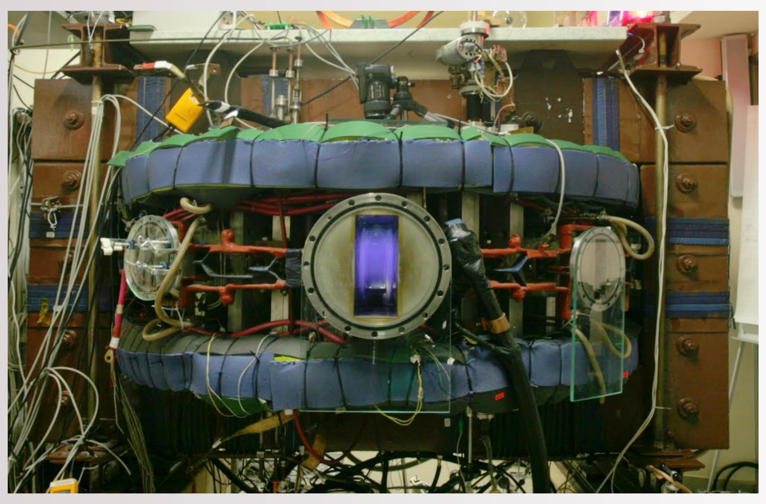
TOKAMAK GOLEM FOR FUSION EDUCATION - CHAPTER 13

P. Macha[1,2], M. Pokorny[3], D. Kropackova[2], M.Humpolec[4], J. Chlum[2], K. Wen[5], M. Tunkl[2], M. Lauerova[5], J. Brotankova[2], J. Stockel[2], V. Svoboda[1], S. Kulkov[2], A. Podolnik[1], J. Caloud[1,2], S. Malec[2]

[1] Institute of Plasma Physics of the CAS, Prague; [2] Faculty of Nuclear Sciences and Physical Engineering CTU in Prague, Prague; [3] Gymnazium Jana Nerudy, Prague;[4] Gymnazium Elisky Krasnohorske; [5] Novy PORG Gymnazium, Prague; Czech. Rep; [6] Prince William County Public Schools, Virginia

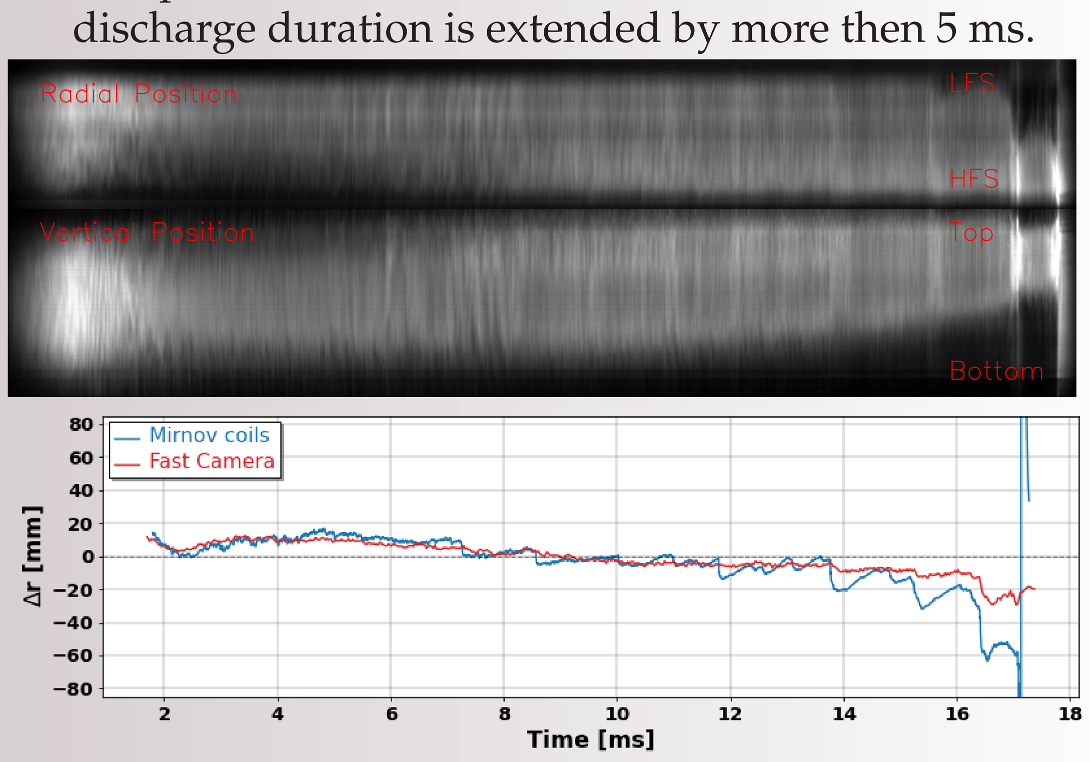
The GOLEM tokamak



- 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].
- Equipped by several plasma diagnostics (electric probes, magnetic probes, RE diagnostics, etc.).
- Great possibility for interesting experiments due to the adaptability and high flexibility.

External Stabilization and Fast Cameras

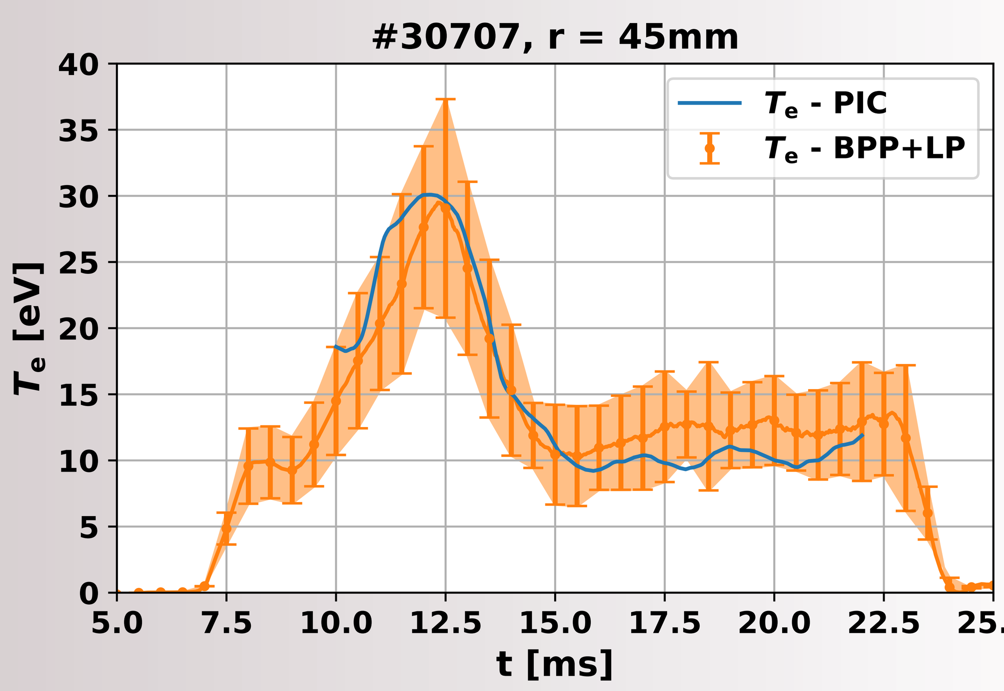
- The upgraded stabilization winding that generates stronger magnetic field provides better plasma position control.
- The new fast cameras have been installed for the better determination of the plasma position and for the Mirnov coils results verification.
- The positive effect of the stabilization is observed. The discharge duration is extended by more then 5 ms.



Top) Plasma displacement taken by fast cameras. Bottom) Comparison between fast cameras and Mirnov coils.

Fast T_e measurements

- Tunnel probe (TP) is used for the fast T_e measurements based on the calibration using PIC code PICCYL [2].
- The results are validated against T_e measured by combined ball-pen (BPP) and Langmuir probe (LP).
- A good agreement between both methods is found.



Time evolution of T_e measured by TP and BPP+LP.

References

[1] Tokamak GOLEM, Czech Technical University in Prague, http://golem.fjfi.cvut.cz/ [online]

[2] J. P. Gunnm et. al 2016 J. Phys.: Conf. Ser. 700 012018

[3] K. Dyabilin, M. Hron, J. Stockel et al. Measurement of poloidal flows on the Castor tokamak. Czech. J. Phys. 50, 57 (2000)

[4] S. Silburn, et. al 2022 Calcam (2.8.3). Zenodo

Contact us

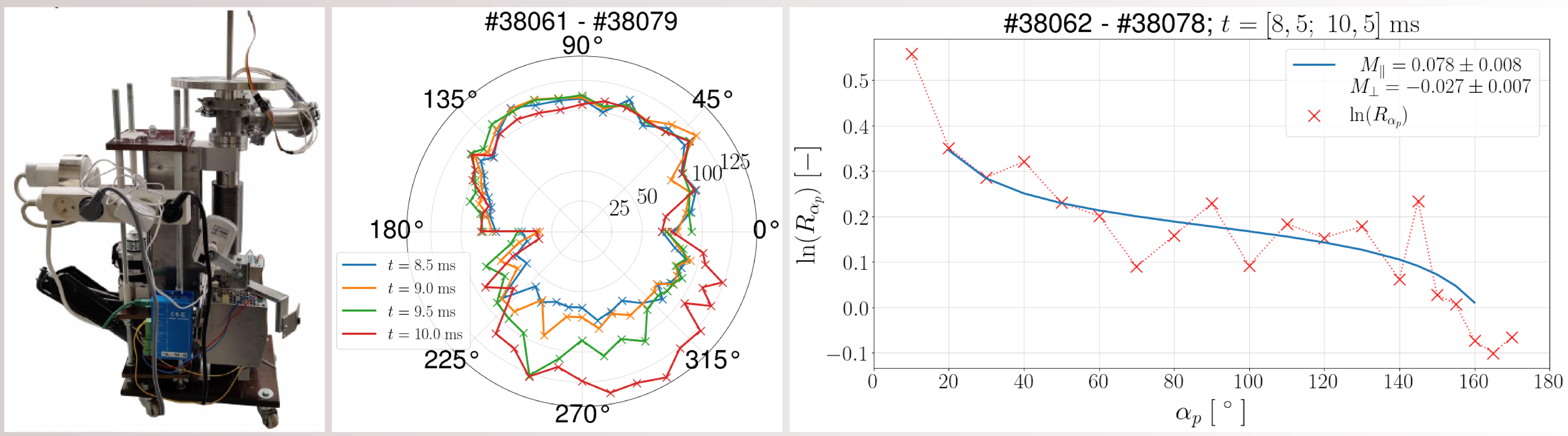
Tokamak GOLEM, Břehová 7, Prague, Czech Republic
`golem.fjfi.cvut.cz` svoboda@fjfi.cvut.cz

Acknowledgment

This work was supported by the Grant Agency of the Czech Technical University in Prague, grant No. SGS22/175/OHK4/3T/14 and SGS21/167/OHK4/3T/14.

Angular scans of ion flows

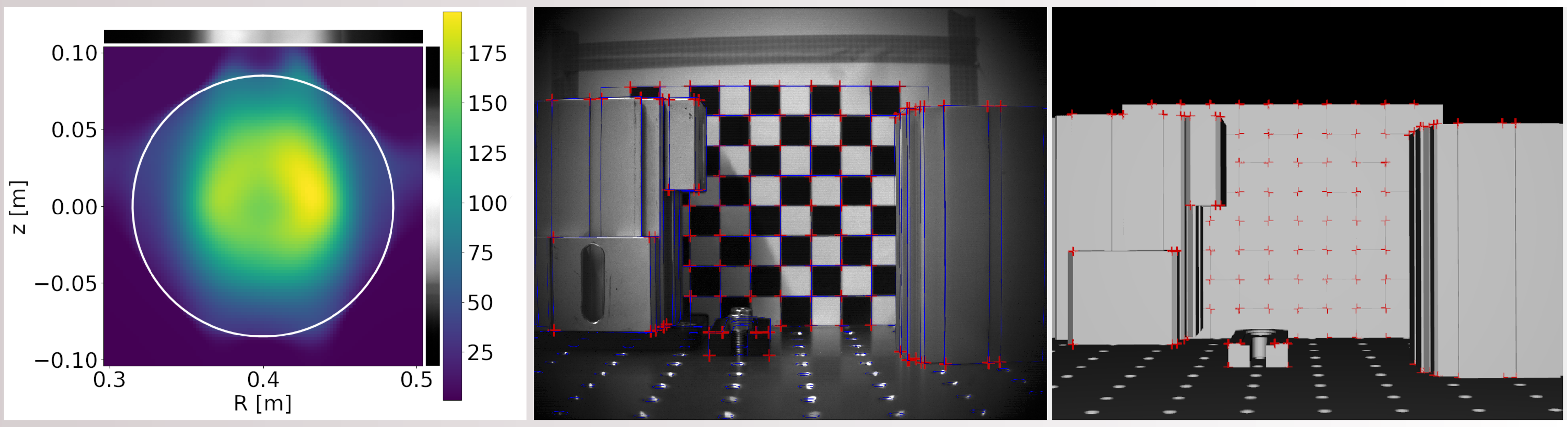
- The new motorized manipulator was installed and calibrated allowing both the radial and angular profiles measurements.
- The manipulator was equipped with the double tunnel probe and the ion flows were measured.
- The angular profile of I_sat is measured and compared with theory and experimental results from other tokamaks [3].
- Parallel and perpendicular components of Mach number were measured on the GOLEM tokamak for the first time.
- Very good agreement is found for both the I_sat and $M_\perp$ profiles.



Left) New motorized manipulator. Center) Angular profile of I_sat. Right) Angular profile of current ratio R.

Plasma tomography

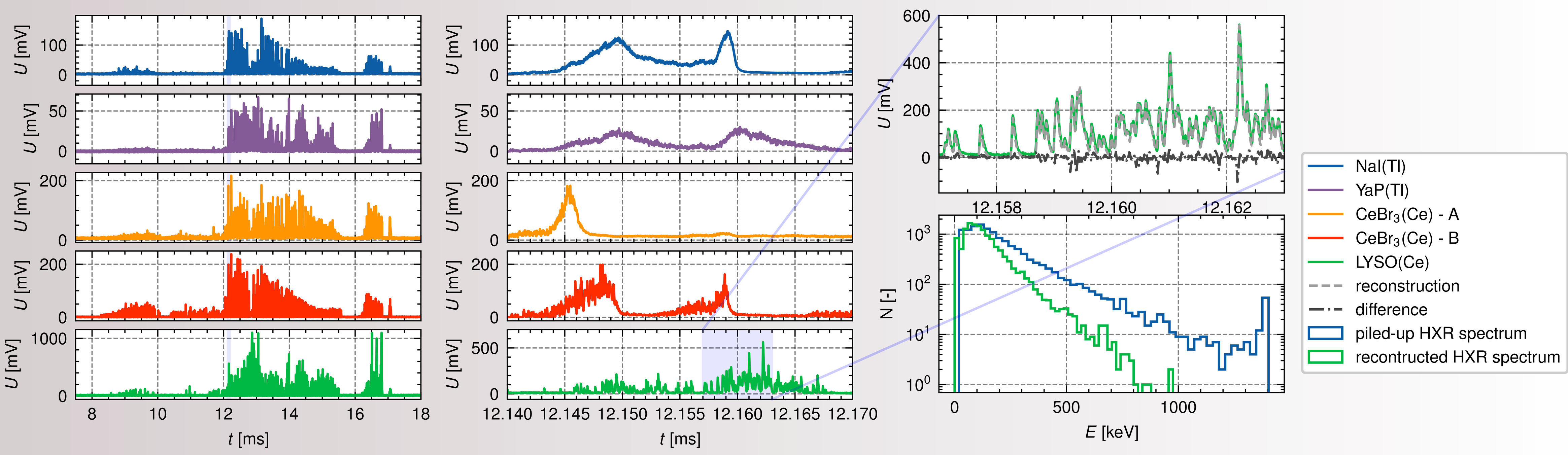
- Two fast visible cameras Photron FASTCAM Mini UX50 (1280 by 24 px at 102,400 fps) were positioned at perpendicular ports.
- Lens calibration was performed using a 3D scene on an optical breadboard using Calcam [4].
- Preliminary results were produced using the Minimum Fisher Regularisation algorithm.
- Accuracy is limited by uncertainties in camera positions. More precise camera positions measurements are foreseen.



Left) preliminary tomographic reconstruction from discharge #39205, frame #231. White line represents the vessel wall. Right) camera lens calibration using Calcam software

Measurements of HXR radiation

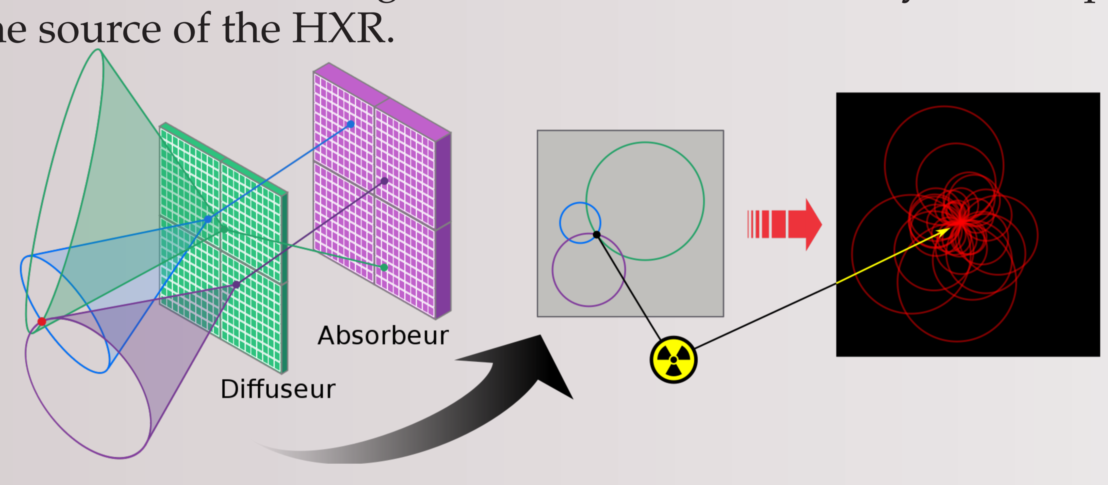
- LYSO coupled with SiPM (silicon photomultiplier) for HXR spectroscopy was installed.
- 3x3x5 mm crystal, 47 nm decay time.
- Peak pile-ups are still present, but individual peaks are identifiable.
- It is possible to reconstruct individual peaks heights.
- Spectrum cleared from pile-up effects was obtained.

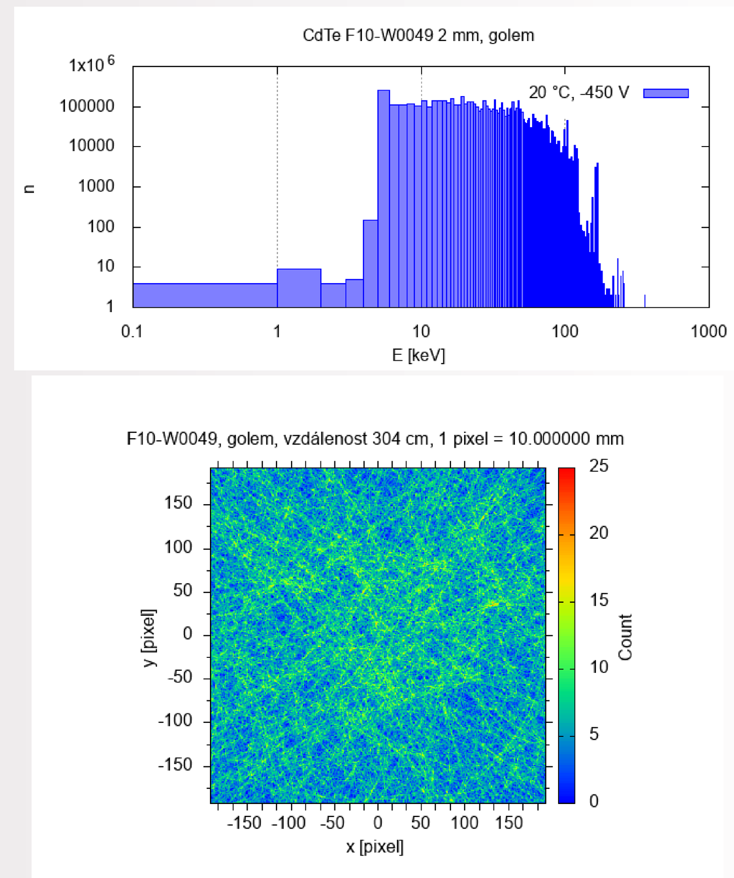


Left) Comparison of HXR signals from 5 scintillation detectors. Center) More detailed plot. Right) HXR signal reconstruction and corresponding spectrum.

Reconstruction of Compton scattering

- Timepix3 detectors with 2 mm thick CdTe sensors were used for the energy spectrum measurements and the Compton scattering reconstruction.
- Detectors were placed 3 m far from the limiter outside of the tokamak and the display plane was 304 cm from the detectors as shown in the diagram bellow.
- There is no evident high intensive area identified yet corresponding to the source of the HXR.





Left) Diagram of experimental setup. Right) Energy spectrum and Compton scattering reconstruction.