MDT Parameter Book (Draft 03)

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1 MDT system

The ATLAS muon system is split into two distinct parts: the barrel and the end-caps. In the barrel the MDT chambers are arranged in three cylindrical layers around the beam axis that are called BI (Barrel Inner), BM (Barrel Middle), and BO (Barrel Outer). The end-cap chambers are arranged in four disks on each side of the interaction point perpendicular to the beam axis, called EI (End-cap Inner), EE (End-cap Extra), EM (End-cap Middle), and EO (End-cap Outer). An auxiliary set of chambers, called BEE (Barrel End-cap Extra), are installed on the cryostats of the end-cap toroids; they are constructed like barrel chambers although functionally they serve in the end-cap system. Barrel chambers are of rectangular shape and arranged cylindrically around the beam pipe; end-cap chambers are trapezoidal and arranged in planes orthogonal to the beam pipe. Table 1 summarises some global quantities of interest for barrel and end-caps. The main tube parameters and the operational parameters of the MDT chambers are given in Table 2.

Table 1: MDT chambers in numbers. The numbers in brackets refer to the pseudorapidity coverage in the EI plane.

Parameter	Barrel	Endcap	Total
Number of chambers	656	494	1150
Number of tubes	191 568	162 816	354 384
Total wire or tube length (km)	620	463	1083
Chamber area (m^2)	3121	2399	5520
Pseudorapidity coverage	0–1	1–2.7 (2.0)	0–2.7 (2.0)
Chamber weight (t)	129	85	214
Gas volume (m^3)	415	310	725

Table 2: Principal MDT chamber parameters.

Parameter	Value
Tube material	Aluminium (Aluman100)
Outer tube diameter	29.97 mm
Tube wall thickness	0.4 ± 0.020 mm
Wire material	W-Re (97%:3%); 3% gold plating
Wire diameter	50 μm
Wire pitch	30.035 mm
Gas mixture	Ar:CO_2 (93%:7%)
Gas pressure	3 bar (absolute)
Gas gain	2×10^4
Wire potential	3080 V
Maximum drift time	$\sim$750 ns
Average tube resolution	$\sim$75 μm

1.1 Barrel

Figure 1 shows a cross-section of the barrel part of the muon system. It illustrates the chamber naming and the numbering of the sectors.

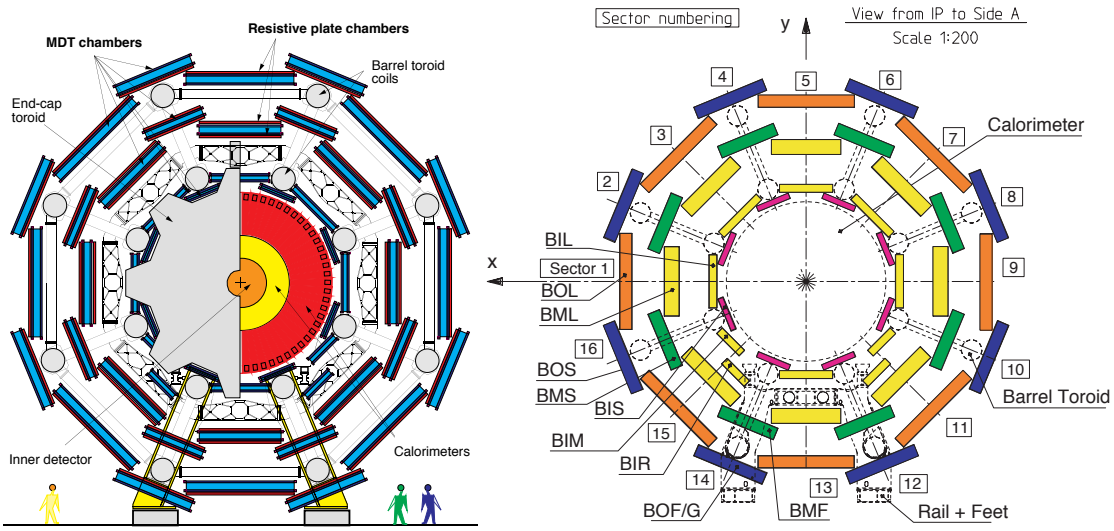

Figure 1: Schematic view of the ATLAS muon spectrometer; cross-section view along the $+z$ direction.

Figure 2 shows the local chamber coordinate system used in the muon system; the y- and z-axes always point away from the interaction point.

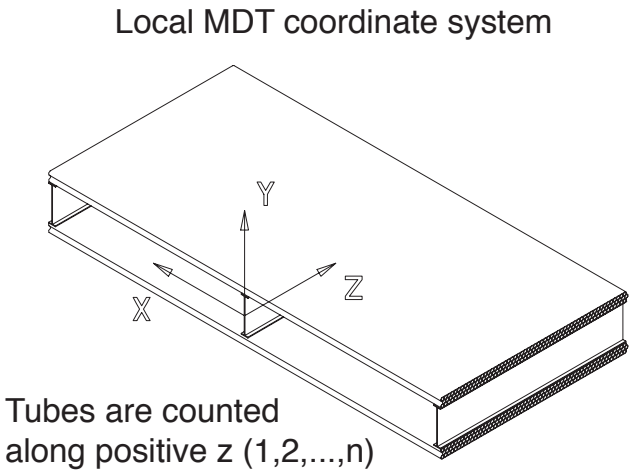

Figure 2: Definition of local chamber coordinate system. The z coordinate of the centre (wire) of the first tube of the chamber is +15 mm.

Figures 3 illustrates the chamber naming and the numbering of the MDT chambers.

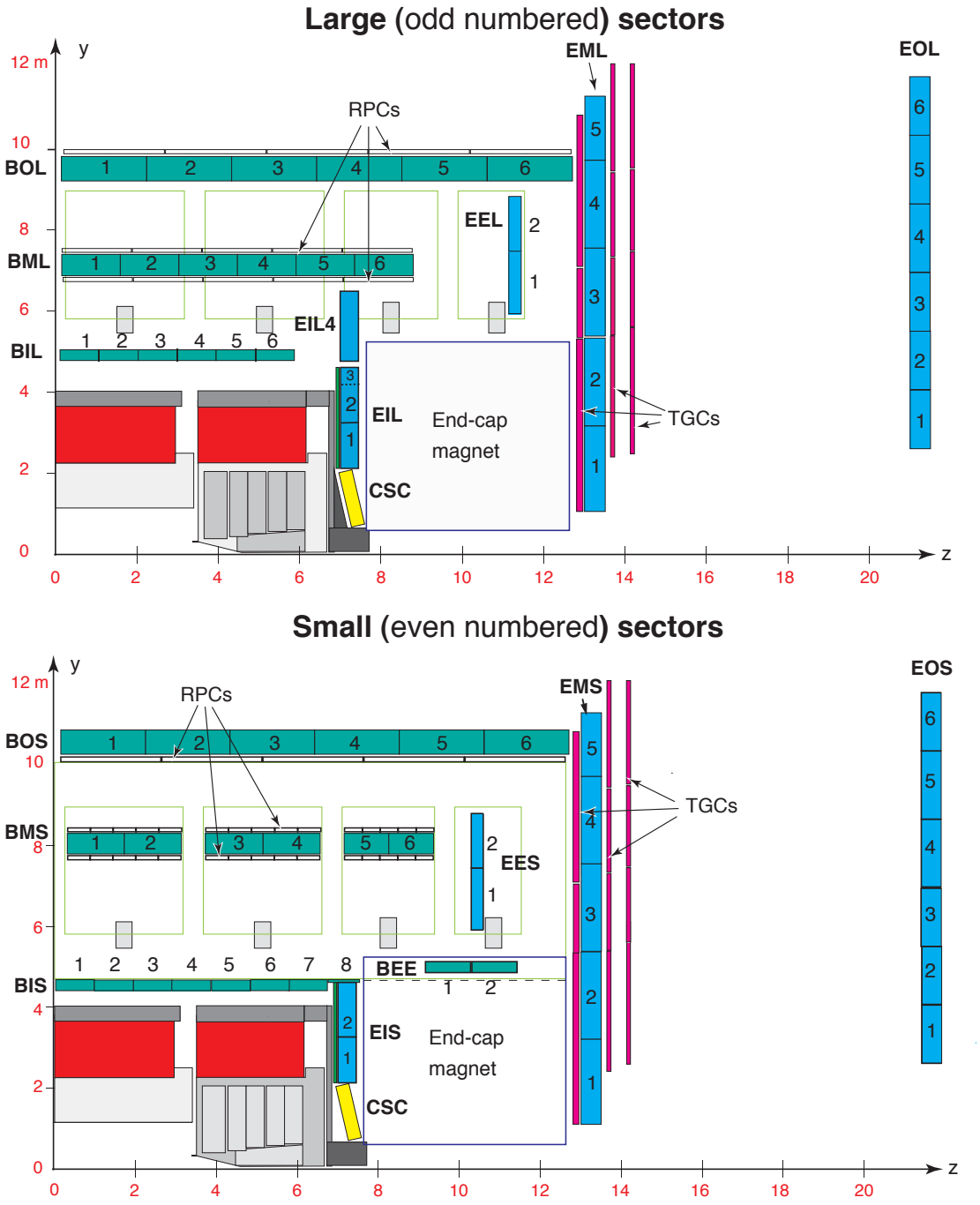

Figure 3: Schematic side view of the ATLAS muon spectrometer depicting the naming and numbering scheme; top: sector with large chambers; bottom: sector with small chambers.

The parameters describing the individual chambers are given in the following tables. Each chamber family comprises, in general, several chamber types that differ from each other in length (barrel) and/or width (end-cap). In the tables there is one column per type. In the barrel the chamber types are named according to their family and length, e.g. a BIS of 'nomimal length'[1] of 900 mm is called BIS900, etc. In the end-caps the chambers are numbered according to their radial position, e.g., EMS2 is the 2^{nd} EMS chamber when counting from the beam axis.

Table 3: Characteristics of BIS chambers; the numbers in brackets refer to sectors 2 and 16.

Construction sites	Beijing (China)	AU Thessaloniki, U and NTU Athens (Greece)	
Type	BIS480	BIS900	BIS1080
Number of chambers	16	90	22
Distance from beam axis (mm)	4620 (4635)	4550 (4635)	4550 (4635)
Chamber length in z (mm)	496.7	916.2	1096.6
Tube length (mm)	851.5	1671.5	1671.5
Tube layers	1×3	2×4	2×4
Tubes/layer	16	30	36
Spacer height (mm)	-	6.5	6.5
Chamber height (mm)	125	284	284
Chamber weight (kg)	20	85	105
Gas volume/chamber (l)	27	269	322
Mezzanine boards/chamber	2	10	12
T-sensors/chamber	3	10	10
B-field sensors/chamber	2	2	2

[1]Nominal length is defined as the number of tubes/layer multiplied by 30 mm; in reality the chambers are longer by half a tube diameter (15 mm) because of the the staggering of the tube layers plus the sum of the additional glue gaps between the tubes.

Table 4: Characteristics of BEE chambers on the end-cap toroid cryostat.

Construction site	Beijing (China)
Type	BEE1440
Number of chambers	32
Distance from beam axis (mm)	4415
Chamber length in z (mm)	1456.7
Tube length (mm)	911.5
Tube layers	1×4
Tubes/layer	48
Spacer height (mm)	-
Chamber height (mm)	170
Chamber weight (kg)	50
Gas volume/chamber (l)	117
Mezzanine boards/chamber	8
T-sensors/chamber	-
B-field sensors/chamber	2 (4)

Table 5: Characteristics of BIL chambers; the number in brackets refers to the two BIL1 chambers in sectors A09 and C09.

Construction sites	Cosenza, Pavia, Rome I (Italy)		
Type	BIL720	BIL900	BIL1080
Number of chambers	2	37	33
Distance from beam axis (mm)	4949	4949 (5465)	4949
Chamber length in z(mm)	735.8	916.2	1096.6
Tube length (mm)	2671.5	2671.5	2671.5
Tube layers	2×4	2×4	2×4
Tubes/layer	24	30	36
Spacer height (mm)	170	170	170
Chamber height (mm)	416	416	416
Chamber weight (kg)	120	140	160
Gas volume/chamber (l)	343	429	515
Mezzanine boards/chamber	8	10	12
T-sensors/chamber	6	6	6
B-field sensors/chamber	2	2	2

Table 6: Characteristics of BIM and BIR chambers; the numbers in brackets refer to the four BIR1 chambers. The BIR720 chambers (BIR5) have only 21 tubes per layer in Multilayer 1; the BIR4 chambers (type BIR900) have only 27 tubes/layer in Multilayer 1.

Construction sites	Cosenza, Pavia, Rome I (Italy)				
Type	BIM1080	BIR720	BIR900	BIR990	BIR1080
Number of chambers	20	4	12	4	4
Distance from beam axis (mm)	5373	6056	6056	6056	6056
Chamber length in z(mm)	1096.6	735.8	916.2	1006.1	1096.6
Tube length (mm)	1536.5	1536.5	1536.5 (2671.5)	1105.5	1105.5
Tube layers	2×4	2×4	2×4	2×4	2×4
Tubes/layer	36	21/24	27/30 (24/30)	33	36
Spacer height (mm)	170	170	170	170	170
Chamber height (mm)	416	416	416	416	416
Chamber weight (kg)	120	85	100 (130)	95	100
Gas volume/chamber (l)	515	185	235 (386)	195	213
Mezzanine boards/chamber	12	8	10	12	12
T-sensors/chamber	6	6	6	6	6
B-field sensors/chamber	1	1	1	-	-

Table 7: Characteristics of BMS and BMF chambers. The numbers in brackets refer to the BMS4 and BMS6 chambers in which the last group of 3×8 tubes in multilayer 1 is missing.

Construction site	JINR Dubna (Russia)				
Type	BMS960	BMS/F1440	BMS1680	BMS/F1920	BMS/F2160
Number of chambers	12	52	12	4	4
Distance from beam axis (mm)	8095	8095	8095	8095	8095
Chamber length in z (mm)	976.1	1456.7	1696.9	1937.2	2177.5
Tube length (mm)	3071.5	3071.5	3071.5	3071.5	3071.5
Tube layers	2×3	2×3	2×3	2×3	2×3
Tubes/layer	32	48 (40)	56	64	72
Spacer height (mm)	170	170	170	170	170
Chamber height (mm)	364	364	364	364	364
Chamber weight (kg)	140	190	215	240	260
Gas volume/chamber (l)	395	592 (543)	691	790	889
Mezzanine boards/chamber	8	12 (11)	14	16	18
T-sensors/chamber	10	10	10	10	10
B-field sensors/chamber	2	2	2	2	2

Table 8: Characteristics of BML chambers.

Construction site	Frascati Nat. Lab. (Italy)			
Type	BML960	BML1200	BML1440	BML1680
Number of chambers	4	35	20	35
Distance from beam axis (mm)	7139	7139	7139	7139
Chamber length in z (mm)	976.1	1216.4	1456.7	1696.9
Tube length (mm)	3551.5	3551.5	3551.5	3551.5
Tube layers	2×3	2×3	2×3	2×3
Tubes/layer	32	40	48	56
Spacer height (mm)	317	317	317	317
Chamber height (mm)	511	511	511	511
Chamber weight (kg)	180	210	240	260
Gas volume/chamber (l)	457	571	685	799
Mezzanine boards/chamber	8	10	12	14
T-sensors/chamber	10	10	10	10
B-field sensors/chamber	-	-	-	-

Table 9: Characteristics of BOS and BOF chambers. The numbers in brackets refer to the BOF chambers (sectors 12 and 14).

Construction sites	LMU and MPI Munich (Germany)			
Type	BOF1200	BOS/F1440	BOS/F1920	BOS/F2160
Number of chambers	4	6	16	62
Distance from beam axis (mm)	10675	10569 (10675)	10569 (10675)	10569 (10675)
Chamber length in z (mm)	1216.4	1456.7	1937.2	2177.5
Tube length (mm)	3773.3	3773.3	3773.3	3773.3
Tube layers	2×3	2×3	2×3	2×3
Tubes/layer	40	48	64	72
Spacer height (mm)	317	317	317	317
Chamber height (mm)	511	511	511	511
Chamber weight (kg)	220	270	300	350
Gas volume/chamber (l)	606	728	970	1092
Mezzanine boards/chamber	10	12	16	18
T-sensors/chamber	18	18	18	18
B-field sensors/chamber	2	2	2	2

Table 10: Characteristics of BOG chambers. These chambers are located inside the detector support feet in sectors 12 and 14; they are T-shaped (except BOG8) and consist of long and short tubes. The dimensions in brackets in the table refer to the first and last six tubes in each tube layer, i.e. 72 tubes out of the 240 total.

Construction site	Freiburg (Germany)	
Type	BOG1200	BOG1200[a]
Number of chambers	14	4
Distance from beam axis (mm)	10675	10675
Chamber length in z (mm)	1216.4	1216.4
Tube length (mm)	3771.5 (1201.5)	3771.5
Tube layers	2×3	2×3
Tubes/layer	28+12[b]	40
Spacer height (mm)	317	317
Chamber height (mm)	511	511
Chamber weight (kg)	200	220
Gas volume/chamber (l)	482	606
Mezzanine boards/chamber	10	10
T-sensors/chamber	28	24
B-field sensors/chamber	2	2

[a]BOG8; these chambers are installed in the last detector support feet on each side of the interaction point; these chambers have no short tubes.

[b]28 long and 12 short tubes

Table 11: Characteristics of BOL chambers.

Construction site	NIKHEF Amsterdam (Netherlands)			
Type	BOL1440	BOL1680	BOL1920	BOL2160
Number of chambers	11	36	1	48
Distance from beam axis (mm)	9500	9500	9500	9500
Chamber length in z (mm)	1456.7	1696.9	1937.2	2177.5
Tube length (mm)	4961.5	4961.5	4961.5	4961.5
Tube layers	2×3	2×3	2×3	2×3
Tubes/layer	48	56	64	72
Spacer height (mm)	317	317	317	317
Chamber height (mm)	511	511	511	511
Chamber weight (kg)	300	340	380	420
Gas volume/chamber (l)	957	1116	1276	1435
Mezzanine boards/chamber	12	14	16	18
T-sensors/chamber	18	18	18	18
B-field sensors/chamber[a]	2	2	2	2

[a]B-field sensors are on all side A chambers, except in sector 13, and on C-side chambers in sectors 5 and 13.

1.2 End-cap chambers

Figure 4 shows the layout of the EI and EE chambers. Figure 5 shows the layout of the EM and EO chambers. The EM chambers are mounted on the movable MDT Big Wheel structures; The EO chambers are fixed and mounted on the HO structures at the two cavern ends.

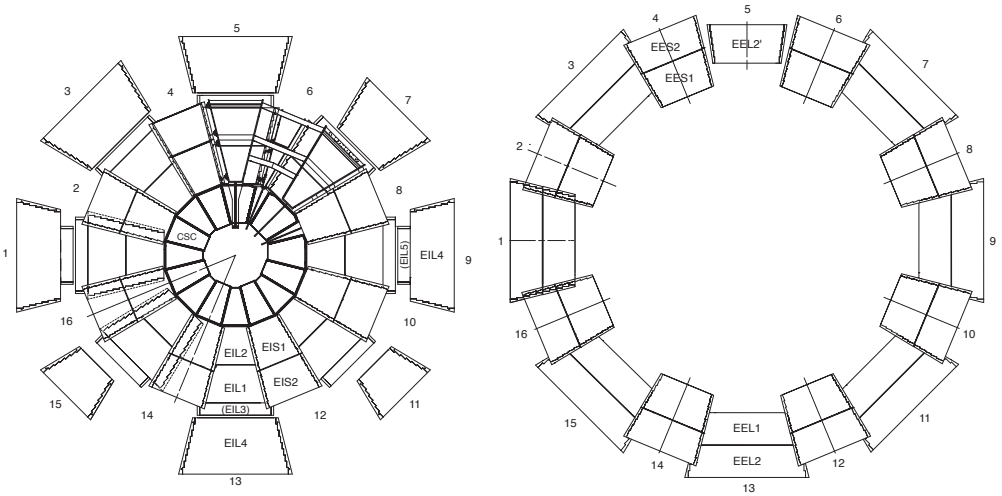

Figure 4: View of the EI (left) and EE (right) chambers from the interaction point onto side A. The EIS chambers of Sector 6 are not drawn to show the Small Wheel support structure.

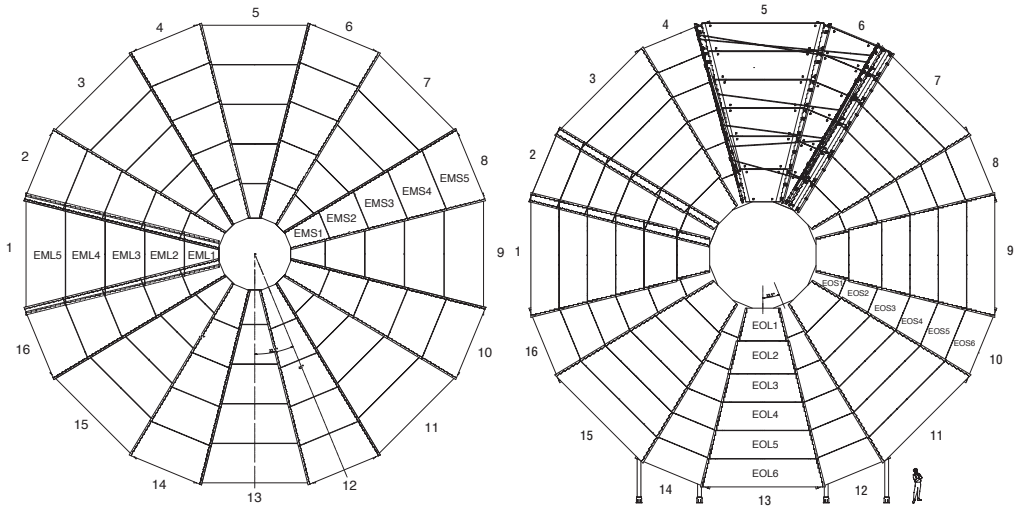

Figure 5: View of the EM (left) and EO (right) chambers from the interaction point onto side A. In Sectors 5 and 6 of the EO chambers the alignment components are shown. .

The parameters of the EI and EE chambers are given in Tables 12, 13, and 14. The parameters of the EM and EO chambers are given in Tables 15, 16, 17, and 18.

Table 12: Characteristics of EIS and EIL chambers on the Small Wheels.

Construction sites	Boston (USA)				Rome I (Italy)	
Type	EIS1	EIS2	EIL1	EIL2	EIL3[a]	
Number of chambers	16	16	16	16	12	4
Distance from beam axis (mm)	2076	3371	2076	3191	4272.3	4272.3
Distance from IP (z mm)	7261	7261	7675	7675	7675	7675
Chamber length in r (mm)	1276.5	1096.2	1096.2	1096.2	375.4	375.4
Tube length min (mm)	898.5	1276.5	1321.5	1861.5	2071.5	1741.5
Tube length max (mm)	1222.5	1546.5	1771.5	2311.5	2071.5	1741.5
Tube layers	2×3	2×3	2×3	2×3	2×3	2×3
Tubes/layer	42	36	36	36	12	12
Spacer height (mm)	121	121	121	121	121	121
Chamber height (mm)	367	367	367	367	367	367
Chamber weight (kg)	140	160	130	190	50	45
Gas volume/chamber (l)	239	272	298	402	133	112
Mezzanine boards/chamber	14	12	12	12	4	4
T-sensors/chamber	8	8	8	8	-	-
B-field sensors/chamber	-	-	-	-	-	-

[a]The EIL3 chambers are not separate chambers; they are physically connected to the upper end of and are read out together with the EIL2 chambers, but were constructed separately.

Table 13: Characteristics of EIL4 chambers; $z = \pm 7641.5$ mm.

Construction sites	Seattle (USA)				Rome I (Italy)
Type (Sectors)	EIL4 (1,9)	EIL4 (3,5,13)	EIL4 (7)	EIL4 (11,15)	EIL5 (1,9)[a]
Number of chambers	4	6	2	4	4
Distance from beam axis (mm)	5080.4	4720	4720	5080.4	4720
Chamber length in r (mm)	1276.5	1636.9	1636.9	1276.5	375.4
Tube length min (mm)	2531.5	2531.5	1651.5	1281.5	1536.5
Tube length max (mm)	3071.5	3071.5	2371.5	1821.5	1536.5
Tube layers	2×3	2×3	2×3	2×3	2×3
Tubes/layer	42	54	54	42	12
Spacer height (mm)	121	121	121	121	121
Chamber height (mm)	367	367	367	367	367
Chamber weight (kg)	190	230	185	140	40
Gas volume/chamber (l)	630	784	582	349	99
Mezzanine boards/chamber	14	18	18	14	4
T-sensors/chamber	20	20	20	20	-
B-field sensors/chamber	4	2	4	4	2

[a]The EIL5 chambers are not separate chambers; they are physically connected to the inner end of and are read out together with the EIL4 chambers, but were constructed separately.

Table 14: Characteristics of EES and EEL chambers.

Construction site	Protvino (Russia)				
Type (Sector)	EES1	EES2	EEL1	EEL2	EEL2 (5)
Number of chambers	16	16	14	14	2
Distance from beam axis (mm)	5893	7370	6513	7749.7	6718
Distance from IP (mm)	10276.5	10276.5	11322.5	11322.5	10518.5
Chamber length in r (mm)	1456.7	1216.4	1216.4	1216.4	1456.7
Tube length min (mm)	2014.5	2446.5	3361.5	3961.5	2446.5
Tube length max (mm)	2374.5	2734.5	3841.5	4441.5	2806.5
Tube layers	2×3	2×3	2×3	2×3	2×3
Tubes/layer	48	40	40	40	48
Spacer height (mm)	121	121	121	121	121
Chamber height (mm)	315	315	315	315	315
Chamber weight (kg)	150	140	170	190	160
Gas volume/chamber (l)	423	416	579	675	507
Mezzanine boards/chamber	12	10	10	10	12
T-sensors/chamber	8	8	8	8	8
B-field sensors/chamber	4	2	4	4	2

Table 15: Characteristics of EMS chambers. All chambers are at a distance of $z = \pm 13878.5$ mm from the interaction point.

Construction sites	Boston (USA)	Seattle (USA)		Michigan (USA)	
Type	EMS1	EMS2	EMS3	EMS4	EMS5
Number of chambers	16	16	16	16	16
Distance from beam axis (mm)	1770	3725	5680	7635	9590
Chamber length in r (mm)	1937.2	1937.2	1937.2	1937.2	1937.2
Tube length min (mm)	835.5	1411.5	1987.5	2563.5	3139.5
Tube length max (mm)	1339.5	1915.5	2491.5	3067.5	3643.5
Tube layers	2×3	2×3	2×3	2×3	2×3
Tubes/layer	64	64	64	64	64
Spacer height (mm)	170	170	170	170	170
Chamber height (mm)	364	364	364	364	364
Chamber weight (kg)	140	180	210	235	260
Gas volume/chamber (l)	280	428	576	724	872
Mezzanine boards/chamber	16	16	16	16	16
T-sensors/chamber	8	20	20	20	20
B-field sensors/chamber	4	2	4	4	2

Table 16: Characteristics of EML chambers. All chambers are at a distance of $z = \pm 14294.5$ mm from the interaction point.

Construction sites	Seattle (USA)		Michigan (USA)		
Type	EML1	EML2	EML3	EML4	EML5
Number of chambers	16	16	16	16	16
Distance from beam axis (mm)	1770	3485	5440	7395	9350
Chamber length in r (mm)	1696.9	1937.2	1937.2	1937.2	1937.2
Tube length min (mm)	1186.5	2026.5	2986.5	3946.5	4906.5
Tube length max (mm)	1906.5	2866.5	3826.5	4786.5	5746.5
Tube layers	2×3	2×3	2×3	2×3	2×3
Tubes/layer	56	64	64	64	64
Spacer height (mm)	170	170	170	170	170
Chamber height (mm)	364	364	364	364	364
Chamber weight (kg)	150	210	250	290	330
Gas volume/chamber (l)	348	629	876	1123	1370
Mezzanine boards/chamber	14	16	16	16	16
T-sensors/chamber	28	20	20	20	20
B-field sensors/chamber	4	4	2	-	-

Table 17: Characteristics of EOS chambers; all chambers are at $z = \pm 21820.5$ mm.

Construction site	Protvino (Russia)					
Type	EOS1	EOS2	EOS3	EOS4	EOS5	EOS6
Number of chambers	16	16	16	16	16	16
Distance from beam axis (mm)	2770	4485	6200	7915	9390	10865
Chamber length in r (mm)	1696.9	1696.9	1696.9	1456.7	1456.7	1456.7
Tube length min (mm)	1249.5	1753.5	2257.5	2761.5	3193.5	3625.5
Tube length max (mm)	1681.5	2185.5	2689.5	3121.5	3553.5	3985.5
Tube layers	2×3	2×3	2×3	2×3	2×3	2×3
Tubes/layer	56	56	56	48	48	48
Spacer height (mm)	170	170	170	170	170	170
Chamber height (mm)	364	364	364	364	364	364
Chamber weight (kg)	140	160	180	180	190	210
Gas volume/chamber (l)	330	443	557	567	651	734
Mezzanine boards/chamber	14	14	14	12	12	12
T-sensors/chamber	8	8	8	8	8	8
B-field sensors/chamber	-	-	-	-	-	-

Table 18: Characteristics of EOL chambers; all chambers are at $z = \pm 21404.5$ mm.

Construction site	Protvino (Russia)					
Type	EOL1	EOL2	EOL3	EOL4	EOL5	EOL6
Number of chambers	16	16	16	16	16	16
Distance from beam axis (mm)	2770	4485	6200	7675	9150	10625
Chamber length in r (mm)	1696.9	1696.9	1456.7	1456.7	1456.7	1456.7
Tube length min (mm)	1681.5	2641.5	3481.5	4201.5	4921.5	5641.5
Tube length max (mm)	2401.5	3361.5	4081.5	4801.5	5521.5	6241.5
Tube layers	2×3	2×3	2×3	2×3	2×3	2×3
Tubes/layer	56	56	48	48	48	48
Spacer height (mm)	170	170	170	170	170	170
Chamber height (mm)	364	364	364	364	364	364
Chamber weight (kg)	170	210	215	235	260	285
Gas volume/chamber (l)	459	675	729	868	1007	1146
Mezzanine boards/chamber	14	14	12	12	12	12
T-sensors/chamber	8	8	8	8	8	8
B-field sensors/chamber	-	-	-	-	-	-