Reduced versions of the triplet string: impact on cryostat, electrical powering, protection and cryogenics

M. Bajko

on behalf of STRING collaboration with special imput from

D. Duarte Ramos, S. Yammine, H. Thiesen, A. Perin, H. Mainaud Durand, G. Riddone, and M. Zerlaut

February 2019

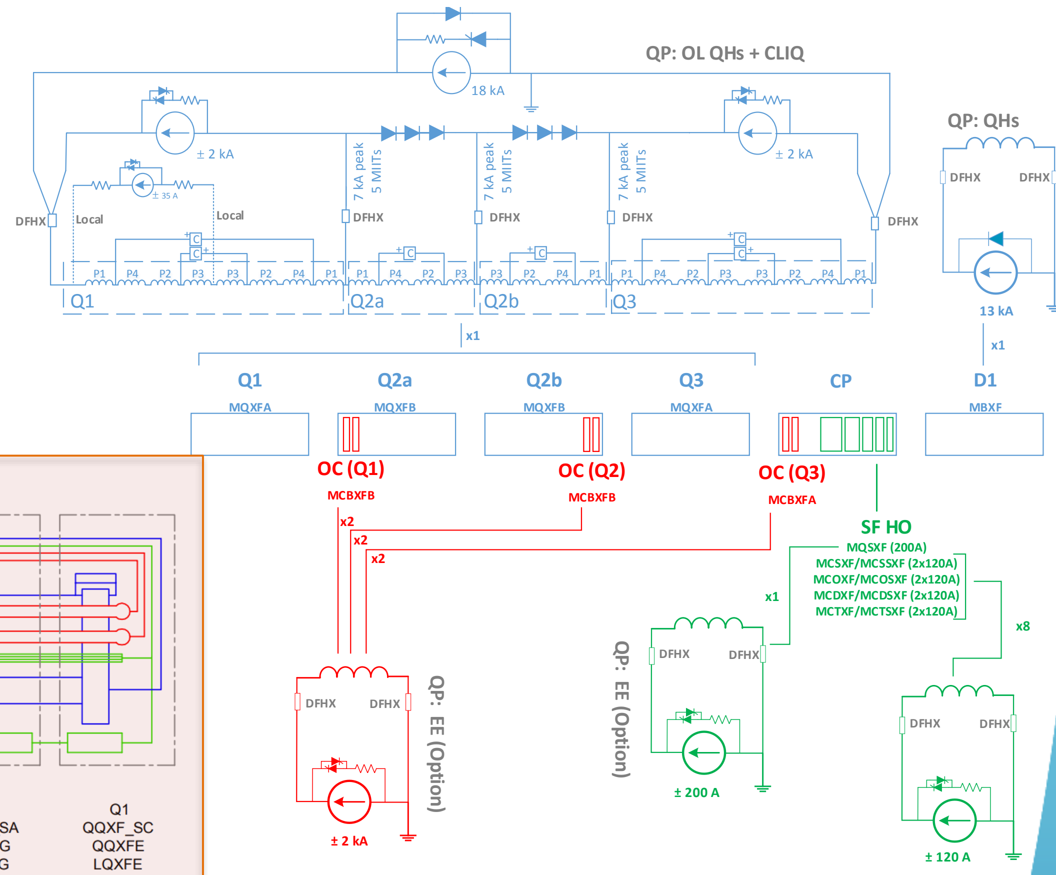
Content of the talk

- Different configurations wrt the full baseline
  - without Q1/3
  - without Q2A/B
  - without Q2A/B and Q1/3
  - without CP
  - without D1
  - without D1 and CP
- 80 K STRING
- Summary table of configurations
- Possible saving
- Summary table of savings
- Budget and planning updates
- Conclusions
- Remarks

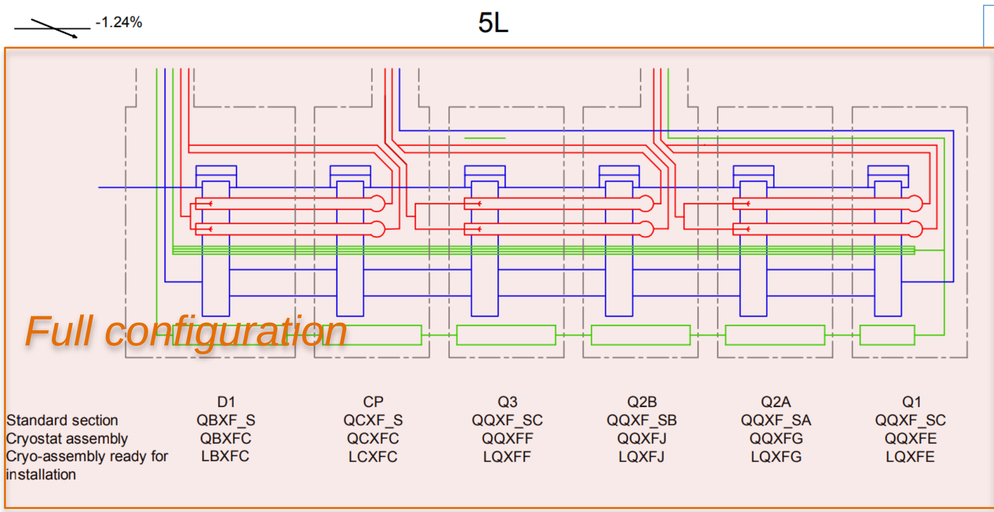
FULL STRING: present BASELINE

There is no beam screen installed in any of the magnets; common vacuum is considered

Electrical circuit



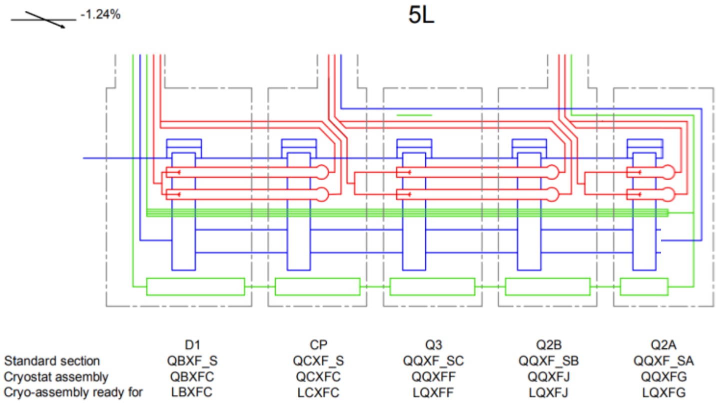
Hydraulic and mechanical connections

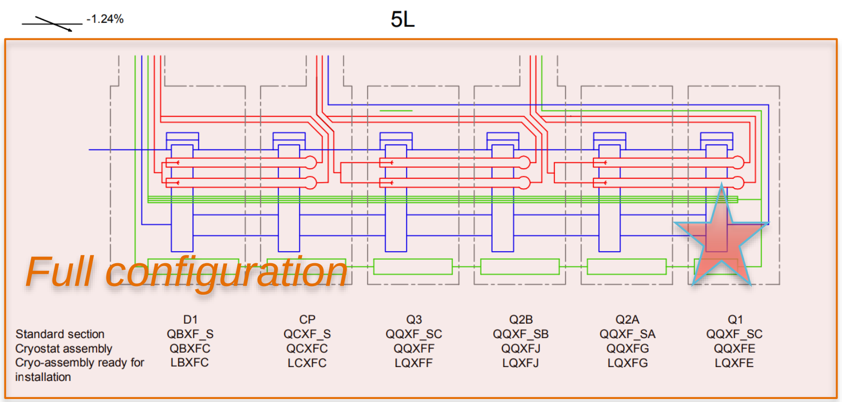


This new baseline would require an ECR

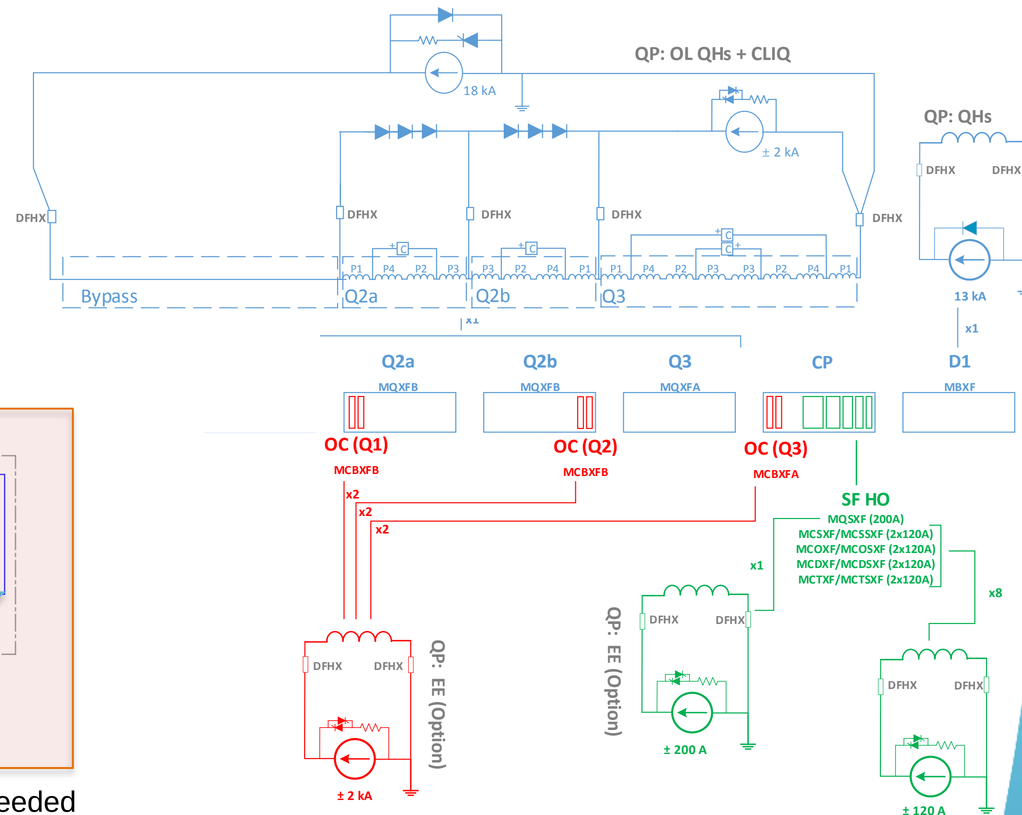
STRING without Q1

Hydraulic and mechanical connections





Electrical circuit



A service module with phase separators and end cover are needed on Q2A :

20 kCHF design office
50 kCHF for components
40 kCHF for manpower assembly a total of **extra cost** wrt baseline : total **110 kCHF**

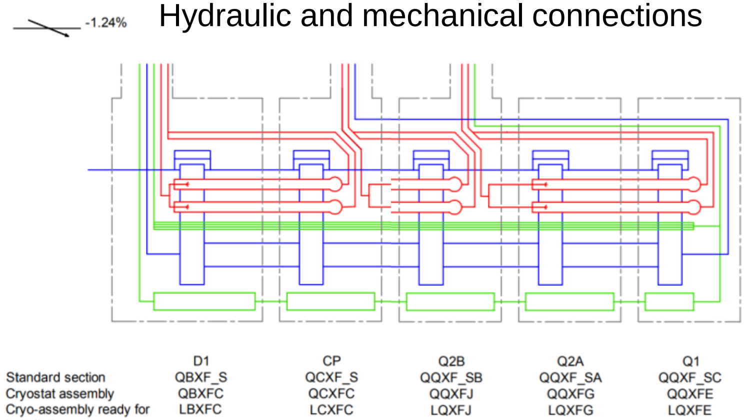
Studied by. D. Duarte MSC, S. Yammine EPC, M. Zerlaut MPE, A. Perin CRG

In general any missing triplet magnet has a **major implication in the validation of the quench detection, protection as well as on the EMC studies. No k-modulation** circuit, test only one layer decoupling matrix.

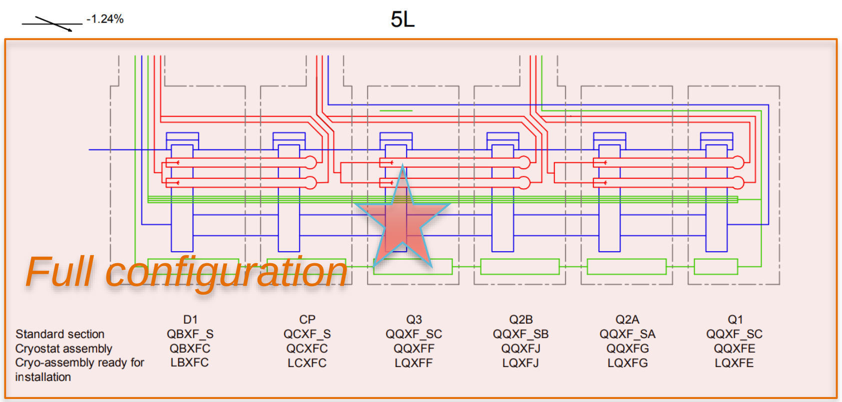
No cost reduction on powering nor on protection as the components are spare parts.

STRING without Q3

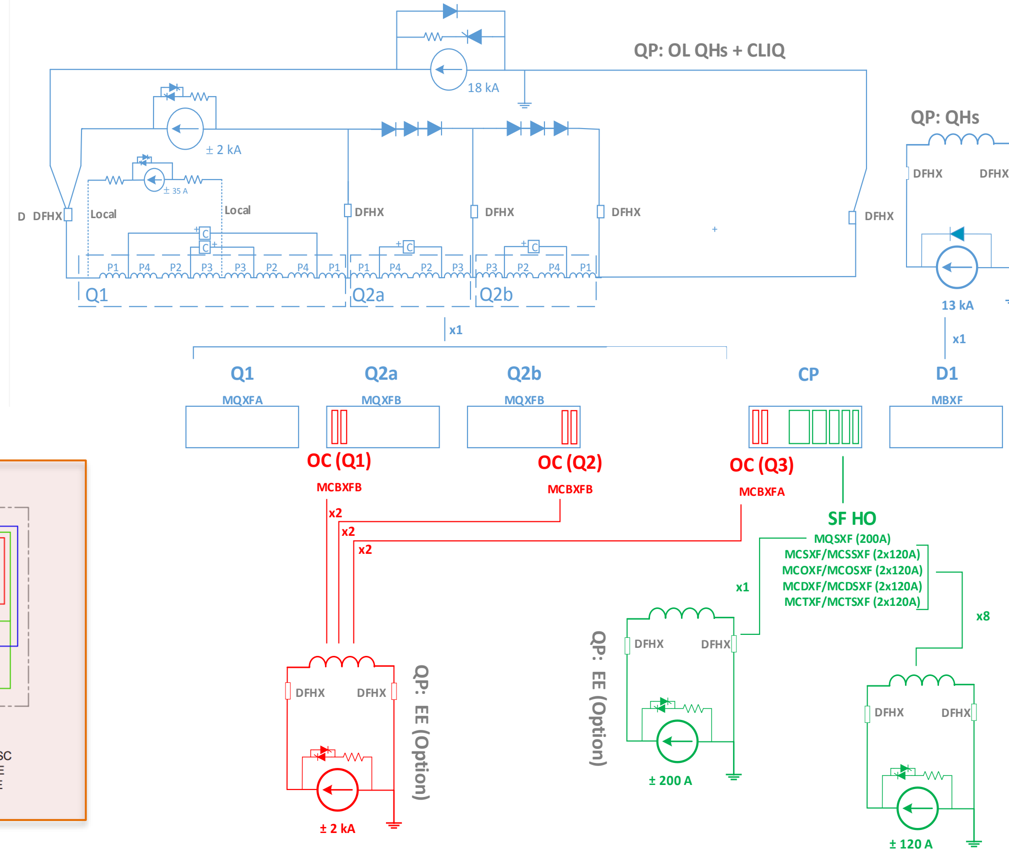
Hydraulic and mechanical connections



5L



Electrical circuit



Negligible impact on cost (20 kCHF wrt baseline) , <u>if planned sufficiently in advance.</u> There are changes in the jumper and there will be *an impact on the cryo supply line*.

In general any missing triplet magnet implies has a **major implication in the validation of the quench detection, protection as well as on the EMC studies.**

No cost reduction on powering nor on protection as the components are spare parts.

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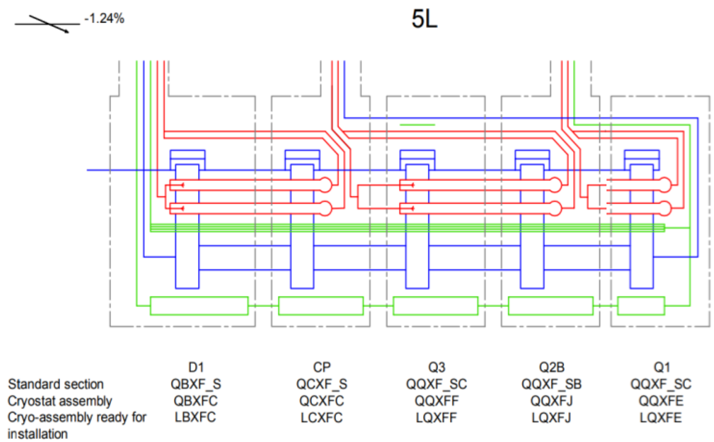
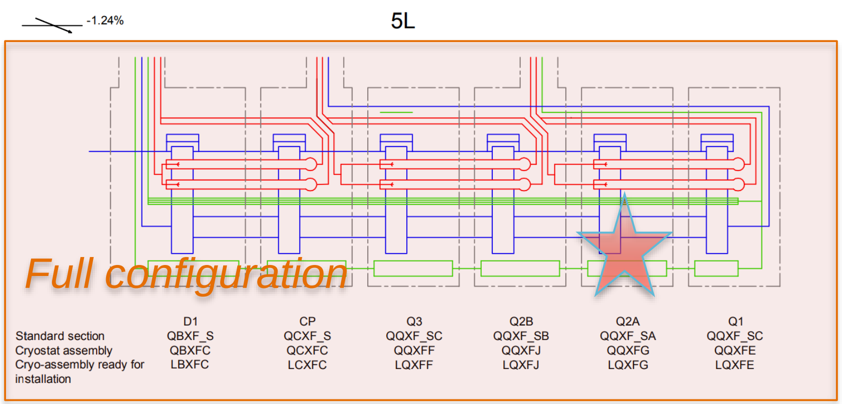
STRING without Q2a or Q2b

Hydraulic and mechanical connections





In this scenario it is **<u>better to not install Q2A</u>**. **Negligible impact on cost** *<u>if planned sufficiently in advance</u>*. *(Not installing Q2B would require building a service module with jumper on Q3 which would have to be removed later and replaced with a tunnel version.*)

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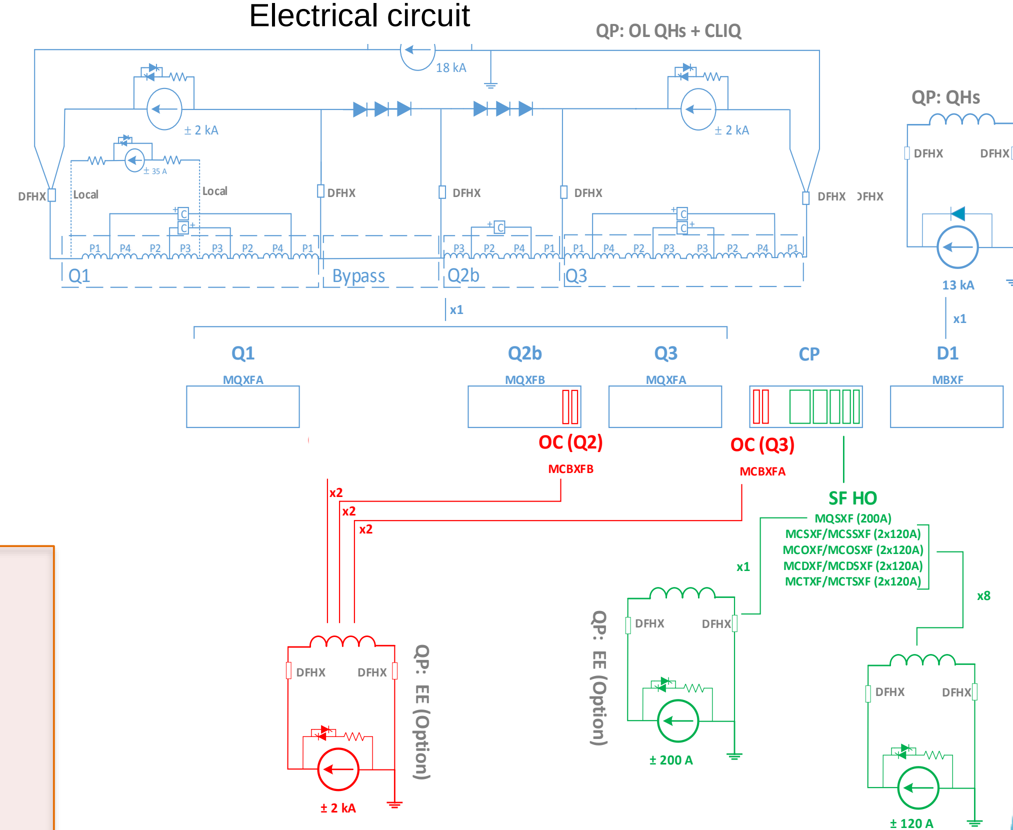
Electrical circuit

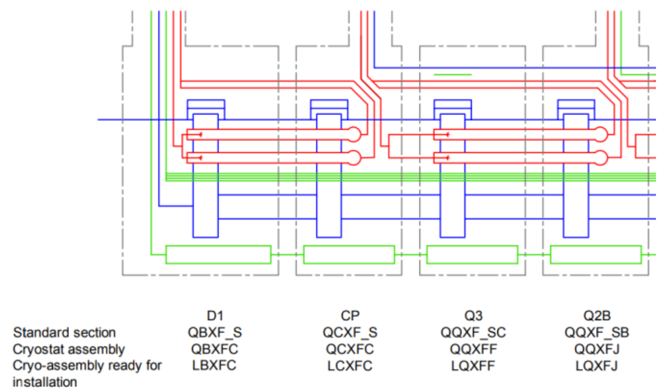


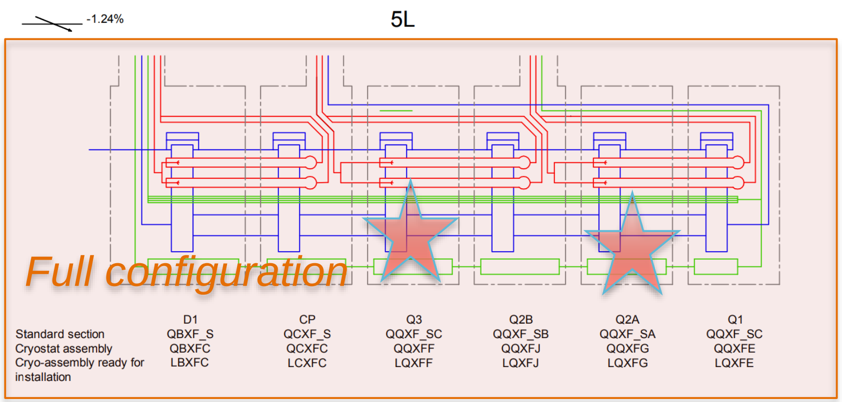
For powering point of view, although to a smaller extent than missing Q1/Q3, a missing Q2 still represents a **major implication in the validation of the quench detection and protection as well as on the EMC studies.**

No cost reduction on powering nor on protection as the components are spares, **but compensated by large efforts for simulations.**

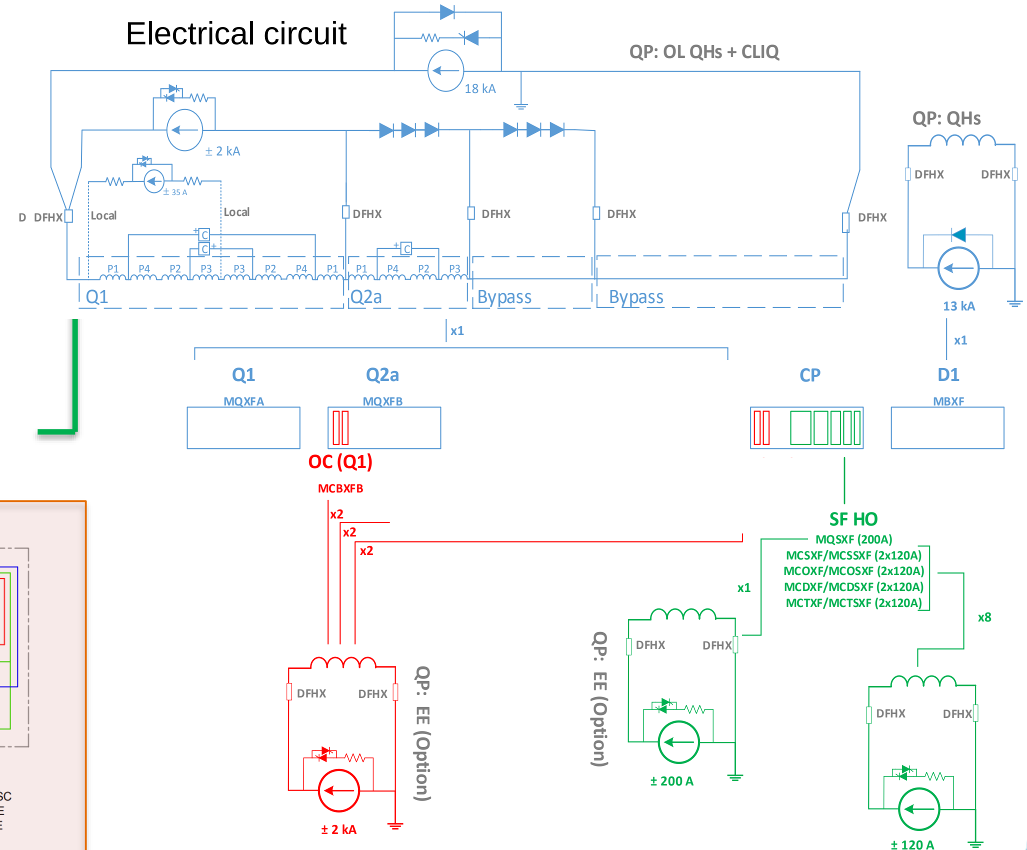
STRING without Q2a/Q2b + Q1/Q3

Hydraulic and mechanical connections





Electrical circuit



Changes on the Q2B service module are required, implying extra costs:

- 15 kCHF design office
- 40 kCHF for components
- 17 kCHF for manpower assembly
- A total of **72 kCHF extra cost** wrt the baseline

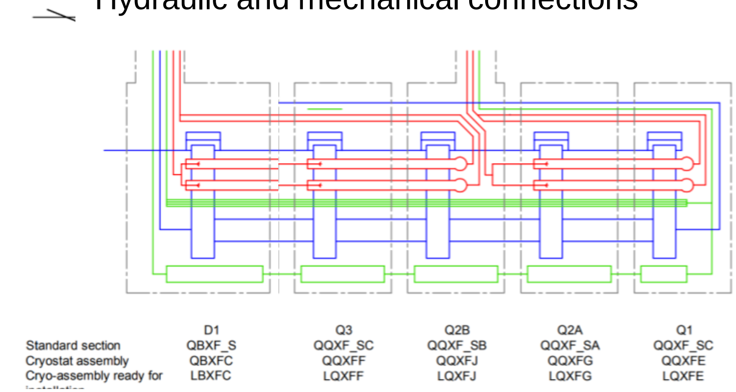
Studied by. D. Duarte MSC, S. Yammine EPC, M. Zerlaut MPE, A. Perin CRG

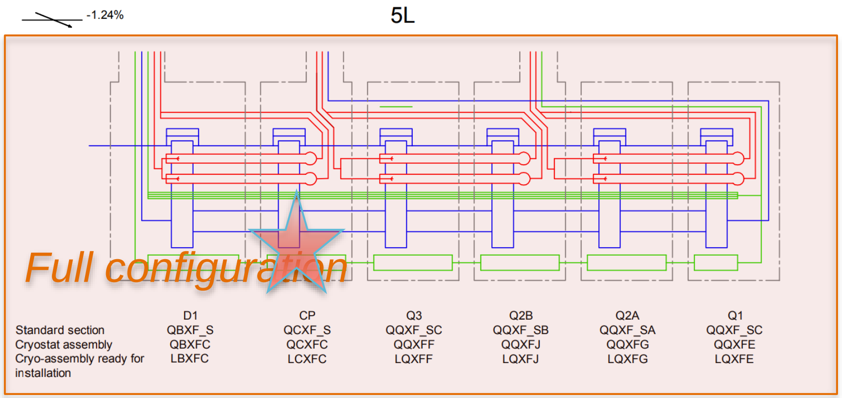
2 or 3 Layer Nested Circuit Control Configuration can be done but not fully representative. Precision studies could be representative . No cost reduction on powering (some installation cost)

Configuration degraded to an extent where MPE considers such STRING test not valuable.

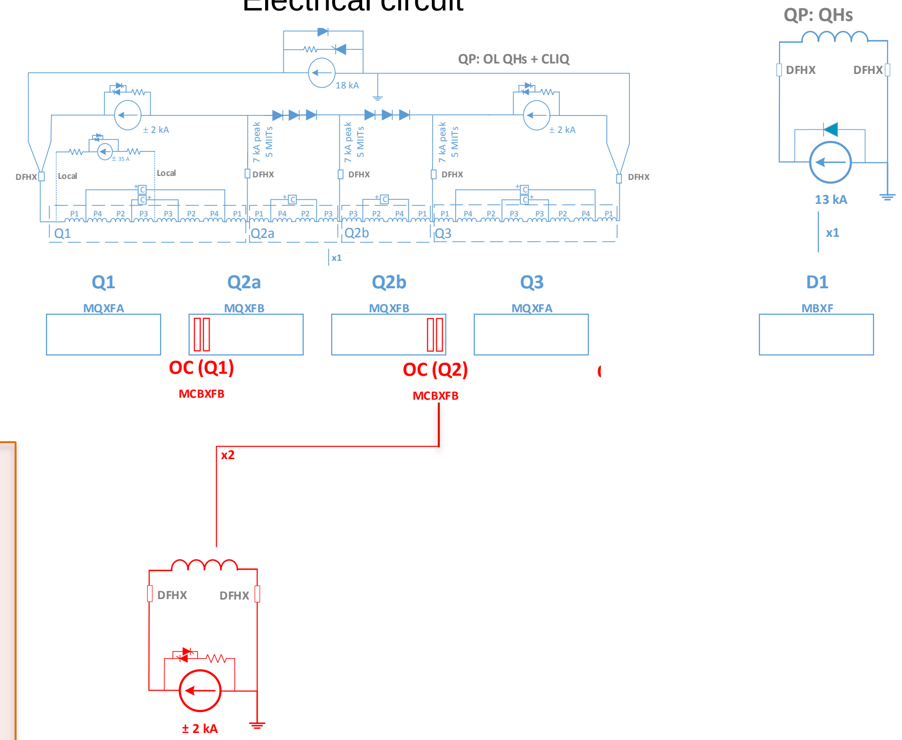
STRING without CP

Hydraulic and mechanical connections





Electrical circuit



The location of the D1 jumper will change, thus impacting the cryo supply line. A special service module must be designed and built on D1, with additional costs

- +35 kCHF design office
- +50 kCHF for components
- +70 kCHF for assembly manpower
- +20 kCHF from CRG side for supply line modification (0.2 TFE)
- -50 kCHF for jumper

A total of **125 kCHF** extra cost wrt baseline and <u>should be planned not later than 2019.</u>

Studied by. D. Duarte MSC, S. Yammine EPC, M. Zerlaut MPE, A. Perin CRG

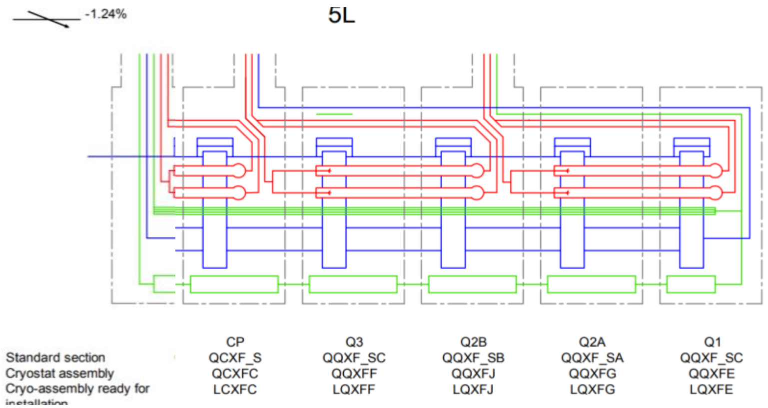
No need for 2 x 2 kA + 9 x 600 A PCs. No impact on powering systems (unless possibly cross-talk between circuits)

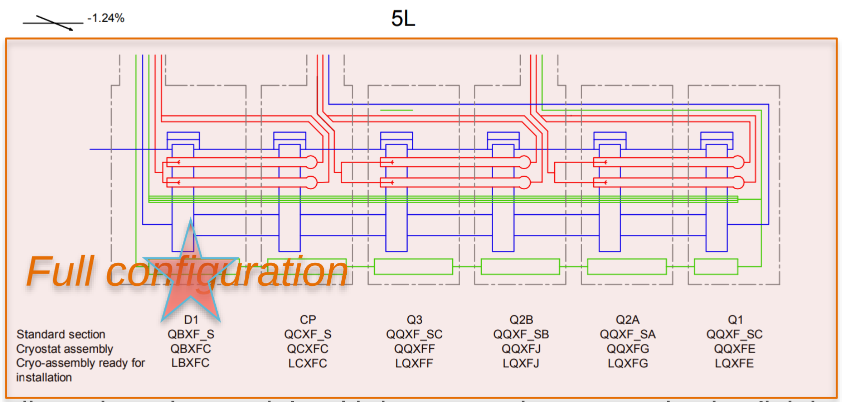
Not possible the test of 2 kA EE system for corrector magnets, in particalar for their effect and EM coupling during Fast Power Aborts on other circuits (albeit locally powered)

No impact on cost for powering expect installation since the PCs are either spare LHC PCs or pre-series for HL-LHC

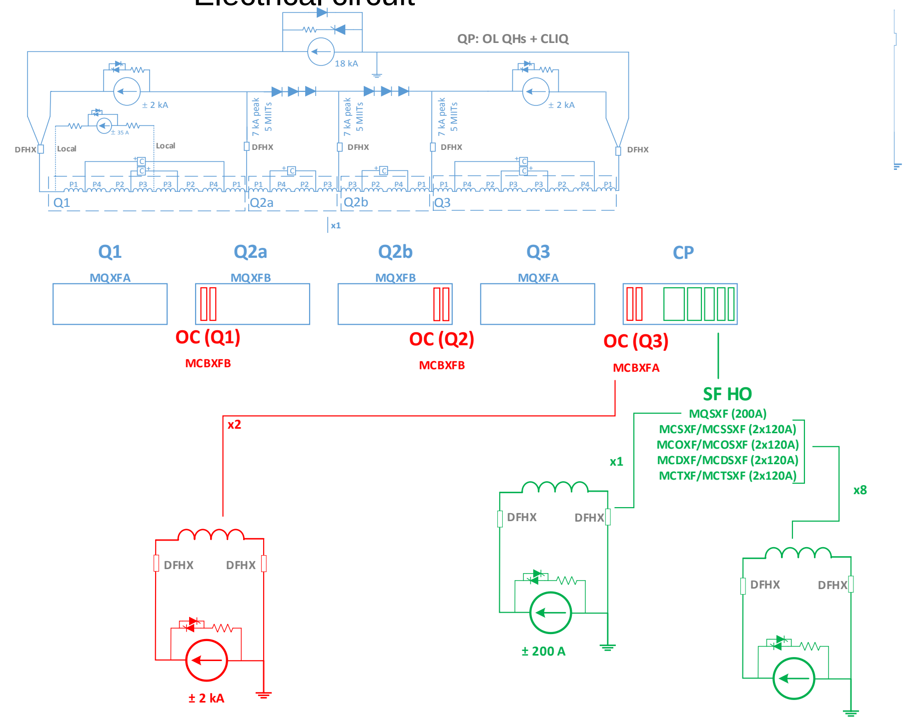
STRING without D1

Hydraulic and mechanical connections





Electrical circuit



A dedicated service module with jumper and superconducting link interfaces must be built on the non-IP end of CP, with additional costs

- +60 kCHF for design office
- +90 kCHF for compoments
- +55 kCHF for assembly manpower
- +20 kCHF from CRG side (0.2 FTE)
- -50 kCHF jumper cost

A total of **175 kCHF** extra cost wrt the base line and should be planned

No need for 13 kA PC. No foreseen impact on powering systems (unless possibly cross-talk between circuits)

Little impact on cost for powering expect installation since the PCs are either spare LHC PCs or pre-series for HL-LHC. Reduction of **10-15 kCHF** at the installation of 13 kA PC.

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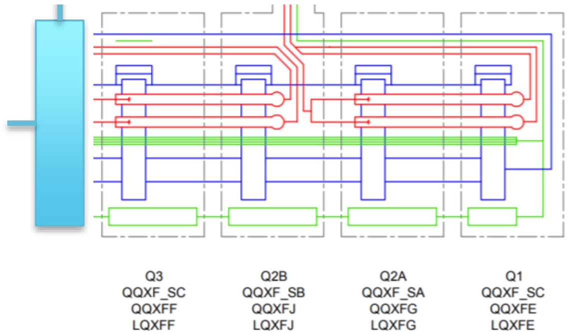
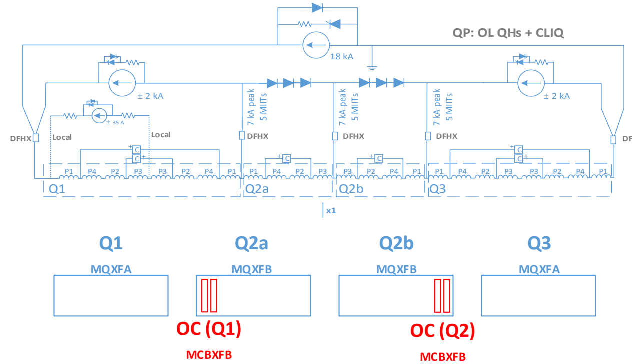
STRING without D1 and CP

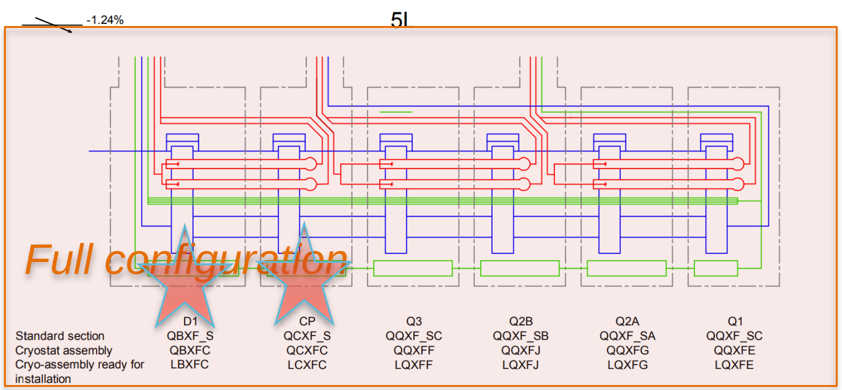
5L

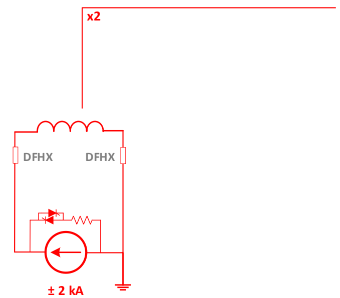
Hydraulic and mechanical connections



Electrical circuit







A dedicated and independent module must be designed and built. It must comprise a jumper to the cryo distribution line, a connection to the Sc link and have a reinforced structure to handle vacuum and quench forces:

+150 kCHF for design office

+250 kCHF for components

+140 kCHF for assembly manpower (~1.5 FTE engineer)

+ 20 kCHF on CRg sude(0.2 FTE)

-50 kCHF by recovering a jumber

A total of **520 kCHF** extra cost wrt the base line and <u>should be planned in 2019</u>

No need for 2 x 2 kA + 9 x 600 A and 13 kA PC.

No impact on powering systems (unless possibly cross-talk between circuits)

Little impact on cost for powering expect installation since the PCs are either spare LHC PCs or pre-series for HL-LHC

Installation cost is higher for the 13 kA PC (to be evaluated) that can be reduced, but less than **10-15 kCHF.**

Studied by. D. Duarte MSC, S. Yammine EPC, M. Zerlaut MPE, A. Perin CRG

COOLING THE STRING TO 80 K

All these are is very preliminary estimations

Cooling with GN2 directly (to be checked if it is possible)

- Cooling to 80 K with LN2
- Possible He test
- Equipment: **400 kCHF**
  - LN2 transfer lines + exhaust: 100 kCHF
  - Valve box/heater & interfaces for cool down/warmup: 200 kCHF
  - Instrumentation, control: 100 kCHF

Cooling with He circulation to 80 K

- Using existing pre-cooler/cold box
- Cryogenic distribution system, heater, etc.
- Equipment: rough estimation: **500 kCHF**
  - Transfer lines: 100 kCHF
  - Valve boxes, interfaces: 200 kCHF
  - Connection/valve boxes to connect to SM18 infra: 150 kCHF
  - Instrumentation/control: 150 kCHF

Studied by. A. Perin and CRG

Studied by. M. Bajko

			2464 COST
Magnet Protection System (TE-MPE)	*WP7*	**D. Wollmann**	0
	Supervision	D. Wollmann	
	Protection Heater Supplys	F. Rodriguez Mateos	
	CLIQ System	F. Rodriguez Mateos	
	Quench Detection System	R. Denz	
	Energy Extraction (Switch and Dump)	F. Rodriguez Mateos	
	Powering Interlocks (PIC)	J. Uythoven / A. Antoine	50
	Controls Infrastructure and Software	**M. Zerlauth**	50
	Performance evalutation (MP3)	A. Verweij	
	Racks, Cabling, Integration, Proximity Equipment, IFS	F. Rodriguez Mateos	250
	ELQA	F. Rodriguez Mateos	25
	By-pass diodes	F. Rodriguez Mateos	20
Magnets Cryostats&Connections (MSC)	*WP3*	E. Todesco	**418**
	Cryoassemblies coordination and MP3	S. Le Naour	
	Performance evaluation	E. Todesco	
	Installation of magnet supports (jacks)	D. Duarte	50
	Magnets support motorisation by survey	H. Mainaud	
	Magnet Interconnections, including DFX	H. Prin	158
	QA / QC	H. Prin/D. Duarte	
	Measuring Systems	M. Charrondiere	10
	WP6a	A. Ballarino	**360**
	Sc link system supervision	A. Ballarino	
	DFX/DFH Supervision	V. Parma	
	SC Link installation	J. Hurte/A. Gharib	50
	DFX, DFH Installation	Y. Leclecr	50
	Interconnections DFH (HTS)	J. Hurte/A. Gharib	100
	QA / QC	J Fleiter	
	Measuring Systems	M. Charrondiere	10
Cryogenic System (TE-CRG)	*WP16*	**A. Perin**	**500**
	Cryogenic infrastructure	A. Perin/ F. Dhalla	
	Proximity Cryogenics	M. Sisti	
	Electricity and controls	M. Pezzetti	
Warm powering system (EPC)	WP6B	M. Martino	**0**
	Circuit coordination	**S. Yammine**	
	Power Converters (EPC)	H. Thiessen	
	Control Instrumentation and Software	S. Yammine	50
Vacuum (TE-VSC)	*WP12*	**V. Baglin**	**406**
	Hardware	**J. Hansen**	88
	Hardware instrumentation	J. Hansen	0
	Hardwarecontrols	J. Hansen	96
	Experimental instrumentation	J. Hansen	0
Control technologies (BE-CO/ EN-SMM)	*WP18*	**J. Serrano**	**0**
	Control coordination	M.Gourber Pace	
	Standard System Integartion	A. Rijlaart/ J. Serrano	100
	String specifique system development	A. Rijlaart/ J. Serrano	100
	Network (Including Wfip)		10
	Control room and cabling	M. Charrondiere	10
Utilities (GS, EN, HSE)			**400**
	Metalic Structures (GS)	E. Perez Duenas	0
	Demineralised Water distribution (EN CV)	A. J. Broche	0
	Water Cooled Cables (EN EL)	L. Sburlino	0
	Survey System (EN ACE)	H. Mainaud	10
	Transport and Handling EN-HE)	S. Pelletier	50
	Safety (HSE)	C. Arregui	50
	Design and Integration	A.Kosmicki	250
STRING Coordination (TE-MSC)	WP16	M. Bajko	**100**
Commisioning Coordination (BE-OP)	WP16	M. Pojer	**280**

The validation of electrical circuits, quench detection, protection, electromagnetic coupling and even the alignment issues can not be done in such configuration. Non of the implied WG or Groups is considering as an added value for the project. The total cost of a STRING at 80 K is estimated to 2.4 MCHF.

Summary table of (studied) configurations

case nr	CONFIGURATION without beam screen	COST (extra or savings wrt baseline [kCHF])	PROGRAM representative of HL-LHC	Comments
1	**Q1,Q2a,Q2b,Q3,CP,D1**	**0**	**yes**	**Full program**
2	~~Q1~~, Q2a,Q2b,Q3,CP,D1	110	not	no K-modulation, Lack of possibility to test the trim for the protection of the leads , QP not standard LHC for triplet*
3	Q1,Q2a,Q2b,~~Q3~~,CP,D1	20	not	Feasible if decided in advance, K modulation ok, QP not standard LHC for triplet*
4	Q1, Q2a,~~Q2b~~,Q3,CP,D1	0	not	Representative Nested Circuit Control Configuration as the full string ; Precision studies are representative. QP not standard LHC for triplet *
5	~~Q1, Q2a~~,Q2b,Q3,CP,D1	72	not	NOT VALID for any WP
6	Q1, Q2a,Q2b,Q3,~~CP~~,D1	125	not	Not possible the testing in the string of 2 kA EE system for Sc corrector magnets, in particular for their effect and EMC during FPA on other circuits.
7	Q1, Q2a,Q2b,Q3,CP,~~D1~~	175	not	As long as service module is maintained in a ‘machine-like’ version, a missing D1 would still allow the full qualification of the complex quadrupole circuit
8	Q1, Q2a,Q2b,Q3,~~CP,D1~~	505	not	Not possible testing in the string of 2 kA EE system for Sc corrector magnets, and is important to keep the service modul to validate Sc link and EMC..
9	Full STRING @ 80 K	4000	not	NOT VALID for any WP

***Any of the triplet magnets missing has a major implication for the significance and validation of the overall circuit configuration, in particular for quench detection schemes, quench studies (magnets and sc link) as well as studies of electromagnetic coupling and relevant failure scenarios**

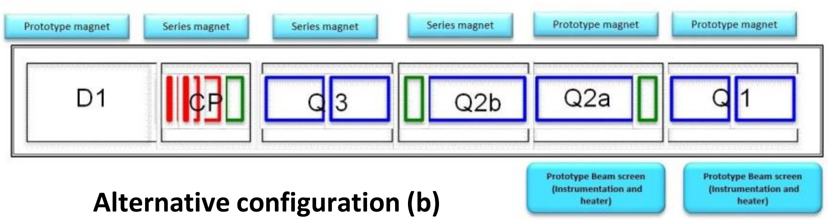
No cost reduction for powering however largely compensated by additional simulation + reconfiguration efforts!!!)

.

SAVINGS: Vacuum 749 kCHF+30 kCHF

Alternative configuration (b)

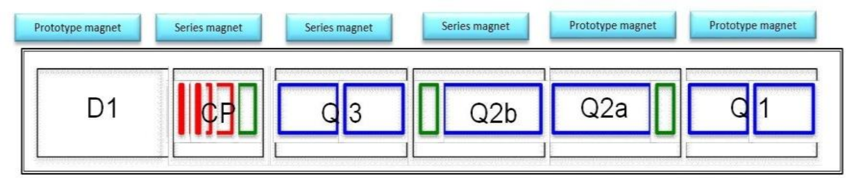
•No series beam screens in series magnets;
•Prototype beam screens for Q2a and Q1 only;
•Common beam and insulation vacuum;
•No vacuum membrane;
•Pumping and instrumentation hardware can be covered by WP12 if dismantled before 2024;
•Prototype beam screens can be installed with heaters on the tungsten blocks at the request of TE/CRG;
•No PIM with dummy BPM, prototype BPM at Q2a/Q1 interconnect (supplied by BE/BI);
•No PIM with BPM, prototype PIM at Q2a/Q1 interconnect.



Alternative configuration (b)

Alternative configuration (f)

- No beam screens in series magnets or prototype magnets;
- Common beam and insulation vacuum;
- Pumping and instrumentation hardware covered by WP12 but dismantled before 2024;
- No experimental instrumentation.



Alternative configuration (f)

Studied by. G. Riddone, P. Cruikshank, J. Hansen VSC, A. Perin CRG

	Hardware [kCHF]	Industrial Support [kCHF]	MPA [kCHF]	Total [kCHF]
Maximal configuration	1275	315	369	1959
No MPA for 2021-2022			-185	-185
No prototype BS in D1	-180		-30	-210
Common beam vacuum	-147.5			-147.5
Vacuum equipment dismantled before 2024, therefore part of the CtC WP12	-121.5			-121.5
Total for alternative configuration				**1295**

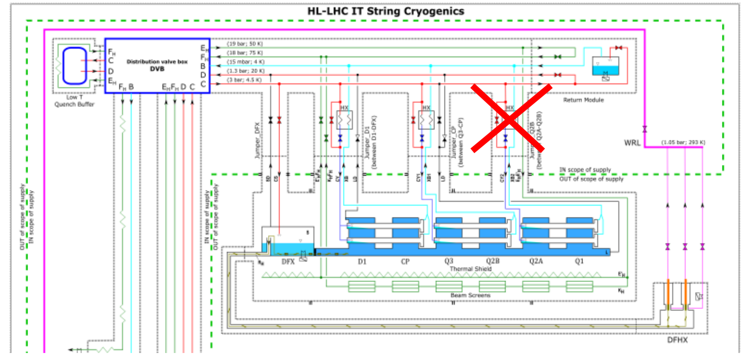
Material	2018	2019	2020	2021	2022	2023	Total required [kCHF]
Hardware	0	0	88	0	0	0	88
Hardware instrumentation	0	0	93	22	0	0	115
Hardware controls	0	0	75	21	0	0	96
Industrial support	0	0	50	172	25	0	247
MPA	0	0	0			0	0
Total budget (Installation & commissioning)	0	0	306	215	25	0	**546**

https://edms.cern.ch/document/1820998/2.2https://edms.cern.ch/document/1820998/2.2

SAVINGS: Cryogenics 200 kCHF

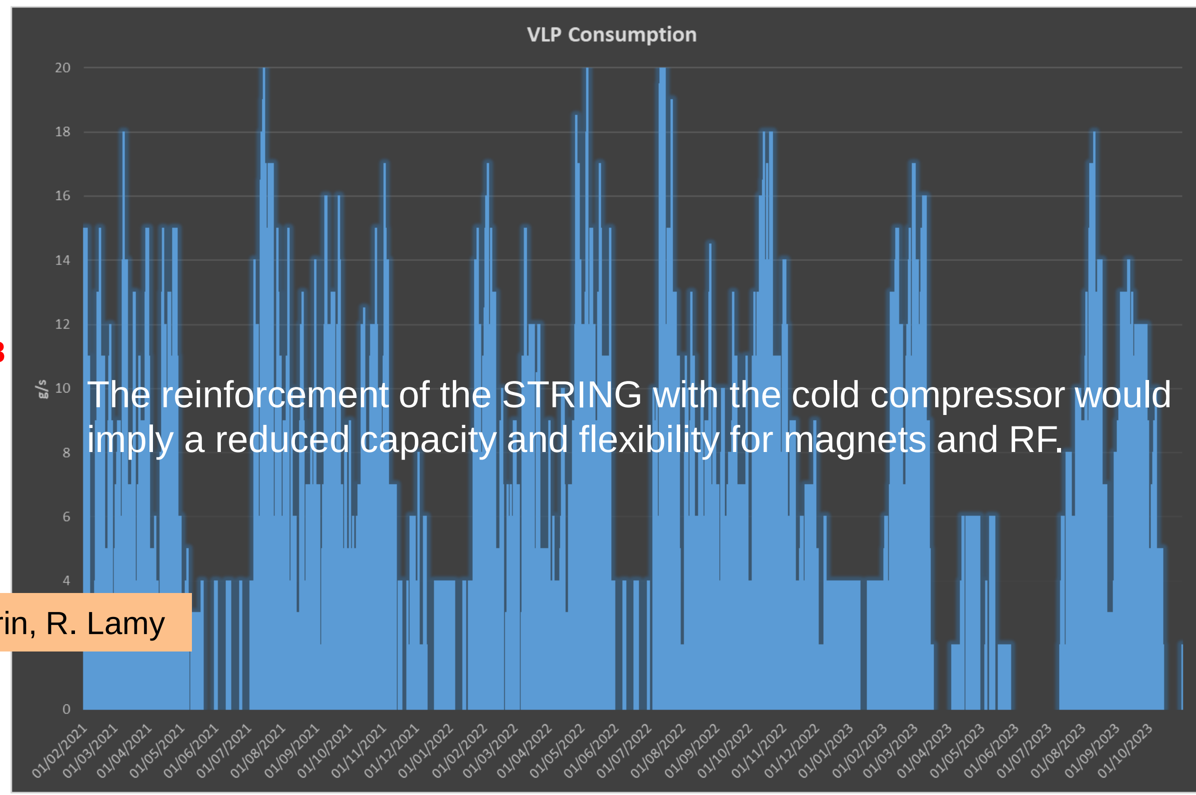
a. <u>no jumper at Q2 (cost neutral !)</u>

+ Possibly savings of 50 kCHF – 70 kCHF
- Requires modification of pipe routing in cryostat and CP jumper of aprox. 70 kCHF (see slide on Q2a missing)



b. <u>no cold compressor</u>: 200 kCHF :

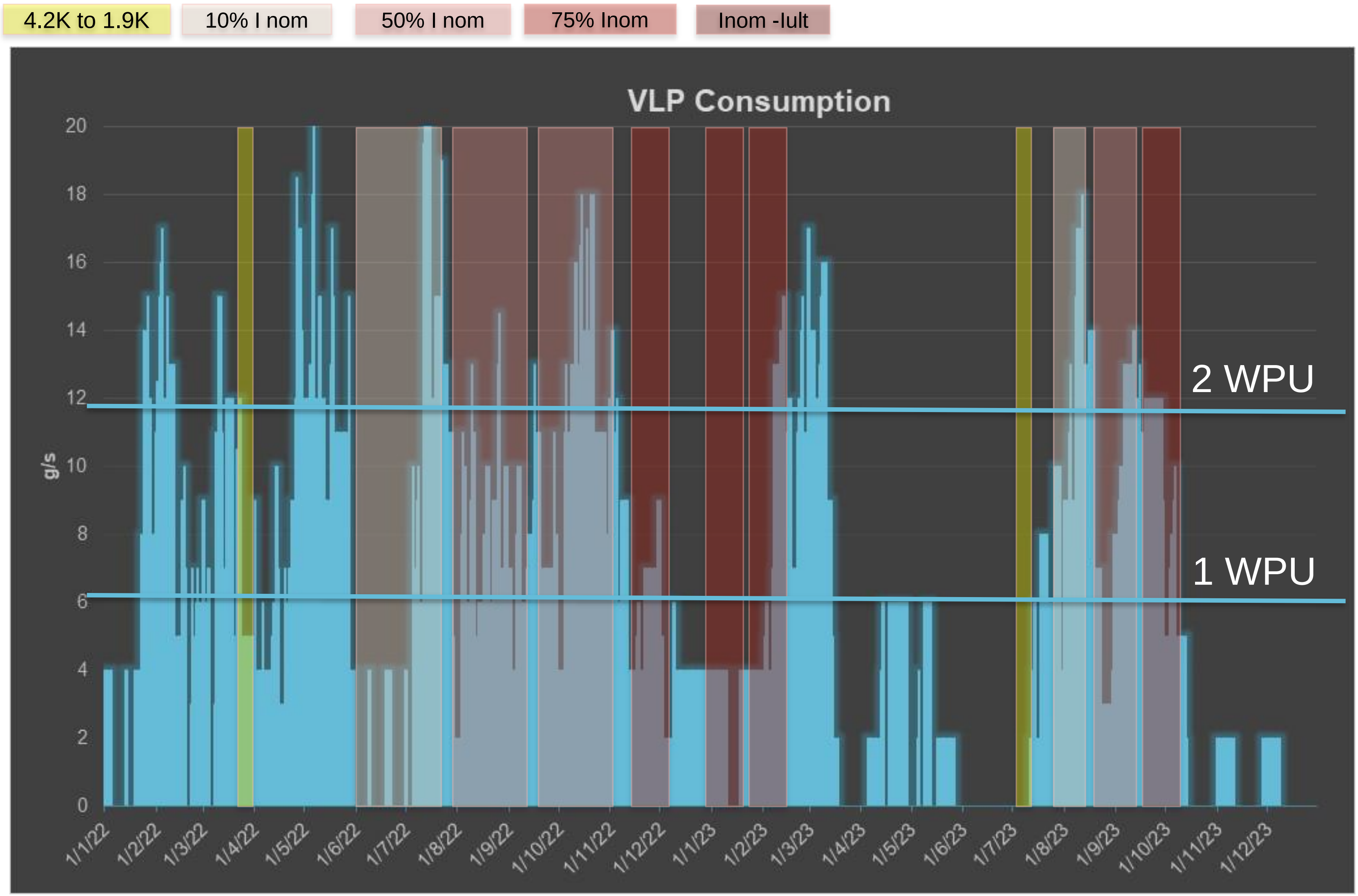
+ No refurbishment of the cold compressor.
+ Less demanding pumping line.
+ saving of approx. 200 kCHF + resources
- **Need two WPUs for high load tests (impact on SM18 operation).**
- **Not possible to reproduce precisely the HL-LHC cryogenic conditions at high loads**



The reinforcement of the STRING with the cold compressor would imply a reduced capacity and flexibility for magnets and RF.

Studied by. M. Bajko, E. Vergara, A. Perin, R. Lamy

Looking into the consumptions with STRING



SAVINGS: Warm powering max 250 kCHF
(tbc with the baseline)

Initial estimate without control cables but with ACC and WCC of max length 10 m was 500 kCHF.

Section (mm2)	Type cable	Long. Totale (m)	Nbre câbles	Nbre cosses
70	ACC	180	18	36
500	WCC	160	16	28
2x1000	WCC	40	4	8
2 x 1300	WCC	40	4	8

If we do no use WCC but we add the OPTION B for 20 kA power converter late arrival : powering from Cluster A temporary + control cables the estimate is 250 kCHF

Section (mm2)	Type cable	Long. Totale (m)	Nbre câbles	Nbre cosses
70	ACC	180	18	36
~~500~~	~~WCC~~	~~160~~	~~16~~	~~28~~
~~2x1000~~	~~WCC~~	~~40~~	~~4~~	~~8~~
2 x 1300	WCC	40	4	8

To be confirmed the final design of connection between current leads and power converters

HiLumi HL-LHC PROJECT

Summary table of savings

case nr	CONFIGURATION without beam screen	COST [kCHF]	PROGRAM representative of HL-LHC Comments
	Baseline	**7447**	**Full program with 1 MCHF extra cost not aproved**
1	No Beam Screen and common vacuum	**779**	No studies of heat transfer nor CLIC induced deformations, interconnections ect.
3	No Cold Compressor for 1.9 K operation	**200**	This solution has to be abandoned to better serve the magnet testing
4	No Water cooled cables	**250**	Potential savings but not yet defined the HL-LHC baseline*
9	Full STRING @ 80 K	**4000**	NOT VALID for any WP

The total cost of the HL-LHC STRING can be reduced with 779+ 200 = 979 kCHF considering not to use the beam screen and not to use the cold compressor.

The operation of the SM18 with STRNG will require careful and optimized coordination as the total required pumping capacity is higher than the capacity we have.

The details of the BUDGET with SAVINGS

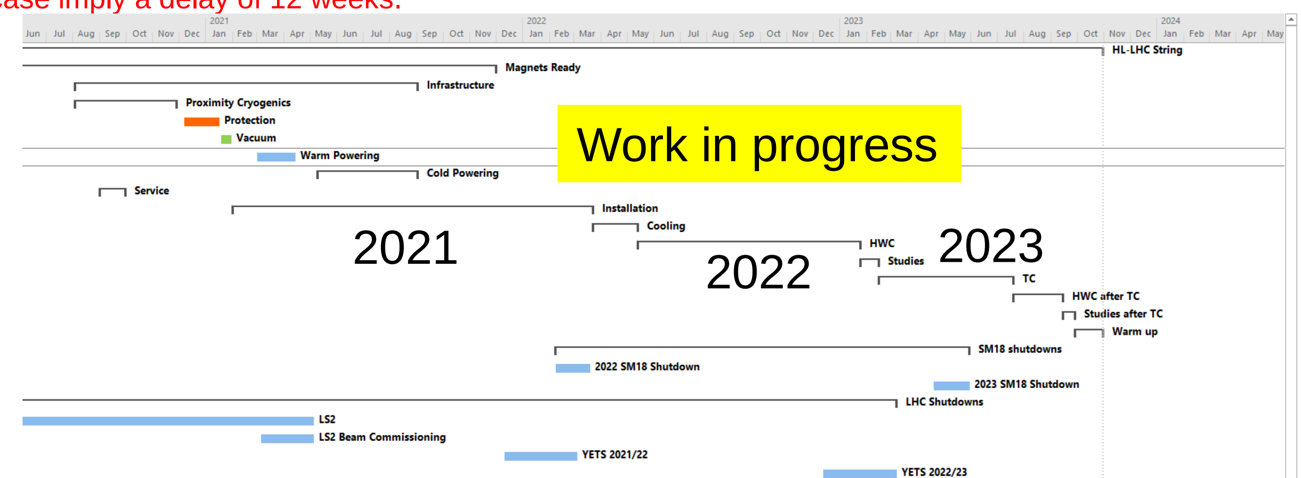
			7447	6488
			COST	COST
Magnet Protection System (TE-MPE)	*WP7*	D. Wollmann	**615**	**615**
	Supervision	D. Wollmann		
	Protection Heater Supplys	F. Rodriguez Mateos		
	CLIQ System	F. Rodriguez Mateos		
	Quench Detection System	R. Denz		
	Energy Extraction (Switch and Dump)	F. Rodriguez Mateos		
	Powering Interlocks (PIC)	J. Uythoven / A. Antoine	50	50
	Controls Infrastructure and Software	M. Zerlauth	50	50
	Performance evalutation (MP3)	A. Verweij		
	Racks, Cabling, Integration, Proximity Equipment, IFS	F. Rodriguez Mateos	250	250
	ELQA	F. Rodriguez Mateos	25	25
	By-pass diodes	F. Rodriguez Mateos	20	20
Magnets Cryostats&Connections (MSC)	*WP3*	E. Todesco	**418**	**418**
	Cryoassemblies coordination and MP3	S. Le Naour		
	Performance evaluation	E. Todesco		
	Installation of magnet supports (jacks)	D. Duarte	50	50
	Magnets support motorisation by survey	H. Mainaud		
	Magnet Interconnections, including DFX	H. Prin	158	158
	QA / QC	H. Prin/D. Duarte		
	Measuring Systems	M. Charrondiere	10	10
	WP6a	A. Ballarino	**360**	**360**
	Sc link system supervision	A. Ballarino		
	DFX/DFH Supervision	V. Parma		
	SC Link installation	J. Hurte/A. Gharib	50	50
	DFX, DFH Installation	Y. Leclerc	50	50
	Interconnections DFH (HTS)	J. Hurte/A. Gharib	100	100
	QA / QC	J Fleiter		
	Measuring Systems	M. Charrondiere	10	10
Cryogenic System (TE-CRG)	*WP16*	A. Perin	**2490**	**2260**
	Cryogenic infrastructure	A. Perin/ F. Dhalla	200	
	Proximity Cryogenics	M. Sisti	1300	1300
	Electricity and controls	M. Pezzetti	280	280
Warm powering system (EPC)	WP6B	M. Martino	**460**	**460**
	Circuit coordination	S. Yammine		
	Power Converters (EPC)	H. Thiessen		
	Control Instrumentation and Software	S. Yammine	50	50
Vacuum (TE-VSC)	*WP12*	V. Baglin	**1250**	**521**
	Hardware	J. Hansen	480	88
	Hardware instrumentation	J. Hansen	106	115
	Hardwarecontrols	J. Hansen	125	96
	Experimental instrumentation	J. Hansen	115	0
Control technologies (BE-CO/ EN-SMM)	*WP18*	J. Serrano	**220**	**220**
	Control coordination	M.Gourber Pace		
	Standard System Integartion	A. Rijlaart/ J. Serrano	100	100
	String specifique system development	A. Rijlaart/ J. Serrano	100	100
	Network (Including Wip)		10	10
	Control room and cabling	M. Charrondiere	10	10
Utilities (GS, EN, HSE)			**1154**	**1154**
	Metalic Structures (GS)	E. Perez Duenas	204	204
	Demineralised Water distribution (EN CV)	A. J. Broche	50	50
	Water Cooled Cables (EN EL)	L. Sburlino	500	500
	Survey System (EN ACE)	H. Mainaud	10	10
	Transport and Handling EN-HE)	S. Pelletier	50	50
	Safety (HSE)	C. Arregui	50	50
	Design and Integration	A.Kosmicki	250	250
STRING Coordination (TE-MSC)	WP16	M. Bajko	**200**	**200**
Commisioning Coordination (BE-OP)	WP16	M. Pojer	**280**	**280**

From 7.45 kCHF to 6.48 kCHF

Planning modifications

The STRING test plan was up dated following :

1. The changes in the master plan regarding the delivery of magnets from the USA. This imply a delay!
2. The number of quenches for HWC of the string reducing with a 40% justified by the fact that the Q!-Q3 are in a single circuit and any quench provoked in any of the 4 cold masses implies a quench in all others offering the possibility to analyze them all and also to vary from quench to quench the magnet in which we provoke it).This imply a time reduction for operation!
3. Revised time delay for ELQA. This imply a time reduction for operation!
4. Revised time delay for cooling and warming from 300-80 K and vice versa. This imply a time reduction in the cooling and warming phase so in operation.
5. Revised time for studies justified by the fact that we are not going to install beam screen so all associated test have been cancelled. This imply a time reduction for operation.
6. We delayed the delivery of major components as warm and cold powering and cooling to the dates that are in line with the delays of the magnets indicating the deadline for them. This has no effect on the present planning but gives more margin for some systems.
7. We implemented the 2 yearly shut-down of SM18 of a duration of 6 weeks each (as usual) and in the most optimal position for test of magnets and HL-LHC STRING. However the baseline of the SM18 UPG project is such that SM18 operation is linked to SPS operation and as a consequence the yearly SM18 shut –down would be during the YETS. This is under discussion and feed back on the solution will be given April 2019 (ref. discussions with V. Mertens). The shut down in the best case imply a delay of 12 weeks.



We end in October 2023 with an operation that is (17+3 =) 20 months long

Conclusions

- **Any deviation from the baseline implies either :**
  - **an extra cost** due to compensations by additional simulations and/or **reconfiguration** efforts or
  - **no cost savings as** the current plan for the HL-LHC STRING uses either PROTOTYPES that **must be built anyway** or SERIES components that will be installed in the machine).
- Some **possible variants**, would allow a quite complete learning but:
  - require extensive design and specific procurement of components, hence go-ahead must be given well in advance (ex: at least 2 years in the case of **no D1** and **no CP**).
  - A non negligible **extra cost (0.5 MCHF)** would require for its implementation and

- The **80 K version** of cooling does **not** seems to **bring added value** for the different users of the STRING and this including the alignment that is requiring also 1.9 K operation, although this would be the only option for real savings.

- Independent of these options a p**ossible savings are in the order of 970 kCHF**

- The optimization of the planning is ongoing . The present version includes the late arrival of the USA magnet bringing us to end the STRING operation October 2023.

Remarks

- **Any reduced version** of the HL-LHC STRING may **prevent us from detecting unforeseen failure** modes and therefore will not represent a full validation test of the cryo-assembly.
- **In particular a configuration without one of the triplet magnets would seriously impact the our learning** as would completely change the circuit topology and its behaviour and therefor not represent a full validation test.
- Some **possible variants**, would allow a quite complete learning but would require additional charge for engineering on the same teams (persons, groups, wp) while the baseline options are under development
- The **80 K version** of cooling does **not** seems to **bring added value** for the different users of the STRING and this including the alignment that is requiring also 1.9 K operation and clearly would not allow us to test the technological challenges of the whole new Nb_3SN Sc based inner triplet.

The priority is the full qualification of the complex, nested quadrupole circuit (including the magnet STRING and the Sc link)

- As the mechanical design of the String QXL started from January 2019, it will not be possible to significantly modify it at a later stage without compromising the commissioning date of end of 2020. Similarly for the cold mass modifications the latest date is mid 2019.

Extra slide : Planning details on magnet arrival

Task Name	Duration	Start	Finish	Predecessors
HL-LHC String	**1058 day**	**Mon 29/07/19**	**Mon 30/10/23**	
Magnets Ready	**580 days**	**Mon 29/07/19**	**Wed 01/12/21**	
~~Q1 Prototype~~	~~617 days~~	~~Tue 21/11/17~~	~~Mon 08/06/20~~	
~~Test SM18~~	~~0 days~~	~~Mon 08/06/20~~	~~Mon 08/06/20~~	
~~Q1 Prototype Ready~~	~~0 days~~	~~Tue 21/11/17~~	~~Tue 21/11/17~~	
Q1	**20 days**	**Mon 02/08/21**	**Fri 27/08/21**	
Delivery at CERN	0 days	Mon 02/08/21	Mon 02/08/21	
Test at CERN	1 mon	Mon 02/08/21	Fri 27/08/21	7
Q1 Prototype Ready	0 days	Fri 27/08/21	Fri 27/08/21	8
Q2a Prototype	**0 days**	**Mon 29/07/19**	**Mon 29/07/19**	
Test SM18	0 days	Mon 29/07/19	Mon 29/07/19	
Q2a Prototype Ready	0 days	Mon 29/07/19	Mon 29/07/19	11
Q2b Prototype	**0 days**	**Fri 13/03/20**	**Fri 13/03/20**	
Test SM18	0 days	Fri 13/03/20	Fri 13/03/20	
Q2b Prototype Ready	0 days	Fri 13/03/20	Fri 13/03/20	14
Q3 serie	**0 days**	**Wed 01/12/21**	**Wed 01/12/21**	
Delivery at CERN	0 days	Wed 01/12/21	Wed 01/12/21	
~~Test at CERN~~	~~2 mons~~	~~Wed 01/12/21~~	~~Tue 08/02/22~~	~~17~~
Q3 serie Ready	0 days	Wed 01/12/21	Wed 01/12/21	17
D1 Prototype	**0 days**	**Fri 05/03/21**	**Fri 05/03/21**	
D1 prototype Ready	0 days	Fri 05/03/21	Fri 05/03/21	
CP serie	**0 days**	**Fri 05/03/21**	**Fri 05/03/21**	3
CP serie Ready	0 days	Fri 05/03/21	Fri 05/03/21	
Infrastructure	**267 days**	**Mon 03/08/20**	**Wed 01/09/21**	
Installation	**282 days**	**Mon 01/02/21**	**Tue 22/03/22**	
Handling and installation	45 wks	Mon 01/02/21	Fri 17/12/21	2FF,38,32FF,
ELQA warm 1	3 days	Mon 20/12/21	Wed 05/01/22	43
Alignment	3 wks	Thu 06/01/22	Wed 26/01/22	44
Electrical Interconnections	3 wks	Thu 27/01/22	Wed 16/02/22	45
ELQA warm 1	3 days	Mon 20/12/21	Wed 05/01/22	43
Hydraulic Interconnections	15 days	Thu 27/01/22	Wed 16/02/22	
Insert of PIMs	3 wks	Thu 27/01/22	Wed 16/02/22	46SS
Installation of vacuum membranes	3 wks	Thu 27/01/22	Wed 16/02/22	46SS
Installation of pumping modules and gauges	3 wks	Thu 27/01/22	Wed 16/02/22	46SS
Vacuum	**15 days**	**Thu 27/01/22**	**Wed 16/02/22**	
Intermediate leak Beam Vac, He lines, Ins Vac	2 wks	Thu 27/01/22	Wed 09/02/22	46SS
Interconnect closure	1 wk	Thu 27/01/22	Wed 02/02/22	46SS
Pumping ins Vac	2 wks	Thu 03/02/22	Wed 16/02/22	54
ELQA Warm 3	3 days	Thu 17/02/22	Mon 21/02/22	52
Connection ELQA monitoring	2 days	Tue 22/02/22	Wed 23/02/22	56
Connection of instrumentation (cryo and beam)	1 wk	Thu 24/02/22	Wed 02/03/22	57
ELQA warm 4	3 days	Thu 03/03/22	Mon 07/03/22	58
Pressure and leak test	1 wk	Tue 08/03/22	Mon 14/03/22	59