WP6A
Safety Update

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AGENDA

1. DESIGN UPDATE
2. FMEA
3. ONGOING PARAMETRIC STUDY

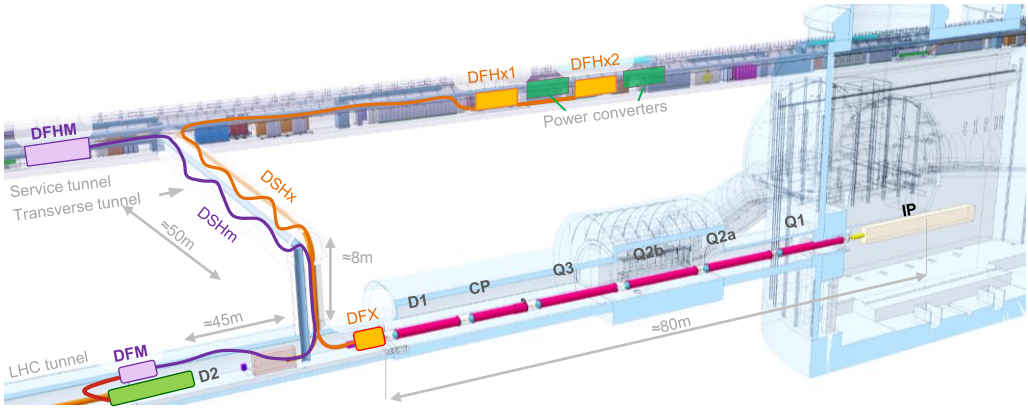
Design update

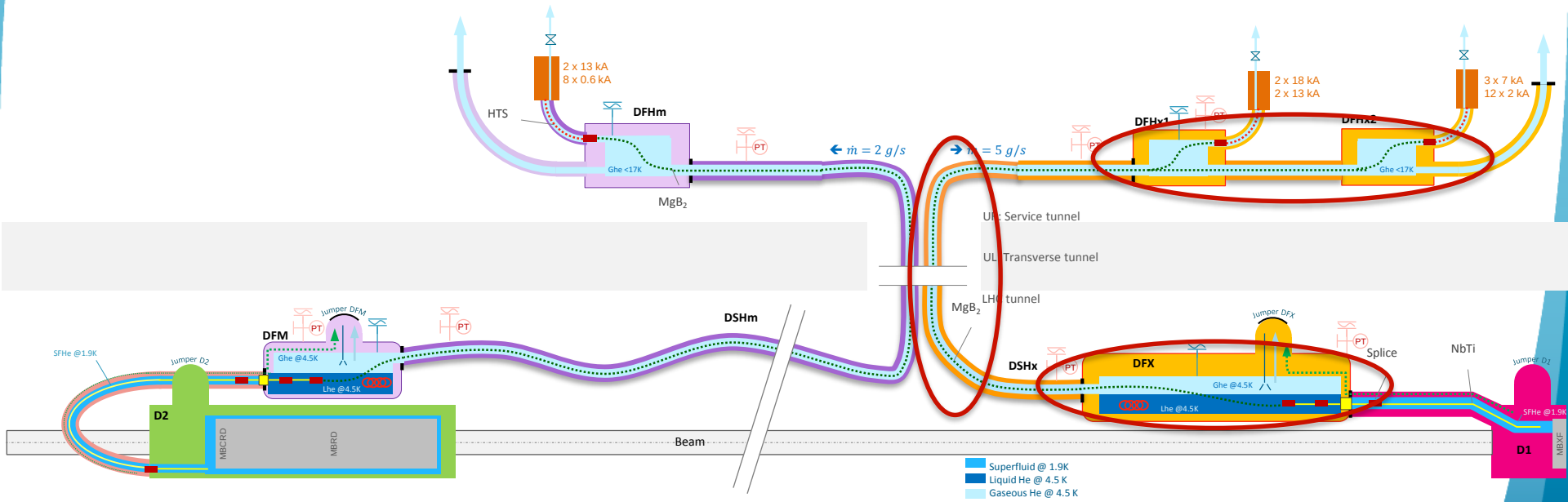
Each IP1 and IP5 sides equipped with 2 cold powering chains of cryostats

- Triplet insertion : DFHx – SC Link (DSH) – DFX
- Matching sections : DFHm – SC Link - DFM

DFX/DFM basic functions:

- Electrical interface between SC Link and superconducting magnets
- Supply cryogenics to the SCLink





Courtesy of WP6A

Failure Modes and Effects Analysis

- Investigation of the potential failure modes leading to a Cryogenic Incident in the HL-LHC UR
- Investigation of the potential causes
- What does already exist in terms of:
  - Design controls
  - Detection methods
- What are the recommended actions?

Cold Powering for Inner Triplets		Failure Modes and Effects Analysis : MATRIX			
Location:	IP1 and IP5	System:	12 – DSHx	Date:	05/11/2018
Work package:	WP6A			Revision:	

ID	Lifecycle	Function	Associated components	Potential failure modes	Potential failure effects		Potential causes	Current design controls / Detection methods	Recommended actions
					Local	Final			
12.1	Operation	Cool MgB2 cables with gHe	Cryogenic supply	Low debit	Heating of HTS cables, Quench of HTS	Overpressure in DFHx2 and DFHx1, He spill in UR	Lack of He supply from DFX jumper, heater failure in DFX	Level gauge in DFX, Safety devices on DFHx1 cryostat	
12.2			GHe (T<17K)	GHe does not cool HTS cables	Heating of HTS cables, Quench of HTS	Overpressure in DFHx2 and DFHx1, He spill in UR	Lack of He supply from DFX jumper, heater failure in DFX	Level gauge + temperature sensor in DFX, Safety devices on DFHx1 cryostat	
12.3		Ensure electrical continuity between DFHx1 and DFX	HTS cables	Short-circuit, electrical arc	Heating of HTS, loss of superconductivity	Overpressure in DFHx1 and DFHx2, He spill in UR, Mechanical choc	Insulation fault between conductors, damaged polymer (radiations)	QA of polymer	
12.4				Icing of current leads	Loss of power, Breaking of cables	Loss of power	Oversupply of LHe from DFX jumper		
12.5			Splices	Rupture of splices	Quench of HTS cables	Overpressure in DFHx1 and DFHx2, Helium spill in UR, Mechanical choc	Bad quality of welds, fatigue	QA of polymer	
12.6			GHe (T<17K)	GHe does not cool HTS cables	Heating of HTS cables, Quench of HTS	Overpressure in DFHx2 and DFHx1, He spill in UR	Lack of He supply from DFX jumper, heater failure in DFX	Level gauge + temperature sensor in DFX, Safety devices on DFHx1 cryostat	
12.7		Withstand a pressure rise	Safety devices	Safety device does not open at the set pressure	Overpressure in DFHx1 and DFHx2		Failure of safety device	Redundancy of safety devices on DFHx1 cryostat and insulation vacuum	Opening pressure DFX < Opening pressure DFHx1
12.8		Withstand vacuum conditions	Insulation vacuum	Air in leak	Cryo-condensation, helium boil-off, overpressure	He spill in UR	Mechanical damage of bellows	Redundancy of safety devices on DFHx1 cryostat and insulation vacuum	Opening pressure DFX < Opening pressure DFHx1
12.9				He in leak	Cryo-condensation, helium boil-off,	He spill in UR	Internal damage, short-circuit, electrical arc		

Identification

Analysis

Improvement

Failures leading to a Helium Spill in UR

System	Potential Failure modes	Design control
DFHx1,2	• IV leak from inside (short circuit, electrical arc)	Safety devices available on IV and cryostat
	• IV leak from outside (insulation damage)	
	• He recuperation line blocked	Safety device on cryostat
DSHx/DSHm	• Quench of MgB2	Safety device of cryostats of DFX, DFM and DFH
	• IV leak from inside	Safety devices at both ends of DSH on IV
	• IV leak from outside	
DFM/DFX	• Quench in D2/IT, plug damaged	Safety device must blow off in LHC • Sufficient capacity • Opening pressure < opening pressure DFHm/DFHx (tbd)
	• Heater failure	Monitoring heater parameters (current, voltage) Level sensor in DFM/DFX
	• Cryo supply failure	Level sensor in DFM/DFX

HiLumi HL-LHC PROJECT

Ongoing parametric study

Need	Mitigations

• Helium masses:
  • DFX
  • DFM
  • DSHx, DSHm
  • DFHx1, DFHx2, DFHM
• Helium thermodynamic state: p, T, V, dV/dt (flow)
• Hypothesis on immediate Helium flow to "leak".
• Size of safety devices
• Mass flow rate through safety device: rate and duration, total
	• Orientation of spill points, direction away from bystanders
	• Possibly release at ceiling
	• Spill points for DSH in UL, inaccessible
	• All safety devices doubled (safety valve and burst disk

Thank you