Recent progress on WP6a activity

A. Ballarino for the WP6a

Special TCC Meeting

19/12/2018

Outline

- WP6a recent progress (Nov-Dec 2018)
  - DFX, DFH, DFM
  - Tunnel integration aspects
  - Large industrial contracts
- Demo 1
- Preparation for Demo 2

Topical Working Meetings

- **DFX. Weekly meeting (Friday afternoon,** 14:00 – 15:00**)**

  Coordinator: Y. Yang. Participants: A. Ballarino, J. Fleiter, Y. Leclercq, V. Parma,

  S. Claudet, A. Perin, R. Betemps, D. Perini

- **DFM + DFHX + DFHM. Weekly meeting (Wednesday afternoon,** 14:00 – 15:00**)**

  Coordinator: Y. Leclercq. Participants: A. Ballarino, J. Fleiter, V. Parma,

  S. Claudet, A. Perin, R. Betemps, D. Perini, Y. Yang, A. Foussat

- **Integration. Weekly meetings** (**Tuesday afternoon**, 16:00-17:00)

  Coordinator: A. Ballarino. Participants: J. Fleiter, A. Gharib, Y. Leclercq, V. Parma, P. Retz, J. Ph. Tock, P. Fessia, M. Modena, C. Bertone, Y. Yang

Presentations available at: https://indico.cern.ch/category/3668/

Meetings will continue in 2019 – with a bi-weekly frequency and in the context of the WP6a meetings

DFX, DFM and DFH

- **DFX**: most advanced conceptual design – among the three types of cryostats. Several design options studied in 2018 – and most promising retained. **Conceptual design review** by end of **January 2019**. **Detailed design review** by end of **March 2019**. Work done in the framework of the UK HL-LHC Collaboration agreement. See next presentation (by myself)

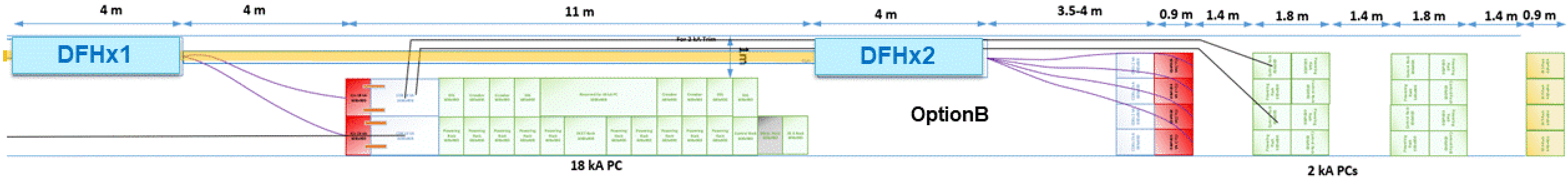
- **DFH**: progress on conceptual design. Iterations still required for finalization of concept and choice of final configuration. **Conceptual design review** could be possible by end of **February/March 2019**. See next presentation (by Yann)

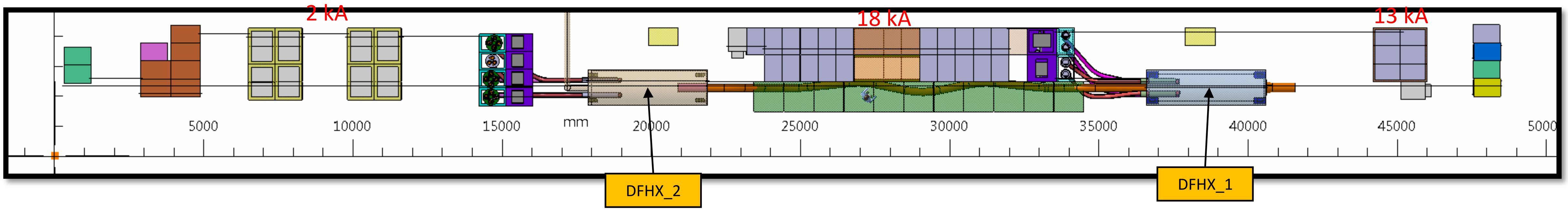
- **DFM**: as for DFH. Required more iterations on tunnel integration aspects. See next presentation (by Yann)

Integration aspects

New layout for Triplets. Boundary conditions:

- **Two DFHs**;
- **HTS flexible section** of current leads **not more than 4 m** long;
- **Accessibility** of current **leads**;
- **Accessibility** of **power converters**;
- Stay within **allocated space in the tunnel**





Location of Trim Current Leads and Power Converters to be re-iterated (to optimize routing of RT power cables)

Integration aspects

List of ancillary equipment for WP6a

- To operate the Sc- Link several ancillaries are required to be installed and operated in the UL, UR and LHC tunnel:
  - QDS (Quench Detection System) (UR)
  - Thermoswitch on the current leads (UR)
  - Heater for Current Leads (UR)
  - Vacuum pumping units (UR and LHC tunnel)
  - He gas panel and control valves (UR)
  - Cryo instrumentation racks (UR)

J. Fleiter, WP6a Weekly Integration Meeting December 2018

CERN CH-1211 Geneva 23 Switzerland

CERN TE-MSC

EDMS NO.	REV.	VALIDITY
2060126	1	DRAFT

REFERENCE

Date: 2018-03-14

Functional specification

Functional specification for the ancillary equipment of the WP6a cold powering system

ABSTRACT:

This Functional Specification describes the requirements of different ancillary equipment that need to be installed in the tunnel for the operation of the different Sc-Link of HL-LHC.

- Functional specification will be finalized by end of this monthEDMS 2060126
- Space reservation to WP15 will be performed in Q1 2019

Two large industrial contracts – for series

- Following ITs and offers from industry, presented at last week FC meeting:
  - Proposal to proceed with **procurement of 850 km of MgB_2 wire** (single supplier);
  - Proposal to proceed with **contract for cabling MgB_2** (prototype for Triplets and Matching Sections plus series)

- In line with WP6a Master Plan – and within cost

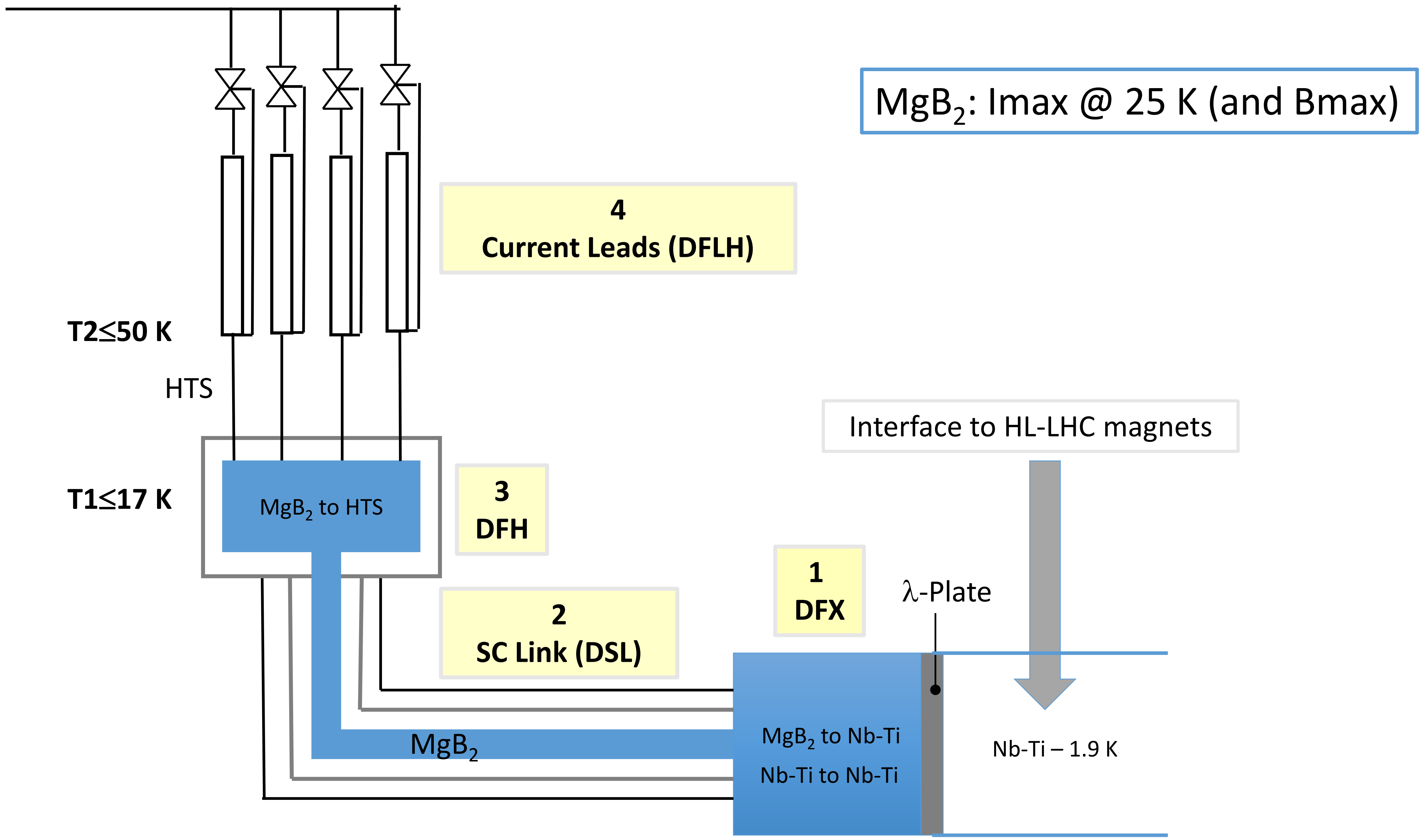
Demo 1

Demo 1

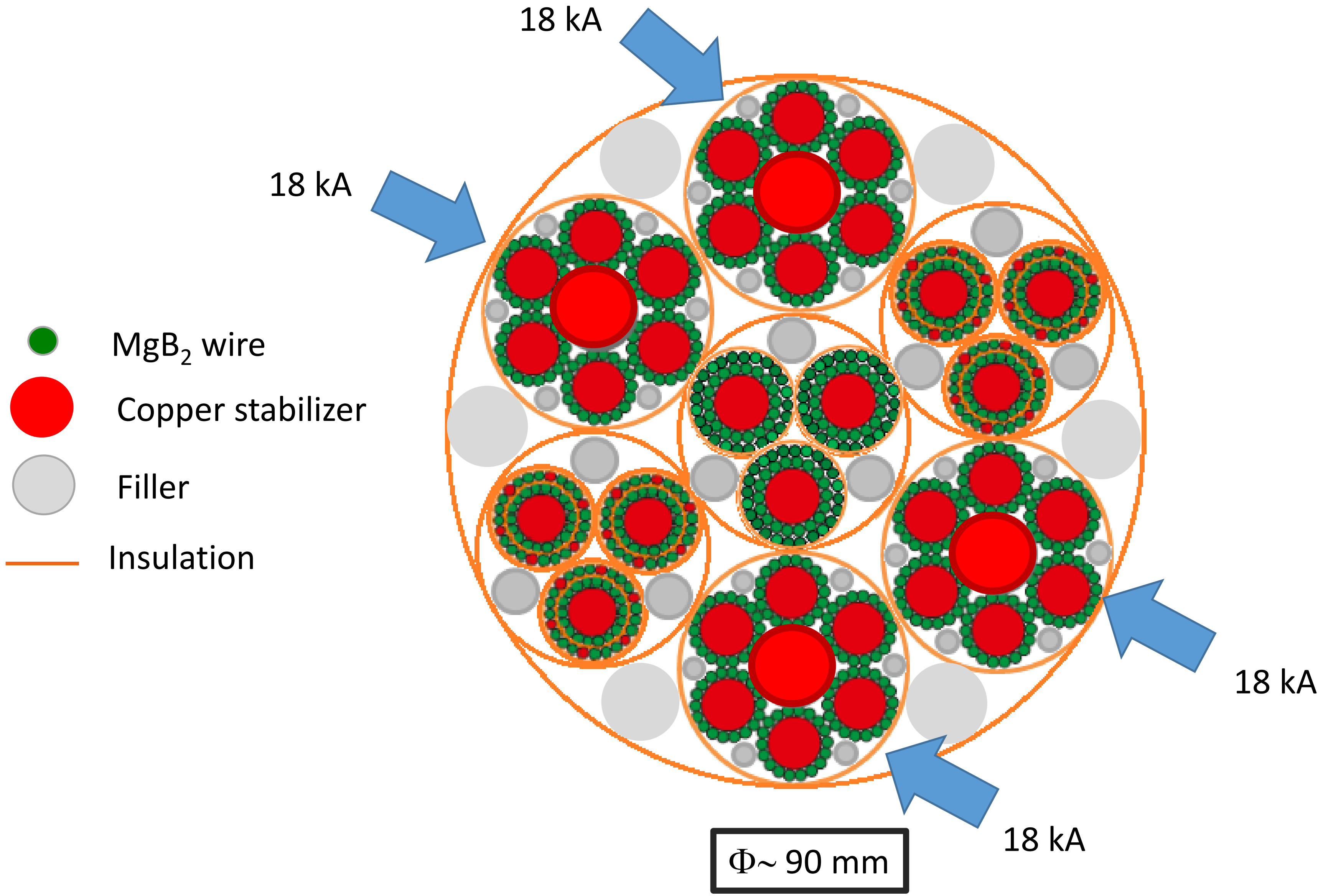
- **System Demonstrator of Cold Powering for HL-LHC Triplets** incorporating:
  - A **DDFX Demonstrator**;
  - A **SC Link with a 60 m long cryostat** – with performance representative of the final system – and a **pair of 18 kA MgB_2 cables**;
  - A **DDFH Demonstrator**;
  - A pair of **18 kA HTS current leads** connected to the DDFH.

- **Design and construction** of all components was done in **2018** – apart from the DDFH – available since mid 2017. Also **cryogenic upgrade of the SM-18 test station** was done in 2018 (instrumentation and control system)

Cold Powering System



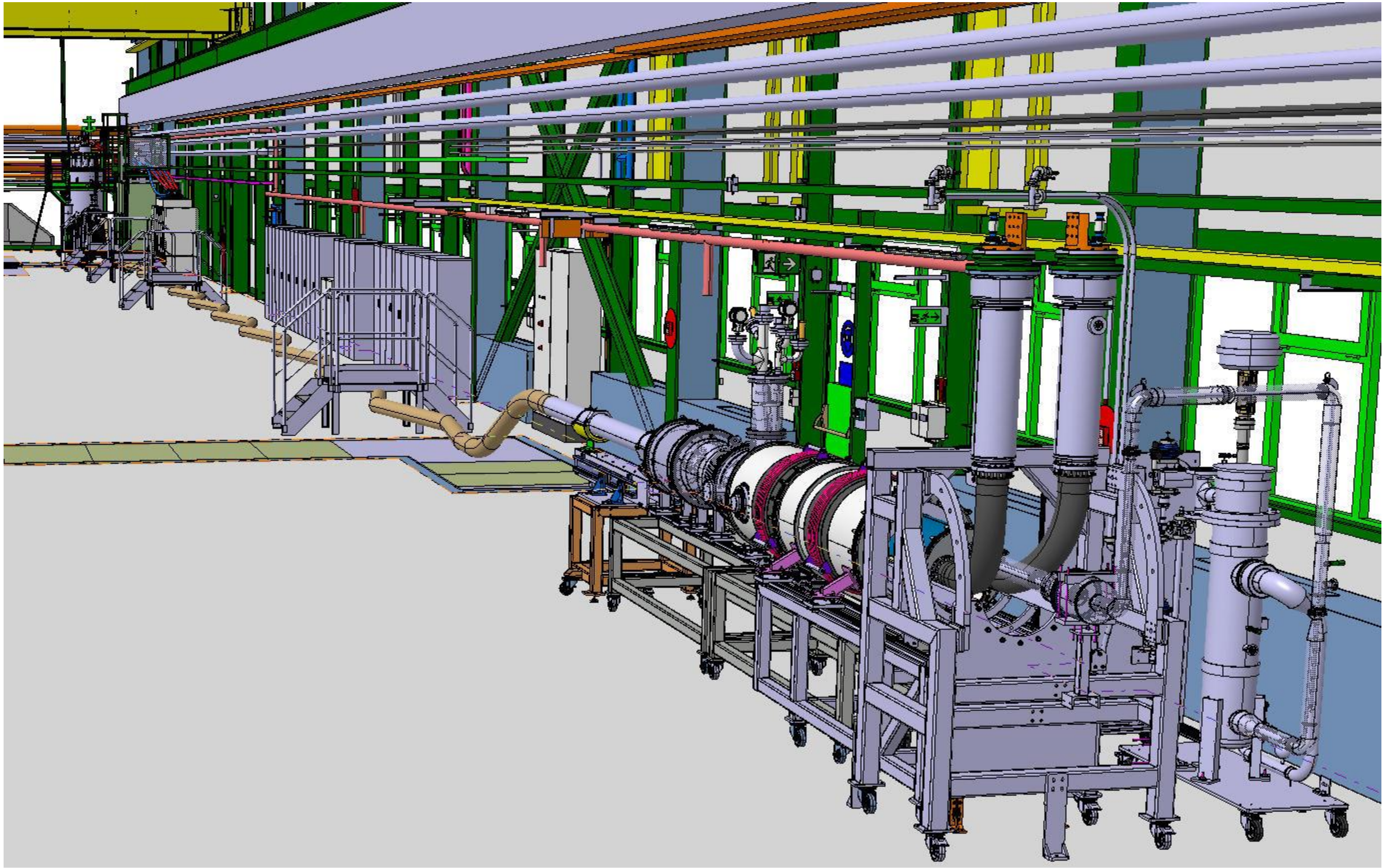
SC Link MgB_2 cables layout



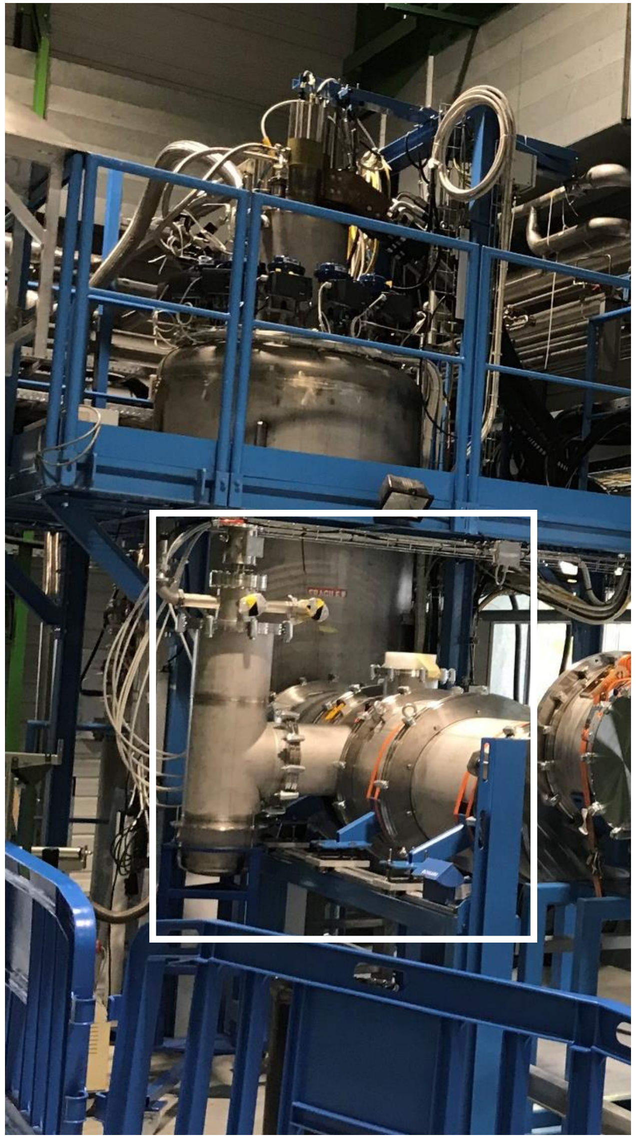
Demo 1

- **SC Link Cryostat**: TE-MSC-SCD
- **MgB_2 Cables:** TE-MSC-SCD
- **Splices:** TE-MSC-SCD
- **Instrumentation for protection/acquisition** (V-Taps/Tsensors): TE-MSC-SCD
- **Safety Devices:** TE-MSC-SCD
- **DFHX (with LHe gauge and heater):** TE-MSC-CMI
- **Plug (with Nb-Ti bus):** TE-MSC-SCD
- **DDFH:** TE-MSC-SCD
- **Cryo-control, cables of signals and heater for gas recovery:** TE-CRG
- **Installation in SM-18**:
  - SC Link, MgB_2 cables and DDFH: TE-MSC-SCD
  - DDFFX: TE-MSC-CMI
- **Cryo-tests operation**: TE-CRG
- **Powering tests**: TE-TF

Demo 1



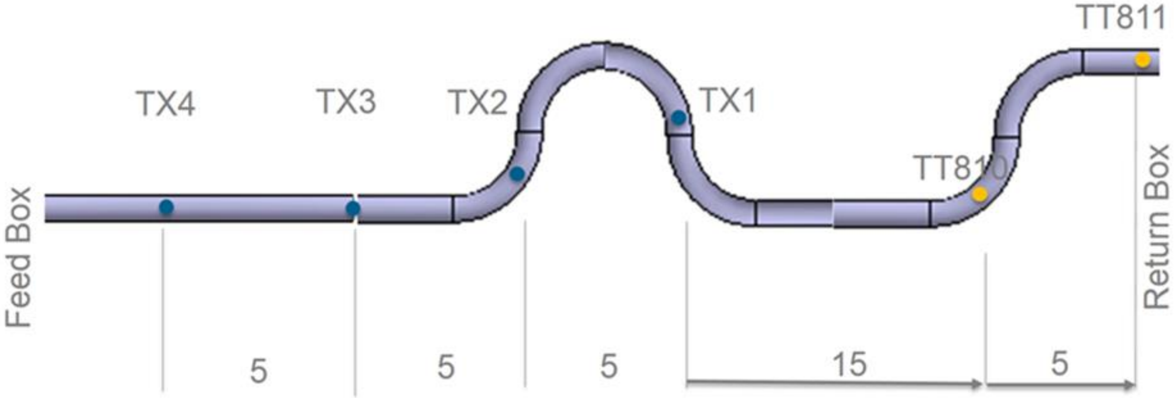
DDFX

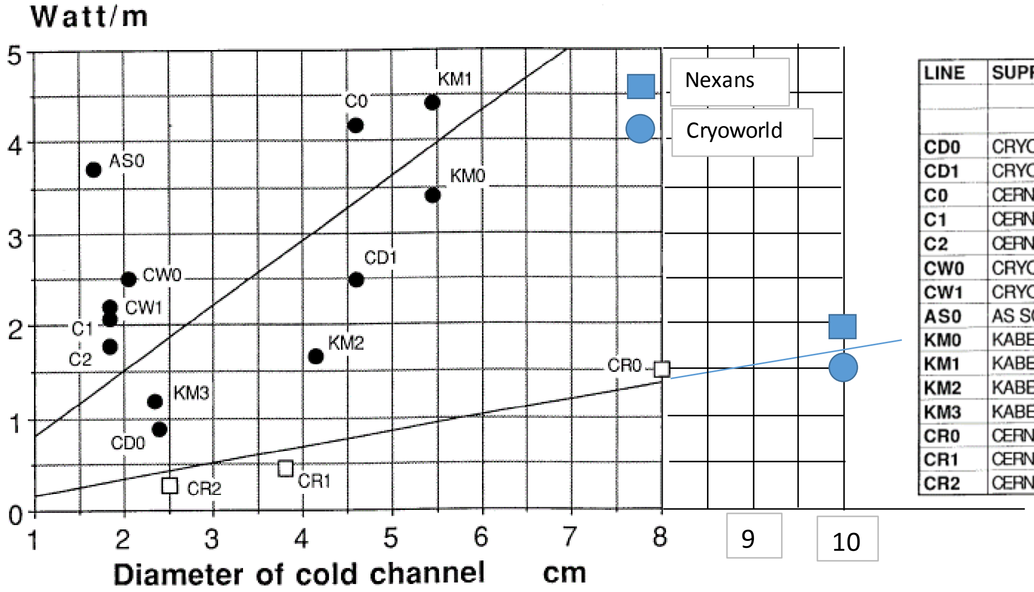


DDFH

Previous to Demo 1 - 2018

- Qualification on industrially procured SC Link cryostats

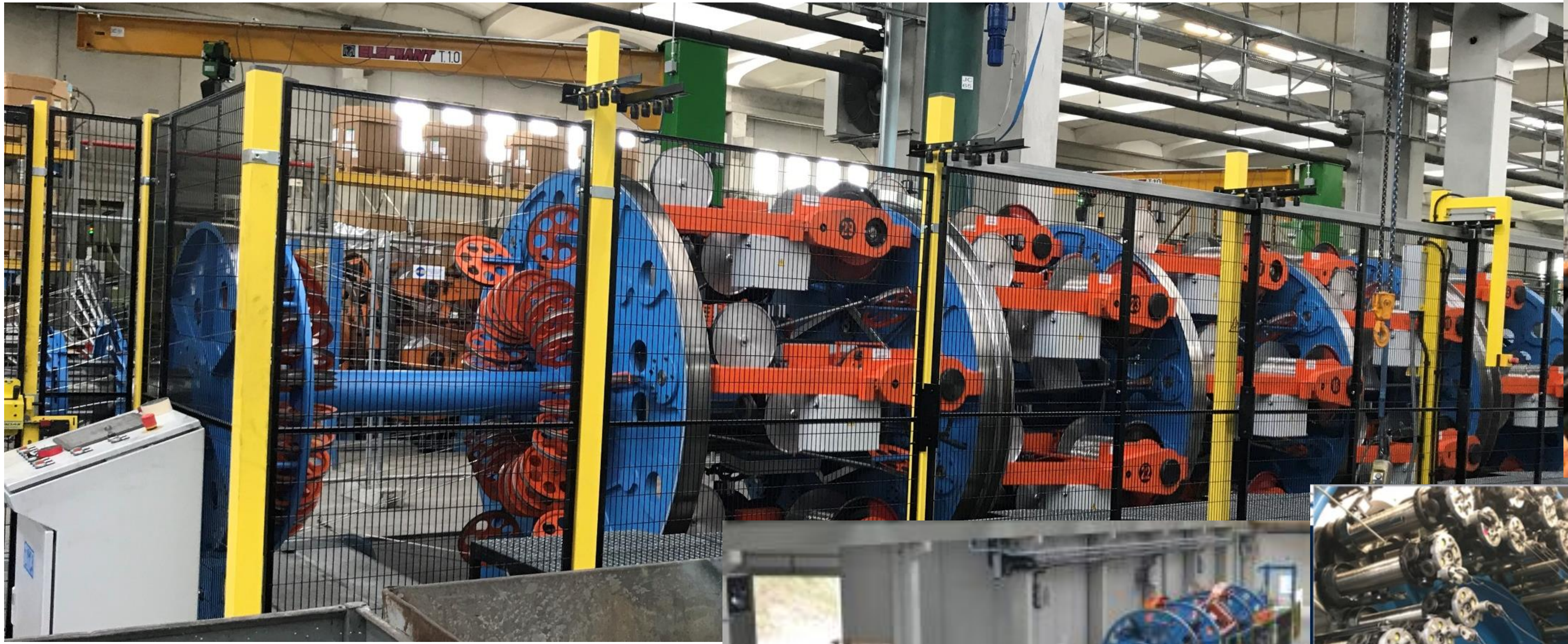




LINE	SUPPLIER	APPLICATION	LENGTH m	TYPE
CD0	CRYODIFFUSION	ALEPH TEST	9	flexible single
CD1	CRYODIFFUSION	SPS SC CAVITIES	27	flexible single
C0	CERN	SPS SC CAVITIES	6	flexible coaxial
C1	CERN	SPS SC CAVITIES	6	flexible single
C2	CERN	SPS SC CAVITIES	6	flexible single
CW0	CRYOWATT	LEP 200	6	flexible single
CW1	CRYOWATT	LEP 200	6	same line
AS0	AS SCIENTIFIC PRODUCTS	CRYOLABORATORY	6	flexible single
KM0	KABELMETAL	ISR SC QUADRUPOLES	50	flexible coaxial
KM1	KABELMETAL	SPS SC CAVITIES TEST	100	flexible coaxial
KM2	KABELMETAL	LEP SC QUADRUPOLES	50 to 90	flexible coaxial
KM3	KABELMETAL	CRYOLABORATORY	11	flexible single
CR0	CERN	DELPHI	10	rigid shield
CR1	CERN	ALEPH	11	rigid single
CR2	CERN	ALEPH	11	rigid single

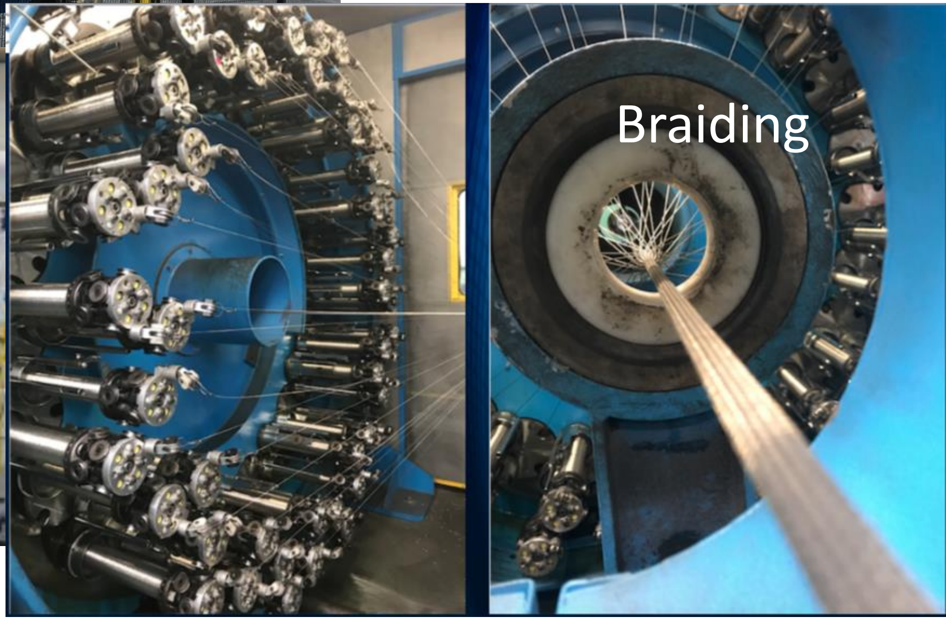
ECR in September 2019

Previous to Demo 1 - 2018



Spools of 18-strand MgB_2 sub-cables: with core diameter of 800 mm

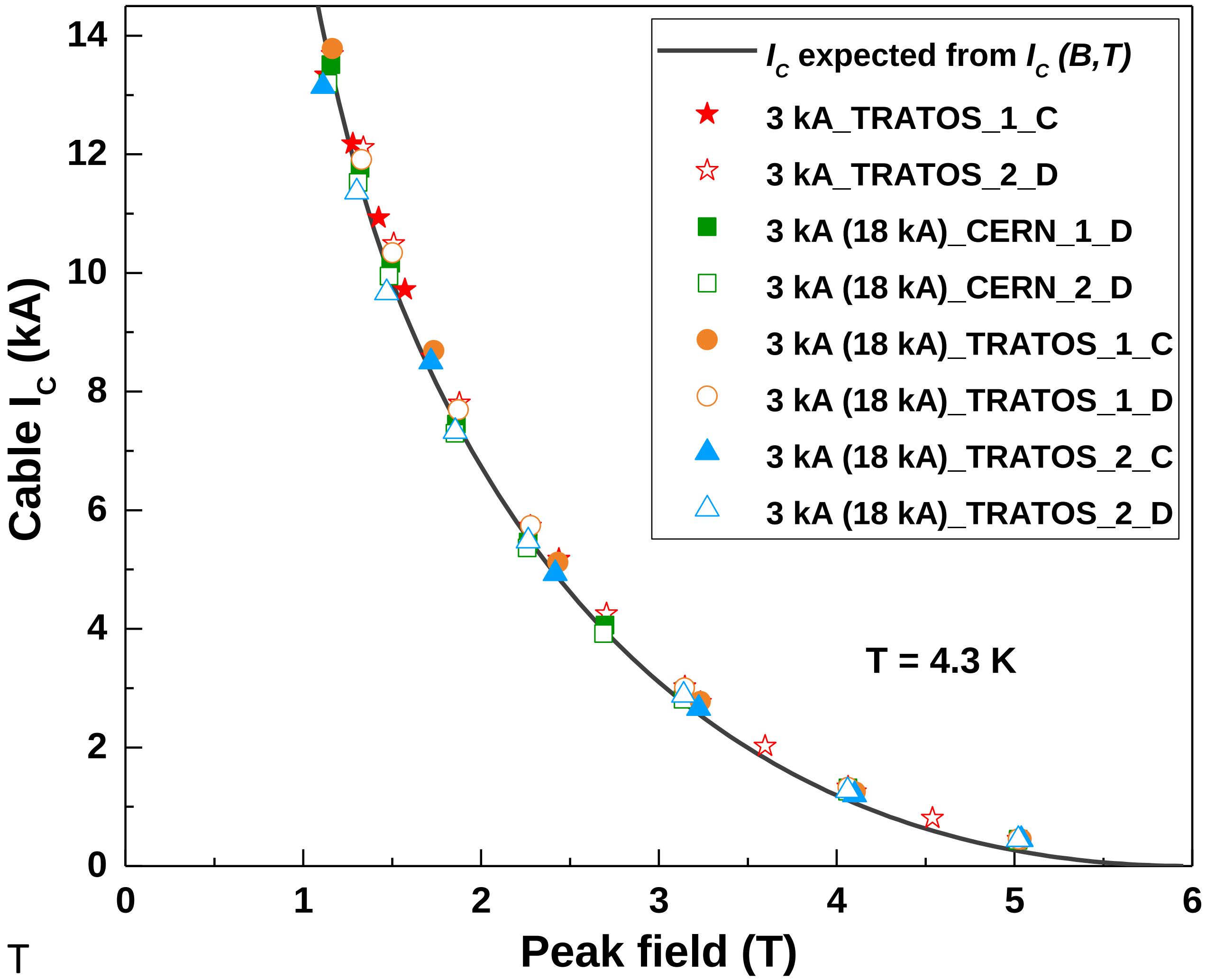
Validation of twist pitch and tension, implementation of QA



Planetary machine – Operation in fully detorsional mode

Qualification of MgB_2 cables at CERN

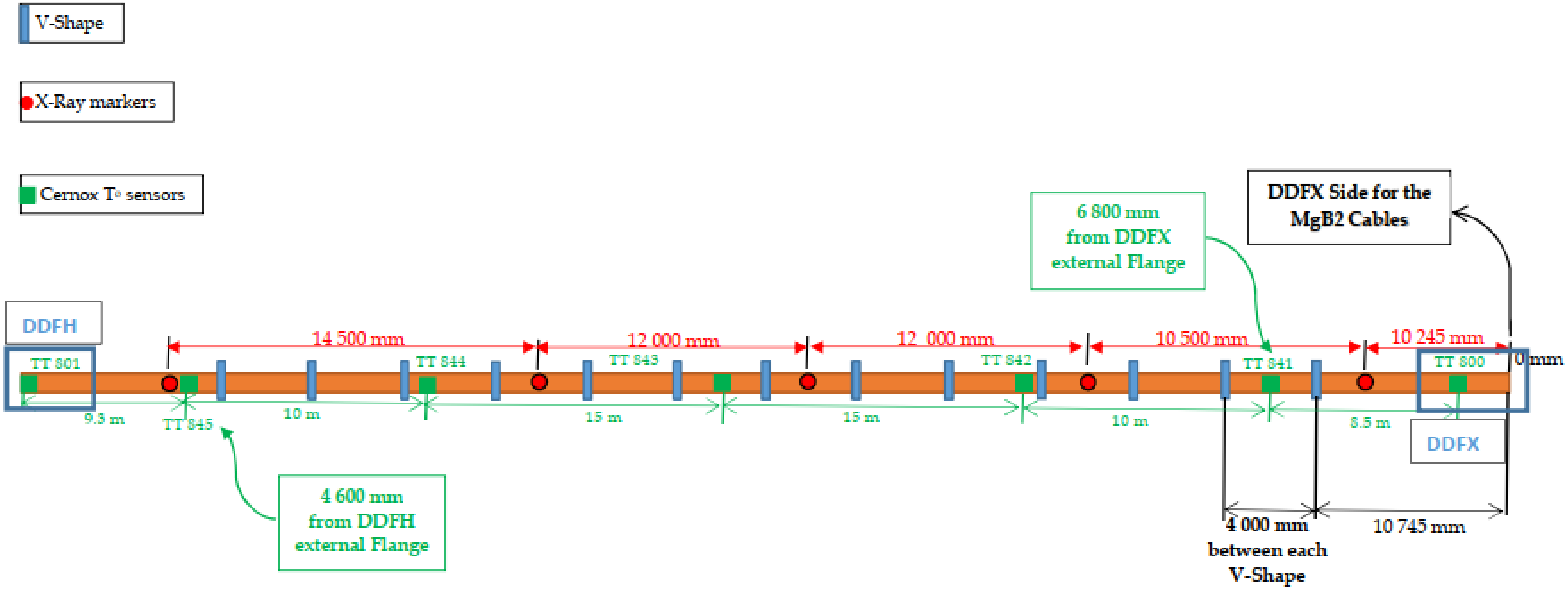
Sub-cables (2 m long) measured at 4.2 K



3000 A at 25.5 K and 1 T

No degradation of Ic measured

Instrumentation

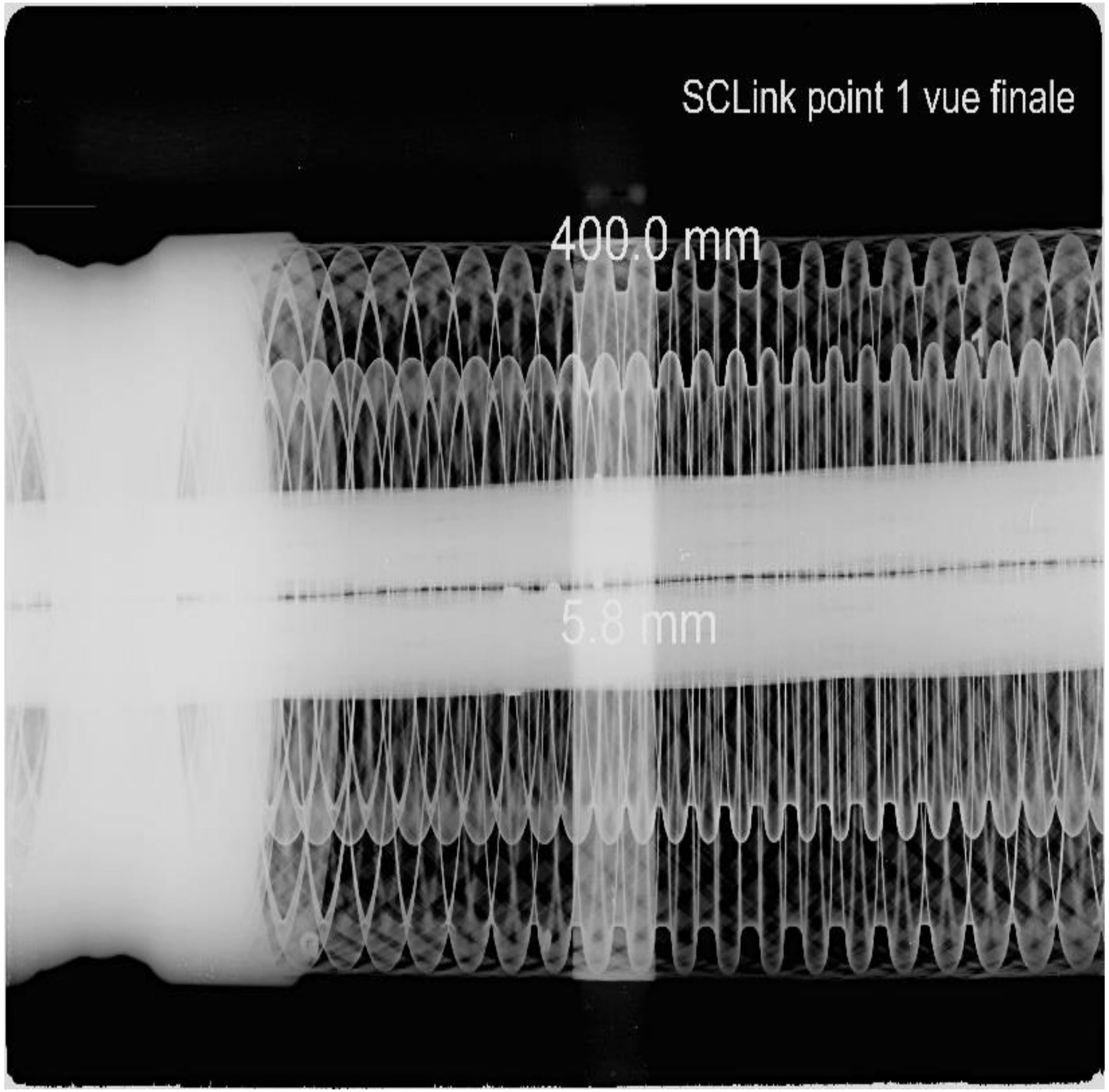


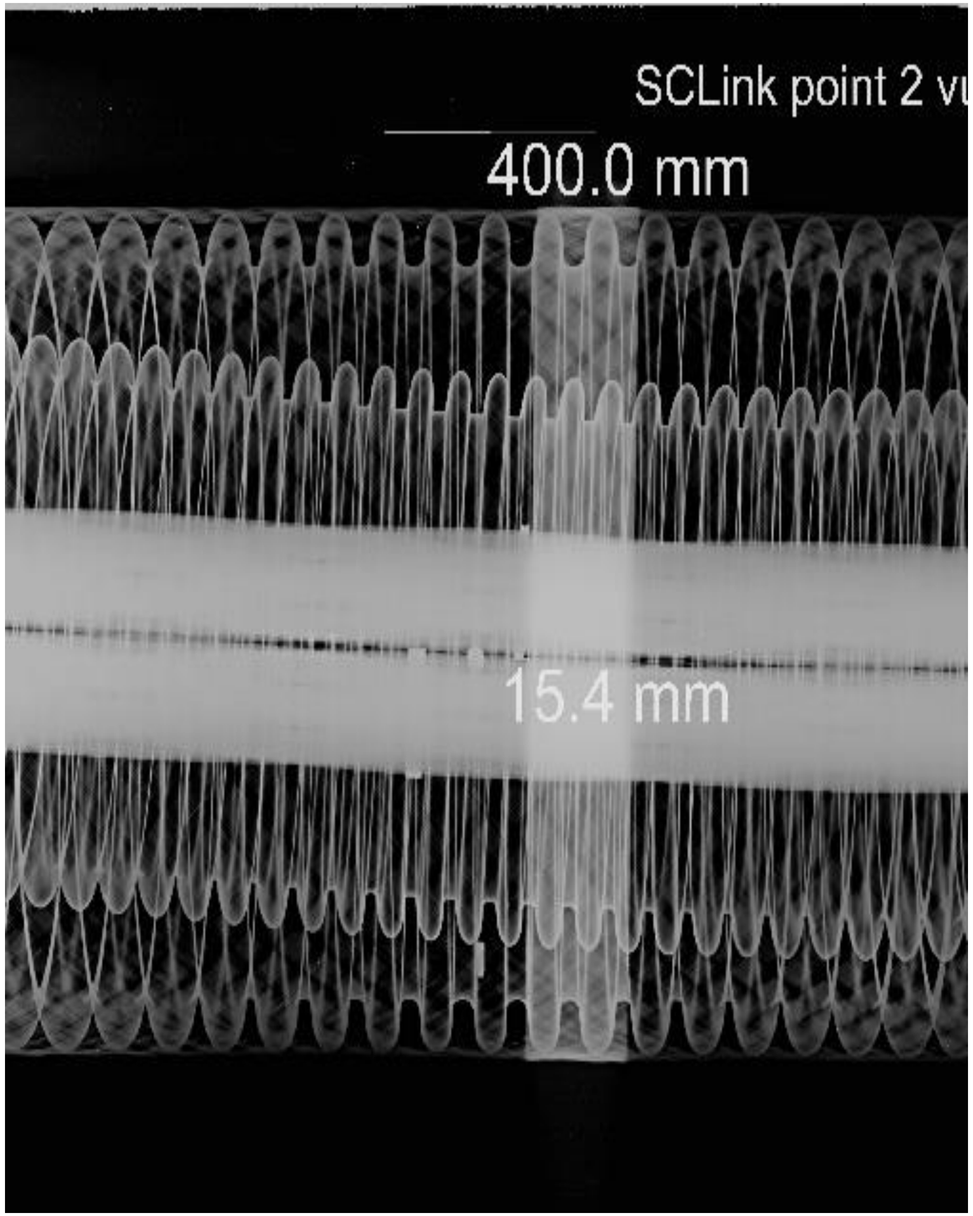
SC Link geometry

Quantification of thermal contraction

- X-ray Tomography to quantify displacement of MgB_2 cables – with EN-MME-EN
- Lead ball (Φ = 5 mm) in the valley between the two cables, Silver-Lead wire around both cables, Ag tape around one of the two cables
- From RT to cryogenic temperature: adjustment of cable inside cryostat. Found manual displacement of the cryostat wrt RT position – reason not identified
- From cryogenic temperature to RT: behavior according to expectations. No axial displacement within the wavy configurations

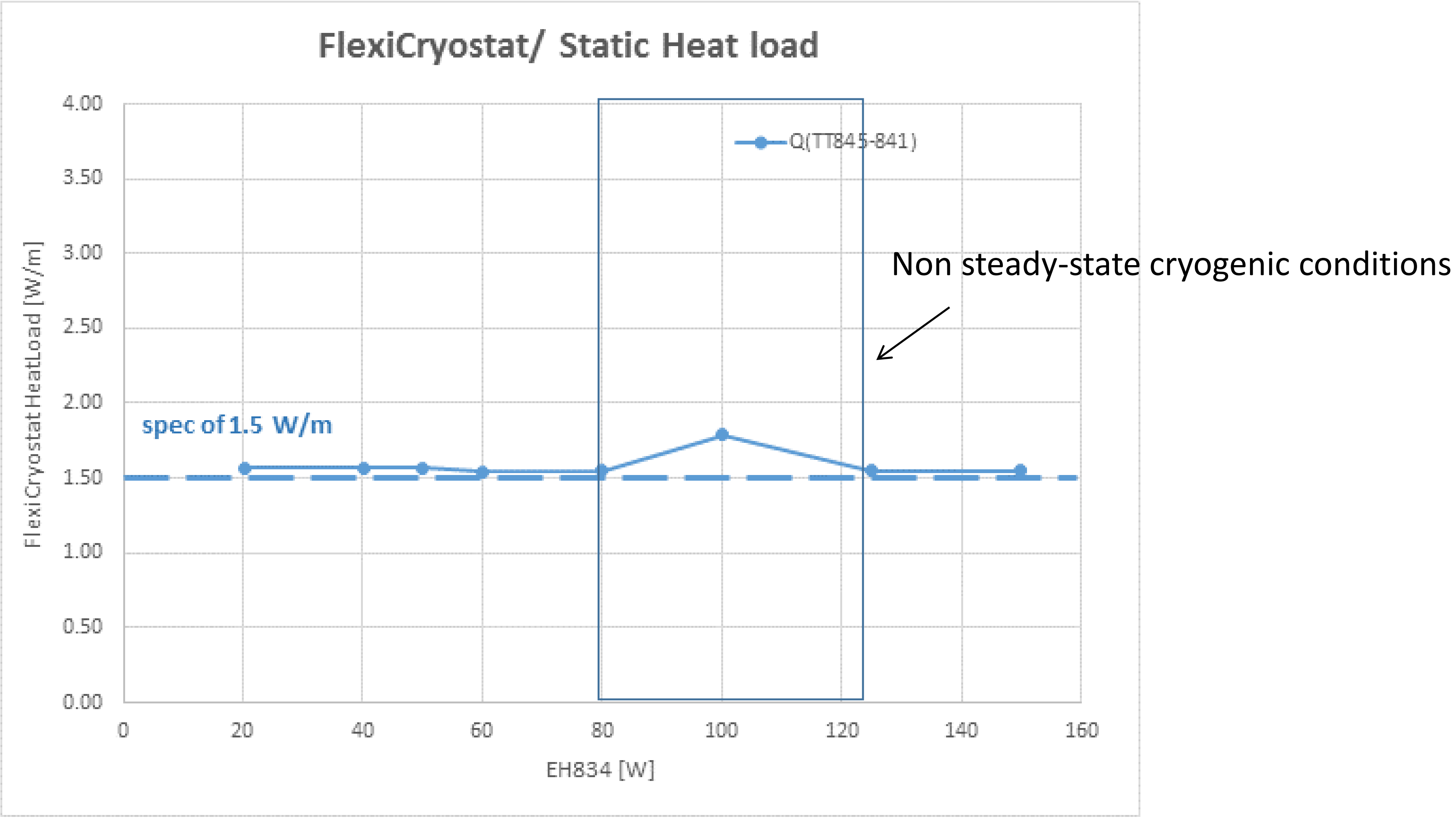
Found one of the MgB_2 cables bent and plastically deformed – from Friday evening to Monday morning(terminations prepared for making splices). Luckily the deformation was at the level of the splices – in the DDFH


SCLink point 1 vue finale
400.0 mm
5.8 mm

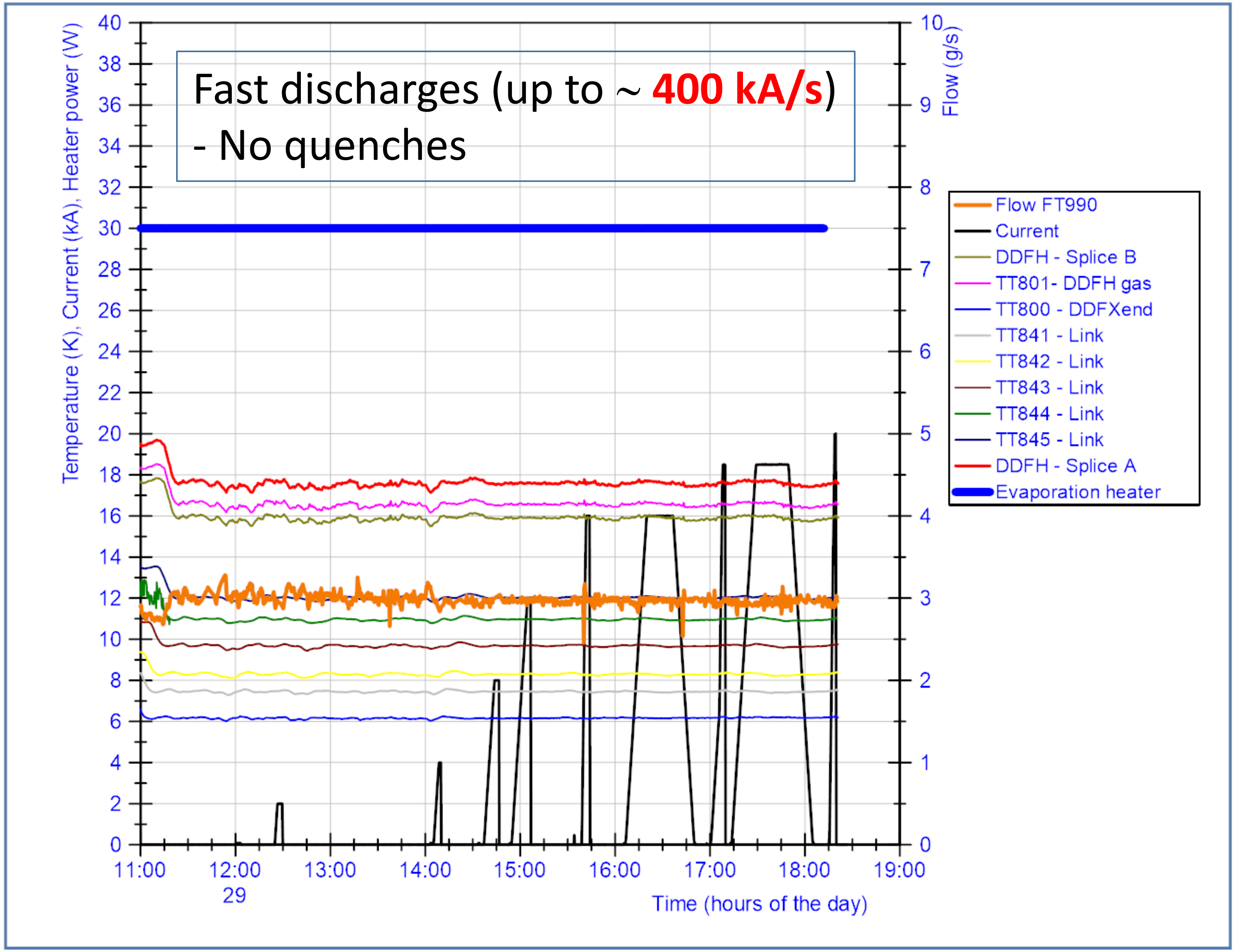

400.0 mm
15.4 mm

Quantification of static load of the cryostat

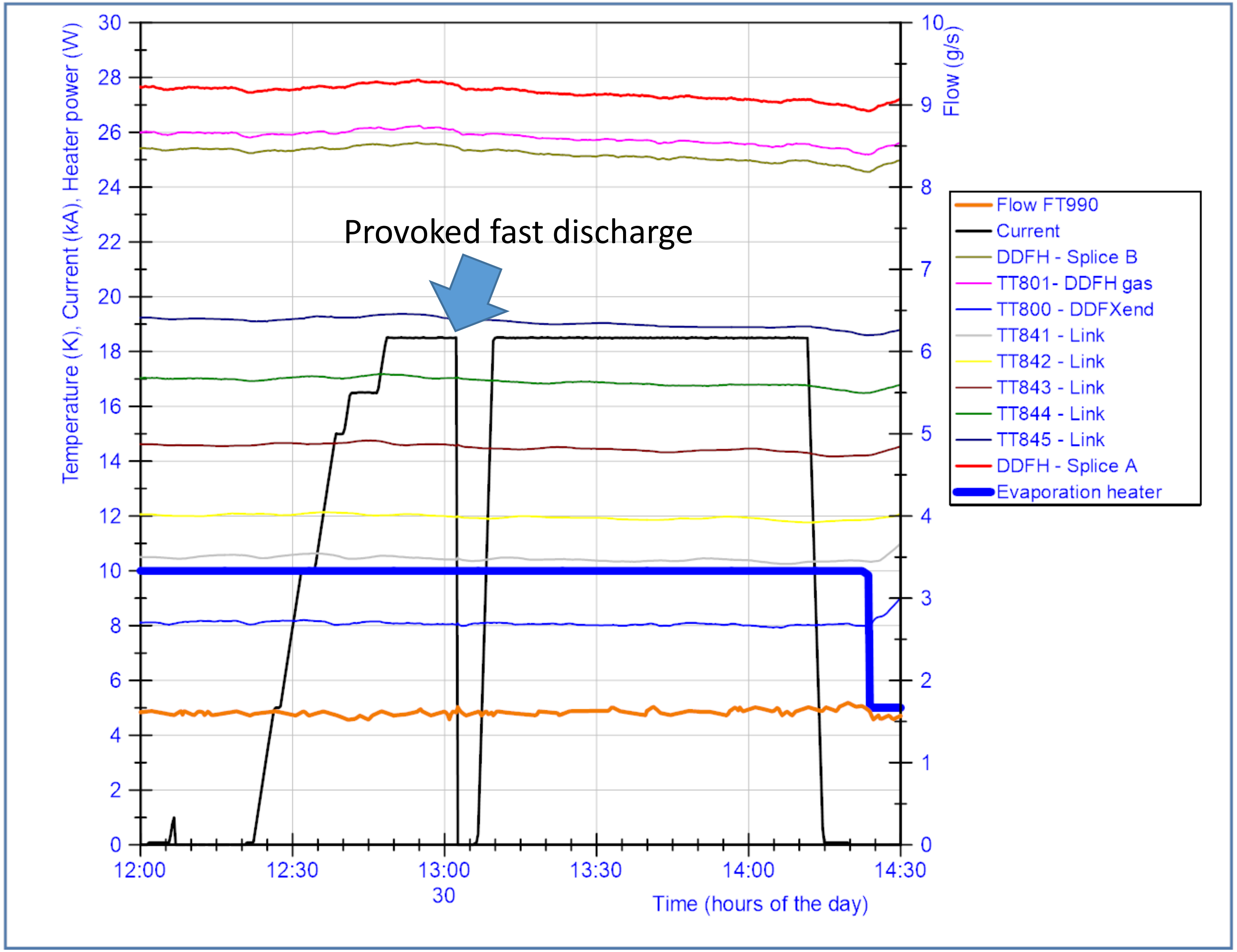
Confirmed ~ 1.5 W/m



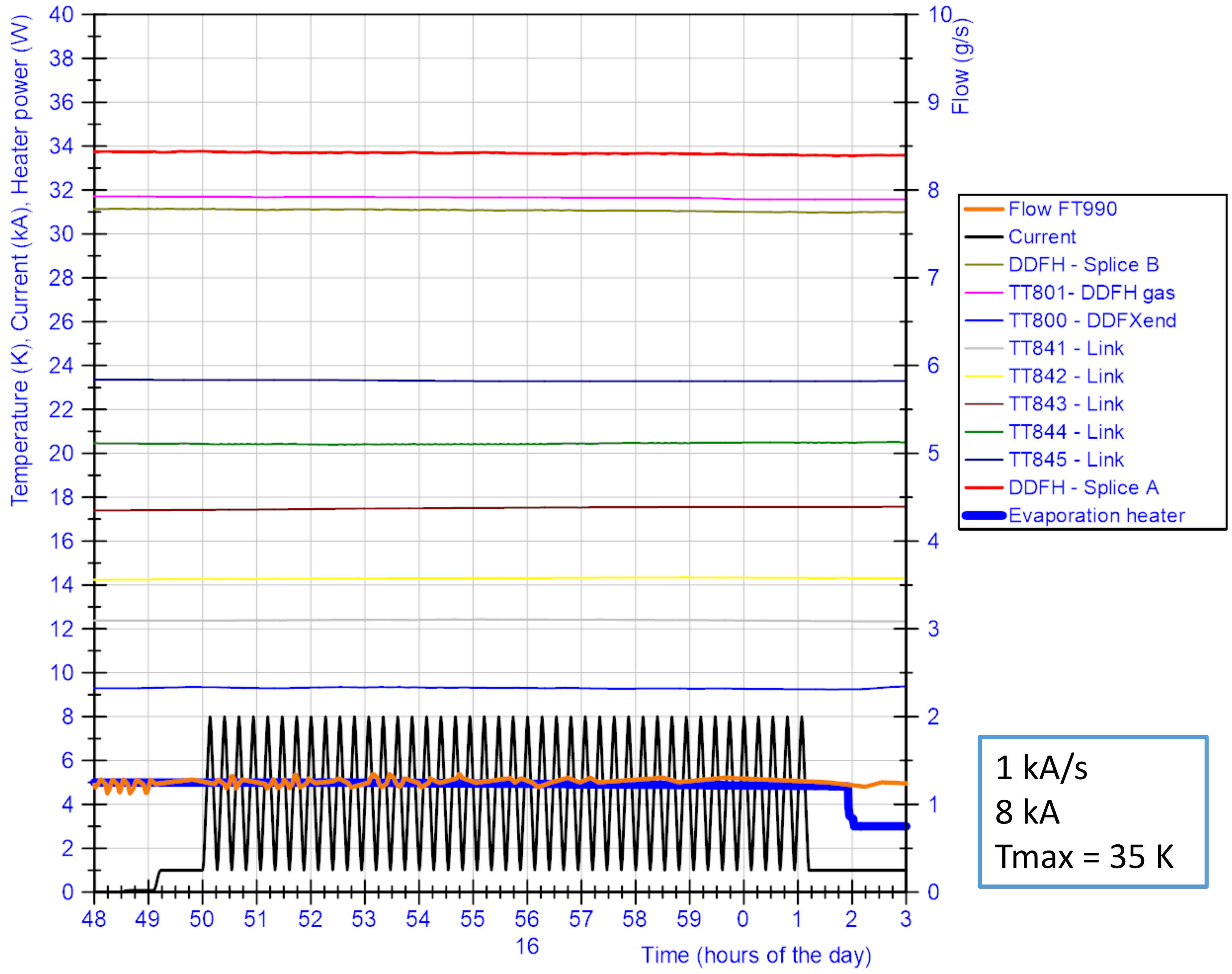
20 kA @ 18 K – No quench



18.5 kA – 1 hour (Tmax ~ 26 K)

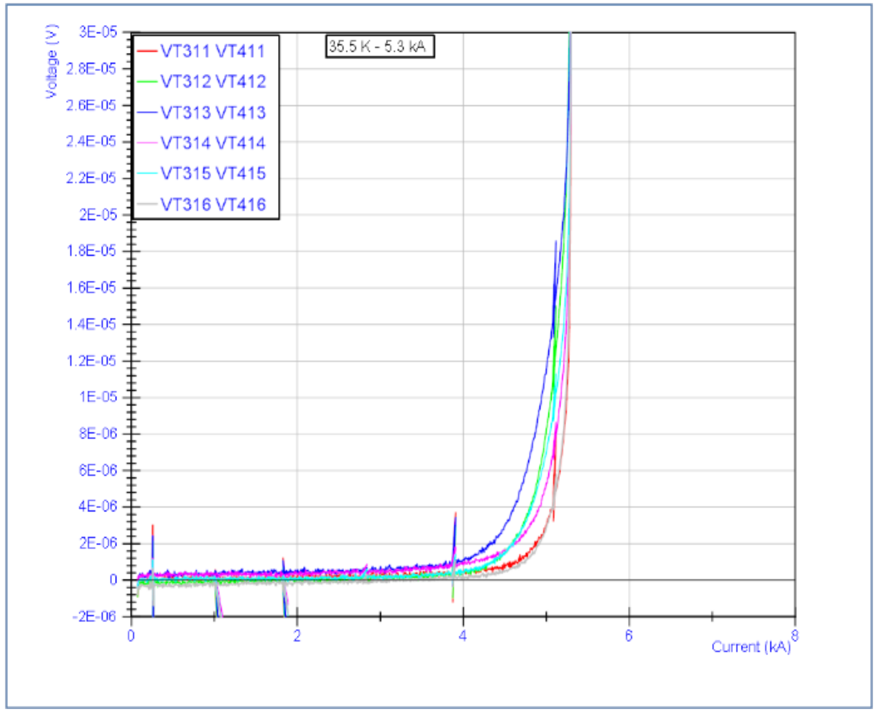


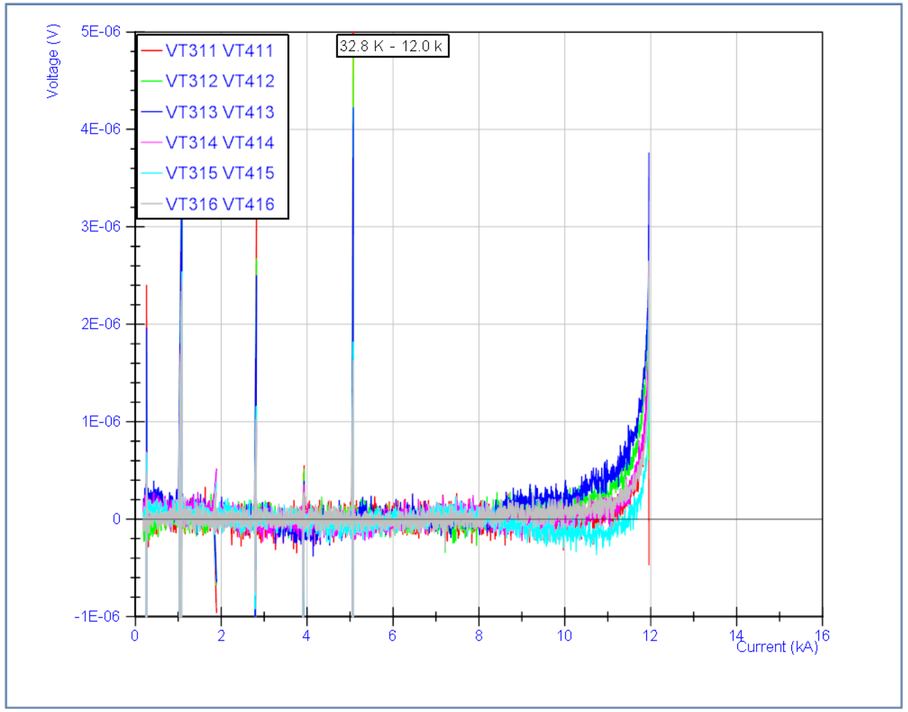
Losses – or better “No losses”



1 kA/s
8 kA
Tmax = 35 K

Several quenches – No degradation



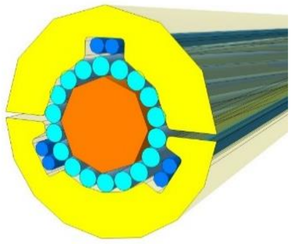


Calculated Tc

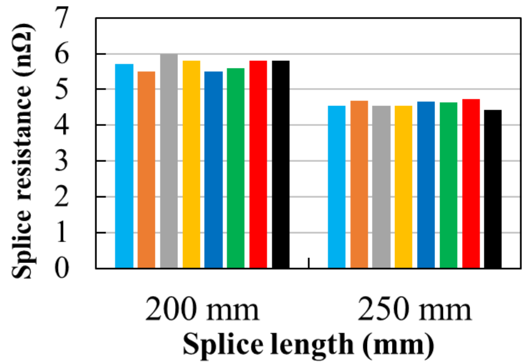
31.33 K @ 18 kA

32.3 K @ 12 kA

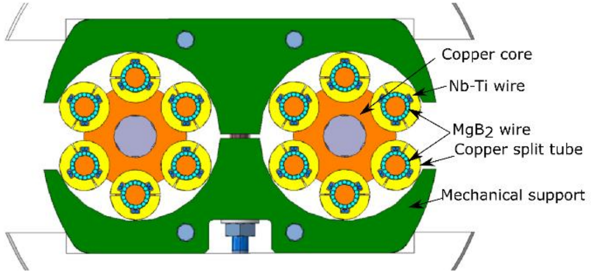
Splices – MgB_2 to Nb-Ti



- MgB_2 wires ex-situ 1 mm diameter
  - 37 filaments with Nb barriers in a Ni matrix
  - 200 µm thick Monel sheath
  - 20 µm copper layer with Staybright coating



- Each of the 3 kA strands of 18 kA cable spliced to six Nb-Ti wire
  - Soldered with Sn-Pb
  - Splice provides continuity of cross section of stabilizer
  - Promote homogeneous current sharing
  - Expected and measured (FRESCA) resistance of 5.7 nΩ (200 mm long splice)
  - Scale with length as expected
  - Splice resistance constant vs. Temp.

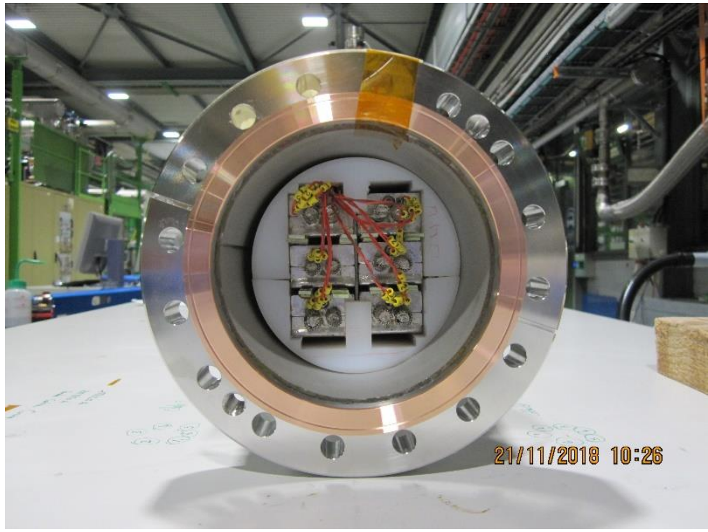


- The six 3 kA splice are then spliced together with Sn-In
- **Expected resistance of the 18 kA MgB_2/NbTi splice :0.9 nΩ**

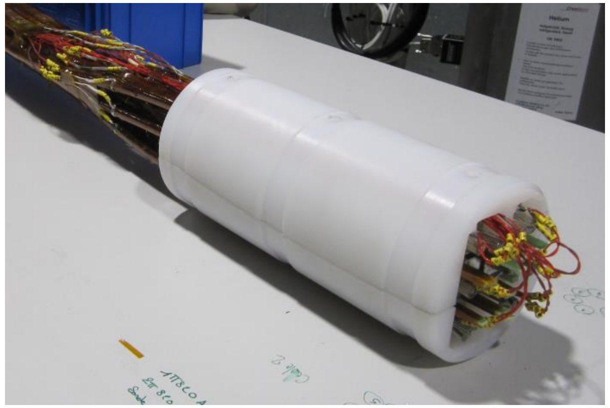
MgB_2/NbTi
Splice of DEMO1

Splices – MgB_2 to MgB_2

DDFH

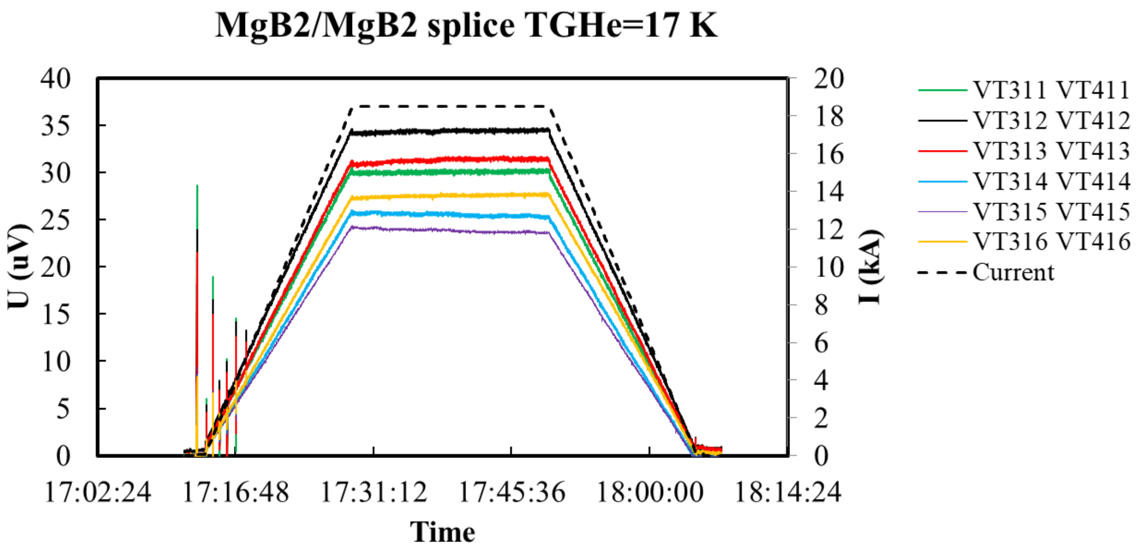


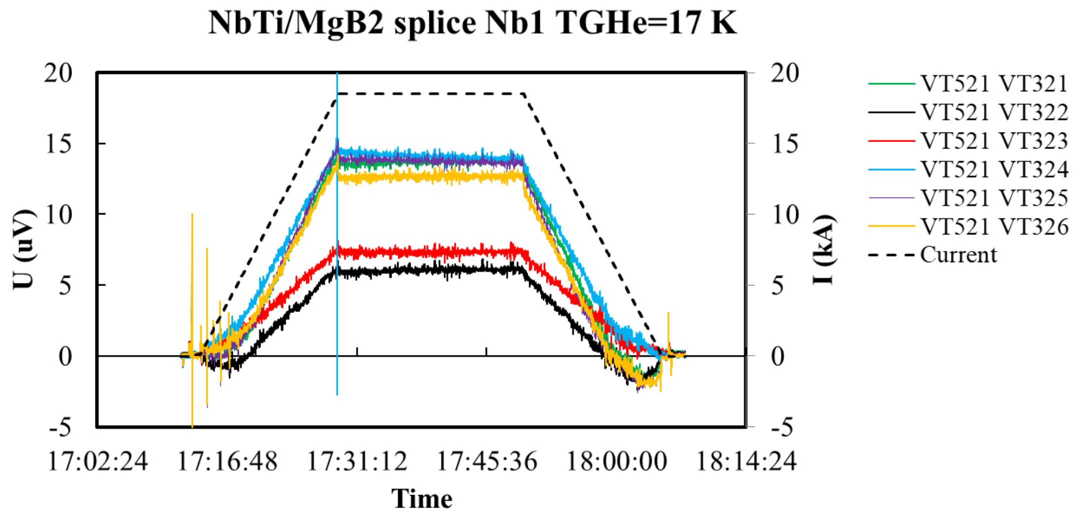
- Six individual 200 mm long 3 kA splice (Sn-Pb)
- Expected 3 kA splice resistance of 11 nΩ
- Expected **18 kA splice** resistance **1.83 nΩ**
- Splices elec. insulated from each others
- He gas flow diverted in the splice package with minimum pressure drop
- Voltage drop of each splice monitored
- Temp. of splice monitored



Demo 1 measurements at 18.5 kA – 17 K

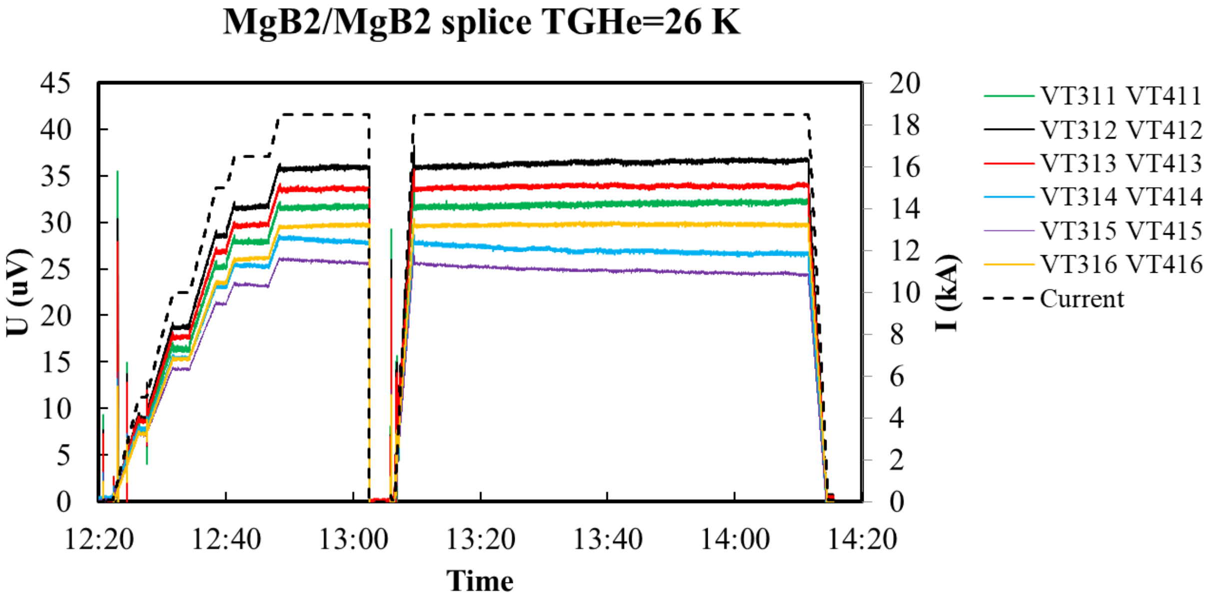
- **Ramp to 18.5 kA at 20 A/s**
- Plateau of 10 mins
- Stable on plateau, no voltage drift
- Total resist. of Link circuit in line with expectation: ~**5 nΩ**
  - Two MgB_2/NbTi splices:~ **2x 1 nΩ**
  - MgB_2/MgB_2 splices:~ **1.5 nΩ**
  - Two NbTi/NbTi splices: **1x 0.4 and 1x 0.7 nΩ**

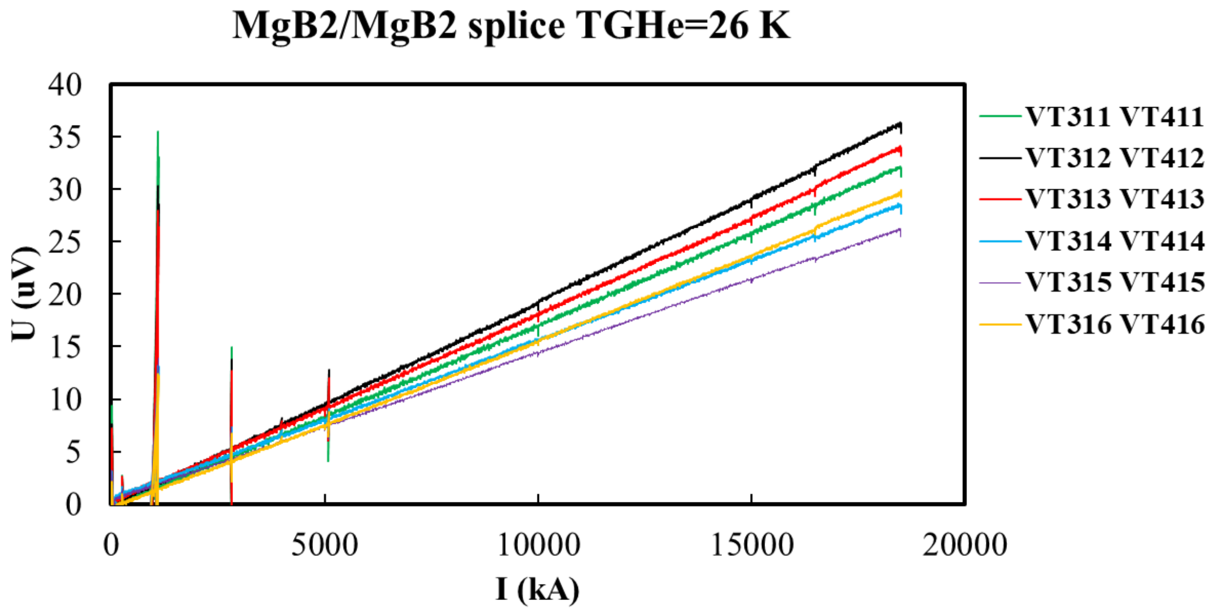




Demo 1 measurements at 18.5 kA –26 K

- Ramp to **18.5 kA, T_{GHE}=26 K**
- Manual trigger after 15 mins on plateau
- **Ramp up to 18.5 kA and hold for 1 hr**
- Stable on plateau, **no voltage drift**
- Same resistance of splice as at T_{GHE}=17 K, as expected





Next steps

- What is missing from this test campaign: **system qualification** (Control of flow vs Temperature, Tset _points,…..). To be performed in the next text campaign

- Qualification of **HTS current leads** connected to the MgB_2 in the DDFH – February 2019. Recently qualified MgB_2 cables for up to 50 K at 18 kA operation and MgB_2 to REBCO splices

- Measurement of full cable assembly (**Demo 2**) – contract for cable running as from Jan. 2019. Tests foreseen at CERN in September 2019. Design work for test adaptation of test station as from January 2018