HiLumi
HL-LHC PROJECT

DFH Detail Design Review

Cables, splices and instrumentation

J. Fleiter and A. Ballarino on behalf of WP6a

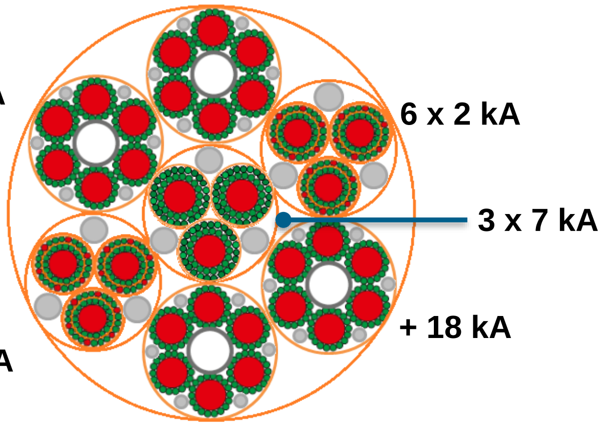
CERN

Outline

- MgB_2 and HTS cables
- Routing of cables
- Splices geometry and fix point
- Dielectric insulation requirements
- Instrumentation (Vtaps and temperature)

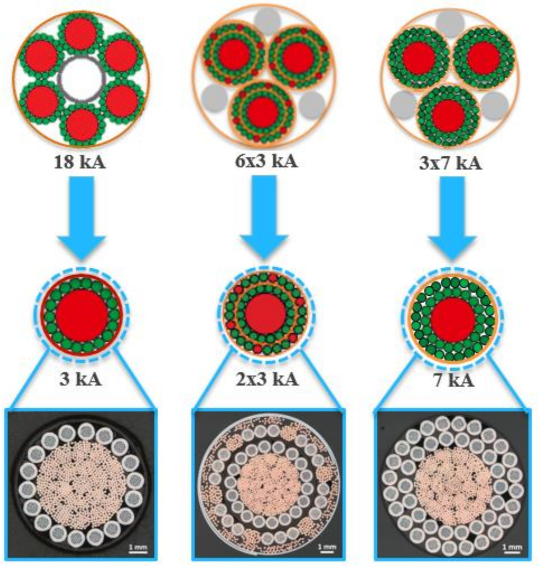
MgB_2 cables of IT Sc Link

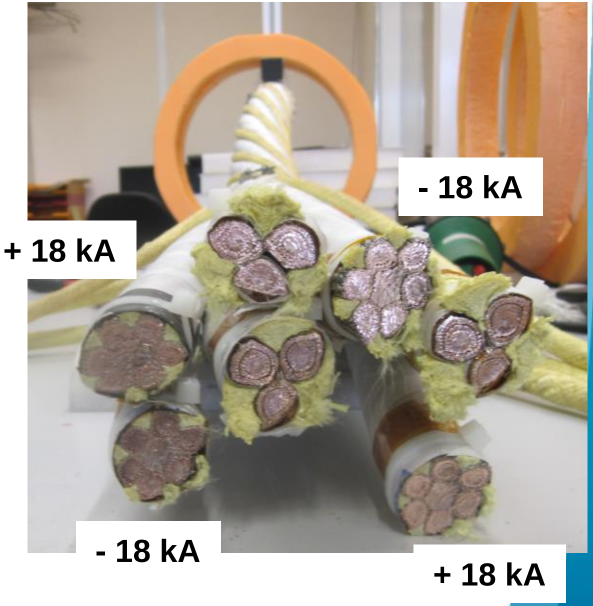
MgB_2 multi-cable assembly made of 19 cables



Φ ~ 90 mm

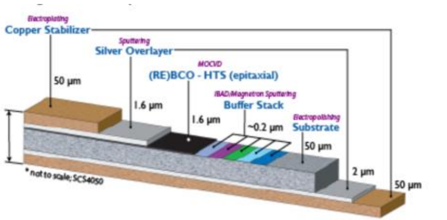
3 main sub-cables

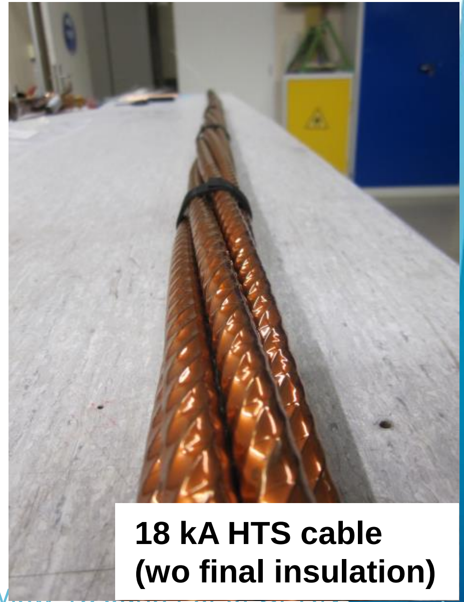




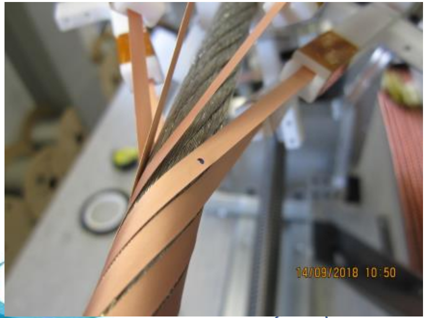
HTS cables of IT Sc Link

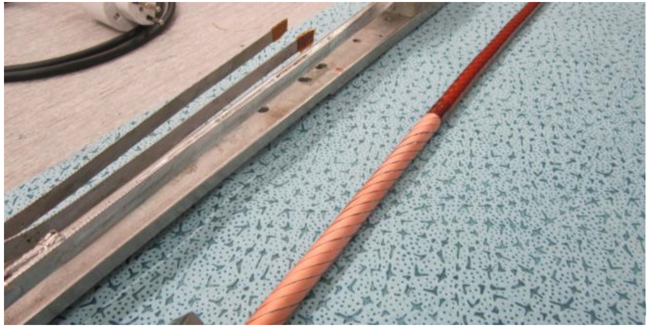
- HTS cables will operate between 50 K and 20 K with field ~ 1 T
- HTS cables made from REBCO tapes (4 mm x 0.1 mm)
- HTS tapes helically wound around a multi strand core 11 mm OD to form 3 kA sub cables.
- Sub cables insulated with Kapton tapes, (11.5 mm OD)
- Six sub-cables assembled to form the 18 kA cables (40 mm OD)
- Two 3 kA sub-cables for the trims circuits (arranged in six around 1)
- Orbit corrector cable made of a single sub cable (arranged by groups of four)





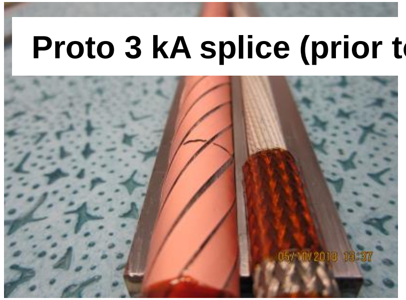
18 kA HTS cable
(wo final insulation)





MgB_2/HTS splices

- HTS/MgB_2 splice will be performed by soldering (Sn-Pb or Sn-In)
- Sub-cables will be spliced in equipotential to allow current redistribution
- Splices dimensions:
  - **18-14 kA** 300mm x 70 mm x 60 mm
  - **2 kA trim** 300 mm x 20 mm x 45 mm
  - **2 kA** 650 mm x 20 mm x 30 mm
  - **0.6 kA** 300 mm x 20 mm x 30 mm

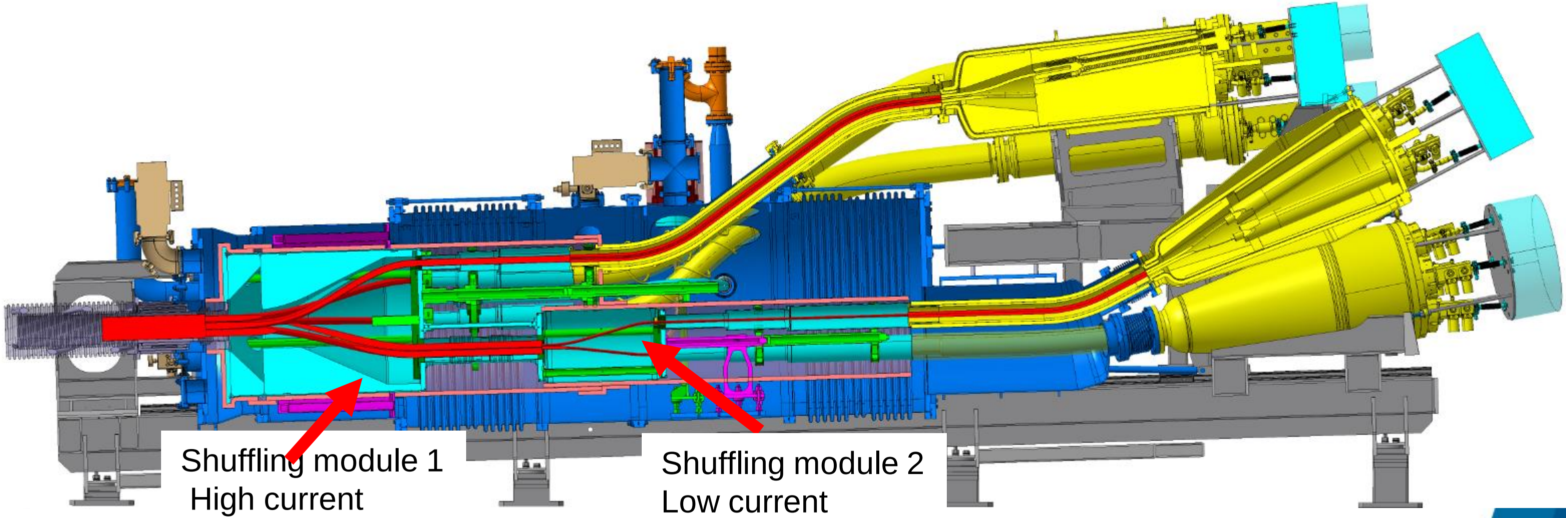


Proto 3 kA splice (prior to soldering)

- MgB_2/HTS splices will be fix points. Splice will be encapsulated in insulated structure allowing GHe convection and rigid contact with the He sleeves (see next slides) providing sufficient dielectric insulation.

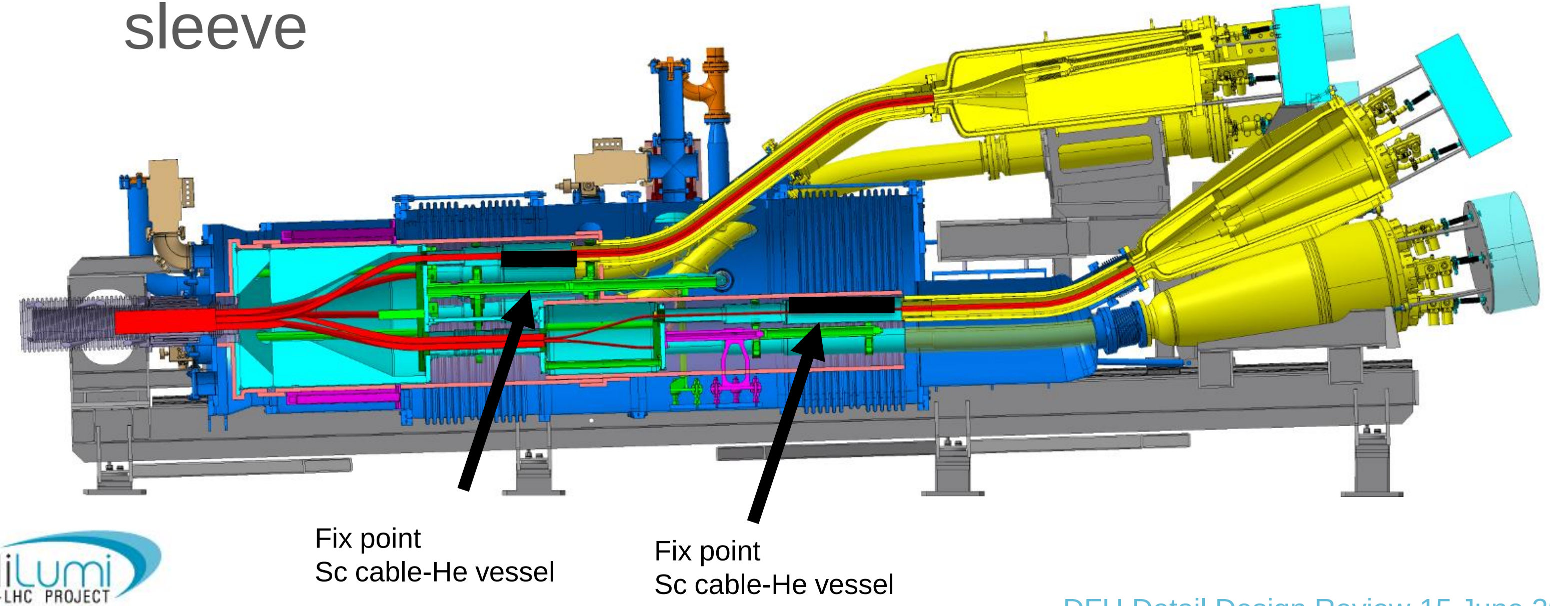
Routing of cables in DFH

- From DSH each MgB_2 cable is routed to its current leads via shuffling modules
  - DFHx equipped with two shuffling modules (high and low current)
  - DFHm equipped with only one shuffling module
- S-bend of Sc cable in shuffling module and till the leads designed to accommodate differential thermal shrinkage
- Routing of MgB_2 and HTS cables respect the minimum bending radius.



Fix points at splice location

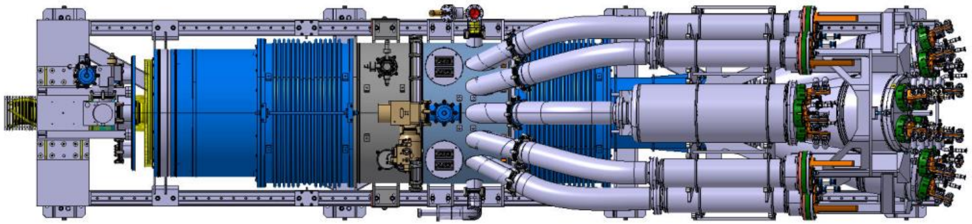
- Each MgB_2/HTS splice will be a fix point
- Splice will be encapsulated in insulating material that allow He flow, sufficient arc length and longitudinal contact with sleeve

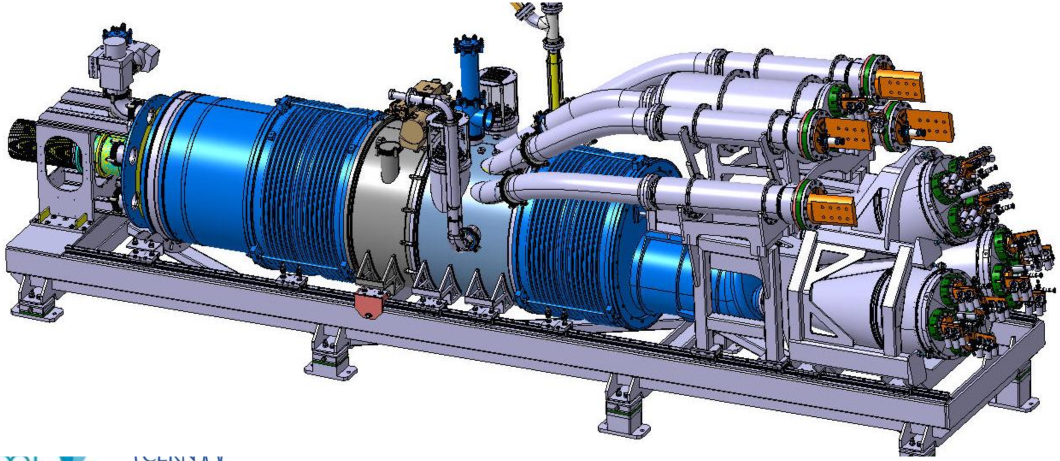


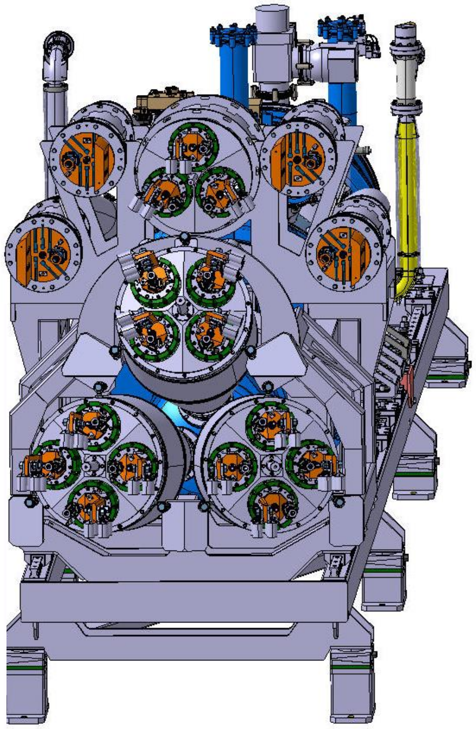
Lorentz forces on cable in DFH

- Cables are maintained together in the Sc Link assembly via the structure of the cable
- In the shuffling modules, cables maintained in place via adapted mechanical structure
- Typical forces:
  - 650 N/m for 2x18 kA @ 100 mm
  - 8 N/m for 2x2 kA @ 100 mm
  - 72 N/m for 2 and 18 kA @ 100 mm
- Length of shuffling module is about 600 mm

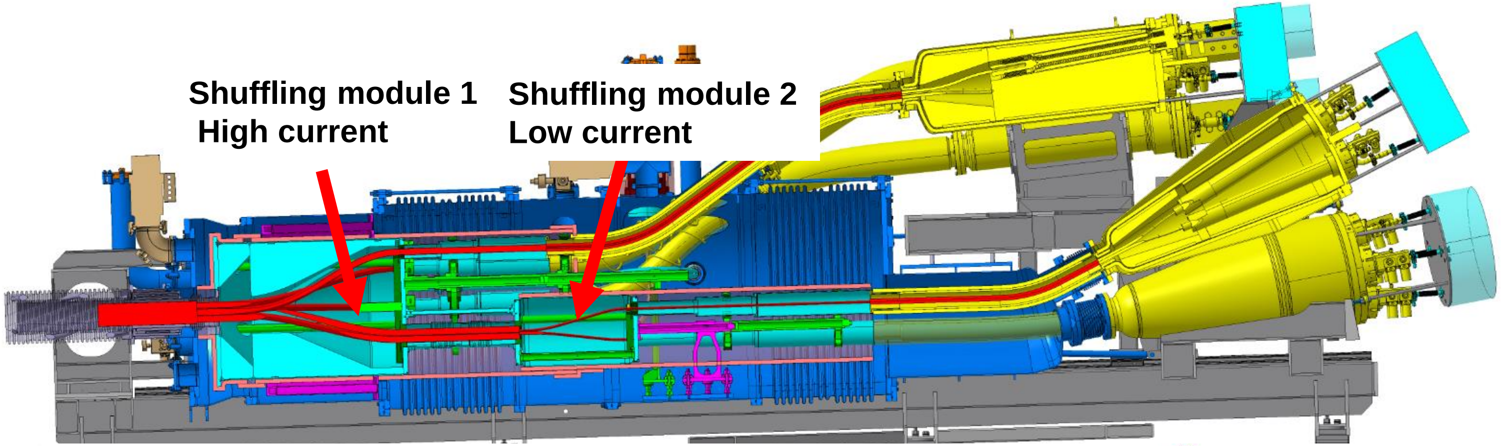
Routing of Sc cables in DFHX

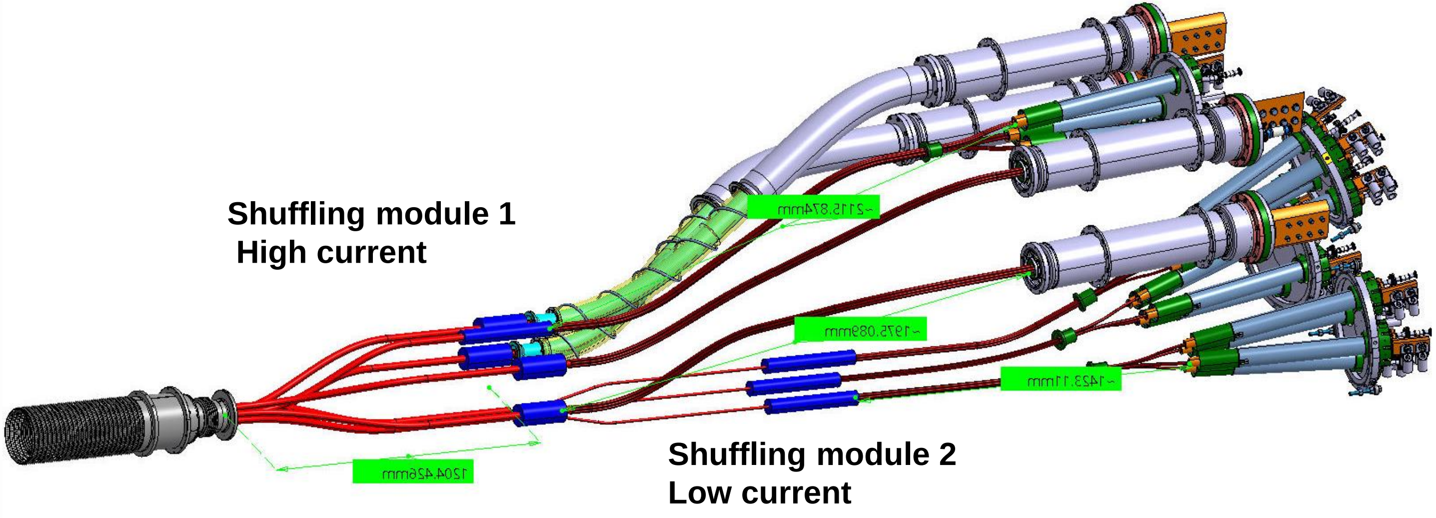






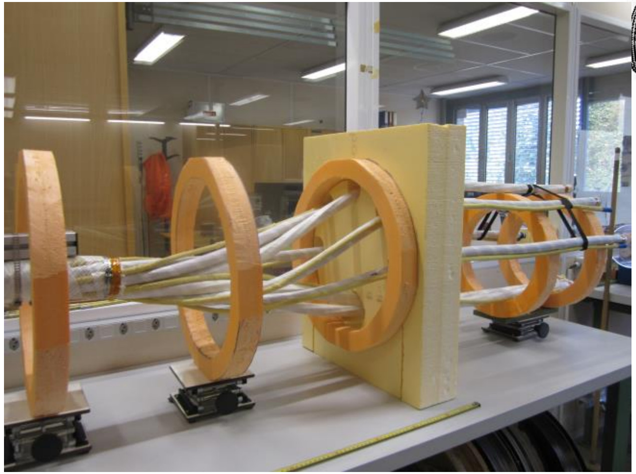
Routing of Sc cables in DFHX

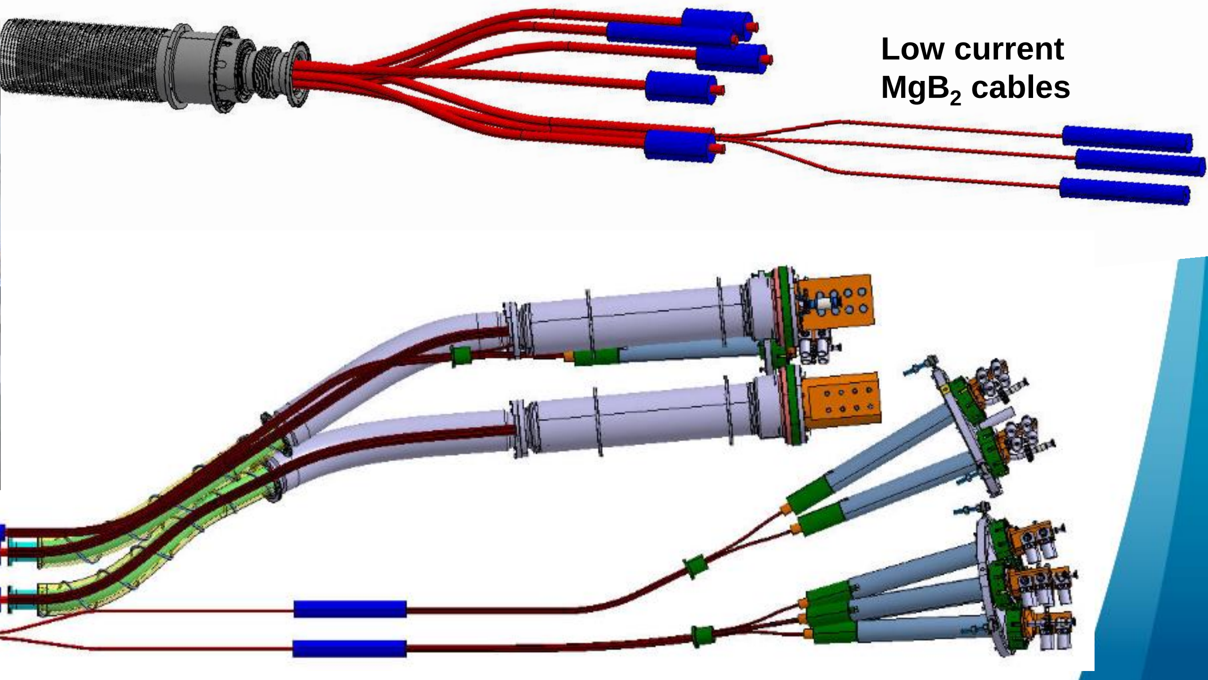




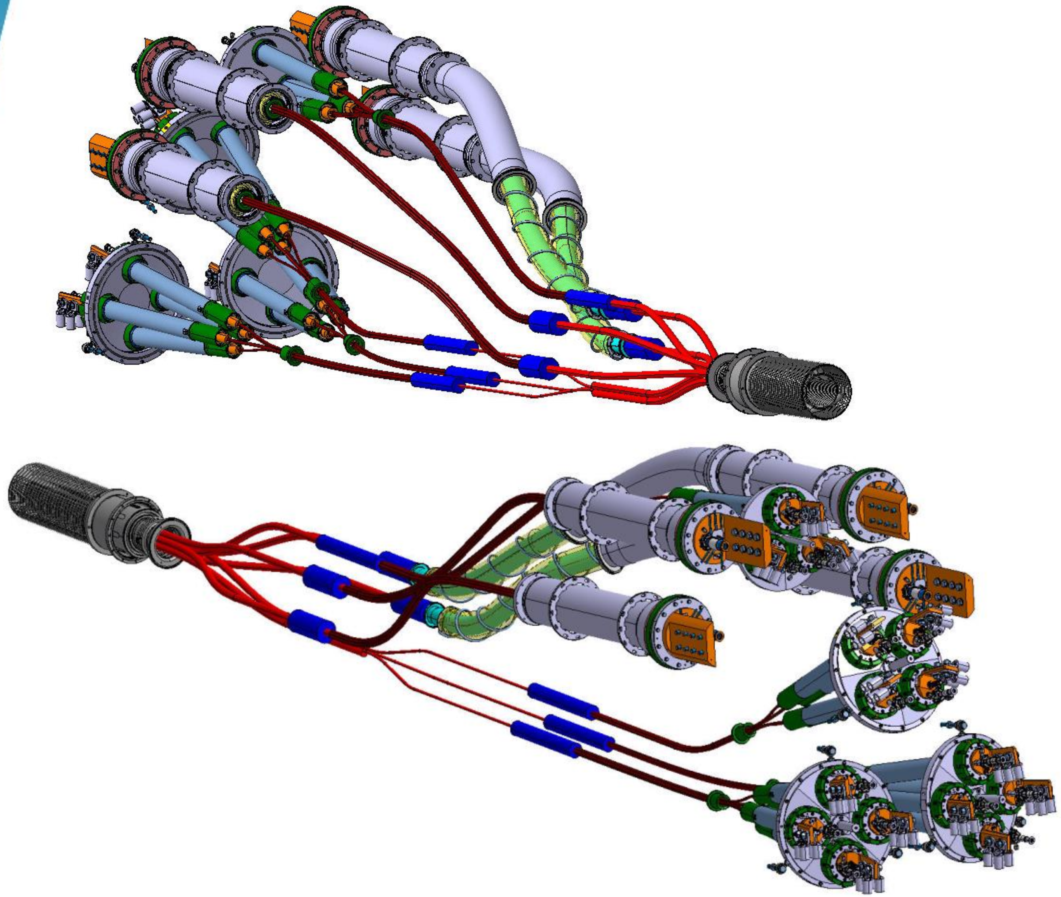
Routing of Sc cables in DFHX

- Phase of MgB_2 cable entering DFH selected during assembly=>pre defined routing

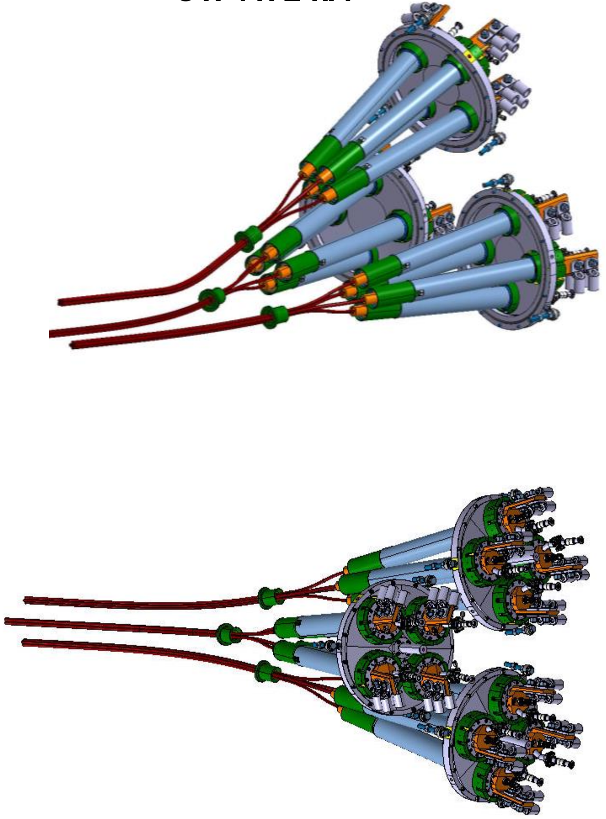




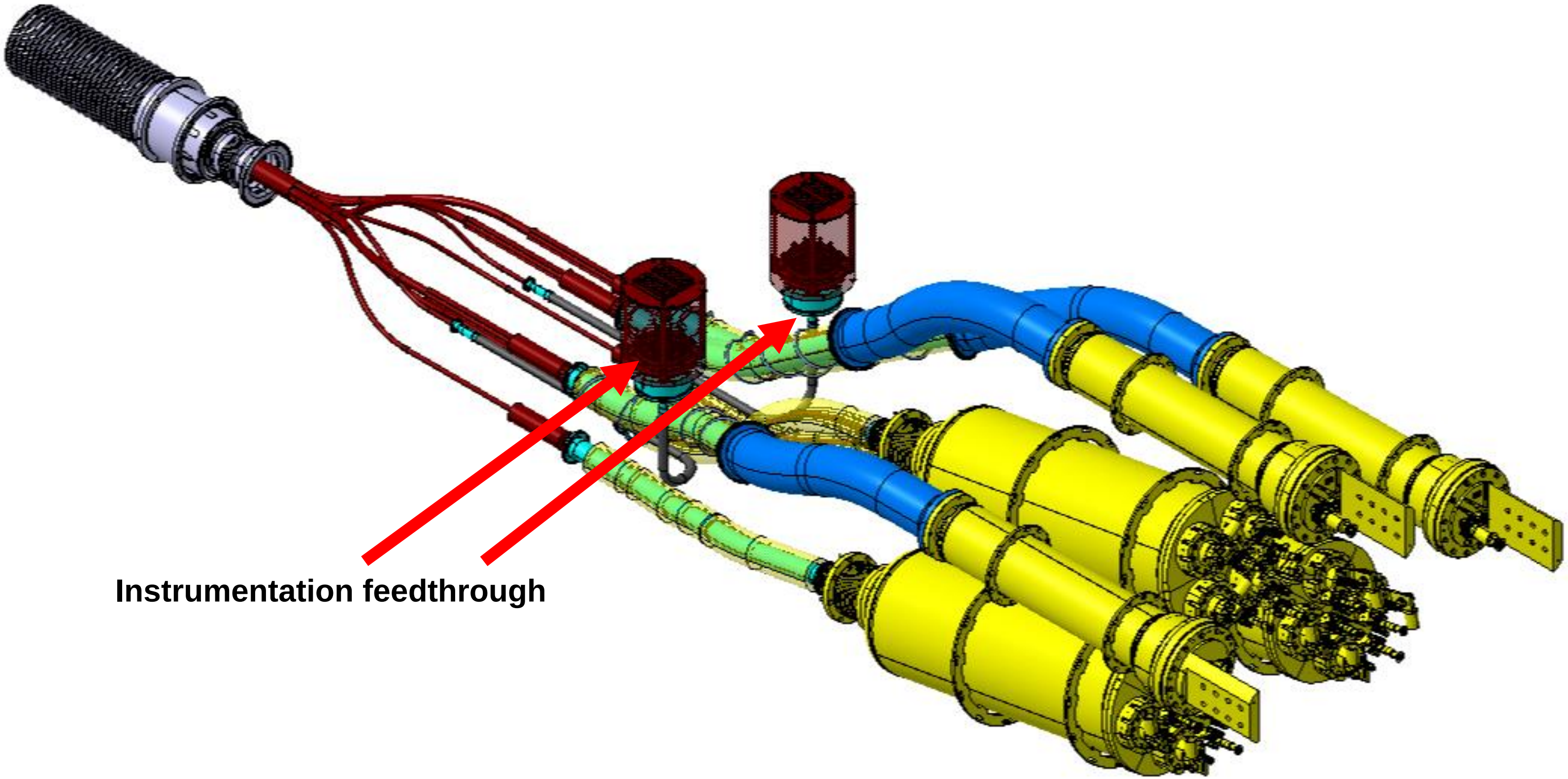
Routing of Sc cables in DFHX



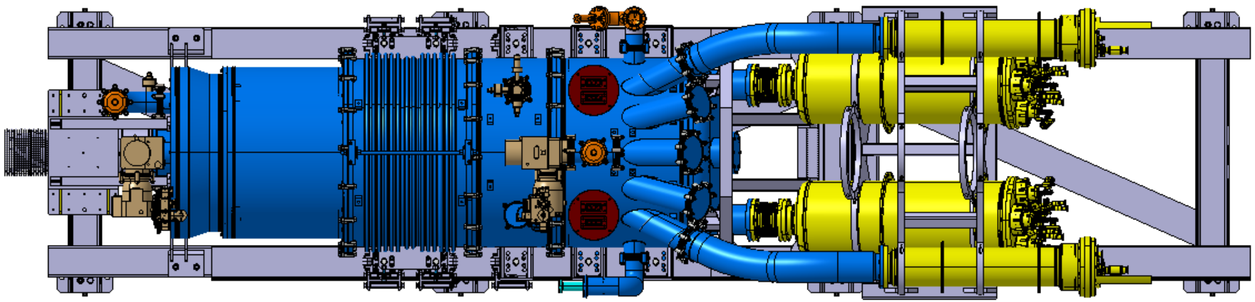
3 x 4 x 2 kA

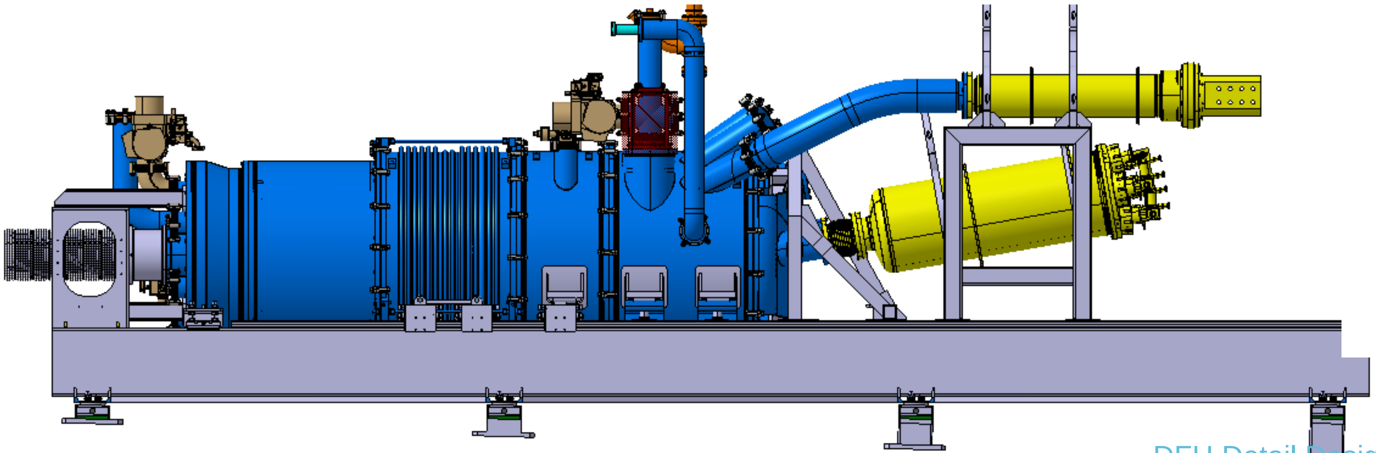


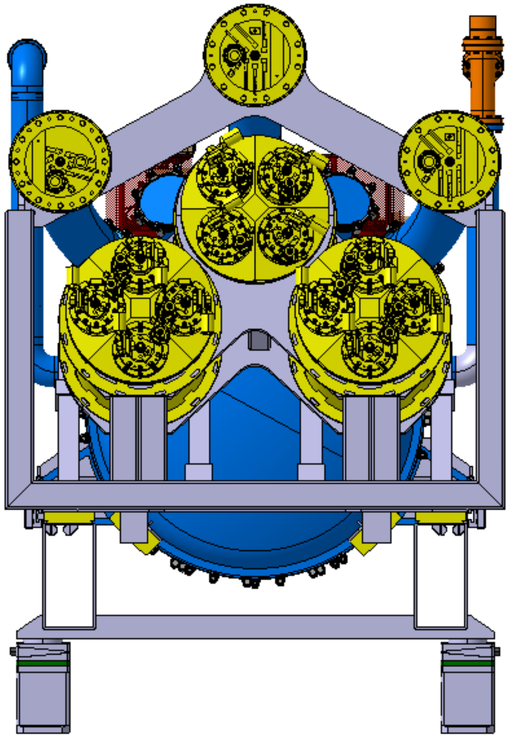
Routing of Sc cables in DFHX



Routing of Sc cables in DFHm

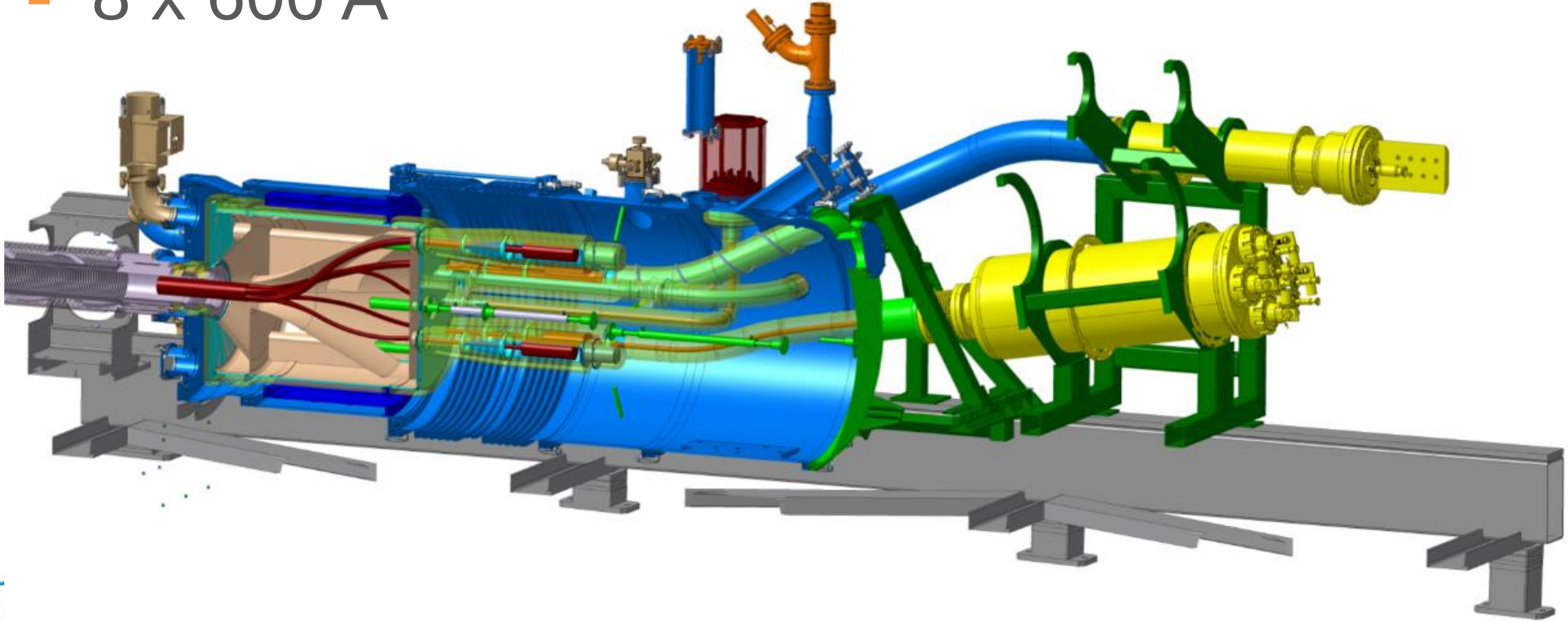




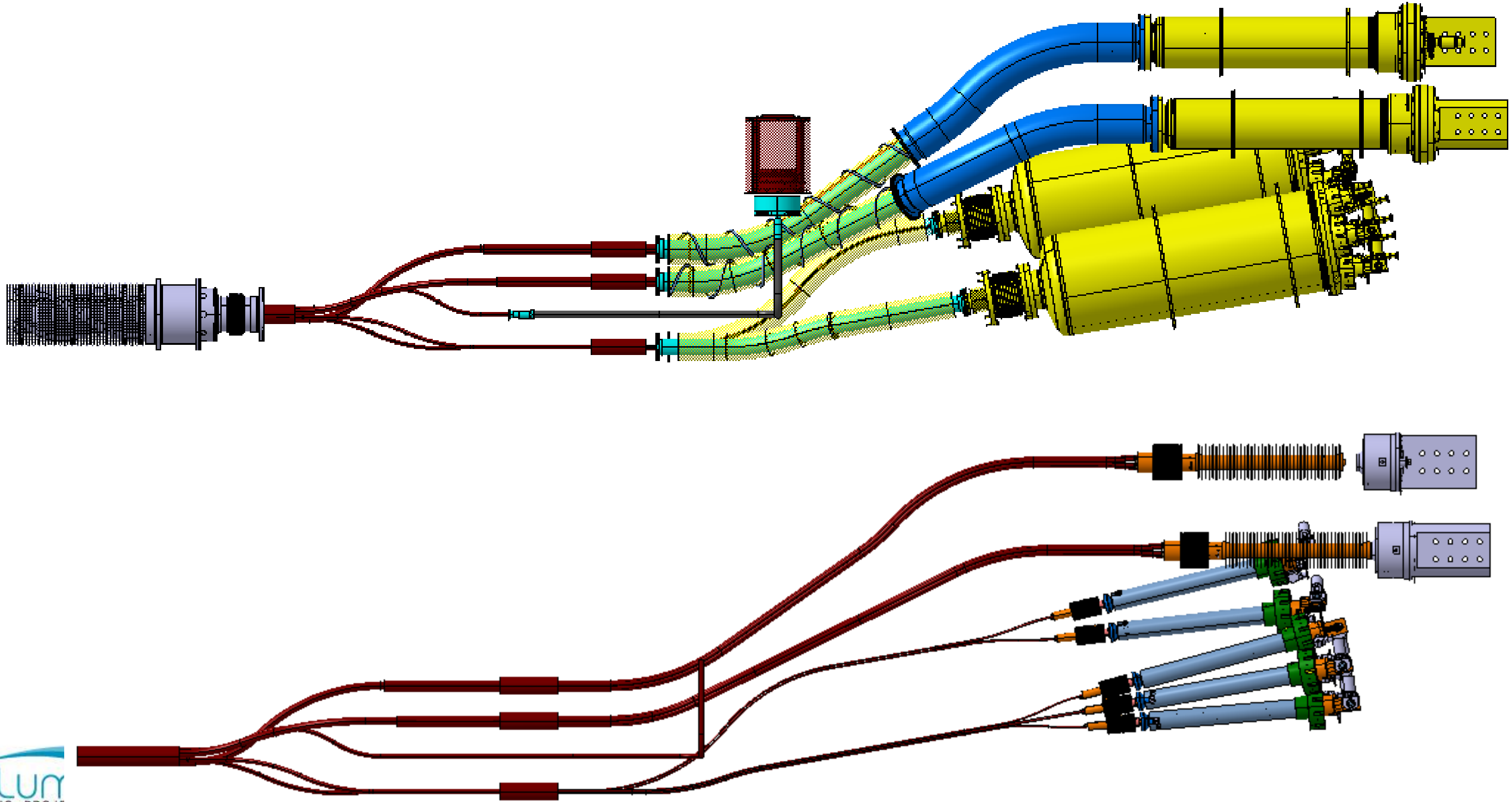


Routing of Sc cables in DFHm

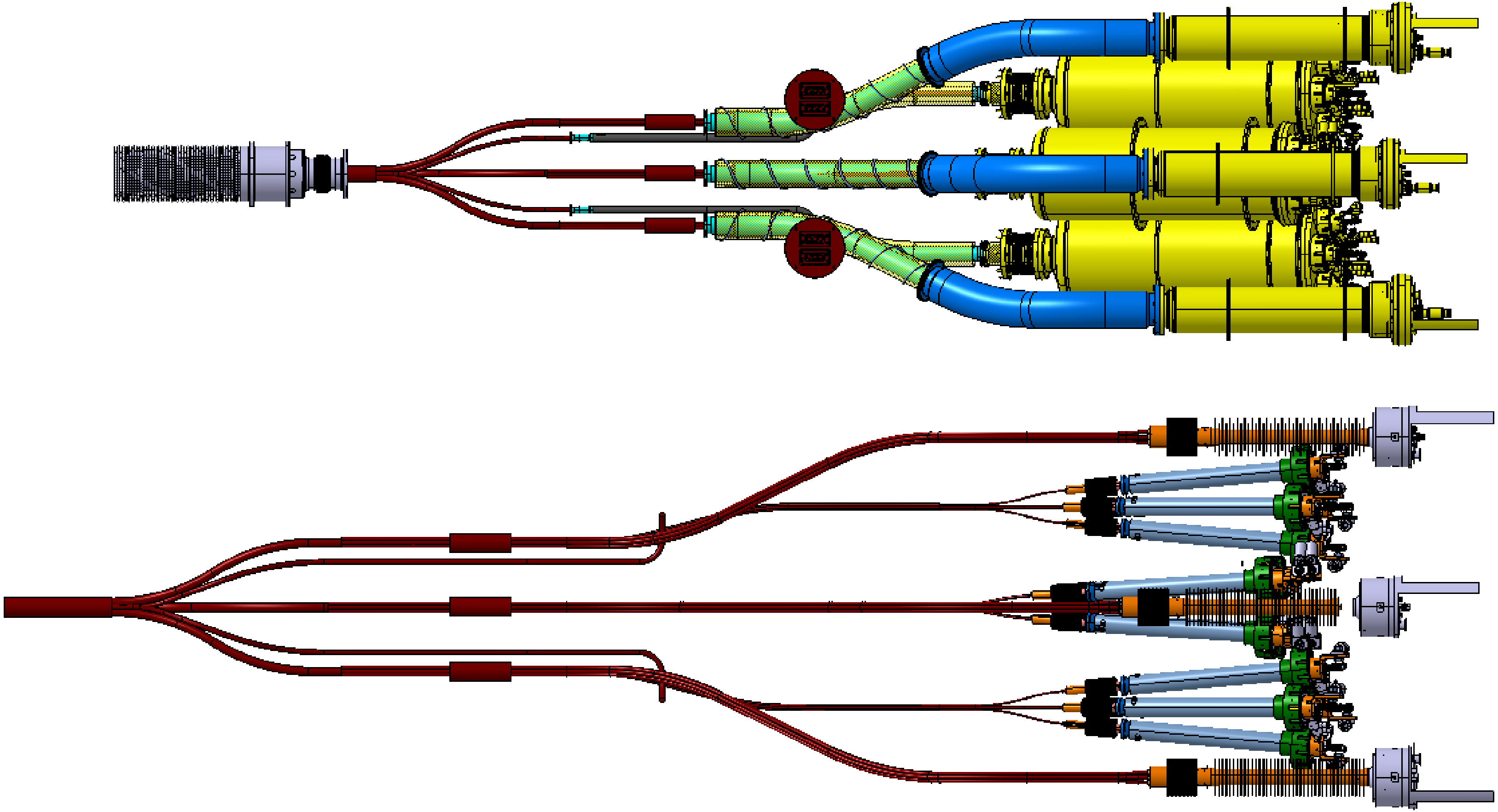
- 2 x14 kA (and 1 spare)
- 8 x 600 A



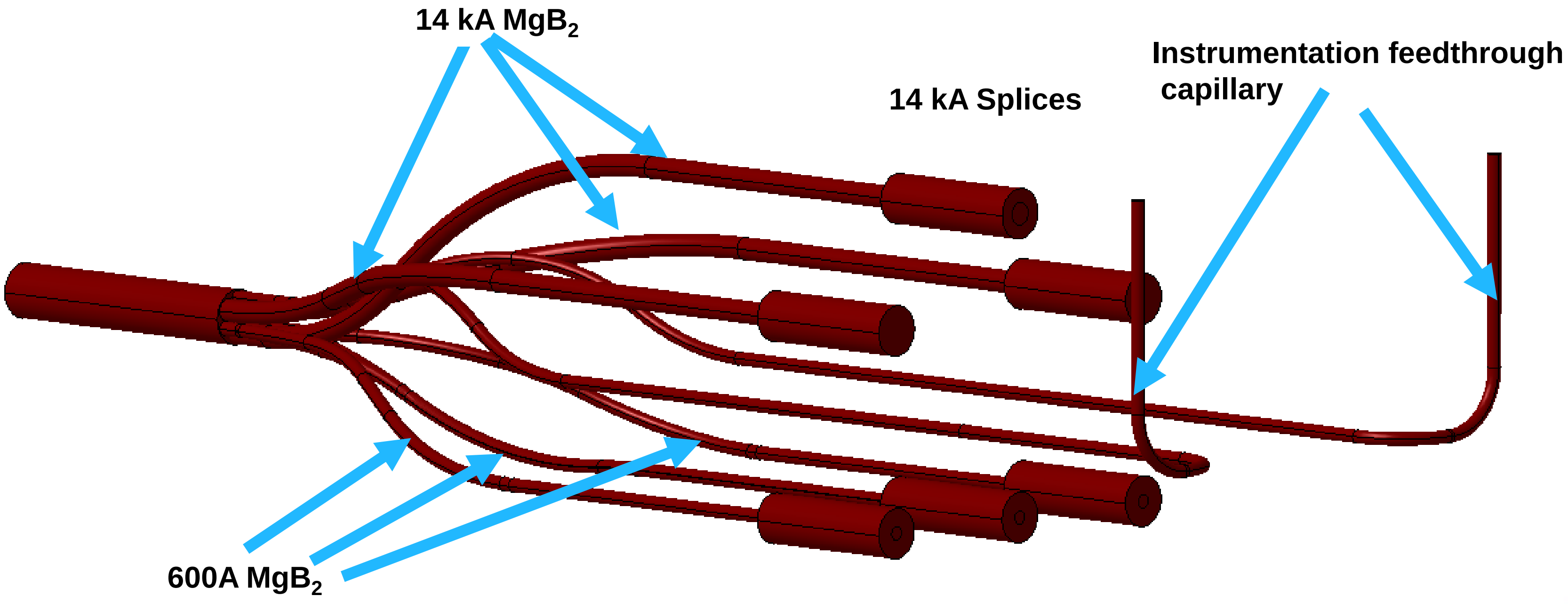
Routing of Sc cables in DFHm



Routing of Sc cables in DFHm



Routing of Sc cables in DFHm



Cryogenic instrumentation of DFH

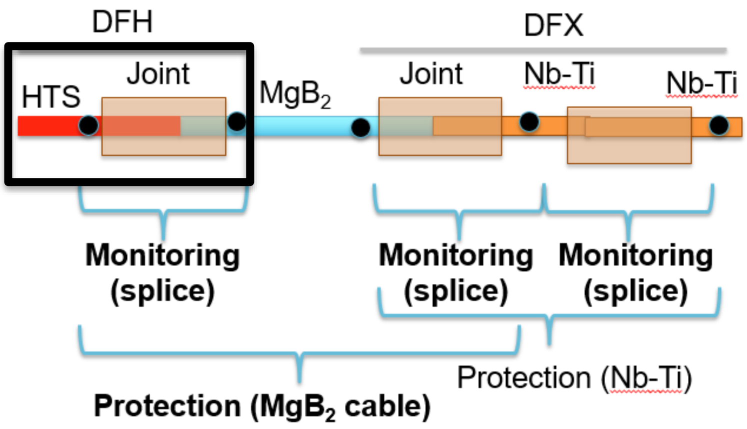
- Wiring of cryo Instrumentation of DFH routed via DFH feedthrough
- No routing of cryo instrumentation of DFX and current leads via the DFH
- For the prototype DFH, the temperature of each splice monitored thanks to Cernox sensor embedded in Cu matrix of the splice
  - 19 active Thermal transducers for DFHx
  - 10 active Thermal transducers for DFHm
- Temperature of GHe monitored
  - 1 active Thermal transducers for DFHx
  - 1 active Thermal transducers for DFHm
- Each active temperature sensor has a spare
- 1 He pressure gage, external to He tank for DFHx and DFHm
- Each Cernox (4 xCu AWG 32 (EDMS 320597)) is cabled till the feedthrough on the same connector has the Vtaps of its circuit in similar way as for current leads of LHC
- 160 wires at DFHx feedthrough for cryo instrumentation
- 88 wires at DFHm feedthrough for cryo instrumentation

DFH Instrumentation for circuit protection

- Each circuit branch will be equipped with voltage taps:
  - **1 pair within the DFH cold mass to monitor the MgB_2/HTS splice**
  - **1 pair routed via the DFH to monitor the MgB_2 cable**
  - 1 pair to protect the HTS cable (routed at current lead)
  - 1 pair to protect the Cu HEX of the leads (routed at current lead)
  - One spare for each of the above

  →8 wires per circuit branch to route out from the DFH
    - **152 Vtaps for DFHx**
    - **80 Vtaps for DFHm**

- Wire for voltage taps:Polyimide insulated Cu wire, AWG 26 (used for magnet instrumentation) [1]
- Design of feedthroughs is considering the different electric potential of the circuits (during operation and insulation tests) EDMS 1821907



A. Ballarino, Requirements for the protection of the Sc-links components, Indico 643197

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

[1] Axon HH2619, EDMS 2030599

Conclusions

- **Routing of MgB_2 and HTS cables respect their minimum bending radius and allow to cope with thermal contraction**
- **MgB_2/HTs splice are fix points**
- **Cryo instrumentation in DFH**:
  - 40 Temp probes in DFHx, 22 in DFHm
  - All wiring of Temp probes routed at feedthrough of DFH
  - 1 pressure transducer per DFH
- **Instrumentation for Electrical Protection**
  - **8 Vtaps per branch of circuit: 152 Vtaps (DFHx) 80 Vtaps (DFHm)**
  - All wiring of above listed Vtaps routed at feedthrough of DFH
  - Design of feedthroughs is considering the different electric potential of the circuits (EDMS 1821207)

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Thanks for your attention

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Additional slides

HV Levels - Triplets

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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

Thermalization of Splices

- **Splices thermalized by forced GHe convection**
  - **For the high current** circuits (**18 kA and 13 kA**), **each splice is in hydraulic series** with its HTS cable and Current Lead. So splice mass flow rate is ~**1 g/s**
  - **For the low current** circuits (**2-7 kA**) 3-4 splices are regrouped in same He piping and put in hydraulic series with their relative currents leads (**semi-series** configuration).

- **Series and semi series configuration** flow assure **weighted balanced flow and controlled heat exchange**
- ΔT<1 K between GHe and 18 kA splice at nominal flow and current (with safety margin on splice resistance)
- The helium gas temperature has limited influence on the ΔT between gas and splice surface
- T_{GHE} has direct influence on Tsplice
- Pressure drop in the splice piping < 5 mB at nominal (flow, Temp and pressure)
- **Series and semi series configuration** flow assure **sufficient cooling of splices**