Rev.05 of June 16, 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

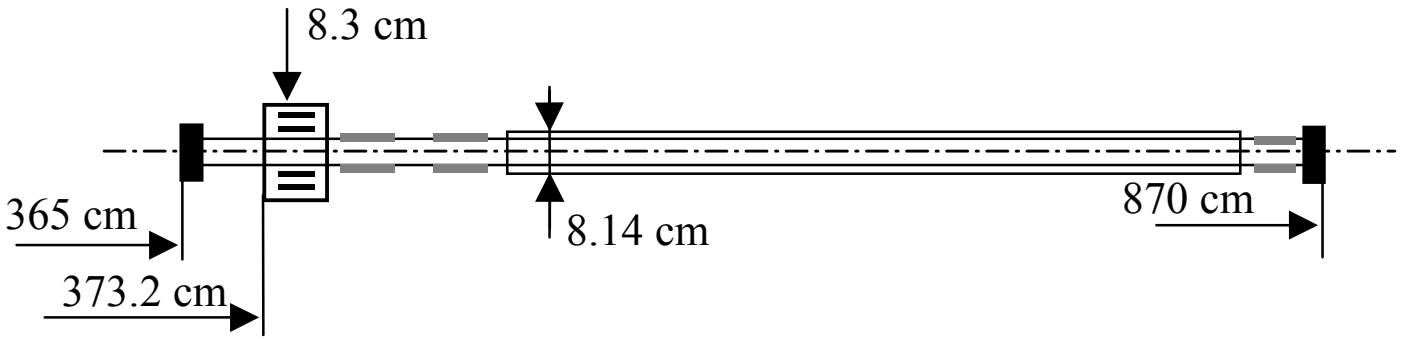

Fig. 1 Sketch of the LAr Beam pipe section.

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	72.4	367.6											52.3	8.7
5	70.1	339.8	684.2	445.5	73.4	63.3	93.9	71.5	56.8	51.4	50.9	36.0	50.1	8.0
7	68.0	280.6	589.2	388.3	58.6	44.3	60.6	46.5	37.0	33.5	32.8	25.2	23.7	7.4
10	64.0	224.2	409.7	298.7	48.4	32.7	40.6	31.4	24.9	22.6	21.8	17.3	13.7	6.5
15	55.8	149.5	211.4	180.8	39.8	24.2	26.5	20.6	16.3	14.8	14.0	11.2	8.2	5.2
20	47.4	100.6	124.0	114.3	34.3	19.9	19.8	15.4	12.2	11.0	10.3	8.1	5.9	4.3
25	39.7	70.6	81.0	77.4	29.8	17.2	15.8	12.3	9.7	8.8	8.1	6.3	4.7	3.6
50	17.1	20.8	21.6	21.7	15.6	10.4	8.2	6.2	4.9	4.3	3.8	2.9	2.4	2.1
75	9.1	10.0	10.2	10.3	9.0	7.1	5.5	4.1	3.2	2.8	2.4	1.9	1.6	1.5
100	5.6	6.0	6.1	6.2	5.8	5.0	4.1	3.1	2.4	2.1	1.8	1.4	1.3	1.2
125	3.9	4.1	4.1	4.2	4.1	3.7	3.2	2.4	1.9	1.7	1.4	1.2	1.0	1.0
150	2.9	3.0	3.0	3.0	3.0	2.9	2.5	2.0	1.6	1.4	1.2	1.0	0.9	0.9
175	2.2	2.3	2.3	2.3	2.3	2.3	2.1	1.7	1.3	1.2	1.0	0.8	0.8	0.8
200	1.8	1.8	1.8	1.9	1.9	1.8	1.7	1.4	1.1	1.0	0.9	0.7	0.7	0.7
225	1.5	1.5	1.5	1.5	1.5	1.5	1.4	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	96.7	579.8											193.5	31.6
5	93.4	544.5	867.5	611.2	193.1	212.6	343.1	262.1	209.9	190.7	188.9	133.2	185.1	29.0
7	90.5	386.8	728.1	510.5	139.1	142.0	218.3	169.6	136.1	123.9	121.5	93.0	87.1	26.9
10	84.9	290.7	502.2	384.3	103.8	99.1	143.5	113.7	91.4	83.2	80.6	63.7	50.1	23.6
15	73.9	190.3	262.5	233.3	77.1	68.0	90.8	73.8	59.4	54.1	51.5	40.8	29.9	18.8
20	62.8	128.9	156.9	149.8	62.6	52.7	65.7	54.5	44.0	40.0	37.5	29.4	21.5	15.4
25	52.9	91.7	104.6	103.4	52.7	43.3	51.1	43.1	34.9	31.7	29.3	22.7	16.8	12.9
50	24.2	29.5	30.7	31.9	26.7	23.0	23.3	20.5	16.8	15.1	13.3	10.2	8.2	7.2
75	13.7	15.3	15.7	16.4	15.9	14.9	14.5	13.0	10.7	9.6	8.3	6.4	5.5	5.0
100	9.1	9.8	10.0	10.4	10.7	10.4	10.2	9.2	7.7	6.9	5.9	4.7	4.1	3.9
125	6.6	7.0	7.1	7.4	7.7	7.7	7.6	7.0	5.9	5.2	4.5	3.7	3.3	3.1
150	5.1	5.4	5.4	5.6	5.9	6.0	6.0	5.5	4.7	4.2	3.6	3.0	2.8	2.6
175	4.1	4.3	4.3	4.5	4.7	4.8	4.8	4.5	3.8	3.5	3.0	2.6	2.4	2.3
200	3.4	3.5	3.6	3.7	3.8	3.9	3.9	3.7	3.2	2.9	2.6	2.2	2.1	2.0
225	2.9	3.0	3.0	3.1	3.2	3.3	3.3	3.1	2.7	2.5	2.2	1.9	1.8	1.7

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	15.6	97.8											37.5	6.1
5	15.1	92.3	137.6	99.3	36.0	40.8	66.2	50.6	40.4	36.8	36.4	25.8	35.9	5.6
7	14.6	63.0	114.6	81.9	25.6	27.1	42.1	32.7	26.2	23.9	23.4	18.0	16.9	5.2
10	13.7	46.5	78.9	61.3	18.7	18.8	27.6	21.9	17.6	16.0	15.5	12.3	9.7	4.6
15	11.9	30.2	41.4	37.3	13.7	12.8	17.4	14.2	11.4	10.4	9.9	7.9	5.8	3.6
20	10.1	20.5	24.9	24.0	11.0	9.8	12.6	10.5	8.5	7.7	7.2	5.7	4.1	3.0
25	8.5	14.7	16.7	16.7	9.2	8.0	9.8	8.3	6.7	6.1	5.6	4.4	3.2	2.5
50	4.0	4.8	5.1	5.3	4.6	4.2	4.4	3.9	3.2	2.9	2.6	2.0	1.6	1.4
75	2.3	2.6	2.6	2.8	2.8	2.7	2.7	2.5	2.0	1.8	1.6	1.2	1.1	1.0
100	1.5	1.7	1.7	1.8	1.9	1.9	1.9	1.7	1.5	1.3	1.1	0.9	0.8	0.7
125	1.1	1.2	1.2	1.3	1.4	1.4	1.4	1.3	1.1	1.0	0.9	0.7	0.6	0.6
150	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.0	0.9	0.8	0.7	0.6	0.5	0.5
175	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.8	0.7	0.7	0.6	0.5	0.5	0.4
200	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.5	0.4	0.4	0.4
225	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.5	0.5	0.4	0.4	0.3	0.3

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	36.6	289.6											172.2	28.0
5	35.2	277.8	291.6	244.3	149.3	182.8	302.6	232.0	185.5	168.6	167.0	118.2	164.9	25.6
7	34.0	155.8	229.0	187.0	101.4	119.9	191.7	149.8	120.2	109.4	107.4	82.4	77.4	23.8
10	31.7	103.1	154.6	134.0	70.6	81.7	125.2	100.2	80.6	73.4	71.2	56.4	44.4	20.8
15	27.5	64.6	83.7	81.9	48.3	54.3	78.4	64.8	52.3	47.6	45.4	36.1	26.4	16.6
20	23.4	44.5	52.6	54.5	37.2	40.8	56.1	47.7	38.6	35.2	33.0	25.9	18.9	13.5
25	20.0	32.7	36.8	39.2	30.3	32.7	43.2	37.6	30.6	27.8	25.7	20.0	14.8	11.3
50	10.2	12.5	13.1	14.3	14.8	15.9	18.7	17.5	14.5	13.1	11.6	8.8	7.1	6.3
75	6.5	7.4	7.6	8.3	9.1	10.0	11.1	10.8	9.1	8.2	7.1	5.5	4.7	4.3
100	4.7	5.1	5.3	5.7	6.3	6.9	7.6	7.5	6.5	5.8	5.0	4.0	3.5	3.3
125	3.6	3.9	4.0	4.3	4.7	5.2	5.6	5.6	4.9	4.4	3.8	3.1	2.8	2.6
150	2.9	3.1	3.2	3.4	3.7	4.0	4.3	4.4	3.8	3.5	3.0	2.5	2.3	2.2
175	2.5	2.6	2.6	2.8	3.0	3.2	3.4	3.5	3.1	2.8	2.5	2.1	1.9	1.9
200	2.1	2.2	2.2	2.3	2.5	2.6	2.8	2.9	2.6	2.4	2.1	1.8	1.7	1.6
225	1.8	1.9	1.9	2.0	2.1	2.2	2.4	2.4	2.2	2.0	1.8	1.6	1.5	1.4

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	3.27	14.65											0.17	0.04
5	3.17	13.56	30.39	19.23	1.64	0.69	1.06	0.48	0.21	0.19	0.18	0.11	0.17	0.03
7	3.08	12.36	27.42	17.39	1.58	0.61	0.72	0.32	0.15	0.13	0.12	0.08	0.08	0.03
10	2.90	10.29	19.68	13.76	1.51	0.55	0.51	0.23	0.11	0.09	0.08	0.06	0.05	0.03
15	2.54	6.98	10.10	8.40	1.39	0.50	0.37	0.17	0.08	0.07	0.06	0.04	0.03	0.03
20	2.16	4.69	5.84	5.27	1.26	0.47	0.30	0.13	0.07	0.06	0.05	0.04	0.03	0.02
25	1.81	3.27	3.77	3.53	1.13	0.44	0.26	0.12	0.06	0.05	0.04	0.03	0.02	0.02
50	0.75	0.92	0.95	0.94	0.61	0.33	0.18	0.08	0.04	0.03	0.03	0.02	0.02	0.02
75	0.38	0.42	0.43	0.43	0.35	0.23	0.14	0.06	0.04	0.03	0.02	0.02	0.02	0.02
100	0.23	0.24	0.25	0.25	0.22	0.17	0.11	0.05	0.03	0.02	0.02	0.02	0.01	0.01
125	0.15	0.16	0.16	0.16	0.15	0.12	0.09	0.05	0.03	0.02	0.02	0.02	0.01	0.01
150	0.11	0.11	0.11	0.11	0.11	0.09	0.07	0.04	0.03	0.02	0.02	0.01	0.01	0.01
175	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
200	0.06	0.07	0.07	0.07	0.06	0.06	0.05	0.03	0.02	0.02	0.02	0.01	0.01	0.01
225	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

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	8.60	38.09											0.26	0.07
5	8.35	35.35	79.12	50.14	4.17	1.53	1.72	0.74	0.34	0.30	0.27	0.17	0.27	0.06
7	8.11	32.44	72.18	45.59	4.06	1.40	1.22	0.52	0.24	0.21	0.19	0.13	0.13	0.06
10	7.65	27.15	52.28	36.28	3.90	1.31	0.93	0.39	0.19	0.16	0.14	0.10	0.09	0.06
15	6.71	18.47	26.81	22.22	3.61	1.23	0.72	0.30	0.15	0.12	0.10	0.08	0.06	0.05
20	5.70	12.41	15.48	13.93	3.29	1.17	0.62	0.25	0.13	0.10	0.09	0.07	0.05	0.05
25	4.76	8.64	9.97	9.34	2.95	1.11	0.56	0.23	0.11	0.09	0.08	0.06	0.05	0.04
50	1.99	2.43	2.51	2.48	1.59	0.83	0.42	0.17	0.09	0.07	0.06	0.04	0.04	0.04
75	1.01	1.11	1.13	1.12	0.90	0.59	0.34	0.15	0.08	0.06	0.05	0.04	0.04	0.03
100	0.60	0.64	0.64	0.64	0.56	0.43	0.27	0.13	0.07	0.06	0.05	0.04	0.03	0.03
125	0.40	0.41	0.42	0.42	0.38	0.32	0.22	0.11	0.07	0.05	0.04	0.04	0.03	0.03
150	0.29	0.29	0.29	0.29	0.28	0.24	0.18	0.10	0.06	0.05	0.04	0.03	0.03	0.03
175	0.21	0.22	0.22	0.22	0.21	0.19	0.15	0.09	0.06	0.05	0.04	0.03	0.03	0.03
200	0.17	0.17	0.17	0.17	0.16	0.15	0.13	0.08	0.05	0.04	0.04	0.03	0.03	0.03
225	0.14	0.14	0.14	0.14	0.13	0.12	0.11	0.07	0.05	0.04	0.03	0.03	0.03	0.03

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	0.01
5	1.62	6.89	15.46	9.79	0.83	0.32	0.39	0.16	0.08	0.07	0.06	0.04	0.06	0.01
7	1.57	6.30	13.99	8.86	0.80	0.29	0.27	0.11	0.06	0.05	0.04	0.03	0.03	0.01
10	1.48	5.25	10.07	7.02	0.76	0.27	0.20	0.08	0.04	0.04	0.03	0.02	0.02	0.01
15	1.30	3.57	5.16	4.29	0.70	0.25	0.15	0.06	0.03	0.03	0.02	0.02	0.01	0.01
20	1.10	2.40	2.99	2.69	0.64	0.23	0.13	0.05	0.03	0.02	0.02	0.01	0.01	0.01
25	0.92	1.67	1.93	1.80	0.57	0.22	0.11	0.05	0.02	0.02	0.02	0.01	0.01	0.01
50	0.38	0.47	0.49	0.48	0.31	0.16	0.08	0.03	0.02	0.01	0.01	0.01	0.01	0.01
75	0.20	0.21	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	0.12	0.12	0.11	0.08	0.05	0.03	0.01	0.01	0.01	0.01	0.01	0.01
125	0.08	0.08	0.08	0.08	0.07	0.06	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01
150	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
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	0.02	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	0.02	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=100d

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	6.63	29.24											0.13	0.04
5	6.44	27.16	60.77	38.53	3.18	1.08	0.94	0.38	0.18	0.16	0.14	0.09	0.14	0.04
7	6.26	24.99	55.66	35.11	3.10	1.01	0.70	0.28	0.14	0.12	0.10	0.07	0.07	0.04
10	5.90	20.95	40.44	27.99	2.99	0.96	0.56	0.22	0.11	0.09	0.08	0.06	0.05	0.04
15	5.17	14.26	20.73	17.16	2.77	0.91	0.46	0.18	0.09	0.07	0.06	0.05	0.04	0.03
20	4.40	9.58	11.96	10.76	2.53	0.87	0.41	0.16	0.08	0.06	0.05	0.04	0.03	0.03
25	3.67	6.67	7.70	7.21	2.27	0.83	0.38	0.15	0.07	0.06	0.05	0.04	0.03	0.03
50	1.53	1.87	1.94	1.91	1.22	0.63	0.30	0.12	0.06	0.05	0.04	0.03	0.03	0.03
75	0.78	0.85	0.87	0.86	0.69	0.45	0.25	0.10	0.06	0.04	0.03	0.03	0.03	0.02
100	0.46	0.49	0.49	0.49	0.43	0.33	0.21	0.09	0.05	0.04	0.03	0.03	0.02	0.02
125	0.31	0.32	0.32	0.32	0.29	0.24	0.17	0.08	0.05	0.04	0.03	0.03	0.02	0.02
150	0.22	0.22	0.22	0.22	0.21	0.18	0.14	0.08	0.05	0.04	0.03	0.02	0.02	0.02
175	0.16	0.17	0.17	0.17	0.16	0.14	0.11	0.07	0.04	0.03	0.03	0.02	0.02	0.02
200	0.13	0.13	0.13	0.13	0.13	0.12	0.10	0.06	0.04	0.03	0.03	0.02	0.02	0.02
225	0.10	0.10	0.10	0.10	0.10	0.09	0.08	0.06	0.04	0.03	0.03	0.02	0.02	0.02

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	357.8	3406.9											2540.6	414.8
5	342.6	3305.9	2502.6	2566.8	2100.6	2669.3	4926.9	3712.1	2852.9	2533.3	2513.5	1764.9	2432.2	380.1
7	329.6	1589.9	1808.1	1804.0	1406.1	1753.6	3111.5	2395.1	1848.8	1645.4	1615.9	1230.7	1144.1	352.8
10	306.1	939.4	1185.2	1223.6	960.4	1196.1	2024.4	1600.2	1240.4	1105.1	1070.6	842.0	657.9	309.2
15	264.6	564.3	677.4	749.7	641.2	793.4	1258.5	1033.1	805.8	718.3	682.8	538.9	392.5	246.4
20	227.2	396.9	454.4	517.8	485.3	595.3	895.8	759.4	595.9	531.2	496.8	388.0	281.7	201.3
25	196.5	302.8	336.8	387.6	390.5	475.6	685.3	597.2	471.3	420.1	387.5	299.1	220.5	169.3
50	111.8	136.1	143.8	163.4	190.9	228.4	288.7	275.6	223.5	199.0	175.1	132.6	107.2	93.9
75	77.3	88.1	91.7	102.1	120.7	142.1	169.3	169.1	140.7	125.2	108.0	83.3	71.1	64.9
100	58.8	65.1	67.2	73.5	85.6	98.8	114.1	116.7	99.4	88.6	76.1	60.1	53.0	49.4
125	47.2	51.3	52.6	56.8	64.8	73.5	83.2	86.1	74.8	66.9	57.7	46.7	42.0	39.7
150	39.2	42.0	42.9	45.7	51.3	57.2	63.7	66.4	58.6	52.7	45.8	37.9	34.6	33.0
175	33.2	35.2	35.9	37.9	41.9	46.0	50.7	52.8	47.3	42.9	37.6	31.6	29.2	28.0
200	28.7	30.1	30.6	32.1	35.0	38.0	41.4	43.1	39.1	35.6	31.5	27.0	25.1	24.2
225	25.0	26.1	26.5	27.6	29.8	32.0	34.5	35.9	32.8	30.1	26.9	23.4	21.9	21.2

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	402.0	3824.9											2858.0	466.6
5	384.9	3711.8	2810.0	2879.9	2364.8	3008.9	5571.7	4182.9	3209.7	2850.7	2827.7	1984.6	2735.9	427.6
7	370.3	1785.3	2030.4	2024.6	1582.7	1976.9	3518.2	2698.8	2080.0	1851.5	1817.9	1384.0	1287.0	396.9
10	344.0	1055.0	1331.1	1373.6	1080.8	1348.6	2288.8	1803.1	1395.5	1243.5	1204.5	946.9	740.0	347.8
15	297.3	633.9	760.9	841.9	721.6	894.6	1422.5	1164.1	906.6	808.4	768.1	606.1	441.5	277.2
20	255.4	445.9	510.5	581.7	546.2	671.3	1012.3	855.8	670.4	597.8	559.0	436.4	316.8	226.4
25	220.8	340.3	378.5	435.6	439.6	536.4	774.3	673.0	530.3	472.8	436.0	336.5	248.0	190.4
50	125.8	153.1	161.8	183.9	215.0	257.6	326.0	310.6	251.5	223.9	197.1	149.2	120.6	105.7
75	87.0	99.2	103.3	114.9	136.0	160.2	191.1	190.6	158.4	140.9	121.6	93.7	80.0	73.1
100	66.2	73.3	75.7	82.8	96.4	111.4	128.7	131.5	111.9	99.7	85.6	67.7	59.6	55.6
125	53.2	57.8	59.3	64.0	73.0	82.9	93.8	97.0	84.2	75.3	64.9	52.5	47.3	44.7
150	44.1	47.3	48.3	51.5	57.8	64.5	71.9	74.8	66.0	59.4	51.6	42.6	38.9	37.1
175	37.4	39.7	40.4	42.7	47.2	51.9	57.1	59.5	53.3	48.3	42.3	35.6	32.9	31.5
200	32.3	33.9	34.5	36.2	39.4	42.8	46.6	48.6	44.0	40.1	35.5	30.4	28.3	27.3
225	28.2	29.5	29.9	31.1	33.5	36.1	38.9	40.4	37.0	33.9	30.3	26.3	24.7	23.9

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	60.8	568.8											440.7	72.1
5	58.2	552.1	421.6	436.7	359.9	466.2	901.6	666.9	504.4	443.1	438.4	306.8	421.6	66.1
7	56.0	267.0	305.5	307.2	241.3	306.9	568.8	430.2	326.8	287.9	281.9	214.0	198.5	61.3
10	52.1	158.6	200.9	208.6	165.1	209.9	369.6	287.4	219.3	193.5	186.8	146.5	114.2	53.8
15	45.2	95.9	115.2	128.1	110.6	139.6	229.4	185.5	142.4	125.9	119.2	93.8	68.3	42.9
20	38.9	67.7	77.5	88.7	84.0	105.0	163.0	136.4	105.3	93.2	86.8	67.6	49.0	35.1
25	33.7	51.8	57.7	66.5	67.7	84.1	124.5	107.3	83.3	73.7	67.7	52.2	38.4	29.5
50	19.4	23.6	24.9	28.4	33.4	40.6	52.1	49.5	39.6	35.0	30.7	23.2	18.8	16.4
75	13.5	15.4	16.0	17.9	21.3	25.3	30.4	30.3	24.9	22.1	19.0	14.6	12.5	11.4
100	10.3	11.4	11.8	12.9	15.1	17.6	20.5	20.9	17.6	15.7	13.4	10.6	9.3	8.7
125	8.3	9.1	9.3	10.0	11.5	13.1	14.9	15.4	13.3	11.8	10.2	8.2	7.4	7.0
150	6.9	7.4	7.6	8.1	9.1	10.2	11.4	11.9	10.4	9.3	8.1	6.7	6.1	5.8
175	5.9	6.2	6.4	6.7	7.4	8.2	9.0	9.4	8.4	7.6	6.6	5.6	5.2	5.0
200	5.1	5.3	5.4	5.7	6.2	6.8	7.4	7.7	6.9	6.3	5.6	4.8	4.4	4.3
225	4.4	4.6	4.7	4.9	5.3	5.7	6.2	6.4	5.8	5.3	4.8	4.1	3.9	3.8

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	91.8	862.4											664.8	108.6
5	87.9	837.2	637.5	657.2	543.3	705.1	1350.6	995.2	755.4	666.1	660.2	462.0	636.0	99.6
7	84.6	404.2	461.6	462.5	364.1	463.8	852.0	641.9	489.4	432.8	424.4	322.2	299.3	92.4
10	78.7	239.9	303.4	314.2	249.1	316.9	553.8	428.8	328.3	290.8	281.3	220.5	172.2	81.0
15	68.1	144.7	173.9	193.0	166.8	210.6	343.7	276.9	213.3	189.2	179.4	141.2	102.8	64.6
20	58.7	102.1	117.0	133.6	126.5	158.3	244.2	203.6	157.7	140.0	130.6	101.7	73.8	52.8
25	50.8	78.2	86.9	100.2	102.1	126.6	186.6	160.1	124.8	110.8	101.9	78.5	57.8	44.4
50	29.2	35.5	37.5	42.8	50.3	61.0	78.1	73.9	59.2	52.6	46.1	34.9	28.2	24.7
75	20.3	23.2	24.1	26.9	32.0	38.0	45.6	45.3	37.3	33.1	28.5	22.0	18.7	17.1
100	15.5	17.2	17.8	19.5	22.7	26.4	30.7	31.3	26.4	23.5	20.1	15.9	14.0	13.1
125	12.5	13.6	14.0	15.1	17.3	19.6	22.3	23.0	19.9	17.7	15.3	12.3	11.1	10.5
150	10.4	11.1	11.4	12.2	13.7	15.3	17.1	17.8	15.6	14.0	12.1	10.0	9.2	8.7
175	8.8	9.4	9.5	10.1	11.2	12.3	13.6	14.1	12.6	11.4	10.0	8.4	7.7	7.4
200	7.6	8.0	8.2	8.5	9.3	10.1	11.1	11.5	10.4	9.5	8.4	7.2	6.7	6.4
225	6.7	7.0	7.1	7.4	7.9	8.5	9.2	9.6	8.7	8.0	7.2	6.2	5.8	5.6

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	10.1	75.8											50.1	8.3
5	9.8	76.8	66.0	62.0	39.2	83.4	322.4	148.9	61.3	55.1	51.5	30.4	52.6	7.7
7	9.4	40.1	52.2	46.1	28.5	57.5	200.0	94.8	40.0	35.6	33.0	21.7	23.1	7.1
10	8.9	25.8	36.1	33.0	21.5	41.6	128.0	63.0	27.3	24.1	22.0	15.3	12.9	6.2
15	7.9	16.5	20.6	21.0	16.2	29.7	77.6	40.7	18.3	15.9	14.2	10.2	7.7	5.0
20	6.9	11.9	13.8	14.8	13.4	23.4	53.8	30.0	13.9	11.9	10.5	7.6	5.6	4.1
25	6.1	9.2	10.3	11.4	11.6	19.3	40.2	23.7	11.3	9.6	8.3	6.0	4.5	3.5
50	3.8	4.5	4.8	5.5	6.9	9.9	15.2	11.1	6.0	4.9	4.0	2.9	2.4	2.1
75	2.8	3.2	3.3	3.7	4.7	6.2	8.3	6.8	4.1	3.3	2.7	2.0	1.7	1.6
100	2.2	2.5	2.6	2.8	3.5	4.3	5.3	4.7	3.0	2.5	2.0	1.5	1.4	1.3
125	1.8	2.0	2.1	2.2	2.7	3.1	3.7	3.4	2.4	2.0	1.6	1.3	1.1	1.1
150	1.5	1.7	1.7	1.8	2.1	2.4	2.7	2.6	1.9	1.6	1.3	1.1	1.0	0.9
175	1.3	1.4	1.4	1.5	1.7	1.9	2.1	2.0	1.6	1.3	1.1	0.9	0.9	0.8
200	1.1	1.2	1.2	1.3	1.4	1.6	1.7	1.7	1.3	1.1	1.0	0.8	0.8	0.7
225	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.4	1.1	1.0	0.9	0.7	0.7	0.7

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	20.5	147.1											67.0	11.2
5	19.8	149.7	144.8	133.4	89.4	143.6	425.4	187.9	81.7	73.4	68.5	40.7	70.5	10.2
7	19.1	82.4	117.8	101.9	62.2	96.6	263.9	120.0	53.2	47.5	43.9	29.1	31.0	9.5
10	18.0	55.1	82.3	73.8	44.6	68.2	168.9	80.0	36.3	32.1	29.3	20.5	17.3	8.3
15	15.8	35.4	45.8	46.1	31.8	47.2	102.5	51.8	24.3	21.1	19.0	13.6	10.3	6.7
20	13.7	25.0	29.5	31.5	25.3	36.4	71.3	38.3	18.5	15.9	14.0	10.1	7.5	5.5
25	11.9	18.9	21.3	23.3	21.1	29.6	53.4	30.4	15.0	12.7	11.1	8.0	6.0	4.7
50	6.8	8.2	8.7	9.8	11.4	14.7	20.5	14.4	7.9	6.5	5.4	3.9	3.2	2.9
75	4.6	5.3	5.5	6.2	7.4	9.1	11.3	8.9	5.4	4.4	3.6	2.7	2.3	2.1
100	3.5	3.9	4.0	4.4	5.2	6.2	7.3	6.2	4.0	3.3	2.7	2.1	1.8	1.7
125	2.8	3.1	3.2	3.4	3.9	4.5	5.1	4.5	3.2	2.6	2.1	1.7	1.5	1.4
150	2.3	2.5	2.6	2.7	3.1	3.5	3.8	3.5	2.6	2.2	1.8	1.4	1.3	1.3
175	2.0	2.1	2.1	2.2	2.5	2.7	3.0	2.8	2.1	1.8	1.5	1.3	1.2	1.1
200	1.7	1.8	1.8	1.9	2.0	2.2	2.4	2.3	1.8	1.5	1.3	1.1	1.0	1.0
225	1.4	1.5	1.5	1.6	1.7	1.8	1.9	1.9	1.5	1.3	1.2	1.0	0.9	0.9

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	4.8	35.8											22.0	3.7
5	4.7	36.3	32.1	30.0	19.3	38.4	140.3	64.3	26.8	24.1	22.6	13.3	23.1	3.4
7	4.5	19.2	25.6	22.5	13.8	26.3	87.0	41.0	17.5	15.6	14.4	9.5	10.1	3.1
10	4.2	12.5	17.7	16.1	10.3	18.9	55.7	27.3	11.9	10.5	9.6	6.7	5.7	2.7
15	3.7	8.0	10.1	10.2	7.7	13.4	33.8	17.6	8.0	7.0	6.2	4.5	3.4	2.2
20	3.3	5.7	6.7	7.2	6.3	10.5	23.4	13.0	6.1	5.2	4.6	3.3	2.5	1.8
25	2.9	4.4	4.9	5.4	5.4	8.7	17.5	10.3	4.9	4.2	3.6	2.6	2.0	1.5
50	1.7	2.1	2.2	2.5	3.1	4.4	6.7	4.8	2.6	2.1	1.8	1.3	1.1	0.9
75	1.3	1.5	1.5	1.7	2.1	2.8	3.6	3.0	1.8	1.4	1.2	0.9	0.8	0.7
100	1.0	1.1	1.2	1.3	1.5	1.9	2.3	2.0	1.3	1.1	0.9	0.7	0.6	0.6
125	0.8	0.9	0.9	1.0	1.2	1.4	1.6	1.5	1.0	0.9	0.7	0.6	0.5	0.5
150	0.7	0.7	0.8	0.8	0.9	1.1	1.2	1.1	0.8	0.7	0.6	0.5	0.4	0.4
175	0.6	0.6	0.6	0.7	0.8	0.8	0.9	0.9	0.7	0.6	0.5	0.4	0.4	0.4
200	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.7	0.6	0.5	0.4	0.4	0.3	0.3
225	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.4	0.4	0.3	0.3	0.3

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	14.1	99.2											33.9	5.7
5	13.6	101.2	103.8	94.8	65.2	90.1	212.3	89.2	41.3	37.1	34.6	20.6	35.8	5.2
7	13.2	57.3	85.5	73.3	44.5	59.6	131.7	57.1	26.9	24.0	22.2	14.8	15.7	4.8
10	12.4	39.0	60.0	53.3	31.2	41.3	84.3	38.2	18.3	16.2	14.8	10.4	8.8	4.2
15	10.8	25.1	33.0	33.0	21.6	27.9	51.3	24.8	12.3	10.7	9.6	6.9	5.2	3.4
20	9.4	17.6	21.0	22.2	16.8	21.2	35.8	18.4	9.3	8.0	7.1	5.1	3.8	2.8
25	8.1	13.1	14.9	16.2	13.7	17.1	26.8	14.7	7.6	6.4	5.6	4.1	3.0	2.4
50	4.4	5.3	5.6	6.3	6.9	8.2	10.5	7.1	4.0	3.3	2.7	2.0	1.6	1.5
75	2.9	3.3	3.4	3.7	4.3	5.0	5.8	4.4	2.7	2.2	1.8	1.4	1.2	1.1
100	2.1	2.3	2.4	2.6	3.0	3.4	3.8	3.1	2.0	1.7	1.4	1.1	0.9	0.9
125	1.6	1.8	1.8	2.0	2.2	2.5	2.7	2.3	1.6	1.3	1.1	0.9	0.8	0.7
150	1.3	1.4	1.4	1.5	1.7	1.9	2.0	1.8	1.3	1.1	0.9	0.7	0.7	0.6
175	1.1	1.2	1.2	1.2	1.4	1.5	1.6	1.4	1.1	0.9	0.8	0.6	0.6	0.6
200	0.9	1.0	1.0	1.0	1.1	1.2	1.3	1.2	0.9	0.8	0.7	0.6	0.5	0.5
225	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.0	0.8	0.7	0.6	0.5	0.5	0.5