The tokamak GOLEM for GOMTRAIC

Vojtěch Svoboda on behalf of the GOLEM team

April 8, 2013

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- Ports
- Data acquisition system
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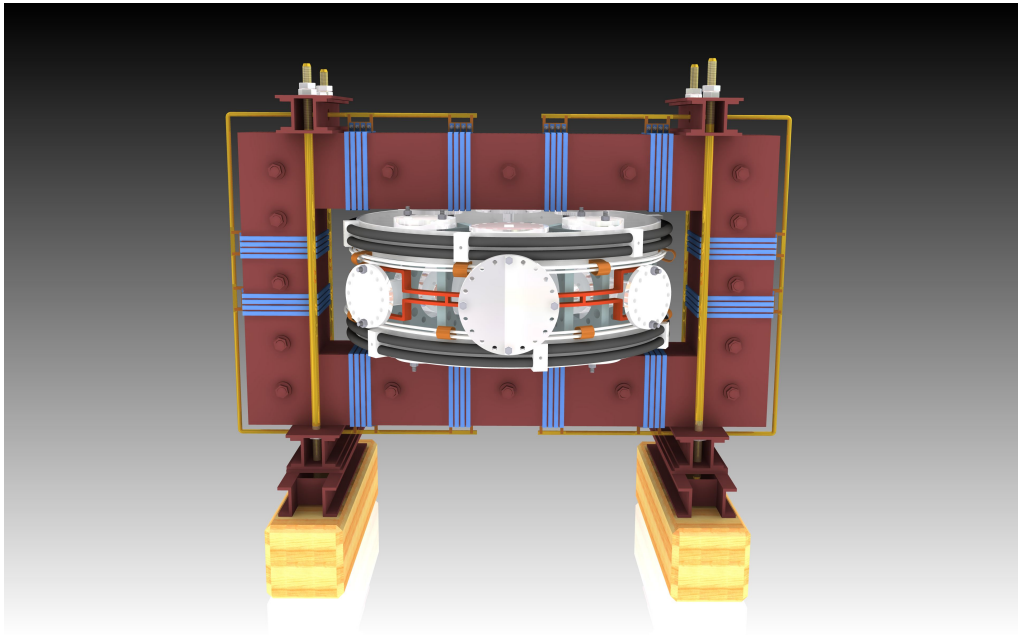
Tokamak GOLEM - basic parameters:



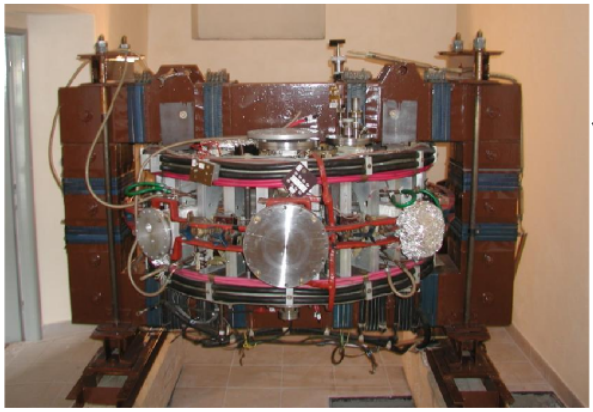
- major radius $R = 0.4$
- minor radius $a = 0.085$ m
- plasma current $I_{pl} < 10$ kA
- pulse length $t < 20$ ms
- toroidal magnetic field $B_{tor} < 1$ T
- plasma density $n_e = 0.2 - 3.0 * 10^{19}/m^3$
- electron temperature $T_e(0) < 200$ eV
- ion temperature $T_i(0) < 100$ eV

GOLEM

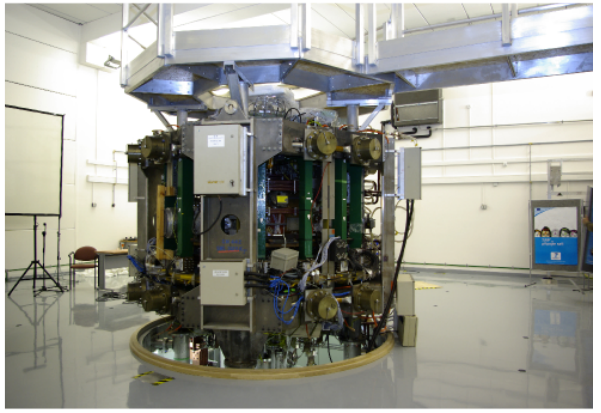
The new location of the tokamak is just next to the old Prague Jewish cemetery where Rabi Loew (Golem builder) is burried, and that is why it was renamed GOLEM (and also for the symbol of potential power you get if you know the magic). Interestingly, here in Prague, where the Golem legend originated, Golem is not perceived as a symbol of evil, but rather as a symbol of power which might be useful but is very challenging to handle. To learn more of the Golem legend, see e.g. wikipedia.

Tokamak GOLEM for Education - Historical Background

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



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



1974

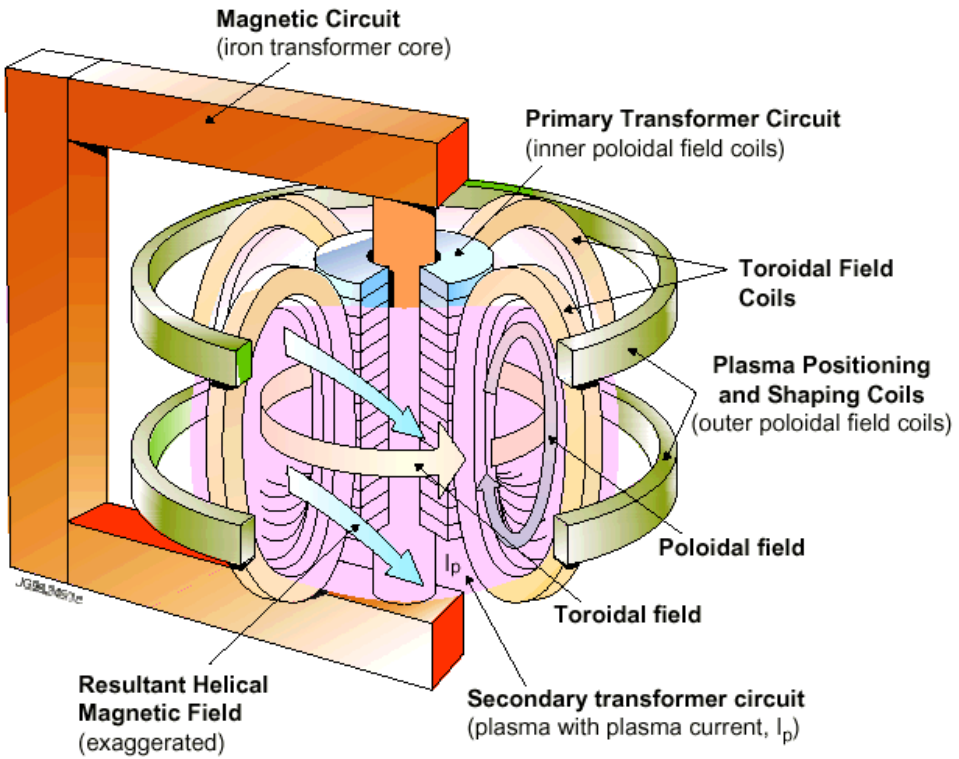
2006

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

2008

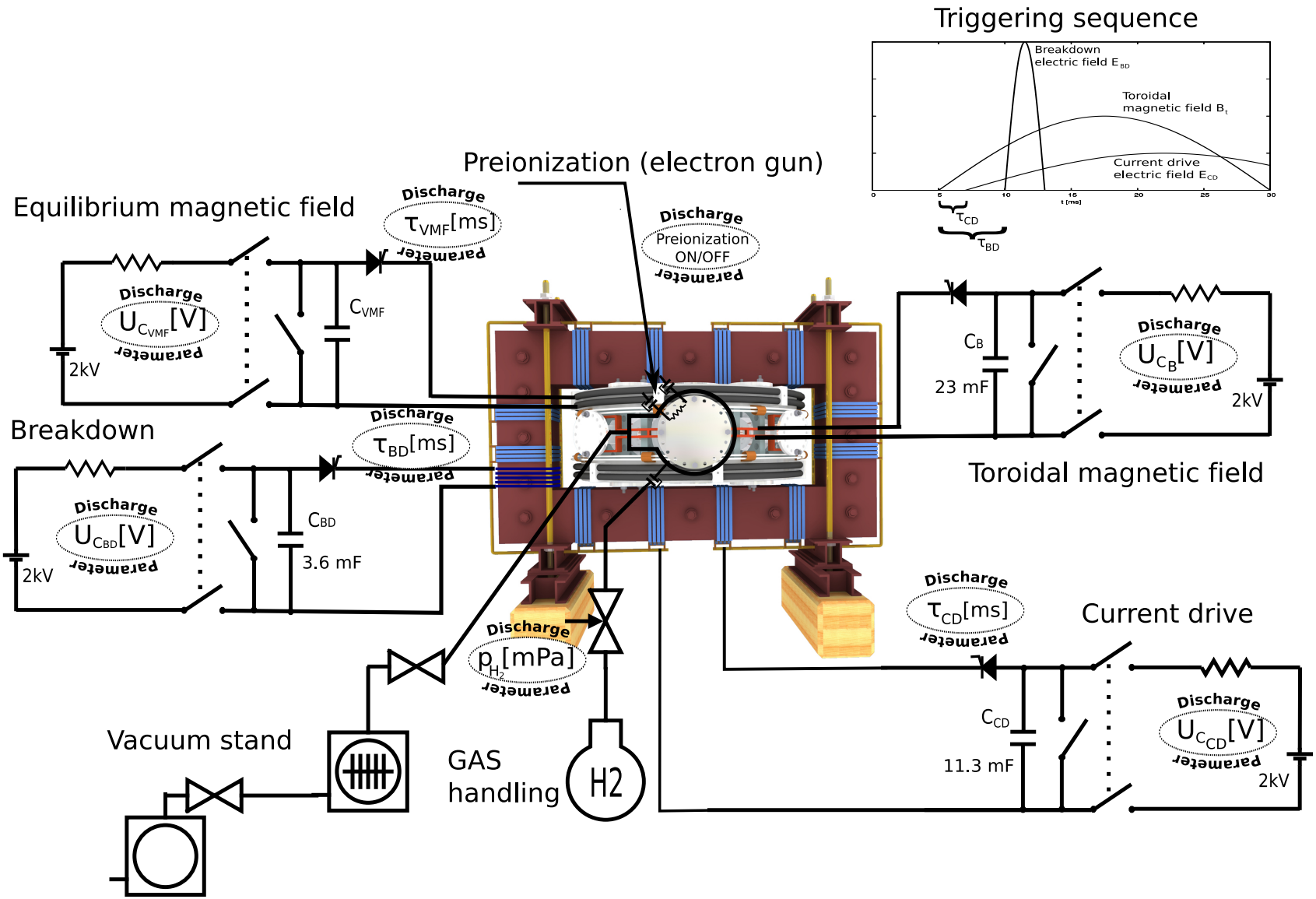
Czech Technical University Prague
Czech republic
GOLEM

Plasma in Tokamak (GOLEM) - the least to do



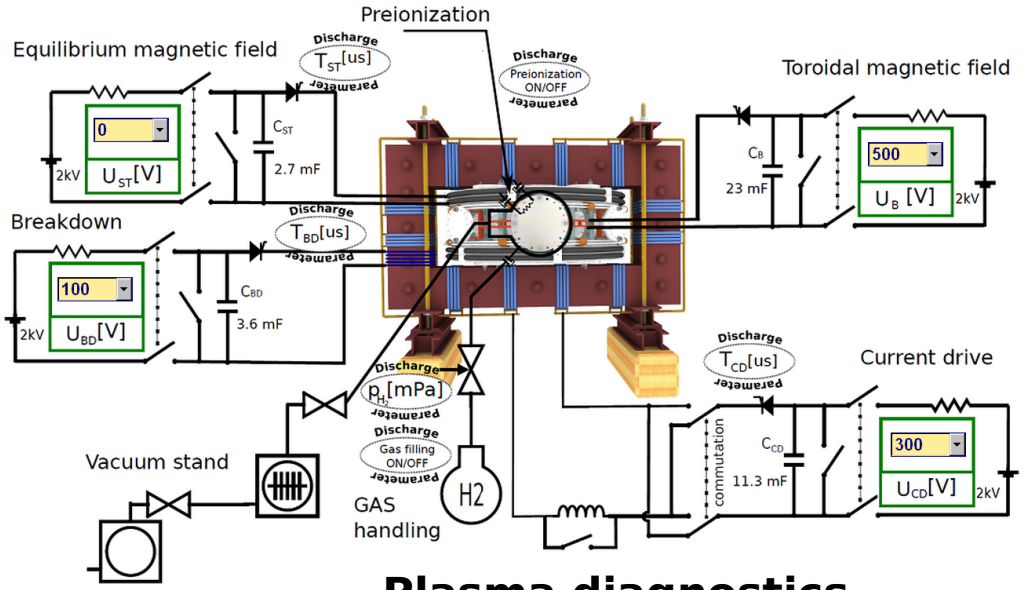
- Evacuate the chamber.
- Fill in the working gas.
- Toroidal magnetic field to confine plasma.
- Toroidal electric field to breakdown neutral gas into plasma.
- Toroidal electric field to heat the plasma.
- Plasma positioning.
- Diagnostics.

Engineering scheme of the GOLEM tokamak

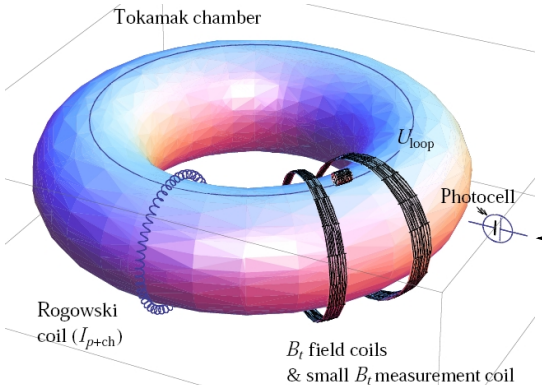


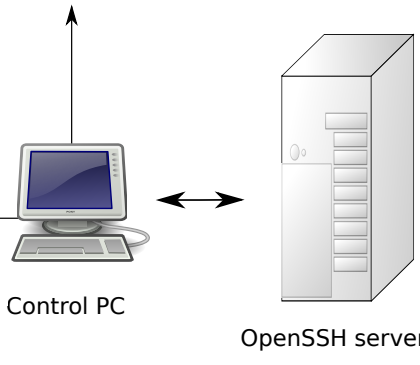
Unique remote operation capability

Tokamak control room



Plasma diagnostics



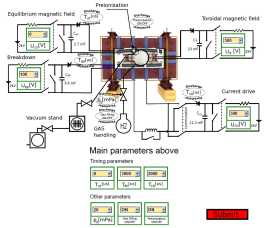


internet

Virtual control room (remote participation)

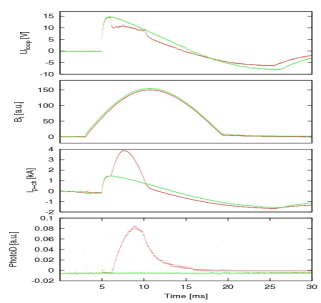
WWW control interface

HTML & PHP scripts



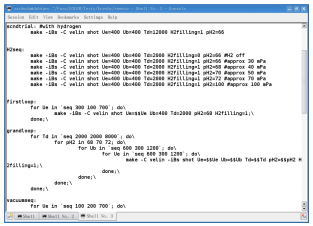
Data presentation

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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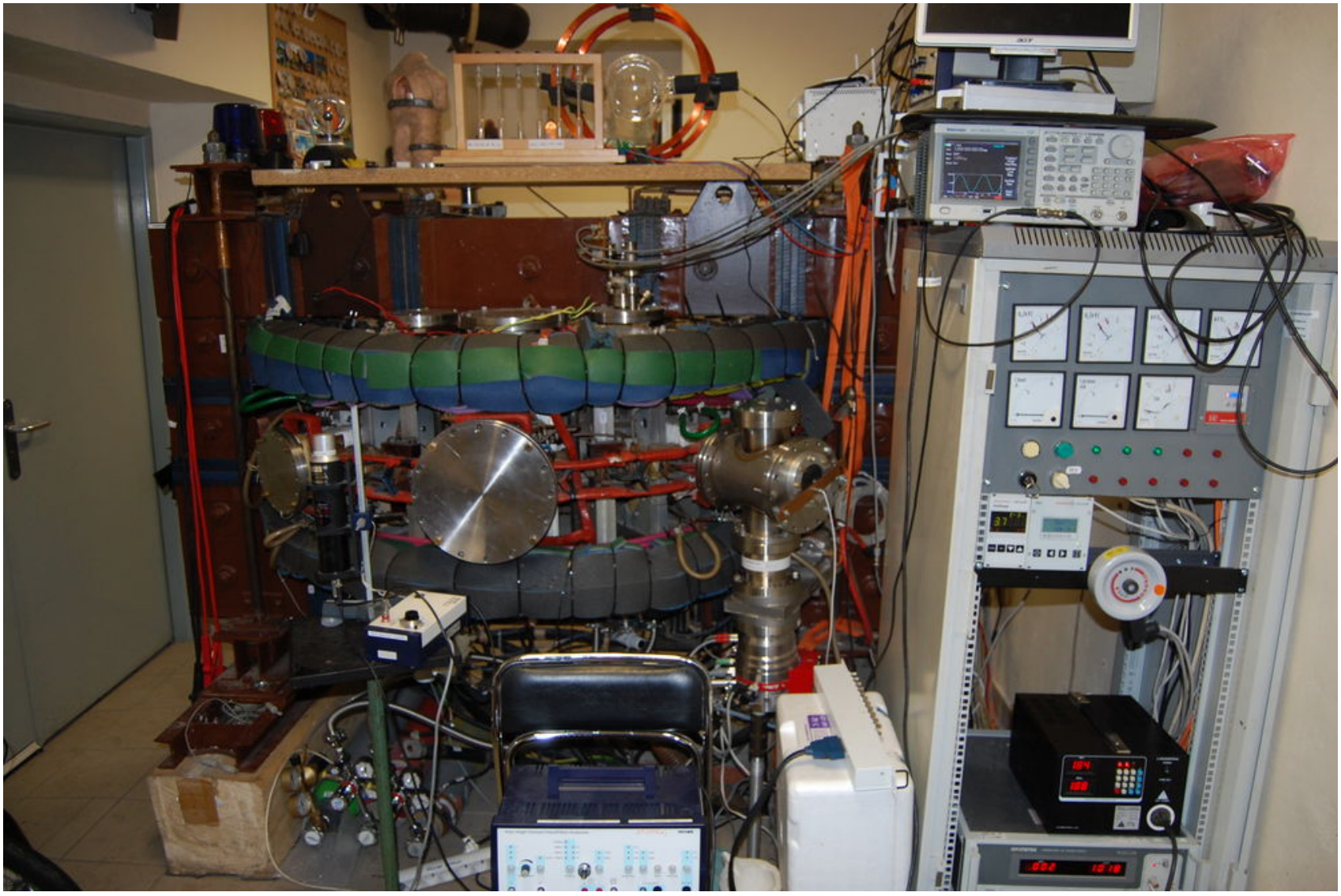
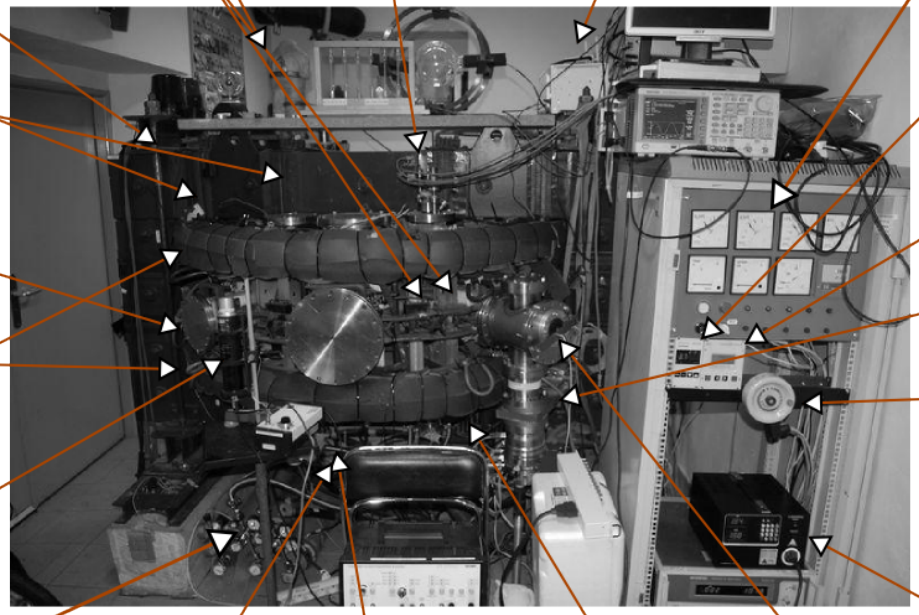
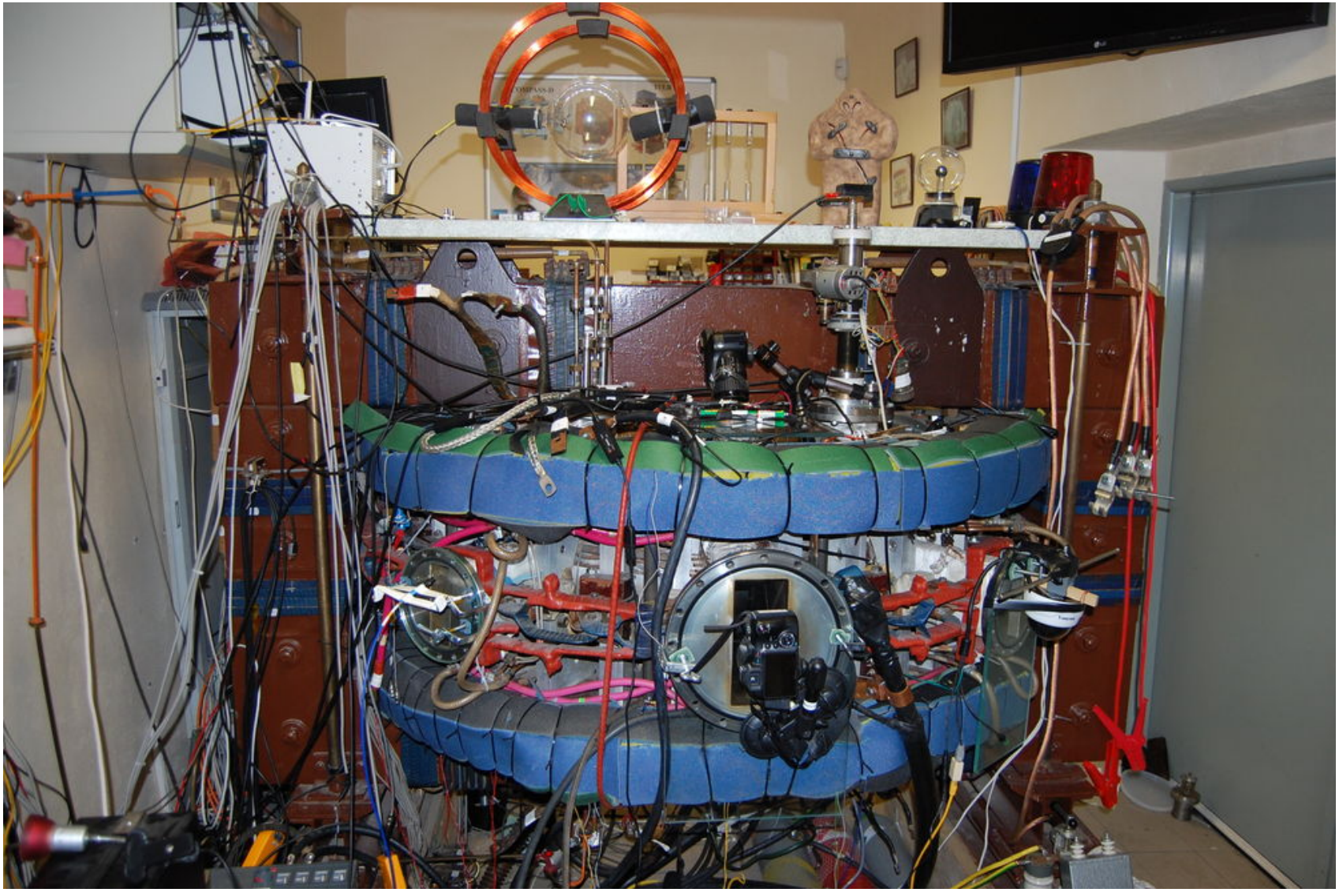
The Golem tokamak - South view (02/12)



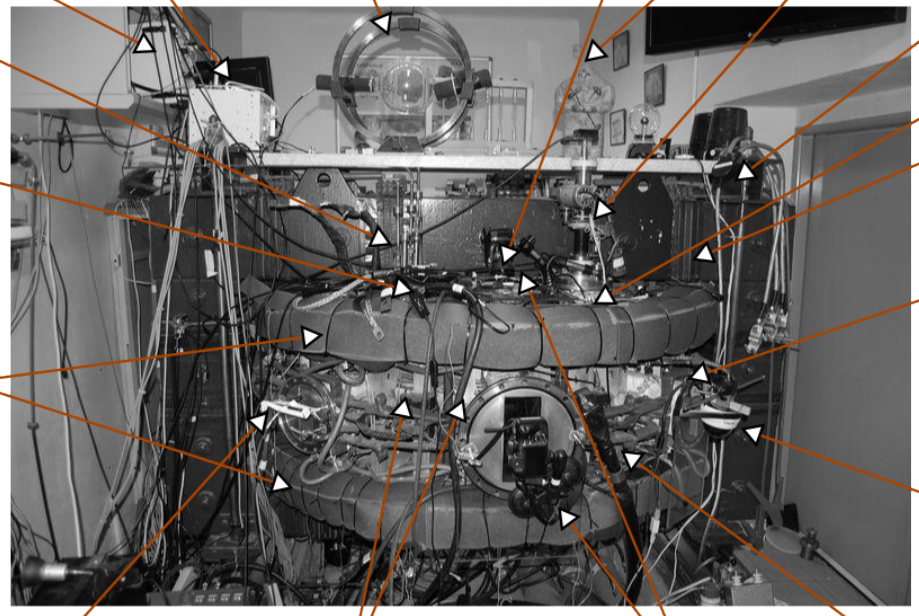
The Golem tokamak - South view (02/12)



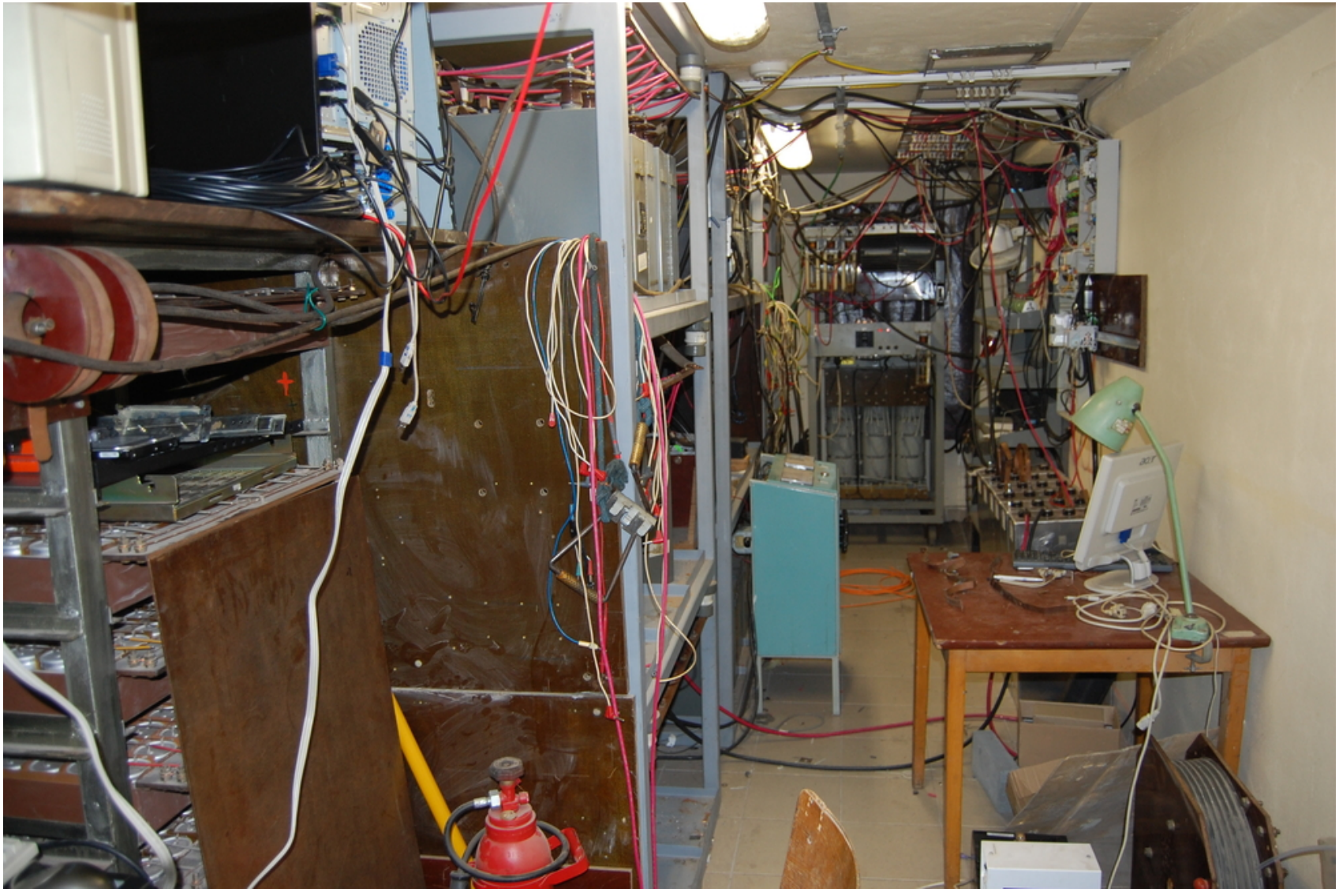
The Golem tokamak - North view (02/12)



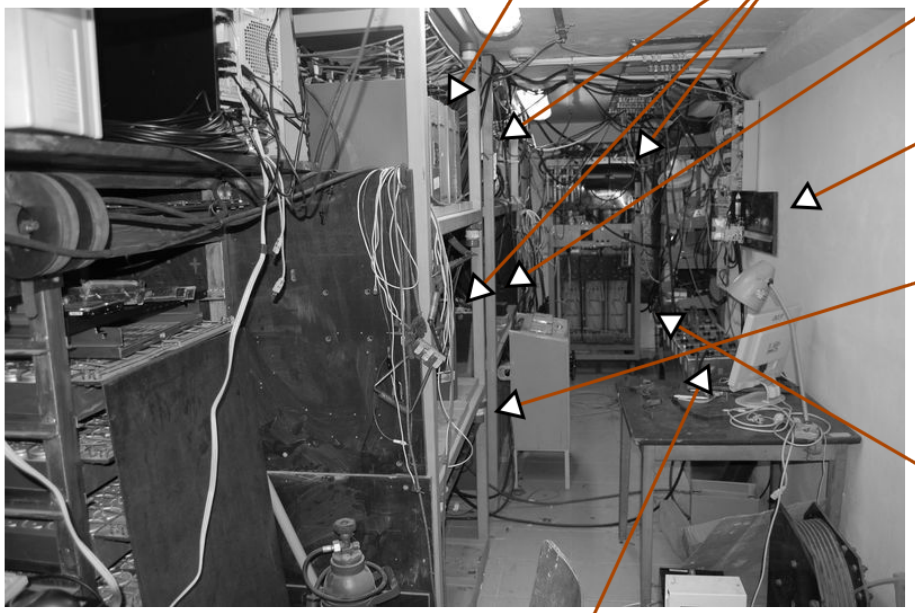
The Golem tokamak - North view (02/12)



Infrastructure room (below tokamak)



Infrastructure room



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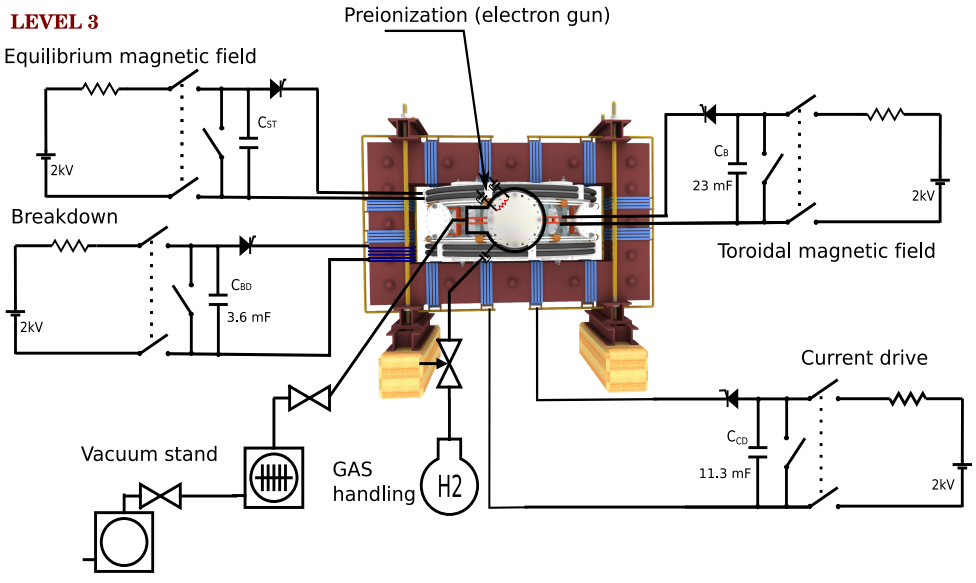
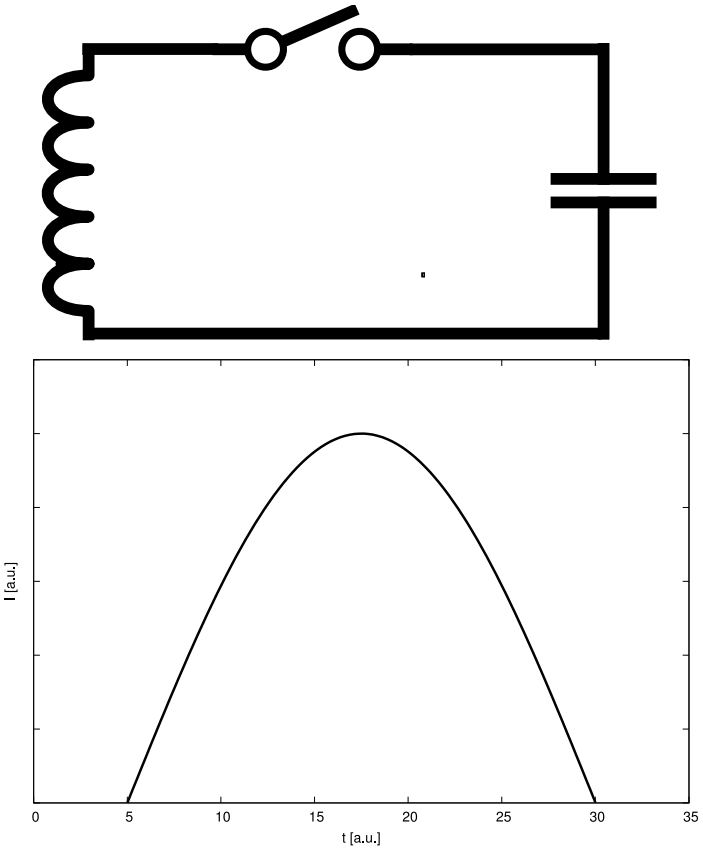
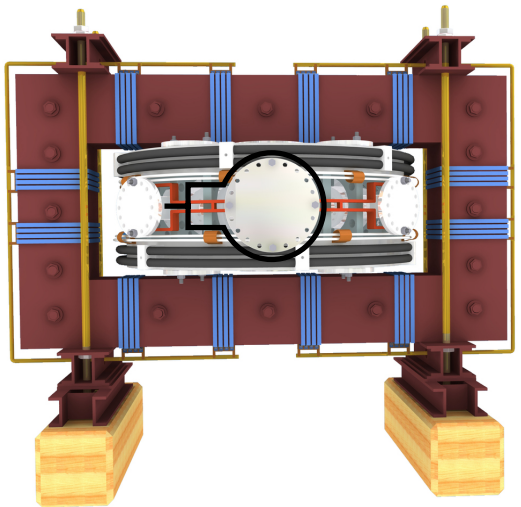
Insertion - LC circuit





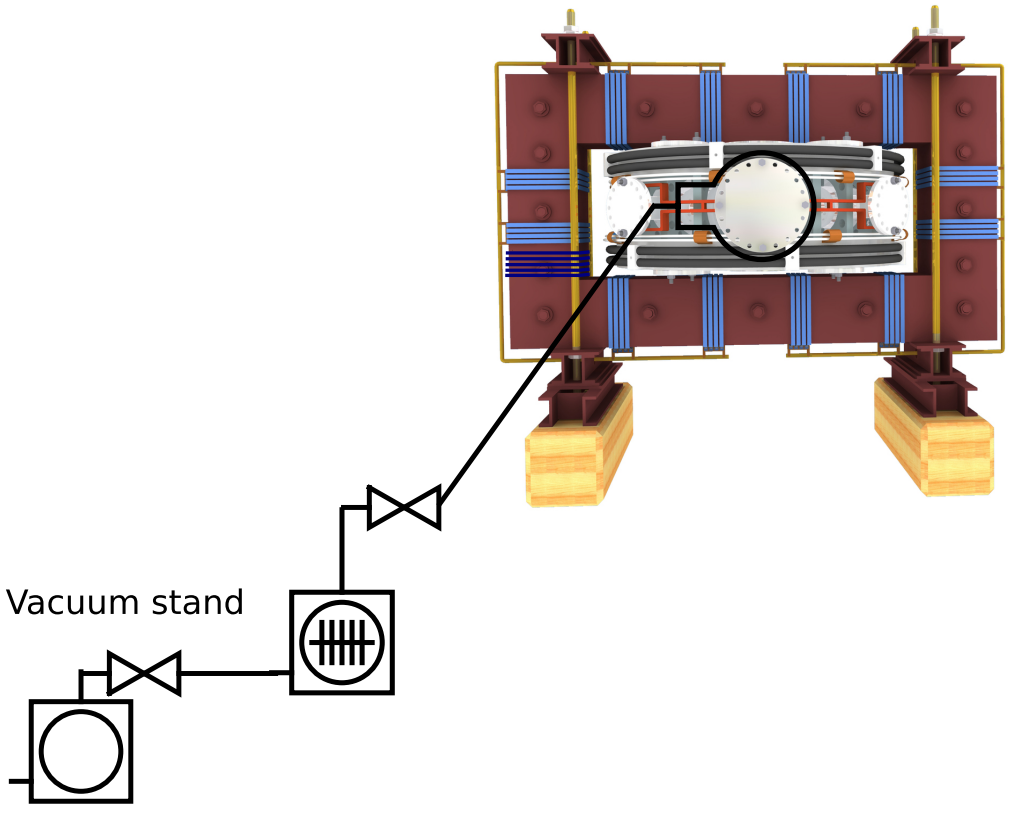
Tokamak GOLEM - basic

LEVEL 0



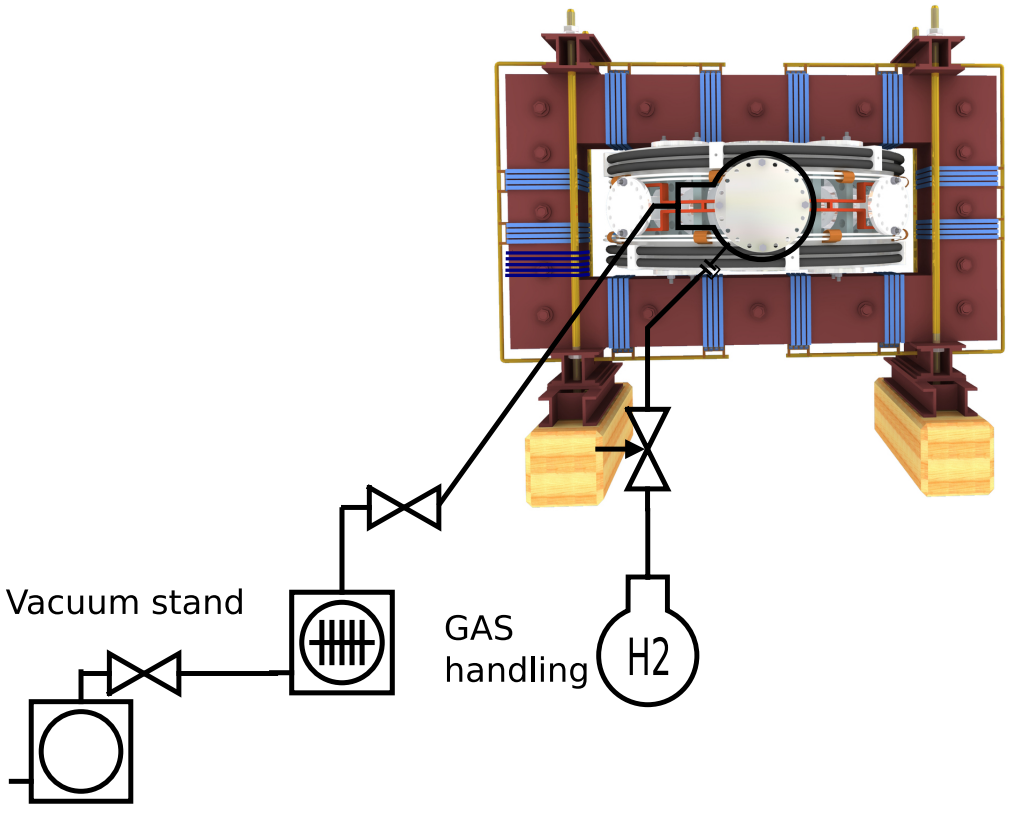
+ vacuum pumping system (100 kPa $\rightarrow \approx$ 1 mPa)

LEVEL 0



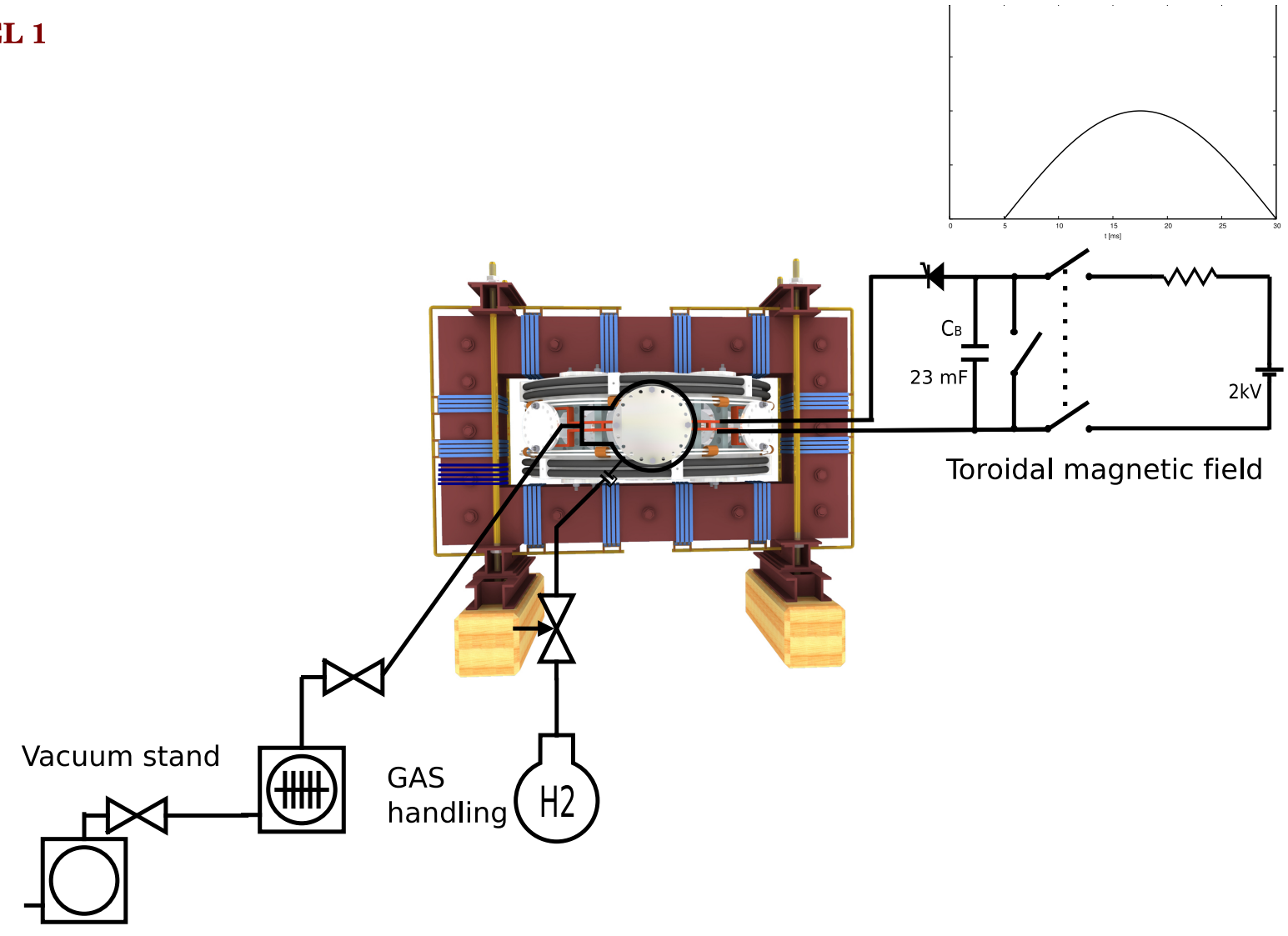
+ working gas management (H_2 or He)

LEVEL 0



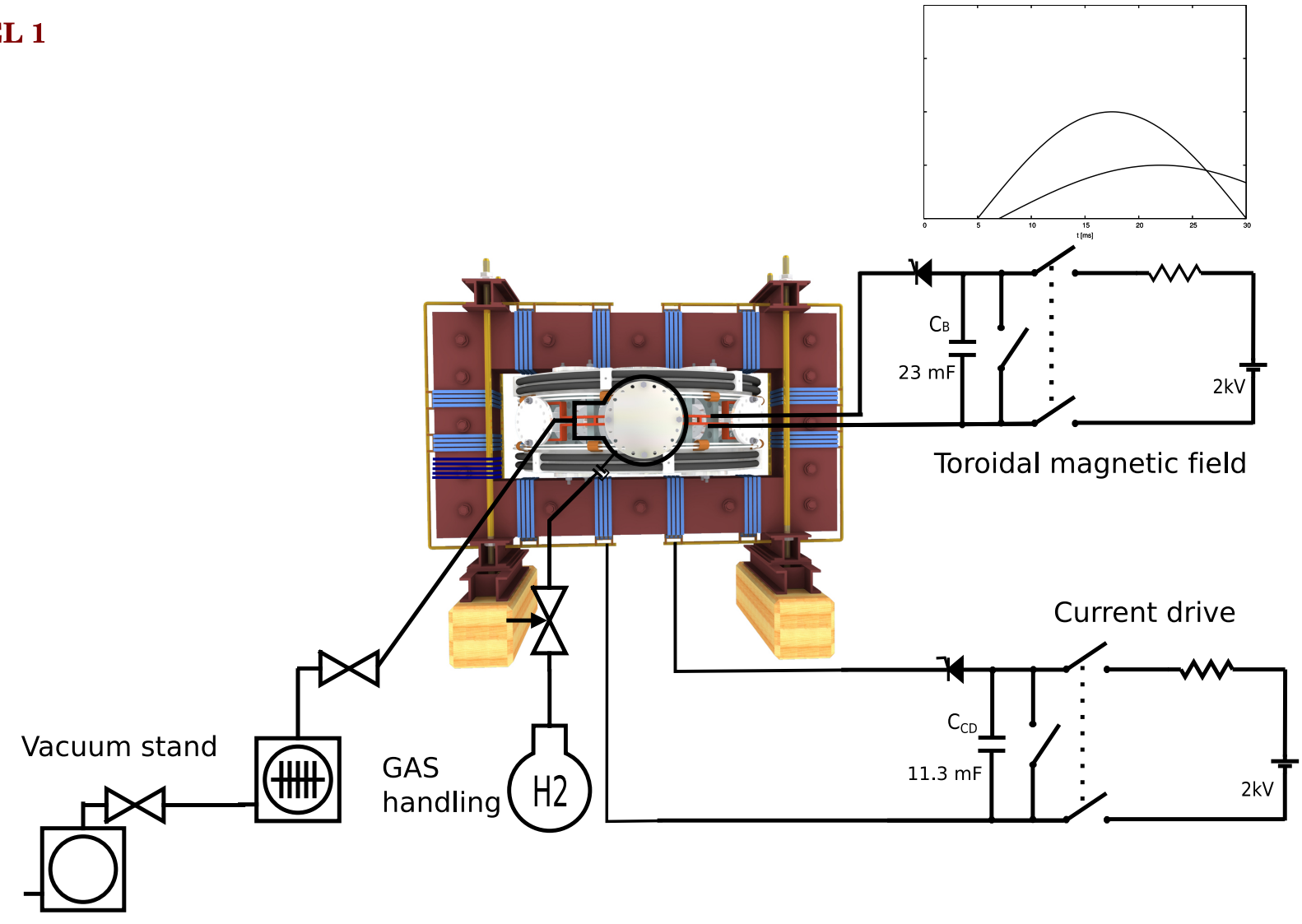
+ toroidal magnetic field B_{tor} .. **plasma confinement**

LEVEL 1



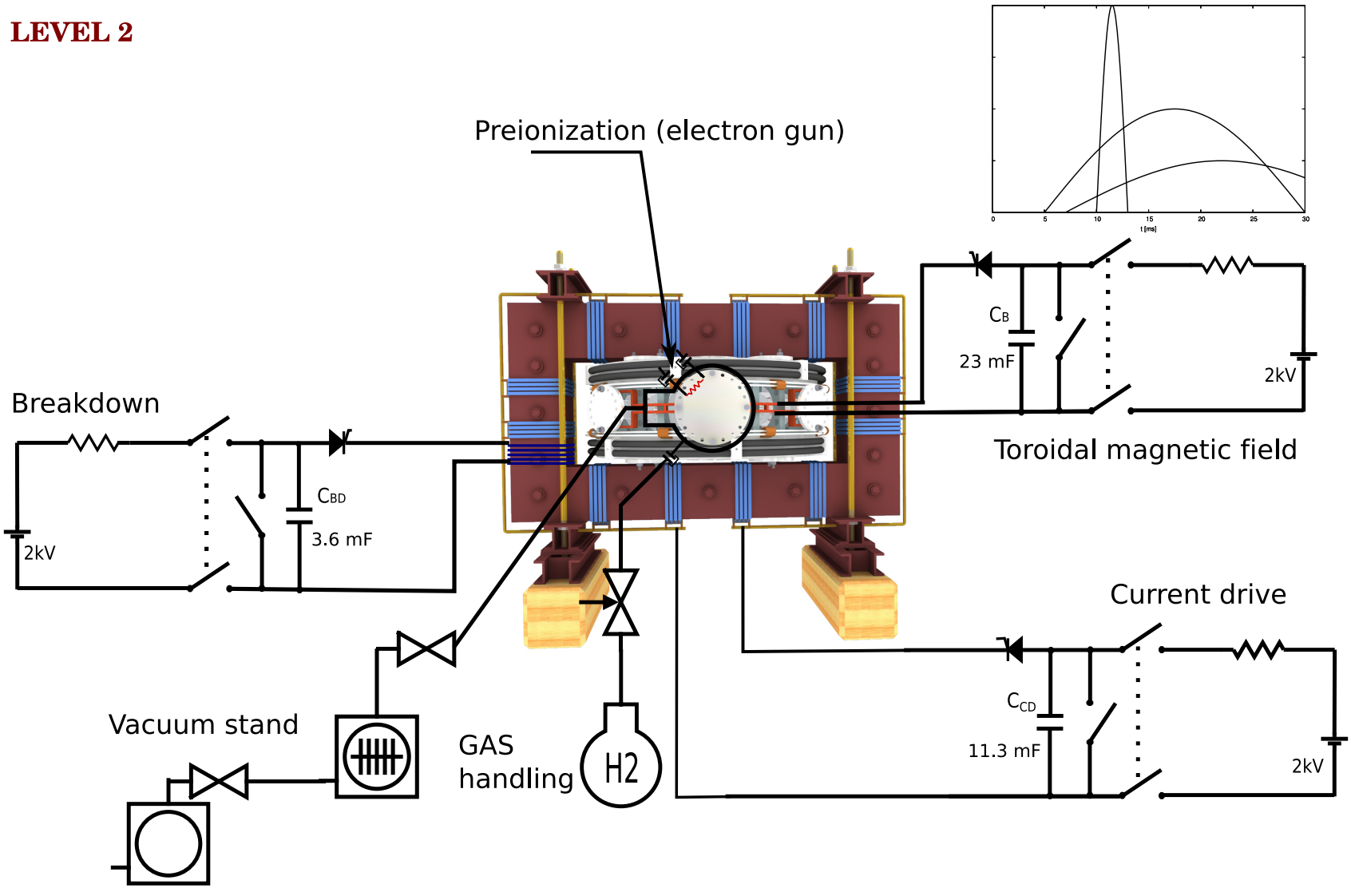
+ toroidal electric field E_{CD} .. **plasma heating**

LEVEL 1



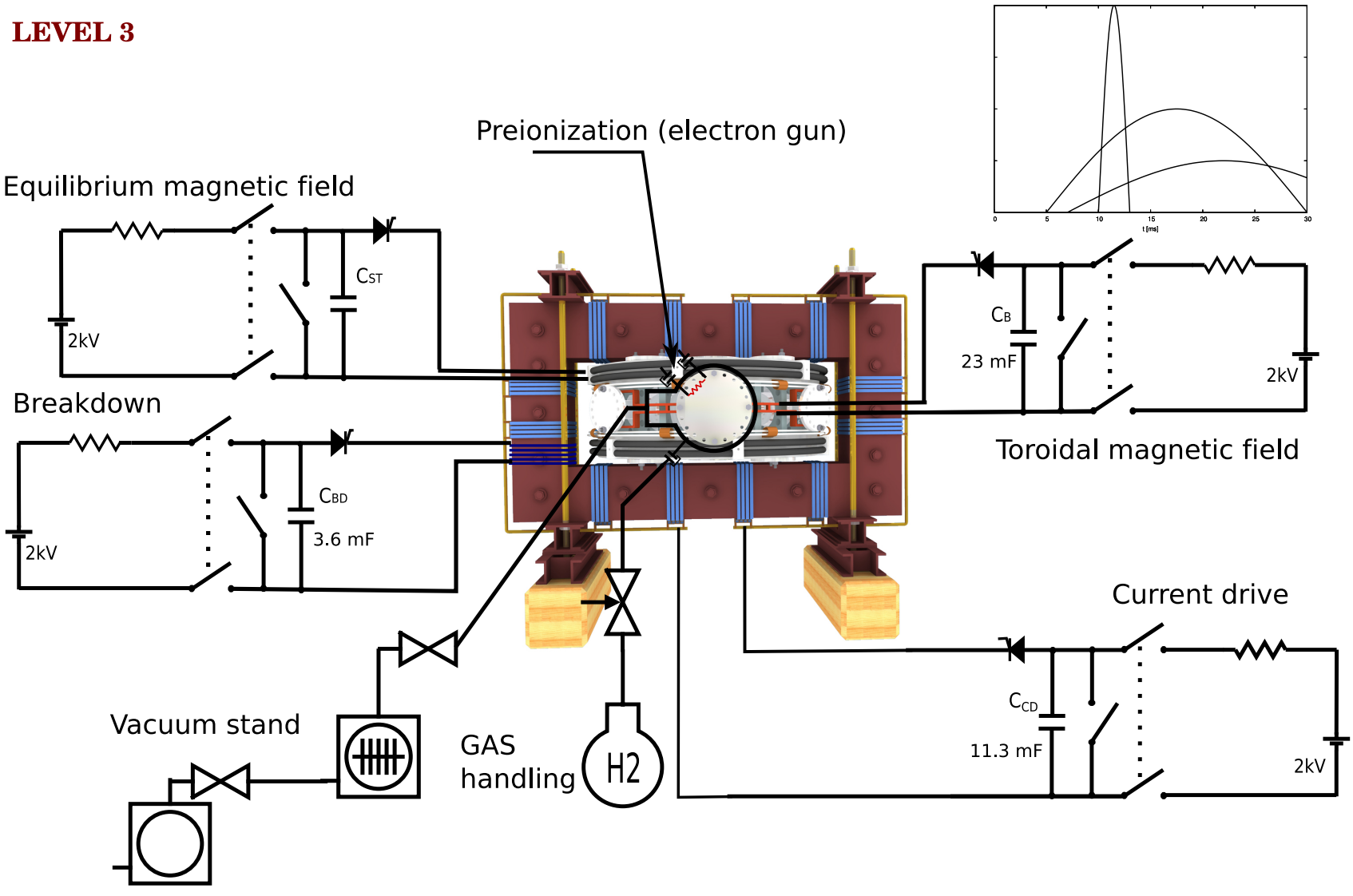
+ toroidal electric field E_{BD} .. **plasma creation**

LEVEL 2



+ equilibrium magnetic field B_{EQ} .. **plasma stabilization**

LEVEL 3



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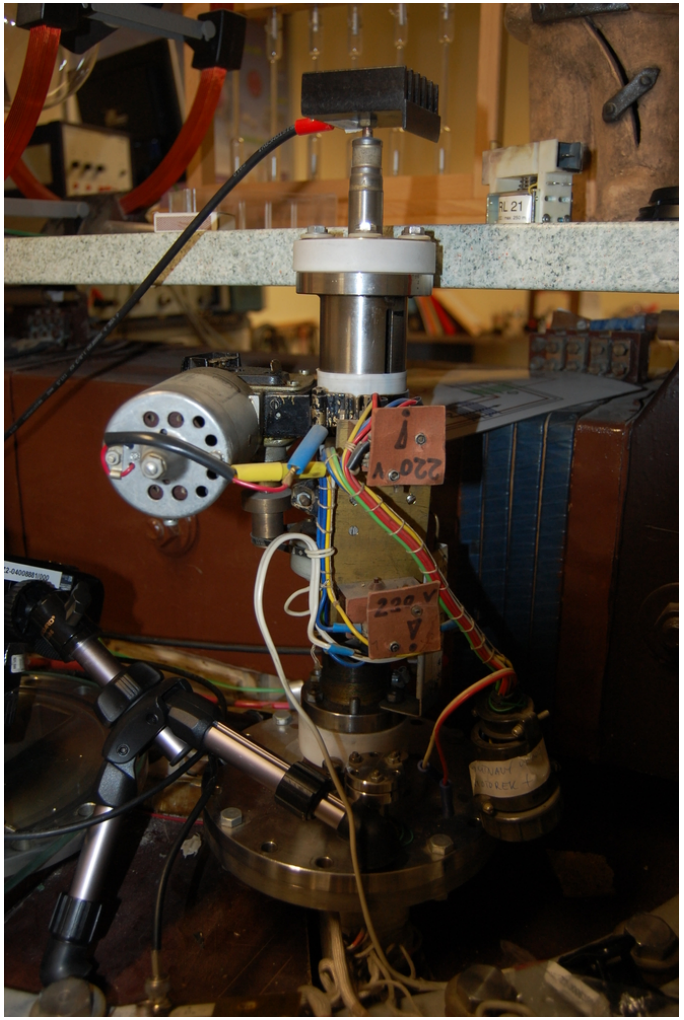
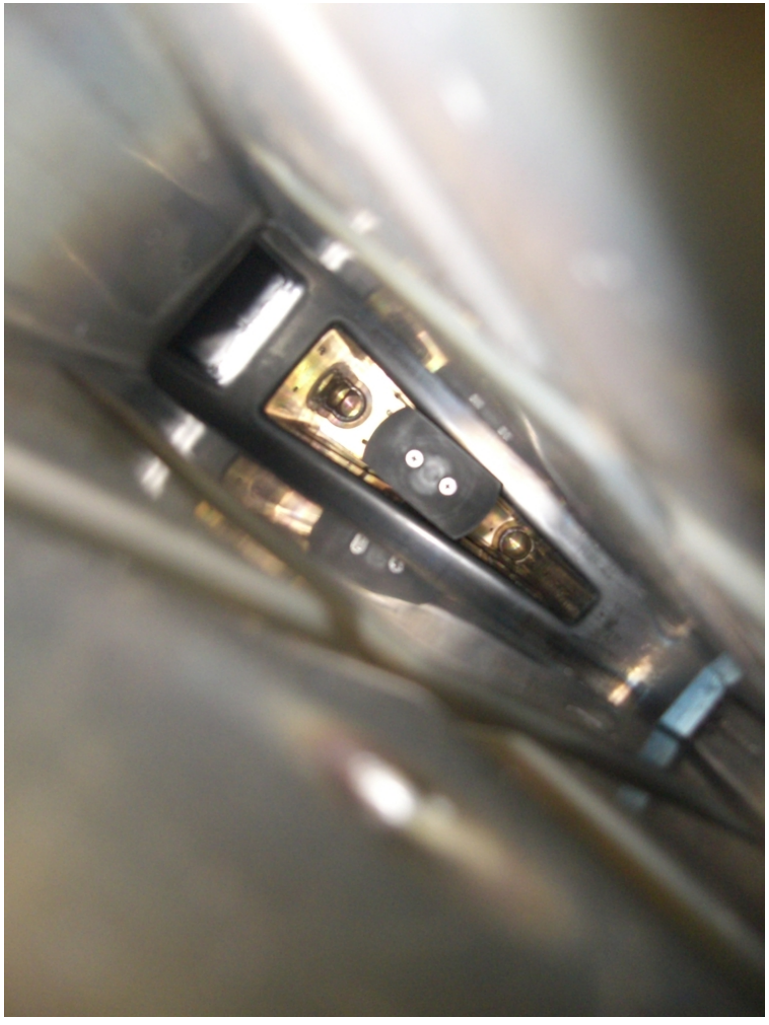
SouthEast-Upper port - glow discharge/biasing electrode



- Glow Discharge

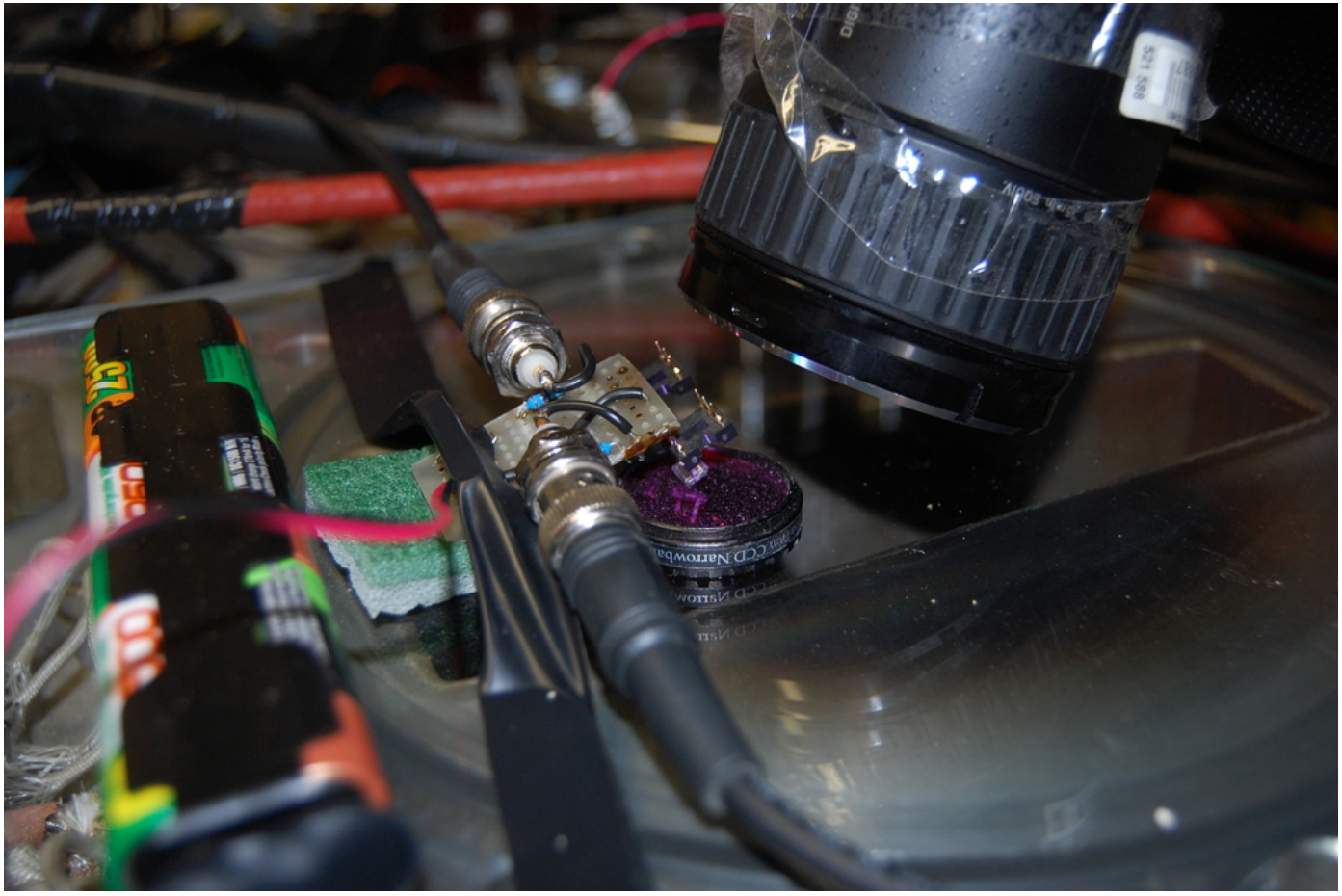
Glow discharge/Biasing electrode - chamber view



South-Upper port: Fast camera CASIO FX1 II

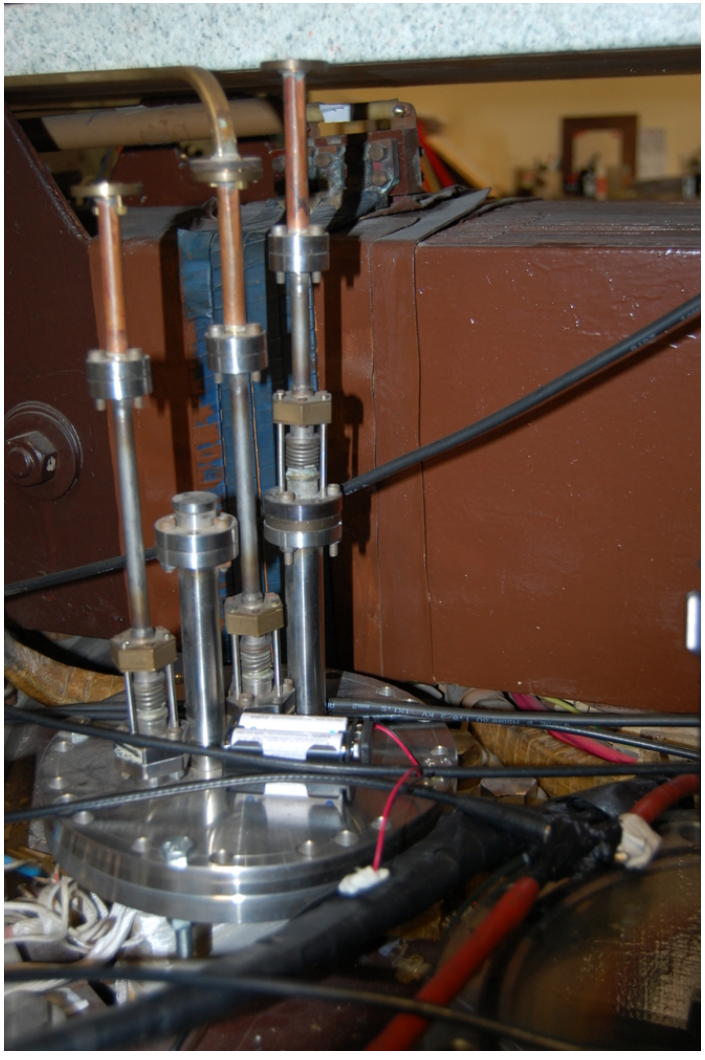
Manual, Discharge sequence

South-Upper port: Photodiodes (I-w/o filter, II-H_α filter)



Manual, H_α Spectral sensitivity

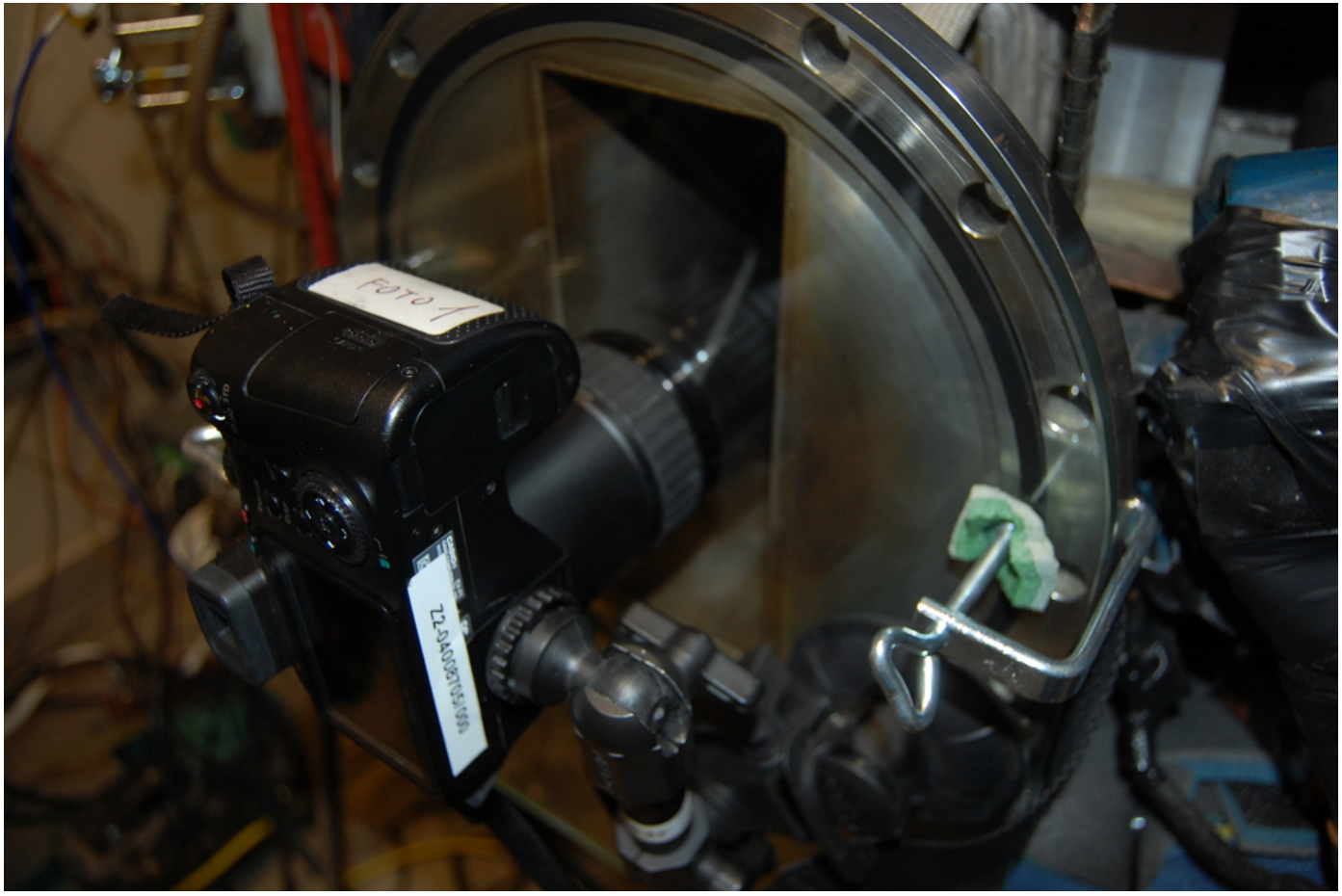
SouthWest-Upper port: Interferometry - input

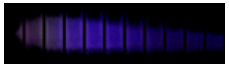


SouthEast-Middle port - IP camera viewing chamber

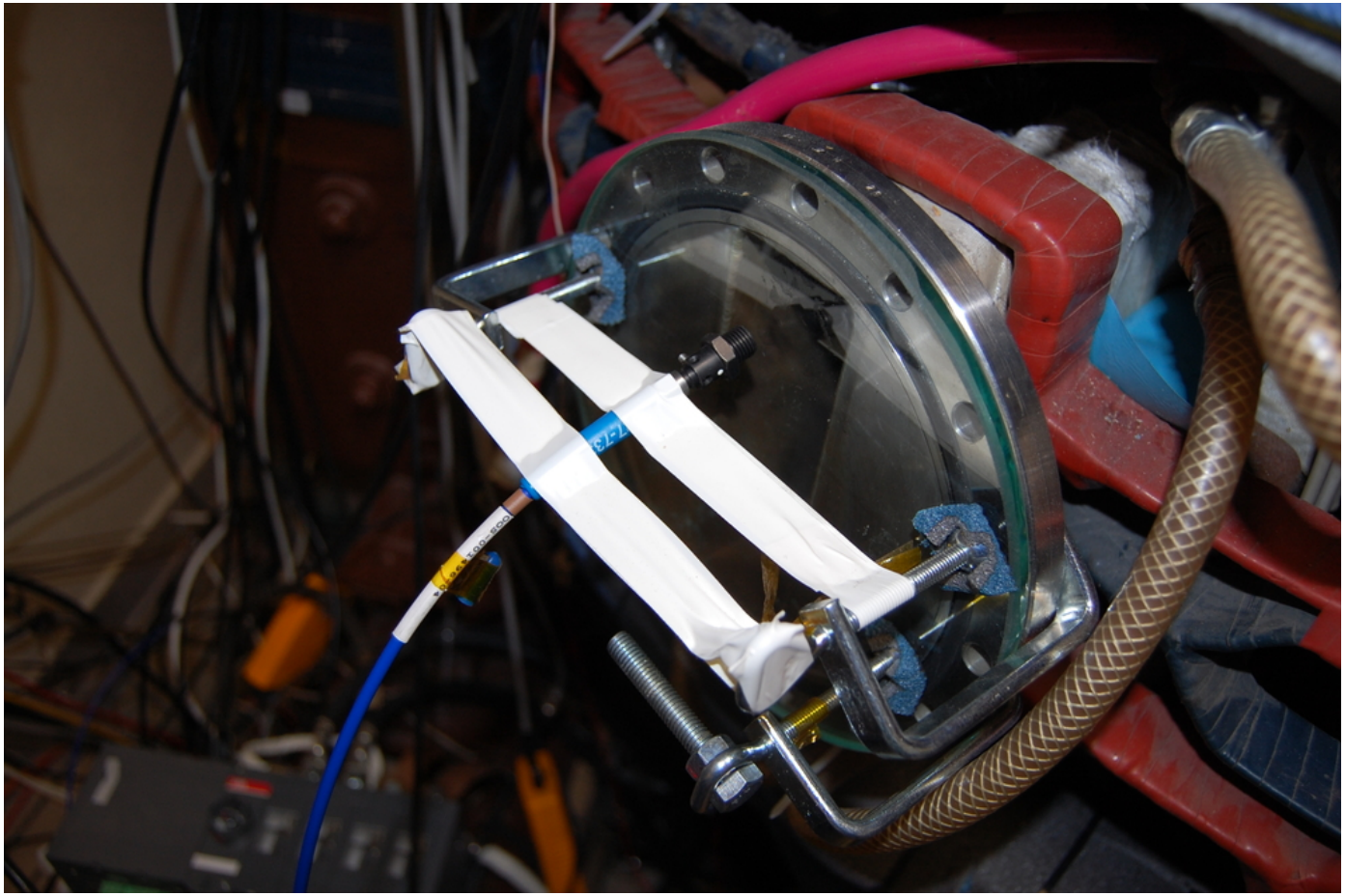
Manual, Tokamak Discharge, Glow Discharge

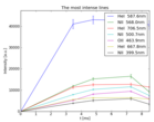
South-Middle port: Fast camera CASIO FX1 I



Manual,  Discharge sequence

SouthEast-MidIle port: Spectroscopy fiber connecting spectrometer HR2000+ES



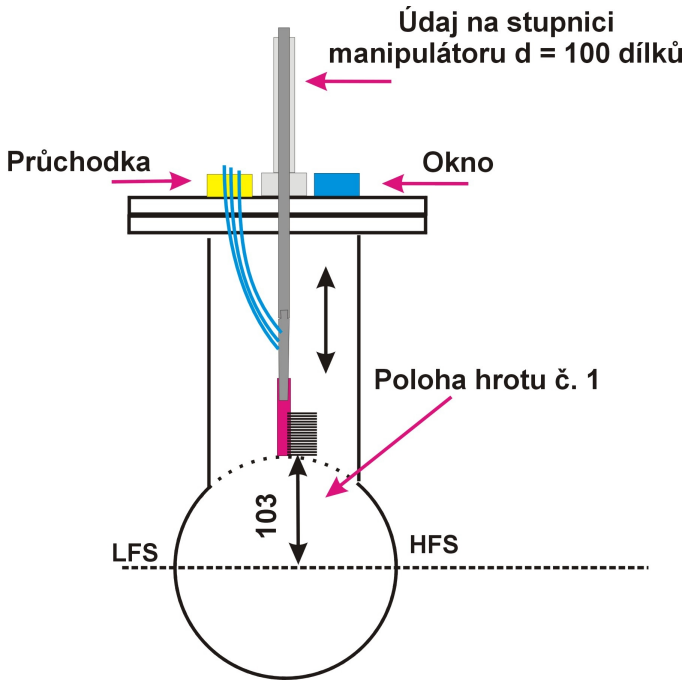


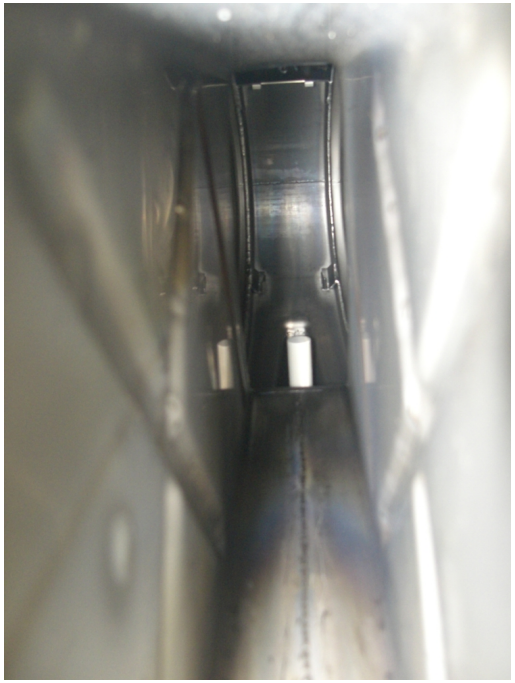
He spectrum No:7163

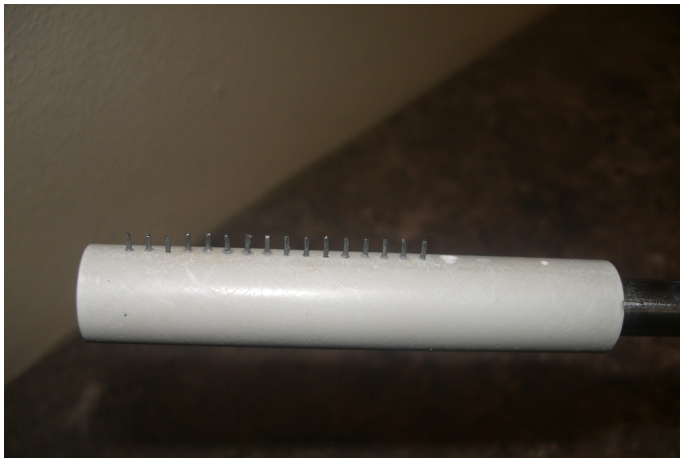
SouthEast-Bottom: Rake probe

Description, Discharge sequence

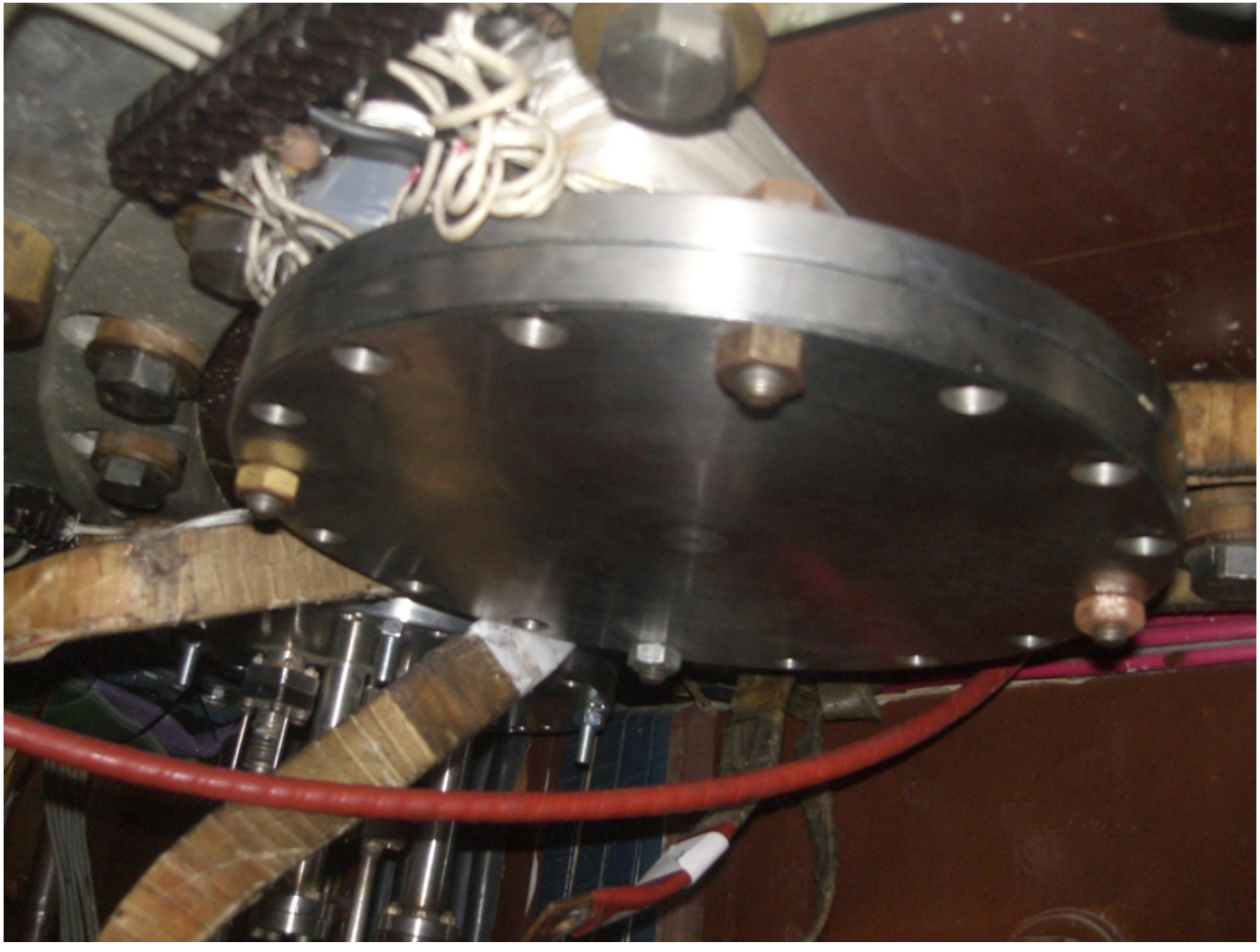
Rake probe (2012)



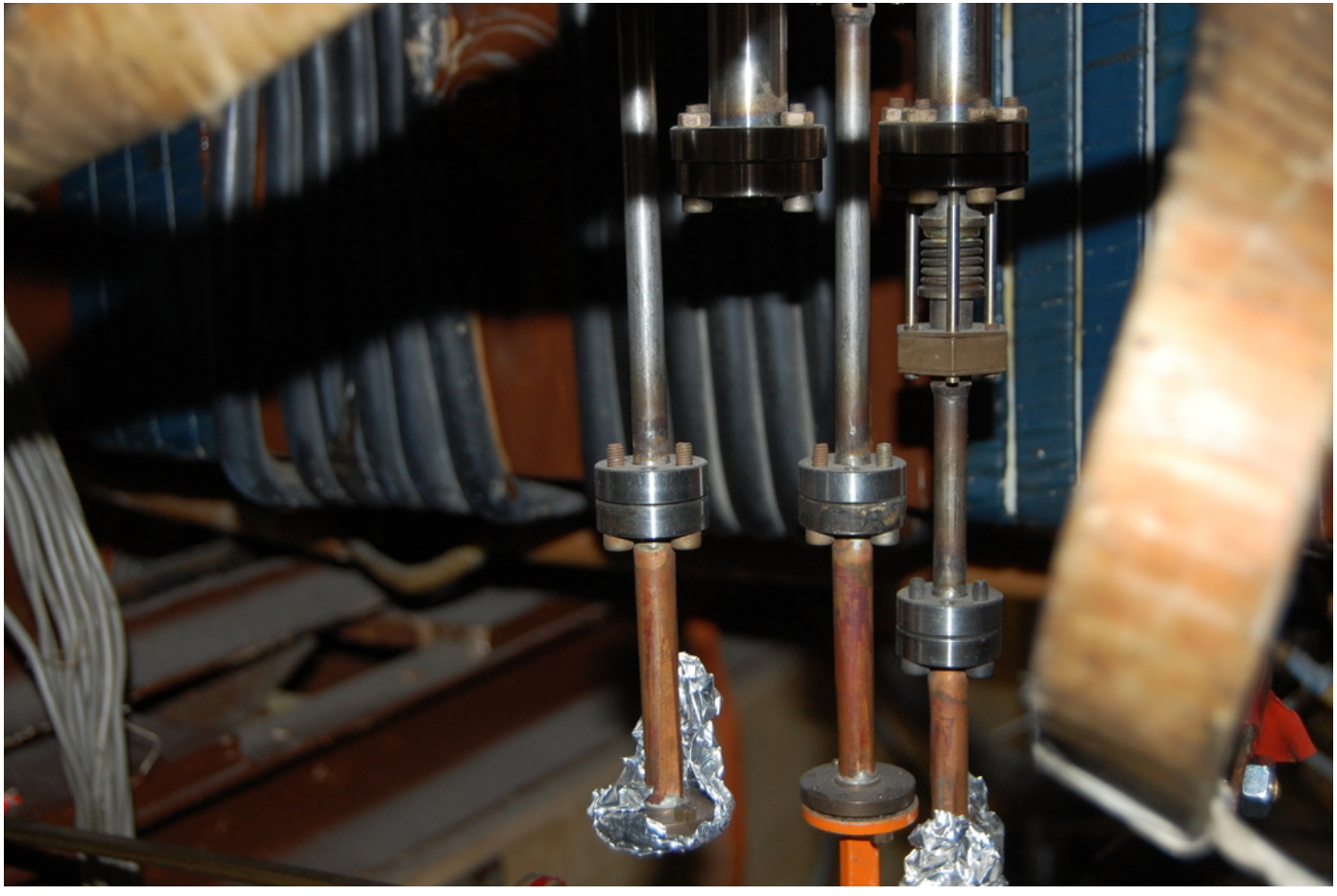




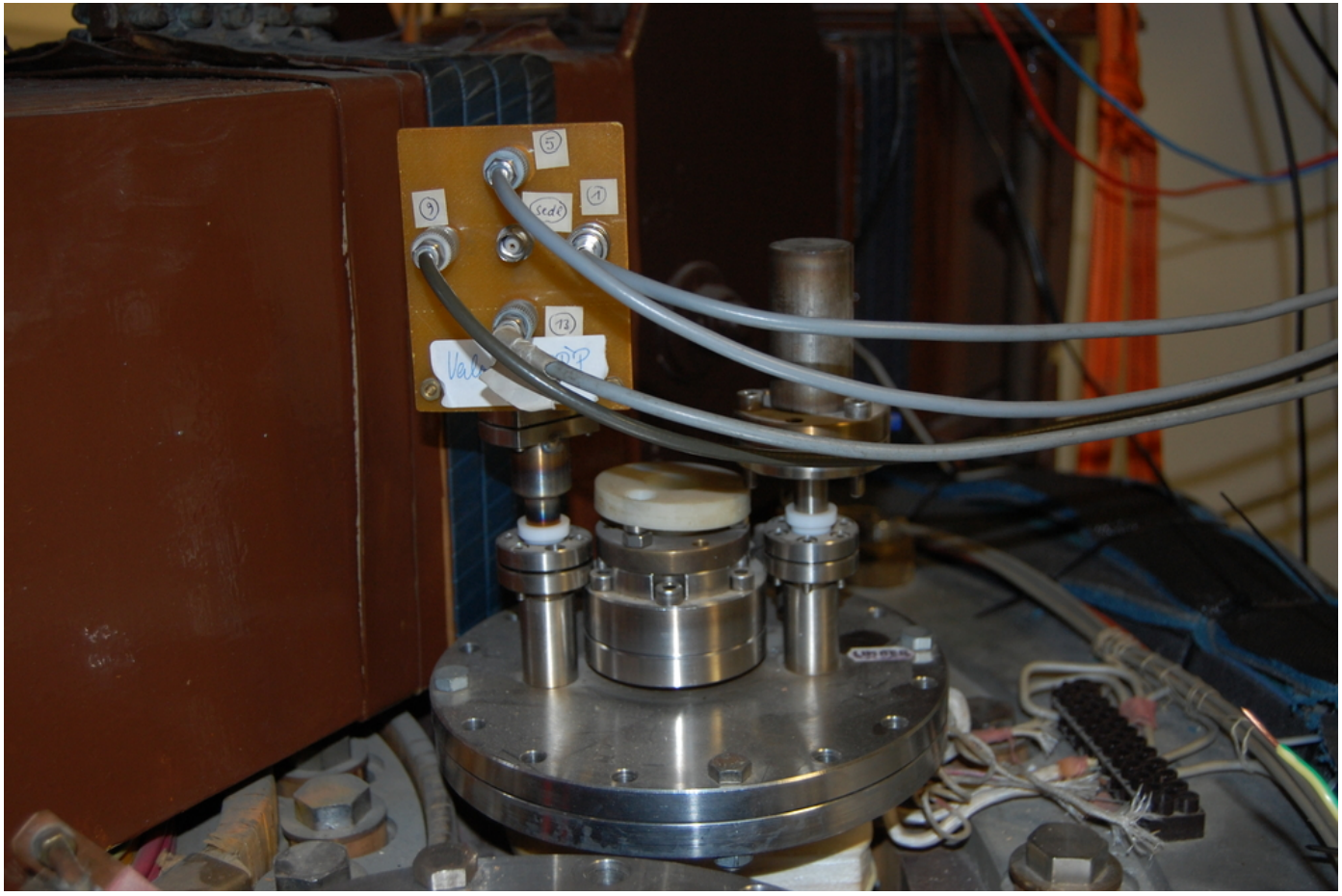
South-Bottom: vacant



SouthWest-Bottom port: Interferometry - output

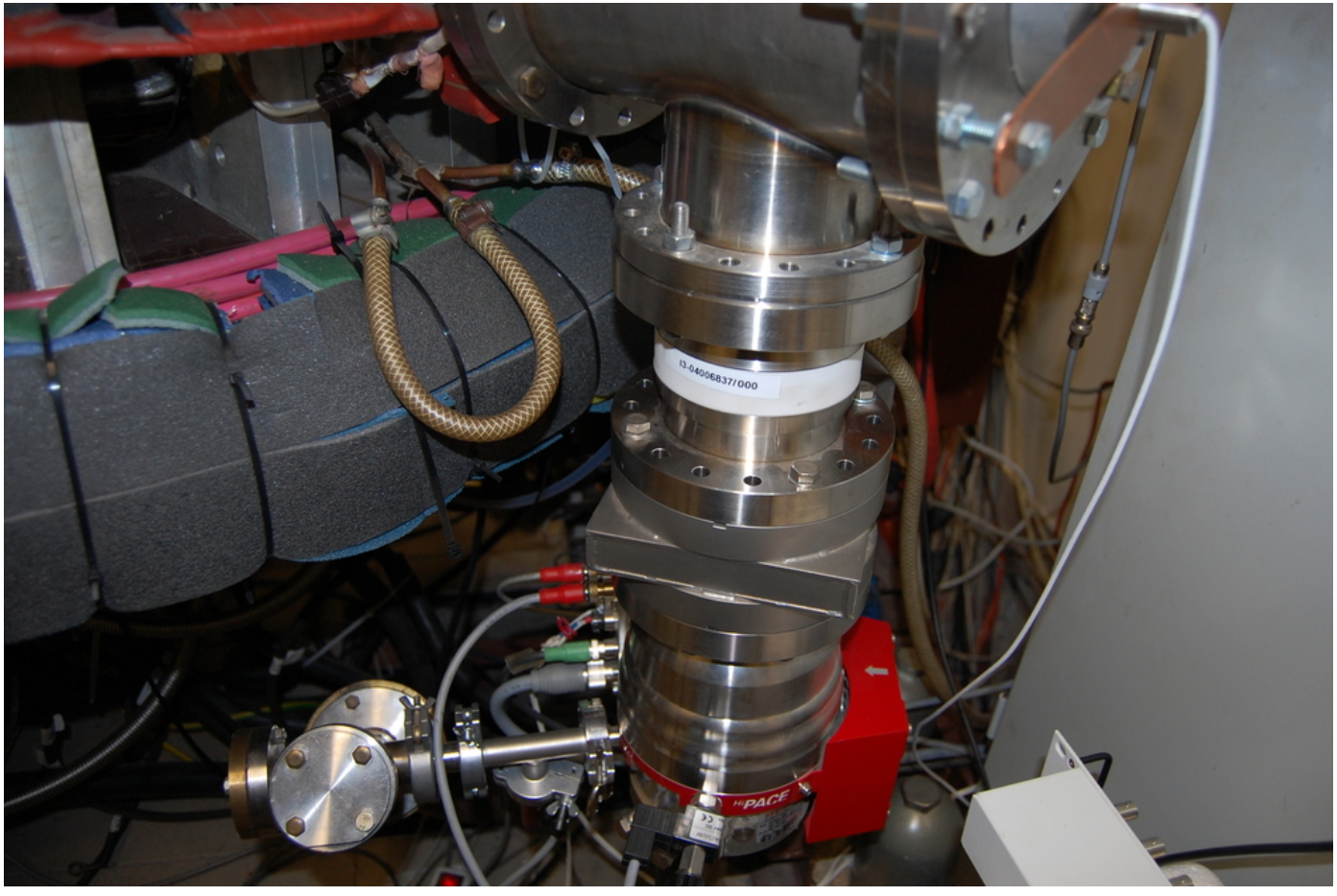


NorthEast-Upper: Mirnov coils

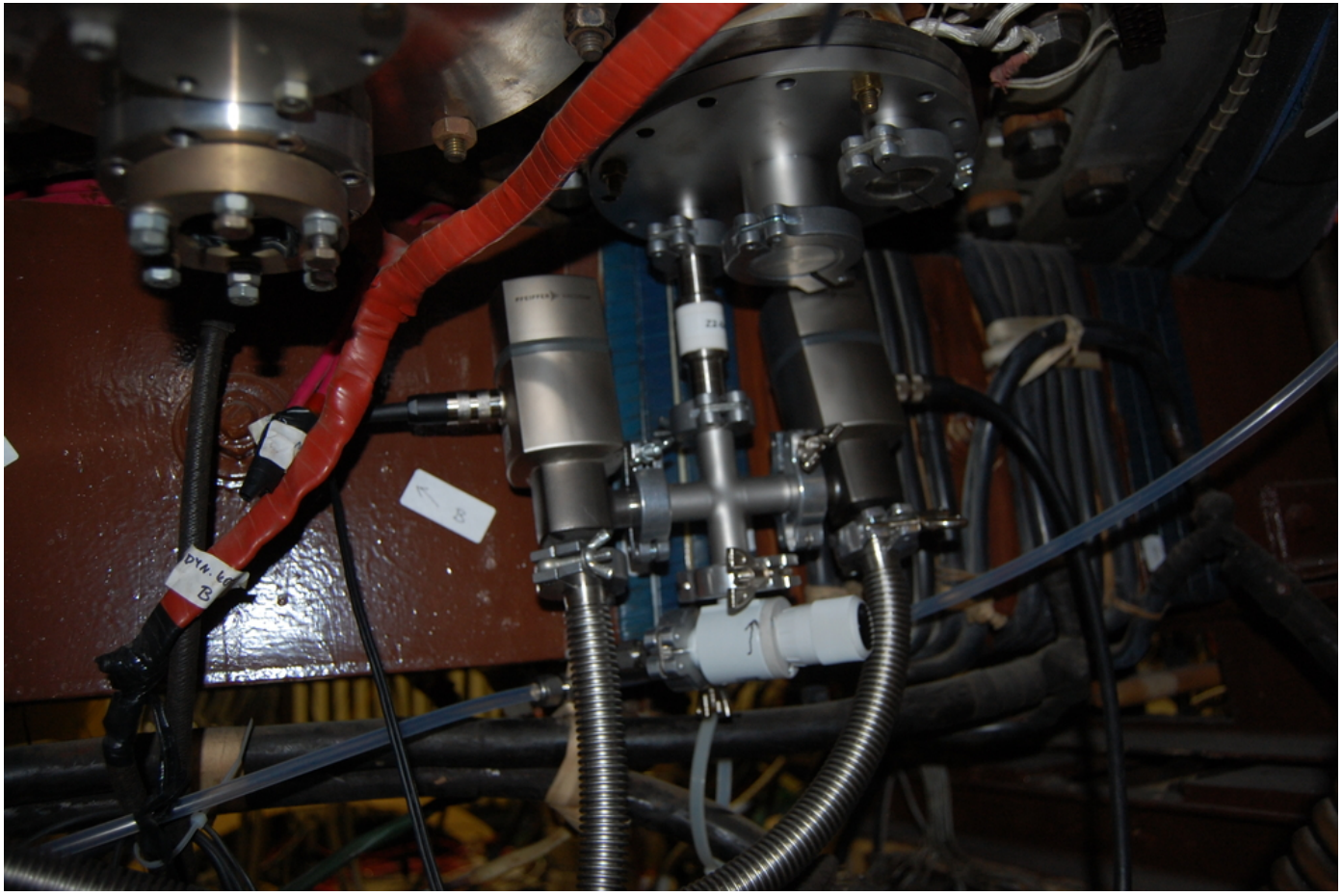


Description

NorthEast-Middle: Vacuum Stand

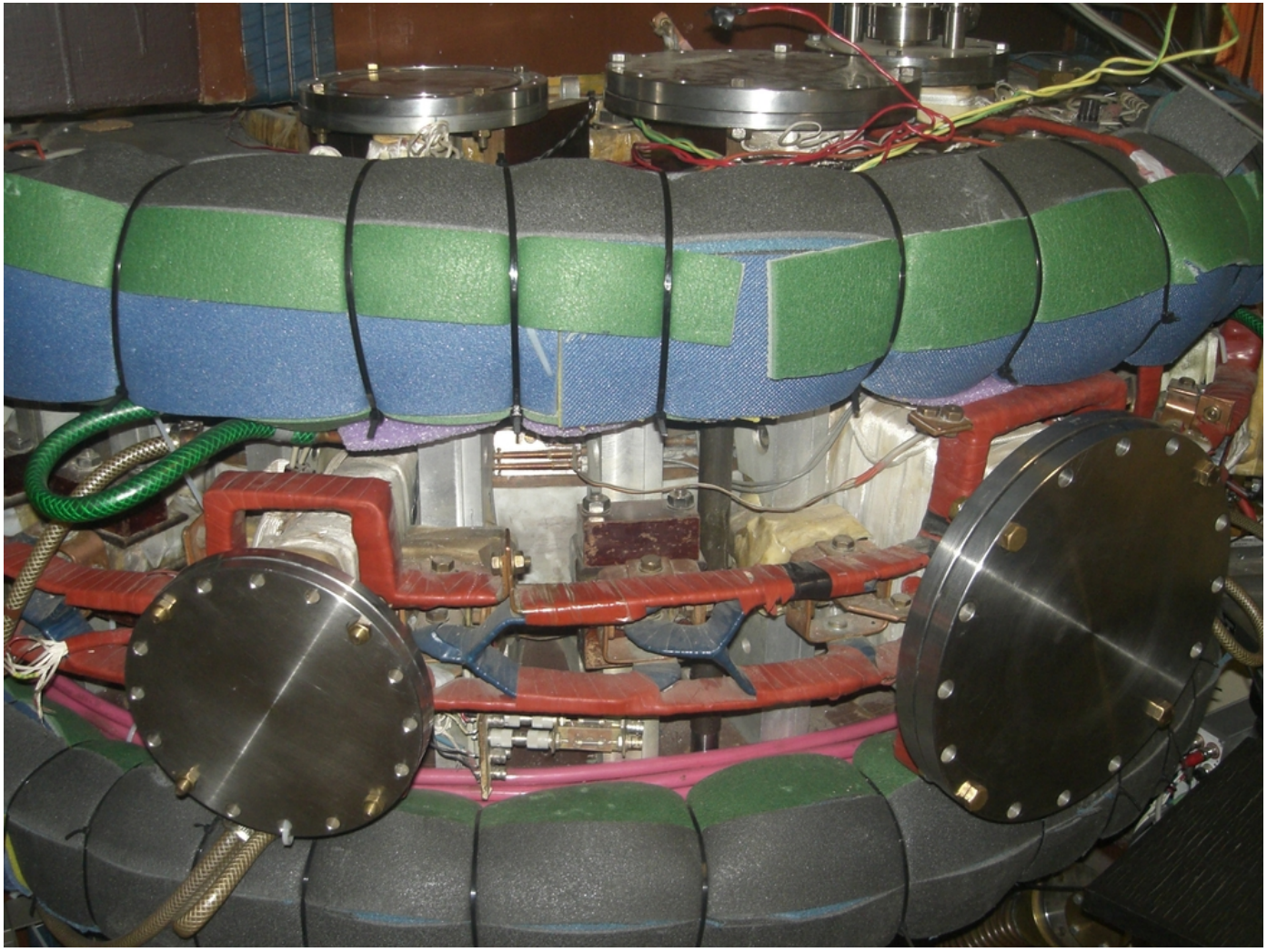


NorthEast - Bottom: Gas injection system - H_2, Air, He

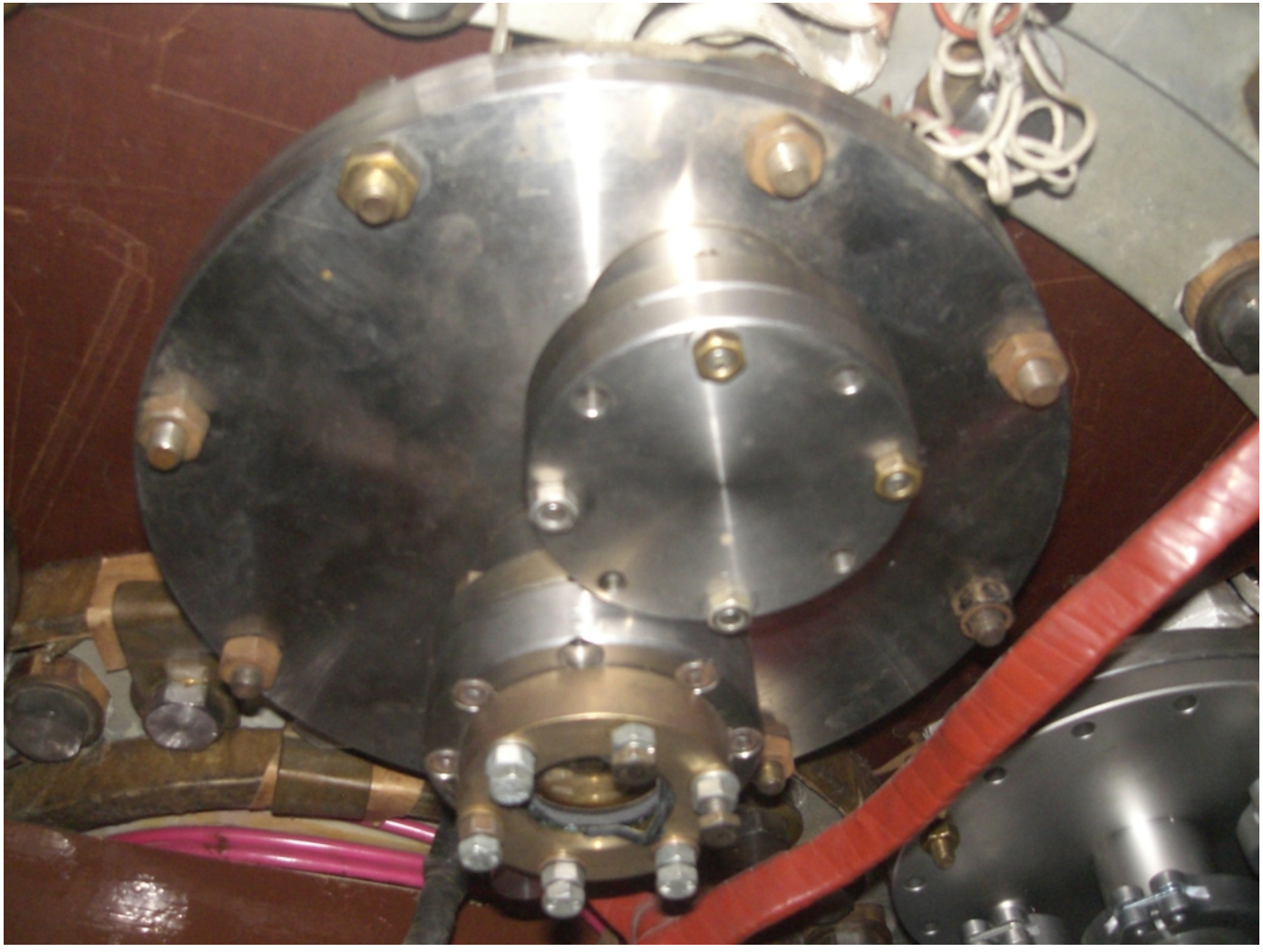


Gas pressure evolution

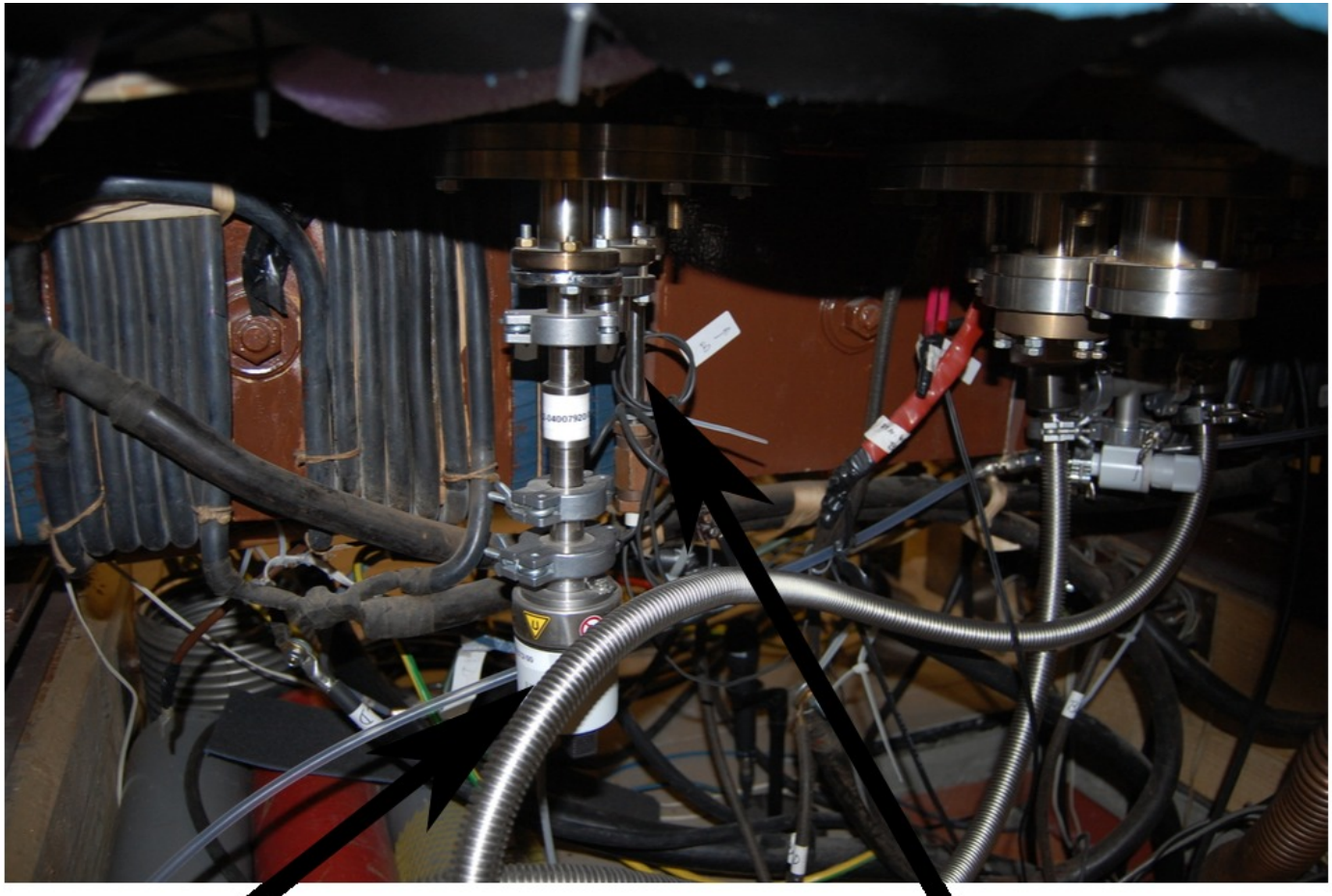
NorthWest and North - Top and Middle: vacant



North - Bottom: vacant



NorthWest - Bottom: Vacuum Gauge & Preionization Gun



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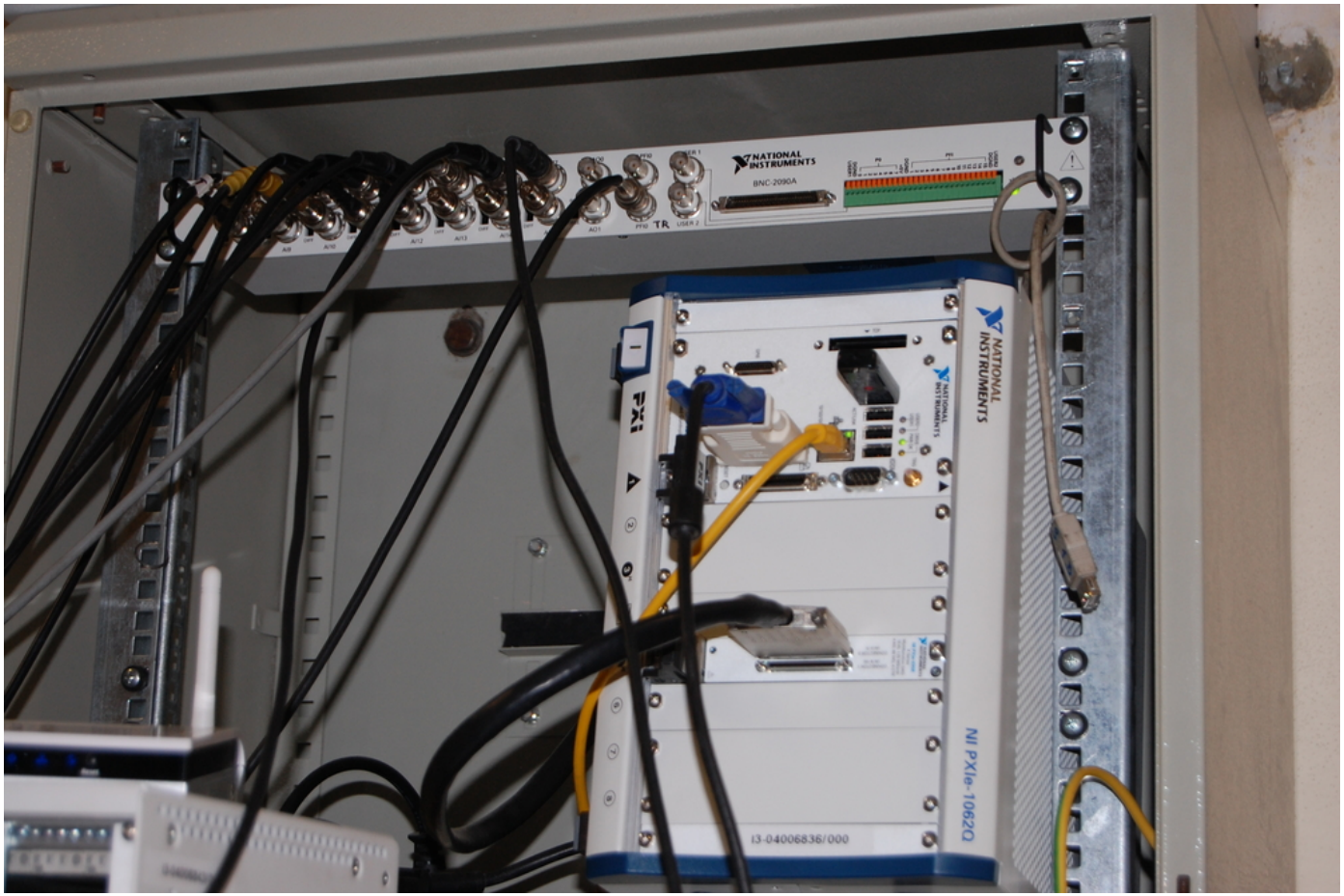
Data acquisition system I - basic

NI PXI-1031, NI PXI-8195, NI PXI-6251

Data acquisition system II - turbo



NI PXIe-1062Q, NI PXIe-8108, NI PXIe-6358

Data acquisition system III - papouchSt

Papouch DAS1210

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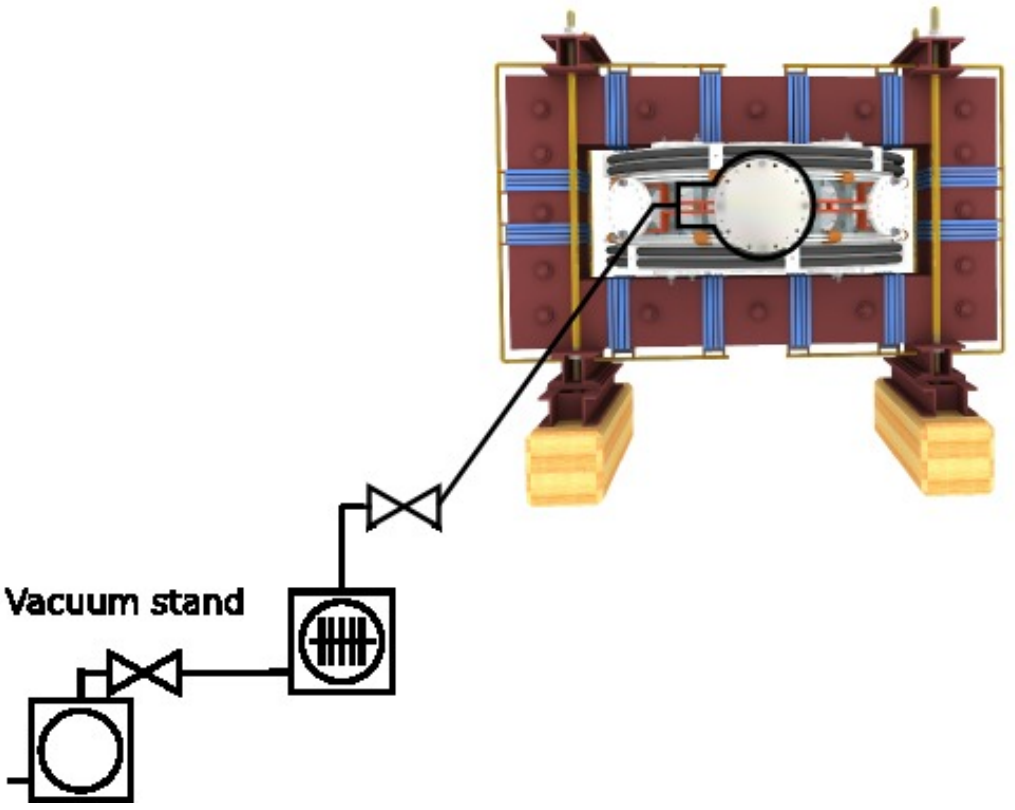
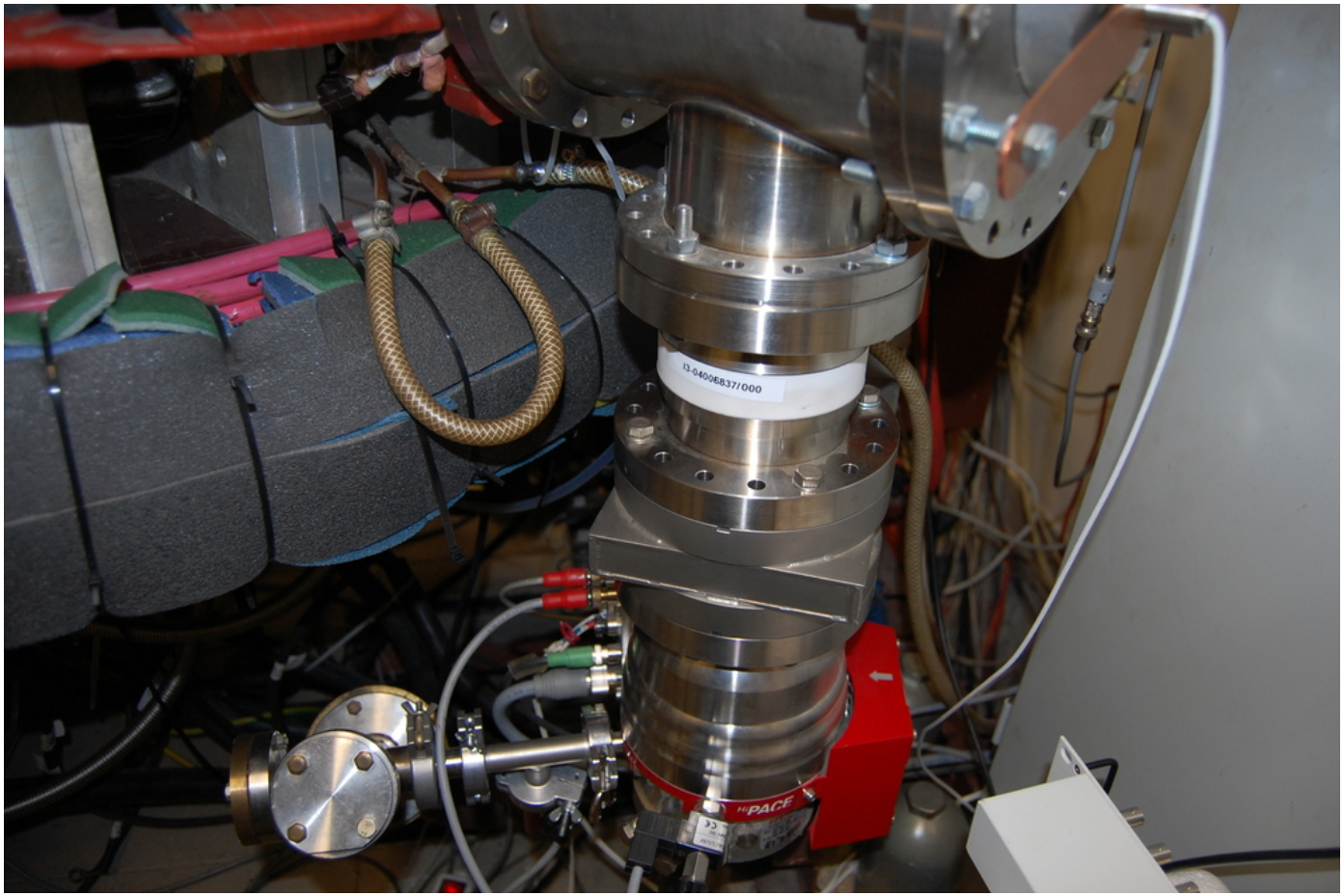
- Preionization
- Energetics infrastructure
- Control system

Vacuum management

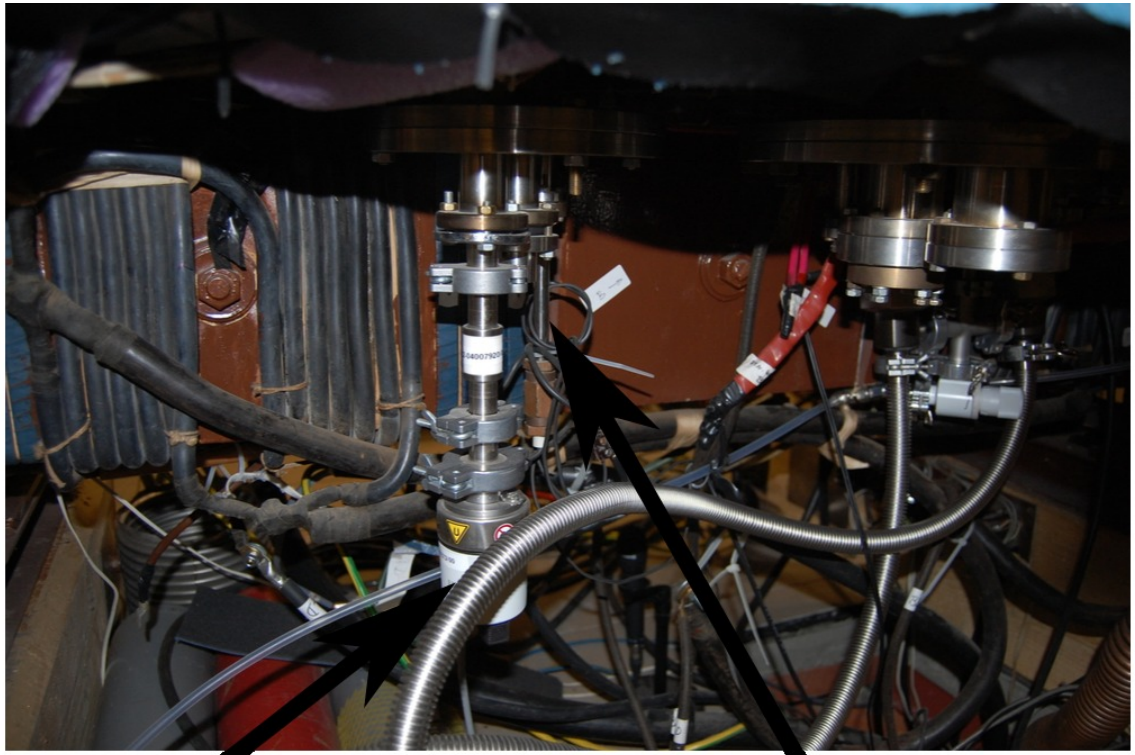


Vacuum Stand - Turbomolecular pump, Ultravacuum gauge, Galvanic insulation



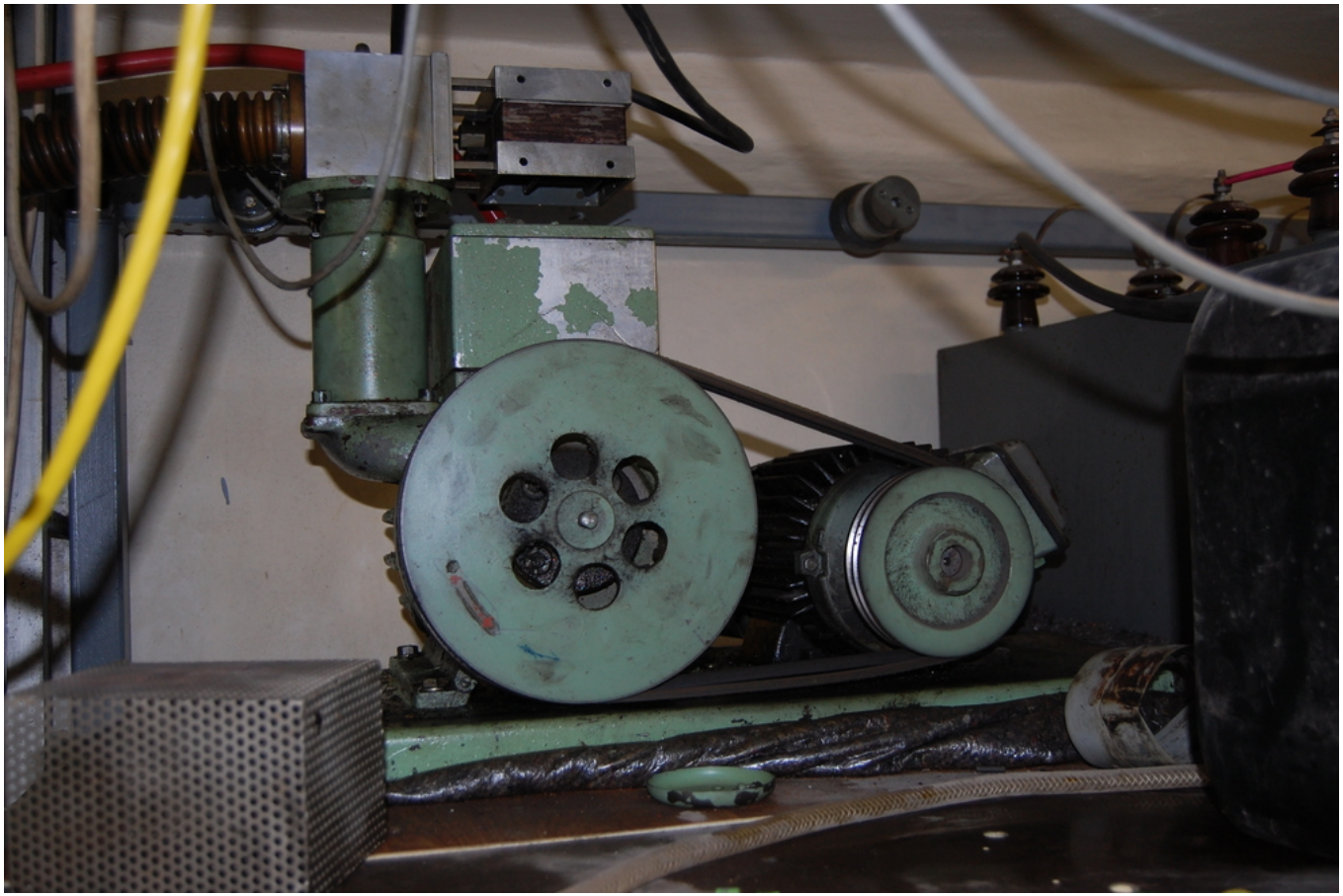
TMP manual, Controller manual

Vacuum Gauge



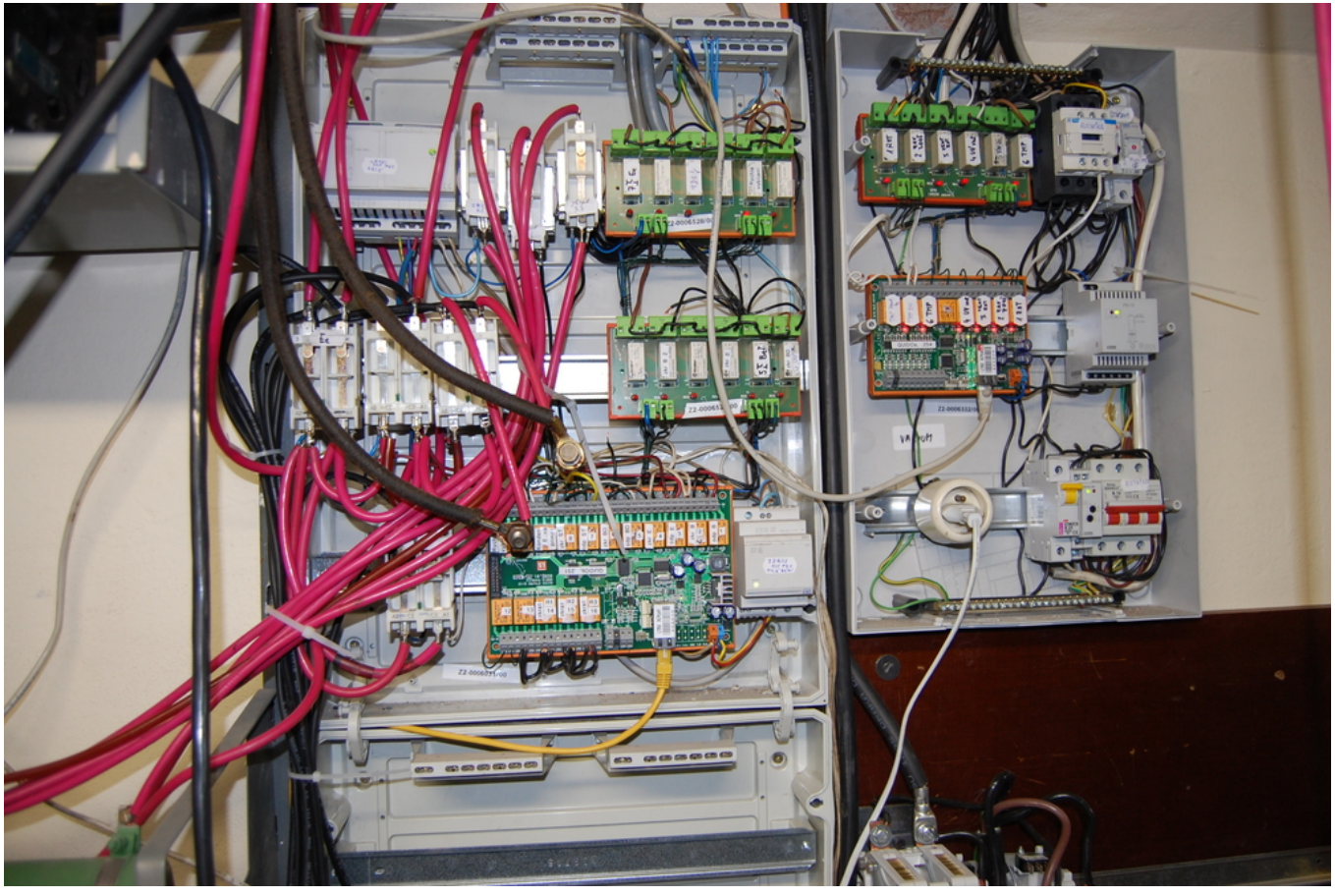
Manual

Rotary Pump with valve



Rotary Pump

Control system for capacitor charging and vacuum management



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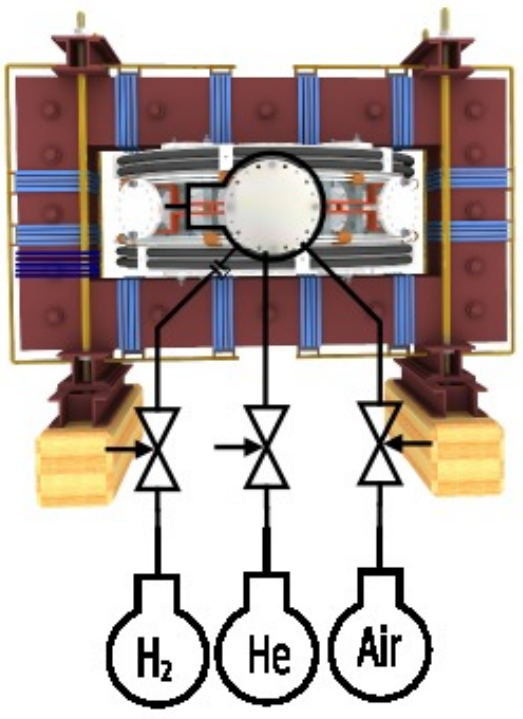
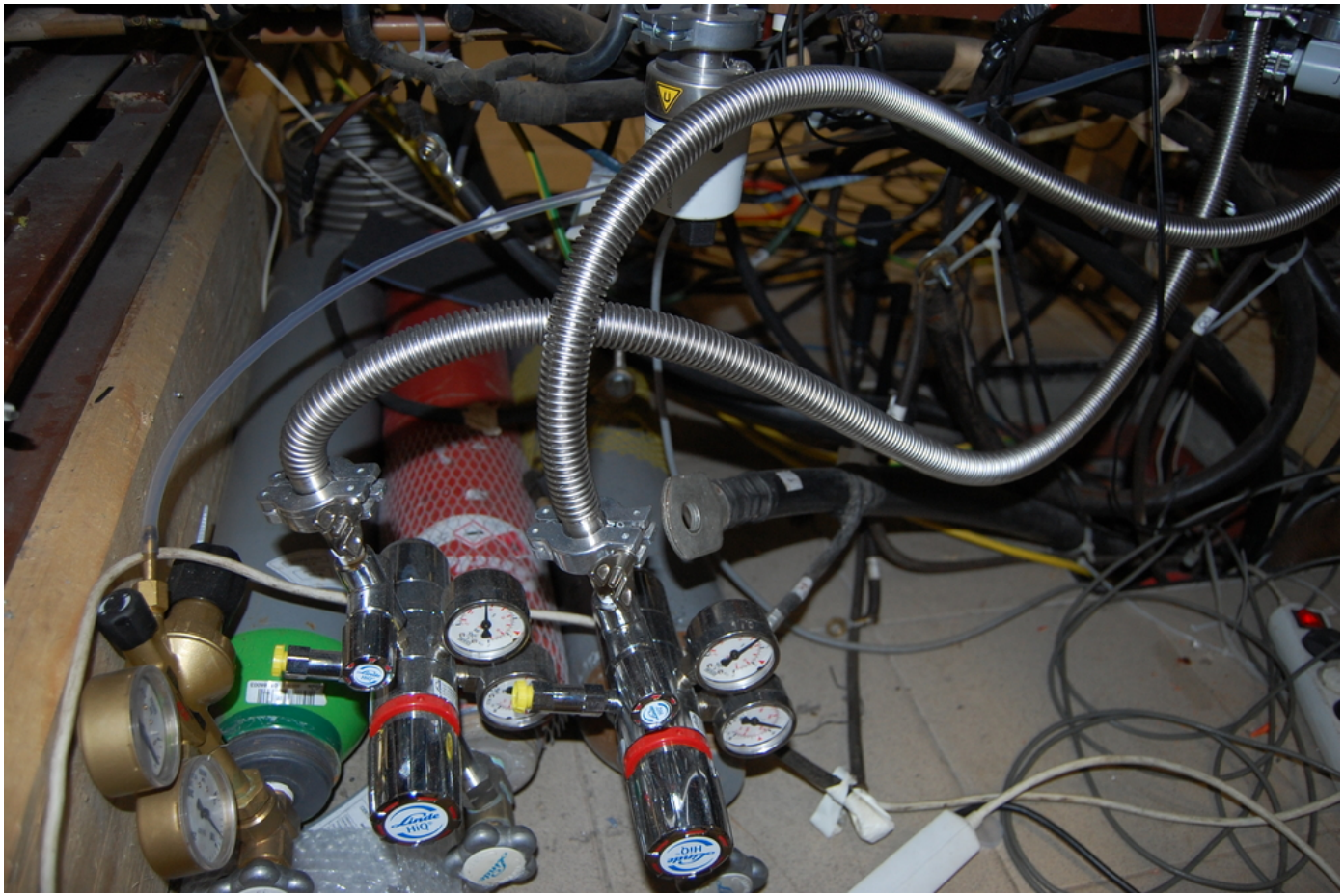
Gas management

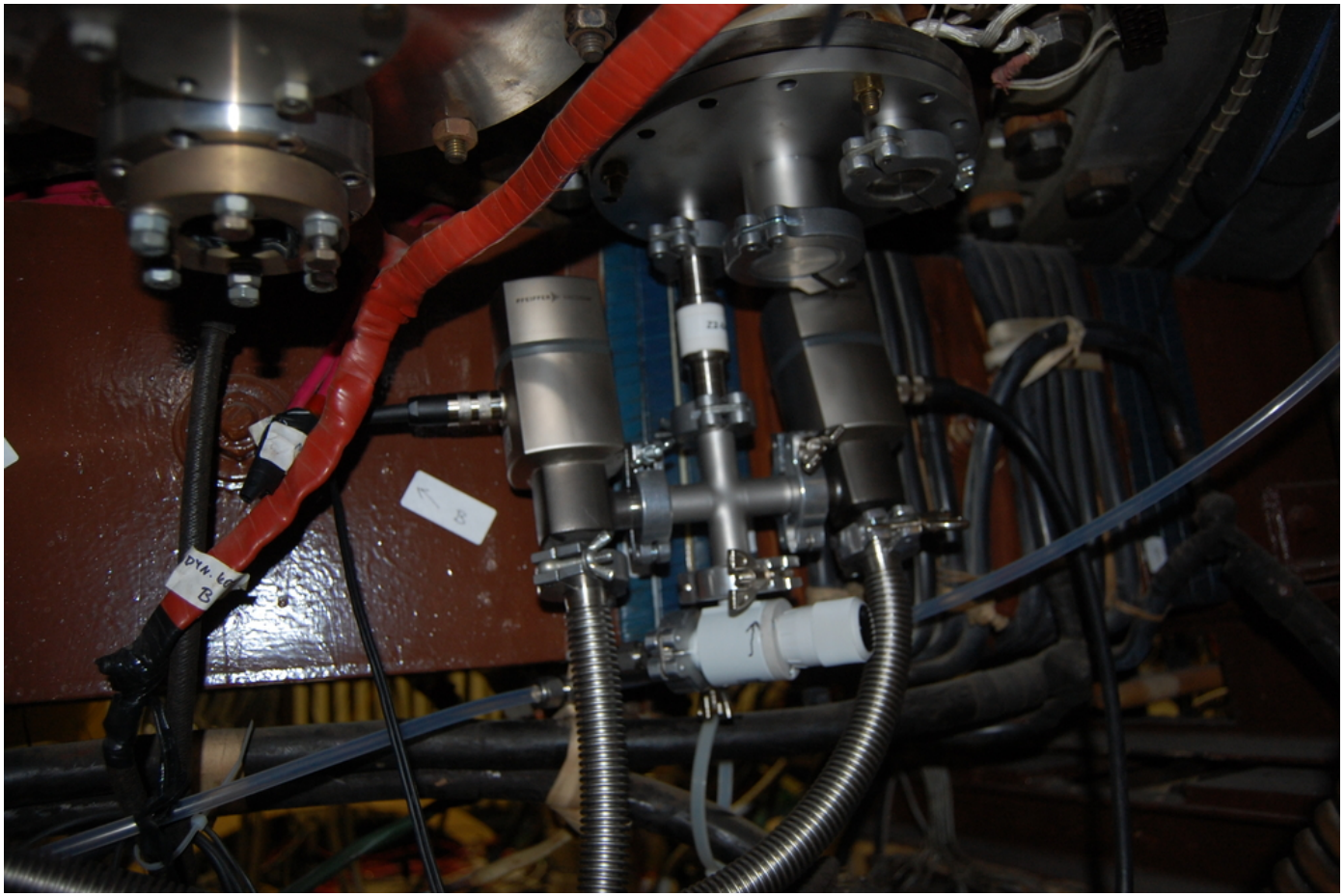


Gas reservoirs - Air, H_2, He



Comparison of discharges in H and He

Gas injection system - H_2, Air, He



Manual

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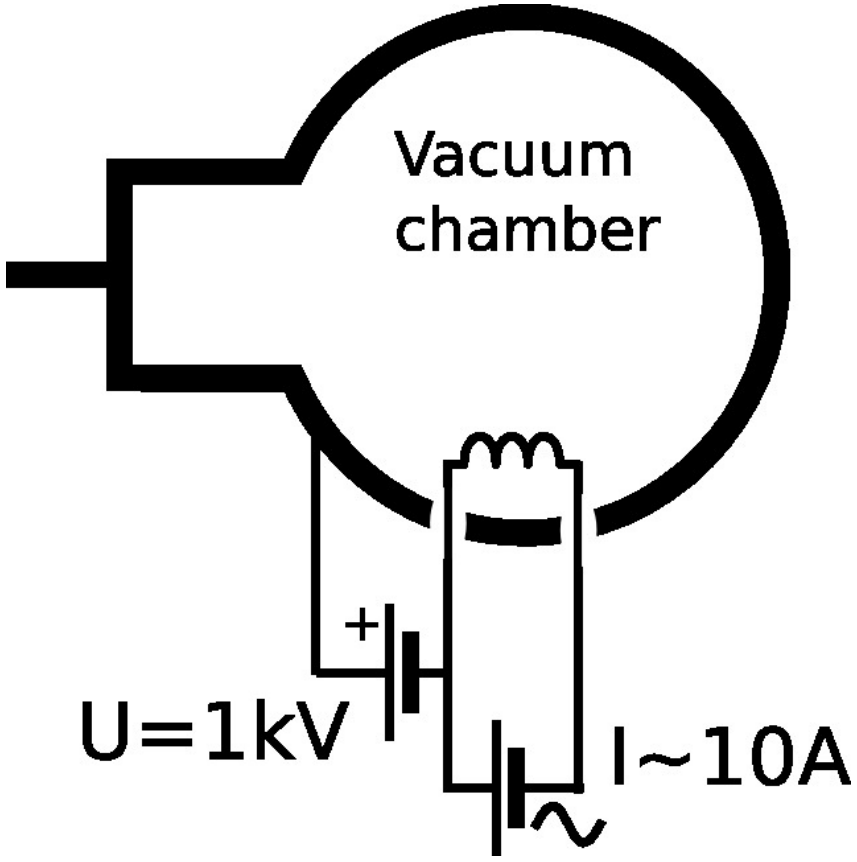
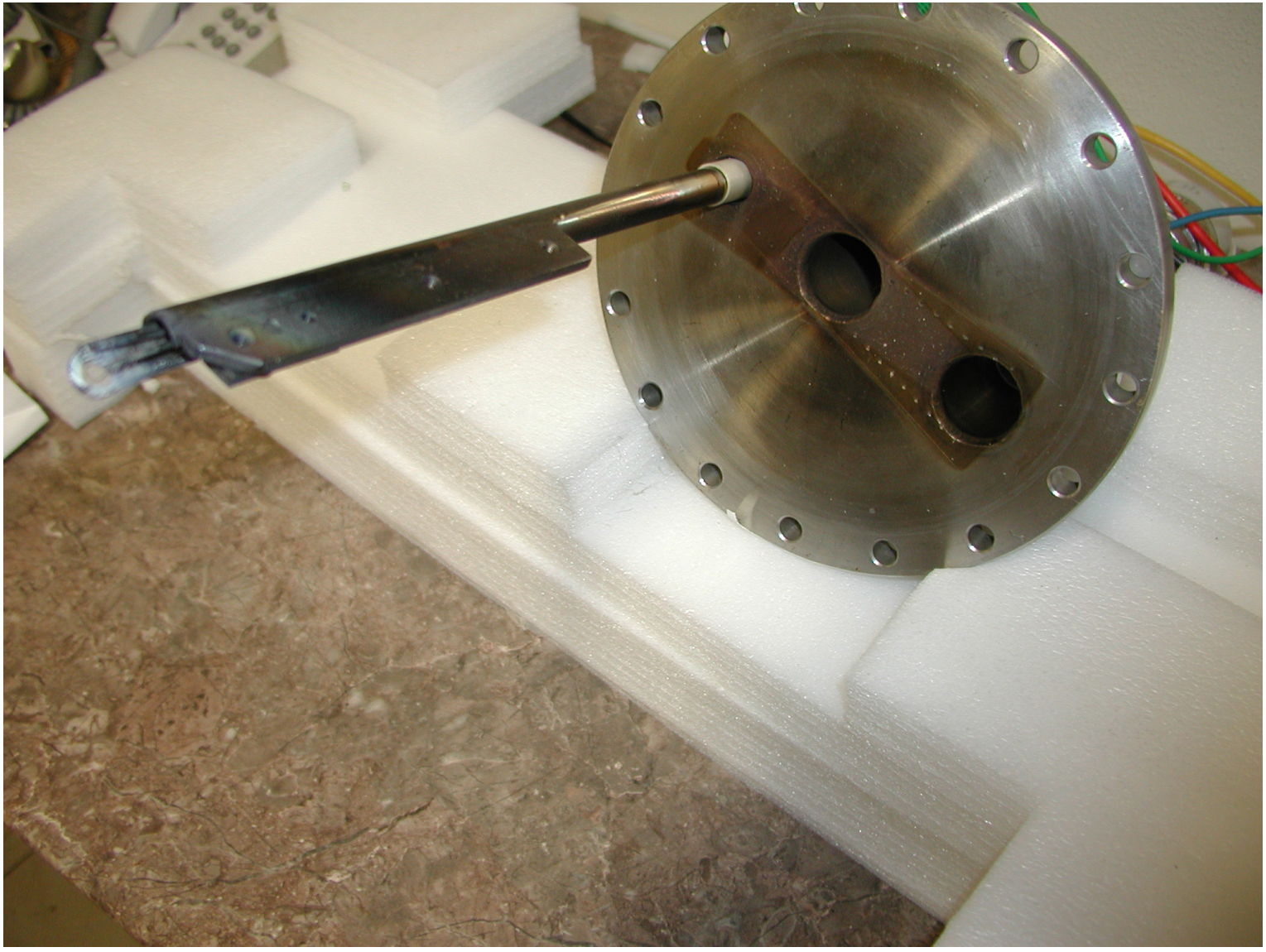
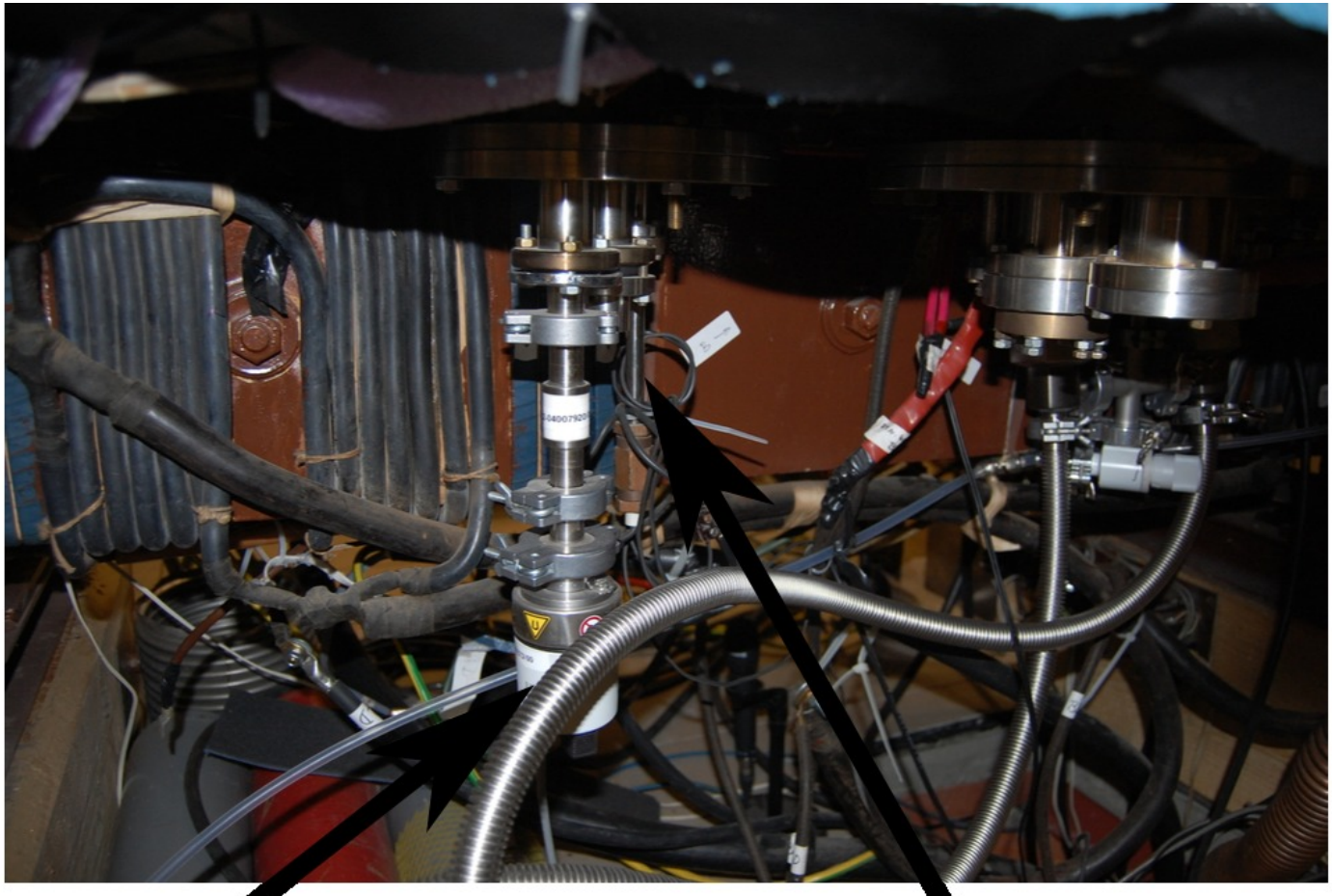
Preionization - scheme



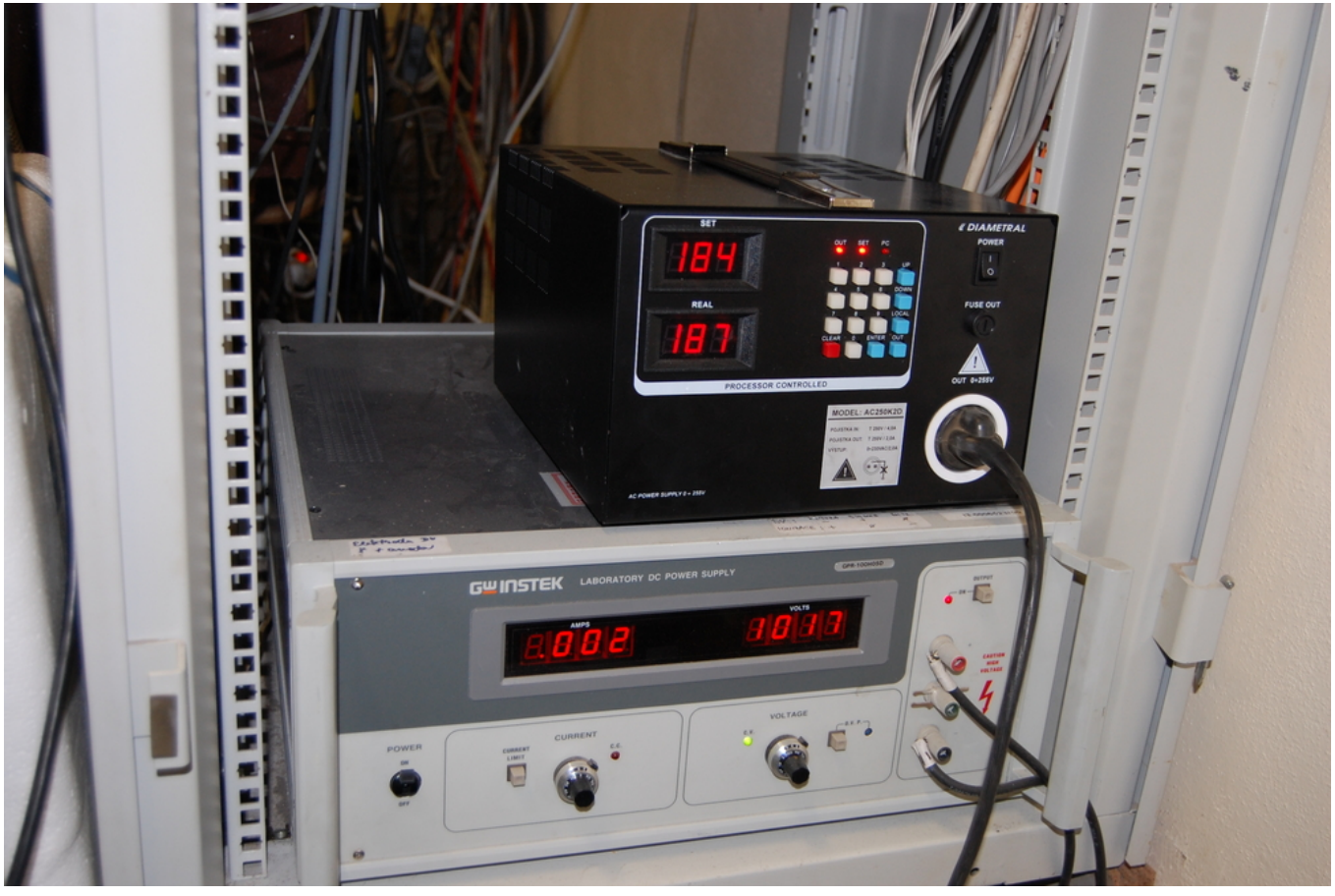
Preionization Gun



NorthWest - Bottom: Vacuum Gauge & Preionization Gun



Preionization - power sources



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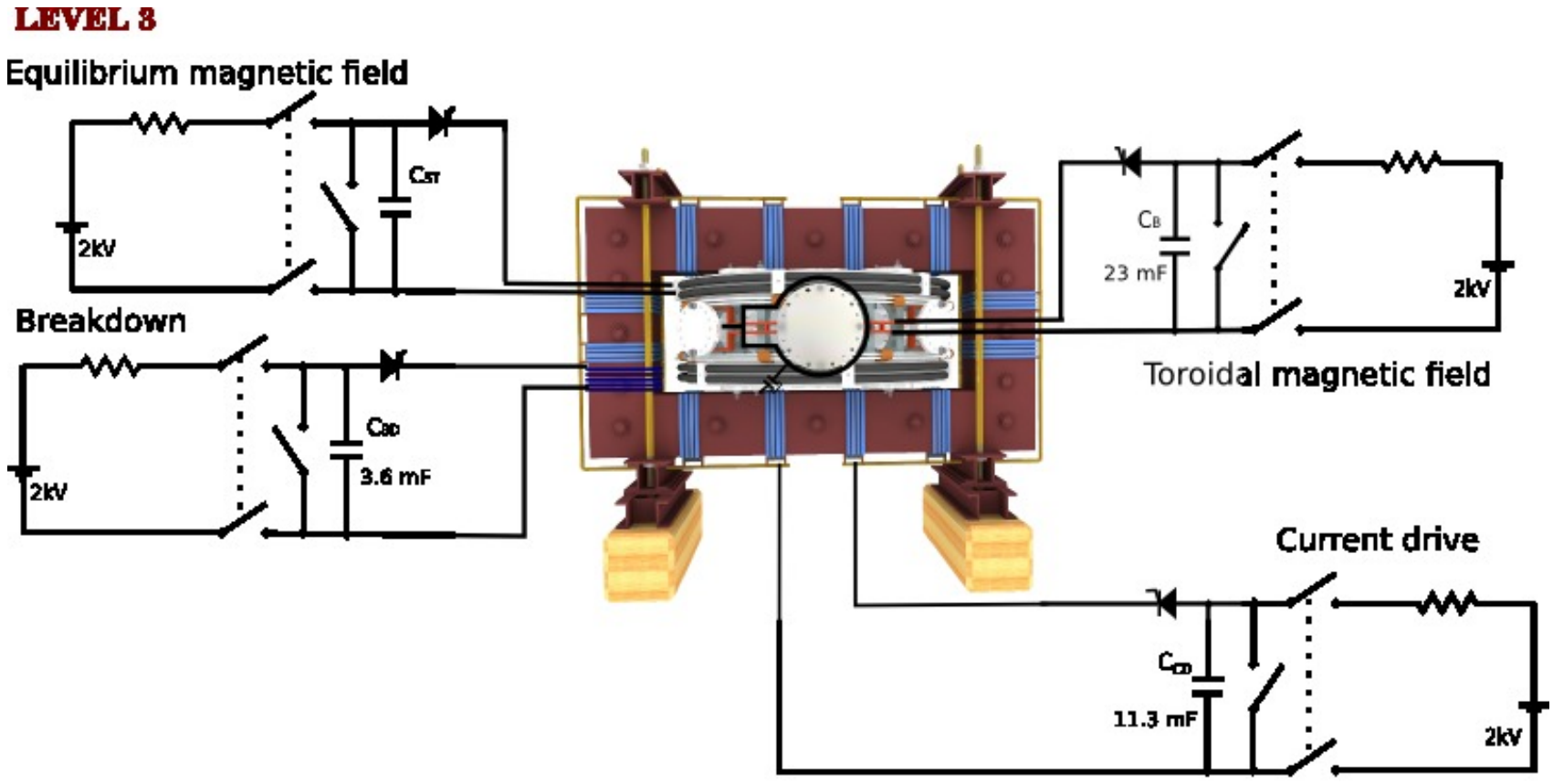
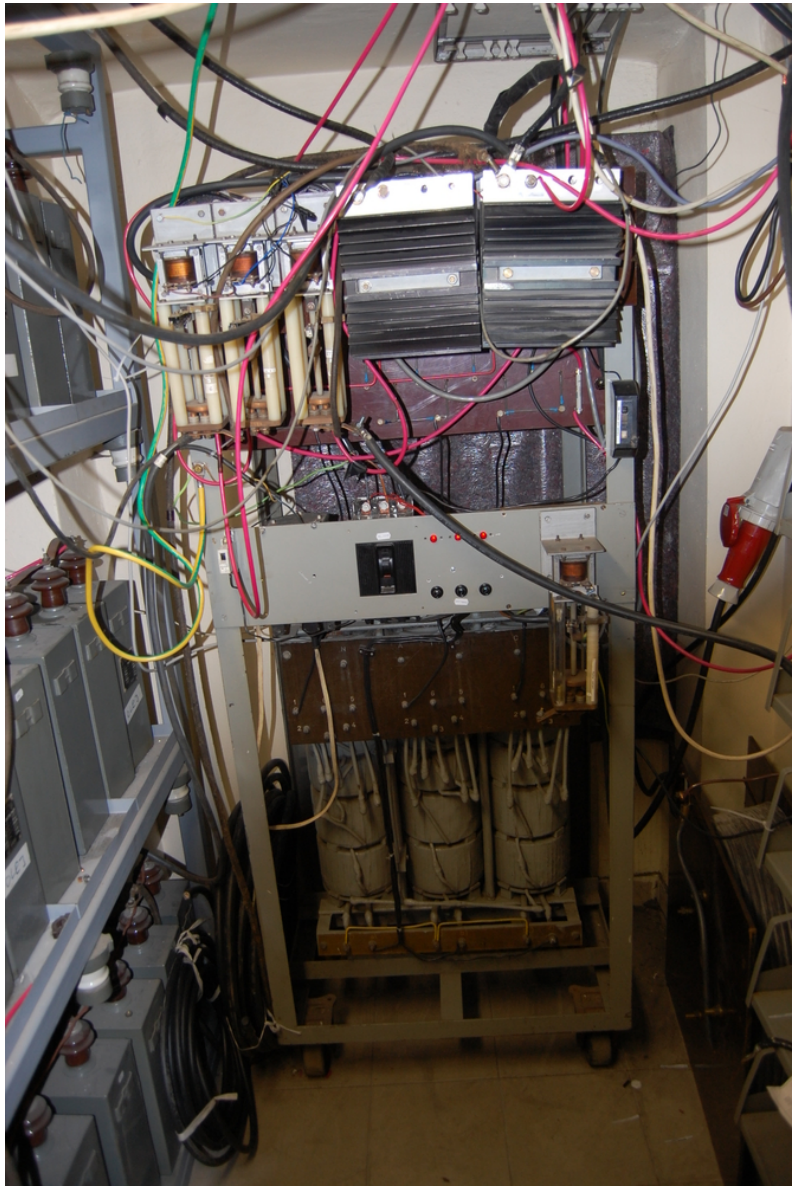
Energetics infrastructure - setup

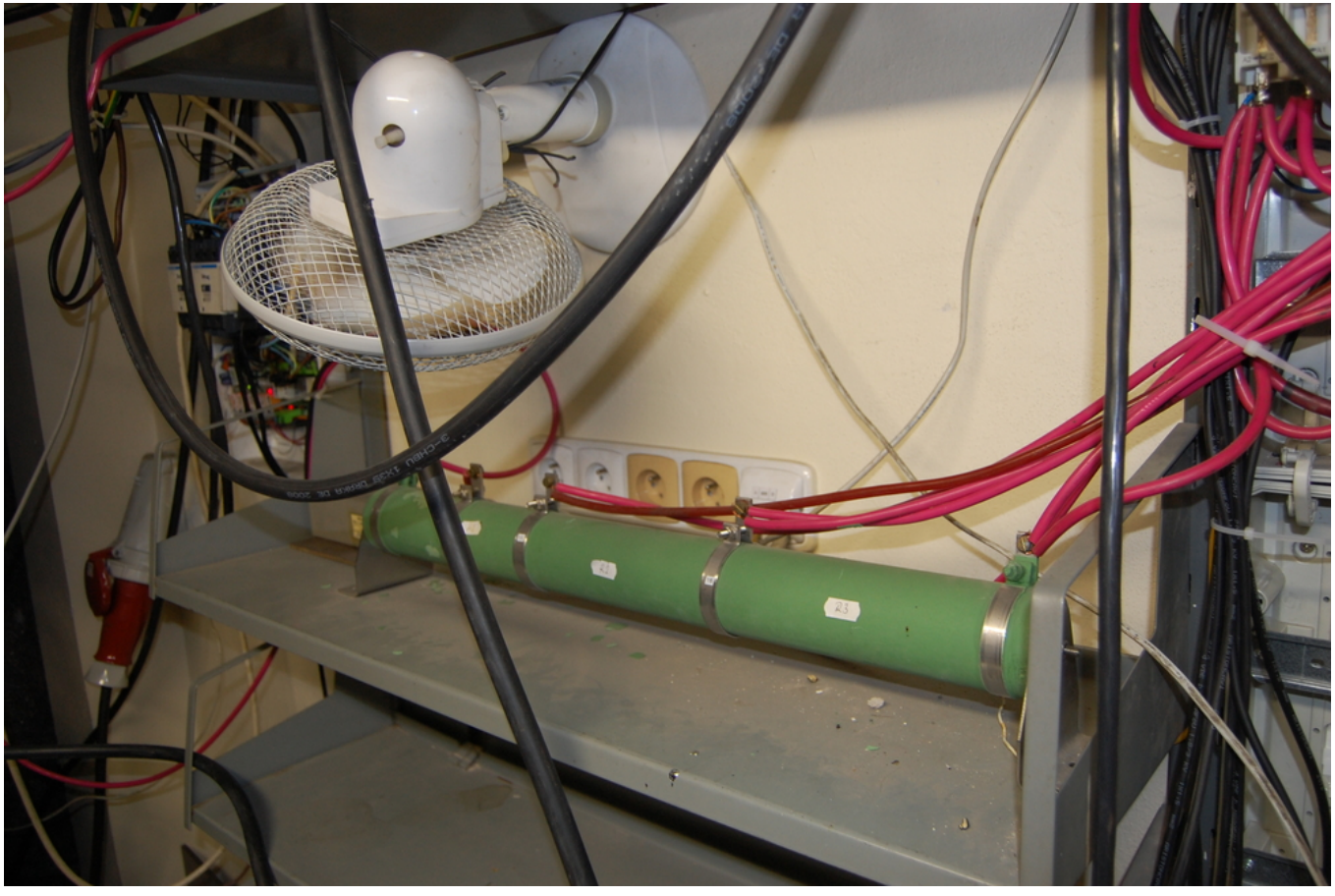


2kV power source, short circuit system and thyristors for breakdown and plasma stabilization

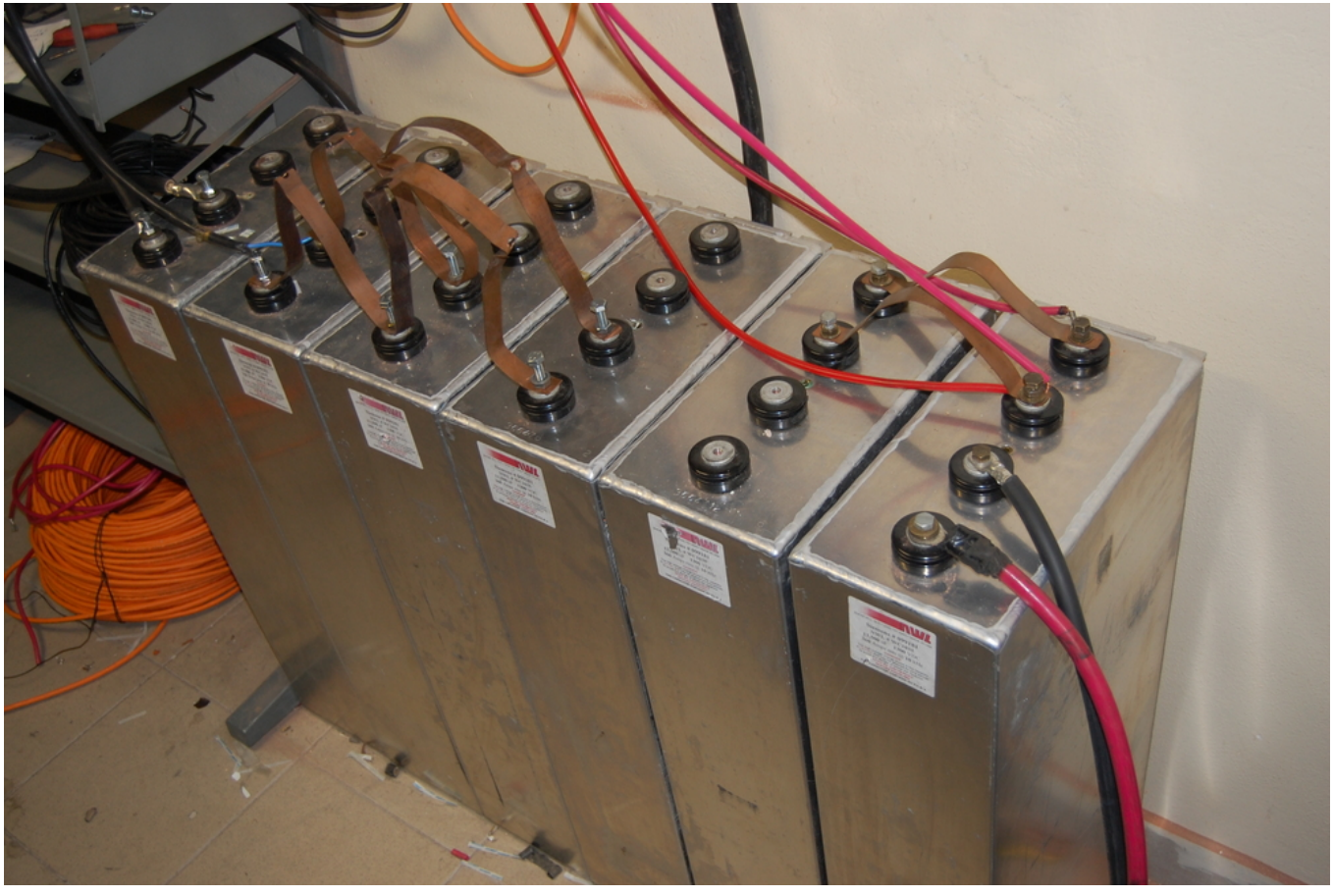


Thyristors for magnetic field and current drive

Charging resistor (common for all 4 circuits)



Capacitor bank for toroidal magnetic field

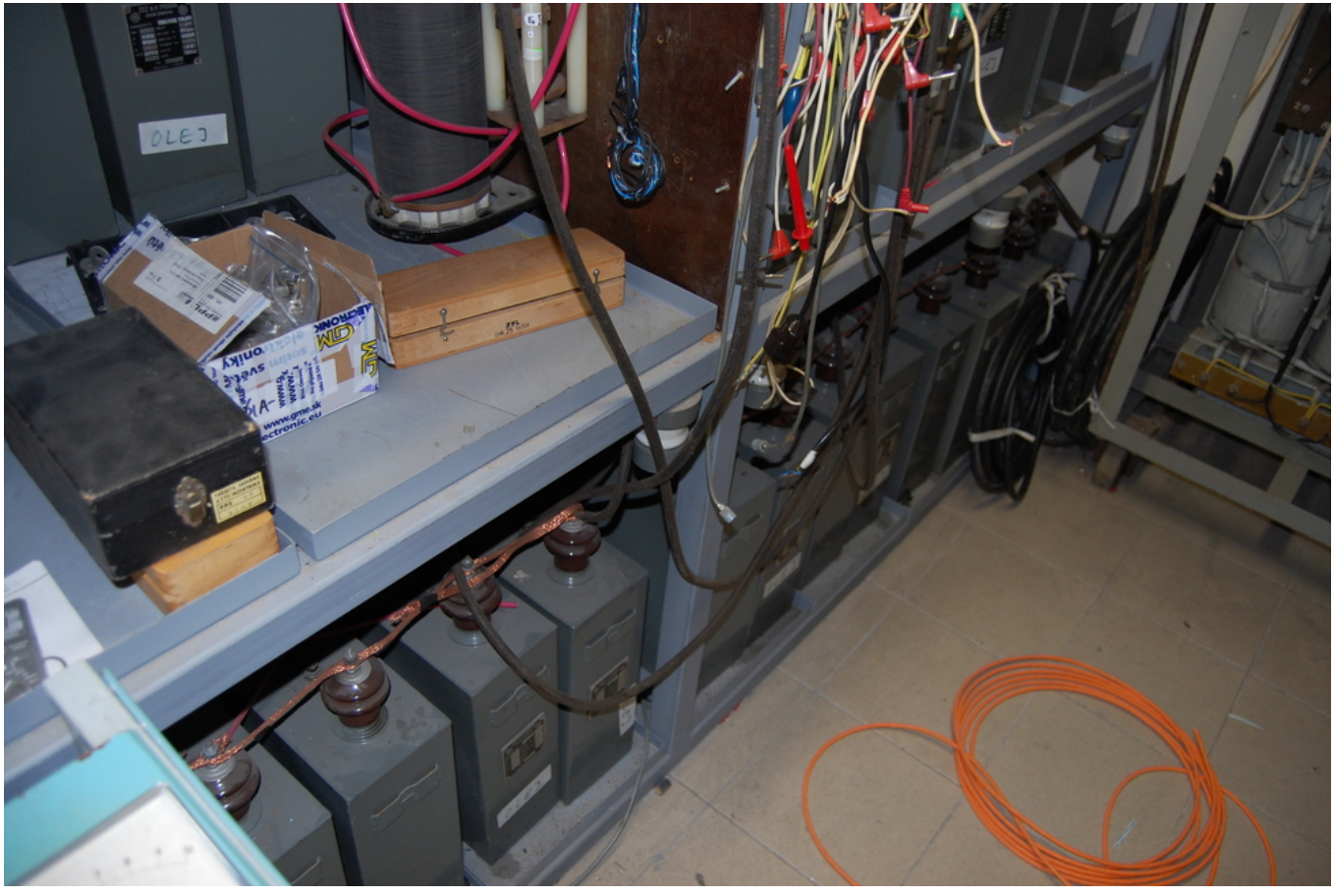


13500 fd, 1300 Volt, 11500 Joule Oil-Filled Energy Storage Capacitor

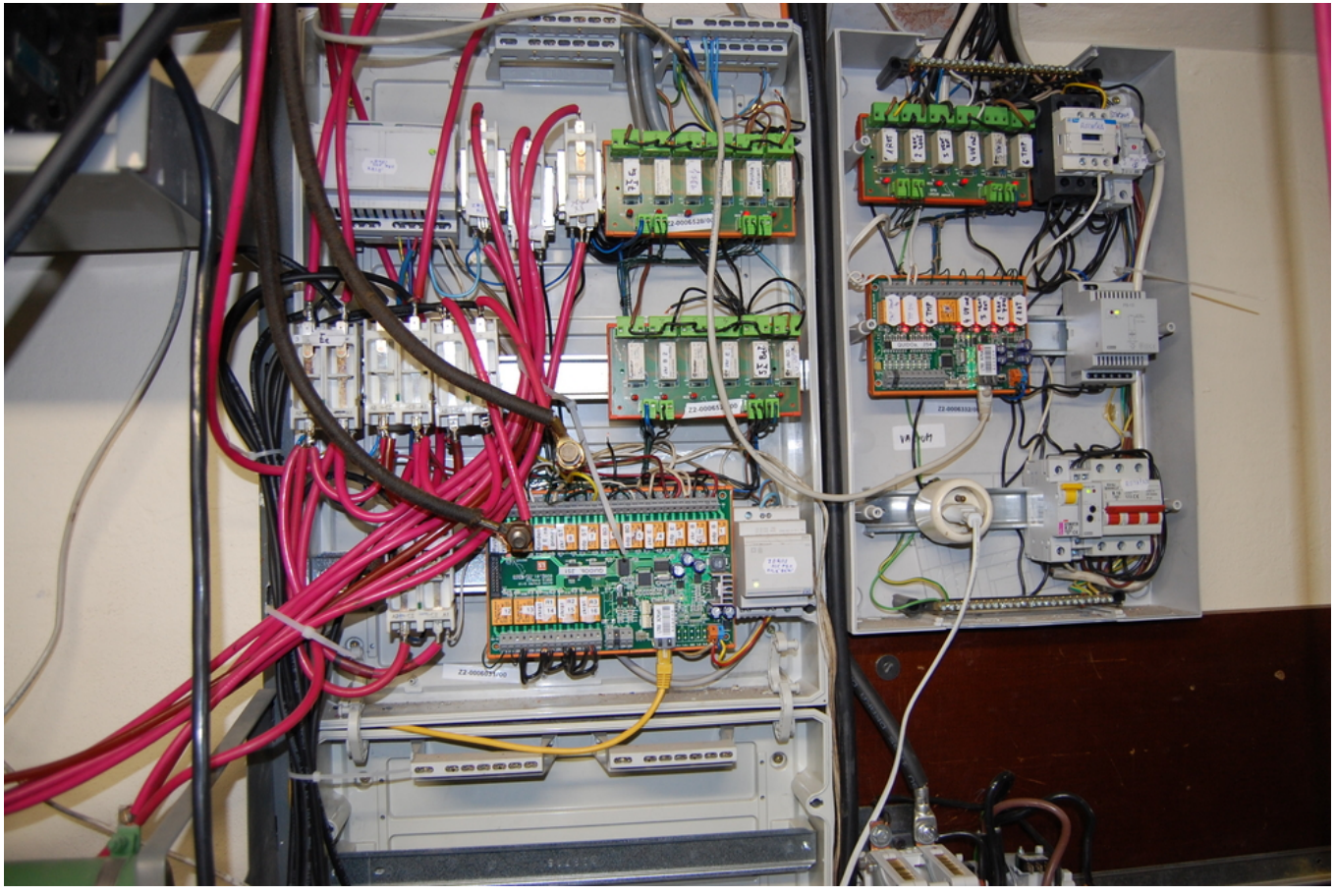
Capacitor bank for current drice

Capacitor bank for breakdown

Capacitor bank for plasma stabilization



Control system for capacitor charging and vacuum management



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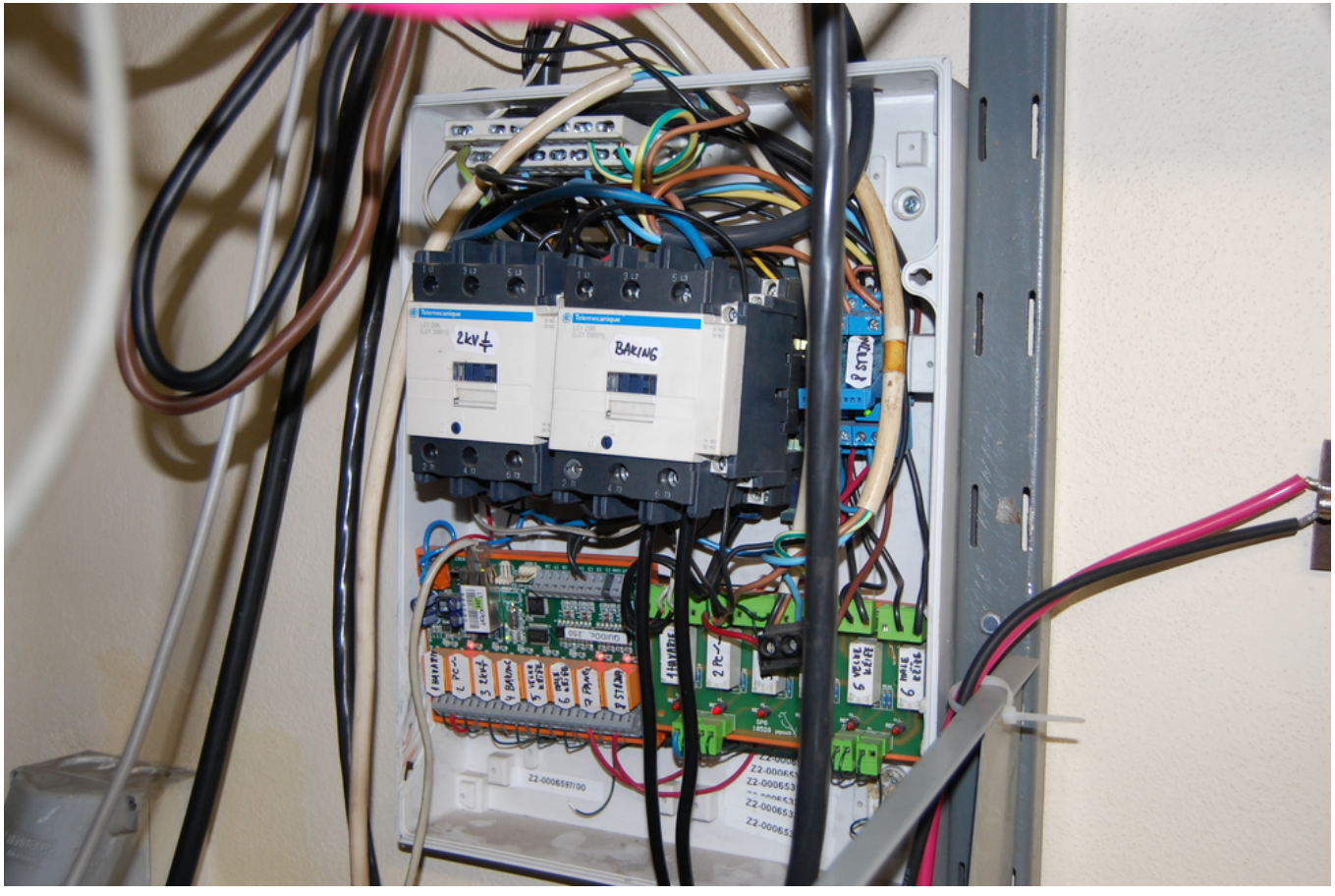
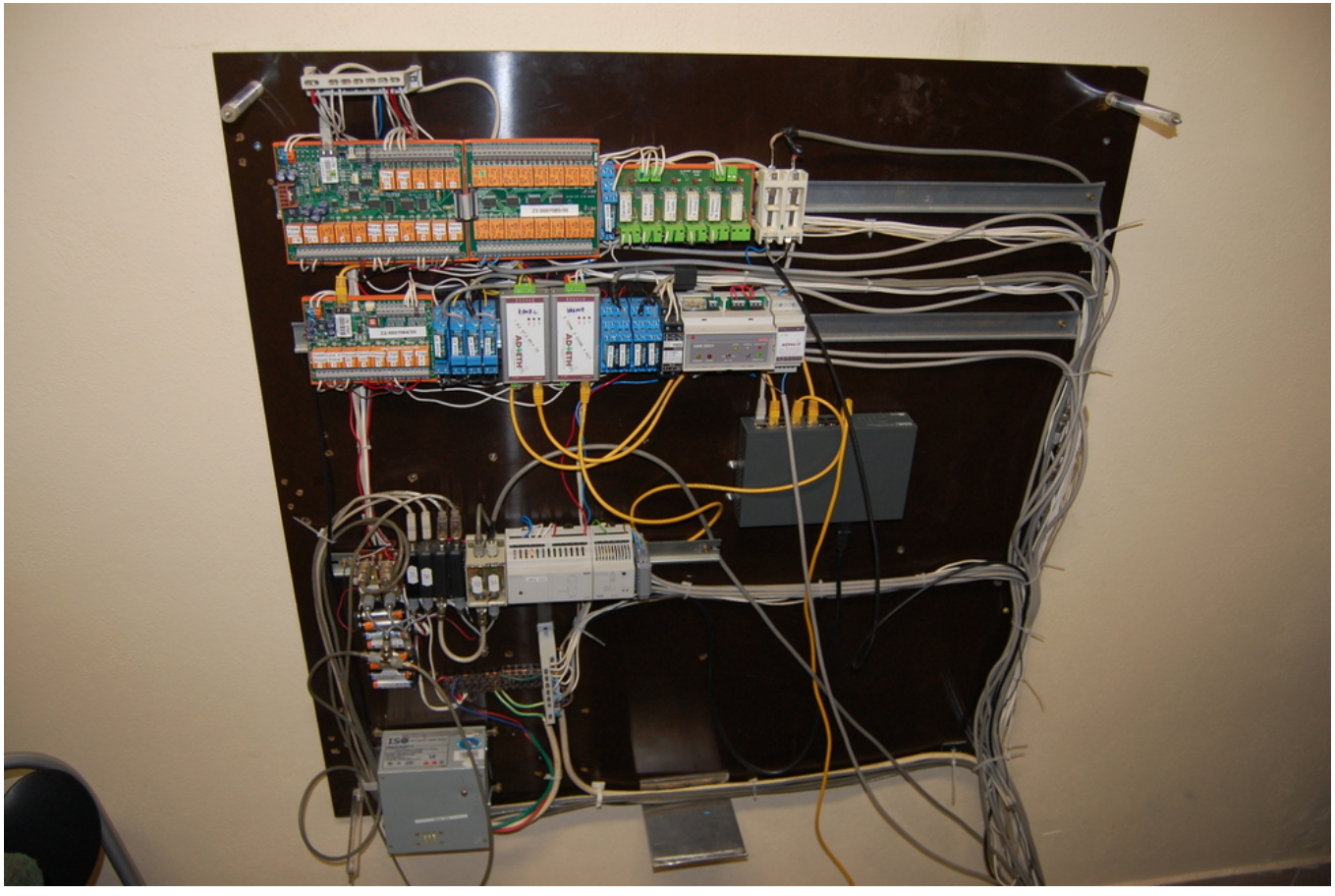
Control system for Global Power source

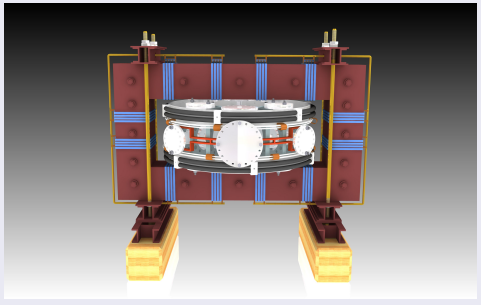


Basic control /including triggering system



Winter school of Plasma Physics - Marianska 2011 (Tokamak, probably COMPASS, with NBI)

Thank you for your attention



http://golem.fjfi.cvut.cz,
you and your students are welcome