TOKAMAK GOLEM FOR FUSION EDUCATION - CHAPTER 14

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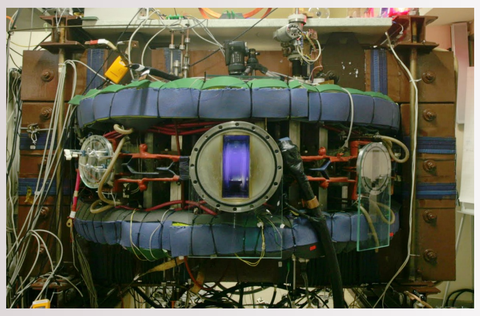
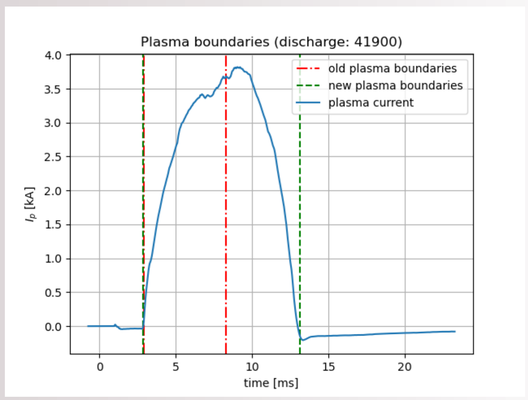
The GOLEM tokamak



- Parameters: $B_t < 0.5$ T, $I_p < 8$ kA, pulse length < 15 ms.
- An educational device for domestic as well as for foreign students via remote participation/handling [1].
- Students become familiar with probe measurements, data analysis and basic tokamak diagnostics.
- Subject of Bachelor's degree projects and Master's degree theses.
- At present used in an experimental laboratory course in the basic physics curriculum.

Plasma boundaries determination

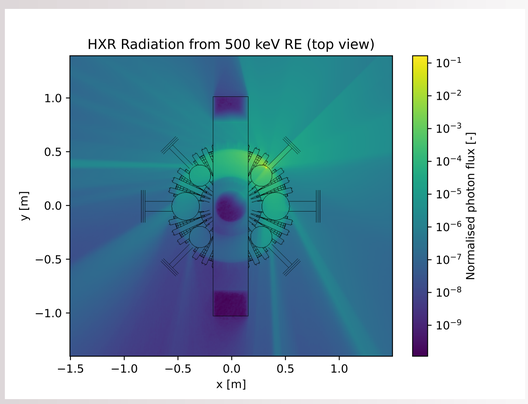
- A new detection method of the plasma boundaries was implemented.
- A photodide signal is used instead of a loop voltage signal.
- Resistant to electromagnetic induction from stabilization coils.



Comparison of wrongly calculated plasma boundaries from a loop voltage signal (red) and the new ones from a photodiode signal (green)

Simulation of X-ray generated by runaway electrons

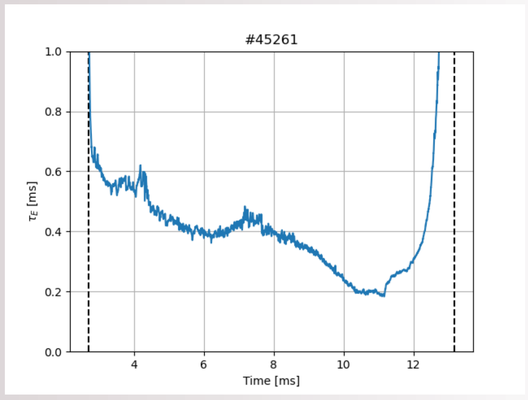
- Simulation of RE beam striking a limiter was performed for several RE beam positions and typical plasma parameters.
- Results will be used for estimation of runaway electron strike point on the limiter and as input for deconvolution of RE energy distribution.



Distribution of HXR radiation generated from runaway electron interaction with the limiter simulated in Geant4.

New system of magnetic coils

- A new system of magnetic coils has been installed into the Golem tokamak and tested.
- The poloidal ring was furnished by Rogowski coil, two toroidal field coils placed on the HFS and the LFS, and a diamagnetic coil.
- New diamagnetic coil enables establishment of the energy confinement time derived from the thermal energy



Energy confinement time of discharge 45261.

References

[1] Tokamak GOLEM, Czech Technical University in Prague, http://golem.fjfi.cvut.cz/ [online]
[2] P. Macha et al., 2023, Nucl. Fusion 63, 104003

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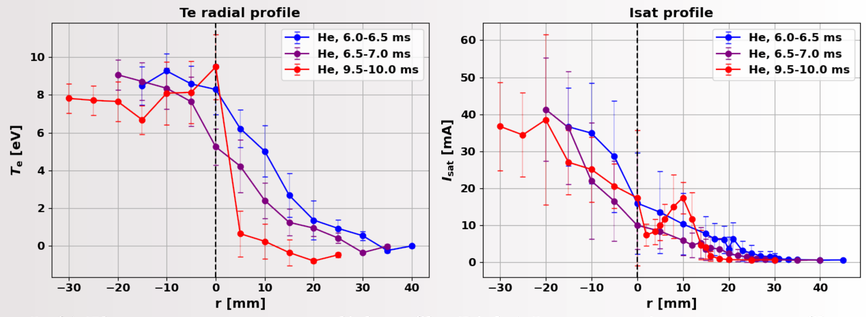
Spontaneous formation of a transport barrier

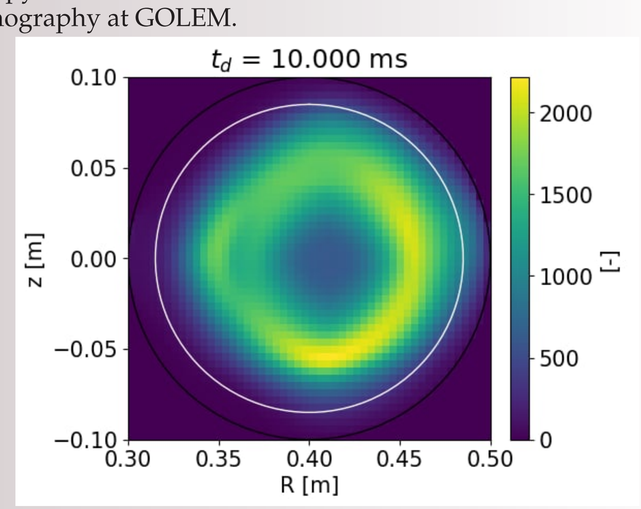
- Spontaneous formation of a transport barrier in a helium plasma in tokamak GOLEM with limiter configurations was successfully reproduced [2].
- The barrier's formation is implied by a steep gradient of T_e and a gradual increase in E_{radial} and shearing rate.
- Measurement of the ion saturation current profile showed plasma and impurity accumulation in the outer vicinity of the transport barrier.
- Barrier's effect is also seen in fluctuations in SOL which is, however, to be verified with an experiment with higher spatial resolution.



Left) Electron temperature radial profile. Right) Ion saturation current profile.

Visible plasma tomography

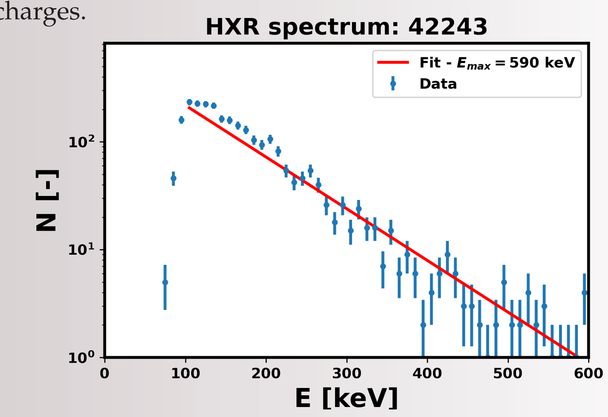
- Visible plasma tomography was integrated into the standard diagnostic.
- Optimization efforts are being made, e.g. by modifying the Minimum Fisher Regularization method.
- Jupyter Notebooks are used as an educational introduction to tomography at GOLEM.



Result of tomographic inversion from discharge 43605.

Scintillation detectors for RE studies

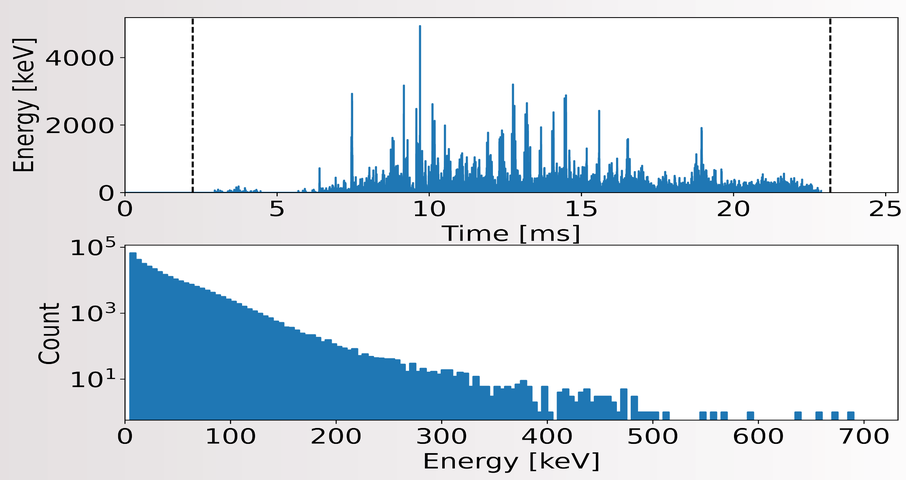
- Runaway electrons investigated by a set of scintillation detectors ($CeBr_3$, NaI(Tl), YAP(Ce)) - detection of their bremsstrahlung radiation.
- Detector energy calibration: routines developed for automatized recognition and fitting of peaks present in spectrum.
- Scintillation detectors had been included in the standard diagnostics.
- Can be used for HXR spectra measurements in GOLEM discharges.



Example of recorded bremsstrahlung spectrum by $CeBr_3$ scintillation detector.

Data analysis from AdvaPIX Timepix3 detector

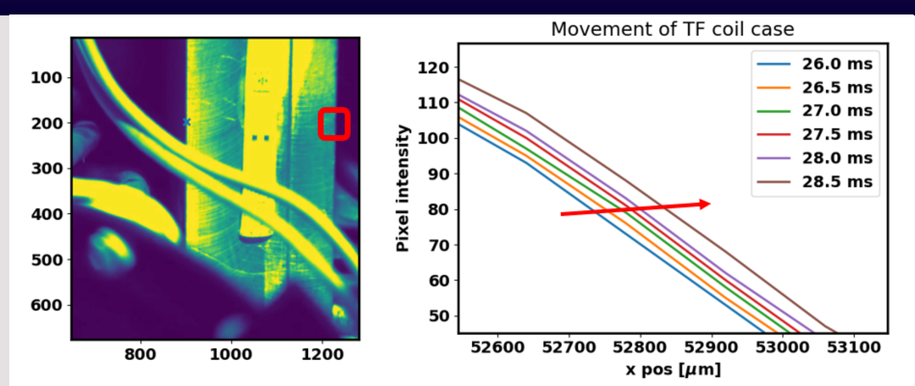
- An AdvaPIX Timepix3 detector with a 1 mm Si sensor has been included in the standard diagnostics on the Golem tokamak.
- During a discharge, it is possible to monitor the activity of X-ray radiation. The resolution for individual discharge segments is set to 100 ns.
- Detector with a 2 mm thick CdTe sensor is being prepared for installation in standard diagnostics



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

Video motion amplification

- Movement of scintillation detector cases and coils observed on GOLEM
- Dedicated DC lighting for discharge sequence was installed to avoid oscillating light intensity
- Movements were measured using fast cameras and neural-network based amplification.
- Automated analysis to be finalized.
- Forces acting on coils could be estimated.

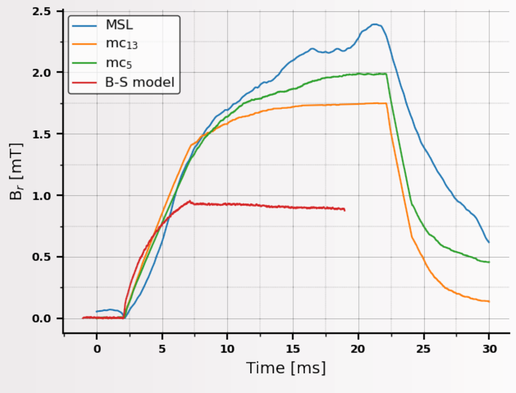


Left) Fast camera image of TF coil. Right) Slice of TF coil border and its position in time.

Magnetic field measurements using the 3D MSL probe

- A step-like input waveform was applied to the poloidal field coils.
- The magnetic field measured by the 3D MSL probe was compared with the Mirnov coils measurements and a simple Biot-Savart model
- A comparison with a model that incorporates the effects of eddy currents induced in conducting structures is envisaged in the future

Right) Comparison of radial component of the magnetic field measured by the MSL probe and Mirnov coils and a simple Biot-Savart model without considering conducting structures.



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