Golem #16 - from #40420 to #43695

Mariánská 2024

Vojtěch Svoboda

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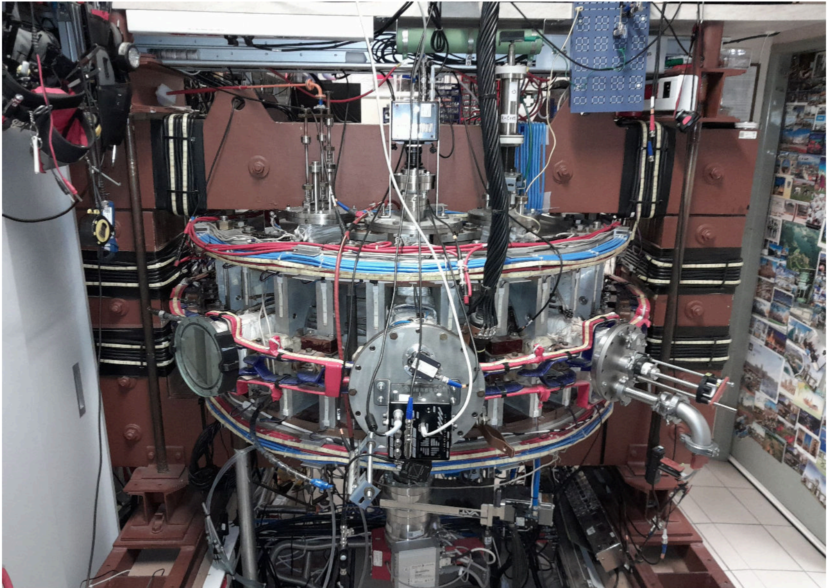
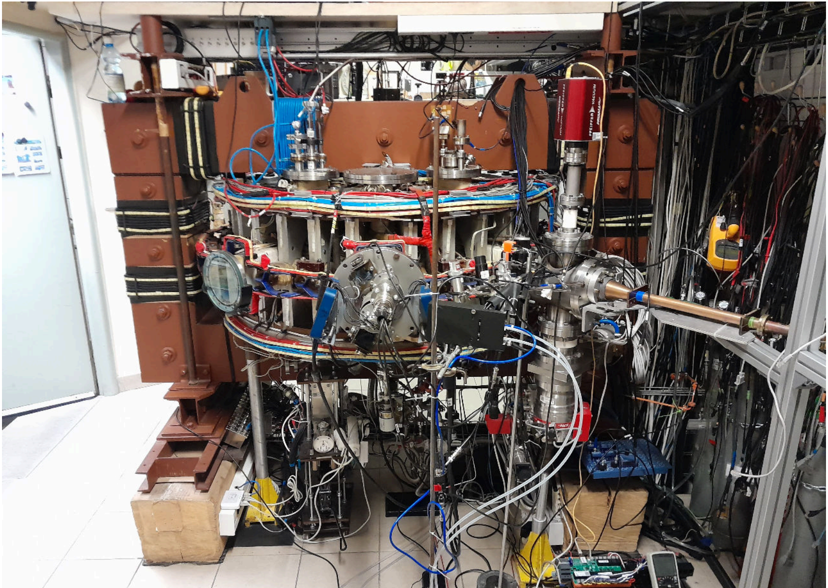
Honza

South 01/2024



North 01/2024



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Articles

- Mácha, Petr *et al.* (Aug. 2023). “Spontaneous formation of a transport barrier in helium plasma in a tokamak with circular configuration”. In: *Nuclear Fusion* 63.10, 104003. DOI: 10.1088/1741-4326/acf1af.
- Pokorny, M., P. Macha, and V. Svoboda (2023). “Magnetic field simulations of the GOLEM tokamak via the NICE code”. In: *Journal of the ASB Society*, 26–34. DOI: 10.51337/JASB20231206003.
- Sarancha, G. *et al.* (2023). “Remote Plasma Physics Research and Teaching by Example of Turbulence Study at the University-Scale Tokamak GOLEM”. In: *Fusion Science and Technology* 79.4, 432–445. DOI: 10.1080/15361055.2022.2148842. URL: https://doi.org/10.1080/15361055.2022.2148842.

Proceedings

Cerovsky, J. *et al.* (Apr. 2023). “Runaway electron studies via HXR spectroscopy at Golem, COMPASS and TCV”. In: *European Conference on Plasma Diagnostics*. Rethymno. URL: http://golem.fjfi.cvut.cz/wiki/Presentations/Conferences/ECPD/5th_Rethymno_2023/poster.pdf.

Chlum, J. *et al.* (2023). “Tokamak GOLEM for fusion education - chapter 14”. In: vol. Europhysics conference abstracts.

Ivanov, V. *et al.* (2023). “Runaway electrons measurements by ECE on the GOLEM tokamak”. In: vol. Europhysics conference abstracts.

Bachelor projects & Master thesis

S. Malec (2023). “Compton camera for detection of hard X-rays produced on the Golem tokamak”. Master Thesis. URL: http://golem.fjfi.cvut.cz/wiki/Presentations/Students/MasterThesis/23MalecStepan.pdf.

Jan Buryanec (2023). “Stabilizace proudu plazmatem na tokamaku Golem”. Bachelor project. URL: http://golem.fjfi.cvut.cz/wiki/Presentations/Students/BachelorProjects/23BuryanecJan.pdf.

M. Vanakova (2023). “Studium oscilací magnetického pole na tokamaku Golem”. Bachelor project. URL: http://golem.fjfi.cvut.cz/wiki/Presentations/Students/BachelorProjects/23VanakovaMarie.pdf.

SOČ

M. Pokorný (2023). "Měření a simulace polohy plazmatu na tokamaku GOLEM". High School Students' Professional Activities SOČ. URL: http://golem.fjfi.cvut.cz/wiki/Presentations/Students/HighSchoolActivities/23PokornyPolohaPlazmatu.pdf.

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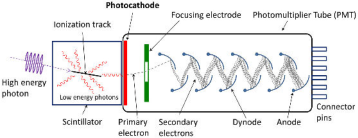
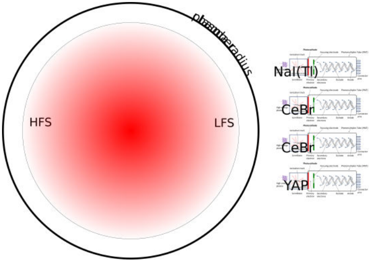
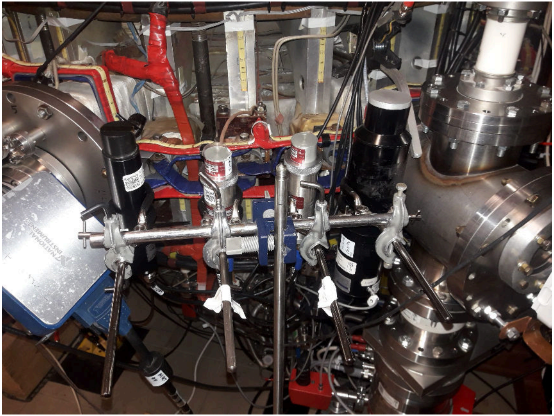
Scintillation probes at the tokamak GOLEM

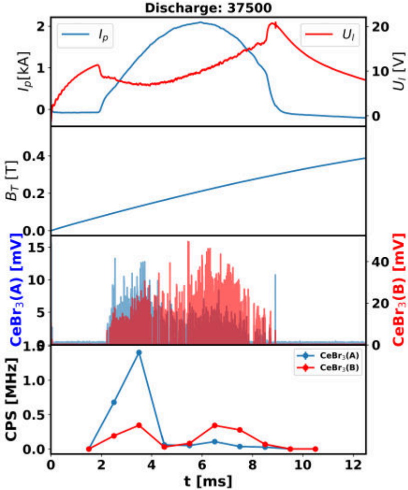






Focus on $CeBr_3$ scintillation crystals with fast decay time (18-25 ns), superior energy resolution (4% FWHM at 662 keV), light yield $\approx$ 60 photons/keV and density $\approx$ 5.1 g/cm^3.

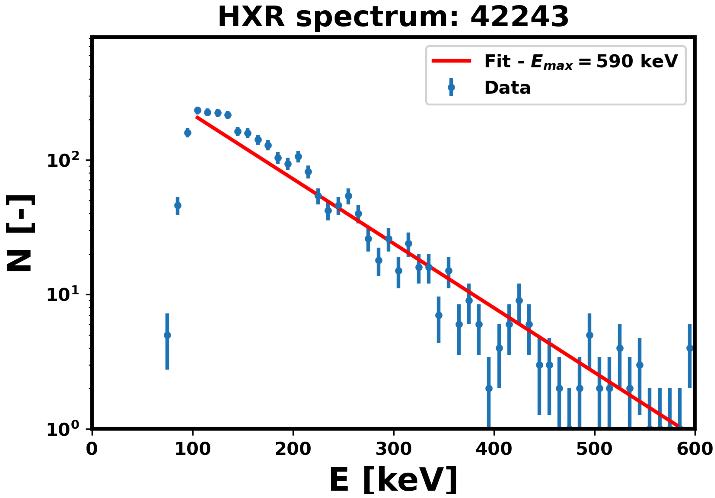
Bremsstrahlung radiation by $CeBr_3$ scintillation detector



- Favorable conditions for runaway electron generation
  - high loop voltage ($E \approx 2 - 5\ \mathrm{V/m}$)
  - low density ($n_e \approx 10^{18}\ \mathrm{m}^{-3}$)
- Density of plasma could be partially controlled by initial pressure of working gas

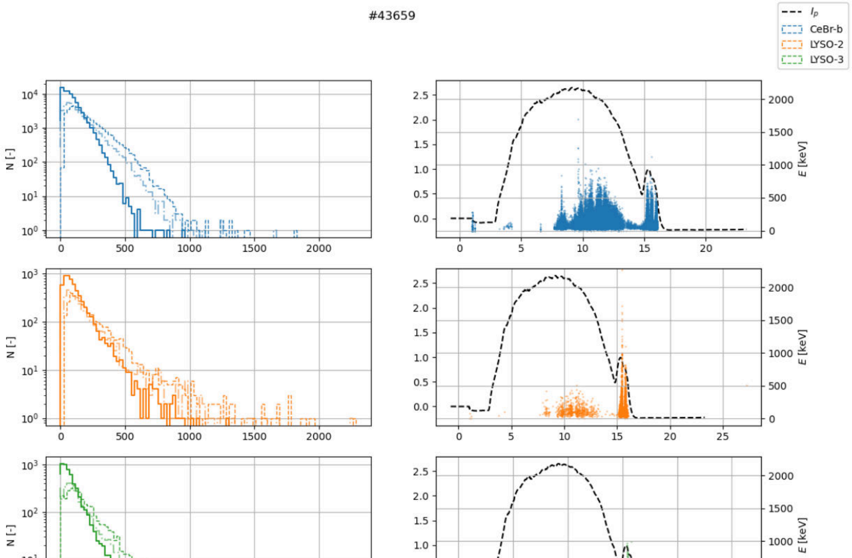
Cerovsky *et al.* 2023 ECPD conf

Bremsstrahlung spectrum by $CeBr_3$ scintillation detector



Cerovsky, Chlum *et al.* 2023 ECPP conf

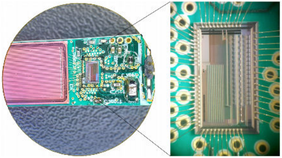
Scintillation probes - energy spectrum



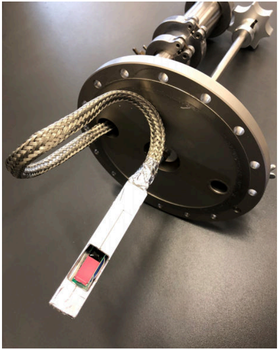
Runaway electron diagnostics using silicon strip detector

In collaboration with the experimental particle group (diagnostics branch)

The silicon n+ -in-p sensor consists of 32 AC coupled 250 um x 18 mm x 525 um strips.



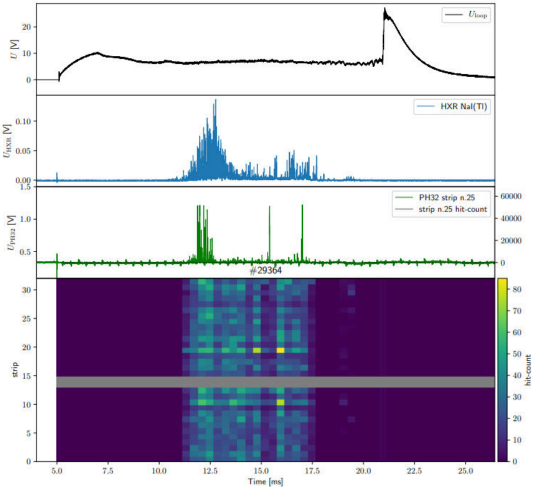
The silicon strip sensor connected to the PH32 readout chip



PH32 detector attached to a radial manipulator.

Svihra *et al.* 2019 *FUSENGDES* **146** 316–319

Runaway electron diagnostics using silicon strip detector

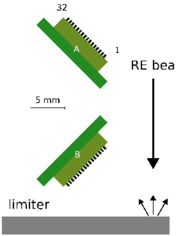


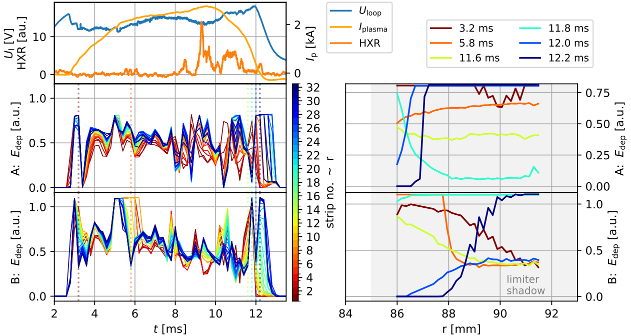
- Loop voltage of plasma discharge.
- HXR scintillation,
- Analog signal voltage in the 25th strip
- Number of hits in all strips.

#29364, the PH32 detector in the LGM collected a number of hits,

Novotny *et al.* 2020 *JINST* **15** C07015

The distribution of REs in SOL





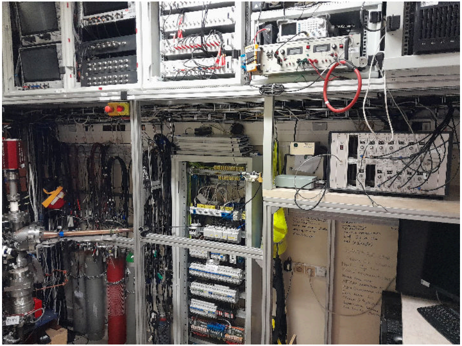
Two opposite-oriented sensors to observe:

- trapped particles,
- RE backscattering from the limiter.

- During the discharge, REs are usually detected near the limiter edge or with a uniform distribution.
- At the end of the discharge, most of the energy is typically deposited on the LFS side of the limiter.

Tunkl, Chlum *et al.* 2023 ECPP conf

26.5 – 40 GHz ECE radiometer

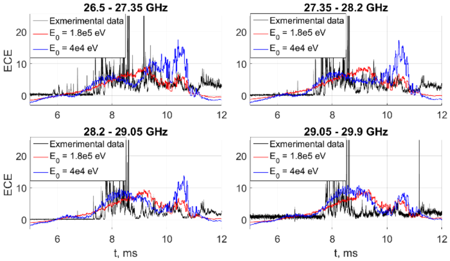


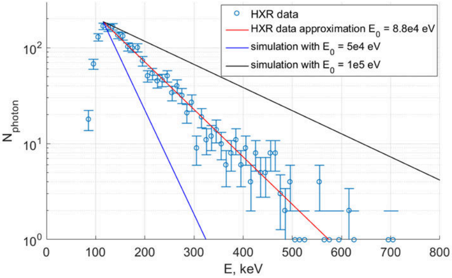
- Due to low electron temperature and density, the ECE radiometer cannot be used for electron temperature measurements.

- The radiometer is sensitive to non-thermal high energy electrons
- Allows simulating radiation from plasma as a combination of single electron radiation.
- Matching model to experimental signal via variation of electron energy distribution function gives possibility to estimate the distribution function.

Ivanov *et al.* 2023 ECPP conf

ECE simulation for optically thin plasma

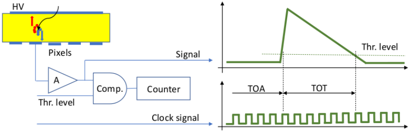


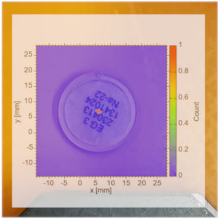


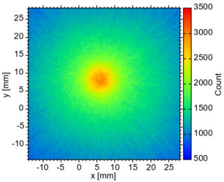
Left) Comparison of thin plasma model and experimental #42245 ECE signal. Right) Comparison of HXR energy distribution and electron energy distribution from ECE measurements. Ivanov *et al.* 2023 ECPP conf

Timepix3 detection module

- Compton camera has the ability to detect the direction of gamma rays produced by radioisotopes.
- The Compton camera was created from a Timepix3 detector with a sensor from Cadmium-Telluride with a thickness of 2 mm.
- Ongoing improvements of the camera resolution and location.



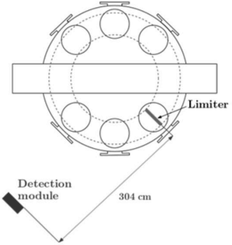


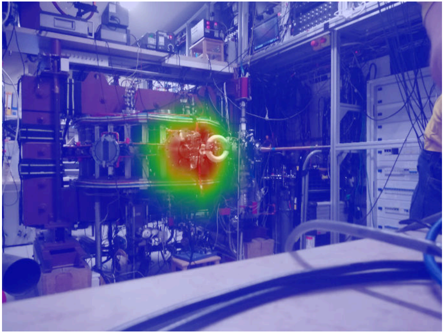


- Example with Na radioisotope radiation detection.

S. Malec 2023 MastThes, Malec *et al.* 2021 NSS/MIC conf

Compton camera on the GOLEM tokamak #39048 to #39097





- Compton camera has the ability to detect the direction of gamma rays produced by radioisotopes.
- The Compton camera was created from a Timepix3 detector with a sensor from Cadmium-Telluride with a thickness of 2 mm.
- Ongoing improvements of the camera resolution and location.

S. Malec 2023 MastThes

Spektra z detektoru Timepix3 s Si senzorem tloušťky 1 mm I

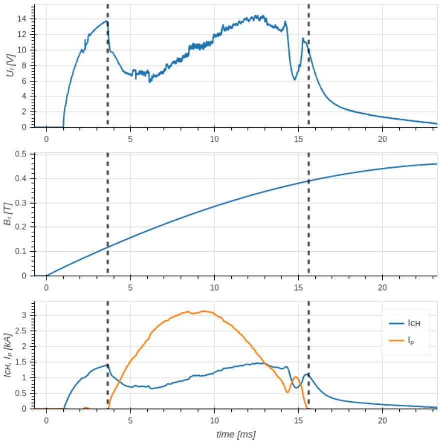


Figure: Discharge #43608 (double breakdown)

Spektra z detektoru Timepix3 s Si senzorem tloušťky 1 mm II

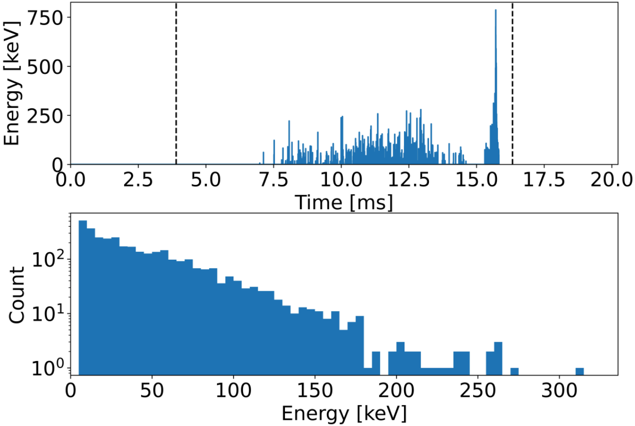


Figure: Detekované energie během výboje (1 bin má šířku 100 ns; nahoře) a spektrum celého výboje (dole)

Spektra z detektoru Timepix3 s Si senzorem tloušťky 1 mm III

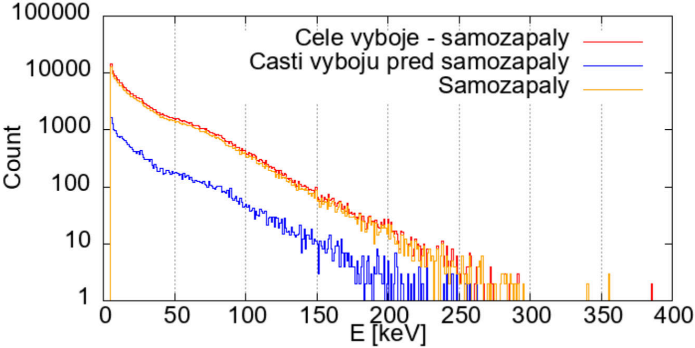
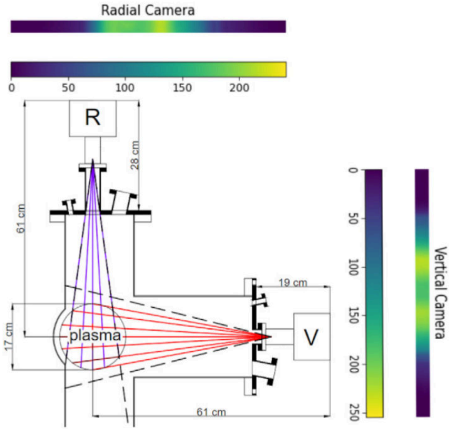
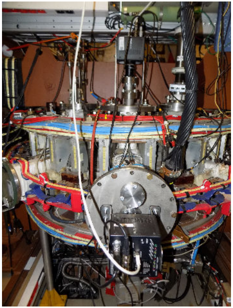


Figure: Souhrnné spektrum všech výbojů, spektrum částí výbojů před "opětovným zapálením" a spektrum částí výbojů při "opětovném zapálení".

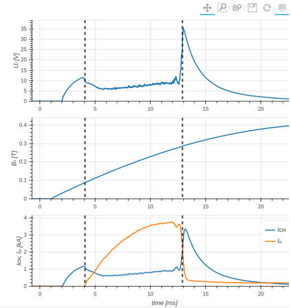
Fast cameras at the GOLEM tokamak

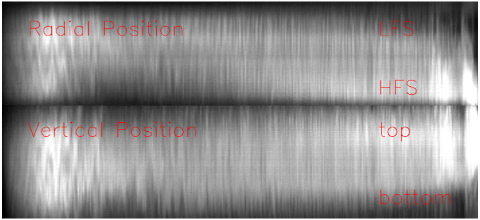




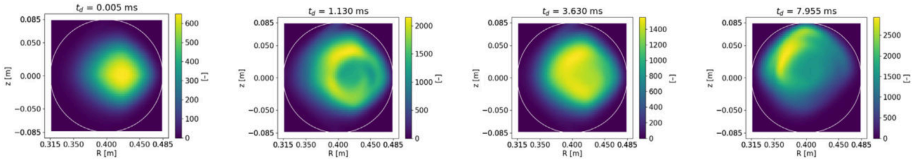
Abbasi *et al.* 2023 *FUSENGDES* **193** 113647

Tomographic reconstruction #39304





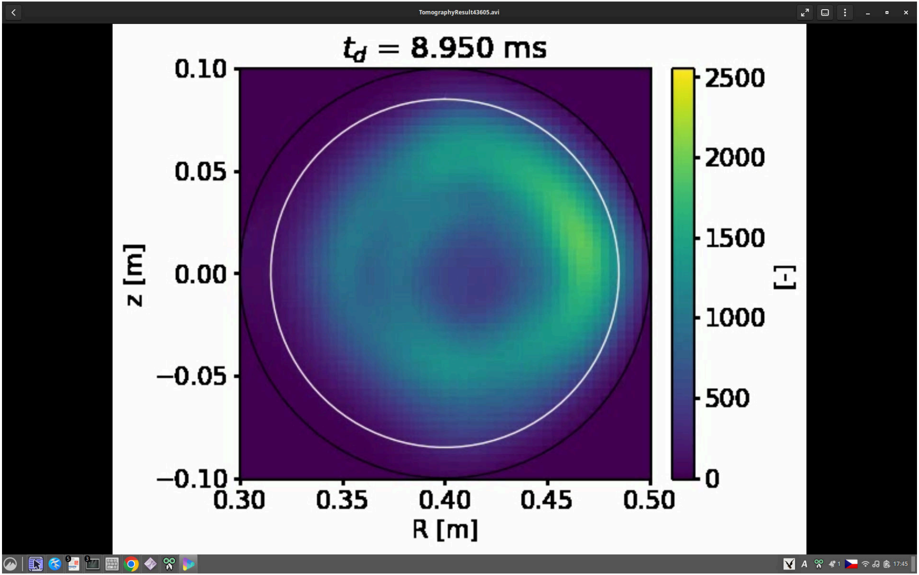
Abbasi *et al.* 2023 *FUSENGDES* **193** 113647



(a) **(b)** **(c)** **(d)**

(a) $t_d = 0.5$ ms, (b) $t_d = 1.13$ ms, (c) $t_d = 3.63$ ms, (d) $t_d = 7.96$ ms.

Tomography - automatic AVI on the horizon



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Spontaneous formation of a transport barrier in helium plasma in a tokamak with circular configuration

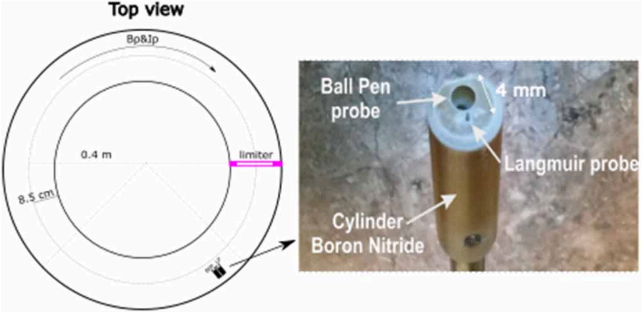

Figure: Left—the experimental arrangement for the combined probe measurements with limiter configuration, top view. Right—the photo of the combined ball-pen (diameter 4 mm) and Langmuir probe (diameter 1 mm) head. Mirnov coil ring consisting of 4 coils is placed around the limiter. The magnetic field and the plasma current are clockwise oriented.

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Spontaneous formation of a transport barrier in helium plasma in a tokamak with circular configuration

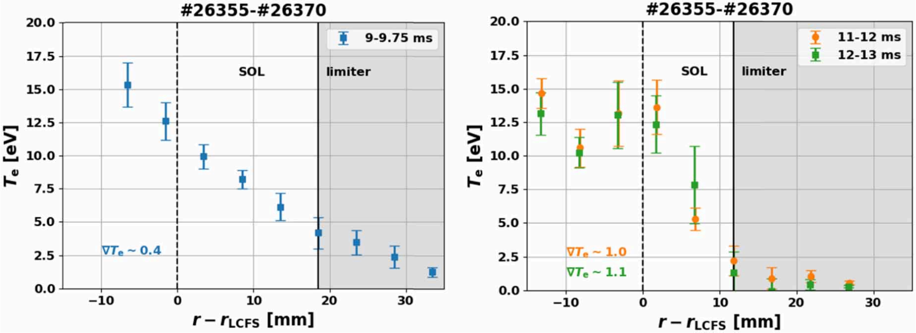

Figure: Radial profiles of electron temperature before (left) and during (right) the transport barrier formation. The strong gradient of electron temperature is observed at 11–13 ms.

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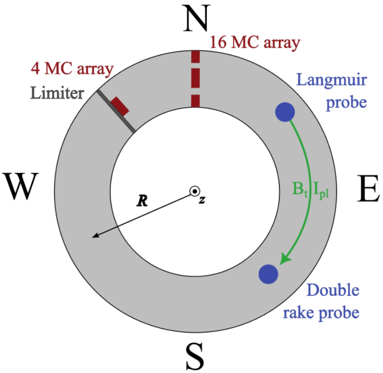

Figure: 1. Setup of GOLEM diagnostics. View from the top of the tokamak.

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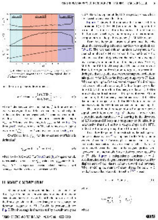
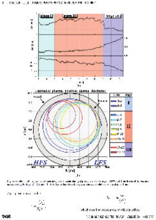
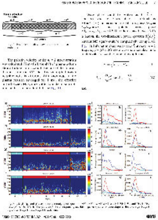
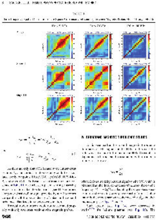
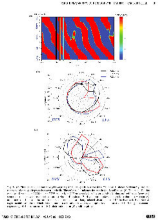
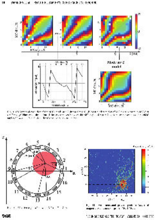
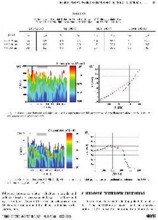
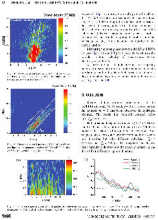
Article in a few pages

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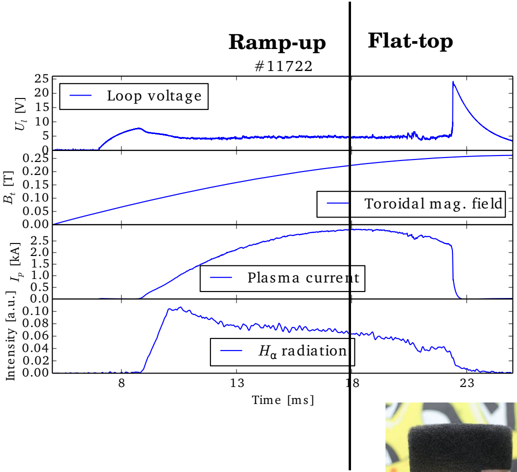
BP Honza B.: Plasma Current I_p flat top



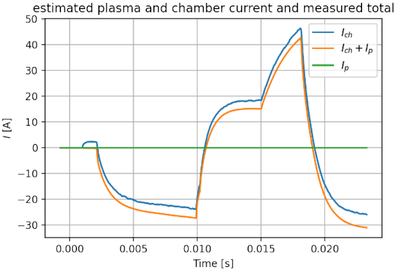
Transformer primary current control

Gas puff control

First kludge

Commissioning of I_p stabilization (into the chamber)

The request



Chamber current

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High precision spectrometer

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Remote control 2009-2023 rough inventory

- Demonstrations: Ghent University 09; Bochum University 13; Garching 13; Lemvig High School 14; Instituto Tecnologico Costa Rica 10; Armidale University 17.
- Training courses: French Training Course & EM 12-14,16-19; Bangkok 16-19; TU Eindhoven 11,15-19;TU Kobehaven 14,15,18;Grenoble TU 15, University of Belgrade 15-18; BUTE Budapest 10,12-18; University of Padova 14,16,18; TU Torino 16-18, St. Peterburg University 18-19. Kharkov University 19
- Workshops Kiten: 14,16,18; Observatorium Valasske Mezirici 14; Islamabad 14.
- Miscellaneous: Global Tokamak Experiment 10

New level of remote training - with publication on the horizon.

- Workshop "Kiten 2018" : Operational Domain in Hydrogen Plasmas on the GOLEM Tokamak. [J. Stockel *et al.* 2019 *JOFE* **38** 253–261]
- Training course for the Kharkiv National University: Breakdown Phase in The Golem Tokamak and its Impact on Plasma Performance. [Siusko *et al.* 2021 *UJP* **66** 231–239]
- Training for the National Research Nuclear University "MEPhI", Moscow:
  - Hydrogen and Helium Plasmas in the GOLEM Tokamak. [G.A. Sarancha *et al.* 2021 *PAST* **4** 92–110]
  - Magnetic turbulence and long-range correlation studies in the Golem tokamak. [Sarancha *et al.* 2021 *JPCS* **2055** 012003]
  - Remote Plasma Physics Research and Teaching by Example of Turbulence Study at the University-Scale Tokamak GOLEM [G. Sarancha *et al.* 2023 *FST* **79** 432–445]

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- EMTRAIC (with Jana and Tomáš)

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Generally

- UA training
- Fast spectrometry on specific lines.
- High resolution Fast spectrometry on specific lines (with Matěj T.).
- Mácha *et al.* 2023 *Nucl. Fusion* **63** 104003 cont.

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Acknowledgement

Financial support highly appreciated:

CTU RVO68407700, SGS22/175/OHK4/3T/14,EUROFUSION & MEYS cofund.

Students, teachers, technicians (random order):

Honorary: Vladimír Fuchs, **Ondřej Grover**, Tomáš Odstrčil, Gergo Pokol, **Gabriel Vondrášek**, **Jan Stockel**, **Jan Mlynář**, Tomáš Markovič

currently: **Martin Himmel**, **Petr Mácha**, Filip Papoušek, Martina Lauerová, Jan Buryanec, **Daniela Kropáčková**, Jarda Zajac, Jana Brotánková, Lukáš Lobko, Marek Tunkl, Jakub Chlum, Sara Abbasi, Eliška Pumprlová, Matyáš Pokorný, Vladislav Ivanov Štepán Malec, Kateřina Jiráková, Jaroslav Čeřovský.