WP4 Summary

Alessandro Ratti

For the WP4 collaboration

May 19, 2016

Introduction

- This complements the overview talk by Rama
  - Covered all highlights for the CC program
  - Including planning for SPS installation and testing
- Just adding some news, details, comments, concerns from the working sessions
- Also complements GianLuigi's presentation covering the joint WP2/WP4 session
  - 200 MHz, LLRF, Impedance

With References to the presentations in the breakout sessions

Overview of DQW MIP

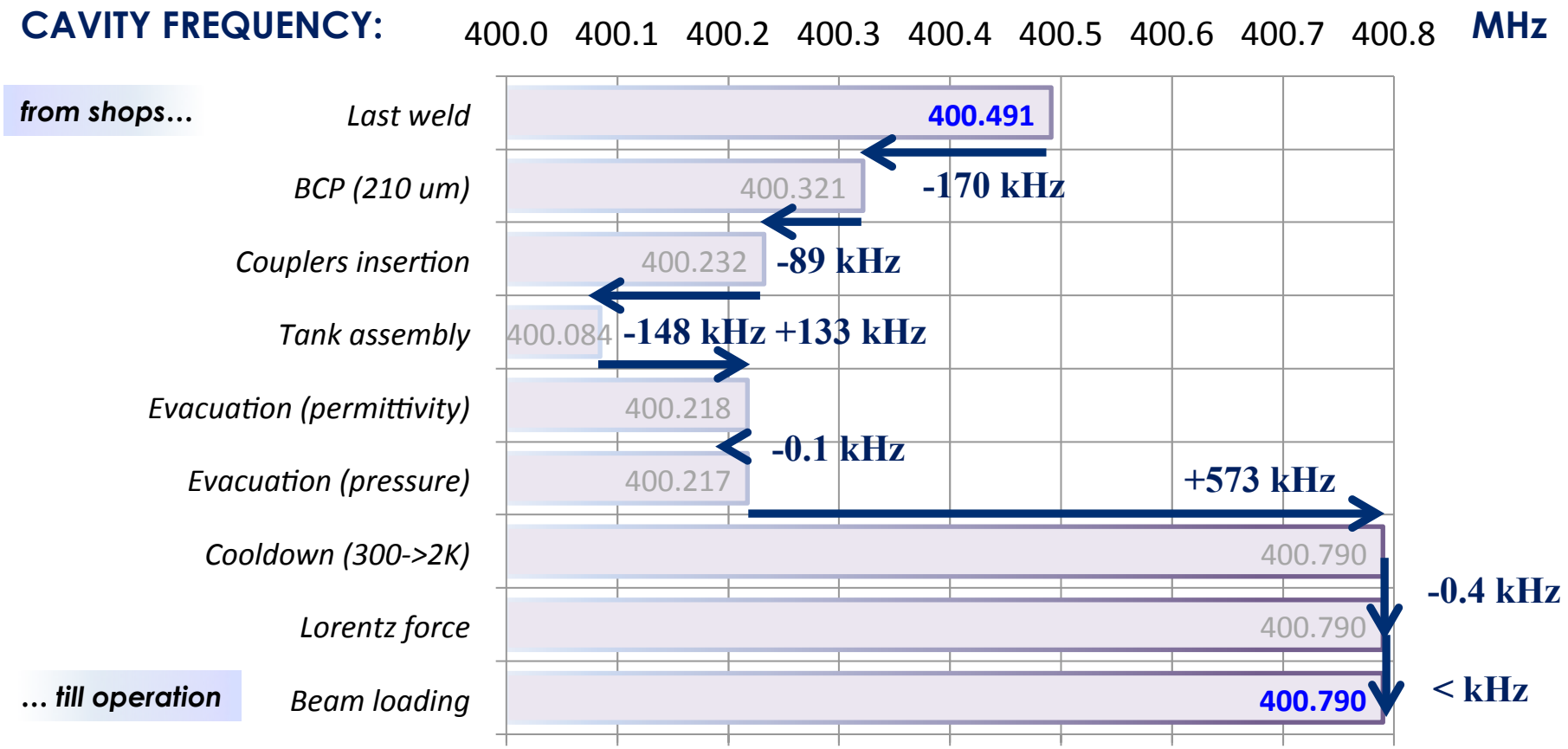
Detuning due to coupler insertion
Trimming of subassemblies
Final EB weld of the cavity
Bead pull measurement
Bulk chemical polishing
Heat treatment
Pre-tuning
Light chemical polishing
High pressure water rinse
Evacuation and helium leak test
120 C low temperature bake
RF acceptance tests at cold temperature (without and with HOM couplers)

MIP follows all cavity life, from manufacturing of parts, through bare cavity test, to SPS test.

Frequency Trip of a DQW

from the shops to operation

- Given the *goal frequency for* the cavity at *nominal operation*, the **frequency trip** provides: *goal frequency for the manufactured cavity.*



Frequency step		Temp	Pressure		Permittivity (air/vacuum)	Cum. thickness removal	Couplers in (1) / out (0)		RF off/on	Beam off/on
			outer	inner			FPC	HOM		
Step ID	Status / Action	[K]	[mbar]	[mbar]	ε_r	[µm]				
BC-20-QA	*Final EB weld of cavity*	300	1013.3	1013.3	1.00067	0	0	0	off	off
↓										
BC-26-QC	*Pre-tuning with freq check*	300	1013.3	1013.3	1.00067	0	0	0	off	off
↓						↓				
BC-33-QA	*Bulk BCP* (150 µm)	300	1013.3	1013.3	1.00067	150	0	0	off	off
↓										
BC-37-QA	*Heat treatment*	300	1013.3	1013.3	1.00067	150	0	0	off	off
↓						↓				
BC-38-QA	*Light BCP* (30 µm)	300	1013.3	1013.3	1.00067	180	0	0	off	off
↓							↓	↓		
	Assembly test couplers	300	1013.3	1013.3	1.00067	180				
↓				↓	↓					
BC-47-QC	*Evacuation*	300	1013.3	vacuum 0	1	180				
↓										
BC-48-QC	*120°C bake*	300	1013.3	vacuum	1	180				
↓		↓	↓							
BC-49-QC	*Cooldown*	2	30	vacuum 0	1	180				
↓										
	RF on (nominal operation)	2	30	vacuum	1	180				
↓		↓	↓							

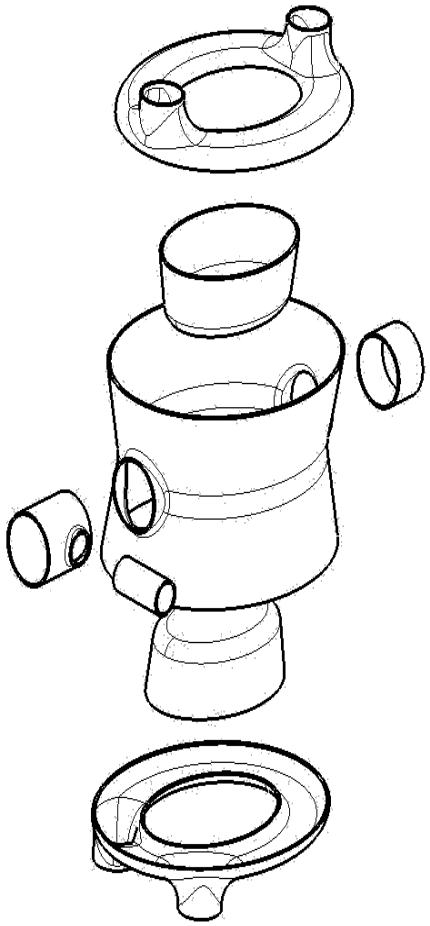
Expected frequency shift		Expected frequency after action		Measured frequency after action
		(from simulations)	(corrected from freq measured in previous step)	
Due to…	[kHz]	[MHz]	[MHz]	[MHz]
Last weld-A shrinkage	980.0			
Last weld A sagging	-70.0	400.3431	#VALUE!	
Pre-tune for bare cavity test	0.0	400.3431	0.0000	
Thickness removal	-121.4	400.2217	-0.1214	
*High-T bake***	0.0	400.2217	0.0000	
Thickness removal	-24.3	400.1974	-0.0243	
Test couplers in	0.0	400.1974	0.0000	
Vacuum pressure	0.1			
Permittivity change	133.3	400.3308	0.1334	
*Low-T bake***	0.0	400.3308	0.0000	
Thermal contraction	573.0			
He pressure	-0.1	400.9037	0.5729	
Lorentz force (RF on)	-0.4	400.9033	-0.0004	

Frequency trip control

Traveler to keep track of cavity frequency trip.
May be useful later on for preparation of LHC CCs.
Interesting to also include frequency trip of main HOMs.

S. Verdu-Andres

DQW Cavity Production



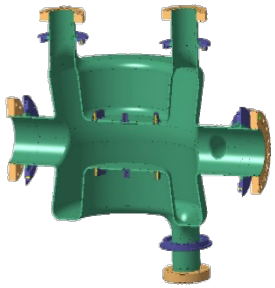
Manufacturing Strategy

- TESTS:
  - Explore different option in **parallel**
  - Annealed **Cu→ Nb**

Circular Tests**:**

Cheaper & **easier** production for **quicker understanding & ruling out** of non-viable options

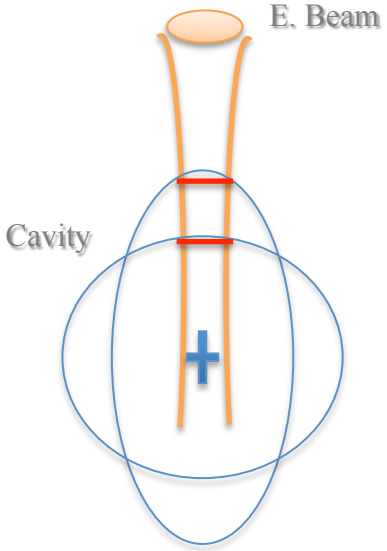
20x Tools potentially. Big effort for all stakeholders



Cavity - Extremities

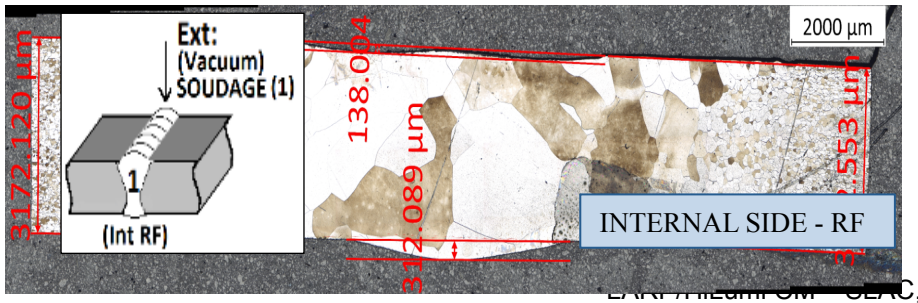
Welds #8 & #9

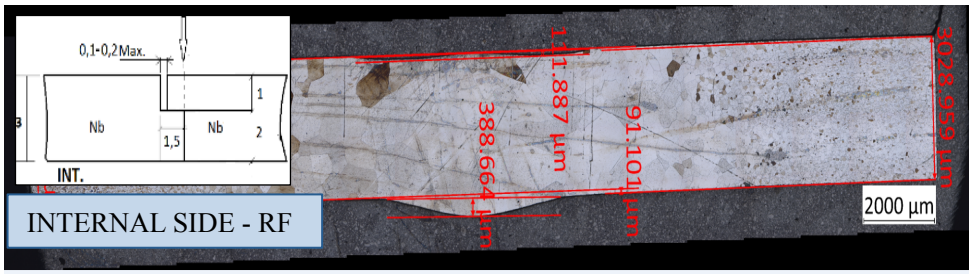
- Dedicated **circular and elliptical tests**
- Baseline: beam parameters w. **large acceptance**
- Options: transversal movement, change of focus
- Finalizing test equipment now



- Linear weld tests performed
- Two configurations: Key (*Clé*) and Butt Weld (*Bords droits*)

- BOTH CONFIGURATIONS WITH SATISFACTORY RESULTS
- NO VOLUMETRIC DEFECTS FOUND
- WELDING IMPERFECTIONS COMPLIANT WITH ISO 13919-2 LEVEL B





Frequency Control

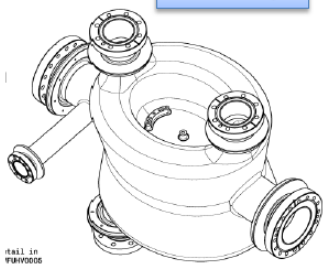
- One of the biggest challenges
- Must be able to control frequency at all steps
  - Due to the available tuner range
- Some are predictable, some quite unknown
  - Connection of He Tank can have unpredictable results
    - Plan to test and monitor in preparation for the Pre-Series and Series

Status Weld Certification at JLAB

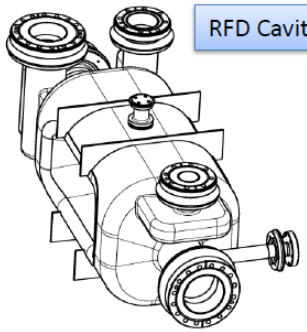
Analysed welds

A: 3mm for 1 side
A1: 3mm for both sides

DQW Cavity



RFD Cavity



B: 4mm for 1 side
B1: 4mm for both sides

- Documentation received according to ASME:
  VERY GOOD
- PQR EBW Nb 001-A_WPS EBW Nb 001-A
- PQR EBW Nb 002-A1_WPS EBW Nb 002-A1
- PQR EBW Nb 003-B_WPS EBW Nb 003-B
- PQR EBW Nb 006-B1_WPS EBW Nb 006-B1
- WPQ EBW Nb 001-A & EBW Nb 002-A1
- WPQ EBW Nb 003-B & EBW Nb 006-B1

Acceptance criteria:
- Stringent (level B) of ISO 13919-2
- Additional Restrictions (range 0.1-0.2mm) of Table 7 from Engineering Specification

Paula Freijedo

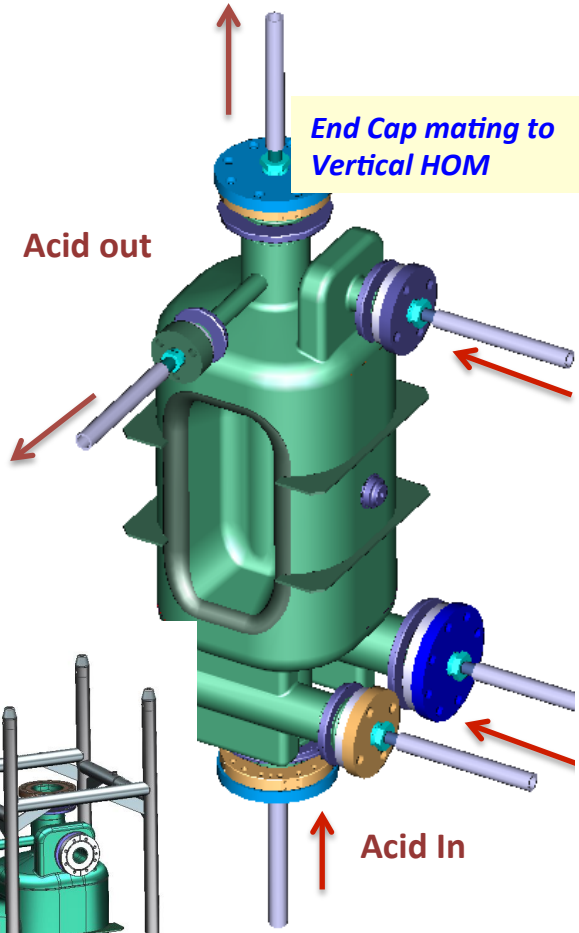
2

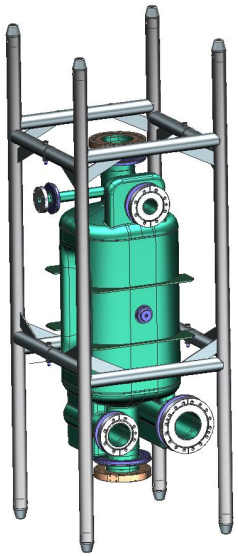
Courtesy of Paula Freijedo CERN

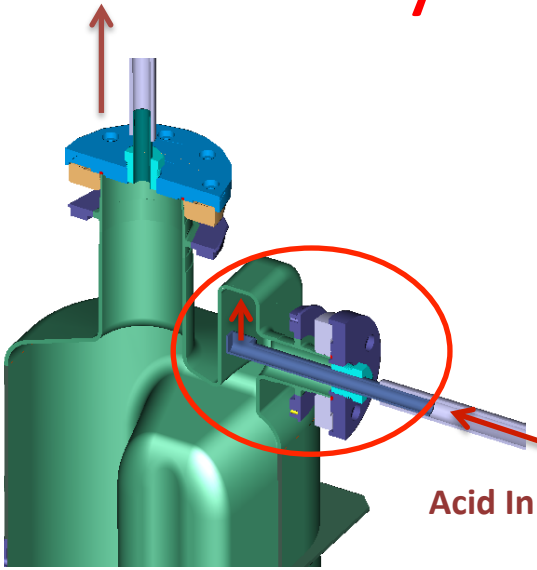
Status : JLAB Weld Qualification to CERN requirements complete Dec.2015
Final documentation found in CERN EDMS 1612289 V.1

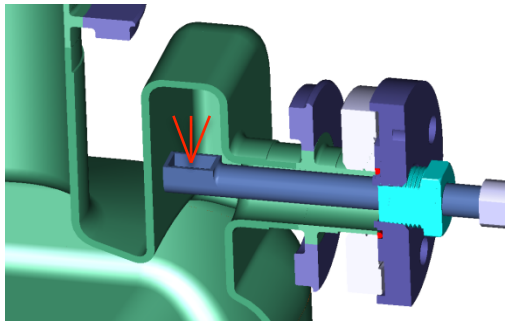
A. McEwen, S. De Silva

Final BCP Closed Chemistry Cabinet

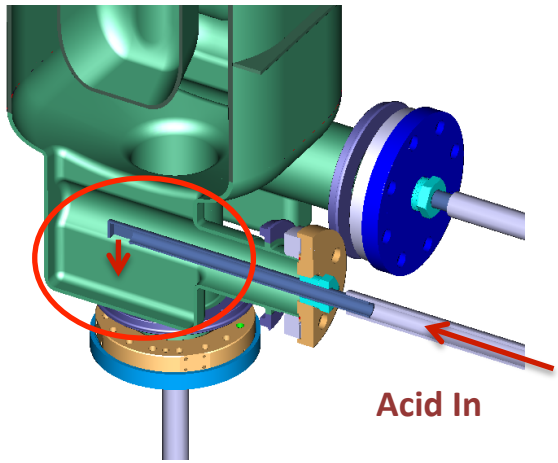








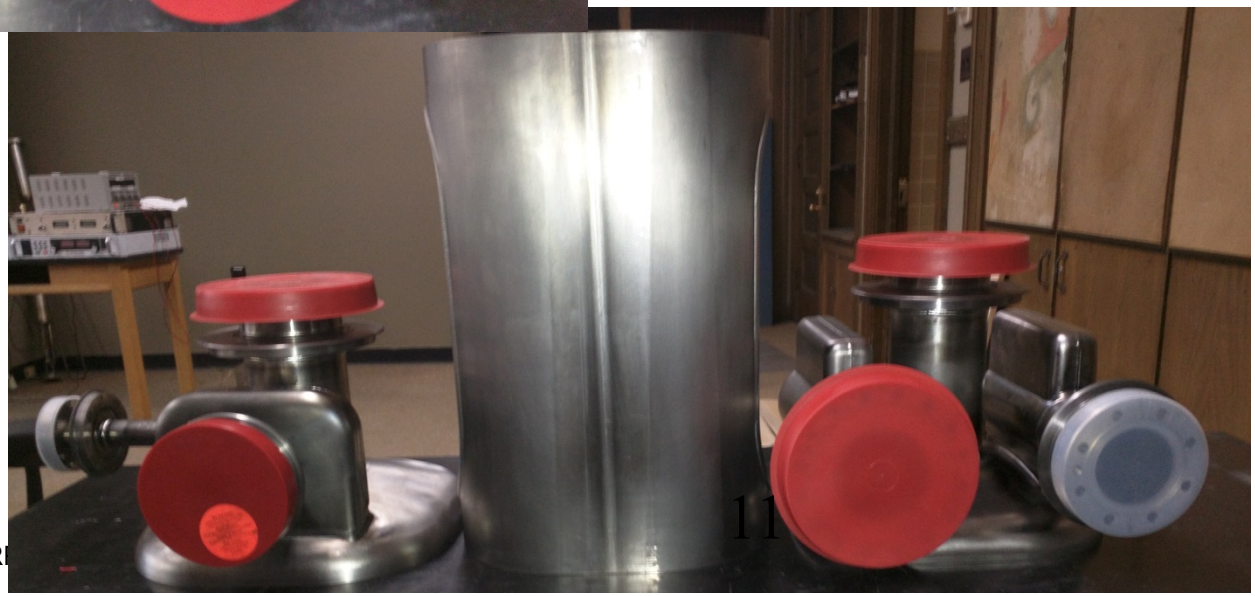
Chemical Injection Quill "*Snorkel*" directs the flow of Acid & Water



Status :

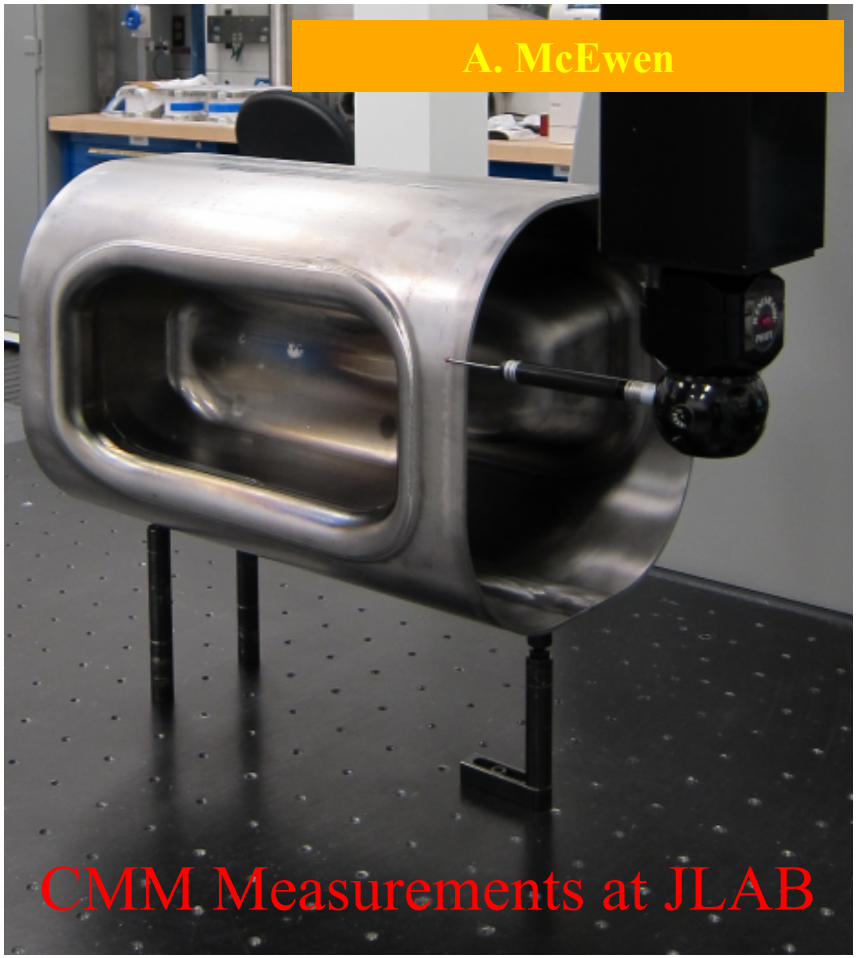
- Tooling Design in process
- Tooling Fabrication, Procedure & Traveler to follow

RFD Cavity Subassemblies



NIOWAVE
www.niowaveinc.com

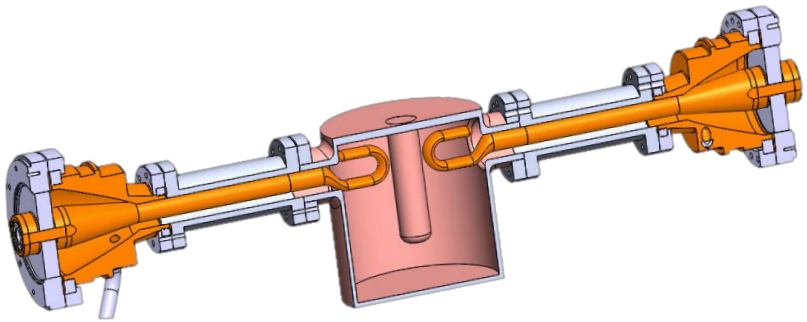
RF Dipole Stackup and CMM

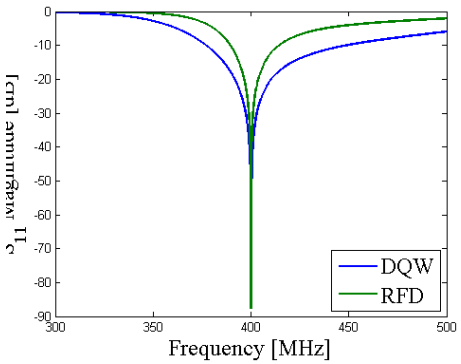


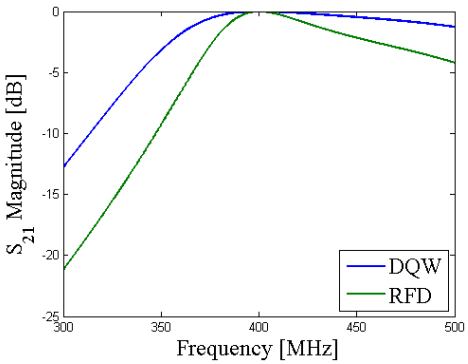
J. Mitchell

FPC Test Box for DQW and RFD

- Test box design is based on a Quarter Wave Resonator (QWR).
- The design allows the testing and conditioning of **both the DQW and RFD FPCs** – reducing cost
- and time needed – two sets of 'false walls' required to allow correct insertion depths.
- The structure has been designed to operate at the **deflecting mode frequency (400 MHz)**.
- A high transmission between the coupler ports allows conditioning of the couplers at high power (~ 100 kW) in order to prepare them for operation on the respective crab cavities.
- A **'dual' coupler test box** has also been designed. The orientation of the couplers needed to be altered in order to ensure good coupling between the fields and hence a good transmission.

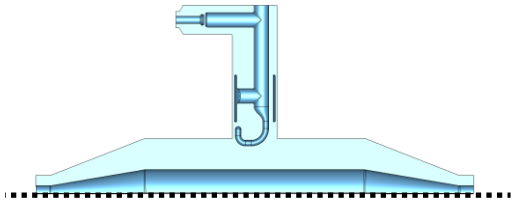




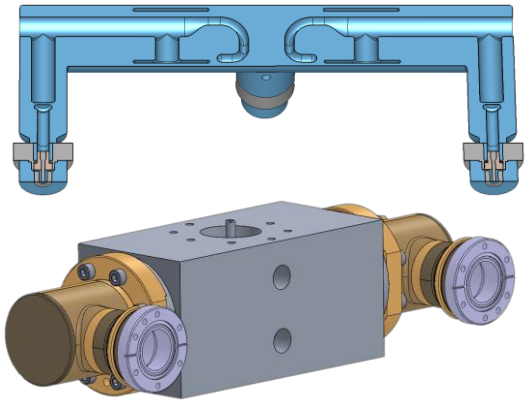


DQW HOM Test Box

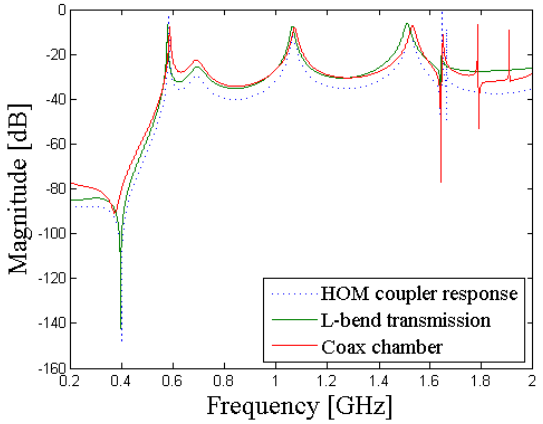
- Two test boxes have been designed for characterisation of the HOM coupler frequency response; **the coaxial chamber** and **the L-bend transmission line**.
  - Both designs allow accurate measurement of the HOM coupler response.
- The test boxes will therefore allow any errors in operation to be quantified
  - the corresponding error causing geometries can then be identified.



Coaxial chamber test box
Constructed from rigid line components which are commercially available.

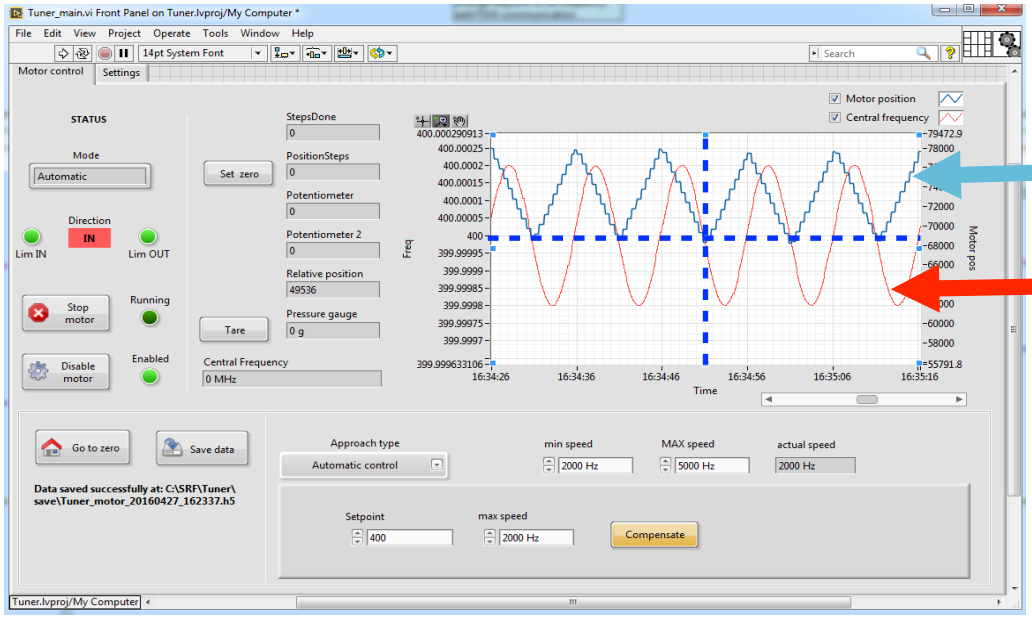


L-bend transmission test box
Uses L-shaped probes to pick up transmission characteristics of HOM couplers.



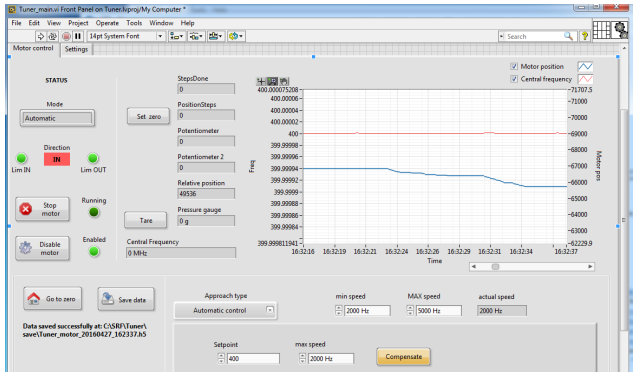
S21 frequency responses

First Test of Tuner Motor Drive



Tuner Motor Drive

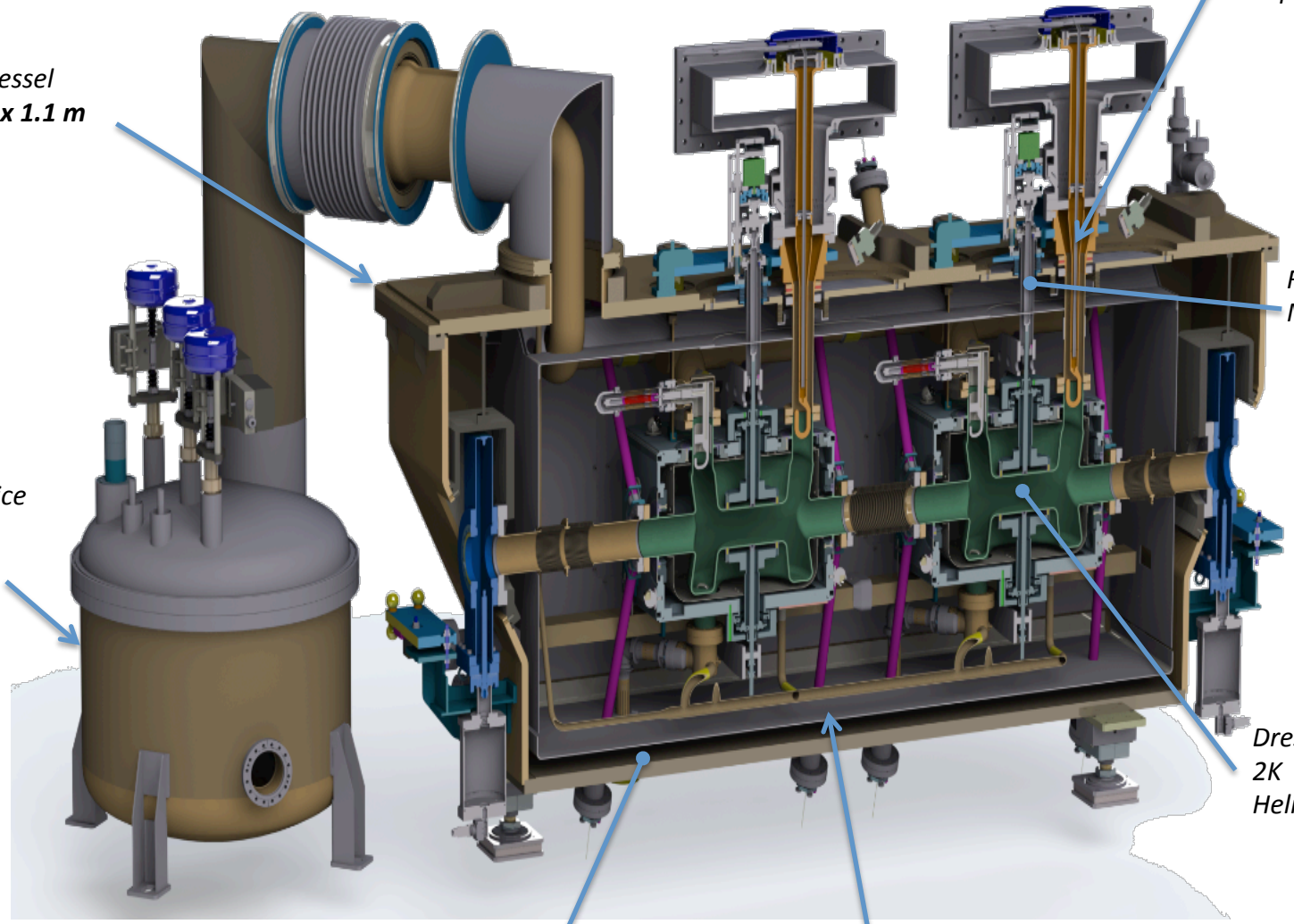
Frequency Modulation



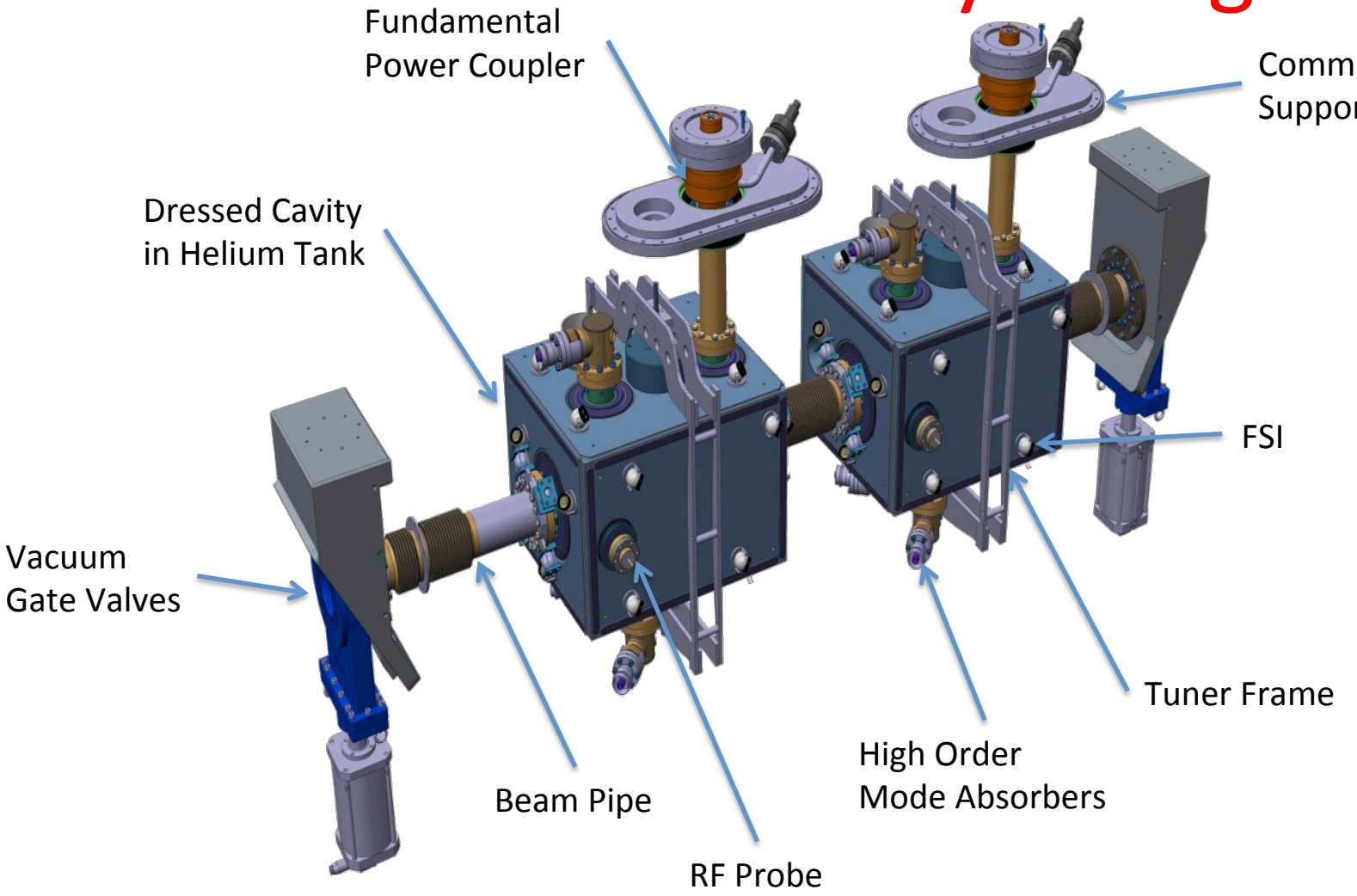
In steady-state with feedback not fully closed, we see integration of noise => drift. This should not be an issue for the cavity with fully closed loop.

N. Templeton

SPS Test Prototype Cryomodule

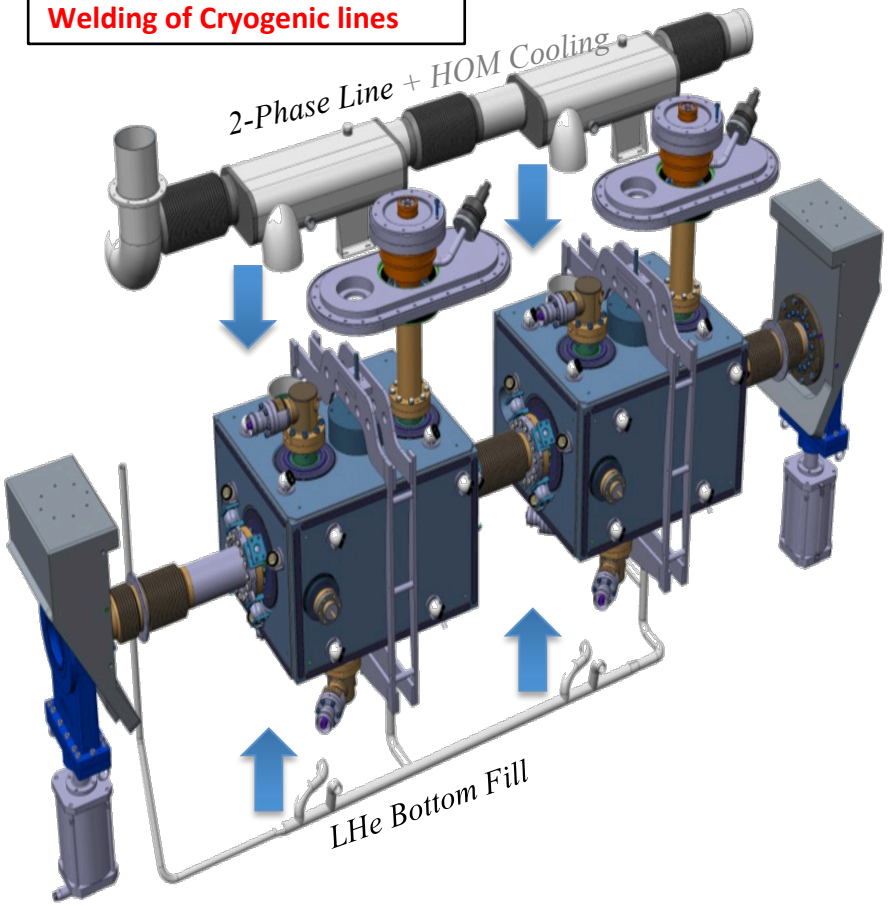


Assembled Cavity String

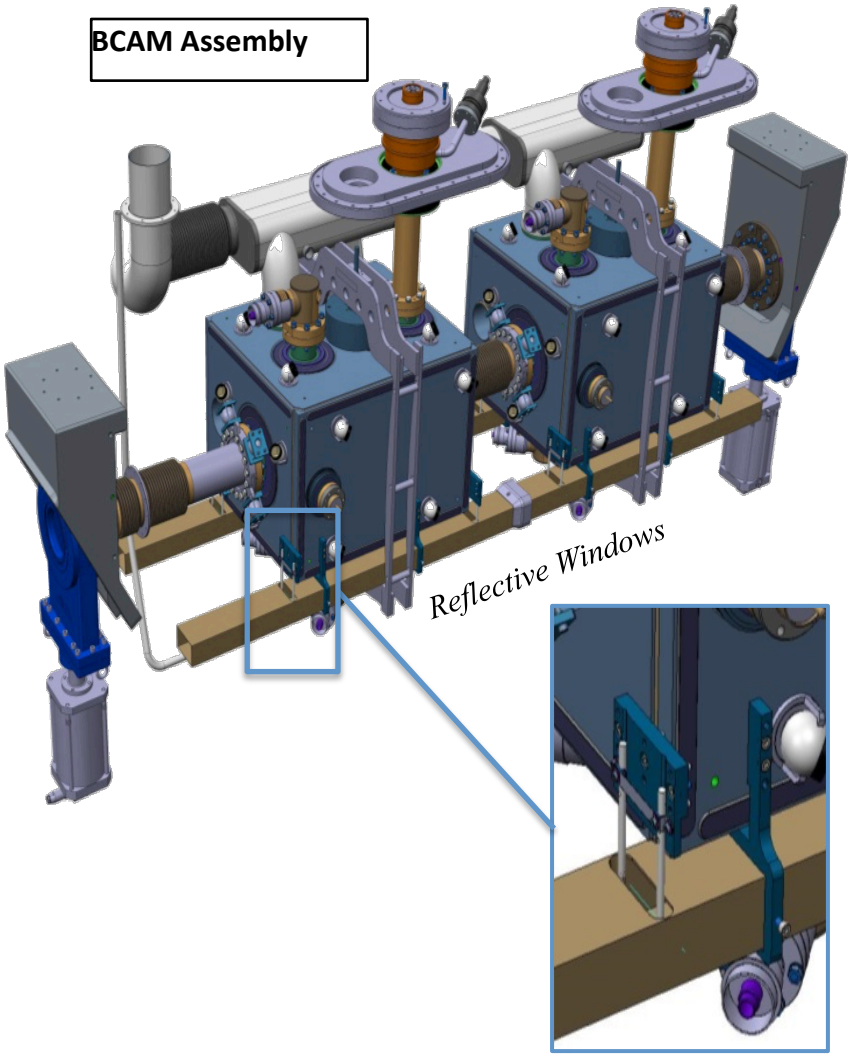


Cryomodule Assembly

Welding of Cryogenic lines

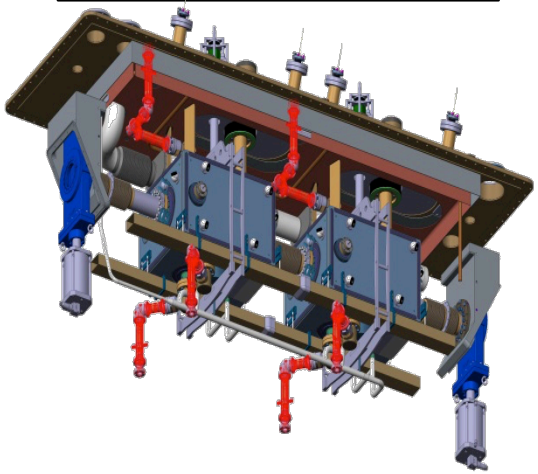


BCAM Assembly



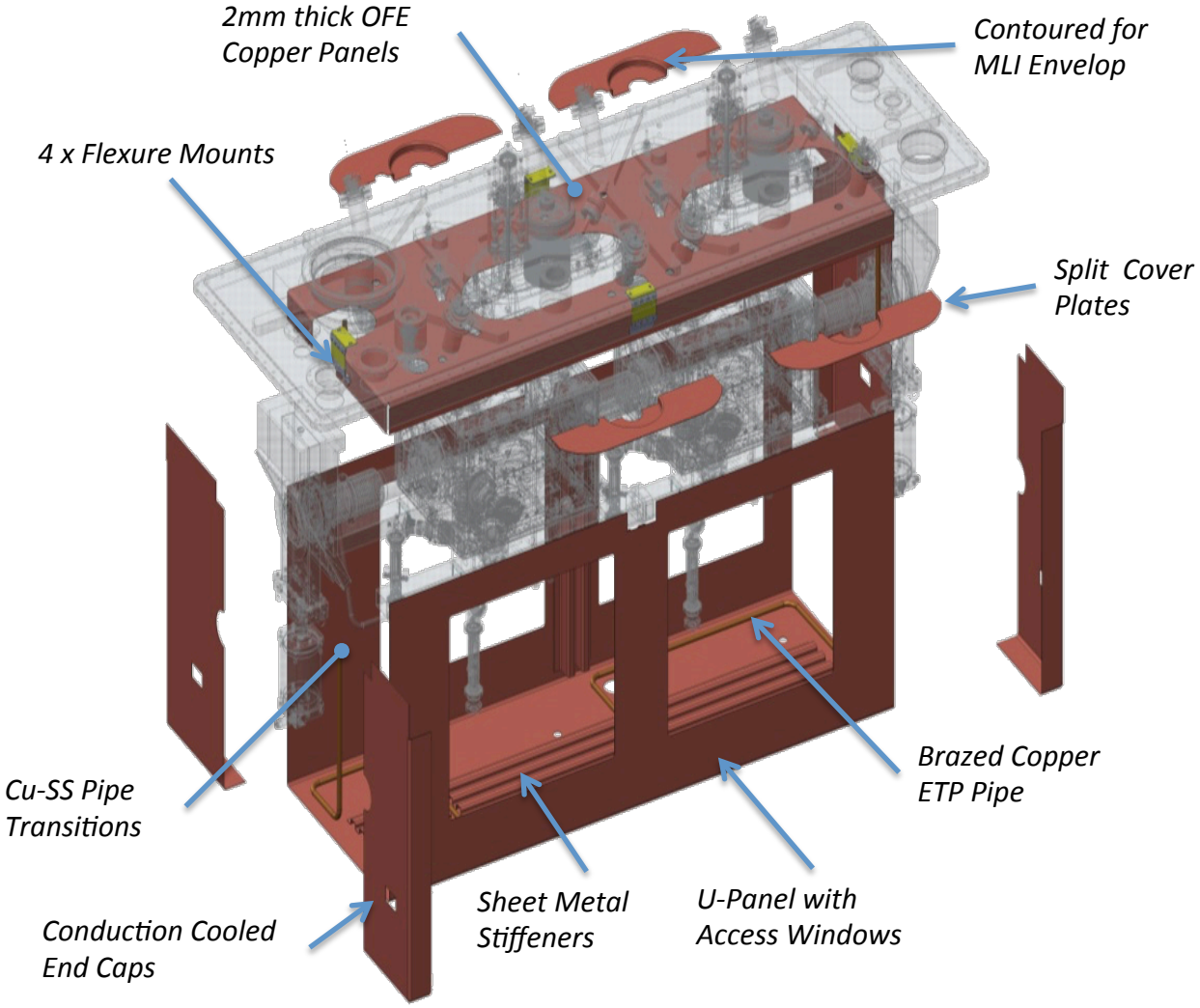
Cryomodule Assembly

HOM Coaxial Connection



6 x HOM Coaxial lines with thermal intercepts

Thermal Shield Assembly



Manufacturing processes

- Establishing processes and procedures
  - From machining, to welding, to chemistry, to assembly
- Testing, documenting and evolving
- Documentation and tracking systems also evolving
- Prototyping and testing all key components
  - FPCs, HOMs, Tuners
- Cryomodule design, planning and integration also well underway

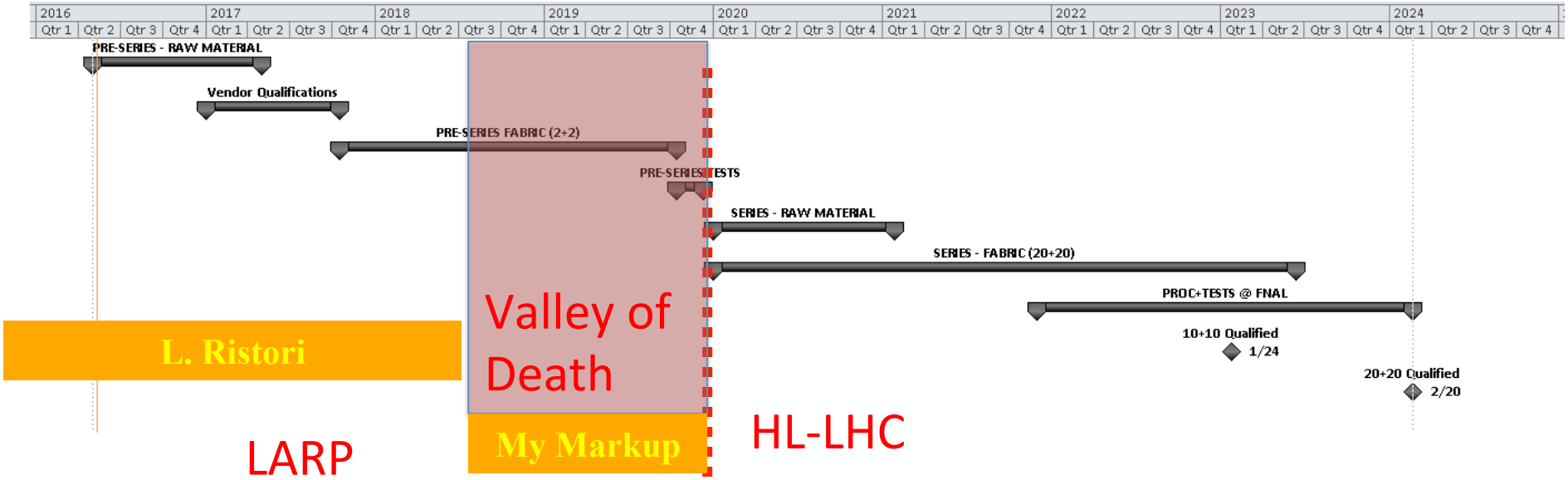
Planning – Key Documents

- Existing EDMS documents for the SPS test can be easily evolved to cover HL-LHC
  - Functional requirements, engineering specifications…
- Existing manufacturing processes and procedures are directly applicable to the series production
- Acceptance criteria document drafted and under review at CERN
- These are necessary for the cavities before CD2 in the HL-AUP project

Planning - Pre-Series Cavities

- Raw Materials
  - Outcome of fabrication of prototype cavities will confirm material needs
    - EBW quality issues may require alternative approaches to forming/welding certain components
  - Request for Quotation: RRR Niobium & Nb55Ti Alloy. 316LN provided by CERN, determine logistics.
    - Procurement process and Inspections at Fermilab (see slide ahead)
- Cavity Fabrication
    - TO DO: Prepare a Fabrication Specification Document
  - Contract Award:
    - RFP + Technical Award
    - If 2 suppliers are successfully qualified, preferred option is to split contract (reduced risk)
    - Award contract(s) for a total of 2 RFD + 2 DQW
  - Fabrication:
    - Tight supplier oversight to provide to CERN status updates, necessary documentation and samples
    - Intermediate and final Inspections at supplier's premises with Fermilab involvement
- Chemistry and Tests (ANL+Fermilab)
  - BCP, HPR and Clean-Room assemblies at joint ANL/Fermilab Facilities
  - Cold Tests at Fermilab's VTS Facility
  - CERN/LARP to review/approve Cavity Design, Fabrication Process, Processing Plan, Clean Room Procedures

Sleepless Nights



- The gap in funding between the end of LARP and funds becoming available in HL-LHC AUP could cripple the pre-series and endanger the overall plan.
- Funding deliverables through LARP has been very 'challenging' until today.

Summary

- Tremendous amount of progress
  - Very dedicated and talented group with many young scientists
- CERN has allocated a lot of resources to the project
- DQW production for SPS well underway
  - Including auxiliary systems (FPC, HOMs, Tuners)
- RFD cavities from US industry now at JLAB for QA, welding, processing and testing
  - DQW coming soon
- Magnetic shields from UK ready and waiting for cavities
- Cryomodule design also advanced significantly
- Schedule for the SPS test remains challenging

Conclusions

- Major progress in all areas of the system
- Collaboration is working well
  - Major contribution now from CERN effort
- All ongoing activities are preparing towards construction
  - The SPS test is a major driver to test all processes
- Nonetheless, there are still plenty of reasons to stay awake at night
  - Not just preparing the WP4 summary talk!

Questions