TOKAMAK GOLEM FOR FUSION EDUCATION - CHAPTER 12

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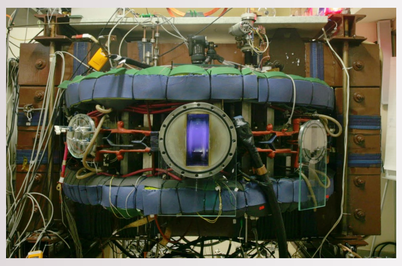
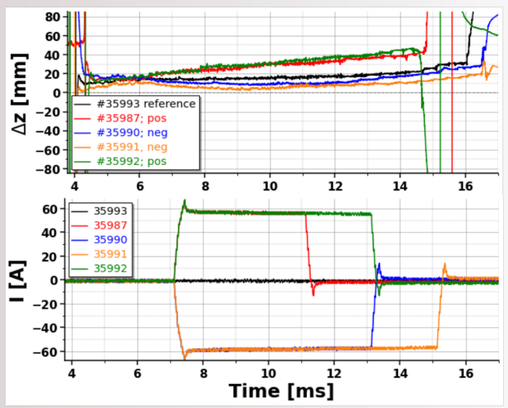
The GOLEM tokamak



- Parameters: $B_\mathrm{t} < 0.5$ T, $I_\mathrm{p} < 8$ kA, pulse length < 15 ms.
- An educational device for domestic as well as for foreign students via remote participation/handling [1], [2].
- Students become familiar with probe measurements, data analysis and basic tokamak diagnostics.
- Subject of Bachelor's degree projects and Master's degree theses.

External plasma stabilization

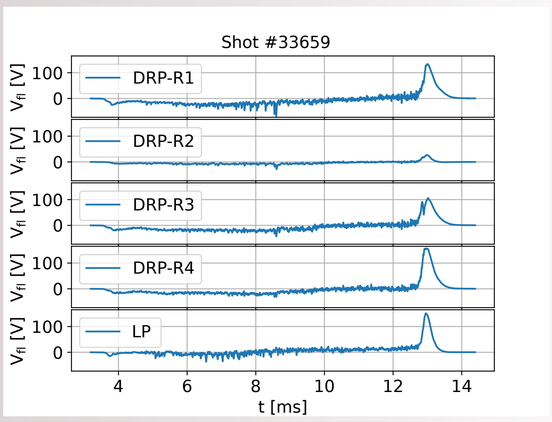
- 2 external windings generating predefined poloidal magnetic field used for plasma control (horizontal, vertical).
- Plasma position is determined by Mirnov coils.
- The influence of the horizontal mg. field on the discharge duration is shown.



Plasma vertical displacement for discharges with stabilization generating horizontal magnetic field.

Long-range correlations

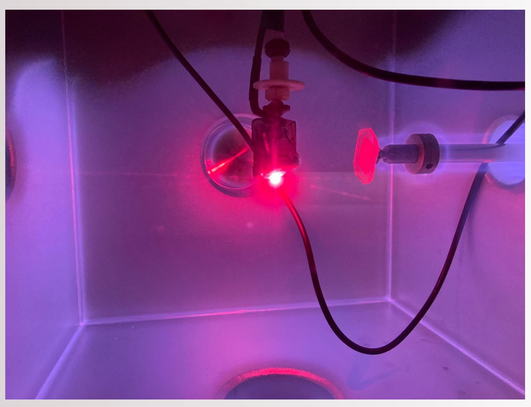
- Long-range correlations studies using 2 toroidaly separated Langmuir probes with focus on GAMs.
- The coherence for GAM confirmation in progress.



An example of U_fl signals from double rake probe and Langmuir probe.

Lithization tests in vacuum tube

- Lithization setup tests performed in a small vacuum tube.
- Several critical problems need to be handled before usage in the tokamak wall - oxidation of the metallic lithium and potential melting of electrodes.
- A spectral line of neutral Li has been observed.



Snapshot of the glow discharge with the apparent red neutral lithium line.

References

[1] V. Svoboda, et al., Fus. Eng. and Des. 68, 1310-1314 (2011)
[2] V. Svoboda, et al., Journal of Fusion Energy volume 38, pages253–261 (2019)
[3] J. Adamek et al 2021 Nucl. Fusion 61 036023 https://iopscience.iop.org/article/10.1088/1741-4326/abd41d
[4] J. Adamek et al., Czechoslovak Journal of Physics. (2004) 54, 95–99.

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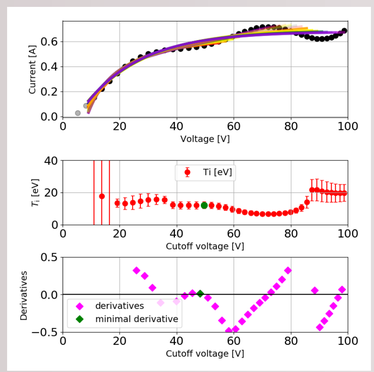
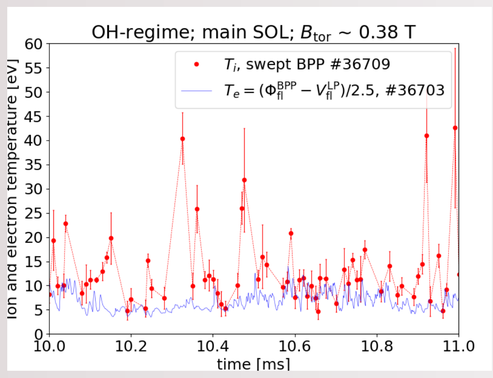
Fast ion temperature measurement using swept ball-pen probe

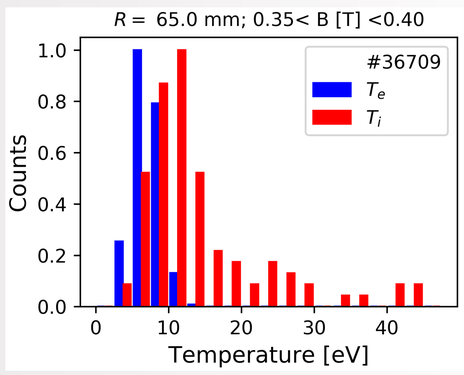
- Ion temperature is measured with 5 μs temporal resolution based on the measurements of the electron branch of a ball-pen probe (BPP) IV characteristics [3].
- The probe collector is biased with a voltage swept between -30V to +130 V at a frequency of 100 kHz.
- The T_i is obtained from $I(V) = I^+_\mathrm{sat} \cdot \left(\exp(\alpha_\mathrm{BPP}) \cdot [1 + K \cdot (V - \Phi)] - \exp\left(\frac{\Phi - V}{T_\mathrm{i}}\right)\right), \alpha = \ln \frac{I^-_\mathrm{sat}}{I^+_\mathrm{sat}} = 0.25 \pm 0.09\,(B_\mathrm{t} > 0.22\,\mathrm{T})$.
- Cut-off fitting technique is applied to all the IV characteristics.
- Fluctuations of the ion temperature ranging between 5 eV up to 40 eV reveal the turbulent behavior of the edge plasma.
- NON-Gaussian shaped histograms of T_e and T_e are observed with a peak at low temperature and a tail towards high temperatures.



Cut-off technique.



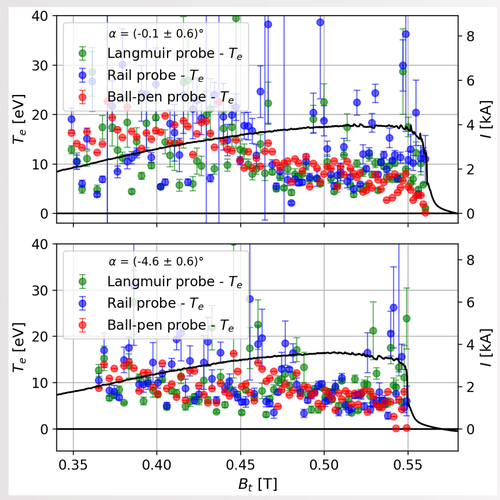
Temporal evolution of T_i and T_e.



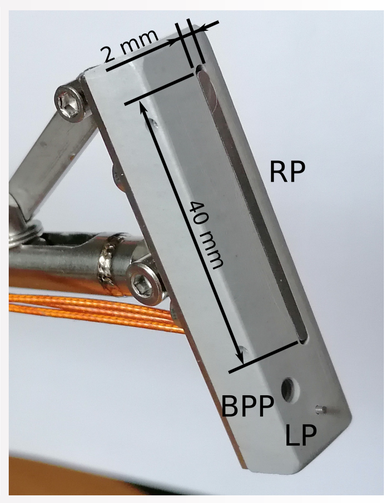
Histograms of T_i and T_e.

Electron temperature measurements using rail probe

- The rail probe concept can sustain exceptionally high heat flux and reduce the sheath expansion effect.
- A probe head consists of a rail probe (RP, length = 40 mm, wide = 2 mm), Langmuir probe (LP, length 1.5 mm, diameter 1 mm), and ball-pen probe (BPP) [4] has been designed
- Special manipulator with changable inclination to B_t within $\pm 10^\circ$ has been installed.
- Electron temperature is measured using a swept Langmuir and rail probe (f = 5 kHz) and a floating ball-pen probe.
- Capability of RP to reduce the sheath expansion effect was confirmed.
- Good agreement between LP, RP and BPP electron temperature measurements for large magnetic field.

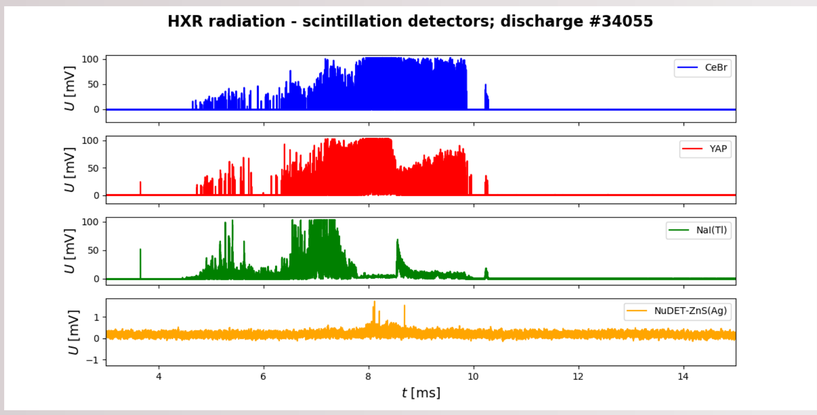


Left) Comparison of T_e measured by BPP, LP and RP. Right) Diagram of the combined probe head.

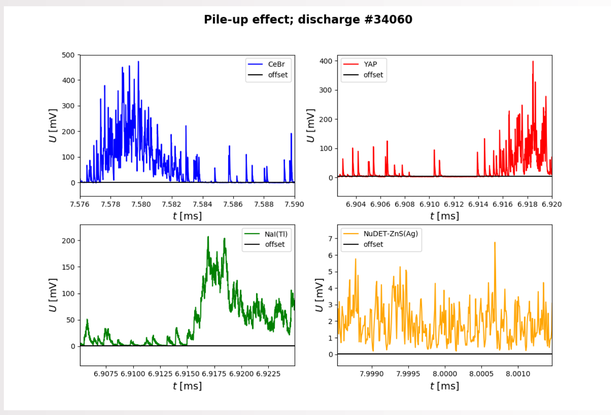


Measurements of HXR radiation

- Scintillation detectors were used for HXR spectrometry.
- Two problems occured:
  - Standard photomultiplier tubes of scintillation detectors can not withstand intensive HXR fluxes (NaI(Tl) detector drops around 8 ms).
  - Piled-up areas of signal - still too high HXR fluxes
- Optimal setup must be found by ensuring sufficient lead shielding and the distance from tokamak.



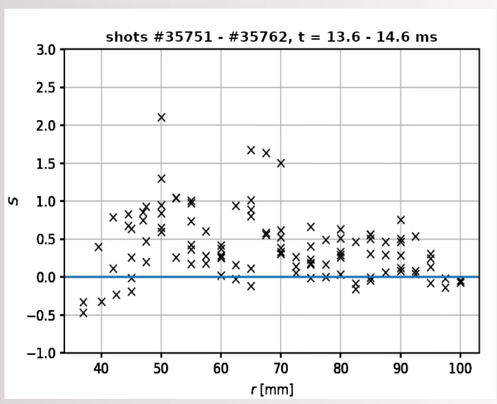
Comparison of HXR signals from 4 different scintillation detectors.



Comparison of piled-up signals and individual peaks.

Turbulent structures

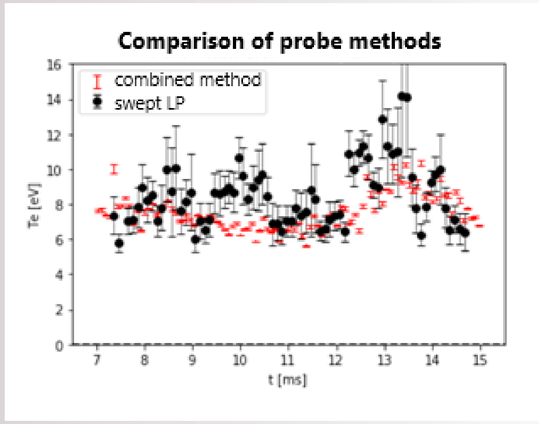
- Exchange turbulence (blob-hole pair generation and propagation) in the plasma edge enhances energy and particle losses.
- Double rake probe (tokamak bottom port) measured I_sat at $r = 37 - 90$ mm (limiter at $r = 85$ mm).
- I_sat histograms found asymmetric with positive skewness indicates the presence of blobs.
- Skewness seems to decrease to negative values at $r = 40$ mm, possible location of the blob birth zone.



Radial profile of ion saturated current skewness. Positive values indicate the presence of blobs throughout the investigated region.

Electron temperature measurements

- Swept Langmuir probe – verified but complicated and time-consuming.
- Combined method (floating ball-pen and Langmuir probe) – straightforward and high time resolution, but rather new.
- It was verified that both methods give the same results.
- We suggest that the combined method is suitable for measuring the edge plasma T_e.



Time evolution of T_e in two identical GOLEM discharges, showing good correspondence between the two methods ($\#35729 - \#35791$).

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