The GOLEM documentation collection

The GOLEM experimental setup

Vojtěch Svoboda & the GOLEM team

September 26, 2012

Outline of the talk

1. Introduction
2. Experimental setup
3. Golem discharge
4. (Remote) operation of the GOLEM tokamak
5. Conclusion

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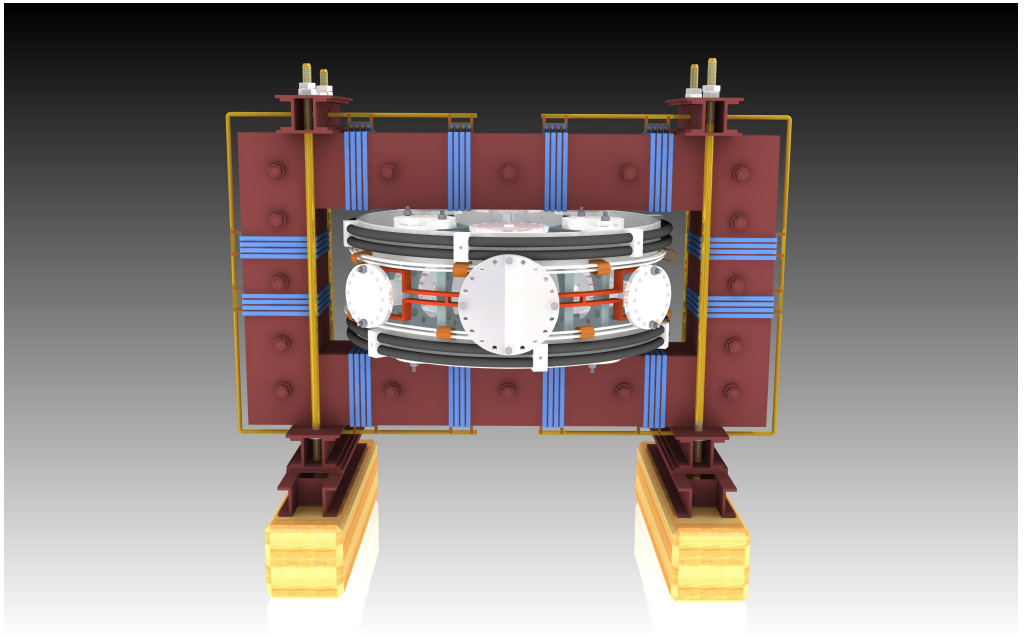
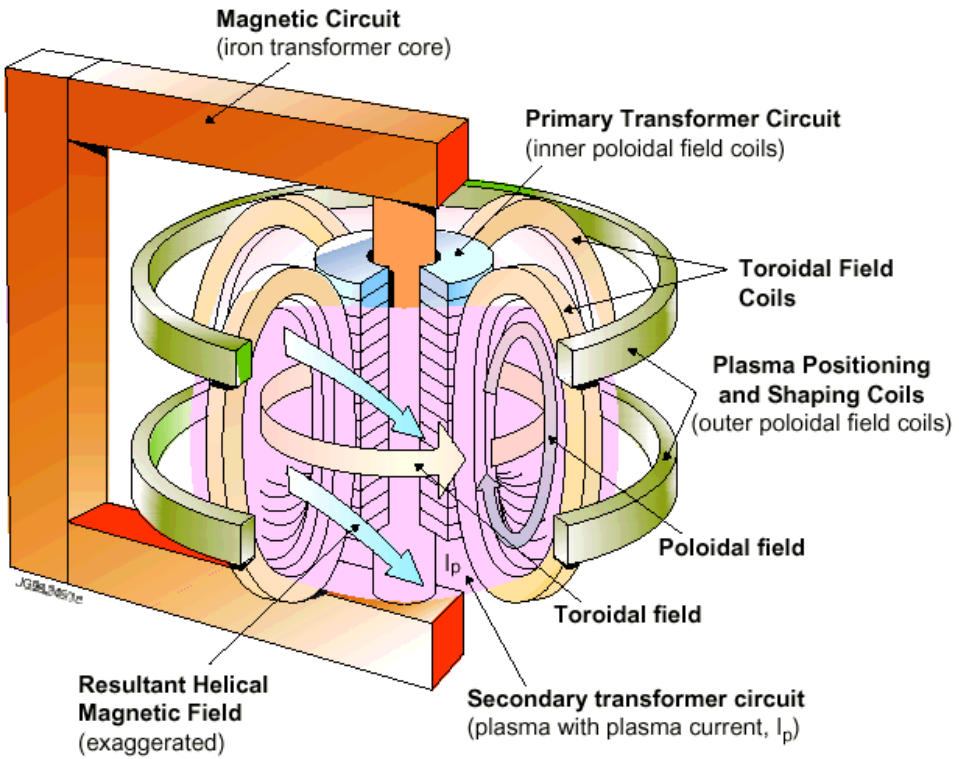
Tokamak GOLEM - basic parameters:



- major radius $R = 0.4$
- minor radius $a = 0.085$ m
- plasma current $I_{pl} < 10$ kA
- pulse length $t < 20$ ms
- toroidal magnetic field $B_{tor} < 1$ T
- plasma density $n_e = 0.2 - 3.0 * 10^{19}/m^3$
- electron temperature $T_e(0) < 200$ eV
- ion temperature $T_i(0) < 100$ eV

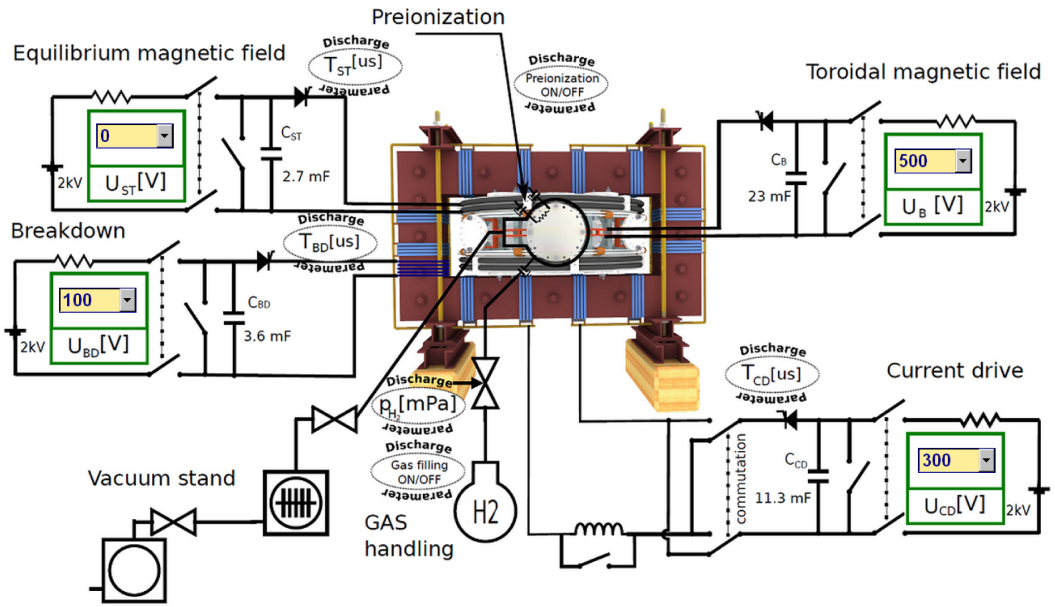
Plasma in Tokamak (GOLEM) - the least to do



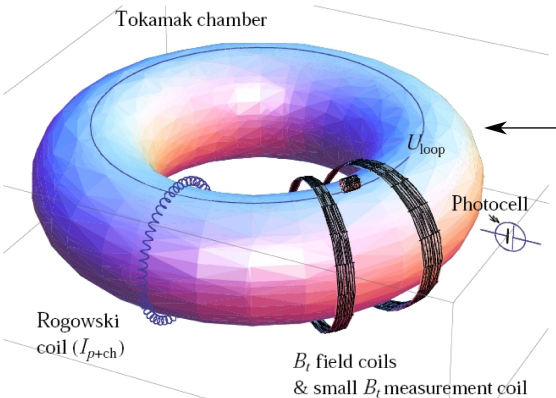
- Evacuate the chamber.
- Fill in the working gas.
- Toroidal magnetic field to confine plasma.
- Toroidal electric field to breakdown neutral gas into plasma.
- Toroidal electric field to heat the plasma.
- Plasma positioning.
- Diagnostics.

Unique remote operation capability

Tokamak control room



Plasma diagnostics



Control PC

OpenSSH server

WWW server

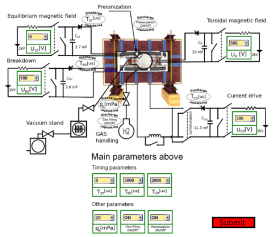
OpenSSH server

internet

Virtual control room (remote participation)

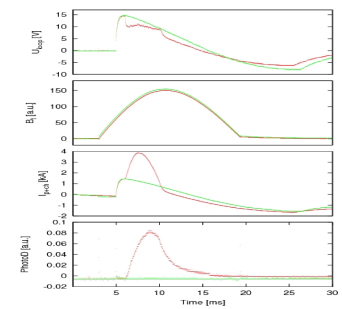
WWW control interface

HTML & PHP scripts



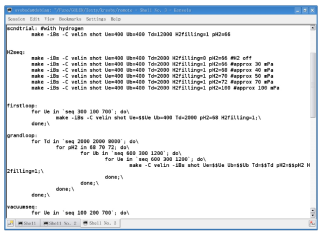
Data presentation

HTML (www pages)



SSH control interface

WINDOWS via putty



LINUX via ssh
or ssh+X tunnel
(advanced mode)

Data handling

*wget
*gnuplot
*idl
*mathematica
*matlab
*etc...

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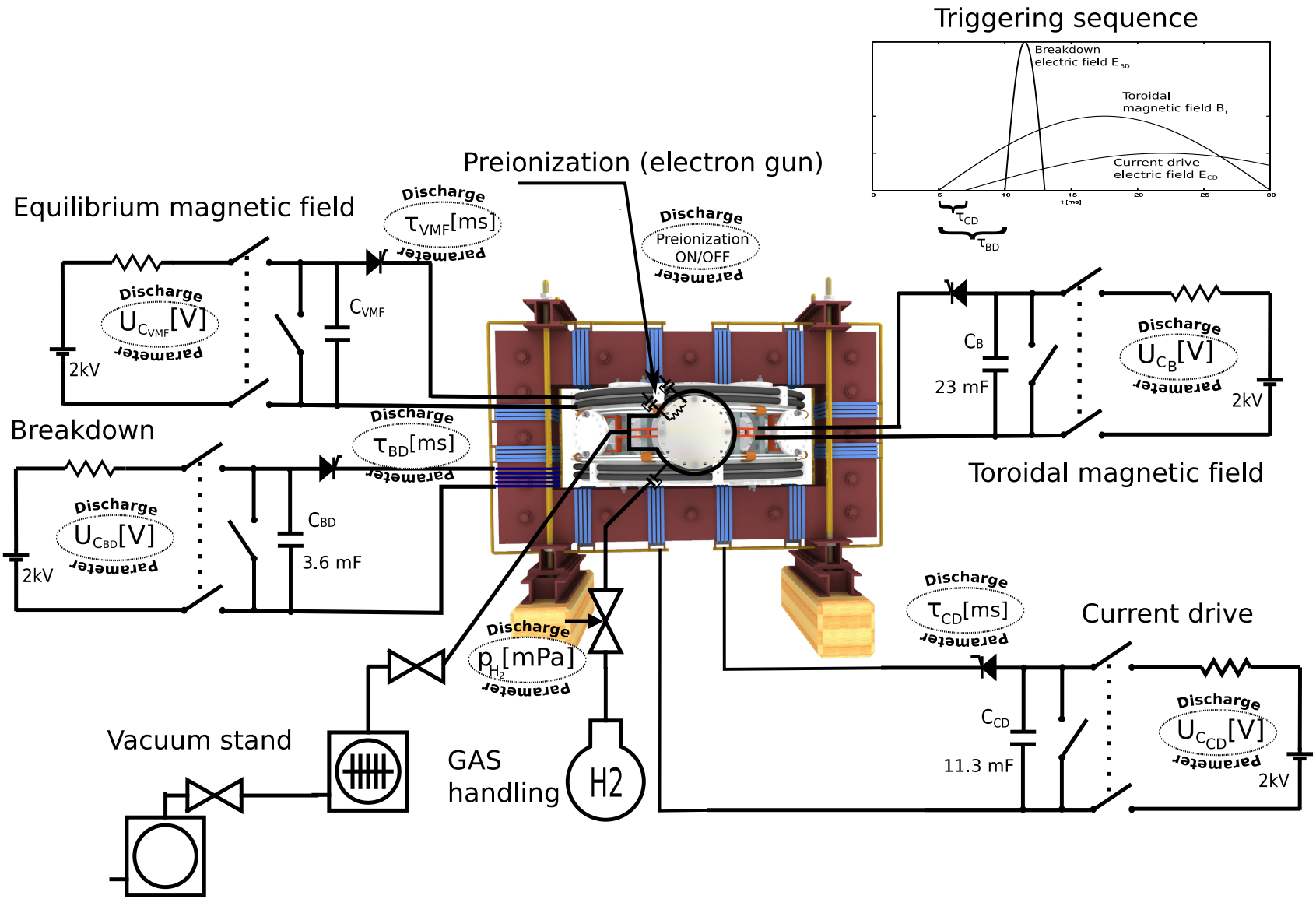
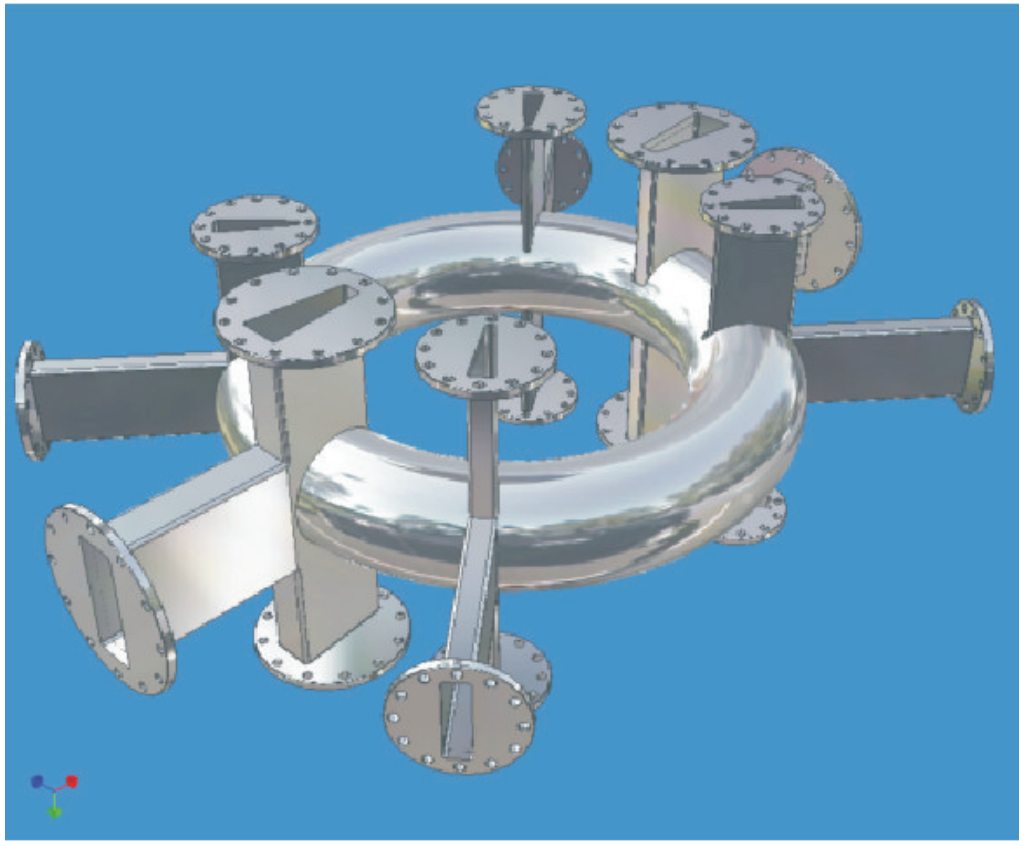
Engineering scheme of the GOLEM tokamak

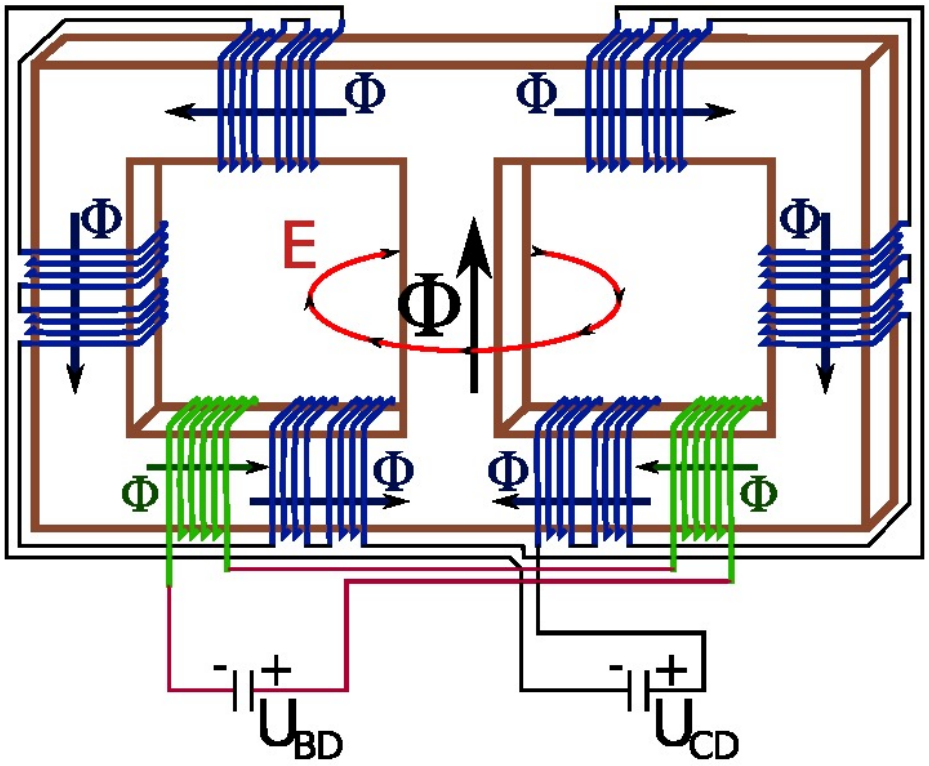


The GOLEM chamber



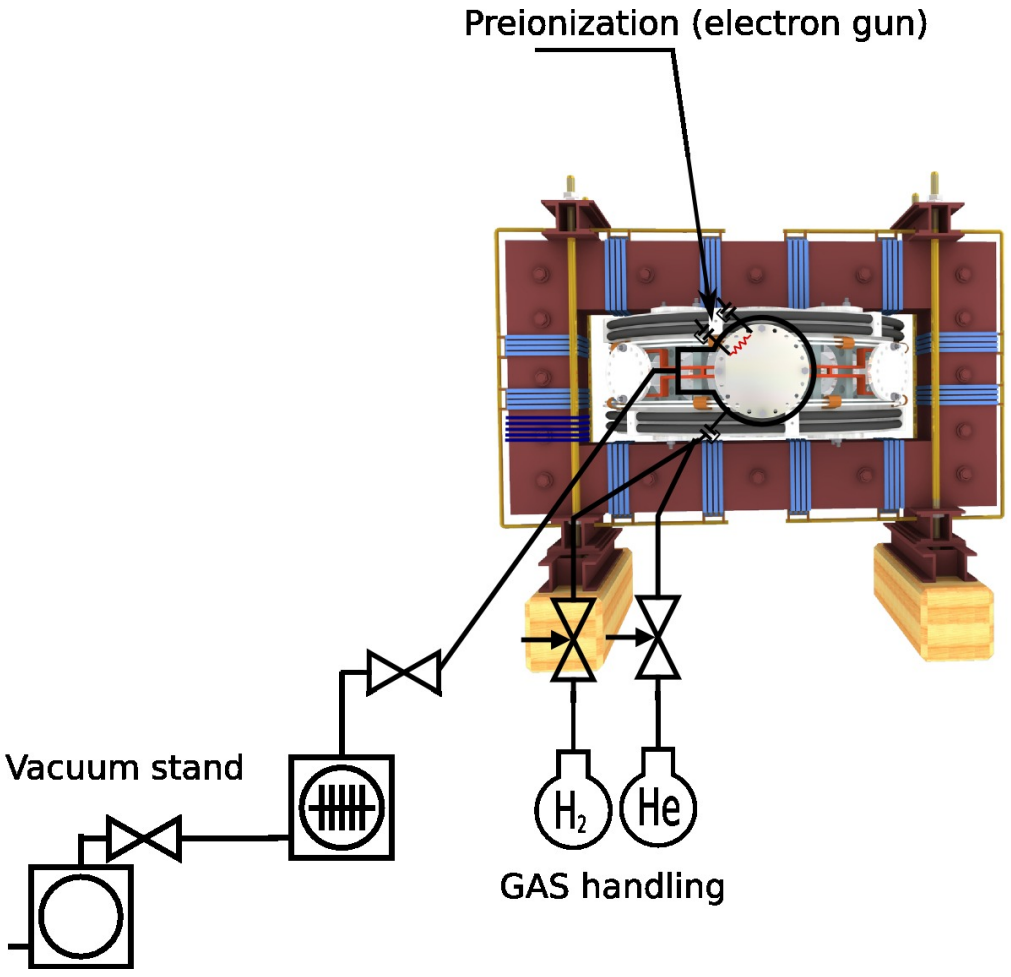
- The plasma cross section is circular.
- The vacuum vessel is made of stainless steel.
- It is /on request/ baked with a series of cycles at 200°C before an experiment.

Golem transformer

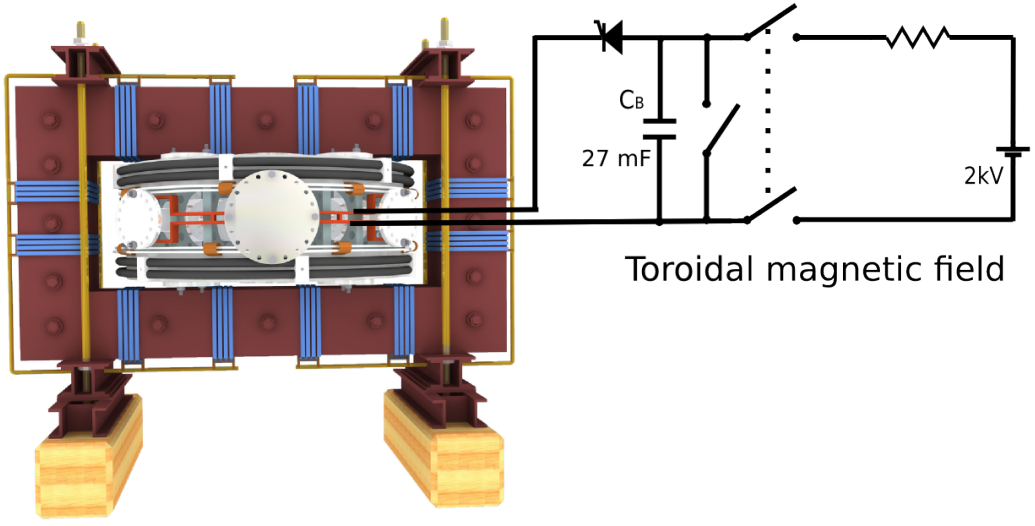


- Iron transformer core.

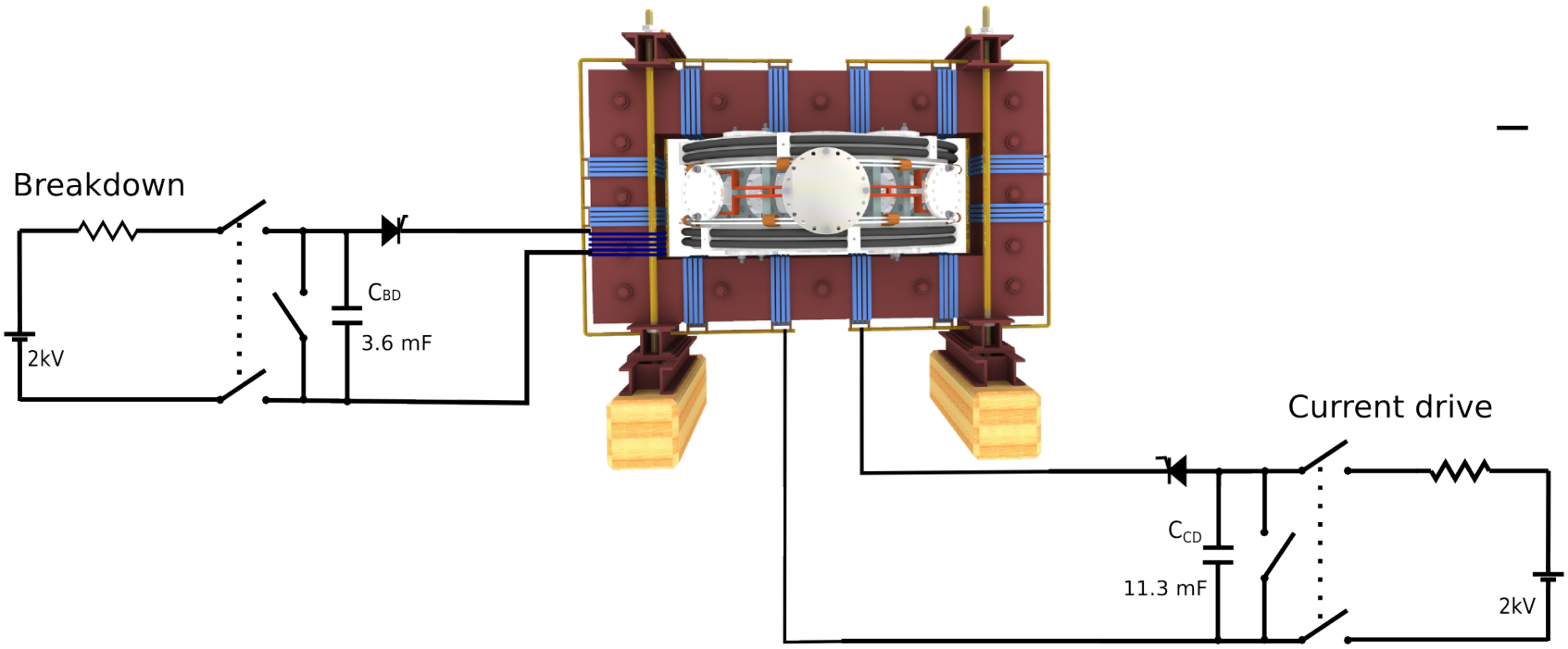
Preionization, Vacuum and Gas management



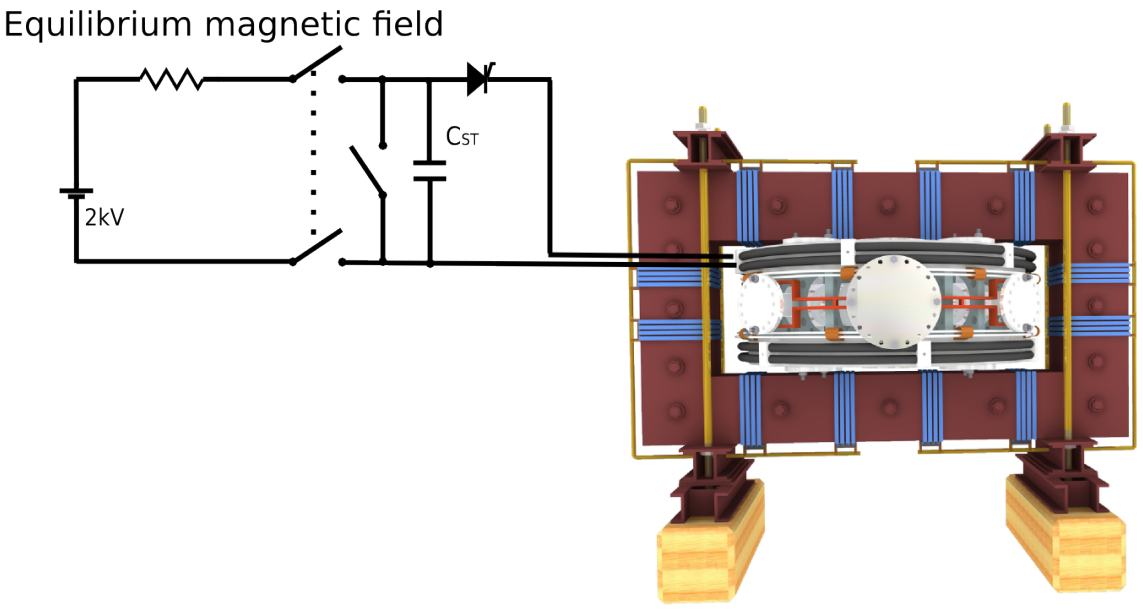
Toroidal magnetic field B_{tor} circuit



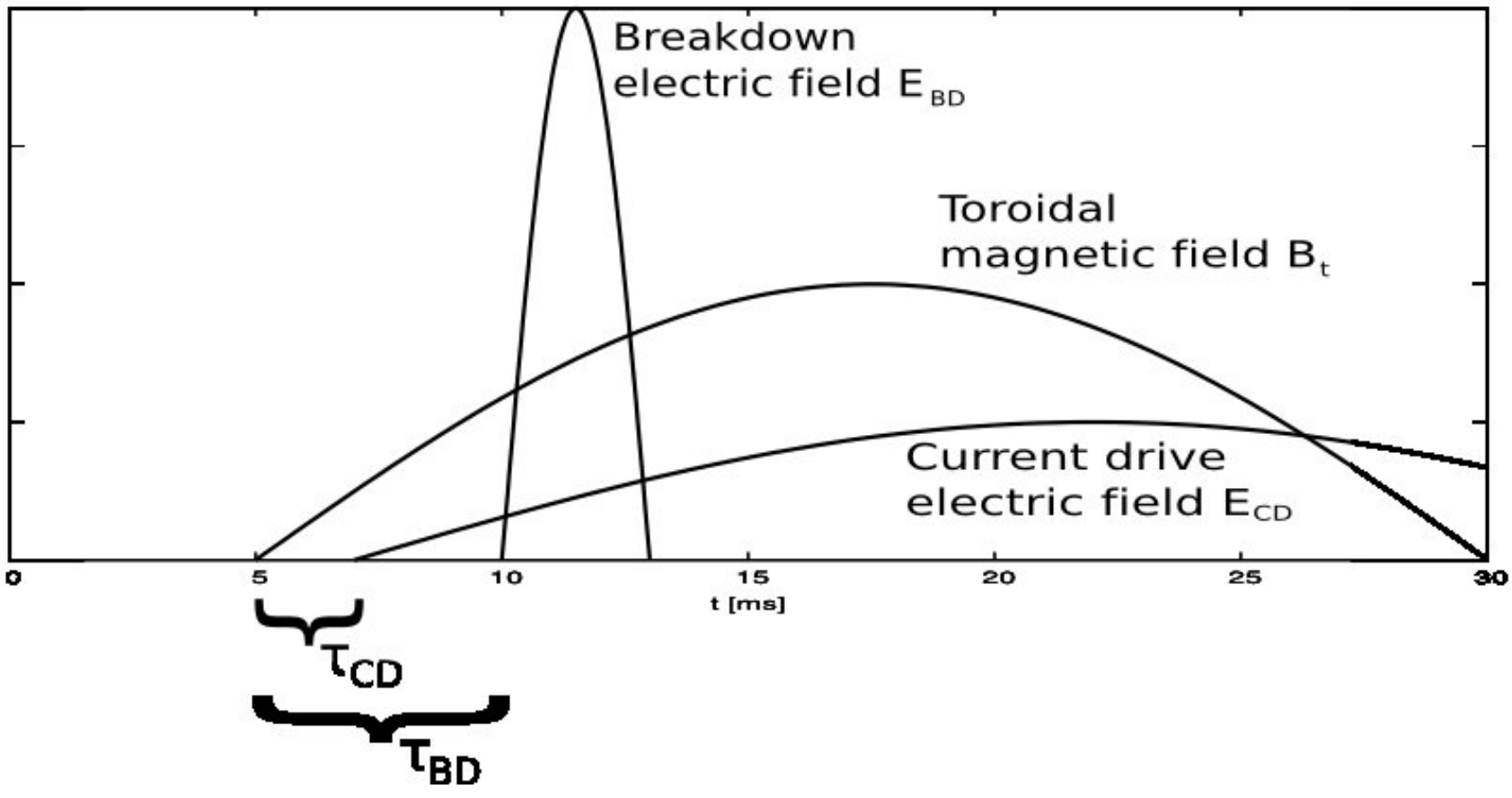
Toroidal electric field E_{tor} circuit



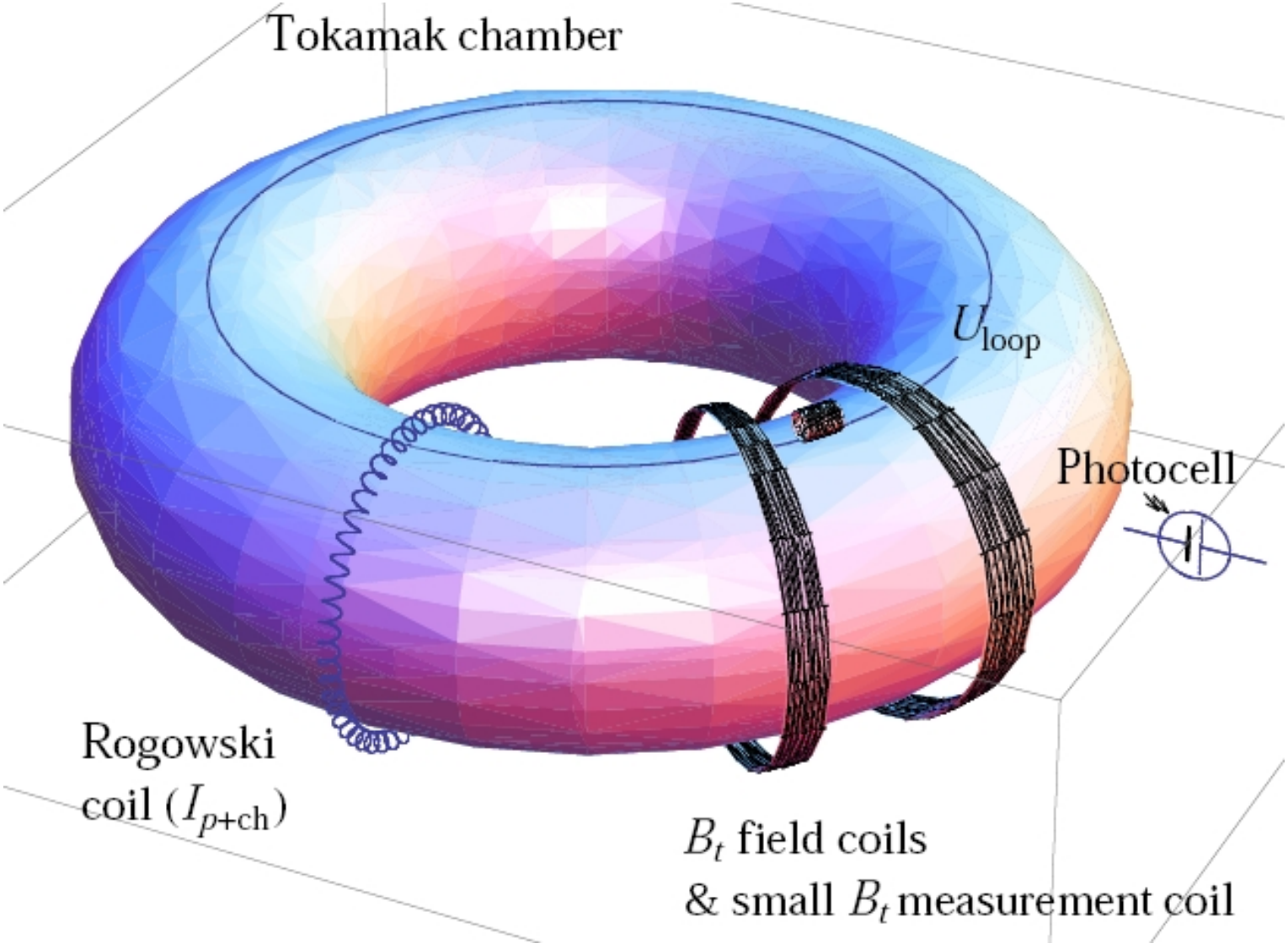
Vertical magnetic (stabilization) field B_{ST} circuit



Trigger sequence



Basic plasma diagnostics on tokamak GOLEM



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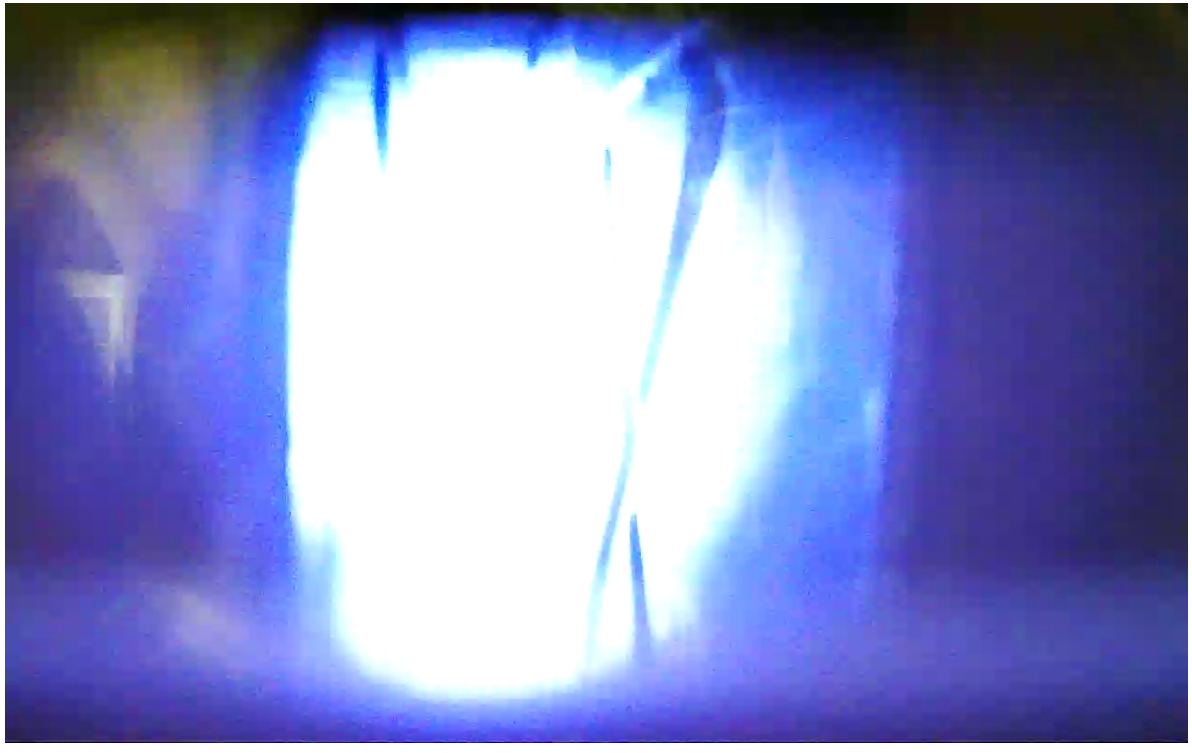
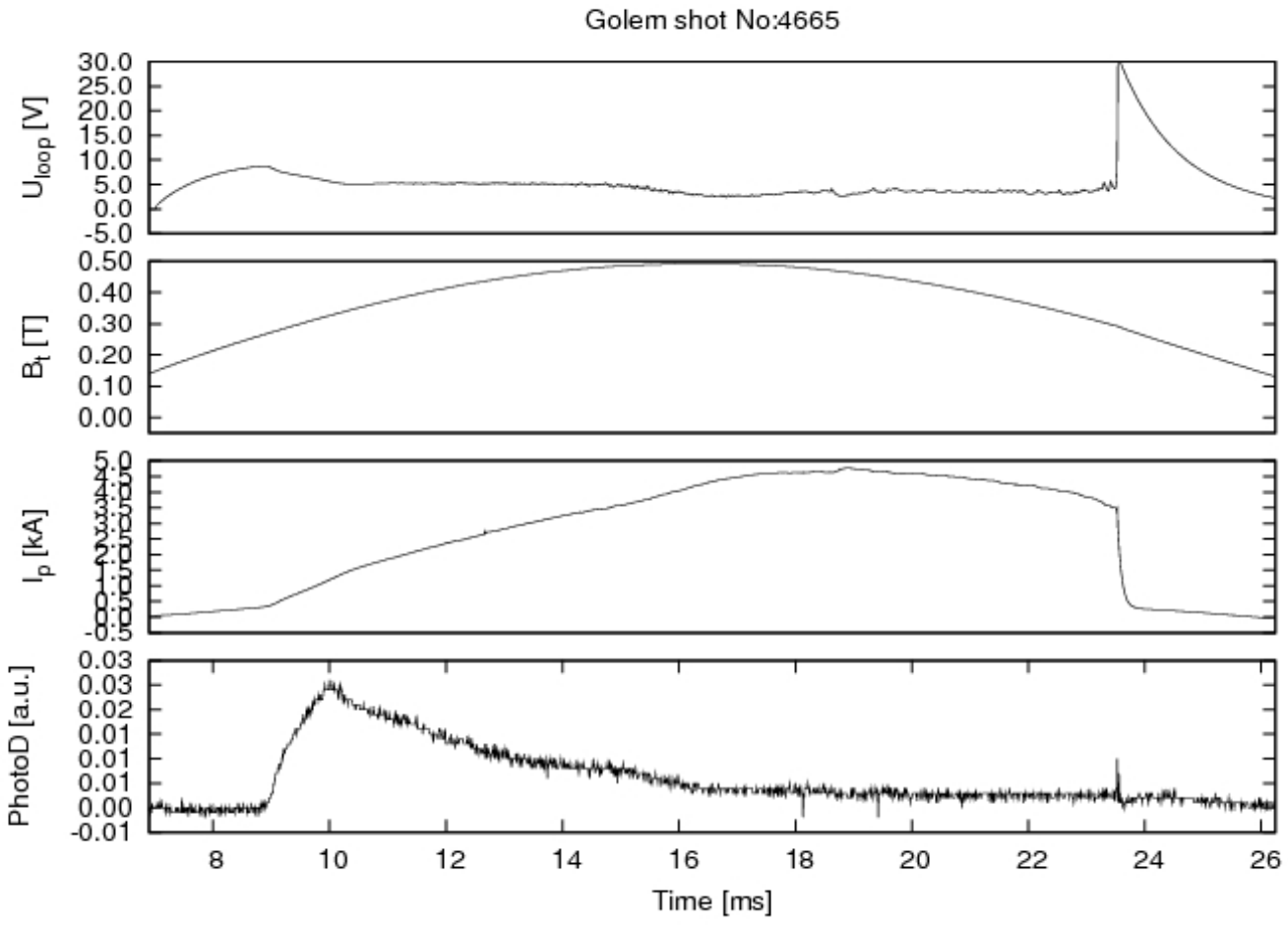
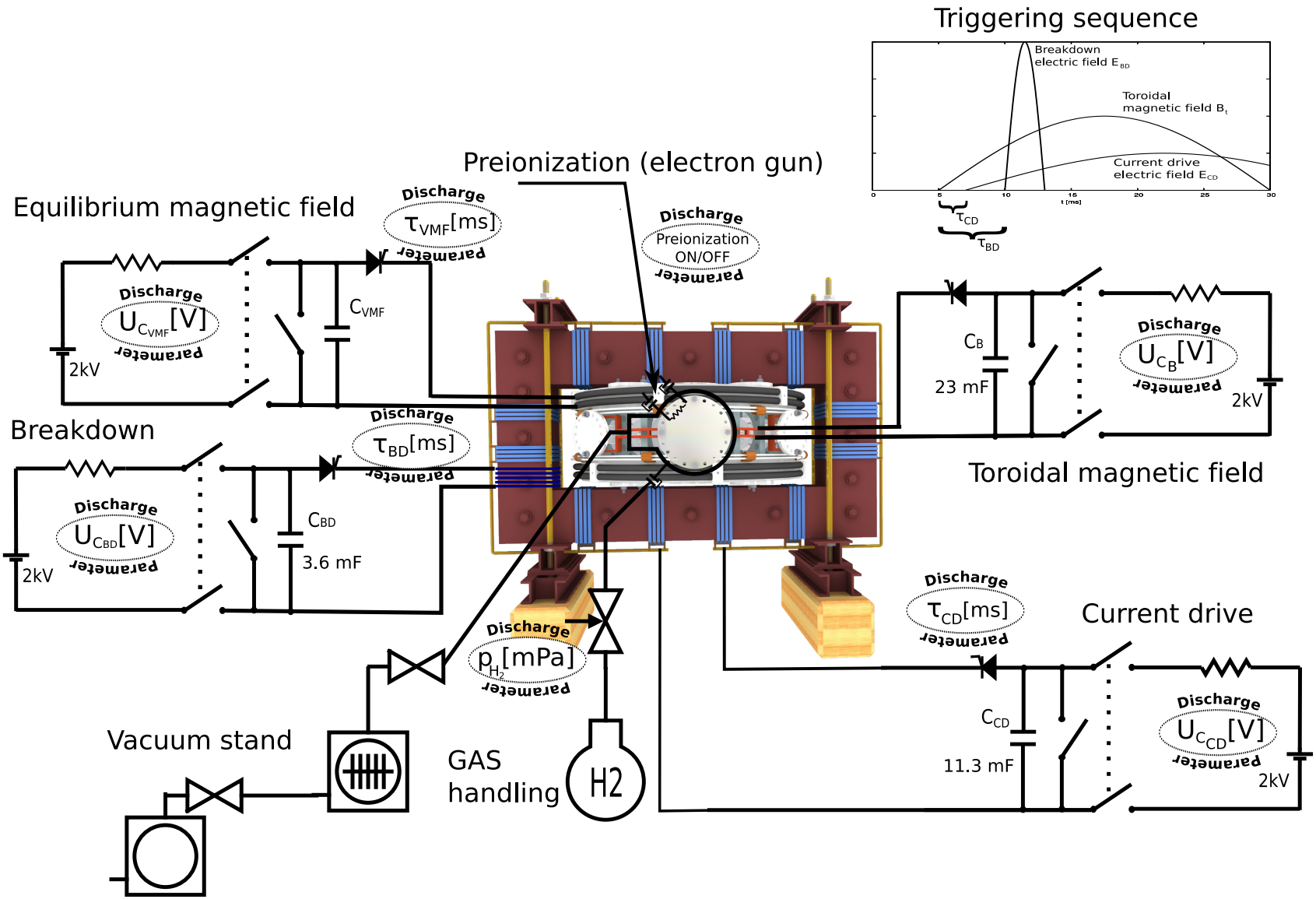
The plasma generation



Golem discharge



Engineering scheme of the GOLEM tokamak



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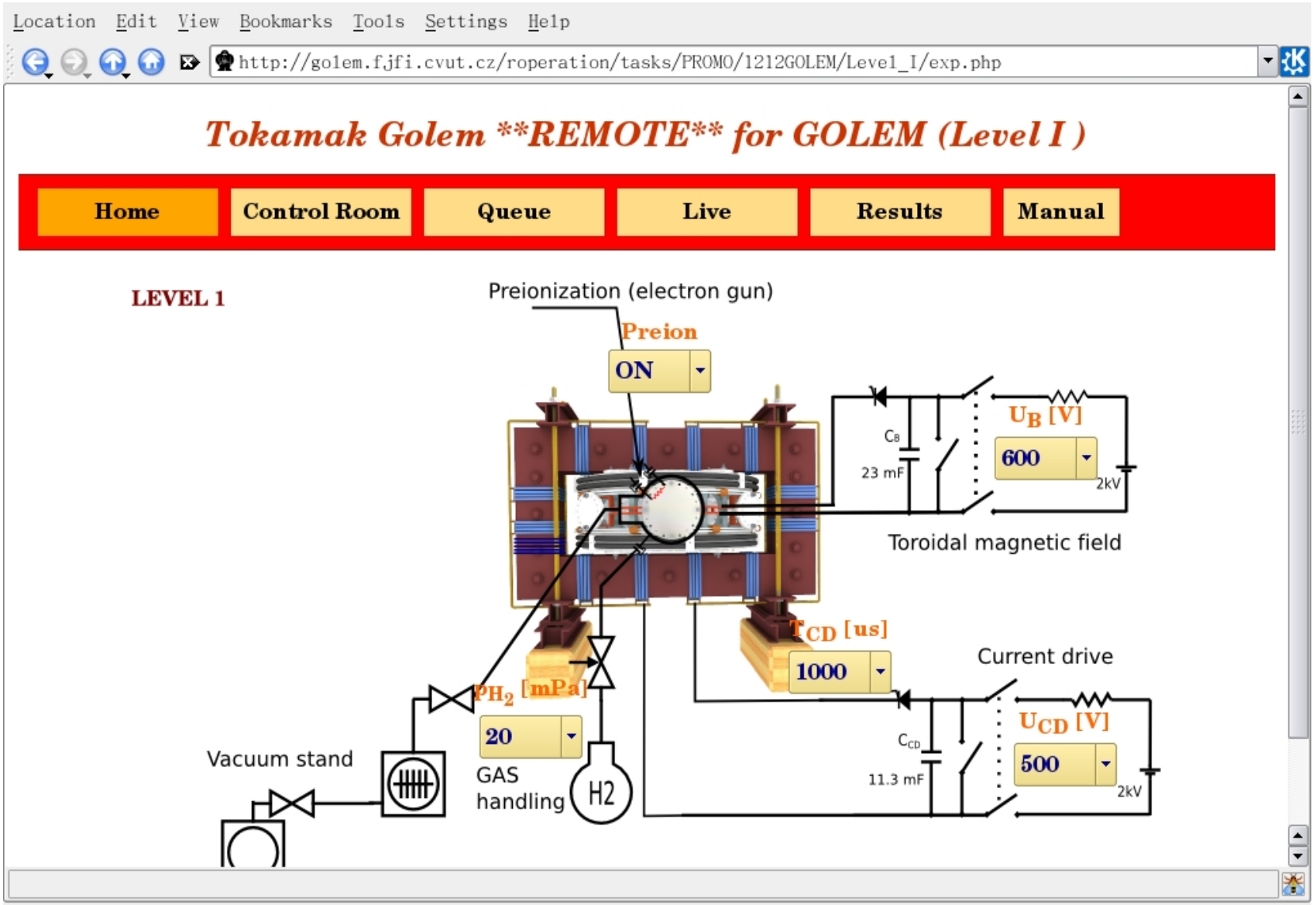
The GOLEM tokamak **real** Control Room



The result webpage

Diagnostics

- ✕ PlasmaPosition
- ✓ Flukes
- ✕ MirnovCoils
- ✓ HXR
- ✓ FastCamera
- ✕ Spectrometer

Analysis

- ✓ AdvancedAnalysis
- ✓ ShotHomepage
- ✕ MagFieldEvolution
- ✕ MultiCWT
- ✕ MHD

DAS

- ✓ NIturbo
- ✓ NIstandard
- ✕ Papouch
- ✓ NIbasic
- ✕ Papouch

Vacuum + Energetics

Log

Other

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Navigation

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Go to shot

9694 Go

Tokamak GOLEM - Shot Database - 9694

[Template source]
[WebLog]

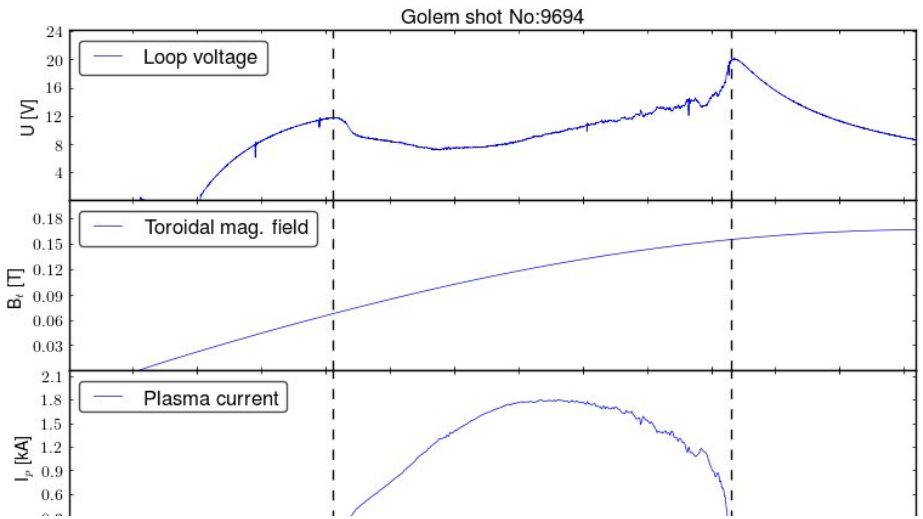
Date: 2012-09-07 - **121544**
Session: Technological/Software/Debugging/0912Optimization
Comment: `USER_A - three`

Basic parameters:

- Chamber pressure $p_{chamber}$: `1.27`-> `19.28` mPa (request: 20 mPa)
- Working gas: `N/A`
- Chamber temperature: N/A C
- C_{B_t} capacitors (23.0 mF) charged to: `600 V`, triggered `5.0 ms`
- C_{BD} capacitors (3.6 mF) charged to: `0 V`, triggered `5.0 ms`
- C_{CD} capacitors (11.2 mF) charged to: `500 V`, triggered `6.0 ms`
- C_{ST} capacitors (2.7 mF) charged to: `0 V`, triggered `5.0 ms`
- Max saturation of iron core transformator: 47%
- Time since session beginning: 0:51:47 h

Plasma parameters:

- Plasma life time **6.2** [ms] (from 8.1 to 14.3)
- Mean toroidal magnetic field Bt: 0.12 T
- Mean plasma current: 1.43 kA
- Mean Uloop: 9.71 V
- Break down voltage: 11.9 V
- Ohmic heating power: 13.87 kW
- Q edge: 7.6
- Central electron temperature: `25.3 eV`



Operational parameters and their limits

The parameters to be set remotely:

- Toroidal magnetic field (B_t) through the voltage of the toroidal field capacitor bank U_B, range: $400 - 1300\ \mathrm{V}$.
- Toroidal electric field (E_{CD}) through the capacitor bank for the current drive U_{CD}, range: $200 - 600\ \mathrm{V}$.
- Toroidal electric field (E_{BD}) through the capacitor bank for the breakdown U_{BD}, range: $100 - 200\ \mathrm{V}$.
- The time delay between the triggers of the toroidal magnetic field and the current drive T_{CD}, range: $0 - 20000\ \mu\mathrm{s}$.
- The time delay between the triggers of the toroidal magnetic field and the breakdown T_{BD}, range: $0 - 20000\ \mu\mathrm{s}$.
- Hydrogen or Helium gas pressure p_{WG}, range: $0 - 100\ \mathrm{mPa}$.
- Status of preionization (ON/OFF).
- Requested working gas (H2/He).

Data access

All the recorded data and the settings for each shot are available at the GOLEM website. The root directory for the files is:

`http://golem.fjfi.cvut.cz/operation/shots/<shotnumber>/`

Basic data of the shot series are collected at a page to be reached at:

`http://golem.fjfi.cvut.cz/operation/tasks/<session>/`

Actual discharge has the web page:

`http://golem.fjfi.cvut.cz/operation/currentshot`.

Actual session has the web page:

`http://golem.fjfi.cvut.cz/operation/currentsession`.

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Acknowledgement

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GOLEM team (students, teachers, technicians)

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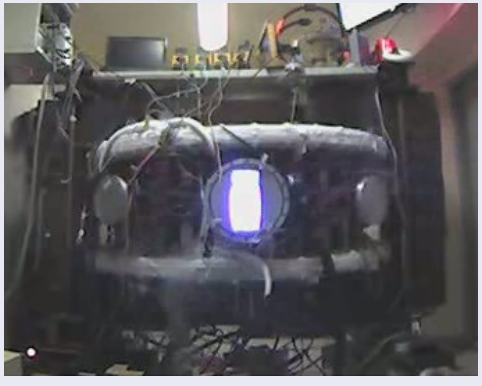
Special thanks: NATIONAL INSTRUMENTS™

Final

Thank you for your attention



http://gomtraic.fjfi.cvut.cz,
you are welcome.

References I

G. Van Oost, M. Berta, J. Brotankova, R. Dejarnac, E. Del Bosco, E. Dufkova, I. Duran, M. P. Gryaznevich, J. Horacek, M. Hron, A. Malaquias, G. Mank, P. Peleman, J. Sentkerestiova, J. Stoeckel, V. Weinzett, S. Zoletnik, B. Tal, J. Ferrera, A. Fonseca, H. Hegazy, Y. Kuznetsov, A. Ossyannikov, A. Singh, M. Sokholov, and A. Talebitaher.
Joint experiments on small tokamaks: edge plasma studies on CASTOR.
NUCLEAR FUSION, 47(5):378–386, MAY 2007.

References II

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.

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

References III

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

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.