The GOLEM tour

Vojtěch Svoboda & the GOLEM team

March 20, 2012

Outline of the talk

1 Introduction

2 Overviews

3 Ports

4 Data acquisition system

5 Vacuum management system

6 Gas management system

7 Preionization

8 Energetics infrastructure

9 Control system

10 Others

11 Conclusion

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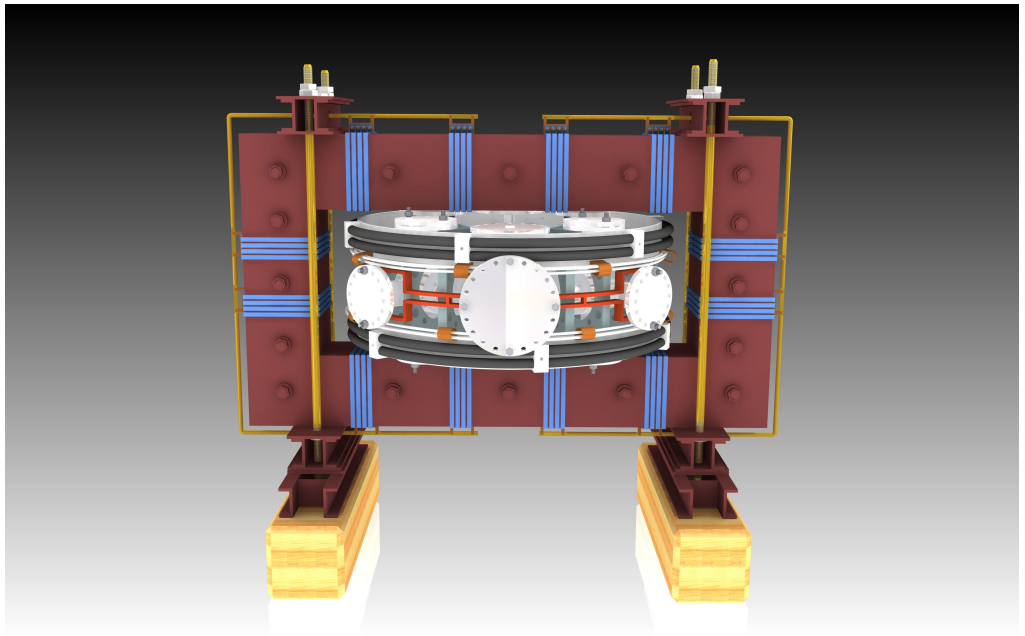
Tokamak GOLEM - basic parameters:



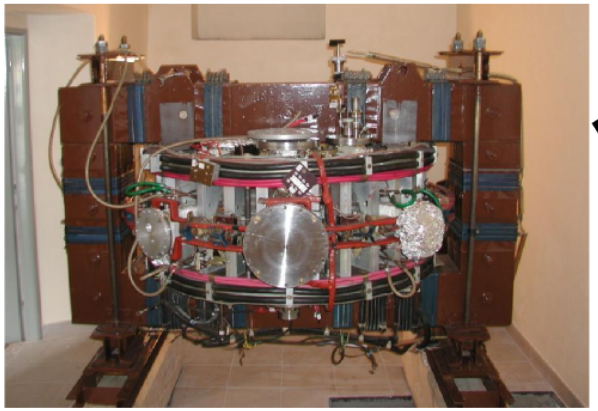
- major radius $R = 0.4$
- plasma current $I_{pl} < 10$ kA
- toroidal magnetic field $B_{tor} < 1$ T
- electron temperature $T_e(0) < 200$ eV
- minor radius $a = 0.085$ m
- pulse length $t < 20$ ms
- plasma density $n_e = 0.2 - 3.0 * 10^{19}/m^3$
- ion temperature $T_i(0) < 100$ eV

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.

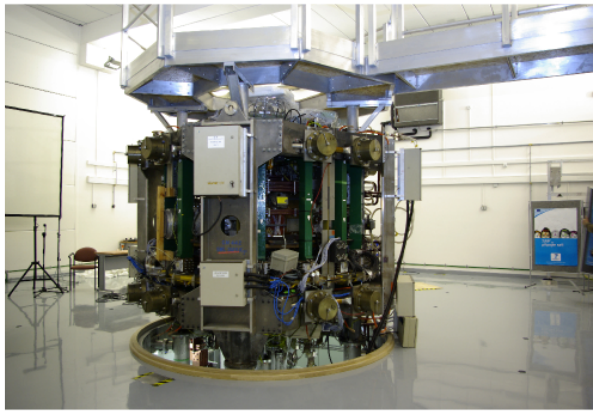
Tokamak GOLEM for Education - Historical Background

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



1974

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



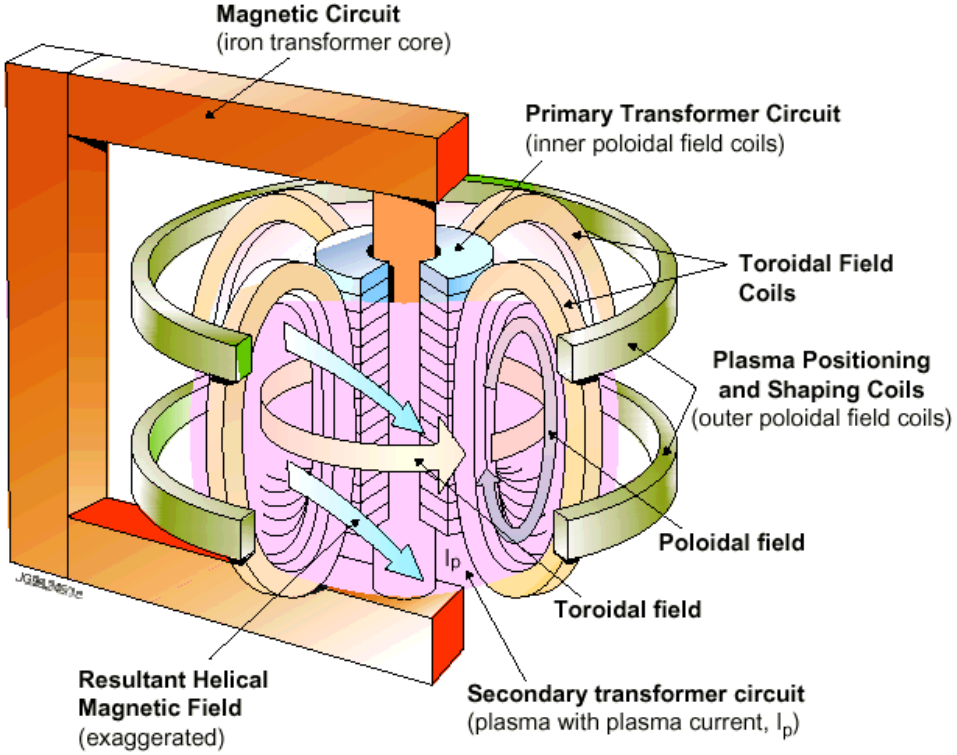
2006

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

2008

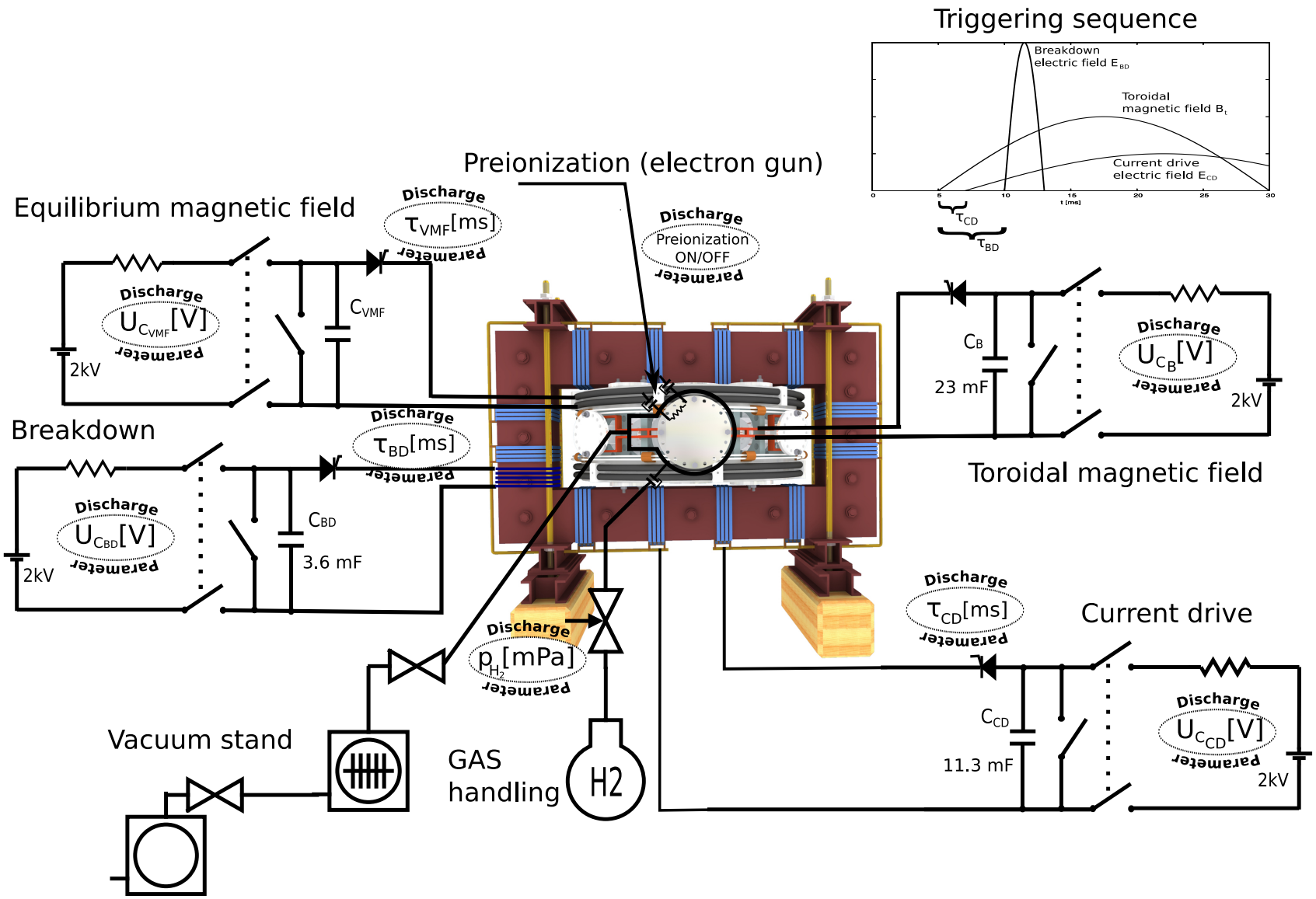
Czech Technical University Prague
Czech republic
GOLEM

Plasma in Tokamak (GOLEM) - the least to do



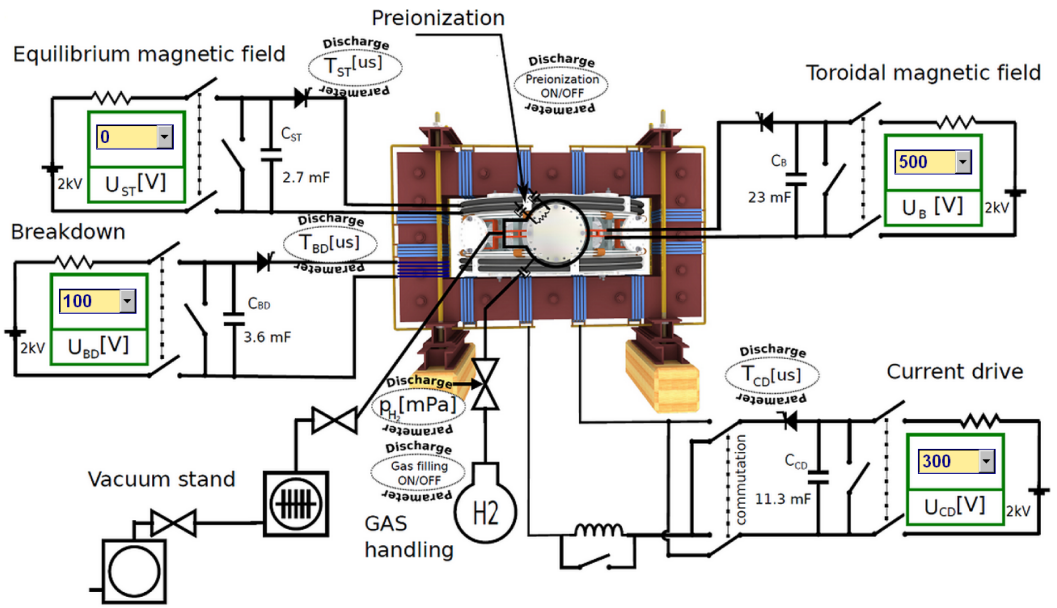
- Evacuate the chamber.
- Fill in the working gas.
- Toroidal magnetic field to confine plasma.
- Toroidal electric field to breakdown neutral gas into plasma.
- Toroidal electric field to heat the plasma.
- Plasma positioning.
- Diagnostics.

Engineering scheme of the GOLEM tokamak

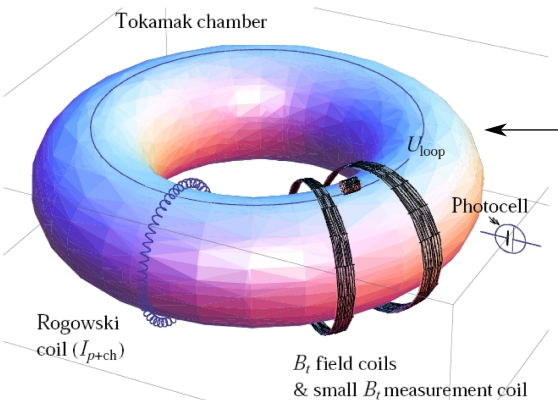


Unique remote operation capability

Tokamak control room



Plasma diagnostics



Control PC

OpenSSH server

WWW server

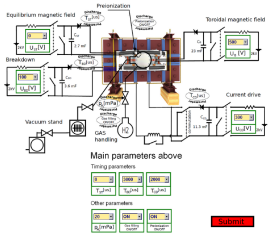
OpenSSH server

internet

Virtual control room (remote participation)

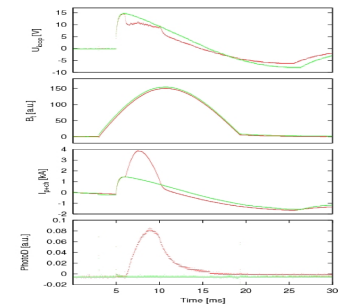
WWW control interface

HTML & PHP scripts



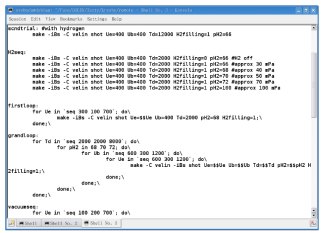
Data presentation

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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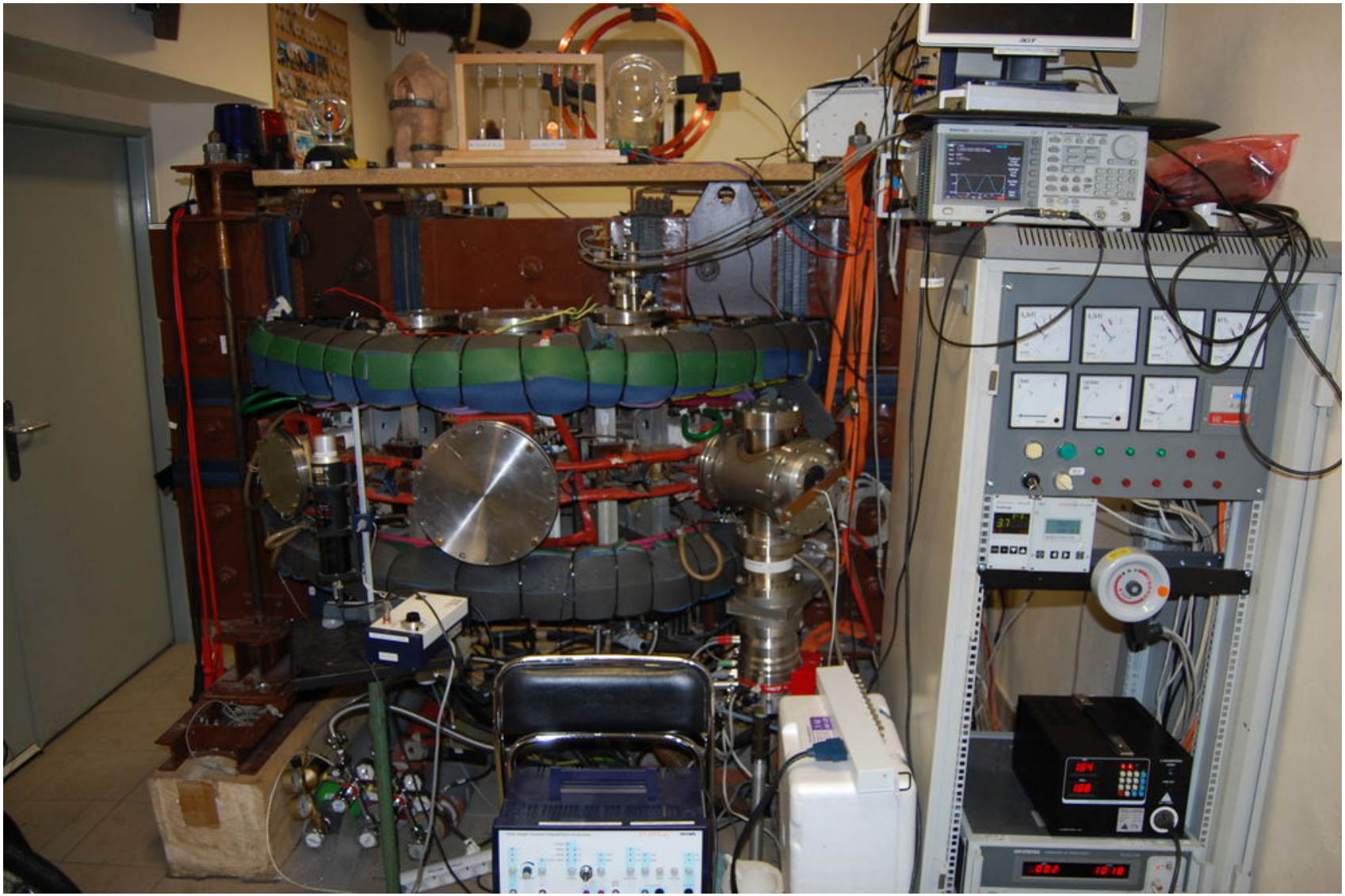
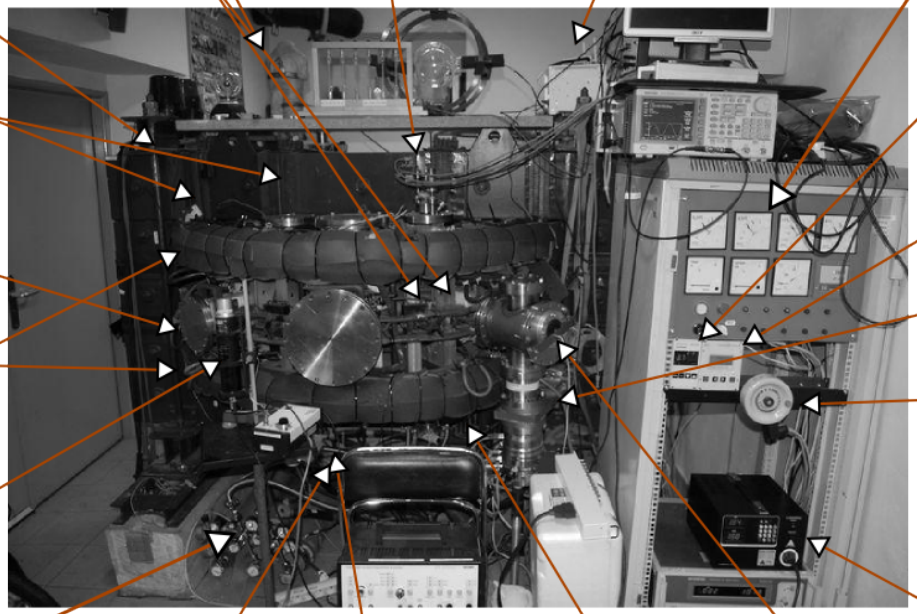
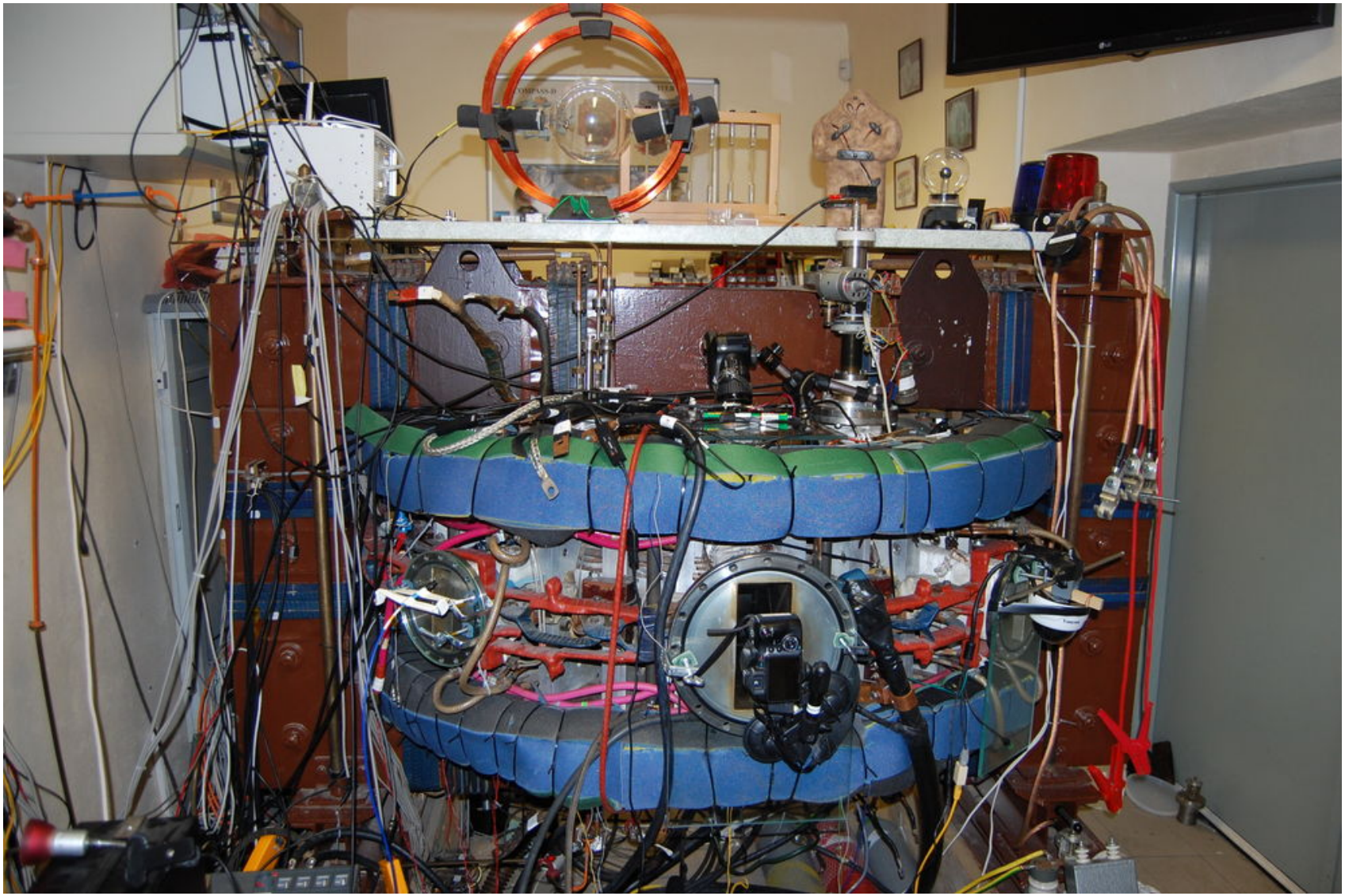
The Golem tokamak - South view (02/12)



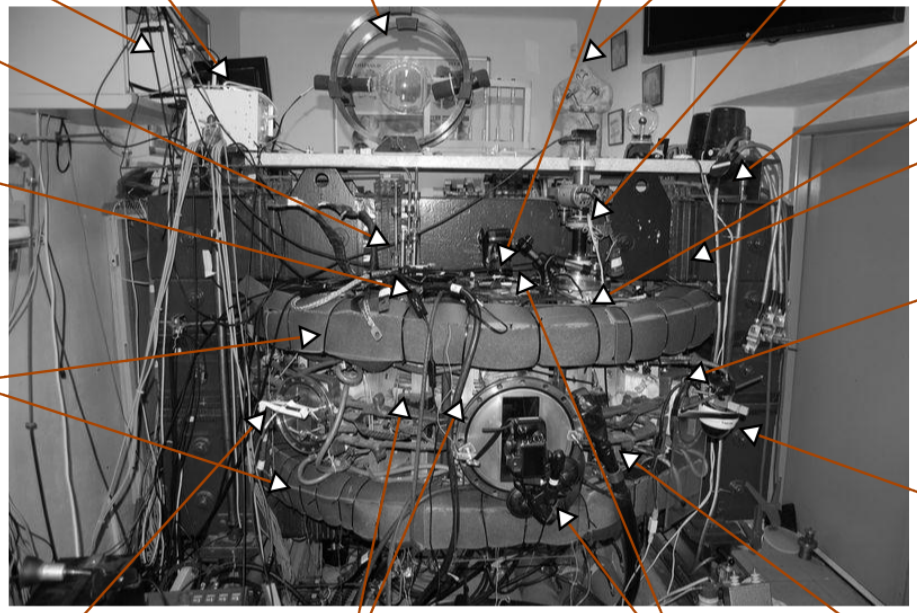
The Golem tokamak - South view (02/12)



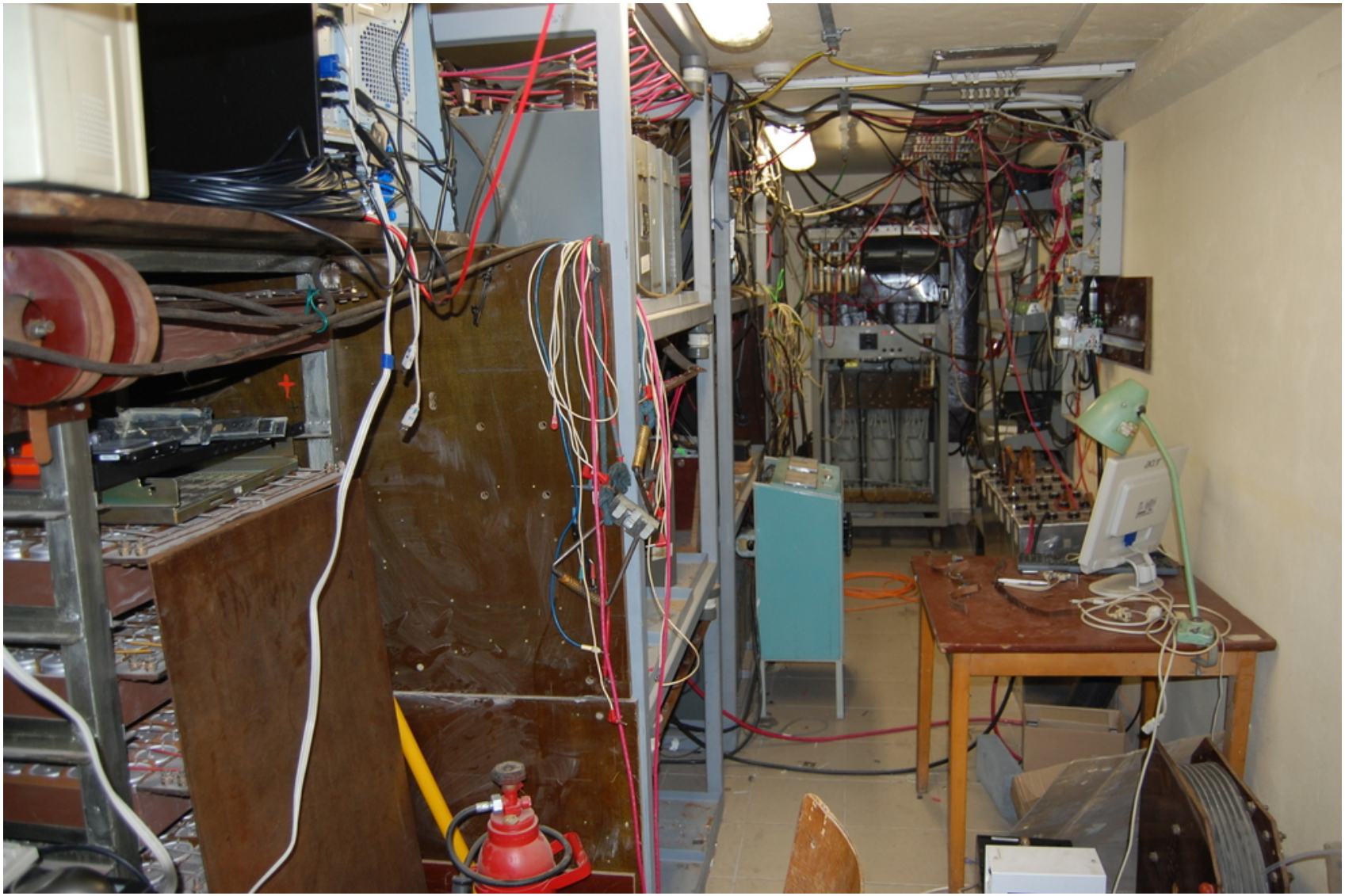
The Golem tokamak - North view (02/12)



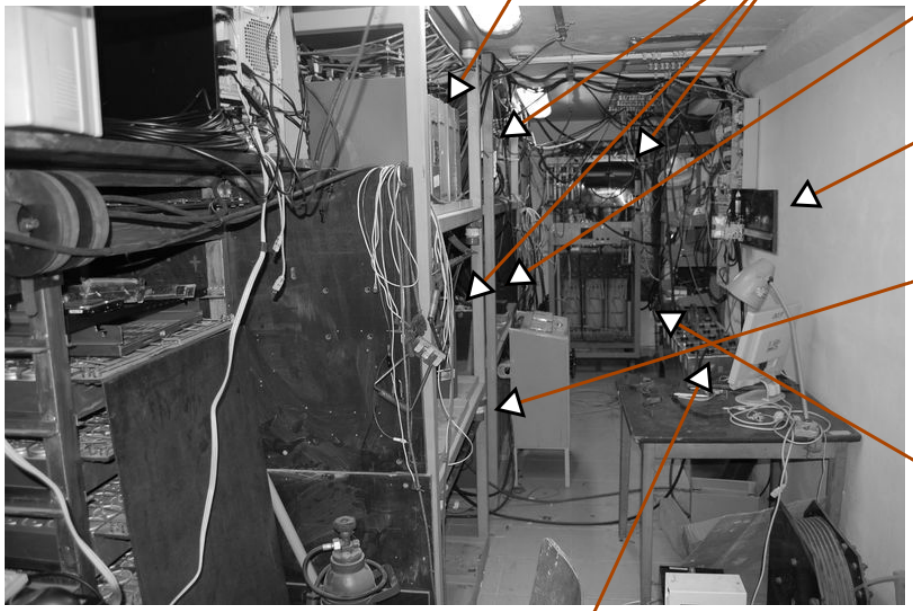
The Golem tokamak - North view (02/12)



Infrastructure room (below tokamak)



Infrastructure room



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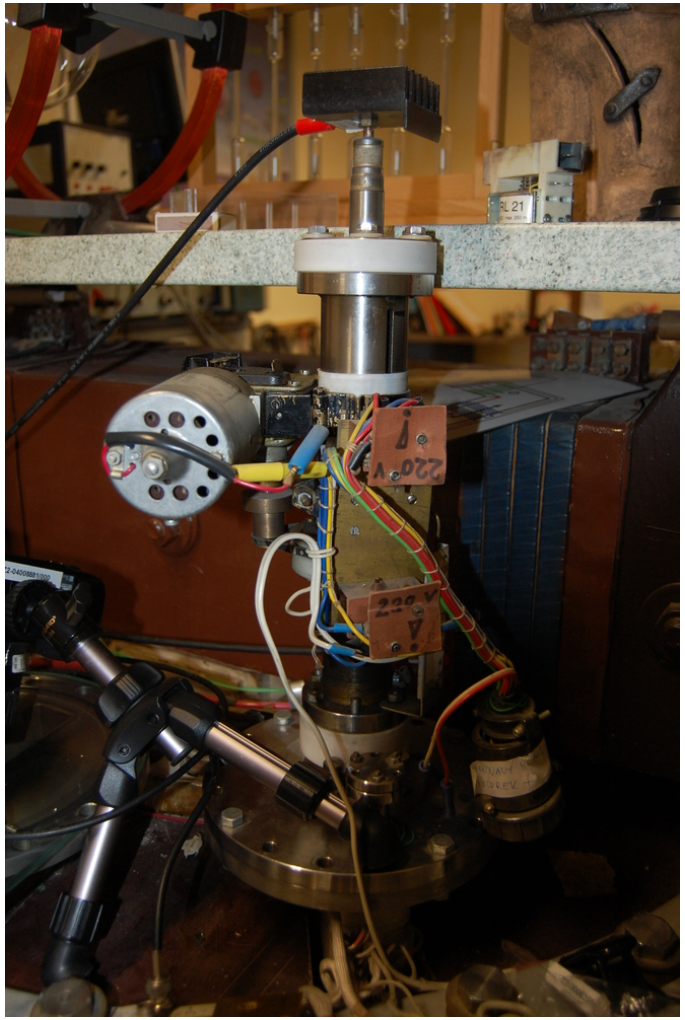
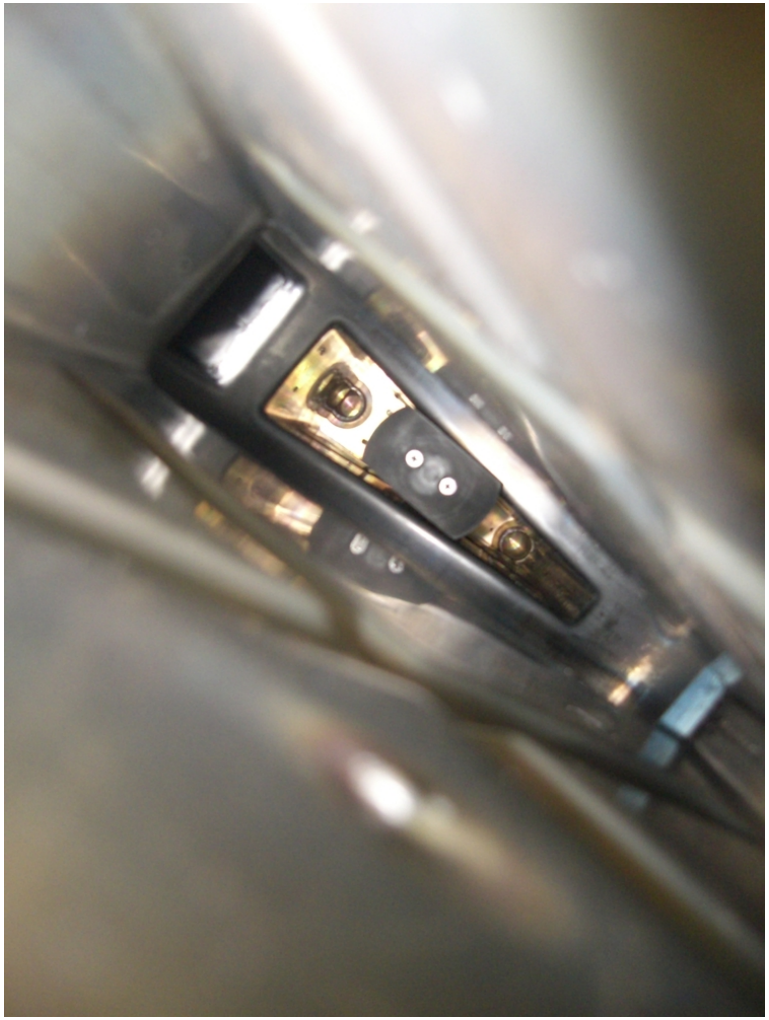
SouthEast-Upper port - glow discharge/biasing electrode



Glow Discharge

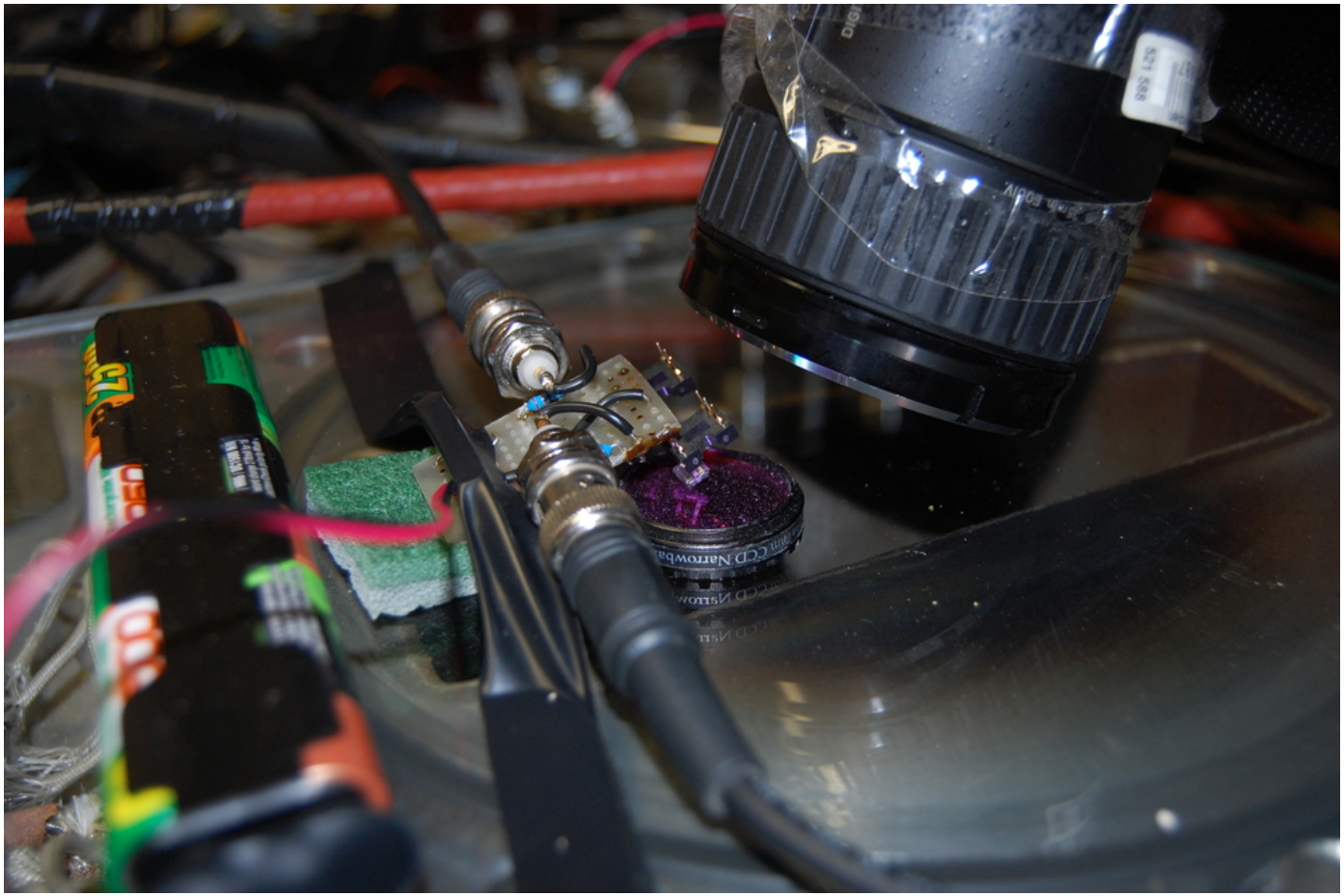
Glow discharge/Biasing electrode - chamber view



South-Upper port: Fast camera CASIO FX1 II

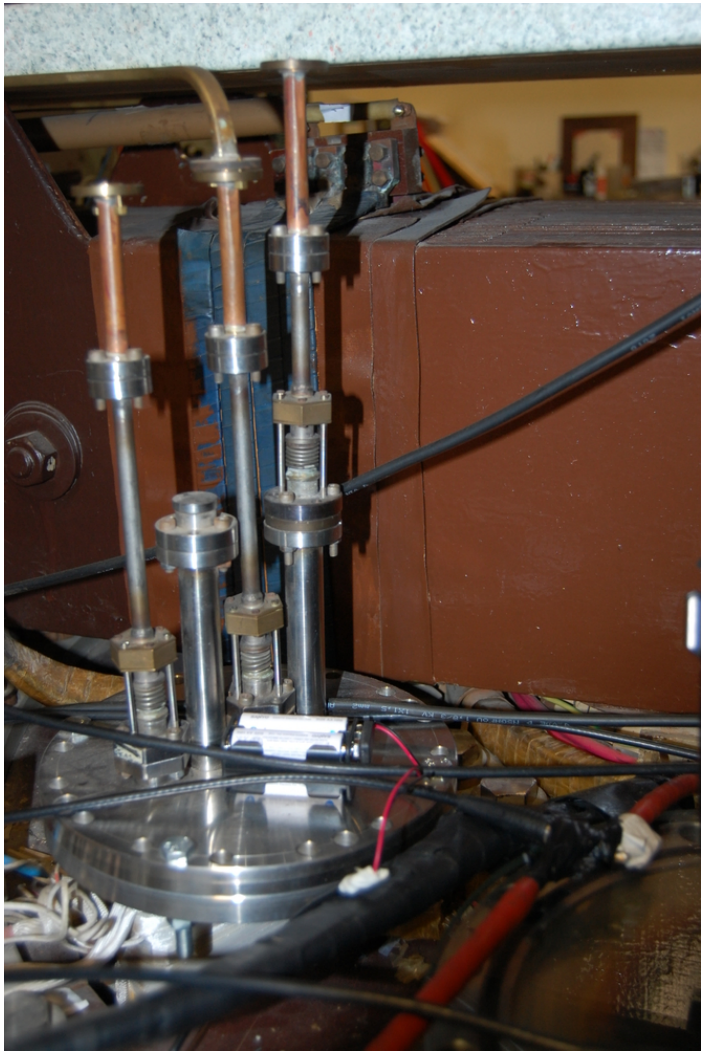
Manual, Discharge sequence

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



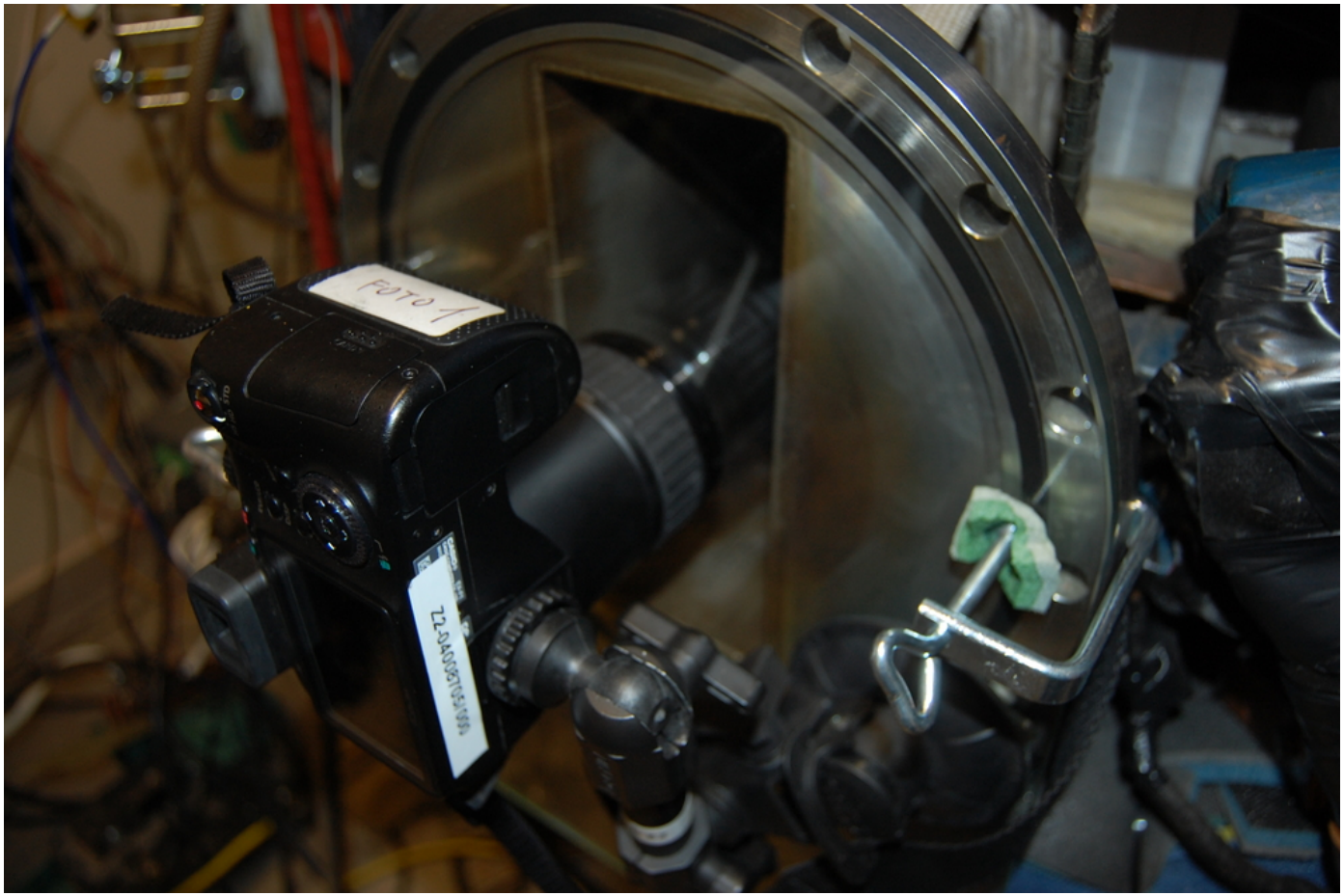
Manual, H_α Spectral sensitivity

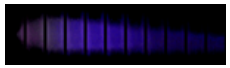
SouthWest-Upper port: Interferometry - input



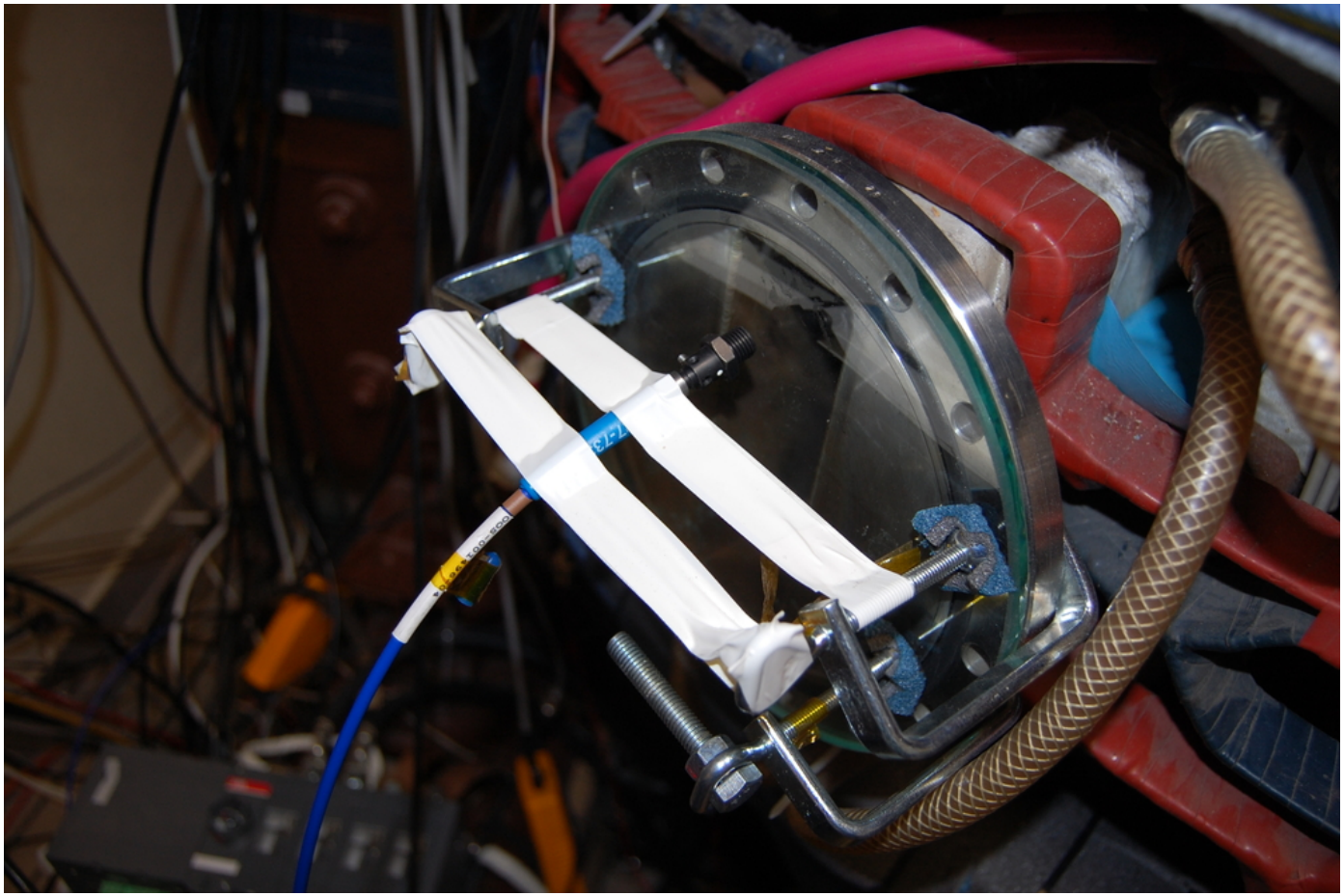
SouthEast-Middle port - IP camera viewing chamber

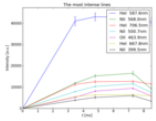
South-Middle port: Fast camera CASIO FX1 I



Manual,  Discharge sequence

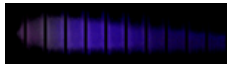
SouthEast-Midlle port: Spectroscopy fiber connecting spectrometer HR2000+ES



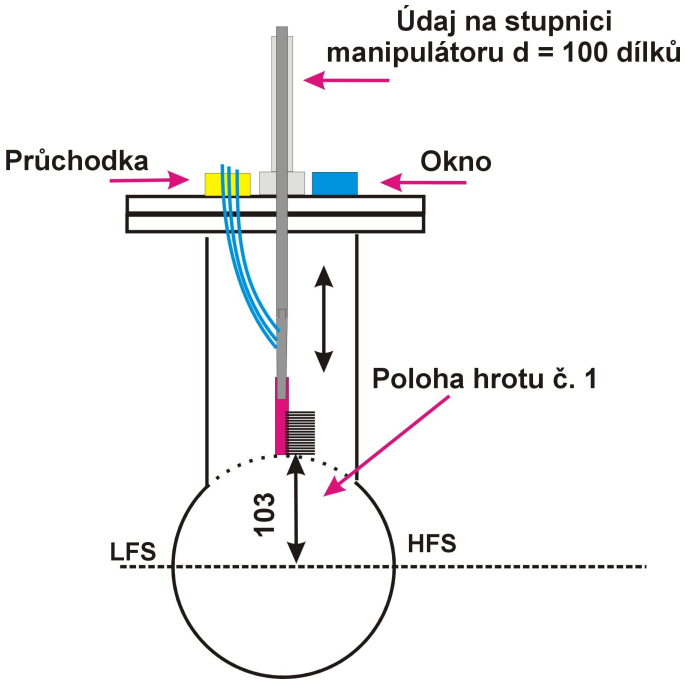


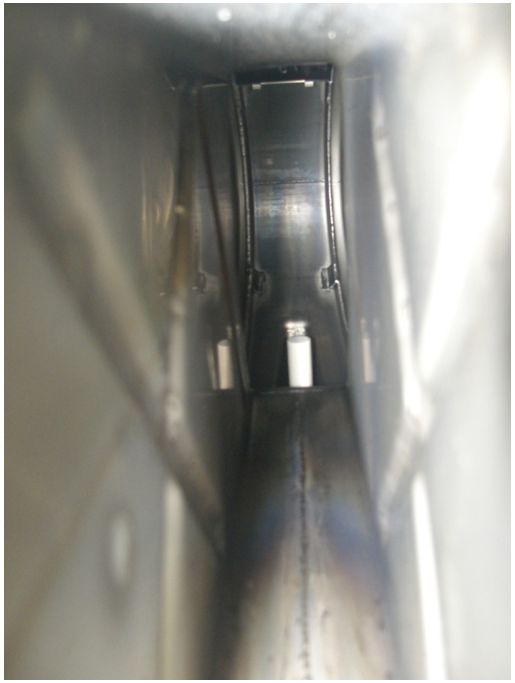
He spectrum No:7163

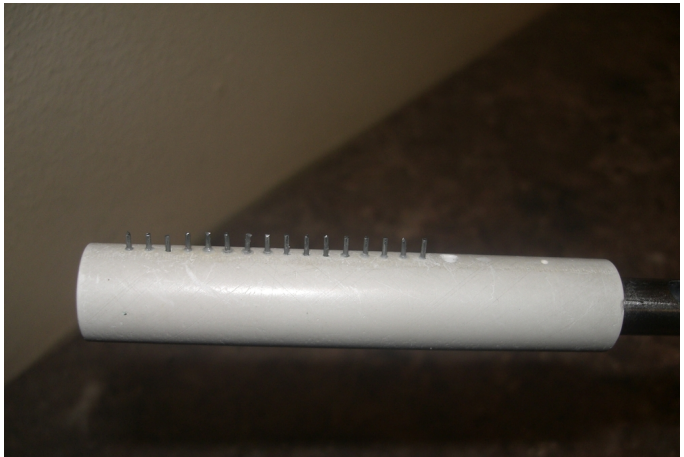
SouthEast-Bottom: Rake probe

Description,  Discharge sequence

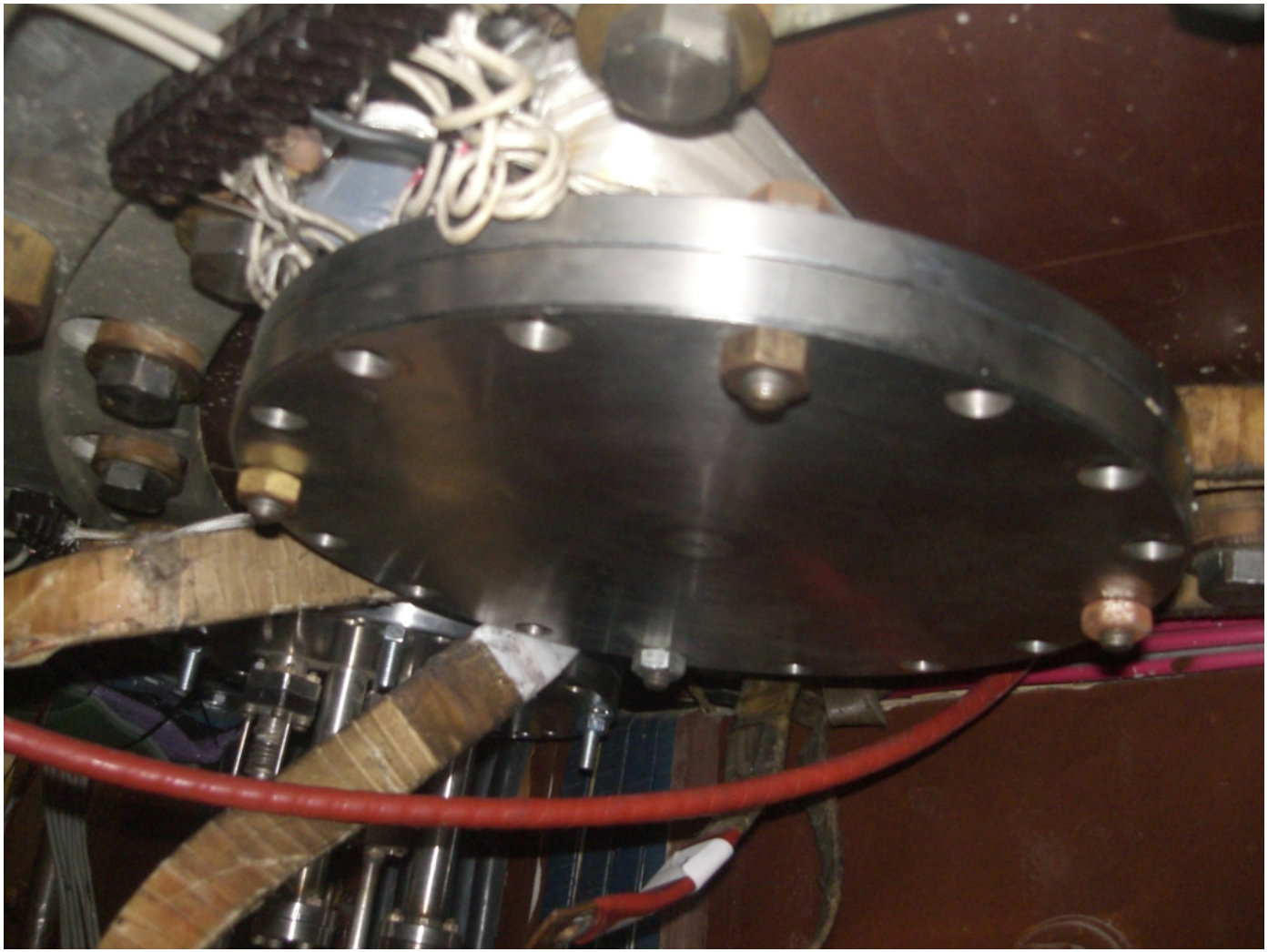
Rake probe (2012)



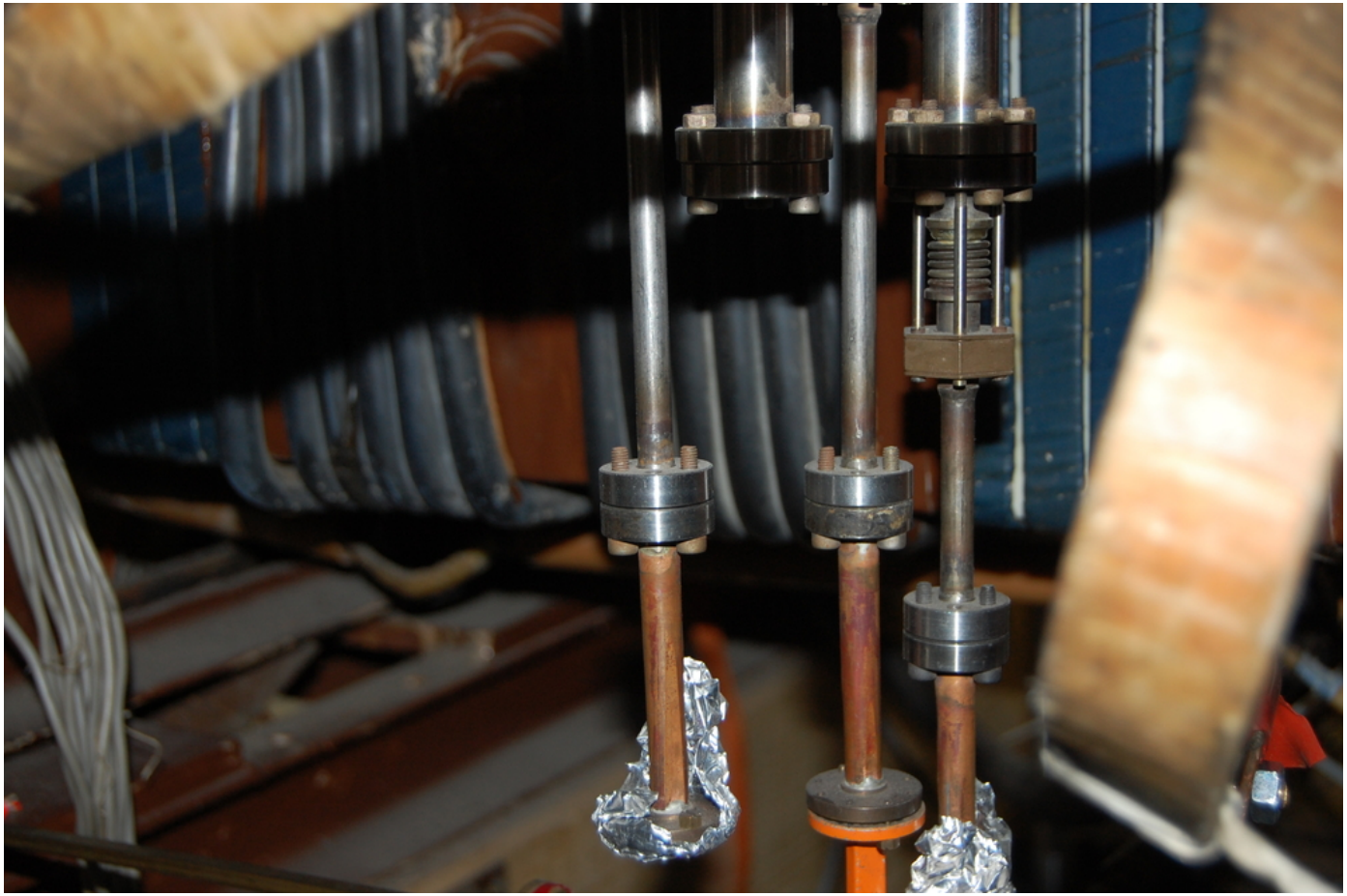




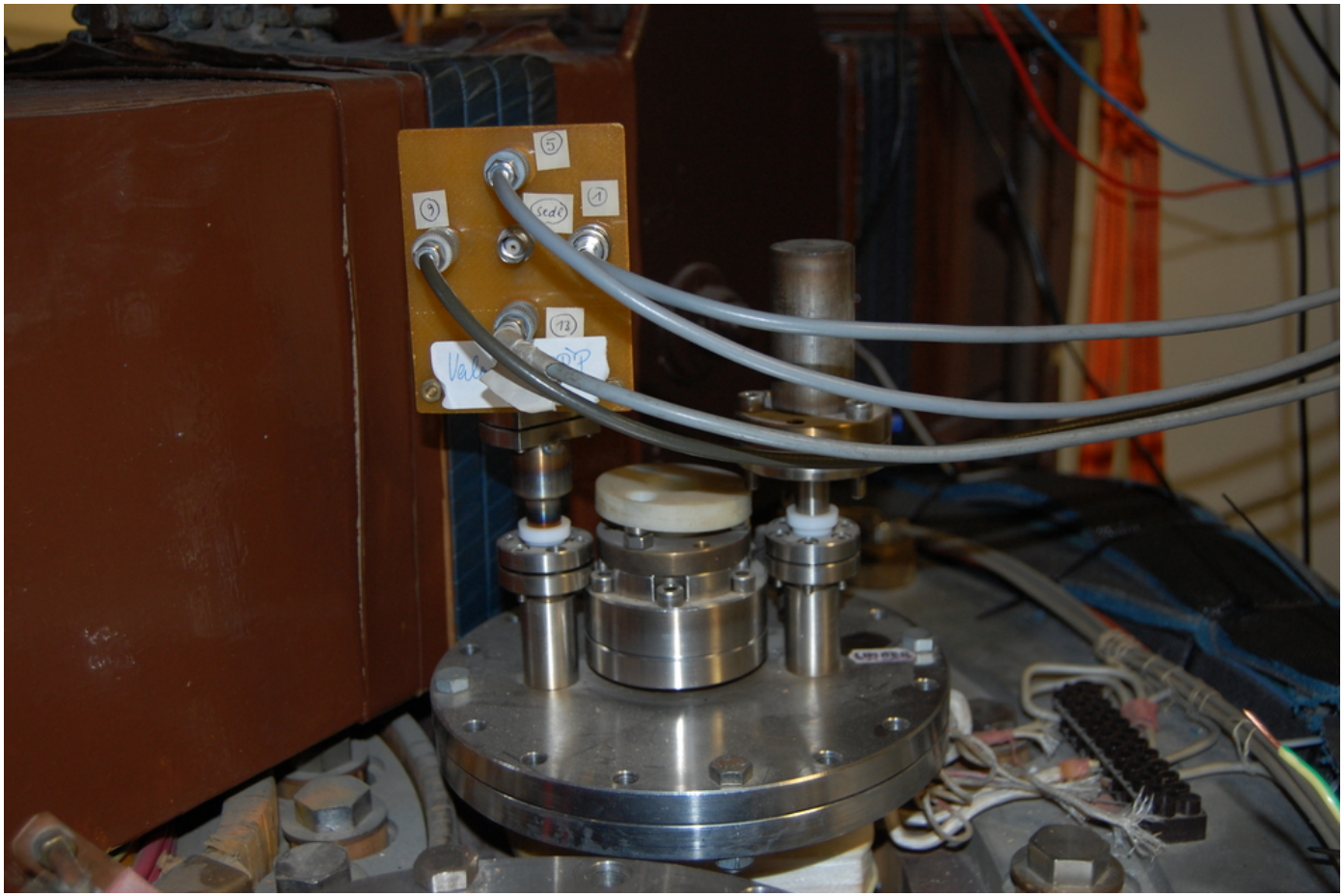
South-Bottom: vacant



SouthWest-Bottom port: Interferometry - output

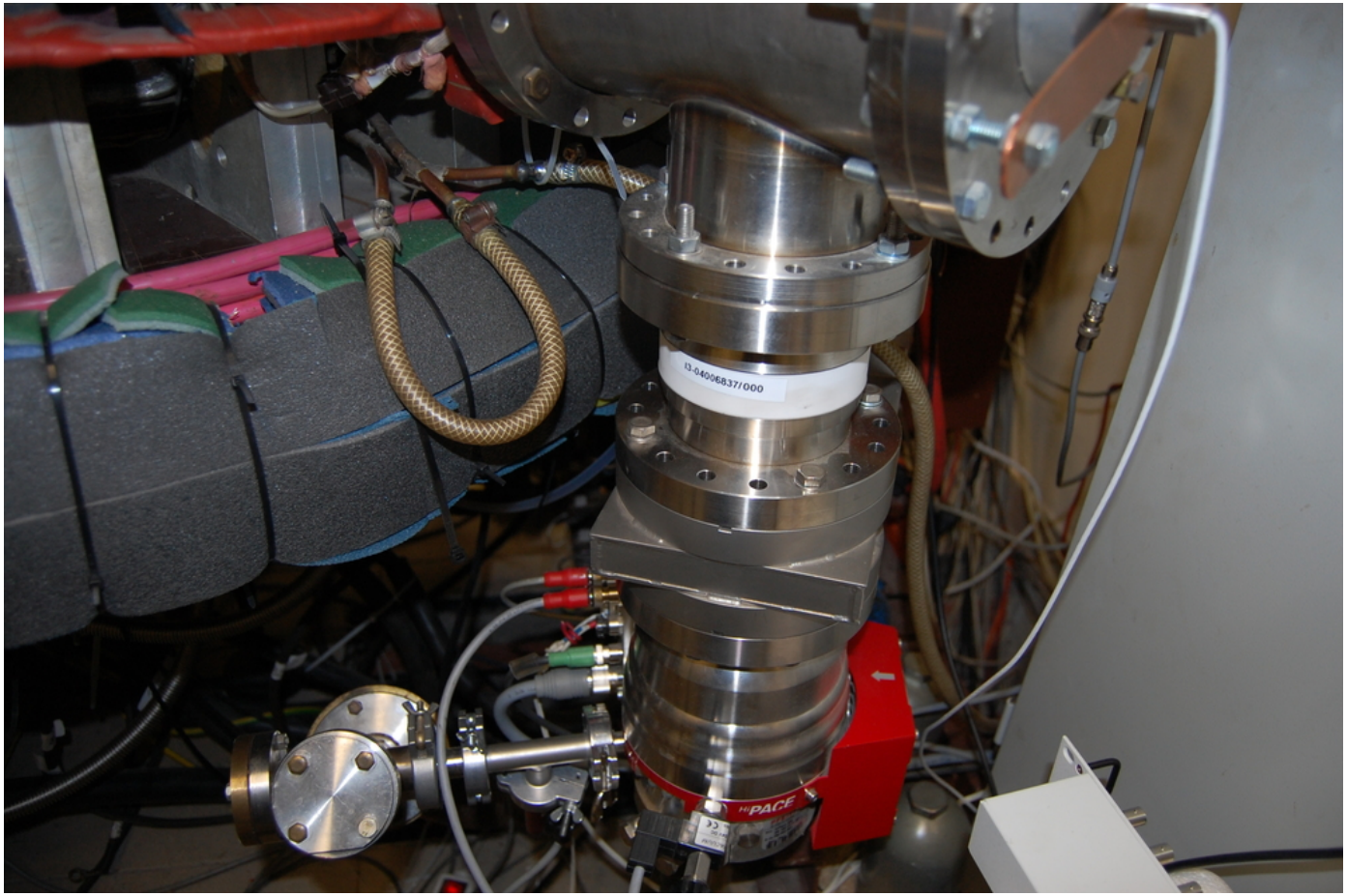


NorthEast-Upper: Mirnov coils

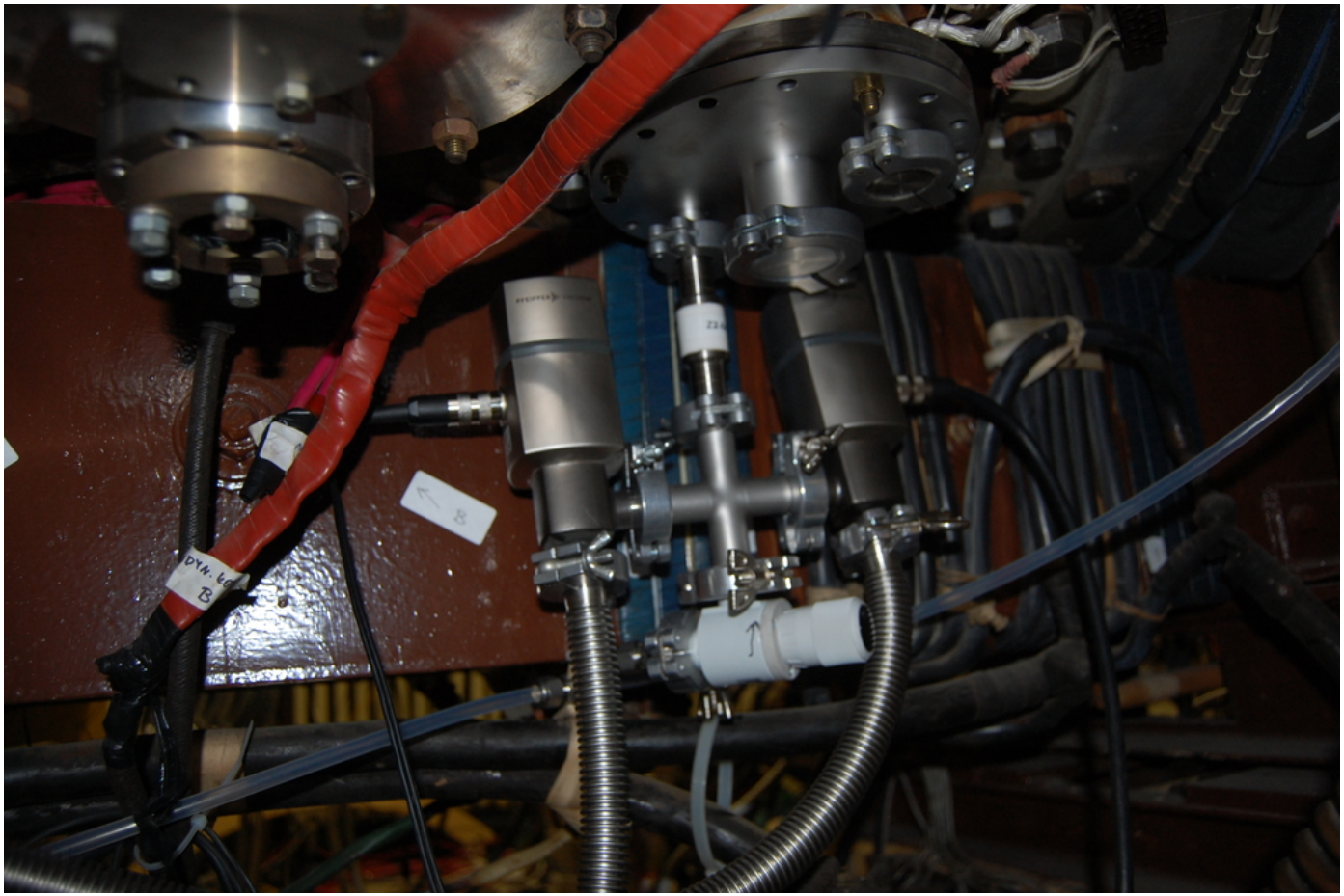


Description

NorthEast-Middle: Vacuum Stand

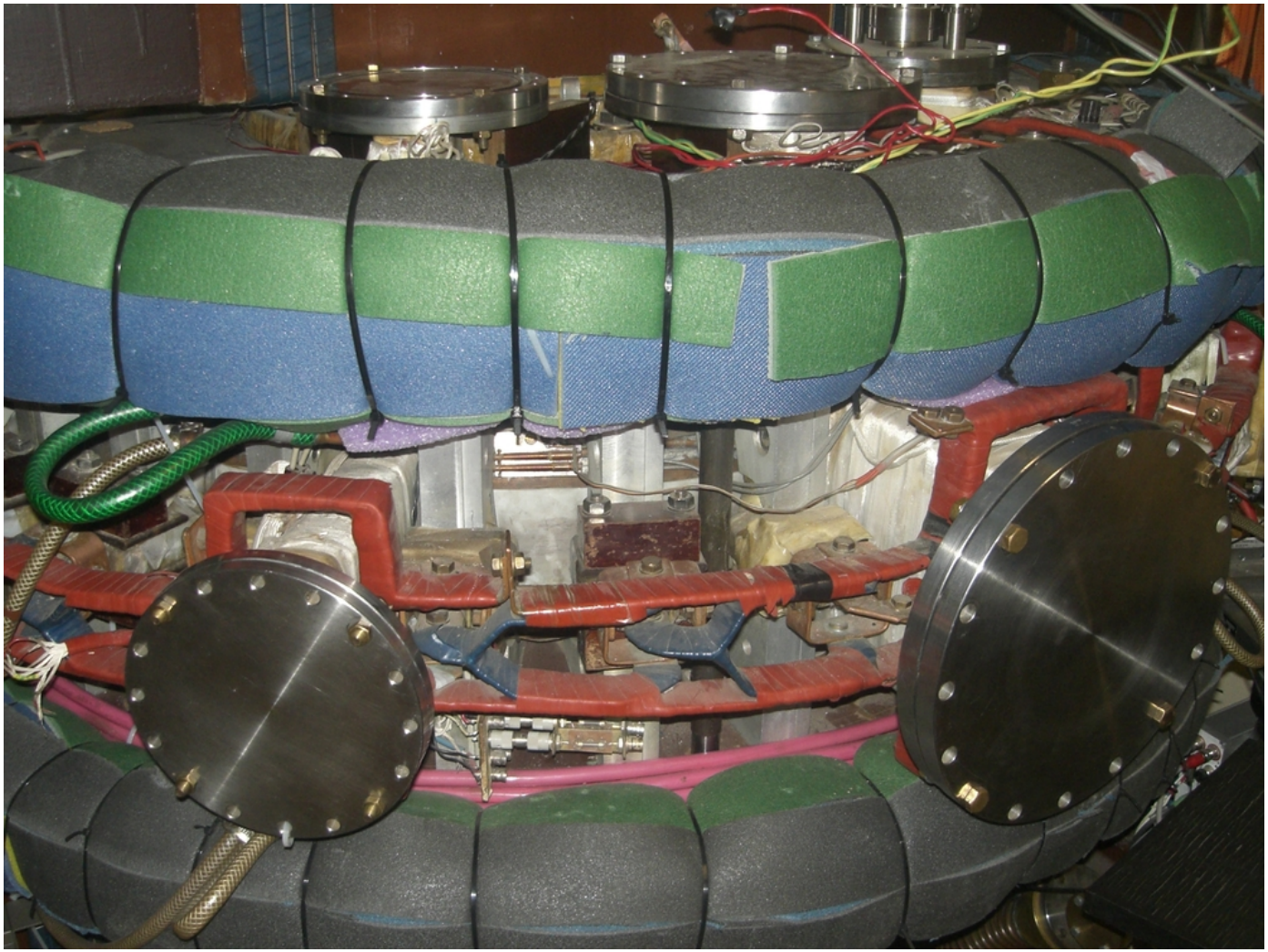


NorthEast - Bottom: Gas injection system - H_2, Air, He

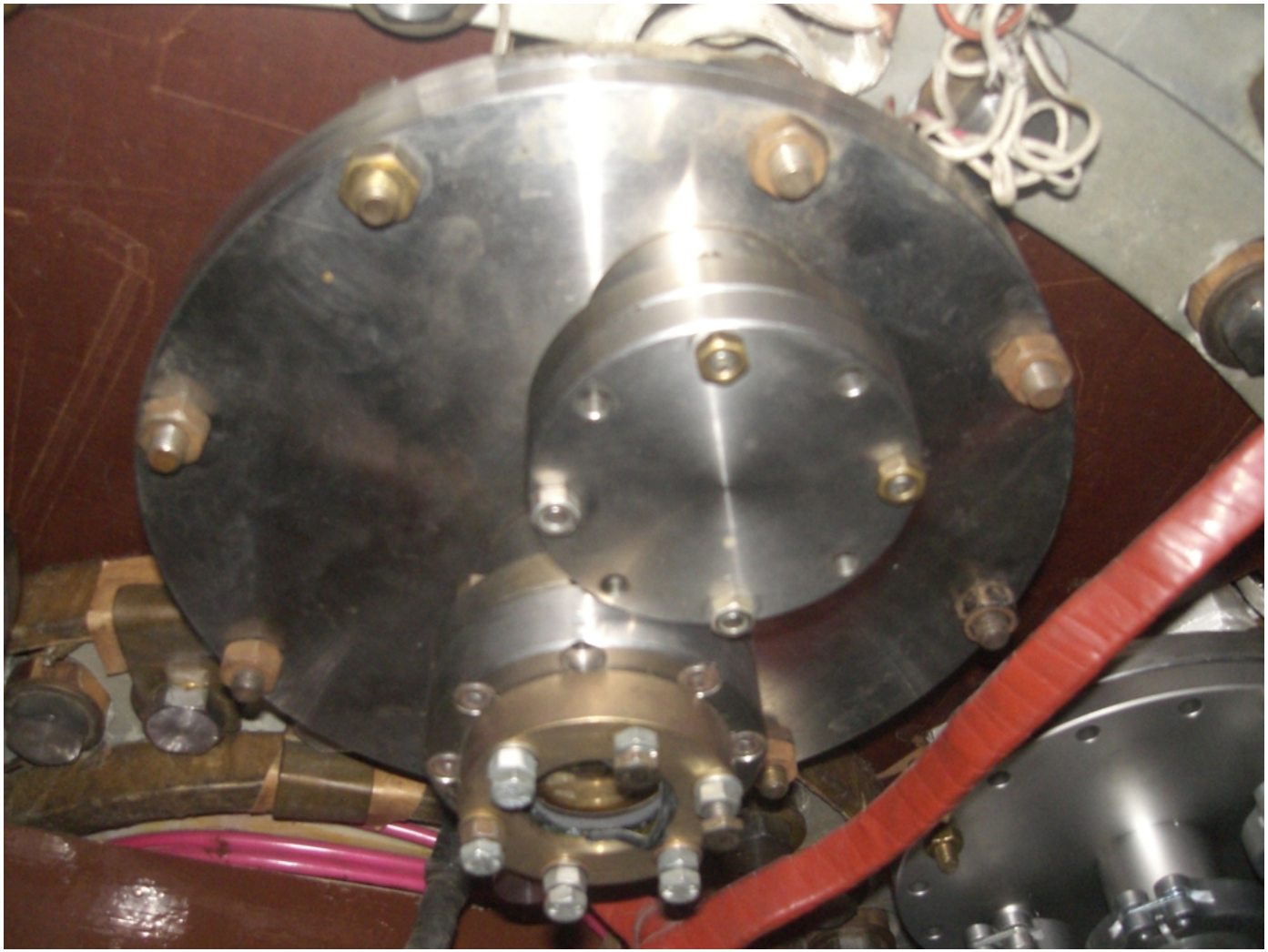


Gas pressure evolution

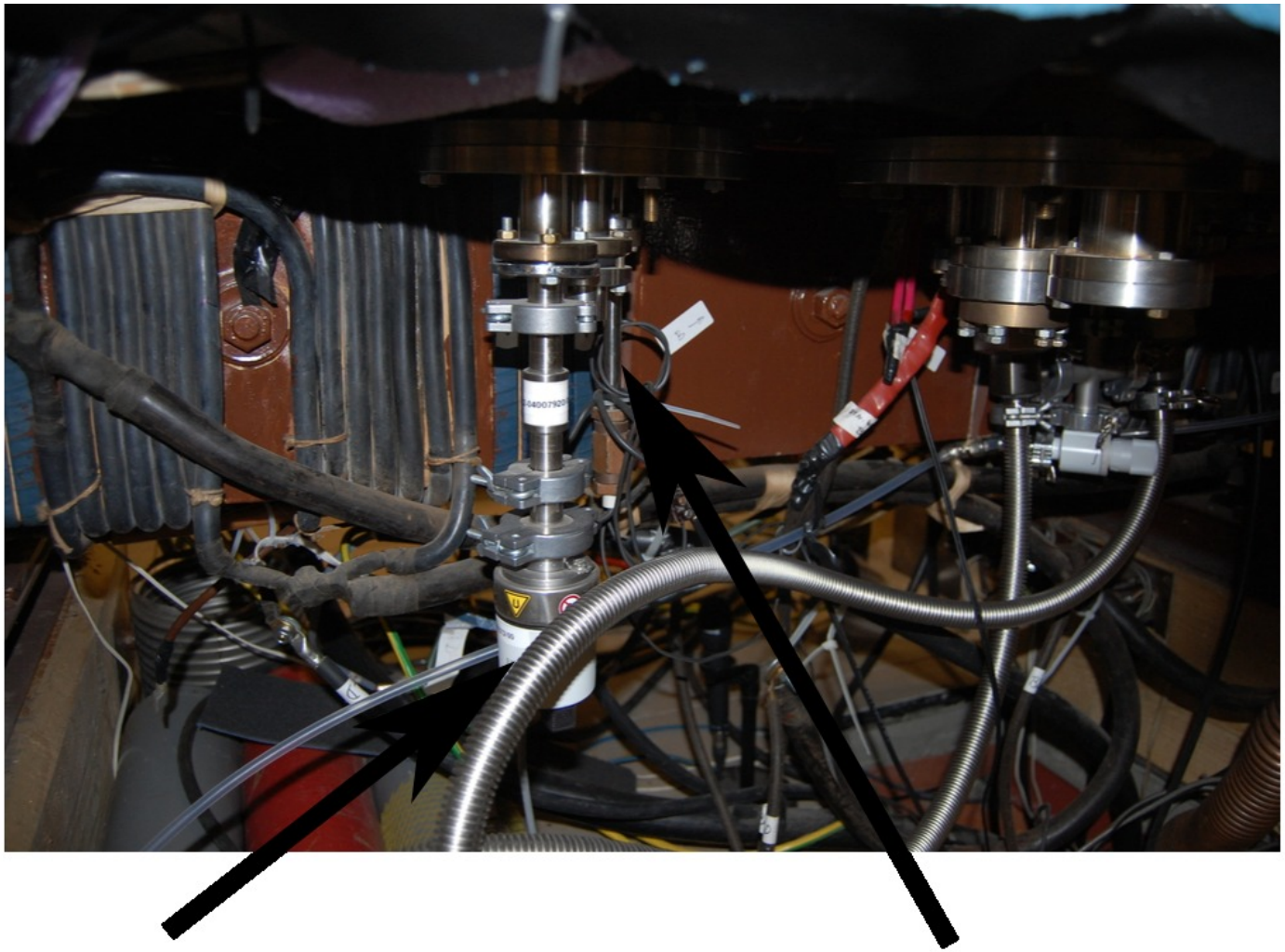
NorthWest and North - Top and Middle: vacant



North - Bottom: vacant



NorthWest - Bottom: Vacuum Gauge & Preionization Gun



Vacuum gauge Preionization gun

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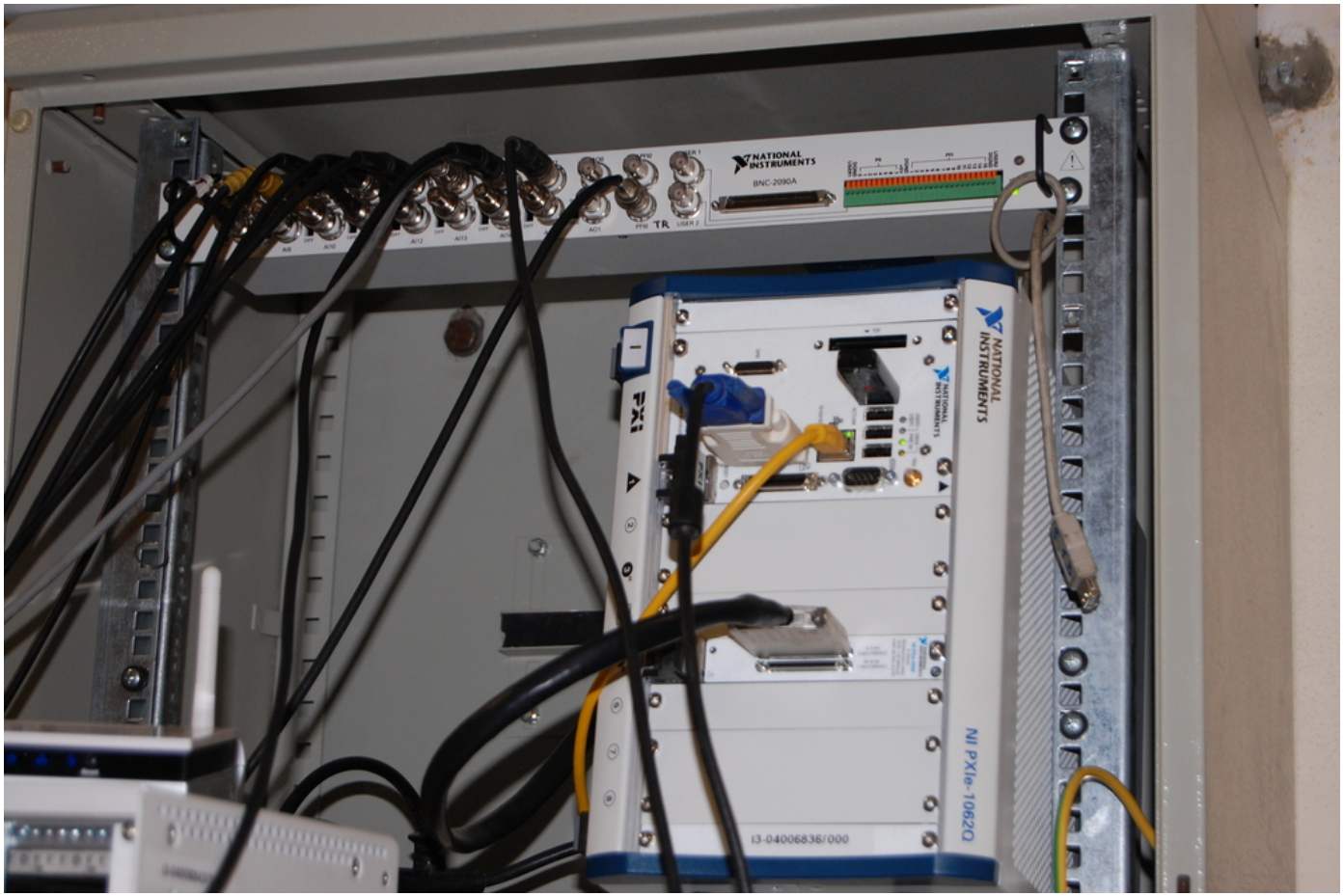
Data acquisition system I - basic

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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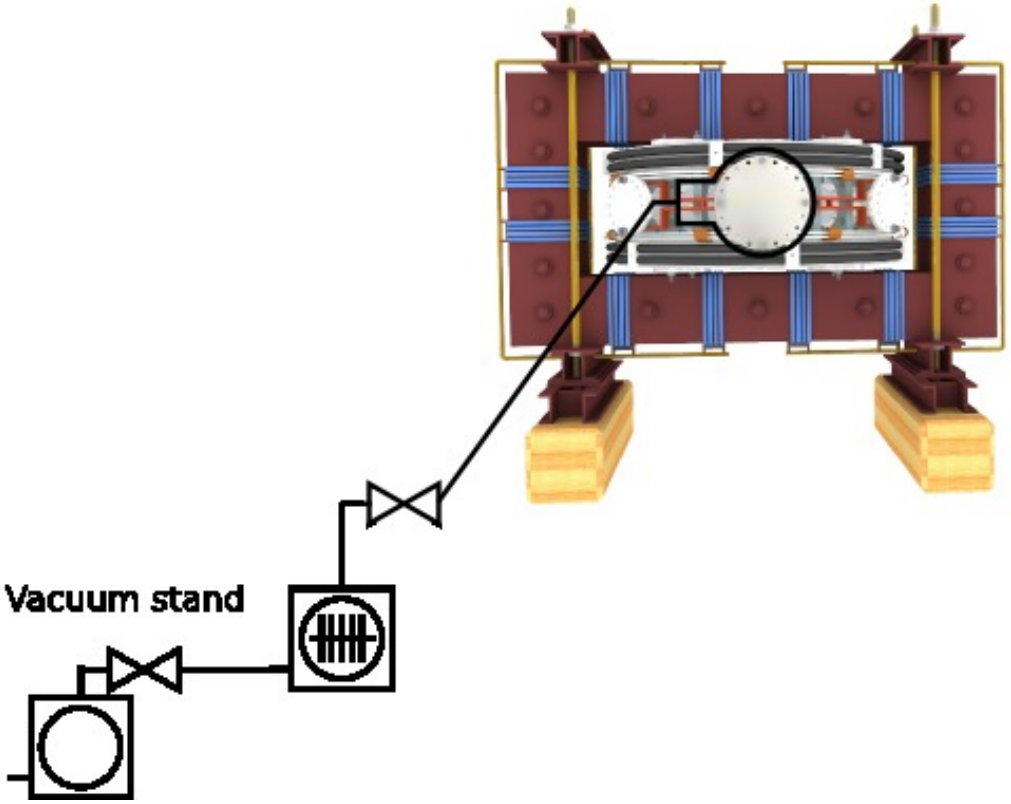
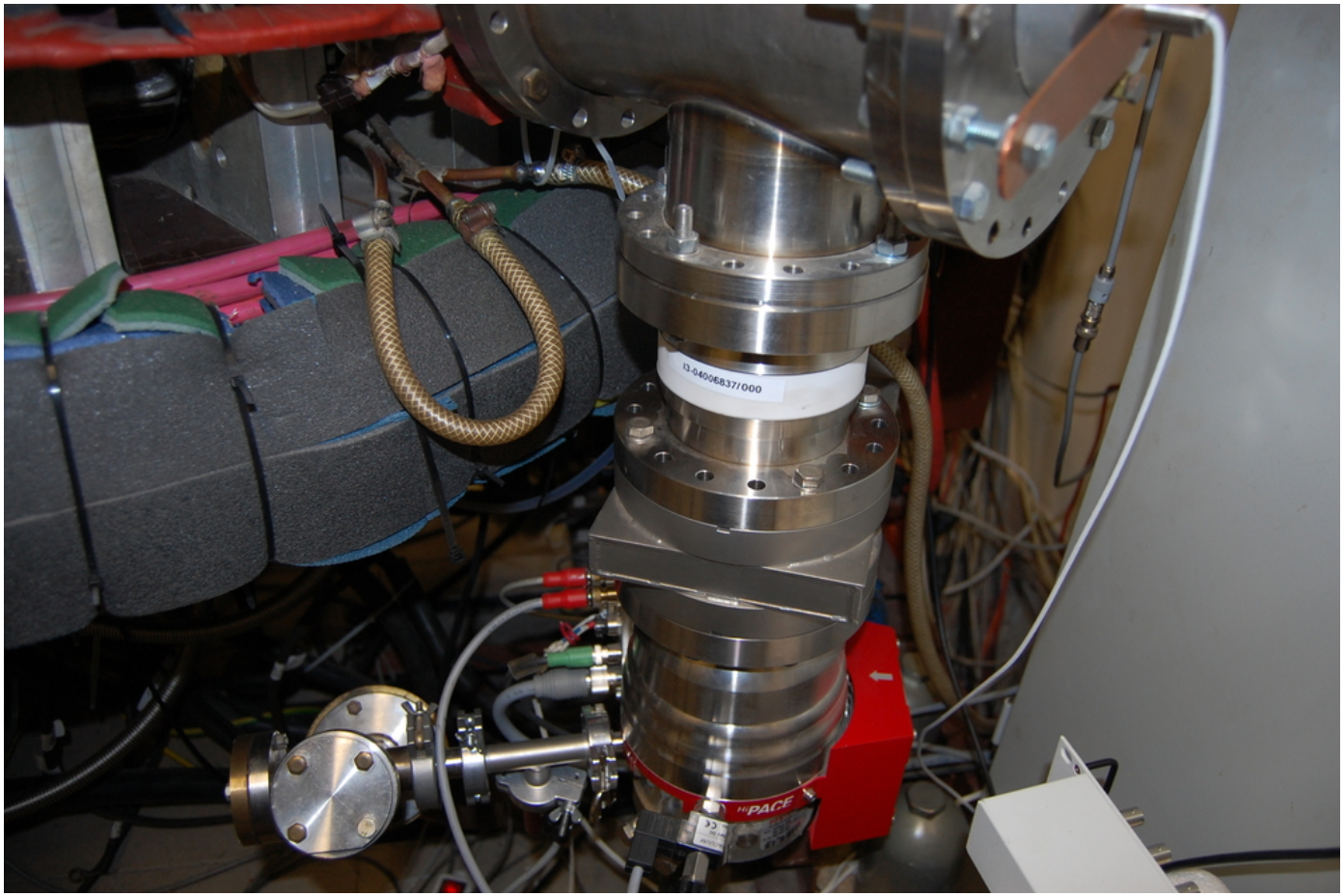
Vacuum management

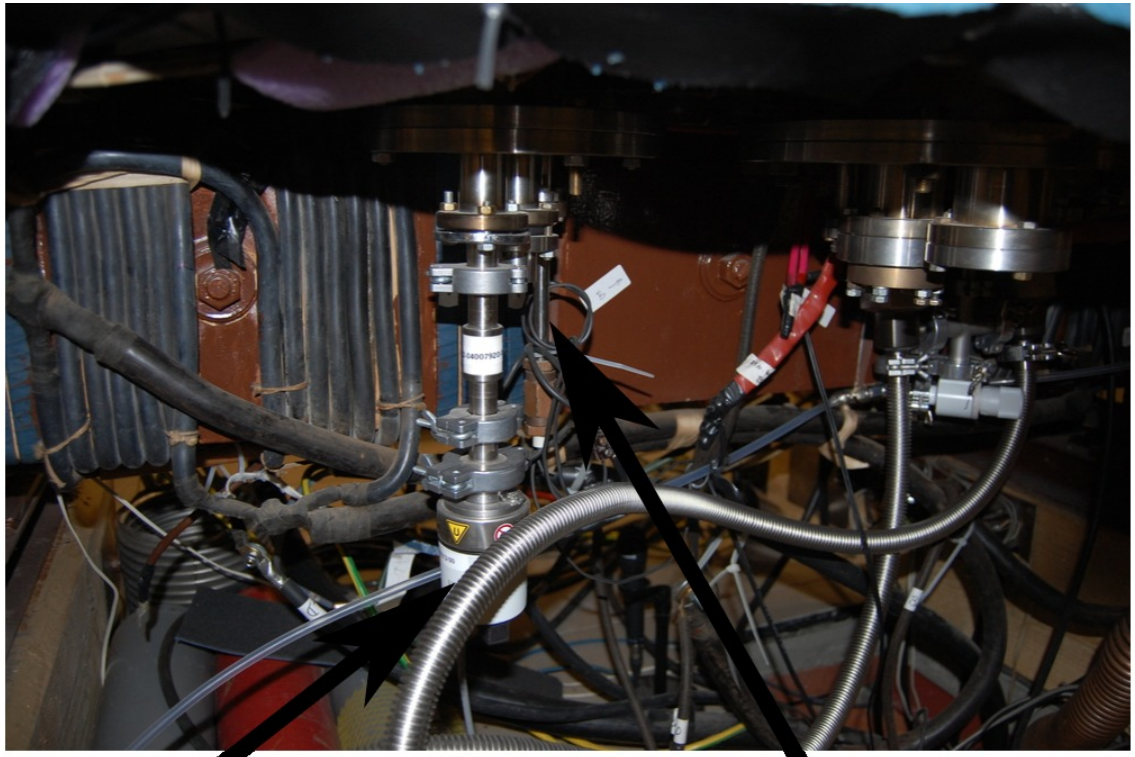


Vacuum Stand - Turbomolecular pump, Ultravacuum gauge, Galvanic insulation



TMP manual, Controller manual

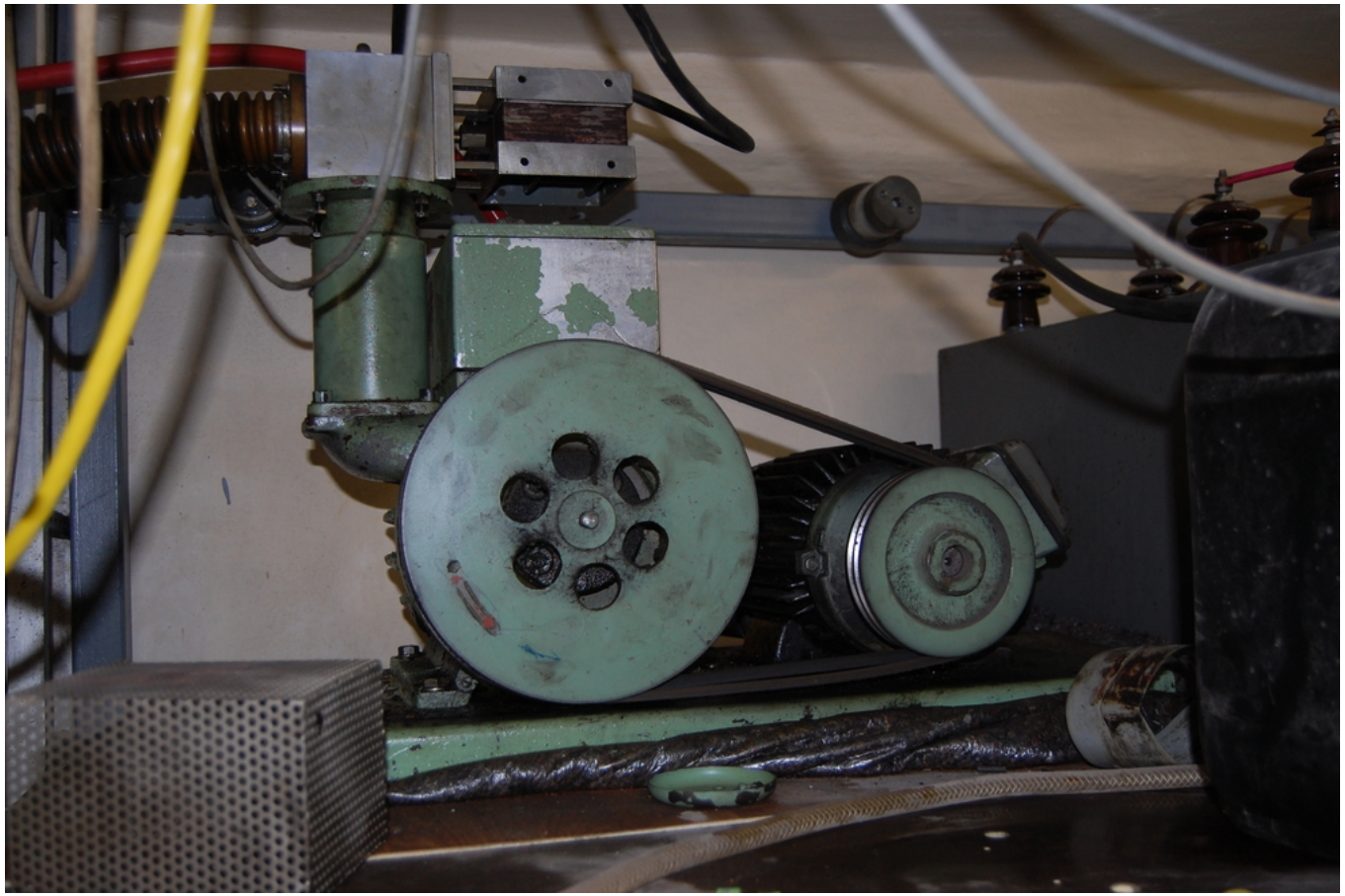
Vacuum Gauge



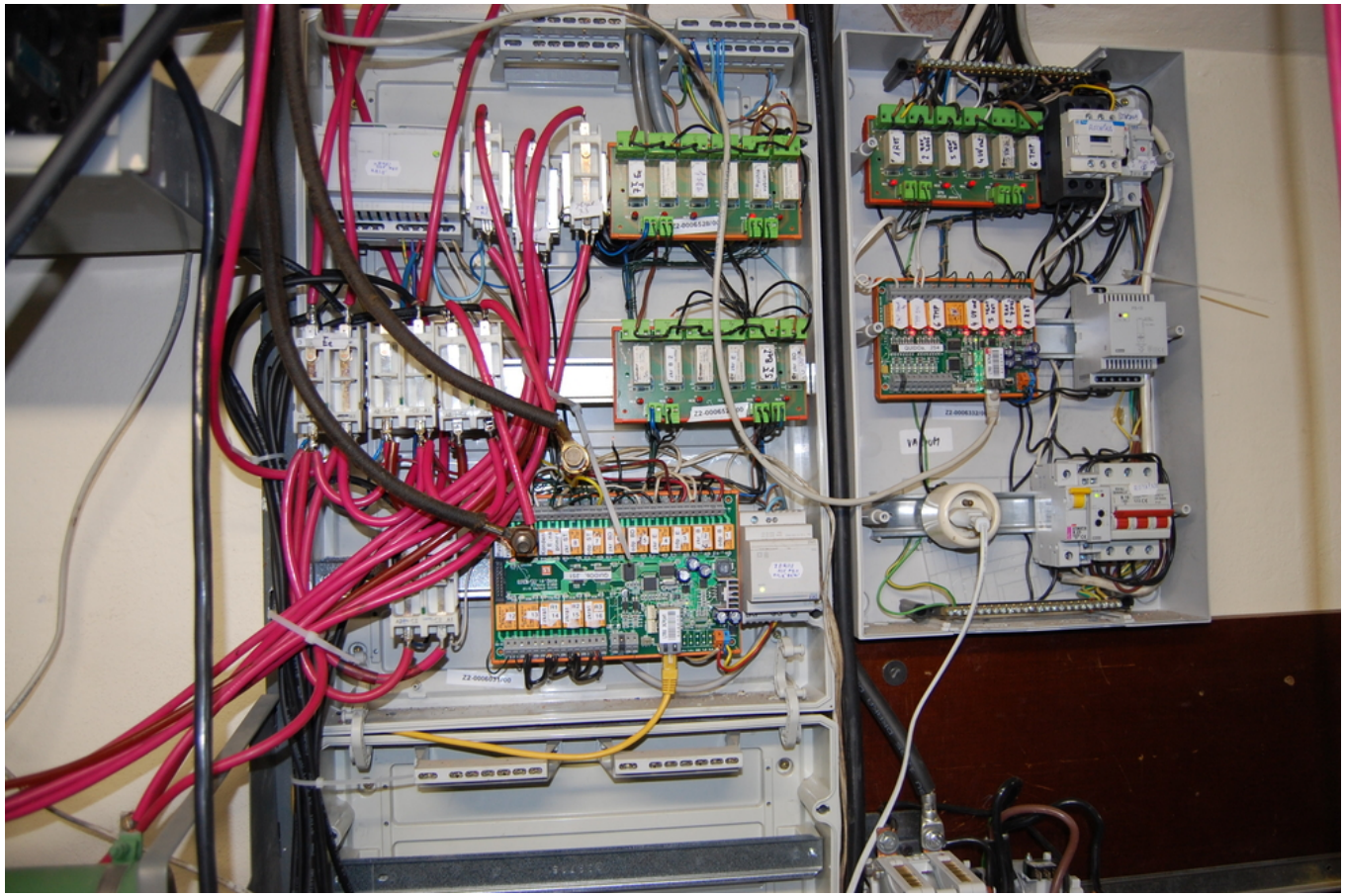
Vacuum gauge Preionization gun

Manual

Rotary Pump with valve



Control system for capacitor charging and vacuum management



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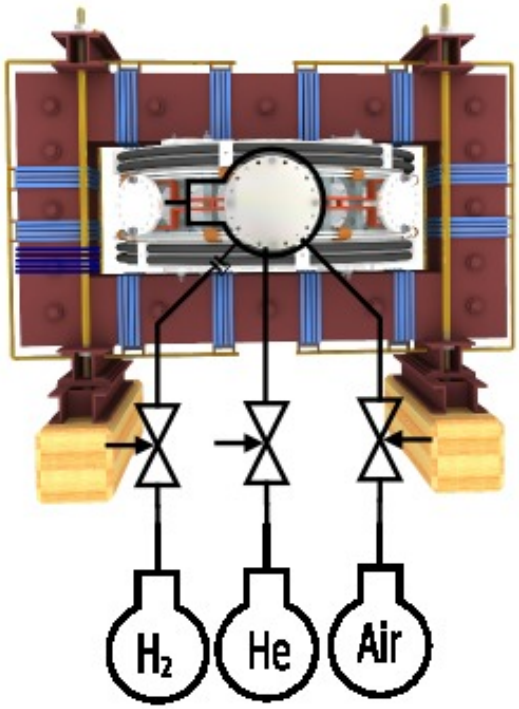
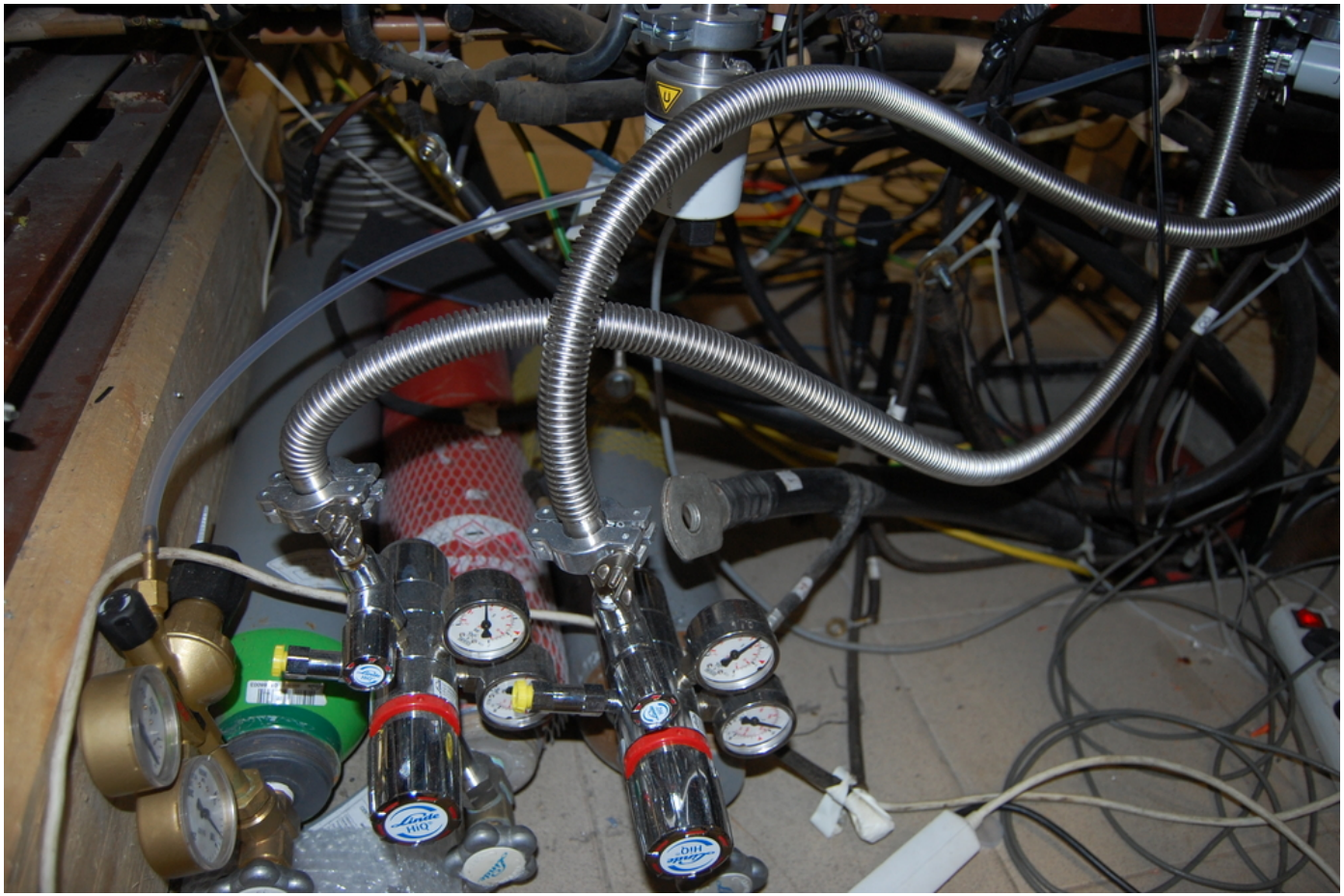
Gas management

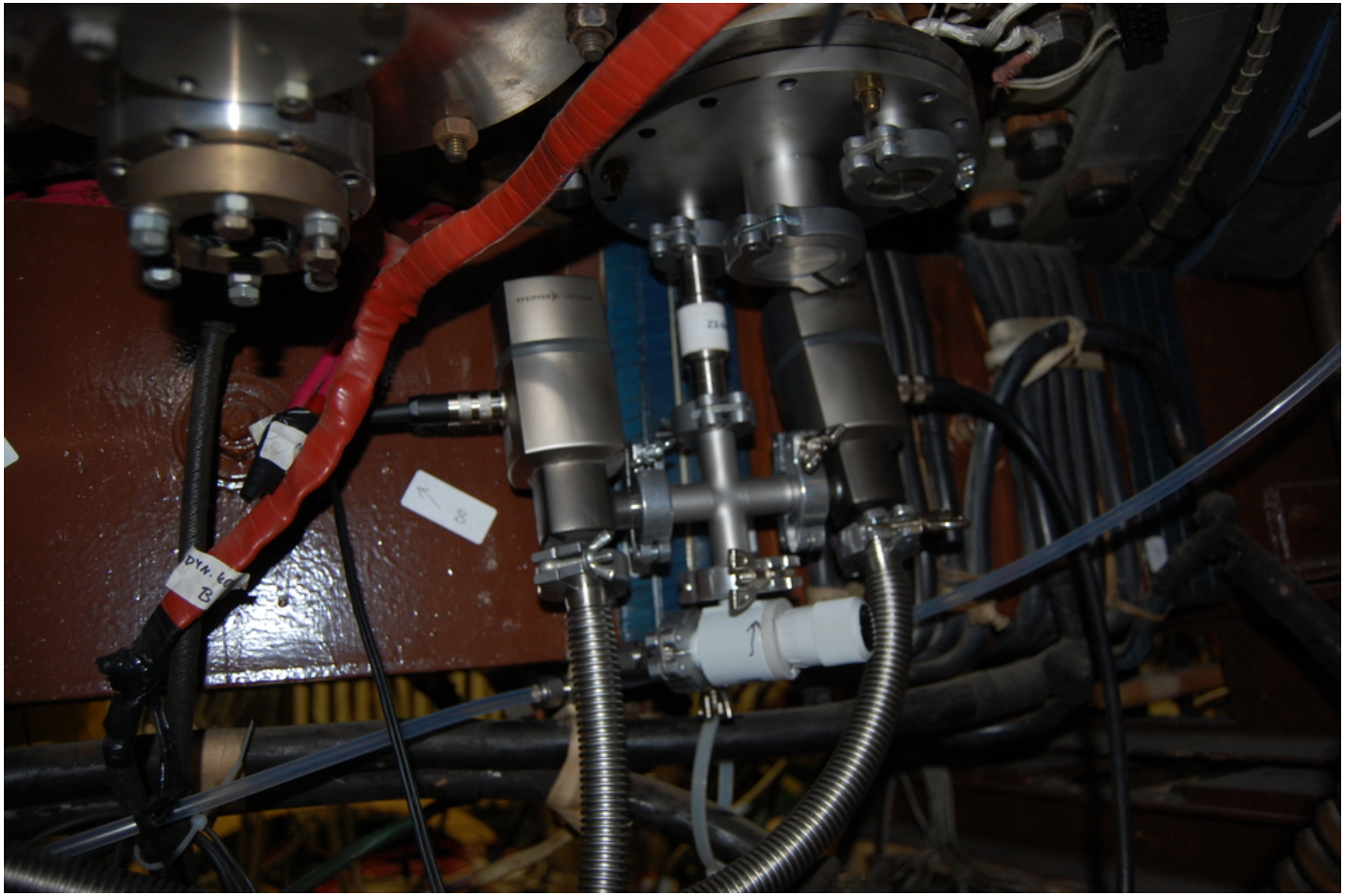


Gas reservoirs - Air, H_2, He



Comparison of discharges in H and He

Gas injection system - H_2, Air, He



Manual

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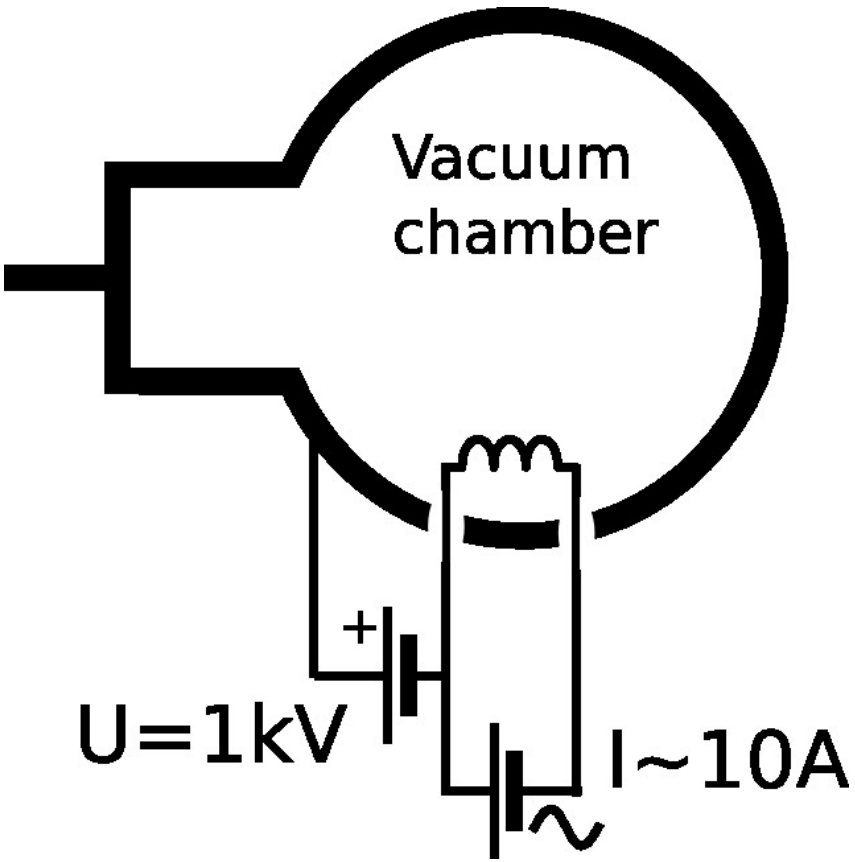
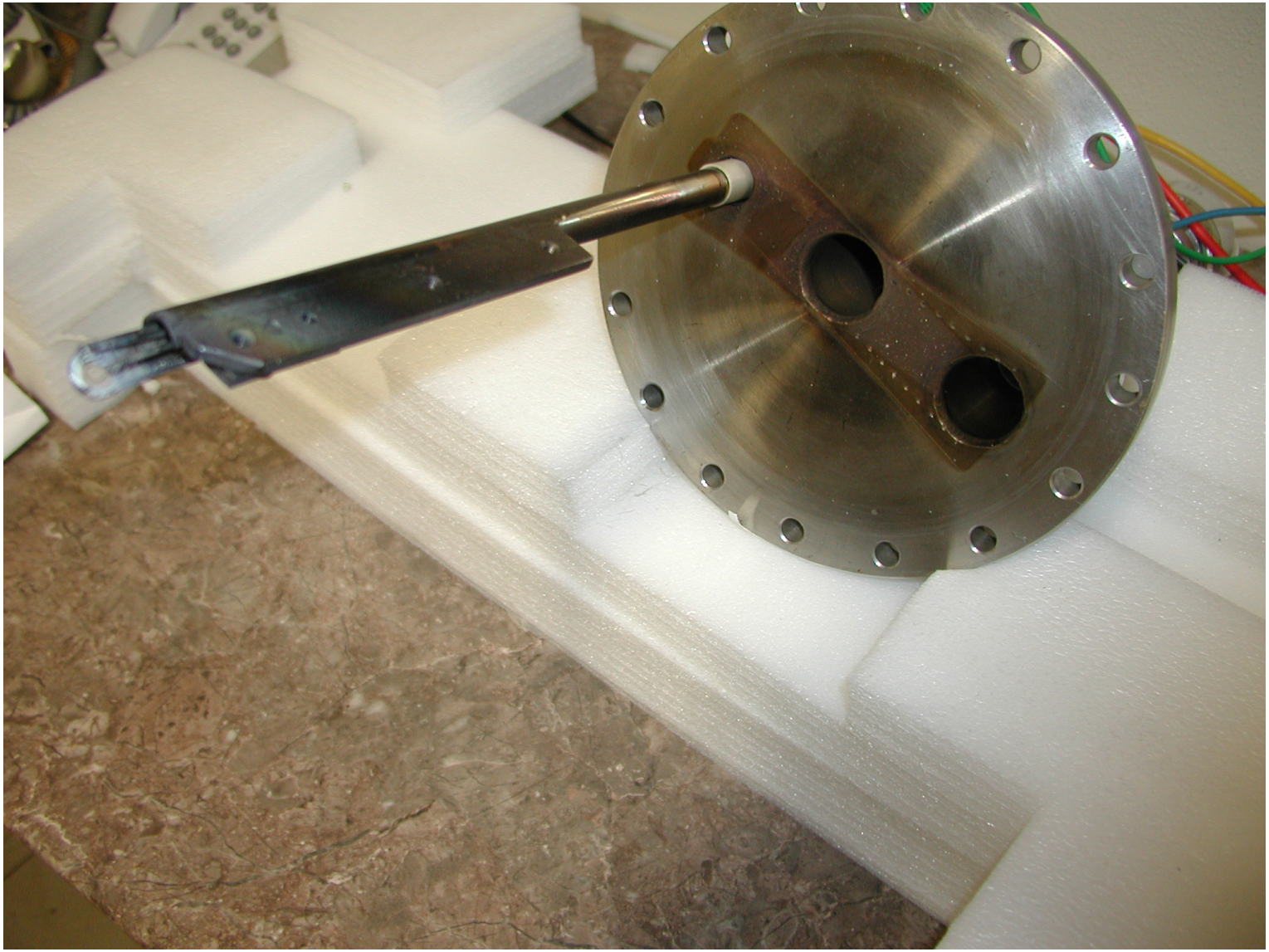
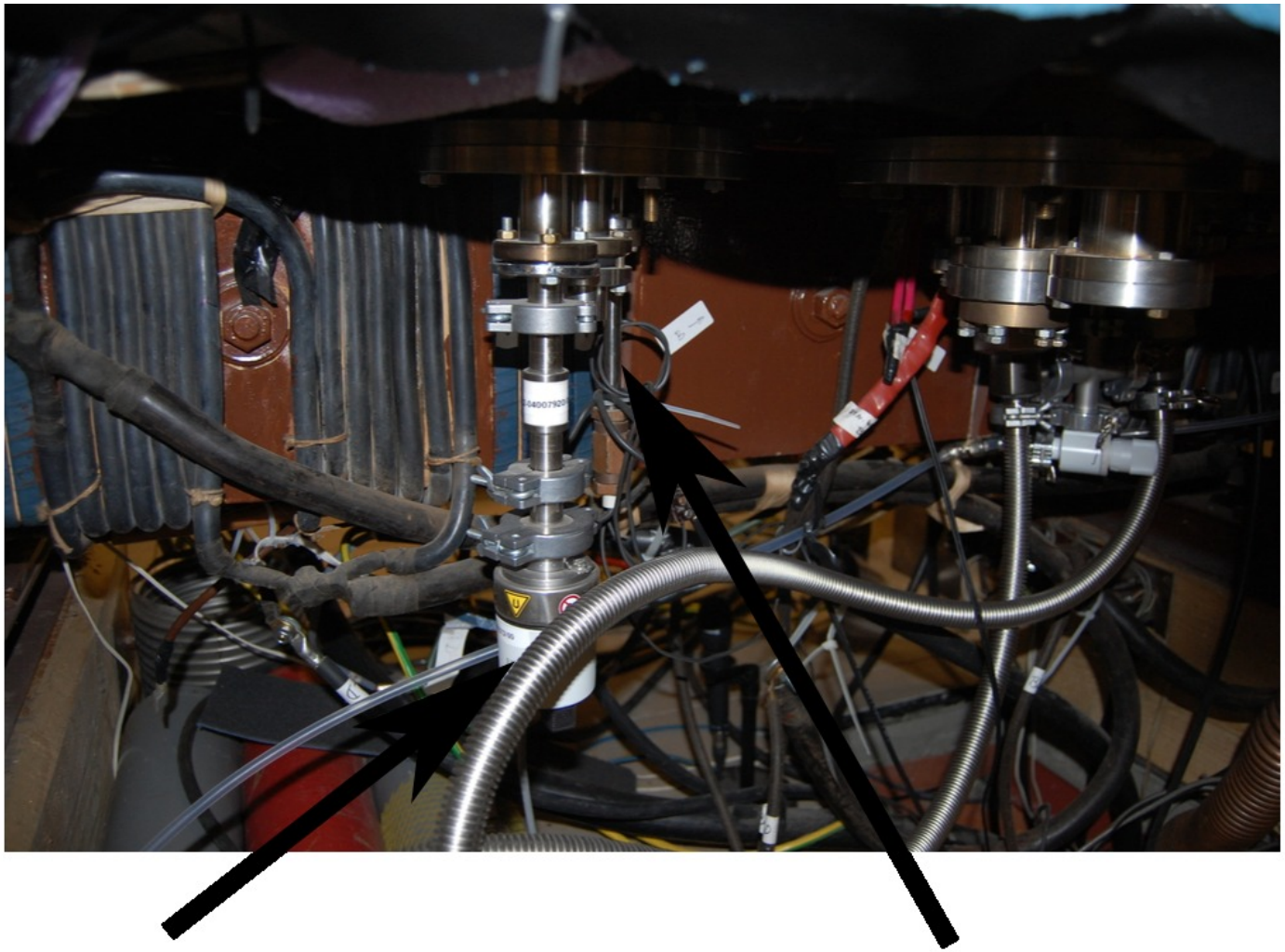
Preionization - scheme



Preionization Gun

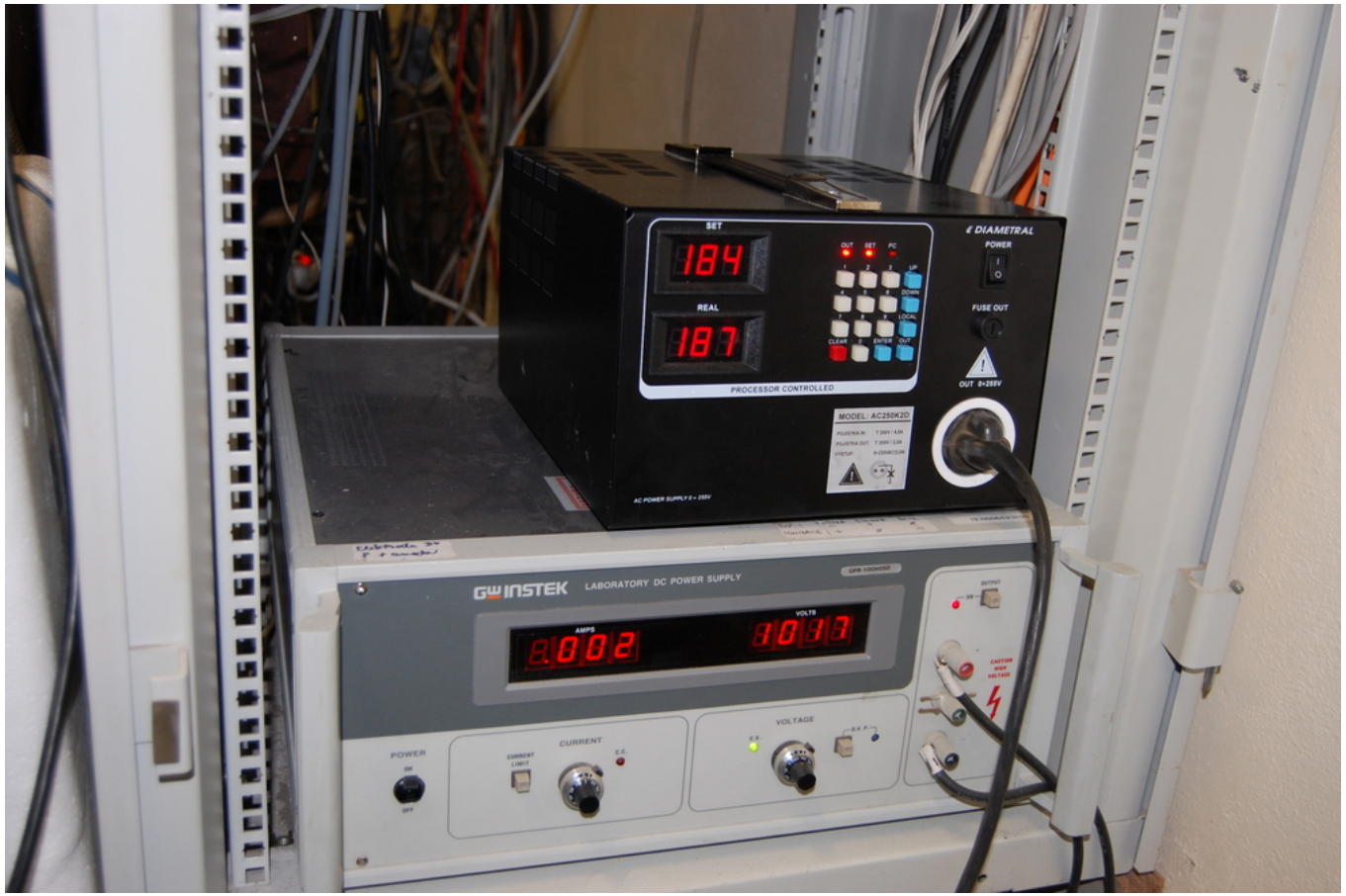


NorthWest - Bottom: Vacuum Gauge & Preionization Gun



Vacuum gauge Preionization gun

Preionization - power sources



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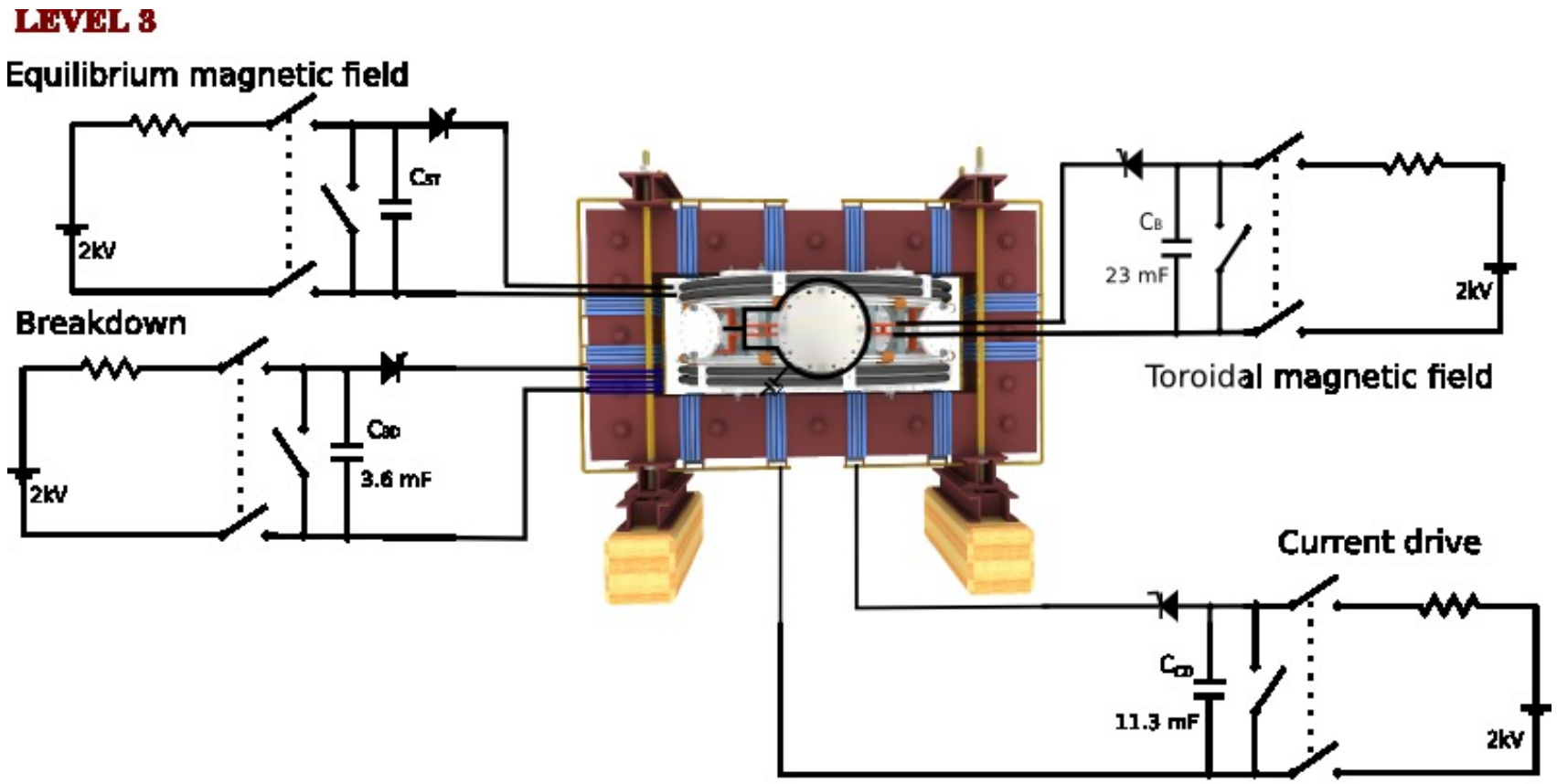
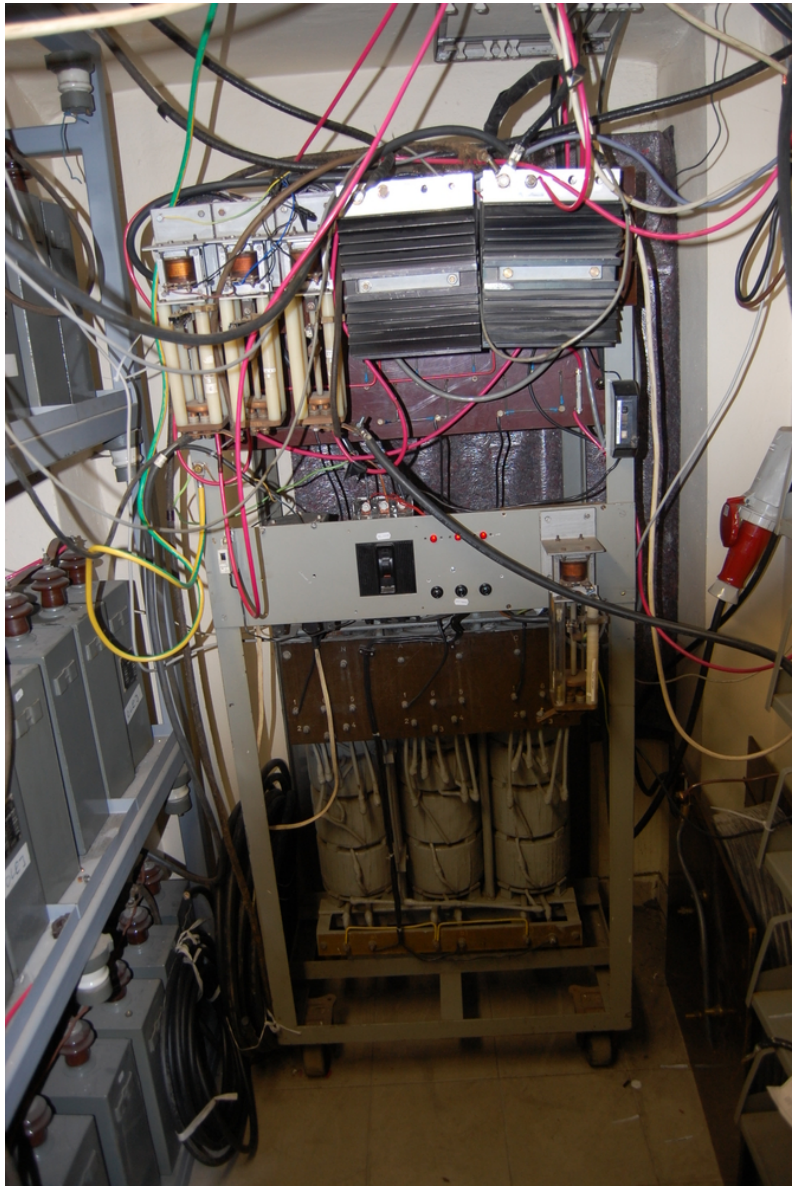
Energetics infrastructure - setup

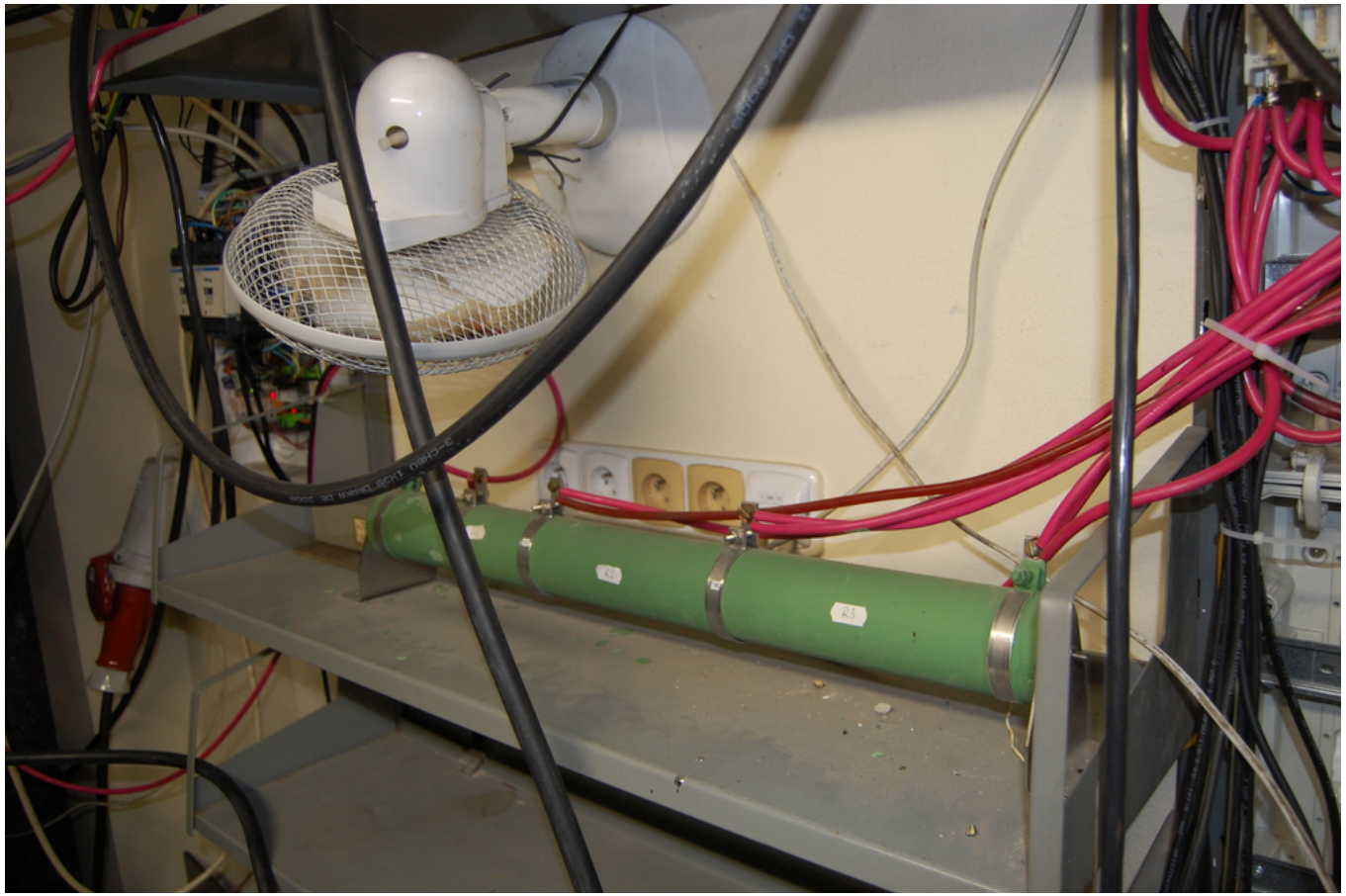


2kV power source, short circuit system and thyristors for breakdown and plasma stabilization

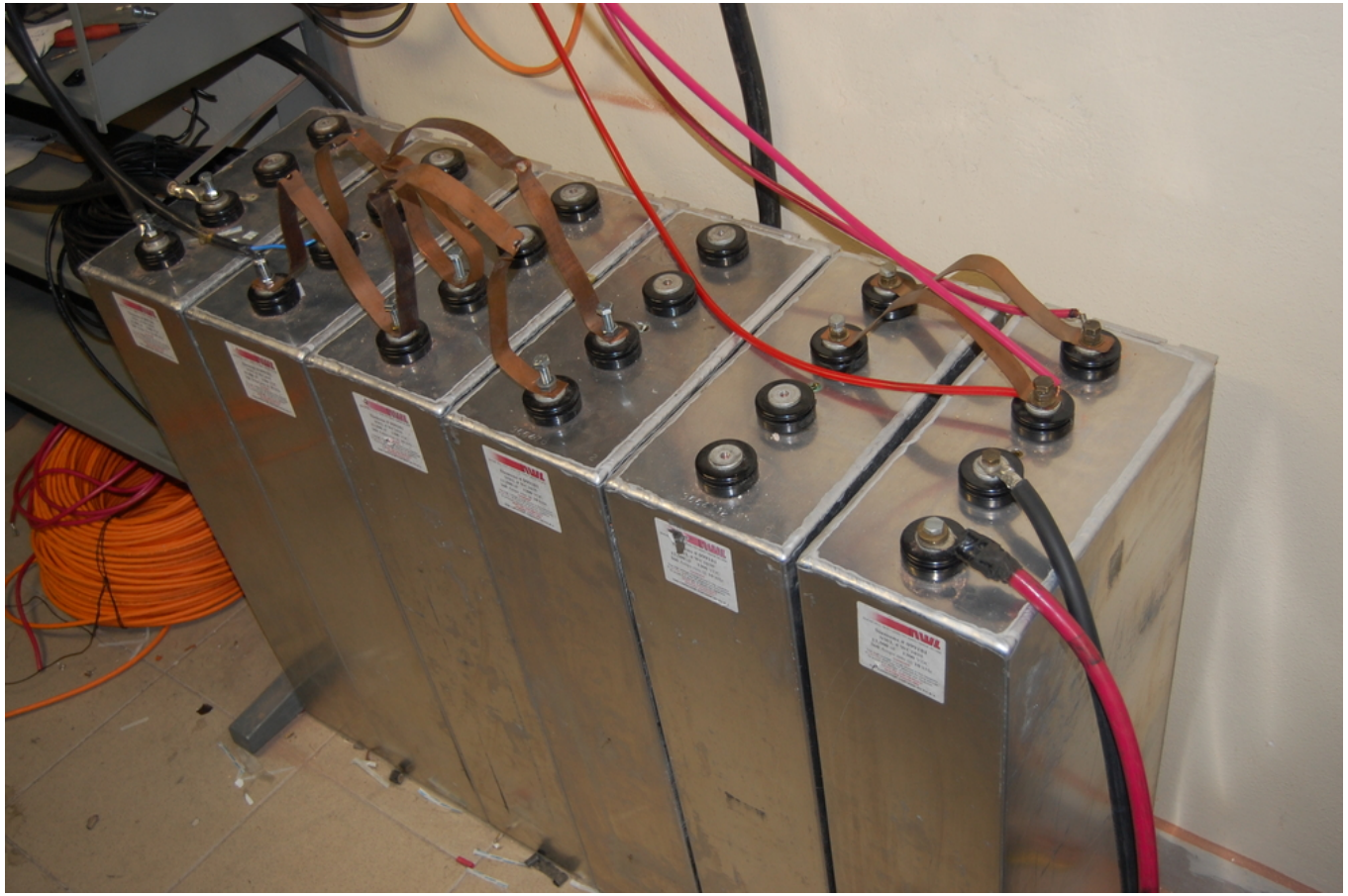


Thyristors for magnetic field and current drive

Charging resistor (common for all 4 circuits)



Capacitor bank for toroidal magnetic field

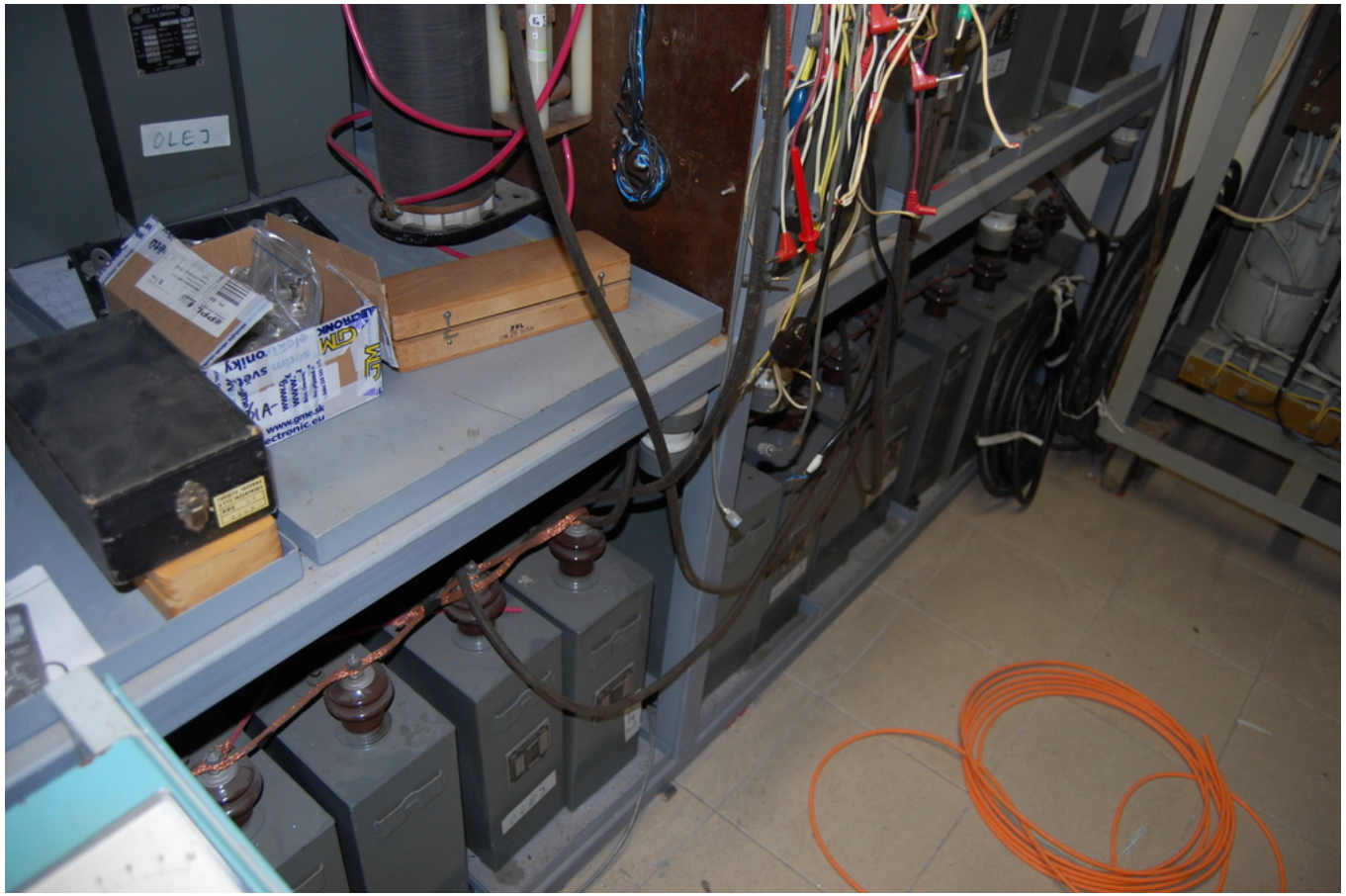


13500 fd, 1300 Volt, 11500 Joule Oil-Filled Energy Storage Capacitor

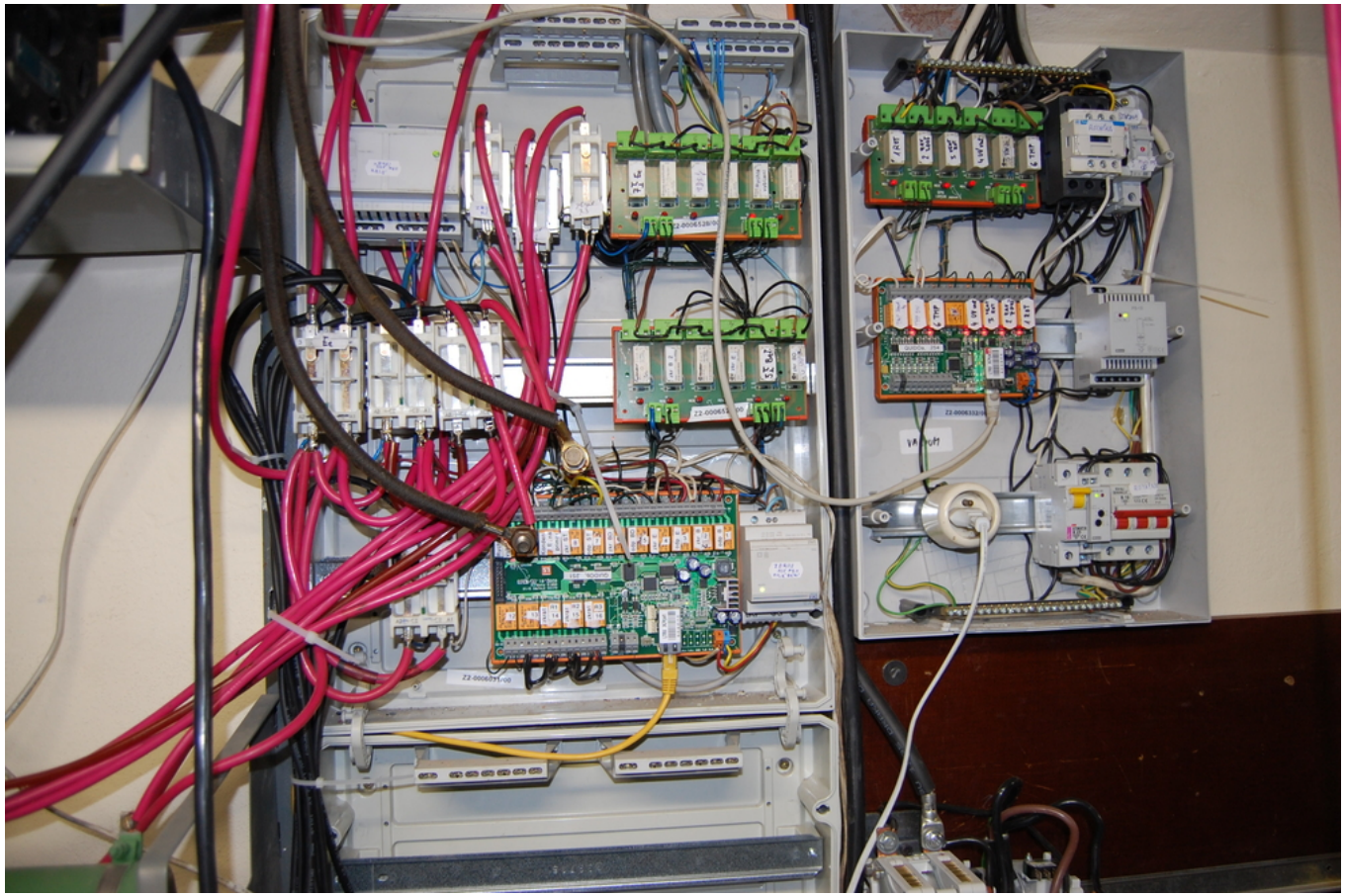
Capacitor bank for current drice

Capacitor bank for breakdown

Capacitor bank for plasma stabilization



Control system for capacitor charging and vacuum management



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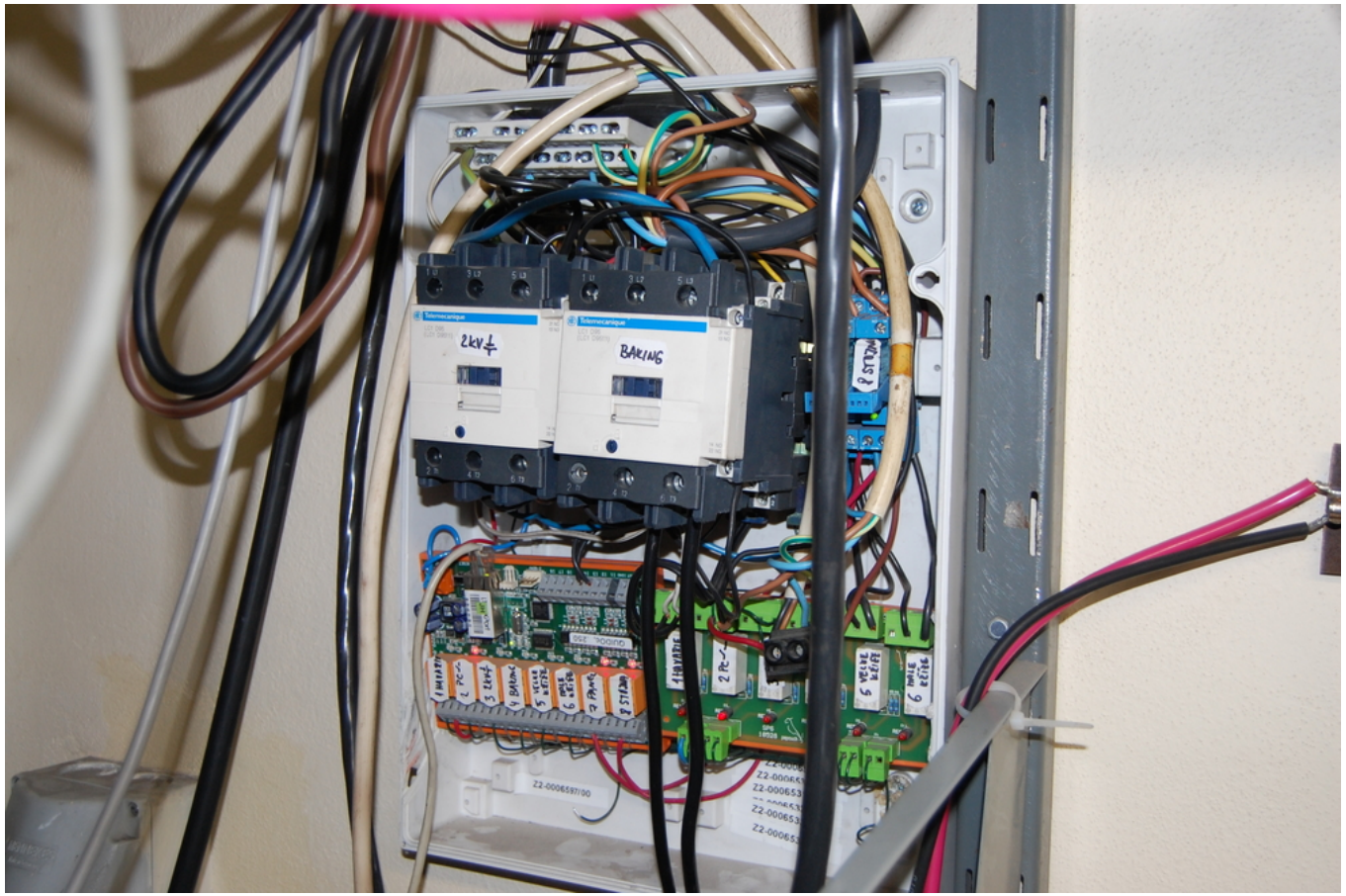
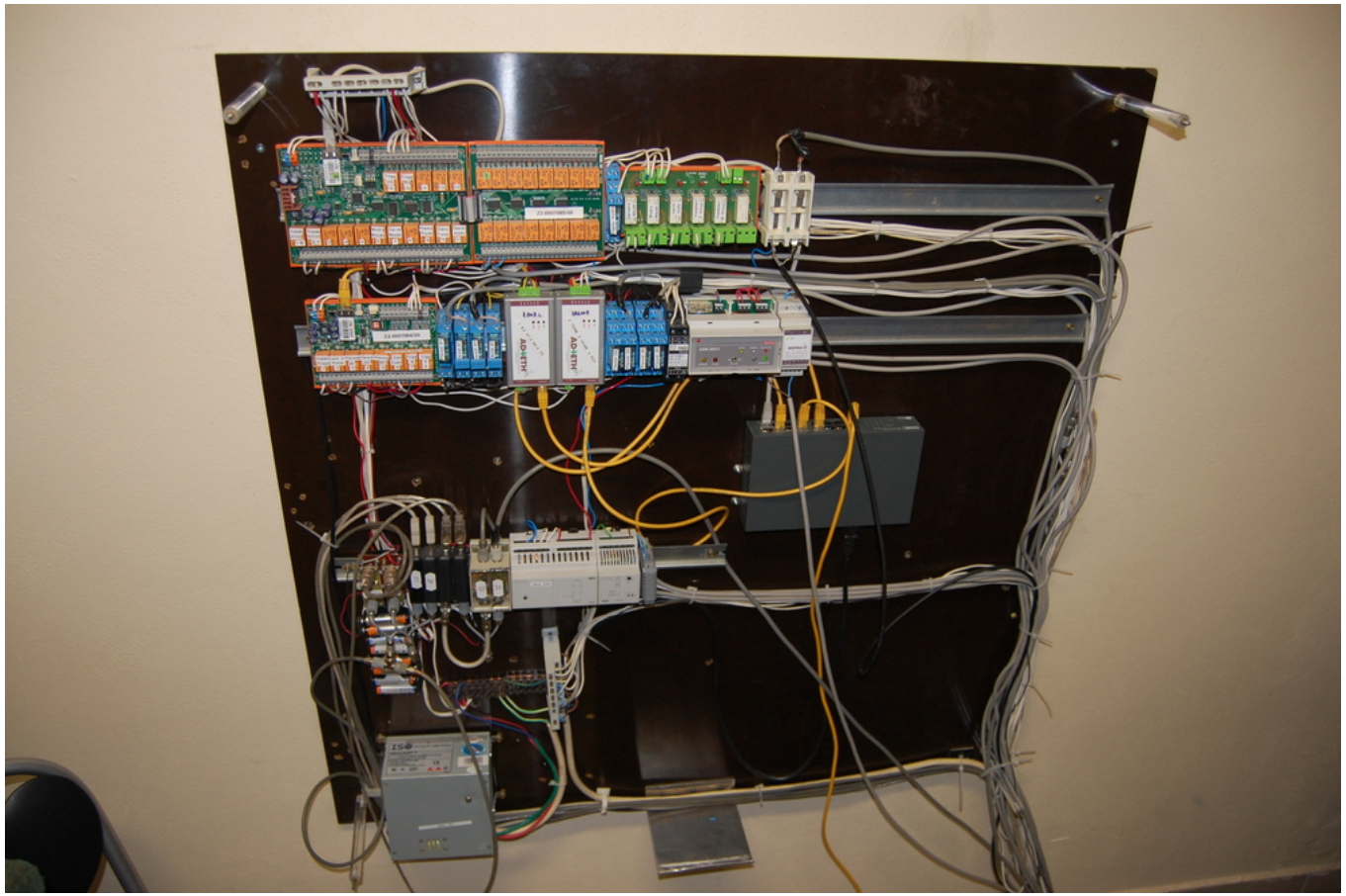
Control system for Global Power source



Basic control /including triggering system



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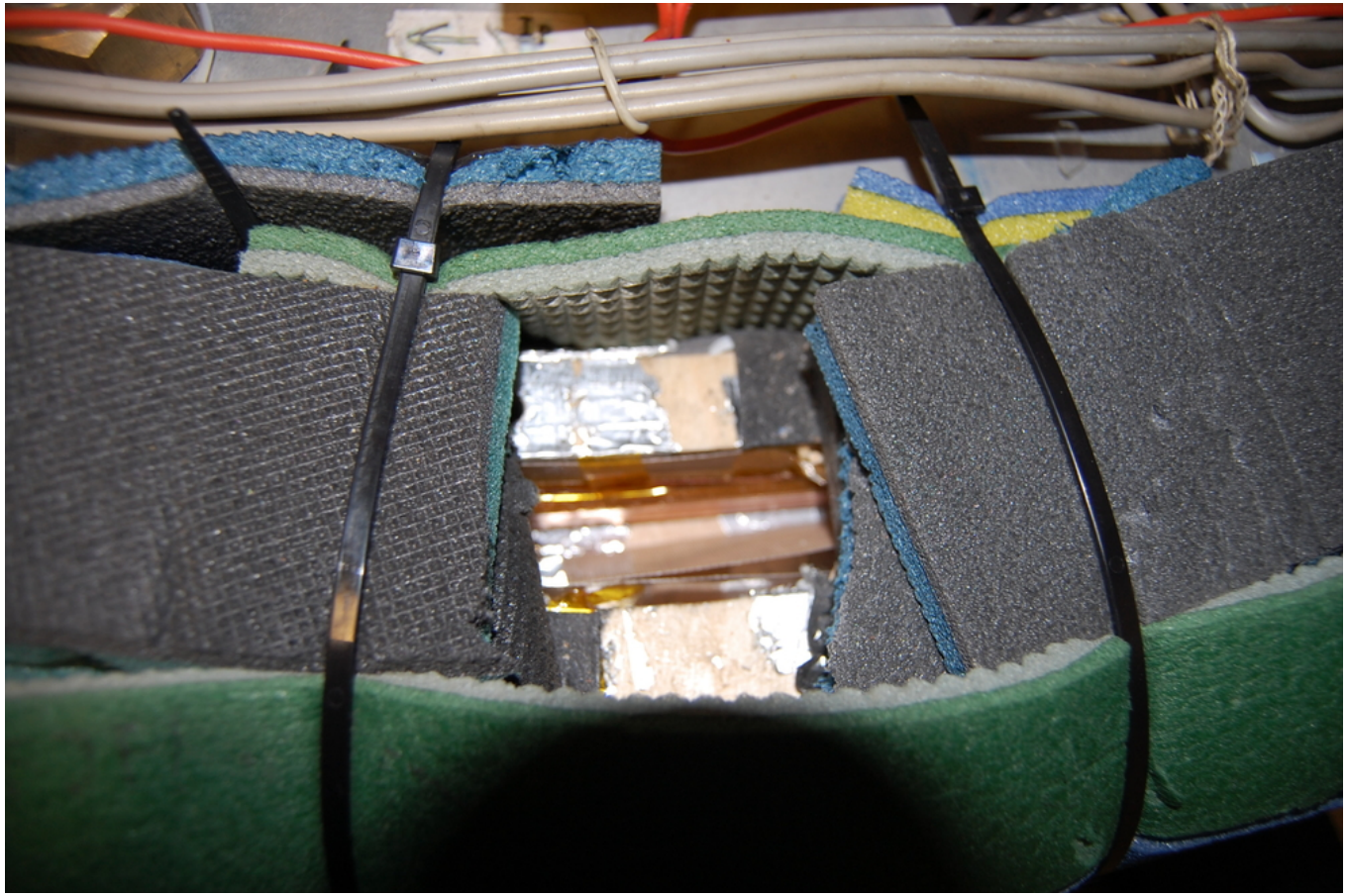
Looking into chamber with the help of glow discharge

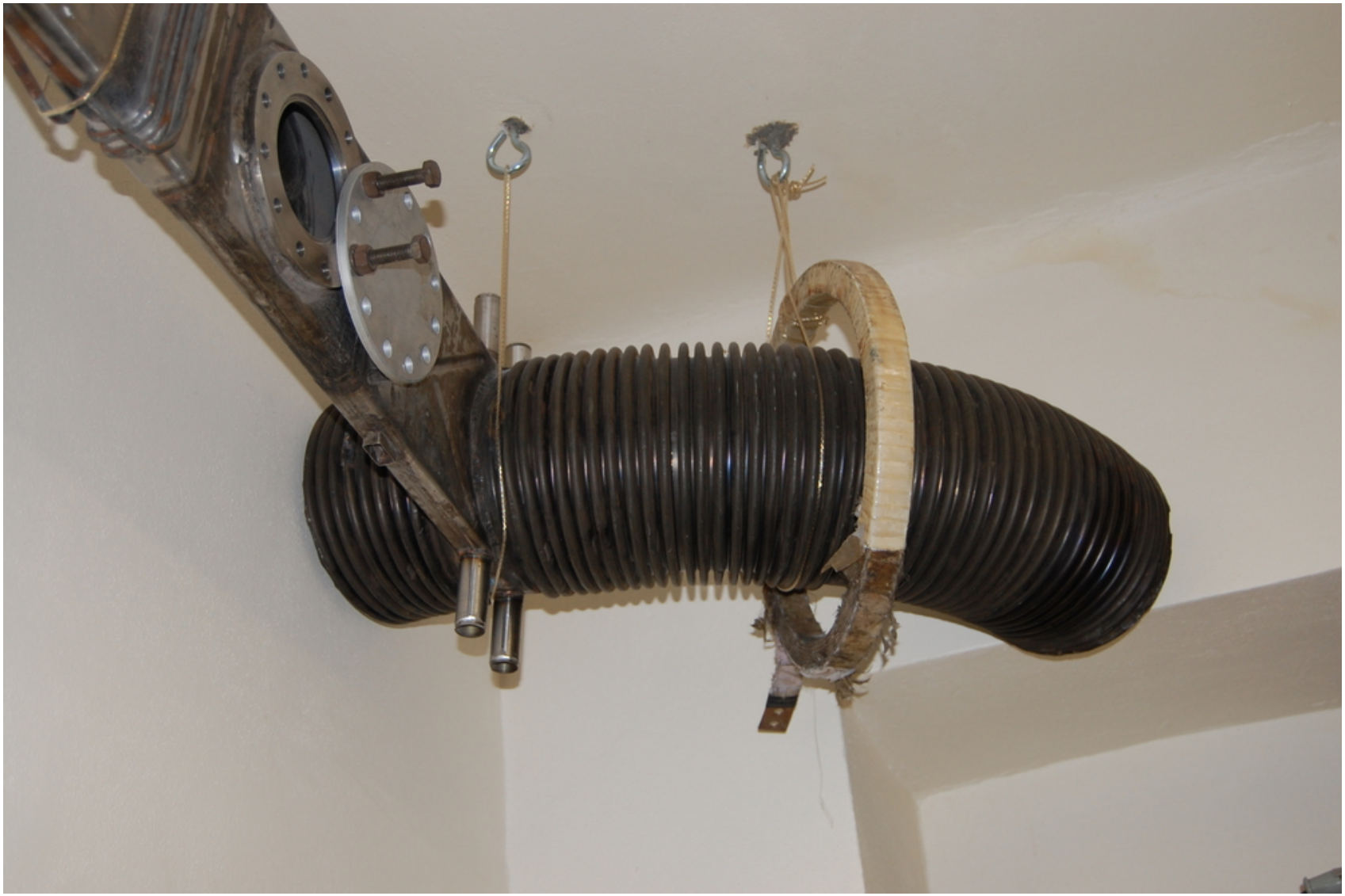
High Temperature Superconductor in cryostat



2 x 6 turns of the 2nd generation HTS (Re)BCO tape

VIP wall. Do you know somebody?

Original TM1 chamber



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GOLEM team (students, teachers, technicians)

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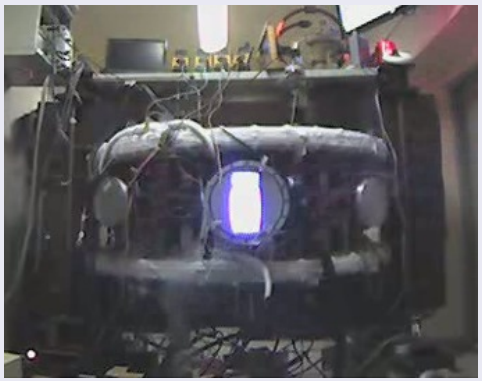
Special thanks: NATIONAL INSTRUMENTS™

Final

Thank you for your attention



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

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