

sMDT Chamber Parameter Book

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Abstract: The geometrical layout and the parameters of the small-diameter drift tube (sMDT) chambers already installed in the ATLAS muon spectrometer or under design and construction for phase 1 and phase 2 upgrades are summarised.

1. sMDT Chambers in General

Table 1: Material and operating parameters of ATLAS sMDT chambers [1, 2] compared to MDT chambers [3, 4]. 500 Hz/cm² and 200 kHz/tube are the maximum background rates expected in the barrel inner layer of the ATLAS muon spectrometer at HL-LHC.

Type	MDT	sMDT
Tube material	Aluminium Aluman100	Aluminium AW 6060-T6/ AlMgSi
Tube inner&outer surface		Surtec 650 chromatisation
Tube outer diameter	29.970 mm	15.000 mm
Tube wall thickness	0.4 mm	0.4 mm
Inactive length of Al tube	90.5 mm	71 mm
Wire material	W-Re (97:3)	W-Re (97:3)
Wire diameter	50 μm	50 μm
with gold plating thickness	3%	3%
Wire resistance	44 Ω/m	44 Ω/m
Wire pitch	30.035 mm	15.099 mm
Wire tension	350 \pm 15 g	350 \pm 15 g
Gas mixture	Ar:CO ₂ (93:7)	Ar:CO ₂ (93:7)
Gas pressure	3 bar (abs.)	3 bar (abs.)
Gas gain	2 \cdot 10 ⁴	2 \cdot 10 ⁴
Wire potential	3080 V	2730 V
Maximum drift time	720 ns	175 ns
Average tube spatial resolution without backgr. irradiation	83 μm	106 μm
Average tube spatial resolution at 500 Hz/cm ² background rate	160 μm	110 μm
Drift tube muon efficiency without backgr. irradiation	95%	94%
Drift tube muon efficiency at 200 kHz/tube backgr. rate	80%	90%
Wire positioning accuracy	< 20 μm rms	< 10 μm rms

2. The BME Chambers

Table 2: Parameters of BME chambers [5, 6]

Type	BME-A	BME-C
Number of chambers	1	1
Radial distance from beam axis (mm)	7606	7606
Chamber width in z (mm)	1200	1200
Tubes width in z (mm)	1185	1185
Chamber length in x (mm)	2339	2339
Aluminium tube length (mm)	2150	2150
Assembled tube length (mm)	2159	2159
Sense wire length (mm)	2132	2132
Active tube length (mm)	2079	2079
Active area/chamber (m ²)	2.46	2.46
Tube layers	2×4	2×4
Tubes/layer	78	78
Tubes/chamber	624	624
Spacer height (mm)	135.4	135.4
Tubes height (mm)	229	229
Chamber height (mm)	315	315
Gas volume/chamber (l)	212	212
Chamber weight (kg)	145	145
Mezz. cards (24 ch.)/chamber	26	26
Mezz. cards/CSM 2/1 (LH RO side)	12	14
Mezz. cards/CSM 1/2 (RH RO side)	14	12
CSMs/chamber	2	2
T-sensors/chamber	16	16
B-field sensors/chamber	0	0
In-plane systems/chamber	4	4
Axial alignment sensors/chamber	2	2
Praxial alignment sensors/chamber	2	2
CCC alignment sensors/chamber	0	0
Survey targets/chamber	4	4

Table 3: BME sMDT chambers summary

Parameter	Value
Number of chambers	2
Number of tubes	1248
Total tube and wire length	2.68 km
Total chamber active area	4.9 m ²
Total gas volume	0.42 m ³
Total chamber weight	0.29 tons
Number of mezzanine cards	52
Number of hedgehog boards	104
Number of CSMs	4

Table 4: Nominal wire grid parameters of the BME sMDT chambers from the average of the CMM measurements of HV and RO sides of both chambers (multilayer z -shift sign from RO side). The measured parameters of the individual chambers and the link to the individual sense wire positions are given in [7].

Parameter	Value
z pitch [mm]	15.0991
y pitch [mm]	13.091
Multilayer z shift (wires) [mm]	0.010
Multilayer y distance (wires) [mm]	135.320
rms _{z} (σ_z) [μ m]	12.6 (9.5)
rms _{y} (σ_y) [μ m]	16.7 (11.9)
rms _{r} (σ_r) [μ m]	14.8 (10.8)

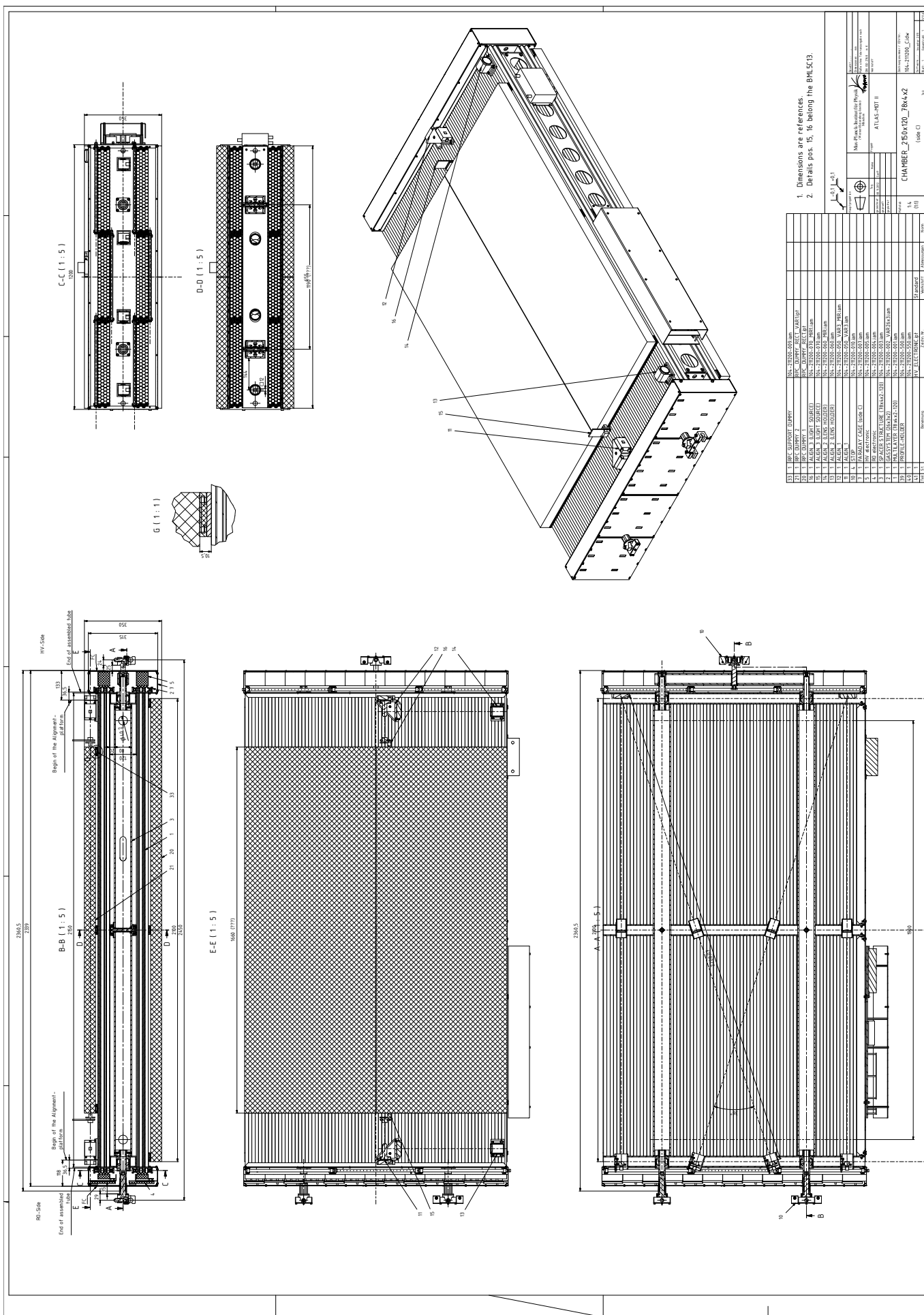


Figure 1: Drawings of a BME-C chamber installed in April 2014 and, with new RPCs, in April 2017.

3. The BMG Chambers

Table 5: Parameters of BMG chambers [8, 9]

Type sector 12	BMG-2A-12	BMG-2C-12	BMG-4A-12	BMG-4C-12	BMG-6A-12	BMG-6C-12
Radial distance from beam (mm)	8095	8095	8095	8095	8095	8095
Chamber width in z (mm)	860	860	860	860	860	860
Tubes width in z (mm)	823	823	823	823	823	823
Chamber length in x (mm)	1307	1307	1307	1307	1307	1307
Aluminium tube length (mm)	1120	1120	1120	1120	1120	1120
Assembled tube length (mm)	1129	1129	1129	1129	1129	1129
Active tube length (mm)	1049	1049	1049	1049	1049	1049
Sense wire length (mm)	1102	1102	1102	1102	1102	1102
Active area/chamber (m ²)	0.74	0.74	0.74	0.74	0.74	0.74
Tube layers	2 × 4	2 × 4	2 × 4	2 × 4	2 × 4	2 × 4
Tube positions/layer	54	54	54	54	54	54
Tube positions/chamber	432	432	432	432	432	432
Tubes/top ML	188	189	184	183	160	166
Tubes/bottom ML	188	188	184	184	160	162
Tubes/chamber	376	377	368	367	320	328
Spacer height (mm)	184.965	184.965	184.965	184.965	184.965	184.965
Tubes height (mm)	271	271	271	271	271	271
Chamber height (mm)	358	358	358	358	358	358
Gas volume/chamber (l)	67.2	67.4	65.8	65.6	57.2	58.6
Chamber weight (kg)	95	95	95	95	95	95
Mezz. cards (24 ch.)/chamber	18	17	18	18	16	16
CSMs/chamber	1	1	1	1	1	1
T-sensors/chamber	14	14	14	14	14	14
B-field sensors/chamber	0	0	0	0	0	0
In-plane systems/chamber	0	0	0	0	0	0
Axial alignment sensors/chamber	2	2	2	2	2	2
Praxial alignment sensors/chamber	4	4	4	4	2	2
CCC alignment sensors/chamber	0	0	0	0	0	0
Survey targets/chamber	4	4	4	4	4	4

Type sector 14	BMG-2A14	BMG-2C-14	BMG-4A-14	BMG-4C-14	BMG-6A-14	BMG-6C-14
Radial distance from beam (mm)	8095	8095	8095	8095	8095	8095
Chamber width in z (mm)	860	860	860	860	860	860
Tubes width in z (mm)	823	823	823	823	823	823
Chamber length in x (mm)	1307	1307	1307	1307	1307	1307
Aluminium tube length (mm)	1120	1120	1120	1120	1120	1120
Assembled tube length (mm)	1129	1129	1129	1129	1129	1129
Active tube length (mm)	1049	1049	1049	1049	1049	1049
Sense wire length (mm)	1102	1102	1102	1102	1102	1102
Active area/chamber (m ²)	0.74	0.74	0.74	0.74	0.74	0.74
Tube layers	2 × 4	2 × 4	2 × 4	2 × 4	2 × 4	2 × 4
Tube positions/layer	54	54	54	54	54	54
Tube positions/chamber	432	432	432	432	432	432
Tubes/top ML	189	188	183	184	178	176
Tubes/bottom ML	188	188	184	184	190	178
Tubes/chamber	377	376	367	368	368	354
Spacer height (mm)	184.965	184.965	184.965	184.965	184.965	184.965
Tubes height (mm)	271	271	271	271	271	271
Chamber height (mm)	358	358	358	358	358	358
Gas volume/chamber (l)	67.4	67.2	65.6	65.8	65.8	63.3
Chamber weight (kg)	95	95	95	95	95	95
Mezz. cards (24 ch.)/chamber	17	18	18	18	18	18
CSMs/chamber	1	1	1	1	1	1
T-sensors/chamber	14	14	14	14	14	14
B-field sensors/chamber	0	0	0	0	0	0
In-plane systems/chamber	0	0	0	0	0	0
Axial alignment sensors/chamber	2	2	2	2	2	2
Praxial alignment sensors/chamber	4	4	4	4	2	2
CCC alignment sensors/chamber	0	0	0	0	0	0
Survey targets/chamber	4	4	4	4	4	4

Table 6: BMG sMDT chambers summary

Parameter	Value
Number of chambers	12
Number of tubes	4346
Total tube and wire length	4.87 km
Total chamber active area	8.8 m ²
Total gas volume	0.77 m ³
Total chamber weight	1.14 t
Number of mezzanine cards	210
Number of hedgehog boards	420
Number of CSMs	12

Table 7: Nominal wire grid parameters of the BMG chambers from a combined fit of the CMM measurements of the HV and RO sides of all chambers (multilayer z-shift sign from RO side). The measured parameters of the individual chambers, including torsion between the RO and HV ends of the chambers, and the link to the individual sense wire and axial/praxial alignment sensor platform positions are given in [10].

Parameter	Value
z pitch [mm]	15.0991
y pitch [mm]	13.082
Multilayer z shift [mm]	-0.006
Multilayer y distance [mm]	184.980
rms _z (σ_z) [μm]	7.6 (6.2)
rms _y (σ_y) [μm]	10.1 (8.4)
rms _r (σ_r) [μm]	10.5 (6.9)

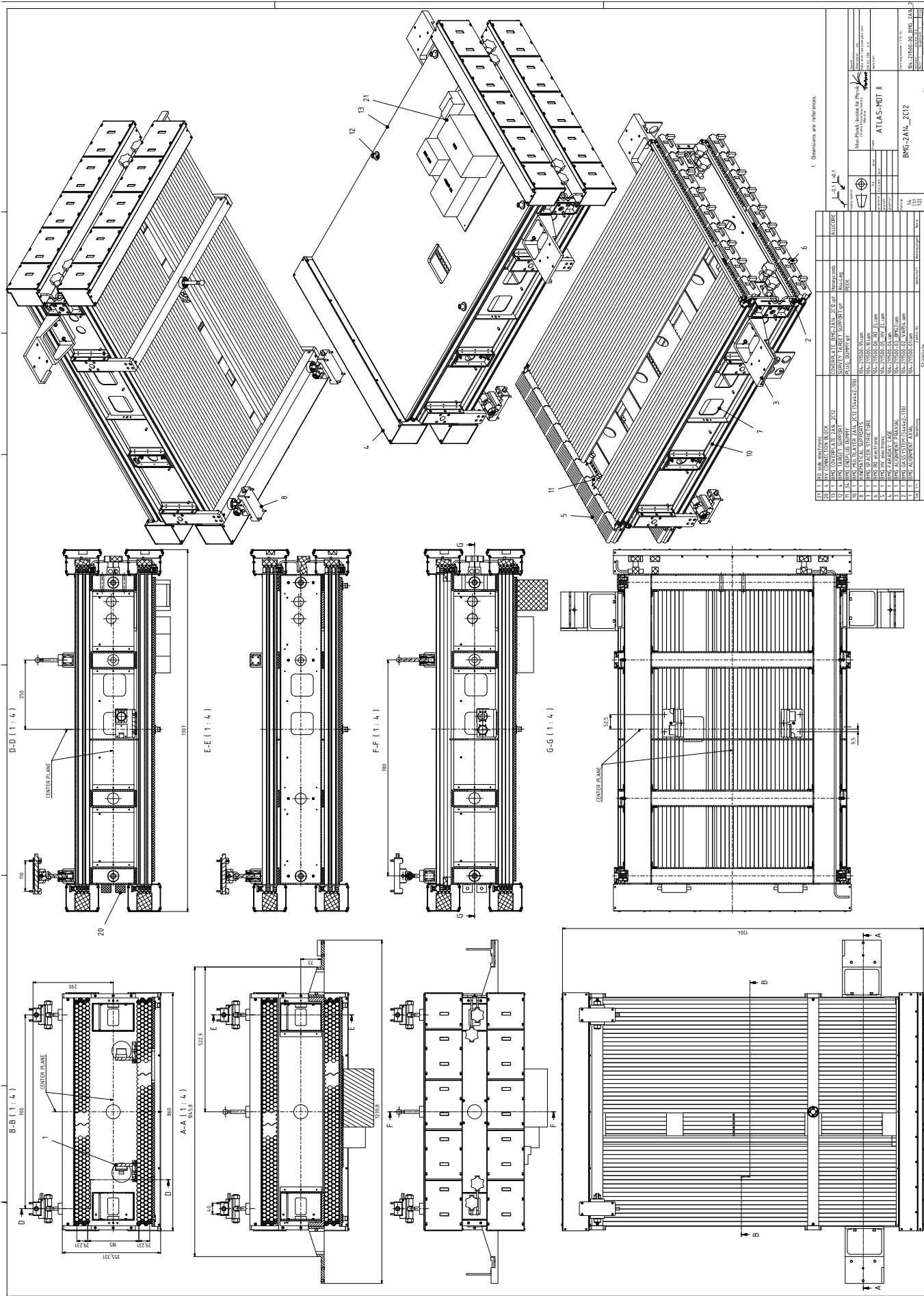


Figure 2: Drawings of a BMG chamber installed in the EYETS January 2017.

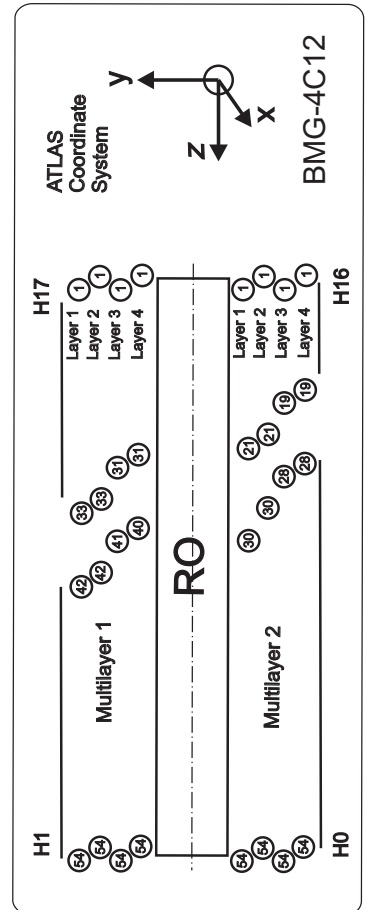
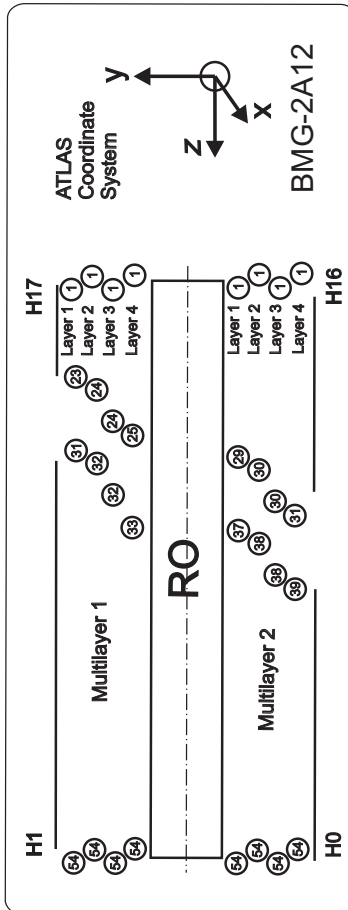
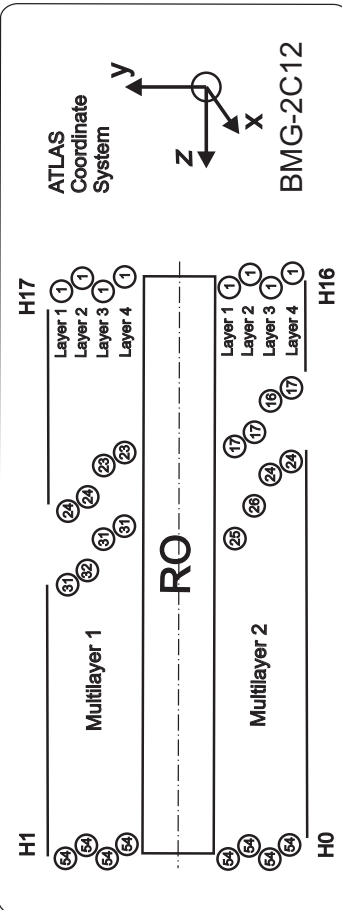
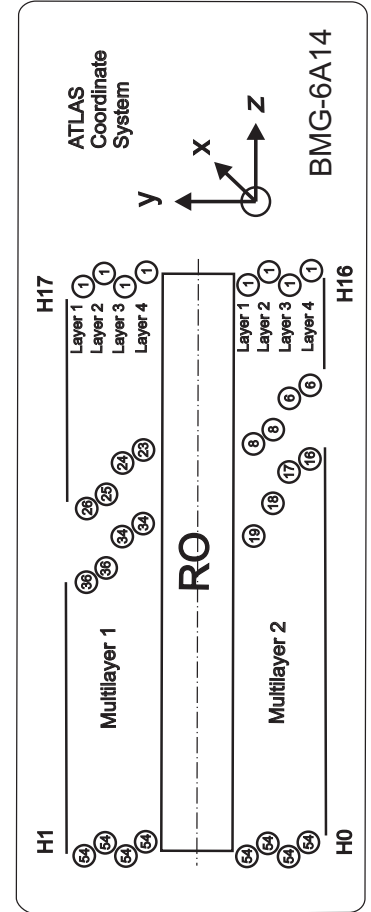
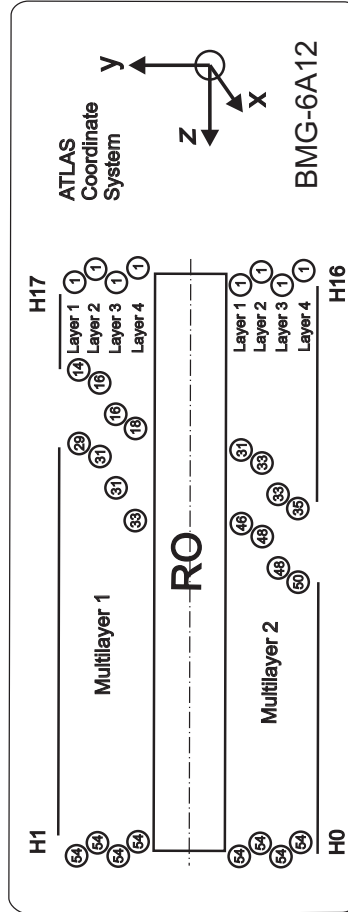
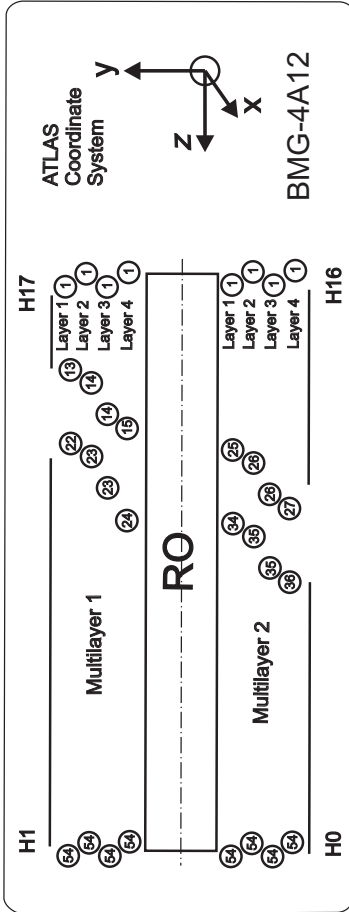


Figure 3: Tube layout and numbering scheme of the BMG chambers (part 1).

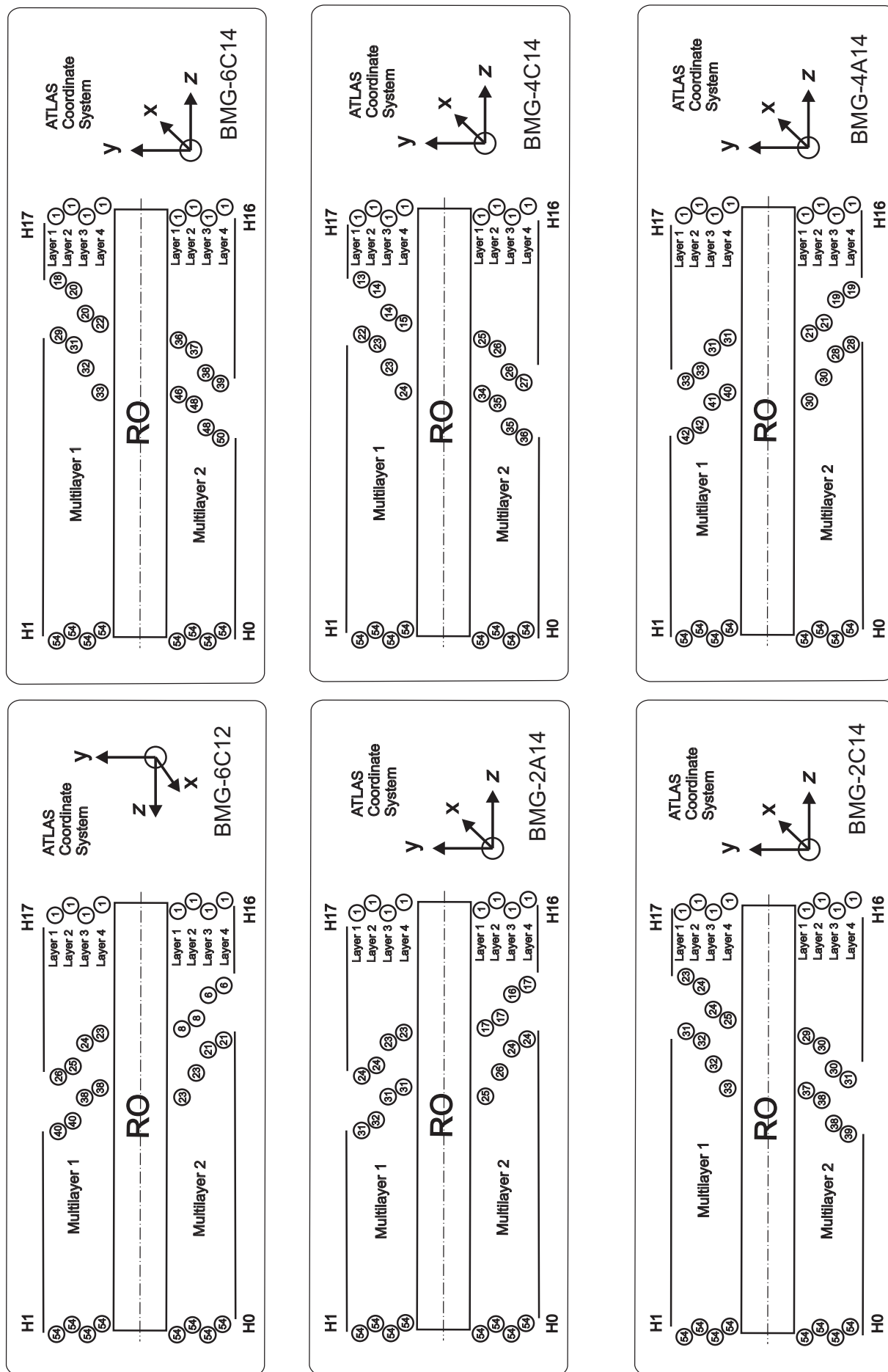


Figure 4: Tube layout and numbering scheme of the BMG chambers (part 2).

4. The BIS 7/8 Chambers (Side A)

Table 8: Parameters of BIS 7/8 A chambers [11, 12]

Type side A	BIS-78A-2	BIS-78A-4/6	BIS-78A-8/10	BIS-78A-12	BIS-78A-14	BIS-78A-16
Radial distance from beam (mm)	4592	4550	4550	4550	4550	4635
Chamber width in z (mm)	1655	1655	1474	1474	1474	1474
Tubes width in z (mm)	1638	1638	1457	1457	1457	1457
Tubes width in z (mm), long, ML1	1185	1457	1276	1004	1004	1004
Tubes width in z (mm), long, ML2	1004	1457	1276	823	823	1004
Tubes width in z (mm), cutout	461			461	461	461
Tubes width in z (mm), short	189	189	189	189	189	189
Tubes width in z (mm), short	189	189	189	189	189	189
Chamber length in x (mm), long	1855	1855	1855	1825	1825	1855
Chamber length in x (mm), cutout	1725			1725	1725	1725
Chamber length in x (mm), short	1195	1195	1195	1195	1195	1195
Aluminium tube length (mm), long	1660	1660	1660	1630	1630	1660
Assembled tube length (mm), long	1669	1669	1669	1639	1639	1669
Sense wire length (mm), long	1642	1642	1642	1612	1612	1642
Active tube length (mm), long	1589	1589	1589	1559	1559	1589
Aluminium tube length (mm), cutout	1530			1530	1530	1530
Assembled tube length (mm), cutout	1539			1539	1539	1539
Sense wire length (mm), cutout	1512			1512	1512	1512
Active tube length (mm), cutout	1459			1459	1459	1459
Aluminium tube length (mm), short	1000	1000	1000	1000	1000	1000
Assembled tube length (mm), short	1009	1009	1009	1009	1009	1009
Sense wire length (mm), short	982	982	982	982	982	982
Active tube length (mm), short	929	929	929	929	929	929
Active area/chamber (m ²)	2.47	2.49	2.20	2.15	2.15	2.18
Tube layers, long/cutout	2 × 4	2 × 4	2 × 4	2 × 4	2 × 4	2 × 4
Tube layers, short/cutout	4	4	4	4	4	4
Tubes/layer, long, ML1/2	78/66	78/96	66/84	66/54	66/54	66/54
Tubes/layer, cutout ML2	30			30	30	30
Tubes/layer, short ML2	12	12	12	12	12	12
Tubes/layer, ML1	78	78	65	66	66	66
Tubes/layer, ML2	108	108	96	96	96	96
Tubes/chamber, long	576	696	600	480	480	480
Tubes/chamber, cutout	120			120	120	120
Tubes/chamber, short	48	48	48	48	48	48
Tubes/chamber	744	744	648	648	648	648
Spacer height (mm), long	45.6	45.6	45.6	45.6	45.6	45.6
Tubes height (mm)	139	139	139	139	139	139
Chamber height (mm)	249	249	249	249	249	249
Gas volume/chamber (l)	188.1	190.6	165.3	160.6	160.6	162.9
Chamber weight (kg)	170	170	150	150	150	150
Mezz. cards (24 ch.)/chamber	31	31	27	27	27	27
CSMs/chamber	2	2	2	2	2	2
T-sensors/chamber	16	16	16	16	16	16
B-field sensors/chamber	2	2	2	2	2	2
In-plane alignment systems/chamber	4	4	4	4	4	4
Axial alignment sensors/chamber	2	2	2	2	2	2
Praxial alignment sensors/chamber	4	4	4	4	4	4
CCC alignment sensors/chamber	2	2	2	2	2	2
Endcap-barrel sensors/chamber	2	2	2	2	2	2
Survey targets/chamber	2	2	2	2	2	2

BIS 7/8 Chambers (Side C)

Table 9: Parameters of BIS 7/8 C chambers [11, 12]

Type side C	BIS-78C-2	BIS-78C-4/6	BIS-78C-8/10	BIS-78C-12	BIS-78C-14	BIS-78C-16
Radial distance from beam (mm)	4635	4550	4550	4550	4550	4635
Chamber width in z (mm)	1655	1655	1474	1474	1474	1474
Tubes width in z (mm)	1638	1638	1457	1457	1457	1457
Tubes width in z (mm), long, ML1	1185	1457	1276	1004	1004	1004
Tubes width in z (mm), long, ML2	1004	1457	1276	823	823	1004
Tubes width in z (mm), cutout	461			461	461	461
Tubes width in z (mm), short	189	189	189	189	189	189
Chamber length in x (mm), long	1855	1855	1855	1825	1825	1855
Chamber length in x (mm), cutout	1725			1725	1725	1725
Chamber length in x (mm), short	1195	1195	1195	1195	1195	1195
Aluminium tube length (mm), long	1660	1660	1660	1630	1630	1660
Assembled tube length (mm), long	1669	1669	1669	1639	1639	1669
Sense wire length (mm), long	1642	1642	1642	1612	1612	1642
Active tube length (mm), long	1589	1589	1589	1559	1559	1589
Aluminium tube length (mm), cutout	1530			1530	1530	1530
Assembled tube length (mm), cutout	1539			1539	1539	1539
Sense wire length (mm), cutout	1512			1512	1512	1512
Active tube length (mm), cutout	1459			1459	1459	1459
Aluminium tube length (mm), short	1000	1000	1000	1000	1000	1000
Assembled tube length (mm), short	1009	1009	1009	1009	1009	1009
Sense wire length (mm), short	982	982	982	982	982	982
Active tube length (mm), short	929	929	929	929	929	929
Active area/chamber (m ²)	2.47	2.49	2.20	2.15	2.15	2.18
Tube layers, long/cutout	2 × 4	2 × 4	2 × 4	2 × 4	2 × 4	2 × 4
Tube layers, short/cutout	4	4	4	4	4	4
Tubes/layer, long, ML1/2	78/66	78/96	66/84	66/54	66/54	66/54
Tubes/layer, cutout ML2	30			30	30	30
Tubes/layer, short ML2	12	12	12	12	12	12
Tubes/layer, ML1	78	78	66	66	66	66
Tubes/layer, ML2	108	108	96	96	96	96
Tubes/chamber, long	576	696	600	480	480	480
Tubes/chamber, cutout	120			120	120	120
Tubes/chamber, short	48	48	48	48	48	48
Tubes/chamber	744	744	648	648	648	648
Spacer height (mm), long	45.6	45.6	45.6	45.6	45.6	45.6
Tubes height (mm)	139	139	139	139	139	139
Chamber height (mm)	249	249	249	249	249	249
Gas volume/chamber (l)	188.1	190.6	165.3	160.6	160.6	162.9
Chamber weight (kg)	170	170	150	150	150	150
Mezz. cards (24 ch.)/chamber	31	31	27	27	27	27
CSMs/chamber	2	2	2	2	2	2
T-sensors/chamber	16	16	16	16	16	16
B-field sensors/chamber	2	2	2	2	2	2
In-plane alignment systems/chamber	4	4	4	4	4	4
Axial alignment sensors/chamber	2	2	2	2	2	2
Praxial alignment sensors/chamber	4	4	4	4	4	4
CCC alignment sensors/chamber	2	2	2	2	2	2
Endcap-barrel sensors/chamber	2	2	2	2	2	2
Survey targets/chamber	2	2	2	2	2	2

Table 10: BIS 7/8 sMDT chambers summary

Parameter	Value
Number of chambers	16
Number of tubes, long	9216
Number of tubes, cutout	960
Number of tubes, short	768
Number of tubes, total	10944
Total tube length, long	10.94 km
Total tube length, cutout	1.47 km
Total tube length short	0.77 km
Total tube and wire length	13.2 km
Total chamber active area	36.7 m ²
Total gas volume	2.77 m ³
Total chamber weight	1.88 t
Number of mezzanine cards	456
Number of hedgehog boards	912
Number of CSMs	32

Table 11: Nominal wire grid parameters of the BIS 7/8 chambers from a combined fit of the CMM measurements of the HV and RO sides of all chambers (multilayer z-shift sign from RO side).

Parameter	Value
z pitch [mm]	15.0991
y pitch [mm]	13.0889
Multilayer z shift [mm]	0.015
Multilayer y distance [mm]	45.59
rms _z (σ_z) [μm]	12 (12)
rms _y (σ_y) [μm]	17 (16)
rms _r (σ_r) [μm]	14 (13)

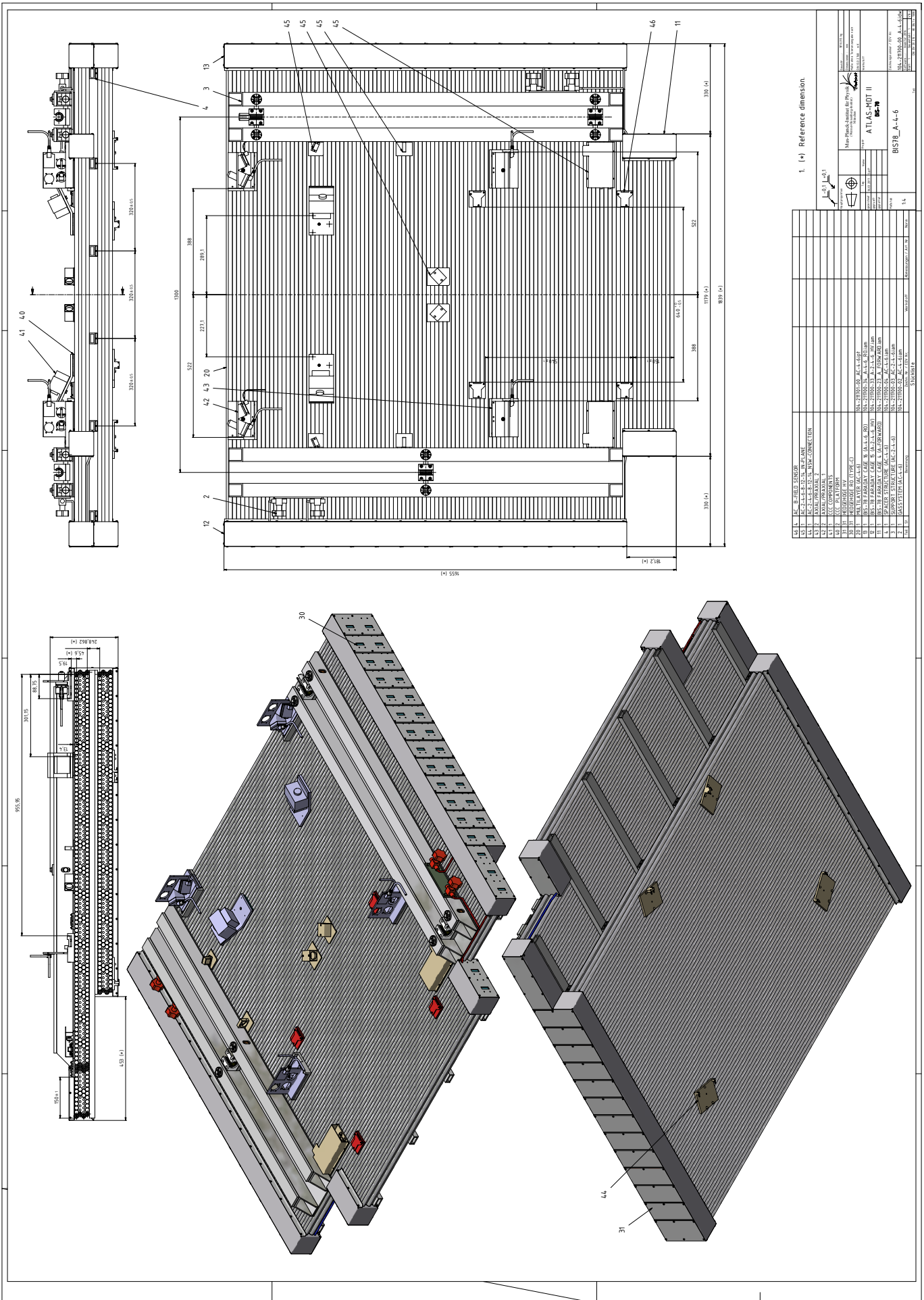


Figure 5: Drawings of a BIS 7/8 chamber (sectors 4 and 6 on side C) for phase 1 upgrade.

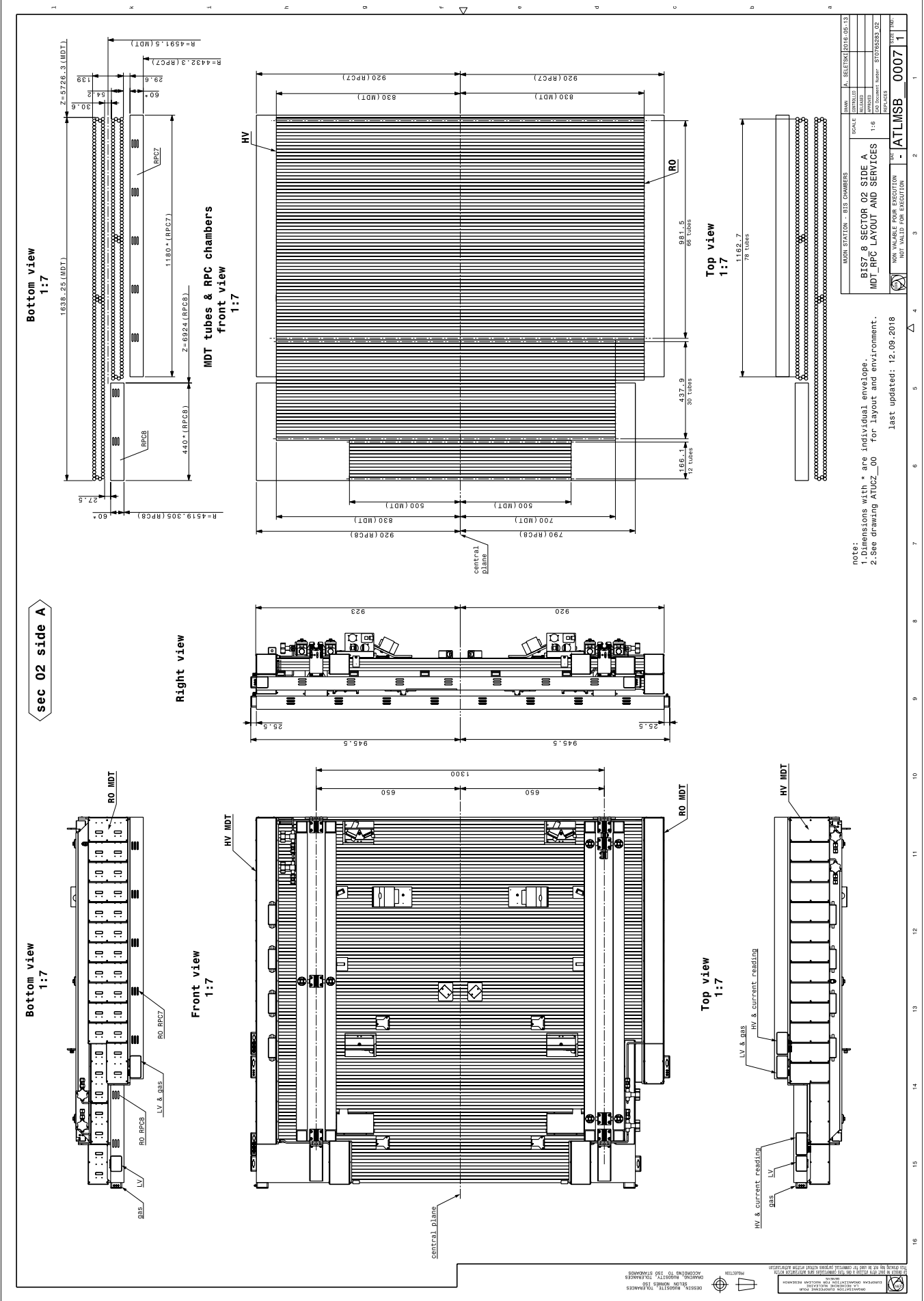


Figure 6: Layout of a BIS-78A-02 chamber [13].

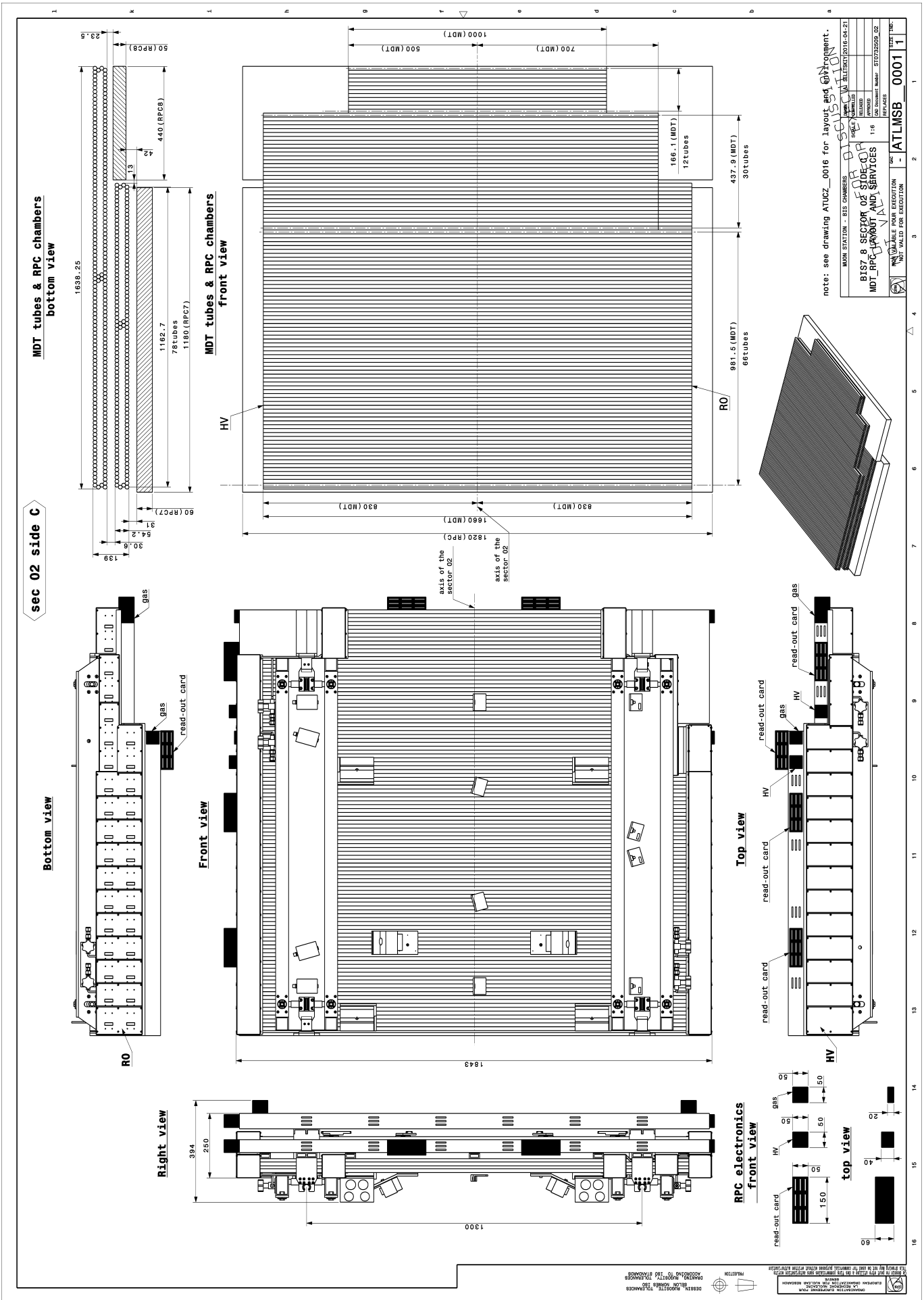


Figure 7: Layout of a BIS-78C-02 chamber [13].

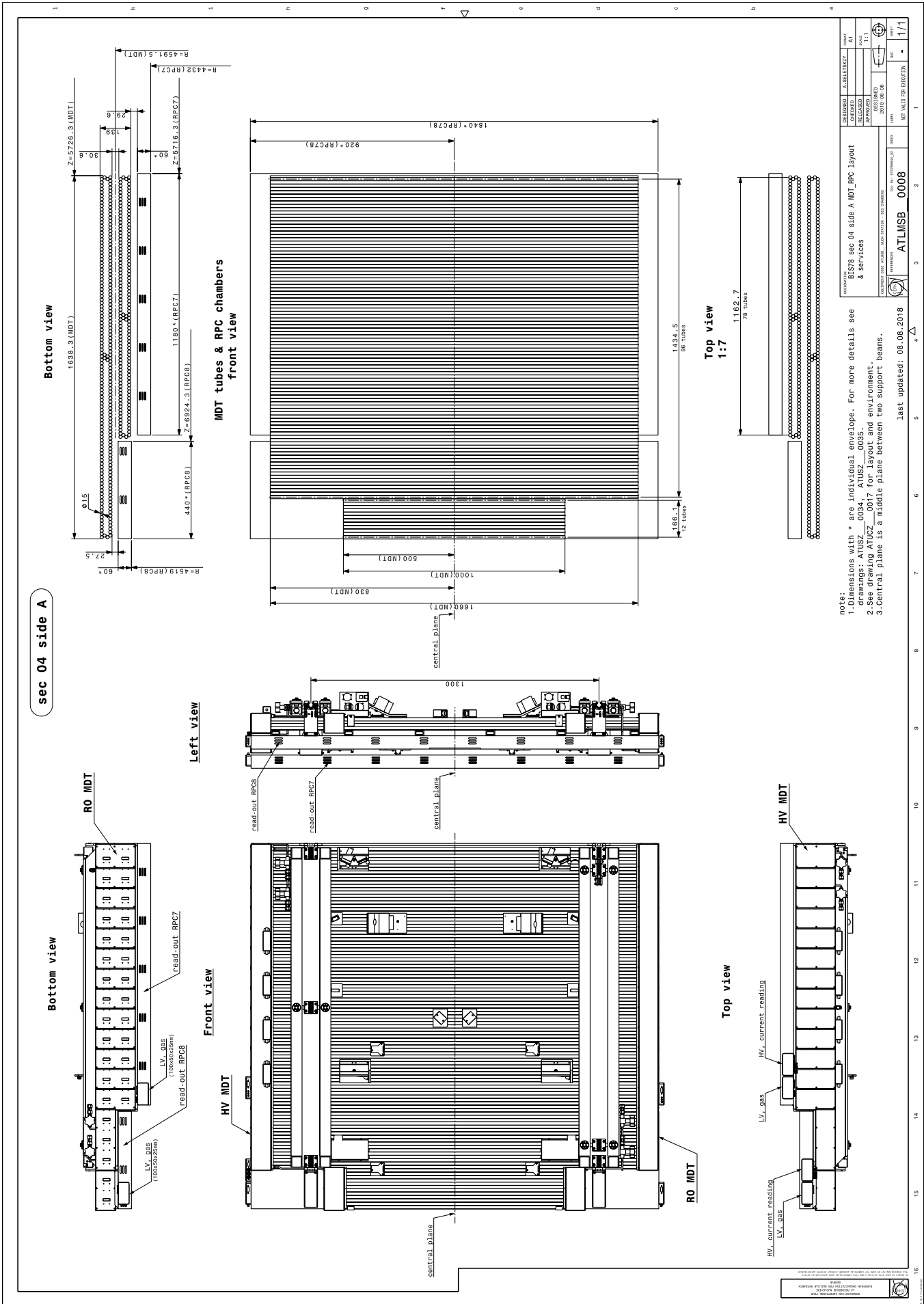


Figure 8: Layout of a BIS-78A-04 chamber [13].

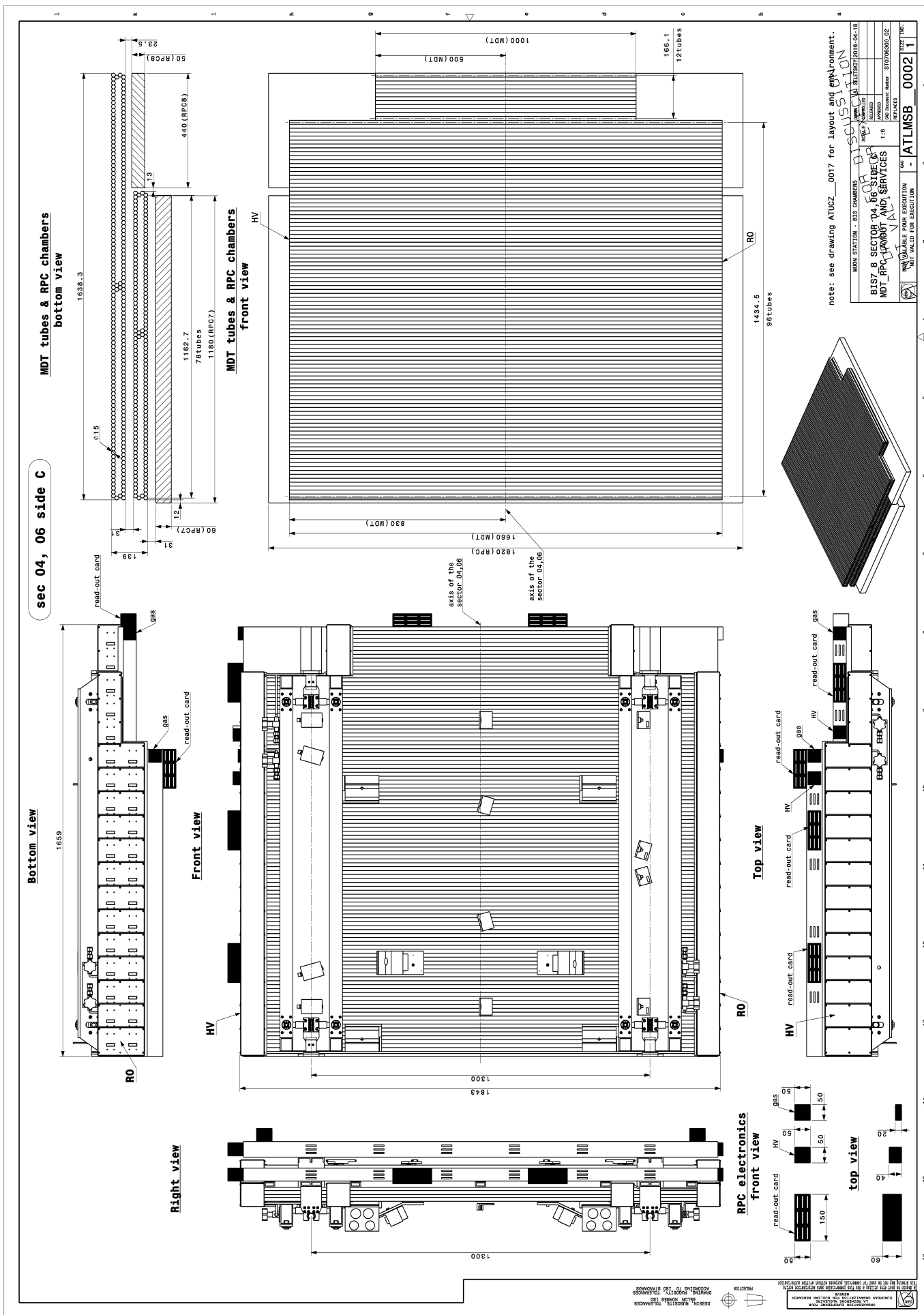


Figure 9: Layout of a BIS-78C-04 chamber [13].

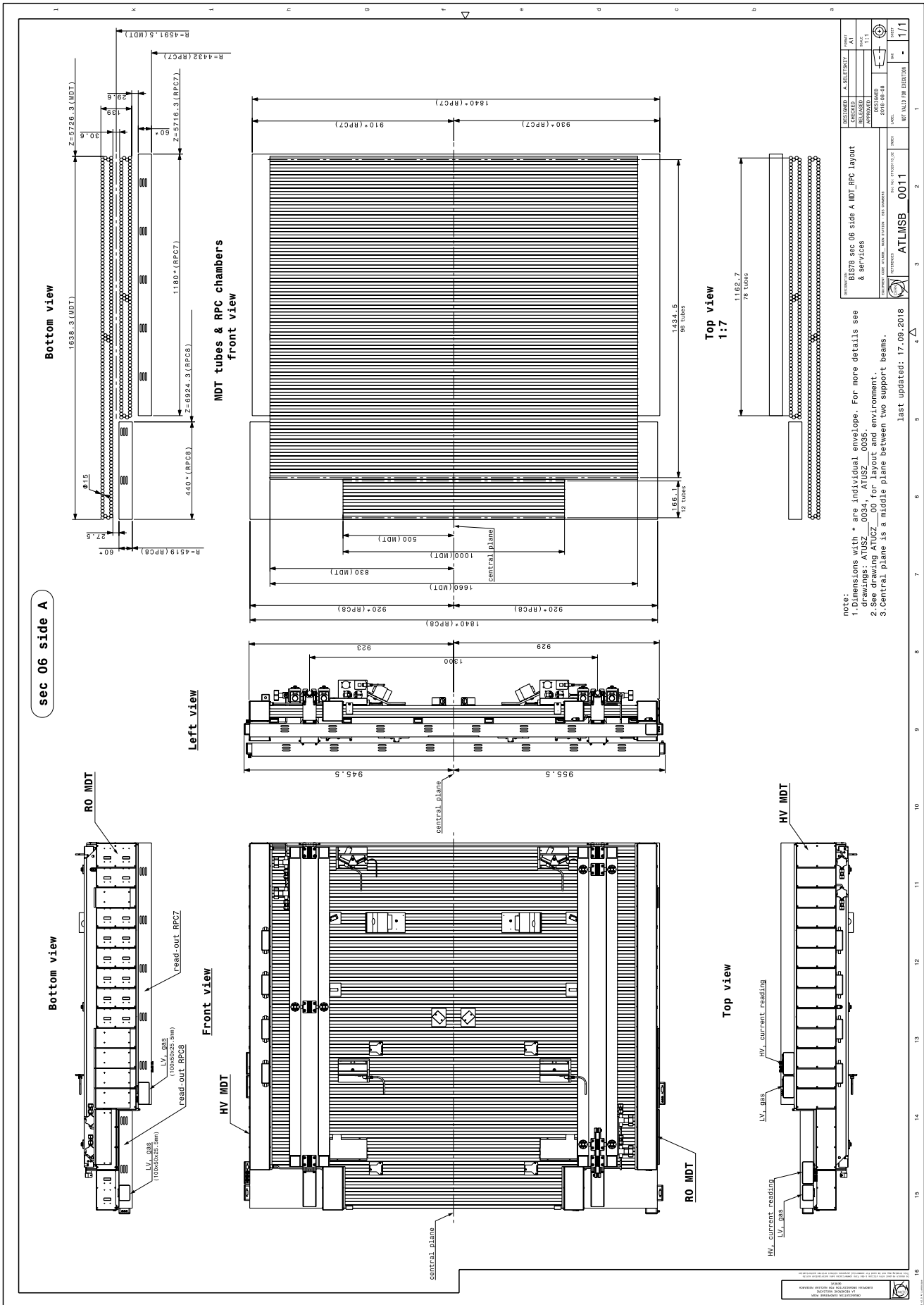


Figure 10: Layout of a BIS-78A-06 chamber [13].

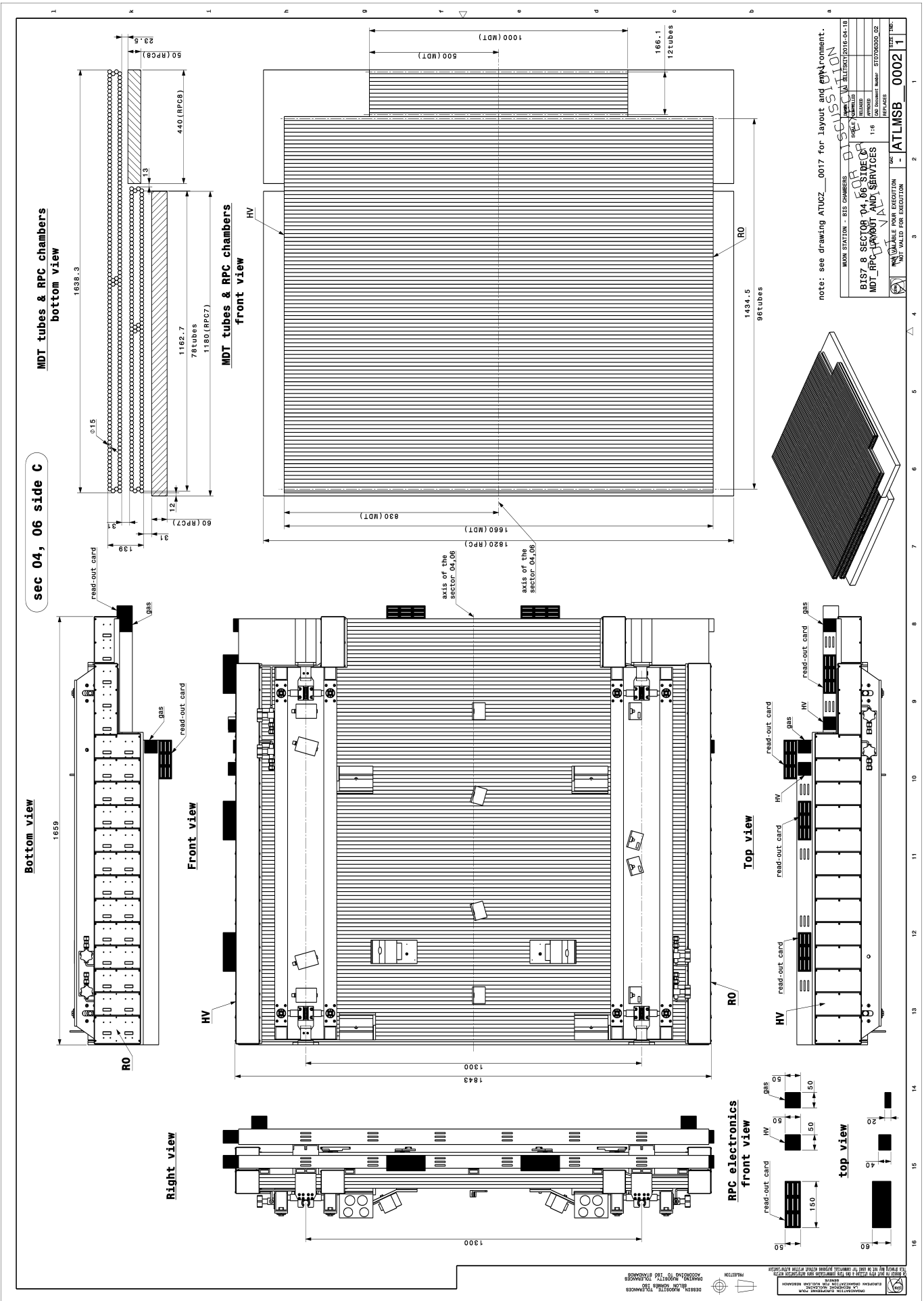


Figure 11: Layout of a BIS-78C-06 chamber [13].

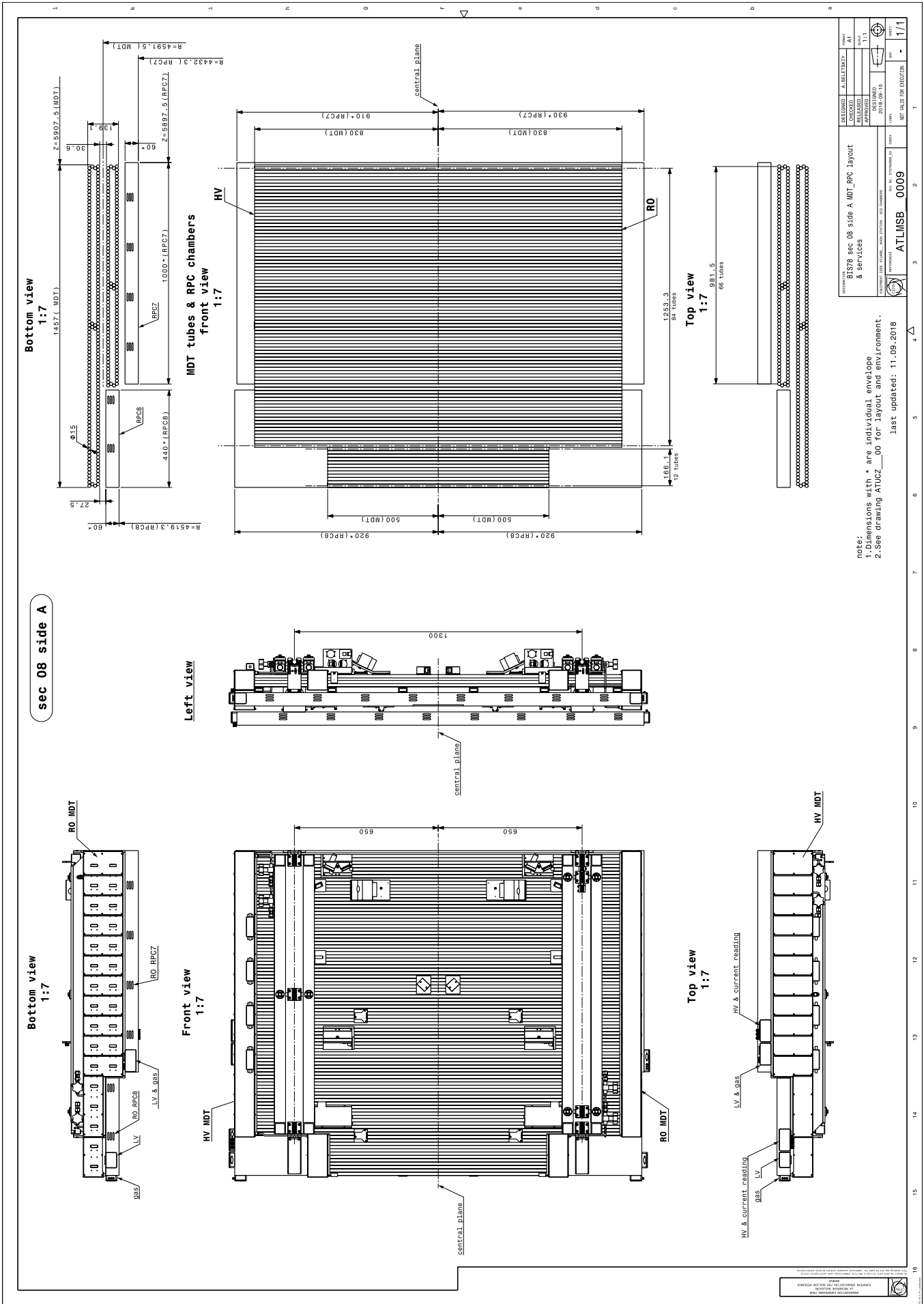


Figure 12: Layout of a BIS-78A-08 chamber [13].

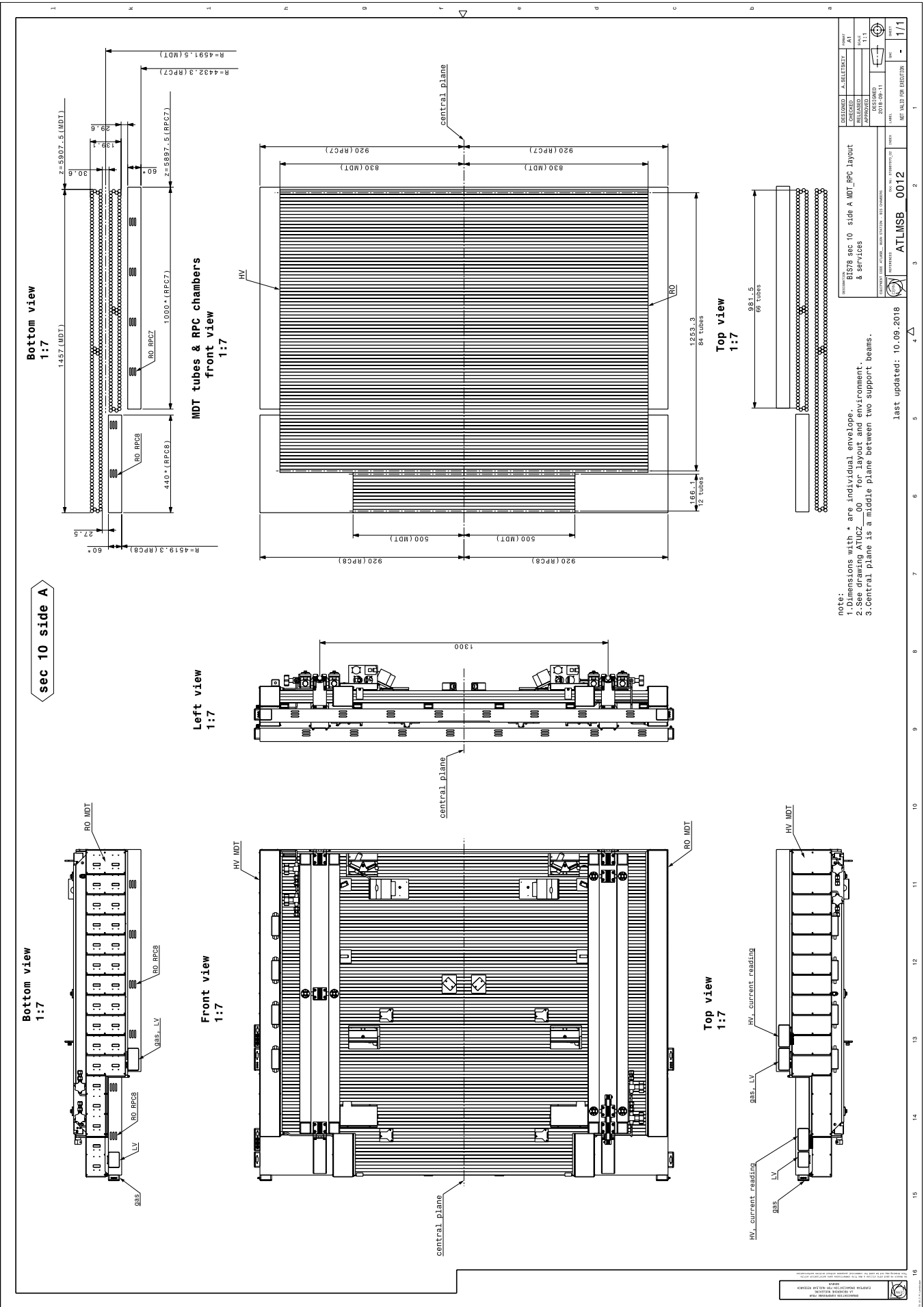


Figure 14: Layout of a BIS-78A-10 chamber [13].

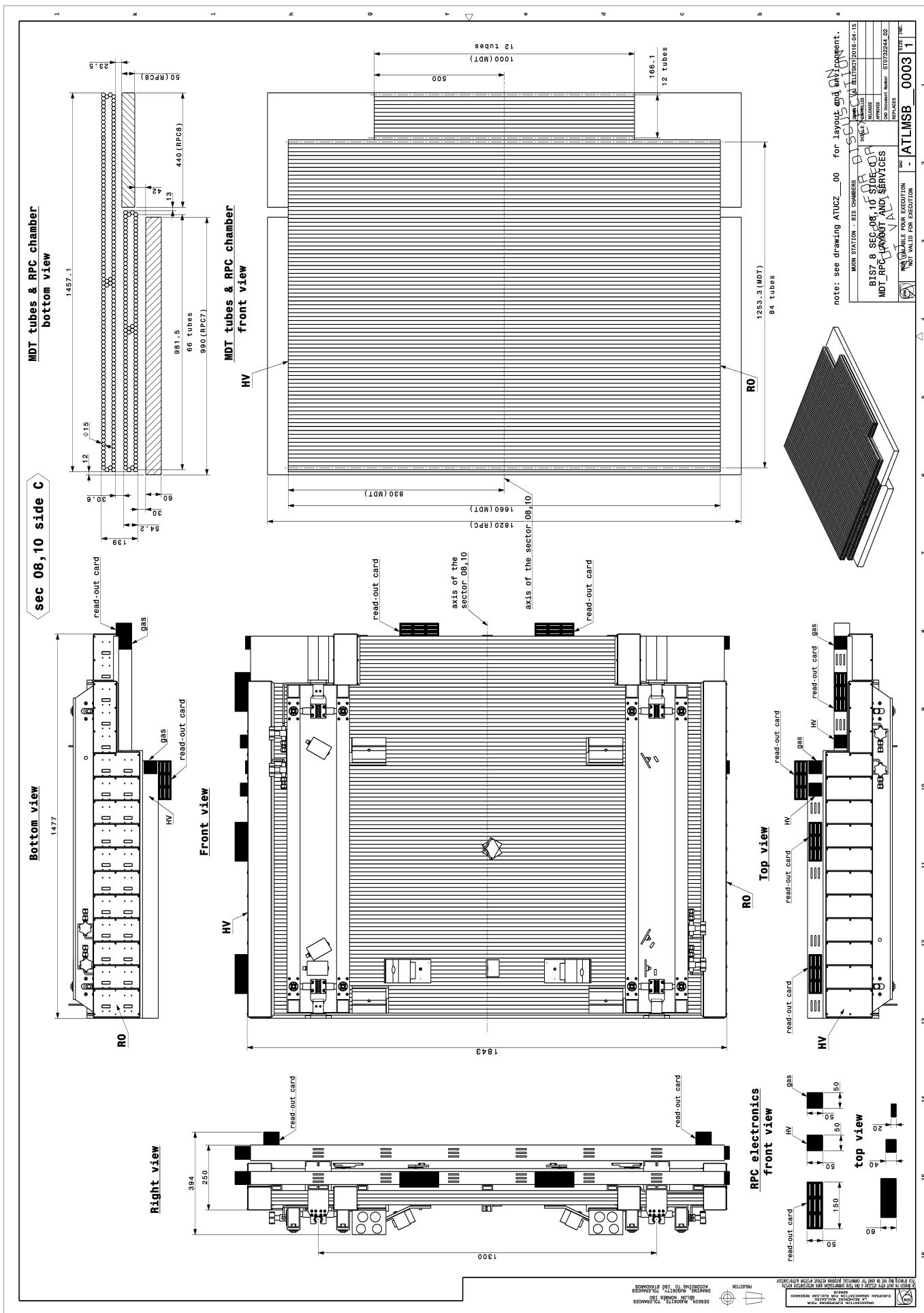


Figure 15: Layout of a BIS-78C-10 chamber [13].

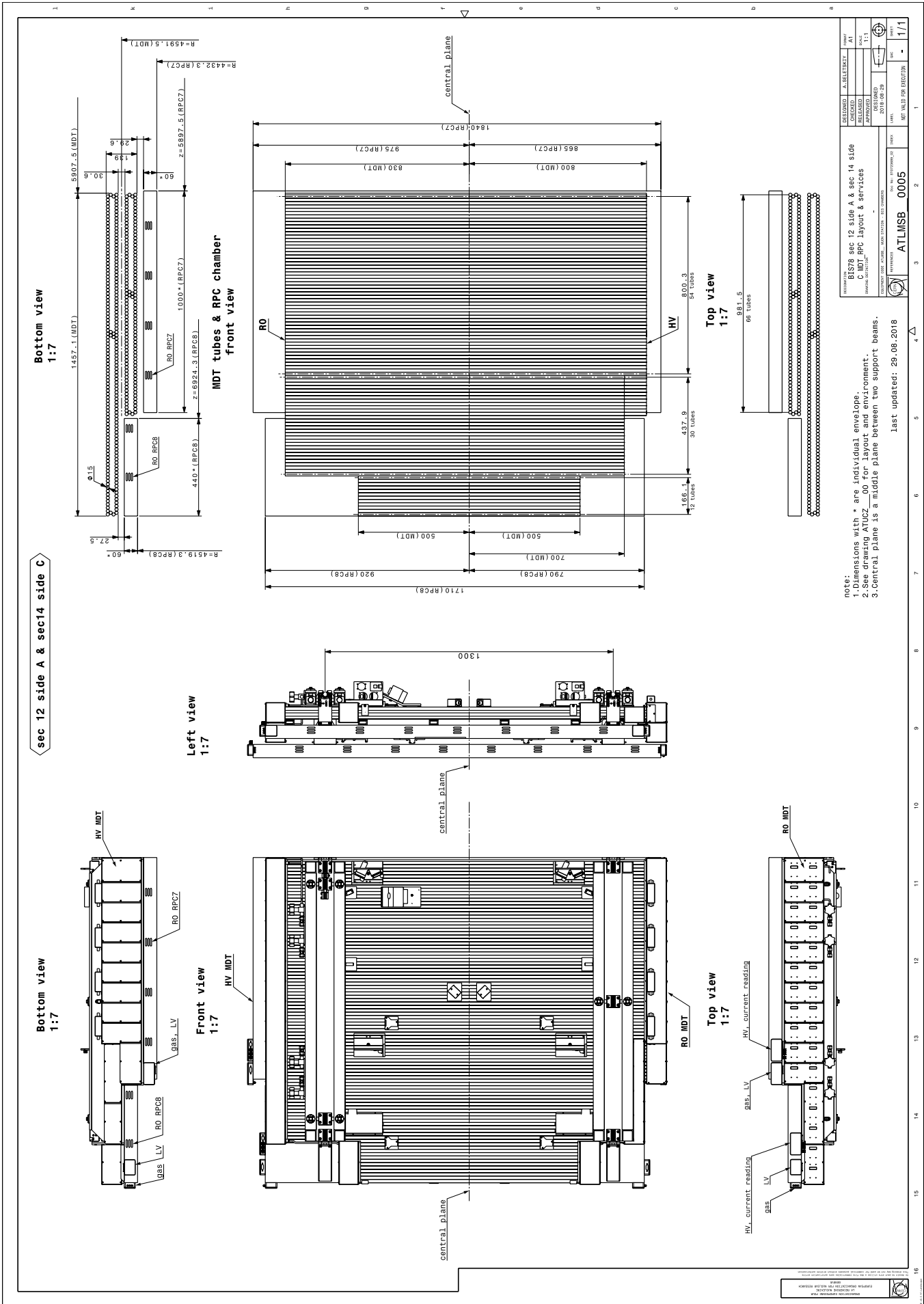


Figure 16: Layout of a BIS-78A-12 chamber [13].

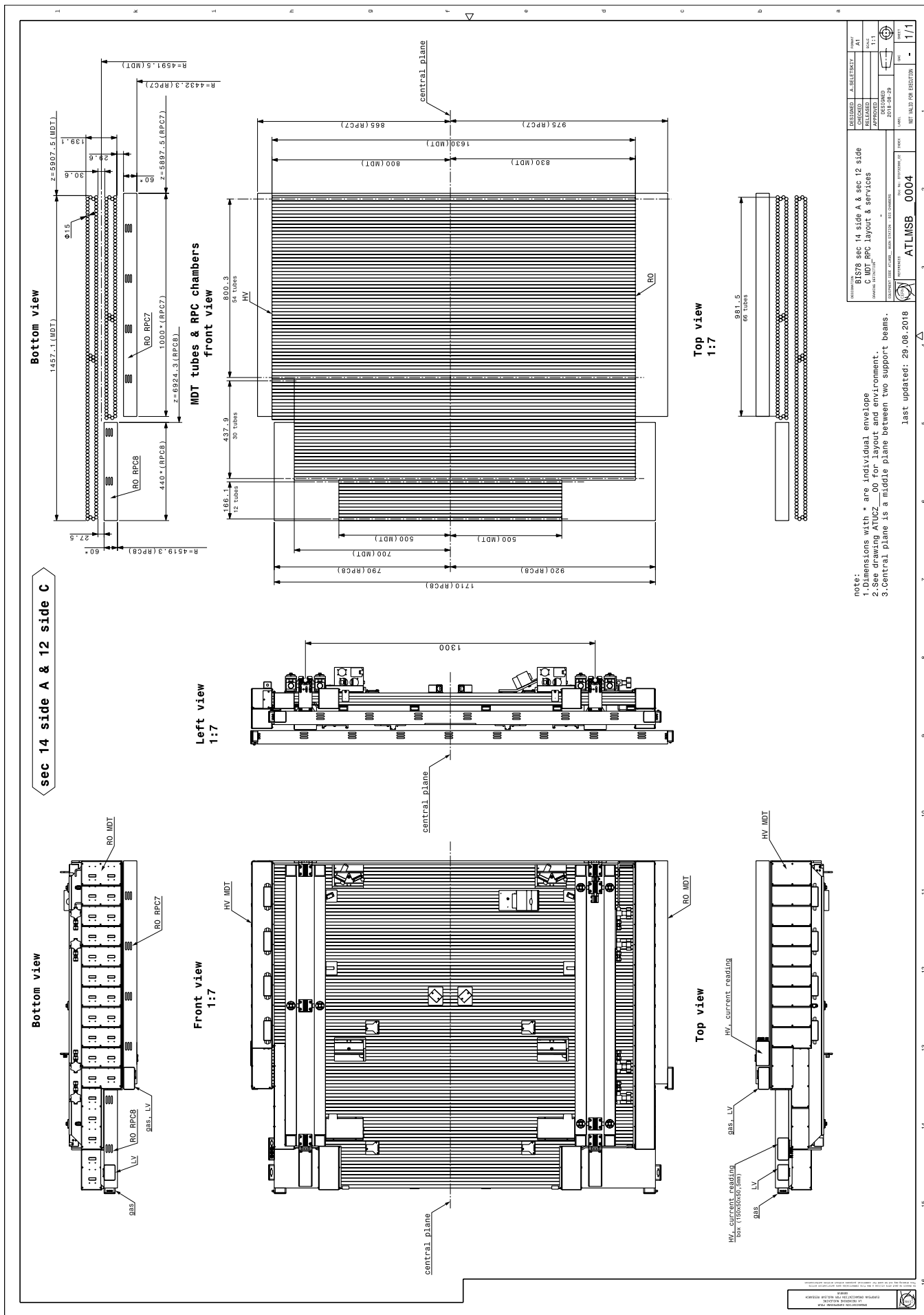
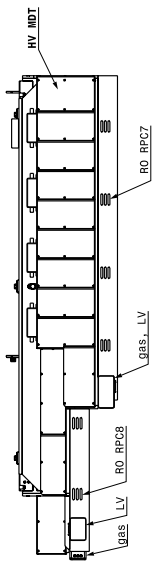


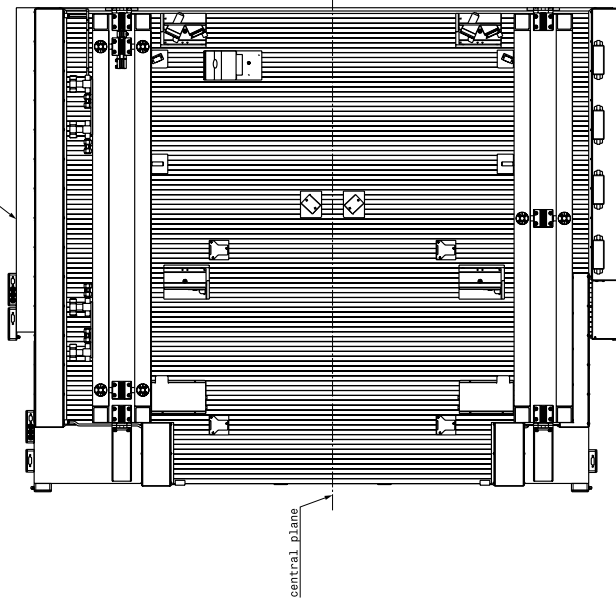
Figure 18: Layout of a BIS-78A-14 chambers [13].

sec 12 side A & sec14 side C

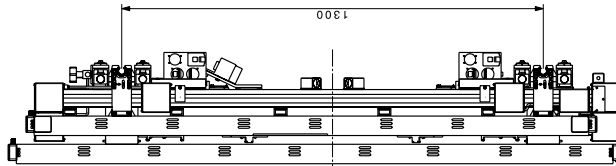
Bottom view
1:7



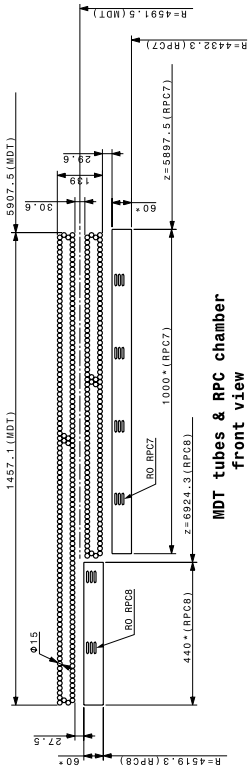
Front view
1:7



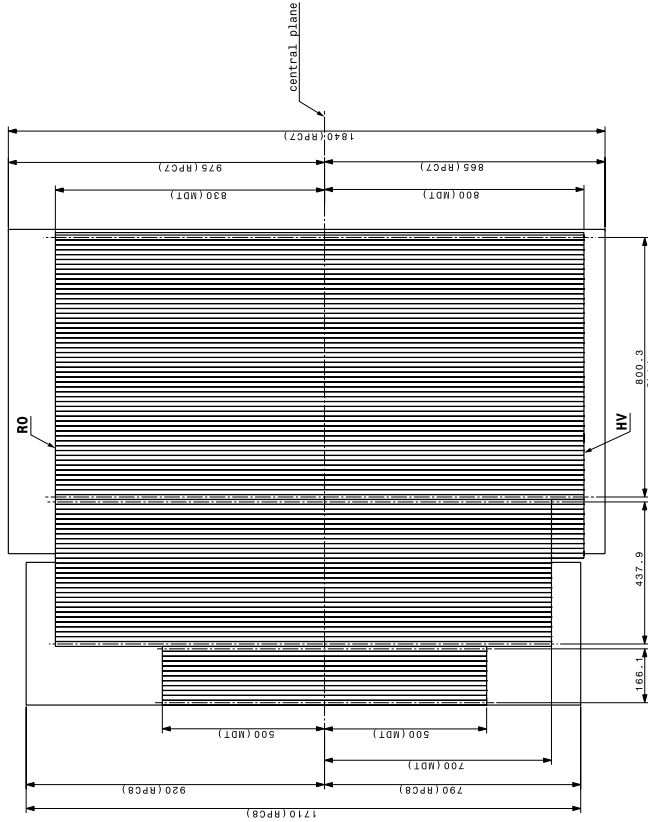
Left view
1:7



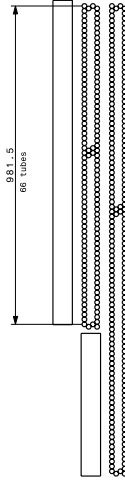
Bottom view
1:7



MDT tubes & RPC chamber
front view

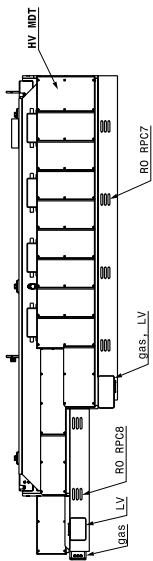


Top view
1:7

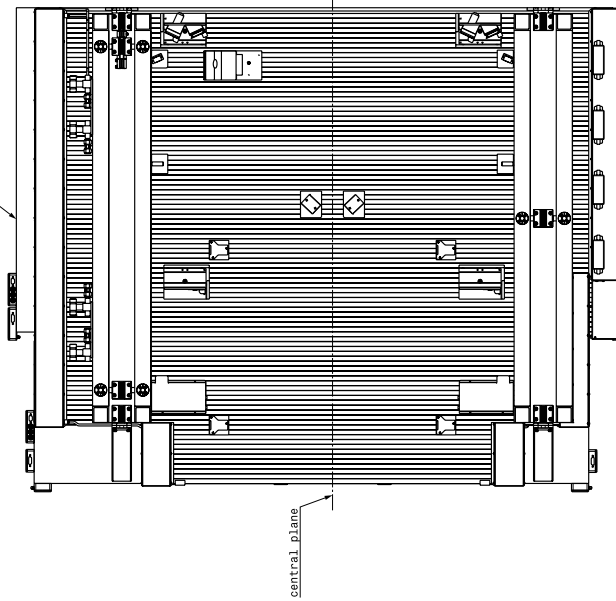


sec 12 side A & sec14 side C

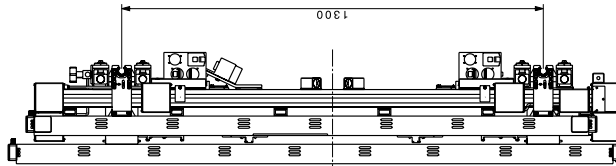
Bottom view
1:7



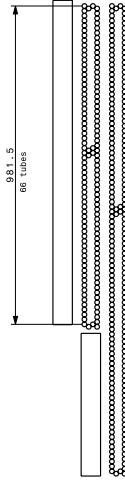
Front view
1:7



Left view
1:7



Top view
1:7



note:
1. Dimensions with * are individual envelope.
2. See drawing ATUCZ_00 for layout and environment.
3. Central plane is a middle plane between two support beams.
Last updated: 29.06.2018

DESIGNED	A. BELUBERICH	DATE	11.11
CHECKED	AI	DATE	11.11
APPROVED		DATE	

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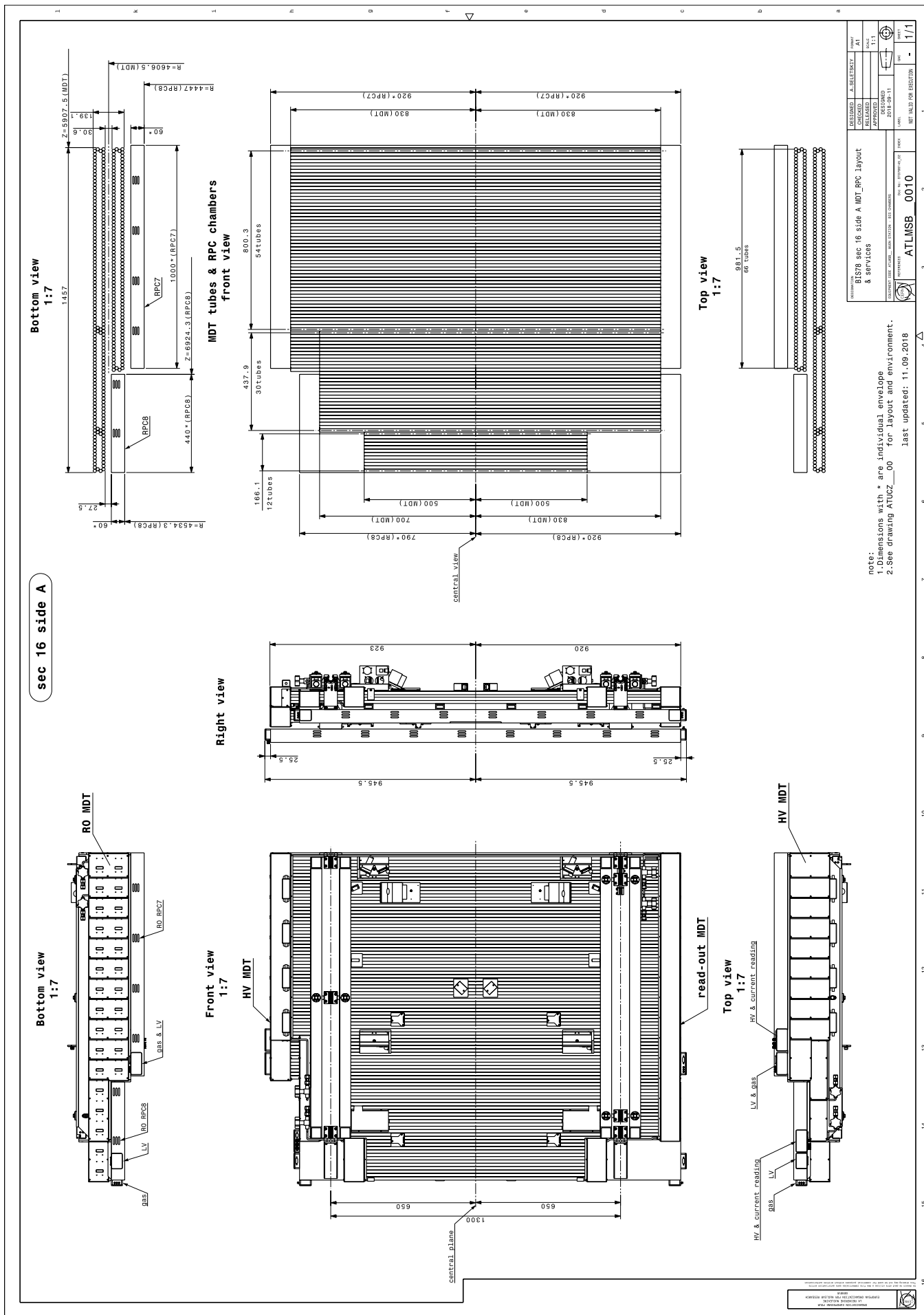


Figure 20: Layout of a BIS-78A-16 chamber [13].

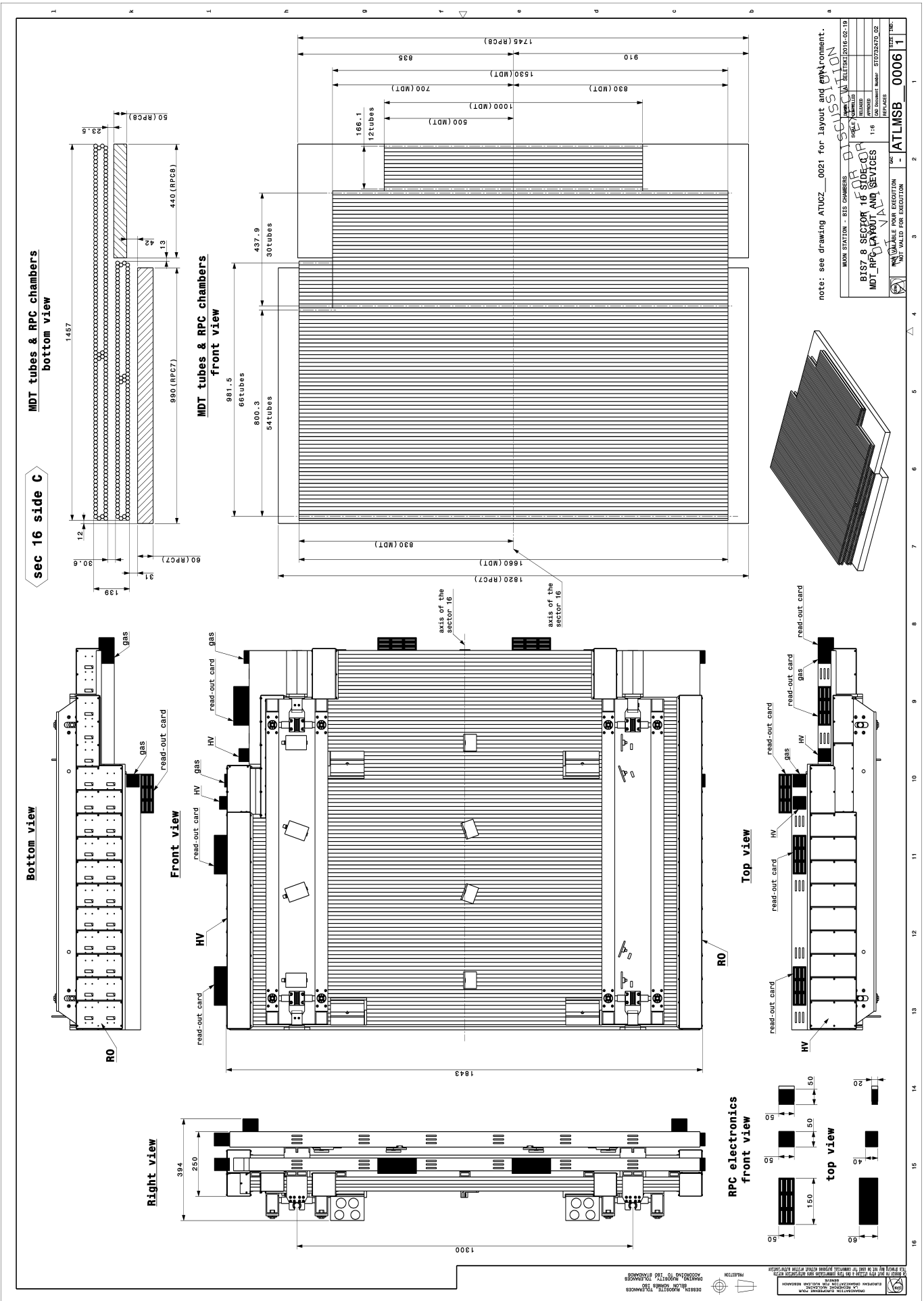


Figure 21: Layout of a BIS-78C-16 chamber [13].

5. The BIS 1-6 Chambers

Table 12: Parameters of BIS 1-6 chambers [14]

Type	BIS 1	BIS 2-6
Number of chambers	16	80
Radial distance from beam axis (mm)	4550 (4635)*	4550 (4635)*
Chamber width in z (mm)	1097	916
Tubes width in z (mm)	1065	884
Chamber length in x (mm)	1796	1796
Aluminum tube length (mm)	1615	1615
Assembled tube length (mm)	1624	1624
Sense wire length (mm)	1597	1597
Active tube length (mm)	1544	1544
Gas volume length (mm)	1574	1574
Active area/chamber (m ²)	1.64	1.36
Tube layers	2×4	2×4
Tubes/layer	70	58
Tubes/chamber	560	464
Spacer height (mm)	45.6	45.6
Multilayer height (mm)	139	139
Chamber height (mm)	249	249
Gas volume/chamber (l)	139.4	115.5
Chamber weight (kg)	140	115
Mezz. cards (24 ch.)/chamber	24	20
CSMs/chamber	2	2
T sensors/chamber	10	10
B-field sensors/chamber	2	2
In-plane alignment systems/chamber	4	4
Axial alignment sensors/chamber	2	4
Praxial alignment sensors/chamber	4	8
CCC alignment sensors/chamber	2	0
Survey targets/chamber	4	4

* Numbers in brackets refer to sectors 2 and 16.

Table 13: BIS 1-6 sMDT chambers summary

Parameter	Value
Number of chambers	96
Number of tubes	46080
Total tube and wire length	74.5 km
Total chamber active area	135 m ²
Total gas volume	114.7 m ³
Total chamber weight	11.5 tons
Number of mezzanine cards	1984
Number of hedgehog boards	3968
Number of CSMs	192

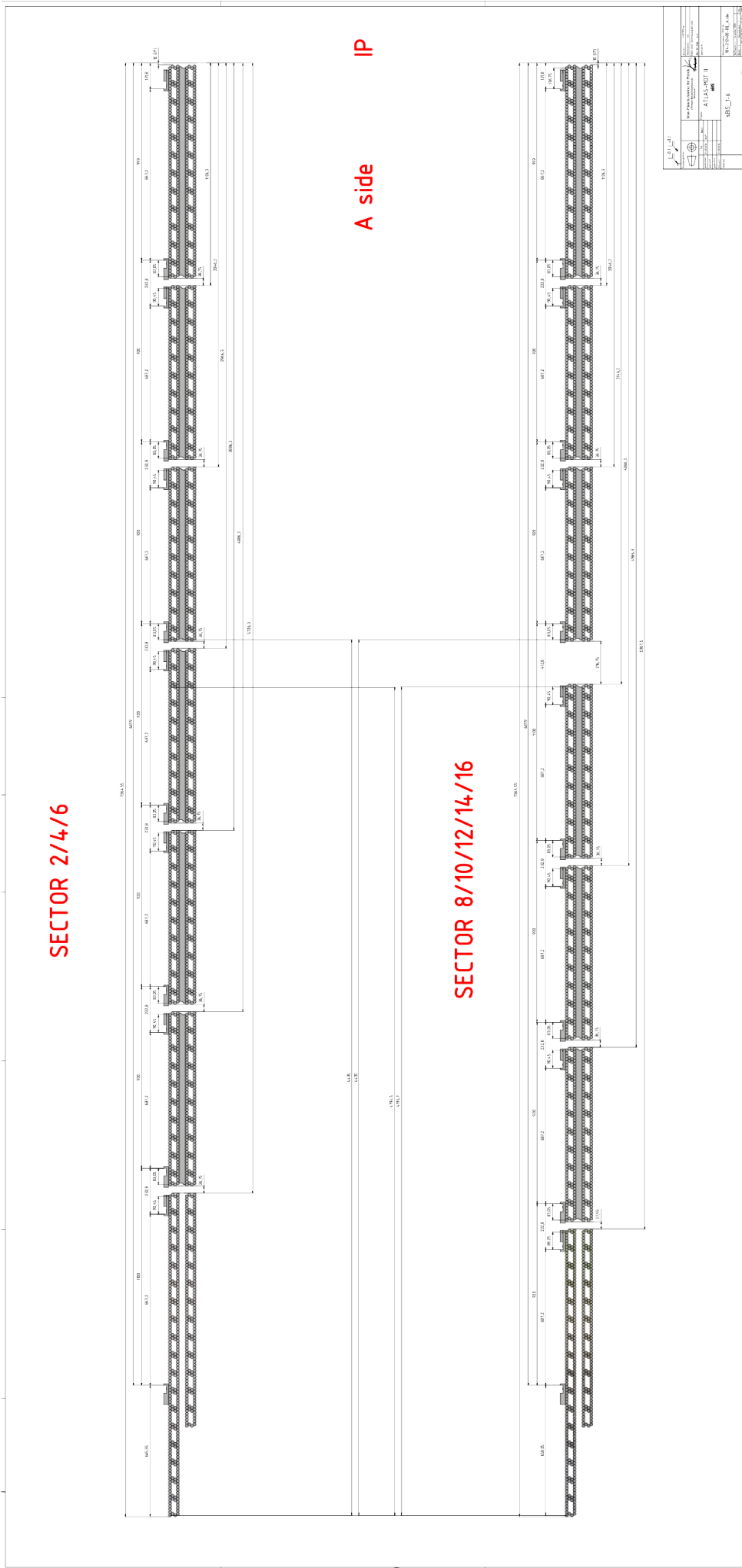


Figure 22: Layout of the BIS 1-6 sMDT chambers for the phase 2 upgrade.

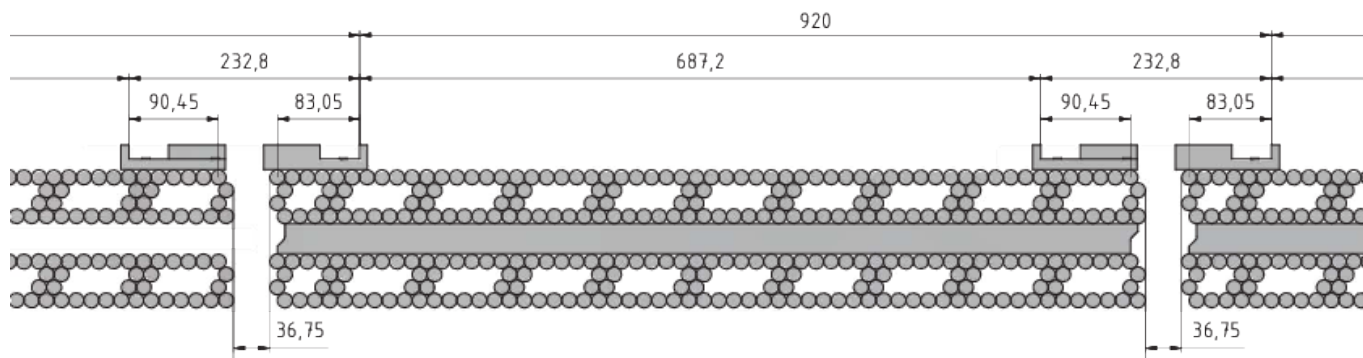


Figure 23: Layout of the BIS 1-6 sMDT chambers for the phase 2 upgrade (enlarged)

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