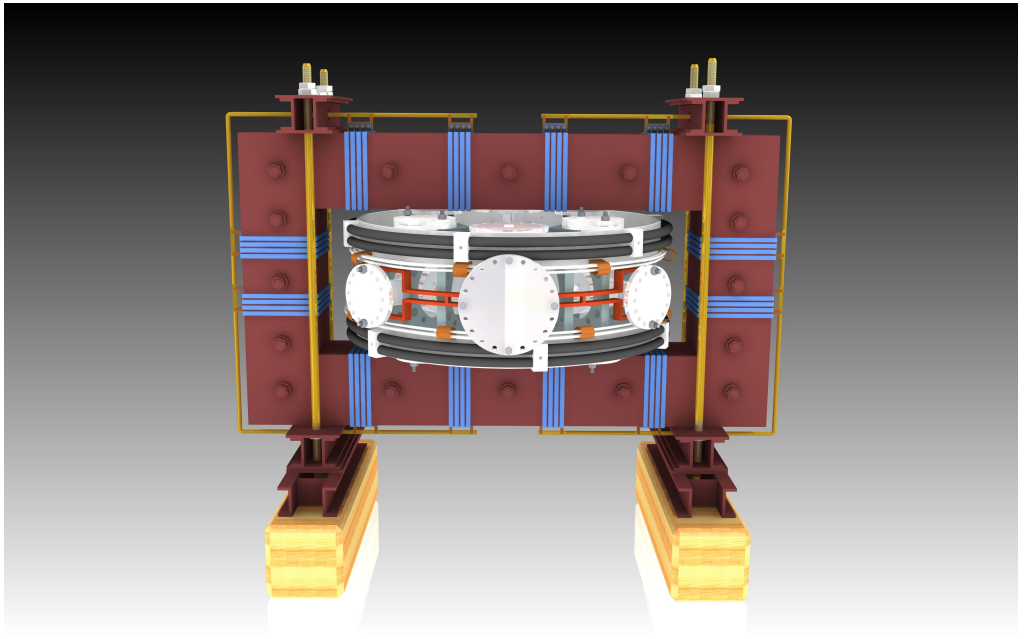
Golem 2013 - from #10658 to #13807

Mariánská 2014

Vojtěch Svoboda

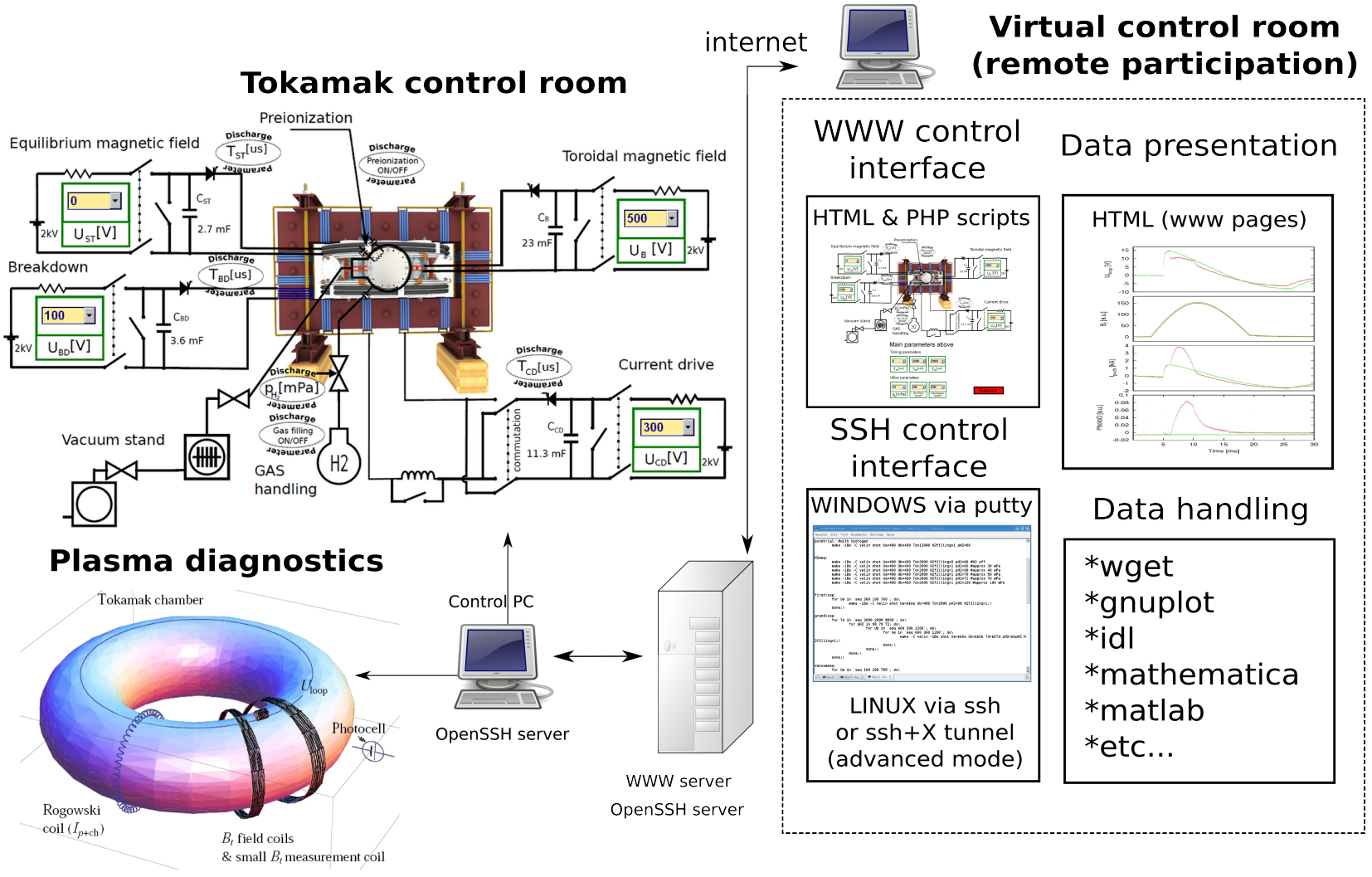


Outline

Road to CTU, at the IPP (12.12.2007)

Road to CTU, at the CTU (12.12.2007)

The smallest & oldest operational tokamak with the biggest control room in the world



Technological achievements

Reconstruction: from kludge to normal operation design

HW, control and web presentation SW (python), database oriented analysis (SQL), WIKI (gitit).

- Vertical stabilization.
- Plasma breakdown with 2.45 GHz MW launcher.
- Bottom and top preionization gunn instalation (breakdown studies).
- Both E_{CD} orientation.
- Both B_t orientation.

Outline

Forecast IBA, October 2012

- 10/12 Remote practica from Budapest II. .. OK
- 10/12 Remote demonstration from Trieste IAEA workshop. .. OK
- Bachelor and Diploma Thesis - cont. ... OK
- Excursions - cont. .. OK
- University of third age - cont. ... Finished
- The week of science - cont. ... OK
- GOMTRAIC II - spring 2013. ... OK
- SUMTRAIC 2013- cont. ... OK
- FUMTRAIC II - Feb. 2013. ... OK
- Remote practica.
- HTS (temporary slowed down), RF preionization .. OK, magnetic phenomena .. OK, probes measurements .. OK.

Feb.: Cadarache Winter Event 2013

A whole-week event in Cadarache:

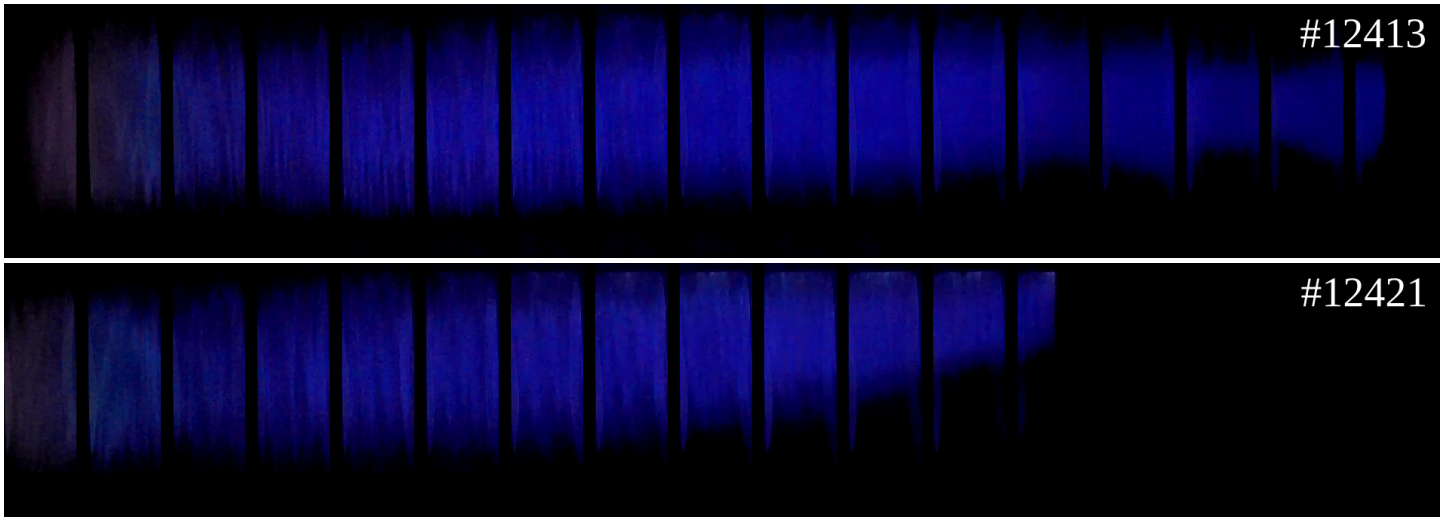
- Monday: Lecture "Introduction to tokamak operation" and demonstration session (1 remote shot made by a tutor)
- Tuesday: experimental session I (75 remote shots made by students)
- Wednesday: experimental session II (14 remote shots made by tutor and students)

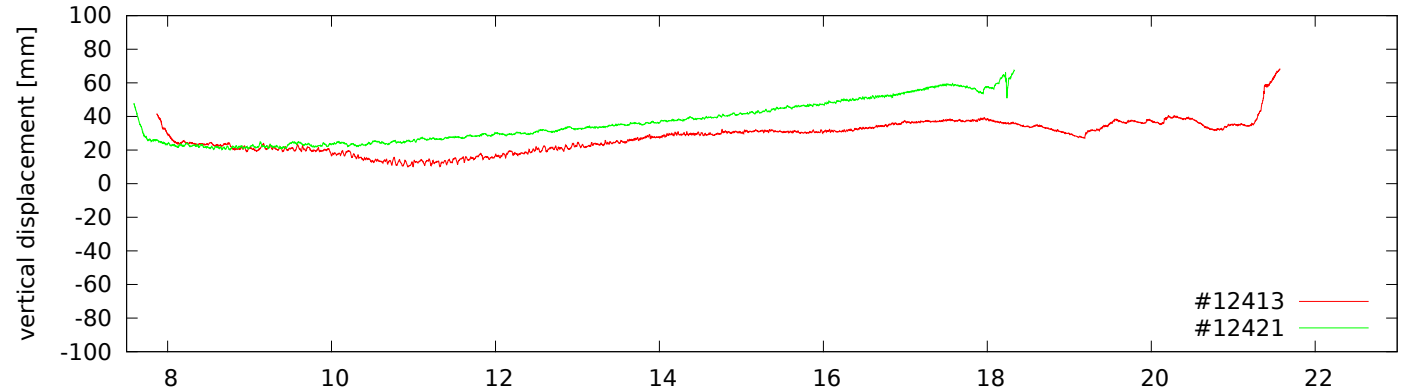
My feeling is that this event was a success. With an extra day of work compared to last year, the students have had time to go more in depth into the analysis. The new diagnostics (rake probe and magnetics) and the spectroscopy data analysis have also proven invaluable. The oral examination .. were quite good.

Remy Guirlet, FUMTRAIC 2013 tutor

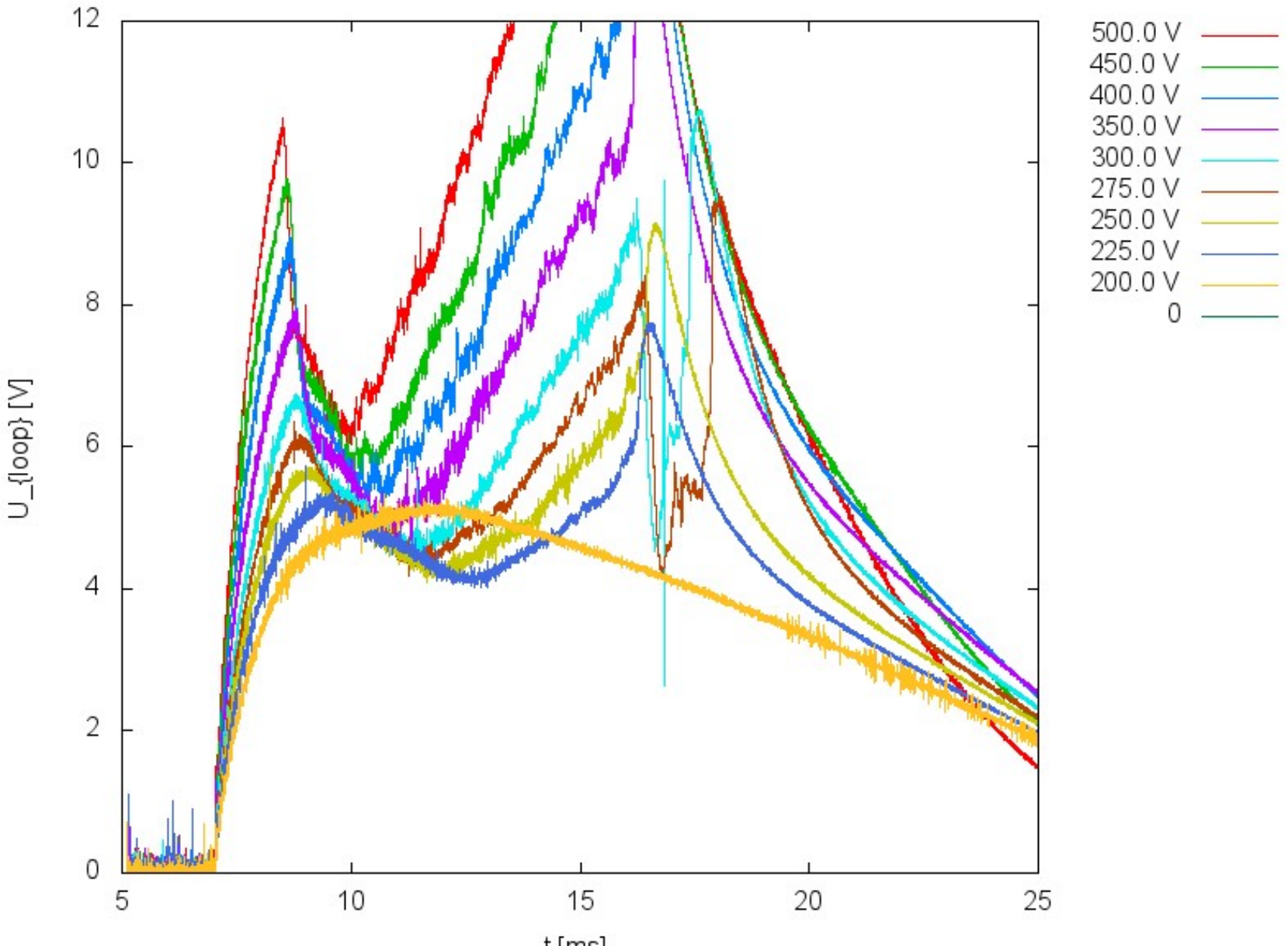
March: J. Kocman et al.: Vertical plasma stabilization

4 Mirnov coils at poloidal angles. Computer with real-time OS for calculating the plasma position with a frequency of 50 kHz. Voltage source driven by the computer controls a current in a poloidal coils. The prolongation of the plasma life was over 2 ms.

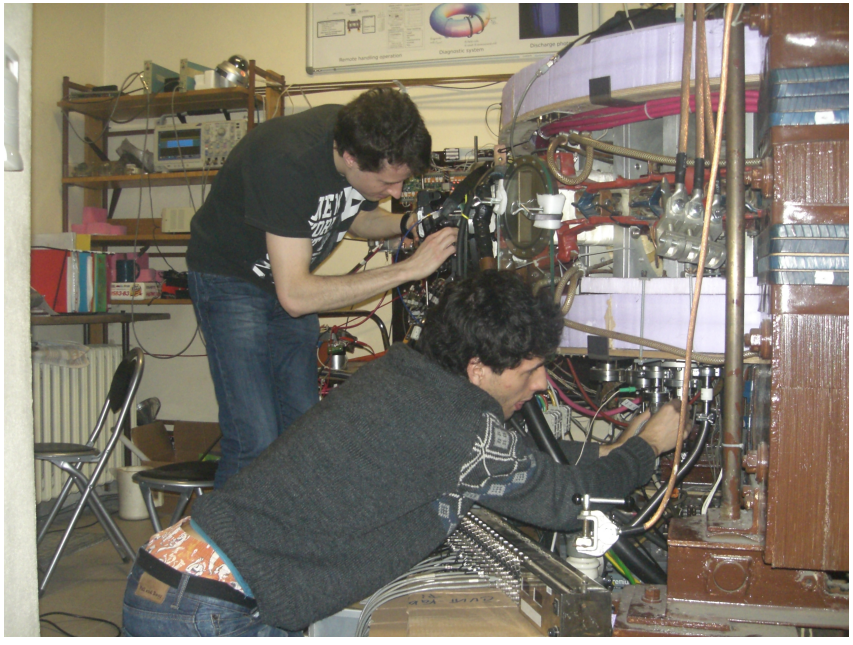




April: Vorobyev et al.: Breakdown otimization with the 2.45 GHz MW launcher



Spring: GOMTRAIC 2013 - flagship of the FUSENET project



- In-situ (PERFECT) and remote (NOT SO GOOD) part.
- 7 foreign students.
- 5 Czech students (remote and in-situ) and 1 Hungarian student **as tasks supervisors**.
- MHD, Tomography, HXR, Rake probe.
- Remote shots from Costa Rica, Mexico and India.

July: EPS Stockholm - Poster presentation "The tokamak GOLEM for fusion education - chapter 4"

poster.pdf – Okular <2>

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UPGRADE OF THE PERFORMANCE OF THE GOLEM TOKAMAK

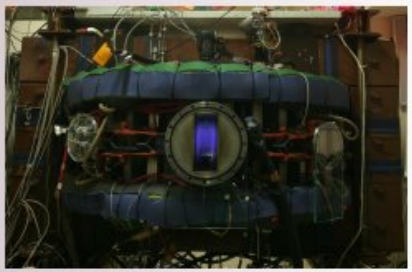
D. Hernandez-Arriaga[1], J. Brotánková[2], O. Grover[2], J. Kocman[2], T. Markovič[2,3], M. Odstrčil[2], T. Odstrčil[2], T. Růžičková[2], J. Stöckel[3], V. Svoboda[2], G. Vondrášek[2]

[1]Instituto Politécnico Nacional - CICATA Querétaro, Querétaro, México

[2] Faculty of Nuclear Sciences and Physical Engineering CTU in Prague, Praha, Czech Rep.

[3] Institute of Plasma Physics AS CR, v. v. i., Assoc. EURATOM-IPP.CR, Praha, Czech Rep.

The GOLEM Tokamak



- An educational device for domestic as well as for foreign students via remote participation/handling.
- Operating routinely for nearly two years at a modest range of parameters $B_t < 0.5$ T, $I_p < 8$ kA, pulse length < 15 ms, and with a limited set of diagnostics.
- Wide range of tasks with varying levels of complexity covering tokamak physics, technology and operation can be studied by the future fusion specialists.

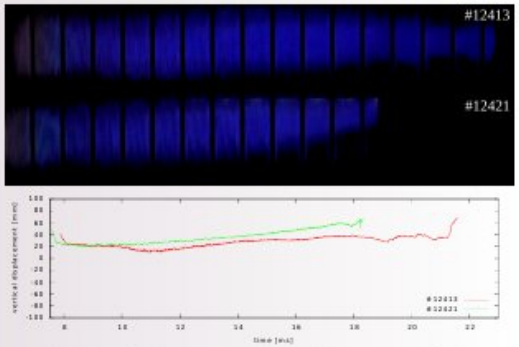
GOMTRAIC

Plasma stabilisation

Feedback control system:

- 4 Mirnov coils at poloidal angles of $\theta = 0, \pi/2, \pi, 3\pi/2$.
- Computer with real-time OS for integratign signals and calculating the plasma position
- Program for determination of the vertical position of plasma is written in LabVIEW and counts with a frequency of 50 kHz
- Voltage source driven by the computer controls a current in a poloidal coils
- Poloidal coils affects the vertical plasma position

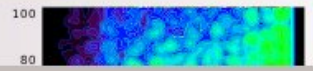
The average prolongation of the plasma life was over 2 ms. However, there are pending issues with Mirnov coil signal integration, which are planned to be solved in the future. Meanwhile, changes of plasma position are taken as more relevant, rather than absolute calculated position.



Evolution of the vertical displacement of plasma using fast camera. The upper image (#12413) is with the feedback stabilization, middle (#12421) is without. Bottom: comparison of their vertical displacements using Mirnov coils.

MHD studies

- Substantial improvement of the diagnostics means of B_θ perturbations (for detection of co-



Spectrogram of

1 of 1

June: Tokamak Operation Demonstration for Bochum students

The participants of the "Introduction to Plasma Physics" had the possibility to operate the GOLEM Tokamak remotely and got familiar with its operation principle. First, the 3D model of the tokamak was presented, with the possibility to virtually visit the control room with the tokamak, to see all the essential parts in detail and even to see the plasma chamber from inside. Afterwards, the effect of different plasma parameters such as pressure, magnetic field and preconditioning of the reactor chamber with glow discharge were tested.

Thanks to the GOLEM team, lead by Dr. Vojtěch Svoboda, the physic students at RUB will have now the opportunity to operate the Golem Tokamak also in the following years. Moreover, the organization of a remote practica, Bachelor theses or even short training visits in Prague is now being prepared.

Jun. Prof. Jan Benedikt, organizer

Sept.: Prague Museum Night

Sept: Fusenet final brochure - GOLEM page

Learn to operate a real tokamak

The GOLEM Tokamak for Fusion Education

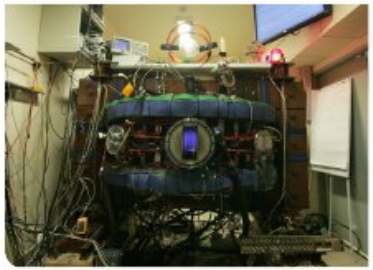
The GOLEM tokamak is located at the Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University (CTU). CTU hosts a Fusion Masters program, but GOLEM is for the benefit of a wider audience. It is a small-sized tokamak device equipped with basic controls and diagnostics and full remote-control capability for educational purposes.

Target group

Bachelors and Master Students wanting to learn about tokamak operation.

On an introductory level: the very basics of tokamak operation are demonstrated, and students are acquainted with key plasma properties and tokamak operational limits.

On an advanced level: the concept of MHD equilibrium, MHD eigenmodes, turbulence and radiation are studied by measuring basic properties with simple measurements. Any other fields can be considered for studies based on individual proposals.



GOLEM tokamak in operation

Remote operation support

Measurements are to be set up and shots initiated using the **user-friendly web interface of the GOLEM tokamak.**

Student visiting GOLEM

All the **recorded data** and the settings for each shot are **available on a shot homepage**, and download routines exist in several widespread processing languages.

Student instructions and an interactive wiki page have been prepared to guide students through various measurement programs. The aim of these guides is to demonstrate a maximum number of fusion plasma phenomena within a limited time period and using the simple tools available at GOLEM.

Virtual tools aiding the preparation

In order to introduce the GOLEM tokamak to distant users via Internet, an interactive **3D virtual model** has been created.

The virtual model is complemented by a **virtual operation interface**, where students have the opportunity to set up the parameters in the same way as in real operation. The only difference is that virtual operation is inspired by and results are generated from the shot database.

Use and access

Both local and remote users can make good use of the capabilities of the GOLEM tokamak. Numerous measurements have been taken from all over the world, even during regular student laboratory courses. The main use is, however, during concentrated education activities, like the **GOMTRAIC** GOlem reMote TRAIning Course attracting students from thewhole world every year.

Easiest access for individual users is through the yearly GOMTRAICs, while institutions can contact the GOLEM team for regular or occasional operational windows.

Students performing remote operation exercise from Budapest

Contact information

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October: M. Gryaznevich et al: Progress in application of high temperature superconductor in tokamak magnets

Fusion Engineering and Design

Volume 88, Issues 9–10, October 2013, Pages 1593–1596

Proceedings of the 27th Symposium On Fusion Technology (SOFT-27); Liège, Belgium, September 24-28, 2012

http://dx.doi.org/10.1016/j.fusengdes.2013.01.101

Progress in application of high temperature superconductor in tokamak magnets

M. Gryaznevich[a], V. Svoboda[c], J. Stockel[c, e], A. Sykes[a], N. Sykes[a], D. Kingham[a], G. Hammond[a], P. Apte[a, b, c, d, e, f], T.N. Todd[b], S. Ball[d], S. Chappell[d], Z. Melhem[d], I. Ďuran[c, e], K. Kovarik[e], O. Grover[c], T. Markovic[c], M. Odstrcil[c], T. Odstrcil[c], A. Sindlery[c], G. Vondrasek[c], J. Kocman[c], M.K. Lilley[f], P. de Grouchy[f], H.-T. Kim[f]

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October: T. Markovic et al: Evaluation of applicability of 2D iron core model for two-limb configuration of GOLEM

ELSEVIER

Fusion Engineering and Design

Volume 88, Issues 6–8, October 2013, Pages 835–838

Proceedings of the 27th Symposium On Fusion Technology (SOFT-27); Liège, Belgium, September 24-28, 2012

http://dx.doi.org/10.1016/j.fusengdes.2013.02.142

Evaluation of applicability of 2D iron core model for two-limb configuration of GOLEM tokamak

Tomáš Markovič[a, b], Mikhail Gryaznevich[c], Ivan Ďuran[a, b], Vojtěch Svoboda[a], Gabriel Vondráček[a]

[a] Czech Technical University, FNSPE, Prague, Czech Republic

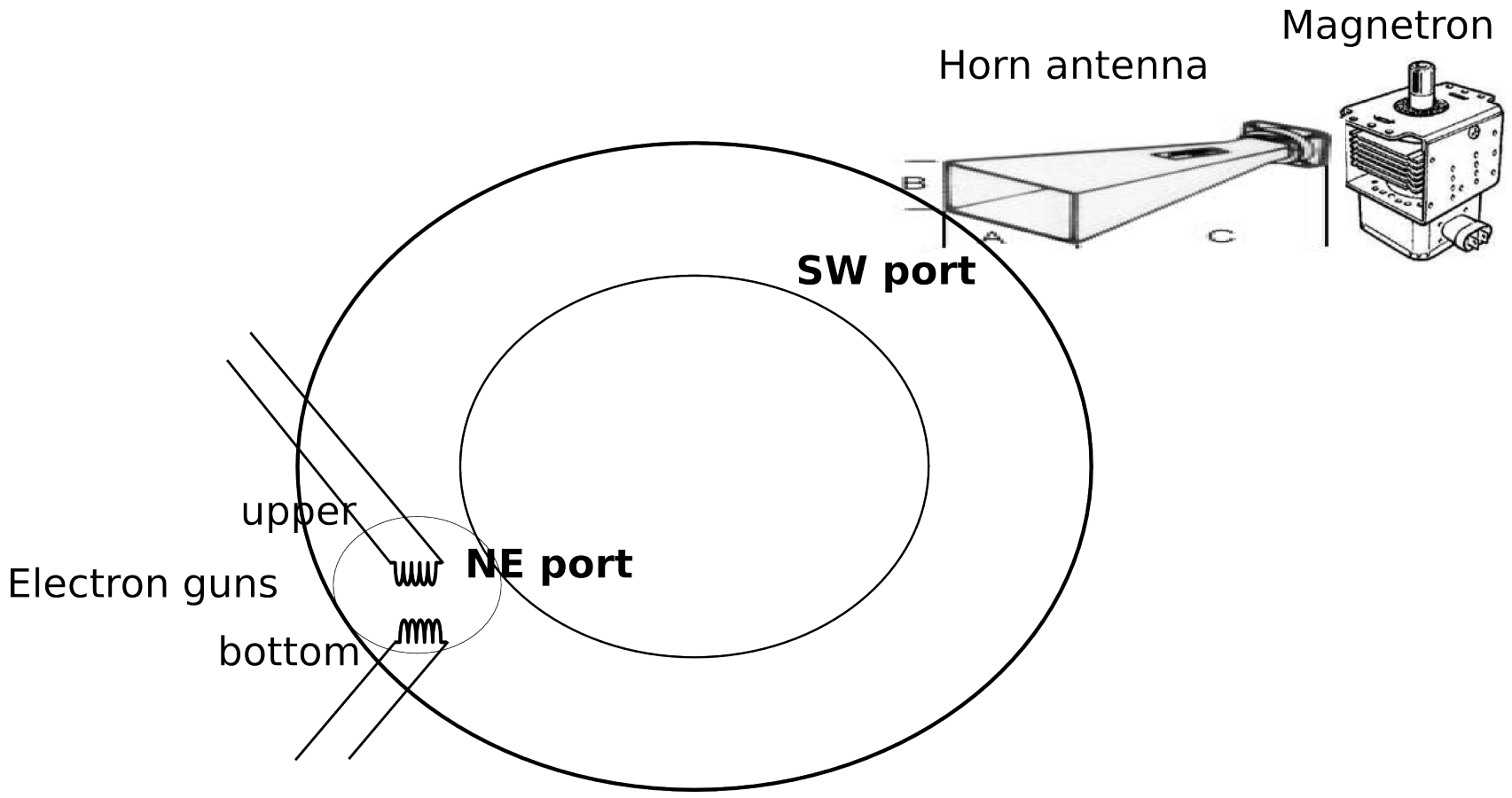
[b] Institute of Plasma Physics AS CR, v.v.i., Association EURATOM/IPP.CR, Prague, Czech Republic

[c] EURATOM/CCFE Fusion Association, Culham Science Centre, Abington, UK

Abstract

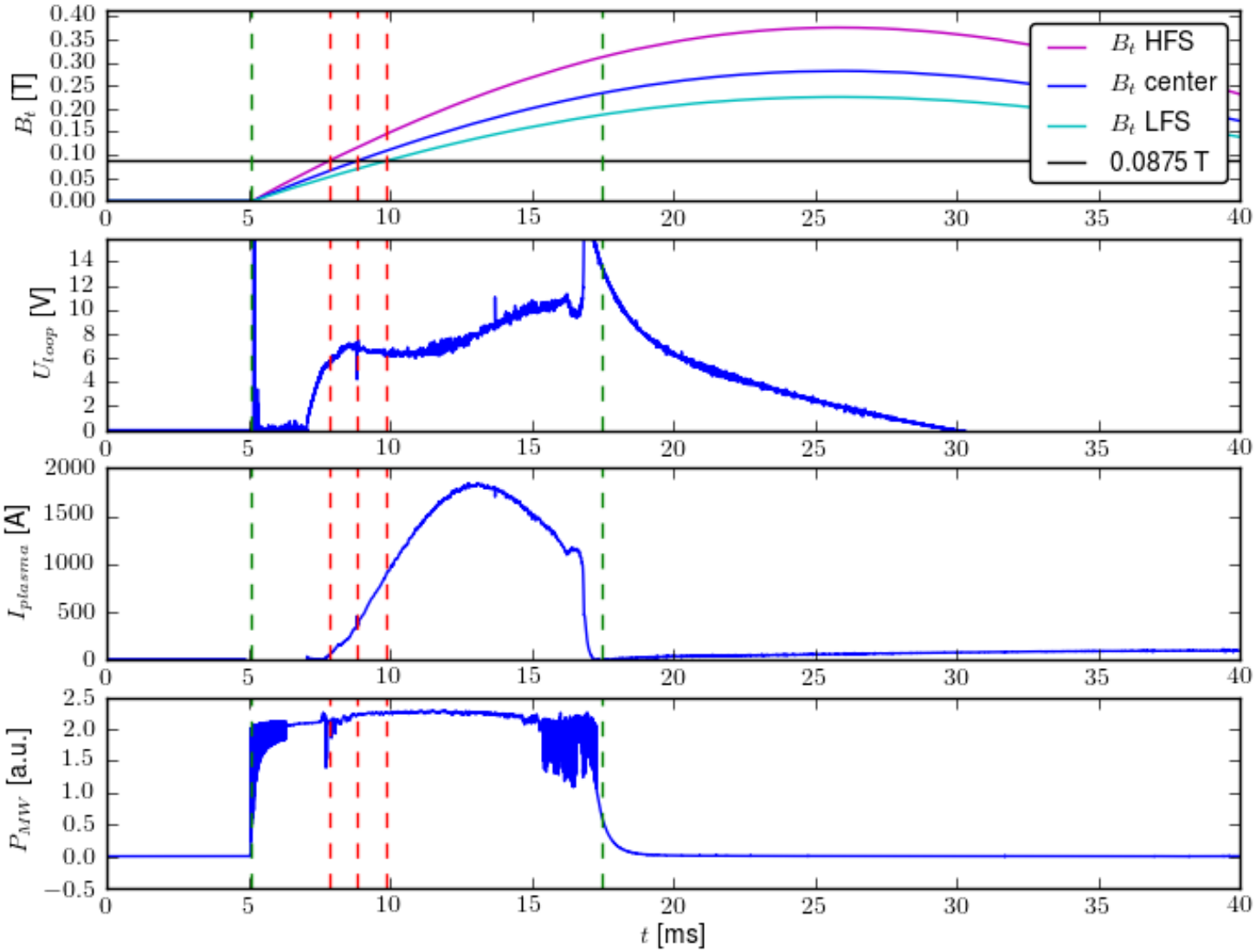
This paper presents evaluation of applicability of 2D iron core model for highly non-axisymmetric two limb configuration of GOLEM tokamak (former CASTOR). Presented results explain the long-term discrepancy between measured magnitudes of external poloidal field and those calculated by air-core approach on this

Nov.: Joint Experiment



- MW preionization
- RF plasma
- Hall probes feasibility studies in the ICRH presence

Nov.: MW preionization - pulsed regime

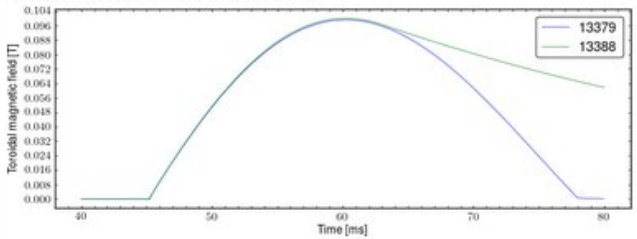


Nov.: RF plasma

RF plasma

13379 vs. 13388 (steady state of the Magnetron operation)

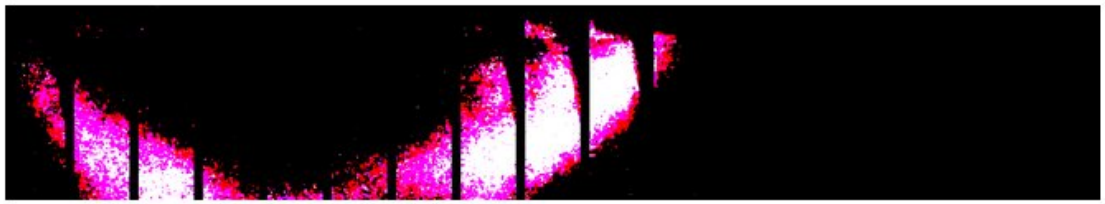
Bt comparism Diode applied to Bt LC circuit.



13379

original (note : there is a flow/ signal):

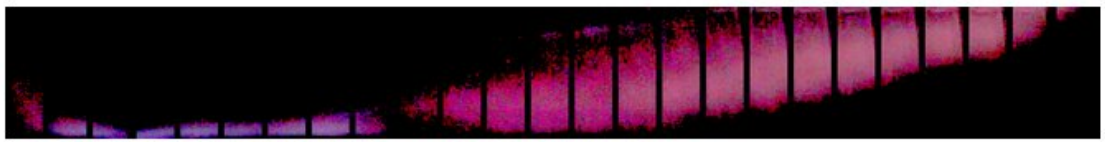
photoshop remake :



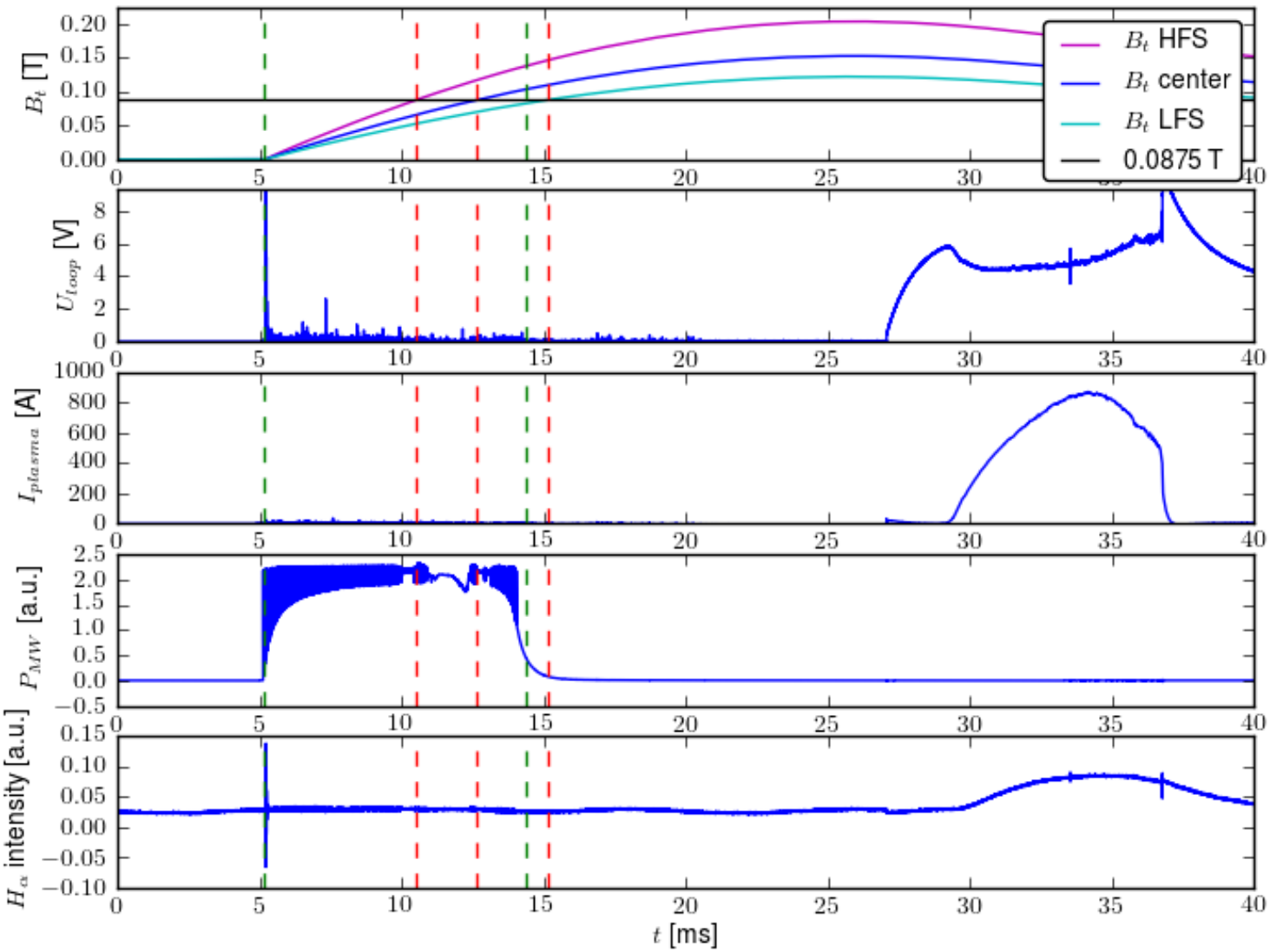
13388

original (note : there is a flow/ signal):

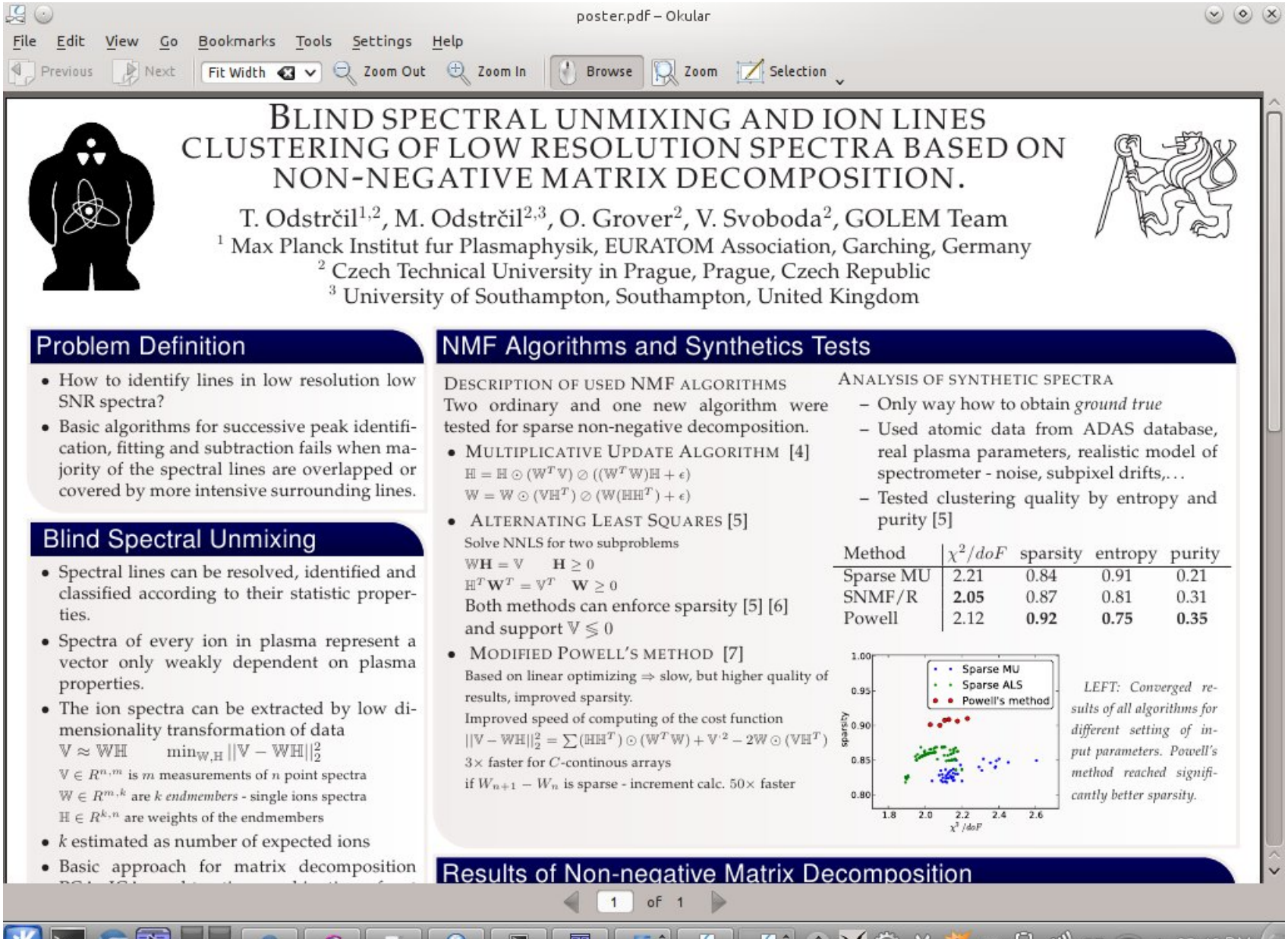
photoshop remake :



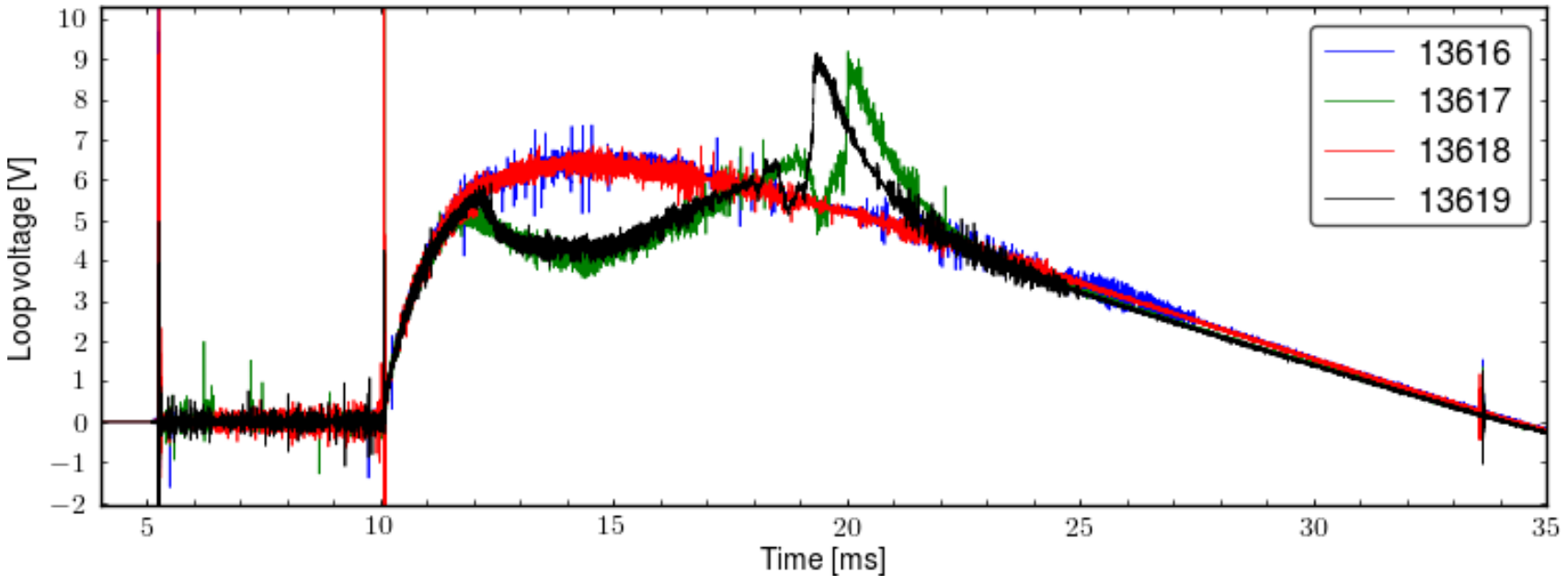
Nov.: MW preionization: Sustained Breakdown Conditions



Nov: T. Odstrcil et al.: Blind spectral unmixing and ion lines clustering of low resolution spectra based on non-negative matrix decomposition.

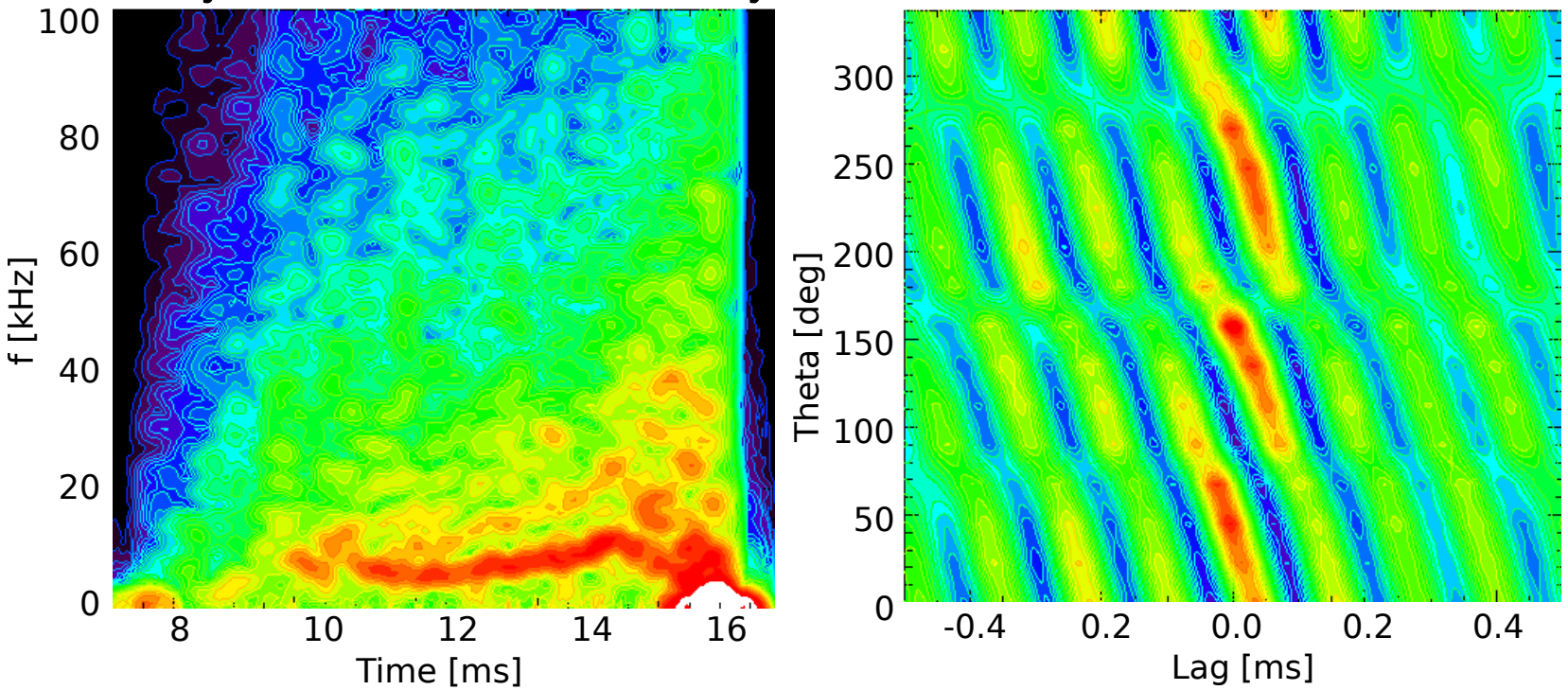


Nov.: B_t & E_t orientation



Autumn: Junior Tech University (Lucie a Matyas & TMarkovic)

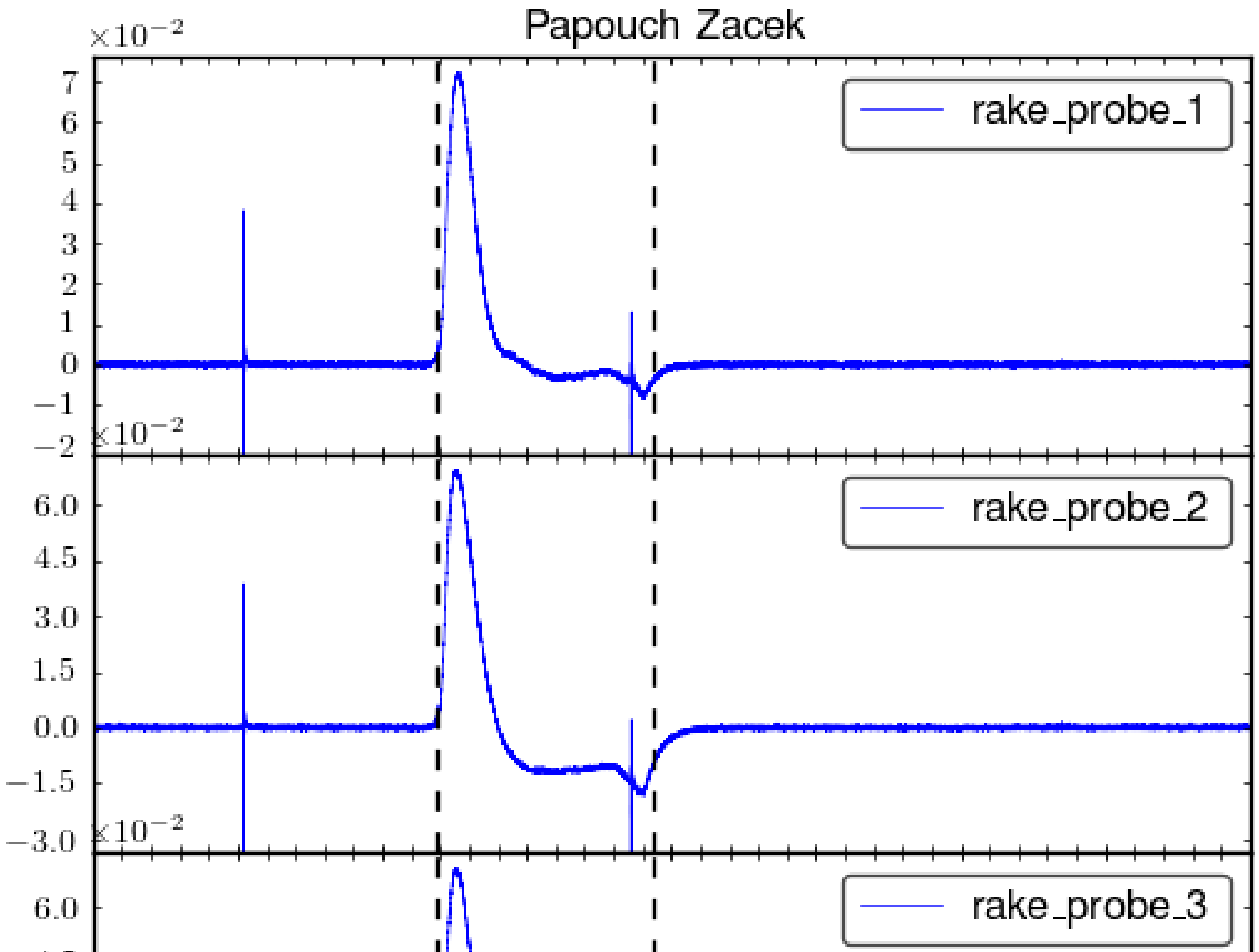
Array of 16 Mirnov coils has been instaled. Magnetic islands detected at low q regime of tokamak $m = 3$ magnetic island – shown by cross-correlation analysis of $14 - 15$ ms interval



Spectrogram of B_θ perturbations detected by a Mirnov coil located on $\theta = \pi/2$, Cross-correlation coefficients of B_θ perturbation signal on an array of 16 Mirnov coils. Reference coil chosen on $\theta = \pi/2$

Autumn:CT:D - Lovci záhad: Slunce na Zemi 12.1.2014, 17:40

Dec: Borek Leitl: Bolometry chip installed



GOLEM party #1

Outline

Forecast 2013/2014

- 5 high school students in the GOLEM team.
- FUMTRAIC III, GOMTRAIC III, SCIWTRAIC IV, HUNTRAIC III, SUMTRAIC day at GOLEM VI.
- Bachelor thesis IV., V., VI., VII.
- Diploma thesis II.
- Feb: FUSENET part II kick-off @ Barcelona
- IRP 2014: 1.75 MKc.

Technological & Scientific horizons

- Poloidal SOL asymetries (Richard Duban)
- ?? HTS ?? (Tereza Ruzickova) !IAEA!
- Plasma stabilization (Jindra Kocman)
- Bolometry (Borek Leitl)
- HW, SW, Wiki reconstruction cont.
- Breakdown optimization cont.
- Plasma time length prolongation from 20 to 30 ms
- Firing rate $\approx$ 1 RPM.

Plans: Poloidal asymmmetries in particle flux in the SOL (R.Pitts at.al. Journal of Nuclear Materials, 1990.)

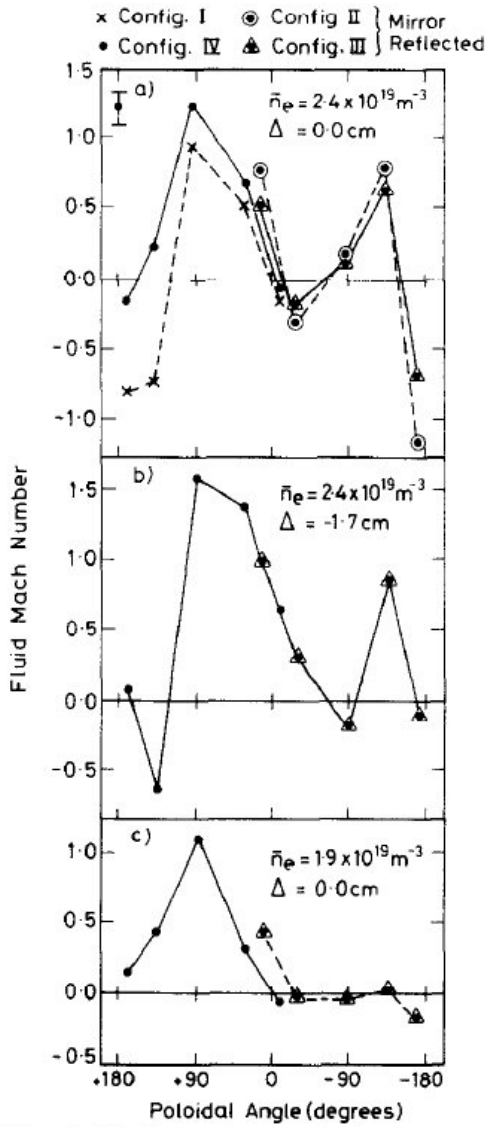


Fig. 5. Full poloidal distribution of Mach number. (a) $\bar{n}_e = 2.4 \times 10^{19}$ m^{-3}, $\Delta = 0.0$ cm, (b) $\bar{n}_e = 2.4 \times 10^{19}$ m^{-3}, $\Delta = -1.7$ cm, (c) $\bar{n}_e = 1.9 \times 10^{19}$ m^{-3}, $\Delta = 0.0$ cm.

Bachelor thesis

- Bolometry studies (Borek Leitl)
- 3D virtual model (Martin Matusu)
- Poloidal SOL asymetries (Richard Duban)
- Probe studies (Jakub Veverka)

Diploma thesis

- Real-time feedback stabilization (Jindra Kocman)

FTTF practica

- UV preionization (Martina Zkov)
- Tomography (Viktor Loffelman)
- Data mining (Jan Ulicn)
- HXR studies (Ondrej Ficker)
- MHD activity (Matus Cvengr)

FUSENET II

- FUSENET !cont.!
- Barcelona: kick-off

Outline

Acknowledgement

Acknowledgement

The financial support by FUSENET, MSM 6840770039, MSM 6840770014 and A1581, SGS SGS11/131/OHK4/2T/14 is acknowledged.

Special thanks to the GOLEM team (students, teachers, technicians)

Edita Bromova, Zdenek Cespiro, Ivan Duran, **Ondrej Grover**, Igor Jex, Jindrich Kocman, **Tomas Markovic**, **Michal Odstrcil**, Tomas Odstrcil, Ondrej Pluhar, Gergo Pokol, Tereza Ruzickova, **Jan Stockel**, **Gabriel Vondrasek**, Ondrej Vrba, Frantisek Zacek, and Jiri Zara.

GOLEM?