Status of CC cryomodules

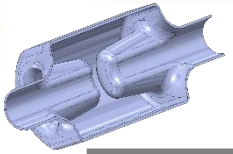
Niklas Templeton – STFC Daresbury Laboratory
On behalf of the UK Crab Cavity collaboration

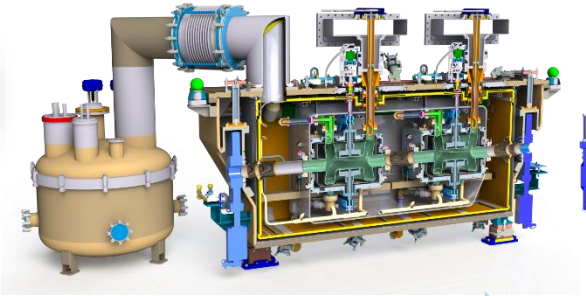
13th HL-LHC Collaboration Meeting – Vancouver (CA) – 26 Sep ‘23

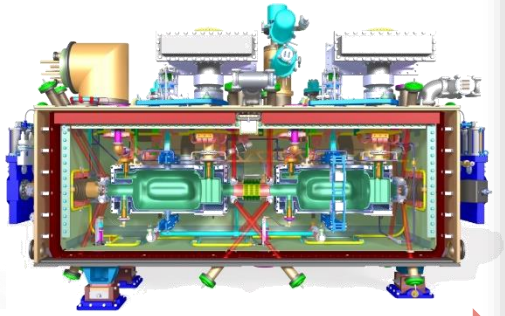
Status of CC cryomodules

- UK involvement in HL-LHC Crab Cavities
- RFD SPS Cryomodule Build
  - Last 12 months
  - Challenges & Lessons Learnt
- DQW LHC Cryomodules
  - Challenges & Continuous Improvement

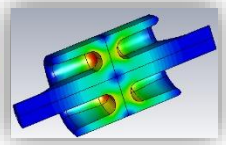
UK involvement in WP4 collaboration

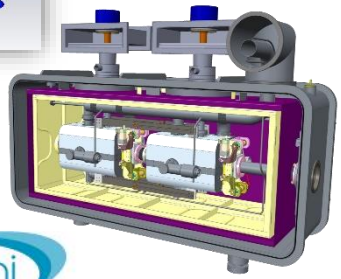


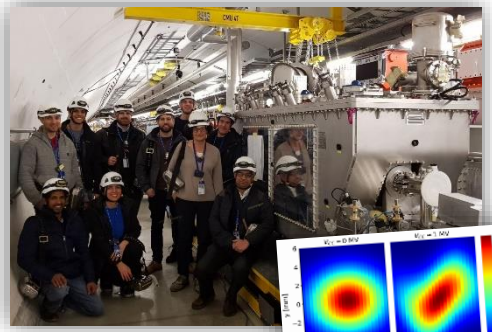




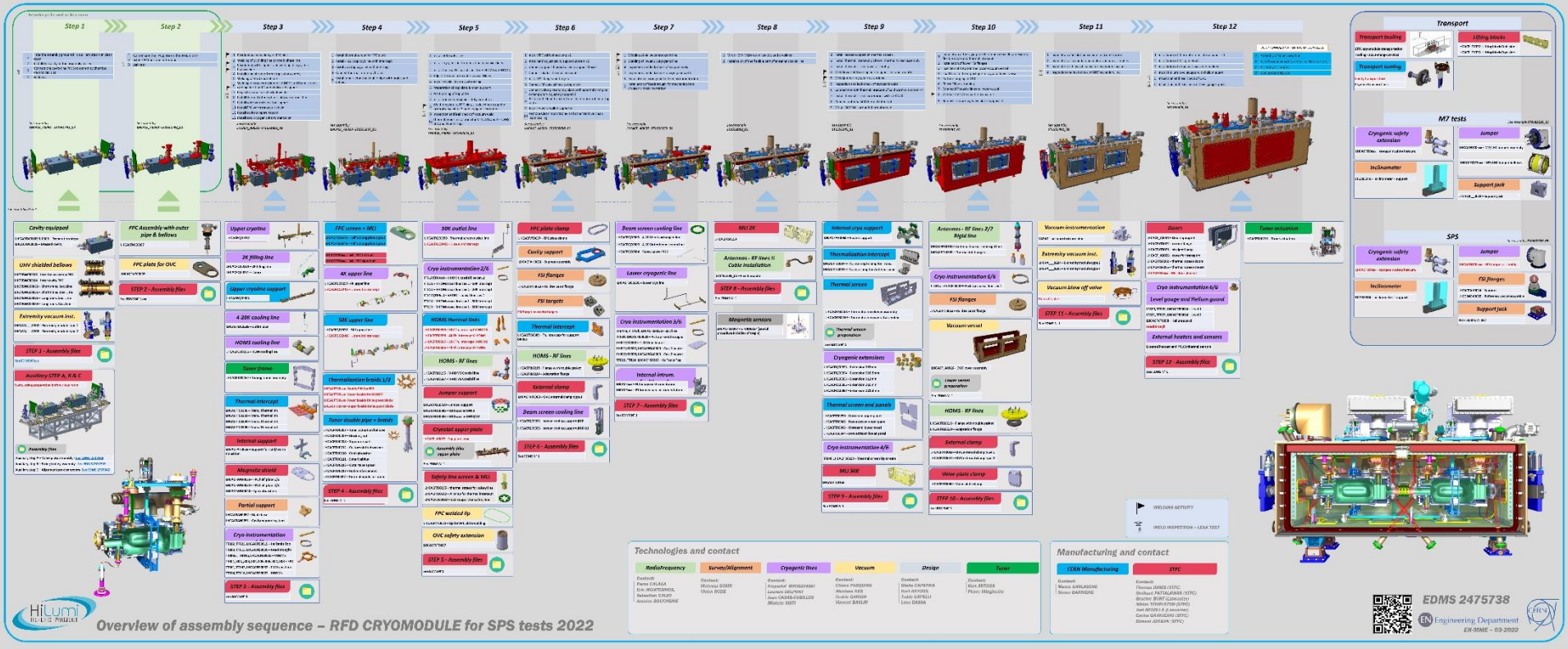
2011 — 4-Rod Crab Cavity → DQW Prototype CM → RFD SPS CM → DQW LHC CMs → 2025





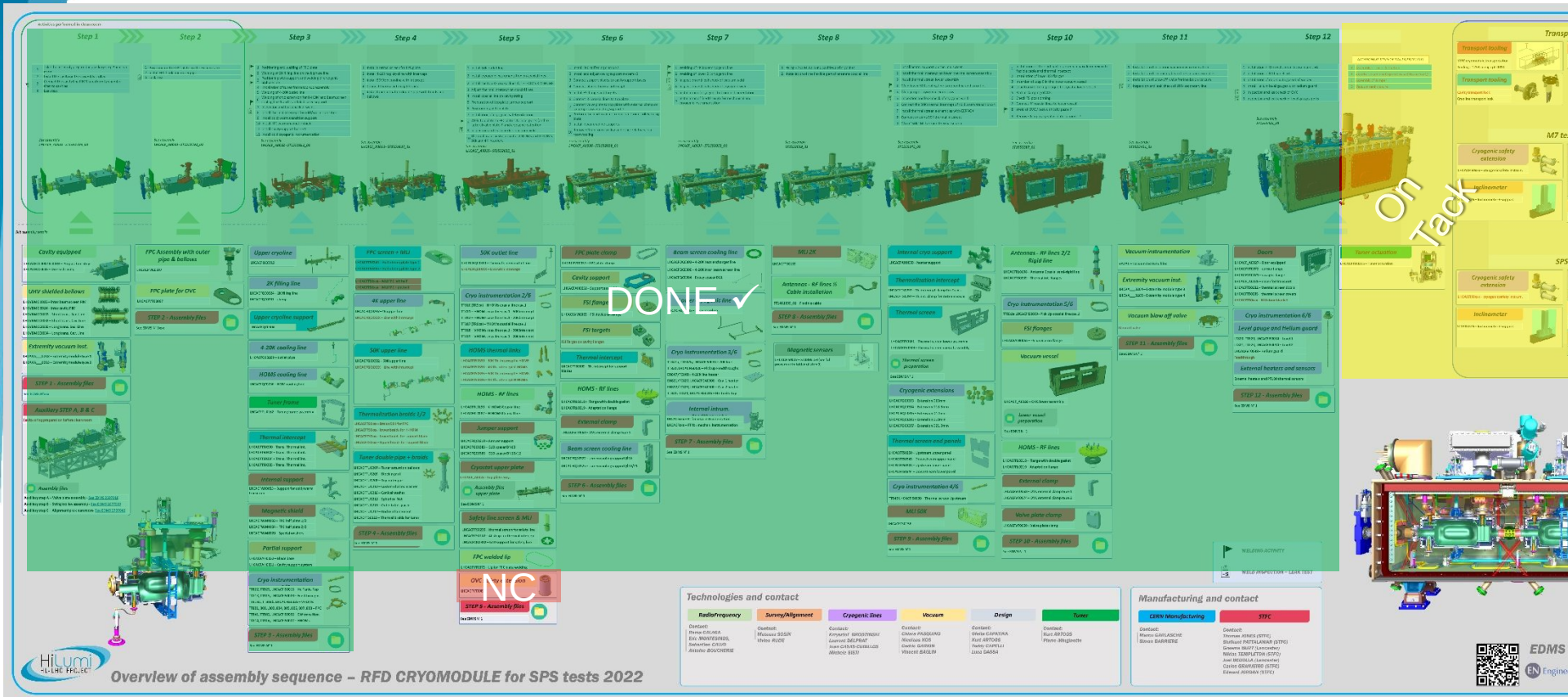


RFD SPS Cryomodule Build

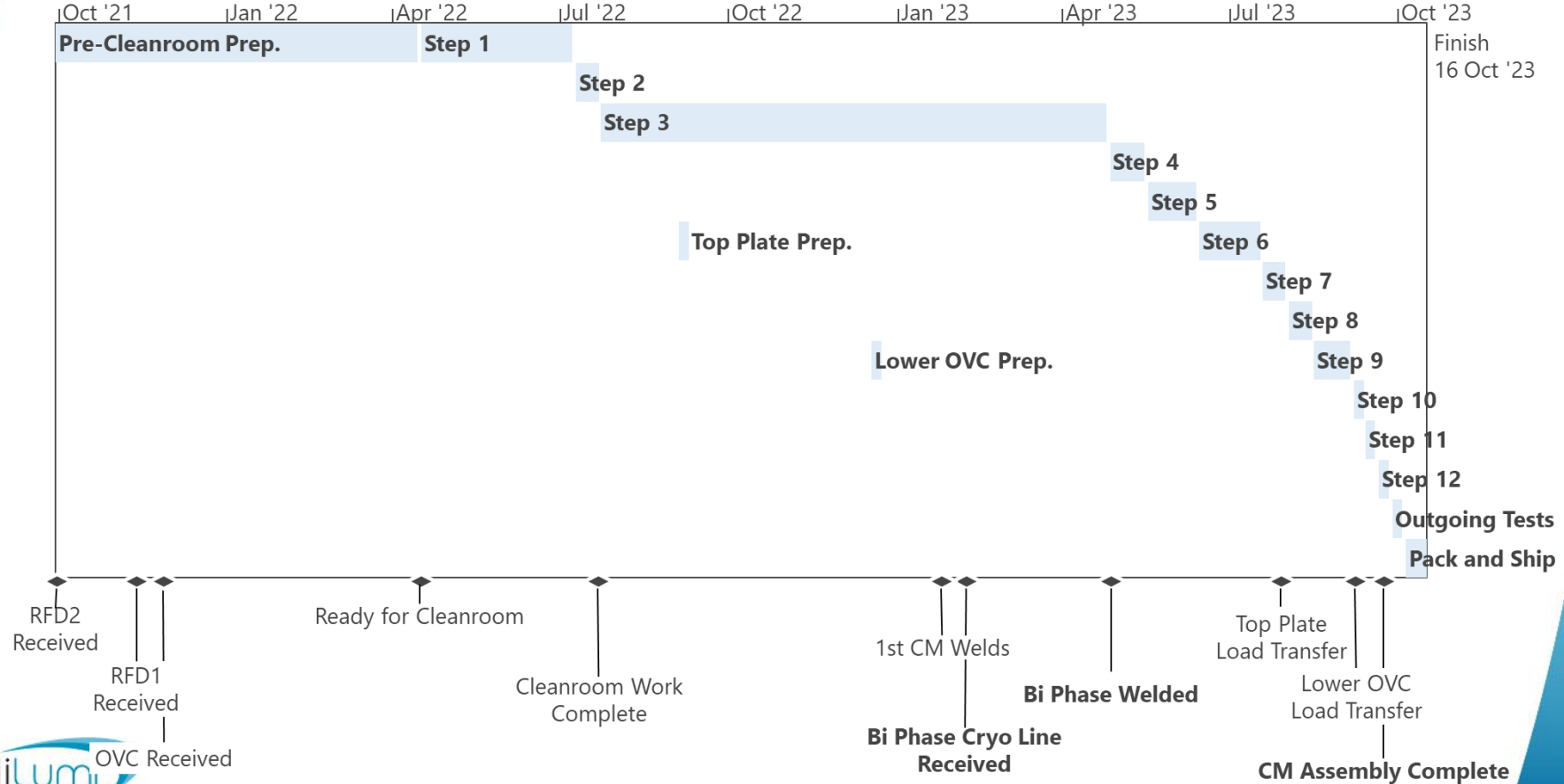


Poster by Teddy Capelli

Status Sep ‘23

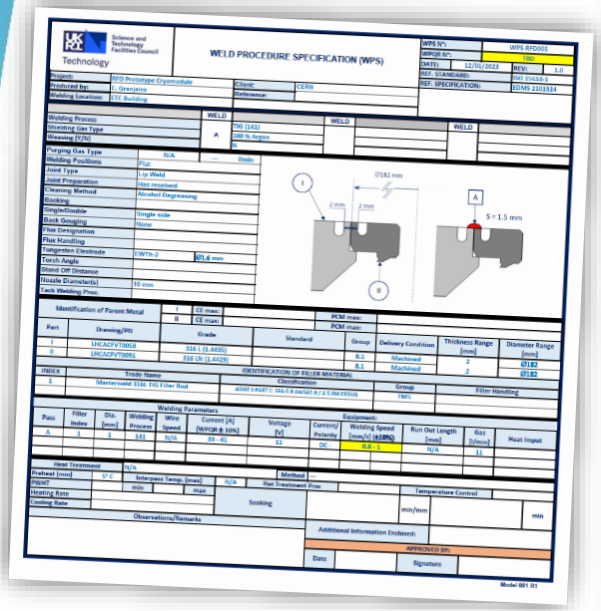


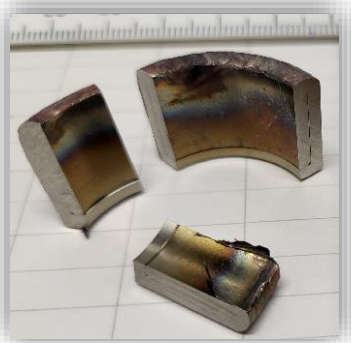
RFD *As-Built* Timeline (simplified)

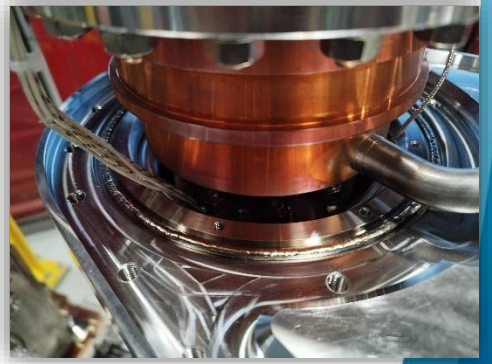


Highlights (last 12 mo.)

- Coded welding qualification & 1st CM welds – Jan ‘23







Highlights (last 12 mo.)

- Top Plate Equipped - Warm Mag Shield, Thermal Screen, MLI
- New MLI skills!

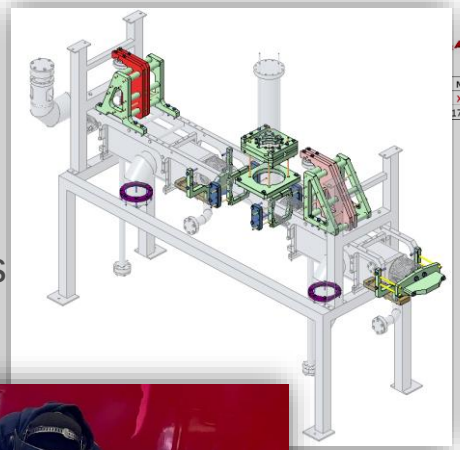
~~Highlights~~ (last 12 mo.)

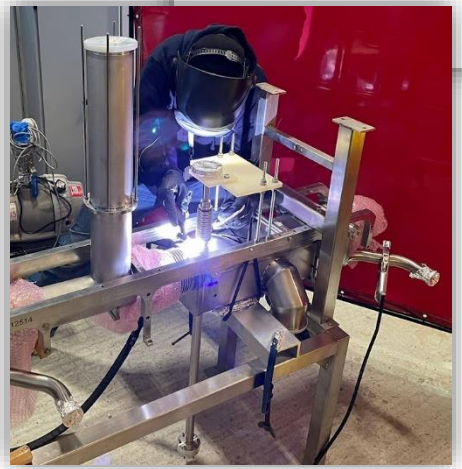
- Bi Phase Cryoline delivered Feb ’23
- 18 months late
- Several NCs found after delivery – some with major impact
- Pressure test failure
  - Rig design not fit for purpose

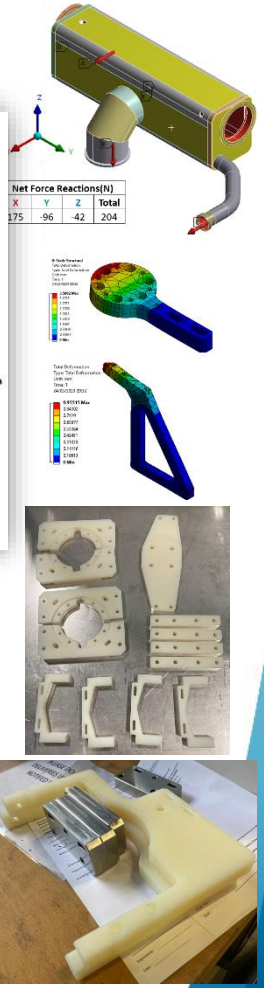
Highlights (last 12 mo.)

Bi Phase line NC resolution

- New Pressure Test Rig
  - Developed & delivered in-house min timescales
  - 54 components
  - 24 unique parts
  - FEA verification
- He Level Ports replaced in-house
- Re-qualification tests passed ✓

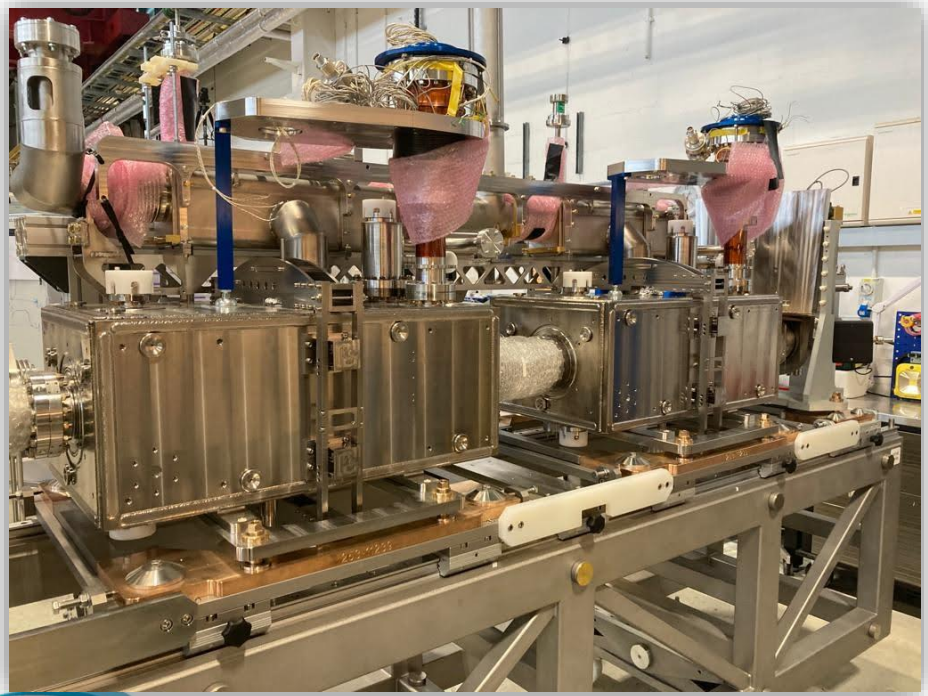






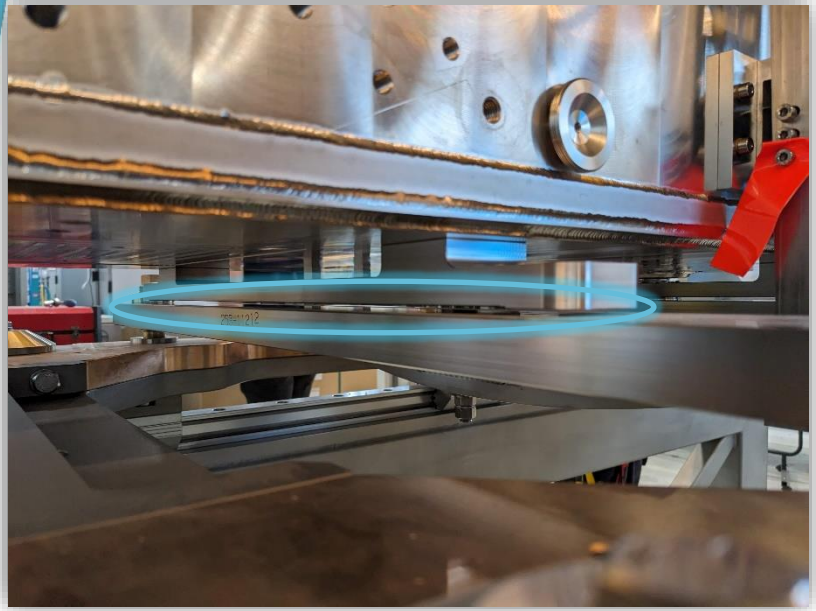
Highlights (last 12 mo.)

- Bi Phase, Tuner & Top Plate integration (steps 3-5)



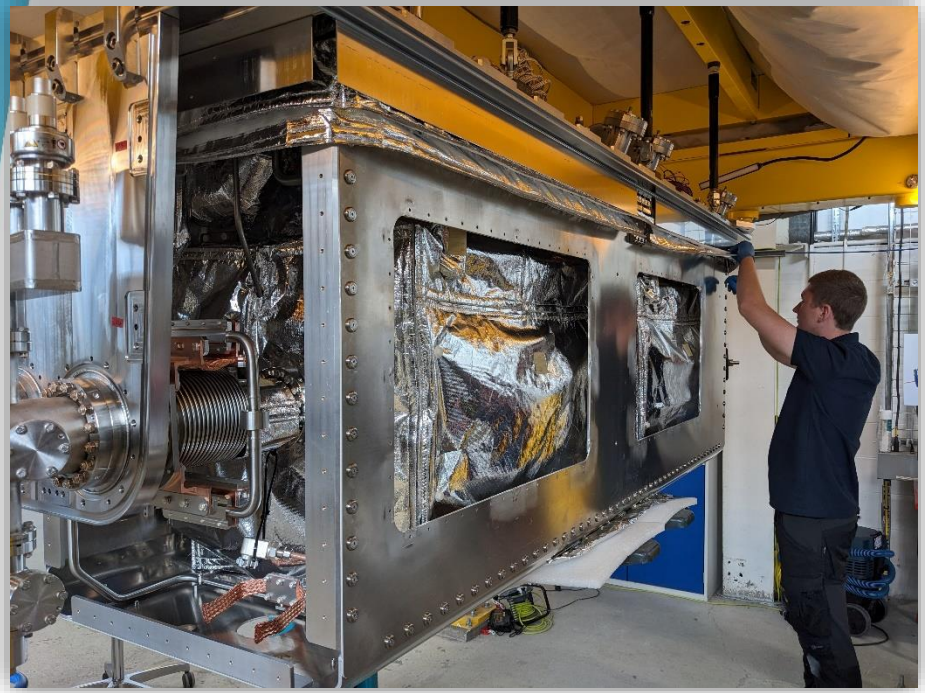
Highlights (last 12 mo.)

- Cavitystring to Top Plate load transfer (step 6)



Highlights (last 12 mo.)

- Thermal Screen & 50K MLI (step 9)



Highlights (last 12 mo.)

- Lower OVC integration

Highlights (last 12 mo.)

Many CERN visitors for knowledge transfer & build support:

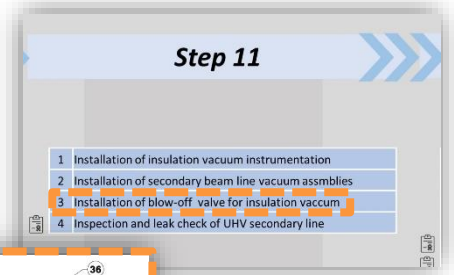
- RF
- Fibre optic strain gauge
- Survey & alignment
- Cryo instrumentation
- TIG & orbital welds
- Tuner assembly
- Management & load transfer oversight
- Transport tooling & logistics

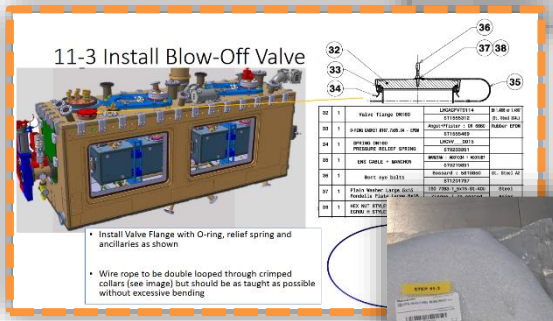
Highlights (last 12 mo.)

- Elegant solutions to incidental challenges
- Faster in-house manufacturing
- Vacuum & pressure test rigs & procedures
- 3D printed leak test tools (clamshells)
- Qualification of assembly tooling & infrastructure
- *Organisational evolution*

Assembly Procedures

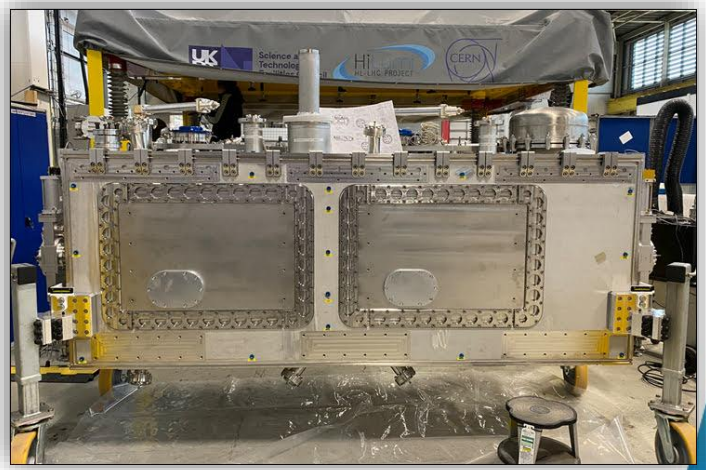
- Based on poster logic + tooling & infrastructure
- To troubleshoot & de-risk technical tasks
- ‘BOM kits’ can be prepped by sub-step
- Extremely valuable for LHC CC Cryomodules
- Includes requirements, torques & sign-off checklists for travellers





Some RFD Metrics

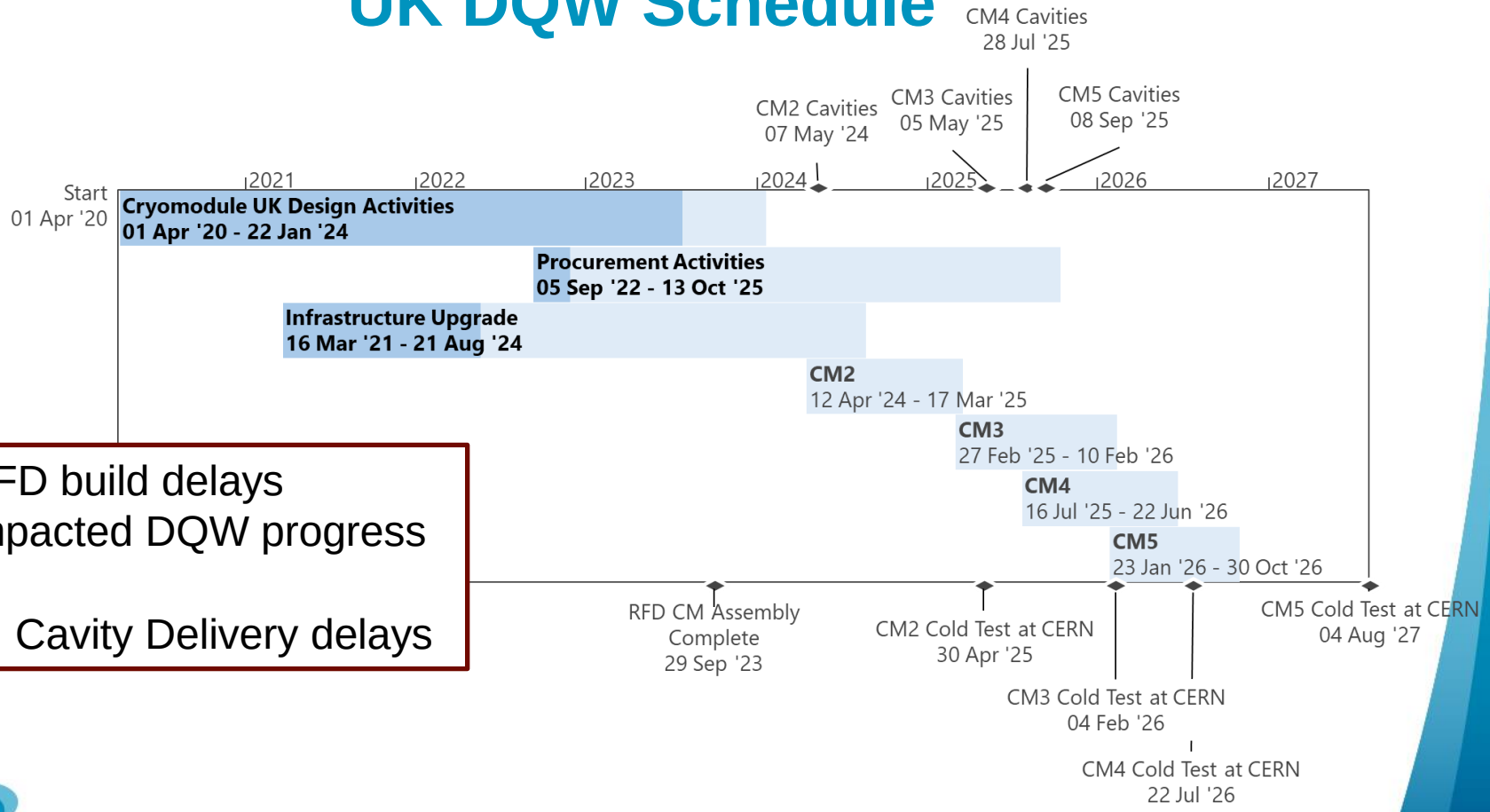
- Total Assembly Procedures = **840 pages!**
- Cryomodule Components: **10K (>5k unique)**
- Tooling drawings: **524**
- **28** NCRs **Resolved**
- Total build team effort **<9 FTE per year**!
  - FT engineers & technicians + shared specialist & support staff
  - *not including apprentice effort



Challenges & Lessons Learnt

- Integration complexity, sensitivity & design ‘teething’
- Recruitment & retention
- Supplier QA Management
- Internal QA & EDMS/MTF management effort
- Material specifications, traceability, coating & cleaning
- Co-ordinating specialist support & visits

UK DQW Schedule



- RFD build delays impacted DQW progress
- RI Cavity Delivery delays

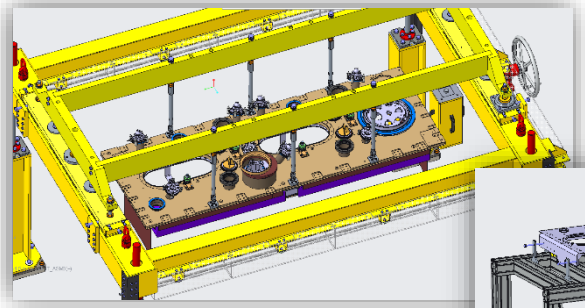
DQW Tooling & Infrastructure

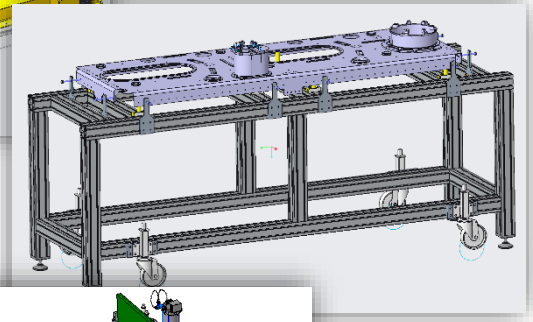
(Re)design work:

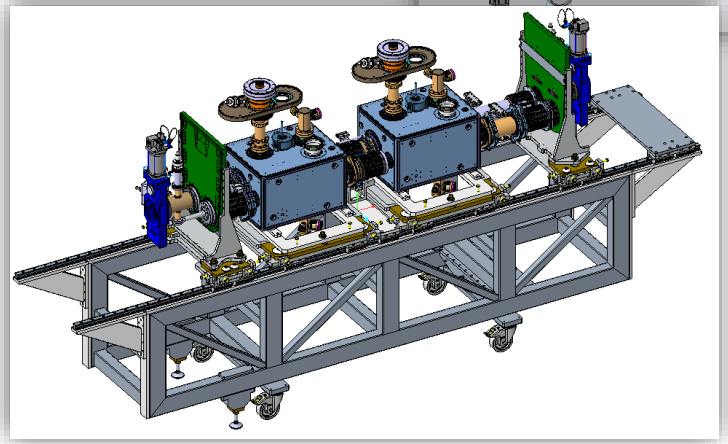
- Top Plate Lifting Gantry Mods ✓
- Transfer Table ✓
- Cavitystring tooling – nearly done

Next:

- Anti-shock transport frame
- Bi Phase Qualification Rig

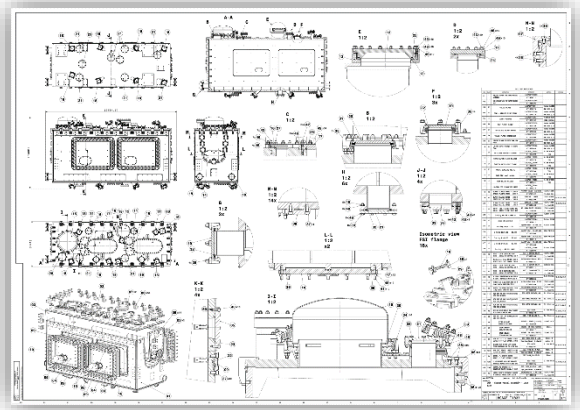


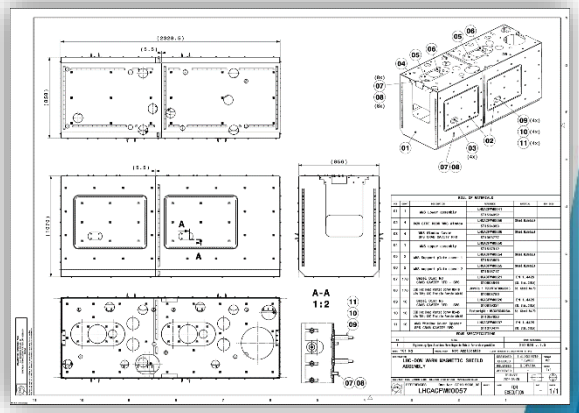




DQW Cryomodule Procurement

- Beamline vac equipment - received or on-order
- Cavitystring Trolley II - received
- 2x common string trolley tooling - on-site
- OVC tender - live
- Warm Mag Shield tender - live
- Cryolines materials & fabrication - on-going (critical)





DQW Improvements

More info in WP4 break-out talks

- More staffing & more experience

Infrastructure upgrades

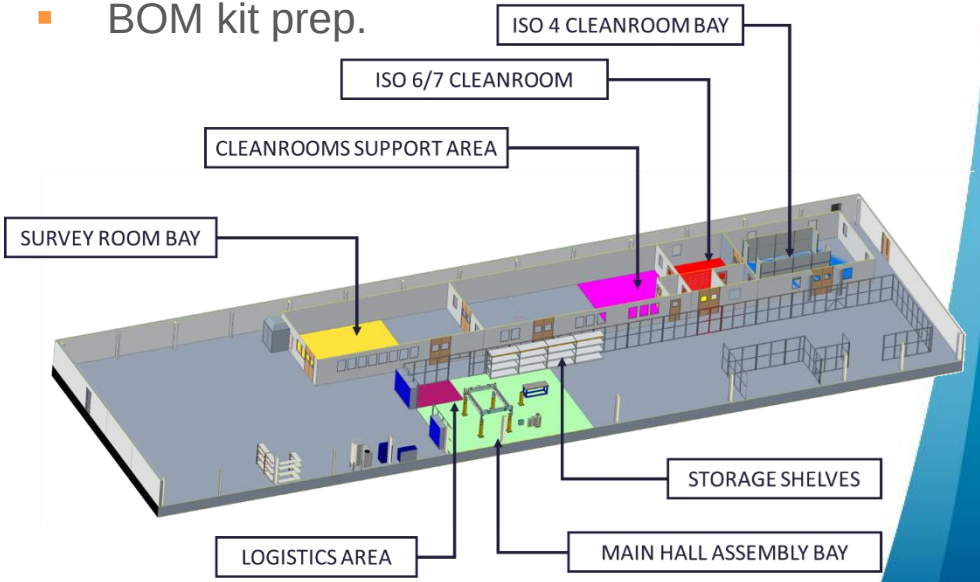
- Parts management workstation ✓
- Build area flooring
- Improved storage, workbenches & layout

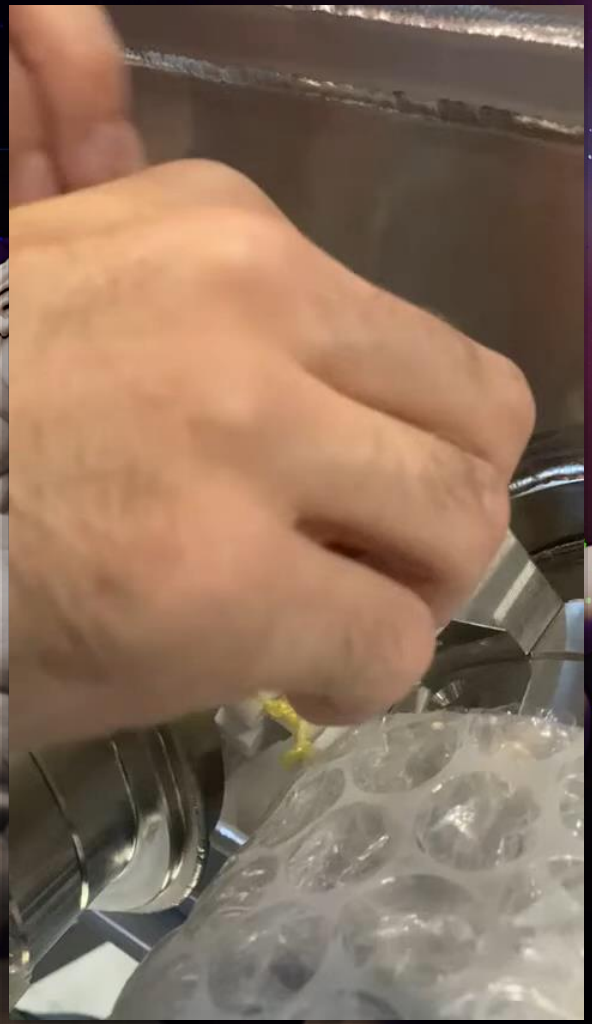
Parts management

- 5S consultancy discussions ✓
- ID > QC > Processing > Label + Storage

Technical sub-team

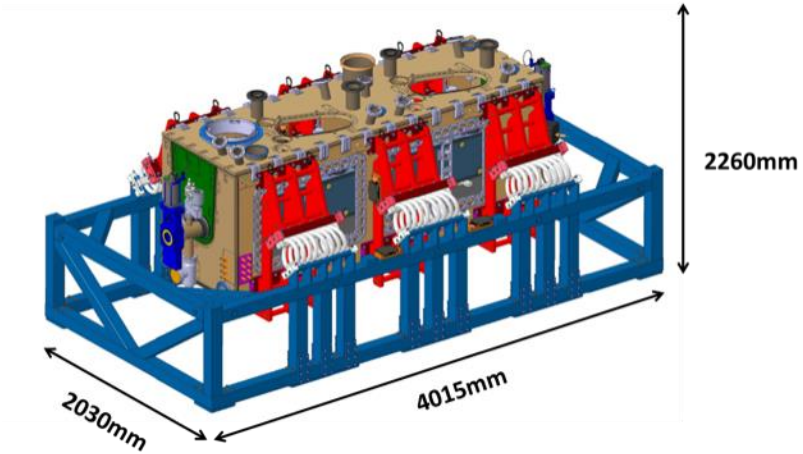
- Dimensional control
- Mock assembly
- Managing cleaning etc.
- BOM kit prep.





Shipping

- Agreed with CERN to use CERN transport team and truck



Formulaire_demarrage | Liste_Poids_lourd | Formulaire_Poids_Lourds

EN ENGINEERING DEPARTMENT

CERN

Poids Lourds

N° CERN 384

Marque :	MERCEDES-BENZ	Type :	ANTOS 1832
Plaques :	GE 565100	Mise en service :	29.10.2015
N° chassis :	WDB 963 003 1L9 878 82	Prix :	CHF 114 500,00
Détenteur :	MAZZARINO THIERRY 160364	Hayon :	LV-00283
Contrôle technique :		N° commande :	CA 6041122
Permis :	Permis 384	Plan :	

Longueur :	9500
Largeur :	2550
Hauteur plateau :	3655
Poids à vide :	9000
PTRA :	18000
PTAC :	18000
Charge Utile :	9000

Recherche par n° CERN | Recherche par plaque | Effacer la recherche

HiLumi HL-LHC PROJECT

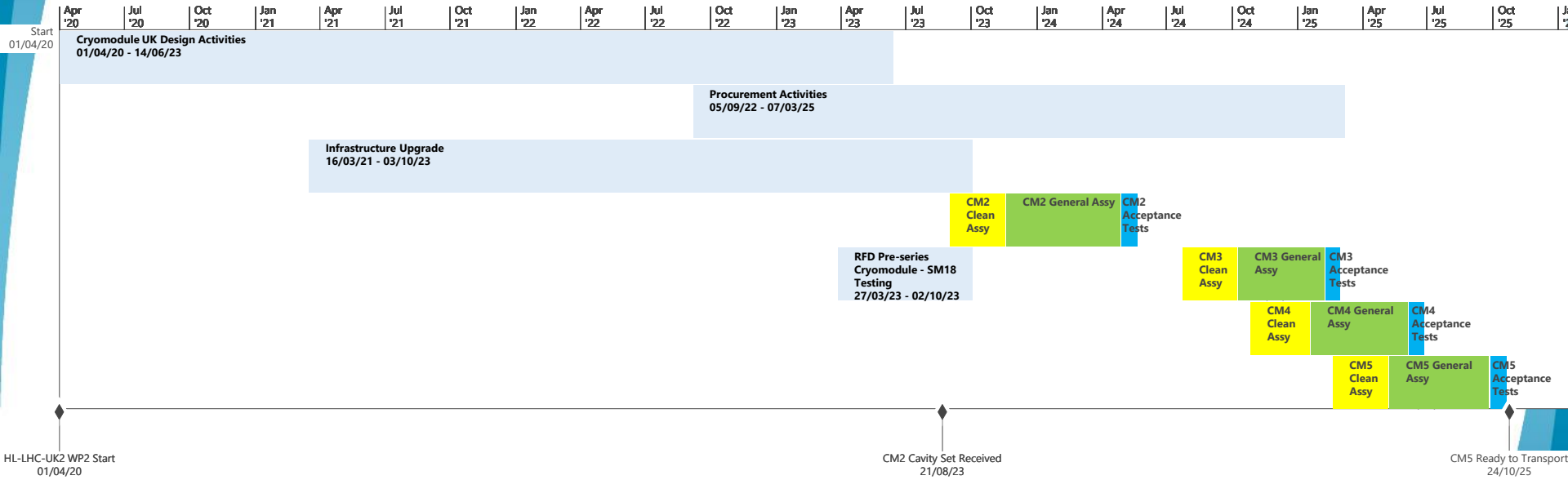
Shipping

- Documentation is progressing well with tight coordination between AJBM + Ben Lewis (STFC Logistics) + Simon Barriere (CERN)

RFD Crab Cryomodule Shipping Items

Category	Grouped sub-system	Total ex. VAT(£k)	Country of origin	Commodity code	Notes	Notes (to be deleted when complete)	Sub-System (to be deleted when complete)	Unit cost ex. VAT (£k) (to be deleted when complet	Quantity Required (to be deleted when complet	Total ex. VAT(£k)	Notes Ofelia - cost from DQW manufacturing (kGPB from kCHF)	kCHF part TTC	Notes
													GBP to CHF exchange rate: 1 GBP =
Cryomodule	2x Jacketed RFD cavities	2079	CH		Shipped from CERN		RFD Cavity	849.4	2	1699	849.4	1145	
							RFD Helium Vessel	178.0	2	356	178.0	240	
							Cold Magnetic shield	12	2	24			
	RF couplers	582	CH		Shipped from CERN	FPC value from UK1_SHIPMENT_TRANSPORT_UST_rev5B_17-09-21	RFD Full set of HOMs	146.1	2	292	146.1	197	
							RFD Probe	14.8	2	30	14.8	20	
							RFD Fundamental Power Coupler	74.2	2	148	74.2	100	
							RF internal lines (HOM, pick-up, FPC double tube)	111.3	1	111	111.3	150	
	2x Mechanical tuners	163	CH		Shipped from CERN		RFD Tuner	81.6	2	163	81.6	110	
	Outer vacuum chamber	126	Italy				Outer Vacuum Chamber	126.1	1	126	126.1	170	includes missing material and flang
	Outer magnetic shield	43	UK			Andy confirmed price from RFS	Outer Magnetic shield	37	1	37	37.1	50	
	Thermal shield	63	CH		Shipped from CERN		Thermal shield	63	1	63	63.1	85	
	Multi-layer insulation blankets	18	France		Shipped from France to UK by UPS, numéro de suivi 1Z2470A3869010363?; add 2 other refs		Multi-Layer Insulation	19	1	19	18.5	25	
	Cavity support system	27	UK			15140+Vat for blade support assemblies from ASSP; Cavity support system 5999x2 from TSW	Cavity Support System	19	2	37	18.5	25	Only blades and adjustement syste
							Cryomodule Support System	11	1	11	11.1	15	lines to be provided by CERN
	Alignment measurement system	37	CH		Shipped from CERN		Cavity FSI Alignment System	37	1	37	37.1	50	
	Cryogenic and vacuum instrumentation	119	CH		Shipped from CERN		Cryogenic Instrumentation	89	1	89	89.0	120	
	8x Vacuum bellows (various)	89	CH		Shipped from CERN		Vacuum Instrumentation	30	1	30	29.7	40	1/2 of gauge budget for BAS from
	4x Vacuum valves	356	CH		Shipped from CERN		Cold to Warm Transition and Shielded Inter-cavity Bellows	22	4	89	22.3	30	
							Vacuum Valves	89	4	356	89.0	120	
	Cryogenic pipework	152	UK			Andy confirmed cost from Oracle+RFS; inc. upper line support	Cryogenic internal lines	100.0	1	100	115.0	155	
							Welding internal lines during assembly	25.0	1	25	51.9	70	based on price of assembly job at C
	Fasteners and ancillaries	74	UK				Fasteners and ancillaries	74	1	74	74.2	100	based on misc job
	Cryogenic ancillaries	20	UK			Helium level, gauge bells total 2100+VAt from HiVac. What else should be included here?	Cryogenic Safety Systems	22	1	22	22.3	30	
Shipping and transportation hardware	Transportation frame, brackets, fasteners, and ancillaries	35	UK		Temporary import required for transport	8845+VAT for frame from GJM; 11250+VAT for arms from GJM	Anti-shock Transportation Frame	30	1	30			
							Transport tooling	5	1	5			
							Fasteners and ancillaries	0.2	1	0			
	TOTAL ex. VAT (£k)	3983								3974.2593			
	TOTAL inc. VAT (£k)	4779								4769.1112			

DQW Series Build Timeline (Sep ‘22)



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