Rev.04 of Apr.2, 2002

Doses from the LAr beam pipe

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. Both high-energy hadrons and low-energy neutrons activation was taken into account.
2. Two design options were studied here: (1) the beam-pipe is made of aluminum (5000 series) except for Ion Pump, which is made of steel in both options and (2) the LAr beam-pipe is made of stainless steel (316 L).
3. Design of the beam pipe section was taken from the LHCVC1A_0001 drawing. 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, 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.
5. 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%.
6. Results for “aluminum LAr beampipe” are given in tables 2 (hadron activation) and 3 (neutron activation). Results for “steel LAr beampipe” are given in tables 4 (hadron activation) and 5 (neutron activation). All values 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	Mass, kg(*	Comment	Material	
							Option 1	Option 2
1	365	366.4	2.9	4.3	0.346	Flange	Aluminum	SS
2	366.4	387.6	2.9	2.98	0.063	Tube	Aluminum	SS
3	373.2	373.28	2.98	8.3	0.075	Pump wall	SS	SS
4	373.28	378.8	8.23	8.3	0.206	Pump wall	SS	SS
5	378.8	378.88	2.98	8.3	0.262	Pump wall	SS	SS
6	374.8	378	4.5	4.7	0.317	Pump electrode	SS	SS
7	374.8	378	6.8	7	0.224	Pump electrode	SS	SS
8	387.6	395.8	2.9	3.04	0.472	Bellows	Aluminum	SS
9	395.8	415.1	2.9	2.98	0.045	Tube	Aluminum	SS
10	415.1	423.3	2.9	3.04	0.472	Bellows	Aluminum	SS
11	423.3	855	2.9	2.98	0.045	Tube	Aluminum	SS
12	855	863.2	2.9	3.04	0.317	Bellows	Aluminum	SS
13	863.2	870	2.9	2.98	0.262	Tube	Aluminum	SS
14	868.6	870	2.98	4.3	0.206	Flunge	Aluminum	SS
15	428.9	849	3.92	4	0.075	Tube	Aluminum	SS

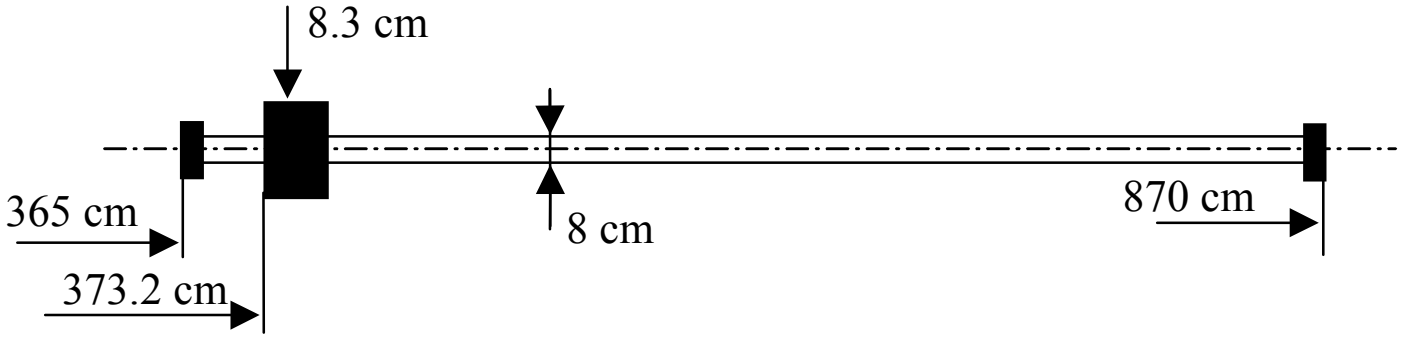

Fig. 1 Sketch of the LAr Beam pipe section.

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	143.2	680.7											75.5	15.4
5	138.8	646.0	1304.2	849.2	112.4	114.0	168.0	128.2	101.8	92.0	90.7	58.7	75.6	14.1
7	134.7	543.3	1125.1	744.9	96.1	79.0	106.6	82.2	65.2	59.1	57.5	39.5	33.9	12.9
10	126.2	424.1	723.6	547.2	84.0	58.2	70.8	55.1	43.7	39.5	37.8	26.7	19.5	11.1
15	108.2	259.0	331.7	297.6	71.9	43.2	45.9	36.0	28.5	25.7	24.0	17.2	12.0	8.6
20	88.9	162.6	185.4	176.7	62.4	35.7	34.2	26.8	21.2	19.1	17.5	12.5	8.9	7.0
25	71.6	109.4	118.6	116.0	54.0	30.9	27.4	21.4	16.9	15.1	13.7	9.8	7.2	5.9
50	26.8	30.3	30.9	31.3	25.8	18.4	14.1	10.6	8.3	7.3	6.3	4.7	3.9	3.5
75	13.5	14.4	14.6	14.8	14.0	11.9	9.4	7.0	5.4	4.7	4.0	3.1	2.7	2.5
100	8.2	8.6	8.7	8.8	8.7	8.1	6.8	5.1	4.0	3.5	2.9	2.3	2.1	2.0
125	5.6	5.8	5.8	5.9	6.0	5.7	5.1	4.0	3.1	2.7	2.3	1.9	1.7	1.6
150	4.1	4.2	4.2	4.3	4.3	4.3	4.0	3.2	2.5	2.2	1.9	1.6	1.5	1.4
175	3.1	3.2	3.2	3.3	3.3	3.3	3.1	2.6	2.1	1.8	1.6	1.4	1.3	1.2
200	2.5	2.5	2.5	2.6	2.6	2.6	2.5	2.2	1.8	1.6	1.4	1.2	1.1	1.1
225	2.0	2.0	2.1	2.1	2.1	2.1	2.1	1.8	1.5	1.4	1.2	1.1	1.0	1.0

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	189.1	1014.1											279.0	56.0
5	182.8	979.3	1637.1	1105.5	258.9	379.3	612.4	469.8	375.9	341.4	336.8	217.1	279.1	51.2
7	176.9	718.5	1372.2	935.2	200.5	249.1	382.5	299.2	240.1	218.4	212.9	145.6	124.7	47.0
10	165.1	535.1	877.4	679.7	160.4	172.1	248.5	199.0	159.9	145.5	139.6	98.1	71.3	40.1
15	140.8	324.5	409.6	375.5	126.6	117.3	155.6	128.4	103.5	94.0	88.2	62.8	43.6	30.8
20	115.8	206.3	234.1	228.4	105.4	90.6	111.9	94.5	76.4	69.2	63.8	45.6	32.2	24.9
25	94.0	141.3	153.2	153.6	89.4	74.3	86.6	74.5	60.3	54.6	49.5	35.4	25.9	21.0
50	38.0	43.3	44.5	46.4	43.2	38.8	38.7	34.8	28.5	25.5	22.0	16.2	13.4	12.0
75	20.8	22.5	23.0	24.1	24.8	24.3	23.7	21.6	17.9	15.9	13.5	10.4	9.1	8.4
100	13.6	14.4	14.7	15.3	16.2	16.5	16.3	15.0	12.6	11.2	9.5	7.6	6.8	6.4
125	9.8	10.3	10.4	10.8	11.5	11.9	12.0	11.1	9.5	8.4	7.3	6.0	5.4	5.2
150	7.5	7.8	7.9	8.2	8.6	9.0	9.1	8.6	7.4	6.7	5.8	4.9	4.5	4.3
175	5.9	6.1	6.2	6.4	6.7	7.0	7.2	6.9	6.0	5.4	4.8	4.1	3.8	3.7
200	4.8	5.0	5.0	5.2	5.4	5.6	5.8	5.6	4.9	4.5	4.0	3.5	3.3	3.2
225	4.0	4.1	4.2	4.3	4.5	4.6	4.7	4.6	4.1	3.8	3.4	3.0	2.9	2.8

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	30.4	168.6											54.1	10.8
5	29.4	163.6	258.7	176.8	47.4	72.7	118.1	90.6	72.4	65.8	64.9	42.0	54.2	9.9
7	28.4	115.5	215.0	147.9	36.1	47.5	73.7	57.7	46.3	42.1	41.0	28.1	24.2	9.1
10	26.5	84.8	137.3	107.2	28.4	32.5	47.8	38.3	30.8	28.0	26.9	18.9	13.8	7.7
15	22.5	51.3	64.5	59.5	22.0	21.9	29.8	24.7	19.9	18.1	17.0	12.1	8.4	6.0
20	18.6	32.8	37.1	36.5	18.1	16.8	21.4	18.2	14.7	13.3	12.3	8.8	6.2	4.8
25	15.1	22.6	24.5	24.7	15.3	13.7	16.5	14.3	11.6	10.5	9.5	6.8	5.0	4.0
50	6.3	7.1	7.4	7.7	7.4	7.0	7.2	6.6	5.5	4.9	4.2	3.1	2.6	2.3
75	3.5	3.8	3.9	4.1	4.3	4.3	4.4	4.1	3.4	3.0	2.6	2.0	1.7	1.6
100	2.3	2.5	2.5	2.7	2.8	3.0	3.0	2.8	2.4	2.1	1.8	1.5	1.3	1.2
125	1.7	1.8	1.8	1.9	2.0	2.1	2.2	2.1	1.8	1.6	1.4	1.1	1.0	1.0
150	1.3	1.4	1.4	1.4	1.5	1.6	1.7	1.6	1.4	1.3	1.1	0.9	0.9	0.8
175	1.0	1.1	1.1	1.1	1.2	1.3	1.3	1.3	1.1	1.0	0.9	0.8	0.7	0.7
200	0.9	0.9	0.9	0.9	1.0	1.0	1.1	1.0	0.9	0.8	0.8	0.7	0.6	0.6
225	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.8	0.7	0.6	0.6	0.5	0.5

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	69.9	466.7											248.1	49.6
5	67.1	462.7	536.5	396.0	185.3	324.7	539.7	415.6	332.3	301.9	297.9	192.5	248.5	45.3
7	64.6	266.3	416.1	307.0	133.8	208.9	335.4	264.3	212.0	193.0	188.2	129.0	110.8	41.5
10	59.7	177.8	261.8	217.0	99.4	140.4	216.4	175.2	141.0	128.4	123.3	86.7	63.1	35.3
15	50.4	105.9	128.8	124.9	72.4	92.0	133.8	112.6	91.0	82.8	77.8	55.4	38.4	27.1
20	41.7	69.6	78.0	80.5	57.6	68.5	95.0	82.5	67.0	60.8	56.1	40.1	28.3	21.9
25	34.4	49.8	53.9	57.2	47.6	54.6	72.5	64.8	52.8	47.9	43.5	31.1	22.7	18.4
50	16.2	18.7	19.4	21.2	23.4	26.0	30.5	29.5	24.6	22.1	19.1	14.1	11.6	10.4
75	10.1	11.2	11.5	12.5	14.2	15.9	17.8	17.9	15.3	13.6	11.6	8.9	7.8	7.2
100	7.2	7.8	8.0	8.6	9.7	10.8	11.9	12.2	10.6	9.5	8.1	6.5	5.8	5.4
125	5.6	5.9	6.1	6.4	7.2	7.9	8.6	8.9	7.8	7.0	6.1	5.0	4.6	4.3
150	4.4	4.7	4.8	5.0	5.5	6.0	6.5	6.7	6.1	5.5	4.8	4.0	3.7	3.6
175	3.6	3.8	3.9	4.1	4.4	4.7	5.1	5.3	4.8	4.4	3.9	3.3	3.1	3.0
200	3.0	3.2	3.2	3.3	3.6	3.8	4.1	4.2	3.9	3.6	3.2	2.8	2.7	2.6
225	2.6	2.7	2.7	2.8	3.0	3.2	3.4	3.5	3.2	3.0	2.7	2.4	2.3	2.2

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	6.52	28.01											0.25	0.07
5	6.33	26.7	57.78	37.57	3.18	1.34	1.93	0.86	0.39	0.34	0.32	0.18	0.27	0.06
7	6.16	24.51	53.12	34.28	3.09	1.18	1.29	0.58	0.27	0.23	0.21	0.13	0.13	0.06
10	5.79	19.88	35.43	25.91	2.97	1.08	0.93	0.41	0.2	0.17	0.15	0.1	0.08	0.06
15	4.99	12.27	15.97	14.08	2.74	0.99	0.68	0.3	0.15	0.12	0.11	0.08	0.06	0.05
20	4.1	7.65	8.78	8.25	2.47	0.93	0.56	0.25	0.12	0.1	0.09	0.06	0.05	0.04
25	3.3	5.1	5.54	5.34	2.17	0.87	0.49	0.22	0.11	0.09	0.07	0.05	0.04	0.04
50	1.2	1.34	1.37	1.36	1.04	0.62	0.33	0.15	0.08	0.06	0.05	0.04	0.03	0.03
75	0.58	0.61	0.62	0.62	0.55	0.41	0.26	0.12	0.07	0.05	0.04	0.03	0.03	0.03
100	0.34	0.35	0.35	0.35	0.33	0.28	0.2	0.1	0.06	0.05	0.04	0.03	0.03	0.03
125	0.23	0.23	0.23	0.23	0.22	0.2	0.16	0.09	0.05	0.04	0.04	0.03	0.03	0.03
150	0.16	0.16	0.16	0.16	0.16	0.15	0.12	0.08	0.05	0.04	0.03	0.03	0.03	0.02
175	0.12	0.12	0.12	0.12	0.12	0.11	0.1	0.07	0.05	0.04	0.03	0.03	0.02	0.02
200	0.1	0.1	0.1	0.1	0.09	0.09	0.08	0.06	0.04	0.03	0.03	0.02	0.02	0.02
225	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.05	0.04	0.03	0.03	0.02	0.02	0.02

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	17.16	72.8											0.39	0.13
5	16.68	69.66	149.94	97.9	8.2	2.98	3.15	1.35	0.62	0.54	0.5	0.3	0.42	0.12
7	16.22	64.43	140.13	90.03	8.02	2.74	2.23	0.94	0.45	0.38	0.34	0.22	0.21	0.11
10	15.27	52.56	94.47	68.58	7.74	2.58	1.71	0.71	0.34	0.29	0.25	0.18	0.14	0.11
15	13.16	32.52	42.45	37.32	7.16	2.42	1.34	0.55	0.27	0.22	0.19	0.14	0.11	0.1
20	10.83	20.26	23.26	21.84	6.45	2.3	1.17	0.47	0.24	0.19	0.16	0.12	0.1	0.09
25	8.7	13.48	14.65	14.12	5.69	2.19	1.06	0.43	0.22	0.17	0.14	0.11	0.09	0.08
50	3.15	3.53	3.6	3.57	2.71	1.58	0.8	0.33	0.17	0.13	0.11	0.08	0.08	0.07
75	1.52	1.6	1.61	1.61	1.42	1.06	0.64	0.28	0.15	0.12	0.1	0.08	0.07	0.07
100	0.89	0.91	0.92	0.92	0.86	0.72	0.5	0.25	0.14	0.11	0.09	0.07	0.07	0.06
125	0.59	0.6	0.6	0.6	0.57	0.51	0.4	0.22	0.13	0.1	0.08	0.07	0.06	0.06
150	0.42	0.42	0.42	0.42	0.41	0.38	0.31	0.19	0.12	0.1	0.08	0.07	0.06	0.06
175	0.31	0.32	0.32	0.32	0.31	0.29	0.25	0.17	0.11	0.09	0.08	0.06	0.06	0.06
200	0.25	0.25	0.25	0.25	0.24	0.23	0.21	0.15	0.1	0.08	0.07	0.06	0.06	0.05
225	0.2	0.2	0.2	0.2	0.2	0.19	0.17	0.13	0.09	0.08	0.07	0.06	0.05	0.05

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	3.32	14.23											0.09	0.03
5	3.23	13.58	29.37	19.11	1.61	0.63	0.71	0.3	0.14	0.12	0.12	0.07	0.1	0.03
7	3.14	12.5	27.12	17.48	1.57	0.56	0.49	0.21	0.1	0.09	0.08	0.05	0.05	0.02
10	2.96	10.16	18.14	13.24	1.51	0.52	0.37	0.15	0.08	0.06	0.06	0.04	0.03	0.02
15	2.55	6.27	8.17	7.2	1.39	0.48	0.28	0.12	0.06	0.05	0.04	0.03	0.02	0.02
20	2.09	3.91	4.49	4.22	1.25	0.46	0.24	0.1	0.05	0.04	0.03	0.03	0.02	0.02
25	1.68	2.6	2.83	2.73	1.1	0.43	0.22	0.09	0.05	0.04	0.03	0.02	0.02	0.02
50	0.61	0.68	0.7	0.69	0.53	0.31	0.16	0.07	0.04	0.03	0.02	0.02	0.02	0.01
75	0.29	0.31	0.31	0.31	0.28	0.21	0.13	0.06	0.03	0.02	0.02	0.02	0.01	0.01
100	0.17	0.18	0.18	0.18	0.17	0.14	0.1	0.05	0.03	0.02	0.02	0.01	0.01	0.01
125	0.11	0.12	0.12	0.12	0.11	0.1	0.08	0.04	0.03	0.02	0.02	0.01	0.01	0.01
150	0.08	0.08	0.08	0.08	0.08	0.07	0.06	0.04	0.02	0.02	0.02	0.01	0.01	0.01
175	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.03	0.02	0.02	0.01	0.01	0.01	0.01
200	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.01
225	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.02	0.02	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	13.23	55.88											0.21	0.08
5	12.86	53.54	115.04	75.23	6.27	2.12	1.75	0.71	0.34	0.29	0.27	0.16	0.22	0.07
7	12.51	49.66	108.14	69.37	6.15	1.99	1.31	0.52	0.25	0.21	0.19	0.13	0.12	0.07
10	11.78	40.59	73.19	52.99	5.94	1.9	1.06	0.41	0.2	0.17	0.15	0.1	0.09	0.07
15	10.15	25.13	32.85	28.85	5.5	1.81	0.88	0.34	0.17	0.14	0.11	0.09	0.07	0.06
20	8.36	15.65	17.98	16.87	4.96	1.73	0.79	0.3	0.15	0.12	0.1	0.08	0.06	0.06
25	6.72	10.41	11.31	10.9	4.37	1.65	0.74	0.28	0.14	0.11	0.09	0.07	0.06	0.06
50	2.42	2.72	2.77	2.75	2.08	1.2	0.59	0.23	0.12	0.09	0.07	0.06	0.05	0.05
75	1.17	1.23	1.24	1.23	1.09	0.81	0.48	0.2	0.11	0.09	0.07	0.06	0.05	0.05
100	0.68	0.7	0.7	0.7	0.66	0.55	0.38	0.18	0.1	0.08	0.06	0.05	0.05	0.05
125	0.45	0.46	0.46	0.46	0.44	0.39	0.3	0.16	0.1	0.08	0.06	0.05	0.05	0.05
150	0.32	0.32	0.32	0.32	0.31	0.29	0.24	0.14	0.09	0.07	0.06	0.05	0.05	0.04
175	0.24	0.24	0.24	0.24	0.24	0.22	0.19	0.13	0.08	0.07	0.06	0.05	0.04	0.04
200	0.19	0.19	0.19	0.19	0.19	0.18	0.16	0.11	0.08	0.06	0.05	0.04	0.04	0.04
225	0.15	0.15	0.15	0.15	0.15	0.14	0.13	0.1	0.07	0.06	0.05	0.04	0.04	0.04

Table 4

Equivalent dose rate induced by high-energy hadrons from steel 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	666	5228											3664	736
5	637	5268	4464	3749	2559	4746	8778	6649	5110	4538	4483	2878	3669	673
7	610	2527	3115	2616	1811	3058	5436	4225	3262	2903	2831	1930	1639	617
10	559	1506	1917	1775	1314	2057	3491	2799	2172	1934	1855	1298	937	526
15	469	883	1022	1073	930	1345	2142	1795	1403	1249	1171	831	573	405
20	390	606	670	739	727	999	1510	1313	1034	920	846	602	424	327
25	328	457	494	556	596	792	1146	1029	815	725	655	467	340	275
50	178	208	218	246	300	371	468	465	380	337	289	212	174	156
75	122	137	142	158	189	226	268	278	235	208	176	135	117	108
100	93	102	105	114	133	154	177	188	163	144	123	98	87	82
125	74	80	82	87	99	112	127	135	120	107	92	76	69	66
150	60	64	66	70	77	86	96	102	92	83	73	61	56	54
175	50	53	54	57	62	68	75	79	73	67	59	50	47	45
200	43	45	45	47	51	55	60	64	59	54	49	43	40	39
225	36	38	38	40	43	46	49	52	49	45	41	36	35	34

Table 4 (continuation)

Equivalent dose rate induced by high-energy hadrons from steel 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	748	5870											4123	828
5	715	5915	5012	4207	2881	5351	9927	7493	5749	5106	5043	3237	4127	757
7	685	2838	3499	2937	2038	3447	6147	4761	3670	3266	3185	2170	1844	694
10	629	1692	2153	1993	1478	2319	3946	3154	2443	2176	2087	1460	1054	592
15	527	992	1149	1206	1047	1517	2421	2023	1578	1406	1317	934	644	455
20	438	682	753	831	819	1127	1707	1480	1163	1035	951	677	476	368
25	369	514	556	625	671	894	1295	1159	917	816	737	525	382	309
50	200	234	245	277	338	418	529	524	428	379	325	239	196	175
75	138	155	160	178	213	254	303	314	264	234	198	152	132	122
100	105	115	118	129	150	173	200	211	183	163	138	110	98	93
125	83	90	92	99	112	127	143	152	135	121	104	85	78	74
150	68	72	74	78	87	97	108	115	104	94	82	69	63	61
175	57	60	61	64	70	77	84	90	82	75	66	57	53	51
200	48	50	51	53	58	62	68	72	67	61	55	48	45	44
225	41	43	43	45	48	52	55	58	55	51	46	41	39	38

Table 4 (continuation)

Equivalent dose rate induced by high-energy hadrons from steel 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	113	874											636	128
5	108	881	752	638	440	830	1606	1194	903	794	782	501	636	117
7	104	425	527	446	312	536	994	759	577	508	494	336	285	107
10	95	255	325	303	227	362	637	503	384	339	324	226	163	92
15	80	150	174	184	161	237	390	322	248	219	205	145	100	71
20	67	104	115	127	126	177	275	236	183	161	148	105	74	57
25	56	79	85	96	104	141	208	185	144	127	115	82	59	48
50	31	36	38	43	53	66	85	83	67	59	51	37	31	27
75	21	24	25	28	34	40	48	50	42	37	31	24	21	19
100	16	18	19	20	24	27	32	34	29	26	22	17	15	14
125	13	14	14	16	18	20	23	24	21	19	16	13	12	12
150	11	11	12	12	14	15	17	18	16	15	13	11	10	10
175	9	9	10	10	11	12	13	14	13	12	10	9	8	8
200	8	8	8	8	9	10	11	11	11	10	9	8	7	7
225	6	7	7	7	8	8	9	9	9	8	7	6	6	6

Table 4 (continuation)

Equivalent dose rate induced by high-energy hadrons from steel 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	171	1325											959	193
5	163	1335	1137	961	664	1255	2407	1783	1353	1193	1177	754	960	176
7	157	643	796	672	471	810	1489	1132	864	764	744	506	429	162
10	144	385	491	457	342	546	955	750	575	509	487	340	246	138
15	121	227	263	277	243	358	585	481	371	329	308	218	150	106
20	101	156	173	191	190	266	412	352	274	243	222	158	111	86
25	85	118	128	144	157	212	312	276	216	191	172	123	89	72
50	47	55	57	65	79	99	127	125	101	89	76	56	46	41
75	32	36	38	42	50	60	72	75	62	55	46	36	31	29
100	25	27	28	30	35	41	48	50	43	38	32	26	23	22
125	20	21	22	23	27	30	34	36	32	28	24	20	18	17
150	16	17	17	19	21	23	26	27	25	22	19	16	15	14
175	13	14	14	15	17	18	20	21	19	18	16	13	13	12
200	11	12	12	13	14	15	16	17	16	14	13	11	11	10
225	10	10	10	11	11	12	13	14	13	12	11	10	9	9

Table 5

Equivalent dose rate induced by low-energy neutrons from steel 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	19.5	121.0											73.2	15.4
5	18.8	126.3	121.3	96.8	53.8	151.8	576.3	267.3	110.5	99.1	92.3	51.7	80.7	14.1
7	18.2	67.4	94.9	73.5	41.8	103.6	349.8	167.5	71.1	63.2	58.1	35.7	33.9	12.9
10	17.0	44.3	61.8	53.0	33.7	74.8	220.4	110.5	48.3	42.4	38.4	24.8	19.0	11.0
15	14.7	27.5	32.6	32.9	26.9	53.1	131.4	71.0	32.3	27.9	24.7	16.5	11.8	8.6
20	12.6	19.4	21.5	23.1	22.9	41.6	90.0	52.3	24.6	20.9	18.2	12.4	8.9	7.0
25	10.9	15.0	16.1	17.9	20.1	34.2	66.5	41.2	20.0	16.8	14.3	9.8	7.3	6.0
50	6.6	7.7	8.1	9.2	12.0	17.0	24.3	19.0	10.6	8.5	6.9	5.0	4.2	3.7
75	4.9	5.5	5.8	6.5	8.1	10.3	13.0	11.4	7.1	5.7	4.6	3.5	3.0	2.8
100	3.9	4.3	4.4	4.9	5.8	7.0	8.2	7.6	5.3	4.3	3.5	2.7	2.4	2.3
125	3.2	3.5	3.6	3.8	4.4	5.0	5.7	5.5	4.1	3.4	2.8	2.2	2.0	1.9
150	2.7	2.8	2.9	3.1	3.4	3.8	4.2	4.1	3.2	2.7	2.3	1.9	1.7	1.7
175	2.3	2.4	2.4	2.5	2.8	3.0	3.2	3.2	2.6	2.3	1.9	1.6	1.5	1.5
200	1.9	2.0	2.0	2.1	2.3	2.4	2.6	2.5	2.2	1.9	1.7	1.4	1.3	1.3
225	1.7	1.7	1.7	1.8	1.9	2.0	2.1	2.1	1.8	1.6	1.4	1.3	1.2	1.2

Table 5 (continuation)

Equivalent dose rate induced by low-energy neutrons from steel 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	39.3	238.4											97.8	20.5
5	37.9	249.3	265.8	209.2	112.4	258.9	760.0	337.6	147.2	132.1	122.9	69.1	108.1	18.8
7	36.6	141.1	215.7	163.4	84.1	171.7	461.2	212.0	94.6	84.2	77.4	47.7	45.4	17.3
10	34.1	95.6	141.6	118.4	64.9	120.3	290.7	140.2	64.3	56.5	51.2	33.1	25.4	14.8
15	29.3	58.9	71.5	70.7	49.6	82.6	173.6	90.5	43.0	37.1	32.9	22.1	15.7	11.5
20	24.8	40.0	44.8	47.4	40.8	63.3	119.3	66.8	32.7	27.8	24.2	16.5	11.9	9.4
25	21.0	29.7	32.2	35.1	34.7	51.3	88.4	52.9	26.6	22.3	19.1	13.1	9.7	8.1
50	11.3	13.2	13.8	15.5	19.0	24.7	32.8	24.7	14.0	11.4	9.2	6.7	5.5	5.0
75	7.8	8.8	9.1	10.1	12.2	14.8	17.7	15.0	9.5	7.7	6.1	4.6	4.0	3.8
100	6.0	6.5	6.7	7.3	8.6	9.9	11.2	10.1	7.0	5.7	4.6	3.6	3.2	3.1
125	4.8	5.1	5.2	5.6	6.3	7.1	7.8	7.3	5.4	4.5	3.7	3.0	2.7	2.6
150	3.9	4.1	4.2	4.4	4.9	5.4	5.8	5.5	4.3	3.7	3.1	2.5	2.3	2.2
175	3.3	3.4	3.5	3.6	3.9	4.2	4.5	4.3	3.5	3.1	2.6	2.2	2.0	2.0
200	2.8	2.9	2.9	3.0	3.2	3.4	3.6	3.5	2.9	2.6	2.2	1.9	1.8	1.7
225	2.4	2.4	2.5	2.5	2.7	2.8	2.9	2.9	2.5	2.2	2.0	1.7	1.6	1.6

Table 5 (continuation)

Equivalent dose rate induced by low-energy neutrons from steel 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	9.3	57.4											32.1	6.7
5	9.0	59.9	59.0	47.0	25.9	69.7	250.7	115.5	48.4	43.4	40.4	22.7	35.4	6.2
7	8.7	32.4	46.6	35.9	19.9	47.3	152.2	72.4	31.1	27.7	25.5	15.7	14.9	5.7
10	8.1	21.4	30.4	25.9	15.9	33.9	95.9	47.8	21.1	18.6	16.8	10.9	8.3	4.8
15	7.0	13.3	15.9	15.9	12.6	23.9	57.2	30.7	14.1	12.2	10.8	7.2	5.2	3.8
20	6.0	9.3	10.3	11.0	10.6	18.6	39.2	22.6	10.8	9.1	8.0	5.4	3.9	3.1
25	5.1	7.1	7.7	8.5	9.2	15.2	29.0	17.9	8.8	7.3	6.3	4.3	3.2	2.6
50	3.0	3.5	3.7	4.2	5.4	7.5	10.6	8.3	4.6	3.7	3.0	2.2	1.8	1.6
75	2.2	2.5	2.6	2.9	3.6	4.6	5.7	5.0	3.1	2.5	2.0	1.5	1.3	1.2
100	1.8	1.9	2.0	2.2	2.6	3.1	3.6	3.3	2.3	1.9	1.5	1.2	1.1	1.0
125	1.4	1.5	1.6	1.7	1.9	2.2	2.5	2.4	1.8	1.5	1.2	1.0	0.9	0.8
150	1.2	1.3	1.3	1.4	1.5	1.7	1.8	1.8	1.4	1.2	1.0	0.8	0.8	0.7
175	1.0	1.1	1.1	1.1	1.2	1.3	1.4	1.4	1.2	1.0	0.9	0.7	0.7	0.6
200	0.9	0.9	0.9	0.9	1.0	1.1	1.1	1.1	1.0	0.8	0.7	0.6	0.6	0.6
225	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.8	0.7	0.6	0.6	0.5	0.5

Table 5 (continuation)

Equivalent dose rate induced by low-energy neutrons from steel 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	27.0	162.0											49.5	10.4
5	26.0	169.7	190.4	149.0	78.8	161.4	379.0	160.2	74.4	66.8	62.0	35.0	54.9	9.5
7	25.1	98.9	157.1	117.9	57.8	104.9	229.9	100.9	47.8	42.5	39.1	24.2	23.0	8.8
10	23.4	68.1	103.5	85.6	43.6	71.9	145.0	67.0	32.4	28.5	25.8	16.8	12.9	7.5
15	20.0	41.7	51.2	50.2	32.4	48.1	86.8	43.4	21.7	18.7	16.6	11.2	8.0	5.8
20	16.8	27.9	31.4	32.9	26.1	36.2	59.8	32.2	16.5	14.0	12.2	8.3	6.0	4.8
25	14.1	20.3	22.0	23.8	21.8	29.0	44.4	25.6	13.4	11.3	9.6	6.7	4.9	4.1
50	7.1	8.3	8.6	9.6	11.2	13.6	16.8	12.1	7.0	5.7	4.7	3.4	2.8	2.5
75	4.7	5.2	5.4	5.9	6.9	8.1	9.1	7.5	4.8	3.9	3.1	2.4	2.1	1.9
100	3.4	3.7	3.8	4.1	4.7	5.3	5.8	5.1	3.5	2.9	2.3	1.8	1.6	1.6
125	2.7	2.9	2.9	3.1	3.5	3.8	4.1	3.7	2.7	2.3	1.9	1.5	1.4	1.3
150	2.2	2.3	2.3	2.4	2.7	2.9	3.0	2.8	2.2	1.9	1.6	1.3	1.2	1.1
175	1.8	1.9	1.9	2.0	2.1	2.2	2.3	2.2	1.8	1.6	1.3	1.1	1.0	1.0
200	1.5	1.6	1.6	1.6	1.7	1.8	1.9	1.8	1.5	1.3	1.2	1.0	0.9	0.9
225	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.5	1.3	1.1	1.0	0.9	0.8	0.8