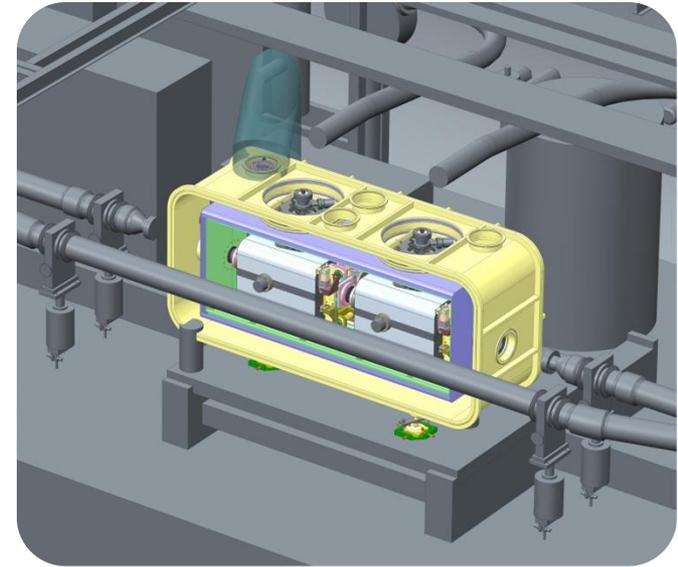




High
Luminosity
LHC



Cryomodule for 4-Rod Crab Cavity

Shrikant Pattalwar

Accelerator Science and Technology Centre
STFC Daresbury Laboratory, UK

CC13- CERN

Acknowledgements

STFC

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CERN

Ofelia Capatina, Krzysztof Brodzinski, Rama Calaga, Alick Macpherson,
Luis Alberty, Thierry Renaglia, Eric Montesinos *and many others...*

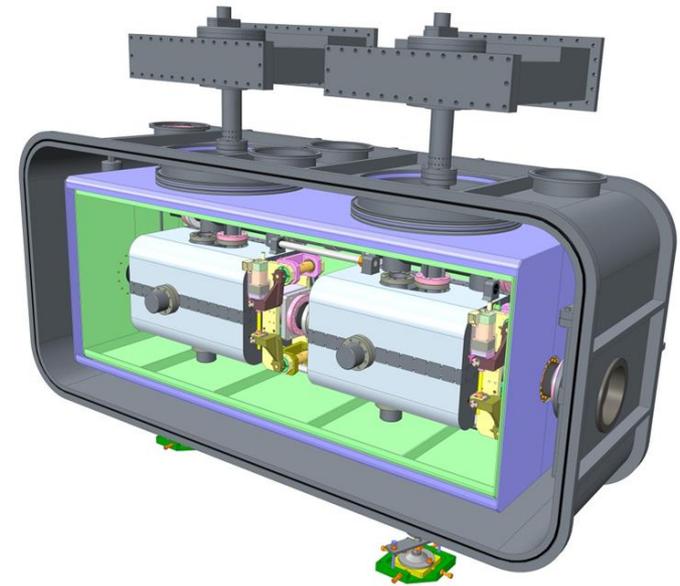
FNAL

Tom Peterson and Tom Nichols

HiLumi WP4 collaboration including the members of US-LARP

Cryomodule for 4-Rod Crab Cavity

- Design Overview
- Thermal Management
- Future Plans
- Summary

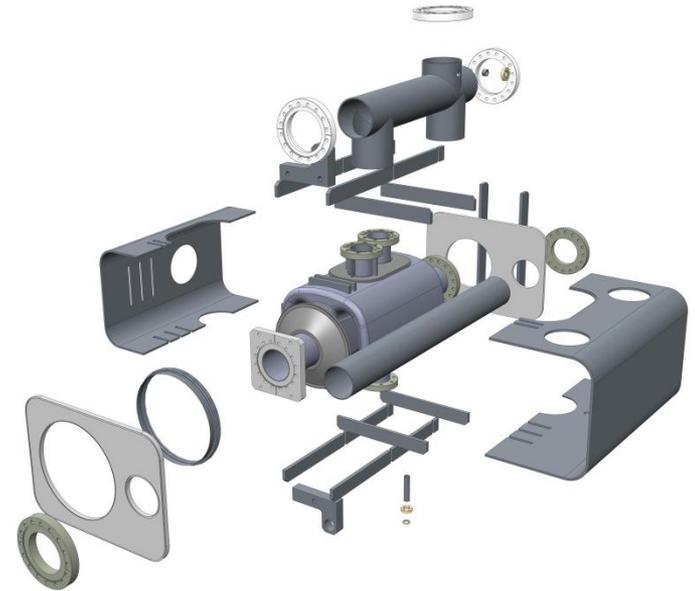
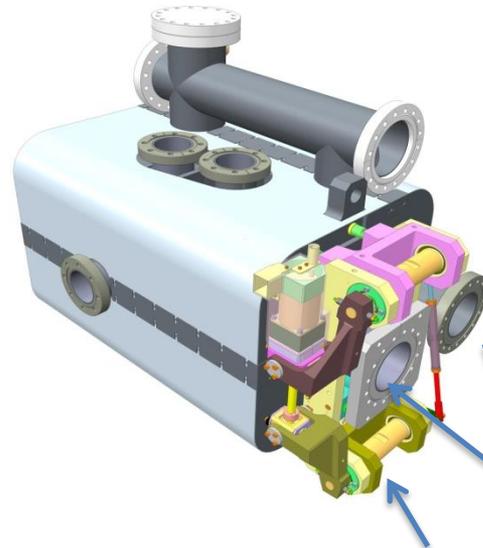
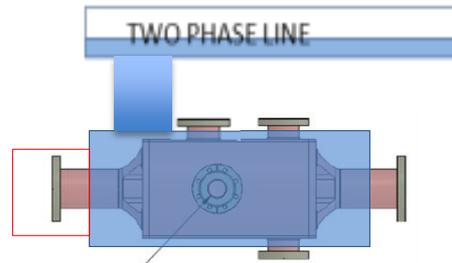


Helium Vessel

UK 4-Rod Cavity

Cavity in He Vessel

Parts of the Vessel



LHC (dummy) beam pipe

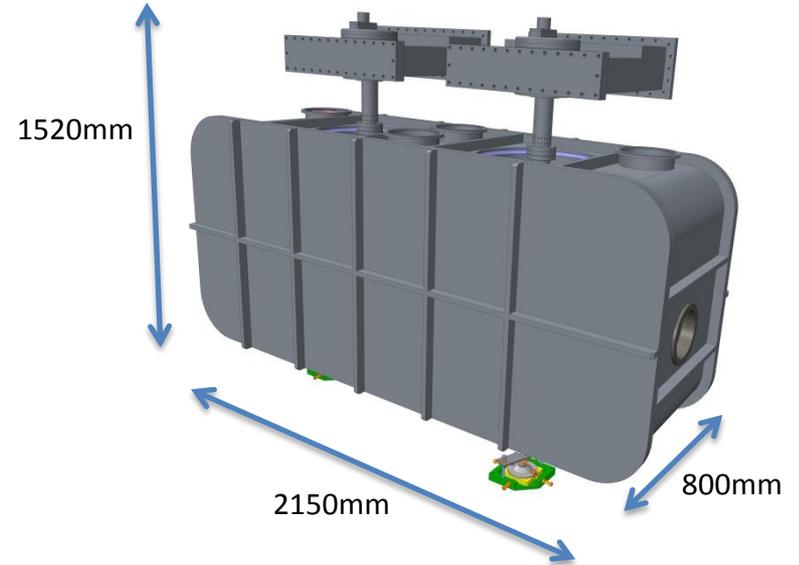
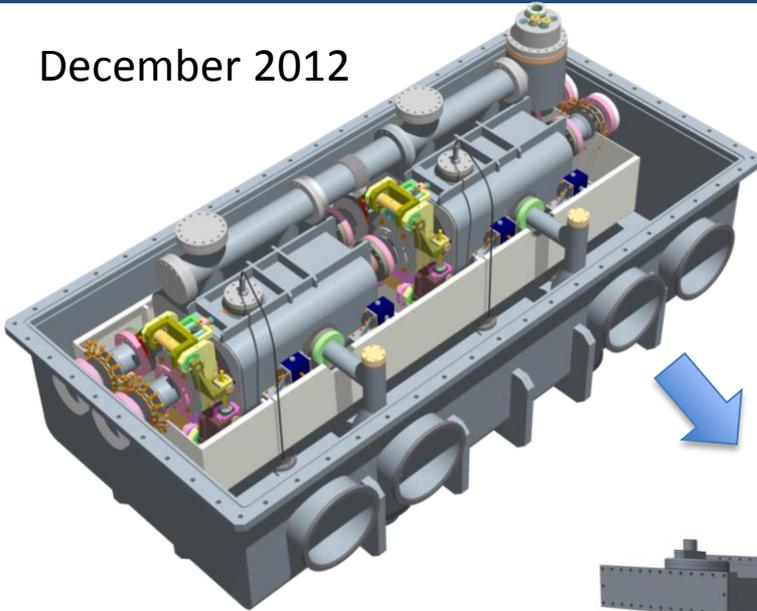
SPS beam pipe

Saclay-II type tuner

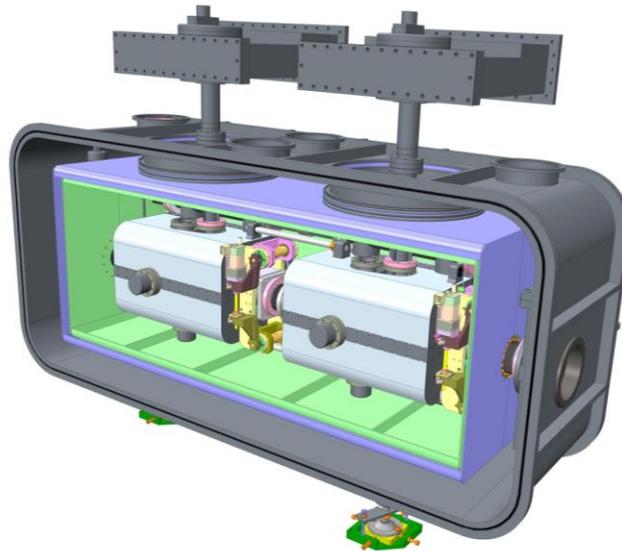
More details by Thomas Jones in this workshop

Cryomodule Concept

December 2012



August 2013

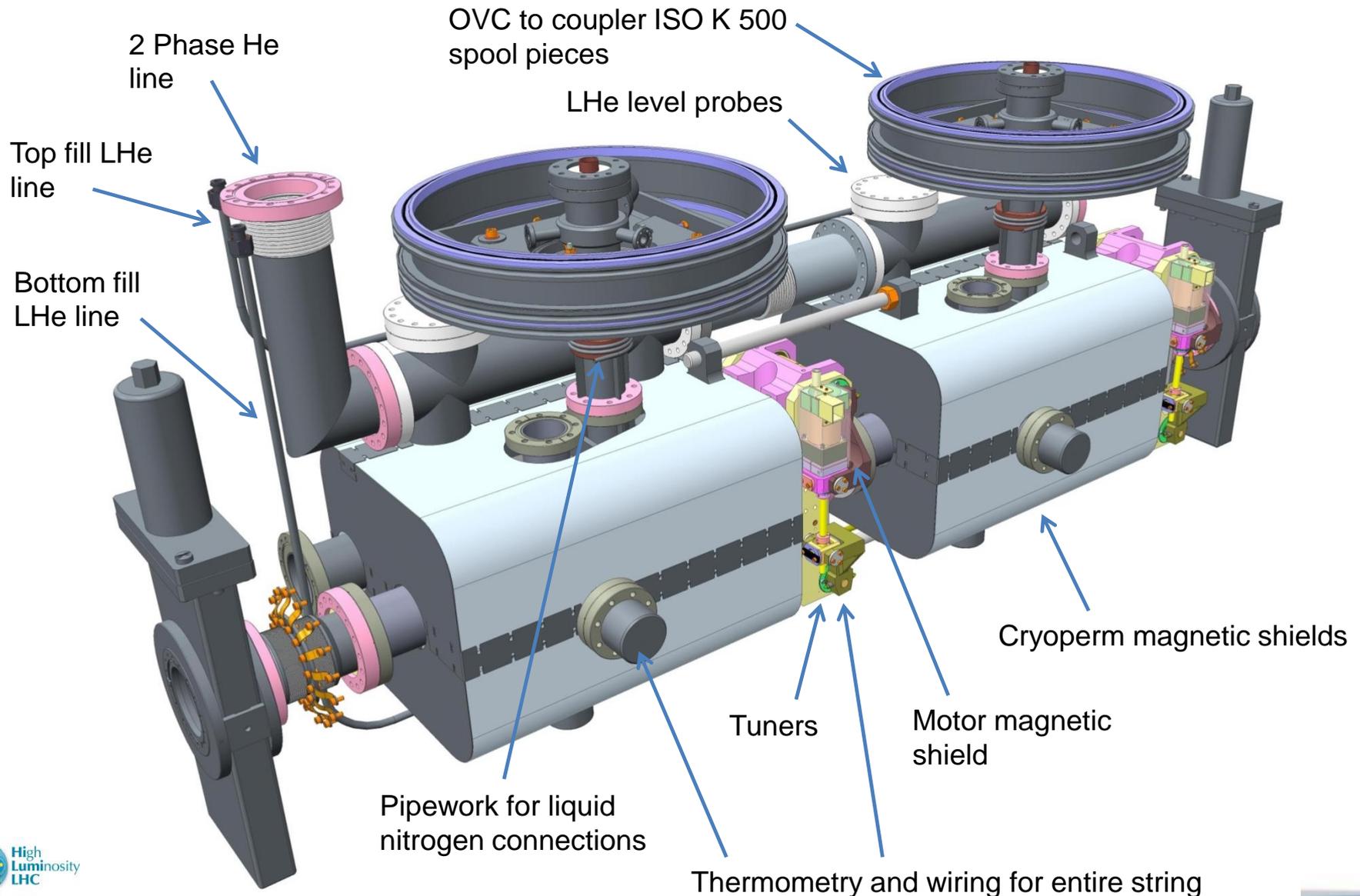


Design Approach

Provide sufficient and easy access to internal components during assembly and after installation

More details in - *Conceptual design of a Cryomodule for Crab Cavities for HiLumi-LHC*
S. Pattalwar, et al, MOP 087, SRF 2013, Paris

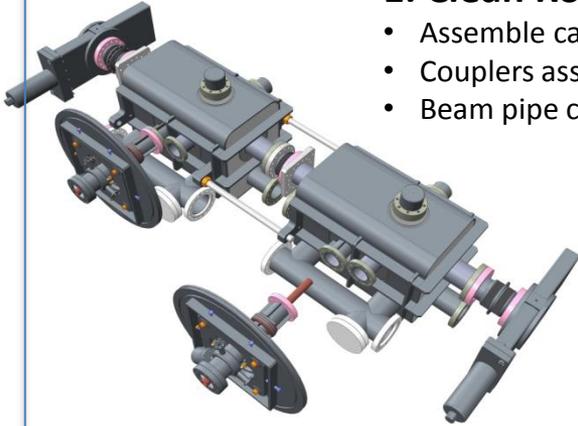
Fully Assembled Cavity String (4R)



Basic Assembly Sequence

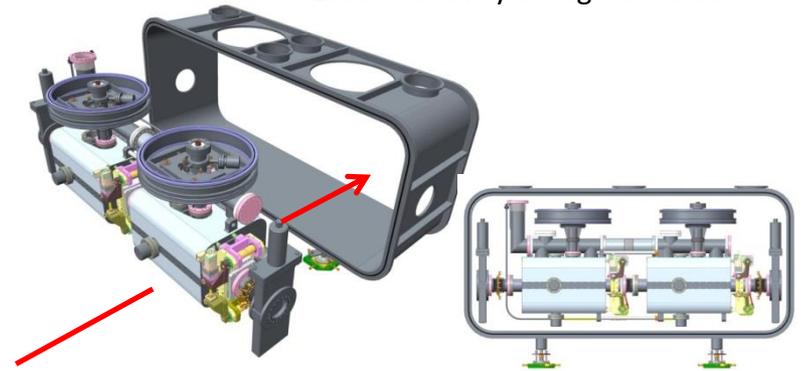
1. Clean Room Operations

- Assemble cavity string
- Couplers assembled at 90°
- Beam pipe closed with gate Valves



2. Outside the clean Room

- Load the cavity String from Side



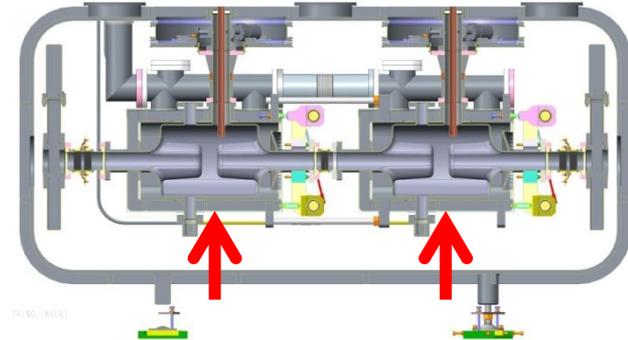
4. Align the string

with the outer tube adjustment system and a laser tracker.

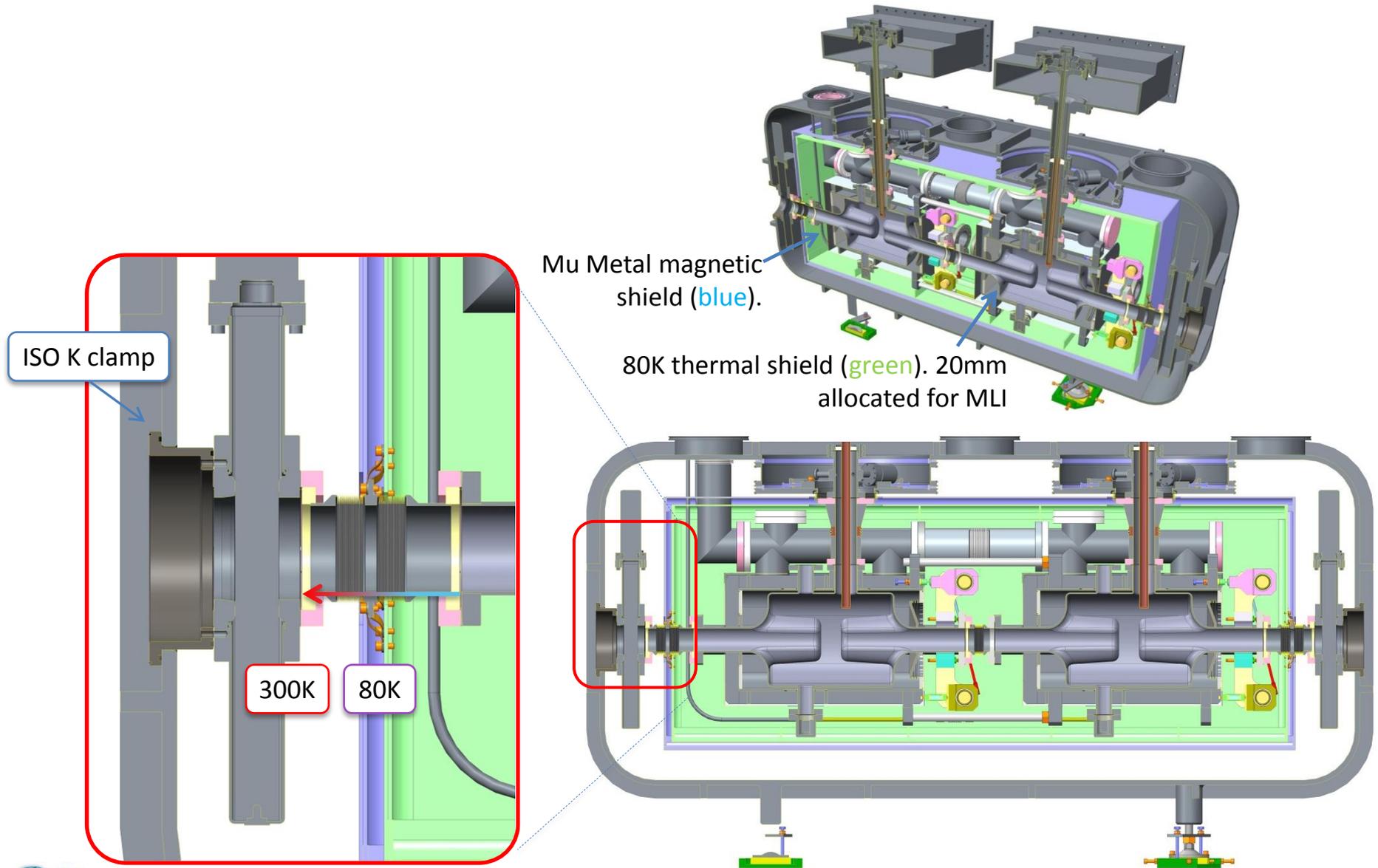


3. Lift and assemble

using sliding frame, or **lower** Outer Vacuum Chamber

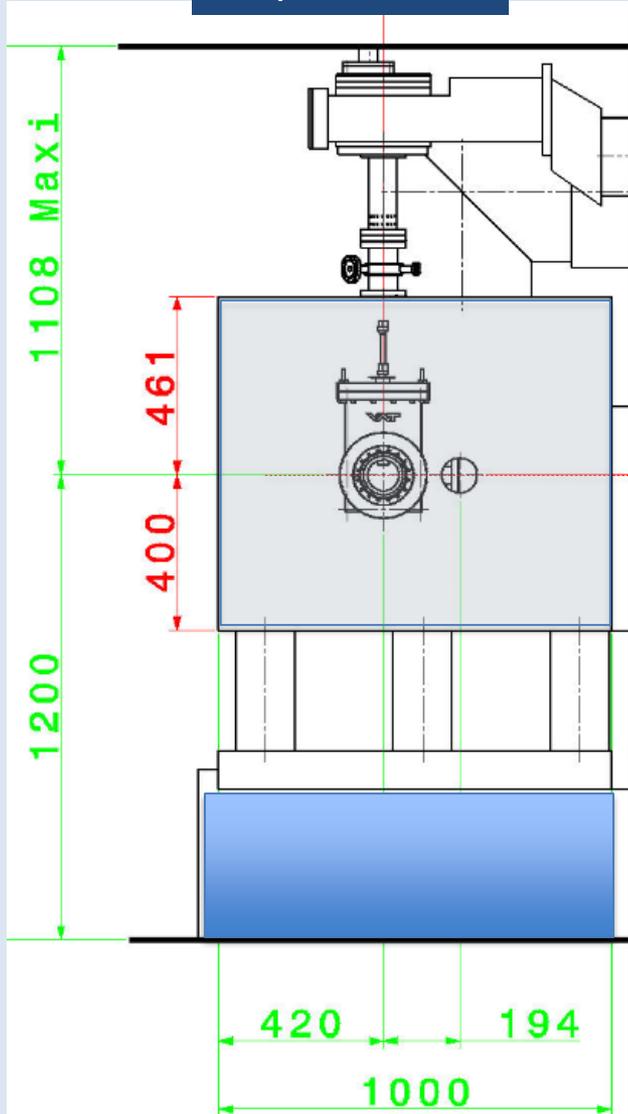


Final Assembly

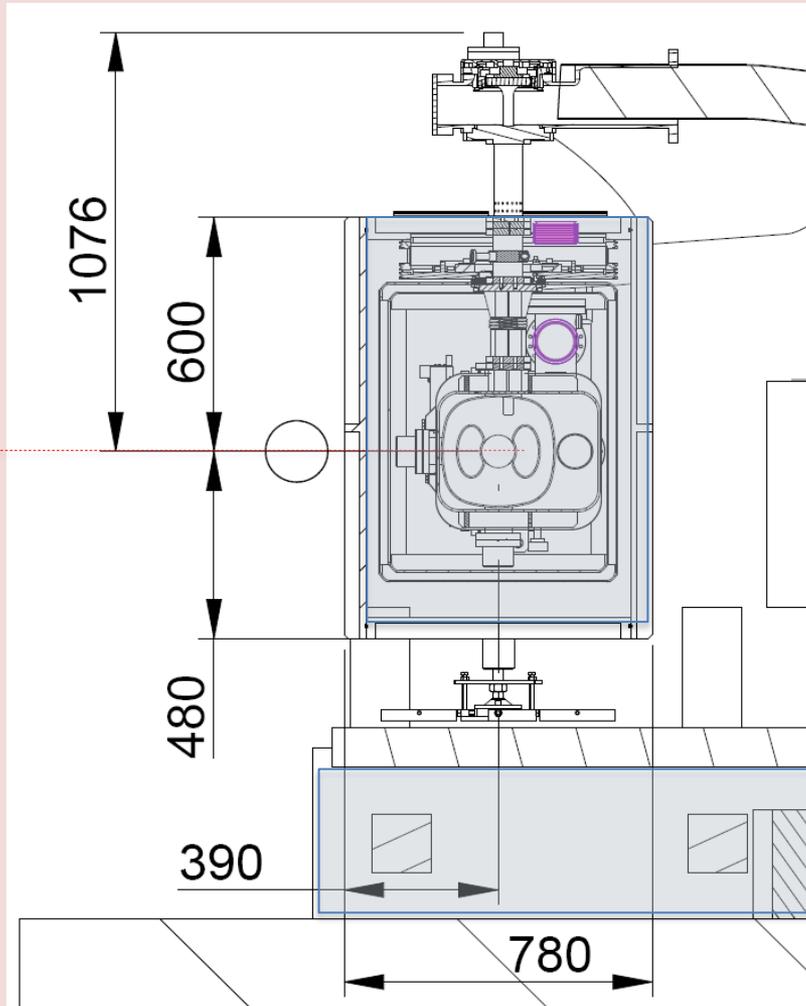


Compatibility with SPS Infrastructure

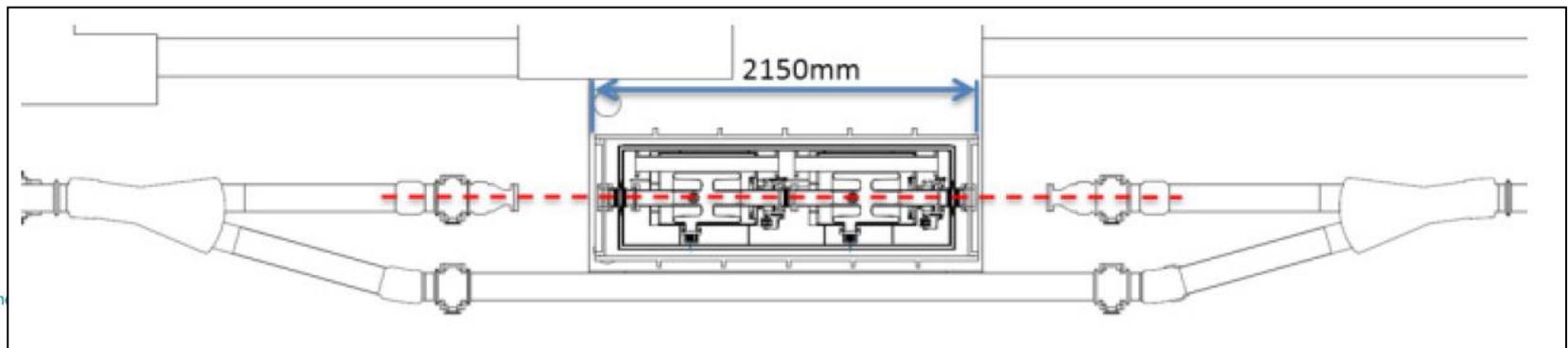
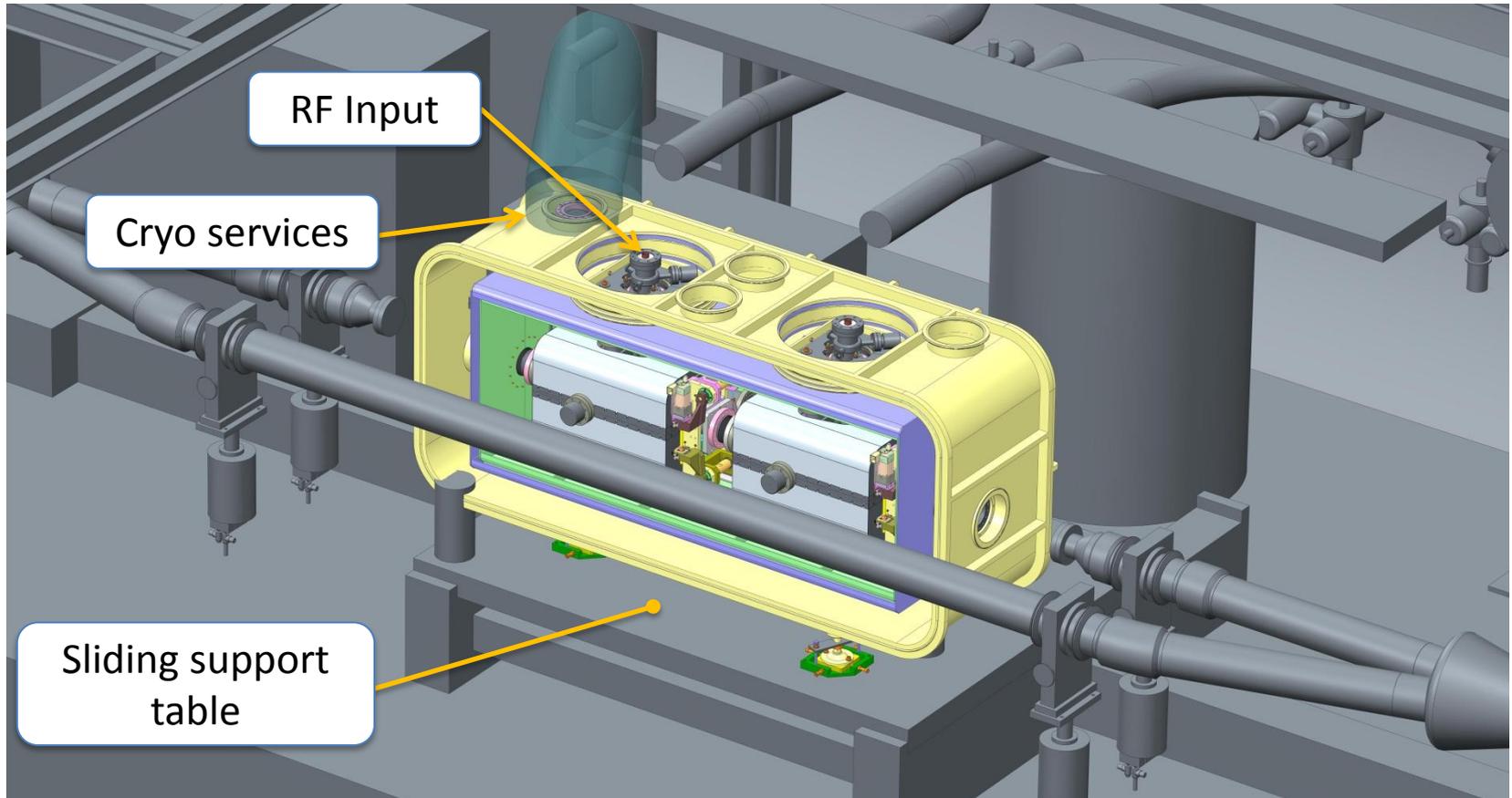
Requirements



Concept Design



Cryomodule in SPS

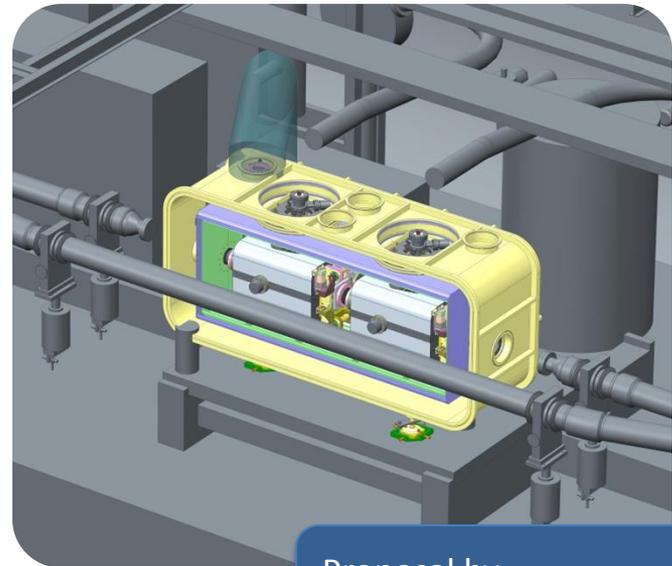


Side Loaded Cryomodule - Key Features

Key Features

1. Side Loading

- **Full and quick access** to inside components **in the installed position** with beam line connected.
- An important feature advantageous during prototyping
for any modifications, leak checks accessing tuners, Installing additional diagnostics
- Simplifies Assembly process
Requires less tooling during assembly
- Requires less vertical height or longitudinal space during assembly
- Less expensive



Proposal by
Ofelia Capatina *et al*

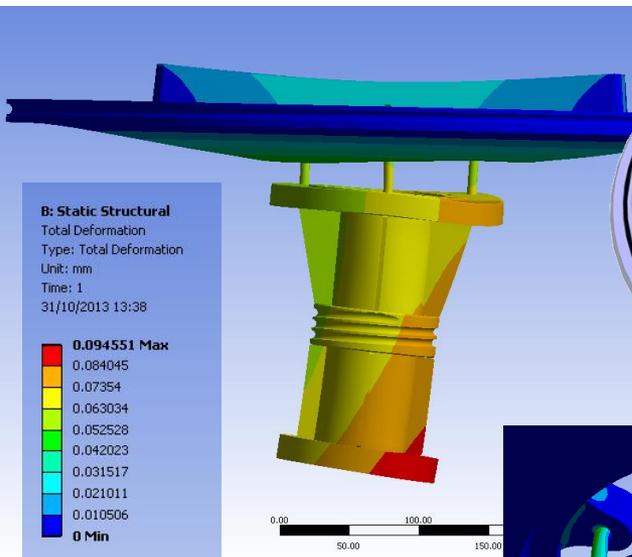
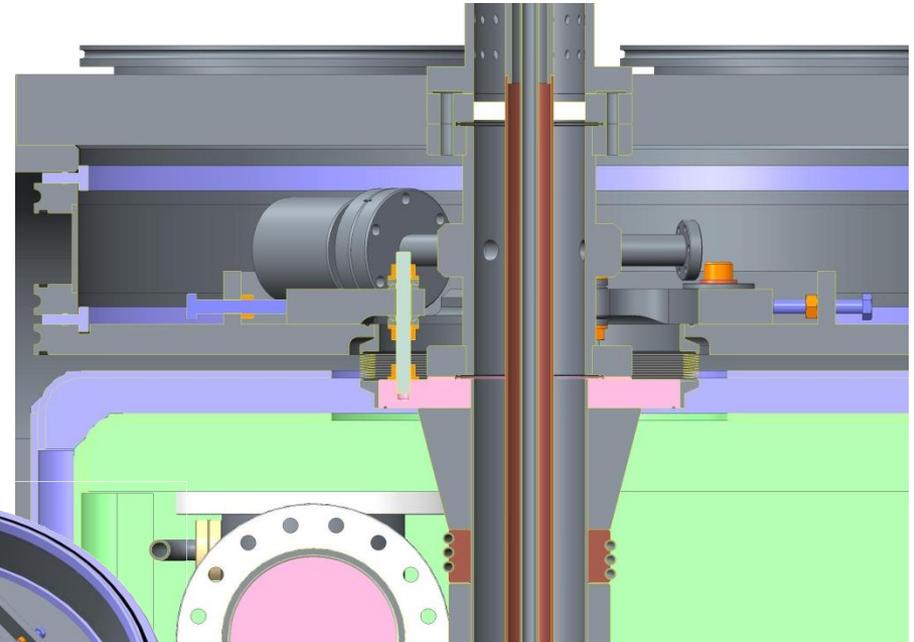
Key Features

2. FPC to function as cavity Support

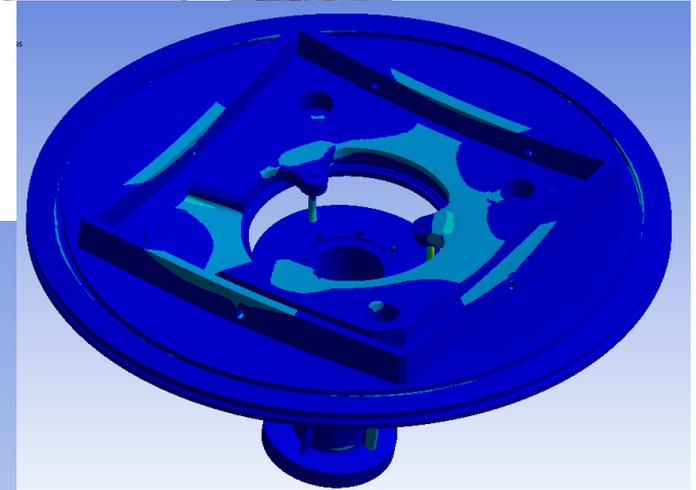
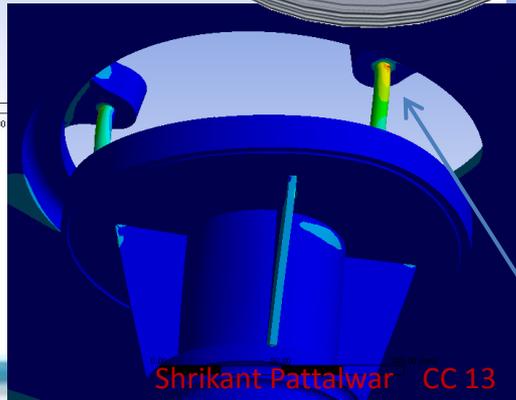
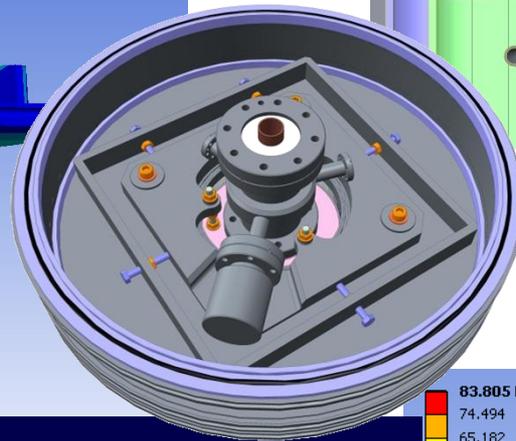
- Input RF Coupler (fixed point) also functions as support for the dressed cavity
- XYZ stage added at the top for alignment

FEA for using Power Coupler as cavity support

- FEA has been performed to estimate the likely deformation of the structure caused by the combination of the following loads;
 - Atmospheric pressure (0.1MPa)
 - Mass of the cavity string (250Kg in total)
 - Moment induced by off centre tuner (~100Nm)
- The maximum deformation of the coupler outer wall is approximately 100 μ m, however, the position of the cavity string can be adjusted after pump down using the studding on the coupler.



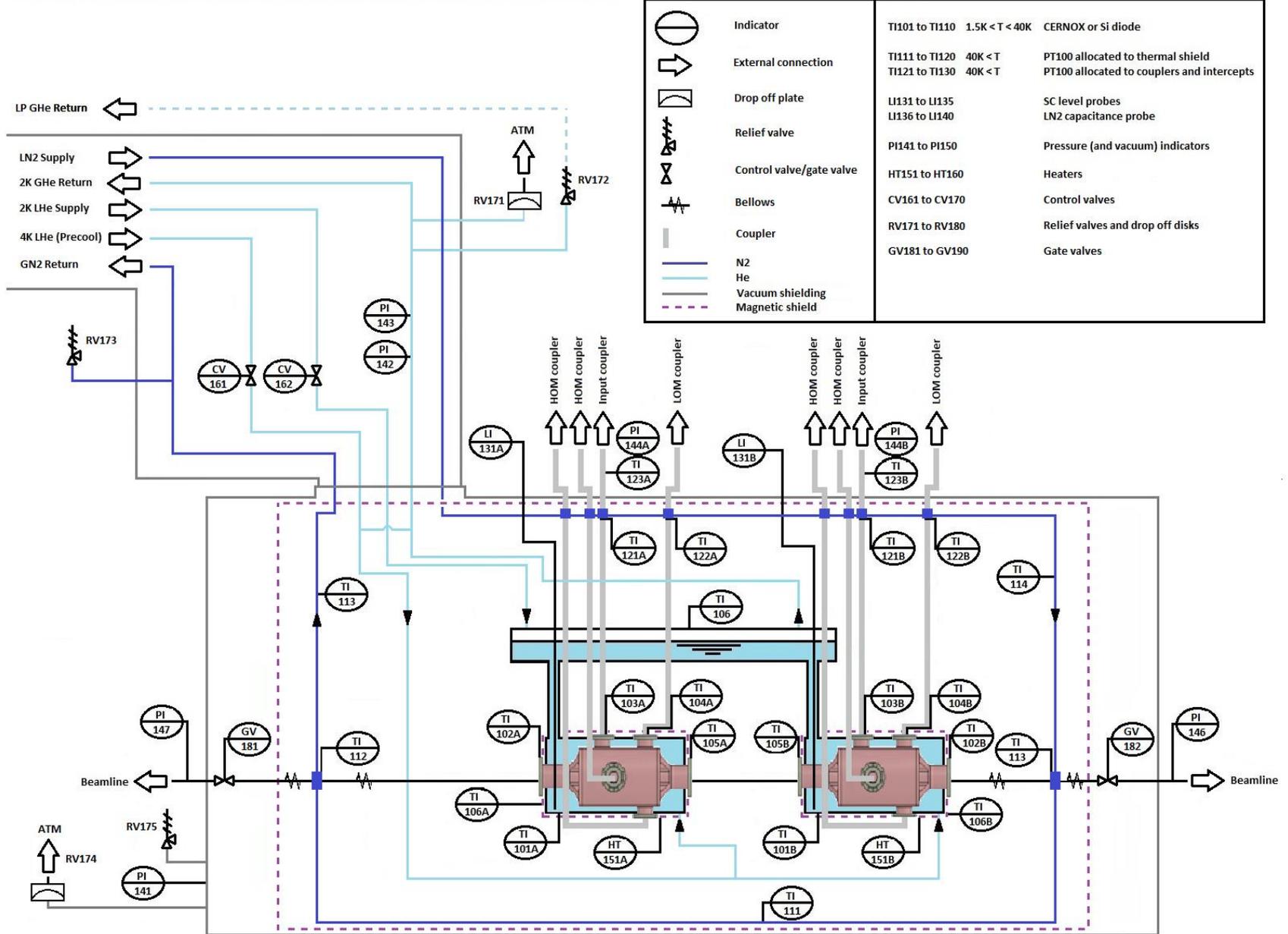
Max deformation 95 μ m
Vertical deformation 85 μ m



Maximum stress 84MPa in stud.
Minor diameter (6.6mm) of M8
stud used for analysis.

Cryomodule Schematic (P&ID)

Piping and Instrumentation diagram for LHC Crab Cavity Cryogenics System



Heat Load Estimates

300K to 80K				
Radiation Heat		static	dynamic	Total
Surface are of the Shield	m ²	6.4		
Emmissvity		0.01		
Black Body Radiation	W/m ²	460		
Total heat absorbed	W	29.44		
Heat Leak via conduction		static	dynamic	Total
Input Coupler	W	21	2	23
LOM Coupler	W	21	2	23
HOM Coupler 1	W	2	2	4
HOM Coupler 2	W	2	2	4
Other	W	2	0	2
Beam pipe	W	1	0.5	1.5
Total cavity string		2	2	2
Total	W	127.44	17	144.44
With 50% Overhead	W	191.16	25.5	216.66
LN2 consumption	l/hr	3.0586	0.408	3.46656
GN2 flow	g/S			
Size of the phase saperator	l			6.93312

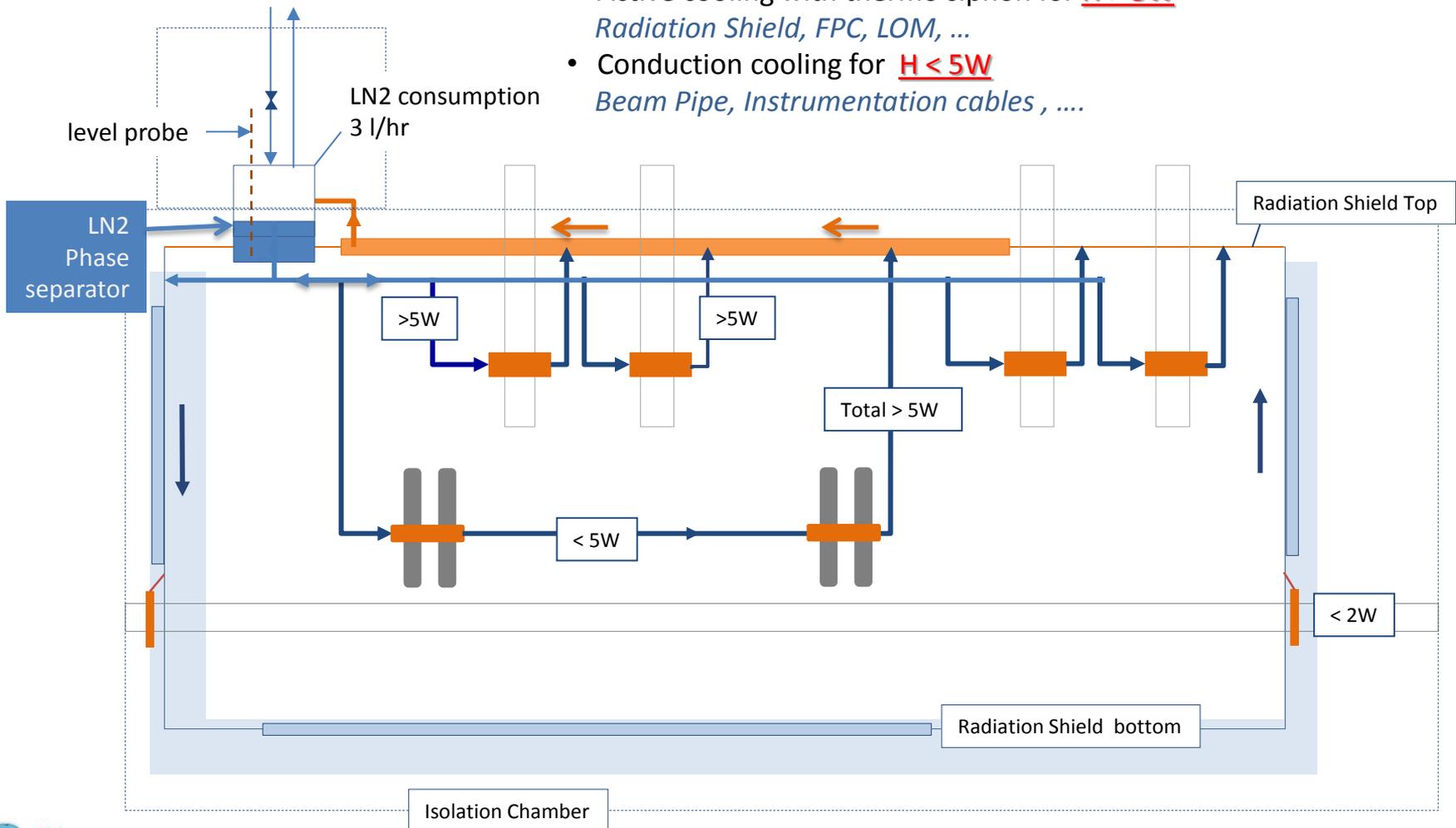
80K to 2K				
Radiation Heat		static	dynamic	Total
Surface are of the He vessel	m ²	1		
Emmissvity		0.1		
Black Body Radiation	W/m ²	2		
Total heat absorbed	W	0.2		
Heat Leak via conduction		static	dynamic	Total
Input Coupler	W	1.5	1	2.5
LOM Coupler	W	1.5	1	2.5
HOM Coupler 1	W	0.5	1	1.5
HOM Coupler 2	W	0.5	1	1.5
Other (including CWT)		0.5	0	0.5
Beam pipe	W	0.5	0.5	1
Cavties	W	0	4	4
No of cavities		2	2	2
Total	W	10.4	17	27
With 50% overhead	W	15.6	25.5	40.5
LHe consumption	l/hr	21.84	35.7	56.7

Is there a scope to reduce them?

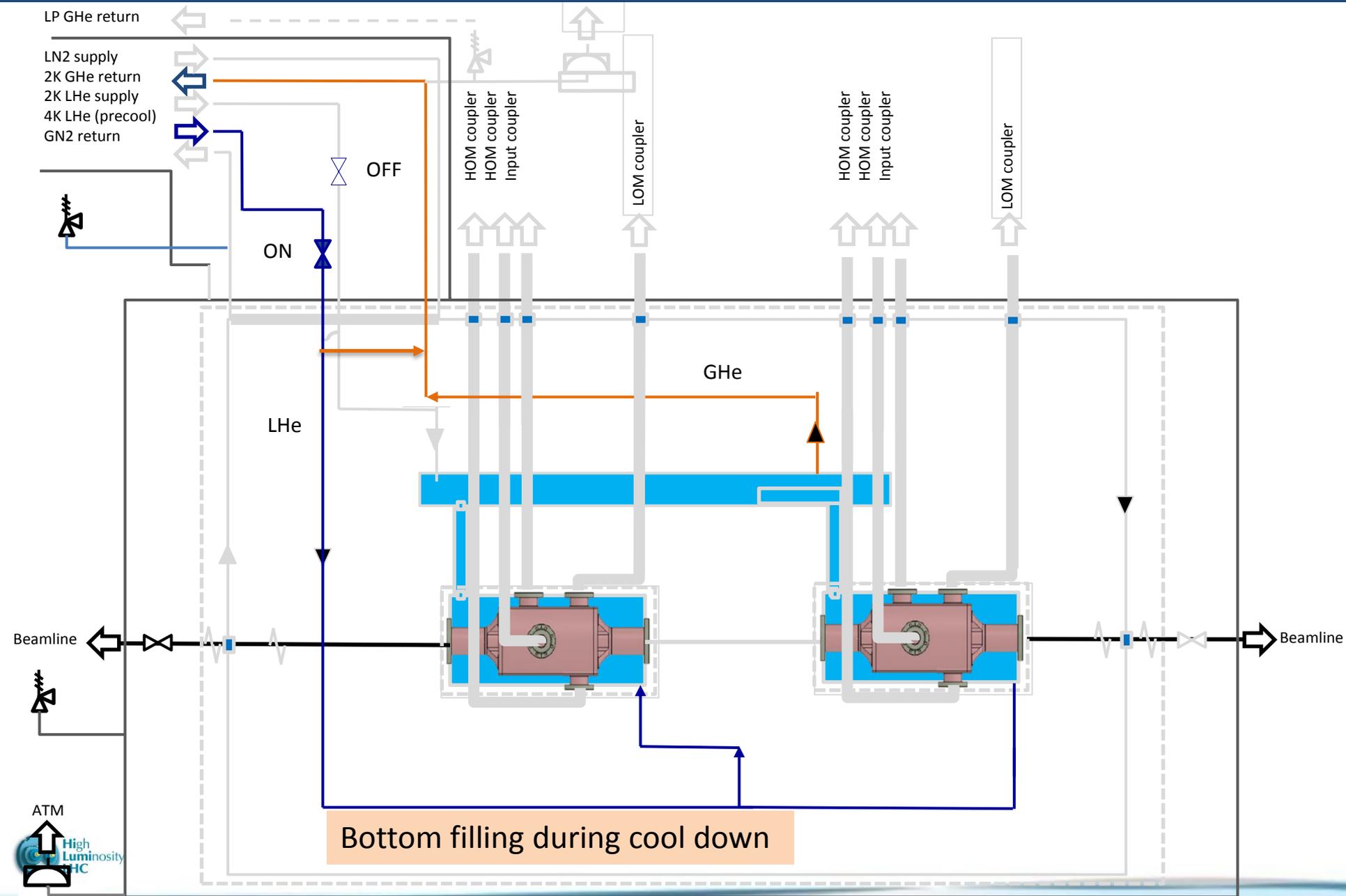
The main issue is not the limitation on the plant capacity but to match the duration of the operation with LHe inventory.

Cooling with LN2

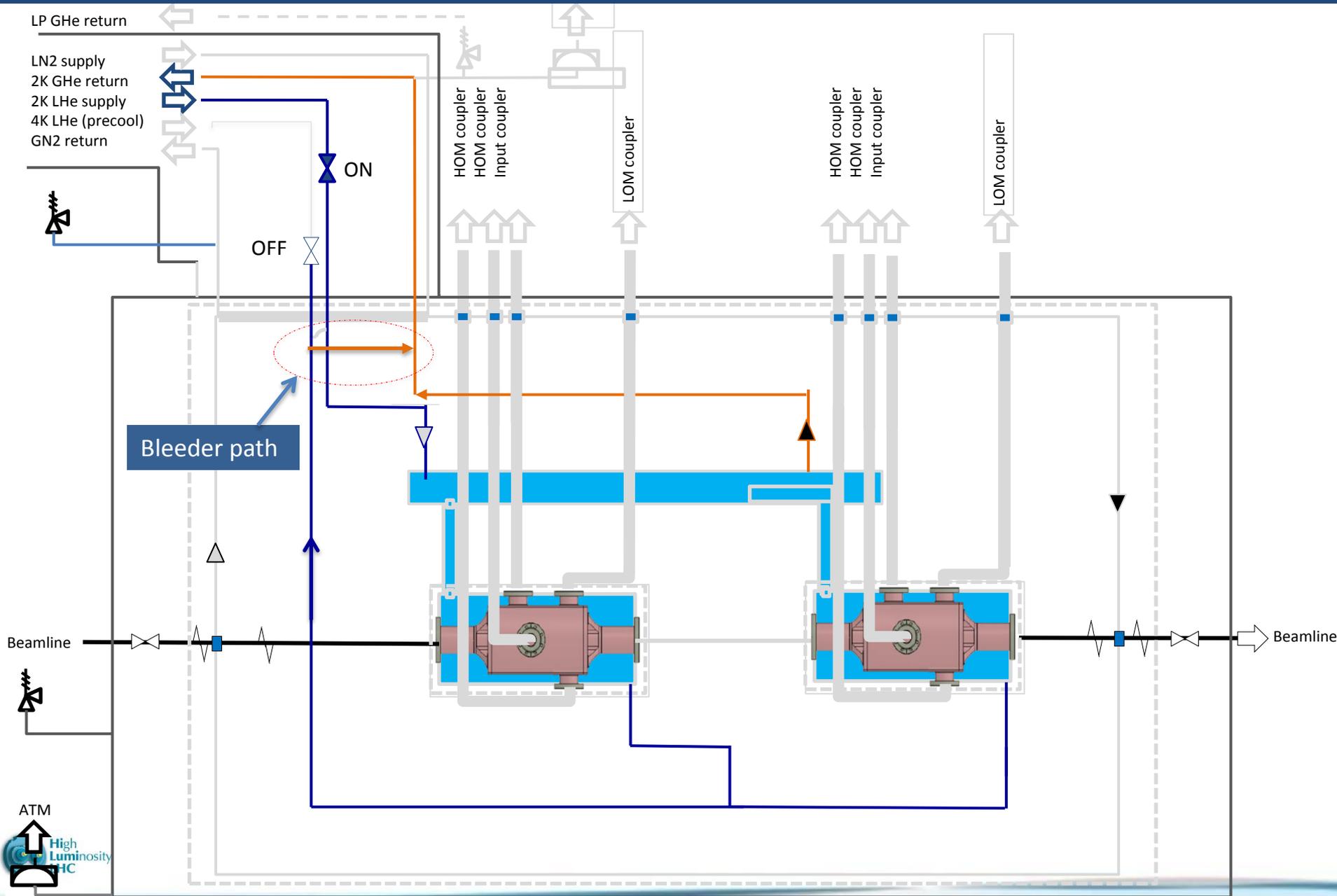
- LN2 phase separator (~ 5 lts) inside or outside the CM
- Active cooling with thermo siphon for $H > 5W$
Radiation Shield, FPC, LOM, ...
- Conduction cooling for $H < 5W$
Beam Pipe, Instrumentation cables , ...



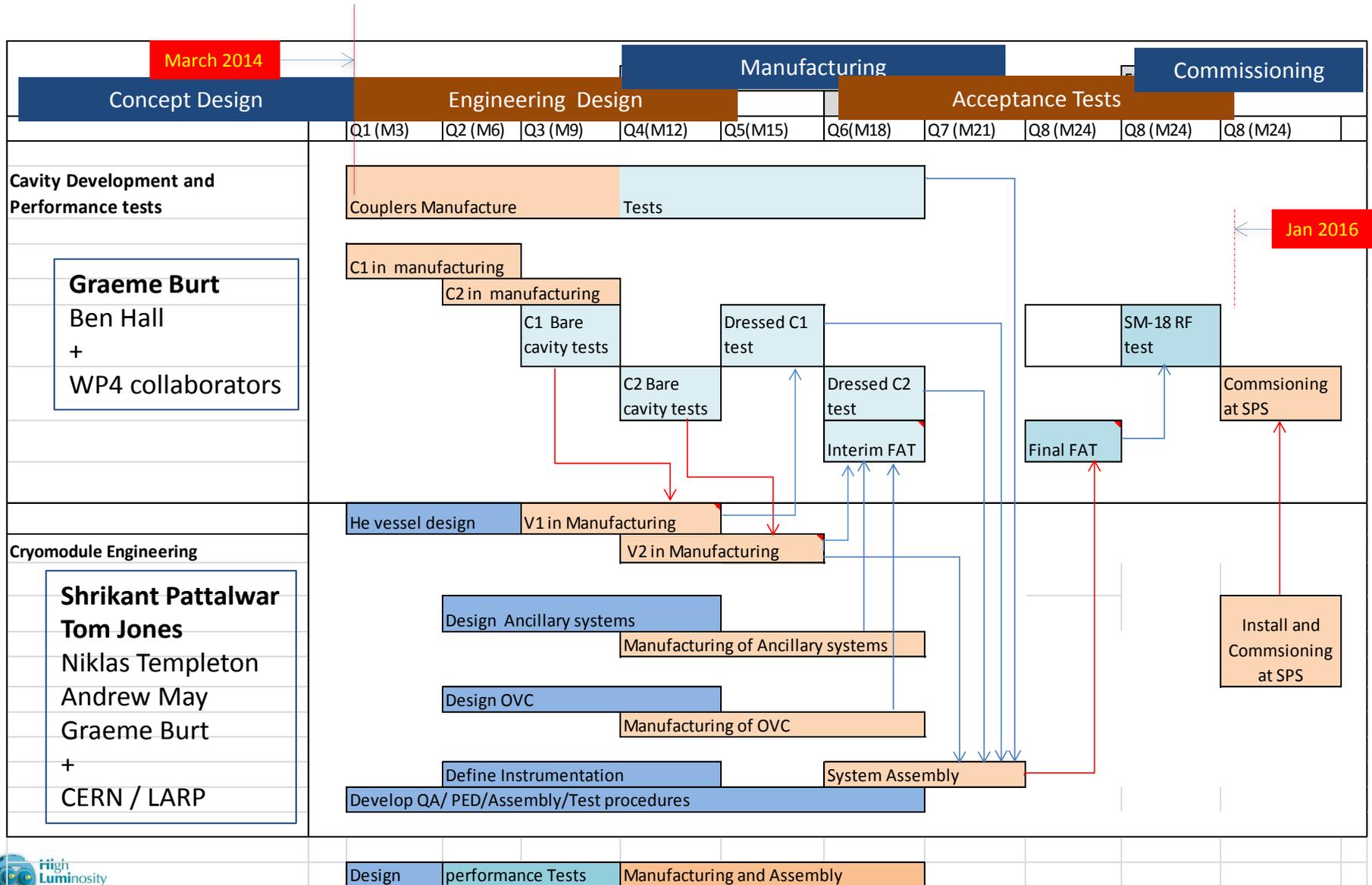
Cool down to 4K



Operation at 2K



Future Plan



Graeme Burt
Ben Hall
+
WP4 collaborators

Shrikant Pattalwar
Tom Jones
Niklas Templeton
Andrew May
Graeme Burt
+
CERN / LARP



Summary

Design Status - Some Top Level Issues		
Internal to Cryomodule		
Geometrical constraints due to Cavities (4R)	Green	
Dressed Cavity String in the Cryomodule	Green	
Cavity String with Tuner	Green	
Coupler designs (All Couplers)	Red	Red
Coupler Integration withing Cryomodule	Red	Red
Cavity and String Alignment	Yellow	Work in Progress
Heat Load Estimates	Yellow	Scope for improvement
Cryogenic Process at 4K/2K	Green	To be agreed
Cryogenic Process at 80K	Green	To be agreed
Concept Design of 80K shield	Yellow	Work in Progress
External to Cryomodule		
Compatibility with SPS	Green	
External Interfaces for RF	Red	Red
External Interfaces for Cryo	Yellow	To be defined
PED/ Safety	Yellow	Work in Progress
Harmanisation of 3 cryomodule designs	Yellow	Work in Progress
Operations and tests at SM-18	Yellow	Need More Information
Integration with SPS infrastructure (Platform)	Yellow	
Any Other ?		
.....		

Recommend to hold a special **Brainstorm** session on these issues

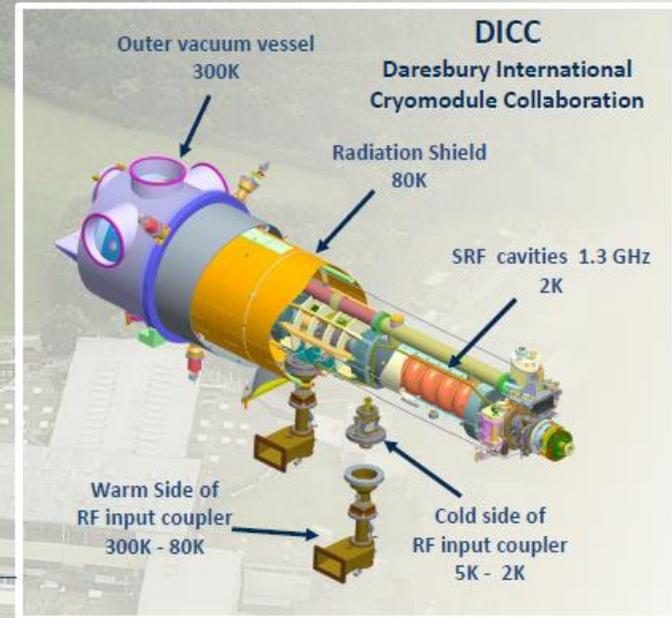
Key

- No longer an issue
- Options identified
- Issues not understood clearly



Cryogenics for Superconducting RF Development

Largest Cryoplant in the UK
operating at 2K



Collaboration with industry

Cavity Design and Manufacture

ISO 4 Clean Room

Vertical Test Facility

VTF insert

VTF in position with magnetic and Radiation shielding



cern.ch