A detailed 3D wireframe model of the Super-FRS magnet structure. The model shows a large, oval-shaped ring of magnets in the foreground, with a more complex, multi-loop structure in the background. The entire structure is rendered in a black wireframe style, showing the intricate geometry of the particle accelerator components.

# **Super-FRS magnet testing at CERN: update of the status and resources situation**

Haik Simon  
CERN, November 25<sup>th</sup>, 2021

# Current collaboration contracts



## CERN-GSI/FAIR collaborations: superconducting magnets

all collaborations in the framework of the 2010 agreement K1727/DG

TITLE/SCOPE	Machine	Status	Addendum	Date
<b>Cryogenic testing of the superconducting magnets for the Super-FRS</b>	Super-FRS	active	#2	2012
			#4	2014
			#5	2016
			#12, KR3912	2018

31/10/2023

- Append Agreement to Amendment to #12 on Multi Risk Insurance (12/2021)
  - Last exchange insurance agents 20211109
- ➔ CERN to propose text.
- Alternative means of compensation payments for enhanced living cost to GSI team.

- 2.1 The Parties shall jointly identify collaborative research topics on accelerator-based technology and instrumentation for physics, life sciences and medical applications for execution under this Agreement. The scope of each collaborative research topic shall include the required resources, the contribution of each Party, the management of the joint organization, the joint organization of the personnel of one Party in the training programmes of the other Party. The collaboration may also include the provision of specific professional expertise against such financial conditions as the Parties may agree on a case-by-case basis.
- 2.2 An initial list of potential collaborative research topics is given in Annex 1 hereto.

Collaborative research topics !

# Super-FRS: testing of sc. magnets



K1727/DG (2010); Addendum #2 (2012), #4 (2014), #5 (2016) for infrastructure refurbishment + #12 (2018) for testing phase

## purpose

refurbishment and adaption of the cryogenic test facility at B180/CERN (add. #2, #4, #5).

testing of all superconducting magnets for the Super-FRS depicting the SAT for acceptance (add. #12).



## contribution

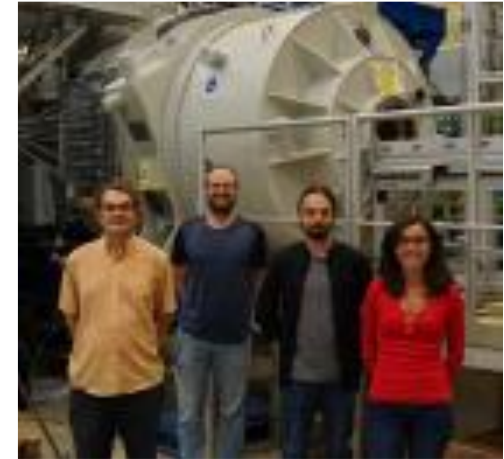
Add.	GSI		CERN	
#2	• 5.000.000 €	✓	• Refurbishment of test facility B180	✓
#4	• 1.860.000 CHF	✓	• Procurement of pre-cooler, QD-system, survey tooling	✓
#5	• 210.000 CHF	✓	• Integration work, modification of cryo lines • Implementation of preparation test bench and control room	✓
#12	<ul style="list-style-type: none"> <li>• Testing of the magnets</li> <li>• <b>4 (/5) FTEs</b></li> <li>• <b>Further personnel if required</b></li> <li>• <b>Experts of survey at pre-series testing</b></li> <li>• Cost-recovery for operational services</li> </ul>	ongoing ✓ tbd ongoing ongoing	<ul style="list-style-type: none"> <li>• <b>1 FTE: test engineer to oversee functioning of test facility</b></li> <li>• <b>0.4 FTE: support of equipment groups on best-effort basis</b></li> <li>• Energy costs (no cryogenics)</li> <li>• Office space and infrastructure</li> </ul>	Ongoing (2022) tbd ongoing ✓

facility will be made available for similar testing after Super-FRS activities

# Resources

## GSI

- Replacement of the 4<sup>th</sup> member in March 2021 (hiring process completed in 4.5 months)
- temporary secondment from GSI of a 5<sup>th</sup> member from February 2021 to August 2021. Definitive secondment starting from 2022; in preparation
- travel arrangement for seconded members ends after 4y



## CERN

Test facility coordinator selected; starting from January 2022

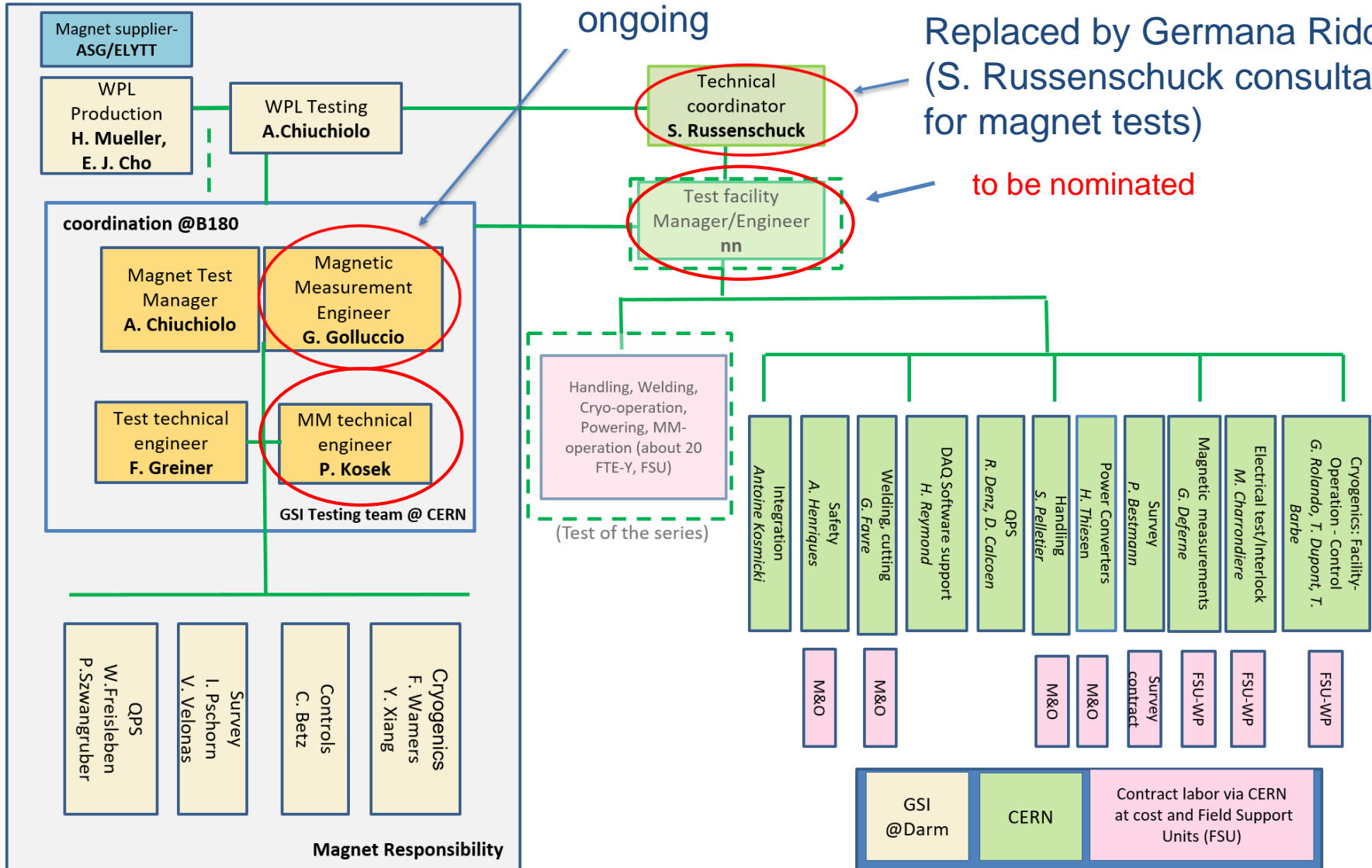
# Team@CERN (2020)



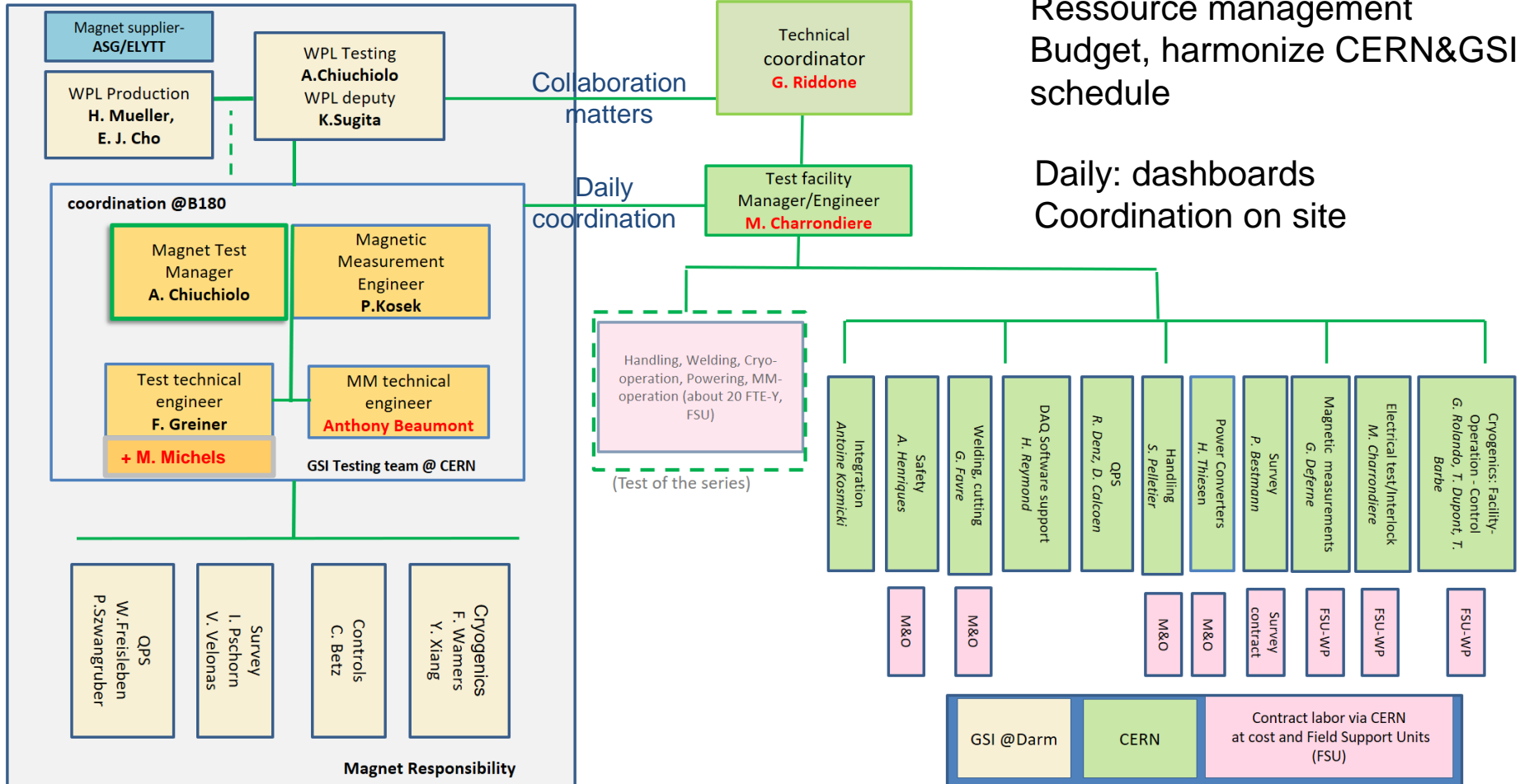
Restaffing G.G. ongoing

Replaced by Germana Riddone (S. Russenschuck consultant for magnet tests)

to be nominated



# Team@CERN (2022)





# Roles and responsibilities

## **GSI** executes the **testing**

- deploys 4/5 FTEs to work on site
- further personnel if necessary
- defines tests plan and procedures
- gives support for operation, upgrade and maintenance of the interfaces
- pays operation costs

## **CERN** prepares and maintains the **facility** available

- guarantees the functionality of the facility
- contributes 1 FTE (test facility coordinator) + 0.4 FTEs
- Coordinates Field Support Units (FSU paid by GSI)
- supports GSI activities and training
- offers standard offices and IT network
- covers energy cost

# Status of testing

## First of Series Magnets



Arrived on 20.02.2019  
 Tested in 2019-2020  
 on TB1 and TB2

Arrived on 24.11.2020  
 Tested from Q2 2020  
 Actual: warm up

Arrived on 07.02.2021  
 Leakage issue → Elytt  
 → 2<sup>nd</sup> FoS dipole in

Next SM expected next week. 2<sup>nd</sup> thermal cycle -03/2022

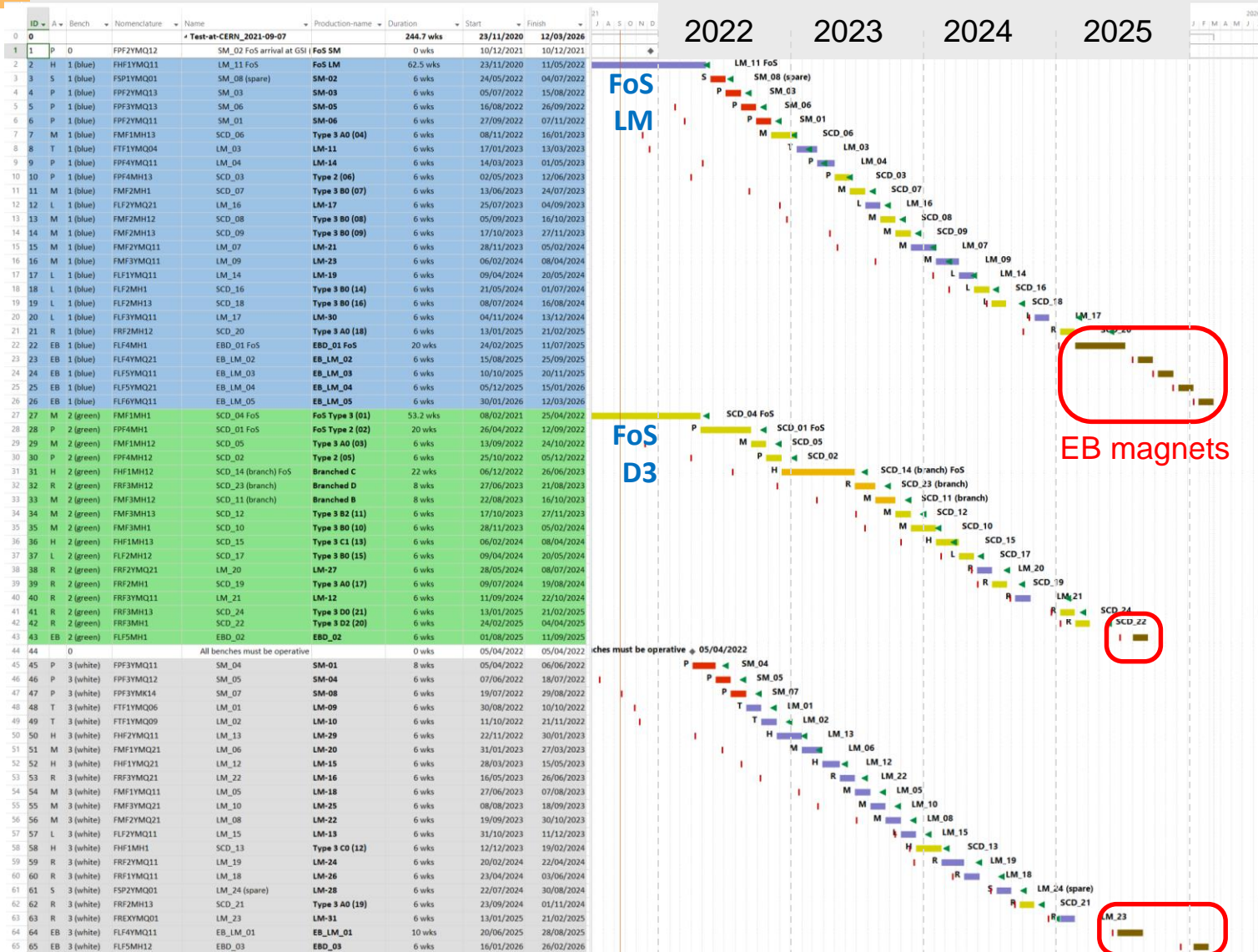
2022





# Testing project plan overview

3 benches:  
(blue, green, white)  
6 weeks testing  
during series



Buffer of already produced magnets is anticipated for whole testing period !

| FAT dates  
◀ baseline dates  
of SAT

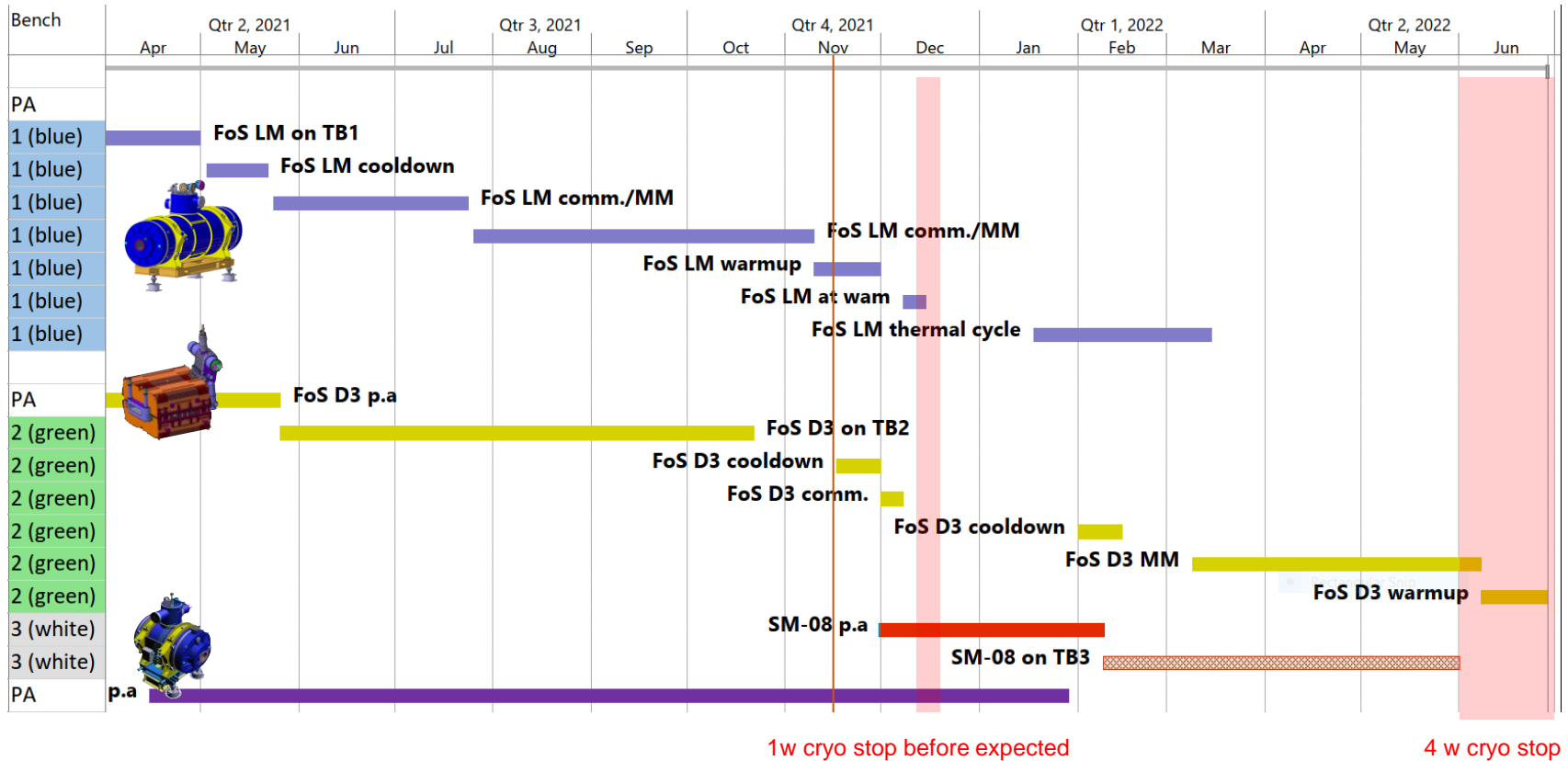
# Multiplet production status

- Production of series short multiplet (SM) is in progress
  - FAT was completed for SM01, 02, 03, 04 (followed by GSI remotely)
  - FAT for SM 08 in October (followed by GSI colleagues on site)
  - FAT for the last two series SMs → March and April in 2022.
- Production of series long multiplet (LM)
  - FAT for two long multiplets → October ~ January 2022.
  - FAT for about 7 multiplets per year from 2022 to 2024.



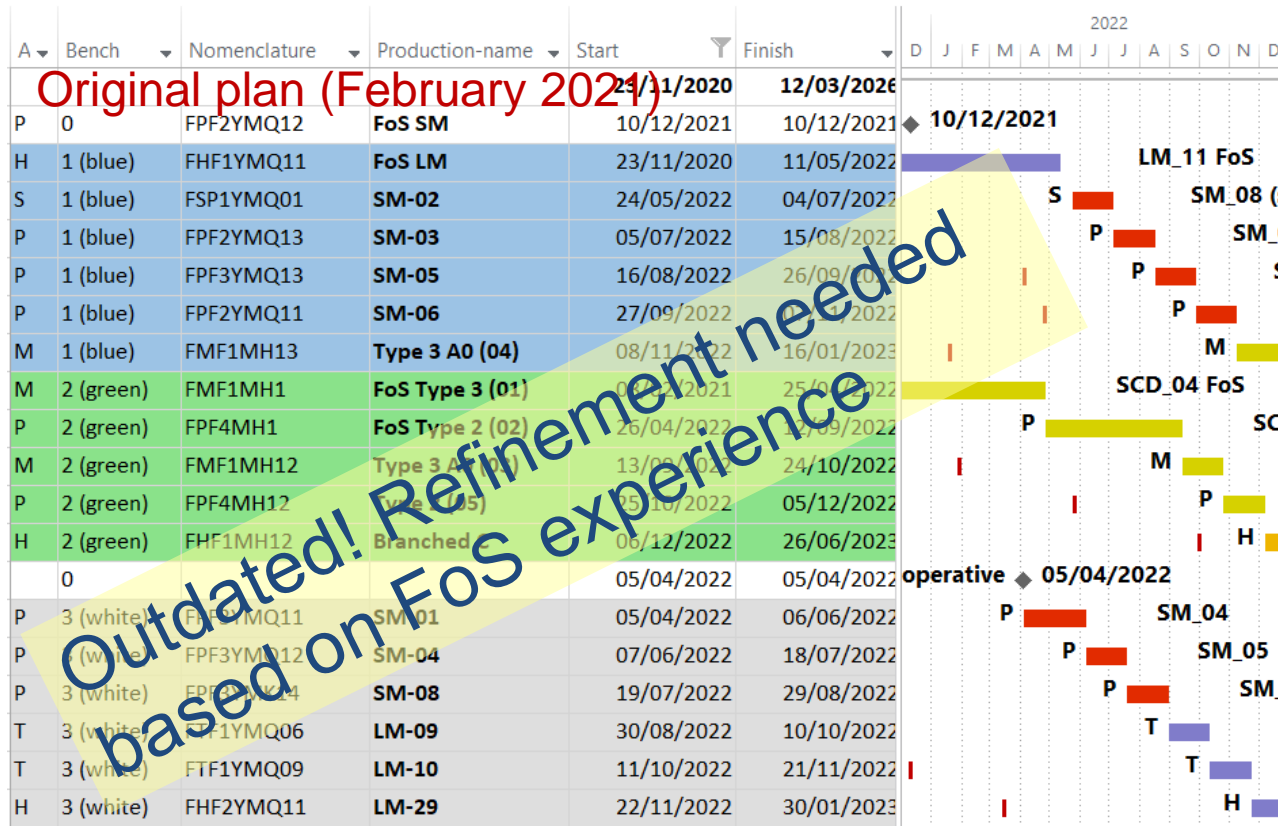
# Timeline November '21 – June '22

## 1<sup>st</sup> reschedule due to nc. FoS Dipole



Antonella Chiuchiolo / Super-FRS magnets testing: test plan 2021

# Test plan in 2022



## New:

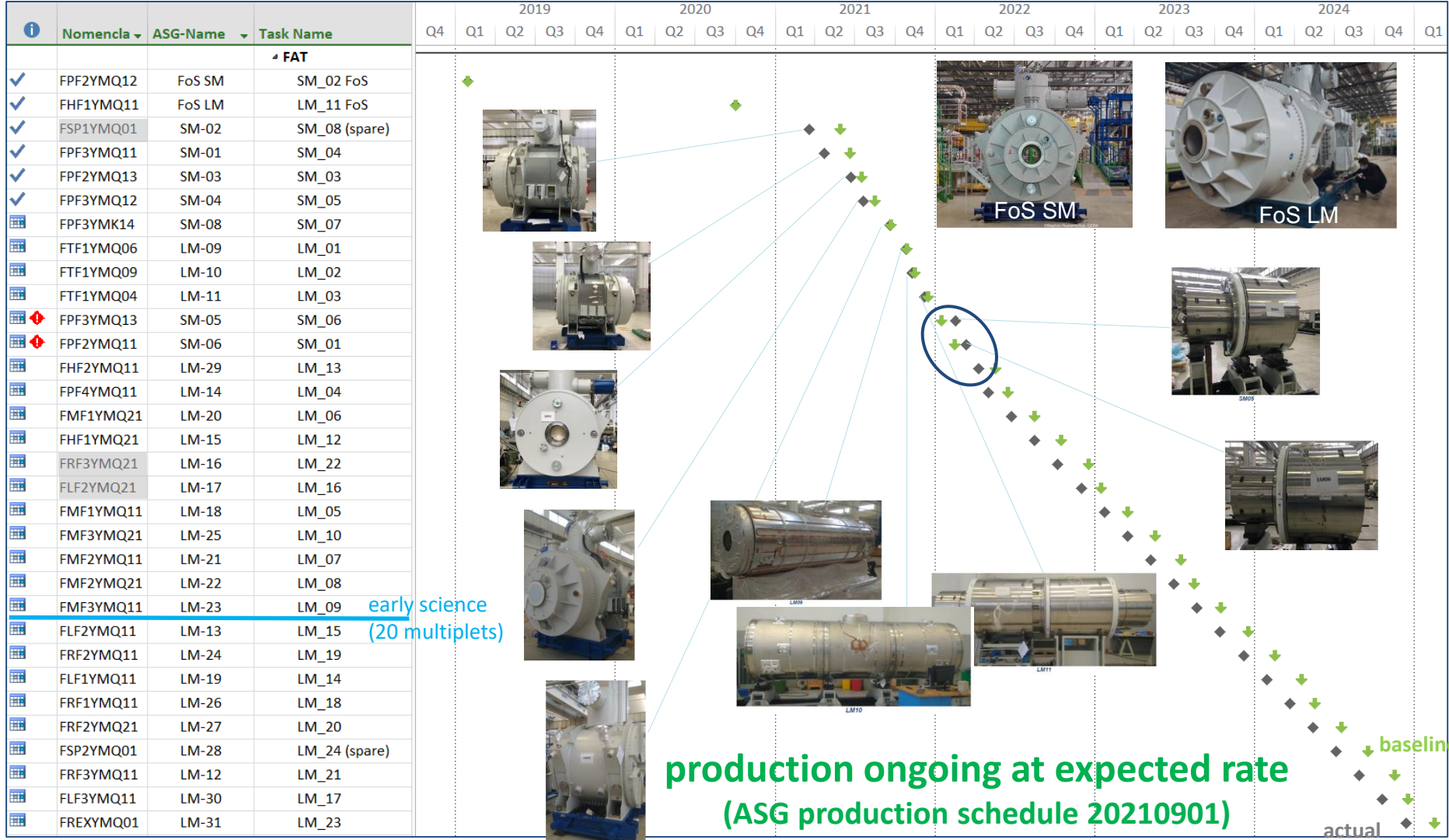
FoS LM test finishes 2 months **earlier**

FoS Dipole Type 3: test stopped. (shield leak)  
FoS Dipole Type 2: test will be anticipated

SM series multiplets: test starts 4 months **earlier**, includes bench 3 commissioning.

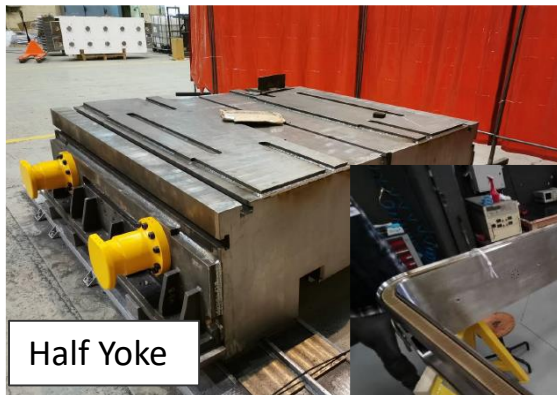
- Schedule flexibility thanks to possible alternating test benches and magnet production ahead testing
- 2022: Ramp up of necessary staff should be foreseen; include necessary training/hand over period

# sc multiplets schedule



# Dipole production status

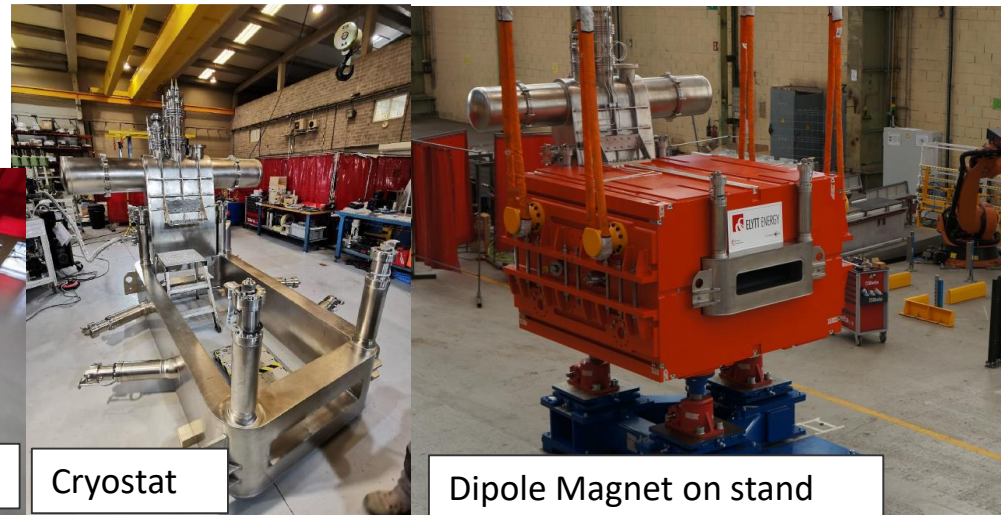
- Two production sites have been set up:
  - Artea: Coil and Cryostat production
  - Llodio: Yokes and Integration (+intermediate storage)
- Production of series dipole is in progress.
  - FAT was completed for FOS type 2, stored in Elytt.
  - FAT for 8 Dipoles (3 branch type) foreseen from Nov. 2021 to Nov. 2022.



Half Yoke



Coil inside the coil casing



Cryostat



Dipole Magnet on stand

# Test schedule

- Experience based on FoS testing:
  - For SM short cooldown time was achieved (7d vs. 14d)
  - For LM cool down time slightly longer (16d vs. 14d)
  - For SM warmup time (8d vs. 14d)
  - For LM warmup time (prediction ~ 14d )

With SM-01 to SM-04, and SM-08 as well as 3 long multiplets already produced by the end of 2021, there seems to be a backlog developing for the testing. Evaluate if the testing procedures could be streamlined in view of a possible backlog in magnet testing developing in 2022.

**Backlog required to cope with longer production times**

Recommendations: MAC24

(R6) Review the voltage withstand and testing levels, based on norms and learnt practices, for all accelerator components.

(R7) Explore further possible streamlining of the magnetic measurement needs from the beam physics point of view. Present at the next MAC.

## Test schedule

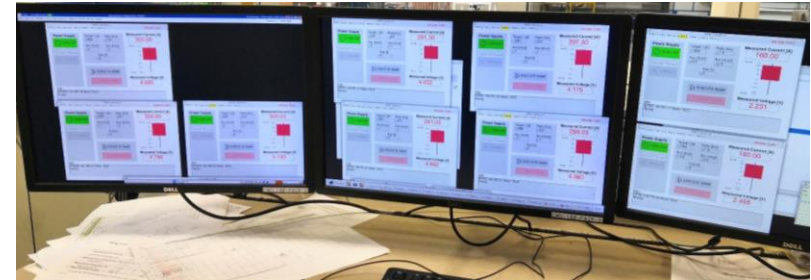
- Non Conformities are addressed at producer
  - 2<sup>nd</sup> Dipole is free of dirt in pipes
  - Piping issues (causing leak) in ASG multiplets appears solved
  - Assembly faults (octupole coils turned by 45°) are addressed
  
- ➔ Uncertainty in parallel Operation of several magnets on all benches!
  - Mass flow that can nominally be achieved is ~20% below spec. (50g/s)
  - Achieved currently is 26g/s, but still many unknowns. (max  $\Delta T$  coil vs. plant, blocking issue at thermal shield)
  
- Commissioning (Q1/2022) and parallel testing (03/2022 D3↓+LM↑) is key to understand achievable mass flow.
  - Stable test at cold with warm up/cool down also



# Achievements: FoS LM

## 1. Powering

- ✓ 9 magnets parallel operation validated for PC, QDS and power application
- ✓ All magnets powered with nominal ramp rate to nominal current
  - ✓ Only the octupoles magnets powered first at intermediate ramp rate before nominal
  - ✓ 7 magnets over 9 powered with discordant current: octupole magnets operated only with positive current



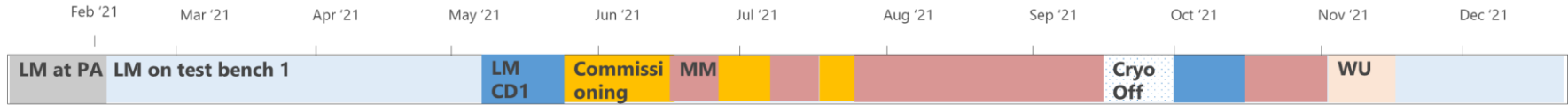
## 2. Cryogenic tests

- Static and dynamic (during magnet powering) heat load measurements. Analysis on going

## 3. Dynamic warmup started work in progress



# Achievements FoS LM

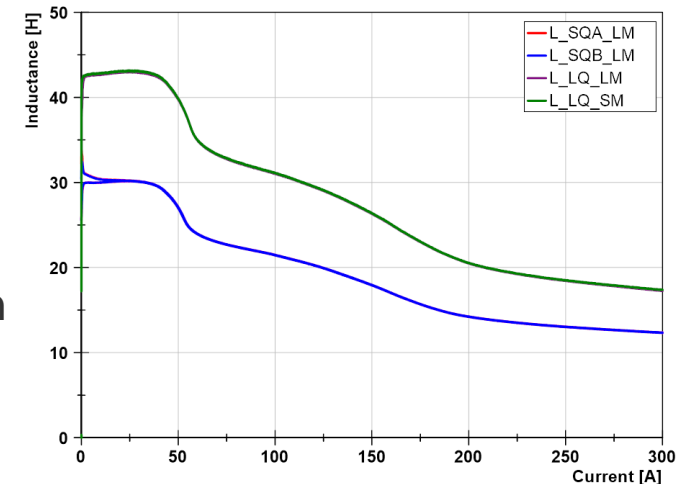


◆  
Dipole Arrival  
7/02/21

◆  
LM cooldown 1  
to 4.5 K

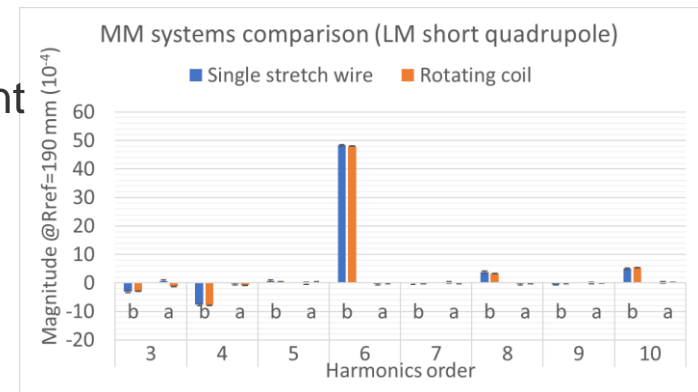
## ■ Powering commissioning:

- 9 magnets tested individually and in cross talk configuration up to ultimate current levels
- Test bench 1 fully commissioned in 22 days (9 power circuits, quench protection, interlock)
- Inductance agreement of Long Quadrupoles in SM and LM
- Inductance agreement of 2 Short quadrupoles in LM



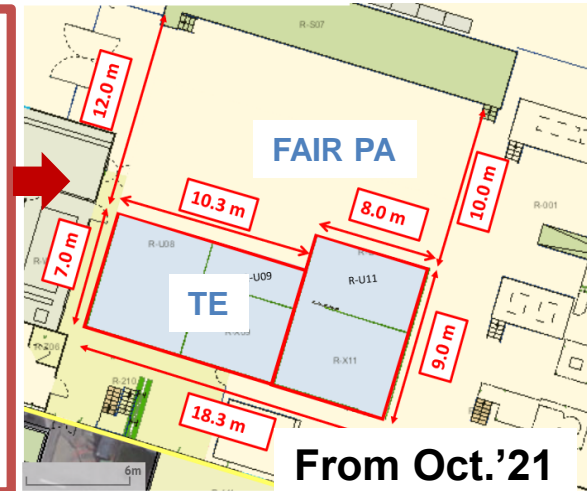
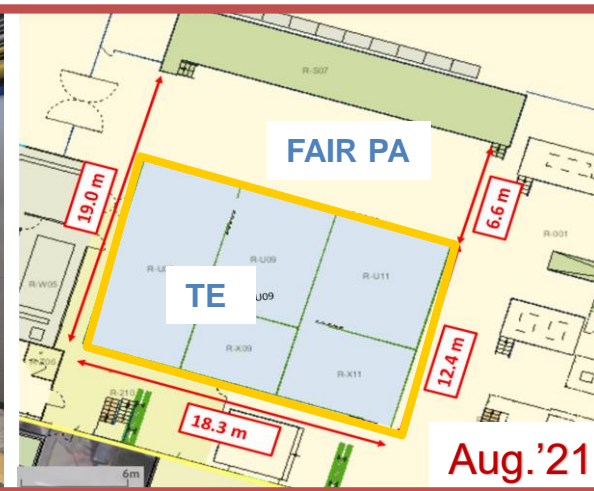
## ■ Magnetic measurements:

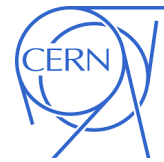
- Challenging especially for cross talk, alignment among 9 magnets and survey
- Test procedure improvement and optimization (11 weeks total measurements for 9 magnets vs. 6 weeks for 2 magnets in the SM)
- Validation of measurements system for series tests



# Logistics at CERN

- Preparation Area increased
  - Unloading and loading on the tracks (reception and departure)
  - Preparation for integration in the test benches (heavy handling operation, electrical tests)
  - Preparation for packaging (heavy handling operation, electrical tests)





## Summary/Open issues

Very successful collaboration!

Many Milestones achieved –  
now at the transition from FoS to series testing

Collaboration:

- Rooms/integration with CERN collaborators

Contracts:

- Additional agreement to amendment #12
  - MRI separation from CERN insurance  
(from 12/21-01/22: div. handling)
  - Alternative Compensation options for enhanced living cost at CERN
  - Potential use of CERN budget code
- Prepare new Amendment from 31/10/2023 including EB

Organisation:

- Implement working scheme in series testing configuration of the org. chart.

