Max-Planck-Institut für Plasmaphysik

Turbulent transport in the Scrape-Off Layer of Wendelstein 7-X

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Motivation

- anomalous cross-field transport in the SOL is widely assumed to be turbulent
- self-consistent interplay of turbulent transport and profile shape in the SOL → expect $\Gamma_r \sim \nabla p$ (if turbulence is driven by local gradients, i.e. no turbulence spreading

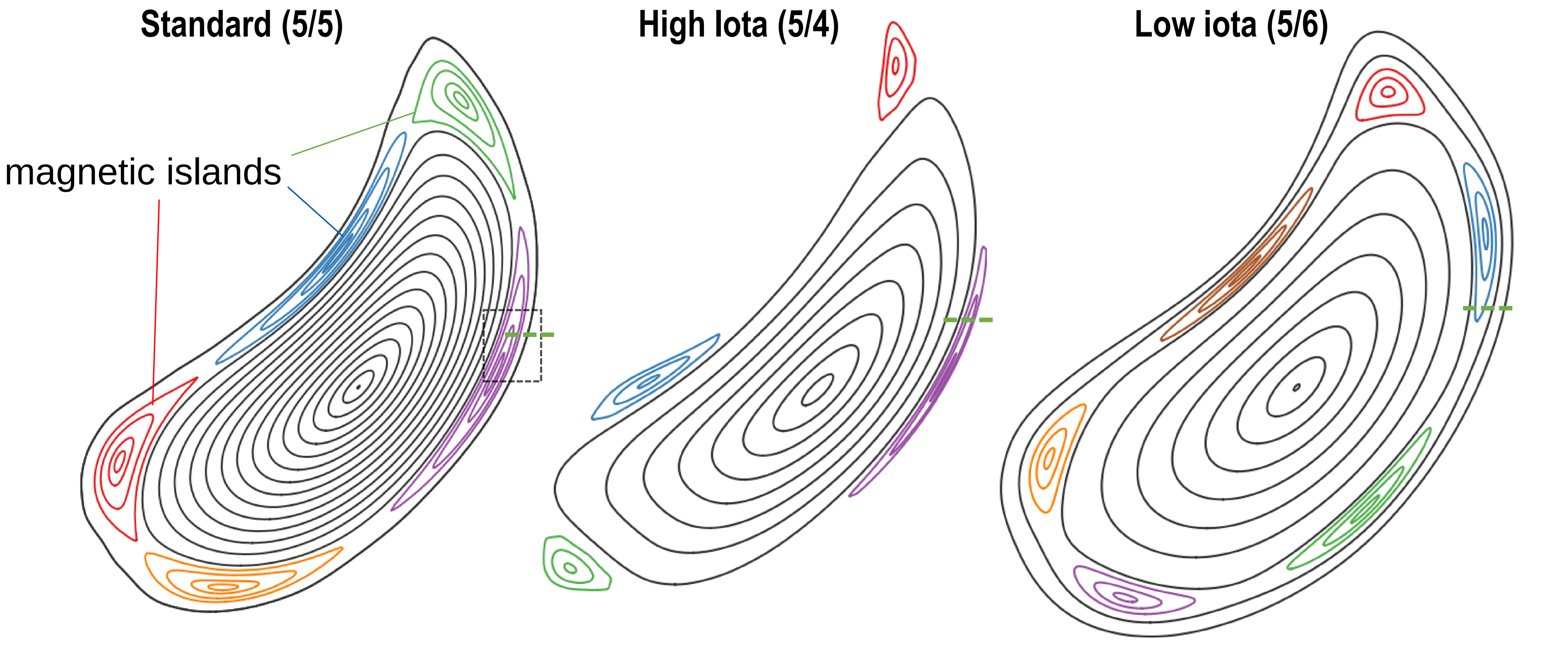
Experimental approach

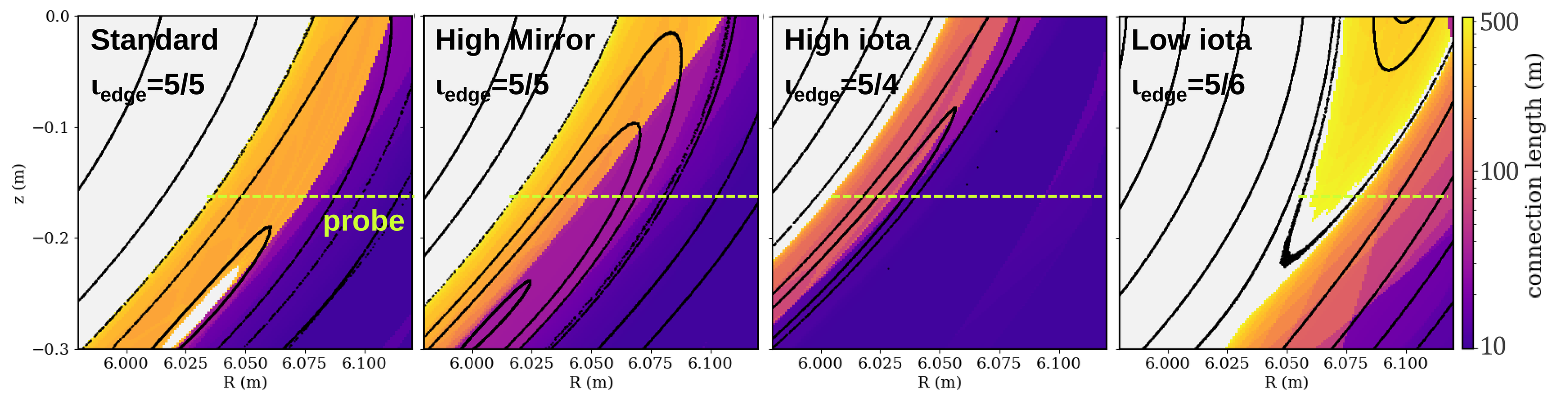
- Reciprocating Langmuir probe measurements in the W7-X SOL → T_e, n profiles
- poloidal array of I_{sat}, V_{fl} pin → $\Gamma_r = \tilde{n}\,\tilde{v}_r = \tilde{n}\,\tilde{E}_{pol}/B$

Main results

- generally: $\Gamma_r \sim \nabla p$ holds radially across the SOL, over a wide range of magnetic configurations, plasma scenarios → turbulent transport is driven by local gradients
- exception: in magnetic islands, plasma profiles can be flattened and or 3D. Here, $\Gamma_r \sim \nabla p$ does **not** hold → indicates additional transport processes

Reciprocating probe in the SOL of W7-X

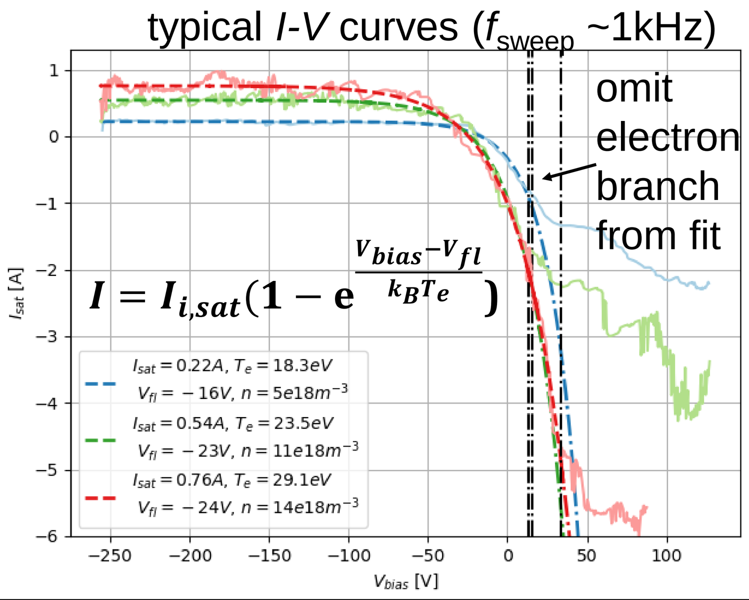


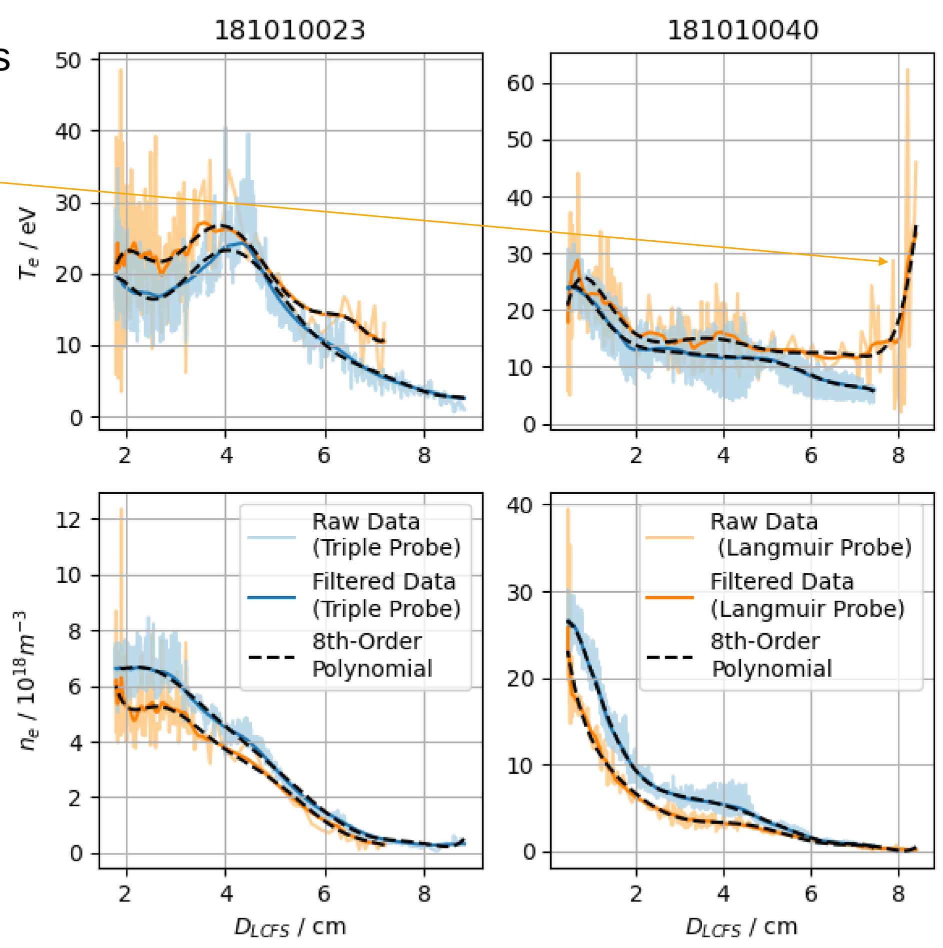


SOL Profiles from Langmuir probes

- compare classic swept and triple probes
- generally good agreement, but swept probe unreliable in far SOL
  → use triple probe, smoothed by polynomial fit, for further analysis

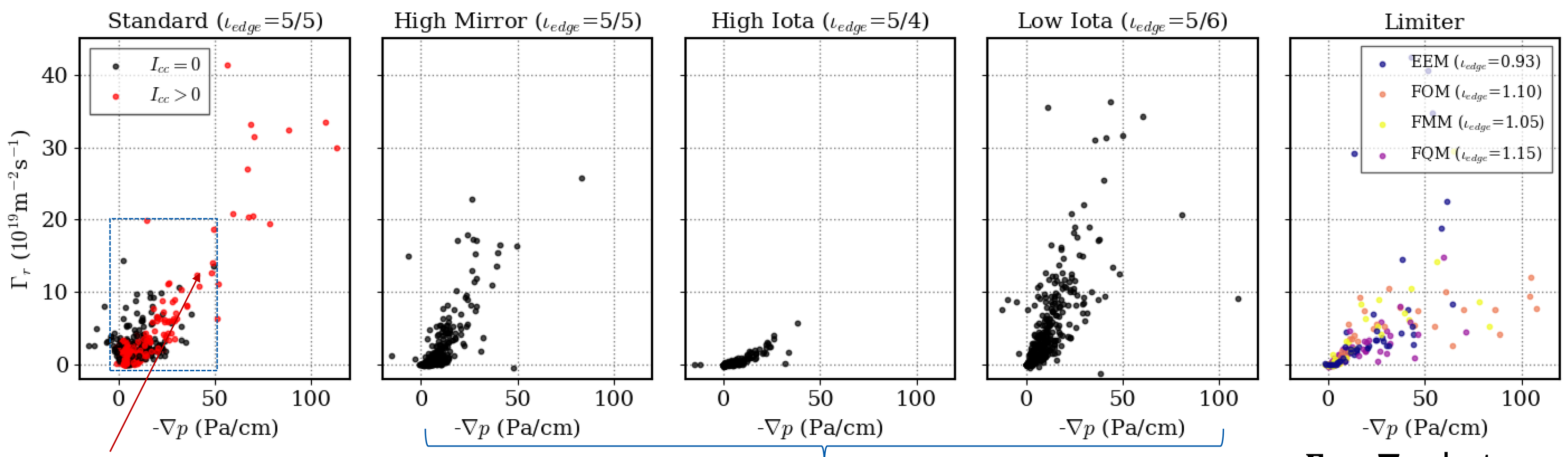
typical *I-V* curves (f_{sweep} ~1kHz)





Flux-gradient relation (Γ_r vs ∇p) in the W7-X SOL

- data base: >200 measurements in >100 plasma programs, including different magnetic configurations and plasma conditions (P_{ECRH}=[1-6]MW, n_{dl}=[2-12]e19m^{-2})
- sliced into 5ms segments (probe can be considered approximately stationary)



only I_{cc}>0 (*control coils manipulate island size*) data appears linear

good agreement with linear relation Γ_r vs ∇p, but slope depends on magnetic configuration

$\Gamma_r \sim \nabla p$, but exact relation unclear (few data points)

→ $\Gamma_r \sim \nabla p$ holds mostly, but magnetic configuration (even island size)seems to play a role

→ investigate possible role of connection lengths, which depends on configuration

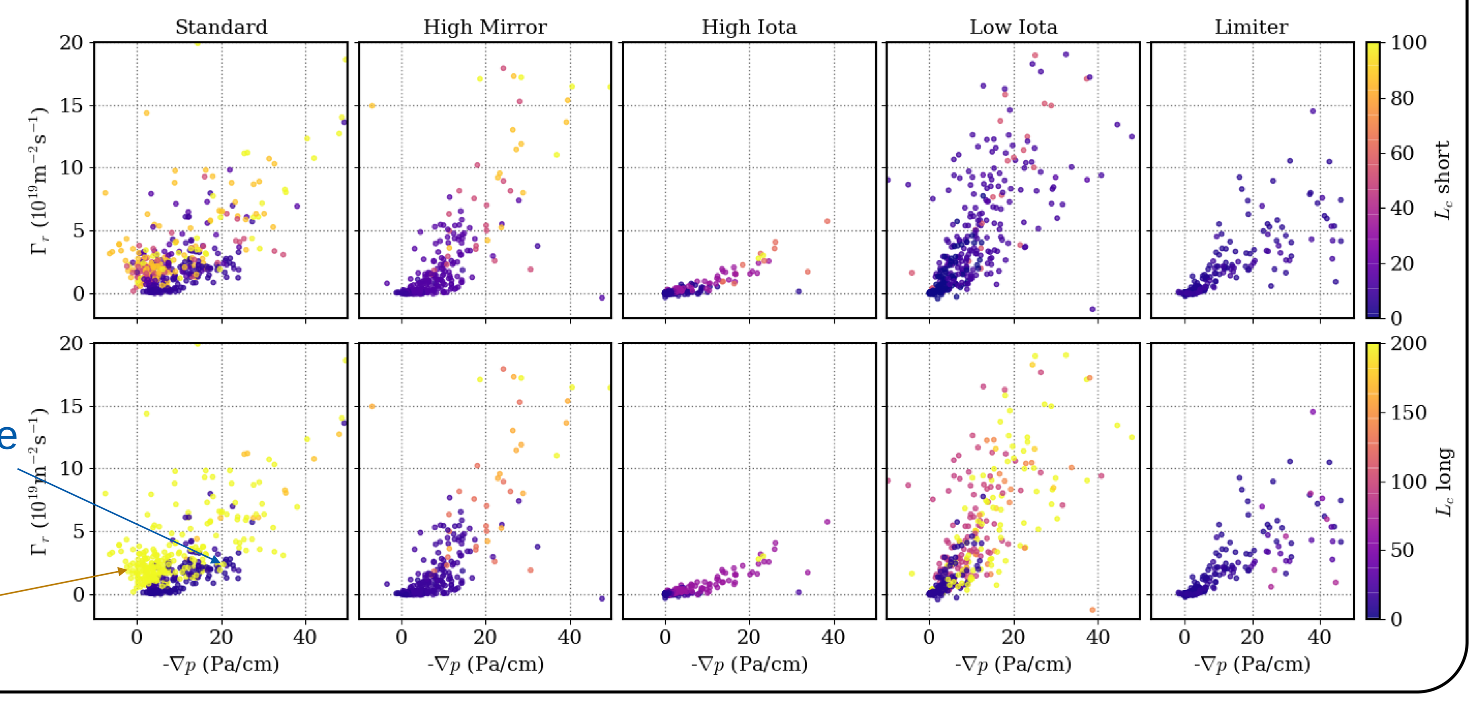
same data as above, but L_c color coded, smaller axis limits

no clear relation of L_c to Γ_r vs ∇p scaling

except:

short L_c data appears more linear

long L_c data has more scatter



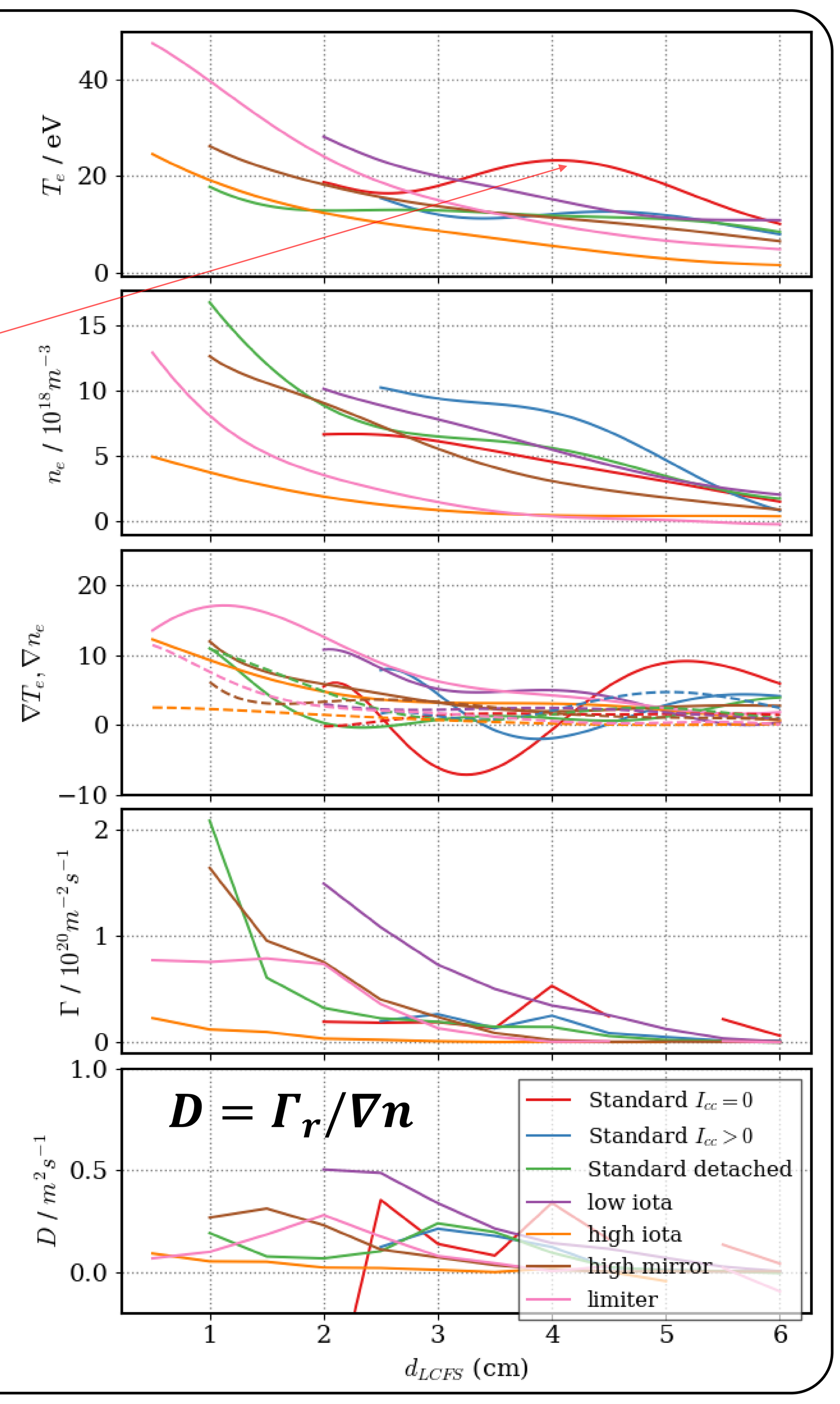
Typical SOL profiles

- one profile for each magnetic configuration (not identical heating / fuelling scenarios)
- flattening / local peak in T_e,n profiles in standard configuration
  → aligns with the transition between short and long L_c part of the island

Turbulent transport as diffusive process

- for modeling purposes, turbulent transport is often considered as a diffusive process $D = \Gamma_r/\nabla n$
- here: D=[0.1-0.5] m^2/s

→ this is relatively small compared to typical EMC3-EIRENE simulations, which assume D=[0.5-1.5] m^2/s

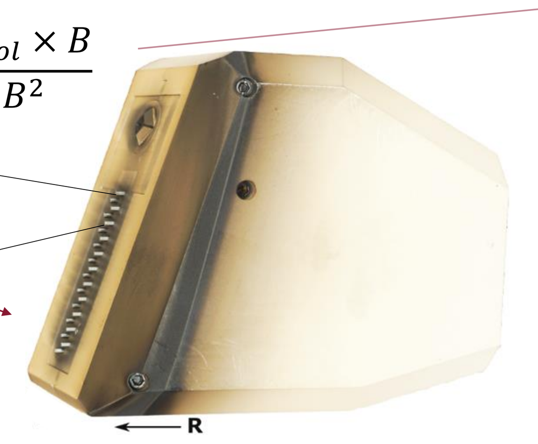


Fluctuation analysis

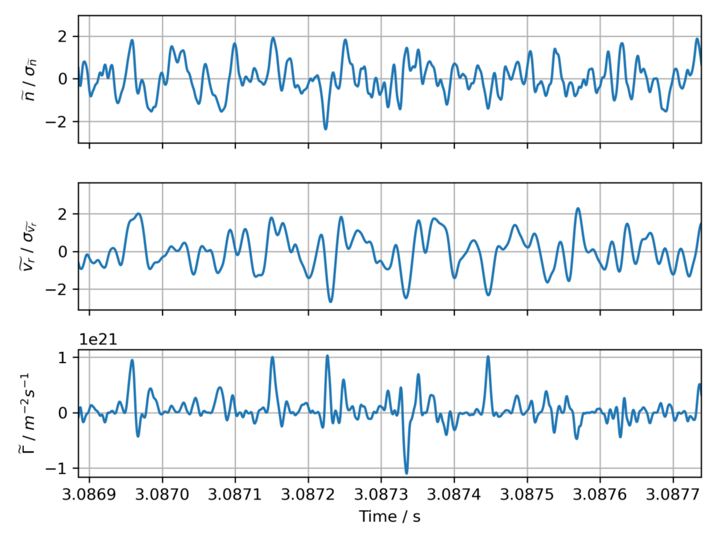
- poloidal probe array including swept, triple, I_{sat}, V_{fl} probes

$$E_{pol} = -\frac{\phi_{f,1} - \phi_{f,2}}{d_{pins}}$$

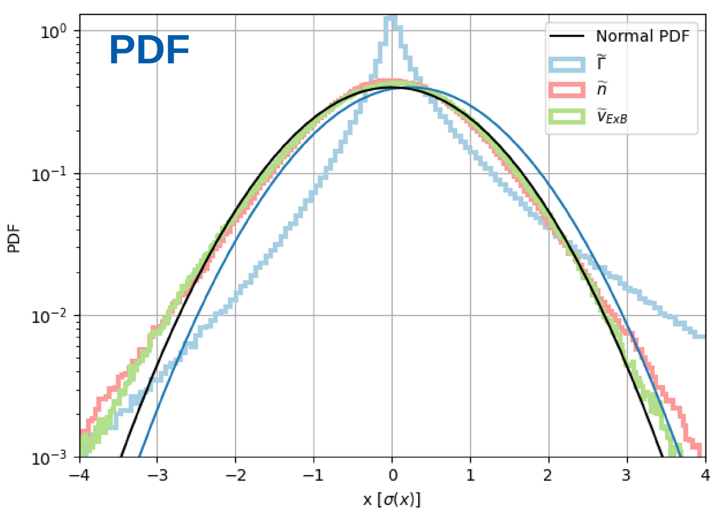
$$v_r = \frac{E_{pol} \times B}{B^2}$$



typical time traces, band-pass filter from (5-50) kHz



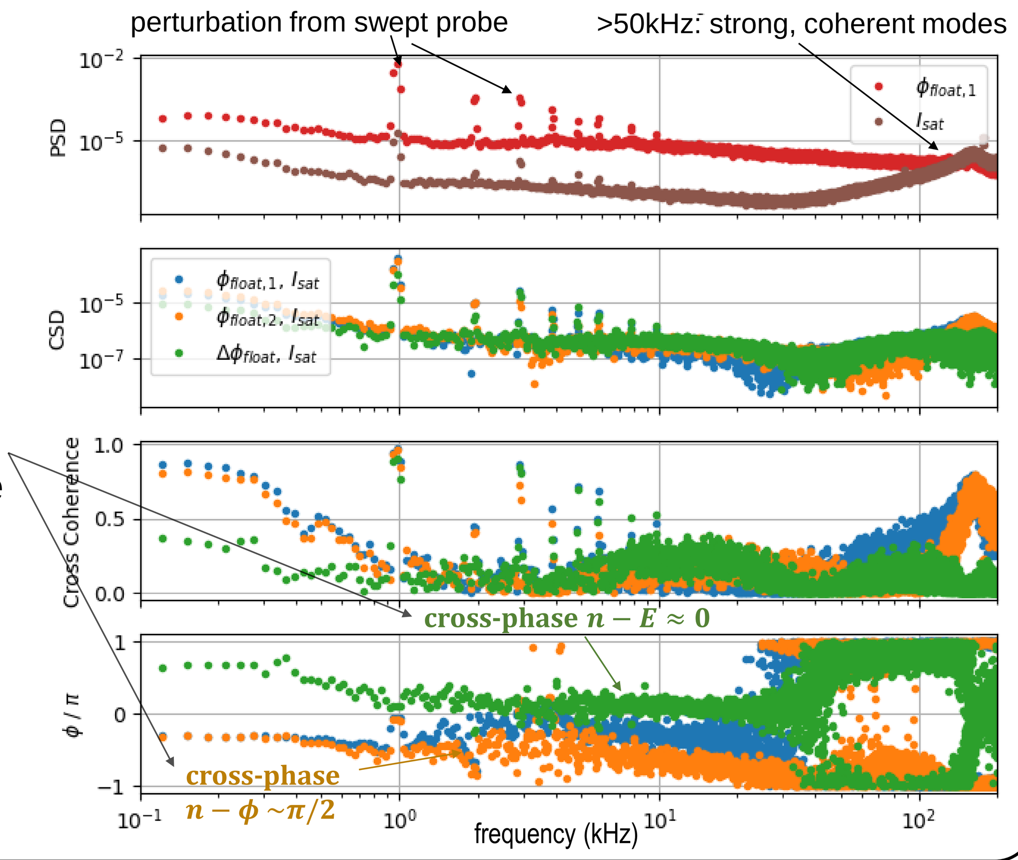
$$\Gamma_r = \tilde{n}\tilde{v}_r = \tilde{n}\tilde{E}_{pol}/B$$



fluctuations agree with interchange character

	σ	mean	skew-ness	(excess) kurtosis
Γ_r	4.45 m^{-2}s^{-1}	1.04 σ	2.04	16.47
n	0.84 e18 m^{-3}	0	-0.09	1.36
v_r	479 m/s	0	-0.10	0.49

- n and v_r close to normal distribution
- Γ_r is due to cross-phase n - v_r



[C. Killer et al. NF 2019 / C. Killer et al. PPCF 2020]

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