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Doses from the LAr beam pipe

It was shown in the previous notes that activity induced in stainless steel VA will be a serious problem and that replacement of steel parts with aluminum may decrease activation by at a factor of 10, at least. Though the simulations had been done on the base of the same hadron fluxes (i.e. calculated in stainless steel pipe) and consequently may be considered as a coarse estimation only. The note reports activation dose rate fields simulated on the base of new hadron fluxes calculated with respect to proposed change of VA material.

1. Both high-energy hadrons and low-energy neutrons activation was taken into account.
2. A possible design options for the LAr beam-pipe was studied. The beam-pipe is made of aluminum (5000 series) except for Ion Pump, which is made of stainless steel (316 L). Design of the beam pipe section was taken from the LHCVC1A_0001 drawing and the thickness of the both inner and outer pipe was taken as 1.5 mm (bellows thickness was increased relatively, too). Ion Pump is represented as an 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.
3. Geometry for activation calculations is given in the table 1. A sketch of the beam pipe is given on fig. 1.
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 for “aluminum LAr beampipe” are given in tables 2 (hadron activation) and 3 (neutron activation). All doses are in μSv/h. Dimensions 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	Comment	Material
1	365	366.4	2.9	4.30	Flange	Aluminum
2	366.4	387.6	2.9	3.05	Tube	Aluminum
3	373.2	373.28	3.05	8.30	Pump wall	SS
4	373.28	378.8	8.23	8.30	Pump wall	SS
5	378.8	378.88	3.05	8.30	Pump wall	SS
6	374.8	378	4.5	4.70	Pump electrode	SS
7	374.8	378	6.8	7.00	Pump electrode	SS
8	387.6	395.8	2.9	3.16	Bellows	Aluminum
9	395.8	415.1	2.9	3.05	Tube	Aluminum
10	415.1	423.3	2.9	3.16	Bellows	Aluminum
11	423.3	855	2.9	3.05	Tube	Aluminum
12	855	863.2	2.9	3.16	Bellows	Aluminum
13	863.2	870	2.9	3.05	Tube	Aluminum
14	868.6	870	3.05	4.30	Flunge	Aluminum
15	428.9	849	3.92	4.07	Tube	Aluminum

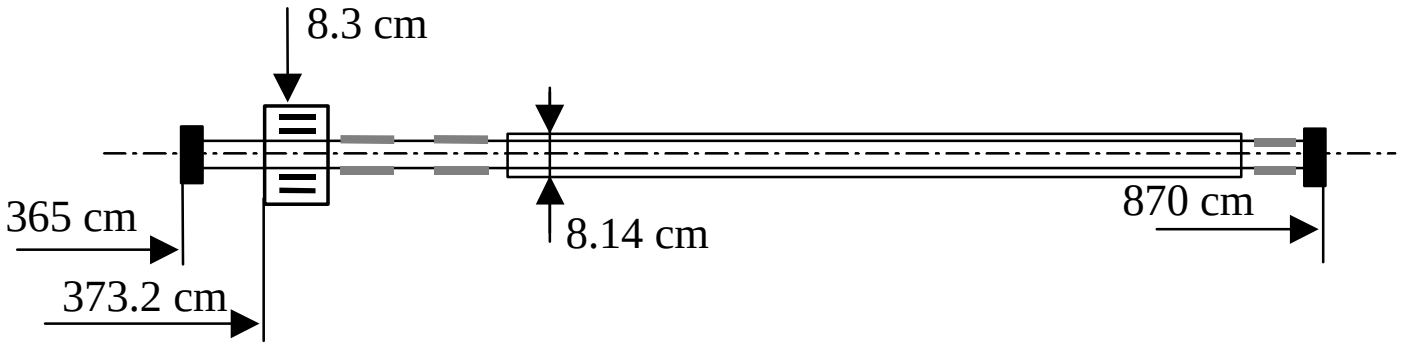

Fig. 1 Sketch of the LAr Beam pipe section.

Table 2

Equivalent dose rate induced by high-energy hadrons from aluminum 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	49.3	253.6											43.5	7.7
5	47.7	234.3	465.3	307.7	58.3	67.4	126.4	88.5	67.1	61.2	57.4	33.5	42.3	7.1
7	46.3	190.7	395.8	265.4	45.7	45.3	78.4	55.9	42.6	38.7	36.1	23.8	20.2	6.6
10	43.6	151.3	272.9	202.5	37.1	32.5	51.1	37.3	28.6	25.8	23.8	16.5	11.9	5.9
15	38.1	100.7	141.4	122.5	30.1	23.2	32.3	24.3	18.7	16.8	15.2	10.8	7.4	4.8
20	32.4	68.0	83.5	77.7	25.7	18.6	23.4	18.0	13.9	12.4	11.1	7.9	5.5	4.0
25	27.2	48.0	54.9	53.0	22.3	15.7	18.2	14.3	11.0	9.8	8.7	6.2	4.4	3.5
50	12.0	14.6	15.2	15.4	11.8	9.0	8.5	6.9	5.4	4.7	4.1	2.9	2.4	2.1
75	6.5	7.3	7.4	7.6	7.0	6.0	5.4	4.5	3.5	3.1	2.6	1.9	1.7	1.5
100	4.2	4.5	4.6	4.7	4.6	4.2	3.9	3.2	2.5	2.2	1.9	1.5	1.3	1.2
125	3.0	3.1	3.2	3.2	3.3	3.1	2.9	2.5	2.0	1.7	1.5	1.2	1.1	1.0
150	2.2	2.3	2.4	2.4	2.5	2.4	2.3	2.0	1.6	1.4	1.2	1.0	0.9	0.9
175	1.8	1.8	1.8	1.9	1.9	1.9	1.9	1.6	1.3	1.2	1.0	0.8	0.8	0.7
200	1.4	1.5	1.5	1.5	1.6	1.6	1.5	1.4	1.1	1.0	0.9	0.7	0.7	0.7
225	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.2	1.0	0.9	0.8	0.7	0.6	0.6

Table 2 (continuation)

Equivalent dose rate induced by high-energy hadrons from aluminum 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	68.8	415.4											161.8	28.2
5	66.5	391.3	601.6	442.8	164.1	236.2	467.6	326.0	248.9	227.4	213.6	124.6	157.5	26.0
7	64.4	271.7	498.6	363.9	117.7	154.0	287.7	205.4	157.6	143.7	134.0	88.4	74.9	24.3
10	60.5	202.1	341.8	271.0	87.6	106.2	185.8	136.6	105.4	95.6	88.3	61.2	44.0	21.5
15	52.9	132.5	180.7	164.8	64.8	72.0	115.1	88.3	68.5	61.9	56.3	39.8	27.2	17.5
20	45.2	90.6	109.6	107.0	52.6	55.2	82.0	65.1	50.8	45.6	41.0	29.1	20.1	14.6
25	38.4	65.3	74.3	75.0	44.3	44.9	62.8	51.4	40.2	36.0	32.0	22.7	16.1	12.5
50	18.5	22.5	23.5	24.9	23.0	23.0	26.9	24.1	19.2	17.0	14.6	10.6	8.4	7.4
75	11.1	12.5	12.8	13.7	14.2	14.7	16.1	15.0	12.2	10.7	9.1	6.8	5.8	5.3
100	7.7	8.4	8.6	9.1	9.8	10.3	11.0	10.5	8.7	7.6	6.5	5.0	4.4	4.1
125	5.8	6.2	6.3	6.7	7.2	7.7	8.1	7.8	6.6	5.8	5.0	4.0	3.6	3.4
150	4.6	4.9	5.0	5.2	5.6	6.0	6.3	6.1	5.2	4.6	4.0	3.3	3.0	2.8
175	3.8	4.0	4.0	4.2	4.5	4.8	5.0	4.9	4.2	3.8	3.3	2.8	2.5	2.4
200	3.2	3.3	3.4	3.5	3.7	3.9	4.1	4.0	3.5	3.2	2.8	2.4	2.2	2.1
225	2.7	2.8	2.9	3.0	3.1	3.3	3.4	3.4	3.0	2.7	2.4	2.1	1.9	1.9

Table 2 (continuation)

Equivalent dose rate induced by high-energy hadrons from aluminum 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	10.9	69.3											31.4	5.5
5	10.5	65.7	92.5	70.8	30.7	45.5	90.3	62.9	48.3	44.2	41.5	24.2	30.6	5.0
7	10.2	43.4	76.0	57.2	21.7	29.6	55.5	39.6	30.6	27.9	26.0	17.2	14.5	4.7
10	9.6	31.5	52.0	42.3	15.9	20.3	35.8	26.3	20.4	18.6	17.2	11.9	8.6	4.2
15	8.4	20.5	27.7	25.8	11.6	13.7	22.2	17.0	13.3	12.0	10.9	7.7	5.3	3.4
20	7.2	14.1	17.0	16.9	9.3	10.4	15.8	12.5	9.8	8.9	8.0	5.6	3.9	2.8
25	6.1	10.3	11.6	11.9	7.8	8.4	12.1	9.9	7.8	7.0	6.2	4.4	3.1	2.4
50	3.0	3.7	3.9	4.1	4.0	4.2	5.1	4.6	3.7	3.3	2.8	2.0	1.6	1.4
75	1.9	2.1	2.2	2.3	2.5	2.7	3.0	2.9	2.3	2.1	1.8	1.3	1.1	1.0
100	1.3	1.5	1.5	1.6	1.7	1.9	2.1	2.0	1.7	1.5	1.2	1.0	0.9	0.8
125	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.5	1.3	1.1	1.0	0.8	0.7	0.6
150	0.8	0.9	0.9	0.9	1.0	1.1	1.2	1.2	1.0	0.9	0.8	0.6	0.6	0.5
175	0.7	0.7	0.7	0.8	0.8	0.9	0.9	0.9	0.8	0.7	0.6	0.5	0.5	0.5
200	0.6	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.7	0.6	0.5	0.5	0.4	0.4
225	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.4	0.4	0.4

Table 2 (continuation)

Equivalent dose rate induced by high-energy hadrons from aluminum 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	28.1	217.3											144.2	25.0
5	27.0	209.5	208.9	191.0	131.0	206.1	414.0	288.7	221.8	202.7	190.4	110.9	140.3	23.0
7	26.1	115.3	162.3	143.6	89.8	132.9	254.2	181.8	140.3	128.0	119.4	78.6	66.6	21.5
10	24.5	75.7	109.6	101.8	63.4	90.3	163.6	120.7	93.7	85.1	78.6	54.4	39.1	19.0
15	21.4	47.9	61.0	62.7	44.1	59.9	100.8	77.9	60.8	55.0	50.1	35.4	24.2	15.5
20	18.5	33.7	39.5	42.6	34.4	45.1	71.4	57.3	45.0	40.5	36.4	25.8	17.8	12.9
25	16.0	25.4	28.5	31.4	28.3	36.1	54.4	45.1	35.6	31.9	28.4	20.1	14.3	11.0
50	8.9	10.8	11.4	12.8	14.5	17.5	22.6	21.0	16.9	15.0	12.8	9.3	7.4	6.5
75	6.1	6.9	7.2	7.9	9.3	10.9	13.2	12.9	10.6	9.4	7.9	6.0	5.1	4.6
100	4.6	5.1	5.2	5.7	6.6	7.6	8.8	8.9	7.5	6.6	5.6	4.4	3.8	3.6
125	3.7	4.0	4.1	4.4	5.0	5.7	6.4	6.6	5.6	5.0	4.3	3.4	3.1	2.9
150	3.0	3.2	3.3	3.5	4.0	4.4	4.9	5.1	4.4	4.0	3.4	2.8	2.5	2.4
175	2.6	2.7	2.8	2.9	3.2	3.5	3.9	4.0	3.6	3.2	2.8	2.3	2.2	2.1
200	2.2	2.3	2.4	2.5	2.7	2.9	3.2	3.3	3.0	2.7	2.4	2.0	1.9	1.8
225	1.9	2.0	2.0	2.1	2.3	2.5	2.6	2.7	2.5	2.3	2.0	1.7	1.6	1.6

Table 3

Equivalent dose rate induced by low-energy neutrons from aluminum 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	1.27	5.73											0.07	0.02
5	1.23	5.27	11.96	7.56	0.66	0.48	1.52	0.54	0.17	0.14	0.12	0.06	0.07	0.02
7	1.19	4.79	10.62	6.78	0.63	0.38	0.94	0.35	0.11	0.09	0.08	0.04	0.04	0.02
10	1.13	3.98	7.52	5.32	0.61	0.32	0.61	0.24	0.08	0.06	0.05	0.03	0.02	0.01
15	0.99	2.69	3.87	3.24	0.56	0.27	0.39	0.16	0.06	0.05	0.04	0.02	0.02	0.01
20	0.84	1.81	2.25	2.03	0.51	0.24	0.29	0.12	0.05	0.04	0.03	0.02	0.01	0.01
25	0.70	1.26	1.45	1.37	0.46	0.22	0.23	0.10	0.04	0.03	0.02	0.02	0.01	0.01
50	0.30	0.36	0.37	0.37	0.25	0.15	0.11	0.06	0.03	0.02	0.02	0.01	0.01	0.01
75	0.15	0.17	0.17	0.17	0.14	0.11	0.08	0.04	0.02	0.02	0.01	0.01	0.01	0.01
100	0.09	0.10	0.10	0.10	0.09	0.08	0.06	0.03	0.02	0.01	0.01	0.01	0.01	0.01
125	0.06	0.07	0.07	0.07	0.06	0.06	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01
150	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01
175	0.03	0.04	0.04	0.04	0.04	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01
200	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
225	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table 3 (continuation)

Equivalent dose rate induced by low-energy neutrons from aluminum 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	1.95	8.78											0.10	0.03
5	1.89	8.10	18.32	11.60	1.01	0.72	2.19	0.77	0.24	0.20	0.17	0.09	0.10	0.02
7	1.84	7.37	16.34	10.42	0.97	0.57	1.35	0.50	0.16	0.13	0.11	0.06	0.05	0.02
10	1.73	6.12	11.63	8.20	0.93	0.48	0.89	0.34	0.12	0.09	0.08	0.05	0.03	0.02
15	1.52	4.15	5.97	4.99	0.86	0.41	0.57	0.23	0.08	0.07	0.05	0.04	0.03	0.02
20	1.29	2.79	3.47	3.14	0.78	0.37	0.42	0.18	0.07	0.05	0.04	0.03	0.02	0.02
25	1.08	1.95	2.24	2.11	0.70	0.34	0.33	0.15	0.06	0.05	0.04	0.02	0.02	0.02
50	0.46	0.56	0.58	0.57	0.38	0.23	0.17	0.08	0.04	0.03	0.02	0.02	0.01	0.01
75	0.24	0.26	0.26	0.26	0.22	0.16	0.11	0.06	0.03	0.02	0.02	0.01	0.01	0.01
100	0.14	0.15	0.15	0.15	0.14	0.11	0.09	0.05	0.03	0.02	0.02	0.01	0.01	0.01
125	0.10	0.10	0.10	0.10	0.10	0.08	0.07	0.04	0.02	0.02	0.01	0.01	0.01	0.01
150	0.07	0.07	0.07	0.07	0.07	0.06	0.05	0.03	0.02	0.02	0.01	0.01	0.01	0.01
175	0.05	0.05	0.05	0.06	0.05	0.05	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.01
200	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01
225	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01

Table 3 (continuation)

Equivalent dose rate induced by low-energy neutrons from aluminum 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	1.67	7.44											0.06	0.02
5	1.62	6.89	15.46	9.79	0.83	0.4	0.63	0.27	0.12	0.1	0.1	0.05	0.06	0.02
7	1.57	6.3	13.99	8.86	0.8	0.34	0.41	0.18	0.08	0.07	0.06	0.04	0.03	0.01
10	1.48	5.26	10.07	7.03	0.77	0.3	0.29	0.12	0.06	0.05	0.04	0.03	0.02	0.01
15	1.3	3.57	5.17	4.29	0.71	0.27	0.21	0.09	0.04	0.04	0.03	0.02	0.02	0.01
20	1.1	2.4	2.99	2.69	0.65	0.25	0.17	0.07	0.04	0.03	0.03	0.02	0.01	0.01
25	0.92	1.67	1.93	1.81	0.58	0.23	0.14	0.06	0.03	0.03	0.02	0.02	0.01	0.01
50	0.39	0.47	0.49	0.48	0.31	0.17	0.09	0.04	0.02	0.02	0.01	0.01	0.01	0.01
75	0.2	0.22	0.22	0.22	0.18	0.12	0.07	0.03	0.02	0.01	0.01	0.01	0.01	0.01
100	0.12	0.12	0.13	0.13	0.11	0.09	0.06	0.03	0.02	0.01	0.01	0.01	0.01	0.01
125	0.08	0.08	0.08	0.08	0.08	0.06	0.05	0.02	0.01	0.01	0.01	0.01	0.01	0.01
150	0.06	0.06	0.06	0.06	0.06	0.05	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01
175	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01
200	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01
225	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01

Table 3 (continuation)

Equivalent dose rate induced by low-energy neutrons from aluminum 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	1.13	5.06											0.05	0.01
5	1.09	4.67	10.54	6.68	0.58	0.39	1.06	0.36	0.12	0.10	0.08	0.04	0.05	0.01
7	1.06	4.26	9.44	6.01	0.56	0.31	0.66	0.23	0.08	0.07	0.06	0.03	0.03	0.01
10	1.00	3.54	6.74	4.74	0.53	0.26	0.43	0.16	0.06	0.05	0.04	0.02	0.02	0.01
15	0.88	2.40	3.46	2.89	0.49	0.22	0.28	0.11	0.04	0.03	0.03	0.02	0.01	0.01
20	0.75	1.61	2.01	1.82	0.45	0.20	0.21	0.09	0.03	0.03	0.02	0.01	0.01	0.01
25	0.62	1.13	1.30	1.22	0.40	0.19	0.17	0.07	0.03	0.02	0.02	0.01	0.01	0.01
50	0.26	0.32	0.33	0.33	0.22	0.13	0.09	0.04	0.02	0.02	0.01	0.01	0.01	0.01
75	0.14	0.15	0.15	0.15	0.13	0.09	0.06	0.03	0.02	0.01	0.01	0.01	0.01	0.01
100	0.08	0.09	0.09	0.09	0.08	0.06	0.05	0.03	0.01	0.01	0.01	0.01	0.01	0.01
125	0.06	0.06	0.06	0.06	0.05	0.05	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01
150	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01
175	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
200	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00
225	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00