# Experimental characterization of edge turbulence on the COMPASS tokamak

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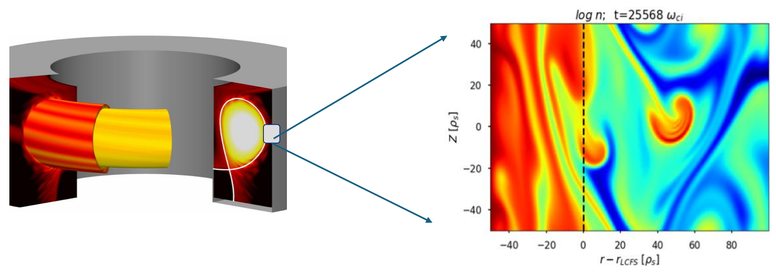
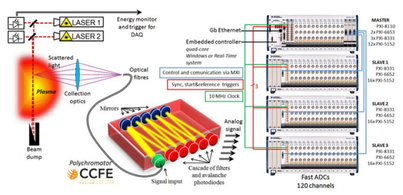
## Motivation

Edge turbulence is one of the major challenges in magnetic confinement fusion. It drives particle and heat transport, affecting plasma confinement and heat loads. Turbulent transport in the edge is dominated by intermittent filamentary structures (**blobs**). Understanding better parallel transport of blobs from midplane to divertor is **required** for a fully predictive capability for tokamak divertor performance.

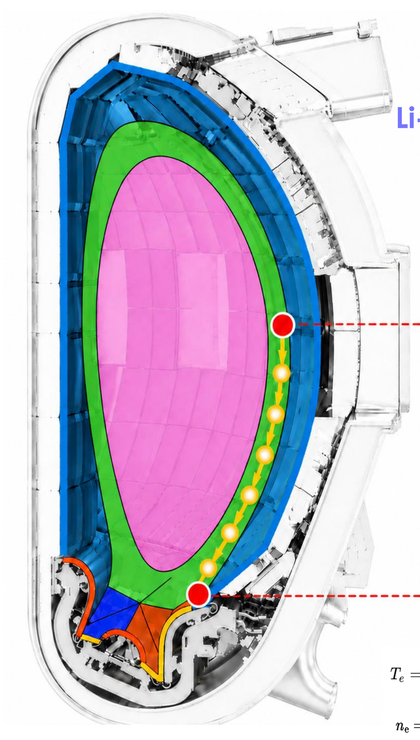



## Introduction to blobs

### Thomson scattering




### TOP VIEW

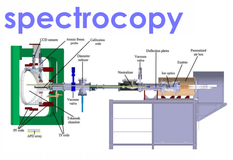


(Not an illustration of the COMPASS tokamak)

### Meet the blobs

- Blobs = edge (SOL) turbulence
- Hot and dense filaments moving radially outward due to ExB drift, giving rise to the plasma fluctuations
- Dominant transport at SOL in L-mode
- Play role in degradation of plasma confinement, heat loads, plasma-wall interactions, L-H transitions

### Li-Beam emission spectrocopy



### Reciprocating probe


**UNIQUE COMPASS DATASET:**
**SIMULTANEOUS µs SCALE FLUCTUATION MEASUREMENTS on midplane and divertor**

### MIDPLANE

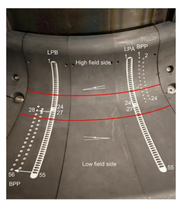
### Two-point model

- Correct systematic error from EFIT reconstruction
- Matching TS, div. and RCP probes
- Particle, pressure and power balance assumed

$$2n_tT_t = n_uT_u$$
$$T_u^{7/2} = T_t^{7/2} + \frac{7}{2}\frac{q_{\parallel}L}{\kappa_{0e}}$$
$$q_{\parallel} = \gamma n_t k T_t c_{st}$$

### DIVERTOR

$$T_e = \frac{\Phi - V_{fl}}{\alpha}$$
$$n_e = \frac{I_{sat}^i}{eA_{\mathrm{eff}}c_s}$$
$$q_{II} = \gamma I_{sat,corr} T_e / S_{probes}$$

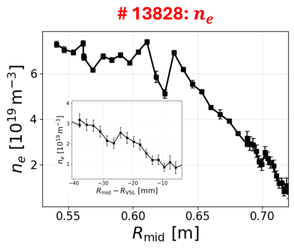



### Measurements

**TS**: $n_e$, $T_e$ profiles
**LP**: fluct. of $T_e, V_p, I_{sat}, V_{fl}, n_e$
**BPP**: fluct. of $T_e, V_p, I_{sat}, V_{fl}, q_{II}, n_e$
**Li-BES**: fluct. of light

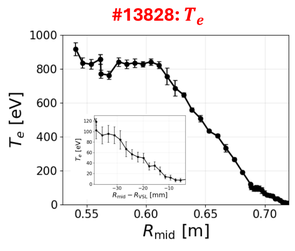
## Radial profiles

#13828: $n_e$




- $n_e$ and $T_e$ profiles from TS diagnostics
- Edge region is better resolved than the core
- Used in two-point model for matching diagnostics in $T_e$ and $P_e$ to find EFIT shift

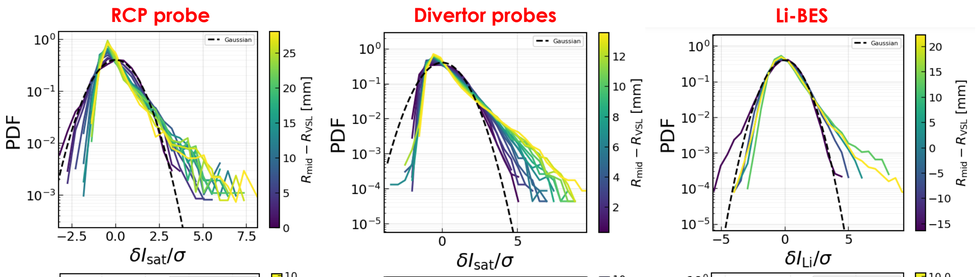
#13828: $T_e$



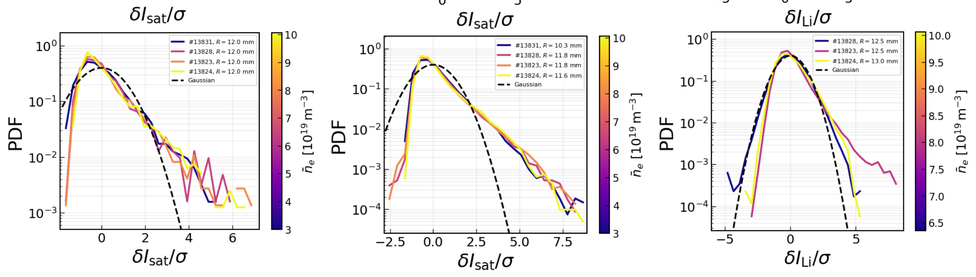

## Probability density functions

RCP probe | Divertor probes | Li-BES

**Radial scan** $n_e = 8 \cdot 10^{19} m^{-3}$ **#13823**



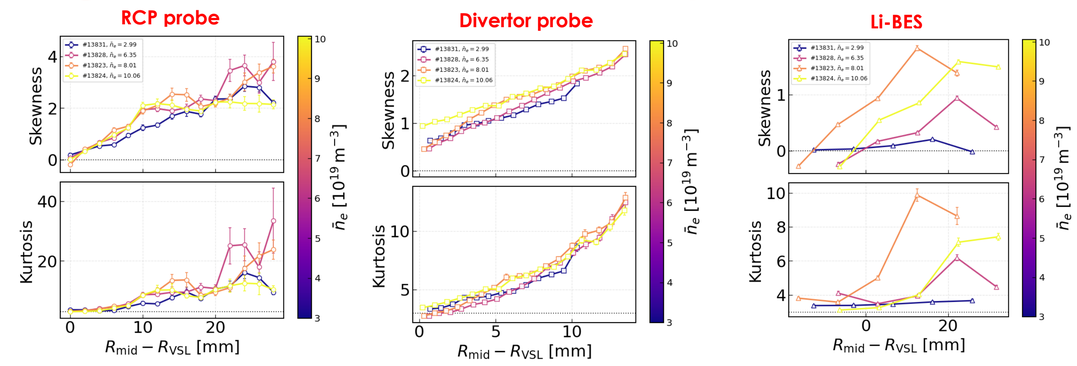

**Density scan** $\delta R = 12mm$



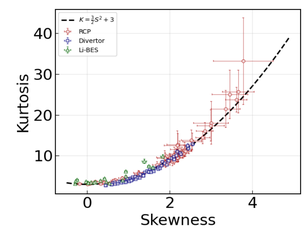

- **PDFs become increasingly Gamma-like toward the far SOL**, consistent with enhanced blob intermittency, **including on the divertor**
- Divertor and RCP measurements capture this behavior most clearly, whereas Li-BES shows reduced blob sensitivity.
- Intermittency depends more strongly on radial position than on density.

## Higher statistical moments and parabolic relation

RCP probe | Divertor probe | Li-BES



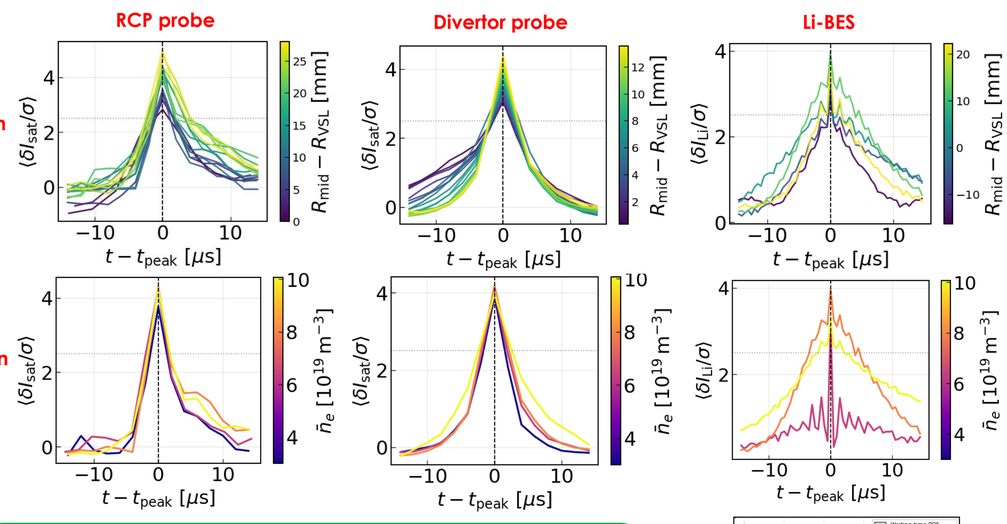

- Skewness and kurtosis increase radially for all three diagnostics, indicating stronger blob intermittency in the far SOL.
- RCP and **divertor measurements follow the Poisson-process $K$-$S$ scaling**, whereas Li-BES shows larger scatter and reduced sensitivity to intermittent events.
- **Radial position is a stronger parameter of intermittency than density.**



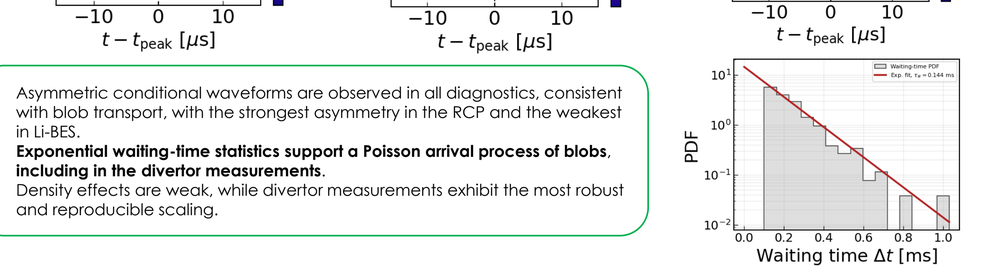

## Blob CA waveform and waiting times

RCP probe | Divertor probe | Li-BES

**Radial scan #13823**




**Density scan** $\delta R = 12mm$

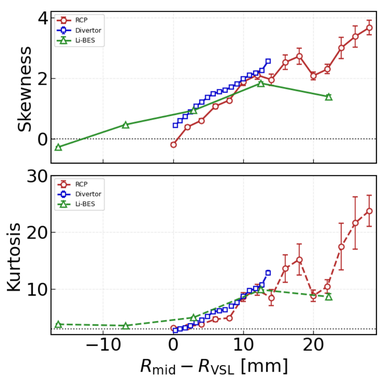



- Asymmetric conditional waveforms are observed in all diagnostics, consistent with blob transport, with the strongest asymmetry in the RCP and the weakest in Li-BES.
- **Exponential waiting-time statistics support a Poisson arrival process of blobs, including in the divertor measurements.**
- Density effects are weak, while divertor measurements exhibit the most robust and reproducible scaling.

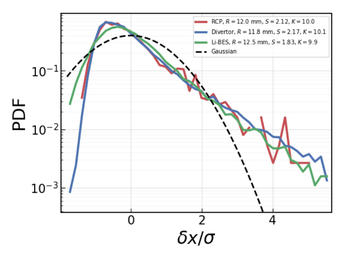



## Midplane-divertor comparison

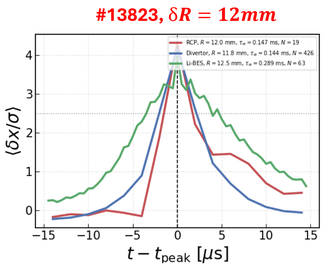
#13823




#13823, $\delta R = 12mm$



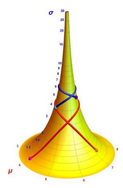

#13823, $\delta R = 12mm$

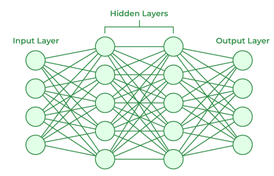



- **Blob statistics are remarkably similar** at matched $R - R_{VSL}$(matched flux surface) **in the midplane and divertor.**
- This agreement suggests that **blob properties are largely preserved along magnetic field lines from the midplane to the divertor.**
- Here the parallel transport of blobs seems to be dominant.

## Future work

- Analysis with fluctuations of $T_e$ and $V_p$
- Using information geometry for comparing distributions
- Different parameter scan besides density
- Implementing Machine learning for 10 000 discharges
- Comparing the results with simulations






## Conclusions

- RCP results agree with established blob transport observations in the SOL
- **Novel: divertor fluctuations exhibit the same statistical signatures and closely follow Poisson-process scaling, demonstrating that blob statistics are preserved along the magnetic field line**
- Li-BES captures the overall trends but shows reduced sensitivity to intermittent events compared to probe measurements
- **Radial position has a stronger influence on intermittency than density over the investigated parameter range**

## References and acknowledgement

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The work was performed on the Large Research Infrastructure COMPASS III, code 90245, which operation was funded by MEYS project LM2023045

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.