

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
- Overall tokamak GOLEM reconstruction

4 Diagnostics improvements

- Fast cameras
- HXR

5 Education

- Undergraduate Projects
- Remote trainings

Forecast 2020

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

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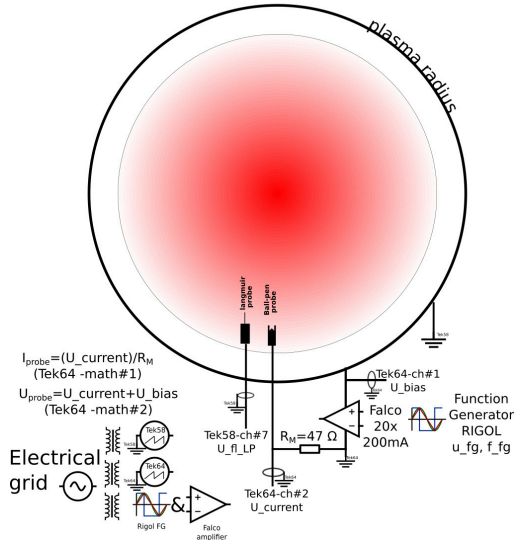
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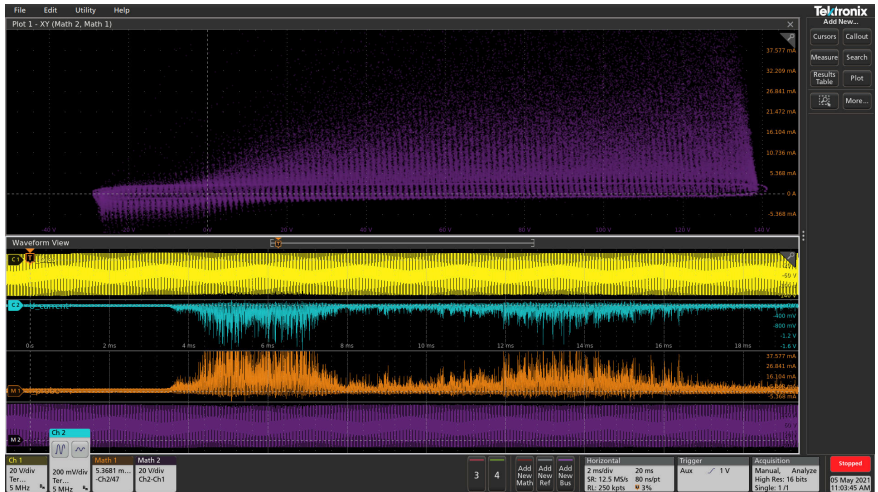
Dario Cipciar (Jiří Adámek): Swept BPP probe. MSc project. 2021



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

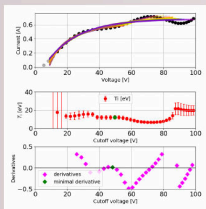


Dario Cipciar (Jiří Adámek): Swept BPP probe: Oscilloscope screenshot

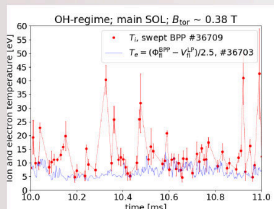


Fast ion temperature measurement using swept ball-pen probe. MSc thesis. 2021

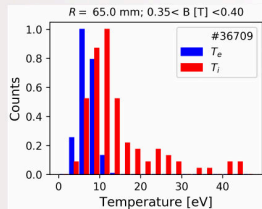
- Ion temperature is measured with $5 \mu\text{s}$ temporal resolution based on the measurements of the electron branch of a ball-pen probe (BPP) IV characteristics [3].
- The probe collector is biased with a voltage swept between -30V to $+130\text{V}$ at a frequency of 100 kHz .
- The T_i is obtained from $I(V) = I_{\text{sat}}^+ \cdot \left(\exp(\alpha_{\text{BPP}}) \cdot [1 + K \cdot (V - \Phi)] - \exp\left(\frac{\Phi - V}{T_i}\right) \right)$, $\alpha = \ln \frac{I_{\text{sat}}^-}{I_{\text{sat}}^+} = 0.25 \pm 0.09$ ($B_t > 0.22\text{ T}$).
- 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.



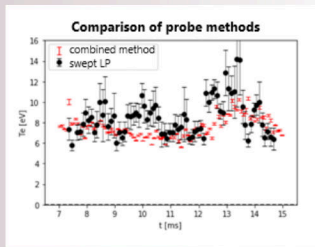
Temporal evolution of T_i and T_e .



Histograms of T_i and T_e .

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

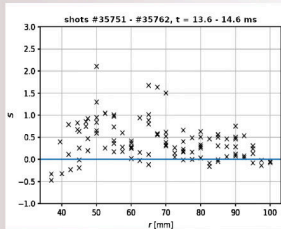
- Swept Langmuir probe – verified but complicated and time-consuming.
- Combined method (floating ball-pen and Langmuir probe) – straightforward and high time resolution, but rather new.
- It was verified that both methods give the same results.
- We suggest that the combined method is suitable for measuring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



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

Aleš Socha (Kateřina Hromasová), Turbulent structures 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.

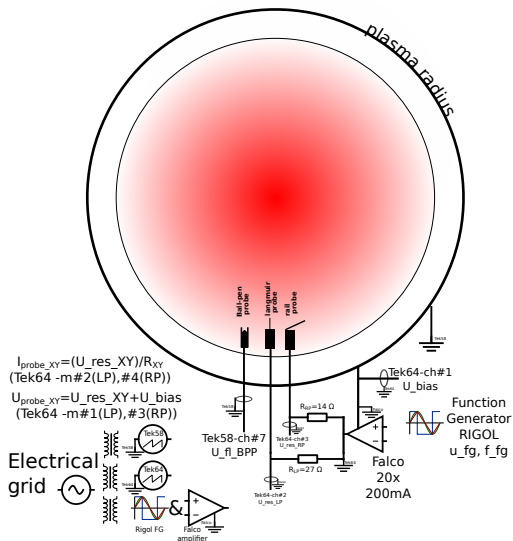
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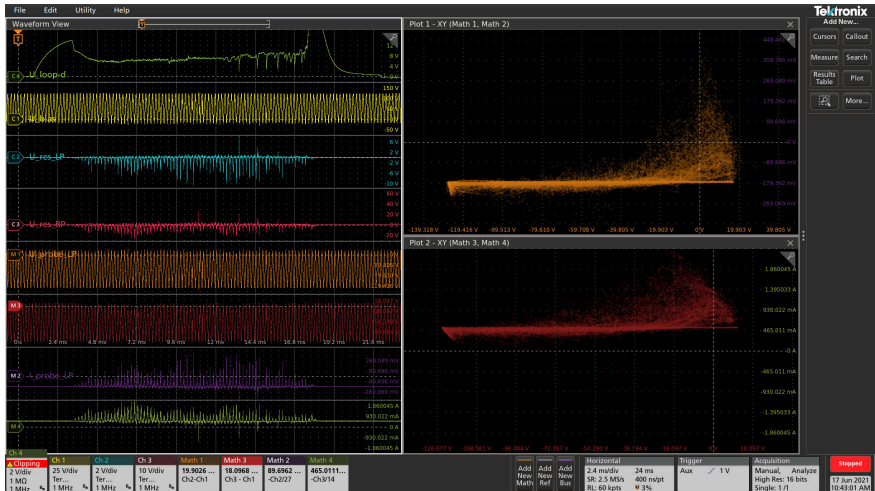
Jiří Malinak (Jiří Adámek): Rail probe. BSc project. 2021



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



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

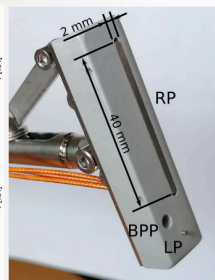
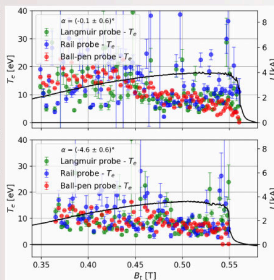


Electron temperature measurements using rail probe

- 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)

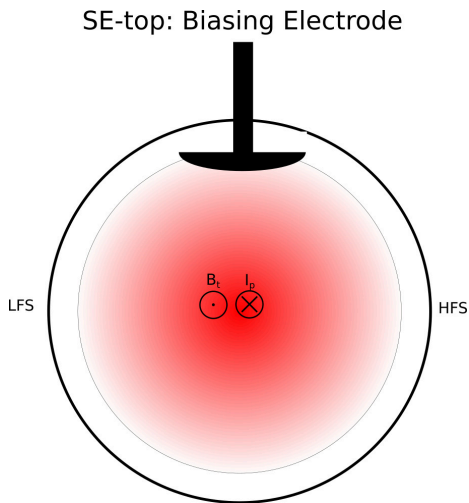
Diagram of the combined probe head.



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

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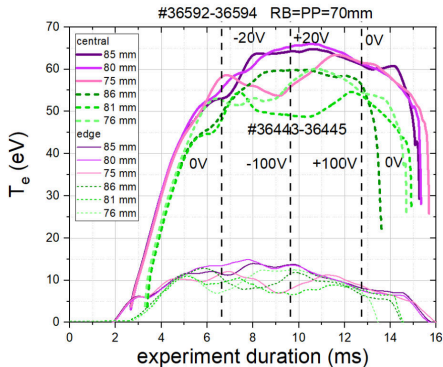
Biasing electrode



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

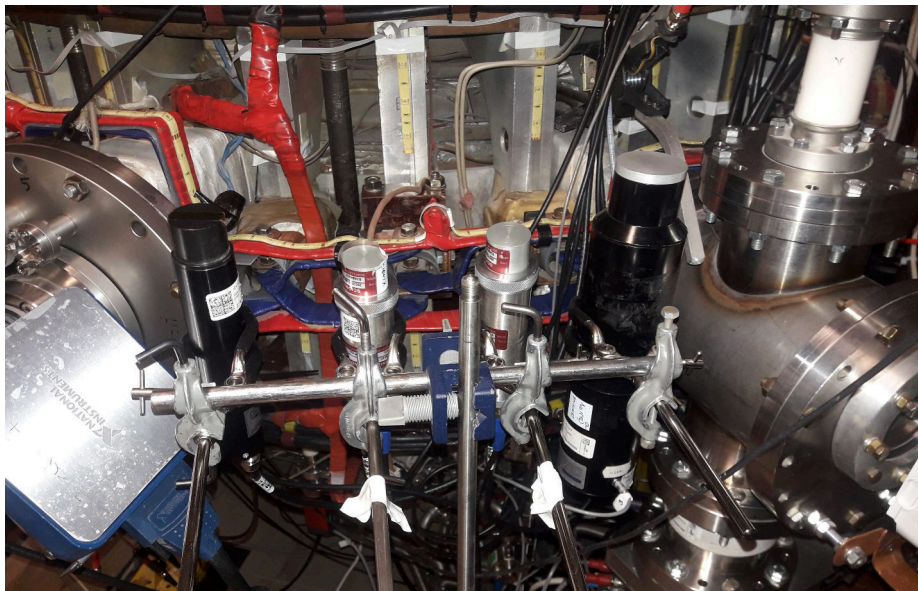
$U_{CD} = 450$ V $p = 16$
mPA

$U_{Bt} = 800$ V gas H

Outline

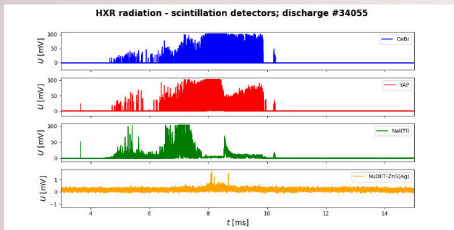
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Lukáš Lobko (Jan Čerovský, Ondřej Ficker): Měření ubíhajících elektronů na tokamaku GOLEM prostřednictvím scintilačních detektorů. Lab. work. 2021

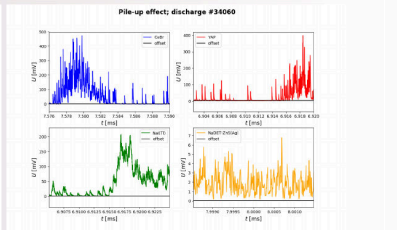


Measurements of HXR radiation

- Scintillation detectors were used for HXR spectrometry.
- Two problems occurred:
 - 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.

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



PUBLISHED BY IOP PUBLISHING FOR SISSA MEDIALAB

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ACCEPTED: *February 14, 2020*

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.

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



Progress in HXR diagnostics at GOLEM and COMPASS tokamaks

J. Čerovský^{1,2,*}, O. Ficker^{1,2}, V. Svoboda², E. Macusova¹, J. Mlynář¹, J. Caloud^{1,2}, V. Weinzettl¹, M. Hron¹, the COMPASS team and EUROfusion MST1 team**

¹ Institute of Plasma Physics of the CAS, Prague, Czech Republic

* contact: cerovsky@ipp.cas.cz

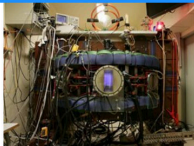
² Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Prague, Czech Republic

** See author list B. Labit et al., 2019 Nucl. Fusion 59 086020

GOLEM and COMPASS tokamaks

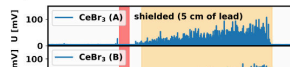
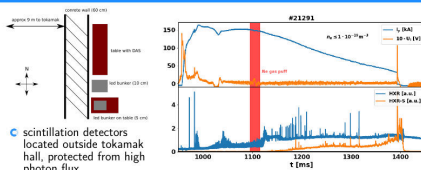
- the GOLEM tokamak [1] is a small size device operated at FNSPE CTU
- former tokamak CASTOR operated at IPP in Prague
- serves mainly for educational purposes and for diagnostics testing (probes and various HXR detectors)

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



- HXR radiation detected mainly during RE beam phase

-

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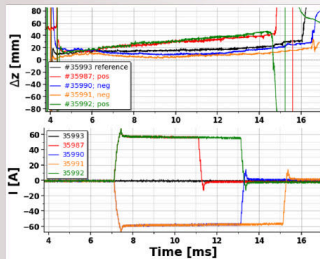
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ERDF Plasmalab pro tGOLEM. 10x Kepco 20V-20A for horizontal and vertical plasma position stabilization



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.

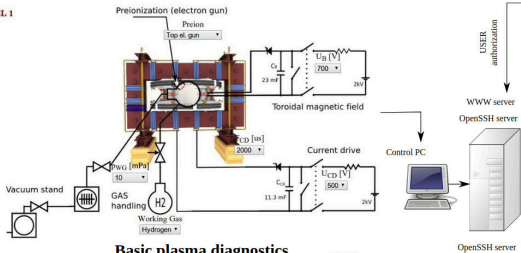


Plasma vertical displacement for discharges with stabilization generating

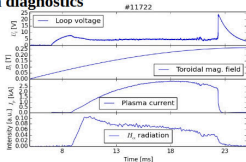
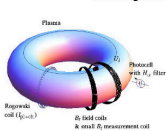
Higher B_t . Now up to ≈ 0.7 T.

LEVEL 1

Tokamak technology setup



Basic plasma diagnostics



internet



Virtual control room (remote participation)

USER authorization

WWW control interface



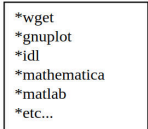
SSH control interface



Data presentation



Data handling



WWW server
OpenSSH server

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Global tokamak reconstruction - Never ending story

To ensure

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

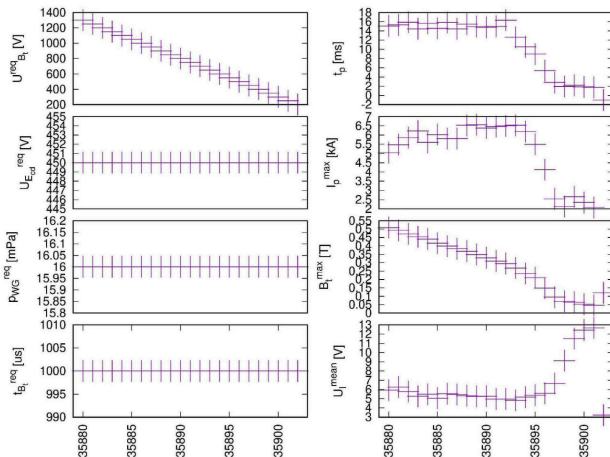
■ HWs

- 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

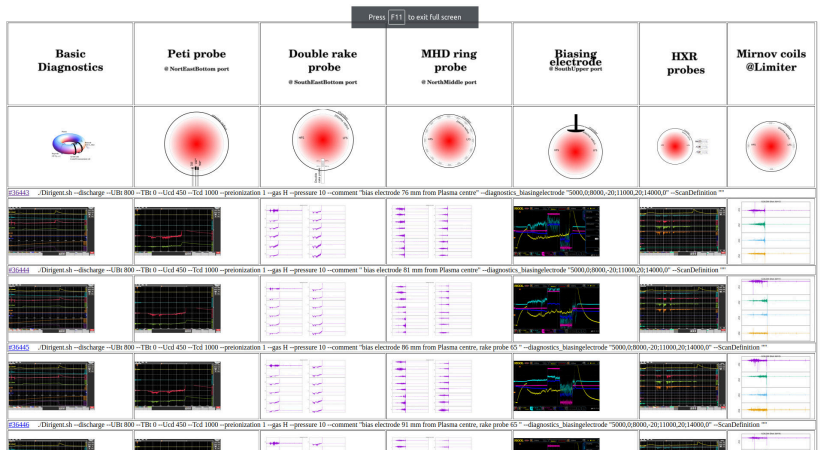
Session overview (e.g. B_t scan)



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

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

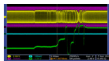
Diagnostics overview (e.g. Biasing experiment)



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

Data plotting

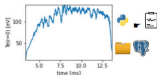
Interferom-
© ResearchGate



Analysis

Name Analysis results

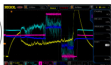
Advanced
Analysis



Name	Python3	Gnuplot	Octave	Matlab	Mathematica
Data plotting					

Infrastructure

Biassing
electrode
© ResearchGate



<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

The screenshot displays the Photron FASTCAM Viewer software interface. The main window shows a high-speed video of a champagne bottle being opened, with a ruler visible on the left side. The software interface includes a menu bar (File, View, Option, Window, Help), a toolbar with various icons for navigation and settings, and a control panel on the right. The control panel includes tabs for Camera, Data Save, and File View, and a section for Viewer number (005) with various playback and save options.

Current Time
+00:01:00.883333

File Info
Unknown
30 fps
1/frame sec
1024 x 1024
Start
5457 frames
181.9 sec
LUT:019,-39.1
Zoom rate:55%
X:0401 Y:0481
R:074 G:074 B:074

Viewer number : 005

Total frame : 5457 frames
Resolution : 1024 x 1024
Color bit : 8Bit Gray
File Format : CM (JPEG)

Show info Edit info
 Synchro play

Save layout Cursor save
 Info save Save info Save layout
 Save

JPEG Option Save
 Skip save

Speed 4 fps

EN 7:40 AM

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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 řízení 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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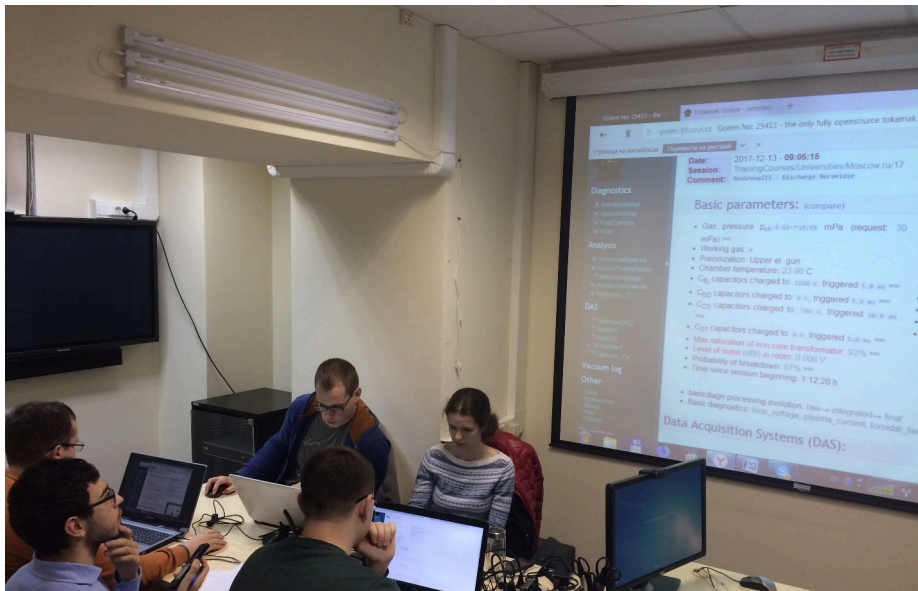
Remote from Budapest. November 2020



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

[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_Elg0Gjk

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

1. Zajímá jste se i o reakci D-D?
2. Je princip měření Langmuírovou 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

D Středoškolská odborná činnost - 2 - Daniela Krop...



Copy link



SOČ
středoškolská
odborná činnost

Obor: 02. Fyzika

Stabilizace plazmatu na tokamaku GOLEM

Jméno: Daniela Kropáčková
Škola: Gymnázium Brno, Křenová, p. o.
Kraj: Jihomoravský

MORE VIDEOS



0:01 / 8:34



YouTube



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



A

Středoškolská odborná činnost -2- Aleš...

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Obor: 2. Fyzika

SOČ
středoškolská
odborná činnost

Poloha zóny vytváření turbulentních struktur v okrajovém plazmatu tokamaku GOLEM

Aleš Socha
Gymnázium a SOŠ, Frýdek-Místek
Moravskoslezský kraj

Watch on  YouTube

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

M

Středoškolská odborná činnost 2 Marti...



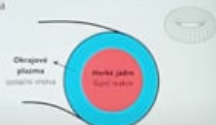
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Měření elektronové teploty T_e

- PROČ? Zajištění optimálních podmínek pro průběh fúzní reakce v tokamaku (tzn. maximalizace energetické účinnosti termojaderné fúze)*
- KDE? Izolační vrstva = okrajové plazma
- JAK? ELEKTRICKÉ SONDY



* T_e přímo souvisí se rychlostí fúzní reakce, protože vyšší teplota T_e způsobí větší počet fúzních reakcí na jednotku objemu plazmy. (Důležitější je rozdíl mezi teplotami elektronů a iontů, protože ionty jsou těžší a pohybují se pomaleji.)

MORE VIDEOS



0:41 / 9:05



YouTube



Outline

- 1 Introduction
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 - Overall tokamak GOLEM reconstruction
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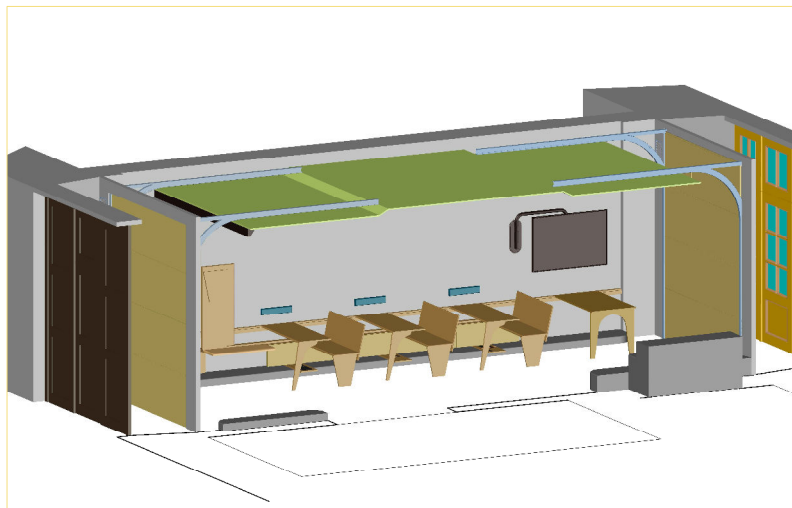
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Kauza průjezd

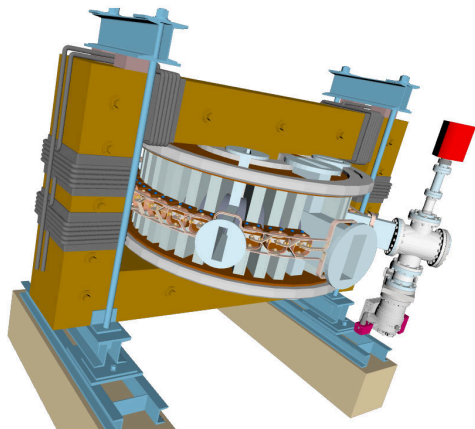


Himmel, M. Průjezd, verze 2. 2020.



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



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<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

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V SVOBODA², A MELNIKOV^{5,6} , R KAMENDJE⁷, A MALAQUIAS⁸ ,
G MANK¹⁰, R MIKLASZEWSKI¹¹, the IAEA CRP¹² and JEs Teams¹²

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⁴ INPE, São José dos Campos 12227-010, Brazil

⁵ National Research Centre 'Kurchatov Institute'. 123182 Moscow, Russia

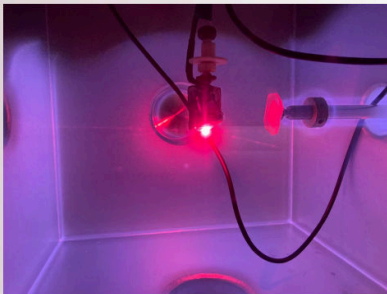
M Gryaznevich et al 2020 Plasma Sci. Technol. **22** 055102.

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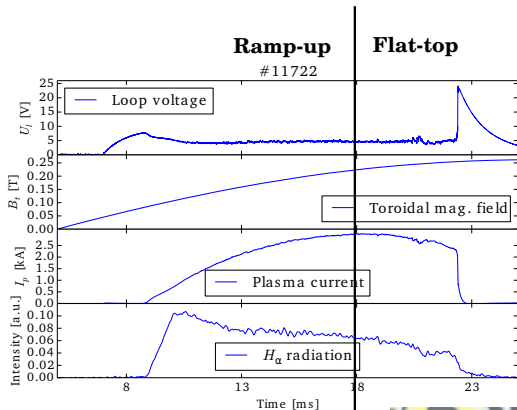
Jan Čečrdle (Jan Horáček). Lithization tests in vacuum cube. Lab. work. 2021

- 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.

Jan Buryanec (Vojtěch Svoboda): Plasma current control



**Transformer
primary current
control**

Gas puff control



Gabo Vondrášek. Maxi přepínač

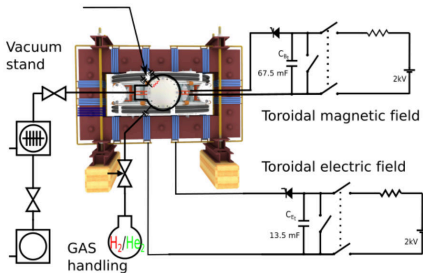
GOLEM remote Introduction Control room Live Results

Master Access: Level 2 Help

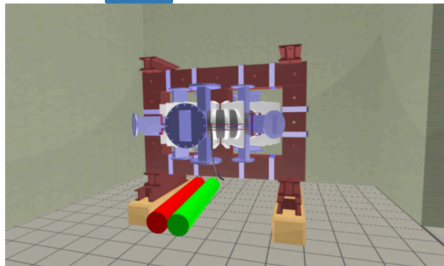
Introduction Working gas Preionization Magnetic field Electric field Submit

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.

Preionization (electron gun)



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



Oprava interferometru (bedna šampaňského)



Free post discharge analysis script upload/access for trained students

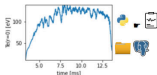
Interferom
© ResearchGate



Analysis

Name Analysis results

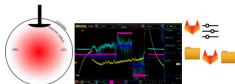
Advanced
Analysis



Name	Python3	Gnuplot	Octave	Matlab	Mathematica
Data plotting					

Infrastructure

Biassing
electrode
© ResearchGate



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

Start to explore all the stuff

Google search results for "start science".

Search bar: start science

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Filters: data science, computer science, workbook, viva, click start, class 8, Project START! posts, curriculum, neha sharma, start right, TART children, basf, word

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- Popular topics: Science book, Science, Workbook
- Start Up Science 5, 201... amazon.in
- 3Doodler Start Science & E... the3doodler.com · In stock

Footer: PFV-Window-pr...png, Interferometr.jpg, DSCN1817.JPG, Click Science, Predictions = Hypothesis

Čaloud, J. Kalometrická sonda.

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Petr Mácha



Katka Hromasová



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