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Doses from the LAr beam pipe

A new design of LAr beam-pipe (VA) was studied. Here are given results of simulations of dose rate that results from activation of the beam pipe section placed inside the LAr End Cap Calorimeter (Zmin=365 cm, Zmax=870 cm).

1. Only stainless steel activation by hadrons and low energy neutron activation was taken into account. Total mass of stainless steel (316 L) is approximately 15.6 kg.
2. Design of the beam pipe section was taken from the LHCVC1A_0001 and O-TB-0049-177-01-R(3) drawings. A new design feature was introduces in order to decrease activation – the beam-pipe radius was increased in the Ion pump region. Geometry for activation calculations is given in the Table 1. A sketch of the beam pipe under study is given on Fig. 1.
3. For the purpose of the study, a more realistic description of Ion Pump was used. Previously it was represented as a 2 kg SS cylinder with uniform density. Now it is represented as outer box of 0.8 mm SS thickness with a diameter of 166 mm and height along Z of 56 mm. The inner part of the pump itself will be two cylindrical electrodes, which are 2 mm thick SS and 32 mm long sitting at a radius of 45 and 68 mm. Mass of the pump is 0.75 kg.
4. For the purpose of the study the beam pipe was subdivided onto a set of circular radiation sources centered along Z-axis and the dose was calculated as sum over all the sources. At that the doses will be conservative as no self-attenuation of gamma radiation was taken into account. Consequently doses may be slightly overestimated by some 10%.
5. Results of hadron activation calculations are presented in the Table 2 and neutron activation in the Table 3 for various running and cooling times. All values are in μSv/h. Dimensions by Z-axis are given in cm from the interaction point.

Table 1

Material zones of the LAr beam pipe section

##	Z_{min}, cm	Z_{max}, cm	R_{min}, cm	R_{max}, cm	Mass, kg(*	Comment
1	365	366.4	2.9	4.3	0.346	Flange
2	366.4	370.65	3.75	3.83	0.063	Cone
3	370.65	374.8	4.6	4.68	0.075	Cone
4	374.5	382.8	6.3	6.38	0.206	Cone
5	382.5	390.8	8	8.08	0.262	Cone
6	390.5	398.8	9.7	9.78	0.317	Cone
7	398.5	403.5	11.4	11.48	0.224	Tube
8	403.5	409.5	11.4	11.54	0.472	Bellows
9	409.5	410.5	11.4	11.48	0.045	Tube
10	410.5	416.5	11.4	11.54	0.472	Bellows
11	416.5	417.5	11.4	11.48	0.045	Tube
12	417.2	425.5	9.7	9.78	0.317	Cone
13	425.2	433.5	8	8.08	0.262	Cone
14	433.2	441.5	6.3	6.38	0.206	Cone
15	441.2	445.35	4.6	4.68	0.075	Cone
16	445.35	449.5	3.75	3.83	0.062	Cone
17	397	397.08	2.98	8.3	0.118	Pump wall
18	397.08	402.6	8.23	8.3	0.156	Pump wall
19	402.6	402.68	2.98	8.3	0.118	Pump wall
20	398.6	401.8	4.5	4.7	0.144	Electrode
21	398.6	401.8	6.8	7	0.216	Electrode
22	449.5	855	2.9	2.98	4.672	Tube
23	855	863.2	2.9	3.04	0.167	Bellows
24	863.2	870	2.9	2.98	0.078	Tube
25	449.5	849	3.92	4	6.199	Tube
26	868.6	870	2.98	4.3	0.330	Flange
(* - calculated as product of density by volume						

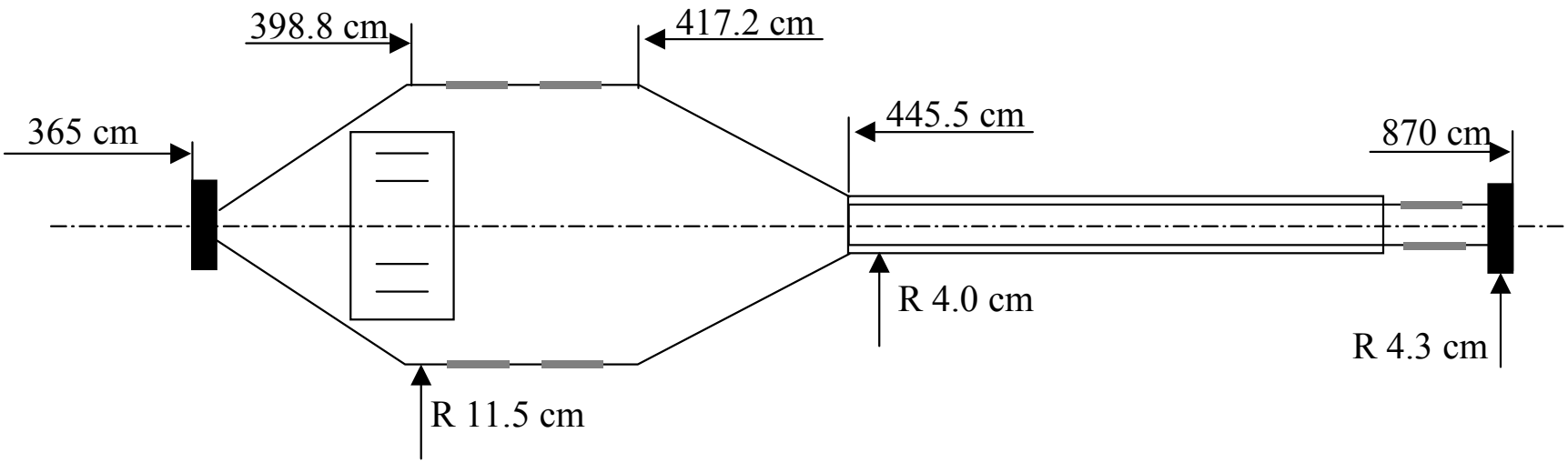

Fig. 1. Sketch of the LAr Beam pipe section.

Table 2

Equivalent dose rate induced by high-energy hadrons from LAr Beam Pipe for T= 100d, t=5d

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	479	3887											3713	741
5	457	4216					8818	6696	5146	4571	4517	2900	3666	678
7	437	1750	1738			2279	5424	4232	3269	2910	2839	1936	1643	621
11.5	400	968	1083	1499	1440	1615	3467	2797	2172	1935	1857	1300	939	529
15	337	580	654	863	975	1113	2116	1791	1401	1249	1171	831	573	407
20	285	425	472	605	692	856	1484	1309	1032	919	845	601	424	329
25	246	339	371	462	545	694	1121	1024	813	723	654	466	339	277
50	148	175	184	212	267	340	452	460	378	335	288	212	174	157
75	107	121	125	140	172	210	257	274	233	207	175	134	116	110
100	83	92	95	104	122	144	170	184	161	143	122	97	87	83
125	67	73	75	81	92	106	121	132	118	106	91	75	68	67
150	56	59	61	65	73	81	91	99	91	82	72	60	56	55
175	47	49	50	53	59	64	71	77	72	65	58	50	46	46
200	40	42	42	44	48	52	57	62	58	53	48	42	39	40
225	34	36	36	38	41	44	47	50	48	44	40	36	34	35

Table 2 (continuation)

Equivalent dose rate induced by high-energy hadrons from LAr Beam Pipe for T= 10y, t=5d

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	538	4364											4177	831
5	514	4734					9973	7545	5789	5144	5082	3261	4124	759
7	491	1966	1952			2571	6134	4769	3678	3275	3194	2177	1849	696
11.5	450	1088	1217	1686	1621	1823	3920	3152	2444	2177	2089	1462	1056	593
15	379	652	736	970	1098	1257	2392	2018	1577	1405	1317	935	645	455
20	320	478	531	681	779	966	1678	1475	1161	1034	950	677	476	367
25	277	381	417	519	614	784	1267	1154	915	814	736	525	382	309
50	167	197	208	239	301	384	510	519	426	378	324	238	196	175
75	120	136	141	158	193	237	291	309	262	233	197	151	131	121
100	94	103	107	117	138	162	192	207	181	161	137	109	98	92
125	76	82	84	91	104	119	137	149	133	119	103	84	77	73
150	63	67	69	73	82	92	103	112	102	92	81	68	63	60
175	53	56	57	60	66	73	81	87	81	74	65	56	52	50
200	45	47	48	50	54	59	65	70	65	60	54	47	44	43
225	39	40	41	42	46	49	53	57	54	50	45	40	38	37

Table 2 (continuation)

Equivalent dose rate induced by high-energy hadrons from LAr Beam Pipe for T= 100d, t=100d

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	82	649											644	128
5	78	704					1614	1203	910	800	788	505	636	117
7	75	295	294			403	992	760	578	509	495	337	285	108
11.5	69	165	185	260	255	286	633	502	384	339	324	226	163	92
15	58	100	113	150	173	198	386	322	248	219	204	145	100	71
20	49	74	82	106	122	153	270	235	182	161	148	105	74	57
25	43	59	65	81	96	124	204	184	144	127	114	81	59	48
50	26	31	33	38	47	61	82	83	67	59	51	37	30	27
75	19	21	22	25	31	38	46	49	41	37	31	24	20	19
100	15	16	17	18	22	26	31	33	29	25	22	17	15	14
125	12	13	13	14	17	19	22	24	21	19	16	13	12	11
150	9.9	11	11	12	13	15	16	18	16	15	13	11	9.8	9.4
175	8.4	8.9	9.0	10	10	12	13	14	13	12	10.3	8.8	8.2	7.9
200	7.1	7.5	7.6	8.0	8.6	9.4	10	11	10	9.5	8.5	7.4	7.0	6.8
225	6.1	6.4	6.5	6.7	7.3	7.8	8.4	9.0	8.5	7.9	7.2	6.4	6.0	5.9

Table 2 (continuation)

Equivalent dose rate induced by high-energy hadrons from LAr Beam Pipe for T= 10y, t=100d

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	123	985											972	194
5	118	1068					2418	1795	1363	1202	1186	760	959	177
7	113	446	445			608	1486	1134	866	766	746	507	430	162
11.5	104	249	279	391	381	432	949	750	575	509	488	341	246	138
15	87	150	170	225	258	298	578	480	371	329	308	218	150	106
20	74	111	123	159	183	230	405	351	273	242	222	158	111	86
25	64	89	97	121	145	187	306	275	215	191	172	123	89	72
50	39	46	49	56	71	92	122	124	100	89	76	56	46	41
75	28	32	33	37	46	56	70	74	62	55	46	35	31	28
100	22	25	25	28	33	39	46	49	43	38	32	26	23	22
125	18	20	20	22	25	28	33	35	32	28	24	20	18	17
150	15	16	16	17	19	22	25	27	24	22	19	16	15	14
175	13	13	14	14	16	17	19	21	19	17	15	13	12	12
200	11	11	11	12	13	14	15	17	15	14	13	11	10	10
225	9.2	9.6	9.7	10	11	12	13	13	13	12	11	9.5	9.0	8.8

Table 3

Equivalent dose rate induced by low-energy neutrons from LAr Beam Pipe for T= 100d, t=5d

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	18.8	99.3											74.1	15.4
5	18.3	108.7					581.6	269.7	111.3	99.9	93.1	52.1	80.7	14.2
7	17.8	54.7	63.7			97.3	351.8	168.3	71.4	63.4	58.4	35.9	34.1	13.0
11.5	16.8	36.5	44.7	88.7	110.4	75.7	221.7	110.9	48.5	42.5	38.5	24.9	19.1	11.1
15	15.1	25.9	30.7	49.8	68.9	57.1	132.5	71.3	32.5	28.0	24.8	16.6	11.8	8.6
20	13.5	20.7	23.8	34.7	44.9	46.0	91.1	52.5	24.7	21.0	18.2	12.4	8.9	7.1
25	12.2	17.3	19.4	26.4	33.7	38.3	67.5	41.5	20.1	16.9	14.4	9.9	7.4	6.1
50	8.0	9.6	10.1	11.8	15.1	19.1	25.2	19.3	10.7	8.6	7.0	5.1	4.2	3.8
75	5.8	6.6	6.8	7.7	9.4	11.4	13.6	11.6	7.3	5.8	4.7	3.5	3.1	2.9
100	4.5	4.9	5.1	5.6	6.5	7.6	8.7	7.8	5.4	4.4	3.5	2.8	2.5	2.3
125	3.6	3.9	4.0	4.3	4.8	5.5	6.0	5.6	4.2	3.5	2.8	2.3	2.1	2.0
150	3.0	3.1	3.2	3.4	3.7	4.1	4.4	4.3	3.3	2.8	2.4	1.9	1.8	1.7
175	2.5	2.6	2.6	2.8	3.0	3.2	3.4	3.3	2.7	2.4	2.0	1.7	1.6	1.5
200	2.1	2.2	2.2	2.3	2.4	2.6	2.7	2.7	2.3	2.0	1.7	1.5	1.4	1.3
225	1.8	1.9	1.9	1.9	2.0	2.1	2.2	2.2	1.9	1.7	1.5	1.3	1.2	1.2

Table 3 (continuation)

Equivalent dose rate induced by low-energy neutrons from LAr Beam Pipe for T= 10y, t=5d

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	40.6	197.7											99.0	20.7
5	39.5	216.0					769.5	341.1	148.6	133.3	124.0	69.7	108.2	19.0
7	38.5	116.8	145.3			170.7	466.3	213.6	95.3	84.7	77.8	48.0	45.6	17.5
11.5	36.5	81.9	104.3	231.4	291.9	132.2	294.8	141.3	64.8	56.9	51.5	33.4	25.7	14.9
15	32.9	59.5	72.3	126.6	174.8	98.7	177.4	91.4	43.4	37.4	33.1	22.3	15.9	11.6
20	29.4	47.4	55.4	85.5	107.5	79.0	123.0	67.7	33.1	28.1	24.4	16.7	12.1	9.6
25	26.4	39.2	44.6	62.6	76.6	65.3	92.0	53.8	27.0	22.6	19.3	13.3	9.9	8.2
50	16.1	19.5	20.6	24.0	28.7	31.6	35.8	25.6	14.4	11.7	9.5	6.9	5.7	5.2
75	10.8	12.2	12.7	14.0	16.4	18.4	19.9	15.8	9.8	7.9	6.4	4.8	4.2	3.9
100	7.9	8.7	8.9	9.6	10.9	12.1	12.8	10.8	7.4	6.0	4.8	3.8	3.4	3.2
125	6.1	6.5	6.7	7.1	7.8	8.5	9.0	7.9	5.8	4.8	3.9	3.1	2.9	2.7
150	4.9	5.1	5.2	5.5	6.0	6.4	6.7	6.1	4.6	3.9	3.3	2.7	2.5	2.4
175	4.0	4.2	4.2	4.4	4.7	5.0	5.1	4.8	3.8	3.3	2.8	2.4	2.2	2.1
200	3.4	3.5	3.5	3.6	3.8	4.0	4.1	3.9	3.2	2.8	2.4	2.1	1.9	1.9
225	2.9	2.9	3.0	3.0	3.2	3.3	3.4	3.2	2.7	2.4	2.1	1.8	1.7	1.7

Table 3 (continuation)

Equivalent dose rate induced by low-energy neutrons from LAr Beam Pipe for T= 100d, t=100d

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	9.1	47.2											32.5	6.8
5	8.8	51.6					253.2	116.6	48.7	43.8	40.8	22.9	35.4	6.2
7	8.6	26.4	31.3			44.9	153.2	72.8	31.3	27.8	25.6	15.7	14.9	5.7
11.5	8.1	17.9	22.1	45.1	56.4	34.9	96.6	48.0	21.2	18.6	16.9	10.9	8.4	4.9
15	7.3	12.7	15.2	25.1	34.8	26.2	57.8	30.9	14.2	12.3	10.9	7.3	5.2	3.8
20	6.5	10.2	11.7	17.4	22.3	21.1	39.8	22.8	10.8	9.2	8.0	5.4	3.9	3.1
25	5.9	8.5	9.5	13.1	16.5	17.5	29.6	18.0	8.8	7.4	6.3	4.3	3.2	2.7
50	3.8	4.6	4.8	5.6	7.1	8.7	11.1	8.4	4.7	3.8	3.1	2.2	1.8	1.7
75	2.7	3.1	3.2	3.6	4.3	5.2	6.1	5.1	3.2	2.6	2.1	1.5	1.4	1.3
100	2.1	2.3	2.3	2.6	3.0	3.4	3.9	3.4	2.4	1.9	1.6	1.2	1.1	1.0
125	1.7	1.8	1.8	1.9	2.2	2.5	2.7	2.5	1.8	1.5	1.2	1.0	0.9	0.9
150	1.3	1.4	1.5	1.5	1.7	1.8	2.0	1.9	1.5	1.2	1.0	0.9	0.8	0.8
175	1.1	1.2	1.2	1.2	1.3	1.4	1.5	1.5	1.2	1.0	0.9	0.7	0.7	0.7
200	1.0	1.0	1.0	1.0	1.1	1.2	1.2	1.2	1.0	0.9	0.8	0.7	0.6	0.6
225	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	0.8	0.8	0.7	0.6	0.5	0.5

Table 3 (continuation)

Equivalent dose rate induced by low-energy neutrons from LAr Beam Pipe for T= 10y, t=100d

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	28.8	135.1											50.2	10.6
5	28.1	147.4					385.0	162.2	75.2	67.5	62.7	35.4	55.0	9.7
7	27.4	82.6	105.9			108.4	233.8	101.9	48.2	42.9	39.4	24.4	23.2	8.9
11.5	26.1	59.3	76.8	177.9	225.5	83.6	148.3	67.8	32.8	28.8	26.1	17.0	13.1	7.6
15	23.5	43.5	53.4	96.4	133.0	62.1	89.9	44.2	22.0	19.0	16.8	11.3	8.1	6.0
20	21.0	34.6	40.8	64.3	80.0	49.4	62.9	33.0	16.8	14.3	12.4	8.5	6.2	4.9
25	18.8	28.5	32.6	46.5	55.8	40.7	47.4	26.3	13.7	11.5	9.8	6.8	5.1	4.2
50	11.1	13.5	14.3	16.6	19.2	19.2	19.2	12.8	7.4	6.0	4.9	3.5	3.0	2.7
75	7.1	8.0	8.3	9.1	10.4	11.0	11.0	8.1	5.1	4.1	3.3	2.5	2.2	2.0
100	5.0	5.5	5.6	6.0	6.7	7.1	7.2	5.7	3.8	3.1	2.5	2.0	1.8	1.7
125	3.8	4.0	4.1	4.3	4.7	5.0	5.1	4.2	3.0	2.5	2.1	1.7	1.5	1.4
150	3.0	3.1	3.2	3.3	3.5	3.7	3.8	3.3	2.5	2.1	1.7	1.4	1.3	1.3
175	2.4	2.5	2.5	2.6	2.8	2.9	2.9	2.6	2.0	1.8	1.5	1.3	1.2	1.1
200	2.0	2.1	2.1	2.1	2.2	2.3	2.3	2.1	1.7	1.5	1.3	1.1	1.0	1.0
225	1.7	1.7	1.7	1.8	1.8	1.9	1.9	1.8	1.5	1.3	1.1	1.0	0.9	0.9