

## 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 ( $Z_{min}=365$  cm,  $Z_{max}=870$  cm).

1. Only hadron activation was taken into account as low energy neutron activation of stainless steel in this region can be neglected (see report ACTIVATION STUDY IN THE ATLAS DETECTOR, pp. 59-68).
2. Only stainless steel activation was taken into account. Total mass of stainless steel (316 L) is approximately 15.9 kg.
3. Design of the beam pipe section was taken from the LHCVC1A\_0001 drawing. Geometry for activation calculations is given in the table 1. Material of the beam pipe section is 316 L (stainless steel). 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 of calculations are presented in the table 2 for various running and cooling times. All values are in  $\mu\text{Sv/h}$ . Dimensions are given in cm from the interaction point.
6. As compared to the previously estimated dose rate around the beam pipe, the new results are twice as high. A rather coarse hadron flux binning along R ( $\Delta R=10$  cm) axis had been used for the previous estimation. Here we use hadron flux on a fine grid ( $\Delta R=0.1$  cm for  $0 < R < 4$  cm and  $\Delta R=1$  cm for  $4 < R < 120$  cm), which was produced by Mike Shupe.

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	0.34 <sup>**</sup>	Flange
2	366.4	387.6	2.9	2.98	0.24	Tube
3	373.2	381	2.98	8.9	2.00 <sup>*</sup>	Ion pump
4	387.6	395.8	2.9	3.6	0.45 <sup>*</sup>	Bellows
5	395.8	415.1	2.9	2.98	0.22	Tube
6	415.1	423.3	2.9	3.6	0.45 <sup>*</sup>	Bellows
7	423.3	855	2.9	2.98	4.91	Tube
8	855	863.2	2.9	3.6	0.45 <sup>*</sup>	Bellows
9	863.2	870	2.9	2.98	0.08	Tube
10	428.9	849	3.92	4	6.44	Tube
11	868.6	870	2.98	4.3	0.34 <sup>**</sup>	Flange

<sup>\*</sup> - mass taken from LHCVC1A\_0001; uniform distribution over the volume is assumed  
<sup>\*\*</sup> - calculated as product of density by volume; on the LHCVC1A\_0001 mass of the flange is 900 g --?? **Looks like a problem!**

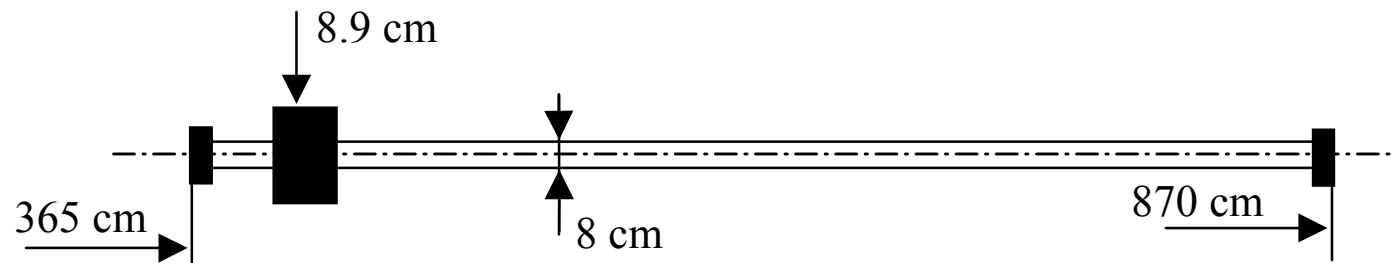


Fig. 1 Sketch of the LAr Beam pipe section.

Table 2

Equivalent dose rate induced by high-energy hadrons from LAr Beam Pipe for T= 30d, t=1d

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	994	6897											4482	918
5	954	6737	6785	7111	4445	5417	9839	7335	5610	5019	4966	3595	4338	842
7	919	3633	5025	5224	2934	3503	6069	4639	3566	3197	3126	2449	2076	774
10	850	2358	3244	3470	2017	2382	3896	3071	2372	2127	2049	1645	1226	663
15	722	1444	1740	1933	1371	1583	2397	1971	1534	1375	1297	1031	742	511
20	604	989	1116	1254	1048	1191	1695	1444	1132	1013	939	733	535	409
25	507	733	800	902	845	953	1291	1133	893	799	730	560	420	339
50	256	300	313	349	398	453	536	516	419	374	325	246	205	183
75	166	185	191	209	242	275	311	311	261	232	198	155	135	125
100	121	131	135	146	166	186	207	211	182	162	139	111	100	94
125	94	100	103	109	122	135	149	153	135	121	104	86	79	75
150	75	80	81	86	94	103	112	116	104	94	82	69	64	62
175	62	65	66	69	75	81	88	91	83	75	67	57	54	52
200	52	54	55	57	61	66	70	73	67	62	56	49	46	44
225	44	46	46	48	51	54	58	60	56	52	47	42	39	38

Table 2 (continuation)

Equivalent dose rate induced by high-energy hadrons from LAr Beam Pipe for T= 30d, t=5d

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	647	4486											2927	600
5	622	4381	4419	4651	2909	3518	6367	4795	3674	3276	3243	2351	2834	550
7	598	2365	3273	3413	1919	2276	3929	3033	2336	2087	2041	1602	1356	506
10	554	1536	2114	2266	1318	1548	2524	2008	1554	1389	1338	1075	801	433
15	470	941	1135	1262	895	1029	1553	1288	1005	898	847	674	485	334
20	394	645	728	818	684	774	1099	944	741	662	614	479	350	267
25	331	478	522	588	551	619	837	740	585	522	477	366	275	222
50	167	195	204	227	259	294	349	337	274	244	212	161	134	120
75	108	120	124	136	157	179	203	203	171	152	130	101	88	82
100	79	86	88	95	108	121	135	138	119	106	91	73	65	62
125	61	65	67	71	80	88	97	100	88	79	68	56	51	49
150	49	52	53	56	61	67	73	76	68	61	54	45	42	40
175	40	42	43	45	49	53	57	59	54	49	44	38	35	34
200	34	35	36	37	40	43	46	48	44	40	36	32	30	29
225	29	30	30	31	33	35	38	39	36	34	31	27	26	25

Table 2 (continuation)

Equivalent dose rate induced by high-energy hadrons from LAr Beam Pipe for T= 100d, t=1d

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	1256	8687											5709	1169
5	1206	8484	8567	9012	5661	6872	12496	9353	7177	6395	6329	4585	5526	1073
7	1161	4584	6347	6619	3735	4445	7708	5916	4561	4074	3983	3124	2645	987
10	1074	2978	4101	4396	2566	3023	4949	3916	3033	2711	2611	2097	1562	845
15	913	1826	2201	2450	1742	2010	3045	2513	1960	1752	1653	1314	946	651
20	764	1252	1412	1589	1331	1512	2154	1841	1446	1292	1197	934	682	521
25	642	928	1014	1143	1073	1209	1640	1444	1141	1019	930	715	536	433
50	325	380	397	442	506	575	682	657	535	476	414	314	261	234
75	211	235	242	265	307	349	396	397	333	296	253	197	172	160
100	153	167	172	185	211	237	263	269	232	207	177	142	127	120
125	119	127	130	139	155	172	189	195	172	154	133	110	100	96
150	95	101	103	109	120	131	143	148	133	120	105	88	82	79
175	79	83	84	88	95	103	112	116	105	96	85	73	68	66
200	66	69	70	73	78	84	90	93	86	79	71	62	58	57
225	56	58	59	61	65	69	73	76	71	66	60	53	50	49

Table 2 (continuation)

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	896	6181											4088	838
5	861	6035	6107	6455	4057	4897	8878	6713	5158	4579	4533	3288	3957	768
7	828	3266	4528	4737	2676	3168	5478	4246	3278	2917	2853	2240	1894	707
10	767	2125	2927	3145	1837	2155	3520	2811	2180	1942	1871	1504	1119	606
15	652	1304	1572	1752	1247	1433	2167	1804	1409	1256	1184	942	678	466
20	546	894	1009	1136	952	1078	1534	1321	1039	926	858	670	489	373
25	459	663	724	817	767	863	1169	1036	820	730	667	512	384	310
50	232	272	284	316	361	410	487	471	384	342	297	225	187	168
75	150	168	173	190	219	249	283	284	239	212	181	141	123	114
100	110	119	123	132	150	169	188	193	166	148	127	102	91	86
125	85	91	93	99	111	123	135	140	123	110	95	79	72	68
150	68	72	74	78	86	94	102	106	95	86	75	63	59	56
175	56	59	60	63	68	74	80	83	76	69	61	53	49	47
200	47	49	50	52	56	60	64	67	61	57	51	44	42	40
225	40	42	42	44	46	49	53	55	51	47	43	38	36	35

Table 2 (continuation)

Equivalent dose rate induced by high-energy hadrons from LAr Beam Pipe for T= 5 y, t=1d

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	1365	9431											6209	1272
5	1311	9211	9308	9779	6166	7499	13640	10196	7821	6967	6895	4988	6009	1167
7	1262	4980	6900	7188	4068	4849	8414	6449	4970	4438	4339	3399	2877	1074
10	1168	3237	4459	4778	2794	3298	5403	4268	3305	2954	2844	2282	1700	920
15	992	1986	2394	2663	1897	2192	3324	2740	2136	1909	1800	1431	1029	708
20	831	1362	1536	1728	1449	1648	2351	2007	1575	1407	1304	1017	743	567
25	698	1010	1102	1243	1168	1319	1790	1574	1243	1110	1013	778	583	471
50	354	414	432	481	551	627	744	717	583	519	451	342	284	255
75	229	255	264	289	334	381	432	433	363	322	275	215	187	174
100	167	182	187	202	229	258	287	293	253	225	193	155	139	131
125	129	139	142	151	169	187	206	213	187	168	145	120	109	104
150	104	110	112	119	130	143	156	161	145	131	114	96	89	86
175	86	90	92	96	104	113	122	126	115	105	93	80	75	72
200	72	75	76	79	85	91	98	102	93	86	77	67	64	62
225	61	63	64	67	71	75	80	83	77	72	65	58	55	53

Table 2 (continuation)

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

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	1003	6915											4582	939
5	963	6752	6835	7220	4541	5499	9983	7541	5783	5134	5082	3684	4435	861
7	927	3655	5068	5300	2995	3558	6161	4770	3676	3271	3199	2510	2123	792
10	858	2378	3277	3520	2057	2420	3958	3157	2444	2178	2097	1685	1254	679
15	730	1460	1760	1961	1397	1609	2437	2026	1580	1408	1327	1056	760	523
20	611	1001	1130	1272	1067	1211	1725	1484	1165	1038	962	750	548	418
25	514	743	811	915	860	969	1314	1164	919	819	747	574	430	347
50	260	305	318	354	405	461	547	529	431	383	333	252	210	188
75	169	188	194	213	246	280	318	319	268	238	203	158	138	128
100	123	134	138	148	169	190	211	217	187	166	142	114	102	97
125	95	102	104	111	124	138	152	157	138	124	107	88	81	77
150	77	81	83	87	96	105	115	119	107	96	84	71	66	63
175	63	66	67	71	77	83	90	93	85	77	68	59	55	53
200	53	55	56	58	63	67	72	75	69	63	57	50	47	45
225	45	47	47	49	52	55	59	61	57	53	48	43	40	39



Table 2 (continuation)

Equivalent dose rate induced by high-energy hadrons from LAr Beam Pipe for T= 10y, t=1d

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	1369	9458											6226	1276
5	1315	9237	9334	9821	6185	7521	13663	10251	7843	6986	6913	5002	6026	1170
7	1266	4994	6920	7217	4080	4863	8428	6483	4984	4450	4351	3408	2885	1077
10	1172	3247	4472	4795	2803	3307	5413	4290	3315	2962	2852	2288	1704	922
15	995	1992	2401	2673	1903	2198	3330	2753	2142	1915	1805	1435	1032	710
20	834	1366	1541	1734	1454	1653	2356	2017	1580	1411	1308	1020	745	568
25	701	1013	1106	1247	1172	1322	1794	1582	1247	1113	1016	780	585	472
50	355	415	434	483	552	628	746	719	585	521	453	343	285	255
75	230	256	265	290	335	382	433	434	364	323	276	215	188	174
100	168	183	187	202	230	259	288	295	254	226	193	155	139	131
125	130	139	142	152	170	188	207	214	188	168	145	120	110	104
150	104	111	113	119	131	143	156	162	145	131	115	97	89	86
175	86	90	92	96	104	113	122	127	115	105	93	80	75	72
200	72	75	76	79	85	91	98	102	94	86	77	68	64	62
225	61	64	64	67	71	76	80	83	78	72	65	58	55	53

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	1006	6940											4599	942
5	967	6777	6859	7245	4567	5520	10039	7565	5803	5152	5100	3698	4451	864
7	931	3668	5086	5319	3012	3571	6194	4785	3688	3283	3210	2519	2131	795
10	862	2387	3289	3533	2067	2430	3979	3167	2453	2185	2105	1691	1259	681
15	732	1465	1767	1969	1403	1616	2449	2032	1585	1413	1332	1060	762	525
20	613	1005	1134	1277	1072	1216	1733	1489	1169	1042	965	753	550	420
25	516	745	814	919	863	973	1320	1168	922	822	750	576	432	349
50	262	306	320	356	407	463	549	531	432	385	334	253	210	189
75	169	189	195	213	247	281	319	320	269	239	204	159	139	129
100	123	134	138	149	170	191	212	217	187	167	143	115	103	97
125	96	103	105	112	125	138	152	158	139	124	107	89	81	77
150	77	82	83	88	96	106	115	119	107	97	85	71	66	63
175	63	67	68	71	77	83	90	94	85	78	69	59	55	53
200	53	55	56	59	63	67	72	75	69	64	57	50	47	46
225	45	47	48	49	52	56	59	62	57	53	48	43	41	39

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	152	1036											709	146
5	146	1012	1033	1099	695	856	1625	1207	912	801	791	572	686	134
7	141	552	769	808	459	555	1001	763	580	511	498	389	329	123
10	131	361	498	537	316	378	642	505	385	340	326	262	194	105
15	111	222	268	300	215	252	395	324	249	220	207	164	118	81
20	93	153	173	195	165	190	279	237	184	162	150	117	85	65
25	79	114	124	140	133	153	212	186	145	128	117	89	67	54
50	40	47	49	55	63	73	88	85	68	60	52	39	33	29
75	26	29	30	33	39	44	51	51	42	37	32	25	22	20
100	19	21	22	23	27	30	34	34	30	26	22	18	16	15
125	15	16	16	18	20	22	24	25	22	20	17	14	13	12
150	12	13	13	14	15	17	18	19	17	15	13	11	10	10
175	10	10	11	11	12	13	14	15	13	12	11	9	9	8
200	8	9	9	9	10	11	11	12	11	10	9	8	7	7
225	7	7	7	8	8	9	9	10	9	8	8	7	6	6

Table 2 (continuation)

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

R/Z, cm	350	365	370	385	415	450	500	600	700	750	800	850	870	880
0	226	1540	1879	2082	1357	1521	2868	2124	1624	1440	1432	1121	1049	215
5	217	1504	1532	1625	1028	1271	2400	1773	1342	1182	1169	844	1015	197
7	209	818	1139	1195	679	823	1479	1121	853	753	736	575	486	182
10	194	535	738	795	467	561	949	742	567	502	482	386	287	156
15	165	329	397	444	318	374	583	476	366	325	305	242	174	120
20	138	227	256	288	244	282	412	349	270	240	221	172	126	96
25	117	168	184	208	197	226	313	274	213	189	172	132	99	80
50	60	70	73	81	94	108	129	124	100	89	77	58	48	43
75	39	43	45	49	57	65	75	75	62	55	47	37	32	30
100	28	31	32	34	39	44	50	51	43	39	33	26	24	22
125	22	24	24	26	29	32	36	37	32	29	25	20	19	18
150	18	19	19	20	22	25	27	28	25	22	20	17	15	15
175	15	15	16	16	18	19	21	22	20	18	16	14	13	12
200	12	13	13	14	15	16	17	17	16	15	13	12	11	11
225	10	11	11	11	12	13	14	14	13	12	11	10	9	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	230	1570	1915	2120	1385	1550	2907	2157	1653	1467	1459	1143	1070	219
5	221	1533	1561	1655	1049	1295	2433	1801	1366	1204	1191	860	1035	201
7	213	834	1161	1217	693	838	1499	1138	868	768	750	586	496	185
10	197	545	752	810	477	571	962	753	577	511	491	394	293	159
15	168	336	405	452	324	381	591	484	373	331	311	247	178	122
20	141	231	260	294	248	287	418	354	275	244	226	176	128	98
25	119	171	187	212	200	230	318	278	217	193	175	134	101	81
50	61	71	74	83	95	109	131	126	102	90	78	59	49	44
75	40	44	46	50	58	66	76	76	63	56	48	37	33	30
100	29	32	32	35	40	45	50	52	44	39	34	27	24	23
125	22	24	25	26	29	33	36	37	33	29	25	21	19	18
150	18	19	20	21	23	25	27	28	25	23	20	17	16	15
175	15	16	16	17	18	20	21	22	20	18	16	14	13	13
200	13	13	13	14	15	16	17	18	16	15	13	12	11	11
225	11	11	11	12	12	13	14	15	14	13	11	10	10	9