

Experimental characterization of edge turbulence on the COMPASS tokamak

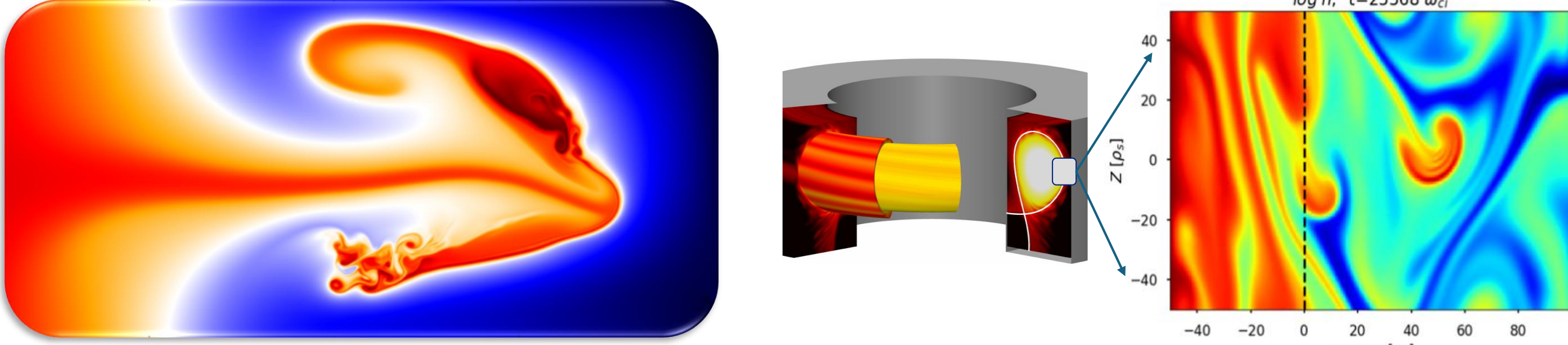
N. Petkovic^{1,3}, J. Seidl², P. Macha², J. Adamek², G. Verdoolaege¹

Contact: nastasija.petkovic@ugent.be

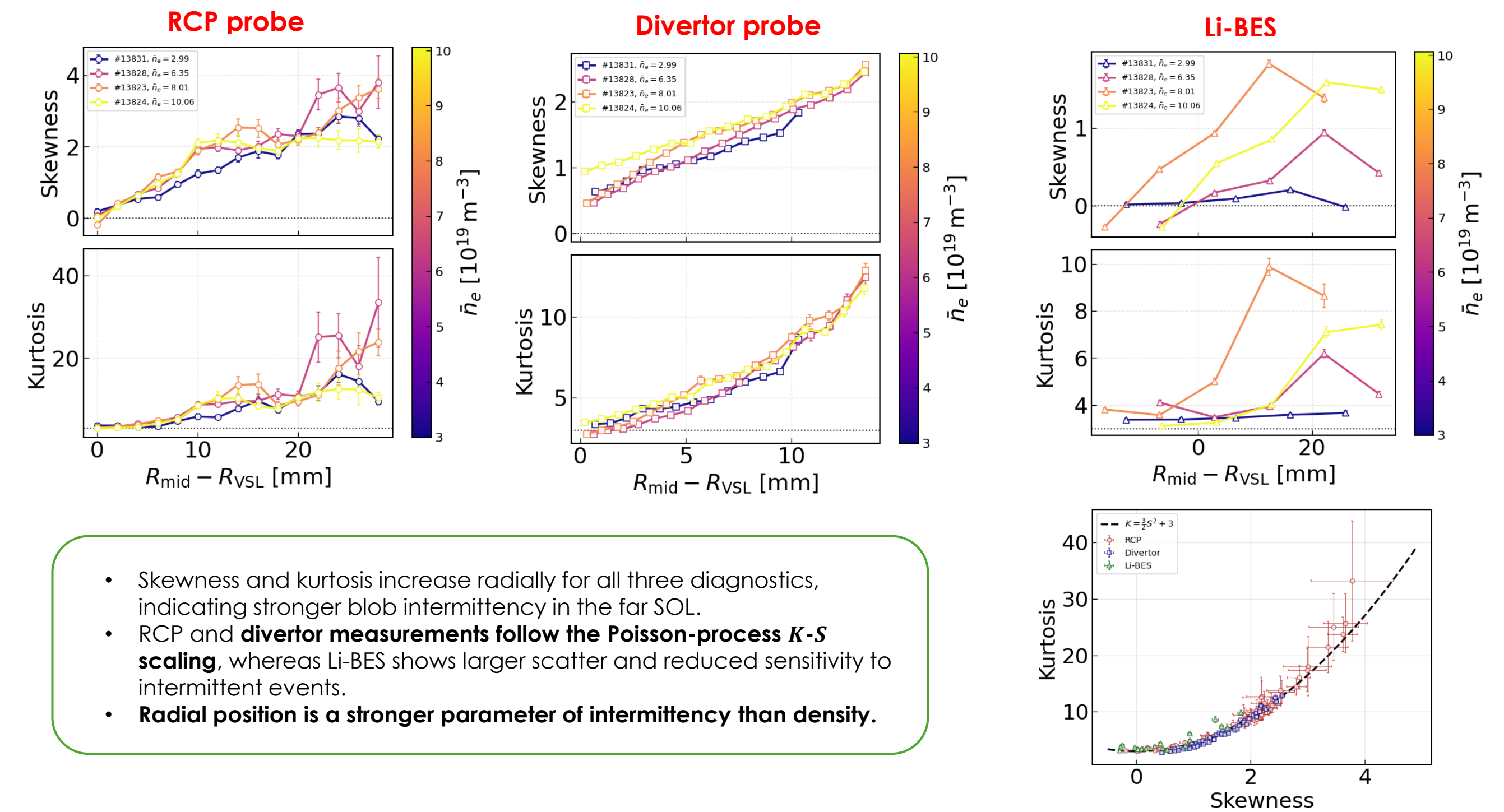
¹ Ghent University, Belgium ² Institute of Plasma Physics in Prague, Czech Republic ³ Czech Technical University in Prague, Czech Republic

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.



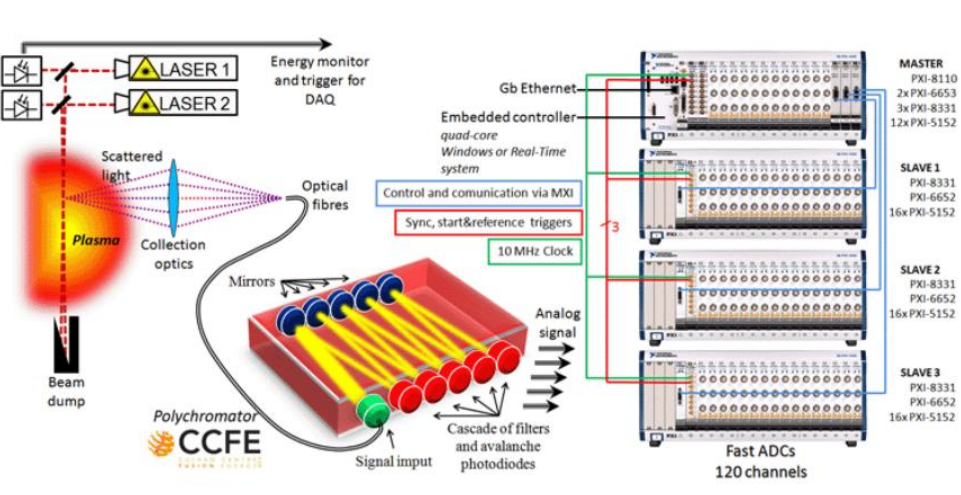
Higher statistical moments and parabolic relation



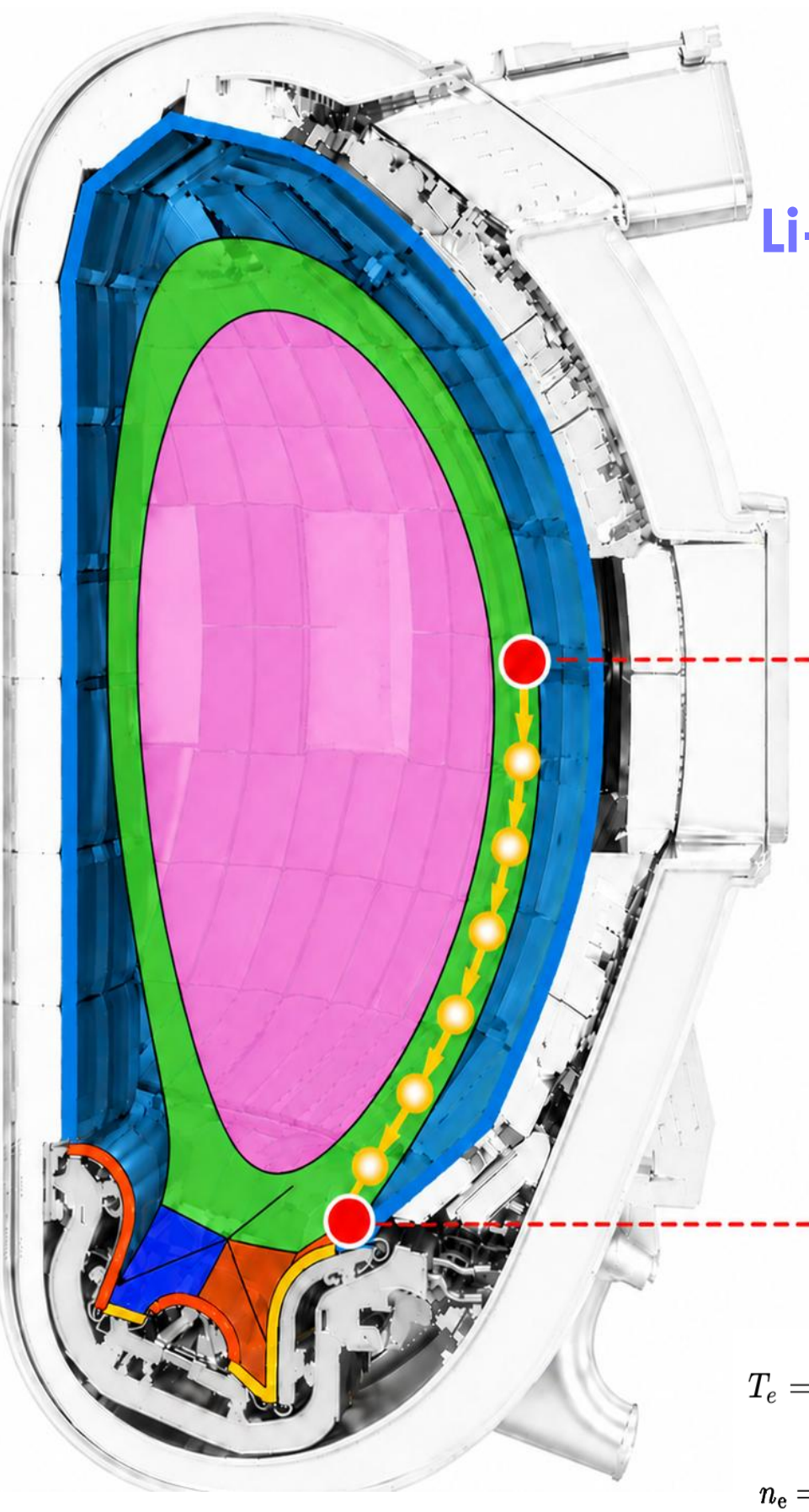
- Skewness and kurtosis increase radially for all three diagnostics, indicating stronger blob intermittency in the far SOL.
- RCP and divertor measurements follow the Poisson-process $K-S$ scaling, whereas LI-BES shows larger scatter and reduced sensitivity to intermittent events.
- Radial position is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

Introduction to blobs

Thomson scattering



TOP VIEW



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 Reciprocating spectroscopy probe

UNIQUE COMPASS DATASET: SIMULTANEOUS μ s SCALE FLUCTUATION MEASUREMENTS on midplane and divertor

Two-point model

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

$$2n_i T_i = n_u T_u$$

$$T_u^{-7/2} = T_i^{-7/2} + \frac{7}{2} \frac{q_{||} L}{k_{0e}}$$

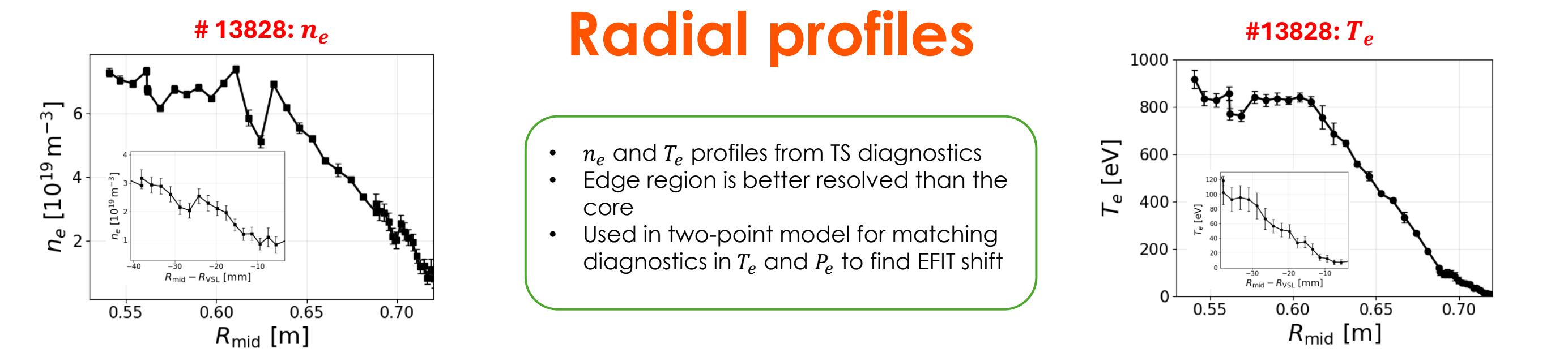
$$q_{||} = \gamma n_i k T_i c_{st}$$

Measurements

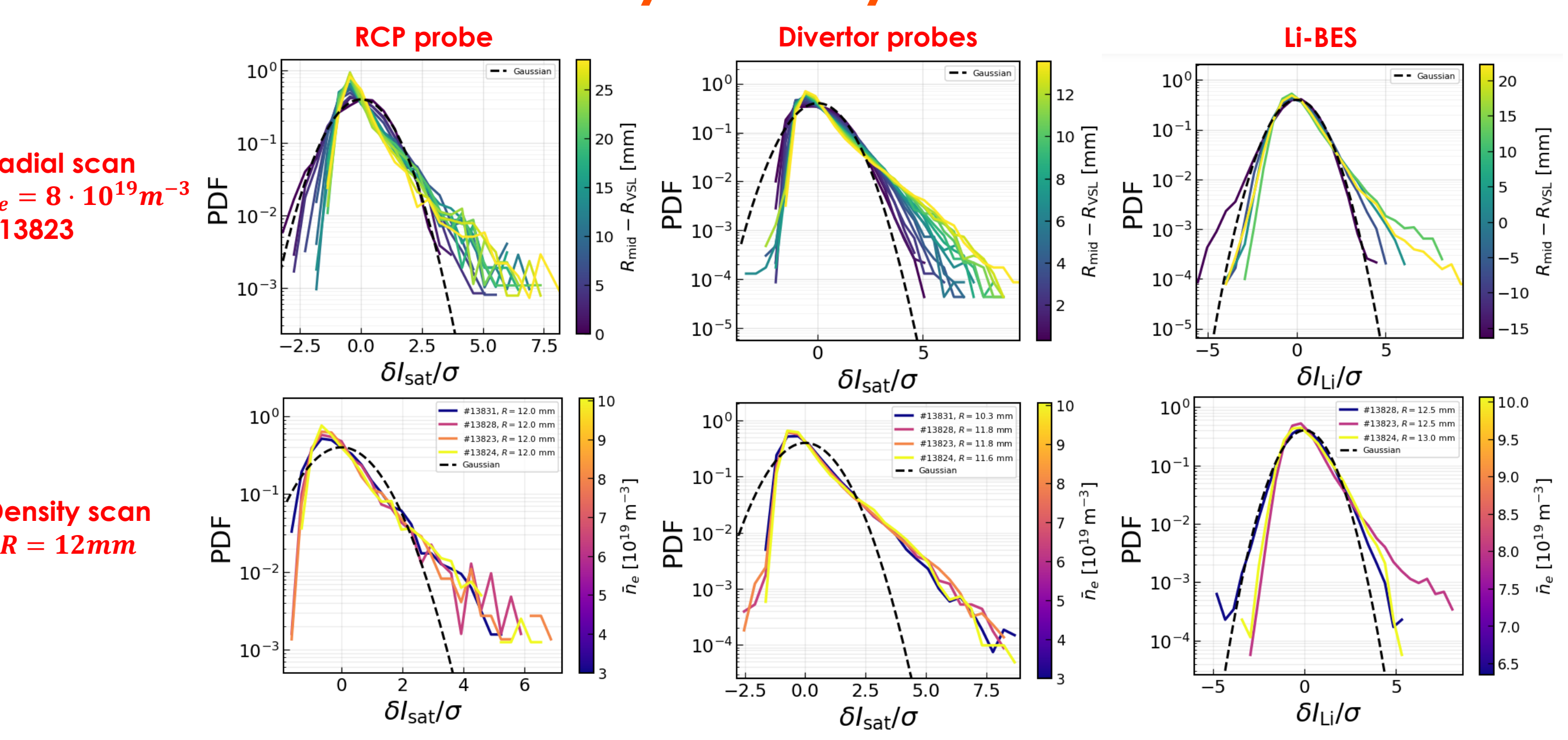
TS: n_e , T_e profiles
LP: fluct. of T_e , V_p , I_{sat} , V_{fl} , n_e
BPP: fluct. of T_e , V_p , I_{sat} , V_{fl} , $q_{||}$, n_e
LI-BES: fluct. of light

(Not an illustration of the COMPASS tokamak)

Divertor probes

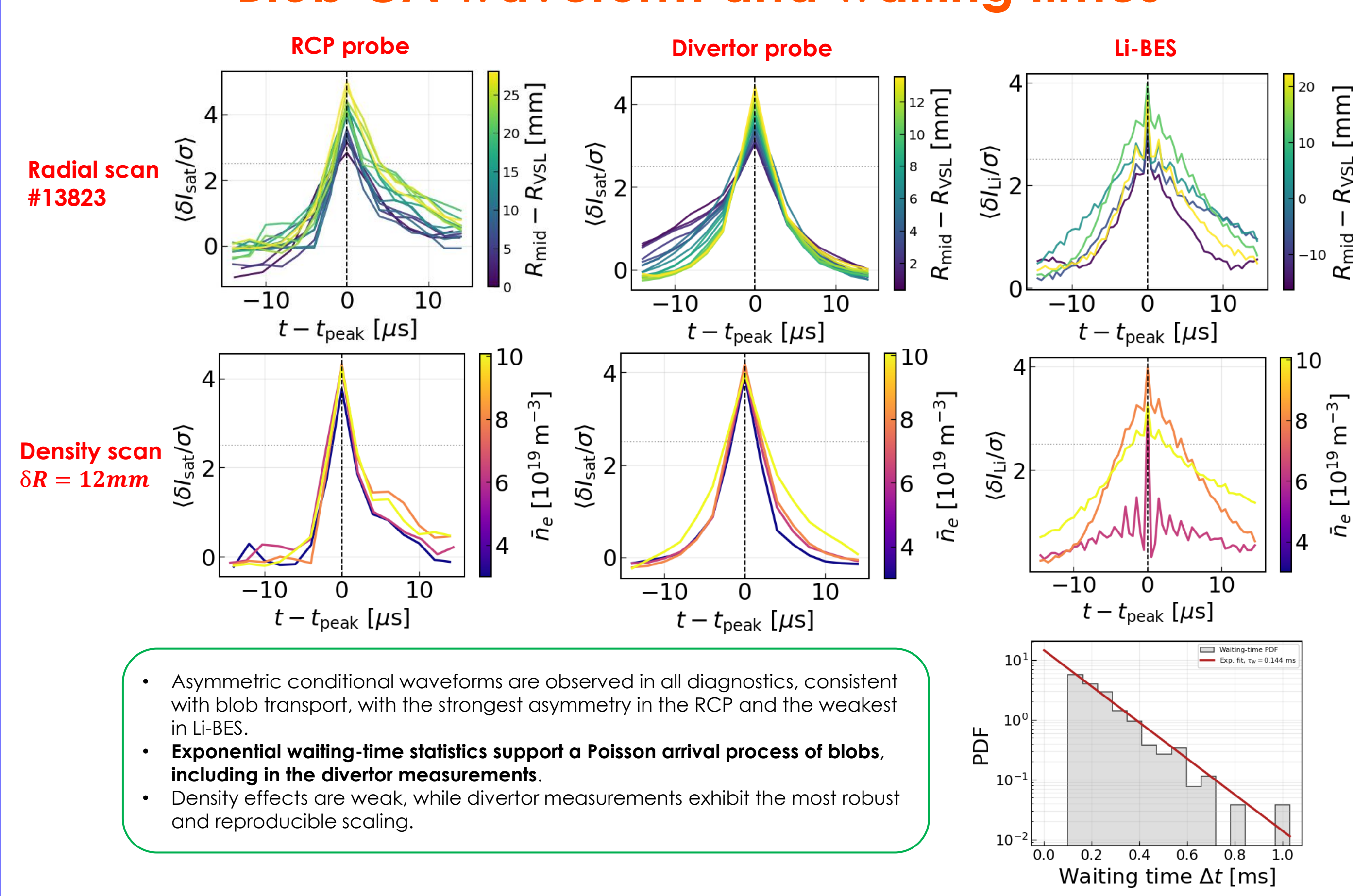


Probability density functions



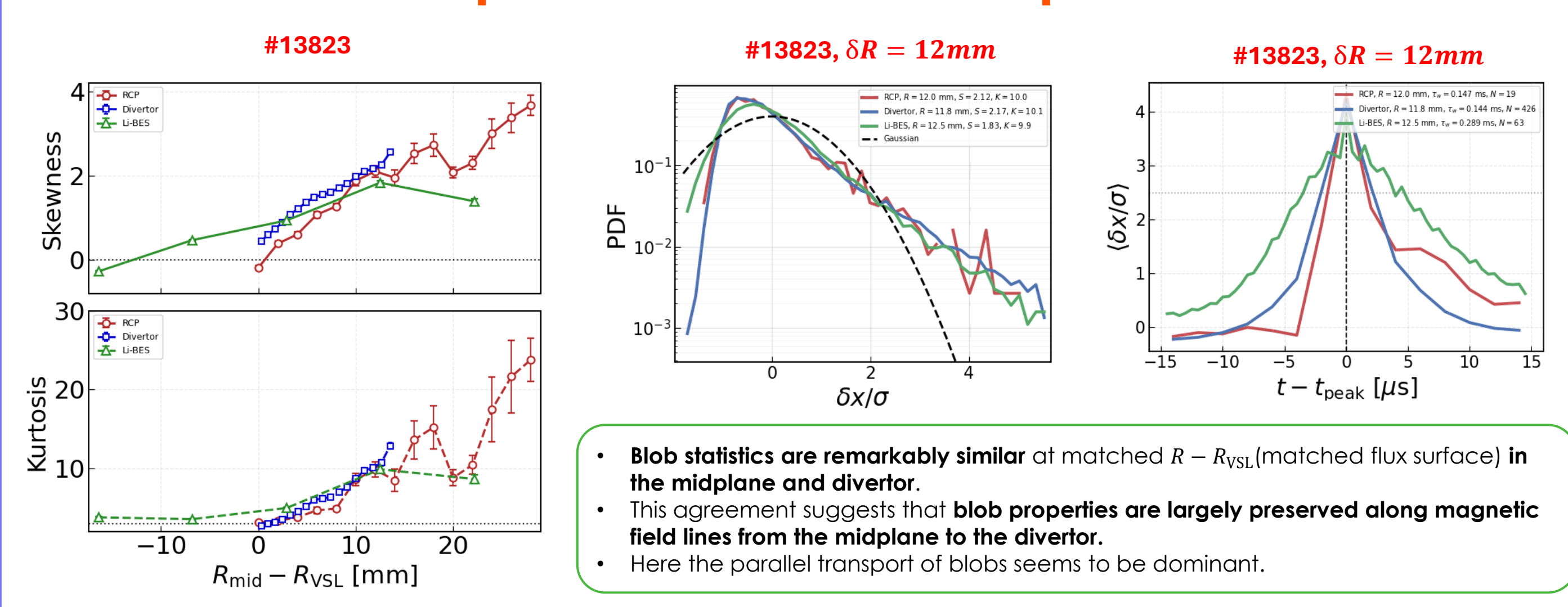
- PDFs become increasingly Gamma-like toward the far SOL, consistent with enhanced blob intermittency, including on the divertor
- Divertor and RCP measurements capture this behavior most clearly, whereas LI-BES shows reduced blob sensitivity.
- Intermittency depends more strongly on radial position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

Blob CA waveform and waiting times



- 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.

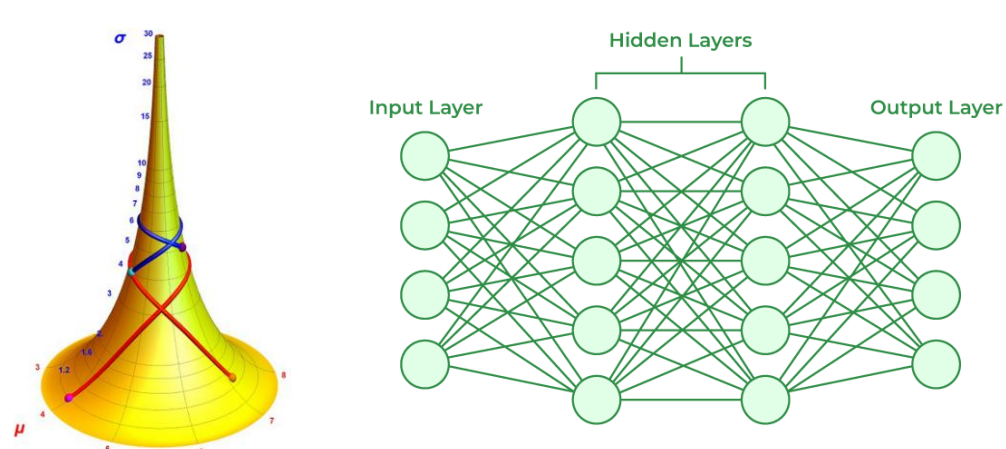
Midplane-divertor comparison



- 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

- [1] D.A. D'ippolito et al., Physics of Plasmas 18(6) (2011)
- [2] O.E. Garcia, Physical review letters, 108(26), 265001 (2004)
- [3] S. Ahmed, PhD thesis, The Arctic University of Norway (2023)
- [4] D. Cipciar et al., Plasma Physics Controlled Fusion 64(5), 055021 (2022)
- [5] D.S. Oliveira et al., Nuclear Fusion 62, 096001 (2022)
- [6] J. Adamek et al., Nuclear Fusion, 57(11), 116017 (2017)
- [7] K. Jirakova et al., Journal of Instrumentation, 14(11), C11020-C11020 (2019)
- [8] P. Stangeby, Series in Plasma Physics (2000)

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