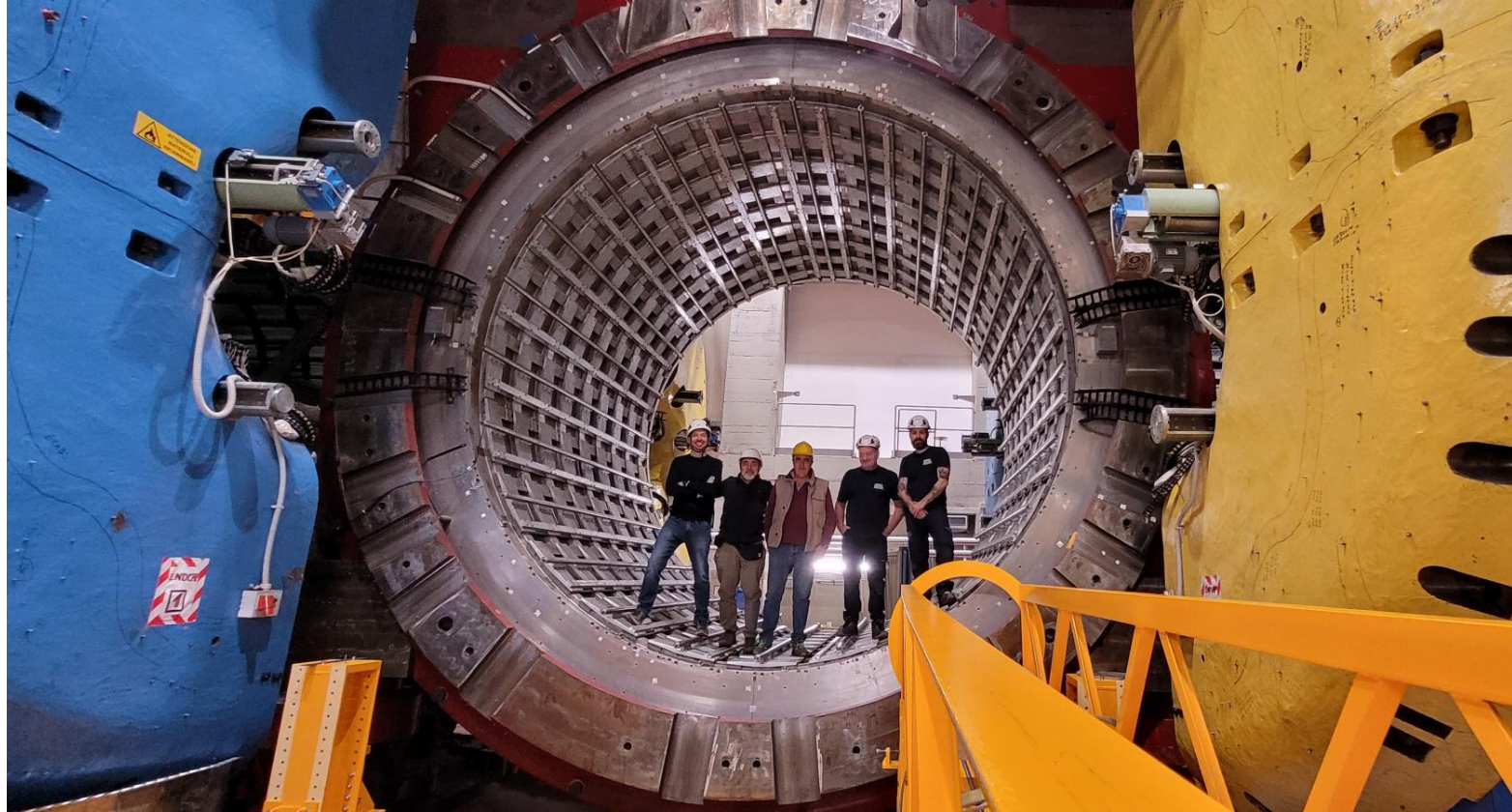


# **CSN1 Review of SAND Status of the Magnet**

Danilo Domenici (INFN – Laboratori Nazionali di Frascati)

Antonio Di Domenico (Sapienza Università di Roma and INFN – Roma)

# The KLOE/SAND Superconductive Solenoid Magnet



Diameter 5.80 m  
Length 4,40 m  
Weight 42 t

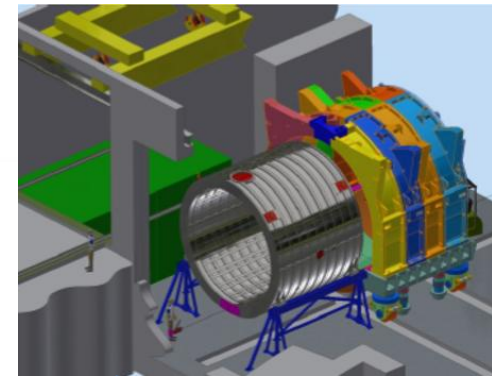
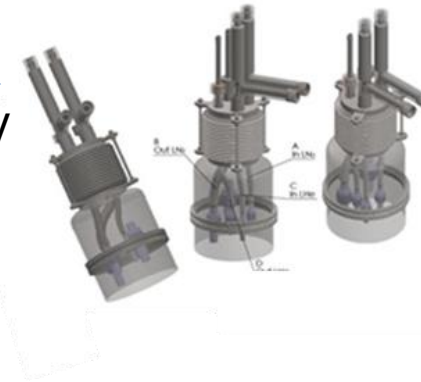
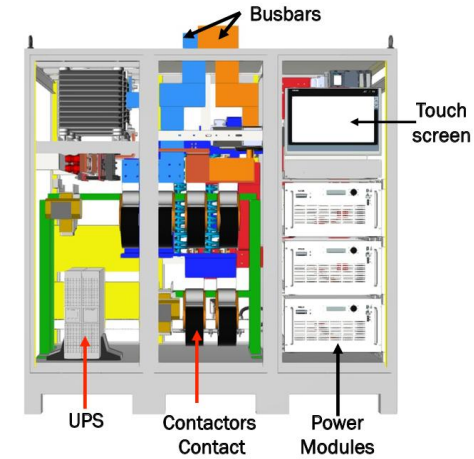
Cryogenics and Operation: Giovanni Delle Monache  
Power Supply: Alessandro Vannozzi  
Extraction: Alessandro Saputi  
Shipping: Daniele Pasciuto

# Magnet Repurpose Phases

## Recommendation 3.2.1

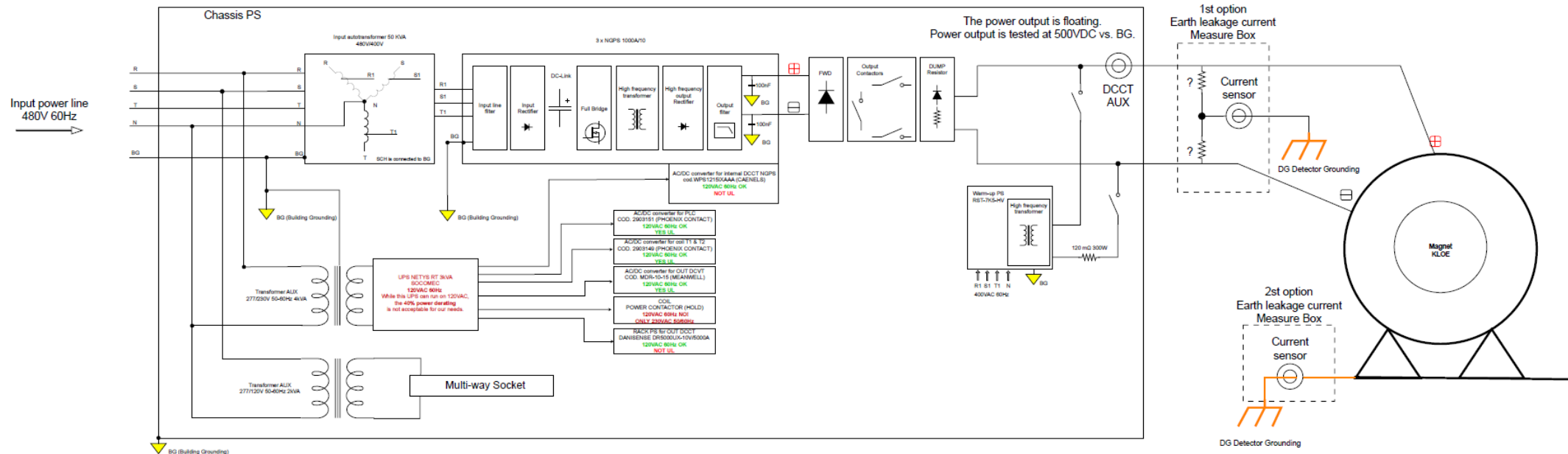
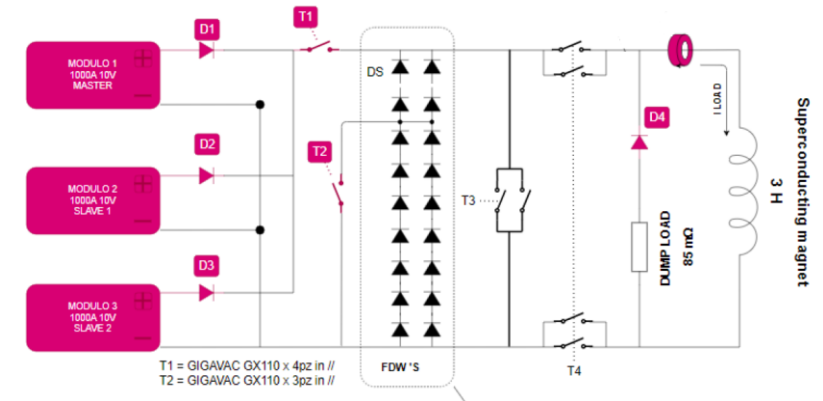
Clarify the interplay between magnet dismantling, magnet tests and power supplies procurement.

- **Power Supply due delivery date: beginning of May**
  - Produced by OCEM company by deeply refurbishing the old KLOE PS
  - Regular meetings ongoing for feedback/monitoring the procurement
- **Magnet Test planned for: end of 2026 / beginning of 2027**
  - Cryogenic interface already in place
  - Cryo liquids (22kl LN<sub>2</sub> + 6kl LHe) ordered by AirLiquid company
  - Old Quench Detector used for this test
  - Old Control System SW used for this test
  - FNAL people overview expected
- **Magnet extraction planned for: mid 2027**
  - Operation strictly related to yoke disassembly
  - Baldon company to be contracted for execution of both
  - Cryosystem Engineering company contracted for dismantling of service turret
  - Mechanical tools for magnet extraction designed and ready for construction

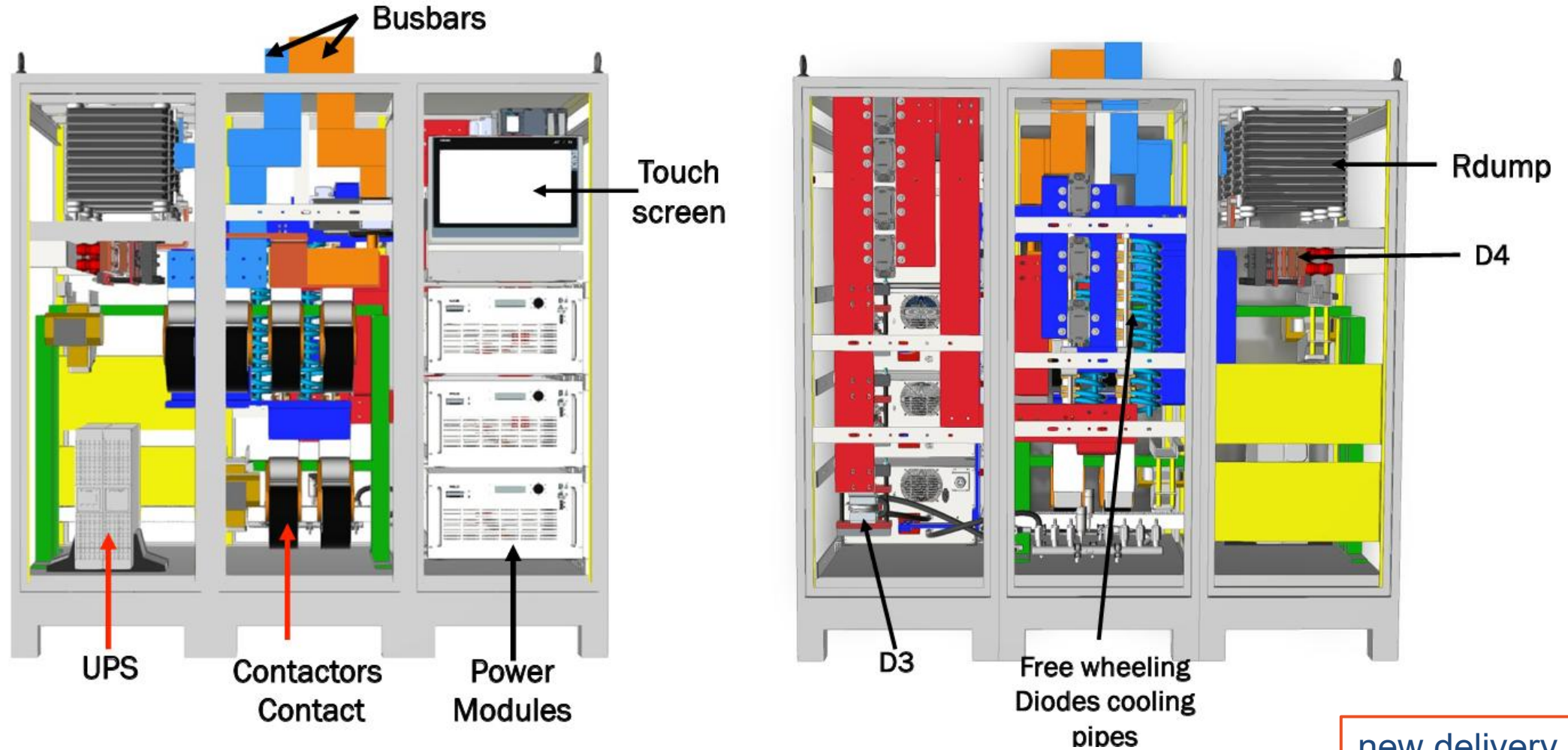


# Magnet Power Supply Status

- **OCEM SpA** company is in charge for the PS procurement
- The procurement of all the new parts is completed except for the **transformers for auxiliaries power**
- In last months several interactions with FNAL and OCEM
- **Final Design Report (FDR)** has been completed including **grounding layout**
- FDR and other documentation will be needed for **FNAL acceptance of parts without USA certification**



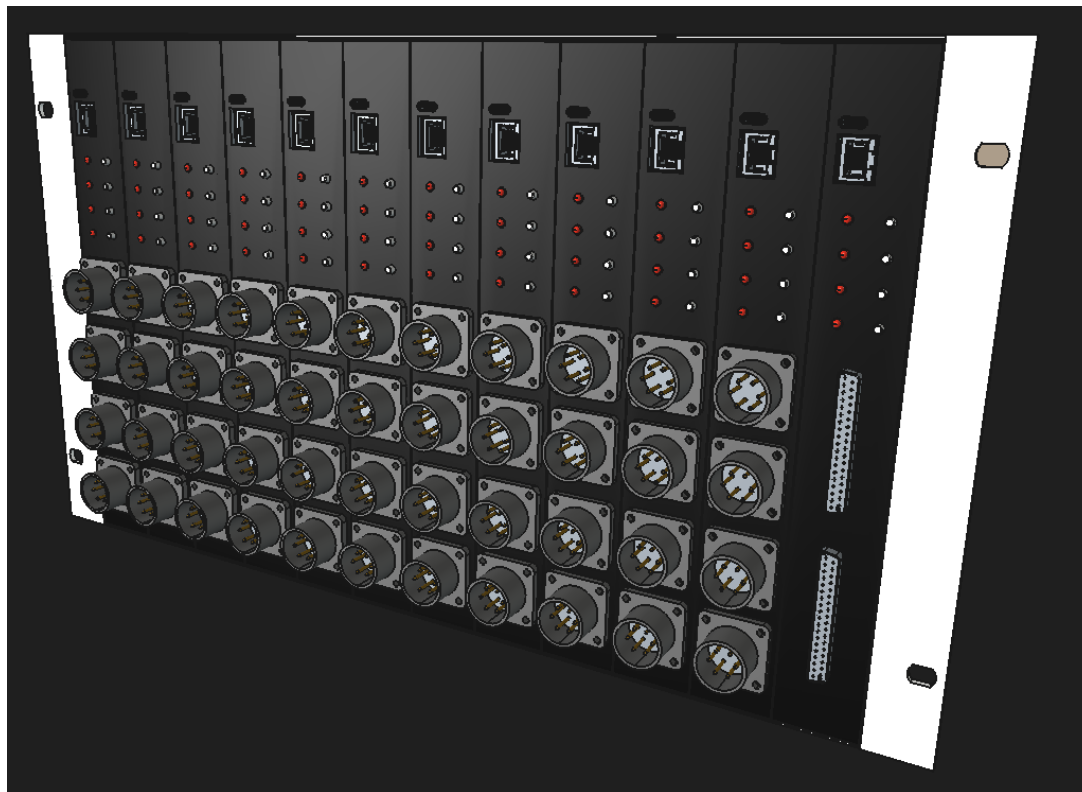
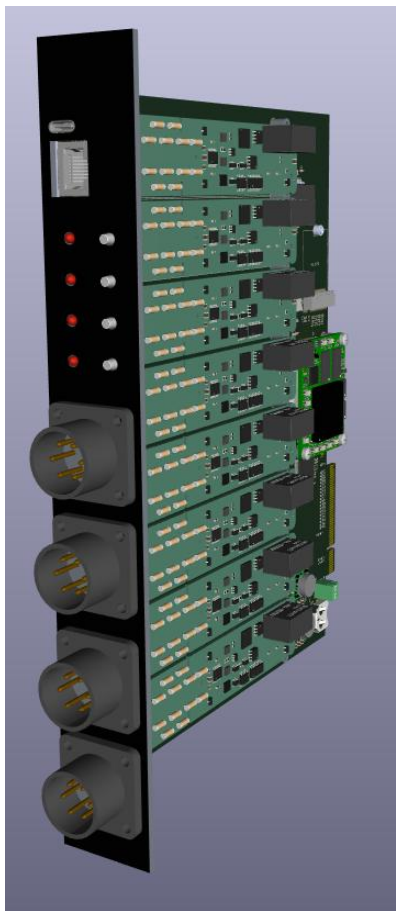
# Magnet Power Supply Status



new delivery date:  
May 2026

# Magnet Quench Protection System

- **Quench Protection System (QPS)** will be provide by FNAL starting from the Mu2e project
- Original KLOE Control System and QPS will be used for LNF test



	MDAQ + 24b2M-HV
Channels/Device	Up to 96
Resolution	24-bit
Sample Rate	2MSPS
Bandwidth	1MHz
SINAD (Gain=1)	114dB
Input Range	40mV - 4.2kV
Input Connector Voltage	4.2kV
Isolation	4.2kV
Drift (Gain=1)	0.3uV/C
THD	-130dB
CMRR	-132dB
Interface	1GbE/Card
Protocol	TCP/IP, UDP
Filter	1ms to 6s*
Validation Time	1ms to 10s*
Ch-Ch Bucking	Yes
di/dt Bucking	Yes
Module-Module Sync	Yes
Hardware Fault Detection	Open Circuit, Power, Overtemperature, ADC
Modulated Status Out	Yes
Ext Interlocks/Trigger In	32/IsoDIO Module
Trigger Out	32/IsoDIO Module
Software Interface	Websocket, JSON API
Mass Storage	SDXC Card + NVME
Capacity/Module	2TB + 2TB per Card
Cost/Ch (@ 1 chassis qty)	\$200

Courtesy of T. Cummings, FNAL

# Magnet Cold Test @ LNF – operations

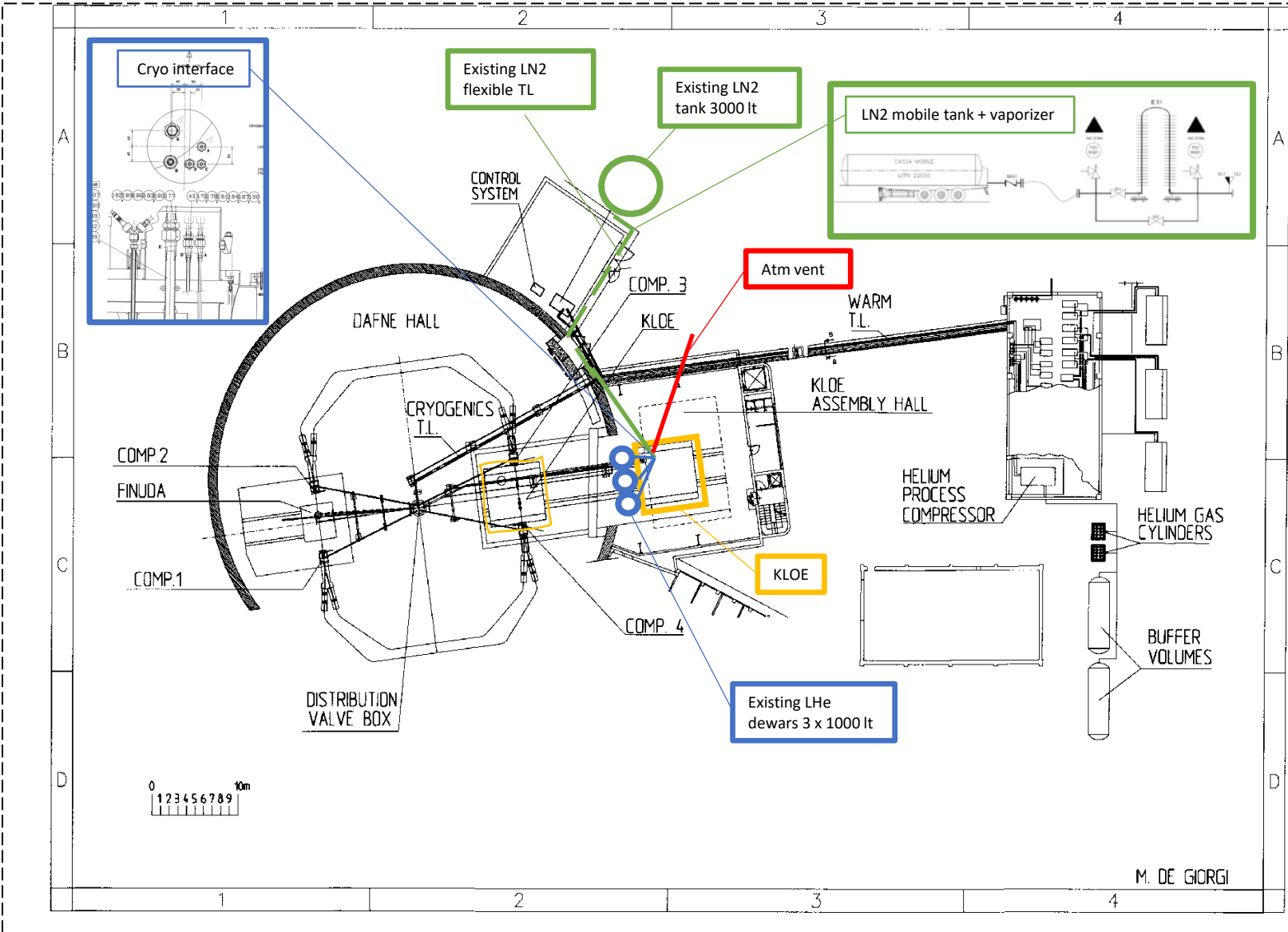
A test of the magnet must be performed to put it back to service.

It can be divided in two phases:

- **Warm Test** - will check the electrical, mechanical, fluidic and control operational status of all the subsystems at 300 K: vacuum, temperature sensors, pressure sensors, actuators, control system, **PS interlocks**, **heaters**
- **Cold Test** - will check the previous list at 4.4 K in addition to all the test that must be performed on the PS and the quench detector with the coil energized to a limited current

Tests at LNF will be repeated at FNAL, and both performed in presence of FNAL representatives as part of training program and compliant hand-off

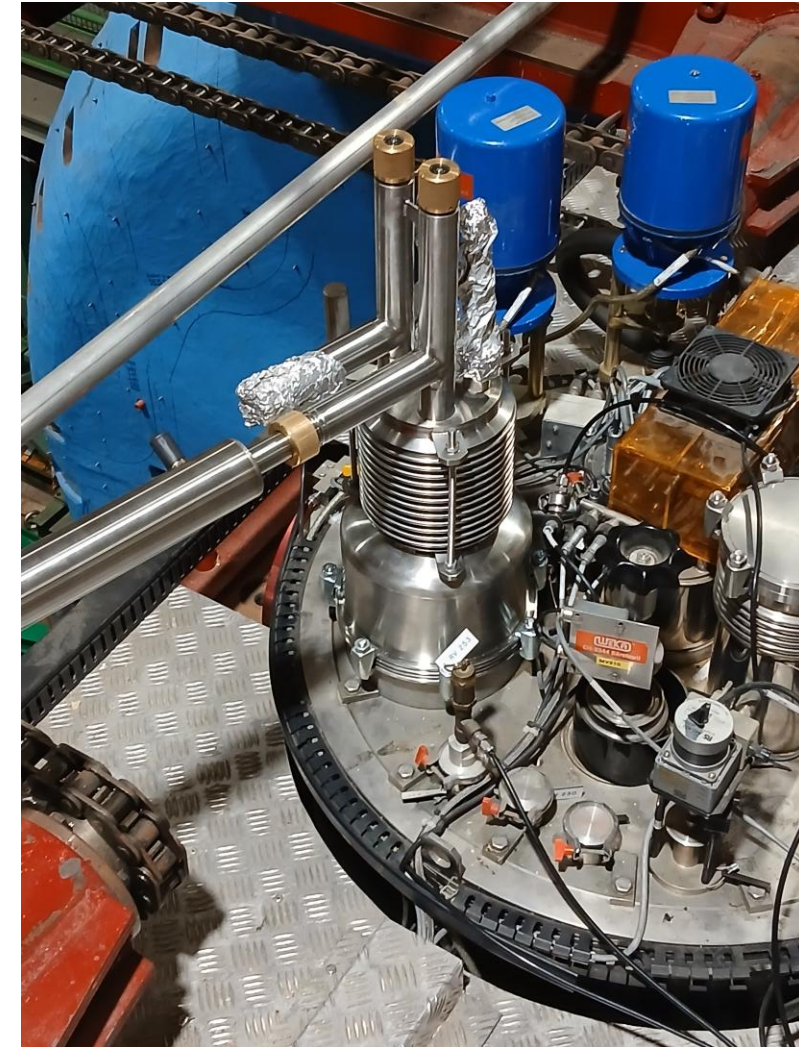
# Magnet Cold Test @ LNF – Cryo layout



# Magnet Cold Test @ LNF – preparation

## Cryogenic interface and Transfer Lines

- Delivered in late December. Has been integrated with the magnet
- TL from the LN2 external tank has been inserted in the experimental hall



# Magnet Cold Test @ LNF – preparation

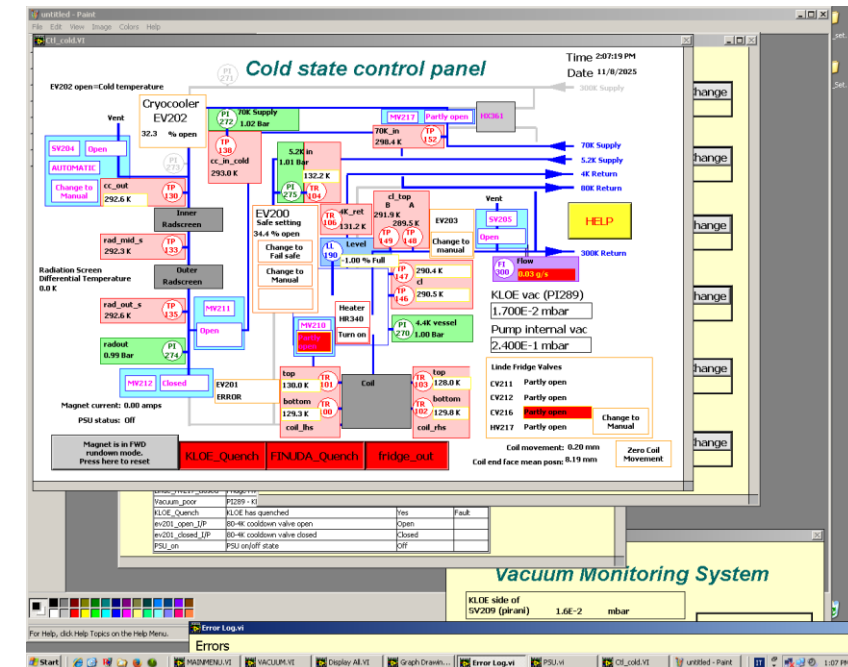
## Vacuum

- Vacuum pumping system has been reconnected to the cryostat, to the Control System and to the power line. It is fully operational
- In 6 days vacuum in the cryostat reached  $2.8 \times 10^{-2}$  mbar and counting (pump limit  $1.0 \times 10^{-2}$  shown in the picture)
- Complete revamping of the pumps will occur before the test at LNF (order already placed)



## Control System

- Actuators of Valves EV 200 and EV 201 have been re-assembled
- Power and signal interfaces have been reconnected
- All sensors read expected values
- Commands to the actuators work properly



# Magnet Compliance

## Recommendation 3.2.2

Clarify with Fermilab the requirements of the exceptional-vessel operational qualification procedure.

The fitness-for-service (FFS) of the KLOE pressure equipment (pressure vessel and piping) for **construction** and **post-construction** must be assessed to be operative in the cavern.

**FNAL awarded** a contract for the assessment to an expert consultant  
**FFS ASSESSMENT(FNAL Project No. 721261)**

### 2.1 Construction Conclusion

DOE 10CFR851 "Worker Safety and Health Program" Appendix A.4 "Pressure Safety" requires the construction (materials, design, fabrication) of pressure vessels and piping comply with:

- The ASME Boiler and Pressure Vessel (B&PV) Code Section VIII "Rules for Construction of Pressure Vessels" (2015 edition).
- The ASME B31.3 "Process Piping" code (2014 edition).

In the case of the KLOE pressure equipment (vessels and piping) the construction was performed in Europe and the construction records (materials, design, fabrication) are incomplete. Therefore, the pressure equipment construction cannot be demonstrated to be compliant with DOE 10CFR851.

Eleven construction verification compensatory measures are recommended in Section 7, numbered **★C1** through **★C11**.

### 2.2 Post-construction Conclusion

Fitness-for-service (FFS) is the assessment of the integrity of the pressure boundary (i.e., prevention of leak or rupture of the pressure boundary) for the remaining service life beyond construction. The FFS assessment consists of:

- Periodic inspections and tests based on risk-ranking of the equipment. Risk ranking may be implemented in accordance with a standard such as ASME post-construction committee standard ASME PCC-3 "Inspection Planning Using Risk-Based Methods" (2022 edition).
- Assessment of damage identified during the periodic inspections and tests in accordance with a FFS standard such as API 579-1/ASME FFS-1 "Fitness-for-Service" (2021 edition).
- Repairs, if necessary, in accordance with a standard such as ASME post-construction committee standard ASME PCC-2 "Repair of Pressure Equipment and Piping" (2022 edition).

Note: Post-construction Codes and standards are not explicitly addressed in 10CFR851. Instead, 10CFR851 Appendix A.4.(c).3 simply requires "Documentation, traceability, and accountability must be maintained for each unique pressure vessel or system, including descriptions of design, pressure conditions, testing, inspection, operation, repair, and maintenance."

The KLOE pressure boundary is classified as Medium Risk in Section 5.

Five FFS measures are recommended in Section 8, numbered **★F1** through **★F5**.

# Compensatory measures

Compensatory measure	Owner/Note
C1 – performing PMI on the SS He vessel, SS piping, AL piping, SS inner and outer vacuum cases. This will determine specific grades of steel or aluminum used for construction. This information will then get crossed checked against the drawings and specifications. If SS grades are of low carbon “L”, then there will be no need to UT check for evidence of intergranular attacks (measure C2).	Cryosystem/CND Control (after the test). Order issued
C2 – if needed, perform UT check for evidence of intergranular attacks for welds in non-type-L SS material.	
C3 – prepare (as much detailed as possible) isometric drawings for piping anchored to the inlet and outlets of the cooling channels and analyze for max thermal contraction and compliance with B31.3 or EN13480 requirements.	
C4 - determine the rate of cool-down and warm-up and predict the number of thermal cycles from past plus a conservative projection of future operation. By heat transfer determine the maximum temperature gradient through the wall, from there estimate the through-wall stress and perform a fatigue check for cracking caused by through-wall temperature gradients.	LNF/FNAL
C5 - Estimate the potential for pressure transient up to relief valve set point. If a dynamic pressure rise is credible, apply a dynamic load factor to the pressure rise, and check the stresses in the pipe caused by the total pressure against B31.3 stress limit for occasional loads caused by a pressure surge to relief valve set point.	FNAL? (see KLOE commissioning-acceptance test.pdf for pressure transient up)
C6 – Verify the connection points, sizing, settings of the pressure reliefs and verify that they are adequately set and sized as required by applicable US Codes and Standards, e.g. e.g. ASME B31.3, ASME VIII Div.1, API 520 and CGA S-1.3.	FNAL

# Compensatory measures

Compensatory measure	Owner/Note
<p>C7 - Perform radiographic examinations ( RT) or ultrasonic (shear wave UT) of the following welds: 3 random accessible welds in the SS pipe; 3 random accessible welds in the AL pipe; all accessible bi-metallic SS-AL welds; 3 random accessible locations on the inner and the outer vacuum cases; 3 random accessible locations on the He vessel. Use instructions and requirements per ASME (BPVC Section V and B31.3) or PED (EN13445 and EN13480). If the criteria of ASME B31.3 Chapter VI Para.340 applied, do not permit any incomplete penetration (where B31.3 would permit some) as they may indicate poor argon or helium purging of the first pass of the SS welds and even AL welds.</p>	<p>Cryosystem/CND Control (after the test). Order issued</p>
<p>C8 – perform a pressure test for each pipe segment using 1.1 x design pressure. This is accomplished by test 1 (see above) or by the test done after cooldown &amp; warmup if any welds require repairs.</p>	
<p>C9 – perform a pressure test for helium vessel using 1.1 x design pressure. This is accomplished by test 1 (see above) or by the test done after cooldown &amp; warmup if any welds require repairs.</p>	<p>Cryosystem (after the test). Order emitted</p>
<p>C10 – perform a sensitive leak test for all pressure piping circuits and helium vessel. This is accomplished by test 1 (see above) or by the test done after cooldown &amp; warmup or if any welds require repairs.</p>	
<p>C11 - If the PMI results under C1 are satisfactory (confirming the SS and AL alloys), no need for tensile testing. If the PMI results are not satisfactory, the root cause and extent of the material issue needs to be established, and remediation actions implemented accordingly.</p>	<p>TBD</p>

# FFS measures

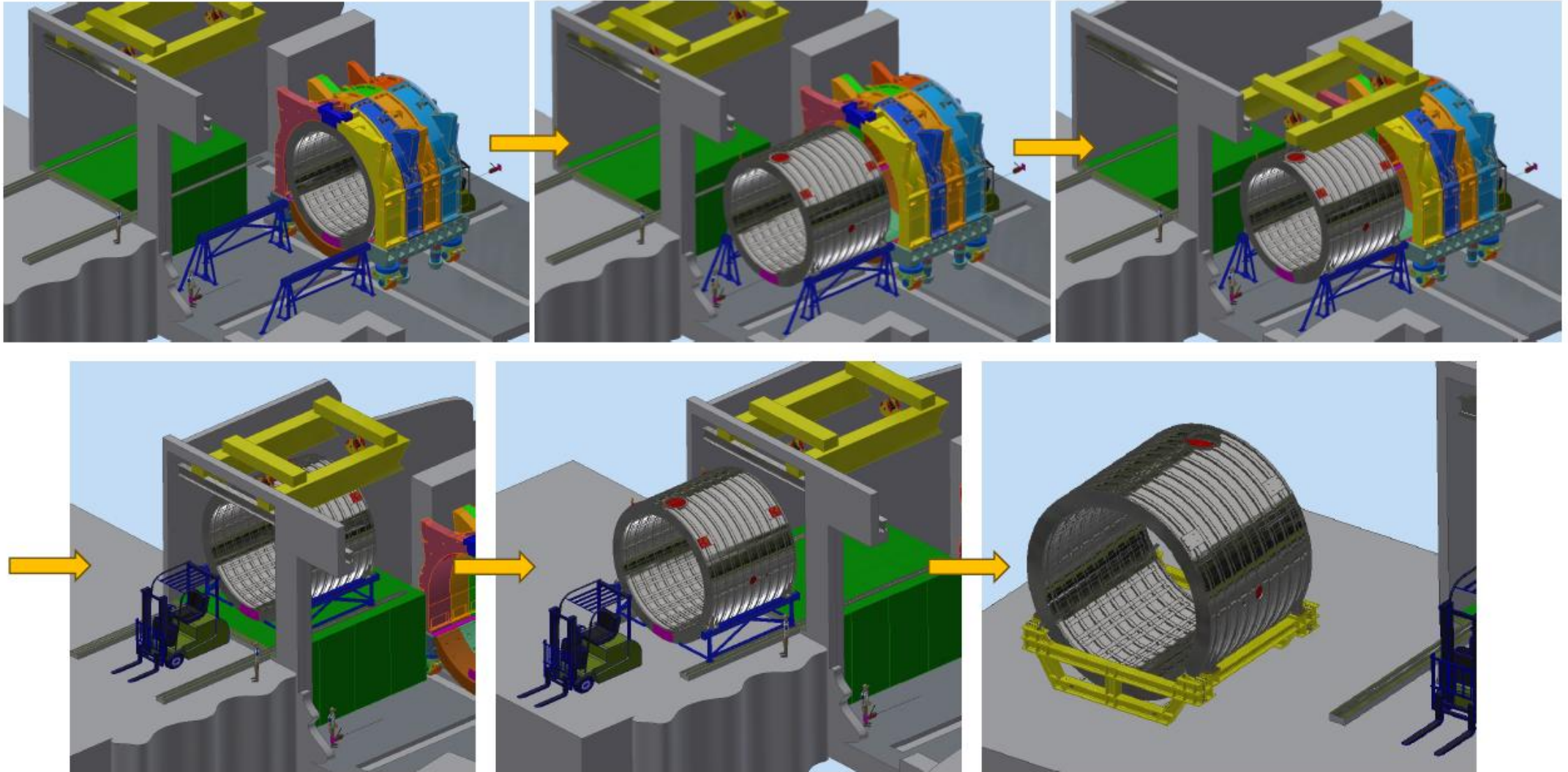
Periodic inspection	Owner/Notse
<p>F1 - At the first outage, when the He vessel is accessible and at ambient temperature, the same welds as were examined in Section 7.4, should be re-examined using the same technique. Once the results of in-service inspections (NDE) are obtained, they shall be evaluated in accordance with the API 579-1/ASME FFS-1 "Fitness-for-Service" standard.</p>	<p>C1-C2 can be performed only after test at LNF (at the first outage)</p> <ul style="list-style-type: none"> <li>• Welds examination CND Control</li> <li>• Results evaluation FNAL</li> </ul>
<p>F2 - When the He vessel is accessible and at ambient temperature, the same welds as were examined in Section 7.4, should be re-examined using the same RT technique.</p>	<p>C1- C2 can be performed only after test at LNF (at the first outage)</p> <ul style="list-style-type: none"> <li>• Welds examination CND Control</li> <li>• Results evaluation FNAL</li> </ul>
<p>F3 - Periodically perform a sensitive leak test, such as He leak test in accordance with ASME Boiler and Pressure Vessel Code Section V Part 10. The periodicity to be established by Fermi Lab depending on the accessibility of the pipes and vessel for leak testing.</p>	<p>FNAL</p>
<p>F4 - Leak tightness and operability of valves should be tested periodically at a scheduled established by Fermi Lab.</p>	<p>FNAL</p>
<p>F5 - Safety relief valves should be tested or replaced periodically as recommended by the valve manufacturer.</p>	<p>FNAL</p>

# Magnet Extraction and Yoke Dismount

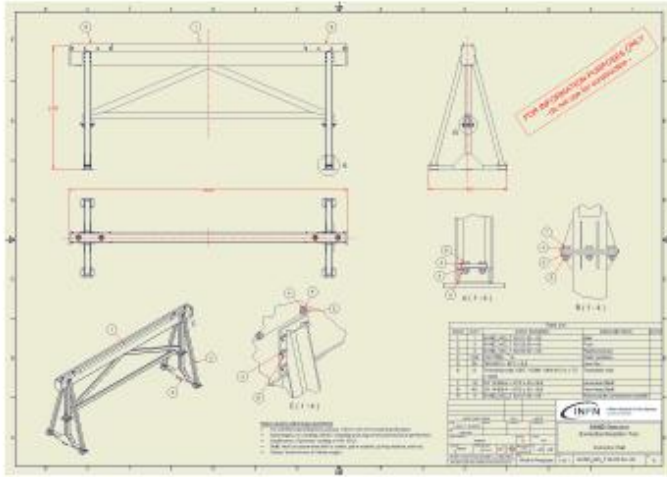
- Dismount Iron EndCaps and closing ring
- Extract magnet on rails inside KLOE hall
- Dismount service turret
- Lift magnet on deck with crane
- Move out magnet from hall
- Lift and lay on cradle
- Dismount Yoke



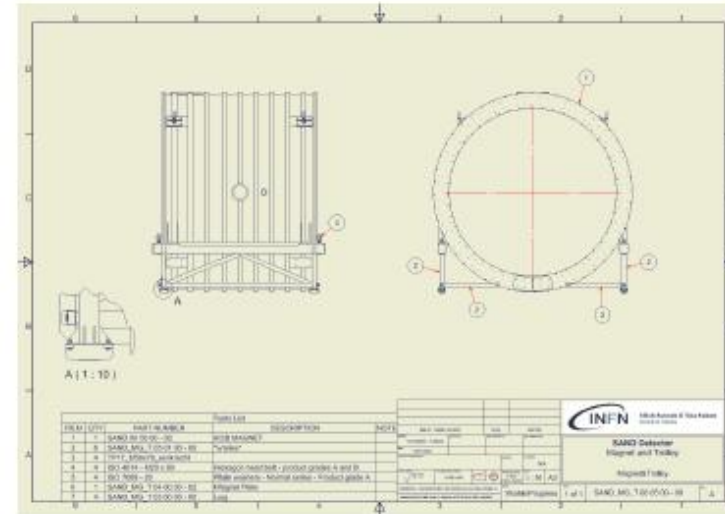
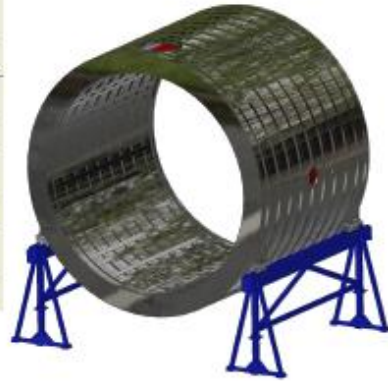
# Magnet Extraction Procedure



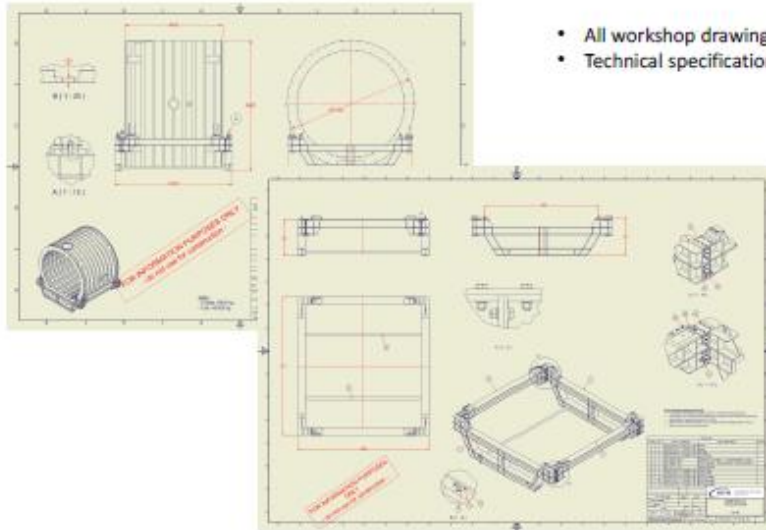
# Magnet Extraction Tools Drawings



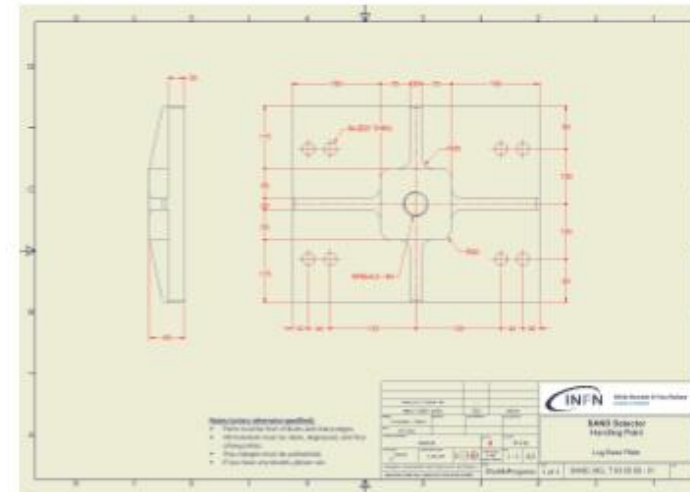
- All workshop drawings are ready
- Technical specification is ready



- All workshop drawings are ready
- Technical specification is ready



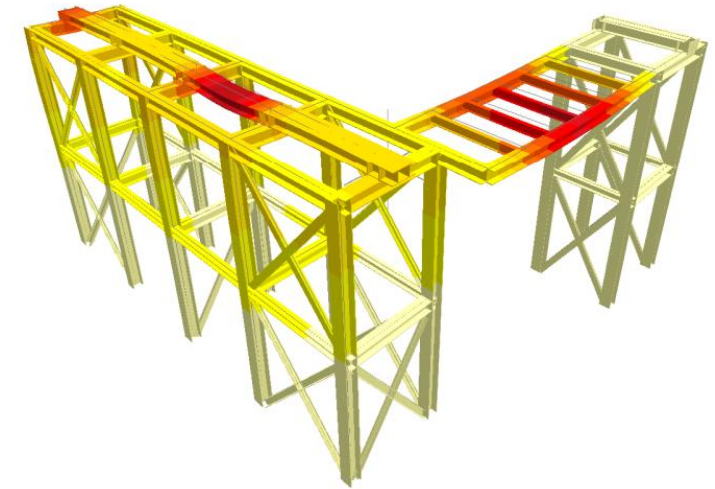
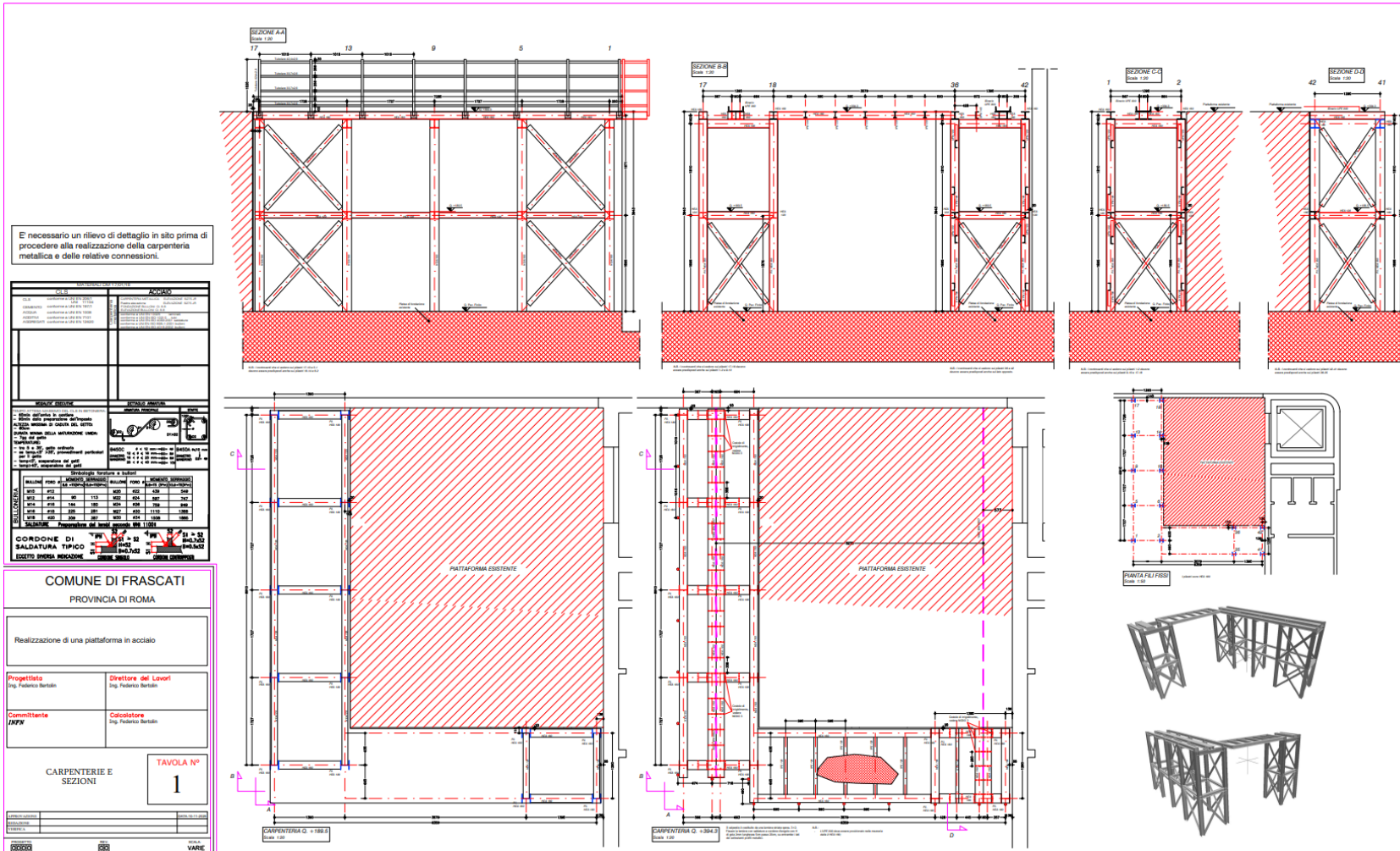
- All workshop drawings are ready
- Technical specification is ready



- All workshop drawings are ready
- Technical specification is ready
- Holes centre spacing to be checked

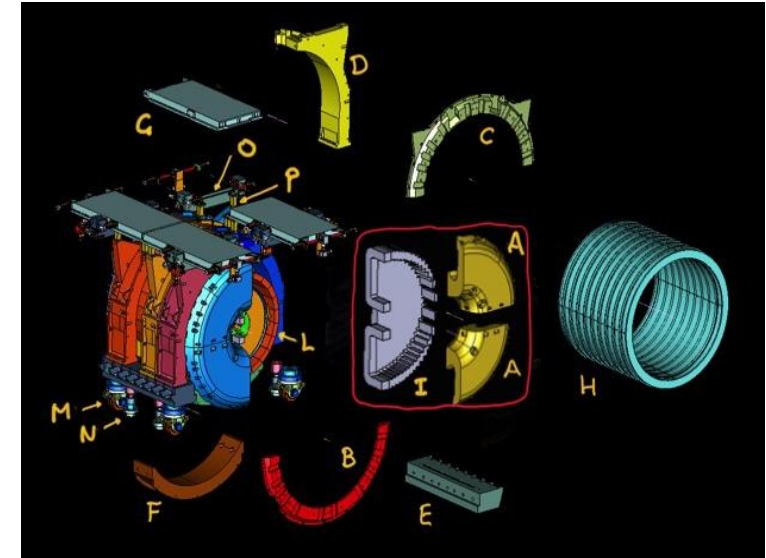


# KLOE Hall Deck Extension Project



# Yoke Disassembly

- **42 parts** excluding connections
- weight from 2 to **30 tons**
- total weight about **1000 tons**
- all drawings and manual available
- Baldon Company is in charge of the disassembling (same that assembled in 1997)
- They are available for the re-assembling at FNAL



**INNSE**

M M  
TIPO

MANUALE D'USO E MANUTENZIONE

H 0 0 3 5 7	/
CODICE NUMERO	REV.

VOLUME SINGOLO

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ISTITUTO NAZIONALE DI FISICA NUCLEARE  
LABORATORI DI FRASCATI

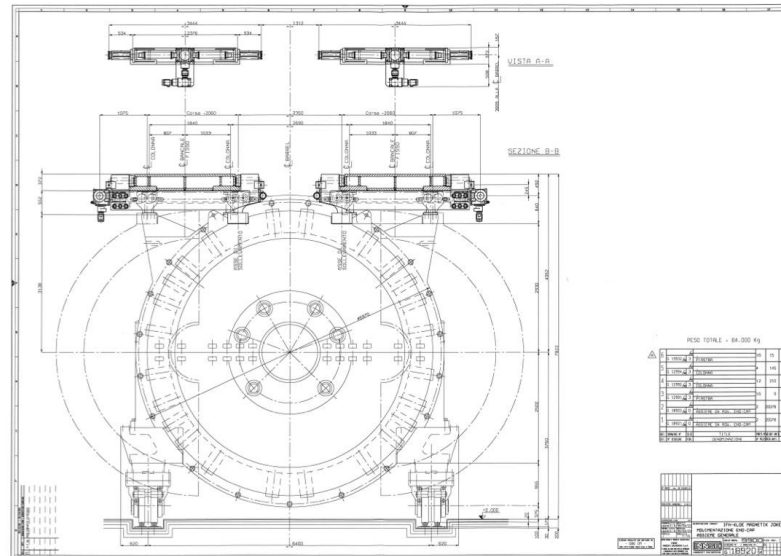
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**GIOGO MAGNETICO  
PER ESPERIMENTO KLOE**

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PREPARATO		CONTROLLATO		EMESSO	
Firma	Data	Firma	Data	Firma	Data
<i>[Signature]</i>	01-97	<i>[Signature]</i>	07-97	SET	03-97

INNSE SI RISERVA TUTTI I DIRITTI RIGUARDANTI QUESTO DOCUMENTO.  
SENZA PREVENTIVA AUTORIZZAZIONE QUESTO DOCUMENTO NON PUO' ESSERE  
RIPRODOTTO, RESEO DISPONIBILE A TERZI, O COMUNQUE USATO IN MODO CHE POSSA  
PREGIUDICARE GLI INTERESSI DI INNSE.

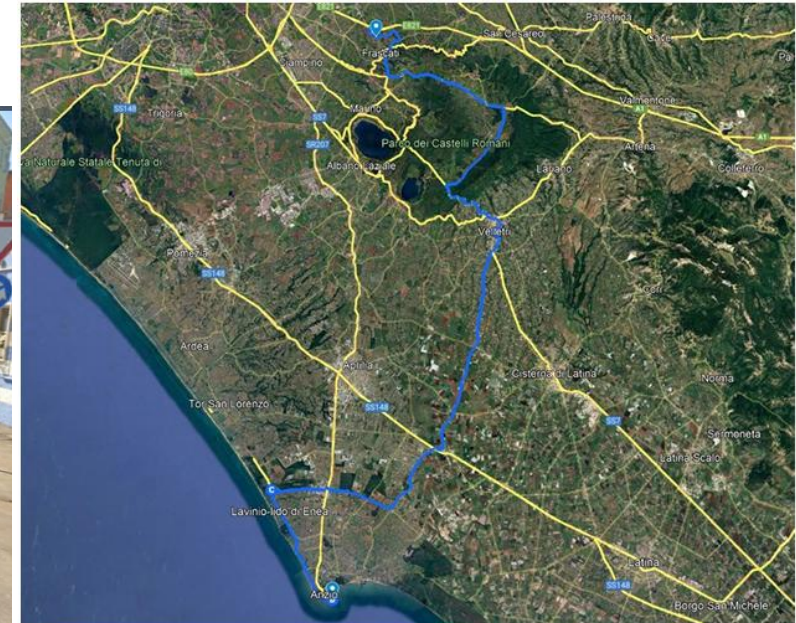
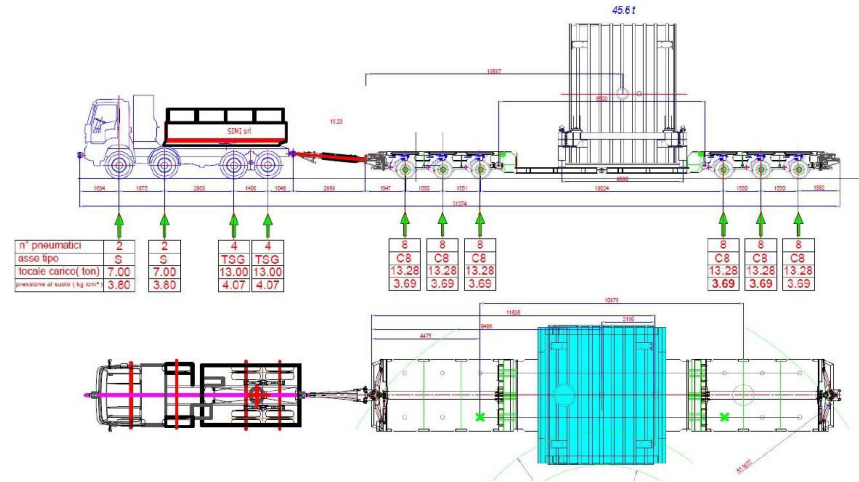


# Magnet Shipping

Route survey document (31 pages)

		ROUTE SURVEY			
Issued by:	Revision	Language	Document:	Order	
AS	0	IT	39437_INFN-LNF - KLOE	N° 23988	INFN-LNF PROJECT FRASCATI – ANZIO

- LNF – Anzio harbor: special truck
- Anzio – Civitavecchia harbor: barge
- Civitavecchia – Chicago: dedicated MDL boat
- Chicago – Romeoville: barge
- Romeoville – FNAL: special truck
- ECAL will go LNF – Civitavecchia direct



# KLOE-to-SAND Updated Time Schedule

