Conceptual Design of the DFH

DFH Conceptual Design Review

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- DFH Functionality
- The DDFH in Demo 1
- DFH: Design evolution
- DFH: Concept
- SC Link connection to DFH: surface vs underground assembly
- Conclusions

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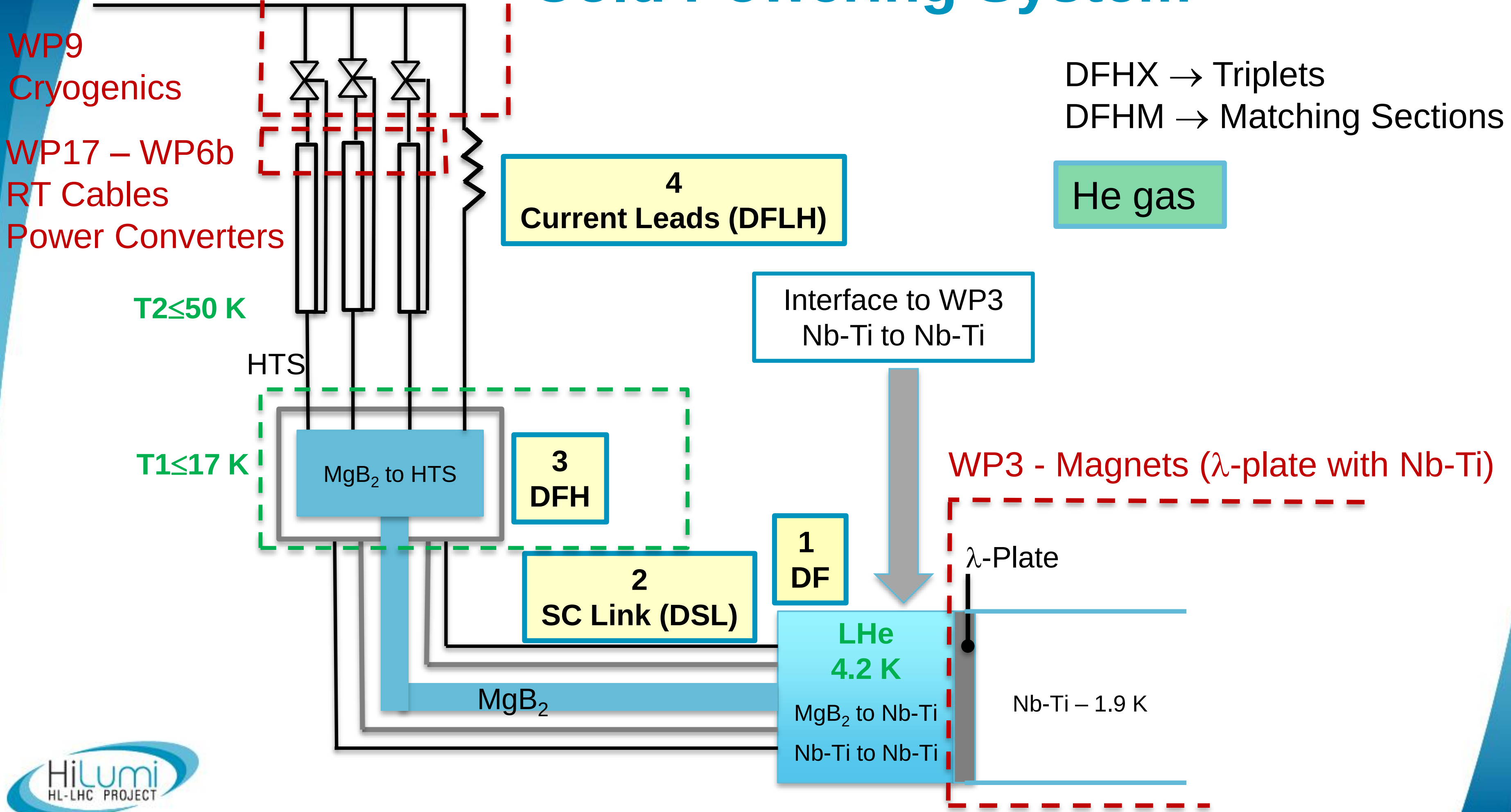
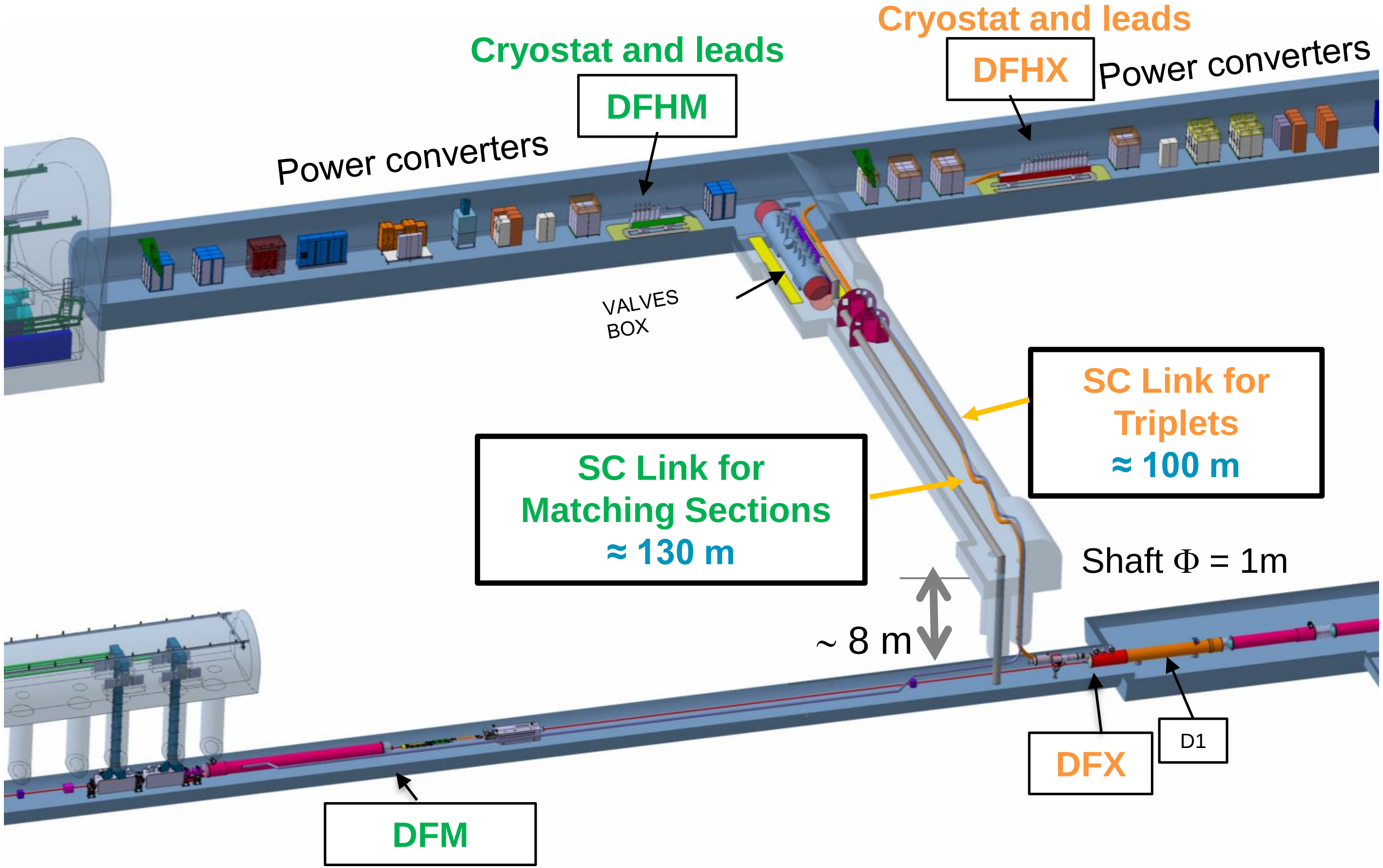
Cold Powering System



Cold Powering System



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DFH Functionality

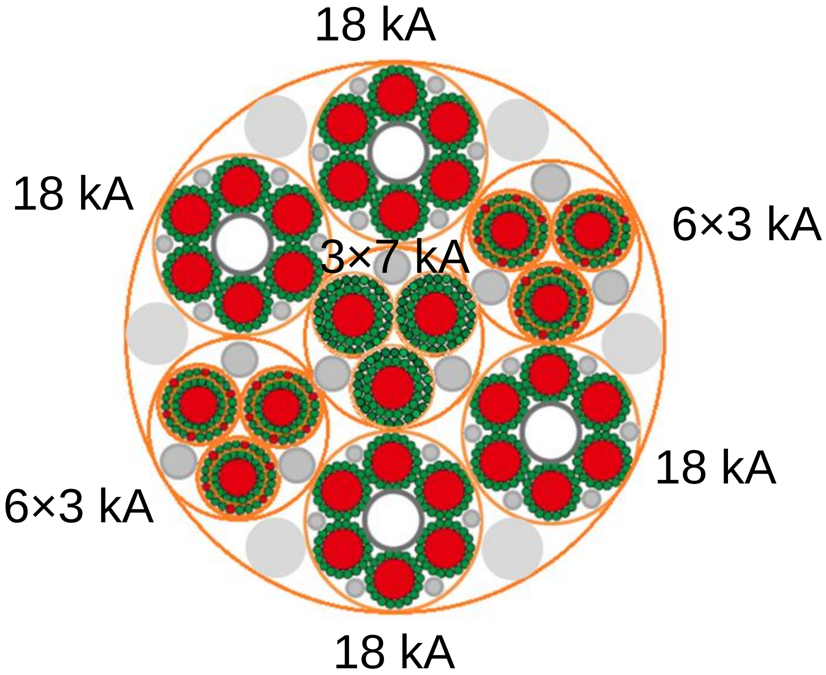
- Receive and shuffle the MgB_2 cables from the SC Link and connect to the HTS cables of the current leads;
- Provide appropriate space for making/hosting the electrical splices between the MgB_2 cables and the HTS cables of the current leads. The preference is to have the splices accessible for - highly unlikely - need for repair;
- Flow the He gas received at about 17 K from the SC Link and provide appropriate cooling of the electrical connections;
- Connect the current leads, distributed near the DFH, to the MgB_2 cables in the SC Link with the most appropriate and compact configuration;
- Extract instrumentation signals (Vtaps, Tsensors).

HiLumi HL-LHC PROJECT

DFH Installation

- Present baseline (not based on a detailed design):
  - The SC Link is lowered in the LHC underground areas, routed in its final configuration and then connected to the DFH cryostat;
  - Routing of MgB_2 and HTS cables and MgB_2 to HTS splices are done in the tunnel (and not tested till final operation in the machine);
  - Each SC Link is tested at the surface in a dedicated test station; each current lead is tested at the surface in dedicated test station.

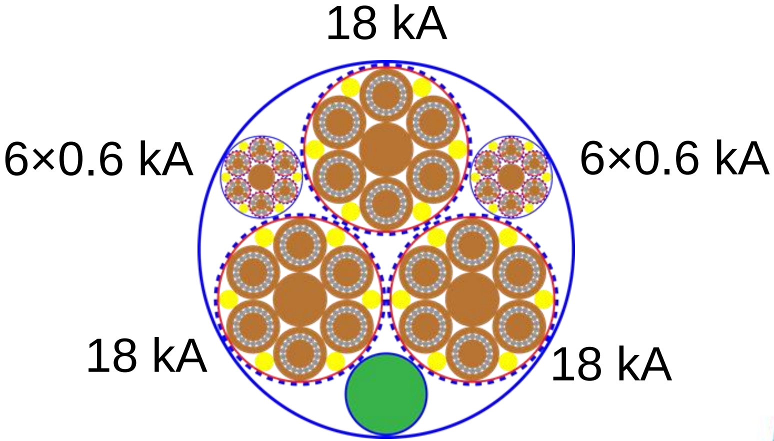
MgB_2 cables in the SC Link



Φext ~ 90 mm

19 Cables

~ 120 kA



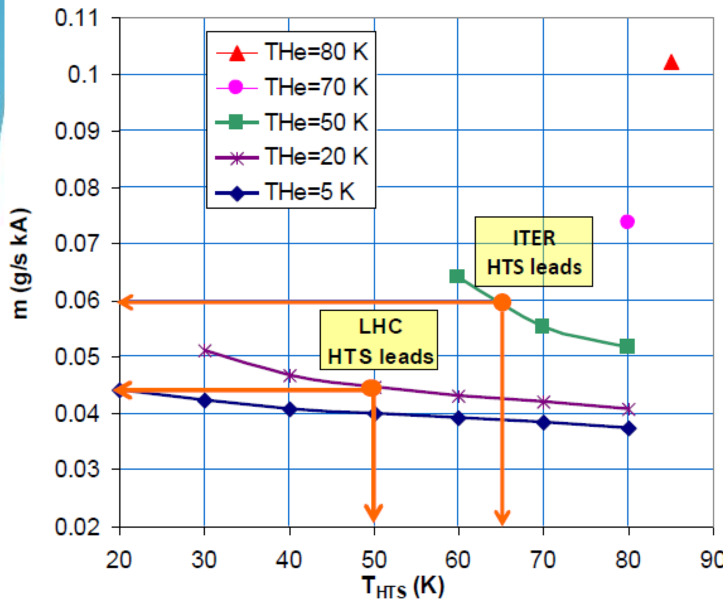
Φext ~ 60 mm

14 Cables + 1

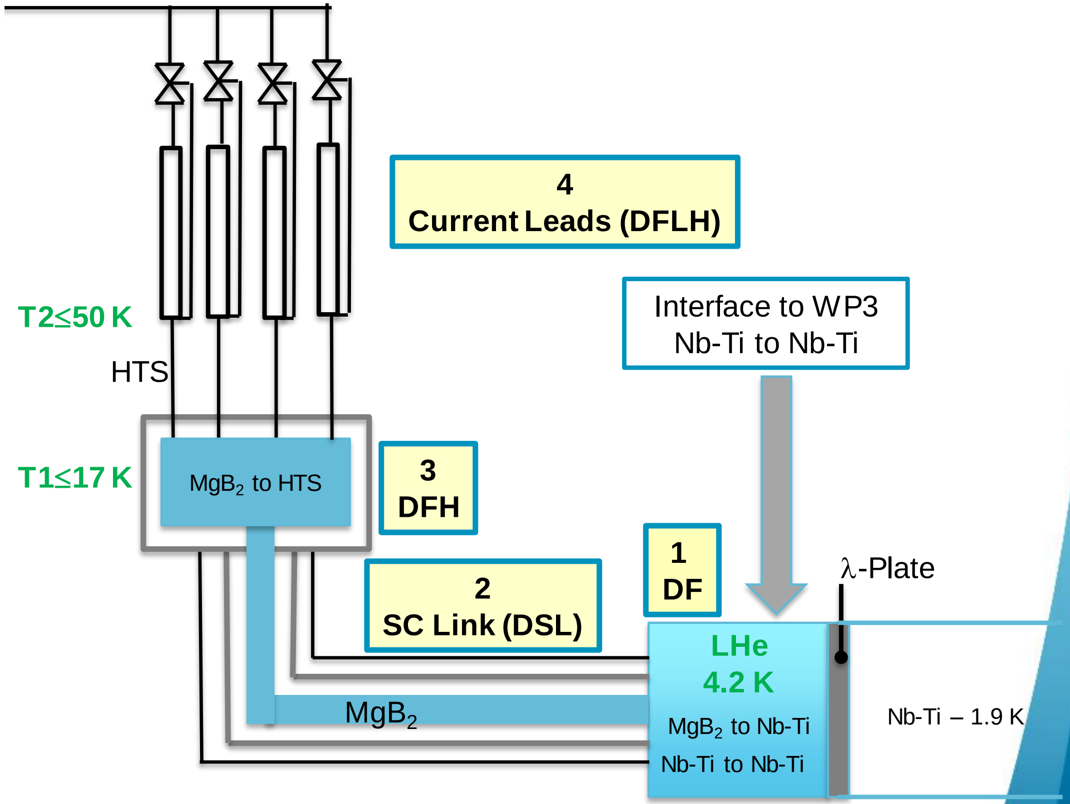
~ 60 kA

Helium mass flow rate in the DFH

~ 5.4 g/s for Triplets
~ 2.5 g/s for Matching Sections



https://arxiv.org/abs/1501.07166



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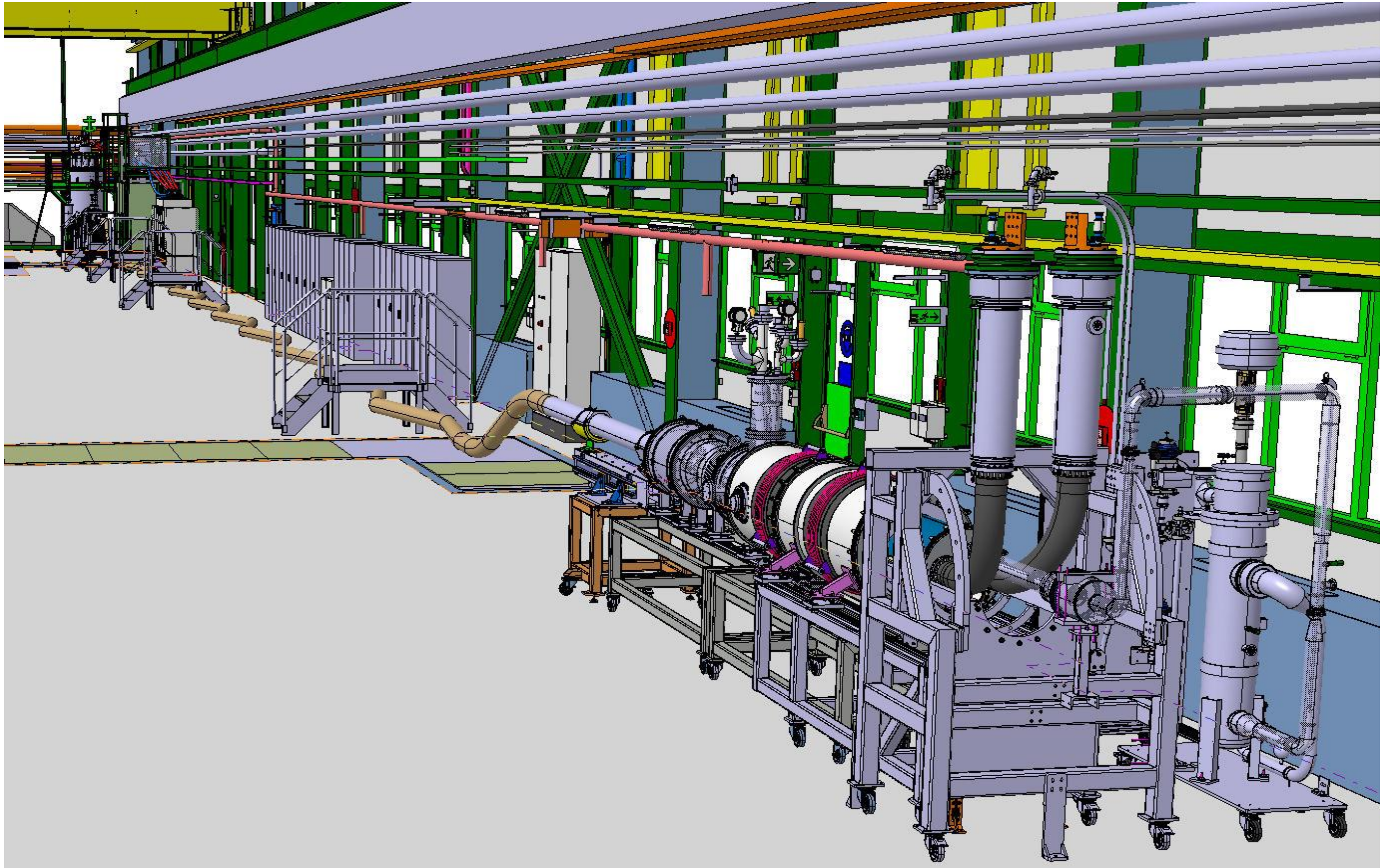
Demo 1



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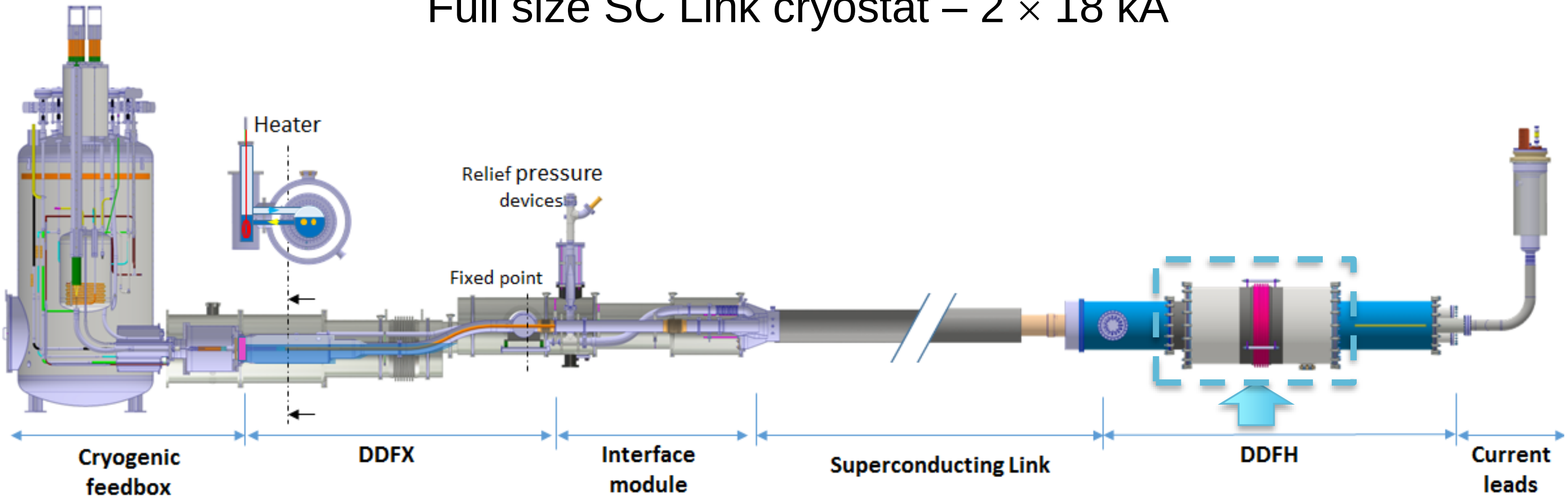
DDFH in Demo 1

System test in SM-18 (completed in March 2019)

Full size SC Link cryostat – 2 × 18 kA



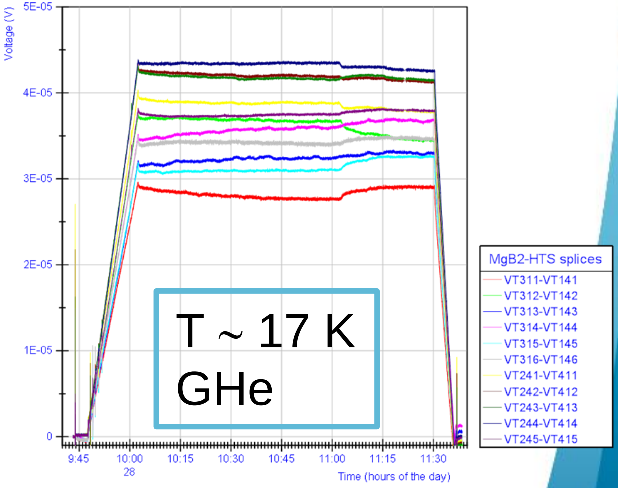
DDFH in Demo 1

- Construction of DDFX demonstrator
  - Double chamber with thermal shield (thermally floating)
  - Acceptable heat load
  - Assembly process
- Realization of two 18 kA splices
- Splices fixed to the cold mass
- Optimization of splices' cooling - GHe
- Routing of HTS and MgB_2 cables
- Routing out of instrumentation (from cold mass to RT)
- Vertical leads

DDFH in Demo 1

MgB$_2$/HTS splices:**1.9 nΩ** at 18 kA (**measured**)

Expected **18 kA splice** resistance of **1.7 nΩ** (prediction based based on FEM simulation validated via measurements in LHe at 4.5 K)



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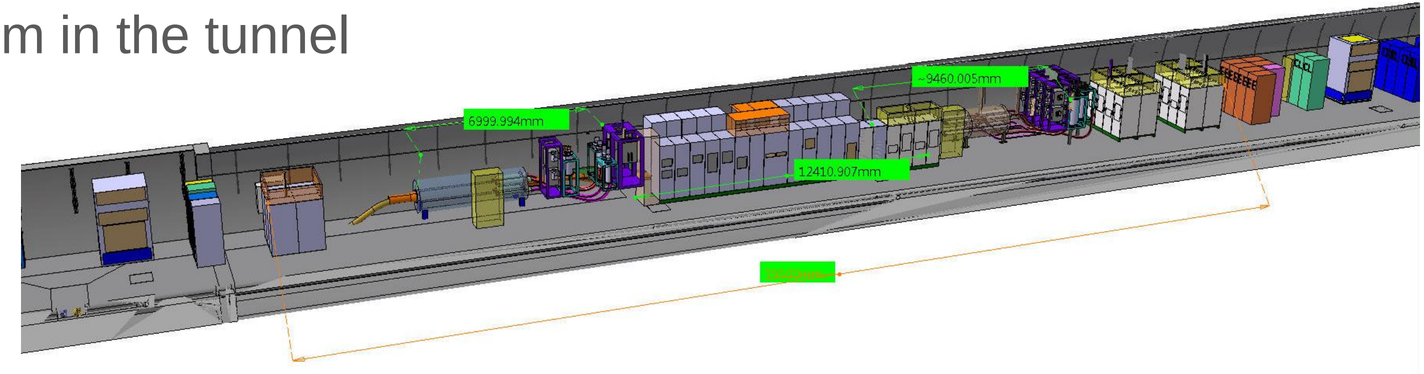
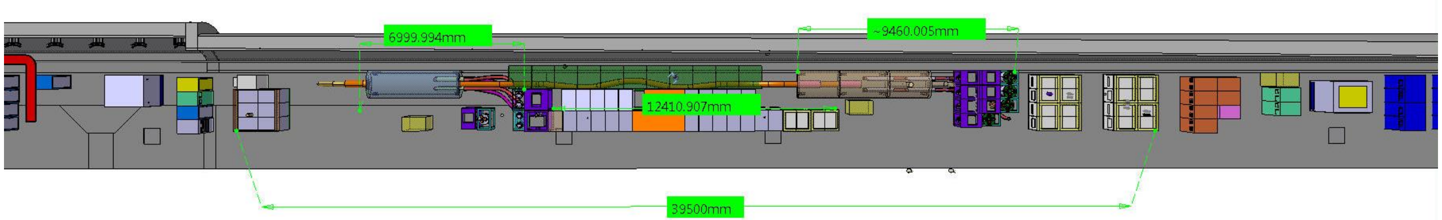
DDFX Design Evolution

DFH Working Reference

- **Two modules** each 4 m long ø - 1,2 m (length without current leads)
- Total length with current leads ~ 15 m (plus SC Link in between)
- SC Link in between modules: ~ 14.7 m
- ~ 30 m in the tunnel





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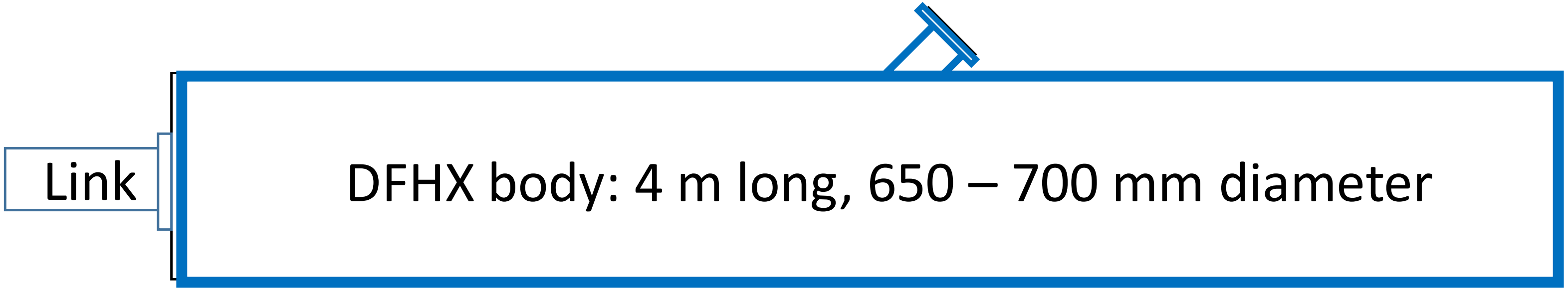
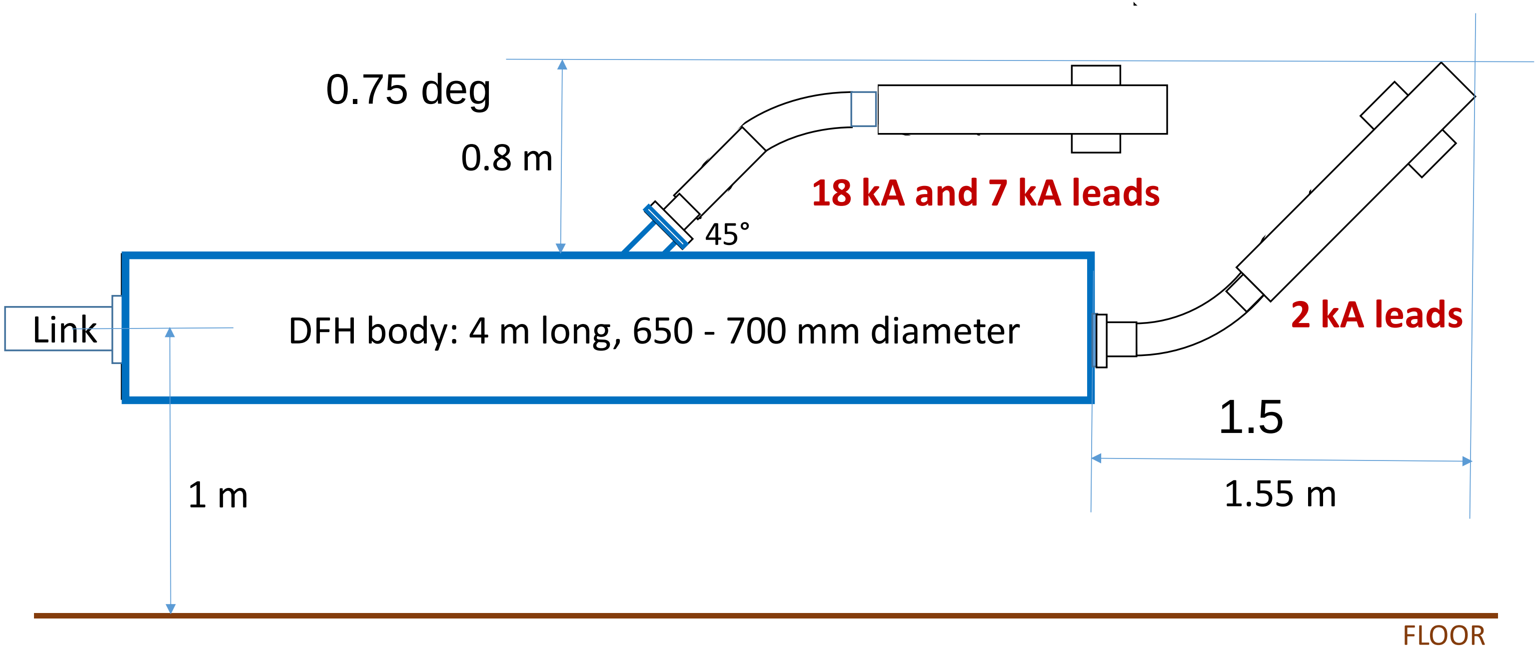
DFHX Concept – The cryostat



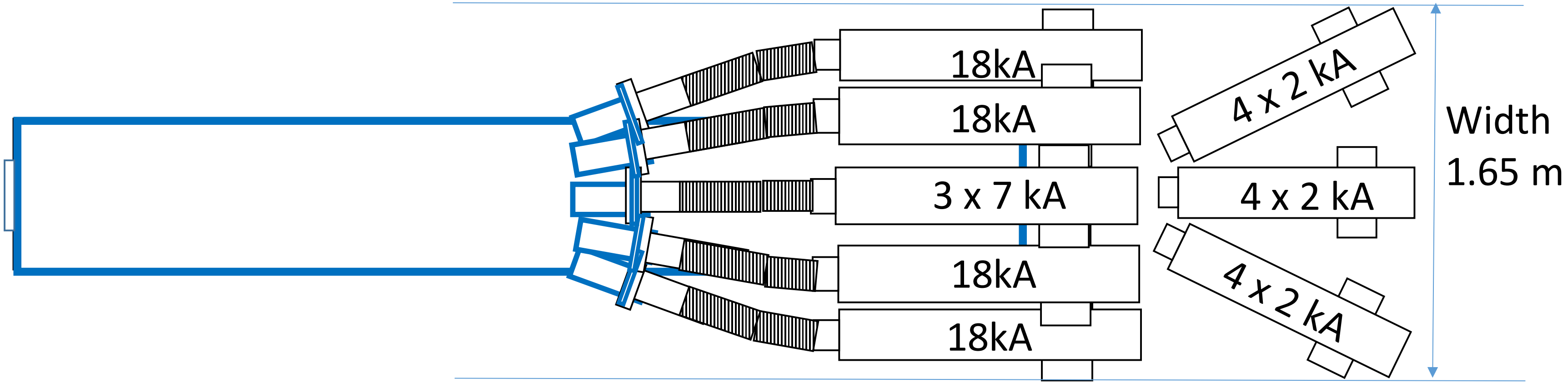
One single module

DFHX Concept – Cryostat with Current Leads



DFHX Concept – Cryostat with Current Leads

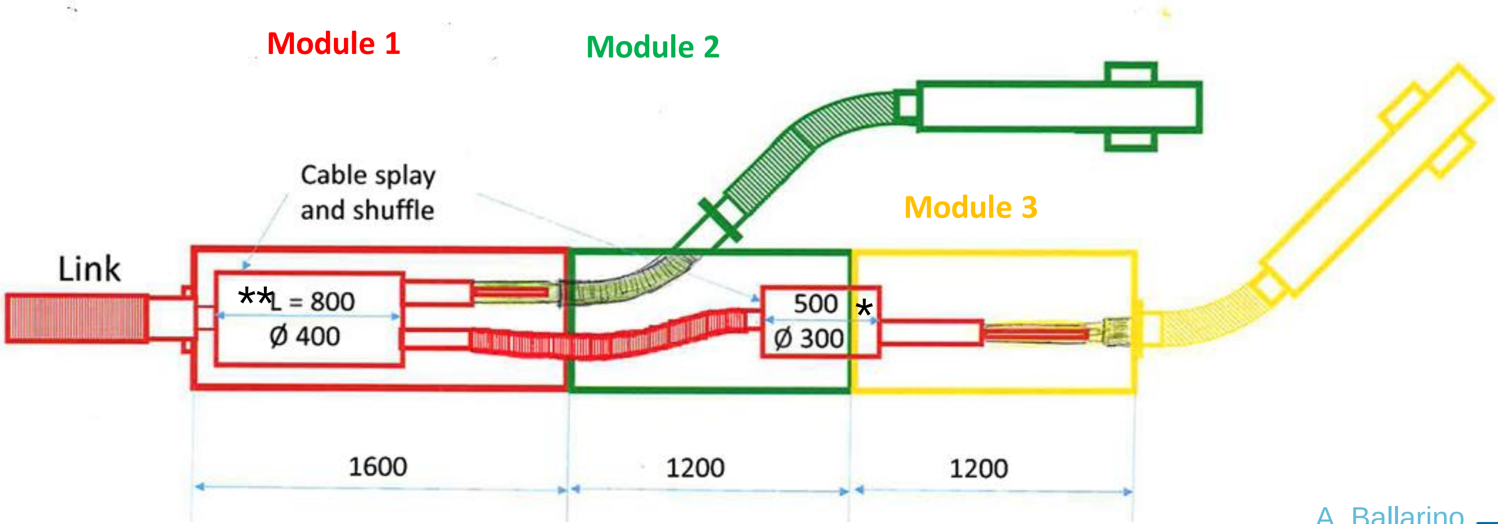
Top view



DFH Concept

Module 1:

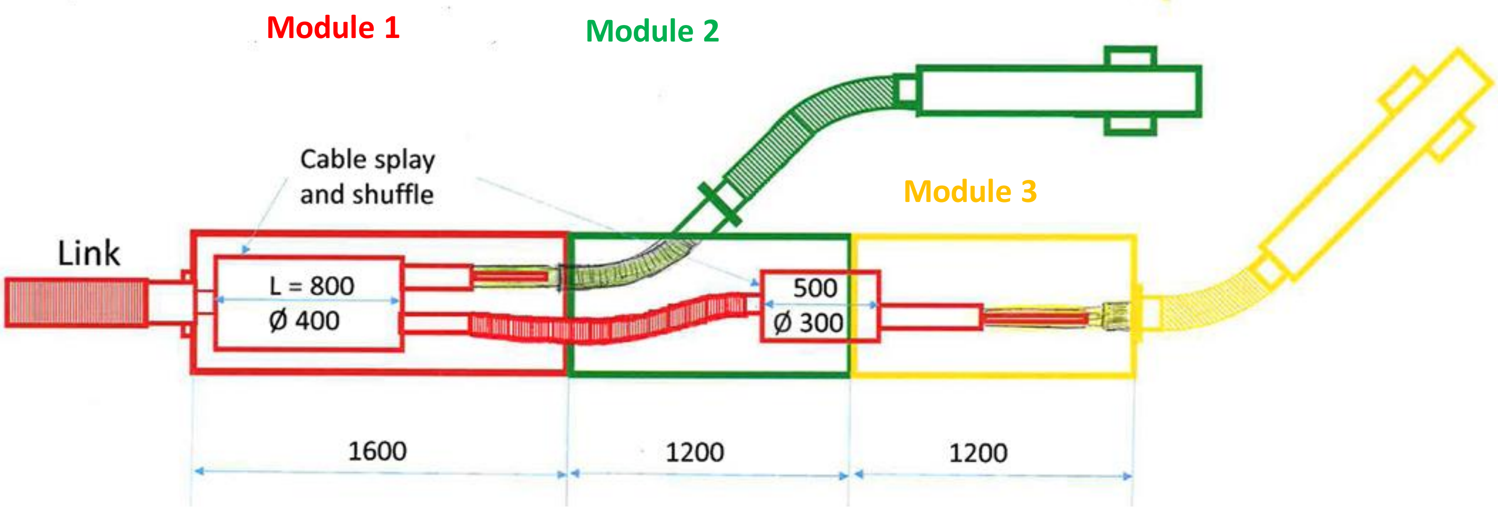
- It **splays and shuffles all MgB_2 cables** coming out from the SC Link.
  The 3 kA MgB_2 cables are routed out from the shuffling module (into Module 2) via a single pipe containing the six 3 kA coaxial MgB_2 cables.
- It contain the **7 kA and 18 kA joints between MgB2 and HTS**. The length of each of the **five pipes** allocated for the joints (four pipes, one for each of the 18 kA joints, and one pipe for the three 7 kA joints) is $\geq$ 300 mm.



DFH Concept

Module 2:

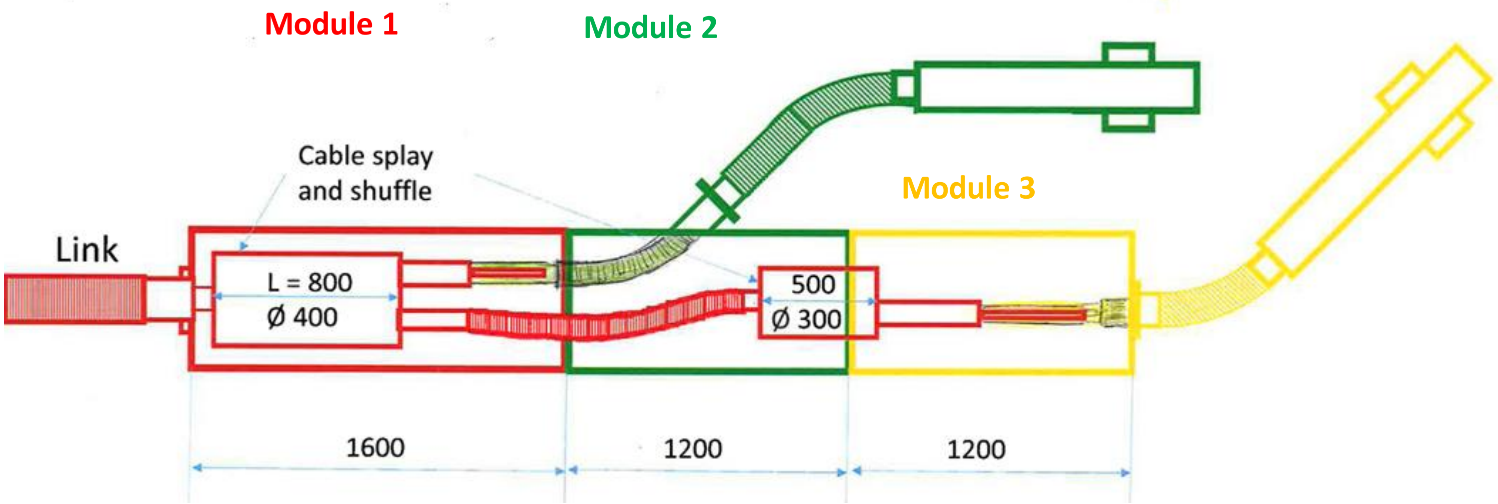
- This module routes out the HTS cables of the 7 kA and 18 kA current leads, and contains the box that splays and shuffles the 3 kA MgB_2 cables to Module 3.



DFH Concept

Module 3:

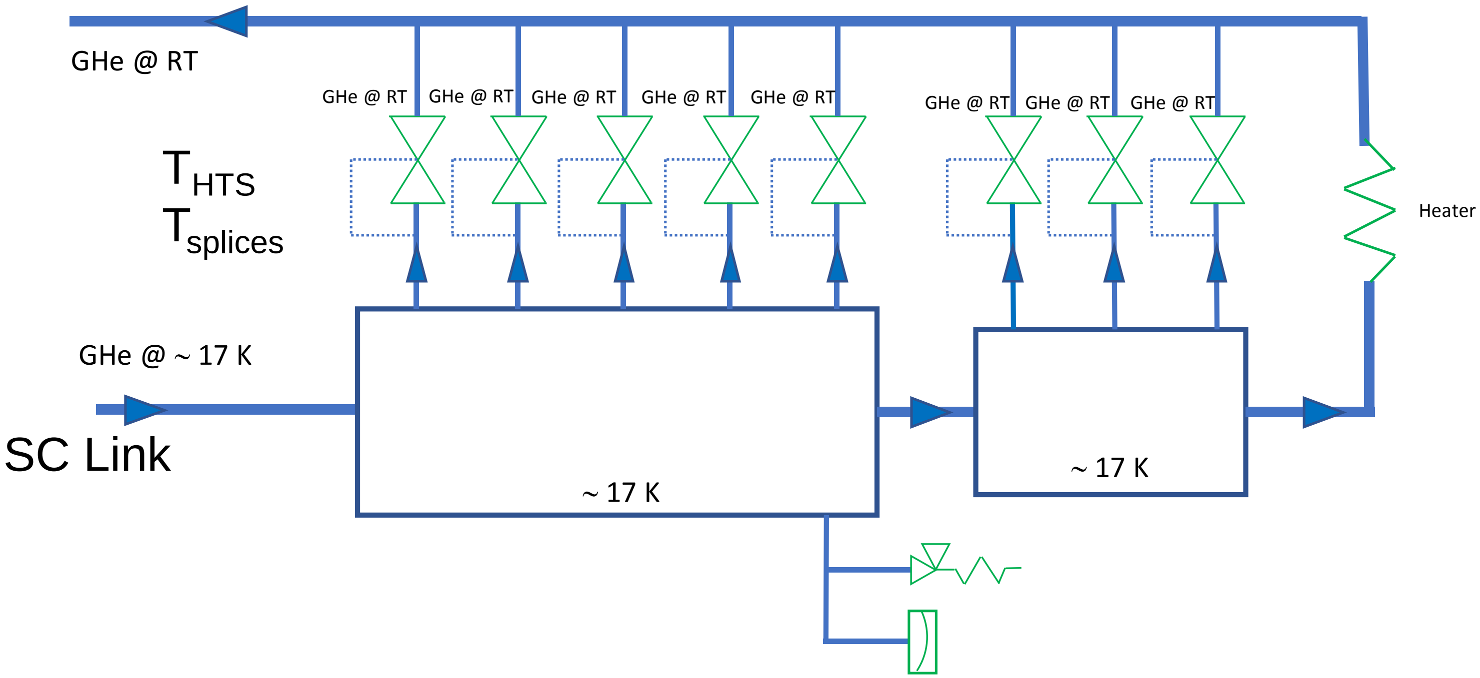
- This module contains the **3 kA joints between MgB_2 and HTS**, and it **routes out the 3 kA HTS cables**. The length allocated for the two joints to the coaxial cables is 450 mm. There are **three pipes for the MgB_2 to HTS joints**, and each pipe contains four joints (two coaxial MgB_2 cables connected to four HTS cables).



DFH Concept

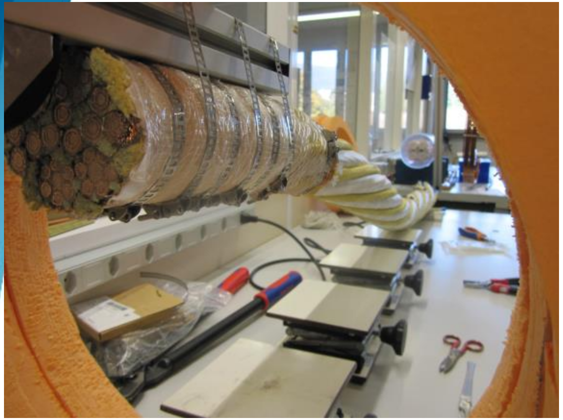
- Each DFH module is assembled separately. The modules are then put together for the routing and the splicing of the superconducting cables.
- The length of the HTS part of the leads is maintained to less than 2.5 m.

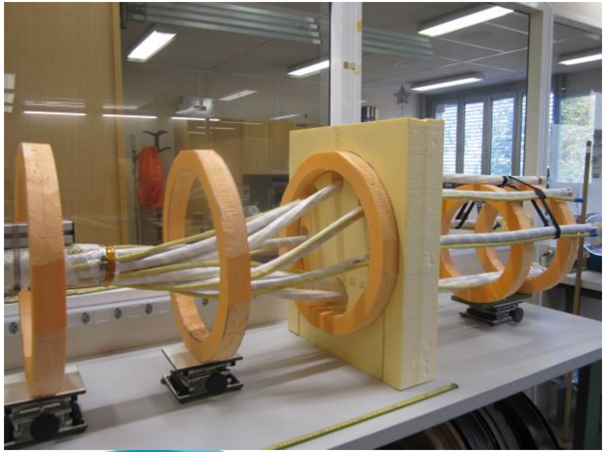
DFH Concept – GHe flow



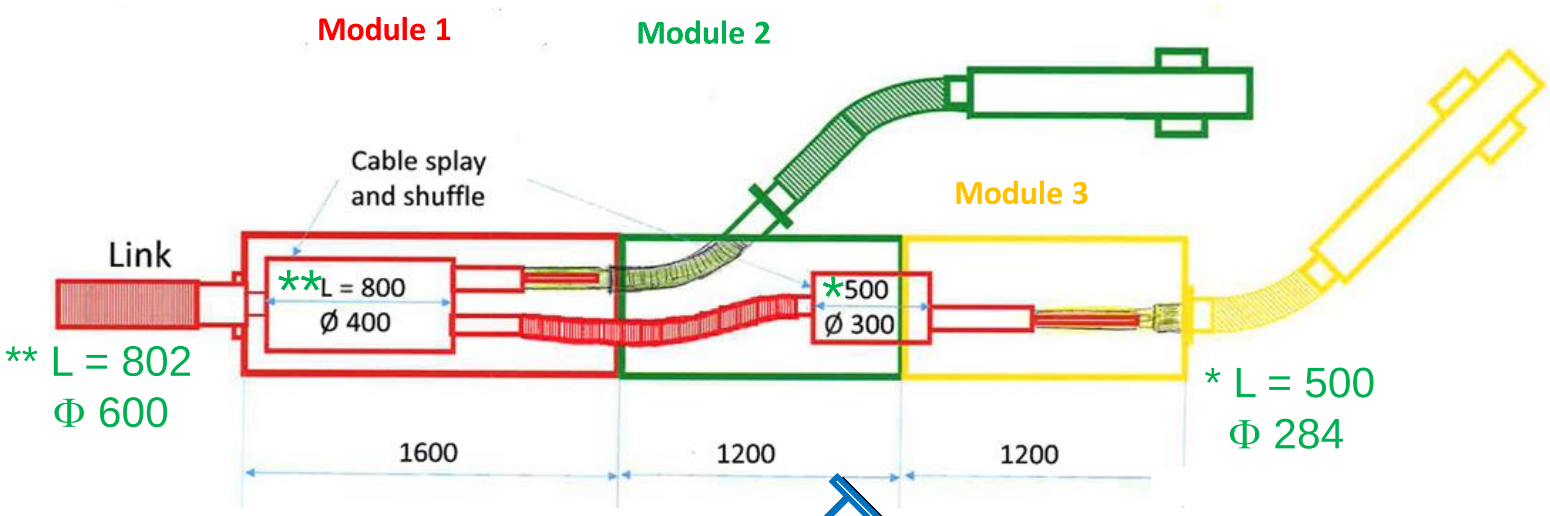
Mock-up

Building 288





From Concept to Design



Link

DFHX body: 4 m long, 650 – 700 mm diameter

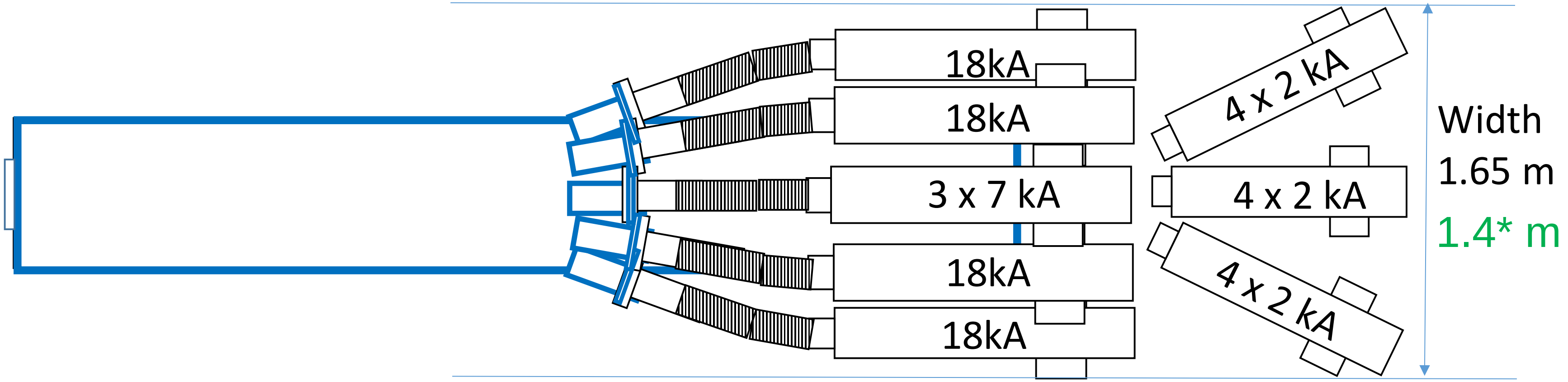
3.90 m 500 - 910*** mm

*** Taking into account size of Cutting/Welding machines

Green: 3D design, Black: concept

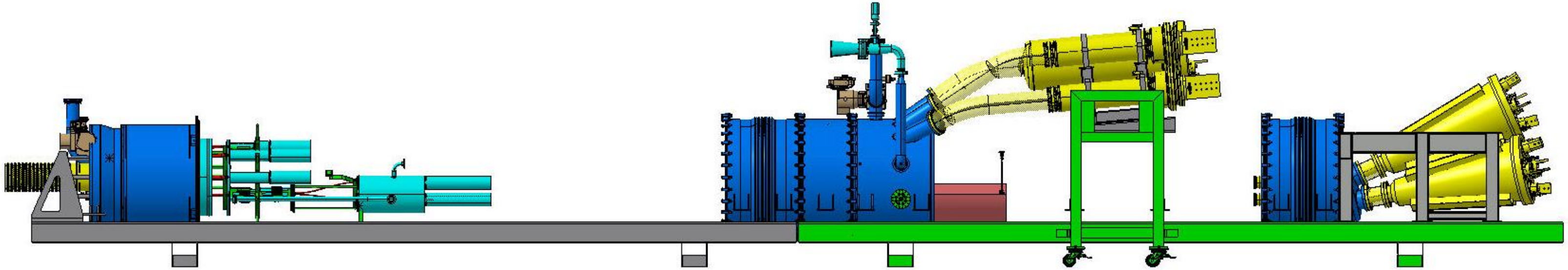
From Concept to Design

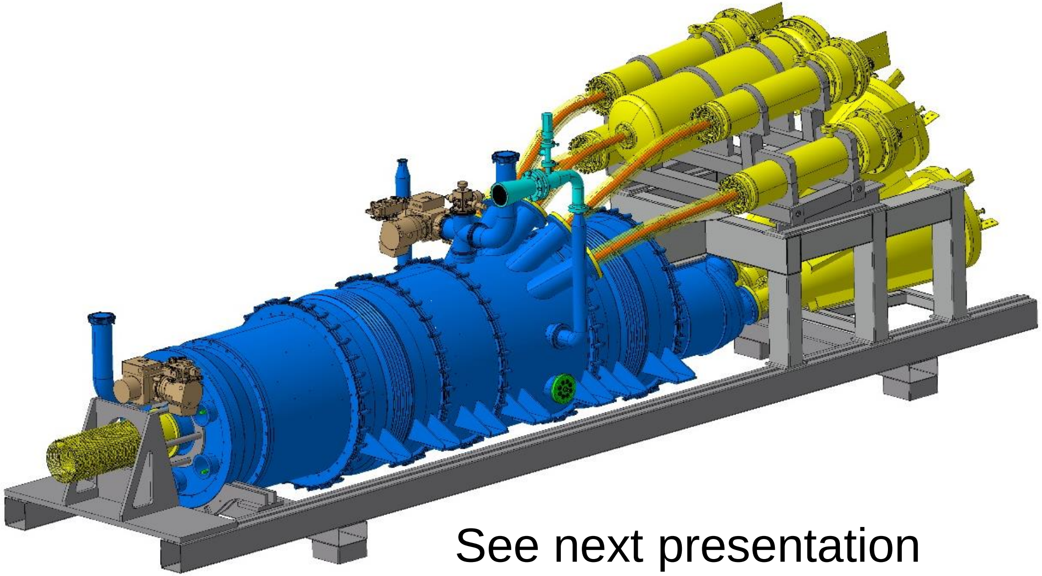
Top view



* Iteration with transport

DFH Design





See next presentation

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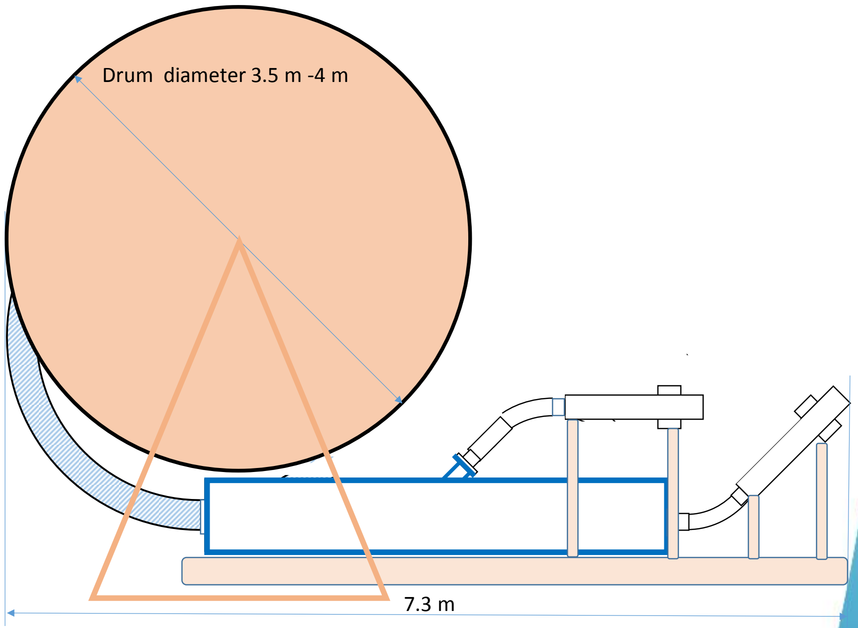
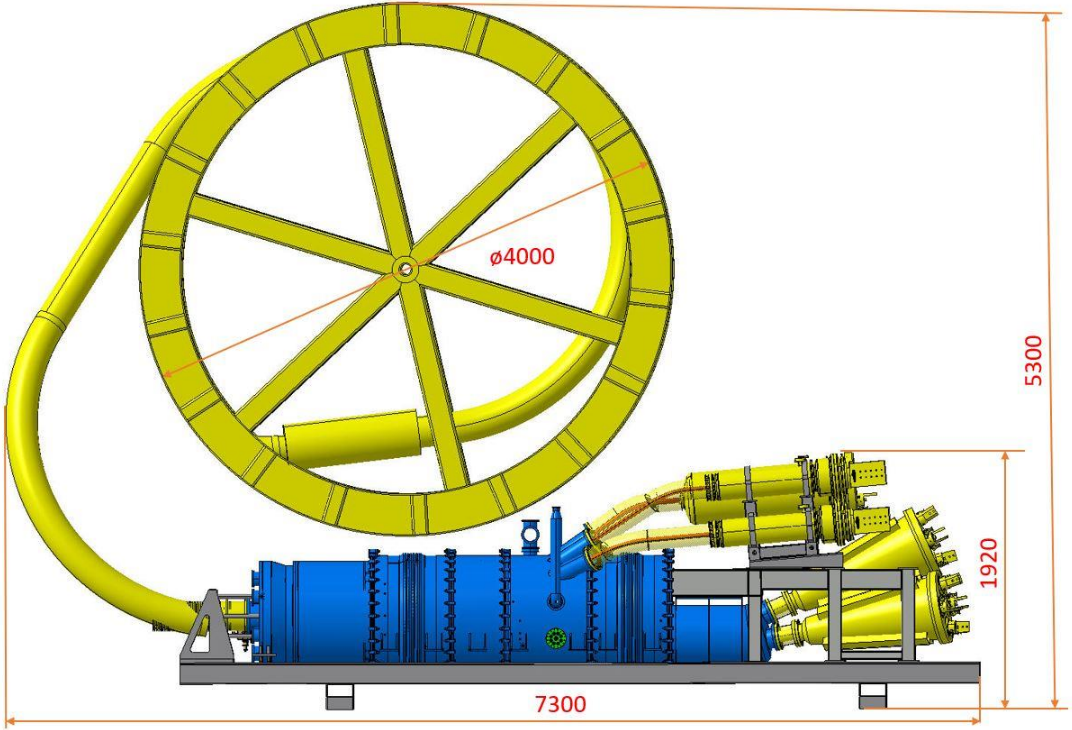
DFH Concept

Compact concept: possibility of lowering the **full system in the tunnel after test at the surface**. In addition to system cost reduction because (one module and shorter length of MgB_2 and SC Link), the main advantages are:

- Performance of **all assembly** operations **at the surface**;
- **Full qualification** of the system **at the surface** (including splices);
- **No manipulation** of cables (handling/cutting/splicing) **after qualification at the surface**;
- **Test station for SC Links** largely **simplified** (use of series DFH and current leads).



From Concept to Design



Conclusions

- A 3D DFH **concept** has been **developed**
- The compact concept brings in **several advantages** and guarantee full WP6a functionality
- To date, the concept has been validated with a **mock-up** and engineered in a **3D design**
- **Experience from Demo 1** has been essential for validating several aspects of the proposed concept
- Possibility of **lowering the system in the tunnel after cryogenic tests** brings in a huge advantage for the system

HiLumi HL-LHC PROJECT

Thanks for your attention

Additional slides

HV Levels - Triplets

EDMS NO.	REV.	VALIDITY
1821907	2.0	APPROVED

Rating (kA)	Worst case voltage to ground during operation (V)	Acceptance tests of components to ground (V)		Insulation test voltage of system to ground (V)		Leakage current per component (µA)	Test duration (s)
		RT	NOC	RT	NOC		
18	900	4600	2300	460	1080	≤10	30
7	900	4600	2300	460	1080	≤10	30
2	540	3160	1580	316	648	≤10	30
0.2	540	3160	1580	316	648	≤10	30
0.12	40	1160	580	220	360	≤10	30
0.035	900	4600	2300	460	1080	≤10	30

RT = Room Temperature (20 ± 5 °C)

NOC = Nominal Operating Conditions. For all WP6s components, it corresponds to GHe at RT and 1.30 ± 0.05 bar

HV Levels – Matching Sections

D2: treated as for a 18 kA circuit – conservative

18 kA

Rating (kA)	Worst case voltage to ground during operation (V)	Acceptance tests of components to ground (V)		Insulation test voltage of system to ground (V)		Leakage current per component (µA)	Test duration (s)
		RT	NOC	RT	NOC		
18	900	4600	2300	460	1080	≤10	30

D2

Rating kA	Worst case voltage to ground during operation (V)	Acceptance of components to ground (V)		Insulation voltage of system to ground (V)		Leakage current per component (µA)	Test duration (s)
		RT	NOC	RT	NOC		
D2	525	3100	1550	310	630	≤10	30

D2 correctors: 0.6 kA rating, Worst case to ground = 590 V, Components test: 5.7 kV (RT) - Components test 2.860 kV (NOC)