Cold powering: Updated baseline and Results from Demo 1 construction

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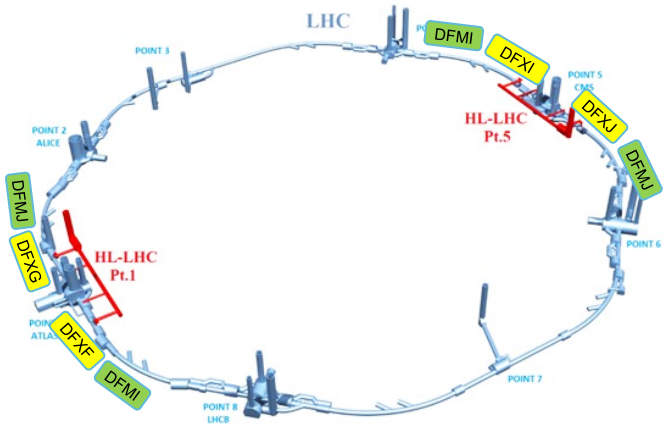
8th HL-LHC Collaboration Meeting
15-18 October 2018
CERN

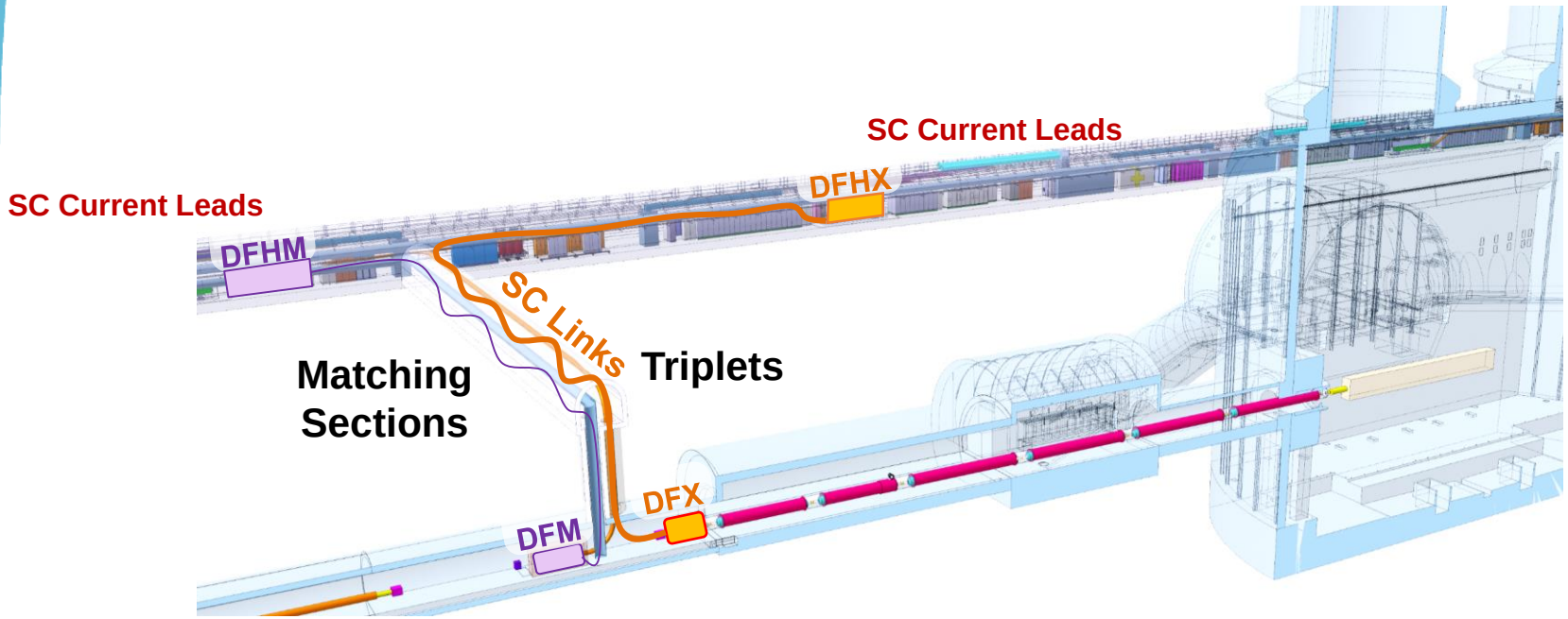
Outline

- Cold Powering of HL-LHC magnets (WP6a)
- Updated baseline
  - Implemented changes wrt 2017 baseline
- Achievements in 2018
  - Major technical achievements
  - Master plan and milestones vs work progress
- Demo 1: a turning point toward a system demonstrator
  - Scope and progress to date
- Conclusions

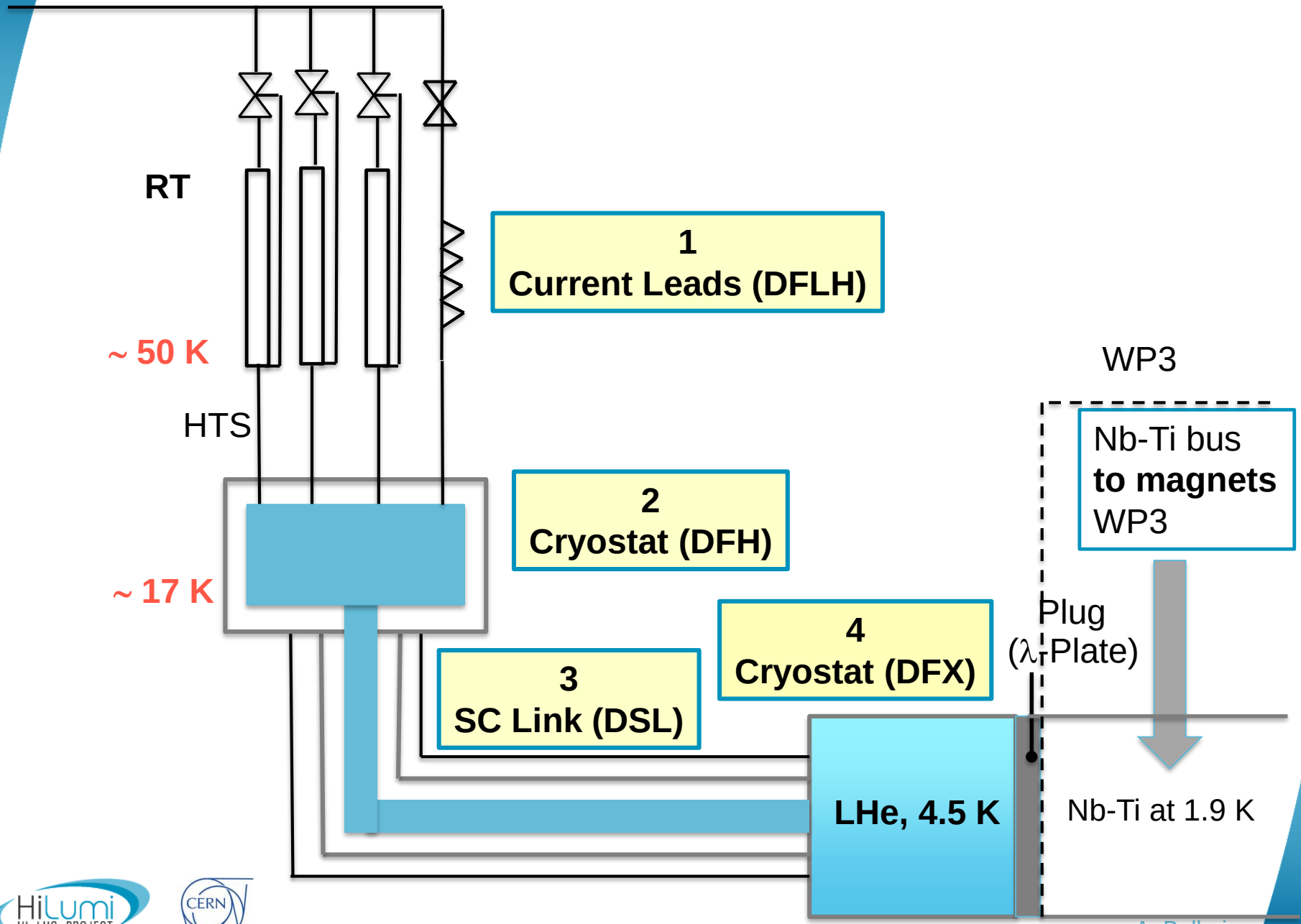
Cold Powering Systems for HL-LHC

- **Eight Cold Powering Systems**
- **Two different types** (one for the **Triplets** and one for the **Matching Sections** - D2 and its correctors)

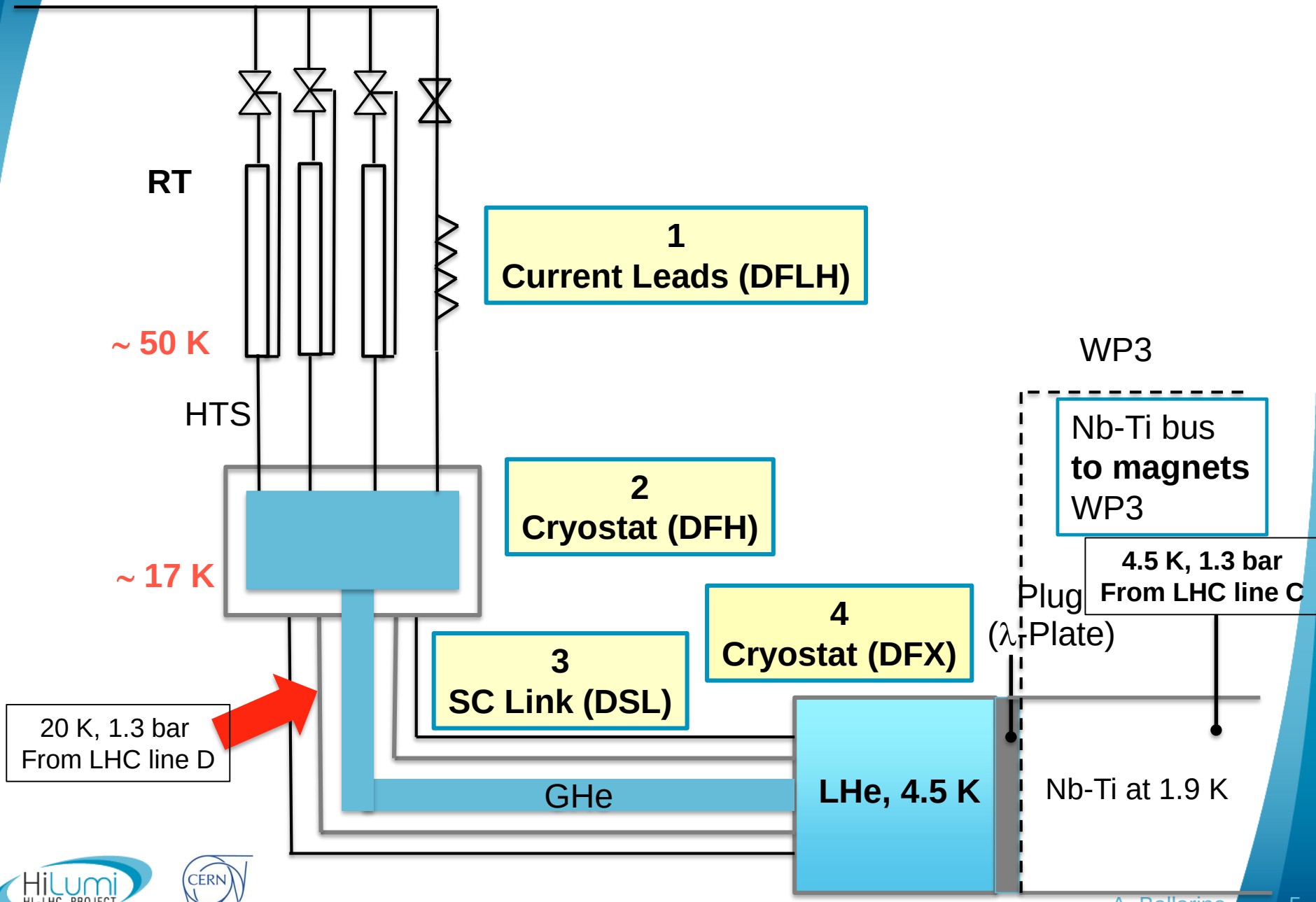




Cold Powering System for HL-LHC



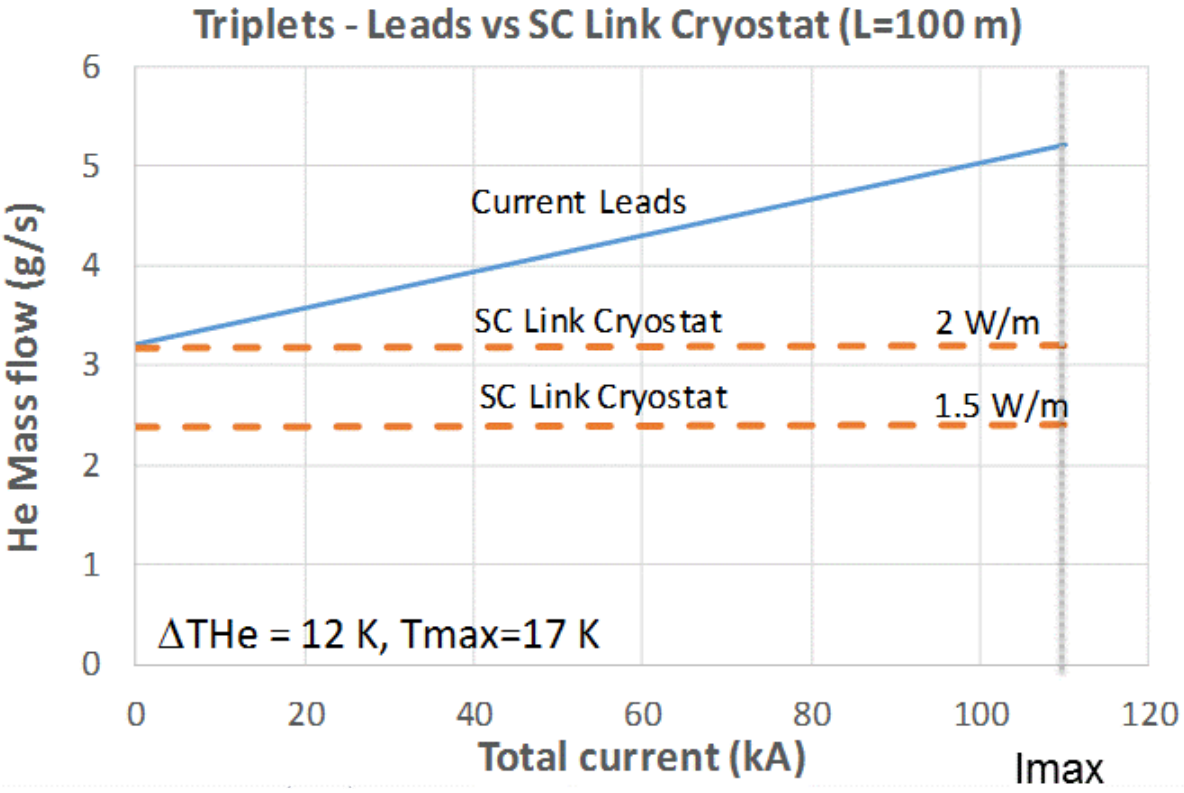
Baseline 2017 - Cryogenic



Change in baseline N.1

Elimination of actively cooled thermal shield from SC Link cryostat (and of associated cryogenic circuit)

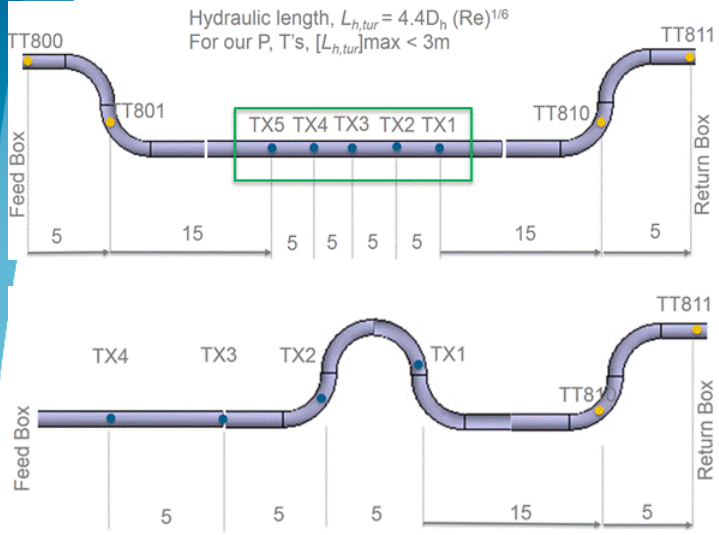
Procurement and qualification of three 60 m long prototype cryostats (with no active shield), two of with static load (at ~ 10 K) of less than 2 W/m (**~ 1.5 W/m**). Cryogenic performance dominated by current leads - the SC link cryogenically "transparent" to the system



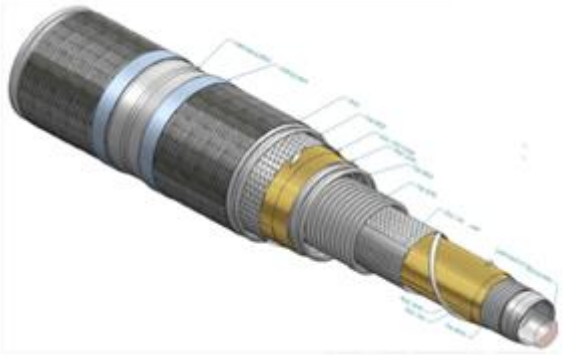
For Triplets:
$Q \leq 1.5$ W/m

For Matching Sections:
$Q \leq 0{,}7$ W/m

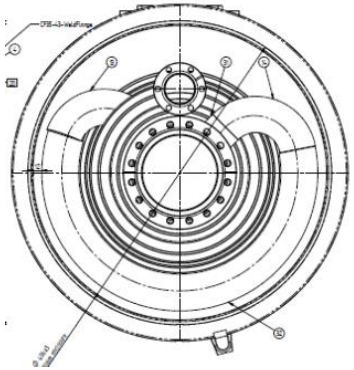
Change in baseline N.1



Tests with dummy cable inside the cryostat



3 m



Φext ~ 180 mm

Advantages:

- **Cost reduction (mainly for SC Link, but also for DFX and DFX)**
- **Smaller diameters and lower weight of the SC Link**
- **Easier handling and installation in the tunnel**

Electrical baseline

Trim Q1a (35 A) → Local powering

EDMS N. 1821907

	Magnet	Cold Powering			
	I_{ult}(kA)	I_{peak}(kA)	I_{lead} (kA)	I_{cable}(kA)	N_{leads}/N_{cables}
MQXF	17.82	-	18	18	2
Trim Q1	2	2.4	2*	7	1
Q2a/Q2b	Protec.	5.6	2*	7	1
Trim Q3	2	6.8	2*	7	1
MCBXFB	1.73	-	2	2	2+2
MCBXFB	1.59	-	2	2	2+2
MCBXFA	1.73	-	2	2	2
MCBXFA	1.5				2
MQSXF	0.2	-	0.2	0.2	2
MCSXF/MCSSXF	0.12	-	0.12	0.12	2+2
MCOXF/MCOSXF	0.12	-	0.12	0.12	2+2
MCDXF/MCDSXF	0.12	-	0.12	0.12	2+2
MCTXF/MCTSXF	0.12	-	0.12	0.12	2+2
D1	12.96	-	18	18	2

18 Low-Current Current Leads

Change in baseline N.2

- **Local powering of magnets rated at 120 A and 200 A**.
- Integration of current leads in the Correctors Package cryostat. Conduction-cooled current leads thermalized at 60 K-80 K.
- Additional heat load on the 1.9 K bath acceptable.

Advantages:

Simplification of WP6a Cold Powering System

Cost reduction of WP6a (elimination of control valves, MgB_2 cables, splices, protection equipment, simplification of DFH cryostat)

Disadvantages:

Need to bring RT power cables to the local current leads (and coordinate related installation work)

Altogether: some cost saving

Input from WP6a, WP6b, WP3, WP9, WP7, WP17, WP15

Outline

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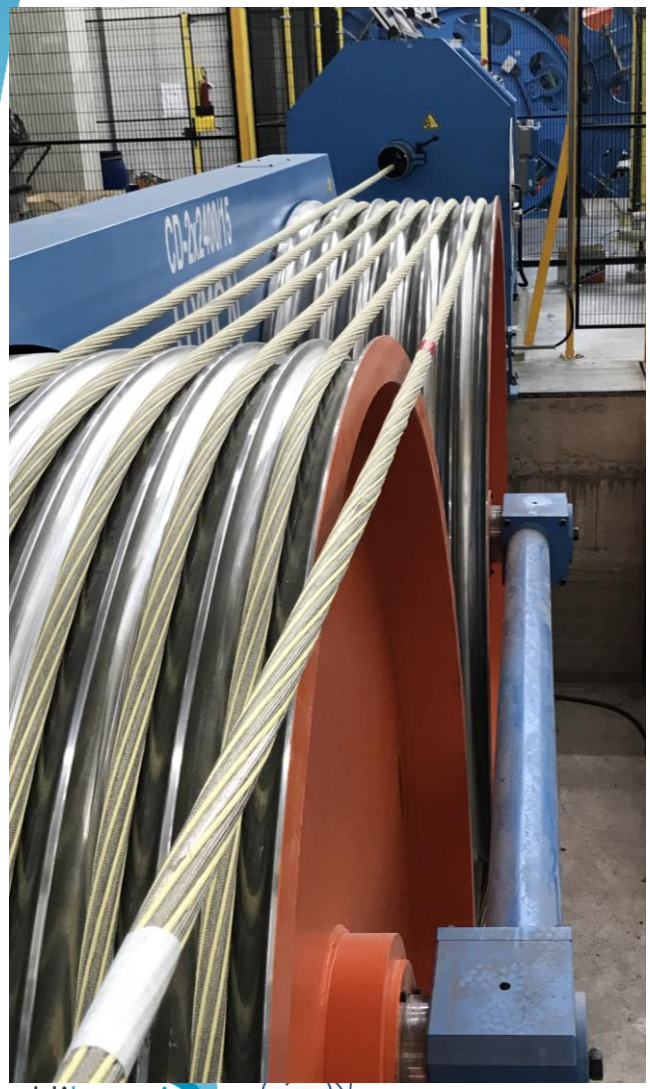
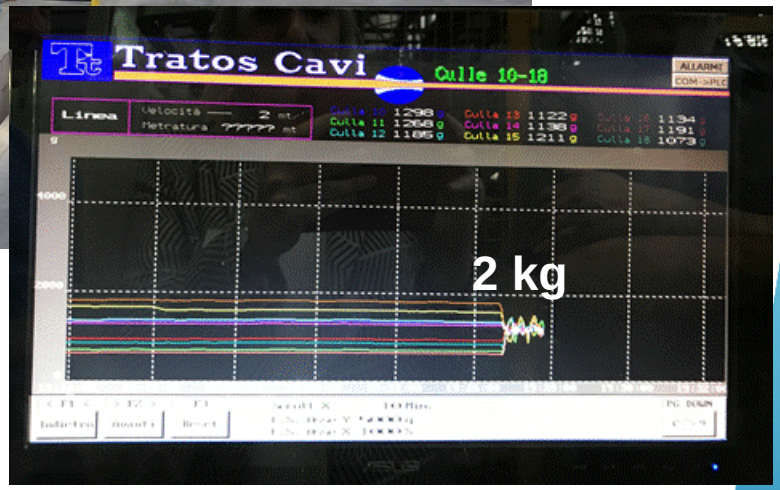
Main achievements (2018)

Launched industrial cabling of MgB_2 in industry

Cabling of 30 + 36 elements on
630 mm OD spools



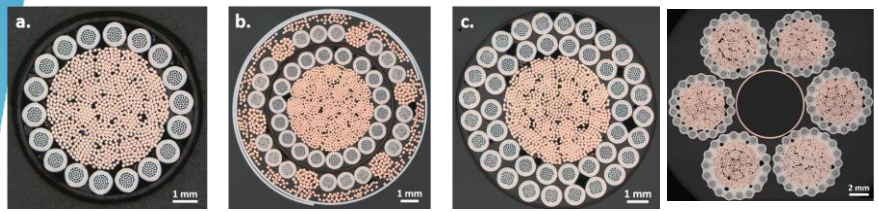


-Company producing conventional cables
-QA for MgB_2 implemented

Main achievements (2018)

Validation of MgB_2 in industrial cabling

3 kA



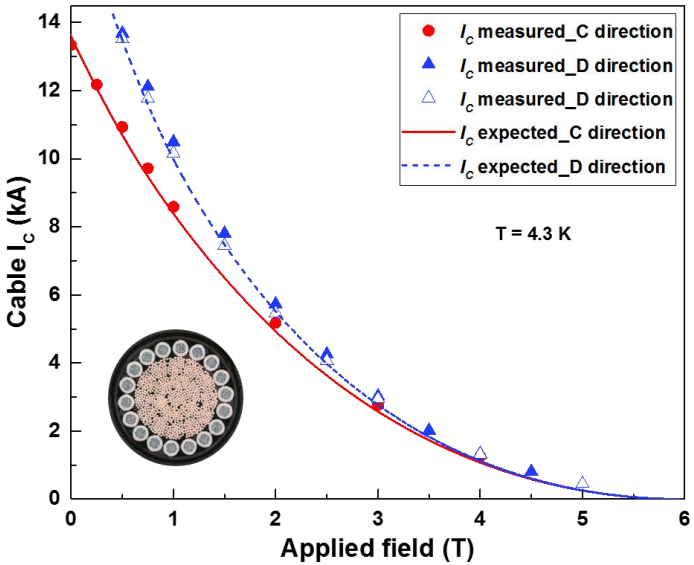
Φ~6.5 mm

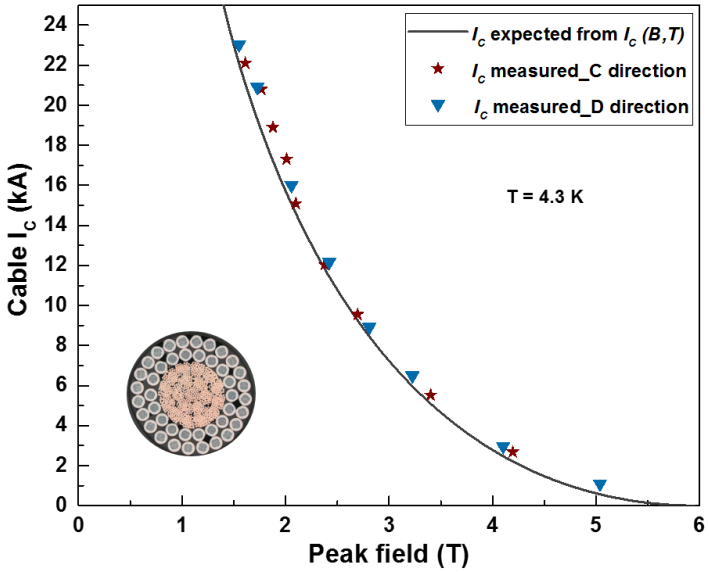
18 kA

Φ~19.5 mm

200 m of MgB_2 18 kA cable

R&W Technology

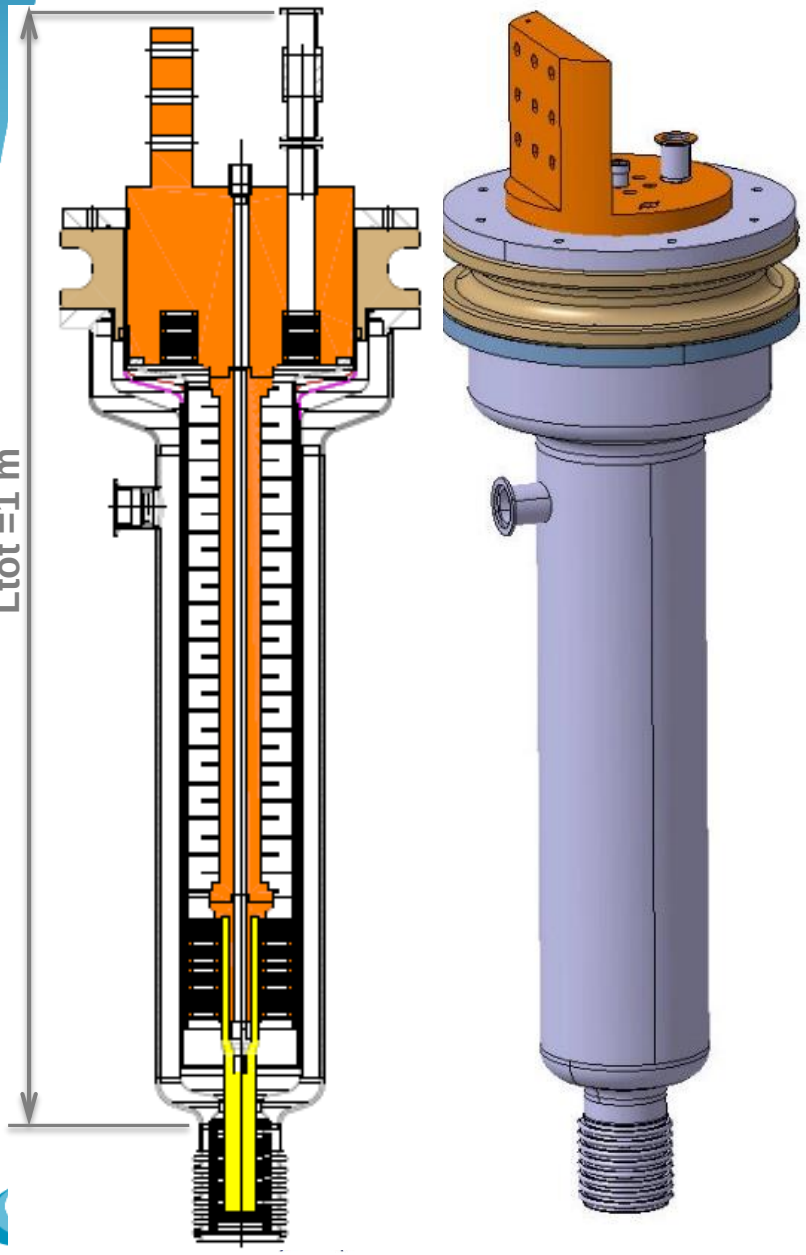




Measurements & Analysis by K. Konstantopoulou

Main achievements (2018)

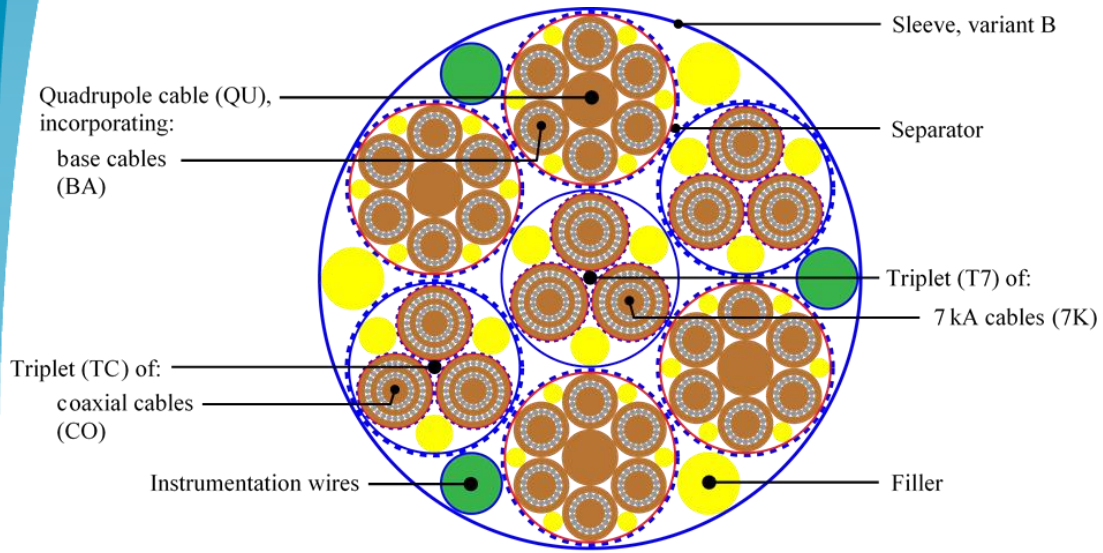
Design and production (at CERN) of a pair of 18 kA HTS leads



Main achievements (2018)

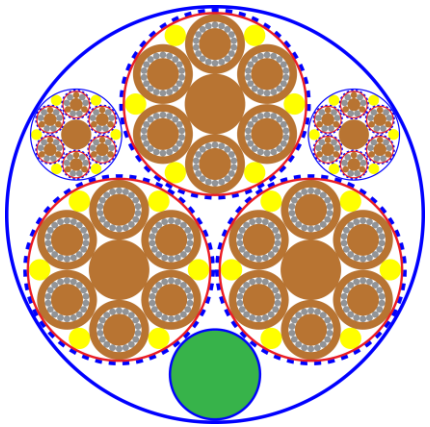
Final design of MgB_2 cable assemblies for powering **Triplets** and **Matching Sections**

Triplets



Nominal length	130 m
Max diameter	91 mm
Twist pitch	1000 ± 20, LH
Min bend radius	1250 mm
Max nominal tensile load	800 N

Matching Sections

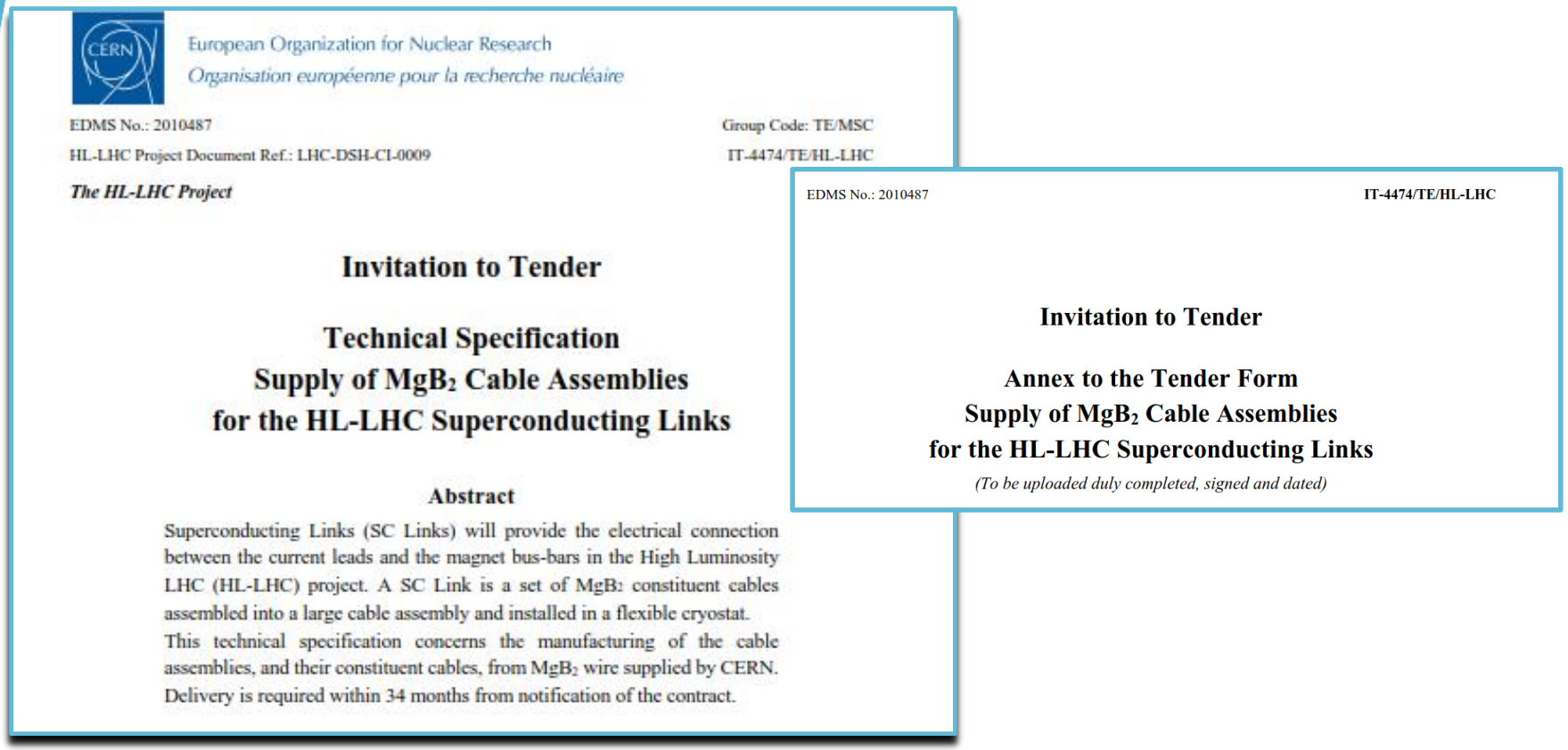


3×18 kA
12×0.6 kA

Nominal length	150 m
Max diameter	63 mm
Twist pitch	800 ± 20, LH
Min bend radius	1250 mm
Max nominal tensile load	400 N

Main achievements (2018)

IT-4474/TE/HL-LHC for procurement of 60 m long MgB_2 **prototype cable assembly** (June 2019) and **series MgB_2 cable assemblies for both Triplets and Matching Sections** sent out to industry



European Organization for Nuclear Research
Organisation européenne pour la recherche nucléaire

EDMS No.: 2010487 — Group Code: TE/MSC
HL-LHC Project Document Ref.: LHC-DSH-CI-0009 — IT-4474/TE/HL-LHC
The HL-LHC Project

Invitation to Tender

Technical Specification
Supply of MgB_2 Cable Assemblies
for the HL-LHC Superconducting Links

Abstract

Superconducting Links (SC Links) will provide the electrical connection between the current leads and the magnet bus-bars in the High Luminosity LHC (HL-LHC) project. A SC Link is a set of MgB_2 constituent cables assembled into a large cable assembly and installed in a flexible cryostat. This technical specification concerns the manufacturing of the cable assemblies, and their constituent cables, from MgB_2 wire supplied by CERN. Delivery is required within 34 months from notification of the contract.

EDMS No.: 2010487 — IT-4474/TE/HL-LHC

Invitation to Tender

Annex to the Tender Form
Supply of MgB_2 Cable Assemblies
for the HL-LHC Superconducting Links

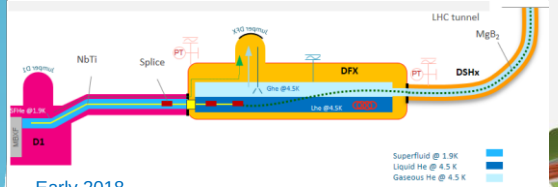
(To be uploaded duly completed, signed and dated)

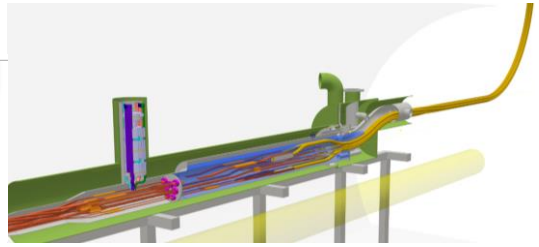
IT-4253/TE/HL-LHC for procurement of (200+650) km **series MgB_2** wire sent out to industry (Columbus Superconductors). To date procured and delivered to CERN: 80+260 km of MgB_2 wire (UL ~ 1 km)

Main achievements (2018)

Elaboration of different concepts of DFX and selection of most suitable design

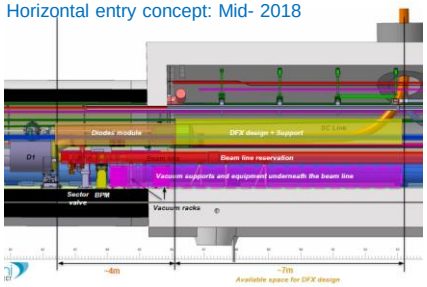
Concept 1



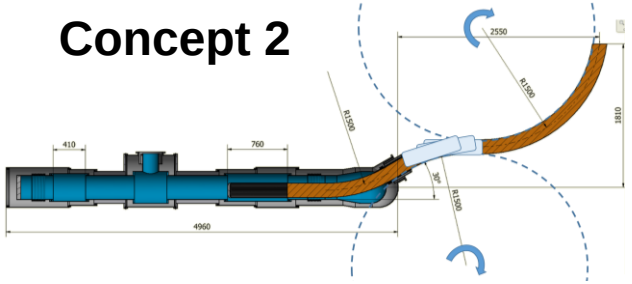


Early-2018

Horizontal entry concept: Mid- 2018

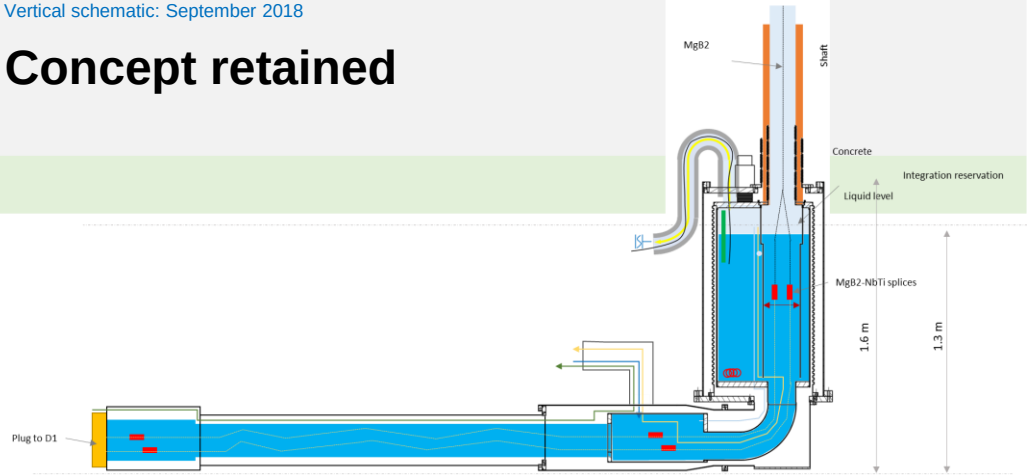


Concept 2



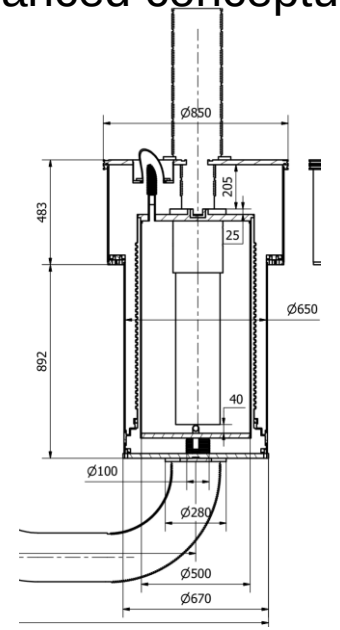
Vertical schematic: September 2018

Concept retained



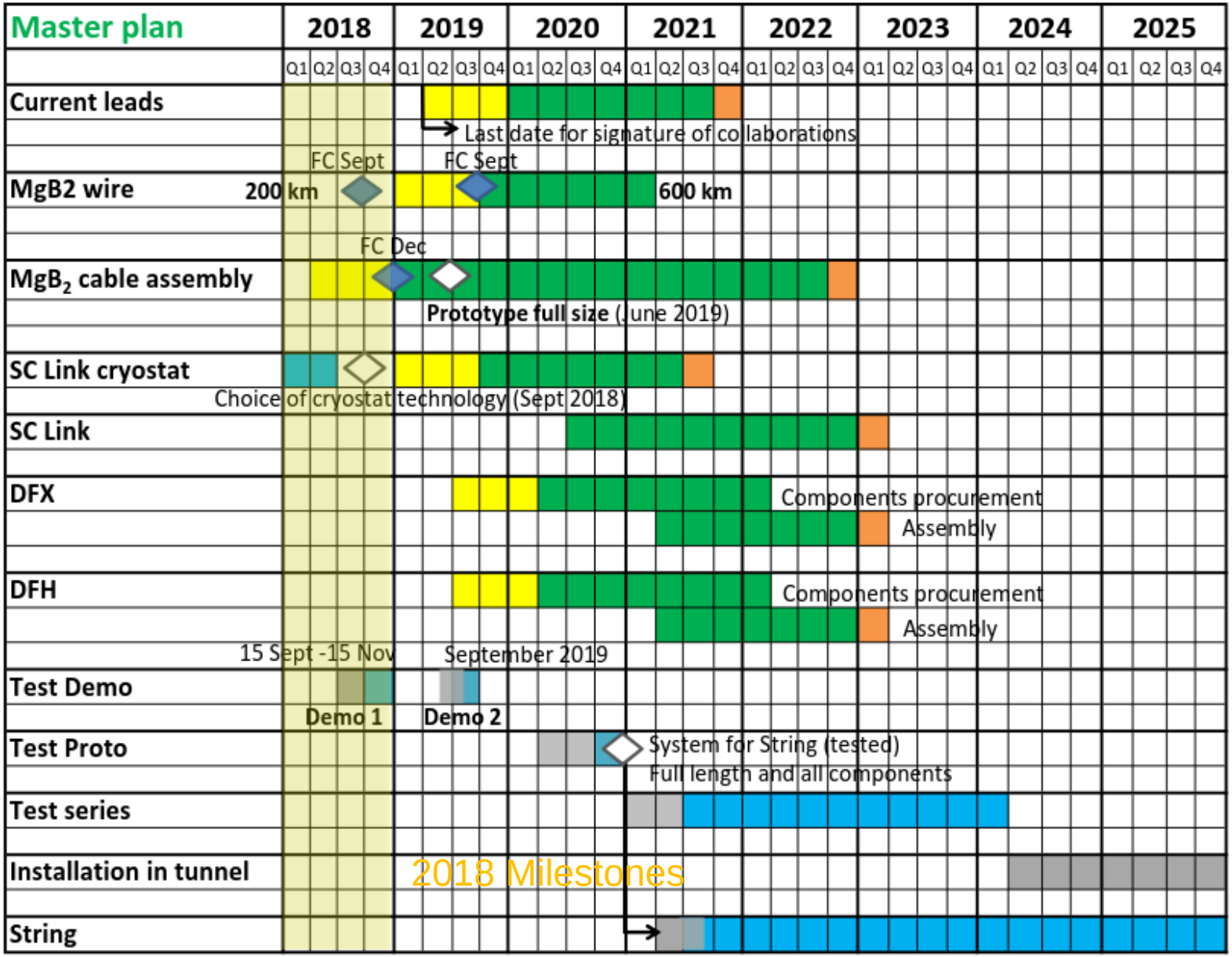
		Weight	Horiz.	Vert.	
	1.Design				
3	c)Space margin for length MGB2-NbTi splices	8	3	0	2
6	f)DFX complexity	3	2	4	
7	g)DFX supports and installation tooling design effort	1	3	4	
8	h)Integration: longitudinal tolerance plug to shaft	2	1	4	
9	i)Integration flexibility: at shafts location	2	5	2	2
10	j)Standardisation with DFM	2	3	0	
12	**2.Manufacturing**				
13	a)DFX manufacturing complexity	2	1	4	
16	d)Manufacturing cost (# of parts, standards, QA)	2	2	4	
17	**3.Testing**				1
18	a)Homogeneity of DSH testing configurations in SM18	2	3	0	
19	b)Risk of cable deterioration - test in SM18 & operation	10	1	4	
20	**4.Installation**				
21	a)SCLink installation mech. Assembly complexity	4	1	3	1
22	b)SCLink MgB2 cable handling complexity	12	0	4	
23	c)SCLink to DFX welding complexity (to PED standards)	3	3	1	
24	d)NbTi splices realisation	1	4	2	
26	**5.Transient Phases**				
31	**6.Operation**				
32	a)Splices immersion Level control	6	4	2	
33	**7.Maintenance & ALARA**				
34	a)Replacement heater, level gauges complexity/time	2	4	1	
36	c)In-situ repair MgB2 – NbTi splices	2	3	1	
37	d)Dose to personnel during preventive maintenance	2	3	1	
38	**8.Unexpected event**				
		TOTAL	186	219	

Advanced conceptual study



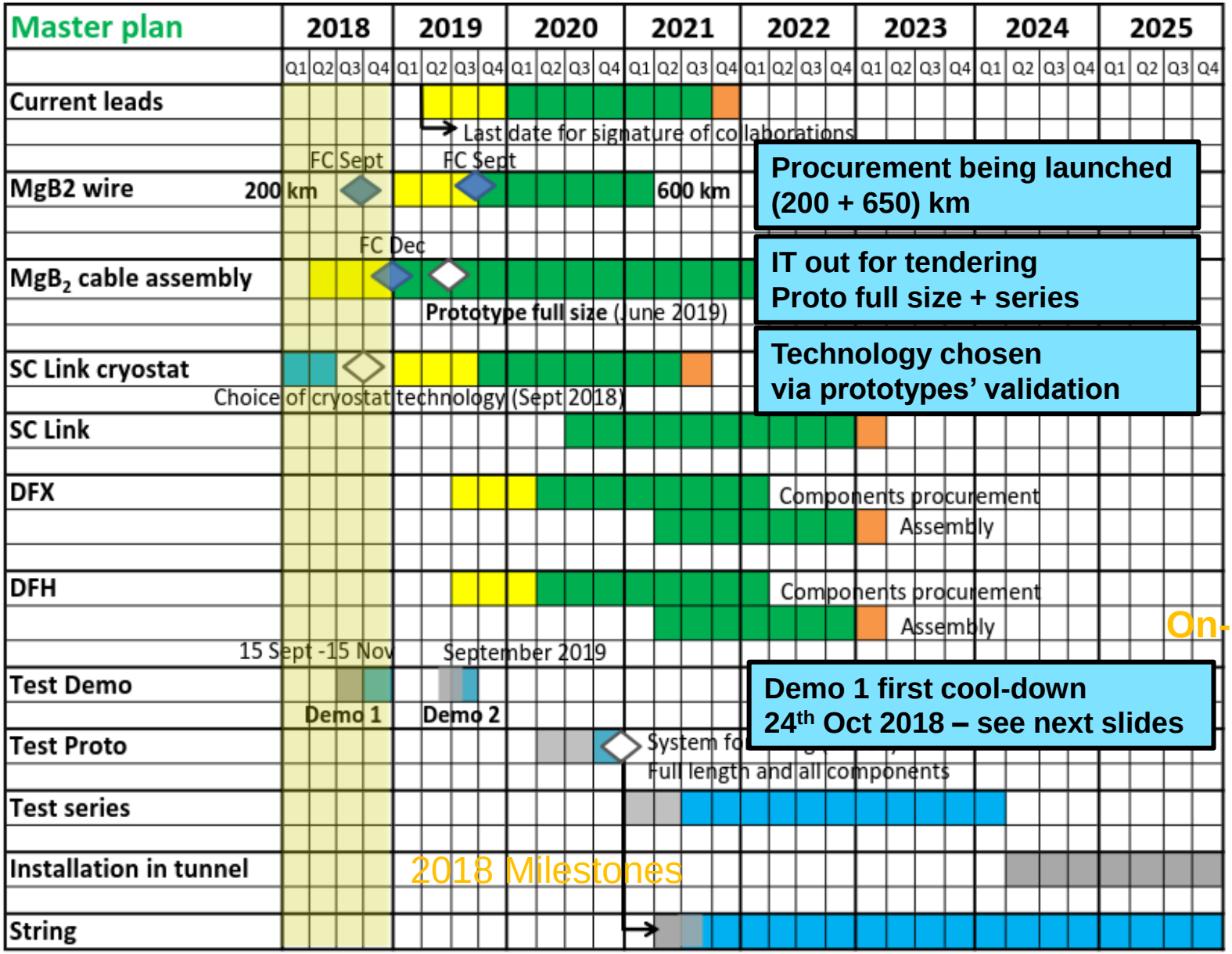
SOTON – UK Contribution

Progress toward Master plan



Master plan presented at Cost & Schedule Review, March 2018

Progress toward Master plan



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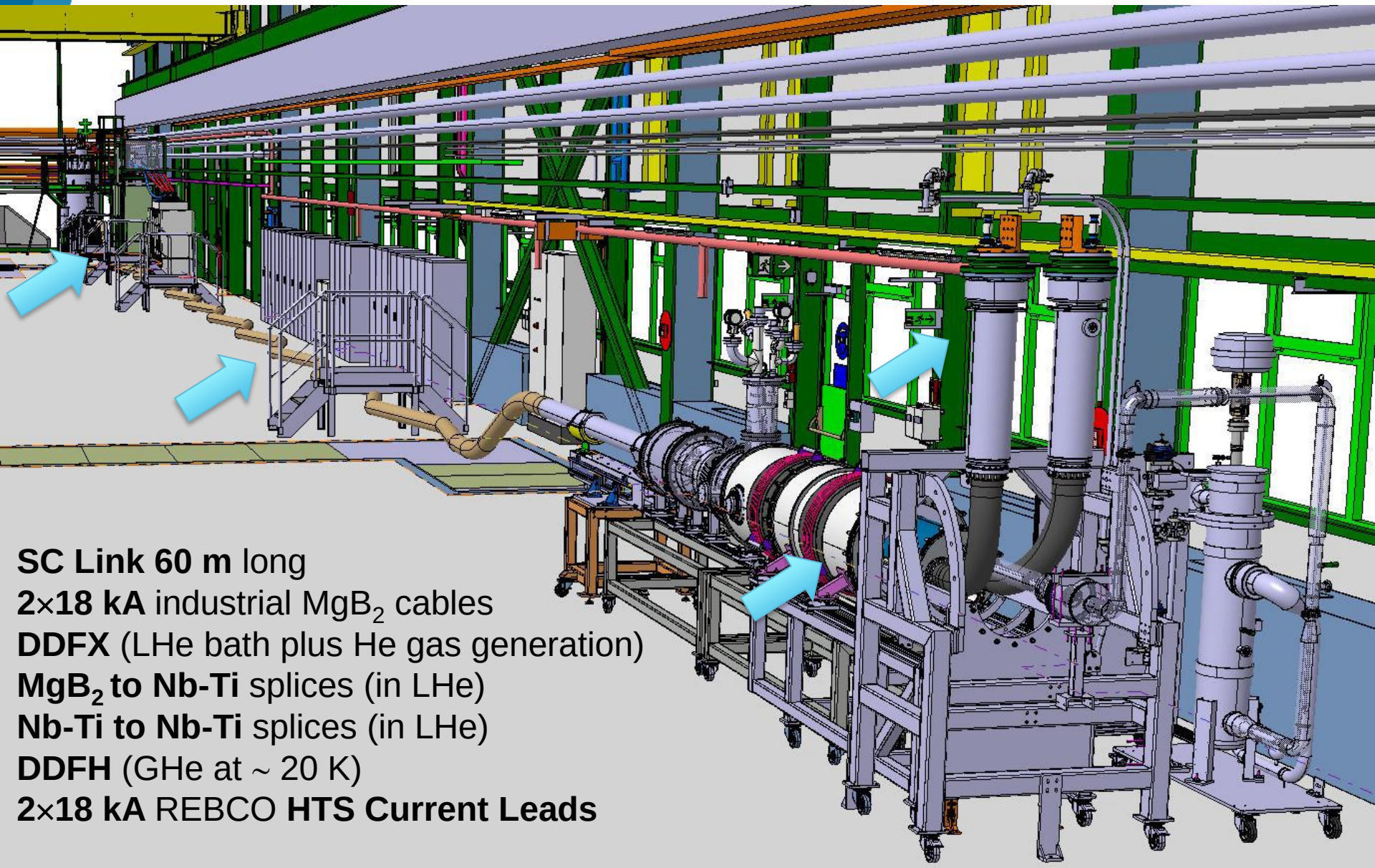
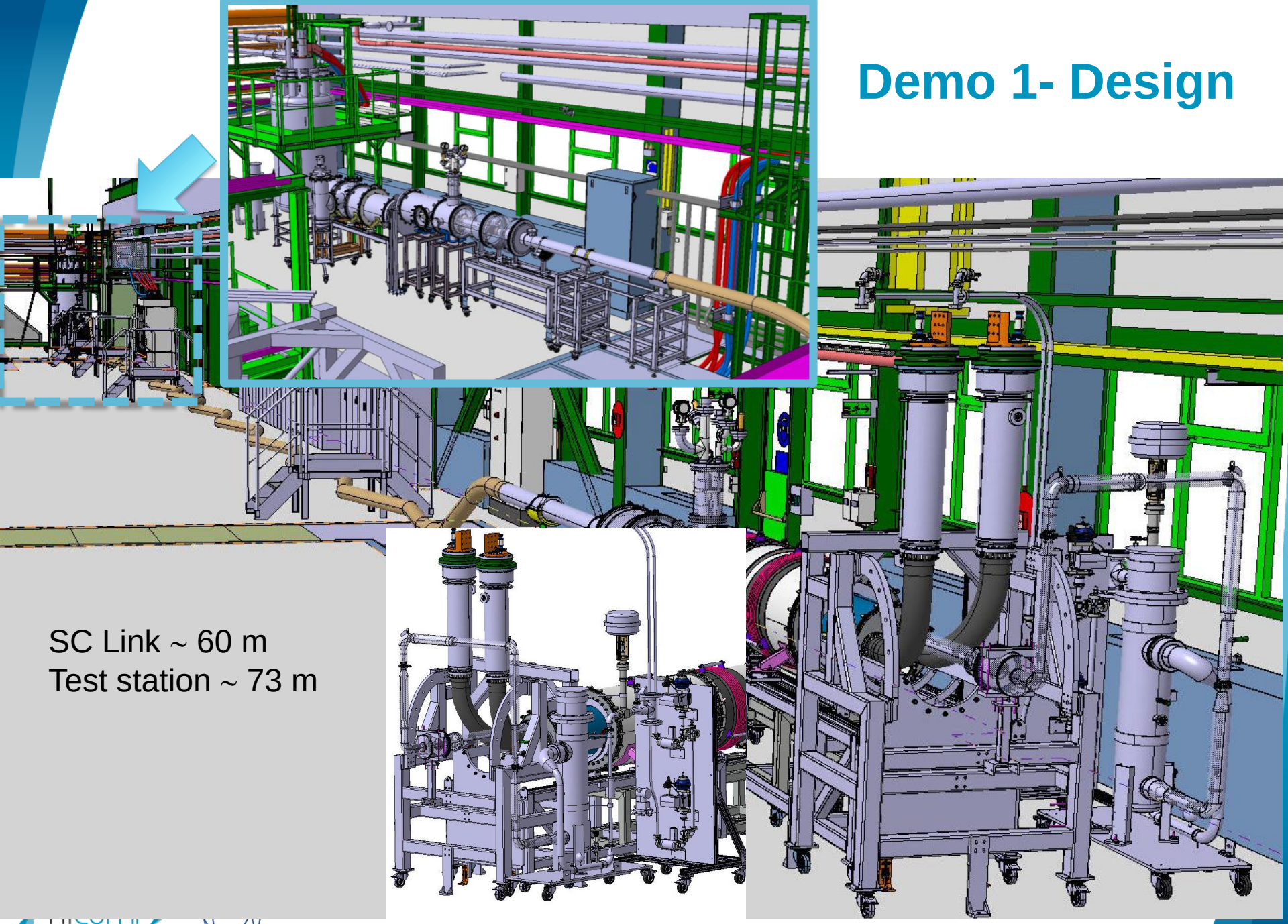
Demo 1 – Demonstrator in SM-18 Test Station



SC Link 60 m long
2×18 kA industrial MgB_2 cables
DDFX (LHe bath plus He gas generation)
MgB_2 to Nb-Ti splices (in LHe)
Nb-Ti to Nb-Ti splices (in LHe)
DDFH (GHe at ~ 20 K)
2×18 kA REBCO **HTS Current Leads**

Demo 1- Design

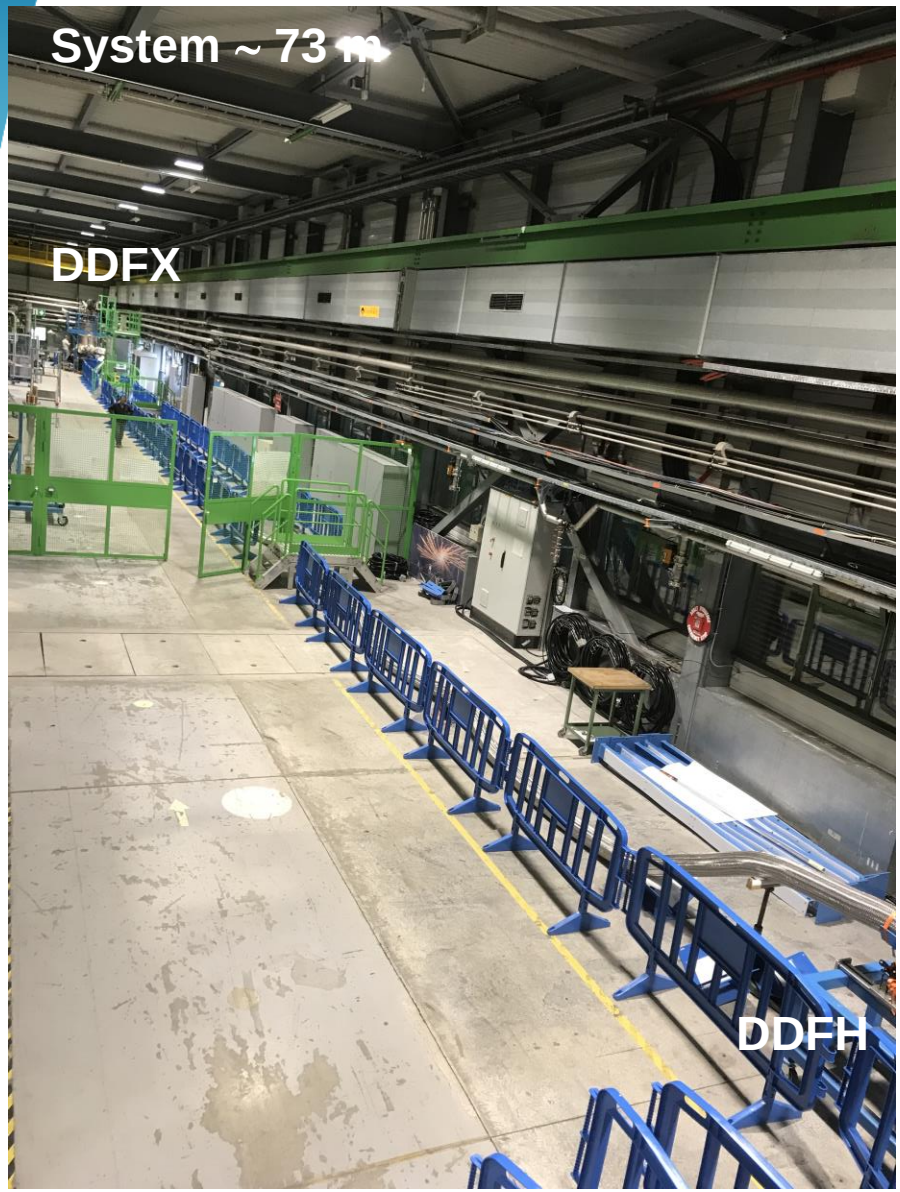


SC Link ~ 60 m
Test station ~ 73 m

Installation and construction of Demo 1

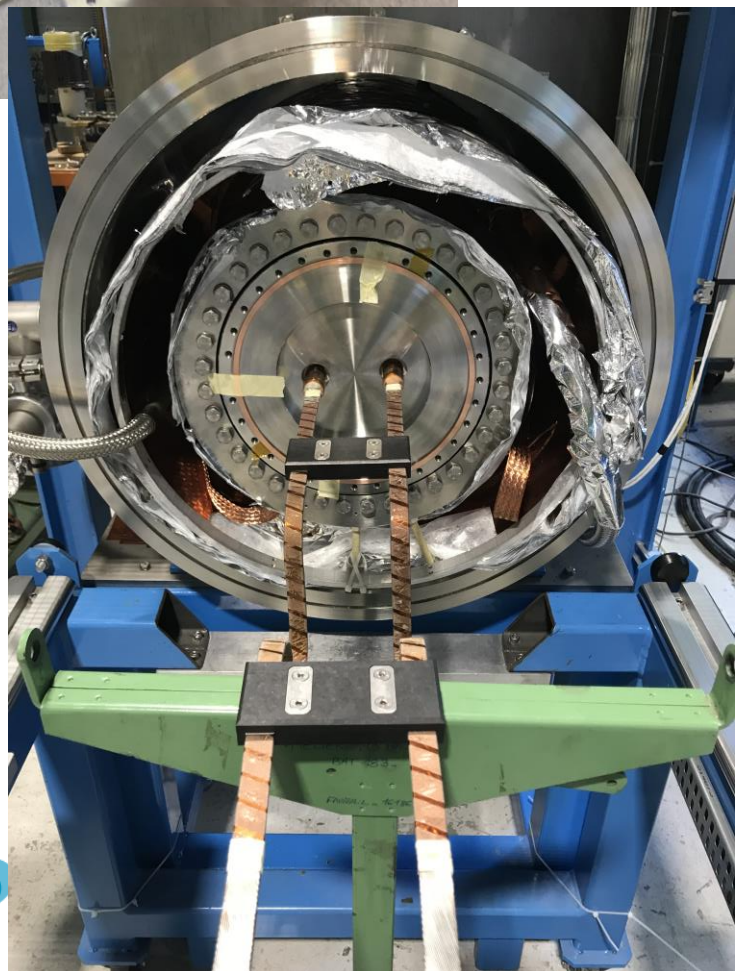
Installing 60 m long flexible cryostats

Demo 1 – SM 18 Test Facility



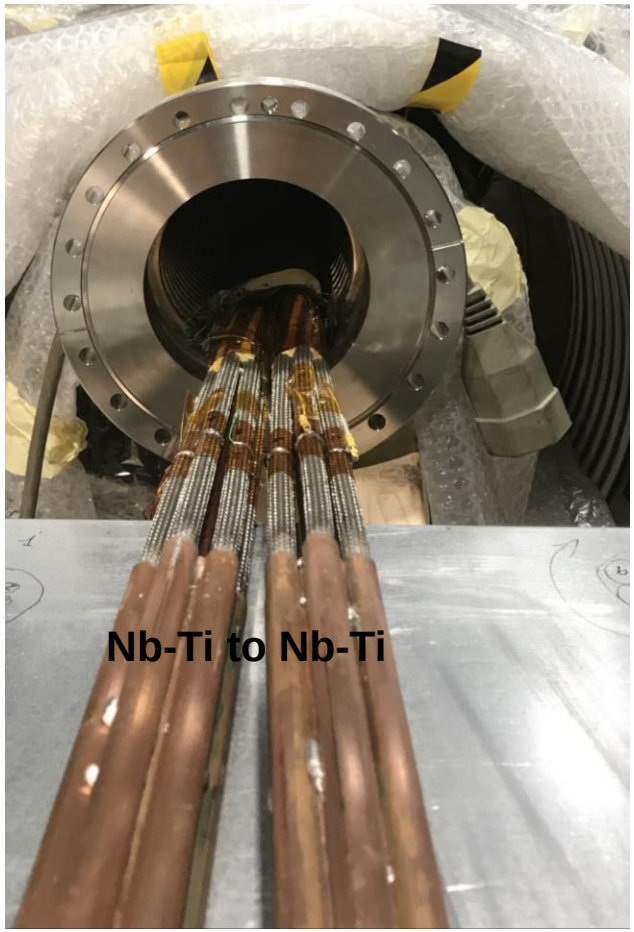
Pulling MgB_2 industrial cables in cryostat

DDFX and SC Cables (Nb-Ti, MgB_2)

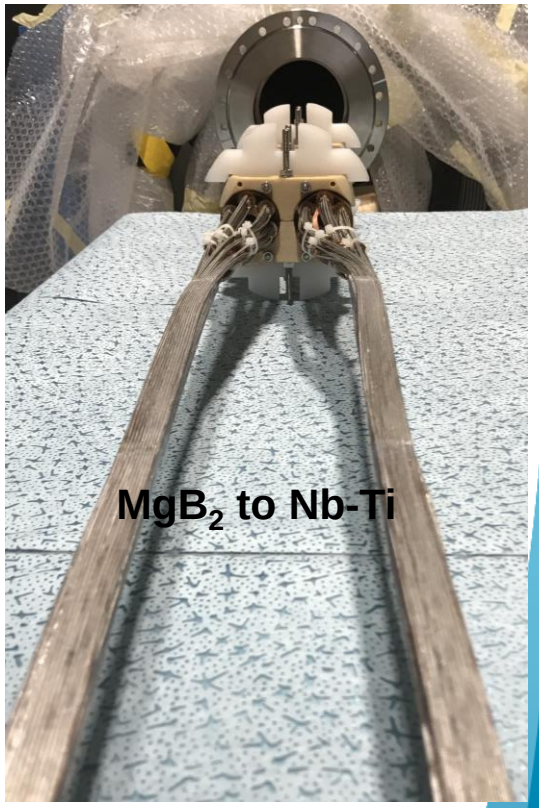


Demo 1 – Electrical connections

Splices between Nb-Ti and MgB_2

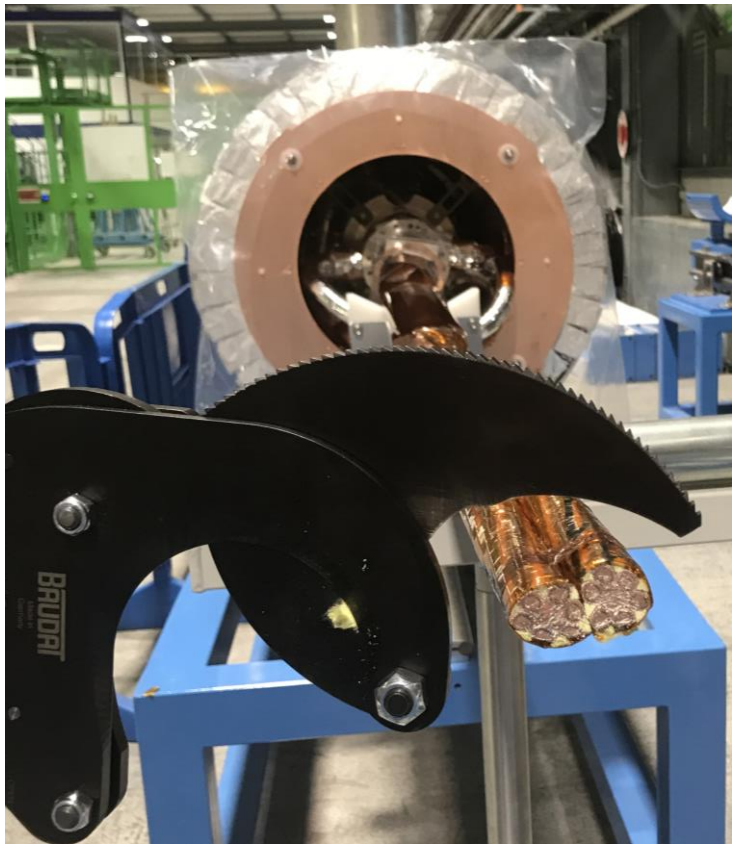


From Nb-Ti (SC Link) to Nb-Ti (magnets' bus-bar)

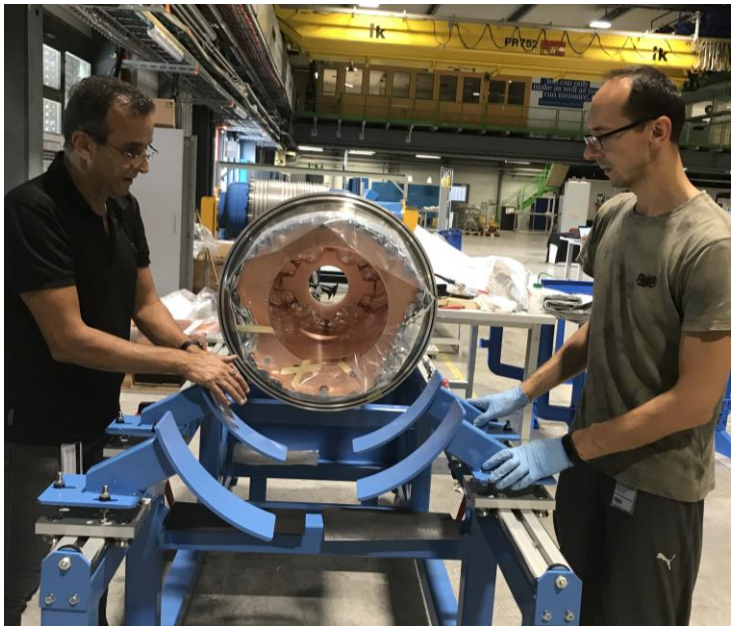


Pre-qualified in LHe in the Fresca test station

Demo 1 – Handling MgB_2



DDFH



Demo 1

- Test station ready for cool-down by end of this week
- First cool-down with no powering tests (no current leads connected)
  - Quantification of thermal contraction of MgB_2 cable (X-ray of cable in cryostat at different locations)
  - Validation of cryogenic flow generation and control
  - Validation of instrumentation
- Second cool-down with powering tests
  - Full validation of 60 m long MgB_2 cables, industrially produced, and integrated in the SC Link cryostat
  - Qualification of splices
- Demo 2: June 2019. Prototype multi-cable assembly for Triplets (first delivery of IT-4474/TE/HL-LHC)

Conclusions

- Key 2017 milestones achieved
- Baseline changes proposed to simplify system and reduce cost
- Technical specification for series production (MgB_2 multi-cable assemblies and MgB_2 wire) sent out to industry
- Demo 1 system demonstrator ready for first cool-down

Acknowledgments

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Thanks for your attention !