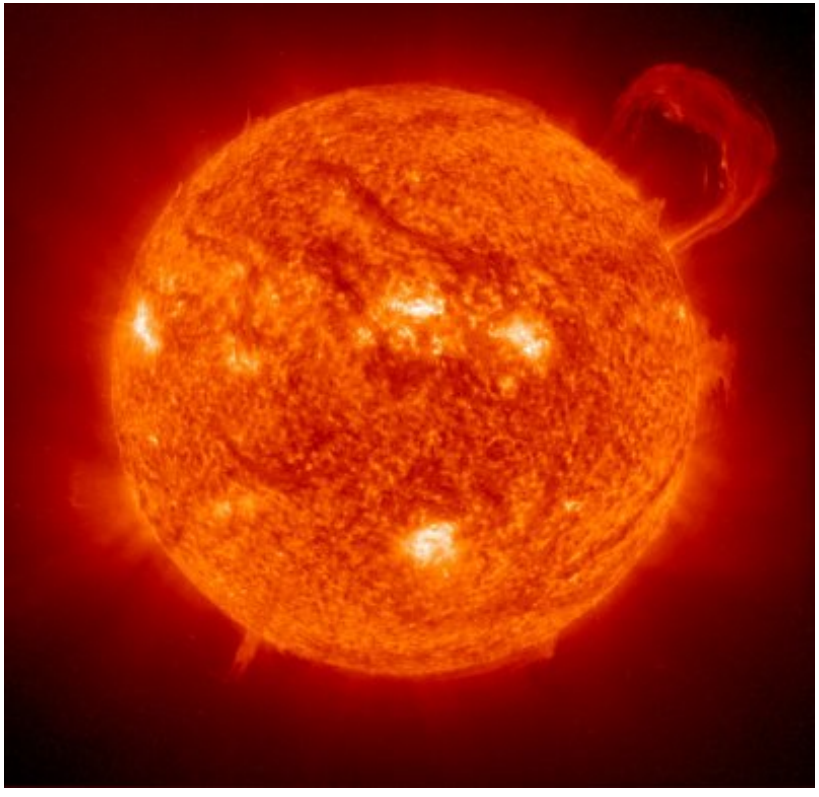
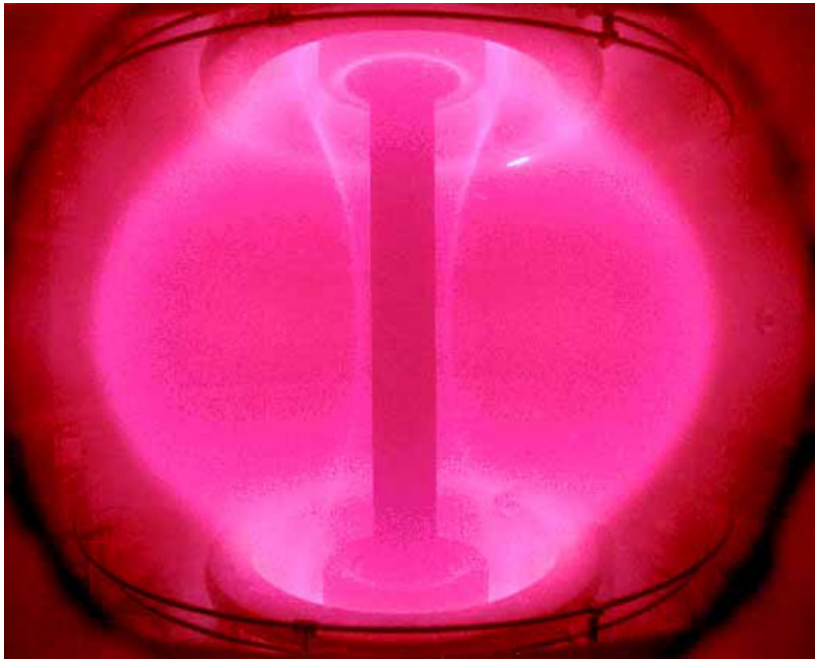
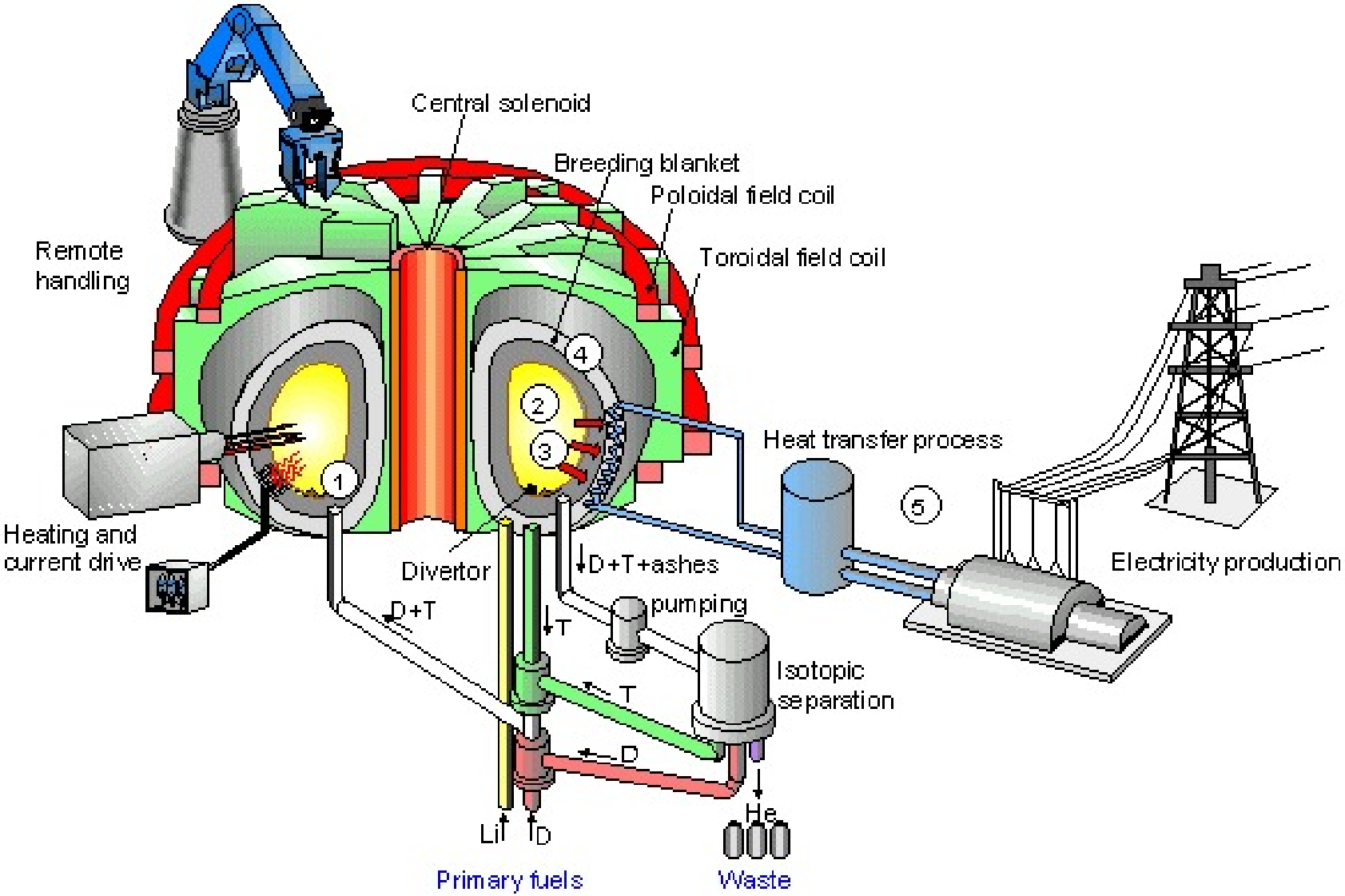
Foreword

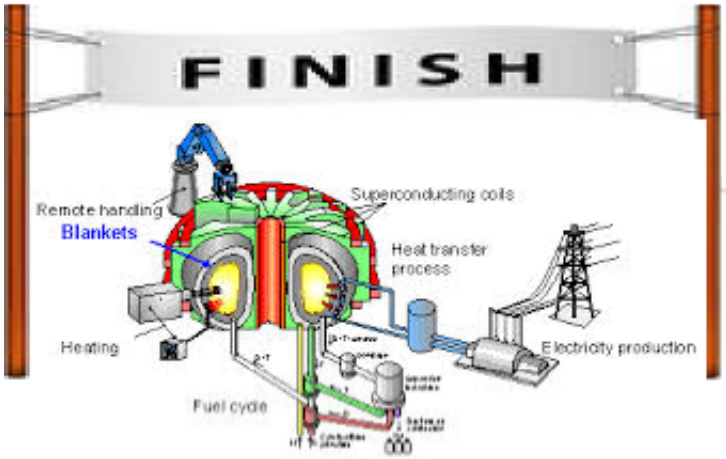


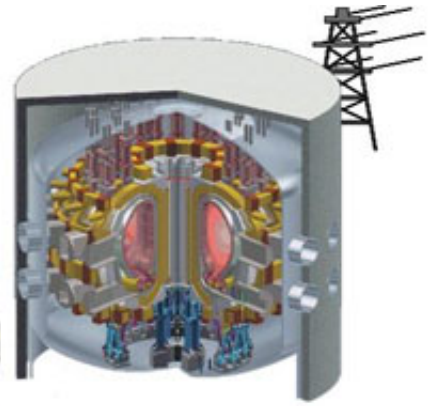


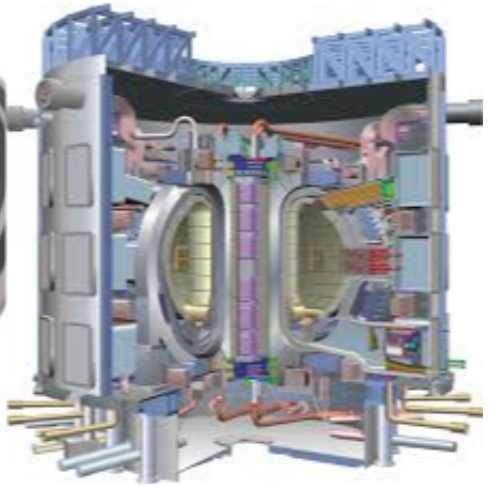
Our mission


Central solenoid
Breeding blanket
Poloidal field coil
Toroidal field coil
Remote handling
Heat transfer process
Heating and current drive
Divertor
D+T+ashes
pumping
D+T
T
Isotopic separation
T
D
He
Li
D
Electricity production
Primary fuels
Waste
1
2
3
4
5

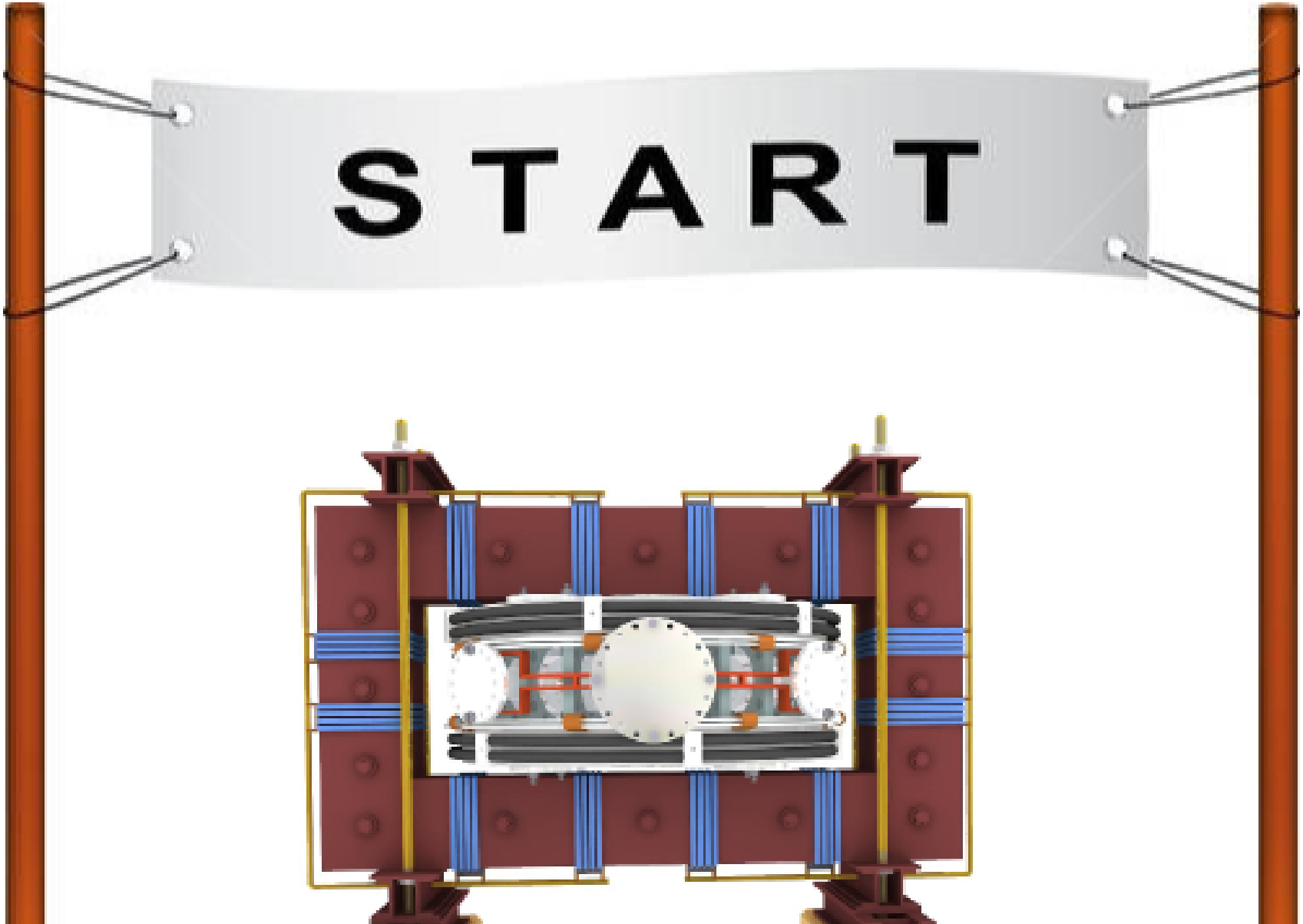
Milestones to Fusion Power Plant







Start with tokamak GOLEM



Introduction to tokamak operation (GOLEM specific) - Level 1

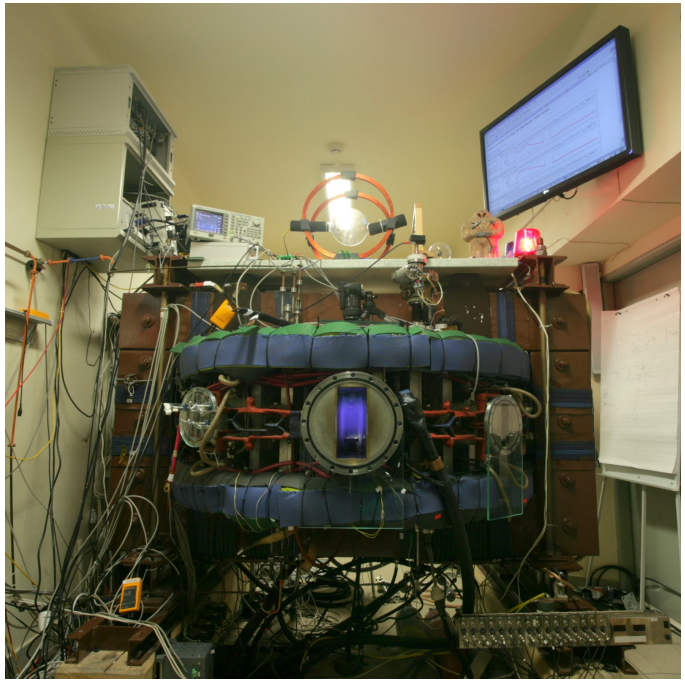
Vojtěch Svoboda
on behalf of the tokamak GOLEM team

November 18, 2014

Outline

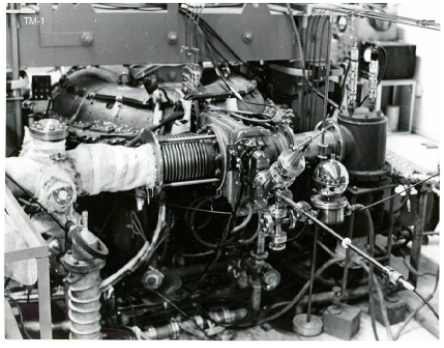
Basic characteristics

- Major radius $R_0 = 0.4$ m
- Minor radius $r_0 = 0.1$ m
- Plasma radius $a = 0.085$ m
- Toroidal magnetic field $B_t < 0.5$ T
- Plasma current $I_p < 8$ kA
- Plasma density
  $n \approx 0.2 - 3 \times 10^{19}/\mathrm{m}^{-3}$
- Electron temperature $T_e < 100$ eV
- Ion temperature $T_i < 50$ eV
- Length of the discharge $\tau < 20$ ms



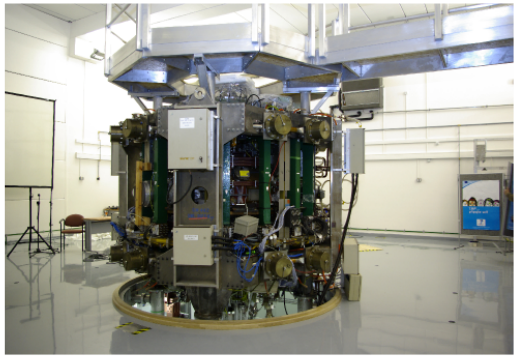
Tokamak GOLEM for education - historical background

Kurchatov Institute near Moscow,
Soviet Union
1960: **TM1-MH**



1974

Culham Centre for Fusion Energy
Great Britain
1989: **COMPASS-D**



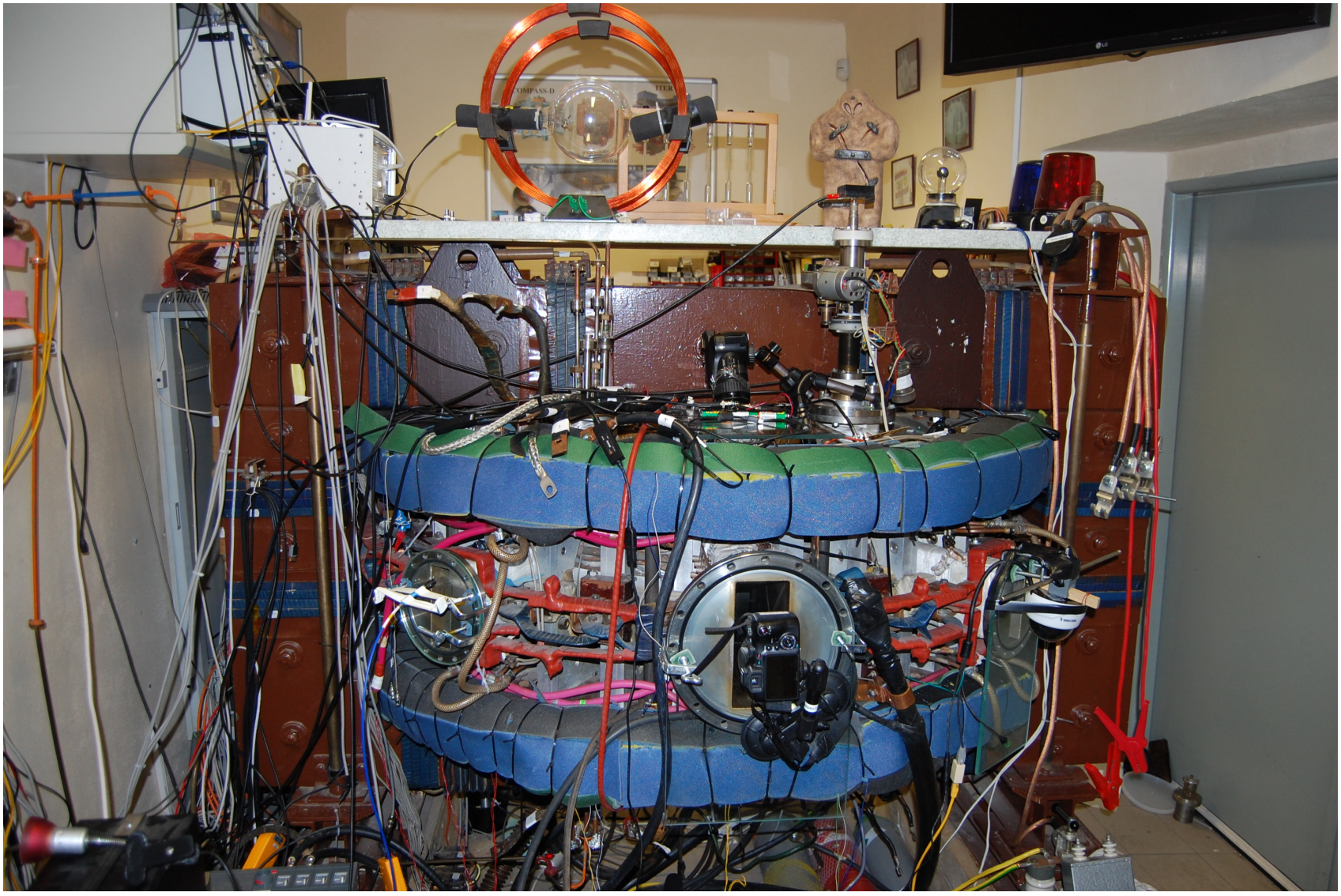
2006

Institute of Plasma Physics
Czech republic
CASTOR **COMPASS**

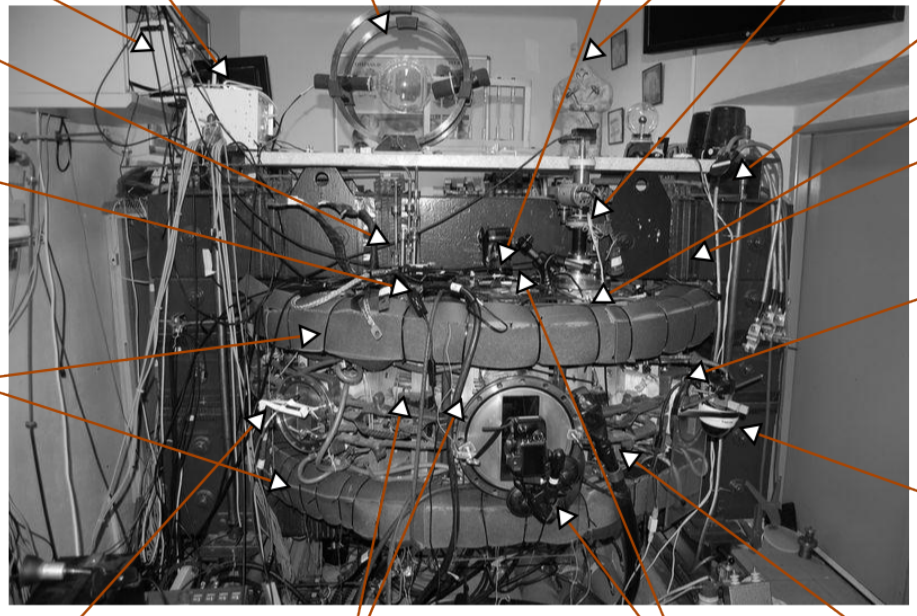
2008

Czech Technical University Prague
Czech republic
GOLEM

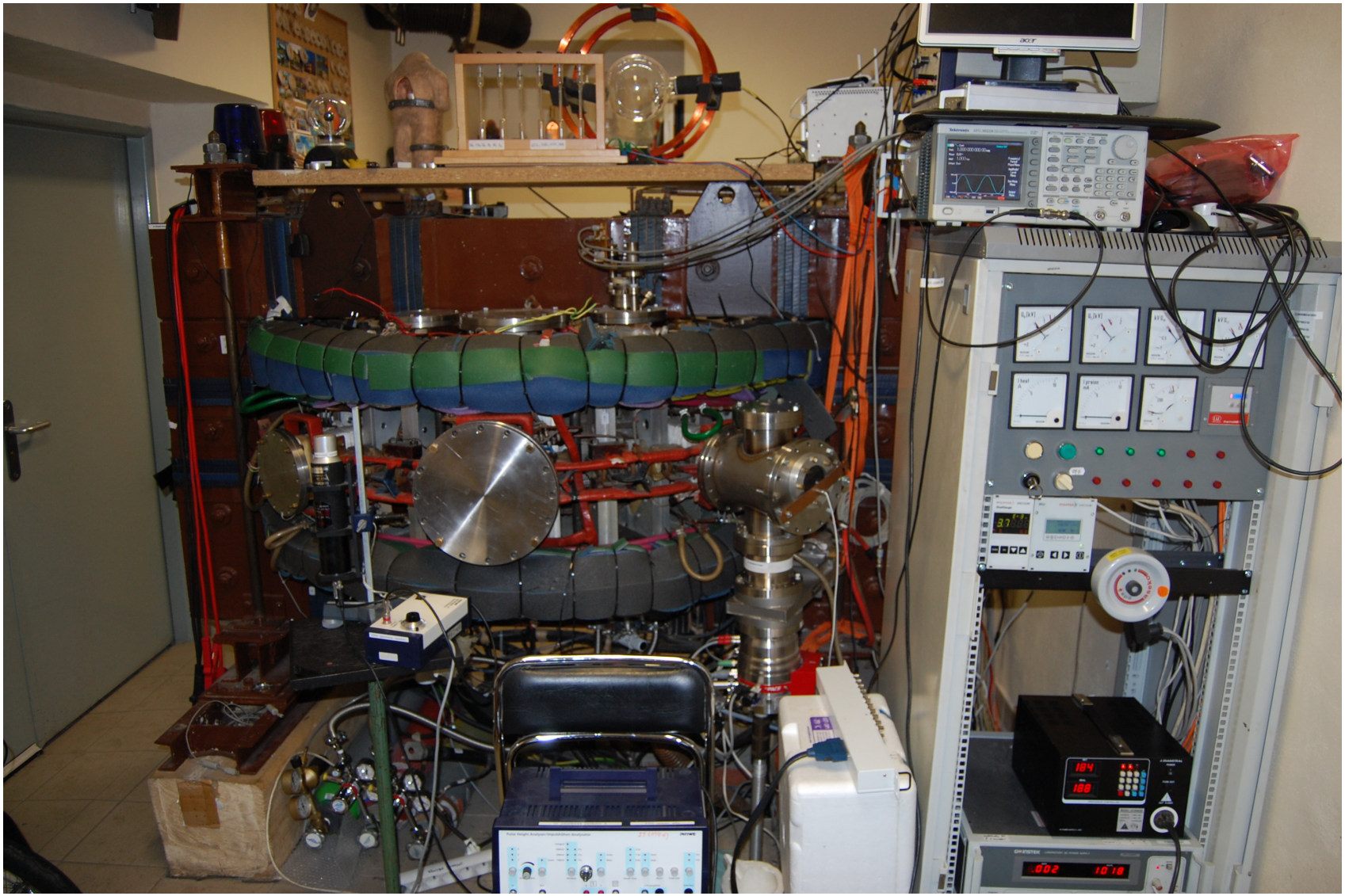
The Golem tokamak - South view (02/12)



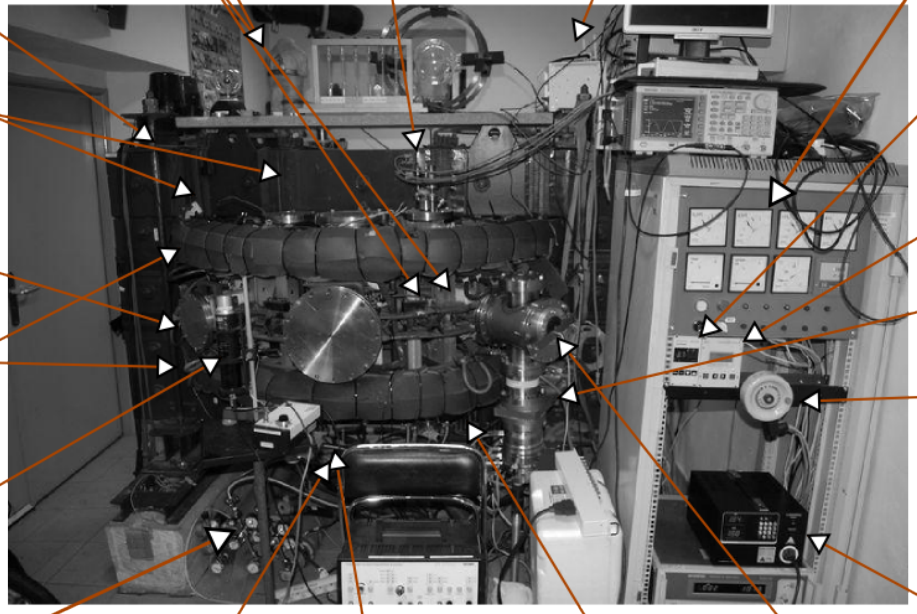
The Golem tokamak - South view (02/12)



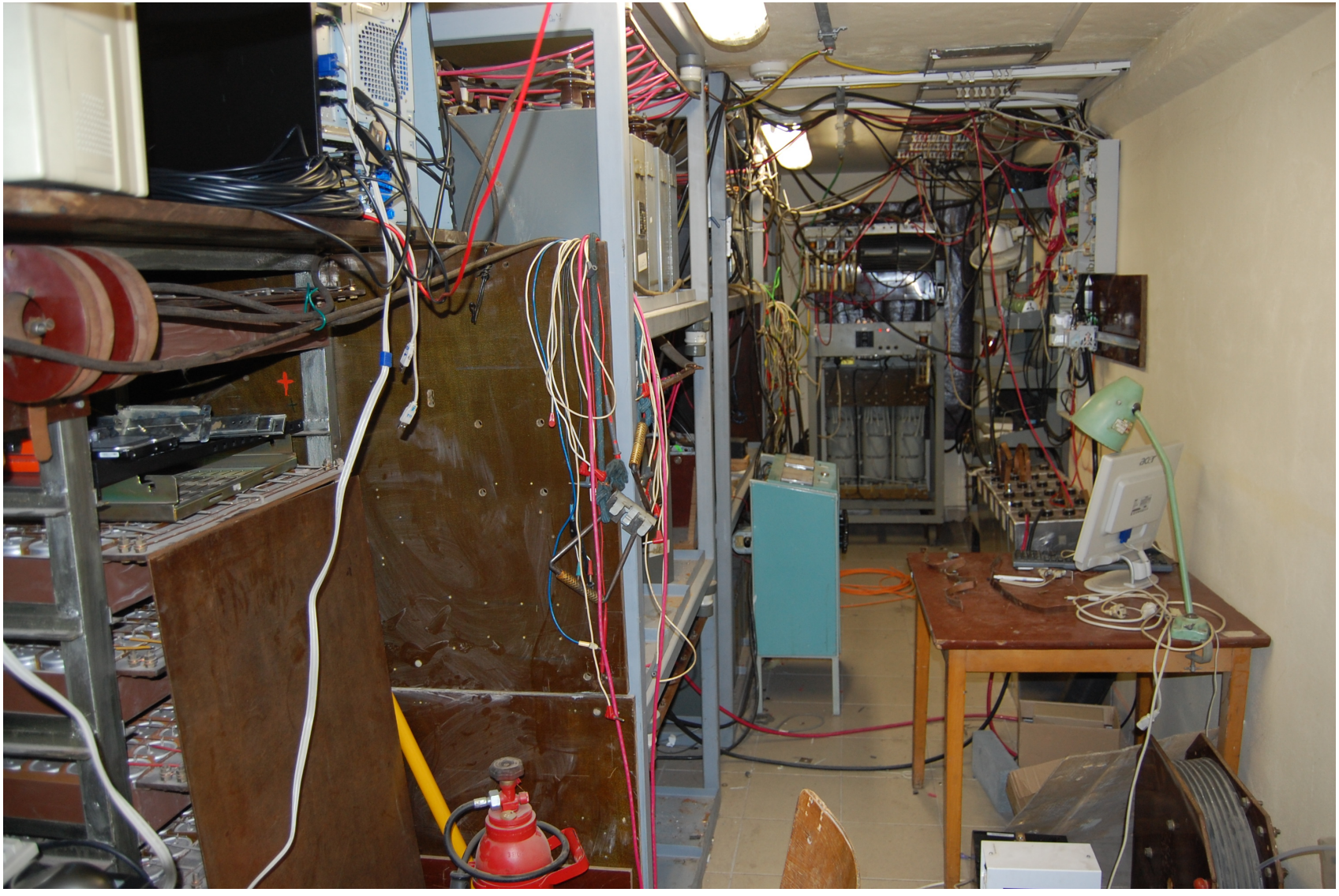
The Golem tokamak - North view (02/12)



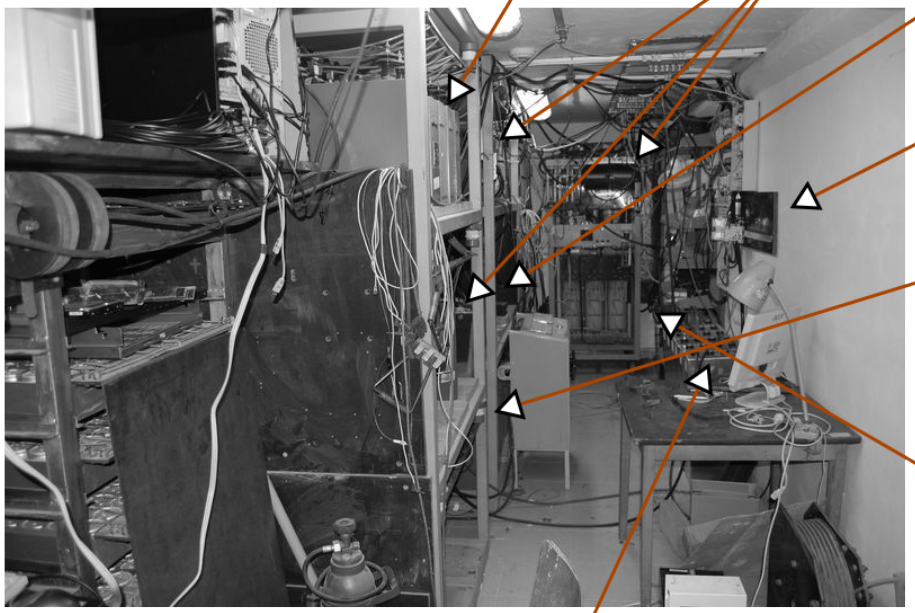
The Golem tokamak - North view (02/12)



Infrastructure room (below tokamak)

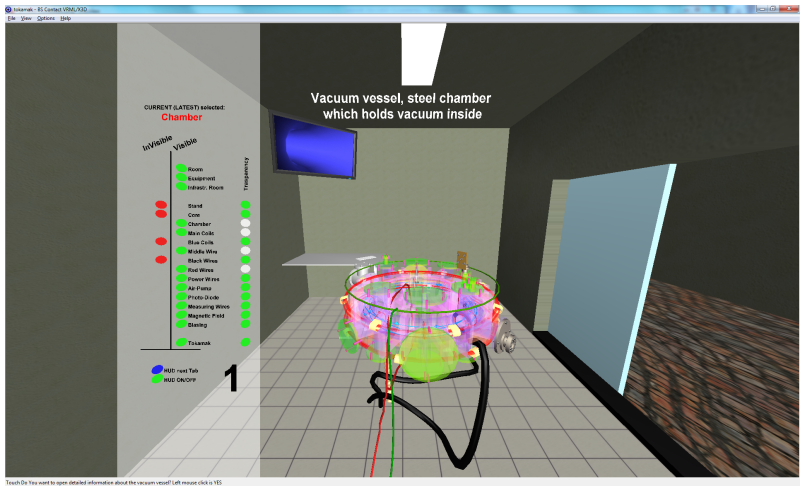


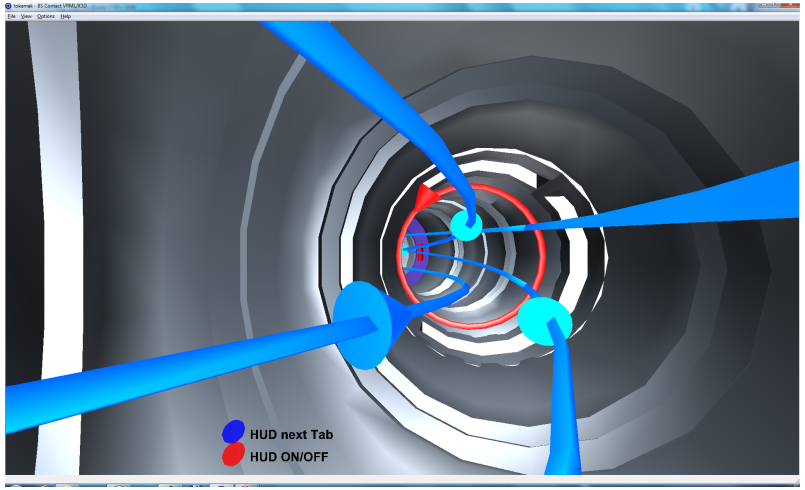
Infrastructure room



The GOLEM tokamak virtual model

Tokamak Room & Infrastructure Room

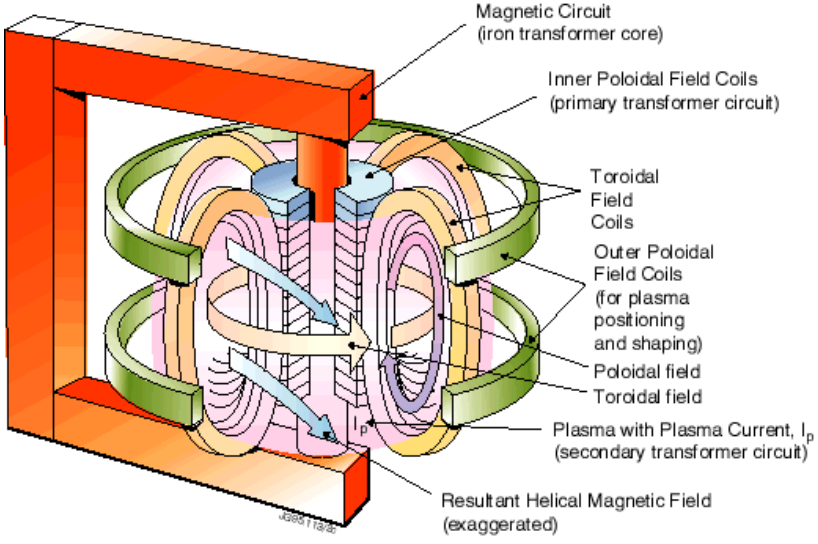




Inner view & Inside chamber

Outline

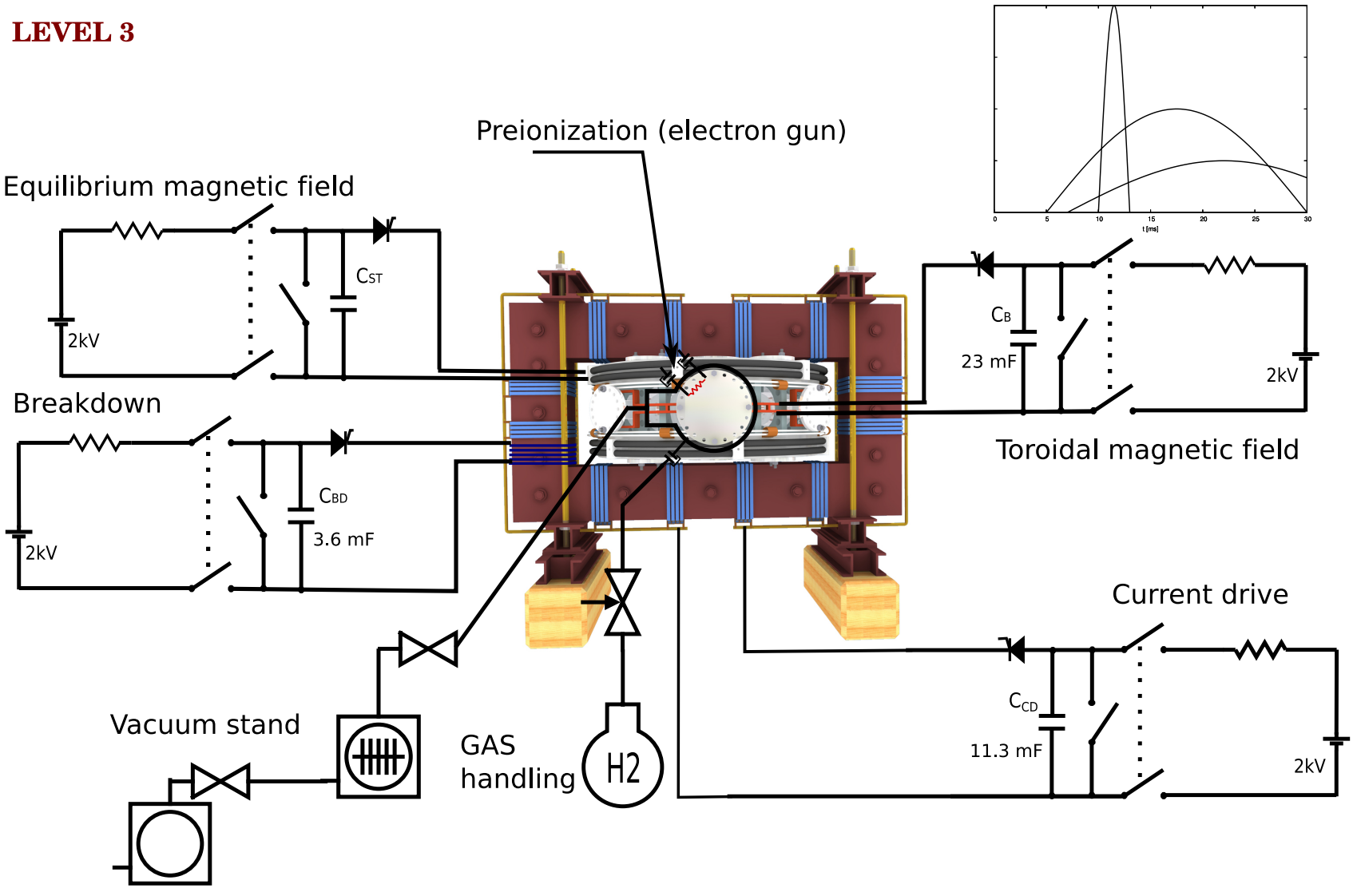
Plasma in Tokamak (GOLEM) - the least to do



- Evacuate the chamber.
- Fill in the working gas.
- Preionization
- Toroidal magnetic field to confine plasma.
- Toroidal electric field to breakdown neutral gas into plasma.
- Toroidal electric field to heat the plasma.
- Plasma positioning (under construction).
- Diagnostics.

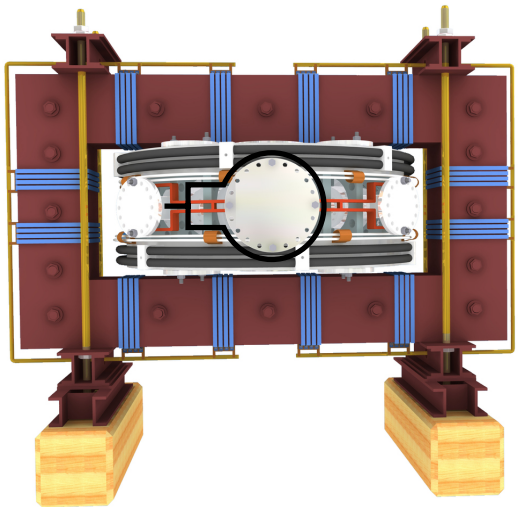
Tokamak GOLEM - engineering scheme

LEVEL 3



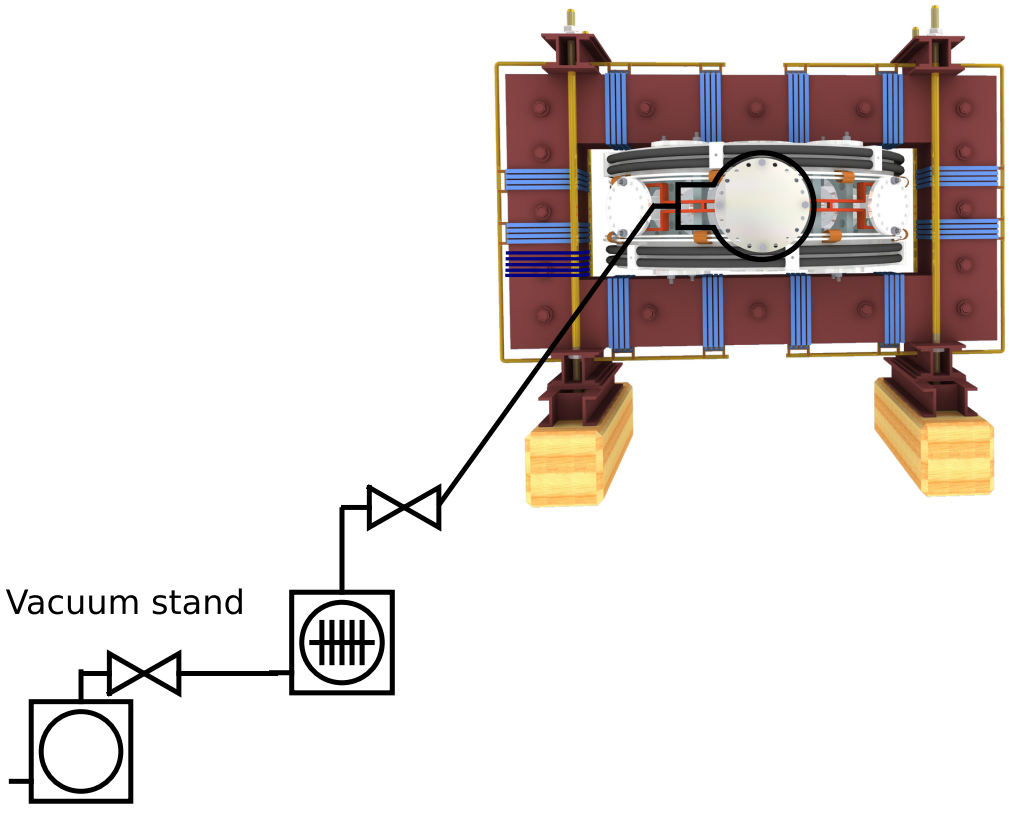
Tokamak GOLEM - basic

LEVEL 0



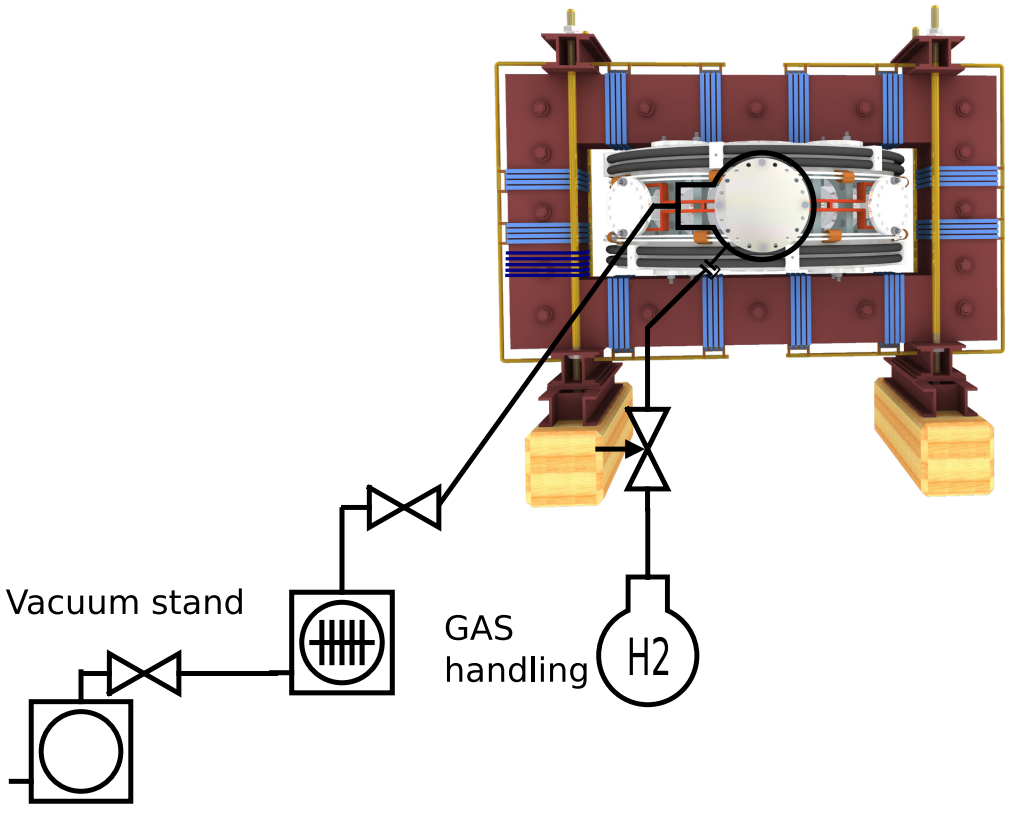
+ vacuum pumping system (100 kPa $\rightarrow \approx$ 1 mPa)

LEVEL 0

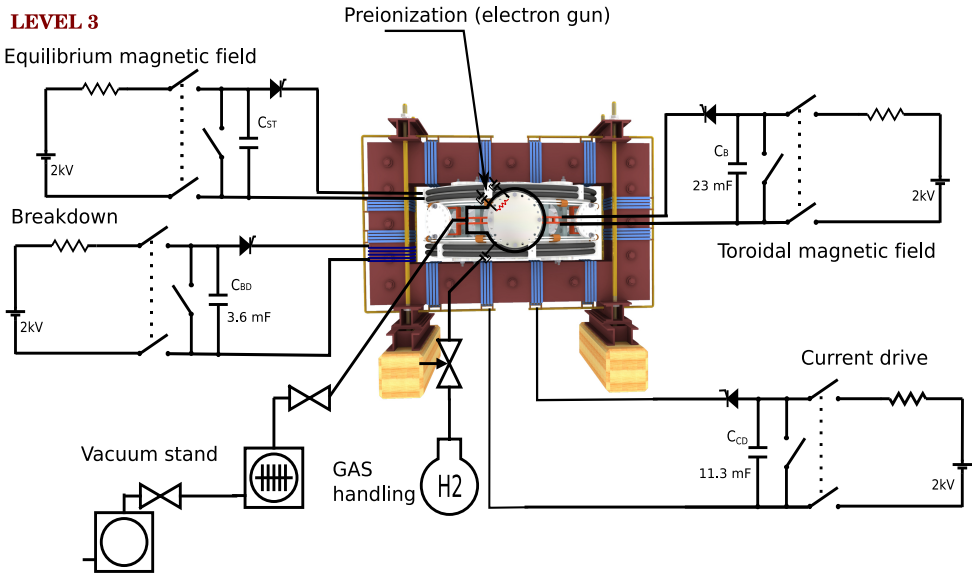


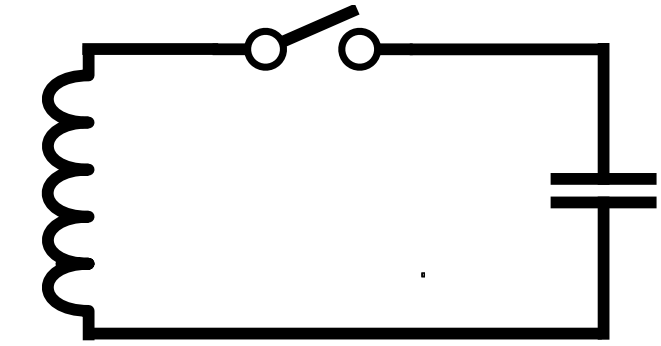
+ working gas management (H_2 or He)

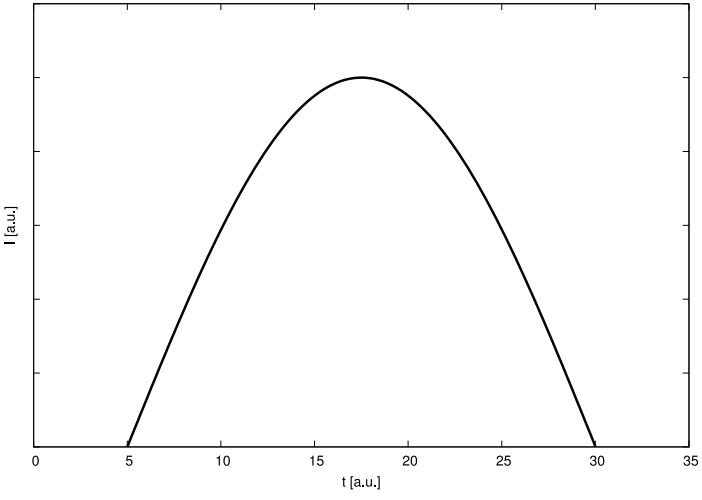
LEVEL 0



Insertion - LC circuit

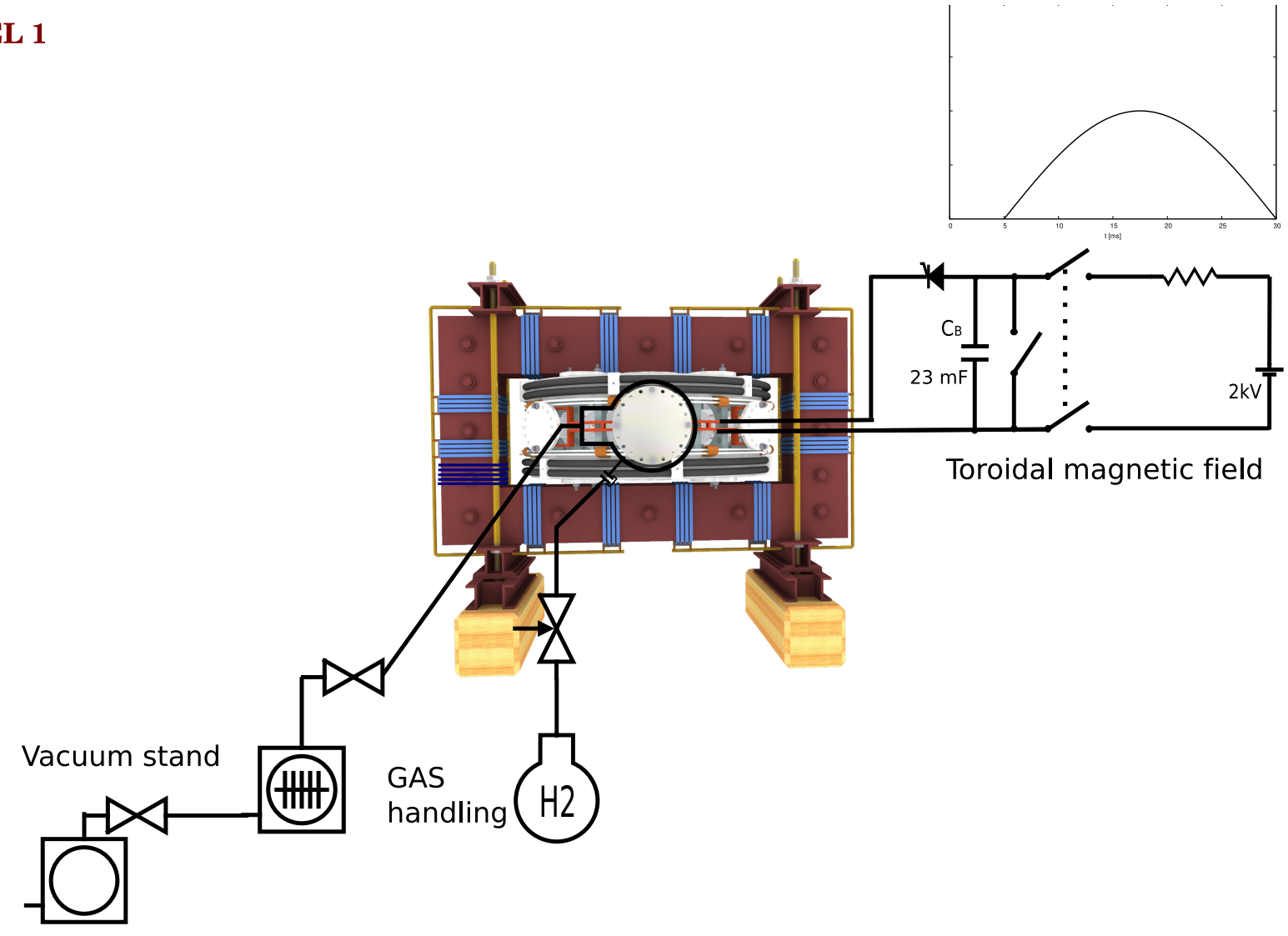






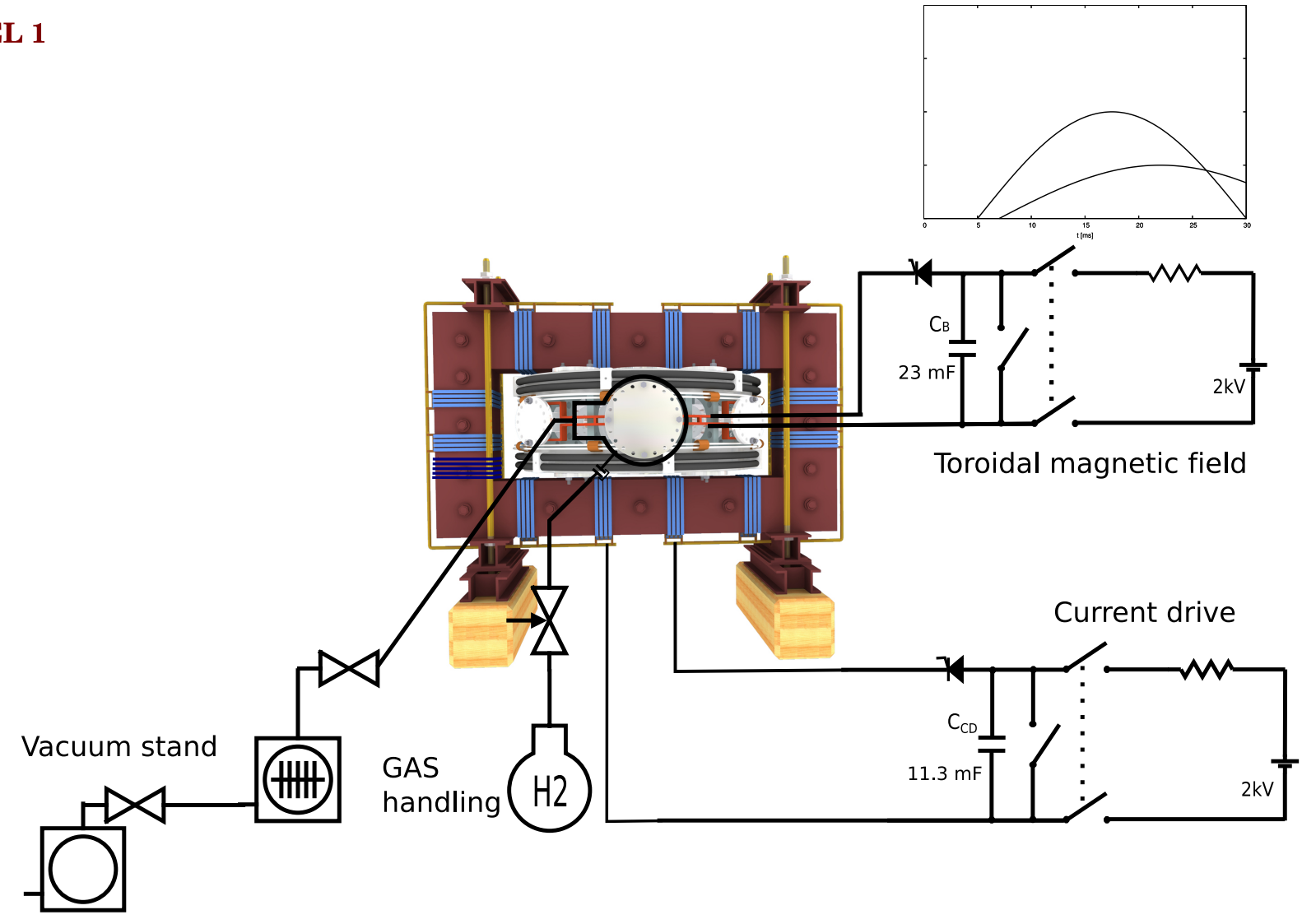
+ toroidal magnetic field B_t .. **plasma confinement**

LEVEL 1

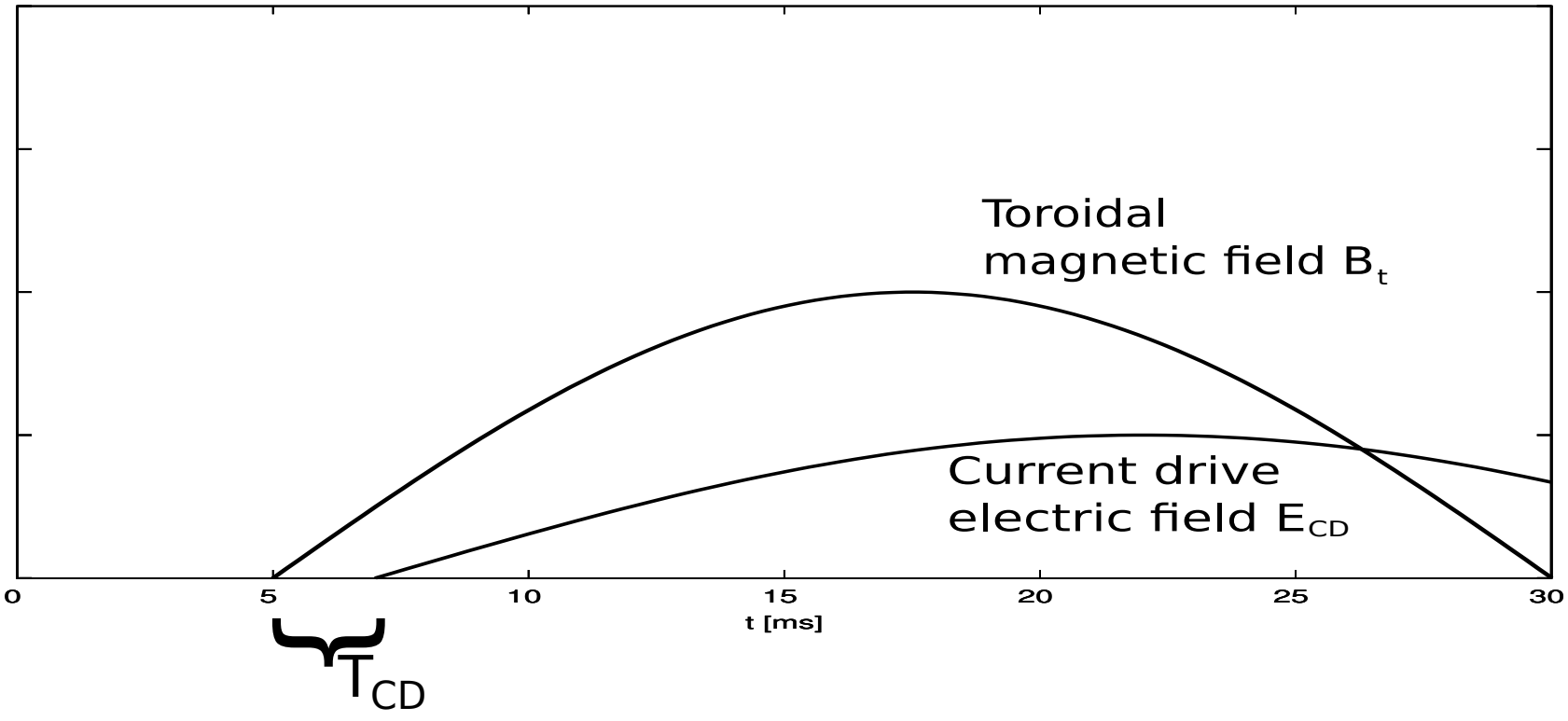


+ toroidal electric field E_{CD} .. **plasma heating**

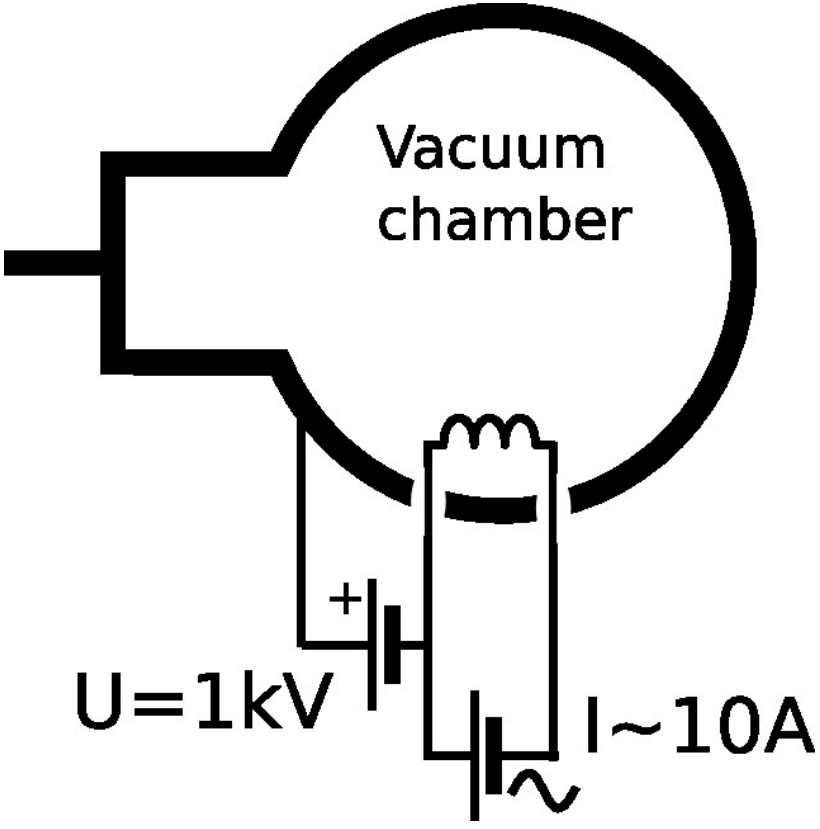
LEVEL 1



Triggering sequence



Preionization



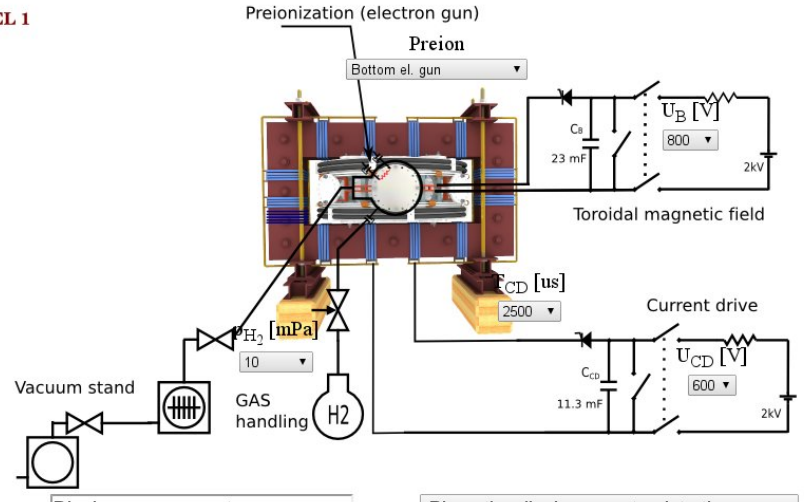
The GOLEM tokamak Control Room - level I

*Tokamak Golem **REMOTE** for MASTER (Level I)*

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

Home | Wiki | Control Room | Queue | Live | Results | Golplot | Chamber status | IP cameras | 3D model | Chat | Feedback | Level I

LEVEL 1



Discharge comment

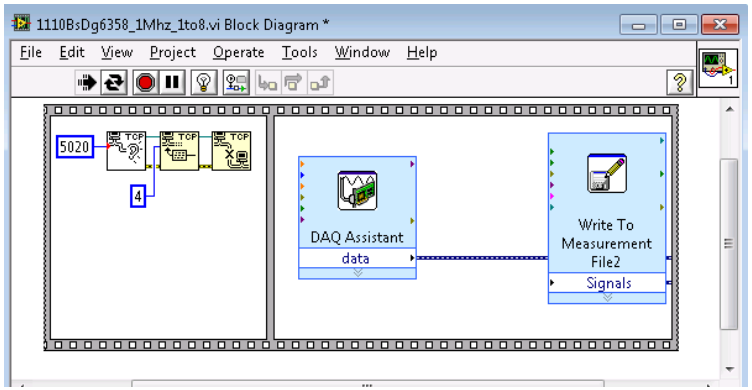
Your email address

Place the discharge setup into the queue

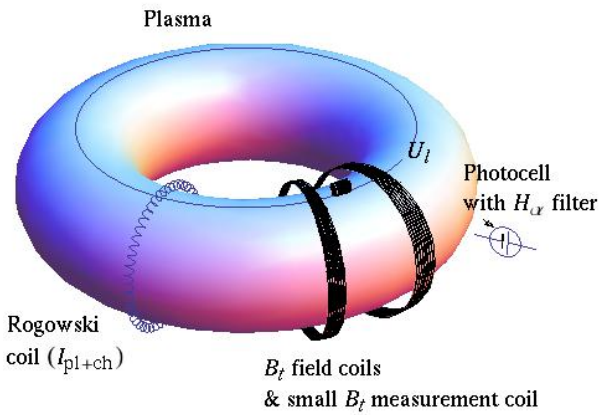
golem.fjfi.cvut.cz/roperation/tasks/XXYYMASTER/Level_I/exp.php

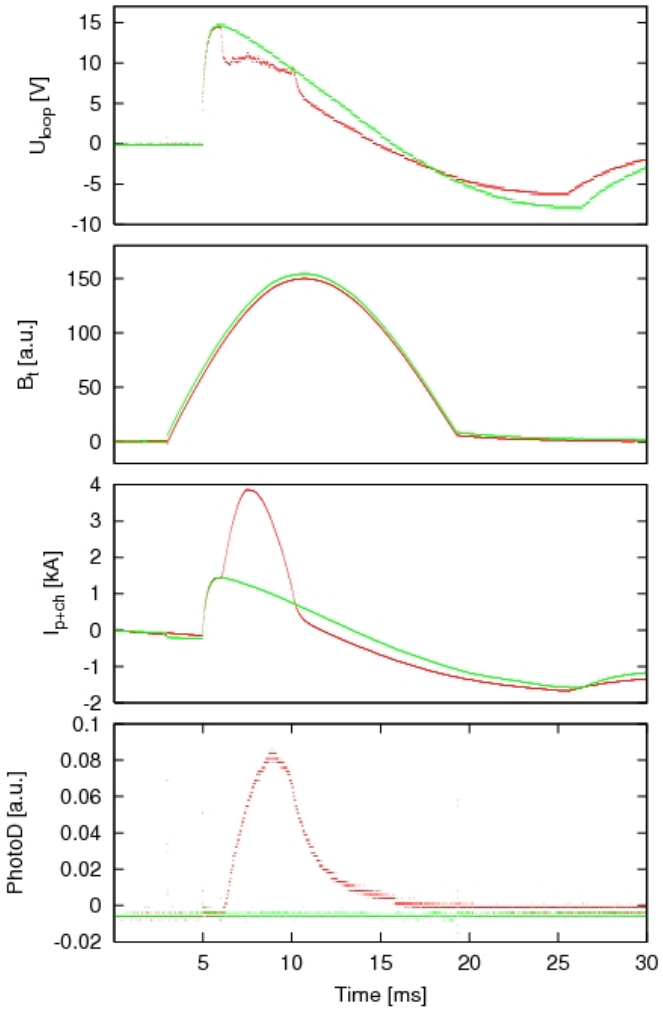
Outline

Basic plasma diagnostics in tokamak GOLEM



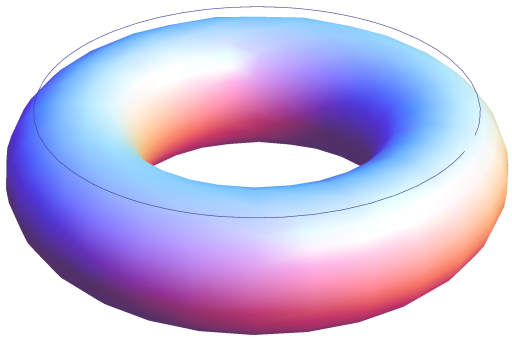
PXI system with PXIe 6358



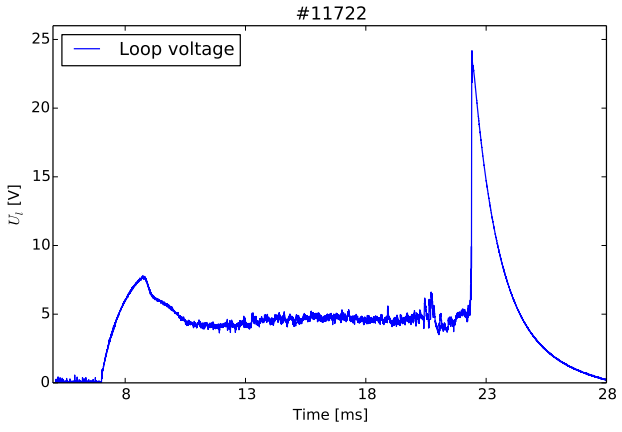


Data Acquisition System based on: NATIONAL INSTRUMENTS

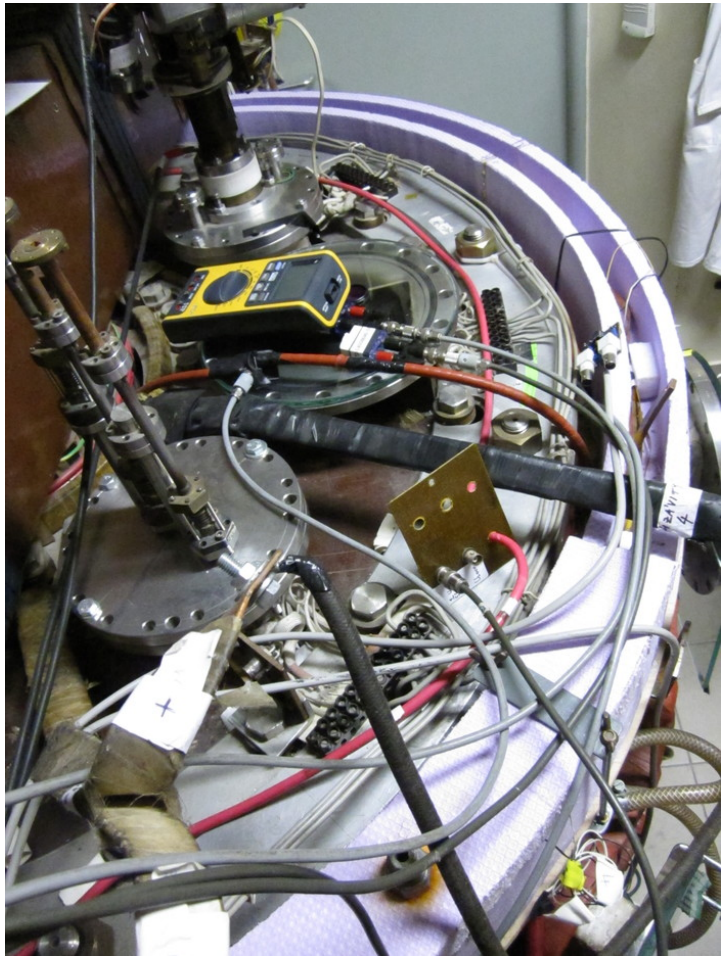
Basic diagnostics: Loop Voltage U_{loop}



Principle

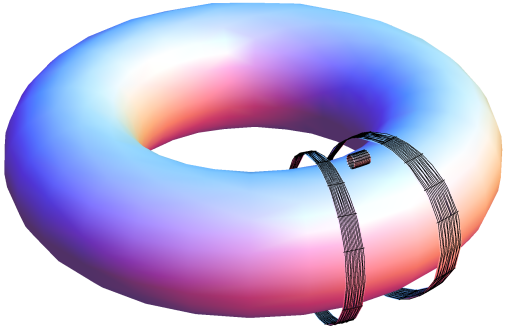


Signal

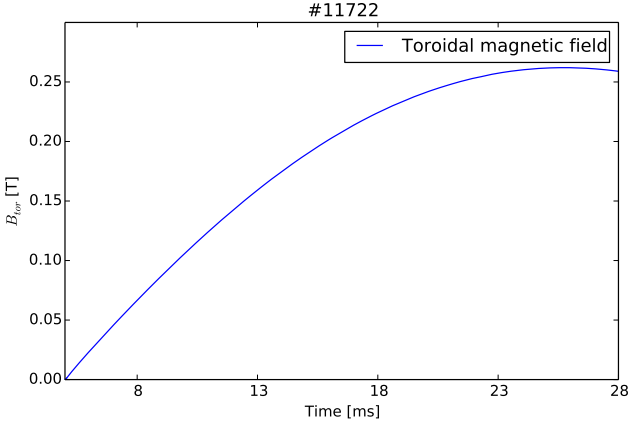


Photo

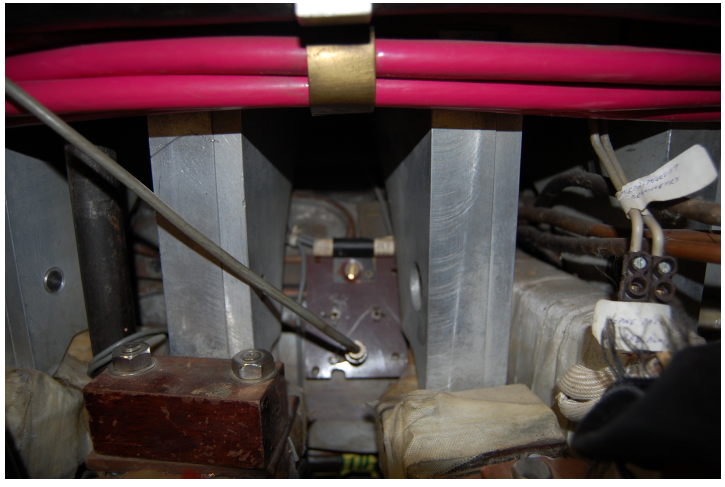
Basic diagnostics: Toroidal magnetic field B_{tor}



Principle

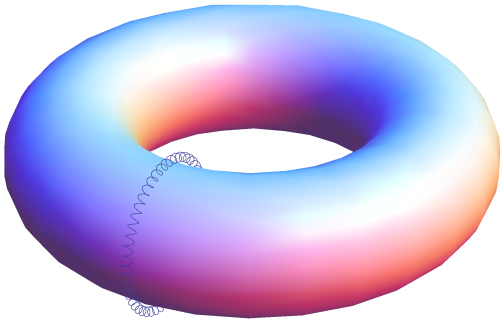


Signal

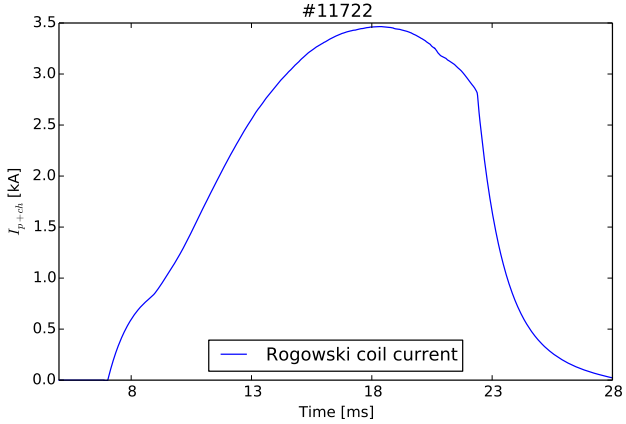


Photo

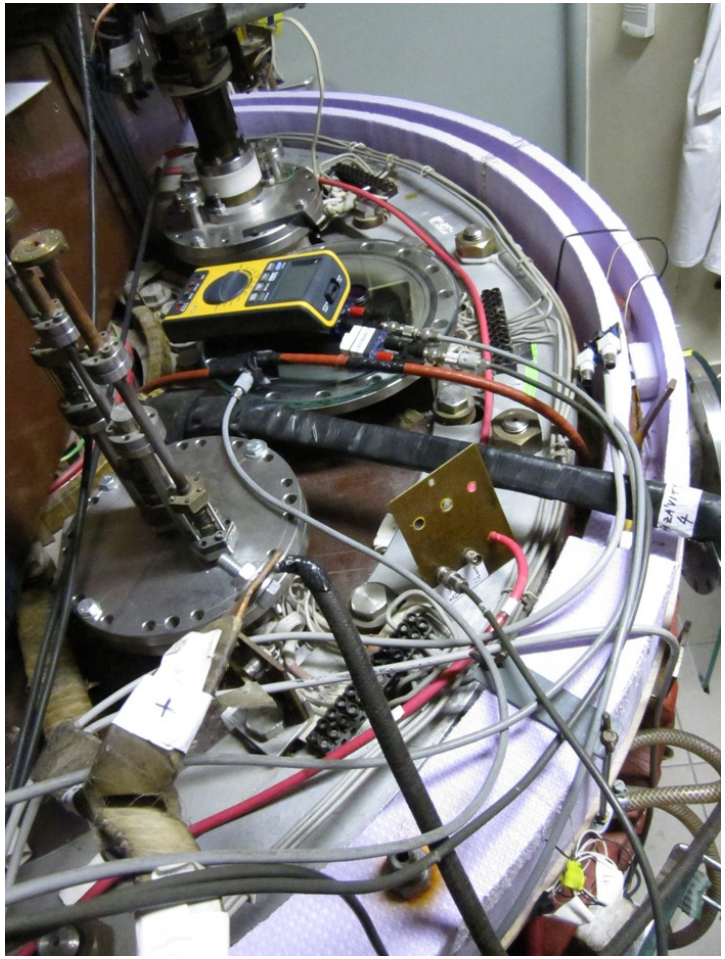
Basic diagnostics: Total chamber+plasma current I_{ch+p}



Principle

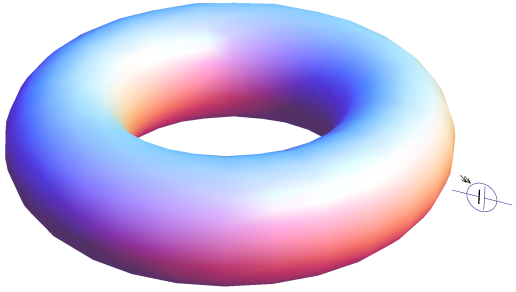


Signal

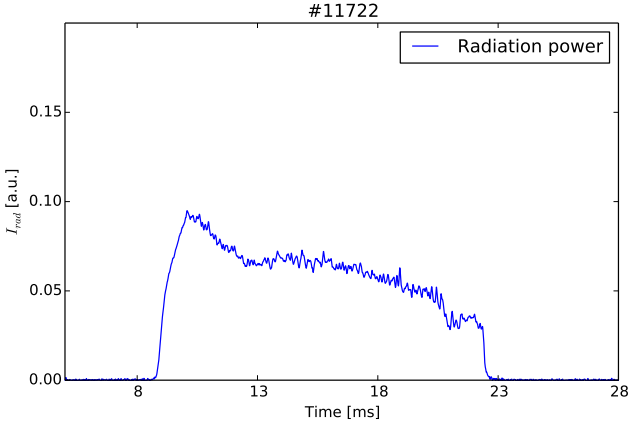


Photo

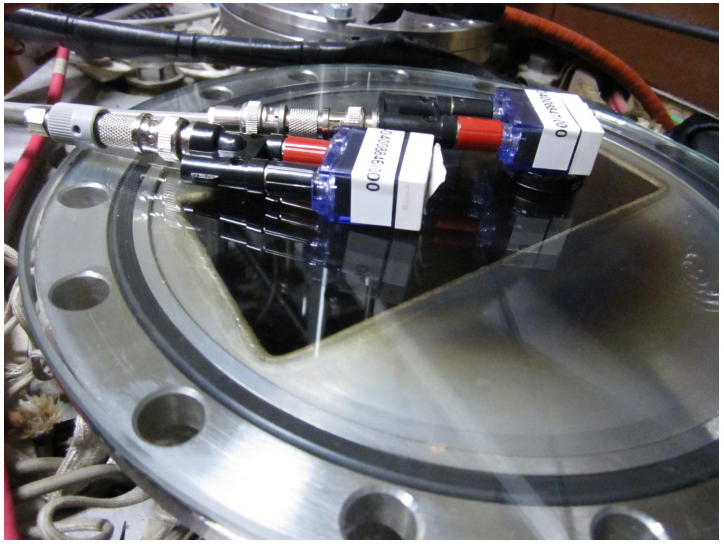
Basic diagnostics: Visible radiation I_{rad}



Principle

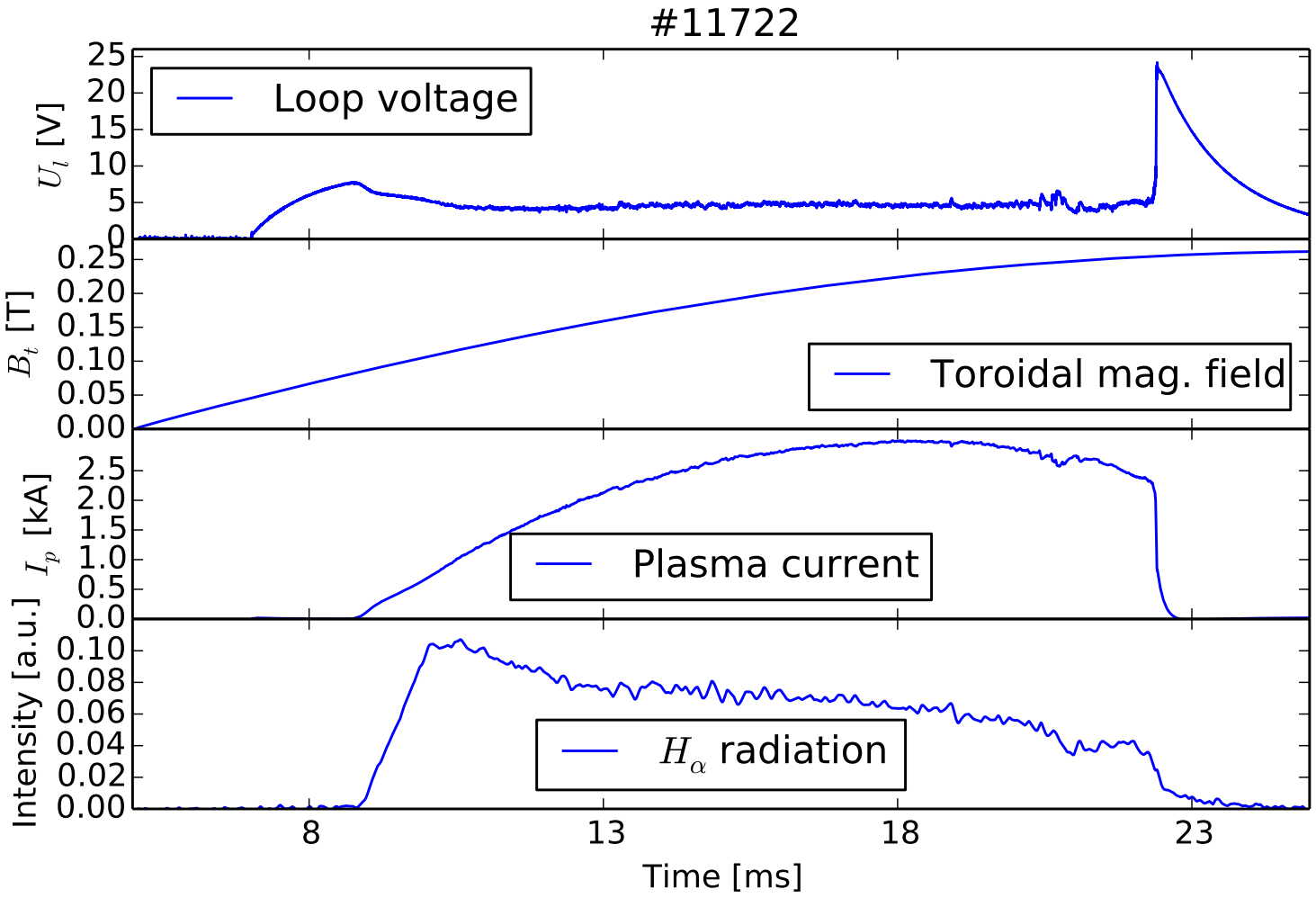


Signal



Photo

Shot #11722


#11722
Loop voltage
U_l [V]
Toroidal mag. field
B_t [T]
Plasma current
I_p [kA]
H_α radiation
Intensity [a.u.]
Time [ms]

Outline

Production

- Everything via `http://golem.fjfi.cvut.cz/current`
  - This presentation
  - Control rooms
  - Contact: Vojtech Svoboda, +420 737673903,
  - possible chat: vojtech.svob@gmail.com
- Any shot from mobile phone?


E. Bromova, I. Duran, O. Grover, J. Kocman, T. Markovic, M. Odstrcil, T. Odstrcil, O. Pluhar, J. Stockel, V. Svoboda, A. Sindlery, G. Vondrasek, and J. Zara.
The GOLEM Tokamak for Fusion Education .
In *Europhysics Conference Abstracts. 38th EPS Conference on Plasma Physics (online: `http://ocs.ciemat.es/EPS2011PAP/pdf/P1.021.pdf`)*, volume 35G, 2011.


Brotankova, J.
Study of high temperature plasma in tokamak-like experimental devices.
PhD. thesis 2009.


V. Svoboda, B. Huang, J. Mlynar, G.I. Pokol, J. Stockel, and G Vondrasek.
Multi-mode Remote Participation on the GOLEM Tokamak.

Fusion Engineering and Design, 86(6-8):1310–1314, 2011.

V. Svoboda, J. Mlynář, G. Pokol, D. Réfy, J. Stöckel, and G. Vondrášek.
Former Tokamak CASTOR becomes remotely controllable GOLEM at the Czech Technical University in Prague .
In *Europhysics Conference Abstracts. 37th EPS Conference on Plasma Physics (online: `http://ocs.ciemat.es/EPS2010PAP/pdf/P2.111.pdf`)*, volume 34A, 2010.

Tokamak GOLEM team.
Tokamak GOLEM at the Czech Technical University in Prague.
http://golem.fjfi.cvut.cz, 2007.