

## 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 ( $Z_{min}=365$  cm,  $Z_{max}=870$  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 introduced 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  $\mu\text{Sv/h}$ . Dimensions by Z-axis are given in cm from the interaction point.

Table 1

## Material zones of the LAr beam pipe section

##	Z <sub>min</sub> , cm	Z <sub>max</sub> , cm	R <sub>min</sub> , cm	R <sub>max</sub> , cm	Mass, kg <sup>(*)</sup>	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

<sup>(\*)</sup> - calculated as product of density by volume

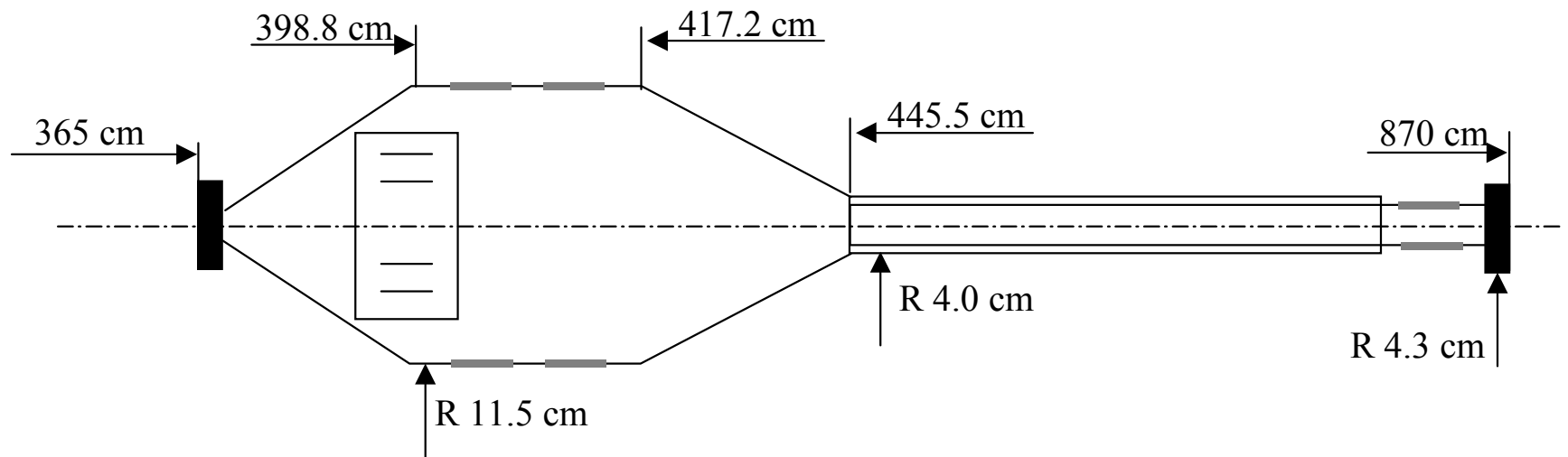


Fig. 1. Sketch of the LAr Beam pipe section.

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	242	2578											2376	371
5	231	2691					4924	3722	2859	2538	2515	1589	2289	339
7	222	1118	967			1261	3094	2394	1848	1644	1611	1087	1028	314
11.5	205	595	630	830	767	898	2005	1597	1238	1103	1065	740	570	274
15	177	345	385	489	537	622	1239	1029	803	716	677	478	338	218
20	153	248	276	351	388	480	877	756	593	529	491	349	245	179
25	134	197	217	271	308	391	667	593	469	417	382	273	195	151
50	83	101	107	125	154	198	275	272	221	196	171	125	100	87
75	61	70	73	82	101	125	159	166	139	123	105	79	67	61
100	49	54	56	62	74	88	107	114	97	87	74	58	51	47
125	40	44	45	49	57	66	78	83	73	65	56	45	40	38
150	34	36	37	40	46	52	59	64	57	51	44	36	33	32
175	29	31	32	34	37	42	47	51	46	41	36	30	28	27
200	25	27	27	29	32	35	38	41	38	34	30	26	24	23
225	22	23	24	25	27	29	32	34	32	29	26	22	21	20

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	272	2895												418
5	260	3021					5569	4194	3217	2856	2829	1787	2575	381
7	249	1256	1086			1422	3499	2698	2079	1850	1813	1223	1156	353
11.5	231	668	708	933	863	1013	2267	1800	1393	1241	1198	832	642	308
15	199	387	432	550	604	702	1401	1160	904	805	762	538	380	245
20	172	279	311	395	436	542	991	851	668	595	553	393	276	201
25	151	221	244	305	347	442	754	669	528	470	430	307	219	170
50	94	114	121	141	174	223	311	306	249	221	193	140	112	98
75	69	79	83	93	114	141	180	187	156	138	118	89	76	69
100	55	61	63	69	83	100	121	128	110	98	83	65	57	53
125	45	49	51	55	64	75	88	94	82	73	63	50	45	43
150	38	41	42	45	51	58	67	72	64	58	50	41	37	36
175	33	35	36	38	42	47	53	57	52	47	41	34	32	30
200	29	30	31	32	36	39	43	46	42	39	34	29	27	26
225	25	26	27	28	30	33	36	38	36	33	29	25	24	23

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	41	430												65
5	40	449					901	669	505	444	439	276	397	59
7	38	188	164			222	566	430	327	288	281	189	178	55
11.5	35	101	107	144	136	159	366	287	219	193	186	129	99	48
15	31	59	66	85	95	111	226	185	142	125	118	83	59	38
20	27	43	48	61	68	86	160	136	105	93	86	61	43	31
25	23	34	38	47	55	70	121	107	83	73	67	48	34	26
50	15	18	19	22	27	35	50	49	39	35	30	22	17	15
75	11	12	13	15	18	22	29	30	25	22	18	14	12	11
100	9	10	10	11	13	16	19	20	17	15	13	10	9	8
125	7	8	8	9	10	12	14	15	13	12	10	8	7	7
150	6	7	7	7	8	9	11	11	10	9	8	6	6	6
175	5	6	6	6	7	8	8	9	8	7	6	5	5	5
200	5	5	5	5	6	6	7	7	7	6	5	5	4	4
225	4	4	4	4	5	5	6	6	6	5	5	4	4	4

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	62	652											622	97
5	60	681					1350	998	757	667	661	416	599	89
7	57	284	247			336	848	642	489	432	423	285	269	82
11.5	53	152	162	216	203	240	549	428	328	290	280	194	149	72
15	46	89	99	128	142	167	339	276	213	189	178	126	89	57
20	40	64	72	92	103	129	239	203	157	139	129	92	64	47
25	35	51	57	71	82	105	182	159	124	110	101	72	51	40
50	22	27	28	33	41	53	75	73	59	52	45	33	26	23
75	16	19	19	22	27	34	43	44	37	33	28	21	18	16
100	13	14	15	16	20	24	29	30	26	23	20	15	13	12
125	11	12	12	13	15	18	21	22	19	17	15	12	11	10
150	9	10	10	11	12	14	16	17	15	14	12	10	9	8
175	8	8	8	9	10	11	13	14	12	11	10	8	7	7
200	7	7	7	8	8	9	10	11	10	9	8	7	6	6
225	6	6	6	7	7	8	9	9	8	8	7	6	6	5

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	9.4	62.66											47.72	7.75
5	9.13	66.72					324.96	149.5	61.56	55.31	51.66	28.14	50.5	7.09
7	8.89	32.47	34.35			51.97	200.97	95.04	40.05	35.68	32.98	19.88	21.47	6.57
11.5	8.46	20.67	24.65	49.15	59.6	40.48	128.61	63.17	27.34	24.1	21.96	13.95	11.65	5.75
15	7.68	14.27	17	28.08	38.66	30.69	78.07	40.8	18.32	15.89	14.19	9.38	6.91	4.61
20	6.97	11.32	13.16	19.94	25.7	24.92	54.3	30.11	13.95	11.92	10.47	7.06	5.1	3.83
25	6.34	9.5	10.8	15.31	19.46	20.93	40.63	23.81	11.33	9.58	8.28	5.65	4.14	3.3
50	4.28	5.33	5.71	6.87	8.73	10.93	15.62	11.2	6.01	4.9	4.02	2.87	2.32	2.06
75	3.18	3.69	3.87	4.42	5.49	6.8	8.58	6.91	4.1	3.31	2.67	1.98	1.69	1.55
100	2.49	2.8	2.9	3.22	3.88	4.65	5.51	4.75	3.06	2.49	2	1.53	1.35	1.26
125	2.03	2.22	2.29	2.5	2.92	3.39	3.86	3.48	2.41	1.98	1.61	1.26	1.13	1.07
150	1.69	1.82	1.87	2	2.28	2.58	2.87	2.66	1.95	1.63	1.34	1.07	0.98	0.93
175	1.43	1.52	1.55	1.65	1.84	2.04	2.23	2.11	1.61	1.37	1.14	0.93	0.86	0.82
200	1.23	1.29	1.32	1.39	1.52	1.66	1.78	1.71	1.36	1.17	0.99	0.82	0.76	0.73
225	1.07	1.12	1.13	1.18	1.28	1.37	1.46	1.41	1.16	1.01	0.87	0.73	0.68	0.66



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	20.29	122.1											63.78	10.41
5	19.74	130.25					429.78	189.02	82.16	73.8	68.81	37.63	67.7	9.52
7	19.25	67.63	77.75			91.26	266.2	120.5	53.45	47.64	43.96	26.59	28.75	8.83
11.5	18.37	45.4	56.92	128.53	158.5	70.74	170.81	80.39	36.52	32.2	29.31	18.68	15.62	7.74
15	16.73	32.37	39.76	71.82	99.33	53.22	104.25	52.21	24.48	21.25	18.97	12.58	9.28	6.22
20	15.14	25.81	30.7	49.72	62.88	42.92	72.99	38.73	18.65	15.97	14.01	9.48	6.87	5.17
25	13.72	21.5	24.9	37.13	45.63	35.84	54.99	30.75	15.17	12.84	11.1	7.6	5.58	4.46
50	8.78	11.15	12.01	14.56	17.44	18.23	21.87	14.77	8.08	6.6	5.43	3.89	3.15	2.8
75	6.12	7.13	7.48	8.48	10.01	11.09	12.34	9.28	5.54	4.49	3.62	2.7	2.31	2.13
100	4.55	5.09	5.27	5.8	6.7	7.46	8.06	6.49	4.18	3.4	2.74	2.11	1.86	1.74
125	3.56	3.88	3.99	4.3	4.87	5.37	5.71	4.83	3.31	2.72	2.21	1.74	1.57	1.48
150	2.87	3.08	3.15	3.35	3.72	4.05	4.28	3.74	2.7	2.25	1.85	1.49	1.36	1.3
175	2.38	2.52	2.57	2.71	2.95	3.18	3.33	2.99	2.25	1.9	1.59	1.3	1.2	1.15
200	2.01	2.11	2.14	2.24	2.41	2.57	2.67	2.44	1.91	1.64	1.39	1.16	1.07	1.03
225	1.72	1.79	1.82	1.89	2.01	2.12	2.2	2.04	1.64	1.42	1.22	1.04	0.97	0.93

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	4.42	31.56											22.12	3.11
5	4.3	15.59					87.51	41.11	17.53	15.63	14.45	8.71	9.41	2.88
7	4.1	10.05	12.14			18.64	56.03	27.35	11.97	10.56	9.62	6.12	5.11	2.52
11.5	3.72	6.99	8.39	14.2	19.58	14.1	34.04	17.68	8.02	6.96	6.22	4.11	3.03	2.02
15	3.37	5.55	6.49	10.01	12.84	11.43	23.71	13.06	6.11	5.23	4.59	3.1	2.24	1.68
20	3.07	4.65	5.31	7.63	9.61	9.59	17.76	10.33	4.96	4.2	3.63	2.48	1.82	1.45
25	2.04	2.55	2.74	3.3	4.14	4.98	6.87	4.88	2.63	2.15	1.76	1.26	1.02	0.9
50	1.49	1.73	1.82	2.07	2.55	3.08	3.79	3.02	1.79	1.45	1.17	0.87	0.74	0.68
75	1.16	1.3	1.35	1.49	1.78	2.1	2.44	2.08	1.34	1.09	0.88	0.67	0.59	0.56
100	0.93	1.02	1.05	1.14	1.33	1.53	1.72	1.53	1.06	0.87	0.71	0.56	0.5	0.47
125	0.77	0.83	0.85	0.91	1.03	1.16	1.28	1.17	0.86	0.71	0.59	0.47	0.43	0.41
150	0.65	0.69	0.71	0.75	0.83	0.92	0.99	0.93	0.71	0.6	0.5	0.41	0.38	0.36
175	0.56	0.59	0.6	0.63	0.68	0.74	0.79	0.75	0.6	0.51	0.44	0.36	0.34	0.32
200	0.48	0.5	0.51	0.53	0.57	0.62	0.65	0.63	0.51	0.45	0.38	0.32	0.3	0.29
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	14.43	82.51											32.33	5.3
5	14.05	88.1					214.97	89.82	41.57	37.35	34.76	19.09	34.42	4.85
7	13.71	47.29	56.51			57.96	133.37	57.46	27.06	24.12	22.22	13.5	14.61	4.5
11.5	13.1	32.56	41.72	98.87	122.68	44.78	85.82	38.5	18.49	16.32	14.84	9.49	7.94	3.95
15	11.94	23.55	29.3	54.8	75.93	33.52	52.69	25.17	12.41	10.78	9.62	6.4	4.73	3.18
20	10.81	18.81	22.59	37.58	47.2	26.9	37.14	18.77	9.46	8.11	7.12	4.83	3.51	2.65
25	9.77	15.63	18.24	27.77	33.66	22.37	28.19	14.99	7.7	6.53	5.64	3.88	2.85	2.28
50	6.09	7.81	8.44	10.27	11.93	11.18	11.61	7.37	4.12	3.38	2.78	2	1.63	1.45
75	4.1	4.79	5.03	5.68	6.5	6.69	6.71	4.72	2.85	2.31	1.87	1.4	1.2	1.1
100	2.96	3.31	3.42	3.74	4.2	4.45	4.45	3.36	2.16	1.76	1.42	1.1	0.97	0.91
125	2.26	2.45	2.52	2.7	2.98	3.17	3.19	2.54	1.73	1.42	1.16	0.91	0.82	0.78
150	1.79	1.91	1.95	2.06	2.25	2.38	2.4	1.99	1.42	1.18	0.97	0.79	0.72	0.68
175	1.46	1.54	1.56	1.64	1.76	1.85	1.87	1.6	1.19	1.01	0.84	0.69	0.64	0.61
200	1.21	1.27	1.29	1.34	1.42	1.49	1.51	1.32	1.02	0.87	0.74	0.62	0.57	0.55
225	1.03	1.07	1.08	1.12	1.18	1.23	1.24	1.11	0.88	0.76	0.65	0.55	0.52	0.5