

CERN-GSI Collaboration Steering Board Meeting

Super-FRS Magnet Testing

Building 180 - Test facilities and CERN activities

26 April 2024

G. Riddone, CERN

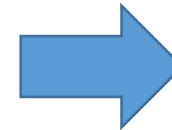
Content

- KR3912/TE – Short reminder
- Status of the cryogenic and QP/EE systems
- On-site CERN coordination and test follow-up
- CERN involvement in the joint task forces
- Conclusions

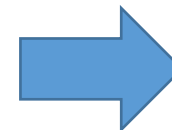
Collaboration agreement KR3912/TE

Test facility at CERN for the tests of Super Fragment Separator (Super-FRS) magnets for FAIR

- GSI is leading the activity, and contributes to it with:
 - 4 FTE: operation team (2 eng. and 2 technical eng.)
- CERN is contributing with:
 - 0.4 FTE: support with best –effort service from its equipment groups (cryogenics, survey, power converters, energy extraction, quench protection, data acquisition and control)
 - 1 FTE: on-site technical engineer - support and coordination with internal services and CERN contractors
- Industrial support from other groups which is charged to GSI on cost-recovery basis
- The total cost estimated at 5.4 MCHF for the two phases now until Q4/2026 (originally until Q1/2024).
- **Amendment on extension of duration: now until end 2026 (see also H. Simon presentation)**



FTE for 2022: 0.8
FTE for 2023: 1.1



- 2 persons from industrial support (full time)
- Logistics and storekeeper: 0.2



Test Facility in B180

Test benches and preparation area



Test Bench 1



Test Bench 2



Test Bench 3



Preparation area
(Dipole from Elytt)

Cryogenic operation follow-up

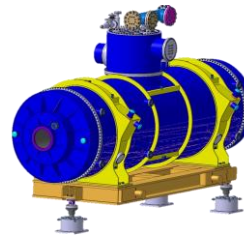
ACTION	MAGNET	BENCH	START DATE 1
COOLDOWN	LM09	1 (BLEU)	1/16/23 11:30
WARMUP	LM09	1 (BLEU)	2/14/23 11:30
COOLDOWN	SM06	3 (WHITE)	2/16/23 10:15
COOLDOWN	LM09	1 (BLEU)	3/13/23 13:00
WARMUP	SM06	3 (WHITE)	3/23/23 10:30
WARMUP	LM09	1 (BLEU)	3/24/23 10:30
COOLDOWN	LM11	2 (GREEN)	4/4/23 9:10
COOLDOWN	LM09	1 (BLEU)	5/12/23 10:00
COOLDOWN	SM03	3 (WHITE)	5/17/23 13:00
WARMUP	LM11	2 (GREEN)	5/23/23 10:00
WARMUP	LM09	1 (BLEU)	5/23/23 22:00
WARMUP	SM03	3 (WHITE)	6/27/23 15:30
COOLDOWN	LM09	1 (BLEU)	7/27/23 11:00
WARMUP	LM09	1 (BLEU)	8/8/23 11:30
COOLDOWN	SM02	3 (WHITE)	8/2/23 14:30
WARMUP	SM02	3 (WHITE)	8/28/23 9:00
COOLDOWN	SM05	1 (BLEU)	9/6/23 14:15
WARMUP	SM05	1 (BLEU)	10/9/23 15:15
COOLDOWN	SM05	1 (BLEU)	10/17/23 13:30
COOLDOWN	SM04	3 (WHITE)	10/19/23 13:30
WARMUP	SM05	1 (BLEU)	10/23/23 14:00
WARMUP	SM04	3 (WHITE)	11/17/23 10:30
COOLDOWN	SM04	3 (WHITE)	11/24/23 10:00
COOLDOWN	SM05	1 (BLEU)	12/4/23 15:00
WARMUP	SM05	1 (BLEU)	12/11/23 10:30

Cryogenic service in 2023 (4.5K cryoplant only) :

Working hours: 6523 h

Total facility availability: 99.6% (Utilities default)

Cryo availability: 100%



LM09, LM11



SM02,SM03,SM04,SM05,SM06

2 LM and 5 SM tested

Total 2023: 13 Cooldown & 12 Warm Up

	2019	2020	2021	2022	2023
LM			1	2	2
SM	1			2	5
Dipole				1	

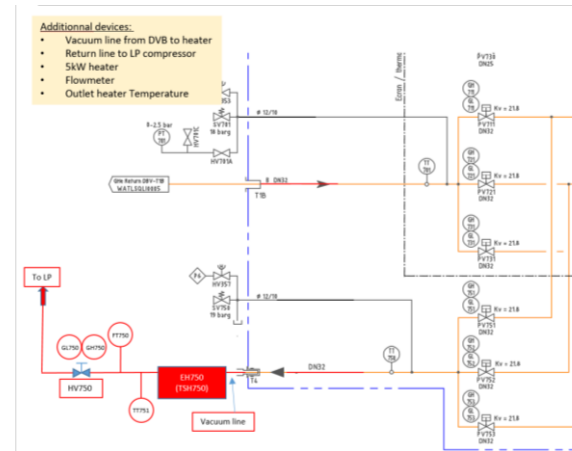
Cryo consolidations and maintenance

Consolidations

1. Bypass SVB to LP (**Perturbations limitation between 80 k to 4.5 K**)
2. Cold box water inlet filter upgrade (sized with respect to found impurities)
3. Process requirements upgrade (Automatic GSI changing modes following Cryo modes)
4. Under study: additional dryer, conditioning and circuit analyses

Maintenance and Major Overhauling Cryo equipment deadline

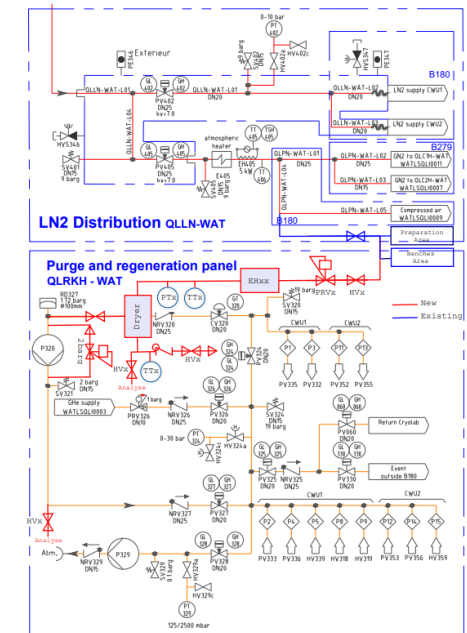
- Compressor station 4.5 K (from July 23 up to March 24: 3500 h of operation)
 - Compressor C120, PM (40000 h), Next major overhauling in ~12000 h
 - Electrical Motor M120, PM (40000 h), Next major overhauling in ~12000 h
- Precooler Compressor Station (from July 23 up to March 24: 3500 h of operation)
 - Compressor C120, PM (40000 h), Next major overhauling in ~25500 h
 - Electrical Motor M120, PM (40000 h), Next major overhauling in ~15500 h



1. Bypass SVB to LP



2. Cold box water inlet filter



4. Project under study

QP and EE systems

WP Quench Protection System (TE-MPE)

Mandate: Provide the Quench Detection System
+ controls layer for the Test Benches.

WP Energy Extraction System (TE-MPE)

Mandate: Provide the Energy Extraction System
+ controls layer for the Test Benches.

Status:

TB1 : 6 x UQDS units installed and running

TB2 : 6 x UQDS units installed and running

TB3 : 6 x UQDS units installed and running

3 x 600 A Energy Extraction system installed and running

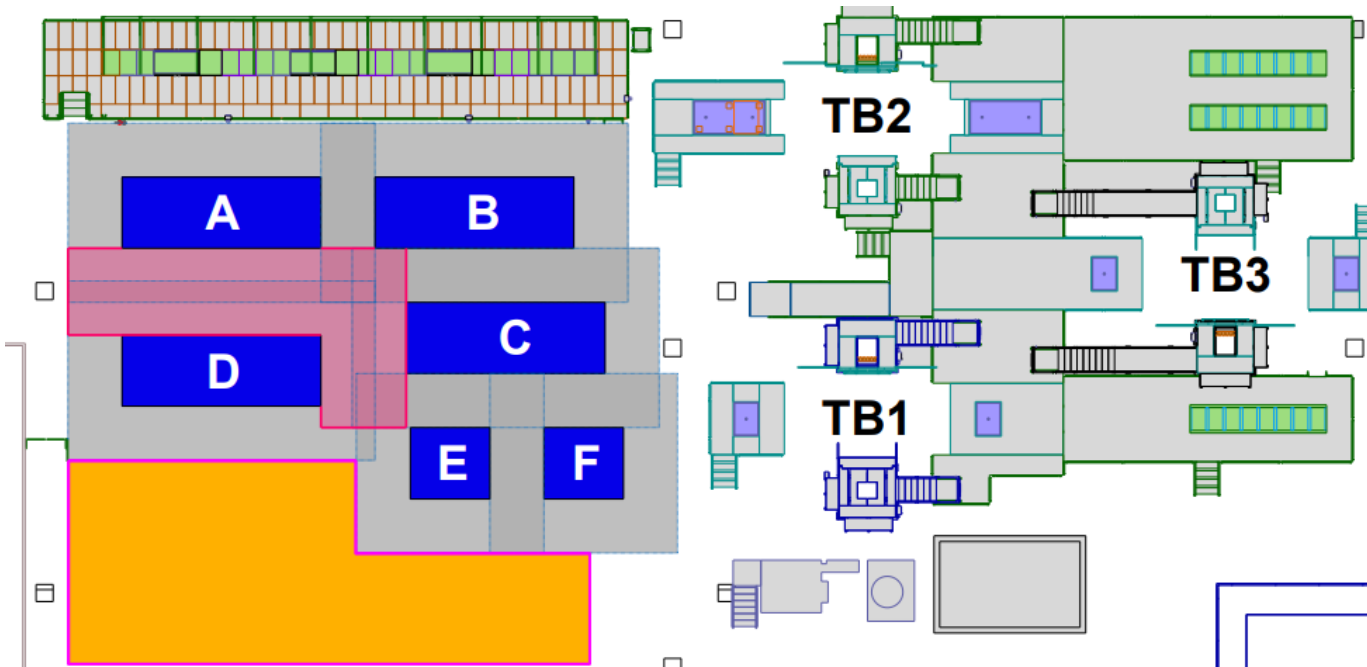
on 3 Nov 2023, GSI quench detection system was tested successfully (while CERN QDS was also active)

Reminder:

we did not have the opportunity to run TB2 nor TB3 with the 9 magnets multiplet (the final commissioning of the TB)



Preparation area improvements



- Optimization was needed for magnet delivery, shipping and preparation
- Integration of all possible delivery flow and tests
- Allocated 5 zones for long magnets (included zone E-F that could be used for 2 short magnets)

On-site coordination

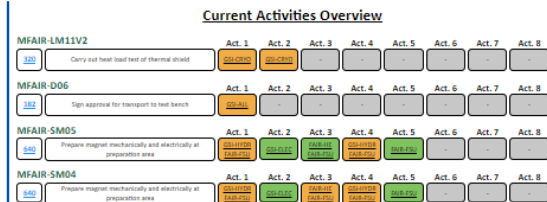
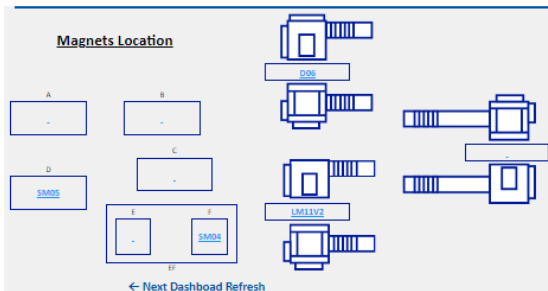
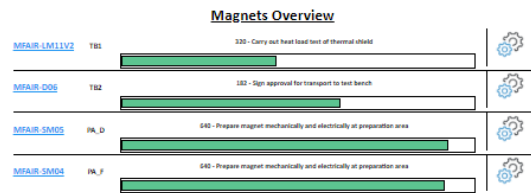
- **Weekly coordination meetings** with GSI and CERN teams to prepare activities of coming week(s)
- Magnet test workflow taken as a reference and implemented in a **sequencer tool (ST)**
- Each task identified with responsibilities to avoid oversights - important from safety aspect
- Once a task is completed and signed, ST sends automatically notifications to the following team to start their activity

Cool down magnet					
T	300 - Pre-cool magnet down to 80K			WO Completed: 19-Apr-2024	
	5 - Start pre-cooldown with CWU1	Checklist: 1/1	Responsibilities: FAIR-CRG -	No Signature Required	No Signature Required
	10 - Start pre-cooldown with CWU2	Checklist: 1/1	Responsibilities: FAIR-CRG -	No Signature Required	No Signature Required
RC	320 - Carry out heat load test of thermal shield				
	5 - Carry out heat load test of thermal shield	Checklist: 0/1	Responsibilities: GSI-CRYO -	No Signature Required	No Signature Required
	10 - Switch on level sensors (change GSI mode after CD2 starts)	Checklist: 0/1	Responsibilities: GSI-CRYO -	No Signature Required	No Signature Required
RW	340 - Cool magnet down to 4.5K and fill it with helium				
	5 - Start cooldown	Checklist: 0/1	Responsibilities: FAIR-CRG -	No Signature Required	No Signature Required
	10 - Indicate that magnet is in "Cryo ready" state	Checklist: 0/1	Responsibilities: FAIR-CRG -	No Signature Required	No Signature Required

➔ ST became a practice for every users, allowing for fluent interactions

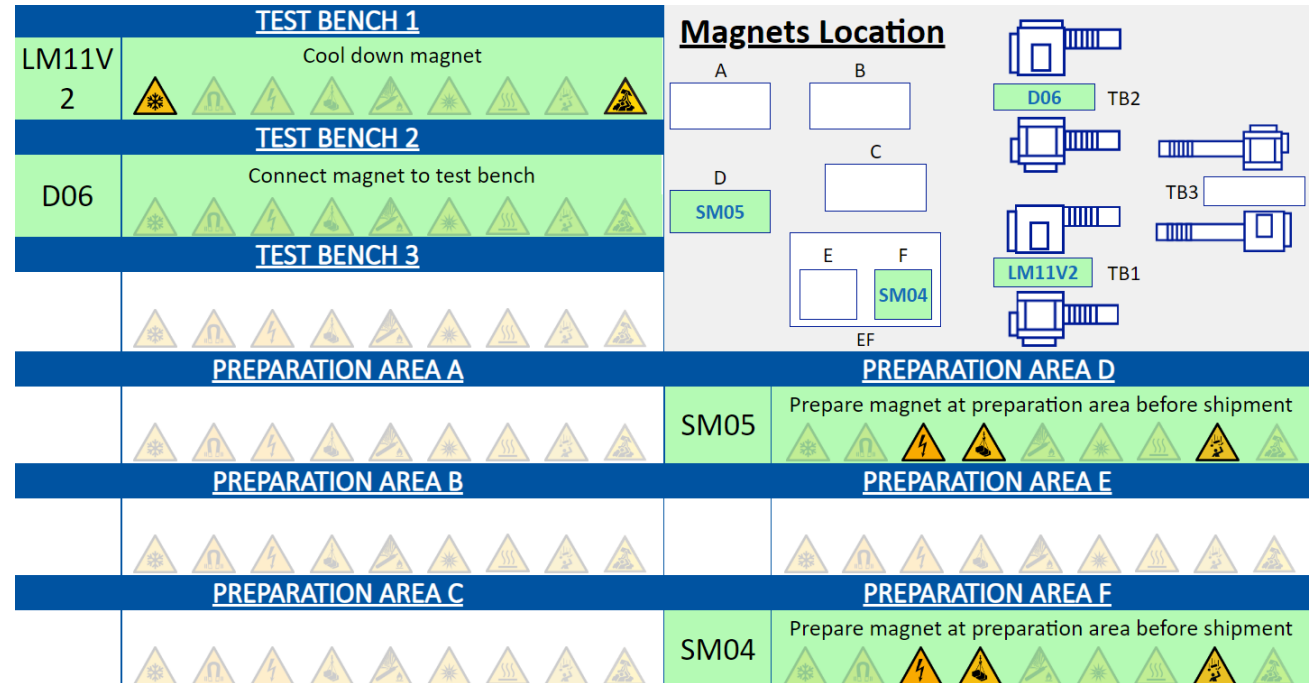
On-line dashboards

Overview of steps and signature upon completion



Signatures in current Activities

Work Order	Work Order Description	Activity Description	Responsibility
MFAIR-D06	Sign approval for transport to test bench	Sign approval for transport to test bench	SM05



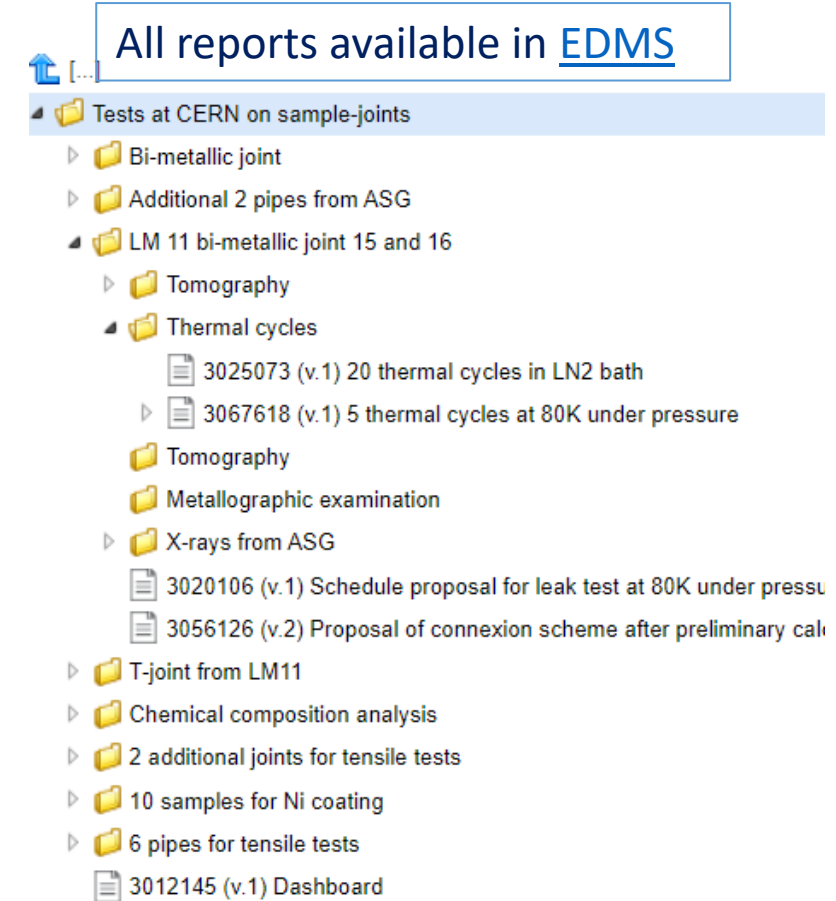
Overview of safety risks vs. ongoing tests

Joint task forces

- CERN participated to the task forces organized by GSI with ASG and Elytt
- CERN provided support and recommendations on:
 - on-site leak localization
 - brazing and x-rays (meetings every two weeks) on magnets to be repaired
 - mechanical design and FEM simulations (monthly meetings)
- CERN coordinated and performed the tests on samples as requested by GSI-ASG and GSI-Elytt (more details in the next slides)

Joint task force CERN-GSI-ASG

- 47 samples at CERN - Dec 2023 - May 2024
- CERN support: EN/MME, TE/CRG, TE/VSC, TE/RAS
 - Tomography x13
 - Metallographic analysis x3
 - Thermal shocks on 14 samples
 - Ni coating x10
 - Chemical composition analysis x3
 - Thermal cycles under pressure on 2 samples
 - Tensile tests at ambient temperature and at 80 K x13

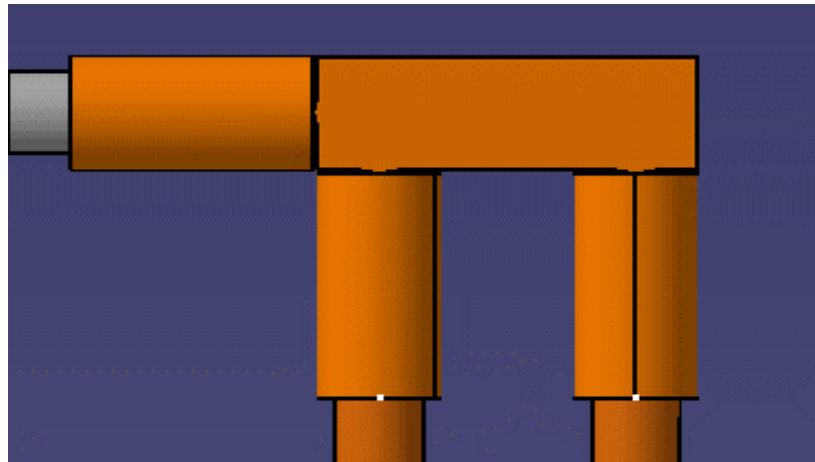
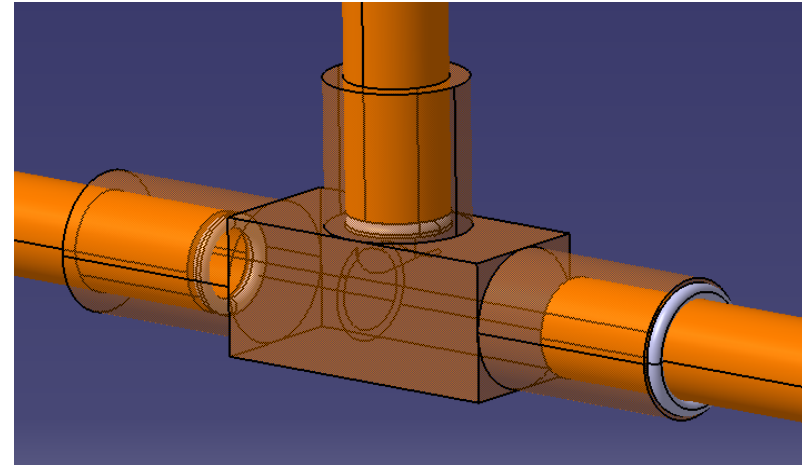
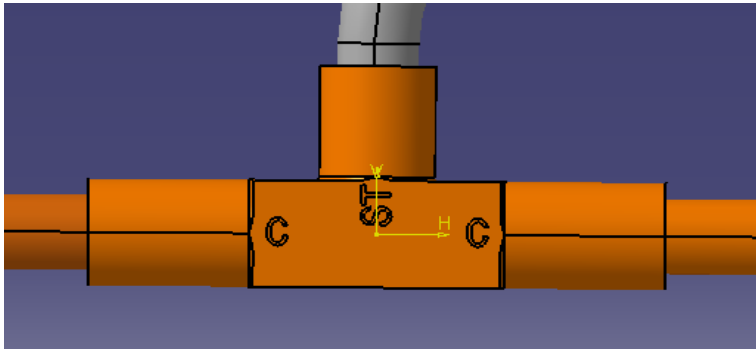


Joint task force CERN-GSI-ASG (dashboard)

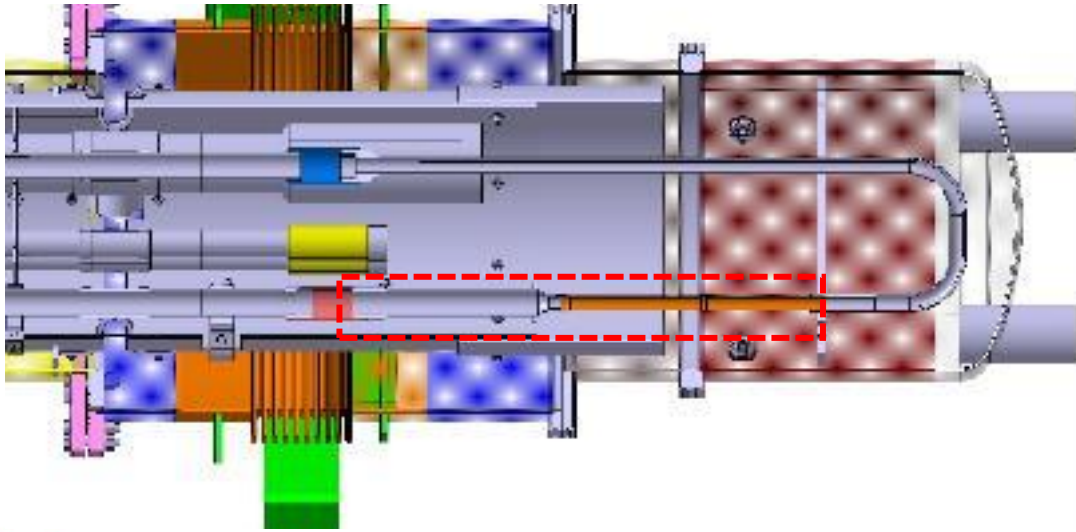
Samples ASG	Description of sample	Objective	STATUS
1. Bi-metallic joint	Inox – Cu bimetallic, new design mock-up sample from workbench	Check ASG x-ray results and further analysis for qualification (Tomography and Metallographic examination)	Report published
2. Additional 2 pipes from ASG	2 Cu-Cu socket joints – sample joints from the work bench	Confirm ASG x-ray results and further analysis qualification (Tomography)	Report published
3. LM 11 bi-metallic joints 15 and 16	Inox – Cu bimetallic, new design, prepared on workbench, extracted from LM11	Confirm ASG x-ray results and further analysis/testing for qualification (tomography, thermal cycles, metallographic examinations, tensile tests at cold)	Sent to tomography after thermal cycles
4. T-joint from LM11	Cu-Cu-Cu, leaking joint, tomography already performed at CERN and ASG	Further root-cause analysis of leakage (tomography)	Reports published
5. 3 samples for chemical composition analysis	stains collected from LM11 turret	identification of chemical compositions (no presence of flux) with SEM	Reports published
6. additional 6 pipes	2 Cu-Cu socket joints – sample joints from the work bench	Check mechanical strength after thermal shocks (tensile tests after thermal shocks)	Tensile tests in preparation
7. Ni coating on stainless steel pipes	10 x commercial stainless steel pipes (316L), L = 100 mm, OD= 18 mm, d=1.5mm	to improve brazing quality by prevent re-passivation of the SS pipe	Samples coated. Delivered to ASG
8. Additional 6 pipes	annealed Cu pipes (DHP R200)	Check mechanical strength after thermal shocks ((tensile tests after thermal shocks)	Tensile tests in preparation
9. 5 x Cu-Cu brazed joint from LM09/SM02	selected Cu-Cu brazed joints after X-ray scan at ASG. Cold leak test done at ASG.	Root-cause analysis of cold leak from a thermal shield of LM09 and SM02 (tomography)	Received at CERN on 24.04

Joint task force CERN-GSI-Elytt

Samples Elytt	Description of sample	Objective	STATUS
11 joint types	Various configuration of Cu-Cu-SS joints	Check joints by x-rays Ultrasound and microtomography	Final reports to be prepared



Tests in-situ: sample installed in the jumper (design validated by dedicated structural analysis)



REFERENCE: Germana Riddone TE/RAS
 EDMS NO.: 3020214
 REV.: 1.0
 VALIDITY: APPROVED

Thermal cycles at cold and under pressure

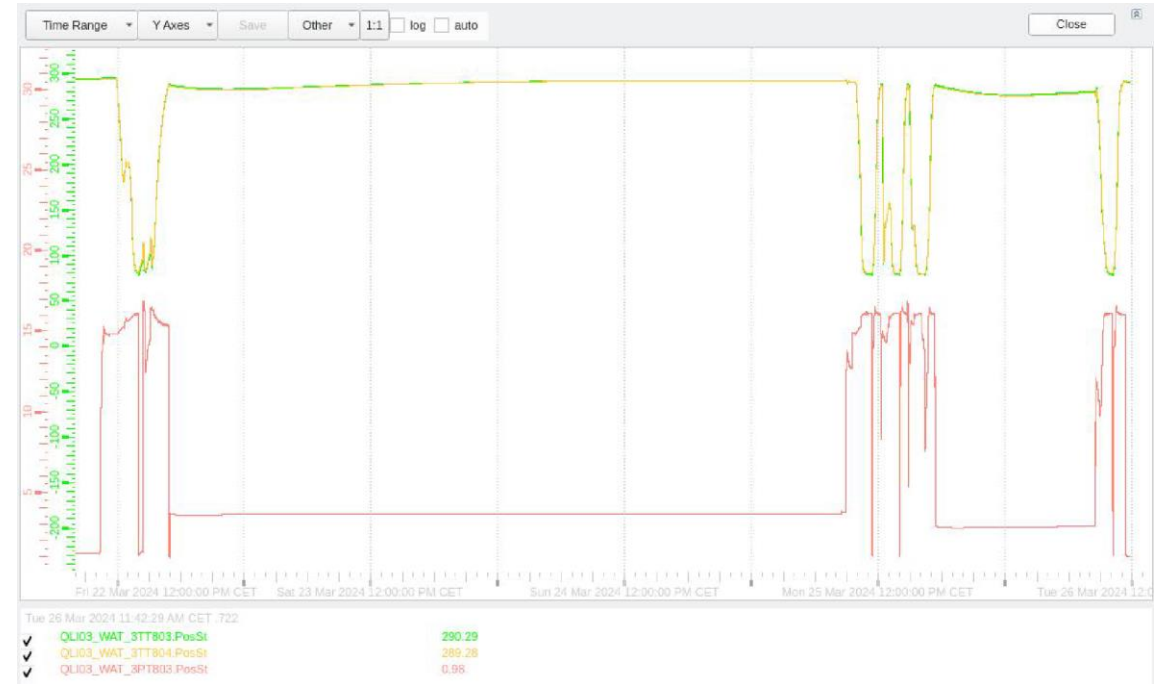


Figure 1. Inspected samples

No leaks detected after the thermal cycles

Dipole D06 repair

Intervention started on 17.04 and lasted for about 7 days
CERN support for handling, welding and leak testing

- ➔ Final leak test (cryostat integrated in the yoke) on 24.04.2024 showing no leaks on the vacuum vessel
- ➔ Ready to be moved to the dedicated test bench for electrical tests

4



1



2



3



Conclusions

- CERN systems commissioned and test facility fulfills the requirements
- Transition phase towards series productions started in 2022, but slowed down due to non-conformities on both ASG and Elytt magnets (internal leaks)
- Currently, we are in the ***validation phase of the new design***, being the highest priority the LM11 (ASG) and D06 (Elytt) tests
- 2023: CERN resources were higher than expected
- Fruitful collaboration between CERN and GSI (and ASG/Elytt) has been demonstrated in the dedicated task forces
- At present, the preliminary planning shows the end of the tests in 2028 (see K. Sugita presentation). If testing of the additional Energy Buncher magnets is confirmed, the end of the tests will then occur in 2029.
- Amendment to the contract will be prepared in 2025 with evaluation of CERN impact.

Thanks to GSI colleagues for the
nice and fruitful collaborations

Thanks for your attention