



# Status of WP4 Crab Cavities

**HL-LHC WP4 & Collaborations**

**CERN**

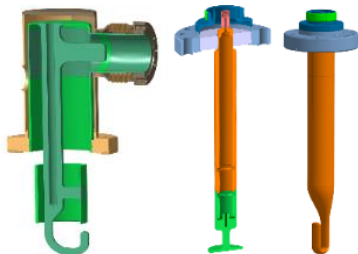
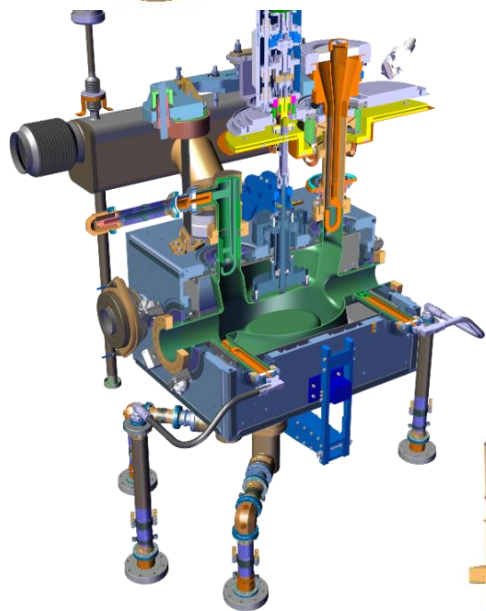
- DQW-SPS operation & RF Dipole Plans
- Status of series production including collaborations



19 September 2022

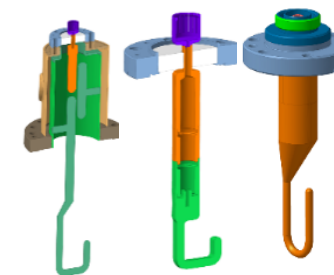
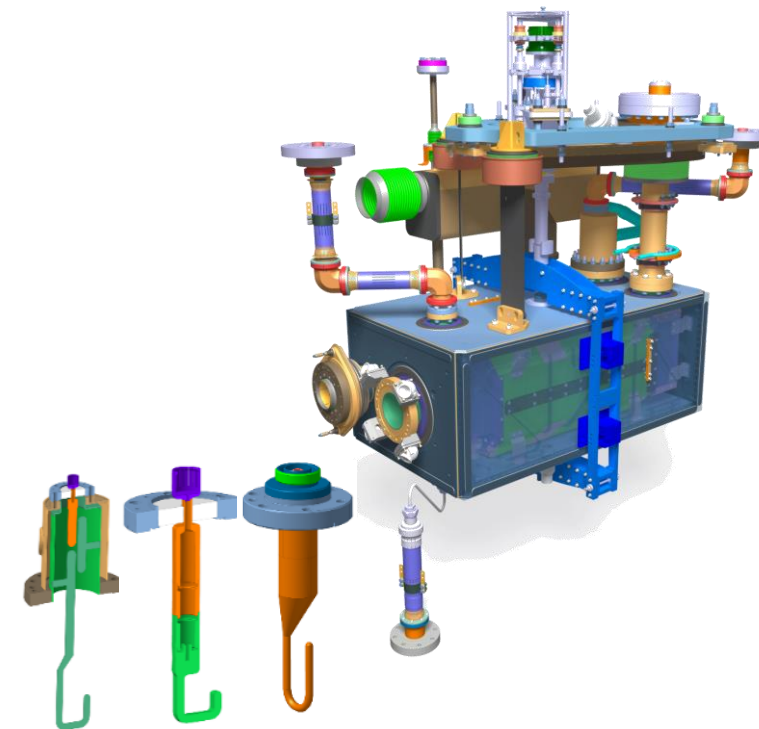
# HL-LHC Cavity Geometries

## Double Quarter Wave

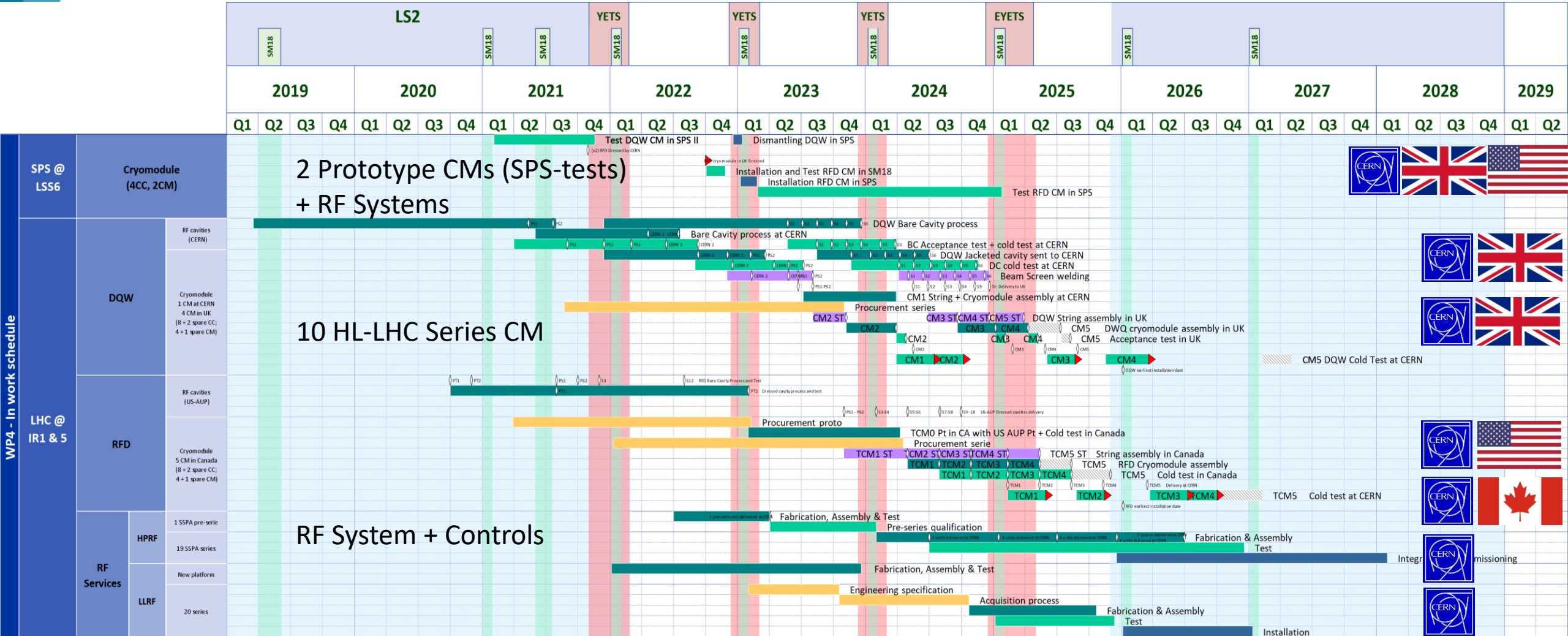


$f_0 = 400 \text{ MHz}$   
 $V_T = 3.4 \text{ MV/cavity}^*$   
( $E_p, B_p < 40 \text{ MV/m}, 70 \text{ mT}$ )  
Beam aperture = 84 mm  
RF power = 40 kW-CW  
Operating Temp = 2 K

## RF Dipole



# Masterplan of WP4



# Timeline, Crab Cavities

← High Power RF system not shown below →

2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
------	------	------	------	------	------	------	------	------	------

DQW CM SPS-tests



RFD CM SPS-tests



USAUP-RFD proto (x2)



RI-DQW pre-series (x2)



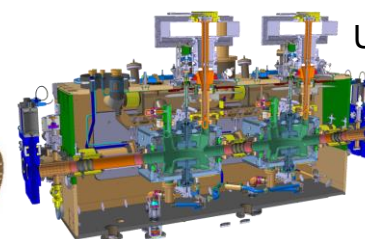
CERN-DQW series (x2)



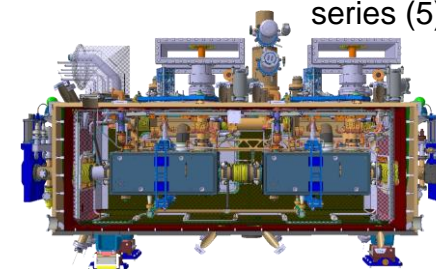
RI-DQW series (x6)



UK-CERN DQW CMs series (4 + 1)



Canada-CERN RFD CMs series (5)



USAUP-RFD pre-series (2)

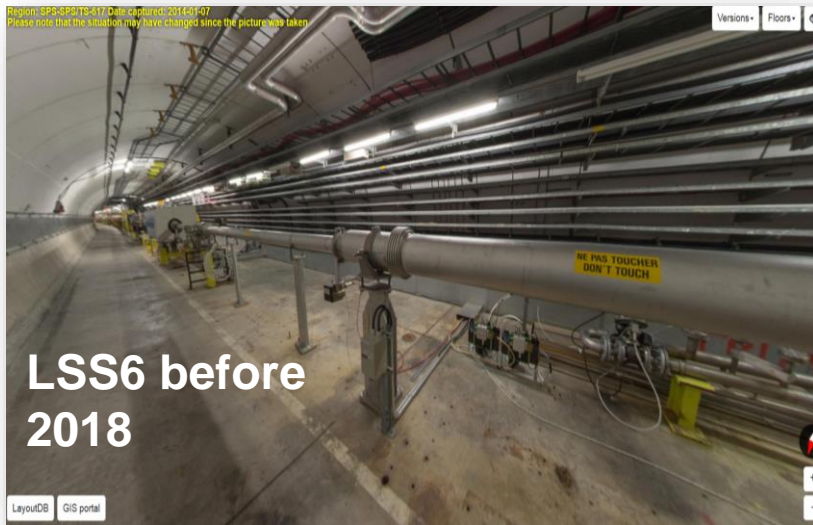
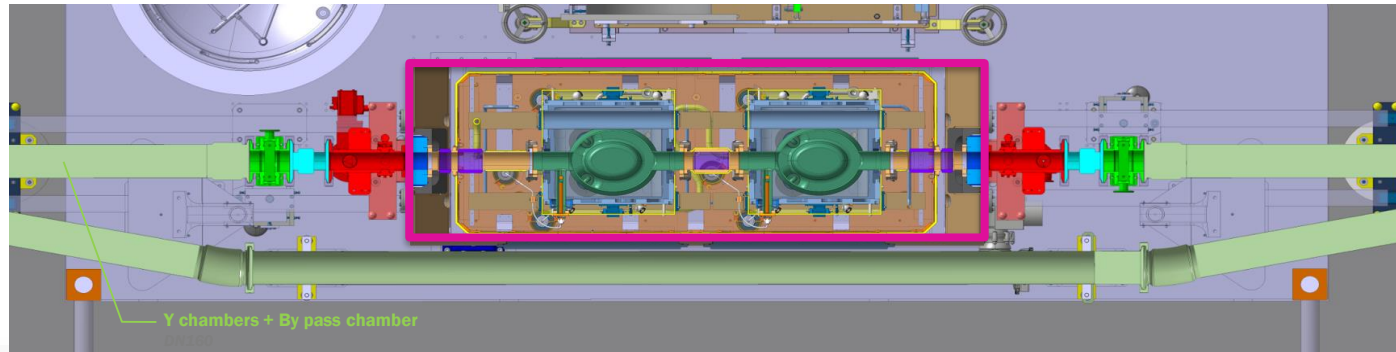


USAUP-RFD series (10)



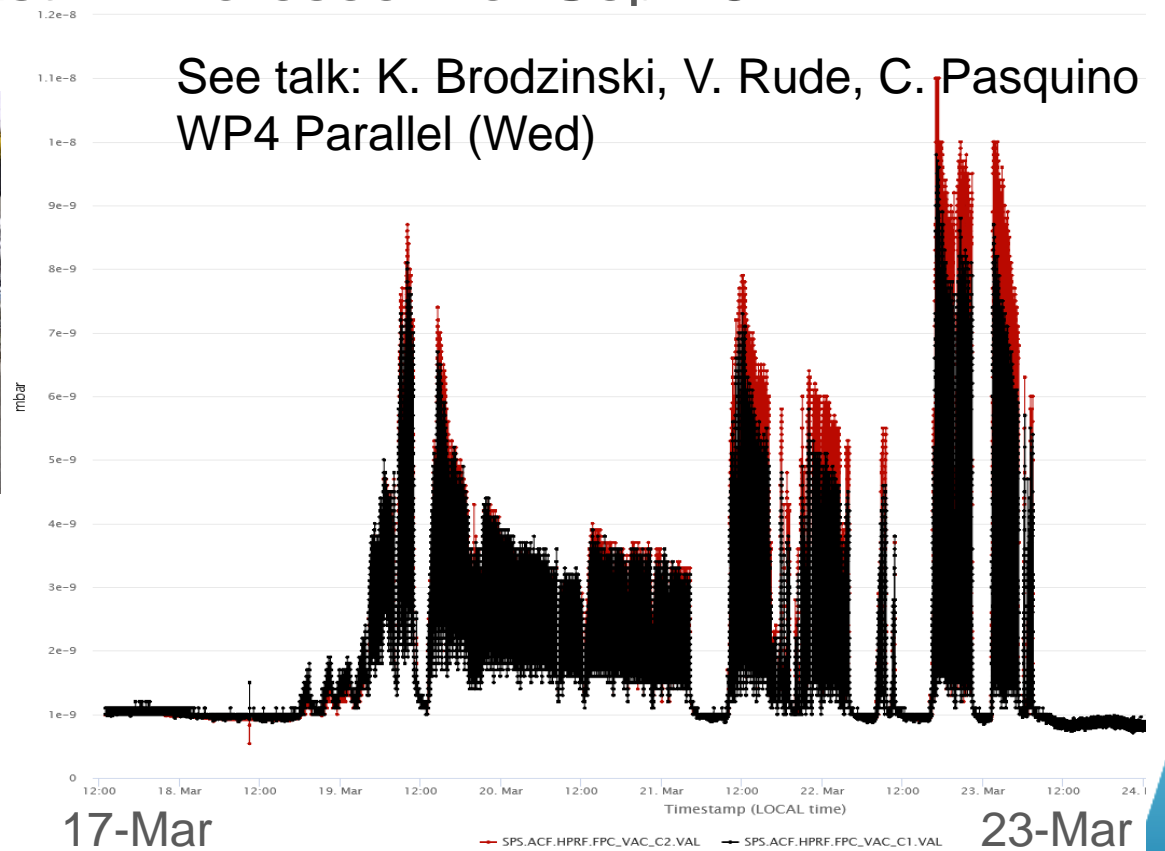
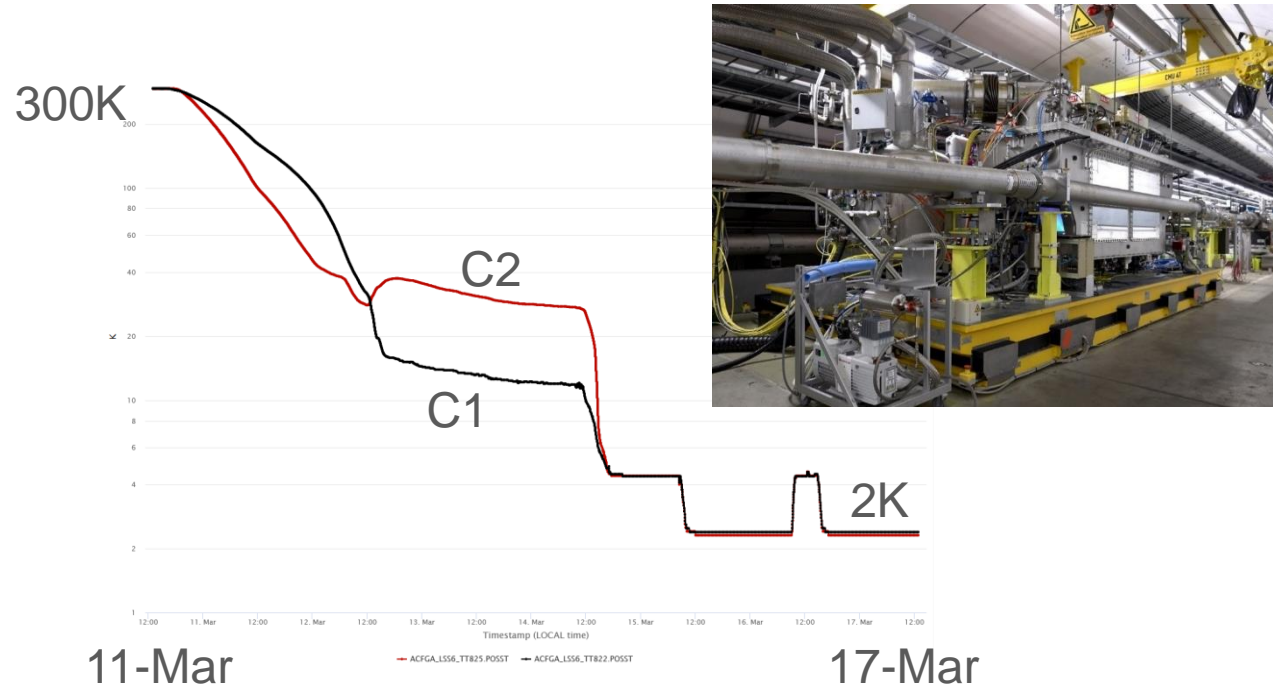
## Reminder: SPS as test bench

- Installed 2-cavity **DQW** cryomodule in the **SPS-LSS6** as a demonstrator with Hadron beams (2018)



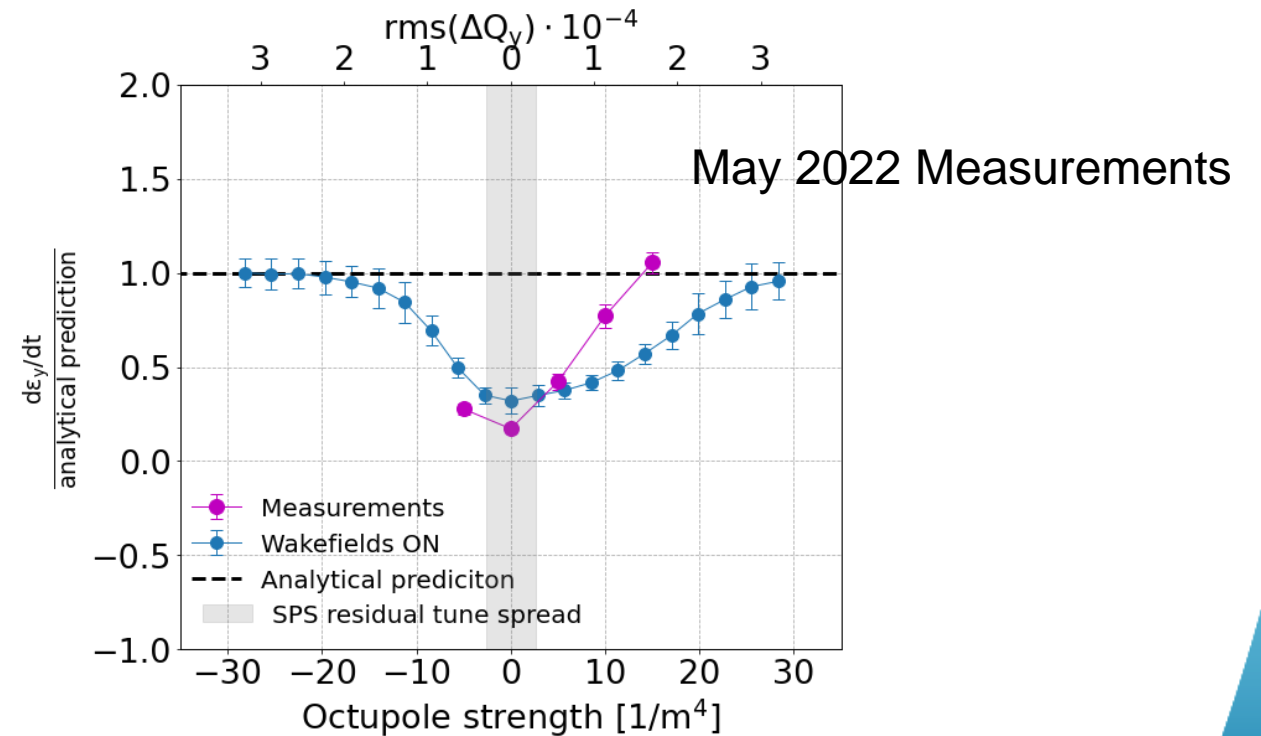
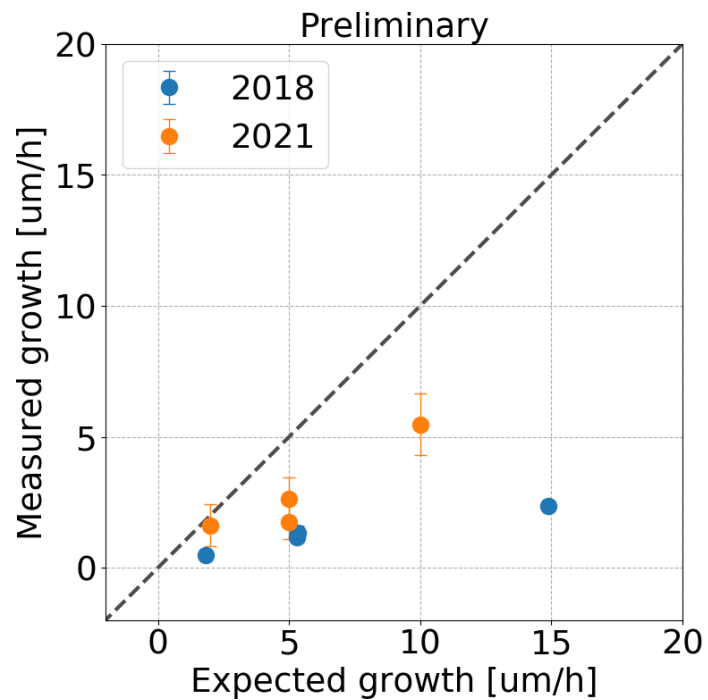
# DQW-SPS Re-commissioning, 2022

- Module at 2K Mar-Jun & Sep-Oct
- Scrubbing successfully performed at 26 GeV up to **5-batches of 72 bunches at  $1.7 \times 10^{11}$  p/b**
- 3 out of 4 MDs completed this year, last MD foreseen for Sep 28

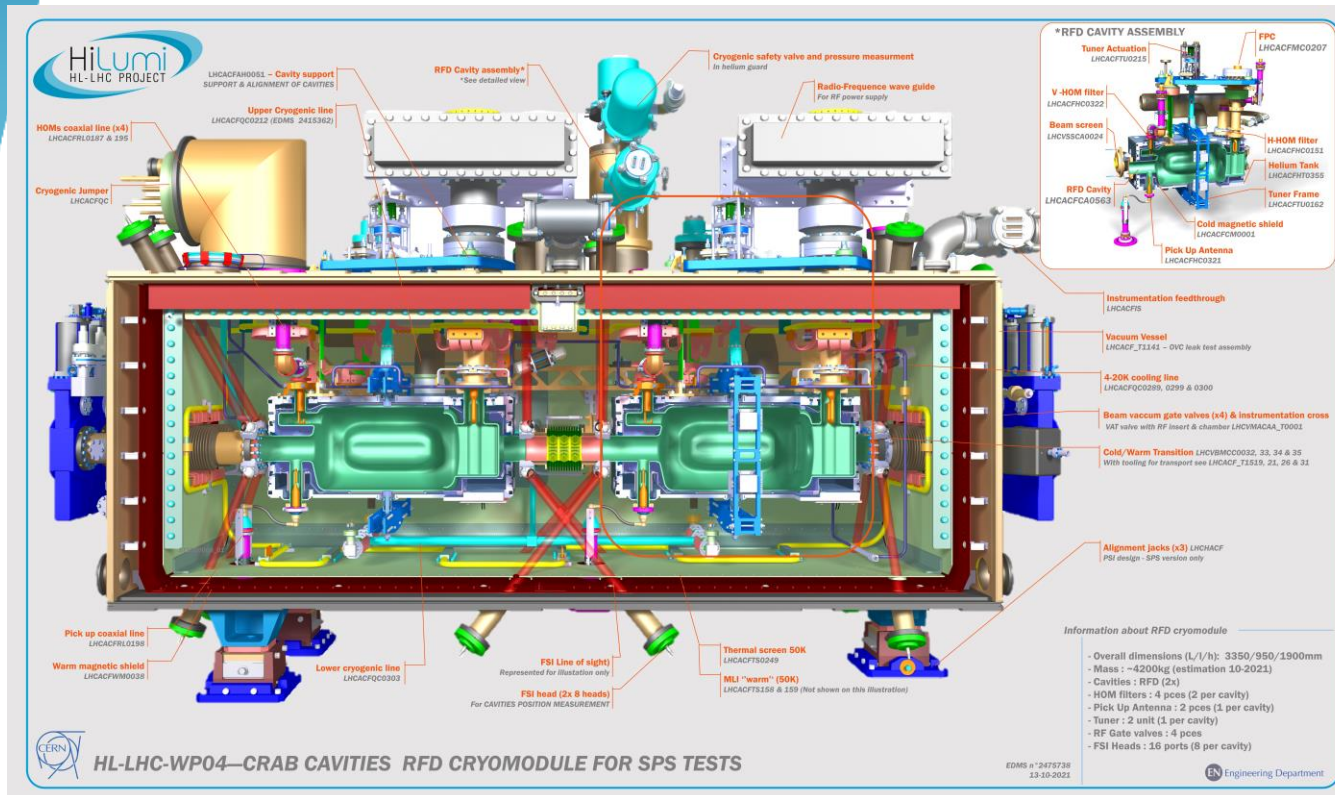


# Highlight Result: Emittance Growth with RF noise

- Measured growth smaller by x4 than predicted (2018 & 2022)
- Suppression of emittance growth due SPS machine impedance confirmed – **see talk by N. Triantafyllou Thursday**



# Next step: RF Dipole UK & CERN joint effort



RFD module (horizontal crabbing) for SPS-tests, also fully compatible with HL-LHC

See talks: T. Capelli, A. Gallifa Terricabras, E. Jordan, A. May, K. Turaj, H. Garcia Gavela WP4 Parallel (Wed)

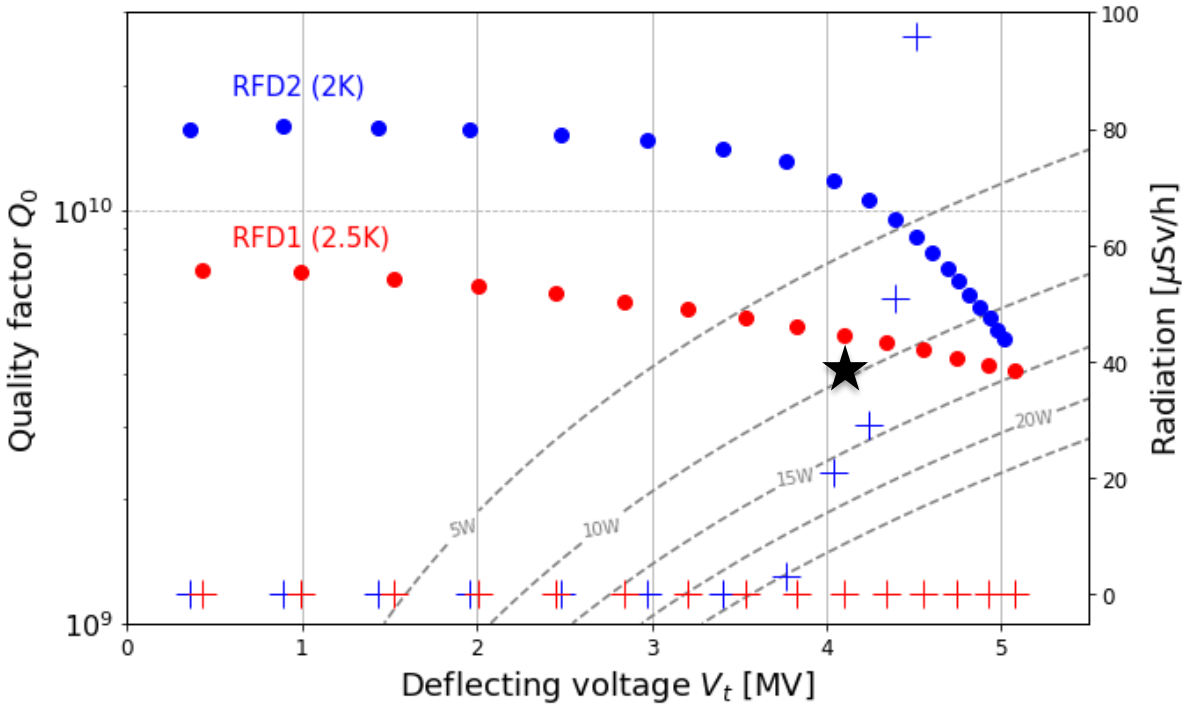


## 2023 Run

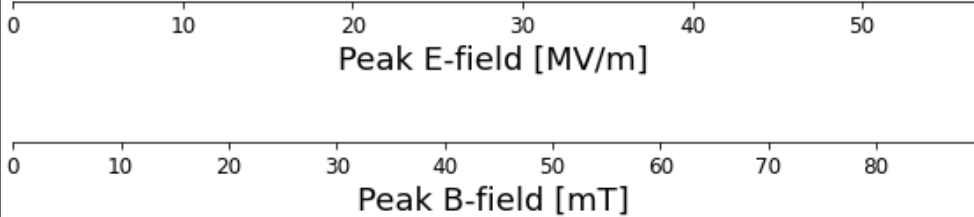
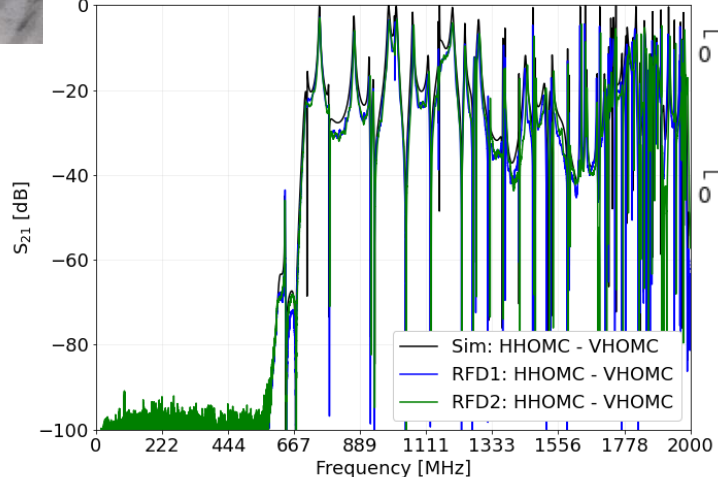
- Due to delays in production, the installation of the next module (RF Dipole) postponed to **2023-24 YETS**
- HL-WP4 proposed to keep existing DQW module in the SPS for 2023 run
  - Minimize risks associated to safeguard infrastructure
  - For 2023 - consolidated operation to **3 months with 3 high intensity MDs requested**
  - Primarily probe the beam stability aspects with high intensity LIU beams

# RFD Dressed Cavity with HOMs (2021)

CERN-RFD2



HOM Measurements



# RFD Dressed Cavities to UK (2021)

Preparations after the dressed cavity validation for beam vacuum, secondary line and ancillary equipment. Due to proximity of the secondary beam line, assembly of it inside He-tank

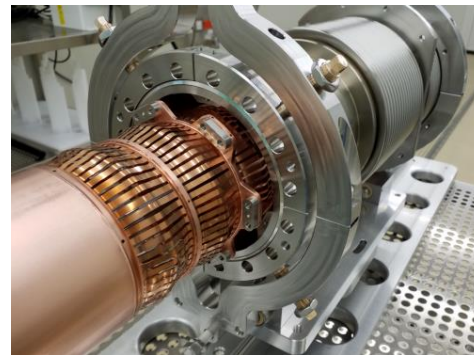
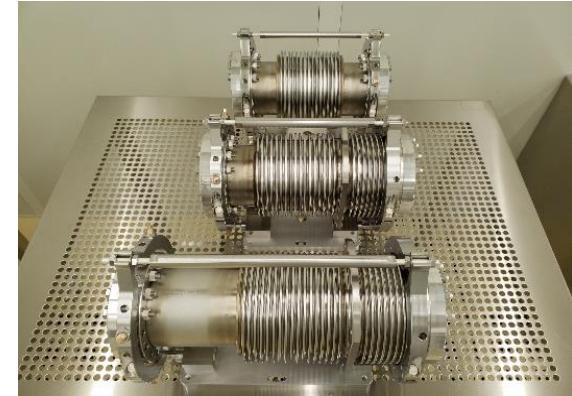
RFD2 dressed cavity & beam screen assembly



RFD Power couplers



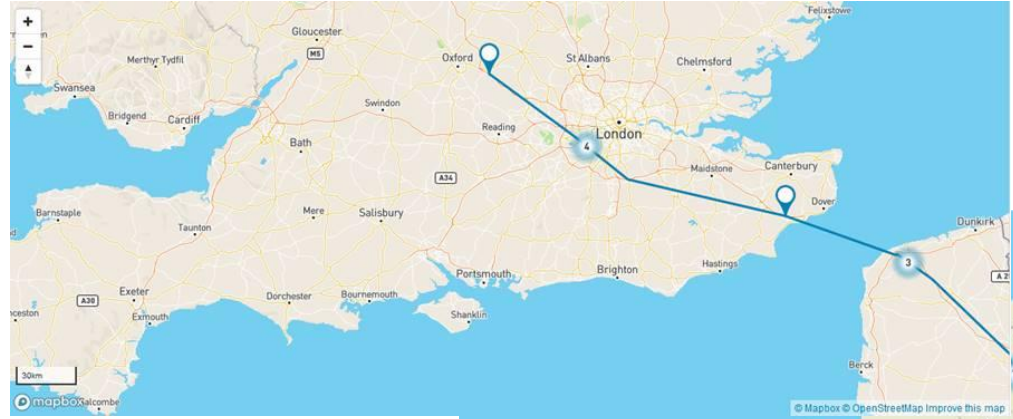
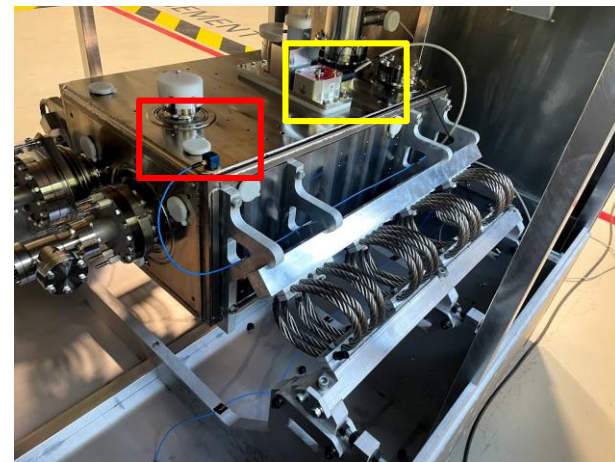
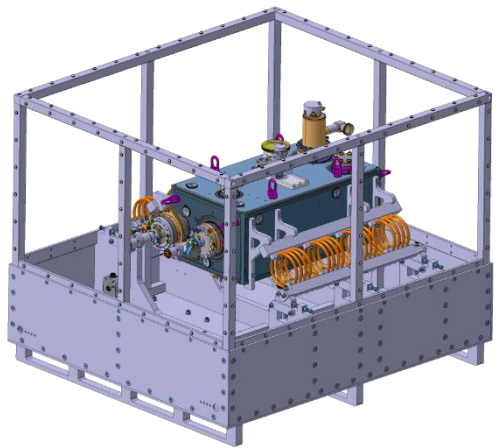
Plug-in-module assembly  
Cavity line



See talk: C. Pasquino  
WP4 parallel (Wed)

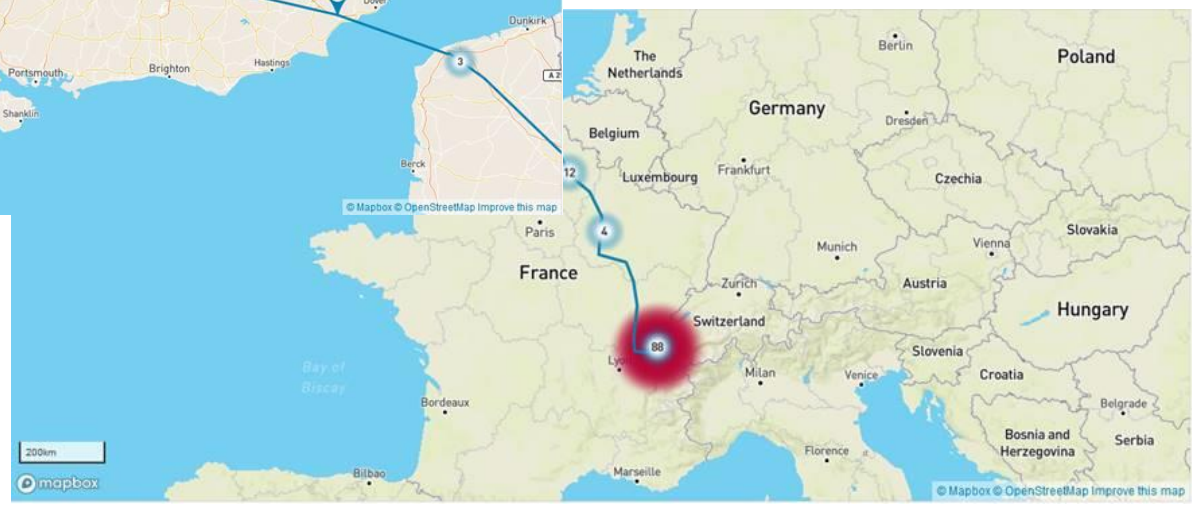
# Transport to UK-STFC

See talk: M. Garlasche  
WP4 parallel (Wed)



Live acquisition of shocks and vibration during transport

- Shocklog: online with GPS tracking, shock detection, tilt & roll
- Accelerometers : continuous monitoring, for vibrational spectrum check

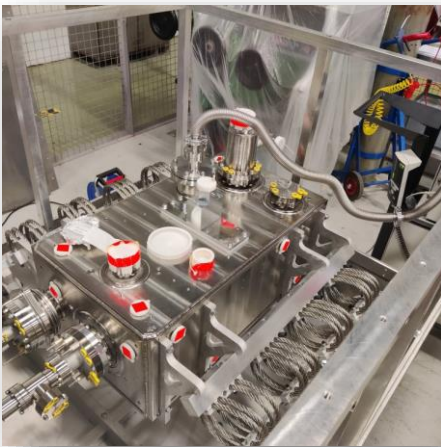


Transport of the two cavities  
performed successfully

## RFD Cryomodule: UK & CERN joint effort

- Dressed RFD cavities and vacuum components assembly received without incidents and successfully integrated into the clean room for string assembly
- FPCs and all string assembly components installed successfully this summer

Reception tests



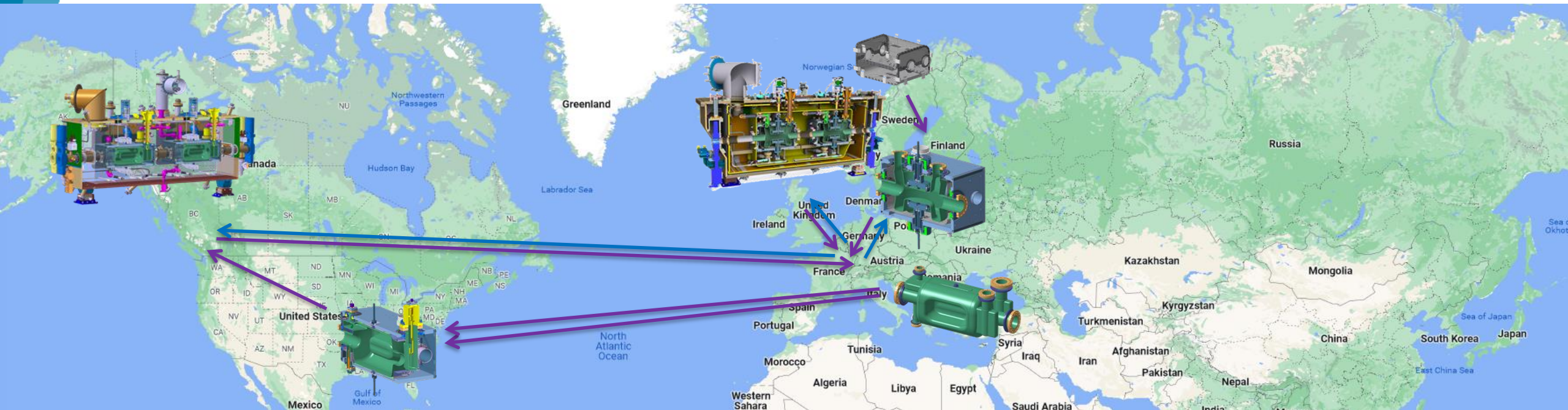
String Prep, Precision Trolley



Beam vacuum connections, ISO4



# HL-LHC Crab Cavity Series



## 5 DQW cryomodules

- Cavities + processing + helium vessels by Research Instruments (**DE**) & **CERN**
- Cold magnetic shields by **UK**
- HOM couplers + antennas by **CERN**
- 4 CM by **UK** (STFC) & 1 CM at **CERN** with some components from **CERN**
- All cavities & CM cold validation tests at **CERN** (and a back up at Uppsala-Sweden)

## 5 RFD cryomodules

- Bare cavities by Zanon (**IT**) under **US-AUP**
- Processing + cold magnetic shield + helium vessel + HOM couplers + antennas + cold tests by **US-AUP**
- 5 CM by **TRIUMF-Canada** with some components by **CERN**
- CM cold validation tests at **CERN**

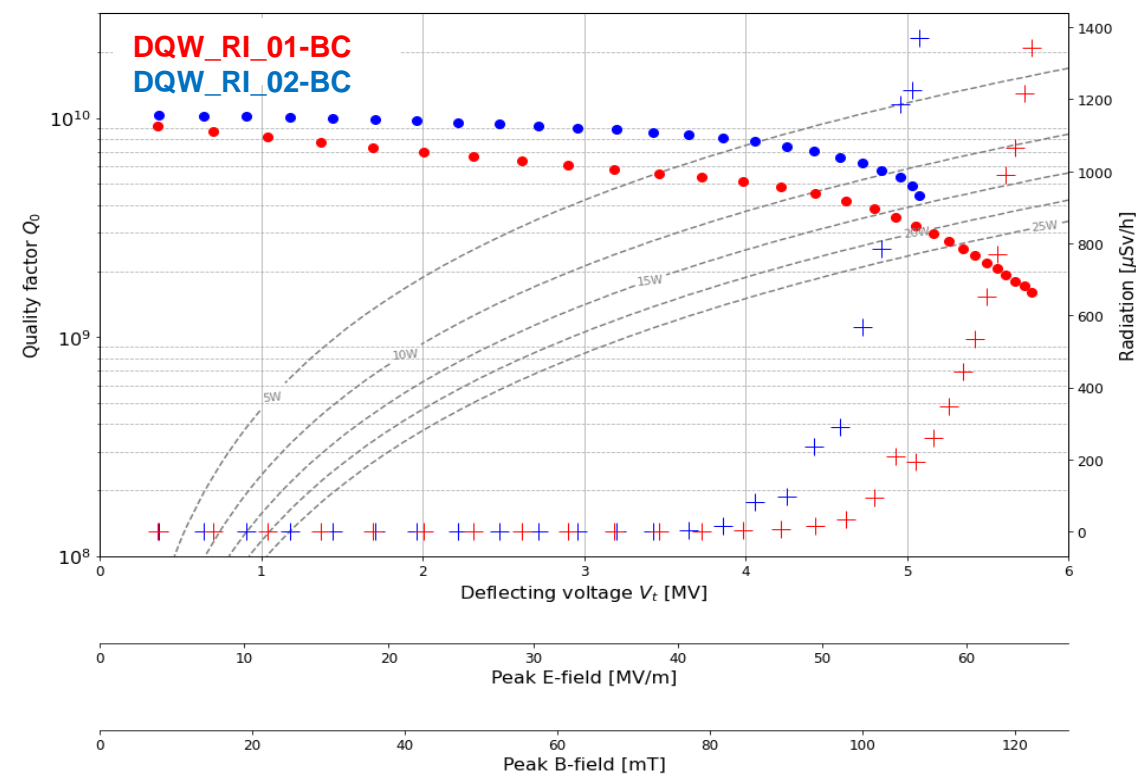
## 20 IOT RF Systems

- High power amplifiers (IOT) **CERN**
- High power RF lines, circulators, loads by **CERN** (exploring new frontiers)
- $\mu$ TCA platform for LLRF by **CERN**

## DQW-Series with Industry

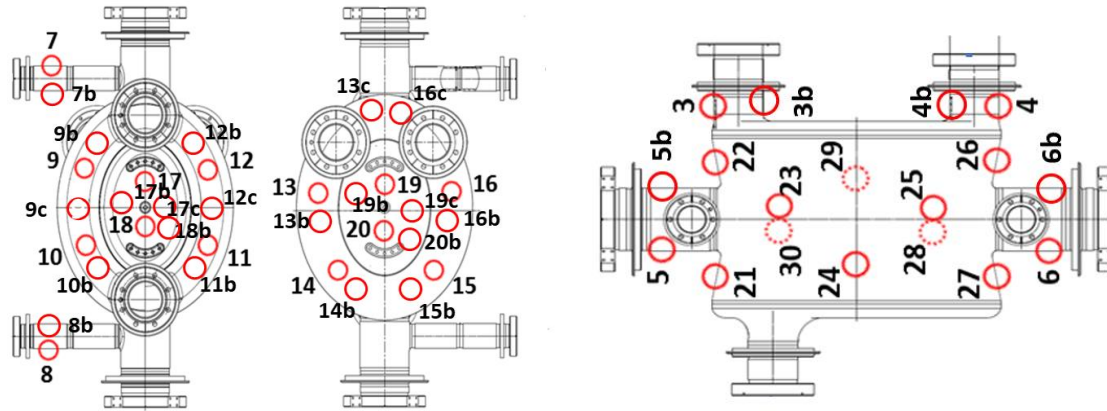
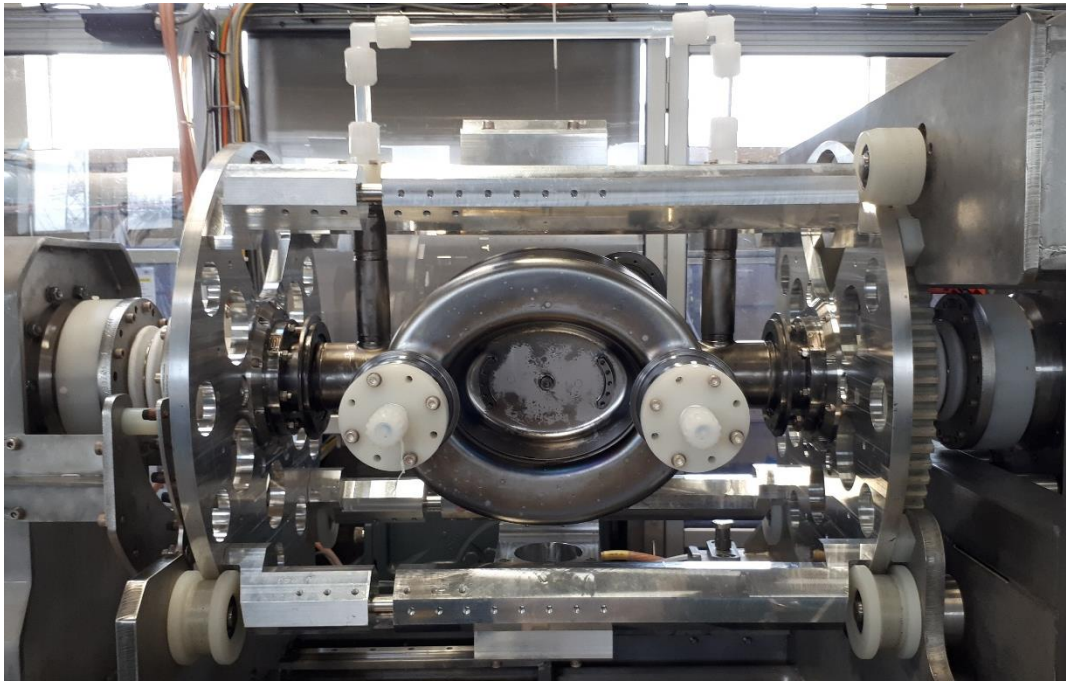
- Successful manufacturing of 2 pre-series cavities with industry (**RI**) with 1-cavity reaching excellent results. 2<sup>nd</sup> cavity retreated and to be tested
- 6 Series launched with industry with 2 series cavities being built at CERN as a schedule mitigation

DQW-RI

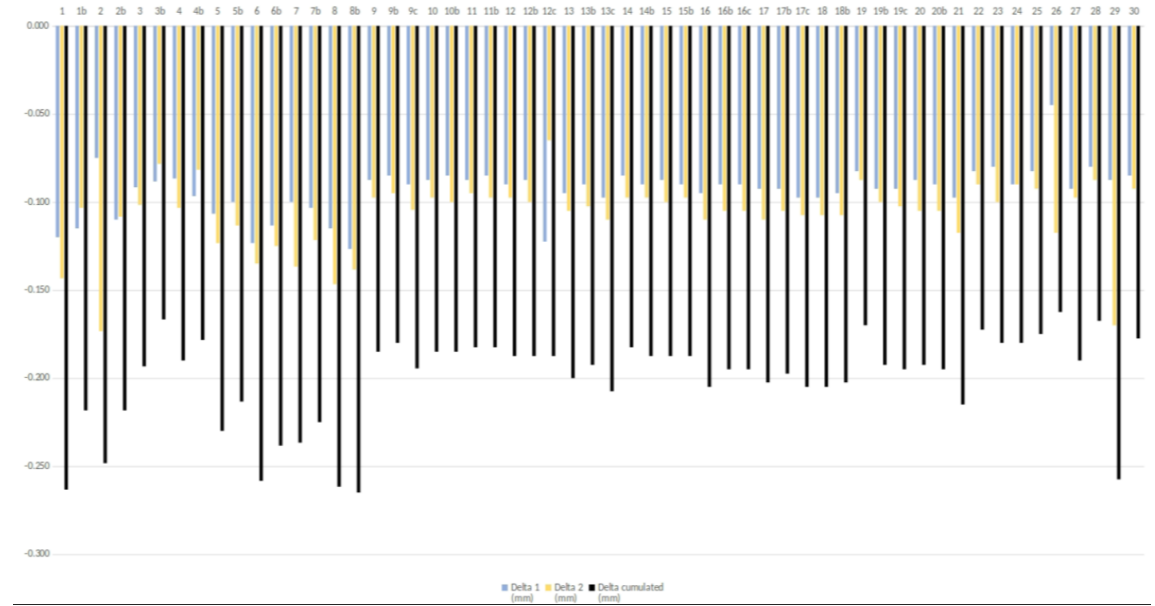


# DQW-Series, Surface etching

Very uniform removal with the rotational facility. Also used to recover RI cavity



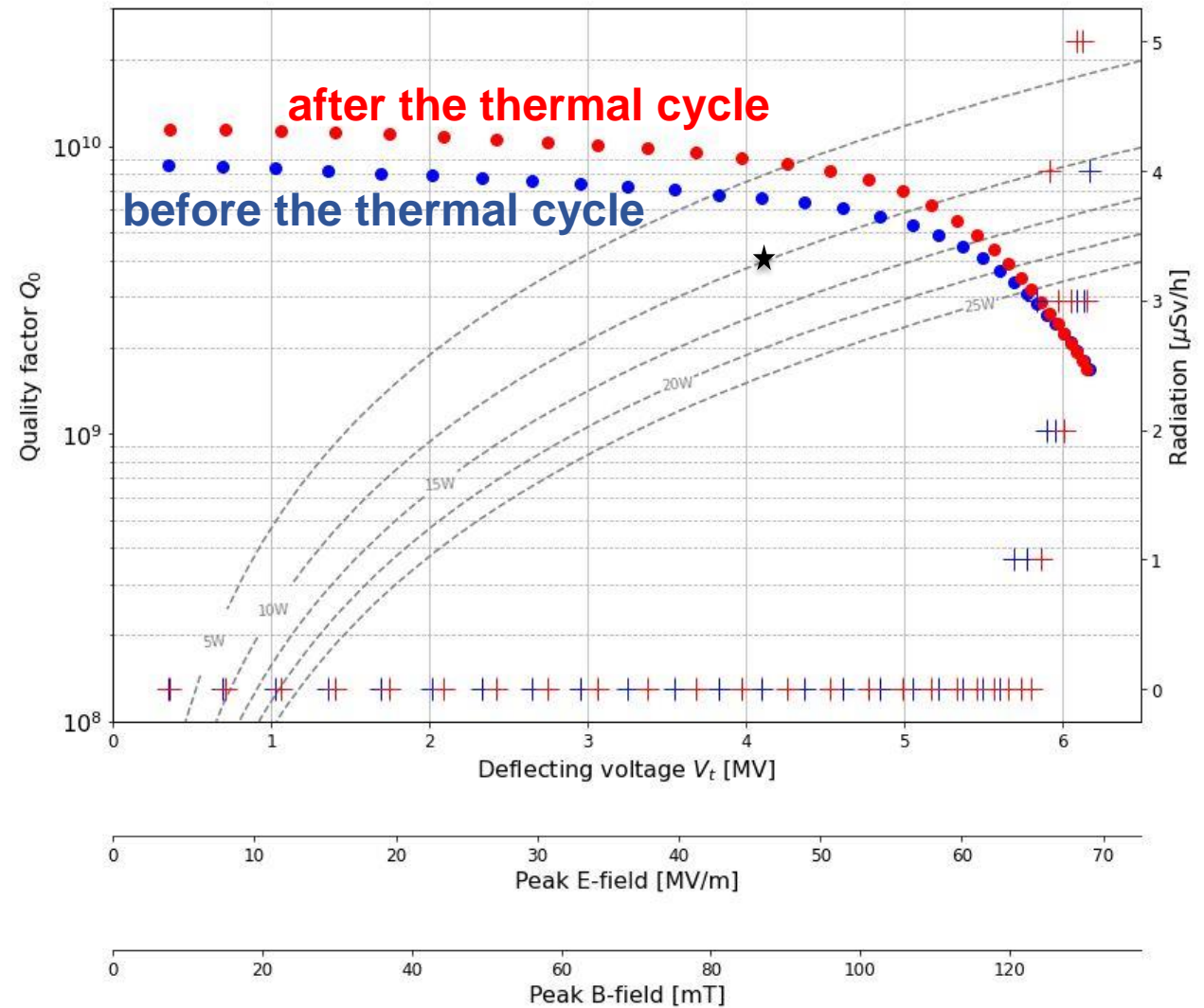
Thickness change Avg removal  $\sim 200 \mu\text{m}$





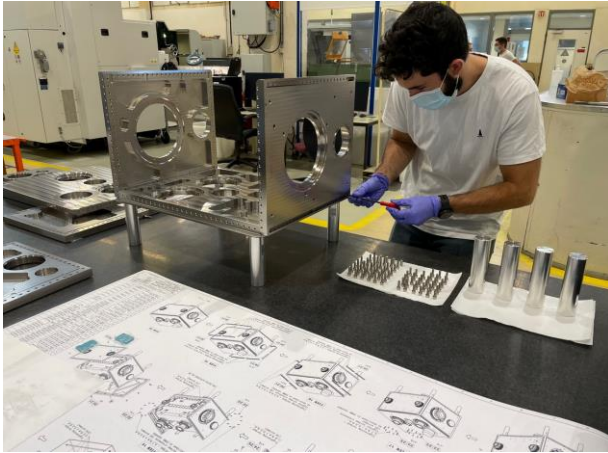
# CERN-DQW Series, Cold Test

See K. Turaj  
Wed WP4-Parallel



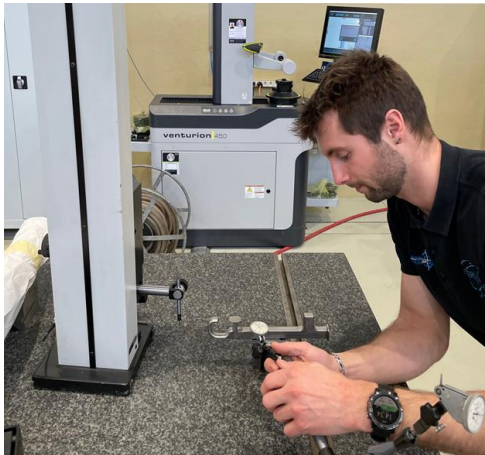
# CERN-DQW Series, He-tank & Couplers

Blank assembly completed, cavity He jacketing started



See E. Montesinos  
Wed WP4-Parallel

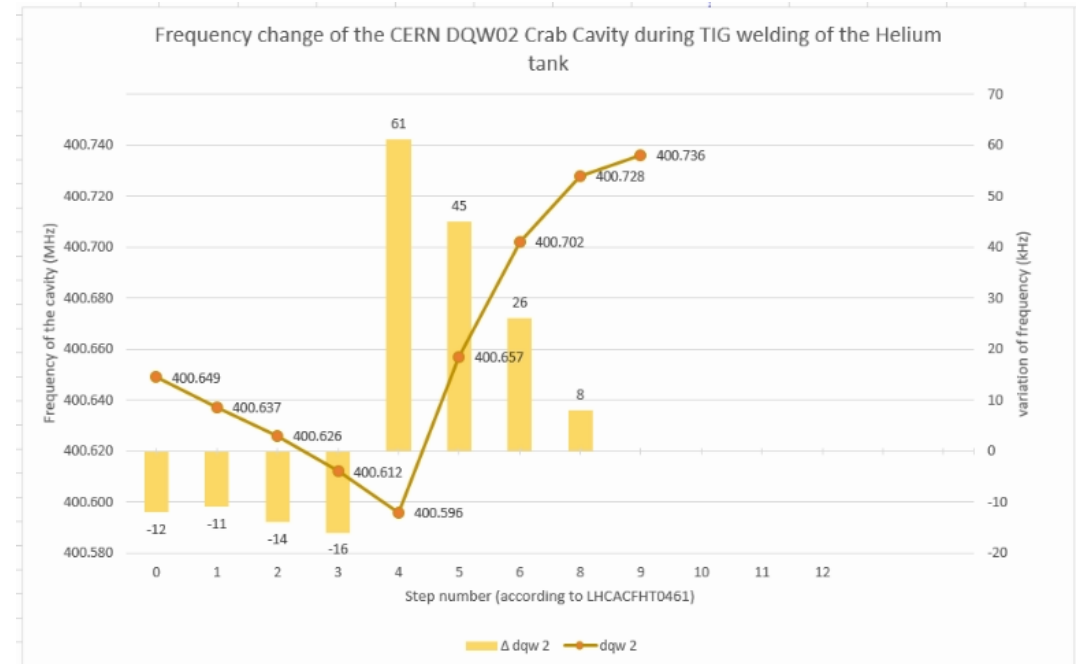
HOM couplers & Field Antennas



# CERN-DQW: Titanium He-tank Welding



Frequency shifts consistent with 2017 SPS-DQW cavities and close to expected





# US-AUP Pre-Series

See talk: A. Ratti, M. Narduzzi,  
N. Huque, Plenary & WP4  
Parallel, Wed

Two pre-series fabrication launched at industry  
(Zanon) with very good progress.



First set of prototypes for HOMs fabricated  
by Jlab. Cold tests validation ongoing with  
the two prototypes

H-HOM



V-HOM



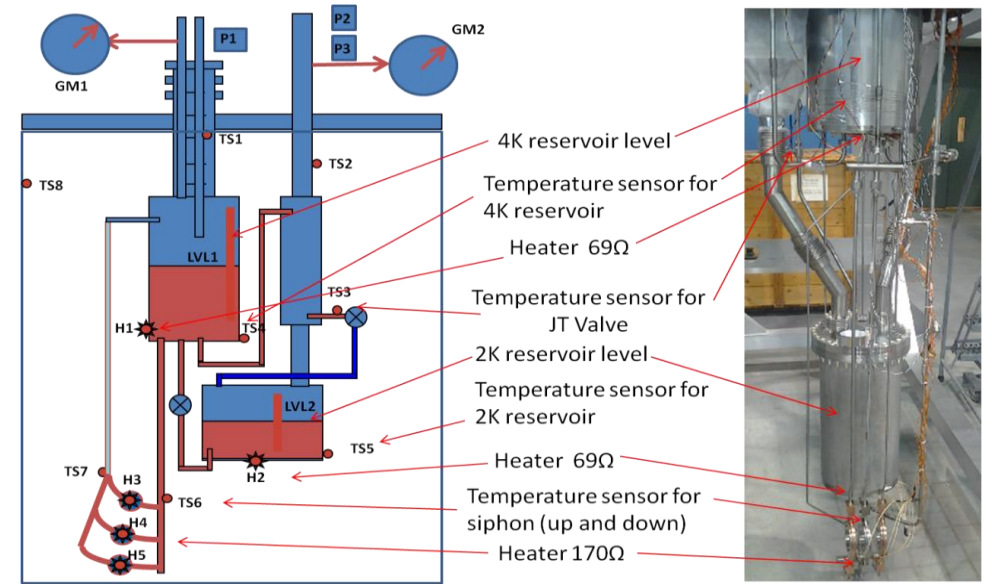
Leak check



# TRIUMF-Canada Activities

See talk: O. Kester, B. Laxdal  
Plenary & WP4 Parallel

- Vertical test infrastructure upgrade for testing dressed cavities from US-AUP at TRIUMF before cryostating
- TCM0 prototype cryomodule preparations to house US-AUP built RFD prototype cavities



# HPRF (more news at next collaboration meeting)

