Strategy for Integration & Services

G.Vandoni

International review of the Crab cavity system design and production plan for the HL-LHC, 19-21 June 2019

SPS crab-cavity test stand as a

- scaled-down
- complete
- integrated in machine

crab-cavity system with all related services

→ SPS learned view of integration of crab system

→ Interfaces to other systems identified

→ Sequencing of installation

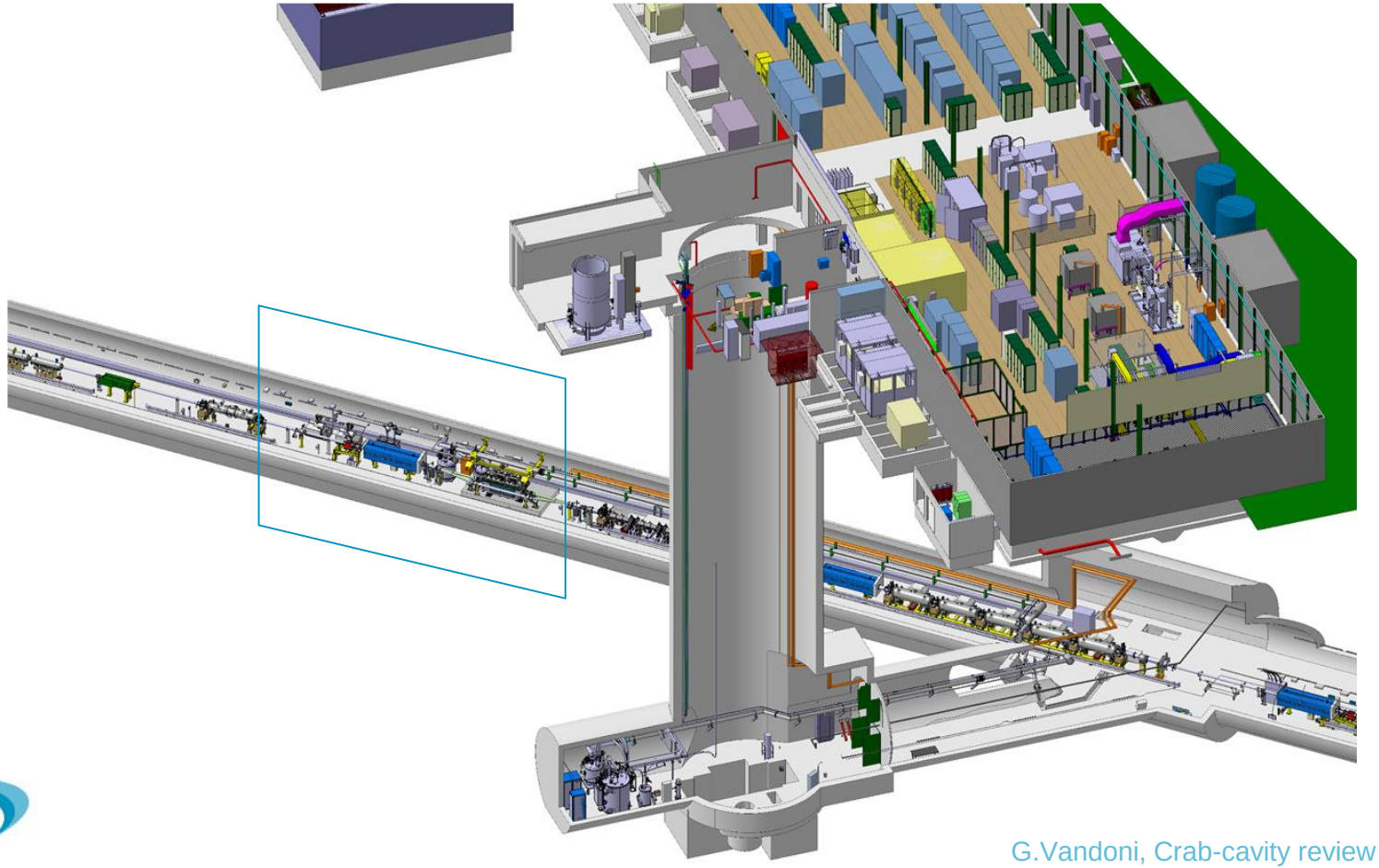
Ensure no

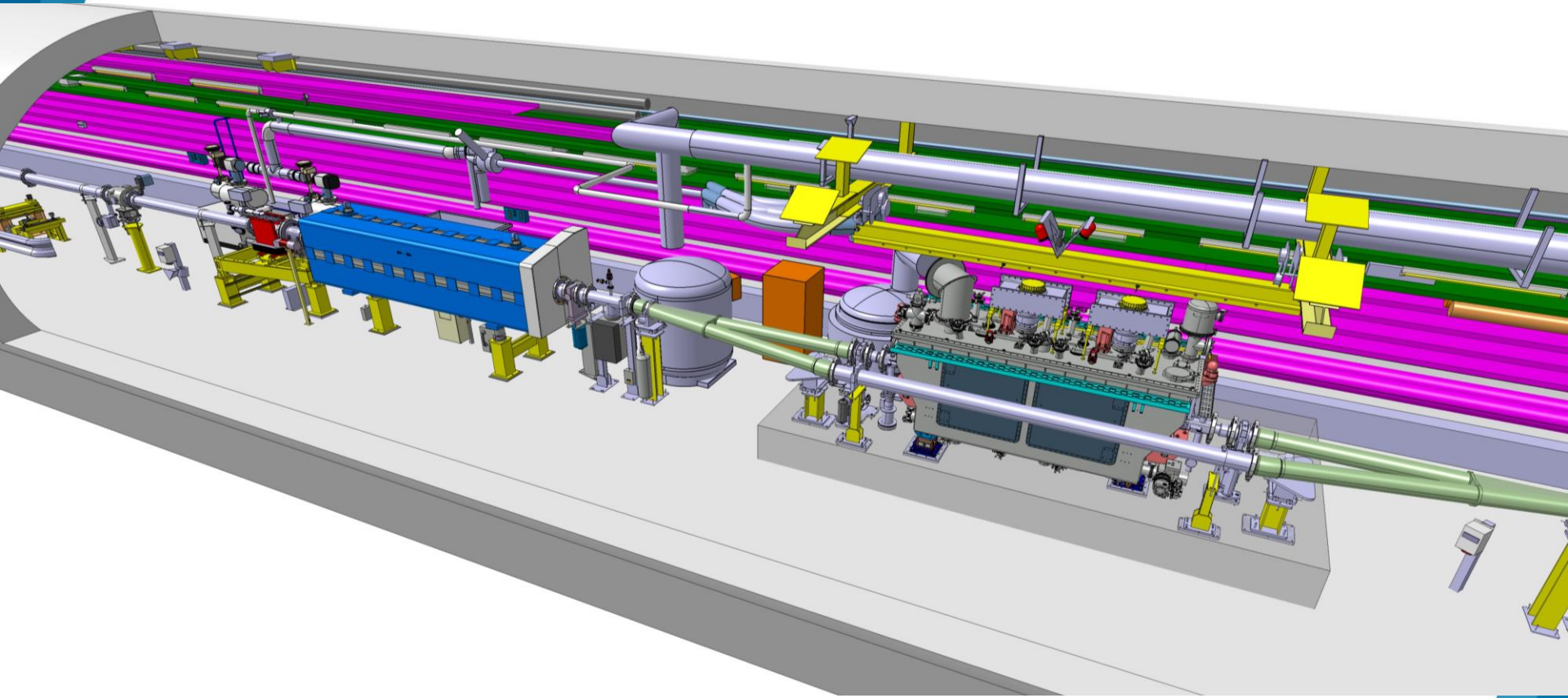
- deliverable
- service
- spec

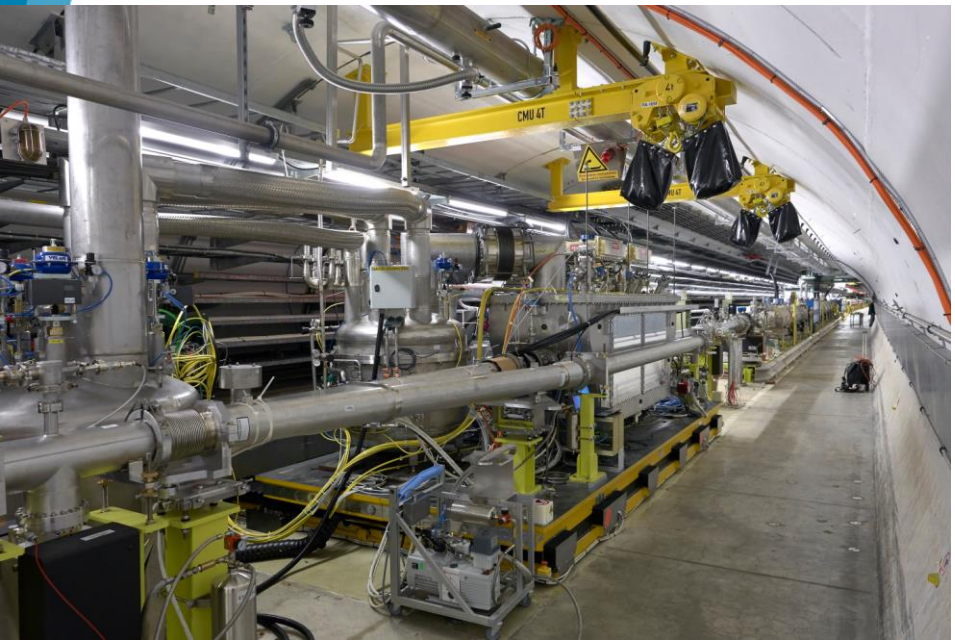
is orphan in **crab-cavity system**

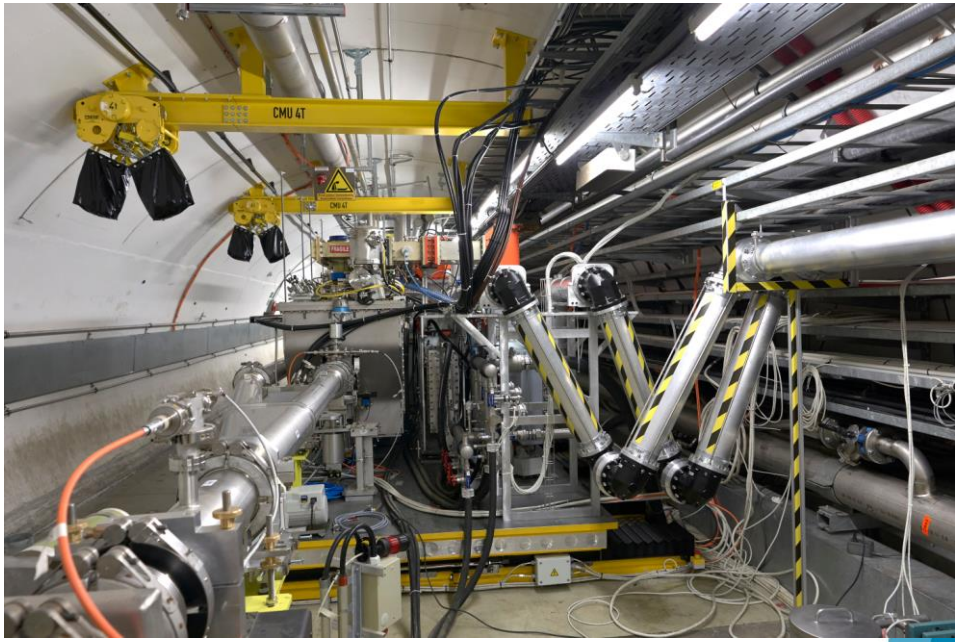
HL-LHC WP4 = “Crab-cavity system”

SPS crab-cavity test stand & infrastructure



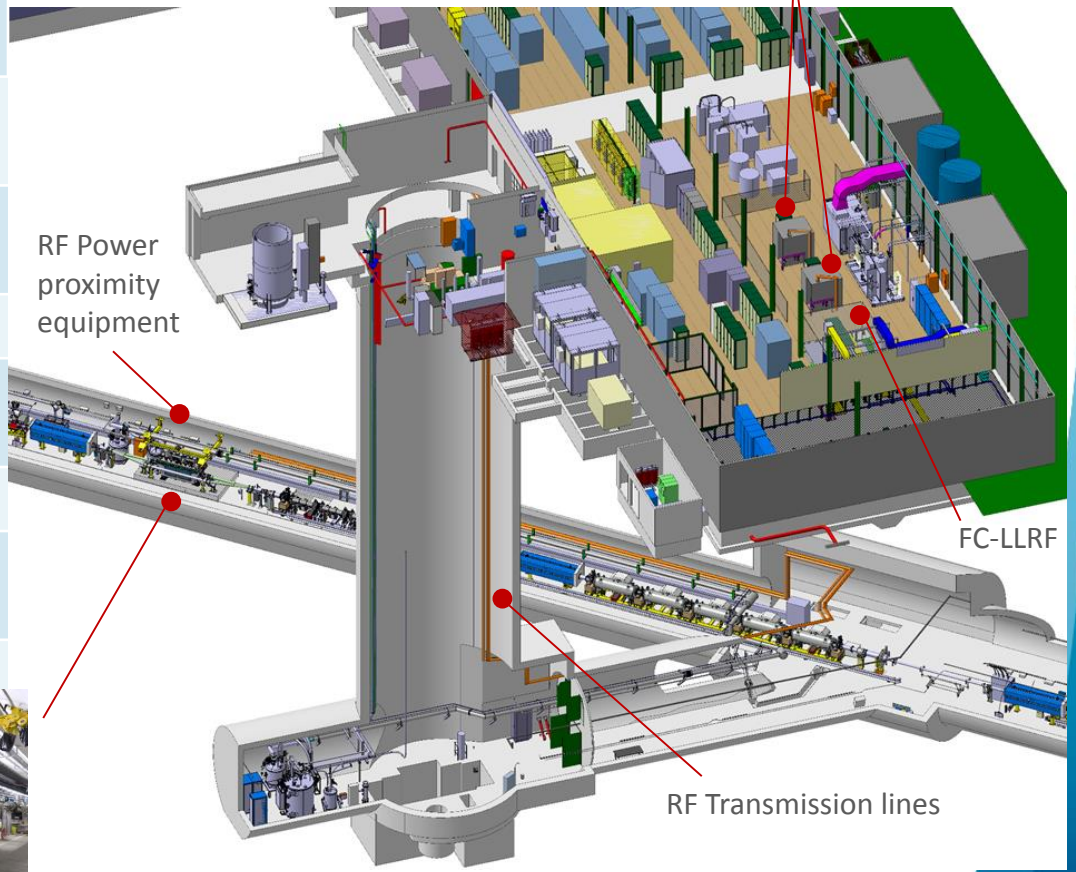



CMU 4T

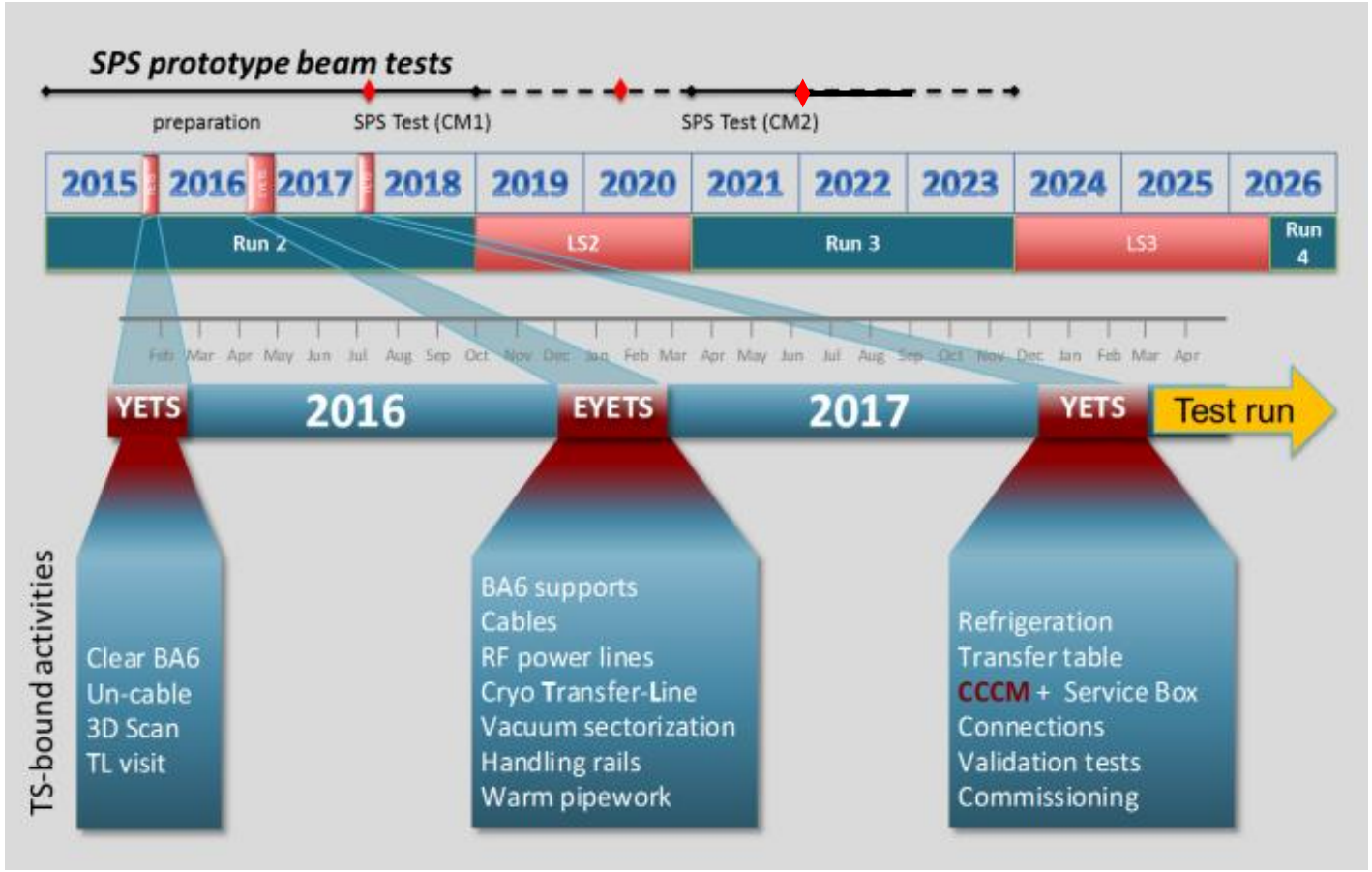

CMU 4T

Integration of crab-system in SPS

Cryogenics	Refrigeration Distribution/ Buffer/ storage
Vacuum	Vacuum sectorization, Y-chambers
Electrical distribution	Transformer Switchboards, UPS
Controls	Racks, cryo control room
Ventilation	Forced ventilation unit for Faraday Cage (FC)
Infrastructure	Cables, supporting structures
Safety	ODH detectors /beacons Interlocks: access, table movmnt
CM support	Motorized transfer table



Installation in Technical stops – overview



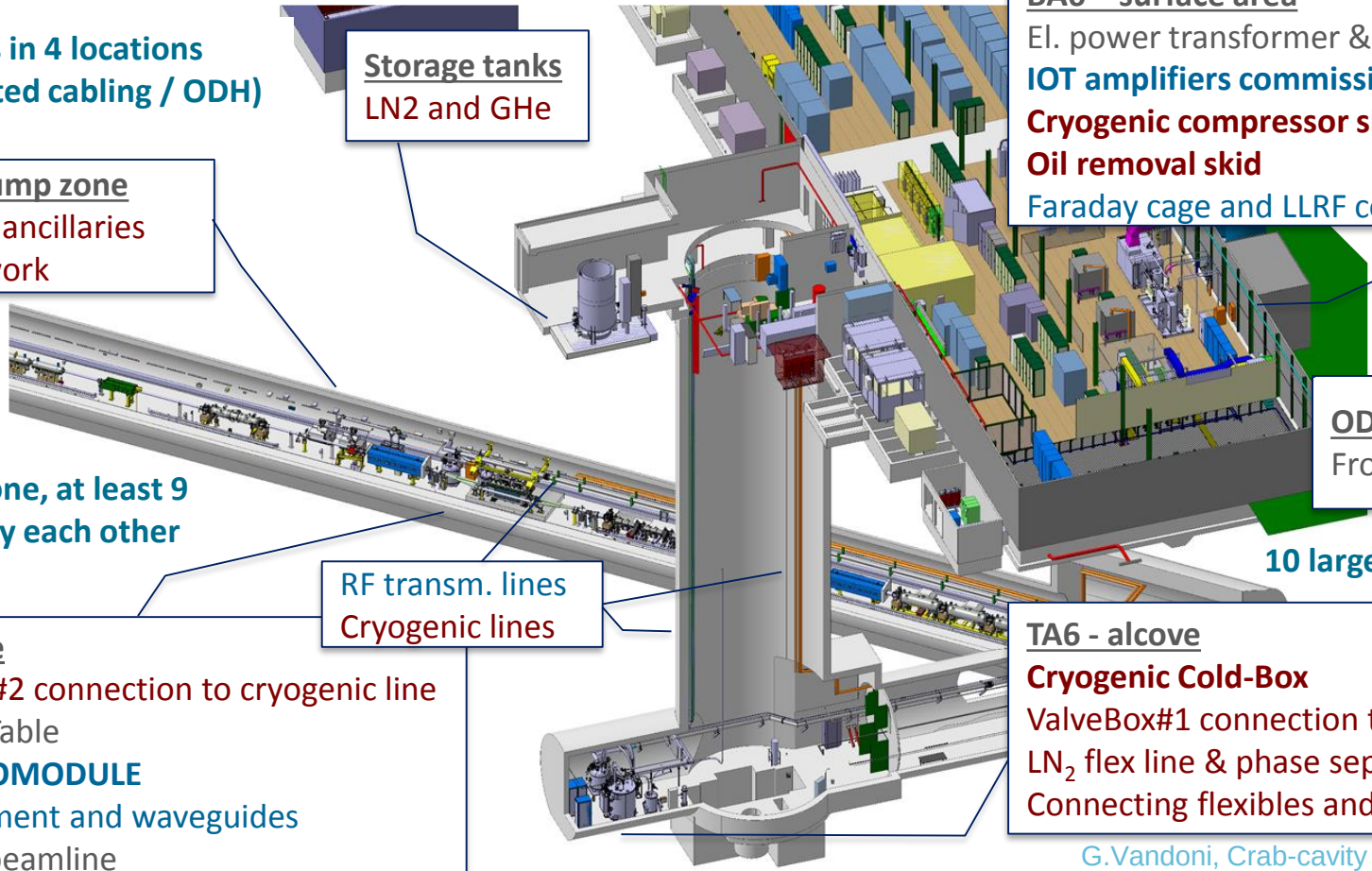
Installation in 2018 Technical stop – overview

~20 teams in 4 locations
(+distributed cabling / ODH)

Storage tanks
LN2 and GHe

Helium pump zone
Cryogenic ancillaries
and pipework

BA6 – surface area
El. power transformer & switchboards
IOT amplifiers commissioning
Cryogenic compressor skid
Oil removal skid
Faraday cage and LLRF commissioning



ODH and Alarms
From TS6- to TS6+

On crab-zone, at least 9
teams relay each other

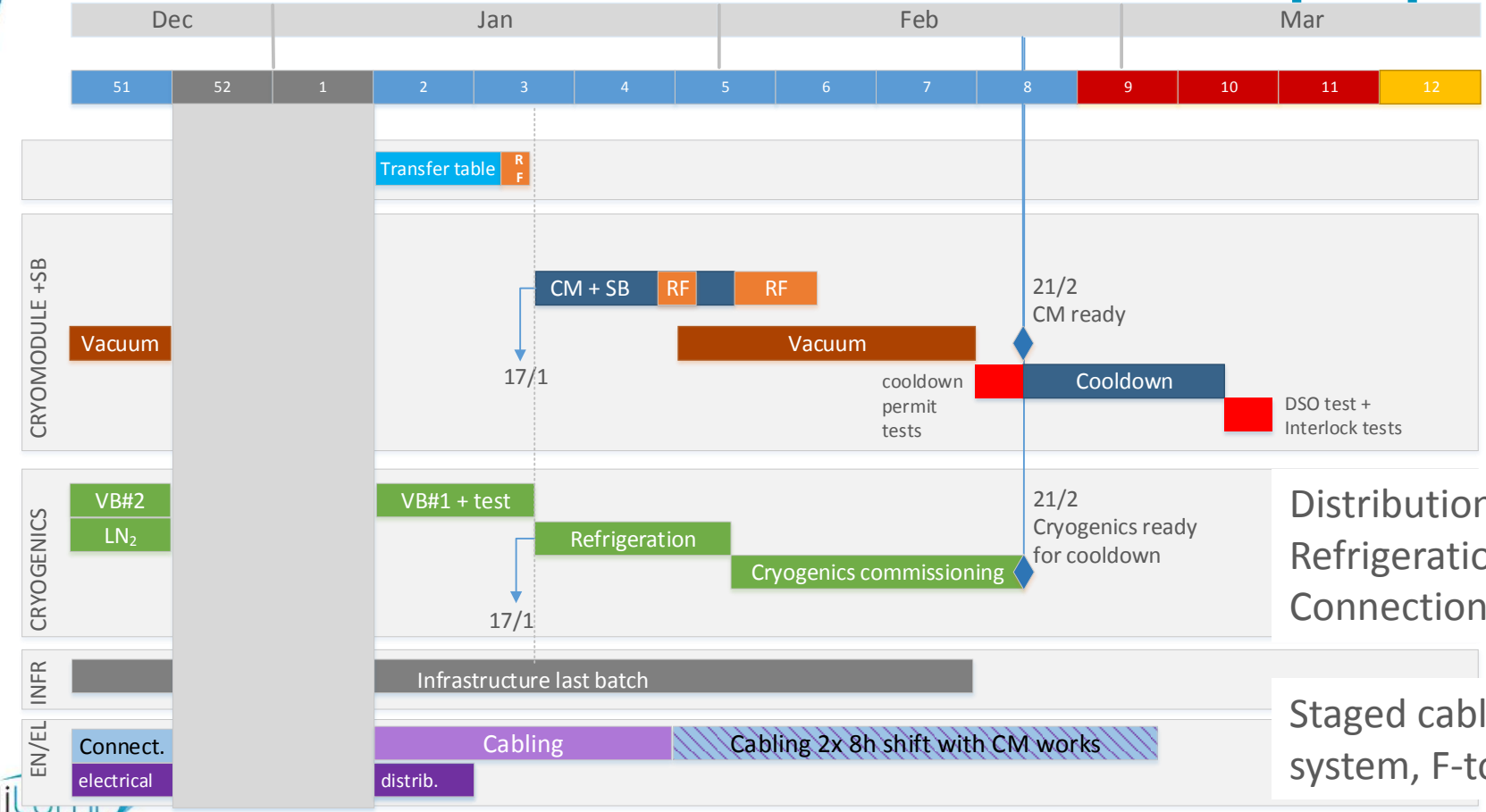
10 large transport items

RF transm. lines
Cryogenic lines

Crab zone
ValveBox#2 connection to cryogenic line
Transfer Table
SB + CRYOMODULE
RF equipment and waveguides
Vacuum beamline

TA6 - alcove
Cryogenic Cold-Box
ValveBox#1 connection to cryogenic line
LN_2 flex line & phase separator
Connecting flexibles and pipework

Installation in 2017-2018 Technical stop – plan

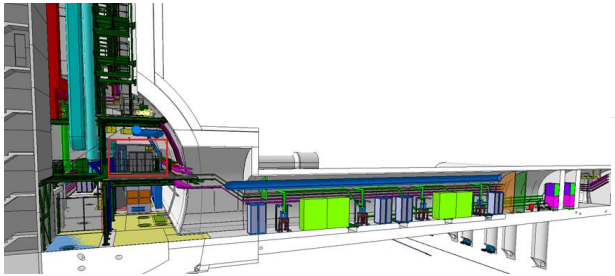


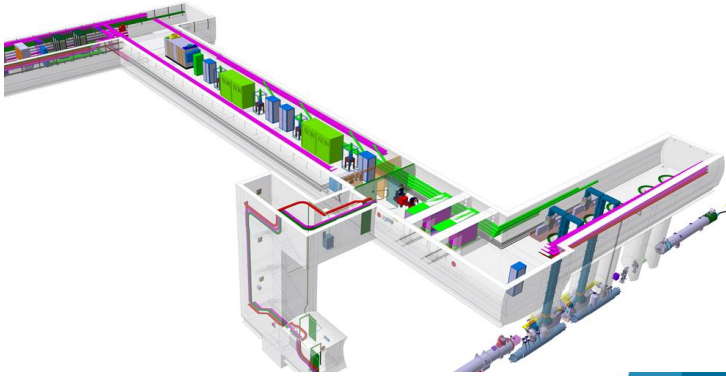
Distribution
Refrigeration
Connections

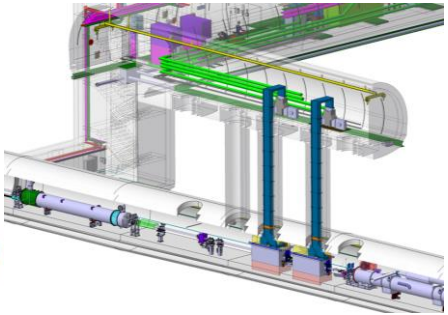
Staged cabling by system, F-to-F

Crab-cavity system integration in HLLHC

→ P.Fessia, Friday morning



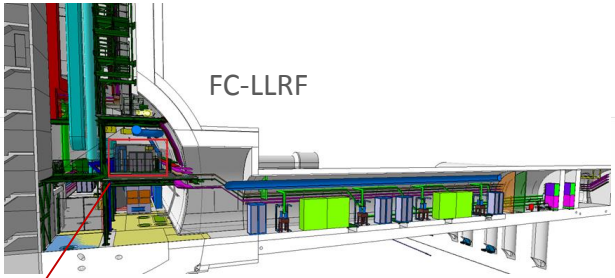




P5, for illustration only, courtesy M.Gonzalez

Crab-cavity system integration in HLLHC

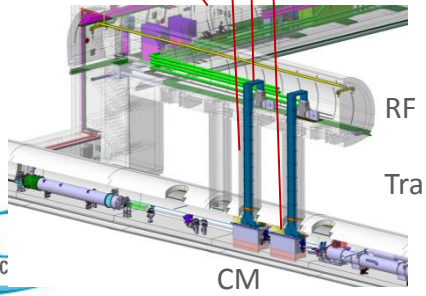
→ P.Fessia, Friday morning



FC-LLRF

FC-LLRF

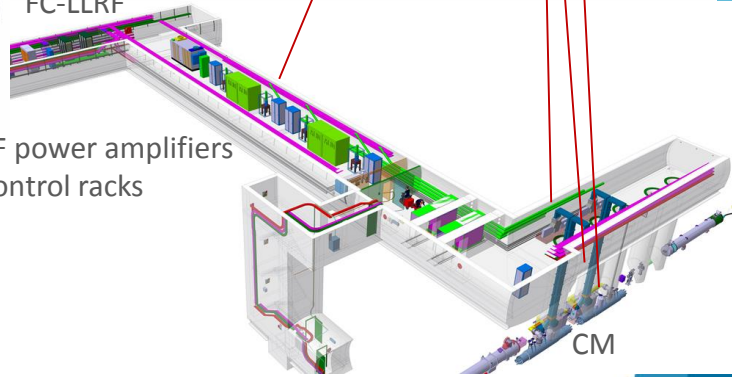
RF power amplifiers
Control racks



RF Power passive proximity equipment

Transmission lines

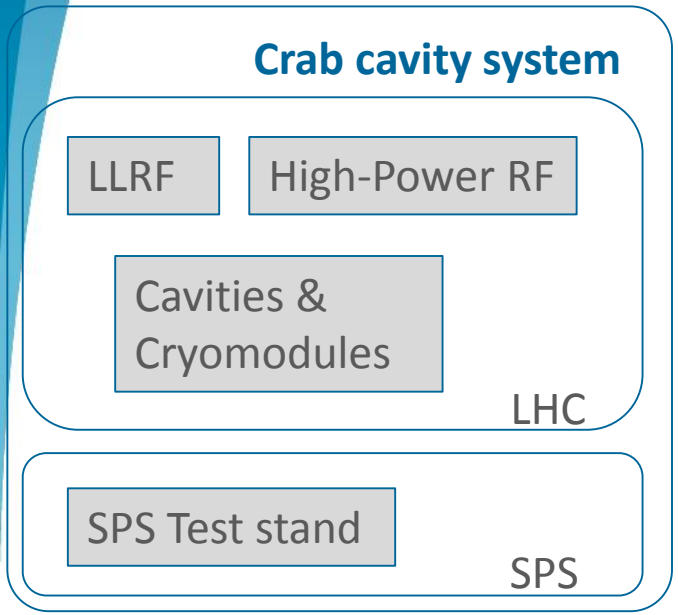
CM



CM

P5, for illustration only, courtesy M.Gonzalez

Overall interfaces of Crab-cavity system

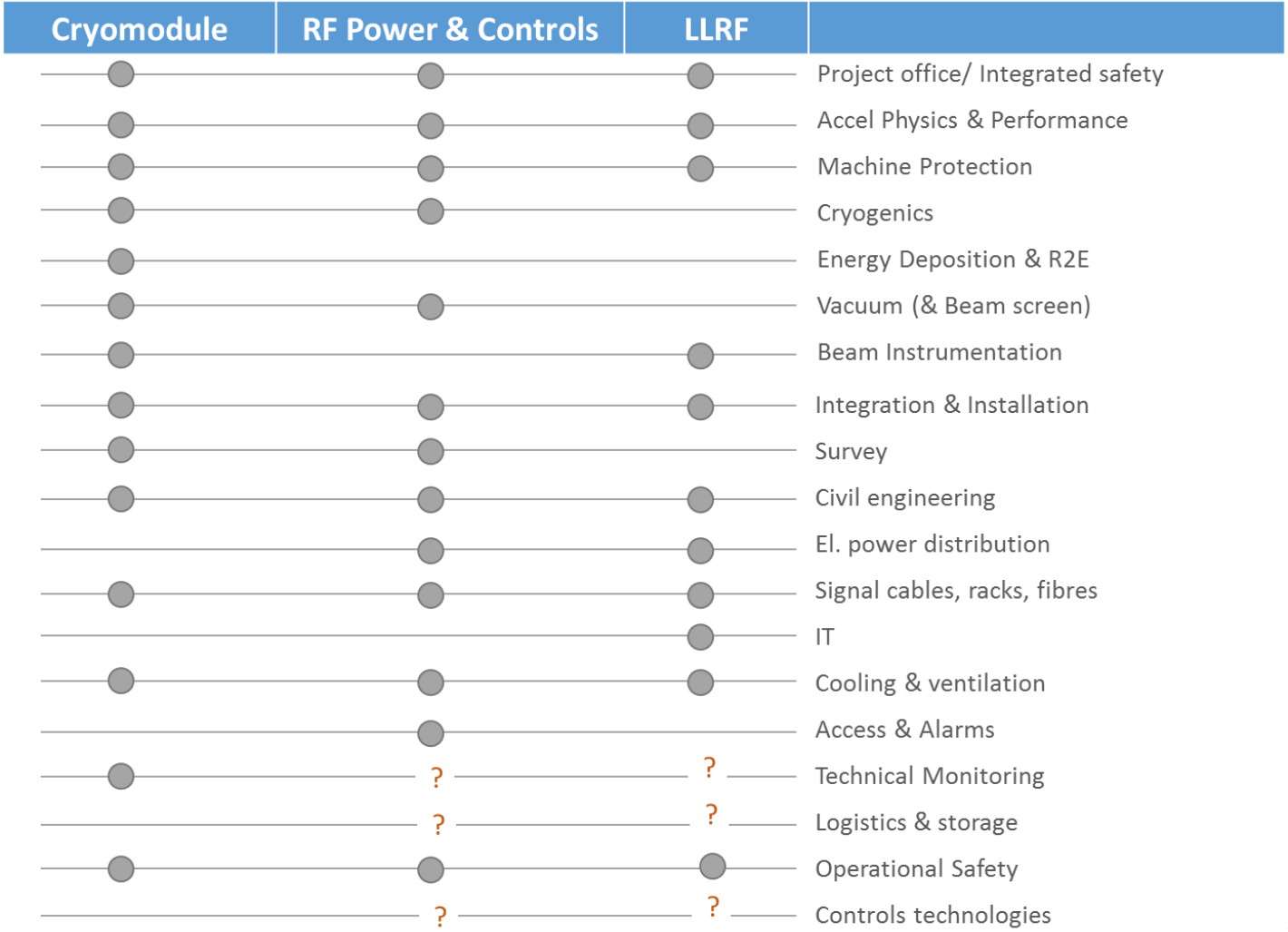


- Project office/ Integrated safety
- Accel Physics & Performance
- Machine Protection
- Cryogenics
- Energy Deposition & R2E
- Vacuum (& Beam screen)
- Beam Instrumentation

- Integration & Installation
- Survey
- Civil engineering
- Electricity: el. power distribution
- Electricity: signal cables, racks, fibres
- IT
- Cooling & ventilation
- Access & Alarms
- Technical Monitoring
- Logistics & storage
- Operational Safety
- Controls technologies

Interfaces specific to each sub-system of crab system detailed slides 14-17

INTERFACES


Cryomodule
RF Power & Controls
LLRF
Project office/ Integrated safety
Accel Physics & Performance
Machine Protection
Cryogenics
Energy Deposition & R2E
Vacuum (& Beam screen)
Beam Instrumentation
Integration & Installation
Survey
Civil engineering
El. power distribution
Signal cables, racks, fibres
IT
Cooling & ventilation
Access & Alarms
Technical Monitoring
Logistics & storage
Operational Safety
Controls technologies
?

Overall interfaces of Crab-cavity system – CM –

Electricity
Signal & Control cables

Cooling & Vent
Coupler's cooling

RF Power
Power lines/ Local signal coax

Energy Dep & R2E
Dose estimates

Cryogenics
Refrig. & distribution

WP4	**RF Power**		Power & HOM couplers
CRYOMODULE	**Cryogenics**	spec	cryogenic lines
		deliv	cryo instrum
	Vacuum	spec	beam/ insul vacuum
		deliv	beam screen & transitions
		serv	acceptance tests
	Survey	deliv	FSI
		serv	Knowledge transfer

Vacuum
Beam/ Insul vacuum
Intermodules

Beam Instr
BI for HL-LHC/ crabs: head-tail, streak camera…
Wide-band longitudinal pick-ups for LLRF

Survey
Jacks
Remote alignment

Civil Eng
Tunnel surfacing

WP4 : activity & budget
Services: activity in unit, budget in WP4

HL-WPs: activity & budget
To define

Overall interfaces of Crab-cavity system – CM –

Electricity
Signal & Control cables

Cooling & Vent
Coupler's cooling

RF Power
Power lines/ Local signal coax

Energy Dep & R2E
Dose estimates

Cryogenics
Refrig. & distribution

CRYOMODULE WP4	**RF Power**		Power & HOM couplers
	Cryogenics	spec	cryogenic lines
		deliv	cryo instrum
	Vacuum	spec	beam/ insul vacuum
		deliv	beam screen & transitions
		serv	acceptance tests
	Survey	deliv	FSI
		serv	Knowledge transfer

Vacuum
Beam/ Insul vacuum
Intermodules

Beam Instr
BI for HL-LHC/ crabs: head-tail, streak camera…
Wide-band longitudinal pick-ups for LLRF

Survey
Jacks
Remote alignment

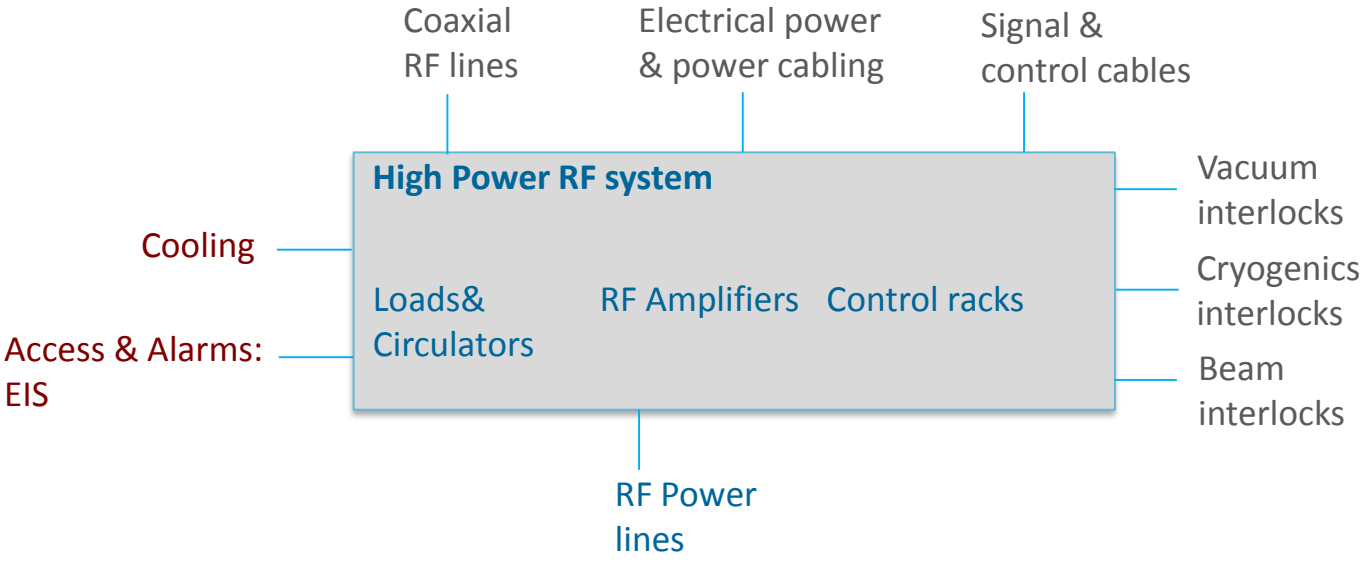
Civil Eng
Tunnel surfacing

SERVICES
Integration
Installation transport
Connection of systems
Validation tests
Technical monitoring
Alarms & Access

WP4 : activity & budget
Services: activity in unit, budget in WP4

HL-WPs: activity & budget
To define

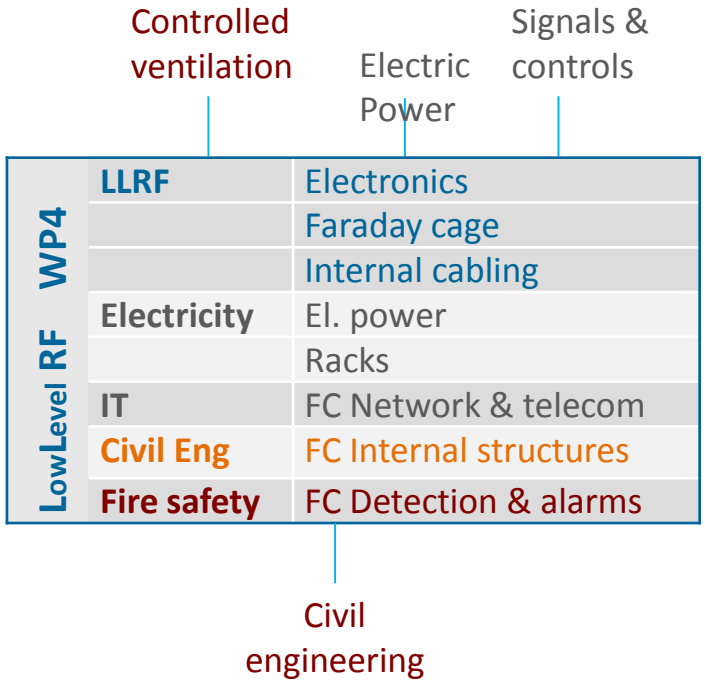
Overall interfaces of Crab-cavity system – RF Power/Controls –



WP4 : activity & budget — **HL-WPs**: activity & budget

Services: activity in unit, budget in WP4 — **To define**

Overall interfaces of Crab-cavity system – LLRF Infrastructure –



WP4 : activity & budget

Services: activity in unit, budget in WP4

HL-WPs: activity & budget

To define

Integrated safety – SPS lesson & methodology

SAFETY DOMAINS	
Mechanical	Pressure, Vacuum, Lifting, Mech. energy, hot works, hot surfaces
Cryogenic	Cryogenic fluids
Structural	Bearing structures
Electrical	Electrical equipment, HV equipment, UPS
Non-ionizing rad	RF, Laser
Workplace	Noise, Temperature, work at height
Environment	Potentially polluting substances
Worksite	Construction, dismantling, co-activity
Fire	Non-standard layout, combustible material

- All sub-systems registered
- All locations registered
- All hazards identified

PRELIMINARY Risk analysis

⬇

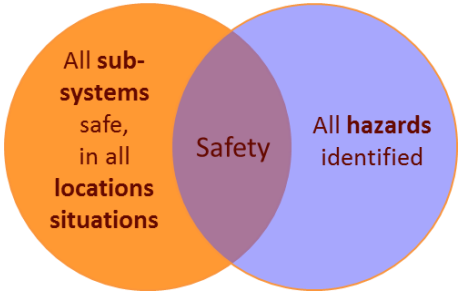
set of actions

⬇

FINAL Risk analysis

SPS test stand Safety file:

- Descriptive part
- Demonstrative part
- Operational part



Status of Interface definition

System	Status	Needed
PO Integrated safety	SPS Safety file checked, to approve	In progress for LHC
Accel Physics & Performance	Work in progress ECR integration modification	Beam based cavity alignment Cavity field quality requirements
Machine Protection	Failure modes under study in SPS	In progress
Cryogenics	Specifications defined	Proposal for cryo sectorization CM cryo instrumentation Integration QXL to jumper Definition of work share at interfaces
Energy Deposition & R2E	In progress	Specific simulation scores asked
Vacuum (& Beam screen)	Summary document in approval	NTH
Beam Instrumentation	In progress	Wide-band longitudinal pick-ups to simplify

G.Riddone, Friday

Status of Interface definition

System	Status	Needed
Integration & Installation	ECR integration modification Transport share defined	Transport specifications to be worked out as design progresses
Survey	Summary document in review	Jacks choice
Civil engineering	P.Fessia, Friday	Cores position Tunnel surfacing Internal supports in FC
Electricity: el. power distribution	Requested	Approval of spec for FC load
Electricity: signal cables, racks, fibres	Requested, in check	Fibres for LLRF
IT	Summary document in approval	NTH
Cooling & ventilation	Mostly requested	Approval of spec for FC ventilation Cooling for RF power couplers
Access & Alarms	Spec in work	FC Fire safety
Technical Monitoring	No request done	To define
Logistics & storage	No request done	To define
Operational Safety (at installation)	No request done	To define
Controls technologies	No request done	To define

WP4 installation/ test sequence

Meeting
HL-LHC Installation Planning
P.Fessia/ L.Tavian

Goals

- Identify boundary conditions for main equipment to be installed of each WP:
  - Precedence
  - Transport/space constraints, interference and sequence
  - Delivery dates constraints
  - Identify activities that are not decoupled from LS3 LHC installation (eg. those affected by CE cores)
  - Identify succeeding activities related to GI (eg. Signal and control cables, IT, cooling…)
- Define a preliminary planning where the main activities are identified in terms of duration and sequence.

16/05/2019

Task	SPS crab-cavity test stand - YETS-2017-2018 Sequence
File	Task-list-for-SPS-BA6-YETS.xlsx
EDMS Doc	https://edms.cern.ch/document/1843665/1
Budget Code	69 065
Rev. / Checked on	08/09/2017 G.Vandoni

87	16	3	16.3		Install MLI on jumper lines	EN/MME	D.Lombard
88	16	4	16.4		Close external jumper sleeve	EN/MME	D.Lombard
89	16	5	16.5		Connect pumping group and leak detector	AL4030	A.Grimaud
90	16	6	16.6		Connect pump and He bottle to the SB lines	AL4030	A.Grimaud
91	16	7	16.7		Pumpdown insulation vacuum	AL4030	A.Grimaud
92	16	8	16.8		Pumpdown then pressurize the 2 cryogenic circuits fo the jumper	AL4030	A.Grimaud
93	16	9	16.9		Check leak on insulation vacuum	AL4030	A.Grimaud
94	16	10	16.10		Close valve on insulation vacuum and remove pumping group	AL4030	A.Grimaud
95	17			Close Cryomodule beam vacuum			
96	17	1	17.1		install and align sector valves	TE/VSC	C.Pasquino
97	17	2	17.2		install BPMs then bellows between BPMs and VVS	TE/VSC	C.Pasquino
98	17	3	17.3		Survey measurement of BPM positions	EN/ACE/SU	M.Sosin
99	17	4	17.4		install beam vacuum pumping and mobile group on BPM sectors	TE/VSC	C.Pasquino
100	18		18.0	Cabling of all services of the Cryomodule		All	
101	18	1	18.1		Cable FPC Pennings to local TPG		
102	18	2	18.2		Cable Pumping group and gauges		
103	18	3	18.3		Install cable trays on cryomodule	EN/MME	(M.Garlasche)
104	18	4	18.4		Cables (Antenna, HOM) under the Cryomodule	BE/RF	S.Calvo
105	18	5	18.5		Cables (FSI) under the Cryomodule	EN/ACE/SU	M.Sosin
106	18	6	18.6		Install and cable Survey themometry cables	EN/ACE/SU	M.Sosin
107	18	7	18.7		Cable FSI on top plate of the cryomodule	EN/ACE/SU	M.Sosin
108	18	8	18.8		Cable all fibers to the Cryomodule	EN/ACE/SU	M.Sosin
109	18	9	18.9		Cable mechanical instrumentation on the cryomodule	EN/MME	M.Guinchard
110	18	10	18.10		Cable insulation vacuum cables	TE/VSC	Abel Gutierrez
111	18	11	18.11		Cable cryogenic instrumentation	TE/CRG	Francisco Diez Nicolas
112	19		19.0	Cable Service Box instrumentation			
113	19	1	19.1		Cable valves and instruments on SB	TE/CRG	Francisco Diez Nicolas
114	20		20.0	Open plug-in valves			
115	20	1	20.1		Start pumping on both BPM sectors		
116	20	2	20.2		Leak check BPM sectors and validate		
117	20	3	20.3		Check FCP Penning		
118	20	4	20.4		Open plug-in valves		
119	21		21.0	Install waveguides from loads + circulators to Cryomodule		BE/RF	S.Calvo
120	21	1	21.1		Install FPC adaptor pieces		
121	21	2	21.2		Check beam vacuum		
122	21	3	21.3		Connect circulators & loads to FPCs		
123	22		22.0	Install flexible lines from ValveBox#2 to Service Box		TE/CRG	J.Metselaar
124	22	2	22.2		Check connection of flexibles to Service Box	TE/CRG	J.Metselaar
125	22	3	22.3		Secure flexibles to the ceiling supports		
126	22	4	22.4		Weld flexibles on the VB#2 side		
127	22	5	22.5		X-rays		
128	22	6	22.6		Stop for partial cryogenic commissioning		
129	22	7	22.7		Warmup VB#2		
130	22	8	22.8		Break insulation vacuum of VB#2?		
131	22	9	22.9		Weld flexibles on the SB side	TE/CRG	J.Metselaar

First baseline for C&S review 2019

CONCLUSIONS

SPS exercice **LESSONS learnt** ✓

- Implementation of all systems interfacing crab cavity system

  → **Analysis of system for LHC made easy**

  - Main interfaces identified and being detailed
  - Mitigation of risk of orphan deliverables / activities
  - Collaboration with all CERN partners for completion

- Integration in existing machine environment
- Installation sequence was performed successfully in very reduced time

  → **Ready to work out sequence for HiLUMI**

Thank you

Contribution by the whole SPS crab test stand team is gratefully acknowledged

Spare slides

Crabs integration in LHC, versus SPS

LHC		SPS
Two beams, two beam pipes	beam	One beam, vacuum by-pass
Remote alignment	alignment	Manual alignment, transfer table
Beam interlocks for machine protection	interlocks	SPS specific, beam extraction interlock
New underground tunnels for integration of RF equipment	integration	Surface integration of RF ampli, controls, LLRF
Connect to new QXL, upgraded plants	cryogenics	Dedicated cryoplant & distribution, new ODH
LHC-specific CM design	cryomodule	SPS-specific DQW CM design

WP4 categories of interfaces

Scope/ Budget in WP4

Interface to CERN-Unit

Specification :

WP4 for compliance with scope (performance…)

CERN unit for operational responsibility

Scope/ Budget in WPx

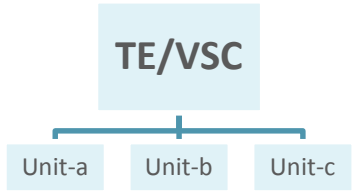
Interface to HL-LHC WP

Specification :

WP4 as requestor

WPx as responsible of scope

WP4 needs vacuum components



WP4 needs installation of crab CM

WP15 executes transport from surface to tunnel for all WPs

WP4 : activity & budget

Services: activity in unit, budget in WP4

HL-WPs: activity & budget

To define

WP4 interface to Vacuum

TE/VSC operates beam vacuum:

SPECIFICATION of beam & insulation vacuum / Beam screen

- defines general layout, acceptance criteria, control process
- specifies operational vacuum conditions for optimal performance and integration
- Defines and designs the beam screens

DELIVERABLES (cryomodule internal equipment and vacuum)

- Cryomodule inner beam vacuum/ beam screen elements
- Interconnections between 2 modules and related supports
- Pumping & diagnostics equipment and controls, beam and insulation vacuum

SERVICES

- Acceptance tests, beam & insulation vacuum
- Installation, conditioning, tests and commissioning

WP4 Interface to Vacuum

TE/VSC opera

SPECIFICATIO

- defines ge
- specifies c
- Defines ar

DELIVERABLE

- Cryomodu
- Interconne
- Pumping &

SERVICES

- Acceptanc
- Installatio

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nd insulation vacuum

EDMS NO.	REV.	VALIDITY
1754567	0.17	DRAFT

WP4: CRAB CAVITIES & RF

SUMMARY OF TE-VSC CONTRIBUTION TO WP4

Abstract

This document summarises the TE-VSC involvement in WP4.
It describes the activities, schedule, resources and the related documentation.
This document was updated following the C&S on 26-28th March 2018 and several meetings between WP4, WP12 and HI-LHC management stakeholders in 2019. The last meeting was held on 2nd May 2019.
The cost for this TE-VSC contribution is within the CtC of the WP4.

TRACEABILITY

Prepared by: A. Carvalho, G. Riddone	***Date:*** 2019-05-02
To be verified by: V. Baglin, R. Calaga, P. Cruikshank, C. Garion, J. Hansen, C. Pasquino, J. Perez Espinos, G. Vandoni	***Date:*** 2019-05-30
To be approved by: P. Chiggiato, B. Delille, M. Jimenez, L. Rossi, L. Tavian	***Date:*** 2019-05-30
Distribution: G. Bregliozzi, N. Kos, G. Pigny, R. Tavares Rego, M. Taborelli	

WP4 versus Transport & Installation

WP 17.7 All transport in new underground premises
WP 15 All transport/standard installation in existing premises
WP 4 All surface transport/ specific installation

WP15

Tunnel	Transport & installation of CMs to final position
UA, US, UR	Transport & installation of RF power amplifiers, ancillaries and waveguides, Control and LLRF racks, FC
	Transport vehicles and tools
Surface	Surface transport related to fabrication/ test: cavities, CMs Surface transport, RF amplifiers & ancillaries, transmission lines, FC

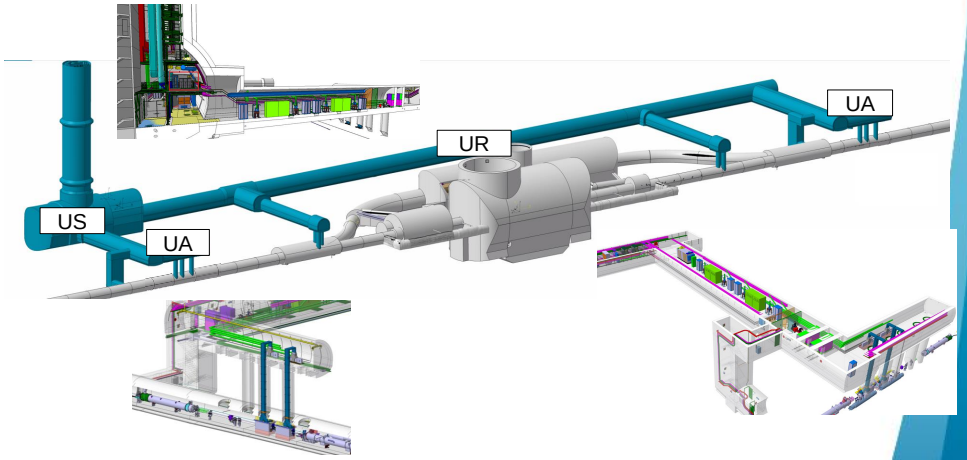
WP4 : activity & budget
Services: activity in unit, budget in WP4

HL-WPs: activity & budget
To define

WP4 versus Signals & controls cables

UA, UR, US	RF amplifiers & ancillaries, Control racks, Faraday cage & LLRF
Cores	Supports and transmission lines / Signal & Control cables
Tunnel	Connection to CM of all interfaces (RF power, signals & controls, vacuum, cryo, FSI, cooling)

- Electrical powering cabling
- FC internal cabling
- RF systems controls cabling
- Vacuum, cryo instr, FSI system controls cabling
- Interface/ interlock cabling



Within HiLumi, the electricity service is collecting Cable Installation pre-Requests

WP4 versus Survey & Alignment

Included in WP4 from Survey

- Cavity position monitoring by FSI:
  - FSI targets/ supports
  - FSI feedthroughs
  - FSI DAQ, patch panels, cables, fibers, field bus
  - 1 laser per IP
- Resources/ activities
  - Procedures
  - Purchase, validation, calibration of FSI
  - Knowledge transfer to UK, Canada on FSI
  - Knowledge transfer on conventional survey
  - Support and FSI installation at crab production, CM assembly at CERN
  - Survey & alignment for RFD-SPS

WP15.4, not included in WP4 scope

- Remote cryomodule position monitoring:
  - WPS sensors
  - Inclinometers
  - Wire protection
  - Associated cables/ fibers and DAQ
- Remote adjustment of the cryomodules
  - Motorization of jacks
  - Associated DAQ, controls/ commands
- Survey & Alignment during installation