Approach to achieving 'Fast Cool-Down' for PIP-II High Beta SRF cavities during vertical tests at the UKRI-STFC Daresbury Laboratory

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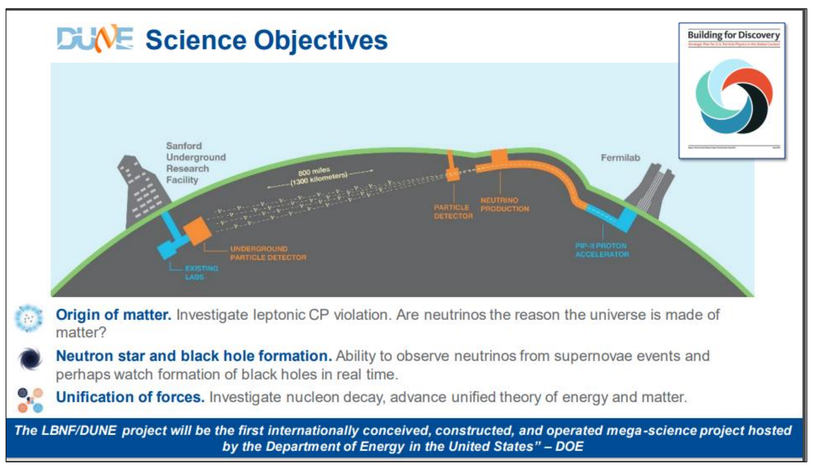
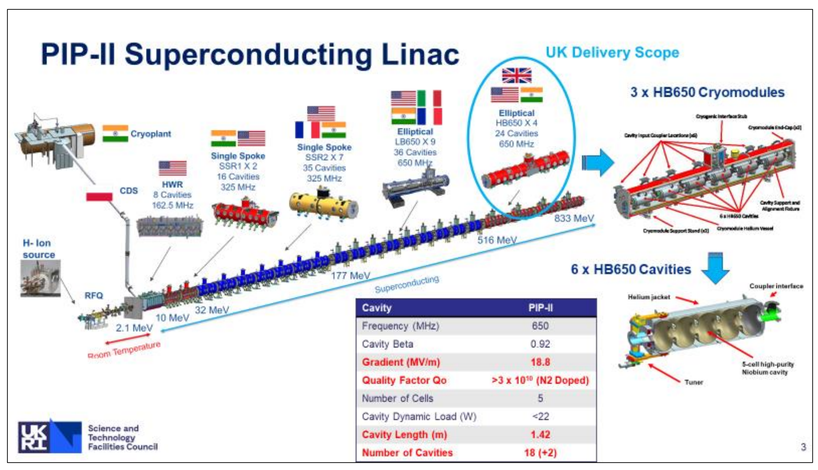
Project PIP-II through International Collaboration[5]



UKRI's in-kind Contribution[6]



Cavity	PIP-II
Frequency (MHz)	650
Cavity Beta	0.92
Gradient (MV/m)	18.8
Quality Factor Qo	>3 x 10^{10} (N2 Doped)
Number of Cells	5
Cavity Dynamic Load (W)	<22
Cavity Length (m)	1.42
Number of Cavities	18 (+2)

The Challenge

PIP-II HB650 SRF cavities have a very ambitious performance specifications of achieving a Q factor of 3 x 10^{10} at 20 MV/m
Each cavity must undergo vertical tests and demonstrate its performance before it can be qualified for assembly into a cryomodule.

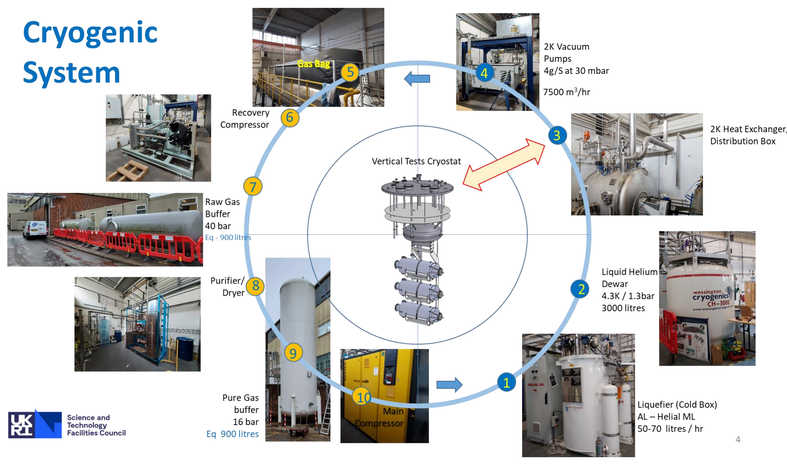
The vertical tests are conducted at 2K, in very low residual magnetic field less than 0.5μT.

In order to expel the magnetic field trapped inside the cavity it must be cooled at a very fast rate exceeding 20 K/min [1, 2,3] in the temperature range between 45K and 4K.

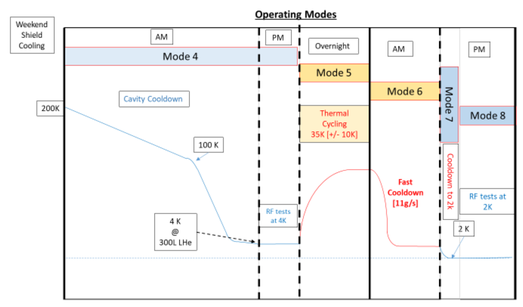
In terms of managing the process this requires a liquid helium flow rate of higher than ~ 13 g/s which is challenging to achieve in a small vertical cryostat.

In this paper we describe our solution by modifying the existing VTF design and associated cryogenic processes to meet the requirements.

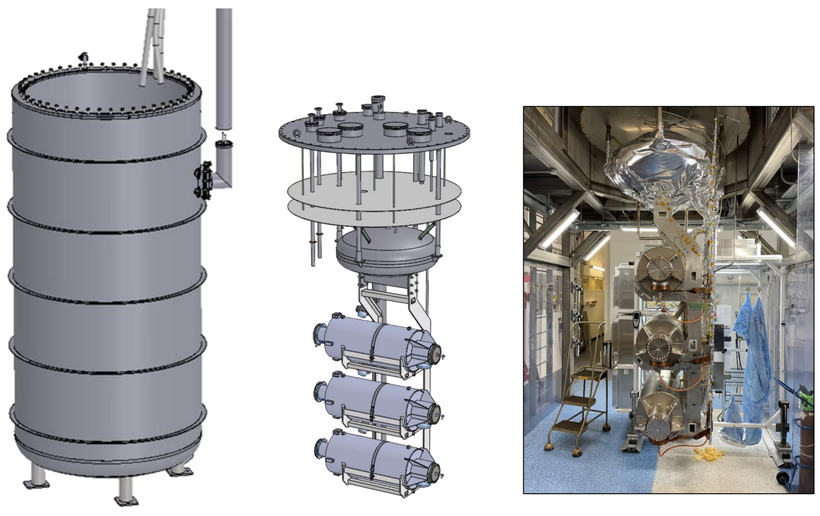
The Cryogenic System for the Vertical Tests at Daresbury Laboratory

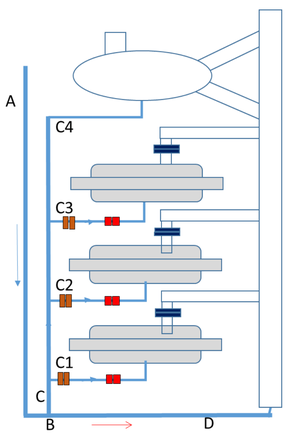


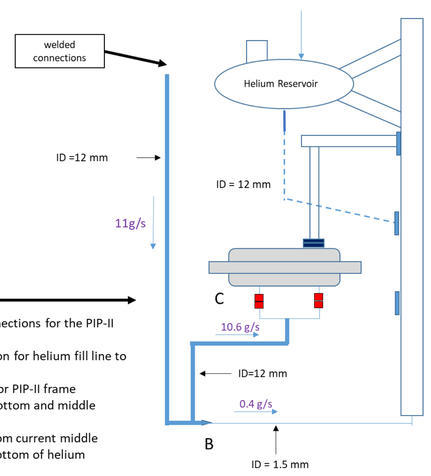
Typical Test Cycle – 10 days



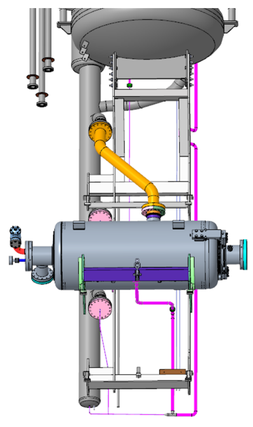
RUN N			CSI A		
Mode	WK-Day	Day	Task	Hours	Op_Type
1	Wed	1	Load the Cavity	2	Manual
			Make Cryo Connections	2	Manual
			Connect RF cables	0.5	Manual
			Install Thermometry	2	Manual
2	Thu	2	RF Checks	2	Manual
			Cryo-Leak Checks	3	Manual
			Install MLI	1	Manual
	Fri	3	Move to Bunker	1	Manual
			Cryo-Connections	2	Manual
			RF Connections	2	Manual
	Key Target >>		P&P + Start Cooldown	4	Manual
3	Sat	4	Shield Cooldown		Auto
4	Sun	5	CSI cooldown / 4K		Auto
5	Mon	6	RF Cable Cal and Thermal Cycling		Manual
6	Tue	7	Fast Cooldown	2	Manual
7			Top up and Cooldon to 2k	3	Auto
8			RF Tests - Day 1	6	Manual
7a	Wed	8	LHe- Top up Spare	5	Auto
8a			RF Test dat 2 Spare	6	Manual
9	Wed		Warm up		Auto
	Thu	9	Warm up		Auto
	Fri	10	Warm up		Auto
	Sat	11	Warm up		Auto
	Sun	12	Warm up		Auto
10	Mon	13	CSI Removal - to Stand		Manual
			Disconnect Cryo		Manual
			Unload cavity (Key Target)		Manual
			Run Complete		
	Tue	14	Preparations for Next Run		

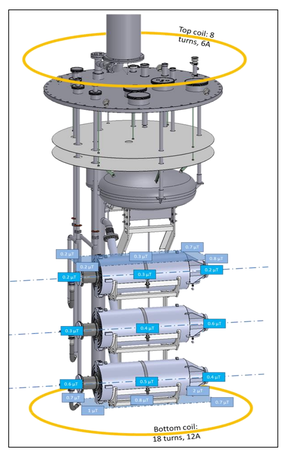






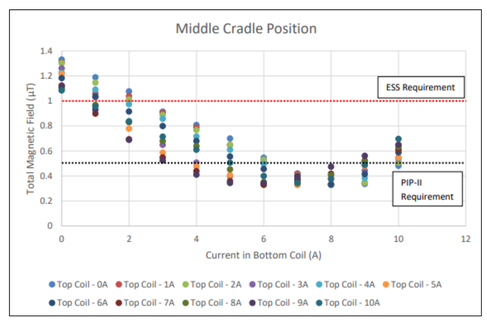
- Weld all connections for the PIP-II configuration
- Tee connection for helium fill line to cavity
- ESS bracket for PIP-II frame
- Cut off the bottom and middle phase.
- Weld pipe from current middle diphase to bottom of helium reservoir





- The existing VTF is designed to test 3 x HB704 cavities for the **ESS**[4] . LHe flow is distributed in 5 parallel branches and each cavity is cooled very slowly (< 1g/s) .
- The limiting flow of 11 g/s is primarily governed by the capacity of the helium recovery system.

- In the modified design we propose to flow liquid helium through one branch (with only one cavity) and maximise the LHe flow to 11 g/s.
- The cavity is positioned in the region of with the magnetic field below the required limit 0.5 μT.
- The Earth's magnetic field is reduced firstly by using the Mu metal shield around the cryostat and secondly with 3 active field coils



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References

1. **Wu, G. et al.**, Achievement of Ultra-High Quality Factor in Prototype Cryomodule for LCLS-II https://arxiv.org/pdf/1812.09368

2. Romanenko, A. et al., Dependence of the residual surface resistance of superconducting radio frequency cavities on the cooling dynamics around Tc https://pubs.aip.org/aip/jap/article/115/18/184903/138836/Dependence-of-the-residual-surface-resistance-of

3. Posen, S. et al., Role of magnetic flux expulsion to reach Q0>3×10e10 in superconducting rf cryomodules https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.22.032001

4. **May, A. J., et al.,** "Results and analysis of the first year of operation of the UKRI STFC Daresbury Vertical Test Facility", ICEC28-ICMC2022, Hangzhou, China, 2023

5. https://pip2.fnal.gov/how-it-works/introduction/

6. https://gtr.ukri.org/projects?ref=ST%2FS005773%2F1