



SM18 Assembly and Testing Infrastructure

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International Review of the Crab Cavity system design and production
plan for the HL-LHC, CERN, 19-21 June 2019

Outline

- Overview of the cavity and cryomodule reception and testing at CERN and lessons learned from SPS-CCs test
- Detailed planning for the RFD-PROTO, DQW series in SM18
- Readiness of the testing infrastructure for vertical testing of cavities and bunker tests of cryomodules
- Preparations ongoing towards the series testing and main bottlenecks

Lessons learned from SPS-CCs test

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- Cold test preparation (~2 weeks):
 - Stiffening frame assembly → time consuming, freq. follow up necessary during whole process
- Cold test (~2 weeks):
 - Clear definition of responsibilities and roles
 - Planning and preparation of tooling/components/software in advance
 - Allocation of time for the eventual re-test
- String assembly in clean room (~2 months):
 - Components and tooling in advance
 - All parts can't be proceeded at the same place
 - Time for blank assembly
 - Allocation of the resources



Planning

RF Cold Test in 2019 - 2020

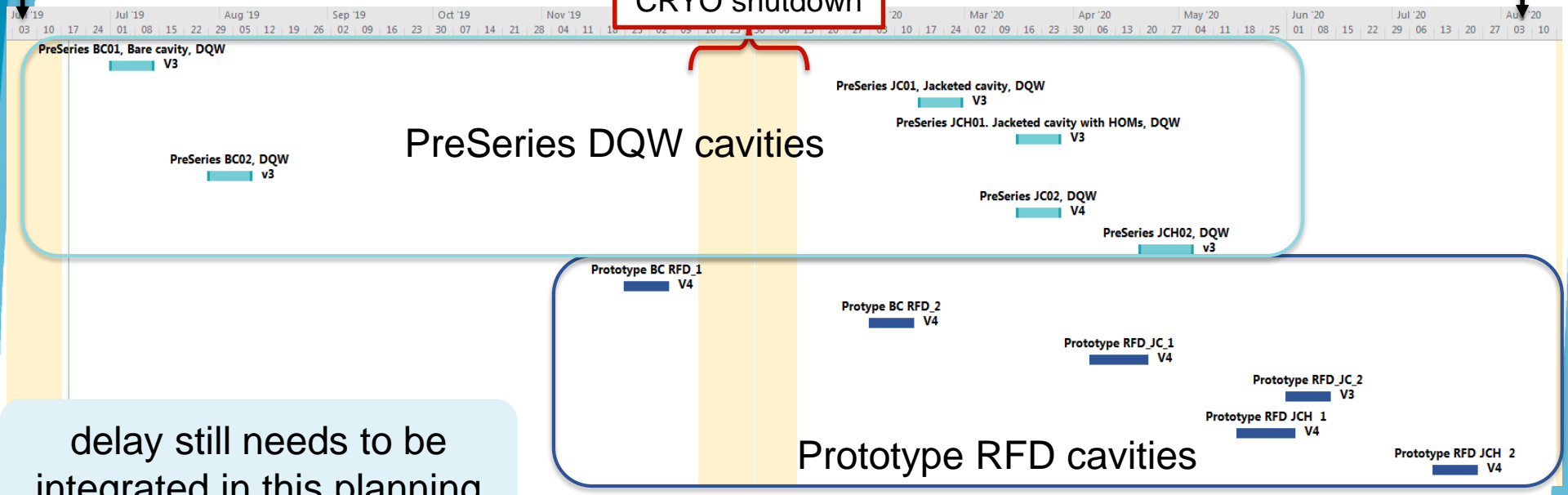
RF Cold test of DQW pre-series cavities: 2 cavities (BC, JC, JCH)

RF Cold test of RFD prototype cavities: 2 cavities (BC, JC, JCH)

Jun '19

Aug '20

CRYO shutdown



delay still needs to be integrated in this planning

Cavities: 2 weeks of CT (3,9)

2019											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						DQW_BC01	DQW_BC02			RFD_BC01	
2020											
	RFD_BC02 DQW_JC01	DQW_JC02 DQW_JCH01	RFD_JC01 DQW_JCH02	RFD_JCH01 RFD_JC02			RFD_JCH02				

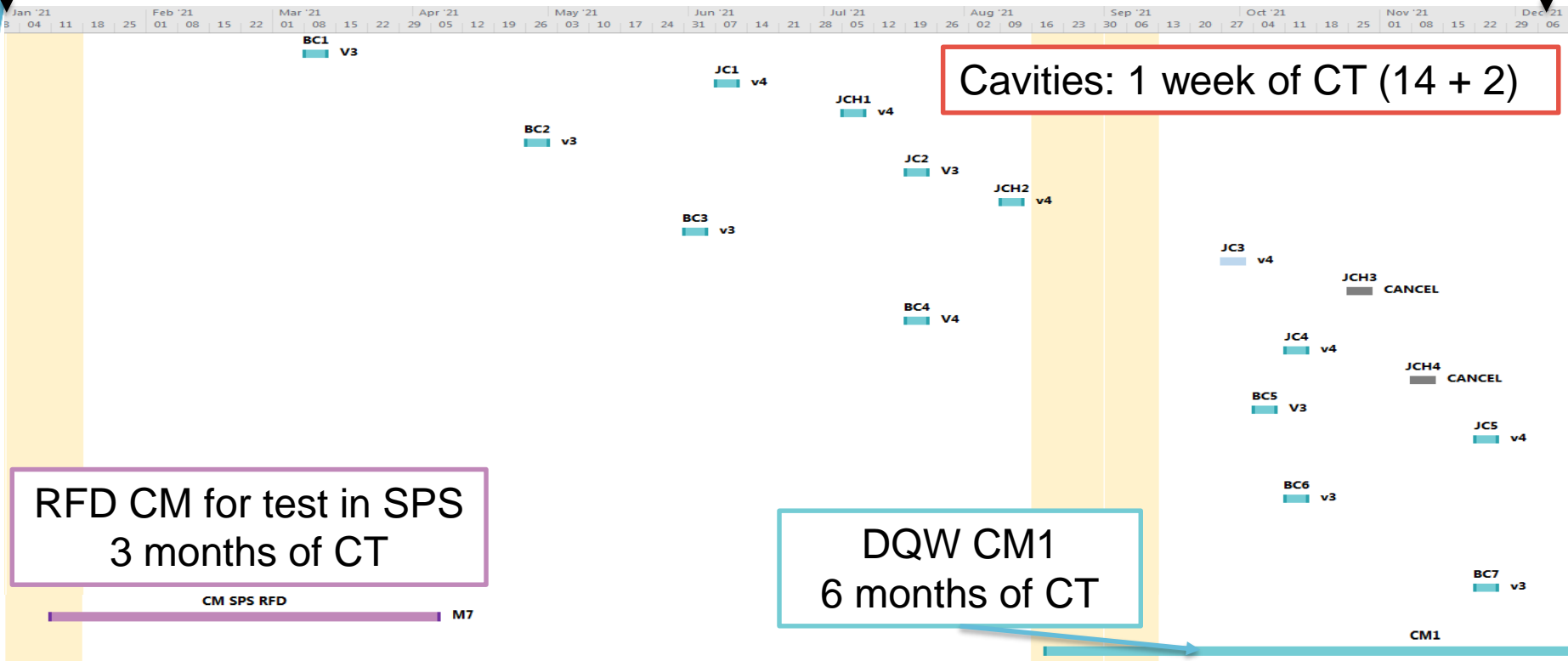
DQW CM1:
fabrication and string ass.
25.06.20 - 18.08.21

RF Cold Test in 2021

- RF Cold test of DQW series cavities: 9 cavities (BC, JC, JCH)
- RF Cold test of DQW CM
- RF Cold test of RFD CM for test in SPS

Jan '21

Dec '21



RFD CM for test in SPS
3 months of CT

DQW CM1
6 months of CT

2021											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CM_SPS_RFD	CM_SPS_RFD	CM_SPS_RFD DQW_BC01	DQW_BC02	DQW_BC03	DQW_JC01	DQW_JCH01 DQW_JC02 DQW_BC04	DQW_JCH02	CM_DQW01 DQW_JC03	CM_DQW01 DQW_BC05 DQW_JC04 DQW_BC06 DQW_JCH03	CM_DQW01 DQW_JC05 DQW_BC07 DQW_JCH04	CM_DQW01

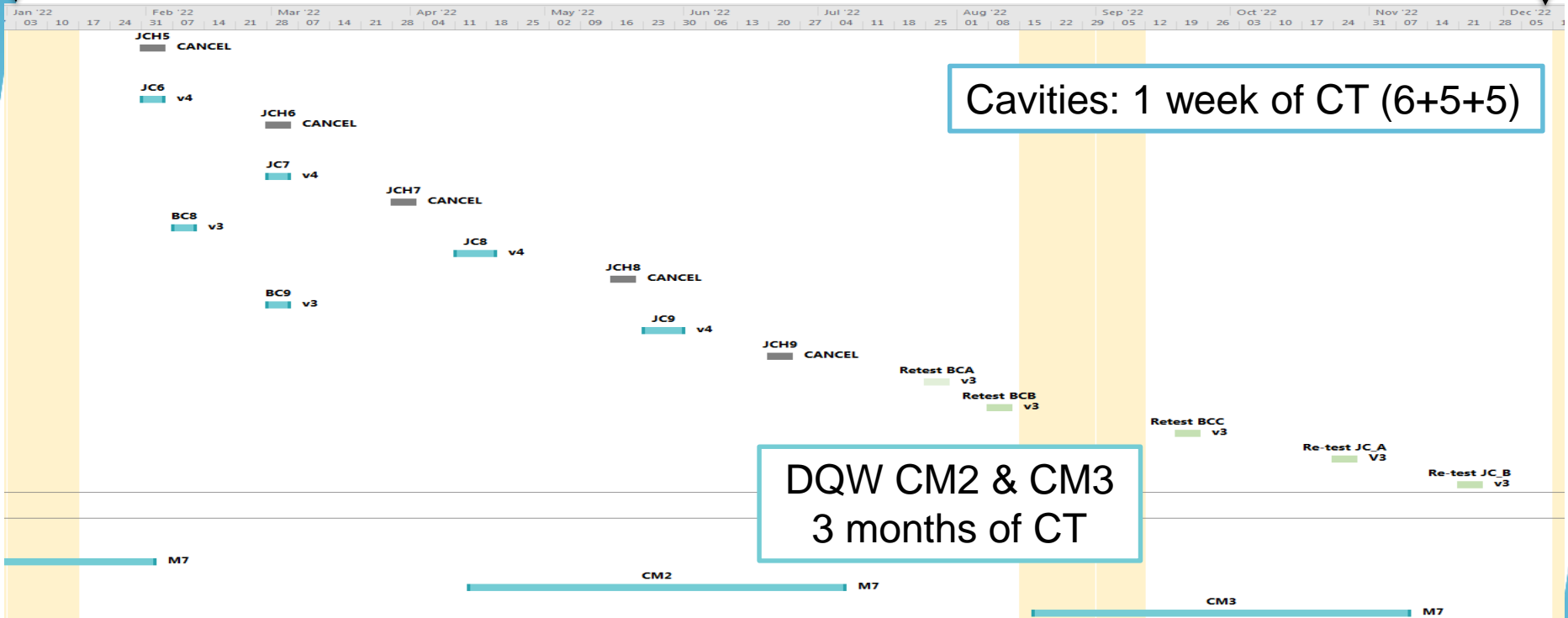


RF Cold Test in 2022

- █ RF Cold test of DQW series cavities: 9 cavities (BC, JC, JCH)
- █ RF Cold test of DQW CM

Jan '22

Dec '22



Cavities: 1 week of CT (6+5+5)

DQW CM2 & CM3
3 months of CT

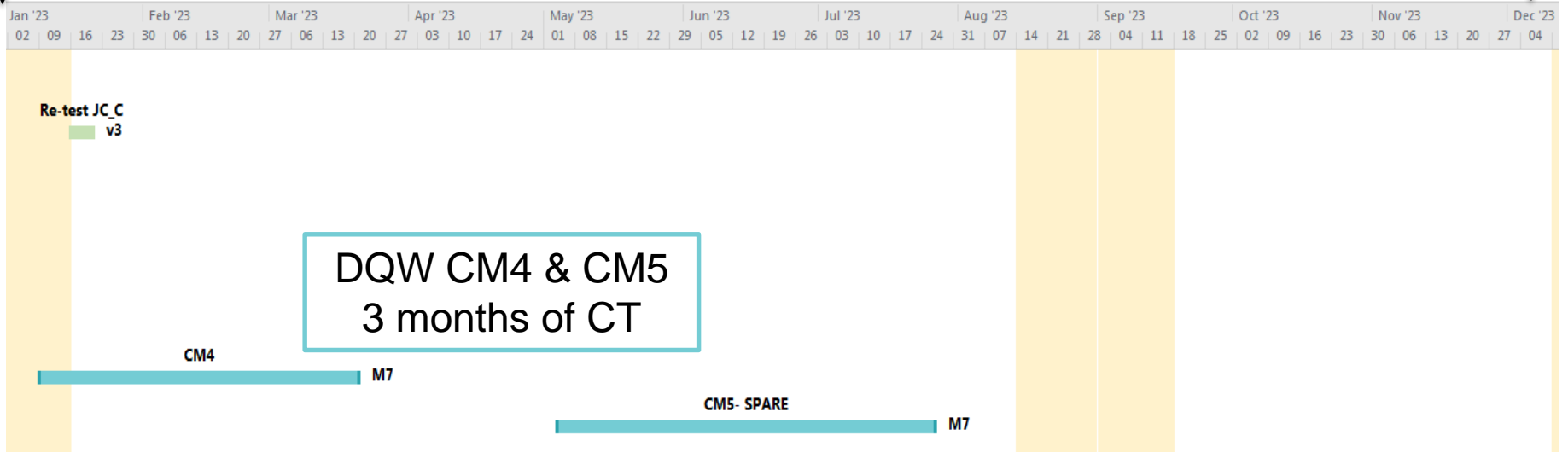
2022											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CM_DQW01 DQW_JC06 DQW_JCH05	DQW_BC08 DQW_BC09 DQW_JC07	DQW_JCH06 DQW_JCH07	DQW_JC08 CM_DQW02	CM_DQW02 DQW_JCH08 DQW_JC09	CM_DQW02 DQW_JCH09	CM_DQW02 RE-TEST	RE-TEST CM_DQW03	CM_DQW03 RE-TEST	CM_DQW03 RE-TEST	CM_DQW03 RE-TEST	

RF Cold Test in 2023

- RF Cold test of DQW CM
- RF Cold test of RFD CM

Jan '23

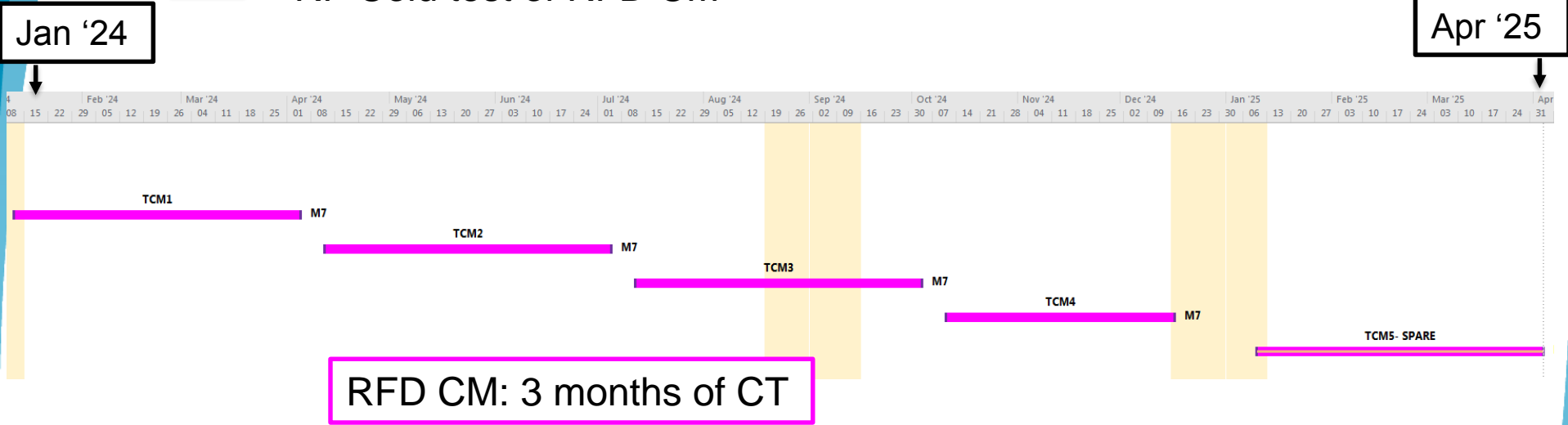
Dec '23



2023											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CM_DQW04 RE-TEST	CM_DQW04	CM_DQW04	CM_DQW05	CM_DQW05	CM_DQW05	CM_DQW05					

RF Cold Test in 2024 - 2025

- RF Cold test of DQW CM
- RF Cold test of RFD CM



2024											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CM_RFD01	CM_RFD01	CM_RFD01	CM_RFD02	CM_RFD02	CM_RFD02	CM_RFD03	CM_RFD03	CM_RFD03	CM_RFD04	CM_RFD04	CM_RFD04
2025											
CM_RFD05	CM_RFD05	CM_RFD05	CM_RFD05								

Planning - conclusion

CAVITIES

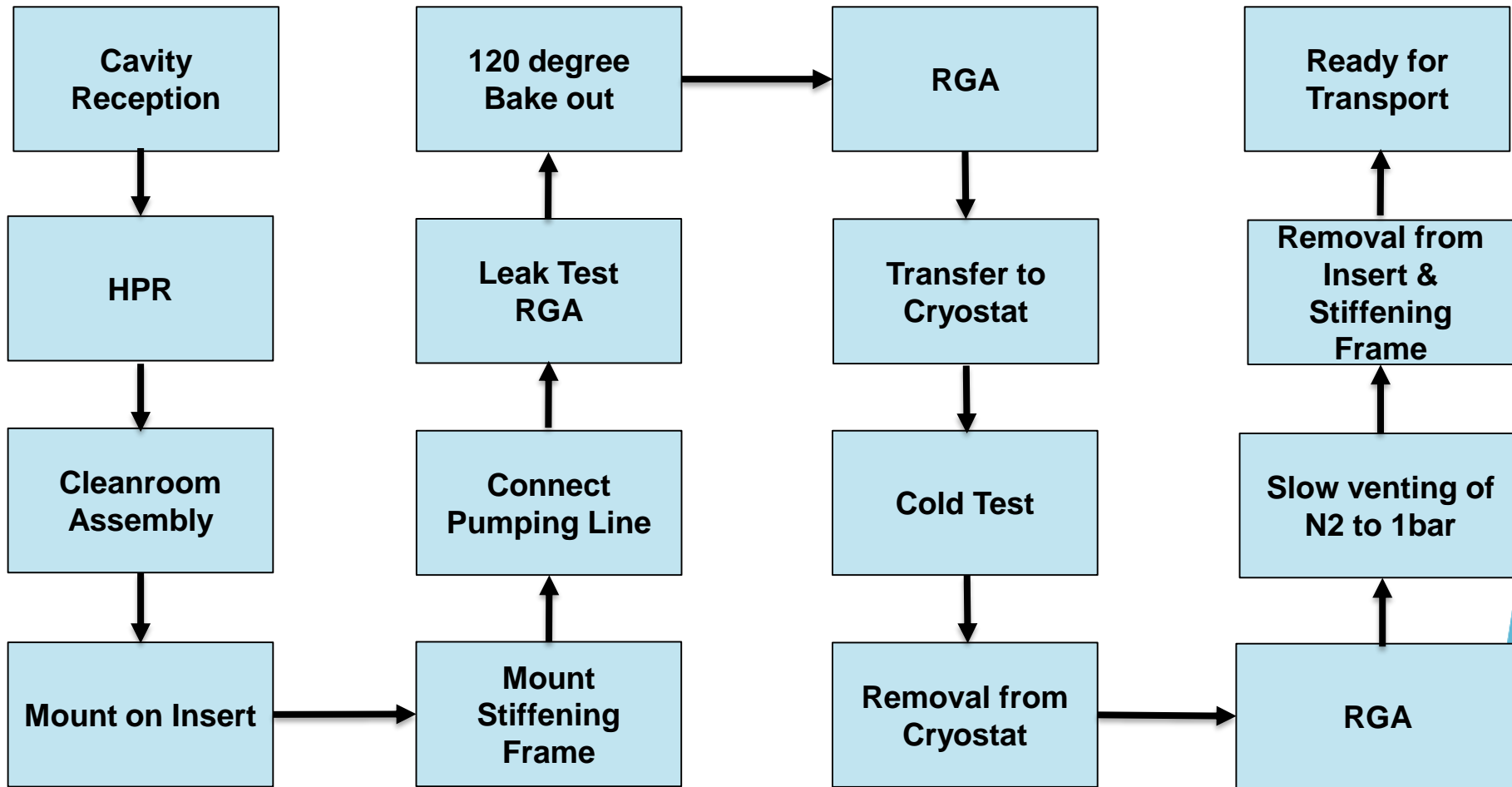
- 13 cavities will be tested at CERN (2019 - 2022)
 - 2 RFD cavities for the SPS test (**done at CERN**)
 - 2 pre-series DQW cavities
 - 9 series DQW series cavities
- Each cavity being tested at maximum 3 times → maximum **39 cold tests** in vertical cryostat is foreseen

CRYOMODULES

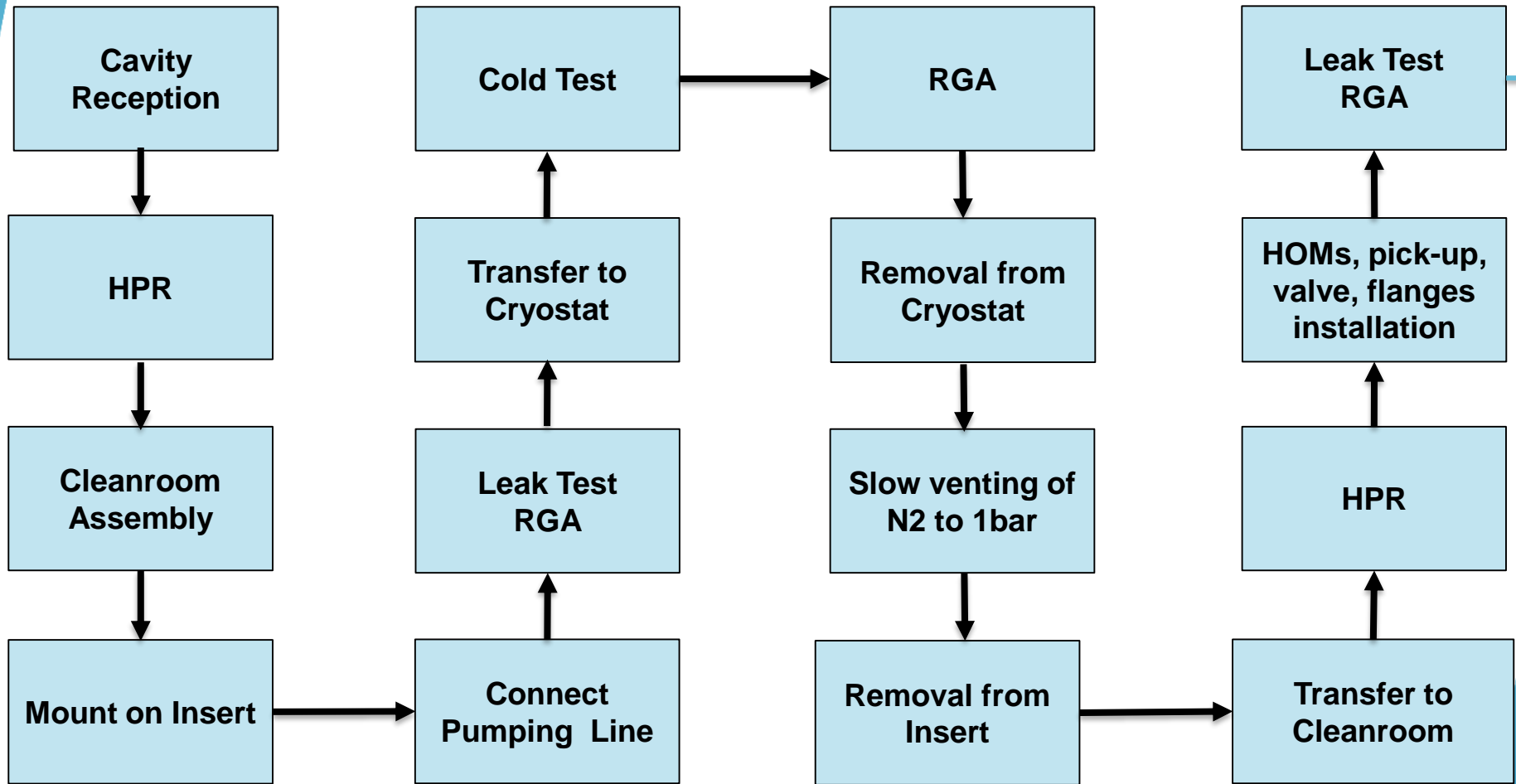
- 11 CM will be tested at CERN (2021 – 2025)
 - 1 RFD CM for the SPS test
 - 5 DQW CM (**CM1 string assembly at CERN**)
 - 5 RFD CM

Workflow

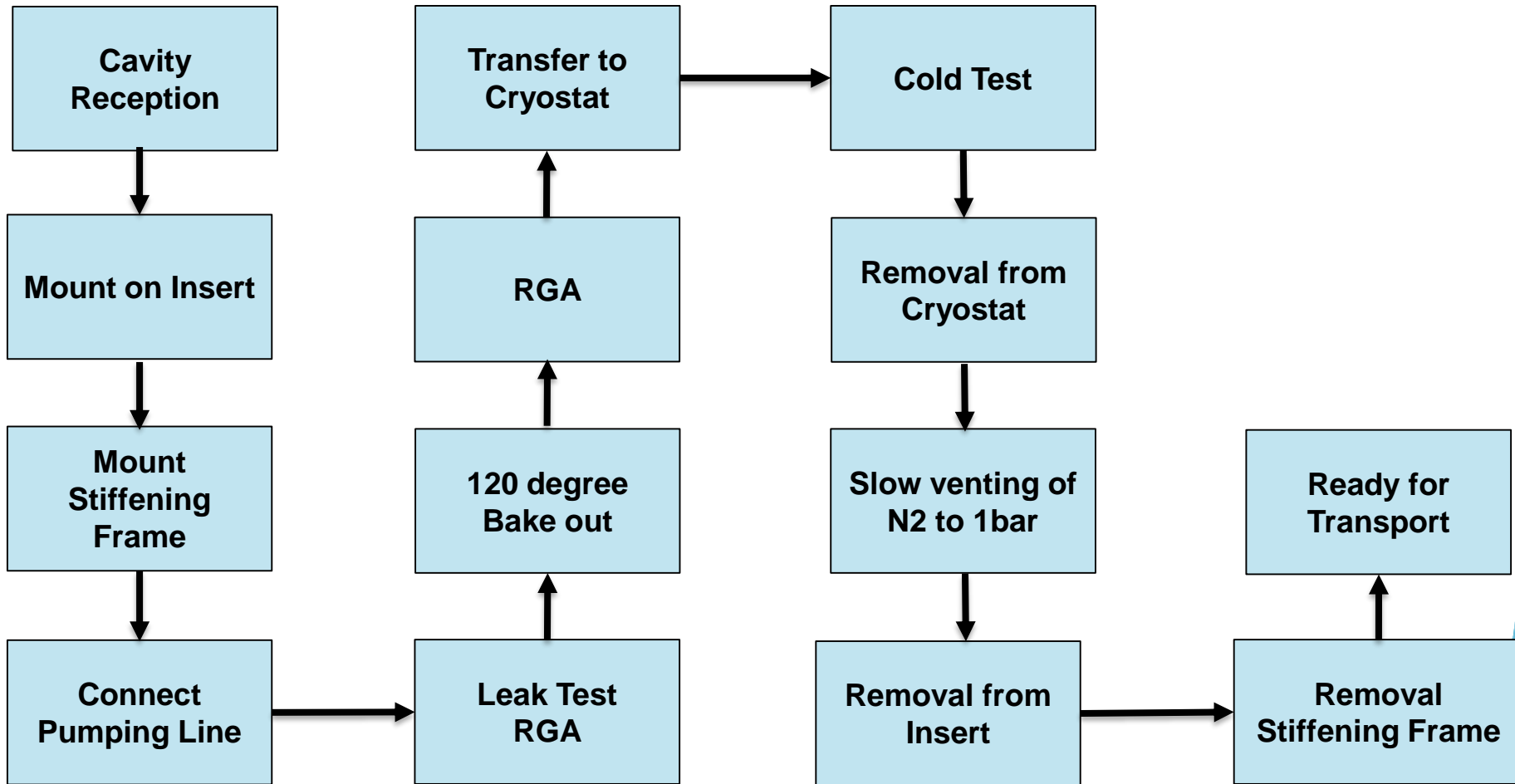
Workflow in SM18 – RFD SPS Test Bare Cavity



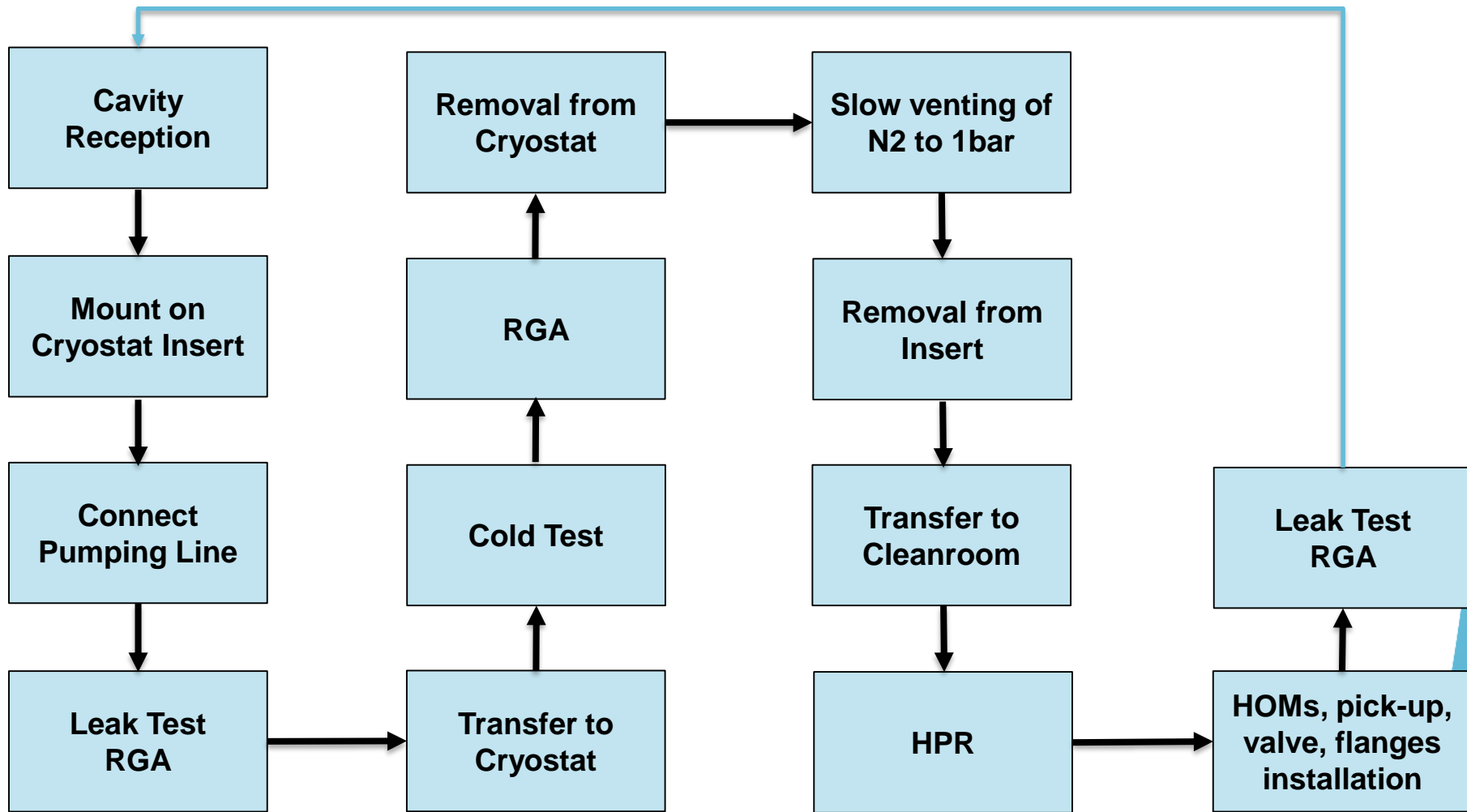
Workflow in SM18 – RFD SPS Test Jacketed Cavity



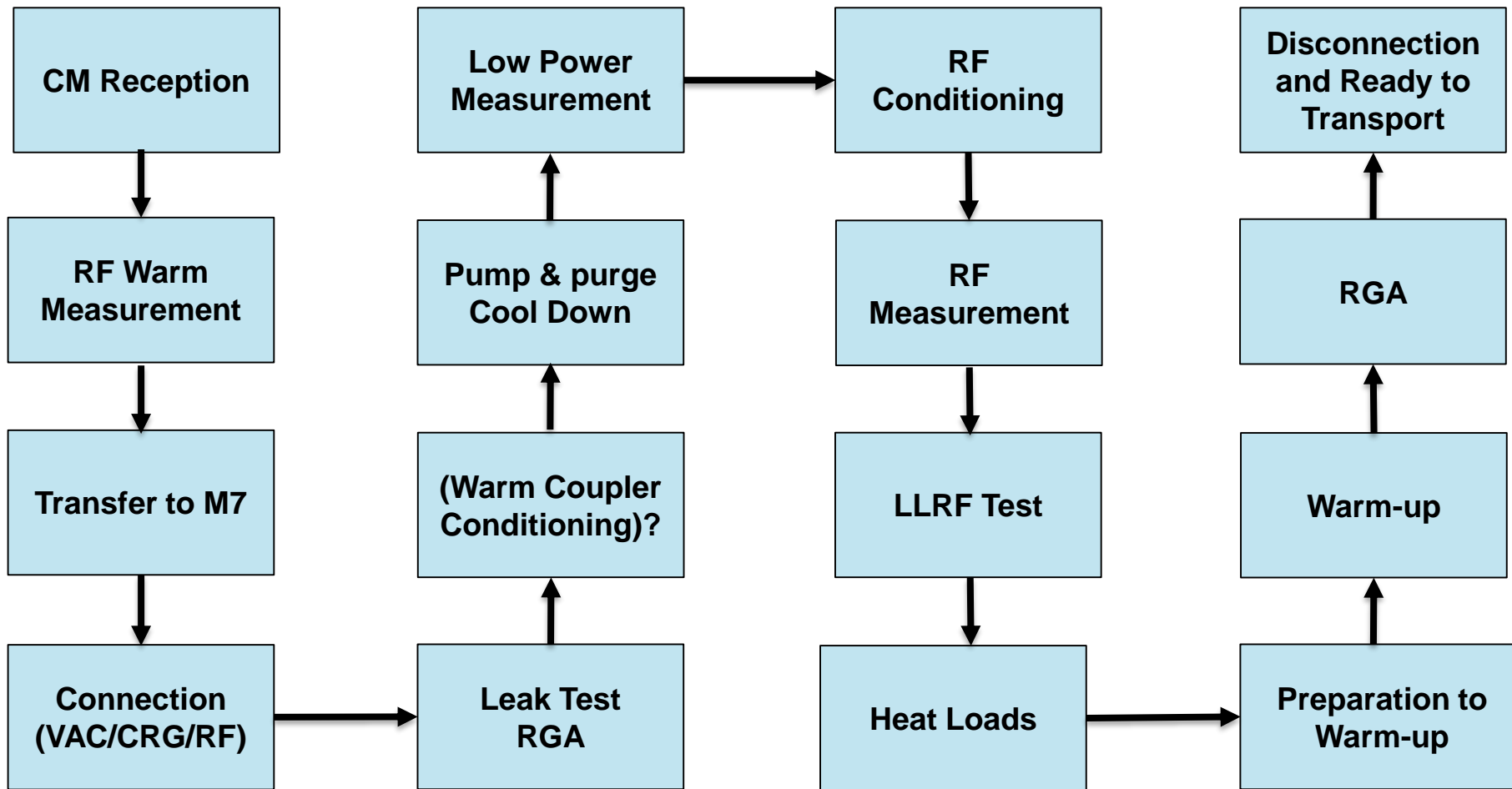
Workflow in SM18 - DQW Bare Cavity



Workflow in SM18 - DQW Jacketed Cavity



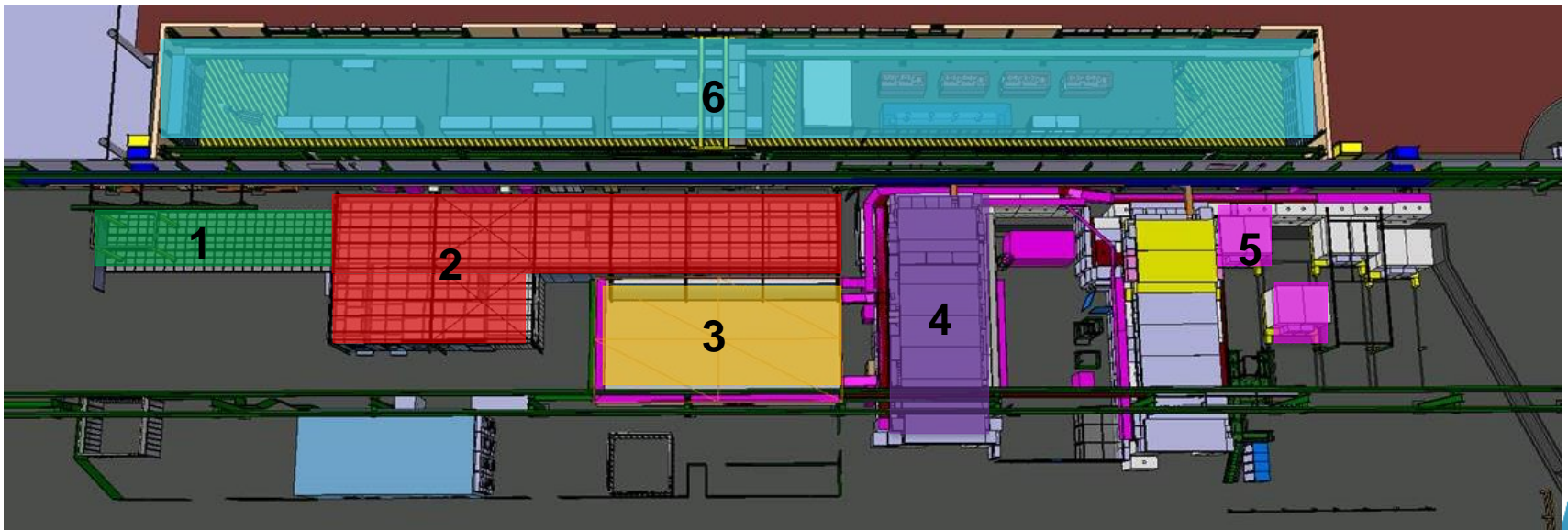
Workflow RFD CM and DQW CM



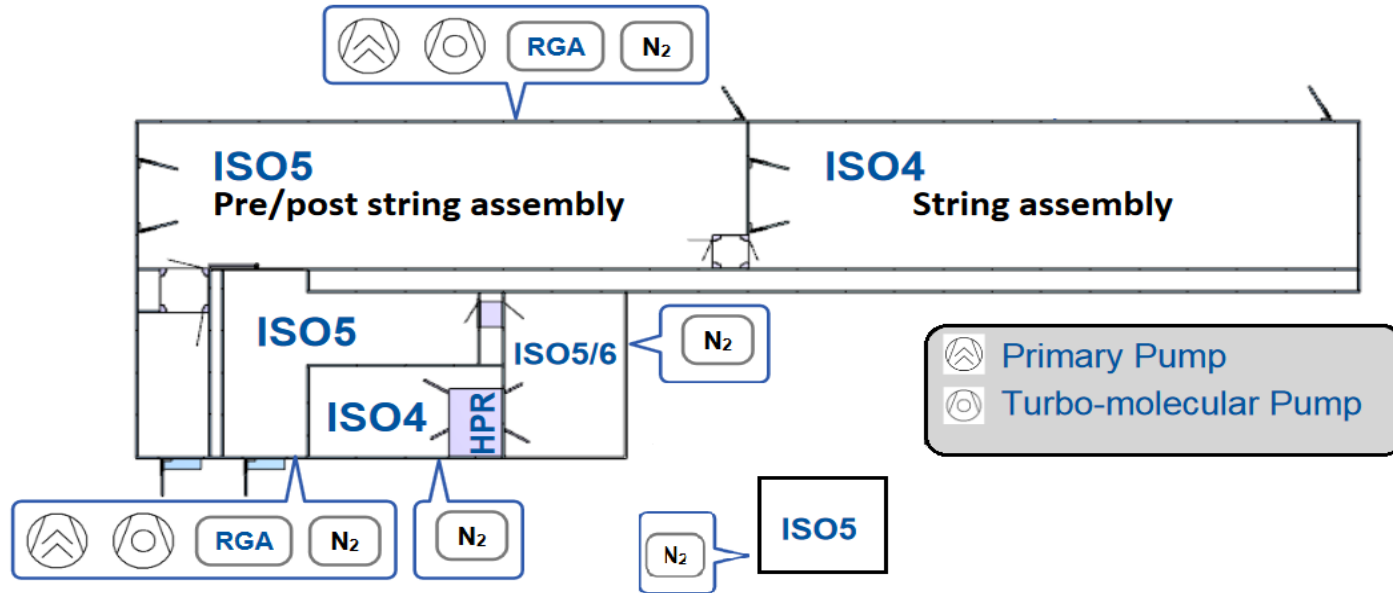
Readiness of the infrastructure

SM18 Test & Assembly facilities

- 1 External rail system: Cryostating
- 2 Clean room: ISO4, ISO5, HPR cabinet
- 3 Control room: Faraday cage with measurement stand
- 4 Horizontal bunker: Cryomodule Test
- 5 Vertical cryostats: V3 & V4 for testing of bare and dressed cavities
- 6 Extension: ~600 m² of the reception and storage space



Clean room



ISO4



ISO5



Panel outside clean room

Cleanroom

- Knowledge and experience gained with the SPS test prototype
- DQW SPS test string assembly and cryostating has been successfully completed even with incomplete set of tooling.
 - Installation of cavities on the trolley outside the cleanroom → missing tooling
 - Alignment system to be improved
- Assembly has been done without N₂ gas flushing (available if necessary)
- Significant amount of leak check to be performed
- Preparation of ancillaries in bldg. 252 clean room



To be done:

- Tooling (e.g. valve and cavity lifters) → waiting for finalization of the design of the cryomodule, before finalizing the design of some of the tooling
 - Tooling being updated from SPS test to LHC – a bit more complexity in the LHC design.
- Components and blank assembly in advance

Vertical test stands

Two vertical test stands (V3, V4)

- Equipped with the SEL system (CW or pulsed mode operation possible)
- X-ray detectors (Top & Bottom)
- Earth magnetic field compensation coils

V3

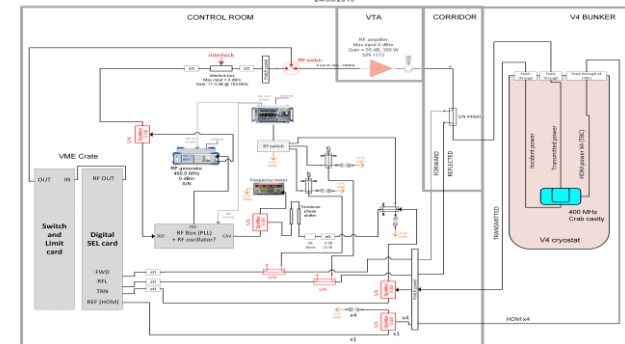
- Volume: 2500 litres
- In addition: OST sensors + AB & RuO₂

V4

- Volume: 1500 litres
- Dedicated for Crab Cavities tests

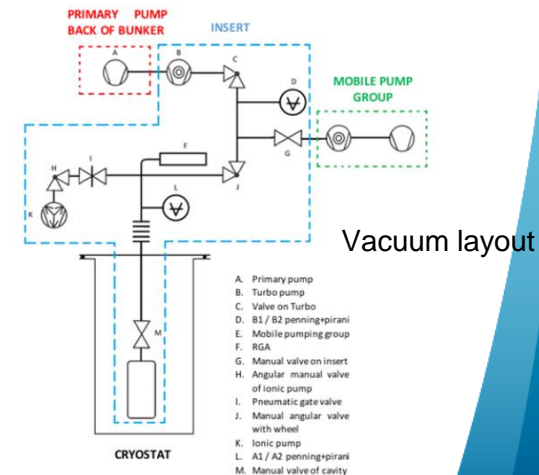
Cryo process	Consumption
Cool down to 4.2K	up to 15 g/s
Stabilization phase at 4.2K	~3 g/s
Pumping to 2K	up to 6 g/s
Stabilization phase at 2K	~3 g/s

V4 RF system block diagram



To be done:

- Validation test of V4 (July 2019)
- PLL system integration
- Software validation
- Mobile cleanroom
- New baking system

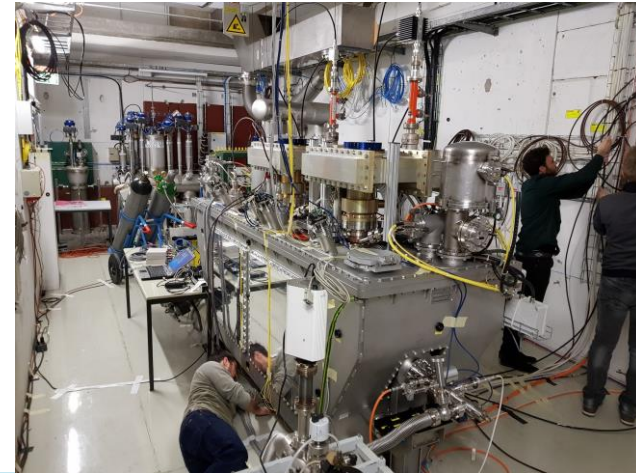


Horizontal test stand

- Cryomodule test in M7 (2017)
 - Cool - down cycle performed
 - Limited RF tests (cavity tuning & conditioning)
- Cryogenic:
 - DQW CM: ready
 - RFD CM: beam screen circuit required modification
- Vacuum → mobile pumping groups
- Access System
- Radiation System
- Water System
- Interlock System
- Rack allocation + Cabling

To be done:

- High Power System to be installed
- LLRF system to be installed
- User Interface to be done
- Mobile cleanroom → vacuum connection
- High Power RF Test



DQW SPS CM in M7 bunker



Control rack for Cavity 1

Preparations ongoing towards the series testing and main bottlenecks

Preparations ongoing towards the series testing and main bottlenecks

- Good coordination and communication
- Team readiness → necessary skills
- Infrastructure preparation
 - Allocation of space for reception, acceptance, storage
→ SM18 extension (~600 m²), bldg. 2002 (~400 m²)
- Necessary tooling (cold test preparation, string assembly)
- Preparation of a sufficient number of spare equipment
- Preparation and test of SW & HW



Insert with RFD cavity

Preparations ongoing towards the series testing and main bottlenecks

Main bottlenecks:

- CRYO capacity in SM18 share with a substantial magnet test facility
- Number of iteration → no guarantee on performance of the cavities or delays in production (cavities, He tanks, couplers, etc.)
 - Many activities are carried out one after another and depending on the previous results, some in parallel
 - CM test is the last in the line and has to absorb potential delays in the schedule
- Procedures to be finalized for the final configuration

Conclusion

- Experienced team with new organization
 - Time needed to restart all activities after 2 years
 - Redundancy foreseen on each activity
- Infrastructure under preparation to handle the crab cavities series
- Many tools (also SW) are being developed/tested to ensure smooth operation
- Crab cavities series will significantly block CERN SRF capacity → stop/delay of other activities
 - LHC, HIE-ISOLDE operational needs during Run III

References

- F. Peauger, Vertical RF Cold Test Procedure of Crab Cavities at CERN, EDMS 2154262
- A. Macpherson, [SM18 Preparation for Cryomodule testing](#), 2017
- M. Therasse, [String Assembly & Lessons Learned](#), 2017
- A. Castilla, [CERN DQW Tests Summary](#), 2017
- A. Castilla, [Bare and Partially Dressed Cavity Preparation for Cold Test Validation](#), 2016
- N. Valverde, [Industrial DQW pre-series status](#), 2018



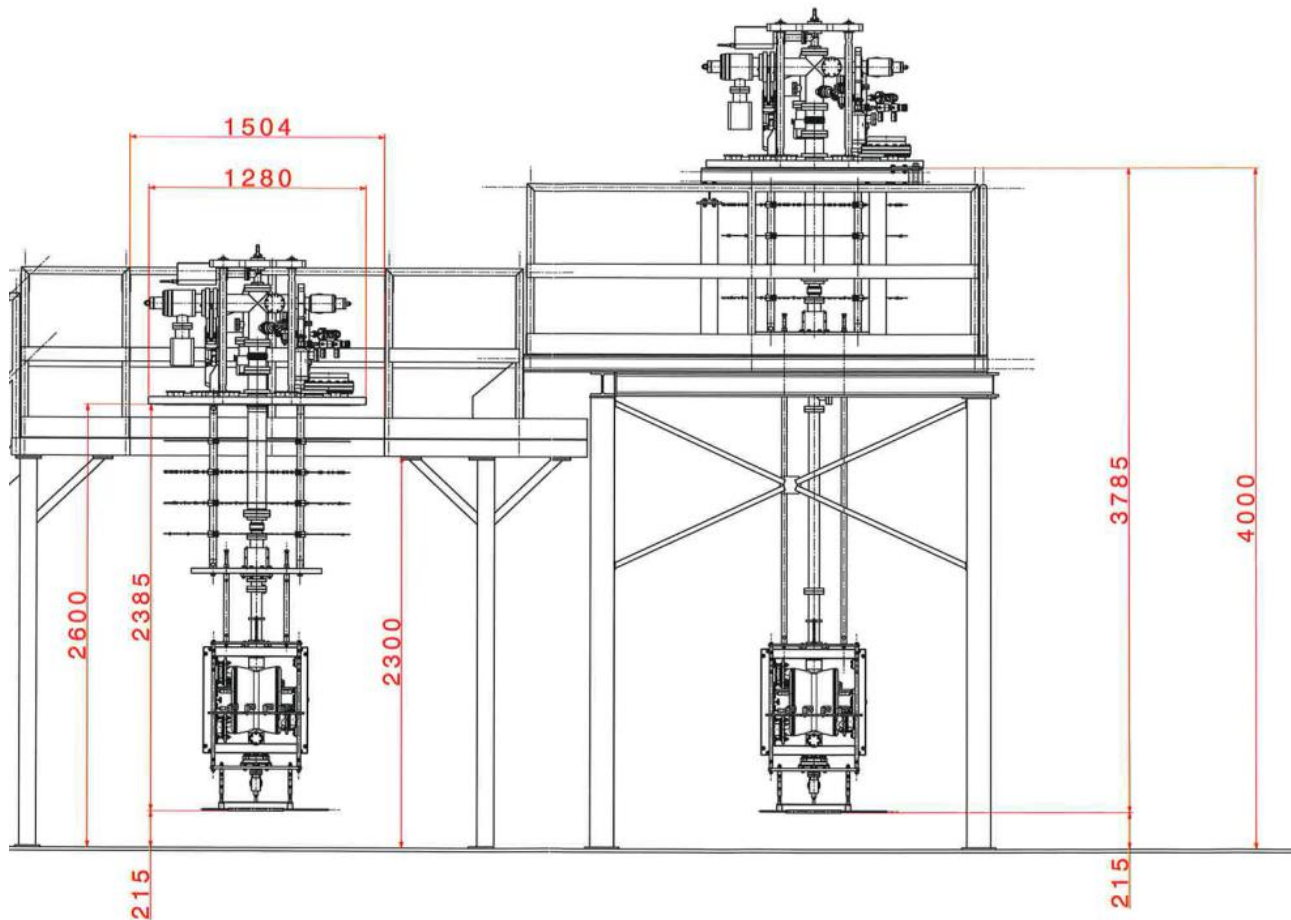
Thank you very much!

Acknowledgments: P. Baudrenghien, S. Barrier, I Ben-Zvi, K. Brodzinski, R. Calaga, A. Castilla, F. Gerigk, D. Glenat, A. Macpherson, T. Mikkola, E. Montesinos, N. Stapley, W. Venturini Delsolaro, IFJ PAN team and entire SM18 team



SPARE: Inserts (V3 & V4)

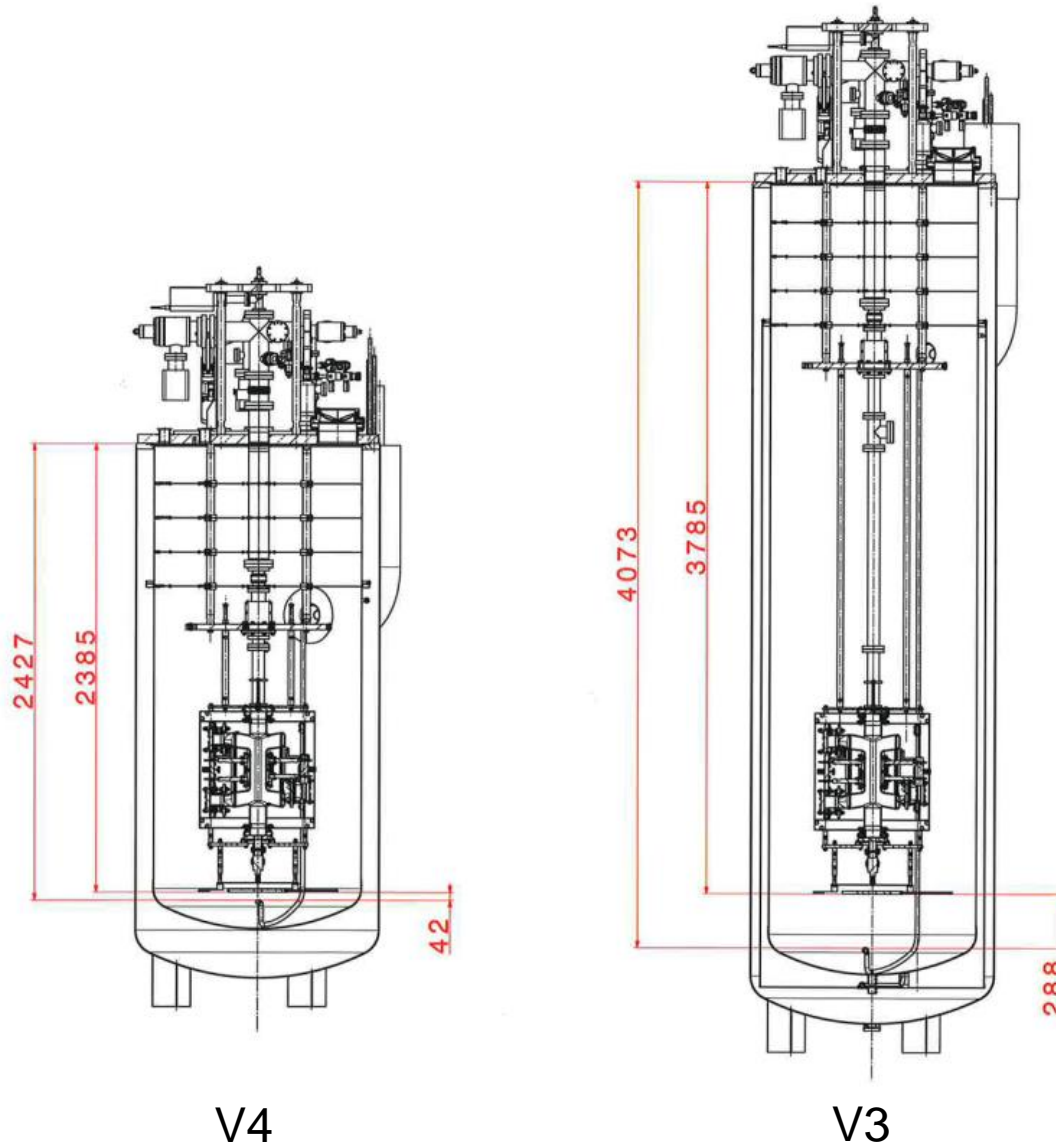
ST0677539_01 (Vertical Test Zone)



V4 Insert

V3 Insert

SPARE: Cryostats (V3 & V4)

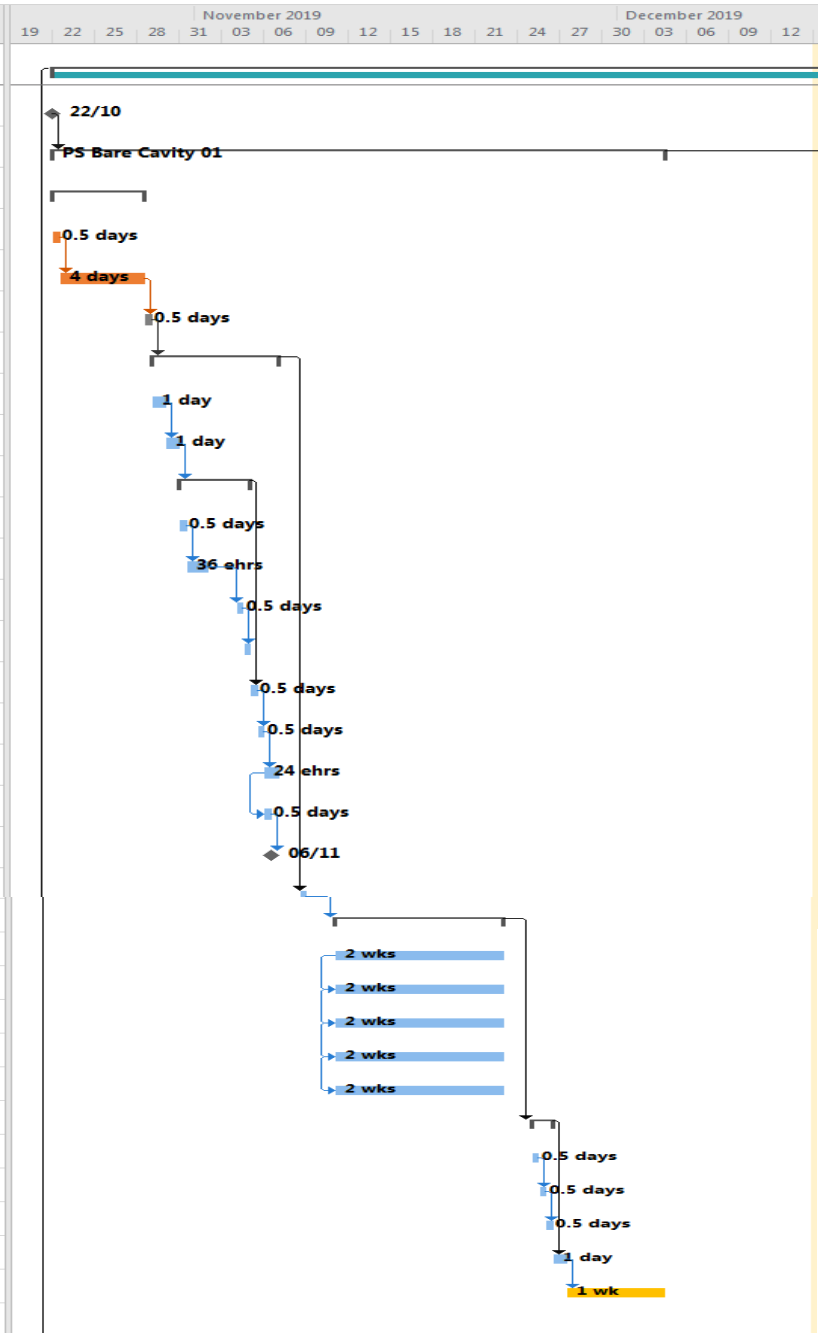


V4

V3

Task Name
Pre-Series DQW Cavity 1
Reception of sealed Bare cavity from supplier
Bare cavity 01
Pre-test validation
Visual inspection (outside) + RF measurement (warm)
Dimensional control
Transport to SM18
Preparation for cold test
Transfer & install cavity + stiffen frame on insert
Leak test + RGA
Bakeout 36 Hrs at 120 C
Preparation
Bakeout
Removal of equipment
Leak test + RGA (internal)
Mounting of insert Diagnostics
Install insert in cryostat
Pressure test and cryostat purge
RF measurement (warm)
validation after cryo shutdown
Launch cooldown
RF Test at 4K and 2K
Measure Q0 vs V
Measure Frequency vs vacuum
Measure Residual Resistance
Measure Lorentz Force detuning sensitivity
Measure bulk and surface RRR
Post-cold test phase
RGA analysis of cavity vacuum
Removal from the insert
Removal of Stiffening Frame
Prepare Transport back to supplier
Contingency
Cavity sent to supplier

Detailed planning
Pre-series DQW_1



Spare: SM18 layout

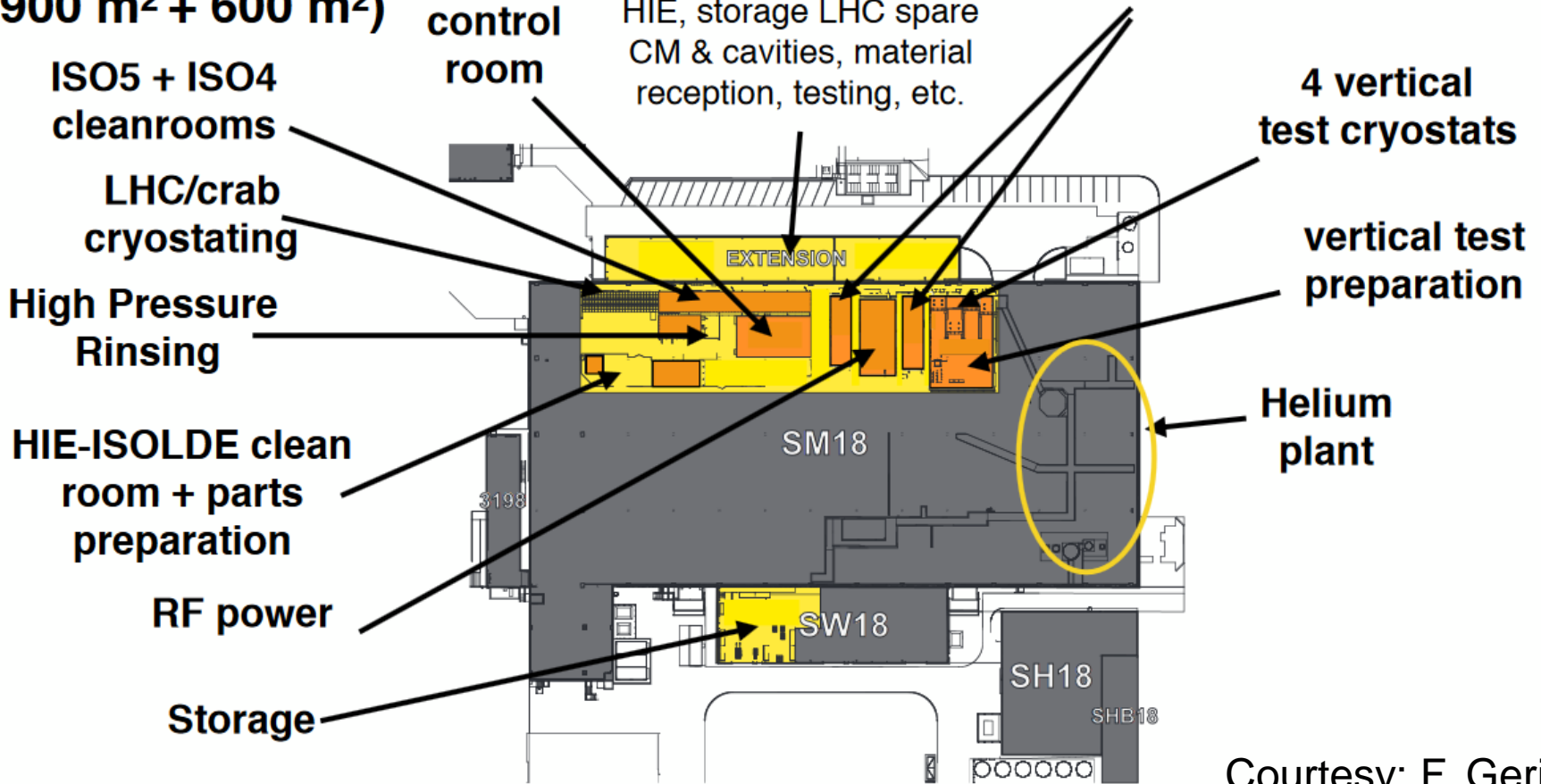
SRF in SM18

(~1900 m² + 600 m²)

new extension (~600 m²):

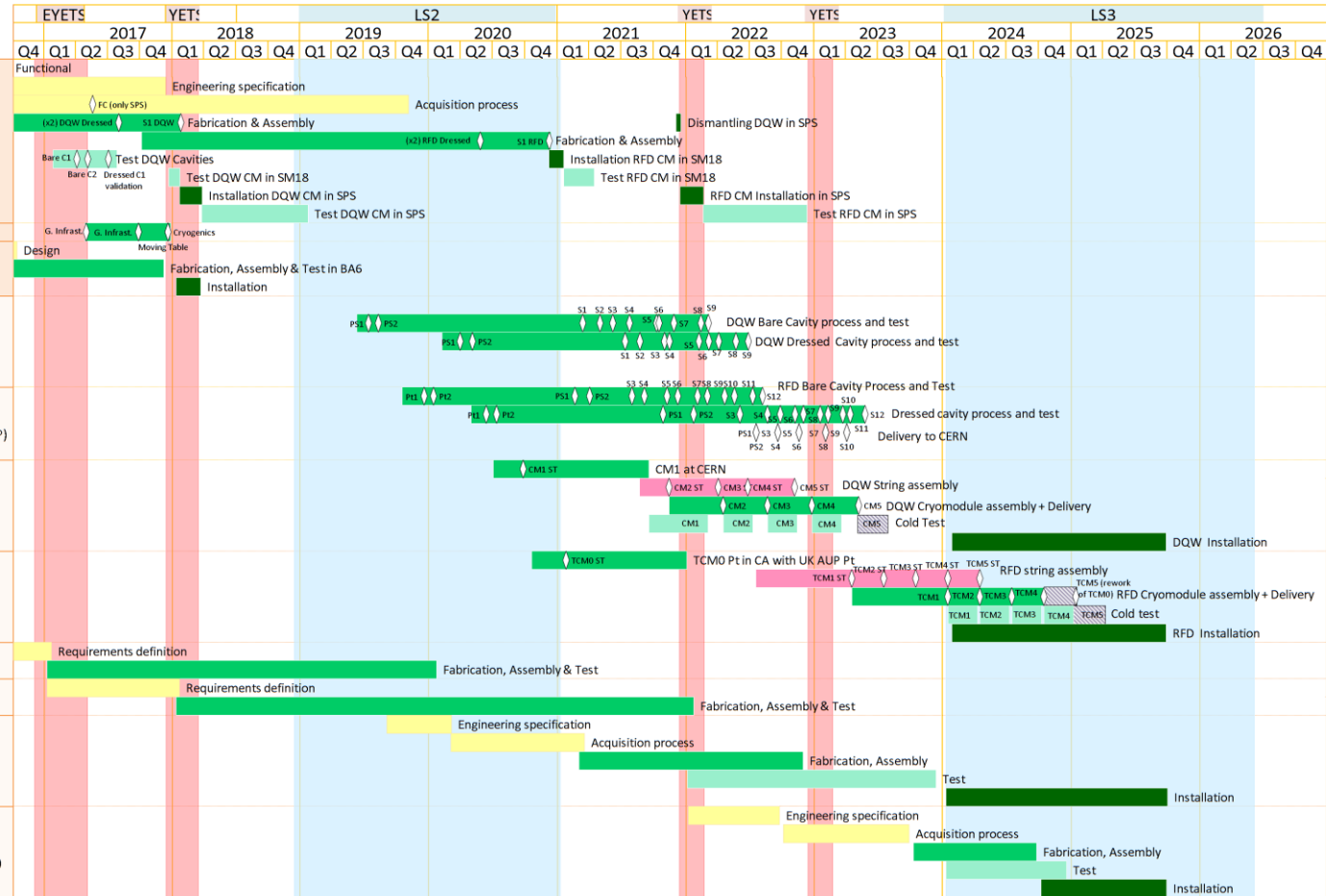
CM assembly & parts preparation for Crab/HIE, storage LHC spare CM & cavities, material reception, testing, etc.

cryomodule test bunker



Courtesy: F. Gerigk

SPARE: General planning overview



WP4- PSM 2018
2nd review