Golem #13 2020 - from #31150 to #34489

Mariánská 2021

Vojtěch Svoboda

Outline

1. Introduction
2. Current scientific topics
   - Probes: BPP + Lang probes
   - Probes: Rail probe
   - Biasing experiments
   - Run Away Electrons
     - Diagnostics (CAAS project)
     - Physics
3. Technology improvements
   - Plasma position Stabilization
   - Overal tokamak GOLEM reconstruction
4. Diagnostics improvements
   - Fast cameras
   - HXR
5. Education
   - Undergraduate Projects
   - Remote trainings

Forecast 2020

- The Night of Scientists V. ✗(#C19)
- FUMTRAIC VI ✗(?), SCIWTRAIC@GOLEM VIII ✗(#C19), HUNTRAIC VII ✓
- GOMTRAIC III (5 days)! ✗(#C19)
- Bachelor thesis ?
- Diploma thesis IV cont.
- papers in FUSENGDES, AJP .. ?
- TRAICS: Eindhoven, Bangkog ✗(?), Torino, Moscow,
- Runaways intensive studies (JČ, postdoc, GACR grant, Valérie,)
- Langmuir probes intensive studies (KJ, PM: TunnelP)

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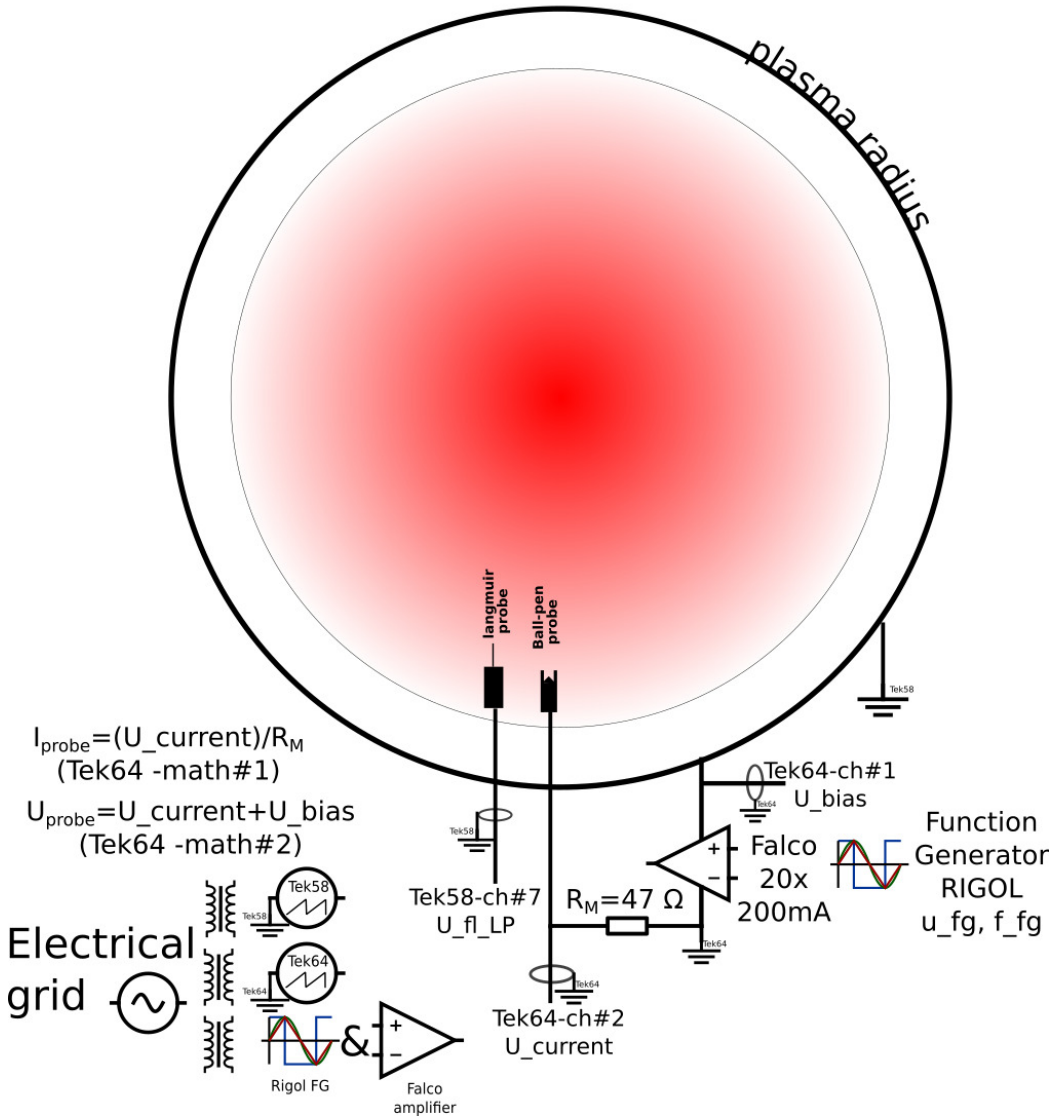
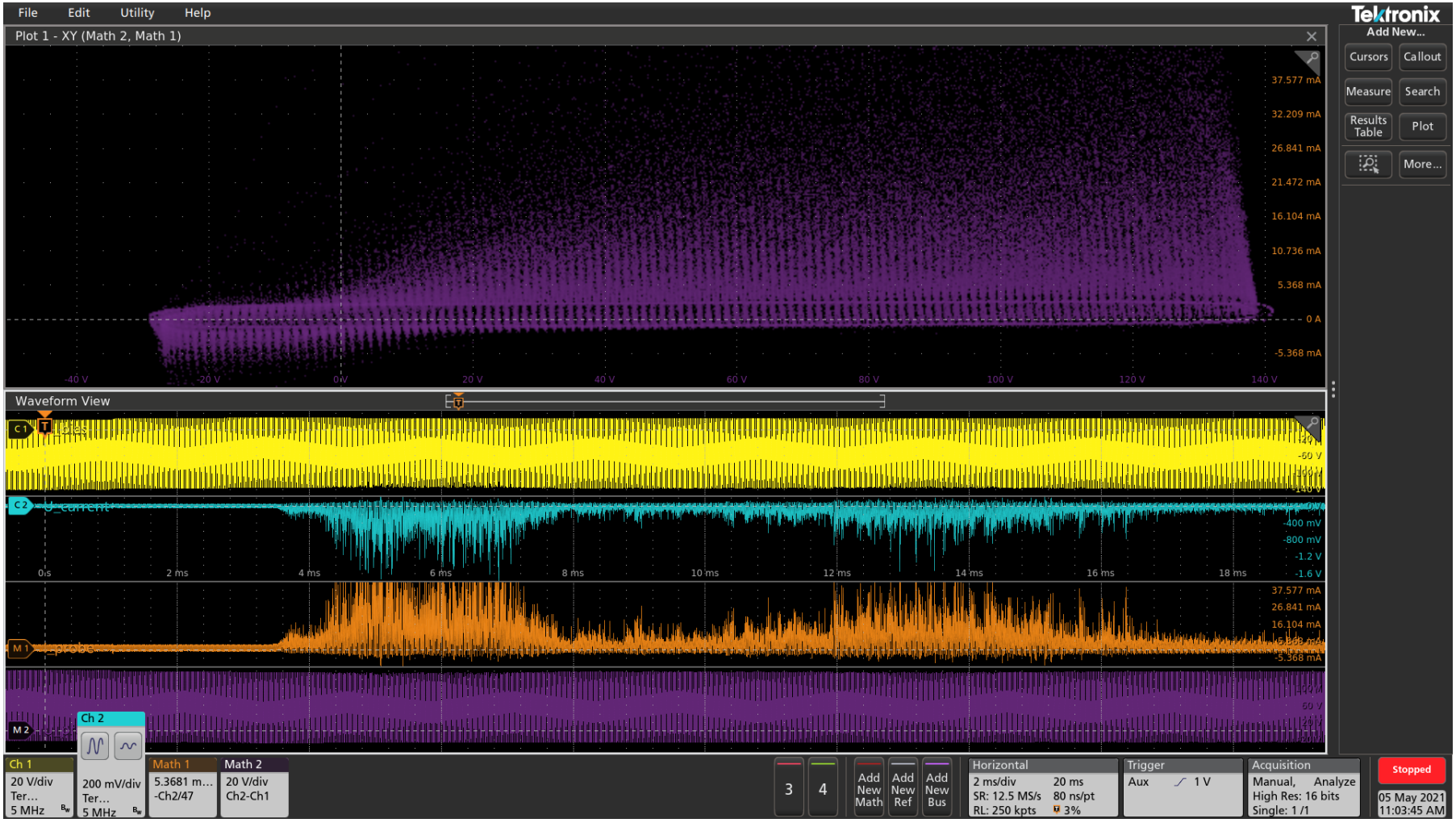
Dario Cipciar (Jiří Adámek): Swept BPP probe. MSc project. 2021

Dario Cipciar(Jiří Adámek): Swept BPP probe: complex set-up

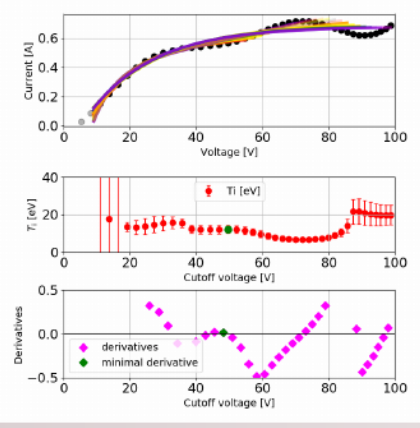


Dario Cipciar(Jiří Adámek): Swept BPP probe: Oscilloscope screenshot

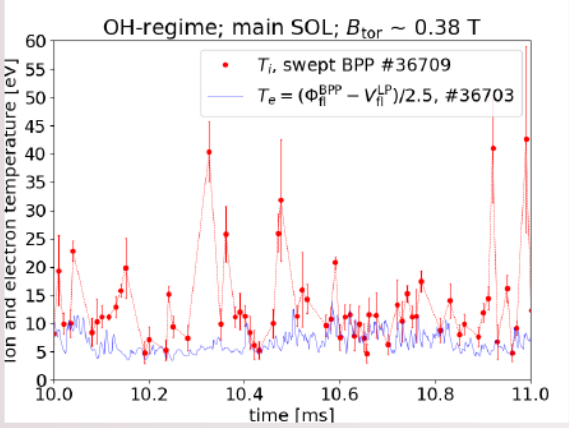


Fast ion temperature measurement using swept ball-pen probe. MSc thesis. 2021

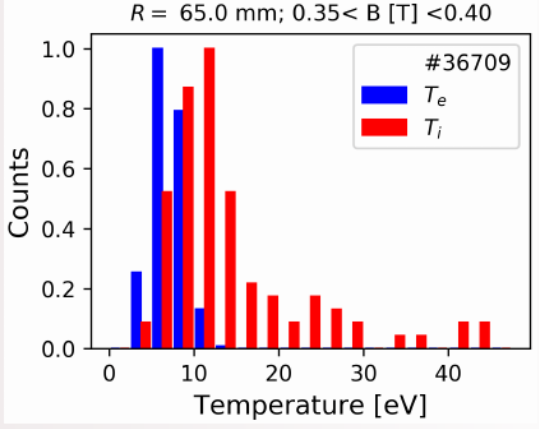
- Ion temperature is measured with 5 μs temporal resolution based on the measurements of the electron branch of a ball-pen probe (BPP) IV characteristics [3].
- The probe collector is biased with a voltage swept between -30V to +130 V at a frequency of 100 kHz.
- The T_i is obtained from $I(V) = I^+_\mathrm{sat} \cdot \left(\exp(\alpha_\mathrm{BPP}) \cdot [1 + K \cdot (V - \Phi)] - \exp\left(\frac{\Phi - V}{T_\mathrm{i}}\right)\right), \alpha = \ln \frac{I^-_\mathrm{sat}}{I^+_\mathrm{sat}} = 0.25 \pm 0.09\,(B_\mathrm{t} > 0.22\,\mathrm{T})$.
- Cut-off fitting technique is applied to all the IV characteristics.
- Fluctuations of the ion temperature ranging between 5 eV up to 40 eV reveal the turbulent behavior of the edge plasma.
- NON-Gaussian shaped histograms of T_e and T_e are observed with a peak at low temperature and a tail towards high temperatures.



Cut-off technique.



Temporal evolution of T_i and T_e.

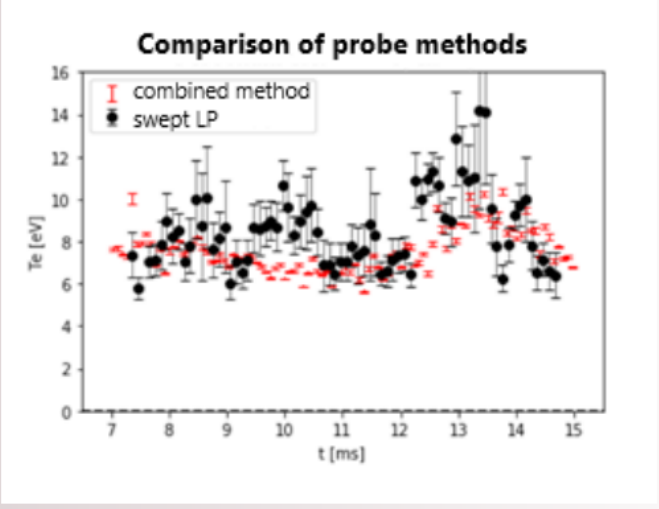


Histograms of T_i and T_e.

Macha, P., Cipciar, D. & Adámek, J. et al. @EPS 2021

Martina Lauerová (Kateřina Hromasová). Electron temperature measurements using Lang and BPP probes. SOČ project 2021

- Swept Langmuir probe – verified but complicated and time-consuming.
- Combined method (floating ball-pen and Langmuir probe) – straightforward and high time resolution, but rather new.
- It was verified that both methods give the same results.
- We suggest that the combined method is suitable for measuring the edge plasma T_e.

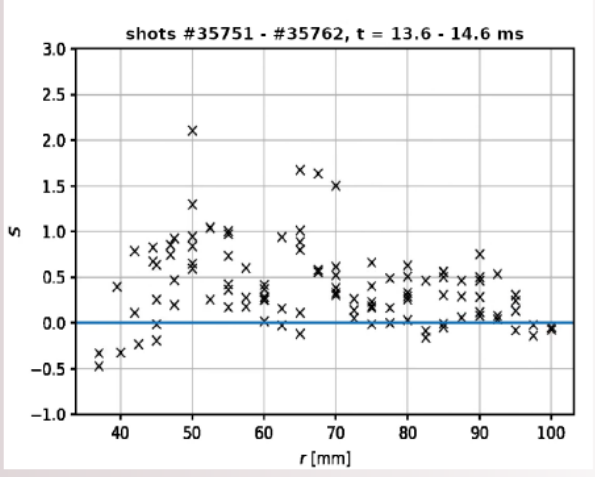


Time evolution of T_e in two identical GOLEM discharges, showing good correspondence between the two methods (#35729 – #35791).

Macha, P., Lauerová, M.. & Hromasová, K. et al. @EPS 2021

Aleš Socha (Kateřina Hromasová), Turbulent structuresusing using Double rake probe. SOČ project 2021

- Exchange turbulence (blob-hole pair generation and propagation) in the plasma edge enhances energy and particle losses.
- Double rake probe (tokamak bottom port) measured I_{sat} at $r = 37 - 90$ mm (limiter at $r = 85$ mm).
- I_{sat} histograms found asymmetric with positive skewness indicates the presence of blobs.
- Skewness seems to decrease to negative values at $r = 40$ mm, possible location of the blob birth zone.



Radial profile of ion saturated current skewness. Positive values indicate the presence of blobs throughout the investigated region.

Macha, P., Socha, A.. & Hromasová, K. et al. @EPS 2021

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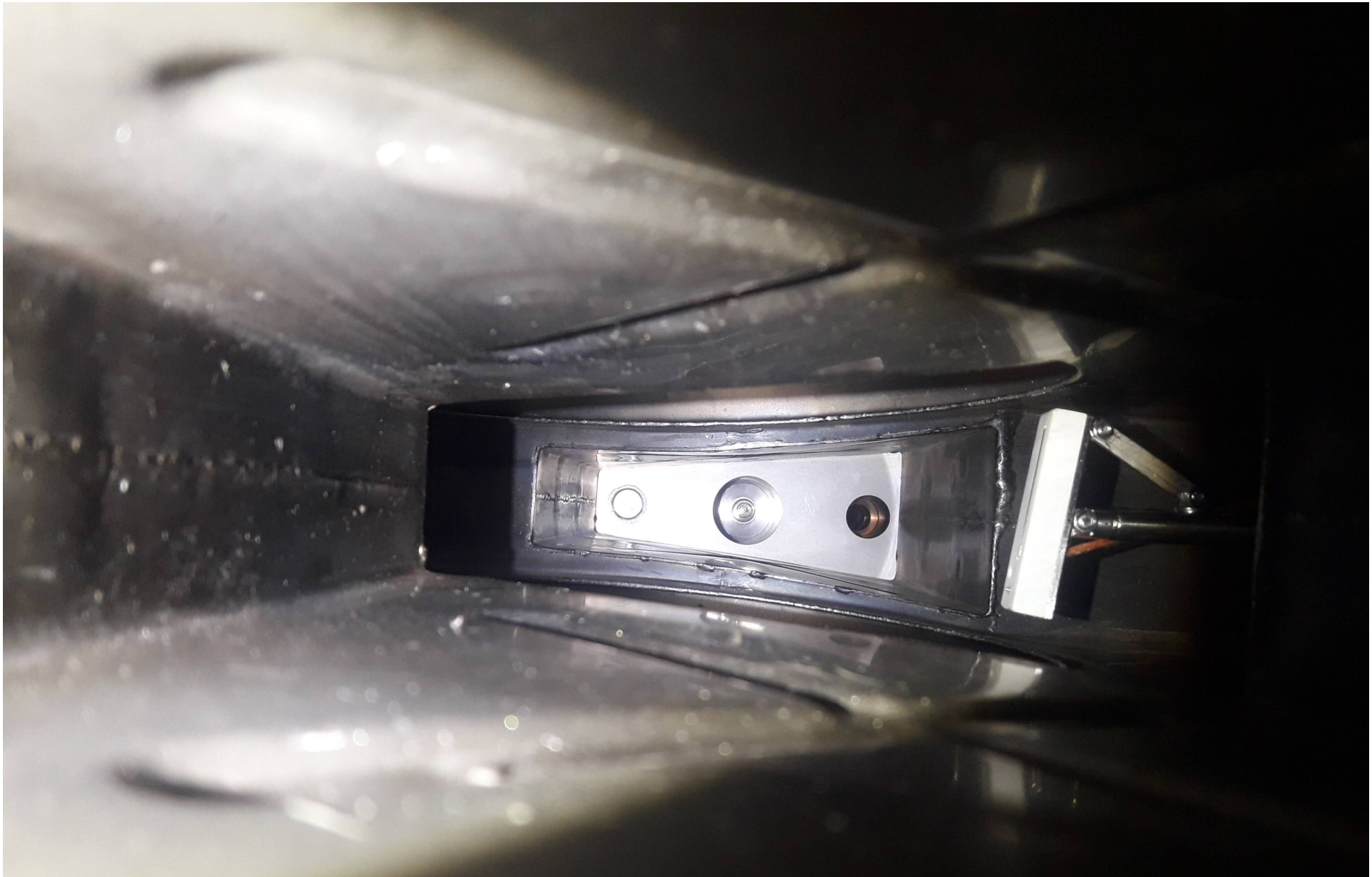
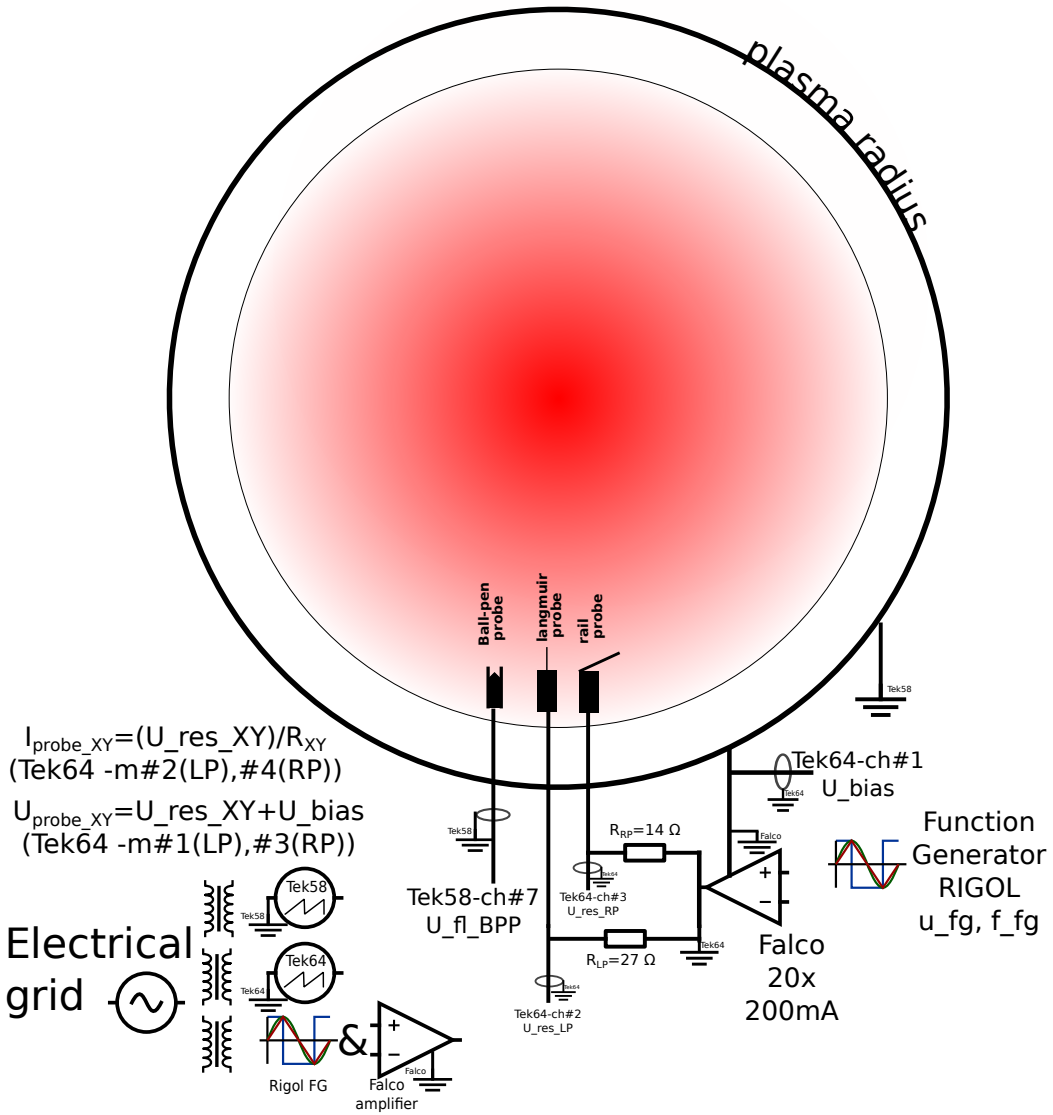
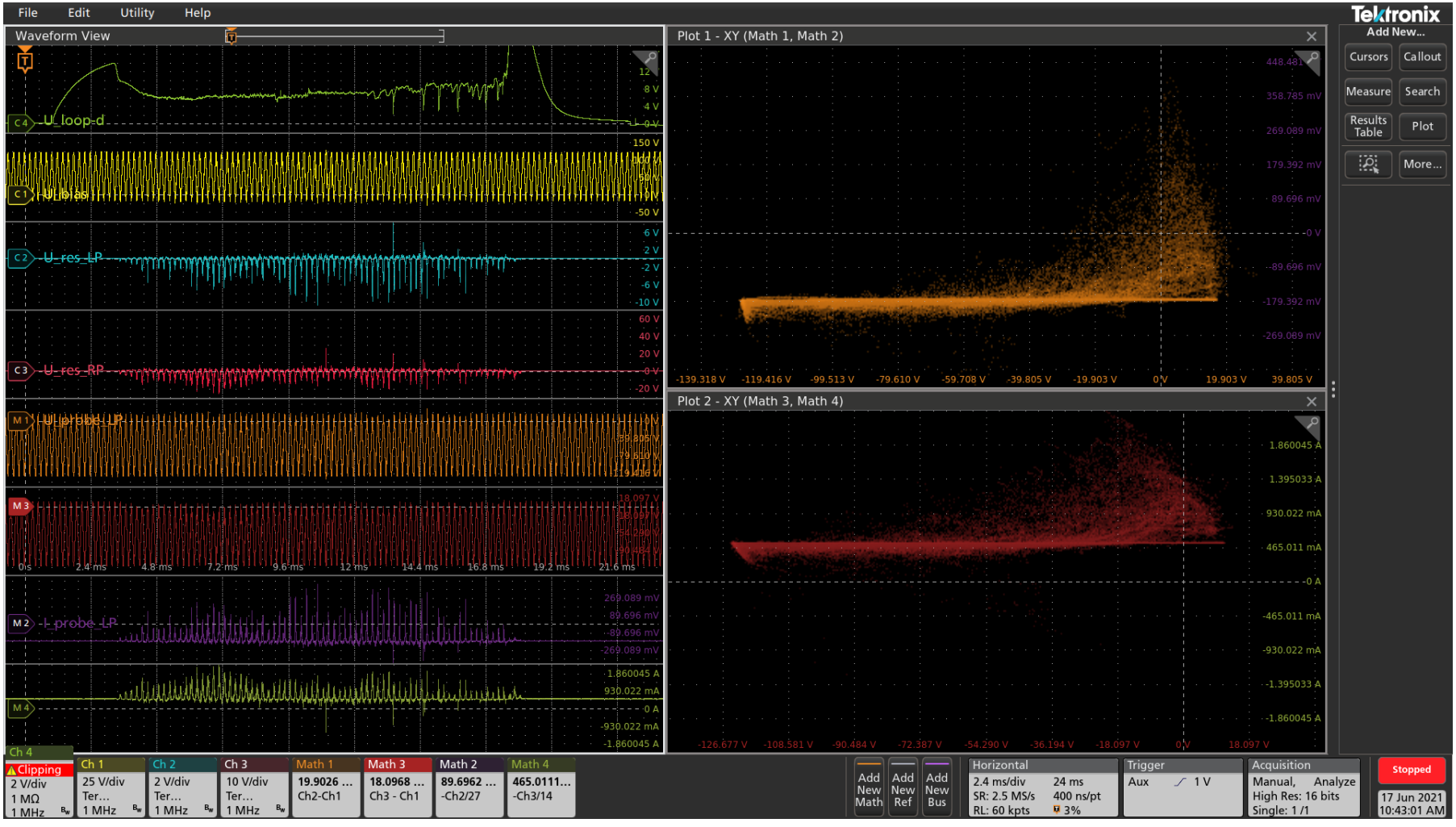
Jiří Malinak (Jiří Adámek): Rail probe. BSc project. 2021



Jiří Malinak (Jiří Adámek): Rail probe: complex set-up

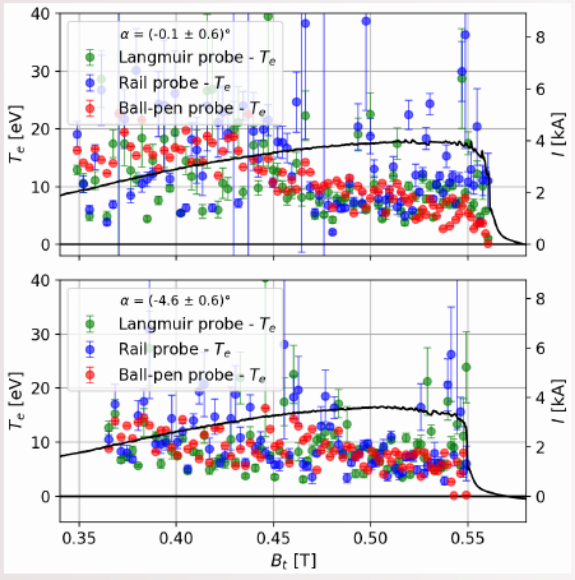


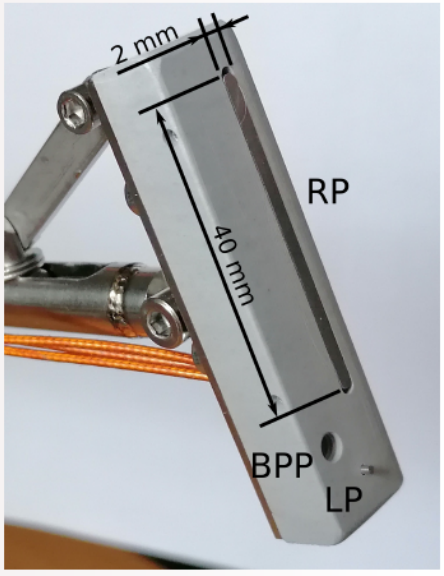
Jiří Malinak (Jiří Adámek): Rail probe: Oscilloscope screenshot



Electron temperature measurements using rail probe

- The rail probe concept can sustain exceptionally high heat flux and reduce the sheath expansion effect.
- A probe head consists of a rail probe (RP, length = 40 mm, wide = 2 mm), Langmuir probe (LP, length 1.5 mm, diameter 1 mm), and ball-pen probe (BPP) [4] has been designed
- Special manipulator with changable inclination to B_t within $\pm 10^\circ$ has been installed.
- Electron temperature is measured using a swept Langmuir and rail probe (f = 5 kHz) and a floating ball-pen probe.
- Capability of RP to reduce the sheath expansion effect was confirmed.
- Good agreement between LP, RP and BPP electron temperature measurements for large magnetic field.





Left) Comparison of T_e measured by BPP, LP and RP. Right) Diagram of the combined probe head.

Macha, P., Malinak, J. & Adámek, J. et al. @EPS 2021

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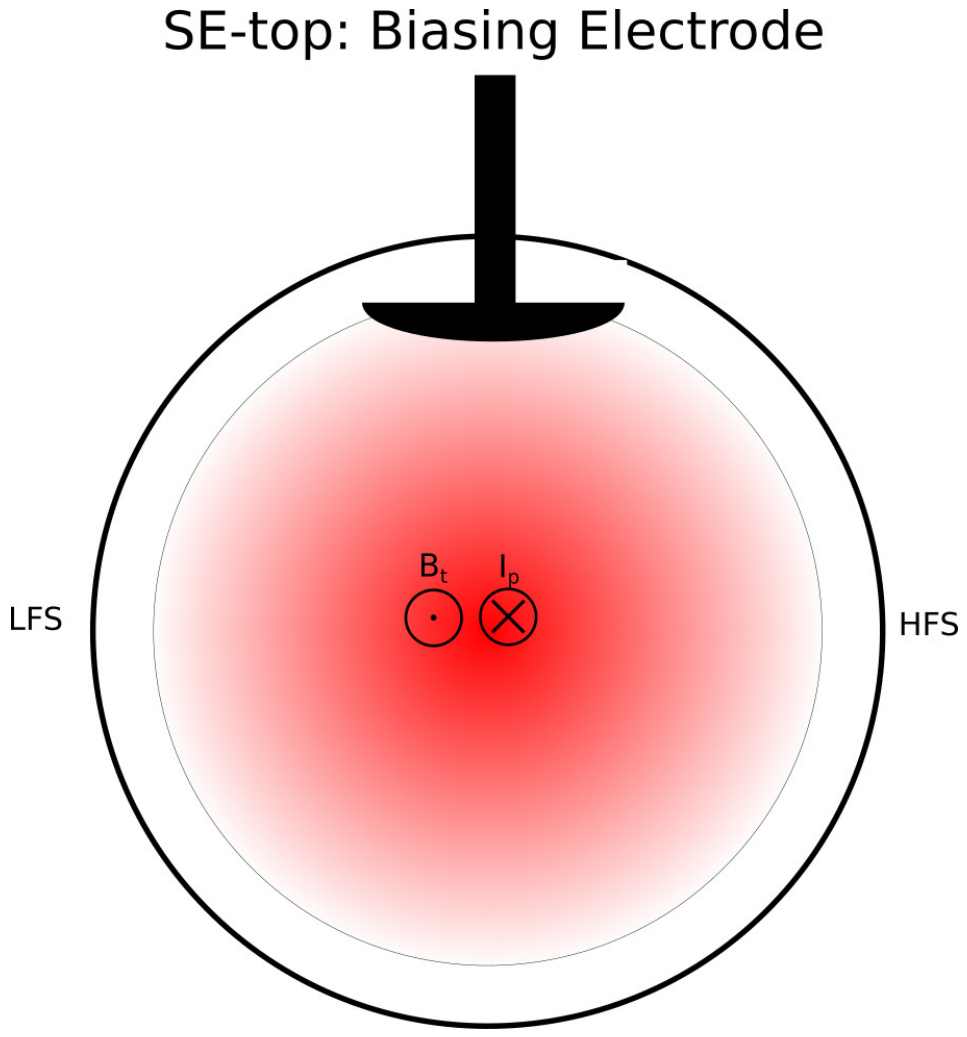
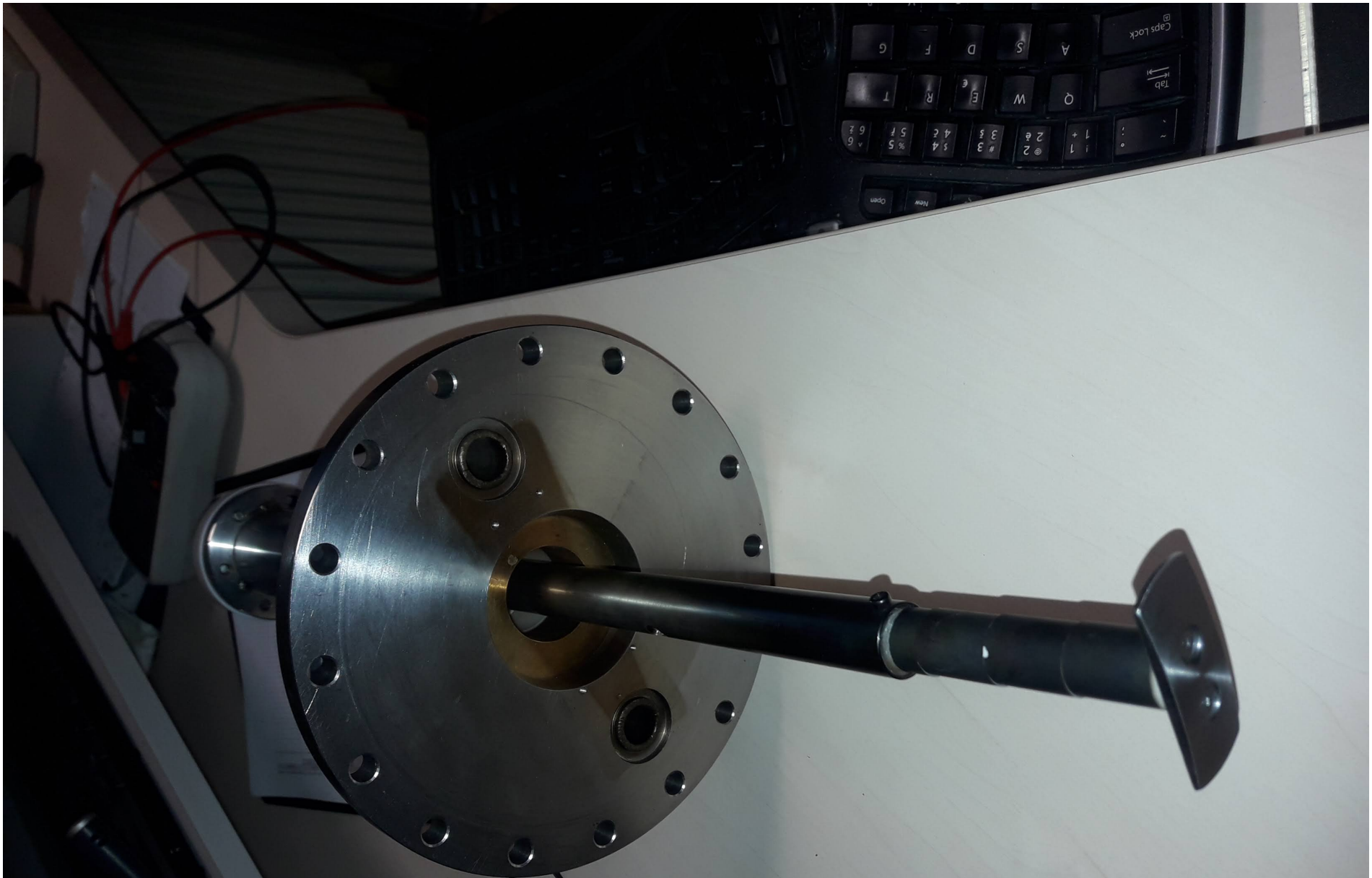
Sasha Melnikov & students. Biasing experiment. April, 2021

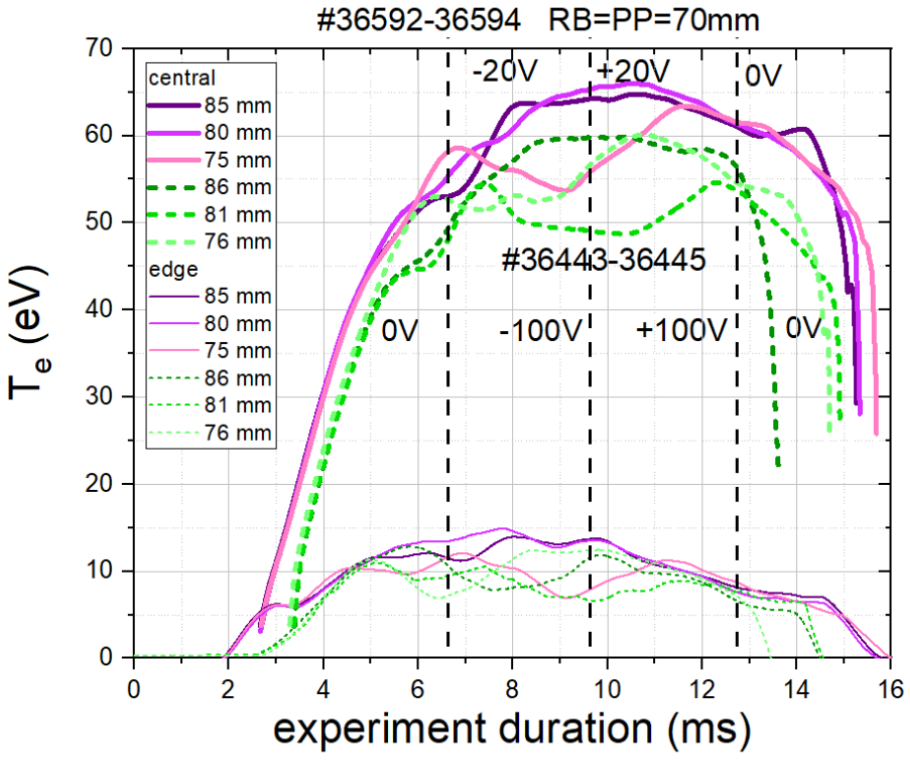


Biasing electrode



Biasing electrode with Double rake probe in tokamak

Comparison with first biasing



First biasing: dash green lines

discharge parameters

U_{CD} = 450 V p = 10 mPA

U_{Bt} = 800 V gas H

Second biasing: solid violet lines

Biasing electrode voltage: +-100V

discharge parameters

U_{CD} = 450 V p = 16 mPA

U_{Bt} = 800 V gas H

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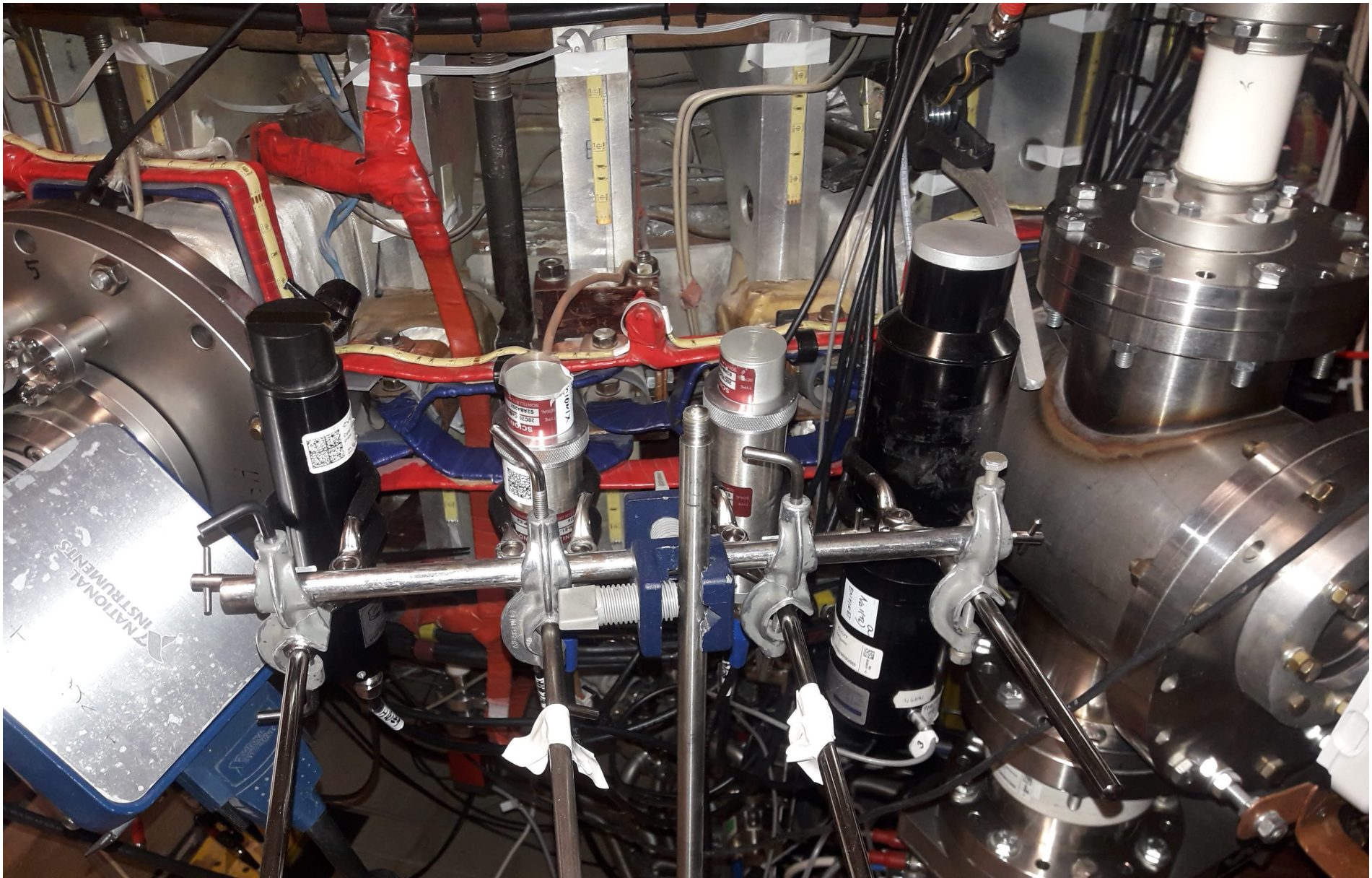
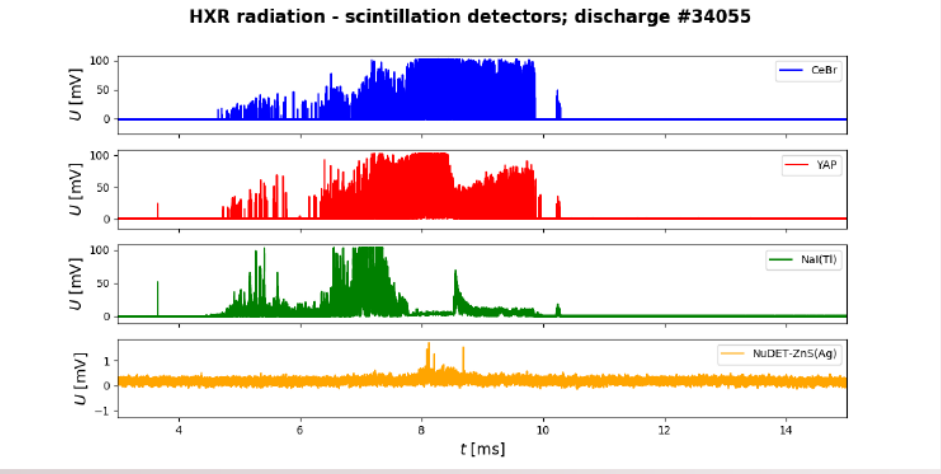
Lukáš Lobko (Jan Čeřovský, Ondřej Ficker): Měření ubíhajících elektronů na tokamaku GOLEM prostřednictvím scintilačních detektorů. Lab. work. 2021

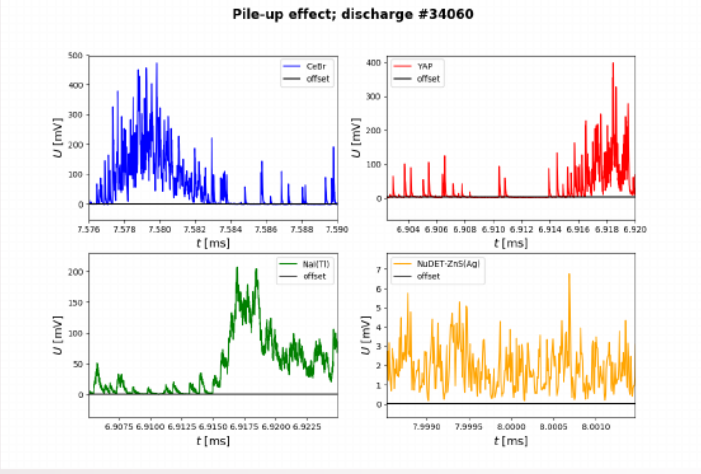


Measurements of HXR radiation

- Scintillation detectors were used for HXR spectrometry.
- Two problems occured:
  - Standard photomultiplier tubes of scintillation detectors can not withstand intensive HXR fluxes (NaI(Tl) detector drops around 8 ms).
  - Piled-up areas of signal - still too high HXR fluxes
- Optimal setup must be found by ensuring sufficient lead shielding and the distance from tokamak.



Comparison of HXR signals from 4 different scintillation detectors.



Comparison of piled-up signals and individual peaks.

Macha, P., Lobko, L. et al. @EPS 2021

To tu ještě nebylo ...

Nakonec, je tu ještě myšlenka, pokud by byla možnost na tokamak GOLEM dostat trochu deuteria, mohli bychom s pomocí NuDET detektoru ověřit přítomnost energií ubíhajících elektronů vyšších než 2,2 MeV. Totiž, HXR fotony o energii 2,2 MeV a vyšší dokáží iniciovat fotojaderné reakce s jádry deuteria za vzniku neutronů, které se dají NuDET detektorem lehce změřit včetně separace od HXR fotonů.

Lobko, L. Lab. work. 2021

Novotný, L. et al. Runaway electron diagnostics using silicon strip detector

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PUBLISHED: *July 10, 2020*

21ST INTERNATIONAL WORKSHOP ON RADIATION IMAGING DETECTORS
7–12 JULY 2019
CRETE, GREECE

Runaway electron diagnostics using silicon strip detector

2020

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

Čeřovský, J. et al. Progress in HXR diagnostics at GOLEM and COMPASS tokamaks

COMPASS
INSTITUTE OF PLASMA PHYSICS ASCR

Progress in HXR diagnostics at GOLEM and COMPASS tokamaks

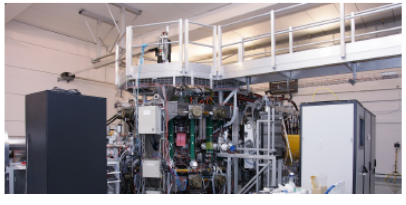
J. Cerovsky[1,2,*], O. Ficker[1,2], V. Svoboda[2], E. Macusova[1], J. Mlynar[1], J. Caloud[1,2] V. Weinzettl[1], M. Hron[1], the COMPASS team and EUROfusion MST1 team[**]

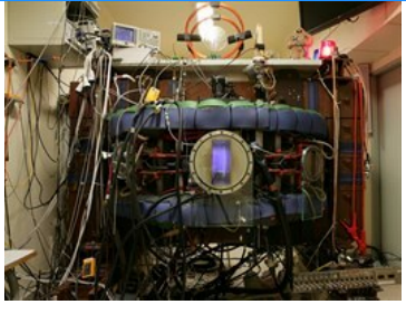
[1] *Institute of Plasma Physics of the CAS, Prague, Czech Republic*
[2] *Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Prague, Czech Republic*
[*] *contact: cerovsky@ipp.cas.cz*
[**] *See author list B. Labit el. al., 2019 Nucl. Fusion 59 086020*

GOLEM and COMPASS tokamaks

- the GOLEM tokamak [1] is a small size device operated at FNSPE CTU
- → former tokamak CASTOR operated at IPP in Prague
- serves mainly for educational purposes and for diagnostics testing (probes and various HXR detectors)

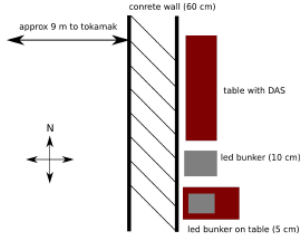
R [m]	a [m]	I_p^{max} [kA]	B_T [T]
0.4	0.085	< 8	< 0.8



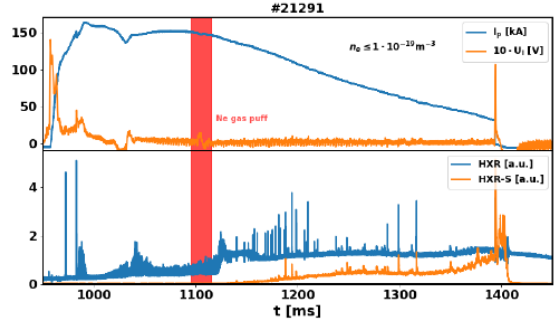


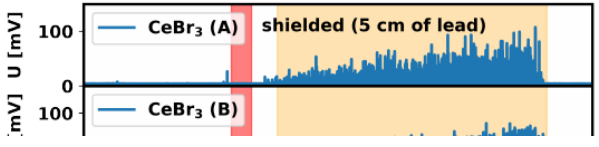
- the COMPASS tokamak [2] is a compact size tokamak operated at IPP Prague
- fields of research: H-mode physics, physics of plasma edge, plasma-wall interaction, physics of runaway electrons [3] and disruptions etc.

Experiments at COMPASS



- scintillation detectors located outside tokamak hall, protected from high photon flux





- HXR radiation detected mainly during RE beam phase

Physics

-

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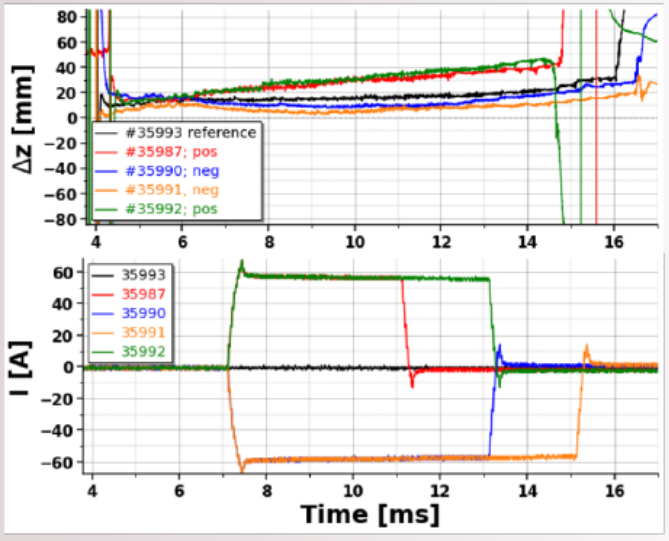
ERDF Plasmalab pro tGOLEM. 10x Kepco 20V-20A for horizontal and vertical plasma position stabilization

Daniela Kropáčková (Vojtech Svoboda). External plasma stabilization. PostSOČ. 2021

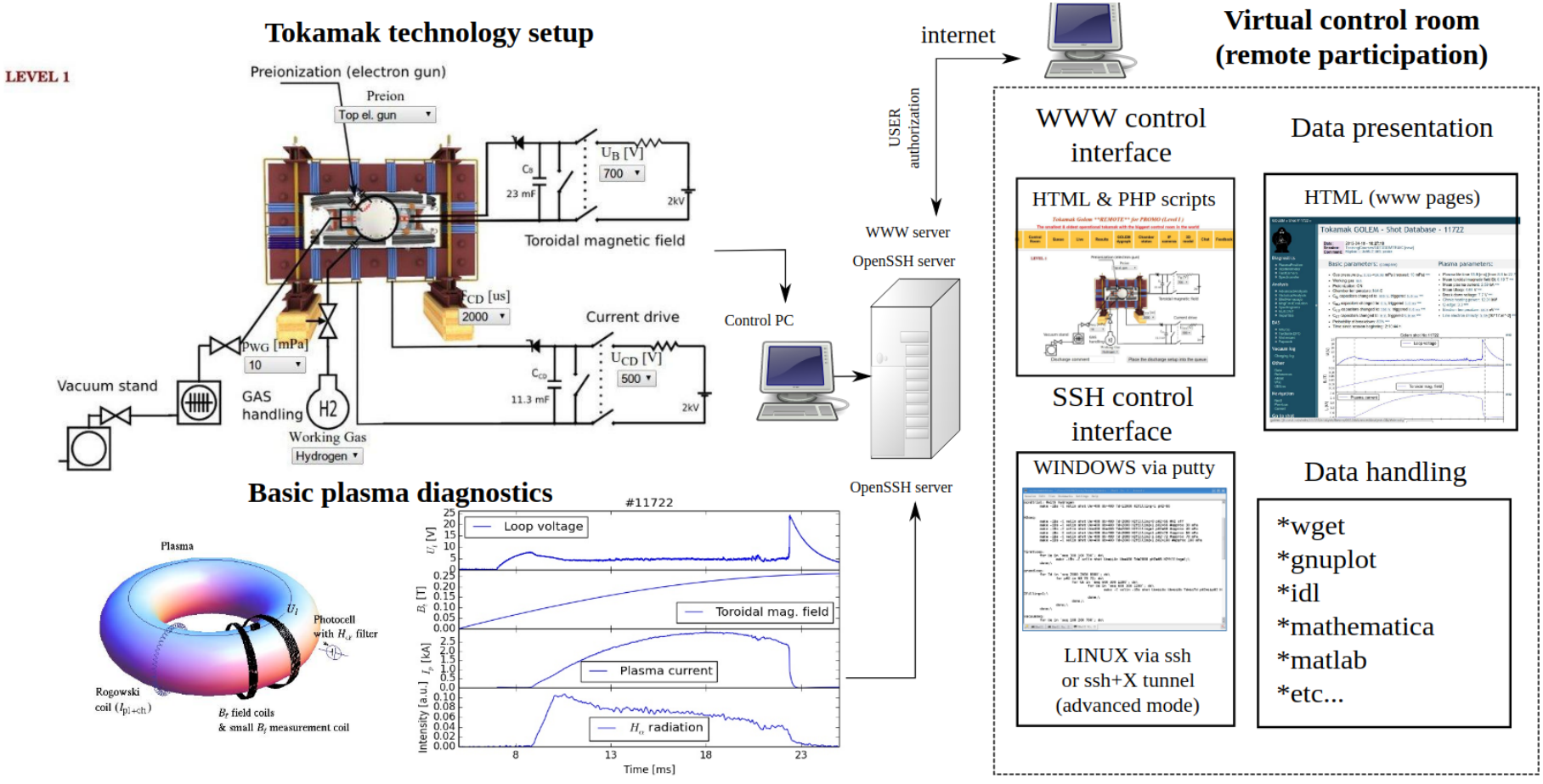
- 2 external windings generating predefined poloidal magnetic field used for plasma control (horizontal, vertical).
- Plasma position is determined by Mirnov coils.
- The influence of the horizontal mg. field on the discharge duration is shown.



Plasma vertical displacement for discharges with stabilization generating

Macha, P., Kropáčková, D. & Svoboda, V. et al. @EPS 2021

Higher B_t. Now up to $\approx$ 0.7 T.



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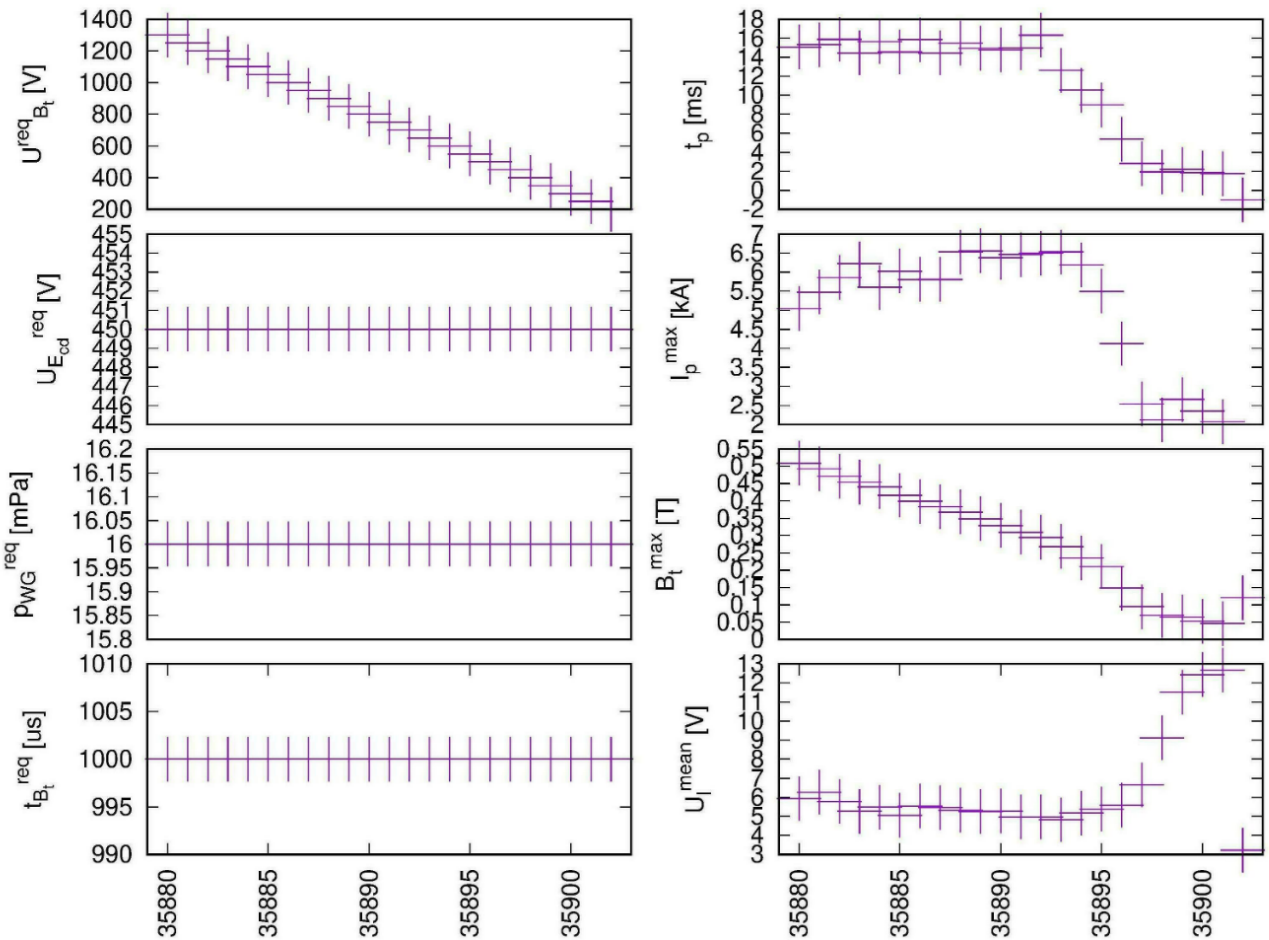
Global tokamak reconstruction - Never ending story

To ensure

reliability, flexibility, education simplicity, high discharge repetition rate.

- HWs
  - New E_{cd} primary coils of transformer.
  - Position stabilization coils reconstruction.
  - Infrastructure & Control system: Rack solution.
  - PM & OG: PC servers migration Golem to Supermicro & Buon to Golem.
- SWs
  - Focus on Flexibility.
  - Database (pSQL) management.
  - Parametrization from command line.
  - Petr Mácha: Dynamic shot homepage (Basic/On stage/Off stage diagnostics).
  - Ondřej Grover: YouTube stream for remote events.
  - Bookmarks2ShotHomepage.
  - Data plotting

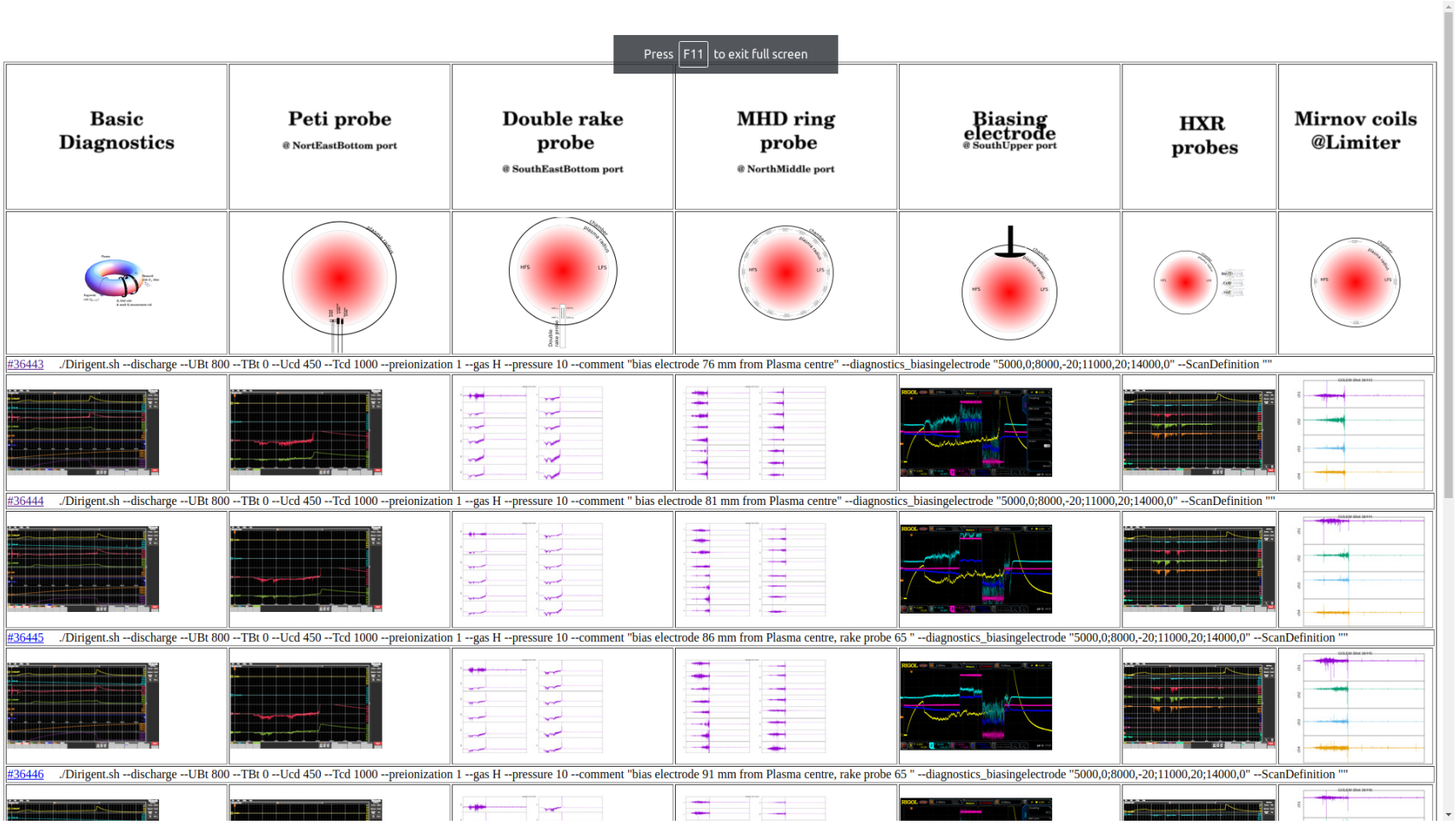
Session overview (e.g. B_t scan)



golem.fjfi.cvut.cz/shots/35902/Analysis/Homepage/Scan/Values.jpg

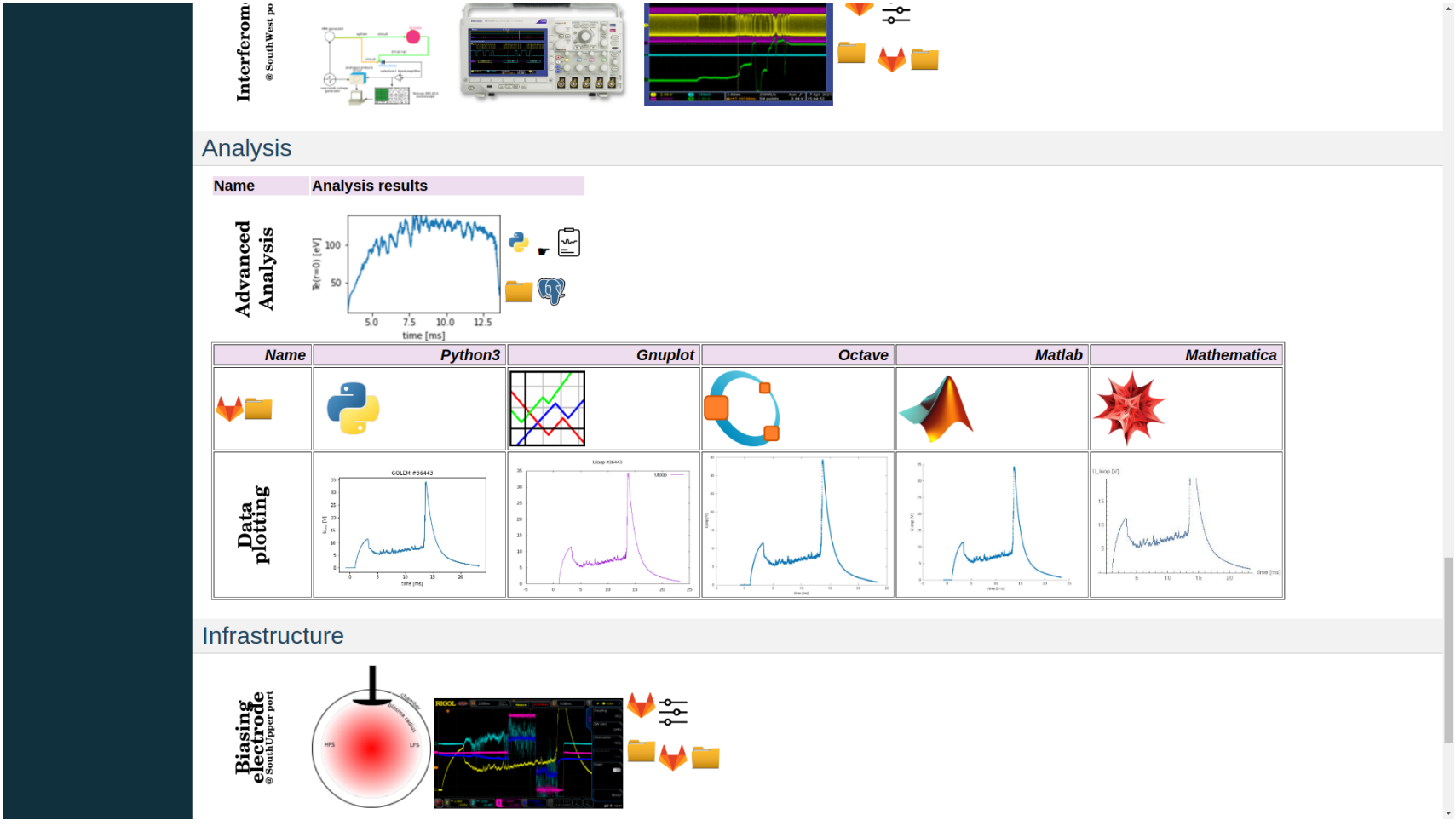
http://golem.fjfi.cvut.cz/shots/35902/

Diagnostics overview (e.g. Biasing experiment)



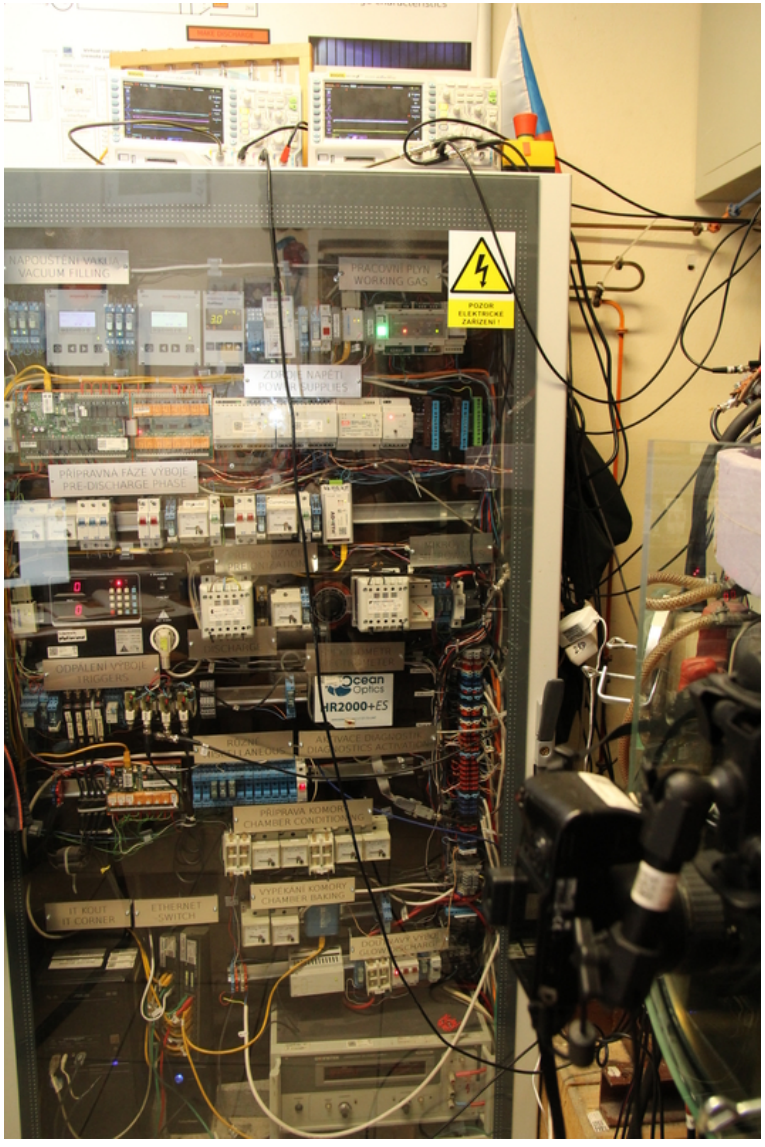
http://golem.fjfi.cvut.cz/shots/36450/Analysis/Homepage/Scan/diags.html

Data plotting



http://golem.fjfi.cvut.cz/shots/36443/

Reconstruction .. cont.: Infrastructure & Control system



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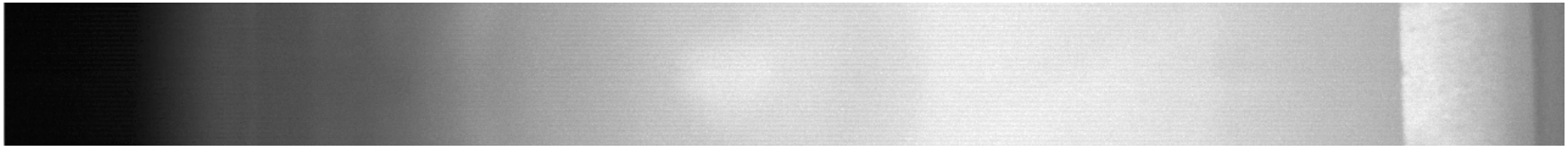
ERDF Plasmalab pro tGOLEM. 2x Fast cameras MiniUX 50

Daniela Kropáčková (Vojtech Svoboda). Fast cameras commissioning #35988



Bedna šampaňského: vyčuchání a znásilnění komunikace

Outline

1. Introduction
2. Current scientific topics
   - Probes: BPP + Lang probes
   - Probes: Rail probe
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CAAS pro tGOLEM. 2x Timepix 3 (Štěpán Malec & Vladimír Linhart)

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Undergraduate Projects

- Adéla Kubincová (Ondřej Kudláček). Sofistikované metody real-time řízeni tokamakových procesů. BP 2021.
- Štěpán Malec (Vladimír Linhart). HXR detection with Timepix3. VU 2021.
- Marek Tunkl (Michal Marcišovský?). Strip detector. BP 2021.
- Petr Mácha. Studium okrajového plazmatu v tokamacích pomocí pokročilých elektrických sond. DP 2020.
- Sergei Kulkov. Timepix3 for HXR detection. PhD 2020.

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   - Biasing experiments
   - Run Away Electrons
     - Diagnostics (CAAS project)
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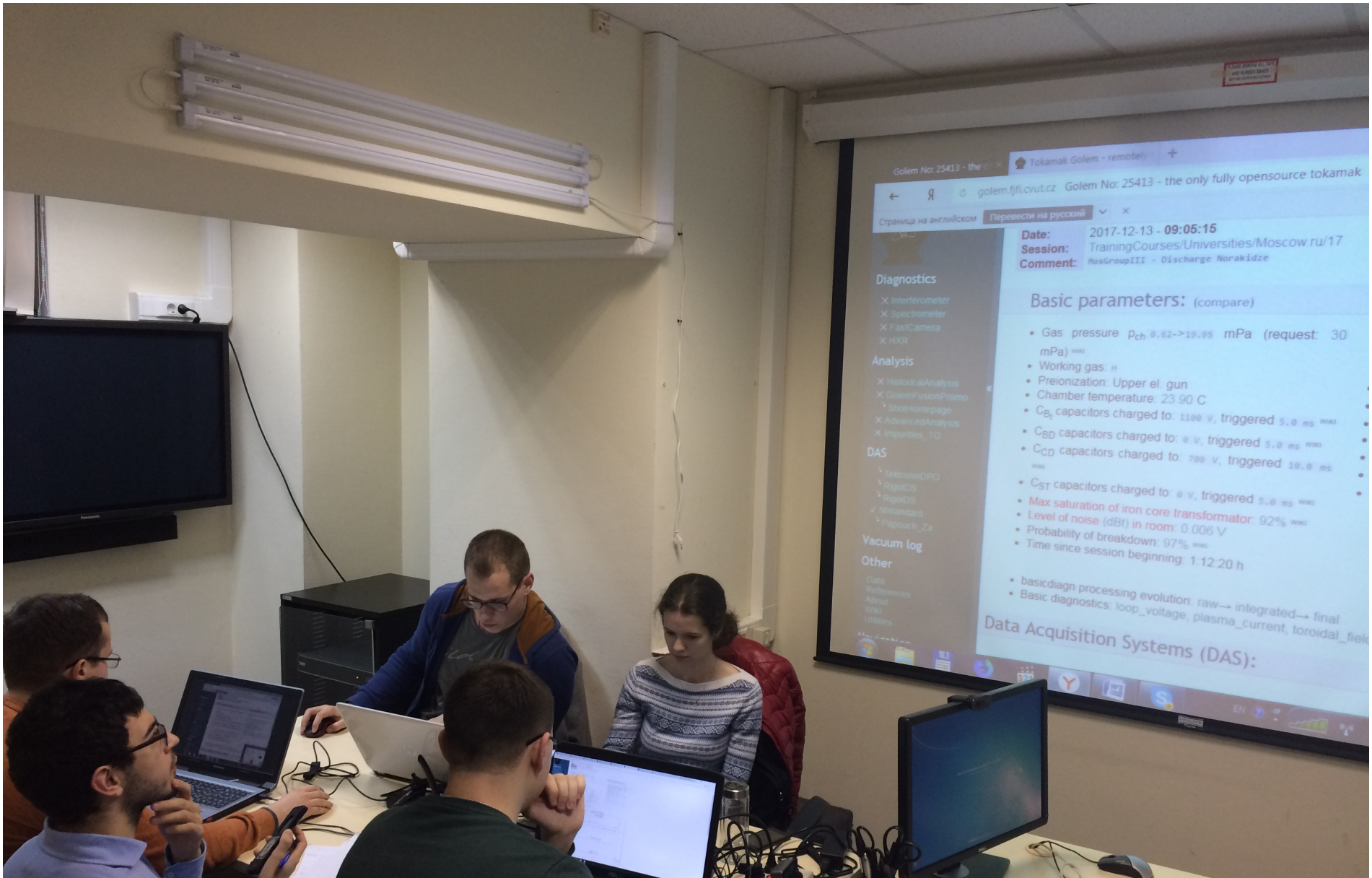
Remote from Budapest. November 2020

Remote from Torino, December 2020

Sasha Melnikov & Gosha Sarancha. A new level of training experiments: towards article



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Matyáš Horák (Katka Hromasová): Profil elektronové teploty v komoře tokamaku

soč středoškolská odborná činnost

facebook soč? soč

Hlavní stránka › Fóra › Forum pro soutěžící SOČ › Obhajoby – Praha › 42-kraj Praha-obory 1,2 › Odpověď na téma: 42-kraj Praha-obory 1,2

27 dubna, 2020 (11:30 am) #21104

Lucie Hunalová
Host

Děkujeme za odpovědi, nyní dostává prostor další soutěžící.

12:30 – 13:00 Matyáš Horák – Profil elektronové teploty v komoře tokamaku
Gymnázium Botičská

https://youtu.be/-OC_EIg0Gjk

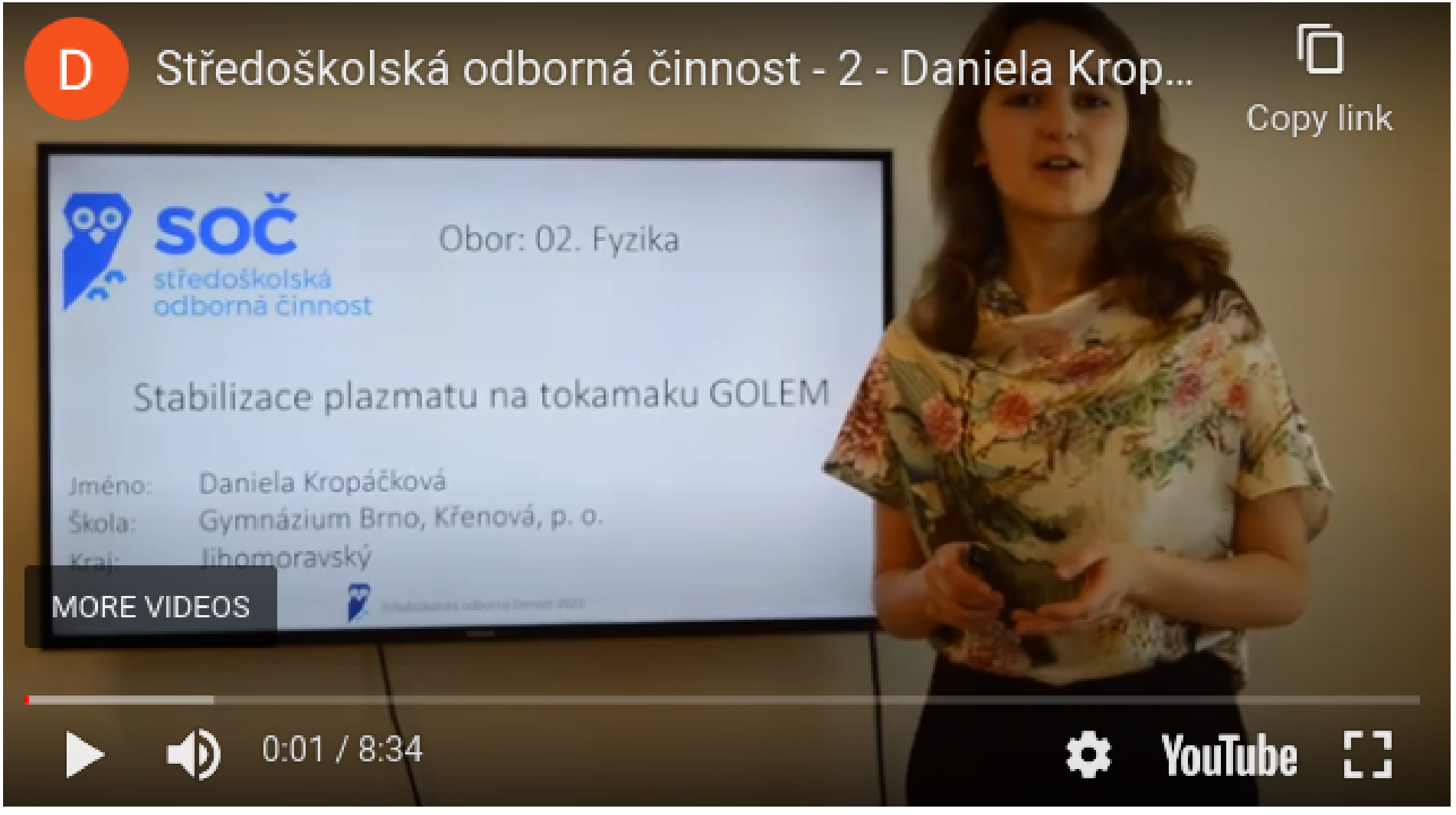
Vítáme Vás, přejeme úspěšné obhajoby a prosíme o dodržení časového limitu. Děkujeme

1. Zajímal jste se i o reakci D-D?

2. Je princip měření Langmuirovou a ball-pen sondou založen na termoelektrickém jevu?

3. V textu se píše „V grafu 1 je také důležité si všimnout nápadné změny ve 14 ms a 20 ms."
Při pohledu na tento graf nám připadá mnohem zajímavější, co stalo v čase 18 ms. Zde pozorujeme výchylku ve všech měřených parametrech. Mohl byste vysvětlit, co tento jev způsobilo?

Daniela Kropáčková (Vojtěch Svoboda): Stabilizace plazmatu na tokamaku GOLEM



Aleš Socha (Katka Hromasová): Poloha zóny vytváření turbulentních struktur v okrajovém plazmatu tokamaku

Martina Lauerová (Katka Hromasová): Měření elektronové teploty na tokamaku GOLEM elektrickými sondami

References I

M GRYAZNEVICH et al. "Contribution of joint experiments on small tokamaks in the framework of IAEA coordinated research projects to mainstream fusion research". In: *Plasma Science and Technology* 22.5 (2020), p. 055102. DOI: 10.1088/2058-6272/ab6d4d. URL: https://doi.org/10.1088%2F2058-6272%2Fab6d4d.

L. Novotny et al. "Runaway electron diagnostics using silicon strip detector". In: *Journal of Instrumentation* 15.07 (2020), pp. C07015–C07015. DOI: 10.1088/1748-0221/15/07/c07015. URL: https://doi.org/10.1088%2F1748-0221%2F15%2F07%2Fc07015.

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Lukáš Lobko. *Měření ubíhajících elektronů na tokamaku GOLEM prostřednictvím různých scintilačních detektorů*. http://golem.fjfi.cvut.cz/wiki/TrainingCourses/FTTF/2019-2020/LukLob/zaverecny_report. [Online; accessed 2-June-2021]. 2021.

Mácha, P., Kulkov, S., V., Kropáčková, D., Adámek, J., Cerovský, J., Ficker, O., Grover, O., Jiráková, K., Stöckel, J., Svoboda, V. "Tokamak GOLEM for fusion education - chapter 11". In: vol. 2021-July. Europhysics conference abstracts. 2021, XY. ISBN: 979-10-96389-11-7. URL: http://ocs.ciemat.es/EPS2021PAP/pdf/PXY.pdf.

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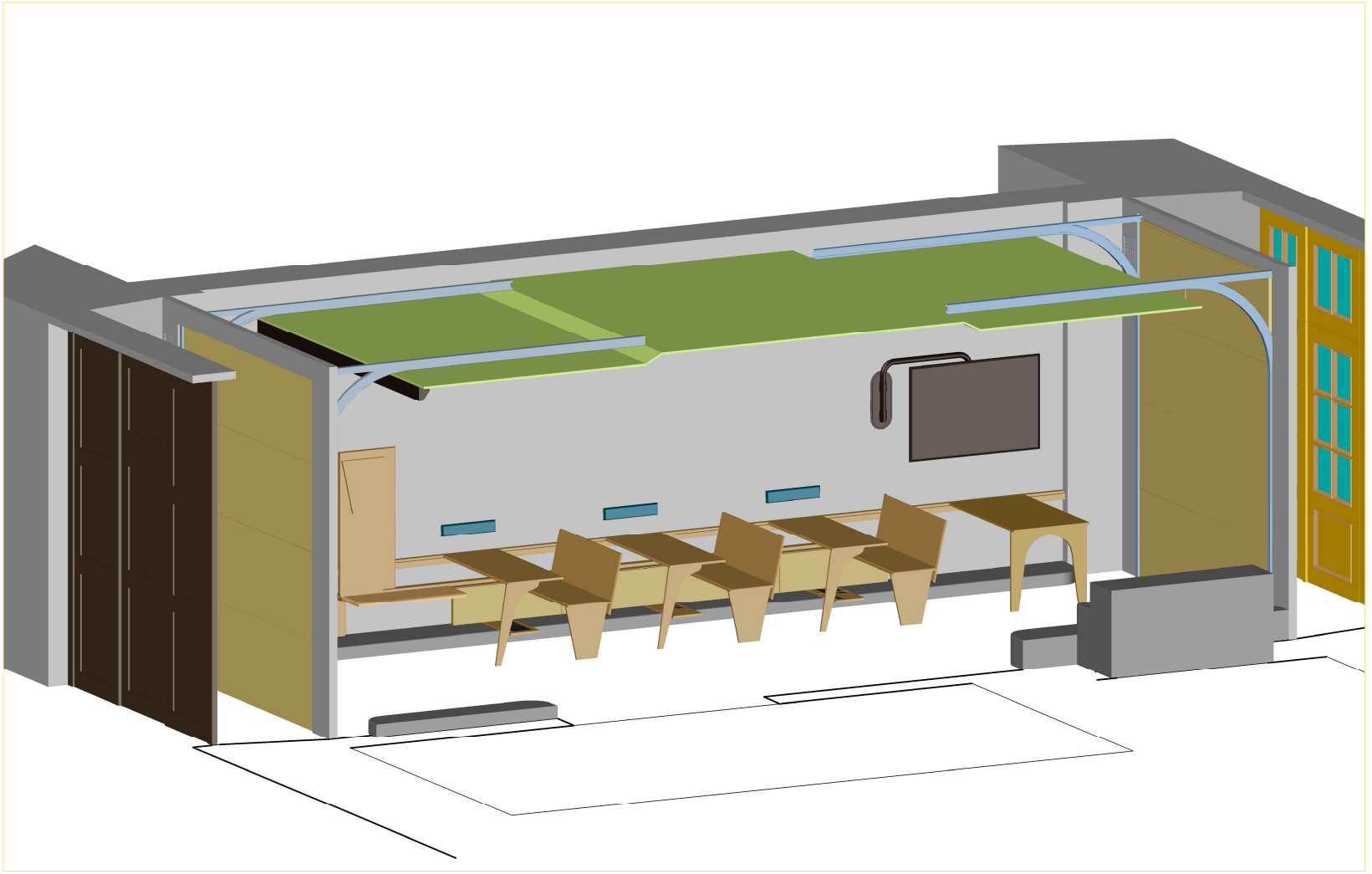
Kauza průjezd

Himmel, M. Průjezd, verze 2. 2020.



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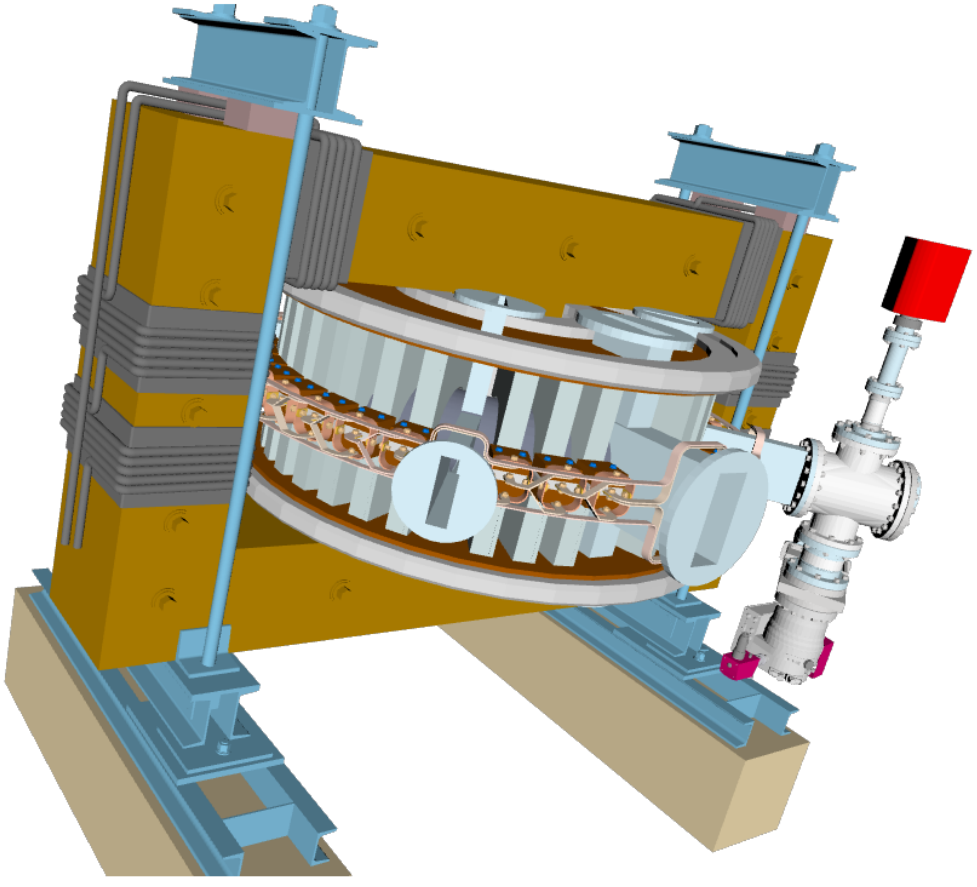
Himmel, M., Grover, O. CAD model



http://golem.fjfi.cvut.cz/VirtualModels/CAD/

Contribution of joint experiments on small tokamaks in the framework of IAEA coordinated research projects to mainstream fusion research

Plasma Science and Technology

Plasma Sci. Technol. **22** (2020) 055102 (10pp) https://doi.org/10.1088/2058-6272/ab6d4d

Contribution of joint experiments on small tokamaks in the framework of IAEA coordinated research projects to mainstream fusion research

M GRYAZNEVICH[1], J STÖCKEL[2,6], G VAN OOST[3,6,9], E DEL BOSCO[4], V SVOBODA[2], A MELNIKOV[5,6], R KAMENDJE[7], A MALAQUIAS[8], G MANK[10], R MIKLASZEWSKI[11], the IAEA CRP[12] and JEs Teams[12]

[1] Tokamak Energy Ltd, Milton Park, Oxon OX14 4SD, United Kingdom
[2] Faculty of Nuclear Phys. and Phys. Eng., Czech Technical University, 115 19 Prague 1, Czech Republic
[3] Dep. of Applied Physics, Ghent University, 9000 Ghent, Belgium
[4] INPE, São José dos Campos 12227-010, Brazil
[5] National Research Centre 'Kurchatov Institute', 123182 Moscow, Russia

M Gryaznevich et al 2020 Plasma Sci. Technol. **22** 055102.

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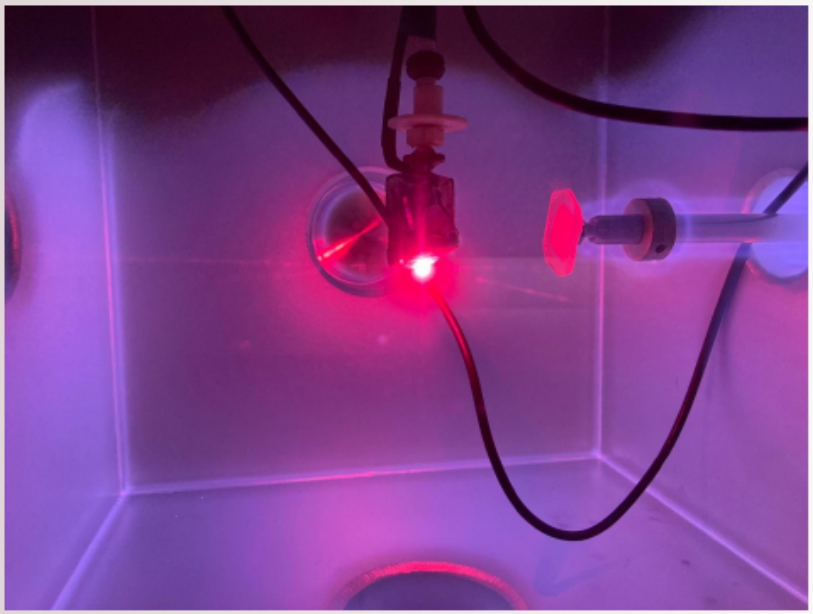
Jan Čečrdle (Jan Horáček). Lithization tests in vacuum cube. Lab. work. 2021

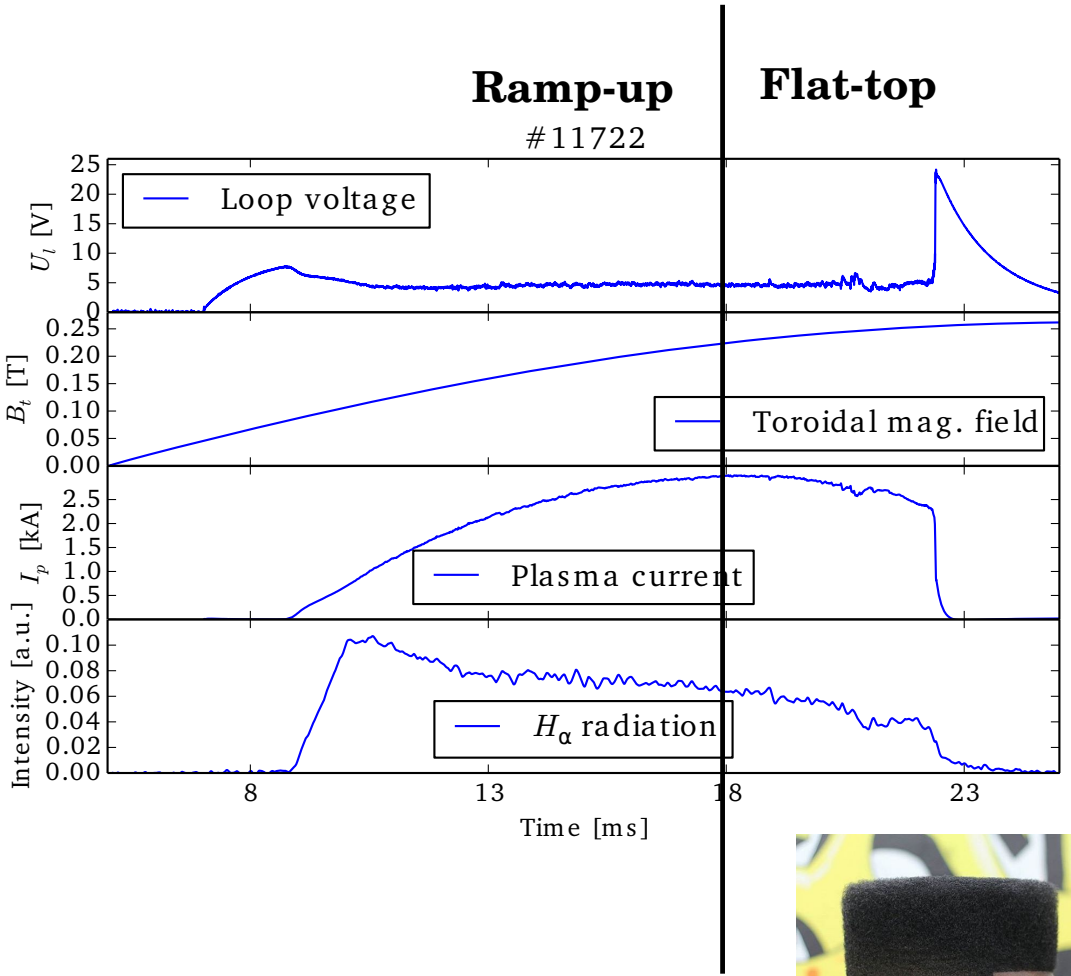
- Lithization setup tests performed in a small vacuum tube.
- Several critical problems need to be handled before usage in the tokamak wall - oxidation of the metallic lithium and potential melting of electrodes.
- A spectral line of neutral Li has been observed.



Snapshot of the glow discharge with the apparent red neutral lithium line.

Macha, P., Čečrdle, J. et al. @EPS 2021

Jan Buryanec (Vojtěch Svoboda): Plasma current control



Transformer primary current control

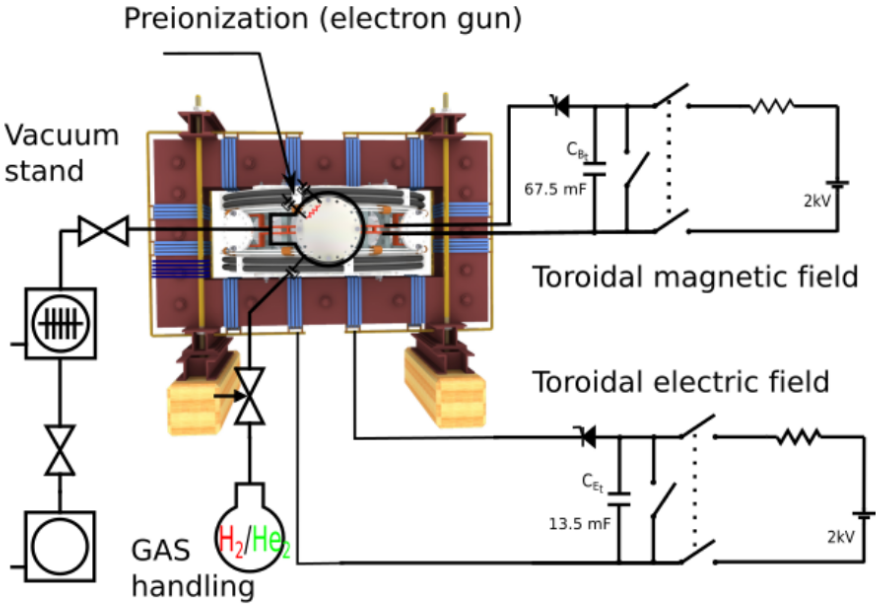
Gas puff control

Gabo Vondrášek. Maxi přepínač

GOLEM remote | Introduction | Control room | Live | Results | Master | Access: Level 2 | Help

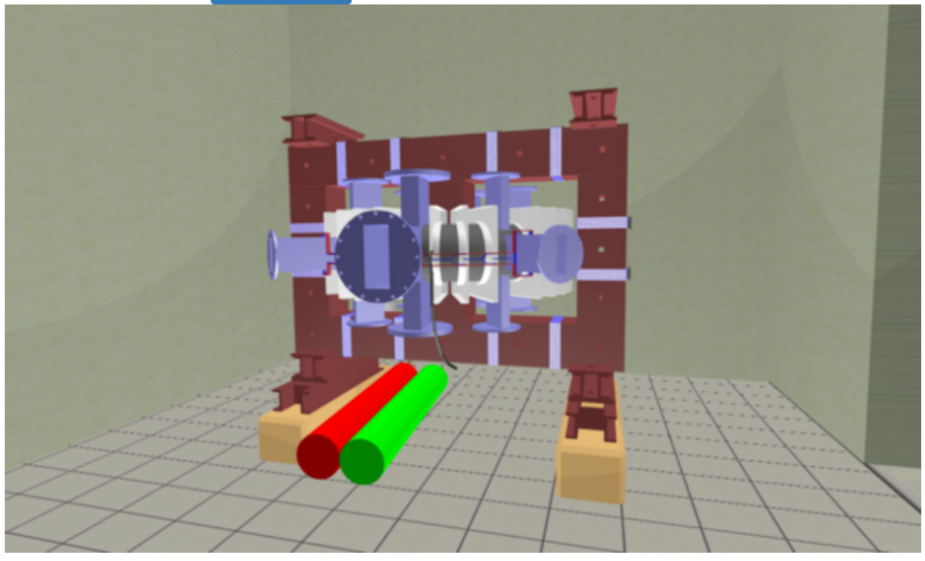
Introduction | Working gas | Preionization | Magnetic field | Electric field | Submit

This web interface will walk you through the process of configuring a discharge in the GOLEM tokamak. All settable values are perfectly safe. Proceed through each step by setting the desired values and then clicking the Next button. You can always go to a specific step by clicking its tab.



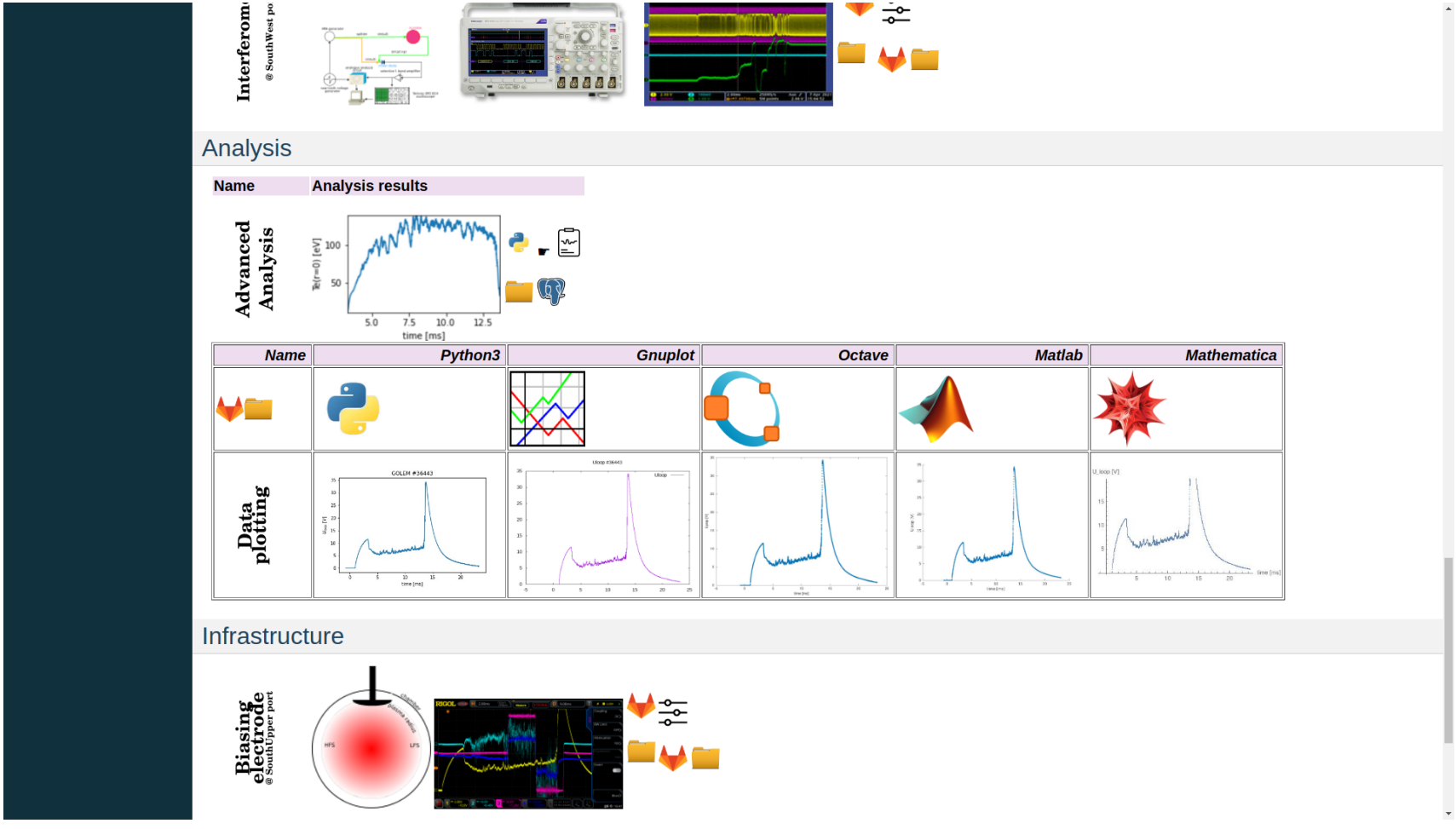
Next

3D model rendering method: Static image (fast) | Interactive X3DOM (slower)



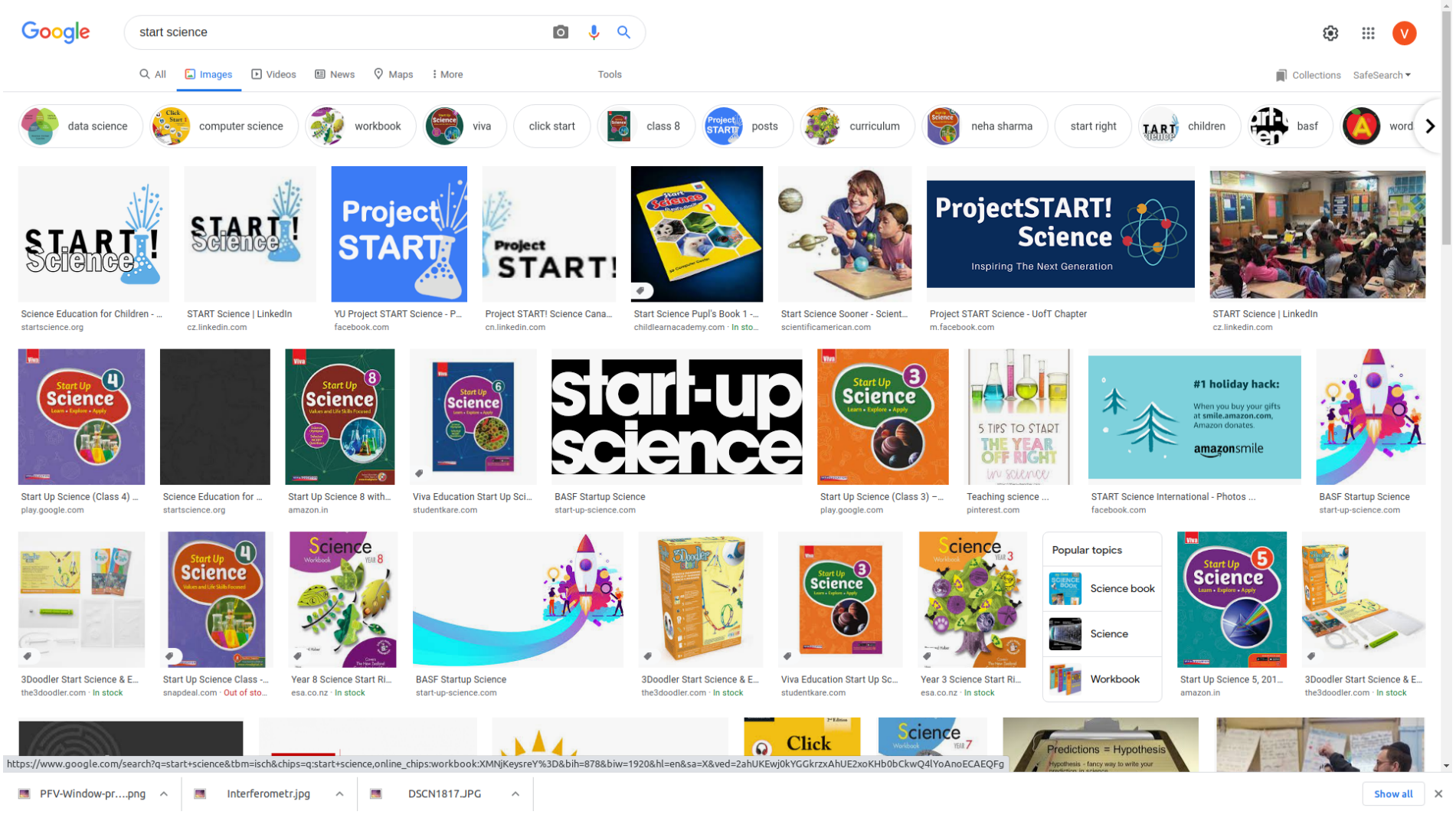
Oprava interferometru (bedna šampaňského)

Free post discharge analysis script upload/access for trained students



http://golem.fjfi.cvut.cz/shots/36443/

Start to explore all the stuff



Čaloud, J. Kalometrická sonda.

-

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Petr Mácha

Katka Hromasová

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CTU RVO68407700, SGS 17/138/OHK4/2T/14, GAČR GA18-02482S, EU funds CZ.02.1.01/0.0/0.0/16_019/0000778 and CZ.02.2.69/0.0/0.0/16_027/0008465, IAEA F13019, FUSENET and EUROFUSION.

Students, teachers, technicians (random order):

Vladimír Fuchs, **Ondřej Grover**, Gergo Pokol, Igor Jex, Martin Štefaňák, Gabriel Vondrášek, František Žácek, **Jan Stockel**, **Jan Mlynář**, Jaroslav Krbec, Vladimír Linhart, **Kateřina Hromasová**, Jaroslav Čeřovský, Martin Himmel, Marek Tunkl, Štěpán Malec **Petr Mácha**, Daniela Kropáčková, Martinal Lauerová, Aleš Socha, Ondřej Kudláček, Adéla Kubincová, Sergei Kulkov.

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