# SM18 Readiness for Preparing and Validating Crab Cavity Cryomodules for SPS

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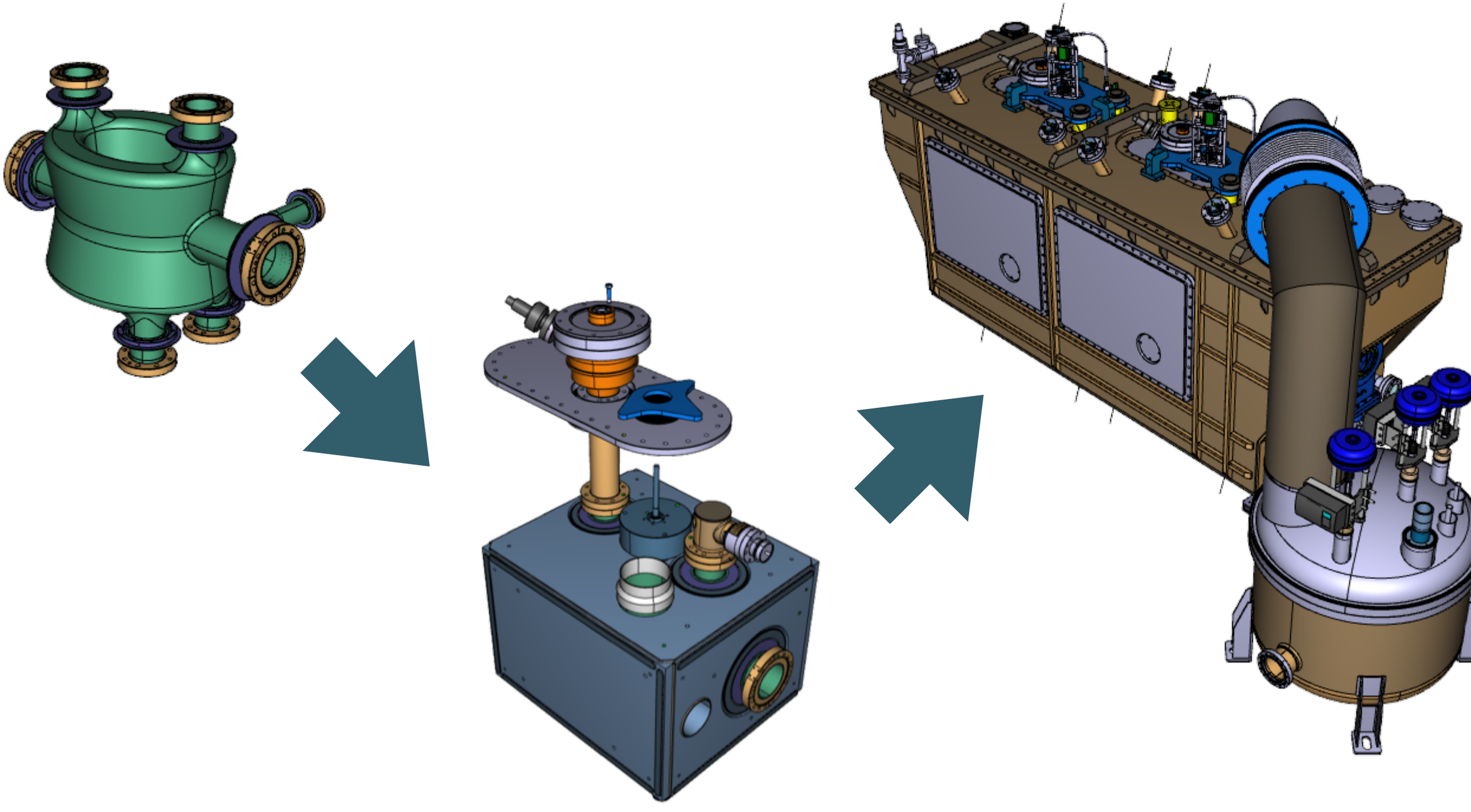
for Crab Cavity team in BE-RF, EN-MME, EN-ACE, TE-CRG, TE-VSC

3rd HL-LHC Technical Coordination Committee (TCC) meeting
25/02/2016

# Overview

- **Objectives of SM18 program:**
  - Prepare & test bare and dressed crab cavities
  - Cavity string assembly & cryostating, then validation of cryo module at 2K



# What this talk addresses

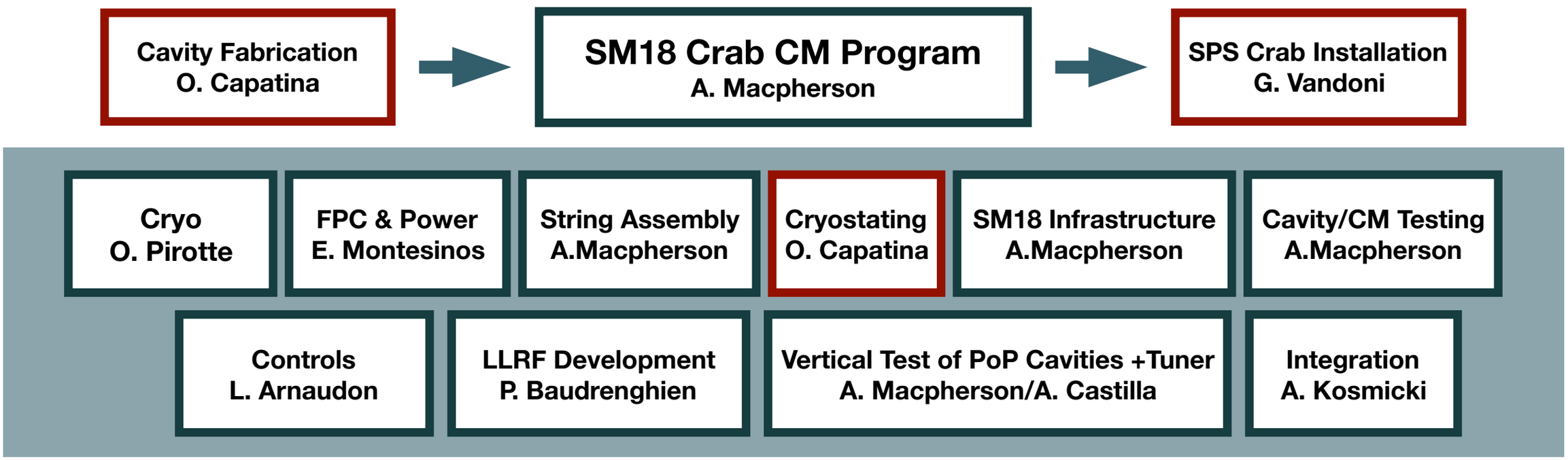
- **SM18 Infrastructure**
  - Vertical test stand upgrade
  - Refurbishment of cabling
  - Cryo 2K upgrade (from 2011)
  - Clean room & tooling

- **Preparation Activities**
  - PoP DQW Tuner test
  - LLRF prototype testing
  - FPC conditioning
  - Chemistry validation - PoP RFD
  - Validation of Cleanroom Process
  - Power system testing (IOTs)

- **Work flow**
  - Cavity Surface Preparation
  - Bare Cavity Testing
  - Assembly of dressed cavities
  - Dressed cavity testing
  - Mounting of FPC
  - String assembly
  - Cryostating
  - Cryomodule installation in SM18
  - Cryomodule testing

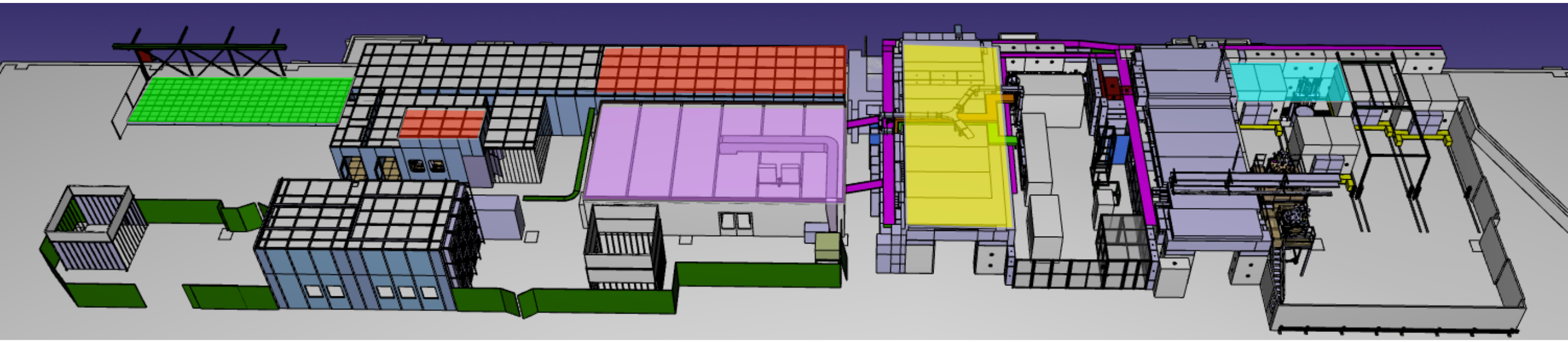
# Roles and Responsibilities

- **Cryomodule Workflow: Assembly and Validation**
  - Cavity Production: EN MME
  - Cavity Surface Preparation: TE-VSC & BE-RF-SRF
  - Bare Cavity Testing: BE-RF-SRF
  - Dressed Cavity Assembly: BE-RF-SRF & EN-MME & BE-RF-PM
  - Dressed Cavity Testing: BE-RF-SRF
  - String Assembly: BE-RF-SRF
  - Cryostating: EN-MME
  - CryoModule Testing: BE-RF-SRF
- **SM18: Infrastructure & Preparation**



# SM18 Facilities: Identification of Working Space

- **Cleanrooms: ISO4 for FPC & HOM Mounting and String Assembly**
- **External rail system: Cryostating of assembled string**
- **Horizontal Bunker (M7): Test of Cryomodule - Power from adjacent IOTs**
- **Vertical Test cryostats: V3 & V4 for testing of bare and dressed cavities**
- **Control room: Faraday cage with measurement stands + LLRF**



- **SM18_RF area: A multi-function & multi-client zone**
  - Significant investment done to upgrade facilities => HL-LHC a key client
  - Already used for cavity assembly, bare cavity tests, CM assembly & testing
  - In 2016 & 2017 SM18_RF facilities & staff must handle 4 different projects
    - LHC upgrade, HIE-ISOLDE Cavities & CMs, HL-LHC cavities & CM, High Gradient Cavities

# SM18 Cleanroom: Becoming operational …

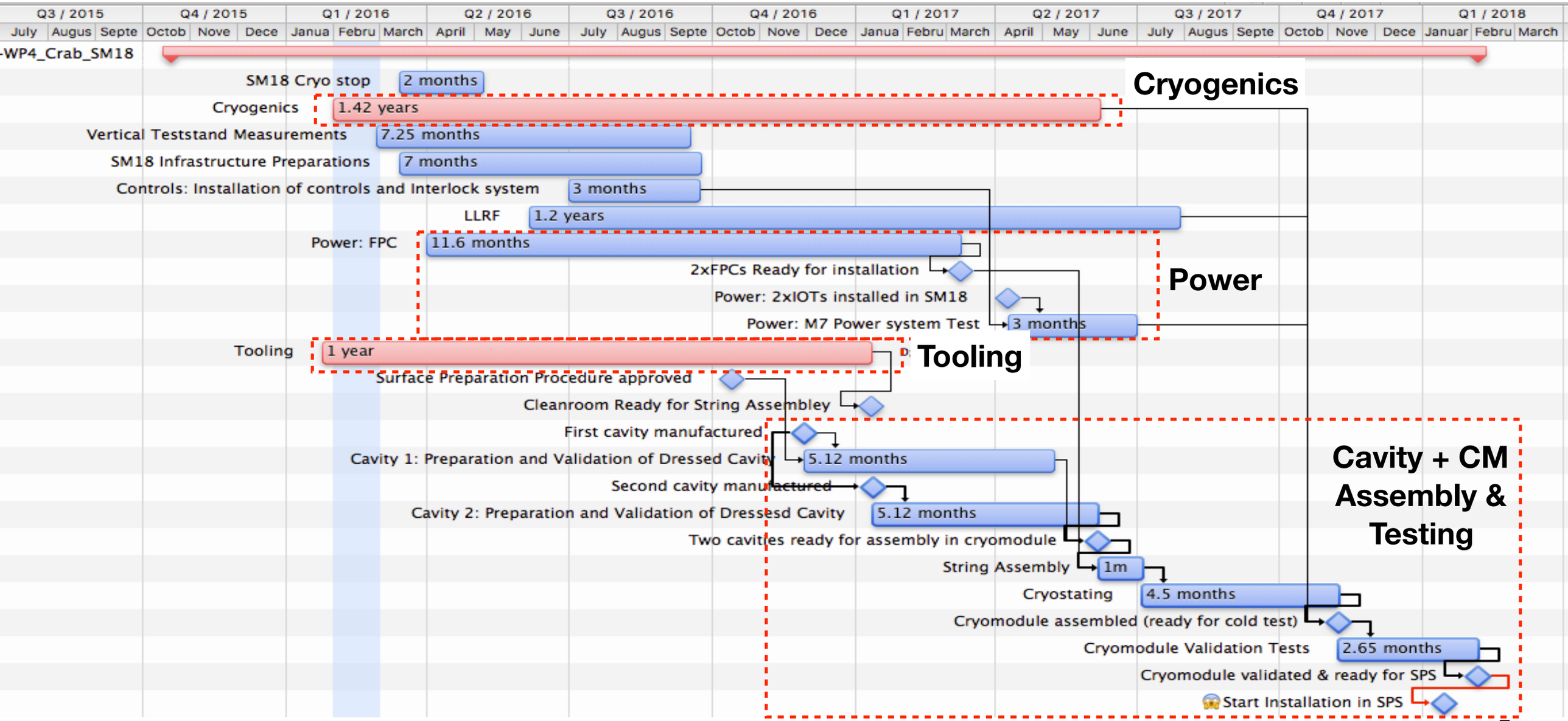
**High Pressure Rinse station**

**PoP DQW Crab in HPR and ISO4 cleanroom**

**LHC Cryomodule on SM18 cleanroom rail system**

# Schedule Overview

- **Baseline schedule assumes 1st crab cavities produced: Nov 2016**
  - Implies tight schedule for cavity preparation, CM assembly & CM testing
- **Infrastructure and services have some margin in the schedule**
  - 2016 crucial for tooling design and infrastructure upgrades



# SM18 Infrastructure Status

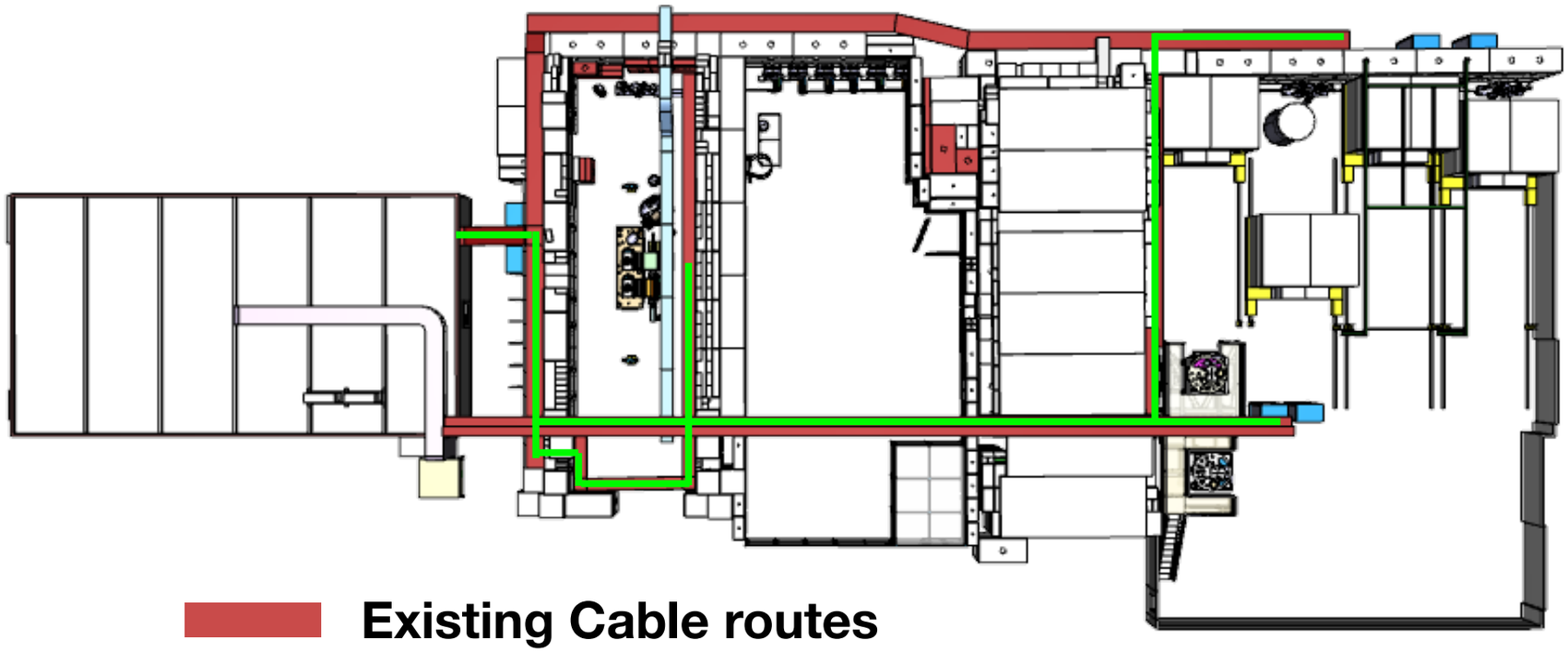
- **Vertical Teststand**
  - **Refurbishment & upgrade of vertical cryostat inserts:** cavity testing (Ongoing)
  - Bringing online V4 cryostat:  to be **dedicated for crab testing** (July 2016)
  - Initial LLRF tests: use cavity + tuner configuration (starting May 2016)
  - High-Q cavity measurement conditioning system for cavity testing (May 2016)

- **M7 Horizontal  Bunker**
  - **Installation of Cryogenic distribution** (Q1 2017)
  - Installation of power system:  Baseline is now for 2 IOTs (Q2 2017)
  - New control system to prototype for SPS installation (Q1 & Q2 2017)
  - Full LLRF system to be installed for CM test: Noise + loop gymnastics  (Q3 2017)

- **Test Installations**
  - Interlock Upgrade: New access safety zoning due to radiation (Q2 & Q3 2016)
  - **Replacement of obsolete cabling**, needed for LLRF development  (May 2016)

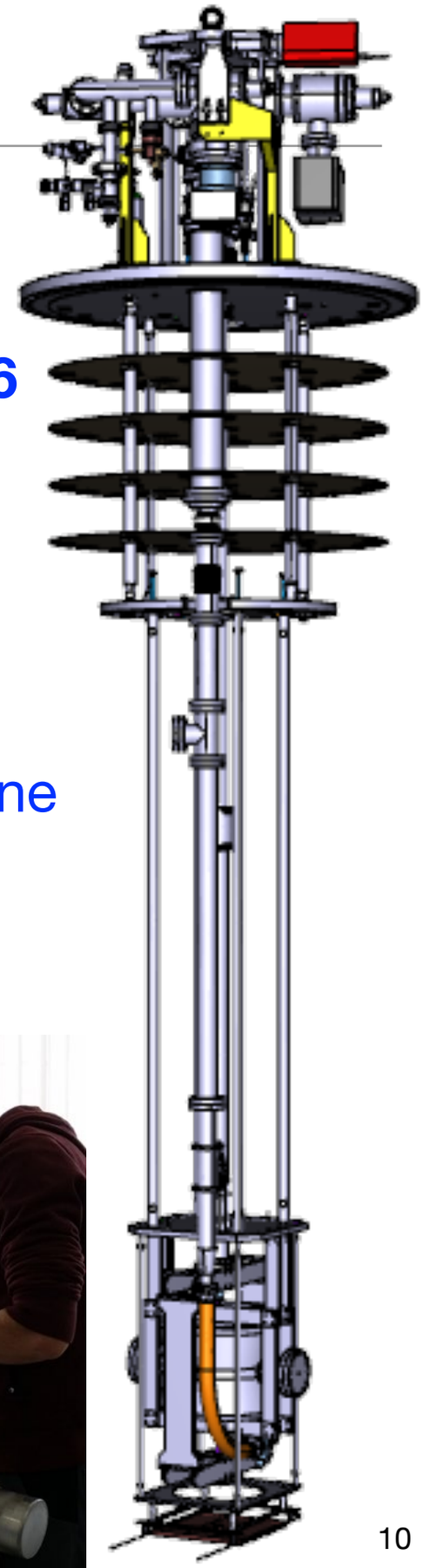
# Cable Infrastructure

- **Measurement & control systems for Crabs require cabling refurbishment**
  - Both High-Q and SPS prototype LLRF require high performance cable
  - Control system is obsolete & not indicative of SPS => New system needed
  - Prototype SPS Crab FESA  interface & develop Crab interlock architecture
- **Insufficient space in overloaded cable trays  (legacy of LEP CM testing)**
  - **Cable campaign being prepared in SM18 cryo stop in April 2016.**

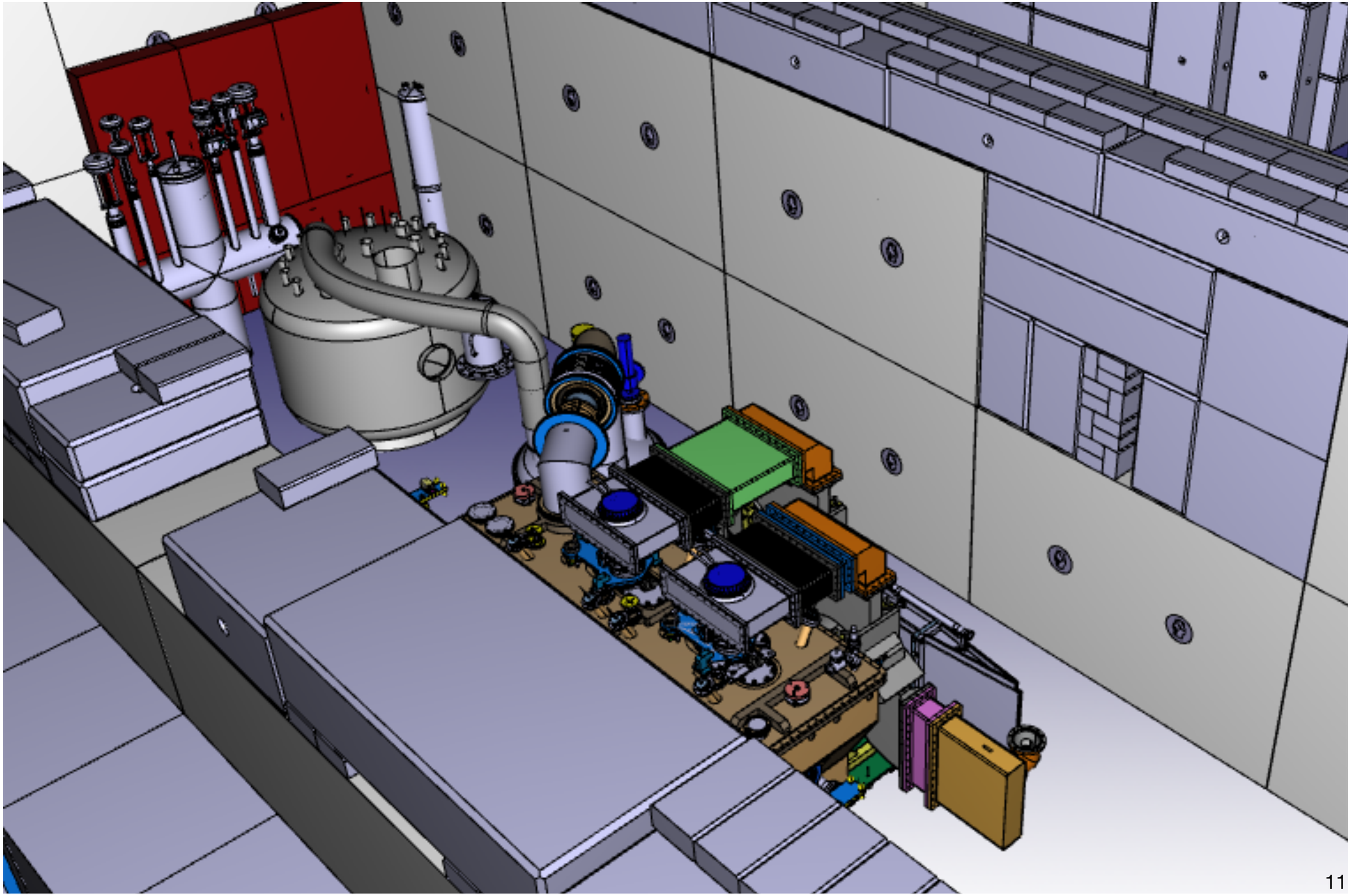


# Vertical Cryostat: Insert Upgrade

- **Present insert insufficient for test of Crab with tuner**
  - Insert designed and sent to fabrication April 2015
  - **Expected commissioning of new insert in April-May 2016**
  - Once V3 insert validated, V4 insert to be commissioned
    - **Will give two operational test cryostats**
- **New insert assembly platform installed December 2015**
  - Improved mechanical safety
  - Improved quality control: connection of cavity -> pumping line
- **New insert needed for DQW Tuner Test**
  - **Scheduled for May 2016 - Preparations ongoing**



# Cryogenics



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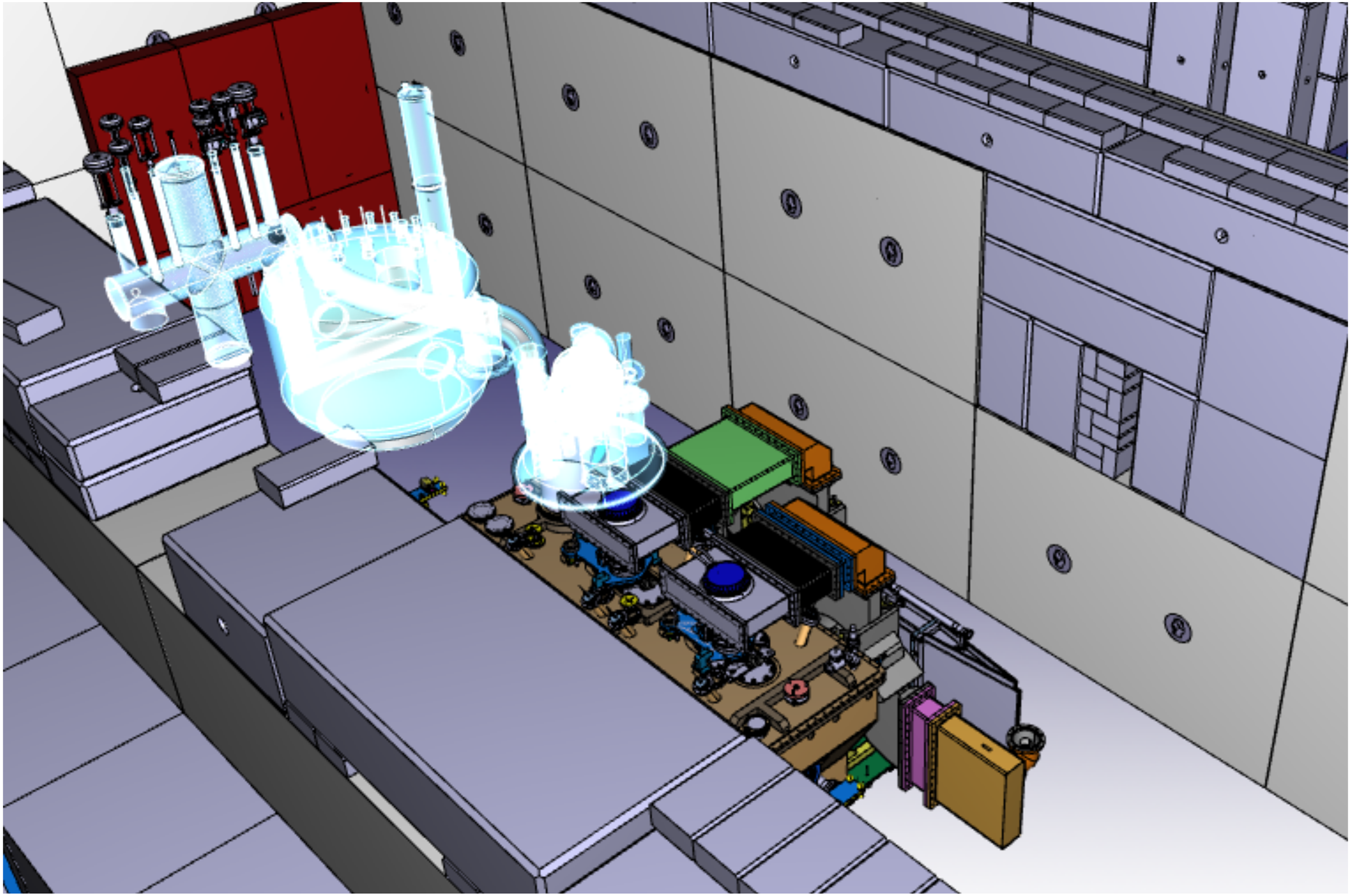
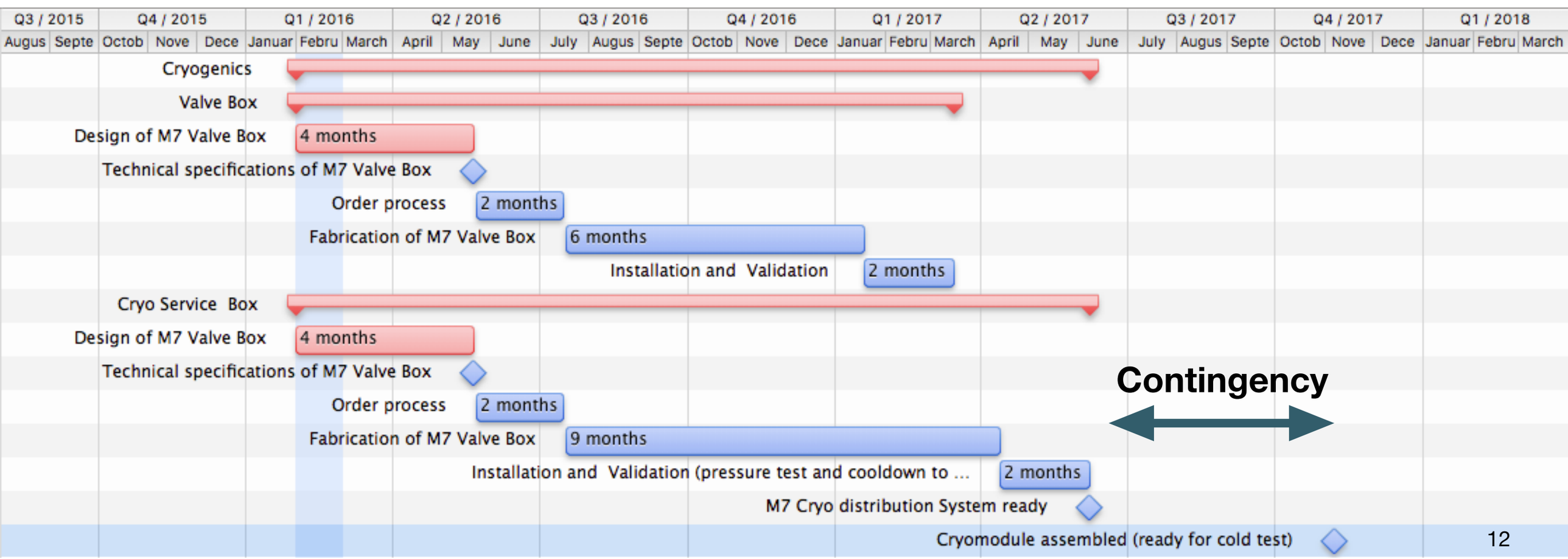


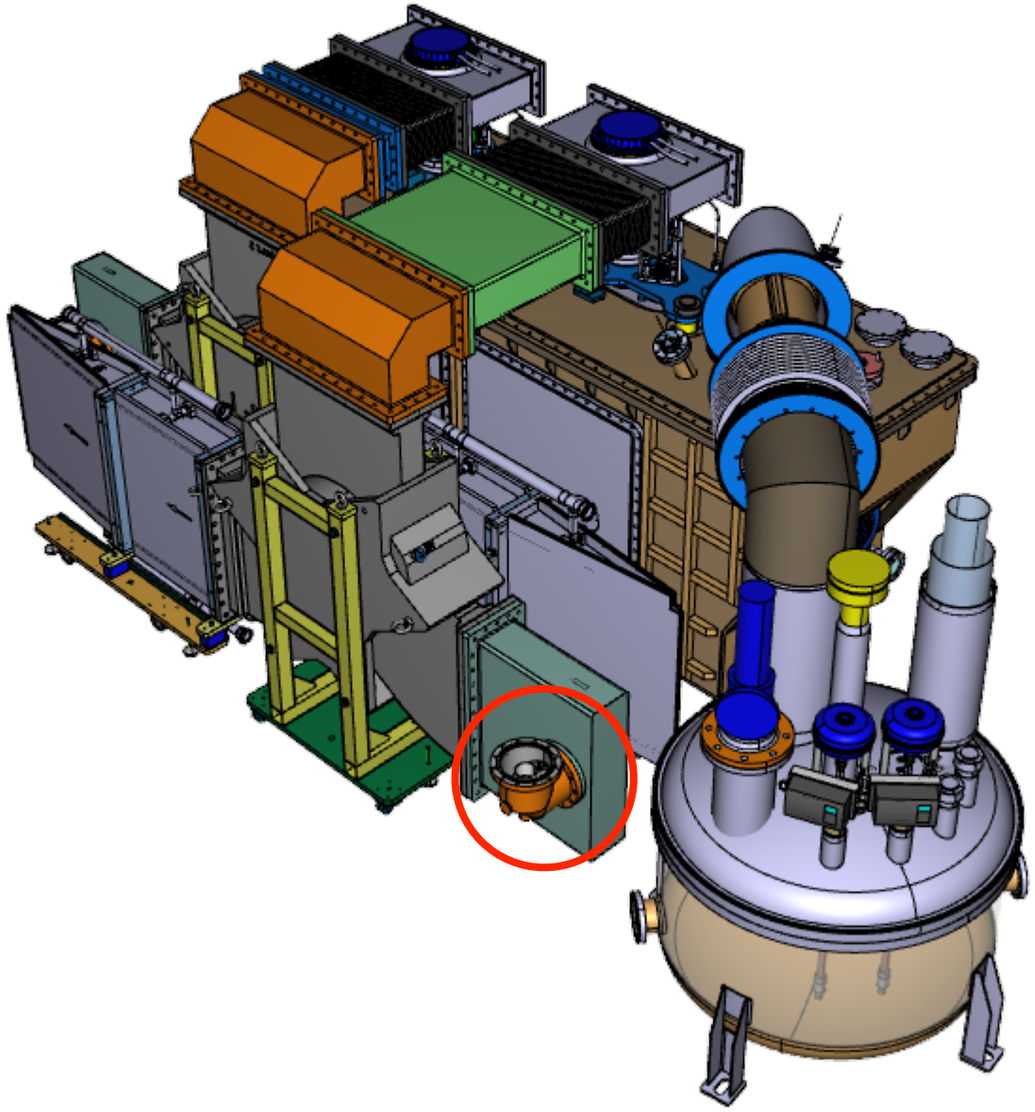
# Cryogenics

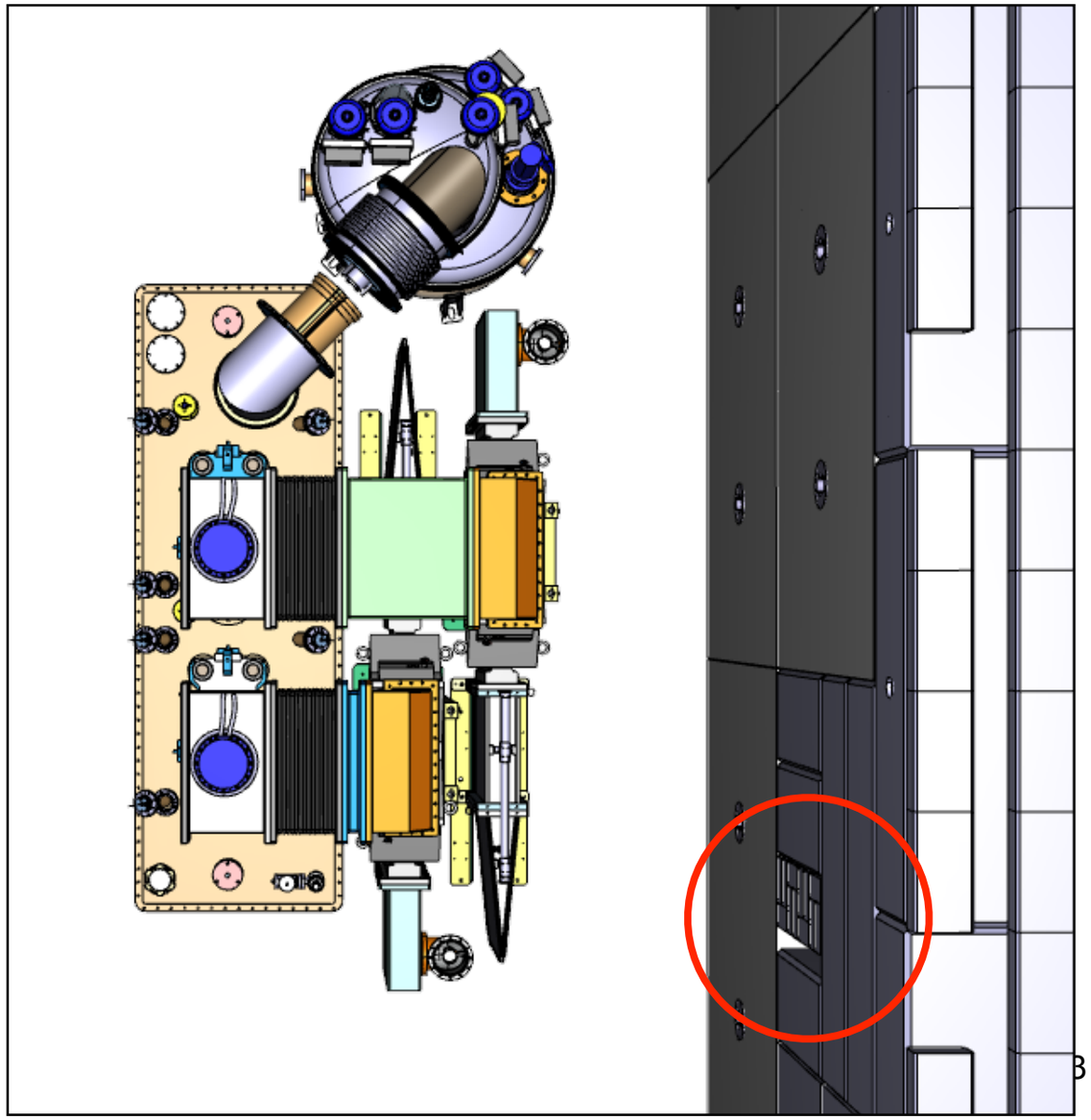
- **Valve Box:**
  - Finalisation of technical specs (mid-May 2016) then release for fabrication
- **Crab Service Box:**
  - Same procedure for design, order and procurement
- **Validation: limited testing after installation ( pressure test + cool down)**
  - Commissioning with PID only when CM installed
    - Expect 2 weeks of commissioning of cryo +CM (but without RF)



# Infrastructure: Placement of Cryomodule in M7

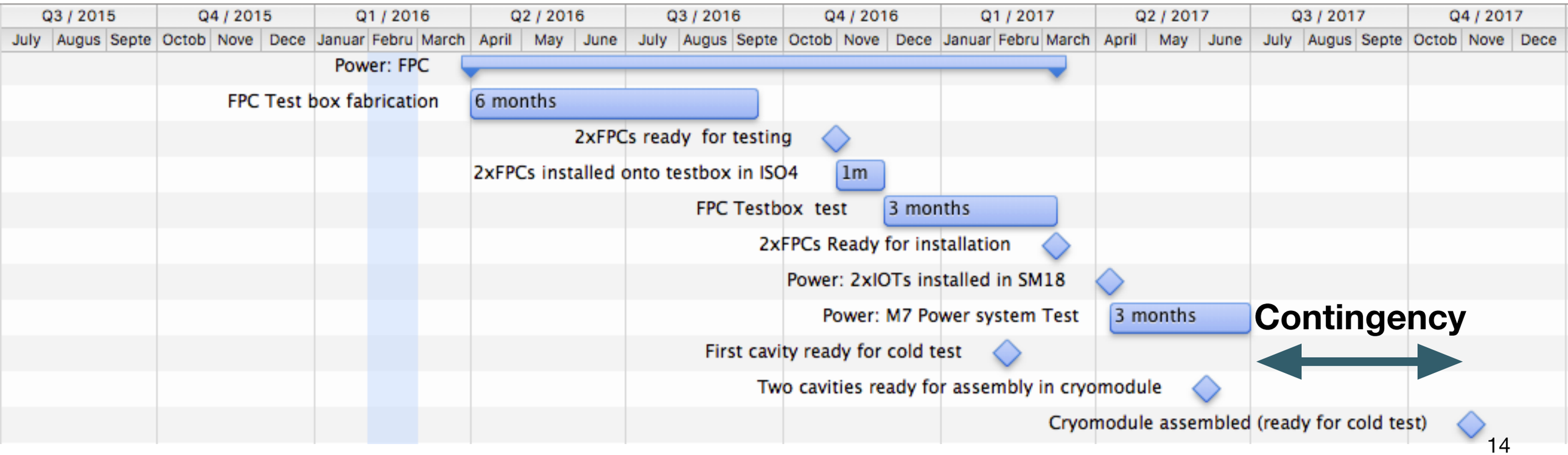
- **Placement consistent with Cryo distribution for multi client use of M7**
- **Adhere to constraints being set by SPS installation**
  - **Dictates routing of services => implications to M7 shielding layout.**
    - **Power is now routable into M7 without requiring opening shielding**





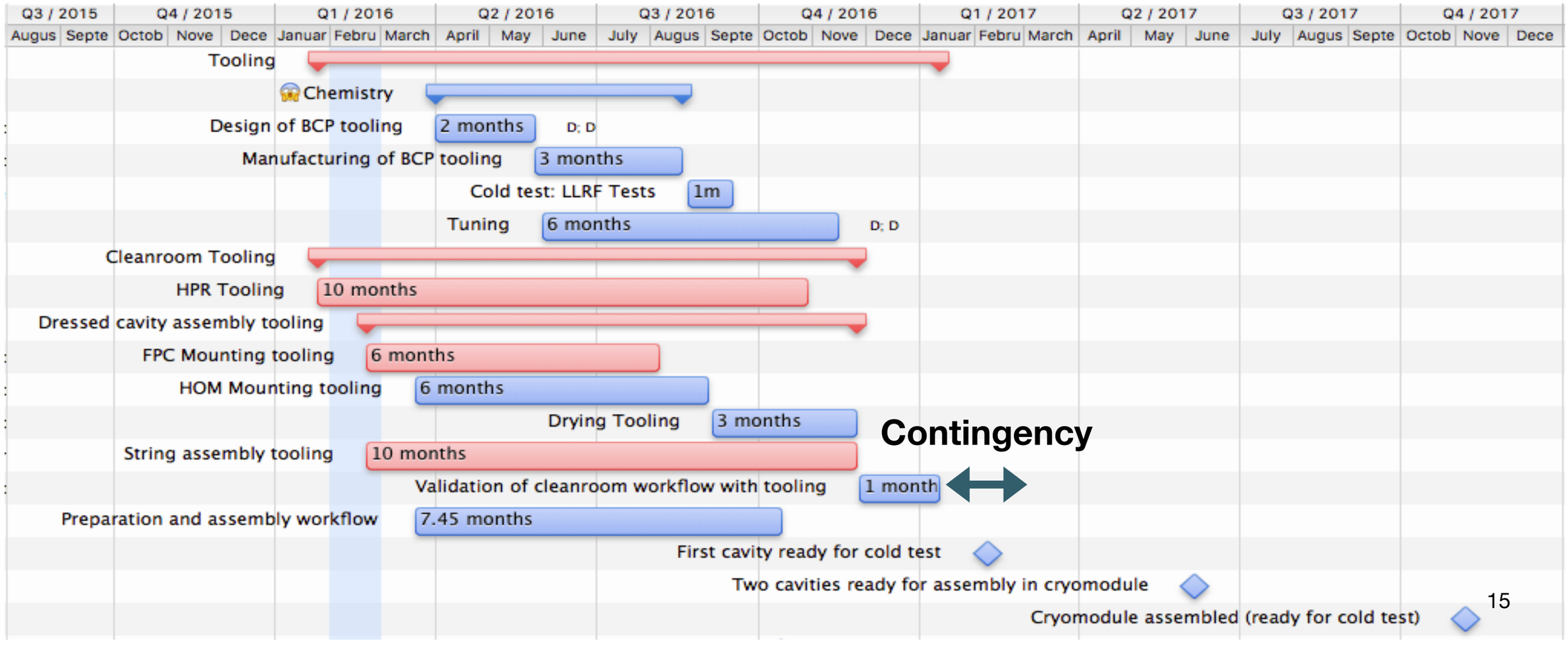
# Power

- **RF Power system**
  - Decision to move from Tetrodes to IOTs. Two IOTs to be installed in SM18
    - **Cavities powered in parallel: Benefits conditioning & LLRF studies**
  - Integration of power system in M7 bunker area now under study
    - Removal of 704 MHz power completed… space for HL-LHC now available
  - **IOTs first being tested in BA6 (Eric Montesinos and team - March 2017)**
- **Fundamental Power coupler**
  - Testbox design being completed
  - Final FPC mounting tooling not needed for FPC Testbox tests



# Tooling

- **Change in project baseline in mid Oct 2015: Cavities now built by CERN**
  - Need to set up RF Surface prep, cavity testing, & dressed cavity assembly chain
    - This is in addition to cleanroom preparations for string assembly
  - Design, fabrication and validation of many different tooling
    - Requires clear understanding of work flow. (Starting to be finalised)
- **Validation process includes both tooling and process**
  - **Must include training of technical support staff: (ie 1st time with this tooling)**



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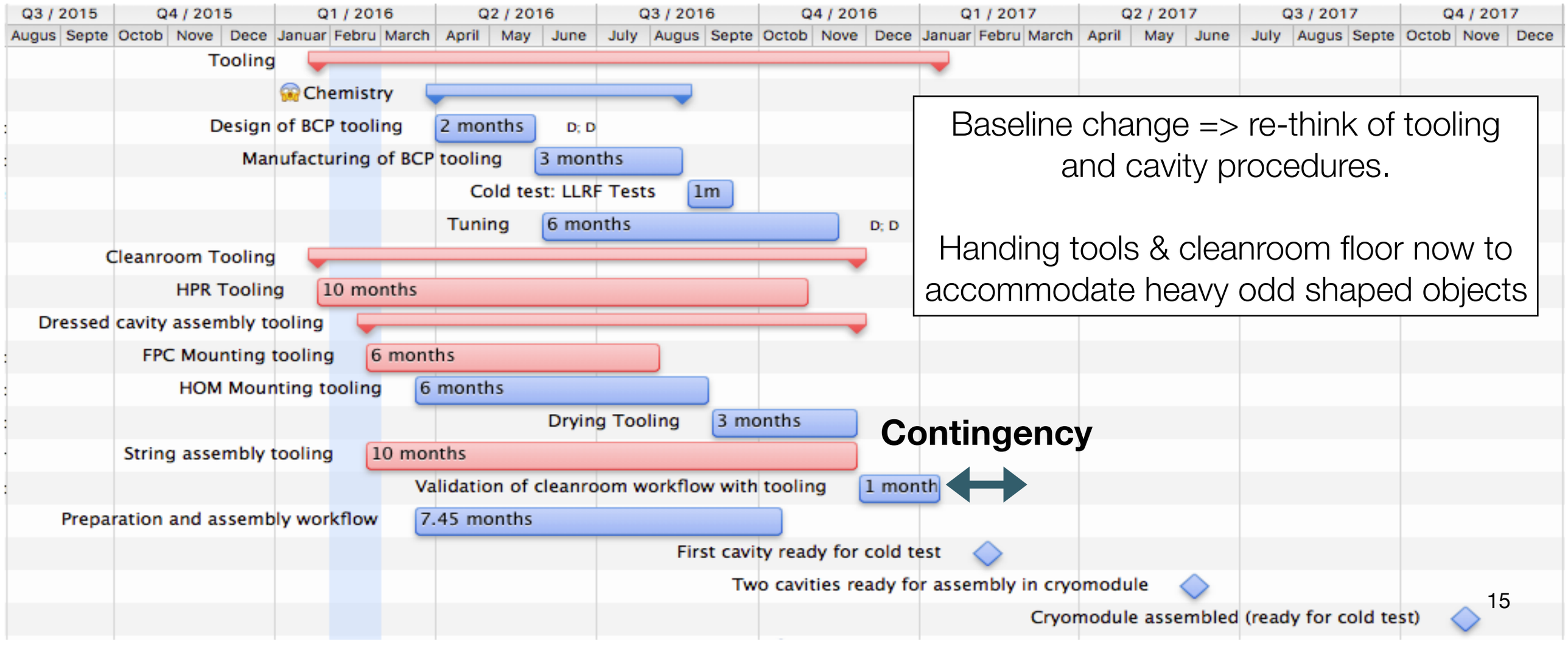


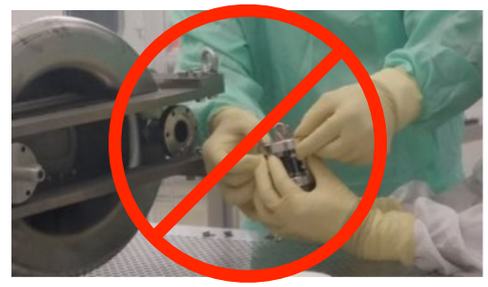

Baseline change => re-think of tooling and cavity procedures.

Handing tools & cleanroom floor now to accommodate heavy odd shaped objects

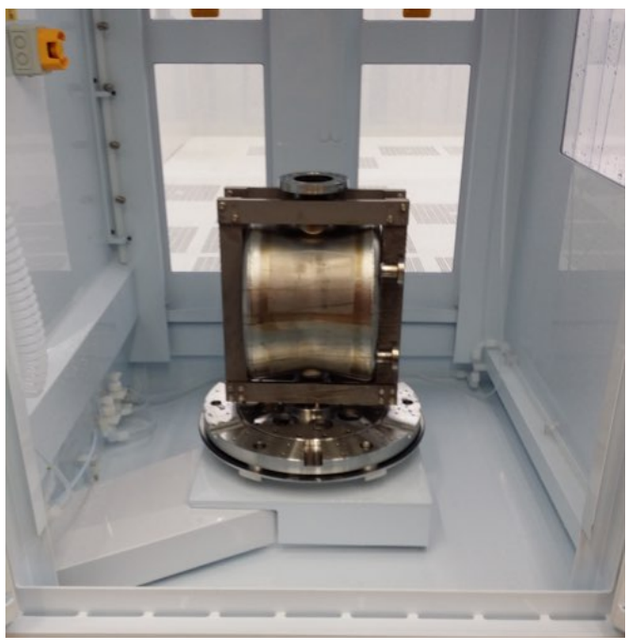
**Contingency**

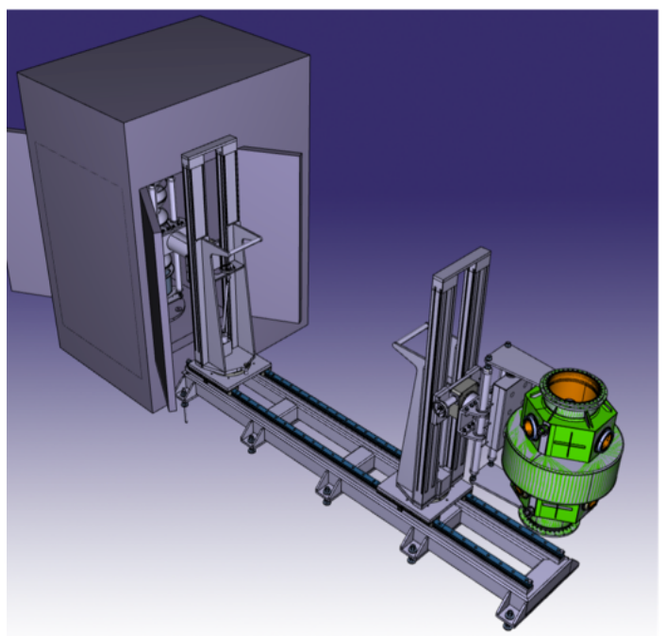
# Cleanroom Tooling

- **Tooling needed to minimise risk of RF Surface contamination**
  - Full set of tooling to be developed for handling bare cavities
  - **FPC and HOM Coupler Tooling starting with BE-RF-PM**
  - String Assembly Tooling
    - **Conceptual study by EN-MME. Now match to cleanroom procedure**



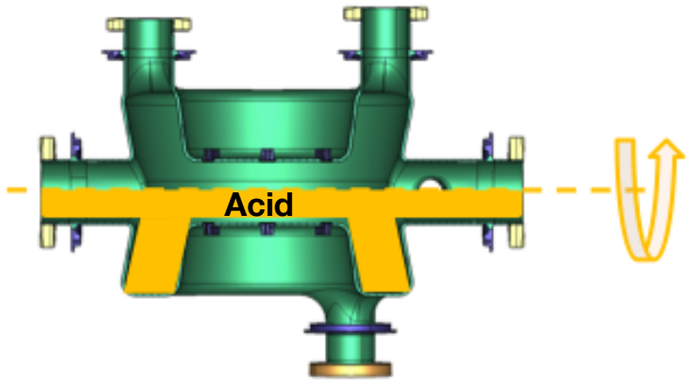
- **SM18 Cleanroom**
  - High Pressure Rinsing (HPR) of bare and dressed cavities
    - **Have to evolve HPR & drying tools to achieve RF-surface quality**
      - Necessary tooling requires reinforcement of Cleanroom flooring
  - HPR tooling from external suppliers, but expertise developed in-house

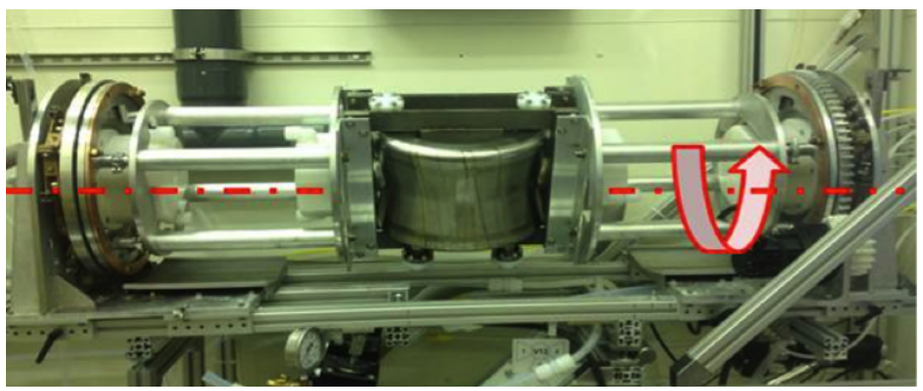




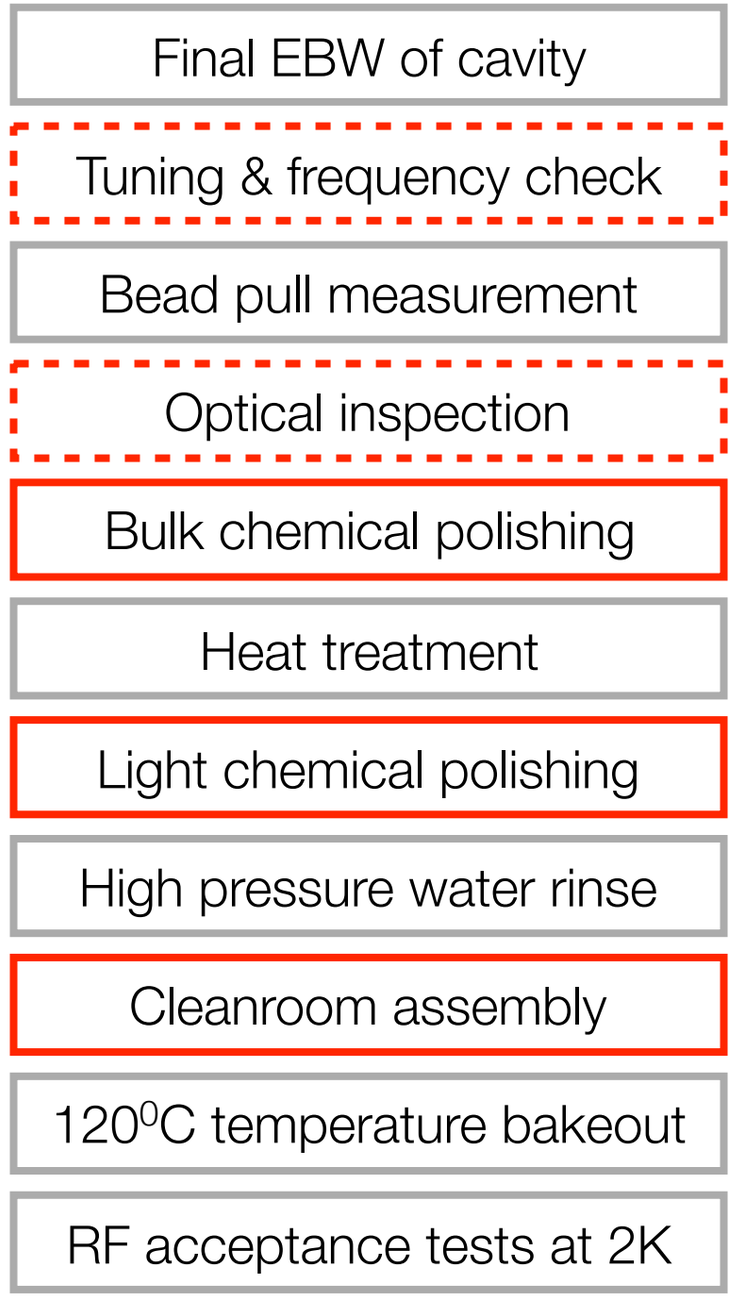
# RF Surface Preparation

- **Baseline  change => cavities now being produced at CERN => chemical preparation of RF surface must also now be done at CERN**
- **Crab collaboration is now defining the required chemistry process**
  - Chemistry: Buffer Chemical Polishing
    - Specifications to being finalised
    - CERN ready to process cavities for SPS but within facilities restrictions
      - **BCP to be done as per PoP cavities**



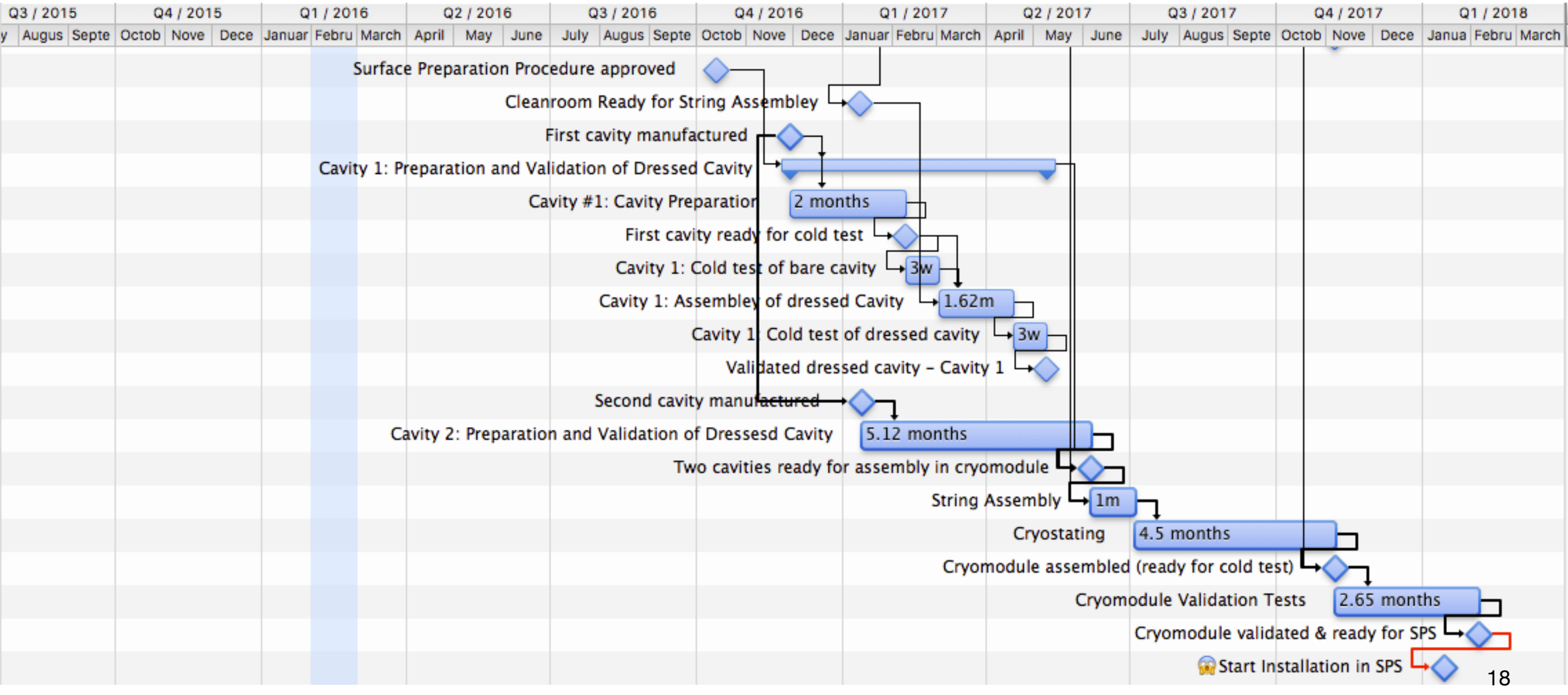



- **High Pressure Rinsing**
  - HPR process well defined in SM18
    - Drying procedure needs validation
    - Verification of RF surface preparation



# Cavity and cryomodule assembly

- **Delivery of 1st cavity in Nov 2016 => full program with no contingency**
  - Present planning with full set of RF validation tests of CM: slightly too long
    - Planning to be optimised now tooling and workflow better understood
- **Handover of CM from SM18 to SPS: after 2017/18 Christmas stop**
  - Minimum time estimated for CM and service box installation



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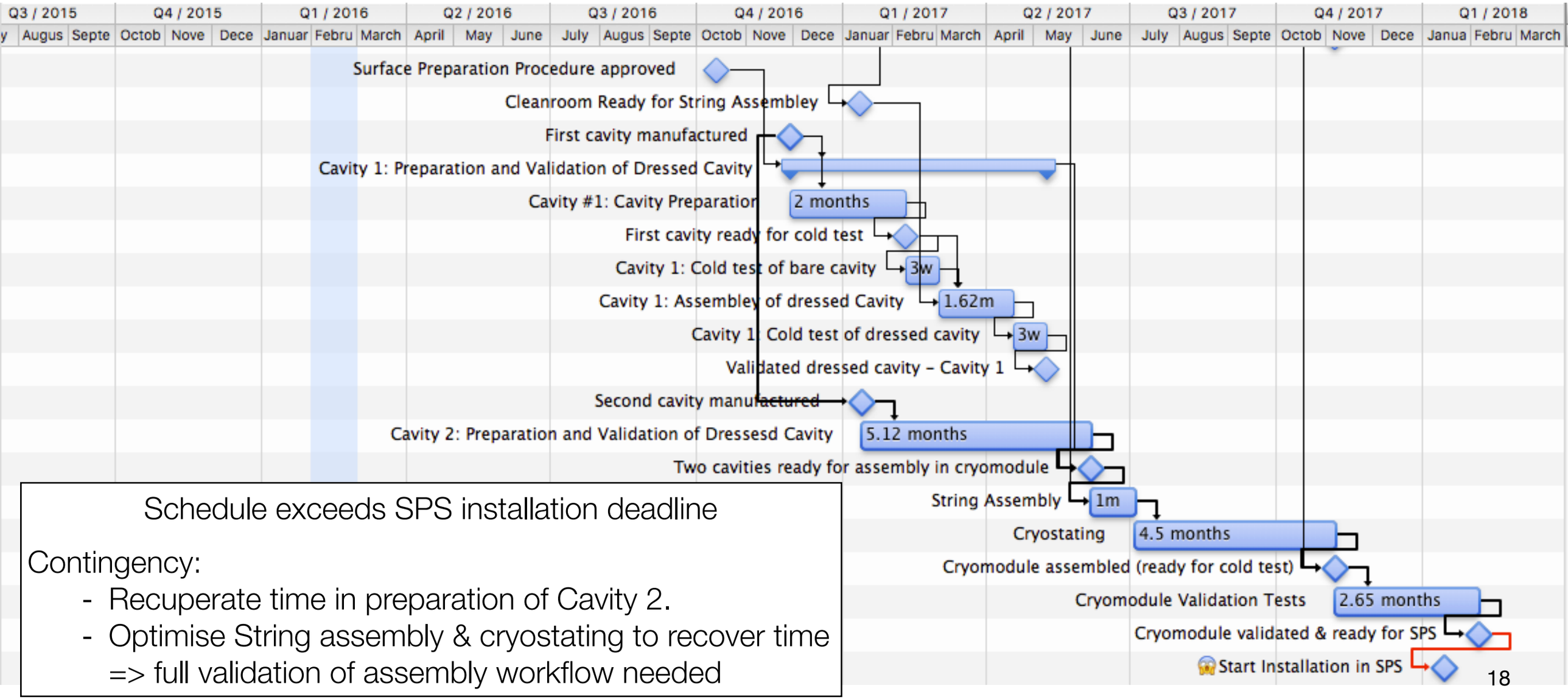


Schedule exceeds SPS installation deadline

Contingency:

- Recuperate time in preparation of Cavity 2.
- Optimise String assembly & cryostating to recover time
  => full validation of assembly workflow needed

# Cryomodule validation tests in SM18_M7

- **Tight program of validation tests**
  - Prior to tests expect 2 wks of cooldown & Cryo commissioning without RF
  - **Must  have top priority for helium in SM18 during this period**
- **RF measurements**
  - Cavities conditioned in parallel (24 hr/day  activity) => difficult to reduce
- **Note: Time estimates are very tight, esp. as testing crab CM for 1st time**
  - Team to gain experience with vertical tests of bare crabs & with LHC CMs
  - CM test straddles Christmas break: availability of Helium & personnel

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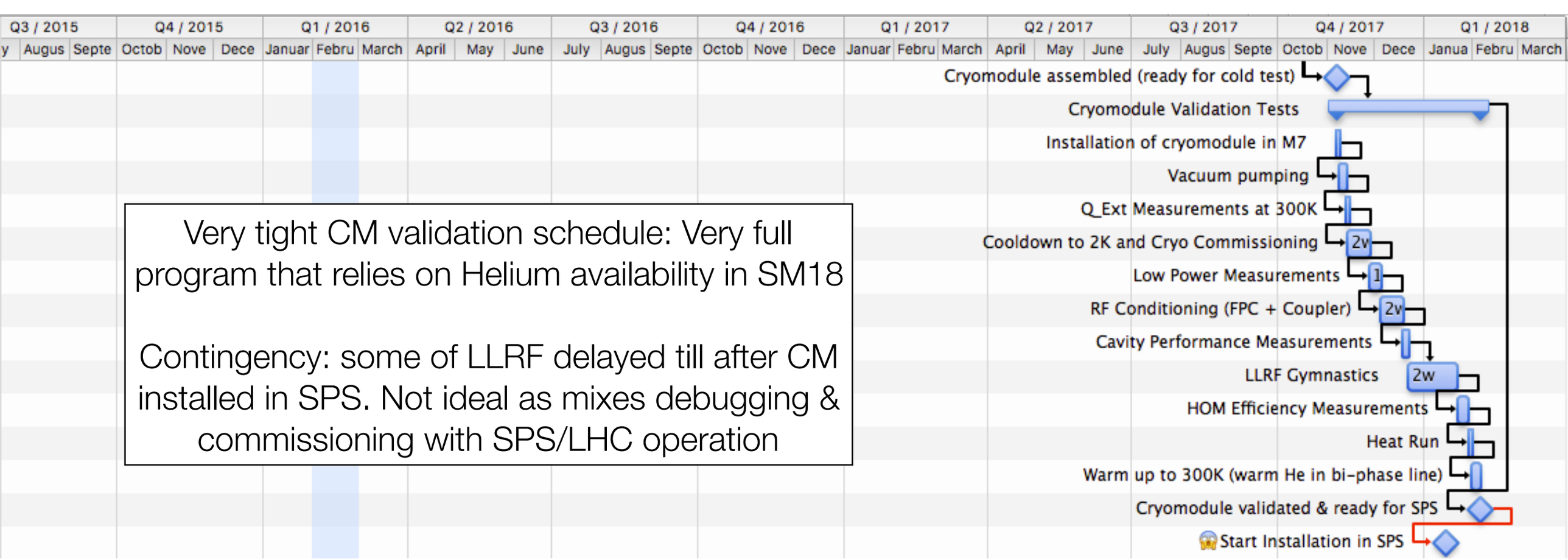
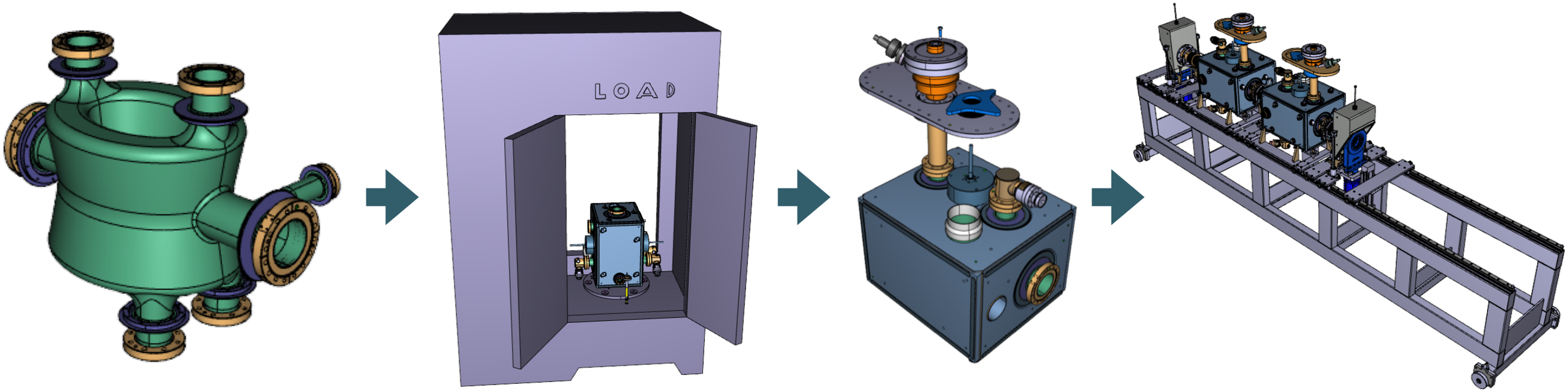
Very tight CM validation schedule: Very full program that relies on Helium availability in SM18

Contingency: some of LLRF delayed till after CM installed in SPS. Not ideal as mixes debugging & commissioning with SPS/LHC operation

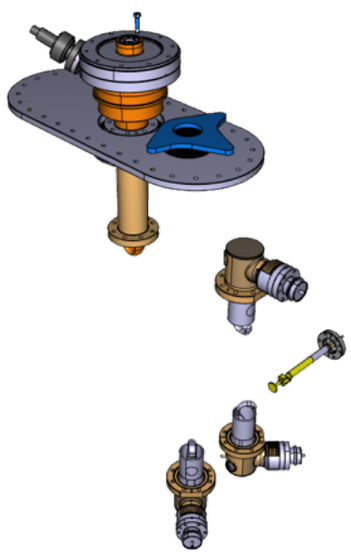


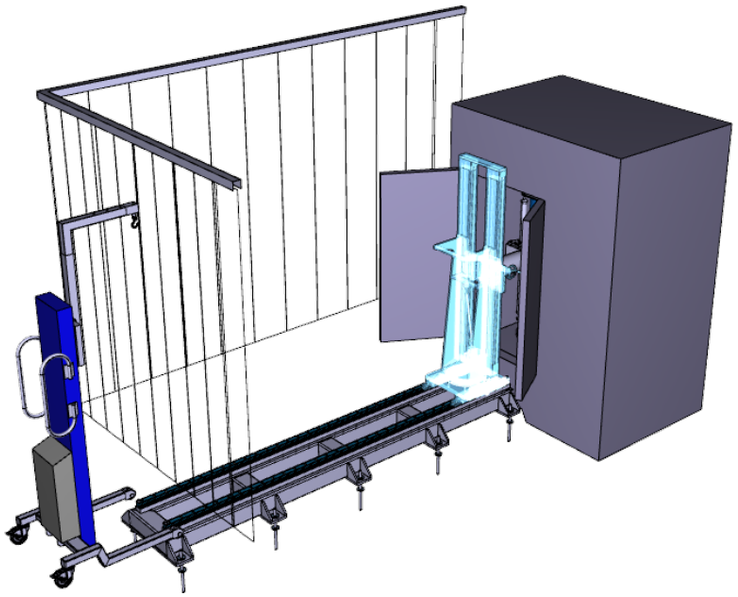
# String Assembly

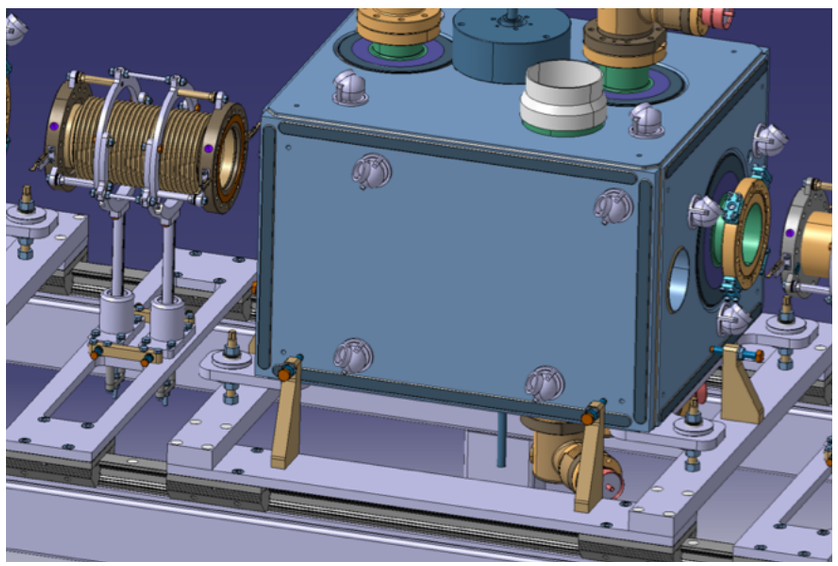
- **String assembly workflow**

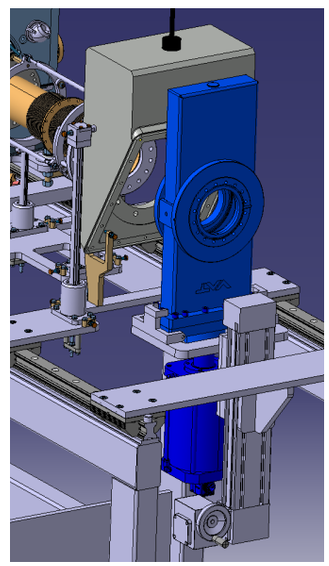



- **Each step requires tooling: design starting now workflow is understood**
  - At present we start to debug interfaces & assembly sequence issues



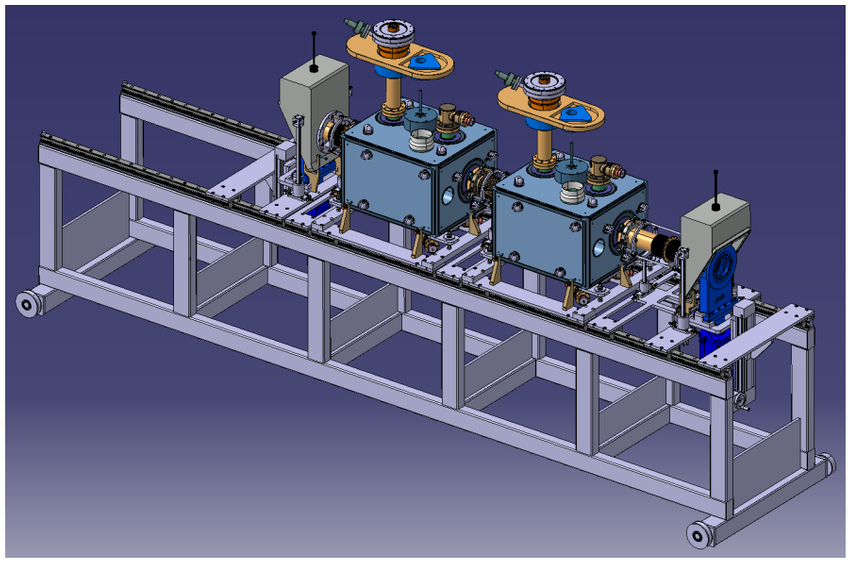


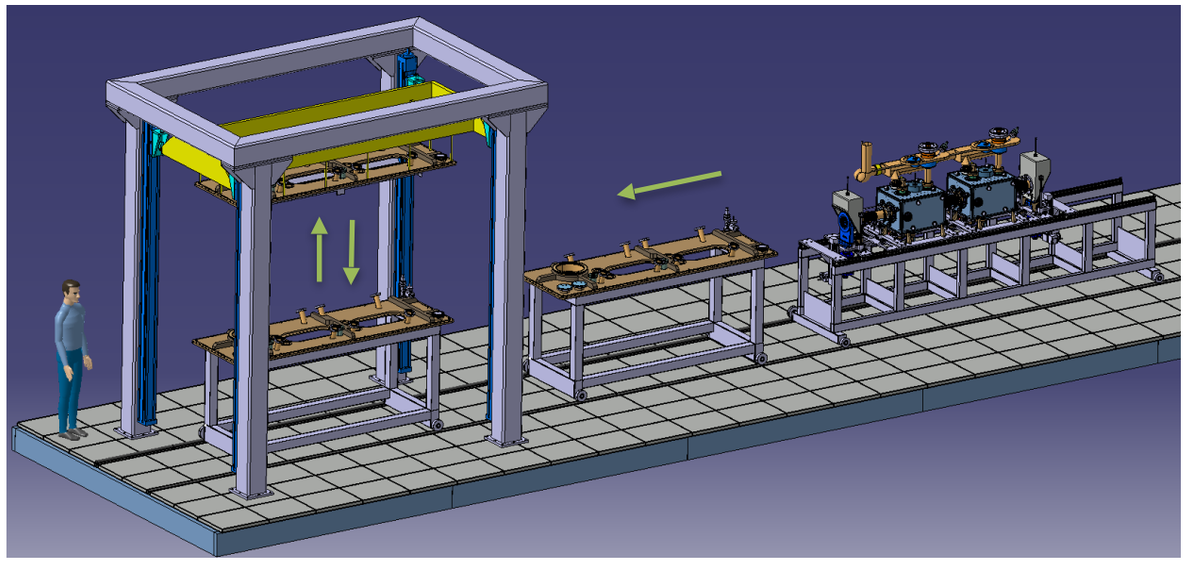


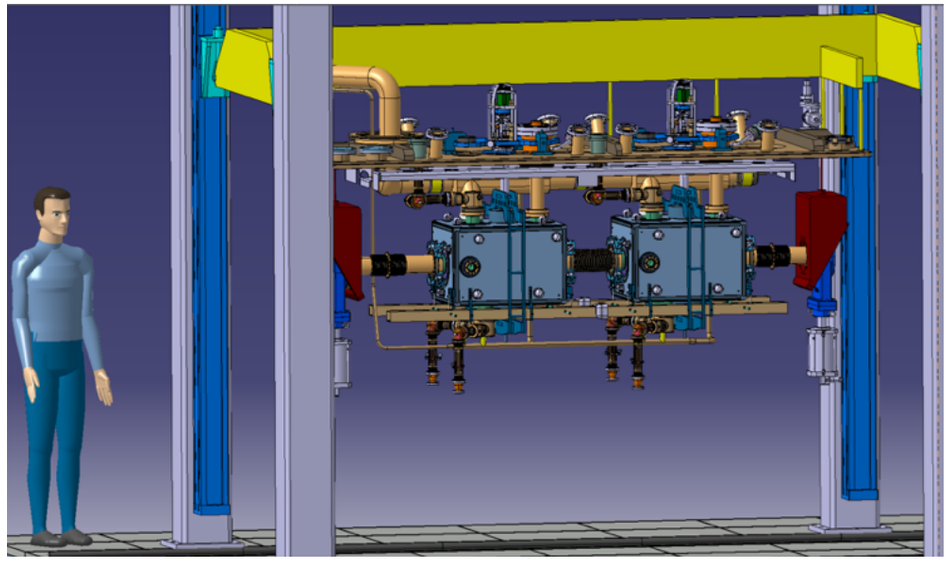


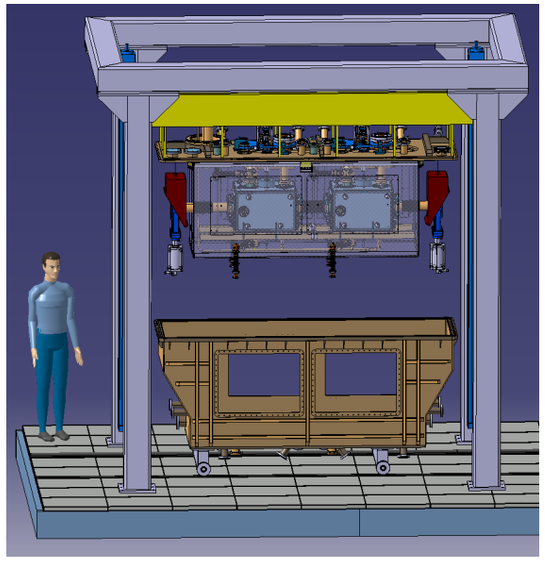
# Cryostating

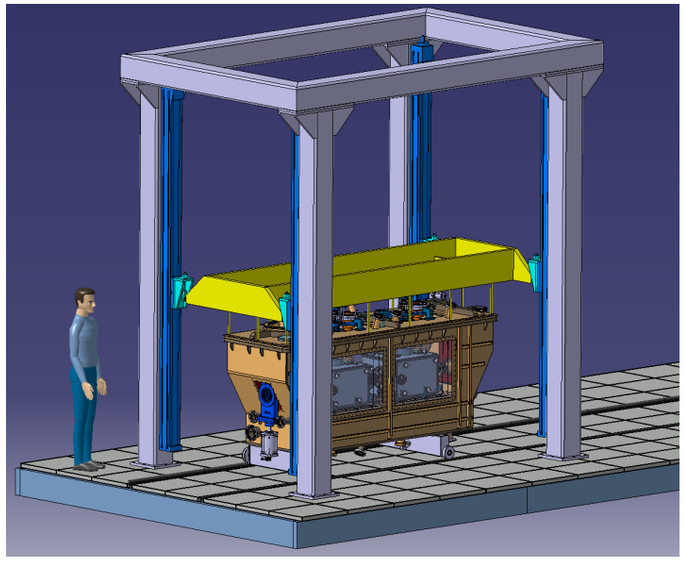
- **Procedure as presented at the Crab Cryomodule Review in Nov 2015**
  - Activity done outside cleanroom after string assembly
  - Work is under responsibility of EN-MME (O. Capatina)











# Activities: open issues and concerns

- **Tooling**
  - Design, workflow and procedures: Shared between EN-MME, BE-RF
    - Wide variety of tooling issues: Chemistry & Tuning to bet addressed
- **Cavity Testing:**
  - Well established team within BE-RF-SRF.  Infrastructure to be validated in 2016
- **Cleanroom assembly**
  - HPR Tooling:  Commercial supplier being sought.
  - FPC & HOM coupler mounting: Conceptual sequences being set with BE-RF-PM
  - Cleanroom: Shared between several projects. Priority scheduling needed
- **Cryogenics**
  - Finalisation of distribution line needed: BE-RF co-supporting TE-CRG fellow
- **LLRF Testing:**
  - LLRF development by BE-RF-FB. Needs FESA development support
- **Power installation and  Cabling**
  - To be scheduled such that minimises disruption to SM18_RF testing schedule

# Summary

- **Cryomodule Assembly: Mature CM design allows finalised workflow**
  - Tooling and procedures now starting to be addressed
- **Project Baseline shift to CERN providing cavities**

  => must now ensure an established RF surface preparation & cavity testing process
- **Infrastructure in SM18**
  - Refurbishment continues. Vertical test stand mostly done. M7 Bunker just starting
- **Schedule**
  - Cavity construction + cavity testing + CM assembly + CM validation defines critical path

    => Cryomodule validation time in SM18 is very tight
- **Resources**
  - SM18_RF: Small expert team (1.5 staff, 2 fellow 1 PhD student). Sufficient
  - Technical support (Preparation & Cleanroom): 3 staff shared by 3 high priority projects
  - Manpower now being re-assessed wrt all SRF projects: Resources should be invested in 2016 for cleanroom and cyrostating preparations to validate workflow and procedures
- **Overall:**
  - Project has back-loaded schedule, but do-able. Need to recover several weeks in cavity testing and/or CM assembly.
    - Requires 2016 be used for SM18 to develop cleanroom tooling & procedure & team

# Cryostating: Compatibility of Activities

- **Cryomodule assembly**
  - Cryostating area to be used for LHC and Crabs, & other projects
  - Available space compatible (in principle) with parallel assembly programs
    - Parallel programs possible but not covered in terms of manpower