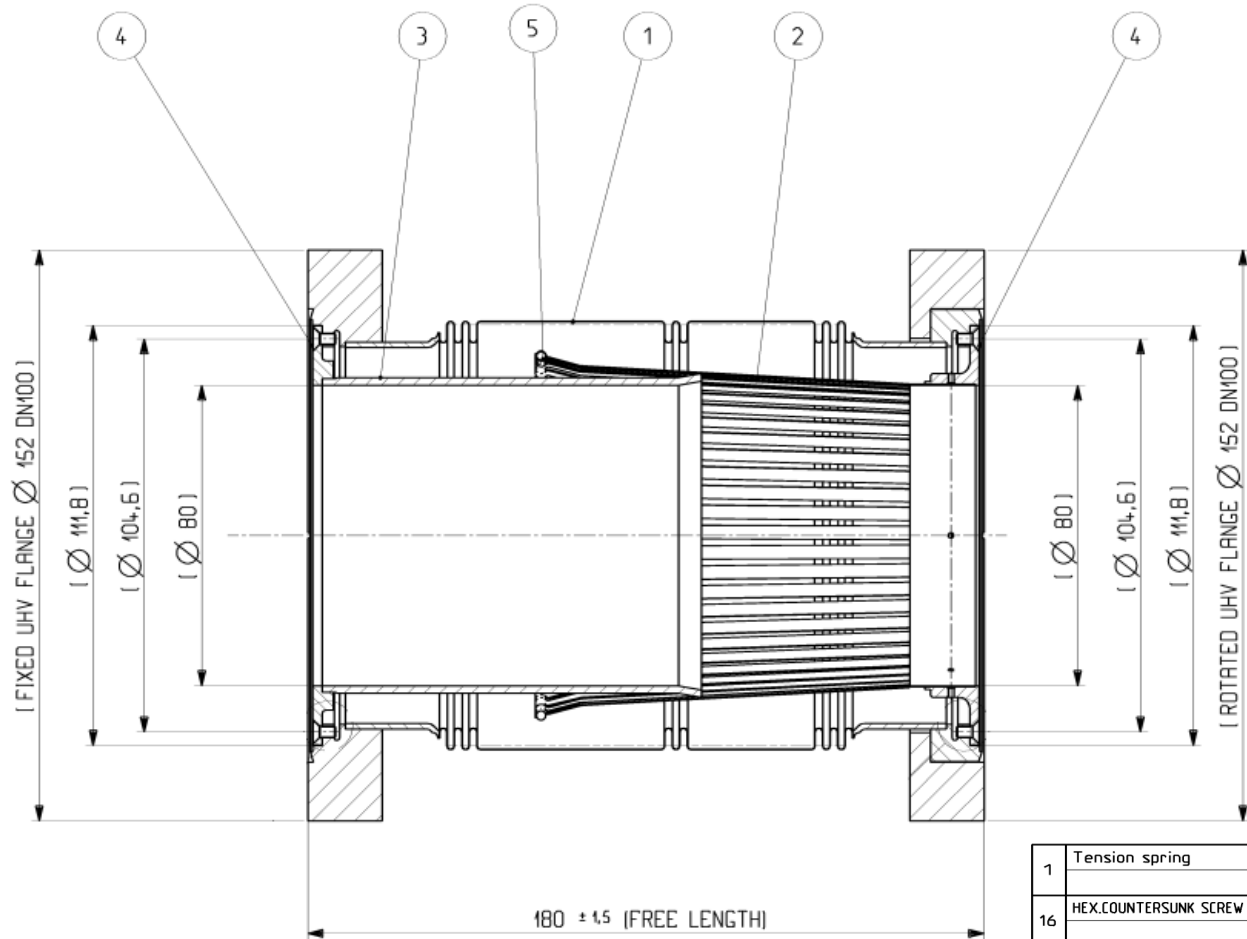


LHC Vacuum Warm modules

Adaptation for areas with transversal offset

Josef Sestak, Viktoras Arapoglou - BVO

LHC VM design (as installed)



1	Tension spring	5		LHCVSR_0011	
16	HEX.COUNTERSUNK SCREW M3x6	4	Stainless steel A4 SILVER COATED	BOSSARD BN4.719	
1	TRANS. TUBE FLANGE \varnothing 80L103.5	3		LHCVSR_0010	
1	RF CONTACT \varnothing 80	2		LHCVSR_0005	
1	WARM BELLOWS DN100 WITHOUT PORT	1		LHCVBU_0012	
QUANT.	DESCRIPTION	POS.	MAT.	OBSERVATIONS	REF.CERN
	ENS./ASS.			S.ENS./S.ASS.	

Operation limits of the design

1. Limits of the RF bridge
2. Limits of the bellow
3. Limits due to interference (1 & 2)

Bellows for warm modules (DN100)

Two types of warm bellows:

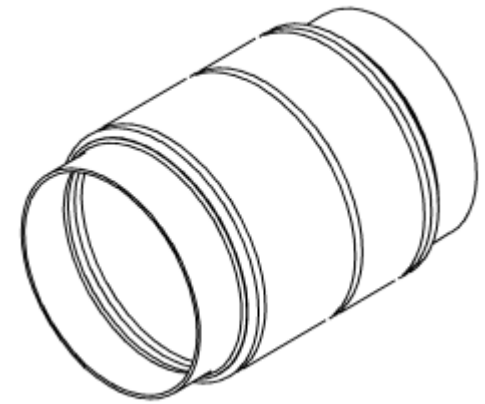
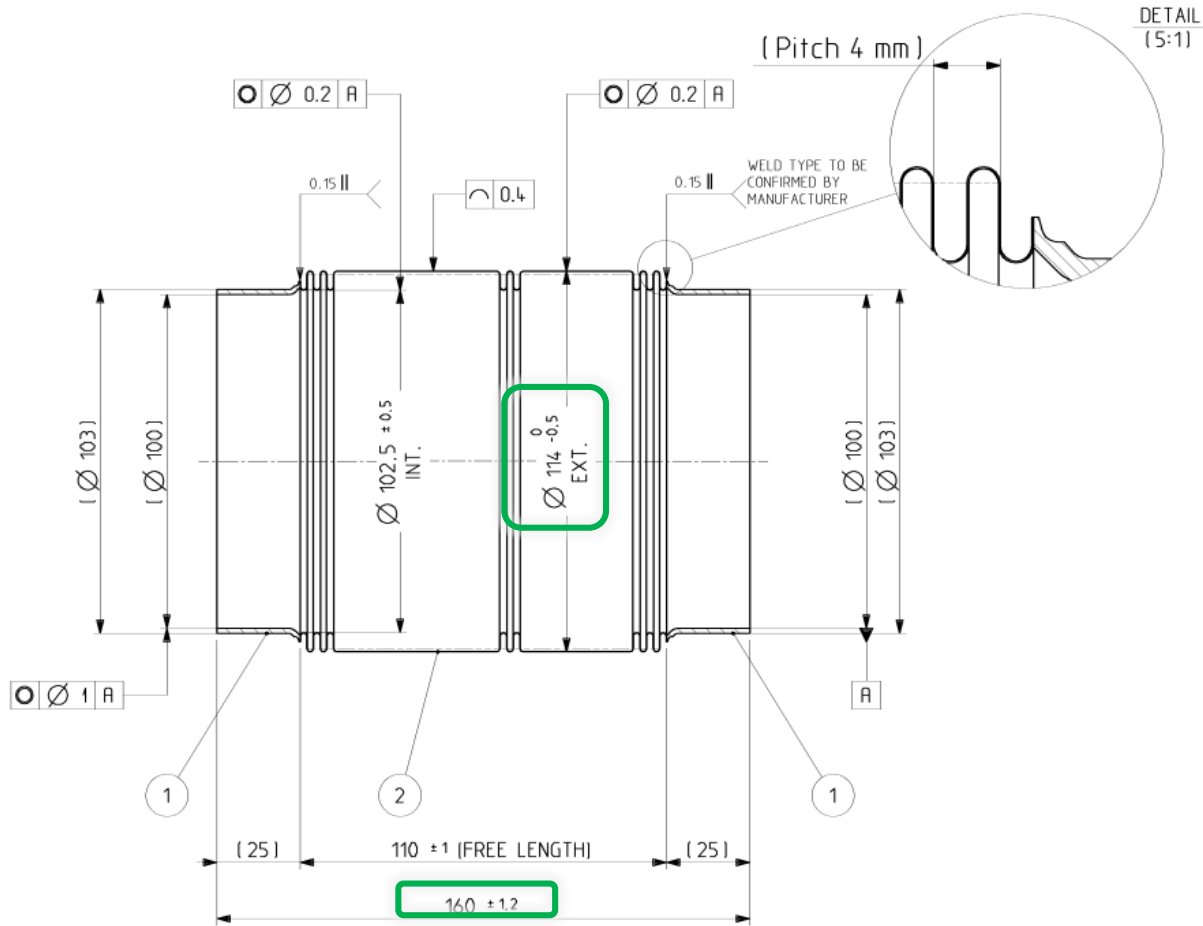
LHCVBU__0006

NUMBER OF PLIES:	1
THICKNESS OF ONE PLY:	0.15
NUMBER OF CONVOLUTIONS:	27
AXIAL STROKE:	$\pm 20\text{mm}$
MAX RADIAL OFFSET OVER FULL STROKE:	2mm
ANGULAR OFFSET BETWEEN ENDS:	$\pm 1.5^\circ$
WORKING PRESSURE	
EXTERNAL:	Atmospheric
INTERNAL:	10^{-1}mbar
TEST PRESSURE:	1.5 bar (Int./Ext.)
NOMINAL WORKING TEMPERATURE:	25°
MAXIMUM WORKING TEMPERATURE:	300°
LIFE TIME:	500CYCLES

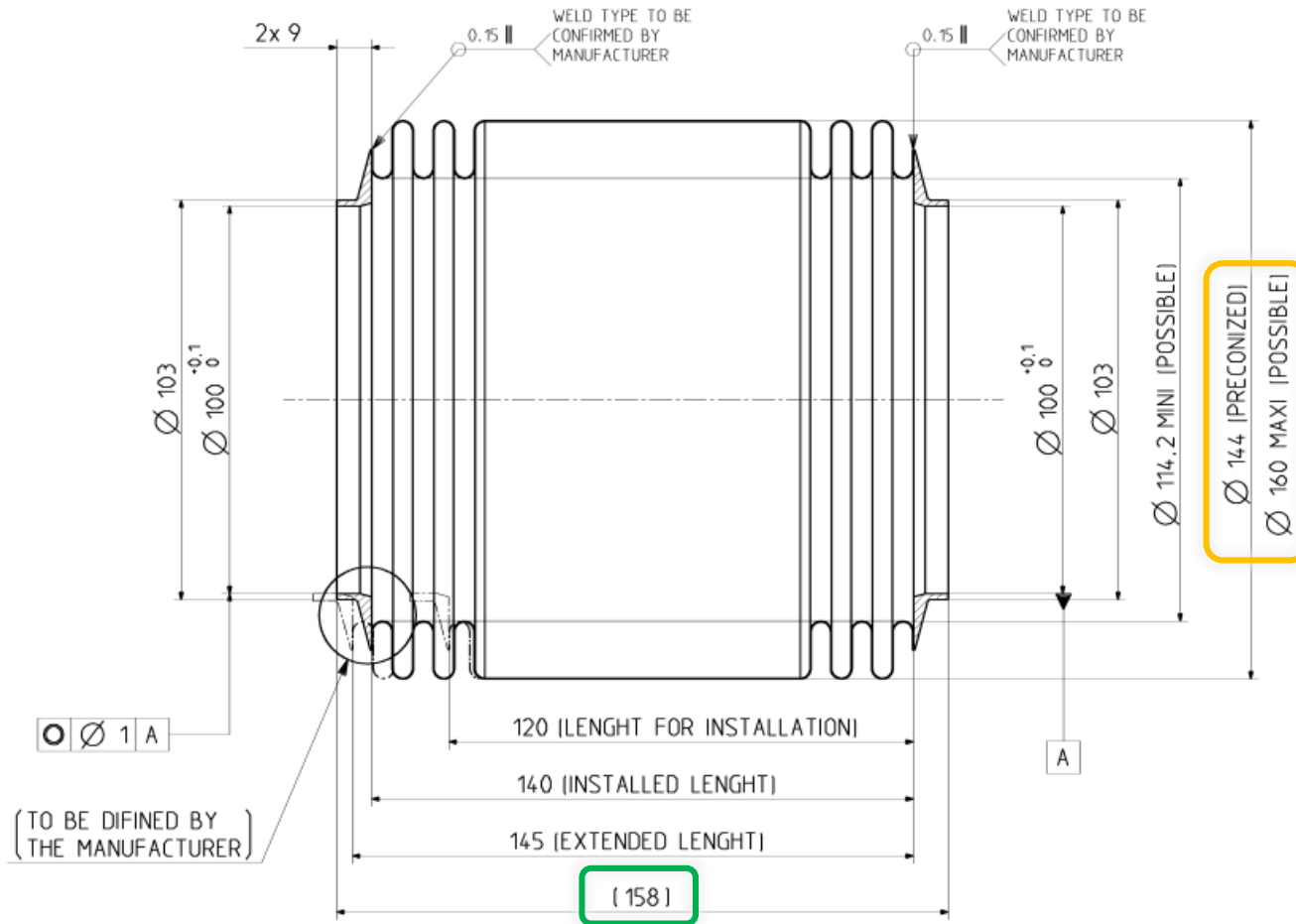
LHCVMTIA0002

NUMBER OF PLIES:	1
THICKNESS OF ONE PLY:	0.2
NUMBER OF CONVOLUTIONS:	13
AXIAL STROKE:	$\pm 20\text{mm}$
MAX RADIAL OFFSET OVER FULL STROKE:	$\pm 10\text{mm}$
ANGULAR OFFSET BETWEEN ENDS:	$\pm 1.5^\circ$
WORKING PRESSURE	
EXTERNAL:	Atmospheric
INTERNAL:	10^{-1}mbar
TEST PRESSURE:	1.5 bar (Int./Ext.)
NOMINAL WORKING TEMPERATURE:	25°
MAXIMUM WORKING TEMPERATURE:	300°
LIFE TIME:	500CYCLES

Standard type LHC VBU__0006



Collimator type LHCVMTIA0002

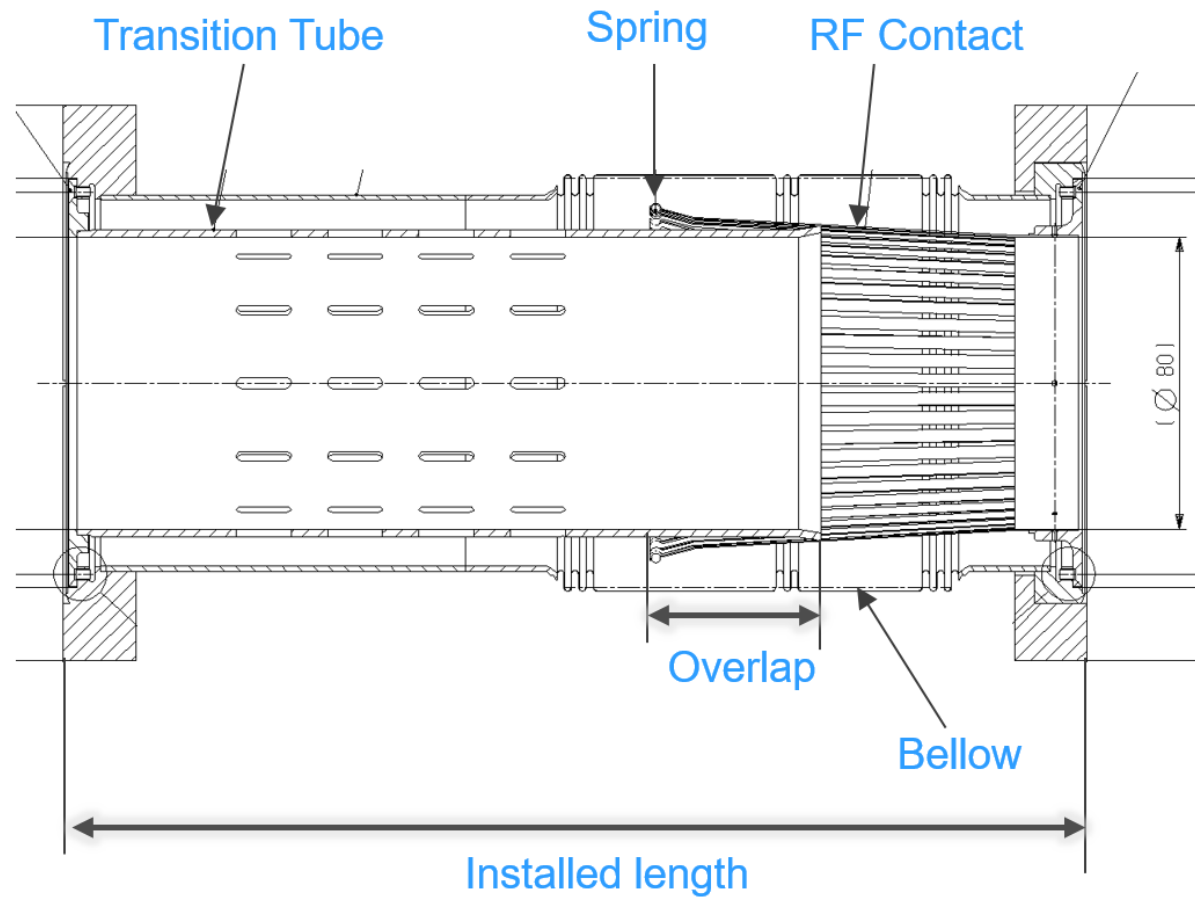


Contact force parameters

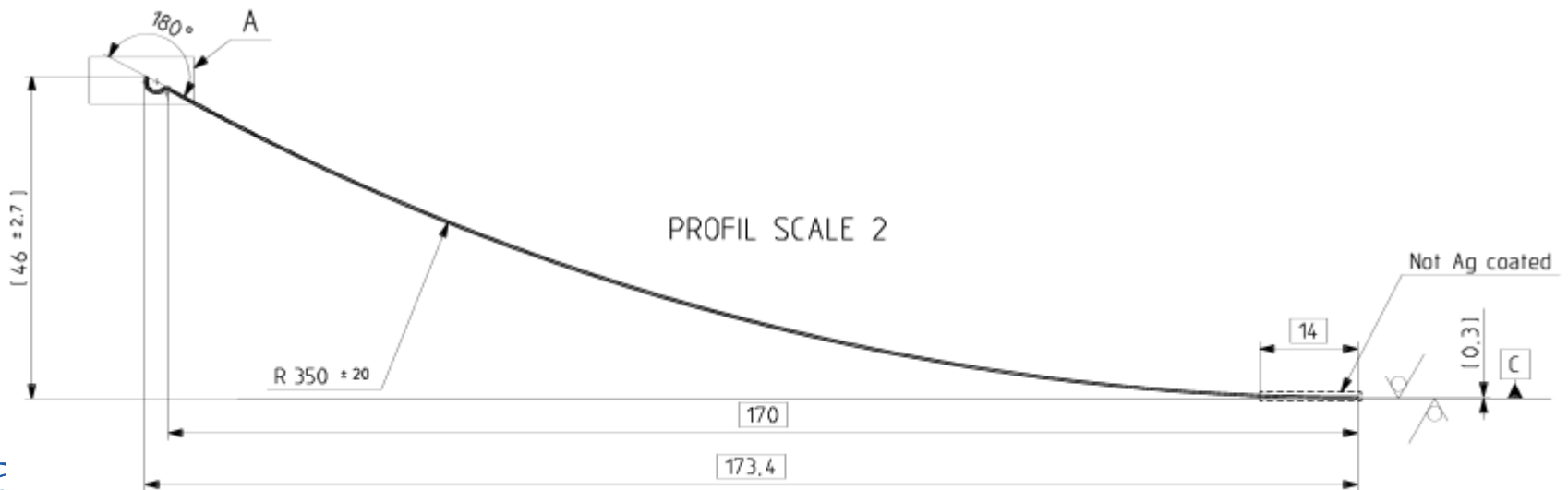
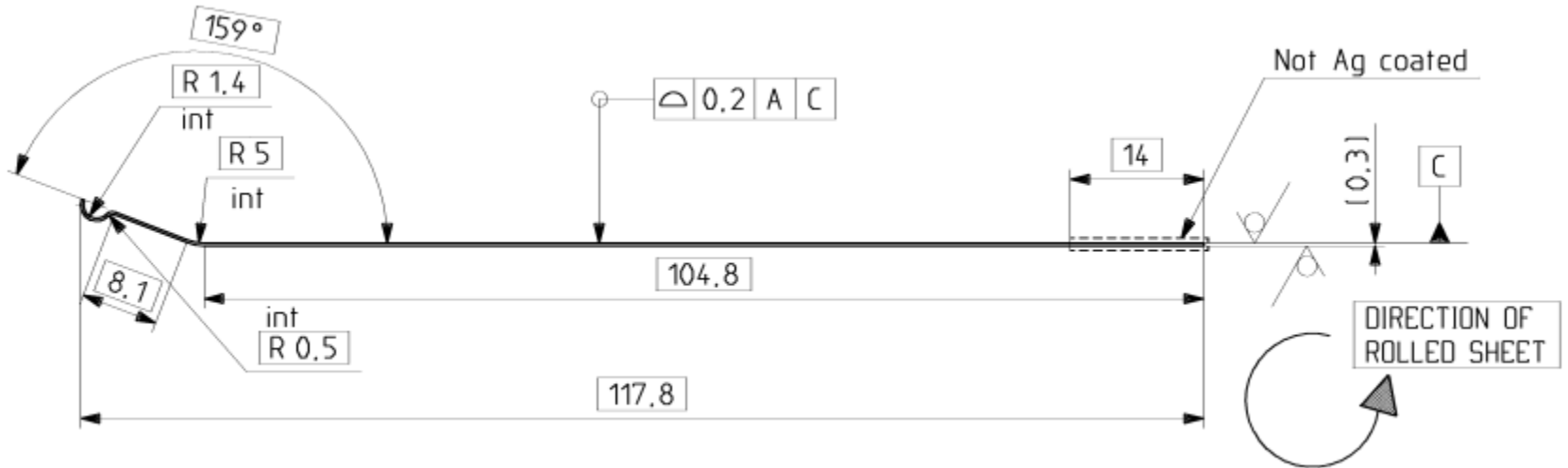
Contact force between the fingers of the RF contact and transition tube is function of:

- **Geometry of the finger,**
- **Length of the RF spring,**
- **Overlap between the RF contact and transition tube.**

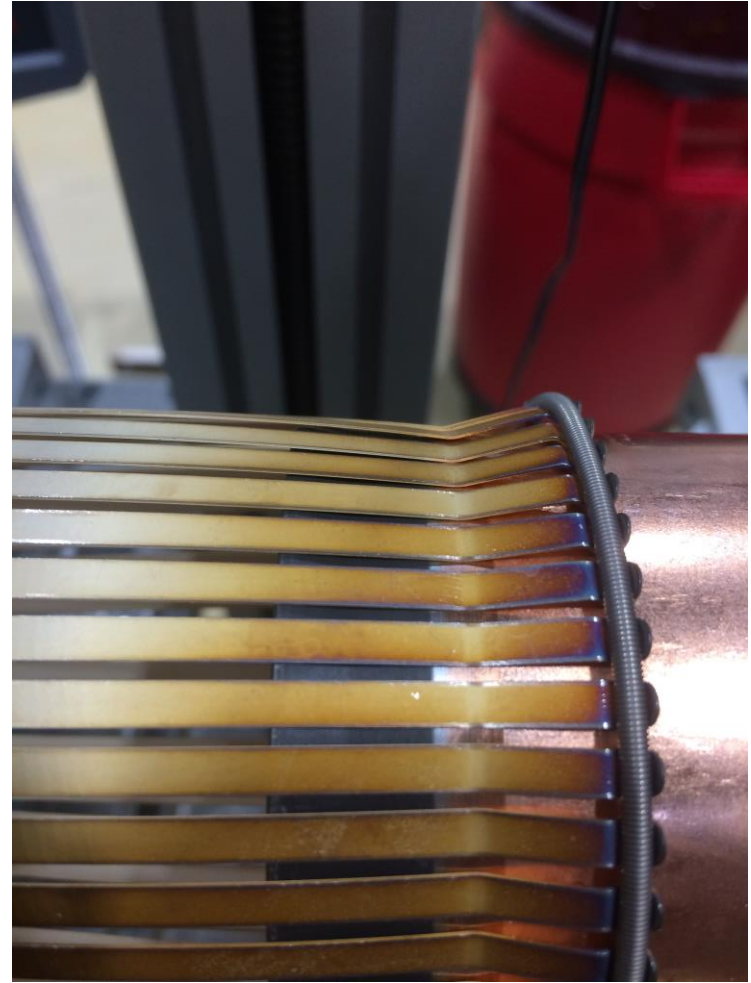
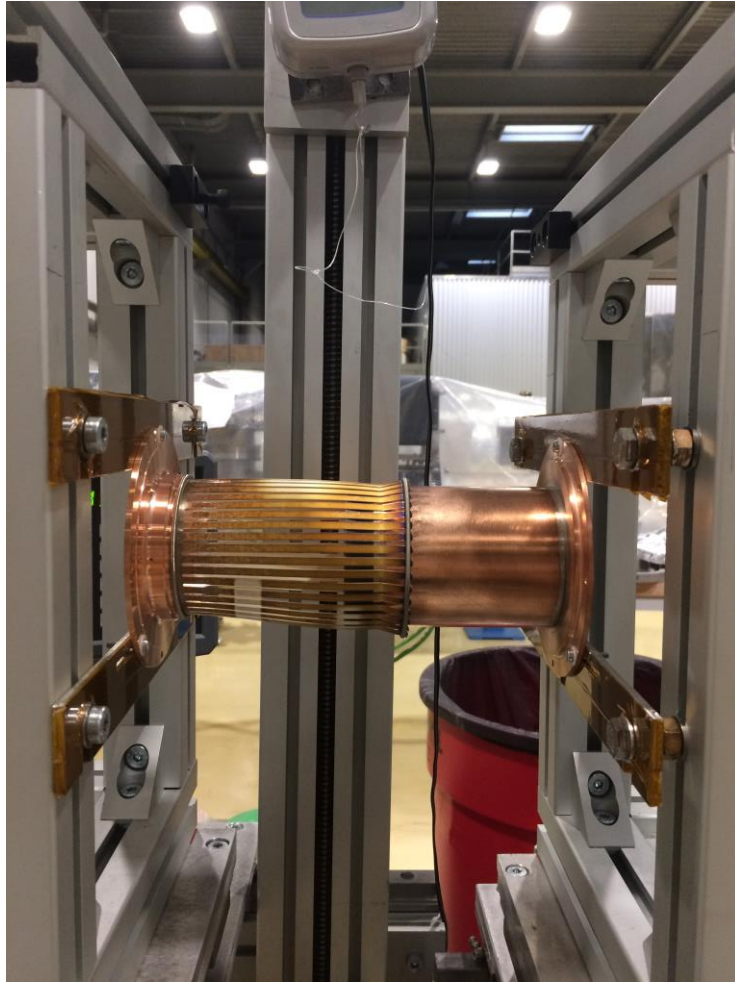
Current design of warm modules



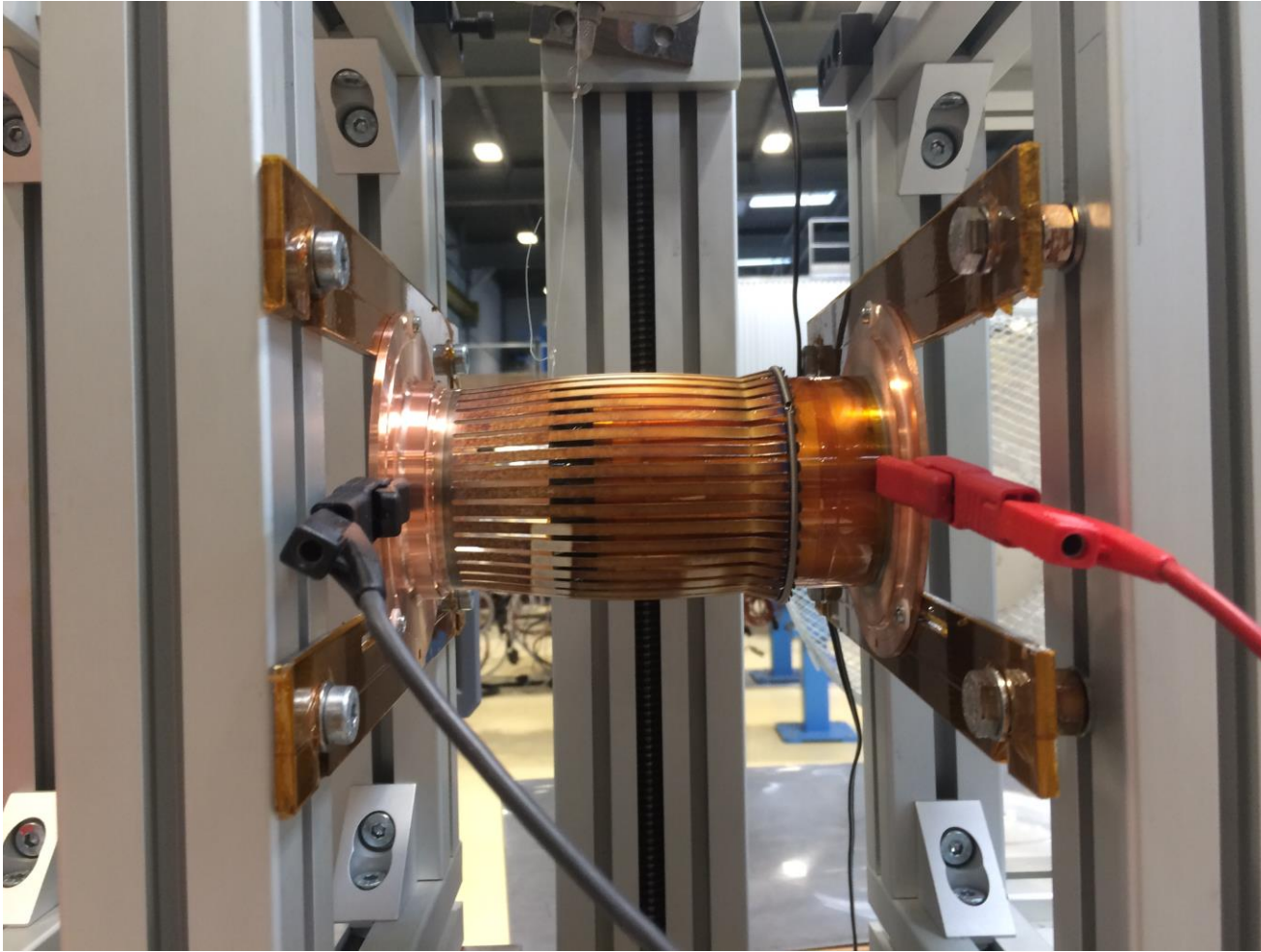
RF contact fingers shapes



Contact force measurements

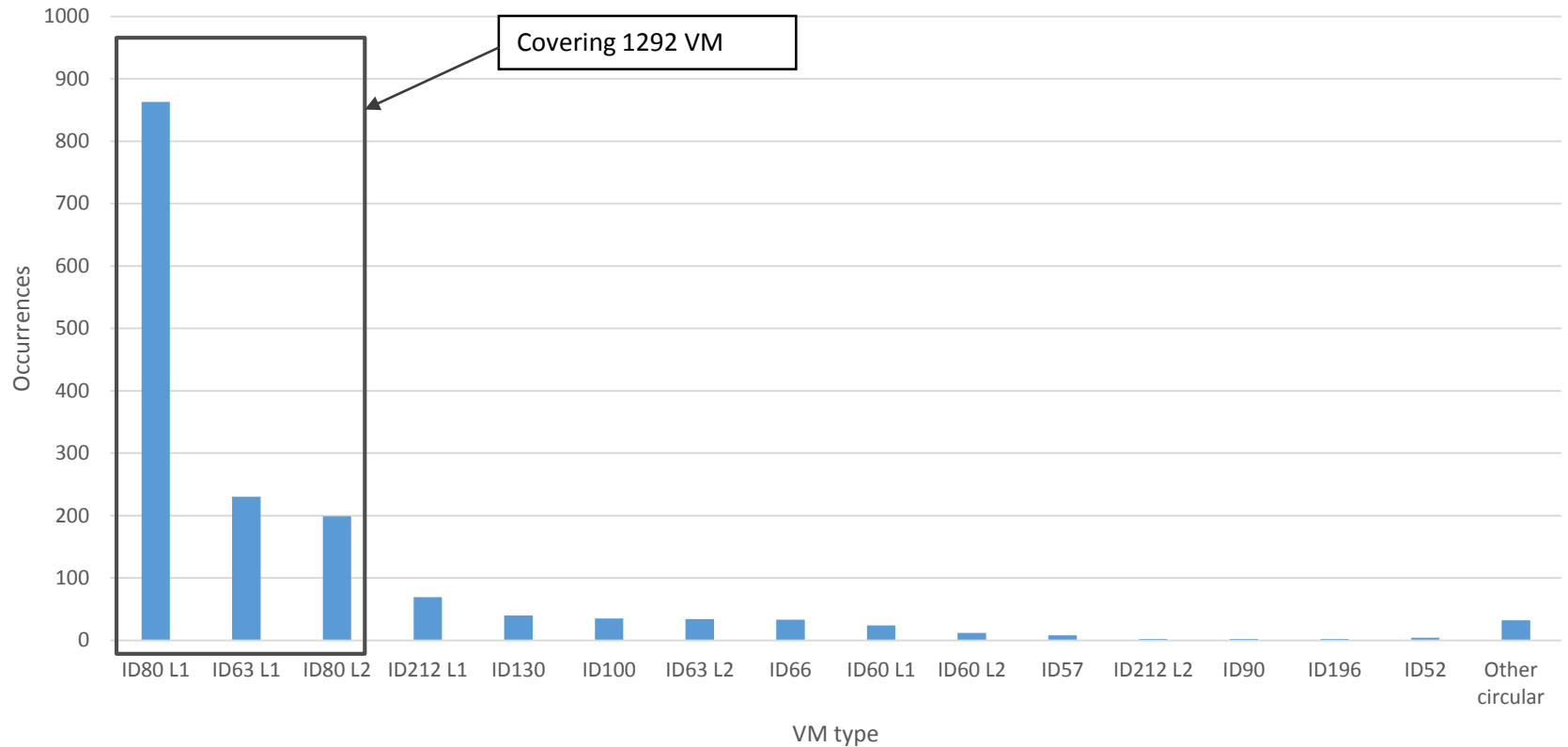


Contact force measurements



Contact force tests overview

Circular VM installed in the LHC



ID80 3 different measurements

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non-conform:	$x < 5g$

- ID80 L1 contact force measurements conducted by Jose on 10/04/2018

AXIAL (mm)/ RADIAL (mm)	Contact Force (g)									
	20	25	30	35	40	45	50	55	60	
-5	17.9	0	0	0	0	0	0	0	0	
-4	23.1	0	0	0	0	0	0	0	0	
-3	24.1	0	0	0	0	0	0	0	0	
-2	25	0.2	0	0	0	0	0	0	6.1	
-1	32.7	7.2	0	0	0	0	0.5	8.9	16.9	
0	34.5	12	0	0	7.4	7.8	9.9	22.1	31.5	
1	32.7	7.2	0	0	0	0	0.5	8.9	16.9	
2	25	0.2	0	0	0	0	0	0	6.1	
3	24.1	0	0	0	0	0	0	0	0	
4	23.1	0	0	0	0	0	0	0	0	
5	17.9	0	0	0	0	0	0	0	0	

- ID80 L1 contact force measurements conducted by Florian on 13/04/2015

AXIAL (mm)/ RADIAL (mm)	Contact Force (g)									
	20	25	30	35	40	45	50	55	60	
-5	20.5									
-4	22									
-3	26	14								
-2	26.5	26								
-1	29	34	5							
0	43	40	17			3	2			
1	29	34	5							
2	26.5	26								
3	26	14								
4	22									
5	20.5									

- ID80 L1 contact force measurements conducted by Viktoras on 05/10/2018

Overlap (mm) AXIAL (mm)/ RADIAL (mm)	Contact force (g)											
	20	22	24	26	28	30	50	52	54	56	58	60
5	8.9	0	0	0	0	0	0	0	0	0	0	0
4	13.8	0	0	0	0	0	0	0	0	0	0	0
3	19.7	0	0	0	0	0	0	0	0	0	0	0
2	26.0	5.5	0	0	0	0	0	0	0	0	0	0
1	33.4	19.1	0	0	0	0	0	0	0	0	0.9	1.9
0	39.7	33.6	16.8	3.0	0	0	0	0.9	3.9	6.0	10.0	12.6
-1	33.4	19.1	0	0	0	0	0	0	0	0	0.9	1.9
-2	26.0	5.5	0	0	0	0	0	0	0	0	0	0
-3	19.7	0	0	0	0	0	0	0	0	0	0	0
-4	13.8	0	0	0	0	0	0	0	0	0	0	0
-5	8.9	0	0	0	0	0	0	0	0	0	0	0



ID80 Contact force results

Conform: x >= 10g
 Transitional region: 5 <= x < 10g
 Non-conform: x < 5g

Installed L (mm) Overlap (mm) Deviation (mm) AXIAL (mm)/ RADIAL (mm)	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74
5	8.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5	10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	13.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5	16.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	19.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5	22.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	26.0	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.8
1.5	30.1	9.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	1.9	3.2	6.1	6.4	16.5
1	33.4	19.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	1.9	2.5	4.4	7.6	11.6	17.1	24.0	33.9
0.5	37.2	25.5	8.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	0.9	1.8	4.1	5.2	9.6	12.5	17.2	21.3	28.3	35.0	46.4
0	39.7	33.6	16.8	3.0	0	0	0	0	0	0	0	0	0	0	0	0.9	3.9	6.0	10.0	12.6	16.8	20.4	25.9	29.8	36.8	45.1	55.7	
-0.5	37.2	25.5	8.8	0	0	0	0	0	0	0	0	0	0	0	0	0.9	0.9	1.8	4.1	5.2	9.6	12.5	17.2	21.3	28.3	35.0	46.4	
-1	33.4	19.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	1.9	2.5	4.4	7.6	11.6	17.1	24.0	33.9		
-1.5	30.1	9.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	1.9	3.2	6.1	6.4	16.5	
-2	26.0	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.8	
-2.5	22.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-3	19.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-3.5	16.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-4	13.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-4.5	10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-5	8.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

ID80 with 260mm spring length (TB v.2)

Installed L (mm) Overlap (mm) Deviation (mm) AXIAL (mm)/ RADIAL (mm)	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74
5	25.5	26.4	25.8	15.5	6.5	0	0	0	0	0	0	0	0	0	0	0	0	1.1	3.2	6.4	7.8	>10	>10	>10	>10	>10	>10	>10
4.5	26.5	27.1	26.1	16.2	6.9	2	0	0	0	0	0	0	0	0	0	0	0	1.8	4.5	6.7	8.9	>10	>10	>10	>10	>10	>10	>10
4	26.9	28.3	27.6	16.7	7.1	2.6	0	0	0	0	0	0	0	0	0	1	1.3	2.7	5.4	7.4	10.2	>10	>10	>10	>10	>10	>10	>10
3.5	28.2	29.8	25.6	18	8.8	3.5	1.8	0	0	0	0	0	0	0	0.5	2.9	2.9	4.8	7.4	9.8	14.3	>10	>10	>10	>10	>10	>10	>10
3	28.5	29	27.1	16.9	8.5	3	0	0	0	0	0	0	0	0	0	1.6	2.1	3.5	6.2	10.5	12.2	>10	>10	>10	>10	>10	>10	>10
2.5	30.4	31.9	24.9	18.5	9.4	5.2	2.1	0	0	0	0	0	1	2.1	4.3	4.5	6.1	9.7	11.6	14.7	11.6	14.7	>10	>10	>10	>10	>10	>10
2	31.9	32.5	25.3	20.1	11	6.9	2.7	2.1	0	1.6	0	1.8	1.5	2.9	3.7	5	6.7	7.3	11.6	12.5	15.3	>10	>10	>10	>10	>10	>10	>10
1.5	32.7	33.7	26.1	20.5	12.1	7.3	2.9	2.5	1.2	2.2	0	2.4	2.3	3.2	5.3	5.8	8.3	9.2	13.2	13.9	18.1	>10	>10	>10	>10	>10	>10	>10
1	34.3	35.2	26.3	24.3	12.3	7.5	4.7	3.8	4.1	5.2	2.8	4.3	4.6	6	7.1	8.4	9.8	11.6	14.7	16.8	19.8	>10	>10	>10	>10	>10	>10	>10
0.5	36.1	37	28.5	29.9	17.2	13.7	9.1	7.3	8	7.6	7.9	8.7	9.3	10.7	11.8	14	14.9	16.4	21.5	20	26.9	>10	>10	>10	>10	>10	>10	>10
0	38.2	39.4	39.2	30.1	21.3	19.4	15	11.8	13.7	10.8	13.2	14.6	14.2	15.8	17.4	18.7	20.6	20.9	24.4	27.9	30.8	>10	>10	>10	>10	>10	>10	>10
-0.5	36.1	37	28.5	29.9	17.2	13.7	9.1	7.3	8	7.6	7.9	8.7	9.3	10.7	11.8	14	14.9	16.4	21.5	20	26.9	>10	>10	>10	>10	>10	>10	>10
-1	34.3	35.2	26.3	24.3	12.3	7.5	4.7	3.8	4.1	5.2	2.8	4.3	4.6	6	7.1	8.4	9.8	11.6	14.7	16.8	19.8	>10	>10	>10	>10	>10	>10	>10
-1.5	32.7	33.7	26.1	20.5	12.1	7.3	2.9	2.5	1.2	2.2	0	2.4	2.3	3.2	5.3	5.8	8.3	9.2	13.2	13.9	18.1	>10	>10	>10	>10	>10	>10	>10
-2	31.9	32.5	25.3	20.1	11	6.9	2.7	2.1	0	1.6	0	1.8	1.5	2.9	3.7	5	6.7	7.3	11.6	12.5	15.3	>10	>10	>10	>10	>10	>10	>10
-2.5	30.4	31.9	24.9	18.5	9.4	5.2	2.1	0	0	0	0	0	0	1	2.1	4.3	4.5	6.1	9.7	11.6	14.7	>10	>10	>10	>10	>10	>10	>10
-3	28.2	29.8	25.6	18	8.8	3.5	1.8	0	0	0	0	0	0	0	0.5	2.9	2.9	4.8	7.4	9.8	14.3	>10	>10	>10	>10	>10	>10	>10
-3.5	28.5	29	27.1	16.9	8.5	3	0	0	0	0	0	0	0	0	1.6	2.1	3.5	6.2	9.8	12.2	>10	>10	>10	>10	>10	>10	>10	>10
-4	26.9	28.3	27.6	16.7	7.1	2.6	0	0	0	0	0	0	0	0	1	1.3	2.7	5.4	7.4	10.2	>10	>10	>10	>10	>10	>10	>10	>10
-4.5	26.5	27.1	26.1	16.2	6.9	2	0	0	0	0	0	0	0	0	0	0	0	1.8	4.5	6.7	8.9	>10	>10	>10	>10	>10	>10	>10
-5	25.5	26.4	25.8	15.5	6.5	0	0	0	0	0	0	0	0	0	0	0	0	1.1	3.2	6.4	7.8	>10	>10	>10	>10	>10	>10	>10

ID80 with 265mm spring length (TB v.1)



Contact force measurements

ID 63 Test results

Installed L (mm)	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
Overlap (mm)	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
Deviation (mm)																				
3	0	6	11	9.5	10.5	9	7.5	6.5	1.5	0	0	0	0	0	0	0	0	0	0	0
2.5	2	9	15	13.5	13	12	11	9	5.5	1	0	0	0	0	0	0	0	0	0	0
2	4	10	20	18	15	14	13	10.5	8.5	5.5	2	0	0	0	0	0	0	0	0	0
1.5	5	12	23	22	21	15	15	13	10.5	9	7	3	2.5	2.5	2.5	0	0	0	0	0
1	7	19	26	25.5	25	22	17	14	12	12	10	8	5.5	7.5	6.5	3.5	4	4	6	6.5
0.5	7.5	22	30	29	30	27.5	23	18	16	13.5	12.5	11	9.5	10.5	10	8	7.5	9	10	9
0	13	25.5	34	31.5	32	30	29	26	22.5	20.5	16.5	14	11.5	13.5	13	10	13	13.5	15	15
-0.5	7.5	22	30	29	30	27.5	23	18	16	13.5	12.5	11	9.5	10.5	10	8	7.5	9	10	9
-1	7	19	26	25.5	25	22	17	14	12	12	10	8	5.5	7.5	6.5	3.5	4	4	6	6.5
-1.5	5	12	23	22	21	15	15	13	10.5	9	7	3	2.5	2.5	2.5	0	0	0	0	0
-2	4	10	20	18	15	14	13	10.5	8.5	5.5	2	0	0	0	0	0	0	0	0	0
-2.5	2	9	15	13.5	13	12	11	9	5.5	1	0	0	0	0	0	0	0	0	0	0
-3	0	6	11	9.5	10.5	9	7.5	6.5	1.5	0	0	0	0	0	0	0	0	0	0	0

Installed L (mm)	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86
Overlap (mm)	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86
Deviation (mm)																			
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	>10	>10	>10
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5	8.5	>10	>10	>10
2	0	0	0	0	0	0	0	0	0	0	0	2	7	13	21	26	>10	>10	>100
1.5	0	0	0	2	1	3	5.5	5	9	14	14	17.5	27	31	42.5	54	>10	>100	>100
1	5.5	6	7.5	8.5	8	10.5	12	14.5	18.5	21.5	27	31.5	39	49.5	63.5	79.5	>100	>100	>100
0.5	10	12.5	12.5	14.5	15	18.5	20	23	29	33.5	39.5	47	55.5	68	84.5	>100	>100	>100	>100
0	15.5	16.5	19	21.5	22.5	25	26.5	30.5	36	43.5	49.5	59.5	70	83	>100	>100	>100	>100	>100
-0.5	10	12.5	12.5	14.5	15	18.5	20	23	29	33.5	39.5	47	55.5	68	84.5	>100	>100	>100	>100
-1	5.5	6	7.5	8.5	8	10.5	12	14.5	18.5	21.5	27	31.5	39	49.5	63.5	79.5	>100	>100	>100
-1.5	0	0	0	2	1	3	5.5	5	9	14	14	17.5	27	31	42.5	54	>10	>100	>100
-2	0	0	0	0	0	0	0	0	0	0	0	2	7	13	21	26	>10	>10	>100
-2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5	8.5	>10	>10	>10
-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	>10	>10	>10

Conform:	x>10g	Non- conform:	x< 5g
Transition:	5<x<10g		



Extension of the working range

- With standard modules
 - For configuration as it is now, the radial offset needs to be assessed individually.
 - Based on the experience the HL-LHC modules can be optimised using exiting components to achieve radial offset <5 mm.
 - What are the real operating limits of the standard bellows? To be tested...

Extension of the working range

