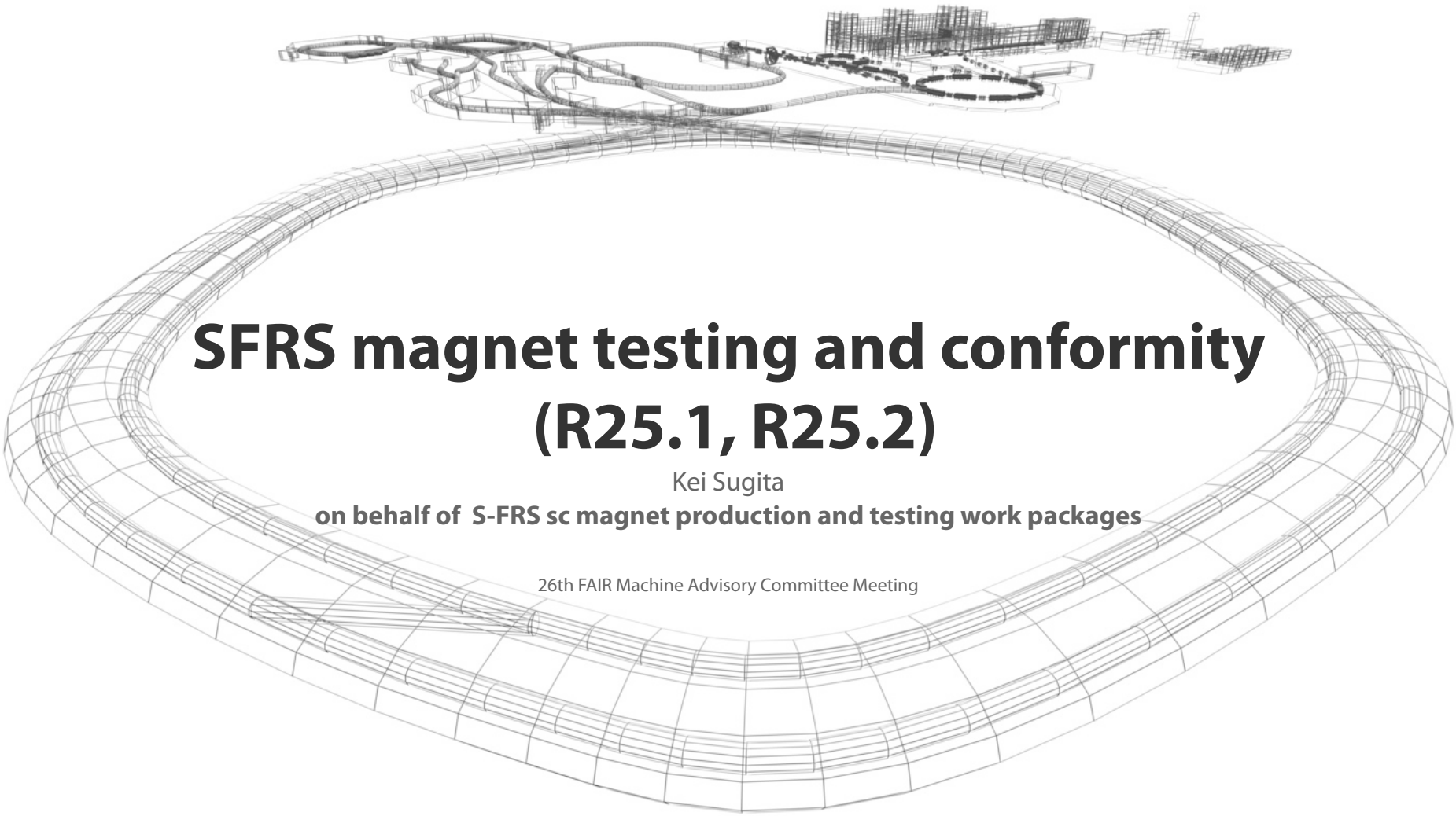


SFRS magnet testing and conformity (R25.1, R25.2)

Kei Sugita

on behalf of S-FRS sc magnet production and testing work packages

26th FAIR Machine Advisory Committee Meeting

Outline

- Work package description
- Recommendations addressed (R25.1, R25.2)
- Magnet production and testing status
- Conformities
- Schedule
- Summary

Work package description

Dipole magnet production

WPL: Hans Müller

FAIR procurement

French in-kind, technical follow-up by CEA

Production & Factory acceptance test (FAT)

FAT acceptance

Transport permission to CERN

SAT acceptance

Transport permission to GSI

Multiplet production

WPL: Eun Jung (Melanie) Cho

German in-kind

Production & Factory acceptance test (FAT)

FAT acceptance

Transport permission to CERN

SAT acceptance

Transport permission to GSI

Magnet testing at CERN

WPL: Kei Sugita (interim)

German in-kind

Collaboration with CERN

Site Acceptance Test (SAT)

Pre-assembly

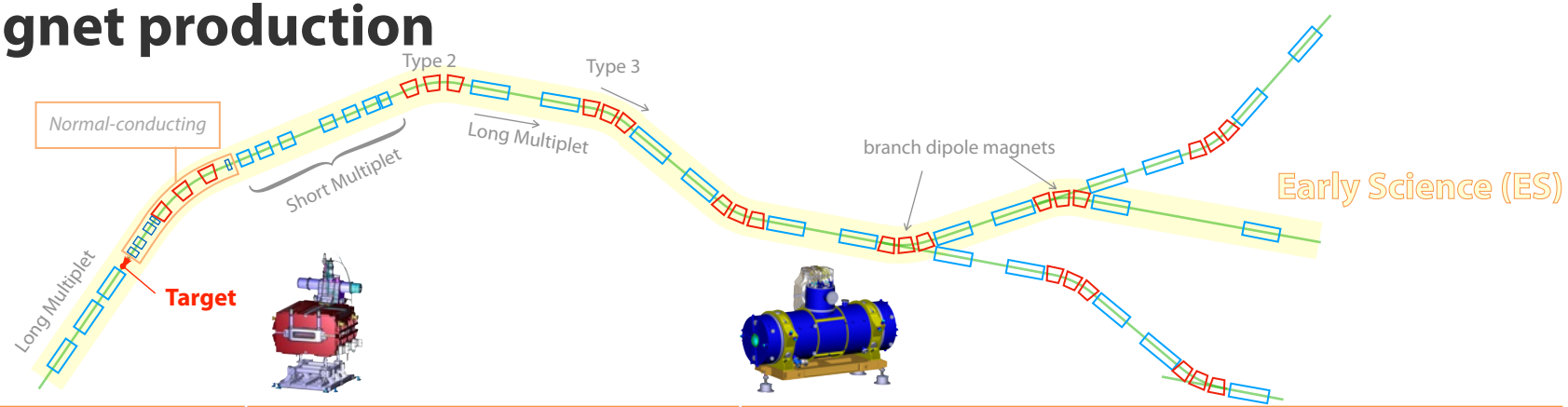
responsible: Vasileios Velonas

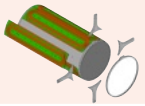
incoming inspections

preparation and interface setup for installation, storage

Work package description

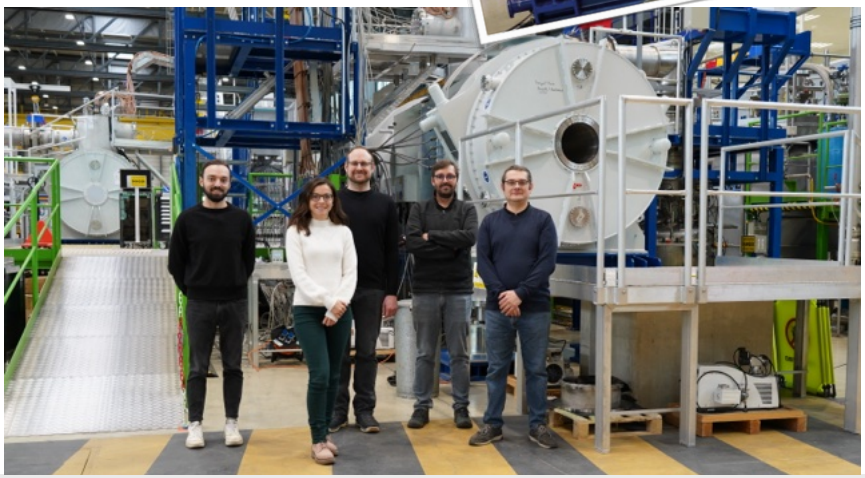
magnet production



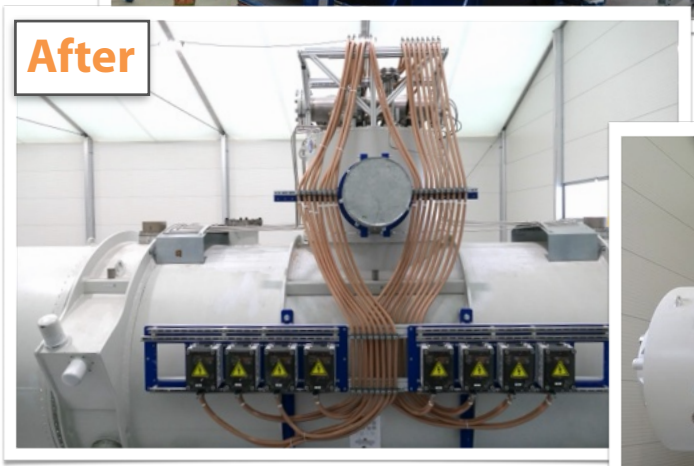
	Dipole magnet (ELYTT ENERGY)			Multiplets (ASG SUPERCONDUCTORS)				
	Type 2	Type 3	Branch	24 different configurations				
total quantity	3	18	3	7 short + 23 long				
for ES	**3**	**10**	**2**	**7 short + 13 long (16 types)**				
length [m]	3.3	3.0	3.0	2.7 to 7.0				
height [m]	4.4	4.4	4.4	4.3				
weight [ton]	52	55	49	27 to 65				
LHe volume [L]	50	50	50	900 to 1350				
aperture [mm]	170×794	170×794	170×794	380				
				Short Quadrupole 	Long Quadrupole	Sextupole 	Steering Dipole 	Octupole (in SQ) 
number of magnets	3	18	3	44	34	41	14	42
max. current [A]	260	260	308	330	330	320	308	176
inductance [H]	26	23	23	30	42	1.04	0.07	0.1
stored energy [MJ]	0.5	0.5	0.7	0.77	1.1	0.037	0.0026	0.0013

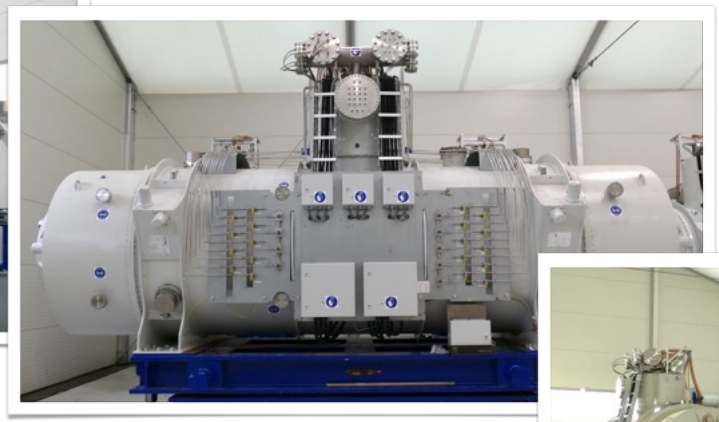
Work package description

- **magnet testing** collaboration with CERN
  - CERN prepares and maintains the facility as available
  - **GSI coordinates and executes the testing**
    - five experts from GSI are seconded
    - **leave of two colleagues** (end of Oct. /early next year)
      - replacement hiring processes ongoing
      - support resource from GSI to CERN

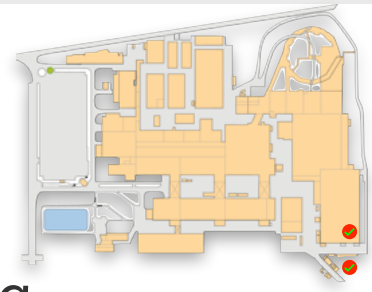


Work package description





- **pre-assembly**
  - incoming check
  - setup interfaces
  - room temp. testing
  - documentations
  - ready for installation (storage)



Experts from various GSI departments involved.
Respectful cooperation is essential.

Recommendations addressed

- R25.1
  - Consider the design, procurement and validation of a spare moving fluxmeter.
- **Critical components of the fluxmeter were delivered.**
- As redundancy, we have **a stretched wire system**, which will be actually used as main device for the field measurement of the series dipole magnets. The existing fluxmeter can be used as back up of the stretched wire.

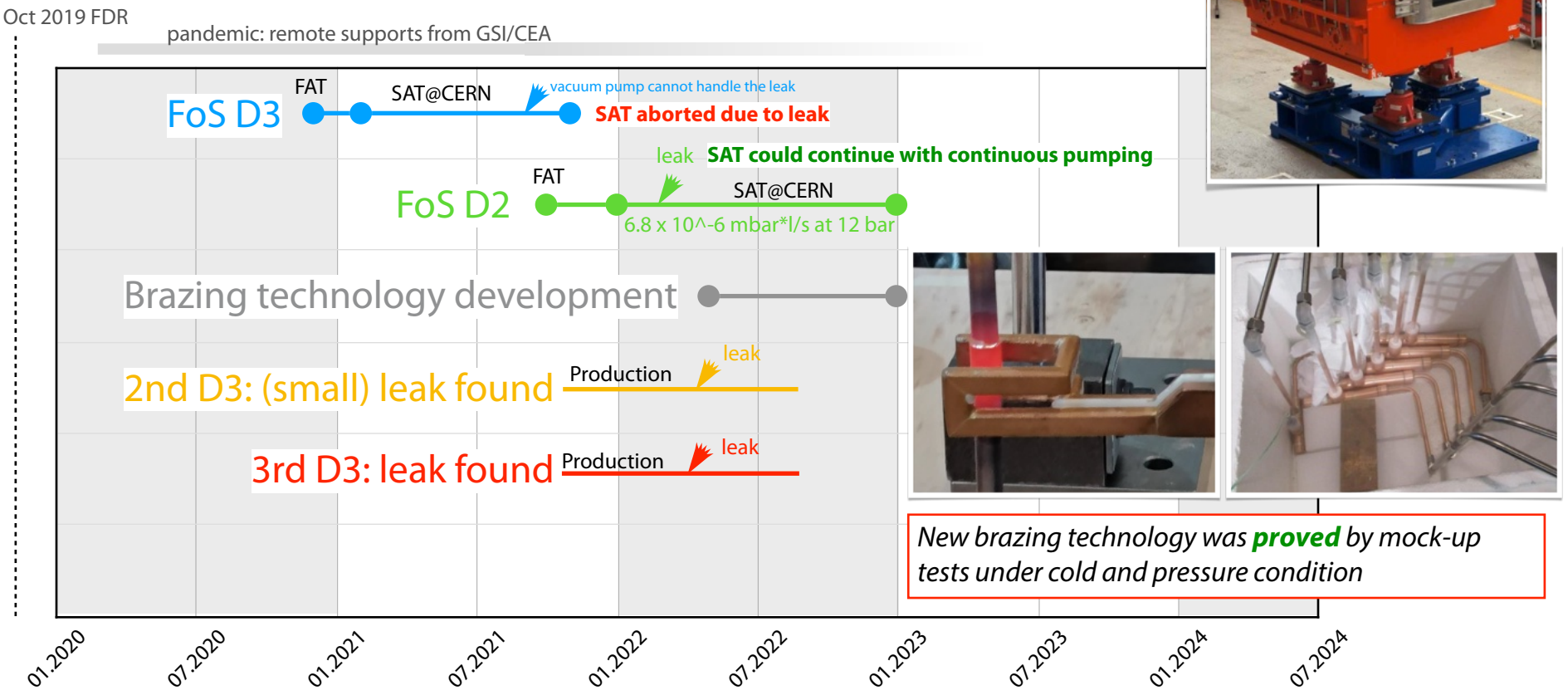
Recommendations addressed

- R25.2
  - Add additional holding points and reception tests both at the manufacturer's premises and after delivery to CERN.
- **Yes. Most of the contents below are related to finding of non-conformities and actions taken by GSI/FAIR**

Magnet production and testing status

- dipole magnet (2022)

Leak from the thermal shield requiring
new brazing technology development (completed)

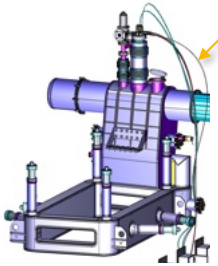


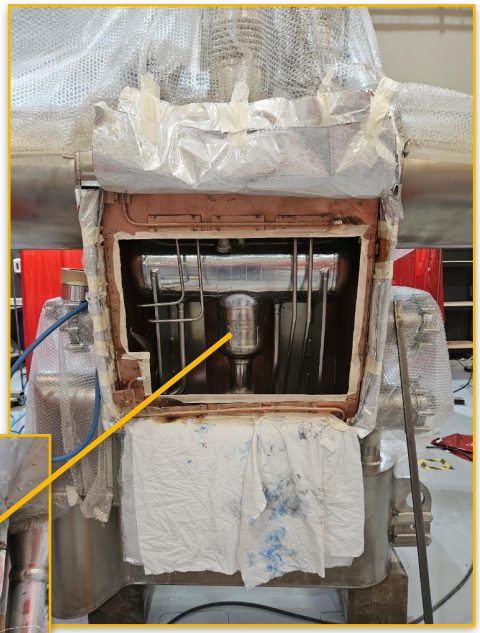
*New brazing technology was **proved** by mock-up tests under cold and pressure condition*

Magnet production and testing status

- dipole magnet (2023)

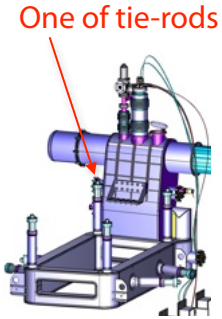
2nd D3: High voltage test failure (Jan.)





3rd D3: leak and bad quality of old brazings

leak vacuum/outside (Sep.)



Many problems

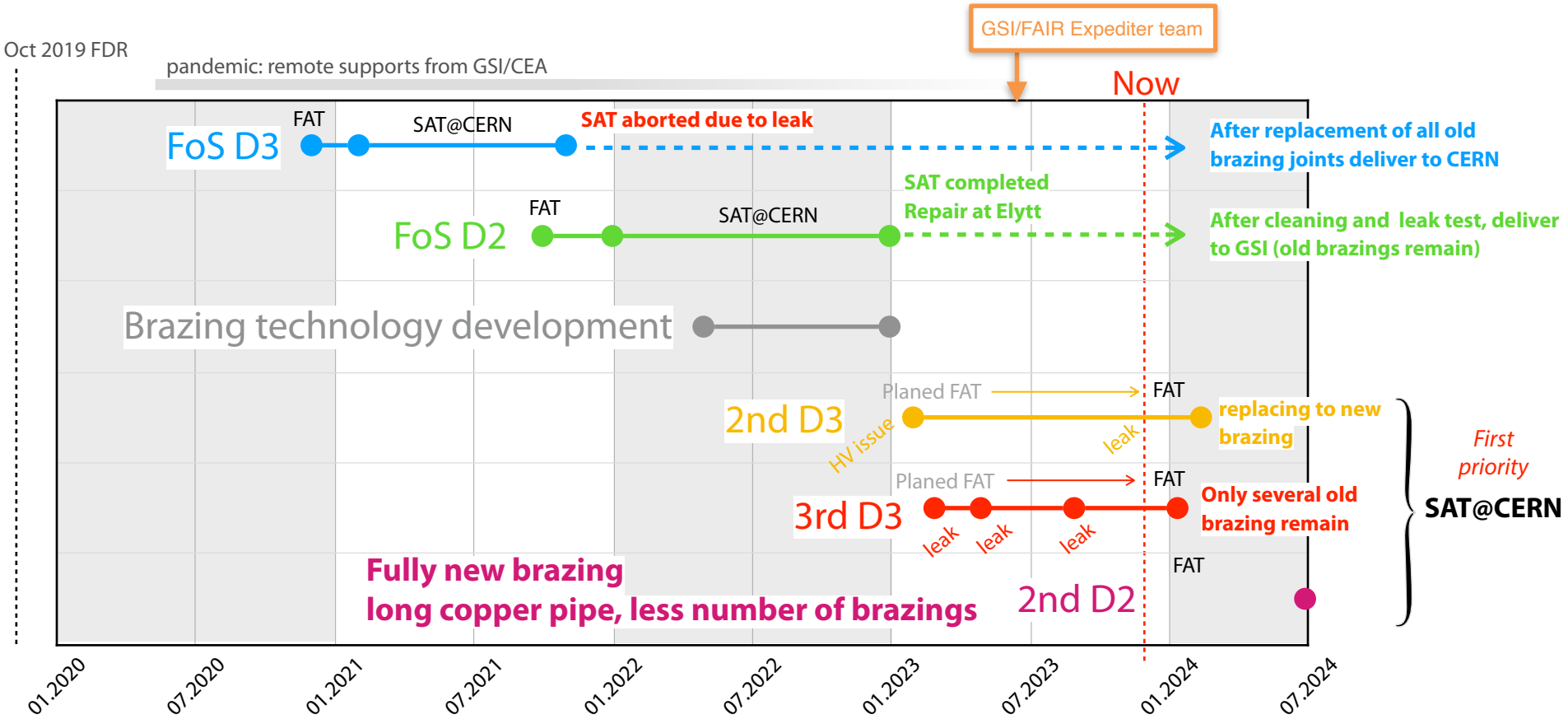
Reparation actions and re-assembly process required more time and efforts than expected.

Magnet production and testing status

- dipole magnet

No magnet delivery in 2023

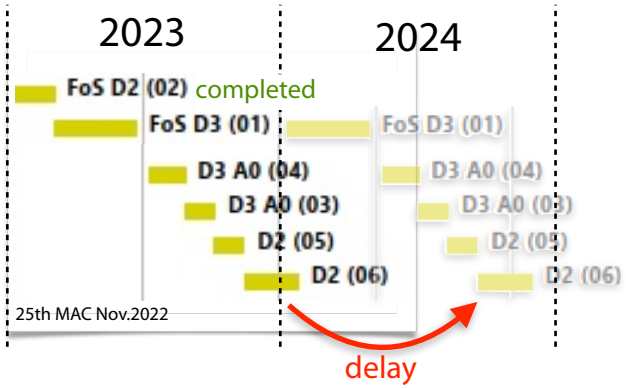
Beginning of 2024, 2 dipole magnets will be delivered to CERN



Magnet production and testing status

- dipole magnet

	dipole magnet (ES relevant)		
	Name	status / issues	next step
1	FoS D2	SAT completed	reparation at Elytt, transport to GSI
2	2nd D2	production ongoing (fully new brazing)	transport to CERN (prio. 1)
3	3rd D2		
4	FoS D3	reparation (leak)	transport to CERN
5	2nd D3	reparation (HV, leak)	transport to CERN (prio. 1)
6	3rd D3	reparation (leak)	transport to CERN (prio. 1)
7	D07 (B0)		
8	D08 (B0)		
9	D09 (B0)		
10	D10 (B0)		
11	D11 (Branch B)		
12	D12 (B2)		
13	D13 (C0)		
14	D14 (Branch C)		
15	D15 (C1)		



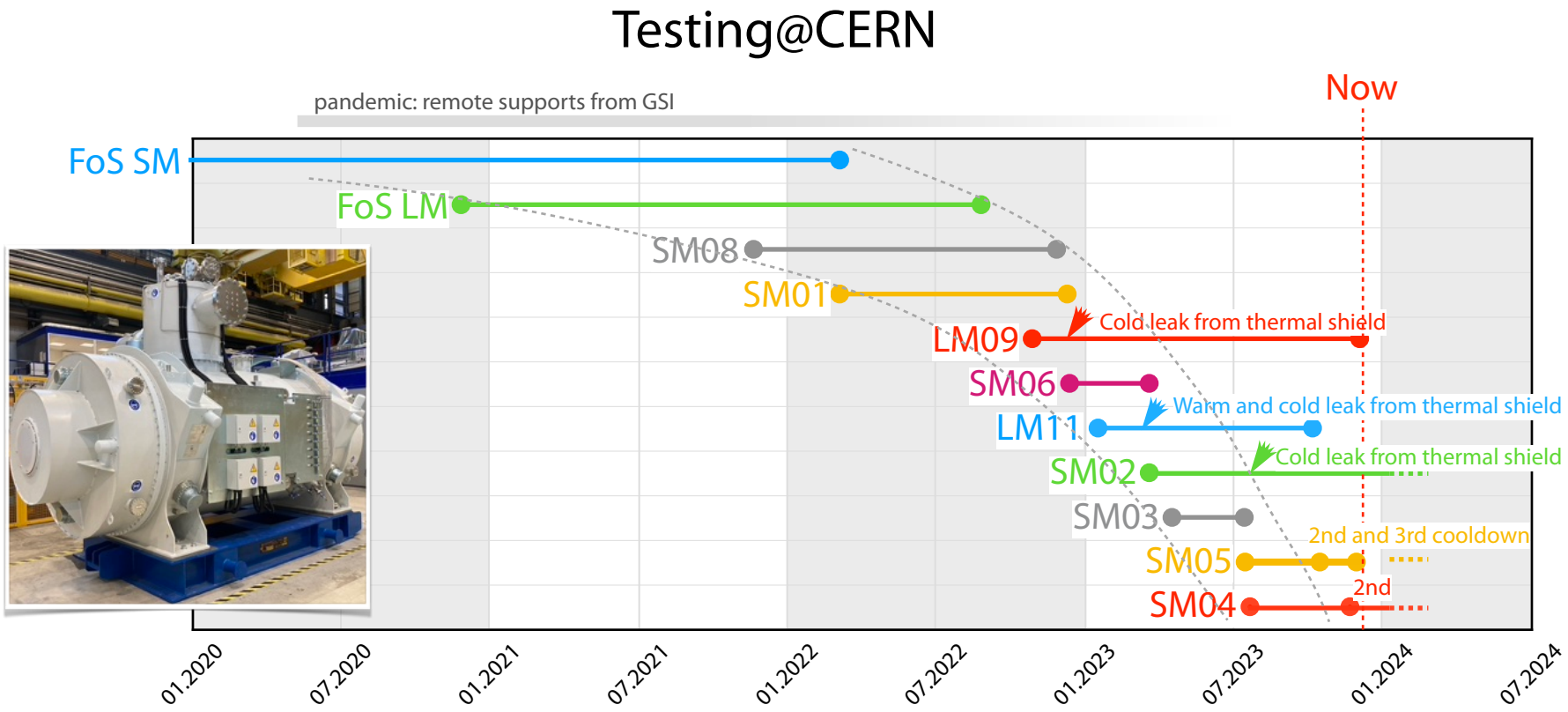
Production status

- coil: completed for 11 magnets
- yoke: completed for 6 magnets, for 5 magnets ongoing
- branch dipole magnets
  - cryostat production resumed (subcontractor in China)
  - an alternative manufacturer (subcontractor in EU) of the coil casing (soon)

- **2 production lines are operational** since mid-2023
- **presence of GSI and CEA for critical production, testing, FAT process**
- additional platform will be available in Feb. 2024 for **2 dipole magnets at benches**

Magnet production and testing status

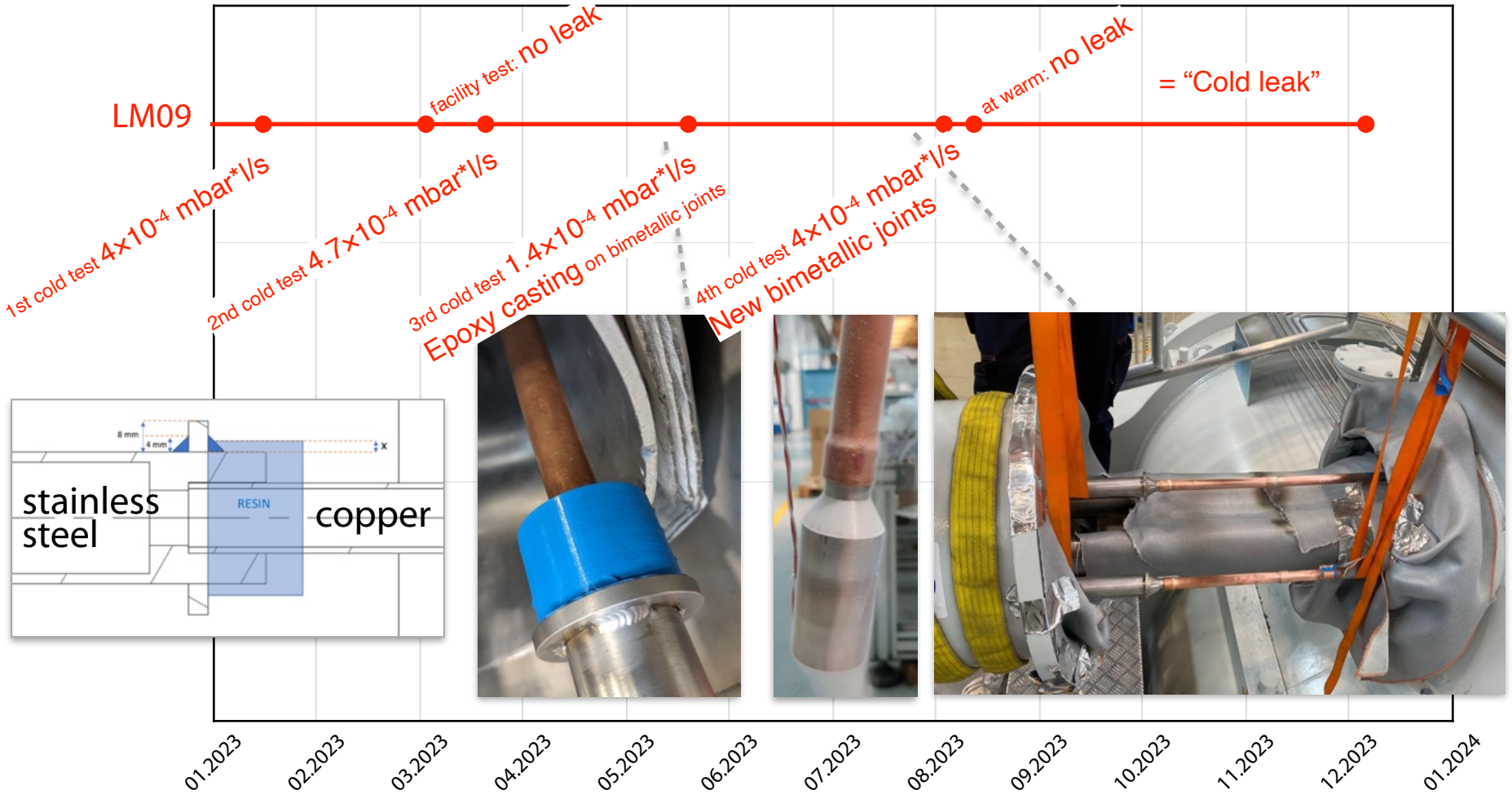
- multiplets



- **Testing is "series" mode:** SM06, SM03 / SM05, SM04 (several cold down to prove no leak)
  - **Delay is due to non-conformity of the multiplets** (**NOT** due to test activity/facility)
- **LM09, LM11, SM02: leak from the thermal shield, no leak detected at warm FAT**

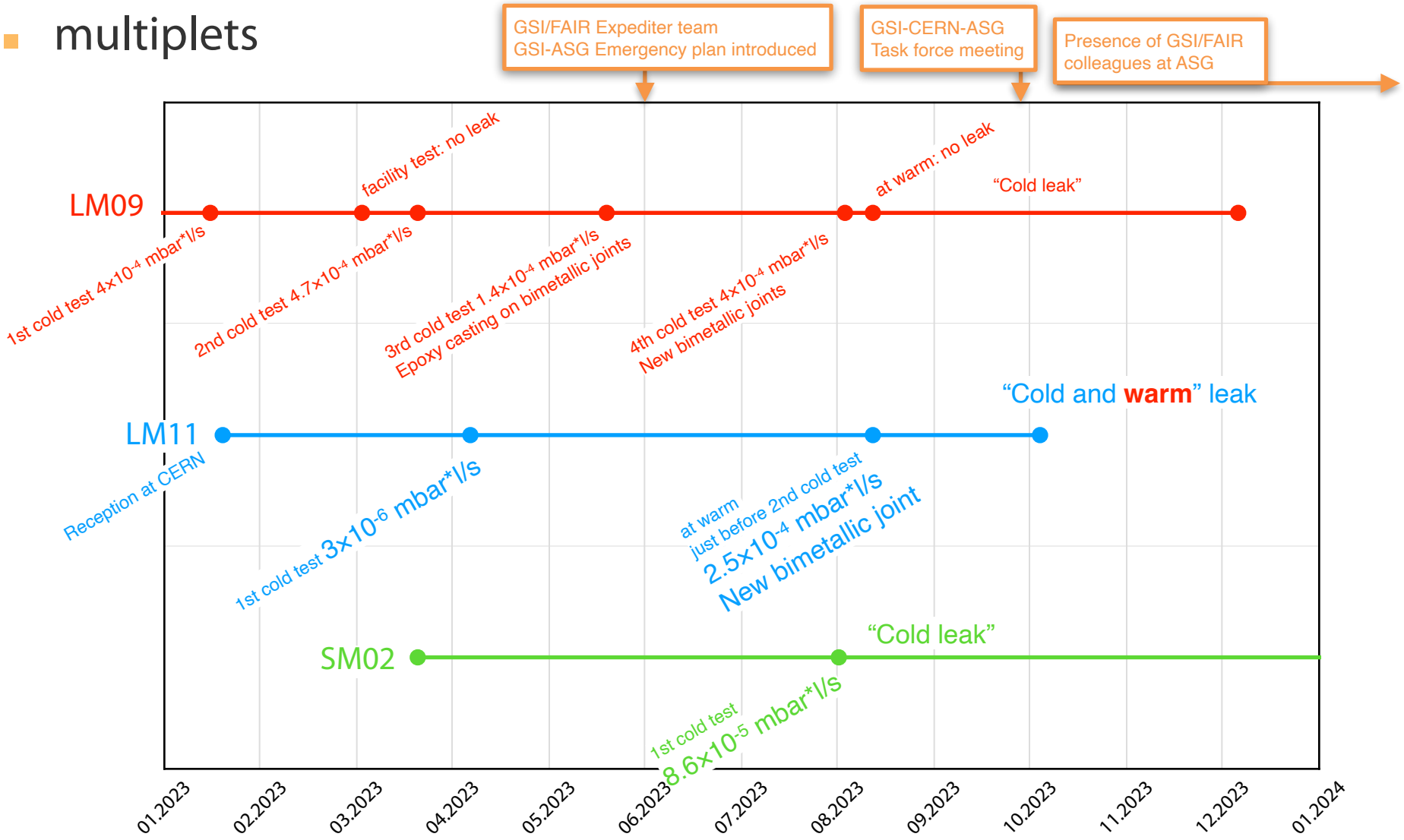
Magnet production and testing status

- multiplets LM09



Magnet production and testing status

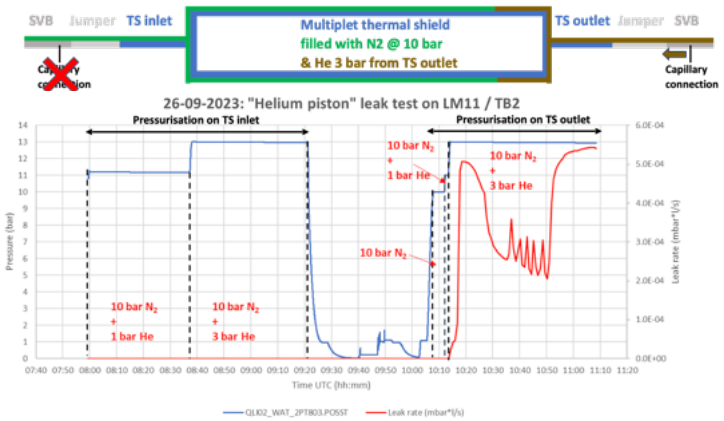
- multiplets



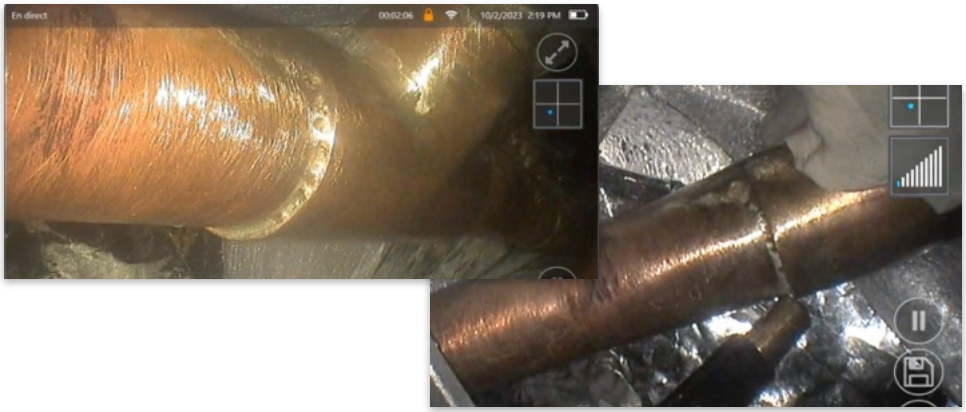
Magnet production and testing status

- multiplets LM11

Investigation at CERN by GSI/CERN

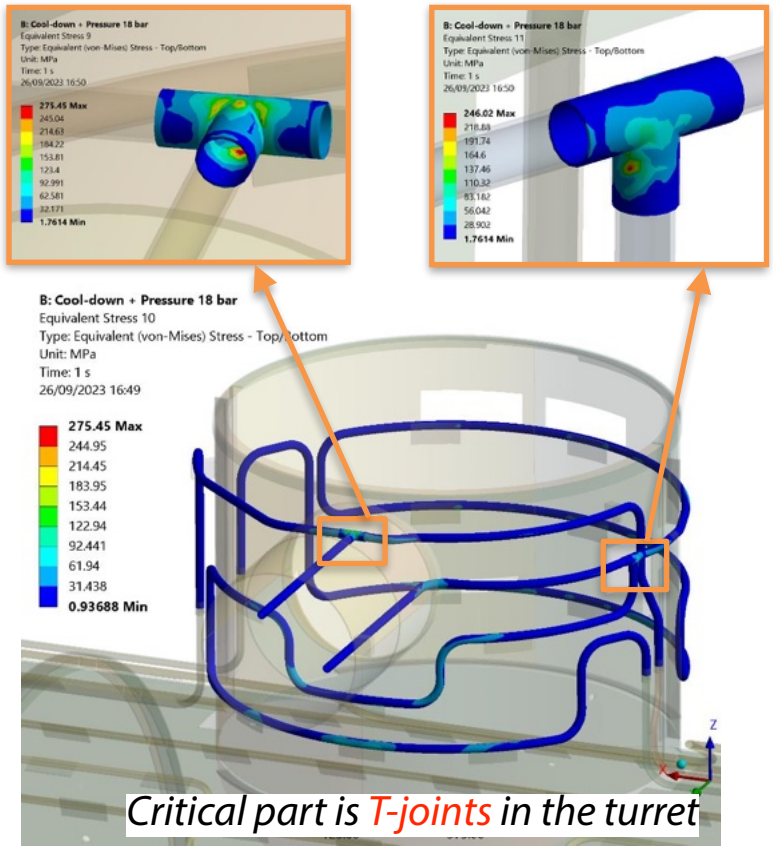


Helium piston indicated the leak at outlet side



Endoscope and sniffer identified leak at T-joint outlet side

FEM simulation by ASG



Critical part is T-joints in the turret

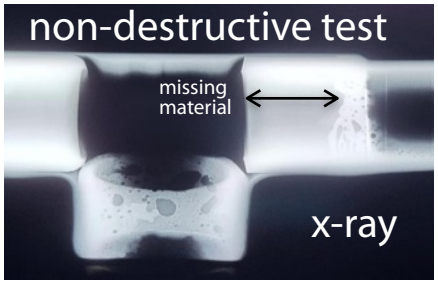
LM11 was sent back to ASG for further investigation and reparation

Magnet production and testing status

- multiplets LM11

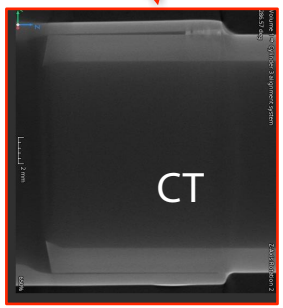
Investigation by GSI-CERN-ASG

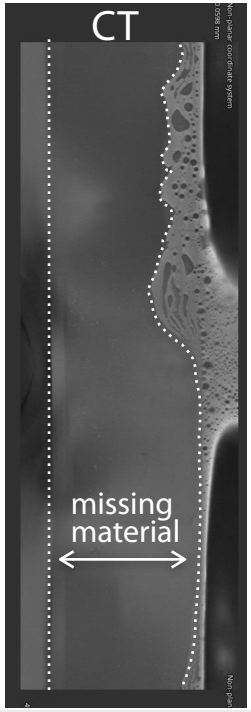
x-ray inspection
- validated for brazing qualification
- all joints from now on will be x-ray tested
- acceptance decided with agreed criteria
- to be introduced to the dipole magnet as well (under discussion)

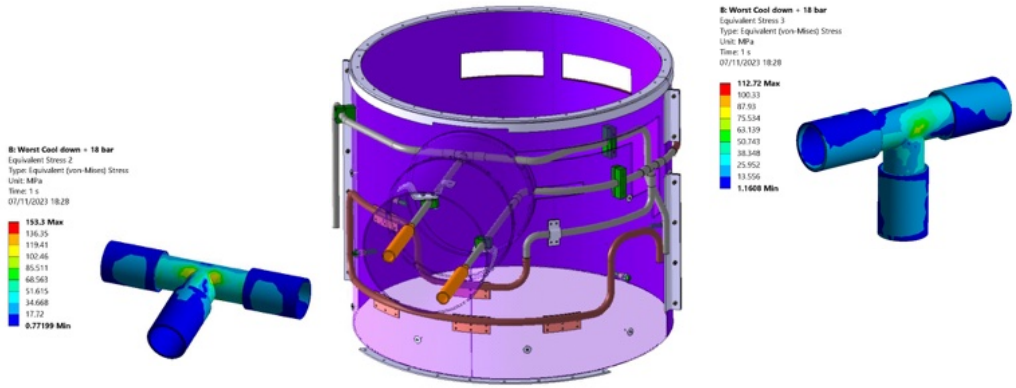


Root cause:
Bad brazing quality of T joint, possible damage associated with the high stress.

Proposed solution (under discussion):
Replacement with stainless steel pipes and welding to reduce number of brazing/ additional mechanical supports







- reparation at ASG **with presence of GSI at workshop**
- after reparation and successful FAT, **LM11 will be delivered to CERN in Feb. 2024 for re-SAT.**
- root cause investigation and reparation on LM09 and SM02 must be done (only "cold leak")
- discussion on the other manufactured multiplets is ongoing

Magnet production and testing status

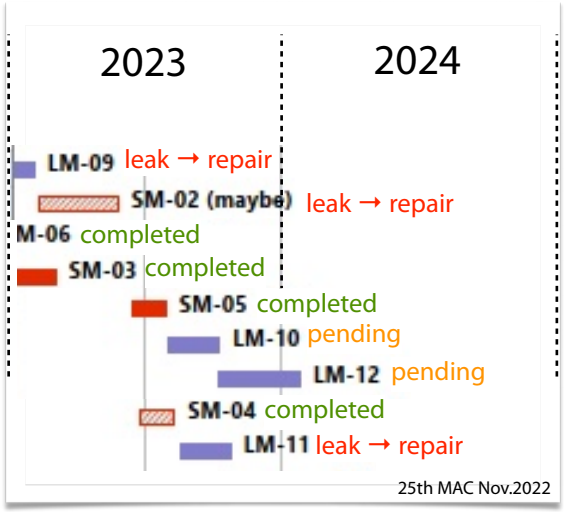
- multiplets

going well
critical
on-hold

	multiplets (ES relevant)		
	name	status	next step
1	LM11	cold and warm leak / repair at ASG	re-test at CERN
2	LM09	cold leak	repair
3	LM10	FAT approved (test pending)	repair or CERN
4	SM06	pre-assembly completed	repair
5	FoS SM	pre-assembly completed (leak accepted)	installation
6	SM03	pre-assembly ongoing	installation
7	SM01	pre-assembly completed	installation
8	SM04	cold test at CERN (no leak)	repair or GSI
9	SM05	cold test at CERN (no leak)	repair or GSI
10	SM08	pre-assembly completed	installation
11	LM14	FAT approved (test pending)	repair or CERN
12	LM18	assembly suspended	x-ray inspec.
13	LM20	FAT approved (test pending)	repair or CERN
14	LM21	magnet production ongoing	
15	LM22	magnet production ongoing	
16	LM23	magnet set completed	module assembly
17	LM25	magnet production ongoing	
18	FoS LM	pre-assembly completed (to be swapped to LM12)	installation
19	LM15	FAT approved (conditional)	repair or CERN
20	LM29	FAT approved (test pending)	repair or CERN
	LM12	magnet production ongoing	
	LM13	magnet production ongoing	

high radiation area

multiplets (not ES relevant)		
name	status	next step
SM02	spare / cold leak	repair
LM16	FAT 90%	FAT completion
LM17	FAT submitted (approval pending)	FAT approval
LM19	magnet set completed	module assembly
LM27	magnet set completed	module assembly



Magnet production and testing status

- multiplets

Conformities

- SAT results

	condition	subject	FoS D2	FoS SM	FoS LM	SM08	SM01	LM09	SM06	SM03
SAT Aa	on lorry	incoming goods inspection								
	warm	accelerometer								
		visual check								
		continuity test								
		sensor alive test								
		LV test								
		HV test								
		continuity test								
		sensor alive test								
		LV test								
SAT Ab	warm	continuity test								
		sensor alive test								
	warm vacuum	external vacuum leak test								
		internal helim leak test								
		external helium leak test								
	cool down	cool down duration to 80 K								
	at 4 K	static heat load to 80 K								
		static heat load to 4 K								
		HV test								
		sensor alive test								
	powering	dynamic heat load								
		powering test								
		magnetic field measurement*								
		magnetic axis measurement								
	warm vacuum	continuity test								
		sensor alive test								
	warm	HV test								
		continuity test								
		sensor alive test								
	others	fiducialization								
		accelerometer								
		Acceptance							to be repaired	

ok
partially ok
not ok

accepted
conditionally accepted
rejected

electrical test failures / leak from connectors mostly solved by interventions by the manufacturers

criteria of the magnetic property is set to most demanding magnets, but which is actually depends on the location along S-FRS.
for every magnet, beam optics evaluation is being executed.

clarification of the criteria ✔
- clear evaluation of FAT at the manufacturers

on big issues
- emergency plan, task forces ✔

regular meeting on QA ✔
- follow up of non-conformities, to track and monitor the quality in general

minor issues / non-conformities
- intervention: time consuming at CERN/GSI
- tighter quality control at the manufacturers is being introduced.
- presence of GSI at workshop

*as set of the magnets
**evaluation on FoSD3, LM11, SM02 (to be prepared) and SM05, SM04 are ongoing.

Schedule

- testing planning: critical (incl. re-test of the repaired magnets)
  - with number of assumptions on the productions
  - must be optimised and adapted to the reality with flexibilities
  - intensive "repaired" and "improved" magnet testing in 2024

2023

	10-2023				11-2023				12-2023			
reception												
test bench	SM05	SM05	SM05	SM05	SM05	SM05	SM05	SM05	SM05	SM05	SM05	SM05
			SM04	SM04	SM04	SM04	SM04	SM04	SM04	SM04	SM04	SM04
shipping	LM09	LM09	LM09	LM09	LM09	LM09	LM09	LM09	LM09			
	SM02	SM02	SM02	SM02	SM02	SM02	SM02	SM02	SM02	SM02	SM02	SM02
	LM11	LM11										

tentative schedule, to be confirmed

2024

	01-2024				02-2024				03-2024				04-2024				05-2024				06-2024			
reception					SCD_06	SCD_06							LM09(Re)	LM09(Re)	LM09(Re)		SM06(Re)	SM06(Re)	SM06(Re)	SM06(Re)	SM06(Re)	SM06(Re)		
						LM11(Re)	LM11(Re)								LM10	LM10					SM02(Re)	SM02(Re)	SM02(Re)	SM02(Re)
									SCD_05	SCD_05														
test bench	SM05	SM05	SM05	SM05							SCD_05	SCD_05	SCD_05	SCD_05	SCD_05	LM09(Re)	LM09(Re)	LM09(Re)	LM09(Re)	LM09(Re)	LM09(Re)	LM09(Re)	LM09(Re)	LM09(Re)
							SCD_06	SCD_06	SCD_06	SCD_06	SCD_06	SCD_06	SCD_06	SCD_06	SCD_06	SCD_06	SCD_06	SCD_06	SCD_06	SCD_06	SCD_06		SM06(Re)	SM06(Re)
	SM04	SM04	SM04	SM04	SM04	SM04		LM11(Re)	LM11(Re)	LM11(Re)	LM11(Re)	LM11(Re)	LM11(Re)	LM11(Re)	LM11(Re)	LM11(Re)	LM10	LM10	LM10	LM10	LM10	LM10	LM10	LM10
shipping					SM05	SM05	SM05										LM11(Re)	LM11(Re)				SCD_06	SCD_06	SCD_06
	SM02	SM02	SM02													SCD_05	SCD_05	SCD_05	SCD_05					
							SM04	SM04	SM04															

Summary

- **dipole magnets**
  - new brazing technology is being implemented. **(technical /schedule risk)**
  - all defects on all magnets must be cured. **(technical risk)**
- **multiplets**
  - GSI approved reparation and quality control strategy must be implemented. **(technical / schedule risk)**
- **testing**
  - the magnet modules must be passed **FAT with presence of GSI**.
  - the magnet modules **quality must be verified by GSI** at SAT@CERN.
  - **GSI resource at CERN** must be refilled very urgently **(schedule risk)**
  - how to speed-up testing, compress test duration (under discussion)
- **overall project schedule**
  - **must be re-established** as soon as reliable production plans are available.

Many thanks to GSI/FAIR colleagues, CEA and CERN experts as well as the colleagues from the manufacturers.