HiLumi LHC-LARP

5th joint Annual Meeting 26 - 30 October 2015, CERN

SPS Double-Quarter Wave Crab Cavities

Discussion on CAVITY PREPARATION PROCEDURES

Silvia Verdú-Andrés, *Toohig fellow* at BNL
on behalf of DQW crab cavity design team

Cavity preparation procedures

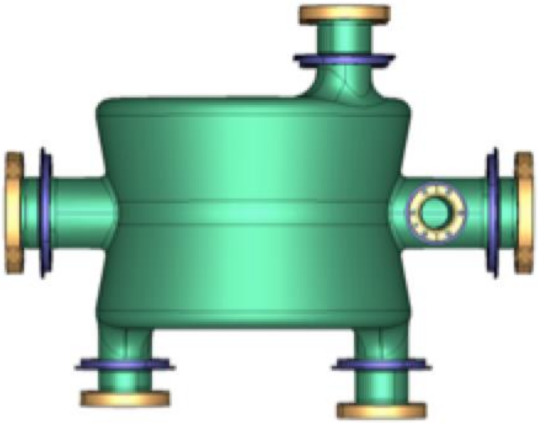
- BCP & HPR
- Baking
- Tuning and RF measurements

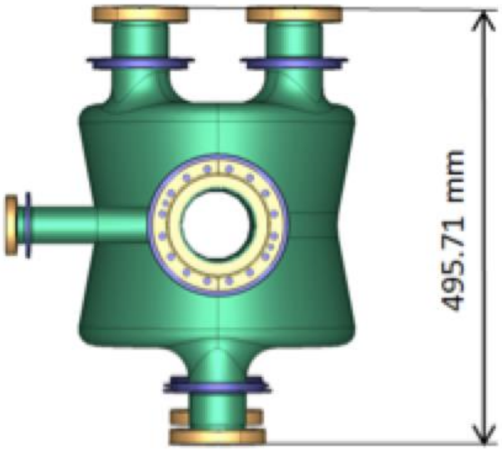
At which stage are bulk and light BCP performed?

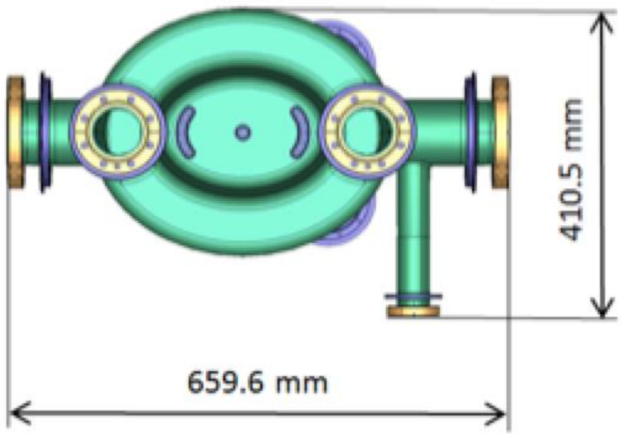
from manufacturing flow chart (version June 2015)

STEP #	STEP NAME
26	Tuning with frequency check
27	Dimensional control (dimensions for He vessel) and pre BCP thickness measurement
28	Bead pull measurement
29	Optical inspection
32	Thickness measurement
33	***Bulk chemical polishing***
34	Visual examination
35	Thickness measurement
36	Resonator frequency check
37	Heat treatment
38	***Light chemical polishing***
39	Thickness measurement
40	Visual examination
44	Manual HPR
45	High pressure water rinse
46	Cleanroom assembly
47	Evacuation and helium leak test
48	120 C low temperature bake
49	RF acceptance tests at cold temperature (without and with HOM couplers)
50	Bead pull measurement with FPC (dummy) and/or HOM couplers

Cavity prototype







CAVITY PARAMETER		UNIT
Maximum length	659.6	mm
Maximum height	495.71	mm
Maximum width	410.5	mm
Inner surface	0.737	m^2
Inner volume	0.022	m^3
Weight (incl. flanges and prep rings)	55	kg

BCP & HPR procedure

- ***Cavity dependent, facility dependent***

Document with specifications common to both DQW and RFD based on Jlab specs was prepared and is compatible with CERN specs:

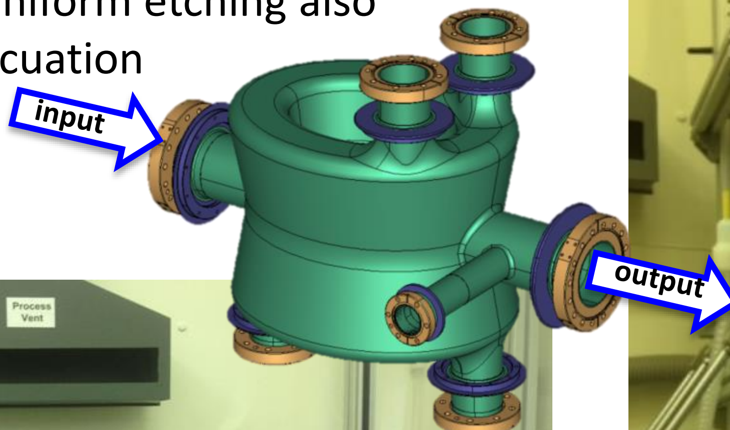
>> "Procedure for Chemical Processing of Finished Crab Cavities" (Sept 3, 2015): https://edms.cern.ch/document/1541180/1

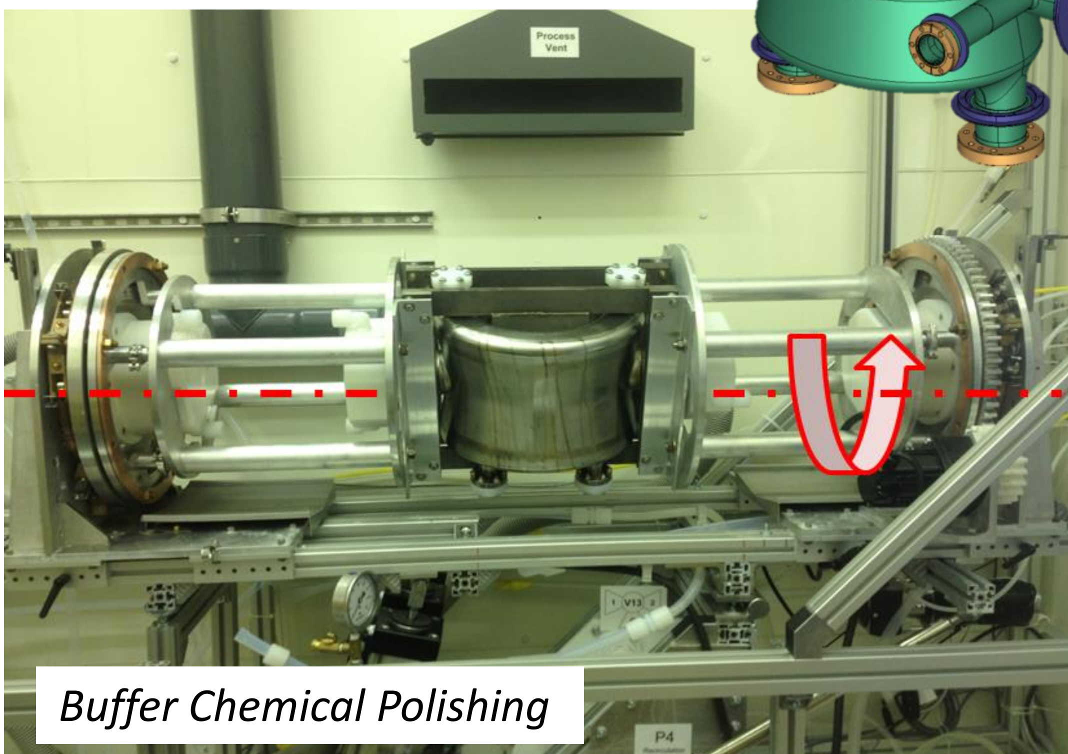
Two procedures prepared with specificities for DQW:

- for ANL facility
- for JLab facility

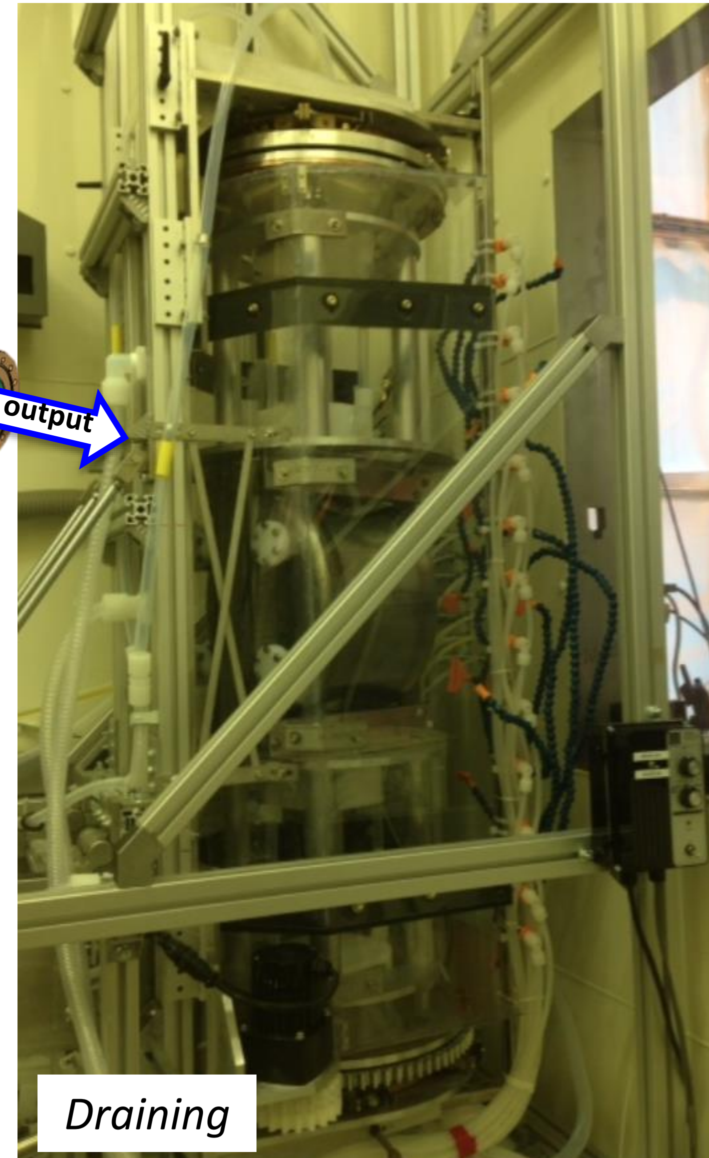
BCP & HPR procedure #1 – ANL facility

- Already experienced with PoP DQW Crab Cavity
  - port adapters ready for SPS DQW CC
- Rotating BCP system for uniform etching also allows enhanced acid evacuation





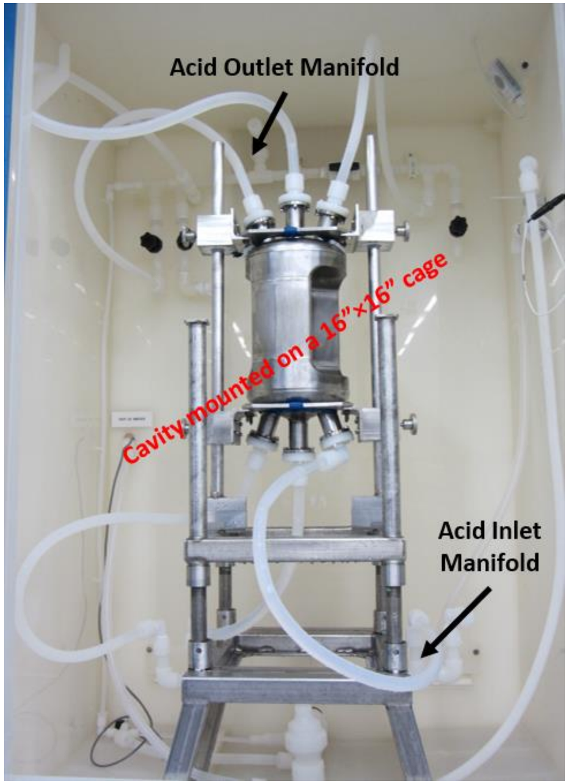
Buffer Chemical Polishing



Draining

BCP & HPR procedure #2 – JLab facility

- Discussions on progress; JLab was given the funds to perform BCP & HPR for CCs
- BCP facility at Jlab uses cabinet

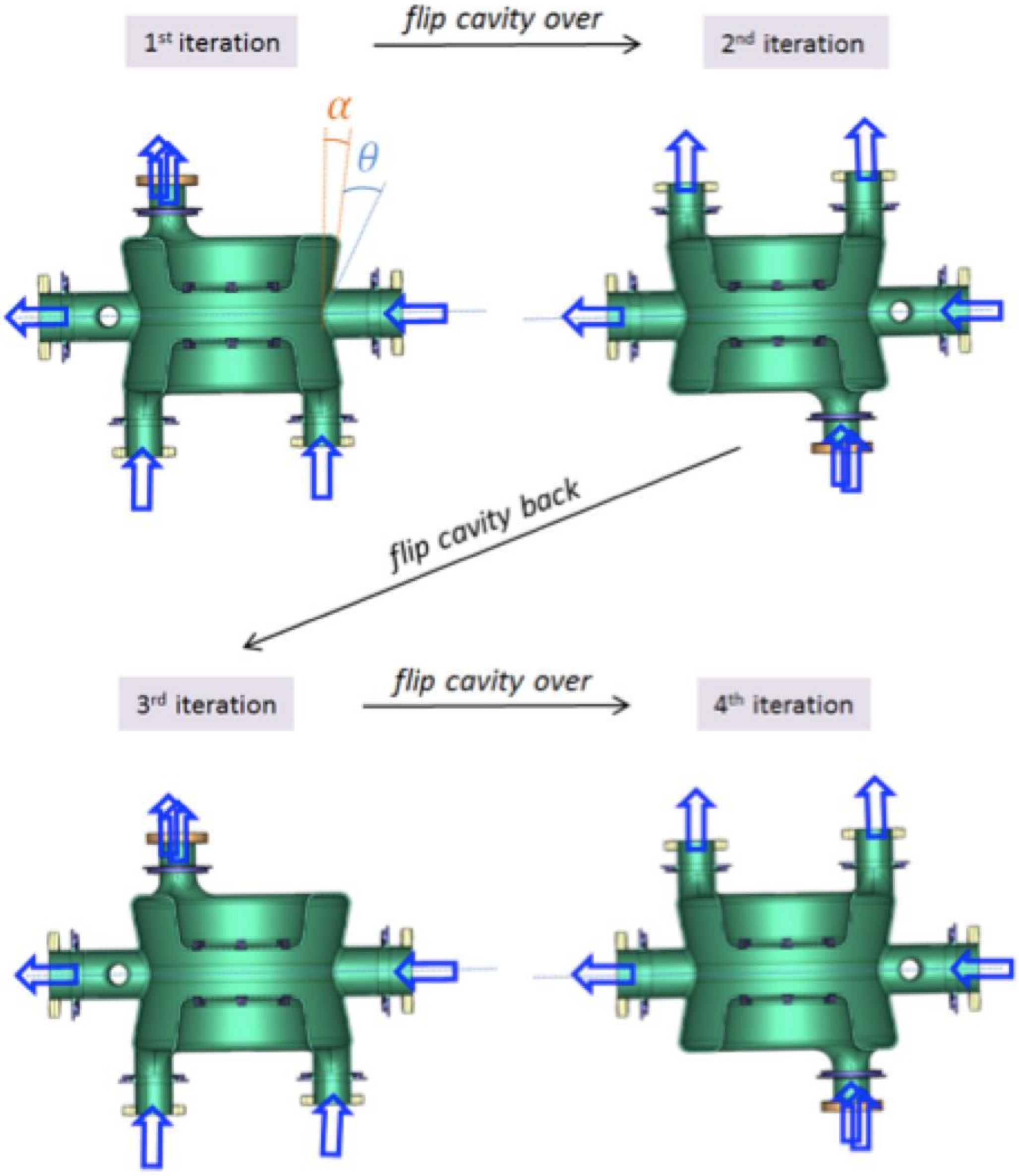


- *Inlet at the bottom*
- *Outlet at the top*

- Possibility to use rotating capabilities of EP facility to perform BCP
  - avoid iterations
  - cavity completely filled with acid → avoid fumes interaction with freshly-polished, reactive Nb

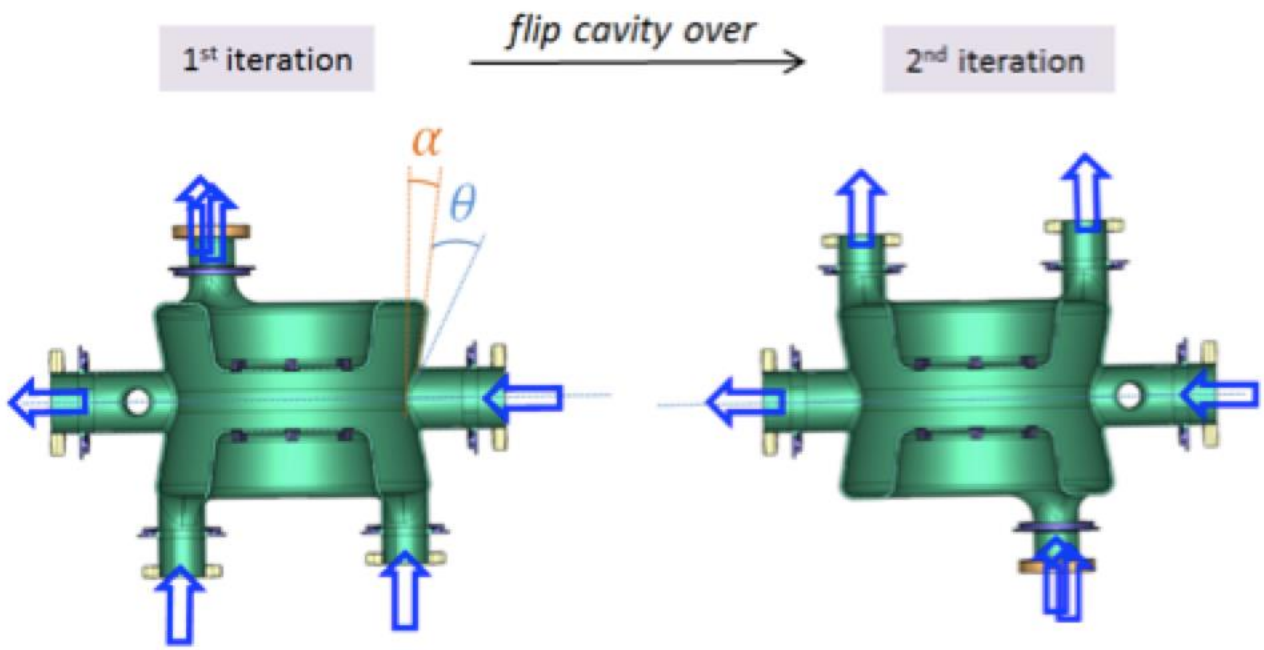
BCP & HPR procedure #2 – JLab facility

Bulk BCP CONFIGURATION
(about 150 μm removal)



BCP & HPR procedure #2 – JLab facility

Light BCP CONFIGURATION
(about 30 μm removal)

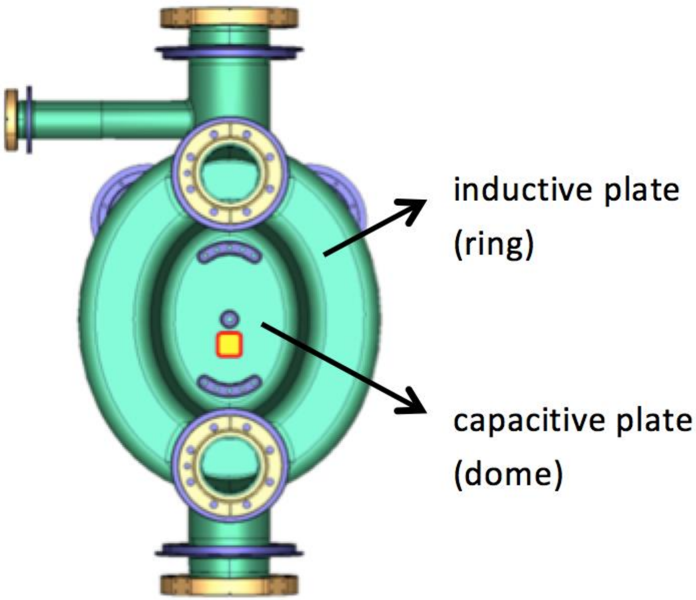


- If BCP is not made in rotating facility,
  Action → define thickness removal at different heights of cavity

- Wish: include at least 4 thickness gauges with active readout during BCP. Currently only 1 thickness gauge available.

Preferred location for thickness gauges during BCP at JLab

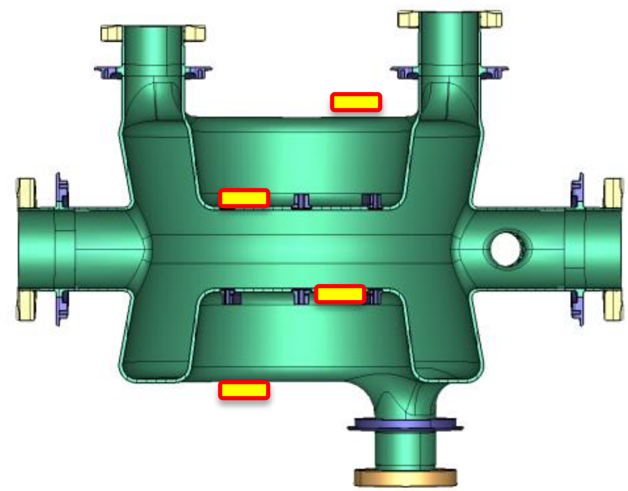
If only one gauge available:



(Wish) At least 4 gauges:

(for monitoring on high freq sensitivity regions)

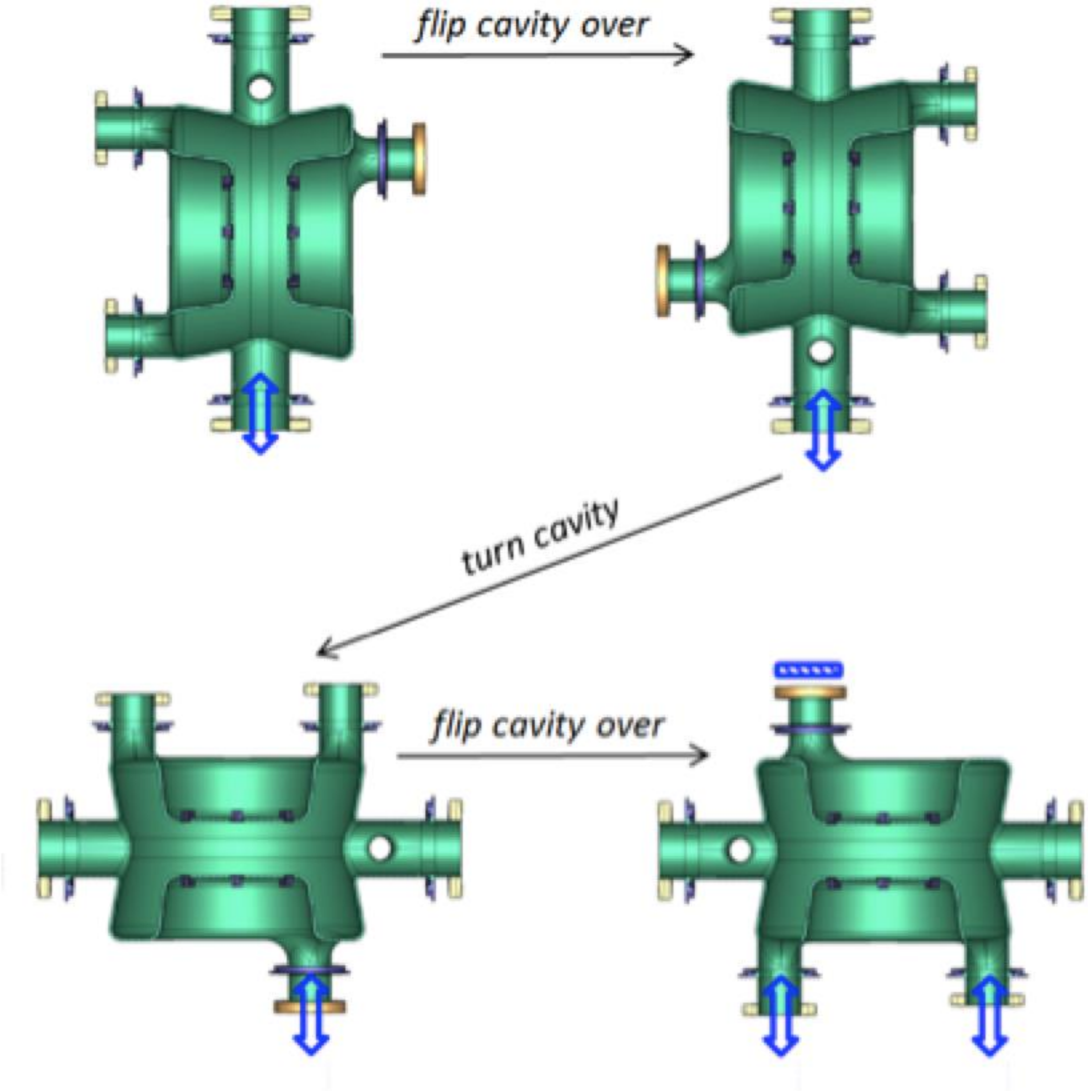
- *one on each inductive plate*
- *one on each capacitive plate*



= thickness gauge

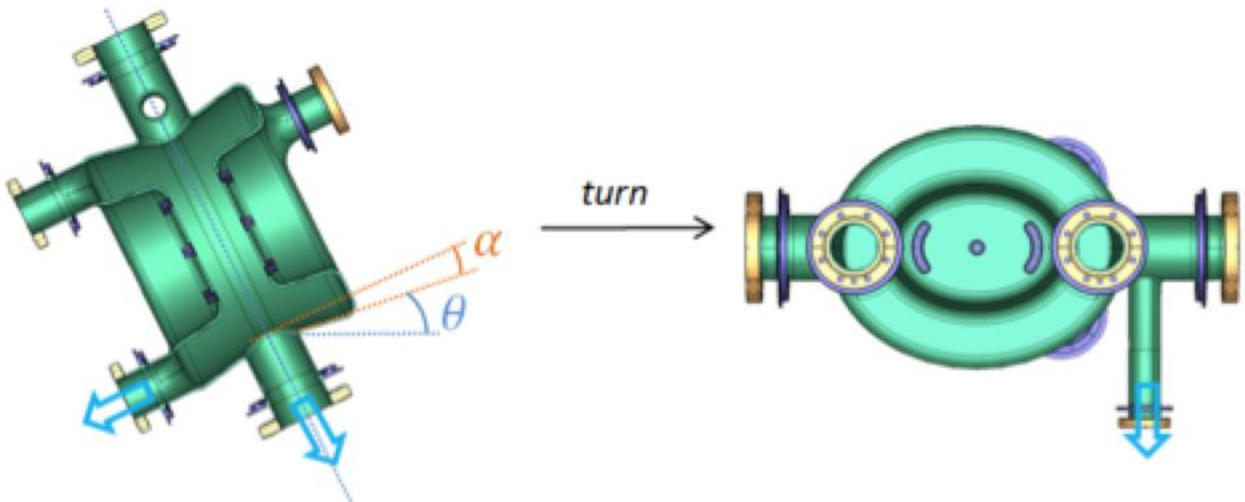
BCP & HPR procedure #2 – JLab facility

HPR CONFIGURATION



BCP & HPR procedure #2 – JLab facility

DRAINING & DRYING CONFIGURATION



Angle α is 10.6 degrees → tilting needed to avoid stagnation in high H-field region

Action → provide cavity model to T. Jones for study of acid flow during BCP

Baking procedure

“Universal” (very similar around facilities)

Main points:

- Cavity degreased and bagged; no stiffening frame to avoid contamination
- Pump down until vacuum is 10^{-6} mbar
- T ~ 600°C for about 10 h; monitor RGA (max. 9 elements)
- Let cavity cool down in furnace
- Temperature ramp rates up and down shall not exceed 75°C/hour
- Furnace must be clean of any residue that might evaporate at this temperature and then adhere to the component surfaces.

Actions → document needs to be written and compared to CERN specs

Tuning procedure

Thanks to Kurt Artoos, Graeme Burt and Carlo Zanoni for reviewing the draft document

Document contents:

→Explains how **“warm” model** was generated **from ideal RF design** accounting from frequency shifts of thermal contraction and chemistry

→ Collects **frequency sensitivity** to manufacturing and assembly tolerances used to assess preparation of functional drawing (August 2014)

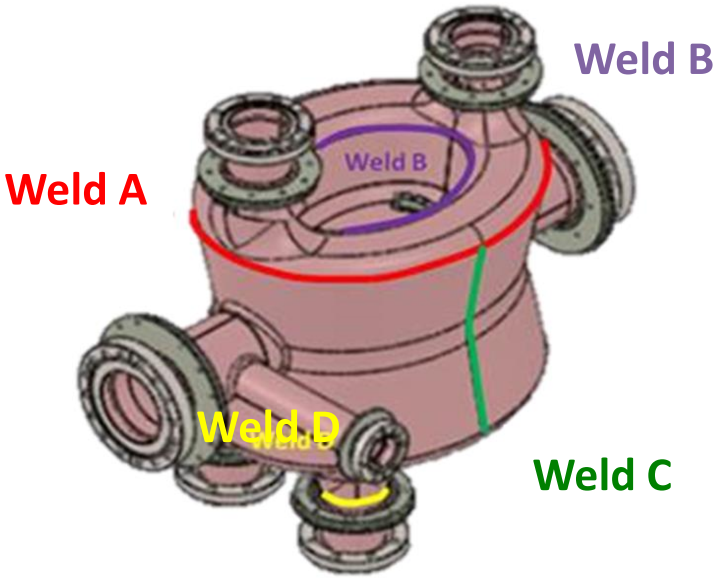
→ Describes **tuning mechanisms, sensitivity and range**

→ Provides **tuning strategy**, incl. trimming and goal frequency after final weld

→ Lists **steps where frequency shift** is **expected**

Action →define required **ancillary**

Tuning procedure – *frequency sensitivity to welds*



Type	No.	Δf/weld [kHz]	Δf [kHz]
A	2	70	140
B	2	99	198
C	2	23	46
D	4	70	280
			664

- **Non-negligible; however,** values here discussed represent the worst-case scenario: chemical polishing procedures will smooth down the weld sagging
- Welding can lead to some shrinkage of the sheets → effect not accounted in this study
- Must be **taken into account** in the tuning strategy and **compensated** before the last weld of the cavity assembly or during pre-tuning
- *Option*: **grind the welds** before any chemical surface treatment to reduce the sagging but grinding can introduce residues
- Note that **grinding** will only be possible for all welds but the last one (weld A).

Question → are all welds performed from the outside?

Tuning procedure – *frequency shifts*

Effect			Unit
Beam loading	Δf_{BL}	0	kHz
FREQUENCY SENSITIVITY TO PRESSURE	$\Delta f_P / P$	-0.103	Hz/mbar
He bath pressure (bath 20mbar ->atm)	Δf_{PHe}	+0.002	kHz
Atmospheric pressure (vacuum -> atm)	Δf_{PAt}	+0.104	kHz
LORENTZ DETUNING COEFFICIENT	$\Delta f_P / V_{defl}$	-40	$Hz/(MV)^2$
LF detuning: RF power on -> off	Δf_{LD}	0.4	kHz
Couplers and ports (baseline assembly → bare cavity)	Δf_C	+89	kHz
Frequency change from vacuum to air	Δf_{ε}	-133.3	kHz
Frequency change from 2 K to 300 K	Δf_T	-573	kHz
Inverse BCP (0.21 mm)	Δf_{Ch}	+170	kHz

* Frequency shift due to BCP is computed assumed uniform thickness removal for all cavity surface… → *not realistic!*

Tuning procedure – *goal frequency*

Goal frequency for bare cavity with all blank-off ports before bulk BCP [kHz] = 400,343.1			
Step	**Frequency shift due to**	**Frequency shift associated to step [kHz]**	**Frequency after step [kHz]**
Bulk BCP (150 um)	*Thickness removal*	-121.4	400,221.7
Light BCP (30 um)	*Thickness removal in preparation for cryogenic RF tests of bare cavity*	-24.3	400,197.4
Light BCP (30 um)	*Thickness removal in preparation for cryogenic RF tests of dressed cavity in SPS*	-24.3	400,173.1
Assembly SPS FPC, PU and 3 HOM filters	*PU in, FPC in and 3HOM in*	-89	400,084.1
Evacuation	*Vacuum pressure and permittivity*	+0.104+133.3	400,217.5
Cooldown *(tuner should plates free!)*	*Thermal contraction and He pressure*	+573 0.102	400,790.4
RF on (nominal operation)	*Lorentz force (RF on)*	-0.4	400,790.0
SPS beam on	*Beam loading*	0	400,790.0

Tuning procedure – *tuning mechanisms, sensitivity and range*

Trimming

2.4 MHz/mm when reducing the length of extra material in only one of the bowls

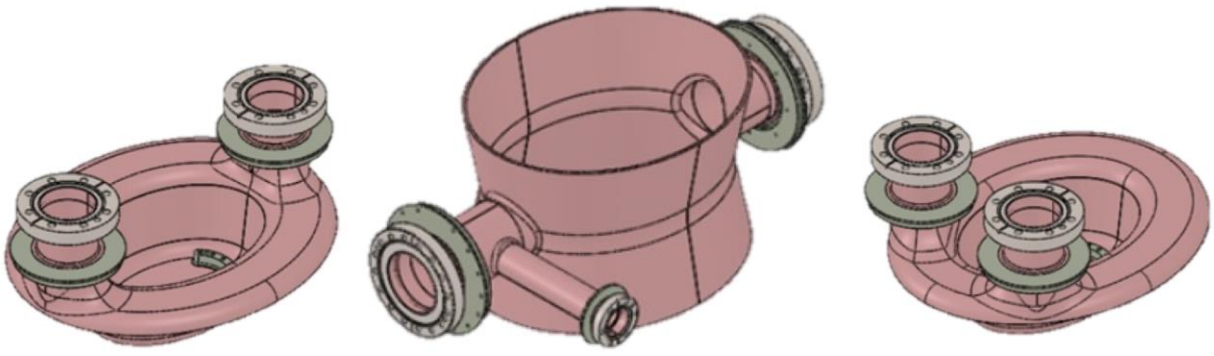
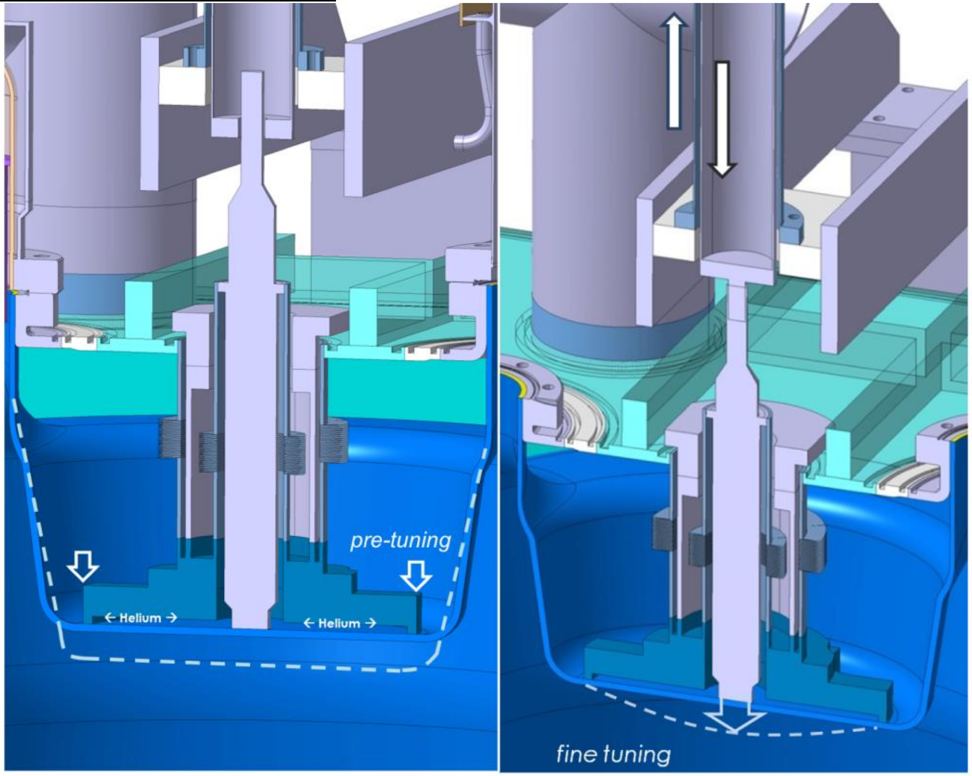


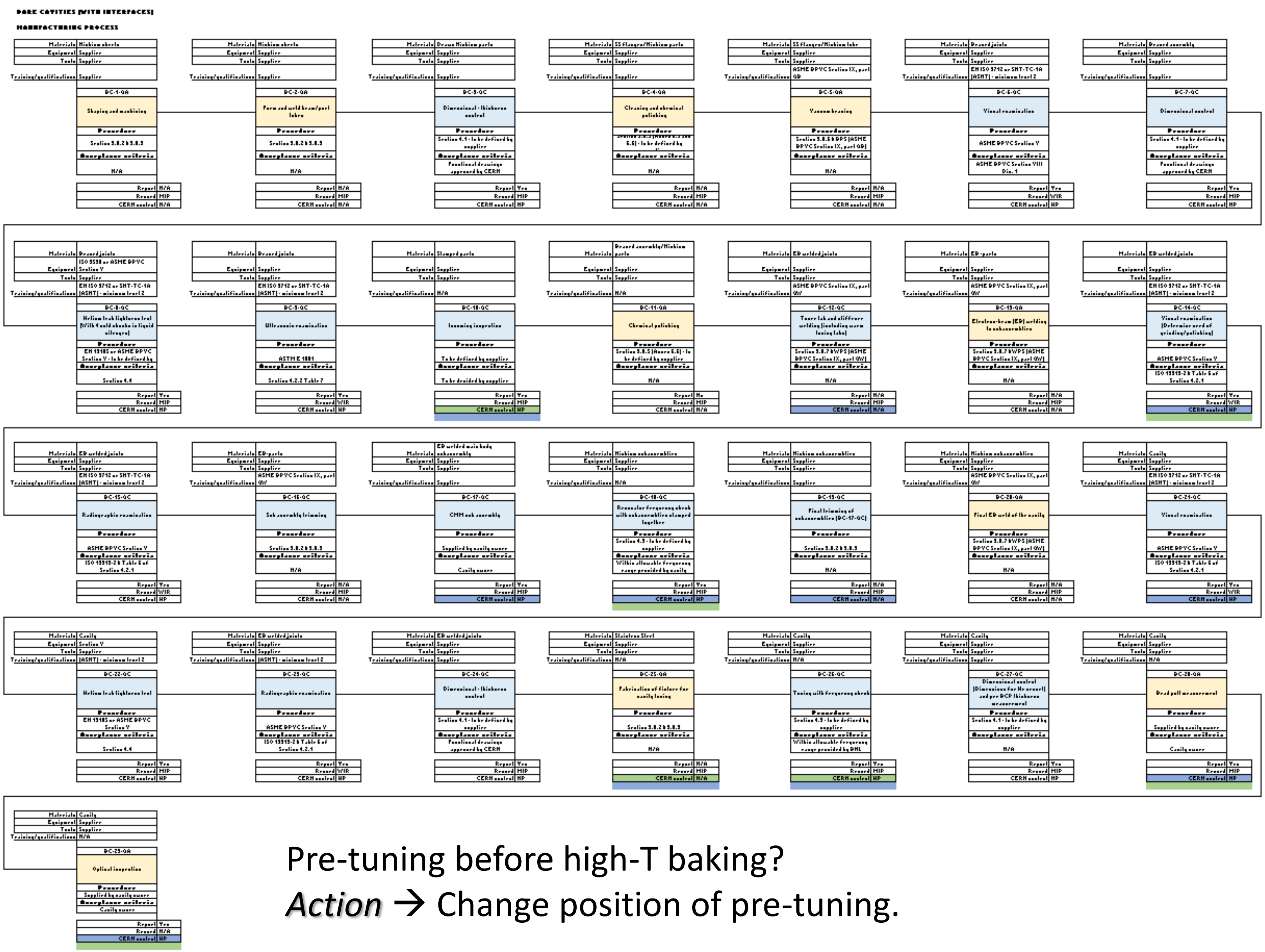
Figure 1. Main subassemblies for the DQW crab cavity. [Left] Top bowl, [center] main body and [right] bottom bowl.

Tuning procedure – *tuning mechanisms, sensitivity and range*

	SENSITIVITY Df/DR_{gap} [MHz/mm]	MAX. DISPLACEMENT DR_{gap} [mm]	FREQ RANGE Df [MHz]
Pre-tuning *(coarse tuning)*	1.604	0.1 (limited by weld Nb-NbTi)	0.3
Push-pull tuning *(slow, fine tuning)*	0.372	0.8 (elastic limit of cavity)	0.62



Manufacturing Flow Chart (latest version, June 2015)



Pre-tuning before high-T baking?

Action → Change position of pre-tuning.

To do list

- BCP & HPR
  - → Provide cavity model to T. Jones for study of acid flow during BCP
  - → Decide where BCP is performed (cabinet or rotating facility, ANL or Jlab)
  - → If BCP at Jlab cabinet, define thickness removal at different heights of cavity
  - → Prepare ancillary:
    - ANL: adaptor for HPR system, thickness gauges?
    - JLab: flanges, hoses, cage, thickness gauges

- Baking
  - → Write document

- Tuning and RF measurements
  - → Define required ancillary (for pre-tuning when He vessel is not assembled yet to cavity)
  - → Define coupler used for low RF power measurements for frequency checks
  - → If elastic deformation for pre-tuning, design for stiffening frame needed that fixes cavity plates. Frame can be used for cold tests of bare cavity.

Tuning procedure – *frequency sensitivity to welds*

Table 1: RF performance comparison for weld types A, B and C.

					Vt = 3.34 MV	
Weld name *#*	**Sag depth** *mm*	**Underbead thickness** *mm*	**Freq** *MHz*	**D f** *MHz*	**Emax** *MV/m*	**Bmax** *mT*
No welds	--	--	404.241		34.53	62.33
A	0.5	5	404.311	-0.07	34.67	62.37
B	0.5	5	404.340	-0.099	34.37	62.85
C	2.0	5	404.334	-0.093	34.62	61.88

Table 2: RF performance comparison for weld type D.

						Vt = 3.34 MV
Weld name *#*	**Sag depth** *mm*	**Underbead thickness** *mm*	**Freq** *MHz*	**D f** *MHz*	**QextFPC**	**Bmax** *mT*
No welds	--	--	399.64		5.33e5	4.5
D FPC	0.5	5	399.58	-0.07	5.37e5	9.0