Impact of X-point geometry and neutrals recycling on edge plasma turbulence

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Bridging mean field and turbulence modelling

- 2 complementary but parallel paths in edge fluid modelling: **mean-field** ("transport") and **turbulence** codes

Code family	Mean-field	3D turbulence
Example codes	SOLEDGE2D SOLPS, EDGE2D, EMC3	TOKAM3X, GBS, BOUT++, GRILLIX
Mean field	✓	✓ (if flux-driven)
Turbulence		✓
3D	(EMC3)	✓
Realistic plasma geom.	✓	
Realistic wall geom.	✓	
Kinetic neutrals	✓	
Multi-species (impur.)	✓	
Drifts	(✓)	✓

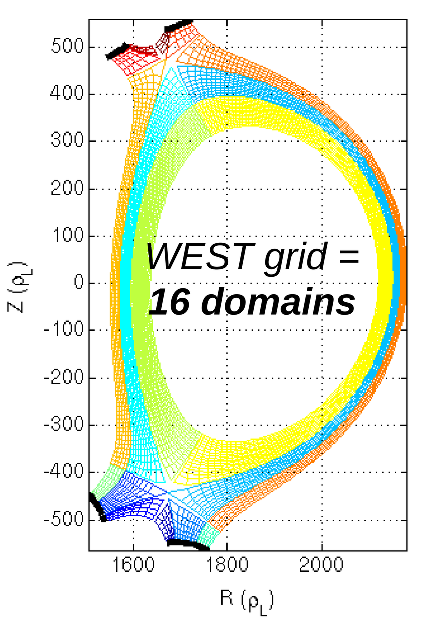
This poster

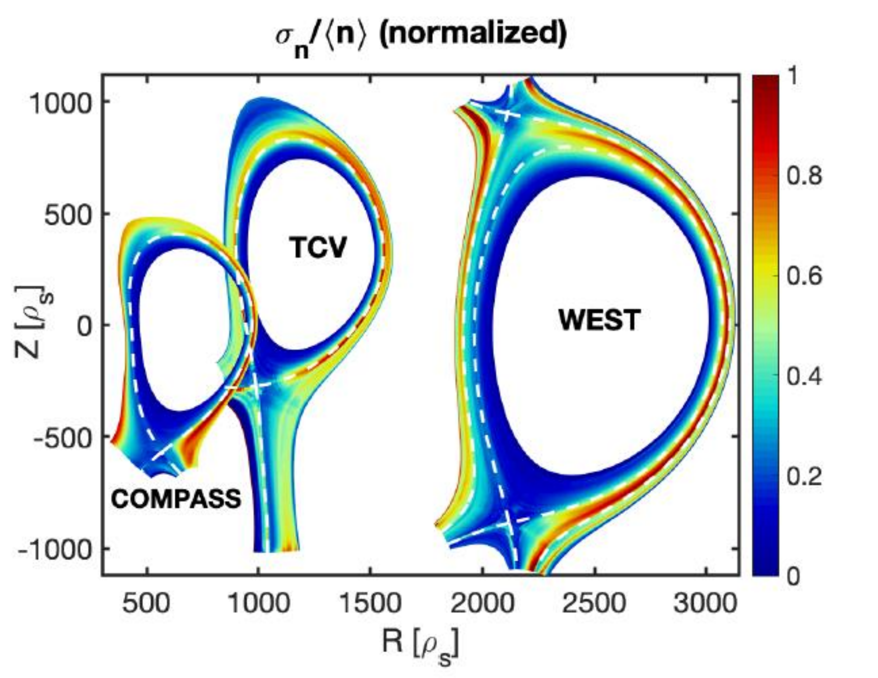
- Experiments: strong interaction between turbulent transport and divertor geometry / density regimes *[T. Eich, EPS2019; A. Wynn, NF2018]*
  - Predictive capabilities possible only with **self-consistent treatment of both facets of physics**

- This presentation: overview of recent results with TOKAM3X code to bridge the gap = **turbulence in X-point geometry** and **with neutrals recycling**
- Parallel effort: new code checking all the above boxes => see **poster 33**

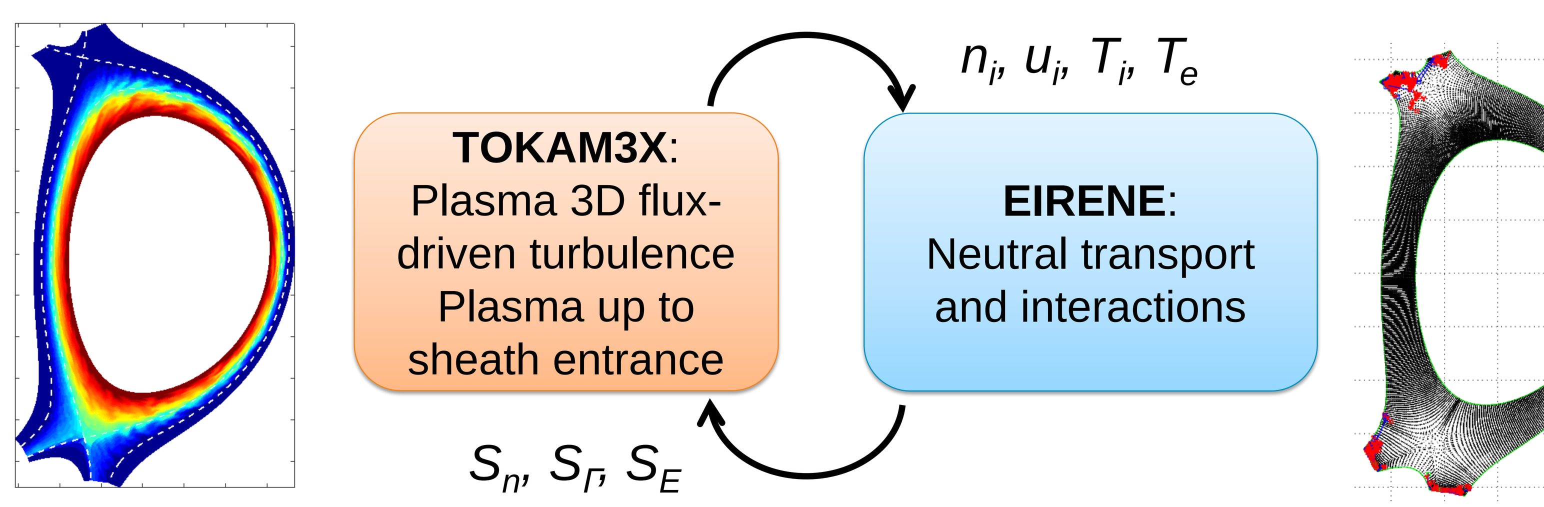
The TOKAM3X-EIRENE code package

- **3D fluid-drift** equations (see attached slides)
  - **arbitrary magnetic geometry** (axisymmetric) made possible by domain decomposition method *[P. Tamain, JCP (2016)]*





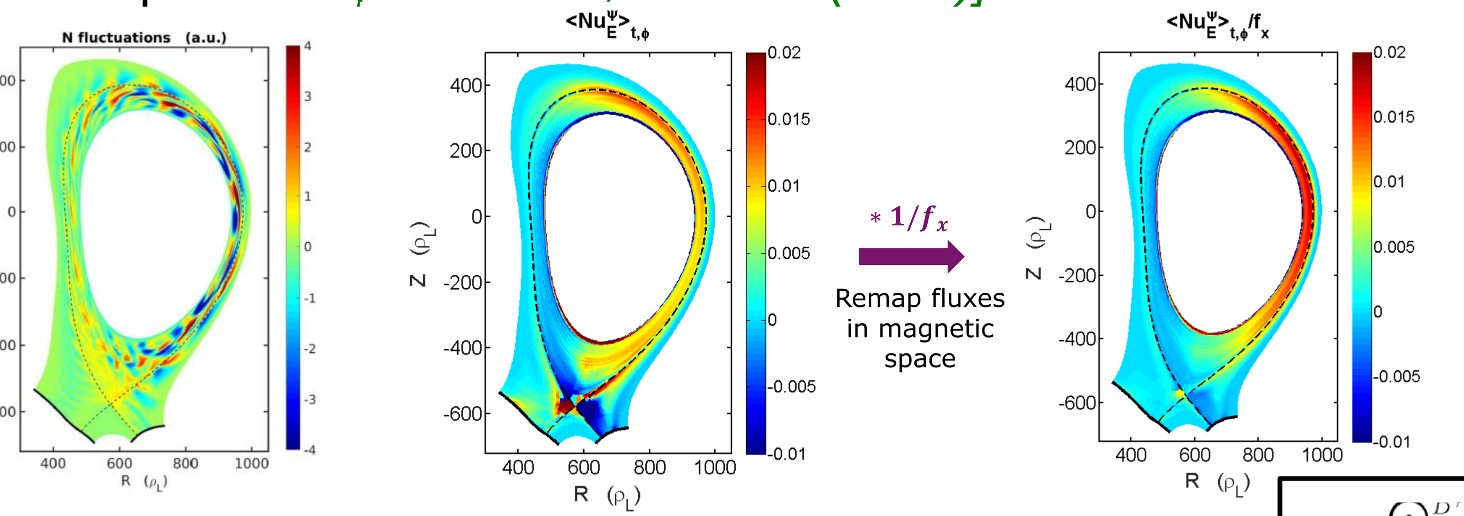
- TOKAM3X **coupled to EIRENE** via same architecture as SOLEDGE2D-EIRENE 2D transport package *[H. Bufferand, NF2015; D.M. Fan, CCP2018]*



Turbulent transport in X-point geometry

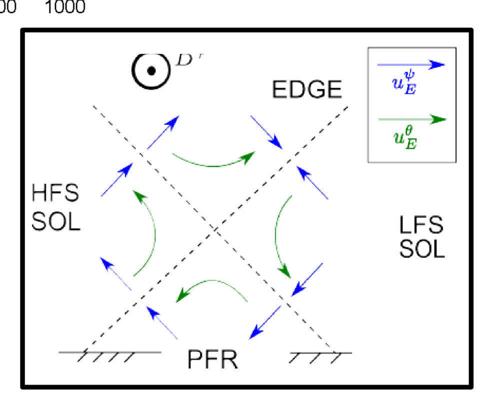
- Key properties of edge **turbulence and flows remain similar to limited plasmas** *[D. Galassi, NF2017]*
  - Large **intermittency and fluctuation level** increasing with r, $k_{//}$**~0**, **ballooning**

- **Shaping (flux expansion) plays important role** in poloidal distribution of transport level *[D. Galassi, NME 12 (2017)]*

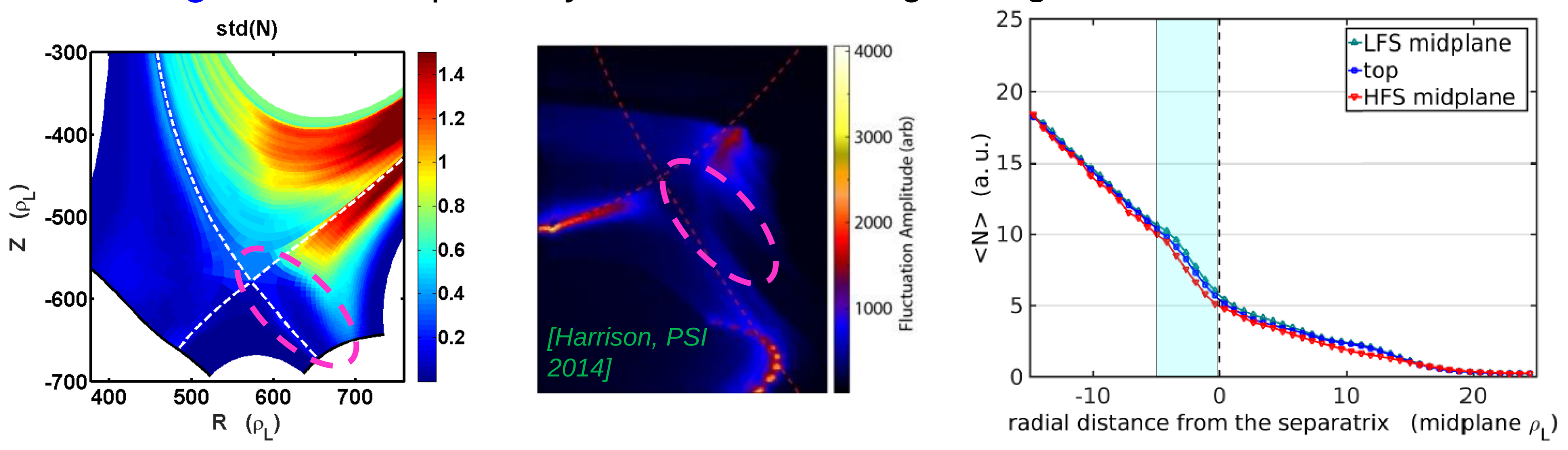


$D_\perp \propto f_x$ or $f_x^{\ 2} \times f_{balloon}$

- Complex **steady ExB flux pattern around X-point** *[D. Galassi, NF2017]*
  - Poloidal shear of radial ExB velocity at X-point as new mechanism for **filament disconnection** identified *[F. Nespoli, submitted to NF]*

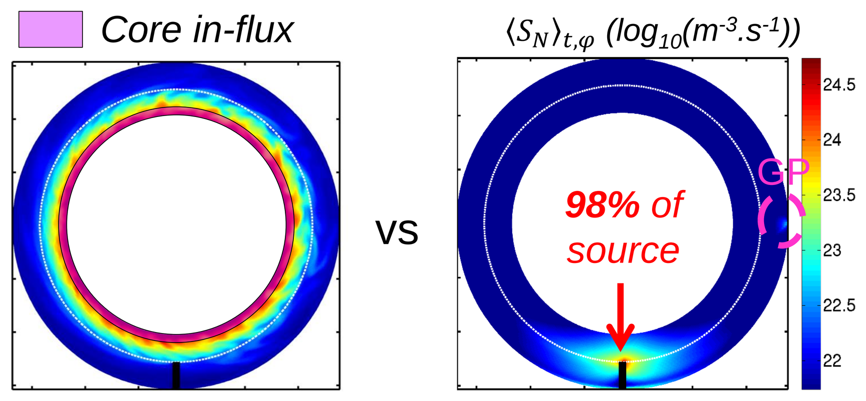


- **Quiescent region** systematically observed in X-point vicinity and along the separatrix *[D. Galassi, Fluids 4 (2019)]*
  - λ_{SOL} **reduced** vs limited simulation
  - mild **edge transport barrier** even upstream
  - **magnetic shear** probably main drive although trong ExB shear also



Turbulence with self-consistent neutrals recycling

- Compare core particle influx with **self-consistent fuelling (GP + recycling)** *[P. Tamain, PSI2018]*



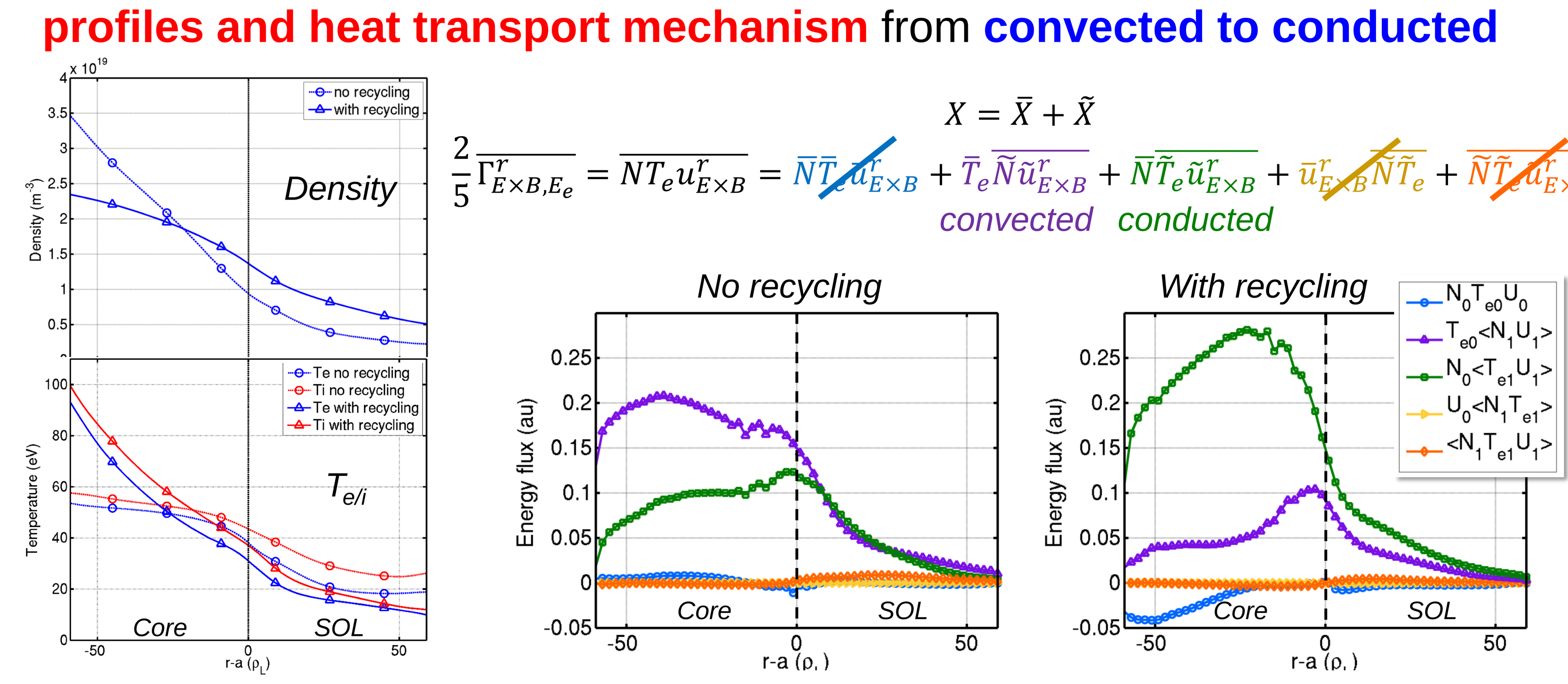
ρ_*	ν_*	$\left(\frac{\nu_{col}}{\omega_c}\right)$	GP (s⁻¹)	P_{heat} (kW)	Wall mat.	R_{rec}
$3.9\cdot10^{-3}$		$5\cdot10^{-2}$	$1.3\cdot10^{20}$	105	Be	0.99

- Change in particle source location leads to major **reorganization of profiles and heat transport mechanism** from **convected to conducted**

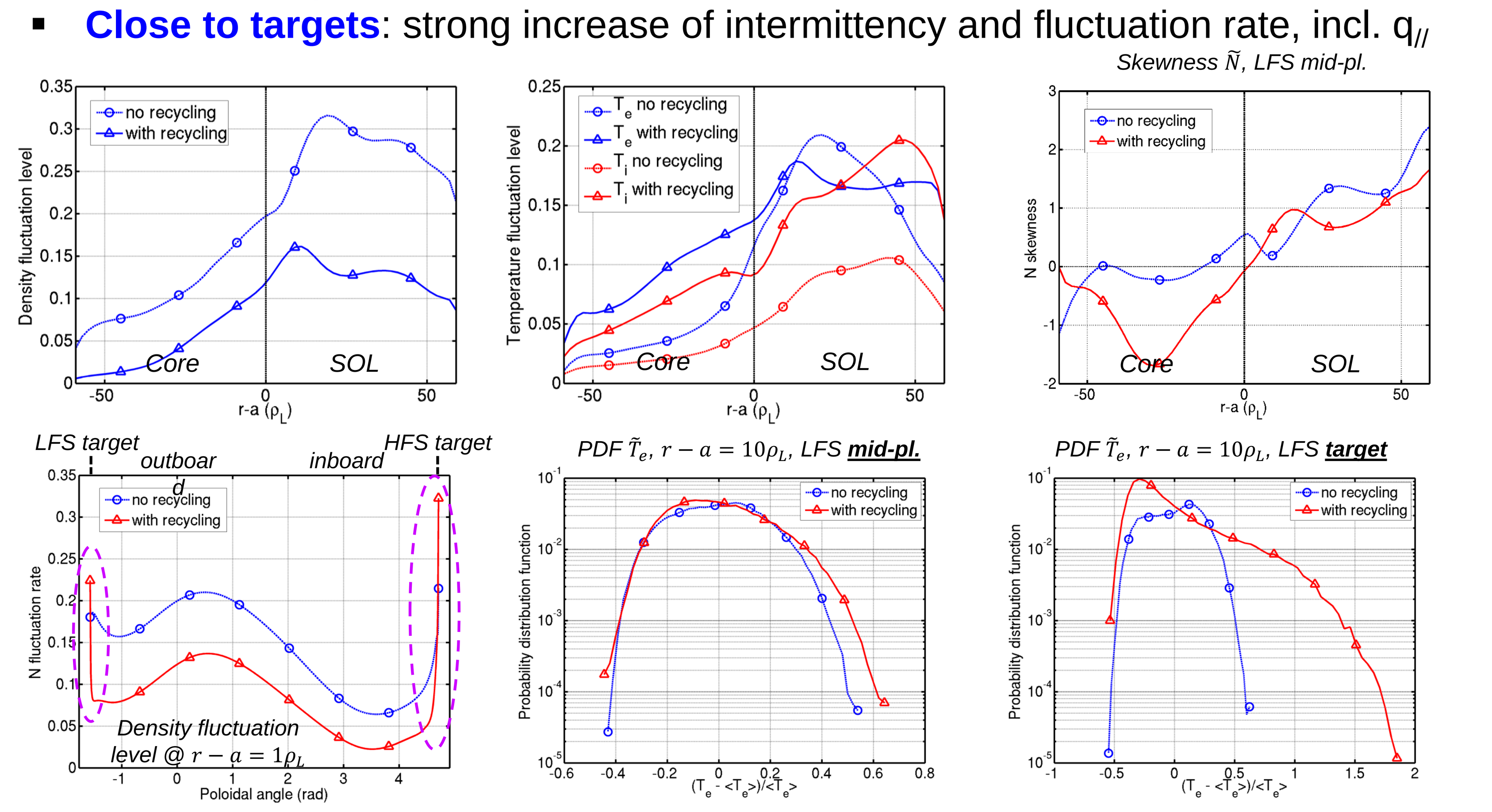
$$X=\bar{X}+\tilde{X}$$

$$\frac{2}{5}\overline{\Gamma^r_{E\times B,E_e}}=\overline{NT_e u^r_{E\times B}}=\bar{N}\bar{T}_e\bar{u}^r_{E\times B}+\bar{T}_e\overline{\tilde{N}\tilde{u}^r_{E\times B}}+\bar{N}\overline{\tilde{T}_e\tilde{u}^r_{E\times B}}+\bar{u}^r_{E\times B}\overline{\tilde{N}\tilde{T}_e}+\overline{\tilde{N}\tilde{T}_e\tilde{u}^r_{E\times B}}$$

convected conducted

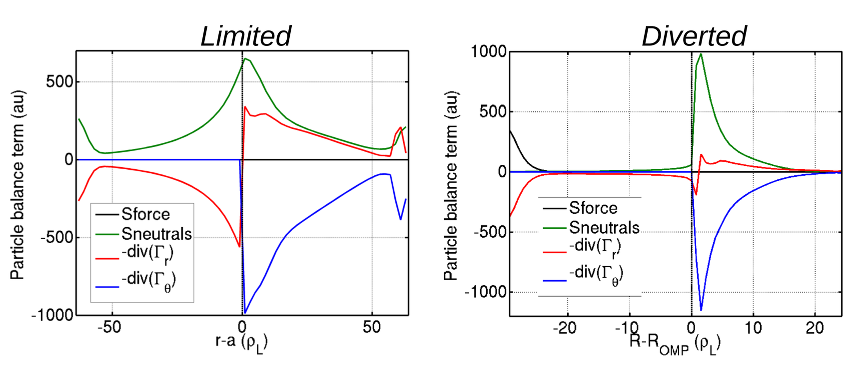


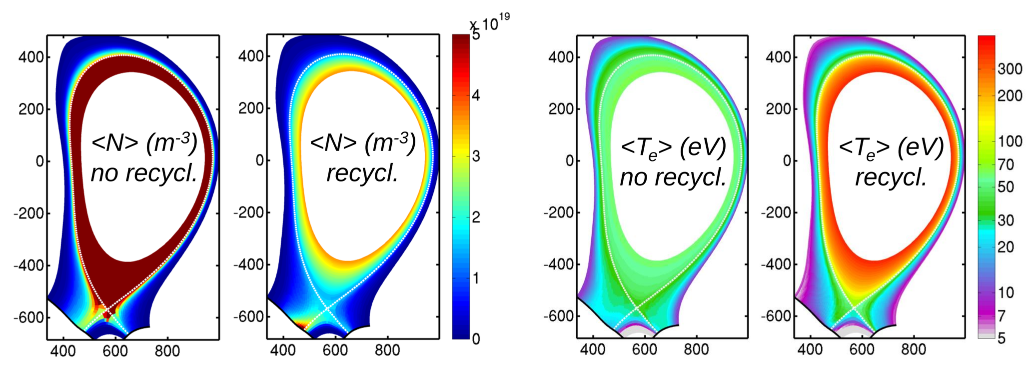
- Response of **turbulence very dependent on poloidal position**
  - **Far from targets**: drop of $\tilde{N}$, increase of $\tilde{T}$, intermittency and structure unchanged
  - **Close to targets**: strong increase of intermittency and fluctuation rate, incl. $q_{//}$

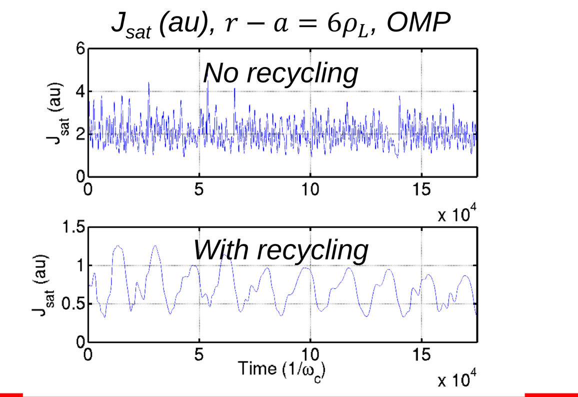


X-point turbulent simulation with neutrals?

- X-point geometry enhances source relocation effect
- Turbulence regime strongly impacted
  - Intermittency replaced by **quasi-coherent mode**
  - **Relevance** of new regime?







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