

# TOKAMAK GOLEM FOR FUSION EDUCATION - CHAPTER 8

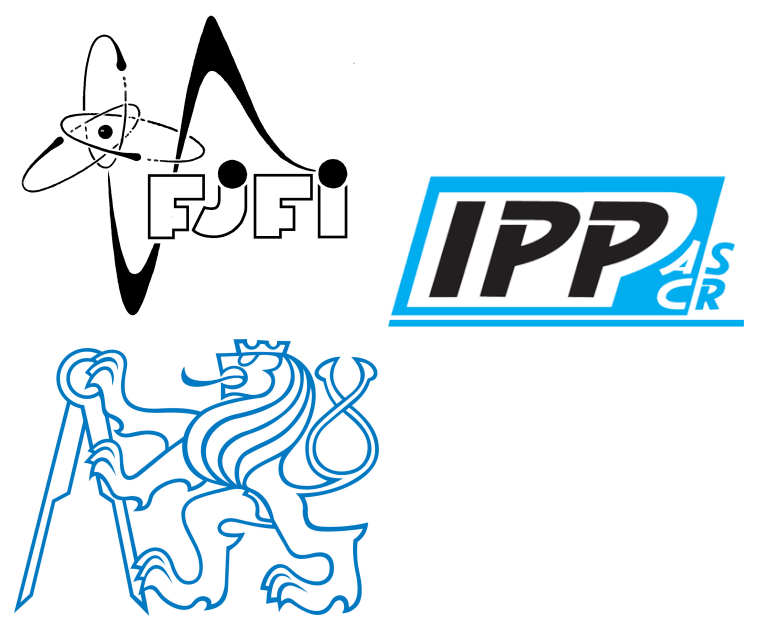
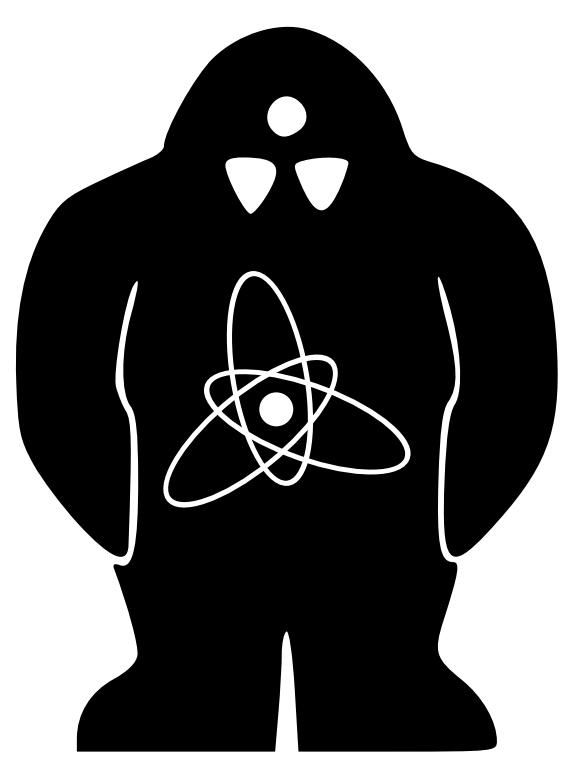
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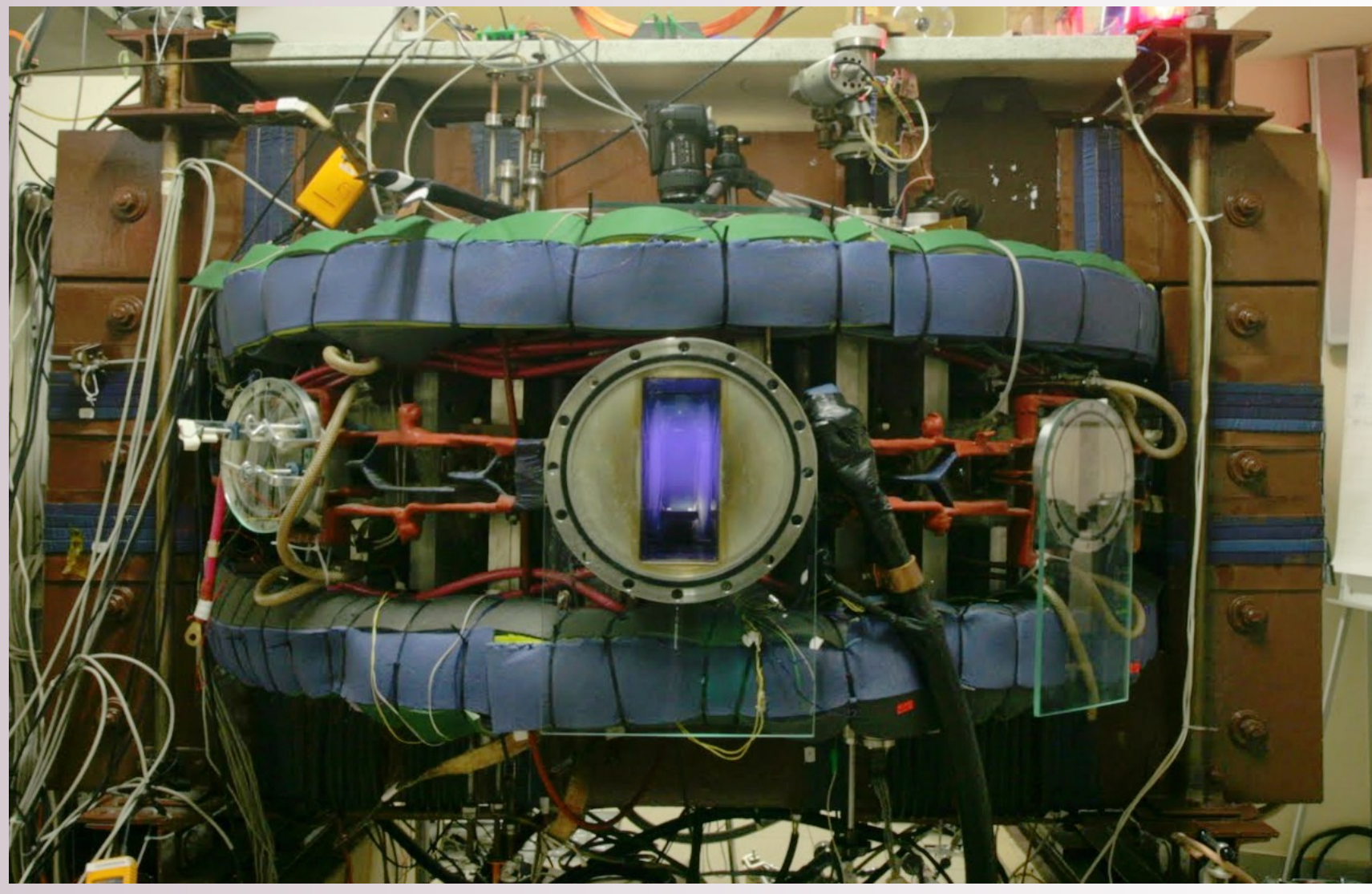
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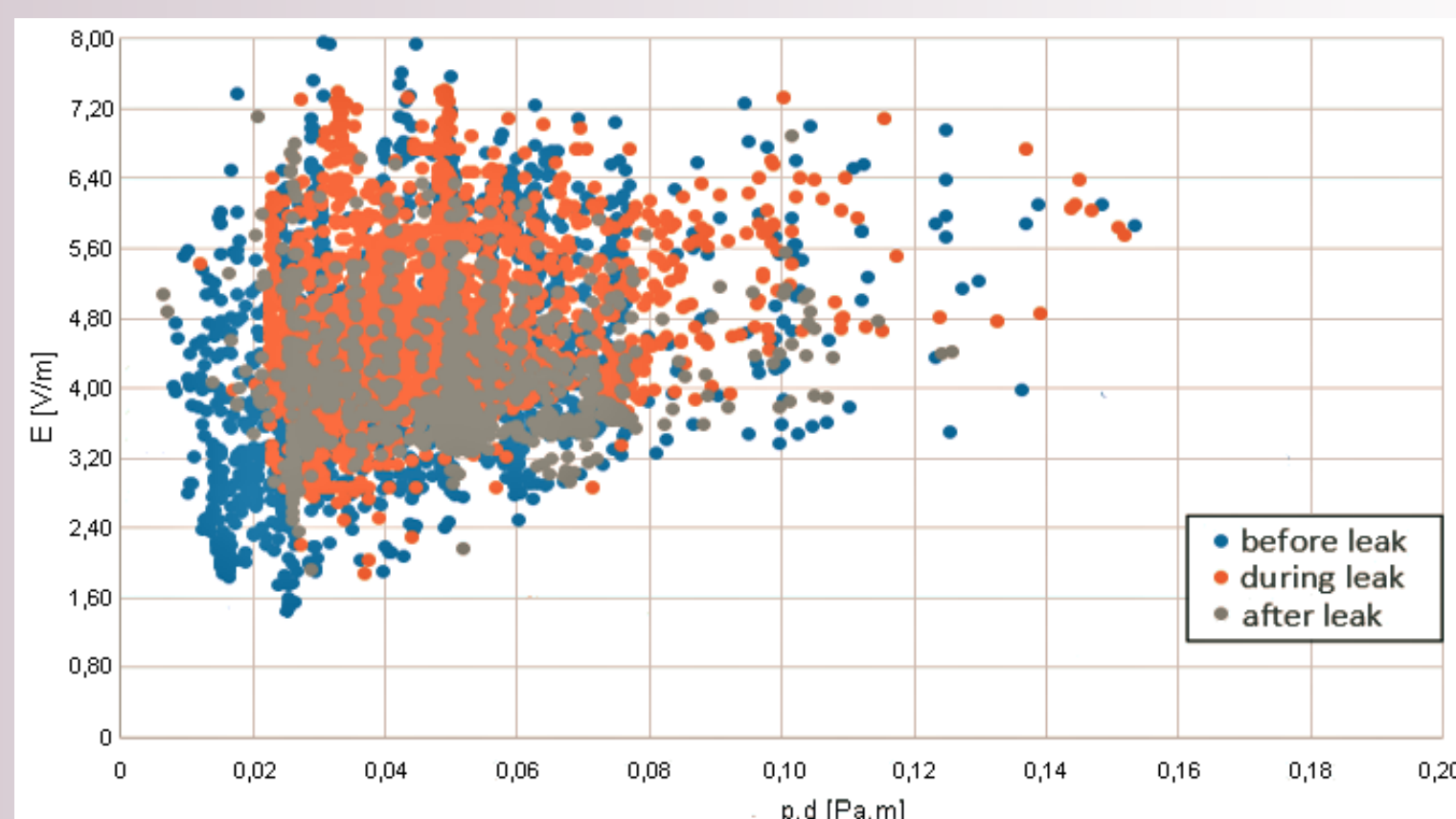
## Tokamak GOLEM



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

## Breakdown studies

- Investigation of the vacuum characteristics, influenced by the chamber leak
- Seen increase of the breakdown voltage after the leak



Paschen curve point from 12 000 shots.

## Data analysis platform

- Interactive data analysis and visualization JupyterHub platform enables students participating in remote training courses
- Offers modern scientific data processing and plotting algorithms

## References

[1] V. Svoboda, et al., Fus. Eng. and Des. **68**, 1310-1314 (2011)

[2] J. Adamek, et al., Contrib. Plasma Phys. **54**, No. 3, 279-284 (2014)

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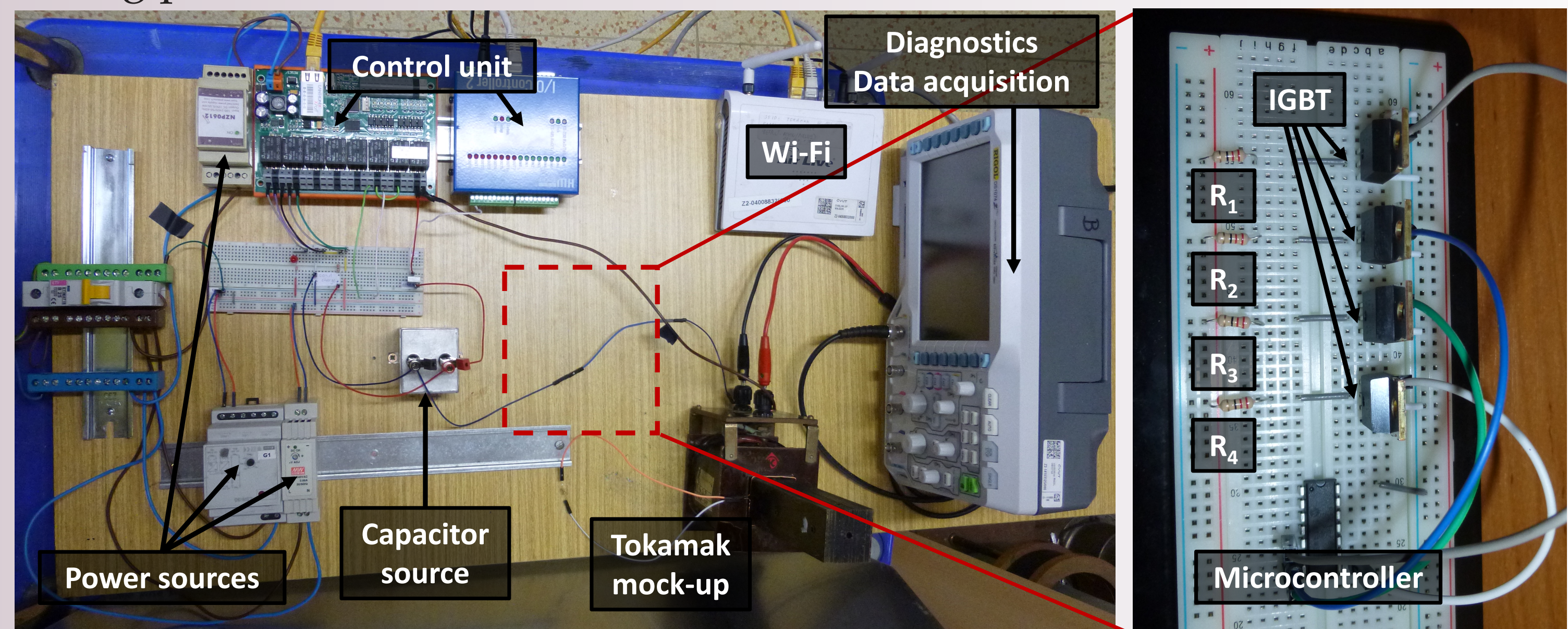


## Acknowledgment

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## Current stabilization

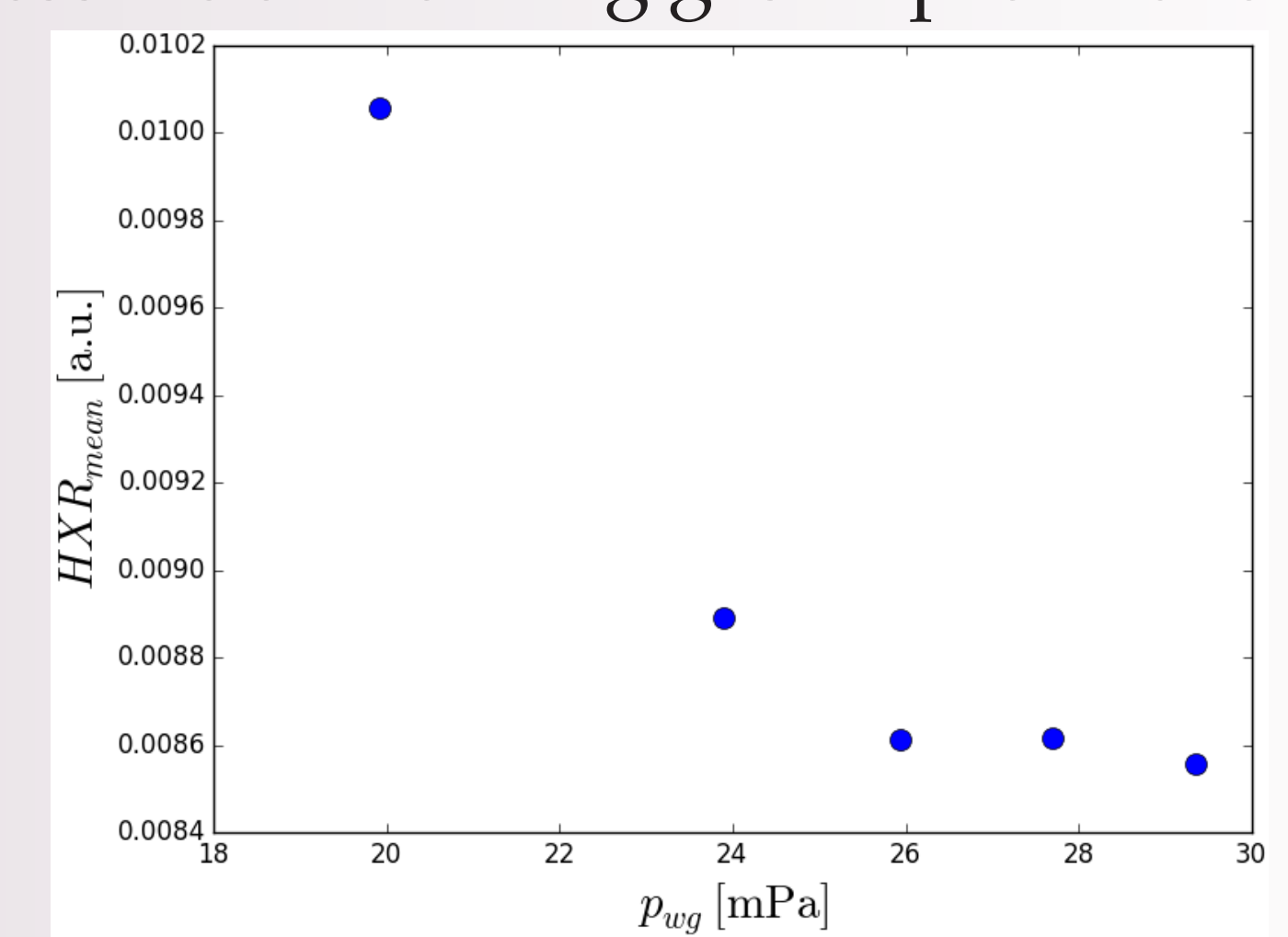
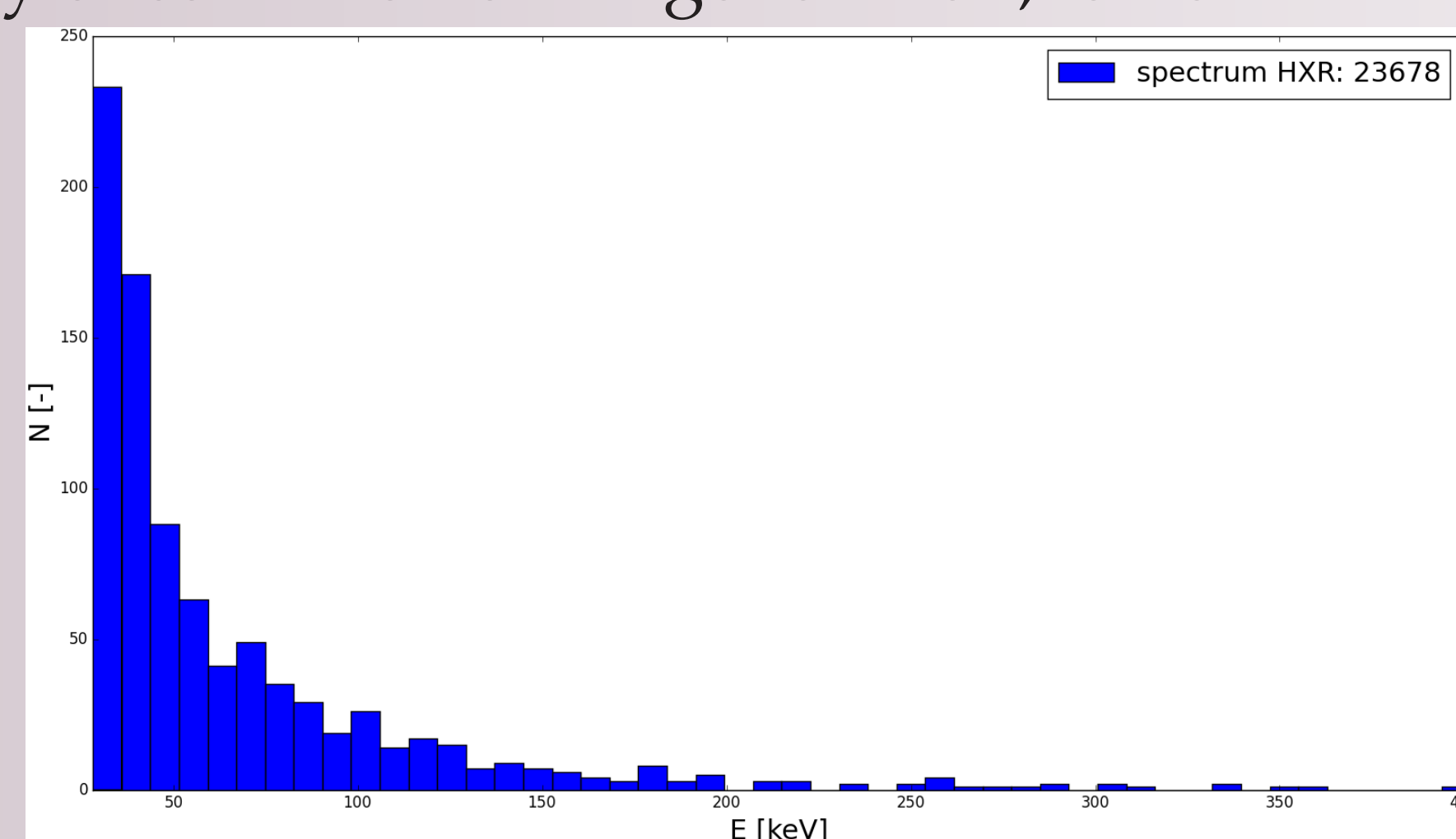
- Operation regime does not enable *flat-top* of plasma current  $\rightarrow$  additional circuit for variable resistance during discharge
- By-product *tabletop tokamak model* = proof of concept and a tool for optimisation process and general training platform



Current state of the tabletop model. Capacitor source, when charged, is discharged to tokamak mock-up. Control and diagnostics unit provides smooth running of the experiment. Remote control is enabled by wi-fi. Resistor array (right side) is prepared to be implemented.

## Runaway electrons

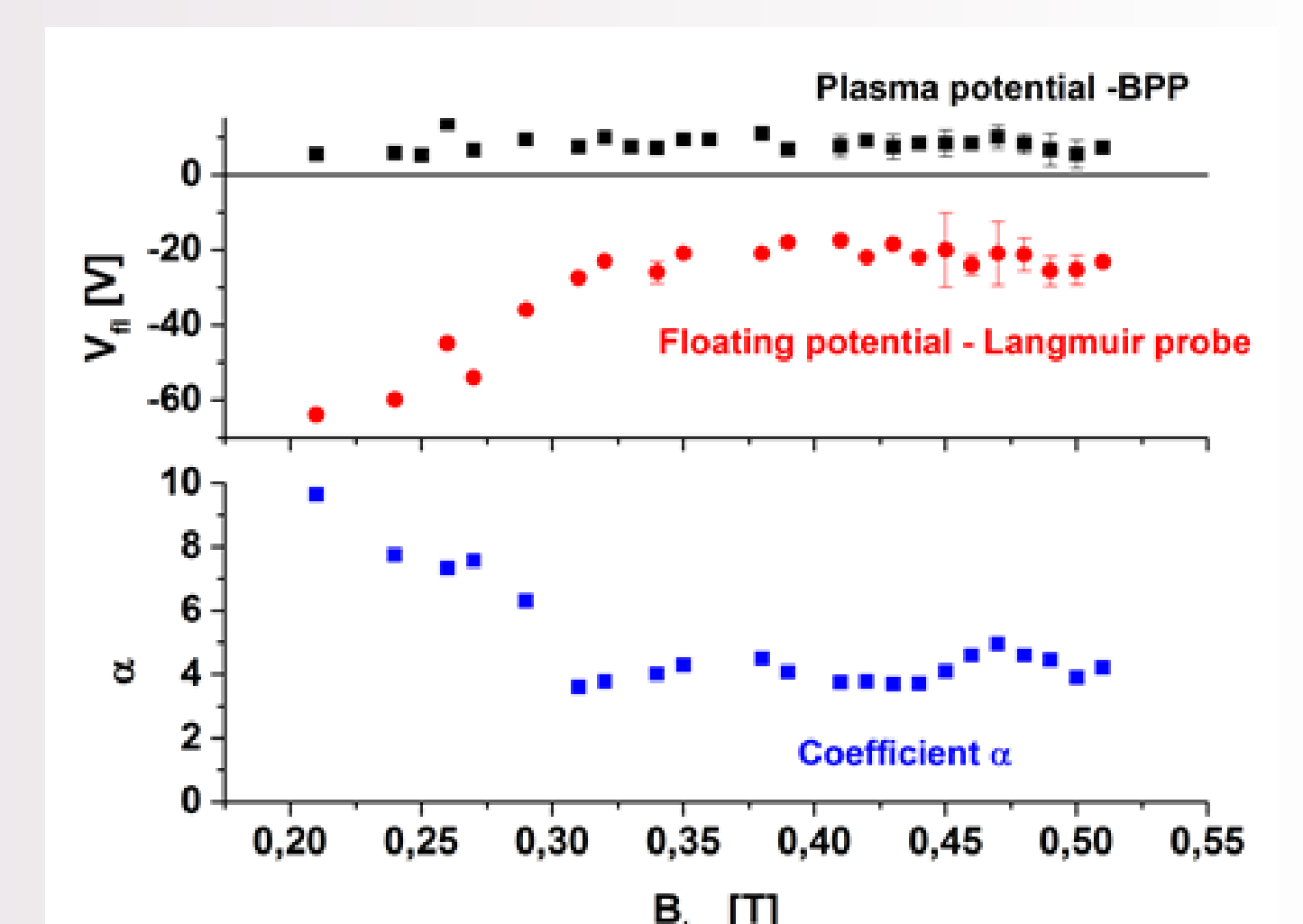
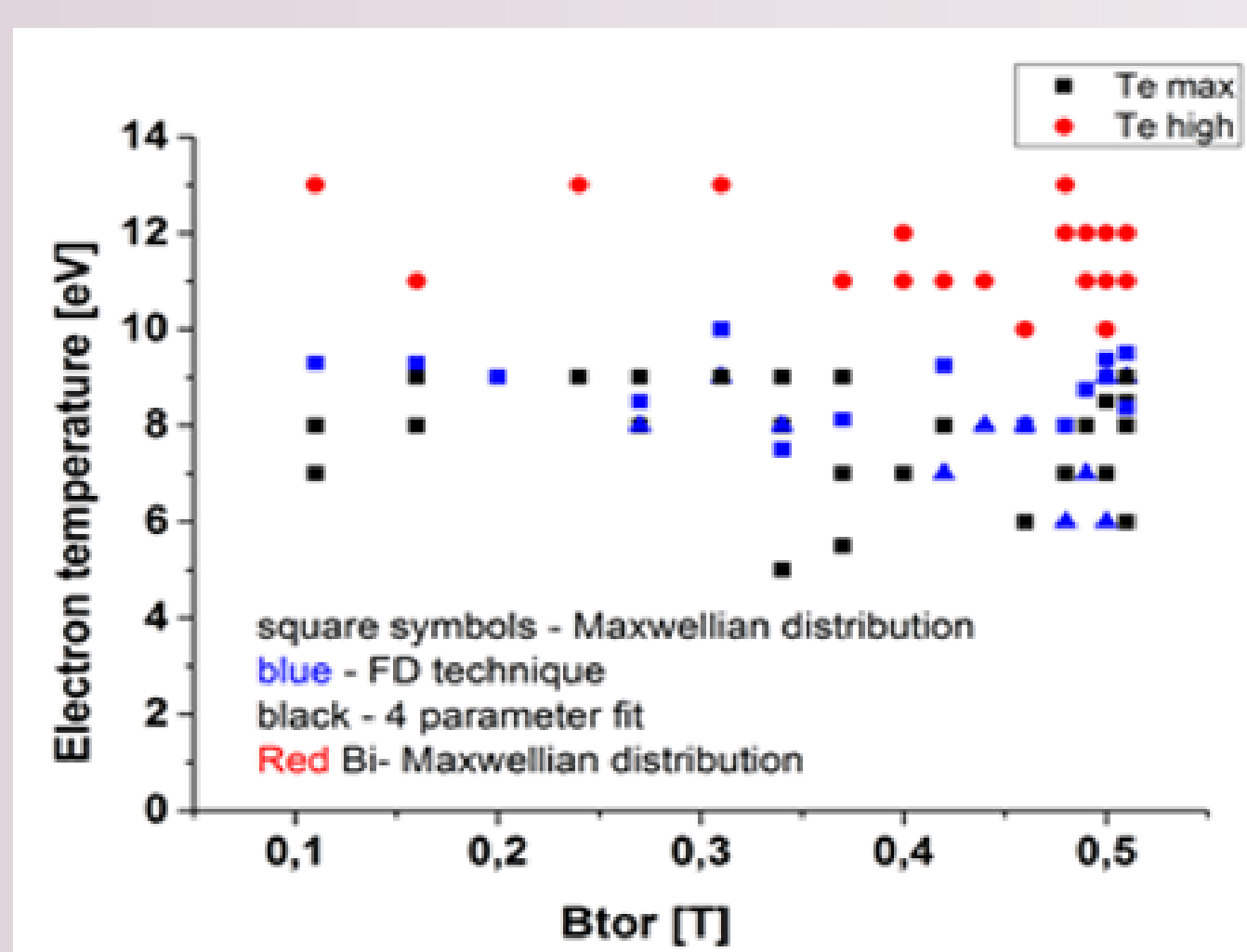
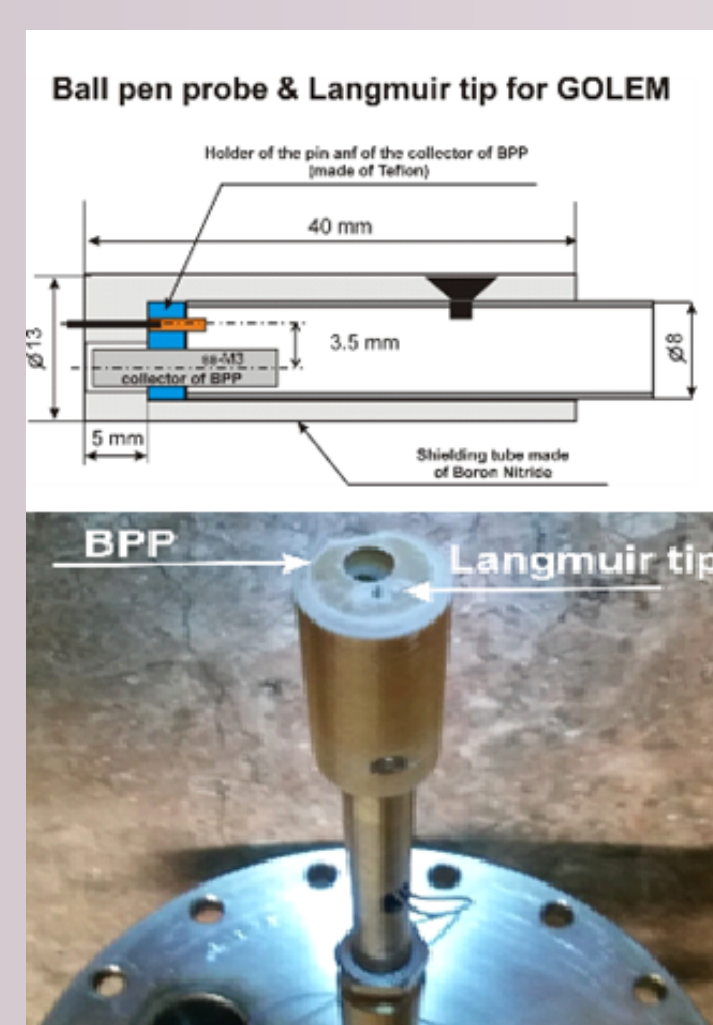
- Low electron tip density ( $4 - 6 \cdot 10^{18} \text{ m}^{-3}$ ) and relatively high loop voltage (4-6 V)  $\rightarrow$  RE
- Investigation of properties of HXR induced by interaction of RE with limiter
- Study of condition of RE generation, lower initial pressure of working gas  $\rightarrow$  production of HXR



Left - spectrum of HXR radiation. Right - dependence of HXR radiation on initial pressure of working gas.

## Measurements with Ball Pen Probe

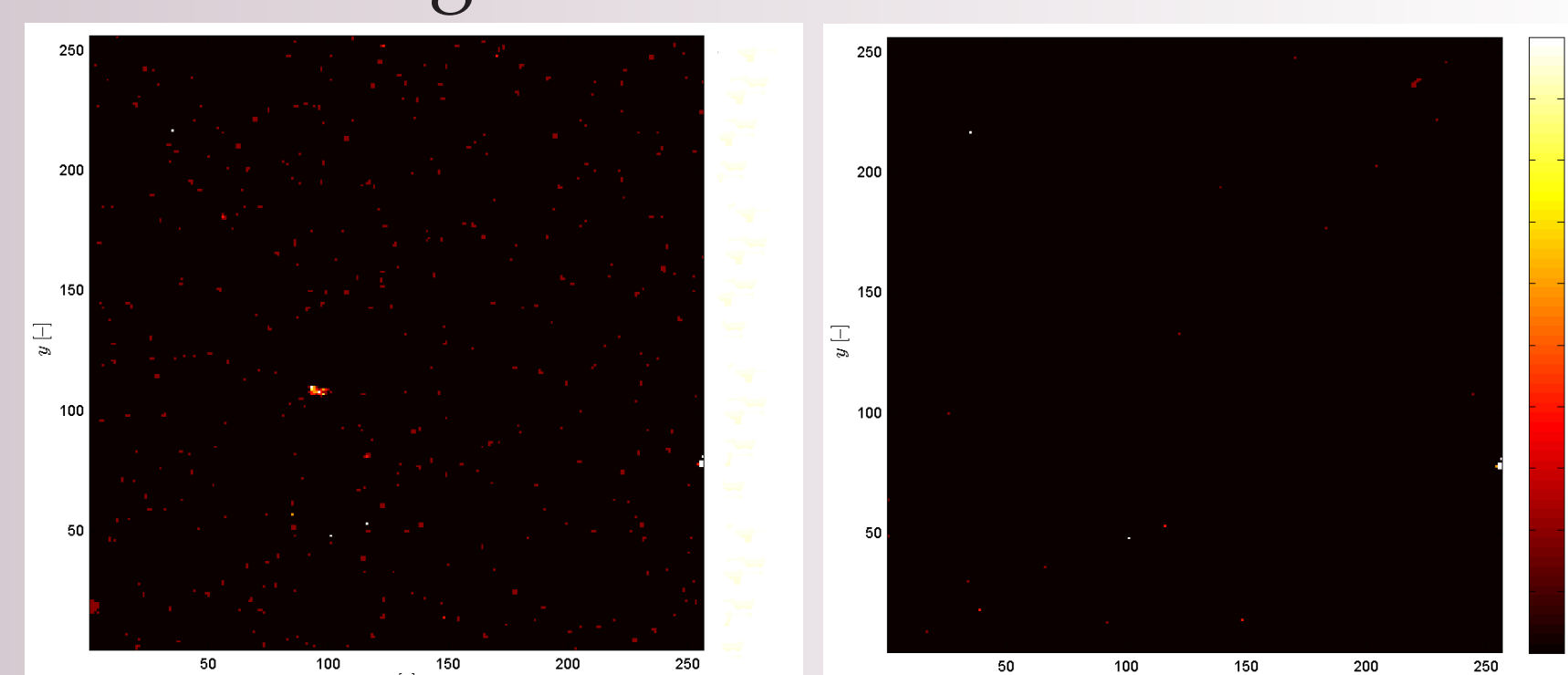
- Combined probe head composed of the Ball Pen Probe and the single Langmuir probe
- Direct measurements of the plasma potential and the electron temperature
- EEDF is bi-maxwellian in some cases, with a tail characterized by higher electron temperature
- The average electron temperature and  $\alpha$  is independent on  $B_{TOR}$  for  $B_{TOR} > 0,3$



Left - Electron temperature versus the toroidal magnetic field in discharges # 23447, 23449, 23450, 23451. Right - Plasma and floating potential and the resulting coefficient  $\alpha$  versus  $B_{TOR}$ .

## RE diagnostics

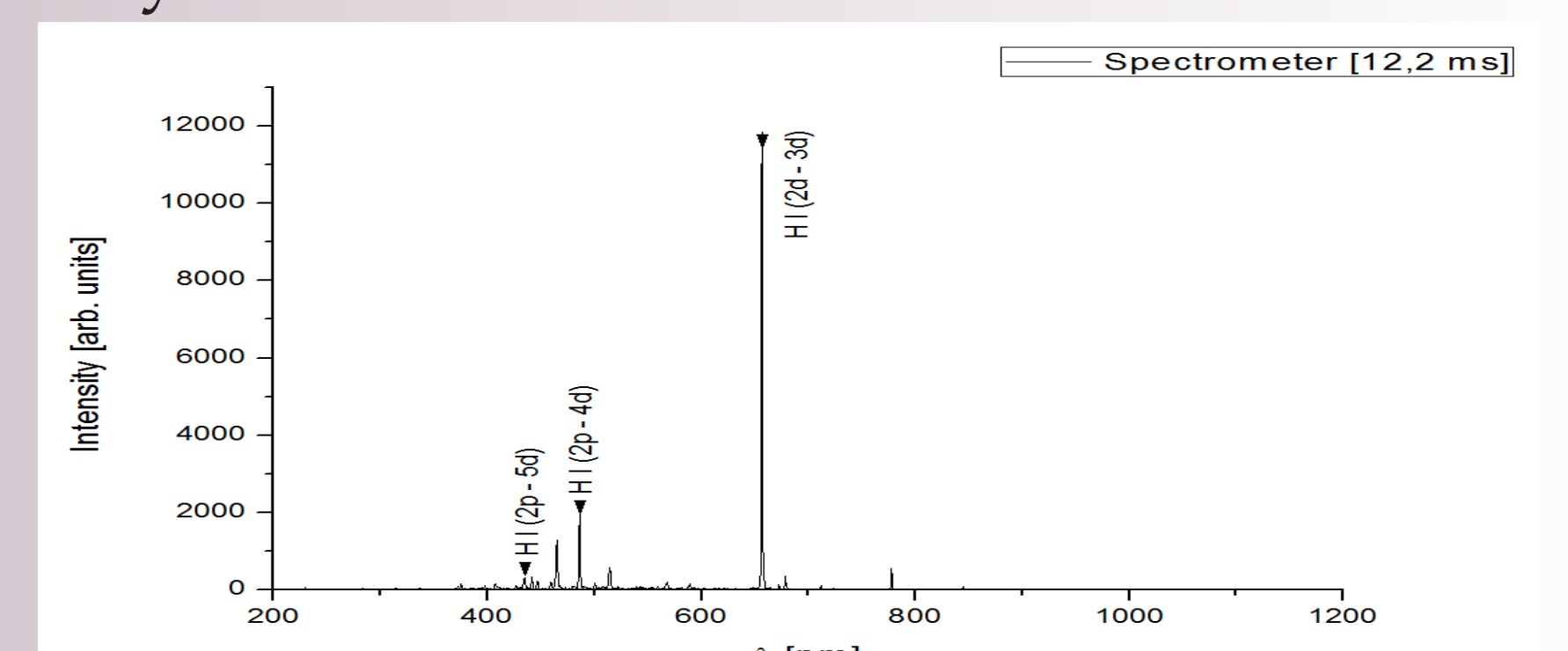
- Detecting charged particles and X-rays.
- Observing interaction of RE with the wall.



Images from the Timepix during and after shot

## Estimation of temperature

- Spectrum of plasma in range 200 - 1100 nm
- Pyrometric line method was used



Spectrum of shot with recognised transitions.