Dose rate in three selected points around Pixel Detector

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Here are given estimations of activation dose rate in the following locations around the Pixel Detector:

Point	R, mm	Z, mm	Comment
1	400	3443	PP1 outer connections
2	175	3340	PP1 inner cooling connections
3	200	700	PP0

1. For the points 1 and 2, contributions to the dose rate were estimated from the following subsystems: ID beam-pipe, Pixel Detector with services, SCT with services, TRT with cervices, Barrel and EndCap LAr Callorimeter. For the point 3, contributions from the Pixel detector with services and ID beam-pipe were estimated.
2. Geometry and concentrations of dangerous materials in the Pixel detector was taken from 'inventory_of_metals_17_01_2002.xls' prepared and supplied by Marco Olcese. Geometry and concentrations of materials in the SCT and TRT detectors were taken from 'sct.doc' and 'trt.doc' (http://cern.ch./vhedberg/atlas/act/activation.html) prepared by Ivan Bedajanek. Geometry of LAr calorimeter was adopted from the latest geometry data file for particle transport simulations with GCALOUR (by Mike Shupe). Geometry of ID beam-pipe was adopted from the drawing LHCVC1I_0003.
3. Both hadron and neutron activation was taken into account. Particle fluxes had been produced by Mike Shupe on a fine grid ($\Delta R=0.1$ cm for $0<R<4$ cm and $\Delta R=1$ cm for $4<R<120$ cm). The fluxes and, consequently, results of the study are normalized for luminosity 10^{34}.
4. In order to calculate dose rate from the ID beam-pipe, Pixel, SCT, and TRT, they were subdivided onto a set of circle radiation sources 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, though this overestimation is negligible, as median density of material in every block of the detector is rather low. Dose rate from LAr calorimeter was calculated with the DOT-3.5 – the discrete-ordinate radiation transport code in two-dimensional geometry.
5. Results of activation dose rate calculations are presented in the Table 1-6 for various cooling time and running time T=100 days and T=10 years (every year assume operation at high luminosity for 120 days and cooling for the rest of the year). All values are in μSv/h.

Table 1

Dose rate at R= 400 mm, Z= 3443 mm for exposure time T=100 days and different cooling time

Type	Element	Cooling time						
		1 d	3 d	5 d	7 d	15 d	30 d	100 d
Hadron activation	ID beam pipe	4.93	1.72	1.33	1.25	1.14	1.04	0.83
	pixel type 2 services	53.2	37.4	33.3	31.3	26.1	21.3	12.0
	pixel	27.9	15.1	12.7	11.7	9.51	7.63	4.71
	sct barrel	0.63	0.39	0.35	0.31	0.26	0.21	0.13
	sct forward	2.00	1.00	0.87	0.82	0.72	0.61	0.39
	sct barrel services	5.10	4.30	3.90	3.70	3.00	2.40	1.22
	sct forward services	6.50	5.50	5.00	4.60	3.80	3.00	1.50
	TRT	6.67	4.55	3.91	3.53	2.68	2.00	1.13
	LAr Barrel	14.80	9.40	7.40	6.20	3.70	2.10	1.80
	LAr EndCap	23.00	13.40	11.00	9.60	6.70	4.70	2.20
Neutron activation	ID beam pipe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	pixel type 2 services	38.8	4.70	2.10	1.90	1.75	1.51	0.76
	pixel	6.40	0.69	0.21	0.14	0.10	0.08	0.05
	sct barrel	0.58	0.23	0.18	0.15	0.12	0.11	0.09
	sct forward	1.47	0.73	0.57	0.49	0.39	0.36	0.30
	sct barrel services	18.70	1.90	0.69	0.60	0.57	0.54	0.44
	sct forward services	17.60	1.80	0.65	0.56	0.54	0.51	0.41
	TRT	15.60	3.23	1.51	0.99	0.46	0.36	0.21
	LAr Barrel	17.00	1.00	0.70	0.67	0.61	0.51	0.40
	LAr EndCap	2.30	0.90	0.50	0.37	0.35	0.33	0.30
Total , μSv/h		263	108	87	79	62	49	29

Table 2

Dose rate at R= 400 mm, Z= 3443 mm for exposure time T=10 years and different cooling time

Type	Element	Cooling time						
		1 d	3 d	5 d	7 d	15 d	30 d	100 d
Hadron activation	ID beam pipe	7.88	4.57	4.17	4.08	4.01	4.85	3.51
	pixel type 2 services	69.3	53.4	49.2	46.9	41.6	36.3	25.2
	pixel	38.8	26.0	23.6	22.5	20.2	18.1	14.4
	sct barrel	0.94	0.70	0.65	0.62	56.00	0.51	0.41
	sct forward	3.10	2.10	1.90	1.80	1.70	1.60	1.31
	sct barrel services	5.90	5.10	4.70	4.40	3.80	3.10	1.75
	sct forward services	7.50	6.50	6.00	5.60	4.70	3.90	2.10
	TRT	8.51	6.40	5.70	5.40	4.47	3.76	2.69
	LAr Barrel	18.70	14.60	11.80	10.00	6.40	5.90	5.50
	LAr EndCap	28.0	19.1	16.0	14.2	10.5	8.0	6.0
Neutron activation	ID beam pipe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	pixel type 2 services	39.10	5.00	2.40	2.20	2.00	1.74	0.89
	pixel	6.50	0.74	0.26	0.20	0.15	0.13	0.10
	sct barrel	0.69	0.35	0.29	0.26	0.23	0.22	0.18
	sct forward	1.97	1.00	0.89	0.81	0.70	0.66	0.54
	sct barrel services	20.90	4.13	2.90	2.80	2.77	2.72	2.55
	sct forward services	19.60	3.87	2.72	2.63	2.59	2.55	2.39
	TRT	15.80	3.40	1.70	1.20	0.65	0.53	0.35
	LAr Barrel	19.00	2.40	2.20	2.16	2.07	1.95	1.80
	LAr EndCap	4.20	3.00	2.10	2.07	2.00	1.95	1.90
Total , μSv/h		316	162	139	130	167	98	74

Table 3

Dose rate at R= 175 mm, Z= 3340 mm for exposure time T=100 days and different cooling time

Type	Element	Cooling time						
		1 d	3 d	5 d	7 d	15 d	30 d	100 d
Hadron activation	ID beam pipe	12.60	4.50	3.50	3.31	3.03	2.73	2.13
	pixel type 2 services	13.40	9.45	8.43	7.88	6.63	5.43	3.06
	pixel	218.	97.5	78.9	72.9	61.6	51.7	36.1
	sct barrel	0.68	0.42	0.36	0.33	0.28	0.25	0.14
	sct forward	2.50	1.20	1.00	0.98	0.86	0.74	0.47
	sct barrel services	5.20	4.40	4.00	3.70	3.10	2.50	1.24
	sct forward services	6.80	5.70	5.20	4.80	4.00	3.10	1.56
	TRT	6.56	4.47	3.84	3.47	2.64	2.00	1.12
	LAr Barrel	14.80	9.50	7.40	6.20	3.70	2.10	1.80
	LAr EndCap	27.0	15.8	13.0	11.3	7.90	5.20	2.40
Neutron activation	ID beam pipe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	pixel type 2 services	12.20	1.40	0.61	0.54	0.50	0.43	0.22
	pixel	20.60	2.20	0.64	0.48	0.38	0.32	0.21
	sct barrel	0.62	0.25	0.19	0.16	0.13	0.12	0.10
	sct forward	1.75	0.87	0.68	0.59	0.64	0.43	0.35
	sct barrel services	19.10	2.00	0.70	0.61	0.58	0.55	0.45
	sct forward services	17.90	1.84	0.66	0.57	0.55	0.52	0.42
	TRT	15.20	3.13	1.47	0.97	0.47	0.36	0.22
	LAr Barrel	17.00	1.00	0.70	0.67	0.61	0.51	0.40
	LAr EndCap	2.50	0.90	0.60	0.45	0.42	0.40	0.38
Total , μSv/h		414	167	132	120	98	79	53

Table 4

Dose rate at R= 175 mm, Z= 3340 mm for exposure time T=10 years and different cooling time

Type	Element	Cooling time						
		1 d	3 d	5 d	7 d	15 d	30 d	100 d
Hadron activation	ID beam pipe	20.00	11.70	10.70	10.40	10.20	9.82	8.86
	pixel type 2 services	17.40	13.50	12.40	11.90	10.50	9.21	6.37
	pixel	324.0	203.0	184.0	187.0	166.0	154.0	132.0
	sct barrel	1.00	0.76	0.70	0.67	0.61	0.55	0.44
	sct forward	3.70	2.50	2.30	2.20	2.10	1.90	1.57
	sct barrel services	6.00	5.20	4.80	4.50	3.80	3.20	1.80
	sct forward services	7.80	6.70	6.20	5.80	4.90	4.00	2.20
	TRT	8.39	6.30	5.60	5.30	4.41	3.71	2.66
	LAr Barrel	18.70	14.60	11.80	10.00	6.40	5.90	5.50
	LAr EndCap	32.00	21.40	18.00	15.90	11.80	9.00	6.70
Neutron activation	ID beam pipe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	pixel type 2 services	12.30	1.51	0.69	0.62	0.57	0.49	0.25
	pixel	21.00	2.50	0.88	0.70	0.60	0.53	0.38
	sct barrel	0.75	0.37	0.31	0.28	0.25	0.23	0.19
	sct forward	2.48	1.26	1.06	0.99	0.84	0.79	0.65
	sct barrel services	21.30	4.21	3.00	2.90	2.82	2.77	2.60
	sct forward services	20.00	3.95	2.80	2.68	2.64	2.60	2.43
	TRT	15.40	3.30	1.67	1.20	0.67	0.54	0.37
	LAr Barrel	19.00	2.40	2.20	2.16	2.07	1.95	1.80
	LAr EndCap	4.40	3.50	2.50	2.40	2.30	2.20	2.20
Total , μSv/h		556	309	272	268	233	213	179

Table 5

Dose rate at R= 200 mm, Z= 700 mm for exposure time T=100 days and different cooling time

Type	Element	Cooling time						
		1 d	3 d	5 d	7 d	15 d	30 d	100 d
Hadron activation	ID beam pipe	1.44	1.27	1.22	1.19	1.07	0.89	0.37
	pixel type 2 services	1.16	0.83	0.74	0.70	0.59	0.48	0.27
	pixel	115.00	61.80	51.60	47.30	38.70	31.30	19.60
Neutron activation	ID beam pipe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	pixel type 2 services	1.56	0.17	0.07	0.06	0.06	0.05	0.03
	pixel	10.20	2.30	1.60	1.50	1.40	1.30	0.98
Total , μSv/h		129	66	55	51	42	34	21

Table 6

Dose rate at R= 200 mm, Z= 700 mm for exposure time T=10 years and different cooling time

Type	Element	Cooling time						
		1 d	3 d	5 d	7 d	15 d	30 d	100 d
Hadron activation	ID beam pipe	1.68	1.50	1.45	1.42	1.29	1.09	0.52
	pixel type 2 services	1.50	1.17	1.08	1.03	0.92	0.80	0.55
	pixel	159.00	106.00	94.50	91.00	81.90	73.60	58.60
Neutron activation	ID beam pipe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	pixel type 2 services	1.57	0.18	0.08	0.07	0.07	0.06	0.03
	pixel	11.20	3.30	2.60	2.50	2.40	2.20	1.70
Total , μSv/h		175	112	100	96	87	78	61