Tokamak GOLEM for fusion education - chapter 15

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The GOLEM tokamak is the oldest operational tokamak in the world. Its main mission is the education of future thermonuclear fusion specialists. The GOLEM tokamak features full remote-control system [1] which extends its reach worldwide. GOLEM facilitates many student projects and theses. This contribution is devoted to current projects.

Spontaneous formation of a transport barrier within a helium plasma in a circular cross-section limiter configuration was successfully recreated and studied six years after the original experiment [2]. The formation of the transport barrier was implied primarily by a steep gradient in electron temperature (see Fig. 1) and an increasing radial electric field and shearing rate. The original experiment was enhanced by a measurement of the ion saturation current profile (see Fig. 1), which indicated plasma and impurity accumulation in the outer vicinity of the transport barrier. Preliminary analysis of fluctuations in SOL showed changes in turbulence properties, including both blob size and amplitude, and is to be improved by a new experiment with higher spatial resolution.

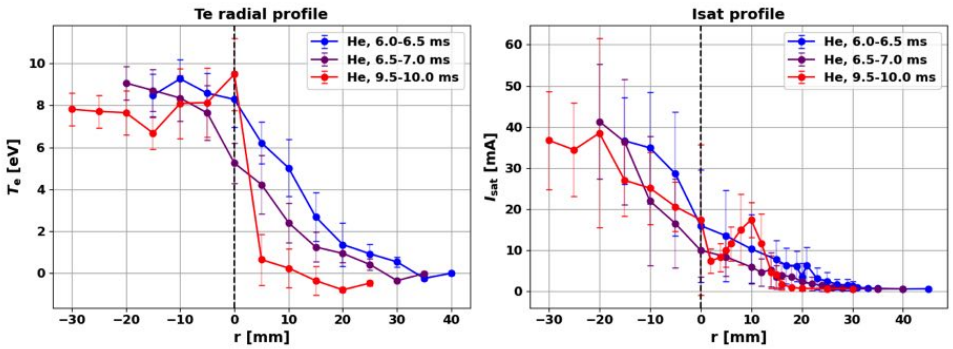

Figure 1: Left) Electron temperature profile. Right) Ion saturation current profile.

With the increasing possibilities of controlling the position of the plasma column and thus making more unique discharges, the current method of identifying the existence of plasma during discharge using characteristic drops in the loop voltage diagnostics is no longer sufficient.

Thus, a new **plasma detection method was successfully implemented using a photodiode signal** that is resistant to electromagnetic induction from stabilization coils and to various plasma behaviour.

An AdvaPIX Timepix3 detector with a 1 mm Si sensor has been installed on the Golem tokamak. The detector is included in the standard diagnostics for radiation detection. Thanks to improved data analysis and good temporal resolution of individual interactions, it is possible to monitor X-rays activity during the discharge. Now this resolution is set to 100 ns. It is shown in Fig. 2, where the deposited energy in the detector sensor during discharge #45502 and the total energy spectrum from the given discharge are shown. Currently, the AdvaPIX Timepix3 detector with a 2 mm thick CdTe sensor is being prepared for installation in standard diagnostics.

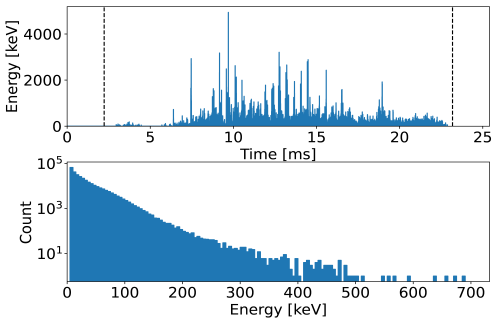

Figure 2: Energy deposited in the detector sensor during discharge #45502 (top). Total energy spectrum of discharge #45502 (bottom).

X-ray radiation from runaway electrons (RE) was simulated in Geant4[3]. Results shown in Fig.3 indicate that the distribution of radiation can be used to estimate the position of the RE limiter strike point. Furthermore, the simulation will be used to optimize the placement of the HXR probes around the tokamak and as input for the algorithm of deconvolution of the RE energy spectra.

Progress was made in **the automatization and energy calibration of scintillation detectors** for RE diagnostics. These detectors are used for the detection of produced bremsstrahlung radiation, which is dominantly caused by runaway electron impact on the molybdenum poloidal limiter. For proper analysis of acquired data detectors need to be periodically calibrated for which automatic methods were developed. A calibrated CeBr3 scintillation detector has been included in the basic GOLEM diagnostic. An illustrative spectrum of Bremsstrahlung radiation recorded during discharge #42243 is shown in in Fig. 4.

Visible tomography is currently integrated into the standard diagnostic[4]. The final version uses Minimal Fisher Regularization for inversion and efforts are being made to optimize various elements of the process. The tomography is implemented using Jupyter Notebook, which also serves as an easily readable introduction to tomography at GOLEM. An artificial neural network-based model for tomography has been developed and is being optimized and investigated.