TOKAMAK GOLEM FOR FUSION EDUCATION - CHAPTER 10

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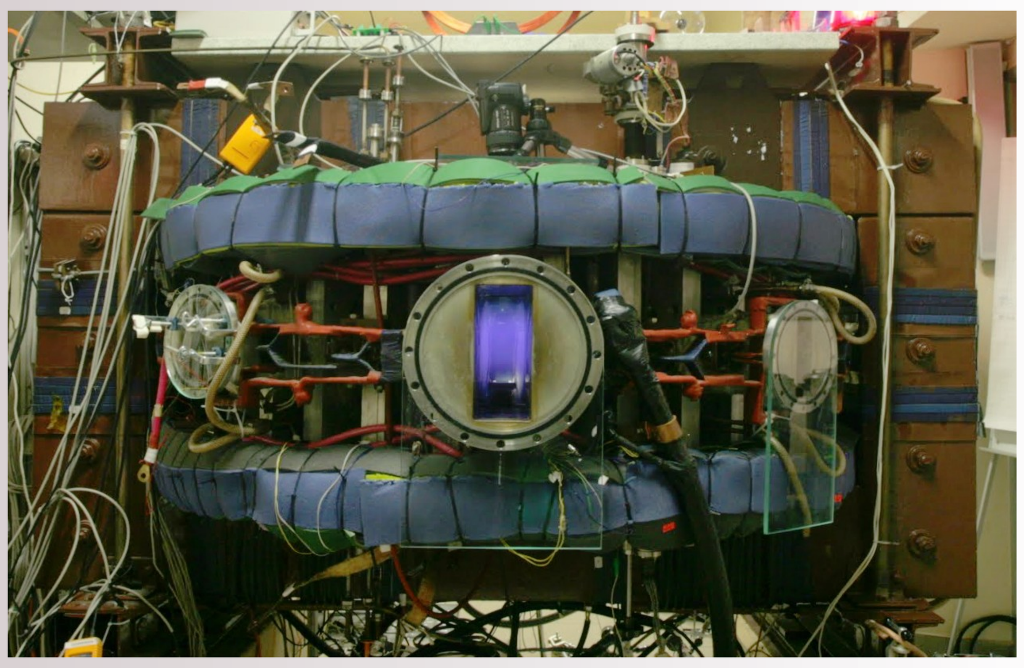
The GOLEM tokamak



- 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 several Bachelor's degree projects and Master's degree theses.
- At present used in an experimental laboratory course in the basic physics curriculum.

GOMTRAIC 2019

- An annual educational and training course for University students.
- One week in Prague, and getting experience with the tokamak, taking first measurements, data processing, and presenting of results.
- This workshop offered an interactive course on fundamental and advanced toroidal plasma physics.
- Five various topics (microwave interferometry, tunnel probe measurements, double rake probe turbulence measurements, runaway electrons (RE), plasma position and control).
- 16 present participants (from undergraduate to doctoral level) from various countries all over the world.

References

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

[2] J. Adamek, et al.,Direct measurements of the electron tempreature by a Ball-pen/Langmuir probe, No. 3, 2214-2217(2005)

[3] A. Scarabosio, et al.,Plasma Physics and Controlled Fusion: Toroidal plasma rotation in the TCV tokamak, (2006)

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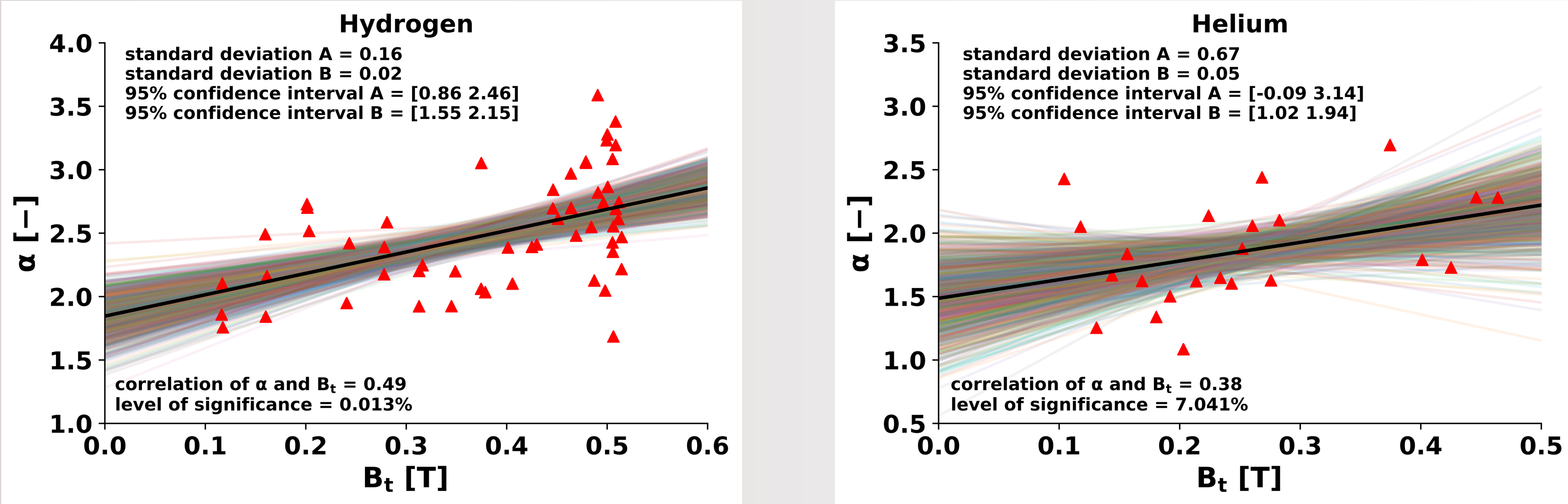
Calibration of the ball-pen probe

- Combined probe head composed of ball-pen and Langmuir probe [2] is used for measuring.
- Calibration coefficient $\alpha = \frac{\Phi - U_{\mathrm{float}}}{T_e}$ in H and He plasma determination for fast T_e measuring.
- Results in H plasma $\alpha = (2.5 \pm 0.7)$ or $\alpha = \alpha(B_t) = 1.89B_t + 1.85$.
- Results in He plasma $\alpha = (1.8 \pm 0.4)$ or $\alpha = \alpha(B_t) = 1.47B_t + 1.49$.

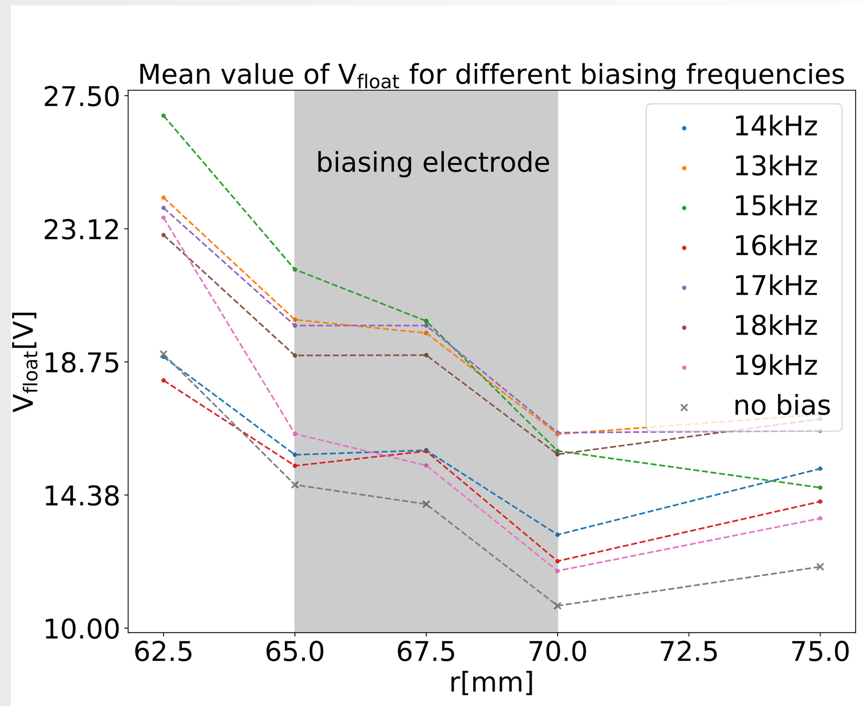


Dependece of calibration coefficient α on B_t in H (left) and He (right) plasma including statistical analysis.

Impact of swept edge potential biasing on turbulence in tokamaks

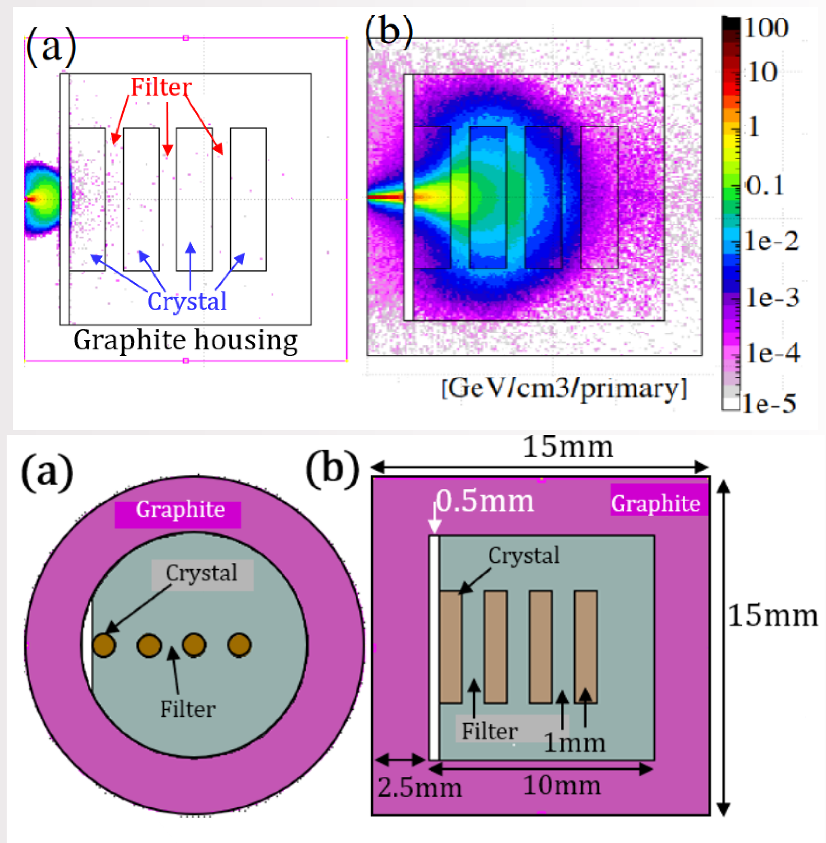
- Double rake probe is used to obtain radial profile of U_{float}.
- A series of shots were performed to describe the plasma response for differnet biasing frequencies on floating potential.
- Slight increase of the U_{float} mean results from biasing.

Right: Mean value of U_{float} from different shots with AC bias applied - grey rectangle, compared to shot without bias.



Development of a probe for runaway electrons energy measurement

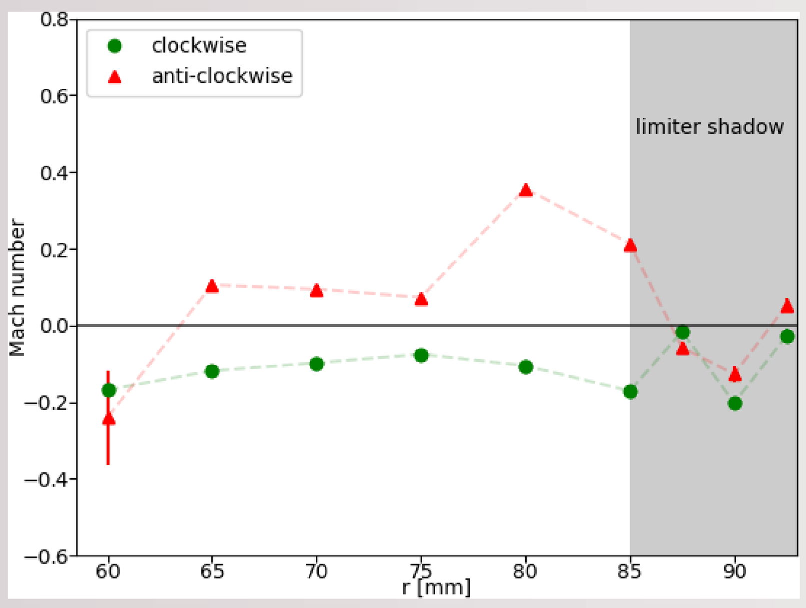
- The simulations of the RE interaction with the probe were performed using the MC FLUKA code to test the probe geometry and design.
- The probe is based on scintillators alternating with heavy materials – different material combinations were tested in simulations (inter alia, NaI(Tl) and Stainess Steel).
- According to the simulations, the energy of the RE might strongly exceed 1 MeV.
- The research on materials and geometry optimization is ongoing.

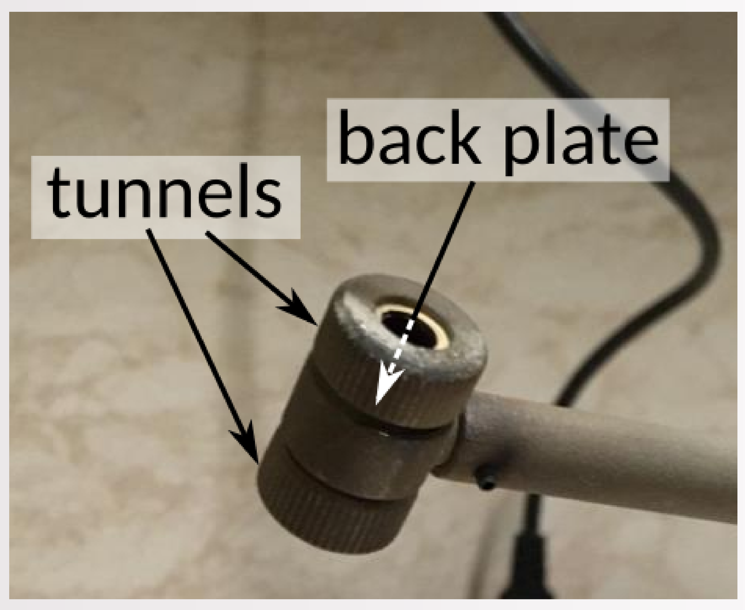


Top: Energy deposite in the probe a) 1 MeV electron beam, b) 10 MeV electron beam. Bottom: a) Top view b) Side view of the probe.

Field reversal effect on toroidal Mach number

- Importance of Mach number $M = \frac{v_t}{c_s}$: toroidal rotation prevents locked-mode disruptions.
- M measured by double tunnel probe, $M = \frac{1}{4} \ln \left(\frac{I_{\mathrm{backplate1}} + I_{\mathrm{tunnel1}}}{I_{\mathrm{backplate2}} + I_{\mathrm{tunnel2}}} \right)$.
- In confined plasma, plasma flows opposite to I_{plasma}.
- In limiter shadow, plasma flows toward the nearest limiter.
- Carried out by a high-school student, confirmation of [3].





Left: Mach number profile in clockwise and anti-clockwise field configuration. Right: double tunnel probe.