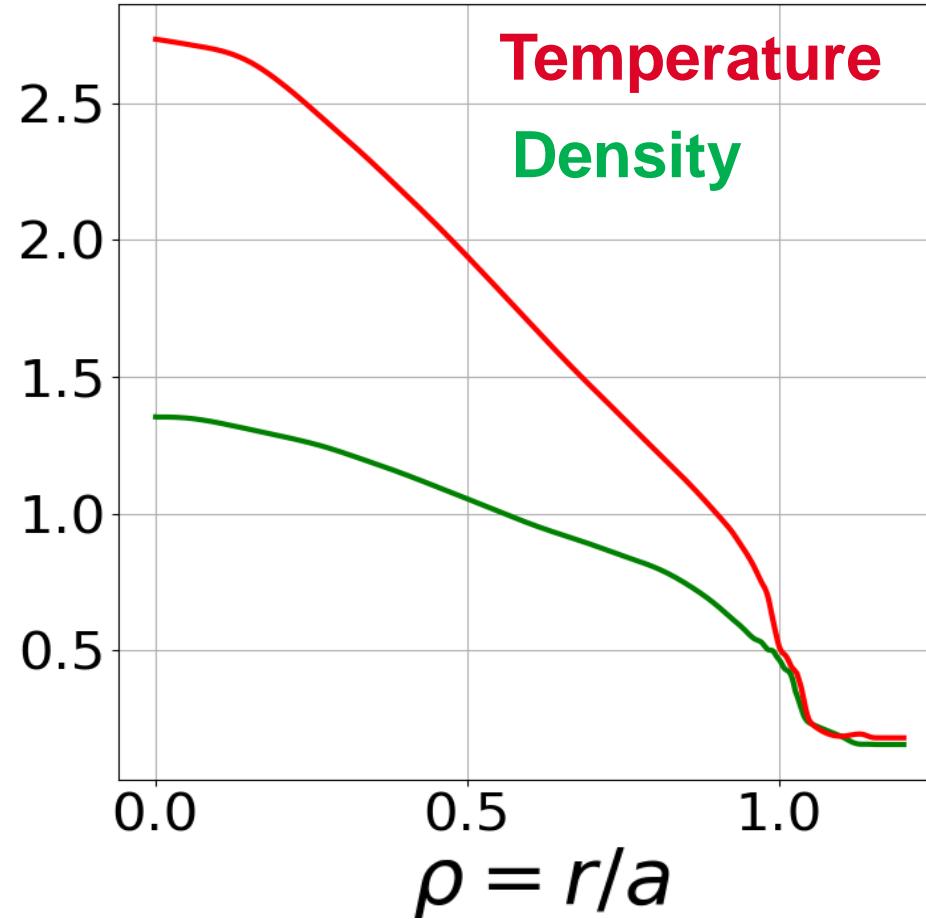


- Vertical drift + SOL flows
- HFS density accumulation
- Barrier at separatrix

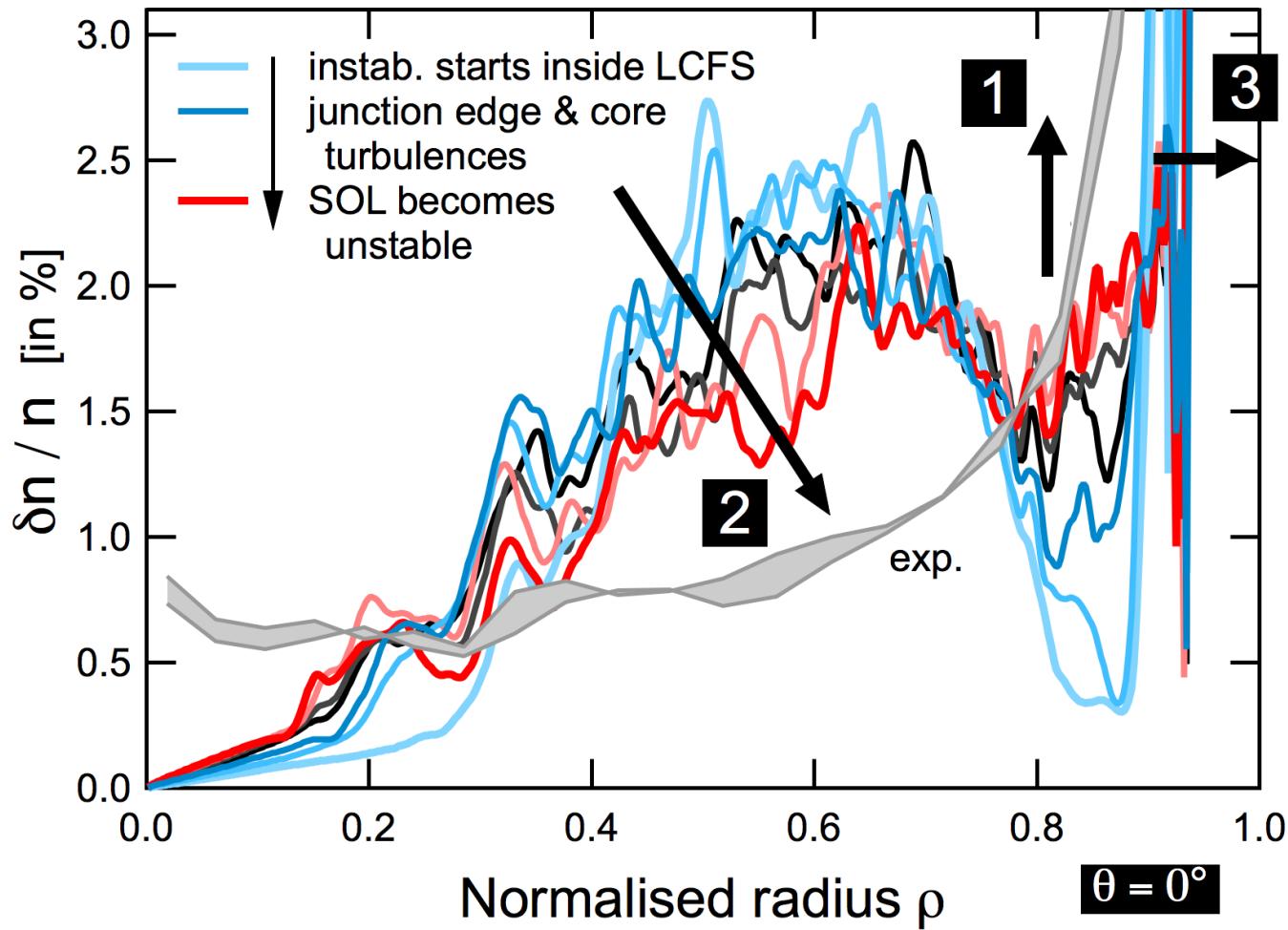
Initial transient in the SOL

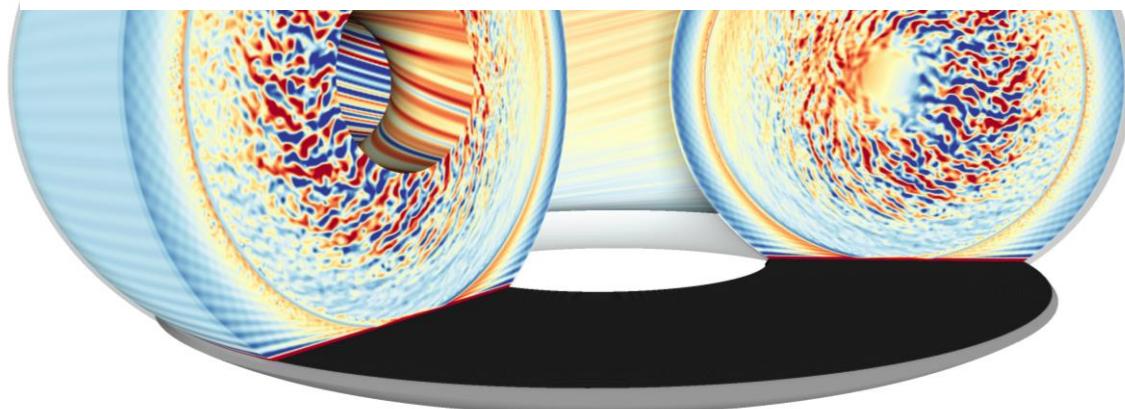
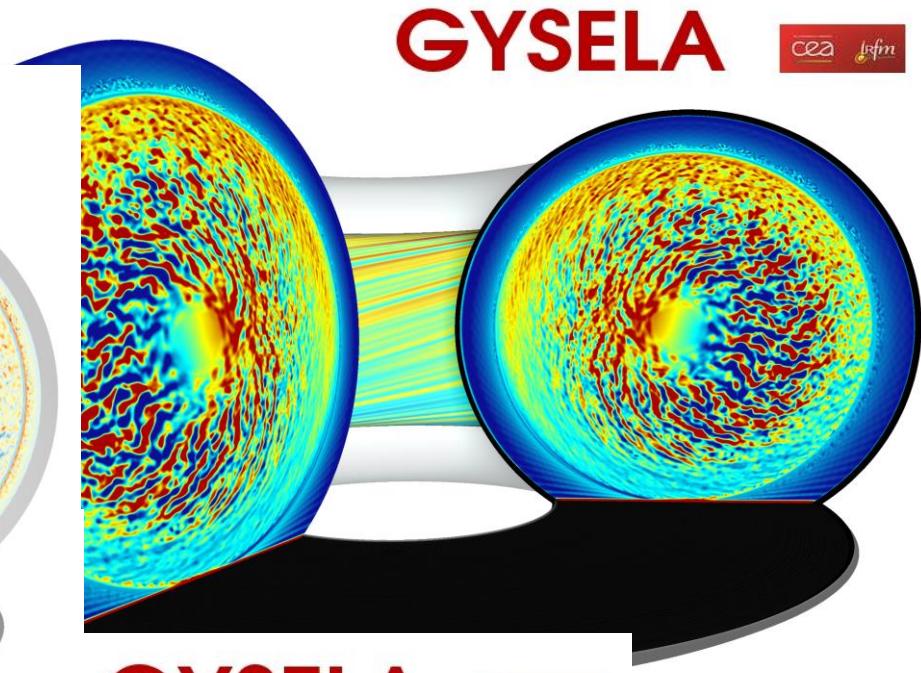
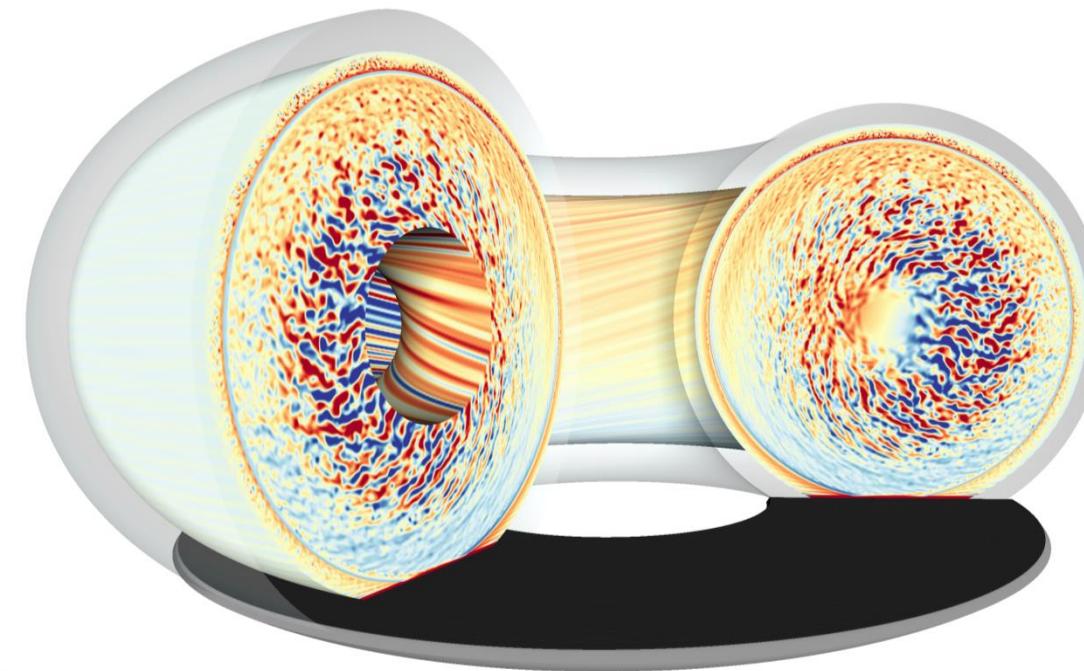


Axisymmetric simulations: barrier on the profiles



Recovering $\delta n/n$ behavior

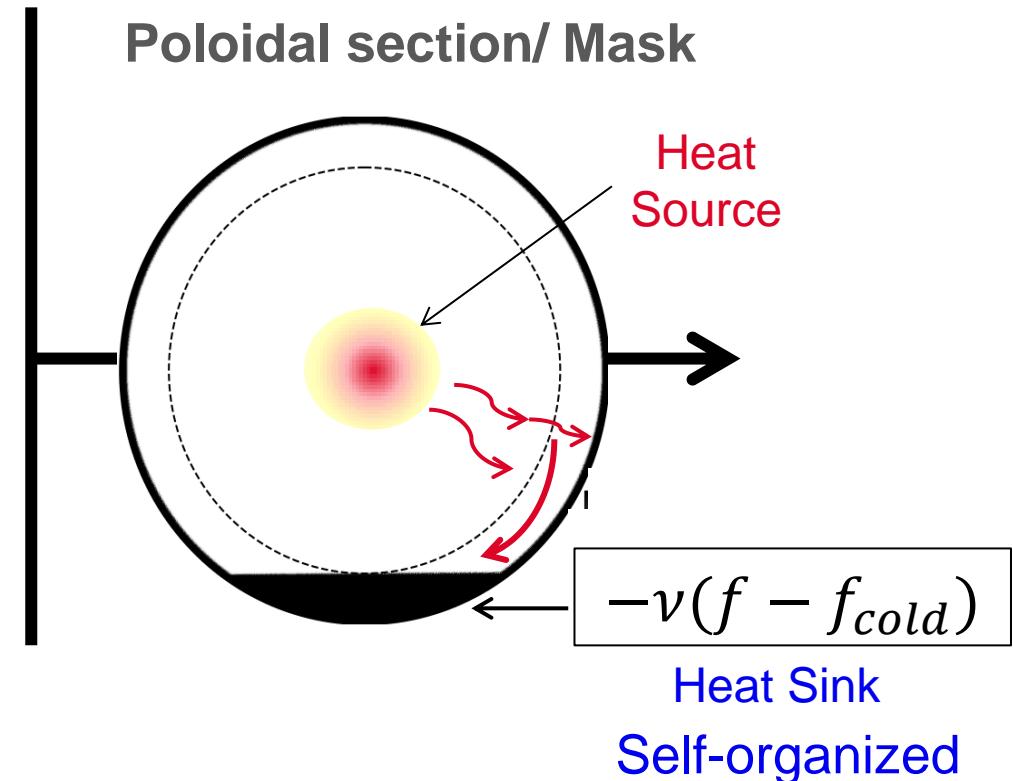




Self-organized heat sink

1. Heat & momentum sink

- Cold immersed boundary
 - Poloidally asymmetric
 - \parallel 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 \perp particle transport

NO recombination

Different SOL equilibrium

Adiabatic electrons

Flux surface averaged profiles

