Test Station Kick-off meeting

v. 10 June 2015

1 Welcome and Introduction 10’

2 Goals of the test 15’

3 Update on the HTS dipole 30’
- Design status
- Manufacture status/plan

Quench detection and protection issues
- Associated equipment
- Temperature probes

Others (voltage taps, magnetic field)

4 LASA Test Station Features 30’
- Cryostat
- FAST Acquisition
- Slow acquisition
- QDS
- Power Supply
- Switch

5 Temperature control design 15’

A proposal for controlled-temperature operation

6 Interface Issues 30’

Signal channels required,
- Number
- Connectors
- Internal wiring characteristics, wire material, twisting etc.

Other information from the test station
- Current
- Pressure, temperatures, others

Mechanical interfaces (magnet fixture)

Power Electrical Connection

Format for offline data exchange

7 Looking forward to testing 20’
- Test schedule
- Magnet transportation & handling requirements
- Room and services required for the instrumentation, ancillaries and people!

8 Conclusions and wrap-up 30’

2. Goals of the test

Milestones and Deliverables

MS64	[illegible] magnet design completion	[illegible]	[illegible]	Report
MS65	Test Station Kick-off	19	26	Report
MS66	First Cable length for magnet winding	1	32	Prototype

D10.4) Magnet Cold test: The test will include: warm measurements, cold down, electrical quality assurance at cold, power test, training curve, magnetic measurements and finally re-training for memory effects (Task 10.4) [month 44]

January 2017

Task and subTasks

Task 10.4. HTS Magnet Stand Alone Test
This task will be led by INFN, with the participation of CERN, CEA, TUT, DTI and Grenoble INP.
Subtask 10.4.1 Test station modification The magnet test station must be adapted to suit the specific features and needs of this magnet. The adaptation includes: (i) Cryogenic verification of the cryostat, with respect to the specific level of stored energy, (ii) Mechanical verification, including magnet weight and forces between stray magnetic field and ferromagnetic structures, (iii) Assembly station modification (iv) Magnet mechanical suspension (v) Electrical power.
Subtask 10.4.2 Magnet cool-down and energization. Perform the magnet cooldown to liquid helium. Current is raised to the magnet up to nominal value; normally spontaneous magnet quenches arise at increasingly higher currents (a behaviour known as training). Quenches may also be triggered intentionally to verify the magnet response. Voltage and possibly other signals are collected during normal operation and quench in order to assess the magnet performance. The magnet may be warmed up and cooled again to verify the impact of the thermal cycle.
Subtask 10 4.3 Magnetic measurements Measure the harmonic content of the magnet at different excitation currents in liquid helium. Measure AC losses during current cycles. The tests will be carefully analysed and will give feed back to design (task 10.2 and task 10.3)

The plan, or what we really want to do

SubTask 10.4.2
Cool down to LHe
Training w/provoked quenches
Warm up and retraining

→

Cooldown to LN
Test at LN
Test at intermediate temperature (likely, but to be demonstrate
Test at LHe

SubTask 10.4.3
Measure the harmonic content at LHe,
at different values of excitation current

→

As it has been emphasized often,
LASA has not the suitable equipment.
It appears hardly feasible, requires ad hoc probes.
Could it be replaced by residual magnetization
measurements with Hall probes?

Measure the AC losses in varying-current regime

→

Can be done,
how interesting is this?

4. LASA Test Station

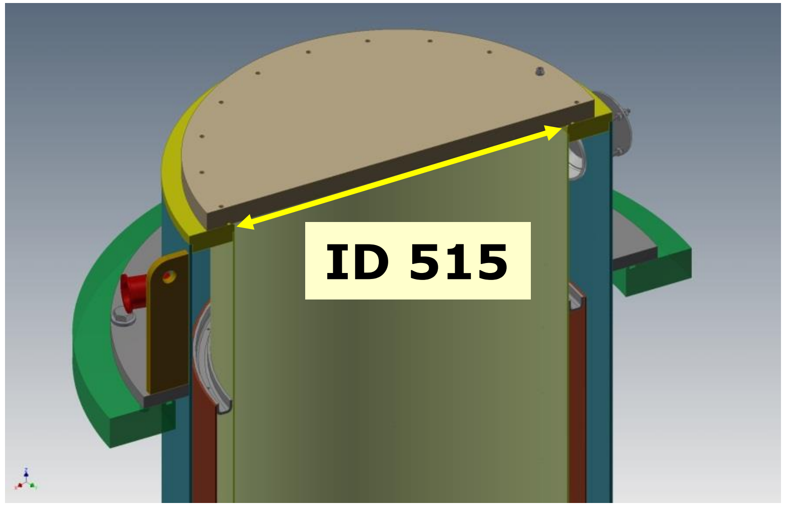
Experimental area

DISCORAP Vertical cryostat

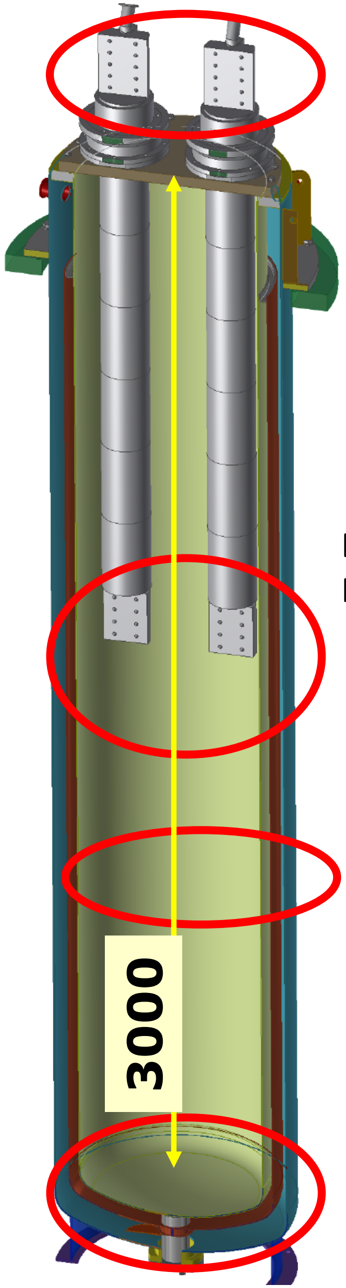
Free ID 697 mm
Max operating pressure 4.5 bar
Thermal shield cooled by LN or evaporated GHe

DUT
max lenght 5 m
max weight 10 ton

Key Issues



2.5 ton design load
Conduction cooled thermal shield
Design option: ring to fix a λ-plate w/ reduces free bore



No of sensor, and wiring to be clarified

Electrical connections magnet to CLs
Must operate in gas flow up to maximum test temperature

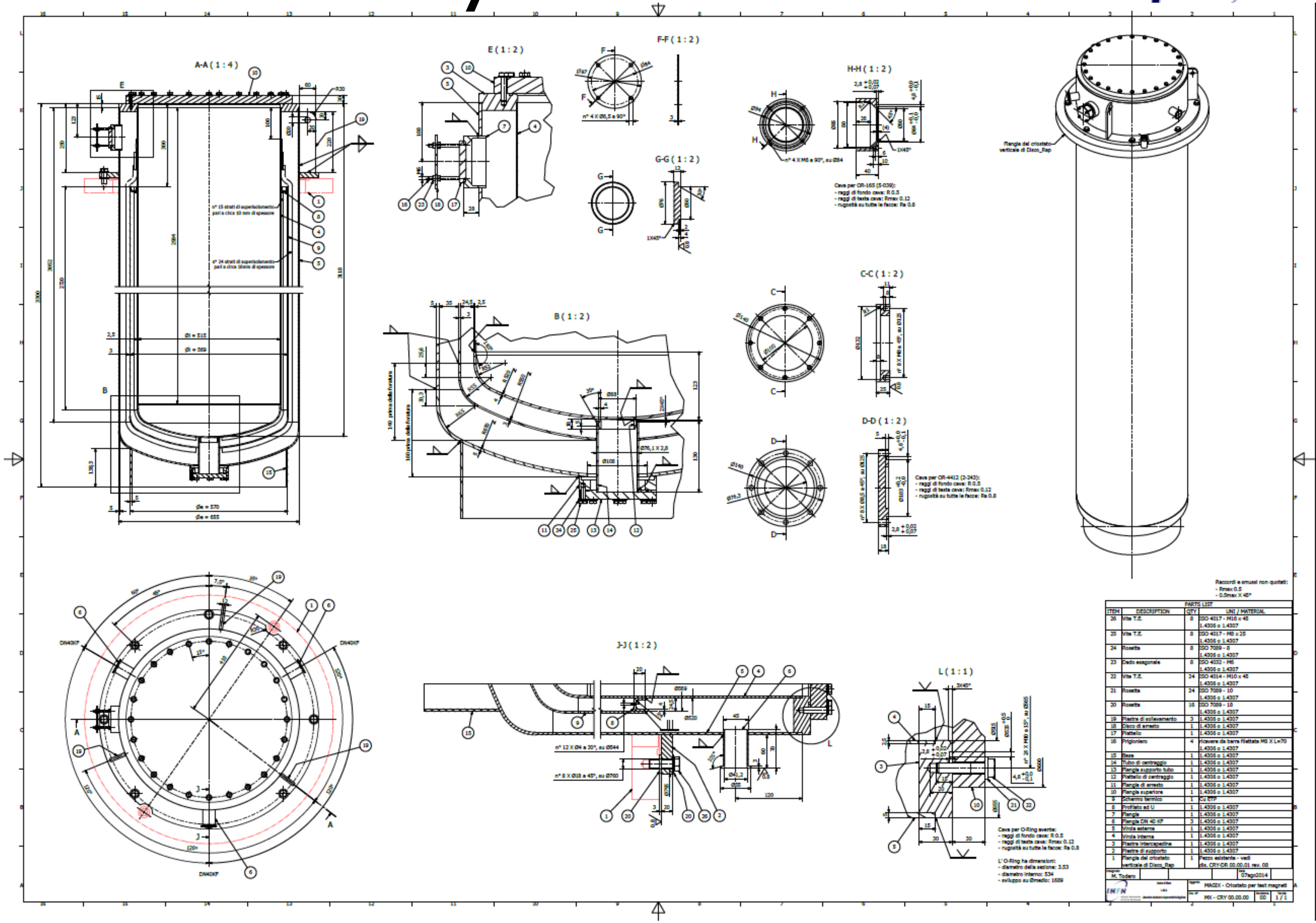
Mechanical connections
Magnet will suspended to three tie rods.

Gas-flow temperature control
A flow of ~1 g/s (30 LHe/h) will be vaporized by heaters to a controlled temperature and then the gas will be fed to the vessel containing the magnet. The exit flow should be enough to keep the CL's cold.
Temperature stability and gradient to be assessed.

MAGIX Cryostat

Cost estimate based on preliminary offer done, 30 kEuro + VAT

Now launching the call for tenders, order awarded in July



Current source

Three 10 kA x 6 V power supplies available at LASA. They can be operated in series or in parallel.

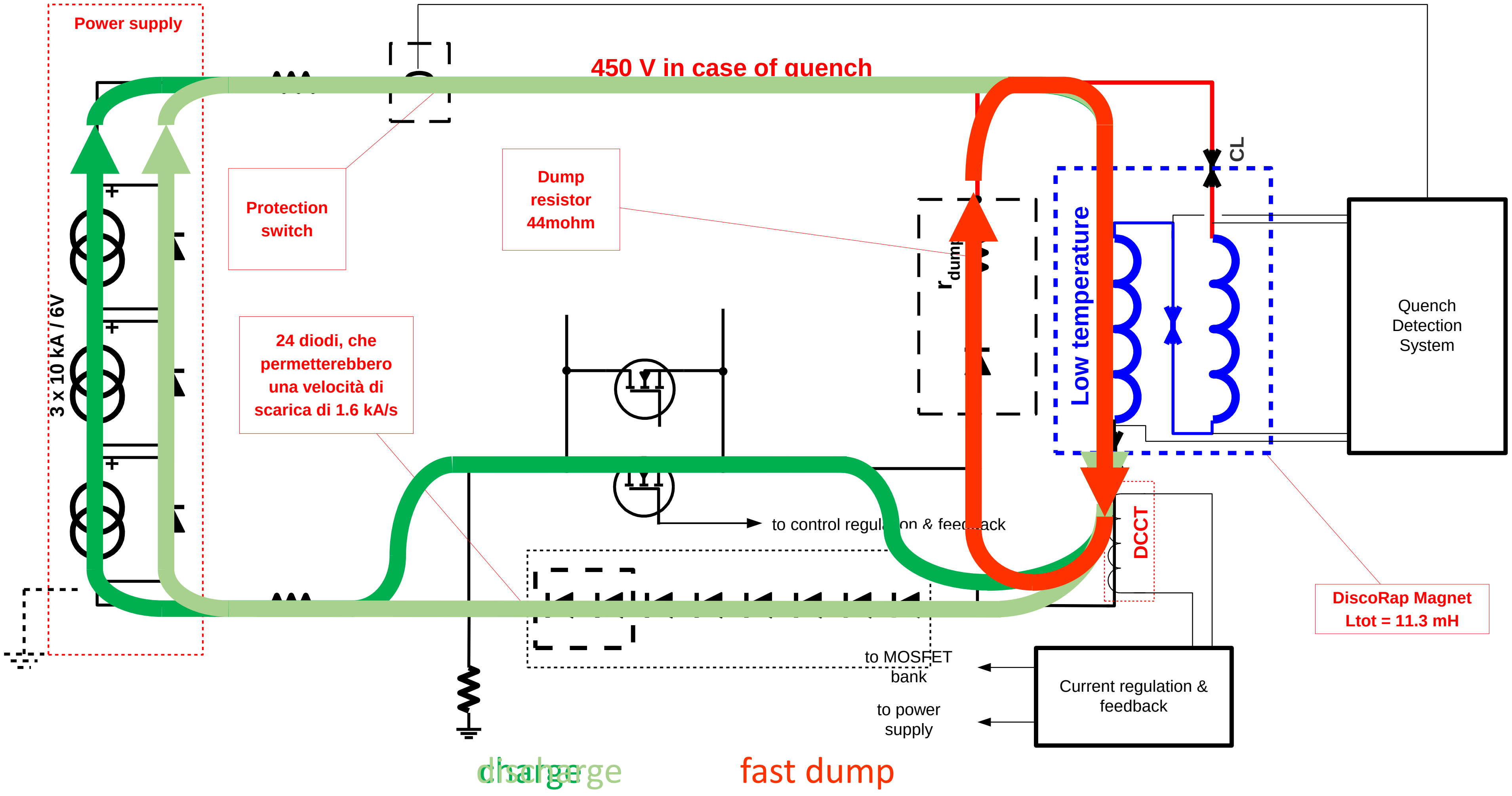
Current measured through a 10 kA DCCT.

External bus bars designed for 10 kA

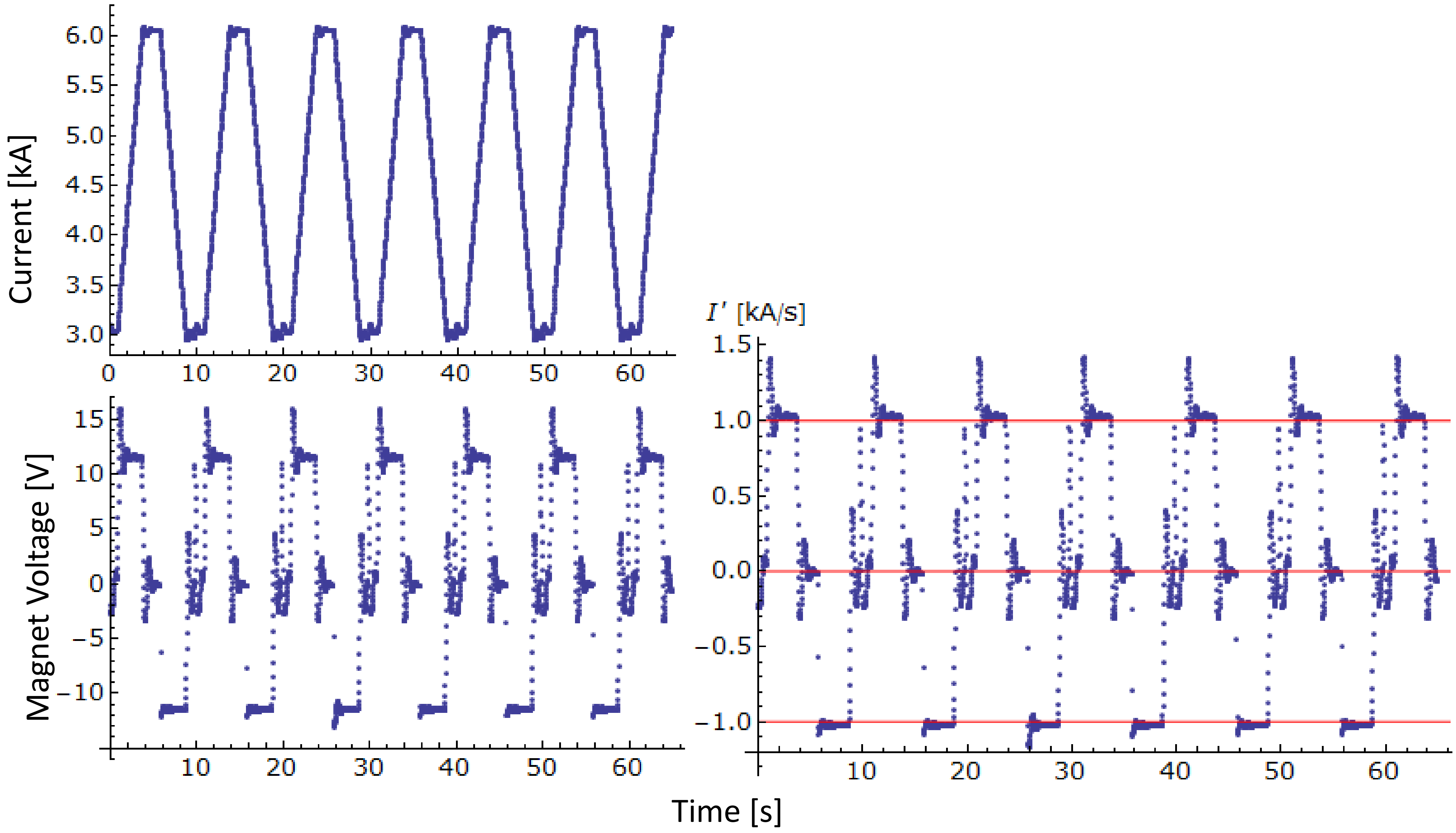
A system to operate the power supply in discharge mode is based on a diode bank which sinks the power, in parallel with Mosfet's which short-circuit the diode bank during the current ramp-up. This allows for ~ -15 V during the discharge cycle.

Sourcing and sinking current

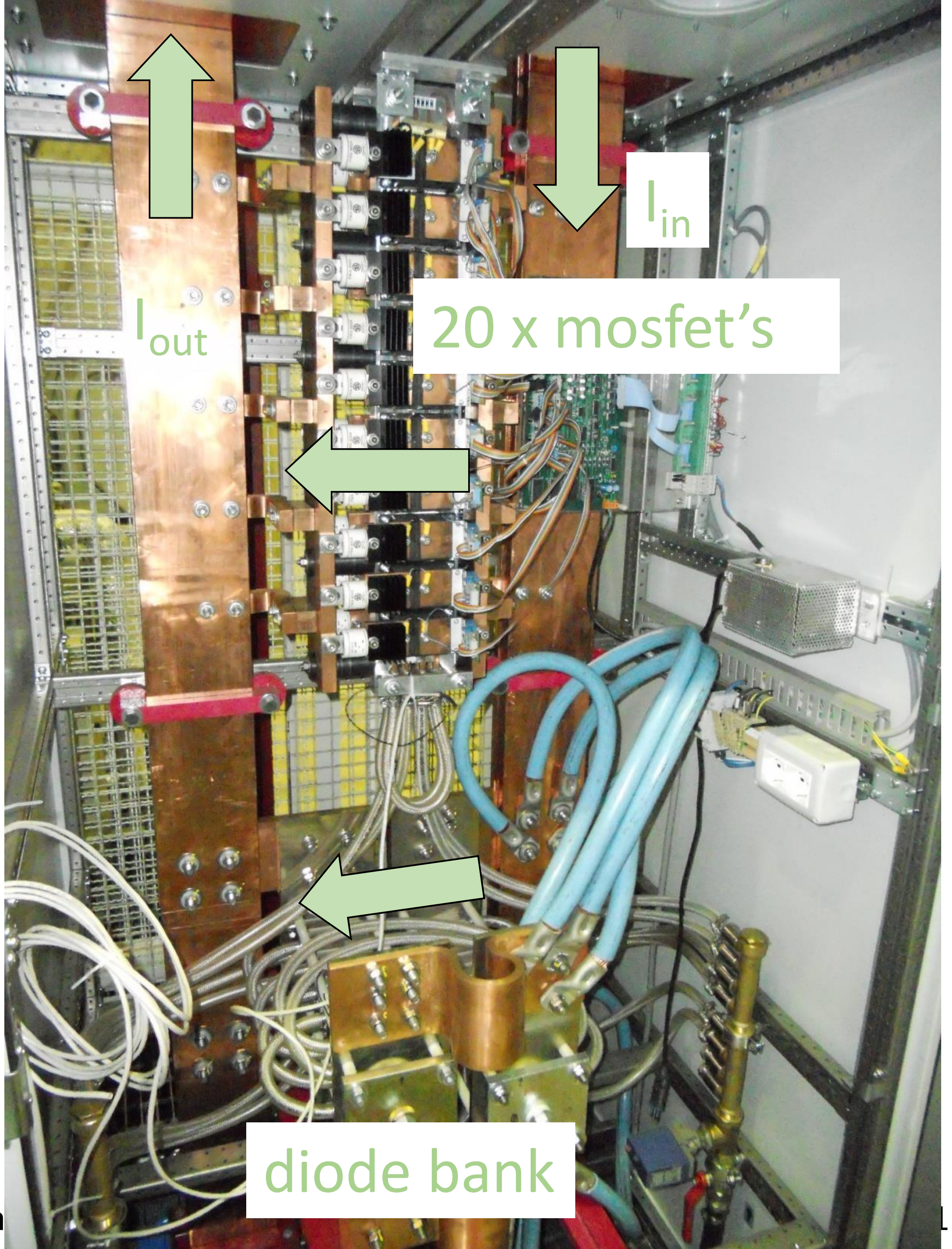
~ +18 V
~ - 15 V



an example : test run 3 to 6 kA @ 1 kA/s (nominal)

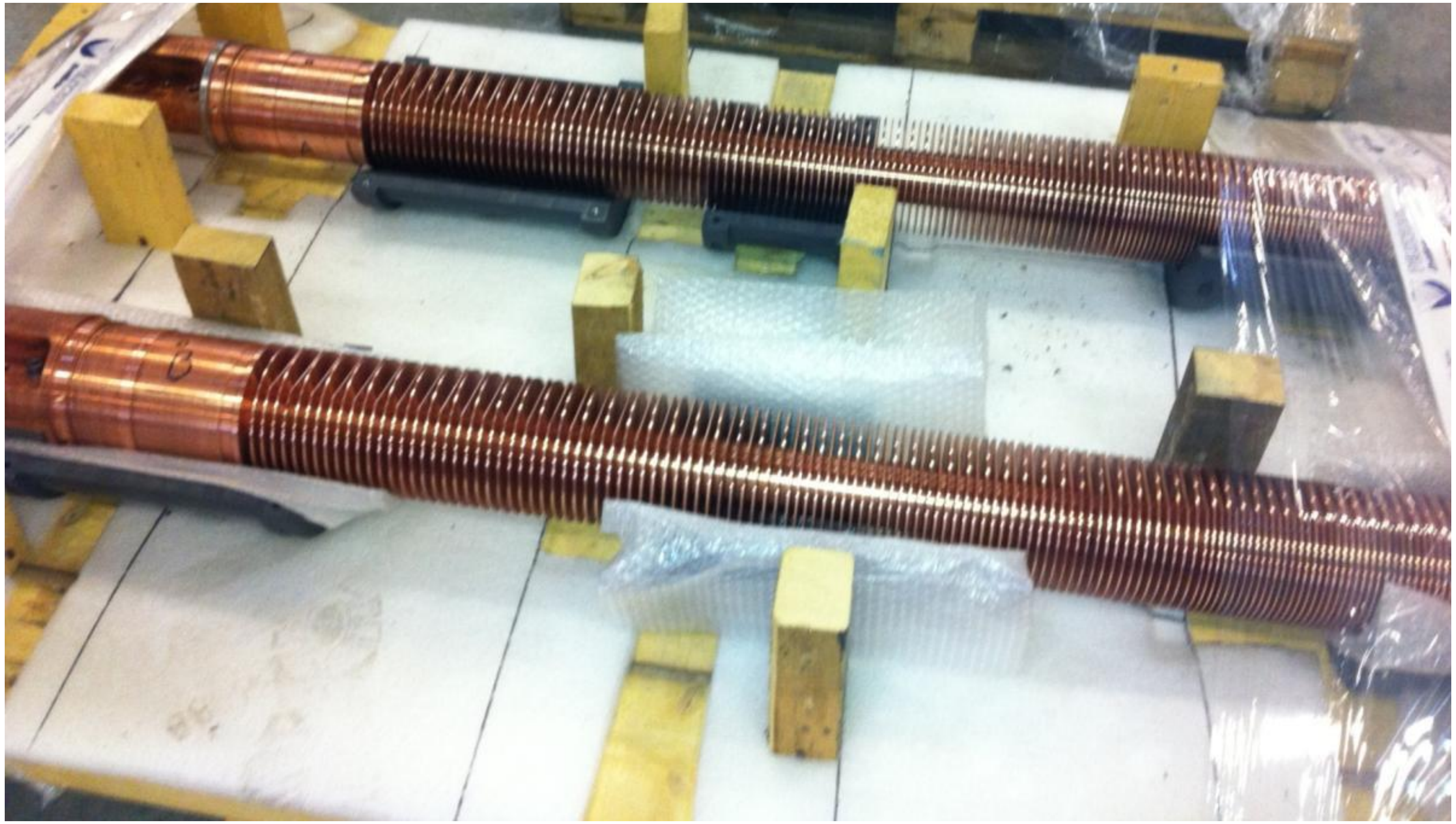


Current control



Current leads

Bare heat exchanger of the 10 kA-class CL designed at LASA and manufactured by RIAL Vacuum.
The use of CuP allows for optimized heat load performance at I=0



Control & Data Acquisition Architecture

1. QDS (MSS Magnet Safety System)
Initiates a fast discharge or switches off the power supply incase some voltage thresholds on the magnet or on its electrical connection are exceeded. Includes a capacitor bank for firing quench heaters.

2. Current Control & Slow Acquisition
Two different functions, implemented in the same hardware & software system.
Slow acquisition monitors and records most important data (temperatures, current, voltage along critical items) from the cooldown to the operation. Data are avalilable to the operator and recorded at about 1 Hz.

3. Fast Acquisition
Records voltages across the magnet under test with 1 kHz sampling frequence, in coincidence with a fast discharge

4. V*I AC losses measurement system
A dedicated system which measures the AC losses by numerical integration of V*I product, measured by a couple of synchronized VMM.

It is completely independent from other systems, from the voltage taps on.
This allows to perform checks, modification on the ground, etc. without affecting other safety-critical systems.

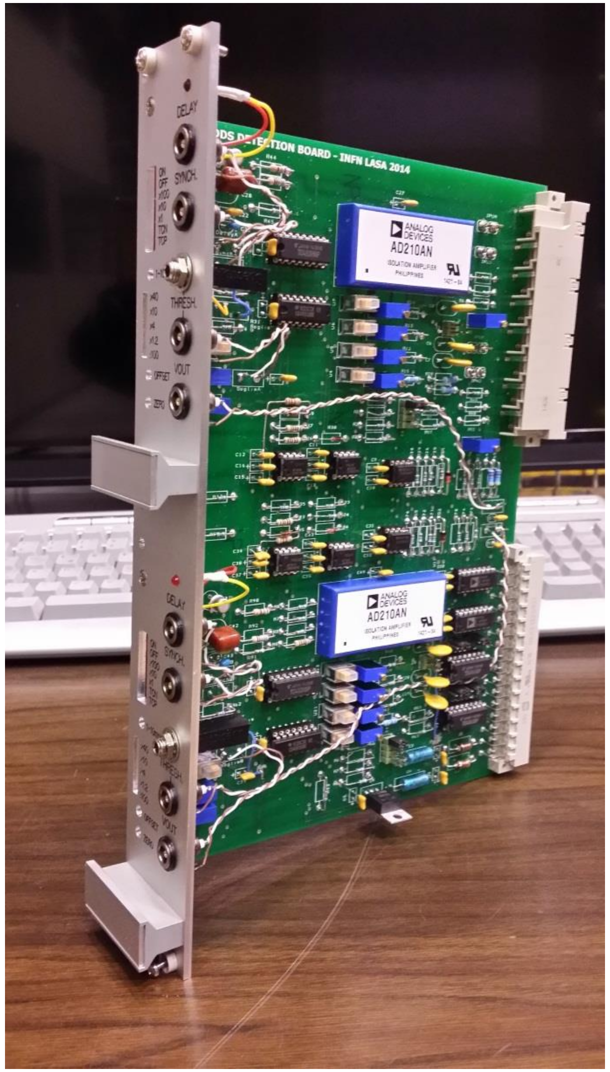
1. Quench Detection System

A system similar to the POTAIM cards.

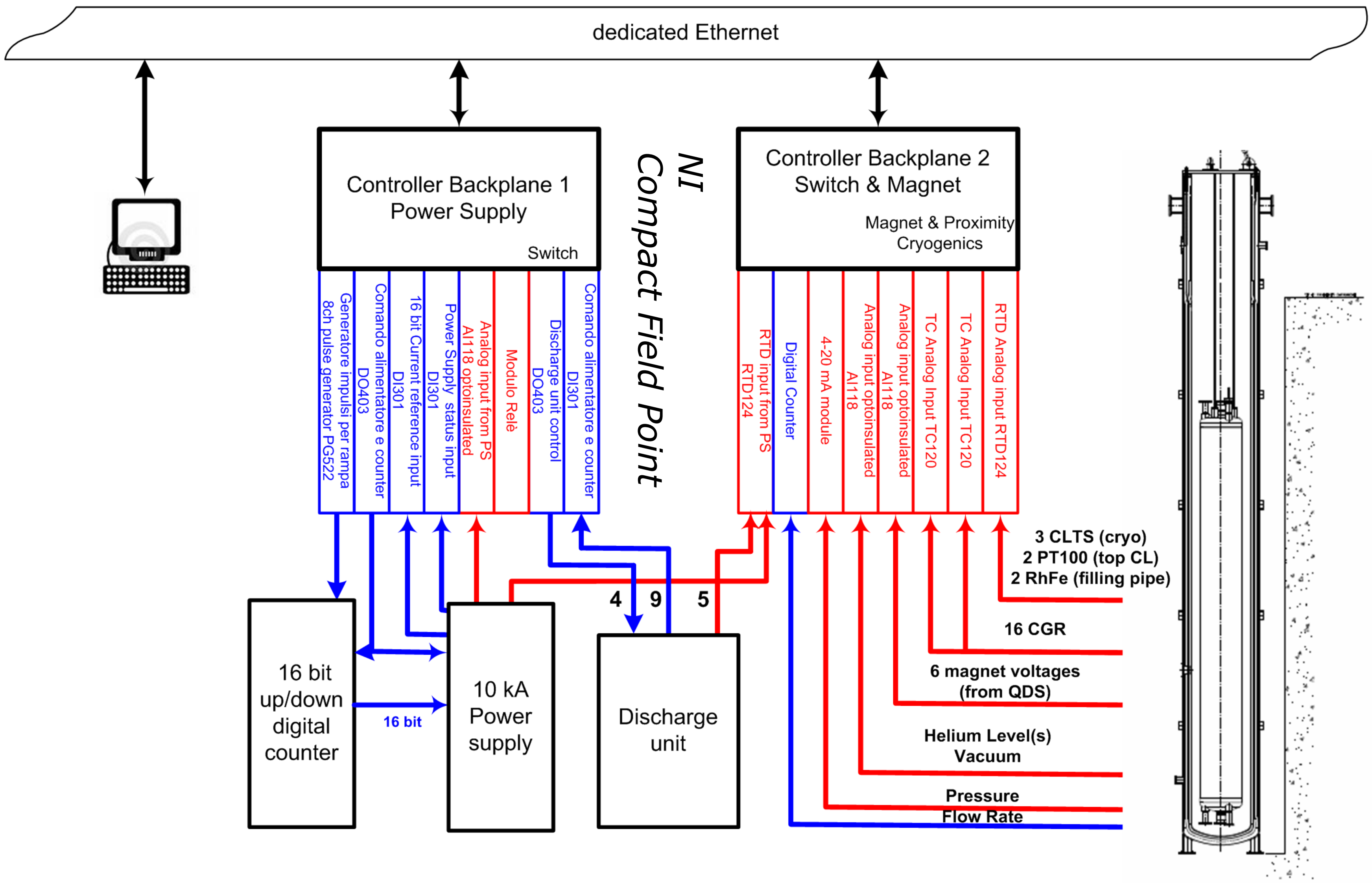
Engineered and built at LASA, it has successfully tested in field conditions during the MAGIX single coil test in April 2015

It includes:

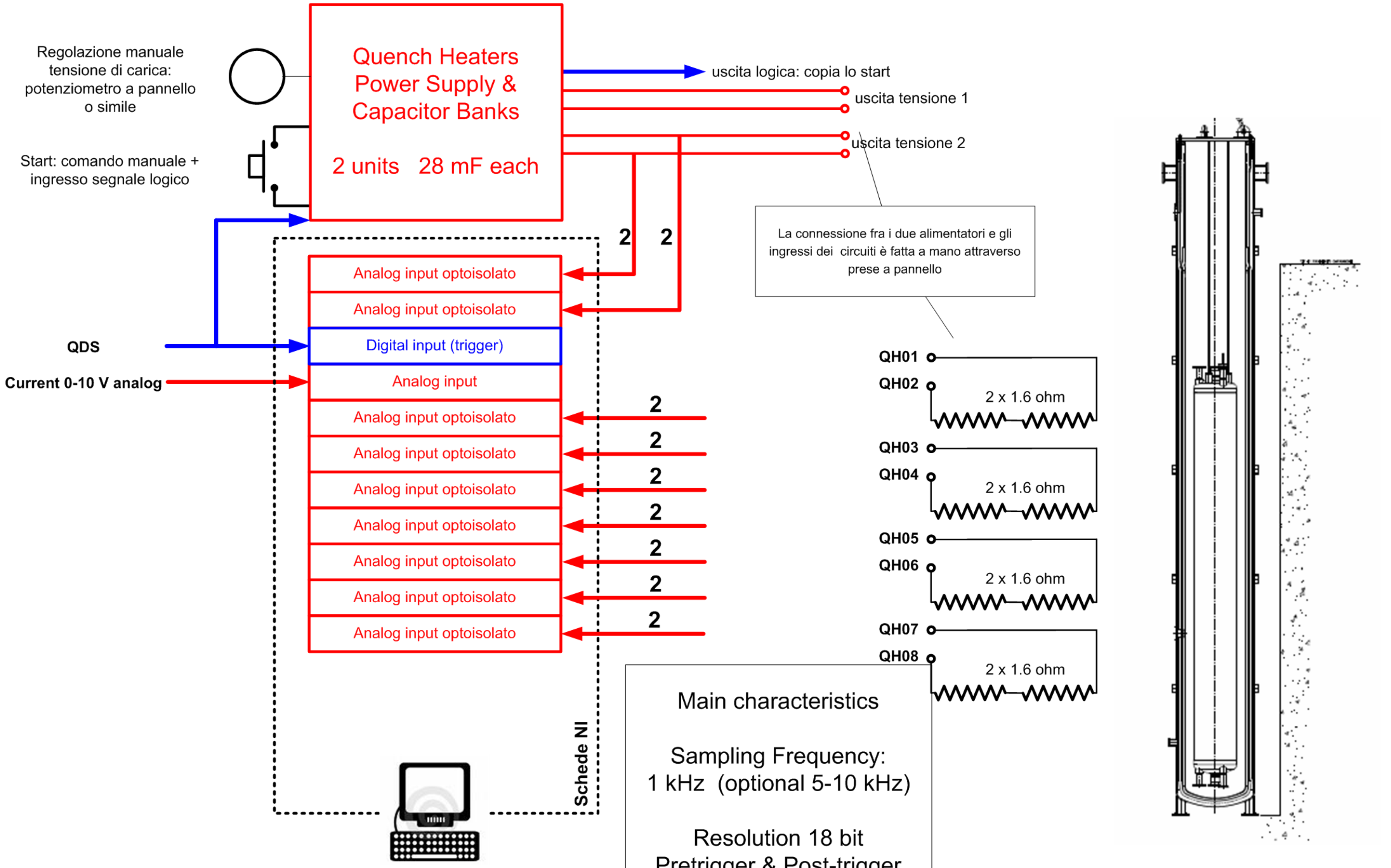
16 channels (may be expanded), each:
- optoinsulated input,
- bridge/single end
- independently configurable
- Voltage thresholds:
  - ±4V, ±1.25V, ±500mV, ±100mV
- Time validation ranges:
  - 0-10 ms, 0-100 ms, 0-1 s
- Input signal made available in copy
- Memory of channels fired



2. Slow Acquisition



3. Fast Acquisition

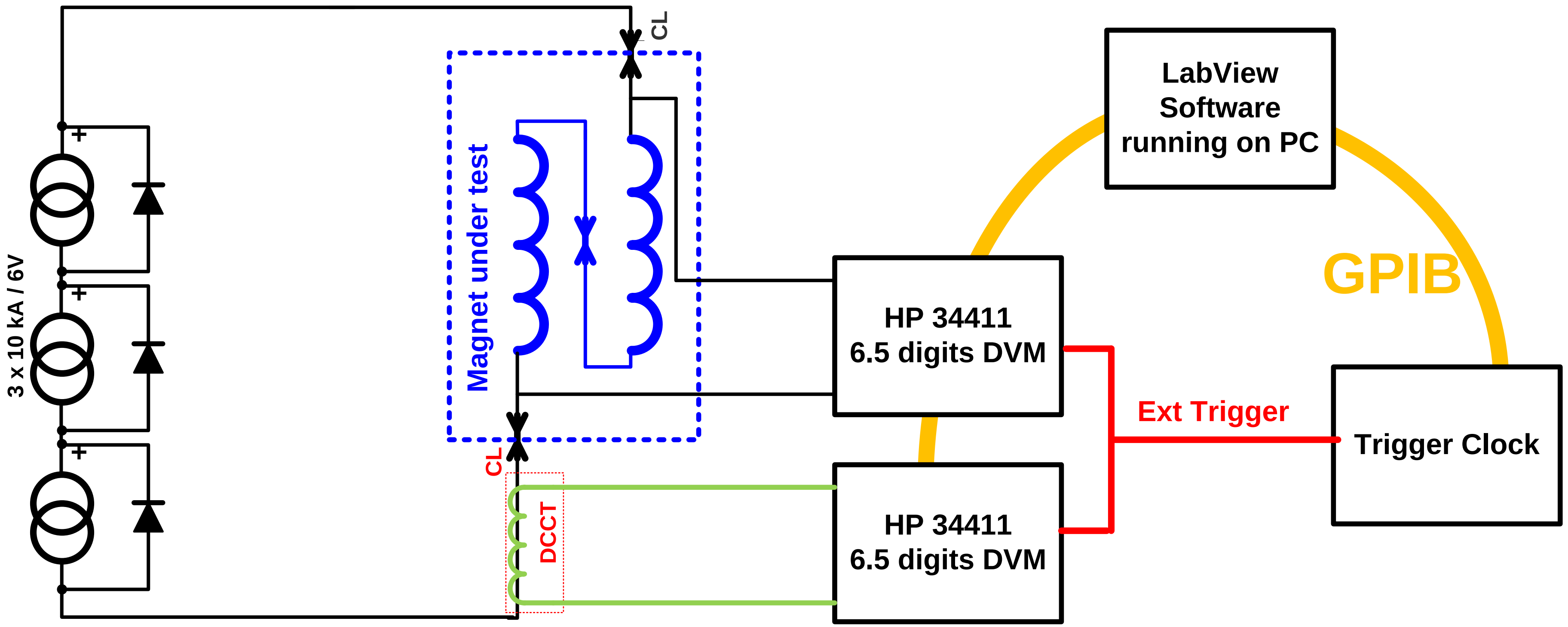


Main characteristics

Sampling Frequency:
1 kHz (optional 5-10 kHz)

Resolution 18 bit
Pretrigger & Post-trigger selectable

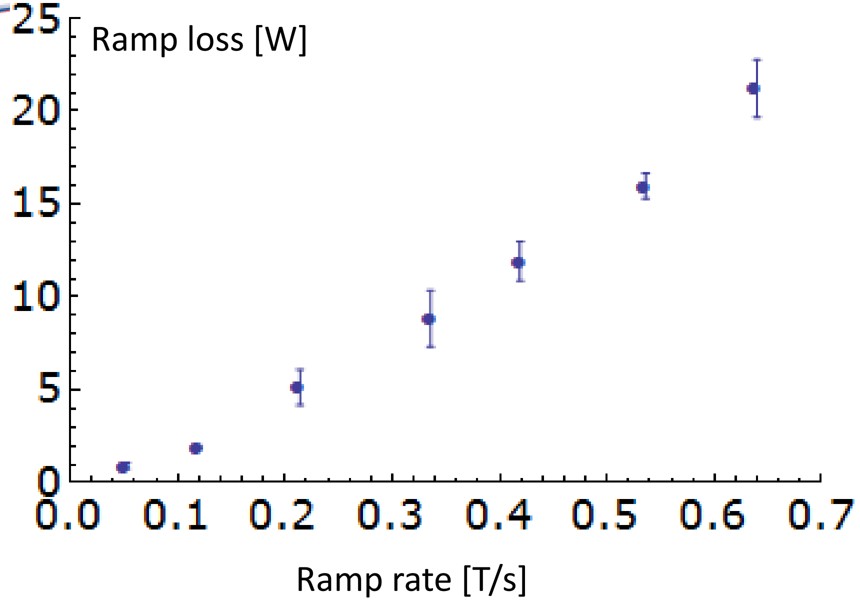
4. AC losses measurement system

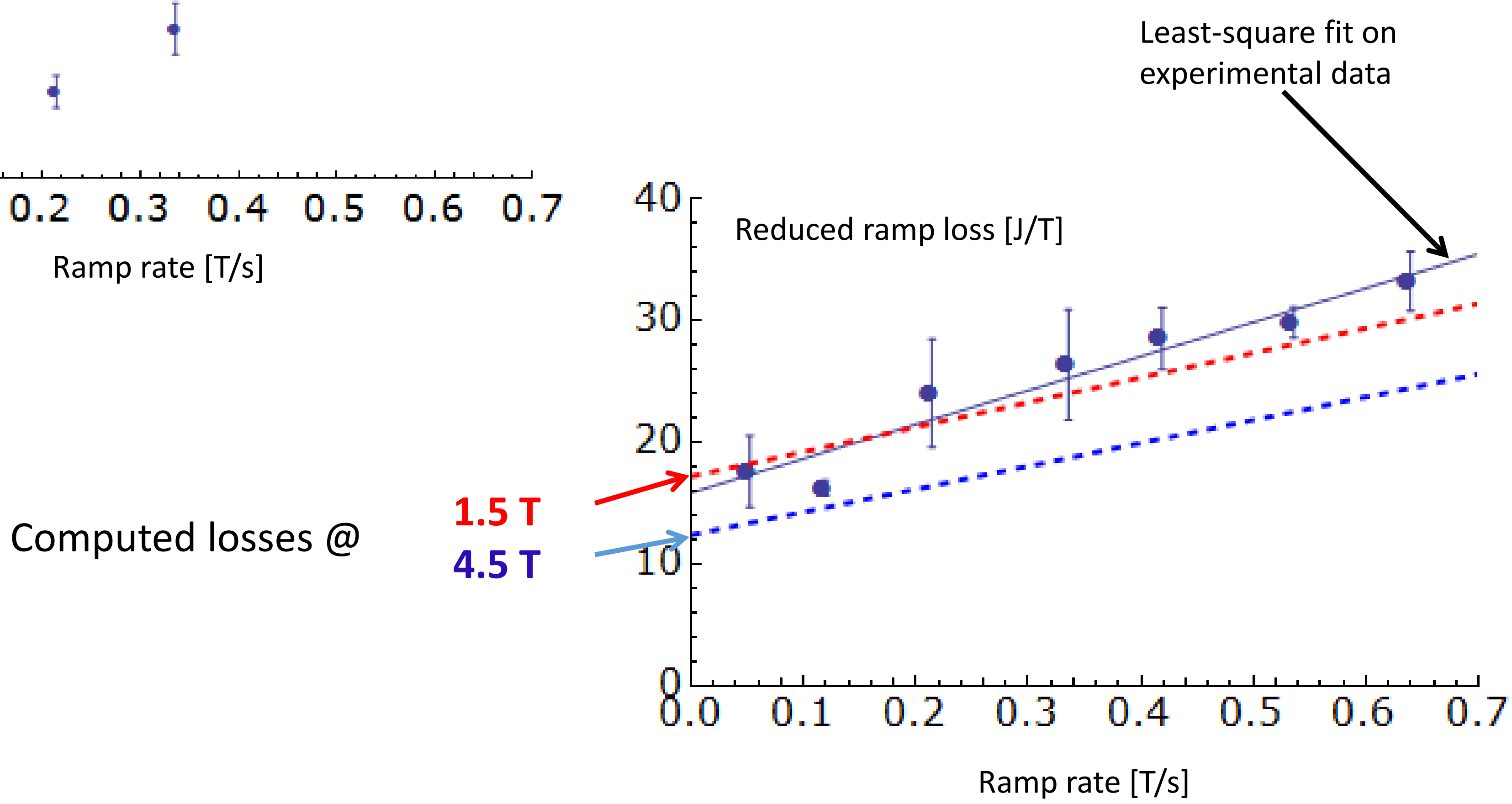


Net work *Q* performed by the power supply on the magnet between t_0 and t_1.

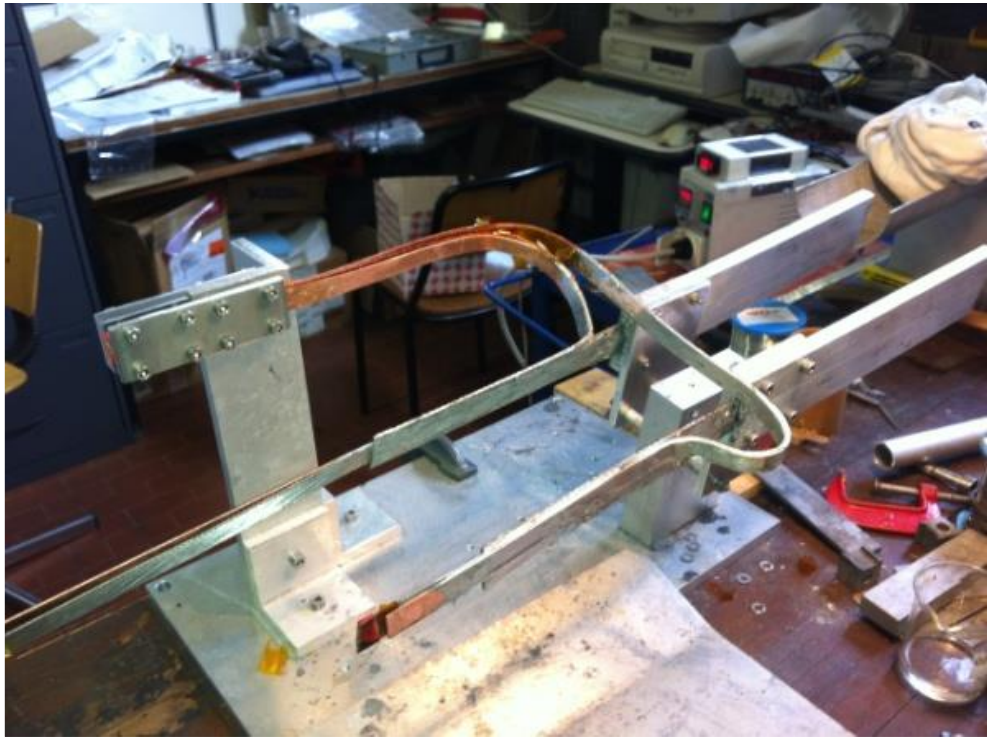
$$Q(t_1, t_0) = \int_{t_0}^{t_1} V \cdot I \, dt \approx \Delta t \sum_{j=1}^{n} V_j \cdot I_j$$

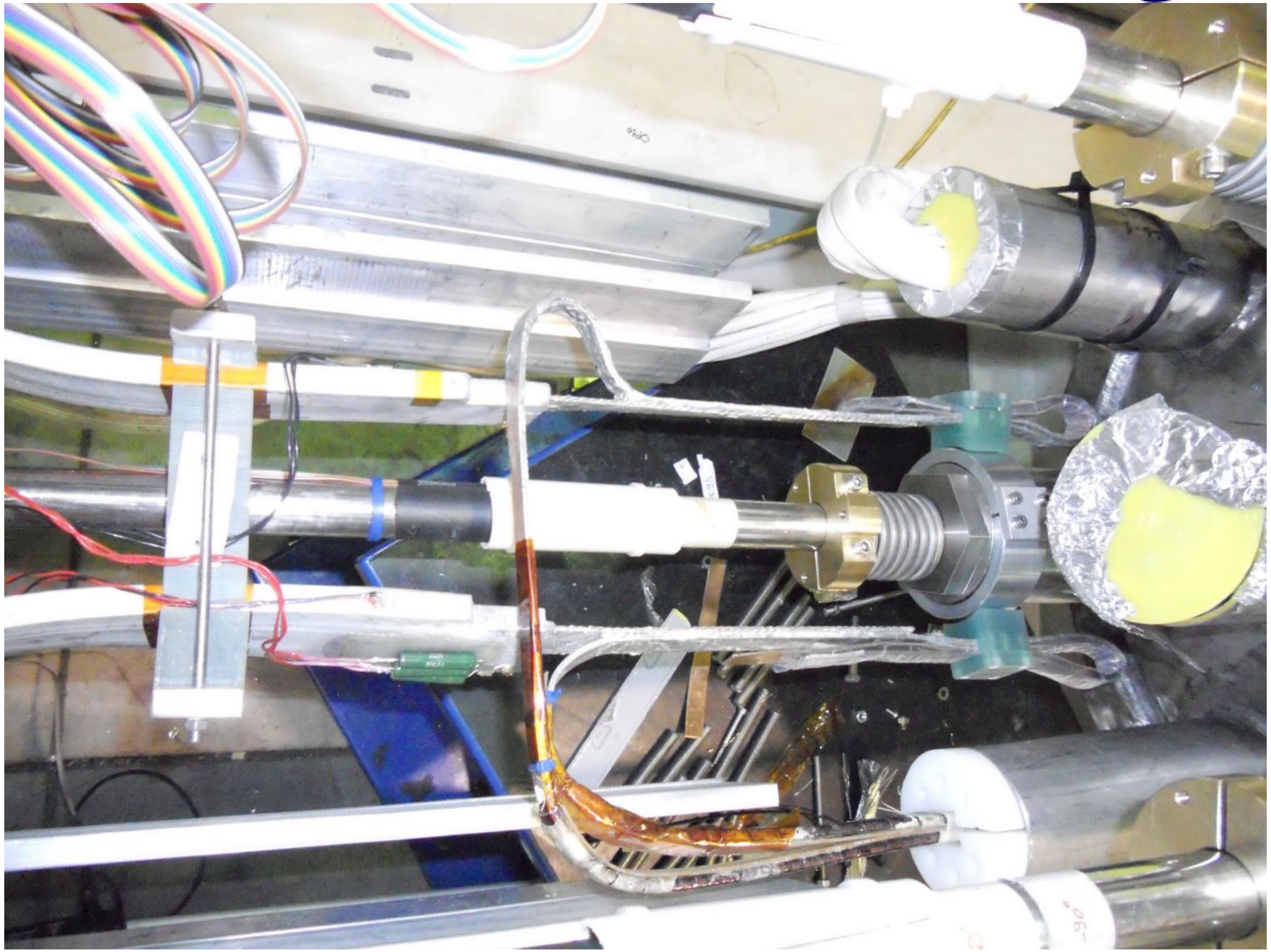
4. AC losses measurement system: Experimental Accuracy





Electrical connection between bus-bar & magnet

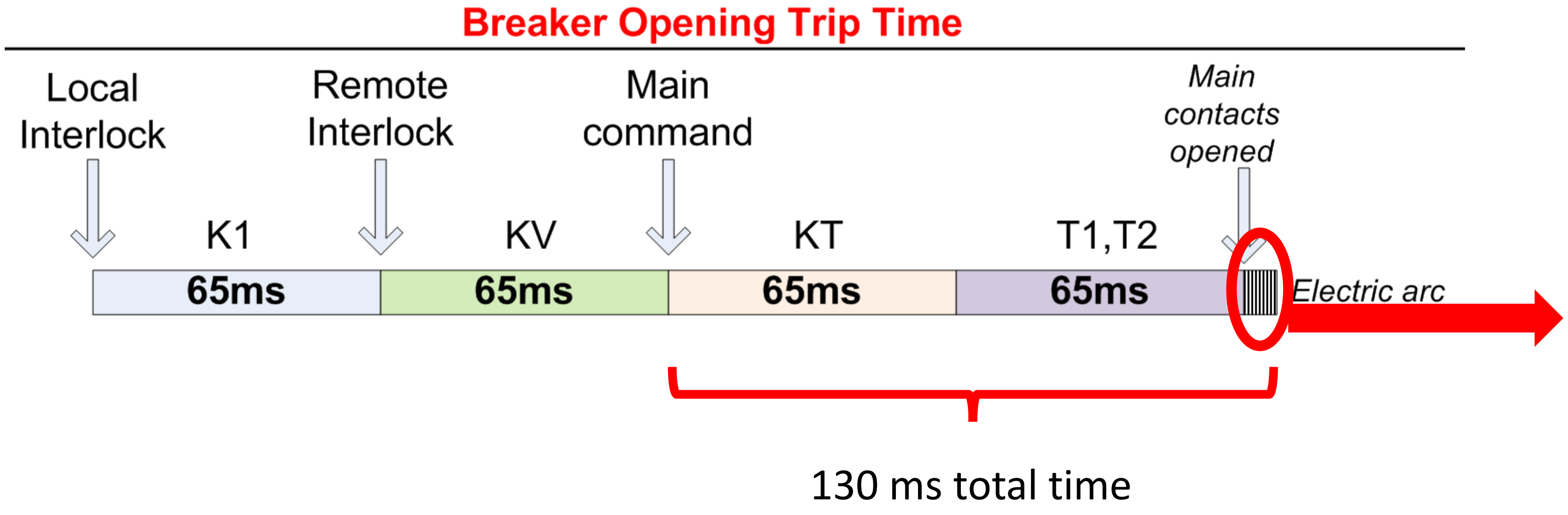


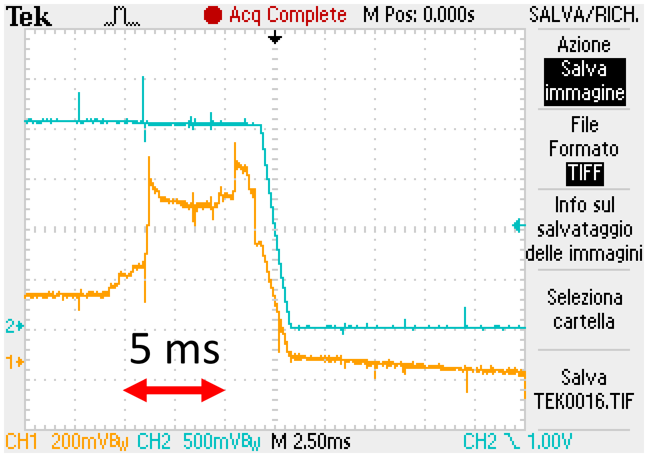


Switch Speed

Test with 10 kA has shown that the opening time is globally 130 ms, given by 65 ms operating relay acting on switch electromagnet + 60 ms switch opening + 5 ms arc extinguished.

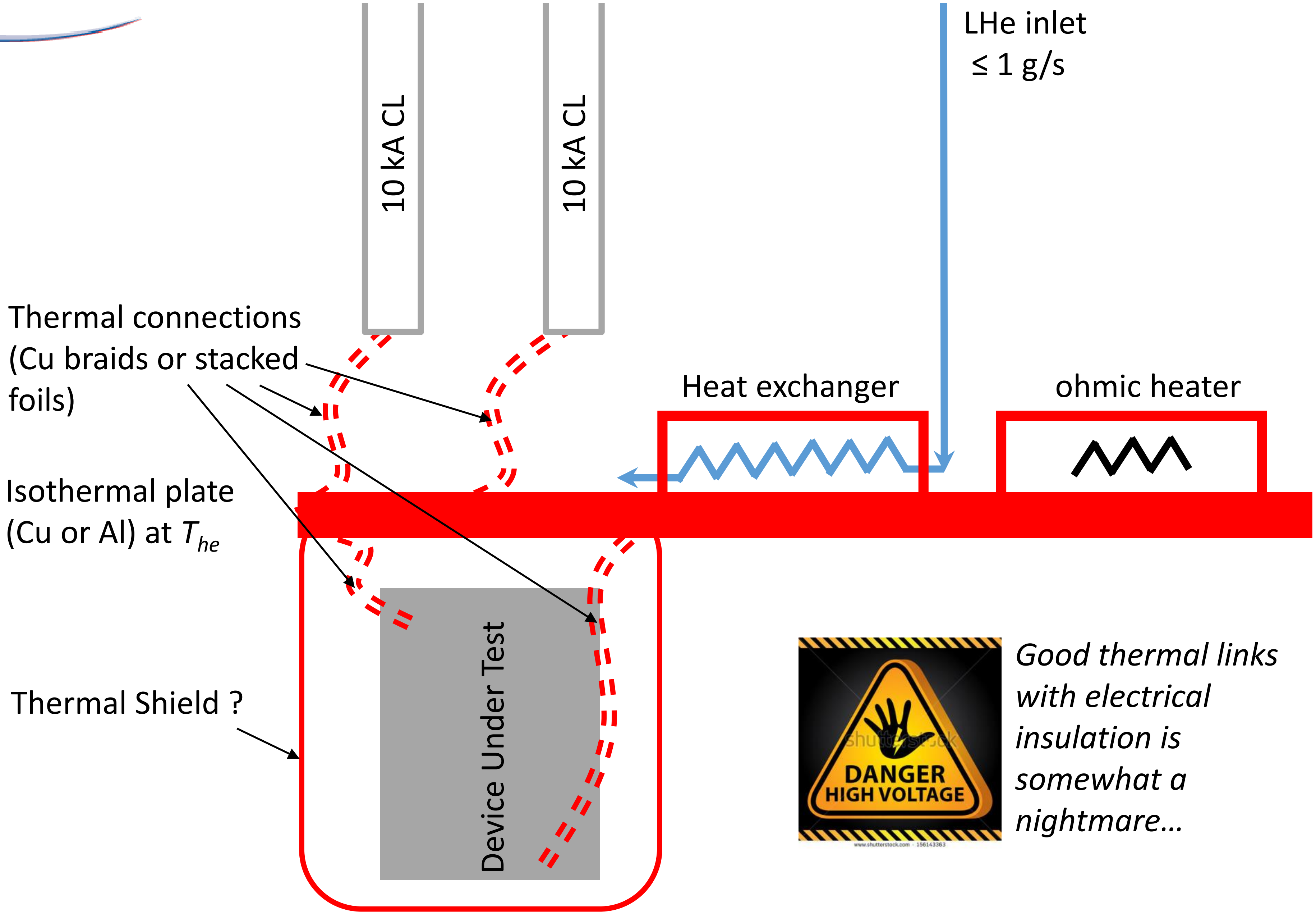
Designed for a slow application, it will be upgraded with a faster relay which will allow some improvement, probably down to 100 ms, **in any case not suitable for a HTS magnet test**





5. Temperature controlled operation

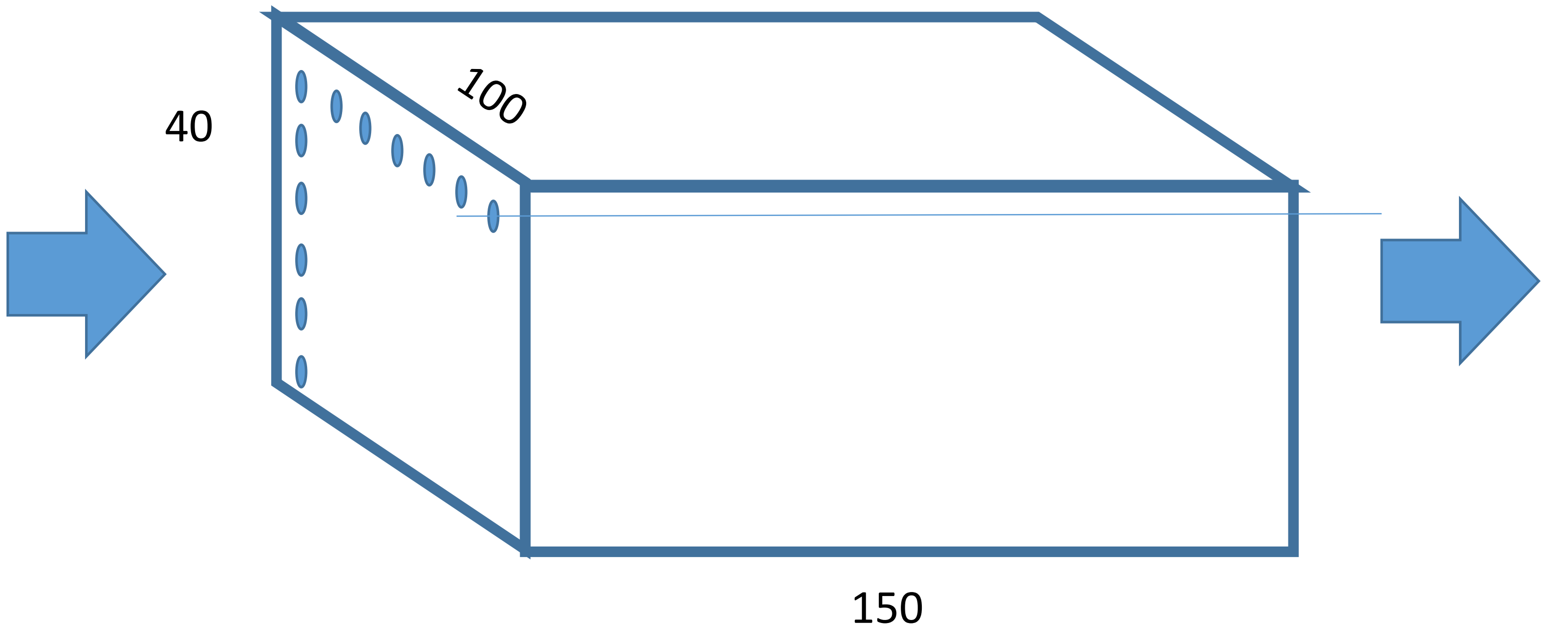
Conceptual scheme



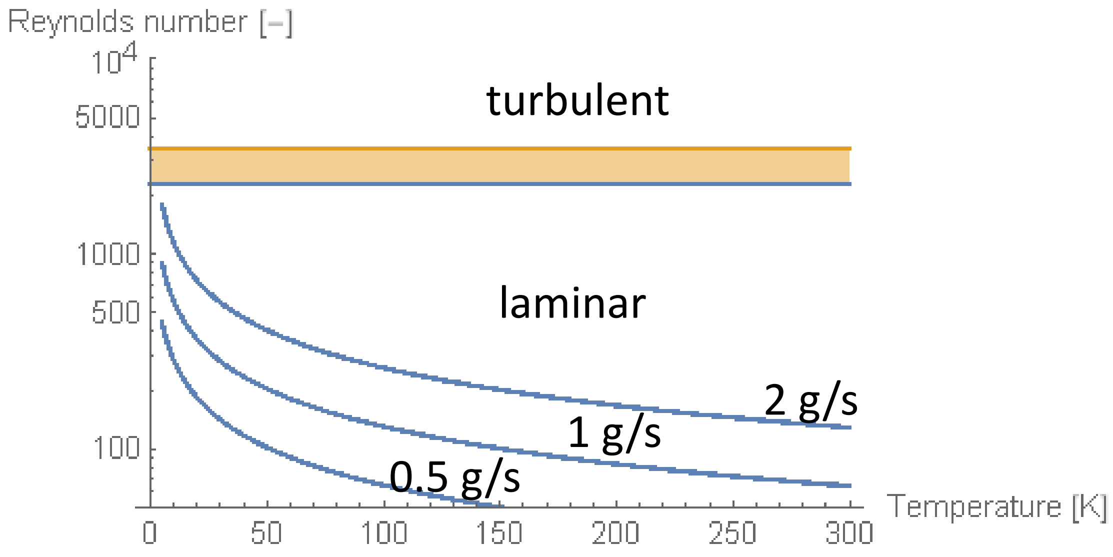
Good thermal links with electrical insulation is somewhat a nightmare…

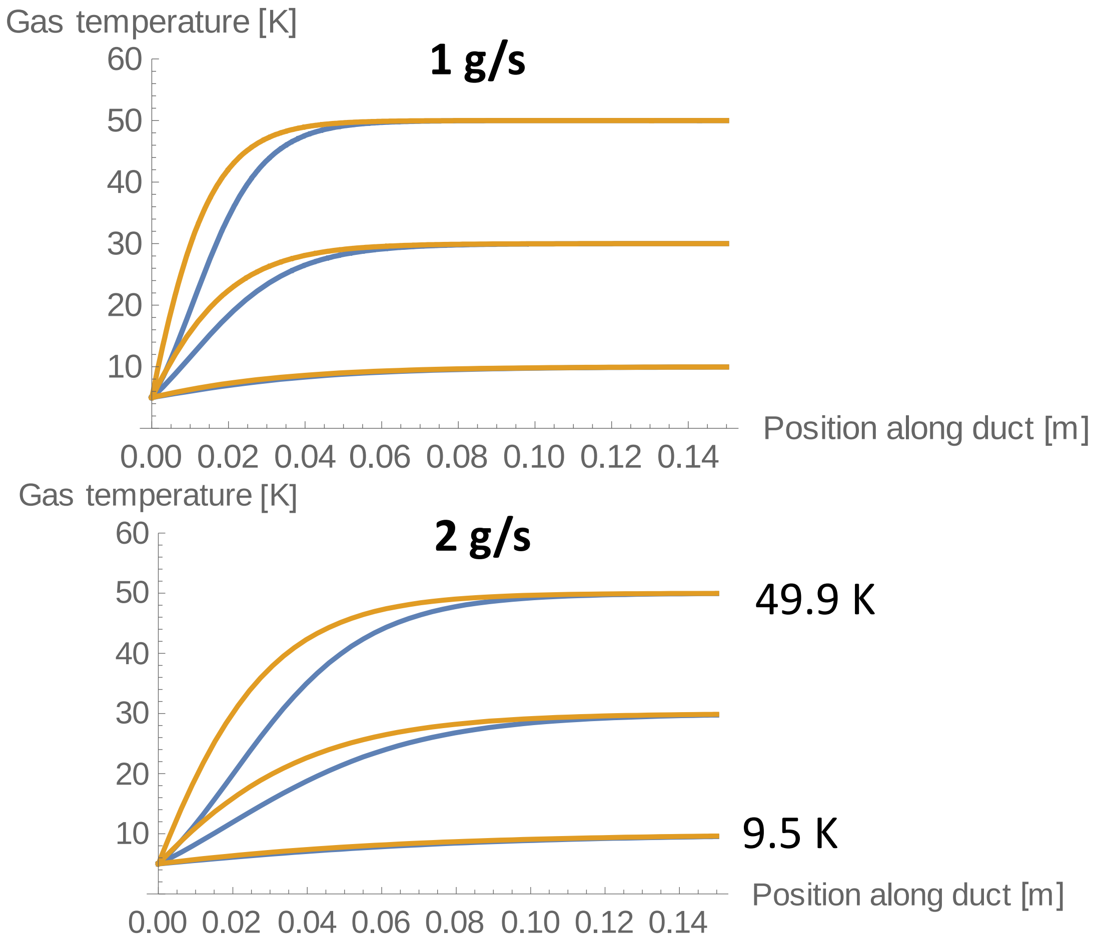
Heat Exchanger

The exchanging element is a copper block, cross section 100 x 40 mm^2 ,length 150 mm,
with 1000 round holes 1 mm in diameter along its length.
This should be feasible by 3D printing. End chambers could be (e-beam) welded at its extremities.



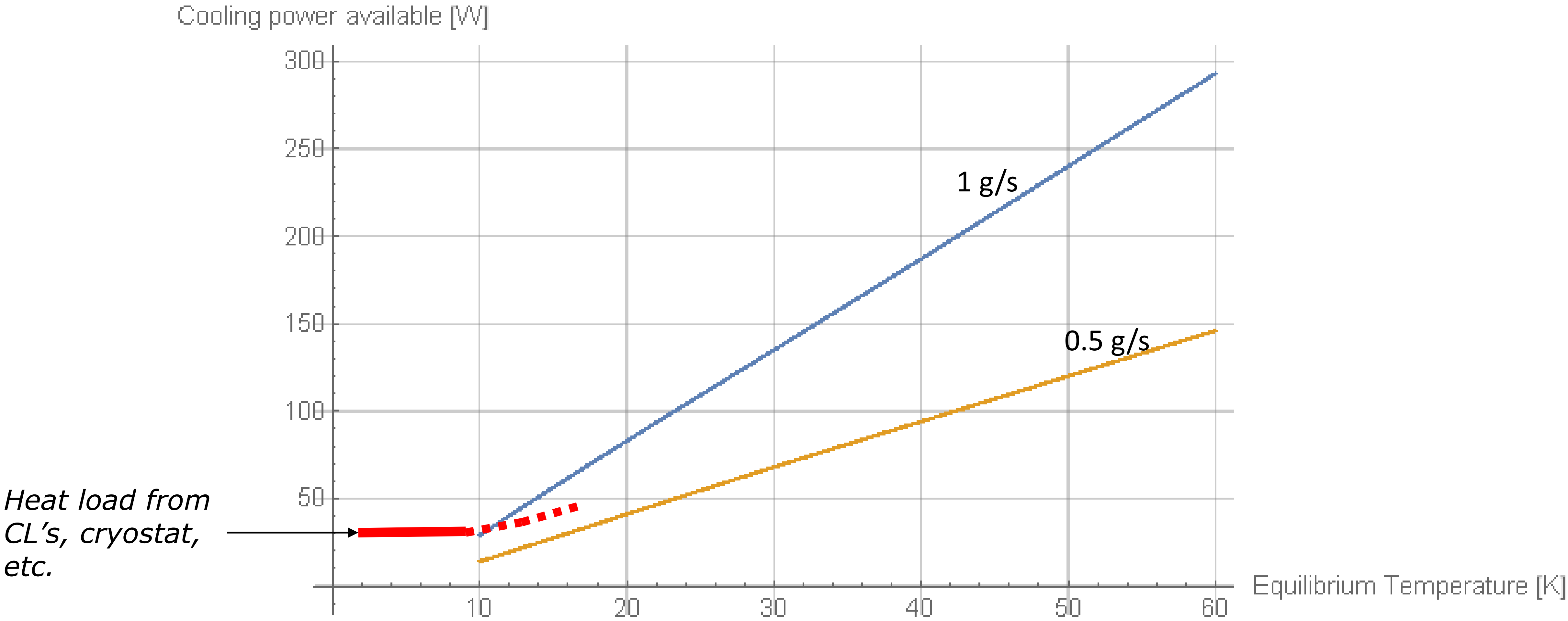
Heat Exchanger Design





Operates in laminar regime.
Not the most efficient situation for heat exchange!
Better solutions (simpler/cheaper) could be devised, confrontation with cryo experts advisable.

Available cooling power



6. Interface Issues

Interface Issues

- Mechanical interfaces (magnet fixture)

- Cold Power Electrical Connection

- Signal channels required ➡ *next slide*

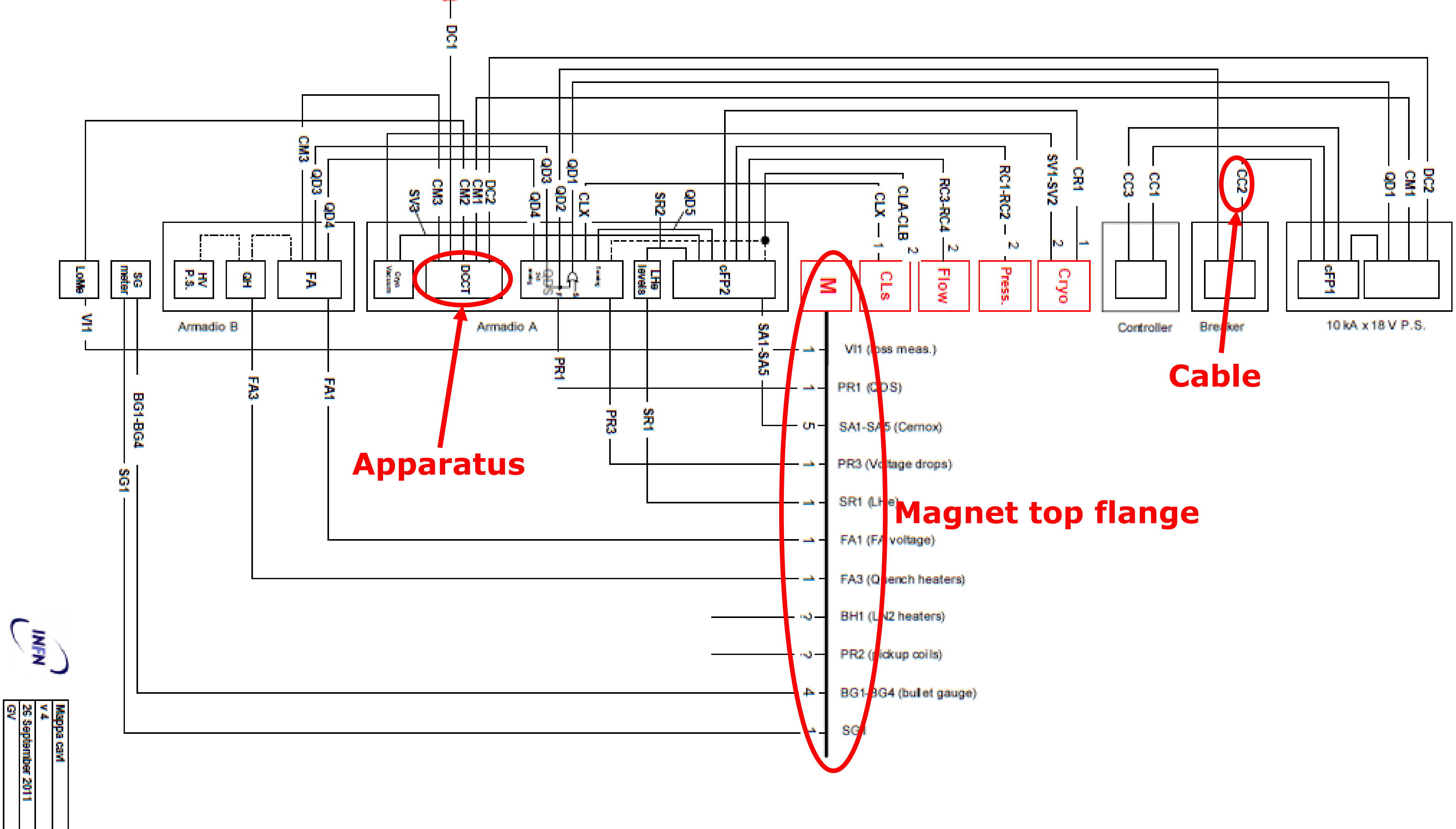
- Other information from the test station:
  - Current
  - Pressure
  - Temperatures
  - others?

- Format for offline data exchange

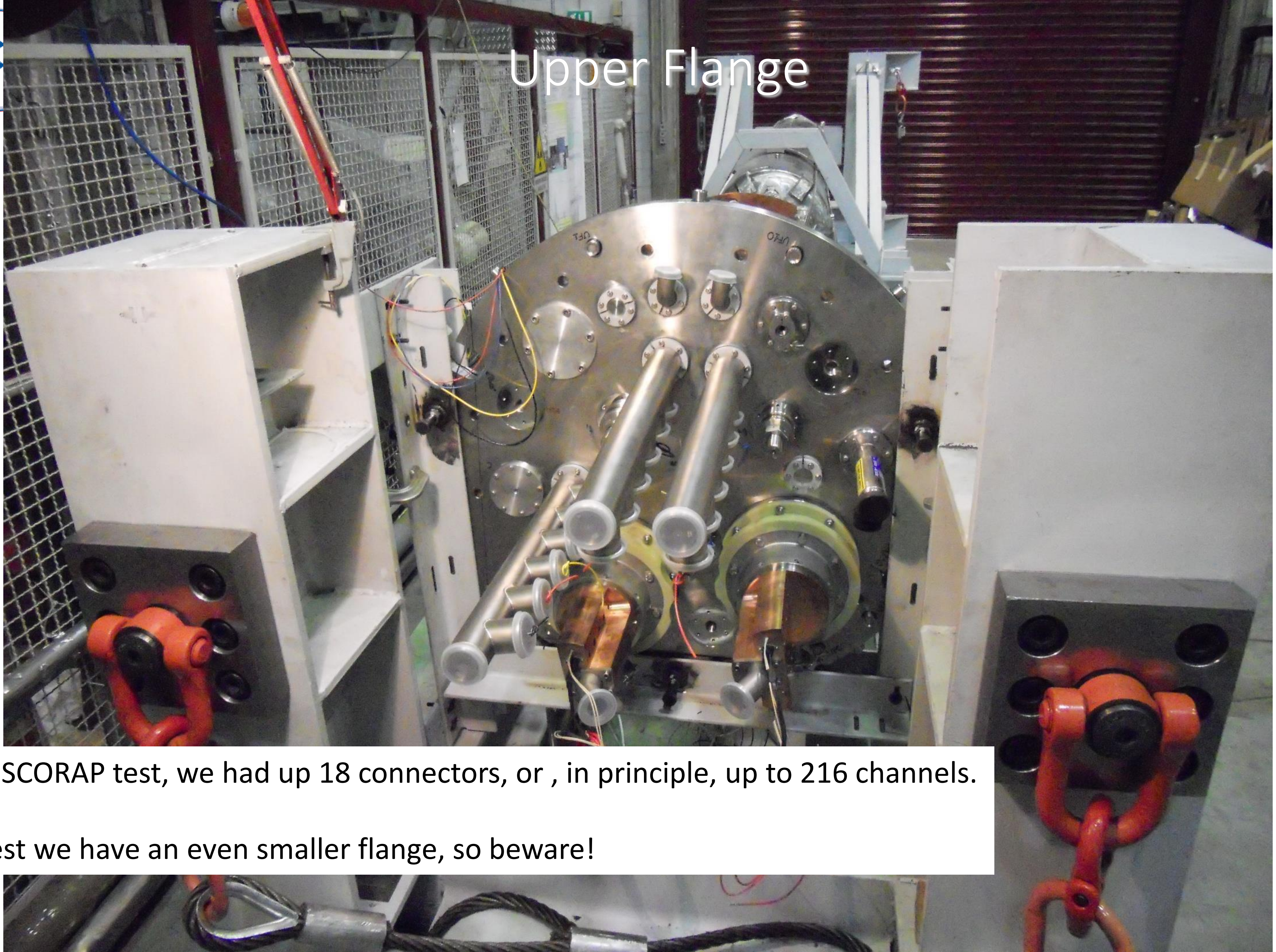
Signals and wiring

- no. of connectors opening required, connector type and size;
- If large number required and/or very crowded connectors, we expect that they will be provided already soldered with cryogenic wiring of suitable length
- From the connector to the external equipment, this is responsibility of the apparatus user
- Cryogenic wiring to be decided:
  - Material
  - Gauge
  - Insulation

Cable Map (example)



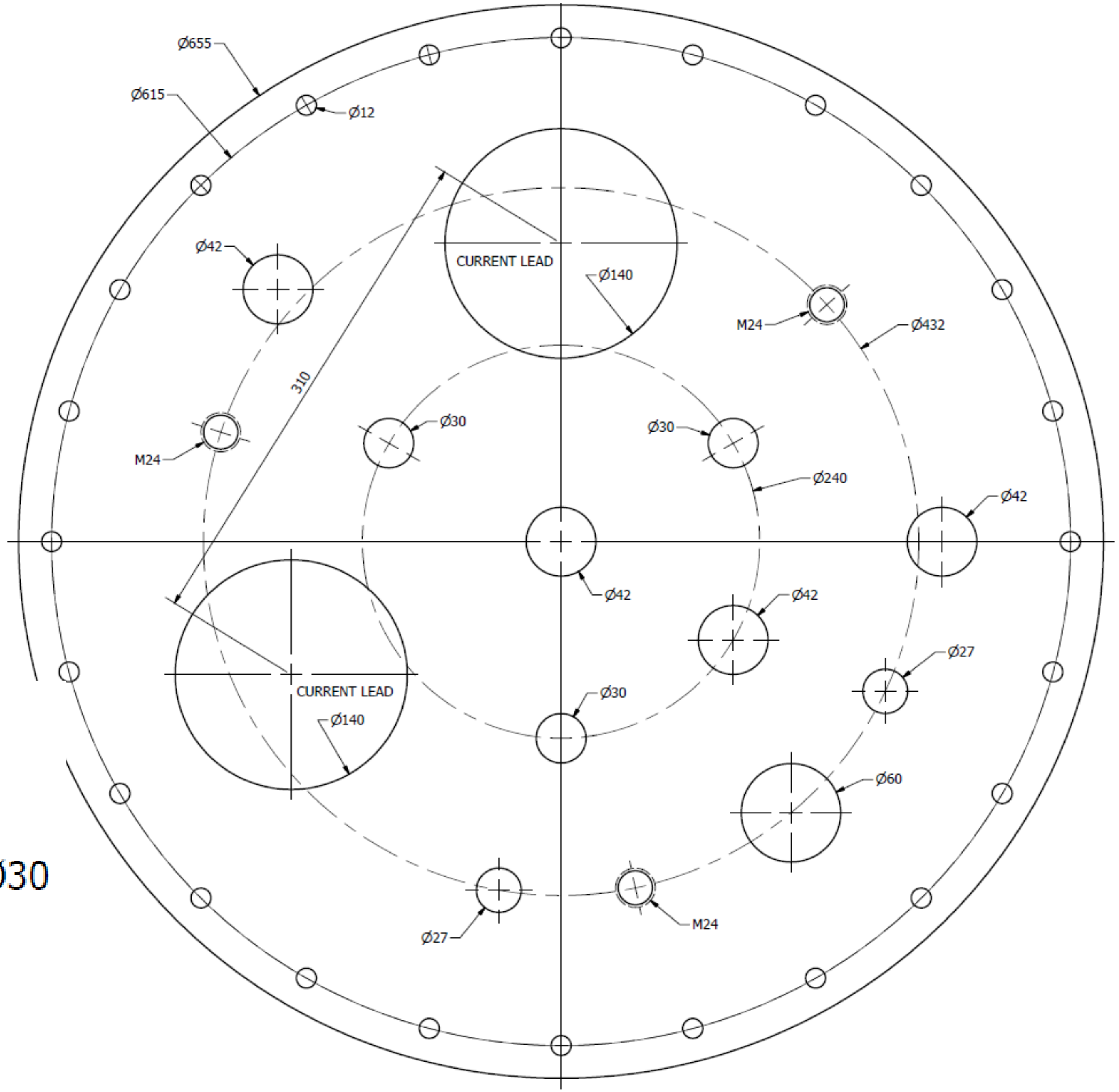
Upper Flange



In the DISCORAP test, we had up 18 connectors, or , in principle, up to 216 channels.

In this test we have an even smaller flange, so beware!

Cryo flange (preliminar)



2 X CURRENT LEADS = Ø140
4 X DN 40 FLANGE = Ø42
2 X DN 25 FLANGE = Ø27
3 X MAGNET SUPPORT RODS = Ø30
3 X FLANGE EYEBOLTS = M24
1 X SAFETY DEVICES = Ø60

Current limiting resistors for high voltage taps protection

For DISCORAP test we used 22K glass-ceramic resistor , but they had a very high failure rate (10% - 20% failed during the test)

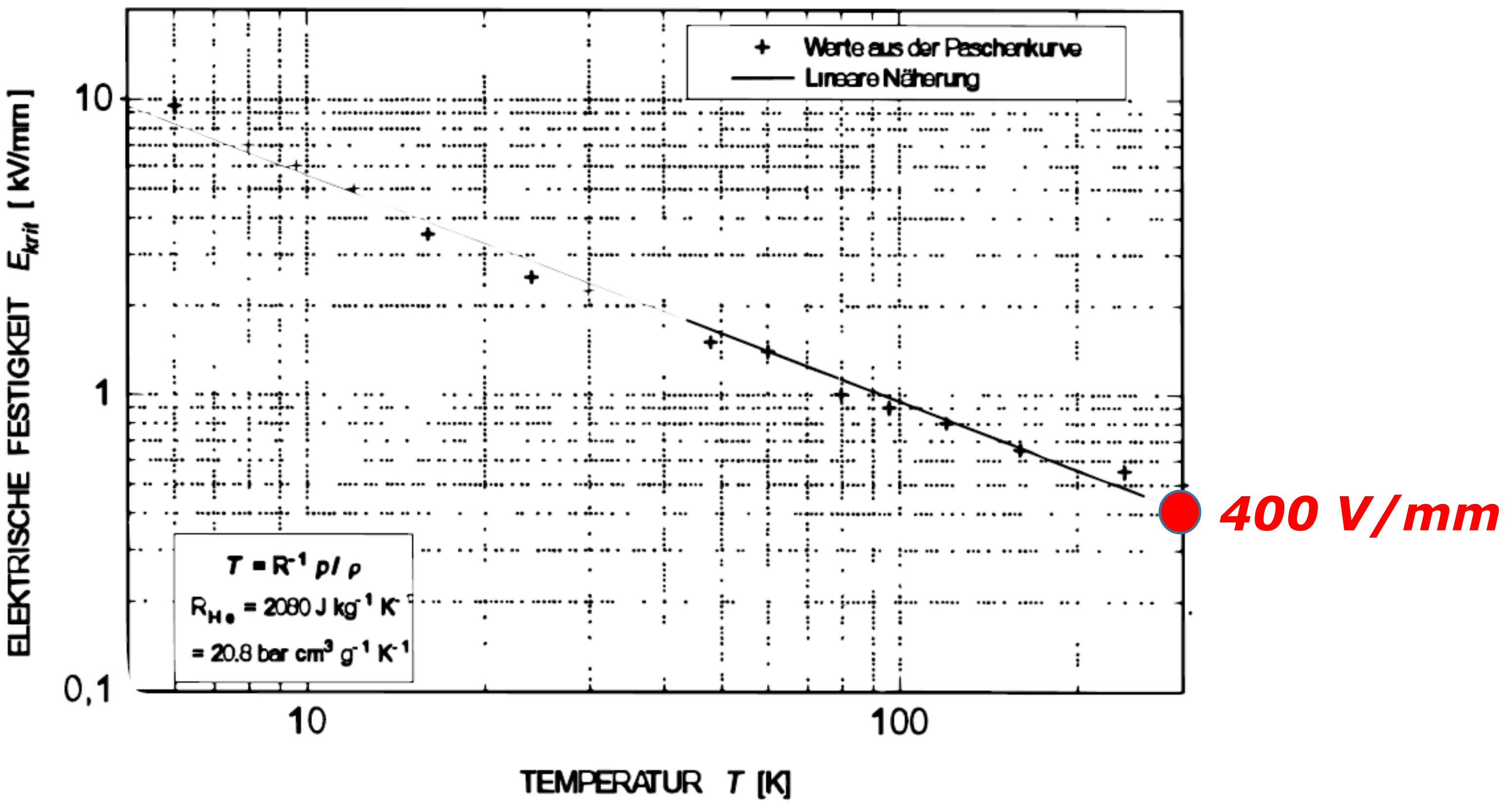
Recently, we have "qualified" at LHe small size 10K power resistance for MAGIX test.
50+ thermal shocked at LN, none failed. Performed well during the LHe test, no failure.

This is our proposal, choice must be done also based on your experience!

Voltage breakdown at connectors

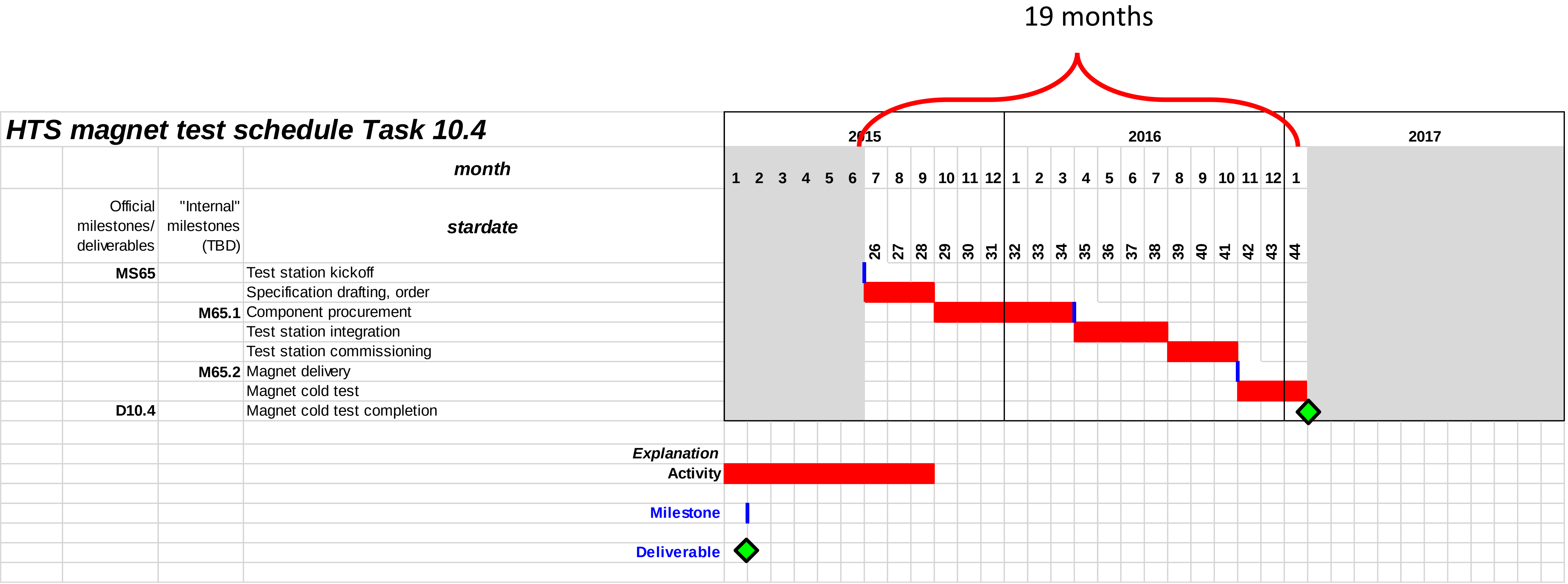
The cryostat (inner) side of the connectors is the place most suitable to voltage breakdown, since pressure is about 1 bar and temperature 300 K.
High voltage wires go through a "atmosphere separation septum" to avoid to have GHe near the pins, basically at RT (worst condition for dielectic insulation)

Breakdown field strength of helium gas for p = 1 bar



7. Looking forward to testing

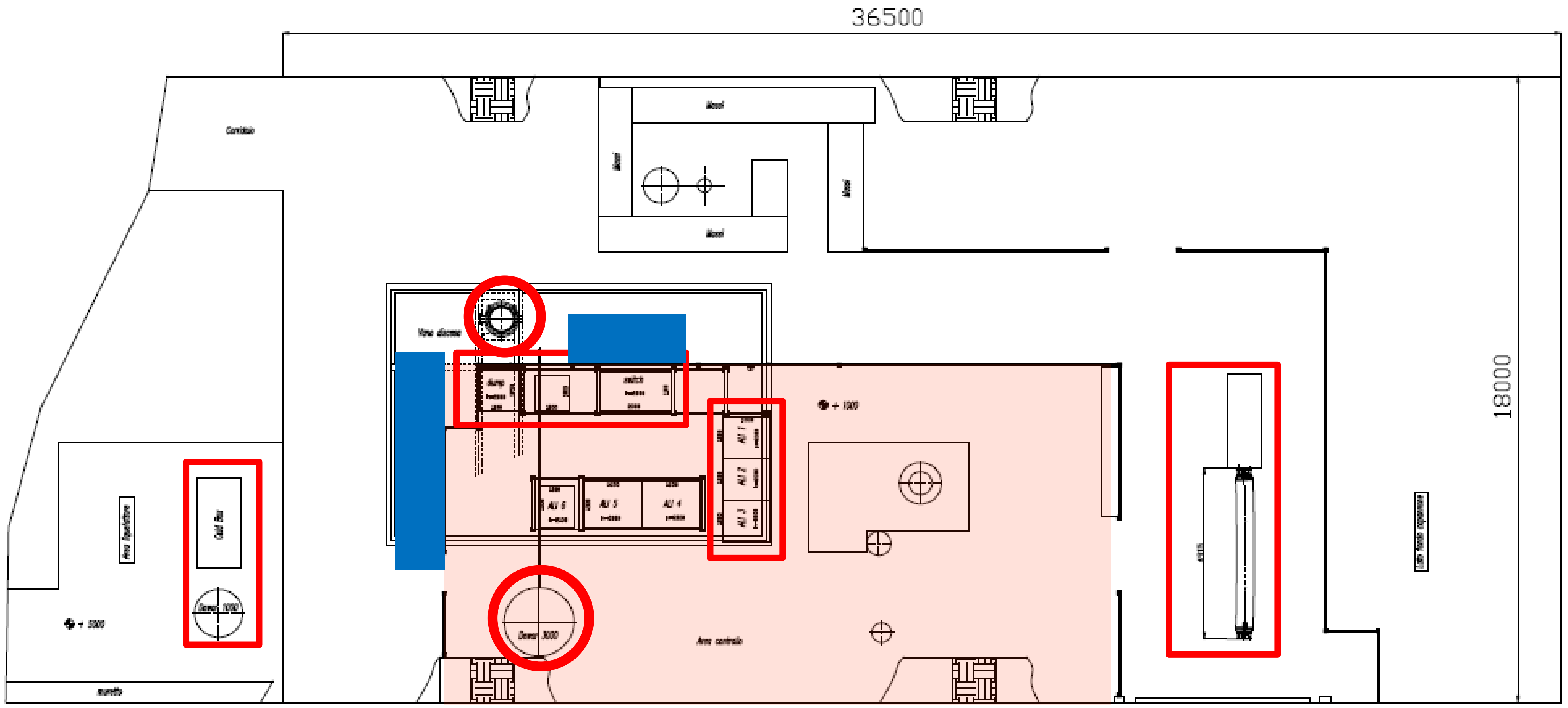
Schedule



19 months
HTS magnet test schedule Task 10.4
month
2015
2016
2017
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1
Official milestones/ deliverables
"Internal" milestones (TBD)
stardate
26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44
MS65 Test station kickoff
Specification drafting, order
M65.1 Component procurement
Test station integration
Test station commissioning
M65.2 Magnet delivery
Magnet cold test
D10.4 Magnet cold test completion
Explanation
Activity
Milestone
Deliverable

Room and services required

Room (tentative) for the equipment;
Other requirements
Number of people participating to the test; list of names



Magnet Transportation and Handling Issues

Transport: special? Max speed, max acceleration?

Handling procedure , etc.
Maybe organize a LASA crew at CERN to practise during packing?

The Start!

The END!

Status of WP10
Indico/354955
8 Jan 2015

Task 4 HTS Magnet Test
Indico/355138
26 Nov 2014

Test Station Kickoff meeting
Indico/
11 June 2015