DFH detailed mechanical design

- Presentation of detailed DFHX design
- Differences for DFHm

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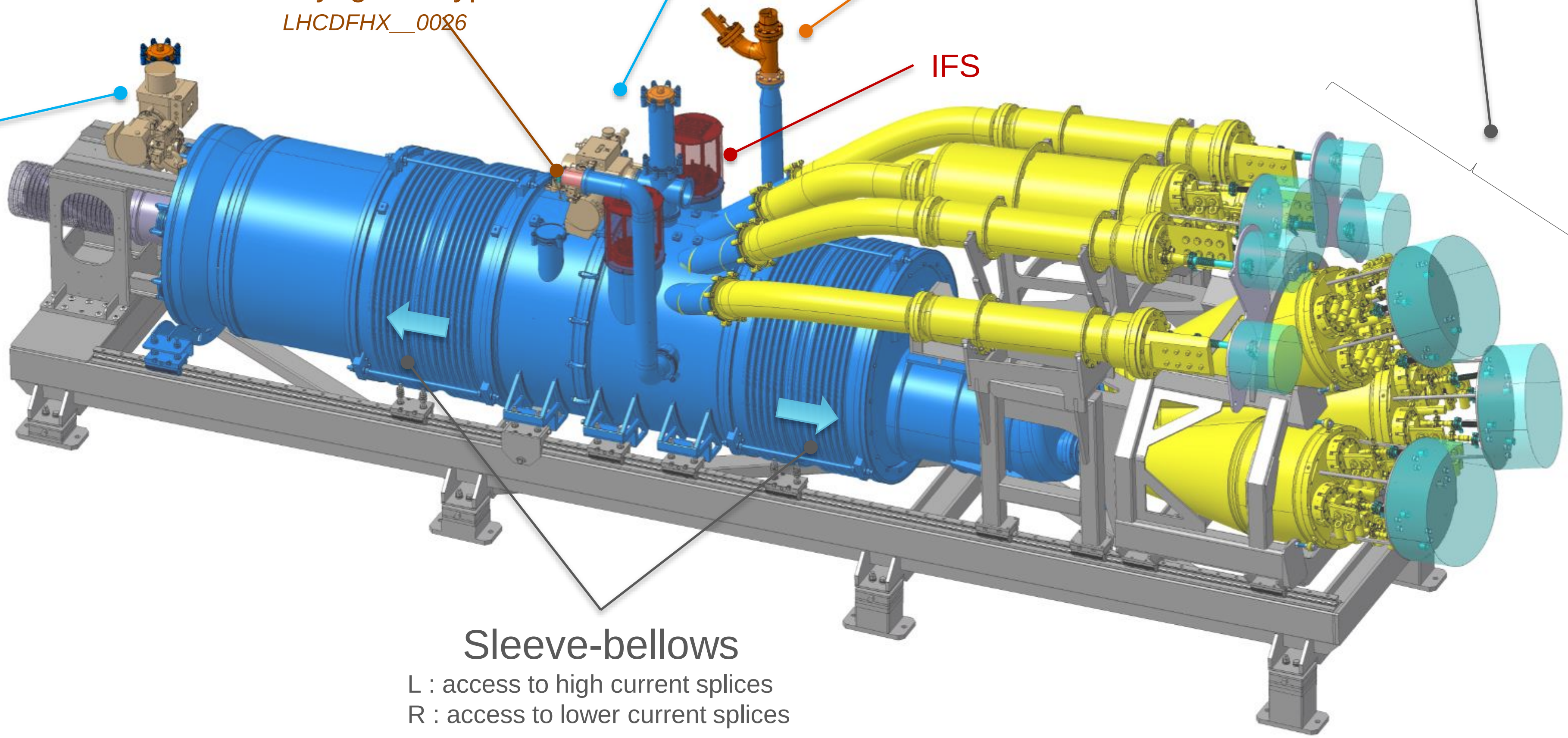
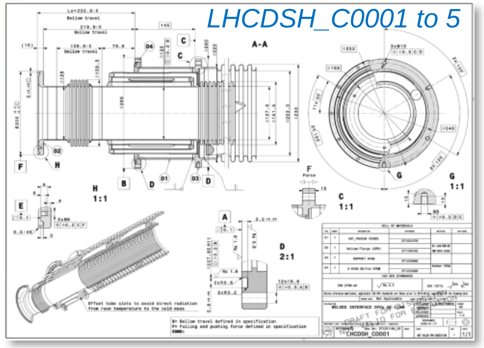
DDR DFH 16 June 2020

DFHx overview external & interfaces distribution

- SC Link & Electrical connection
- Services to two insulation vacuums ; SC Link – DFH+CL
- Cryogenic interfaces ; bypass line from DFH to WRL / CL outlet
- Safety relief devices
- IFS : cryogenic + V-taps instrumentation





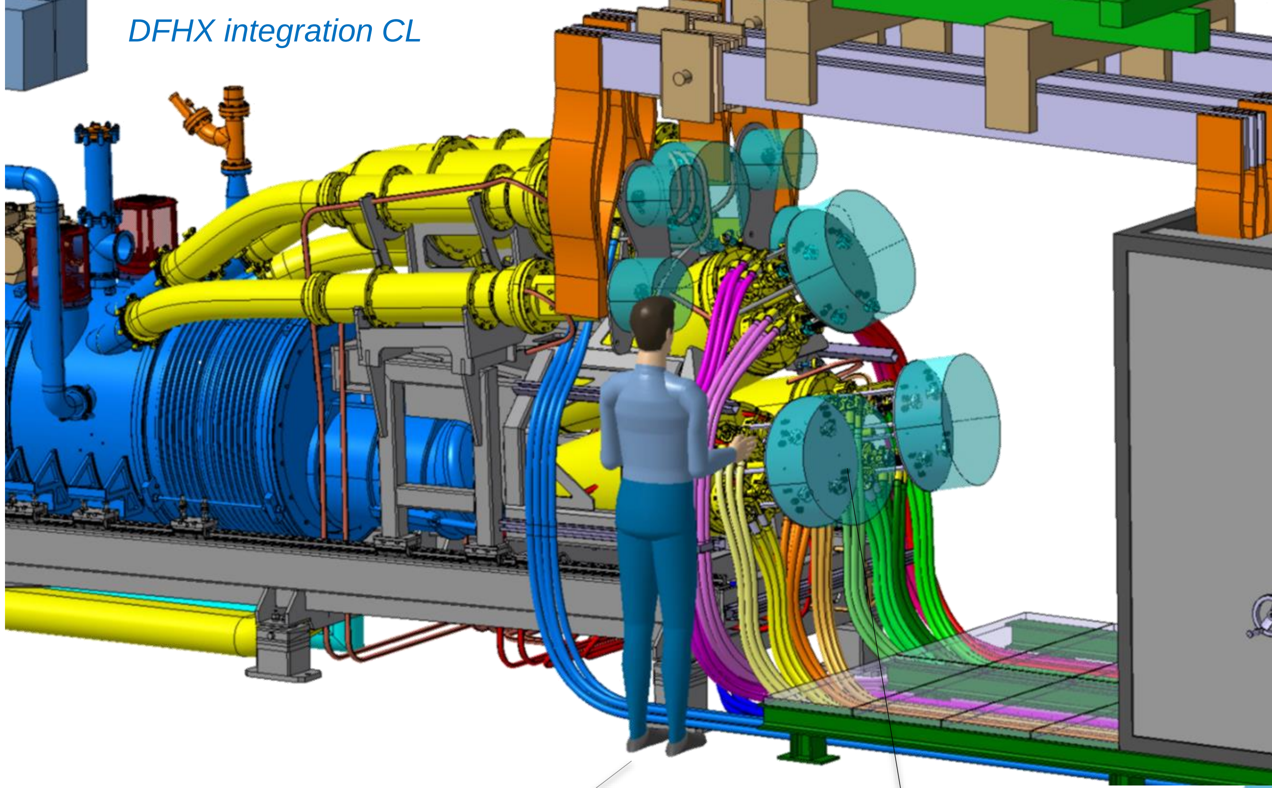
Standard LHC Vacuum equipment

Gauges module : LHCVA___0076
Pumping module : LHCVPGFY0001
DN100 Relief Plate : LHCVV___0011

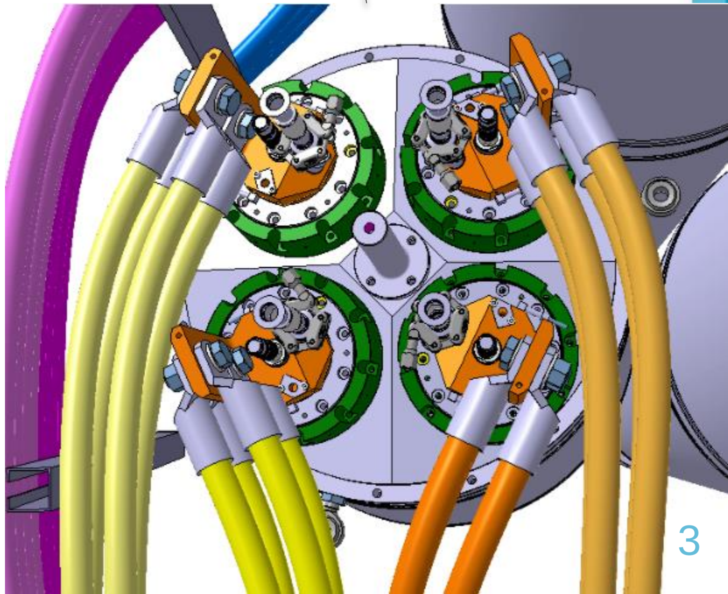
Current leads interfaces

- Compromise outcome from integration study
  - (see dedicated talk)
- Cryogenic circuit interfaces :
  - CL outlet : Ceramic / ISO-K connection to flexible hoses
  - Fixed plate for ceramic integrity and protection
- Electrical :
  - 18 kA and 13 kA bus bars routing above
  - Trims and correctors cables routed at the bottom

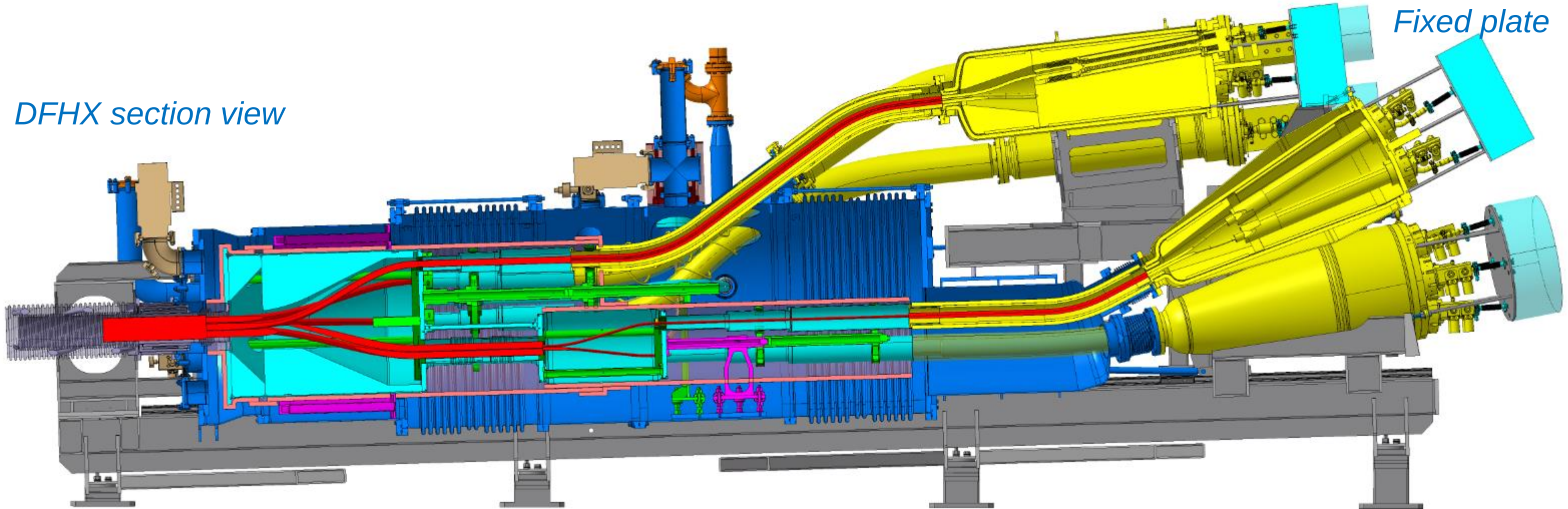
DFHX integration CL



Courtesy P. Orlandi / S.Maridor



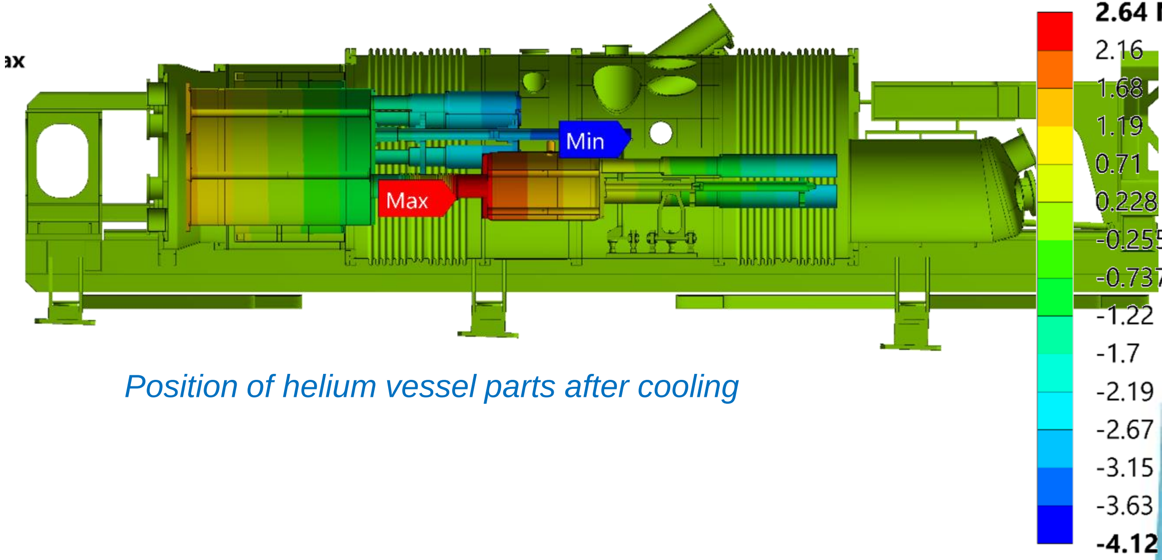
DFHX section view



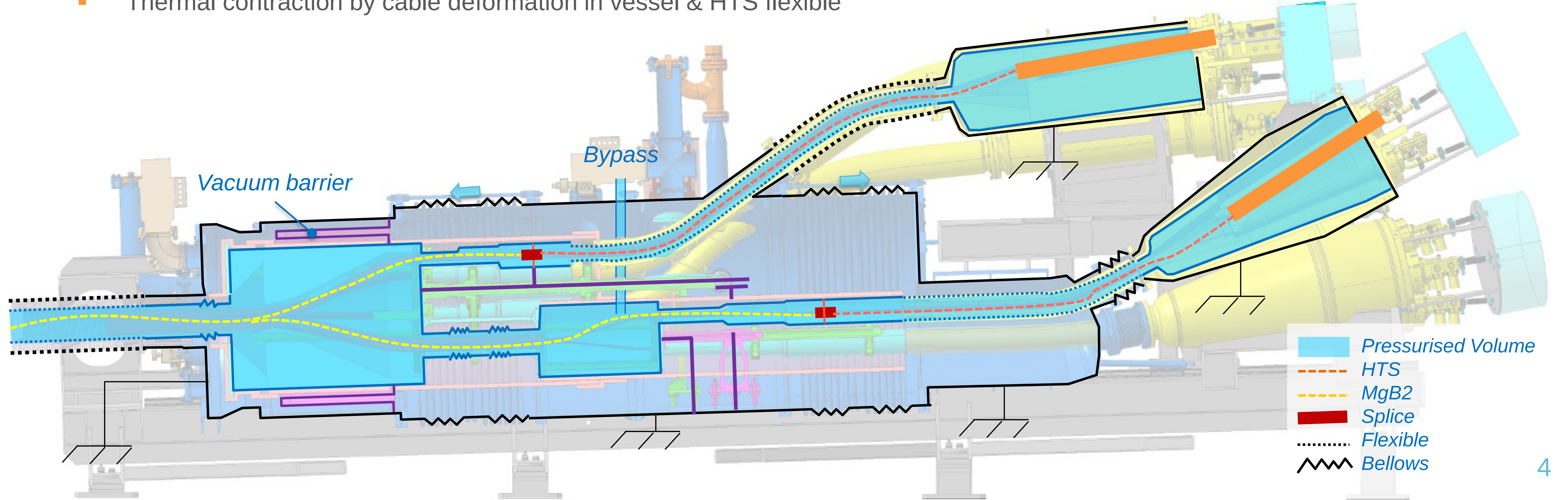
Fixed plate

Detailed Mechanical layout

- Vacuum vessels
  - Bellows as sleeve for access
  - Fixed to frame on either side of bellows
- Helium vessels
  - Shuffling vessels independently fixed
  - Thermal contraction handled by bellows and CL flexibles
  - Slope integrated in the frame design
- Electrical circuit
  - Splices fixed to He vessel
  - Thermal contraction by cable deformation in vessel & HTS flexible



Position of helium vessel parts after cooling

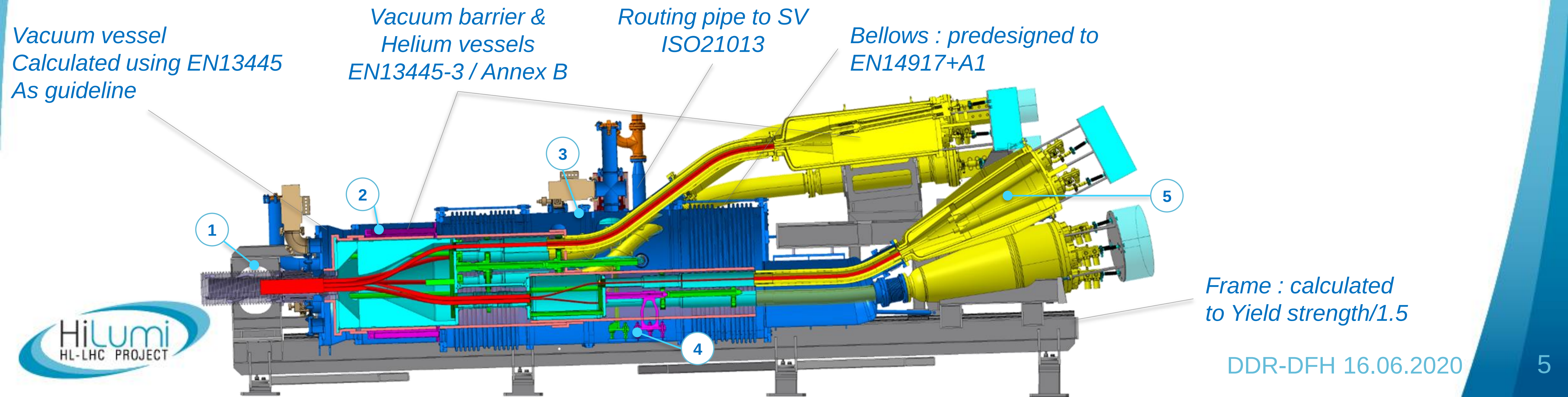


DFHX layout

Thermo- Mechanical calculations

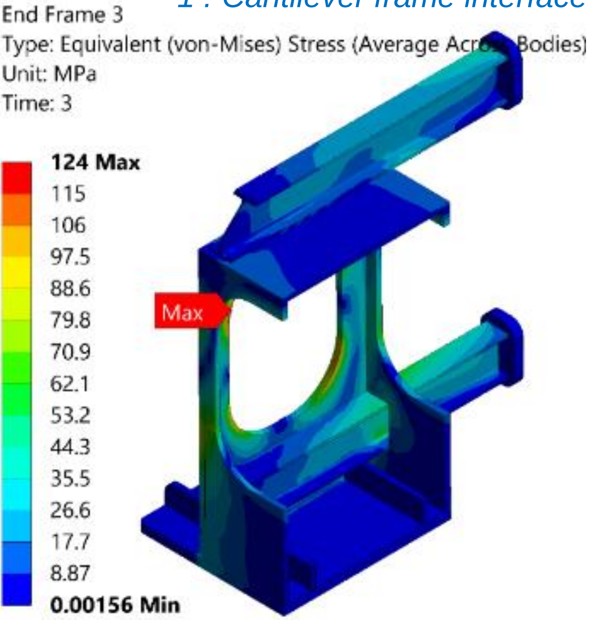
- According to EN13445-3
- Safety piping sizing acc. to ISO21013
- Load cases as defined in functional specification
- Calculations progress
  - Frame : 50 %
  - Helium vessels & Vacuum barrier : 100%
  - Vacuum vessels : 80%
  - Internal supports : 100 %
- Calculations report to be presented to HSE

Transport
Pumping
Pumping insulation vacuum SC Link
Pumping insulation vacuum DFH
Cryogenic circuit purging
Purge of cryogenic circuit without vacuum
Purge of cryogenic circuit with SC Link vacuum
Purge of cryogenic circuit with DFH vacuum
Pressure test
Thermal cycle
DFH Cool down
Nominal
DESIGN
DFH warm up
Non nominal events
Vacuum break SC Link
Vacuum break DFH

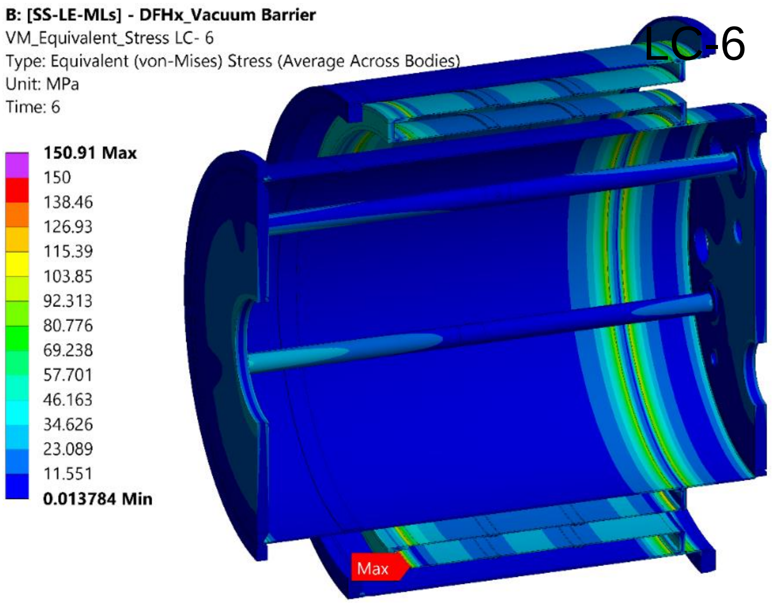


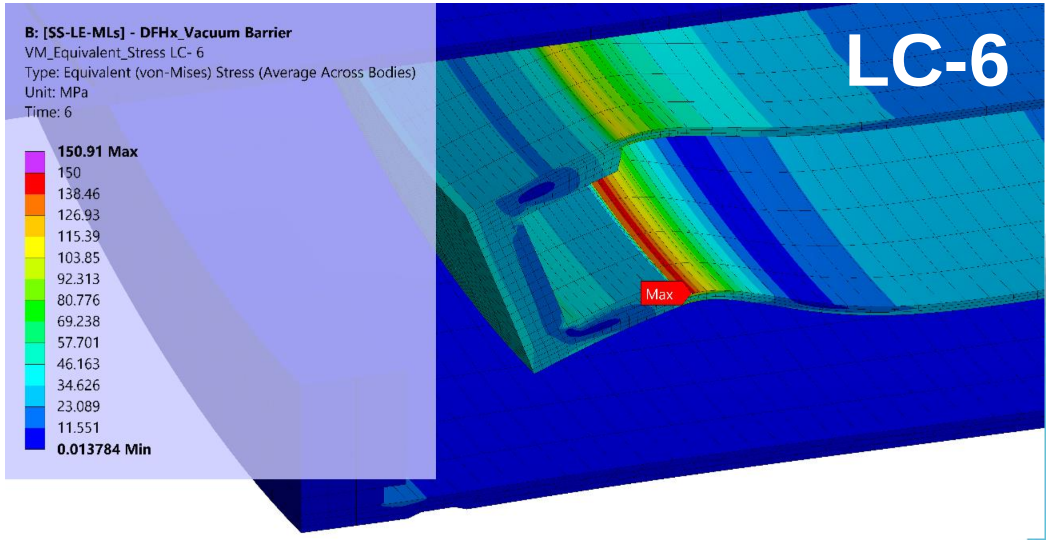
Thermo- Mechanical calculations : stress distribution acc. To EN13445-3

1 : Cantilever frame interface

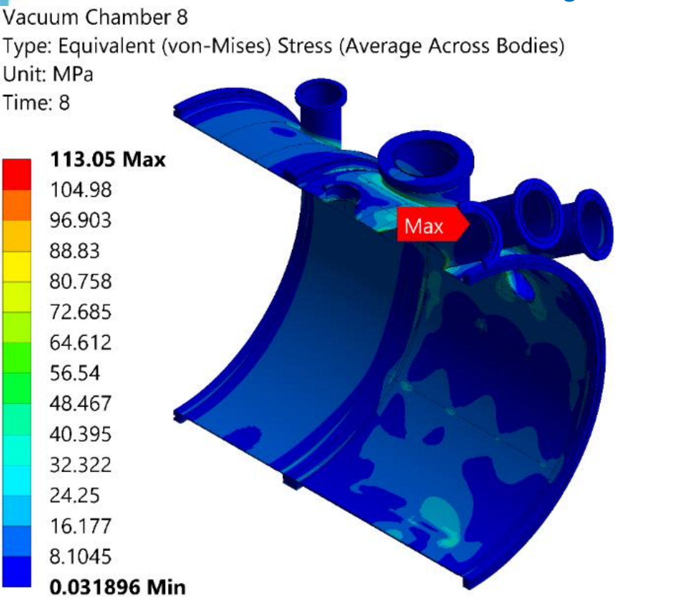


2: Vacuum barrier during vacuum break

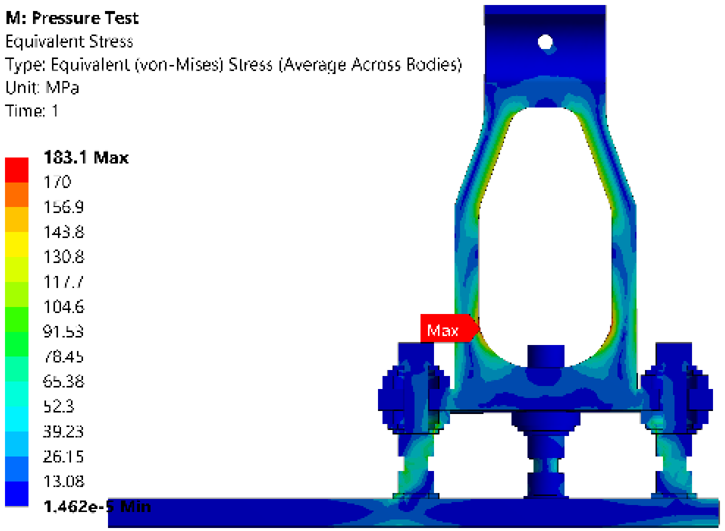




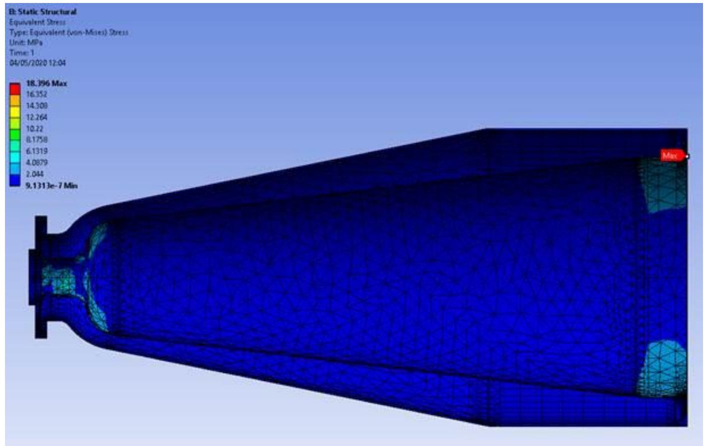
3: vacuum vessel in nominal configuration



4: second support at design pressure

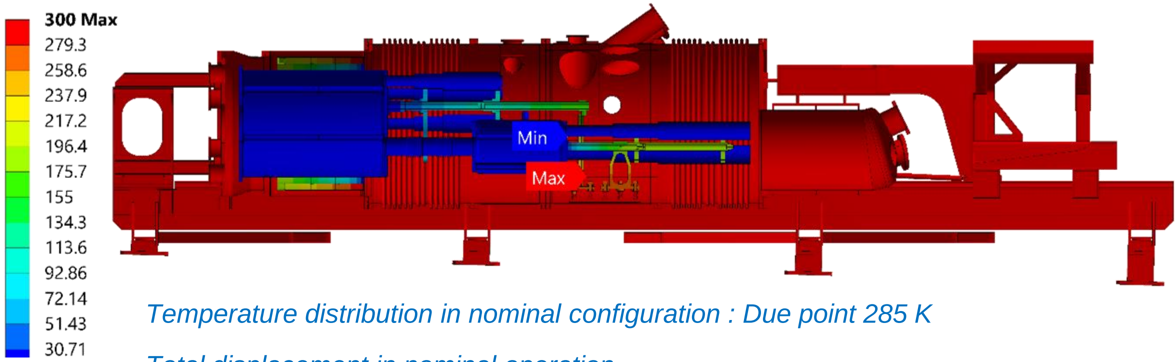


5: helium vessel current leads / conical cryostat



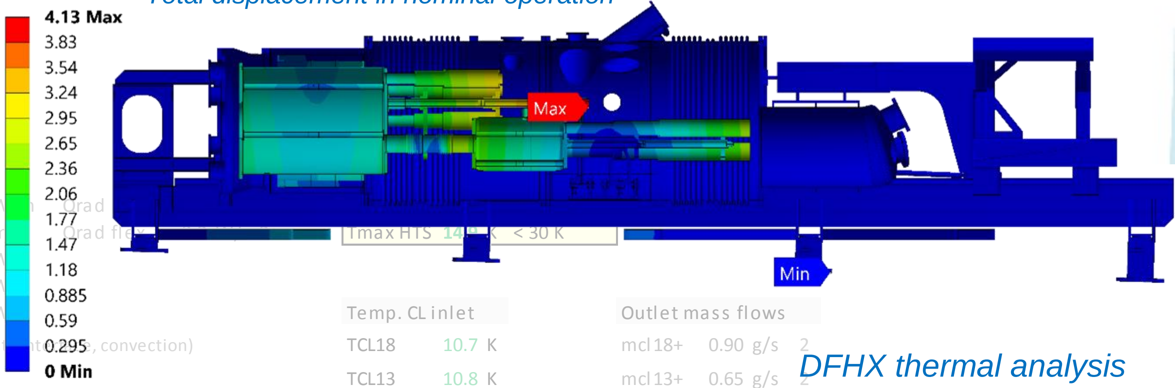
Nominal and transient analyses

- Values
  - T_{GHE} < 20 K at ultimate current & no mass flow in bypass
  - Static Heat loads < 30 W (≈ rad : 5 W / cond : 17 W)
  - No condensation on outer surfaces
- Design
  - All stainless steel
  - MLI : 30 layers on vessels, 10 layers on CL flexibles
  - No thermal shield (provision on 2nd support conduction thermalisation with braids to bypass outlet)
- Margin by flowing in the bypass
- Reminder from CDR
  - Flowing scheme : splices in series with CL
  - Splices heat extraction : convective heat transfer

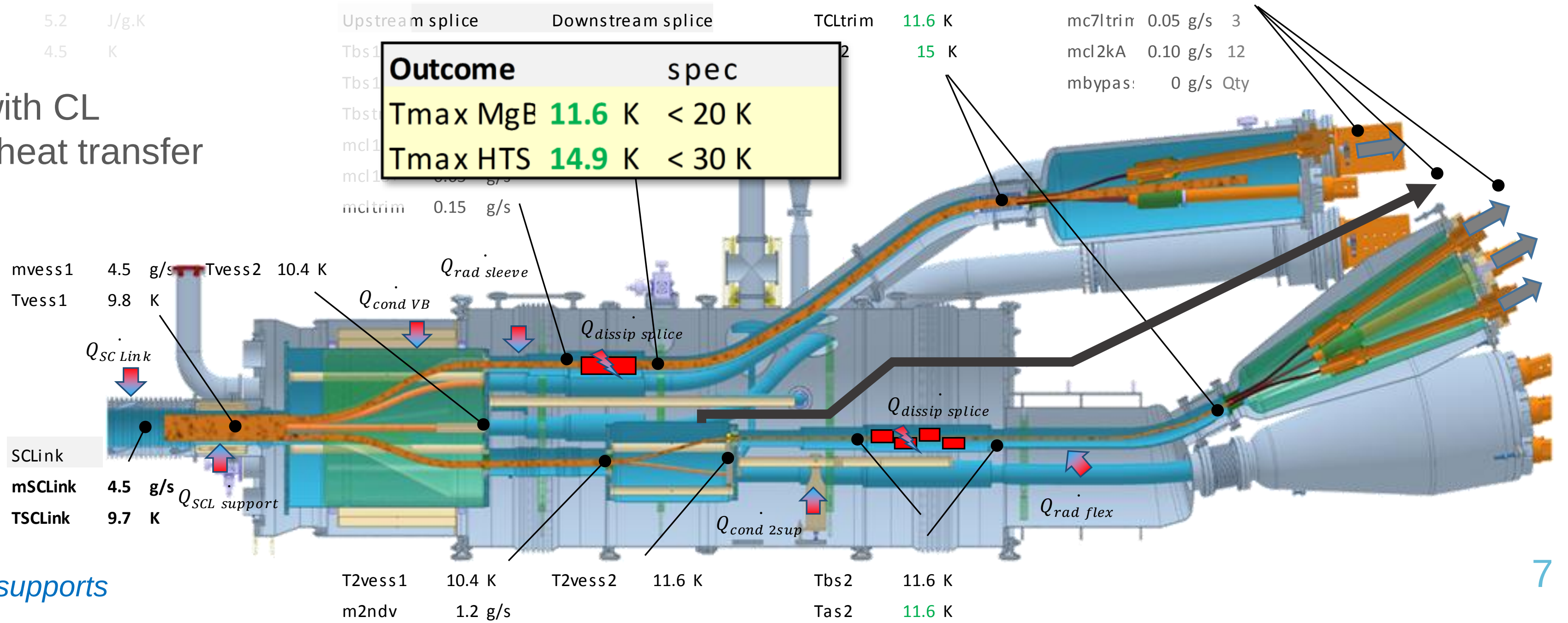


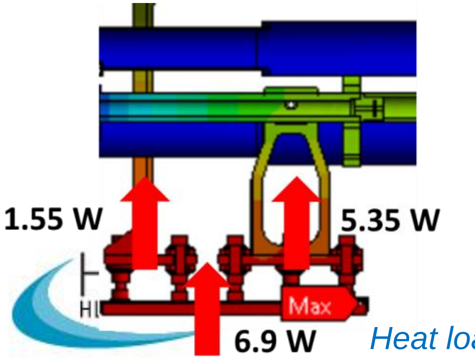
Temperature distribution in nominal configuration : Due point 285 K

Total displacement in nominal operation



DFHX thermal analysis

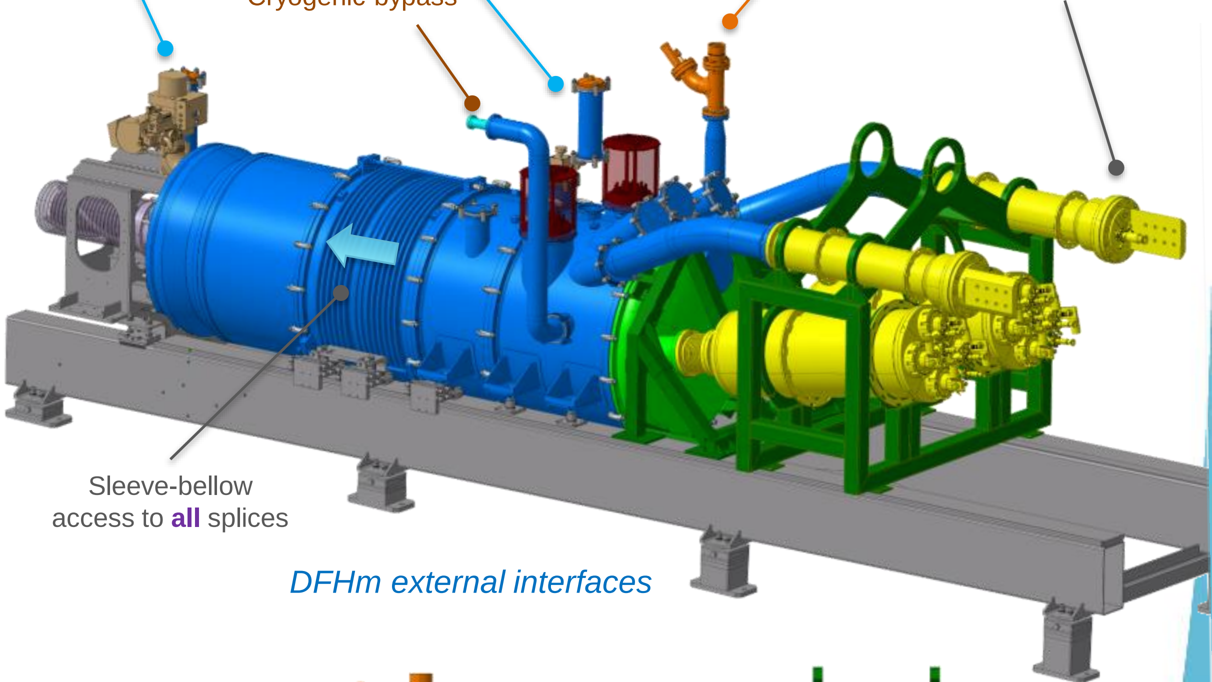




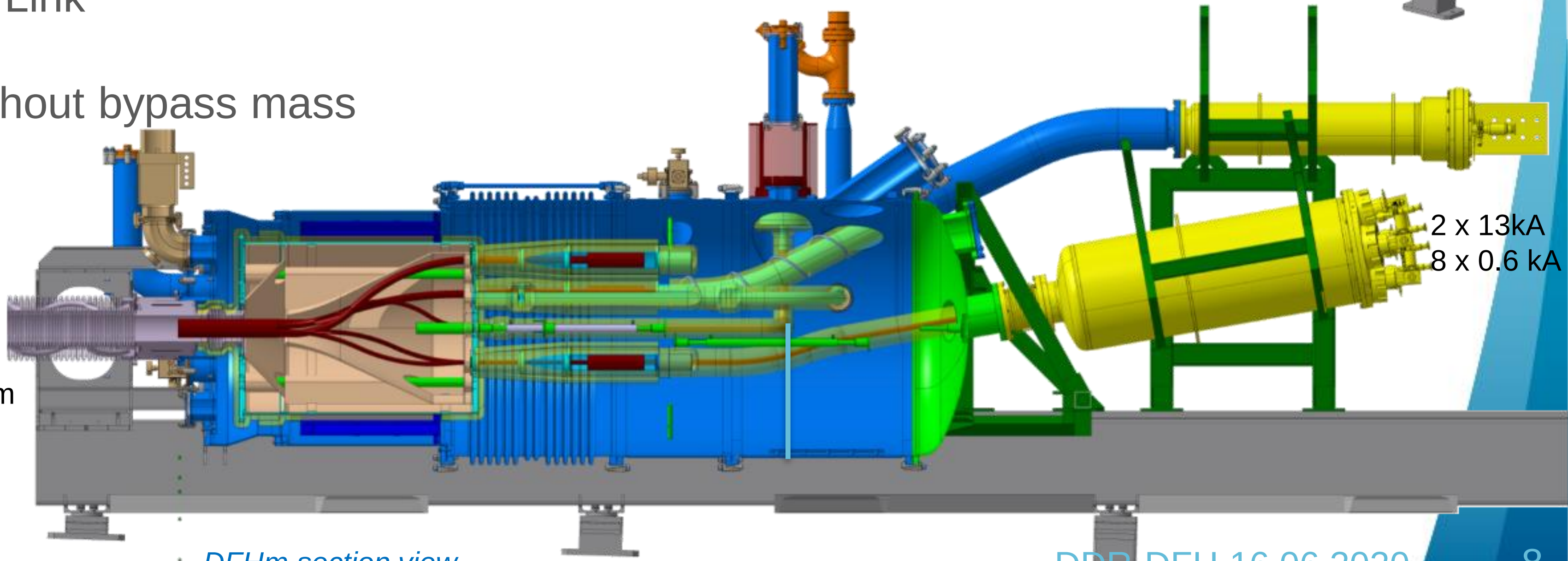
Heat loads through main vessel supports

DFHm Vs DFHx : 'simplified DFHx'

- Design
  - Same approach with 10 conductors
  - Progress slightly behind DFHX to benefit from work
- Mechanical design differences
  - 1 shuffling module ➔ 1 splices area / 1 bellows
  - Adapted CL supporting frame
- Thermal design differences
  - Lower total CL nominal mass flow
  - Lower linear heat loads on SC Link
  - Longer SC Link
  - T max MgB2 & HTS < 20 K without bypass mass flow



DFHm external interfaces



DFHm section view

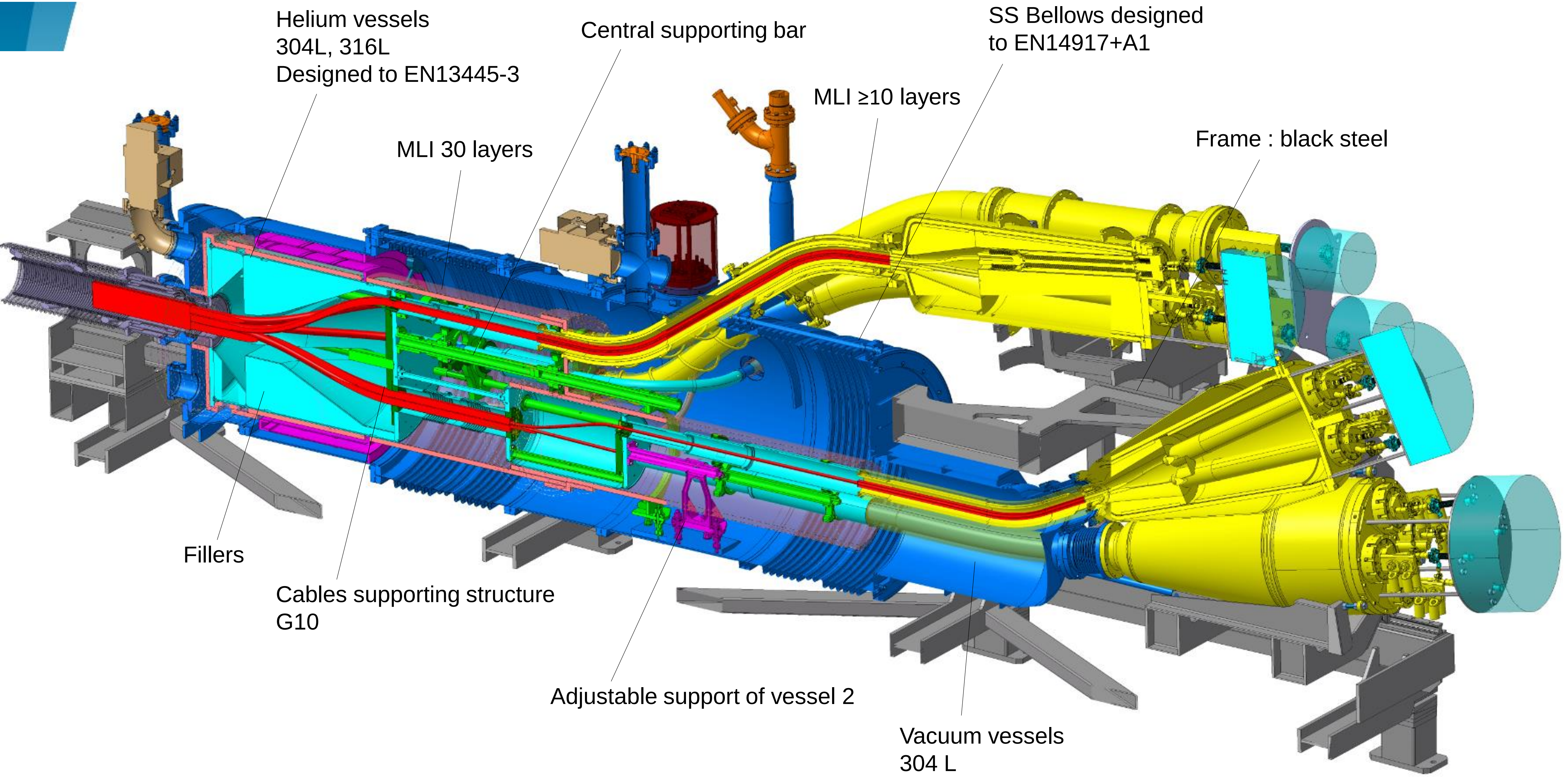
Different parts :
- Dished end
- CL supporting frame
- Main frame
- Shuffling vessel distribution plate

Observations

- Thermo-mechanical detailed design developed to specifications and applicable standards
- Drawings production in progress
- Thermo-mechanical calculations and report being finalised
- Interfaces defined (some to be validated with DEMO2)

Spare slides

DFHx overview internal



Powering		
triplet cir.	18000	A
D1	13000	A
correctors	2000	A
Trims	0	A

Splice properties		
2.5 nΩ eq	0.81	W
2.5 nΩ eq	0.42	W
15 nΩ	0.06	W
7.5 nΩ	0	W

Heat loads					
Qsclink	1.5	W/m	Qrad sleev	1.5	W/m2
SCLink le	80	m	Qrad flex	3.2	W/m2
QSCL sup	3	W			
Qcond VE	11	W			
Qcond2su	6.8	W			

Negligeable (IFS, safety interface, convection)

Outcome			spec
Tmax MgB	11.6	K	< 20 K
Tmax HTS	14.9	K	< 30 K

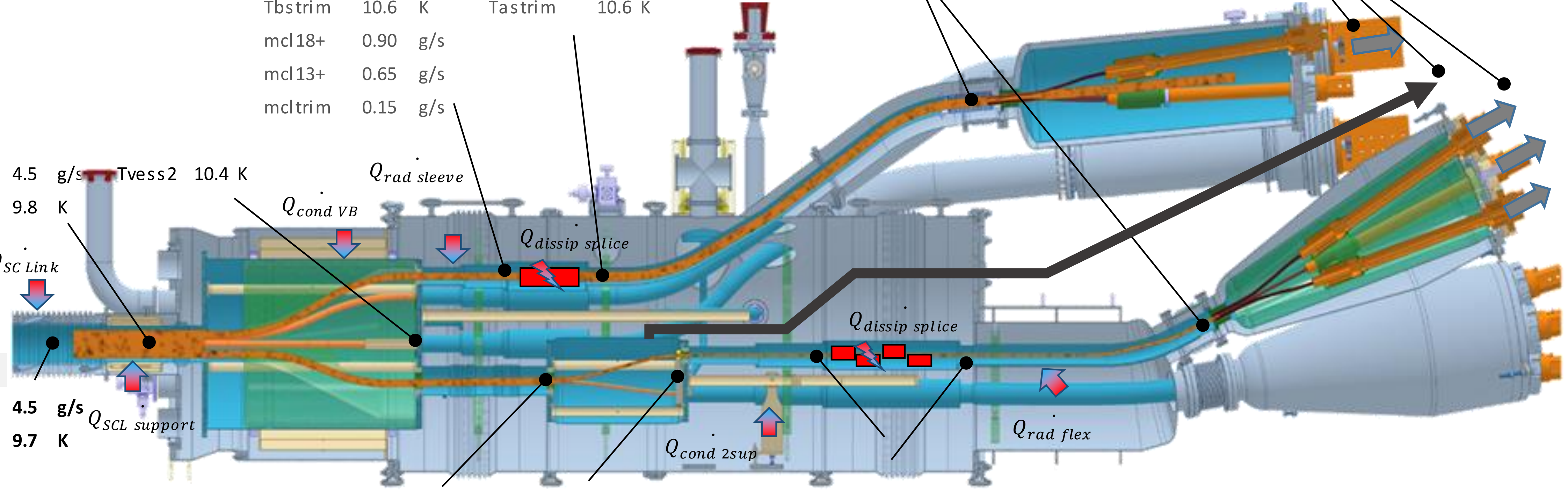
Flow		
mbypass	0	g/s
Cp	5.2	J/g.K
Tdfx	4.5	K

Upstream splice			Downstream splice		
Tbs18	10.4	K	Tas18	10.6	K
Tbs13	10.4	K	Tas13	10.5	K
Tbstrim	10.6	K	Tastrim	10.6	K
mcl18+	0.90	g/s			
mcl13+	0.65	g/s			
mcltrim	0.15	g/s			

Temp. CL inlet		
TCL18	10.7	K
TCL13	10.8	K
TCLtrim	11.6	K
TCL2	15	K

Outlet mass flows			
mcl18+	0.90	g/s	2
mcl13+	0.65	g/s	2
mc7ltrim	0.05	g/s	3
mcl2kA	0.10	g/s	12
mbypas	0	g/s	Qty

mvess1	4.5	g/s	Tvess2	10.4	K
Tvess1	9.8	K			



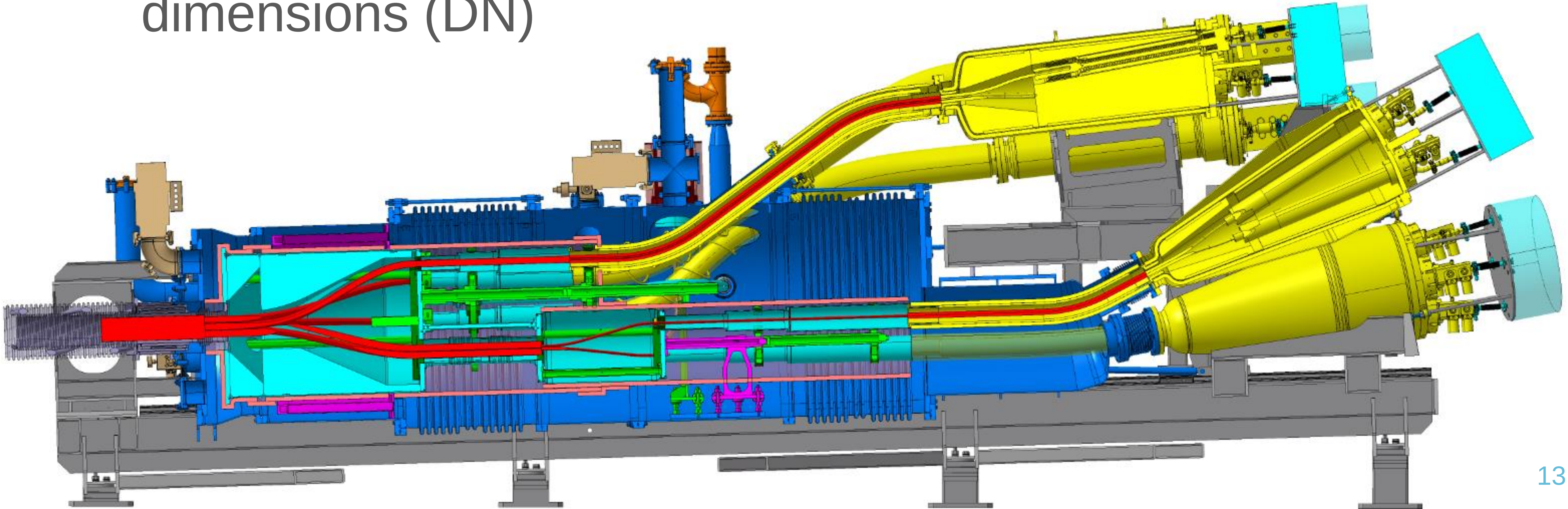
SCLink		
mSCLink	4.5	g/s
TSCLink	9.7	K

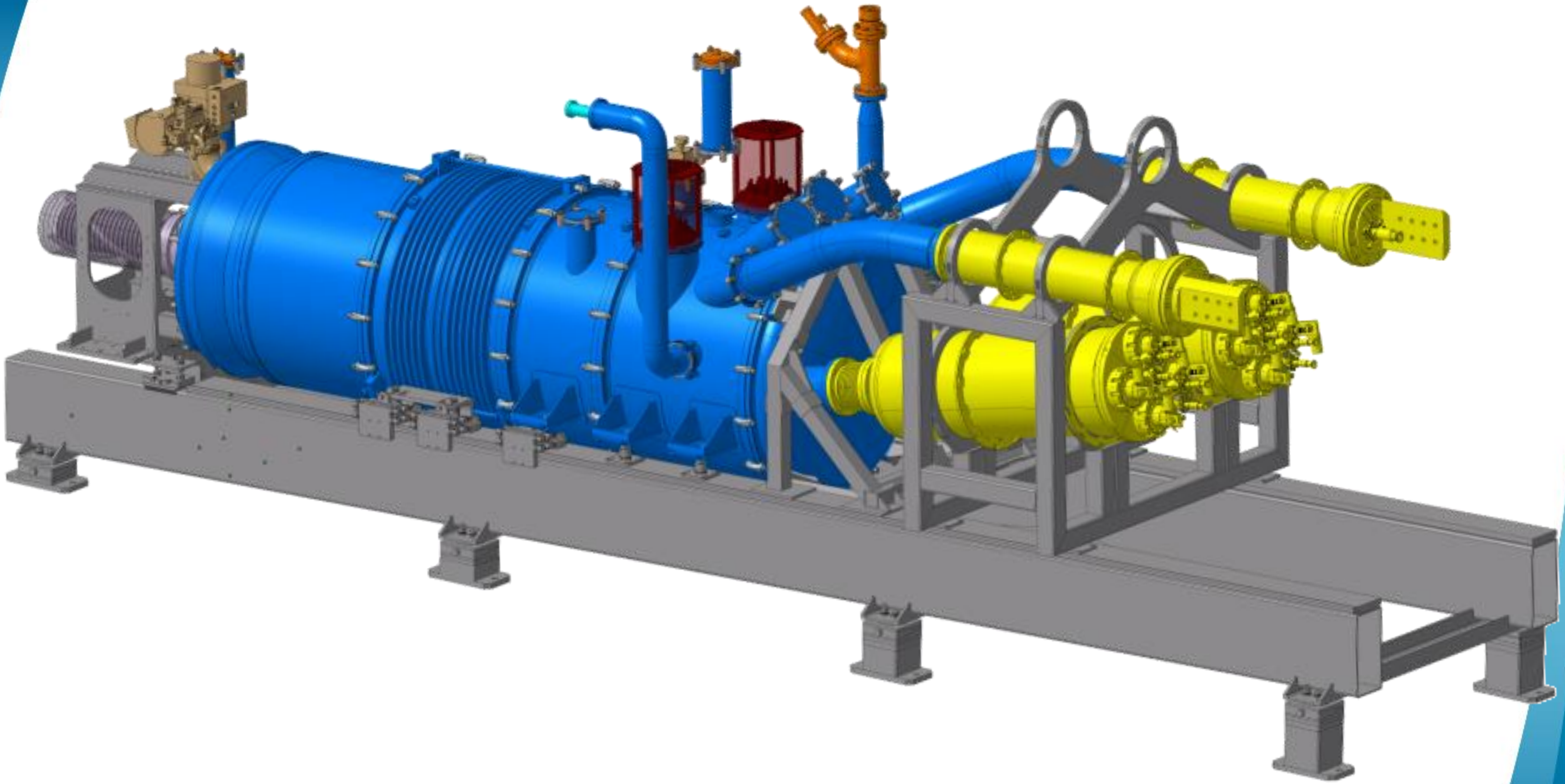
T2vess1	10.4	K	T2vess2	11.6	K
m2ndv	1.2	g/s			

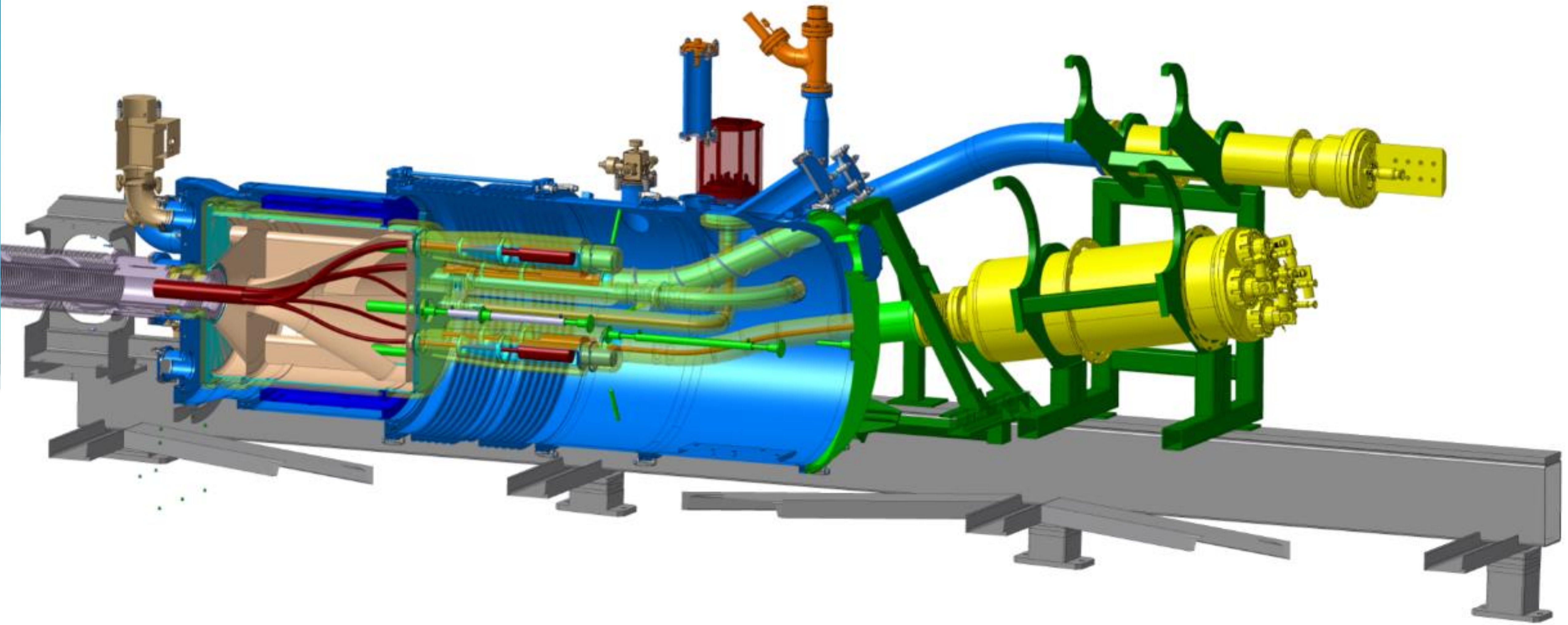
Tbs2	11.6	K
Tas2	11.6	K

Mechanical layout

- Mechanical layout with flexibility
- Thermal contraction process
- Key values (3.5 bara) dimensions (DN)







Powering			Splice properties			Heat loads			Qrad sleeve	1.5	W/m2
D2 circuit	13000	A	2.5 nΩ eq	0.4	W	Qsclink	0.8	W/m	Qrad flex	3.2	W/m2
						SCLink le	120	m			
Correctors	600	A	15 nΩ	0	W	QSCL su	3	W			
						Qcond V	11	W			

Outcome			spec
Tmax Mg	17.3	K	< 20 K
Tmax HT:	18.1	K	< 30 K

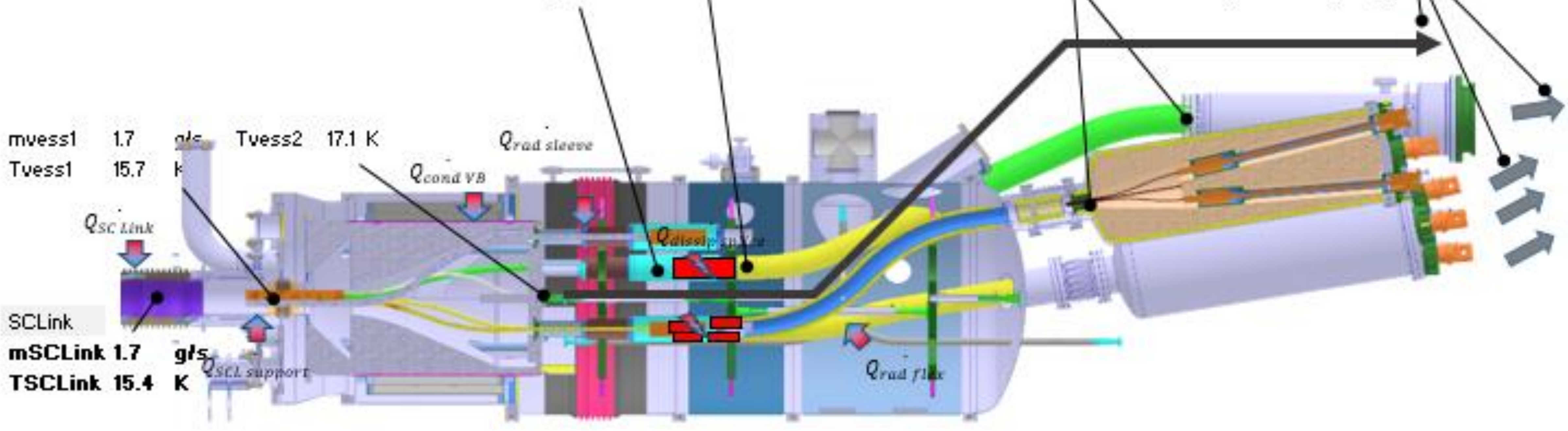
Flow		
mbypass	0	g/s
Cp	5.2	J/g.K
Tdfm	4.5	K

Negligeable (IFS, safety interface, convection)

Upstream splice			Downstream splice		
Tbs13	17.2	K	Tas13	17.3	K
Tbs0.6	17.3	K	Tas0.6	17.3	K
mcl13+	0.65	g/s			

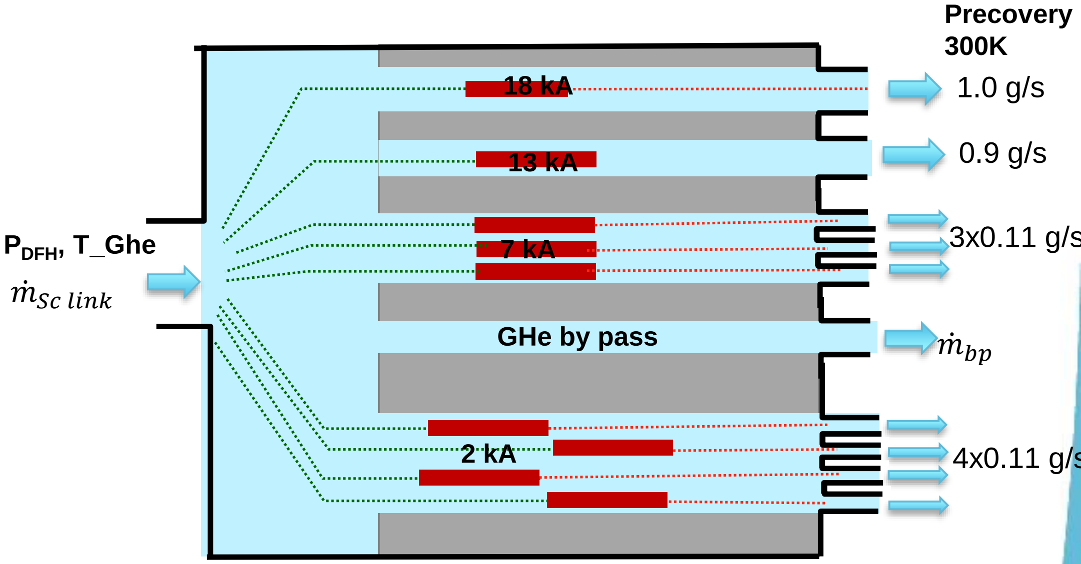
Temp. CL inlet		
Tcl13	17.5	K
Tcl0.6	18.1	K

Outlet mass flows				
mcl13+	0.65	g/s	2	
mcl0.6	0.05	g/s	8	
mbypas	0	g/s	Qty	



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**