



## **Cold Powering System (WP6a-TE-MS)**

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WP6a

***STRING DAY IV – 27.09.2024***

# Cold Powering System in STRING

## Cold Powering System in a nutshell

- 80 m flexible line with 2 interface feedboxes at extremities
- Cryogenic, Instrumentation, Conductors interfaces

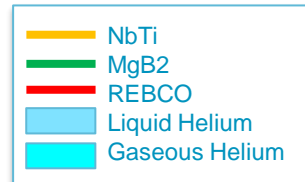
## Superconducting powering line

- Capacity up to |117| kA DC
- 3 superconducting materials : NbTi, MgB2, REBCO
- 19 independent branches

## Convective cooling with liquid and gaseous helium

- Design pressure 3.5 bar abs
- Nominal (design) mass flow through current leads : 5 g/s (10 g/s)
- Temperature range 4.5 K to 300 K

<b>CERN</b> CH-1211 Geneva 23 Switzerland	EDMS NO.	REV.	VALIDITY
	2303664	1.0	RELEASED
REFERENCE <b>HL-LHC Safety</b>			
Date : 2022-01-13			
SAFETY REPORT <b>Failure Modes of the          HL-LHC Cold Powering System (WP 6a)          Leading to cryogenic and electrical hazards</b>			



## DFX

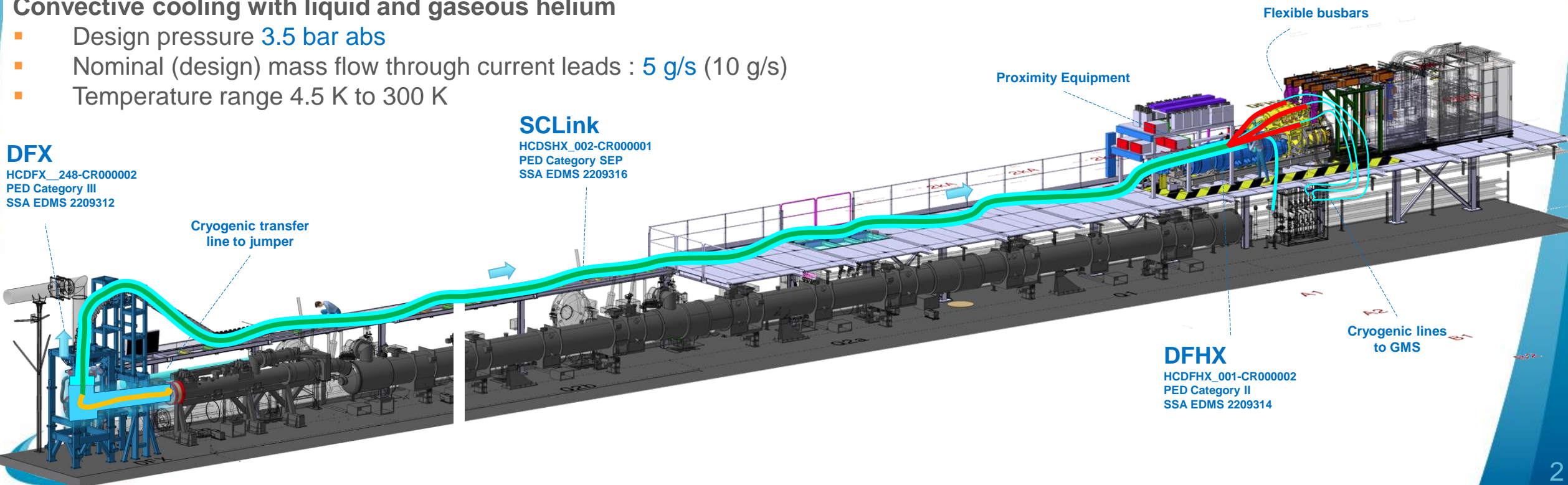
HCDFX\_248-CR000002  
 PED Category III  
 SSA EDMS 2209312

## SCLink

HCDSHX\_002-CR000001  
 PED Category SEP  
 SSA EDMS 2209316

## DFHX

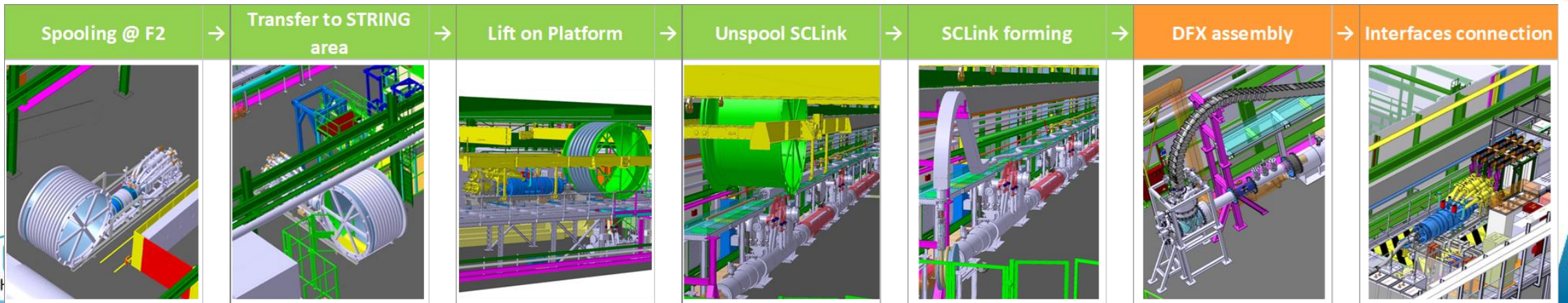
HCDFHX\_001-CR000002  
 PED Category II  
 SSA EDMS 2209314



# Process of the Cold Powering System for STRING

## Key milestones

- Q4-2023 : Cold Powering System Prototype assembly completed
- Q1-2024 : CPS connected to new F2 test bench & commissioned
- March-April 2024 : Successful powering campaign
- Q2-2024 : DFH refurbishment & F2 disconnection
- Q3-2024 : Installation on STRING platform
- Continuing...



# Cold Powering System life cycle

## Procurement

MgB2 cable

Flex cryostat

REBCO cable

Current Leads resistive

DFHX cryostat

DFX cryostat

NbTi busbars

CL assembly

IFS flanges

Mechanical structures

Electrical insulators



## SCLink+DFH Assembly

Flex cryostat Unspooling

Cryostats connections

Cable insertion

MgB2 Cable Shuffling

Shuffling box welding

High current cryostat assembly

Cold mass structure assembly

2kA CL assembly

2 kA MgB2-REBCO splices



18 kA CL assembly

18 kA MgB2-REBCO splices

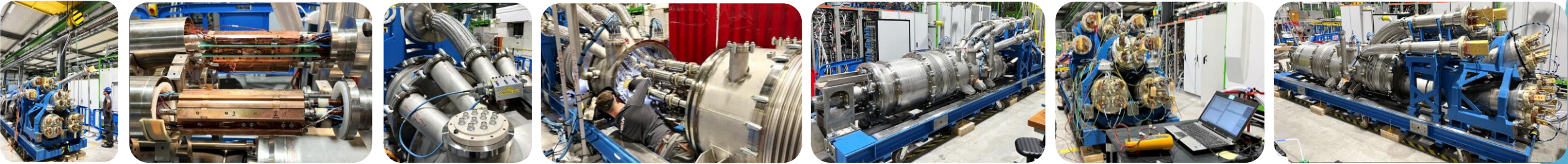
Ancillaries

Cold mass closure

Vacuum vessel closure

Quality Controls

SCLink+DFH assembly



## SCLink+DFH Qualification

MgB2-NbTi connections

SCLink forming

DFX assembly

Electrical shortcuts

DFX connection to F2

DFHX connection to F2

Quality Controls



# Performance of the CPS installed in STRING

## Qualified through prototype Cold Powering System test at F2-SM18

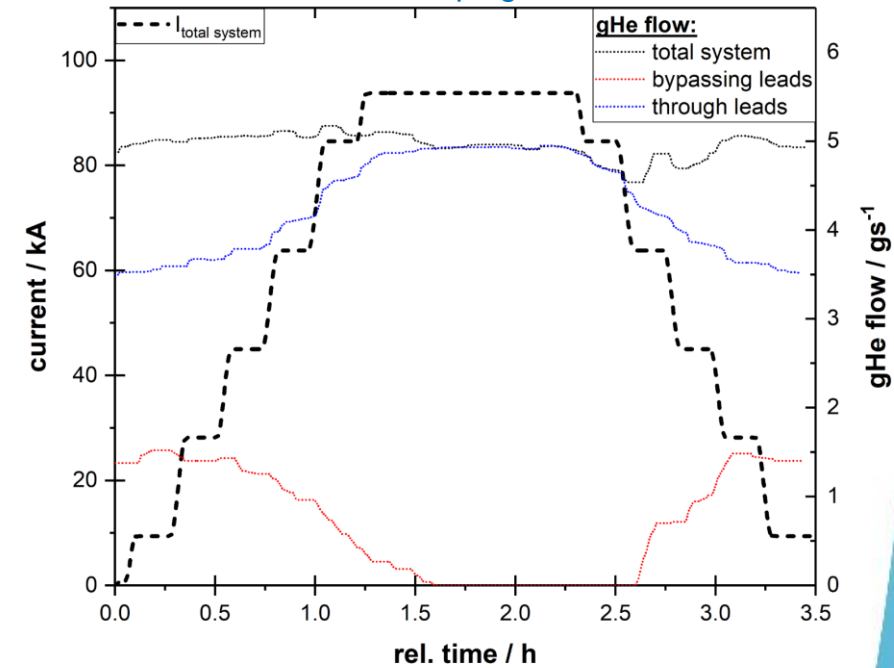
- Cryostats & current leads design, procedure & tooling
- SC cables design, production and handling
- Electrical connections SC & CL flags
- Instrumentation & proximity equipment

## Powered up to 94 kA at 20 K with 5 g/s total mass flow through cold powering system (details TCC 197<sup>th</sup> [link](#))

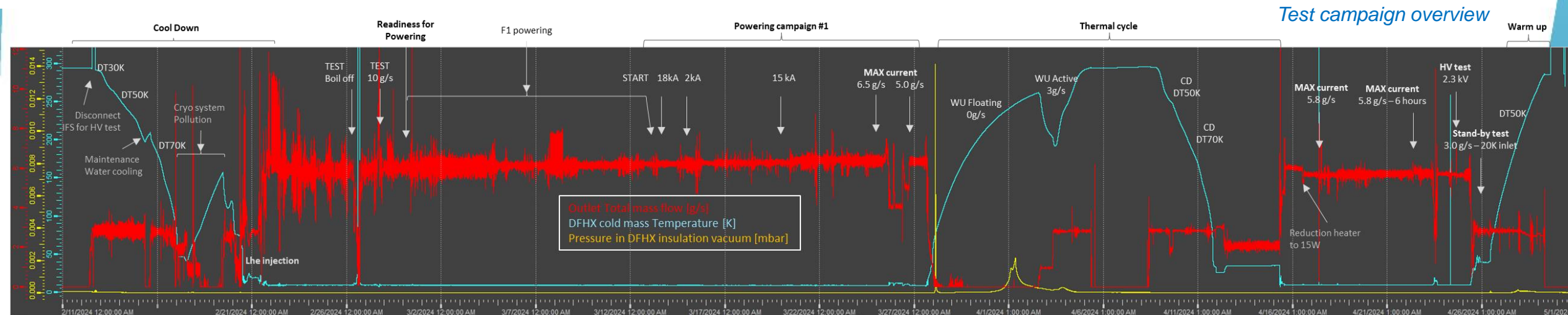
## Issues faced & refurbished

- T-sensors lost during welding operation due to grounding
- Air leak in DFHX bellows O-ring due to dust (most likely)

Total Powering & He mass flows during qualification campaign @F2



## → The CPS Prototype for the STRING is compliant with HL-LHC CPS series



# Wp6a equipment installation in STRING

## Spooling @ F2

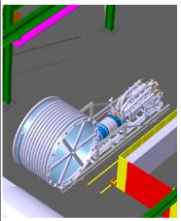
### • Steps

- Disconnect from F2
- Connect DFH end to Ø4m spool on spooler
- Spool & connect DFHX
- Install fixed transport tooling

### • Validation :

- Procedures
- Tooling
- Process
- for the next 9 CPS

Spooling @ F2



## Transfer to STRING Area

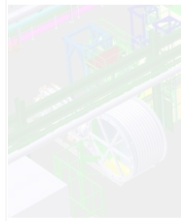
### • Steps

- Pre-assemble STRING lifting tooling
- Install transport tooling on SCLink+DFHX
- Route to STRING area
- Practice
- Measurements on site
- Execution with empty 4m spool + DFH structure + weight 2.5T

### • Validation

- Tooling
- Handling procedure

Transfer to STRING area

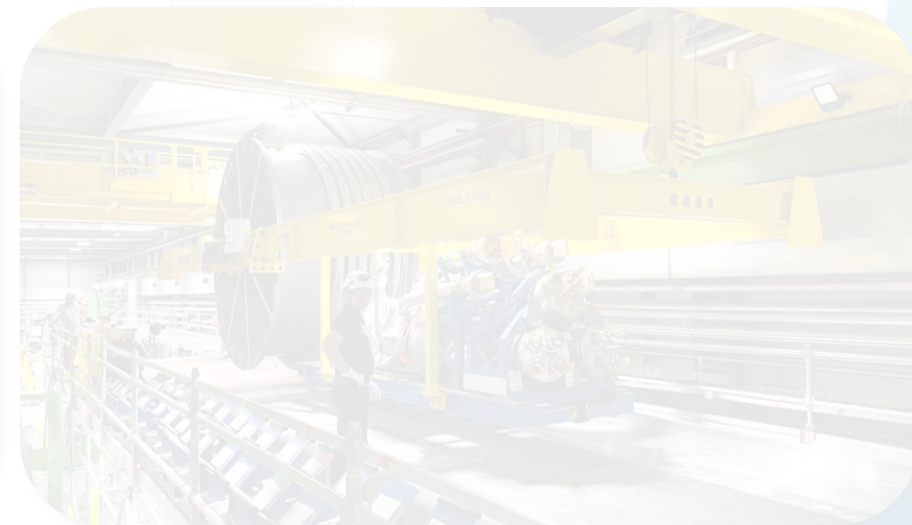
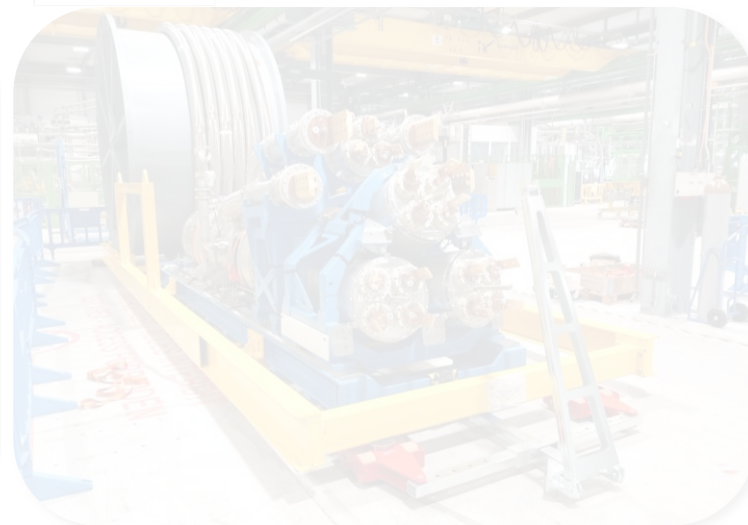


## Lift on Platform

### Steps

- Assemble tooling on SCLink+DFHX
- Disconnect fixed transport tooling
- Lift until DFHX position
- **Practice**
- 3 stages (B181, tooling, dummy SCLink)

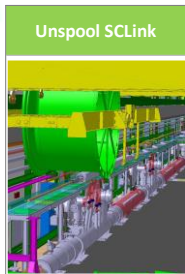
Lift on Platform



# Wp6a equipment installation in STRING

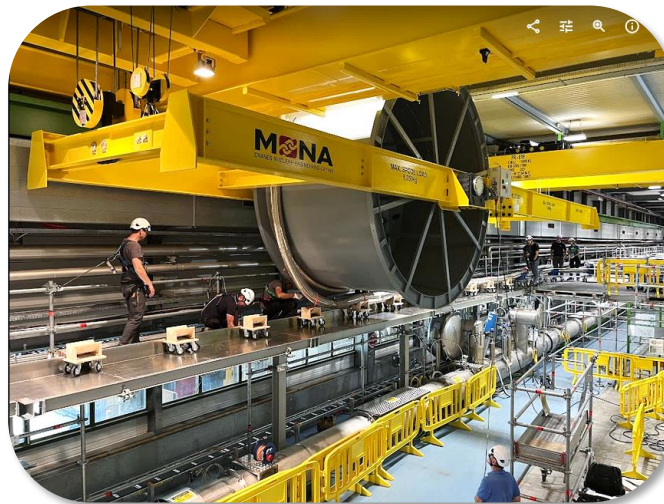
## Unspool SCLink on scaffolding + Trays

- **Steps**
  - Transfer DFHX load to the platform
  - Unspool while waving the flexible
  - Disconnect the DFX end from the spool
  - Remove tooling & spool
- **Practice**
  - Empty spool
  - With 60m dummy
- **Validation**
  - Flex manual handling
  - Procedures & tooling design



## SCLink Forming Preparation

- **Steps**
  - Prepare cable chain
  - Assemble and tune towers tooling
  - Prepare rotative table for NbTi-MgB2 splices protection
- **Practice**
  - Blank installation with dummy cable

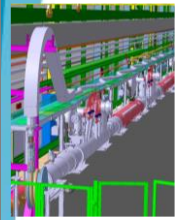


# Wp6a equipment installation in STRING

## SCLink forming

- **Steps**
  - SCLink in cable chain
  - NbTi-MgB2 splices on rotative table
  - Execution
- **Validation :**
  - Procedures & Tooling

SCLink forming



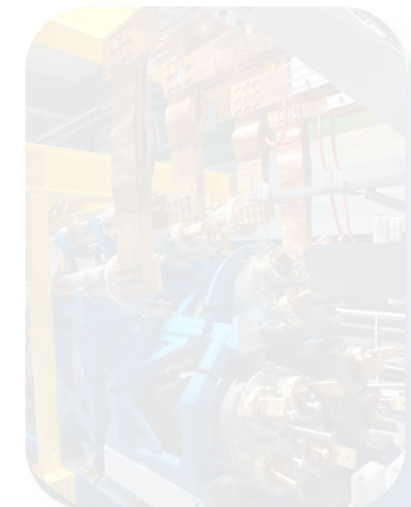
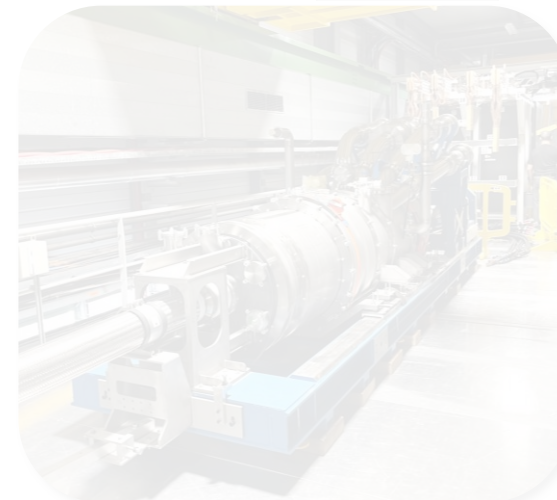
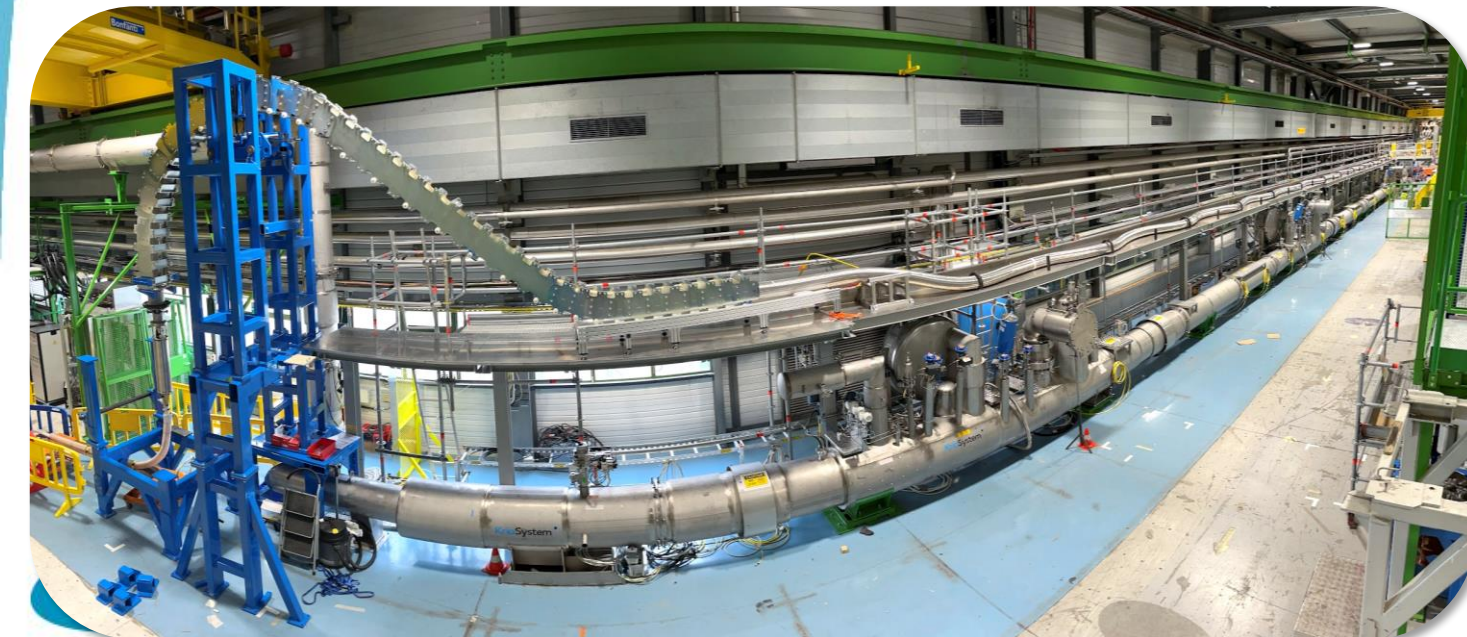
## SCLink Forming : Closure

- **Steps**
  - Remove scaffolding
  - Secure NbTi extension
  - Form waves for thermal compensation
- **→ Free access**

## Interfaces connection

- **Steps**
  - Final positioning DFHX
  - Flexible busbars
    - installation
    - connection
- **Lessons learnt**
  - increased mechanical adjustment range would be beneficial

Interfaces connection





# WP6a equipment installation in STRING : Lessons learnt

## Technical lessons

### SCLink+DFH handling

- With robust inputs, **3D simulations** is a very **reliable tool** for SCLink modelling
- **Practice** is essential
- **Worth investing** in robust and **high quality tooling**
- Wp6a-Transport tooling designs performs as needed
  - Bending limiters, mechanical adjustment, Spooler
  - Manual contribution
- **Level of details, flexibility of WP6a procedures well adapted** for in field application
- Mixed transport & spooling tool is efficient
- **→ Proposal : same team, approach, method for LS3**

### Current leads – busbars interface

- Increase adjusting ranges

## Coordination lessons

### WP6a-EN/HE-Facility coordination & task distribution

- **Common procedure**
  - EN-HE, WP6a & facility responsible (WP16 / WP15)
- **EN-HE responsible for transport of equipment in fixed and secured configuration**
  - Tooling design, procurement, assembly, operation
  - with support from WP6a team
- **WP6a responsible for handling unfixed equipment**
  - Tooling for protection, support, Manual handling
  - With support from EN-HE
- **Facility responsible** (WP16 for STRING) provides
  - schedule, access, tooling, custom made infrastructure, safety considerations
- **→ Proposal : same approach for LS3**

*Equipment fixed in secured structure*



*Equipment unfixed in secured structure*

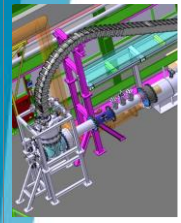


# Wp6a equipment installation in STRING : Upcoming activities

## DFX installation

- QC post forming w39
- Leak Test EDMS 2228665
- HV test 1.1 kV in GHE
- DFX installation as for F2

DFX assembly



## DFX @ F2 test bench

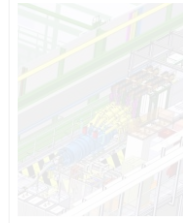
Same assembly procedure for STRING



## Interface connection

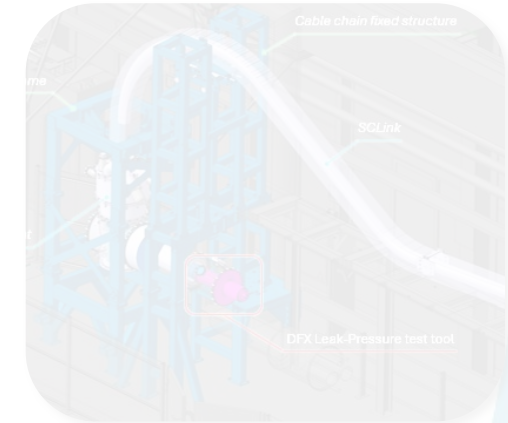
- DFHX cryogenic return lines w44
- DFX cryogenic return line w40
- Proximity equipment
- WP6a-WP3
  - Instrumentation
  - Cold mass & vacuum closure

Interfaces connection



## Final Quality control

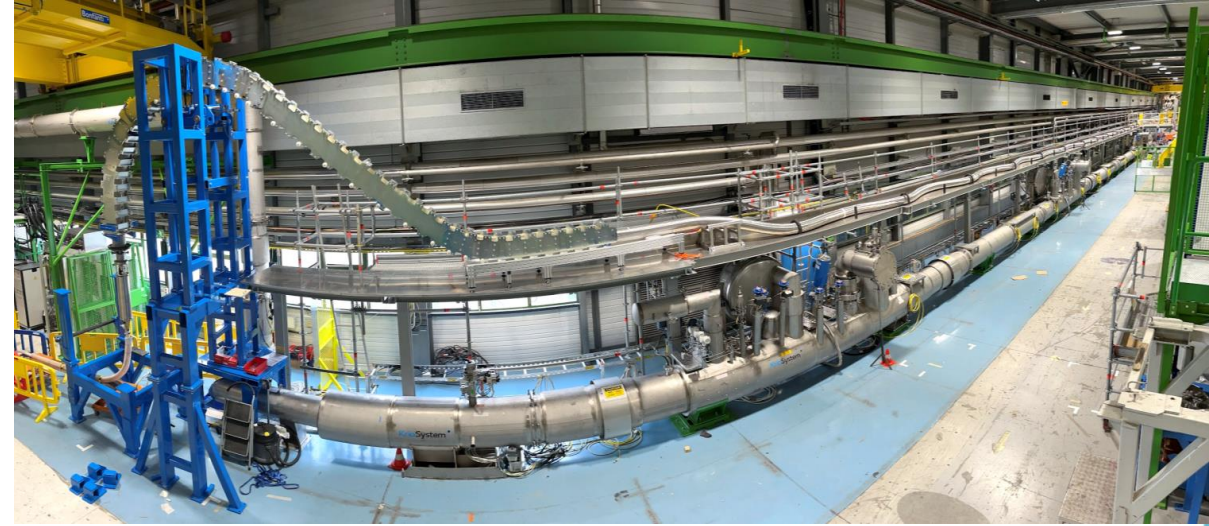
- Procedure & acceptance criteria
  - HV : EDMS 2827527
  - Leak test : EDMS 2228665





# Observations

- Cold Powering system being installed in STRING
  - Complies with prototype and series specifications
  - Is a spare for HL-LHC
- WP6a equipment installation
  - Collaborative work
  - Status
    - SCLink installation is completed
    - Assembly of extremity feedboxes and their interfaces in progress
    - QC/QA & acceptance criteria in place
    - No showstoppers
  - Extensive project successfully executed
  - Natural & successful collaboration with Transport team
- Toward LS3 installation
  - The WP6a-Transport collaboration has built a strong and efficient expertise to be kept for LS3
  - Although different from LS3, installation in STRING is bringing experience on cold powering system handling, for both technical and organizational aspects



# Thanks for the attention !

## Acknowledgement

- WP6a, WP16, WP9, EN-HE, TE-MS-C-TM, TE-MS-C-HSD, TE-MS-C-CMI, TE-MS-C-LSC, TE-VSC, TE-CRG, EN-ACE-COS, EN-MME-FS, EN-MME-MA.
- And in particular : J-B. Deschamps, M-P. Careil, A. Saba, T. Bugnon, N. Gal, P. Denis, S. Hopkins, O. Chamot, D. Garcia Robles, S. Spathopoulos, R. Perez Martinez, A. Gharib, M. Ky, S. Morisi, J. Hurte, D. Richaud, A. Carlon Zurita, J. Mazet, A. Henrique Jorge-Costa, N. Gosselin, P. Viret, T. Colin, V. Gahier, N. Vauthier, B. Didier, D. Lombard, L. Deparis, J-M. Geisser, P. Moyret, S. Kesel, W. Maan, G. Barlow, M. Knoch, A. Grimaud, C. Halbert, P. Catherine, T. Coiffet, M. Bajko, D. Bozzini, S. Yammine, N. Heredia, S. Pelletier, E. Richards... Apologies for those I have certainly forgotten in this non-exhaustive list