



# **Crab- cavities, SPS-BA6 installation & consolidation plans**

G.Vandoni



8th HL-LHC Collaboration Meeting



# Crab- cavities, SPS-BA6 installation & consolidation plans

E.Metral's webpage

**XVI) Working group to study the feasibility of installing a Crab Cavity in the SPS: CCinS**

2009

G.Vandoni

Nicolas Delruelle (Cryogenics) - TE/CRG

Nicolas Gilbert (Space and integration) - EN/MEF

Elias Metral (Chairman, beam dynamics issues and SPS availability) - BE/ABP

Joachim Tuckmantel (Crab cavity expert and RF) - BE/RF

Giovanna Vandoni (Vacuum) - TE/VSC

Jorg Wenninger (Machine protection) - BE/OP

Frank Zimmermann (Crab cavity expert, possible measurements and linkman with KEK) - BE/ABP



8th HL-LHC Collaboration Meeting

ccins members

# OUTLINE

LAYOUT

INSTALLATION

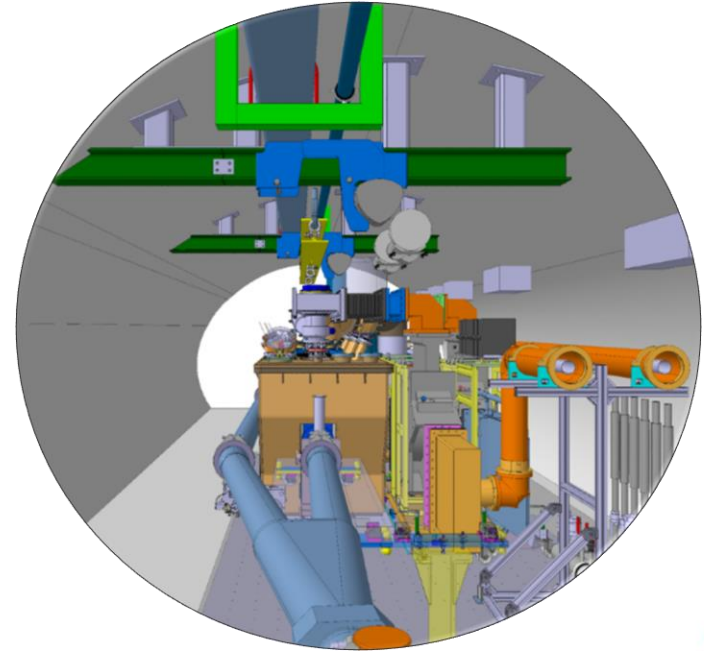
NON-CONFORMITIES & CONSOLIDATION

OUTLOOK to LHC

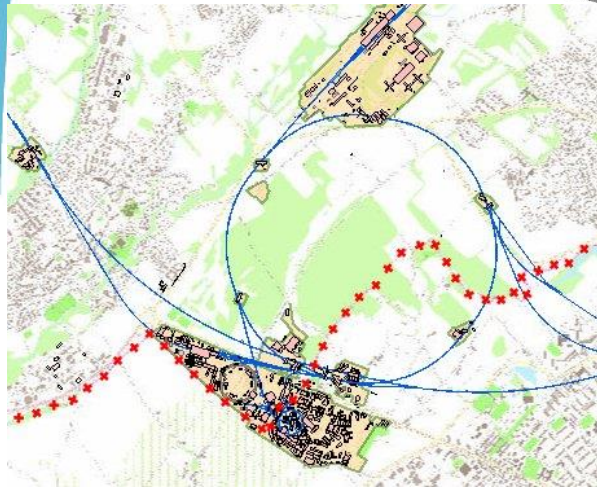
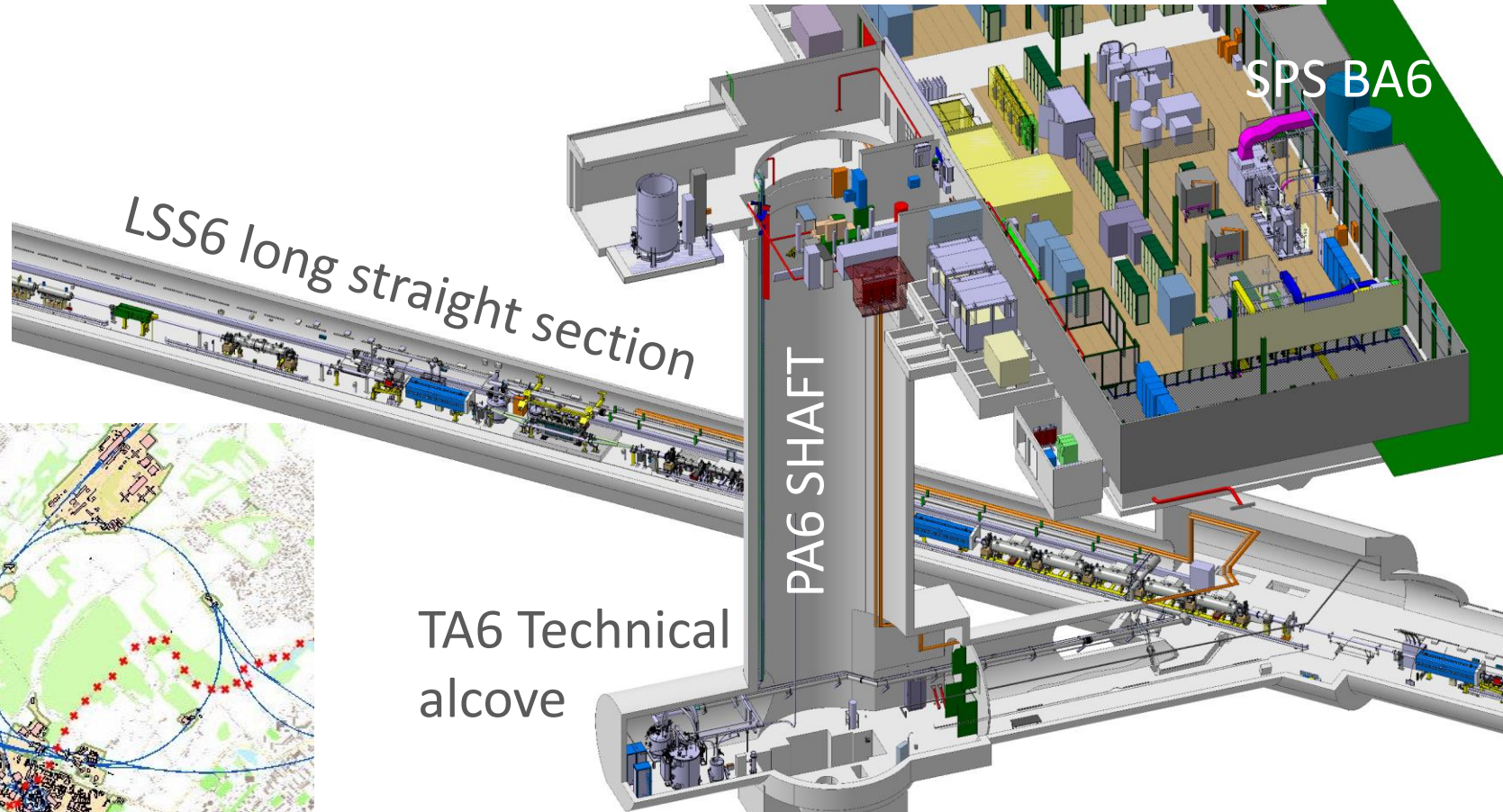




# LAYOUT

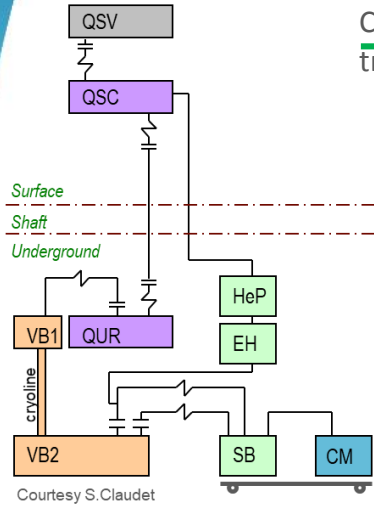


# Surface & Underground areas SPS BA6



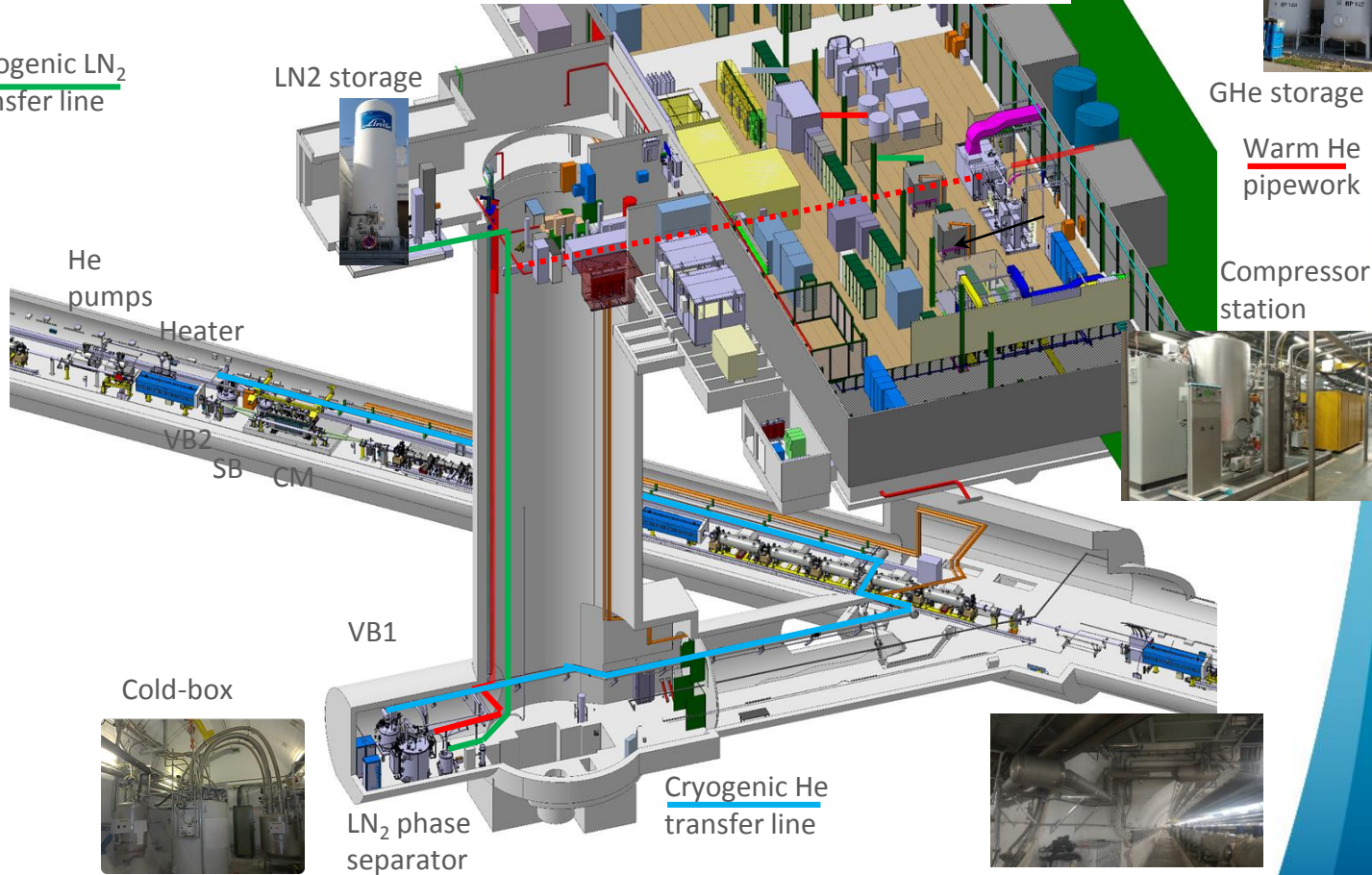


# Cryogenics

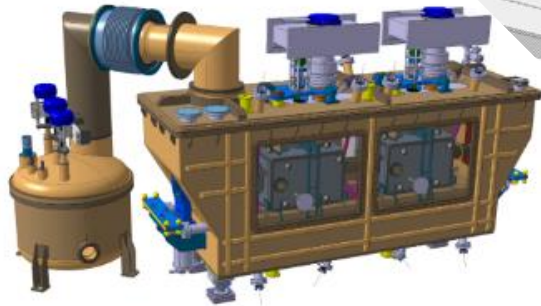
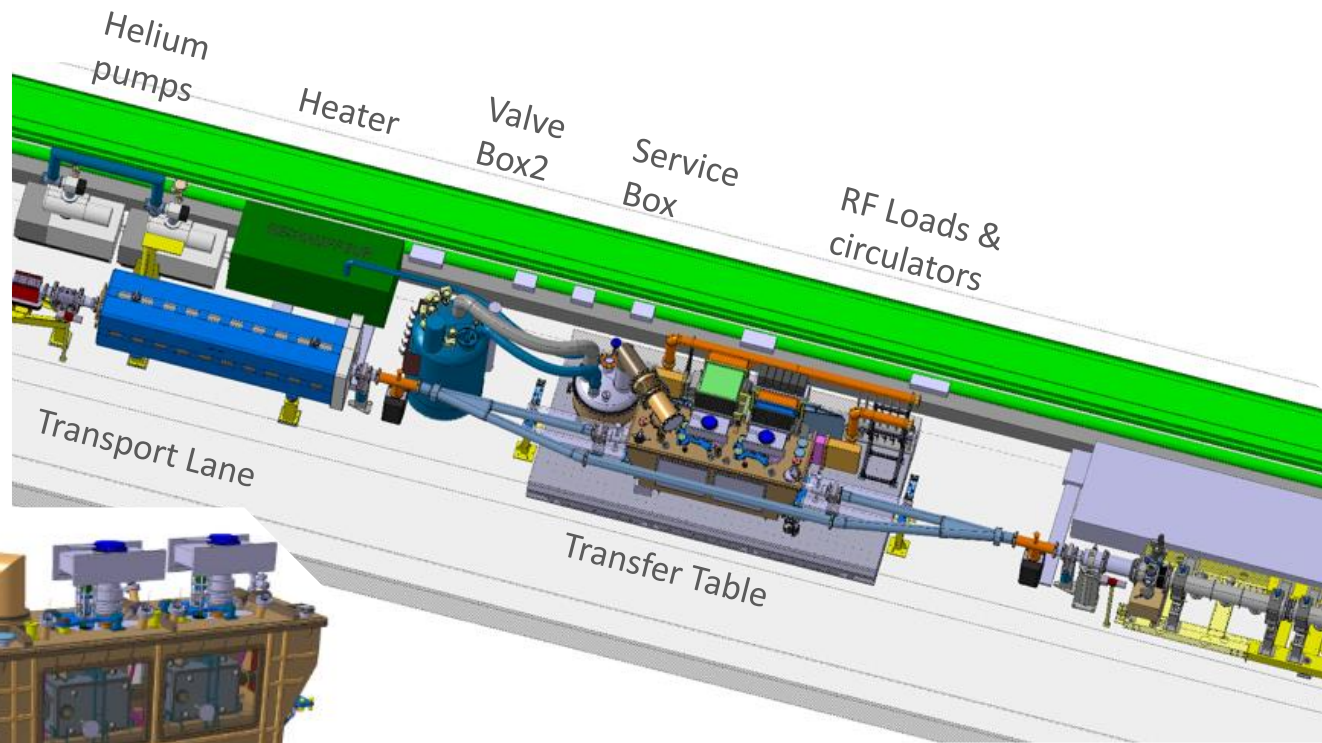


VB1 – valve box 1  
 VB2 – valve box 2  
 SB – service box  
 CM – crab cavity cryomodule

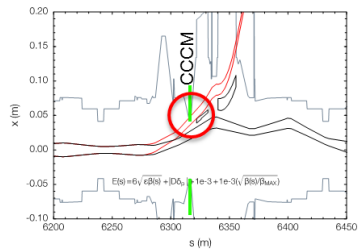
Cryogenic LN<sub>2</sub>  
 transfer line



# Test stand

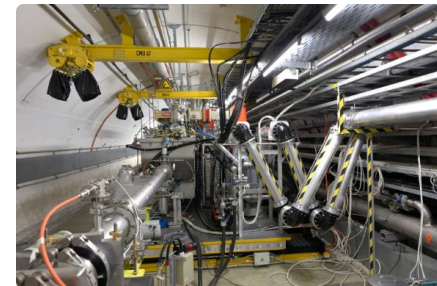
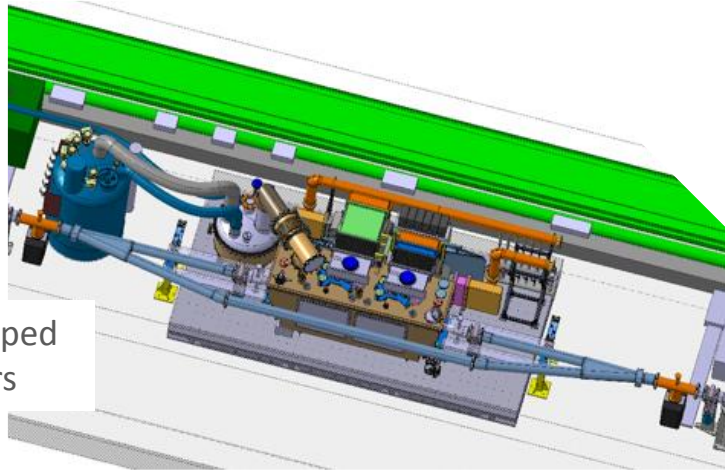


# Table Movement



Fast extraction to LHC

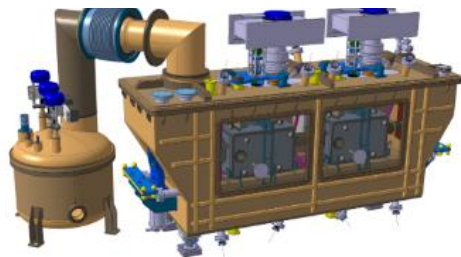
Articulated Y-shaped  
vacuum chambers



RF power transmission  
lines, rotating coupling

Service  
Box

Cryomodule



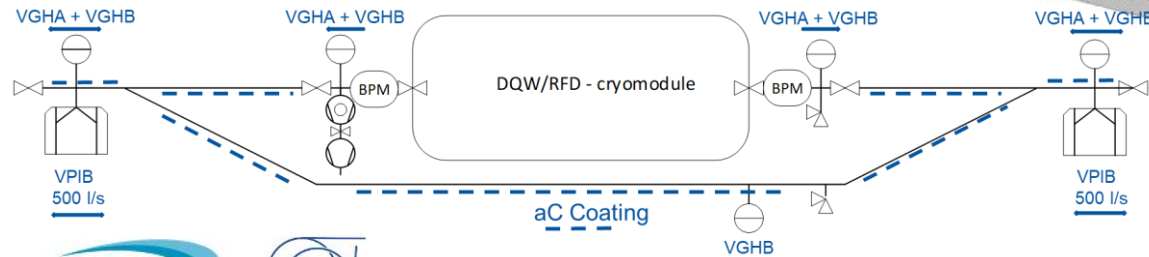
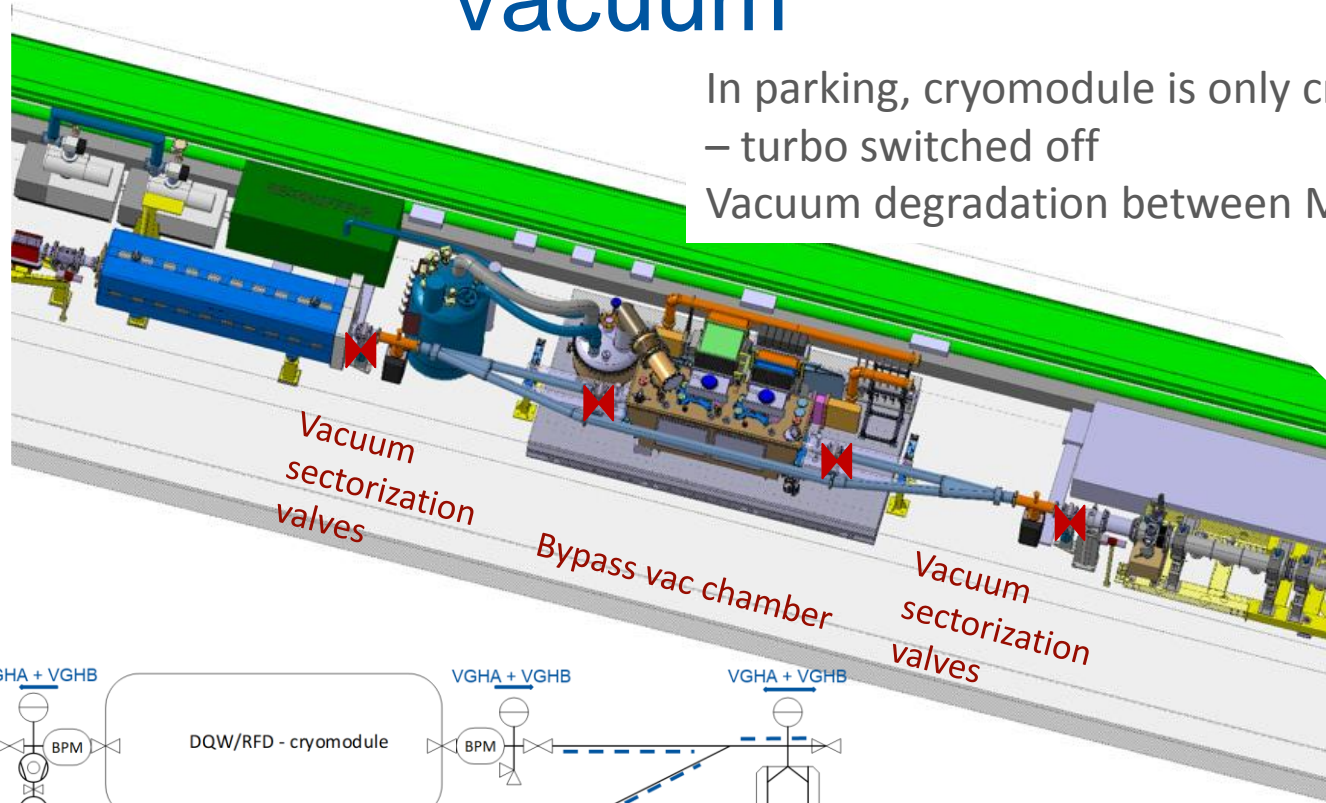
Motorized transfer table 510mm 4 $\mu$ m  
Fully remote handling & control

Bearing CM+SB, RF power circulators  
and loads, vacuum chambers supports



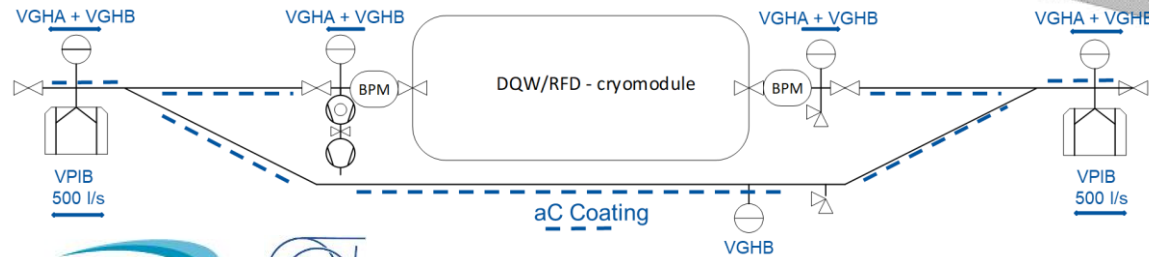
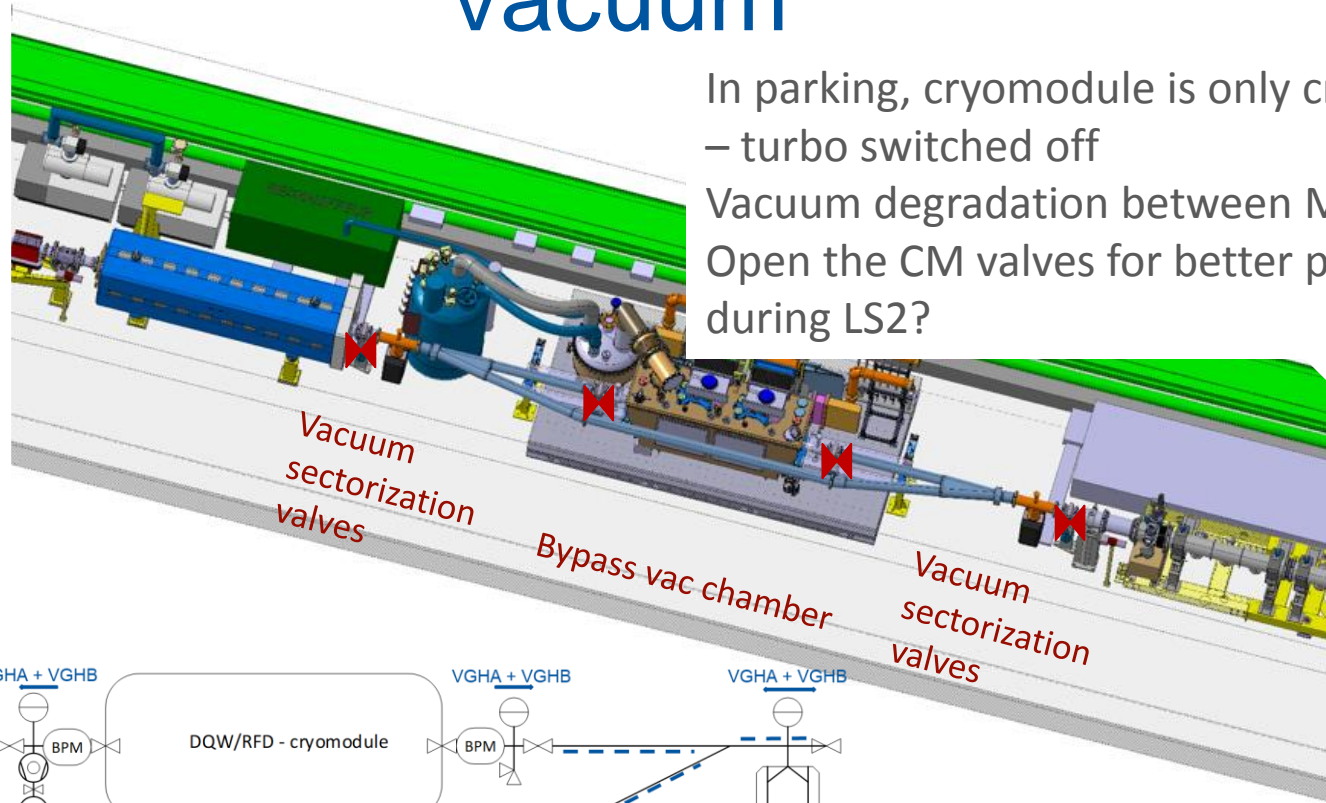
# Vacuum

In parking, cryomodule is only cryopumped  
– turbo switched off  
Vacuum degradation between MDs at 4K



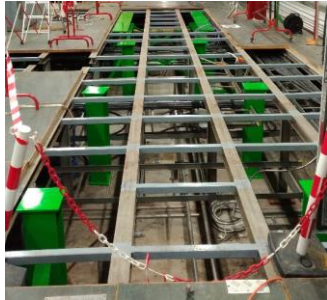
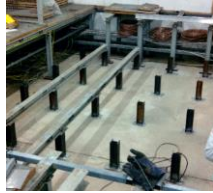
# Vacuum

In parking, cryomodule is only cryopumped  
– turbo switched off  
Vacuum degradation between MDs at 4K  
Open the CM valves for better pumping  
during LS2?



# NEW INFRASTRUCTURE

## CIVIL ENGINEERING



### Supporting structures

- Faraday cage
- Cryo-compressor
- Oil-removal skid

### Concrete slabs

- Gas and liquid tanks
- New transformer

Reinforced resin  
after removal of damaged surface layer



## HANDLING



New overhead rails  
maximal charge 4 tons, in  
tunnel and technical  
alcove



# NEW INFRASTRUCTURE

## ELECTRICAL DISTRIBUTION



New, 2MVA transformer, 18/0.4 kV connected to SPS stable loop.

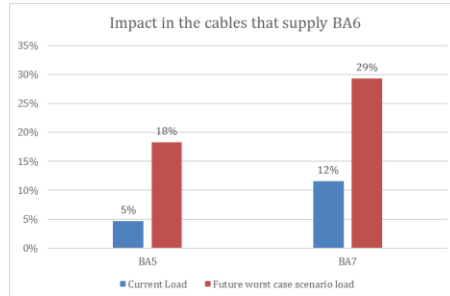


UPS



Switchboards

Network	Requested load
General services	1100 kVA
UPS	17kW
Secured	2kW



## FARADAY CAGE

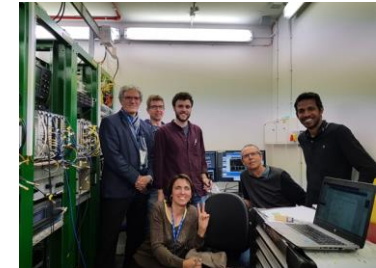


Attenuation of 80 dB minimum at both 400 MHz and 1 GHz

Single power line with filtering capability at 40A  
Single patch panel, feedthroughs 3 GHz, 50Ω



Phonic insulation, fire detection, controlled ventilation



Raw and demineralized water systems modification & recommissioning



# INTERLOCKS

Type	Why	What
<b>Personnel safety</b>	Radiation (X-rays) ODH and cryo hazard mechanical hazard	Access versus RF Power to cavities Table movement/ LHe level
<b>Machine protection</b>	Aperture	Beam & extraction versus table position, table movement, vacuum sector valves
	Protection SPS and cavities	SIS: set of parameters, to define
<b>Equipment protection</b>	Protection of cavities and their ancillaries	RF Power versus Vacuum (beam/ insulation) Cryogenics (cryo OK given manually+ interlocks) Beam versus HOM power

# INTERLOCKS

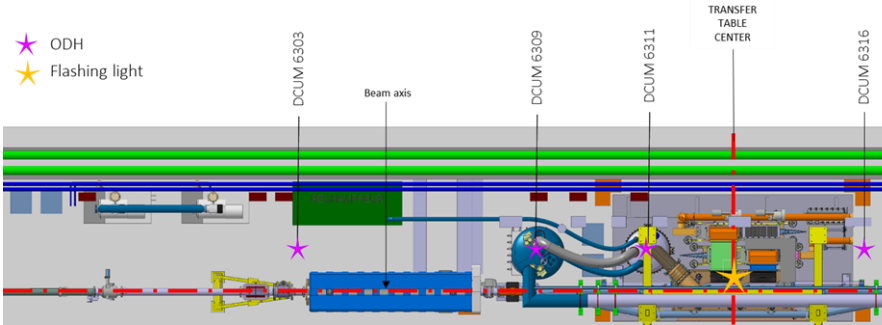
Type	Why	What
Personnel safety	Radiation (X-rays) ODH and cryo hazard mechanical hazard	Access versus RF Power to cavities Table movement/LHe level

**Machine protection** RF Power **cannot be switched on** if the SPS is NOT in Safe Access mode (closed mode)

**Equipment protection** Choice done for simplicity: RF conditioning and LLRF preparation in parking position, during beam time

→ Needs to be over-run or modified (interlock signal to closing off RP doors, or interlock with RP dose at these doors) to allow for tests during LS2

# SAFETY EQUIPMENT



SAFETY ACTION MATRIX				LEGENDE	BA6	BA6	TA6	BA6	TS65
<b>SGGAZ-16001</b> <b>SPS ZONE 16</b> EQUIPEMENT : MX62 Version : 1.0 28/03/2017 EDMS : TBD Status : DRAFT				SEUILS D'ALARMES	SIGNALISATIONS	CSAM	SIGNALISATIONS	ASS	CSAM
				GAZ SON LIE	GAZ	GAZ	GAZ	GAZ	GAZ
				ODH 10% CO	ODH	ODH	ODH	ODH	ODH
				ALARM NIV. 0	ALARM NIV. 0	ALARM NIV. 0	ALARM NIV. 0	ALARM NIV. 0	ALARM NIV. 0
				ALARM NIV. 1	ALARM NIV. 1	ALARM NIV. 1	ALARM NIV. 1	ALARM NIV. 1	ALARM NIV. 1
				ALARM NIV. 2	ALARM NIV. 2	ALARM NIV. 2	ALARM NIV. 2	ALARM NIV. 2	ALARM NIV. 2
				ALARM NIV. 3	ALARM NIV. 3	ALARM NIV. 3	ALARM NIV. 3	ALARM NIV. 3	ALARM NIV. 3
				FLASH	FLASH	FLASH	FLASH	FLASH	FLASH
				SIRINE	SIRINE	SIRINE	SIRINE	SIRINE	SIRINE
				INFORMATION	INFORMATION	INFORMATION	INFORMATION	INFORMATION	INFORMATION
				COUPURE F.L.	COUPURE F.L.	COUPURE F.L.	COUPURE F.L.	COUPURE F.L.	COUPURE F.L.
				COUPURE ELEC.	COUPURE ELEC.	COUPURE ELEC.	COUPURE ELEC.	COUPURE ELEC.	COUPURE ELEC.
				VENTILATION	VENTILATION	VENTILATION	VENTILATION	VENTILATION	VENTILATION
				Code GMAO	Code GMAO	Code GMAO	Code GMAO	Code GMAO	Code GMAO
				DETECTEUR	DETECTEUR	DETECTEUR	DETECTEUR	DETECTEUR	DETECTEUR
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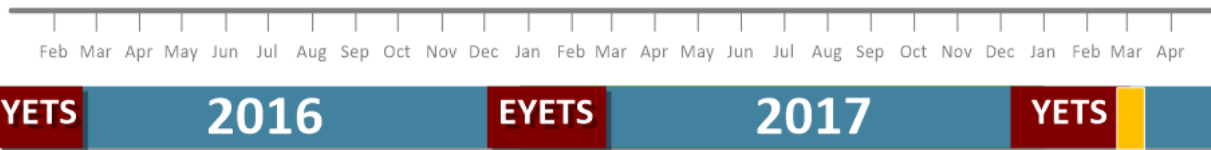
Extended layout of Oxygen Deficiency (ODH) detectors and flashing beacons, triggered tunnel evacuation up to mid-arc on both sides



# ***INSTALLATION***

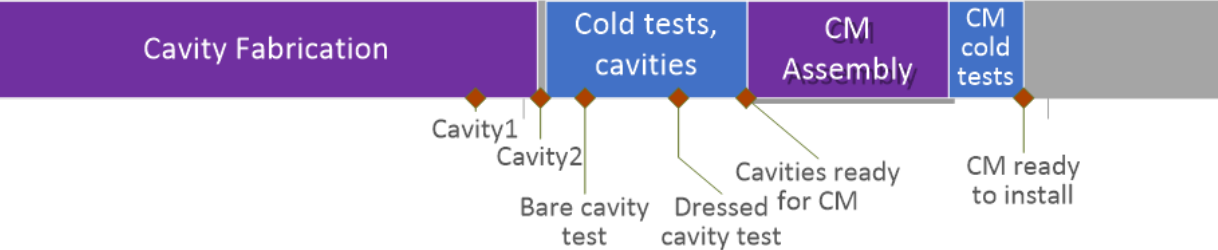






CERN machines schedule

Cavities & cryomodule



SPS works for test-stand



# PLANNING

Clear BA6

Un-cable BA6 and tunnel

Optical 3D Scan

TL Bidder's visit

Measure magnetic field

BA6 supports construction

Uncabling & Cabling

RF power cabling

Cryo Transfer-Line

Vacuum sectorization

New handling equipment

Cooling pipework

Refrigeration

Transfer table

**CCCM** + Service Module

Electrical connections

RF connections

Cryo connections

Validation tests

Commissioning



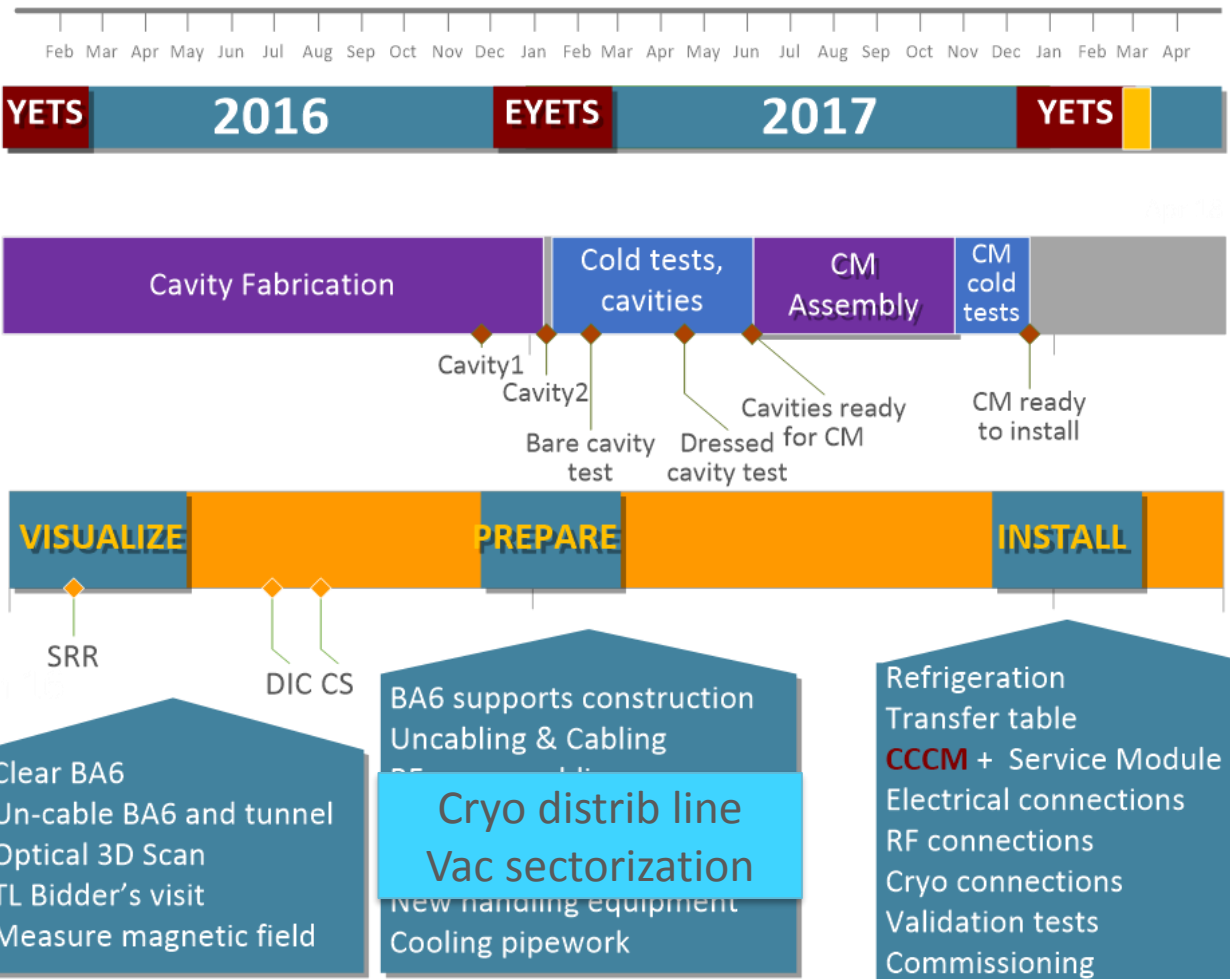
Work allowed only in 3 slots  
of 8 - 12 weeks over 2.5 yrs

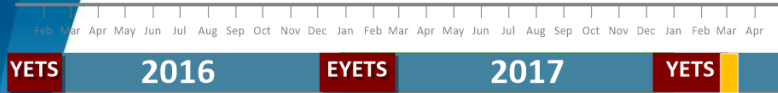
YETS16: Uncabling/ scans

EYETS17: Infrastructure

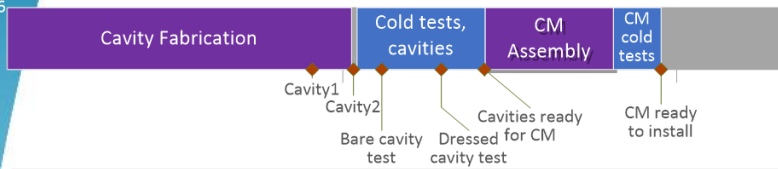
YETS18: Largest, delicate  
equipment in shortest time

# PLANNING





n 16

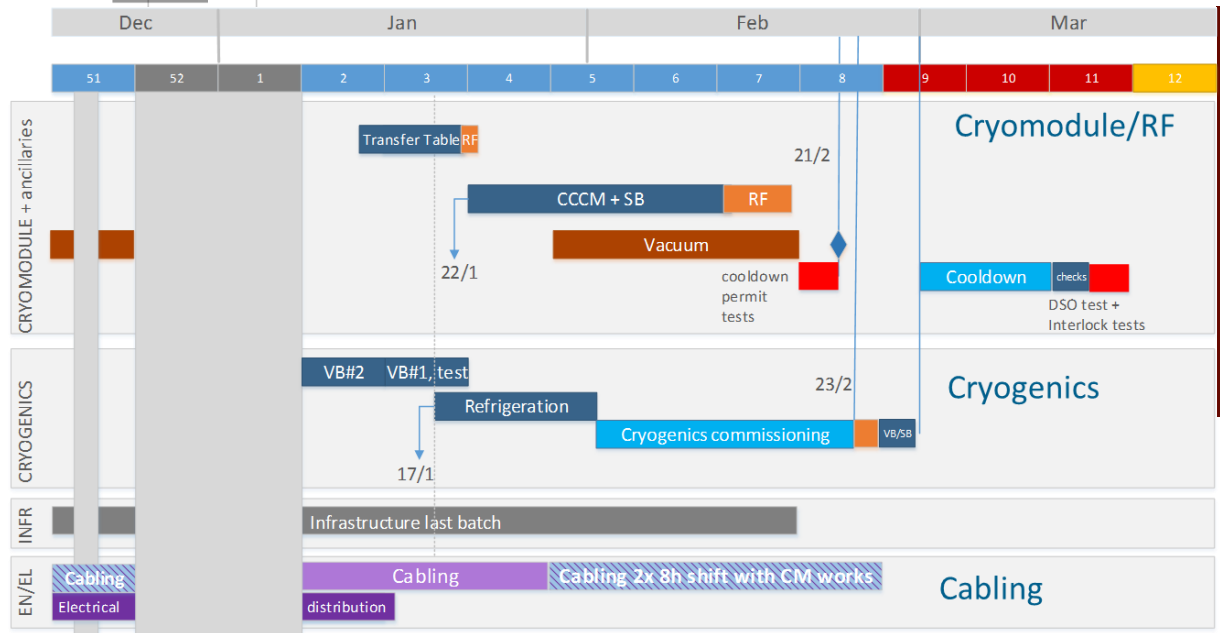


- Clear BA6
- Un-cable BA6 and tunnel
- Optical 3D Scan
- TL Bidder's visit
- Measure magnetic field

BA6 supports construction  
Uncabling & Cabling  
RF power cabling  
Cryo Transfer-Line  
Vacuum sectorization  
New handling equipment  
Cooling pipework

Coactivity in tight space  
Coping with activities involving large teams (cabling)  
Management of unforeseen events

# PLANNING



YETS 2017-2018



# Electricity – coping with coactivity

Cabling/  
El. Distribution

TA6/ shaft

Tunnel

BA6



Staging of works with  
deadline

Arbitration on  
necessities: some cables  
left out

Priority on the field to  
cabling team



Cables prepared for the powering and  
control of the transfer table, right before the  
table installation

## CABLING

EN/EL/FC new cables and fibers		Deadline for use	
BPM	C.Boccard	16/2	
Transfer Table	K.Artoos	12/1	end of week2
Vacuum	F.Dalgault	29/1	Week 5
ODH	N.Broca	7/2	week 6
Fire safety	Miriam Munoz	7/2	
Mechanical instrumentation of CM	M.Guinhard	20/2	Week 8
RF Powering	F.Killing	9/2	week 6
BLM	D.Vaxelaire	16/2	
Cryogenics (to VB#2)	C.Fluder	24/1	week 4
Faraday cage LLRF	P.Baudrenghien	31/1	week 5

## POWERING

EN/EL/EIC Electrical distribution cabling and connections		Deadline for use	
Energization of transformer	G.Velazquez	15/1	week2
Cryogenics	C.Fluder	22/1	week3
Transfer table	K.Artoos	12/1	end week2
Survey rack	M.Sosin	22/1	Week 4
IOTs	F.Killing	9/2	week6
Faraday cage equipment	P.Baudrenghien	31/1	week5
ODH rack	N.Broca	5/2	Week 6

CRYOGENICS

TA6/ shaft

Tunnel

BA6

Cryomodule/RF

Tunnel

Transfer Table  
RF equipment  
CRYOMODULE  
Vacuum

HiLumi  
HL-LHC PROJECT

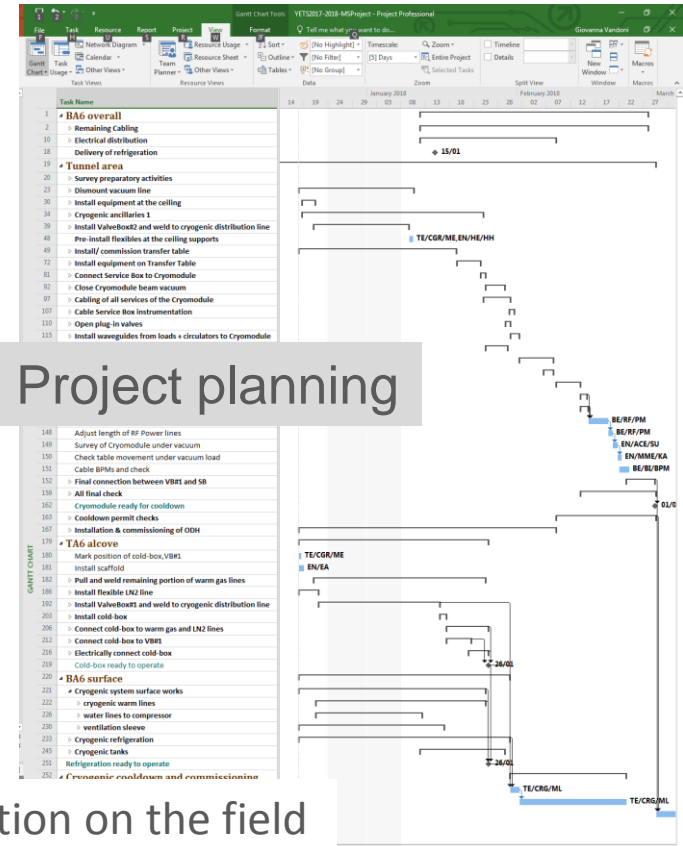




Task list for SPS-BAG-0151 - Excel											
<div> <div>File Home Insert Page Layout Formulas Data Review View Mailings References</div> <div> <span>Clipboard</span> <span>Font</span> <span>Alignment</span> <span>Number</span> <span>Styles</span> <span>Cells</span> <span>Editing</span> </div> <div> <span>File Name</span> <span>Font Face</span> <span>Size</span> <span>Color</span> <span>Background Color</span> <span>Bold</span> <span>Italic</span> <span>Underline</span> <span>Link</span> <span>Text Color</span> <span>Text Background Color</span> <span>Text Direction</span> <span>Text Orientation</span> <span>Text Wrapping</span> <span>Text Color</span> <span>Text Background Color</span> <span>Text Direction</span> <span>Text Orientation</span> <span>Text Wrapping</span> </div> </div>											
1	Task	SPS crab-cavity test stand - YETS-2017-2018 Planning									
2	File	Task-list-for-SPS-BAG-0151.xlsx									
3	EDMS Doc	<a href="https://edms.com.ph/document/183555/">https://edms.com.ph/document/183555/</a>									
4	Budget Code	69 065									
5	Rev./Checked on	08/09/2017									G.Vandoni
6											
7	Task number	Zone	Task	Task1	Task2	Resp Team					
8	0										
9	BAG overall										
10	44	44.0	Remaining cabling			EN/EL					
11	44	1 44.1	cabling tunnel			EN/EL					
12	44	2 44.2	cabling shaft			EN/EL					
13	44	3 44.3	cabling surface			EN/EL					
14	44	4 44.4	connectors tunnel			EN/EL					
15	44	5 44.5	connectors RAL			EN/EL					
16	Tunnel area										
17	0	0.0	Survey preparatory activities			EN/AC/JSU					
18	0	1 0.1	Install patch panel under QDA and connect			EN/AC/JSU					
19	0	2 0.2	Trace position of the transfer table on the floor			EN/AC/JSU					
20	1	1.0	Install equipment at the ceiling								
21	1	1 1.1	ODI detectors at crab zone			BE/ICS					
22	1	2 1.2	CDI cameras			IR/ECO					
23	1	3 1.3	Divers								
24	2	2 2.0	Dismount vacuum line			TE/VSOC					
25	2	1 2.1	Vent sector 633			TE/VSOC					

# Installation sequence

# Project planning



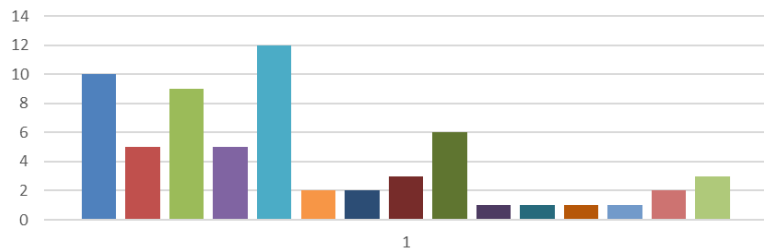
## Tight follow-up and coordination on the field

Time-lapse camera recording

# PLANNING ...vs REALITY

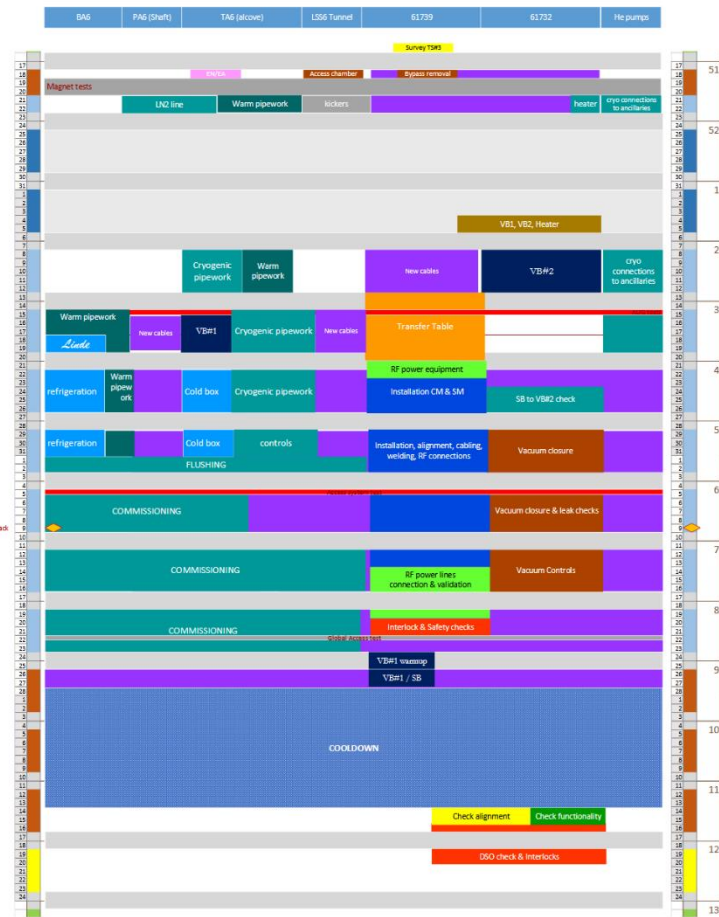
# YETS 2017-2018 Statistics

64 IMPACTS



- Visits
- A - Acceleration
- Q - Cryogenic equipment, cryostats and interconnects
- Radiological Controls
- E - Electricity
- B - Beam Instrumentation
- V - Vacuum
- F - Fluids
- C - Controls
- S - Survey
- Table Installation
- S - General safety
- L - Layouts and assemblies
- J - Infrastructure
- Other

64 IMPACTS  
200 Estimated participants  
~20 Teams involved





# ***CONSOLIDATION & NON-CONFORMITIES***

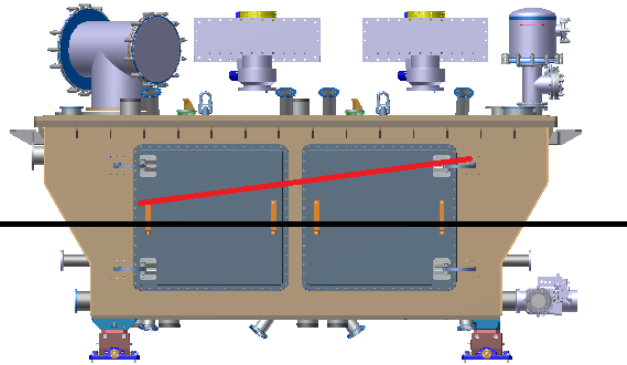




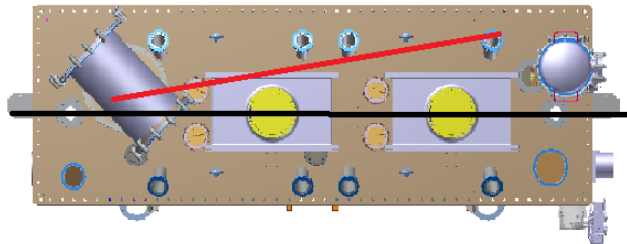
# Main non-conformities

mechanics	{	Cryomodule misaligned by 400µm
		VB2 and SB mutual distance not according to integration
		Water pressure too high, on RF loads and He pumps
		Helium leak on line between CB and VB1
Safety signage	{	Cryo-lines versus insulation vacuum status, procedure not indicated on items
		Cryo danger zone not marked
cabling	{	Mechanical instrumentation cables missing
		Vacuum interlocks to cryo are not hard cabled
		VVS interlock to table position is not hard cabled
		Cable's hard protection missing
		ODH signals impacted by occasional noise, reach pre-alarm
solved in TS		Brakes pulled on transfer table motors

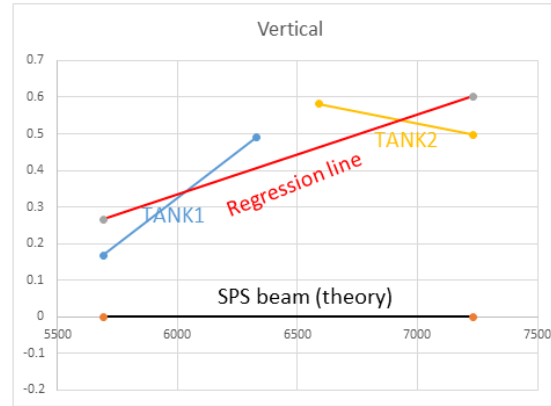
# Cryomodule misalignment



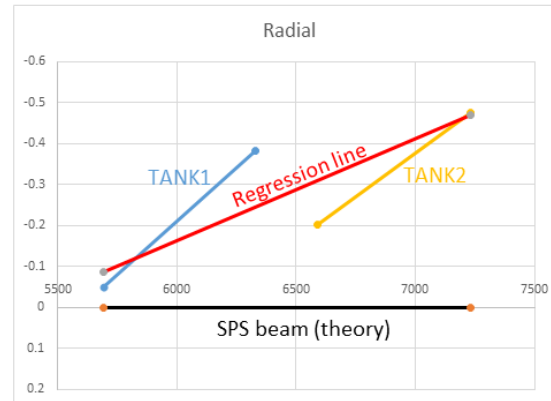
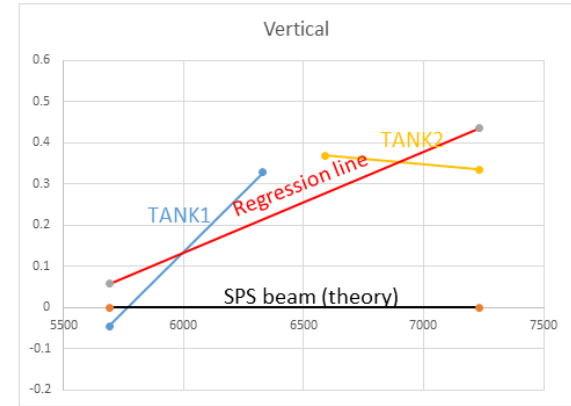
No impact on in-beam performance, correction by orbit bump



Including contraction corrections based on SM18 BUNKER measurements:



Including contraction corrections based on theoretical calculations:

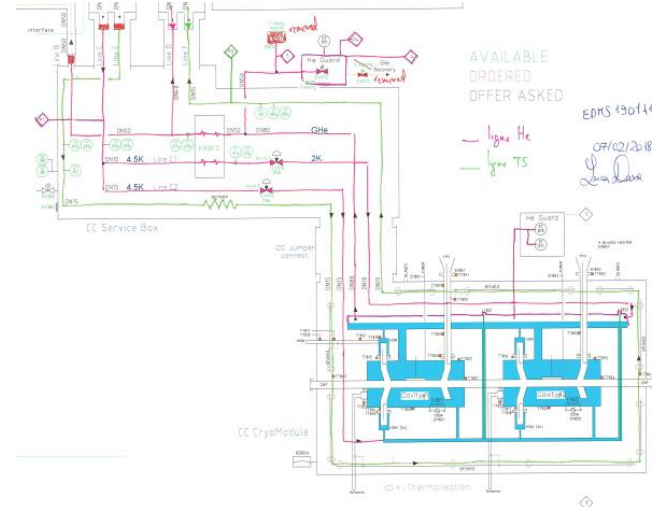
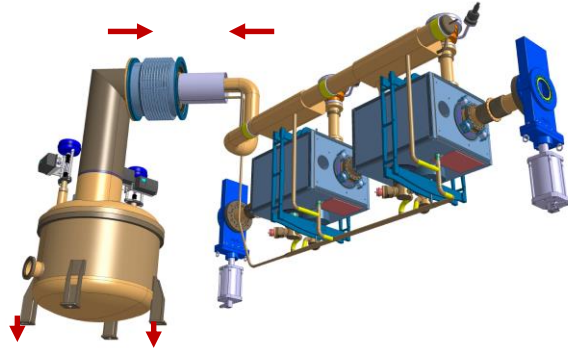


- Insufficient data on effect of vacuum cycling
- No FSI observation during initial alignment
- Successive cycles on insulation vacuum

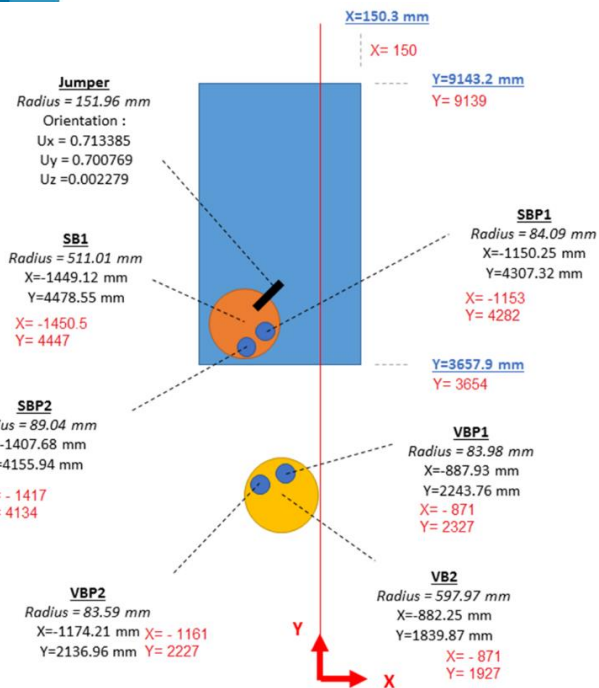
# Layout for leak tests

## COMMON INSULATION VACUUM SB and CM

Necessity to maintain insulation vacuum when internal cryogenic circuits are pumped, to avoid stress from vacuum pull on lines.

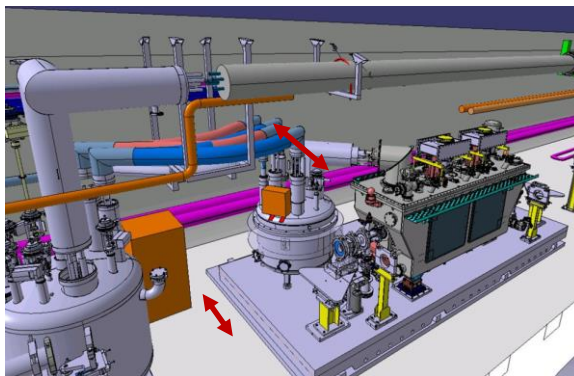


# Distance ValveBox2 to ServiceBox



Comparison between foreseen (red) and measured (black) positions & distances.

	measure	model	$\Delta$
SB1-VB2	2699	2586	113
SBP1-VBP1	2080	1975	105
SBP2-VBP2	2032	1924	108



Flexibles cut and re-installed for stress minimization in parking position



# Works in LS2

## WORKS with Access

- Repair of VB2 to SB distance non-conformity
- Repair of helium leak on flexible line Cold-Box to VB1
- Consolidation of Safety Information signage
- Missing cables
- Alignment correction



Cooldown and RF Power testing,  
reaching nominal voltage  
without beam

## SAFETY REQUIREMENTS

Modify/remove SPS Safe Access interlock on RF Power  
Area closure to passage, transport etc

## TECHNICAL REQUIREMENTS

Services availability: electricity, water...



# An OUTLOOK to LHC

HLLHC:

SPS test-stand mirrors crab-system  
architecture of HL-LHC

- Infrastructure / interfaces :  
integration,  
installation,  
interlocks, controls, cables
- Technical issues being tackled and solved:  
lessons learnt for LHC

CERN		HiLumi HL-LHC PROJECT		EDMS NO. 1754567	REV. 0.13	VALIDITY under approval
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# CONCLUSIONS

Fully functional, unique test stand for superconducting RF cavities in high energy/ high intensity proton beam



Main features:

- Cryogenics for 7g/s liquefaction, 3.5g/s at 2K
- Moving table 510mm range for in-beam/ parking
- Low SEY Y-shape vacuum chambers
- 80kW IOT RF amplifiers
- Beam instrumentation
- Overhead transport rails

Consolidation and non-conformity reduction / Modification for operation during LS2



***All involved teams have spared no effort,  
humbly and keenly, for the success of the  
SPS test stand***

Integration, Safety & SPS Coordination, Safety infrastructure, Civil engineering, Electrical distribution, Cabling, Infrastructure support, Transport, Transfer Table team, RF, Cryogenics, Vacuum, Cryomodule mechanical engineering, Survey, Beam instrumentation, Machine protection...

