Science & Technology Facilities Council

EUROPEAN SPALLATION SOURCE

ESS High Beta Cavities Status Update; Interfaces

10th ESS SRF Collaboration
Mike Ellis

Thanks to all teams for input including:
Cavity Manufacturing;
SuRF Lab;
QA-QC

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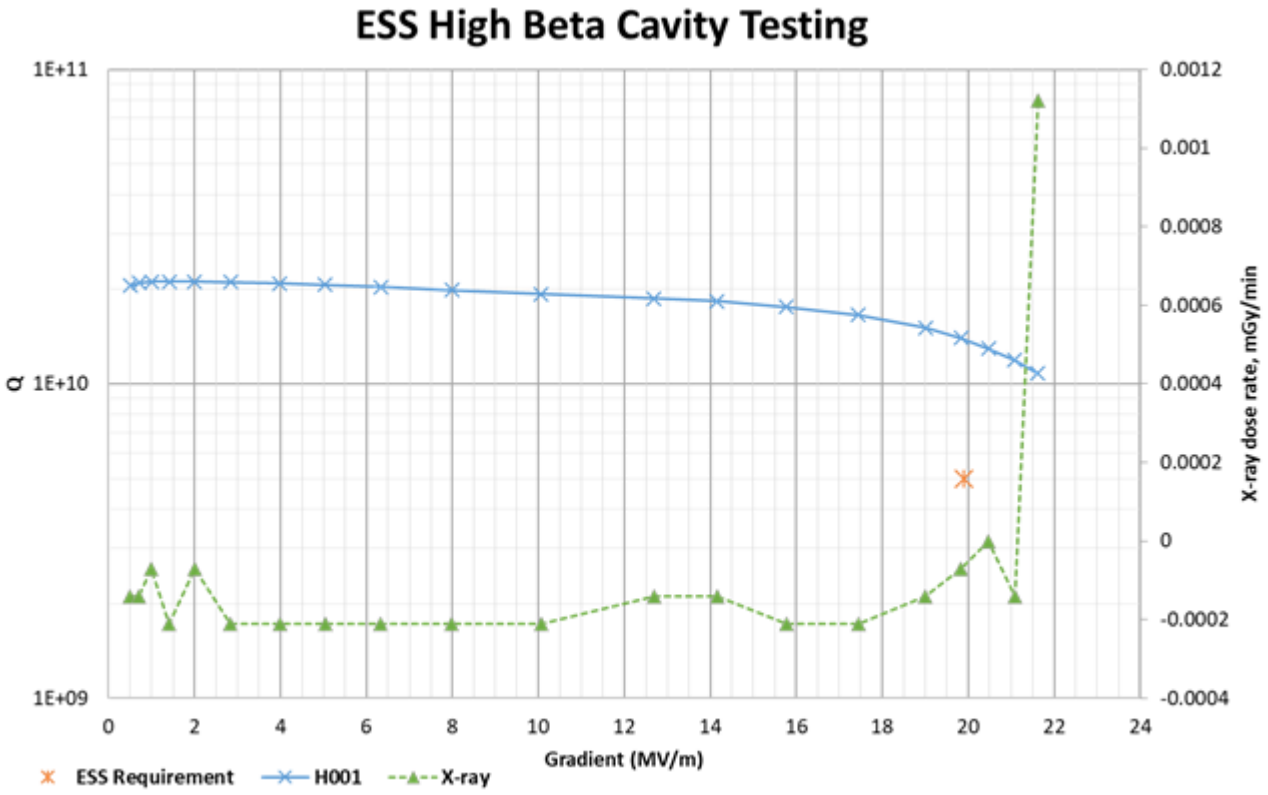
ESS High Beta Cavities
Fabrication & testing and open issues

Item	Description
A	**Cavity Fabrication – Status**
	• H001 data
	• H002 – H004 fabrication status
	• Tolerances – Half-cell and Dumbbell shape
B	**SuRF laboratory & VTF status *(Mark & Paul to present)***
	• Current status
	• Commissioning sequence / schedule
	• Testing limits proposal
C	**Interfaces & status**
	• Antennae – input
	• Elbow
	• Sliding tank
D	**Frequency assessment criteria**
	• Tuning range proposed

A: Fabrication (1) H001 results

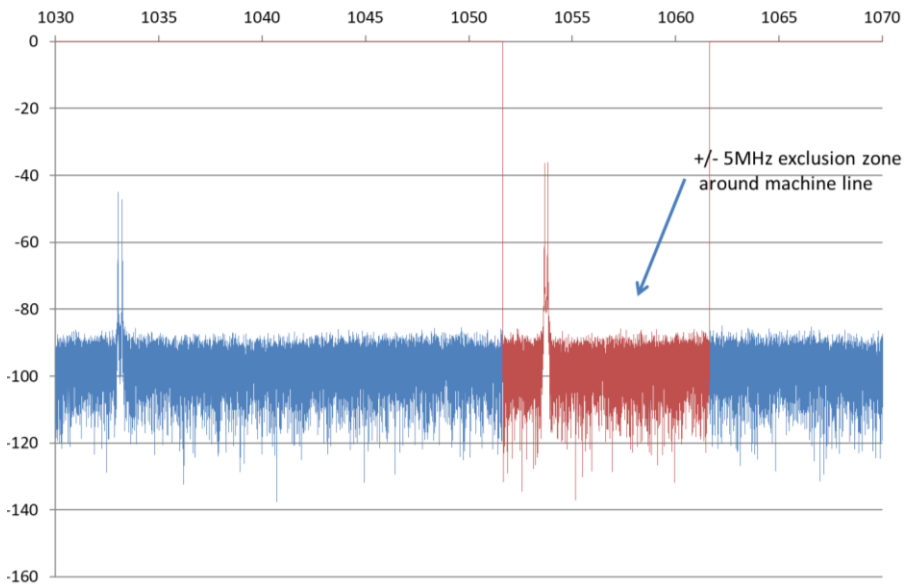


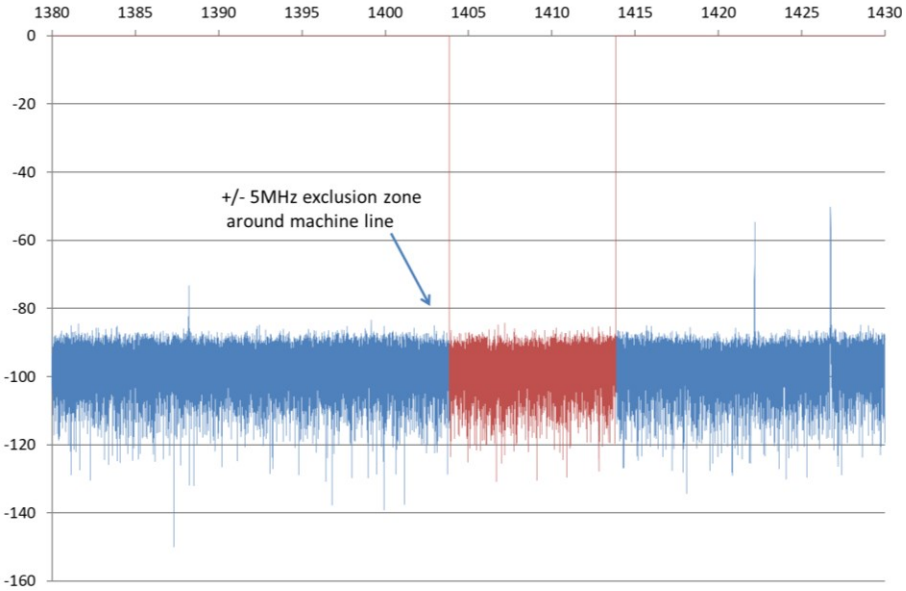
Measurements at highest power reached	
Eacc	21.62 MV/m
Q0	1.08E10
F	704.424 MHz
X-ray top	0.00112 mGy/min
X-ray bottom	0.00182 mGy/min

- Eacc vs Q0
  - OK
- X-ray
  - OK
- F(pi)
  - NOK -> RI to retune cavity, target between [704.030, 704.264] MHz

A: Fabrication (2) H001 results

- HOM measurements @ 2K





- 3rd harmonic
  - 2.97MHz from machine line: NOK?
  - Thanks to Enrico for input & support
    - TE mode, not dangerous?
    - A Farricker et al. MOPOR038 IPAC-> 5kHz from machine-lines should be ok?
- 4th harmonic
  - OK
  - Mode at 1422.172 MHz
  - 8.32MHz from machine-lines

A: Fabrication (3)
HC, DB and H002, H003, H004

- Status of manufacturing:
  - Raw and single parts: 54% complete
    - Half cells: 484 finished, 419 in progress (~54%)
    - Other single parts: 174 finished (2112 required) (~ 8%)
  - Sub assemblies: 3% complete
  - Overall manufacturing: 31% complete
- Pre-series production schedule:

Cavity	Schedule change	1st DESY test (bare)	2nd DESY test (jacket)	Delivery @ STFC	Comments/caveats
H001	None	Complete	26/Jul	30 Aug / 2 Sep*	Pending confirmation of DESY testing in Aug
H002	~1wk behind	14-21/Aug	9/Oct	9/Nov	
H003	Significantly ahead	21-28/Aug	16-18 Oct	16-18 Nov	
H004	Significantly ahead	28/Aug	16-18 Oct	16-18 Nov	Pending replacement/reshaping of 2 DBs out of spec

A: Fabrication (4)
HC, DB and H002, H003, H004

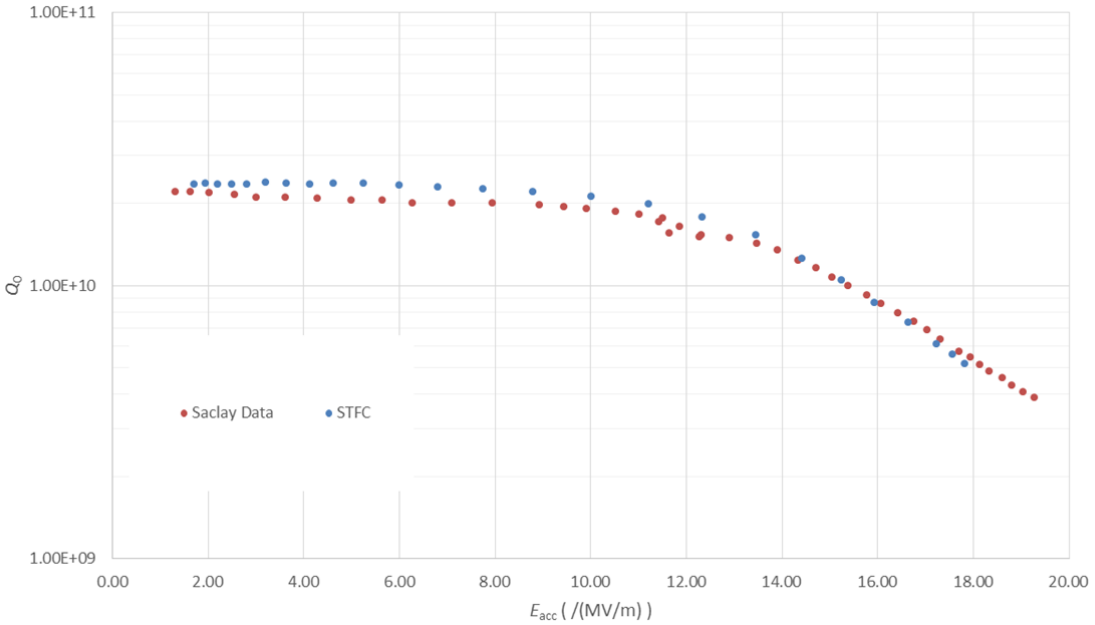
Specifications			
Deviation	Original spec CHC and EHC	Reviewed spec - CHC	Reviewed spec - EHC
Min +/- 0.2	90%	80.0%	85.0%
Max +/- 0.2-0.3	10%	20.0%	10.0%
Max +/- 0.3-0.5	0%	3.5%	3.5%
Max >+/- 0.5	0%	0.0%	0.0%
Estimated pass rates based on sample data			
Prototypes (RI/CEA)	12%	47.5%	90.0%
Pre-series (RI/STFC)	15%	92.5%	91.7%

- Acknowledgements: thanks to CEA:
  - making prototype data available
  - Supporting review of tolerances

- Per STFC understanding, all 5 RI/CEA prototypes met RF specs
- Only 12% of HCs would have met the shape profile tolerances
  - -> Many unnecessary NCRs
- Revised tolerances proposed after consultation with CEA/ESS
  - Now expect c. 92% pass rate -> reduce NCRs to only really the worst half-cells
  - No expected impact on HOMs since population is statistically almost identical to prototype distribution of HC shapes
- DBs: similar situation, under review
  - Will close out after statistics available from pre-series

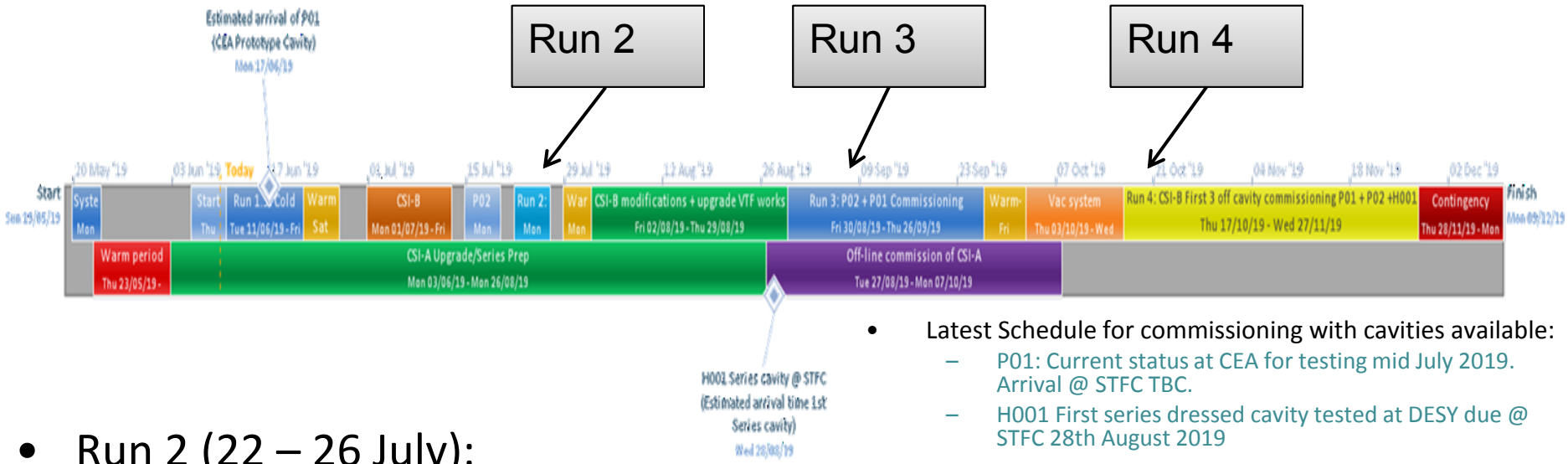
B: SuRF lab (1)
P02 Q_0 vs E_{ACC}, Status Summary

- Same calculation method used as CEA Saclay
- Good agreement within expt. errors
  - Q-10-15%
  - Eacc-5%
- Investigating heat dissipated on input probe
  - Series cavities have a Cu probe
  - Prototypes have a Ti probe
  - 3xRs -> 3 times loss
- Radiation survey in progress
  - To complete when P02 on top cradle
- Cryogenic performance excellent
  - 36hr to cool shields to 75K
  - 6hr to cool CSI insert to 4.2K
  - Stability: ±0.1mBar, ±1mK on static load (no RF)
- Q0 vs Ecc
  - Good agreement with CEA P02 results
  - Investigating heat load on input probe: Cu vs Ti?
  - Run-2 planning to test thermal anchor solution for input antenna



- HOMs measurements
  - Completed through RF rack on cold cavity
- Cleanroom and HPR systems
  - Cleanroom build complete
  - UPW on schedule to complete 8th July
  - HPR final build phase w/c 1st July

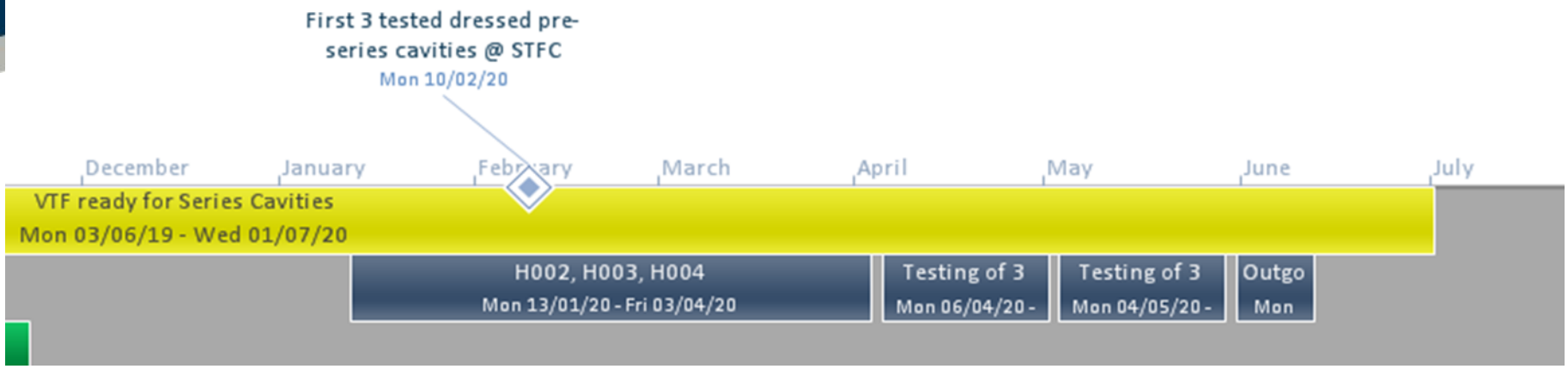
B: SuRF lab (2)
Overall commissioning schedule



- Latest Schedule for commissioning with cavities available:
  - P01: Current status at CEA for testing mid July 2019. Arrival @ STFC TBC.
  - H001 First series dressed cavity tested at DESY due @ STFC 28th August 2019

- Run 2 (22 – 26 July):
  - De-risk: Rad survey completion (P02 Top cradle)
  - High Power Tests ~200W (localised cooling installed on flange)
- Run 3 (30 Aug – 26 Sep):
  - P01 + P02 Commissioning
- Run 4 (17 – 27 Oct):
  - P01 + P02 + H001 Commissioning
- Utilising P01 + P02 + H001 for commissioning and de-risk
- SuRF lab to review and update series schedule after Run 3

B: SuRF lab (3)
Series cavities commissioning



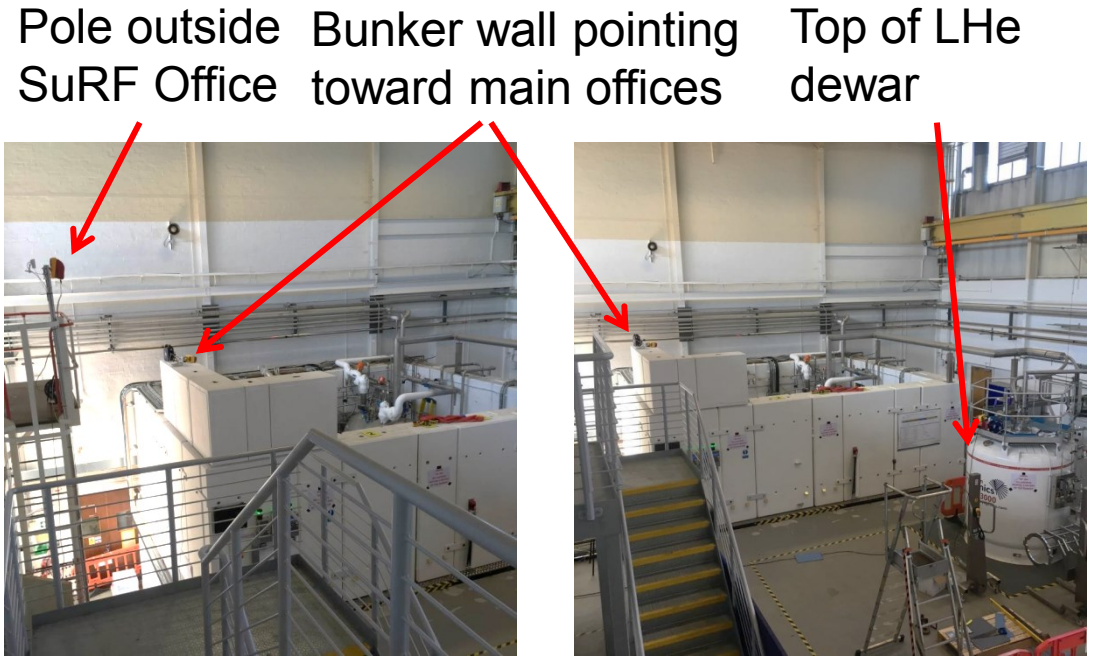
- Proposal: Q1/2020 will be utilised for:
  - Verification and validation with production dressed cavities
  - HB002 + HB003 + HB004 tested from DESY for benchmarks
  - Commissioning times may be shortened dependant on Run-3 conclusions

- Di-Phase pipe cutting validation with DESY:
  - H001 (+ H002?) TBC

- Further De-risk testing strategies under consideration

B: SuRF lab (4) Radiation limit

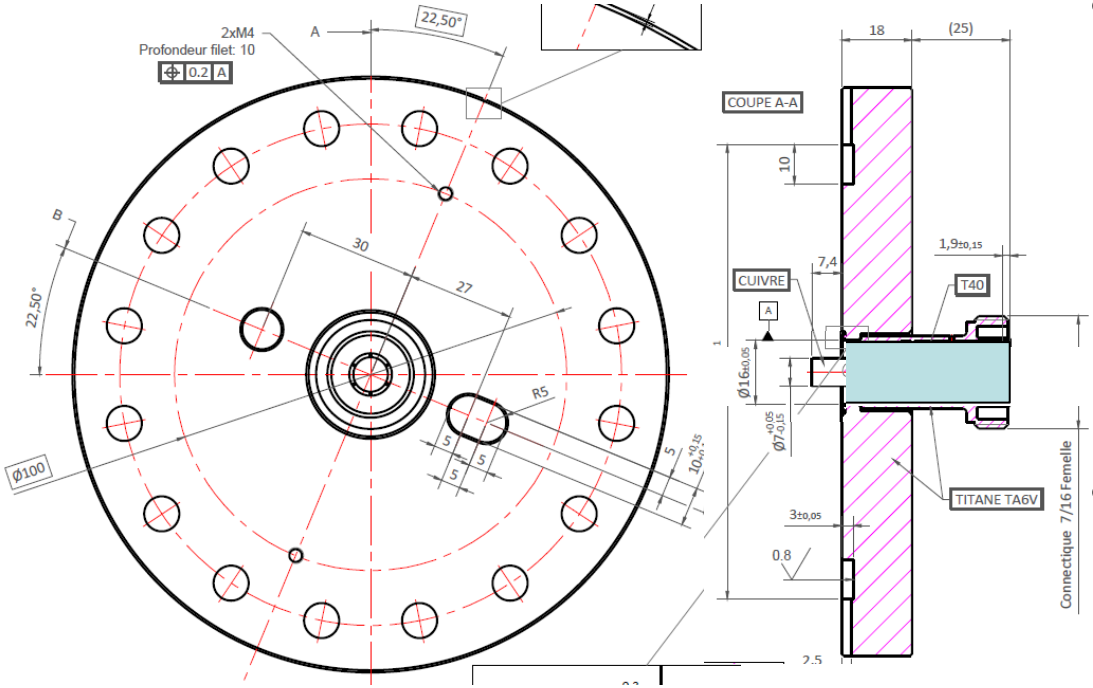
- STFC plan to test cavities up to:
  - Gradient
    - 19.9MV/m: specification pass level
    - Test to 22.9MV/m 'best efforts'
  - RF amplifier power limit:
    - C. 200W incident
  - X-ray limit:
    - Based on safe x-ray level in SuRF lab ("SuRF Office Pole")
    - TBD mSv/hr on cavity axis
  - Thermal power limit
    - TBD



Preliminary radiation survey results:
x-ray data P02, middle CSI cradle

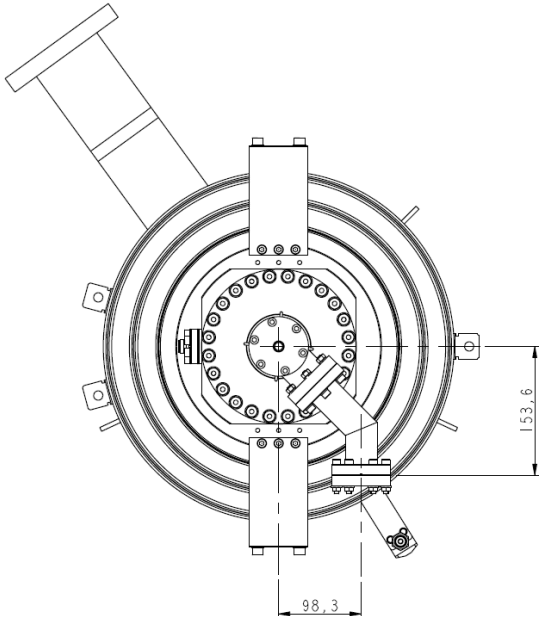
RF Incident Power [W]	Cryostat Lid [µS/hr]	SuRF Office Pole [µS/Hr]	Bunker Wall [µS/Hr]	On LHe Dewar [µS/Hr]	Middle cradle axis [µS/Hr]	Upper cradle axis [µS/Hr]	Lower cradle axis [µS/Hr]
46.9	580	0.85	25	0.4	170,000	40,000	40,000
96	2600	3.2	211	1.5	500-600,000	170,000	170,000

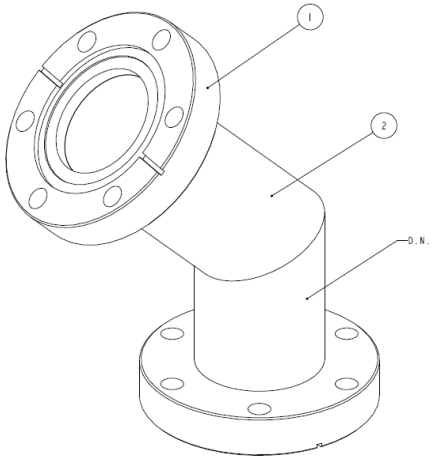
C: Interfaces (1) Input antenna



- Changes:
  - 7/16” connector
  - Direct mount to flange
  - STFC to provide small qty of adapters, supplied with first batch of cavities
- Testing:
  - N2 plunge test at supplier
    - 12x repeats total
- Delivery schedule:
  - First batch July 2019

C: Interfaces (2)
45° Elbow



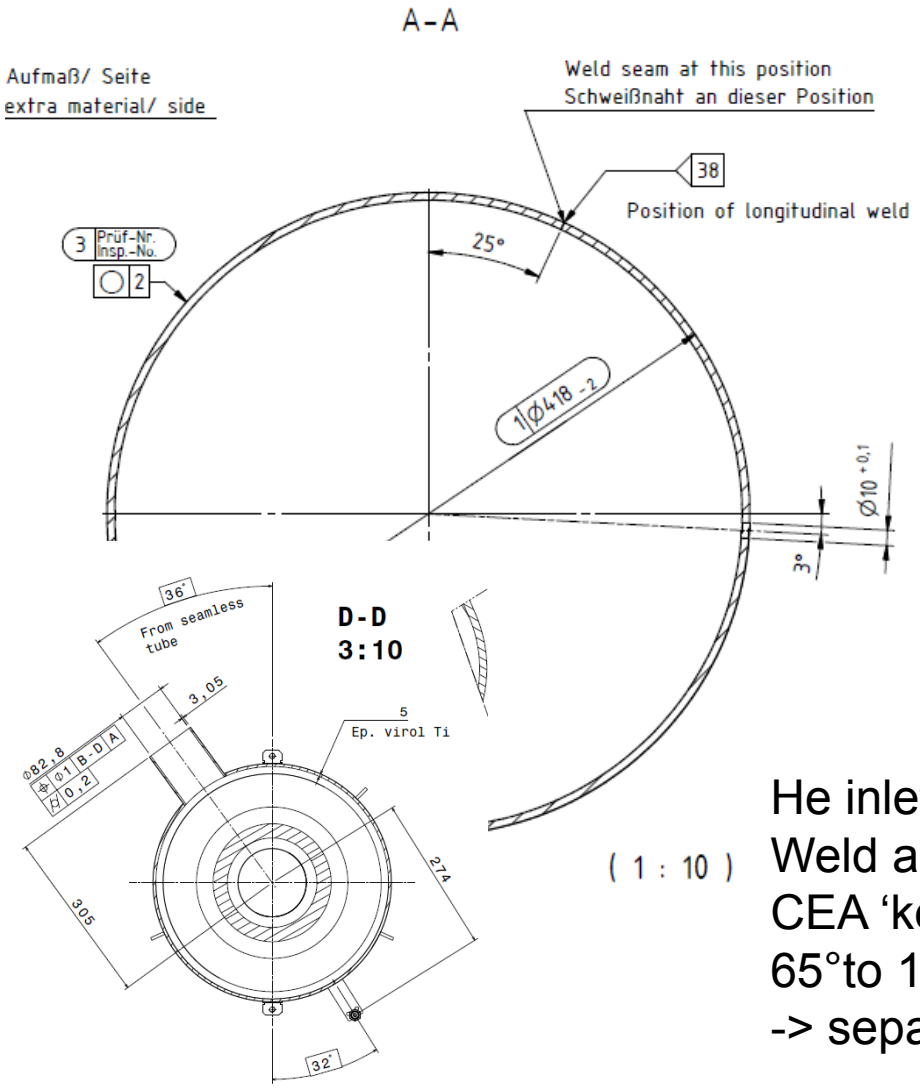


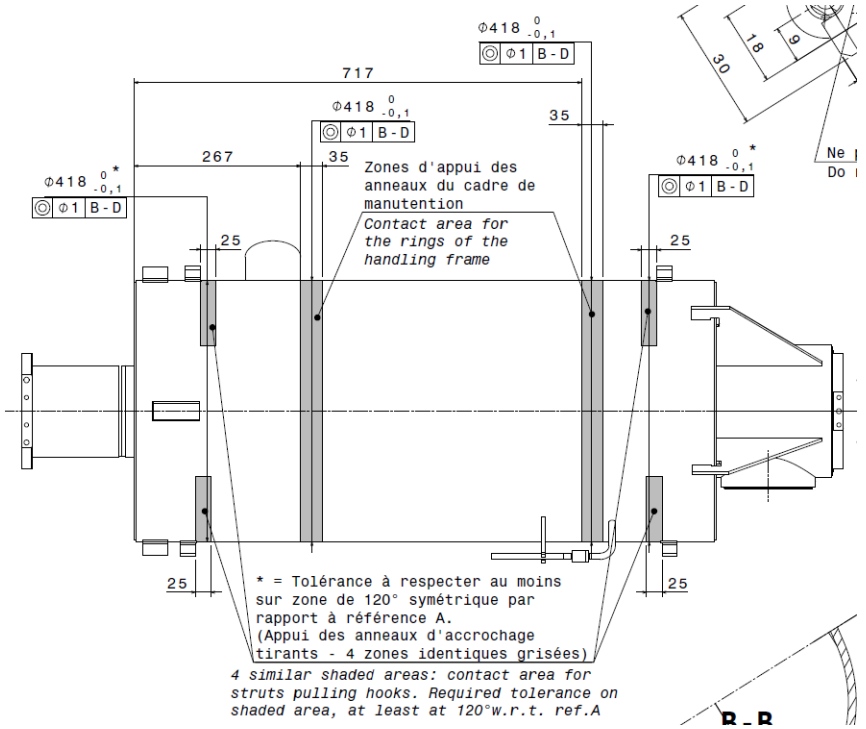
- Material
  - 316LN or 316L with $\mu \leq 1.005$ (1.02?)
- Process sequence / description
  - RI to install in cleanroom;
    - 1 per cavity, no recirculation
  - Delivery to STFC
    - under 1atm with blind flange
  - At STFC:
    - Connection in modular cleanrooms ISO4
    - Cold test
    - Disconnection & removal
- CEA requirements
  - No change to mechanical interfaces
  - Ensure valve cleaned prior to making connection
- Cost, schedule impact:
  - Awaiting RI feedback

C: Interfaces (3)
Sliding tank design & requirements

- Expect there to be no systematic change in frequency:
  - Individual cavities +/-30kHz but average to 0kHz over all cavities
  - To be validated during pre-series cavity testing
- Tuner interfaces (blocks):
  - All geometric & dimensional tolerances included in RI design
    - Condition of approval of design from STFC was respecting CEA interface requirements
    - Suggest Nik / Vincent review in detail specific requirements
  - Welding & machining of blocks expected before final assembly
    - Post machining possible as corrective action if required
  - Will be checked with dummy tuner at RI
    - RI dummy tuner – what are maximum material and least material tuner conditions?
- Pressure test:
  - Main issue is the additional length of pipe
    - Total volume with pipe & flange: 49.2L
    - RI test pressure: 1.5 bar
    - RI issue certificate at 49.2L x 1.01 barg = OK with Art. 4.3
    - STFC remove additional length, volume -> 48L
    - STFC issue new certificate based on RI pressure test
- Weld seam:
  - Outside the identified mounting regions
    - Separation approximately 20°(Z282136)
  - Diameter tolerance on specific areas therefore [-1,0]

C: Interfaces (4)
Sliding tank design & requirements





He inlet pipe as reference
Weld and inlet separated by 68°
CEA ‘keep-out’ areas (relative to RI drawing)
65°to 185° and 245°to 5°
-> separation 20°

D: Frequency (1) Assessment criteria

- ESS-0343220; STFC 1226-WP11-rep-0017-v0.5
- Work completed:
  - Analysis of frequency and variability at each manufacturing step
  - Analysis of CEA / INFN proposal and requirements
  - Proposal for cold frequency target without tuner
- Assessment / acceptance criteria proposed:

Check during	Test	Approval	Conditions	$f(\pi)_{min}$ [MHz]	$f(\pi)_{max}$ [MHz]
AL2 - Tuning	RI	STFC	Bare cavity, FMS installed, 294K, 1atm(?)	702.721	702.955
AL3 outgoing	*RI*	*n/a – reference*	*He tank, 294K, UHV, brackets fitted*	*702.881*	*703.115*
				for transport checks ref. only	
AL4 incoming	*STFC*	*STFC*	*He tank, 294K, UHV, brackets fitted*	*No change from AL3 outgoing Tolerances TBD*	
AL4 cold test	STFC	ESS	He tank, 2K, UHV, no tuner	704.030	704.264
AL4 outgoing	STFC	n/a	*He tank, 294K, UHV, brackets fitted*	*702.881*	*703.115*
				for transport checks ref. only	
AL5 incoming	CEA	ESS	*He tank, 294K, UHV, brackets fitted*	*No change from AL4 outgoing Tolerances TBD*	